Concept for an ILC Detector

LCWS06 Bangalore
March 10, 2006
John Jaros for SiD

Silicon Detector Design Study

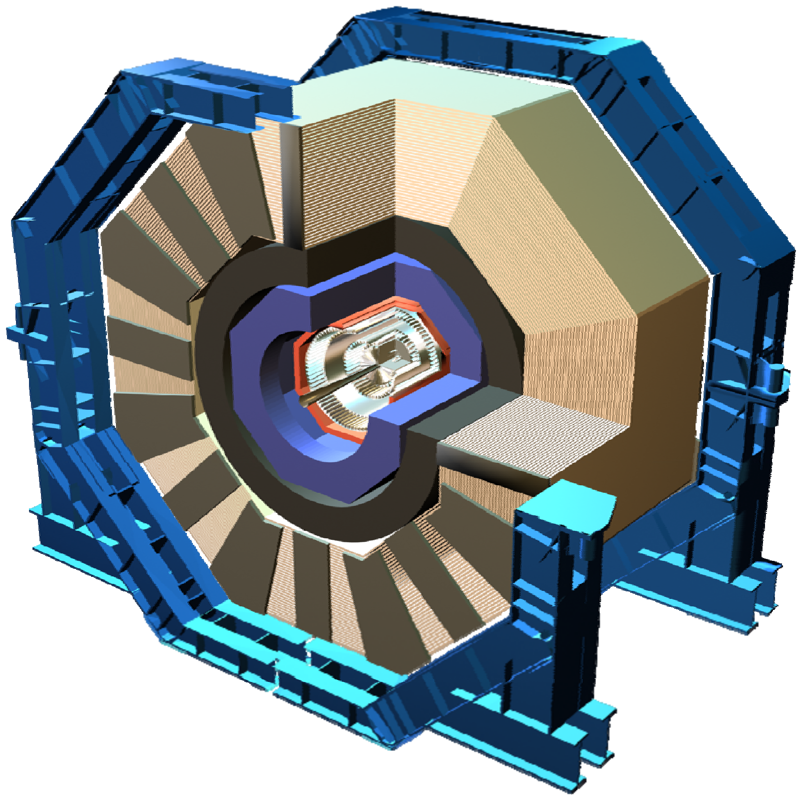
Initiated Victoria ALCPG Meeting 2004

•Design a comprehensive and robust detector for ILC physics, aggressive in performance, but constrained in cost.

•Optimize the ***integrated*** physics performance of its subsystems.

•Identify and encourage development of needed detector R&D.

•Help engage an international community of physicists interested in the ILC.



SiD Rationale

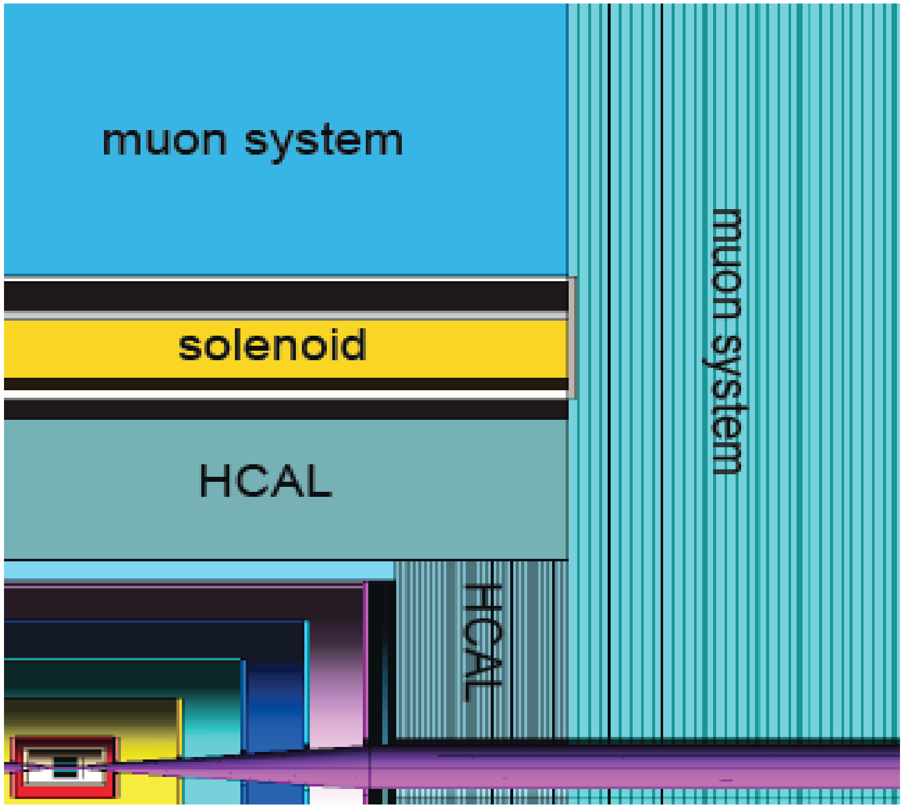
- Jet energy resolution goal is $30\%/\sqrt{E}$. Choose a dense, highly segmented, **SiW Ecal and Hcal.**
- **High magnetic field** limits radius and cost of calorimeters and solenoid and maintains BR^2.

  $B = 5$ Tesla
- **Si strip tracker** for excellent momentum resolution and robust performance $\Delta p_t/p_t^2 \leq 5 \times 10^{-5}$ GeV^{-1}
- **VX Tracker** at minimum possible radius with max Ω

  $\Delta\delta = 5 \oplus 10/p\sin^{3/2}\theta$ μm
- **Instrumented flux return** for muon identification

SiD Starting Point

- 5 layer pixel VXT
- 5 layer Si tracker with endcaps
- Si/W Ecal and Hcal inside the coil
- 5T Solenoid
- Instrumented flux return for muons detection

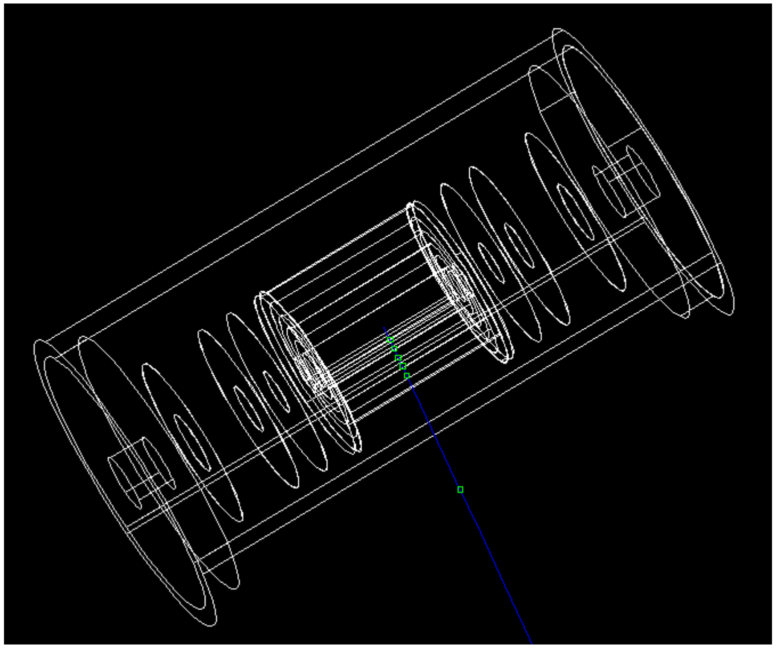


Compact: 12m x 12m x 12 m

SiD is moving beyond the starting point, with subsystem designs, full G4 subsystem descriptions, pattern recognition and PFA code development, and benchmarking studies.

Geant4 Sim Package Input Example: XML definition for SiD VXD

- 5 Layer CCD Barrel
- 4 Layer CCD Disks
- Be supports
- Foam Cryostat



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         <slice material = "Silicon" width = "0.01*cm" sensitive = "yes" />
      </layer>
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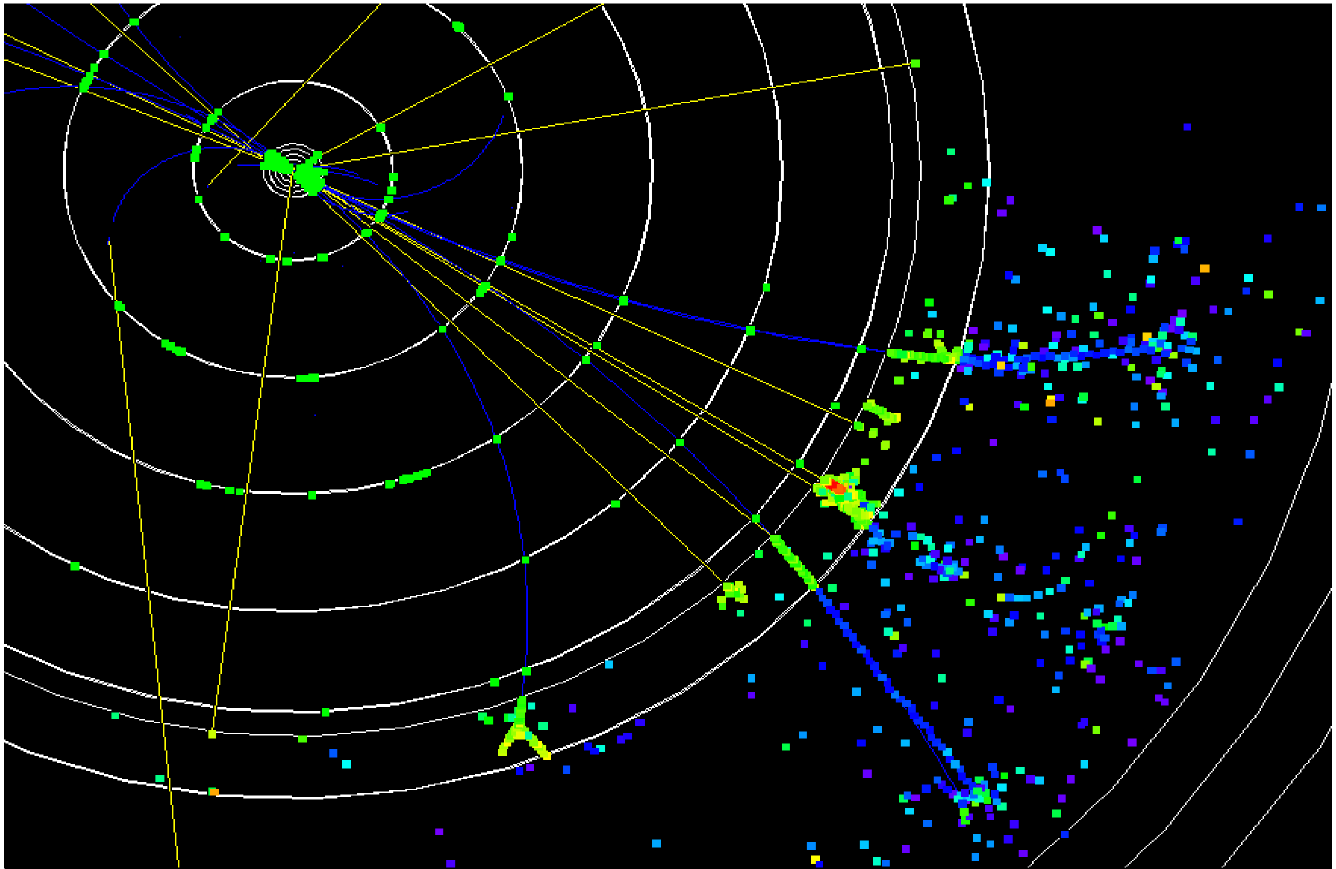
      </layer>
```

Calorimetry drives the SiD Design, and Particle Flow drives the Calorimetry

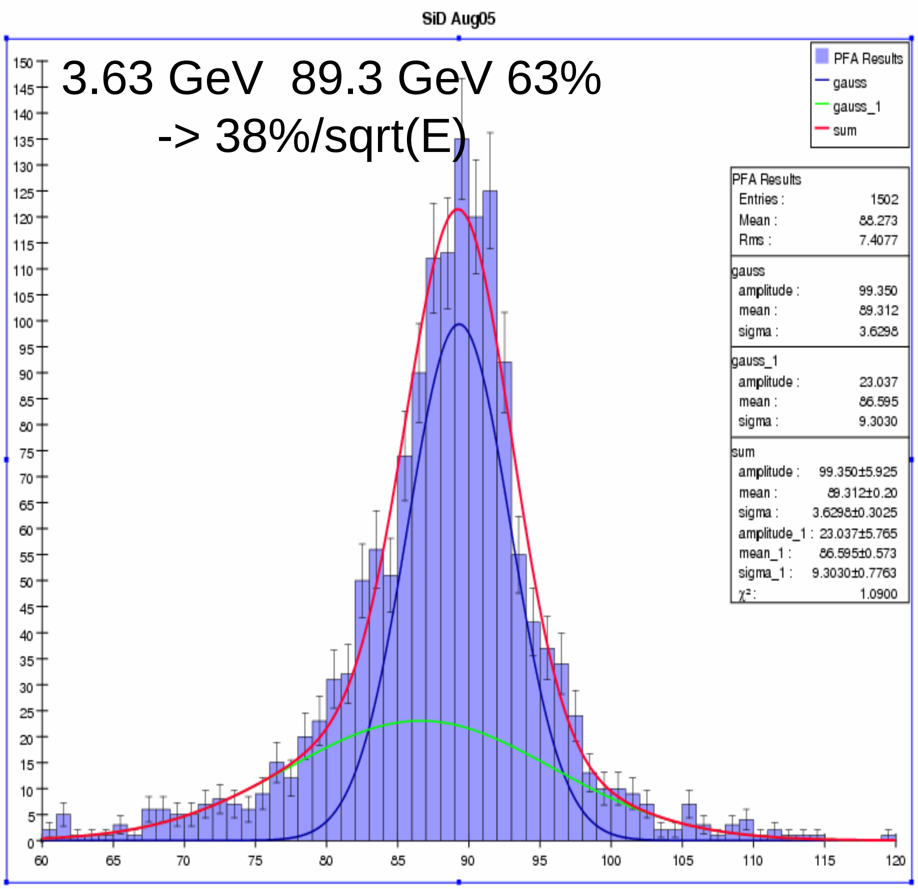


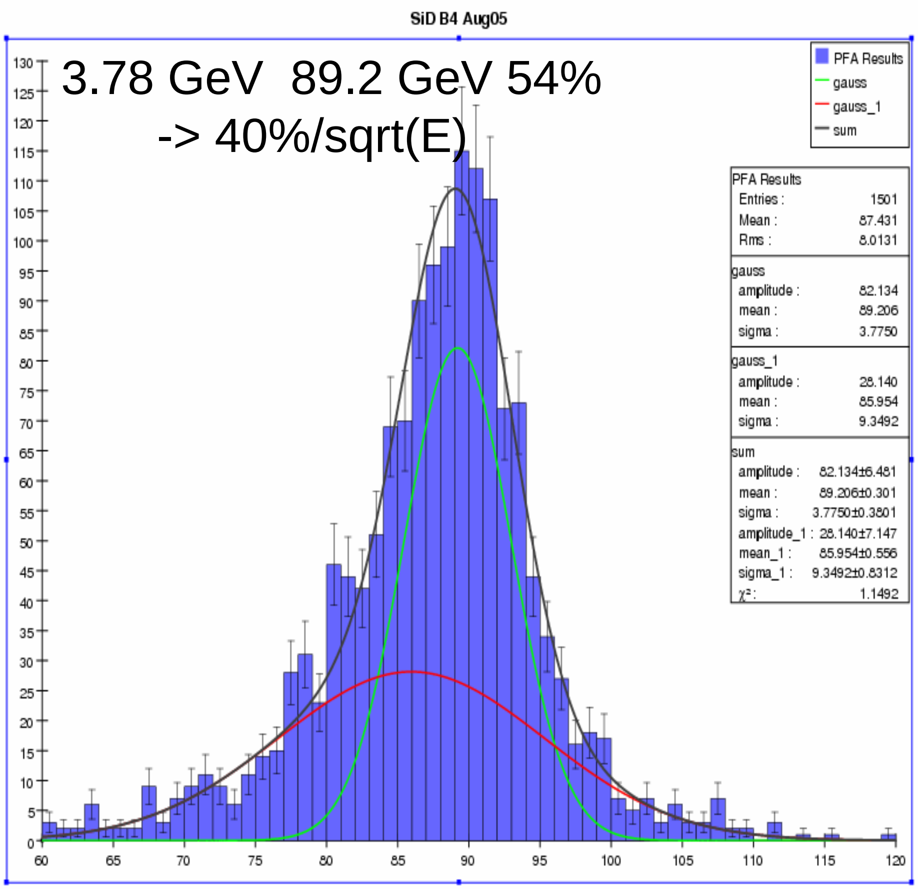
Measure the energy of every particle, not the energy deposited in calorimeter modules.

High transverse and longitudinal segmentation is needed to distinguish individual particles.

Starting Detector Comparisons with PFAs

Vary B-field



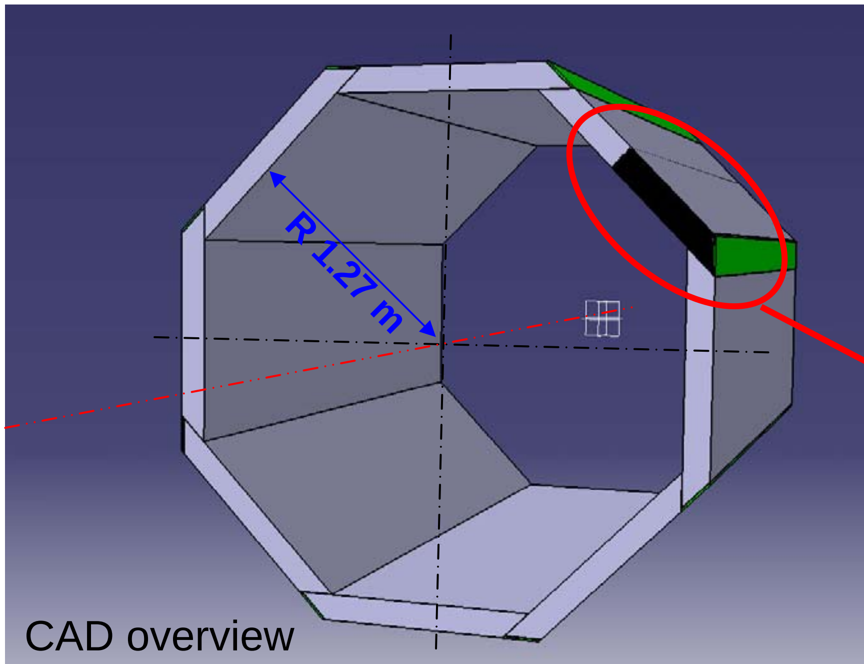


SiD SS/RPC - 5 T field

SiD SS/RPC - 4 T field

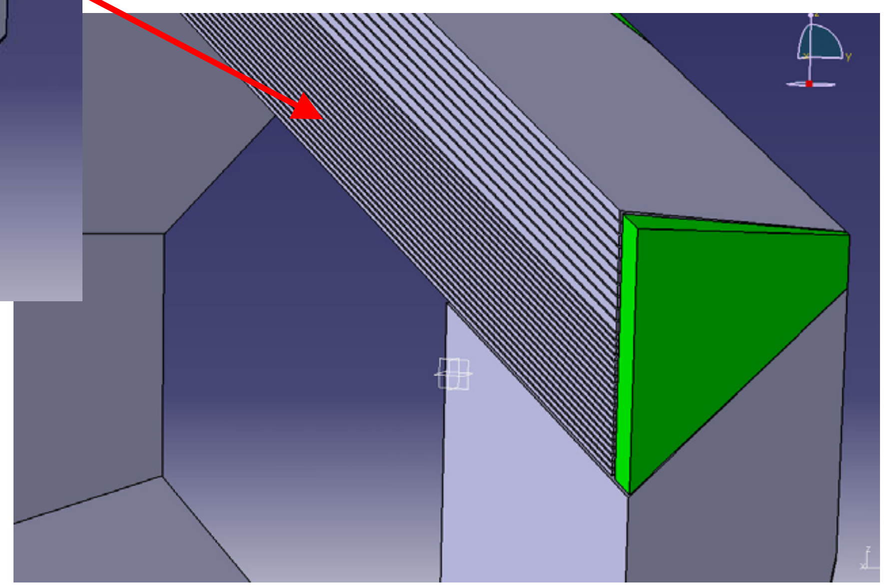
-> Somewhat worse performance in smaller field

ECAL overview



- 20 layers x 2.5 mm thick W

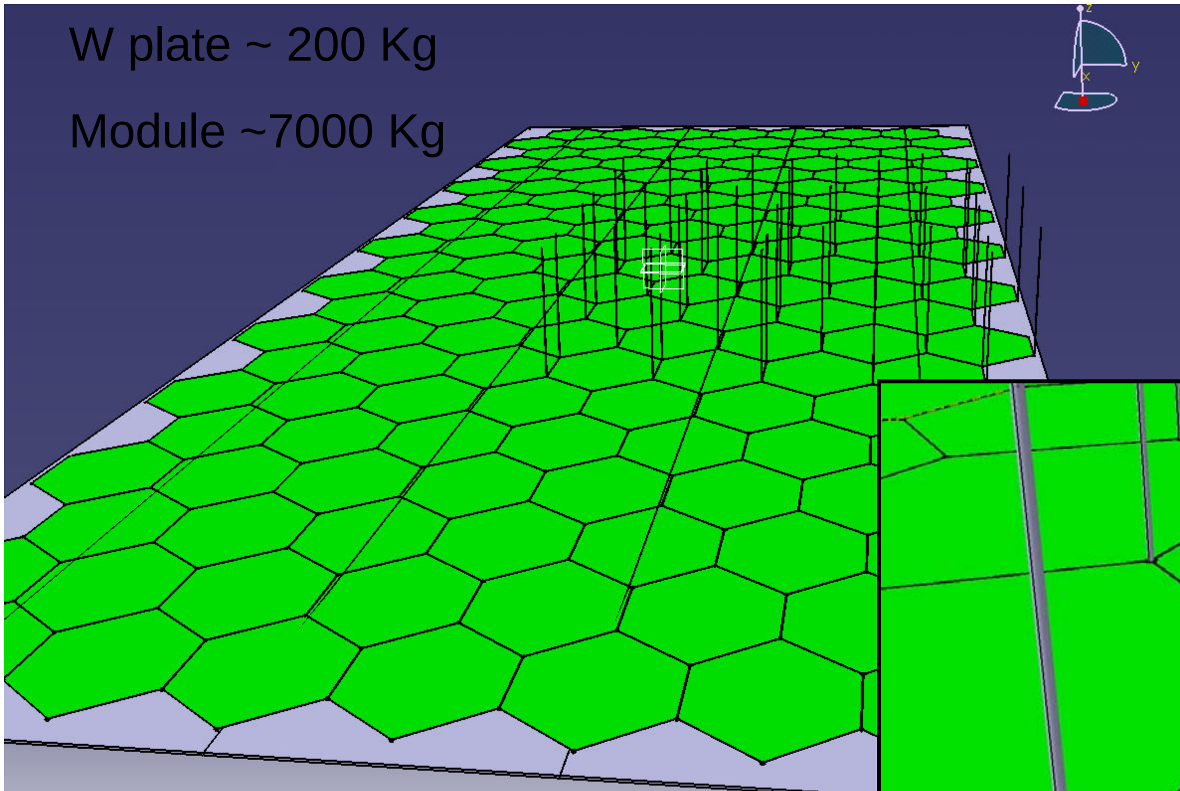
  10 layers x 5 mm thick W
- ~ 1mm Si detector gaps
- Preserve Tungsten $R_{M\ eff}$= 12mm
- Highly segmented Si pads 12 mm^2



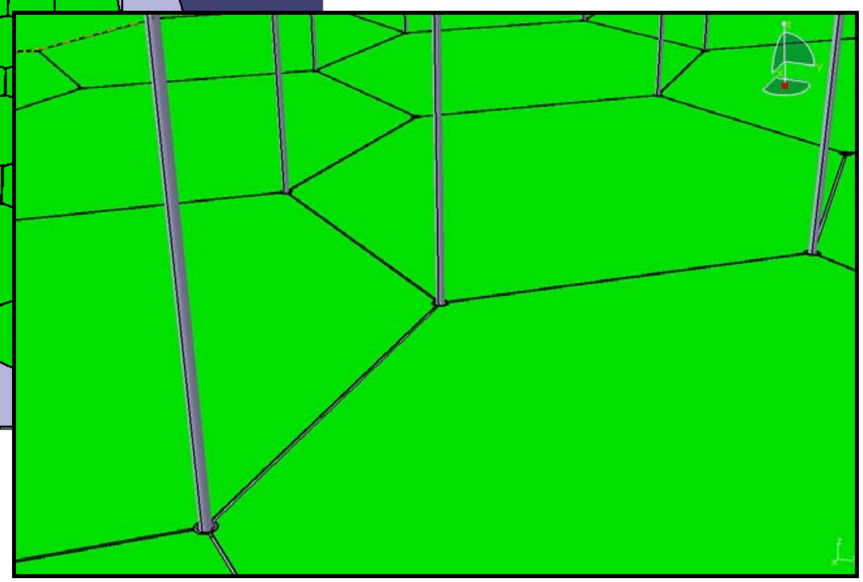
material	R_M
Iron	18.4 mm
Lead	16.5 mm
Tungsten	9.5 mm
Uranium	10.2 mm

Conceptual design

- Very aggressive mechanical and electronics integration is needed to preserve the Moliere radius

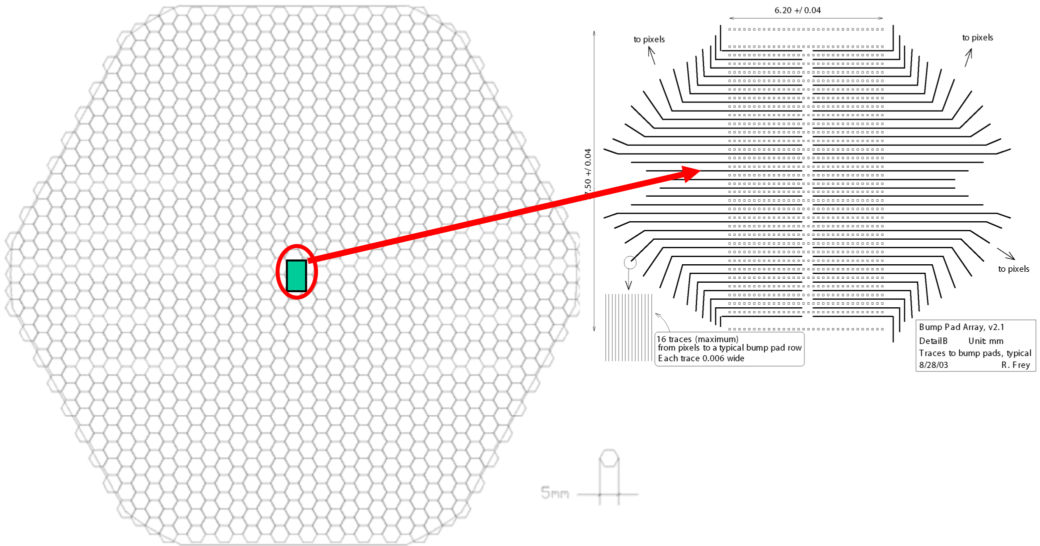


- W plates joined by ‘rods’
- Wafers ‘on’ W
- ReadOut chips on wafers

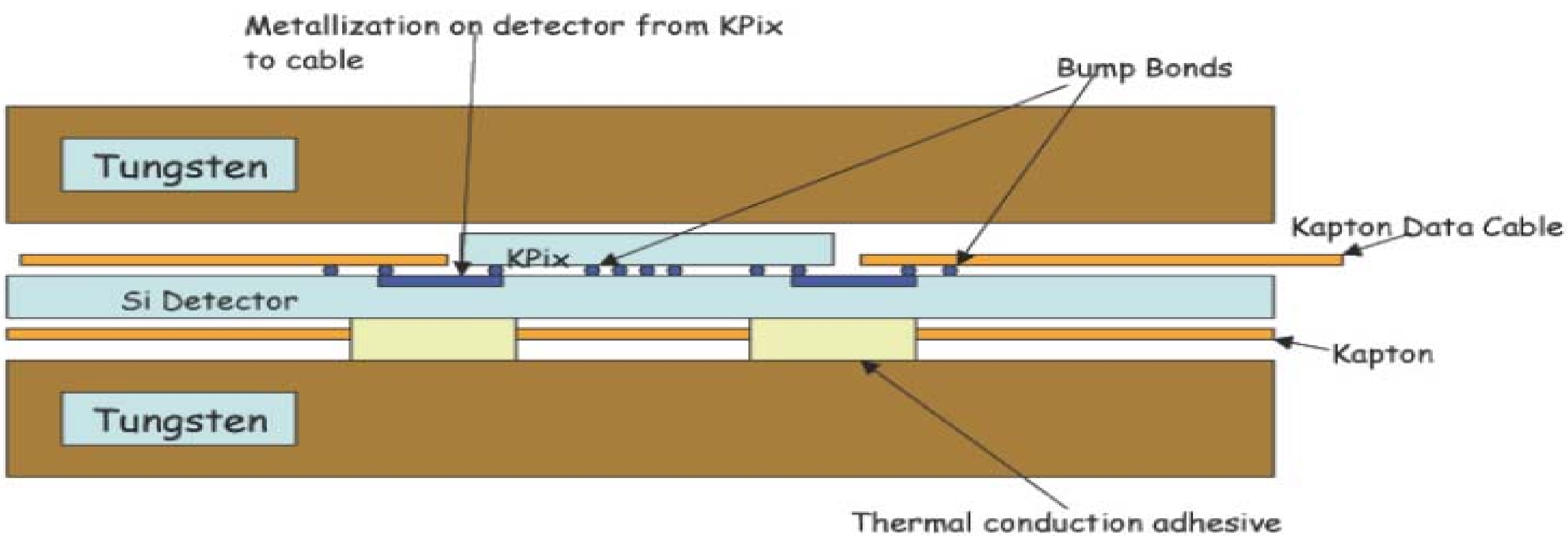


FEA analysis is in progress

Wafers and R/O

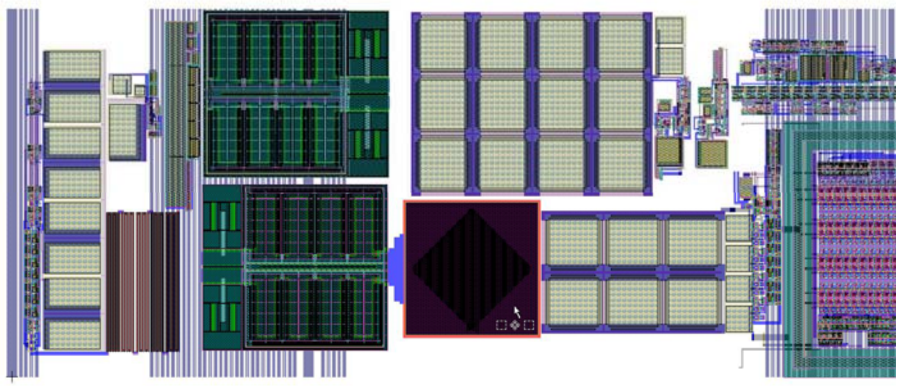


- Single MIP tagging (S/N ~7)
- Dynamic range 0.1 – 2500 MIPs
- Bump bonded to the detector
- Low power <40 mW per wafer, passive cooling
- 4 deep buffer for bunch train

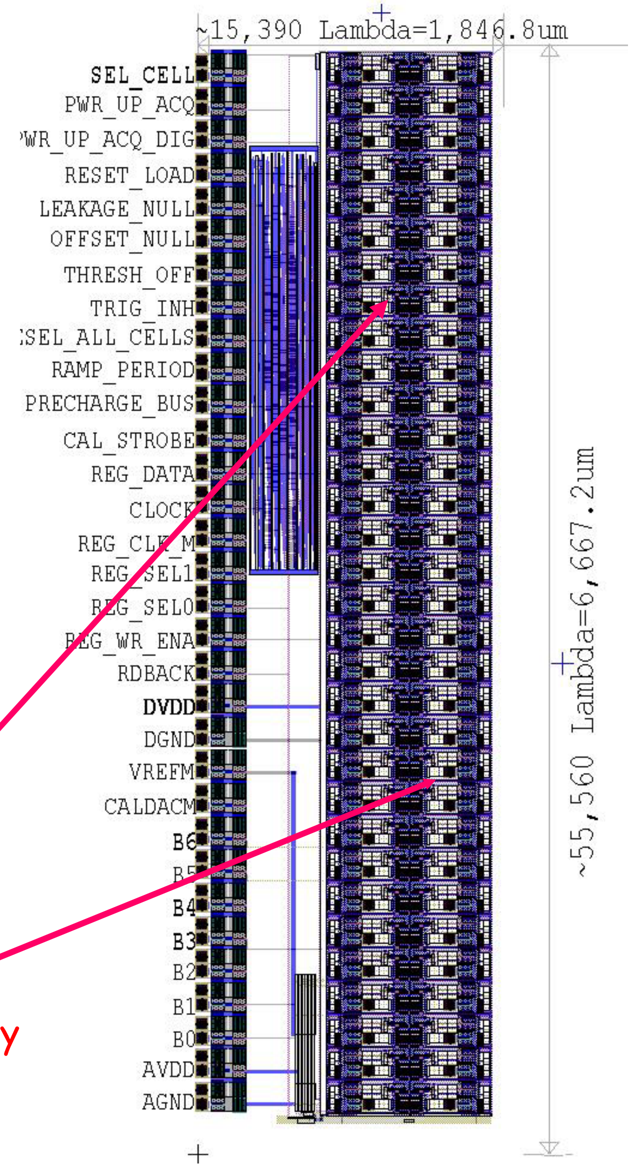


KPiX SiD Readout Chip

Prototype now being tested at SLAC.



One cell. Dual range, time measuring, 13 bit, quad buffered



2 x 16 Si Strip

2x16 Calorimetry

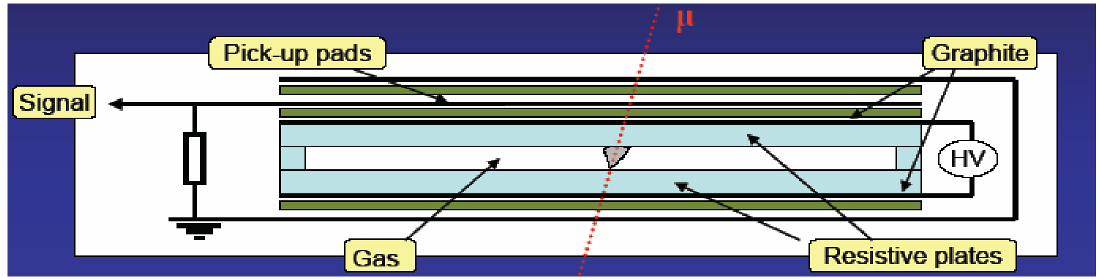
Prototype: 2x32 cells: full: 32x32

Particle Flow Hcal

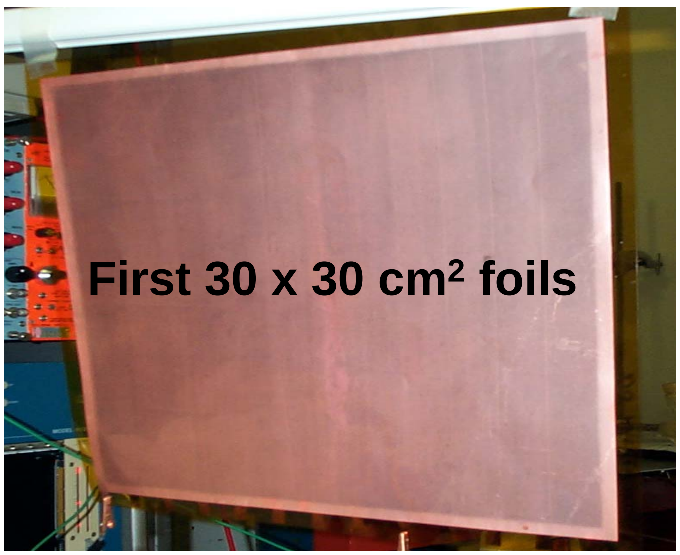
P-Flow demands ~1 x 1 cm^2 segmentation, ~40 layers, 4λ deep

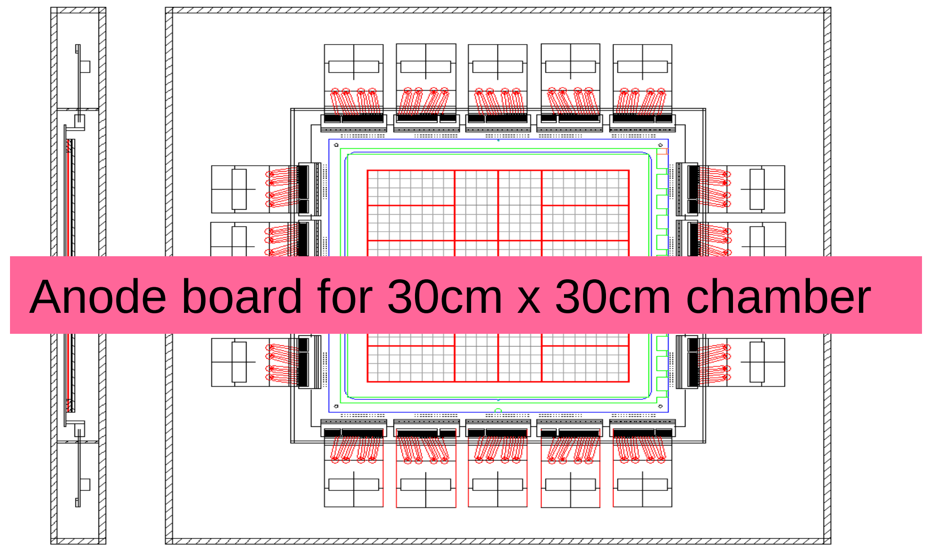
RPCs

- **Glass**
- **SF6/Freon/Isobutane**
- **1 cm thick**



GEMs





SCINT TILEs

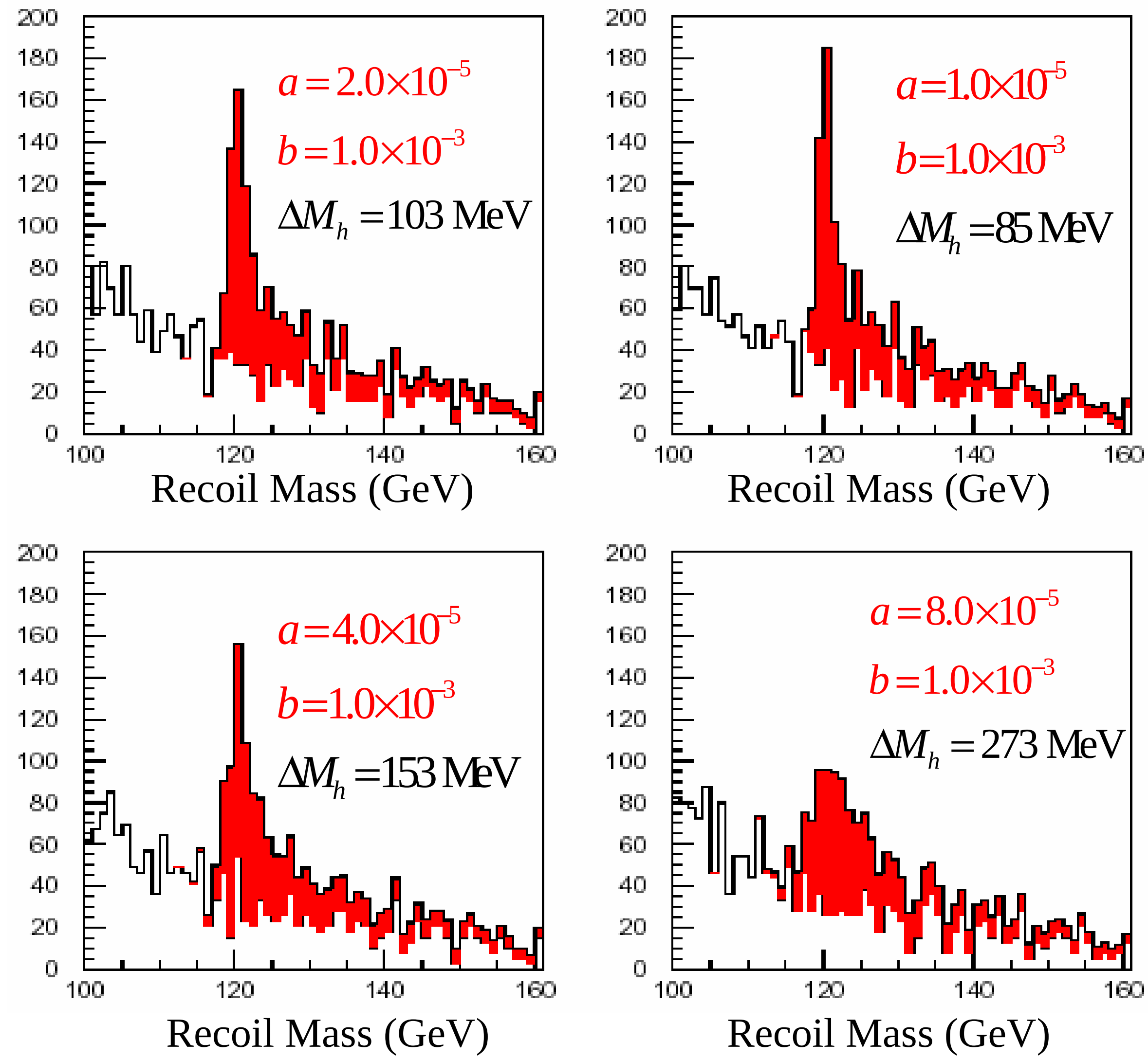
Higgs Studies Push Tracker Momentum Resolution

(T. Barklow Study)

$$e^+e^- \rightarrow ZH$$
$$\rightarrow \mu^+\mu^- X$$

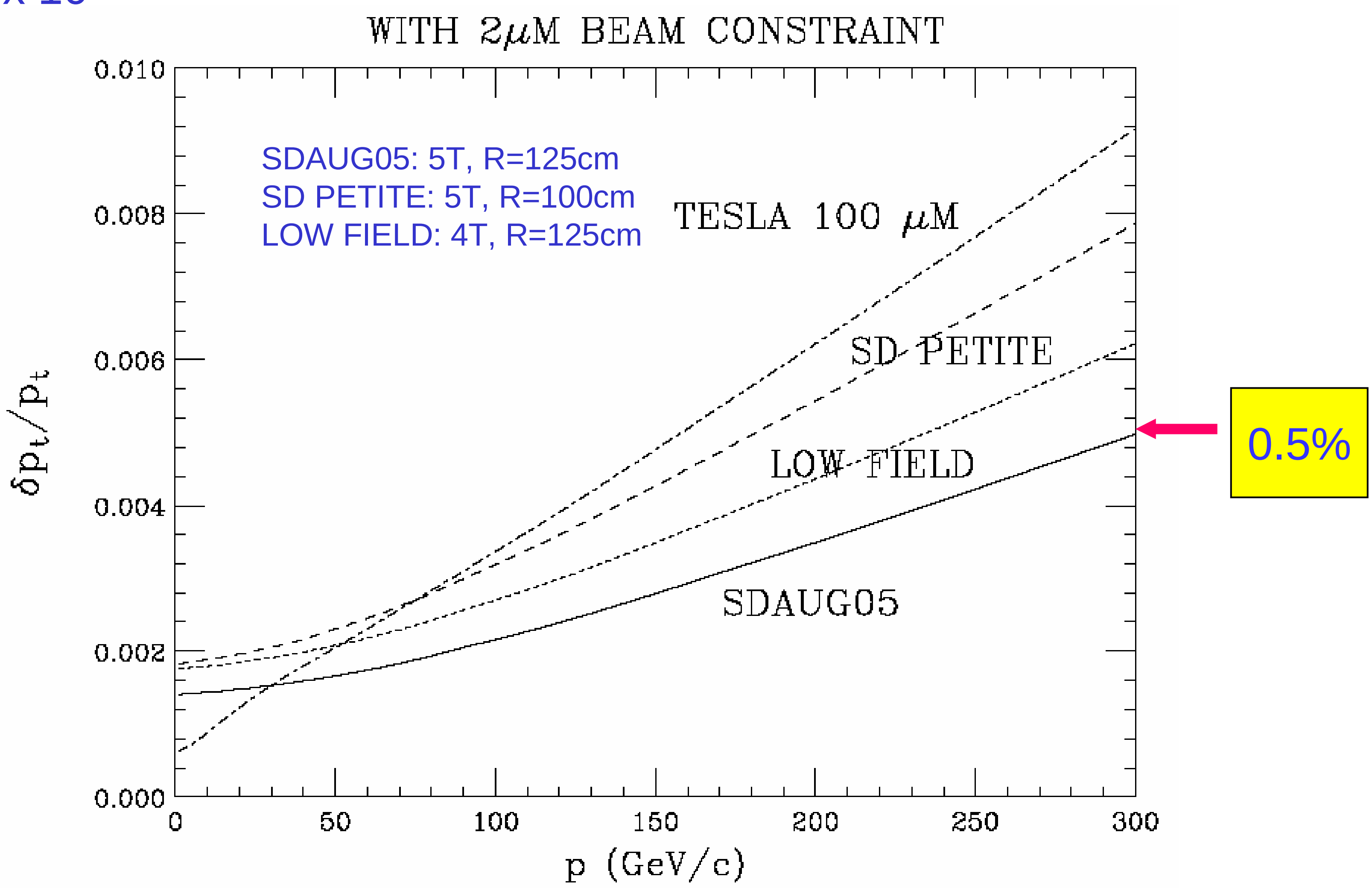
$$\sqrt{s} = 350\ GeV$$
$$L = 500\ fb^{-1}$$

$$\frac{\delta p_t}{p_t^2} = a \oplus \frac{b}{p_t \sin\theta}$$



Si Tracker Momentum Resolution

$\Delta p/p^2 \sim 2 \times 10^{-5}$



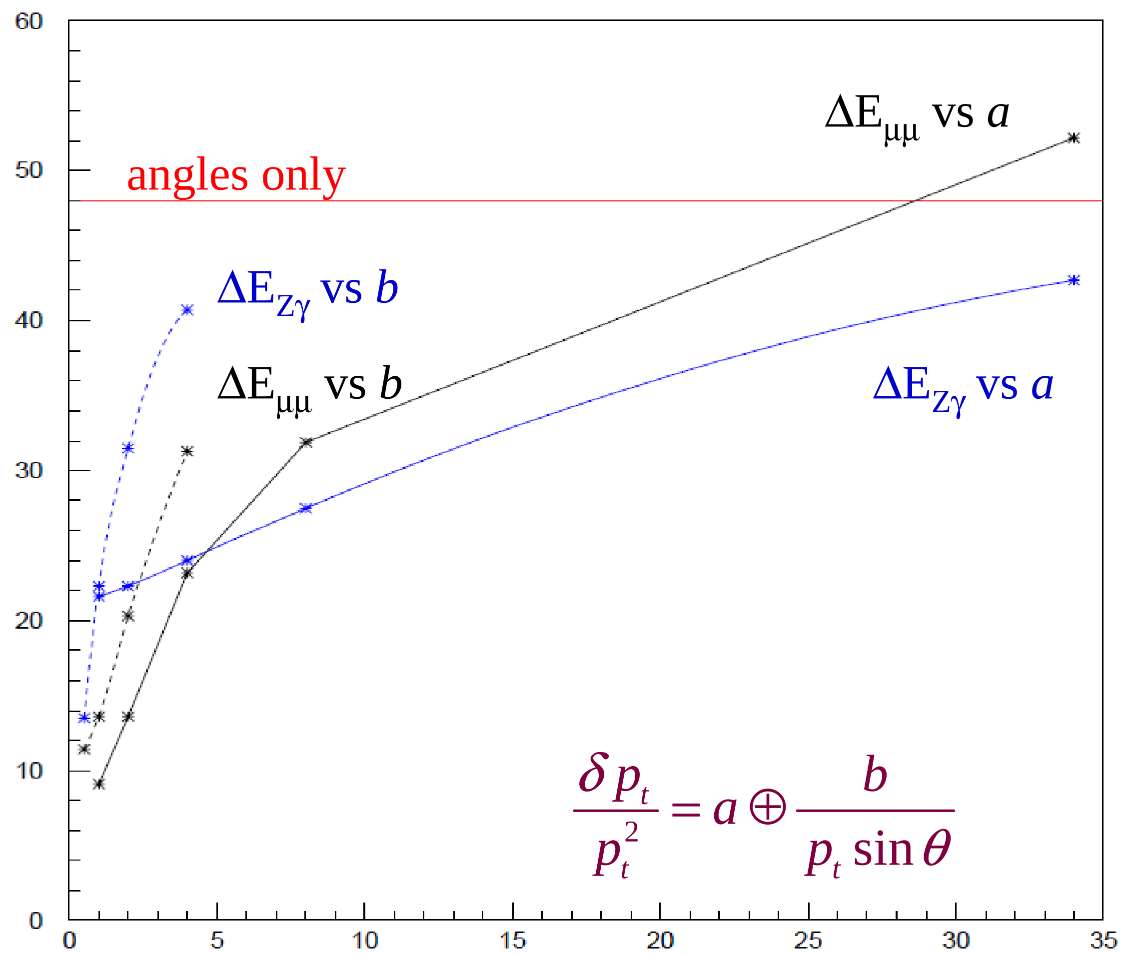
< E_{cm} > Precision Depends on Resolution

(T. Barklow)

Ecm Resolution vs *a* or b

$$e^+e^- \rightarrow \mu^+\mu^-$$

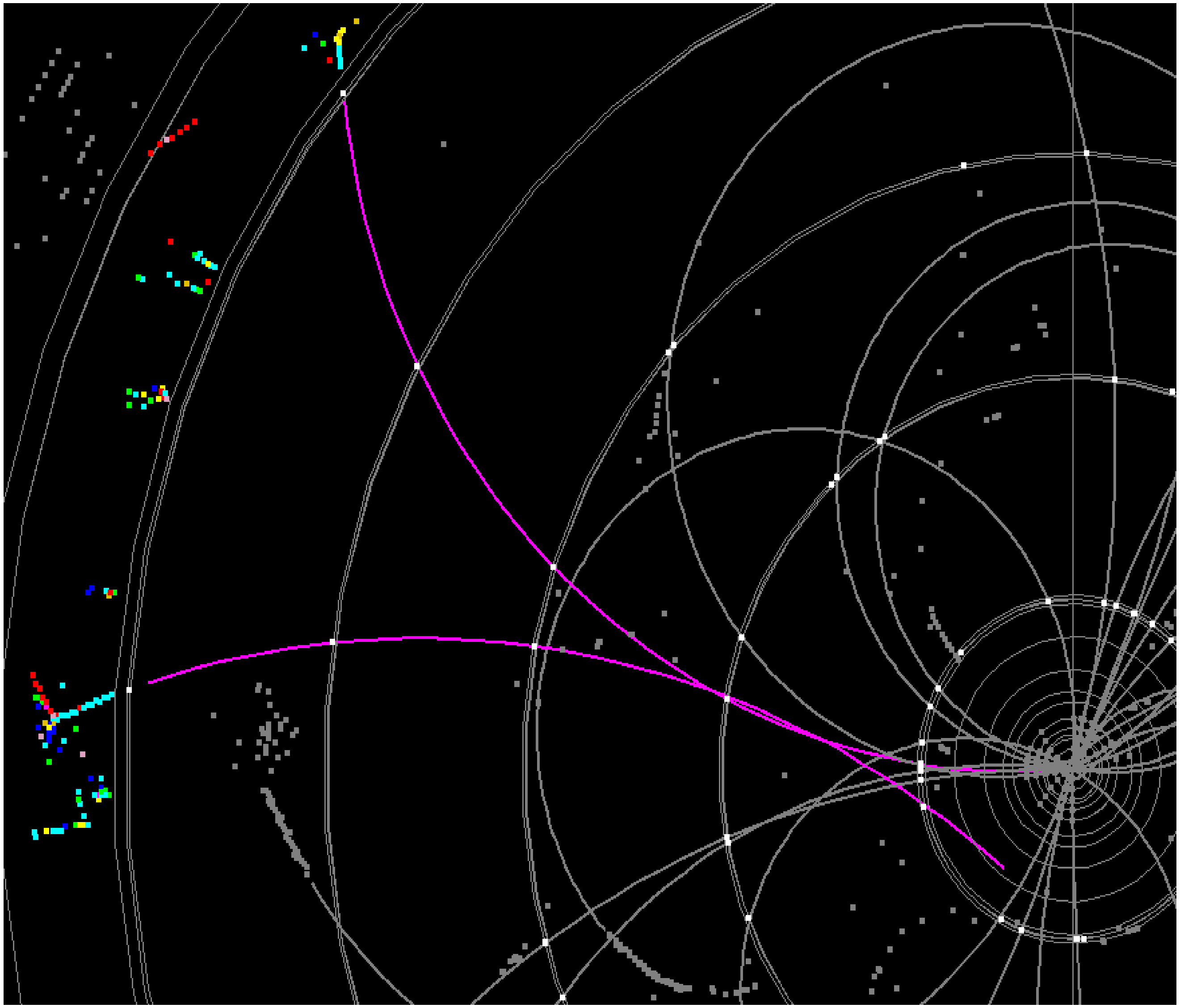
ΔE_{cm} (MeV)



$a \times 10^{-5}$ or $b \times 10^{-3}$

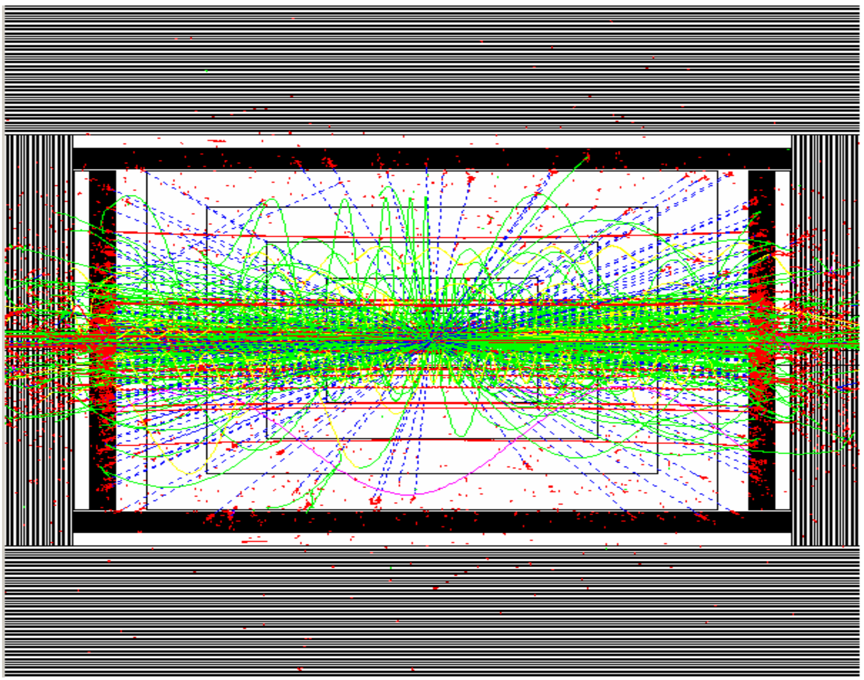
SiD Integrated Tracking

- Silicon Tracker is fast (1 BX only)
- Silicon is robust (No HV trips)
- Tracking System
  - VXD
  - Si Main Tracker
  - Ecal



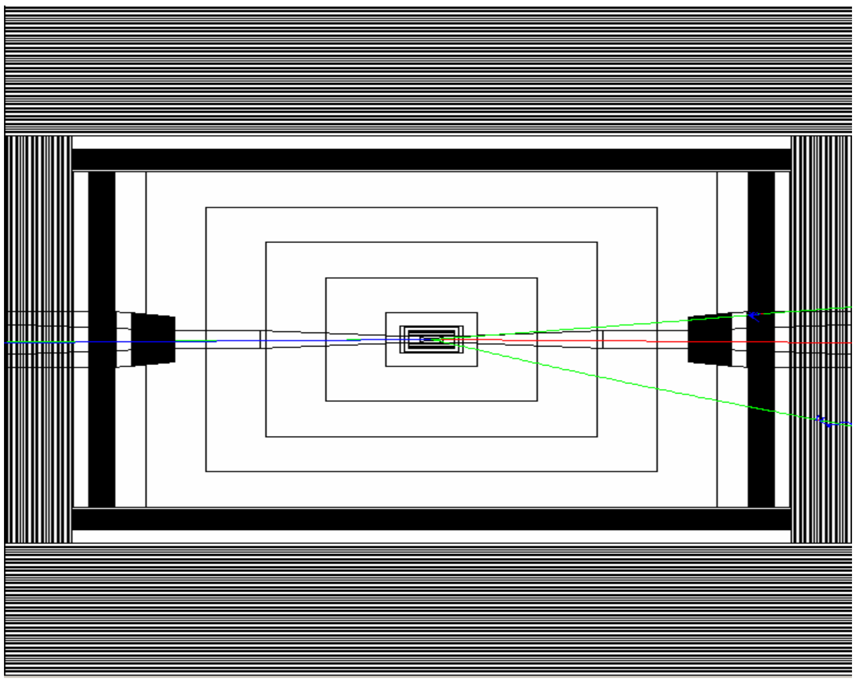
Si Sensors See Just 1 BX

TPC Livetime 40 μs ~ 130 BX



18k e pairs/130 BX
50 μ pairs/130 BX
86 hadronic events/130 BX

Si Tracker Livetime 100ns ~ 1 BX



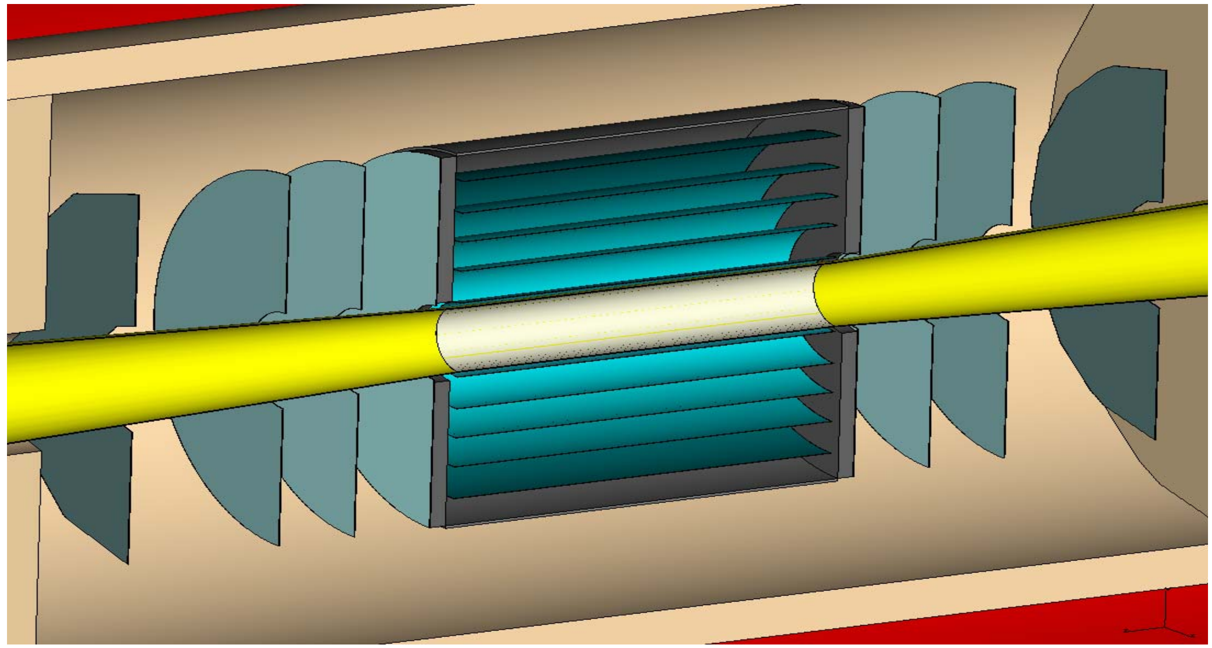
140 e pairs/ BX
0.4 μ pairs/BX
0.7 hadronic events/BX

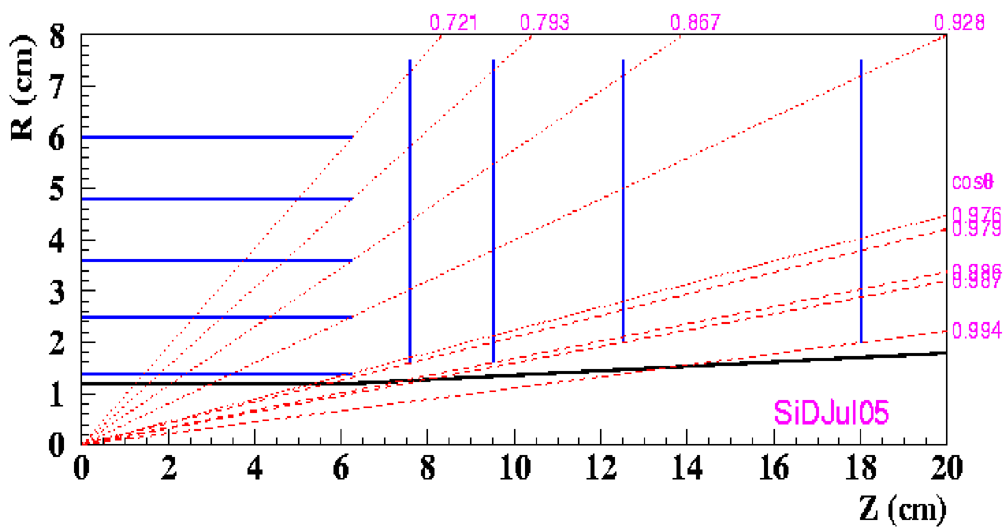
Pixel Vertex Tracker VXT

5 layer |cosΘ| < 0.976

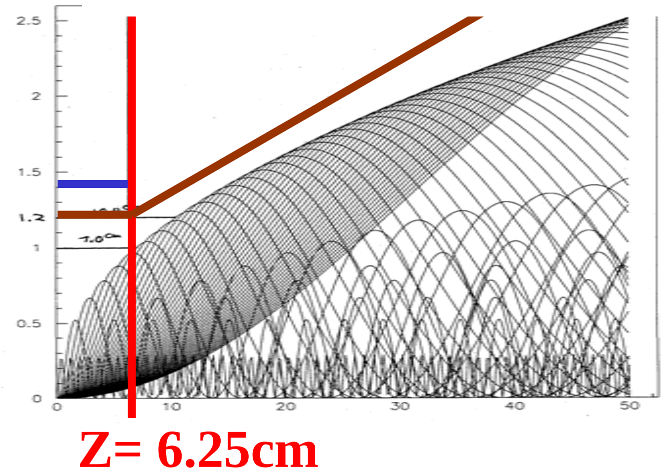
Layer 1 @ 1.4 cm

Δθ/θ ~ 5 x 10^{-5} forward

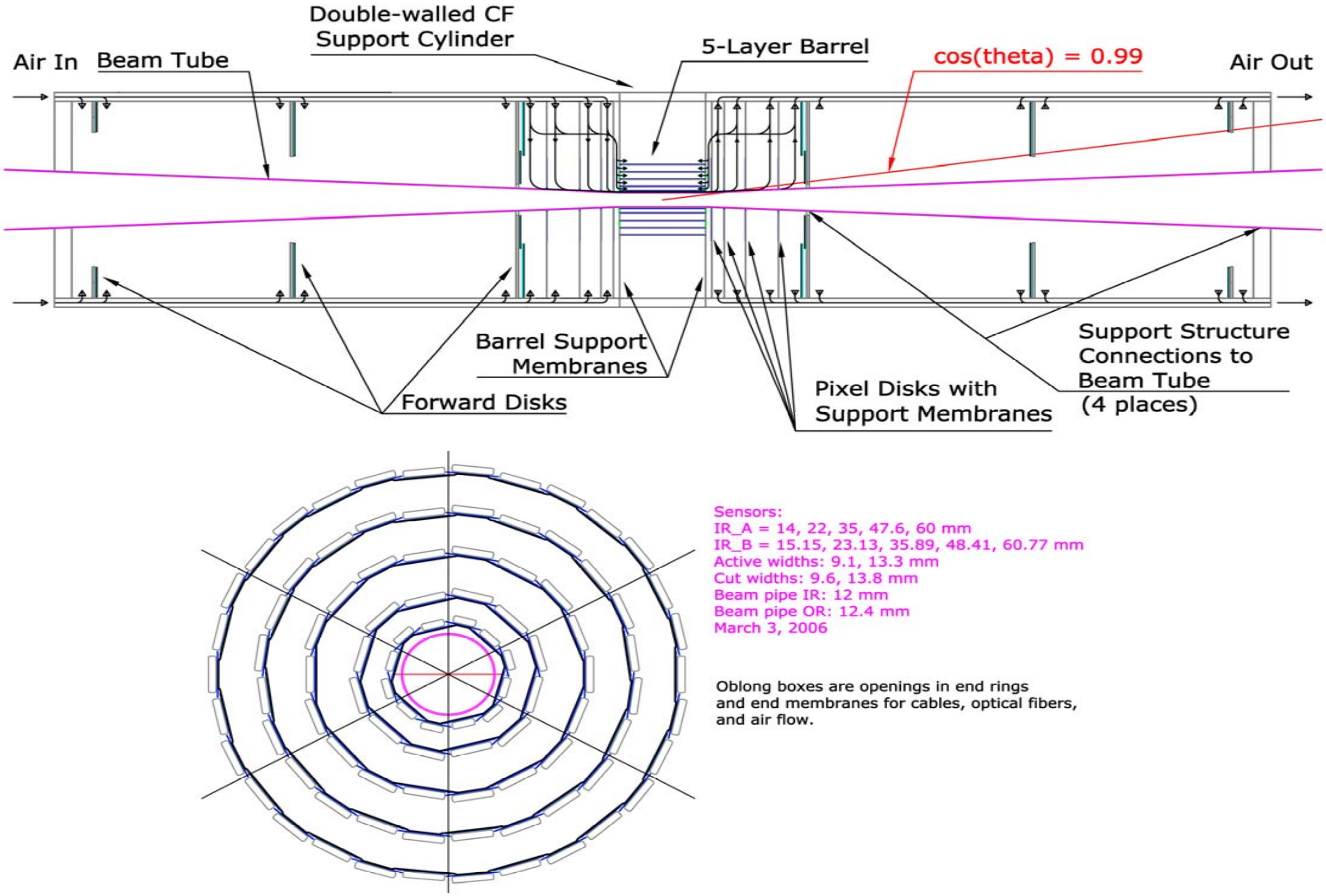




R vs Z for Pairs in 5T

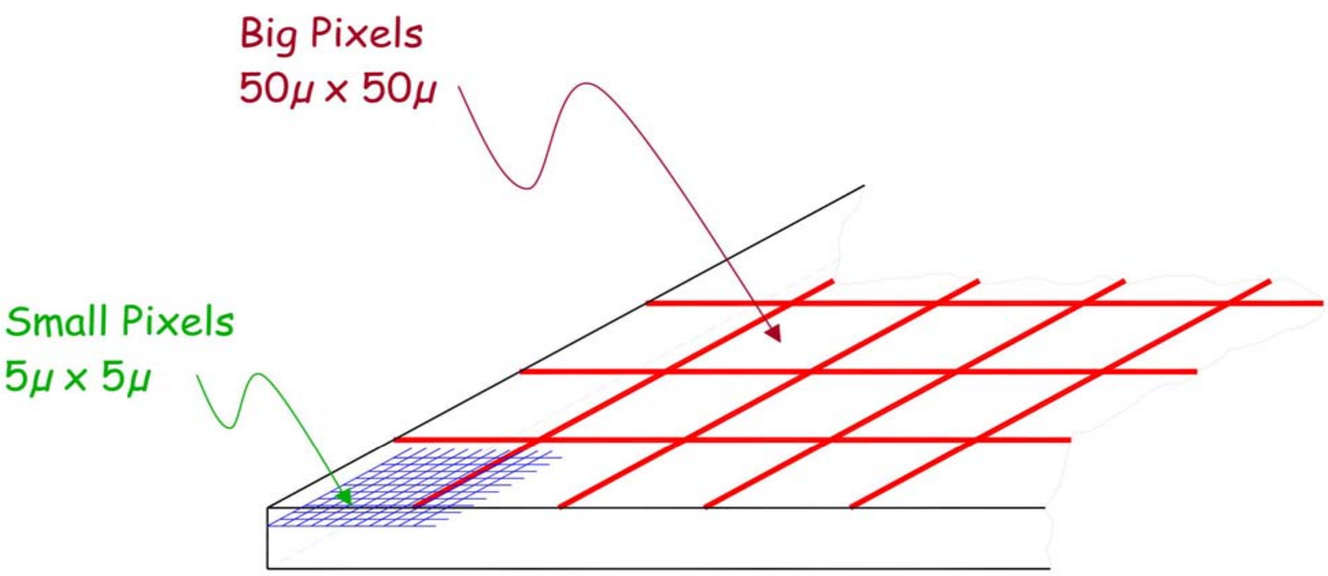


VXT Mechanics



Possible VXT Technology

Monolithic CMOS Pixel Detectors



Two active particle sensitive layers:

Big Pixels – High Speed Array – Hit trigger, time of hit
Small Pixels – High Resolution Array – Precise x,y position, intensity

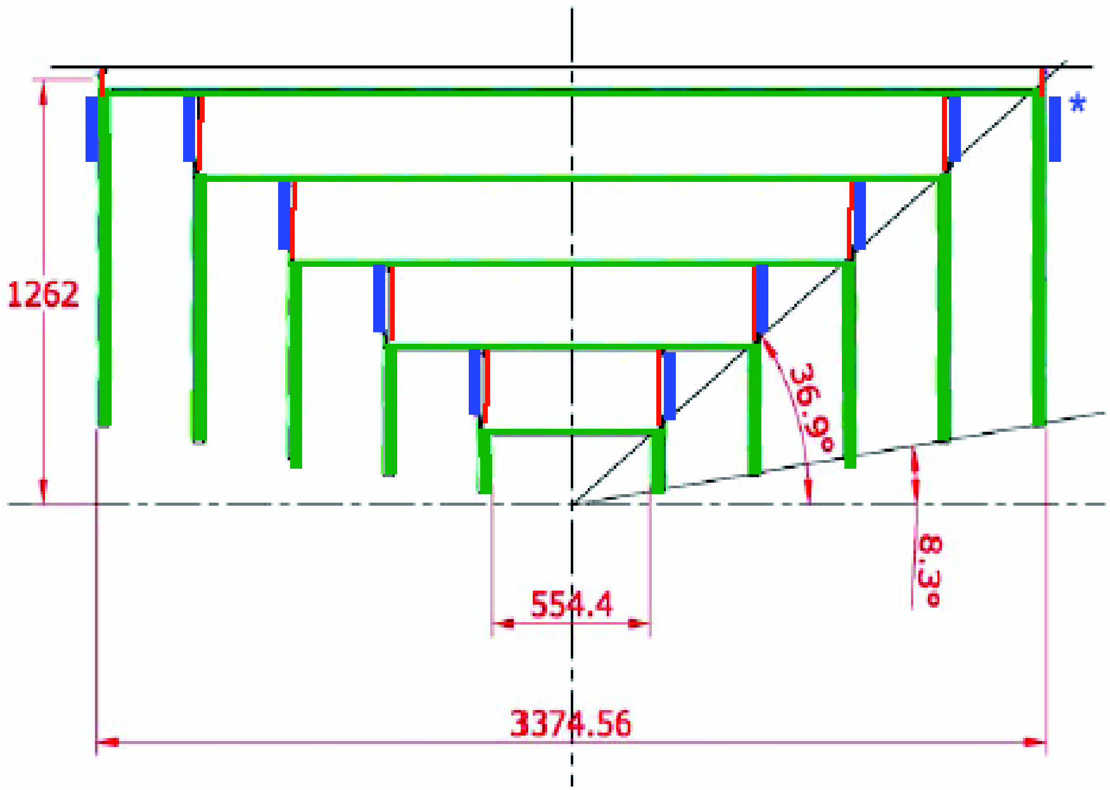
Silicon Main Tracker SMT

5 Axial Si microstrip layers
CF/Rohrcell foam cylinders
0.8% X_0 per layer total

5 Endcap disks
r/ϕ Si microstrips
1.3% X0 per layer total

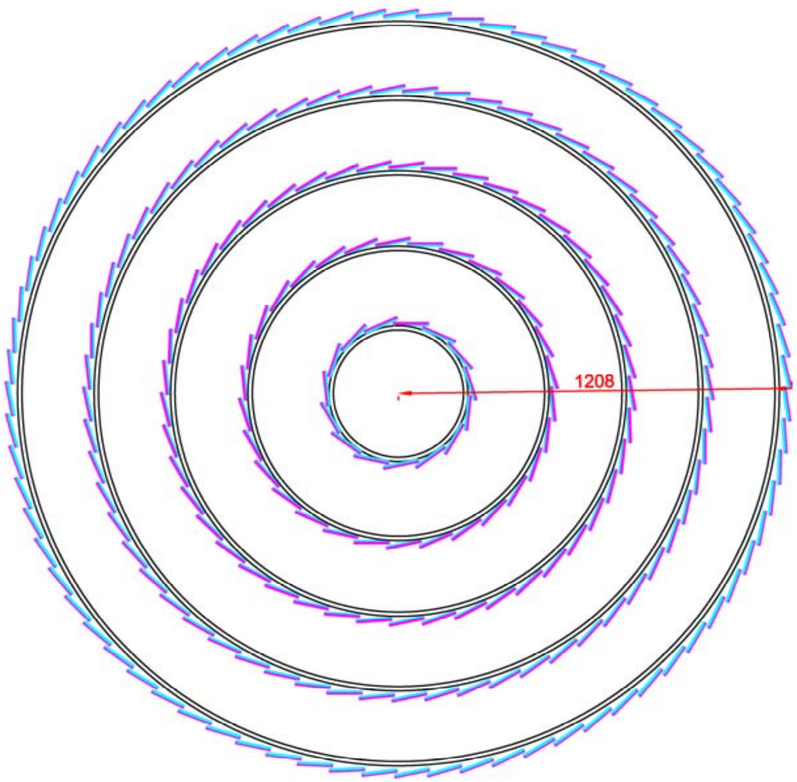
Power and Readout at ends

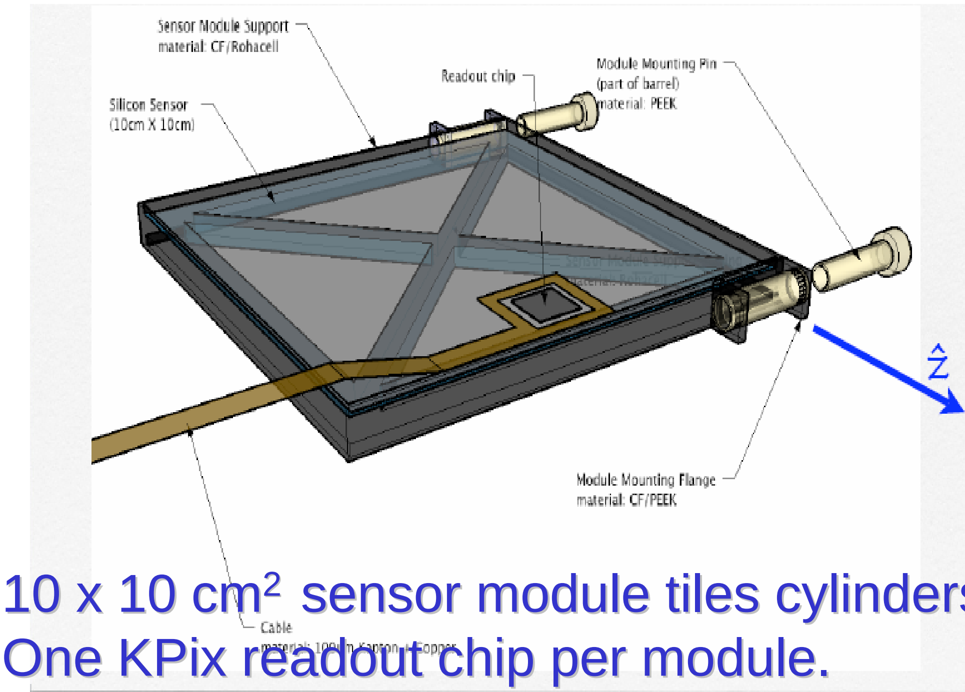
- Closed CF/Rohacell composite cylinders
- Nested support via annular CF rings
- Power/readout distribution mounted on support rings*



Si Tracker

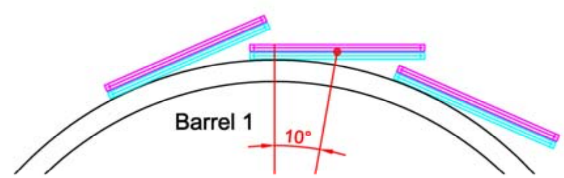
Layout of Tracker Barrels



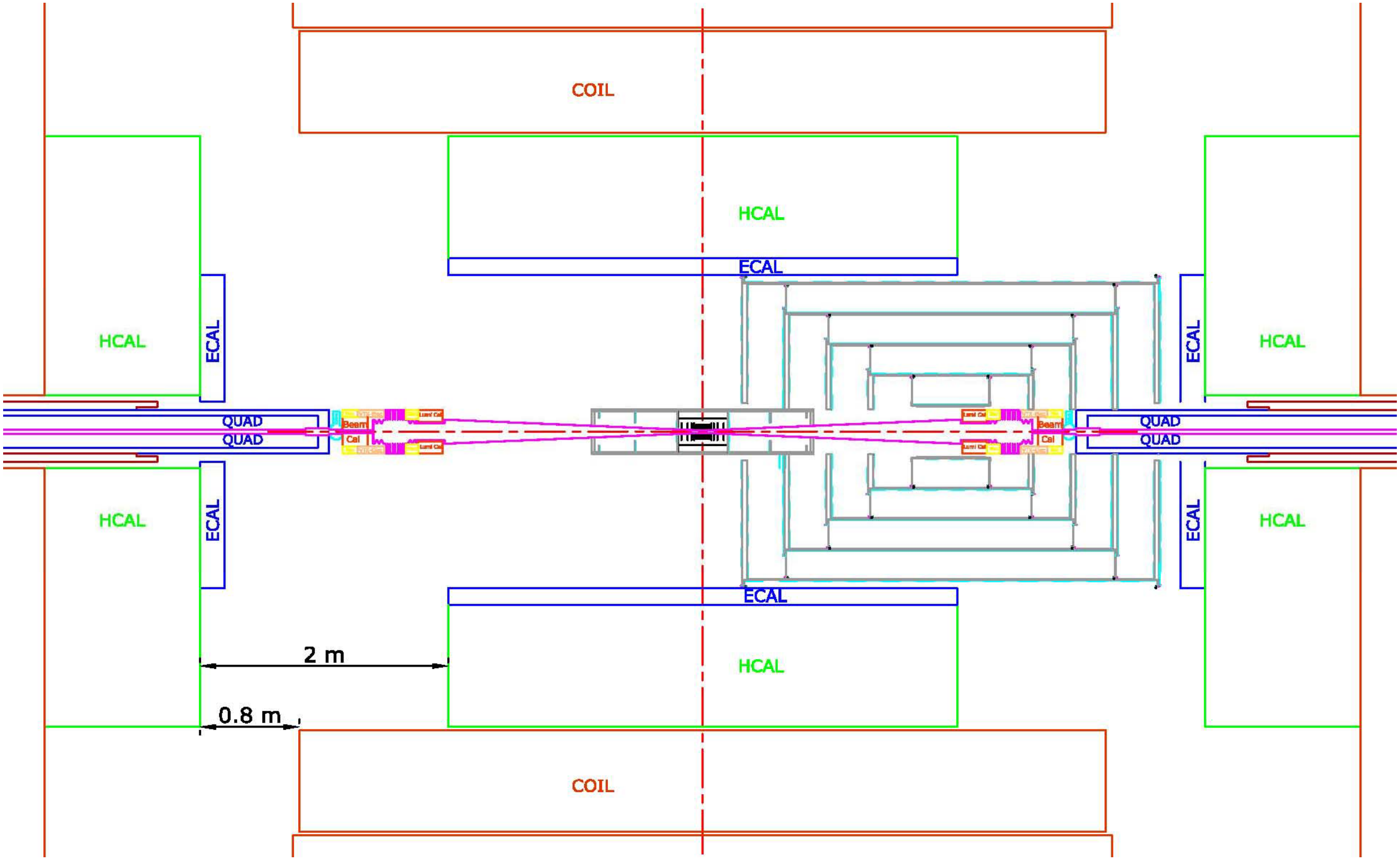


$10 \times 10\ cm^2$ sensor module tiles cylinders

One KPix readout chip per module.



Access to VXT and FWT

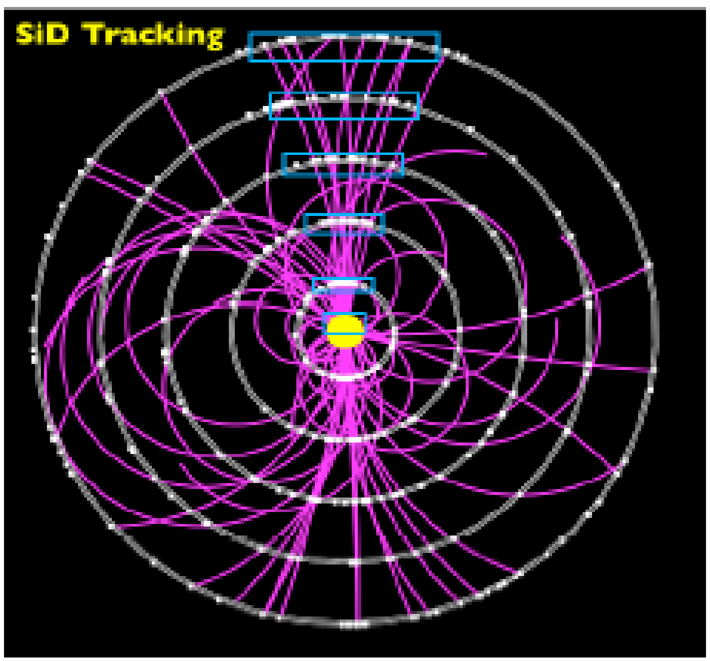


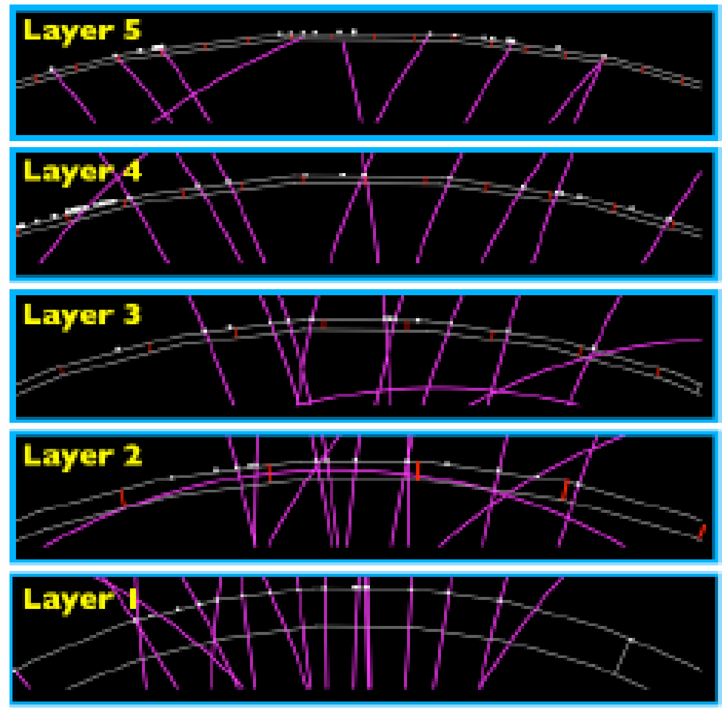
In to Out Pattern Recognition

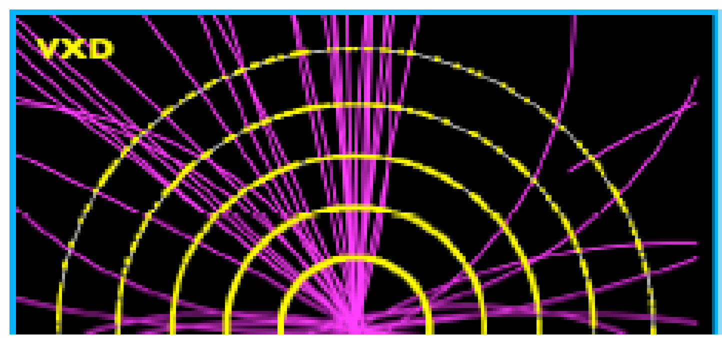
- Begin with

  all combinations of 3D VXD hits.
- Attach hits in tracker in 2D

  space to find tracks.



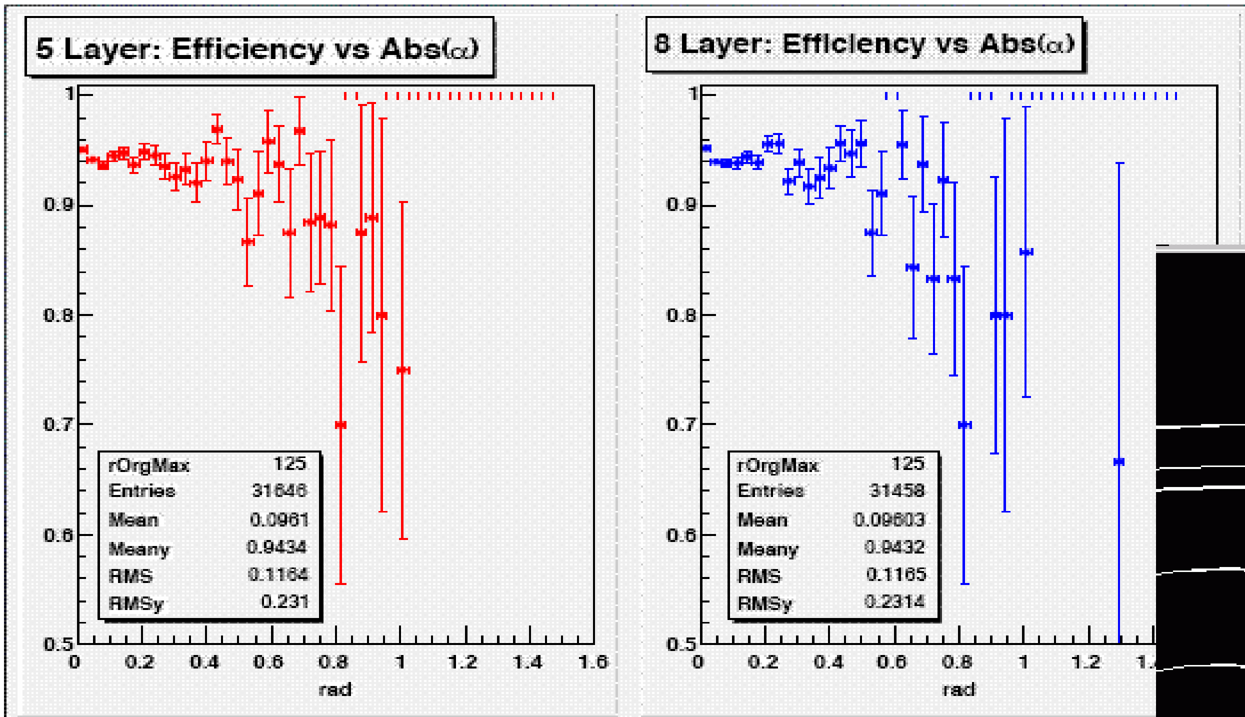




Tracking Efficiency

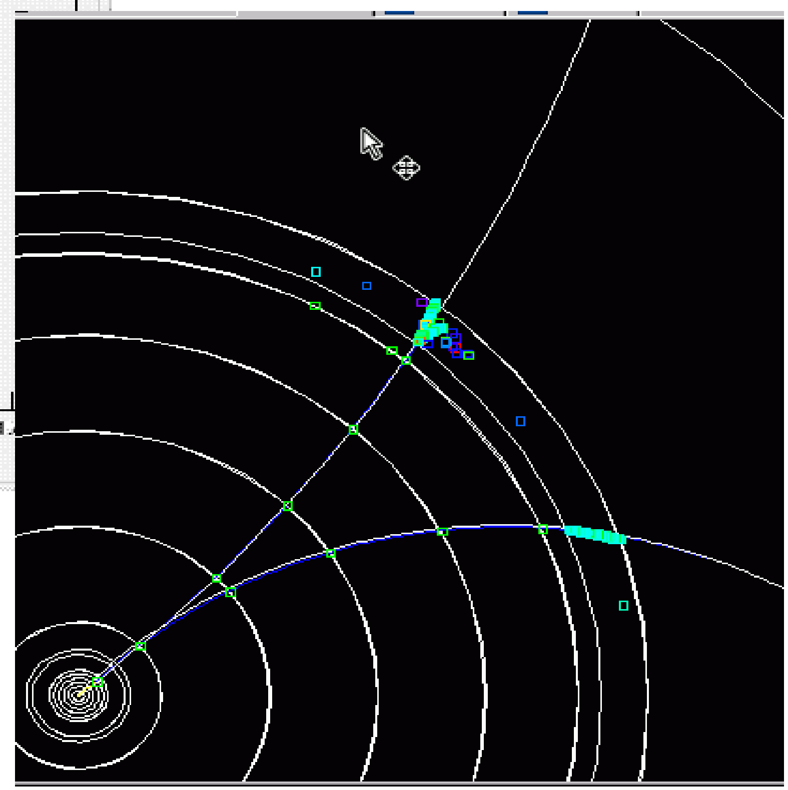
Vertex-Seeded Tracking Efficiency ~ 95%

The rest is K^0's and Λ's and long lived charm and b's.
Catch them with stand-alone and out-in tracking.



α = 1/pt

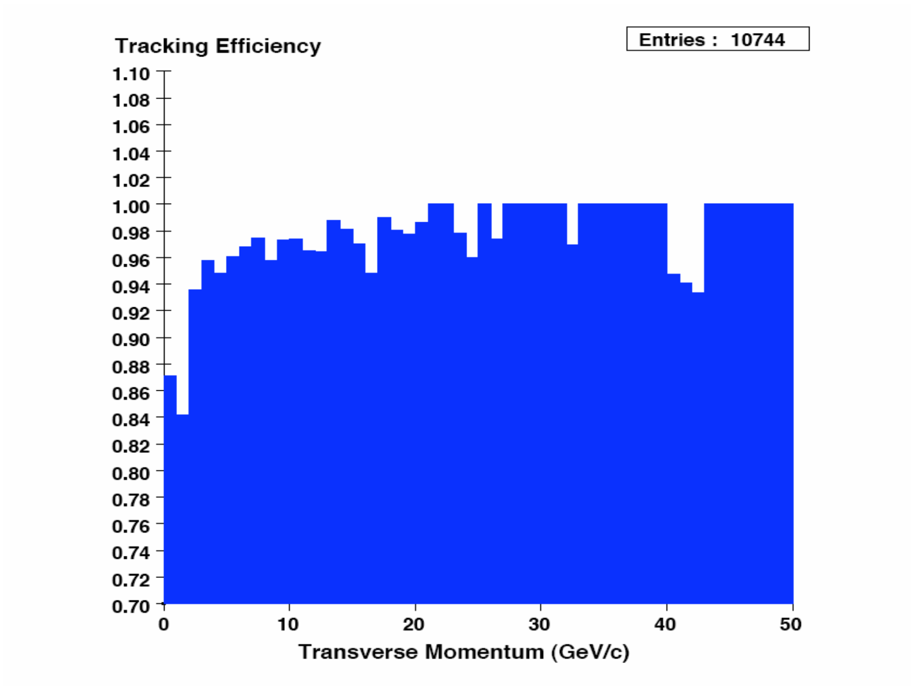
Ecal out-in tracking



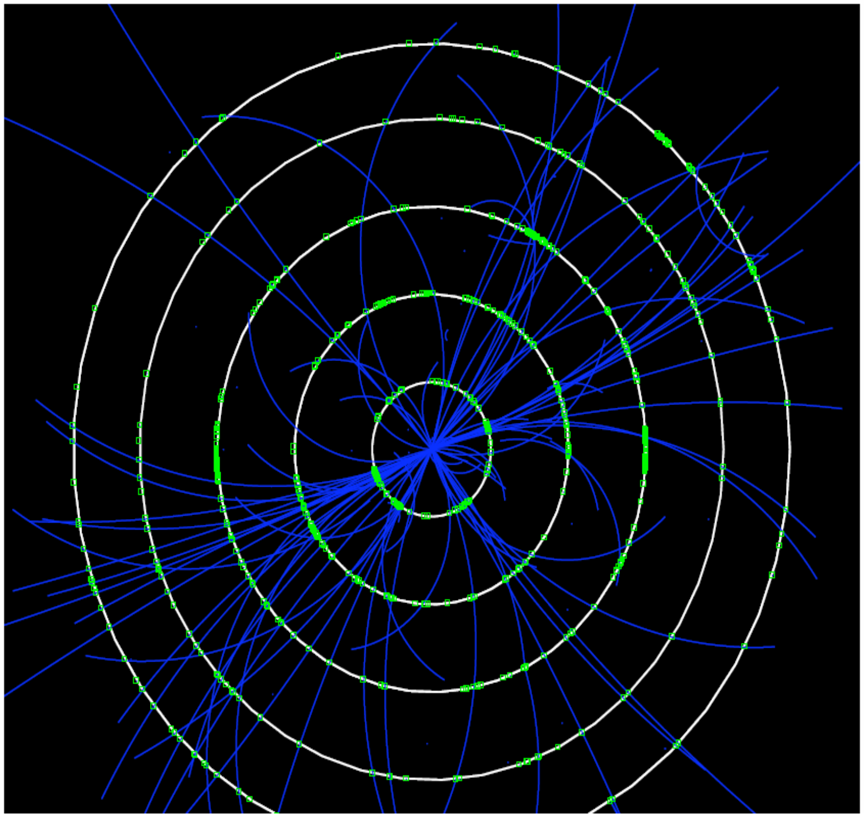
SMT-Only Track Finding is Efficient

T. Nelson

Zh Events



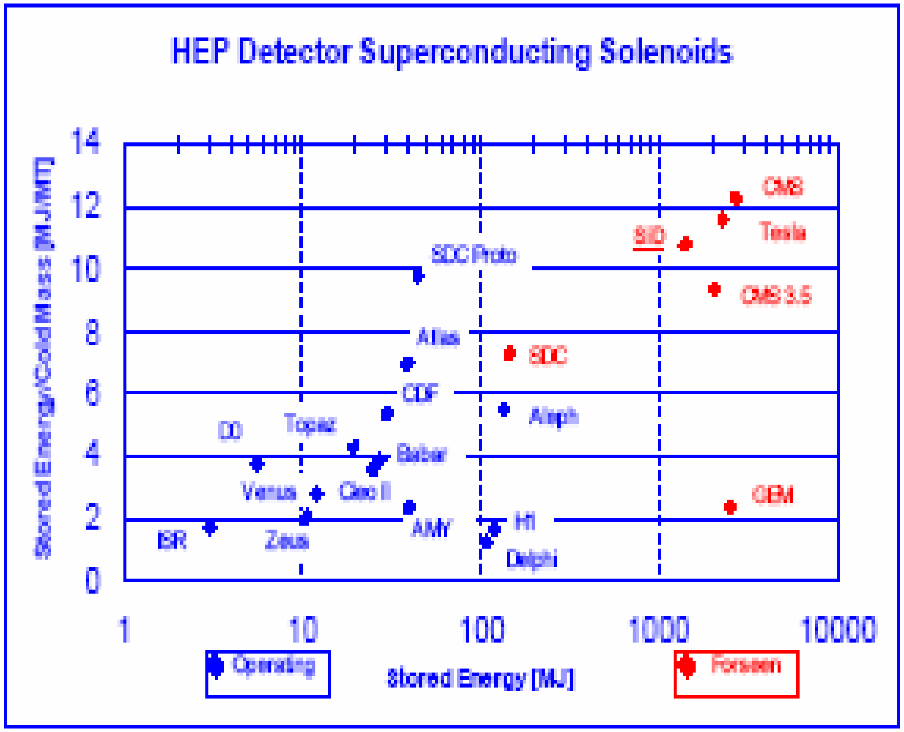
t tbar Events



5T Solenoid

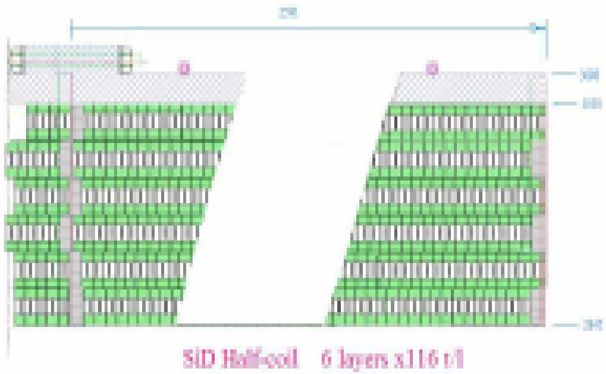
Radius: ~ 2.5m to ~3.32m, L=5.4m; Stored energy ~ 1.2 GJ

Feasibility study at Fermilab demonstrated that this 5T solenoid can be built, based on CMS design & conductor.



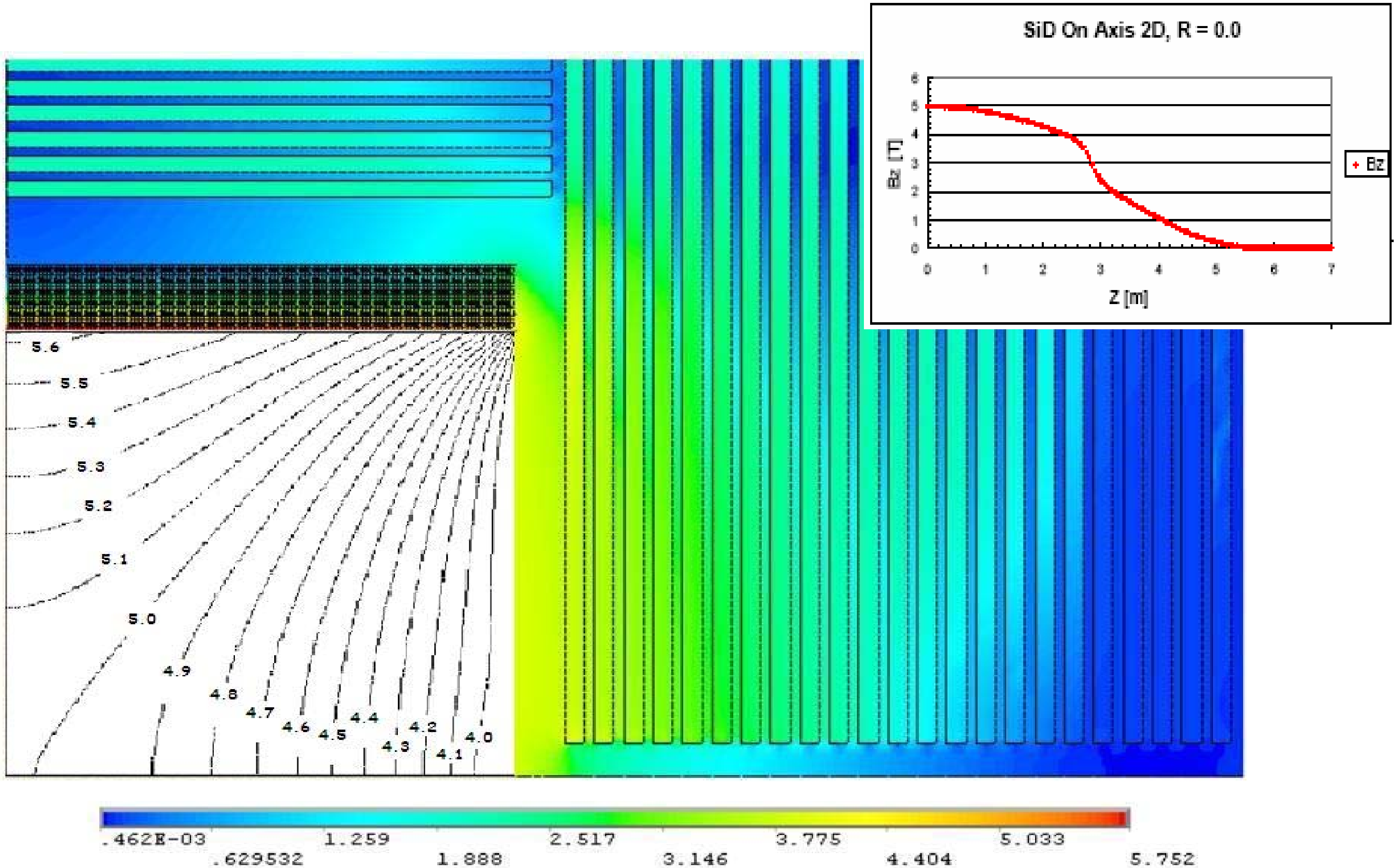
Stresses and forces comparable to CMS.

SiD coil

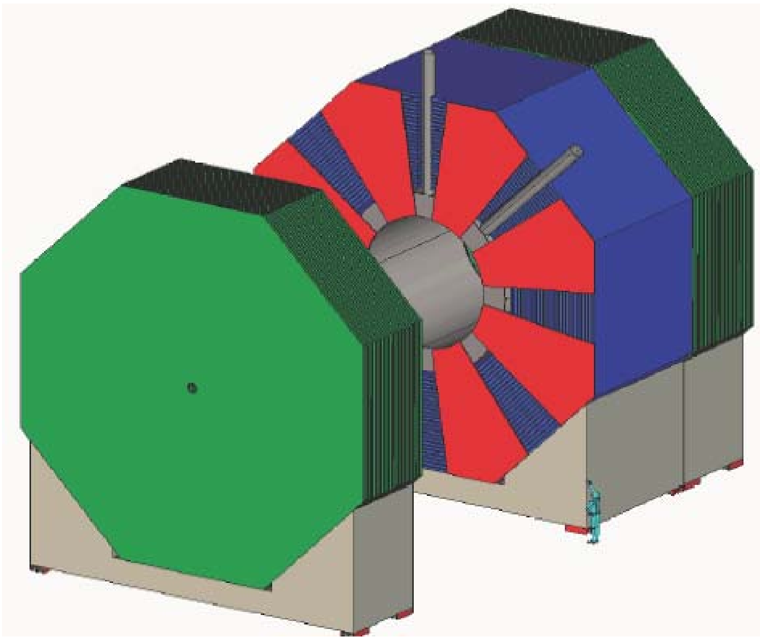


- Same conductor as CMS
- CMS (4 layer)➔ SiD (6 layer)
- CMS 5 modules 2.5 m long ➔SiD 2 modules 2.6 m long

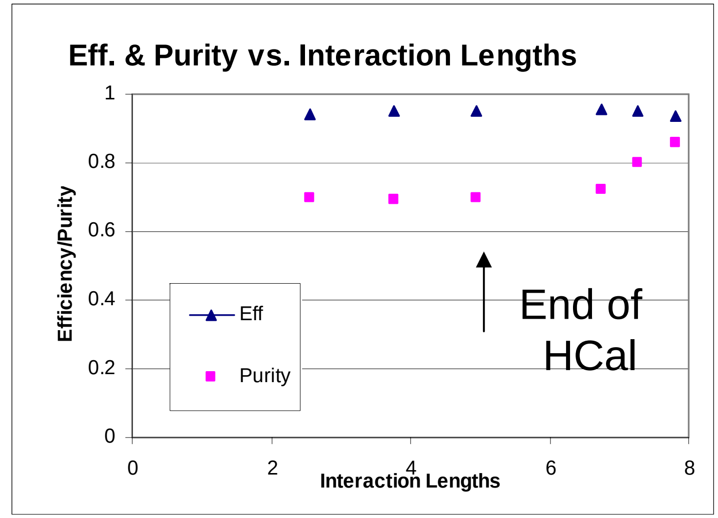
Field Uniformity and Stresses Evaluated



Muon System



Have Hcal, Need Muon system?



2.3m Fe (14λ) 10cm layers
Instrument 12? gaps
Projective xyu readout
σ ~ 1cm

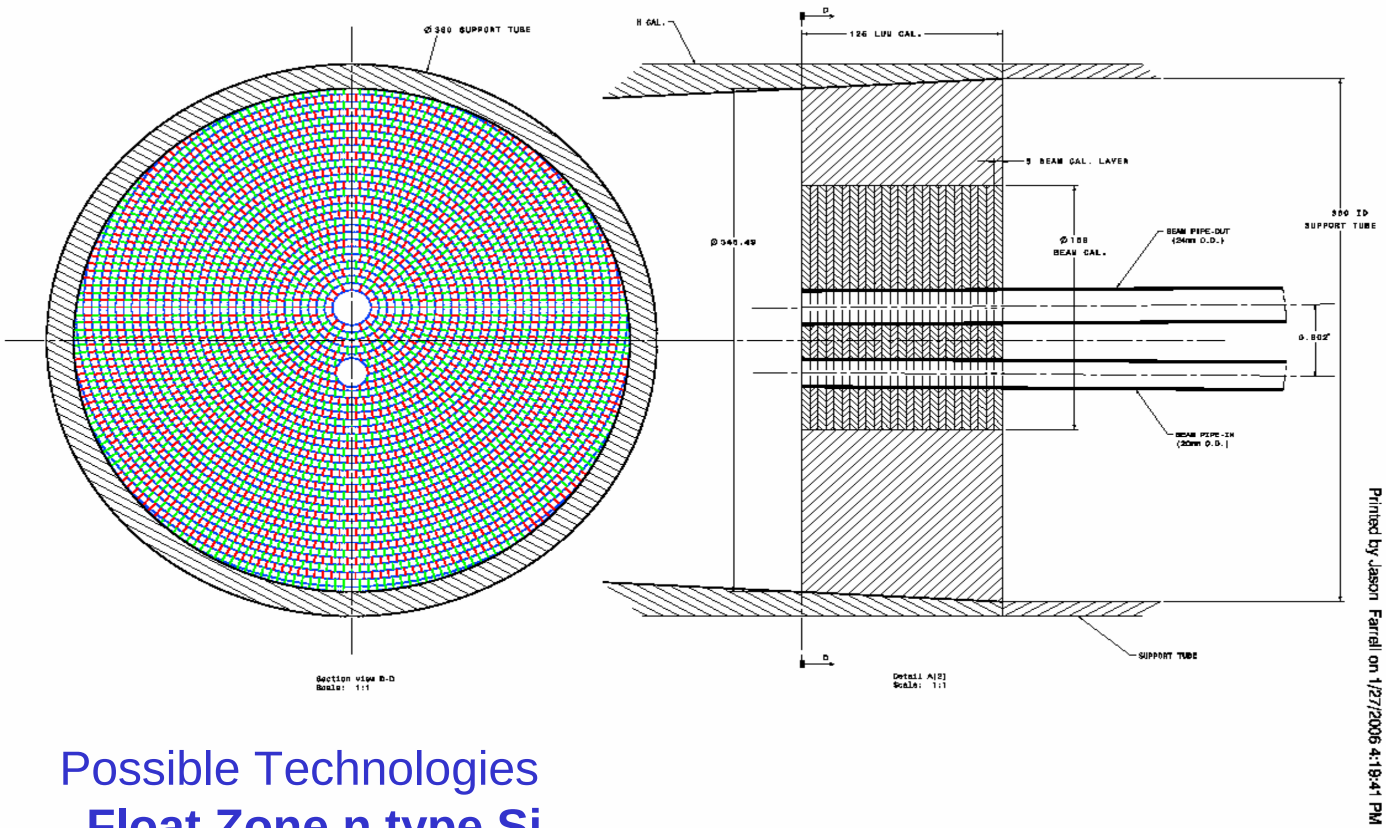
Efficiency ~95%
Increasing λ boosts purity
69% → 86%

Technologies

Glass & Bakelite RPCs
Scintillator and Photo-detectors
GEMs
Wire Chambers

Beamcal

W. Morse et al.

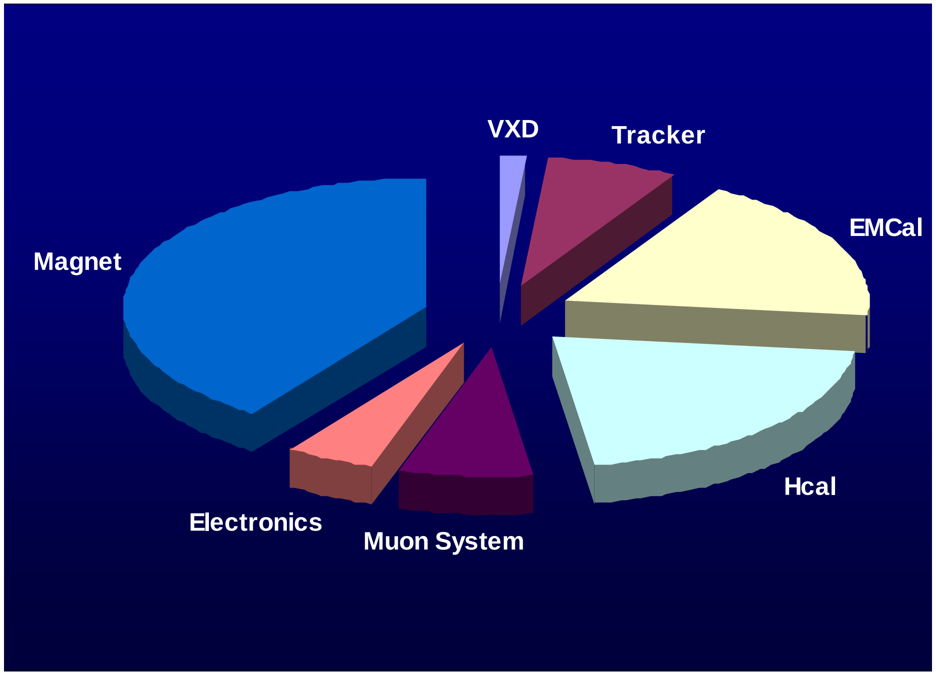


Possible Technologies

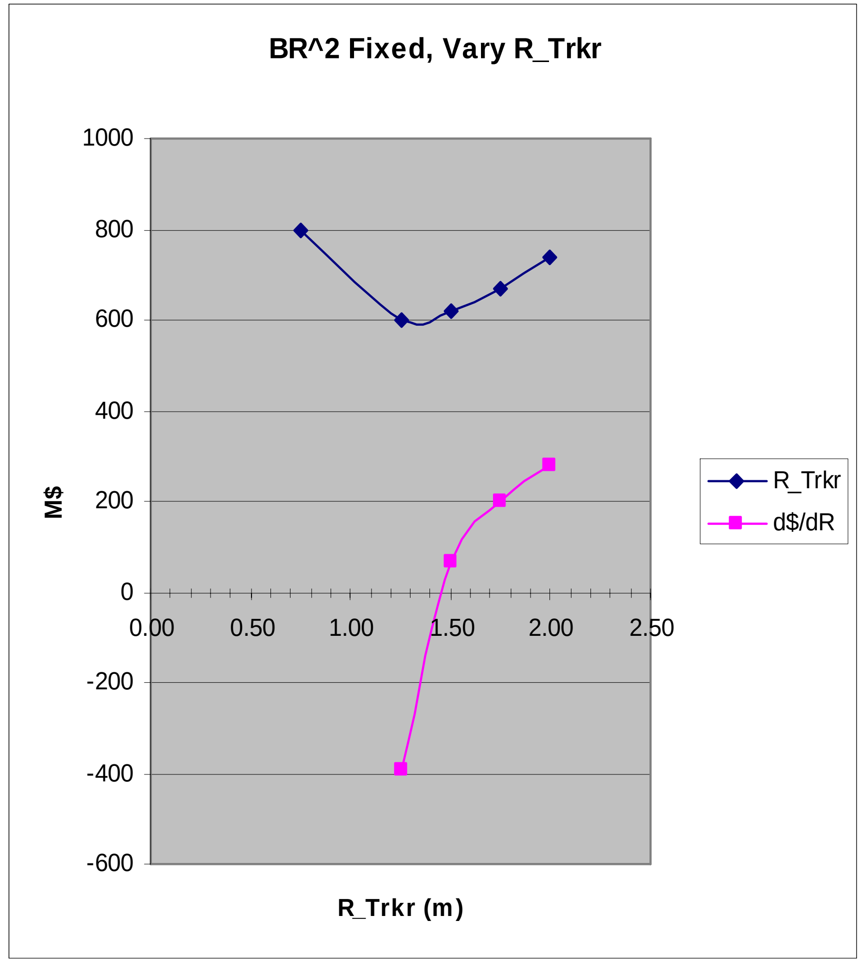
Float Zone n type Si

MCZ Si

Accounting for Costs



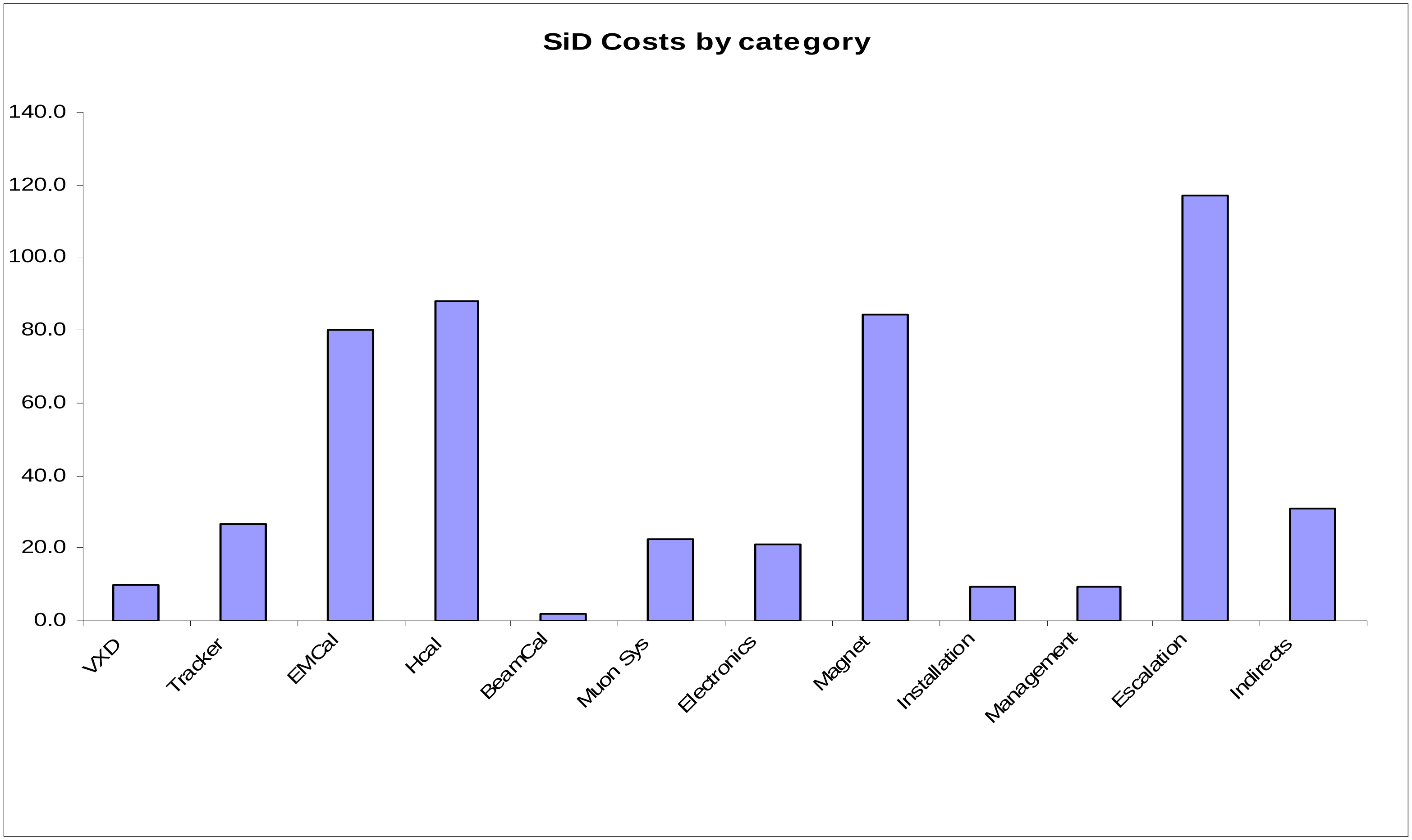
Cost by subsystem



Cost minimum vs. tracker radius

Excel Spreadsheet allows study of costs vs detector parameters, includes fixed costs. US accounting style

SiD Costs



- Ecal, Hcal, Magnet dominate the costs.
- Include contingency, escalation, indirects

SiD's Highpoints

- VXT 5T Field allows smallest beam pipe radius. Endcap design maximizes Ω, improves resolution.
- Tracker Si is robust and fast. Backgrounds are minimized. Momentum resolution is superb. Combined tracking system (VXT+SMT+ECAL) is fully efficient.
- ECAL Good resolution ($\Delta E/E \sim 15\%$), superb transverse and longitudinal segmentation.
- HCAL Moderate resolution ($\Delta E/E \sim 50\text{-}80\%$), good segmentation.
- Solenoid 5T. Follows CMS design. Feasible
- Muon Instrumented flux return
- Cost Constrained and optimized

New Participants for SiD Design Study Welcome!

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

SiD's Next Steps…

- **Finalize the SiD Detector Outline Draft**
  Preliminary Draft available on SiD Website:
  see http://www-sid.slac.stanford.edu
- **Optimize the SiD Design**

  Global Optimization: PFAs $\Rightarrow R_{tracker}, L_{ecal}, B$

  Local Optimization of subsystem parameters

- **Flesh out designs for remaining subsystems**
- **Develop and coordinate SiD R&D Plan**
- **Benchmark SiD performance with physics studies**

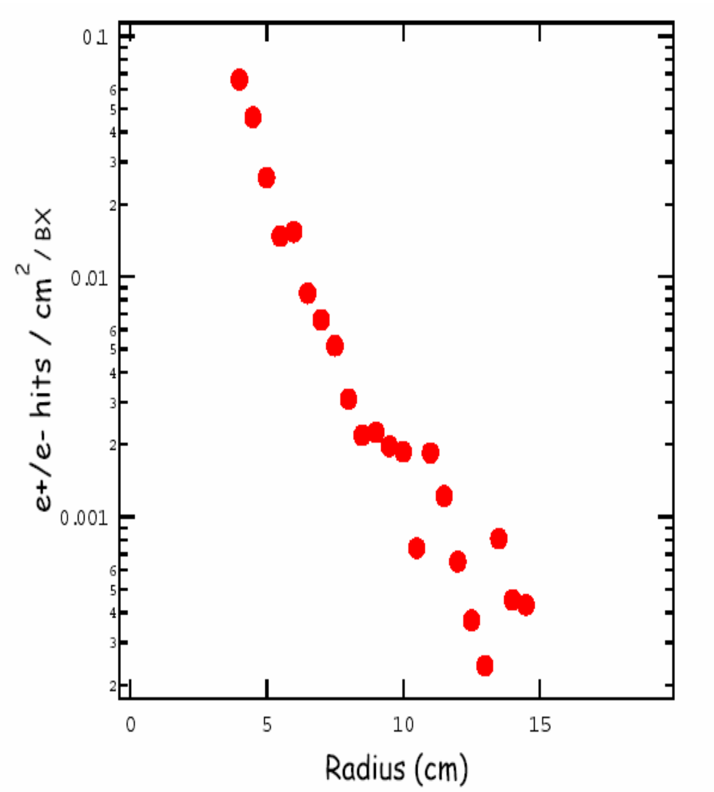
Information Meeting

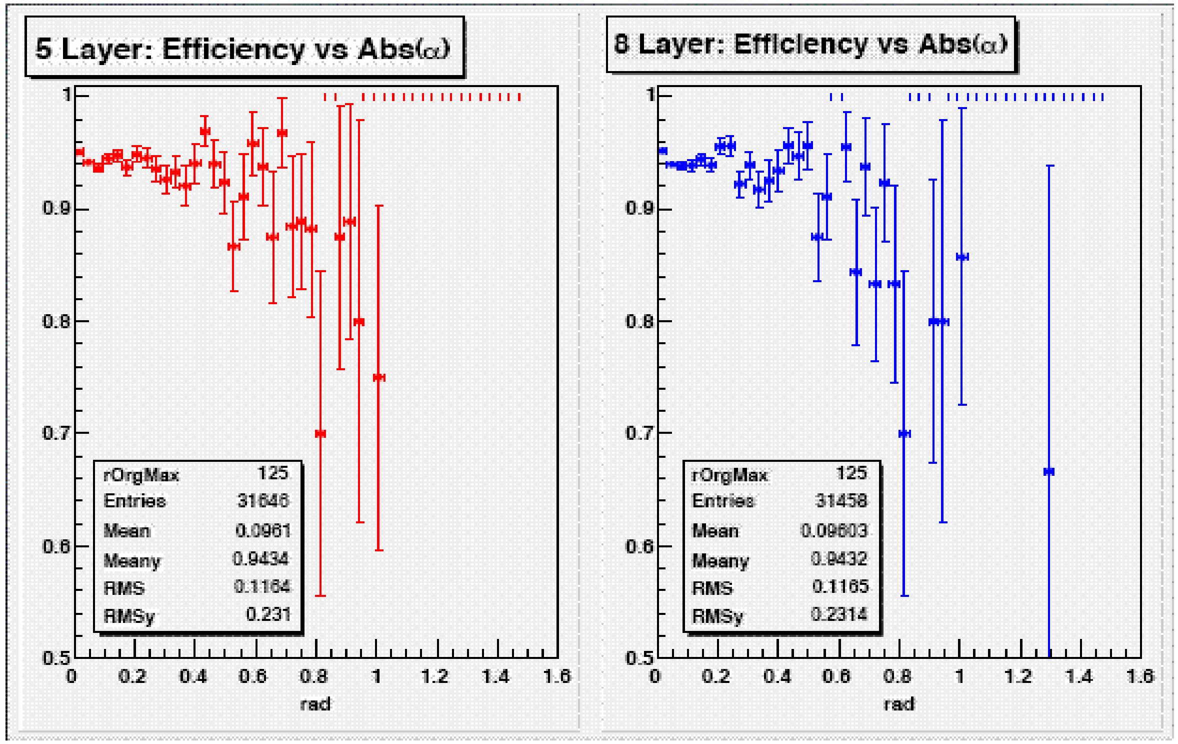
Time: March 11, 2006
Location: SSCU

Agenda

Why SiD for an ILC detector?	**Jim Brau**
SiD R&D Plans	**Andy White**
How to get involved with SiD	**Harry Weerts**
Questions, Answers, and Discussion	**ALL**

Single BX Livetime ⇒ SiD Occupancies are Low, SiD Pattern Recognition Robust





Tracks/cm^2/BX vs Radius of hit Layer #1 of the Forward Tracker

Occupancy < 10^{-3}/BX

"VXD Seeded" Tracking Efficiency ~ 95%.

Losses are K's and Λ's; they are recovered by "Ecal Seeded" tracks and "Stand-alone Tracking"

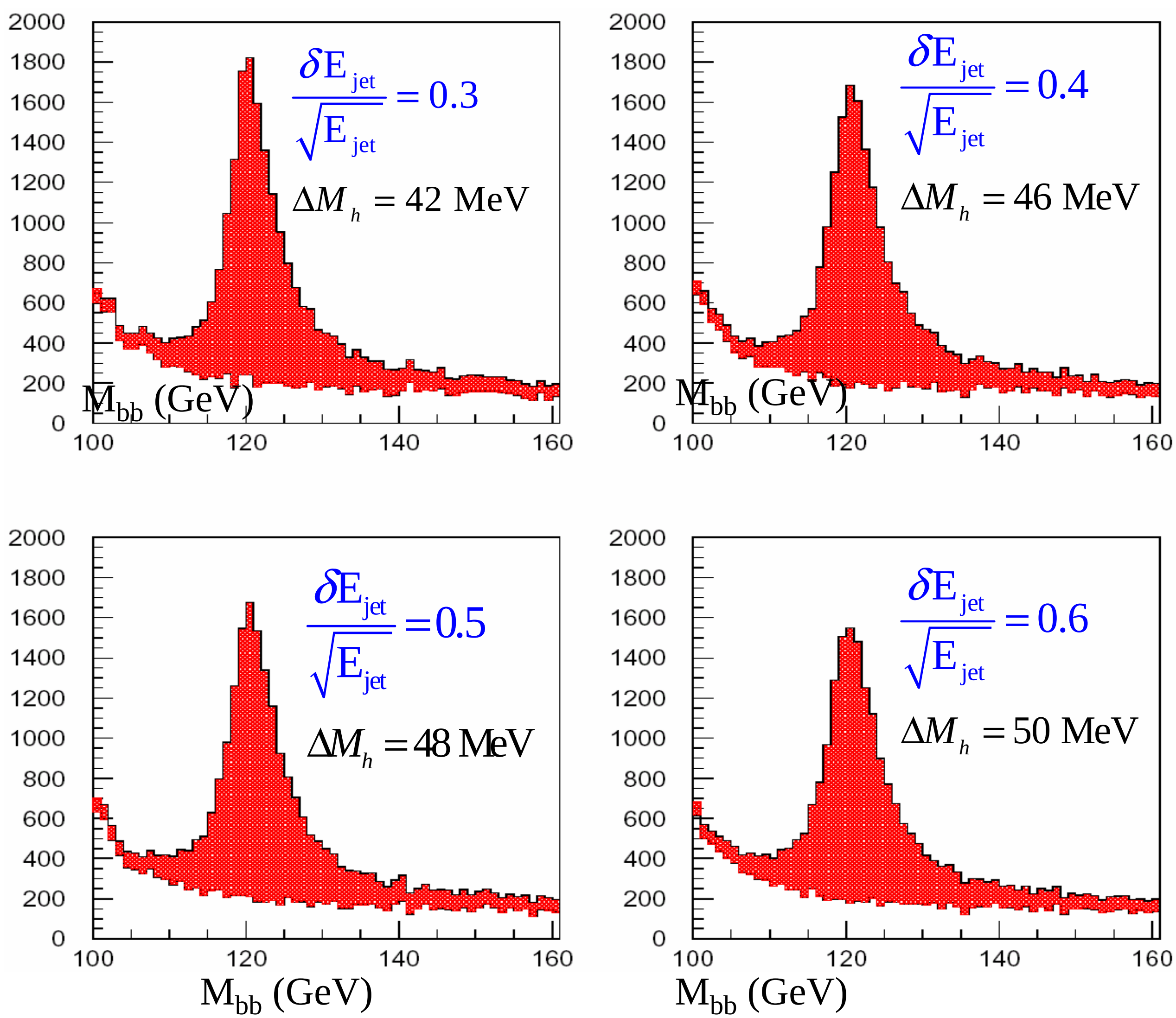
Revisit Performance: Jet Energy Resolution

Higgs Mass Measurement

$$e^+e^- \to ZH$$
$$\to qqb\bar{b}$$

$$\sqrt{s} = 350\,GeV$$

$$L = 500\,fb^{-1}$$



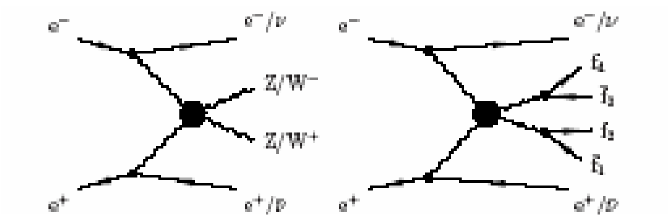
Calorimetry Drives the SiD Design

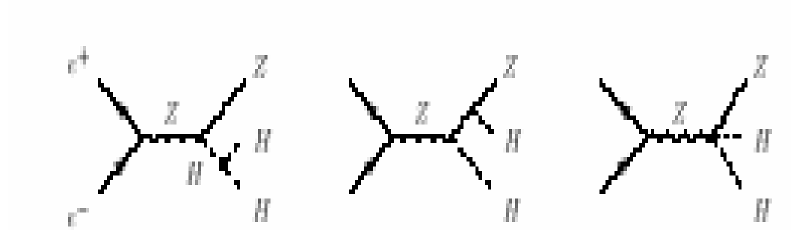
Bread and Butter Precision EW or Signal of Strong EWSB?

Unconstrained kinematics needs **high resolution** cal to discriminate WWνν, WZeν, and ZZνν events.

Measure Higgs Self Coupling λ_{hhh}

Tiny (0.2 fb @ 500 GeV) signal on large multi-jet backgrounds is only visible with **high resolution**





$$e^+ e^- \rightarrow WW \nu\bar{\nu} \quad , \quad e^+ e^- \rightarrow ZZ \nu\bar{\nu}$$