ILC meeting at Fermilab

October 27, 2004

Welcome to the second in the series of ILC meetings at Fermilab

Oct. 20 Accelerator, Shekhar Mishra, WH-1W
Oct. 27 Detector, Harry Weerts, Curia II (WH-2SW)

Nov. 3 Accelerator, Shekhar Mishra - WH-1W
Nov. 10 Site Studies and Outreach, Vic Kuchler and Judy Jackson - Place TBD
Nov. 17 Detector, Harry Weerts - Place TBD

Dec. 1 Accelerator, Shekhar Mishra - Place TBD
Dec. 8 Detector, Harry Weerts - WH-1W
Dec. 15 Accelerator, Shekhar Mishra

ILC Detector Design and R&D

Status of ILC detector design
The SiD concept study
SiD areas to get involved in
Generic detector R&D

H.Weerts
Fermilab/Michigan State University

Introduction

Why am I here and giving this talk ??

In the past have worked on (old) neutrino program at Fermilab and in last 20 years on Dzero at Tevatron.

Important for progress and future of particle physics in world and Fermilab to pursue International Linear Collider

So am taking a sabbatical leave at Fermi to work on ILC, with an emphasis on detectors for ILC.

Started 3 months ago and am still learning, so this talk is incomplete (ask questions !), but it has been fun to work on something totally different and start at the beginning with everybody else (e^+e^- and new physics & detector)

Your convictions should guide your actions……..

Overview

International Linear Collider

Machine

Dominates picture after technology decision
BIG effort
GDI formation is next step
Main parts(Working Groups):

- Overall Design
- Injector
- Main Linac
- Beam Delivery
- Cavities
- Communications & Outreach

CDR in about 1 year

Site preparation (for FNAL)

(twice a month about this here)

Strong link

Detectors

Driven by physics requirements
Adopt to machine parameters

Much smaller effort
(no R&D Funds in past in US)
Final size ~10-15% of total budget

CDR needed as part of machine CDR

(once a month about this here)

The ILC Difference

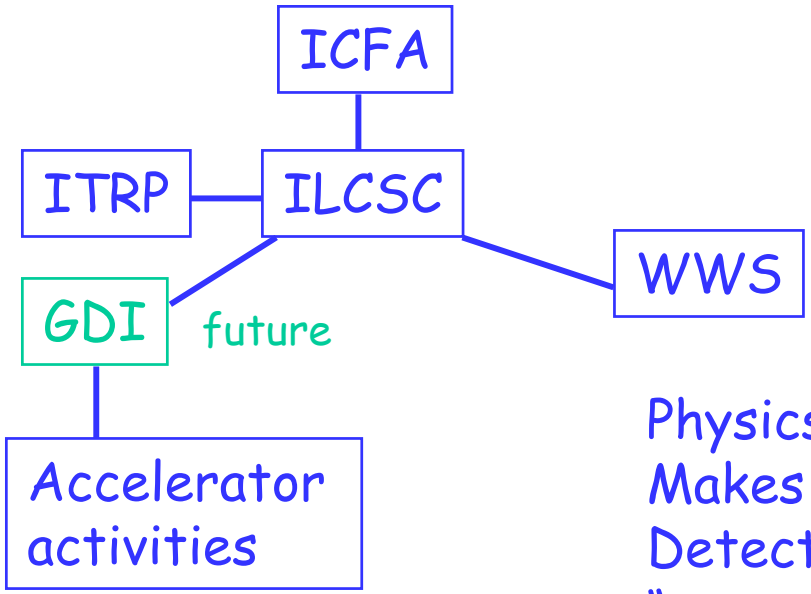
to the normal approach to new experiments at Fermilab or any lab

Historically: Local efforts starts, idea, develop design, flesh out, build, etc.
Users may come from all over the globe (CDF, Dzero)
Detector components even build all around the globe (some in CDF, Dzero but really in CMS & ATLAS)……still local approach to detectors

ILC detectors: Very different….
Global approach from start, includes whole globe, no laboratory defined yet as home, but all institutions involved
Does not make it easier, but is necessary

It is like comparing the United Nations (*action slow*) to national governments (*action can be fast*)

ILC detector history I



= Worldwide Study of the Physics and Detectors for Future Linear e^+e^- Colliders

Physics & Detectors
Makes physics case
Detector development; up to now mainly "generic" detector R&D

R& D activities: Silicon (SiLC)
TPC/Jet chambers
Vertex detectors
Calorimetry (CALICE) (EM & HAD)
Muon System -- at FNAL
.....

There was a TESLA detector design

Well funded in EU and Asia
Not well funded in US

This was situation up to Spring 2004

ILC detector History II

In February 2004 ILCSC asked WWS to develop a plan for detectors corresponding to machine schedule/plan

Machine schedule/plan

2004 International technology selection.
Initiate the Global Design Effort.
2005 Complete the accelerator **CDR**, including site requirements, and initial cost and schedule plan.
2006 Initiate detailed engineering designs under the leadership of the CentralTeam.
2007 A complete detailed accelerator TDR with the cost and schedule plan,establish the roles & responsibilities of regions, and begin the process for site proposals.
2008 Site selection and approval of international roles & responsibilities by the governments.

…….
2009 Start construction
2005 Start operation

WWS plan/answer:

2005 Preliminary costing of **at least two whole detector concepts** (single joint document with performance estimates for each concept, plus R&D done and still required.) Produce in time to be included in the Accelerator CDR process of the GDI.

2007 Detector CDRs –Conceptual Design Reports for experiments (could be different from concepts above) with specification of physics performance on key benchmarks, technical feasibility, and refined cost. Individuals encouraged to sign more than one CDR.

2008 Proposals – Groups united around CDR detector concepts submit Letters of Intent for proposals (including performance, costs, and technical feasibility) to the Global Lab, which will invite some of the groups to produce TDRs.

ILC detector history III

Consequences of this WWS detector plan:

- Start design studies for a limited number of detector concepts
- Evolve to some kind of "CDR" with physics benchmark performance and cost estimate.
- All design concept studies should be global i.e. participation from all regions of globe
- Individuals/groups can participate in more then one concept

Start "proto" collaborations of people interested in a concept

Happened at series of WWS workshops:

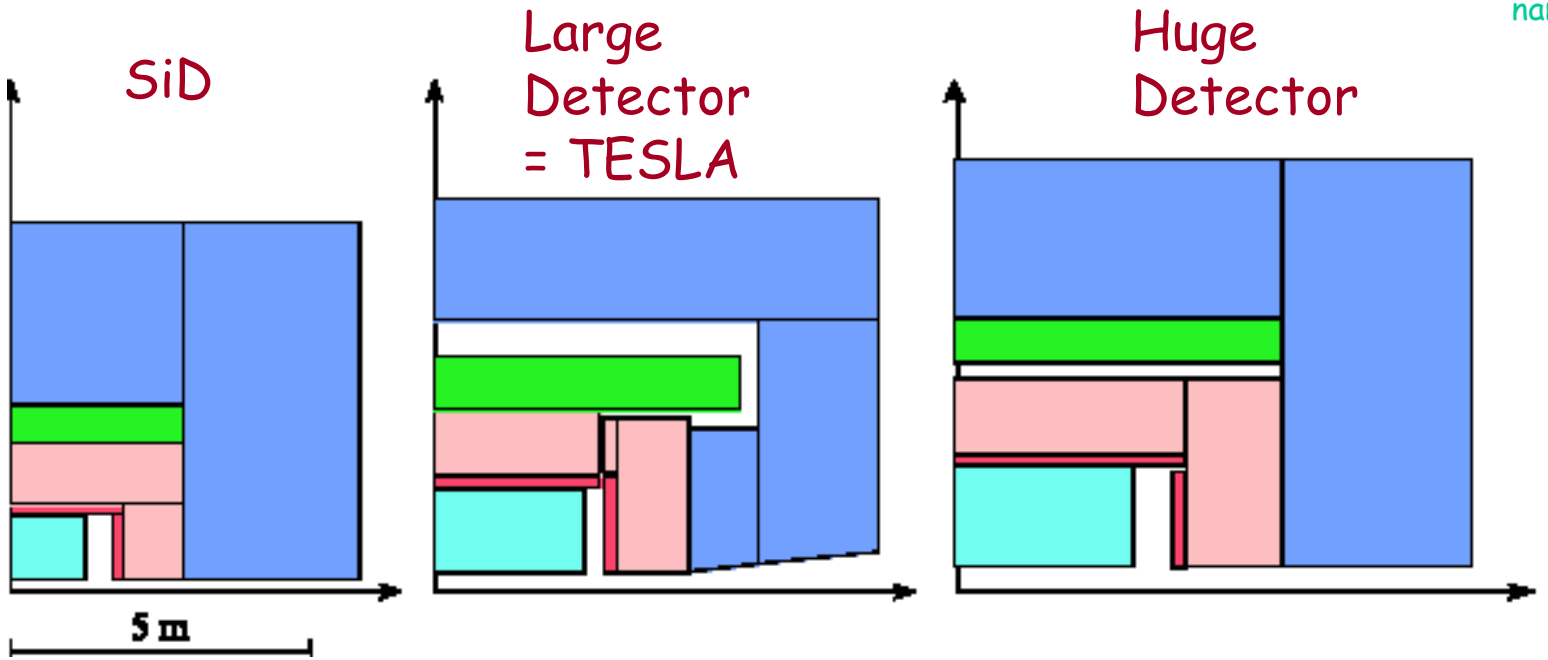
Americas	Europe	Asia
Victoria, BC	Durham, UK	Taipei, Taiwan
August '04	Sept '04	Nov '04

ILC detector concepts

For the moment three concepts have emerged (final meeting in Taiwan) and have been launched.

Innovative names

All detectors are BIG



All Si tracking; smaller; hopefully cheaper with same performance.
Centered in US (SLAC & FNAL + Users)
Leadership at FNAL& SLAC *(Jaros/Weerts)*.
Had mtgs at Victoria & Durham

TPC based tracking + Si tracking
Centered in EU + some US
Just forming
Based on TESLA work = advantage

Similar to Large version, but Bigger.
Driven Asian interests mainly.
Official launch in Taipei

All global, but not easy.....

ILC Machine parameters

bunch spacing	337 nsec (176 ?)
#bunch/train	2820
length of train	950 msec
#train/sec	5 Hz
train spacing	199 msec
crossing angle	0-20 mrad (34 for $\gamma\gamma$)

Triggerless event collection

Requires storage of information/buffering for one train; then readout

Similar to hadron collider machines; new for e^+e^-

Impact on front end electronics

This has impact on event selection/DAQ system.
However no/minimal work done on DAQ up to now for any detector.
Some ideas from Saclay & DESY.

Detector requirements 1

Detector performance goals (Int'l R&D review)

Reference CMS

• central tracking:

$$\sigma(1/pt) \leq 5 \times 10^{-5} (\mathrm{GeV/c})^{-1}$$

7×10^{-4}

(~1/10 LHC; 1/6 material in tracking volume.)

• Jet energy:

Drives design →

$$\frac{\sigma_E}{E} \cong 0.30 \frac{1}{\sqrt{E(GeV)}}$$

0.86

(1/200 calorimeter granularity w.r.t. LHC)

• vertexing:

$$\sigma_{r\phi,z}(ip) \leq 5\mu m \oplus \frac{10\mu m Gev/c}{p \sin^{3/2}\theta}$$

(1/5 r_{beampipe}, 1/30 pixel size, 1/30 thin w.r.t LHC)

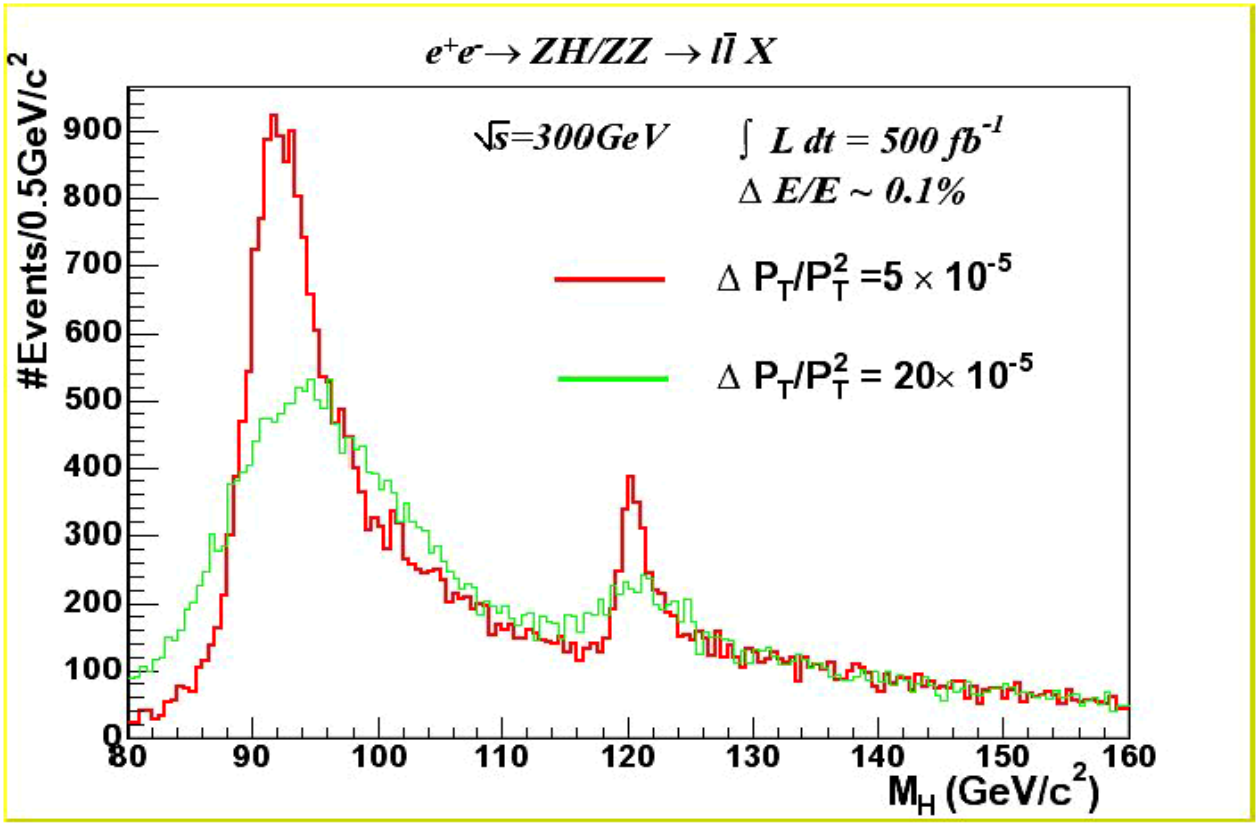
Exploits the clean environments of LC.
Not a luxury, but needed for LC to do its physics.

Pushes detector performance into unexplored territory

Detector requirements 2

e.g: The Higgs tagging mode

$$e^+e^- \to ZH, \quad Z \to \ell^+\ell^-$$



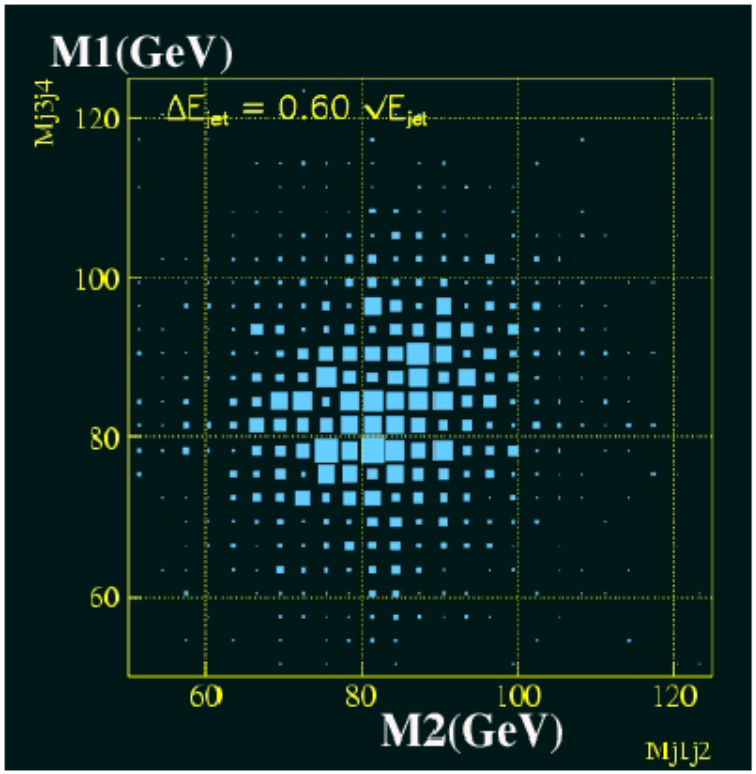
$\sigma_p/p^2 \sim 5 \times 10^{-5}$ is "necessary"

Detector Requirements 3

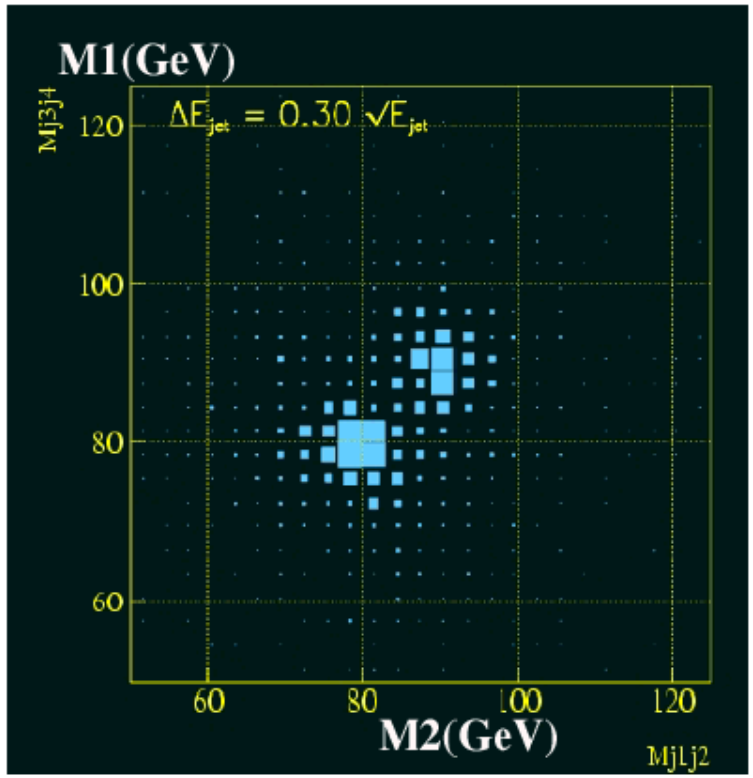
e.g: Separation of WW and ZZ

$$e^+e^- \to \nu\bar{\nu}W^+W^-, \nu\bar{\nu}ZZ\,, \quad W, Z \to 2\text{jets}$$

$$\frac{\sigma_E}{E} = \frac{0.6}{\sqrt{E}}$$



$$\frac{\sigma_E}{E} = \frac{0.3}{\sqrt{E}}$$



$\frac{\sigma_E}{E} \sim \frac{0.3}{\sqrt{E}}$ is 'needed'.

For jets !!!!

Design drivers 1

To be able to achieve the jet resolution can NOT simply use calorimeters as sampling devices.

$$\frac{\sigma_E}{E} \cong 0.30 \frac{1}{\sqrt{E(GeV)}}$$

Have to use "energy/particle flow". Technique has been used to improve jet resolution of existing calorimeters.

Algorithm:

- use EM calorimeter (EMCAL) to measure photons and electrons;
- track charged hadrons from tracker through EMCAL,
- identify energy deposition in hadron calorimeter (HCAL) with charged hadrons & replace deposition with measured momentum (very good)
- When completed only E of neutral hadrons (K's, Lambda's) is left in HCAL. Use HCAL as sampling cal for that.

Require:

Imaging cal (use as tracker = like bubble chamber),
➔ very fine transverse segmentation
Large dynamic range: MIP…. to …..shower
Excellent EM resolution

Design drivers 2

Requirements for optimal "energy/particle flow" now drive the calorimeter design and drive it to extremes in terms of sampling transversely and longitudinally.

However do not know where break even point is i.e. resolution is limited by algorithm and not the detector.

Studies are underway:

- Develop and test algorithm
- Develop and measure response of calorimeters
- Push limits of our current understanding of hadron showers
- Large R&D program including testbeam work with test calorimeters in progress

Basic Ideas & Assumptions for SiD

- ILC detector based on a integrated, optimized and hermetic design
- Aggressive & High performance detector
- Constrain cost and use that from the beginning as a constraint
- Optimize the integrated physics performance of the subsystems
- Assume "particle/energy" flow concept in overall detector design (needed to achieve physics performance)

- Use silicon as the main detector element for all tracking

In some sense this started as a response to a "Standard" e^+e^- detector

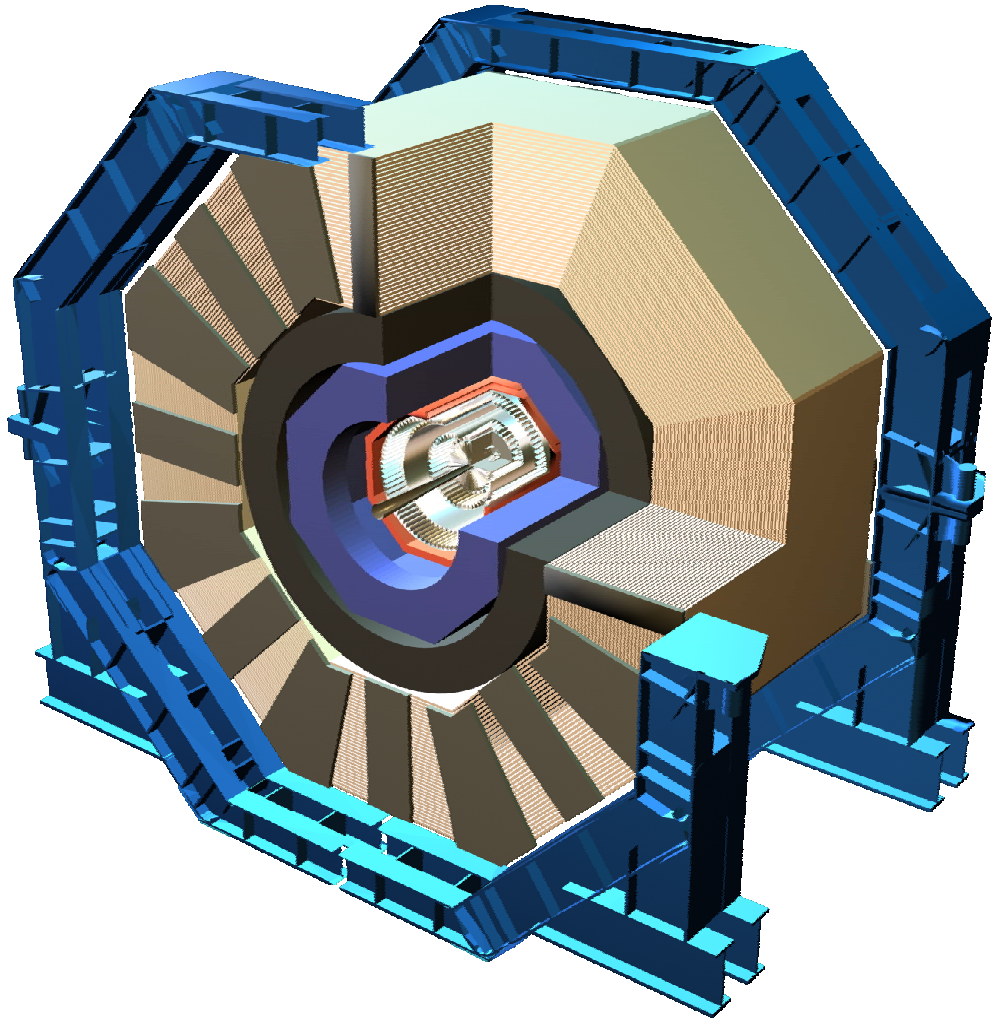
(can it be done a different way ???)

SiD starting point (1)

Starting point: SiD concept

↓

- *Accept* notion that excellent energy flow calorimetry is required, and explore optimization of a Tungsten-Silicon EMCal and the implications for the detector architecture…

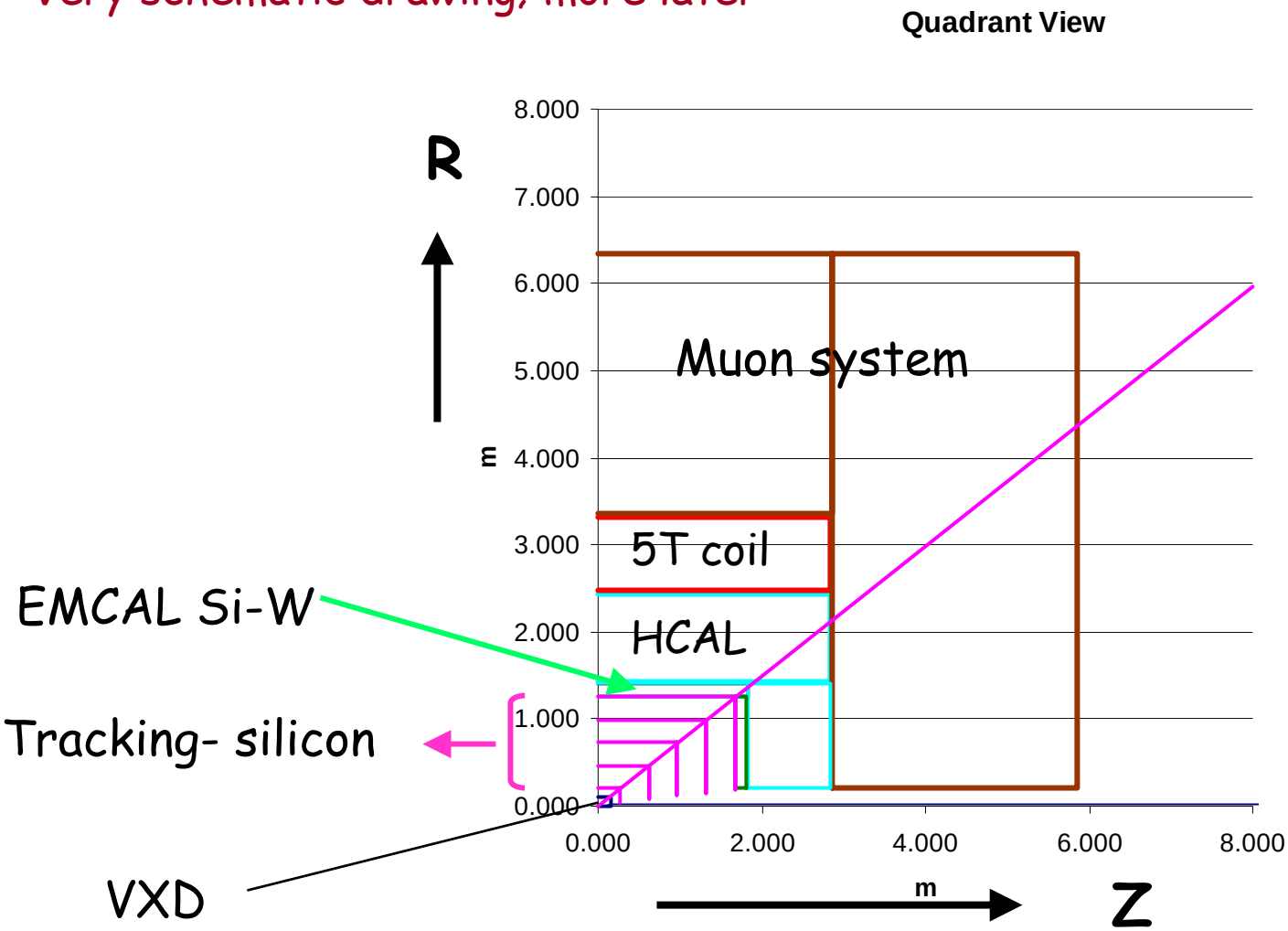


SiD starting point/motivation (2)

- Robustness of silicon against unexpected beam conditions/loss
- Silicon is expensive, so limit area by limiting radius
- Get back BR^2 by pushing B up (~5T)
- Maintain tracking resolution by using silicon strips in tracker
- Buy safety margin for VXD with the 5T B-field (limit radial extent of pair background; smaller radius for VXD.)
- Make full use of 5 VXD space points for pattern recognition

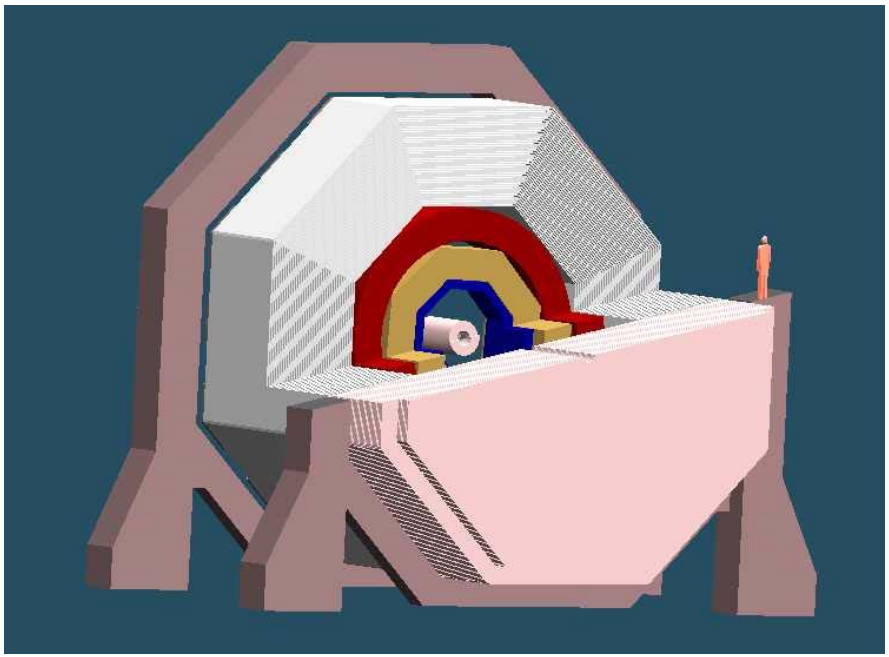
SiD concept overview

Very schematic drawing; more later



NOT A SMALL DETECTOR

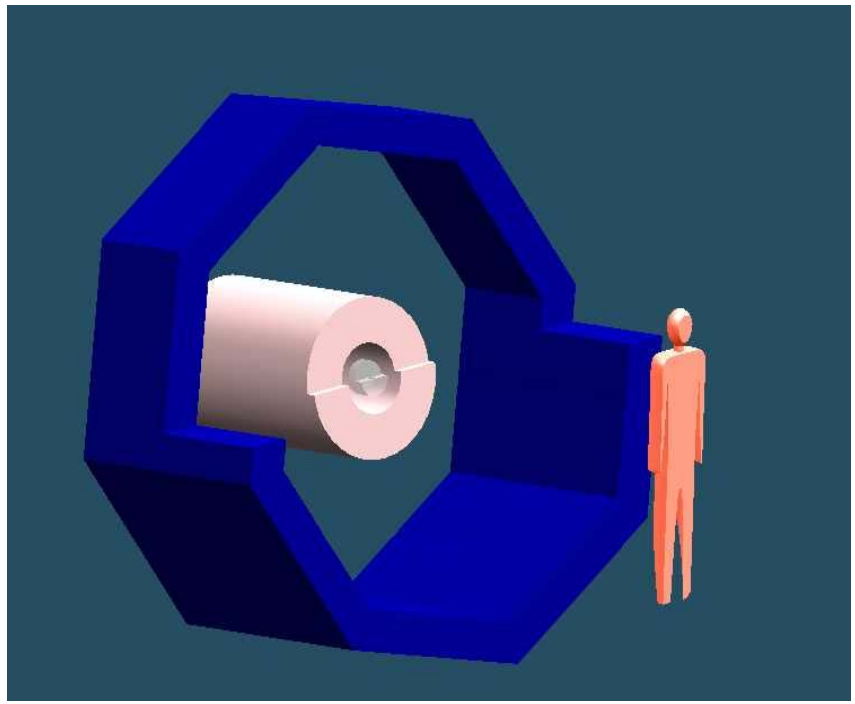
SiD concept sizes



Overall SiD

Size of VXD
outer cryostat
and EMCAL

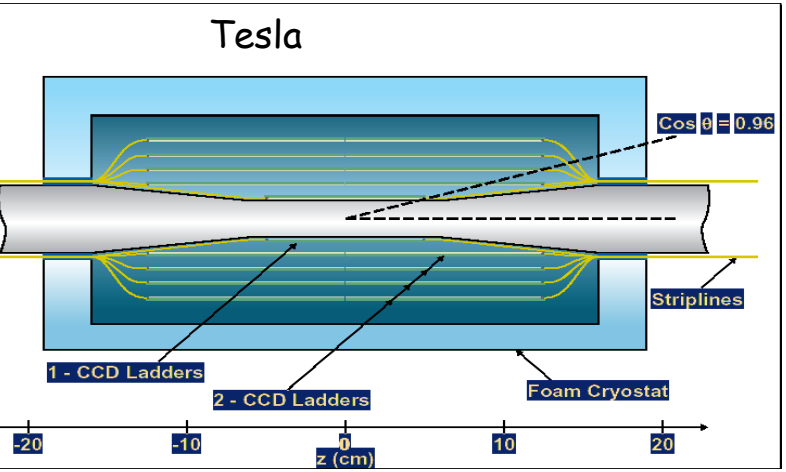
(EMCAL inner radius larger than
Dzero EM cal radius)

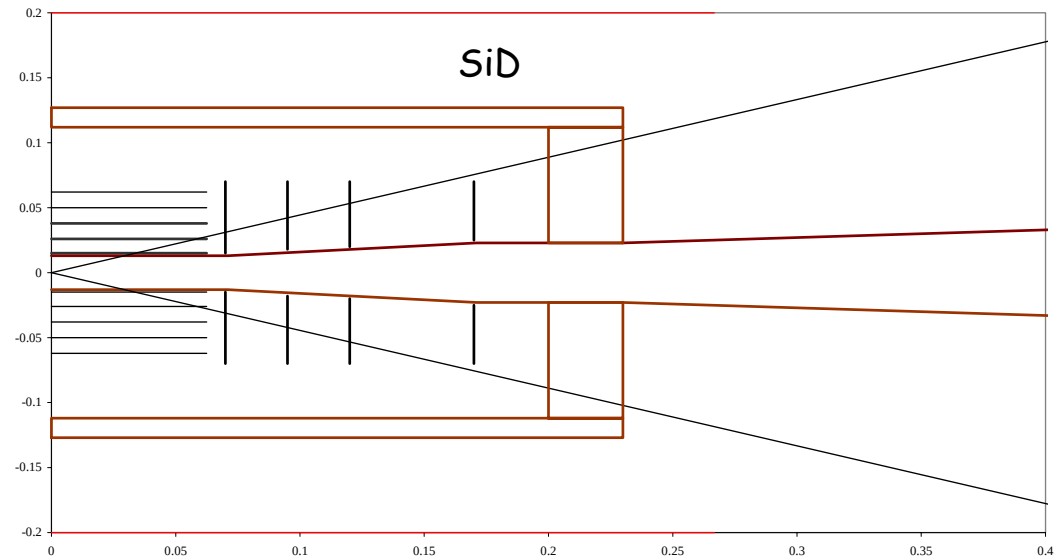


Fermilab: building a model of detector in IDEAS, virtual model & drawings

Vertex detector

H.Weerts





Build on SLD/VX3 success

Radius: inner ~1 –1.5cm outer 10cm, 0.2% X_0

Extend 5 layer tracking over max Ω (5 barrel + 4 forward layers)

→improve Ω Coverage, improve σ_{xy}, σ_{rz}

5 layers $\cos\theta < .97$

4 layers $\cos\theta < .98$

Minimize "CCD" area/cost

→ Shorten Barrels to 12.5 cm (vs. 25.0cm)

Thin the barrel endplate

Simulations of this geometry done already

Tracking

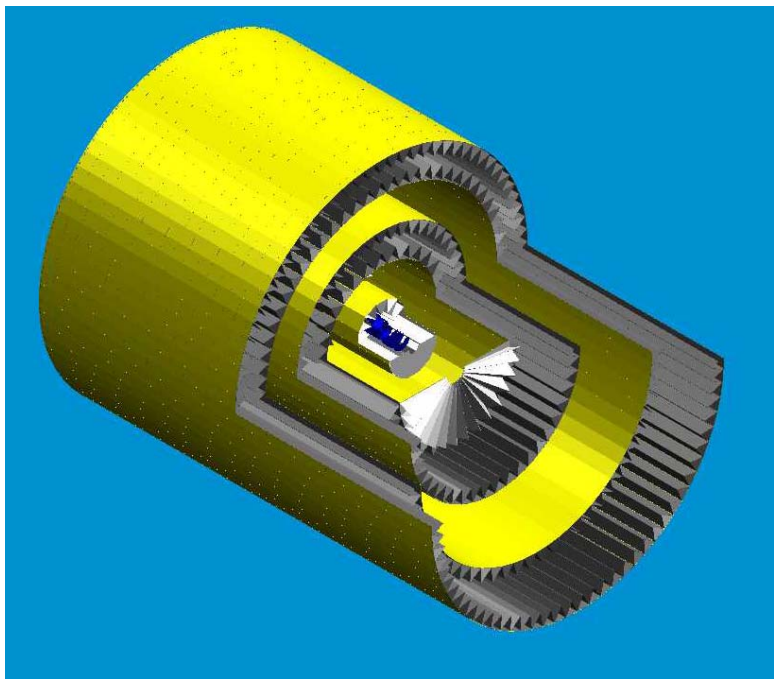
- Silicon; Inner radius 20cm outer radius 125cm; 5 layers
- **SLC/SLD Prejudice**: Silicon is robust against machine mishaps; wires & gas are not.
- Silicon should be relatively easy to commission – no *td* relations, easily modeled Lorentz angle, stable geometry and constants.
- SiD as a *system* should have superb track finding:
  - 5 layers of highly pixellated layers plus
  - 5 layers of Si strips, outer layer measures 2 coordinates
  - EMCAL provides extra tracking for V finding - ~1mm resolution!
- Minimize material before endcap calorimeter
- Simulation Studies have been and are underway
- Hardware developments (just starting)
  - Effort on ASIC…….. adapting for long bunch trains
  - Structure design & layout work at FNAL

Silicon Tracking

Structure and mechanical considerations

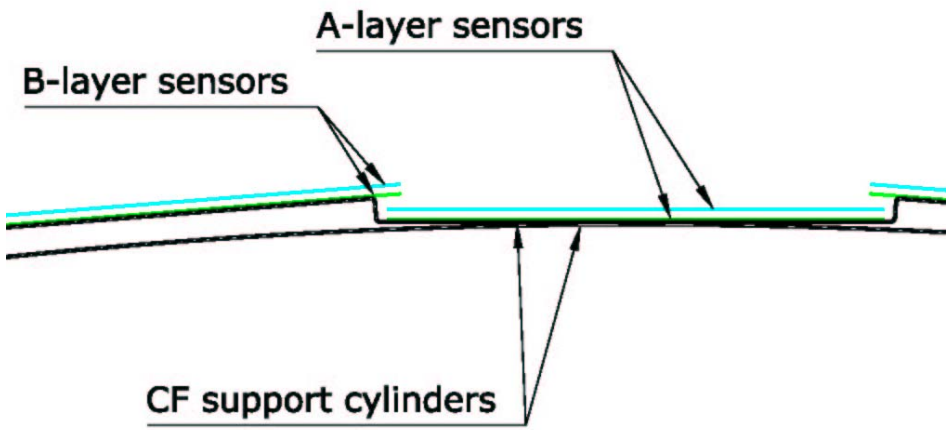
- **Ladder configurations under study.**
- **Minimal electronics and power pulsing make gas cooling easy. No liquids, leaks or associated mass.**

Initial thoughts on support structure



Long ladders evolved to shorter structures & cylinders

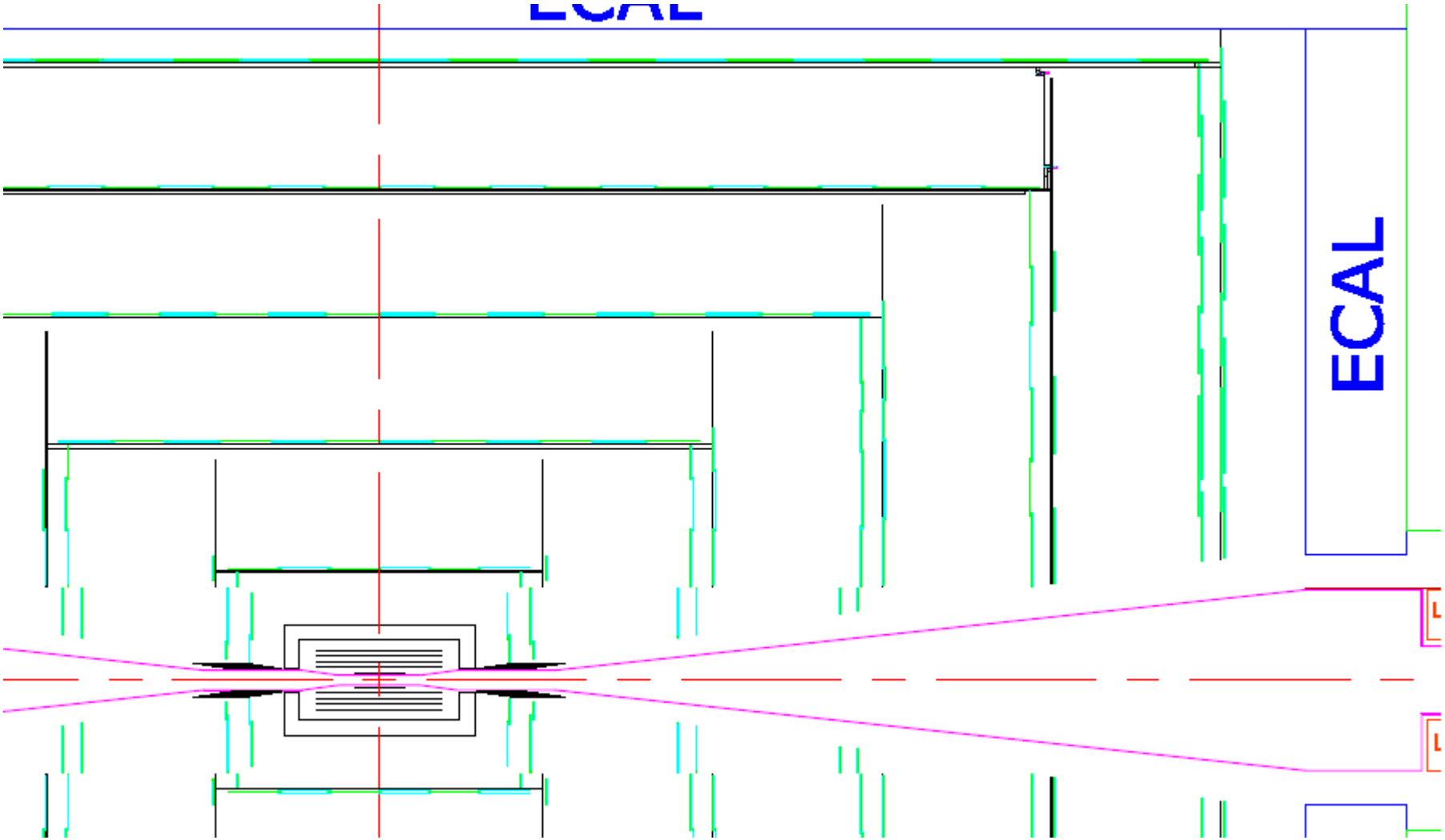
Support structure by Fermilab



Use double carbon fiber support cylinders for each barrel; now the default

Silicon Tracker 3

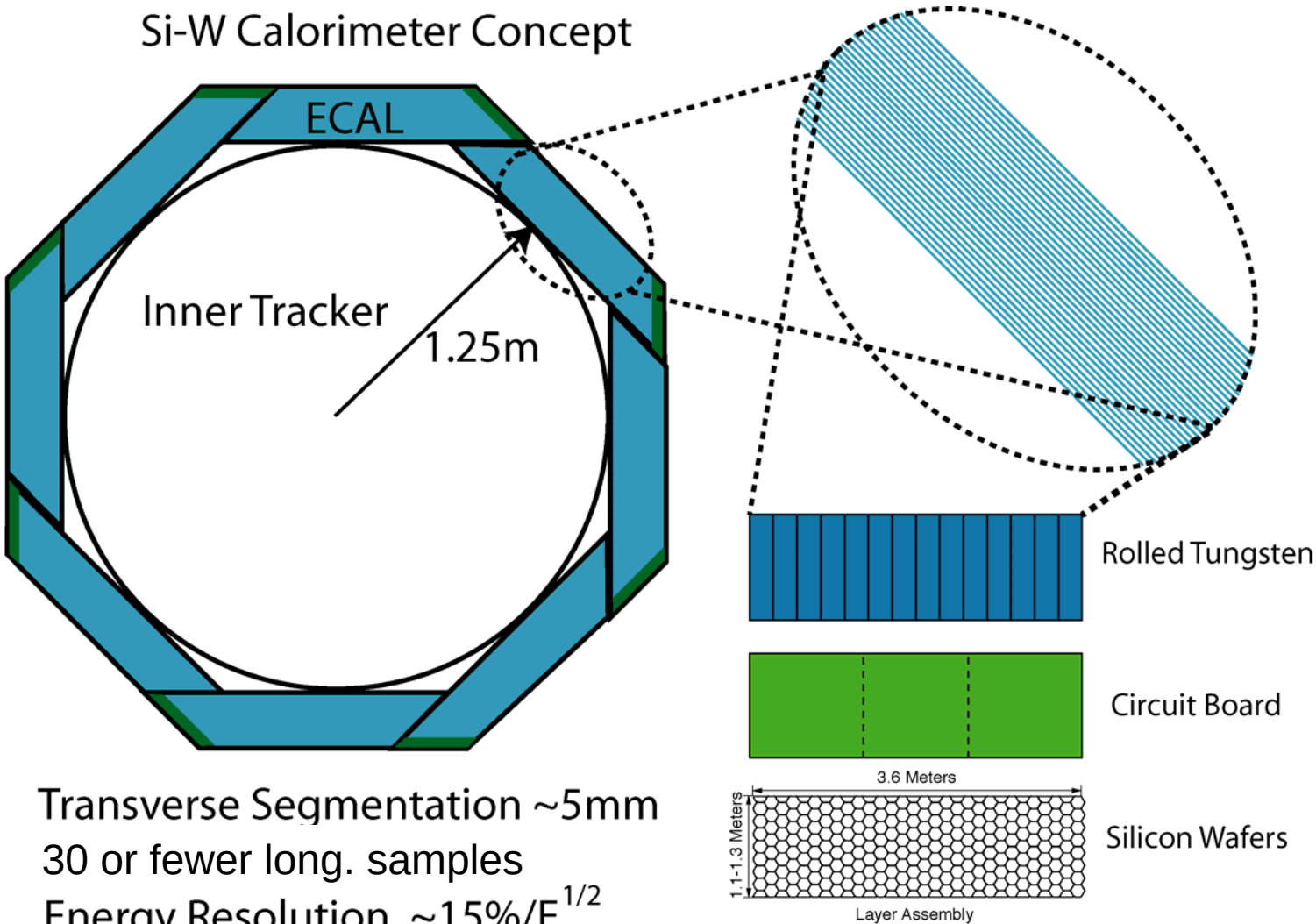
H.Weerts



Fermilab: actively involved in detailed layout of Si tracker
(WC,MD,MH,KK, ++)

EM CAL concept 1

Inner radius: 1.25m , outer radius 1.41 m; 29 X_0



Transverse Segmentation ~5mm

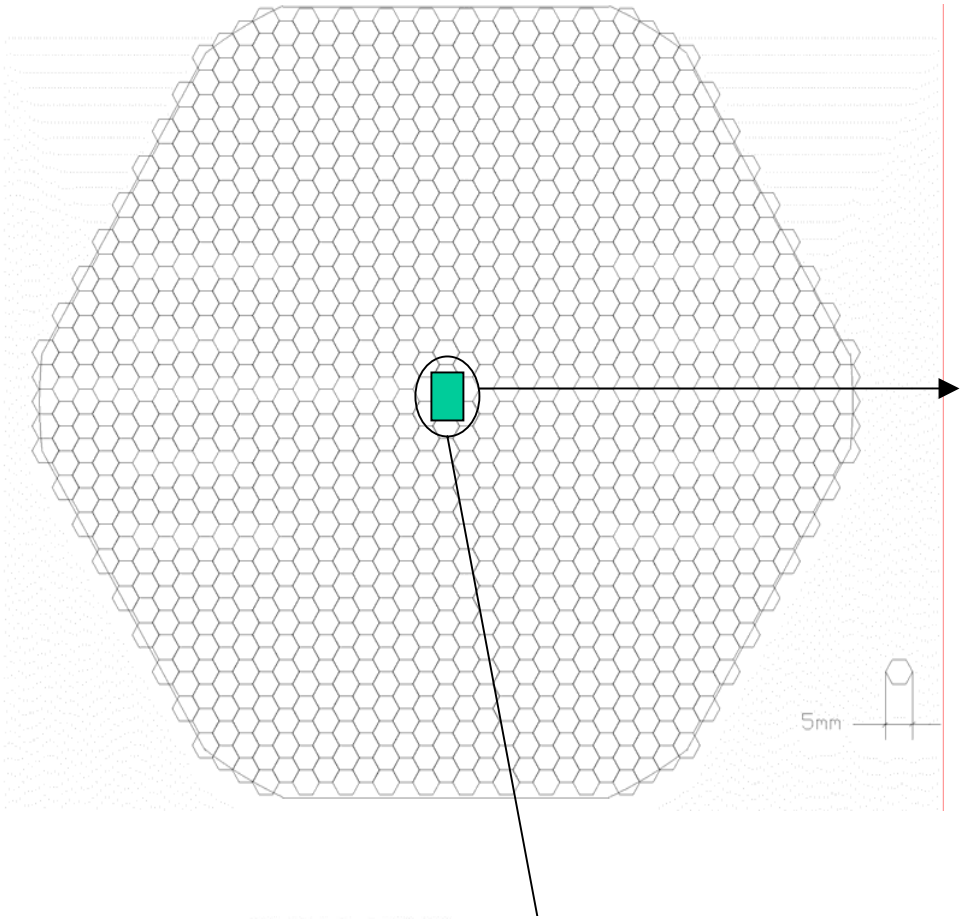
30 or fewer long. samples

Energy Resolution ~15%/$E^{1/2}$

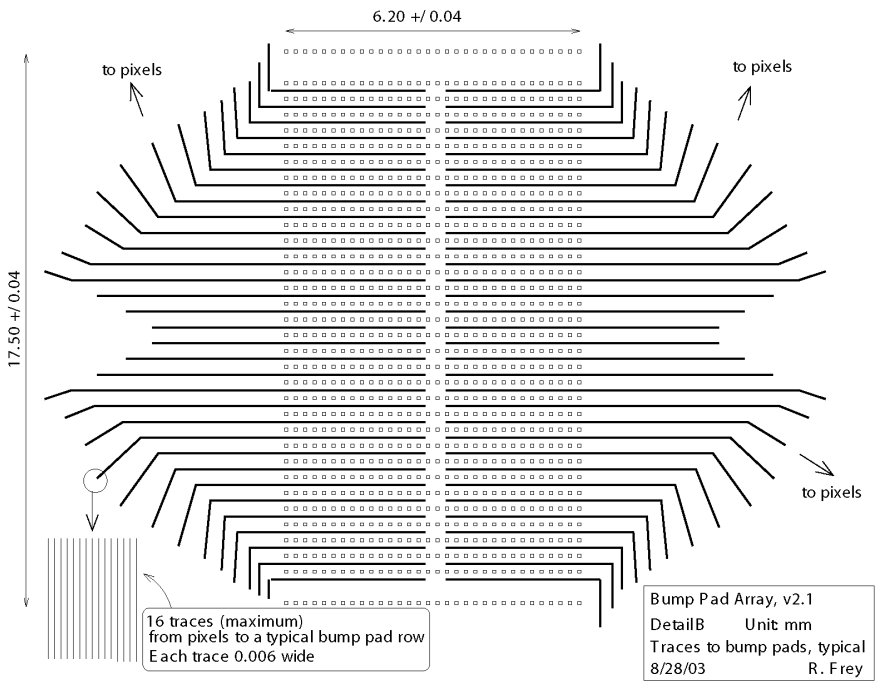
Consider other technologies ??

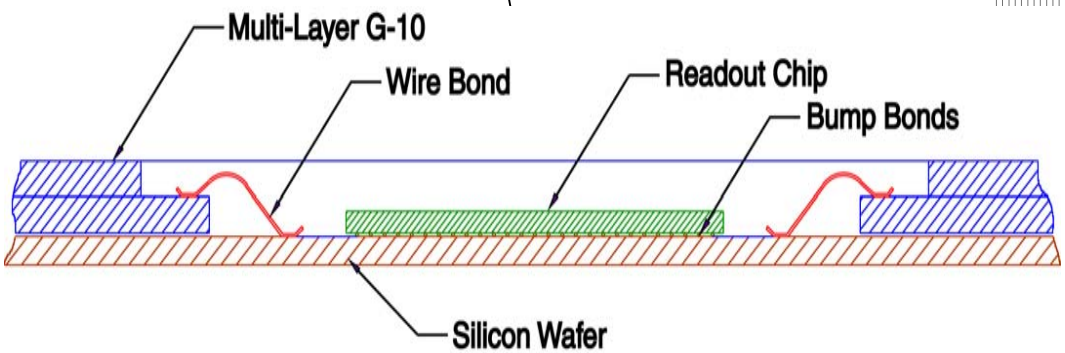
EMCAL concept 2

H.Weerts



Wafer and readout chip





Concept: many channels (1-2K) on one ASIC

Possible ???

HCAL

Inside the coil

Inner Radius ~ 1.42m, outer radius ~ 2.44m; thickness ~4Λ
34 samples; 2cm Fe, 1 mm gap

Technology not specified, dependent on ongoing vibrant Calorimeter R&D

Several possibilities:
- Digital or Analog or mix
- RPC's
- GEM's
- Scintillator (SiPM, APD,……)

Initial starting assumption: use Fe as absorber

Have started to look at this with "detector on a spreadsheet"

HCAL 2

HCAL is on the critical detectors for SiD and any ILC detector

One reason is the desire to keep it inside the solenoid i.e. small

Large worldwide R&D group working on calorimetry (CALICE)
NIU & ANL (close to FNAL) actively working on this.
ANL: digital calorimetry and use RPC
NIU: scintillator development and simulations

Other US group is UTA, pursuing GEMS

All wish to use testbeam at Fermi; proposal written

Fermilab: developing readout chip for test calorimeter RCP & GEM

Fermilab: this is an area where there is expertise at Fermilab and it would be a good area to become involved in. HW interested.

Thursday, Oct 28 @4:00pm; SiDet conference room:
S.Magill (ANL) : "Comparison of W and Fe calorimeters" (for Sid)

Testbeam activities

The ILC detector R&D groups are currently designing and building prototype detectors to be tested in electron and hadron testbeams (~1 GeV to 150GeV).

A worldwide document outlining the testbeam needs has been written and specific proposal to Laboratories are being created. Calorimeter prototypes will exist by beginning of next year.

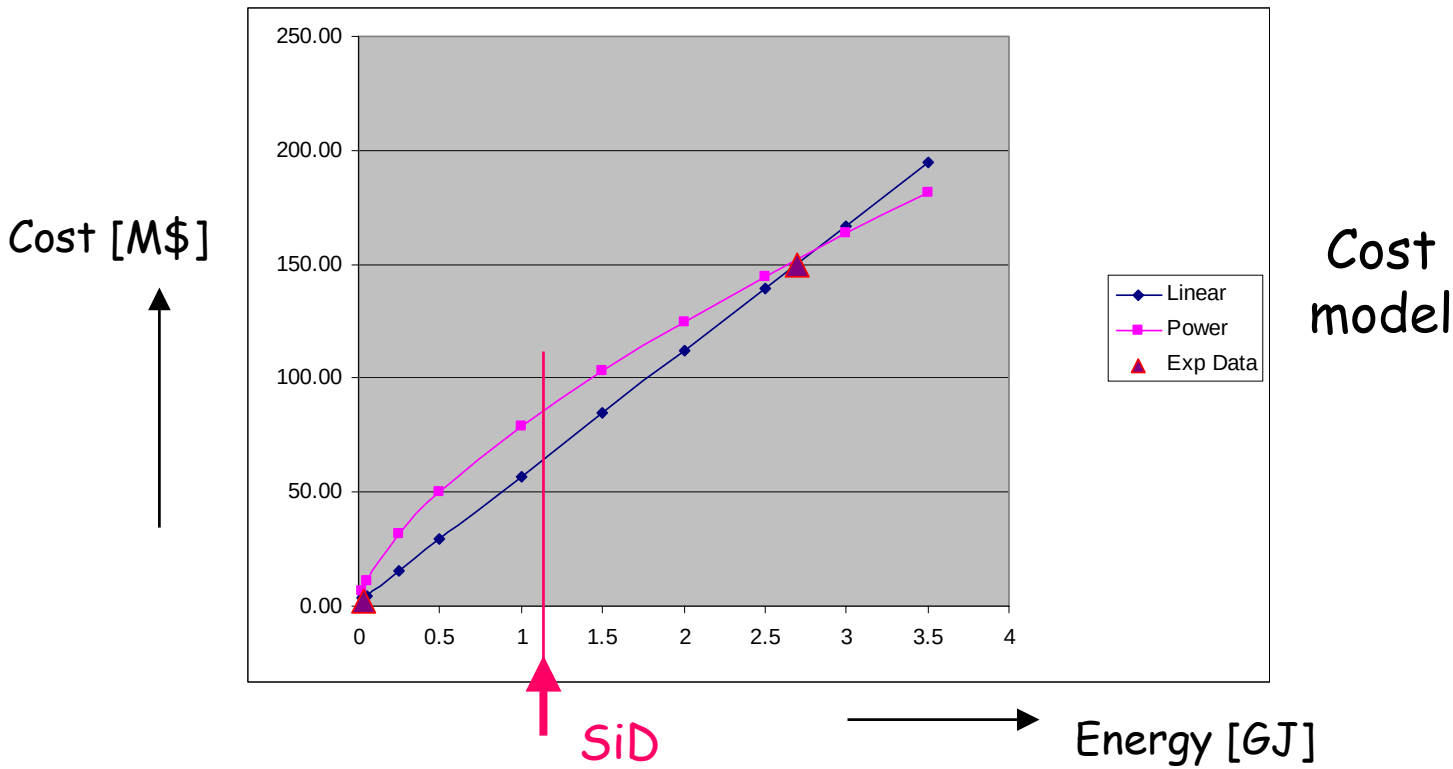
Needs of calorimeter R&D groups are most demanding and there has been a lot of interaction between FNAL testbeam coordinator (*E.Ramberg*) to see how ILC testbeam needs can be addressed at Fermilab.

Solenoid

Inner radius: ~ 2.47m to ~3.32m, L=5.4m; Stored energy ~ 1.1 GJ

Need feasibility study in next year to at least convince ourselves that 5T can be built .

Expertise not readily available. CMS solenoid sets current scale.

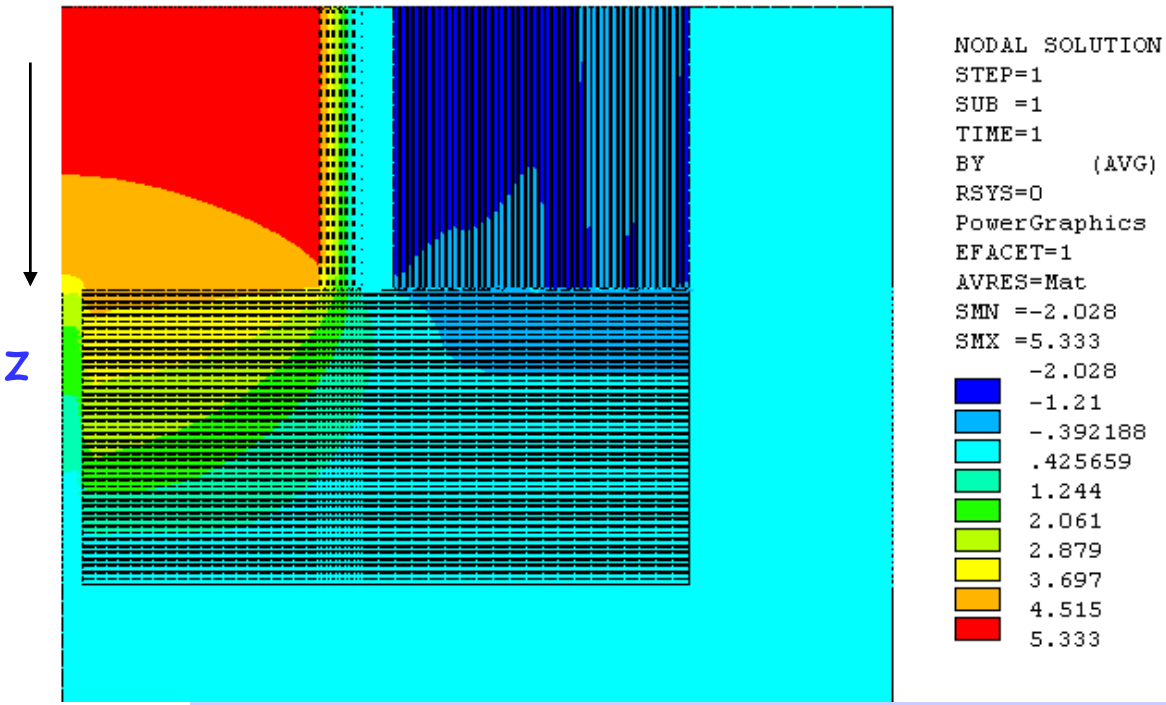


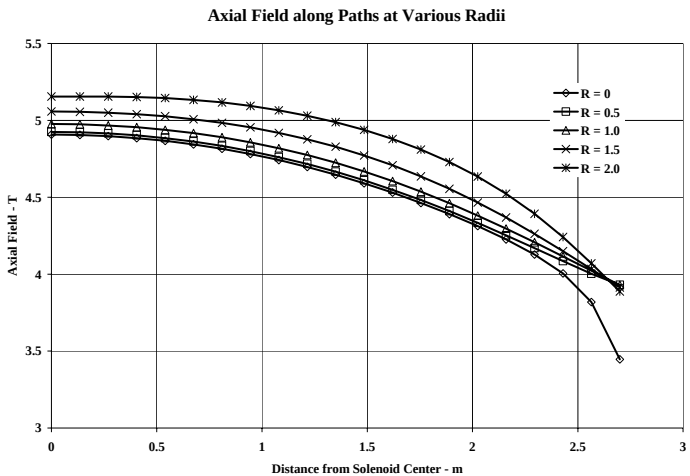
Fermilab: next page

Solenoid Fermilab

Fermilab solenoid activities:

Have started collaboration with Saclay (F.Kirchner)
Use expertise available at Fermi about CMS magnet (R.Smith)
Use CMS as basis for design.
Build a finite element analysis based on CMS conductor and increase #winding/coil from 4 to 6. (4T to 5T); Wands & Krempetz





Very first results; now starting stress analysis

Muon system & flux return

Inner Radius ~ 3.35m, outer radius ~ 6.34m;
44 layers; thickness ~14Λ

Flux return and muon ID, as well as tail catcher for HCal

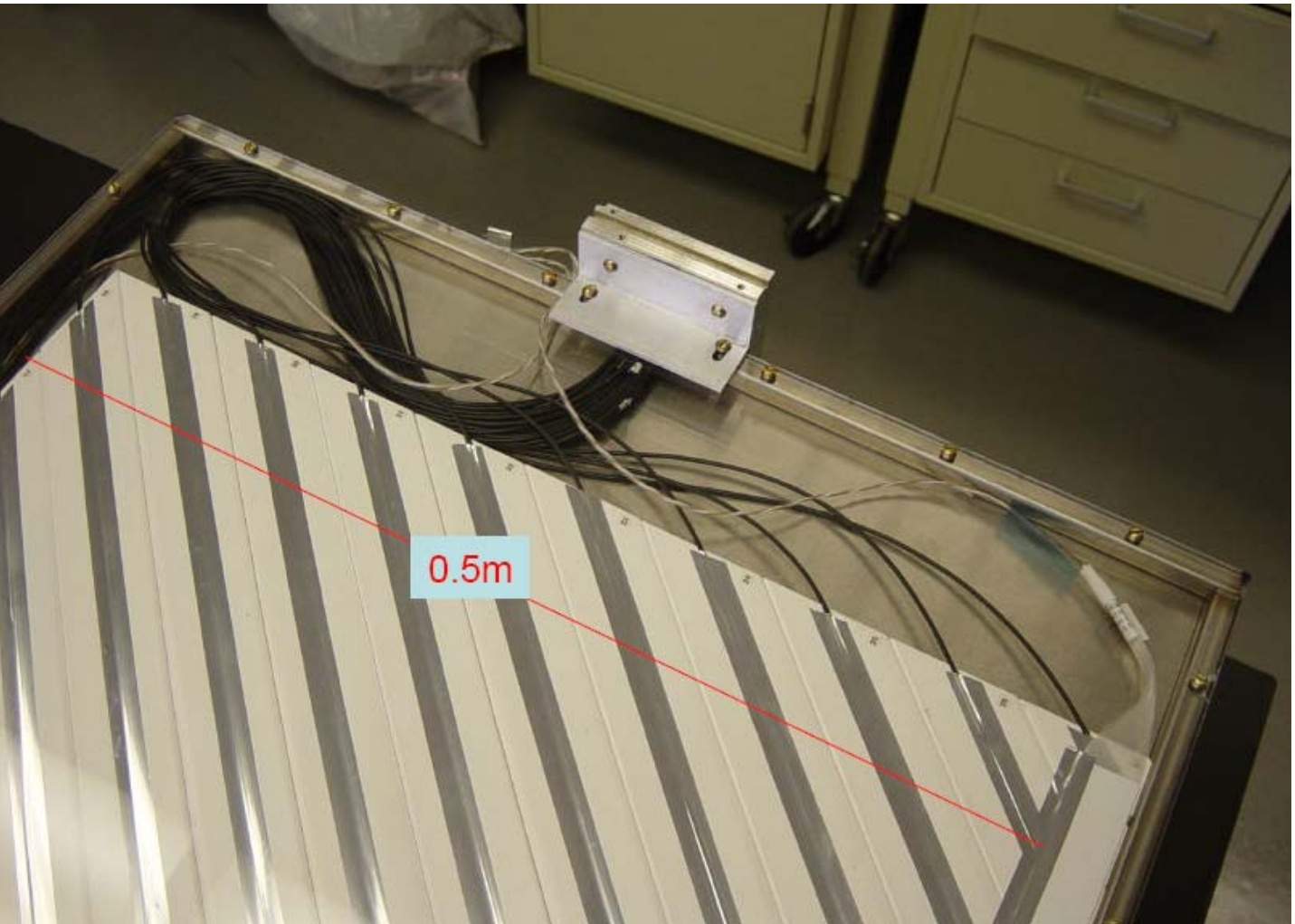
Technology not specified, dependent on ongoing Muon R&D

Possibilities:
- RPC
- GEM
- Scintillator (PMT and Si-PM)

Fermilab: is one of the leading institutions in the muon system and generic muon detector R&D; H.E.Fisk and C.Milstene

Muon detector R&D

- Colo. State, UC Davis, Fermilab,
- Northern Illinois Univ.,
- Univ. of Notre Dame, Wayne State Univ.,
- Univ. of Texas Austin, INFN Frascati



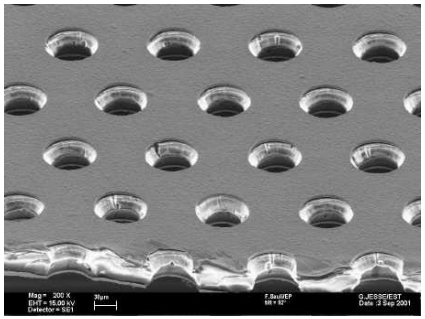
Prototype "0"
~1/4 size

First mock up assembled at Notre Dame and now at FNAL.
Now WLS are fused and testing is about to begin.

Muon R&D

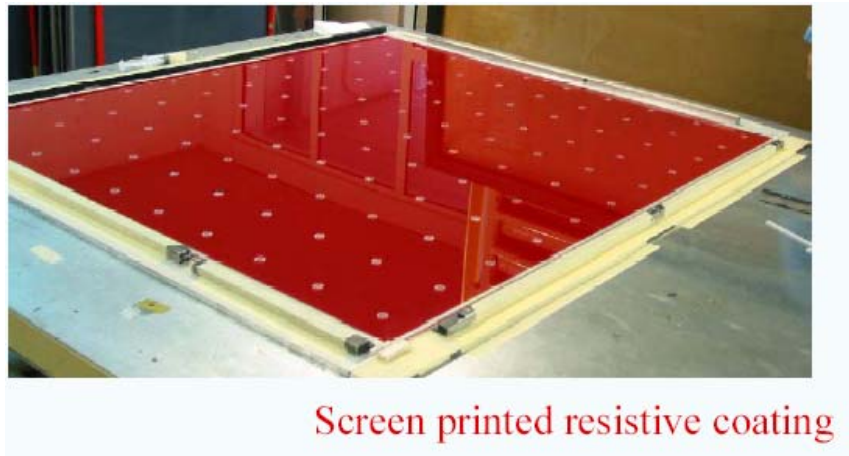
Active Muon Detector R&D

- Gaseous Electron Multiplication
  UTA A. White et al

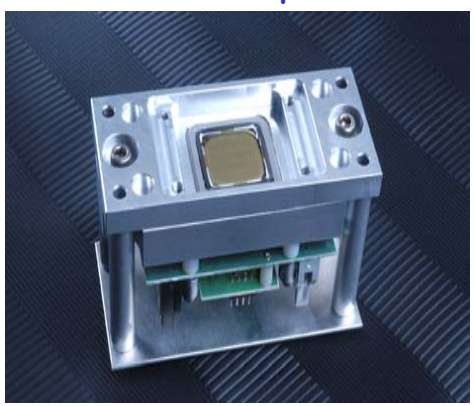


~ 50 μ holes

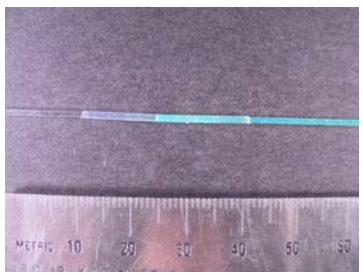
- Resistive Plate Chambers - INFN Frascati – M. Piccolo et al



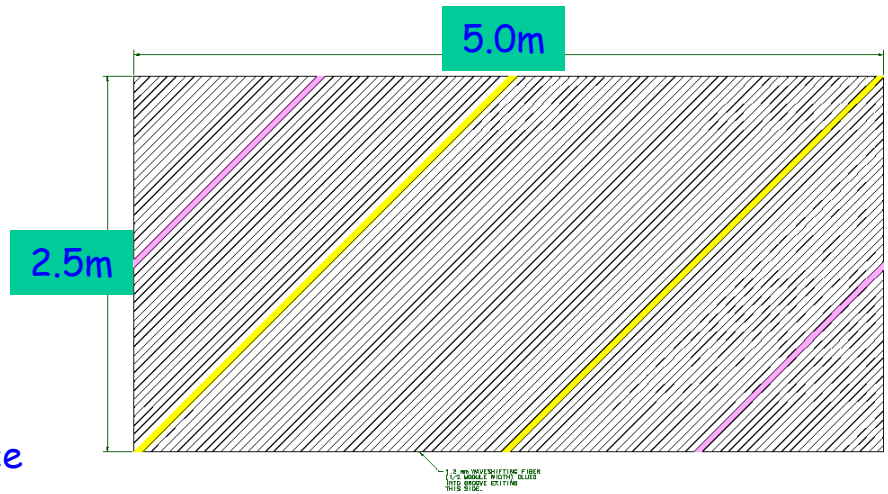
- Scintillator strip panels
  MINOS style: 4 cm X 1 cm
  MAPMT 16 or 64 channels
  4mm X 4mm pix / 16 ch



1.2mm fiber



Thermally fused splice

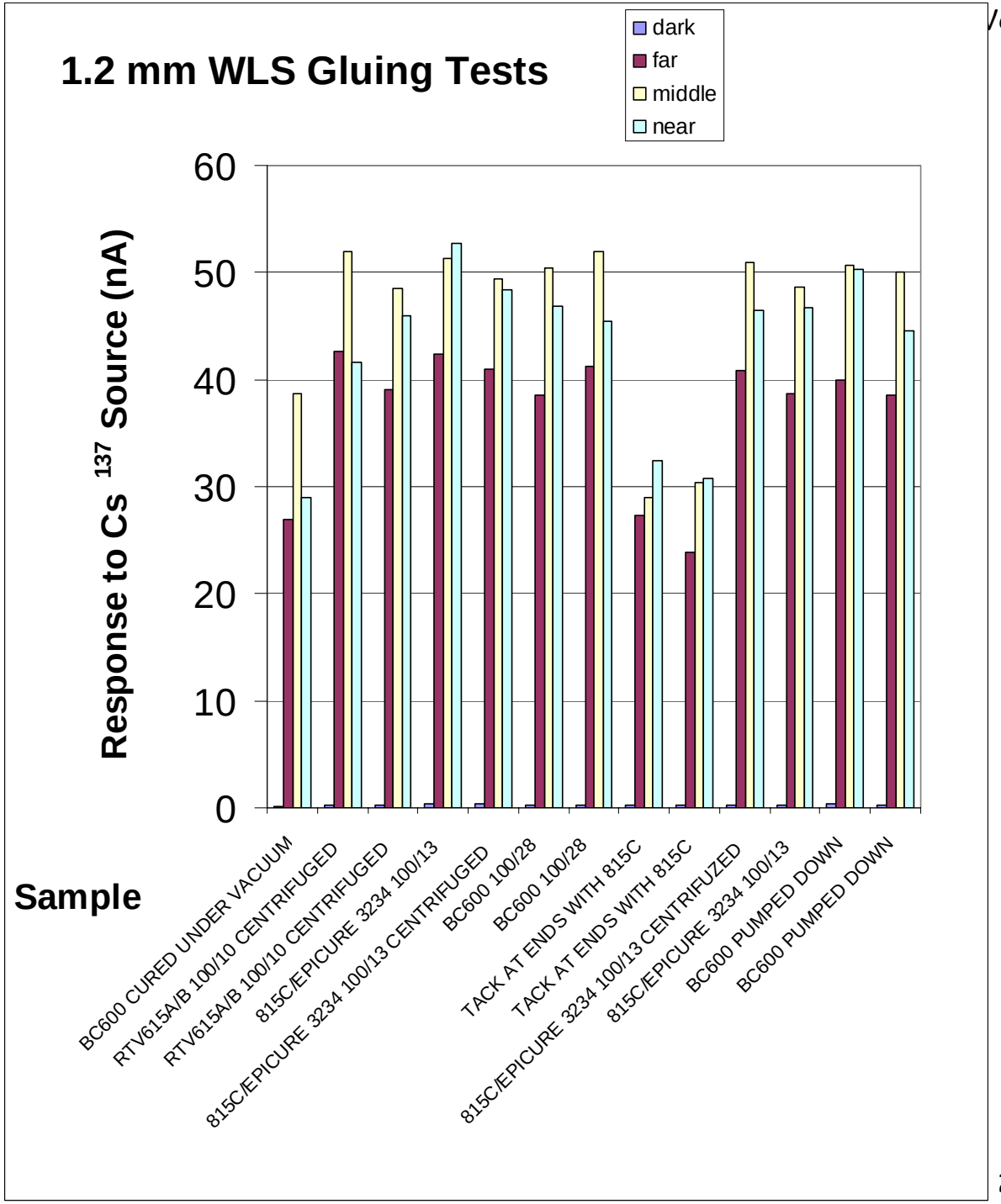


1m long scintillator gluing and light yield tests

Sasha Dychkant's Measurements of Strip Response using a Cs^{137} source.

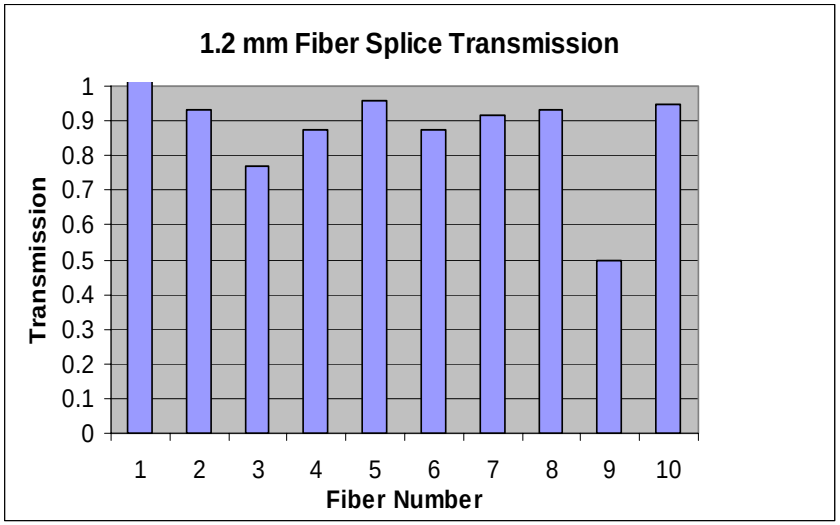
May 19, 2004

~ 15 p.e.s



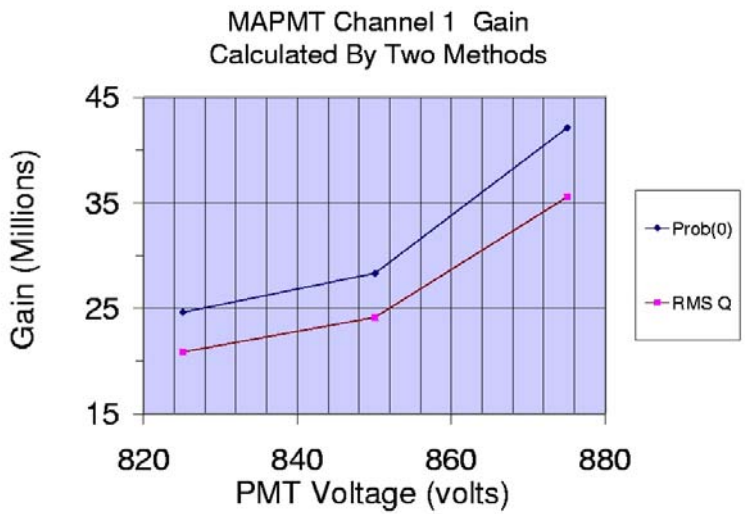
Muon R&D 2

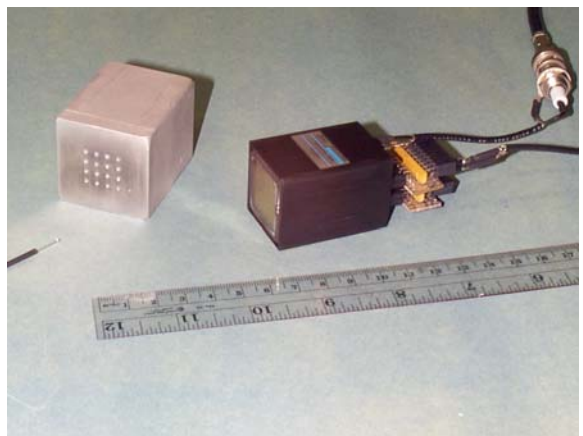
Fiber Splice Test
Notre Dame – M. Wayne



90% Transmission
8 out of 9 splices
#9 was bad;
#1 was not spliced

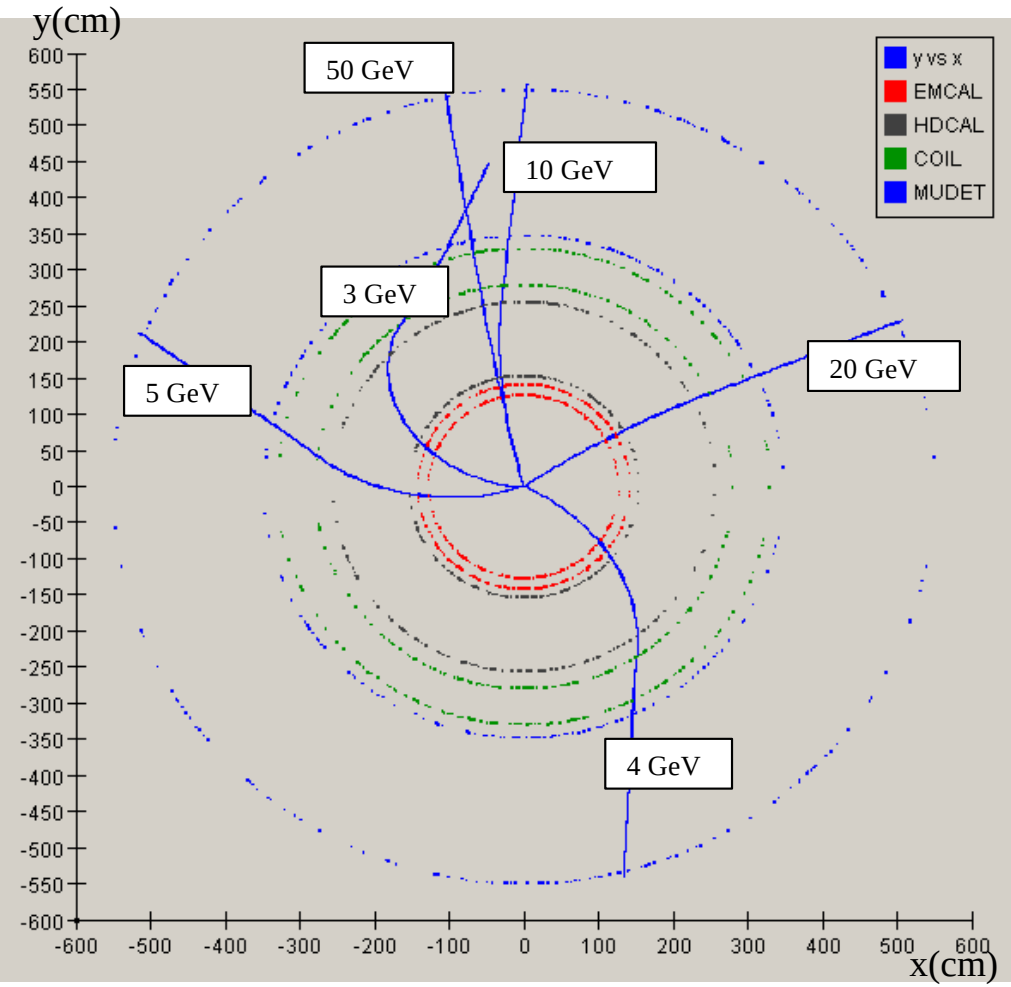
MAPMT Gain Meas.
Wayne State – P. Karchin



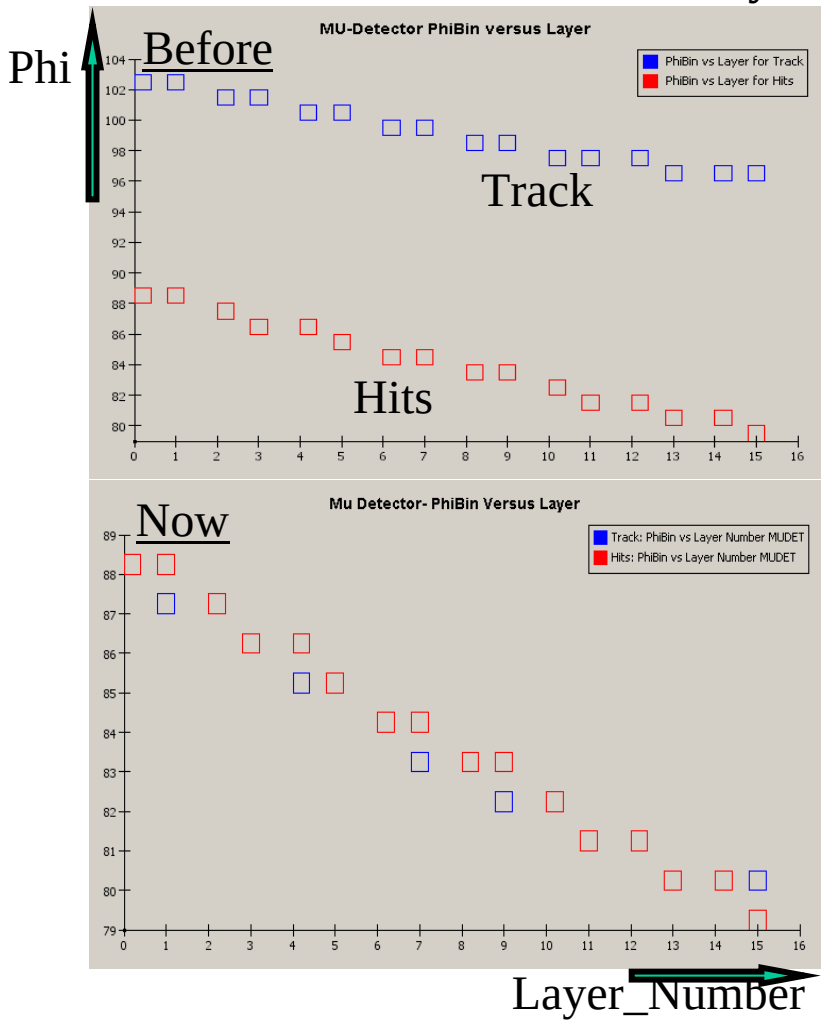


MIP Tracks -Reconstructed By The Stepper In a B=5 Tesla Magnetic Field (C.Milstene)

Muon tracking



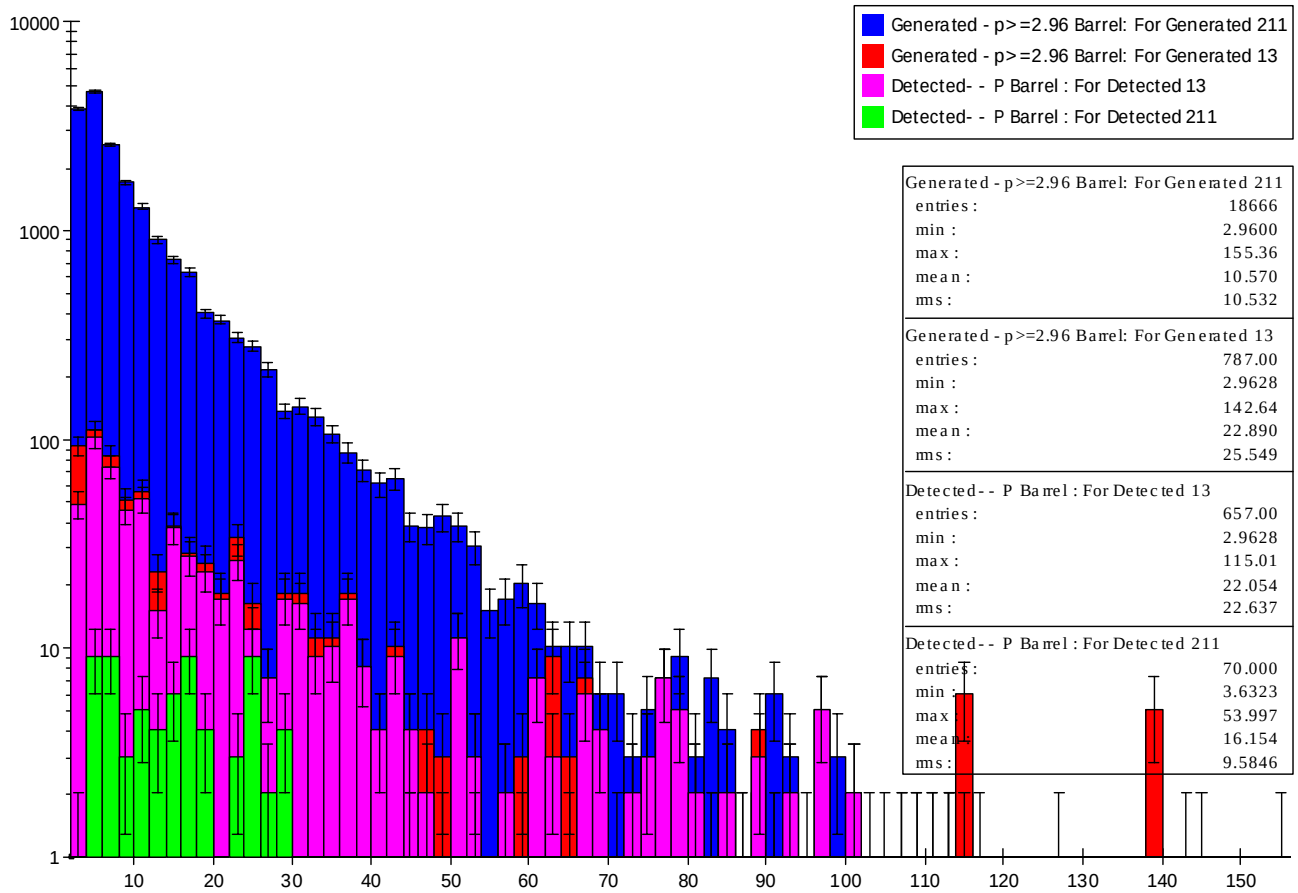
Mu-Detector 300 Phi Bins- 32 Layers



EMCAL -2 RED Rings
HDCAL -2 BLACK Rings
COIL -2 GREEN Rings
MUDET -2 BLUE Rings

B= 5 Tesla

Mu& Pions Background Generated/Detected Out Of 10000 b-bbar Jets By Mu Algorithm-



P(GeV/c)- 2GeV/bin

Signal:

- Generated Muons in Red
- Detected Muons in Magenta

Background:

Generated Pions in Blue

Detected Pions by Mu Algorithm In Green

Remark:

Below 2.96 GeV the Particles do not reach The Muon Detector

Performance Criteria

Should be agreed upon with other detector design studies

Use standard processes: $\nu\nu$ *WW*, $\nu\nu$*ZZ, t-tbar, HZ + some SUSY ?*

Define Physics Benchmarks. How to approach this ……..

Use existing tools & algorithms……. even if incomplete

Simulation efforts

Currently simulation efforts are at SLAC & NIU in the US.
ANL simulation focused on HCAL

There are other efforts in world.

No simulation efforts local at Fermilab, except:
- Muons, C. Milstene
- Tracking of V's, D. Onoprienko , Kansas State

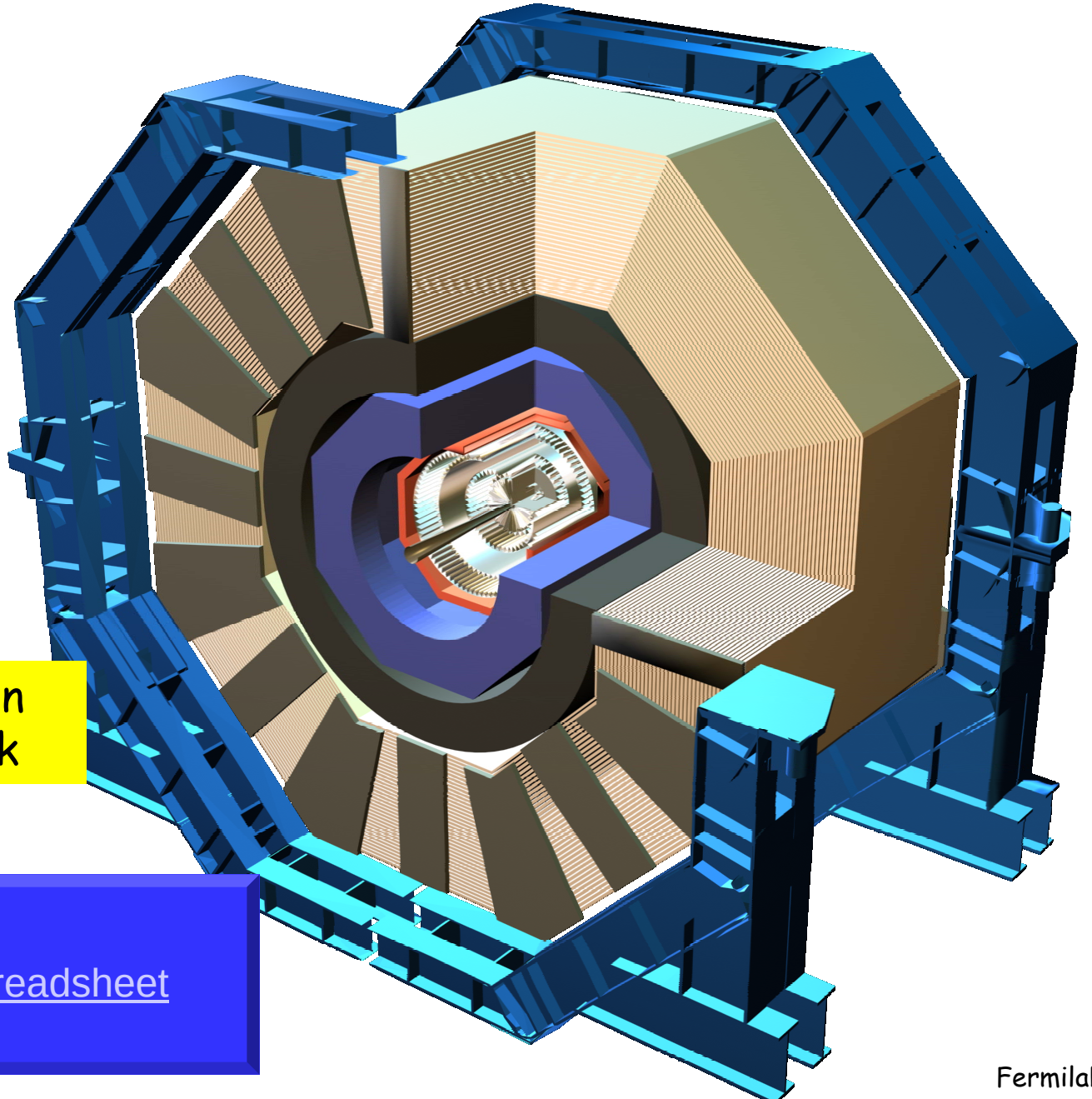
SiD on a spreadsheet

Parameterize the major subdetector boundaries and parameters
Put in cost for materials (per kg for absorber)
Cost for detector elements (per m^2)
A solenoid cost model
Create sliders to change parameters like absorbers, gaps, barrel/forward transition, BR^2, HCAL in or out of coil, etc

Allows one to:

Make a simple drawing detector
Track components/material needed for options
Do simple cost comparisons of options
Identify cost drivers

Very useful tool for overall detector concept/design



Info not in online talk

SiD Spreadsheet

SiD design Study Endpoint

Even though we have a starting point, the resulting final optimal detector configuration is not clear.

Will depend on results of study, new ideas, inputs, simulations and last but not least the participants in the study

Fermilab activities overview

Activities already	Possible future activities
Si tracker layout & design	Tracking simulations (Kansas already)
HCAL electronics Testbeam setup	HCAL detector development & simulation; testbeam
Solenoid feasibility	
Muon detector R&D; muon system in SiD algorithm development	Continue & strengthen
Electronics development (ASICS, readout)	Expand into other areas
	DAQ and trigger
	Simulation

Beam Delivery & Interaction Region

Generally referred to as BDIR

One of the ILC machine working groups

Experts at Fermilab: Nikolai Mokhov et al. Mainly in area of extensive simulation of machine backgrounds and especially their impact on detectors.

Could use some expertise here in terms of defining what is tolerably and not from detector side

Muons, neutrons and photons

Meetings etc.

Local: Si- tracker meetings, wednesdays

Solenoid meetings, infrequently

Muon R&D announced

Global:

SiD meetings: general meeting developing
tracking meeting (fridays)

LCWS 2005: SLAC, Stanford, March 18-25, 2005

ILCW 2005 : August 14-27, 2005 Snowmass, CO

Office Space for ILC

There are two main areas of office space available:

1. Office space in IB2, mainly centered around accelerator work, with emphasis on RF work

2. Office space is available on 13th floor west side for anybody who wants to work on ILC.

Announcements

Thursday October 28, 2004 4:00pm SiDet Conference room:

S.Magill, ANL; "Comparison of Tungsten and Fe absorbers for hadron calorimeter"

First logo version by SLAC designer (on upcoming WEB page)

SiD WEB page:

http://www-sid.slac.stanford.edu

If you are interested …….. sign up here

Conclusion

Fermilab has declared the ILC the highest long term priority

Fermilab wants to be a host site for ILC

This means that Fermilab has to play a leadership role

in

Development & design of ILC machine

&

Detector development for ILC

Time to do this is now with technology decision made, the establishment of GDI within reach and world looking towards Fermilab to take a leading role in ILC activities.

Need to establish a critical "mass' of people and we need YOU or at least part of you

Conclusion 2

How to contact us ?

Feel free to contact any of us: H.E.Fisk, S.Tkaczyk, S.Mishra or myself

We will also be contacting you in the near future or at least will try.

The End

Background: Rejection Efficiency In b-bbar Jets

	Pion BG	K BG	Proton BG
Generated >3 GeV	18666 (55805)*	4473 (8310)*	1622 (2816)*
Detected	70	41	2
Rejection Efficiency	1 to 267	1 to 109	1 to 811

•Generated Particles above >2.96 GeV used To calculate the Rejection Efficiencies.

Using he swimmer we were getting after cuts, out of 787 Generated Mu above 2.96GeV ~603 Muons, 111 Bg

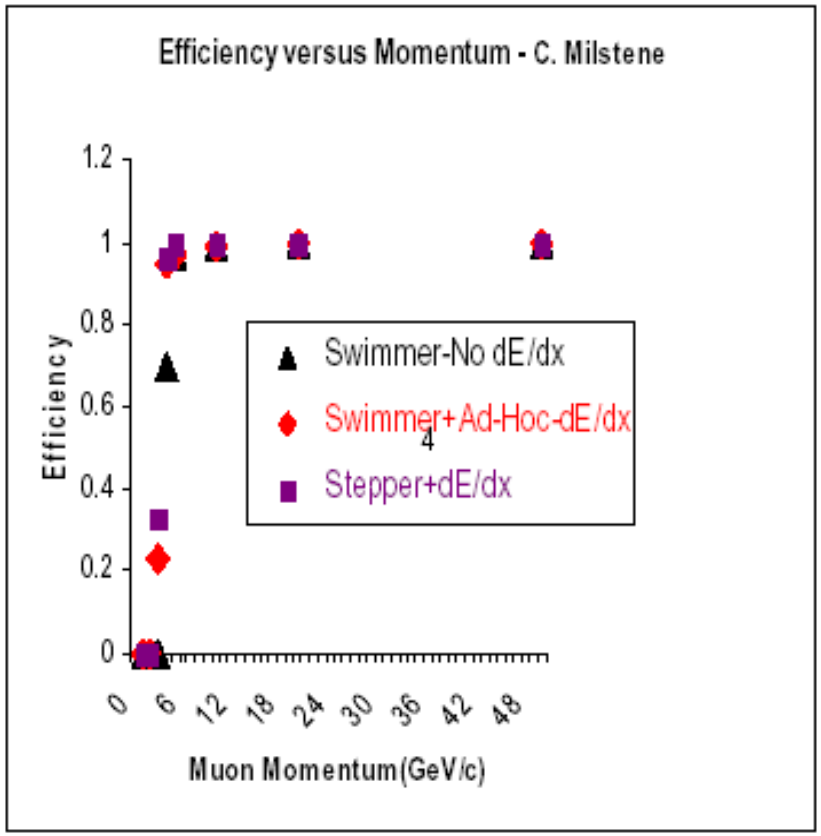
Now with the stepper & the HDCal filtering we get out of 787 Mu: 657 Muons, 113 Bg

*The total Generated

69% of the Muons(787 out of 1147muons) have a Momentum above ~3 GeV. One notices that less than 34% of the Pions, 54% of the Kaons and 58% of the protons have a momentum above ~3 GeV.

Simulation Studies

Caroline Milstene



E(GeV) \ Techn.	3	4	5	10
No dE/dx	0.06 %	70%	97%	99.%
Ad-Hoc dE/dx	23%	95%	97%	99.%
V x B + dE/dx	33%	96%	99%	100%