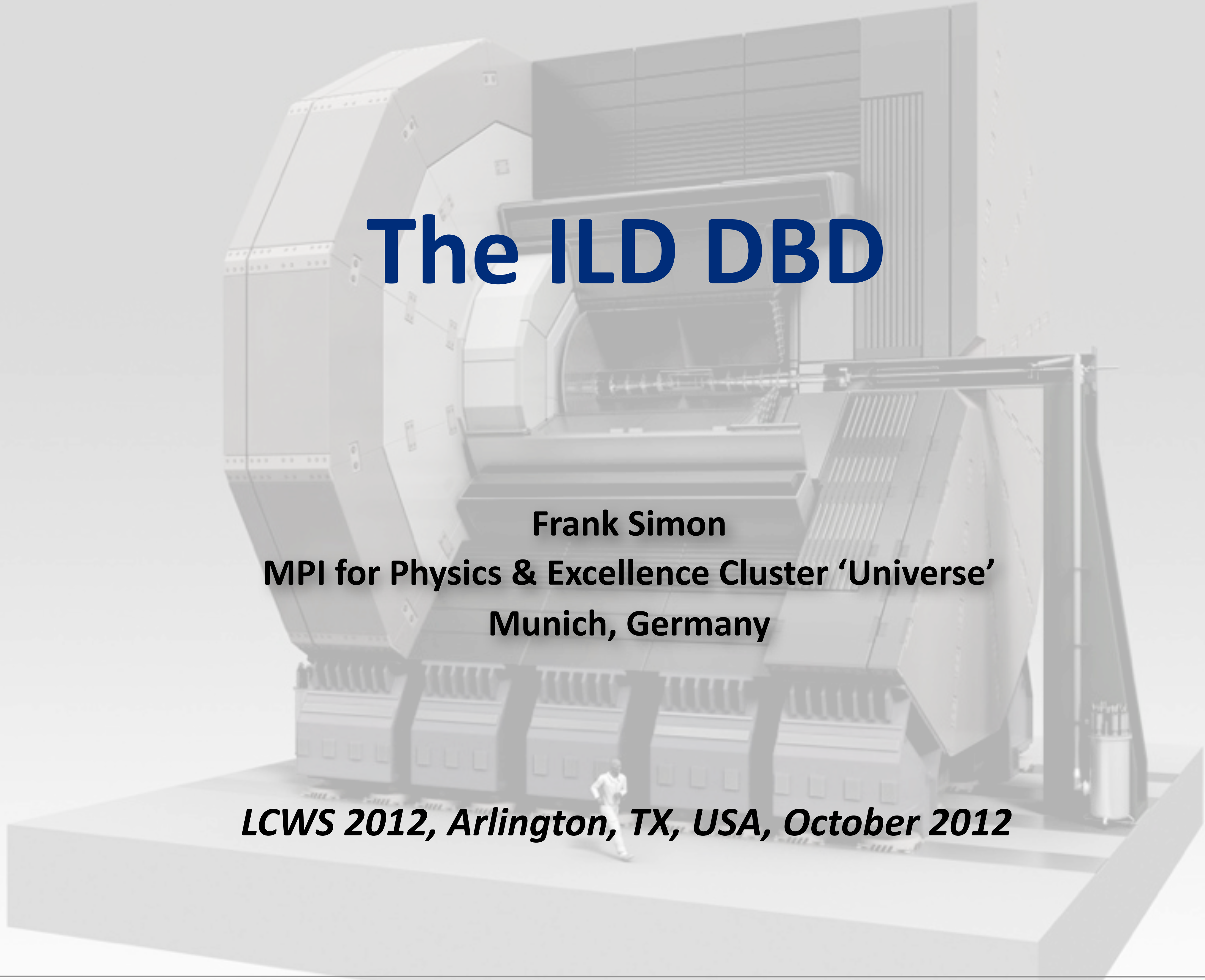


The ILD DBD

Frank Simon
MPI for Physics & Excellence Cluster 'Universe'
Munich, Germany

LCWS 2012, Arlington, TX, USA, October 2012

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

Excellence Cluster
Universe

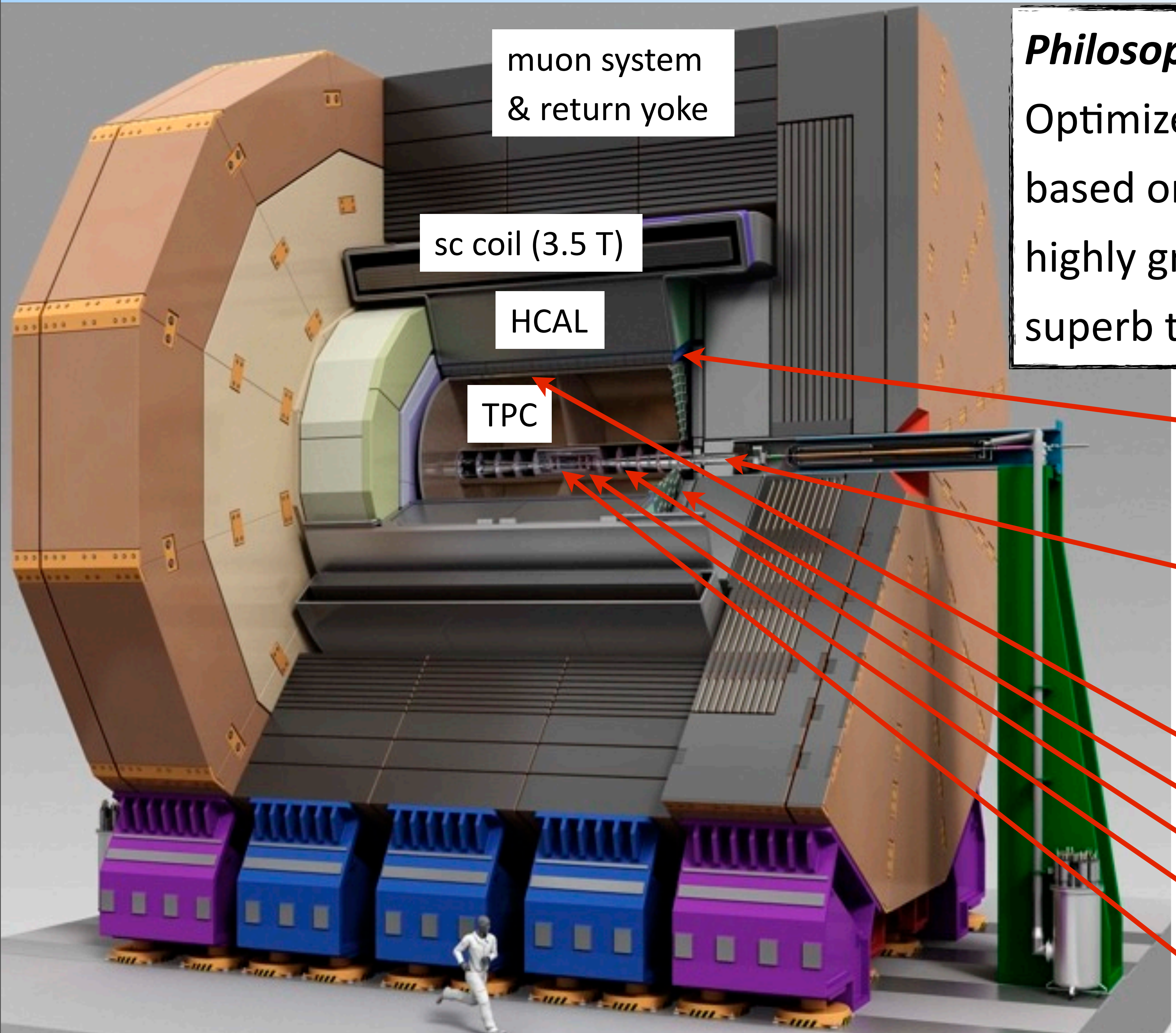
Outline

- The ILD Concept
  - Overview
  - Subsystems
- The ILD Detector System
- Software & Performance
- Summary

From the LOI to the DBD

The ILD Concept

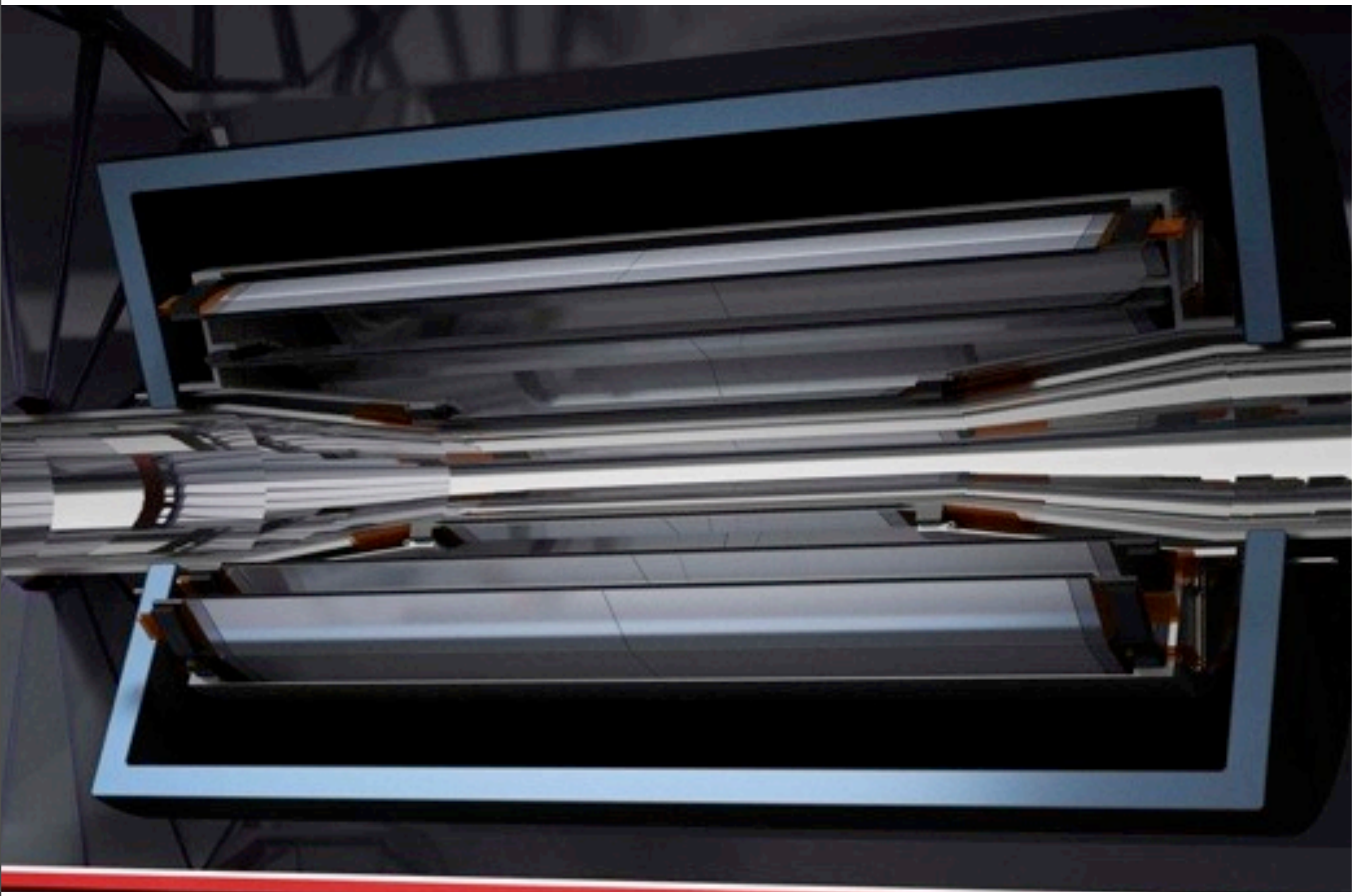
ILD - Overall Design



Philosophy:

Optimized for highest precision, based on Particle Flow with highly granular calorimeters, superb tracking and vertexing

The Vertex Detector



- Performance goal:

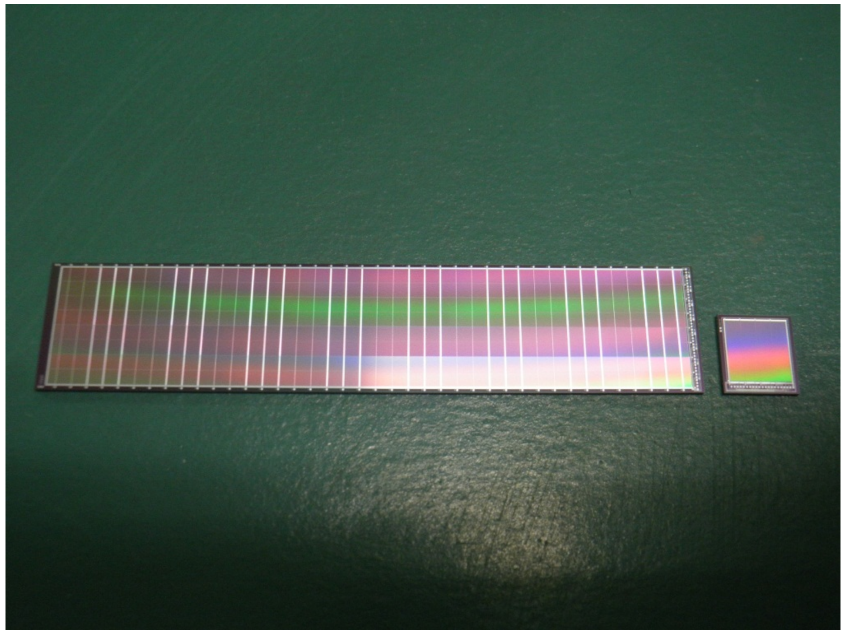
$$\sigma_b < 5 \oplus 10/p\beta \sin^{3/2}\theta \;\mu\mathrm{m}$$

- Requirements:
  - Spatial resolution < 3 µm close to IP
  - Material budget < 0.15% X_0 per layer
  - ▸ low power consumption!
  - Pixel occupancy not exceeding a few %
  - First layer at a radius of ~ 1.6 cm
- VTX design:
  - 3 (almost) cylindrical layers of double-sided ladders from 16 mm to 60 mm
    - Alternative: 5 single layers, from 15 mm to 60 mm
  - Each ladder: Two sensor layers, spaced by 2 mm
  - Several technologies under study: CMOS Pixel Sensors, Fine Pixel CCDs, DEPFET, use of multiple technologies an option

Vertex Detector Technologies

- Active development of several technologies

MIMOSA / PLUME
picture, latest results



FPCCDs

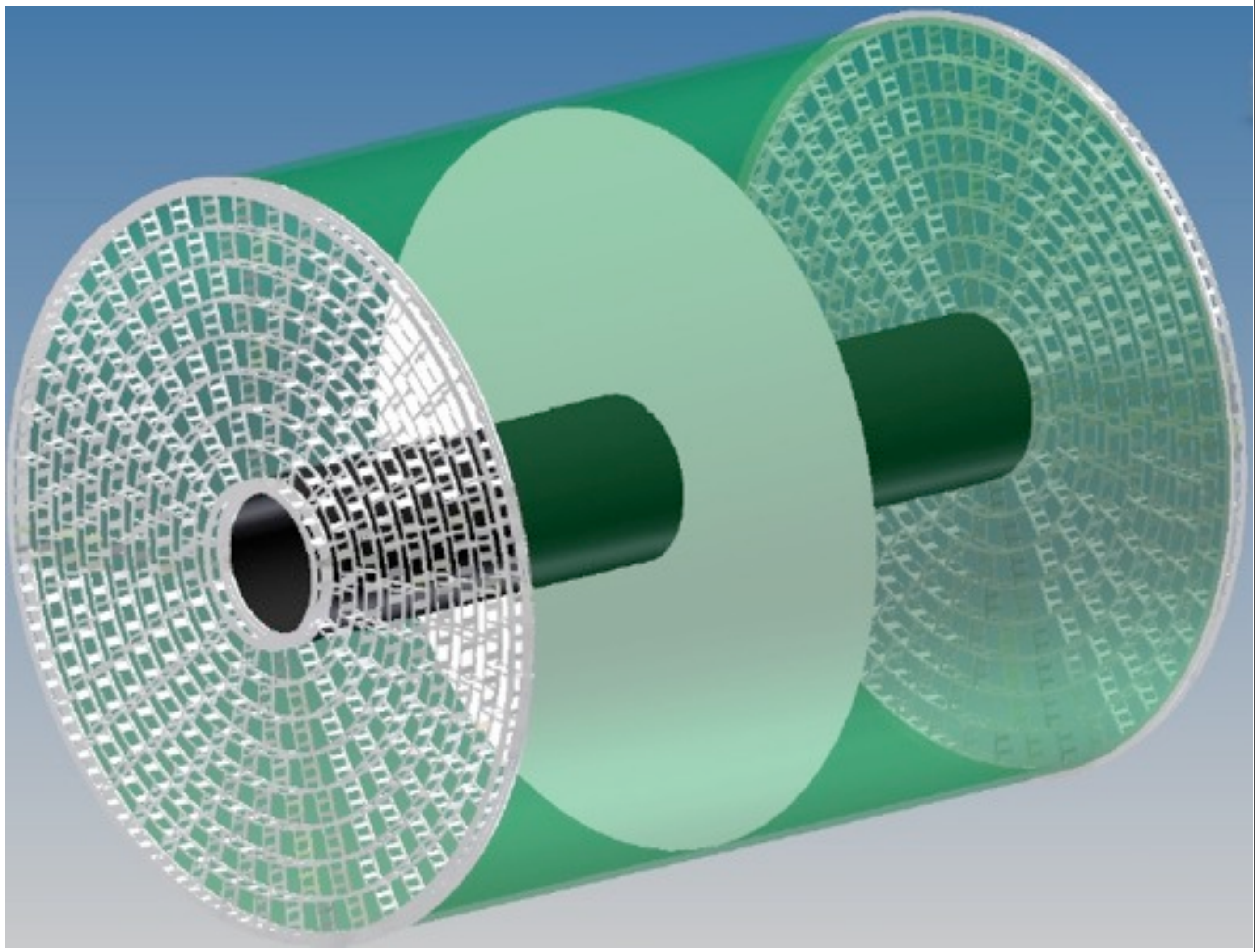
- ~5 µm pixels in inner two layers, ~10 µm pixels in outer four layers
- Small 6 x 6 mm^2 prototype with 6 µm pixels successfully tested
- Large 13.4 x 65 mm^2 prototype now available for tests (almost full size for inner layers)

- In addition: DEPFETs used for pixel detector of Belle-II: technology fully developed, modules currently under construction - > large synergies with ILC

The Main Tracker: TPC

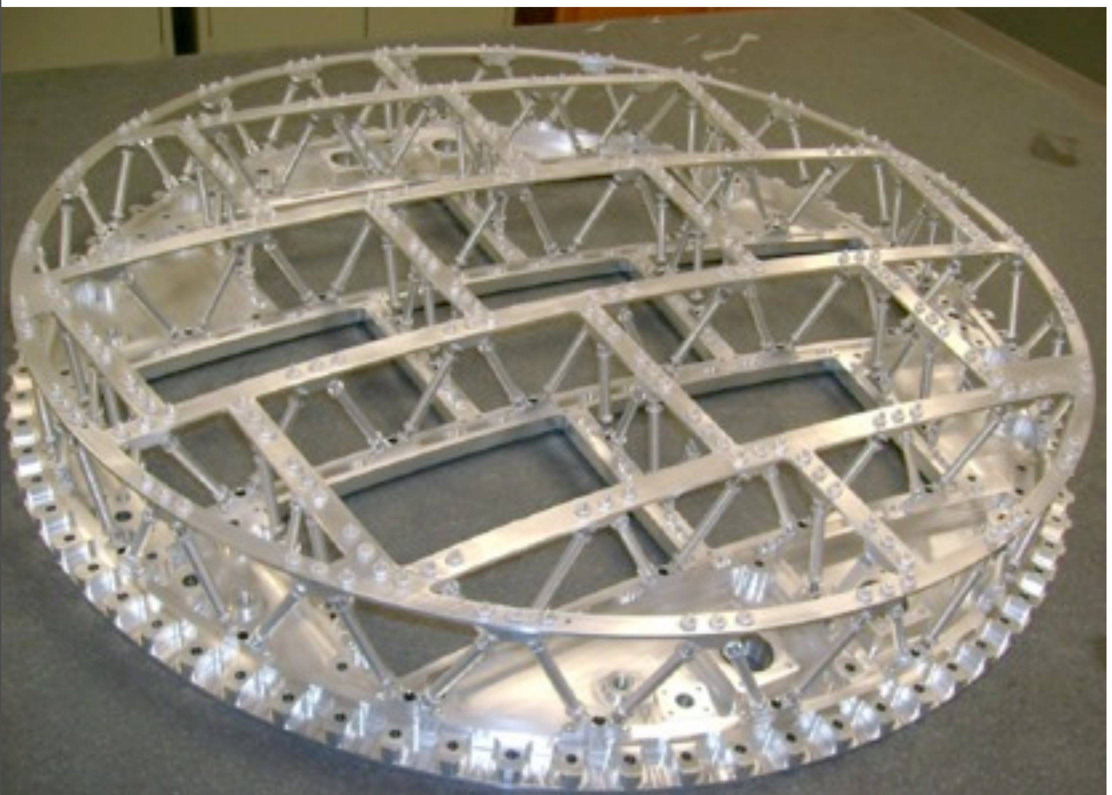
- Main tracker philosophy: Continuous tracking for excellent pattern recognition and dE/dx capability instead of best possible single point resolution
- The ILD TPC
  - Up to 224 space-points per track
  - Single point resolution < 100 µm in rϕ
  - Two-hit separation ~ 2 mm in rϕ
  - Low material budget: 5% X_0 in barrel region, <~ 25% X_0 in the endcaps
  - Standalone momentum resolution

$$\delta(1/p_T) \simeq 10^{-4}/\mathrm{GeV}/c$$

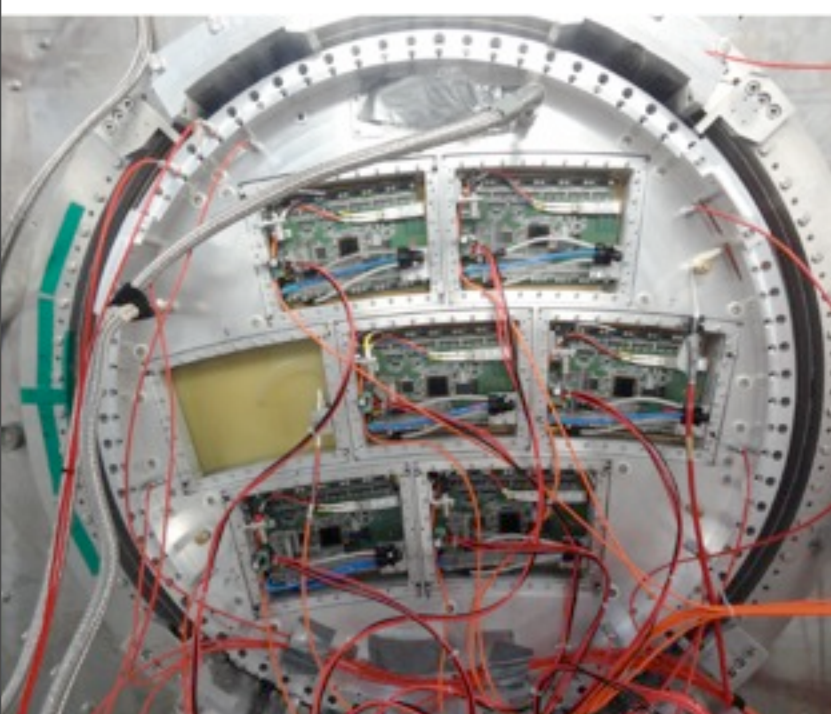


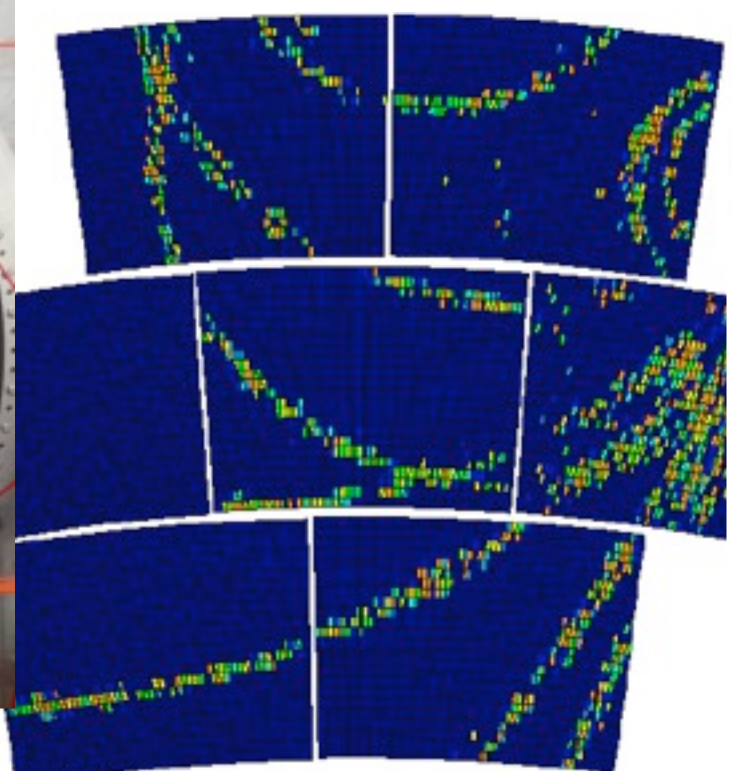
Two main readout options:
GEMs, Micromegas
Alternative: pixel detectors

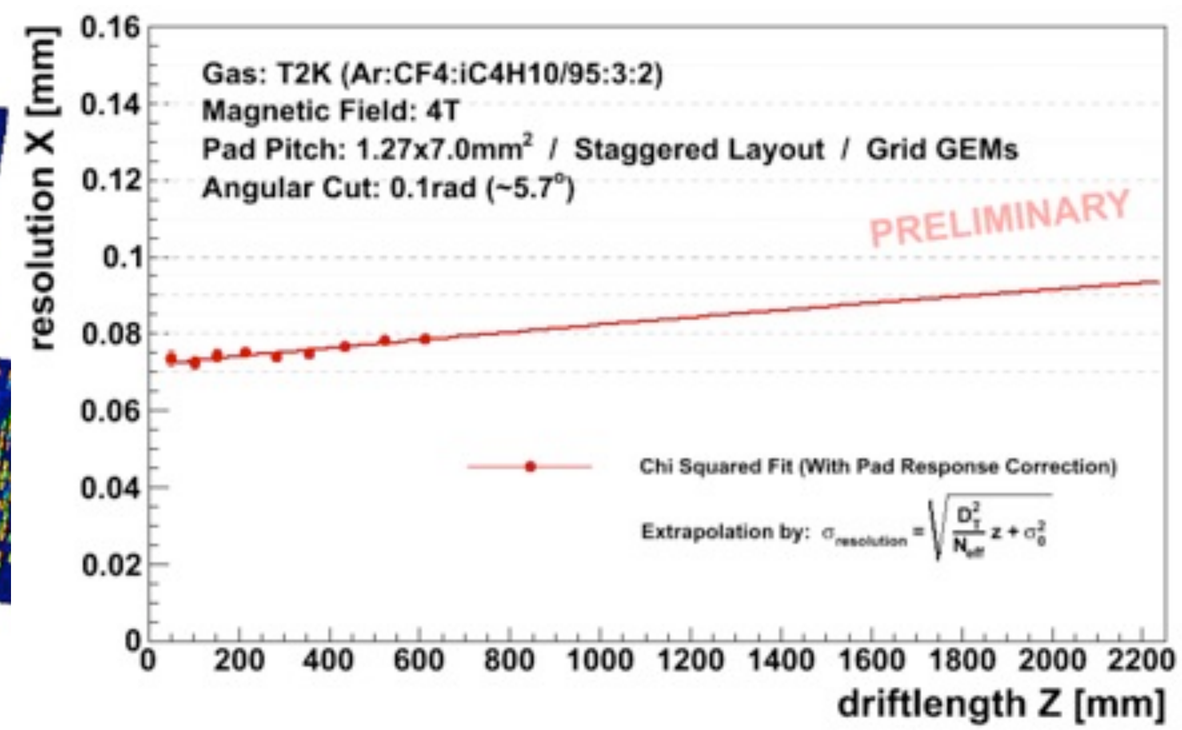
TPC Development



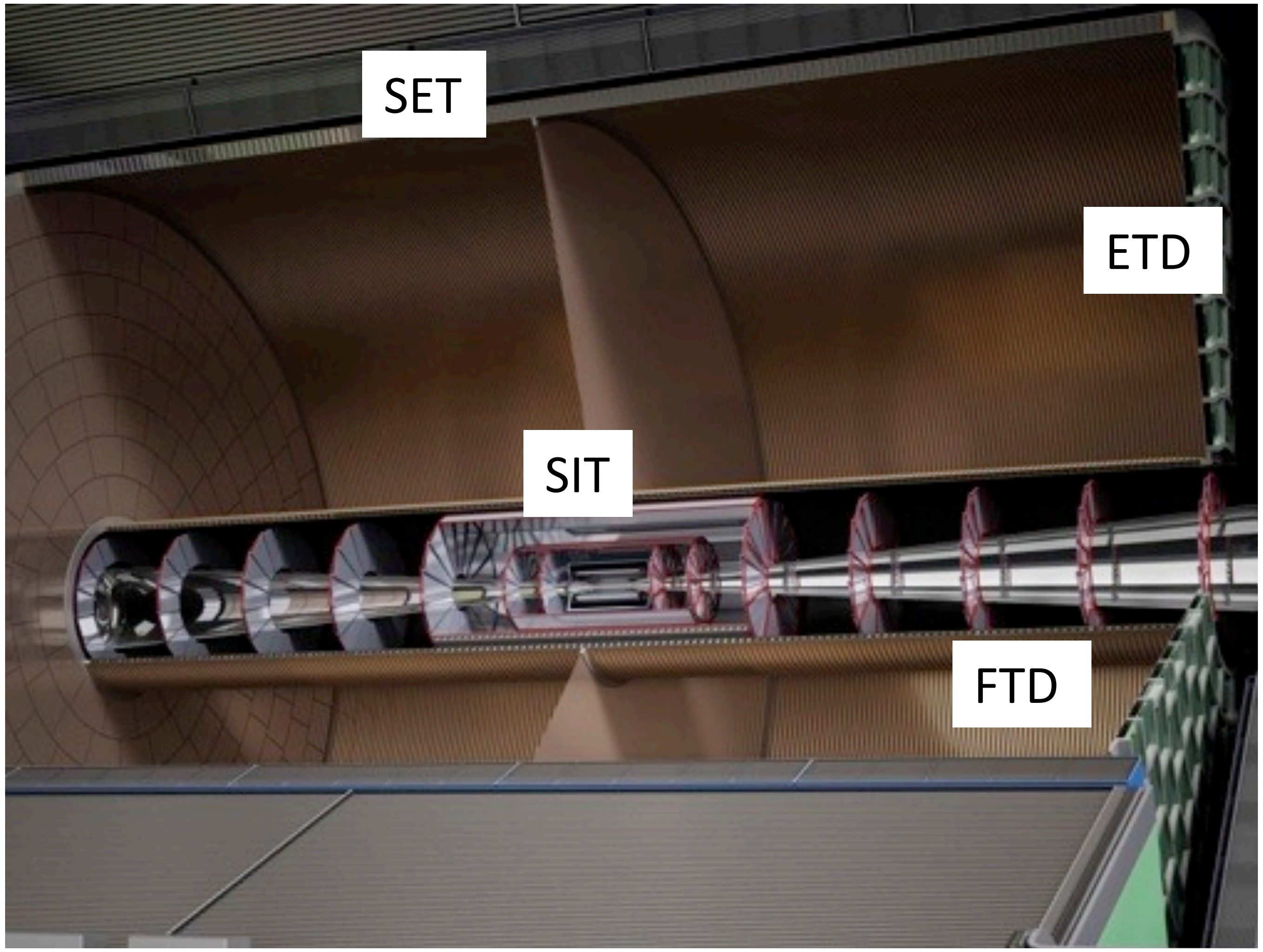
- Large prototype with “space frame” endplate
- Test in magnetic field up to 4 T
- Two readout technologies already tested: Triple-GEM, Micromegas







The Silicon Trackers



- Silicon tracking to complement the TPC main tracker:
  - Improved resolution
  - Time-stamping
  - Calibration of distortions & alignment
  - Extended coverage in the forward region
- Combined tracker resolution:

$$\delta(1/p_T) \simeq 2 \times 10^{-5}/\mathrm{GeV}/c$$

- Inner tracking barrel SIT - 2 fake double-sided strip layers, 2 space points
- Outer tracking barrel SET - 1 fake double sided strip layer, 1 space point
- Outer forward tracking layer ETD - 1 fake double sided strip layer, 1 space point
- Inner forward tracker FTD - 7 disks (2 pixel, 5 strip)

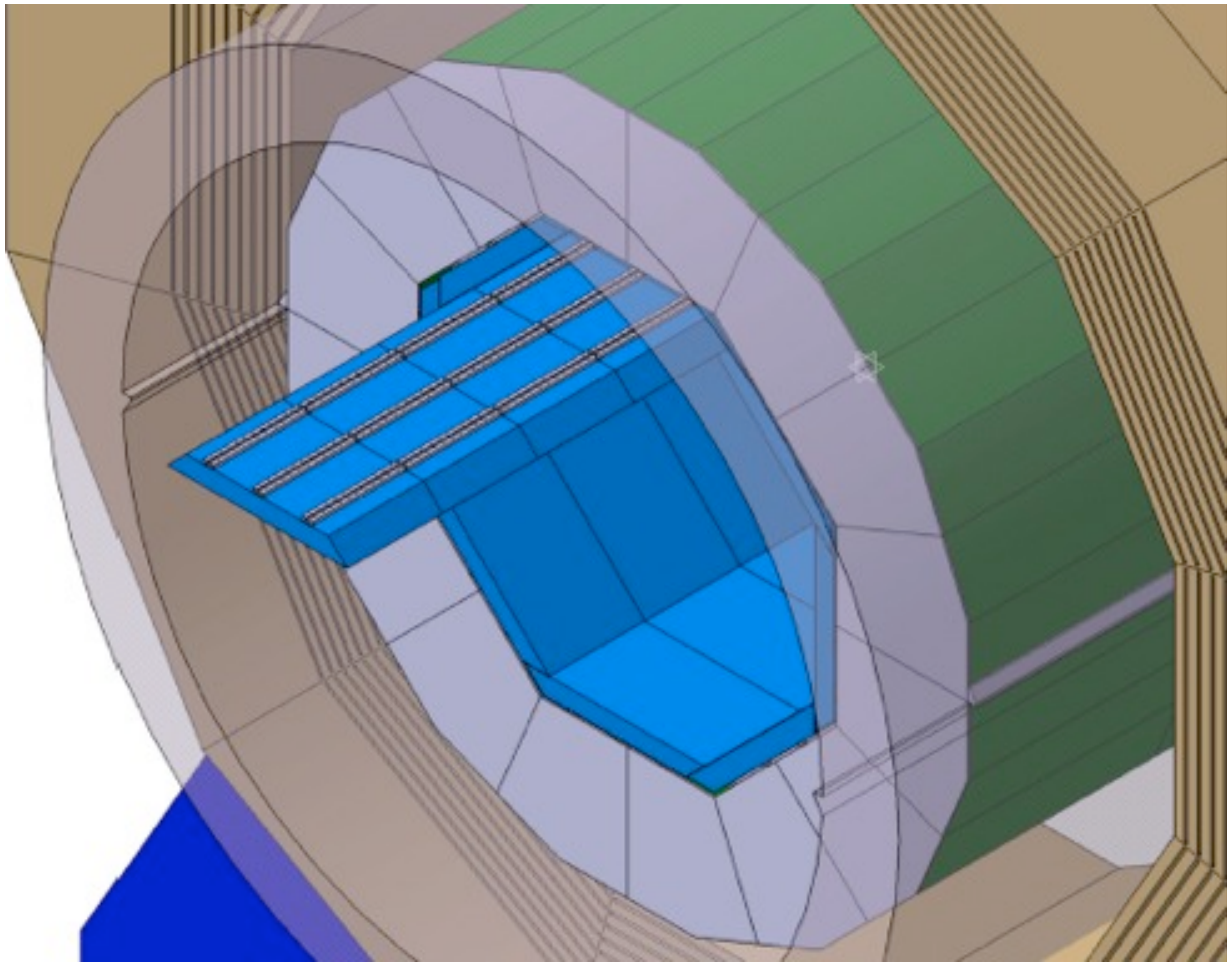
▸ Common technology & design for all strip sensors in the silicon trackers

Silicon Tracker Technology

Pictures, test beam results?

Mention synergy with LHC development

The Main Calorimeters



- Main calorimeters optimized for particle flow:
  - High granularity
  - Small Moliere radius in ECAL for good particle separation & photon identification
  - Sufficient depth of the HCAL to limit leakage also at 1 TeV
  - Compact design to fit inside magnet

- ECAL with tungsten absorbers and silicon and/or scintillator readout
- HCAL with steel absorbers
  - Analog - Scintillator tiles with SiPMs
  - Semi-digital - Glass RPCs with 2 bit readout, Micromegas as alternative

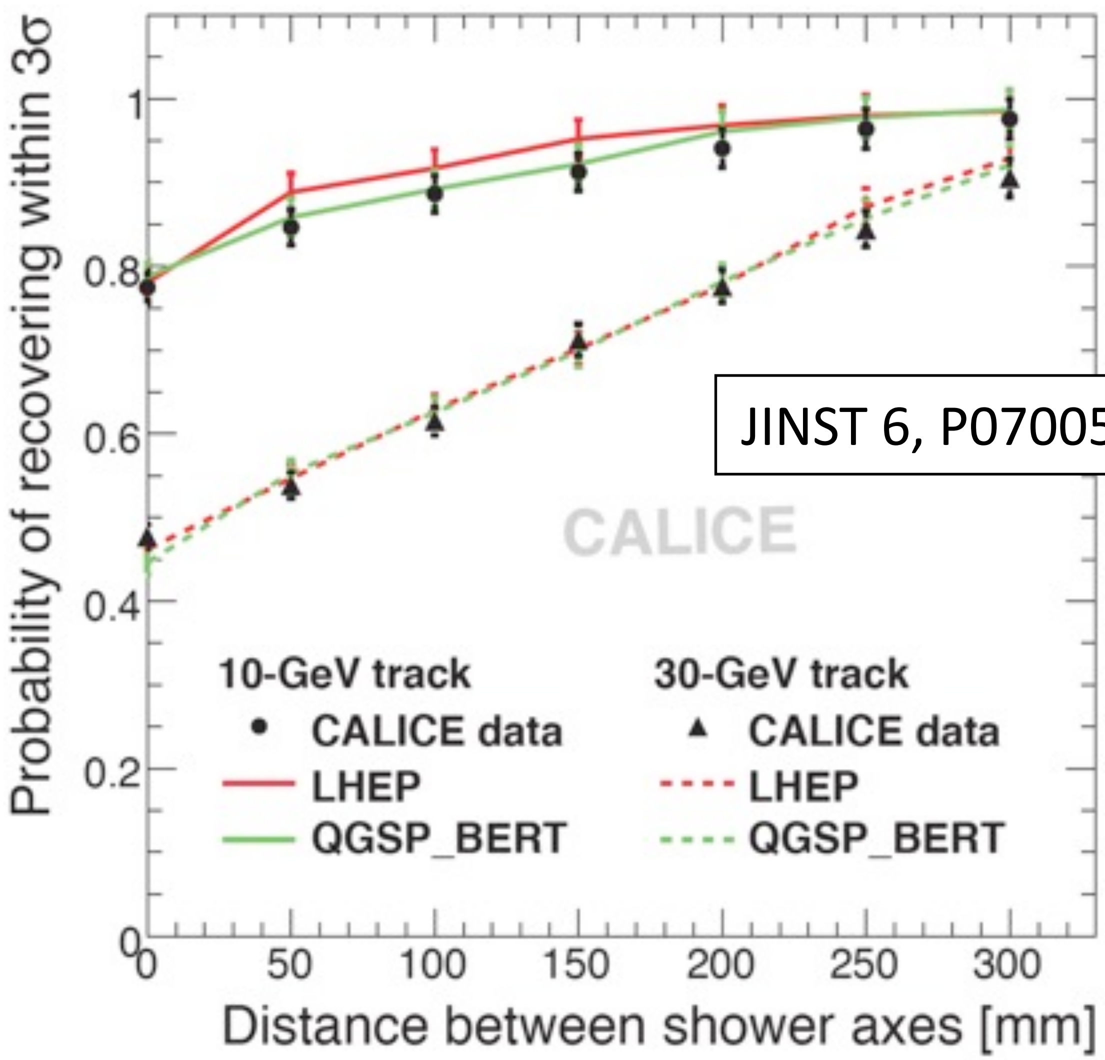
Calorimeter R&D

- Calorimeter technology for ECAL & HCAL developed by CALICE:

  Combined test-beam experiments to demonstrate PFA calorimetry

One highlight:
Shower separation with PandoraPFA in the SiW-ECAL and AHCAL physics prototypes

- Good agreement with simulations demonstrates realism of our full detector simulations & physics studies

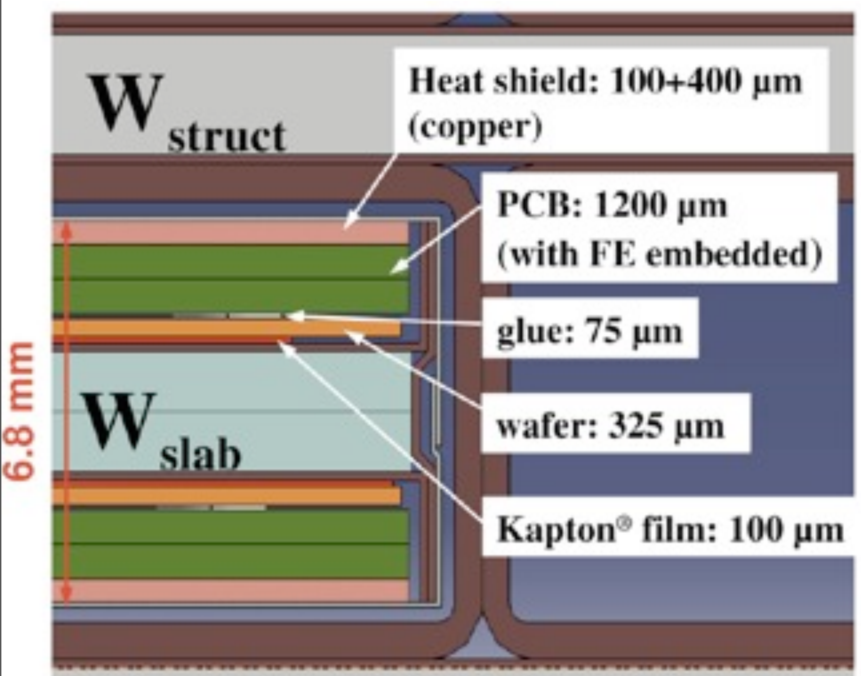


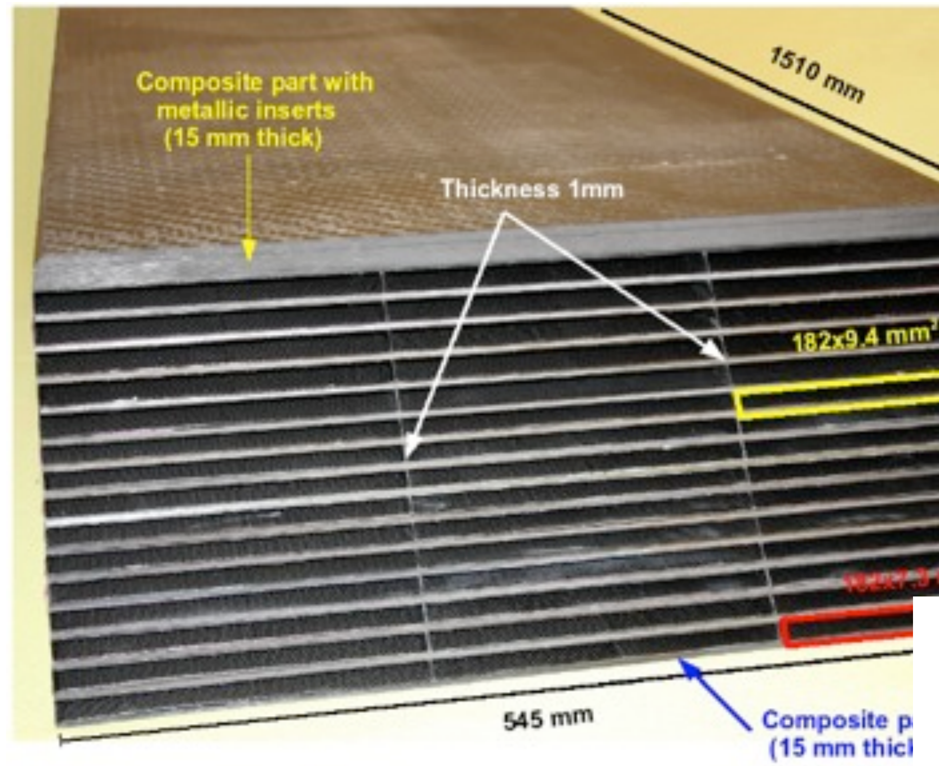
JINST 6, P07005 (2011)

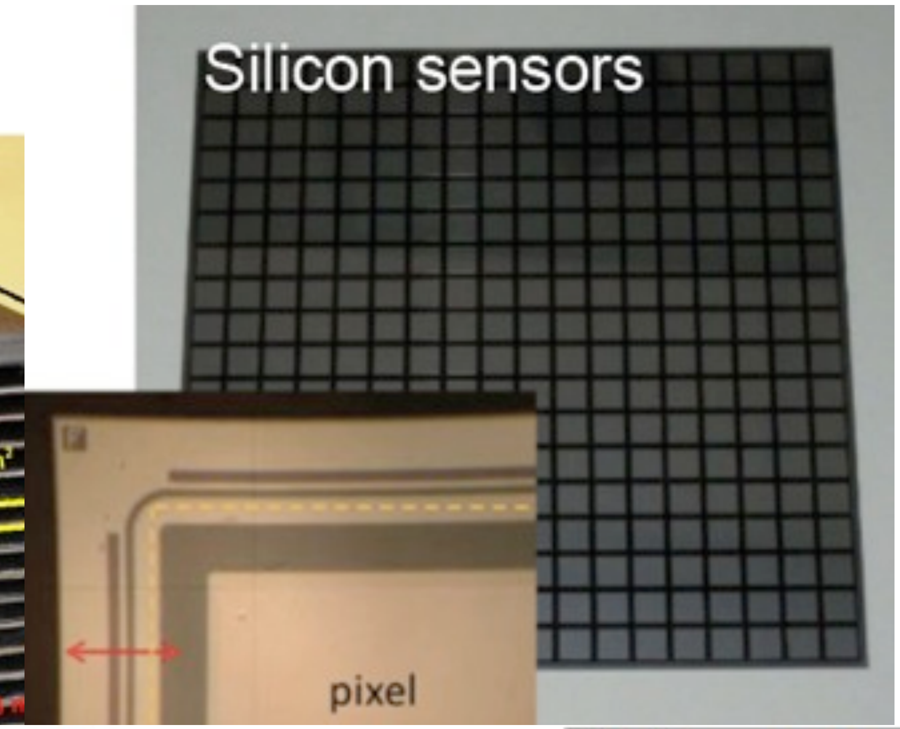
- Readout ASICS for all calorimeter types with a common basis
- Common DAQ system, data format:

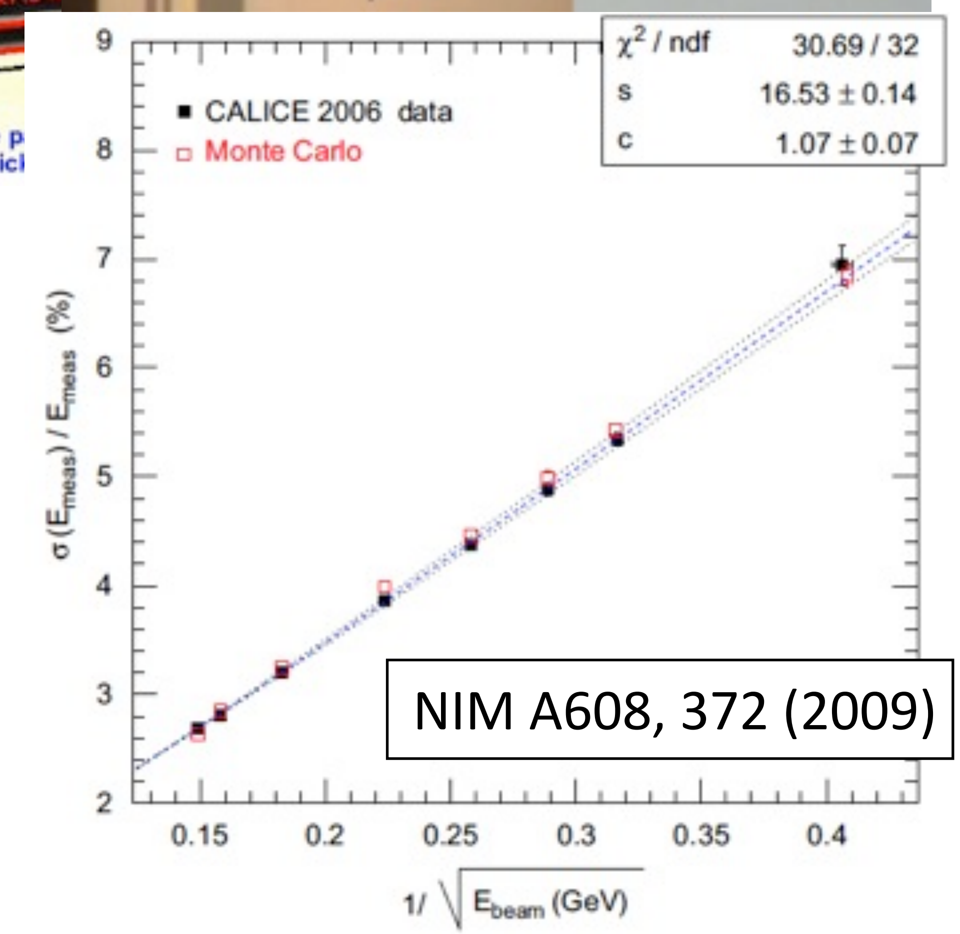
The SiW ECAL

- PIN silicon pad readout with 5.5 x 5.5 mm^2 pads







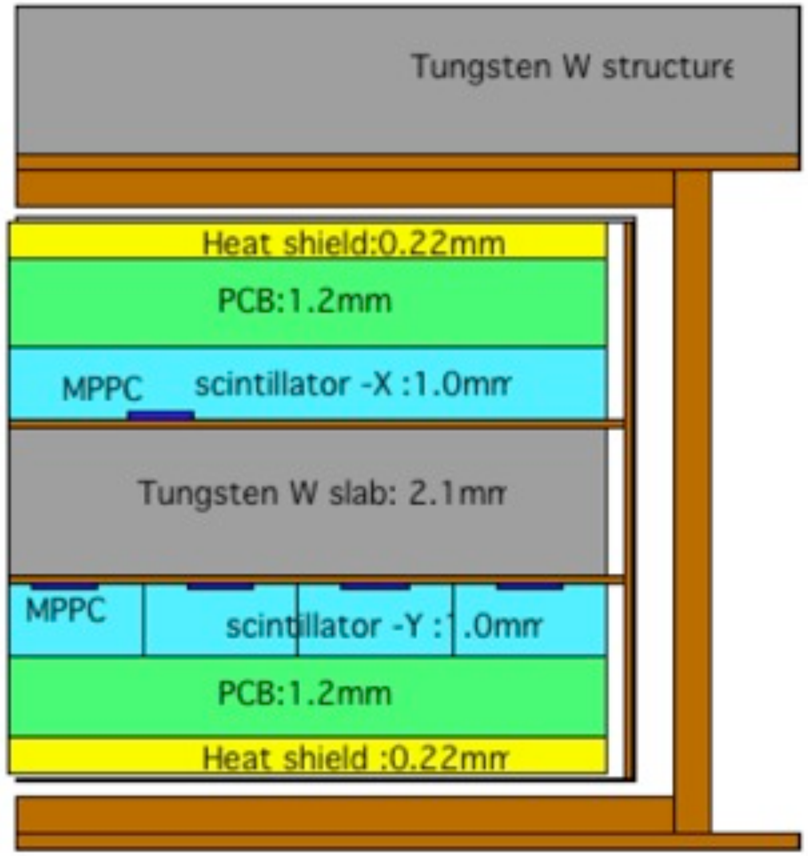


6.8 mm per double layer

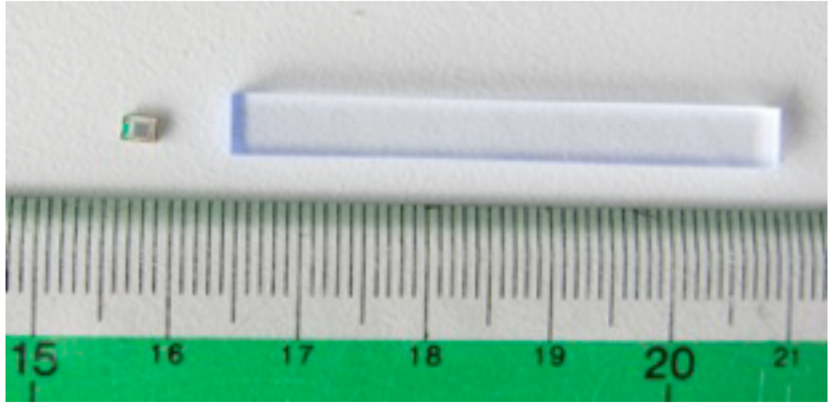
Complete tungsten structure for technological prototype exists

Well-established technology: physics prototype in various beam times since 2006

The Scintillator ECAL



- Scintillator strips (5 x 45 x 1 mm^3) read out with SiPMs
  - 6.9 mm per double layer, 0.1 mm more than SiW ECAL
  - Electronics based on AHCAL design - synergies!



Extensive tests with a physics prototype, first module of technological demonstrator now in test beam at DESY

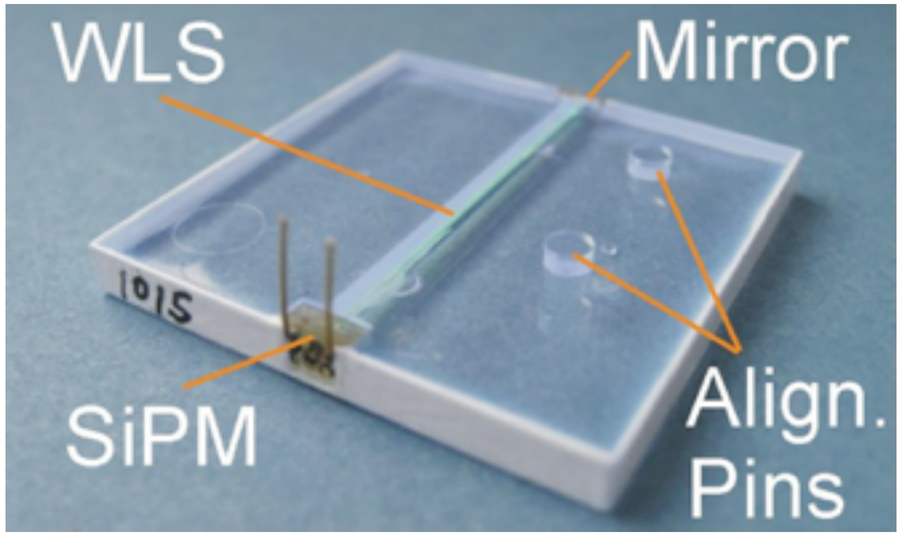
- Recover 5 x 5 mm^2 granularity with strip-splitting algorithm
- SiPMs / MPPC with higher smaller pixels under study to increase dynamic range
- Hybrid solutions together with Si layers (interleaved or as two sections) possible

Updated resolution plot?

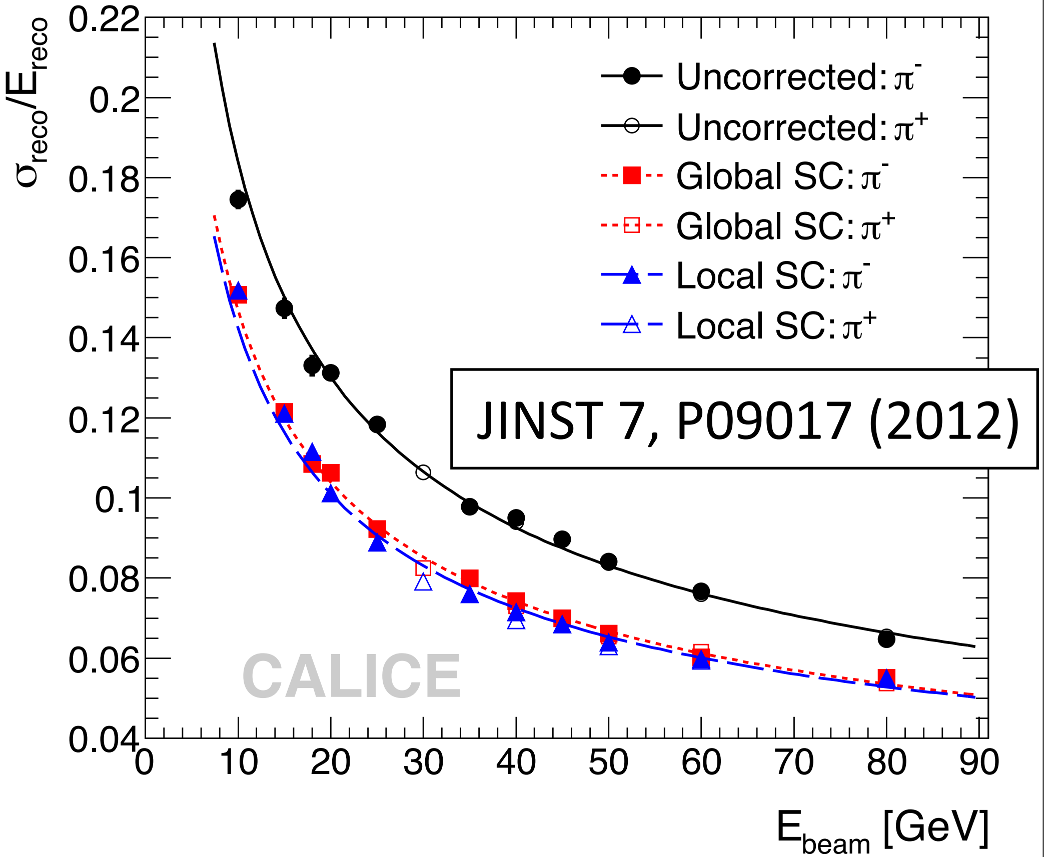
-> Currently under review in CALICE

The Analog HCAL

- Based on 3 x 3 x 0.3 cm^3 scintillator tiles with embedded SiPM



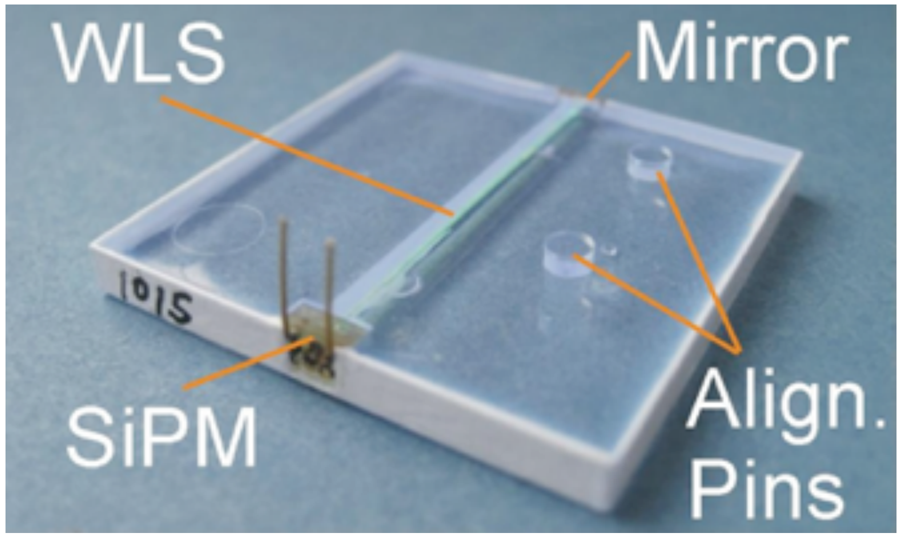
Well-established technology: Extensive tests in beam with a 8 000 channel system since 2006



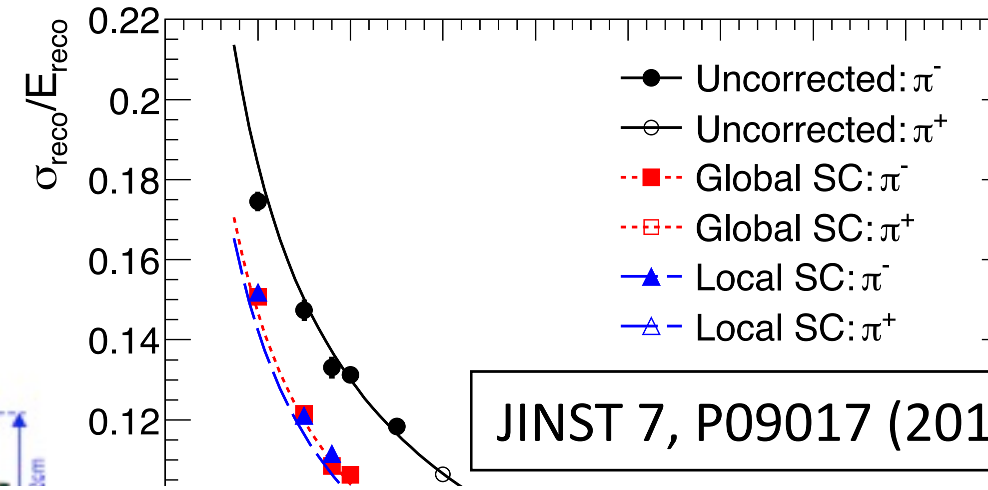
Hadronic energy resolution of physics prototype with software compensation: $45\%/\sqrt{E} \oplus 1.8\%$

The Analog HCAL

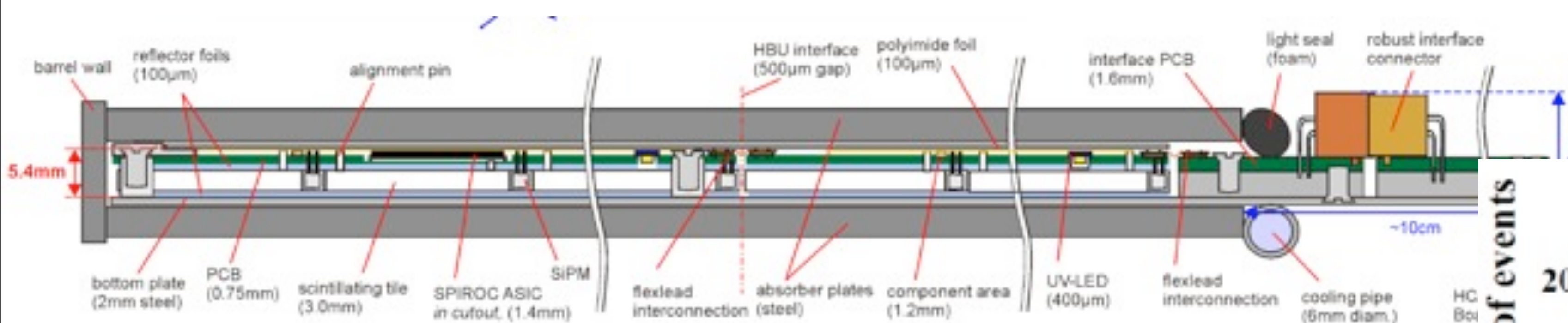
- Based on 3 x 3 x 0.3 cm^3 scintillator tiles with embedded SiPM

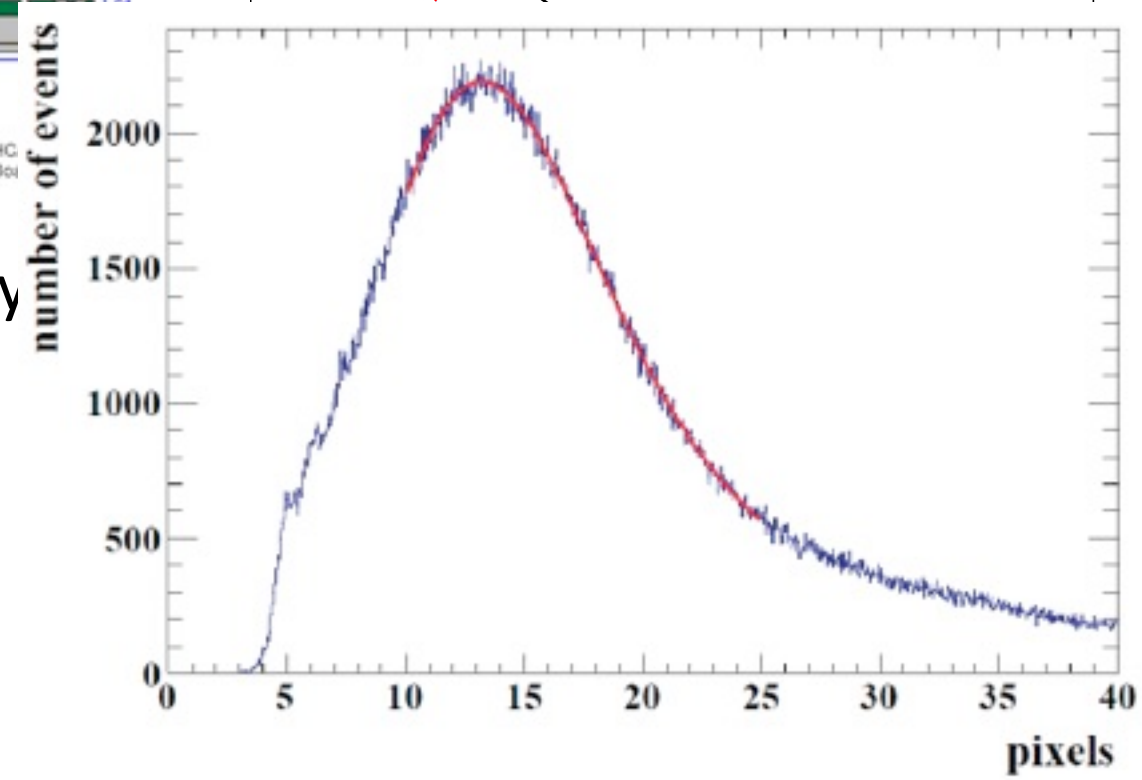


Well-established technology: Extensive tests in beam with a 8 000 channel system since 2006



JINST 7, P09017 (2012)



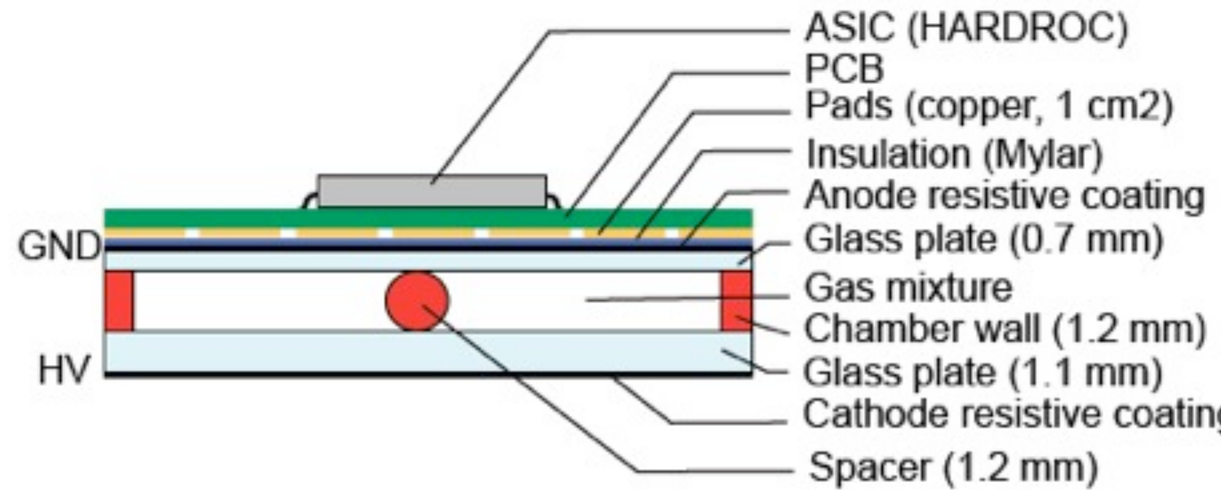


Compact design: < 6 mm non-absorber material per lay

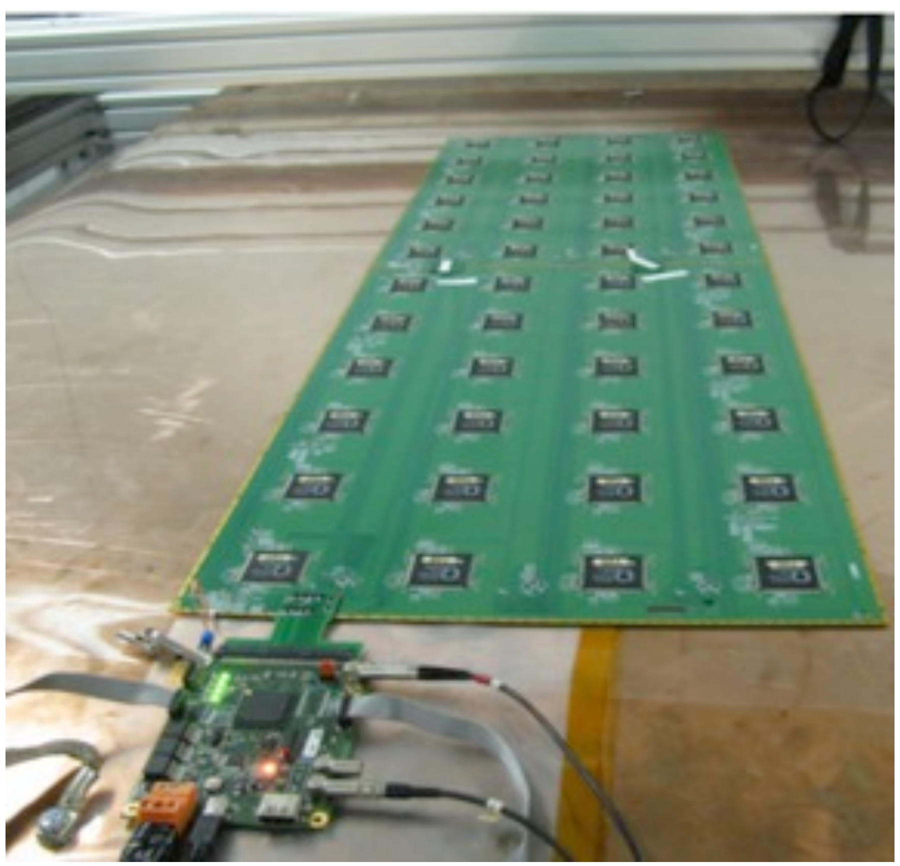
First units (144 channels) of technological demonstrator currently in test beam: - embedded electronics, power pulsing, online zero suppression, channel-by-channel auto-trigger, time stamping

The Semi-Digital HCAL

- Glass RPCs with 1 cm^2 pads
  - 3 thresholds per channel: allows to keep linearity to higher energies, improved resolution at high energies compared to purely digital mode



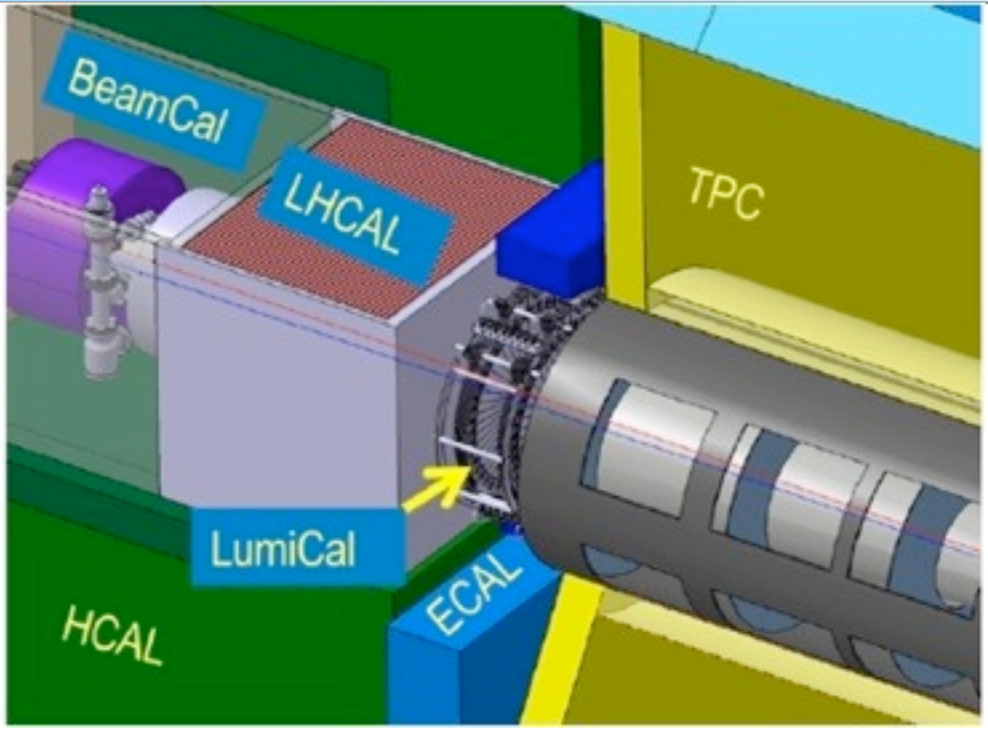
Full 1 m^3 technological prototype with 430k channels & power-pulsing successfully tested in beam



One nice (3D?) event display showing the three thresholds

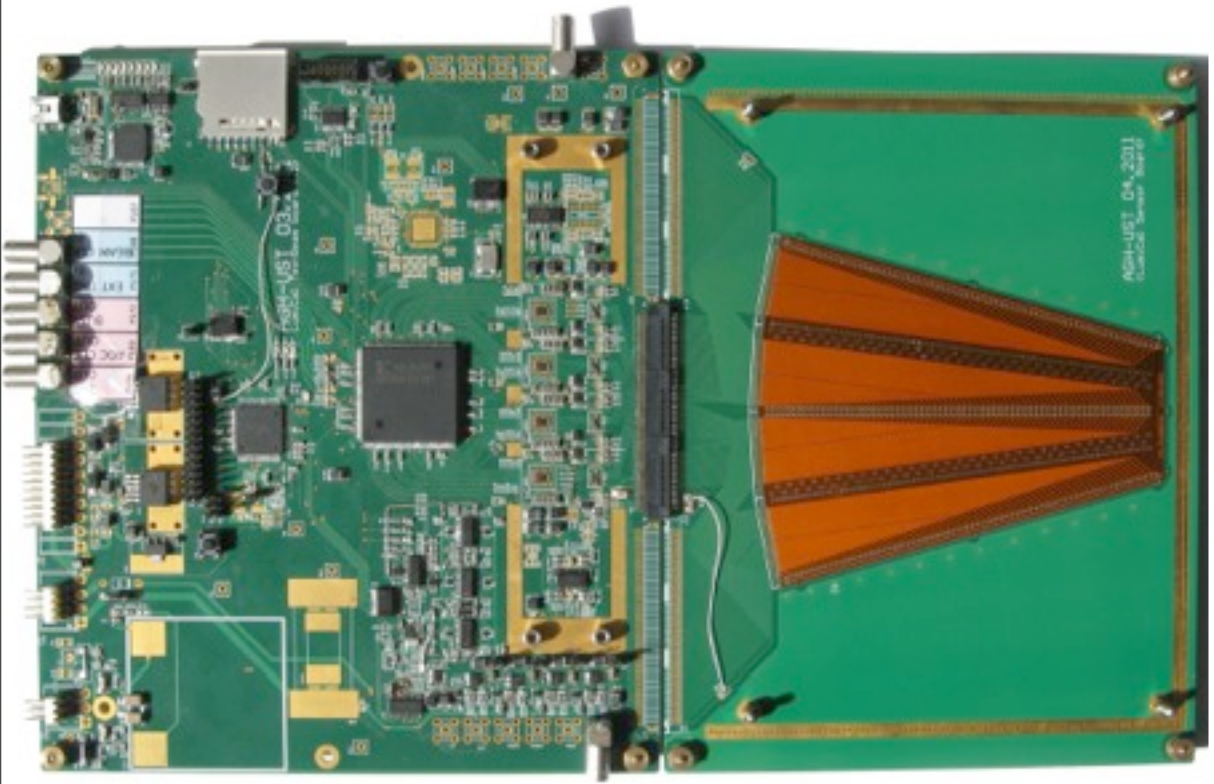
Linearity / Resolution, currently under review

Forward Calorimeters

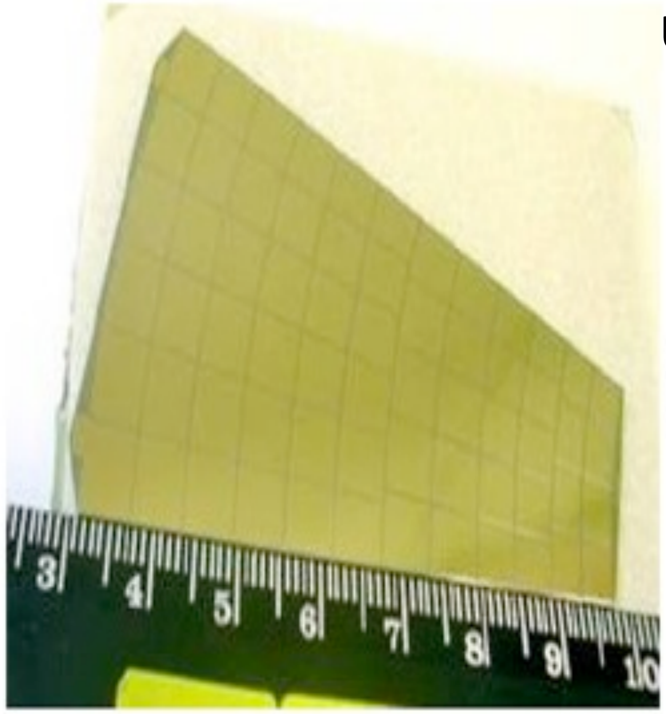


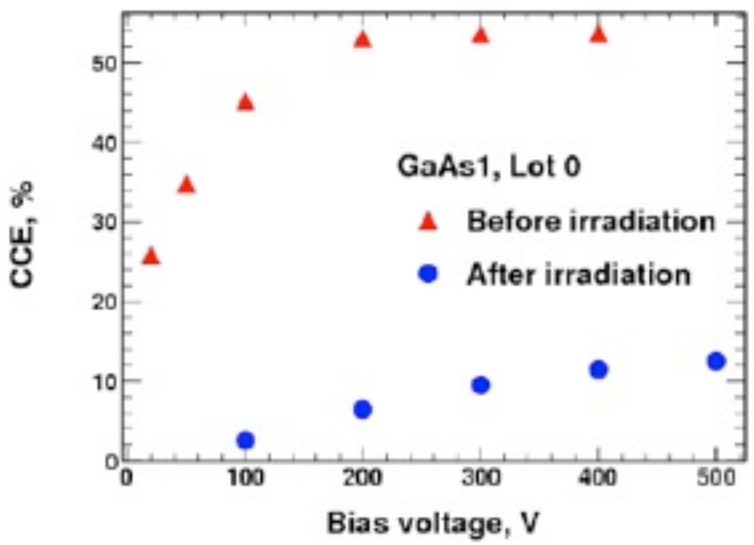
- Luminosity measurement at the 10^{-3} level with LumiCal
- Bunch-by-bunch luminosity monitoring and fast feedback for beam steering with BeamCal
- Extended coverage for energy measurements to low polar angles

Silicon sensors for LumiCal - tested in beam

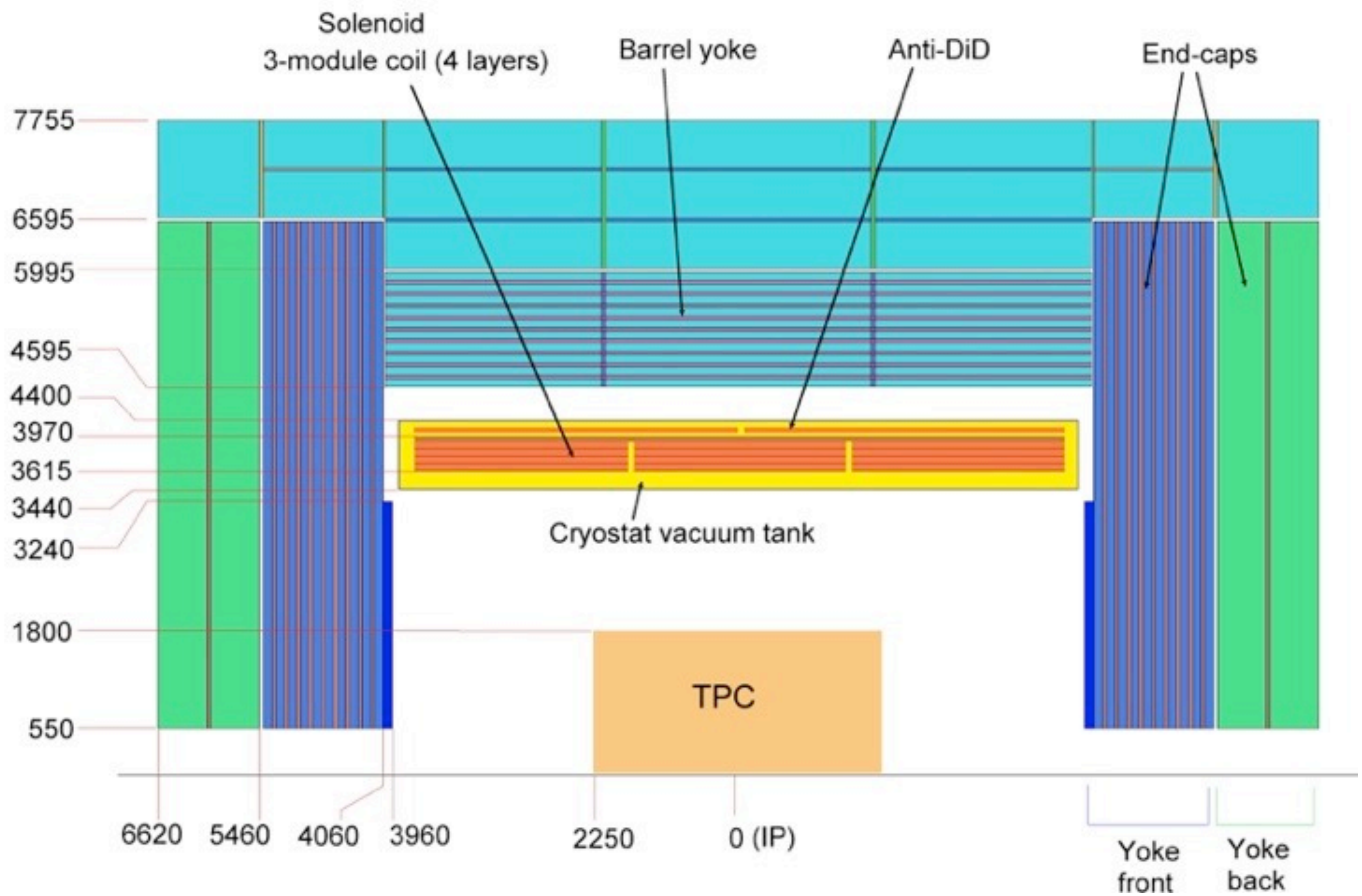


GaAs sensors for BeamCal, CVD Diamond under study for inner pads





Muon System, Yoke and Coil

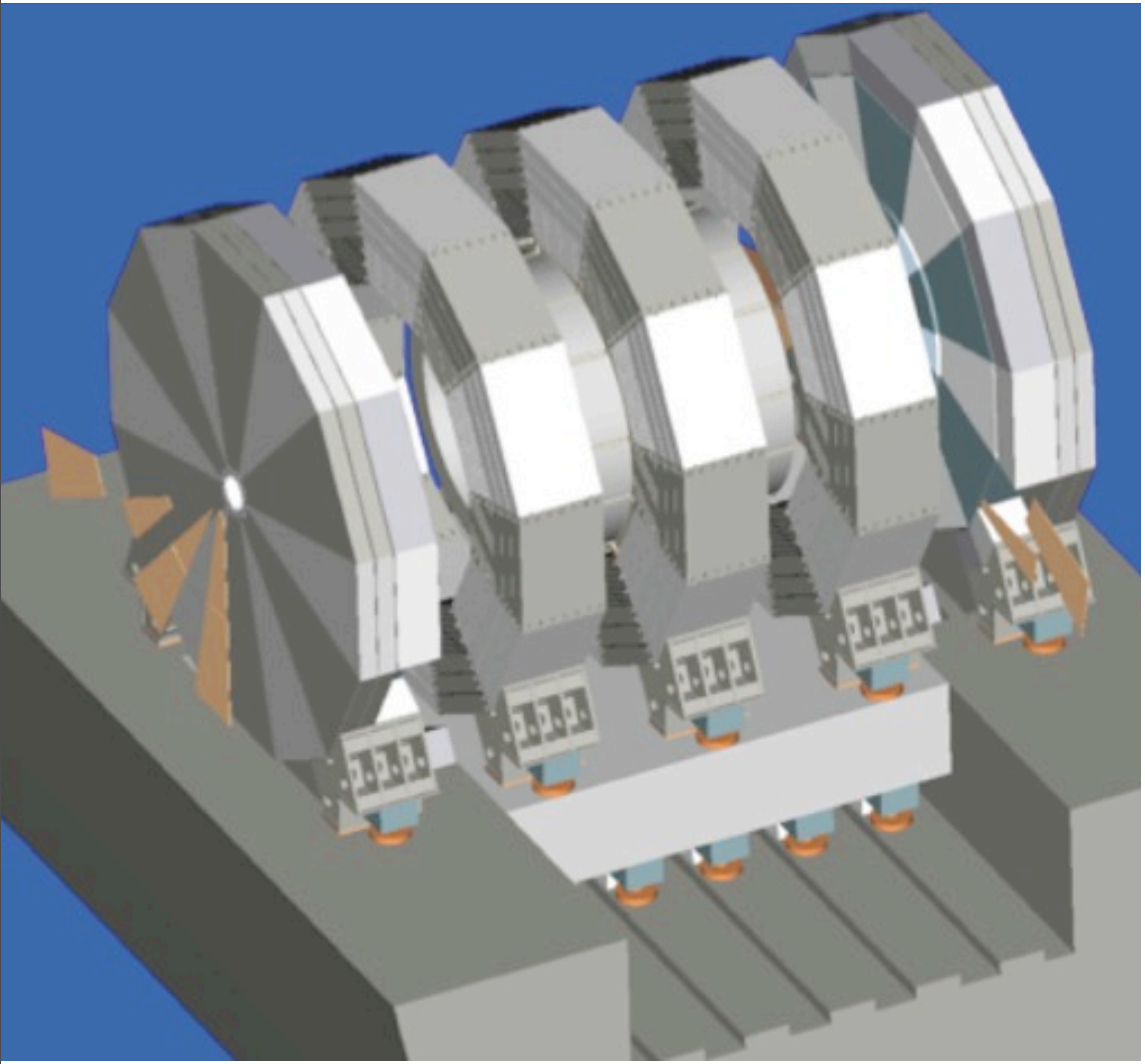


Default operations at 3.5 T, magnet designed for 4 T to allow flexibility at higher energy

- Instrumented iron yoke: Muon tracking and tail-catching
- ~ 10 mm thick, ~ 30 mm wide up to 2.7 m long extruded scintillator strips with SiPM readout

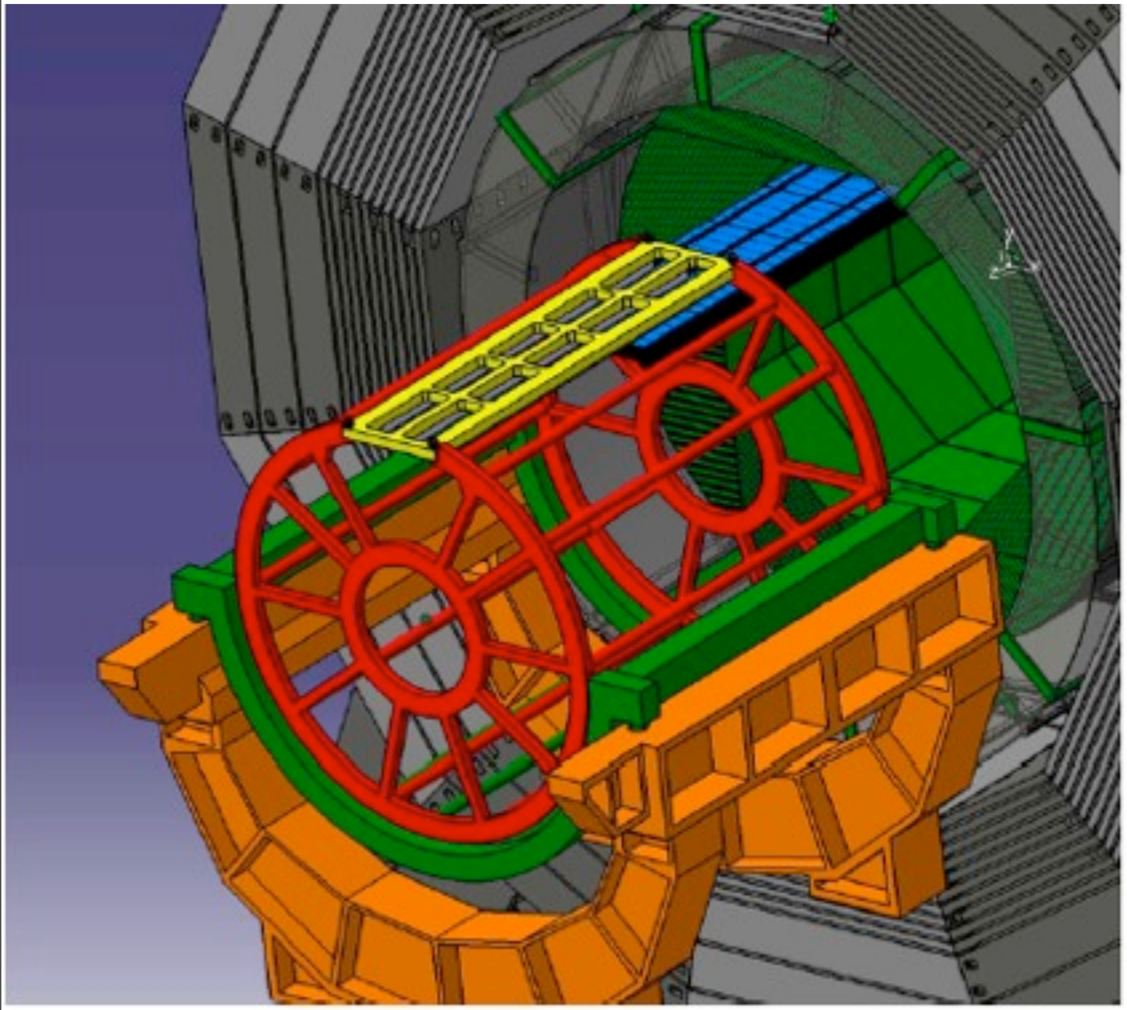
The ILD Detector System

ILD Mechanical Design



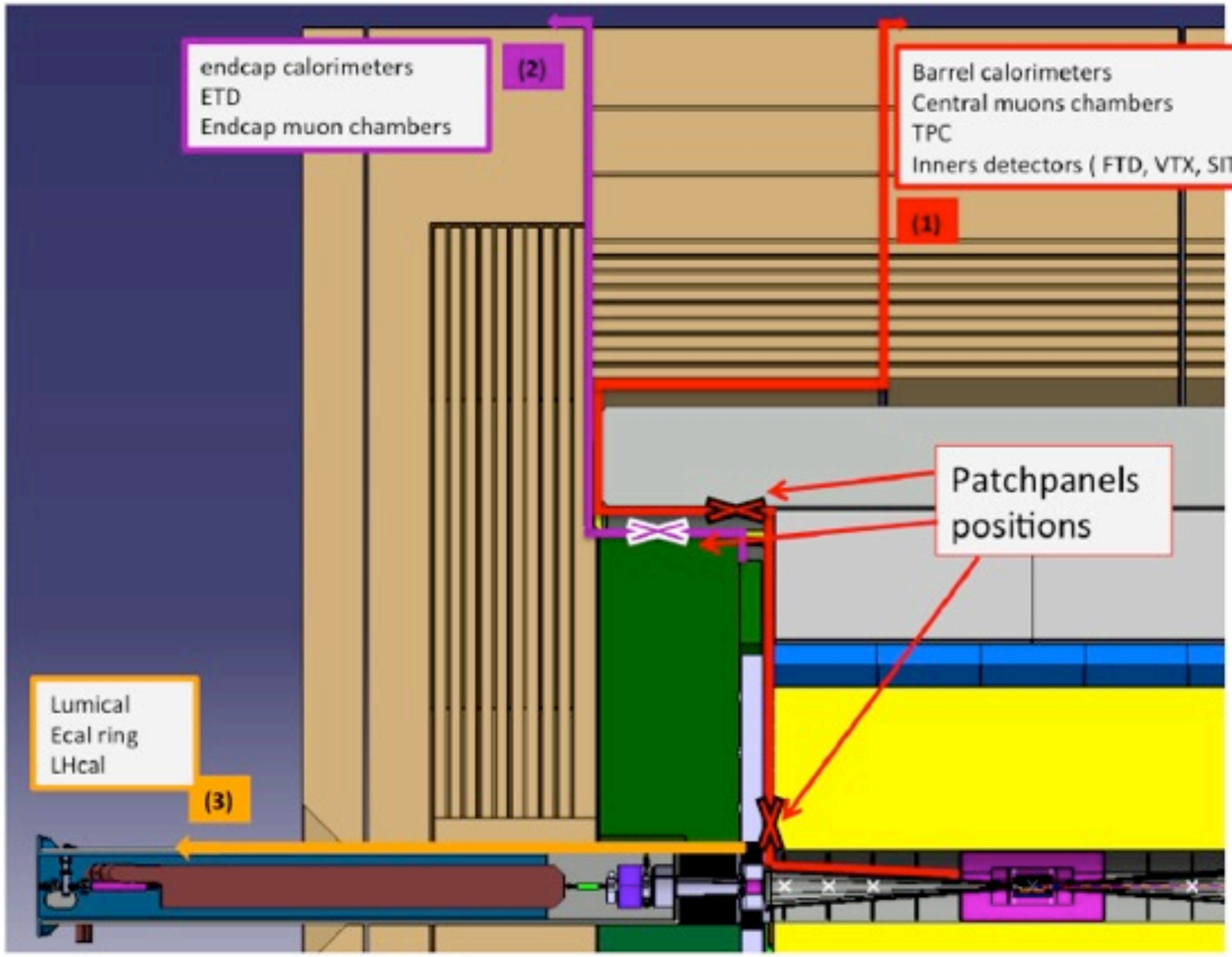
- 5 Yoke rings
- Central ring carries cryostat and solenoid:
  - Defines the minimum diameter of access tunnel required for installation
    - 18 m for vertical access, 3500 t crane capacity
    - > 8.7 m for horizontal access
- Supports calorimeters, TPC and outer Si trackers
- Inner detector & beam pipe supported from TPC

ILD Integration

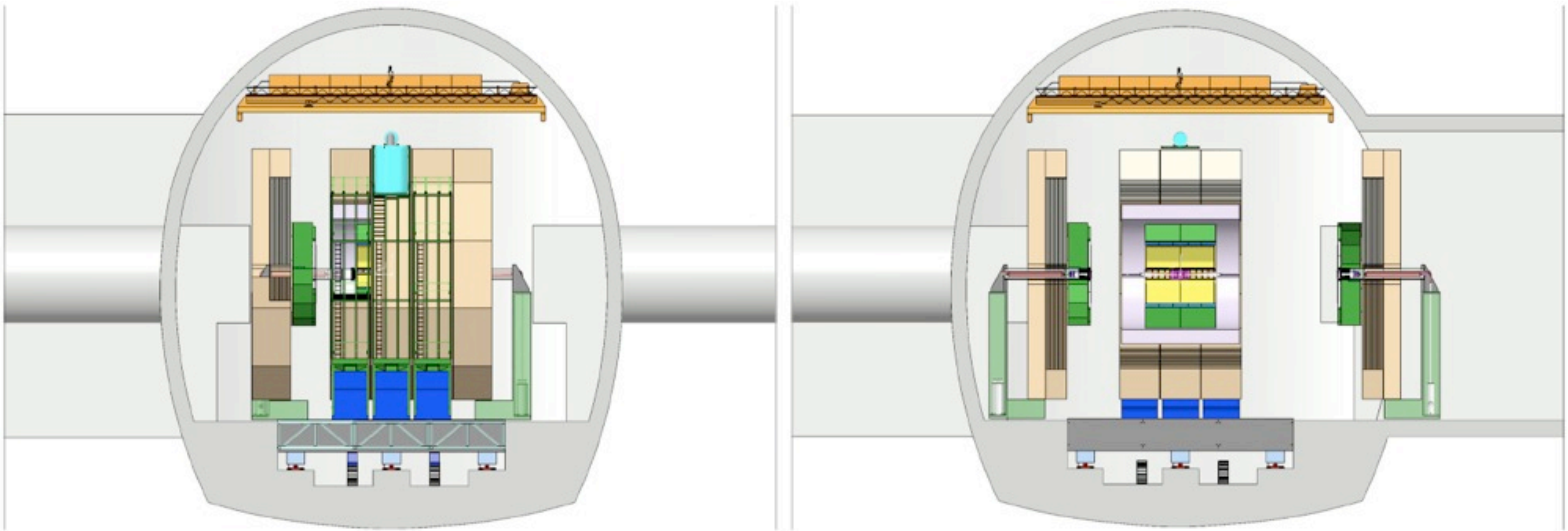


- Assembly strategy with dedicated installation fixtures

- Service paths inside of the detector for power, data, cooling



The Experimental Hall



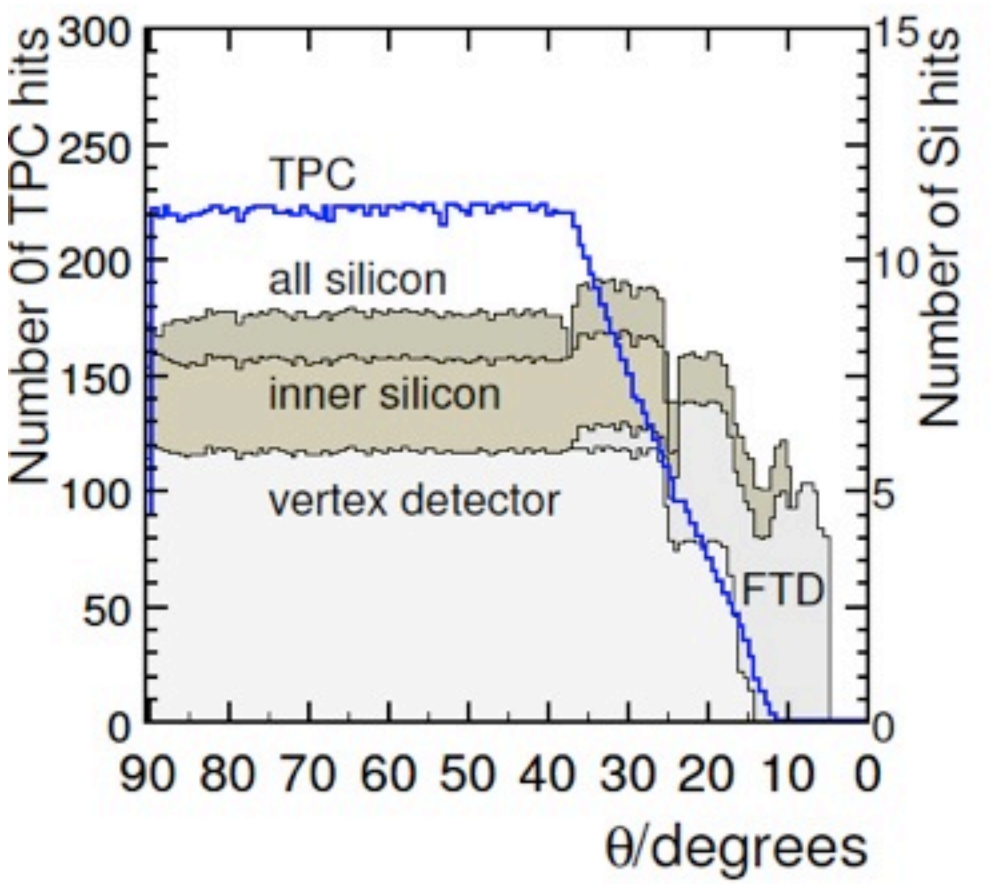
- Each yoke ring mounted on air cushions for easy moving during assembly / dis-assembly / maintenance
- For vertical access: Assembly of yoke rings and central detector system within cryostat on surface
- For horizontal access: Assembly of yoke rings and other large components in detector hall

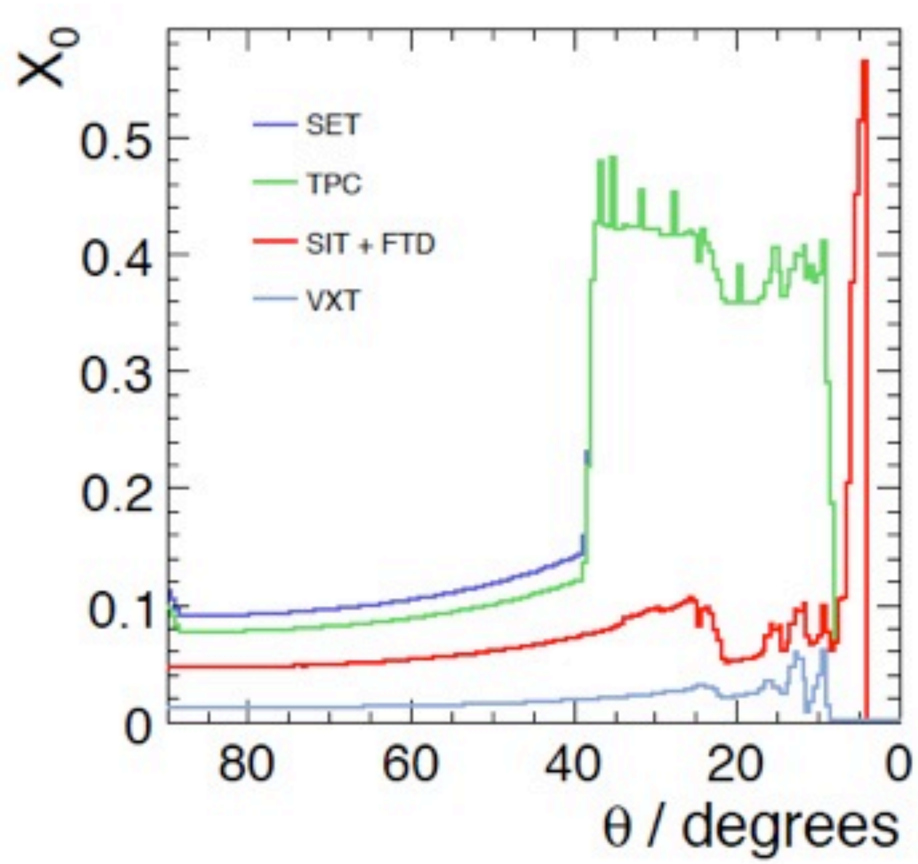
ILD Software & Performance

ILD Simulation & Reconstruction

- Significant enhancements compared to the LOI
  - Increased realism in the detector description
    - Realistic geometry of most subsystems: Individual modules in trackers, engineering details (mechanical supports, electronics, cooling, cabling, ...)
    - Inclusion of dead material, cracks, ...
    - ▸ Material budget estimates based on R&D activities
  - Improved reconstruction software
    - New generation of PandoraPFA
    - Completely new Kalman-Filter-based tracking
    - New flavor tagging based on neural networks trained with fully simulated events

ILD Material & Performance





PFA Performance

Tracking or flavor tagging performance

ILD Physics Performance

Do we dare to show something here? If yes, which analysis?

Something on gg->had background mitigation with k_t jet finding?

Summary