Argonne NATIONAL LABORATORY

… for a brighter future

U.S. Department of Energy

UChicago ▶ Argonne LLC

Office of Science U.S. DEPARTMENT OF ENERGY

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Detector Development R&D in Argonne HEP

Gary Drake

Apr. 26, 2007

Representing the Work of Many People in the Division, Including:

Dave Ayres
Karen Byrum
Pat De Lurgio
Jim Grudzinski
Vic Guarino
Steve Kuhlmann
Steve Magill
Larry Nodulman
Jimmy Proudfoot
Jose Repond
Dave Reyna
Jurgen Reichenbacher
Hal Spinka
Richard Talaga
Dave Underwood
Alexander Vaniachine
Bob Wagner
Lei Xia

+ Excellent Support Staff…

The Nature of ANL HEP Detector R&D:

- **What do we mean by "Detector R&D?"**
  - Often, Detector R&D refers to the development of the "sensor,"
    i.e. photo-sensors, silicon sensors, motion sensors, … → Material Science

  - To us, Detector R&D is the design and development of an ***Integrated Particle Detection and Readout System***, which includes:
    - *Basic R&D on Sensors → Evaluation*
    - *Detector Simulations*
    - *Particle Conversion Media*
    - *Charge Detection & Collection*
    - *Readout Electronics*
    - *Mechanical Support*

    } Close Collaboration Essential as Level of Integration Increases → ASICs

    ⇨ ***Detector R&D Often Leads to Production, Installation, Operation, & Long-Term Support.***

The Nature of ANL HEP Detector R&D:

- **HEP Detectors are Unique, and tend to have:**
  - Large overall physical size (many tons, many meters)
  - High spatial resolution & tight tolerances (mm→ μm)
  - Many channels (1E4 → 1E7)
  - High-level of electronics & mechanical integration
  - One-off design / development / production cycle

⇨ ***Size & Scale Very Different Compared to other Scientific Fields & Industry***

⇨ ***Performance Requirements for HEP are often Leading Edge***

The Nature of ANL HEP Detector R&D:

- **What is our "Program?"**
  - ANL HEP Detector R&D is (mostly) not a separate program
  - Activities spread out over virtually all HEP Experimental Programs
  - Building detectors is a fundamental part of our participation in experiments
    - ⇨ ***Experimental Scientists in the division tend to have strong hardware & technical backgrounds***
  - Building detectors is one of the primary strengths of this division
    - ⇨ ***Strategic Synergy: Scientific Staff & Engineering Support Groups***

Our R&D Program Focuses on Developing Detectors to Do Science!

The Nature of ANL HEP Detector R&D:

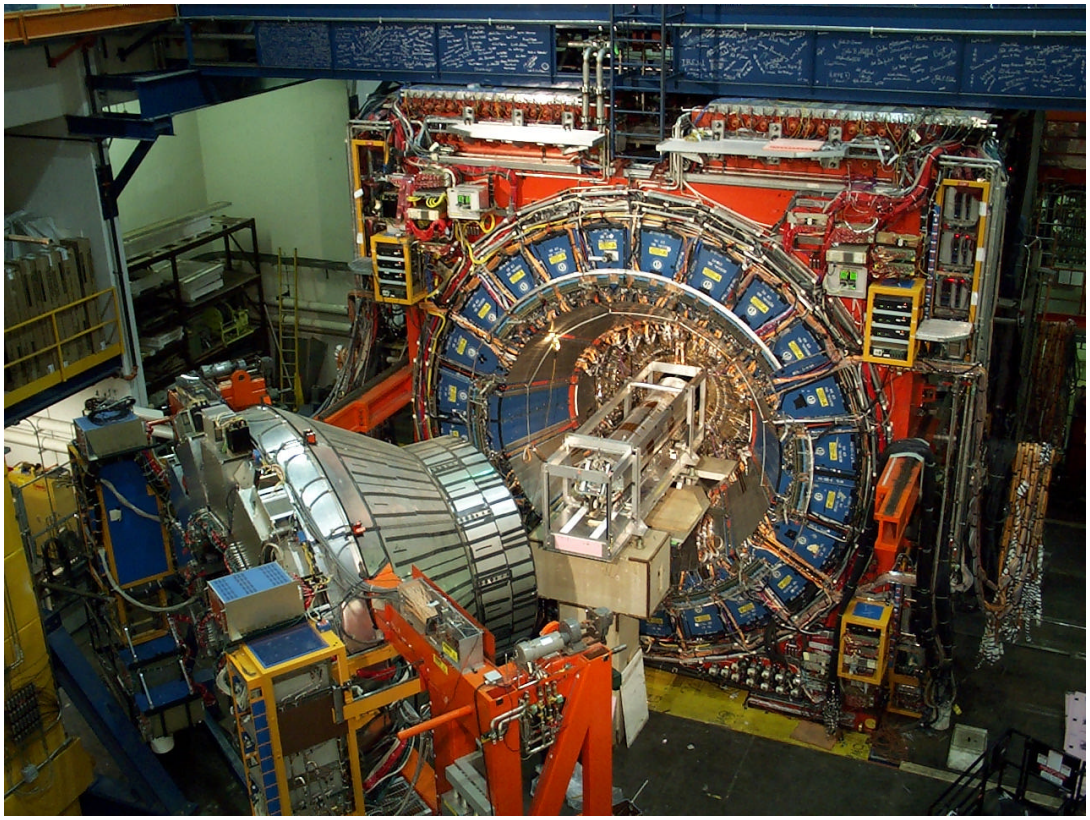
- **Why is this Program Important at Argonne?**
  - National Labs have staff & resources to do this R&D work
  - Multi-disciplinary science program at ANL can leverage expertise from different fields, in different divisions:
    - ⇨ ***Material Science, Nuclear Physics, Chemistry,***
      Advanced Photon Source, Nano-Technology…
  - History & heritage of ANL HEP have accumulated many years of detector design experience, and established our credibility in design & development of HEP detectors

We Contribute to HEP Detector Design in Many World-Class Experiments.

First, A Brief History

We have been building HEP Detectors for a Long Time…

Some History:



CDF @ Fermilab

Run 1 (1980's):

- Built Cent. EM Calorimeter
  → PMT & Scintillator
  → LED Calib. System

Run 2 (1990's):

- Built Central Preshower
  → MAPMT & Scint.
- Collab. on Plug Upgrade
  → MAPMT's
- Built Shower Max Electronics

Some History (Cont.):

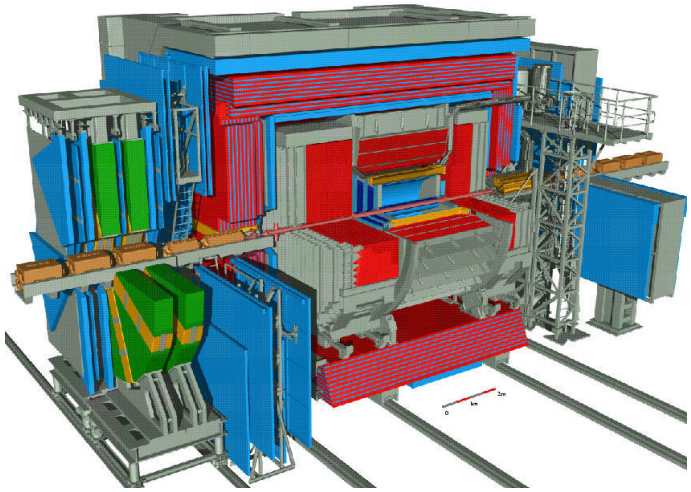
ZEUS @ DESY

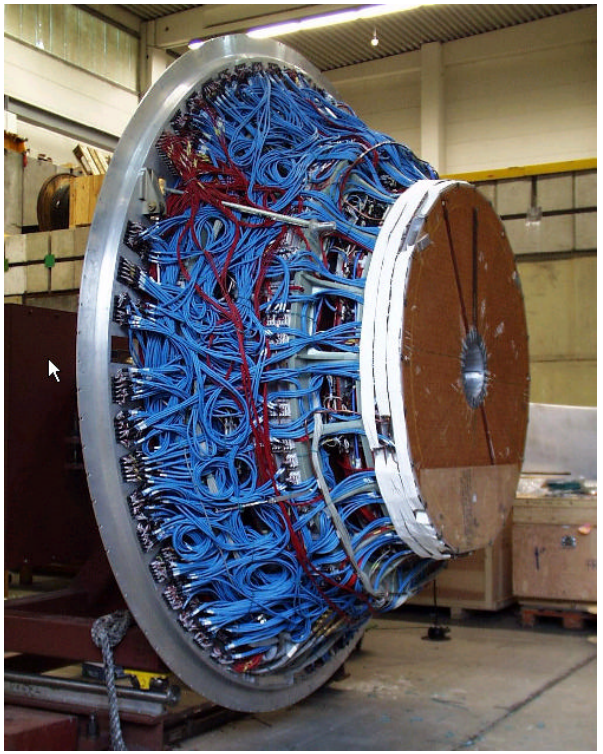
Orig. Constr. (1980's):

- Built Barrel Calorimeter
- Built Barrel Presampler
- Built First-Level Trigger

Upgrade (1990's):

- Collab. on FTD Upgrade
  → Straw Tubes
- Built Front End Electronics



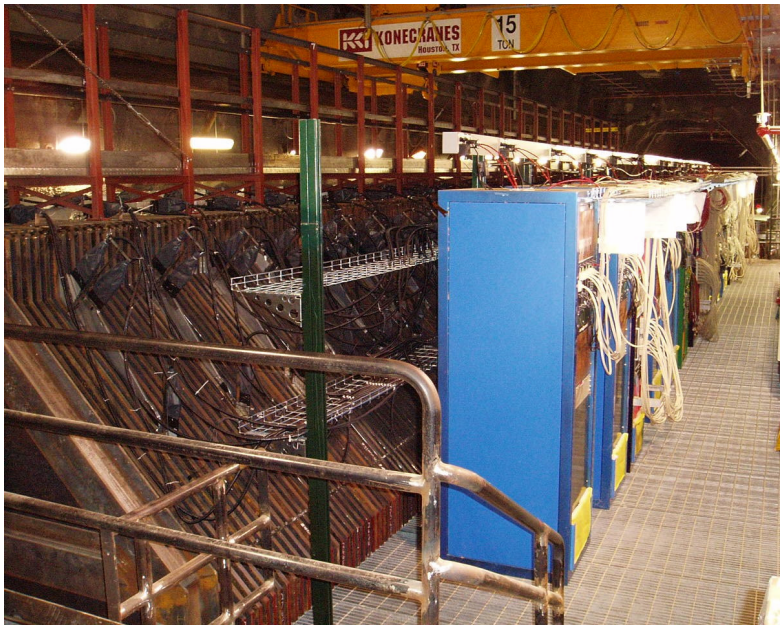


Some History (Cont.):

MINOS @ FNAL

Near Det. Constr. (2000's):

- Built all planes for Near Det.
  → Scint. + WLS Fiber,
  64-ch MAPMTs
- Built equip. for 3 factories
- Built ND Electronics

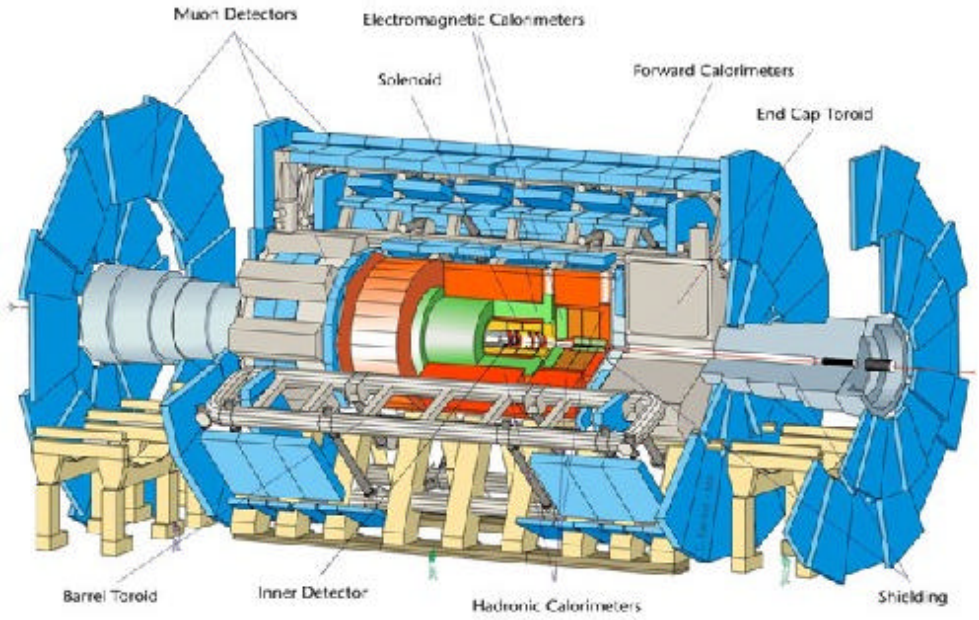


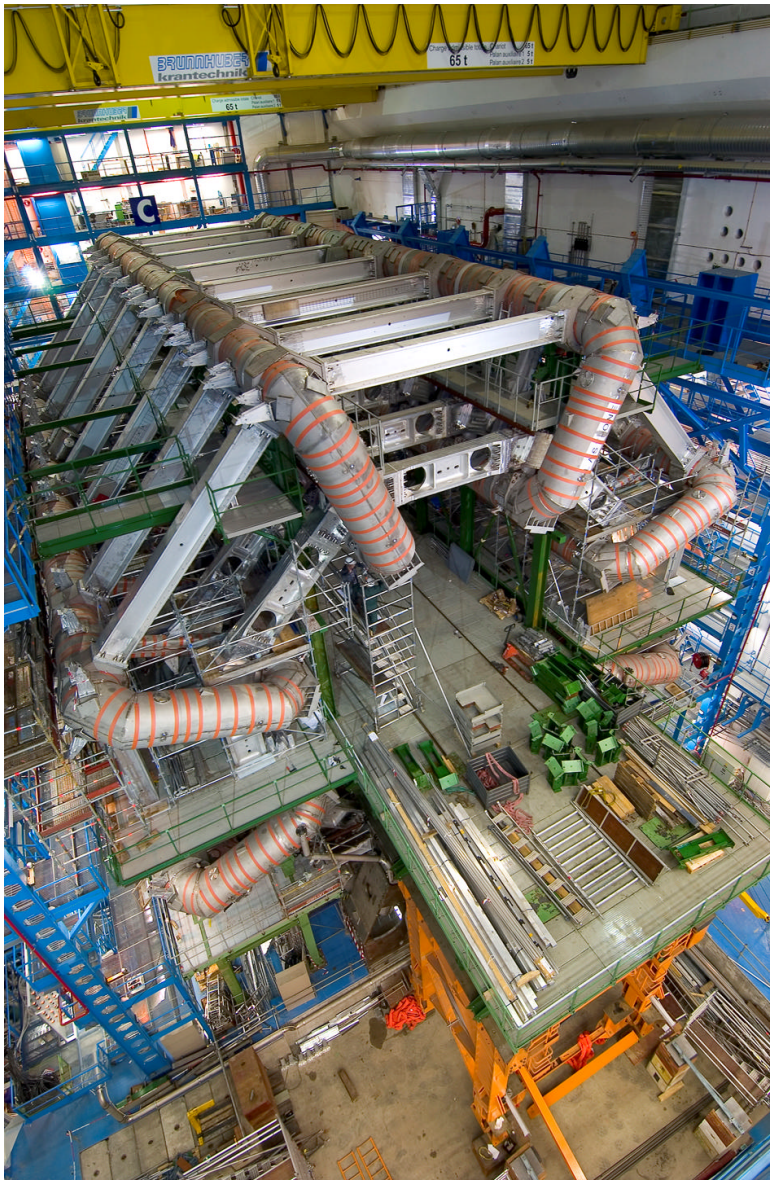
Some History (Cont.):

ATLAS @ LHC

Barrel Construction (2000's):

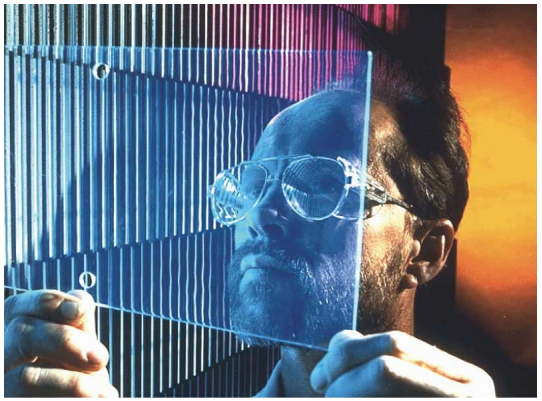
- Built 65 / 256 TileCAL Modules
  → Scint. Tiles w/PMT Readout
- Design of Moving System
- TileCAL Structural Analysis
- Built Part of Level 2 Trigger

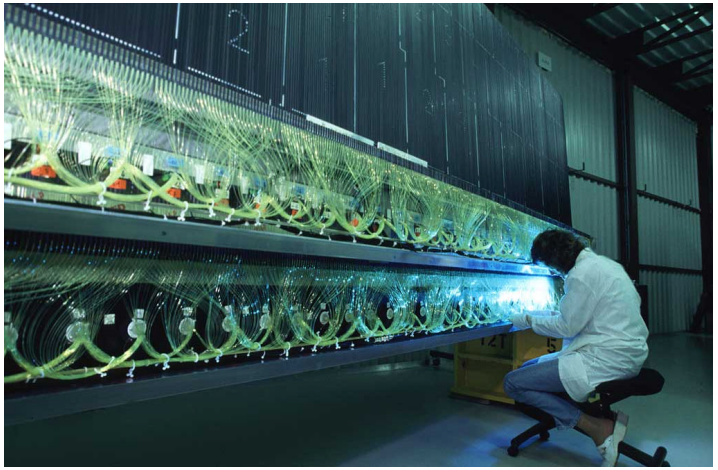


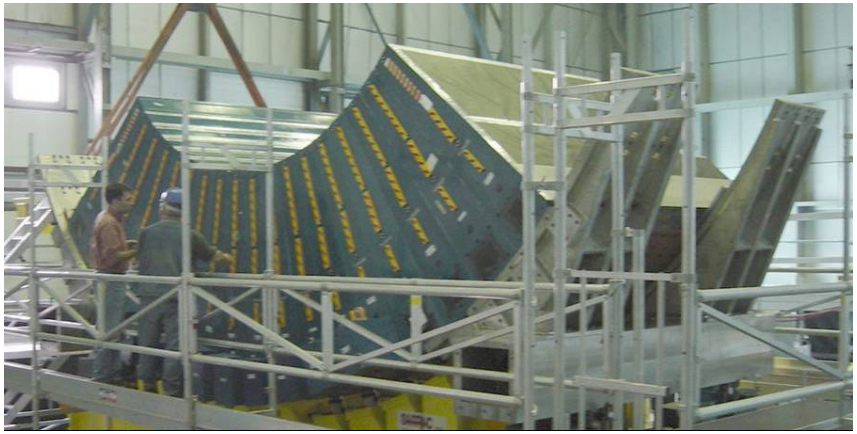


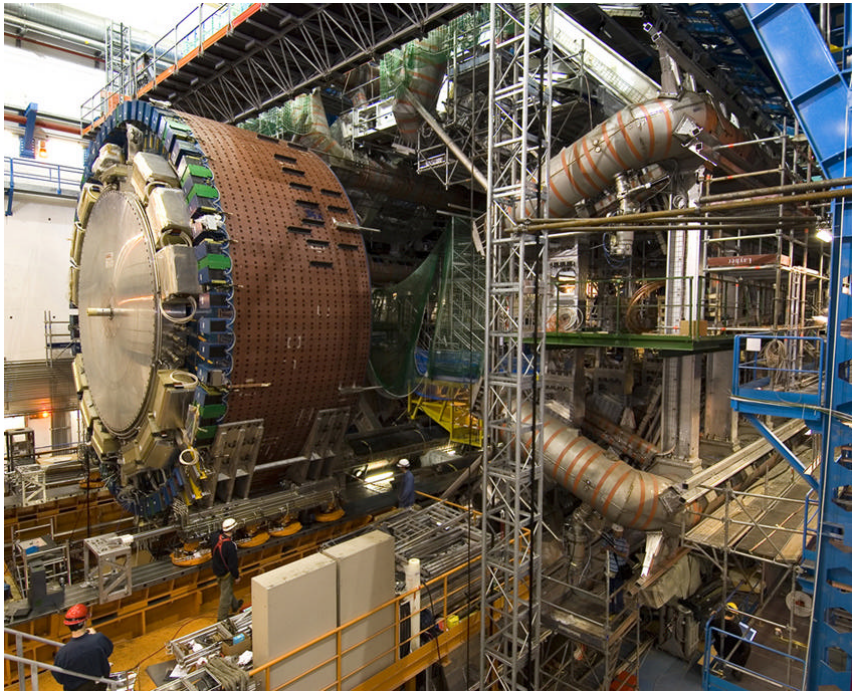
Some History (Cont.):

ATLAS @ LHC (Cont.)







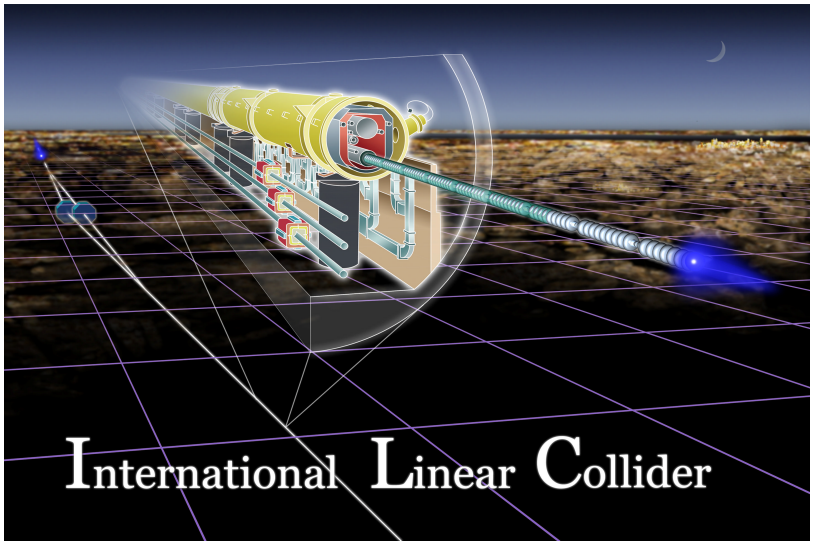


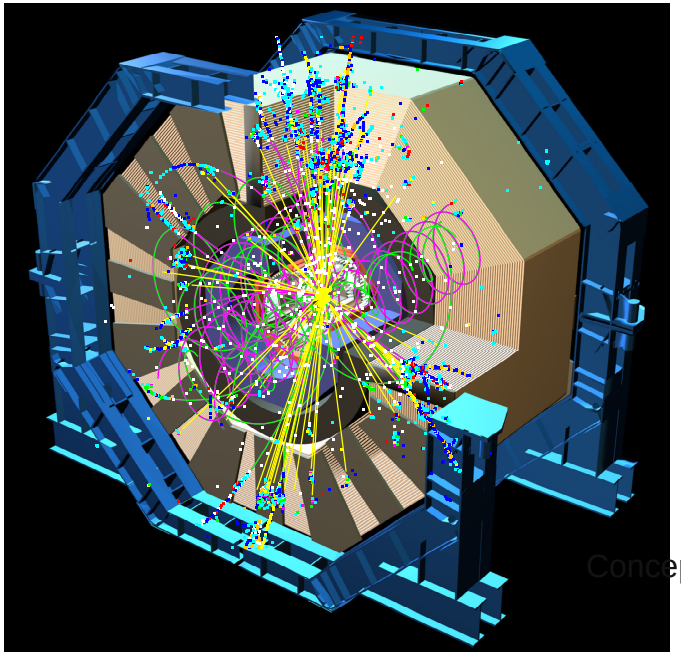
We have contributed to building large detectors for HEP, but the cornerstone for this work is fundamental detector R&D.

It is an important part of our program.

Work in Progress Now

What's Going On Now:



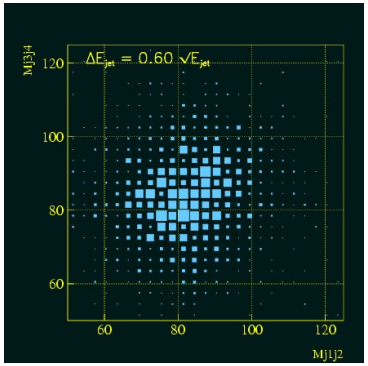


Conceptual View of SiD Detector

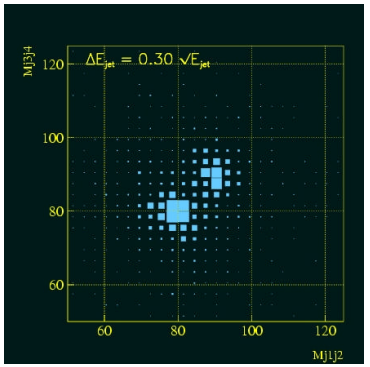
ILC – Hadron Calorimetry Detectors

HCAL Requirements:

- ILC HCAL requires "unprecedented" Jet Energy Resolution: $\frac{s_E}{E} = \frac{30\%}{\sqrt{E}}$
- Approach:
  - ? Particle Flow Algorithms (PFA)
  - ? "Fine-Grained" Sampling



60%/vE$_{jet}$



30%/vE$_{jet}$

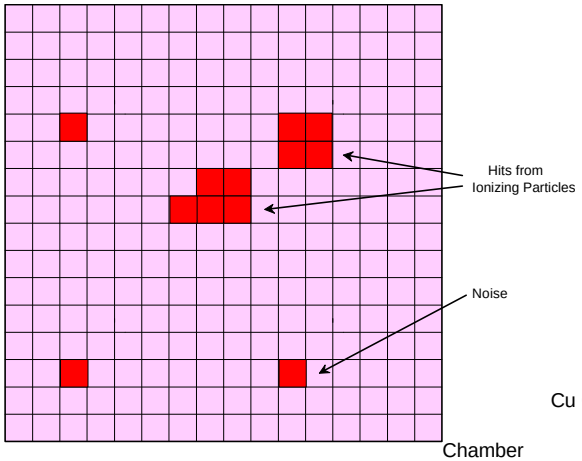
(Repond, Xia, Magil, Underwood, Drake, Guarino, et al.)

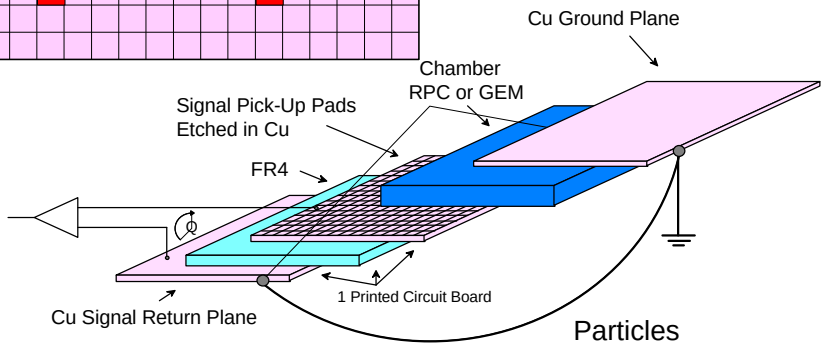
What's Going On Now (Cont.):

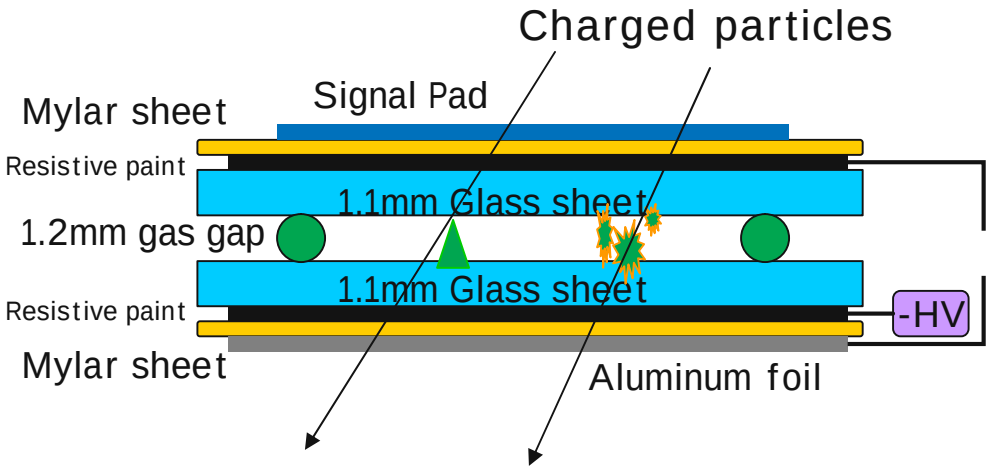
ILC – HCAL Detectors (Cont.)

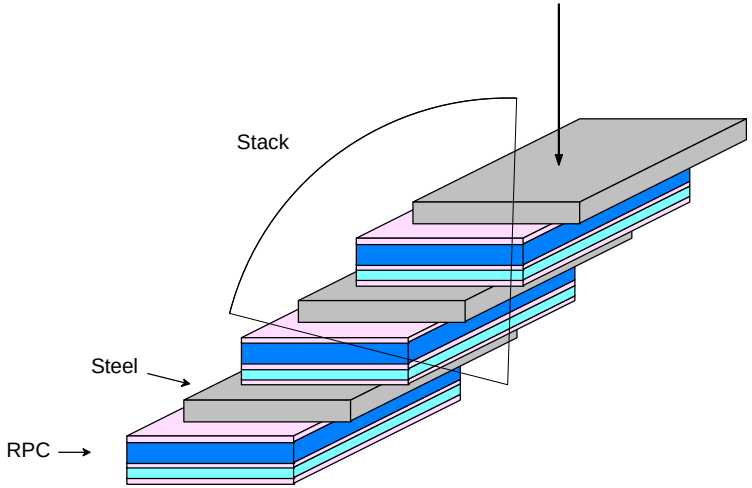
Detector R&D:

- Fine-grained cell size
  → 1 cm x 1 cm
- Read out of each cell, on each layer
- Use "Digital" Readout
  → Simple discriminator on each channel
    → A one-bit ADC
- Make cell size small to image shower
- Detector Technology of choice:
  → **Resistive Plate Chambers**



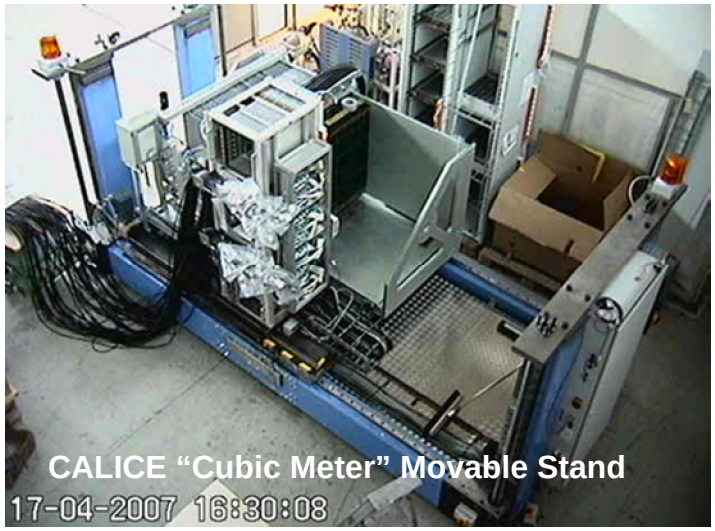






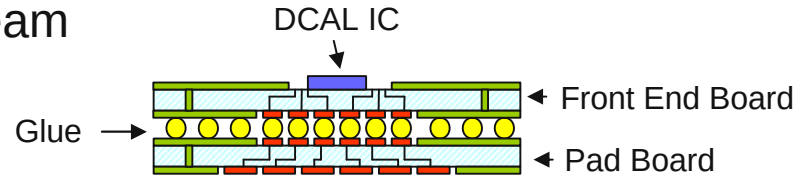
What's Going On Now (Cont.):

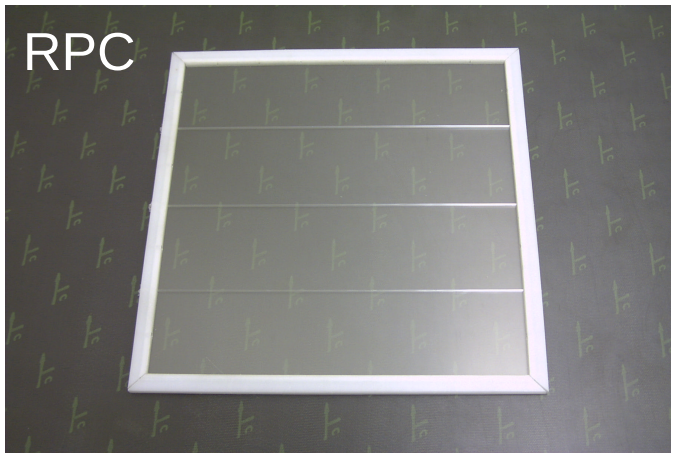
ILC – HCAL Detectors (Cont.)



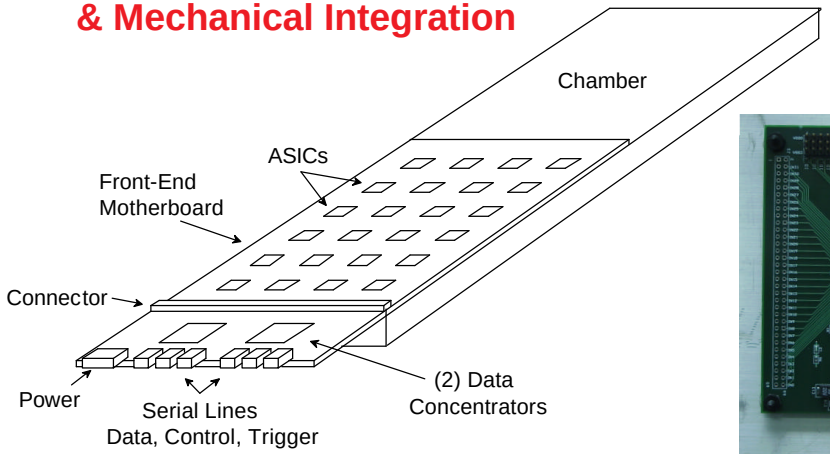
Detector R&D (Cont.):

- Have done significant RPC R&D work here
- DHCAL Scheme requires a Custom IC
  → Designed DCAL, in collab. with FNAL
- Intend to build "1 m^3 Prototype Section" to study PFAs & Shower Development, and vet Monte Carlos, test @ FNAL Test Beam
  → (40) 1-m^2 planes
  → 400,000 readout ch in our "Prototype"
  → Operate with CALICE ECAL

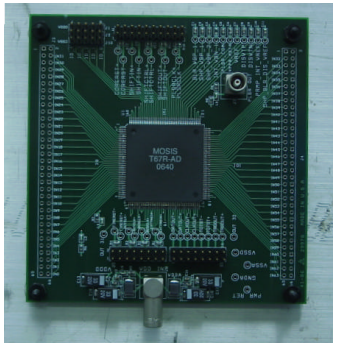




⇨ **High-Level of Electronic & Mechanical Integration**



DCAL Test Board

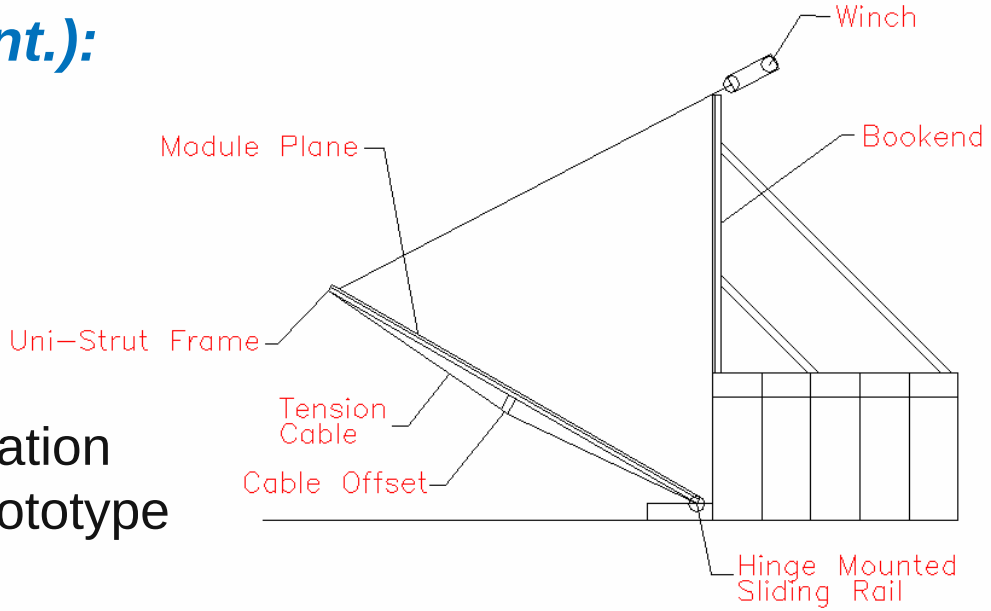


What's Going On Now (Cont.):

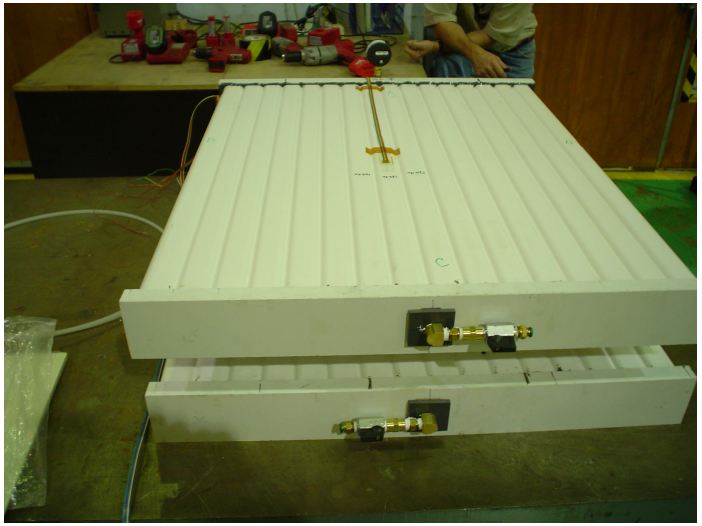
NOnA @ NUMI (FNAL)

Detector R&D:

- PVC extrusions, epoxies
- Structural design & analysis
  → Stress & creep tests, installation
- Have built 15' x 27' 4-plane prototype
- Will construct full-size (53' x 53') prototype @ ANL



(Ayres, Talaga, Guarino, Grudzinski)

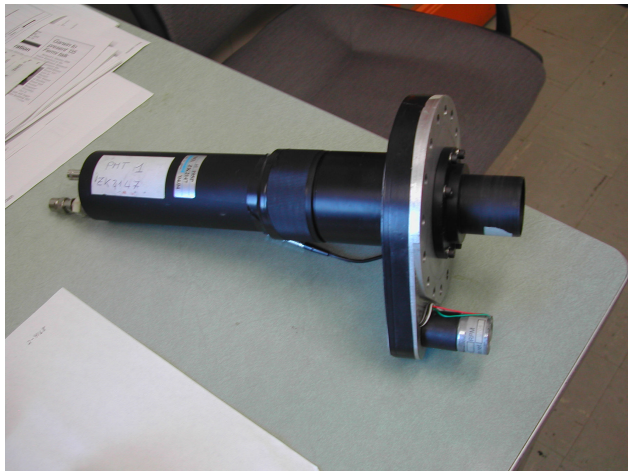


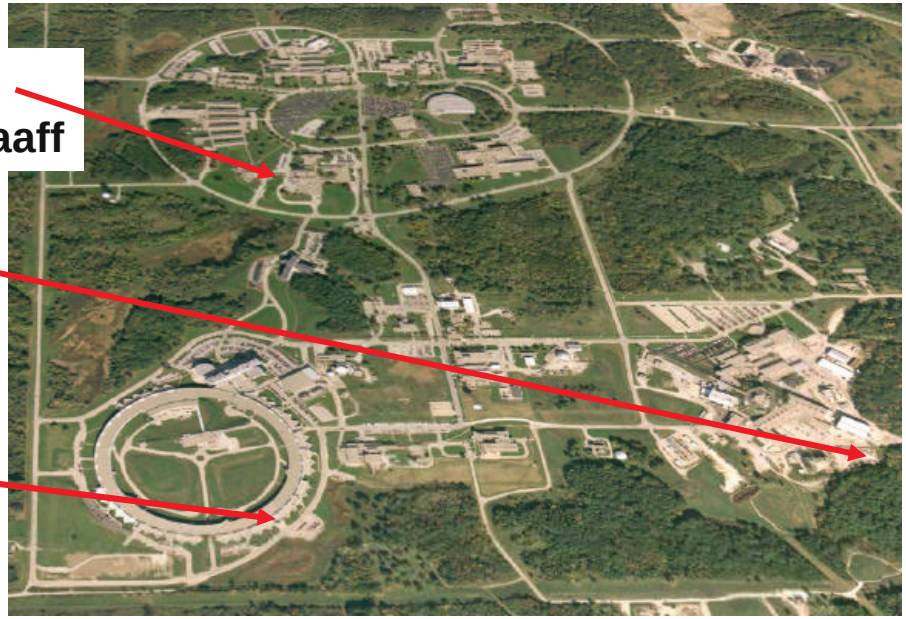
What's Going On Now (Cont.):

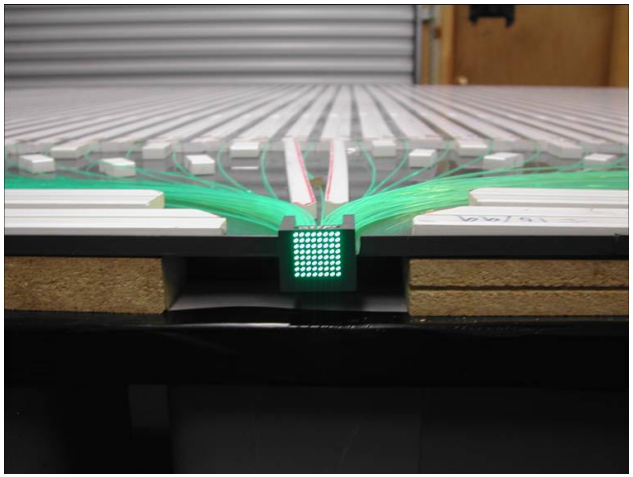
Auger

Detector R&D:

- "Air Fly" detector construction
  → Scintillating Fiber & PMTs
- Fluorescence calibration for Auger
  → Calibrated detector at 3 facilities at ANL
  to span entire energy range – 5 KeV-14 MeV







(Kuhlmann, Spinka, Guarino)

What's Going On Now (Cont.):

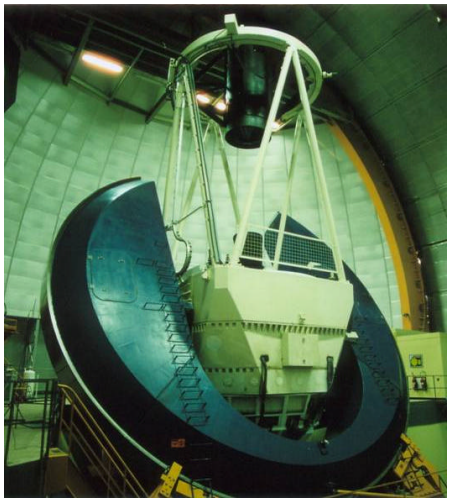
Dark Energy Survey

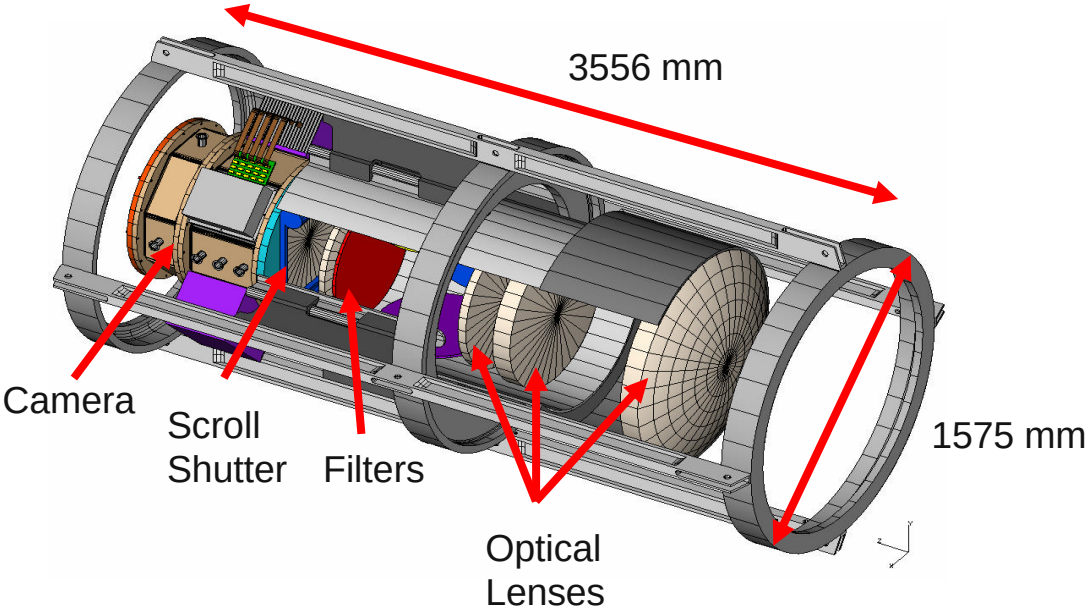
Detector R&D:

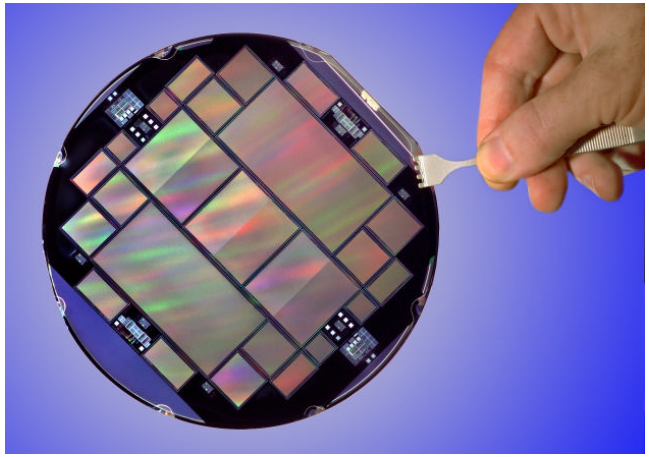
- Working on CCD evaluation & testing (with FNAL)

Controls:

- Developing Control System







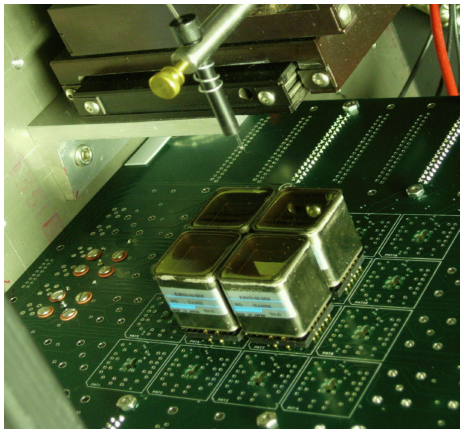
(Kuhlmann, Spinka, Guarino)

What's Going On Now (Cont.):

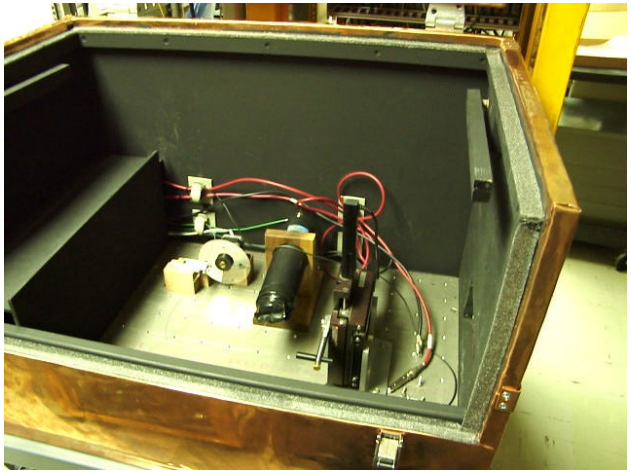
TRICE – Gamma-Ray Telescope R&D

Detector R&D:

- Photodetectors for camera
  → MAPMTs now, SiPM in development



Current:
Hamamatsu R8900
16 ch MAPMTs



Dark Box with 4-Decade Filter Wheel & LED Pulser

(Byrum, Drake, Hays, Kovacs Magill, Nodulman, Wagner, et al.; In Collab. With UC (Swordy et al.))

What's Going On Now (Cont.):

Next Generation Telescope R&D

Detector R&D:

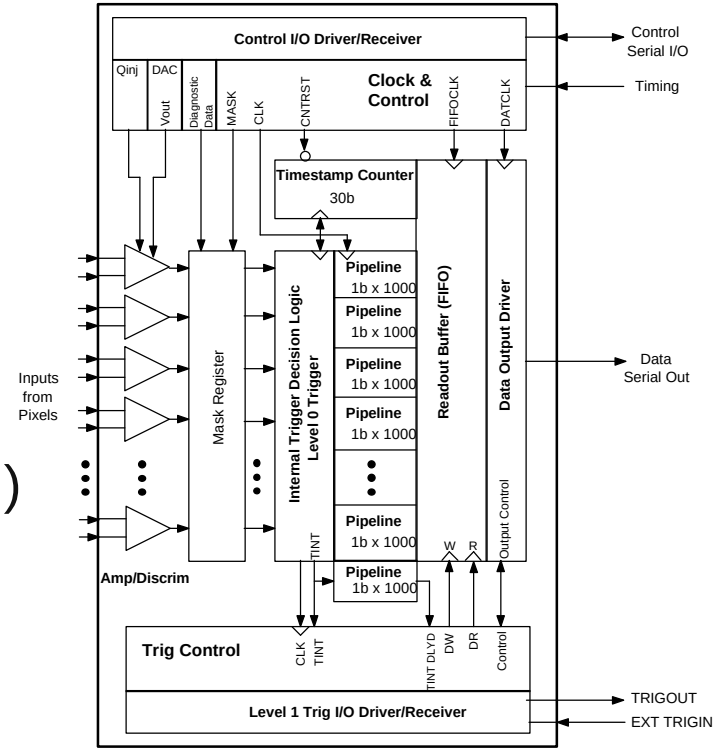
- Photodetectors – leverage TRICE
  → MAPMTs, SiPM

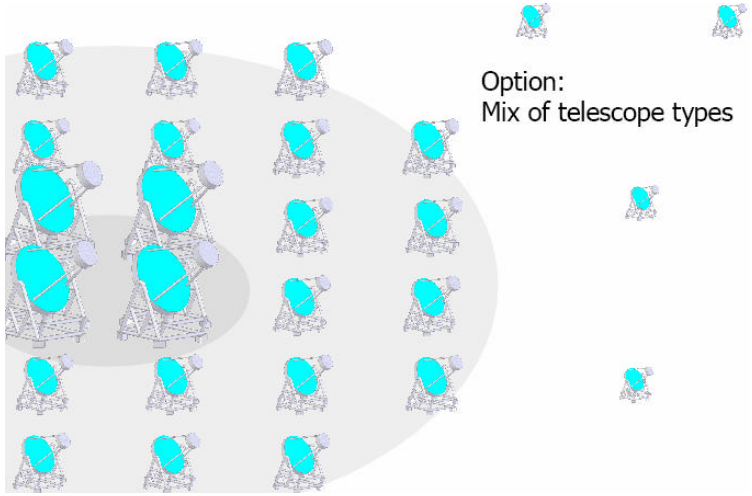
Electronics:

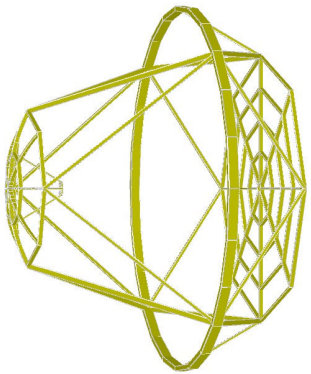
- Developing 1 GHz Photon-Counting ASIC (with NU)

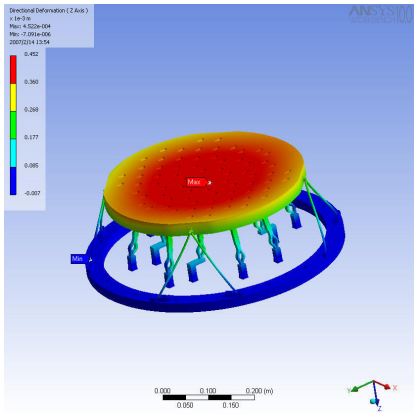
Mechanical:

- R&D on Support Structure & Motion Control









(Byrum, Wagner, Drake, Guarino)

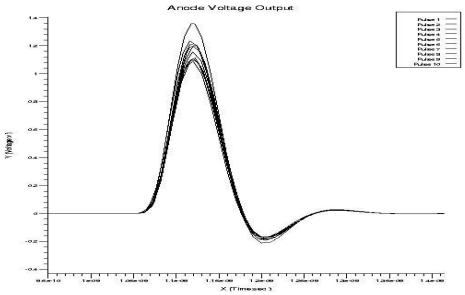
A Few Specific R&D Areas Currently in Progress

(Mostly Funded from LDRDs)

Specific Detector R&D (Cont.)

Fast Timing using Micro-Channel Plates

Simulation:
Jitter on Leading Edge 0.86 psec



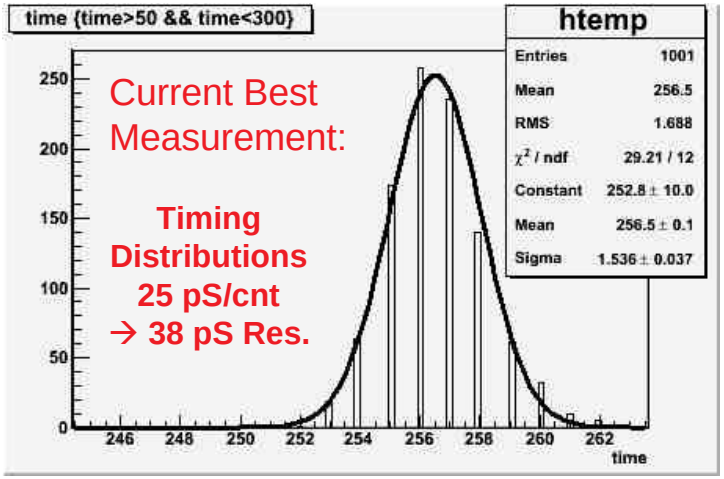
Goal: Develop instrumentation with 1 pSec resolution
Applications: New TOF Detector, Medical Imaging

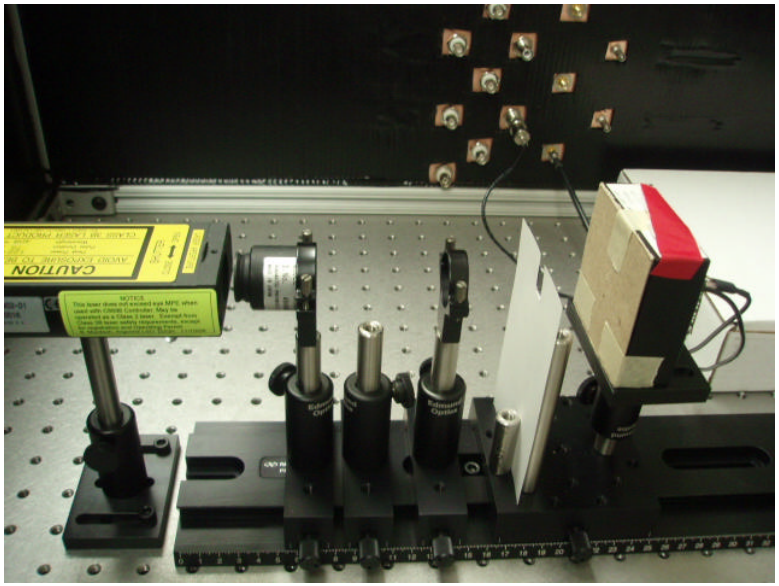
Teststand:

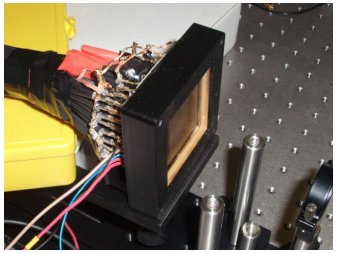
- Built Laser Lab with fast laser, fast electronics

Detector R&D:

- Working with Photonis on MCP development
- Collab. With UC (Frisch, et al.)
  → ASIC, front end elec., applications…







Next Steps:

- Better TDC → 10 pS/cnt
- Continue testing new MCPs from Photonis
- Prepare for ASIC from UC
  → 1 pSec/cnt (or better…)

(Byrum, Ertley, Drake, In Collab. With UC (Frisch, et al.))

Specific Detector R&D (Cont.)

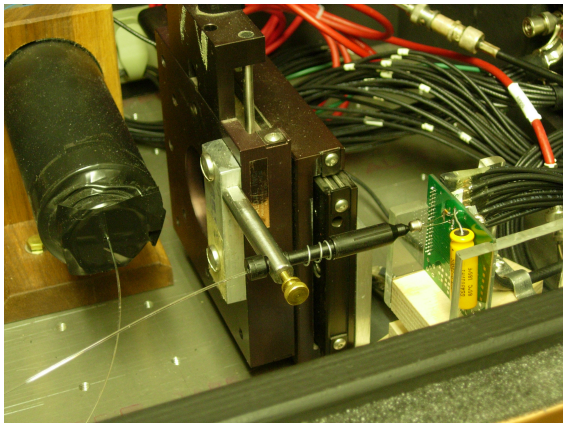
Silicon Photomultipliers (SiPM) – aka Multi-Pixel Photon Counter (MPPC)

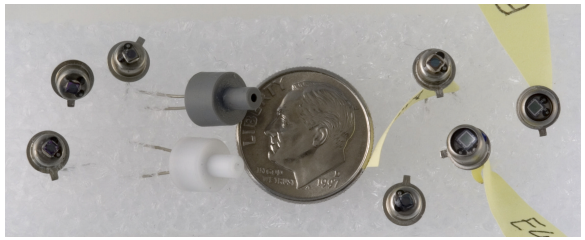
Goal: Understand characteristics, develop electronics for applications

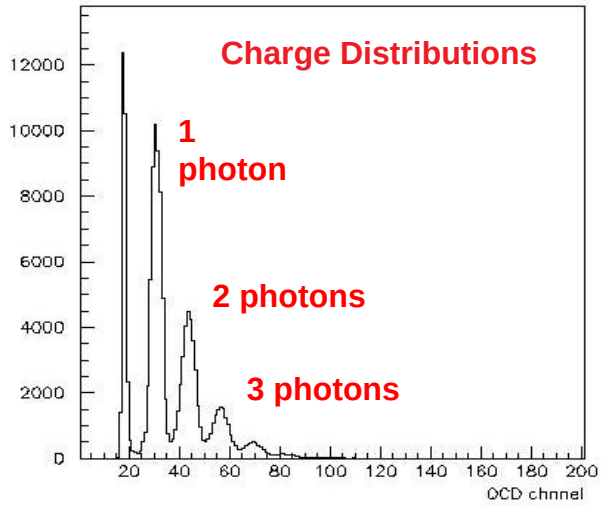
Applications: Telescope Cameras, Medical Imaging (PET) , Muon Detectors, X-Ray Detection (APS), Homeland Security Apps, et al…

Strategic: SiPMs listed as Line Item in DOE FY07 & FY08 Budgets for DOE HEP Advanced Detector Technology R&D Subprogram

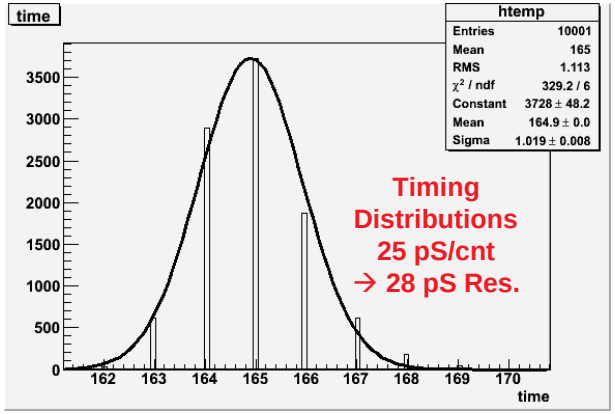
⇨ Exploring Partnerships with Industry







Triggered Data, ~50 nS Gate
V. Saveliev, 5/4/06

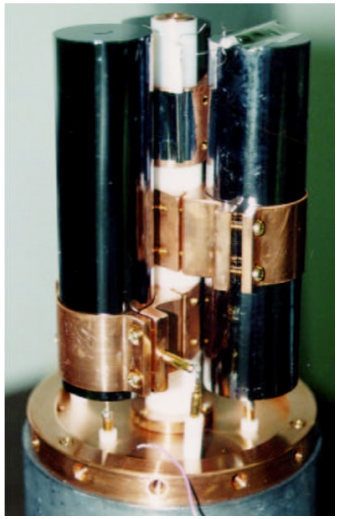


Triggered Data, Laser w/CFD
Ertley, Wagner, & Xie, Apr., 2007

(Wagner, Drake, Vaniachine, In Collab. With APS (Fernandez et al.), & UC (Chen et al.))

What's Going On Now (Cont.):

Low-Noise HPGe Detector Work



Goal: Develop ultra-low noise detector for Neutrino Detection

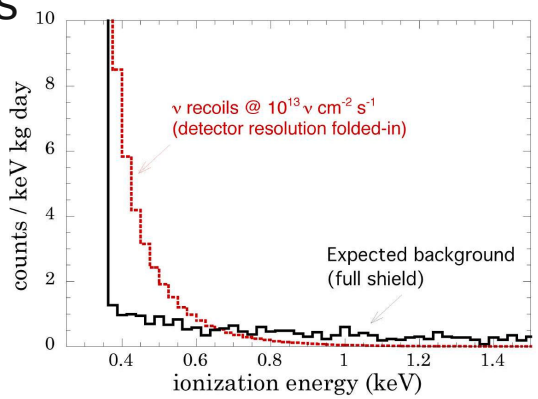
Applications: WIMP Detection, Coherent Neutrino-Nucleus Scattering, Nuclear Deterrence in Reactors

Detector R&D:

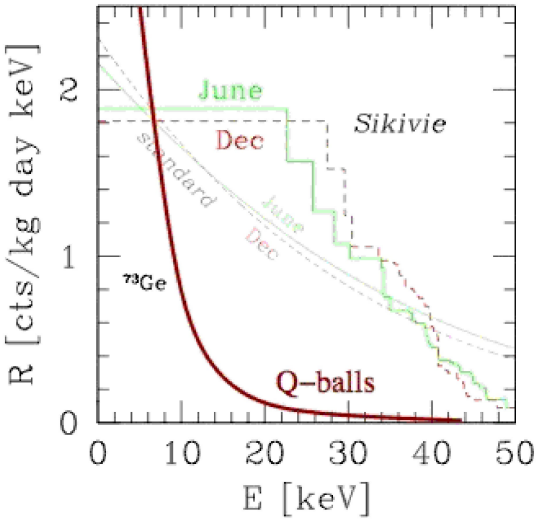
- Characterize Ge detectors
- Consider Si detectors

Electronics:

- Understand noise limitations
- Develop & improve amplifier FET

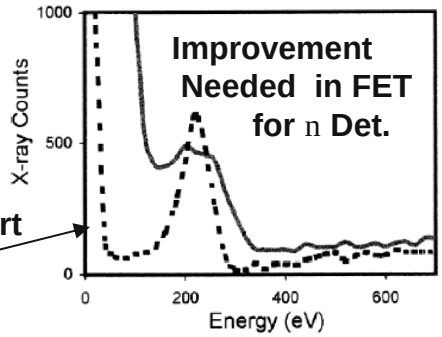


n - Detection from Power Plant



WIMP Search

State-of-the-Art
1 pF

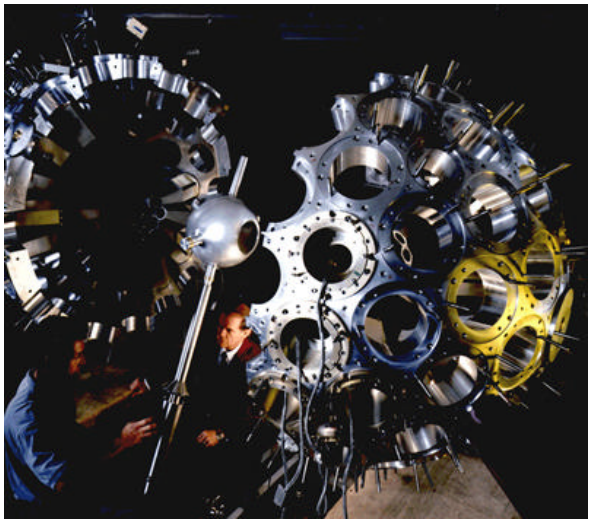


(De Lurgio, Reyna, In Collab. With UC (Collar))

Other Detector R&D Activities:

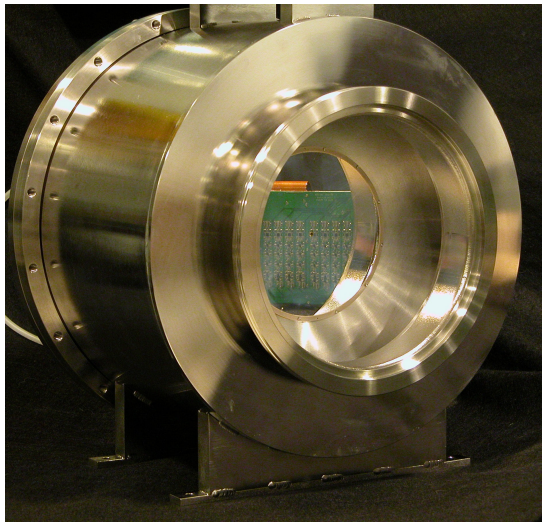
RPC Detector Development for STAR - Developed GEM Tracking DAQ
Used here to read out RPC with
400 μm x and y strips ***(Underwood)***

Design, Development, & Support for Other Divisions:
(Provided by HEP Electronics Group…)



Gammasphere (& Gretina)
– Nuclear Physics

Anger Camera
– Pulsed Neutron Source



Time-Resolved Small-Angle Scattering (TRSAX) - CHEM

Other Detector R&D Activities (Cont.):

- Have started lab-wide Detector Seminar Series (→ Weerts)
  - Hosted & Organized by Bob Wagner (HEP) & Patricia Fernandez (APS)
  - Aimed at promoting inter-divisional dialogue, discussion, & interaction on detector development topics
  - Approximately 1-2 per month

⇨ ***Attendance has been Excellent;***
Talks Interesting, Relevant, & Well-Received

http://www.hep.anl.gov/rgwcdf/detector-rd/Detector-Seminar.html

Conclusions

- Detector R&D is Thriving in ANL HEP
- Activities Cut Through All Programs
- Collaboration Cuts Across Division Boundaries
- Collaboration with Outside Institutions Strong, Particularly with UC
- ANL HEP Scientific Staff has High-Levels of Expertise in Detectors, and High-Levels of Motivation to Pursue New Opportunities
- Relationship of ANL HEP Engineering Groups to Scientific Staff and Experiments Crucial to Success

⇨ **We are Limited, Not by Ideas or Imagination, or Opportunities, or Lack of Expertise… but by Funding & People Resources**

⇨ ***We Could be Doing So Much More….***