SiD
On the Road to the DBD

Marcel Stanitzki
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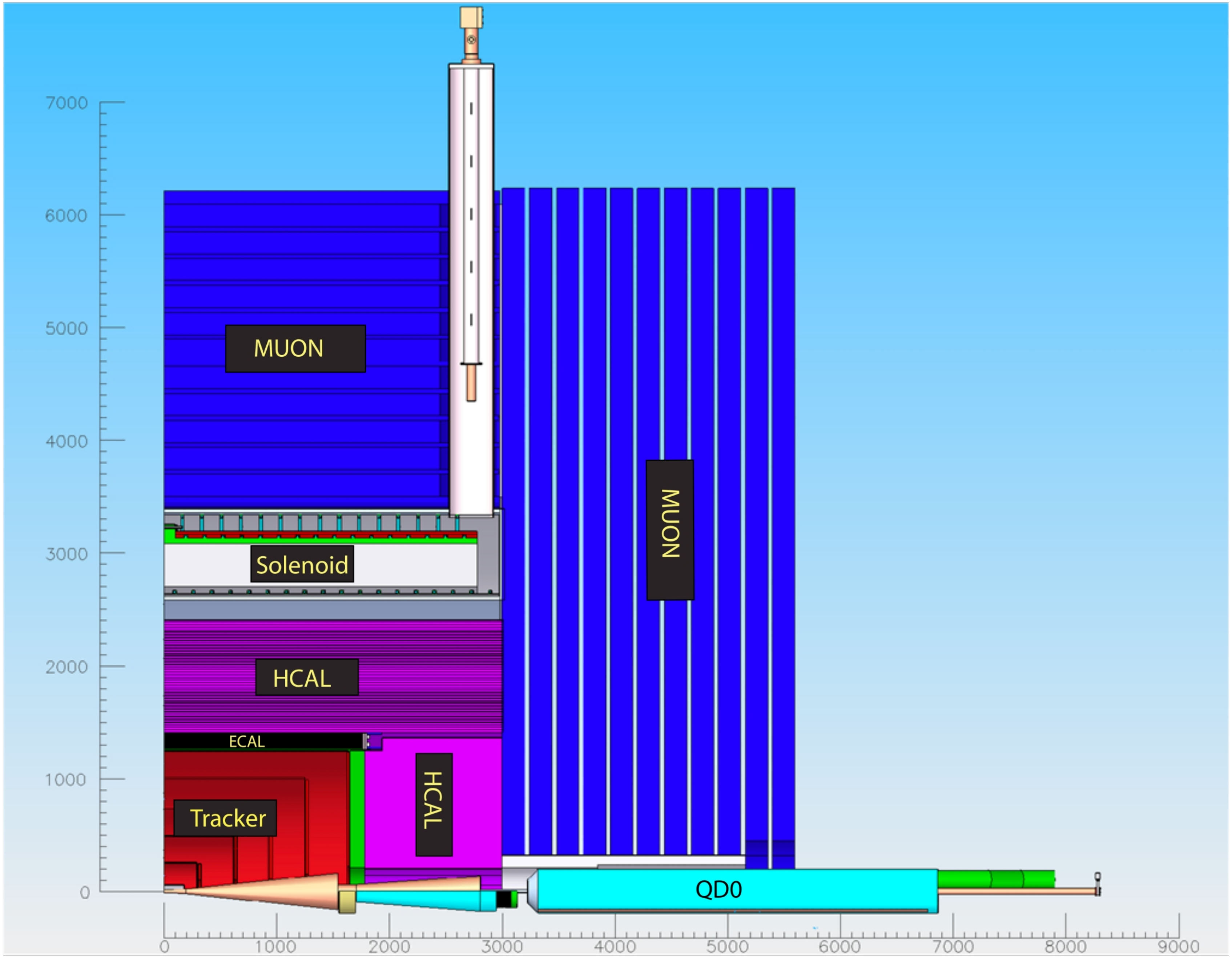
on behalf of the
SiD Detector Concept

ALCPG 2011, Eugene, OR
19.03.2011

SiD Detector overview

- SID Rationale
  - *A compact, cost-constrained detector designed to make precision measurements and be sensitive to a wide range of new phenomena*
- Design choices
  - Compact design with 5T field.
  - Robust silicon vertexing and tracking system with excellent momentum resolution
  - Time-stamping for single bunch crossings.
  - Highly granular Calorimetry optimized for Particle Flow
  - Iron flux return/muon identifier is part of the SiD self-shielding
  - Detector is designed for rapid push-pull operation

The SiD Detector

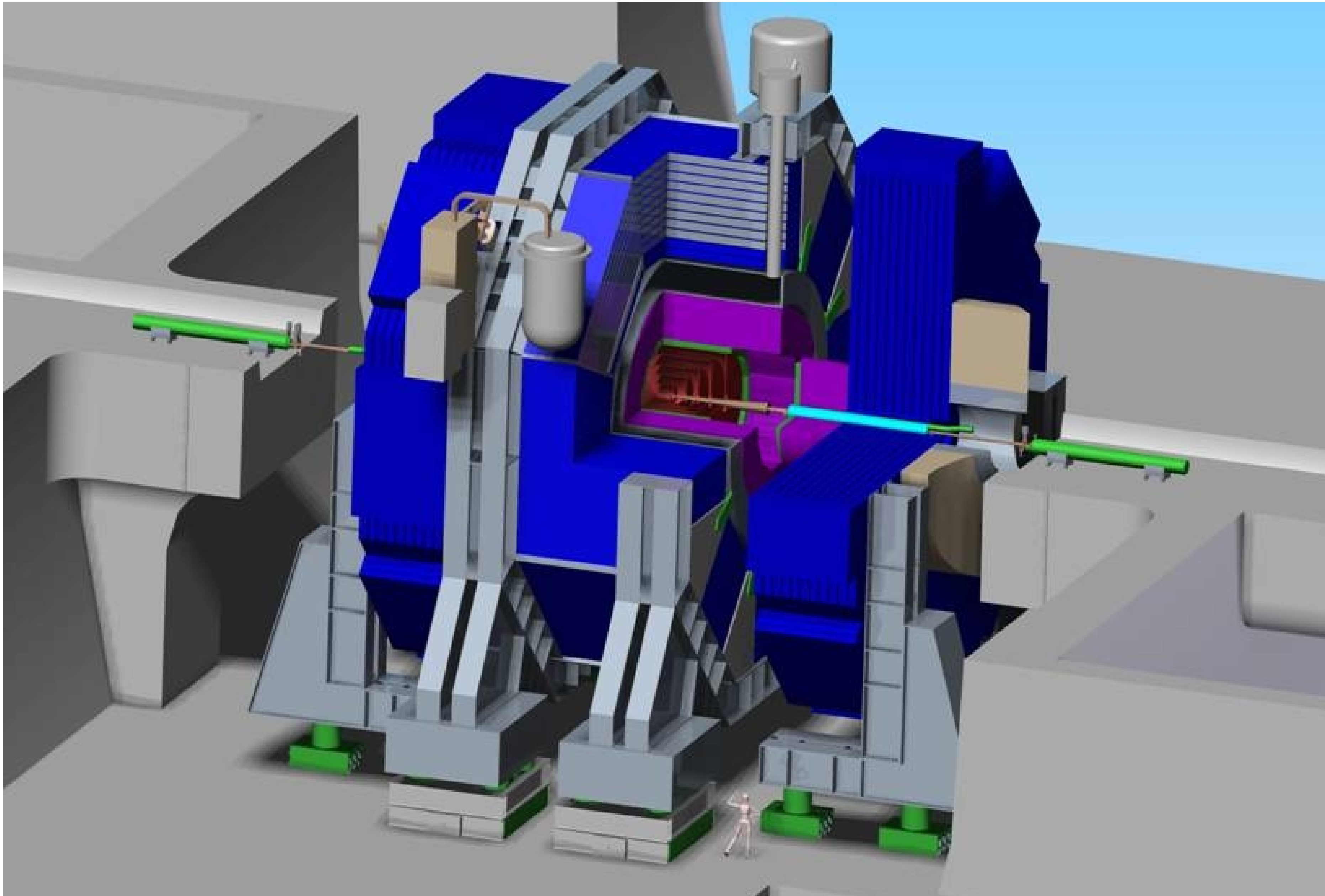


SiD Parameters

- SiD Global Parameters
  - Using baseline design choice

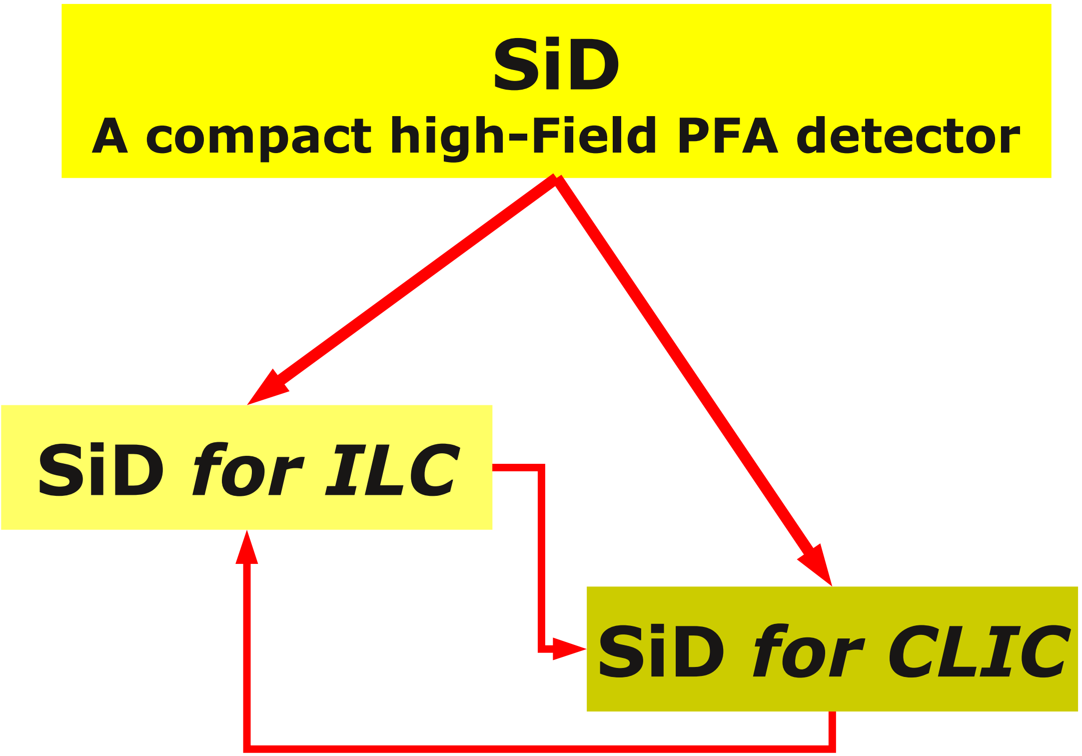
Detector	Technology	Radius (cm)		Z-Axis (cm)	
		r_{min}	r_{max}	z_{min}	z_{max}
Vertex Detector	Si-Pixels	1.4	6.0		18.0
Tracker Barrel	Si-Strips	20.6	125.0		160.7
ECAL Barrel	Si-W	126.5	140.9		176.5
HCAL Barrel	Fe+RPC	141.9	249.3		301.8
5T Coil	Superconductor	259.1	339.2		302.8
Muon Barrel	Fe+RPC	344.2	608.2		303.3
Tracker Endcap	Si-Strips	20.7	49.2	85.0	163.7
ECAL Endcap	Si-W	20.6	125.0	165.7	180.0
HCAL Endcap	Fe+RPC	20.6	140.4	180.6	302.8
Muon Endcap	Fe+RPC	206.6	608.2	303.3	567.3

SiD in the beamline

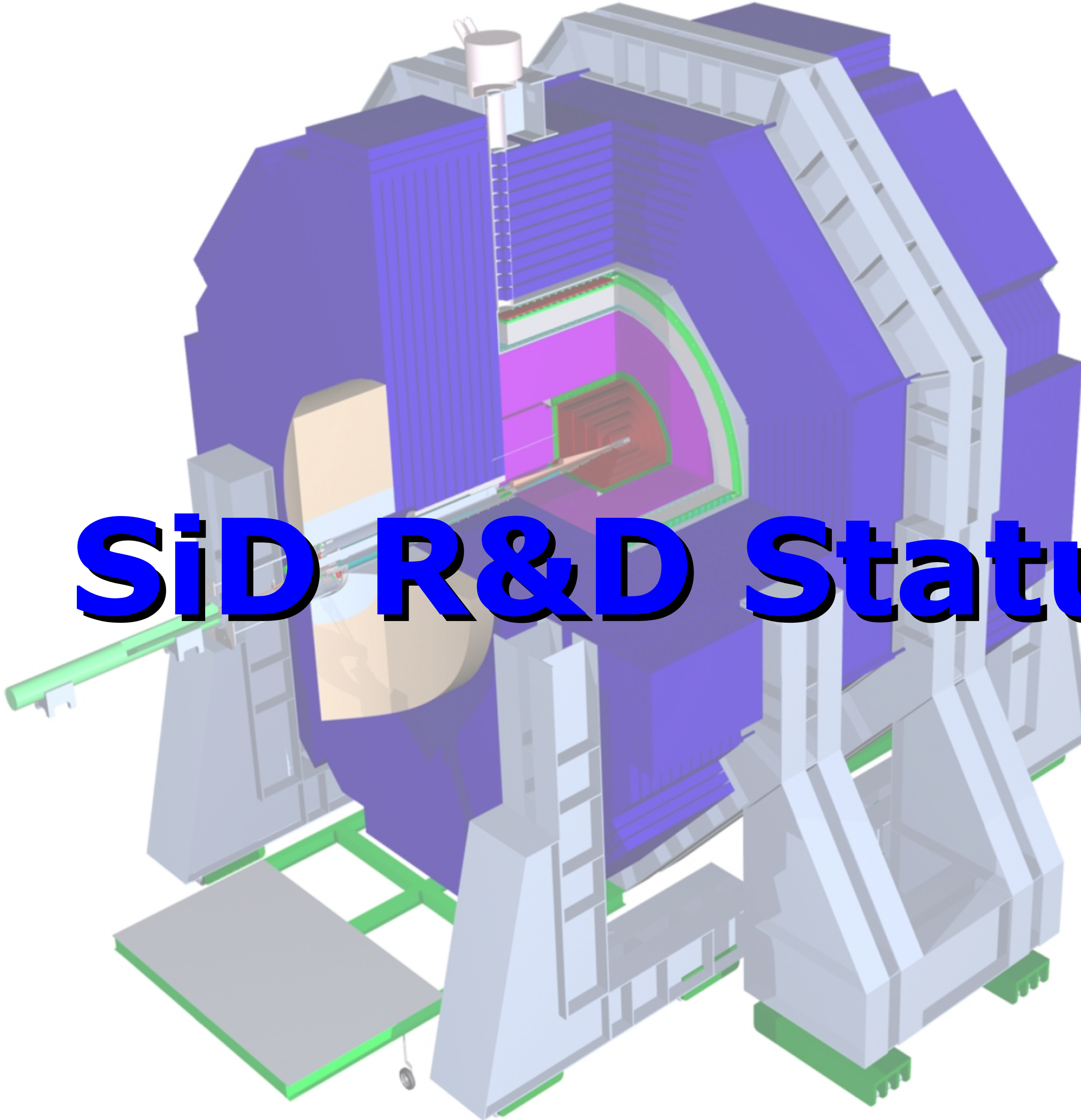


Relations with CLIC

- SiD is supporting the CLIC CDR work
  - Help implementing SiD for CLIC
- Mutual benefits for both
- Currently very active areas
  - Sim/Reco
  - Engineering
  - Coil
- A lot of things come back to SiD (for ILC)



SiD R&D Status



SiD MDI status

- SiD complies with MDI functional requirements document:
- Participate in MDI Common
  - Task Group (Markiewicz, Oriunno, Burrows)
- Working closely with ILD + CLIC colleagues on relevant MDI issues
- More details in the MDI sessions

ILC-Note-2009-050
March 2009
Version 4, 2009-03-19

Functional Requirements on the Design of the Detectors and the Interaction Region of an e^+e^- Linear Collider with a Push-Pull Arrangement of Detectors

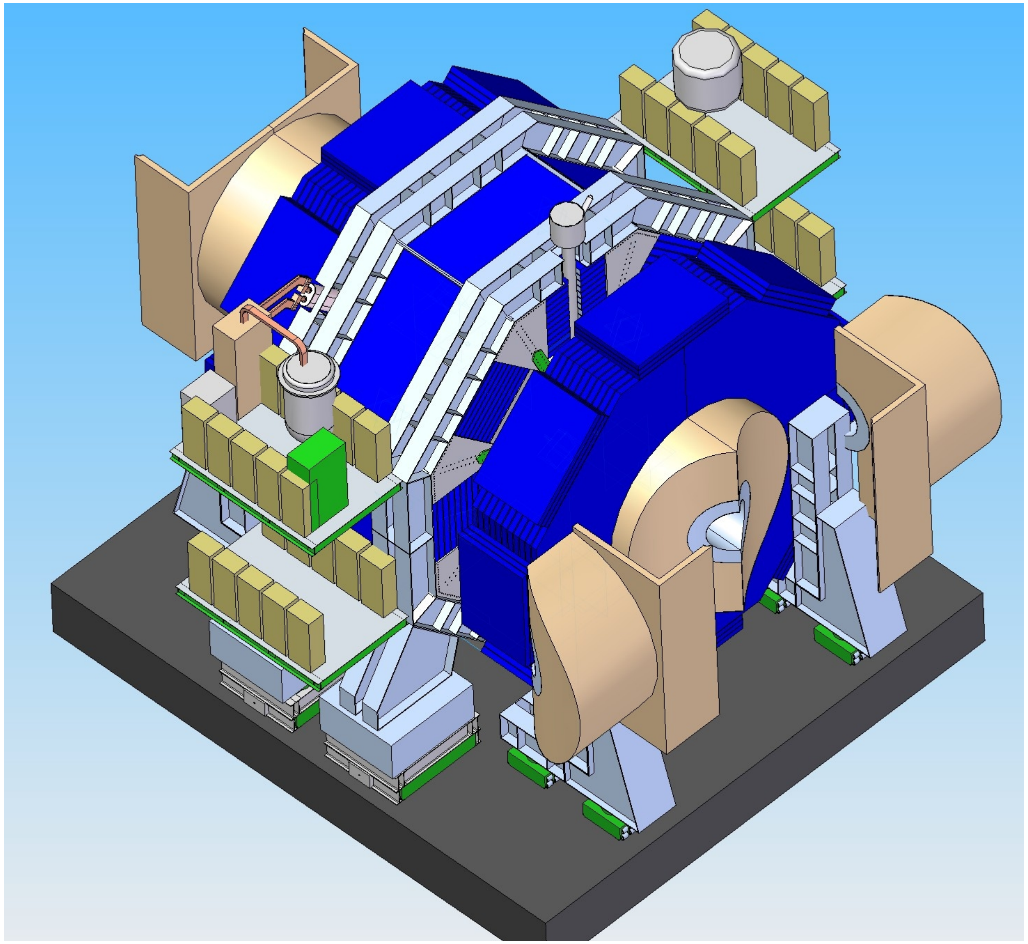
B.Parker (BNL), A.Mikhailichenko (Cornell Univ.), K.Buesser (DESY), J.Hauptman (Iowa State Univ.), T.Tauchi (KEK), P.Burrows (Oxford Univ.), T.Markiewicz, M.Oriunno, A.Seryi (SLAC)

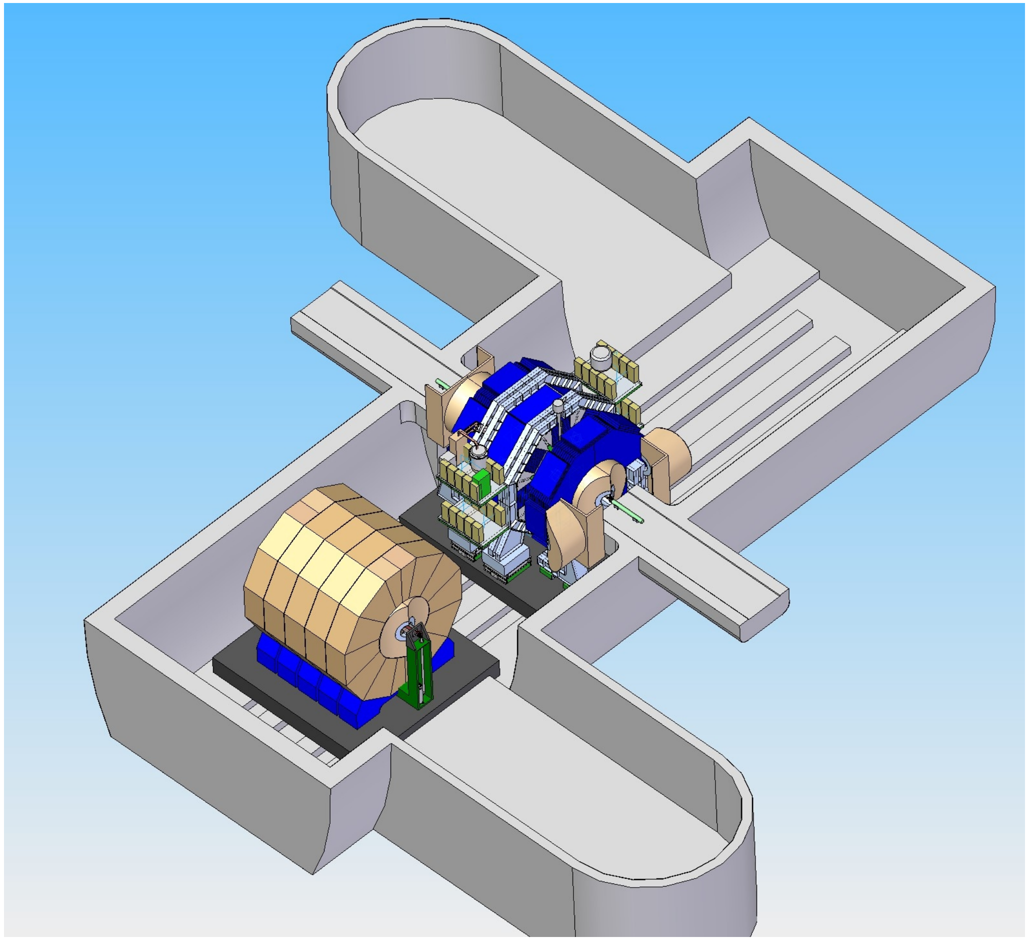
Abstract
The Interaction Region of the International Linear Collider [1] is based on two experimental detectors working in a push-pull mode. A time efficient implementation of this model sets specific requirements and challenges for many detector and machine systems, in particular the IR magnets, the cryogenics and the alignment system, the beamline shielding, the detector design and the overall integration. This paper attempts to separate the functional requirements of a push pull interaction region and machine detector interface from any particular conceptual or technical solution that might have been proposed to date by either the ILC Beam Delivery Group or any of the three detector concepts [2]. As such, we hope that it provides a set of ground rules for interpreting and evaluating the MDI parts of the proposed detector concept's Letters of Intent, due March 2009. The authors of the present paper are the leaders of the IR Integration Working Group within Global Design Effort Beam Delivery System and the representatives from each detector concept submitting the Letters Of Intent.

SiD Detector/QD0 support

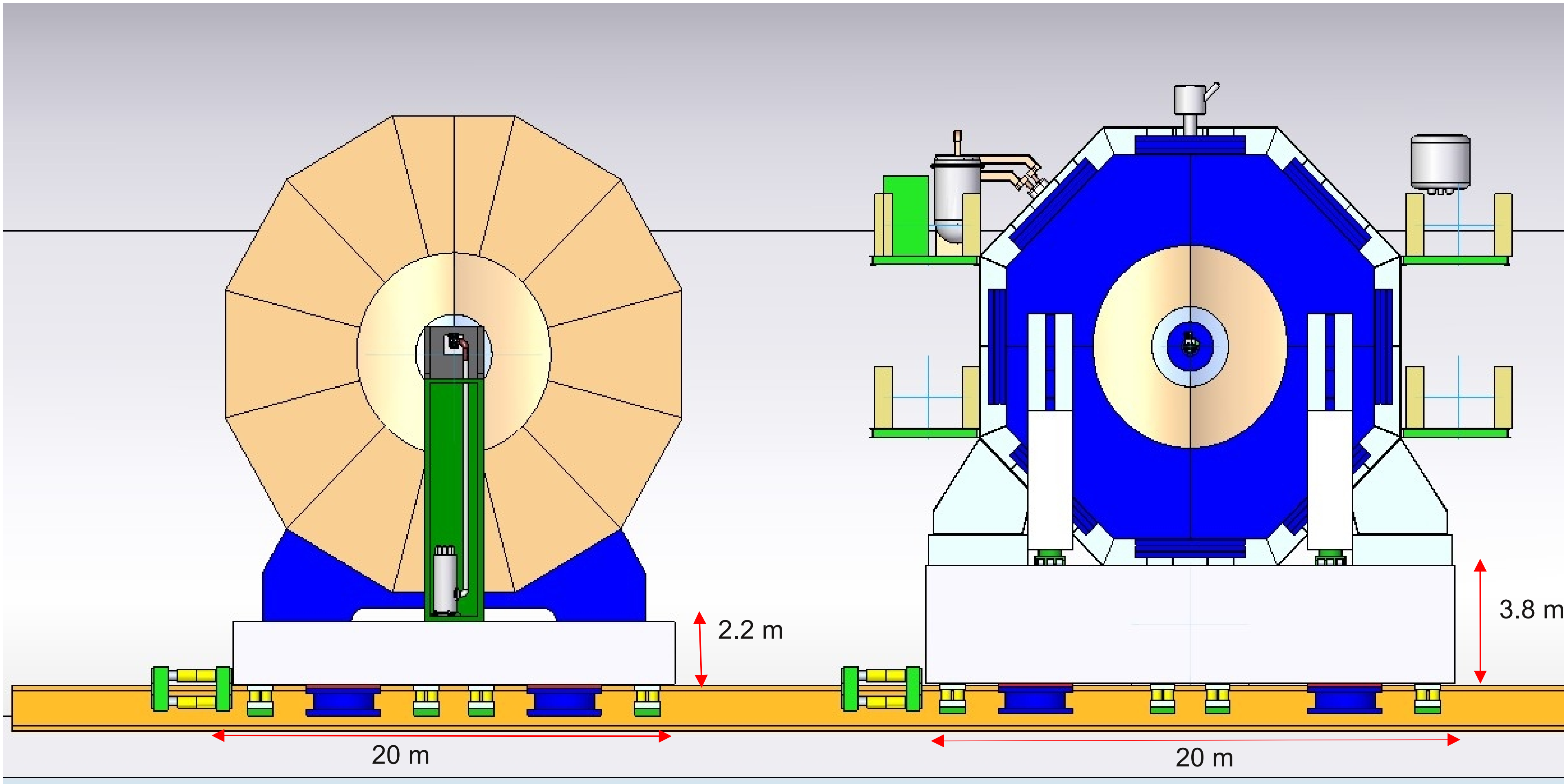
- SiD favors a minimal L*
  - This means that the QD0's are supported by the doors, and the beam-line breaks between QD0 and QF1 for push-pull.
- There is ~1.5 m radial difference between SiD and ILD
  - different technology choices in the tracking region
- Beam height at 9 m from the floor, which increases to 13 m with a platform (platform thickness + motion system)
- Studies are in progress to understand the vibration performances of these approaches, and also their cost implications.

SiD in the Collision Hall





Height differences



Push-Pull

- SiD continues to study both Hillman rollers and a platform
- SiD is designed with the QD0's supported from the doors
- SiD can be moved without a platform, ILD can't
- Having both detector on platforms is the only compatible solution, which not require modification in the design of SiD
- The two platforms do not need to be identical.
  - We expect the CFS group to design them, according to functional requirements defined by the experiments : dimensions, static, vibration, floor, etc.

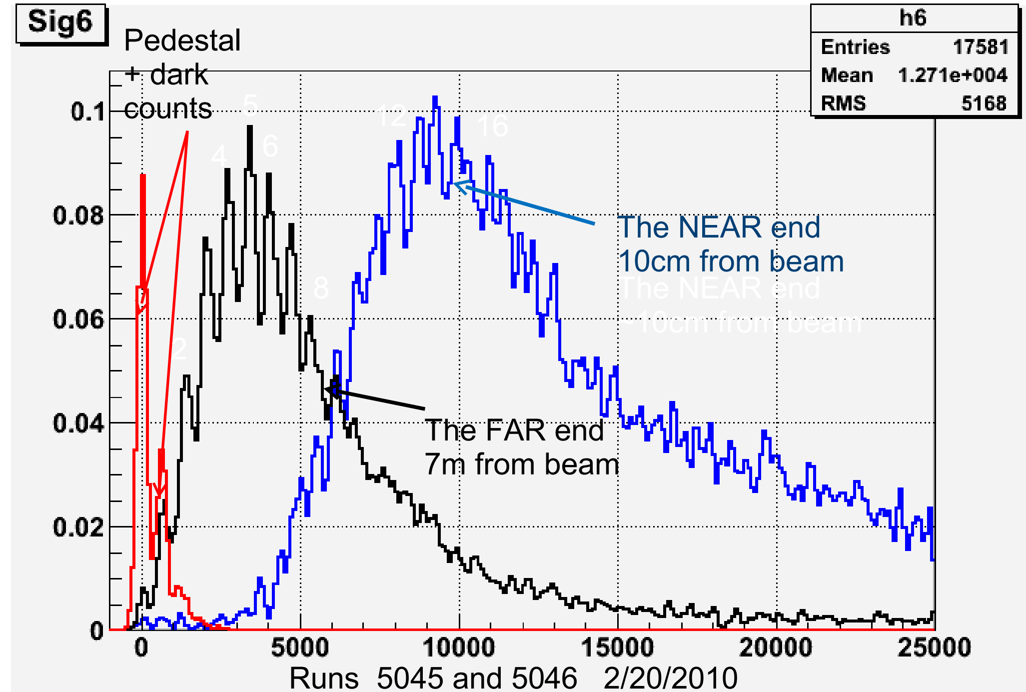
SiD Muons - RPC studies

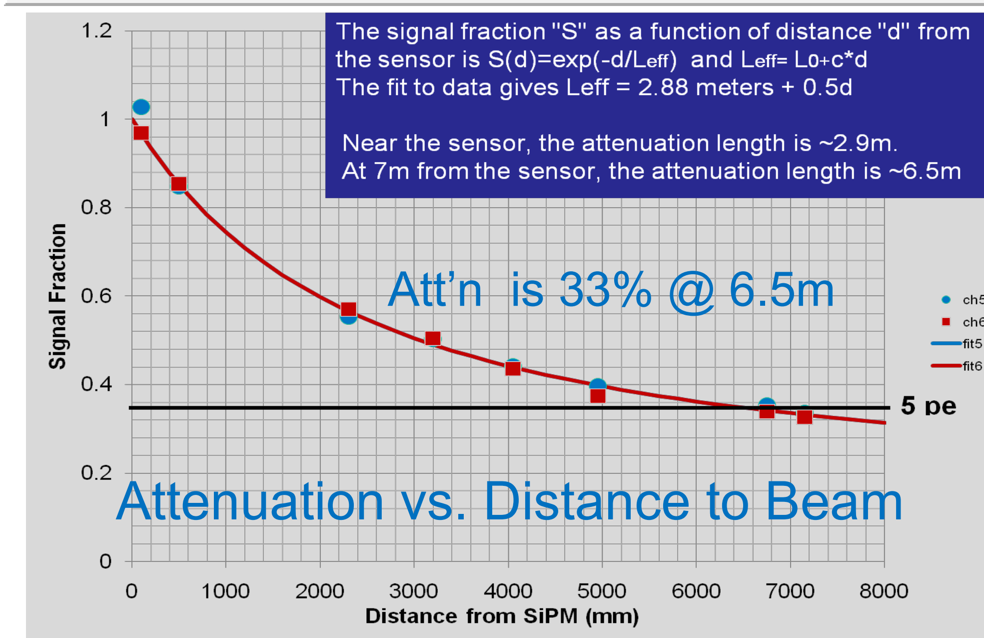
- Babar Forward Endcap RPCs
  - H. Band, U. Wisconsin
- Similar construction to Atlas/CMS RPCs
- Wide range of rates/current accumulated over ~ 6 years
- Good overall efficiency but clear signs of aging

- BESIII/Daya Bay RPCs
  - C. Lu Princeton U.
  - No linseed oil
- Accelerated aging studies with ^{60}Co
  - Sizable efficiency losses
  - Damage from to HF produced in gas
- Testing linseed oil impregnated Bakelite
- Developing thin Bakelite for possible use in HCAL

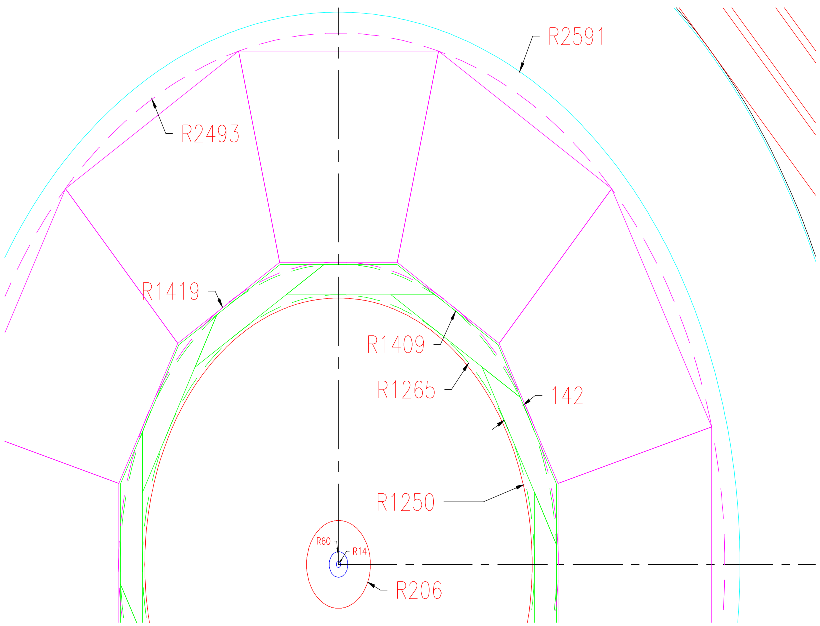
SiD Muons Scintillators

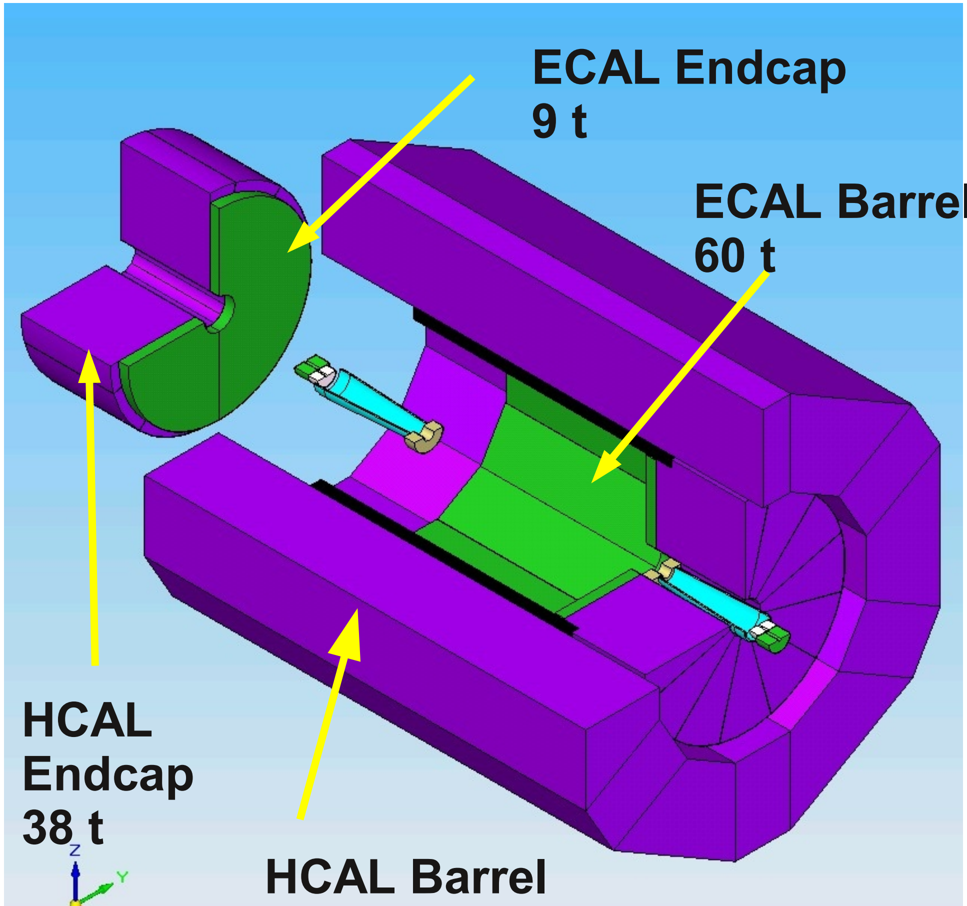
- Alternative baseline
  - Using Scintillator and SiPM's
- Invaluable help and additional manpower from collaboration with another project
  - This helps everybody
- SiPM making huge progress
  - Philips announced SiPM+integrated readout
- If we had to build a muon system for SiD starting tomorrow, we could





Calorimeter Overview





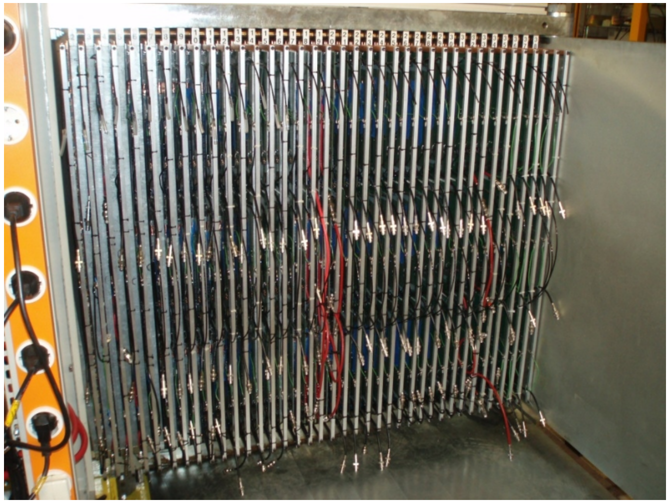
	Technology	X_0/λ_I	Layers	Weight (t)
ECAL Barrel	Si + W	26	30	60
ECAL Endcap	Si + W	26	30	2 x9
HCAL Barrel	Fe + RPC	4.5	40	453
HCAL Endcap	Fe + RPC	4.5	45	2 x38

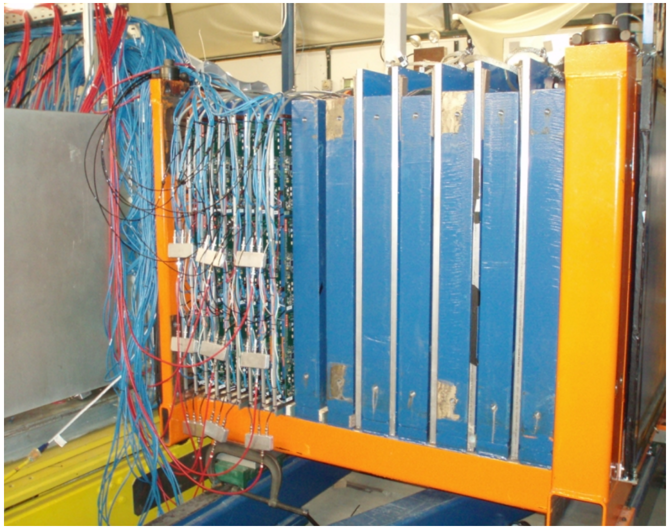
HCAL technology

- Baseline technology for the SiD HCAL is RPC readout
- Two more options
  - GEM
  - Micromegas
- All done within the CALICE framework
  - Using CALICE mech. Structures, DAQ ..
- One orthogonal approach: Crystal Calorimeter
  - Total Absorption
  - Dual-readout based
- Many more details in the Calorimetry parallels

RPC Large Prototype

- DHCAL +TCMT Stack
  - 10,000 DCAL III chips (no design faults)
  - 205 RPCs
  - 337 Readout boards
  - 56 cassettes (with protective covers)
  - Low Voltage system (384 channels)
  - Gas system (with 28 separate lines)
- DHCAL:38 layers with 350,000 readout channels
- TCMT: 13 layers with 120,000 readout channels





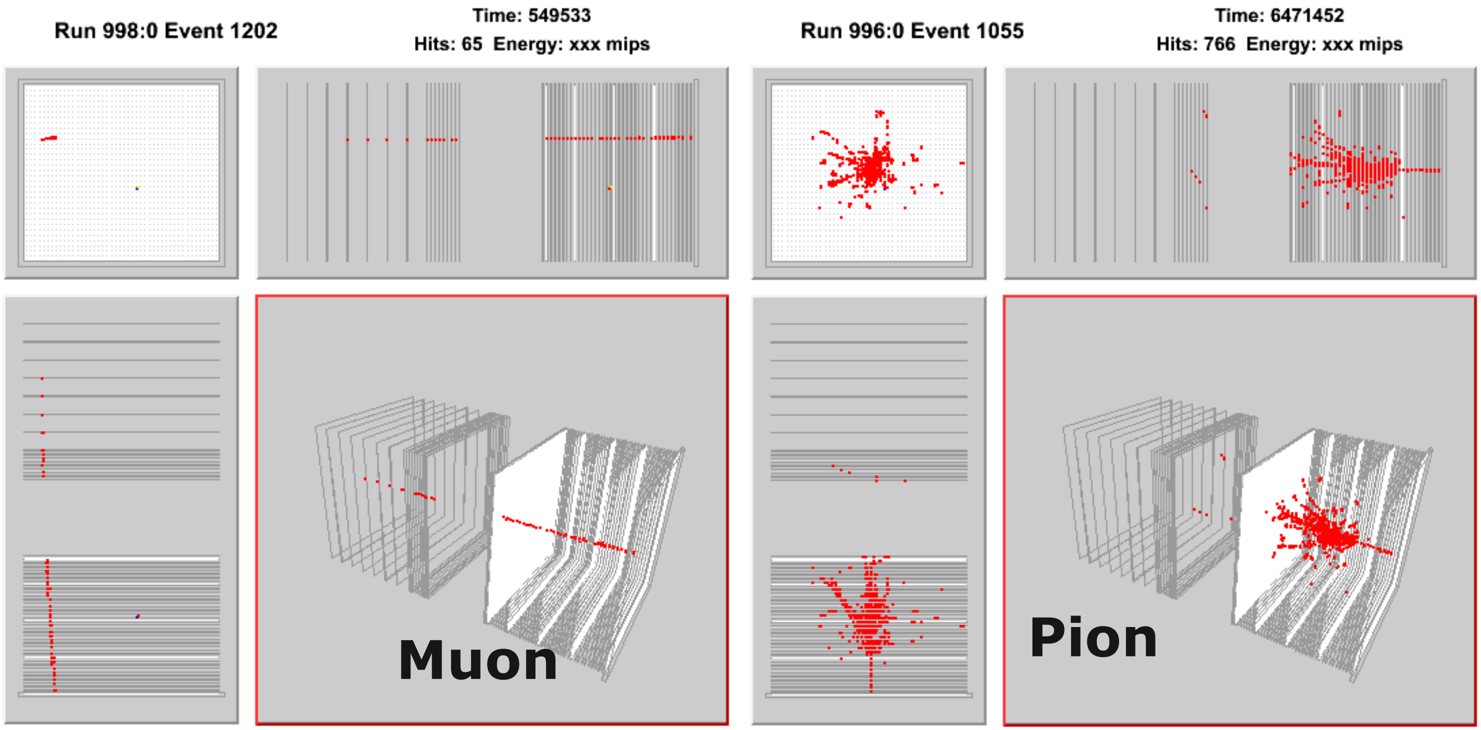
Large effort involving a total of 39 people

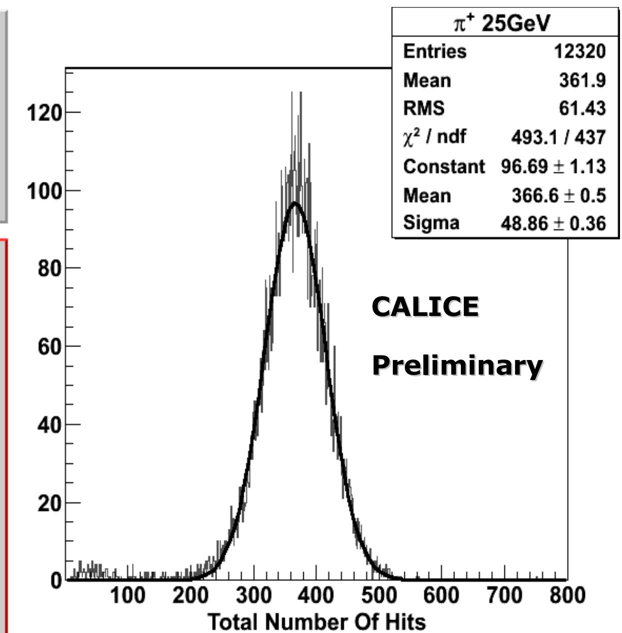
Installation at Fermilab

RPC testbeam campaign

- October 2010
  - 1.4 x 10^6 muon events
  - 1.5 x 10^6 with secondary beams at 2-32 GeV/c
  - Data collected with complete 38 layer DHCAL
- January 2011
  - 1.6 x 10^6 muon events
  - 3.6 x 10^6 with secondary beams at 2 - 60 GeV/c
  - 38 layer DHCAL + up to 13 layers in TCMT
- April 2011
  - Combined run with the CALICE Silicon-Tungsten ECAL
- June 2011
  - Standalone run (DHCAL + TCMT) at high energies
- Grand total of 8 x 10^6 events collected so far

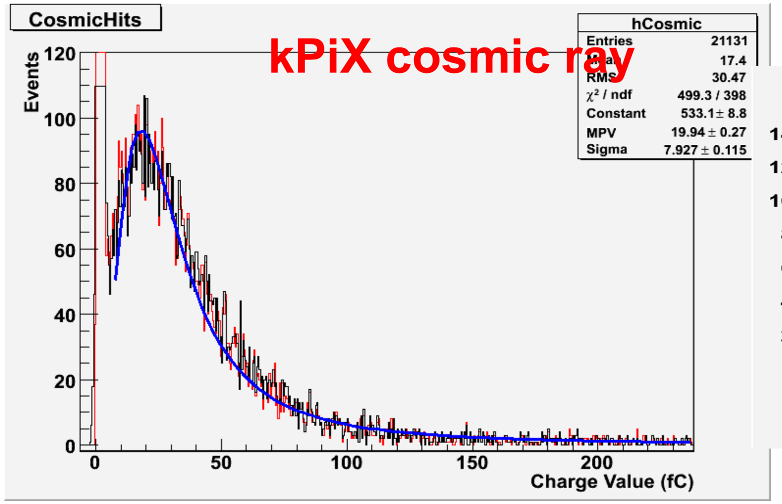
Testbeam Results



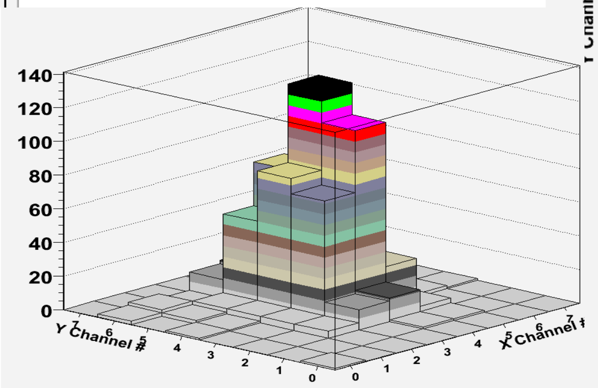


- Very good noise performance (0.1 Hits/event)
- The Concept of a DHCAL with RPC's is close to being validated

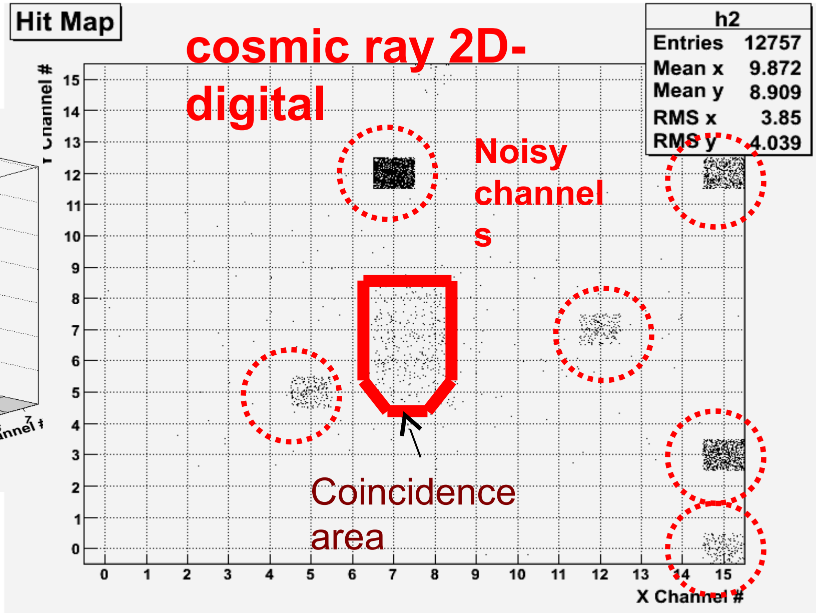
GEM status



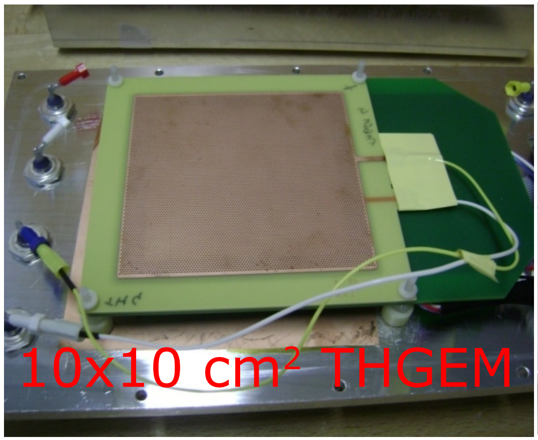
CosmicHits
kPiX cosmic ray
hCosmic
Entries 21131
RMS 30.47
χ^2 / ndf 499.3 / 398
Constant 533.1 ± 8.8
MPV 19.94 ± 0.27
Sigma 7.927 ± 0.115
Events
Charge Value (fC)



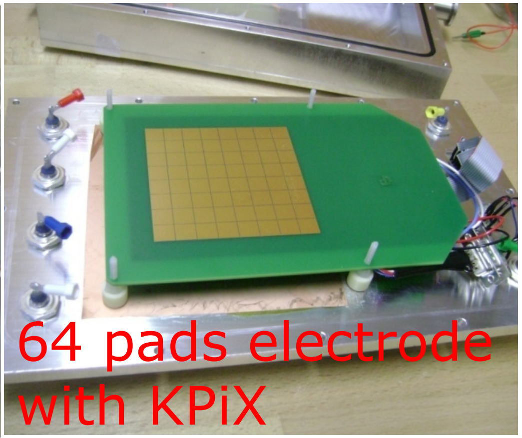
Y Channel #
X Channel #



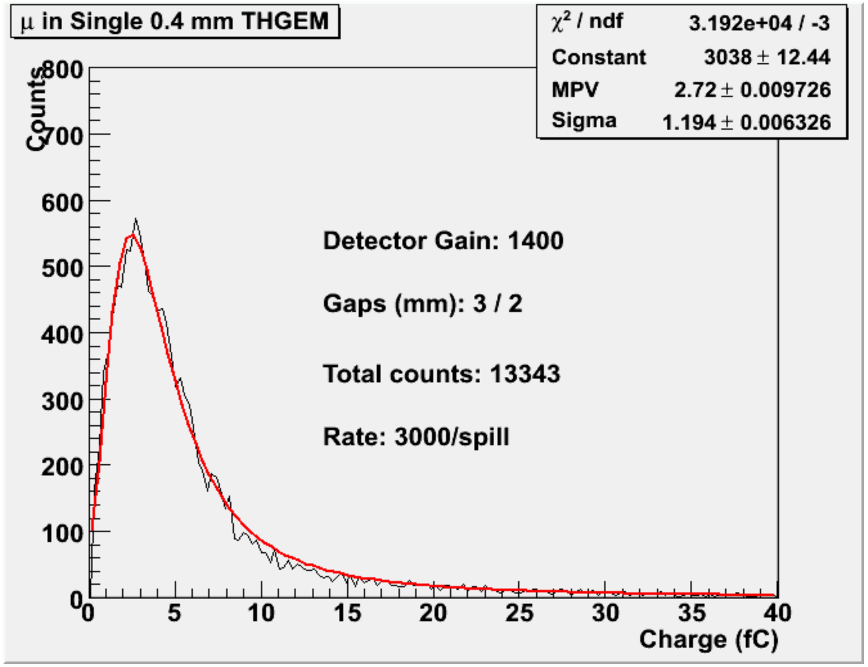
Hit Map
cosmic ray 2D-digital
h2
Entries 12757
Mean x 9.872
Mean y 8.909
RMS x 3.85
RMS y 4.039
Noisy channels
Coincidence area
X Channel #



10x10 cm² THGEM



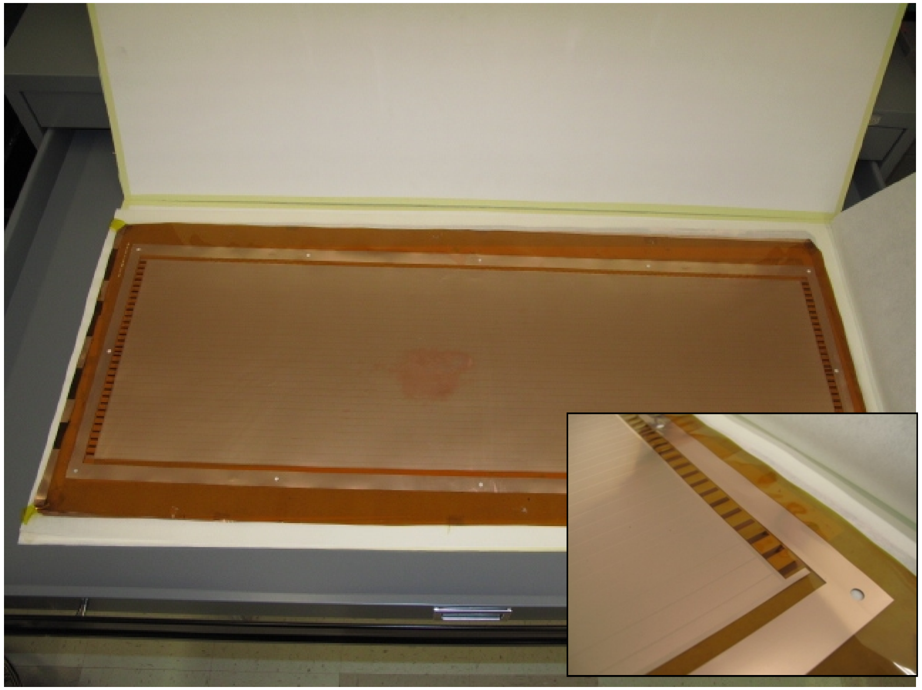
64 pads electrode with KPiX

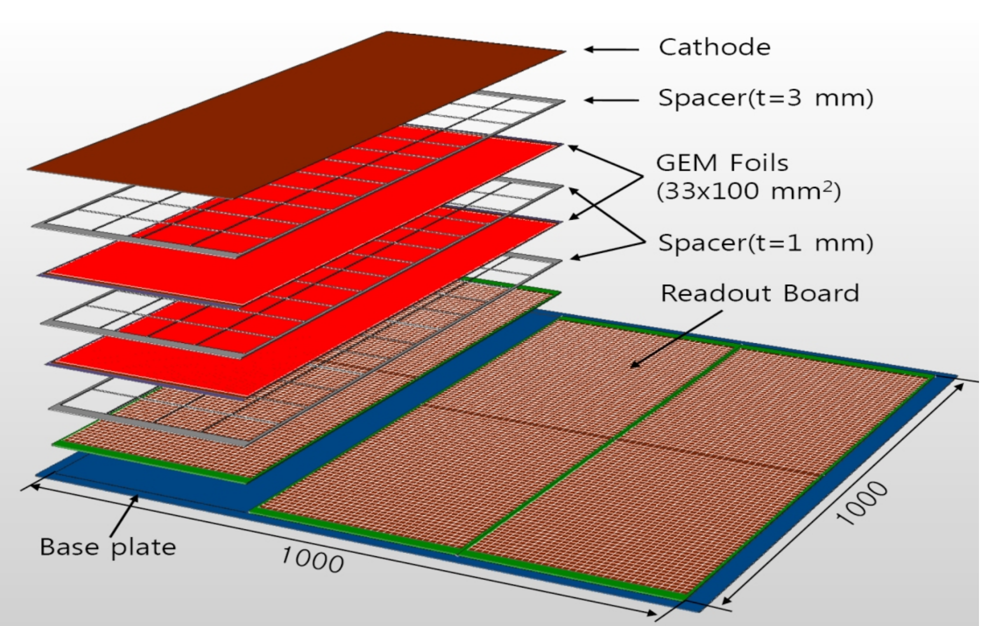


μ in Single 0.4 mm THGEM
χ^2 / ndf 3.192e+04 / -3
Constant 3038 ± 12.44
MPV 2.72 ± 0.009726
Sigma 1.194 ± 0.006326
Counts
Detector Gain: 1400
Gaps (mm): 3 / 2
Total counts: 13343
Rate: 3000/spill
Charge (fC)

Large Area GEM Plans

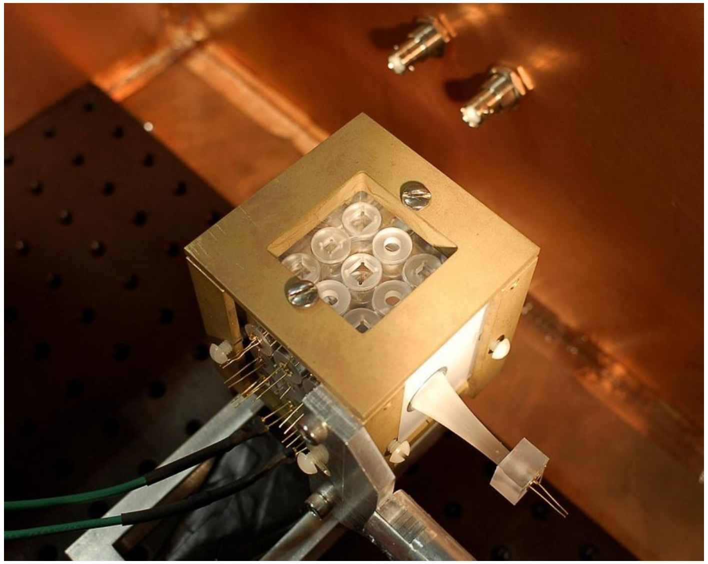
- Current Status
  - CERN GDD Workshop delivered the first 5 of 33 x 100cm GEM foils in 2010 and characterization is done
- **Phase I (Through late 2011)** 33 x 33 cm chamber studies
- **Phase II (late 2011 – early 2013)**: 33 cm x 100 cm chamber development and characterization
- **Phase III (Early 2013 – late 2015)**: 100 cm x 100 cm plane construction, characterization and beam test using CALICE stack

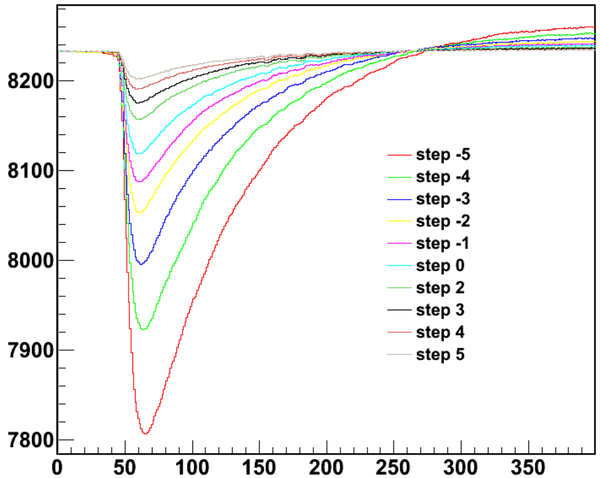




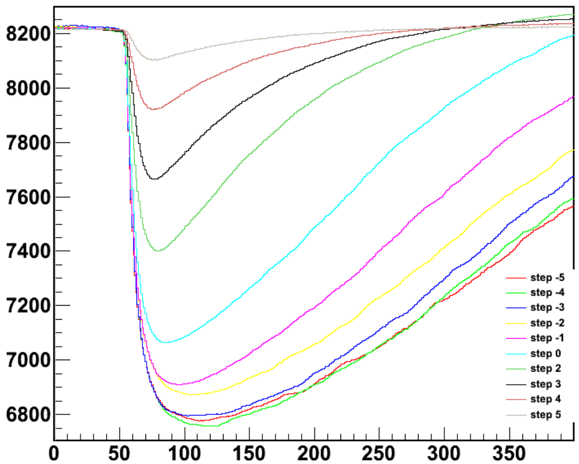
Crystal Calorimeter

- Future Perspective
- Total absorption:
  no sampling fluctuations and other sampling–related contributions. The dominant contribution to resolution: fluctuations of nuclear binding energy losses.
- Leakage is a concern
  - Segmented crystals
- Testbeam with BGO and PbF_6 crystals
  - Inter-Calibrating the crystals is crucial
  - Dual-readout with SiPM demonstrated
  - Analysis on-going



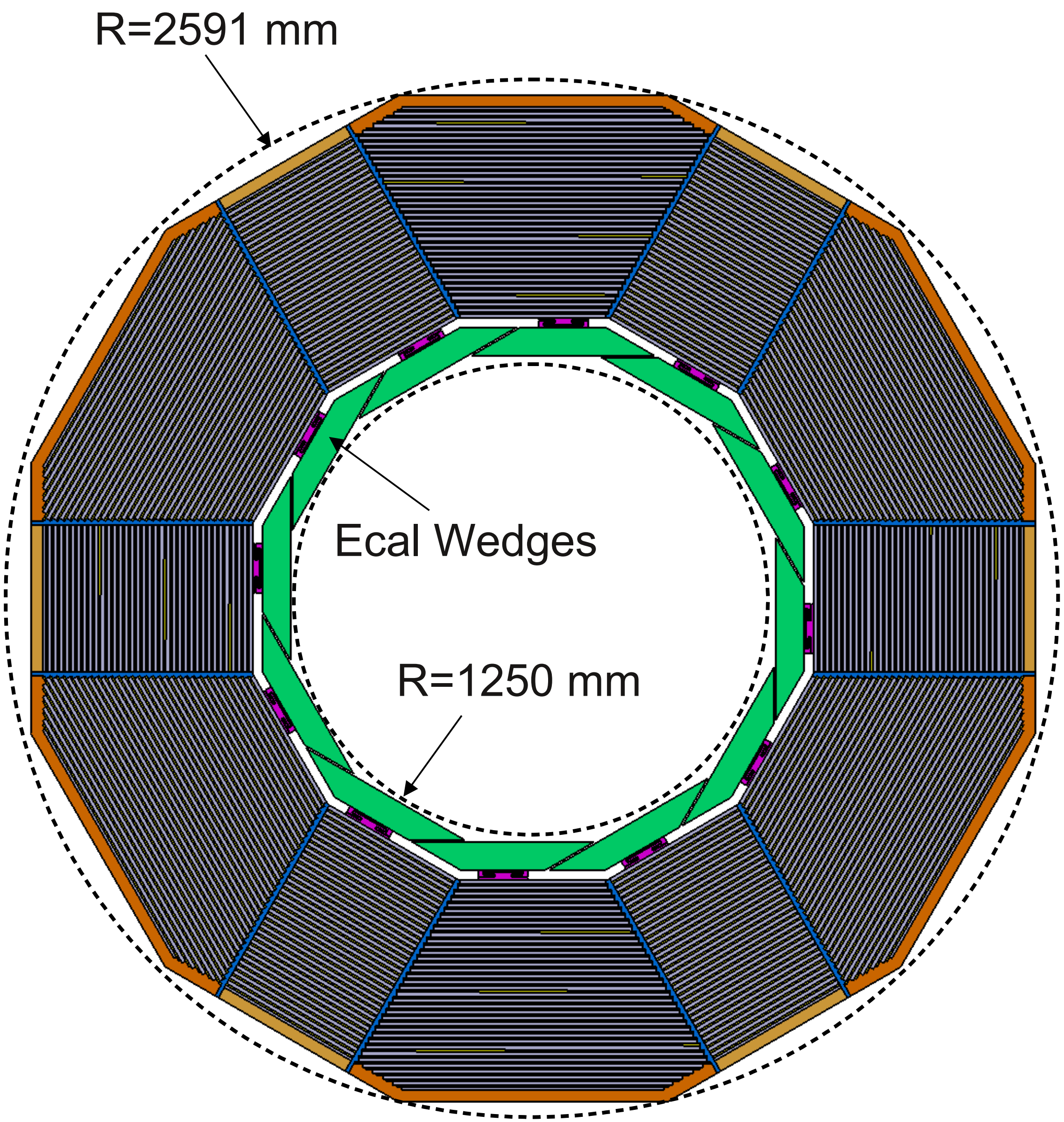


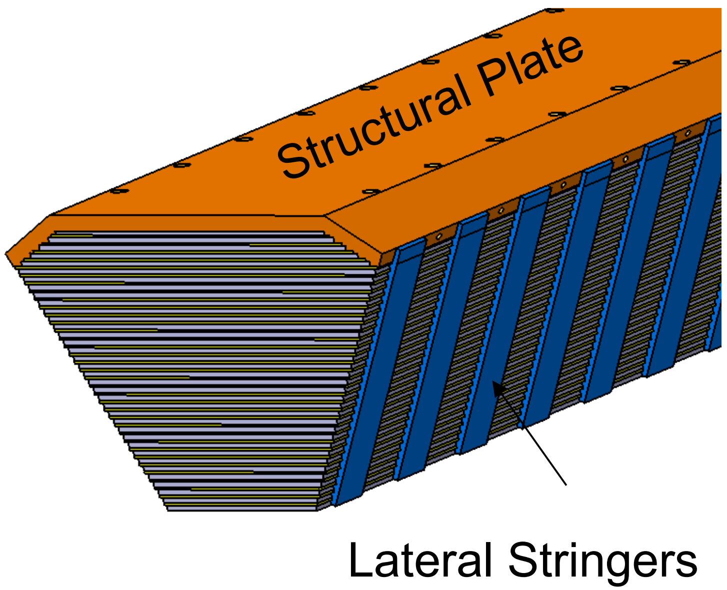
Cherenkov



Scintillator

HCAL Mechanics

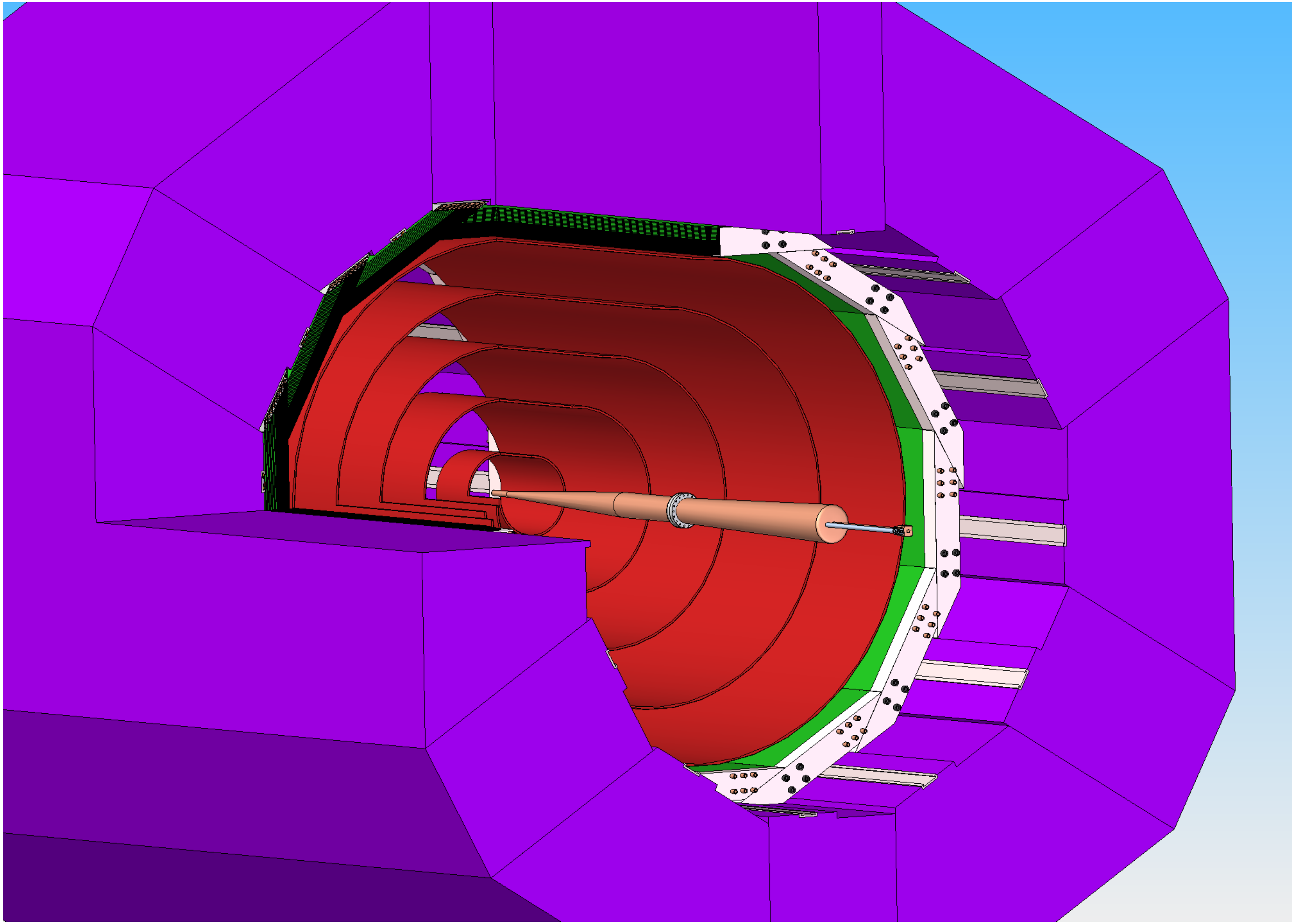




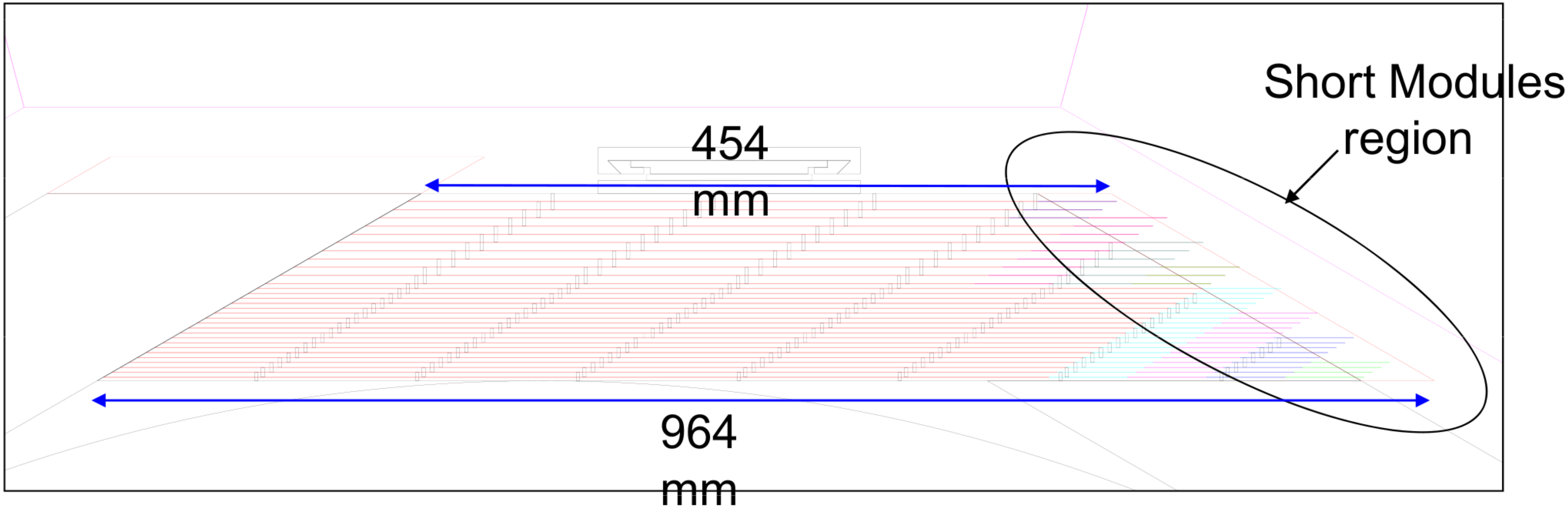
Non-projective version –
LoI choice
DBD choice currently
being discussed

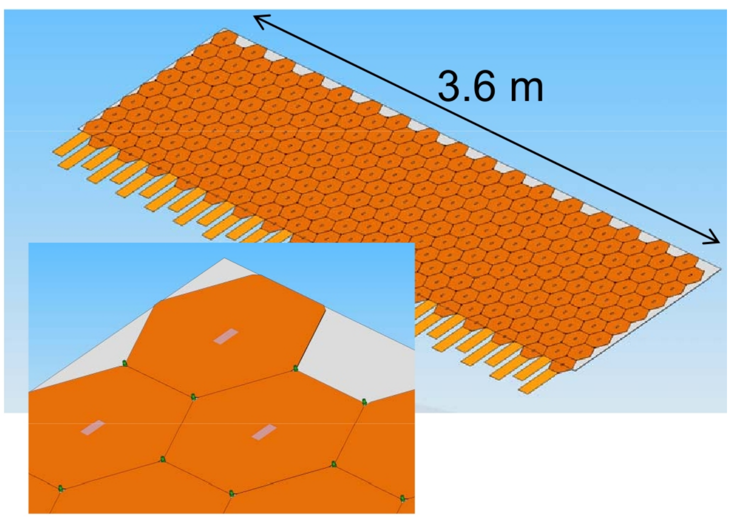
Nicolas Geoffroy - LAPP

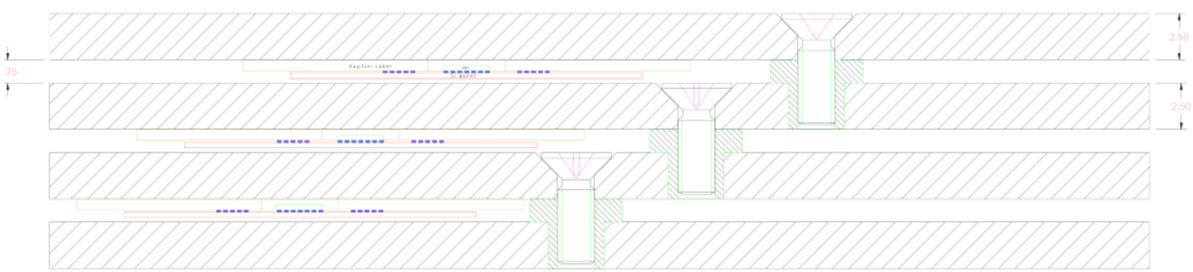
Si-W ECAL

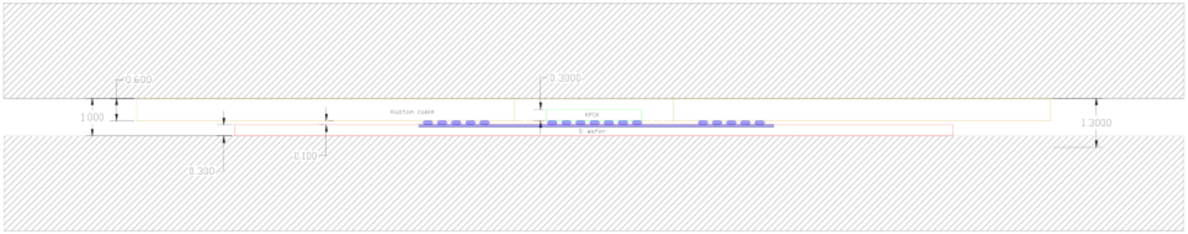


ECAL mechanics









ECAL Status

Analog KPIX

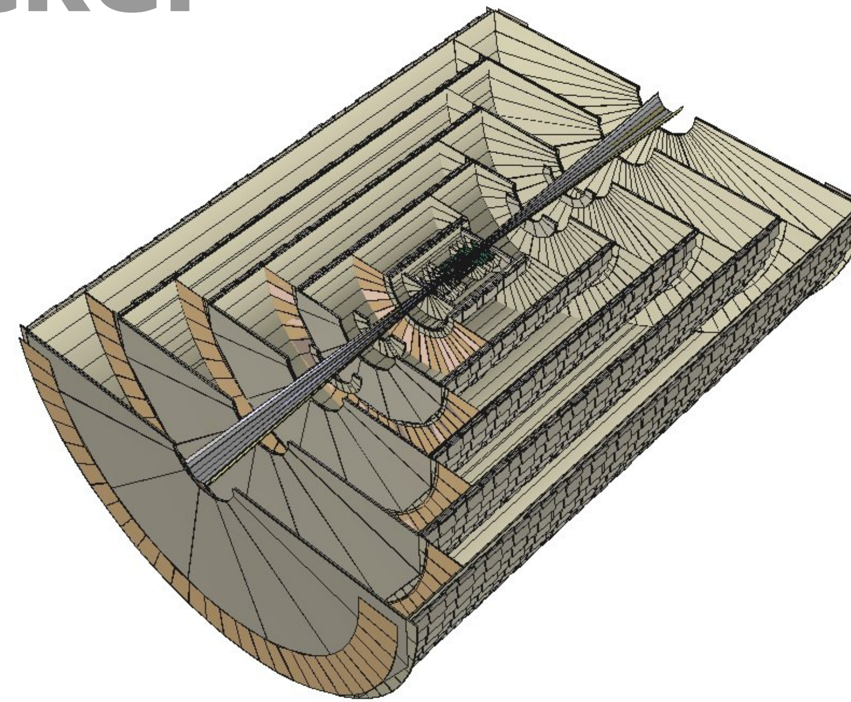
- SiD Baseline
- Expecting KPiX 1024
  - See KPiX
- Si Wafers in hand
- Sorting out bump-bonding issues
  - Moving from gold-studs to solder bumps
- On the way of building ECAL stack
  - Testbeam in 2012

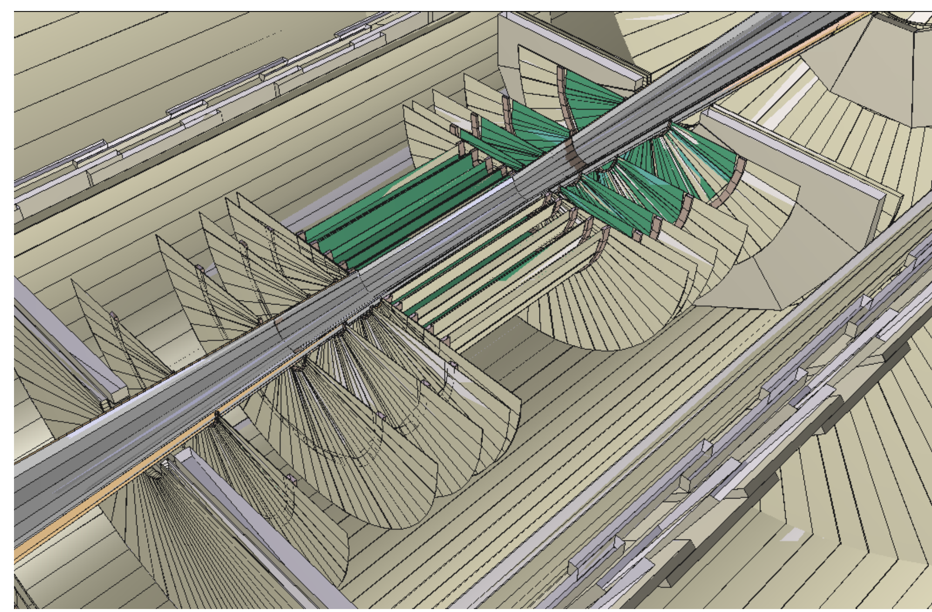
Digital TPAC MAPS

- Alternative Option
- Testbeam data with small chip
  - DESY
  - CERN
- In the process of analyzing
- Making a large Prototype stack is very uncertain
  - Due to UK funding

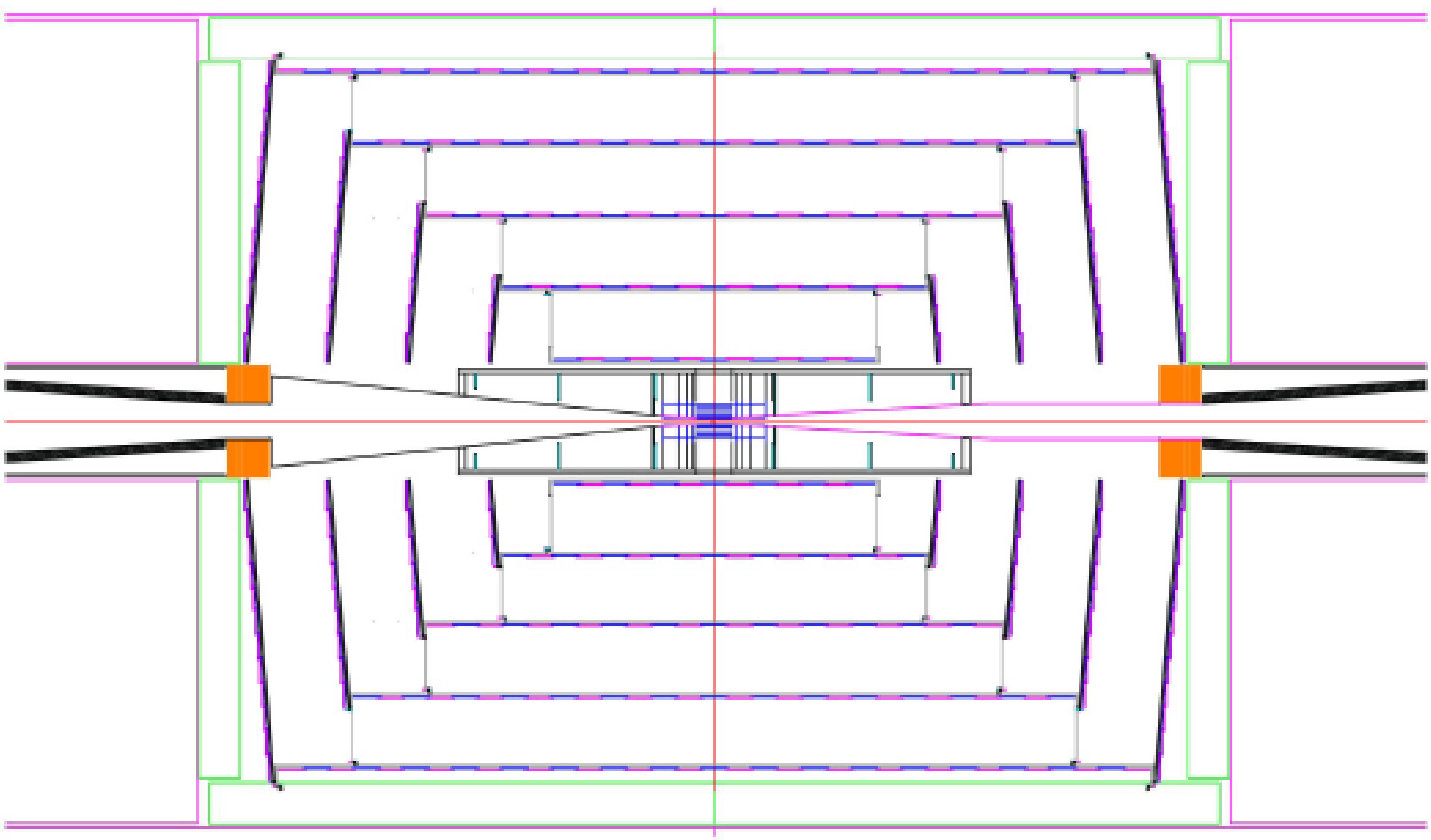
Tracker

- Tracker & Vertex detector
  - Distinct sub-detectors
- SiD views it as one integrated detector
- Vertex detector (Pixels)
  - 5 barrel layers + 7 disks
- Tracker (Strips)
  - 5 barrel layers (axial) + 4 disks (stereo)
- Material budget $X/X_0 < 0.2$
- minimum of 10 hits/track down to small angles

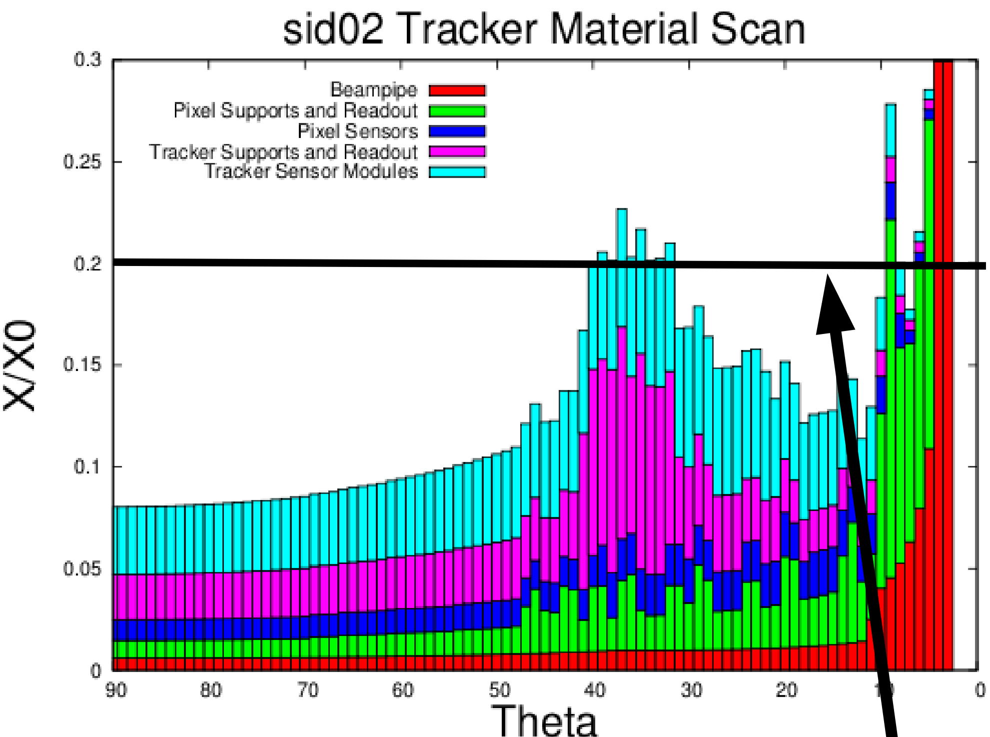


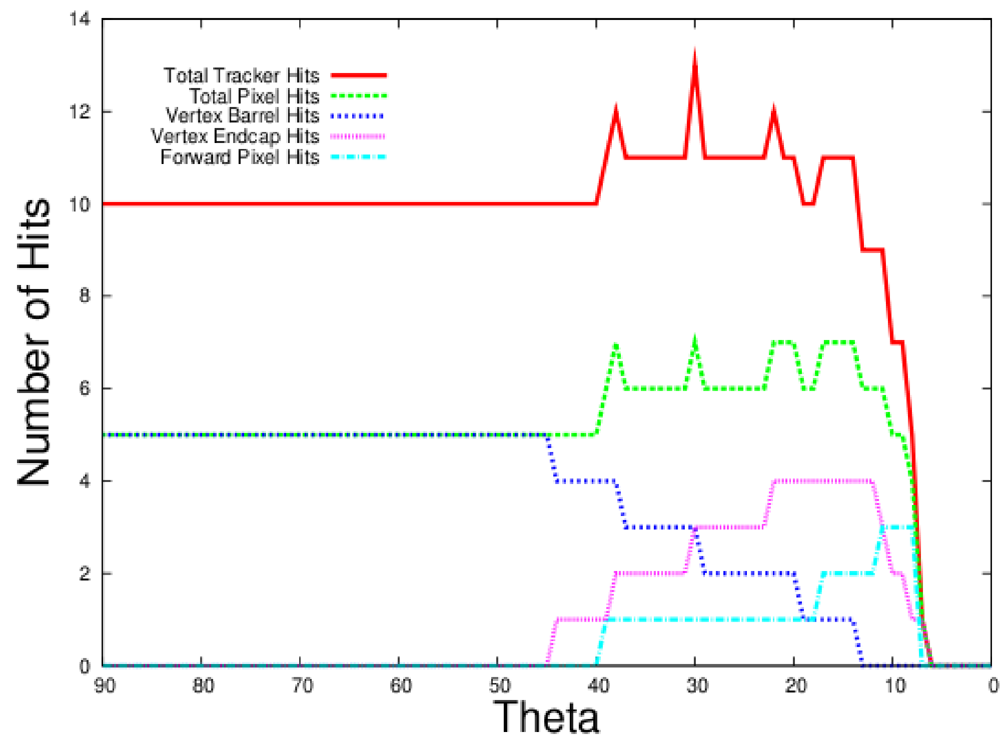


Tracker Overview



Material budget

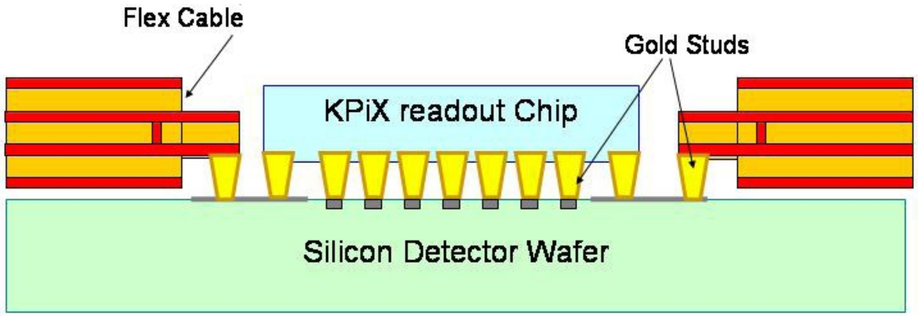




Design Goal

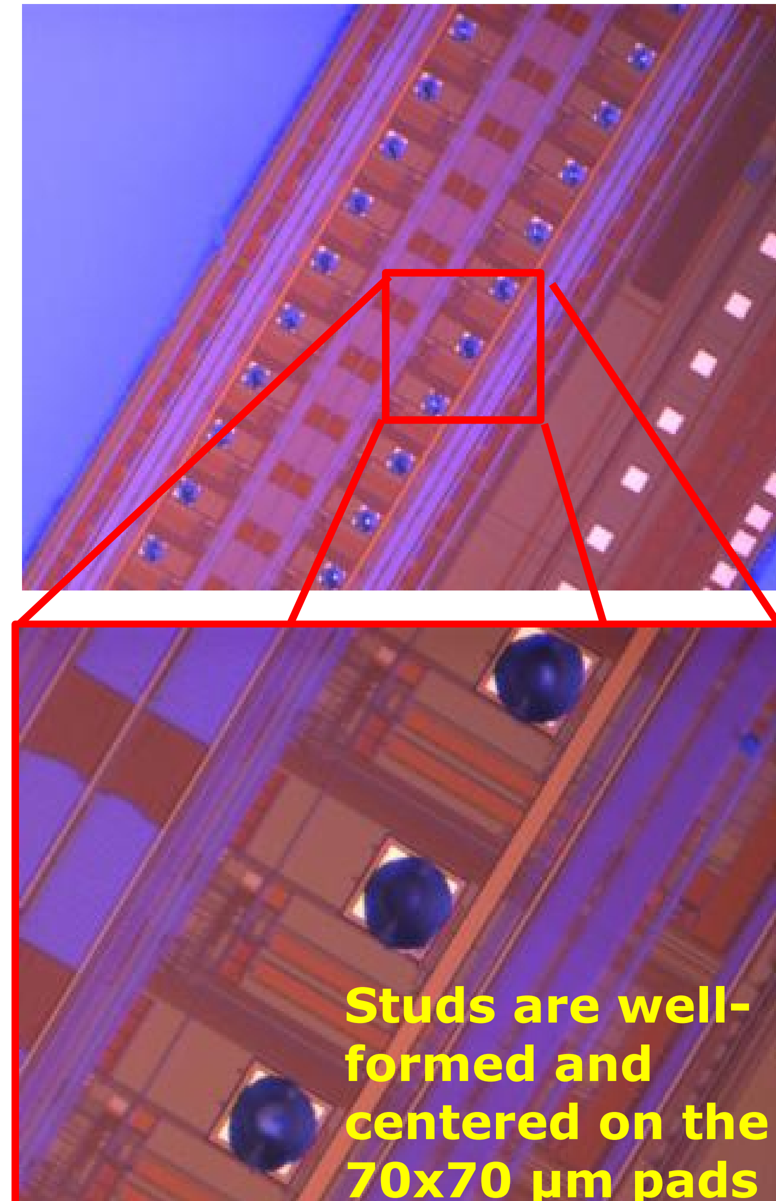
Tracker Modules

- Hybrid-less design with 3 components:
- Silicon Sensor
  - 93.5 x 93.5 mm² sensor 1840 (3679) readout (total) strips
  - Routing of signals through 2nd metal layer
  - Power and clock signals also routed over the sensor
- kPix readout
  - two kPix chips bonded to the sensor
- Flexible readout cable
  - 2-layer, ¼ oz. Cu on 50 μm Kapton

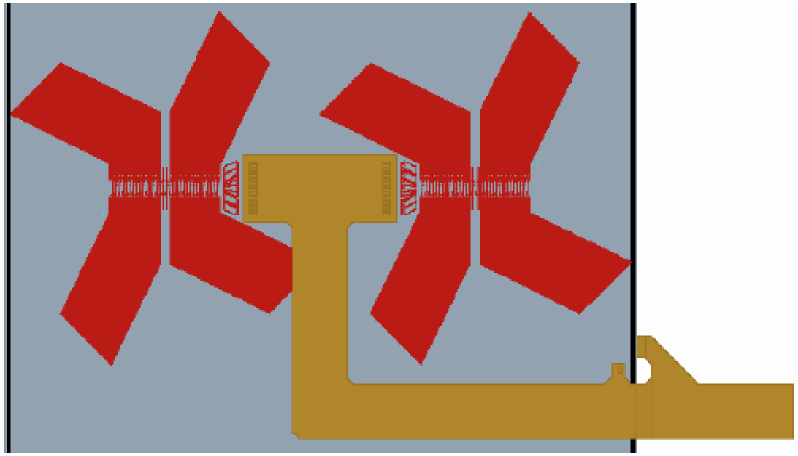


Gold-Stud Bonding

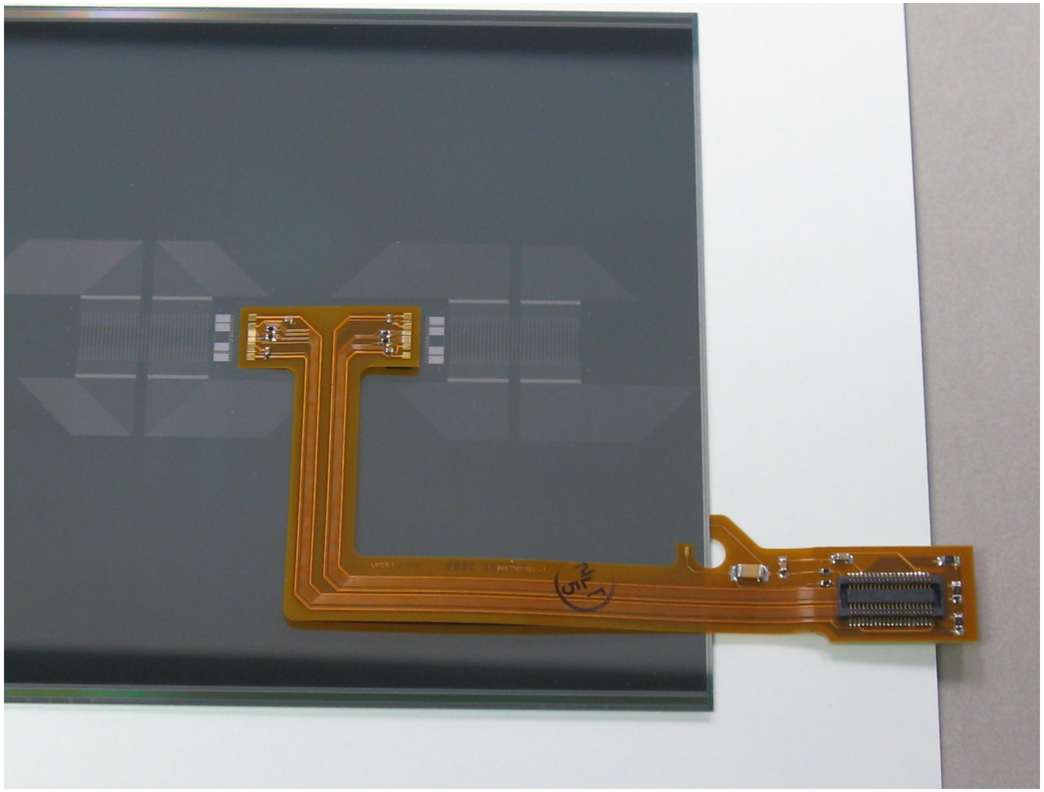
- Gold stud attachment using thermo-compression
  - 300-350 C and 150-200 g/bump.
  - Machine limit ~100-200 kg Limits total number of bumps
- Results
  - 160 g/bump ok
  - 100 g/bump insufficient: 4 of 20 bumps were ~open
- Plans: Study systematics with position, uniformity reproducibility



Tracker Cabling



- Low-mass readout cables connect tracker modules to the concentrator boards mounted at the ends of each barrel.
- This cable has two components:
  - Pigtail, a short cable glued to the module
  - Extension, a long cable connecting the Pigtail to the concentrator

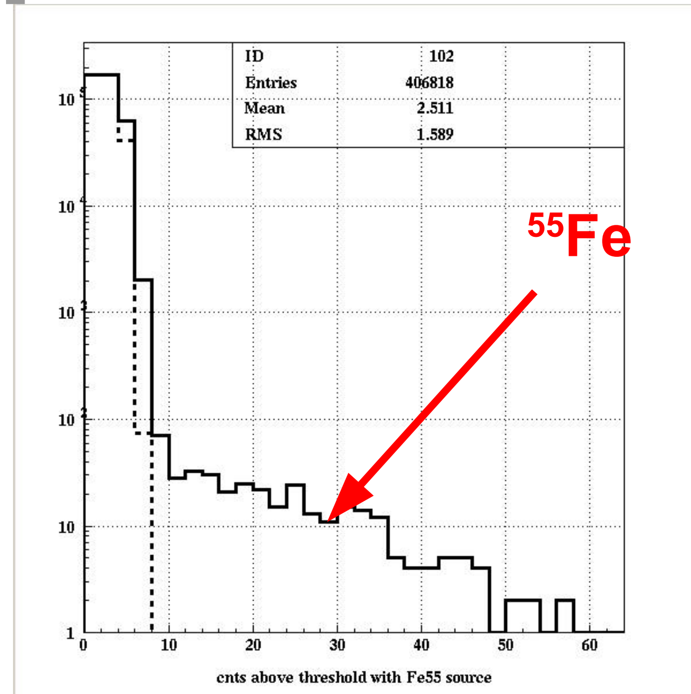


Vertex Detector

- Sensor technology to be decided: Chronopix, 3D, MAPS, DEPFET, SoI, FPCCD …
  - Can only mention a few
- 0.1% X/X_0 per layer
- Sensors glued on edges to form cylinders
- Gas cooled, power pulsed
- Pixel outer disks match coverage of outer tracker
- The vertex detector poses the most challenges
  - Probably the last system with a technology decision

Chronopixels

- Chronopixel -I :General concept is working
  - Error in power distribution net only small part operational.
  - Noise figure is 24 e,
  - No problems with pulsing analog power
- Designing 2nd generation
  - NMOS only , allows to have 100% charge collection
  - To reduce NMOS power consumption, using dynamic power scheme
- Chronopixels for CLIC
  - Simulations promising



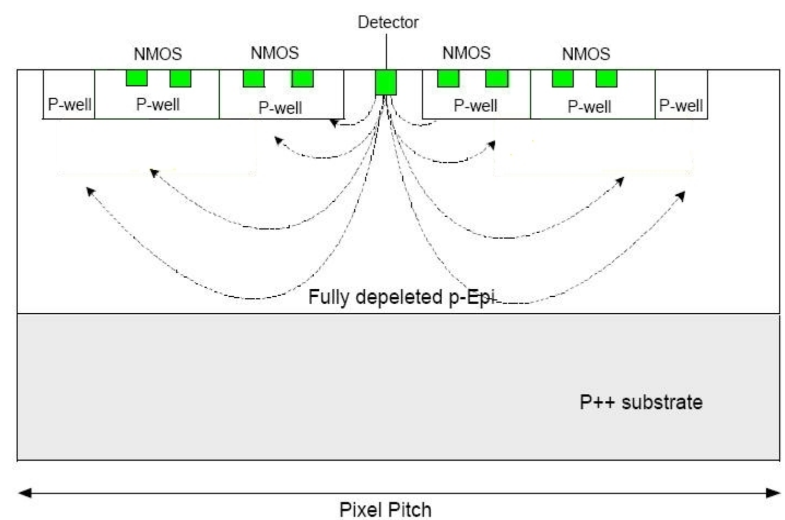
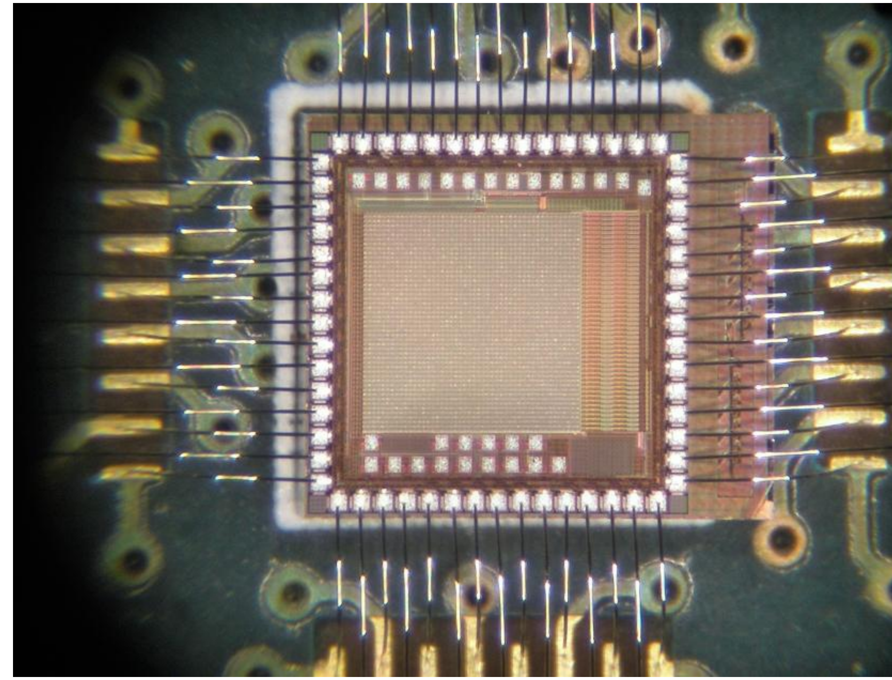
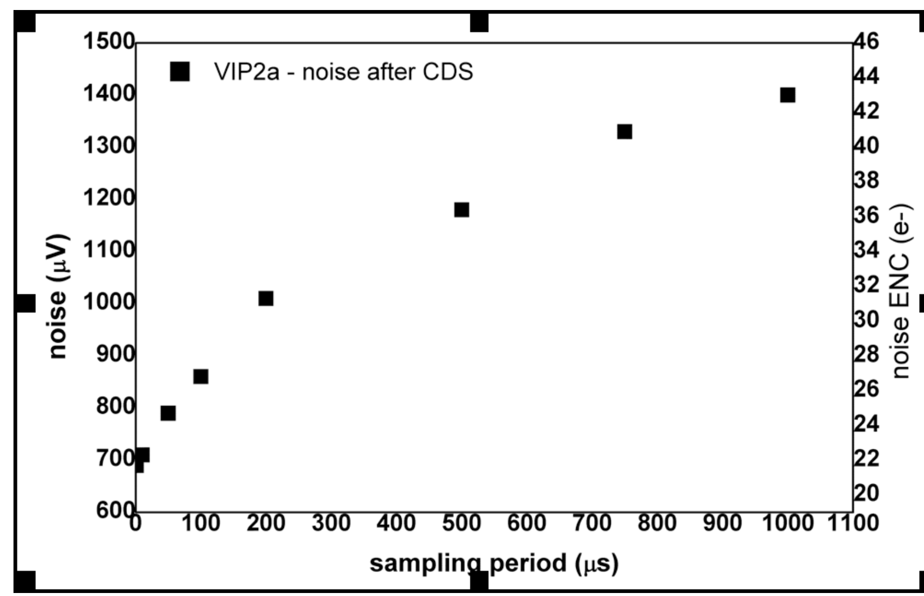


Figure 11.1 Proposed pixel architecture

VIP (3D Pixels)

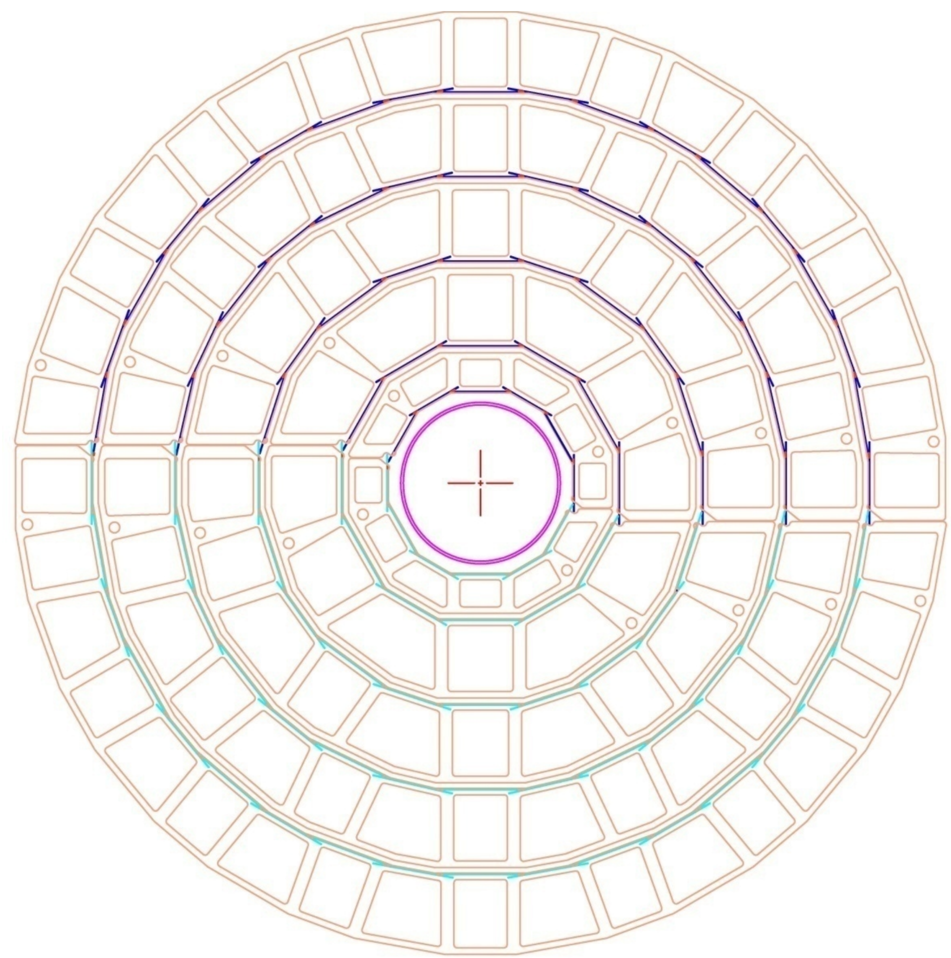
- 2 (VIP2b) or 3 (VIP1,2a) tiers
  - CDS
  - Analog and digital time stamp
- VIP2a back from Lincoln Labs
  - Extensive redesign
  - Improved Yield compared to VIP1
- VIP2b will be back from Tezzaron soon
- 3D Design is challenging
  - A learning experience





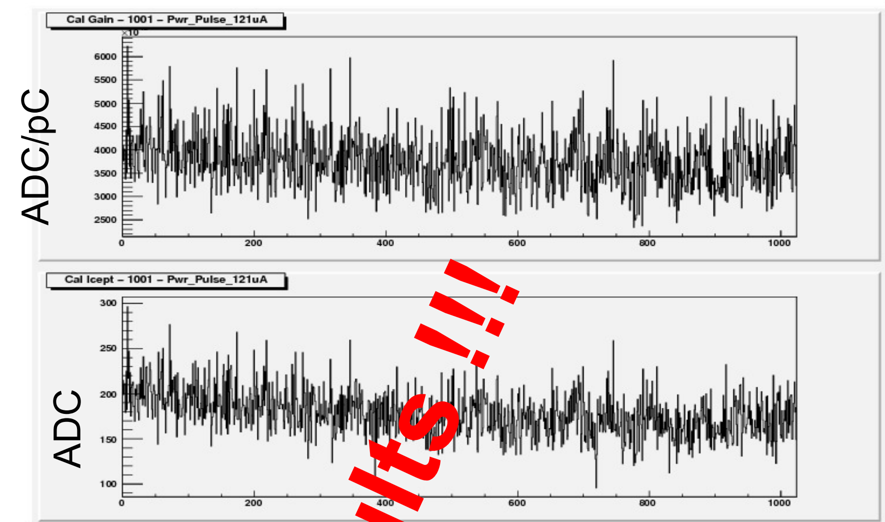
Vertex detector mechanics

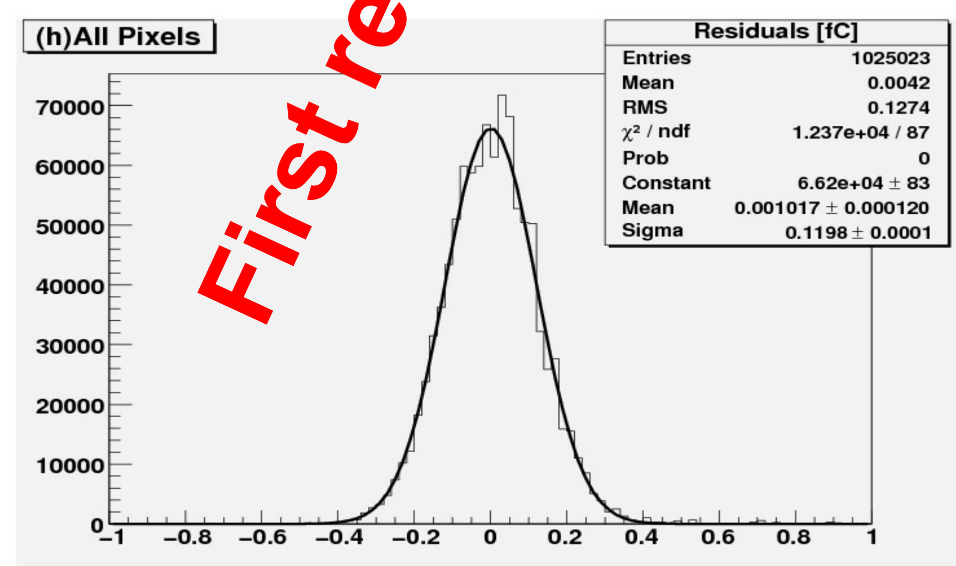
- Two half cylinders
  - Sensors are glued to one another near their long edges
  - Two sensor sizes
- Thermal studies
  - Using 0.13 W/cm^2 and Air cooling
  - Heat removal from the innermost layer is difficult due to beam pipe
  - Benefit from removing heat from both surfaces
- Power studies
  - DC-DC converters and cables
  - 45 % ofPower budget



KPix

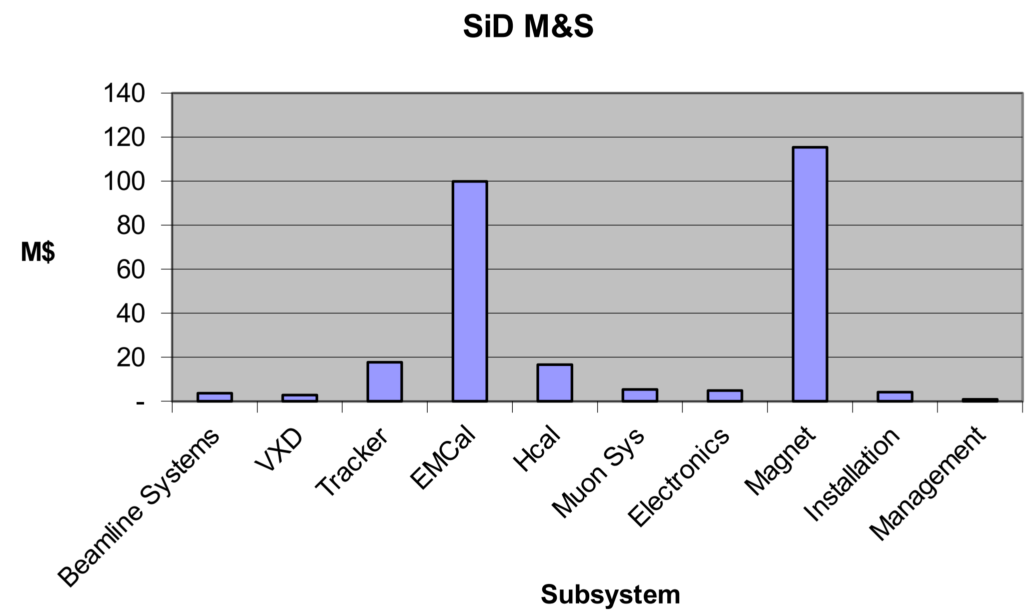
- KPiX is a 1024 channel, power-pulsed chip
- Development aimed for SiD
  - Usage not limited to SiD
- KPiX versions
  - KPiX-7 (2008) with 64 channels
  - KPiX-8 (2009) with 256 channels
  - KPiX-9 (2010) with 512 channels
  - KPiX-A (2011) with 1024 channel
- KPIX-A back since two weeks
  - First tests successful
- More details in parallel sessions

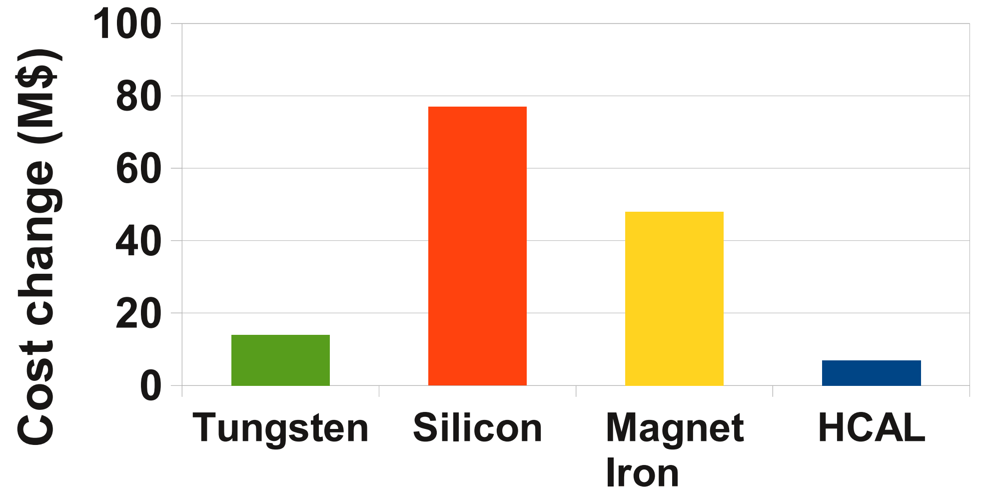


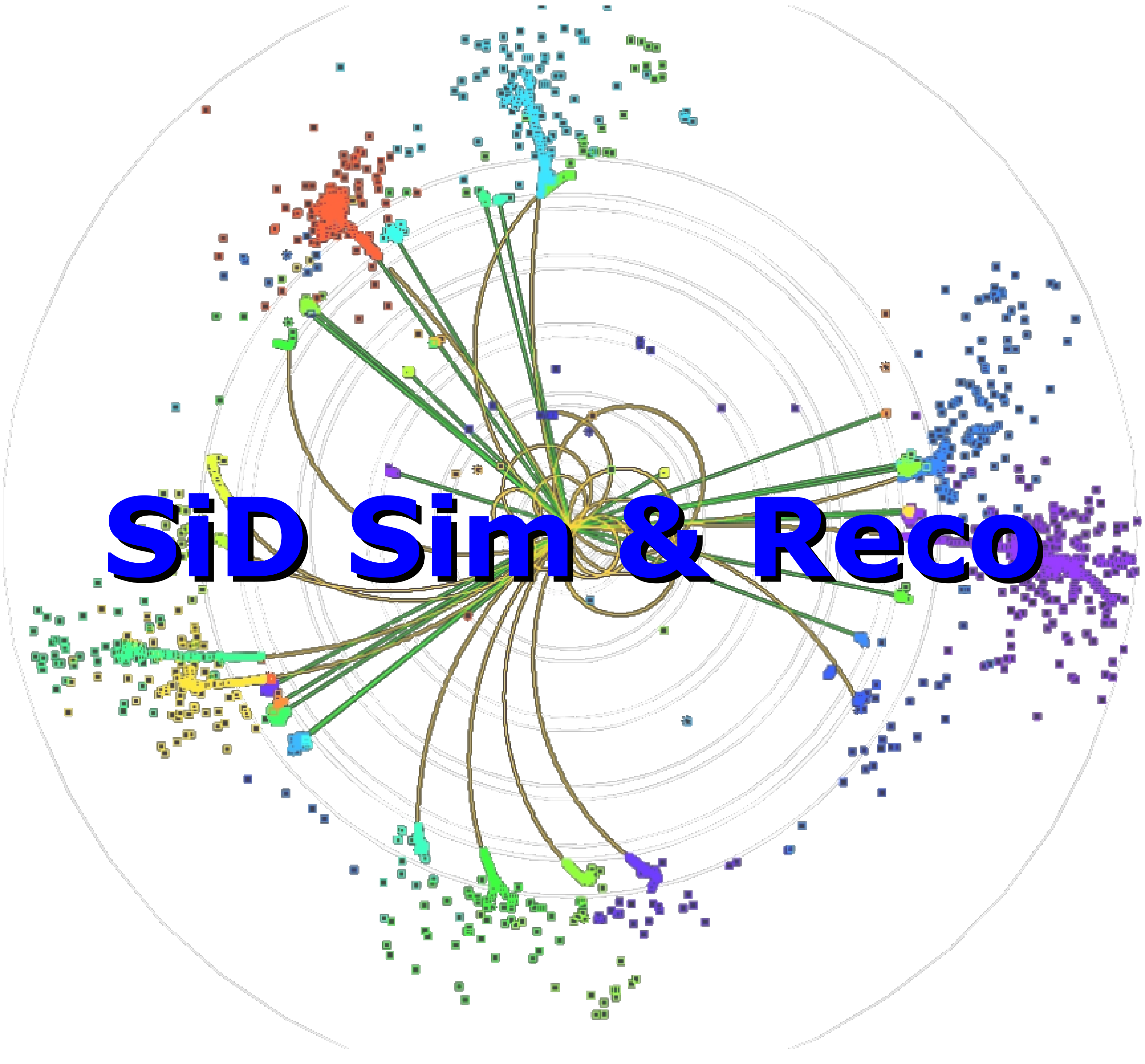


Costing News

- SiD has been working with ILD and CLIC to define common costs and margins
  - Tungsten
  - Steel
  - Silicon
- Incorporated in Cost Model
- Checked impact of doubling material unit costs

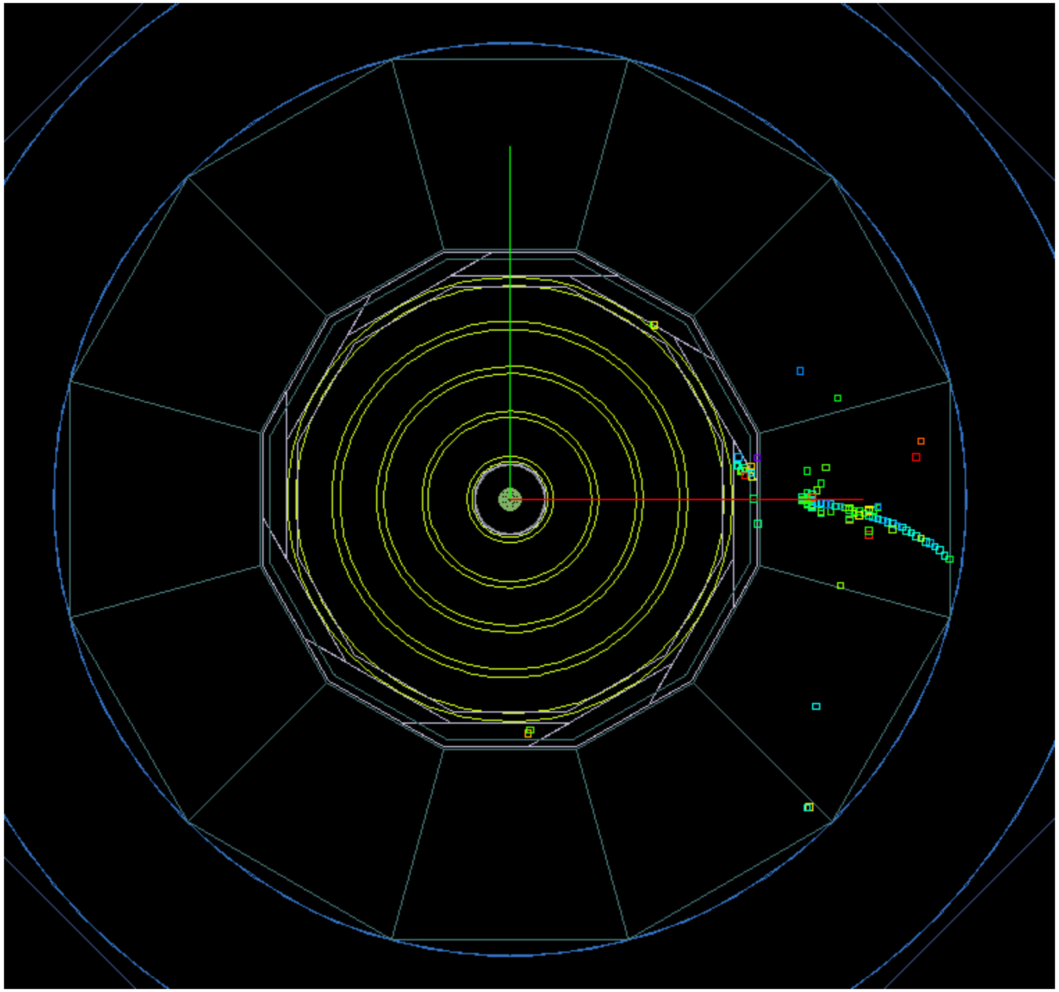




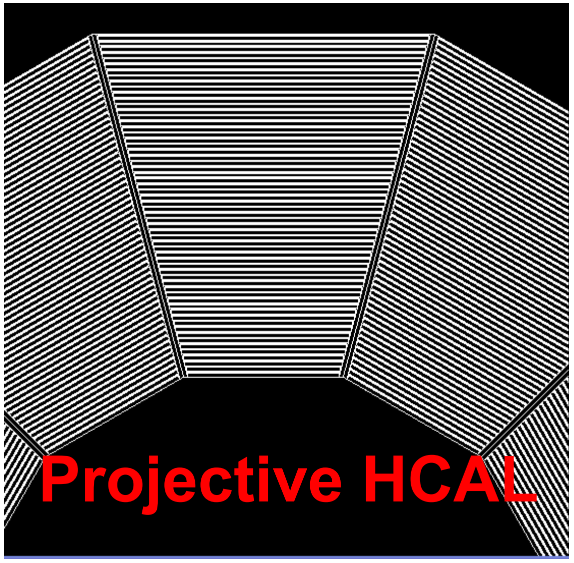

SiD Sim & Reco

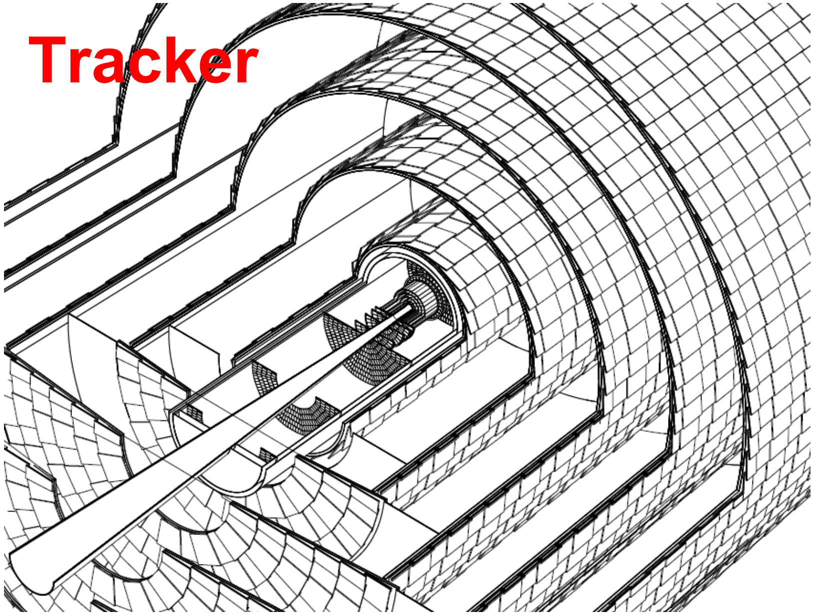
Detector Simulation

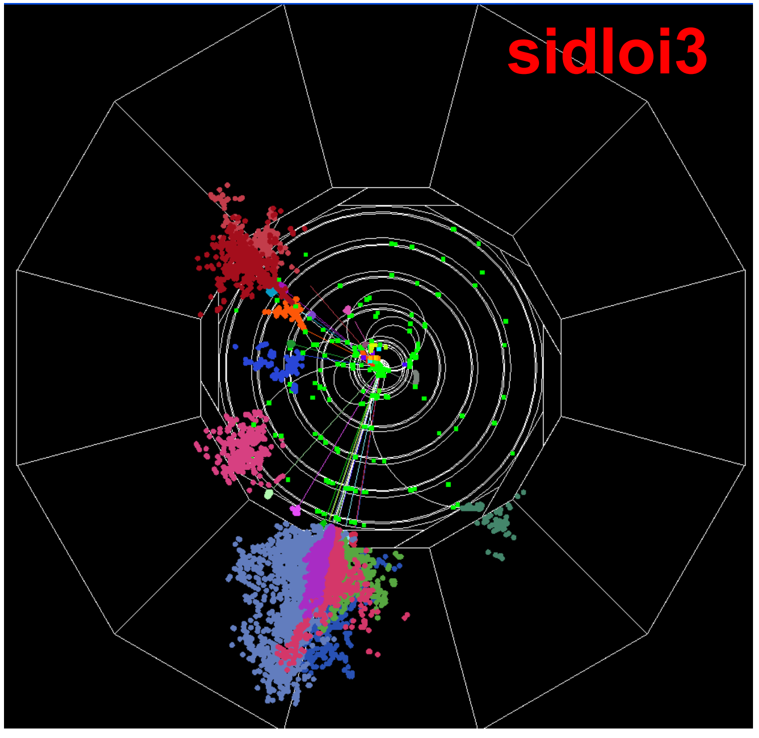
- Current implementation of SiD (sidloi3)
- Improvement w.r.t. LoI
  - HCAL Modules
  - ECAL Modules
  - Segmented Tracker
- A more realistic model of SiD
- More to come
  - Detailed RPC model
  - Non-projective Cracks

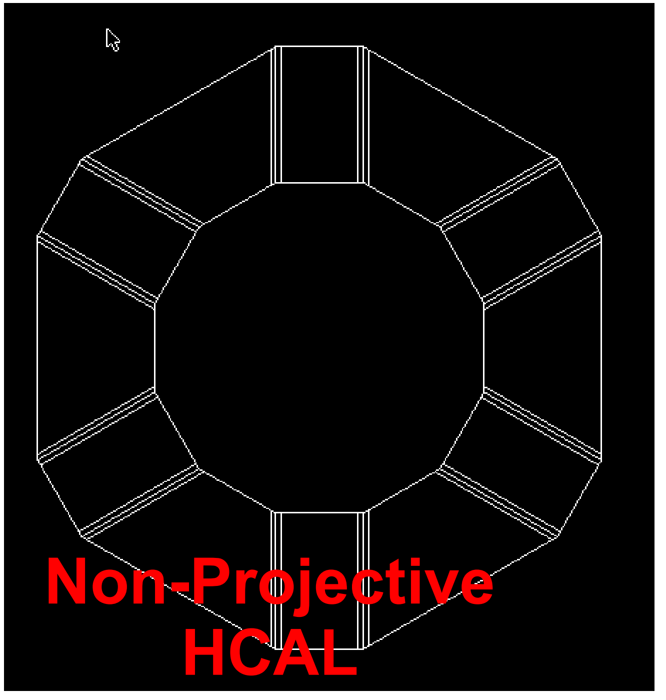


Some more details







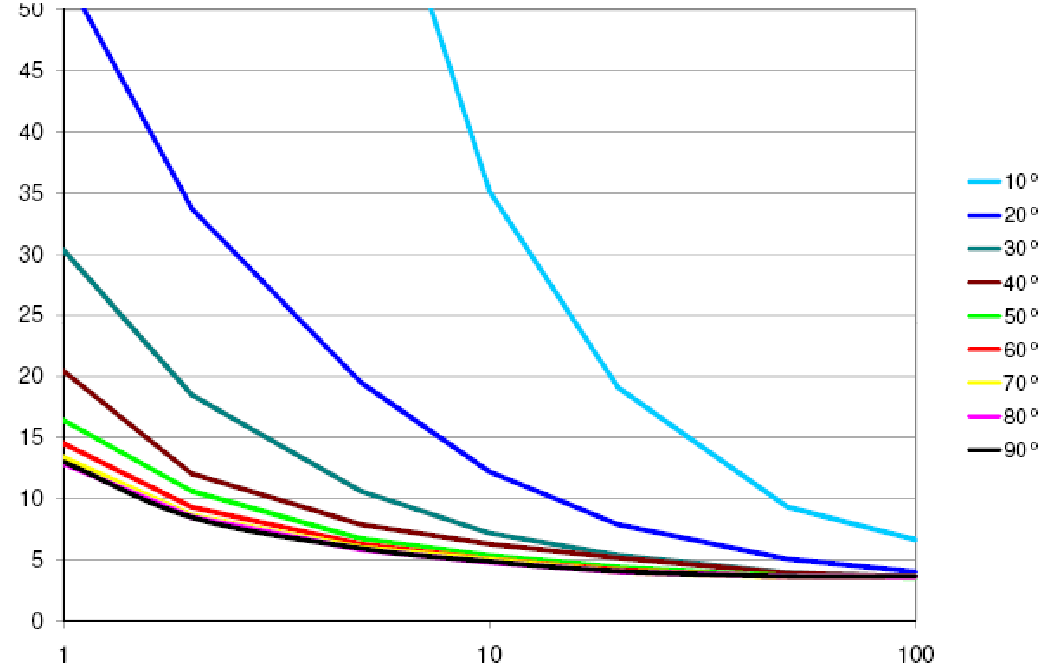


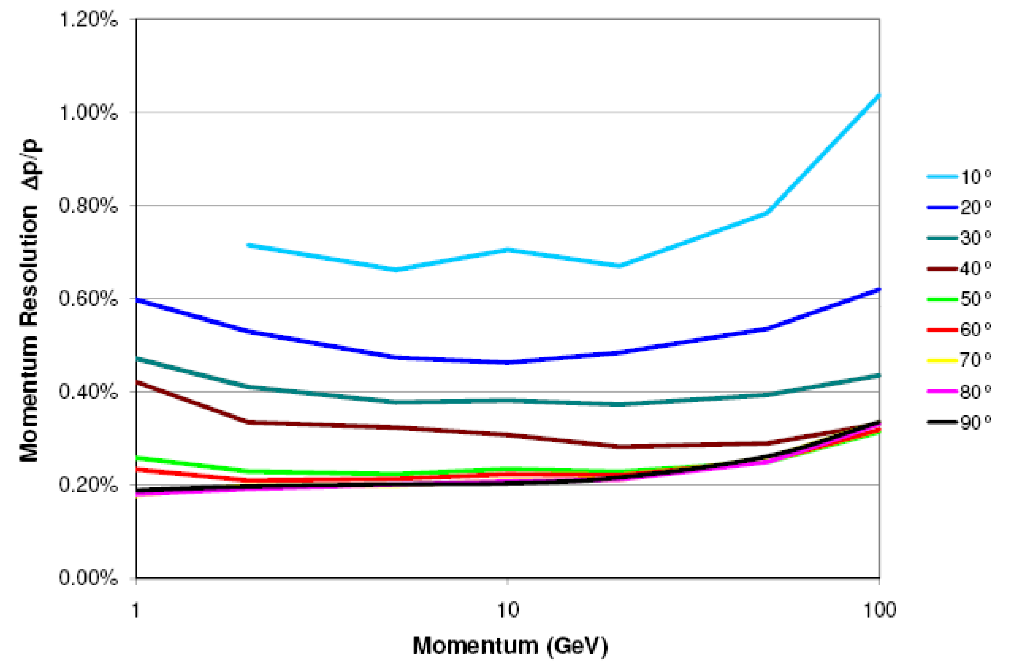
Reco Software status

- Worked well during LoI
- Thanks to the CLIC CDR effort, these bottlenecks were identified
  - Timing issues beyond 500 GeV
  - Tracking problems
  - Performance degradation at 3 TeV
- All of them have been/ are being addressed
  - Tracking improvements
  - PFA
  - Good example of collaboration
- PFA work is continuing
  - Both on SLICPandora and IowaPFA
- More Details in the parallel sessions

Tracking Status

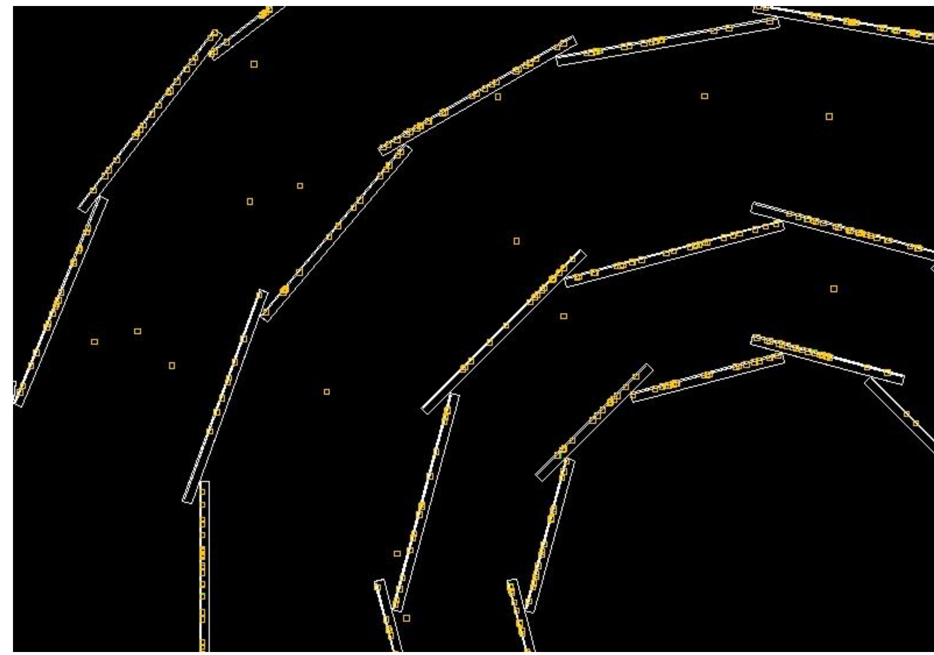
- LoI Achievements
  - >99% track finding efficiency over most of the solid angle
  - Momentum resolution ~0.2% for $|\cos(\theta)| < 0.65$
  - DCA ~15 μm for $p_T = 1$ GeV, $|\cos(\theta)| < 0.65$
  - Most tracks multiple scattering limited – resolution approaches ~4 μm at high p_T
- Slightly better than "design goal" at high momenta
- Slightly worse than "design goal" at low momenta





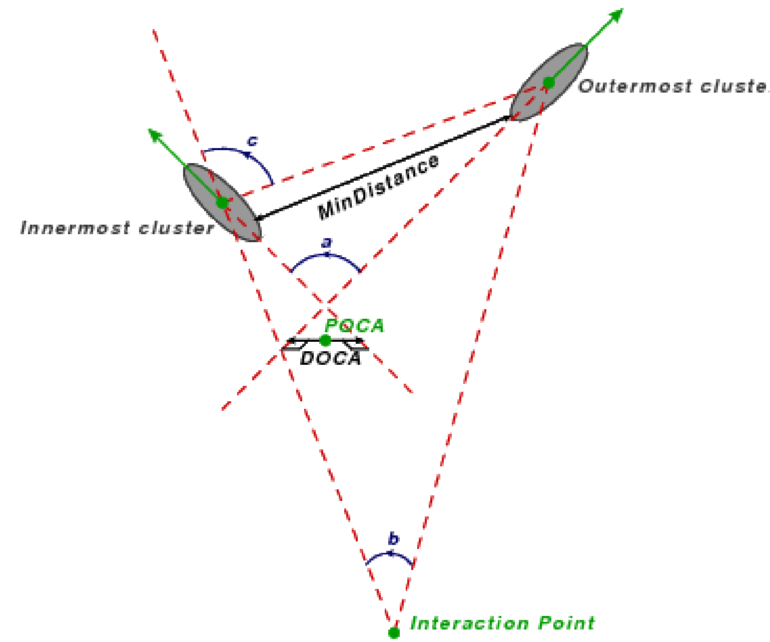
Tracking improvements

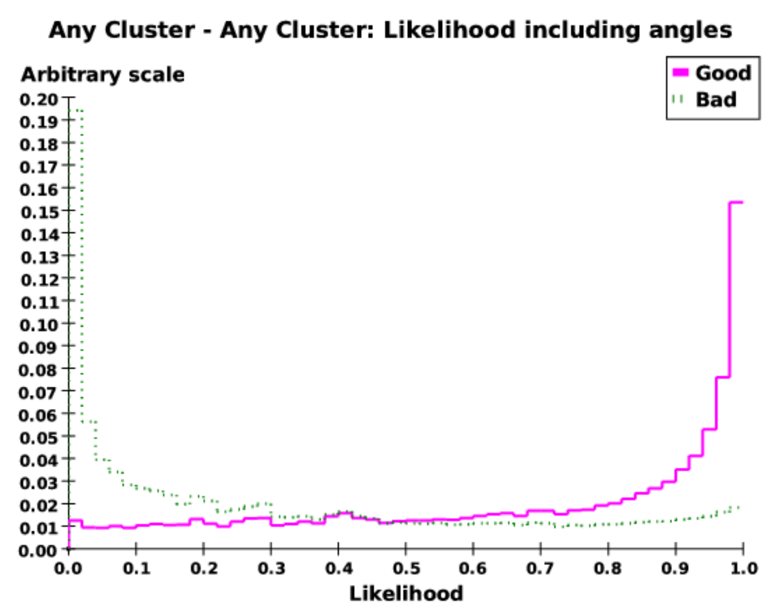
- Planar sensor geometry
- Realistic charge deposition and digitization/clustering
- Improvements to tracking performance for high occupancy (CLIC)
  - Latest news in Sim/Reco
- Working on Kalman Filter implementation



PFA work - IowaPFA

- LOI version was designed for 500 GeV
  - 500 GeV performance sufficient, but could be improved.
- Improvements
  - Targeted diagnostics for each piece
  - Photon reconstruction: Once photons are reconstructed, the hits are taken out from use.
  - Sub-cluster categories (clump purity)
  - Improvements in clump-ID
  - Shower reconstruction (two passes) IN PROGRESS

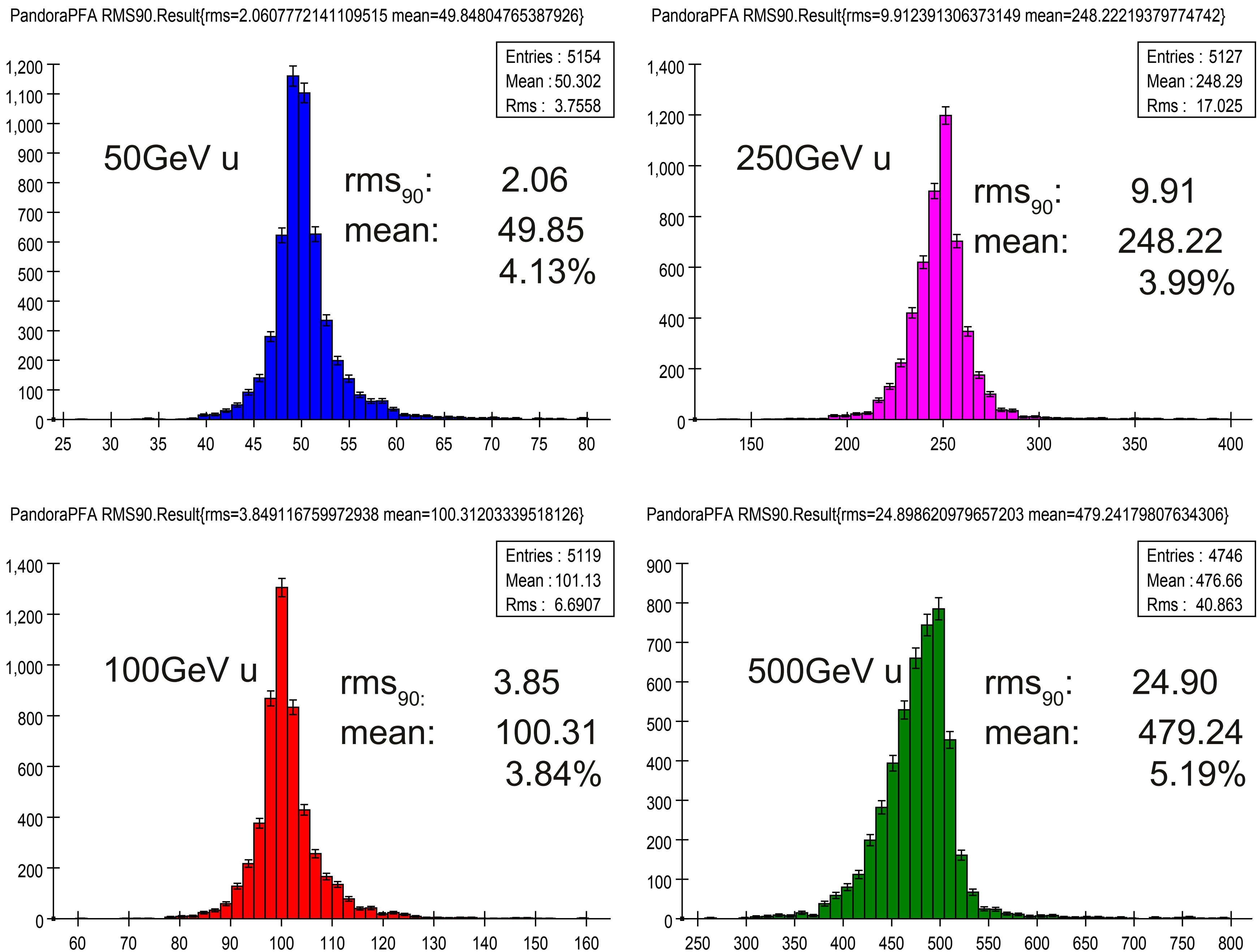




SLICPandora

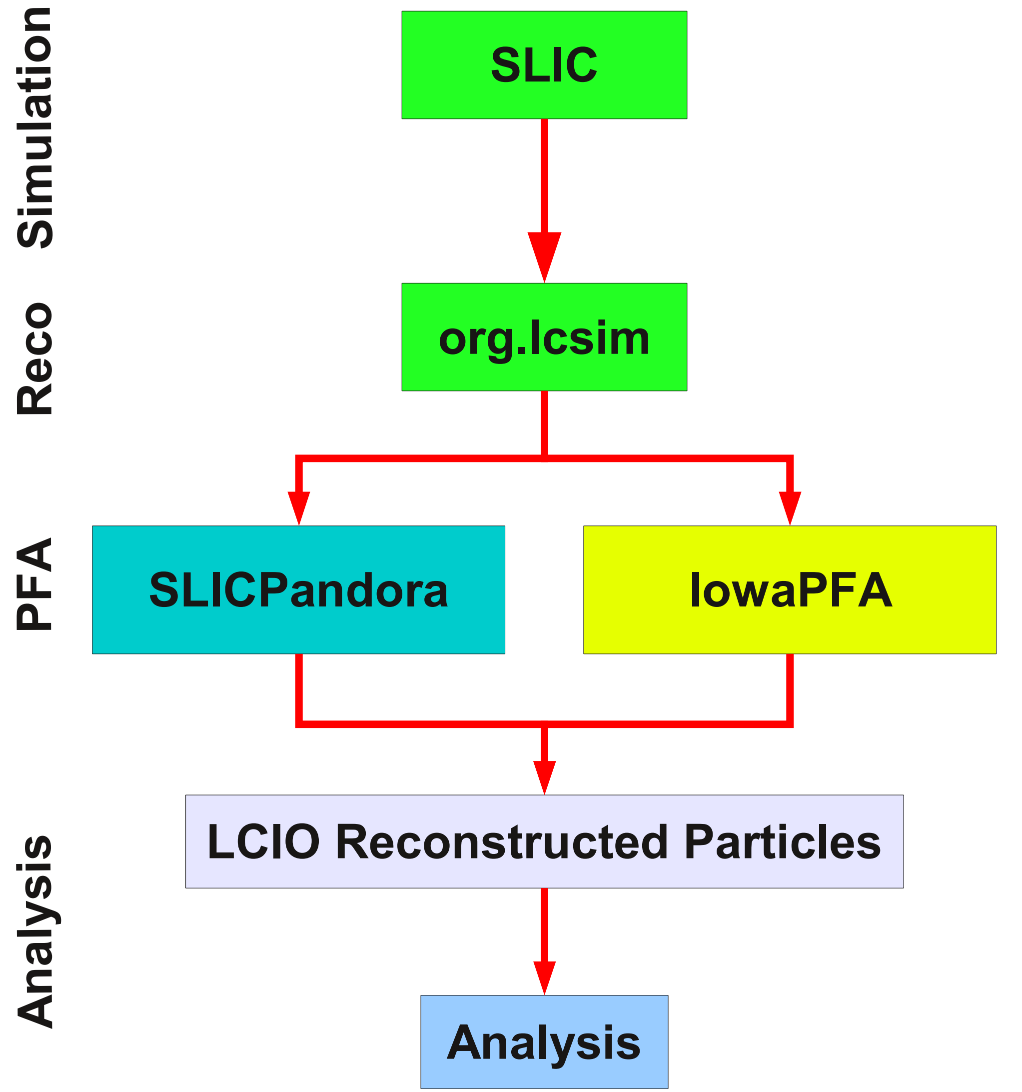
- Frontend to the PandoraPFANew
  - Enables Pandora to process events from SLIC/org.lcsim
- The technical interface is essentially complete.
  - Geometry definition is automated
  - Sampling fraction derivation is automated
  - lcsim-cal-calib + single particle generation
- Detector response of sidloi3 and clic_sid_cdr being studied.
  - Tuning & algorithm iteration ongoing.
  - expect to see further improvements soon
- Getting ready for CDR/DBD physics analyses

SLICPandora Single Jets



PFA comparison

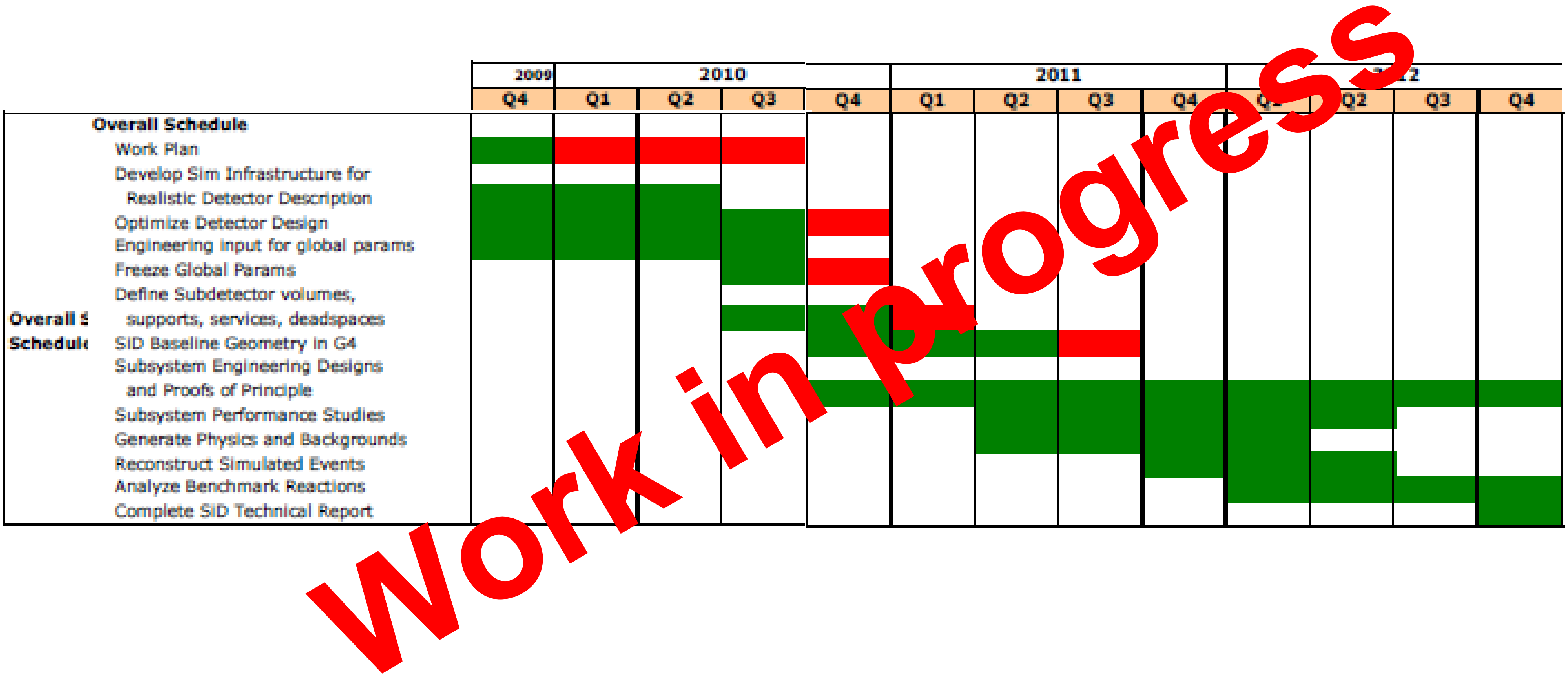
- LoI used IowaPFA
- Since Summer 2010 developed SLICPandora
- We can now compare
  - Two PFA approaches
  - Same detector
  - Same reconstruction
- Keeping the algorithms honest
  - Vital tool for understanding PFA issues
- Comparisons have started



The Road to the DBD

- Recognition by Research Director that LoI was a substantial milestone/result of a large body of work
  - SiD will not repeat the LoI within the DBD
- Status
  - ongoing work in all subsystems, but each on its own timeline (also due to funding)
  - It is already clear that R&D will continue beyond 2012
- Developing more realistic detector description
  - folding in increasing realism in subsystem elements

SiD Workplan



Current Status

- Editorial Work has started
  - Editors appointed
  - Outline produced
- Full engineering designs of all the detector components,
  - These are not imaginable with the present level of support.
  - Instead conceptually engineered designs of detector subsystems and proofs of principle of key engineering assumptions
- Funding remains a concern for the DBD work

The way ahead

- SiD will have dedicated workshops to discuss DBD items
  - This meeting (Tuesday/Wednesday)
  - Over the coming ~ two years
- Discussions on
  - R&D progress
  - Tools for the DBD
- SiD will stay in close contact and discussions with IDAG and the community to ensure that the DBD is the document that is needed in 2012
- Thanks to everybody from SiD for providing material, comments and suggestions