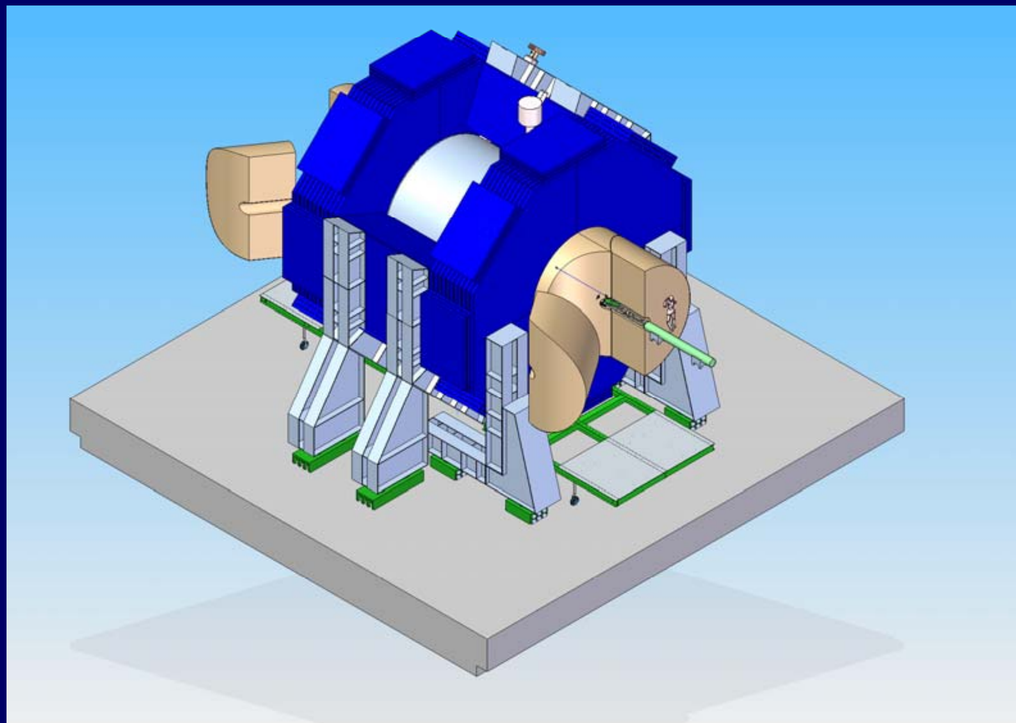
The SiD concept

H.Weerts

Argonne Nat. Lab.

for the SiD concept



Overview

- History of SiD
- Who is SiD
- What is SiD
- Description of detector concept
- SiD Plans for LOI (optimization)
- R&D: activities, plans & needs
- Summary

History of SiD

First presented at Snowmass 1996 (R_{in_ECAL} =50 cm) it was the Small Detector
ECFA workshop 2003 progress, R_in_ECAL = 127cm)
called Silicon Detector ➔ SiD

First exposure and meeting of interested parties at ALCPG 2004, Vancouver

Large push forward at Snowmass 2005

Several meetings/workshops since

Univ. Colorado, Sept 2008
Rutherford, April 2008
SLAC, January 2008
Fermilab, October 2007
SLAC October 2006
Fermilab, Dec 2005
Snowmass 2005
SLAC, March 2005

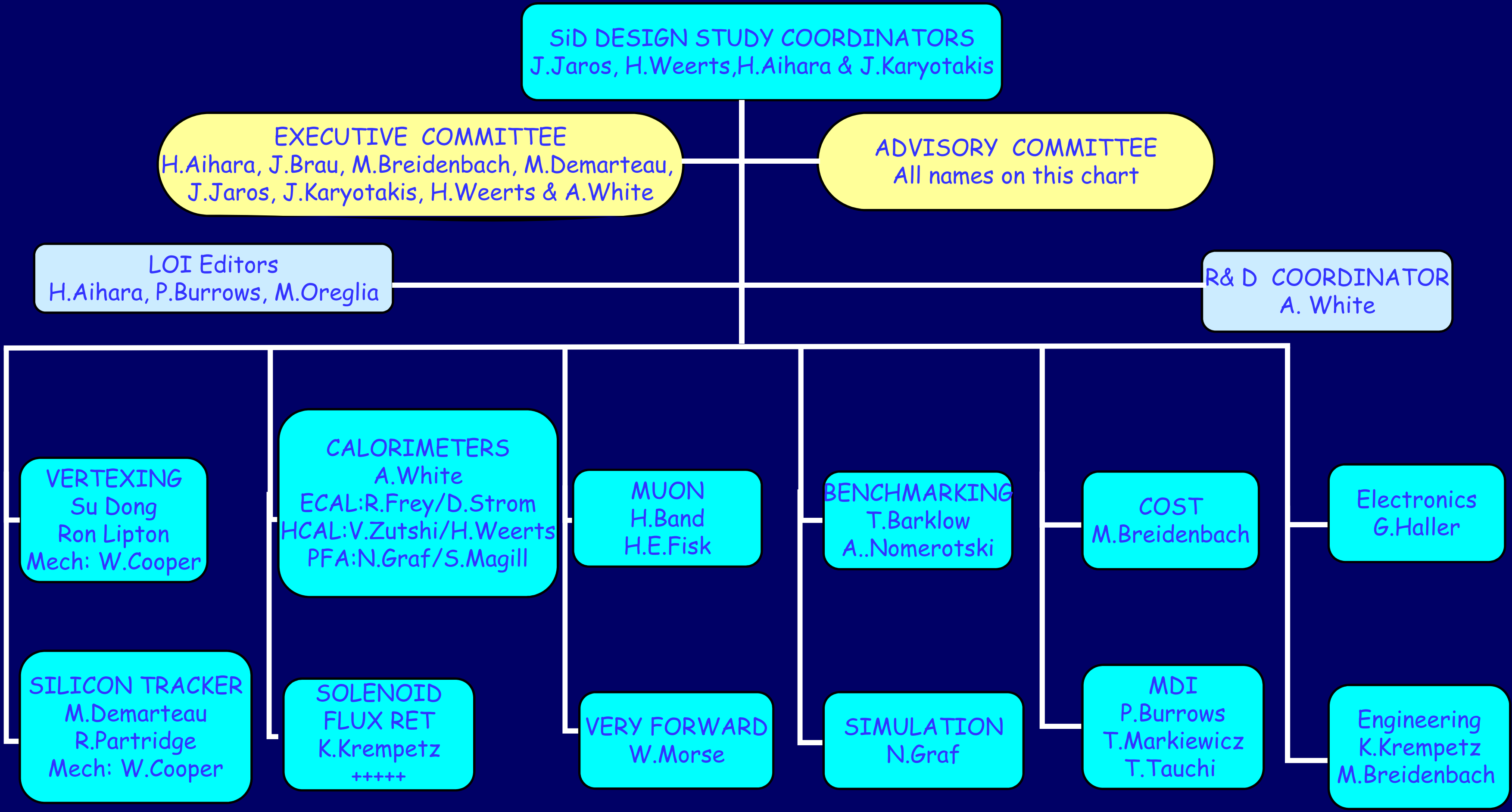
Presence and meetings at all international and regional ILC meetings, since 2004.

Next step: prepare LOI and submit LOI

WEB site: http://silicondetector.org/

Who is SiD;1

Organization



Who is SiD; 2

List of current institutions, signed EOI

Laboratories and Institutes:
Argonne National Laboratory
Brookhaven National Laboratory
Fermi National Accelerator Laboratory
Institute of Physics, Prague
Irfu, CEA/Saclay
LAPP, CNRS/IN2P3 Université de Savoie
LPNHE, CNRS/IN2P3 Universites Paris VI et Paris VII
Lawrence Livermore National Laboratory
Max Planck Institute, Munich
Physical Sciences Laboratory, Wisconsin
Rutherford Appleton Laboratory
Stanford Linear Accelerator Center

Universities:

U. of Bonn
U. of Bristol
Brown U.
U. of California, Davis
U. of California, Santa Cruz
Charles U., Prague
U. of Chicago
Chonbuk National U.
U. of Colorado, Boulder
Colorado State U.
Imperial College, London
Indiana U.
U. of Iowa
Kansas State U.
Kyungpook National U.
U. of Melbourne
U. of Michigan
Massachusetts Institute of Technology
U. of Mississippi
U. of New Mexico
Northern Illinois U.
U. of Notre Dame
U. of Oregon
Oxford U.
U. of Pierre and Marie Curie LPNHE
Princeton U.
Purdue U.
U. of Rochester
Seoul National U.
State U. of New York, Stony Brook
Sungkyunkwan U.
U. of Texas, Arlington
U. of Tokyo
U. of Washington
Wayne State U.
U. of Wisconsin
Yale U.
Yonsei U.

Participating or will participate in developing SiD concept

Silicon Detector Design Study

http://silicondetector.org

Search

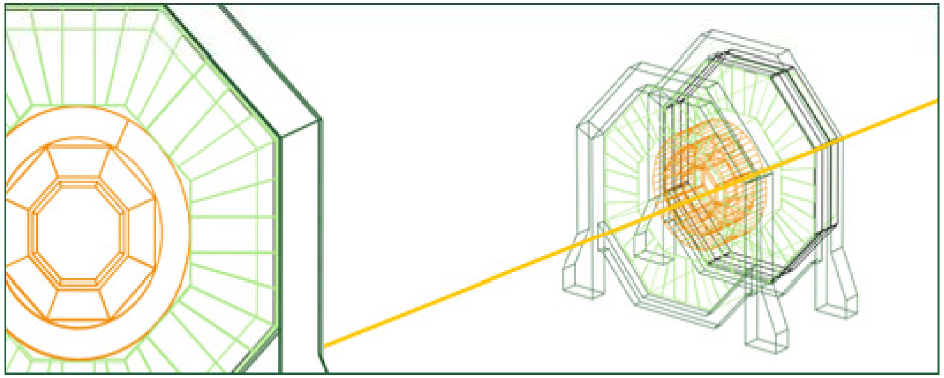
Dashboard > Silicon Detector for ILC > home

SILICON DETECTOR DESIGN STUDY — Log In

- SiD Home
  - Sign Up for SiD Emails
  - Org Chart
- Meetings
  - Monthly Collaboration Meeting
  - Weekly Meetings
  - Workshops and Conferences
  - Previous Events
- Documents
- Simulation
  - Detector versions
- Working Groups
- Web Site
  - Recent Updates
  - Index
  - Search
  - Links

Page Operations

Browse Space



Silicon Detector (SiD) Design Study.

The Silicon Detector Design Study is developing the SiD Detector Concept for the ILC into a detailed, optimized, and fully integrated detector design. The SiD concept incorporates Si/W electromagnetic calorimetry and all-Si tracking in a detector design which attempts to optimize physics performance, constrain costs, and be robust against physics and machine backgrounds.

Optimizing design, benchmarking, doing R&D

Announcements

- SiD Collaboration Phone Meeting on Thursday Dec 6
- Call for Letters of Intent (LOIs)

Upcoming Workshops

- SiD Outreach Meeting Paris Feb 11, 2008
- SiD Meeting, April 14-15, 2008 at RAL

ILC Newsline

- ILC NewsLine - 21 February 2008
- ILC NewsLine - 14 February 2008
- ILC NewsLine - 7 February 2008
- ILC NewsLine - 31 January 2008
- ILC NewsLine - 24 January 2008

What is SiD

Basic & main assumptions underlying SiD concept

- PFA based concept → drives design
- Integrated design of complete detector
- Robust in ILC operations (beam losses)
- Cost constrained optimized design

Currently mainly a US based concept
Have tried to remedy this; partial success only
Has proven to be difficult

Current status of ILC does not help (especially in the US)

Some Detector Design Criteria

Requirement for ILC

- Impact parameter resolution

$$\sigma_{r\phi} \approx \sigma_{rz} \approx 5 \oplus 10/(p\sin^{3/2}\vartheta)$$

- Momentum resolution

$$\sigma\left(\frac{1}{p_T}\right) = 5\times10^{-5}\ (GeV^{-1})$$

- Jet energy resolution goal

$$\frac{\sigma_E}{E} = \frac{30\%}{\sqrt{E}} \qquad \frac{\sigma_E}{E} = 3-4\%$$

- Detector implications:
  - Calorimeter granularity
  - Pixel size
  - Material budget, central
  - Material budget, forward

Compared to best performance to date

- Need factor 3 better than SLD

$$\sigma_{r\phi} = 7.7 \oplus 33/(p\sin^{3/2}\vartheta)$$

- Need factor 10 (3) better than LEP (CMS)
- Need factor 2 better than ZEUS

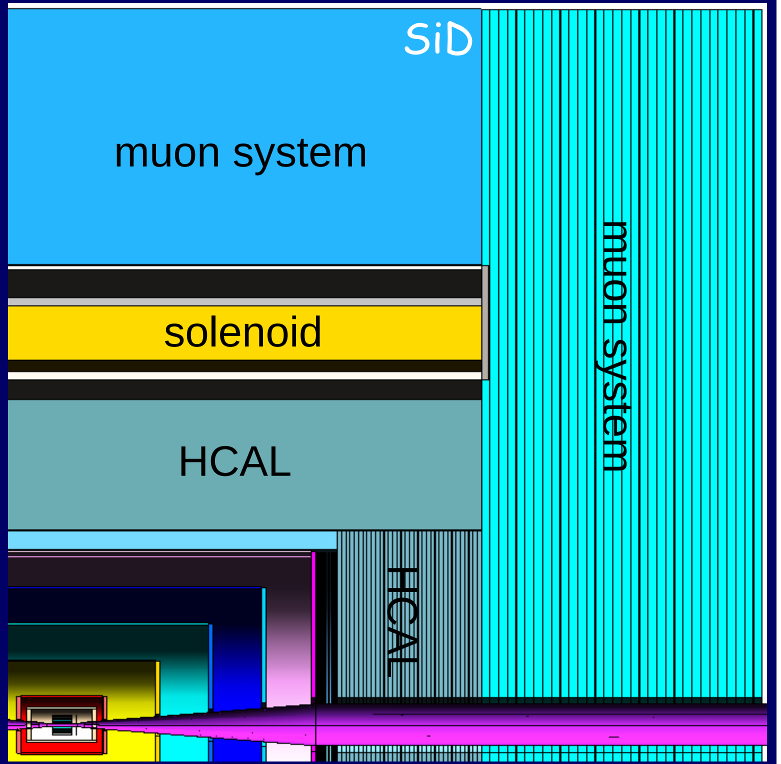
$$\frac{\sigma_E}{E} = \frac{60\%}{\sqrt{E}}$$

- Detector implications:
  - Need factor ~200 better than LHC
  - Need factor ~20 smaller than LHC
  - Need factor ~10 less than LHC
  - Need factor ~ >100 less than LHC

Observation: LHC: staggering increase in scale, but modest extrapolation of performance
ILC: modest increase in scale, but significant push in performance

SiD Design Concept (starting point)

- "Jet Energy measurement =PFA" is the starting point in the SiD design
- Premises at the basis of concept:
  - Particle flow calorimetry will deliver the best possible performance
  - Si/W is the best approach for the ECAL and digital calorimetry for HCAL
  - Limit calorimeter radius to constrain the costs
  - Boost B-field (5T)to maintain BR^2
  - Use Si tracking system for best momentum resolution and lowest mass (5 layers)
  - Use pixel Vertex detector for best pattern recognition (5 layers)
  - Keep track of costs
- Detector is viewed as single fully integrated system, not just a collection of different subdetectors



Compact: 12m x 12m x 12 m

SiD Starting Point
Details & Dimensions

Flux return / muon
R_{in} = 333 cm
R_{out} = 645 cm

Solenoid: 5 T; R_{in} = 250 cm

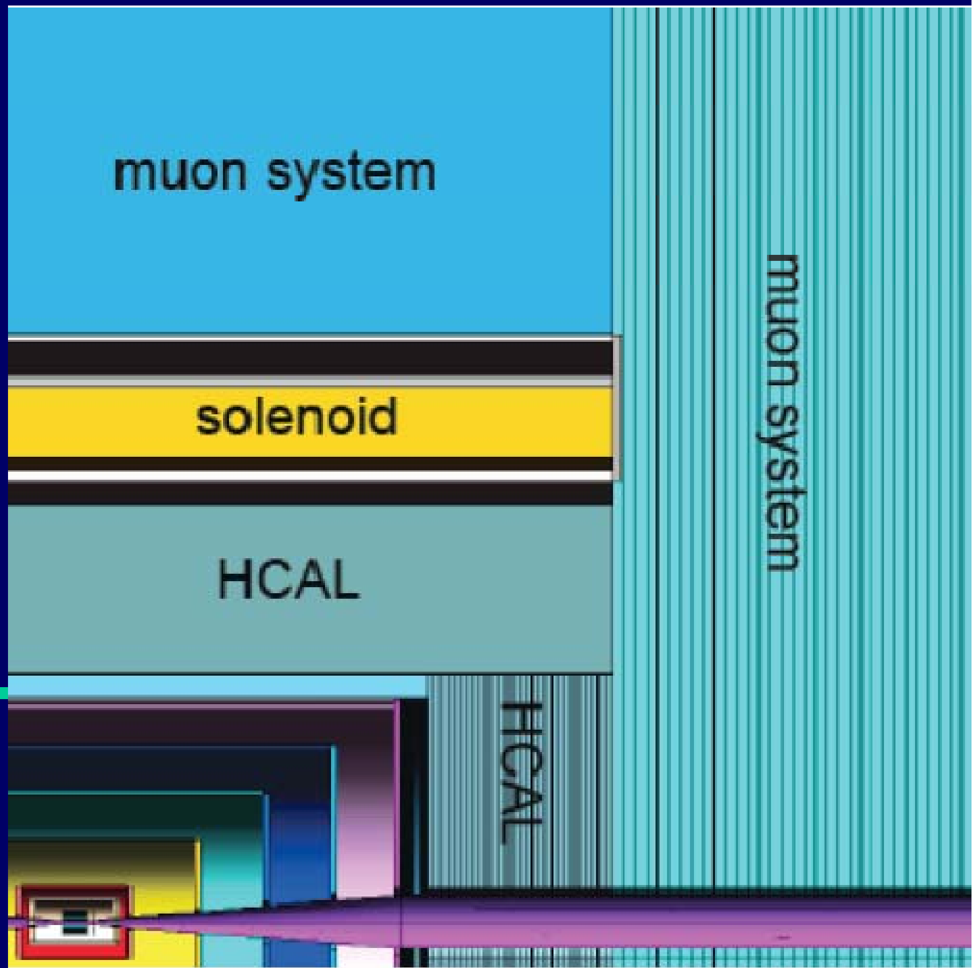
PFA

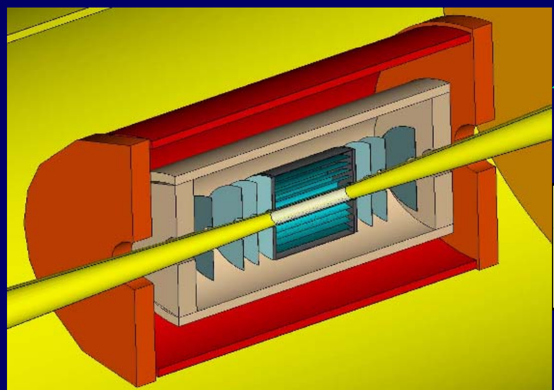
HCAL Fe: 34 layers; R_{in} = 138 cm

EMCAL Si / W: 30 layers R_{in} = 125 cm

Si

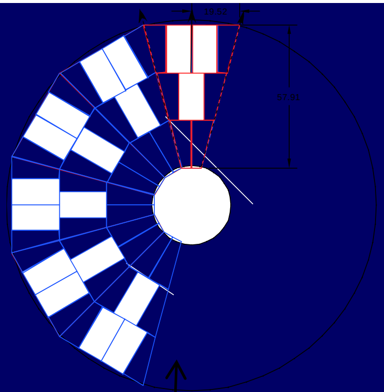
Si tracking: 5 layers; R_{in} = 18 cm





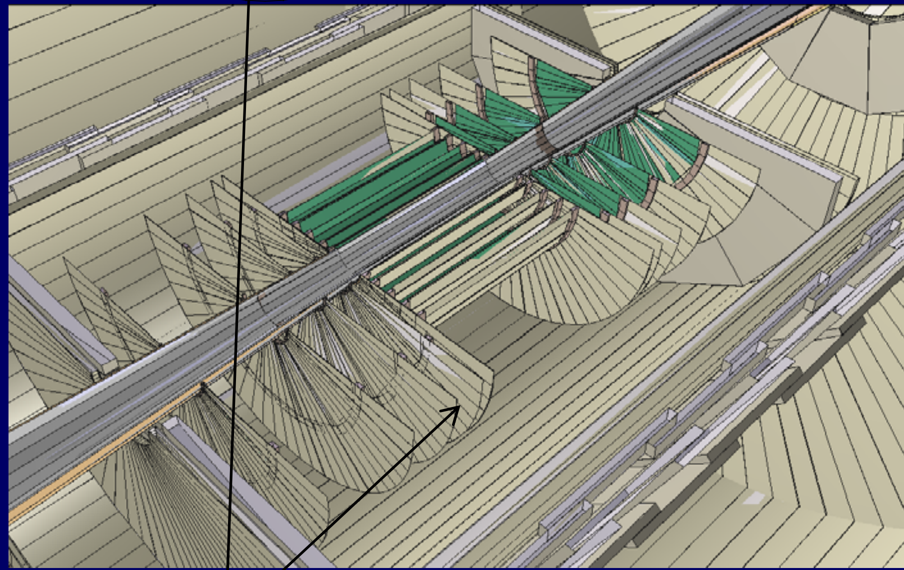
Vertex detector:
5 barrels, 4 disks; R_{in} = 1.4 cm

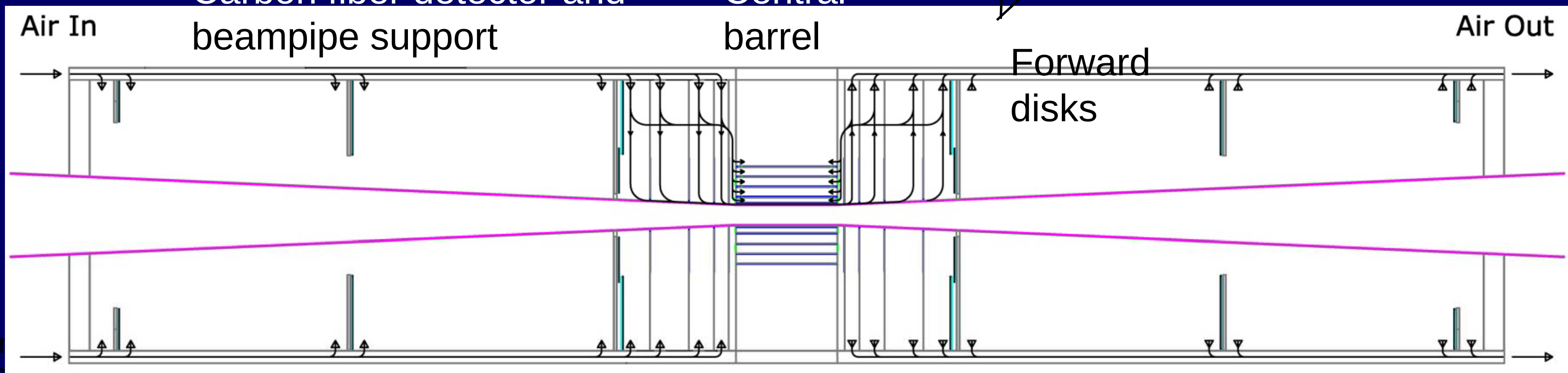
SiD Vertex Detector



SiD Vertex concept is based on short (12 cm) barrels followed by disks

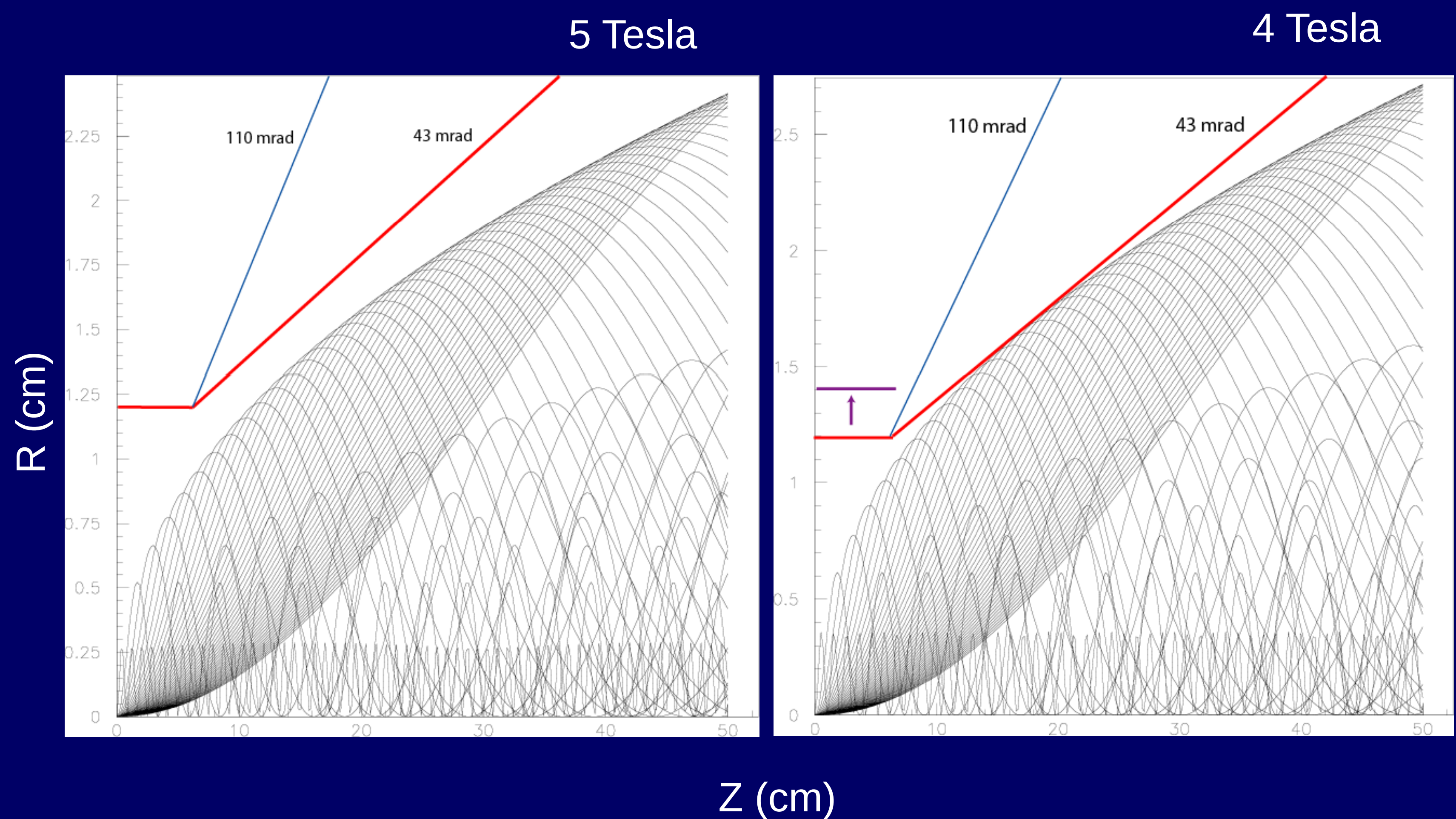
- Detailed mechanical design including carbon fiber support cylinder and services
- 5T field allows small inner radius
- Sensor technologies considered
  - CCD, DEPFET, CMOS, 3D
  - Final detector can be a mix defined by power consumption and performance





Coupling of B field and small VXD radius

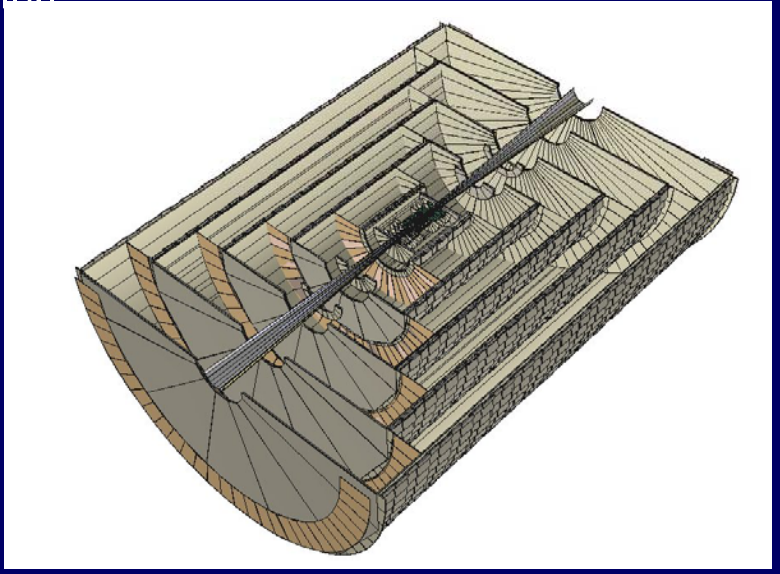
Current Beam pipe is designed for
ILC 500 GeV Nominal + 5 Tesla



For 4 Tesla, R=1.2 cm is tight and 43 mrad is too small.
R=1.4 cm and 110 mrad beam-pipe would work.

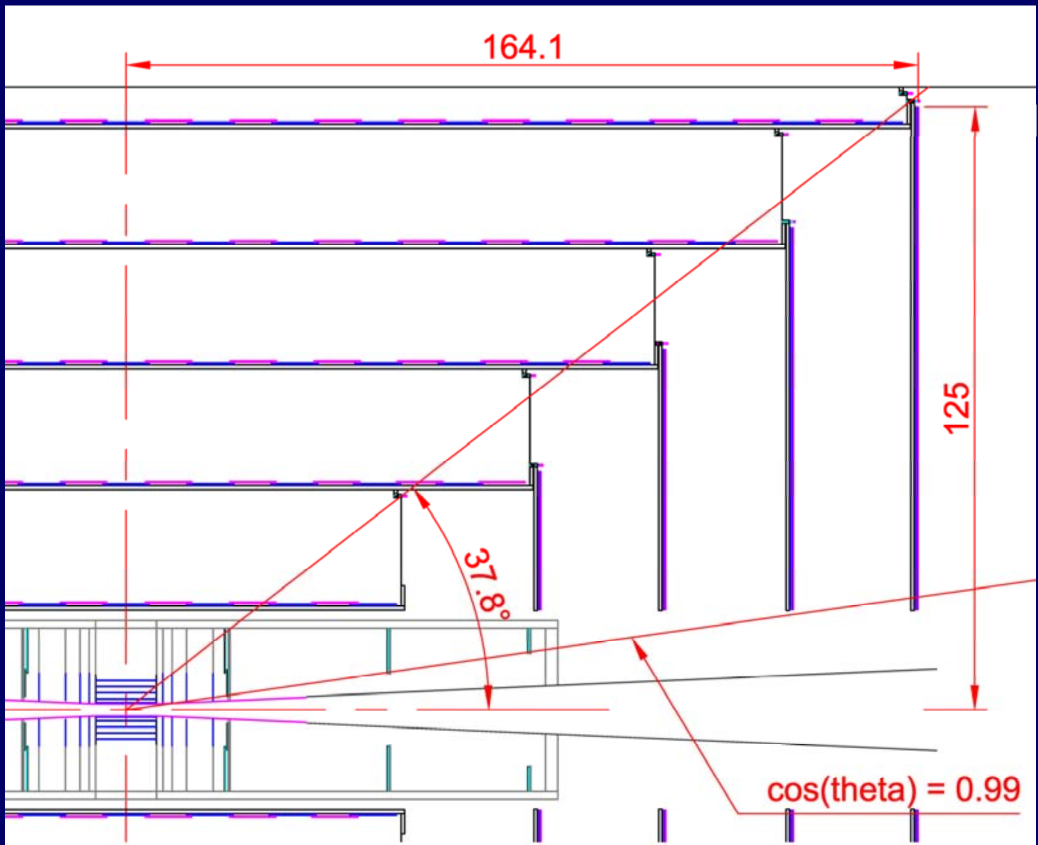
Tracking Detector

- Tracking detector requirements
  - Transparency: 0.8% X_0 per layer average over full fiducial volume
  - Superb point resolution and momentum resolution
    - Strip pitch of 25 μm
    - $\sigma(1/p) = 2\ 10^{-5}\ (GeV^{-1})$ at 90 degrees
  - Good angular coverage; robust pattern recognition
    - Single bunch timing
    - Very high tracking efficiency for PFA
  - Robust against aging and beam accidents
  - Modest radiation tolerance
- Silicon technology chosen
  - Mature technology which allows emphasis on phi resolution
    - Superior asymptotic p_T resolution
  - Allows for flexibility in minimizing material distribution through fiducial volume



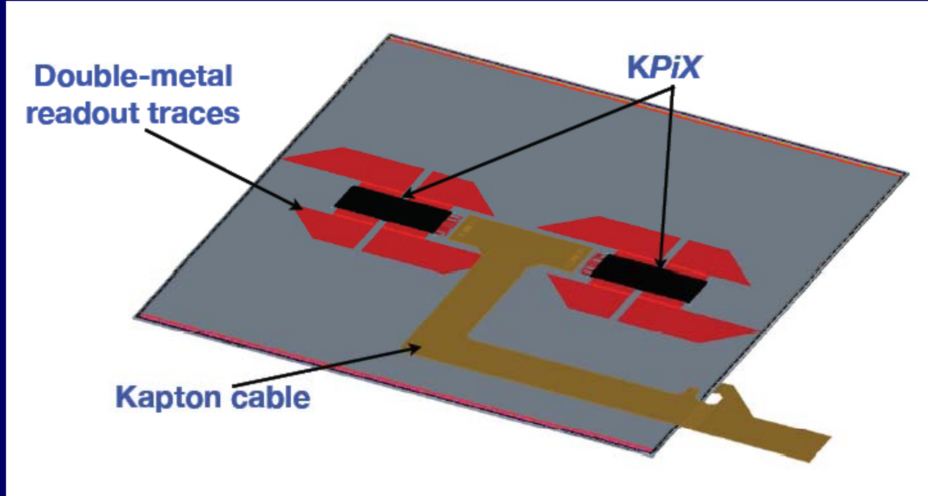
Tracker Mechanical Design

- 5-Layer silicon strip outer tracker, covering R_{in} = 20 cm to R_{out} = 125 cm
- Barrel – Disk structure: goal is 0.8% X_0 per layer

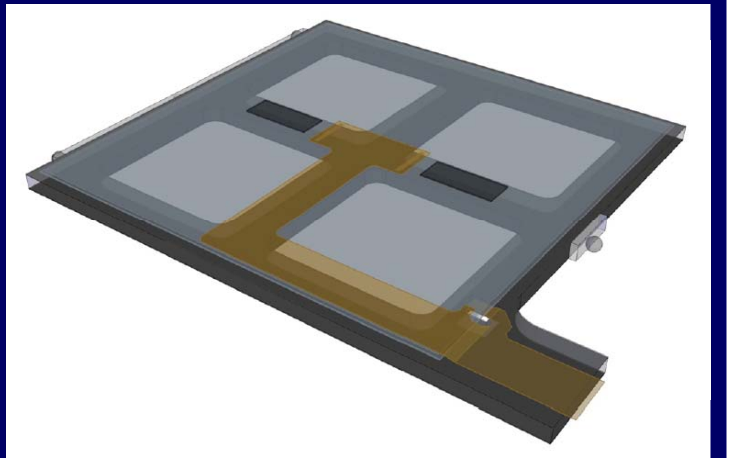


- Support
  - Double-walled CF cylinders
  - Allows full azimuthal and longitudinal coverage
- Barrels
  - Five barrels, measure Phi only
  - 10 cm z segmentation
  - Barrel lengths increase with radius
- Disks
  - Four double-disks per end
  - Measure R and Phi
  - varying R segmentation
  - Disk radii increase with Z

Sensor and Module Design

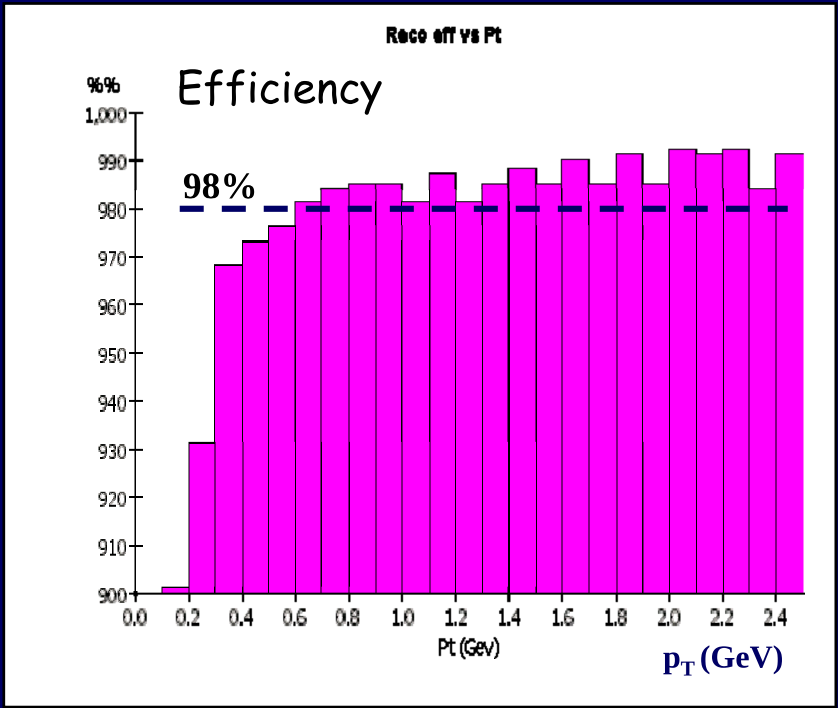


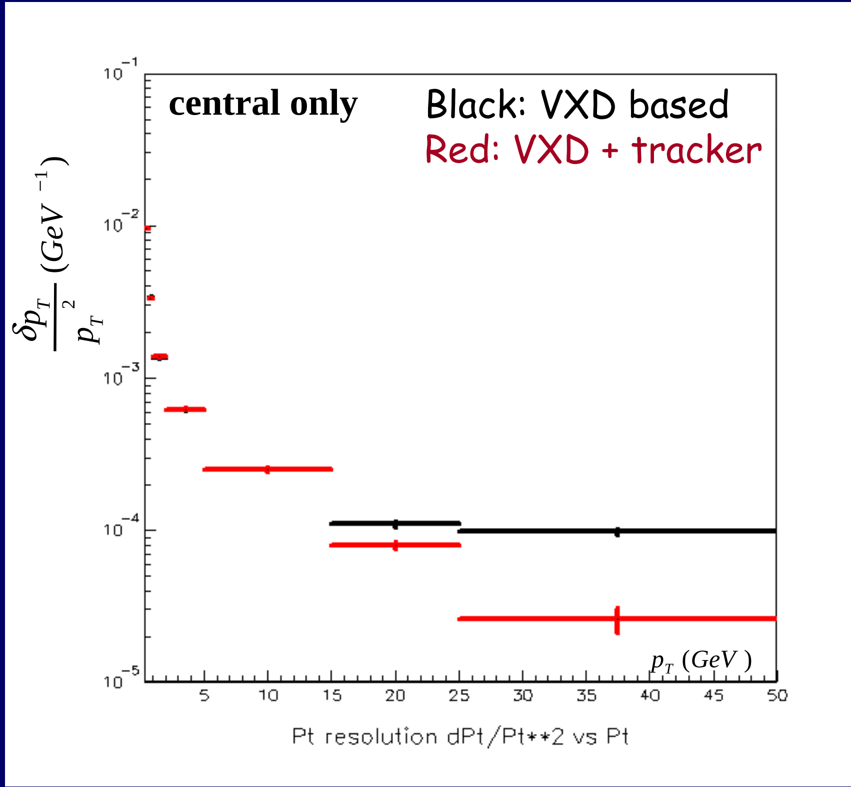
- Hybrid-less design
  - 93.5 x 93.5 mm^2 sensor from 6" wafer with 1840 (3679) readout (total) strips
  - Read out with two asics (kPix) bump-bonded to sensor
  - Routing of signals through 2^{nd} metal layer, optimized for strip geometry
    - Minimize capacitance and balance with trace resistance for S/N goal of 25
  - Power and clock signals also routed over the sensor
- Module support
  - Minimal frame to hold silicon flat and provide precision mounts
    - CF-Rohacell-Torlon frame w/ ceramic mounts
    - CF-Torlon clips glue to large-scale supports
  - Ease of large scale production, assembly and installation/replacement
- Power pulsing for tracker allows for air cooling
  - Factor of >80 in power reduction
  - But have to deal with enormous Lorentz forces



Performance

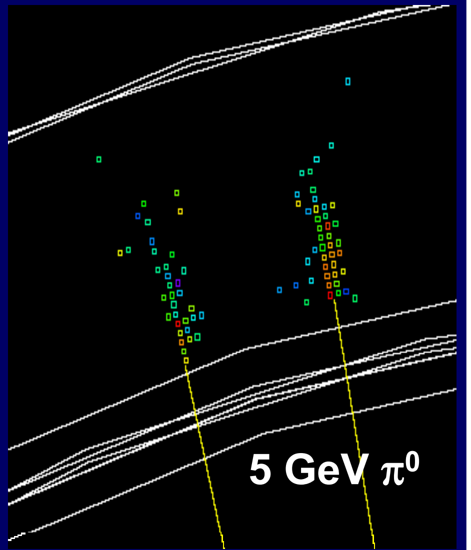
- Vertex detector seeded pattern recognition (3 hit combinations)
  - ttbar-events, full detector simulation and digitization, $\sqrt{s}$ = 500 GeV, background included
    - Efficiency and purity for prompt tracks is good
      - Fake rate <1%; all forward and at low p_T
    - Momentum resolution for central region only
    - Tracks with p_T < 200 MeV difficult in presence of backgrounds

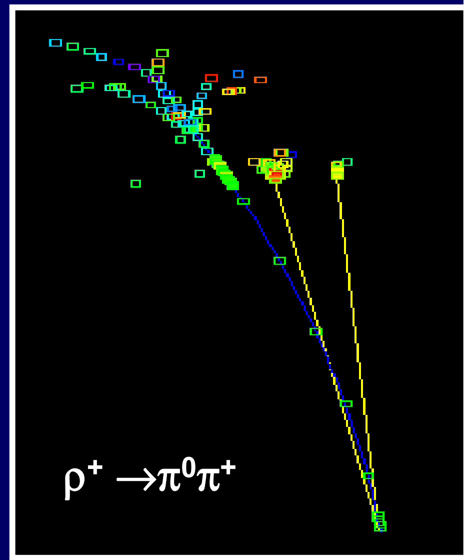


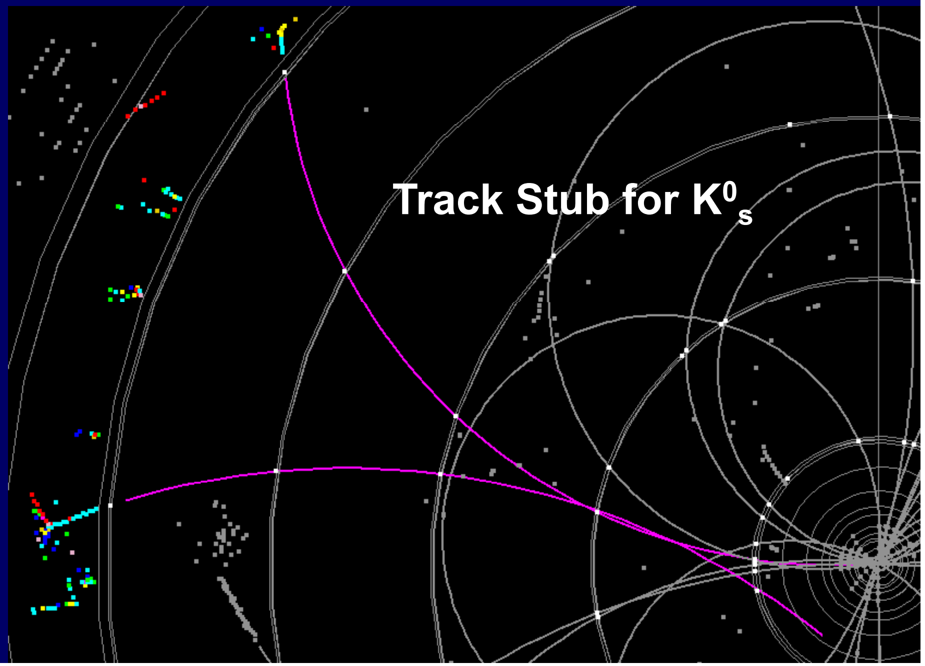


ECAL Requirements

- Measure EM energy in dense jets for PFA
- Isolate photons from π^0's; improve energy resolution.
- Discriminate between different τ decay modes. Use $\tau \rightarrow \rho\nu$ to analyse τ polarization.
- Measure mip trajectories for outside-in tracking and muon id.
- Measure photon directions to search for non-prompt decays.



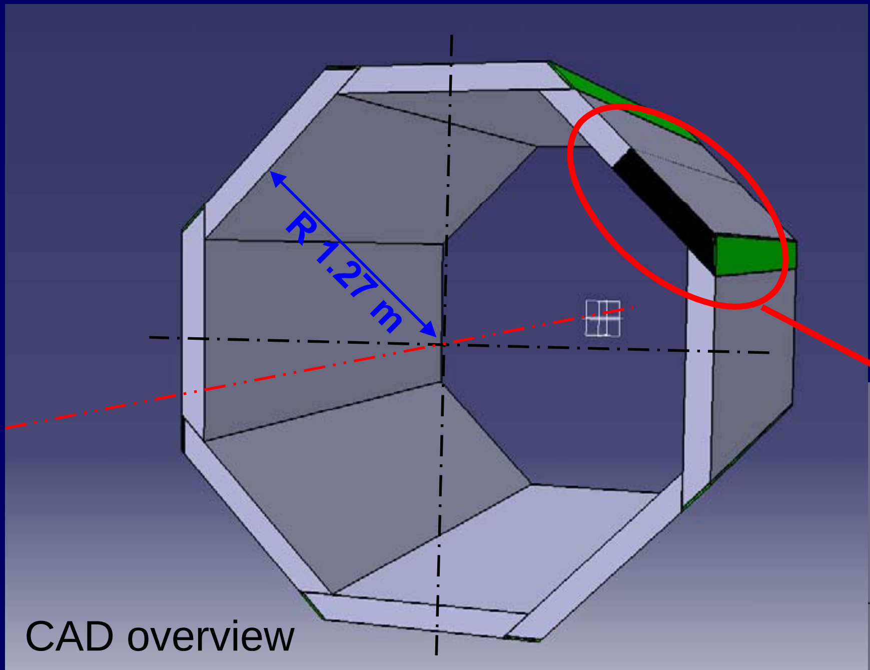


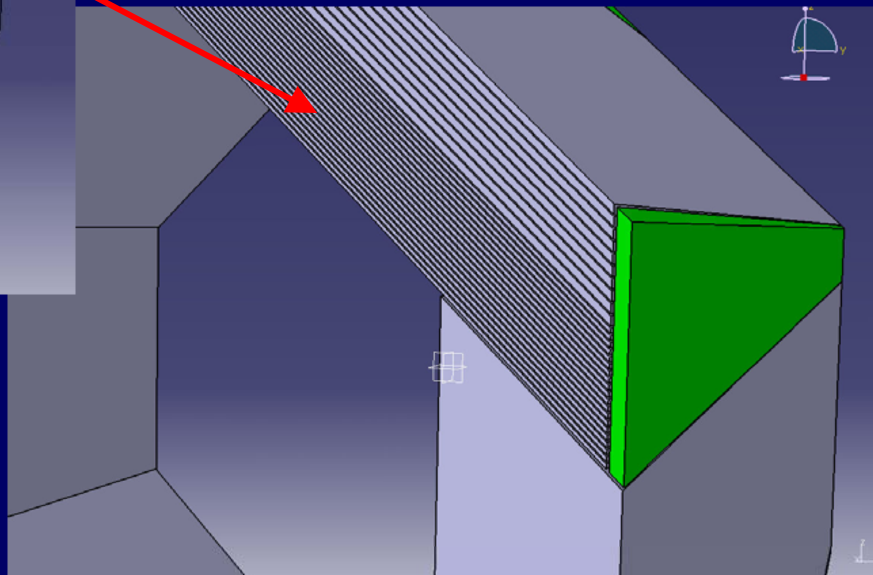


H.Weerts

Si/W Ecal

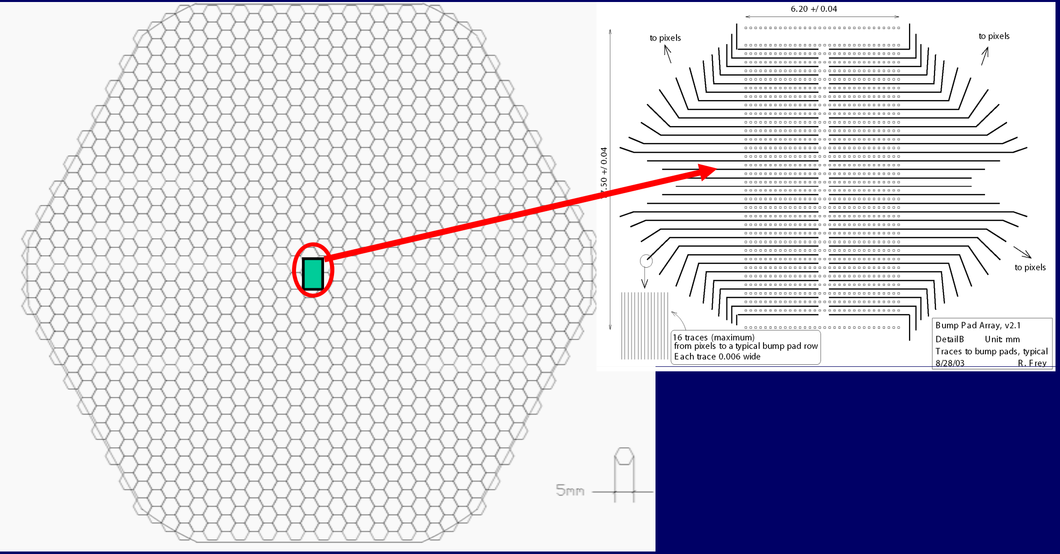
- 20 layers x 2.5 mm thick W
  10 layers x 5 mm thick W
- 1mm Si detector gaps
- Preserve Tungsten $R_{M\ eff}$= 12mm
- Highly segmented Si pads 12 mm^2
- $\Delta E/E = 17\% / \sqrt{E}$



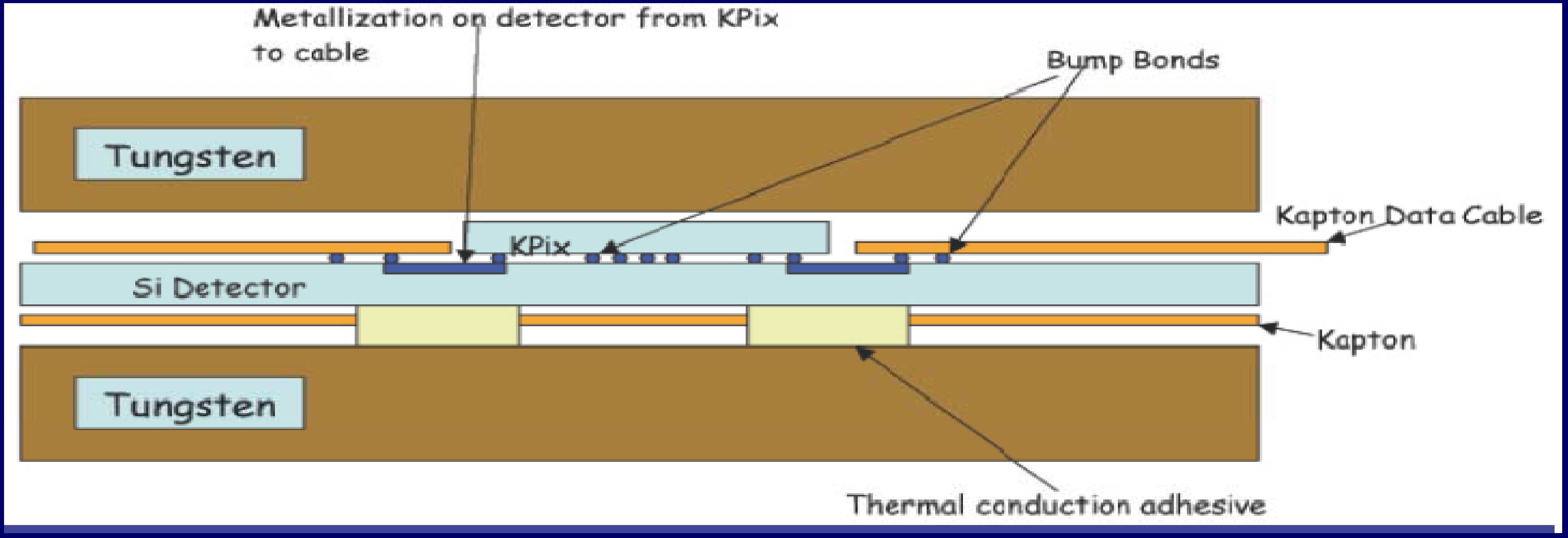


material	R_M
Iron	18.4 mm
Lead	16.5 mm
Tungsten	9.5 mm
Uranium	10.2 mm

Wafers and R/O



- Power pulse for passive cooling
- Minimize gap to preserve $R_{moliere}$
- Bump bond readout to detector
- Readout with Kapton cables

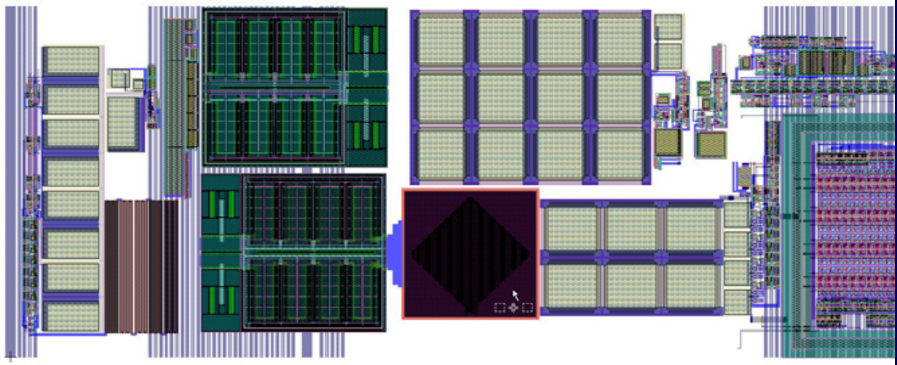


KPiX

1024 channel ASIC for SI pixel readout

- Single MIP tagging (S/N ~7)
- Dynamic range 0.1 – 2500 MIPs
- Low power <40 mW per wafer
- Records bunch crossing time/ 4 deep

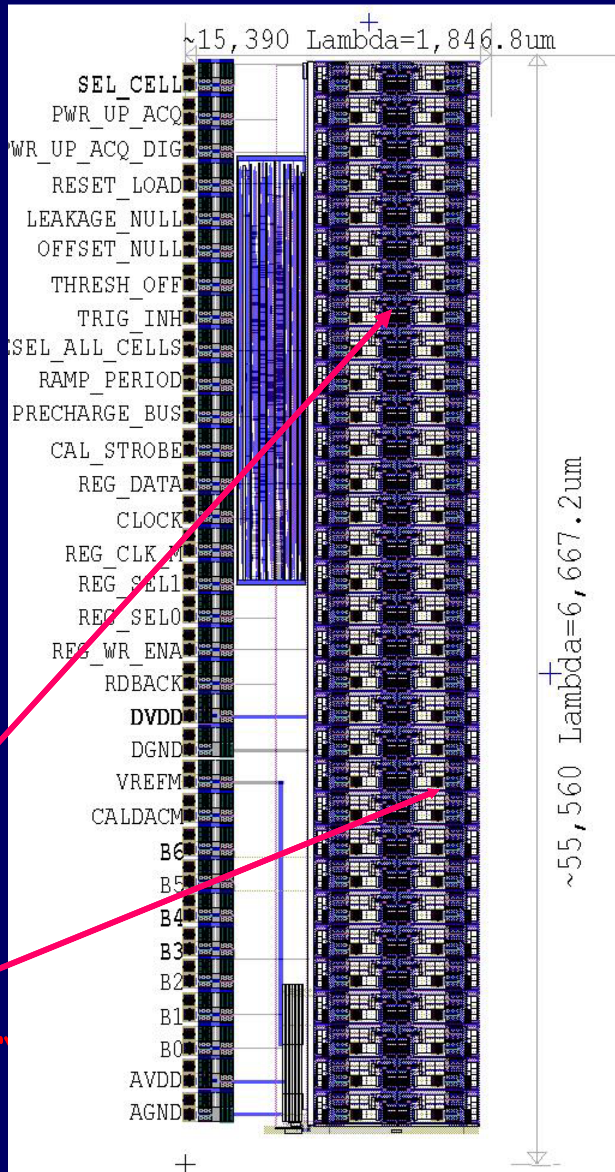
Status: Works! Still reducing ADC noise, but adequate for Ecal



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

2 x 16 Si Strip

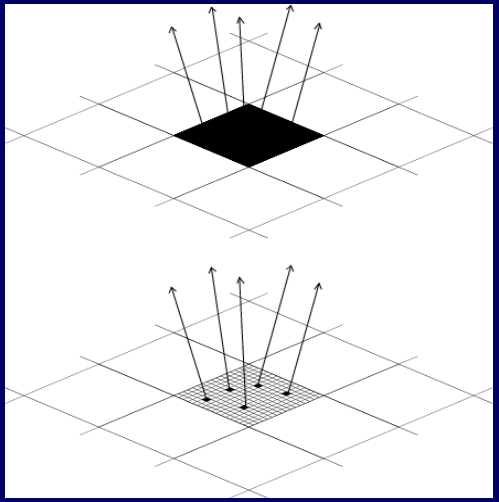
2x16 Calorimetry

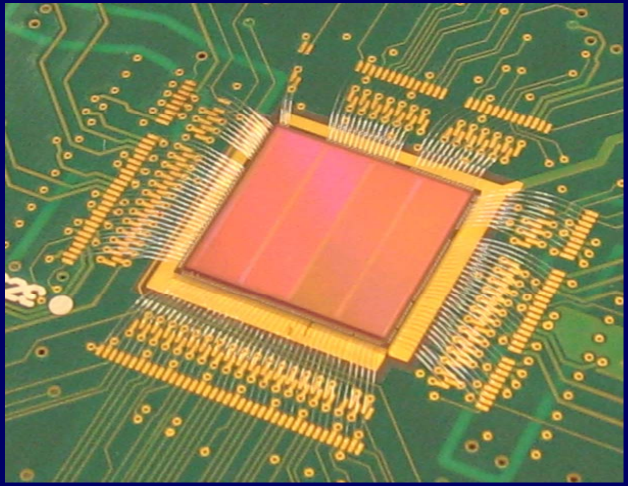


Prototype: 2x32 cells: full: 32x32

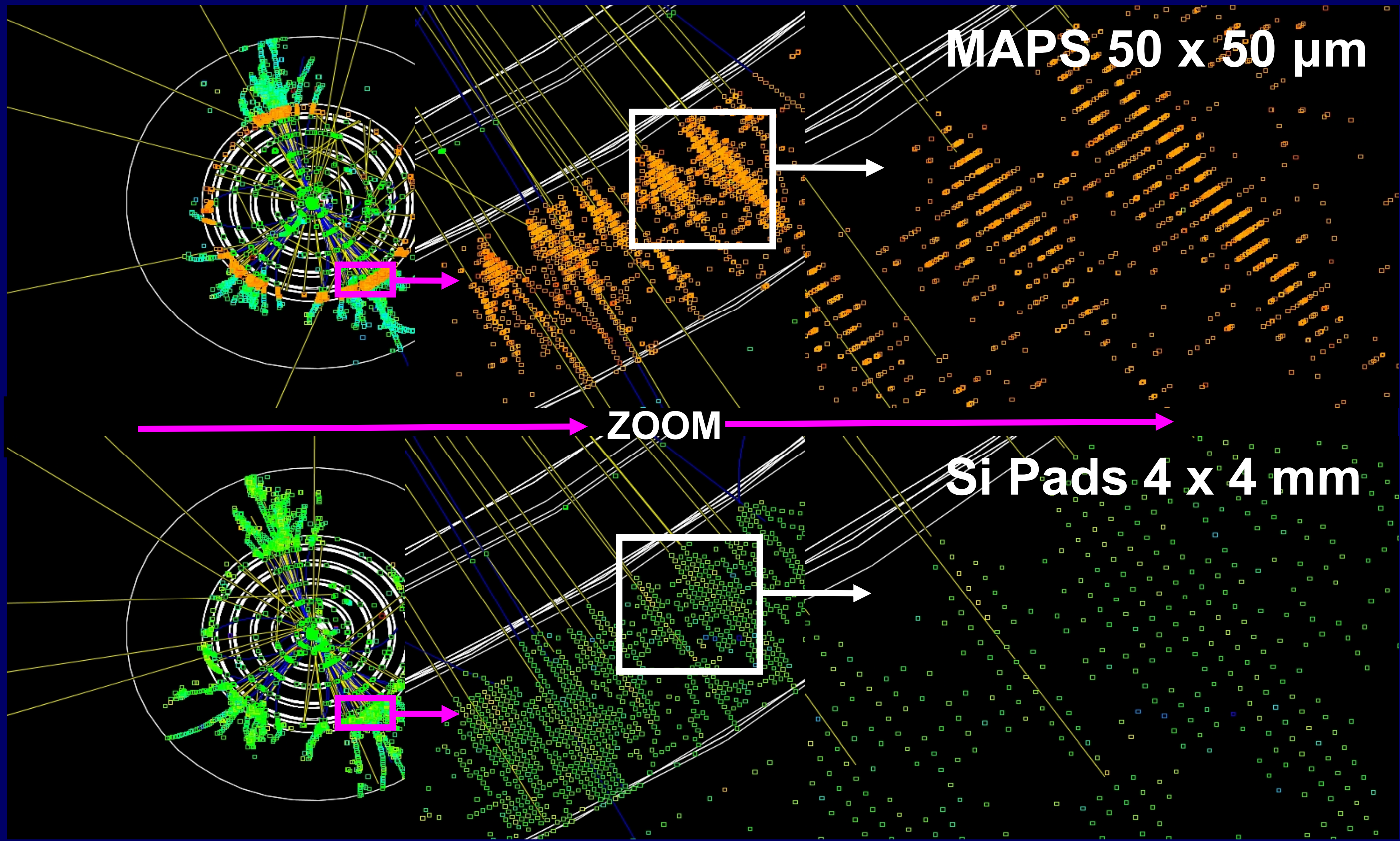
TeraPixel Option for ECAL

- Digital ECAL
  - Operates as a shower particle counter
- Based on MAPS technology
  - Using Deep p-well INMAPS process
  - 50 x50 micron pixels
- First generation sensor TPAC1 has been manufactured
  - 168x168 pixels, 8.2 million transistors

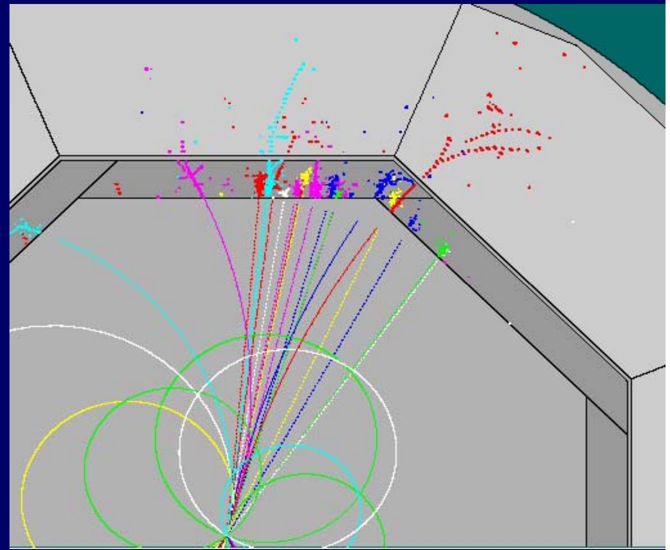




MAPS Showers

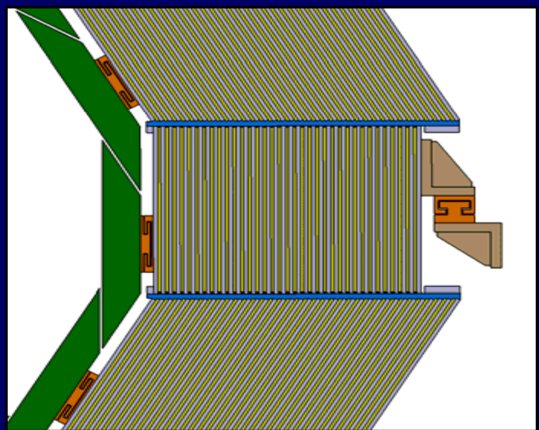


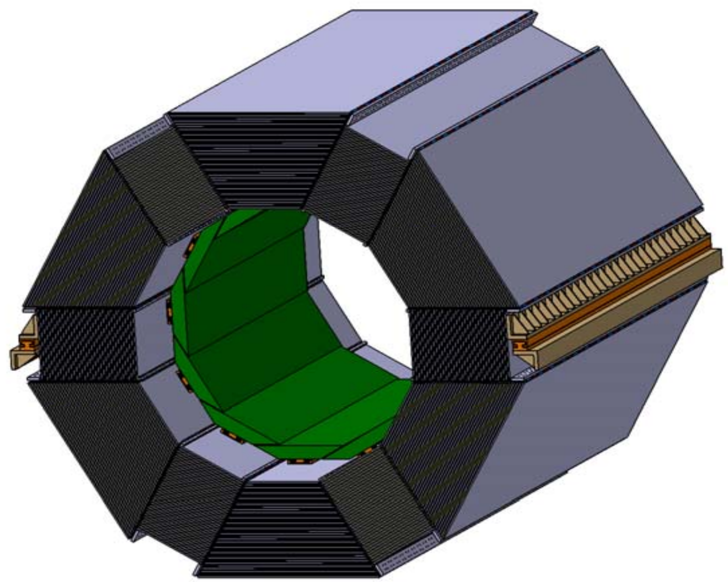
HCAL Requirements



- Isolate neutral hadronic energy from charged particle showers and photons (PFA)
- 1 x 1 cm^2 transverse segmentation
- 40 layers >4λ thick
- $\Delta E/E$ = 60-80 %/$\sqrt{E}$ for neutrals
- Track mips for muon id & PFA

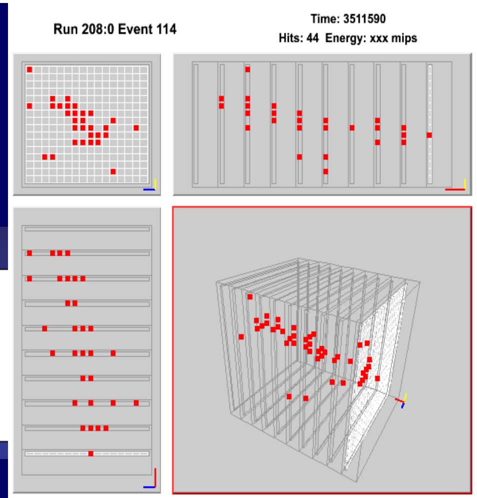
Conceptual Engineering Studies Underway



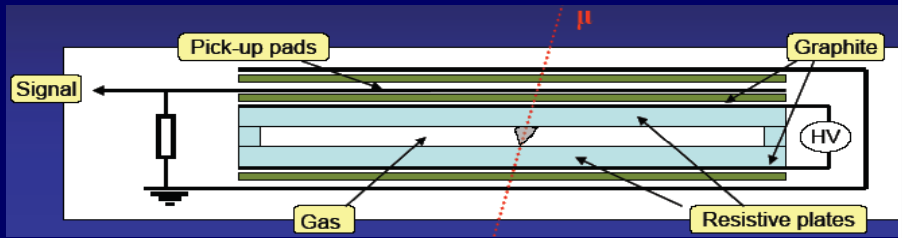


H.Weerts

HCAL Technologies (PFA)



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



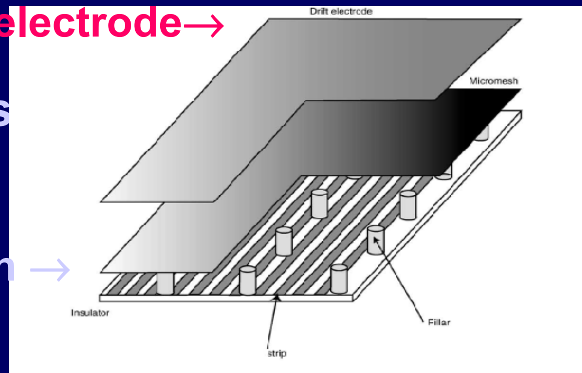
GEMs and μMegas

30 x 30 cm^2 GEM foils

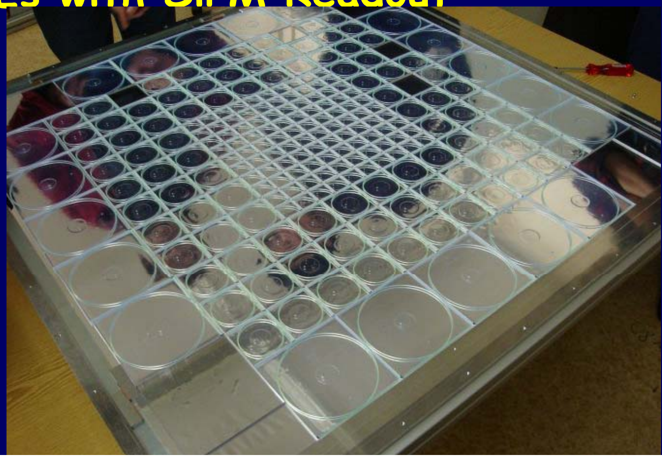
μMegas

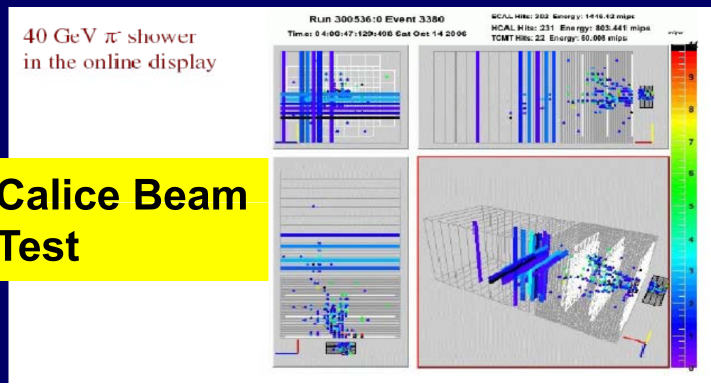
electrode→

μmesh →



SCINT TILEs with SiPM Readout





Calice Beam Test

H.Weerts

Other HCAL technologies

An option (non –PFA based) being considered/pursued is a total absorption crystal based calorimeter using dual-readout.

Simulations being set up.

Implementation of this has consequences for all calorimetry and may impact overall detector design.

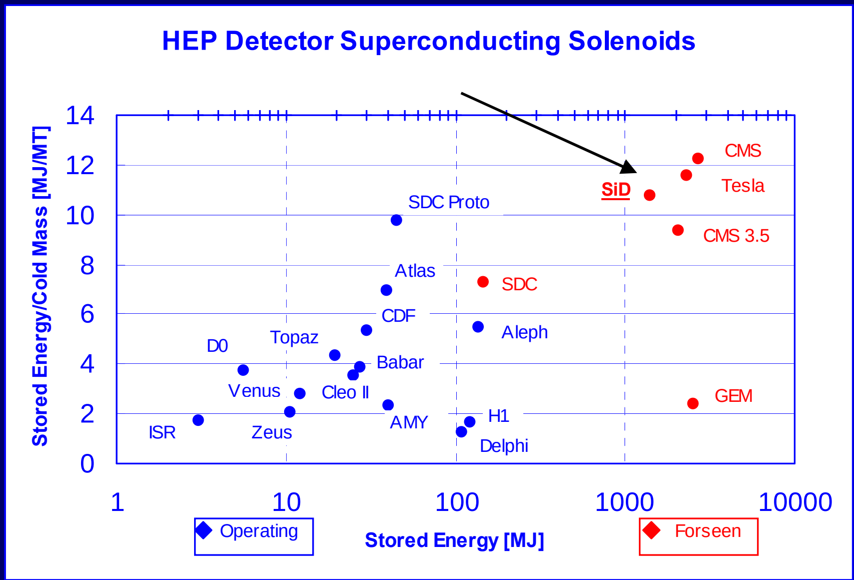
Reasons:

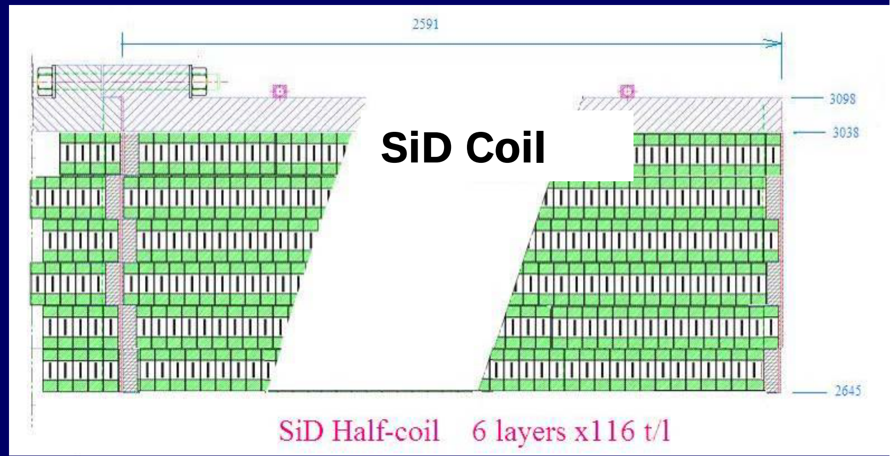
- Backup for a PFA based solution
- May be necessary for required performance beyond 500 GeV

Pursued by “non-PFA” group

Solenoid

- Design calls for a solenoid with B(0,0) = 5T (not done previously)
  - Clear Bore Ø ~ 5 m; L = 5.4 m: Stored Energy ~ 1.2 GJ
    - For comparison, CMS: 4 T, Ø = 6m, L = 13m: 2.7 GJ

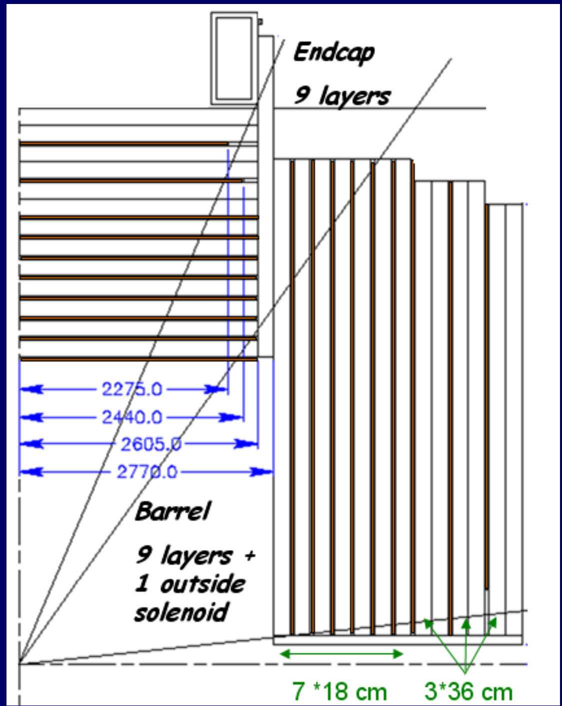




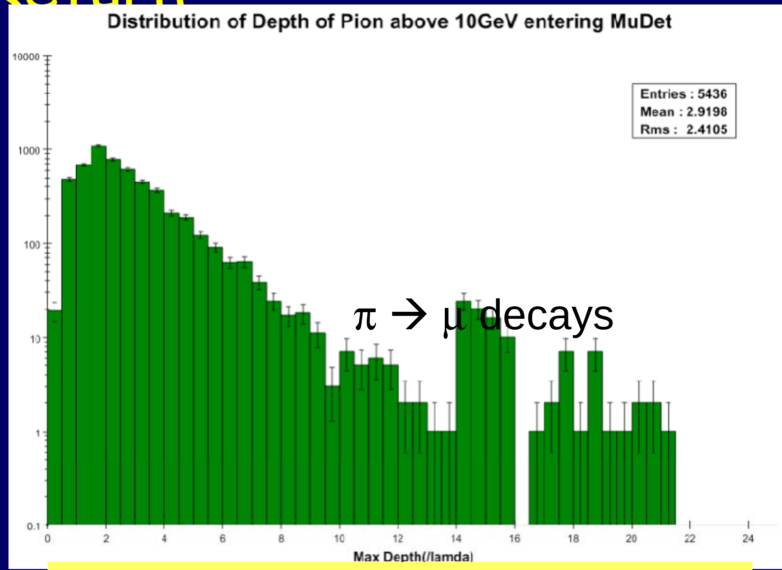
- Full feasibility study of design based on CMS conductor
  - Start with CMS conductor design, but increase winding layers from 4 to 6
    - I(CMS)= 19500 A, I(SiD) = 18000 A; Peak Field (CMS) 4.6 T, (SiD) 5.8
    - Net performance increase needed from conductor is modest

Studies on Dipole in Detector (DID) have been done/are being done as well

Muon / Flux Return

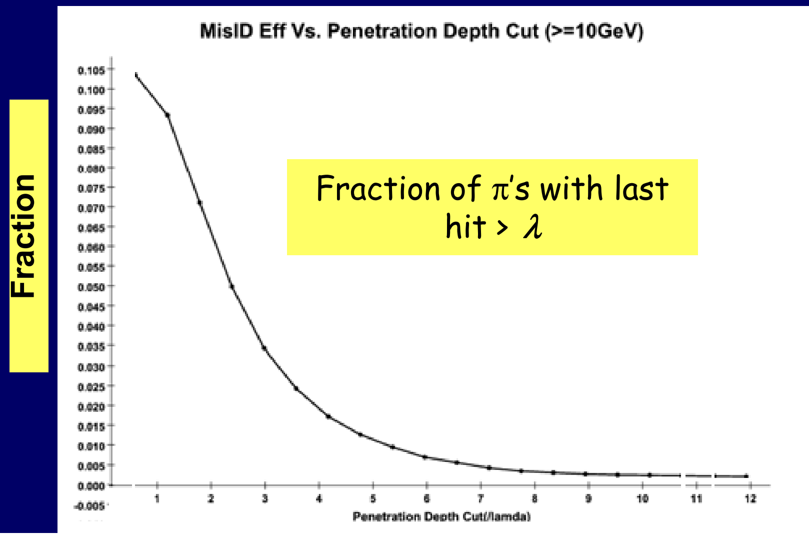


- Steel thickness determined by flux return requirements
- Modest detector resolution needs can be meet by scintillator strips or RPCs
- 9-10 layers
- ECAL + HCAL + Solenoid = 6 λ
- Muon = 14 λ

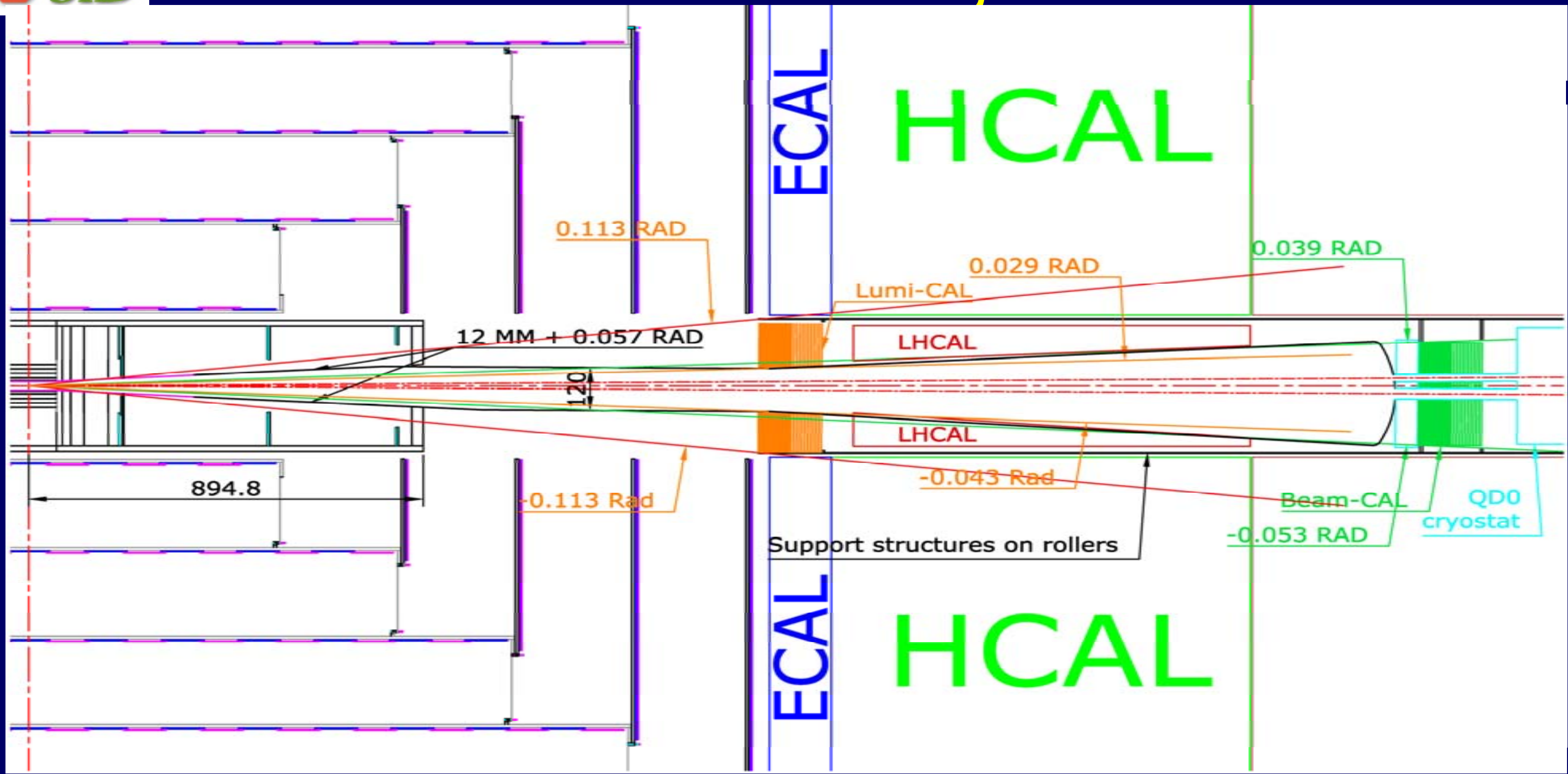


Depth of last hit layer (λ - muon steel only)

- Study of pion return, 10<p<50 GeV/c - flat distribution
- misidentification vs cut on penetration depth in steel flux



Forward region

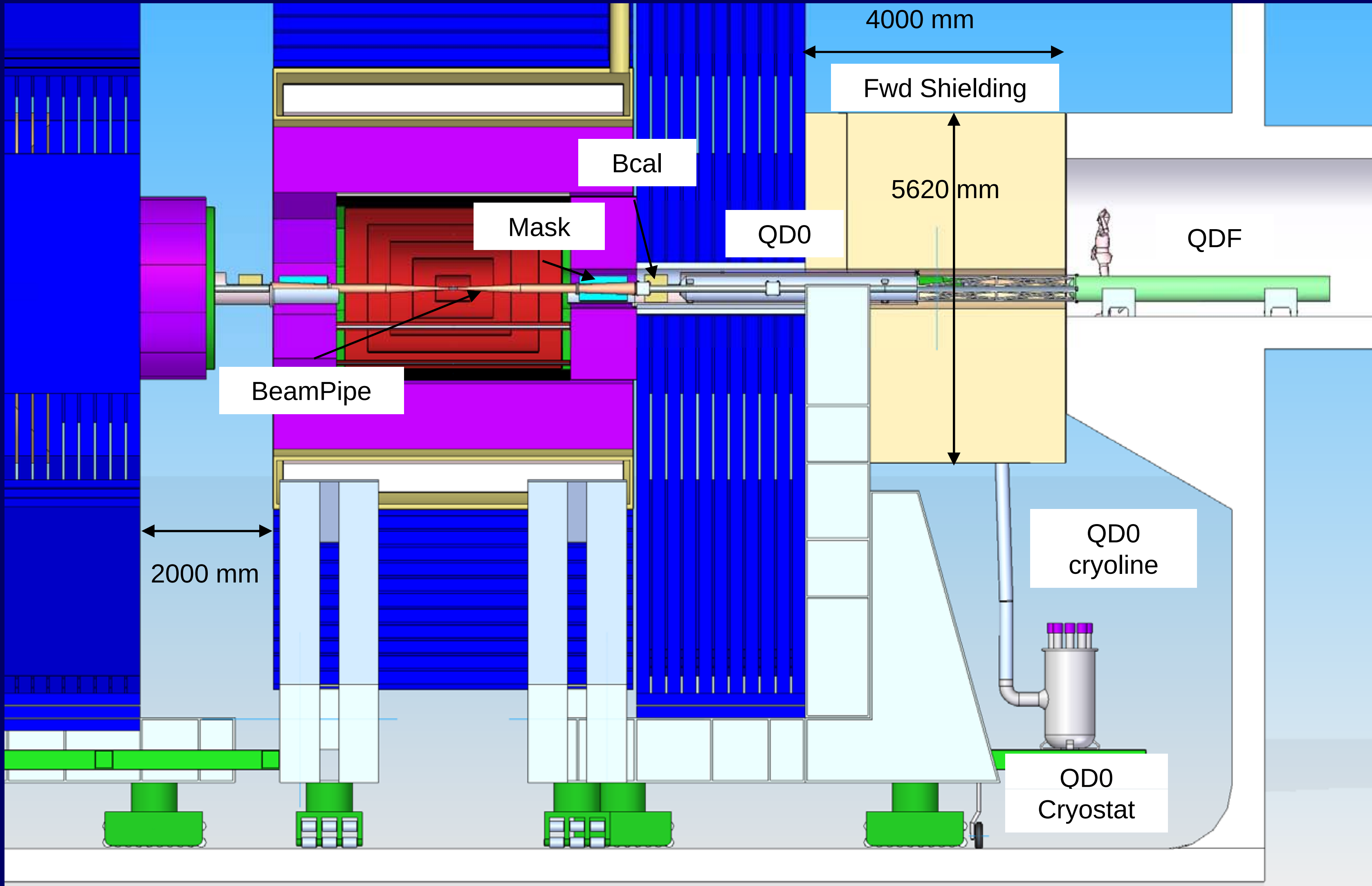


LumiCal inner edge	≈36mrad about outgoing
LumiCal outer edge	≈113mrad about 0mrad
LumiCal fiducial	≈46-86mrad about outgoing
BeamCal outer edge	≈46mrad about outgoing
LumiCal	$30X_0$ Si-W
BeamCal	$30X_0$ rad-hard Si,diamond...

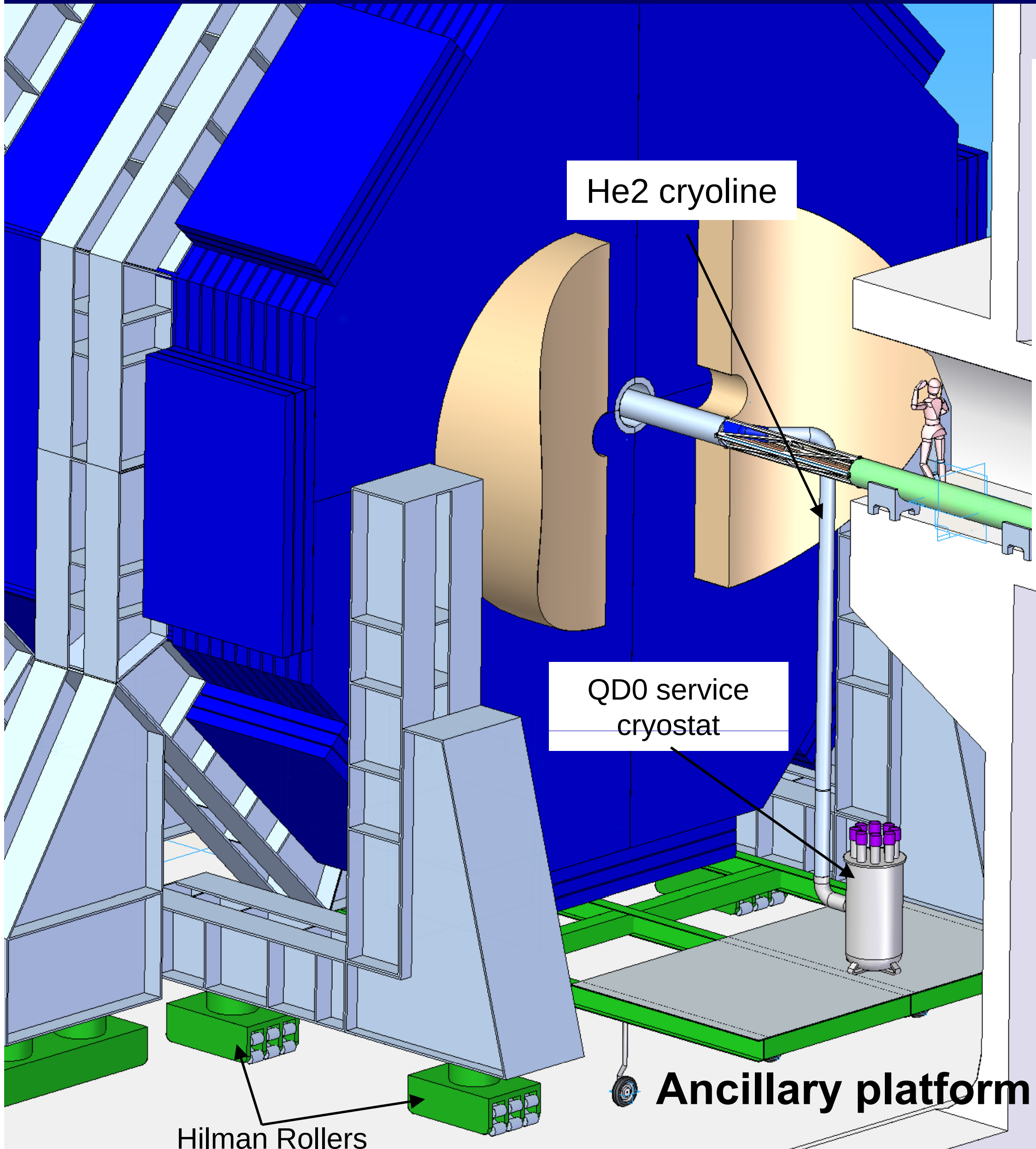
In close cooperation with FCAL collaboration

Machine-Detector Interface

The first step is to translate the parameters in an engineering model, formulating technical solutions, clearances and components integration



Integration of the QD0 cryoline

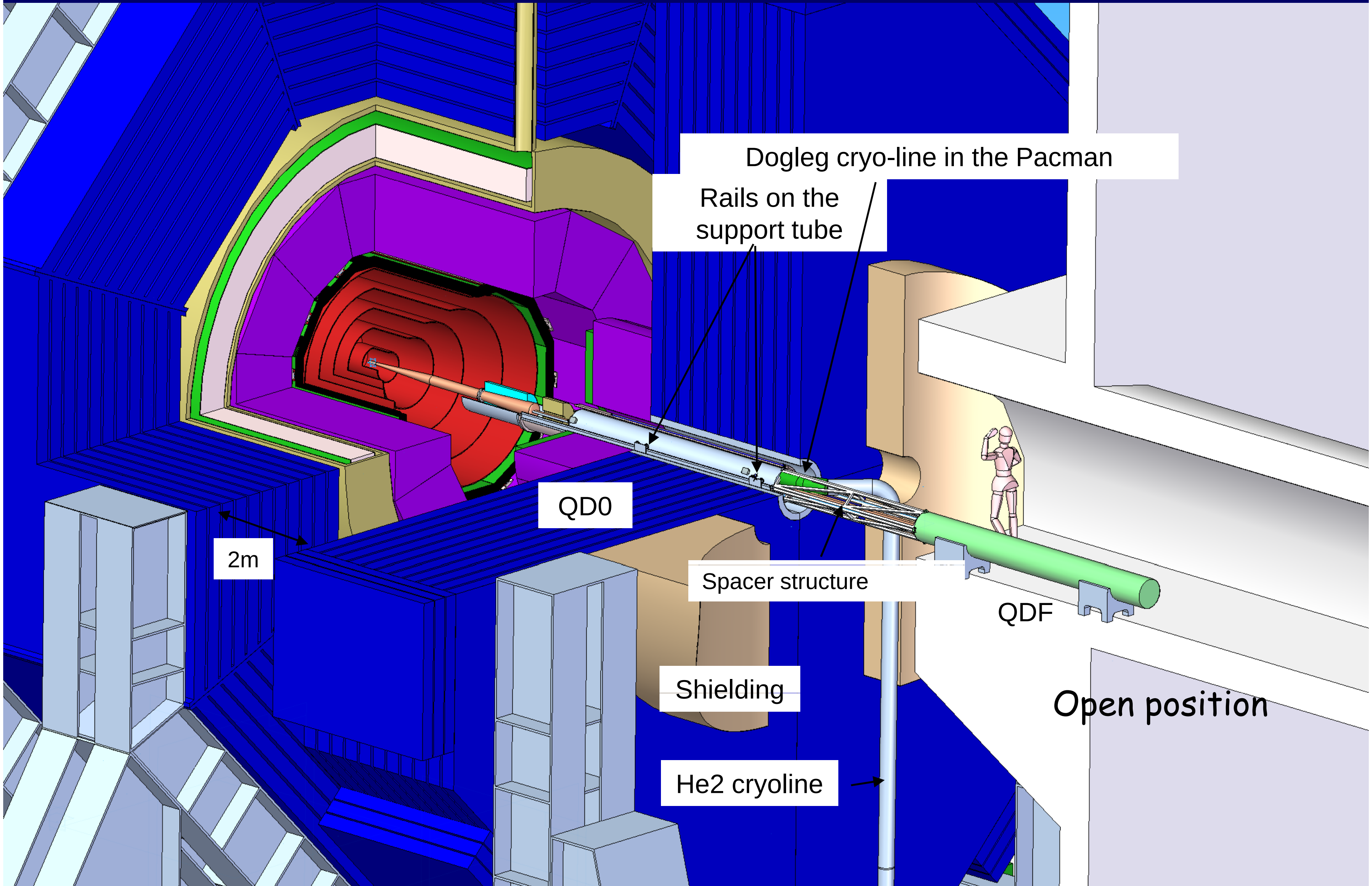


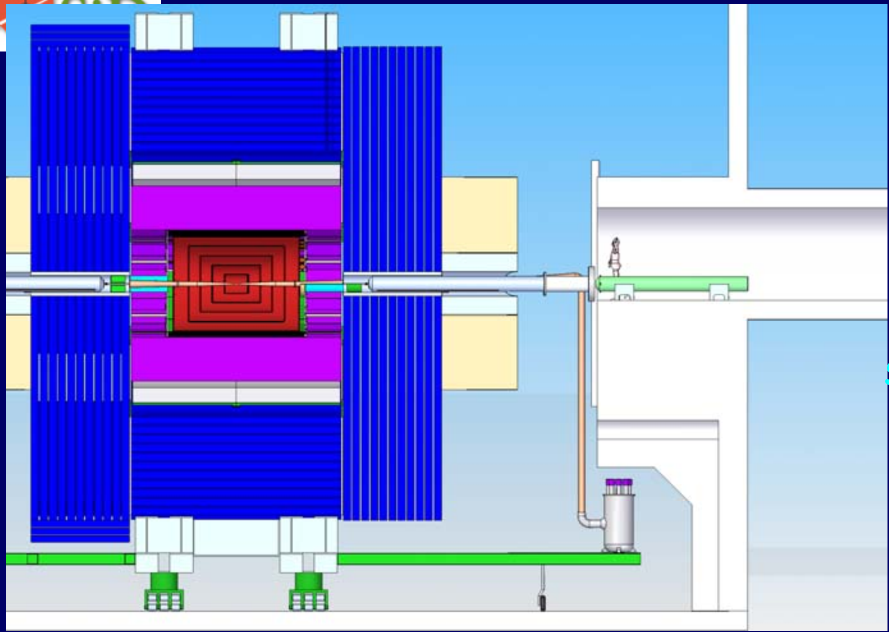
2 m opening on the beam,

1. The QD0 service cryostat on ancillary platform, fixed to the SiD barrel infrastructure
2. He2 cryoline rigid connected to QD0 through the Pacman
3. No relative movement between QD0 and He2 line when door opens.
4. The ancillary platform allows the QD0 cryogenics to travel with detector during push-pull
5. Additional space for racks, controls et al.

Closed position

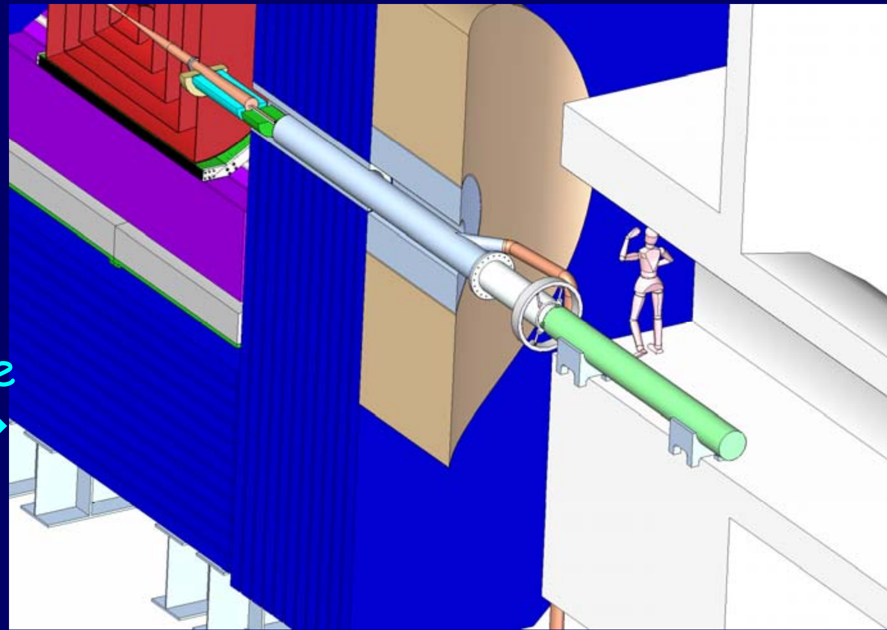
2m Door opening Procedure, on the beam



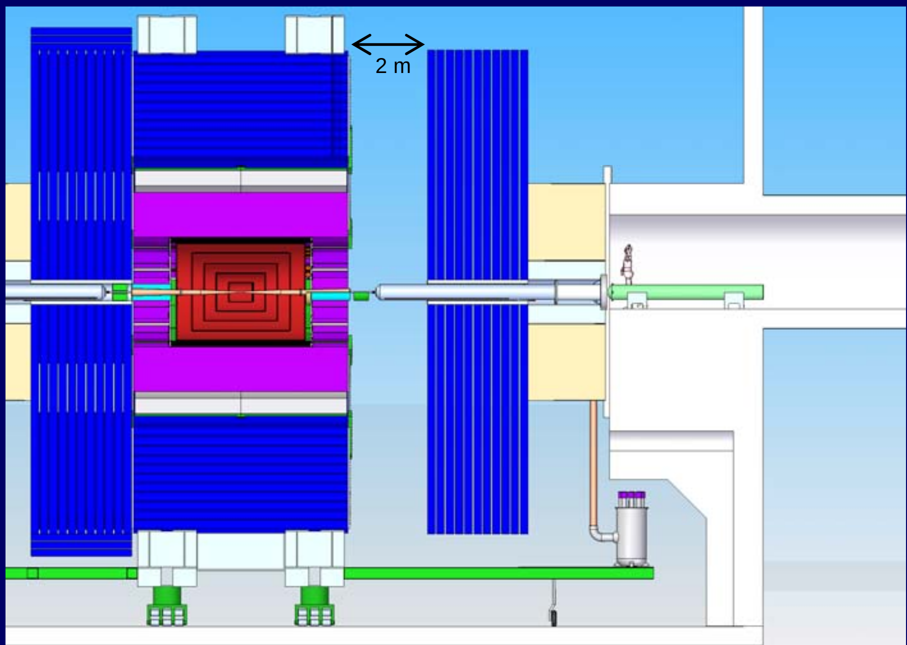


Close Position

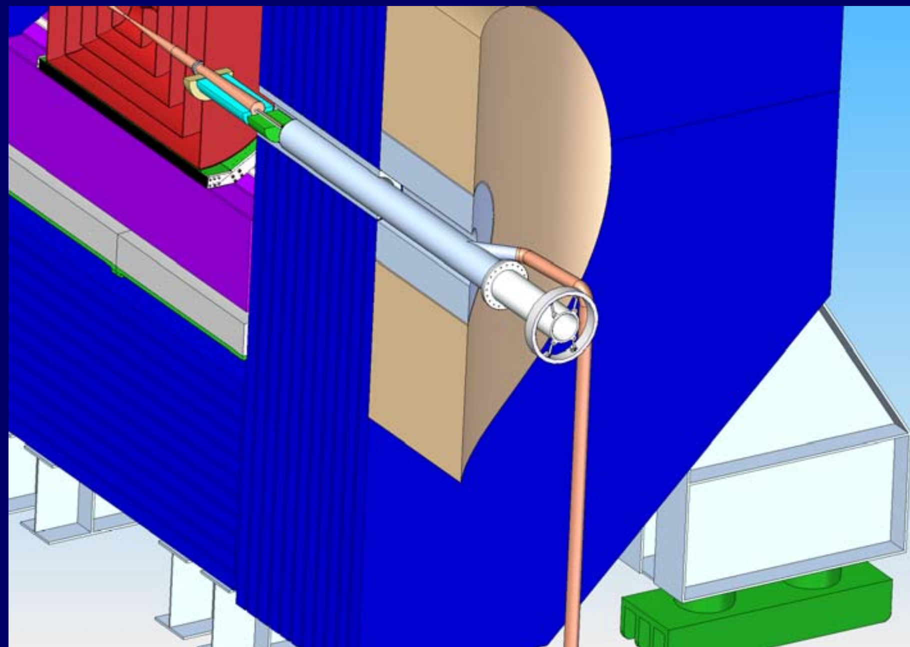
same ↔



Close Position on the beam

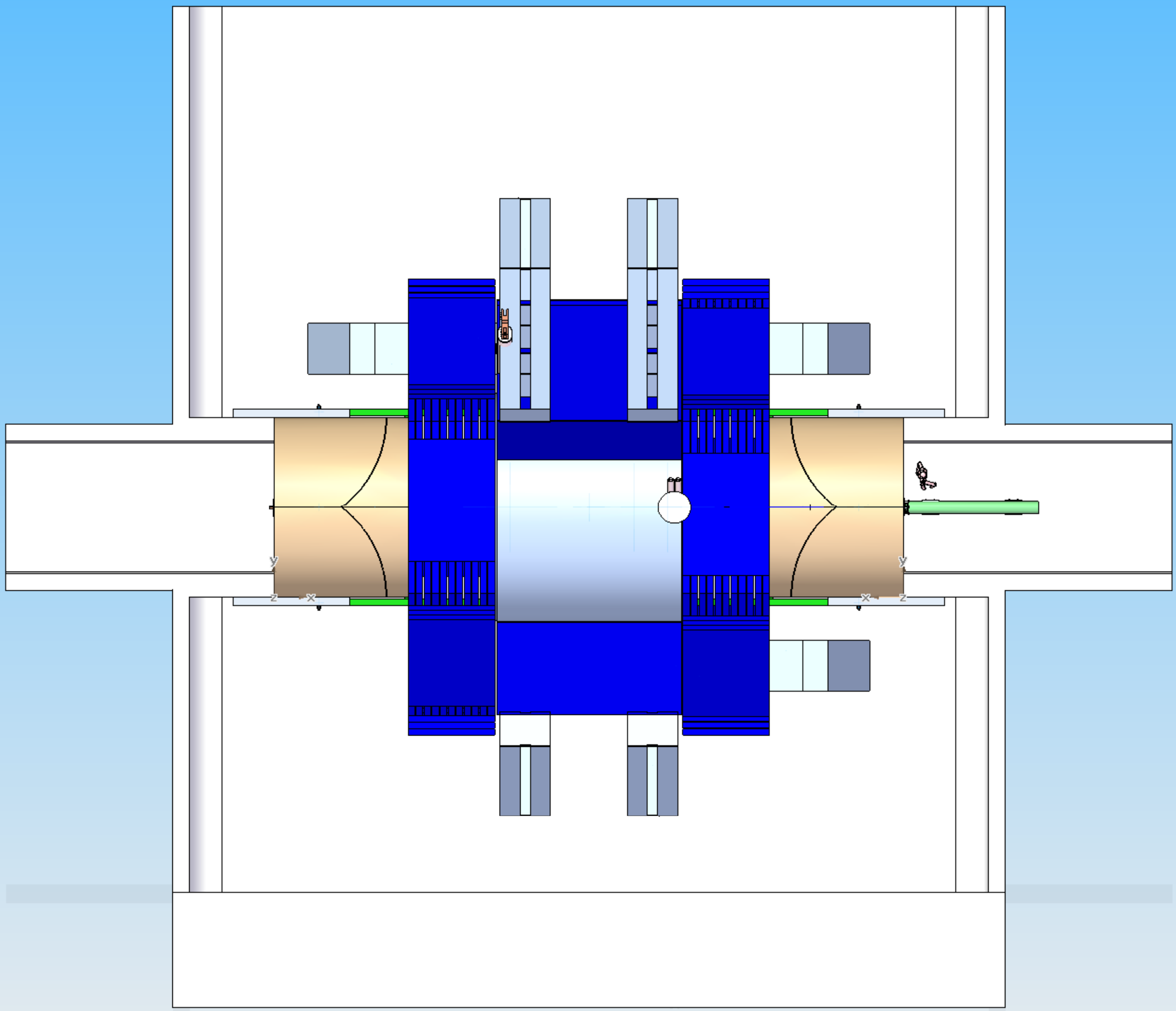


2 m Open Position

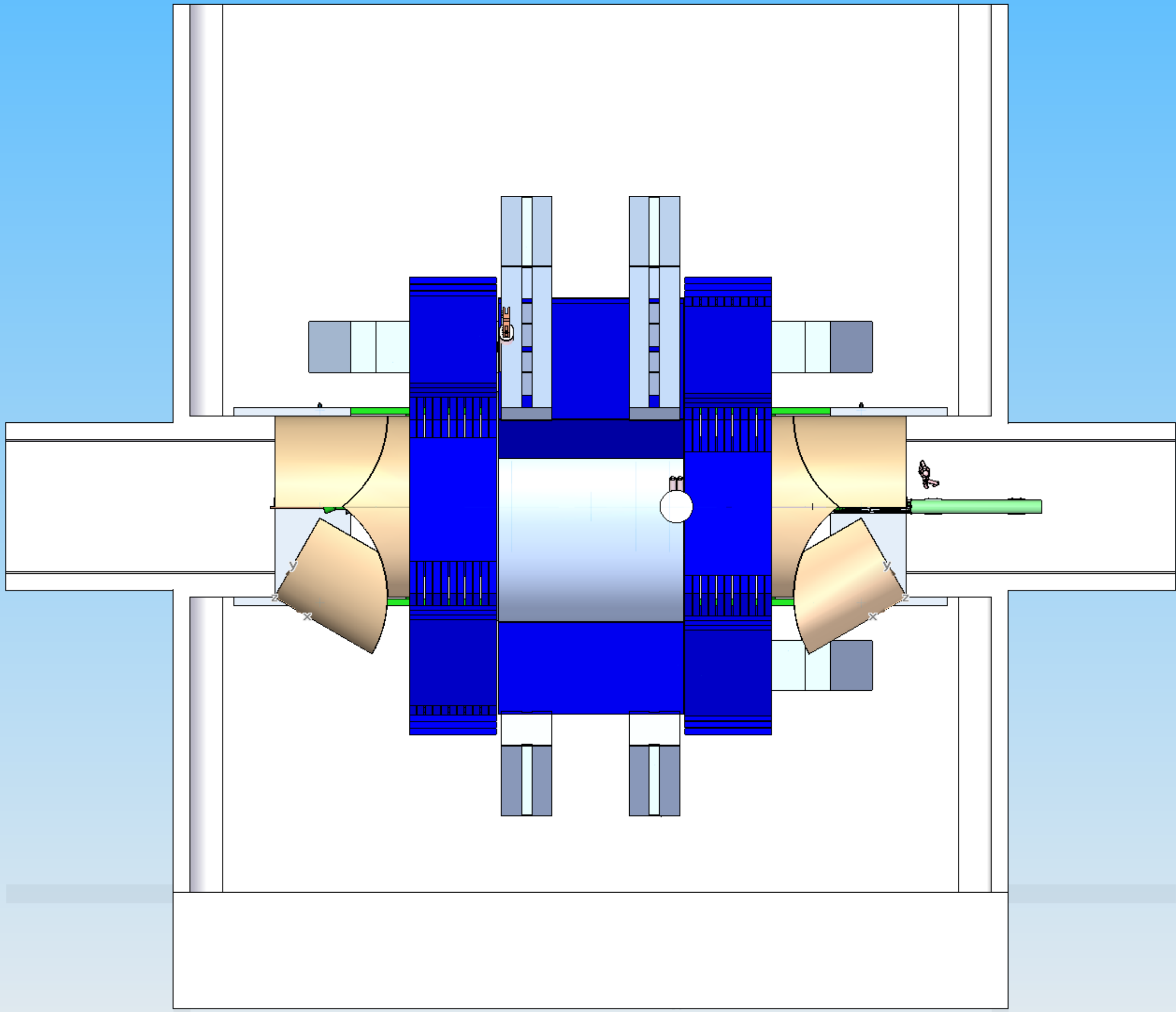


Close Position off the beam

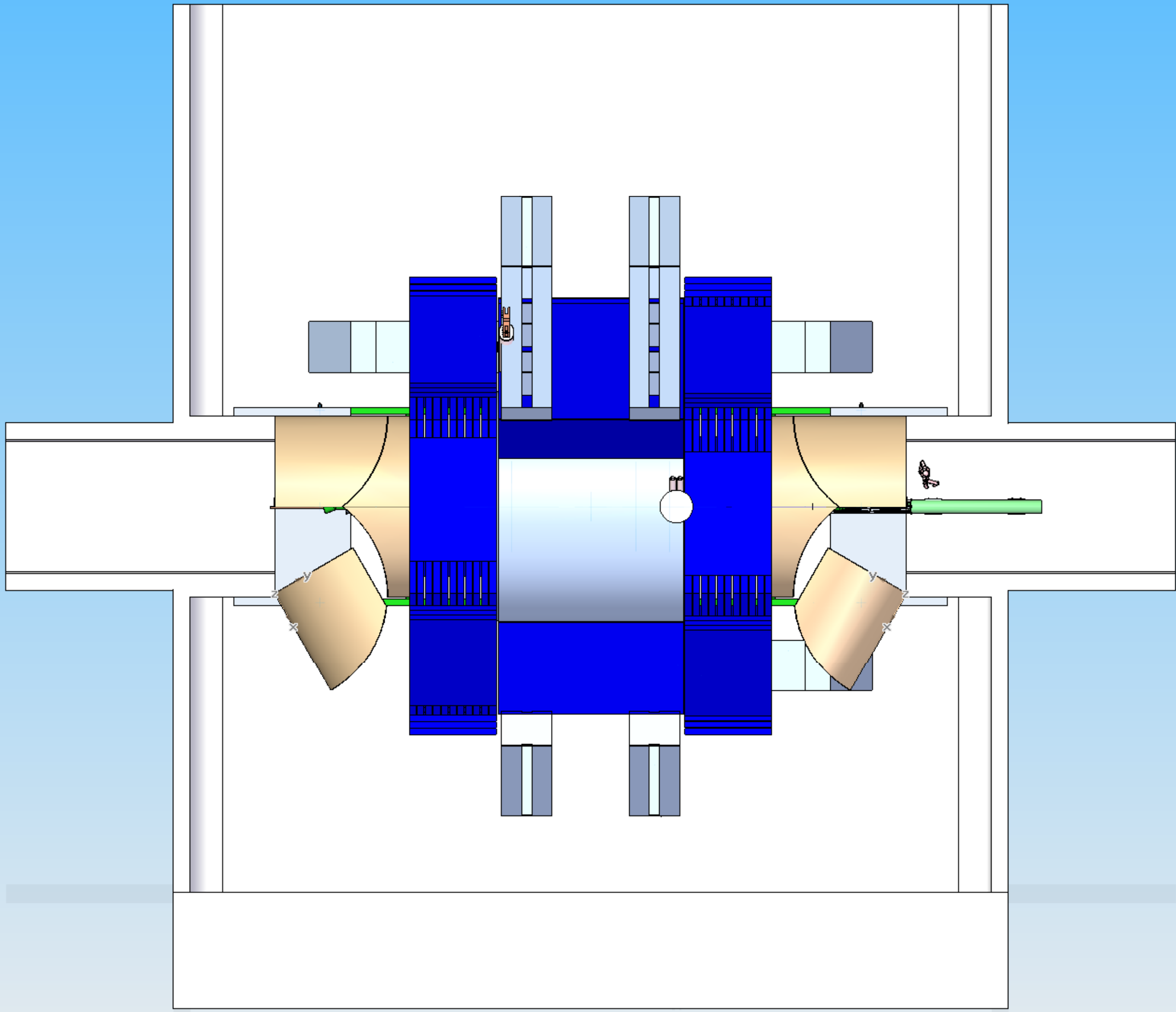
Opening Shielding



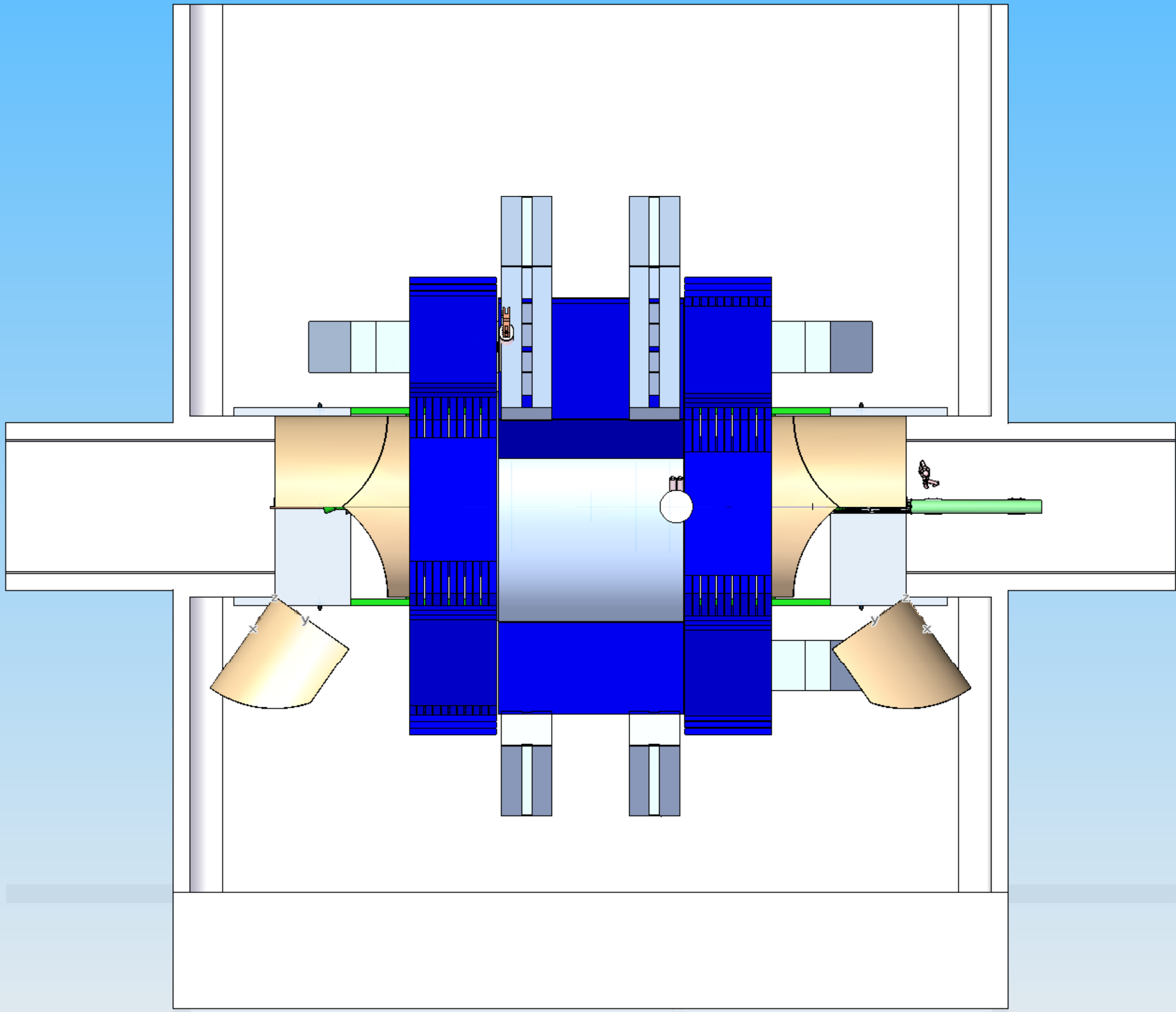
Opening Shielding



Opening Shielding



Opening Shielding



Software

Simulation & Analysis structure easy and flexible   Org.lcsim

Easy interface to define detectors and defined at run time

Several simulated versions of SiD available

Tutorials available on WEB, just need users

Analysis based on JAS3: Java Analysis Studio 3

None of results shown here and in parallel possible without this.

Dashboard > Linear Collider > ... > lcsim Tutorials > lcsim Getting Started

Linear Collider

lcsim Getting Started

View | Info

Added by Jeremy McCormick, last edited by Jan Strube on Jun 27, 2007 (view change)
Labels: (None)

Getting Started with org.lcsim

Basic Installation

- Installing Java
- Installing JAS3 and Plugins

Using the Tools

- Using the LCSim Event Browser
- Using the Event Display

Processing Events

- The Students' Getting Started Guide
- Processing Events using the Analysis101 Sample Driver
- Explanation of Analysis101 Driver
- Creating a Driver using JAS3

Accessing Event Data

- SimTrackerHit Data

More Tutorials

- See also the full list of org.lcsim tutorials.

PFA performance & Optimization I

Area of very active study & work in SiD.

Goal: Have PFA algorithm allowing variation of detector parameters to determine optimal detector configuration with right balance of physics performance & cost

Have and still are developing SiD PFA algorithm as part of a template structure that allows the study the steps inside the algorithm and go from " a perfect type detector" to a realistic detector.

Problem: Performance of current algorithms such that they are not sensitive to variations in detector design.

Global Parameters to be studied:

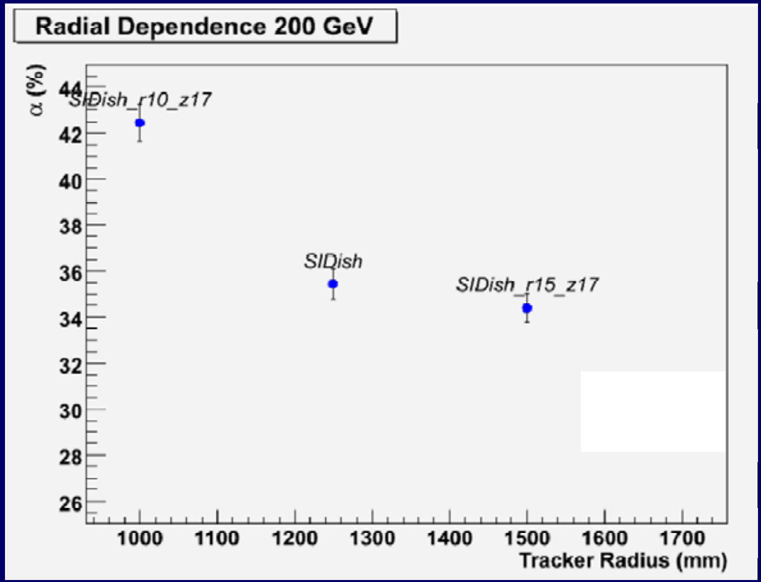
- B field
- Outer tracking radius (R)
- Length of barrel region (aspect ratio, Z)
- Depth of HCAL
- Segmentation in ECAL & HCAL

Started effort several months ago to implement a SiD like detector in PANDORA, called SiDish. (PANDORA has the required performance for LDC detector)

(more details in talk by M.Stanitzki)

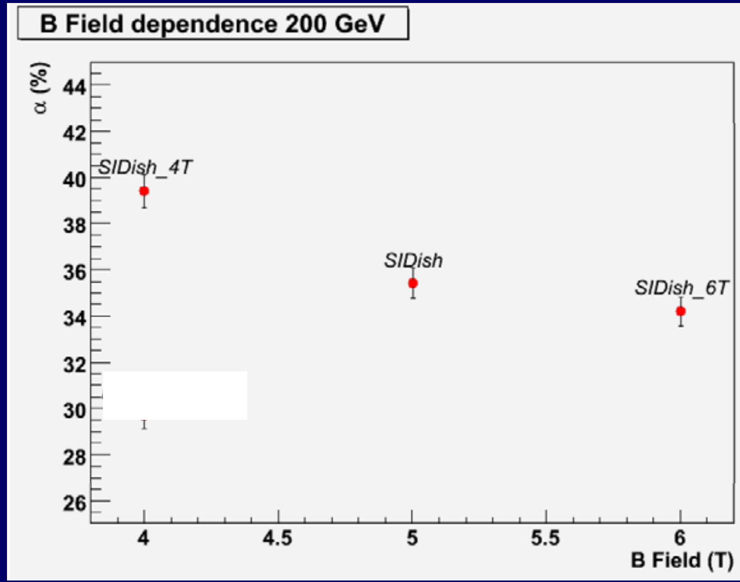
PFA performance & Optimization II

Pandora results at Z pole and at 200GeV qq final state.
Pick 200GeV to emphasize results



α vs. outer tracking radius

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



α vs. B field

More results on ECAL & HCAL segmentation, HCAL depth and length of barrel region. (more results in talk by M.Stanitzki)

Use these results to convert to physics performance vs cost.

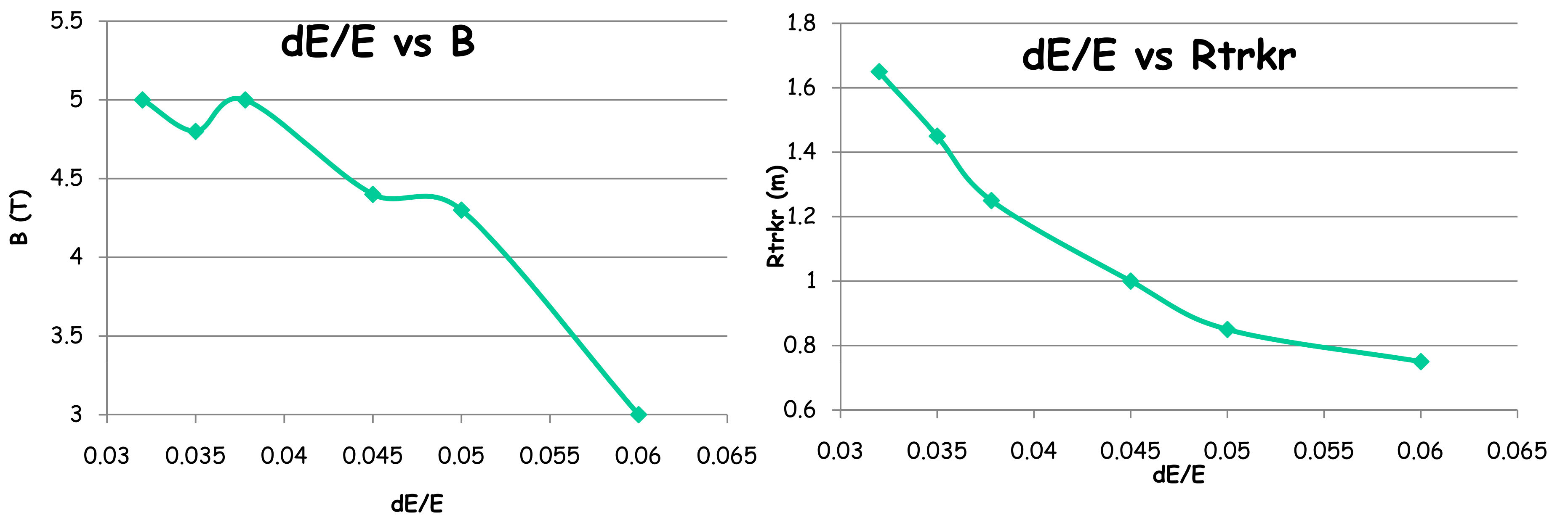
Optimization Model (an illustration)

This is outline of plans to optimize the detector.

(many caveats and under development).

Ingredients:

- Have cost model for detector, cost vs. parameters (B,R)
- Use performance of jet resolution vs. B and R as given by Pandora in an earlier version at qq at 180GeV
- Determine physics precision dependence on jet resolution (benchmarking group, fast MC)



Use ZHH final state (Benchmarking results)

Analysis must be redone with $\frac{\Delta E_{jet}}{E_{jet}}$ that reflects current PFA status.

For now replot triple Higgs coupling error vs. $\frac{\Delta E_{jet}}{E_{jet}}$ using existing results with $\frac{\Delta E_{jet}}{E_{jet}} \equiv \frac{\alpha_{90}}{\sqrt{80}}$

$BR(H \to b\bar{b}) = 0.678$

$e^+e^- \to ZHH$

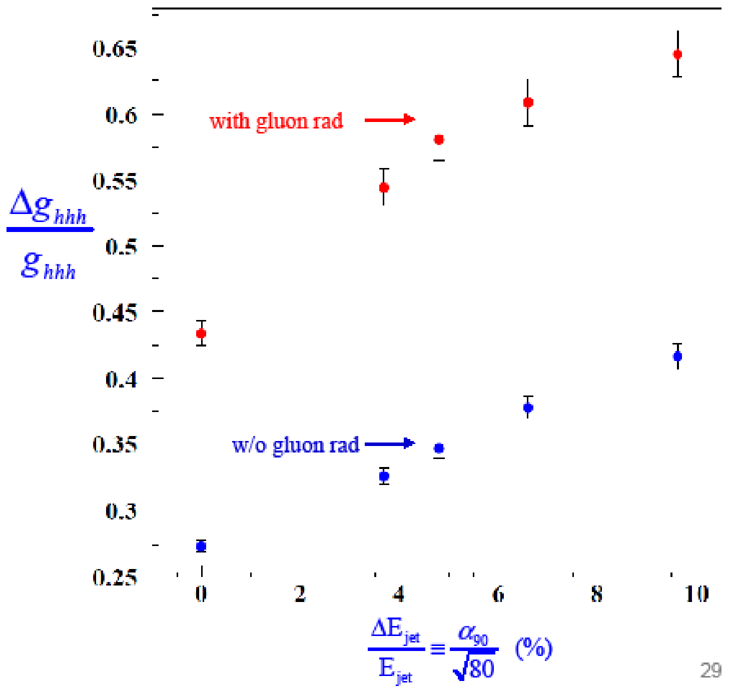
$\to qqb\bar{b}b\bar{b}$

$\sqrt{s} = 500\ GeV$

$L = 2000\ fb^{-1}$

$\Delta E_{jet}/E_{jet} = .067 \to .033$

equiv to $1.4\times$ Lumi



Use fast MC to realte error in triple Higgs coupling to jet resolution (Benchmarking)

Use jet resolution vs. R and B get R and B parameters. Use cost model to convert to $'s.

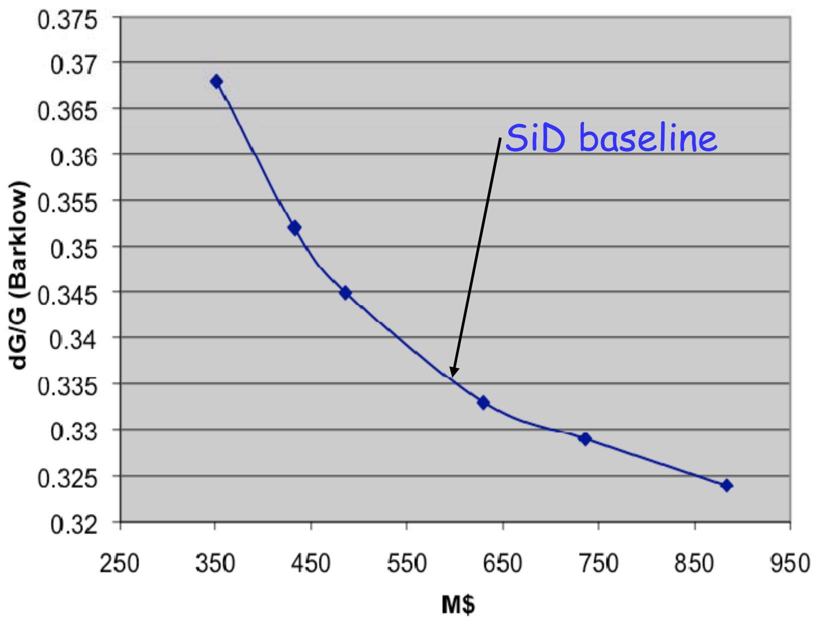


Illustration of what plans are.

H.Weerts

SiD plans for LOI

Time line for LOI

Date	Milestone	
4/09	**Submit LOI**	
3/09	**Begin Final Edit of LOI;** complete authorlist	
2/09	**Complete LOI Draft** Collaboration Review and Comment	
01/09	**Results available**	
	Generation/Reconstruction & Analyses	10/08- 01/09
8/08	**GEANT4 Description Ready** Performance Studies Ready Benchmarking Studies Ready	Start production
6/08	**First pass Global Parameters (baseline)** SubSystems Fully Specified	now
	Subsystem Technologies/Alternates Selected Conceptual Designs Ready	
	First Pass Global Parameters Develop all analyses (benchmarking) Optimization studies	
01/08	**Subgroup Plans Defined** Milestones and Deliverables Manpower Resources Needed	

SiD R&D: activities

R&D collaborations:

Some R&D for ILC detectors is being done in specific R&D collaborations.
Examples: CALICE calorimetry, LCTPC for TPC, SILC for silicon strips

SiD R&D part of "R&D collaborations":

- HCAL: DHCAL RPC and GEM developments (CALICE)
- Sensor development for Vertex detector (all connected worldwide)
- Si tracker connections with SILC
- Total absorption/"dual readout" calorimetry
- Scint. Strips for muon system

SiD specific R&D:

- ECAL development
- KPIX development is unique
- Si tracker R&D , SiD specific (KPiX implementation)
- Solenoid (SC cable development; not on going yet)

Many connections; not easy to put on slide.........

In general in SiD it is felt that R&D should be driven by concept. Few R&D areas are really generic.

Region dependent funding

Some guidance/direction would be useful

SiD R&D needs

R&D area	Covered by
VXD sensor development	Worldwide efforts, some coherence
Si tracker	Mostly in SiD
ECAL	SiD; SiD specific
HCAL, several technologies: Scint, DHCAL, RPC, GEM, μmegas	All SiD participants are in CALICE
Total absorption cal.	Somewhat independent; connected to SiD
Solenoid design & development	Not clear where ultimately
Muon system (RPC, scint)	Part generic/part SiD
Software	SiD

Some/more coordination through Research Director office ?

Summary

SiD is defined based on some clear assumptions & guidelines

Assumptions underlying SiD concept:

- PFA based concept
- Integrated design of complete detector
- Robust in ILC operations (beam losses)
- Cost constrained optimized design

SiD has structure and people in place to produce the LOI

Have been working together for several years

LOI is currently driving all activities in SiD

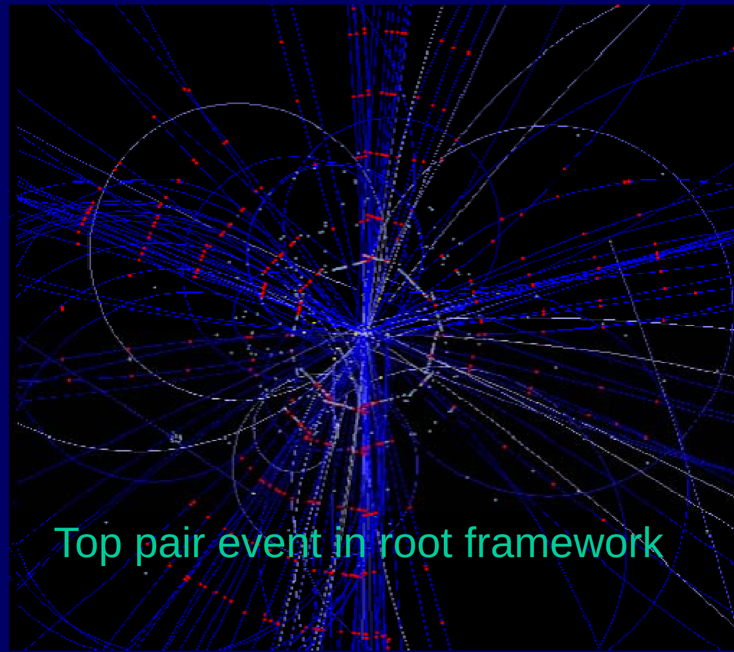
SiD will submit a LOI in time line requested.

Looking forward to working with RD and IDAG

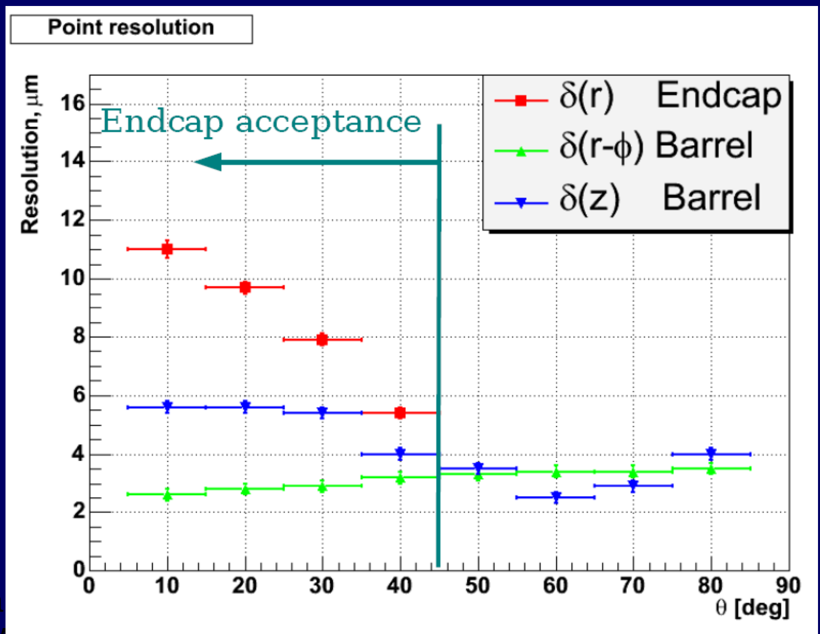
The End

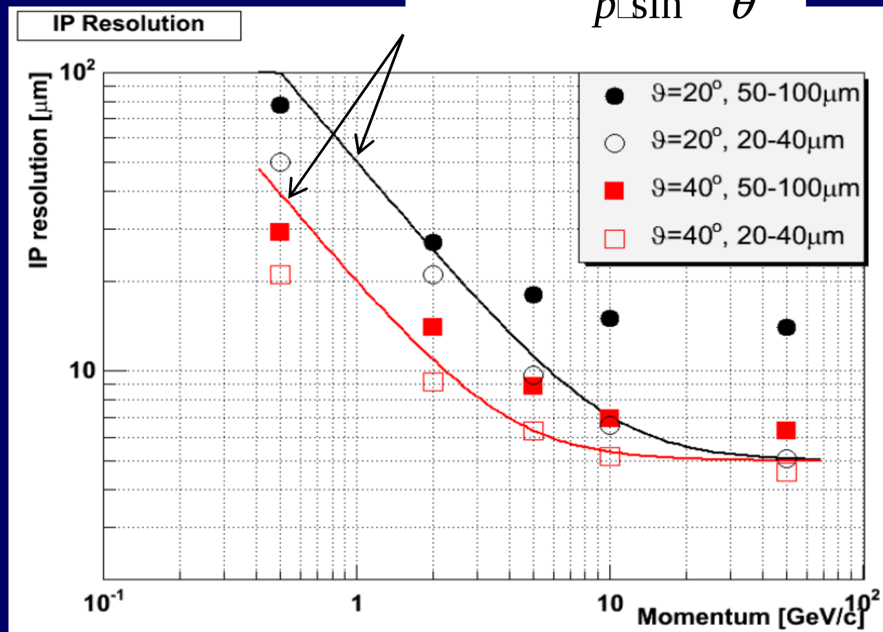
Simulation

- Incorporated SiD geometry into LCFI framework
  - Uses LCIO to transfer from org.lcsim to Marlin
- Optimize the disk/barrel system with realistic material and benchmark physics
  - Studies of interplay of disks and barrel pixel size, resolution and occupancy (A. Raspereza)
  - Building detailed models of cabling and material



$$\sigma(ip) = \frac{5\mu m \oplus 10\mu m}{p \sin^{3/2}\theta}$$





Summary: Technical Strengths
(Leave to more expert talks)

Concentrate LOI

- Generally: compact, highly integrated, hermetic detector
  Bunch by bunch timing resolution
- Tracking:
  - VTD: small radius (5T helps)
  - Tracker: excellent dp/p; minimized material all cos(θ)
  - Demonstrated pattern recognition
  - Solenoid: 5T (difficult but not unprecedented)
- Calorimetry: imaging, hermetic
  - ECAL: excellent segmentation=4x4 mm^2, $R_{Moliere}$=13mm
  - HCAL: excellent segmentation: ~1x1 to 3x3 cm^2
  - Working on PFA performance
- Excellent μ ID: Instrumented flux return & imaging HCAL
- Simulation: Excellent simulation and reconstruction software
  - Results shown only possible with that

SiD Highlights

- Solenoid 5T. Follows CMS design. Feasible.
- VXT 5T Field allows smallest beam pipe radius, best resolution. Endcap design maximizes Ω, improves resolution for forward tracks.
- Tracker Si is robust against unwanted beam backgrounds. Si is "live" for only one bunch crossing, which minimizes occupancy and physics backgrounds. Si precision + 5T magnet gives superb momentum resolution.
- ECAL Si/W has good resolution (ΔE/E~ 17%), superb transverse and longitudinal segmentation.
- HCAL RPC? GEM? Scint? Moderate resolution (ΔE/E~ 60-80%) excellent segmentation for PFA.
- Cost Constrained, balanced with physics performance.

Strip-scintillator Muon Det. R&D

- MAPMT R&D published @ lcws2007: 64 ch H7646B R.O. w/1.2mm ϕ WLS/Clear fiber
- Multi-pix Si-APD studies:

  S10362-11-100U, ~100 devices

  100, 400, 1600 pixels;

  MPPC studies with pulsed photo-diode & X10 pre-amp

  to measure:

  - I vs.V, Gain, Noise vs. Temp.
  - 1 m long strip scint + 1.2mm ϕ WLS fiber X 10 Amp w/Bi^{208} source and cosmic rays.