International Workshop on Future Linear Colliders

LCWS13

11-15 November 2013, The University of Tokyo

ILD Muon System / Tail Catcher

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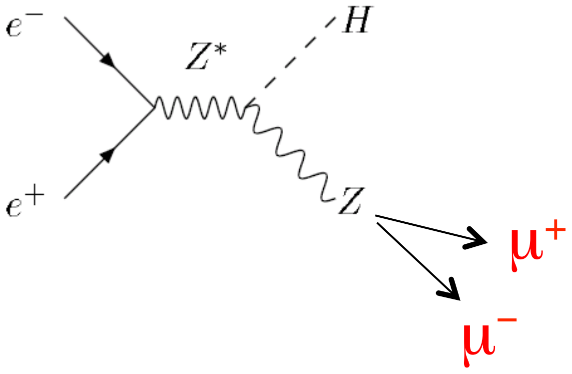
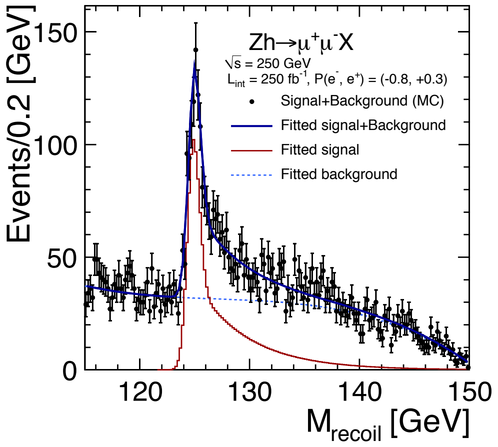
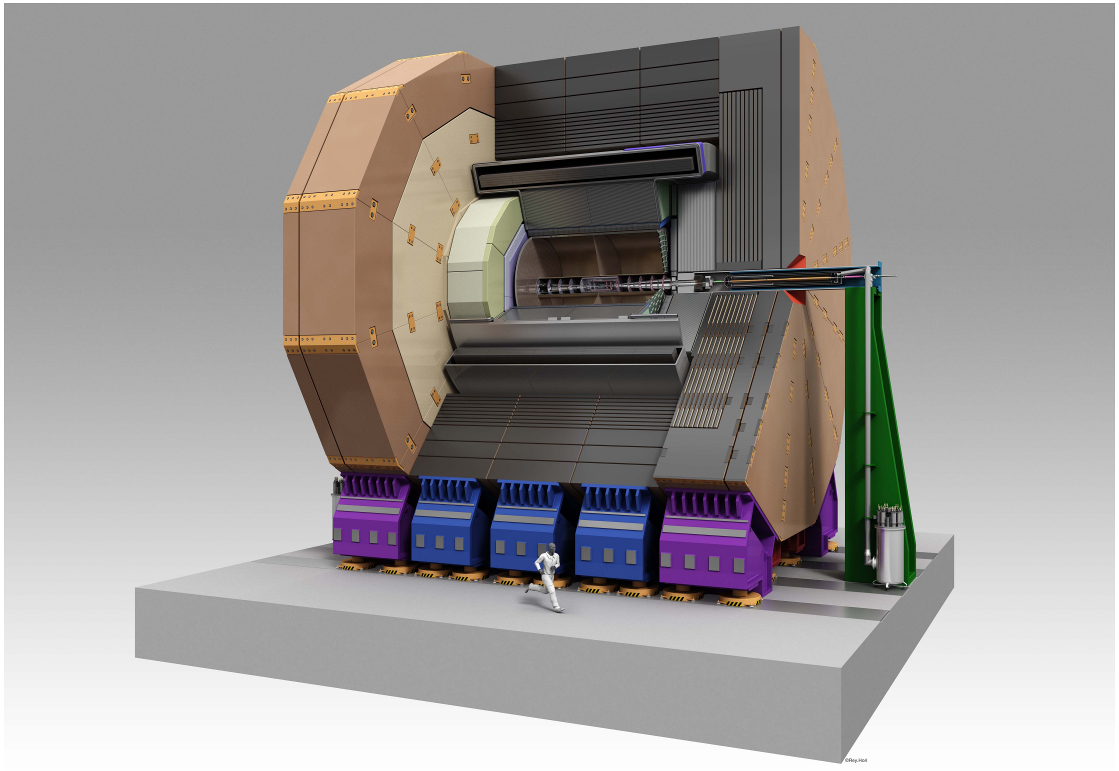
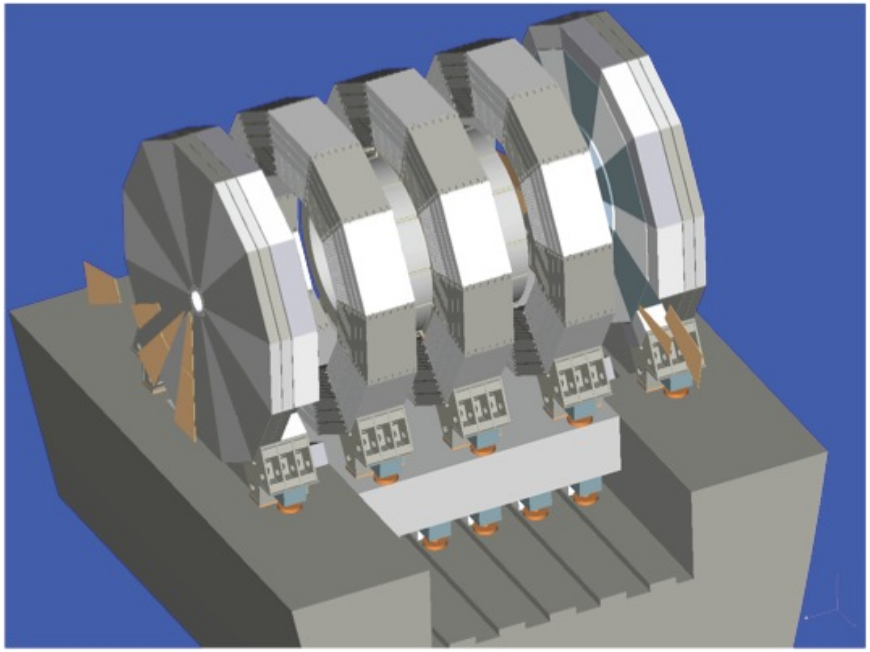
ILD Muon System/Tail Catcher







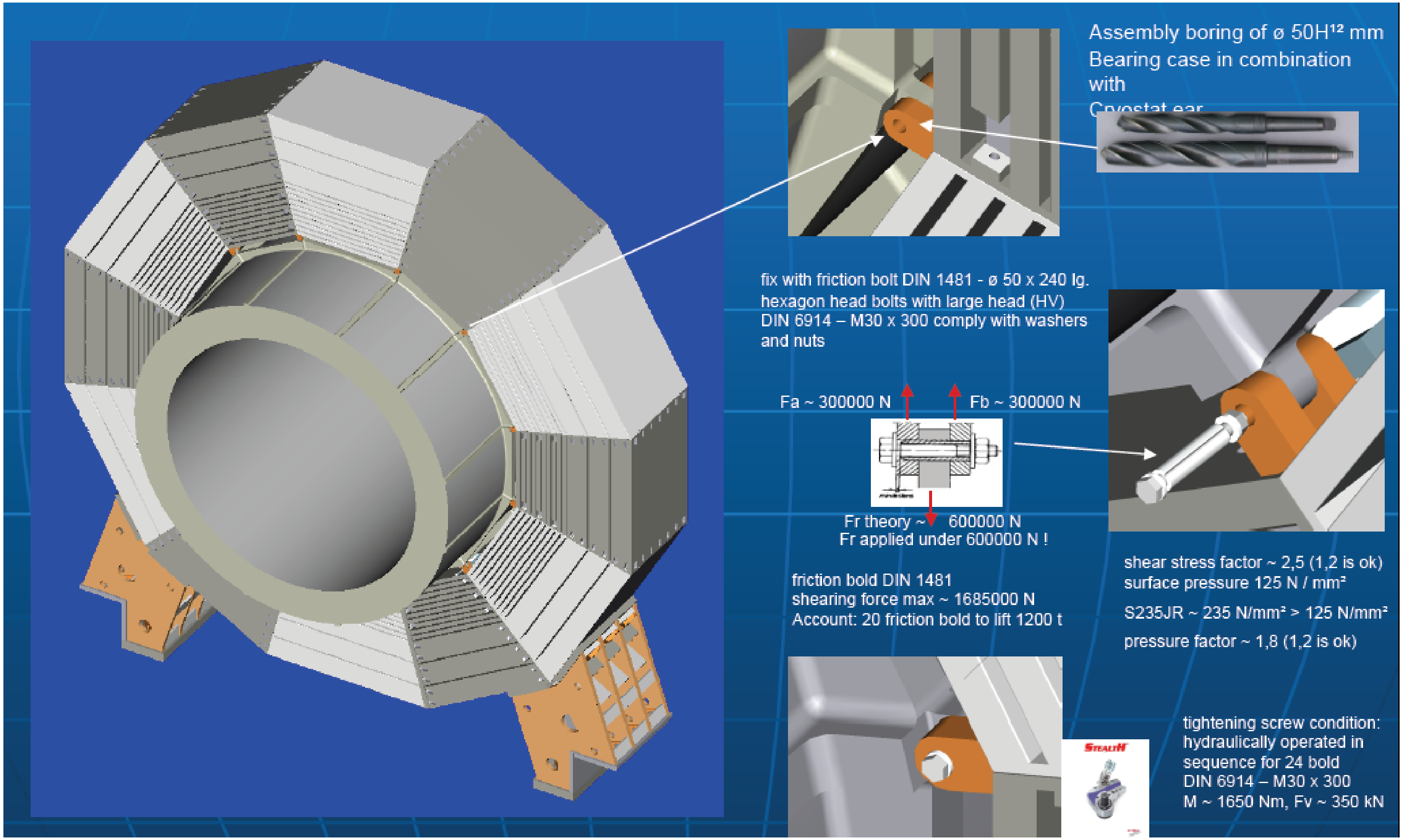
Instrumentation of the Yoke (Muon System/Tail Catcher)



Modules:	3 Barrels	2 EndCaps
Sizes: R min, R max Length	 4450 7760 2800	 300 7760 2560
N of Sensitive Layers	14	12
Scint. Strips/ WLS/SiPM Length Wids Thickness	 max 2800 30 10	 max 2800 30 10

Total Number of Sensitive Elements are 125000

Mechanical Study of the Yoke



Assembly boring of ø $50H^{12}$ mm
Bearing case in combination
with
Cryostat ear

fix with friction bolt DIN 1481 - ø 50 x 240 lg.
hexagon head bolts with large head (HV)
DIN 6914 – M30 x 300 comply with washers
and nuts

Fr applied under 600000 N !

friction bold DIN 1481
shearing force max ~ 1685000 N
Account: 20 friction bold to lift 1200 t

shear stress factor ~ 2,5 (1,2 is ok)
surface pressure 125 N / mm^2

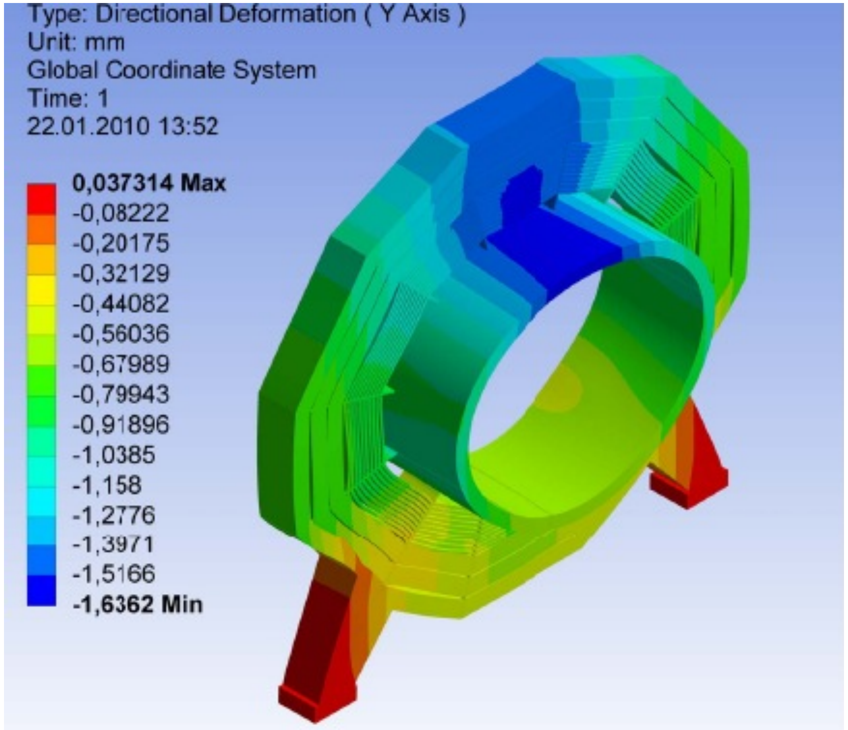
S235JR ~ 235 N/mm^2 > 125 N/mm^2

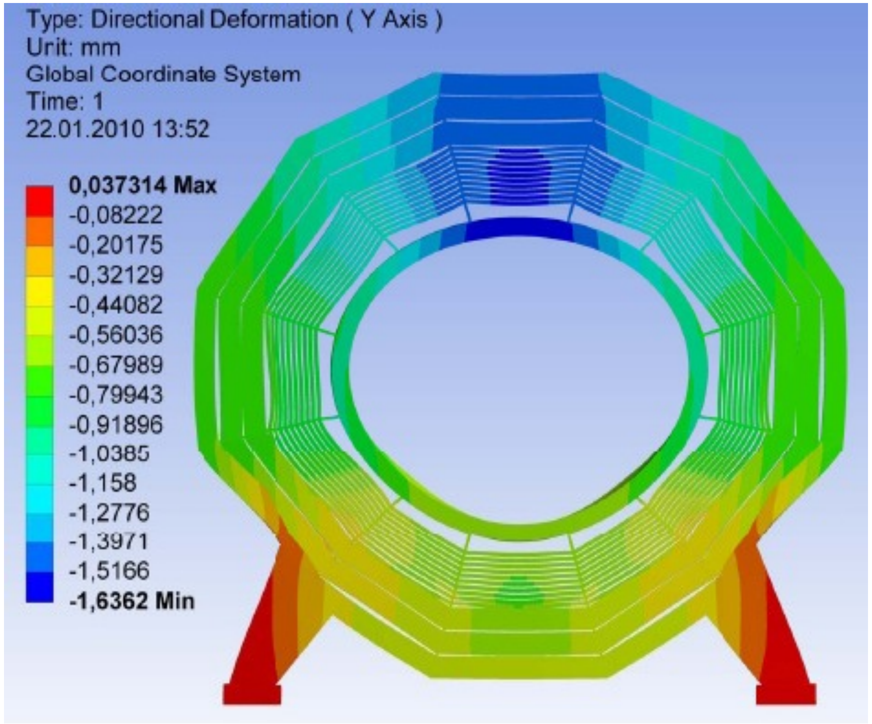
pressure factor ~ 1,8 (1,2 is ok)

tightening screw condition:
hydraulically operated in
sequence for 24 bold
DIN 6914 – M30 x 300
M ~ 1650 Nm, Fv ~ 350 kN

Detailed Mechanical Structure, U. Schneekloth, DESY

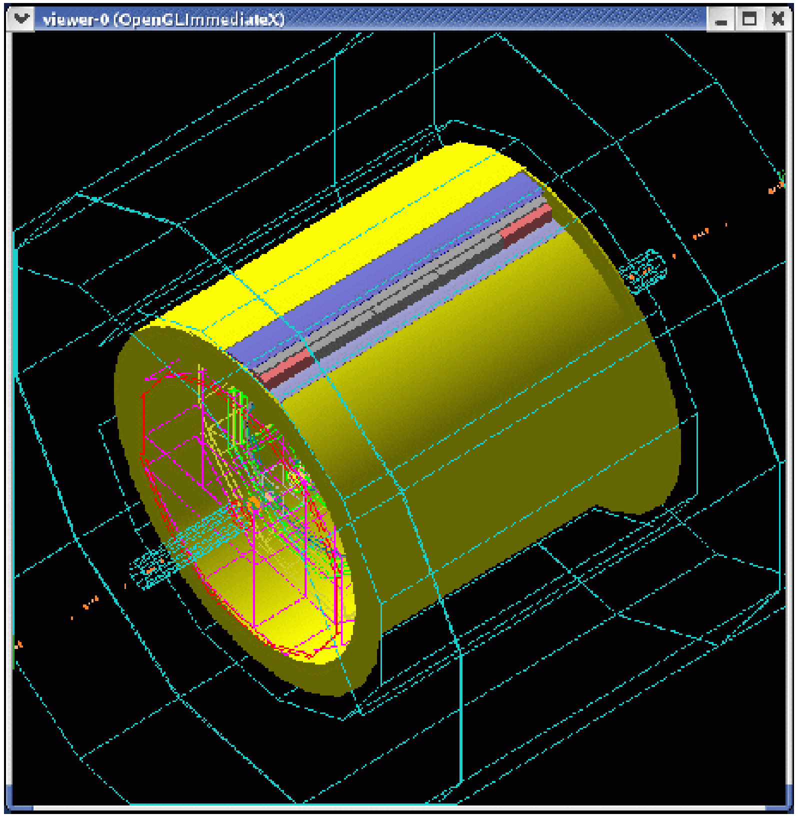
Mechanical Study of the Yoke



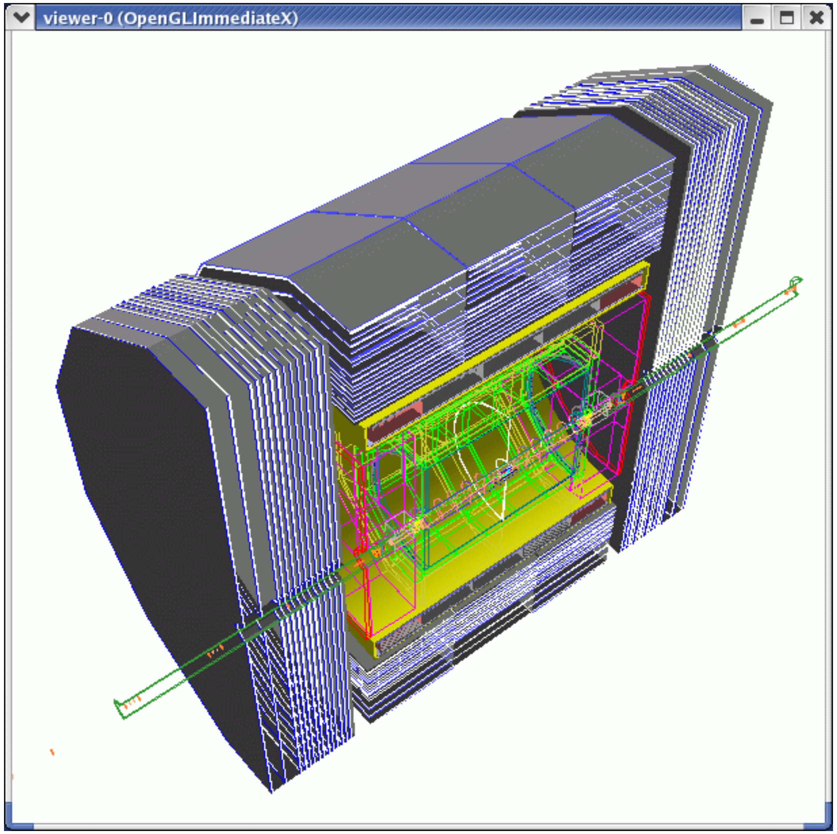


Advance Study of Mechanics Deformations, U. Schneekloth, DESY

Detailed Model of ILD Muon System/Tail Catcher in Mokka

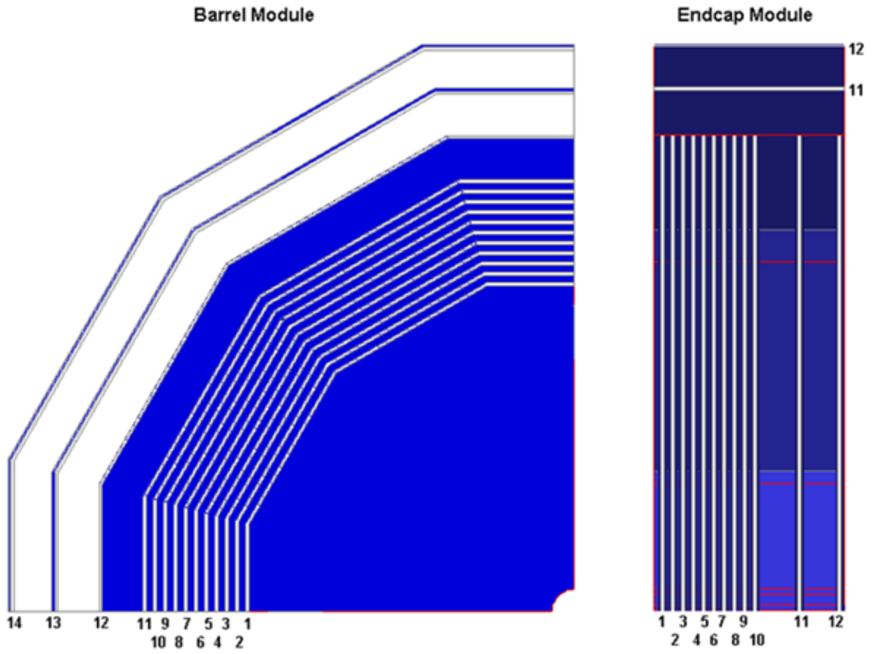


Detailed Cryostat with Coils
in Mokka Simulation Framework



General view of Muon System in
Mokka Simulation Framework

Instrumentation of the Yoke (Muon System/Tail Catcher)



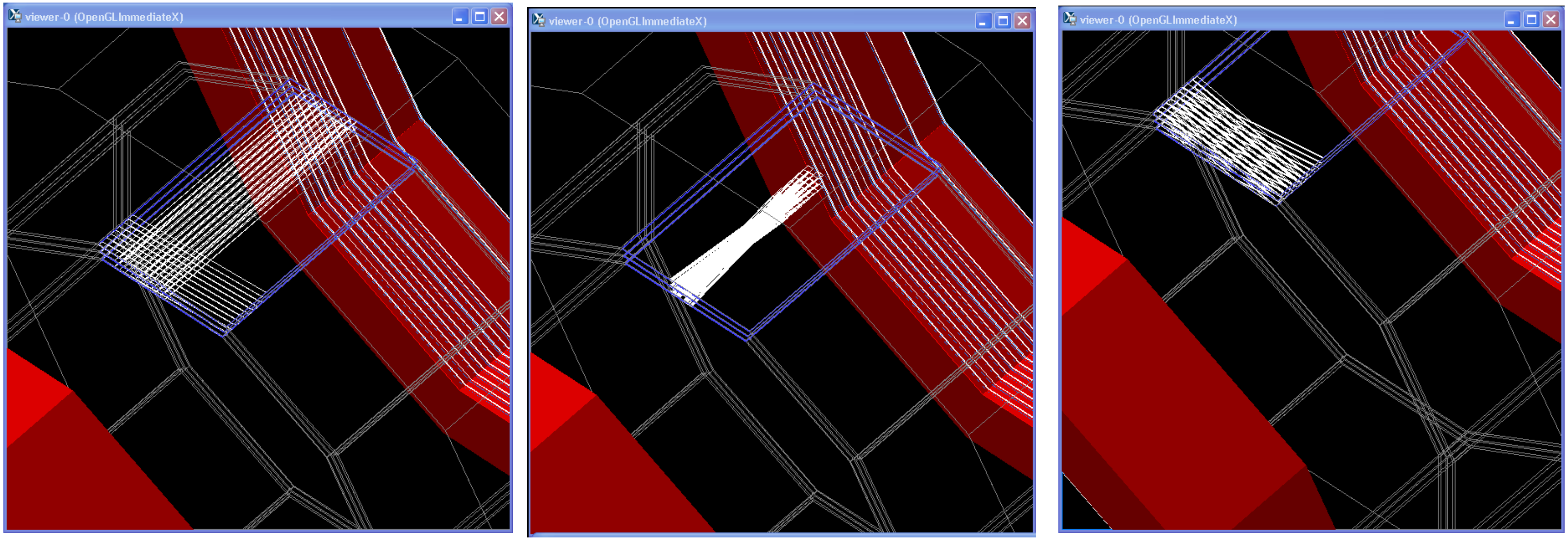
Cryostat : Detailed Geometry
Instrumentation: 2 Scintillation Double Sensitive Layers

Coil : Detailed Geometry,
Coil Segmentation

Yoke : Detailed Geometry based on Mechanical Design
Instrumentation:
Barrel: 40 + 10*(100+40)
+3*(560 + 40) mm (total 14 Layers)
EndCup: 10*(100+40)
+2*(560 + 40) mm (total 12 Layers)

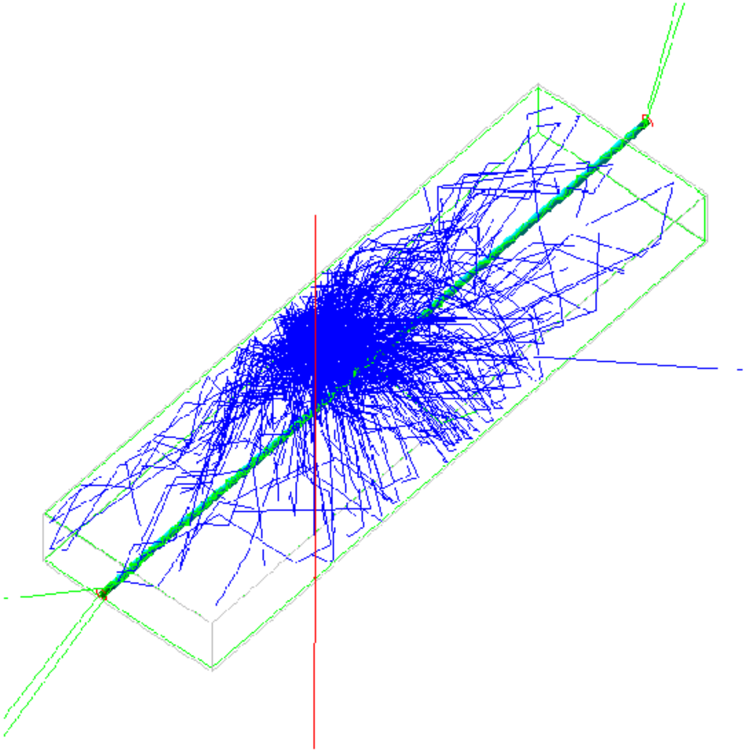
Basic Option for the Simulation is Scintillator Cells 30 x 30 mm

Detail Model of Muon System/Tail Catcher

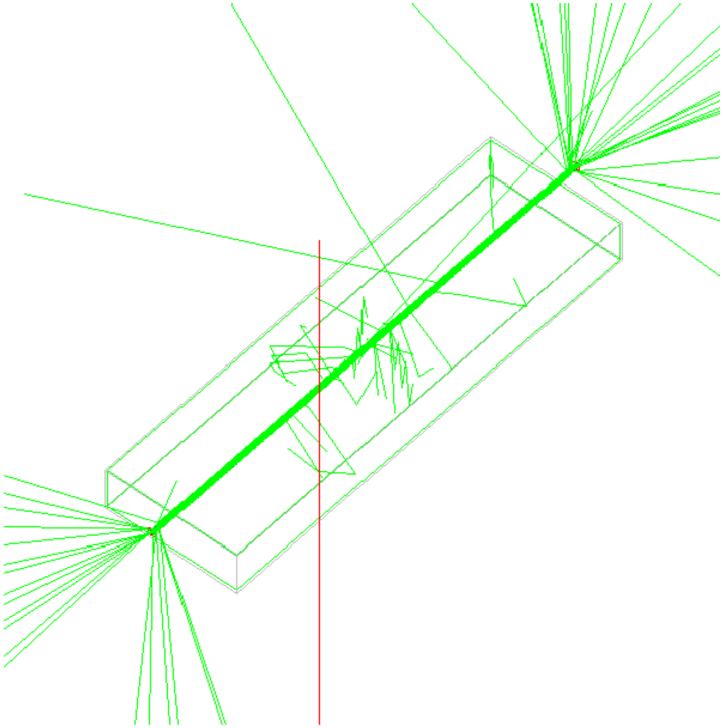


Geometry of Stereolayers of Sensitive Elements: ortogonal, stereoangle along z, stereoangle ortogonal to z

Full Simulation of the Light Propagation and Detection

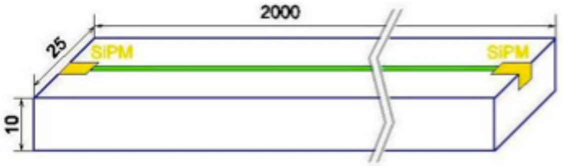


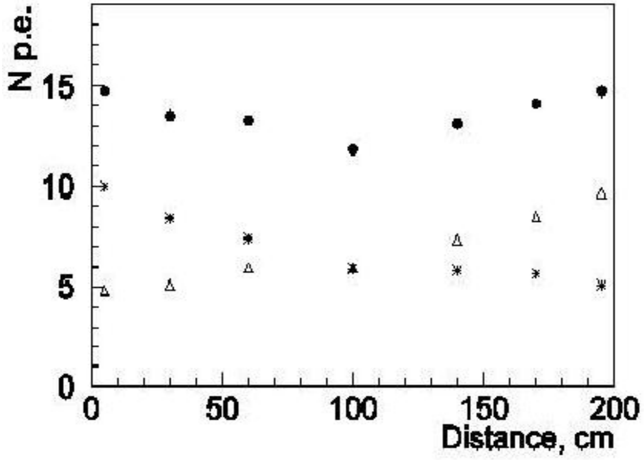
Scintillation UV Photons created by Muon in Sensitive Element



Converted Green Photon in WLS (Scintillation Photons are hidden)

Muon System Sensitive Elements Technology





The Main Option for the Sensitive Layers is extruded Scintillation Strips with thickness of ~10 mm and a width of ~30 mm, maximal Length of ~2800 mm.

The Scintillation Strips are covered by the Reflection Layer TiO_2 that is co-extruded along side the Scintillator during the extrusion Process.

The 1mm wide extruded groove running along the center of the strips is filled with a commercially available WLS fiber 1 mm diameter

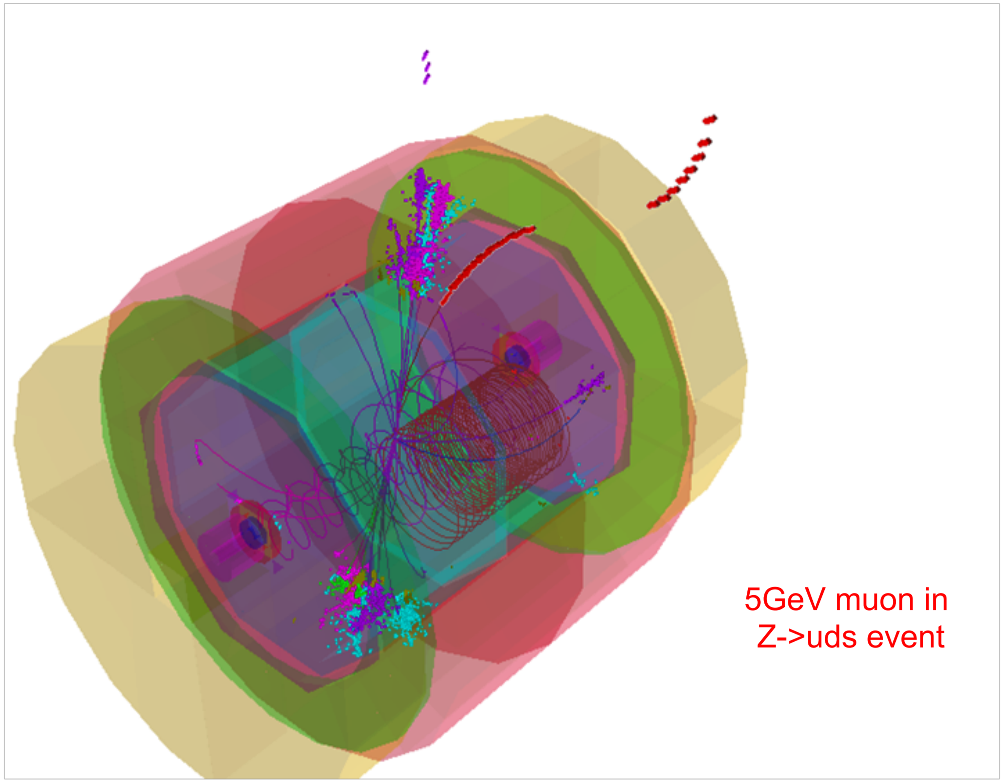
Muon System Sensitive Elements Technology

Resistive Plate Chamber (RPC) are considered as alternative Sensitive Layers. Main feature are exellent granularity up to 1 x 1 cm^2 pads and one threshold (1 bit) Digital Readout.
Several Types of RPCs have been successfully constructed and tested within ILC R&D program

Actually the technology of Muon Sensitive Elements directly related to the Hadron Calorimeter Technology and finally will be correspondent to this technology

PANDORA PFA: Fast Muon Identification

- The number of occupied layers in each of the ECAL, HCAL and YOKE regions
- The energy deposited in the ECAL and HCAL regions. Energies are direction-corrected and cuts are linear functions of associated track energy
- The RMS values for straight-line fits in the ECAL, HCAL and YOKE regions.
- The fraction of mip-like hits in the ECAL and HCAL regions.
- The number of muon yoke hits

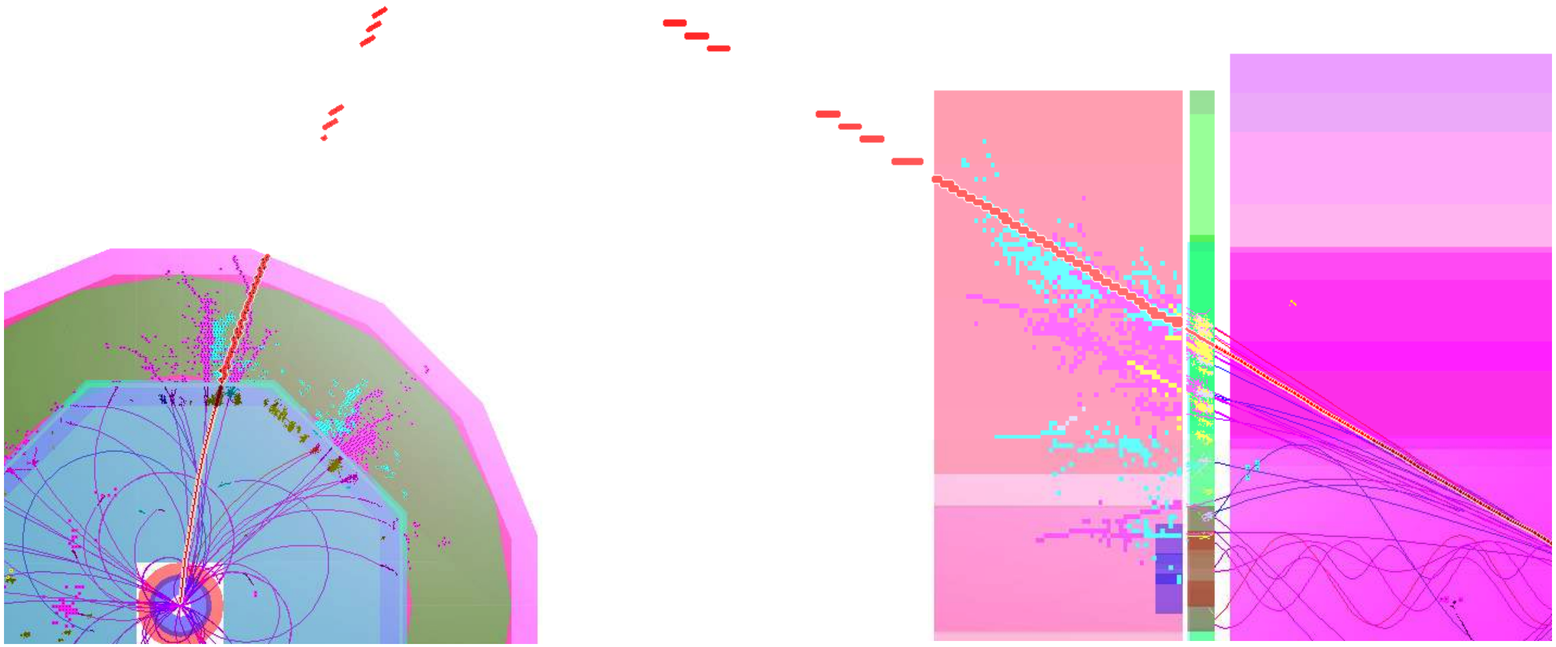


5GeV muon in Z->uds event

Pandora PFA: J. Marshall

Fast Muon Identification is Cut Based and looks for an inner detector followed by consistent, minimal energy deposition through Calorimeter and Muon Systems. It target muons with energy greater than 2.5 MeV

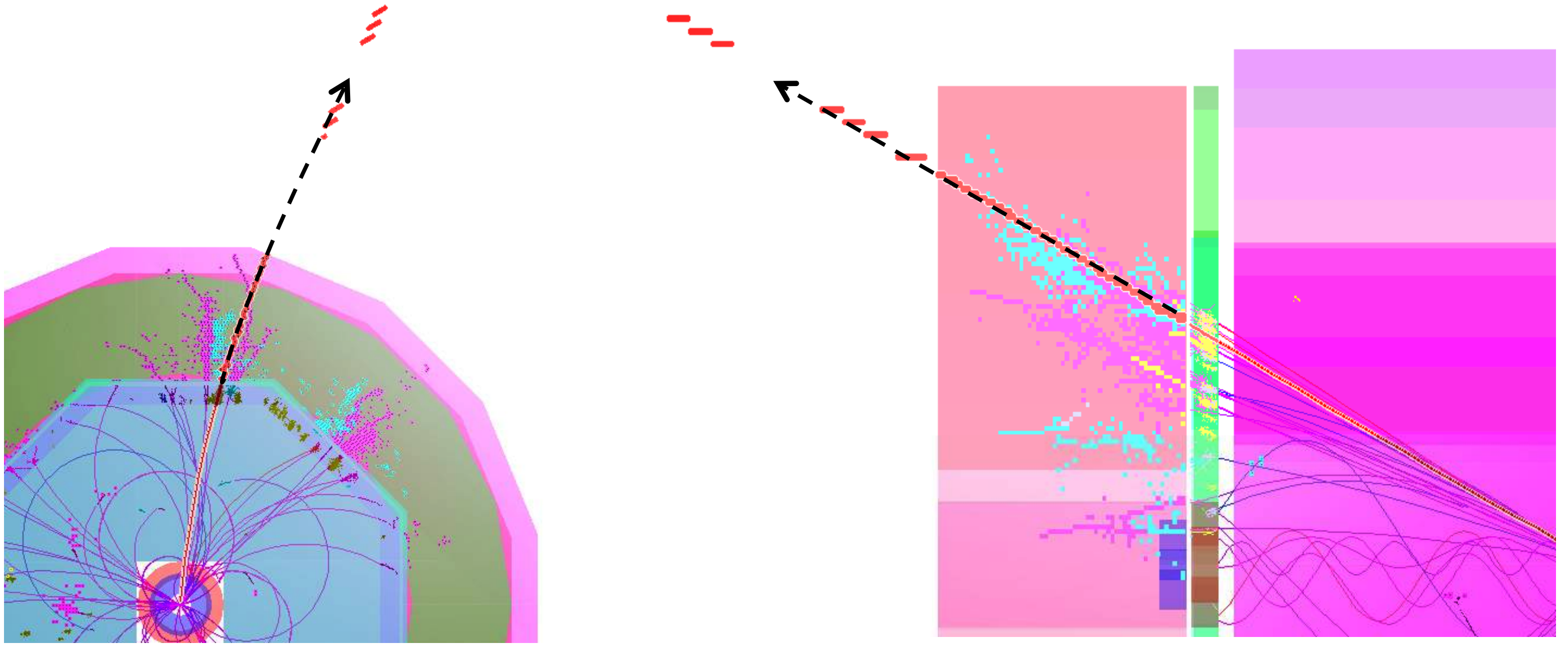
PANDORA PFA: Muon Reconstruction Algorithm



Pandora PFA: J. Marshall

Yoke track candidates are identified using an instance of the Pandora cone-based clustering algorithm, configured appropriately for the coarse instrumentation in this region. Clusters crossing all yoke layers, whilst containing a minimal number of hits are selected

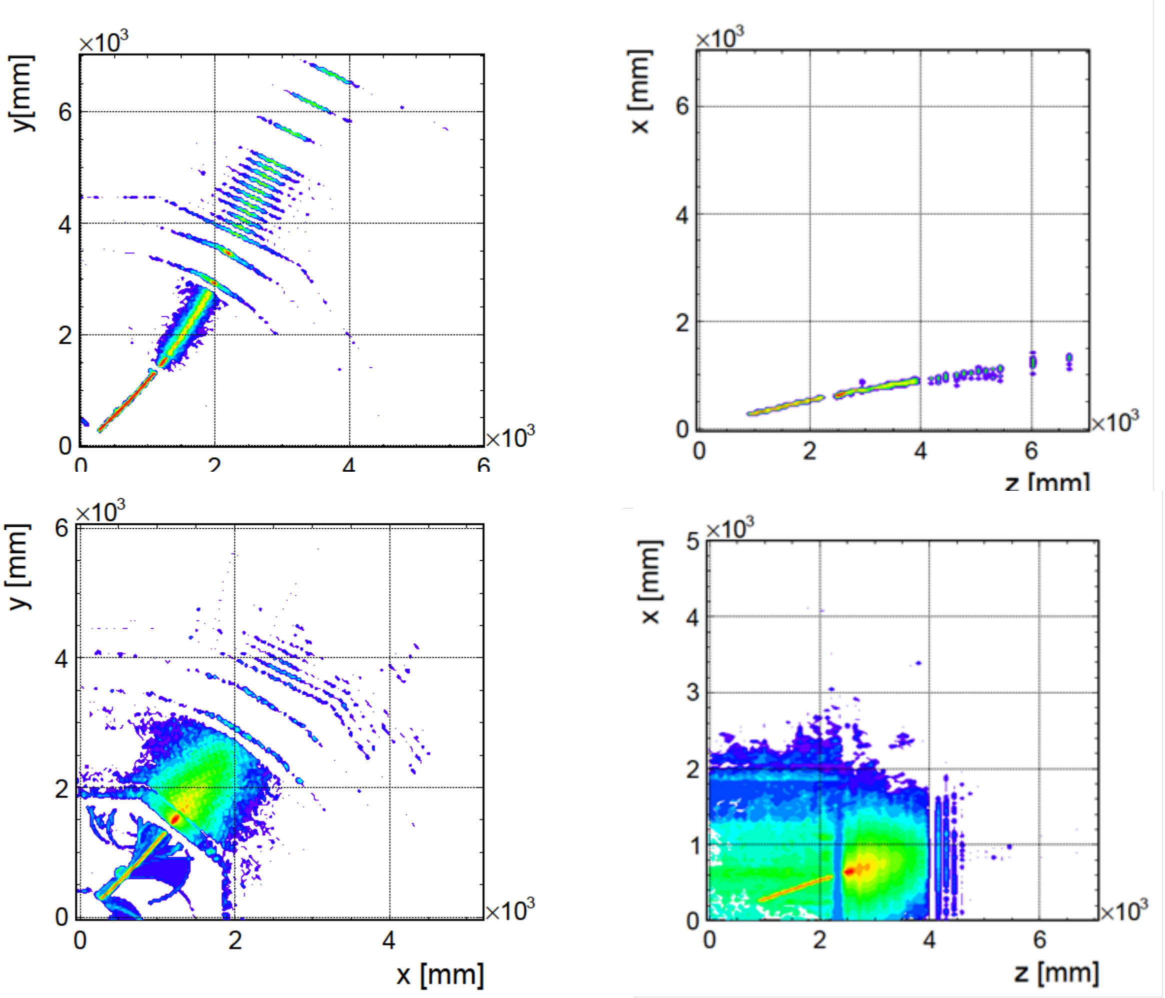
PANDORA PFA: Muon Reconstruction Algorithm



For each inner detector track above 5GeV, a helix fit to the track is extrapolated to the position of yoke cluster.

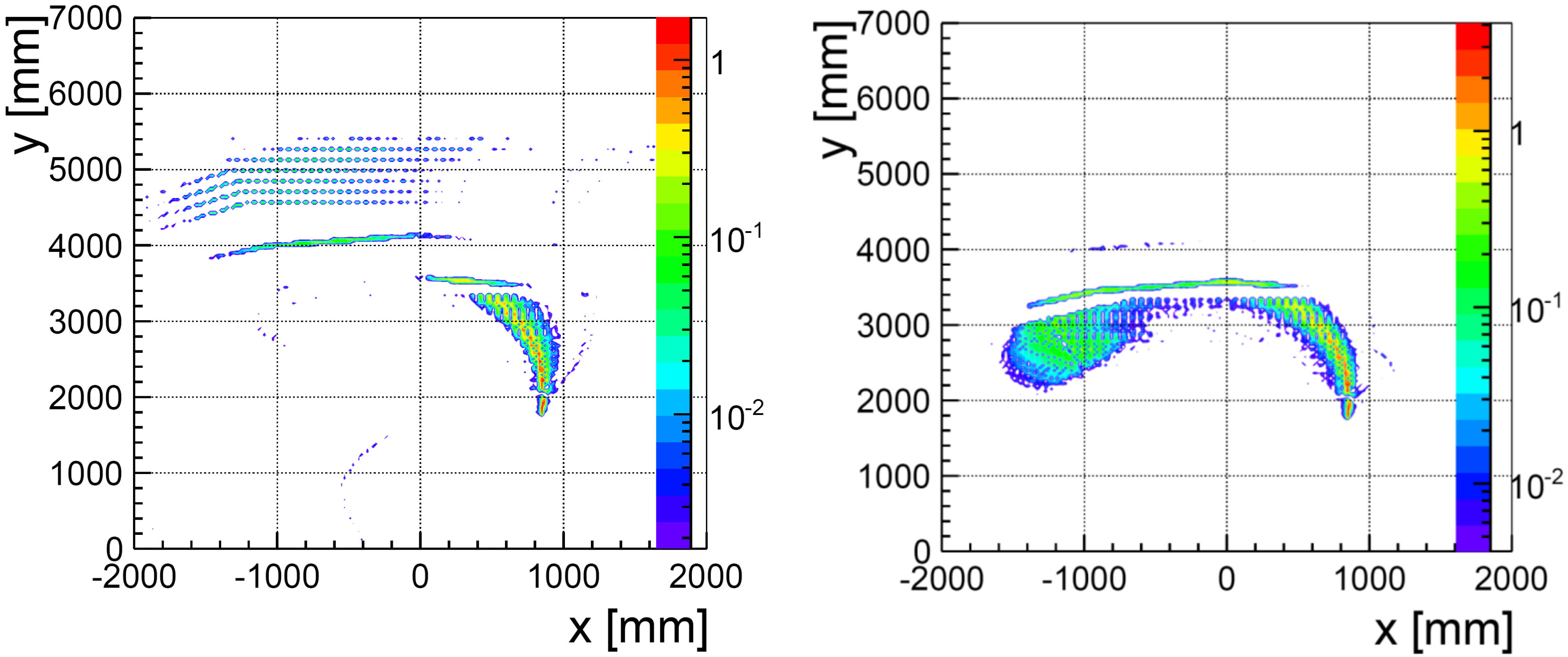
Track candidates with opening angles greater than 0.2rad, or distances greater than 200mm are excluded. The closest track is selected and used to calculate the muon properties.

Single muons and pions Propogations



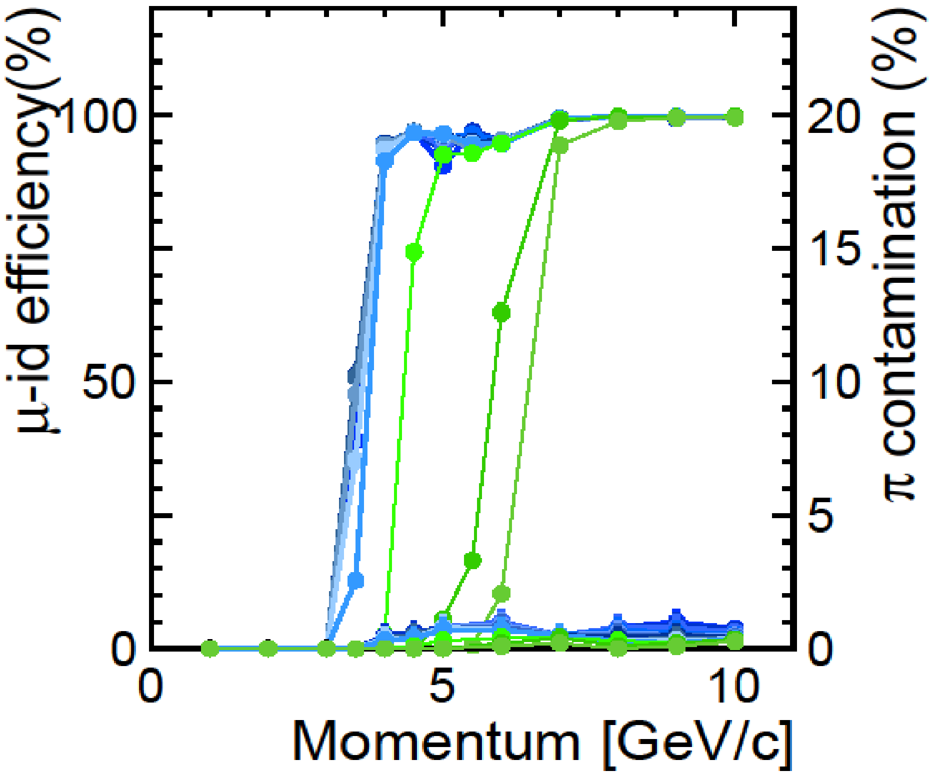
10 GeV Single muons and pions in the Barrel and EndCap Region

Problem of Identification of Low Momenta Muon in Barrel



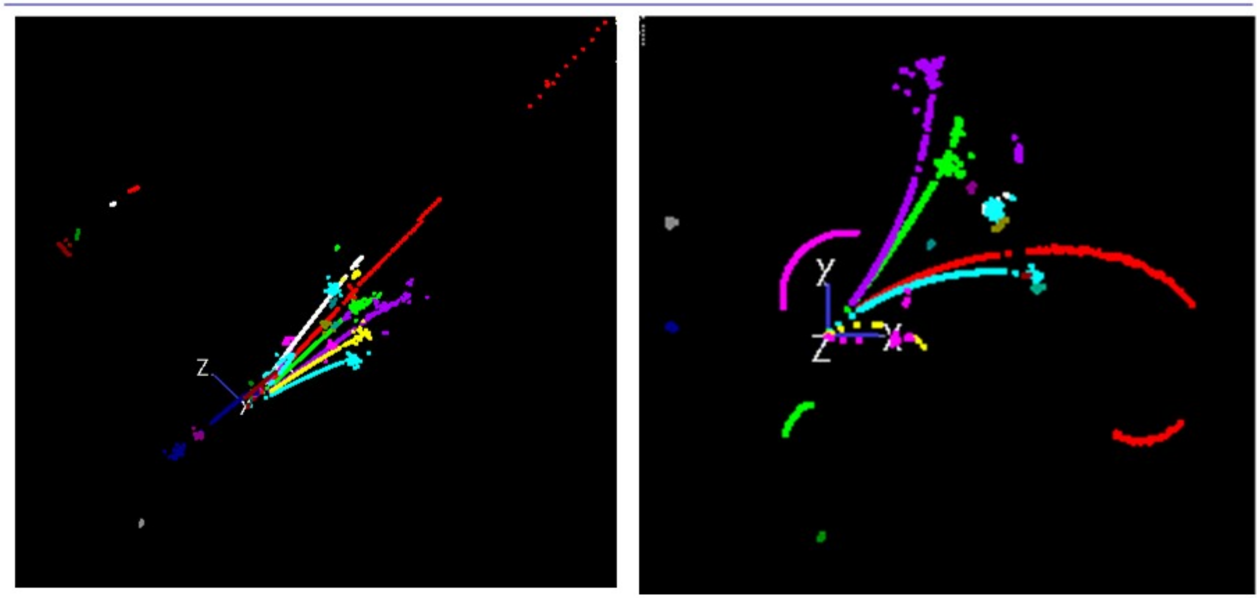
Problem of Identification: 3 GeV single muons in the Barrel Region due to multiplescattering and Magnetic Field, muons partially don’t reach Muon Sensitive Layers

Barrel Muon Identification Performance



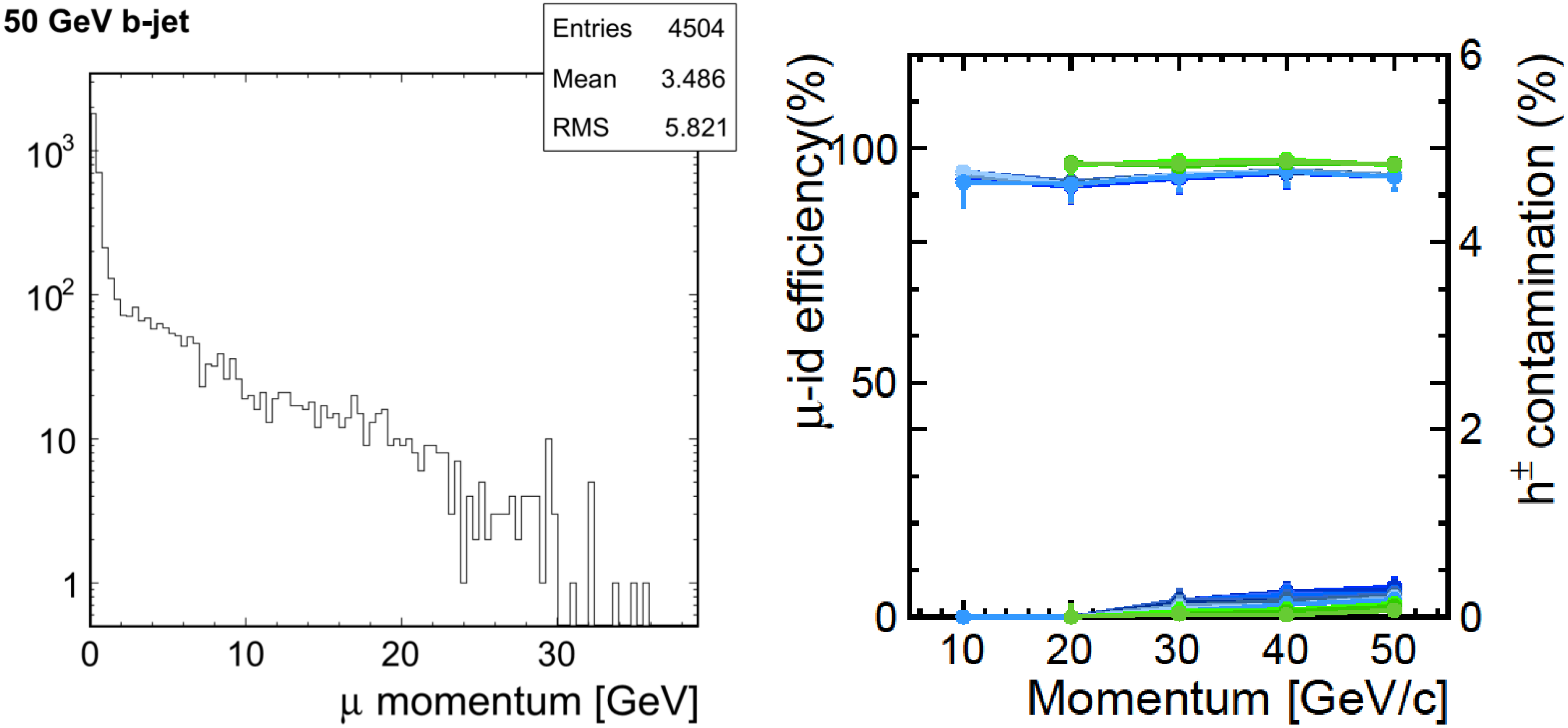
Muon Efficiency and pion Contamination as function of energy of single particles (color of the line is correspond to the layers of the Muon System which are used for identification)

Barrel Muon Identification Performance



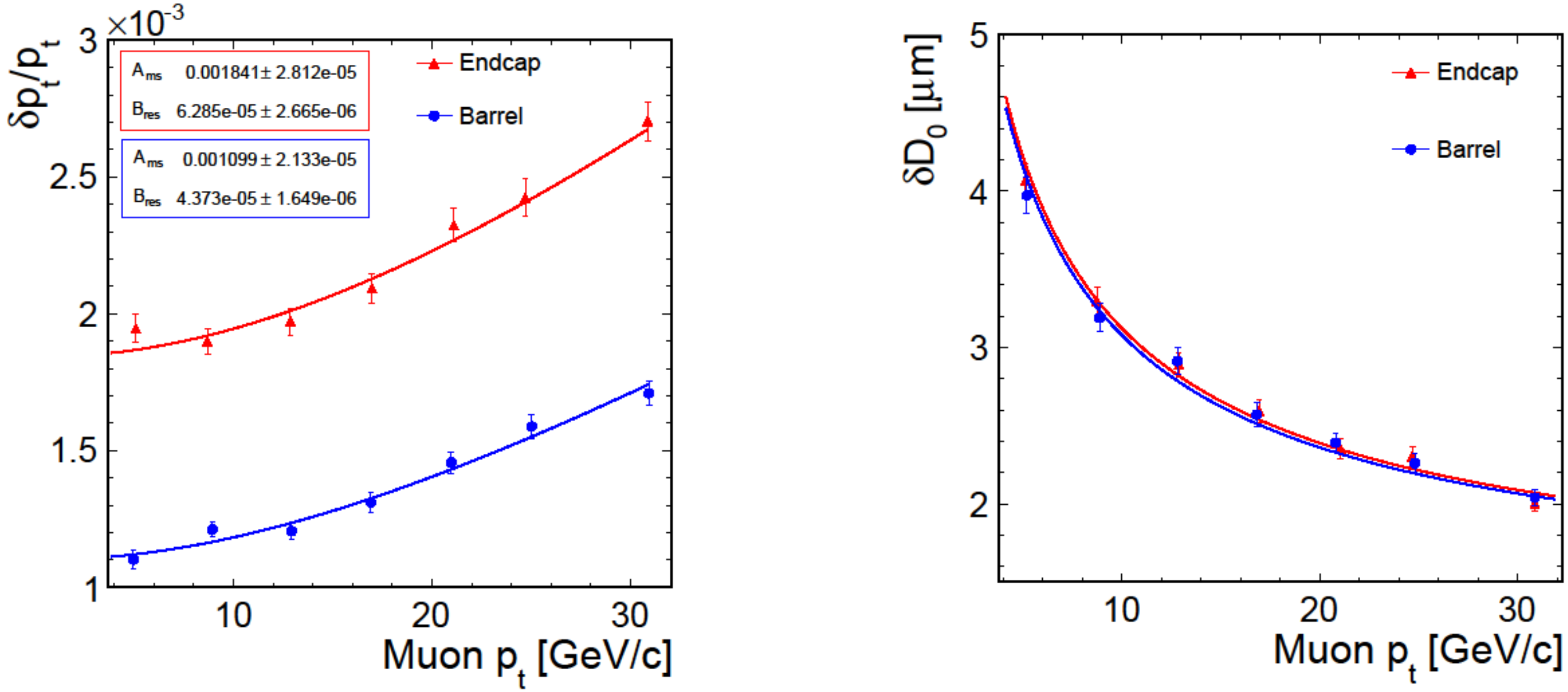
50 GeV b-jet in the ILD, PFA Reconstruction (red - muon traks),
Not all Muons could be identified as Muons by Muon System

Barrel Muon Identification Performance



Muon Identification Efficiency and pion Contaminations in b-jet, normalised on the energy of muons in b-jets > 5 GeV (color of the line is correspond to the layers of the Muon System which are used for identification)

Muon Reconstruction Performance



Single Particles (muons) reconstruction in ILD PFA

Muon System as Tail Catcher on the Energy Resolution

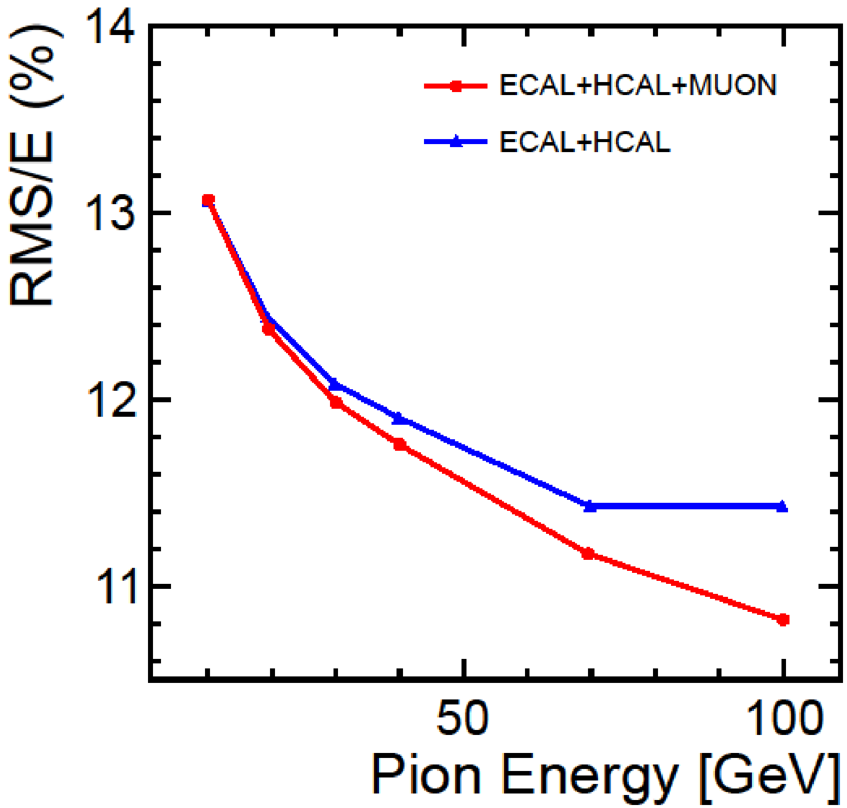
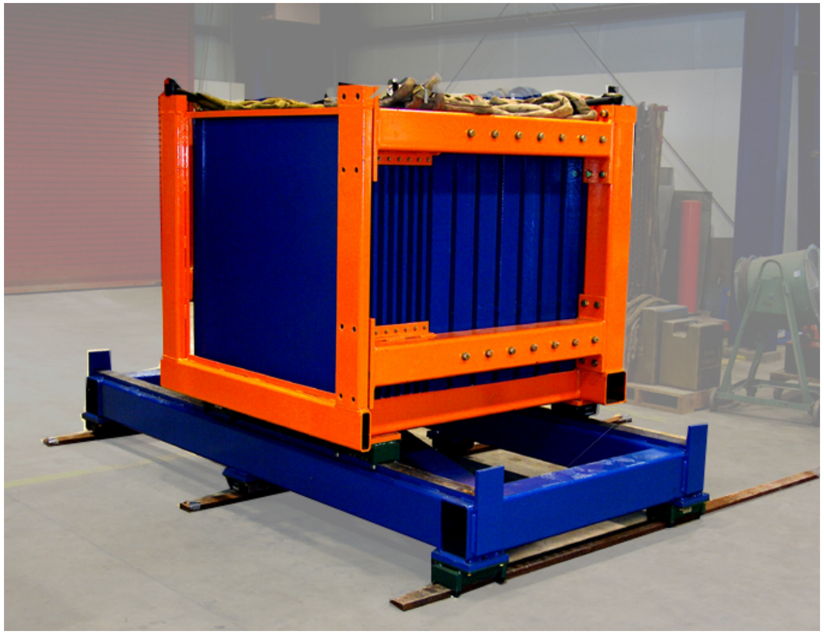
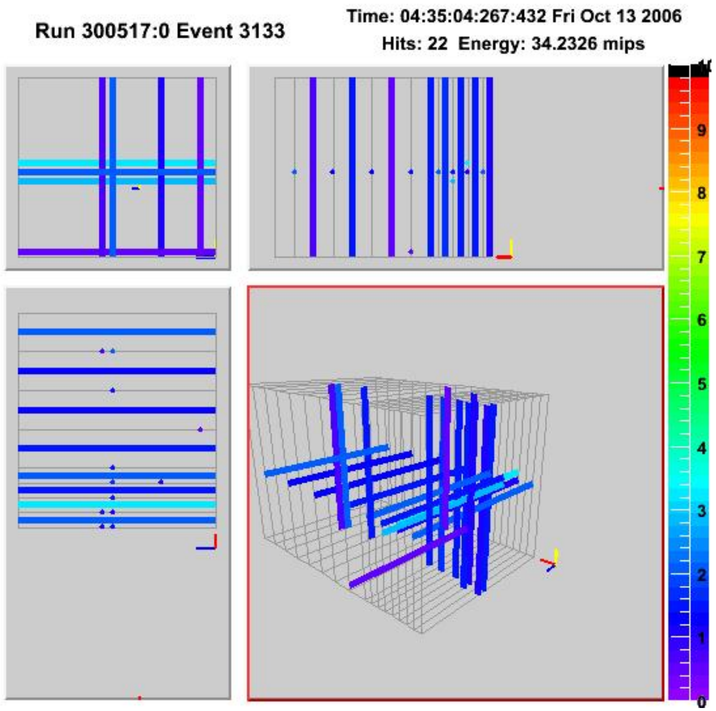


Illustration of the Effect of Tail Catcher on the Energy Resolution:
RMS Visible Energy of Pions detected without and with Muon System as Tile Catcher as function of the Energy

Muon System /Tail Catcher Test Setup

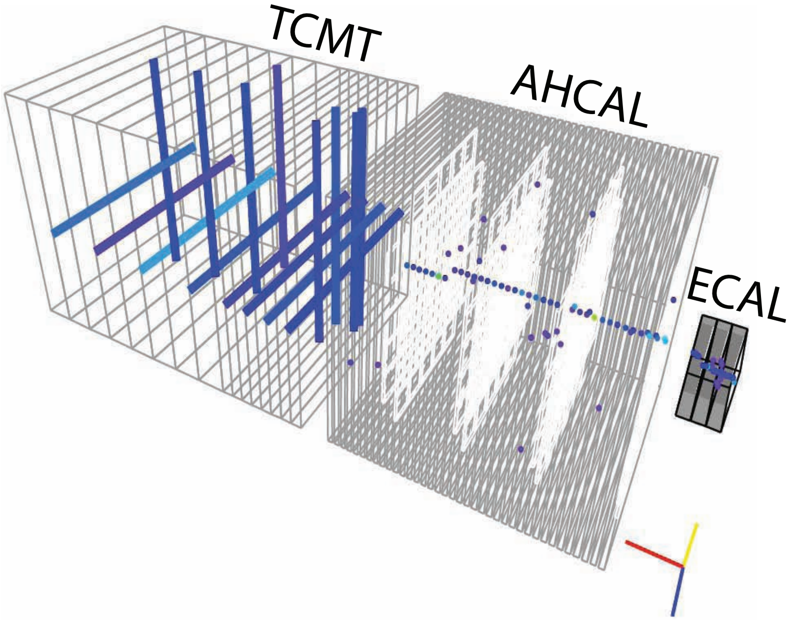




CALICE Scint. Strips\WLS\SiPM - Fe Muon System/Tail Catcher Prototype

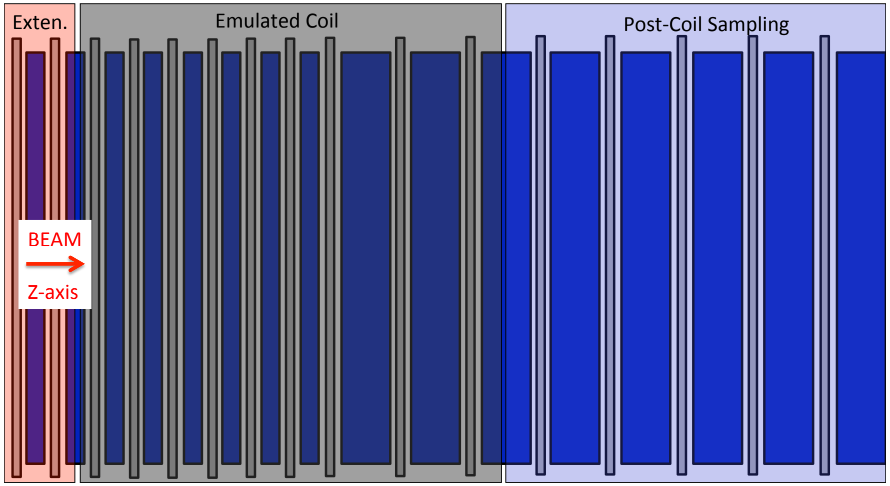
5x100cm^2 strips ~5 λ in 16 layer

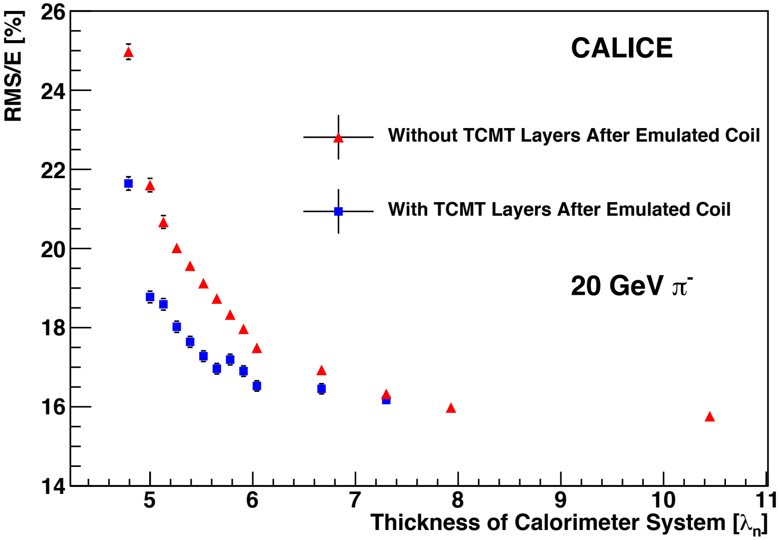
Experimental Study of Muon System/Tail Catcher



CALICE Test Setup at CERN including Muon System/Tail Catcher

Effect of Coil and Tail Catcher on the Energy Resolution





Comparison of energy RMS for 20 GeV pions with an emulated coil with and without TCMT contribution

Muon System/Tail Catcher Readout

Details of Sensitive Elements and Readout Chain:

- Digital SiPM
- Optic Transmission

Muon System/Tail Catcher Readout

- Mainly detected isolated particles,
- Typical Signal ~ 10-20 (photons) photoelectrons per MIP on the face of SiPM,
- Dynamic range could be chosen ~100 (128) pixels
- Digital readout on the SiPM Chip even with local preliminary analysis

Is it enough for Tail Catcher ?

Muon System/Tail Catcher Readout

The data transmission moves from 10 Gb/s to 40 and 100 Gb/s. optical engines and optical transceivers based on silicon photonics will provide small, low-power, single-chip solutions.

Integration of lasers, modulators, drivers, and WDM Multiplexers allow 100 Gb/s chip solutions to be less than a square centimeter.

Wave Division Multiplexing (WDM) is a method for transporting multiple wavelengths over a single optical fiber, greatly reducing the cost of the interconnection. The IEEE 802.3ba standard for 10 km reach specifies that 100 Gb/s pipes use 4 wavelengths over a Single Fiber. Future solutions that support 400 Gb/s, 800 Gb/s or 1 Tb/s will use more wavelengths.

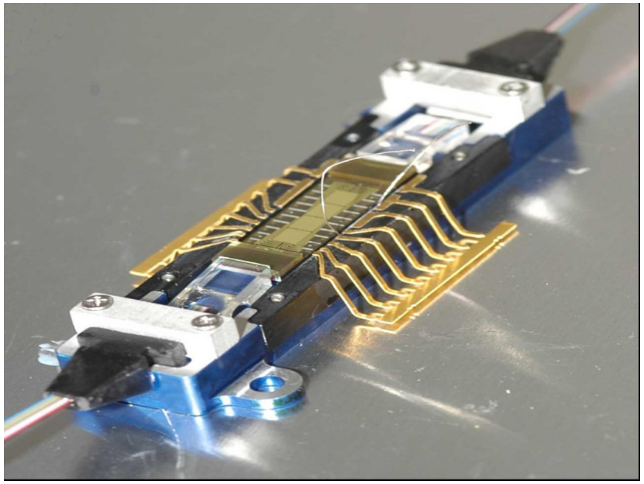
Integrated WDM technology scales easily from 4 to 40 channels or more.

Muon System/Tail Catcher Readout

Development and sells a portfolio of application-specific silicon photonics products that are now deployed in real commercial applications

100 Gigabit Ethernet

(10 channels with Optic Wave Division for Single Optic Fiber)



Muon System/Tail Catcher Readout

3D Hybrid Technology:

Sensors, digital Readout Electronics, Opto Electronic Components in one Chip

Conclusion and Outlook

Muon System:

- Muon identification
  - ~97% muon identification efficiency and correspondingly about 99% pions rejection at energy >4 GeV
  - Muons identification with energies < 4GeV. Needs dedicated analysis
- Muon Reconstruction in the ILD (PFA):
  - $d(1/pt) = 2.3 \; 10^{-5}\ \ \mathrm{GeV}^{-1}$
  - $d(D_0) = 2.5$ microns

Conclusion and Outlook

Tail Catcher:

- Improves energy resolution. In particular at high energies
- Full thickness instrumentation of yoke important for pion rejection (Also needed for achieving low stray field)
- Instrumentation of outer (thick) layers is useful for pion rejection. Much better than just one muon sensitive layer outside.
- Increasing iron plate thickness from 10 to 20 cm will be study

In addition, one very thick instead of three outer iron layers (each about 100tons) would be much more difficult to deal with (manufacturing, transportation and assembly)

Coil Instrumentation:

- Small improvement of energy resolution
- May be useful for low energy muons identification

Conclusion and Outlook

Readout Chain:

- Study of Digital Silicon Photomultiplier as Photosensor for ILD Muon System
- Study of Optic Link with Optic Wavelength Separation