Progress of ILD towards DBD

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On behalf of the ILD Detector Concept

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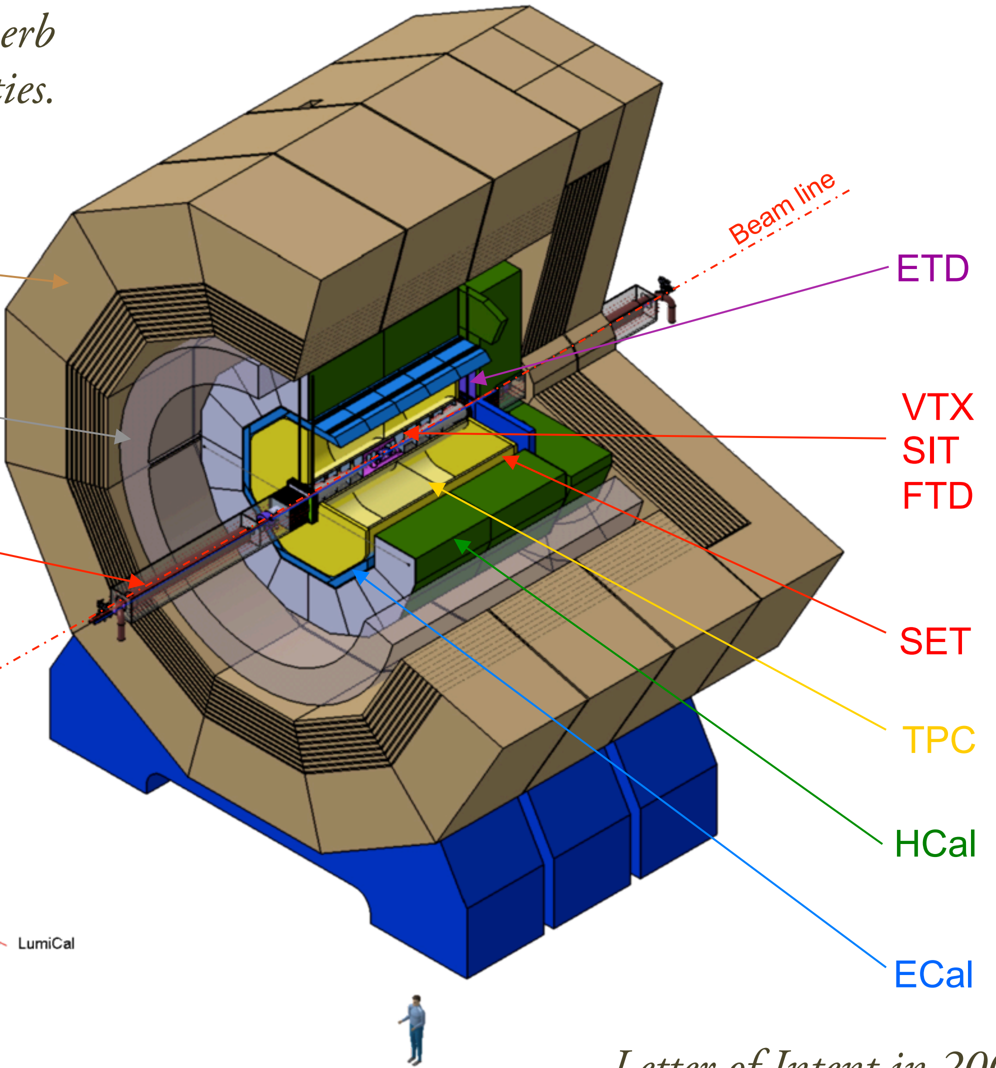
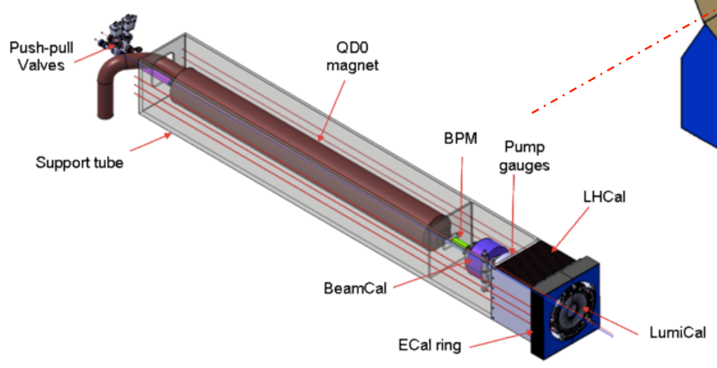
ilc ilcILD.org THE UNIVERSITY OF TOKYO

International Large Detector

Detector optimized for ***particle flow****, with highly granular calorimeters and superb tracking and vertex finding capabilities.*





Letter of Intent in 2009.

Invited by IDAG to work towards a ***DBD for 2012.***

Towards a Detailed Baseline Design

ILD is intensifying its efforts as the deadlines for the DBD become near. Areas in which significant progress are being made are:

Component R&D

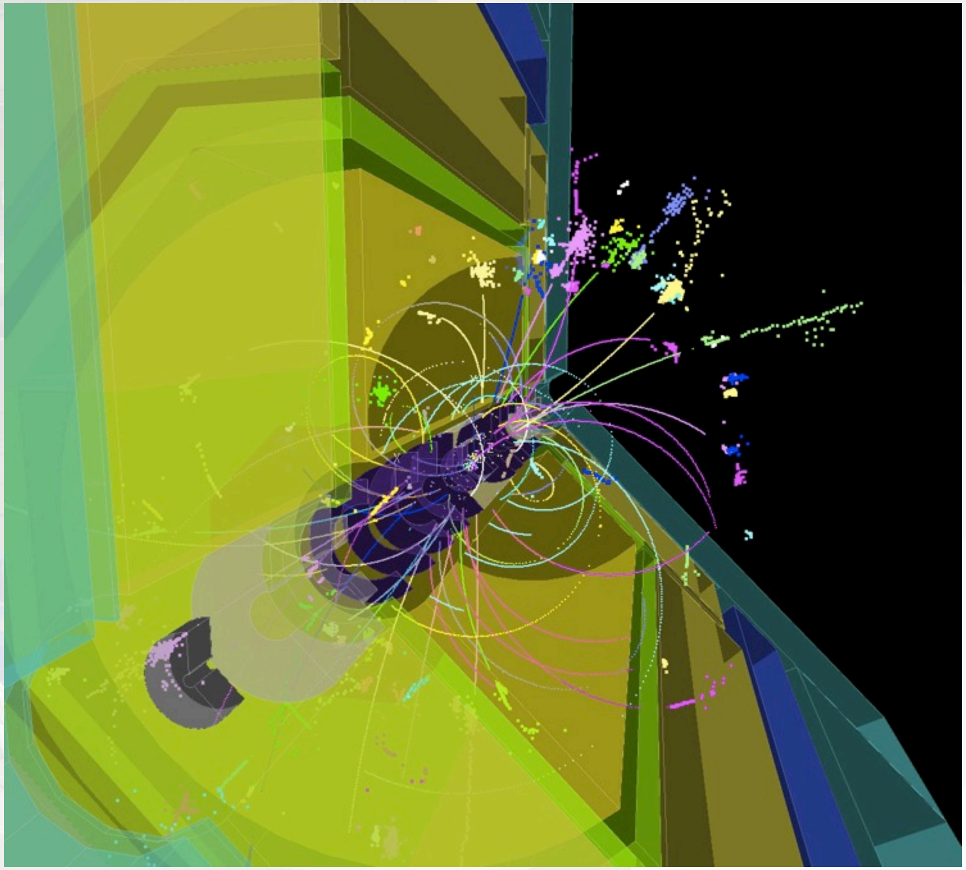
- Construction of prototypes, testing and validation of technologies, test beam results, power-pulsing operation…

Simulation tools

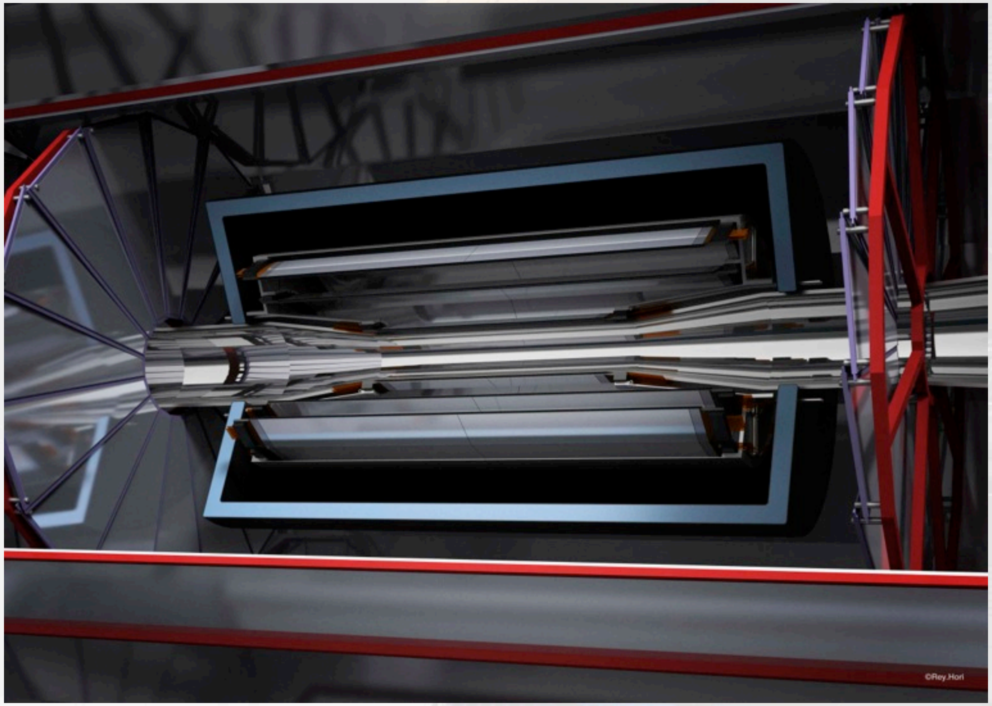
- Implementation of simulation detector models with increased realism, improvement in event reconstruction software

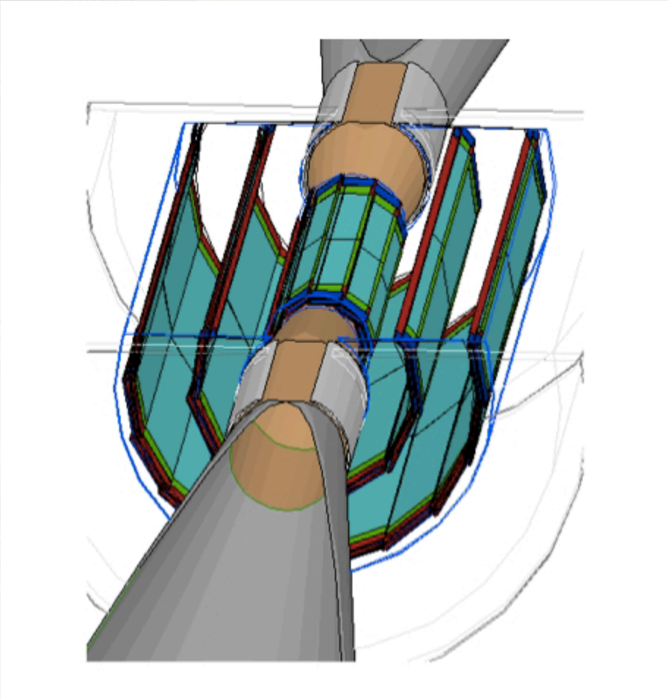
Physics studies

- Benchmark processes, other processes to enrich the ILC physics case



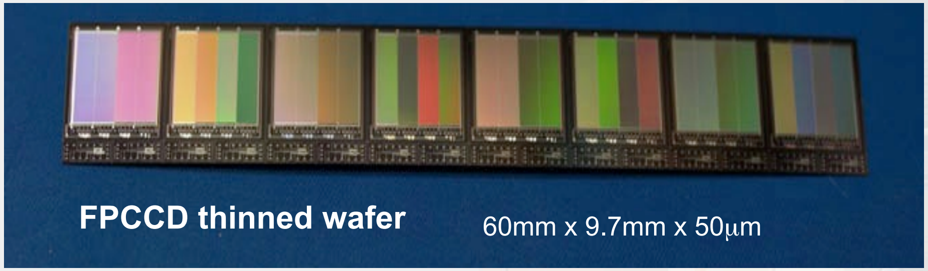
Vertex Detector (1)



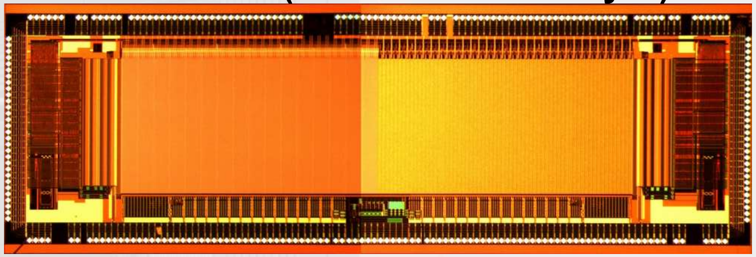


- ✓ Key to flavor tagging by reconstructing vertices
- ✓ Aim for unprecedented performance: $\sigma_b < 5 \oplus 10/p\beta \sin^{3/2}\theta$
  - ✓ Spatial resolution < 3 μm
  - ✓ Material budget 0.2-0.3% per layer
  - ✓ Sufficiently low occupancy
- ✓ Cope with large beam backgrounds
- ✓ Options: FPCCD, DEPFET, CMOS…

Vertex Detector (2)

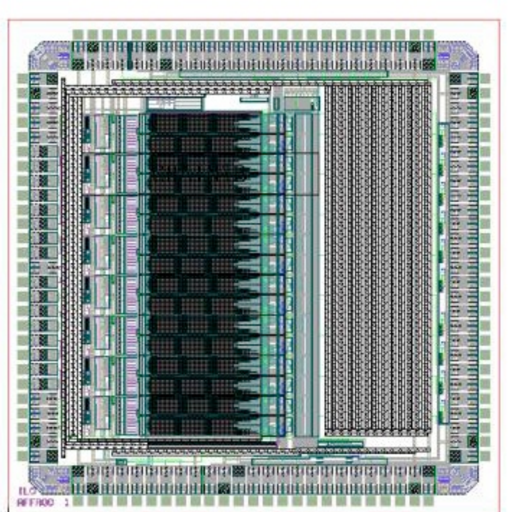


MIMOSA-30 (VXD innermost layer)



FPCCD R&D:

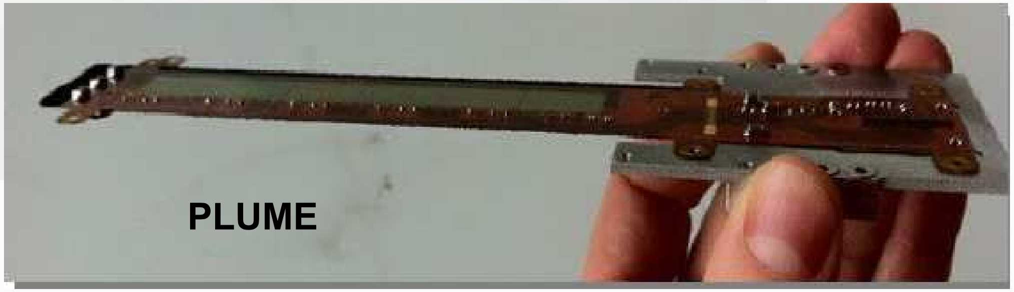
- 8µm pixel prototype developed
- Technology to thin down to 50µm established
- Large prototype with 6µm pixel in FY2012
- Readout ASIC: 3rd prototype delivered in a few months, 10 Mpix/s, ~5mW/ch



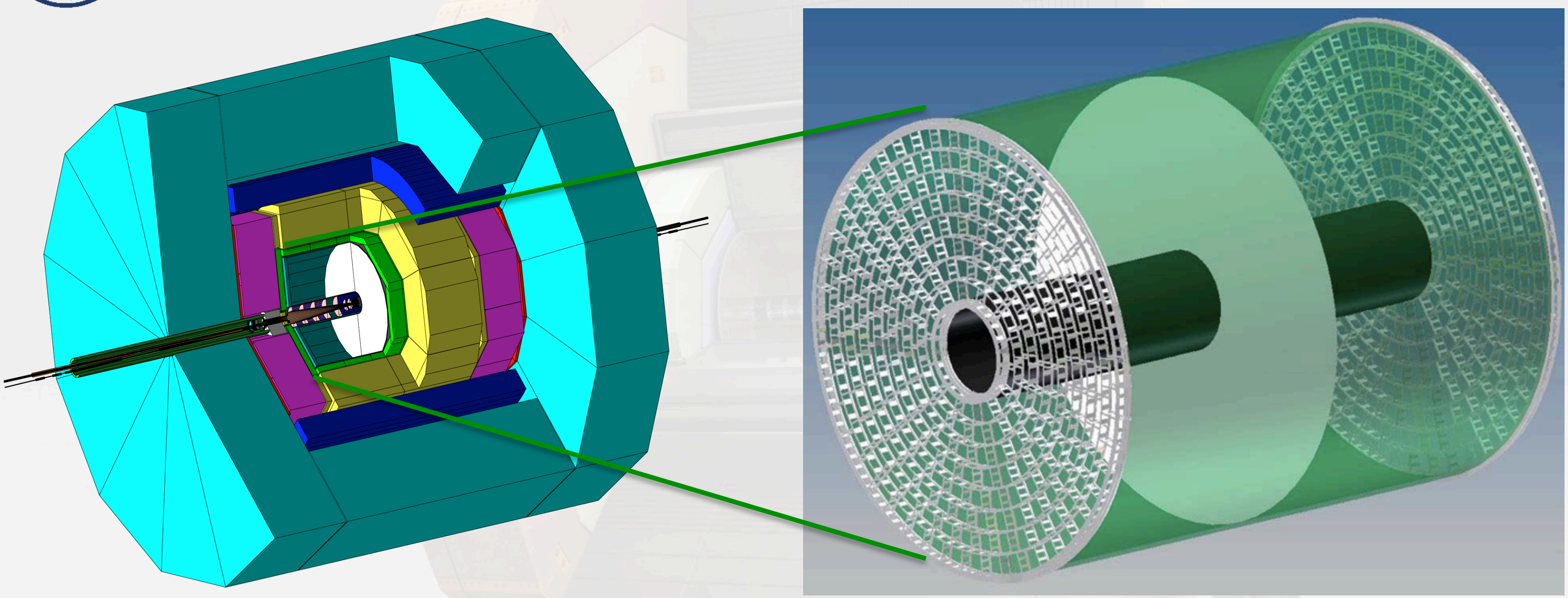
Layout of 3rd ASIC

CMOS pixel R&D:

- MIMOSA-30 (inner) and MIMOSA-31 (outer) fabricated Q4/2011. 10µs read-out (inner) confirmed, TB in June/July.
- PLUME (0.6% X_0) **double-sided ladder prototype** shows good performance. New version (0.35% X_0) under construction, TB scheduled June/July → ***technology validation***
- New 0.18µm process could reduce read-out to 1-2µs → **1 TeV**. MIMOSA-32 fabricated in Q4/2011, being tested.



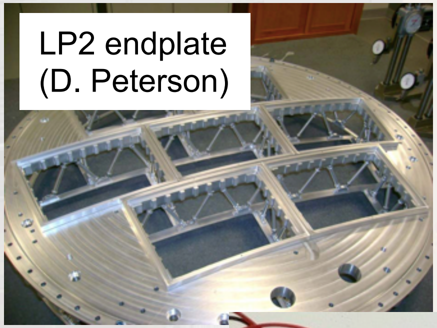
Time Projection Chamber (1)

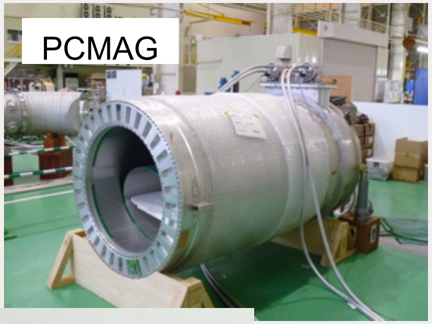


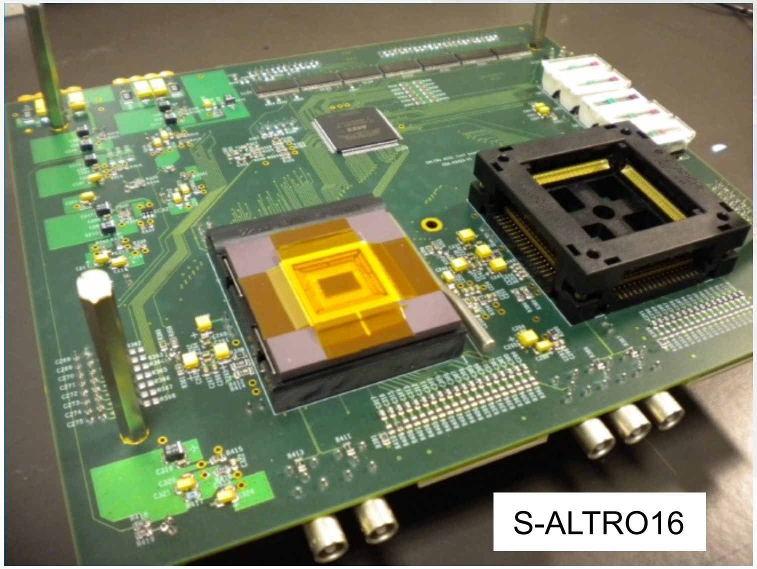
- TPC is the central tracker for ILD
- Large number of 3D space points allows for continuous tracking
- Offers particle identification via *dE/dx*
- Low material budget inside the calorimeters important for PFA
  - Expect maximum of 25% X_0 including electronics/cooling (endplate studies by D. Peterson)
  - ILD inner eldcage with 1.2% X_0 and outer eldcage of 2% X_0
- 3 readout schemes: GEM, Micromegas, pixel

Time Projection Chamber (2)

- LP2 endplates built & tested → good rigidity, agrees with simulation. **Space-frame design viable**.
- PCMAG upgrade completed, shipped from KEK to DESY; LP movable stage upgraded @ DESY.
- TB this summer: 7 new Micromegas modules in June/July, followed by GEM modules (DESY and Asia)

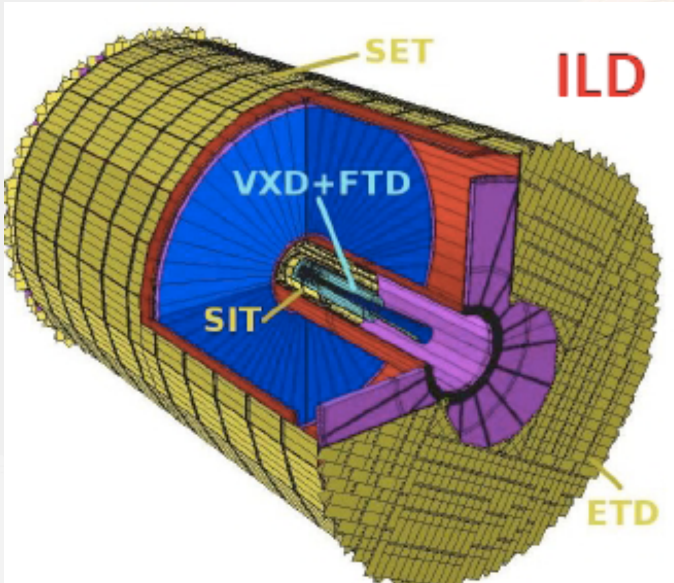


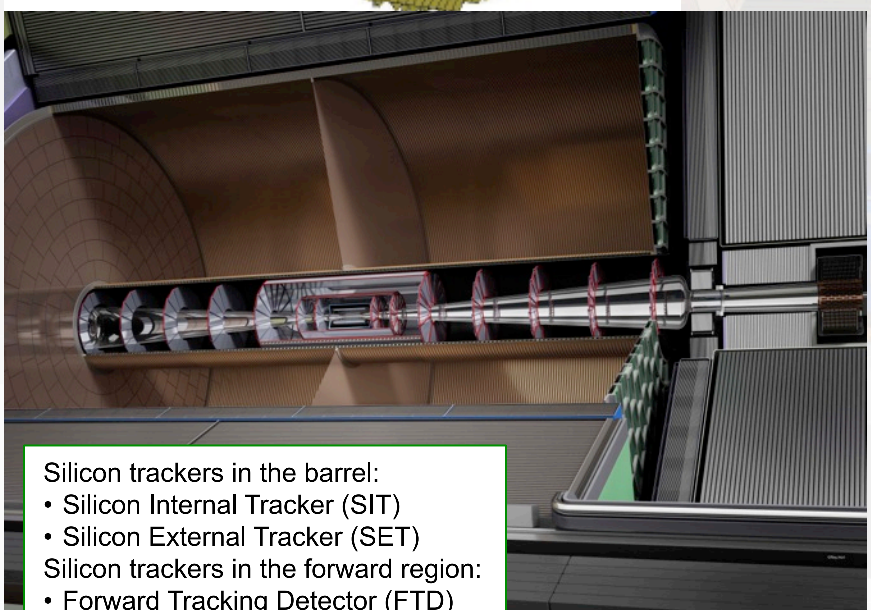




- S-ALTRO16 readout shows nice results, **power-pulsing at the chip-level**; will be implemented in LP
- New readout chip GdSP being developed: more compact, lower power consumption
- Effect of ions in gating devices understood better

Silicon Tracking (1)





Silicon trackers in the barrel:
- Silicon Internal Tracker (SIT)
- Silicon External Tracker (SET)

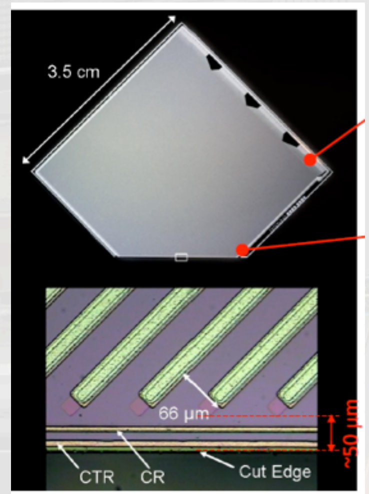
Silicon trackers in the forward region:
- Forward Tracking Detector (FTD)
- End-cap Tracking Detector (ETD)

- Extra silicon trackers are added to provide:
  - Better angular coverage
  - Improve momentum and position resolution
  - Calibration of distortions
  - Alignment
  - Time stamping
  - Redundancy and robustness

- R&D by SiLC collaboration
  - FEE based on <1μm CMOS technology
  - New on-detector electronics connection
  - New support architecture
- Challenge:
  - Material reduction
  - Low power consumption
  - High spatial resolution

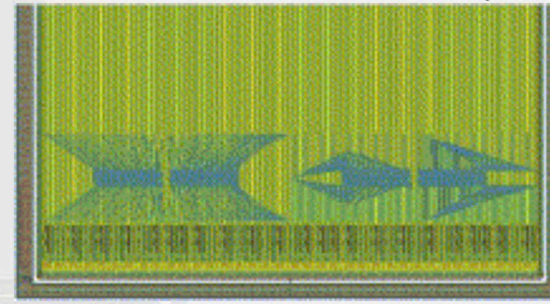
Silicon Tracking (2)

- Solution to limited resources: **ILC-LHC synergy.** Technologies initially developed for the ILC actively pursued for the LHC upgrade, e.g. ***edgeless sensors*** and ***integrated pitch adapters***. ILC will benefit from this in ~2013
- Established 130 nm CMOS technology for mixed mode analogue-digital FEE readout → active development for LHC upgrade. ILD design will be improved for DBD. Use of 65nm technology actively being developed (e.g. timepix or FEI4)
- Use of ***intelligent devices***: *both* support *and* other functions (cooling, services, positioning) at LHC, originally pioneered by ILC → Full architecture of the DAQ signal processing will be updated and included in DBD

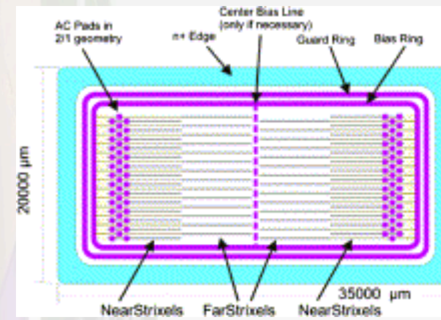


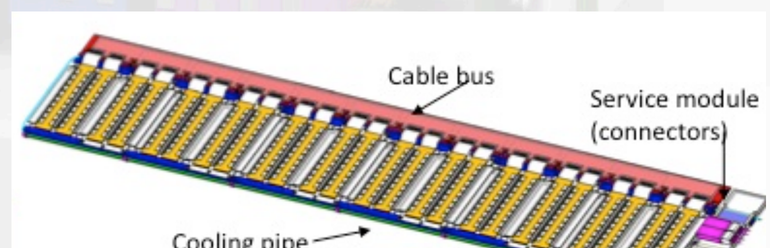
Only 50µm from end of strip to end of sensor!!!

IPA in a second metal layer



Strixels with IPA





supermodules

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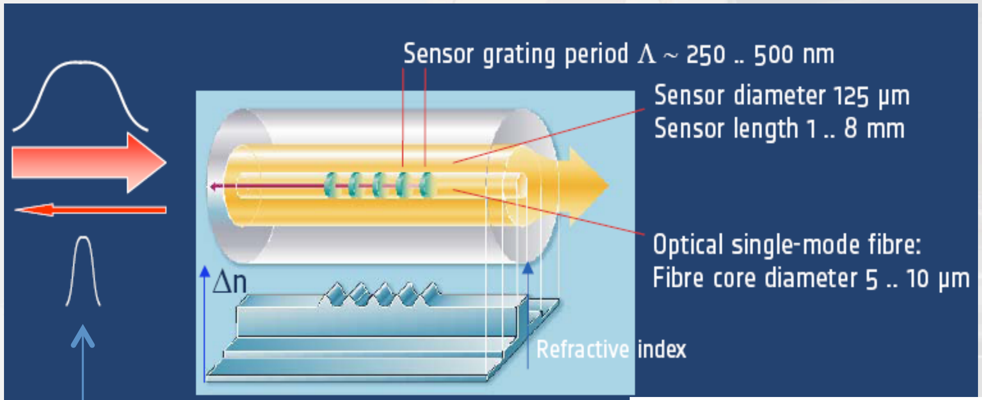
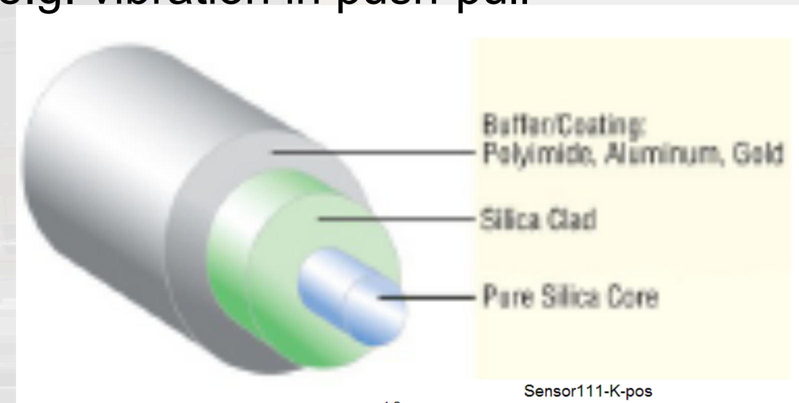
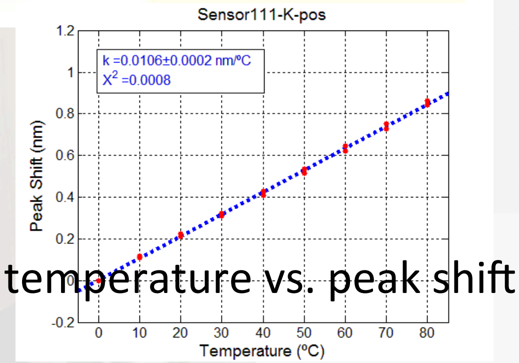
Silicon Tracking (3)

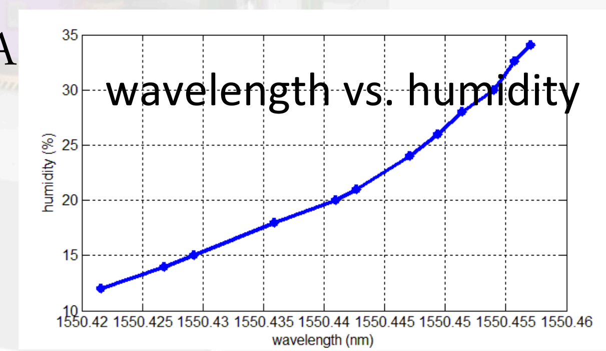
FTD monitoring with fiber optics sensors (FOS) embedded in the sensor (AIDA): monitors environmental variables in real time, e.g. vibration in push-pull

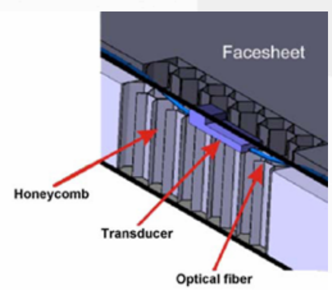


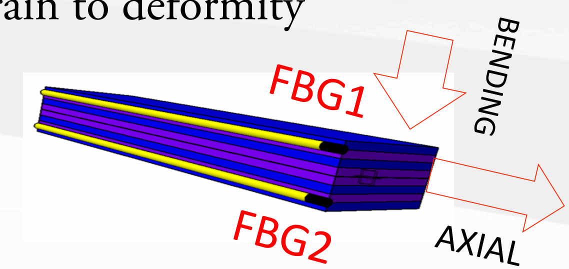


- λ_B is sensitive to strain and T: $\left[\frac{\Delta\lambda_B}{\lambda_B}\right] = C_S\epsilon + C_T\Delta T$ $\begin{cases} \sim 10 \text{ pm/K} \\ \sim 1 \text{ pm}/\mu\epsilon \end{cases}$
- Other quantities (humidity, %CO_2, magnetic field, …) can be measured using coatings sensitive to them.
- FOS are light-weight, small, flexible, immune against EM fields, HV, wide range of operating temperature (4~900K)
- New prototype will be manufactured with FBG sensors; FEA simulations to relate strain to deformity

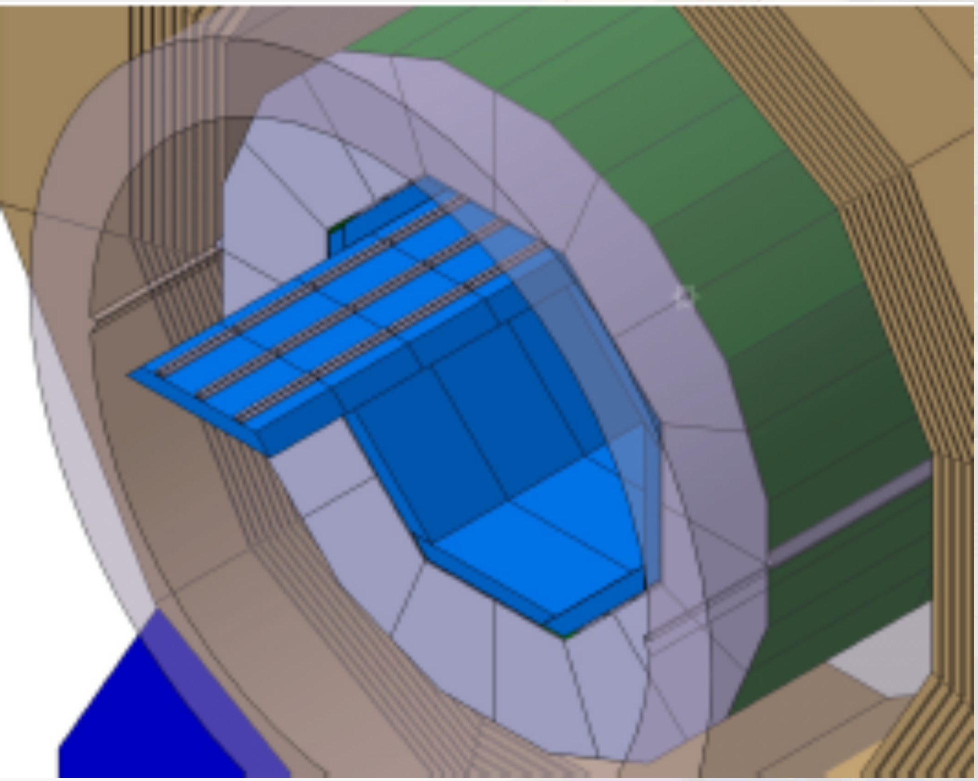








Calorimeters



ECAL

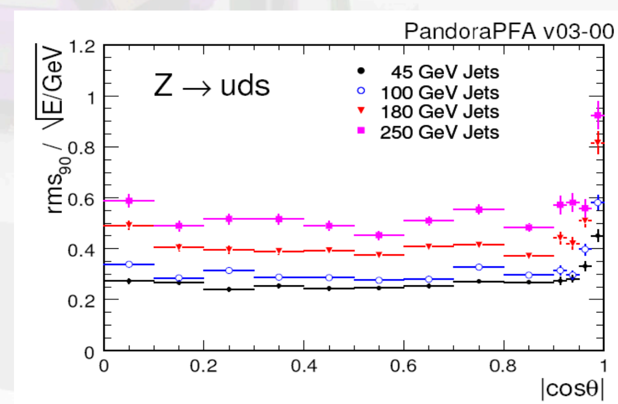
- Tungsten as absorber material
- X_0=3.5mm, RM=9mm. l=96mm
- Narrow showers, compact design
- Silicon and/or scintillator as active material

HCAL

- Digital, Semi-digital: RPC/MicroMegas
- Analog: scintillator tiles read-out by SiPM

Forward Cal

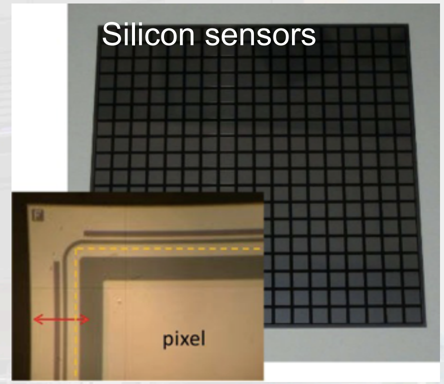
- Luminosity Calorimeter (LumiCal)
- Beam Calorimeter (BeamCal)

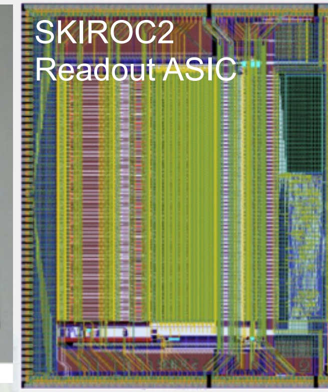


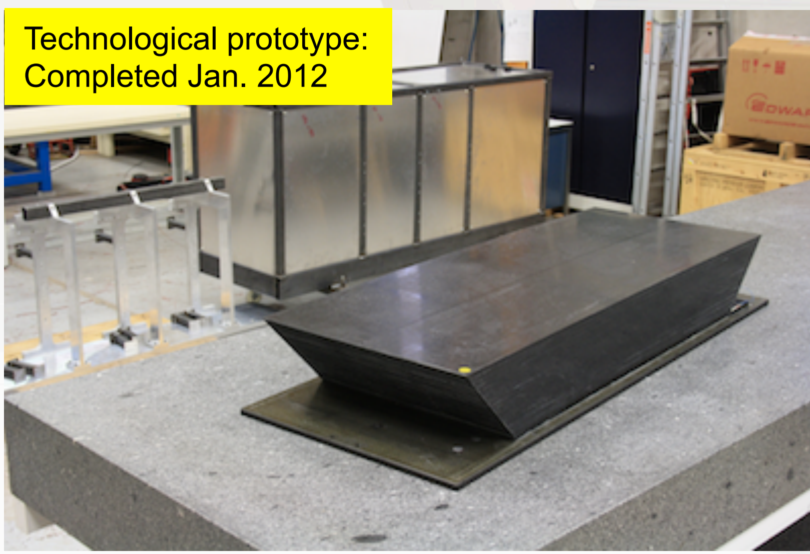
Particle flow approach promises to deliver unprecedented jet energy resolution.

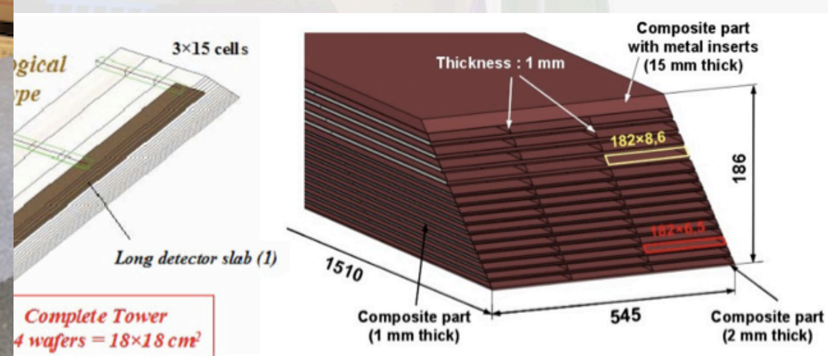
SiECAL

- Sensor R&D: reduced/modified guard ring structure, aspects of large scale production
- Readout ASIC: 35um SiGe, 7.18.5mm2, 64ch/ASIC, low power (~1.5 mW/ch), produced and tested. Power pulsing test July TB
- **Technological prototype completed (Jan 2012)**: alveolar composite/tungsten structure, 15 slabs with integrated FE chips, available for TB



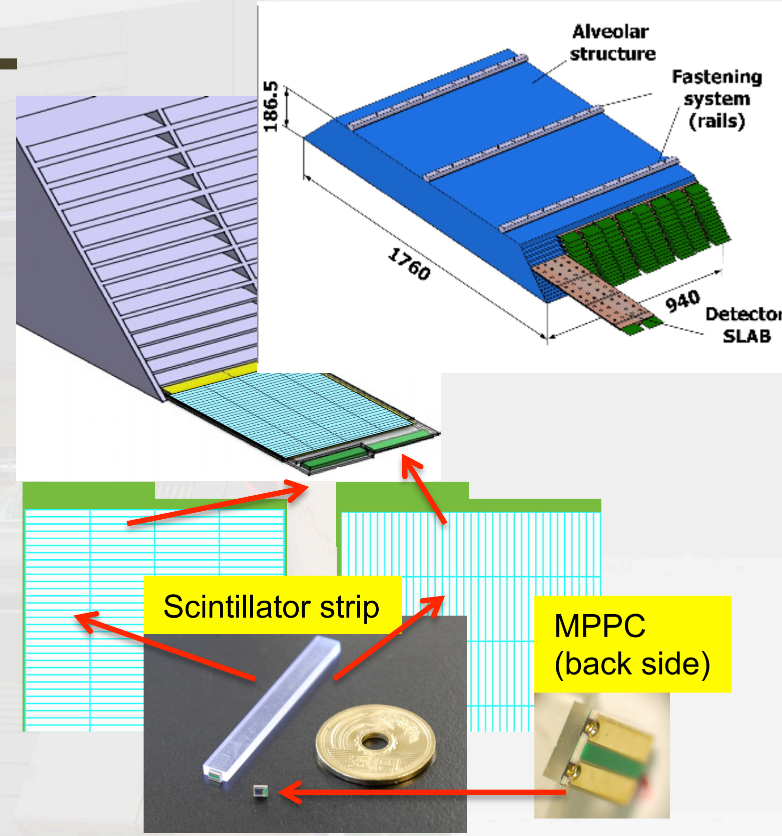


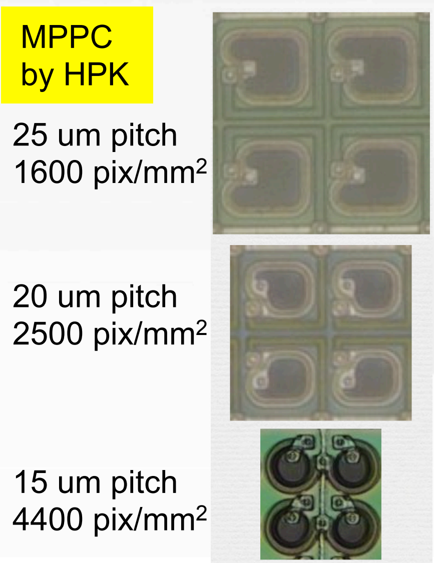


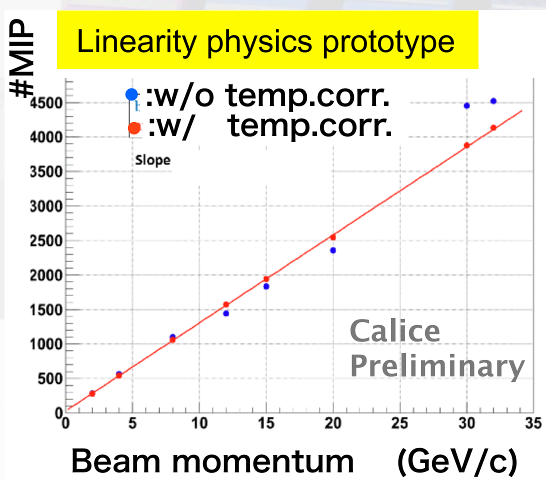


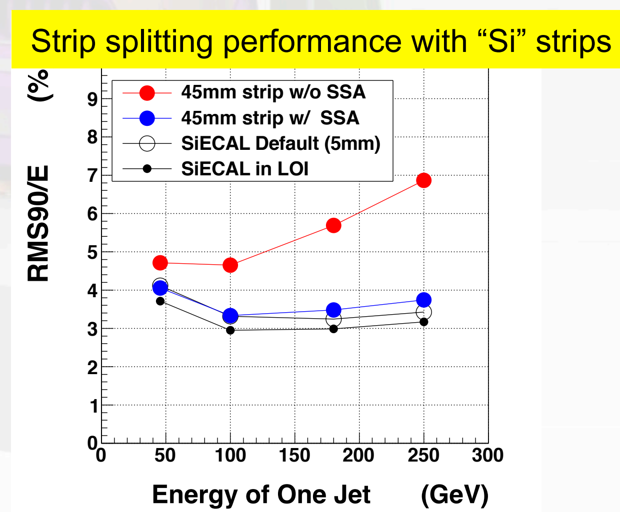
ScECAL

- Scintillator strips as (partial) alternative to silicon pads → help reduce cost of detector
- Analysis of physics prototype 2009 TB
  - after temperature correction, good linearity (<1.5%) and good energy resolution
- One-layer ScECAL **technical prototype under construction**, to be tested at DESY TB September
- Jet energy reconstruction with ***strip splitting algorithm***: performance quite good.
- Saturation in MPPC: addressed by increasing number of pixels

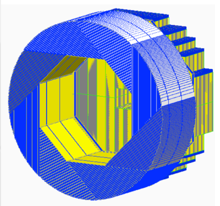




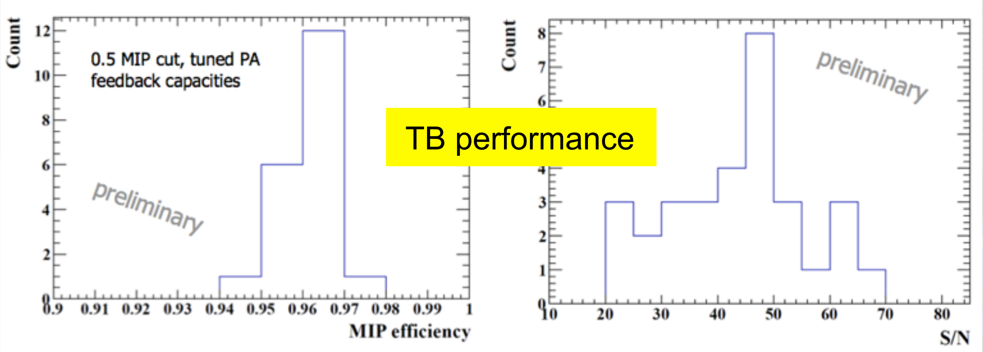


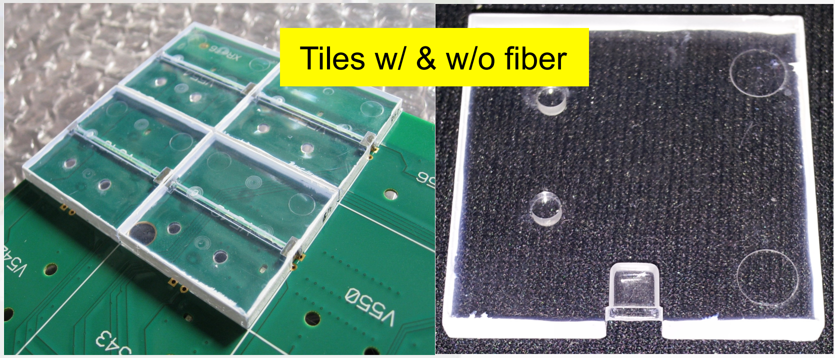


AHCAL



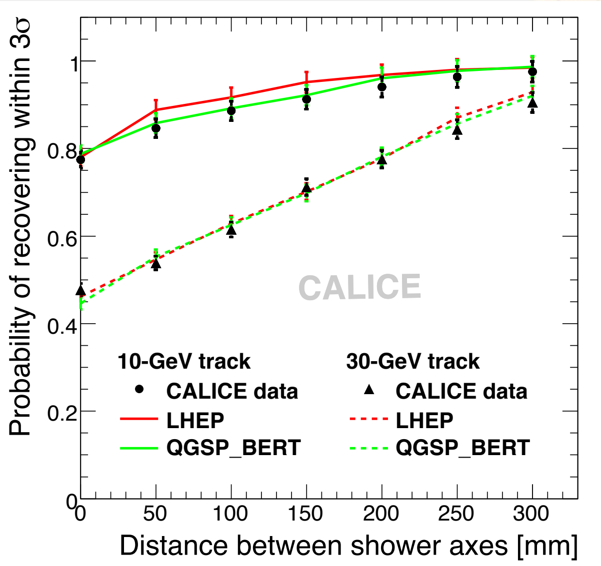
- Engineering and simulation model
  - Simulation model updated, realistic implementation for interfaces and services
  - Second version of barrel geometry implemented
- **Technological demonstrator** for ILD
  - Embedded electronics, power pulsing, zero suppression
  - Auto-trigger and gain equalization established at module level in test beam
  - Full length slab test in preparation: thermal issues, scalability
  - One or two layer beam test in tungsten stack planned, fall 2012
  - Tiles and SiPMs for direct (fiber-less) coupling with mass production technology





- Test beam results
  - Two particle separation with Pandora (+ECAL)
  - More in editorial boards: Geant4 validation low (2-20GeV) and high (8-80GeV) energy data, resolution with software compensation, tracks in showers

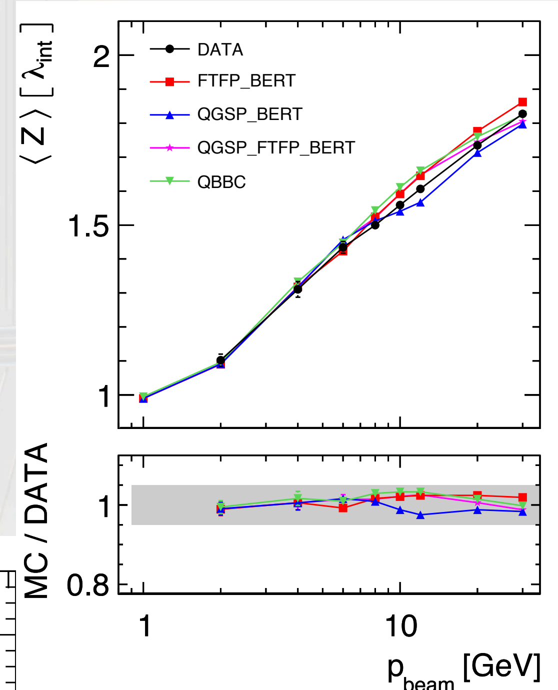
AHCAL test beam results



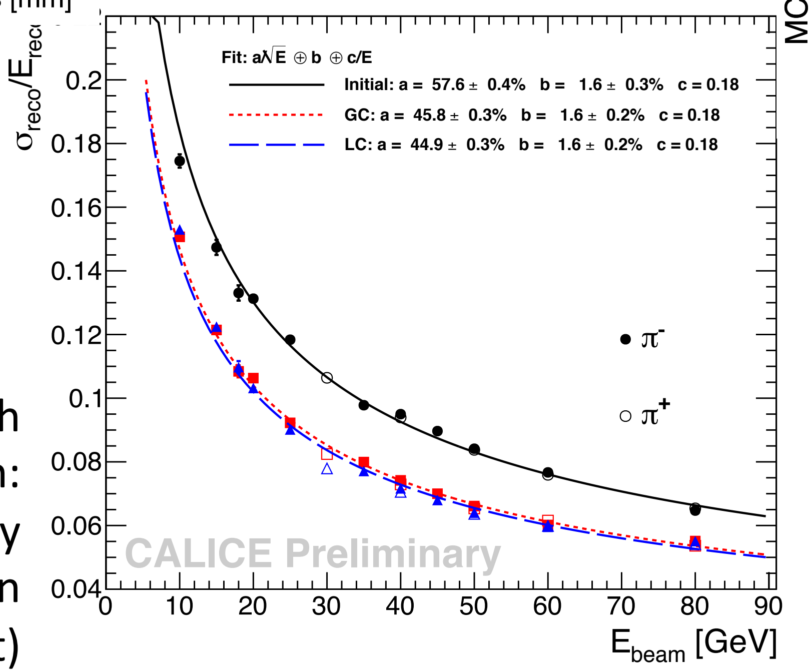
Two particle separation with Pandora

Published:

JINST 6, P07005 (2011)



Geant4 comparison of shower profiles from 2 to 80 GeV (publication draft)

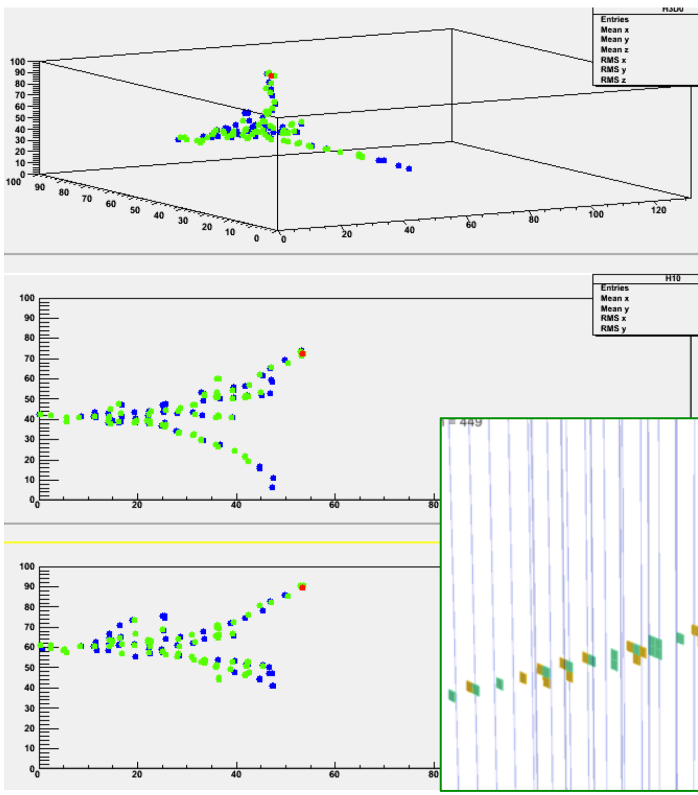


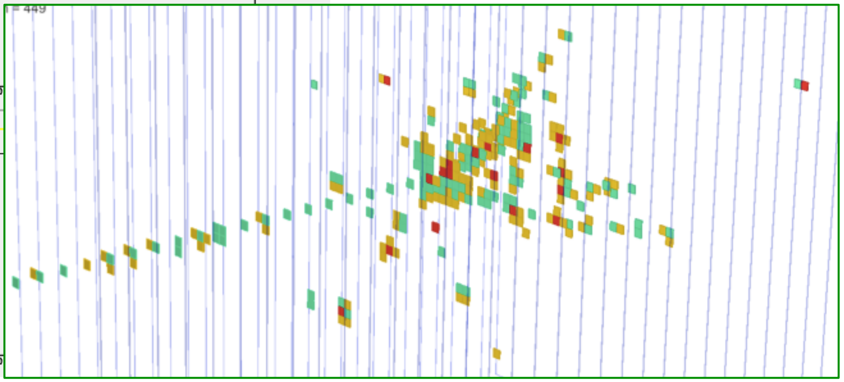
Resolution with software compensation: Improves also jet energy resolution (publication draft)

SDHCAL

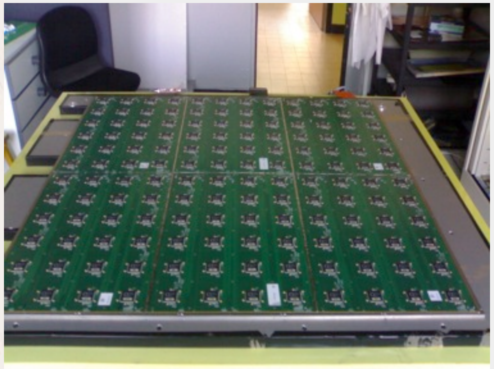
- First technological prototype built:
  - ILD kind, efficiency, compactness, reduced dead zone, self-supporting structure, **power pulsing**
- Currently in **TB** at CERN (4/20-), good first results

10 GeV pion events from CERN-PS

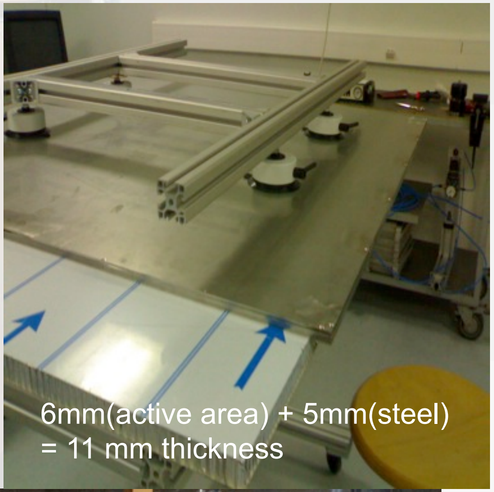


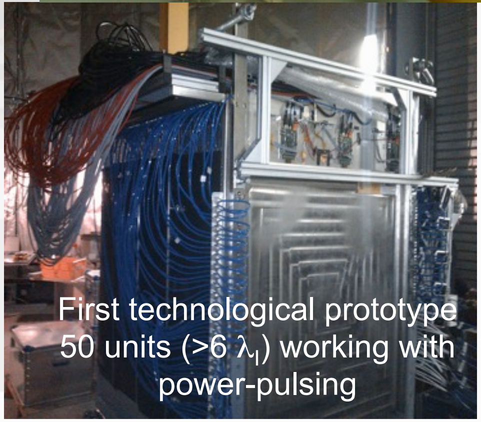


Green: ~100 fC. Blue: ~5 pC. Red: ~18 pC

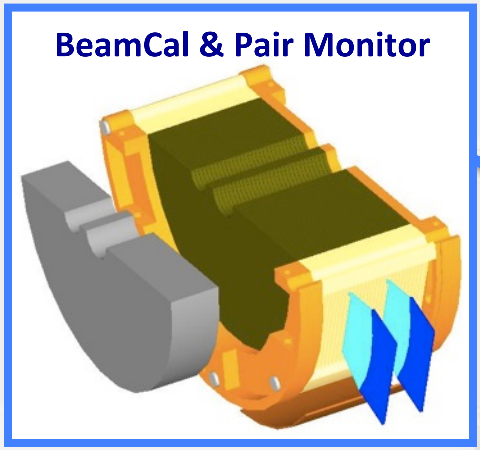


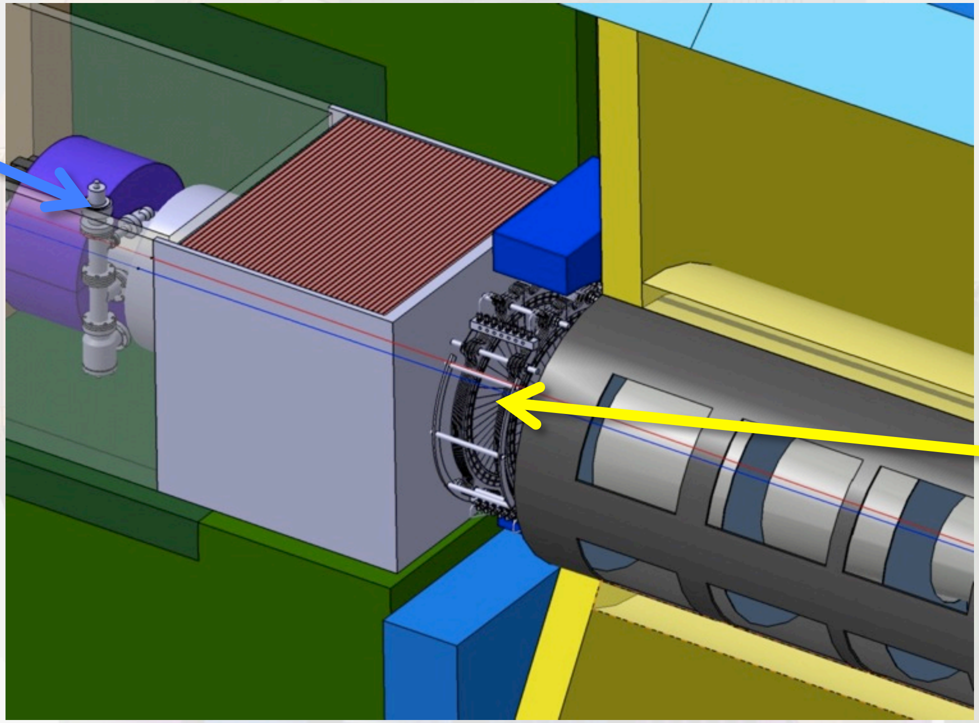
144 ASICs= 9216 channels/1m^2

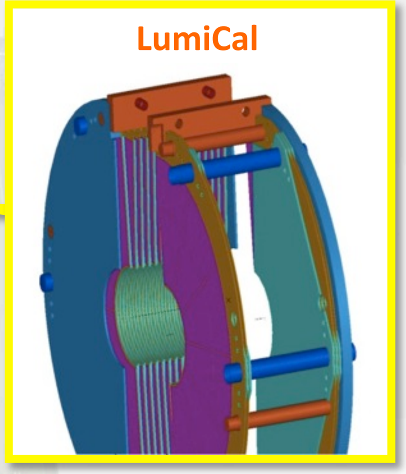




Forward Calorimeters (1)







Forward Calorimeters

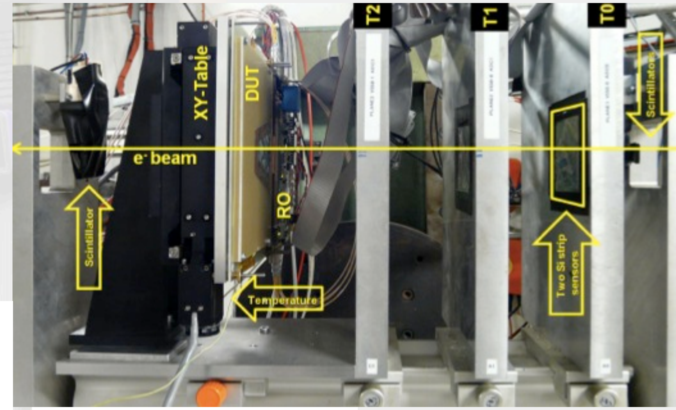
- Precise luminosity measurement
- Hermeticity (electron detection at low polar angles),
- Assisting beam tuning (fast feedback of BeamCal data to machine)

Challenges:

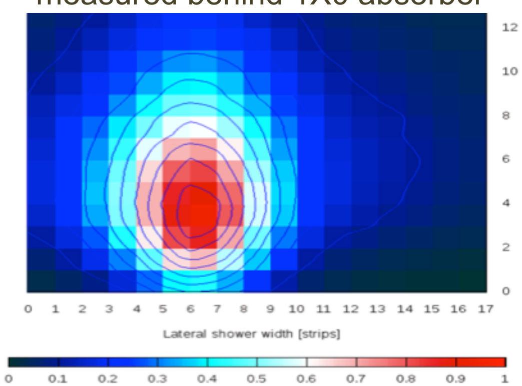
- Radiation hardness (BeamCal), high precision (LumiCal) and fast readout (both)

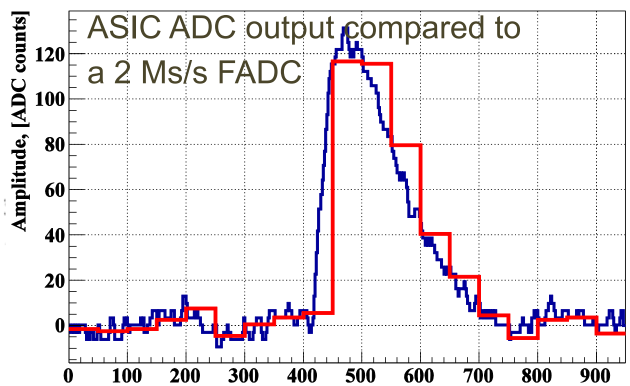
Forward Calorimeters (2)

- TB of fully assembled sensor planes in Nov 2011 (32 channels); 50 million trigger for several areas of LumiCal and BeamCal sensors
- Data analysis ongoing; first results very promising.

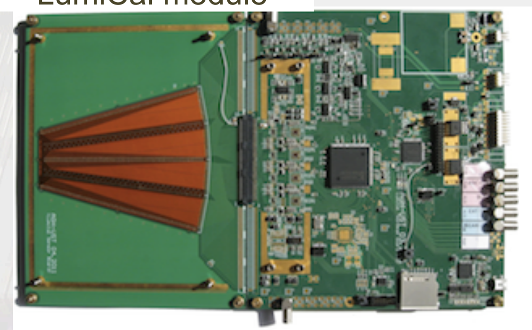


Electromagnetic shower profile measured behind 1X0 absorber



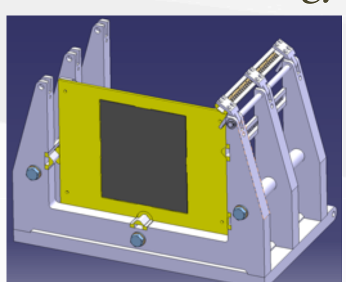


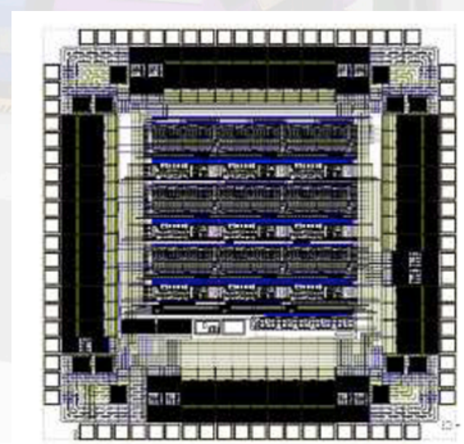
LumiCal module



Future plan: prototype calorimeter (AIDA)

- Flexible frame with tungsten absorber planes
- FE and ADC ASICs in 130 nm technology
- Power pulsing
- DAQ (ILD standard)

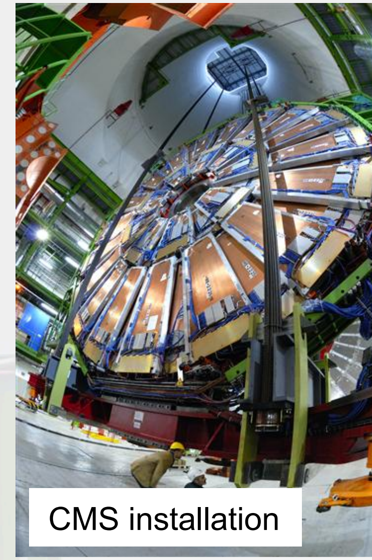




Pair Monitor prototype sensor with integrated ASIC (SoI, 200 nm technology, Tohoku University)

Integration: Site Hall

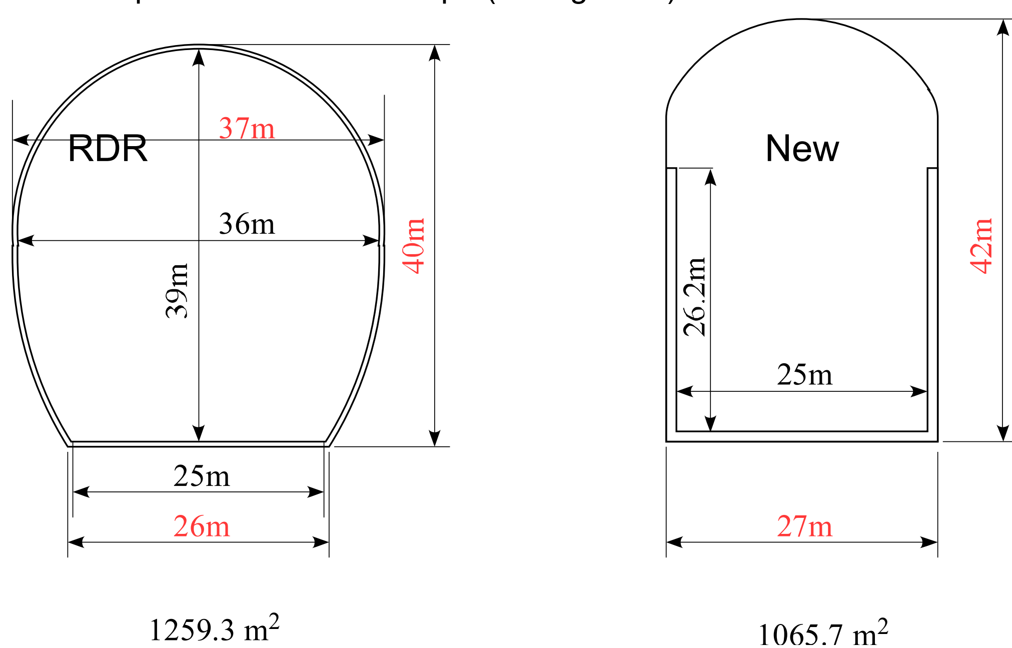
- **ILD assembly is site specific**
  - Non-mountain site: build & test on surface as much as possible, then lower into detector hall (like CMS)
  - Mountain site: **limited by horizontal access** tunnel, require underground assembly of many parts.



CMS installation

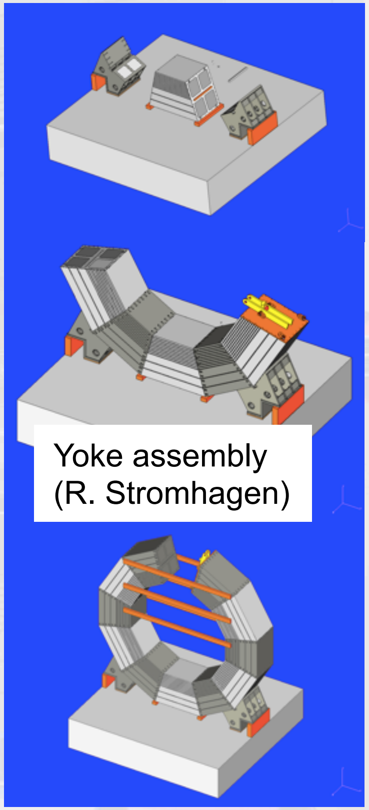
- Since ILD is the larger of the two, it requires more space. The shape of the assembly area is being optimized to **keep cost containment** while securing **assembly space.**

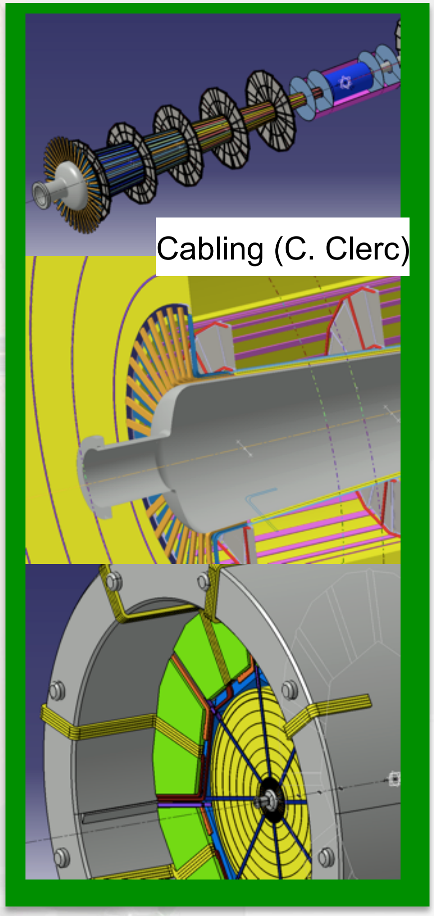
Comparison of cavern shape (Y. Sugimoto)

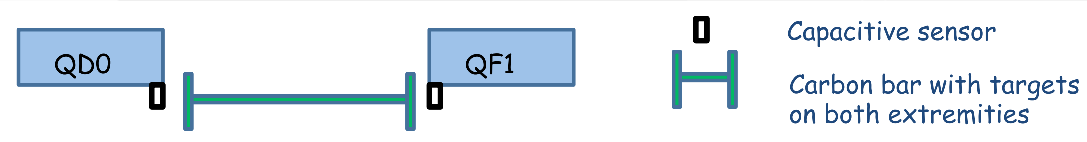


Integration: Detector Assembly

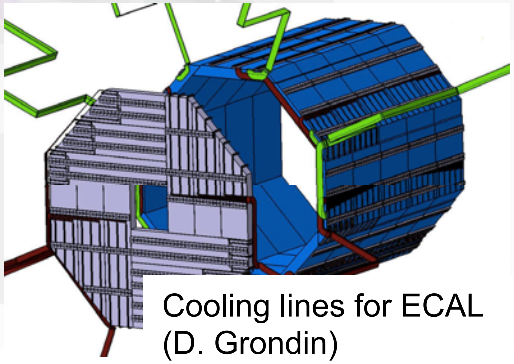
- Rigidity of mechanical structure (both detector and support material) is checked with simulations (FEA)
- Cooling options: leak-less water and/or gas for calorimeters. Requires space.
- Estimation of services (cables and patch panels, etc) from power requirements and geometric constraints
- Precise alignment of the innermost detectors by a common support structure. Needs hardware monitors, which requires access.
- QD0 magnet alignment: working with CLIC experts; they deal with much tighter requirements.





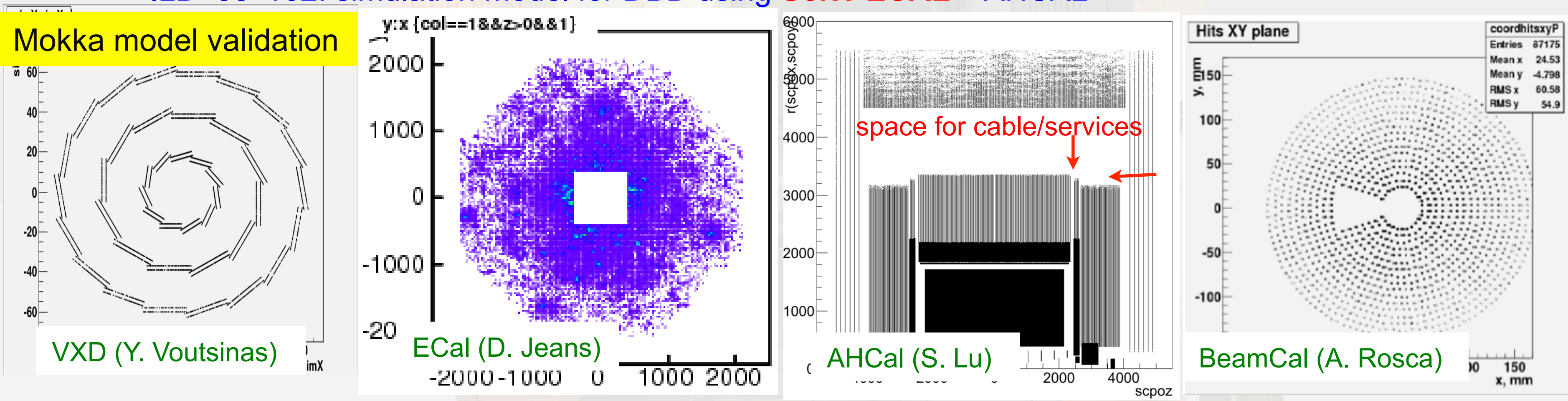


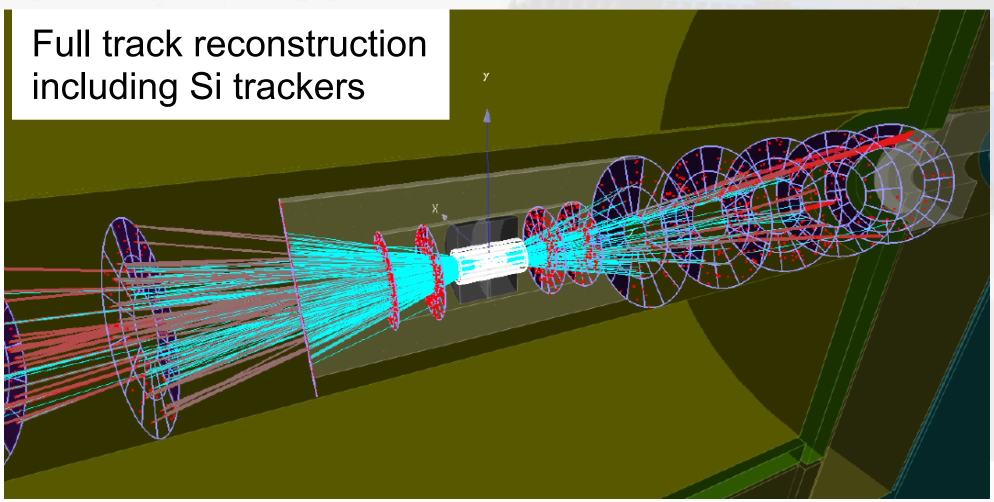
(H. Mainaud Durand, for CLIC)



Software Validation

- Mokka models implemented, ***considerably improved realism*** → validation has started.
  - ILD_o1_v02: simulation model for DBD using SiW ECAL + AHCHAL
  - ILD_o2_v02: simulation model for DBD using SiW ECAL + **SDHCAL**
  - ILD_o3_v02: simulation model for DBD using **SciW ECAL** + AHCAL





- Rewrite of tracking code (FORTRAN free) to cope with background
- Next steps:
  - validate tracking → calibrate PandoraPFA → optimize LCFIPlus
  - Start mass production in *X weeks*

DBD Benchmark Processes

- In the ILD DBD, the Performance chapter will describe the benchmark processes
- As a reminder, the benchmark processes that will be studied by both ILD and SiD are:
  - $e^+e^- \rightarrow \nu\nu h^0$ at E_{CM}=1 TeV with a SM Higgs with m_H=120 GeV, in the final states $h^0 \rightarrow \mu^+\mu^-$, bb, cc, gg, WW^*. The goal is to measure the cross section times branching ratio.
  - $e^+e^- \rightarrow W^+W^-$ at E_{CM}=1 TeV, considering both hadronic and leptonic (e, μ) decays of the W. The goal is to use the forward W pair production cross section to measure in situ the effective left-handed polarization.
  - $e^+e^- \rightarrow tth^0$ at E_{CM}=1 TeV with a SM Higgs with m_H=120 GeV, in the final state $h^0 \rightarrow bb$. The reaction involves the 8 jet mode and the 6 jet + lepton mode. The goal is to measure the Higgs boson Yukawa coupling to tt.
- In addition, repeat one analysis from the 2009 LOI using the final detector configuration and up-to-date simulation software.
  - ILD has chosen ***tt*** at 500 GeV.
- ILD will also update:
  - Higgs self-coupling measurement ***Zhh*** at 500 GeV
- The DBD benchmark processes are covered well.

Analysis will be carried out by:

NDU + KEK

DESY

Birmingham + KEK

LAL

KEK + Tokyo

Physics Studies with ILD

For DBD

Analysis using ILD Full Simulation	Main Analysts	Institution
Measurement of BR(H->bb,cc,gg) at 250 GeV	Hiroaki Ono	Nippon Dental University
Measurement of BR(H->WW*,ZZ*) at 250 GeV	Hiroaki Ono	Nippon Dental University
Measurement of BR(H->gamma+gamma,gamma+Z) at 250 GeV	Constantino Calancha	KEK
Higgs BR measurements with nunuH at 1 TeV	Hiroaki Ono	Nippon Dental University
	Constantino Calancha	KEK
Measurement of Higgs self coupling at 500 GeV	Junping Tian	KEK
	Taikan Suehara	ICEPP, The University of Tokyo
Top Yukawa coupling at 500 GeV	Hajrah Tabassam	Quaid-i-Azam University, Islamabad
	Ryo Yonamine	Sokendai/KEK
Top Yukawa coupling at 1 TeV	Tony Price	University of Birmingham
	Ryo Yonamine	Sokendai/KEK
WW at 1 TeV	Aura Rosca	DESY
Precision measurement of Higgs couplings to gauge bosons at 500 GeV	Junping Tian	KEK
Top pair analysis at 500 GeV	Jeremy Rouene	LAL
	Marcel Vos	IFIC Valencia
Measurement of Higgs total decay width at 250 GeV	Claude Duerig	University of Bonn
Triple gauge couplings and polarization at 500 GeV	Ivan Marchesini	DESY
Very light gravitino with stau NLSP at (500 GeV + threshold scans)	Ryo Katayama	The University of Tokyo
Bilinear R-parity violation SUSY (500 GeV)	Benedikt Vormwald	DESY
Model-independent WIMP characterization (500 GeV)	Christoph Bartels	DESY
Measurement of CP Violation in the MSSM Neutralino Sector (500 GeV)	Mark Terwort	DESY
Mass degenerate Higgsinos in Hidden SUSY (500 GeV)	Hale Sert	DESY
Chargino / Neutralino -> W / Z + LSP (500 GeV)	Madalina Chera	DESY
Full study of an MSSM scenario with rich (SPS1a'-like, but not LHC excluded) ILC phenomenology (500 GeV + threshold scans)	Mikael Berggren, Stefano Caiazza, Nicola d'Ascenzo	DESY

All performed in ILD full simulation!

Some studies currently use LOI samples.

Conclusions

ILD is intensifying its efforts as the deadlines for the DBD become near. Areas in which significant progress are being made are:

Component R&D

- Construction of prototypes, testing and validation of technologies, test beam results, power-pulsing operation…

Simulation tools

- Implementation of simulation detector models with increasing realism, improvement in event reconstruction software

Physics studies

- Benchmark processes, other processes to enrich the ILC physics case

Ambitious program, lots of hard work ahead, many milestones achieved.

We should be in good shape for the DBD and beyond.

Acknowledgments

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I. Laktineh, F. Sefkow, F. Simon (HCAL), W. Lohmann (FCAL),
K. Buesser, C. Clerc (MDI), J. List (Physics)

…plus many others from whom I borrowed material.

ILD Workshop at LAL Orsay

May 2011