<u>Background Material</u>

for Proton Research Activities at Argonne National Laboratory

Introduction

The Proton Accelerator Research B&R code at Argonne covers two areas of research: collider physics at the energy frontier and neutrino physics at the intensity frontier. The Argonne HEP Division has a long history and outstanding record in both fields, going back to being initial collaborators and proponents of CDF, ZEUS, MINOS, ATLAS and NOνA. In all cases members of the Division played a critical role in design, construction, commissioning, maintenance and operation of the detector as well as in physics analysis. Argonne has provided outstanding expertise in the design and construction of large calorimeter systems for these experiments. A good example is the tile calorimeter for ATLAS at the LHC. Argonne had the primary responsibility for developing the infrastructure for tilecal manufacture and for coordinating the tilecal construction contributions of the university groups in the U.S. Another recent example is the prototype assembly technique for NOνA modules, which is currently being developed in the Division. Complementing the calorimeter design and construction efforts, Argonne has made major contributions to front-end and trigger electronics for all of these experiments.

The actual and requested funding for the Proton Accelerator B&R code at Argonne for FY08 through FY12 is given in Table I. This is taken from budget tables submitted for this review. In FY09 this funding supports CDF, ATLAS, MINOS and Nova.

Table I (all numbers in k$)

FY08 (actual)	**FY09**	**FY10**	**FY11**	**FY12**
4,540k$	5,221k$	5,459k$	5,470k$	5,735k$

Starting in 2003-2004 the Division went through a planning exercise to provide a roadmap for the evolution of physicist and engineering effort into the LHC era, taking into account the unique opportunities and responsibilities for a national laboratory program. The planning document, last updated in 2006, can be found at: http://gate.hep.anl.gov/plan_group/Plan2006.doc This is discussed in more detail in the final section of this document "Features and Trends of the Argonne HEP program"

Collider Detector at Fermilab

Overview:

Argonne HEP was one of the founding institutions in the Collider Detector at Fermilab (CDF) collaboration. Argonne's role in CDF included detector design and construction, major detector upgrades, contributions to commissioning, testbeam studies, detector maintenance, B0 operations, and physics analysis. Argonne led the original design and construction of the central electromagnetic calorimeter, including the shower max. detectors and subsequent upgrades with preshower and crack-filler detectors. Argonne contributed strongly to upgrades for central electron and photon triggers during Run I. Argonne led the shower max electronics upgrades for Run II, provided leadership for the Run II muon systems upgrade, and led the preshower replacement upgrade in 2004-2005. Our group has provided physics leadership via conveners and subconveners in the physics groups (electroweak, QCD, and B physics) and in CDF operations. Our group has also contributed to important physics analyses, including b-hadron production and B-meson mixing, precision electroweak measurements, including the W/Z boson and top-quark mass determinations, and QCD studies and searches using prompt photon production.

ANL-HEP Long-Range Plan:

In response to DOE-HEP guidelines, the HEP Division conducted an extensive long-range planning exercise in 2003, which was presented at the 2004 DOE review. The purpose of the exercise was to examine new initiatives, for example in astrophysics and in the ILC, and to project the transition of physicist and engineering effort from CDF and ZEUS into ATLAS/LHC and other new projects. This plan, updated through FY2006, http://gate.hep.anl.gov/plan_group/Plan2006.doc projected an end of ANL participation in ZEUS by the end of FY2007, and gradual reduction of the CDF effort through FY2009. It should be stressed that the "plan" did not enforce any redirection of effort, but rather summarized the choices that were being made in light of the expected shutdown of HERA (2007) and the Tevatron (2009?), and the anticipated startup of LHC (2007-> 2008-> 2009..). The predictions for the transition of FTE effort have proven to be quite accurate. In the period 2006-2009, the ZEUS effort (~4 FTE) has moved entirely into LHC/ATLAS and ILC detector development, while a large fraction of the CDF effort (~6 FTE) has moved into ATLAS and astrophysics. An important consequence of the plan is that new hires (e.g., postdocs) have been made in ATLAS and other programs, but not in CDF; the last CDF postdoc, Masashi Tanaka, left ANL in May 2006. The net flow of FTE effort in CDF has been from ~6 FTE (FY2004) to ~3 FTE (FY2007) to ~2 FTE (FY2009). This is background for the discussion of ANL-HEP involvement in CDF in the two periods January 2006 through June 2009 and June 2009 through June 2012.

June 2009-June 2012:

As of June 2009 the following staff scientists are no longer active in CDF: Proudfoot, Blair, LeCompte, Kuhlmann, Byrum, and Wagner. However, they are available for consultation. Nodulman serves as coconvener of the Electroweak Physics Group, and is heavily involved with the next analysis of the W-boson mass. Nodulman is also co-SPL for CDF calorimetry, and has maintained CEM energy response calibrations using in situ electron data sets. Nodulman has also served as internal reviewer for several top-mass analyses. Wicklund has served as coconvener of the CDF editorial committee since FY2005. This committee reviews all CDF paper drafts, currently around 120 per year. Wicklund also works on B-physics analysis and internal reviews (Bc lifetime, exotic charmonium).

While the duration of the Tevatron run is still under discussion, we assume that the CDF program will continue through FY2010. As of April 2009, CDF has 5.4 fb^{-1} recorded luminosity, while current analyses for publication are based on samples from 1.5 to 4.5 fb^{-1}. With steady-state running through FY2011, CDF is expected to have ~10 fb^{-1} recorded luminosity. By contrast, some of the published flagship analyses are based on much smaller samples: 200 pb^{-1} (W mass), 1 fb^{-1} (Bs mixing measurement), and exotic charmonium (2.7 fb^{-1}). Thus, we are confident that regardless of the duration of Tevatron running, there will remain significant analysis efforts on topics like exotic mesons, CP violation in Bs mixing, precision electroweak measurements, and of course, improved limits on the Higgs sector. Given the rich physics opportunities that remain on CDF, and given the current expectation of running through 2010 or longer, we plan to add one postdoc to the group. This hire would contribute to operations support and physics analysis. Our goal is to assist CDF within the constraints of limited manpower to get out CDF publications and to provide senior-level experience (Nodulman, Wicklund). We would also provide maintenance support as needed for the duration of the run for shower max electronics, as well as calorimeter group leadership and central EM calibrations.

Scientific breakthroughs anticipated:

- Higgs limits: the current 160-170 GeV/c^2 region of exclusion should expand, and some positive indication is possible.
- CPV exclusion in Bs mixing: current interesting indications are currently statistics limited.
- W mass determination to 25 MeV is in progress.
- Top mass determination to 1 GeV requires improved systematic understanding.
- Confirmation of exotic charmonium state(s) reuires more statistics.

Publications expected:

- Completion of PRD's on Bs mixing and on Bc lifetime
- 2 fb^{-1} W mass
- (100's) CDF publications (current ~60 per year).

Resources required for long term goals:

Base support for ~2.8 FTE (including postdoc hire), plus electronics support for shower max front end cards.

January 2006- June 2009:

As of June 2006, the major CDF Run IIb detector upgrade, the replacement of the preshower (CPR II) and crack detectors had been completed under the project management leadership of Steve Kuhlmann. Commissioning and calibrating CPR II and updating the software were ANL responsibilities during this period. Additional ANL maintenance and operations responsibilities included:

- Shower max. electronics (both central and plug).

- CPR II and Crack II high voltage and DAQ readout.

- Central PM tubes and bases.

- Electron reconstruction offline code

- Operations manager support (Wagner).

- Calorimeter SPL's (Nodulman, Byrum)

Convener support for physics groups included:

- CDF Photon Group (Blair)
- CDF Lepton Group (Nodulman)
- CDF Editorial Group (Wicklund)
- CDF Dimuon Group (LeCompte)
- CDF B Mixing Group (Tanaka)
- CDF Electroweak Group (Nodulman)

Physics analysis leadership included the W mass measurement (Nodulman), prompt photon signatures and searches (Blair, Kuhlmann), jet energy resolution (Kuhlmann), B physics and Bs mixing (Wicklund), and b-hadron cross sections (LeCompte). All group members were active in godparenting analyses.

By the time of the DOE review in 2007, ANL CDF staff members Proudfoot, Blair, Kuhlmann, LeCompte, Byrum, and Wagner were primarily involved with ATLAS, VERITAS, and new astrophysics initiatives. Our postdoc Tanaka left in May 2006. The group plan was to continue to support CDF M+O through the end of running, as needed, to support operations through B0 shifts, to assume godparenting responsibilities as needed, and to support the physics program (primarily Wicklund and Nodulman).

Research Highlights 2006-2009:

Bs and D^0 oscillations observed
Tests of CPV in Bs mixing
Exotic charmonium (J/ψ-φ)
Heavy baryons (Σb, Ξb, Ώb), Bc meson
Higgs exclusion limits (160-170 GeV)
W mass determination (with 200 pb^{-1} luminosity)
Top mass measurements
Single top observation
Diboson (WZ, ZZ) observation

CDF Notes:

A. B. Wicklund, Calibration of CES and CPR in Run I, CDF-8387 (2006)

A. B. Wicklund, Blind Selections and Significance for $Bc \rightarrow J/\psi\pi$, CDF-8130 (2006)

L. Nodulman A Kinder Gentler Scheme for Calibrating CEM, CDF-9357 (2008).

D. Beecher, I. Bizjak, C. Hays, B. Jayatilaka, A Kotwal, M. Lancaster, S. Malik, E. Nurse, L. Nodulman, P. Renton, T. Riddick, R. Shekar, O. Stelzer-Chilton, D. Waters, Y. Zeng, An Improved Measurement of the W Boson Mass with CDF in Run II: First Plots of the Data, CDF-9328 (2008)

L. Nodulman, Luminosity Dependence of CEM Gain, CDF-8794 (2007)

C.Hays, A. Kotwal, L. Nodulman, O. Stelzer-Chilton, W. Trischuk, I. Vollrath, First Measurement of the W Boson Mass with CDF in Run II, CDF-8665 (2007)

L. Nodulman, A Fine Tune of CEM for Run II, CDF-8425 (2007)

L. Nodulman, CES Strip/Wire Ratio Tuning in Run II, CDF-8211 (2006)

L. Nodulman, A Tune of CES Wire Gain for Run II, CDF-8150 (2006)

A. Artikov, J. Boudagov, D. Chokhelli, G. Drake. M. Gallinaro, M. Giunta, J. Grudzinski, J. Huston, M. Iori, D. Kim, S. Kuhlmann, S. Lami, R. Miller, L. Nodulman, A. Penzo, J. Suh, N. Turini, F. Ukegawa, CDF Central Preshower and Crack Detector Upgrade, CDF-7995 (2006) (ANL-HEP-PR-07-09).

Selected Publications:

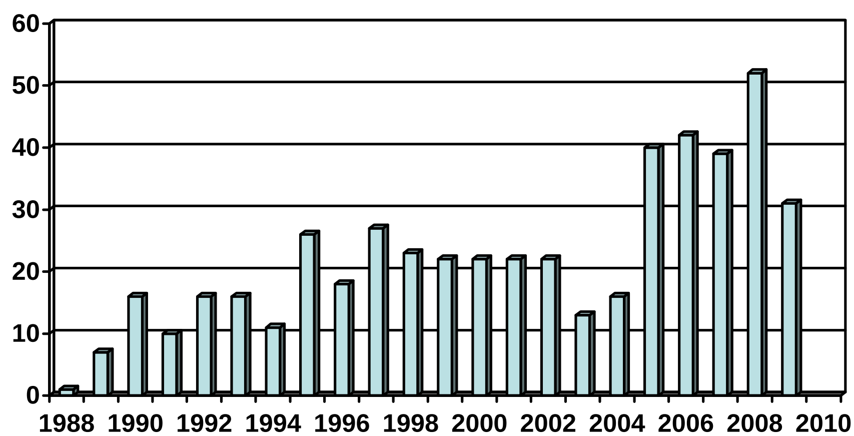
T. Aaltonen et al. (CDF) First Run II Measurement of the W Boson Mass, Phys. Rev. D77, 12001 (2008)

T. Aaltonen et al. (CDF) First Measurement of the W Boson Mass in Run II of the Tevatron, Phys. Rev. Lett. 99, 151

A. Abulencia et al. (CDF) Observation of B0s antiB0s Oscillations, Phys. Rev. Lett. 97, 242003 (2006)

A. Bhatti, S. Kuhlmann, L. Noduman, J. Proudfoot, A. B. Wicklund et al., Determination of the Jet Energy Scale at the Collider Detector at Fermilab, NIMPR A566, 375 (2006)

CDF Publications by Year



http://www-cdf.fnal.gov/physics/preprints/index.html

Major construction completions:

CPR II and Crack II construction, installation, and commissioning

ATLAS – Accomplishments in period from May 2006 – May 2009

Overview:

Argonne has collaborated on the ATLAS experiment since 1994 and the heart of this research program has grown as extensions of our roles in design and construction of the detector: in the calorimeter and trigger systems as well as in core software design and implementation.

Argonne was the lead US institution in the construction of the Tile Calorimeter. Following the mechanical installation of the calorimeter in the ATLAS cavern in May 2006, the focus of our work in the Tile Calorimeter system has become operational in nature. In addition we took on a key responsibility associated with the Low Voltage Power Supply system, which had encountered technical difficulties (this was not previously an Argonne responsibility).

Argonne had a major role in the construction of a key element of the trigger hardware. The 40 MHz of beam crossings are reduced to a 75 kHz rate of crossings with an interaction of interest (as marked by the presence of high energy jets, missing energy or lepton or photon candidates) by the Level 1 trigger. Argonne has developed a unique and scalable interface between the high rate Level 1 trigger and the commodity Level 2 trigger system- the Region of Interest Builder and Level 2 Trigger Supervisor. This has made it possible to use inexpensive commodity computers and networks for all of the remaining Level 2 trigger system. The trigger system is fully installed and commissioned and our role has moved to operational support.

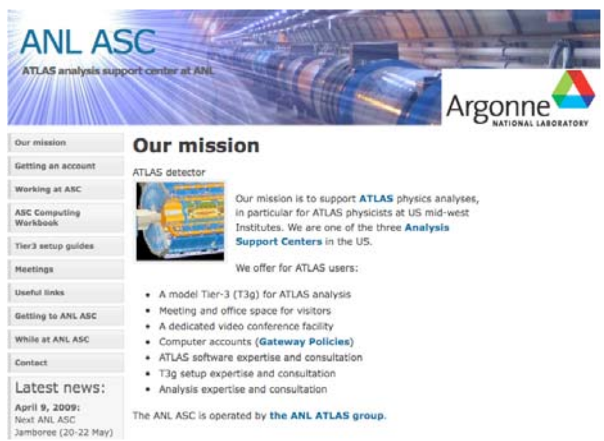


Fig 1. The ATLAS Analysis Support Center – main web page.

As a complement to, and building from, these construction responsibilities, the Argonne group has played a strong role in preparing for physics at the energy frontier of the LHC. Our emphasis has been on areas of physics and performance studies in which early data can provide calibrations and useful tests of both detector performance as well as physics results: in jet reconstruction and jet energy scale determination; Standard Model physics; and in searches for physics beyond the Standard Model. These studies, unfortunately still at the level of Monte Carlo simulation, already provide some insight into how to commission the detector and how to check the first data. In addition to the physics activities of the Argonne group itself, Argonne is playing a significant role in enabling physics for collaborators in the Midwest and in the US as a whole through its Analysis Support Center (figure 1). We recently moved to a larger space in Building 360, with more and larger offices and a larger meeting room, and which in particular offers the opportunity for further expansion.

Argonne physicists have held (and continue to hold) important management and leadership responsibilities within ATLAS and US-ATLAS. R. Stanek was the ATLAS Project Leader for the Tile Calorimeter subsystem (completing his second 2-year term in February 2009); L. Price is US-ATLAS Level 2 manager for Tile Calorimeter detector construction, for Maintenance and Operations, and now upgrades; T. LeCompte was co-convener of the ATLAS Standard Model Physics group from October 2006 until September 2008, he has now been appointed Deputy Physics Coordinator and will shortly become physics Coordinator for ATLAS; J. Proudfoot is convener of the JetEtMiss Combined Performance Group and will complete his 2-year term in September 2009. In addition, Argonne physicists were members of the editorial group for two significant ATLAS publications: the detector reference paper (~450 pages) and the CSC book (~1500 pages), with any given editor having direct responsibility for about 1/10th of the material.

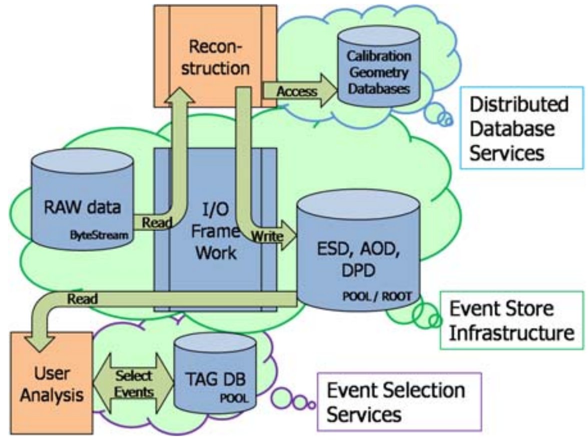


Fig 2. The ATLAS EDM and I/O framework, with areas of responsibility of the Argonne Software group.

At Argonne, we have the presence of several key members of the ATLAS core software development team and bring their skill also to our fellow ATLAS physicists through tutorials at the ANL ASC, and example codes. The ATLAS experiment will generate more than 3 petabytes of raw data per year, and Argonne has been integrally involved in the ATLAS computing and software project since its inception, and has lead responsibility within the collaboration for the definition and construction of a globally distributed, scalable, and efficiently navigable multi-petabyte event store (figure 2). The Argonne Software and Computing group, which is supported by the US-ATLAS Research Program, has key responsibilities for development and operations within the ATLAS core software organization; the unifying thread is infrastructure for flexible and efficient access to ATLAS data. Argonne is providing the event store architecture and design, event store navigational infrastructure, ATLAS control framework input/output infrastructure, an event-level metadata system, support for distributed database servers and services, and, as a shared responsibility with other institutions, integration of event store infrastructure into grid and distributed data management middleware.

The Argonne group itself has changed in character through the last 3 year period. Many of the group who were working less than full time on ATLAS became essentially full time in 2008 as first collisions were expected. Three postdoctoral fellows were hired, of whom one has already completed her position at Argonne and moved on. Physicists from other groups in the Division have moved to the ATLAS group and in particular have strengthened the Analysis Support activities. ATLAS has invented the concept of “institutes” being members of “institutions” to allow groups who are not of sufficient size to be full collaborators on ATLAS in their own right to do so as members of “institution”. A small group of 2 graduate students and 3 staff from Northern Illinois have used this mechanism via Argonne as the institution. This has enabled the NIU group to establish strong roles in ATLAS such that eventually it may become a full member of the collaboration. The students were attached to the ASC while completing their qualifiers and this enabled them to become familiar with ATLAS software and the Tile Calorimeter such that when they eventually moved to CERN they were immediately effective in the system operations team. Even though the LHC upgrade is almost a decade away, we are already looking at opportunities to contribute to ATLAS upgrades for the sLHC and have made particular progress in the Tile Calorimeter in which we have had a long and significant participation.

We now discuss below more specific details of the key research areas covered by the B&R area of Proton Accelerator-Based Research: tile calorimeter maintenance and operations, high level trigger, ATLAS Analysis Support Center, physics and detector performance studies and upgrades.

Tile Calorimeter

The final mechanical section of the ATLAS Tile Calorimeter (Extended Barrel A) was completed in May 2006 under Argonne direction and over the next few months the readout electronics drawers were inserted. An organized process of commissioning the control and readout of the Tile Calorimeter had already begun roughly 1 year before. Actual testing and validation of the calorimeter proceeded in parallel with the development of a rich set of tools for use during commissioning and later in the operation phase of the detector to monitor ongoing operation. While many aspects of the commissioning went smoothly with relatively minor setbacks to be overcome, two areas of significant problems were discovered which required major campaigns in addition to the foreseen program of commissioning. These areas were a) the stability and reliability of the Low Voltage Power Supplies (LVPS) and b) power distribution and connectors within the readout drawers. These problems and the responses are described in some detail below.

Fig.3, Bob Stanek in front of one of the finger Low Voltage Power Suppliers.

During the time when the detector was closed from May to October 2008 in anticipation of first collisions, the Tile Calorimeter (TileCal) worked very well, with only 1.4% of the 5000 readout cells not working in some way. The TileCal group did extensive data quality monitoring, considered an example to other systems in ATLAS, which showed that the extended work in commissioning had been successful in delivering a very well functioning calorimeter.

Argonne provided central leadership in many aspects of the TileCal commissioning, including Bob Stanek's service as overall Project Leader for four years starting from March 2005. Stanek had a comprehensive understanding of the design and implementation of the Tile Calorimeter and was an indispensable element in the multinational team that made it all work so well (figure 3). An Argonne staff physicist, then resident at CERN (Price) took responsibility for the Low Voltage Power Supply (LVPS) subsystem when it ran into trouble and coordinated its successful recovery. Three members of Argonne's TileCal subgroup were resident at CERN during much of the past three years, while several others commuted to CERN a significant fraction of their time. Argonne also has a leadership role within the group of five institutions from the U.S. participating in the Tile Calorimeter. This leadership starts with L. Price's role as U.S. Level 2 manager for TileCal, but has extended also to the work of several group members in specific areas of TileCal.

The LVPS system comprises 256 custom power supplies, each supplying 8 distinct supply voltages and fitting into a special location in the "finger" at the outer radius of each calorimeter module. They were originally built by a group from outside of the US. Very early in 2006 it was realized that the LVPS system as built had significant flaws, focused on stability of operation and overvoltage protection. Argonne and other groups were asked to organize an emergency study and implementation (if possible) of repairs to be made with a rather tight schedule before the expected turn-on of the LHC. With leadership from Argonne, engineers from Argonne, SLAC, Minsk, and Prague proposed a challenging but practicable series of ad-hoc modifications to the existing printed circuit boards. The resulting modifications of the 2700 boards were carried out in an urgent program, with effort supplied by multiple institutes, by the end of 2007 and the modified supplies installed in the detector early in 2008. During the 5 months of "operations" in 2008, only three of the modified boards developed problems (many less than feared before the repair effort). However, these were minor and did not prevent the whole calorimeter from being powered and operational.

In parallel during 2007 and early 2008, virtually all of the 256 readout "superdrawers" were removed from the detector for replacement of internal power connectors and other components that had been found to have early aging problems. As in the case of LVPS, an unanticipated workforce had to be recruited from the TileCal institutes. Argonne participated actively in the resulting large project that was required to refit all of the readout electronics.

Argonne has taken a central role in the development of software, especially databases, for commissioning and for operations for TileCal. For the majority of the last three years, Argonne has provided two full time software developers at CERN working on TileCal. One of those has now left and one is continuing with us and TileCal into the data taking phase. Argonne developers have provided multiple databases for tracking commissioning activities, including detailed tracking of LVPS status and operations, detailed operational status of all aspects of each readout drawer, and several uses of the general ATLAS conditions database for TileCal online initialization and offline reconstruction. Software development has also included the detailed software geometry description of TileCal, necessitating detailed interaction with the geometries of the muon and LAr calorimeter systems. For most of the past three years, Argonne has provided leadership of database organization and planning for TileCal, including the work described above and an extensive series of web-based monitoring and diagnostic tools provided by other developers. It has also included the TileCal implementation of common ATLAS databases, including DCS (for environmental control and monitoring), TDAQ configuration, and others.

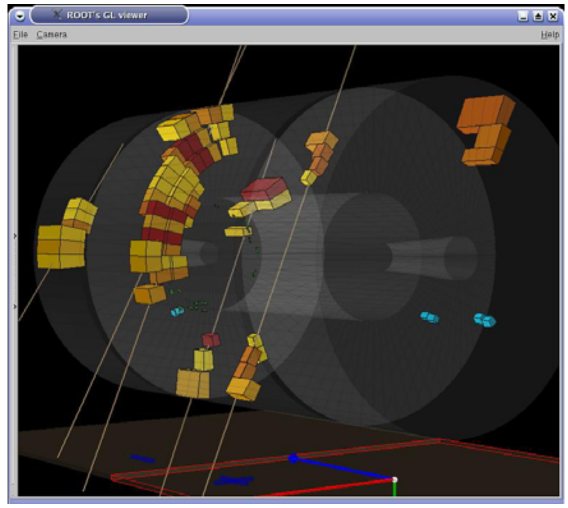


Fig.4, a cosmic ray traversing the ATLAS Calorimeters

As LHC and ATLAS operation approached, ATLAS has held an extensive series of operational exercises focused on data taking with cosmic rays to exercise the detector in increasingly realistic and integrated configurations. TileCal has taken cosmic ray data first alone and then together with the Liquid Argon calorimeter (LAr) since mid-2006 (figure 4). Between December 2006 and July 2008 a series of "milestone weeks" provided increasingly (finally fully) integrated operations of all detector systems with the full TDAQ system. The result was that by the time of the beam data in September 2008 full operation of the detector was rather routine. A related exercise billed as the Full Dress Rehearsal (FDR) was held in two phases during 2008 and exercised as realistically as possible the data writing and subsequent reconstruction, replication, and analysis of simulated data. Argonne personnel participated actively in the Milestone and other integration activities, taking TileCal shifts both in the main ATLAS control room and for the important related functions of data quality (DQ) monitoring and assurance. Argonne personnel had regular assignments in TileCal DQ monitoring, including as one of DQ Validation Leaders. Several Argonne group members took DQ Milestone Week shifts remotely from a special console setup at Argonne.

Related to the Tile Calorimeter was Argonne's work with Technical Coordination, focused on the control and commissioning of the movement system that has the job of positioning the large and heavy sub-assemblies such as calorimeters that make up the moveable parts of ATLAS. The first and highly successful operation of the movement system came in October 2005. Since then, refinements have been made to the control system, including an automated leveling system, modifications needed for moving Muon system components, control system hardware upgrades, and an improved GUI.

High Level Trigger

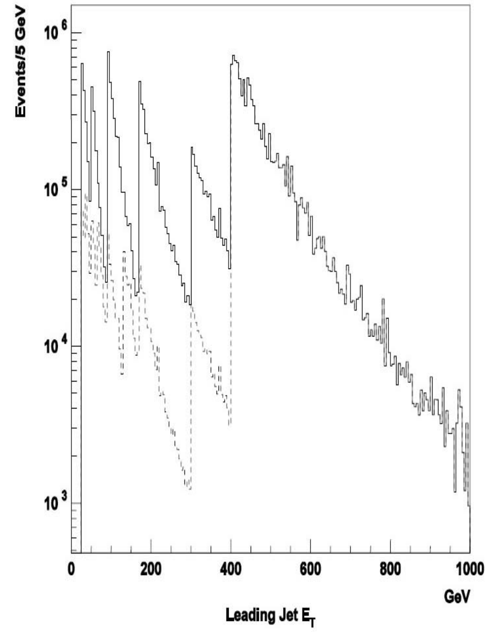


Fig 5. Jet samples acquired before prescale improvements (dashed) and after (solid).

The division has made significant contributions in a number of areas in the ATLAS Trigger and Data Acquisition (TDAQ) system: in hardware, software, performance studies and operations. Division physicists have been involved in trigger menu issues. This includes determining optimal trigger prescales for the jet triggers to obtain better uniformity of the data as a function of E_T (figure 5). The early trigger menus would have provided jet samples with gaps where very little data was collected in the region before the next prescale threshold occurred. Using the many Monte Carlo datasets it was possible to tune the threshold and prescale choices to provide a more uniform data sample for measurement of jet cross sections and for other jet related studies. In addition to these jet trigger studies some cross checks of rate estimates for photon triggers were done.

An algorithm was developed to enable the High Level Trigger (HLT) to identify muons in the TileCal by their characteristic pattern of their minimum ionizing depositions. There are two algorithms that require each cell or all but one cell in the muon path to pass a low and high threshold cut on the measured energy thus identifying a likely minimum ionizing transit in the TileCal (figure 6). Monte Carlo studies indicate that this approach is roughly 85% efficiency with some variation versus η. This algorithm can be executed entirely in the Level 2 trigger. The compute intensive part of the calculation was implemented in the TileCal RODs and can be read out for use by Level 2. This pair of algorithms is particularly useful in identifying low P_T muons.

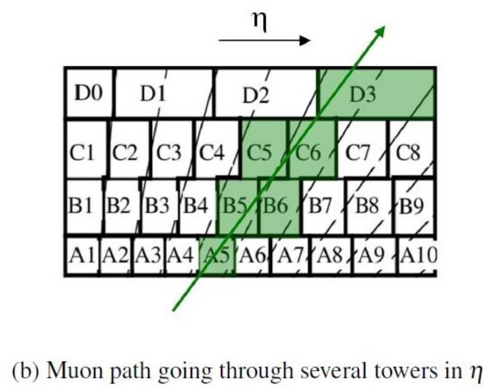


Fig 6. A cartoon showing the path of muons through the tile calorimeter.

Responsibility for the TDAQ software that services the Region of Interest Builder (RoIB) and distributes the Level 1 decisions to the HLT (both control software for the VME based RoIB and the Level 2 supervisor software) is shared by support personnel paid for by US ATLAS and division physicists. This software has been updated a number of times to accommodate both modifications to the TDAQ environment, message passing and error processing, and to improve reliability and report on error conditions that may affect the rest of the system. Possible failure modes and potential performance issues have been reviewed and addressed in the data flow and control software.

The TDAQ hardware built in the division includes the final RoIB crate (1 single board computer, 1 clock board, 4 input boards and 2 builder boards) in USA15 and a second crate (1 single board computer, 1 clock board, 3 input boards and 1 builder board) in SDX1 used for prototyping and tests. An additional minimal system is maintained in the division at Argonne. This system was used for software debugging and to make very long runs that identified issues which required more stable and longer running periods than could be obtained at CERN since the systems there are in high demand. During the past three years the CERN systems were installed and debugged. Problems with the PCI interface in some of the Level 2 supervisors used at CERN were identified and resolved. A firmware upgrade was specified, documented, implemented and tested to check that data integrity was preserved as data passed from one crate component to another. The system was documented in a JINST article. Strategies and policies regarding long term support of the system were worked out. We now have one full time physicist at CERN engaged in work on TDAQ commissioning and support.

Argonne ATLAS Analysis Support Center

The ATLAS Analysis Support Center at Argonne (ANL ASC, http://atlaswww.hep.anl.gov/asc/) is one of the three Atlas ASCs, the others being at BNL and LBNL. The ASCs are charged to "provide US ATLAS physicists with regional resources, tutorials, support, leadership and focal point for meetings". They provide infrastructure and analysis support in basic ATLAS software as well as expertise in certain areas of detector performance. We believe that the ASCs should be, and will be, important centers of LHC physics in the US even as much of the focus of experimental HEP shifts to Europe in the next decade.

In order to carry out the mission to support physics analysis, the ANL ATLAS group has made continuous improvements to the ANL ASC capabilities in the last three years. Since 2007, two staff scientists who transitioned from the ZEUS experiment have spent significant effort on ANL ASC. At the same time, the synergy of the center with the Software, TileCal, and Physics efforts already taking place in the ANL ATLAS group have been identified and increased.

The number of ATLAS analysis meetings (Jamborees) held at the ANL ASC has increased; since winter 2007, a Jamboree is held every two months. The Jamborees in 2008 emphasized the use of Full Dress Rehearsal (FDR) data by the individual analyzers. This was based on our observation that one of the weaker parts of the ATLAS data readiness is the fact that only a relatively small number of physicists are sufficiently familiar with the ATLAS analysis computing environment. More recently we have shifted the theme of the Jamborees to the analyses themselves, as opposed to the handling of the analysis environment. The nine Jamborees, held since December 2007, have attracted 25 to 35 participants each time. One of the workshops was held together with BNL, and another together with BNL and LBNL using video conference connections.

The complexity of ATLAS computing presents a major challenge for those beginning ATLAS analysis. The traditional step-by-step tutorials either in a live presentation or on a web page have been found to be not completely satisfactory. At the ANL ASC, a method has been developed where physicists at all levels of competency with ATLAS software can make rapid progress. This is based on layered, detailed instructions on the web for specific tasks, likely to be of immediate use to the analyzer, combined with working periods in which expert help is readily available. A beginner is able to run a meaningful Athena job and begin to use the grid within a half day using these methods. We estimate as many as 35 students and physicists ran their first Athena and grid jobs from ANL ASC thus far.

The talks and pedagogical material used at the Jamborees at ANL draw heavily on the knowledge-base of the ANL ATLAS group. The physicists provide material based on their current ATLAS efforts (TileCal, Trigger, Software, and Physics) as well as on past experience from CDF and ZEUS. The expertise coming from the ATLAS software and computing group at Argonne is an indispensable part of the collective expertise available at the ASC as well as of the Jamborees. The members of the computing group give talks and prepare examples as well as provide hands-on help for the Jamboree participants. In addition, a strong participation of the personnel from the Midwest Tier2 at the University of Chicago and Indiana University, who also give talks and provide pedagogical material, has been established. For more advanced users, ATLAS analysis packages developed by ANL ATLAS members are available to the ANL ASC users to use as a basis for their own analysis packages. These include analysis packages on jets and prompt photons, as well as TileCal Offline DQM.

In order to accommodate the expanding needs of the ANL ASC, many infrastructure improvements have been made. The local ATLAS computer cluster which served a small number of people (mainly the ANL group and some local university colleagues) in 2007 has been restructured to handle the participants of the Jamborees. This required a reorganization of the account and file management in terms of both software and hardware as well as an increase of interactive computing capabilities. Modifications were made to optimize performance and to minimize the maintenance effort of grid and ATLAS software. Currently the ATLAS cluster handles over 70 accounts of the ANL ASC user community.

For the benefit of ANL ASC users, we have installed a dedicated web server and created a set of web pages with detailed documentation on the usage of the Center which are updated continuously. Dedicated CVS, Twiki pages, and Forum were also created and are maintained. We have also installed two large video screens in the Lobby of the HEP Division building to show ATLAS related videos as well as general HEP information to improve our communication with our non-HEP colleagues at Argonne. Management of Jamborees including attendee registration, security clearance, and computer account management has been streamlined with a strong support of the HEP division administrative staff. So far, ANL ASC has not had to turn away any Jamboree participation application despite the stringent adherence to ANL security clearance procedures.

The participant feedback from the Jamboree attendants has been very positive, with many appreciating the effectiveness of our approach to tutorials and examples. We often receive positive comments on the good accessibility of experts and the easy communications.

As the number of short- and long-term visitors increased, improvements in the meeting infrastructure, such as the video and phone conferencing equipment as well as slide projectors were made. Increasingly, it became clear that the original location of the ANL ASC was barely adequate for the number of visitors. In order to have room for expansion, and to improve the proximity of the ANL ATLAS members to the Center, in early 2009 we seized the opportunity to move the majority of the ANL ATLAS group to a new area on the second floor of Bld. 360, adjoining to, and connected with an indoor walkway with Bld. 362 which houses the rest of the HEP division (figure 7).

Fig. 7, (Left) shows a session during one of the Jamborees in 2008; (Right) is the new conference room for ANL ASC for 2009.

The new area has a large conference room, comfortably seating 40, which is suitable for Jamborees as well as a smaller room seating 12. Both rooms are equipped for Video Conferencing (VC). We are exploring the possibility to upgrade the VC facilities, particularly for the larger room for better large scale interactions with other ASC sites during joint Jamborees. The offices of the ANL ATLAS members are now in one area which adjoins the conference rooms which vastly improves interactions within the ANL group, with long-term visitors, and with the Jamboree attendants. The area also has four guest offices which are used by regular visitors from NIU, Michigan State and Duke as well as Jamboree attendants and other short term visitors. The area also has possibilities for expansion for both additional offices and collaborative areas.

As a part of enabling US ATLAS physics analysis, we have developed an innovative low-cost computer cluster to process ATLAS data locally. The design exploits the relatively recent availability of commodity TB sized disks and multicore CPUs to build a system which is capable of processing ~10 TB of Analysis Object Data (corresponding to ~10 fb^{-1} of data for a typical analysis) overnight. A dedicated software package was developed for data upload, submission and job retrieval to the cluster. We believe that this system has the potential to vastly increase the analysis capabilities of US ATLAS universities. The system has now been recommended as one of the template Tier-3 setups by US ATLAS. The Analysis Facility being built at BNL, for example, is planning to use a system which combines the ANL ASC type cluster with xrootd and PROOF. We have been requested by US ATLAS to set up a how-to website for Tier-3s. ANL ASC will host the first meeting to organize the setting up of Tier-3s for US ATLAS in mid May.

Beyond the Jamborees, the ANL ASC has hosted, and hosts, a number of non-ANL physicists for longer terms; during 2008, two PhD students from NIU, then new to ATLAS, studied at the Center, for one year prior to their departure to CERN. With the ANL HEP members providing guidance, the students participated in analysis of TileCal commissioning data as well as remote, and long-term monitoring. There have been short–term visitors from Toronto and SMU. Currently, there are regular visitors from Duke, NIU and MSU at the Center. The long-term visitor program is an aspect of ASC we hope to increase in the future.

Physics & Detector Performance Studies

With the completion of construction activities and with the (then-expected) first collisions in 2008, Argonne physicists significantly increased their participation in ATLAS physics and performance studies over the last three years. We have held to a few main criteria for the areas in which we have applied our efforts and chosen areas which: take advantage of the detectors we constructed for ATLAS; build on our expertise from other experiments and can have a significant impact on ATLAS physics; are important in establishing expertise with software and analysis tools which can be applied and transferred to others at the Analysis Support center; and lead to early physics. Therefore we have chosen to direct our efforts towards physics with jets and photons: jet energy calibration and optimization of the energy resolution through cell weighting; QCD production of prompt photons; jet trigger studies as well as the development of a muon trigger based on the signals in the outer layer of the tile calorimeter; and exotic processes involving jets. In performing these studies we have contributed analysis and ATLAS internal notes to the Computing Simulation Challenge (and the so-called CSC Book) and to the ATLAS Full Dress Rehearsal. In addition, Argonne hosted a US-ATLAS Standard Model analysis forum meeting in Jan. 2007.

Members of the Argonne group substantially increased their involvement in the ATLAS JetEtMiss Combined Performance group starting in 2005, with the objective of contributing to jet calibration. The ATLAS calorimeter is a finely segmented non-compensating calorimeter and it is crucial for software compensation to be applied to the raw detector signals to obtain the best energy resolution and linearity. The approach that we have developed built on earlier work by collaborators at BNL and the University of Chicago and entails using calorimeter cell energy density as obtained from Monte Carlo simulation of QCD dijet events to optimize the calorimeter energy resolution for jets (this is commonly referred to as the H1 method as it is similar to that developed by the H1 collaboration at HERA). The Monte Carlo is then used to obtain an overall energy dependent scale shift using a variety of numerical methods. In this period we have studied the impact of using different levels of calorimeter granularity in which to bin the weights, the numerical approach used to determine the final energy scale and the use of weighting by layers rather than cells to optimize the resolution (as this is the only granularity of information available to analysis data – the so-called "AOD".) These studies were originally carried out using Athena release 12, which was the basis of the results which are documented in the CSC Book and repeated using Athena Release 14. In the repeat of these studies in Athena Release 14, we re-wrote significant sections of the code to allow the use of finer levels of cell granularity and developed a new code structure for the determination of the weights and application of the weights in event reconstruction. This code is now fully integrated in CVS in the next ATLAS release (15) which is anticipated to become the release for first physics analysis.

An example of the improvement in resolution obtained by the H1 approach is shown in figure 8, where we can see the significant improvement in resolution and linearity, admittedly only in the Monte Carlo, obtained using the weighted cell energies relative to the raw energy (calibrated in the testbeam to be at the electromagnetic scale). In preparation for first data, the software was written in a way in which we can readily compare important response characteristics, such as the longitudinal and lateral shower profile, to those obtained in physics data. In addition to this primary study, members of the group studied the dependence of the jet response on electromagnetic energy fraction with a particular view to optimizing the energy resolution for jets with high transverse momentum. This is motivated by our studies of the jet inclusive energy spectrum and di-jet mass distribution for signatures of physics beyond the Standard Model. In addition, we have performed simulation studies of Z/gamma + jets both as a means to understand the physics model dependence on boson-jet balancing and as intrinsic QCD physics studies. Two members of the group provide operations support to the JetEtMiss combined performance group (one is one of the lead software developers for jet calibration, and the second co-leads the task force assigned to prepare the path to jet calibration with first data, and is MC production and CAF disk space manager) and one staff physicist is presently co-convener of the ATLAS JetEtMiss combined performance group. The number of group members contributing to this activity has steadily increased and we now have 2 staff physicists, and 2 post doctoral fellows participating.

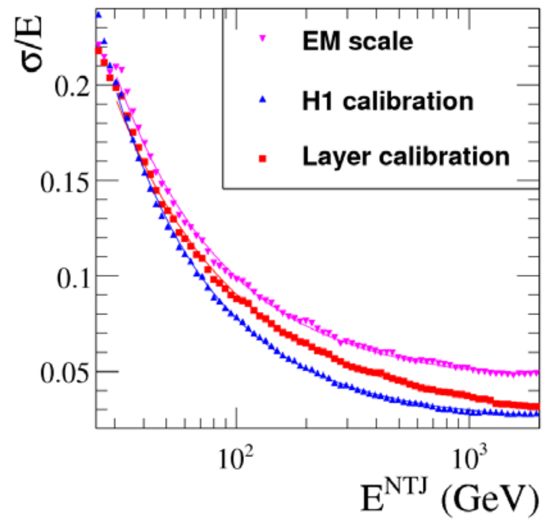


Fig. 8, jet energy resolution for the raw energy scale and two calibration algorithms

Three staff physicists in the group are making significant contribution to studies of prompt photon production in preparation for physics with first data. The rate of background events originating from decays of mesons contributing to direct photon measurements was studied. For the first time, we have studied the background rate as a function of photon isolation-cone radius from 0.2 to 0.6 for PYTHIA and HERWIG Monte Carlo models. We have developed an alternative background filter which allowed us to study the background rate up to 1 TeV. This scale is one order of magnitude higher than that studied previously at ATLAS. The estimated background rate ranges from 42% (with the cone isolation 0.2) to 14% (with the cone isolation 0.6) for p_t(gamma)>25 GeV and the standard ATLAS Monte Carlo simulation. Detector acceptance corrections for typical selection cuts and different cone isolations were calculated. The results were presented during E-Gamma and Direct-Photon Meetings and reported in an ATLAS internal note. In addition, we have investigated a Monte Carlo independent method for background calculations using Z->e^+e^- gamma radiative events as a clean source of photons. We estimate that in an integrated luminosity of 200pb^{-1} about 200 photons from 3-body decays of Z-bosons can be resolved. In performing these studies, analysis software and several analysis tools were developed and have been used as examples in our tutorials at the ASC. Similarly we have used grid computing to access large datasets and this experience has similarly contributed to the tutorials.

As part of their performance studies, Argonne physicists are developing tools for event selection in collaboration with the core software group. One relatively novel way of selecting events is through a "tag database". This allows selecting events not just by run and event number, as done traditionally, but by certain characteristics of the event: for example, a search for top quarks could ask for events with at least one electron, at least one muon, exactly two jets and significant p_t. This tool has also proven to be valuable in the commissioning of the detector, especially with cosmic rays.

Two members of our group have (and are continuing to have) significant roles in the overall leadership of ATLAS towards first physics. From 10/2006 – 10/2008 LeCompte served as co-convener of the ATLAS Standard Model physics group. From 10/2007 and continuing until 10/2009 Proudfoot serves as co-convener of the ATLAS JetEtMiss. LeCompte was appointed ATLAS Deputy Physics Coordinator in 10/2008 and will become Physics Coordinator in 7/2009, continuing until 10/2010.

Upgrades

Upgrade planning for ATLAS began formally with the appointment of an Upgrade Steering Group in 2004. Argonne's systems TileCal and TDAQ were represented and did general planning for the possible scope of an upgrade, but the early work of the Upgrade Steering Group was strongly focused on the replacement of the Inner Detector or tracking system for ATLAS. At the present time, upgrades to the LHC and ATLAS are identified in two phases: I) $L = 3 \times 10^{34}$ cm^{-2} sec^{-1} with installation in 2014; and II) $L = 10^{35}$ cm^{-2} sec^{-1} with installation from late 2017 to early 2019.

Focused planning for an upgrade of TileCal was initiated in late 2007 by Argonne physicist L. Price, who organized and chaired a workshop on TileCal upgrade requirements which was held in February 2008. Following the workshop, the TileCal Project Leader appointed an Upgrade Steering Group (USG) for TileCal of three people including Price. This group led the TileCal organization in the writing of an Expression of Interest, submitted to ATLAS in May 2008, which concluded that virtually all TileCal electronics will need to be replaced. The Tile USG, later expanded to four people, organized further Tile Upgrade meetings and took the leadership in a seminal joint upgrade workshop among TileCal, LAr, and the L1 Calorimeter Trigger (L1Calo) with which both calorimeter triggers must interact. They have since led TileCal in the writing of a proposal for needed Upgrade R&D.

Argonne has centered its interest and early work on the coupled subsystems of readout electronics in the drawers and the upgraded LVPS system. We are working closely with the University of Chicago, as we did on the current Tile Calorimeter for ATLAS. Argonne has taken the lead in specification of an ASIC for use in signal shaping, amplification, calibration, and digitization. Argonne engineer G. Drake gave a detailed systems overview presentation at the February 2009 ATLAS Upgrade Week emphasizing the ways in which the different components of the readout must be designed to work together.

Work at Argonne on the TDAQ upgrade is presently focused on the L1 Calorimeter Trigger. For phase I some minor modifications of the existing system would allow for the option of passing additional cluster data. This could permit topological decisions which require more than just counts of objects above thresholds. There could then be mass or exclusive object cuts (e.g. a high E_T electron and a jet that does not correspond to the electron). Some exploration of what trigger changes at Level 1 would preserve useful signatures but reduce rates has begun. For phase II the possibility of reading out and digitizing the calorimeter data at 40MHz is being explored and this makes more detailed information like depth segmentation usable at Level 1. Some work has already begun on what would be needed for front end electronics to achieve this for TileCal. For phase II TDAQ will have an opportunity to improve or modernize portions of the system. The RoIB will need to move to more current technology or an alternative to the RoI driven approach at Level 2 will need to be developed.

ATLAS – Research Plan: June 2009 – June 2012

Overview:

The ATLAS group has completed the transition from detector construction to operations and physics at the energy frontier at the LHC. Several individuals joined from other experimental groups in the Division (CDF and ZEUS primarily) and have now established themselves within detector operations and physics and performance groups. We have two post doctoral fellows, who have taken significant responsibilities within an ATLAS combined performance group, the co-convener of the ATLAS JetEtMiss Combined Performance group and the ATLAS Deputy Physics Coordinator are also from Argonne. The group is therefore strong and we are excited at the prospect of beginning the physics studies that we have so long anticipated. These data will be the first chance to study the detector performance in a range of beam conditions from which we will begin the groundwork to establish systematic uncertainties on the precision with which we can measure leptons, photons, jets and missing transverse energy. There will be data taken at several beam energies and these will allow us to carry out some unique tests of QCD. Moreover, most importantly, based on studies carried out early in 2009, despite the reduced beam energy, we will begin to challenge the bounds of the Standard Model (ATL-COM-PHYS-2009-069).

We will continue our strong commitment to commissioning tasks into the operations era and to this end plan to increase the number of staff stationed at CERN from presently 2, to 4 (this number has reached 5 at times during the commissioning period). We will hire a replacement for a postdoctoral fellow resident at CERN who recently completed her appointment and also plan to station one additional senior physicist at CERN. Both of these individuals will be expected to play significant roles in tile calorimeter and/or trigger and data acquisition operations. In addition, several staff members who are based at Argonne will spend extended periods at CERN, taking significant operations roles which can be accomplished by being resident for periods of order 4 weeks or more. Finally, where possible we will take on operations tasks which can be carried out remotely using remote operations system we have constructed at Argonne, and data processing, monitoring and software validation tasks. As one element of our contribution to detector monitoring we will significantly increase the level of effort devoted to analysis of cosmic ray data taken in the ATLAS cavern. This will be used both to monitor detector performance when the cavern is closed and to study the effect of maintenance work carried out during shutdown periods. In addition, these data will be used to connect and compare signals recorded in the tile calorimeter with those in the trigger and to perform such tasks as providing an alignment of the tile calorimeter modules to the tracking system. A goal in performing this work is to establish a detector performance baseline so that tests which are done manually at the present time can become automated in the future.

We have established a strong presence both in physics and performance groups and plan to contribute to several of the early physics analyses as well as in performance studies within the photon and jet combined performance groups. One immediate task will be to compare jets in data with those in the simulation to determine the systematic uncertainties on the jet energy scale and for use in tuning the simulation. The software structure to do this has been put in place and can be exercised as soon as first data arrive. Our physics analysis efforts will contribute to the overall effort of the Analysis Support Center, where we expect to build an analysis support force of sufficient depth to cover all issues from software development and use, to data access and efficient data processing and finally to the organization of analysis tasks to result in physics papers. The Analysis Center itself will become a central element in the successful exploitation of ATLAS data by physicists in the U.S.

The next three years will see an increasing deployment of technical and scientific effort towards Phase I and Phase II upgrades of the ATLAS detector for the sLHC. We have at present several areas of opportunity and in the next three years it will be essential to win support for those that are to be adopted in the upgraded detector. At the present time it is difficult to foresee exactly what will happen but we have confidence that our initiatives will be supported by US-ATLAS and that we will complete R&D on them and follow this with contributions to construction, installation and operations. A small group at Fermilab is considering participation in ATLAS – contributing to parts of the upgrades. We are supportive of this initiative and have agreed that once their plans are clearer they can begin to participate in ATLAS through becoming and institute within an Argonne institution as was done for the group at Northern Illinois University.

More details on the above goals and plans for detector operations and upgrades are given below.

Tile Calorimeter

As a leading institution in the building and commissioning of the ATLAS Tile Calorimeter (TileCal), Argonne has also taken responsibility for important aspects of the operation of the calorimeter. ATLAS is now expected to start taking data with LHC collisions during 2009. The coming three years will therefore include the first running and data taking period, expected to last close to a year. Although much experience has been gained in the several exercises and with cosmic rays, still we have to expect much to be learned from real data.

By the end of the first running period, perhaps late in 2010, we should have established a routine for operation, including monitoring and tuning of the hardware and a set of criteria to ensure the best physics performance of the calorimeter. When the detector is shut down and opened for maintenance late in 2011, there will be a period of a few months when repair and testing work are again the major focus of work on TileCal. As LHC operation and ATLAS data taking resume in 2011, we should be entering a relatively steady cycle of beam operations and maintenance shutdowns, perhaps on an annual schedule that will continue at least to the installation of Phase I upgrade components in 2014. Although the annual cycle of collisions and maintenance may become routine, the luminosity will be increasing steadily, first up to the design luminosity of 10^{34} cm^{-2} sec^{-1}, but then continuing to 3×10^{34} cm^{-2} sec^{-1} as the injector accelerator chain is upgraded. Thus we will need to track the performance of the calorimeter with the increasing luminosity and determine what changes in operation (or possibly in hardware) will be indicated.

Argonne physicists and other personnel will continue to play central roles in the ongoing operation of the calorimeter. These will include the more routine responsibilities of taking shifts at CERN in operating and monitoring the performance of the calorimeter as well as from the remote monitoring station that we have established at Argonne. Specific activities and responsibilities for Argonne in TileCal operations include

- *Diagnostics and maintenance of the low voltage power supply system (LVPS).* A test stand for the main printed circuit boards (bricks) comprising the LVPS boxes is operational at Argonne and will be improved during the next several months. It will be used to diagnose and repair bricks that have malfunctioned and have been sent to Argonne for repair. In addition, Argonne has shared responsibility for the LVPS test stations at CERN and will work to keep these operational and upgraded as needed to meet the needs identified for testing and validating the LVPS boxes and circuit boards.

- *Replacement LVPS.* Argonne is currently developing a design for bricks to replace those currently in the LVPS system if that should be judged necessary. As described in the progress report section of this submission, Argonne managed the development of *ad hoc* modifications to the LVPS bricks and other PCBs after they had been built by other TileCal collaborators. Although the system has performed well in the relatively short period of "operations" so far, there is concern that the modified boards may not have the reliability needed for the next several years of operations. This design will be completed during the coming year and a judgment will then be made by TileCal as a whole whether to proceed with construction of the replacement system.

- *Maintenance and improvement of database systems for the Tile Calorimeter.* Argonne personnel will continue to support dedicated databases which we have developed for tracking the operation and status of important parts of the Tile Calorimeter as well as the software to compute and enter attributes into them. The latter includes calculating and filling the conditions database with constants needed for the initialization of the online data taking system. It also includes general systems for providing those doing offline analysis with access to conditions data through channel and subsystem status flags, which are an important connection between the conditions database contents and the operational tracking databases.

- *Maintenance and improvement of operational software for the Tile Calorimeter.* This area includes online and calibration software.

- *Testing and repair of drawer electronics.* Argonne physicist and technical staff will continue to support the Calibration and Test Facility, which is an operating "slice" of the calorimeter now being established in Building 175 at CERN. This will be the focus of hardware evaluation and development while ATLAS is operating and the base of operations during detector maintenance periods.

- *Control room operating shifts.*

- *Data quality monitoring.* This is an active ongoing part of Argonne's leadership in the Tile Calorimeter. We have led and participated in many aspects of calorimeter monitoring and evaluation, including the development of dedicated tools for ongoing tracking, both during the commissioning period and during the initial "operating" period. Work is this area has been and will be done both at CERN and remotely using our remote monitoring station and other (generally web based) tools.

- *General mechanical support of Tilecal operations, including opening and closing operations of the detector endcaps.* Argonne played a central role in the control system for the ATLAS moving system. We expect to participate as needed (consulting and or presence) when the detector is opened and closed.

<u>High Level Trigger</u>

ANL has been a contributor to the ATLAS Trigger and Data Acquisition (TDAQ) team for many years and this will continue. ANL has had a member in the TDAQ coordination group since its inception, and ANL staff have provided coordination of run time operations during the commissioning phase. Runtime operation and coordination by Argonne staff will continue throughout the data taking phase of the experiment.

Besides supporting systems built by Argonne, including the Region of Interest Builder (RoIB) and Level 2 Supervisor (L2SV), members of the Argonne group are playing important roles in ATLAS TDAQ system wide operation and support. We have a member in the TDAQ operation team to commission the TDAQ system, to oversee the daily TDAQ system operation, to carry the DAQ/High Level Trigger (HLT) expert-on-call phone, to provide TDAQ expert support for the whole ATLAS collaboration, to help detectors to integrate and debug, and to train DAQ/HLT run control shifters. We will continue to provide significant manpower in these areas, and seek to take even higher leadership positions associated with ATLAS Control Room Operations.

<u>TDAQ Software</u>

We will continue to provide significant effort in software development and implementation in response to both anticipated and unanticipated needs of the hardware for which we are responsible. During the commissioning phase a number of issues were addressed as part of normal evolution and improvement as well as those resulting from changes in the TDAQ software infrastructure. These included changes in the L2SV software to accommodate both added functionality and better error handling as the understanding of possible failure modes increased with experience. Such software maintenance and development will continue and in particular we expect that much of this development will be in reaction to circumstances that are only present during actual data taking and were not made apparent by cosmic ray and commissioning exercises.

The standard operating system (OS) used throughout the TDAQ system for data taking will be 64 bit Scientific Linux (CERN) 5 (SLC5). This is not the OS used by the L2SV's as there is no tested driver for that OS for the CERN FILAR card that reads the RoIB output. It is likely that there will be a need to unify operating systems throughout the TDAQ system and migrate from the current 32 bit OS to 64 bits for the L2SV. This unification will require substantial review of the buffer management to ensure that all of the software which uses the hardware buffers operates correctly after this change. It will also require testing to ensure that the new FILAR driver operates properly with a 64 bit kernel.

The changes in standards associated with monitoring, message handling and error reporting will require maintenance as the frameworks are altered to deal with runtime problems. During the next three years there may be OS upgrades needed to support more modern hardware (for example as additional systems are added). This will require testing of the online software and its modification to adapt to and perhaps benefit from improved network performance or memory and CPU usage.

The regular software release cycle will be followed and we will keep the associated software for the RoIB and L2SV updated for every new release. We will implement new features when needed and continue optimizing the performance of the software. When a major architecture change does occur, we will participate in the design and implementation.

We will improve and maintain the Tile calorimeter based muon trigger algorithm. We will advocate for it to become a standard algorithm to identify low Pt muons as well as a vital tool to confirm the muon detector based algorithm in case of unexpectedly high cavern background.

Level 1 Calorimeter trigger operations

As one of the initiatives to continue significant contribution to the ATLAS trigger and data acquisition system, we recently joined the Level-1 Calorimeter Trigger (L1CALO) group. We will be involved in system commissioning, calibration, monitoring, measuring and analyzing the trigger performance, and tuning the simulation to the measured detector behavior, as well as L1CALO and trigger shift tasks as summarized below.

The L1CALO trigger system has been fully installed and long integration runs will be performed regularly to record cosmic data for detailed comparison with the calorimeter readout and assessment of the system stability. The L1Calo group has developed some programs that use the TDAQ framework to monitor the operation of L1CALO subsystems and of the whole trigger chain. These programs provide a large number of histograms for experts to debug problems and a set of summary histograms for the shifters to monitor the behavior of the system. We will contribute effort to optimizing and improving the robustness of this monitoring environment, to timing of the trigger system using cosmic rays and pulsars and to the optimization of the software which monitors detector effects affecting trigger rates and efficiency. Prompt efficiency measurement will give quick feedback on a daily or run by run basis. Identifying changes in efficiency, either globally or in regions of the detector, will lead to diagnostic and corrective action.

It is unlikely that simulation will provide an accurate description of the detectors and trigger system at the early stage of data taking. Significant work will be done to tune the simulation to the measured detector behavior and to validate the model. We will become familiar with the low level simulation software of L1CALO and start to use and improve it, concentrating on detailed studies of critical low level quantities such as threshold response, tower energy etc. These studies will impact physics analysis and trigger performance evaluation, in addition to inspiring new ideas for trigger improvements in the future.

Argonne ATLAS Analysis Support Center

It is widely recognized that data analysis at the LHC experiments cannot proceed in the manner of the experiments of the last generation — i.e. centralized at the host laboratory. Thus analysis centers, where a significant community of ATLAS experimenters can form outside of CERN, have been established by USATLAS. The ANL Analysis Support Center (ASC) has been designated as one of the three analysis support centers for the ATLAS experiment, along with BNL and LBNL. These locations are already centers for US physics activities and will become even more important once data arrives.

This is a unique opportunity for ANL HEP to serve the US HEP community as a premier LHC physics center and is a major component of the strategic vision of HEP at ANL. There are currently 42 US institutes in the ATLAS collaboration, with about 500 physicists and students. Of these, currently about 100 are stationed full-time at CERN. In the coming year, as the LHC turns on, the number of experimenters at CERN will increase; however, it is clear that the larger contingent of US experimenters will remain based at their home institutes. For Argonne, nearby institutes include: Chicago, UIUC, NIU, Iowa State, Indiana, Ohio State, Michigan, Michigan State and Wisconsin. The ANL ASC has a strong potential to have a wider reach and has already hosted people from as far away as Duke, SMU, Oklahoma, Arizona and UT Dallas. Therefore, in general terms, a future ANL ATLAS center could serve 50 to 100 ATLAS physicists as users, and host 10-20 physicists as visitors at any given time. Our strategic vision is a vibrant HEP center at which university faculty, Argonne staff, postdoctoral scientists and graduate students work intensively together.

In order to enhance the benefits of the Argonne ASC, we plan to proceed with many initiatives, many of which are already underway:

- *General infrastructure improvement.* We will continue the improvement of hosting infrastructure including office space and video conferencing equipment for collaboration with USATLAS members as well as with the wider US HEP community. This began with our move in early 2009 from office and meeting space distributed through Building 362 into contiguous office and meeting space in Building 360. A larger portion of Bldg. 360 will become available in late summer 2009. We are evaluating options and will install a high-quality videoconferencing system that takes advantage of the existing IP infrastructure for real-time meetings.

- *Computing improvement.* We have had significant impact on the ideas behind, and the implementation of, Tier-3 computing for ATLAS. We will continue to contribute strongly to this effort and to establishing Tier-3 computing facilities at ATLAS Universities. Long-term support of Tier-3 computing for US ATLAS can be based at ANL, if sufficient manpower becomes available.

  We will build and manage a full-scale cluster which is suitable as a university system and which does not require file storage nodes, interconnect fabric and a dedicated computer room with cooling. A prototype for such cluster with 24 cores for data staging and processing has already been constructed at the Argonne ASC and was recently identified by US ATLAS as a model for a Tier3-type computer cluster (T3g). We will expand this prototype to a full-scale cluster with 80 cores and 20TB of file storage which will be used as a template for low-cost clusters to be deployed by Tier3 centers. Our objective is to gain experience with a full scale T3g cluster, document it and then provide our expertise to US ATLAS collaborators who wish to set up their own system. In addition, we will investigate funding opportunities to build a dedicated computer room to host Tier3 clusters from the mid-West universities if desired.

  We are also pursuing opportunities that may transform the effectiveness of the LHC physics center at ANL. One proposal targets the question of how to use pre-eminent Argonne computing facilities based on the BlueGene/P system for ATLAS analysis, and a second focuses on the input/output infrastructure for event processing on exascale supercomputers.

- *Increase the number of ASC participants and cooperation with other universities.* We are exploring ways to increase the number of scientists and students who are long-term visitors at ANL ASC. In the past two years we have hosted 3 graduate students at the center (two from Northern Illinois University and one from Michigan State University). Two of these students recently moved to CERN and their ability to rapidly integrate into the Tile Calorimeter team effort was a direct result of the time spent at Argonne and the opportunity to work on software and monitoring tasks while completing their course work. We are advancing possibilities to offer laboratory graduate fellowships that sponsor students in programs at ATLAS Universities, to come and work at the ANL ASC. In addition, we are looking for opportunities to establish a visitor's program for faculty members and post-docs with shared physics interest. The goal for FY 2010 is to at least double the number of long-term visitors from the current level of ~5 to more than 10 and to maintain this level for subsequent years.

  We aim to further increase cooperation with the University of Chicago ATLAS group which consists of over 20 scientists, programmers and engineers. The ANL ASC already has a close working relationship with the Midwest Tier-2 which is operated by the University of Chicago together with Indiana University and we will further strengthen this as we better understand the needs for data access. We will also continue to foster strong collaboration with the BNL and LBNL ASCs, as this will be an important part of the overall development of ATLAS analysis strategy. The building of a unified strategy among the ASCs will become increasingly important for a strong US ATLAS physics program.

  The ANL Theory Group has several members whose research will be tested at the LHC and who will provide theoretical insight and guidance to the ATLAS community. At our workshops, we are already holding joint sessions for ATLAS and Theory meetings, and plan to continue this into the future.

- *Workshops.* The ATLAS analysis workshops ("Jamborees") will continue to be held at regular intervals. The emphasis will evolve from working on the technical characteristics of the ATLAS analysis environment to working on physics analysis. Depending on developments, the Jamborees will likely evolve into several different types of meetings: pedagogical sessions designed to introduce new-comers to the ATLAS environment; focused meetings for particular physics topics; meetings with general themes where communications among the different groups in ATLAS will be promoted.

From past experience with general HEP collider experiments, we can anticipate that the ATLAS experiment, after an initial startup period, will have more than 50 ongoing physics analyses per year which will lead to refereed publications. This implies that, to make an impact on the LHC physics output commensurate with the size of such a center, the ANL ASC should ultimately be the base for at least 5 working analysis teams at any given time. Examples of topics for analysis teams include searches for Higgs, supersymmetry, extra dimensions, dark matter, as well as Standard Model cross-section analyses such as high Pt jets, and Z and W production. These topics match well the interests of the Argonne group and it is our expectation that our own physics interests will provide the nucleus of the activities that cause these groups to form.

The main objective at the ANL ASC over the next twelve months will be the successful formation of both technical and collaborative infrastructure to support 1 or 2 analysis teams (with both ANL and non-ANL members). These should produce at least one analysis recognized by the international ATLAS collaboration within a reasonably short time after the first LHC data becomes available. What represents a "reasonably short time" will depend strongly on many external circumstances, but one may imagine that this may be ~6 months after taking first data. We aim to host 10-20 regular visitors in this period. In FY2012 and 2013, this user base should grow to 20-30 with at least 3 analysis teams based at the ANL ASC; at this stage, several ATLAS physics papers are produced with significant contributions resulting from the work of these teams. By FY2012, the mode of operation of the center should also be clear, and a desire by the ATLAS community for the expansion of the ANL ASC should be apparent.

Physics & Detector Performance Studies

The work that was accomplished in the preceding three years sets the direction for the physics analysis of the Argonne group: it will be the physics of jets and photons; it will encompass Standard Model measurements of cross sections and kinematics; it includes searches for signatures of physics beyond the standard model. At 10TeV center-of-mass energy, the modest integrated luminosity of $50pb^{-1}$ provides large event samples for analysis: ~400,000 J/Psi decays to di-muons; ~20 000 Z decays to electron pairs; ~700 top events detected in the lepton + jets channel. Therefore, Standard Model physics can begin immediately and search physics can start in some jet channels. It is reasonable to expect that over the next three years we may accumulate in excess of $10fb^{-1}$ in this timeframe and that in 2012 we are in the heart of the discovery program of the LHC.

A key task in the development of Monte Carlo based calibration of jets is to compare the results of simulation to those observed in the detector in physics processes which are considered to be well understood. We will take on the task of performing this work in the context of the cell energy density calorimeter cell weights, which are at present the default approach, as well as for a scheme which we believe will work well for ATLAS in the future – layer based jet corrections. This task will require comparisons between data and Monte Carlo of jet energy density as a function of eta, phi, jet transverse momentum, a number of track-based features as well jet selection criteria. Tools to facilitate this effort are already in place and will be applied and extended once first data tell us what features are most important. From the observed differences we will construct smearing schemes from which we can establish initial ranges for the validity of the correction weights and thereby establish the systematic uncertainty in the jet energy scale. In addition, we will carry out generator-level studies of biases associated with jet and physics process selection – anticipating here that the underlying physics need not be accurately predicted by Monte Carlos tuned for lower center of mass energies.

W and Z boson production in association with jets is one of the key benchmark physics processes - perhaps the benchmark physics process – at the LHC. The detection of these bosons is intrinsic to much of the search physics of the LHC; the signatures of these processes are well defined and have controllable backgrounds; and QCD predictions are thought to be robust such that their production rate can be used as a measure of luminosity. An effort within ATLAS and the JetEtMiss Combined Performance group is now taking shape to establish software and analysis tools to use these processes to benchmark the energy scales for jets and missing transverse energy, and in fact these processes provide a way to ensure that both jets and missing transverse energy are on the same energy scale. Members of the Argonne group have considerable expertise in the physics and measurement of W and Z bosons and our intent is to contribute significantly to these measurements. In performing these energy scale studies, in addition to cross-section measurements, it is natural that we will also analyze jet production and W/Z boson and jet kinematics, which will lead to some of the early physics papers of ATLAS. We can further explore QCD phenomenology by taking advantage of the different beam energies at which the LHC is expected to operate in the first two years.

A second important QCD measurement in the early data-taking period of ATLAS is the QCD production of two prompt photons. This is an important measurement in its own right and is also a major background to the search for Higgs production. Members of our group have already established signal and background studies based on simulation. They are also experienced in prompt photon measurement at colliders (both HERA and the Tevatron) and have sound plans to determine signal and background rates using data-driven observables such as energy isolation and shower profile. QCD two-photon production is expected to be an early physics result of ATLAS, and one which can also take advantage of the different beam energies planned for LHC startup. It is also a process which will have a key role in trigger and event filter algorithm development to ensure efficient detection for the Higgs boson in the two-photon decay channel. These studies will also play a role in our upgrade planning exercises where a central theme is the use of topological information to improve the use of trigger bandwidth.

We have established a role in commissioning a software filter in the High Level Trigger which allows the use of stiff tracks which do not trigger the muon trigger to be an element of the di-muon trigger in the ATLAS High Level Trigger. Based on our experience in prior experiments such a trigger can provide improved trigger efficiency for events in which the signature is a pair of muons (such as from WW or

J/Psi). We also expect that this trigger can provide improved samples of B mesons, relative to what may be obtained from the standard di-muon trigger by extending the Pt reach to lower values. This type of HLT trigger will be especially effective in early data when pileup effects are small. It is also likely that at higher luminosities this additional filter may be necessary to maximize the rate at which W bosons can be triggered inclusively, by allowing additional selection criteria to be applied to the event selection at an earlier trigger stage. More generally, this will provide a context in which to evaluate the effectiveness of topological triggers such as are being pursued for the incremental improvements in the ATLAS trigger with increasing luminosity.

The LHC is of course a search machine and it would not be possible for any serious group to not participate in the excitement of the search for expected new physics (electroweak symmetry breaking) or in searches for physics beyond the standard model. The Higgs boson may appear in our studies of two-photon production. However, our main thrust for the early running period is to explore searches for new physics involving jets, as these will likely be produced at sufficient rates to be detectable at the lower beam energy and integrated luminosities of this first data-taking run. Therefore, we will analyze di-jet mass distributions and jet Pt distributions for deviations from standard model predictions (a task which is crucially dependent on a precise understanding of the uncertainties in the jet energy scale and resolution). t-tbar resonances are also important signatures and ones which we will investigate; we will develop analysis packages with early data and these will then allow rapid updates of physics plots as ATLAS accumulates integrated luminosity. The hadronically decaying W in t-tbar decays is also an important cross check of our jet energy calibration.

Upgrades

Planning for an upgrade of ATLAS for operation when the LHC luminosity is increased to 10^{35} cm^{-2} sec^{-1} (now planned for installation starting in the fall of 2017) is an increasingly prominent activity for Argonne. As detailed above, there is still much to be done to achieve smooth data taking with the current ATLAS detector and to harvest the rich physics results. However, the planned window for upgrade installation is only 8 years away, considerably less time than was taken to design and build the current detector. So we must be working, and even with some urgency, on the upgrade. We are exploring avenues in which we can participate in the major tracking upgrade for ATLAS. In the last few months we have begun a modest effort, in collaboration with Northern Illinois University, to contribute software to tracking system simulation codes: layout of the endcap pixel disks; signal digitization, and an accurate simulation of inert material (such as from services). In addition, we will develop tools for tracking studies with which to assess the performance of different layouts. Our plans for our participation in upgrades for the Tile Calorimeter as well as TDAQ are more advanced and described below.

TileCal Upgrade

TileCal has concluded that essentially all electronics must be replaced for the upgrade, while the calorimeter structure, optical elements, and (importantly for cost) photomultiplier tubes will not need to be replaced. The focus for the very immediate future is the completion of an R&D proposal for Tilecal. The expected time table after that is as follows:

- Organization within TileCal for sharing of R&D activities: through 2009
- ATLAS Expression of Interest Document: late 2009
- Performance of R&D program, including first-round prototyping and radiation testing of important components and subassemblies: FY 2010 – 2012
- ATLAS Technical Proposal: late 2010
- ATLAS Technical Design Report: late 2011
- Final design, prototypes, and system-level testing: FY 2013-4
- Series production and testing: FY 2015-7
- Installation: FY 2018-9

Argonne has been providing the overall leadership for TileCal upgrade planning in both management and planning, and in system engineering. The latter area is receiving special attention now, in order to be sure that the different parts of the TileCal electronics are designed and built as an integrated system in spite of necessarily having work done by many different institutions. Argonne's technical interests in the upgraded TileCal electronics focus on the front end electronics, comprising the majority of the electronics that will be in the readout drawer, and in the closely linked low voltage power supply system. We are also interested in the back-end system, close to the L1 Calorimeter Trigger, because of potential synergies with our work on that system.

Most specific thinking so far has been done on the LVPS and front-end systems. We are continuing our TileCal partnership with the University of Chicago ATLAS group which has existed successfully from the beginning of both institutions' work on ATLAS. The two groups have been meeting frequently and regularly to develop ideas for the front end and power supplies. Work is already under way to compare a dedicated ASIC system with a more conventional discrete component system for the very front-end shaper/amplifier/integrator system. We are also pursuing together ways of simplifying the LVPS system and permitting important redundancy with fewer voltages by using point-of-load (POL) regulators locally on each board in the drawer.

As seen in the list above, work planned for the next three years will be largely in the R&D and preparatory area. At Argonne we will take full advantage of the strong electronics engineering group in the HEP division working together with ATLAS physicists. The greatest urgency, because of the lead time involved, is to make a first design and submission of the ASIC and be able to make a technology decision between the ASIC and discrete solutions for the very front end subsystem by the first part of FY 2011. In parallel, we will begin radiation testing of first components and then subassemblies. Also important in the early period is evaluation of common projects at CERN that we expect to make use of for POL regulators, and for optical links and control systems (GBT project). Early evaluation is important so that time remains in case we find that new designs will be required. By the end of this period, in FY 2012, not only should the major decisions about the designs have been made, but first-round prototypes should be available for extensive radiation testing. The major areas of work will be the following:

- Front-end Board ASIC and comparison with discrete component solution
- DAQ Interface Board and evaluation of number and resolution of ADCs
- Optical links to back end system
- Control and monitoring system
- Low voltage power supply and point of load regulators
- Radiation tolerance evaluation and testing
- Back end system and trigger interface

<u>RoIB upgrade and New Dataflow Architecture</u>

The current ATLAS RoIB is a custom interface to the ATLAS hardware and the commodity equipment. However, multiple high speed S-Link connections (a custom design by CERN) are used for both input and output serial data streams. Since the S-Link technology was designed quite a few years ago, review of the link technology is appropriate from the point of view of both support issues and technology limitation. Particularly the interface to the L2SVs (FILAR card) has reached a point where long term support will be a concern. The FILAR cards used to receive the level 1 data are PCI-X cards and the ability to upgrade the supervisors will be limited by the ability to accommodate this interface. We are planning to have a new design using up-to-date technology and with potentially different data being transferred with respect to the present L1CALO system, which itself will likely undergo a significant redesign.

We will start R&D with ATCA technology to reproduce the functionalities of the current RoIB as a baseline system, i.e., a simple replacement built in ATCA. Then we will design a new system to handle different data and interfaces according to possible upgrades of the LVL1 system, which may include the transfer of RoI data in addition to only RoI pointers (as is the case in the present system). We will explore the feasibility to perform full event building at LVL2 by aggregating such a system. A new DAQ software architecture to unify the current LVL2 and EF framework will be a natural consequence of this work, with members of our group taking leading roles in its design and implementation.

L1CALO Upgrade

The ATLAS upgrade of L1CALO will be needed in order to handle a luminosity which is the three times the present design luminosity. Because of the resource constraints, no major hardware change will happen at Level 1. To cope with the higher data rate, more sophisticated trigger algorithms, for example processing event features individually rather than just counting them, and using event topology, will be implemented with minimal additional hardware. We will identify the benchmark physics channels, generate large Monte Carlo samples with associated pileup according to high luminosity, then use them to examine the possible new trigger algorithms, such as exclusive triggers, angle φ and η correlations, isolated muons with CALO information, missing transverse energy improvement, transverse mass cut, etc. Our initial objective is to show the usefulness of these algorithms before the hardware implementation is considered (retaining high signal detection efficiency while achieving good background rejection)

The tenfold increase in luminosity planned for the sLHC will require a redesign of the whole L1CALO system, as part of the ATLAS phase II upgrade. We will initially focus on a physics driven Monte Carlo study for the high luminosity and identification of cutting-edge technology to handle the extremely high data taking rate, then approach system design and R&D with experience of collision data taking.

Talks at Major Conferences and Workshops

Hadron Calorimetry at the LHC, SLAC Summer Institute 2006, J. Proudfoot
QCD at the LHC, Helmholz Alliance workshop (DESY) 2008, T. LeCompte
The Standard Model, CTEQ Summer School 2008, T. LeCompte
Precision Electroweak Physics at the LHC, Aspen 2007, T. LeCompte
Early LHC Running, Pheno2007, T. LeCompte
Signals and Backgrounds for the LHC, CTEQ Summer School 2007, T. LeCompte
Issues in Perturbative QCD, Hard Probes 2006, T. LeCompte
Early LHC Physics, Loopfest 2006, T. LeCompte
Prompt photon production at the LHC, HERA-LHC meeting, DESY, 2007, S. Chekanov
Reconstruction of top-antitop invariant mass at the LHC using the all-hadronic decay channel, HERA-LHC workshop, DESY, 2007, S. Chekanov
Data analysis using jHEPWork, HERA-LHC meeting, DESY, 2007, S. Chekanov
Event Selection Services in ATLAS, CHEP 2009, J. Cranshaw

Broader Impact

Bob Stanek on 60 Minutes, http://www.cbsnews.com/video/watch/?id=4484053n
Tom LeCompte, Interview for New York Times, September 2008
Tom LeCompte, Interview for Popular Mechanics, September 2008
2 undergraduates have been hired for summer 2009
3 Graduate students stationed at the ASC for more than 1 year

ATLAS Notes

Report of the Event Tag Review and Recommendation Group / Assamagan, K A; Barberis, D; Bentvelsen, Stanislaus Cornelius Maria; Brooijmans, G; Cranmer, K; Cranshaw, J; Dell'Acqua, A; Farbin, A; Froidevaux, D; Gianotti, F et al.
Charge: - Review the current TAG definition. - Evaluate its suitability for analysis, looking at most relevant use cases, taking into account constraints from database and requirements from the computing model. [...]
ATL-SOFT-PUB-2006-002

Jet Energy Correction Using Longitudinal Weighting / Sen-Gupta, A; Merritt, F S; Proudfoot, J
Jet energy corrections based on layer-dependent cell weighting are shown to provide corrected jet energies which are linear to approximately 2% over the range 20 E 2000 GeV. Significant improvement in jet energy resolution is also obtained.
ATL-COM-PHYS-2006-062.- Geneva : CERN, 2006 – 20 p.

Data Streaming in ATLAS / Arguin, J -F; Binet, S; Cranshaw, J; Gadomski, S; Hawkings, R; Hinchliffe, I; Jones, R; Klous, S; LeCompte, T; Malon, D et al.
This report covers the work of the Data Streaming Study Group which took place in the first half of 2006, and part of the subsequent data streaming test. The baseline input, the studies, and results with the reasoning behind them are presented. [...]
ATL-GEN-INT-2007-002; ATL-COM-GEN-2007-004

The Production and Qualification of Scintillator Tiles for the ATLAS Hadronic Calorimeter / Abdallah, J; Adragna, P; Alexa, C; Alves, R; Amaral, P (CERN); Ananiev, A; Anderson, K; Andresen, X (CERN); Antonaki, A; Batusov, V et al. - ATLAS TileCal Collaboration.
The production of the scintillator tiles for the ATLAS Tile Calorimeter is presented. In addition to the manufacture and production, the properties of the tiles will be presented including light yield, uniformity and stability. [...]
ATL-TILECAL-PUB-2007-010; ATL-COM-TILECAL-2007-026.- Geneva : CERN, 2007 - 21 p.

The Production and Qualification of Scintillator Tiles for the ATLAS Hadronic Calorimeter / Abdallah, J; Adragna, P; Alexa, C; Alves, R; Amaral, P (CERN); Ananiev, A; Anderson, K; Andresen, X (CERN); Antonaki, A; Batusov, V et al. - ATLAS TileCal Collaboration.
The production of the scintillator tiles for the ATLAS Tile Calorimeter is presented. In addition to the manufacture and production, the properties of the tiles will be presented including light yield, uniformity and stability. [...]
ATL-TILECAL-PUB-2007-010; ATL-COM-TILECAL-2007-026.- Geneva : CERN, 2007 - 21 p.

The ATLAS Trigger : Commissioning with cosmic rays / Abolins, M; Achenbach, R; Adragna, P; Aielli, G; Aleksandrov, E; Aleksandrov, I; Aloisio, A; Alviggi, M G; Amorim, A; Anderson, K et al.
The ATLAS detector at CERN's LHC will be exposed to proton-proton collisions from beams crossing at 40 MHz. At the design luminosity there are roughly 23 collisions per bunch crossing. [...]
ATL-DAQ-CONF-2007-024; ATL-COM-DAQ-2007-029.- Geneva : CERN, 2008 - 12 p.   Access to fulltext; Access to fulltext - Published in : J. Phys.: Conf. Ser. 119 (2008) 022014
Presented at : International Conference on Computing in High Energy and Nuclear Physics

Implementation and Performance of the ATLAS Second Level Jet Trigger / Conde-Muíño, P; Aracena, I; Brelier, B; Cranmer, K; Delsart, P-A; Dufour, M-A; Eckweiler, S; Ferland, J; Idarraga, J; Johns, K et al.
ATLAS is one of the four major LHC experiments, designed to cover a wide range of physics topics. In order to cope with a rate of 40 MHz and 25 interactions per bunch crossing, the ATLAS trigger system is divided in three different levels. [...]
ATL-DAQ-CONF-2007-025; ATL-COM-DAQ-2007-028.- Geneva : CERN, 2007 - 7 p.

The ATLAS trigger - high-level trigger commissioning and operation during early data taking / Goncalo, R; Abolins, M; Achenbach, R; Adragna, P; Aielli, G; Aleksandrov, E; Aleksandrov, I; Aloisio, A; Alviggi, M G; Amorim, A et al.
The ATLAS experiment is one of the two general-purpose experiments due to start operation soon at the Large Hadron Collider (LHC). The LHC will collide protons at a centre of mass energy of 14~TeV, with a bunch-crossing rate of 40~MHz. [...]
ATL-DAQ-CONF-2007-032; ATL-COM-DAQ-2007-039.- Geneva : CERN, 2007 - 8 p.

The Optical Instrumentation of the ATLAS Tile Calorimeter / Abdallah, J; Adragna, P; Alexa, C; Alves, R; Amaral, P (CERN); Ananiev, A; Anderson, K; Andresen, X (CERN); Antonaki, A; Batusov, V et al. - ATLAS TileCal Collaboration.
The purpose of this Note is to describe the optical assembly procedure called here Optical Instrumentation and the quality tests conducted on the assembled units. Altogether, 65 Barrel (or LB) modules were constructed - including one spare - together with 129 Extended Barrel (EB) modules (including one spare). [...]
ATL-TILECAL-PUB-2008-005; ATL-COM-TILECAL-2007-025.- Geneva : CERN, 2007 - 26 p.

Precision Electroweak Measurements at the LHC / LeCompte, T
I discuss the prospects of ATLAS and CMS precision electroweak measurements, concentrating on the earlier measurements..
ATL-COM-SLIDE-2007-002.- Geneva : CERN, 2007 - 24 p.

Level 1 Jet Efficiency Measurements Using the Tag and Probe Method / LeCompte, T
I measure the Level 1 jet trigger efficiency directly from a Monte Carlo sample with no trigger requirement. I then re-measure it from a sample that is required to pass the simulated trigger, using the tag-and-probe method. [...]
ATL-COM-PHYS-2007-014.- Geneva : CERN, 2007

The Production and Qualification of Scintillator Tiles for the ATLAS Hadronic Calorimeter / Guarino, V; et, al
The production of the scintillator tiles for the ATLAS Tile Calorimeter is presented. In addition to the manufacture and production, the properties of the tiles will be presented including light yield, uniformity and stability.
ATL-COM-TILECAL-2007-017.- Geneva : CERN, 2007 - 20 p.

The Optical Instrumentation of the ATLAS Tile Calorimeter / Guarino, V; et, al
We describe the installation of scintillator tiles and fibers into the Tile Calorimeter and the resulting response and uniformity measured by a cesium source or an LED system..
ATL-COM-TILECAL-2007-024.- Geneva : CERN, 2007 - 26 p.

Pt Balance in Z+jet and Gamma+jet events / Sen-Gupta, A; Merritt, F S; Proudfoot, J; Farilla, A; Verducci, M
Z+jet and Gamma+jet events can be powerful tool for evaluating the jet energy scale directly from data at LHC. In this note we show the results of a study, done at the generator lebel and full simulation, of momentum balance between Z(Gamma) and the hadronic system for various jet topologies, using Pythia and Herwig.
ATL-COM-PHYS-2007-031.- Geneva : CERN, 2007 - 29 p.

Integration of the Trigger and Data Acquisition Systems in ATLAS / Abolins, M; Adragna, P; Aleksandrov, E; Aleksandrov, I; Amorim, A; Anderson, K; Anduaga, X; Dos Anjos, A; Aracena, I; Asquith, L et al.
During 2006 and the first half of 2007, the installation, integration and commissioning of trigger and data acquisition (TDAQ) equipment in the ATLAS experimental area have progressed. There have been a series of technical runs using the final components of the system already installed in the experimental area. [...]
ATL-COM-DAQ-2008-003.- Geneva : CERN, 2008 Fulltext - Published in : J. Phys.: Conf. Ser. 119 (2008) 022001
Presented at : International Conference on Computing in High Energy and Nuclear Physics

The ATLAS Trigger/DAQ Authorlist, version 1.0 / Abolins, M; Achenbach, R; Adorisio, C; Adragna, P; Aharrouche, M; Aielli, G; Al-Shabibi, A; Aleksandrov, I; Alexandre, G; Aloisio, A et al.
This is a reference document giving the ATLAS Trigger/DAQ author list, version 1.0 of 20 Nov 2008. [...]
ATL-DAQ-PUB-2008-004; ATL-COM-DAQ-2008-016.- Geneva : CERN, 2008

Effects of ATLAS Tile calorimeter failures on jets and missing transverse energy measurements / Mermod, P; Arabidze, G; Milstead, D; Stanek, R
Failures of the ATLAS Tile calorimeter would affect the jet energy resolution and would fake tails of missing transverse energy. Significant effects are expected in processes involving high transverse momentum jets (pT > 100 GeV). [...]
ATL-COM-CAL-2008-003.- Geneva : CERN, 2008 - 9 p.

ATLAS Conditions DB Operations Task Force : Recommendations for M6 FDR-1 / De, K; Dimitrov, G; Ernst, M; Jézéquel, S; Hawkings, R; Klimentov, A; Lampl, W; Ma, H; Maeno, T; Malon, D et al.
This document provides recommendations for Conditions DB operations during reprocessing of data from the ATLAS cosmics commissioning run M6 in March 3-10, 2008 and FDR-1 data reprocessing..
ATL-COM-SOFT-2008-003

Muons In the ATLAS Calorimeters : Energy Loss Corrections and Muon Tagging / Assamagan, K A; Bachas, K; Carli, T; Davidek, T; Fassouliotis, D; Flores Castillo, L R; De Groot, N; Hassani, S; Hughes, E W; Kluit, P et al.
The Muon Spectrometer is the outermost subdetector of the ATLAS detector, beginning after a muon has traversed 100 radiation lengths of material. Muon momentum measurements must be corrected for energy loss in the calorimeters and the inert material before the muons reach the Muon Spectrometer. [...]
ATL-COM-MUON-2008-009; CERN-ATL-COM-MUON-2008-009.- Geneva : CERN, 2008 - 36 p.

Online energy and phase reconstruction during commissioning phase of the ATLAS Tile Calorimeter / Salvachúa, B; Abdallah, J; Castillo, V; Cuenca, C; Ferrer, A; Fullana, E; González, V; Higón, E; Poveda, J; Ruiz-Martinez, A et al.
The response of the ATLAS tile hadronic calorimeter is being studied during several years in order to guarantee a good performance during the LHC life. The Read-Out Driver (ROD) system is responsible for reading-out the data from the whole tile calorimeter.
ATL-COM-TILECAL-2008-004.- Geneva :

Study of jet transverse momentum balance with the fraction of energy deposited in the electromagnetic and hadronic calorimeters / Fullana, E
We want to prepare a set of tools to test the jet energy scale and use them to set its uncertainty when the first data is available. The work described here focuses in the reconstructed pt balance of the two pt-leading jets and thus totally Monte Carlo independent.
ATL-COM-PHYS-2008-054.- Geneva : CERN, 2008 - 11 p.

Standard Model CSC Note / ATLAS, Collboration - ATLAS Collaboration.
The collection of CSC notes from the Standard Model group..
ATL-COM-PHYS-2008-064.- Geneva : CERN, 2008 - 140 p.

Jet, Missing Et and Tau Combined Performance / ATLAS Collaboration; Proudfoot, J (Editor); Mader, W F (Editor) - ATLAS Collaboration.
ATL-COM-PHYS-2008-074.- Geneva : CERN, 2008

HW()Wljj Process with Higgs Production via Vector Boson Fusion with the ATLAS Detector / Goldin, D (Southern Methodist University); Proudfoot, J (Argonne National Laboratory)
In this note we consider the HW()Wljj process, with the Higgs boson generated through Vector Boson Fusion (VBF). The VBF Higgs production mode results in a unique signature of two sets of jets in the final state; this allows for an extra handle over an analogous channel produced via gluon fusion.
ATL-COM-PHYS-2008-209.- Geneva : CERN, 2008 - 13 p.

Design, Construction and Installation of the ATLAS Hadronic Barrel Scintillator-Tile Calorimeter / Abdallah, J; Adragna, P; Alexa, C; Alves, R; Amaral, P (CERN); Ananiev, A; Anderson, K; Andresen, X (CERN); Antonaki, A; Batusov, V et al. - ATLAS TileCal Collaboration.
The scintillator tile hadronic calorimeter is a sampling calorimeter using steel as the absorber structure and scintillator as the active medium. The scintillator is located in "pockets" in the steel structure and the wavelength-shifting fibers are contained in channels running radially within the absorber to photomultiplier tubes which are located in the outer support girders of the calorimeter structure. [...]
ATL-TILECAL-PUB-2008-001; ATL-COM-TILECAL-2007-019

Implementation of the Optimal Filtering Reconstruction Algorithm in the TileCal Offline Software / Poveda, J; Fullana, E; Salvachúa, B; Solodkov, A; Abdallah, J; Castillo, V; Cuenca, C; Ferrer, A; Higón, E; Ruiz-Martinez, A et al.
The Optimal Filtering (OF) algorithm is one of the methods developed to reconstruct the energy and timing of the particles impinging TileCal. This method is based on linear combinations of the digital samples sent by the front-end electronics whose coefficients (known as OF weights) are required to minimize the noise contribution to the energy resolution. [...]
ATL-TILECAL-INT-2008-003; ATL-COM-TILECAL-2008-005.

Offline Validation and Performance of the TileCal Optimal Filtering Reconstruction Algorithm / Poveda, J; Abdallah, J; Castillo, V; Cuenca, C; Ferrer, A; Fullana, E; Higón, E; Ruiz-Martinez, A; Salvachúa, B; Solans, C et al.
The Optimal Filtering (OF) algorithm is one of the methods developed to reconstruct the energy and timing of the particles impinging TileCal. This method is based on linear combinations of the digital samples sent by the front-end electronics whose coefficients (known as OF weights) are required to minimize the noise contribution to the energy resolution. [...]
ATL-TILECAL-INT-2009-001; ATL-COM-TILECAL-2008-012.- Geneva : CERN, 2008 - 40 p.

Testbeam Studies of Production Modules of the ATLAS Tile Calorimeter / Adragna, P; Alexa, C; Anderson, K; Antonaki, A; Arabidze, A; Batkova, L; Batusov, V; Beck, H P; Bednar, P; Bergeaas Kuutmann, E et al.
We report test beam studies of {11\,\%} of the production ATLAS Tile Calorimeter modules. The modules were equipped with production front-end electronics and all the calibration systems planned for the final detector. [...]
ATL-TILECAL-PUB-2009-002; ATL-COM-TILECAL-2009-004.- Geneva : CERN, 2009 - 73 p.

Observations from the Trigger Workshop (Beatenberg 2009) / Bee, C; Bosman, M; Brooijmans, G; Charlton, D; Clément, C; Dong, S; Einsweiler, Kevin; Ellis, Nick; Froidevaux, D; Guyot, C et al.
This document summarizes the observations made at the workshop by the panel appointed to set up the Beatenberg trigger workshop program and the session chairs (and many others through their questions during the talks and discussions during breaks and meals.) The observations naturally lead to recommendations aimed at optimizing trigger commissioning and operations. How or whether to follow up on these recommendations will depend on many factors, and is left to trigger management..
ATL-COM-DAQ-2009-009.- Geneva : CERN, 2009 - 7 p.

CERN, 2008 A PC farm for ATLAS Tier3 analysis / Chekanov, S; Yoshida, R
An inexpensive PC farm (PCF) to facilitate ATLAS data analysis at Tier3 is proposed. The PC farm can be build from off-the-shelf components and features a local data storage with multicore processors.
ATL-COM-GEN-2009-016.- Geneva : CERN, 2009 - 10 p.

ATLAS TDAQ System Integration and Commissioning / Negri, A; Abolins, M; Achenbach, R; Adorisio, C; Adragna, P; Aharrouche, M; Aielli, G; Al-Shabibi, A; Aleksandrov, I; Alexandre, G et al.
The ATLAS detector will be exposed to proton proton collisions at a center of mass energy of 14 TeV with the bunch crossing rate of 40 MHz. A three-level trigger system has been designed to reduce this rate down to the level at which only interesting events are fully reconstructed.
ATL-COM-DAQ-2009-030.- Geneva : CERN, 2009 - 3 p.

Understanding the jet energy scale using pT balance for direct photon production with associated jet / Chekanov, S
Detector resolution and resolution biases for direct photons and associated jets are discussed using the ATLAS release 14.2.21. It is shown that the resolution for Egamma AOD photons is more than a factor 5 smaller than that for hadronic jets at pT>50 GeV, which makes it possible to use gamma's momentum as a reference for jet energy corrections.
ATL-COM-PHYS-2009-042.- Geneva : CERN, 2009 - 14 p.

ATLAS Plots on Ecm Dependence of Physics Reach / Collaboration, ATLAS (-); Charlton, D (contact); LeCompte, T (contact)
This is a placeholder for discussions about the twiki page with plots for Chamonix. A PDF version of the twiki is attached, but the live version is better consulted, at:
https://twiki.cern.ch/twiki/bin/viewauth/Atlas/AtlasResultsEcmDependence
ATL-COM-PHYS-2009-069.- Geneva : CERN, 2009 - 3 p.

Understanding the jet energy scale using pT balance for Z+jet events / Chekanov, S
It is shown that the jet transverse momentum can be reconstructed from that of Z within less than 1% accuracy for Z+jet events. The use of HERWIG leads to about 2% systematic uncertainty on the momentum balance.
ATL-COM-PHYS-2009-128.- Geneva : CERN, 2009 - 9 p.

Hadronic background rate for direct photon measurements / Blair, R; Chekanov, S; Price, L
In this note, we discuss the rate of background events originating from decays of mesons contributing to direct photon measurements. The calculations are based on several alternative Monte Carlo simulations.
ATL-COM-PHYS-2009-158.- Geneva : CERN, 2009 - 19 p.

Comparison of MC based Jet Energy Scales applied after H1 calibration / Salvachúa, B (Argonne National Laboratory); Chekanov, S (Argonne National Laboratory); Proudfoot, J (Argonne National Laboratory)
We discuss in this note the jet energy calibration using the H1 cell-weighting technique. We study four different alternatives to improve the energy scale of jets after the H1 calibration.
ATL-COM-PHYS-2009-162.- Geneva : CERN, 2009 - 36 p.

ATLAS Trigger Strategies and Early Physics Perspectives / LeCompte, T
Slides for the Berkeley Workshop on Physics Opportunities with the First LHC Data. I discuss some of the early ATLAS physics with particular attention paid to the interplay between the trigger and the physics..
ATL-COM-PHYS-2009-196.- Geneva : CERN, 2009 - 25 p.

Direct Photon Production / Courneyea, L; Blair, R; Bucci, F; Chekanov, S; Dova, M T; Hamilton, A; Newman, P; Pérez-Réale, V; Price, L; Stockton, M et al.
Direct photon studies provide and ideal arena for testing the pQCD predictions and to constrain the gluon parton density function particularly at large x. These prompt photon processes represent also an important contribution in estimating the background to other physics processes in the SM and beyond
ATL-COM-PHYS-2009-200.- Geneva : CERN, 2009 - 32 p.

ATLAS Preprints

The ATLAS Experiment at the CERN Large Hadron Collider / Aad, G (Marseille, CPPM); Bentvelsen, S (NIKHEF, Amsterdam); Bobbink, G J (NIKHEF, Amsterdam); Bos, K (NIKHEF, Amsterdam); Boterenbrood, H (NIKHEF, Amsterdam); Brouwer, G (NIKHEF, Amsterdam); Buis, E J (NIKHEF, Amsterdam); Buskop, J J F (NIKHEF, Amsterdam); Colijn, A P (NIKHEF, Amsterdam); Dankers, R (NIKHEF, Amsterdam) et al. - ATLAS Collaboration.
2008 SISSA/IOP Open Access article; SISSA/IOP Open Access article - Published in : J. Instrum. 3 (2008) S08003

Integration of the Trigger and Data Acquisition Systems in ATLAS / Abolins, M; Adragna, P; Aleksandrov, E; Aleksandrov, I; Amorim, A; Anderson, K; Anduaga, X; Dos Anjos, A; Aracena, I; Asquith, L et al.
During 2006 and the first half of 2007, the installation, integration and commissioning of trigger and data acquisition (TDAQ) equipment in the ATLAS experimental area have progressed. There have been a series of technical runs using the final components of the system already installed in the experimental area. [...]
ATL-COM-DAQ-2008-003.- Geneva : CERN, 2008 Fulltext - Published in : J. Phys.: Conf. Ser. 119 (2008) 022001
Presented at : International Conference on Computing in High Energy and Nuclear Physics

The ATLAS Event Builder / Vandelli, W; Abolins, M; Battaglia, A; Beck, H P; Blair, R; Bogaerts, A; Bosman, M; Ciobotaru, M; Cranfield, R; Crone, G et al.
Event data from proton-proton collisions at the LHC will be selected by the ATLAS experiment in a three-level trigger system, which, at its first two trigger levels (LVL1+LVL2), reduces the initial bunch crossing rate of 40~MHz to sim3~kHz. At this rate, the Event Builder collects the data from the readout system PCs (ROSs) and provides fully assembled events to the Event Filter (EF). [...]
ATL-DAQ-CONF-2008-005; ATL-COM-DAQ-2007-047.- Geneva : CERN, 2008 - 7 p. Access to fulltext; Access to fulltext; Access to fulltext - Published in : IEEE Trans. Nucl. Sci. 55 (2008) 3556-3562
Presented at : Nuclear Science Symposium and Medical Imaging Conference

The ATLAS High Level Trigger Region of Interest Builder / Blair, R E (Argonne Nat. Lab., Argonne, IL , USA); Dawson, J (Argonne Nat. Lab., Argonne, IL , USA); Drake, G (Argonne Nat. Lab., Argonne, IL , USA); Haberichter, W (Argonne Nat. Lab., Argonne, IL , USA); Schlereth, J L (Argonne Nat. Lab., Argonne, IL , USA); Zhang, J (Argonne Nat. Lab., Argonne, IL , USA); Abolins, M (Michigan State Univ., East Lansing, MI, USA); Ermoline, Y (Michigan State Univ., East Lansing, MI, USA); Pope, B (Michigan State Univ., East Lansing, MI, USA)
This article describes the design, testing and production of the ATLAS Region of Interest Builder (RoIB). This device acts as an interface between the Level 1 trigger and the high level trigger (HLT) farm for the ATLAS LHC detector. [...]
arXiv:0711.3217; ATL-DAQ-PUB-2007-001; CERN-ATL-COM-DAQ-2007-042.- Geneva : CERN, 2008 - 13 p.

The ATLAS Trigger : Commissioning with cosmic rays / Abolins, M; Achenbach, R; Adragna, P; Aielli, G; Aleksandrov, E; Aleksandrov, I; Aloisio, A; Alviggi, M G; Amorim, A; Anderson, K et al.
The ATLAS detector at CERN's LHC will be exposed to proton-proton collisions from beams crossing at 40 MHz. At the design luminosity there are roughly 23 collisions per bunch crossing. [...]
ATL-DAQ-CONF-2007-024; ATL-COM-DAQ-2007-029.- Geneva : CERN, 2008 - 12 p. Access to fulltext; Access to fulltext - Published in : J. Phys.: Conf. Ser. 119 (2008) 022014
Presented at : International Conference on Computing in High Energy and Nuclear Physics

The ATLAS Data Acquisition and Trigger : concept, design and status / Kordas, K; Abolins, M; Alexandrov, I; Amorim, A; Aracena, I; Armstrong, S; Badescu, E; Baines, J T M; Barros, N; Beck, H P et al.
This article presents the base-line design and implementation of the ATLAS Trigger and Data Acquisition system, in particular the Data Flow and High Level Trigger components. The status of the installation and commissioning of the system is also presented..
ATL-DAQ-CONF-2007-022; ATL-COM-DAQ-2007-015.- Geneva : CERN, 2007 - 5 p. Access to fulltext; Access to fulltext; Access to fulltext - Published in : Nucl. Phys. B, Proc. Suppl. 172 (2007) 178-182
Presented at : 10th Topical Seminar on Innovative Particle and Radiation Detectors

ATLAS TDAQ RoI Builder and the Level 2 Supervisor system / Ermoline, Yuri; Blair, R E; Dawson, J; Drake, G; Haberichter, W N; Schlereth, J L; Abolins, M; Pope, B G
ATL-DAQ-CONF-2007-017; ATL-COM-DAQ-2007-023; CERN-ATL-COM-DAQ-2007-023.- 2007 - 5 p. Fulltext; Fulltext; Published version from CERN
Presented at : 12th Workshop on Electronics For LHC and Future Experiments

The ATLAS Data Acquisition and High-Level Trigger : Concept, Design and Status / Gorini, B; Abolins, M; Alexandrov, I; Amorim, A; Aracena, I; Armstrong, S; Badescu, E; Baines, J T M; Barros, N; Beck, H P et al.
The Trigger and Data Acquisition system (TDAQ) of the ATLAS experiment at the CERN Large Hadron Collider is based on a multi-level selection process and a hierarchical acquisition tree. The system, consisting of a combination of custom electronics and commercial products from the computing and telecommunication industry, is required to provide an online selection power of 105 and a total throughput in the range of Terabit/sec. [...]
ATL-DAQ-CONF-2006-016; ATL-COM-DAQ-2006-030.- Geneva : CERN, 2006 - 6 p. Access to fulltext; Access to fulltext; Access to fulltext
Presented at : 15th International Conference on Computing In High Energy and Nuclear Physics

Testing on a Large Scale : running the ATLAS Data Acquisition and High Level Trigger Software on 700 PC Nodes / Burckhart-Chromek, Doris (CERN); Abolins, M; Adragna, P; Albuquerque-Portes, M; Alexandrov, L; Amorim, A; Armstrong, S; Badescu, E; Baines, J T M; Barros, N et al.
The ATLAS Data Acquisition (DAQ) and High Level Trigger (HLT) software system will be comprised initially of 2000 PC nodes which take part in the control, event readout, second level trigger and event filter operations. This high number of PCs will only be purchased before data taking in 2007. [...]
ATL-DAQ-CONF-2006-002; ATL-COM-DAQ-2006-008; CERN-ATL-DAQ-CONF-2006-002.- Geneva : CERN, 2006 - 6 p. Access to fulltext; Access to fulltext
Presented at : 15th International Conference on Computing In High Energy and Nuclear Physics

Studies with the ATLAS Trigger and Data Acquisition "Pre-Series" Setup / Ünel, G; Abolins, M; Adragna, P; Alexandrov, I; Amorim, A; Armstrong, S; Badescu, E; Baines, J T M; Barros, N; Beck, H P et al.
The pre-series test bed is used to validate the technology and implementation choices by comparing the final ATLAS readout requirements, to the results of performance, functionality and stability studies. We show that all the components which are not running reconstruction algorithms match the final ATLAS requirements. [...]
ATL-DAQ-CONF-2006-019; ATL-COM-DAQ-2006-010

Neutrino Group at Proton Accelerators
Accomplishments May 2006 - May 2009

Overview:

The Neutrino group has been actively involved in the study of neutrino oscillations as an outgrowth of the study of atmospheric neutrino oscillations on Soudan 2. It was recognized in the late 1980's that the early hints of neutrino oscillations could be confirmed and studied using an accelerator based neutrino beam from Fermilab, and that the Soudan mine would be an excellent location for that experiment. Much of the early leadership for that work came from the Argonne neutrino group. The sensitivities for a variety of neutrino oscillation tests were initially carried out by the Argonne group, and that forms the basis of most of the current analyses currently being undertaken by the full MINOS collaboration. In the meantime, the ANL neutrino group has concentrated on a few of those analyses, as well as helping to plan the context for the future of neutrino research in the United States. This includes early and active participation in the NOνA collaboration and early participation in the reactor neutrino experiment Double Chooz, not part of "proton accelerator based research", but closely tied to it for all practical purposes.

The MINOS long-baseline experiment

The ANL neutrino group helped to establish MINOS and has been deeply involved since the formation of the collaboration in 1995. Work on a long-baseline neutrino experiment from Fermilab to Soudan was first undertaken at ANL in 1987, which led to the P822 proposal to use the Soudan 2 detector as a target for a new beam from Fermilab in 1992. Much of that work was incorporated by the MINOS collaboration, including beam design and physics strategies, as well as the initial software tools. Since that time, our group has actively participated, at various times, in almost every aspect of the experiment. We have been continuously involved in collaboration organization and management. In the last 3 years, that includes service as Deputy Spokesperson, Chairman of the Institutional Board, Secretary of the Executive Committee, and leadership of several analysis groups. There have been a large number of analyses of MINOS data since the start of beam in 2005, and ANL has had some involvement in all of them. Here, we will discuss four results: 1) measurement of Δm^2_{32} with $\nu_\mu \rightarrow \nu_\tau$ oscillations, in which ANL made significant early conceptual contributions. 2) A $\nu_\mu \rightarrow \nu_e$ oscillation search, where ANL has provided the current leadership for the analysis, Mayly Sanchez. 3) A search for $\nu_\mu \rightarrow \nu_\tau$ oscillations using rock muons, which was performed only at ANL by Aaron McGowan. 4) the measurement and interpretation of the cosmic ray muon charge ratio, also exclusively done within the ANL neutrino group, by Phil Schreiner, Jurgen Reichenbacher and Maury Goodman.

1. Contained Events in MINOS

The most sensitive test for $\nu_\mu \rightarrow \nu_\tau$ neutrino oscillations in the MINOS experiment is the study of events which interact in the far detector, and a comparison of the energy spectrum of the charged current events with the energy spectrum in the near detector, after taking into account a proper extrapolation of the beam. The observed event rate as a function of energy is shown in Figure 1, normalized to the expected rate without oscillations. The apparent disappearance of ν_μ has been studied and fit for the best neutrino oscillation parameters, and the important results were published for 1.27×10^{20} protons on target (pot) in 2006. Those results were updated in 2008 based on 1.27×10^{20} pot. The current best fit parameters are $|\Delta m^2_{32}| = 2.43 \pm 0.13(\text{stat+sys}) \times 10^{-3}\text{eV}^2$ and $\sin^2 2\theta_{23} > 0.90$ at 90% CL (stat+sys). This represents the best current measurement of $|\Delta m^2_{32}|$.

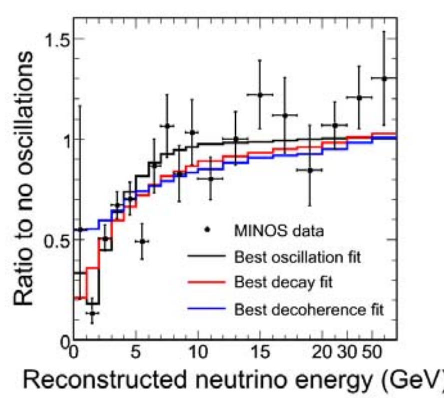


Figure 1 CC neutrino energy distribution measured in MINOS

2. Rock Muons in MINOS

In addition to contained events, another category of neutrino induced events in the MINOS far detector are the so-called rock muons. These are neutrinos which interact via the charged current interaction in the rock outside the MINOS detector. Since high energy muons can travel a large distance before they stop, this increases the potential volume compared to the fiducial volume of the detector. On the other hand, the energy distribution of the ratio of rock muons to fiducial events goes as

$$\int \phi(E)\sigma(E)EdE \,/ \int \phi(E)\sigma(E)dE$$

where ϕ is the neutrino flux and σ is the neutrino charged current cross section. Both event rates are compared in Figure 2. The extra factor of E in the numerator comes from the muon range. Since oscillations go as L/E and appear at low energies in MINOS, and the underlying neutrino energy distribution for rock muons favors higher energy, the sensitivity of a neutrino oscillation test using rock muons smaller than for contained events. Nevertheless, the data set is completely independent of the contained event analysis, and provides a consistency check of the neutrino oscillation hypothesis.

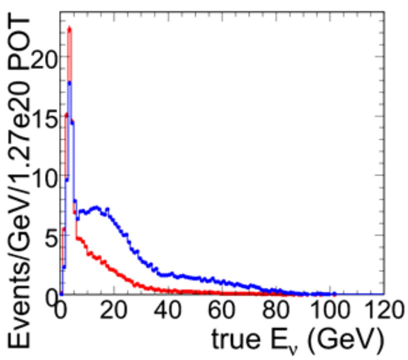


Figure 2: Energy distribution of contained(red) and rock(blue) events.

The analysis of the rock muons for the first 1.27×10^{20} pot was carried out exclusively by the Argonne Neutrino group. An example of a rock muon event is given in Figure 3. The distinguishing feature is that the muon enters the detector at z=0. Some muons also enter the detector from the sides, top or bottom. Other events in the detector for which the vertex is outside the standard fiducial volume were also included in the analysis, but only using information about the muon. The analysis was thus sometimes called the anti-fiducial volume analysis.

The methodology used was parallel to that developed by the MINOS charged current working group. A blind analysis was performed, and the actual data events were kept in a box until the last step of the analysis. While the standard Monte Carlo included rock muons, it did not include sufficient rock volume. Thus an independent Monte Carlo for the rock muons was developed. The vertex distribution for the Monte Carlo that was used is shown in Figure 4 Two features that are apparent in that figure are the fact that the neutrino beam is coming up at 3.5 degrees when it reaches MINOS, and the shape of the cavity, which is partially obscured since muons do come in the sides.

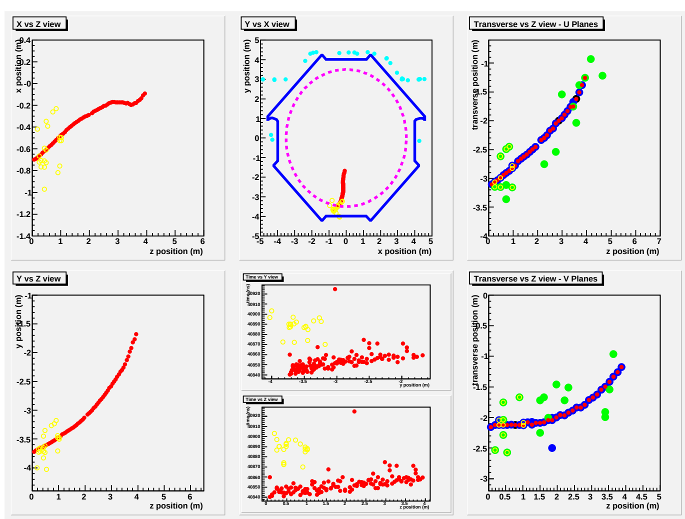


Figure 3: An event display of a “rock muon” in the MINOS detector.

The sensitivity of the rock muon disappearance was calculated for a variety of assumptions about systematic errors. A "mock data" set was simulated and analyzed to confirm the calculations of statistical sensitivity. The expected number of rock muons in the far detector was calculated using an expected neutrino flux based on observations of charged current events in the near detector, together with Monte Carlo studies of the effects of that extrapolation. The vertex position from that Monte Carlo is shown in Figure 4. The expected number of antifiducial muon events below 10 GeV/c for 1.27×10^{20} pot was calculated to be 252 ± 23.7 events under the assumption of no disappearance. MINOS detected 232 such events. Below 3 GeV/c, 117 events were observed, where 150.2 ± 16.1 were expected. In both cases, a disappearance of events consistent with the observations of the contained event analysis was seen. Using a completely independent event sample, the no-disappearance hypothesis was ruled out at 99.5% confidence level. Fitting only to the non-fiducial events, values of $|\Delta m^2_{32}| = 2.32 + 1.06 - 0.75$ (stat+sys) $\times 10^{-3} eV^2$ and $\sin^2 2\theta_{23} > 0.48$ at 68% CL (stat+sys) were obtained. This allowed region of parameter space is shown in Figure 5

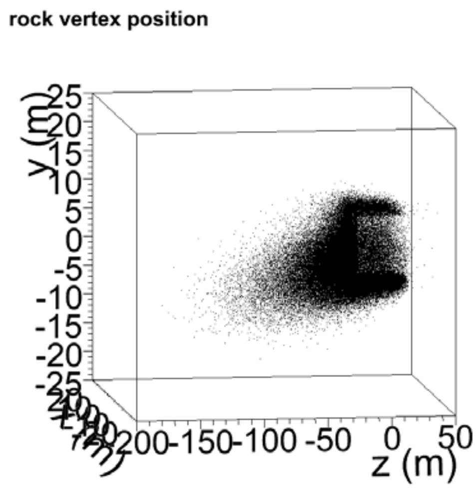


Figure 4: rock event vertex position

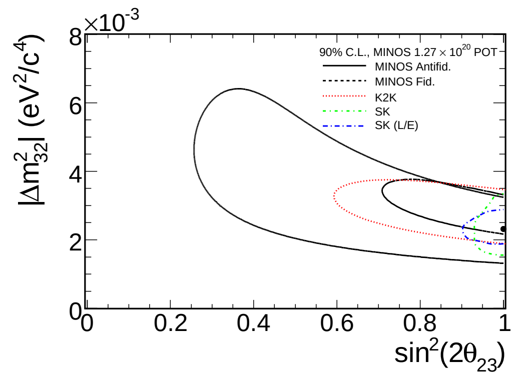


Figure 5 Parameter space allowed by rock muon analysis

3. Analysis of $\nu_\mu \rightarrow \nu_e$ in MINOS

The ANL neutrino group has most recently been concentrating its analysis effort on the search for electron neutrino appearance in the MINOS experiment. This analysis group is led by Mayly Sanchez and includes contributions from ANL postdoc Xiaobo Huang. They have been working especially closely with graduate students from Harvard and Cal Tech. This signal is directly sensitive to a possible non-zero value of the important parameter θ_{13}. A blind analysis was performed in which the most electron-like events were set aside. A particle identification technique for electron like events was developed, based largely on Monte Carlo data sets for understanding efficiency and purity. Near detector events were also studied extensively. And the details of extrapolation of the expected energy distribution were studied. Electron-like events in the near detector were an a-priori unknown mixture of beam ν_μ, which oscillate with a large mixing angle before they get to the far detector, and beam ν_e which do not. Thus the extrapolation method needed to take this into account. At each stage, multiple complementary analysis techniques were developed and studied to deal with each of these problems.

The particle identification method that was chosen was an artificial neural net (ANN) which was based on eleven input variables. It gave a number between zero and one, and the more electron-like events gave a higher ANN. The shapes of background and signal events are shown in Figure 5 on the left. Detailed analysis concentrated on understanding and comparing the results for electron-like events in the near detector and the far detector "sidebands" with Monte Carlo. Sidebands were defined as events with ANN lower than a predetermined cut, and also muon-removed charged current events, which are each estimates of background that could be compared in the near and far detectors. After examining the sideband data sets, we proceeded to count the number of events passing the predetermined selection cut. We observe 35 events in the far detector with an expected background of 27 ± 5(stat) ±3(sys). The ANN distribution is shown on the right of Figure 6.

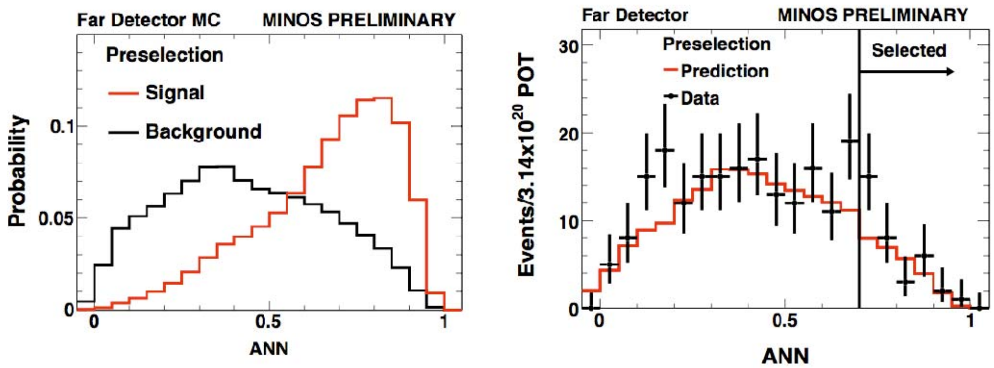


Figure 6. Distributions of ANN variable to separate oscillated ne events from background. The distribution on the left compares Monte Carlo of signal and Background. On the right is data.

The oscillation probability of this small excess was calculated using a full 3-flavor neutrino mixing framework that includes matter effects to which electron neutrinos appearing would be susceptible as they travel through the earth. The answer is sensitive to the value of the CP phase δ_{CP} and the mass hierarchy. Figure 7 shows those values of $\sin^2 2\theta_{13}$ and δ_{CP} for each mass hierarch that would produce an excess of events consistent with the observed excess within 90% Confidence Level, using a Feldman-Cousins approach to deal with statistical and systematic effects.

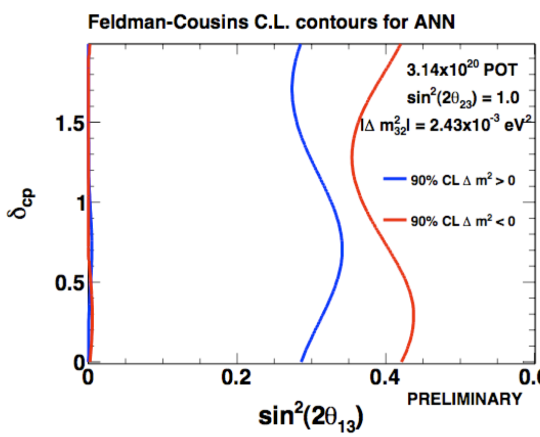


Figure 7. Allowed region for θ_{13} based on ANN analysis of MINOS data.

4. Cosmic Ray Charge Ratio in MINOS and its interpretation

The atmospheric muon charge ratio has previously been measured extensively to be near 1.27 by balloon, surface and underground experiments from about 100 MeV to over 100 GeV. The most precise higher energy measurements come from L3+C which measured 1.285 ± 0.003 (stat) ± 0.019 (sys) from 20 to 500 GeV. MINOS, the first large underground experiment with a magnet, has provided the first high statistics by measuring 1.374 ± 0.004 (stat) +0.012 – 0.010 (sys) for muons near the energy of 1 TeV. The analysis faced two problems. First it was found that the measured charge ratio depended strongly on certain geometric parameters such as azimuthal angle which had no physical basis. ANL developed the procedure to eliminate this systematic error by properly combining data with forward and reversed magnetic fields. A second problem was identified due to poorly measured tracks which went mostly parallel to magnetic field along with extra hits that confused the reconstruction. This effect was never properly simulated by Monte Carlo. An early set of cuts were identified which minimized this effect and a charge ratio was calculated. At ANL, the effect was tracked down, identified and corrected for, and a more precise analysis undertaken. Both analyses were incorporated in the published paper, P. Adamson et al. (200 authors), Phys.Rev.D76:052003 (2007), Vol. 76, No. 5. The resulting measured charge ratio, 1.374 ± 0.004 (stat) +0.012-0.010 (sys.) was noticeably higher than had been measured before. This long awaited first rise in the charge ratio, was considered one of the highlights at the 2007 Cosmic Ray Conference in Merida Mexico, and ANL scientists made several presentations on this subject and coordinated the effort.

While it was long expected that a rise in the charge ratio would be seen, and that the K charge ratio would be involved, the ANL neutrino group put the whole subject on a firm phenomenological basis. An equation for the muon flux underground had previously been developed by Zatsepin and later Gaisser and appears in the PDG. This equation was separated by our Group and used to express the charge ratio as

$$r_\mu = \frac{\left\{ \frac{f_\pi}{1\,+\,1.1 E_\mu \cos\theta/115\ \mathrm{GeV}} \;+\; \frac{\eta \times f_K}{1\,+\,1.1 E_\mu \cos\theta/850\ \mathrm{GeV}} \right\}}{\left\{ \frac{1-f_\pi}{1\,+\,1.1 E_\mu \cos\theta/115\ \mathrm{GeV}} \;+\; \frac{\eta \times (1-f_K)}{1\,+\,1.1 E_\mu \cos\theta/850\ \mathrm{GeV}} \right\}}$$

In this equation, f_π and f_K are the fraction of p and K that are positive, η=0.054 includes the π/K ratio and various decay kinematic factors, and 115 GeV and 850 GeV are the critical energies for which π and K interaction lengths equal their decay lengths at the point in the atmosphere where most m originate, which is about 20 km high. This equation depends only on the combination $E_\mu\cos\theta$, and not on the energy or zenith angle separately. We studied several cosmic ray simulations and found this was a useful way to parameterize the physics. We fit the data, and for the first time extracted the π^+/π^- and K^+/K^- ratios in cosmic rays contributing to atmospheric muons. Our fit is shown in Figure 8 along with data from MINOS and L3+C. This potentially has great impact on neutrino telescopes, where most of the neutrinos come from K decay, and the neutrino and anti-neutrino cross sections are quite different.

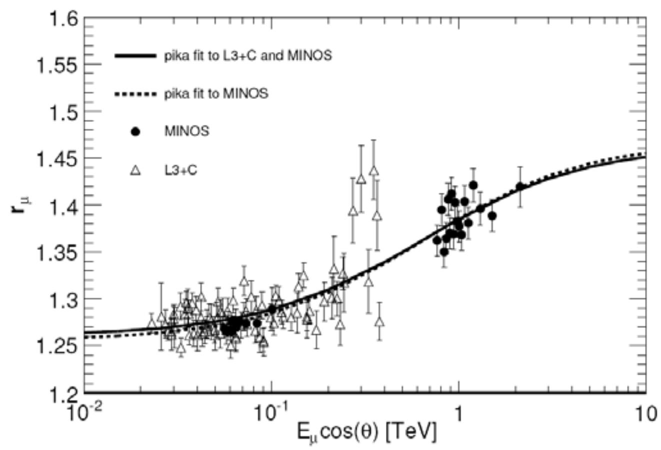


Figure 8: Charge ratio versus $E_\mu\cos\theta$

Overview of the Neutrino Off-Axis Neutrino Appearance NOνA Experiment

The Argonne Neutrino group is a major participant in the multi-institutional project NOνA which is based at Fermilab. Since the beginning of the MINOS collaboration, we have participated in many studies for future neutrino experiments at Fermilab which led to the formation of the NOνA collaboration to further study neutrino properties. The main goal of NOνA is to search for a value of the third and last neutrino mixing parameter θ_{13} over a distance where earth matter effects are expected to play a role. By using the existing NuMI beam, but located a new detector off-axis, a search for $\nu_\mu \rightarrow \nu_e$ oscillations will be performed in a condition where the three main backgrounds to that channel in MINOS are all reduced. Those backgrounds are ν_e in the beam, $\nu_\mu \rightarrow \nu_\tau$ oscillations followed by $\tau \rightarrow e$ decay, and neutral current events, primarily involving π^0s.

ANL group members have been instrumental in preparing for many of the reviews of NOνA, writing the proposal and Technical Design Report, and helping in the evolution of plans, particularly when it looked as if NOνA might not proceed. Dave Ayres, Richard Talaga and Mayly Sanchez all have or will serve on the executive committee for NOνA. The contributions of Richard Talaga, Vic Guarino and Jim Grudzinski were crucial to current design of the experiment.

Assembly Hardware for NOνA prototype detectors

Several devices are being constructed at Argonne in the construction facility in Building 366. The major mechanical devices are the glue machine and the vacuum lifting fixture. These are being used to construct several prototype detectors in stages as follows: (1) construction of the Full Size Assembly Prototype (FSAP), (2) construction of the Integration Prototype Near Detector (IPND), (3) construction of the Full Height Engineering Prototype (FHEP) and (4) construction of the Near Detector (ND). Major items developed at Argonne for the Construction of these prototypes are:

1. Glue Machine (See Figure 9)

The Glue Machine consists of a steel platform that moves along two rails, approximately 60 feet long, at a height of approximately 5 feet. A transverse slide is affixed to the platform to position adhesive dispensing nozzles at a precise location as the platform moves down the length of the rails. The slide and the platform are motor controlled with PLCs to apply the adhesive in a well-controlled manner. Two 55-gallon drums, each containing one of the two adhesive components will eventually be placed on the moving platform to provide adhesive to a commercially-produced machine that meters and distributes the adhesive into dispensing nozzles affixed to the transverse slide. A steel platform moves along two elevated rails about 60 feet long at a height of approximately 5 feet, as shown below. A transverse slide is affixed to the platform to position adhesive dispensing nozzles at a precise location as the platform moves down the length of the rails. The carriage is driven by a DC motor using a rack and pinion system at speeds ranging between 20-40ft/minute. The glue machine uses a PLC for supervisory control of the carriage and transverse slide motion.

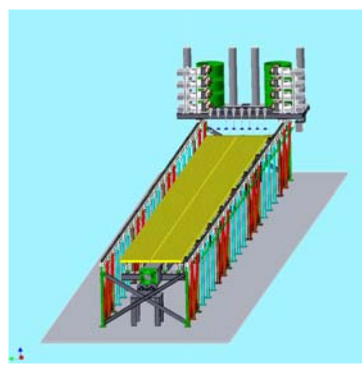


Fig 9. Overview of the Glue Machine

2. Vacuum Lifting Fixture (See Figure 10)

The Vacuum Lifting Fixture (VLF) is used in conjunction with the building 366 overhead crane to move extruded PVC modules to the Glue Machine and to the Assembly Areas for the FSAP and FHEP. At the Glue Machine the VLF's extended trunnions (also called roll-over pieces) are placed on and connected to steel Rotation Tables (one at each end of the glue machine), which support the VLF its and attached module. At this point the attachments to overhead crane are removed. The Rotation Tables positively engage the VLF's trunnions and, under control of HEP Division personnel, use

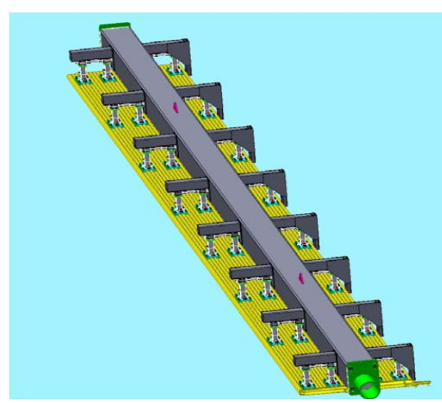


Fig. 10 Vacuum lifting fixture

a motor drive to perform a controlled rotation of the VLF by 180 degrees about the long axis. This presents the proper side of the PVC module for application of the glue. Once the gluing operation is completed, the VLF is rotated back to the original position, the crane attachment is re-connected and the module is lifted to the Assembly Area. An illustration of the lifting fixture holding a module (yellow) is shown below. Note that one of the two trunnions is shown at the near end of the fixture. The vacuum lifting fixture utilizes commercial vacuum cups with a shape appropriate to the module's ridged design. The cups are located precisely along a flat part of the module by a pneumatically actuated mechanisms that use the edge of the module as a reference point to place the vacuum cups along the flat ridges of the module.

PVC extrusions for NOνA

The ANL neutrino group has had primary responsibility for the technical design and production of PVC extrusions for NOνA. The major design criteria were that (1) they are sufficiently reflective to produce the required light yield, (2) they must be sufficiently strong to form a self-supporting NOνA detector structure, filled with liquid scintillator, over the lifetime of the experiment, and (3) their shape must be within the specified tolerances for assembly of modules and detector blocks.

An important parameter is the modulus related to the long term creep properties of the PVC in the extrusion. A large change in the modulus would result in the extrusion not keeping its shape over the lifetime of the experiment. Several independent predictions were made regarding the long term creep predictions for several different potential NOνA materials. There is some variation in the quantities of lubricants in the resin formulation, as well as in the type of stabilizer and type/quantity of impact modifiers. Creep properties are primarily driven by the PVC resin which is identical in all cases.

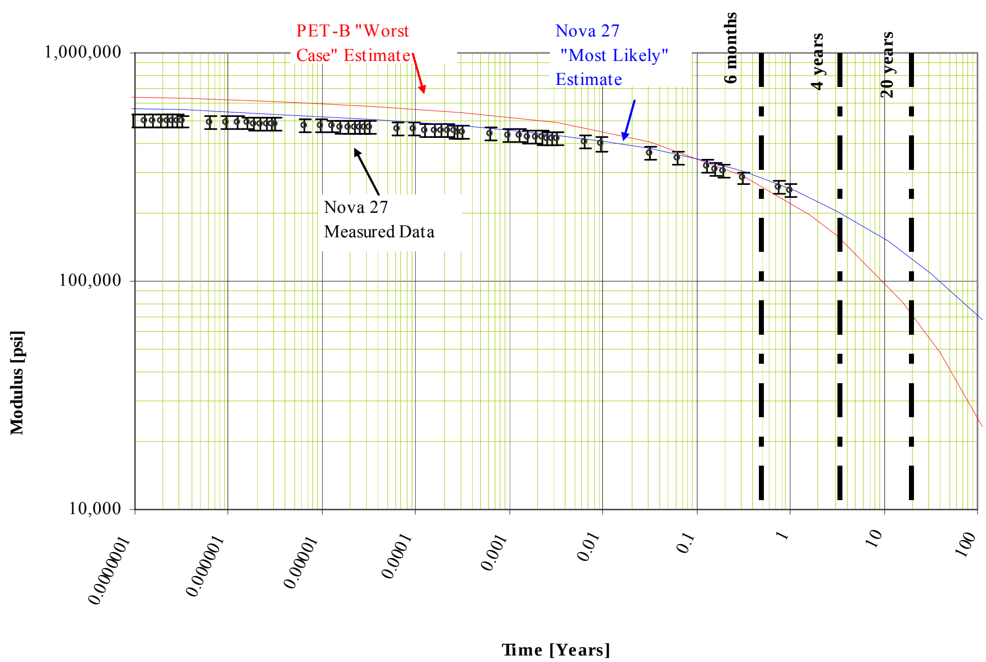


Figure 11: Creep Predictions and measurements for NOνA plastics

Modeling of Detector Structural Issues for NOνA

The primary structural requirement on the far detector is that it be mechanically stable at every stage of the assembly process and also throughout its nominal 20-year operating lifetime. A secondary requirement is that mechanical stability should not be compromised by filling the installed detector blocks with liquid scintillator while additional blocks are still be assembled and installed. The swelling of detector modules under hydrostatic pressure complicates the design of a structure that allows filling with liquid scintillator to begin before all blocks are installed. FEA calculations show that hydrostatic swelling propagates from plane to plane. We have observed such propagation in multi-plane prototype structures and found it to be in agreement with predictions. The far detector design incorporates 2-cm expansion gaps every 155 planes (5 blocks) to stop the propagation of swelling before very large stress levels are reached.

The mechanical design of the NOνA Far Detector structure has required close cooperation of ANL neutrino physicists, engineers, and outside consultants. Finite Element Analysis calculations, performed with ANSYS, have been used to design a detector structure that meets these structural requirements without compromising physics sensitivity. A number of various calculations were performed, as well as long-term structural tests of a large number of candidate plastics for the extrusions. Some of the predictions are shown in Figure 10. Agreement between the FEA predictions and the results of the plastic testing has given us confidence in the long-term mechanical stability of the detector.

Assembly Issues for the NOνA Near Detector and Far Detector

During the preparation of the proposal and technical design report, ANL physicist David Ayres served as the Level 2 manager for Assembly. There were separate tasks for the near detector, to be assembled underground along the NuMI beam at Fermilab, and the far detector, to be assembled on site at Ash River Minnesota. An important assembly task is the close coordination and integration of detector components, including liquid scintillator, PVC modules, electronics, and data acquisition.

The NOνA near detector will be located underground on the Fermilab site, in a new cavern adjacent to the MINOS access tunnel, downstream of the MINOS shaft. The main job of the assembly manager prior to construction was to identify the plan for assembly, including safety issues, the manpower and schedule requirements and anything else that would affect the cost. Figure 12 shows a schematic view of the planned near detector. There is an active detector part, similar to the Far Detector and broken logically into veto, fiducial and shower containment regions, followed by a steel and liquid scintillator muon catcher. The upstream end, without steel, is held firmly in place by a "bookend".

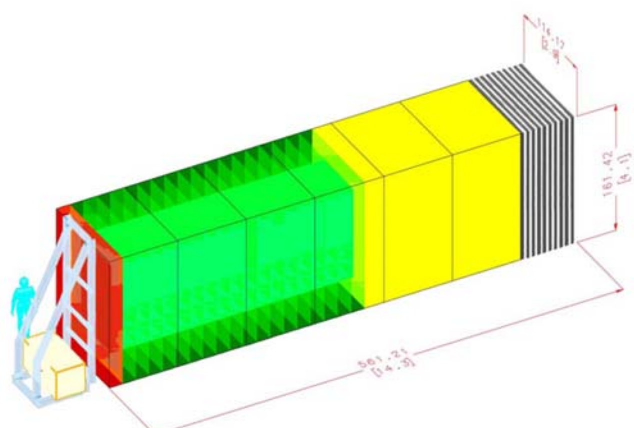


Figure 12 View of various sections of the NOνA Near Detector

The siting of the NOνA near detector had to take into consideration the location of the MINOS shaft, other uses of the NuMI access tunnel, and the physical characteristics of the NuMI neutrino beam. Any modification of the access tunnel involved civil construction which will have affects on continued use of the NuMI beam. The detector axis is aligned so that the neutrinos at the appropriate off-axis angle enter perpendicular to the face. The physical design of the Near Detector was constrained by three requirements. It should be as similar as possible to the far detector in material and segmentation. Ideally, this will allow us to understand both the ne charged current and n neutral current beam spectra seen in the Near Detector as a measure of the expected backgrounds to $\nu_\mu \rightarrow \nu_e$ oscillation signals in the Far Detector. In practice there are three unavoidable differences. The first is that the Near Detector sees the decay region as a line source, while the Far Detector sees a point source. The second is that the near Detector is smaller and thus has wavelength shifting fibers much shorter than those in the Far Detector. Third is that there are multiple events per NuMI spill so the electronics must be different. There must be a fiducial volume of order 20 tons, which sets a minimum size, while the pieces from which the detector is constructed must fit down the MINOS access shaft. This last requirement sets a practical maximum size for the detector transverse dimension.

An assembly plan meeting all of these requirements has been developed for the Near Detector. The main difference from the far detector is the addition of a muon catcher part, which resembles MINOS. After the completion of the mechanical assembly, the active detector planes will be filled with liquid scintillator. A fire protection plan is a key part of the assembly plan.

The far detector installation requires the hiring and training of a crew of technicians that will perform the actual assembly work over a 2.5-year period, beginning with beneficial occupancy of the detector building and ending when the 15 kton detector is fully operational. This includes the assembly of extrusions into planes and blocks, use of a specially designed NOνA block pivoter to put the massive blocks into the vertical position, followed by the filling of each superblock with liquid scintillator. Long before filling is completed, the first block of the next superblock will be in place. It serves as a temporary "bookend" to control any unexpected transient movements during the filling process.

Several steps in assembly of NOνA modules have already been tested at ANL with prototype detectors, and a series of larger prototypes over the next 2 years will completely check out the assembly plan.

ANL neutrino physicists are also getting involved in the DAQ and data analysis. Mayly Sanchez has been named the simulation leader, and a variety of analysis tools are being assembled. Substantial use will be made of the experiences from MINOS which has had to deal with many of the same issues. While NOνA Far Detector data is still several years away, the construction and operation of the Integration Prototype Near Detector near the MINOS surface building in 2010 will provide valuable information on both the composition of the off-axis NuMI beam, and also a severe test of cosmic ray backgrounds.

Selected Publications:

1. P. Schreiner et al. (3 authors) "Interpretation of the Underground Muon Charge Ratio", submitted to Astroparticle Physics, May 2009.
2. M. Sanchez & M. Marengo, "A k-NN Method to Classify Rare Astronomical Sources: Photometric Search of Brown Dwarfs with Spitzer IRAC", Accepted for publication in the Astronomical Journal, arXiv:0904.3749
3. S. Osprey et al., (170 authors) "Sudden Stratospheric Warmings seen in MINOS deep underground muon data", Geophys. Res. Lett. 36, L05809 (2009).
4. C. Amsler et al., (192 authors) "Review of Particle Physics", Physics Letters B667, 1 (2008).
5. P. Adamson et al. (163 authors), "Search for active neutrino disappearance using neutral-current interactions in the MINOS long-baseline experiment," Phys.Rev.Lett. 101, 221804 (2008), Issue 22, 28 November 2008.
6. D.G. Michael et al. (260 authors), "The magnetized steel and scintillator calorimeters of the MINOS experiment," Nucl.Instrum.Meth.A596:190-228(2008), Issue 2, 1 November 2008.
7. P. Adamson et al. (152 authors), "Testing Lorentz invariance and CPT conservation with NuMI neutrinos in the MINOS near detector," Phys.Rev.Lett. 101, 151601 (2008), Issue 15, 10 October 2008.
8. P. Adamson et al. (170 authors), "Measurement of neutrino oscillations with the MINOS detectors in the NuMI beam, "Phys.Rev.Lett. 101, 131802 (2008), Issue 13, 26 September 2008.
9. P. Adamson et al. (198 authors), "Study of muon neutrino disappearance using the Fermilab Main Injector neutrino beam," Phys.Rev.D77:072002 (2008), Vol. 77, No. 7, 1 April 2008.
10. P. Adamson et al. (203 authors), "Measurement of neutrino velocity with the MINOS detectors and NuMI neutrino beam," Phys.Rev.D76:072005 (2007), Vol. 76, No. 7, 1 October 2007.
11. P. Adamson et al. (200 authors), "Measurement of the atmospheric muon charge ratio at TeV energies with the MINOS detector," Phys.Rev.D76:052003 (2007), Vol. 76, No. 5, 1 September 2007.
12. P. Adamson et al. (199 authors), "Charge-separated atmospheric neutrino-induced muons in the MINOS far detector," Phys.Rev.D75:092003 (2007), Vol. 75, No. 9, 1 May 2007.
13. R. Zwaska et al. (17 authors), "Beam-based alignment of the NuMI target station components at FNAL," Nucl.Instrum.Meth.A568:548-560(2006), No. 2, 1 December 2006.
14. W.M. Yao et al., (53 authors) "Review of Particle Physics", J. Phys. G: Nucl. Part. Phys. 33, 1 (2006).
15. D.G. Michael et al. (273 authors), "Observation of muon neutrino disappearance with the MINOS detectors in the NuMI neutrino beam," Phys. Rev. Lett. 97, 191801 (2006).
16. T. Cundiff et al. (14 authors) "The MINOS near detector front end electronics," IEEE Trans. Nucl. Sci. 53, 1347-1355 (2006), June 2006.

Plans for the Argonne Neutrino Group at proton accelerators 2009-2012 and beyond

The ANL neutrino group has been a leader in the establishment of neutrino experiments at proton accelerators, and we will continue to do so. Neutrino Physics is in an intellectually promising situation: there has been tremendous progress in the last decade in establishing the phenomenon of neutrino oscillations, measuring it using solar, reactor, atmospheric and accelerator neutrinos, measuring two of the three mixing angles, and measuring the magnitude of two and the sign of one value of Δm^2. The future questions are well defined, and the most important one is measure or significantly constrain the third mixing angle θ_{13}. And if that angle is sufficiently large, a whole program of accelerator based research on CP violation and matter effects is within the grasp of next generation experiments.

The ANL neutrino group is deeply involved in that quest, both in its non-accelerator aspects, and at proton accelerators. We have been leading the search for θ_{13} within MINOS, and will continue to be involved as the sensitivity increases. We have been involved early and deeply in the NOνA project, which is taking off with significant construction in the next three year period. And we have been active participants in studies for future accelerator projects, including participation in the recently formed Long-Baseline DUSEL collaboration.

The physics opportunities provide a manpower challenge for the neutrino group. At the conclusion of the MINOS construction project, we lost several physicists, including Jonathan Thron, Danny Krakuaer and Tacy Joffe-Minor. In the last three year period, partially as a result of the fluctuating funding for the NOνA project, we have lost David Reyna and David Ayres, as well as postdocs Jurgen Reichenbacher and Gavril Giurgiu. We added physicist Mayly Sanchez and postdoc Xiaobo Huang, and are currently looking for a physicist to replace David Ayres, an assistant physicist, and another postdoc. Mayly Sanchez will move on next year to Iowa State, but we expect to continue to work closely with her on MINOS, NOνA and planning for Long-Baseline DUSEL.

Plans for continuing on the MINOS long-baseline neutrino experiment at Fermilab

The group will continue as part of the MINOS experiment as long as it runs, which will continue at least for the next 3 years. There are several physics analyses which MINOS can improve with more running of neutrinos, and new analyses which can be undertaken with a substantial antineutrino running.

Increased neutrino running would also be important for the main $\nu_\mu \rightarrow \nu_\tau$ oscillation analysis which has provided the world's best measurement of Δm^2_{32}. Since the current MINOS sensitivity is limited by statistics and not systematics, the sensitivity will increase in proportion to the square root of the number of pot. As a reminder, MINOS has the world's best measurement of Δm^2_{32}. The evolution of the MINOS sensitivity on Δm^2_{32} is shown in Figure 1. After the summer 2009 shutdown, MINOS has requested switching to antineutrinos from neutrinos. With a two year run of MINOS with recent proton luminosities (2.5×10^{20} pot per year), MINOS can increase the sensitivity to CPT violation (i.e. a possible difference between Δm^2_{32} measured with neutrinos to that measured with antineutrinos) by an order of magnitude compared with that using the antineutrinos during the regular neutrino running.

MINOS recently presented an analysis searching for evidence of $\nu_\mu \rightarrow \nu_e$ oscillations based on 3.14×10^{20} protons on target (pot). After the 2009 summer shutdown, MINOS plans to open the box on an analysis with at least twice the number of pot. Since the early analysis showed a small excess which might be evidence for a non-zero value of θ_{13}, the increase in sensitivity would be quite important. The sensitivity for a variety of running assumptions is shown in Figure 2.

Another byproduct of running with antineutrinos would be a significant amount of running the far detector with reversed magnetic field. This would provide an opportunity to do a higher statistics measurement of the atmospheric muon charge ratio, which was limited by the amount of reversed field running.

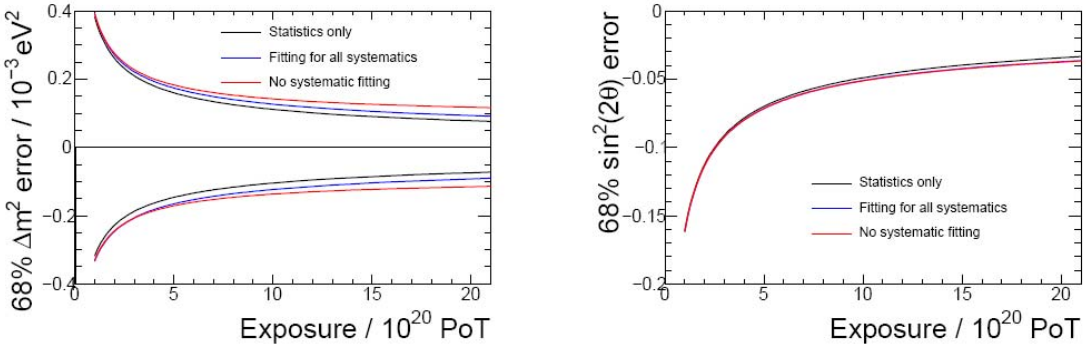


Figure 1. The 68% C.L. percentage error as a function of POTs for additional MINOS running. The left is for Δm^2_{32} and the right is for $\sin^2 2\theta_{13}$.

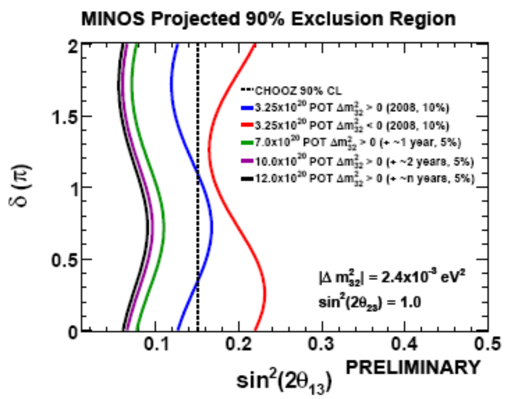


Fig. 2 MINOS sensitivity for θ_{13} as a function of CP parameter δ for various proton on target scenarios.

The Argonne Neutrino Group has been involved in the planning for MINOS for many years, and at one time or another has been involved in almost every analysis. We have recently concentrated some of our analysis efforts on electrons, and we expect that to continue. Some effort may also turn to other analyses. We plan to contribute to most of the following MINOS analysis efforts in the next three years:

1. Continued measurements of Δm^2_{32} with contained events. A crucial issue here is to understand any evolution of beam conditions which might affect the answer. There is some evidence that the target has been degrading, and a new target might change that.
2. More analysis of $\nu_\mu \rightarrow \nu_e$. We already have twice the number of protons on target.
3. The rock muon analysis that was performed at ANL is being extended to the new data by a new graduate student from the University of Minnesota. We will work closely with him on understanding systematic errors, and also work to incorporate a joint analysis of rock muons with fiducial events.
4. The atmospheric muon charge ratio included a number of systematic errors which we were able to cancel even though they were not fully understood. Given the high interest in this result, another independent measurement of the charge ratio would be valuable when new reversed field data is taken.
5. There has been considerable interest in the variations measured in MINOS both as a function of season and also in conjunction with a variety of meteorological conditions. This analysis has been used to extract a p/K ratio in cosmic rays. These studies will continue and the methodologies employed will be further studied.
6. We would like to take a look at inverse muon decay in the near detector

7. The neutral current fraction of events in the far detector can be used to search for sterile neutrinos, but also is an independent test of 3 flavor oscillations. We plan to exploit the MINOS data for this.
8. We will participate as the collaboration seeks to do a combined analysis of NC, CC and rock muons for oscillation studies.
9. Near Detector studies could be used to better understand potential backgrounds in NOνA.

<u>Plans for NOνA</u>

The ANL neutrino group has several responsibilities for hardware issues regarding the NOνA detector that will require extra attention in the short term. For that end, we have hired a new postdoctoral assistant to work on some of these issues. Sarah Budd, who received her Ph.D. from the University of Illinois on single top production, will be joining our group on June 1, 2009, after spending a year teaching at Redlands College in California.

Hardware work for NOνA involves engineering and technical assembly of four prototype neutrino detectors in building 366 and the design and construction of machinery to construct the prototypes. This project will proceed in four stages: (1) construction of the Full Size Assembly Prototype (FSAP), (2) construction of the Integration Prototype Near Detector (IPND), (3) construction of the Full Height Engineering Prototype (FHEP) and (4) construction of the Near Detector (ND). The assembly of ND and IPND are virtually identical. A general outline of the staged NOνA project is given below.

(1) FSAP. The first stage of the NOνA Project is to build the FSAP and the requisite machinery to achieve that task. The FSAP is an assembly of PVC extrusions and modules. Each extrusion is approximately 52 ½ feet long, 26 inches wide and 2 ½ inches high. Each module consists of two extrusions cemented together, side by side, and affixed with end-caps at either end. (Modules were assembled at the University of Minnesota and shipped to ANL). Extrusions weigh approximately 350 pounds each, while modules weigh approximately 700 pounds each or 1,000 pounds each, depending on the cell-wall thickness.

Assembly of FSAP will take place on the concrete floor of building 366. 24 extrusions will be placed side-by-side to form the bottom layer of an eventual stack 6 layers high. All subsequent layers will be glued to the layer below. Because the extrusions and modules are large and heavy, specialized machinery is being constructed to facilitate the assembly process: (1) A vacuum lifting fixture and (2) a glue machine.

The Full Scale Assembly Prototype is a model of the eventual NOνA detector assembly. FSAP consists of six layers of PVC extrusions placed on the floor in building 366. The floor is leveled using shims to ensure the FSAP is constructed on a flat surface. The PVC extrusions are placed in two orientations. The lowest plane of extrusions, which rests on the shimmed floor, consists of 24 extrusions (52’-7” long by 25” wide by 2 and 5/8” high) with their long axis aligned North-South (bldg 366 reference). The extrusions are placed side-by-side to make roughly a 52-foot by 52- foot square. The second layer of extrusions are positioned in a similar manner except their long axis is aligned East-West (bldg 366 reference), resulting in an orthogonal matrix grid. The third layer is similar to the first, the fourth is similar to the second, resulting in an alternating x-y structure 6 layers high.

Construction of the FSAP will proceed in the following manner. After the floor was shimmed, the Vacuum Lifting Fixture picks up two extrusions (or one module). The Vacuum Lifting Fixture and its load is moved to the Rotation Tables and placed in position for gluing. After gluing is completed, the vacuum lifting fixture and its load are moved over the FSAP floor space, the lifting beam is oriented properly (E-W or N-S) and the extrusions (or module) are (is) placed in position and released from the vacuum lifting fixture. Note that the first plane of extrusions was placed in the glue machine for gluing. Glue is being applied to extrusions and only after the first plane of extrusions has been placed on the floor.

Building and operating the IPND, FHEP and ND. Construction of the IPND will necessitate modification or replacement of some of the existing machinery used for the FSAP. The FHEP will be constructed with the same machinery and techniques used for the FSAP and the IPND. A support structure for FHEP will be provided by Fermilab. The Near Detector (ND) will be constructed with the same machinery and techniques as were used for the IPND. No new machinery or procedures will be employed. A recent modification to the plan involves constructing the full ND as part of the IPND and operating it near the MINOS surface building. This requires the identification of a weather proof temporary structure in which to locate the IPND. The operation of the IPND will accomplish several things. In addition to a test of all the mechanical, electronic and DAQ functions required for this experiment, there will be early data obtained in an off-axis component of the NuMI beam. This will be important both to test the understanding of the beam, but also to measure the backgrounds, if any, that will be apparent in operating a detector of this design on the surface of the earth.

Members of the ANL neutrino group will also be deeply involved in planning for the physics goals of the NOνA experiment. The main goal is the observation of $\nu_\mu \rightarrow \nu_e$ oscillations. We will use the knowledge gained in the similar analysis of the MINOS experiment, together with the higher granularity of NOνA to maximize the efficiency and minimize the backgrounds. Early analysis of data from the IPND will be crucial in this regard. One key feature of analysis will be the extrapolation of information from the near detector to the far detector. In principle, electron like events in the near detector come from a mixture of NC events, ν_μ charged current events and ν_e charged current events. Extrapolation of the NC events is unaffected by oscillation. The extrapolation of the electron neutrino events gives the expectation in the absence of oscillations due to θ_{13}. The muon neutrino charged current events need to be extrapolated with oscillations, linked to θ_{23}, taken into account. This was done for MINOS using two different methods, and the optimum method for NOνA has not yet been determined.

Other information will be useful in figuring out the electron-like backgrounds in NOνA. There will not be a test beam, so the simulation efforts, being led by M. Sanchez, will be crucial, and extensive benchmarking of the simulations will need to be done. Data as it becomes available from the MIPP and MINERνA experiments will be useful in this regard.

The sensitivity of NOνA to θ_{13} will depend on its schedule, ultimate mass, and the conditions of the neutrino beam at Fermilab. Figure 3 shows the sensitivity for $\theta_{13} \neq 0$ at the three standard deviation level as a function of δ for each of the two possible mass orderings. A way of comparing the difference between 700 kW, 1.2 MW and 2.3 MW beam power is to note the fraction of the parameter space for which the NOνA three-standard deviation sensitivity is more than an order of magnitude greater than the current 90% CL upper limit. The 2.3 MW and 1.2 MW sensitivities meet this criterion for 64% and 22% of the parameter space, respectively, while the 700 kW sensitivities meet it for only 9.5% of the parameter space.

A positive signal in NOνA would then be used to address the mass ordering of the neutrinos, which is possible due to the different matter effects that would be expected. The mass ordering can only be resolved by NOνA alone for the portion of parameter space in which the matter effect and CP violation affect the oscillation in the same manner. For the remainder of the parameter space, a third measurement is required to resolve the mass ordering. One possibility is to combine NOνA data with data from T2K, which has a much shorter baseline. Reactor experiments will provide additional input on this. Given our close work on reactor experiments, the ANL neutrino group will be well positioned to contribute to these important analyses.

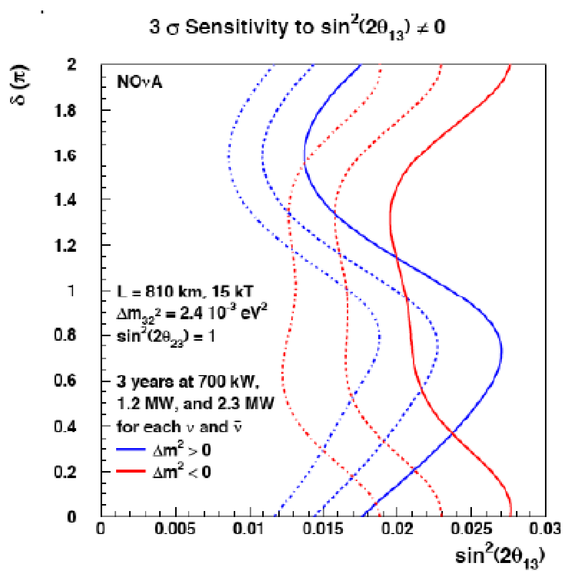


Figure 3. Sensitivity of NOνA to θ_{13}.

<u>Plans for participating in the Long-Baseline DUSEL experiment</u>

In "US Particle Physics: Scientific Opportunities, A Strategic Plan for the Next Ten Years", issued in May 2008, the P5 subpanel of HEPAP wrote:

- ``The panel recommends a world-class neutrino program as a core component of the US program, with the long-term vision of a large detector in the proposed DUSEL laboratory and a high-intensity neutrino source at Fermilab."

- ``The panel recommends proceeding now with an R&D program to design a multi-megawatt proton source at Fermilab and a neutrino beamline to DUSEL and recommends carrying out R\&D on the technology for a large detector at DUSEL."

- ``The panel further recommends that in any funding scenario considered by the panel, Fermilab proceed with the upgrade of the present proton source by about a factor of two, to 700 kilowatts, to allow a timely start for the neutrino program in the Homestake Mine with the 700-kilowatt source."

The ANL neutrino group has been long involved in ideas and plans for new neutrino capabilities from a new underground facility in the United States. This has been a decade's long process and several designs and studies were coauthored by members of the ANL neutrino group. That facility is moving towards reality as the Deep Underground Science and Engineering Laboratory. Although the timeframe for the operation of a DUSEL beam is not clear, it is known that planning and initial design of new experimental facilities will accelerate during the period 2009-2012, and the ANL neutrino group will continue to be increasingly involved. Towards the end of this period, ANL is a founding member of the Long-Baseline DUSEL (LB-DUSEL) collaboration, whose goal is the design, construction, and operation of: (1) large neutrino detectors at the proposed Deep Underground Science and Engineering Laboratory (DUSEL), (2) additional near and/or intermediate detectors and (3) a neutrino beam from Fermi National Accelerator Laboratory (FNAL) to DUSEL. ANL physicist Maury Goodman has been chosen the vice-chairman of the Institutional Board of this collaboration and wrote the by-laws that govern the operation of the collaboration.

The group has participated in the S3 and S4 process for funding from the National Science Foundation, although no funds have been requested from the NSF for ANL. We have helped in the preparation of the document defining the depth requirements for a large detector. ANL physicist Bob Wagner has participated in weekly meetings involved with the design of the neutrino beam.

There is also a detector R&D effort at ANL, with possible applications for a large water Cerenkov Detector at DUSEL. This involves multichannel plate detectors that have very fast timing. One of the efforts, which will be led by Mayly Sanchez and includes a new postdoc Matthew Wettstein, is to study the additional physics that could be achieved with faster timing in a megaton scale water Cerenkov Counter. Of particular interest is whether additional timing capabilities could reduce neutrino backgrounds in proton decay searches. There is also interest in working on ways to implement the front end electronics of a large water Cerenkov detector in a way that reduces or eliminates cables. That could find some synergy with efforts associated with some LHC upgrades to move towards wireless readout.

Future Neutrino Experiment Planning

It is well known that the future course of accelerator based neutrino physics crucially depends on the value of the one unknown mixing parameter θ_{13}. Some further knowledge about that parameter will be obtained soon by Double Chooz; soon thereafter by T2K, and not long after that by Daya Bay. All this information will precede significant NOνA running. At that point in time, the situation will be viewed quite differently if hints for non-zero θ_{13} are being reported than if they are not. The future holds many possible directions, including LB-DUSEL, NOνA upgrades, or more powerful reactor experiments, not to mention possibilities in Japan, Europe or India. While significant planning exercises have taken place in the United States by HEPAP and P5, they have not really paid close attention to possible developments overseas. An extensive planning process is underway in Europe under the aegis of the European Union, and a great deal of work on possible future neutrino programs is taking place. Longer term research is being done on neutrino factories and beta beams. The ANL neutrino group is paying close attention to all of these developments, and will help to lead the way for the best use of DOE resources to learn any new secrets or surprises that the neutrino has in store for us.

Talks at Major Labs, Conferences and Workshops

- Initial Results on ν_e Appearance in MINOS, Moriond 2009, M. Sanchez
- Initial Results for $\nu_\mu \rightarrow \nu_e$ oscillations in MINOS, Fermilab 2009, M. Sanchez
- Neutrino Oscillation Experiments in North America, Neutrino Oscillation Workshop, Otranto Italy 2008, M. Goodman
- Neutrino Experiment searches for theta-13, PANIC, Eilat Israel 2008, M. Goodman
- Electron Neutrino Appearance in the MINOS Experiment, Neutrino 2008, M. Sanchez
- MINOS Status and Prospects, Fermilab PAC, 2008, M. Sanchez
- ADONIS, SN1987a 20^{th} Anniversary Workshop, 2007, R. Talaga.
- Interpretation of the Underground muon charge ratio, ICRC, Merida Mexico, 2007, M. Goodman
- Invited Summary speaker on Experimental Neutrino Physics WIN, Calcutta, India 2007, M. Goodman
- NOvA, IEEE, 2007, R. Talaga.
- Long-baseline neutrino experiments at Fermilab, GLOBES workshop, Heidelberg, 2007, M. Goodman
- Searching for the Neutrino Mixing Angle theta13 at Reactors, Neutrino Telescopes, 2007, M. Goodman
- "Second Generation Neutrino Oscillation Experiments at Reactors, Cryodet Workshop, Gran Sasso Italy, 2007, M. Goodman
- Low Energy Neutrinos, ICFA seminar, Daegu S. Korea, 2006, M. Goodman
- Double Chooz, PANIC, Santa Fe, NM. 2006, M. Goodman

Broader Impact

- Maury Goodman, Interview for Physics Today, 2008
- Maury Goodman, Interview for Physics World, 2007
- Supervised two Ph.D. candidates on MINOS, Eric Beall and Aaron McGowan, both received Ph.Ds from Minnesota
- Mentored 6 high school students from the Illinois Math and Science Academy who come on Wednesdays. This has led to 2 semi-finalists in the Siemen's Competition, and 4 other awards.
- Supervised 3 college summer students
- Provided 2 summer faculty positions
- Provided venues for collaboration meetings of both MINOS and NOvA
- Issue monthly newsletter on neutrinos with >1500 subscribers http:
- Maintain web site on neutrinos for the larger community (www.neutrinooscillation.org) with lists of experiments, meetings, jobs, poetry,

Support and Infrastructure

In all experiments the Division has participated in or is participating in, members of the Division have played major roles in the design and construction of the hardware. Typically these are large calorimeters that are assembled at Argonne, for which we provide electronics, installation systems and maintenance during the operation of the experiment. The following infrastructure is in place to accomplish this:

- We have Bldg. 366, a 23,000 sq ft high bay, 35 ton crane equipped, unique assembly area for large construction projects. ZEUS, MINOS and ATLAS modules as well as moving systems for ATLAS were built here. Currently the first prototype of a 56x56ft NOνA module is being assembled here. The Argonne lab provides and maintains this space.
- There is a mechanical design group within the Division, with two mechanical engineers, typically supported by project funds. Its size varies from a minimum of two FTEs up to three or four FTEs. We also have access to a lab wide engineering group in case more effort is needed. The division mechanical group currently also has four technical people (including one machinist) and typically this group is partially supported by project funds.
- The Division is the home of the electronics group with a total staff of ~ 9 engineers, designers and technicians who support ~10 Argonne divisions. This group designs, builds and maintains electronics associated with detectors provided by the Division for experiments. Typically at least 2-3 members of that group work on HEP activities.
- The Division has one major machine shop (plus machinist) in the large assembly building, plus two smaller machine shops in the electronics area and in one other lab.
- Within the main building for HEP, Bldg. 362, we have about 10 large lab spaces available, which are used for detector and electronics development, electronics repair, a cosmic ray test stand and several other testing and R&D activities.
- Through the competitive Laboratory Directed R&D (LDRD) program, we compete for these lab wide LDRD funds, which are typically used to develop a new idea for a detector or computing project, start a new activity and/or build a proof of principle for a new device. Typically LDRD funding is about $1M/year in the division for several projects.
- Recently the division expanded substantially in office space, as a building became available, connected to our main HEP building. The ATLAS group moved into this new space, providing more coherence to the group, better communications, more office space for visitors and workshops and the possibility to expand in the future.

Broader Impact of the research

This section addresses how well the Argonne HEP program is aligned with the mission of the Office of High Energy Physics within DoE. For completeness that mission is:

"The mission of the High Energy Physics program is to understand how our universe works at its most fundamental level. We do this by discovering the most elementary constituents of matter and energy, exploring the basic nature of space and time itself, and probing the interactions between them. These fundamental ideas are at the heart of physics and hence all of the physical sciences. To enable these discoveries, HEP supports theoretical and experimental research in both elementary particle physics and fundamental accelerator science and technology. HEP underpins and advances the DOE missions and objectives through this research, and by the development of key technologies and trained manpower needed to work at the cutting edge of science."

The CDF experiment at the Tevatron, in which Argonne has played and still plays a very significant role has discovered and/or revealed new particles, measured their properties with very high precision and has probed the interactions among them. It is without a doubt one of the most successful experiments in HEP. Examples of significant progress are:

Observation of Bs and D^0 oscillations
Tests of CPV in Bs mixing
Observation of Exotic charmonium (J/ψ-φ)
Observation of Heavy baryons (Σb, Ξb, Ωb), Bc meson
Higgs exclusion limits (160-170 GeV)
W mass determination (with 200 pb^{-1} luminosity)
Top mass measurements
Observation of Single top
Observation of Diboson (WZ, ZZ) production

In addition to these significant contributions, the group has had several postdocs and students, and members of the group have worked closely with postdocs and students in the CDF research program.

The ZEUS experiment (together with H1) which has also been supported from the Proton Accelerator B&R code has advanced our understanding of the constituents of the proton to a level of accuracy never seen before. These measurements have enabled very precise predictions for all processes at the Tevatron and the future LHC. Without this experiment, the uncertainties in LHC predictions would be very large. The ZEUS group has also supported and supervised three graduate students, as well as several postdocs during the running and analysis periods of ZEUS. Yoshida from Argonne served as spokesman of the experiment for several years up to 2006.

In the neutrino community Argonne has played a leading role in defining the current accelerator based neutrino program in the United States. The original proposal for a long-baseline neutrino beam from Fermilab to Soudan came from Argonne, and our physicists have worked with the rest of the neutrino community to turn that program into a reality. Currently, they are working to further exploit the NuMI beam with the NOνA experiment. And they continue to help shape the future of the oscillation program. A monthly Neutrino Newsletter, with >1500 subscribers, is published at Argonne (Goodman): http://www.hep.anl.gov/ndk/longbnews/ Also a WEB site is maintained for the wider community: http://www.neutrinooscillation.org/

The MINOS experiment has improved our understanding of neutrino mixing and the electron neutrino appearance analysis was spearheaded by Argonne staff (Sanchez). The neutrino group at Argonne has a strong educational/training component in that they have supervised & supported 2 graduate students on MINOS and each year mentor 3 high school students from the Illinois Math and Science Academy, who are at Argonne every Wednesday. The group also typically hosts faculty from several colleges for the summer enabling them to participate in neutrino research.

The energy frontier, one of the main cornerstones of the HEP mission will move to the LHC in the near future. Argonne HEP has played a key role in the ATLAS experiment in the design and construction of the tile calorimeter, which involved and enabled several universities to participate. Another major responsibility is in the trigger/DAQ system for the Region of Interest (RoI) builders. For both cases we had/have several people stationed at CERN. Stanek was leader of the overall tile calorimeter commissioning for several years and appeared prominently in local newspapers (Chicago Tribune) and on national TV on CBS's "60 Minutes", being interviewed for "The Collider":
http://www.cbsnews.com/video/watch/?id=4484053n

An important activity at Argonne, supported by US ATLAS project funds, is the very active science computing support group, consisting of 5 scientific computing experts, who are defining the database access for data for all of ATLAS. This is an important activity within ATLAS and provides a valuable resource for the training workshops we have at Argonne to prepare for the ATLAS data analysis.
The Atlas group is now transitioning towards "analysis" and is playing an "enabling" role for the US ATLAS community, by organizing very well attended workshops to introduce and make scientist familiar with the ATLAS computing and software environment. A reflection of the role that Argonne plays within ATLAS is the fact that LeCompte is the Deputy Physics Coordinator of ATLAS and will become the Physics Coordinator this year.

Features and Trends of the Argonne HEP program

In response to DOE-HEP guidelines, the HEP Division conducted an extensive long-range planning exercise in 2003, which was presented at the 2004 DOE review. The purpose of the exercise was to examine new initiatives, for example in astrophysics and in the ILC, and to project the transition of physicist and engineering effort from CDF and ZEUS into ATLAS/LHC and other new projects. This plan, updated through FY2006, projected an end of ANL participation in ZEUS by the end of FY2007, and gradual reduction of the CDF effort through FY2009. It can be found at http://gate.hep.anl.gov/plan_group/Plan2006.doc.

It should be stressed that the "plan" did not enforce any redirection of effort, but rather summarized the choices that were being made in light of the expected shutdown of HERA (2007) and the Tevatron (2009?), and the anticipated startup of LHC (2007-> 2008-> 2009..). The predictions for the transition of FTE effort have proven to be quite accurate. In the period 2006-2009, the ZEUS effort (~4 FTE) has moved entirely into LHC/ATLAS and ILC detector development, while a large fraction of the CDF effort (~6 FTE) has moved into ATLAS and astrophysics. The net flow of FTE effort in CDF has been from ~6 FTE (FY2004) to ~3 FTE (FY2007) to ~2 FTE (FY2009).

The neutrino group has seen a decline in manpower, due to funding cuts, over several years (before 2006). After a junior member of the group left in 2007, Sanchez was hired as a staff member. Because of the funding reduction in December 2007, budget constraints and the uncertainties associated with Nova, the most senior member of the group (Ayres) decided to take voluntary layoff. We are now in the process of a search to replace him, but are facing the fact that Sanchez will be leaving in September for a faculty position which solves her “two -body” problem, that we could not solve. It is important for the neutrino program in the division that both Ayres and Sanchez will be replaced by new staff.

APPENDIX A: Curriculum Vitae

Robert Eugene Blair

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Education:

B.S. (Physics and English) Carnegie-Mellon University (1971)
Ph.D. (Physics) California Institute of Technology (1981)

Professional Employment:

Physicist, ANL (1989-present)
Assistant Physicist, ANL (1986-1989)
Assistant Professor, Columbia University (1983-1986)
Postdoctoral Fellow, Columbia University (1982-1983)

Awards, Memberships, and Professional Service:

Publications (461) with 27441 citations
D.O.E. Review panels (CMS Lehman Review, 7 SBIR reviews)
Invited talks (6 at international conferences)
Additional published conference proceedings (43)
Unpublished technical reports (31)
CDF Service work (QCD convener, Photon Group convener)
ATLAS service work (TDAQ coordination group, L2 manager for USATLAS trigger)

Selected Research Accomplishments:

Fermilab E356 neutrino experiment cross section measurement (1979-1983)
Demonstration of CDF prompt photon reconstruction (1988)
Initiated isolation triggers for photon measurement in CDF (1988-)
Initiated CDF preshower detector project (1988-)
Developed CDF photon physics program (1988-1996)
Inclusive CDF photon cross-section measurement (1992)
Initiated Region of Interest builder for ATLAS trigger (1996-)
CDF Diphoton cross-section measurements (1994 & 2005)

Selected Publications (Robert E. Blair):

1. Monitoring and Calibration System for Neutrino Flux Measurement in a High-Energy Dichromatic Beam, Nucl.Instrum.Meth.A226:281 (1984).

2. Measurement of the Rate of Increase of Neutrino Cross-Sections with Energy, Phys.Rev.Lett.51:343-346 (1983).

3. A Prompt photon cross-section measurement in anti-p p collisions at s**(1/2) = 1.8-TeV,Phys.Rev.D48:2998-3025 (1993).

4. A Precision measurement of the prompt photon cross-section in p anti-p collisions at S**(1/2) = 1.8-TeV,Phys.Rev.Lett.73:2662-2666 (1994).

5. Searches for new physics in diphoton events in p anti-p collisions at s**(1/2) = 1.8-TeV, Phys.Rev.D59:092002 (1999.)

6. Measurement of the cross section for prompt diphoton production in p anti-p collisions at s**(1/2) = 1.96-TeV, Phys.Rev.Lett.95:022003 (2005).

7. The ATLAS High Level Trigger Region of Interest Builder, JINST 3:P04001 (2008).

Karen Byrum

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Education:

B.S., Old Dominion University 1983
Ph.D., University of Wisconsin, Madison 1991

Professional Employment:

Physicist, ANL (2000-present)
Assistant Physicist, ANL (1995-2000)
Postdoctoral Fellow, ANL (1992-1995)

Awards, Memberships, and Professional Service:

D.O.E. Review panels (LBL, Dark Energy)
Conference organization (15+)
Invited talks (5 at international conferences)
Publications including conference proceedings (532).
Unpublished technical reports (43)
ANL service committee work (LDRD, Strategic Planning, Pacesetter)
ANL Strategic Initiative Leader for Astrophysics and Cosmology
Graduate of first cohort of Strategic Laboratory Leadership Program (2007-2008)
Elected Member of Fermilab Users Committee (1997-1999)
CDF Service work (convenerships, detector reviews, Shift Leader)
VERITAS Service work (Science Board, Speakers Committee, Shifts)

Selected Research Accomplishments:

Leader of Laboratory Astrophysics Program (2007-2010).
White Paper on the Status and Future of Ground-based Gamma-ray Astronomy (2007)
TrICE Telescope (2005/06).
Construction and operation of CDF shower maximum frontend electronics (1995-).
Shower max. e/γ level-2 trigger (1992-).
Observations of first forward/backward muons at CDF (1988-)

<u>Selected Publications (Karen Byrum)</u>:

1. Discovery of Very High-Energy Gamma-Ray Radiation from the BL Lac 1ES 0806+524, Astrophysical Journal Letters, Vol 690, Issue 2, pp. L126-L129 (2009)

2. A Search for Dark Mtter Annihilation with the Whipple 10m Telescope, M.Wood et al, Astrophysical Journal, Vol. 678, Issue 2, pp 594-605 (2008)

3. The TrICE Prototype MAMPT Imaging Camera, K.Byrum et. el., 30th International Cosmic Ray Conference.arXiv:0710.0659v1 (2007)

4. Observation of Bs Oscillations, Phys. Rev. Lett. 97 242003 (2006)

5. Measurement of sin 2β, Phys. Rev. D61: 072005 (2000).

6. Measurement of B^+ and B^0 Lifetimes, Phys. Rev. Lett. 76: 4462 (1996).

7. Shower Maximum Trigger for Electrons and Photons at CDF, K. Byrum, et. el Nucl. Instrum. Methods, A364 (1995).

8. Observation of Top Quark Production in ppbar Collisions with the Collider Detector at Fermilab, (CDF) Phys. Rev. Lett. 74, 2626 (1995).

Sergei Chekanov

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Argonne, IL 60439

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Fax: 630-252-5782
E-mail: chakanau@hep.anl.gov
http://www.hep.anl.gov/chakanau/

Education:

B.S., Belorussian State Univ. Minsk, USSR 1992
Ph.D., Nijmegen/HEFIN, The Netherlands 1997

Professional Employment:

Scientist, ANL (2008- Present)
Assistant Physicist, ANL (2001-2008)
Postdoctoral Fellow, ANL (1998-2001)
Postdoctoral Fellow, Nijmegen/HEFIN (1997)

Awards, Memberships, and Professional Service:

Conference and workshop organization (5)
Invited talks (26 at international conferences), Seminars (6)
Personal publications (about 100) and total (233) with 5600 citations.
Additional published conference proceedings (42)
Unpublished technical reports (19)
Calorimeter DQM 1995-1997 (L3 experiment, CERN), ZEUS shift leader (1998-2008)
QCD group coordinator, 2001-2008 (ZEUS experiment, DESY)
ANL service work: HEP division computing group leader
Responsible for computer infrastructure of the ATLAS Analysis support center at ANL
ATLAS Service work (Calorimeter DQM developer)

Selected Research Accomplishments:

More than 40 theoretical papers,
Primary author of more than 50 publications in refereed journals.
Initiated 7 software projects
13 experimental papers (written + data analysis for ZEUS and L3)
Construction and operation of a preshower detector for the ZEUS Barrel Calorimeter (1998-2008)
Work on ZEUS Calorimeter First Level Trigger Processor (CFLTP) during 2004-2007
Physics coordinator of the ZEUS QCD group at DESY for 8 years. More than 30 ZEUS papers have been prepared for publication in the QCD group since 2001
HEP division computer-group leader
Computing leader of the ATLAS Analysis Support Center at ANL

Selected Publications (Sergei Chekanov):

1. Measurement of prompt photons with associated jets in photoproduction at HERA
   ZEUS Collab., Chekanov, S. and others, Eur. J. Phys C49 (2007) 511
2. Evidence for a narrow baryonic state decaying to K0(S) p and K0(S) anti-p in deep inelastic scattering at HERA (main analysis)
   ZEUS Collab. Chekanov, S. and others, Phys. Lett. B591 (2004) 7
3. Selection and reconstruction of the top quarks in the all- hadronic decays at a linear collider
   Chekanov, S. V. and Morgunov, V. L., Phys. Rev. D67 (2003) p. 074011
4. Uncertainties on the measurements of the top mass at a future e+ e- collider
   Chekanov, S. V., Eur. Phys. J. C26 (2002) p. 173-181
5. Bose-Einstein correlations and color reconnection in W pair production
   Chekanov, S. V., De Wolf, E. A., and Kittel, W., Eur. Phys. J. C6 (1999) p. 403-411
6. Generalized bunching parameters and multiplicity fluctuations in restricted phase-space bins, Chekanov, S. V., Kittel, W., and Kuvshinov, V. I. Z. Phys. C74 (1997) p. 517-529
7. Measurement of D*+- production in deep inelastic e+- p scattering at HERA
   ZEUS Collab., Chekanov, S. and others, Phys. Rev. D69 (2004) 012004
8. Observation of the strange sea in the proton via inclusive Phi-meson production in neutral current deep inelastic scattering at HERA
   ZEUS Collab., Chekanov, S. and others, Phys. Lett. B553 (2003) 141

Gary Drake

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Education:

B.S.E.E., University of Wisconsin – Madison, 1982
M.S.E.E., University of Wisconsin – Madison, 1983

Professional Employment:

Senior Engineer, ANL (2008-)
Engineer, ANL (1997-2008)
Engineer, Fermilab (1983-1997)

Awards, Memberships, and Professional Service:

Member, IEEE (1994)
Argonne Pacesetter Award – June, 2007
Publications (18)
Additional published conference proceedings (25)
Unpublished technical reports (46)

Selected Research Accomplishments:

Design Engineer, design and production of front-end electronics for the calorimeters of the CDF detector, Run I at Fermilab (1983-1989).
Design of custom integrated circuits (1994-1996).
Lead Project Engineer, design and production of front-end electronics for the Shower Maximum Detector for the CDF, Run II Upgrade at Fermilab (1995-1999).
Lead Project Engineer and Level 3 Manager, design and production of the readout instrumentation for the MINOS Near Detector at Fermilab (1999-2005).
Design of Cockroft-Walton photomultiplier base for the BCAL detector of the Zeus Experiment at DESY in Hamburg, Germany (1999-2000).
Design of a custom backplane for the Level 2 Trigger of the ATLAS Experiment at the LHC at CERN in Switzerland (2004-2005).
Development of beam monitoring electronics for the NuMI Beamline at Fermilab (2003-2005).
Telescope camera R&D for the TrICE Telescope at Argonne (2003-2006).
Lead System Engineer, design and production of readout instrumentation for Digital Hadron Detector R&D for CALICE (Detector R&D for the International Linear Collider) (2003-present).
Development of a 1-GHz Photon-Counting Custom Integrated Circuit for Ground-Based Air-Cherenkov Telescopes. (2005-2008).
Development of 1-Picosecond timing instrumentation for HEP applications (2005-present).
R&D on detector development using silicon photomultipliers (2006-2008).
Switching power supply support for the Barrel Calorimeter of the ATLAS Experiment at the LHC at CERN in Switzerland (2006-present).
Lead engineer, design of high-speed topological trigger for future telescope arrays for gamma-ray astronomy (2007-present).
Development of new switching power supplies for the upgrade of the Barrel Calorimeter of the ATLAS Experiment at the LHC at CERN in Switzerland (2008-present).
Development of new readout instrumentation for the upgrade of the Barrel Calorimeter of the ATLAS Experiment at the LHC at CERN in Switzerland (2008-present).

Selected Publications (Gary Drake):

1. "A New High-Speed Pattern Recognition Trigger for Ground-Based Telescope Arrays Used in Gamma-Ray Astronomy," *IEEE 2008 NSS Conf. Rec.,* 2008, 8 pages.

2. "The MINOS Near Detector Front End Electronics *IEEE Trans. Nucl. Sci.,* vol. 53, 2006, pp. 1347-1355.

3. "A Digital Hadron Calorimeter with Resistive Plate Chambers for the Linear Collider," *Int. J. Mod. Phys,* Vol. A20, 2005, pp. 3830-3833.

4. "DCAL: A Custom Integrated Circuit for Calorimetry at the International Linear Collider," *IEEE 2005 NSS Conf. Rec.,* 2005, 8 pages.

5. "The Shower Maximum Front-End Electronics for the CDF Upgrade," *IEEE Trans .Nucl. Sci.,* vol. 49, 2002, pp. 2567-2573.

6. "The Upgraded CDF Front End Electronics for Calorimetry," *IEEE Trans. Nucl. Sci.*, vol. 39, 1992, pp. 1281-1285.

7. "CDF Front End Electronics: The RABBIT System," *Nucl. Instrum. Meth.*, vol. A269, 1988, pp. 68-81.

8. "A Large Dynamic Range Charge Amplifier ADC for the Fermilab Collider Detector Facility," *IEEE Trans. Nucl. Sci.,* vol. 33, 1986, pp. 893-896.

Maury Goodman

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Education:

B.S., MIT 1972
MS., University of Illinois, 1976
Ph.D., University of Illinois, 1979

Professional Employment:

Physicist, ANL (1985- present)
Postdoctoral Staff, MIT (1979-1984)
2nd Lt., 1st Lt. Captain, US Army (1972-1973); US Army Reserve (1974-1986)

Awards, Memberships, and Professional Service:

Fellow of the American Physical Society (2009)
Society of Sigma Xi (1972)
Co-spokesperson for US Double Chooz Collaboration (2006-present)
ANL service committee work (POC-HP, planning group, seminars committee,…)
MINOS Service Work (Executive Committee, Chairman of Institutional Board) 1995-2009
NOvA (Chairman of Speakers Committee) 2009
Spokesperson for THESEUS proposal (FNAL P822, neutrinos to Soudan 2) 1992-1996
Chairman of Organizing Committee Long-Baseline Neutrino Workshop, 1991
International Advisory Committee for Neutrino 2002, Neutrino 2004, Neutrino 2006, Neutrino 2008

Selected Research Accomplishments:

Leader of the ANL-HEP neutrino group. 2007-present
Led a MINOS analysis group on cosmic ray muon studies; first rise in charge ratio seen & explained, 2008
Invited summary speaker on neutrino experiments at 2007 Weak Interactions and Neutrinos Workshop
Detected neutrino oscillations using Rock Muons in MINOS, 2007.
Active Participant & Writer for APS neutrino study, 2004.
Observation of Atmospheric Neutirno Oscillations in Soudan 2, 2003.
Search and limit on neutrinos from Active Galactic Nuclei in Soudan 2, 1999.
Supervised 4 Ph.D. students and 5 postdoctoral appointees, 1996-present.
Member of the Particle Data Group since 1996, spearheaded 2006 neutrino revision
Significant contributions to MINOS (FNAL P875) Proposal, 1995
Issues monthly newsletter on neutrinos with a subscription list over 1500 since 1992
Led efforts to create a long-baseline neutrino oscillation program at Fermilab in the 1990s
Initiated Soudan 2 neutrino oscillation analysis, 1988
Led Soudan 2 data analysis for several nucleon decay modes, 1987-1998
Organized use of Fermilab Experiment E594 for Cosmic Ray Studies, 1982-1984
Mentored numerous undergraduate and High School students (Ill. Math/Science Academy) continuous

Selected Publications (Maury Goodman):

1. Measurement of Neutrino Oscillations with the MINOS Detectors, Phys. Rev. Lett. 101, 2008.

2. Reviews of Particle Properties, Physics Letters, B167, 2008. (Also, 1998, 2000, 2002, 2004 & 2006)

3. Search for the proton decay mode neutrino K+ in Soudan 2, Physics Letters B427, 1998.

4. Other Atmospheric Neutrino Experiments, Nucl Physics B (Proc Supppl.) 118, 2003.

5. A New Nuclear Reactor Neutrino Experiment to Measure theta-13, arXiv:hep-ex/0402041.

6. Double Chooz, A search for the Neutrino Mixing Angle theta-13, arXiv:hep-ex/0606025.

7. Horizontal Muons and a search for AGN neutrinos in Soudan 2, Astroparticle Physics 20, 2004.

8. Interpretation of the Underground Muon Charge Ratio, Submitted to Astroparticle Physics, 2009.

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Education:

B.S., Illinois Institute of Technology 1987
M.S., Illinois Institute of Technology 1988
Ph.D., University of Illinois at Chicago 1999

Professional Employment:

Engineer, ANL (1993-)
Assistant Engineer, ANL (1989-1993)

Awards, Memberships, and Professional Service:

Licensed Illinois Professional Engineer

U.S. ATLAS Tilecalorimeter Project Engineer – responsible for all US structural design, fabrication, and assembly on the ATLAS Tilecalorimeter at the LHC

NOvA Project Engineer – responsible for the analysis of the NOvA structure and the design and fabrication of all construction equipment for the detector

MINOS Project Engineer – responsible for the design and fabrication of machinery for constructing MINOS modules.

Selected Publications (Victor Guarino):

1. "Stability of the EB When Cryostat Load is Applied" Argonne National Laboratory Technical Report ANL-HEP-TR-04-65; June 23, 2004

2. "Analysis of the Connections Between Modules in the EB" Argonne National Laboratory Technical Report ANL-HEP-TR-02-056; May 16, 2002

3. "Stress Analysis Of The Welds In The Girder" Argonne National Laboratory Technical Report ANL-HEP-TR-98-06; December 1, 1997

4. "Extended Barrel Support Saddle Design and Analysis" presented at the Atlas engineering meeting at The European Center for Nuclear Research (CERN), Geneva, Switzerland; August, 2001

5. "Proposal for the Completion of the Outstanding Work, Scheduling and Alignment of the SDC Central Calorimeter" Argonne National Laboratory Technical Report ANL-HEP-TR-93-101; November 1993

Thomas J. LeCompte

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Education:

S.B., MIT (1985)
M.S., Northwestern (1989)
Ph.D., Northwestern (1992)

Professional Employment:

Physicist, ANL (2000-)
Assistant Physicist, ANL (1995-2000)
Visiting Research Assistant Professor, University of Illinois, (1994-1995)
Postdoctoral Fellow, University of Illinois (1992-1994)

Awards, Memberships, and Professional Service:

APS DPF and DNP Member
CTEQ Member
DoE and NSF Review Panels
Fermilab Director's Review Panels
Publications (392) with 20913 citations.
Additional published conference proceedings and technical reports (34)
Lecturer at various summer schools
LHC Theory Initiative Steering Committee

Selected Research Accomplishments:

Deputy Physics Coordinator of ATLAS (2009)
Physics Coordinator of STAR (1998)
CDF Run II Muon Project Leader
Convener of ATLAS, STAR and CDF Physics Working Groups
b-cross section measurements at CDF
Bs mixing measurement at CDF
First Top decay measurements (BF to Wb + FCNC)

Selected Publications (Thomas LeCompte):

1. Expected Performance of the ATLAS Experiment - Detector, Trigger and Physics.
   ATLAS Collaboration (G. Aad et al.). Jan 2009. e-Print: arXiv:0901.0512

2. Measurement of the J/□ meson and *b*-hadron production cross sections in proton-antiproton collisions at $\sqrt{s}$ = 1960 GeV.
   CDF Collaboration (D. Acosta et al.). Published in Phys.Rev.D**71**:032001,2005.
   e-Print Archive: hep-ex/0412071

3. Measurement of the lifetime difference between B_s mass eigenstates.
   CDF Collaboration (D. Acosta et al.). Published in Phys.Rev.Lett.**94**:101803,2005.
   e-Print Archive: hep-ex/0412057

4. Observation of the narrow state X(3872) $\rightarrow J/\varphi\, \pi^+ \pi^-$ in $p\bar{p}$ collisions at $\sqrt{s}$ = 1.96 TeV
   CDF II Collaboration (D. Acosta et al.). Published in Phys.Rev.Lett.**93**:072001,2004.
   e-Print Archive: hep-ex/0312021

5. The CDF and D0 upgrades for Run II.
   T. LeCompte (Argonne) , H.T. Diehl (Fermilab) .Published in
   Ann.Rev.Nucl.Part.Sci.**50**:71- 117,2000.

6. Search for flavor changing neutral current decays of the top quark in proton-antiproton collisions at $\sqrt{s}$ = 1.8 TeV.
   CDF Collaboration (F. Abe et al.). FERMILAB-PUB-97-270-E, Jul 1997. 8pp.
   Published in Phys.Rev.Lett.**80**:2525-2530,1998.

7. Elliptic flow in Au + Au collisions at $\sqrt{s}$ (NN) = 130 GeV.
   STAR Collaboration (K.H. Ackermann et al.). Sep 2000. 5pp.
   Published in Phys.Rev.Lett.86:402-407,2001.
   e-Print Archive: nucl-ex/0009011

8. Measurement of the ratio of *b* quark production cross-sections in antiproton-proton collisions at $\sqrt{s}$ = 630-GeV and $\sqrt{s}$ = 1800-GeV.
   CDF Collaboration (D. Acosta et al.). FERMILAB-PUB-02-116-E, Jun 2002. 8pp.
   Published in Phys.Rev.D**66**:032002,2002.
   e-Print Archive: hep-ex/0206019

Lawrence Jay Nodulman

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Education:

University of Illinois, Urbana BS (1969), MS (1970), PhD (1973)

Professional Employment:

Postdoc, University of Illinois, Urbana (1973-1975)
Postdoc, Adjunct Assistant Professor, University of California, Los Angeles (1975-1978)
Argonne: Assistant Physicist (1979-1983), Physicist (1983-1998), Senior Physicist (1998-)
Visiting Scientist, SSCL 1990

Selected Research Accomplishments:

ZGS pion induced exclusive reactions (1970-3)
AGS neutrino induced neutral current studies (Columbia/Illinois/Rock.) (1973-5)
SPEAR e+e− experments SP10 (antinucleons) and SP25 (DELCO) (1975-8)
Hadron colliders: CDF, SDC, Atlas (1979-)
Online monitoring for SP25 and CDF (run <2)
Calorimeter specialist in CDF (central EM fabrication 1983-5)
SDC (calorimeter leader 1990-1), Atlas/tilecal (1992-)
Disigned wire chambers for CDF central EM shower max (1980)
Missing Et (1985-9) and electroweak physics leader in CDF
Lecturer, exp. EWK Physics,NATO Institute St. Croix (1998)
Thesis committees:
R. StDenis, W. Trischuk (Harvard), D. Saltzburg, M. Hohlmann (Chicago)
482+ publications, 26 published proceedings
Details http://www.hep.anl.gov/ljn/mecv.html

Awards, Memberships, and Professional Service:

APS, AAAS
User: FNAL, CERN
Co-PI for ANL/CDF 1987-
Associate Division Director 1998-
FNAL UEC (chair) 1999-2002
Currently CDF co-leader of Electroweak Physics and of Calorimetry

<u>Selected Publications (Lawrence Nodulman):</u>

1. “A New Measurement of the ω(784) Width,” R. M. Brown et al., Phys. Lett. 42B (1972) 117.

2. “Single Pion Production in Neutrino and Antineutrino Reactions,” W. Lee et al., Phys. Rev. Lett. 38 (1976) 202.

3. “Measurement of the Threshold Behavior of $\tau^+\tau^-$ Production in e^+e^- Annihilations,” W. Bacino et al., Phys. Rev. Lett. 41 (1978) 13.

4. “The CDF Central Electromagnetic Calorimeter,” L. Balka et al., Nucl. Instrum. Methods A267, (1988) 272.

5. “Measurement of W Boson Production in 1.8 TeV pp Collisions,” F. Abe et al., (CDF), Phys. Rev. Lett. 62, (1989) 1005.

6. “Measurement of the W Boson Mass in 1.8 TeV pp Collisions,” F. Abe et al. (CDF), Phys. Rev. D43, (1991) 2070.

7. “Evidence for Top Quark Production in pp Collisions at $\sqrt{s}$ = 1.8 TeV,” F. Abe et al. (CDF), Phys. Rev. D50 (1994) 2296.

8. “First Run II Measurement of the W Boson Mass,” T. Aaltonen et al. (CDF), Phys. Rev. D77 (2008) 112001.

Lawrence E. Price

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Education:

Pomona College	BA 1965
Harvard University	MA 1966
Harvard University	PhD 1970

Professional Employment:

1992-2005	Division Director, Argonne National Laboratory
1988-Present	Senior Physicist, Argonne National Laboratory
1979-88	Physicist, Argonne National Laboratory
1978-79	Assistant Physicist, Argonne National Laboratory
1971-78	Assistant Professor, Columbia University
1970-71	Postdoc, Columbia University

Awards, Memberships, and Professional Service:

Phi Beta Kappa
Pomona College Magna Cum Laude
Fellow, American Physical Society
Fastbus Review Committee, 1980
International Advisory Committee on Generic Detector R&D for the SSC 1987-1993
Chairman, International Conference on Detector Simulation for the SSC, 1987
Secretary, SSC Users Organization 1989-1992
1990-2005: International Computing and Networking Coordination. Organization and leadership of several high level coordination committees.
Int'l Advisory Committee, Conferences on Computing in HEP, 1995-2004 (Conference Chairman, 1998)
Chairman, ESnet Steering Committee, 1996-2005 (member since 1989)
Organizing Committee, American Physical Society Study on "New Directions for High Energy Physics," Snowmass, CO., June 26-July 12, 1996
US/China Joint Committee on Cooperation in High Energy Physics, 1993-2005
High Energy Physics Advisory Panel 1998-2001
Organizing Committee, International Conferences on Advanced Technology and Particle Physics 2005-Present

Selected Publications (Lawrence Price):

1. ATLAS Collaboration (G. Aad et al.). **"**The ATLAS Experiment at the CERN Large Hadron Collider", *JINST 3:S08003,2008*

2. M. Barone, et al., editors, "Astroparticle, particle and space physics, detectors and medical physics applications", *World Scientific (2006)*

3. Soudan 2 Collaboration (D. Wall et al.), "Search For Nucleon Decay Into Lepton + K0 Final States Using Soudan 2", *Phys.Rev.D61:072004,2000*

4. Soudan 2 Collaboration (W.W.M. Allison et al.), "The Atmospheric Neutrino Flavor Ratio From a 3.9 Fiducial Kiloton Year Exposure of Soudan-2", *Phys.Lett.**B449**:137-144,1999*

5. ATLAS/Tilecal Collaboration (Z. Ajaltouni, et al.), "Response of The Atlas Tile Calorimeter Prototype to Muons", *Nucl.Instrum.Meth.**A388**:64-78,1997*

6. Stephen Godfrey (Ottawa Carleton Inst. Phys.), JoAnne L. Hewett (SLAC), Lawrence E. Price (Argonne), "Discovery Potential For New Phenomena", *Proc. of 1996 DPF / DPB Summer Study on New Directions for High-Energy Physics (Snowmass 96), Snowmass, CO, 1996*

7. C.T. Day, S. Loken, J.F. MacFarlane (LBL, Berkeley), E. May, D. Lifka, E. Lusk, L.E. Price (Argonne), A. Baden (Maryland U.), R. Grossman, X. Qin (Illinois U., Chicago), L. Cornell, P. Leibold, D. Liu, U. Nixdorf, B. Scipioni, T. Song (SSCL)," Database Computing In HEP: Progress Report", *Proceedings of 10th International Conference on Computing in High-energy Physics Annecy, France, pp. 557-560, 1992*

8. Soudan-2 collaboration (W.W.M. Allison et al.), "The Soudan-2 Detector: the Operation And Performance of the Tracking Calorimeter Modules", *Nucl.Instrum.Meth.**A381**:385-397,1996*

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Education:

B.Sc., Edinburgh University, 1975
D. Phil., Oxford University, 1978

Professional Employment:

Senior Scientist, ANL (2002-)
Physicist, ANL (1988-2002)
Assistant Physicist, ANL (1983-1988)
Research Associate, Rutherford Appleton Laboratory (1978-1983)

Awards, Memberships, and Professional Service:

University of Chicago Distinguished Performance Award (2004)
ANL Exceptional Performance Award (1993)
Member, American Physical Society
DOE, NSF and BNL Review panels
Conference organization (7)
Publications (514) with about 31545 citations.
Unpublished technical reports (83)
ANL service committee work (POCHP, LDRD, Strategic Planning)
CDF Service work (convenerships, editorial boards, operations)
SDC Service work (Technical Coordination, Calorimeter Subsystem Manager)
ATLAS Service work (convenership, editorial boards, installation and commissioning)

Selected Research Accomplishments:

Construction and testing of CDF central EM calorimeter (1982-1986).
Lead and implemented the initial calibration plan and framework for CDF (1984-1990)
Developed the first non-isolated electron software trigger for CDF (1989-1994)
Carried out extensive simulation studies of calorimeter response to hadrons and jets(1990-)
Co-convenor of the CDF electroweak physics group during the early physics program (1992-1993)
Associate Department Head, CDF Operations (2002-2003)
SDC (SSC) calorimeter design, technical notes and presentations (1990-1993)
SDC R&D for development of radiation hard plastic scintillator (1990-1993)
Co-PI, Compensating Scintillator Plate Calorimeter Subsystem Collaboration (1990-1993)
ATLAS Tile Calorimeter design, construction, testing and installation (1994-2006)
Co-lead final assembly of Tile Calorimeter in ATLAS cavern (2004-2006)
Group leader, Argonne ATLAS Group (2006-)
Co-convener ATLAS Jet And Missing Et Combined Performance Group (2007-)

Selected Publications (James Proudfoot):

1. The ATLAS Experiment at the CERN Large Hadron Collider. By ATLAS Collaboration (G. Aad et al.). 2008. 437pp.Published in JINST 3:S08003, 2008.

2. Observation of Top Quark Production in p anti-p Collisions with the Collider Detector at Fermilab, F. Abe et al., The CDF Collaboration, Phys. Rev. Lett. 74, 2626

3. Measurement of Bottom Quark Production Cross Section using Semi-Leptonic Decay Electrons in p-pbar Collisions at $\sqrt{s}$ = 1.8TeV, F. Abe et al., (CDF) Phys. Rev. Lett. 71, 500 (1995)

4. A Measurement of W Boson Production in 1.8 p-pbar Collisions, F. Abe et el., (CDF) Phys. Rev. Lett. 62, 1005 (1989)

5. Research and Development Results on Scintillating Tile Fiber Calorimetry for the CDF and SDC Detectors, P. de Barbaro et al., Nucl. Instr. Meth. A315, 317 (1992)

6. Exotic Phenomena in High Energy ep Collisions, R.J. Cashmore et al., Phys. Reports 122, 276 (1985).

7. Measurement of R and Search for the Top Quark in e+e- Annihilation Between 39.8 and 45.2GeV, TASSo Collaboration, M Althoff *et al*., Phys Lett. 138B 441 (1984)

8. Production ratios for Hadrons Produced in Muon Proton Inelastic Scattering at 219GeV, J. Proudfoot et *al*., Phys Rev D24 2012 (1981)

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Education:

B.S., Universidad de Los Andes 1995
M.Sc., Tufts University 1998
Ph.D., Tufts University 2003

Professional Employment:

Assistant Physicist, ANL (2007-Present)
Visiting Scholar, Harvard University (2007-)
Research Associate, Harvard University (2003-2007)
Research Assistant, Tufts University (1997-2003)
Teaching Assistant, Universidad de Los Andes (1993-1995)

Awards, Memberships, and Professional Service:

Member, American Physical Society
Presentations at international conferences (10)
Publications (23) with 1134 citations.
Experimental proposals and technical design reports (4)
Additional published conference proceedings (11)
Unpublished technical reports and dissertations (25)
ANL service committee work (seminar committee, long term planning committee)
MINOS Service work (analysis convener, paper review committee)
NOvA Service work (software coordinator)

Selected Research Accomplishments:

Oscillation analysis of atmospheric neutrinos in Soudan 2 (1997-2003)
Author original analysis code for the electron neutrino appearance in MINOS (2003)
Coordinator of the electron neutrino appearance analysis for the MINOS experiment (2004-)
Coordinator of the batch processing group in MINOS (2005-2007)
Leader of the data/Monte Carlo validation effort in the MINOS experiment (2005-2007)
Leader of the offline software group for the NOvA eperiment (2009-)

Selected Publications (Mayly Sanchez):

1. Search for Active Neutrino Disappearance using Neutral-Current Interactions in the MINOS Long-Baseline Experiment, (w/ P. Adamson et. al) PRL **101**, 221804 (2008).

2. Testing Lorentz Invariance and CPT Conservation with NuMI Neutrinos in the MINOS Near Detector, (w/ P. Adamson et. al) PRL **101**, 151601 (2008).

3. Measurement of Neutrino Oscillations with the MINOS Detectors in the NuMI Beam, (w/ P. Adamson et. al) PRL **101**, 131802 (2008).

4. The Magnetized Steel and Scintillator Calorimeters of the MINOS Experiment, (w/ D. Michael et. al) NIM A **596** (2008) pp. 190-228.

5. A study of Muon Neutrino Disappearance with the Fermilab Main Injector Neutrino Beam, (w/ P. Adamson et. al) PRD **66** 113004 (2007).

6. Observation of Muon Neutrino disappearance with the MINOS Detectors and the NuMI Neutrino Beam, (w/ D. Michael et. al) PRL **97** 191801 (2006).

7. Observation of Atmospheric Neutrino Oscillations in Soudan 2, (M. Sanchez et. al) PRD **66** 113004 (2003).

8. The Atmospheric Neutrino Flavor Ratio from a 3.9 Fiducial Kiloton-Year Exposure of Soudan 2, (w/ W.W.M Allison et. al) Phys. Lett. B**449**, 137-144, 1999.

Robert Stanek

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Education:

PhD Physics, March 1980, University of Illinois, Chicago, USA
BS Physics, June 1970, University of Illinois, Chicago, USA

Professional Employment:

1986-present	Physicist, High Energy Physics Division, Argonne National Laboratory
1983-1986	Assistant Physicist, High Energy Physics Division, Argonne National Laboratory
1980-1983	Post Doctoral Appointment, High Energy Physics Division, Argonne National Laboratory

Synergistic Activities:
ATLAS Tile Calorimeter Project Leader at CERN, 2005-2009
ATLAS Tile Calorimeter Testbeam Coordinator at CERN, 1999-2004

Selected Publications (Robert Stanek):

1. The ATLAS Experiment at the CERN Large Hadron Collider, The ATLAS Collaboration, G. Aad et al.; JINST 3 (2008) S08003.

2. Testbeam Studies of Production Modules of the ATLAS Tile Calorimeter, P. Adragna et al.; ATL-TILECAL-PUB-2009-002, Submitted to JINST.

3. Effects of ATLAS Tile Calorimeter Failures on Jets and Missing Transverse Energy Measurements, P. Mermod, G. Arabidze, D. Milstead, R. Stanek; ATL-TILECAL-PUB-2008-011-

4. A Precise Measurement of 180 GeV Muon Energy Losses in Iron, P. Amaral et al.; Eur. Phys J. C20 (2001) 487-95.

Richard Talaga

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Education:

B.S., University of San Francisco 1971
MS., University of Chicago 1973
Ph.D., University of Chicago 1977

Professional Employment:

Physicist, ANL (1989- present)
Assistant Professor, University of Maryland (1982-1988)
Postdoctoral Staff, LANL (1979-1981)
Postdoctoral Staff, LBNL (1978-1979)
Postdoctoral Staff, UCLA (1977-1978)

Awards, Memberships, and Professional Service:

Co-spokesperson for Parity Violation experiment at LAMPF (1980-81)
ZEUS Service work (Run Coordinator, 1992)
University of Maryland Summer Grant (1983)
ANL service committee work (LMS R&D Process, Pacesetter Awards, Astrophysics Initiative)
MINOS Service Work (WBS Level 3 manager)
NOvA Service work (WBS Level 2 manager, EVMS certification, Exec. Board)

Selected Research Accomplishments:

Built low noise ion chambers & electronics to detect parity violation with proton beams (1973-80)
Designed and built highly efficient veto wall and electronics for LAMPF neutrino experiment (1979-81)
Detected electron-neutrino scattering interaction with electrons LAMPF (1986)
Detected electron-neutrino transmutation of carbon nucleus to nitrogen at LAMPF (1987)
Designed CYGNUS cosmic ray experiment muon detection electronics at LAMPF (1985-6)
Designed & built ZEUS First Level Calorimeter Trigger (1989-1992)
Designed and built ZEUS small rear tracking detector Trigger (1993-1995)
Led ANL prototype beam tests for MINOS detector (1996-7)
Developed extruded scintillator for MINOS (1998-2001)
Led MINOS Near Detector Scintillator Assembly Factory (2000-2001)
Led OMNIS and ADONIS supernova neutrino detector design group (2002-2005)
Developed highly reflective PVC extrusions for NOvA (2006-2007)

Selected Publications (Richard Talaga):

1. Measurement of Neutrino Oscillations with the MINOS Detectors in the NuMI Beam, Phys. Rev. Lett. 101, 131802 (2008).

2. The magnetized steel and scintillator calorimeters of the MINOS experiment, NIMA 596, 190 (2008).

3. OMNIS, The Observatory of Multiflavor Neutrinos from Supernovae, Nucl. Phys. A718,222 (2003)

4. Search for Lepton Flavor Violation in e-p collisions at 300 GeV cm energy, Z. Phys C73, 613 (1997)

5. Measurement of the Exclusive Cross Section $^{12}C(\nu_e , e^-)\,^{12}N$(g.s.), Phys. Rev. Lett. 64, (1990).

6. First Observation and Cross Section Measurement of $\nu_e + e^- \rightarrow \nu_e + e^-$, Phys. Rev. Lett. 55, 2401 (1985).

7. Central Collisions with a Projectile of 1.8 GeV/Nucleon ^{40}Ar, Phys. Lett. 79B, 325 (1978).

8. Limit on Parity Violation in p-Nucleus Scattering at 6 Gev/c, Phys. Rev. Lett. 34, 1184 (1975).

Rik Yoshida

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Education:

BA, Northwestern University (1981)
PhD, Northwestern University (1990)

Professional Employment:

Physicist, ANL (2005-)
Assistant Physicist, ANL (1996-2005)
Research Associate, University of Bristol, UK (1993-1996)
Research Associate, NIKHEF, Amsterdam (1990-1993)

Awards, Memberships, and Professional Service:

Spokesman ZEUS experiment (2003-2005)
Deputy Spokesman ZEUS experiment (1999-2001)
Coordinator ANL ASC (2007-)
Member LHCC (2005-)
Member ZEUS editorial panel (2006-)
Member ZEUS planning group (1999-)
Member DOE review panels (FNAL)
Founding member HERA-LHC workshop committee (2004-2006)
Member International Advisory Committee, International Conference on Calorimetry in HEP (1997-)
Coordinator ZEUS structure function and electroweak group (1999)
Coordinator ZEUS calorimeter group (1996-1999)
Deputy Coordinator ZEUS deep inelastic scattering group (1995-1996)
Coordinator ZEUS monte carlo group (1993-1994)
Invited talks (25 at international conferences)
Publications (200) with 12000 citations.

Selected Research Accomplishments

Construction and operation of Fermilab experiment 687 (1985-1990)
Construction and commissioning of the ZEUS Forward and Rear Calorimeter (1990-1993).
Commissioning of ZEUS monte carlo production system (1993-).
Proton Structure Function analysis, main author electron analysis (1994).
Analysis team leader, Structure Function Measurement (1996-1997,1999),
Ex-officio member on all ZEUS paper editorial boards (1999-2005).
ZEUS electron energy calibration strategy (1993-).
ZEUS hadronic and jet energy calibration strategy (1995-)
Lead ZEUS through post-upgrade commissioning (2003).
Lead ZEUS through HERA beam background issues (2003-2004).
36 publications from ZEUS under spokesmanship. (2003-2005)

Selected Publications (Rik Yoshida):

1. Collider Physics at HERA (75 pp.) (M. Klein and RY) Prog. Part. Nucl. Phys. 61 (2008) 343.

2. High-Q2 DIS with Polarized Positron Beam, (ZEUS) PLB 637 (2006) 210.

3. NLO QCD Analysis of DIS and Jet data, (ZEUS) EPJC 42 (2005) 1.

4. Search for CI, Extra-dim, and Finite Quark-radius, (ZEUS) PLB 591, (2004) 23.

5. Charm production in DIS, (ZEUS) Phys. Rev. D 69 (2004) 012004.

6. Proton Structure Function F2, (ZEUS) EPJC 21 (2001) 443.

7. Proton Structure Function F2, (ZEUS) Z. Phys C 72 (1996) 399.

8. Elastic J/Psi Photoproduction, (E687) PLB 316 (1993) 197.

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Education:

Ph.D., Colorado Sate University 2002

Professional Employment:

Assistant Physicist, ANL (2006-)
Research Associate, University of Colorado (2004-2006)
Research Associate, MIT (2002-2004)

Professional Service:

Publications (545) with 16139 citations
ATLAS service work (DAQ/HLT coordination)
BABAR Service work (run coordination)

Selected Research Accomplishments

ATLAS TDAQ commissioning and operation (2006-)
ILC very forward region calorimeter R&D (2004-)
BABAR DCH electronics upgrade (2004-2006)
BABAR muon detector upgrade (2004-2006)
CP angle gamma measurement with Dalitz analysis at BABAR (2004-2007)
Initiated hybrid/glueball search at BABAR (1998-)
PHOBOS data analysis tools (2002-2004)

Selected Publications (Jinlong Zhang):

1. Measurement of CP Violation Parameters with a Dalitz Plot Analysis of B+- -> D_{pi+pi-pi0} K+-, Phys. Rev. Lett. 99, 251801 (2007).

2. Evidence for D0-D0bar Mixing, Phys. Rev. Lett. 98, 211802 (2007).

3. The PHOBOS perspective on discoveries at RHIC, Nucl. Phys. A 757, 28 (2005).

4. Direct CP Violating Asymmetry in B0 -> K+pi- Decays, Phys. Rev. Lett. 93, 131801 (2004).

5. Centrality dependence of charged hadron transverse momentum spectra in d + Au collisions at s(NN)**(1/2) = 200 GeV, Phys. Rev. Lett. 91, 072302 (2003).

6. Rare B Decays into States Containing a J/psi Meson and a Meson with ssbar Quark Content, Phys. Rev. Lett. 91, 071801 (2003).

7. Observation of a Narrow Meson Decaying to D_s^+ pi^0 at a Mass of 2.32 GeV/c^2, Phys. Rev. Lett. 90, 242001 (2003).

8. Observation of CP violation in the B^0 meson system, Phys. Rev. Lett. 87, 091801 (2001).

APPENDIX B: Personnel and Funding Tables

Here only the summary tables are shown, details can be found on a separate spreadsheet. We have used the "Fixed Target" column for FY 08 and 09 to indicate final cost for the ZEUS experiment.

DOE Support FY 2008 (Actual)										
Personnel Support from DOE:	**LHC (ATLAS/CMS)**		**Tevatron (D0/CDF)**		**Neutrinos**		**Fixed-target**		**TOTAL**	
	No. heads	**FTE**	**No. heads**	**FTE**	**No. heads**	**FTE**	**No. heads**	**FTE**	**No. heads**	**FTE**
Permanent PhD	9	5.13	7	2.43	4	2.49	4	0.57	**24**	**10.62**
Temporary PhD	2	2.08	0	0.00	2	0.31	0	0.00	**4**	**2.39**
Graduate Students	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
Engineer	1	0.04	0	0.00	4	1.51	0	0.00	**5**	**1.55**
Computing Professional	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
Technician	0	0.00	0	0.00	2	0.14	0	0.00	**2**	**0.14**
Administrative	1	0.05	0	0.00	2	0.48	0	0.00	**3**	**0.53**
TOTAL	13	7.29	7	2.43	14	4.93	4	0.57	**38**	**15.22**
DOE/HEP Funding (per activity):										
SWF (in $, include overhead)	$1,614,654		$728,372		$1,166,691		$131,825		**$3,641,543**	
M&S (in $, include overhead)	$334,816		$1,802		$300,000		$93,800		**$730,418**	
Travel (in $, include overhead)	$112,843		$3,071		$44,751		$7,375		**$168,039**	
TOTAL	**$2,062,313**		**$733,245**		**$1,511,442**		**$233,000**		**$4,540,000**	

DOE Support FY 2009 (Actual)										
Personnel Support from DOE:	**LHC (ATLAS/CMS)**		**Tevatron (D0/CDF)**		**Neutrinos**		**Fixed-target**		**TOTAL**	
	No. heads	**FTE**	**No. heads**	**FTE**	**No. heads**	**FTE**	**No. heads**	**FTE**	**No. heads**	**FTE**
Permanent PhD	9	6.50	4	2.00	6	3.00	0	0.00	**19**	**11.50**
Temporary PhD	3	2.30	0	0.00	1	0.80	0	0.00	**4**	**3.10**
Graduate Students	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
Engineer	0	0.00	0	0.00	2	0.40	0	0.00	**2**	**0.40**
Computing Professional	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
Technician	0	0.00	0	0.00	2	1.10	0	0.00	**2**	**1.10**
Administrative	1	0.60	0	0.00	1	0.50	0	0.00	**2**	**1.10**
TOTAL	13	9.40	4	2.00	12	5.80	0	0.00	**29**	**17.20**
DOE/HEP Funding (per activity):										
SWF (in $, include overhead)	$2,164,683		$659,079		$1,166,629		$0		**$3,990,392**	
M&S (in $, include overhead)	$573,471		$5,736		$300,000		$138,500		**$1,017,706**	
Travel (in $, include overhead)	$150,000		$8,586		$50,000		$5,000		**$213,586**	
TOTAL	**$2,888,154**		**$673,401**		**$1,516,629**		**$143,500**		**$5,221,684**	

DOE Support FY 2010 (Proposed)										
Personnel Support from DOE:	**LHC (ATLAS/CMS)**		**Tevatron (D0/CDF)**		**Neutrinos**		**Fixed-target**		**TOTAL**	
	No. heads	**FTE**	**No. heads**	**FTE**	**No. heads**	**FTE**	**No. heads**	**FTE**	**No. heads**	**FTE**
Permanent PhD	10	7.52	4	1.90	5	3.00	0	0.00	**19**	**12.42**
Temporary PhD	3	3.00	1	1.00	2	2.00	0	0.00	**6**	**6.00**
Graduate Students	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
Engineer	0	0.00	0	0.00	2	0.40	0	0.00	**2**	**0.40**
Computing Professional	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
Technician	0	0.00	0	0.00	2	1.10	0	0.00	**2**	**1.10**
Administrative	1	1.00	0	0.00	1	0.50	0	0.00	**2**	**1.50**
TOTAL	14	11.52	5	2.90	12	7.00	0	0.00	**31**	**21.42**
DOE/HEP Funding (per activity):										
SWF (in $, include overhead)	$2,651,120		$737,285		$1,327,147		$0		**$4,715,552**	
M&S (in $, include overhead)	$309,319		$11,471		$200,000		$0		**$520,790**	
Travel (in $, include overhead)	$160,000		$8,587		$55,000		$0		**$223,587**	
TOTAL	**$3,120,439**		**$757,343**		**$1,582,147**		**$0**		**$5,459,928**	

DOE Support FY 2011 (Proposed)										
Personnel Support from DOE:	**LHC (ATLAS/CMS)**		**Tevatron (D0/CDF)**		**Neutrinos**		**Fixed-target**		**TOTAL**	
	No. heads	**FTE**	**No. heads**	**FTE**	**No. heads**	**FTE**	**No. heads**	**FTE**	**No. heads**	**FTE**
Permanent PhD	10	7.52	4	1.90	5	3.00	0	0.00	**19**	**12.42**
Temporary PhD	3	3.00	1	1.00	2	2.00	0	0.00	**6**	**6.00**
Graduate Students	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
Engineer	0	0.00	0	0.00	2	0.40	0	0.00	**2**	**0.40**
Computing Professional	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
Technician	0	0.00	0	0.00	2	1.10	0	0.00	**2**	**1.10**
Administrative	1	1.00	0	0.00	1	0.50	0	0.00	**2**	**1.50**
TOTAL	14	11.52	5	2.90	12	7.00	0	0.00	**31**	**21.42**
DOE/HEP Funding (per activity):										
SWF (in $, include overhead)	$2,651,120		$762,354		$1,371,788		$0		**$4,785,262**	
M&S (in $, include overhead)	$350,655		$5,736		$100,000		$0		**$456,391**	
Travel (in $, include overhead)	$160,000		$8,588		$60,000		$0		**$228,588**	
TOTAL	**$3,161,775**		**$776,678**		**$1,531,788**		**$0**		**$5,470,241**	

DOE Support FY 2012 (Proposed)										
Personnel Support from DOE:	LHC (ATLAS/CMS)		Tevatron (D0/CDF)		Neutrinos		Fixed-target		TOTAL	
	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE
Permanent PhD	10	7.52	4	1.90	5	3.00	0	0.00	**19**	**12.42**
Temporary PhD	3	3.00	1	1.00	2	2.00	0	0.00	**6**	**6.00**
Graduate Students	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
Engineer	0	0.00	0	0.00	2	0.40	0	0.00	**2**	**0.40**
Computing Professional	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
Technician	0	0.00	0	0.00	2	1.10	0	0.00	**2**	**1.10**
Administrative	1	1.00	0	0.00	1	0.50	0	0.00	**2**	**1.50**
TOTAL	14	11.52	5	2.90	12	7.00	0	0.00	**31**	**21.42**
DOE/HEP Funding (per activity):										
SWF (in $, include overhead)	$2,740,634		$788,290		$1,417,937		$0		**$4,946,861**	
M&S (in $, include overhead)	$444,220		$5,736		$100,000		$0		**$549,955**	
Travel (in $, include overhead)	$165,000		$8,587		$65,000		$0		**$238,587**	
TOTAL	**$3,349,854**		**$802,612**		**$1,582,937**		**$0**		**$5,735,403**	