Study of the ILD Muon System/Tail Catcher

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DESY

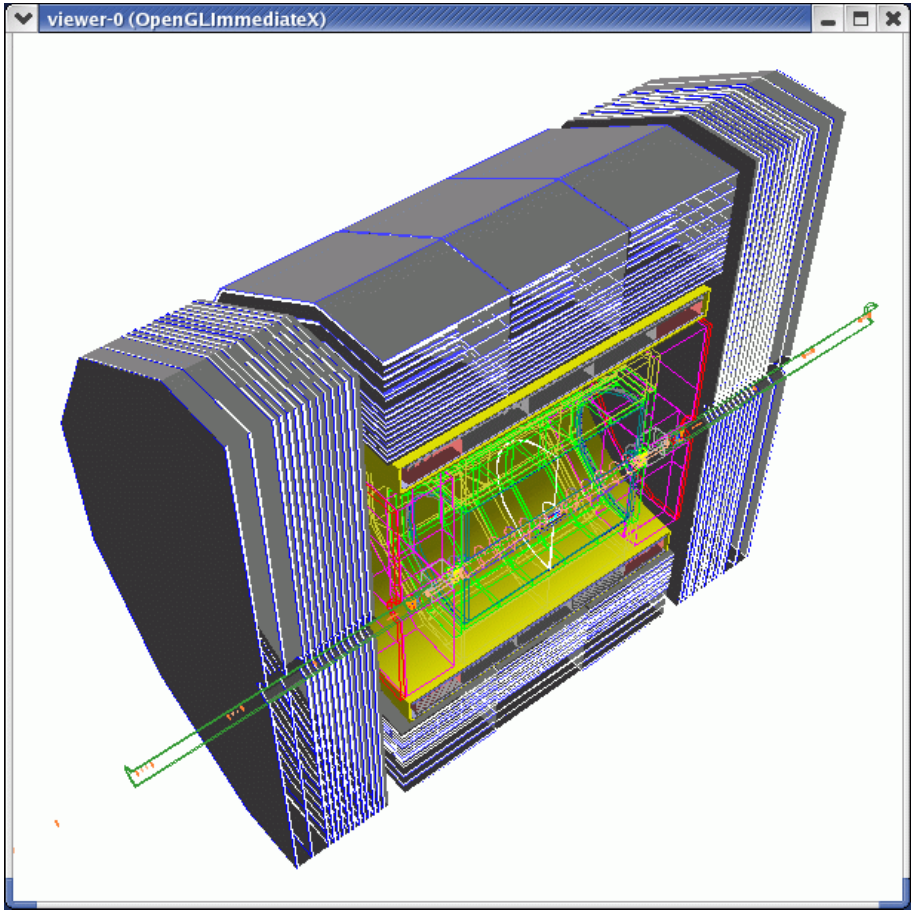
Outline

- Geometry of magnet and muon system
- Analysis and Tools
- Muon momentum resolution
- Muon identification and μ/π separation
- Tail catcher

- Conclusions and outlook

Main work done by N. D'Ascenzo and V.Saveliev

ILD Magnet and Muon System



View of the muon detector, magnet and Yoke of the ILD detector as described in MOKKA

Yoke:

- Barrel: 10x(100+40) +3x(560 +40) mm

- End-cap: 10x(100+40) +2x(560+40) mm

Cryostat:

- Cylinder with 40 mm thick inner wall and 30 mm thick outer wall

- 750 mm distance between walls

- Instrumentation 2 double scintillator layers

Coil:

- 450 mm thick, segmented in 3x1650 mm + 2x1200 mm long modules

Muon Detector System:

- *Scintillator double sensitive layers in the*
- *Yoke gaps (1cm + 1cm scintillator)*

Analysis and tools

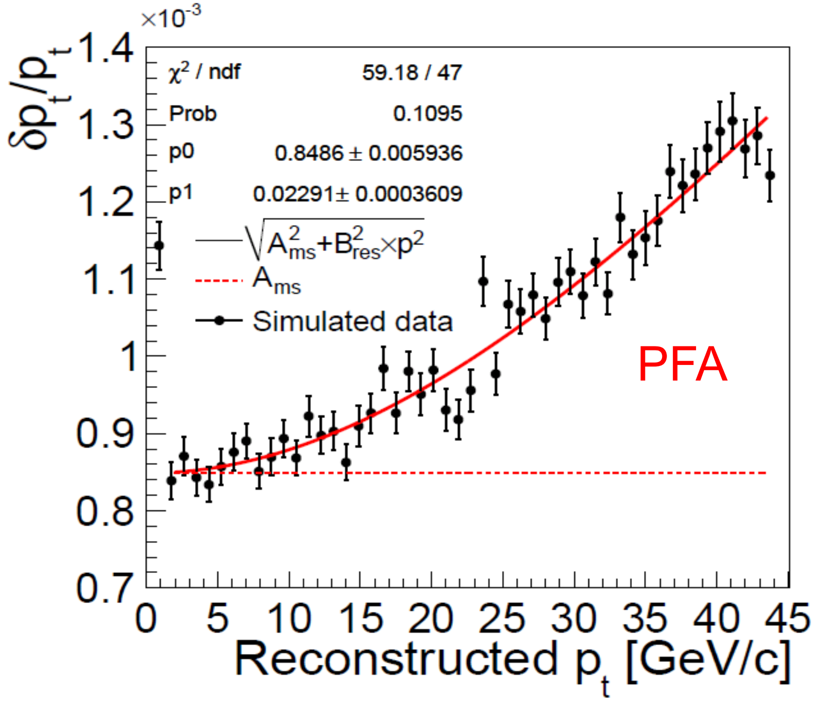
- Tasks of the muon system:
  - Identification of muons and tracking (PFA segment)
  - Tail catcher for HCAL

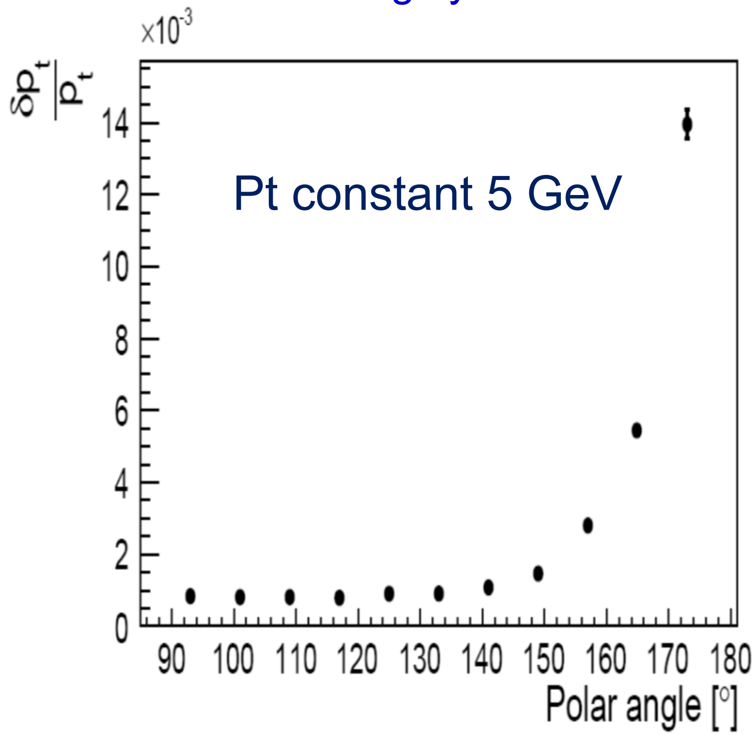
- Topics of analysis:
  - Study of muon reconstruction (muon momentum, impact parameter)
  - Study of muon identification efficiency and μ/π separation

- Analysis data and tools:
  - Simulation with GEANT4, geometry described in MOKKA
  - Reconstruction algorithm: PANDORA (MARLIN)
  - Muons and pions are simulated in the ILD detector with initial momentum between 1 GeV and 500 GeV. The initial direction ranges between 93° (barrel) and 157° (end-cap). 5000 events per point are simulated.

Muon Momentum Resolution Study

Singles muons: Momentum measured with tracking system





Gluckstern parameterization:

Multiple scattering:

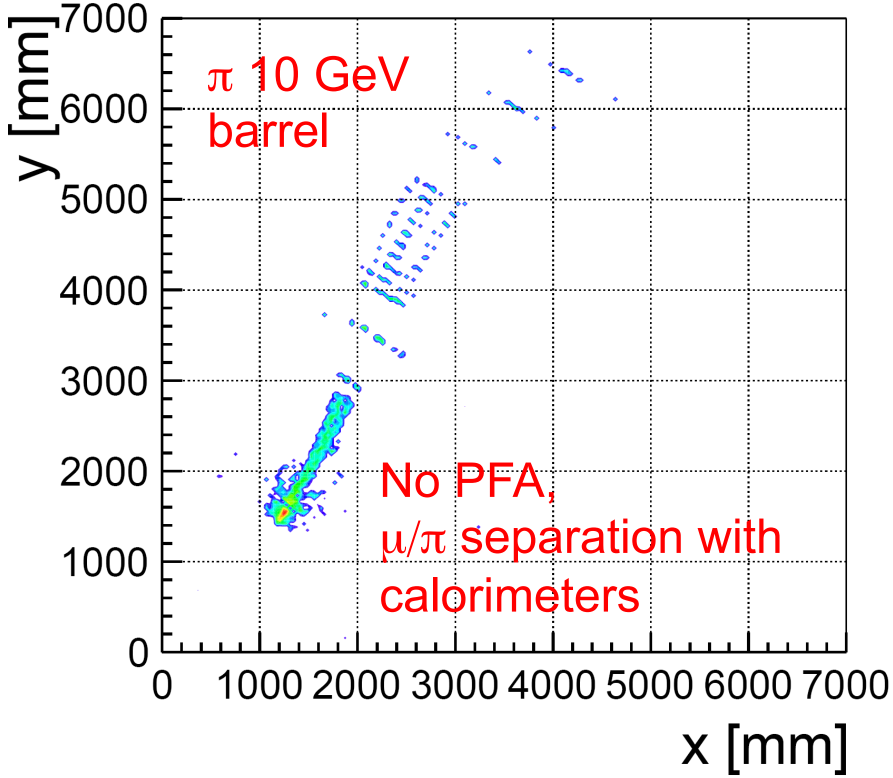
$$A_{ms} = \frac{0.016 \times \sqrt{L / X_0}}{0.3 \int BdL};$$

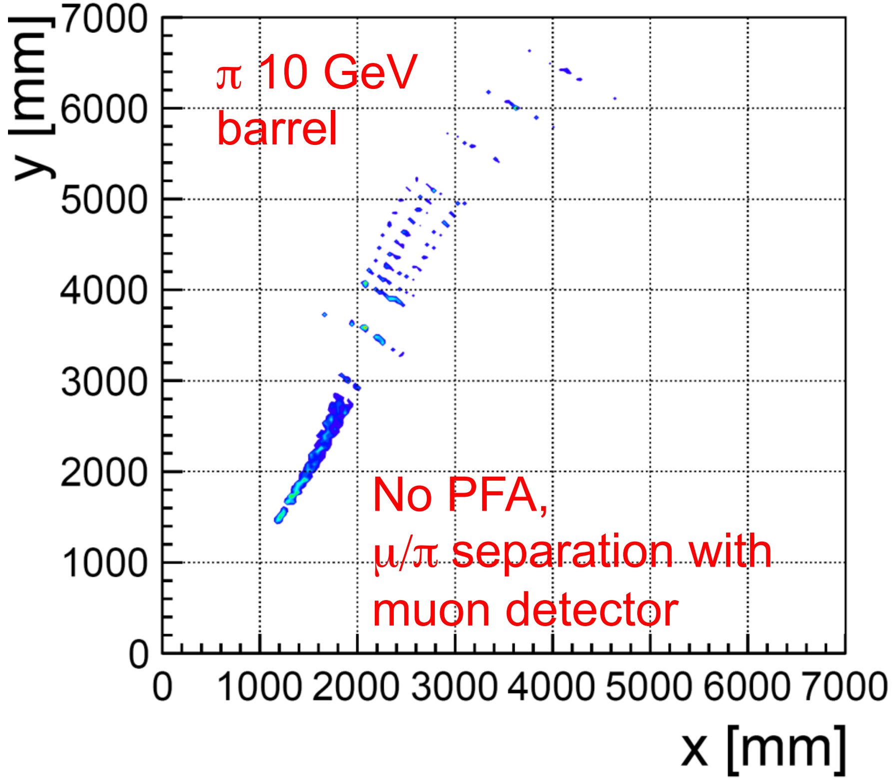
$$A_{ms} = 0.85 \cdot 10^{-3}$$
$$B_{res} = 2.3 \cdot 10^{-5}\, GeV^{-1}$$

Detector resolution:

$$B_{res} = \frac{\delta x \sqrt{720/(N+5)}}{0.3 \int BdL}$$

Muon Identification and μ/π Separation

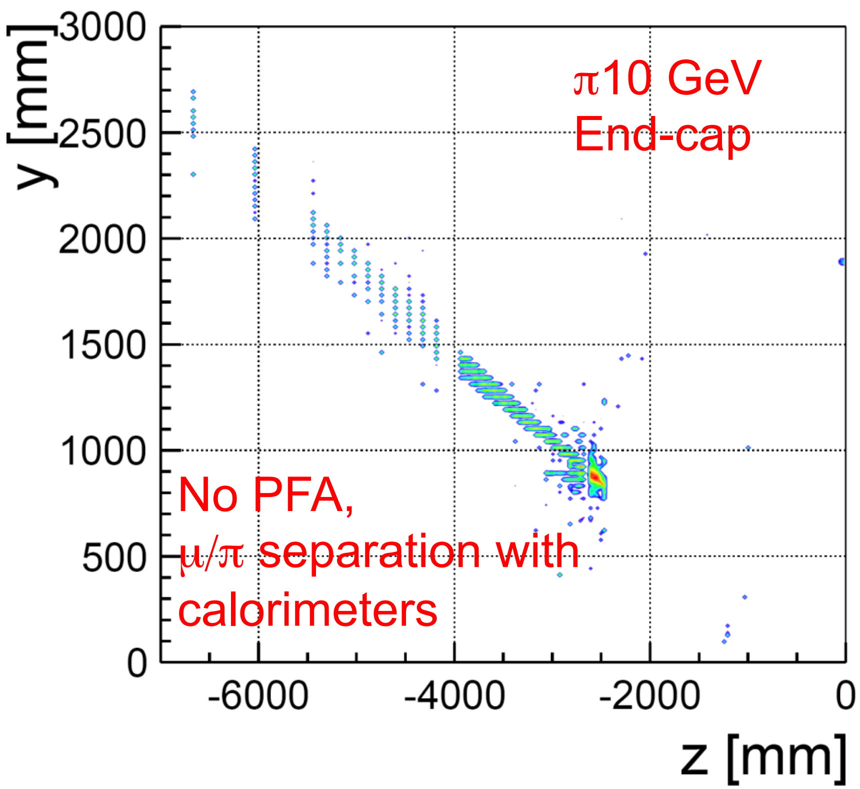


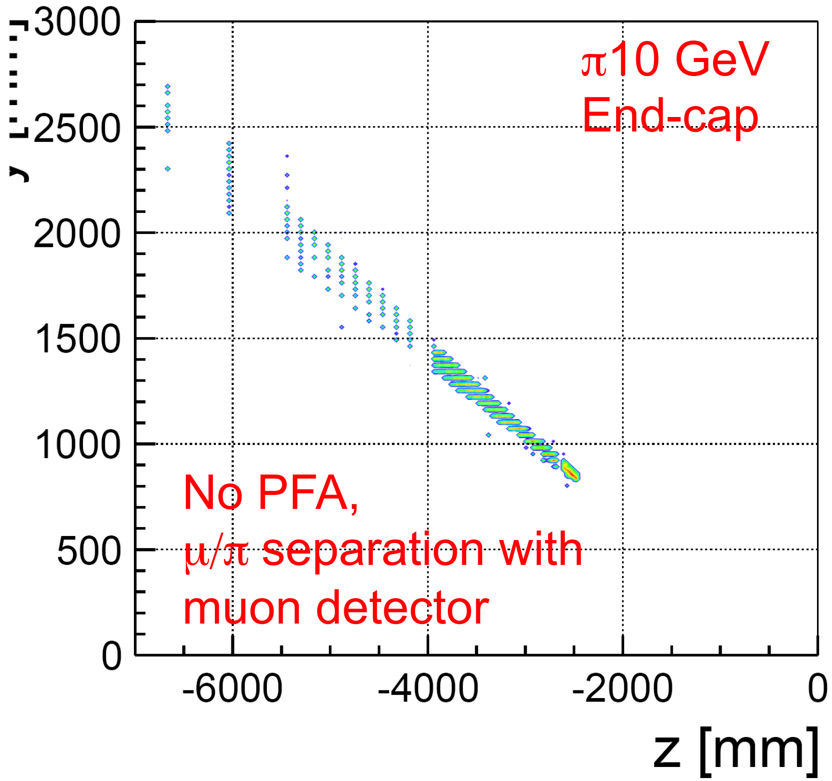


Selection based on <u>visible energy</u> in the <u>calorimeters</u> and in the <u>muon detector</u>

Mainly in-flight decay pions ($\pi \to \mu\, \nu$) are misidentified as muons

Muon Identification and μ/π Separation





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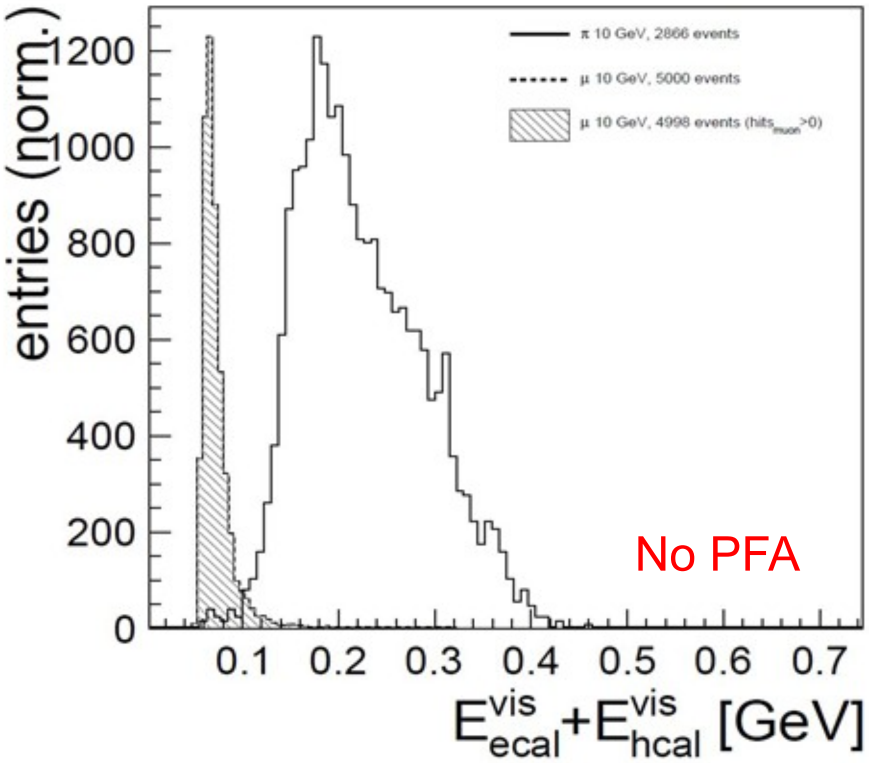
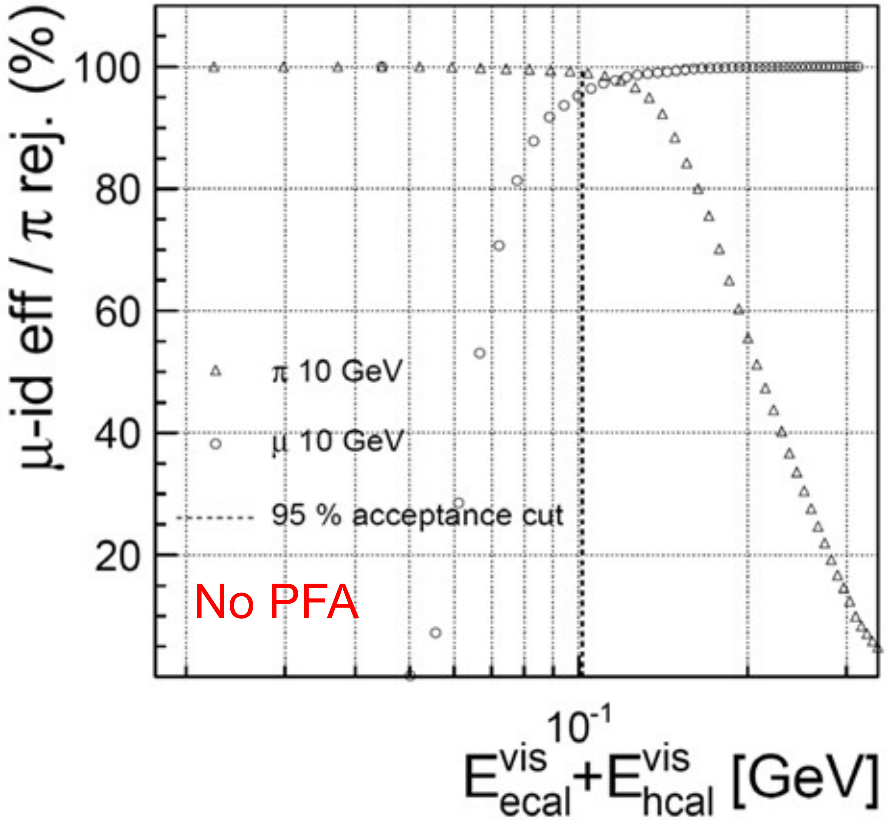




Muon efficiency:

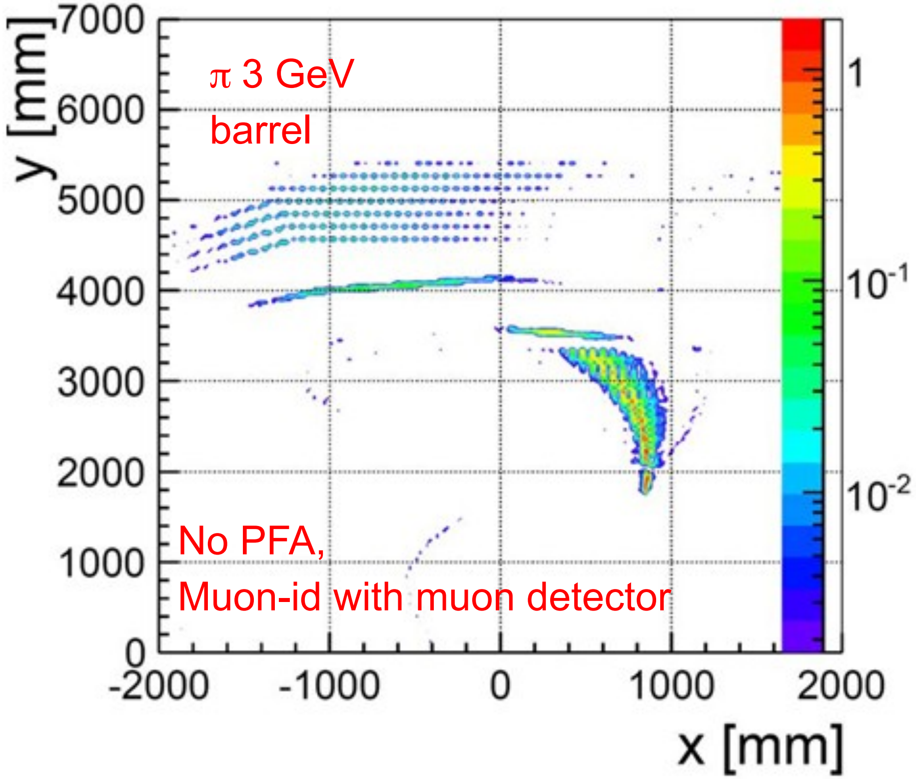
$$\alpha_{\mu}^{cal} = \int_{0}^{E_{+,95}} h_{\mu}(E)dE = 95\%$$

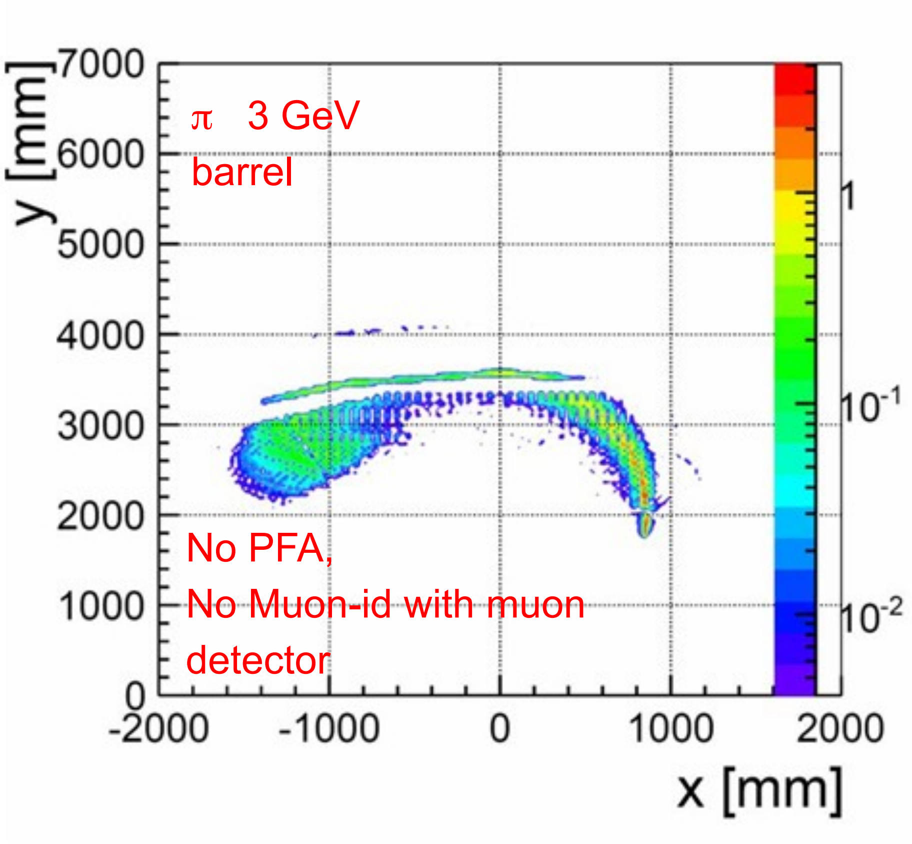
Pion rejection

$$\beta_{\pi}^{cal} = \int_{E+,95}^{\infty} h_{\pi}^{cal}(E)dE$$

(98.98 ± 0.18)% pion rejection

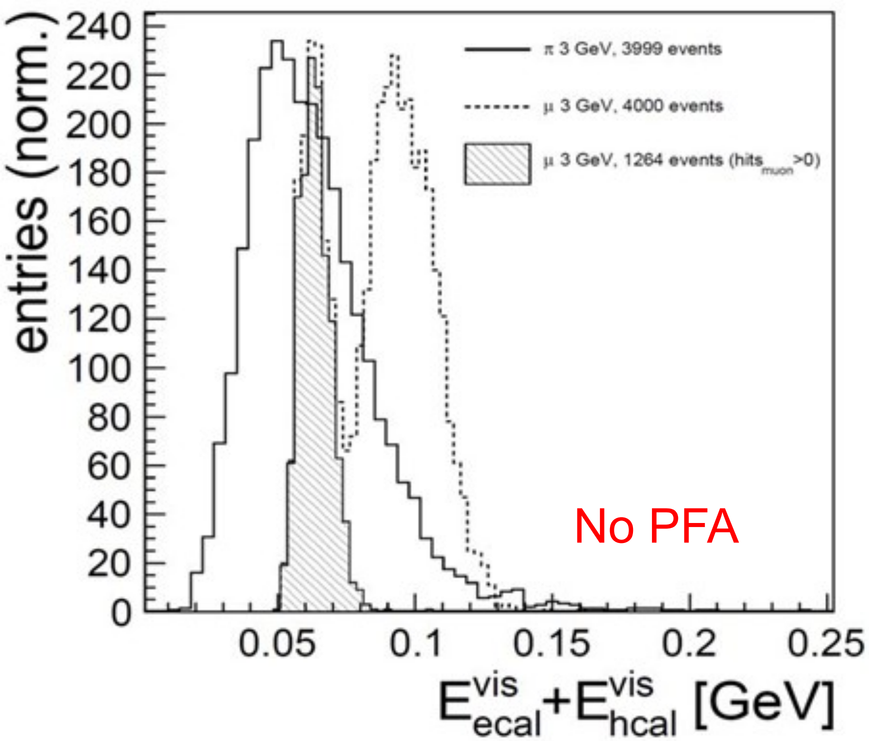
Problem at low Momentum

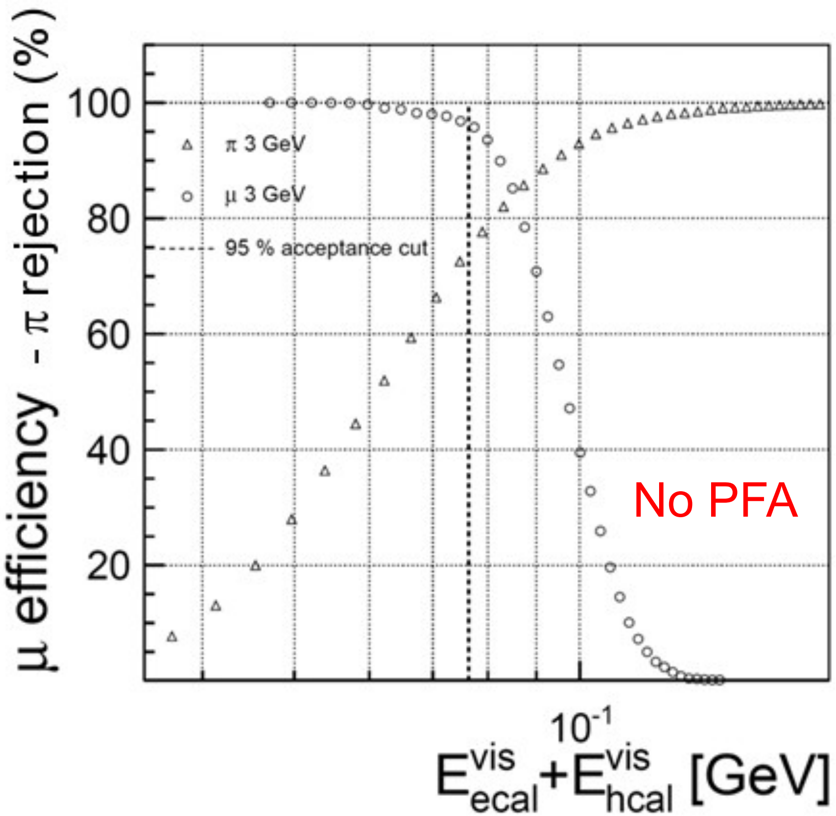




Impact of the coil material on the muon identification

Problem at Low Momentum



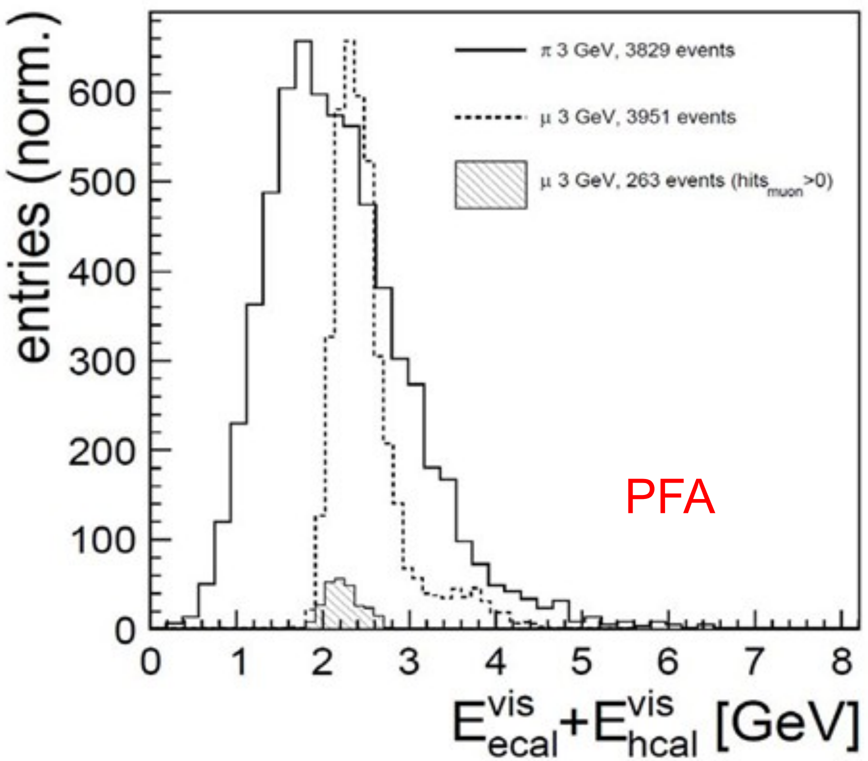


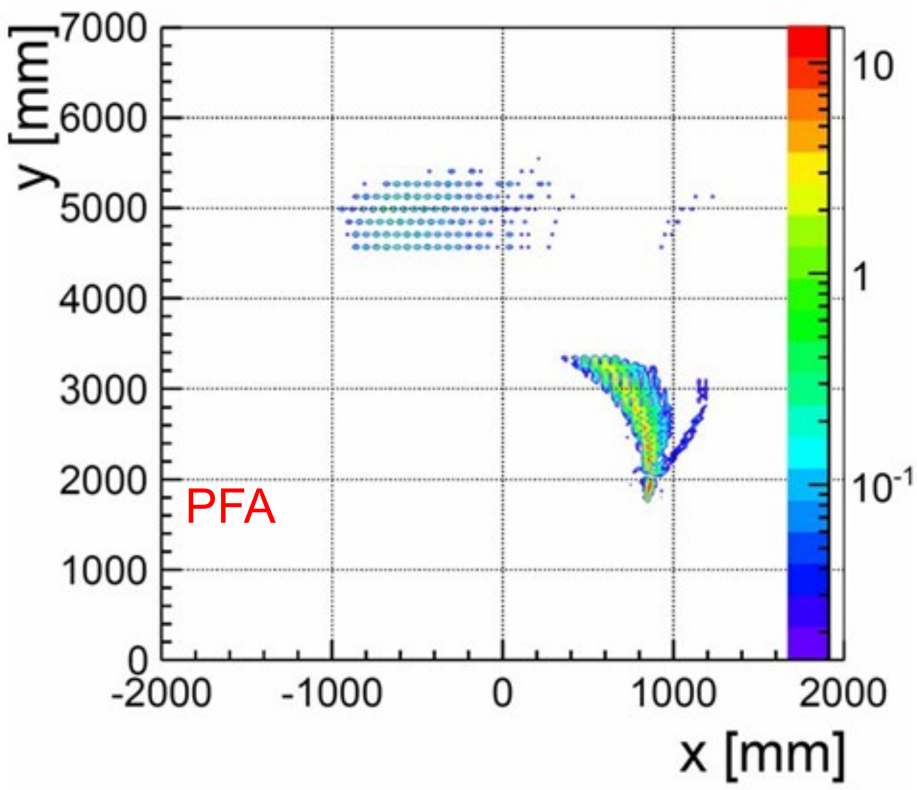
Low energy pions deposit energy mainly in ECAL

For muons which not identified by the muon system, estimation for 95 % muon efficiency, pion rejection (73.75±0.69)%

Necessary special analysis method

Problem at low momentum

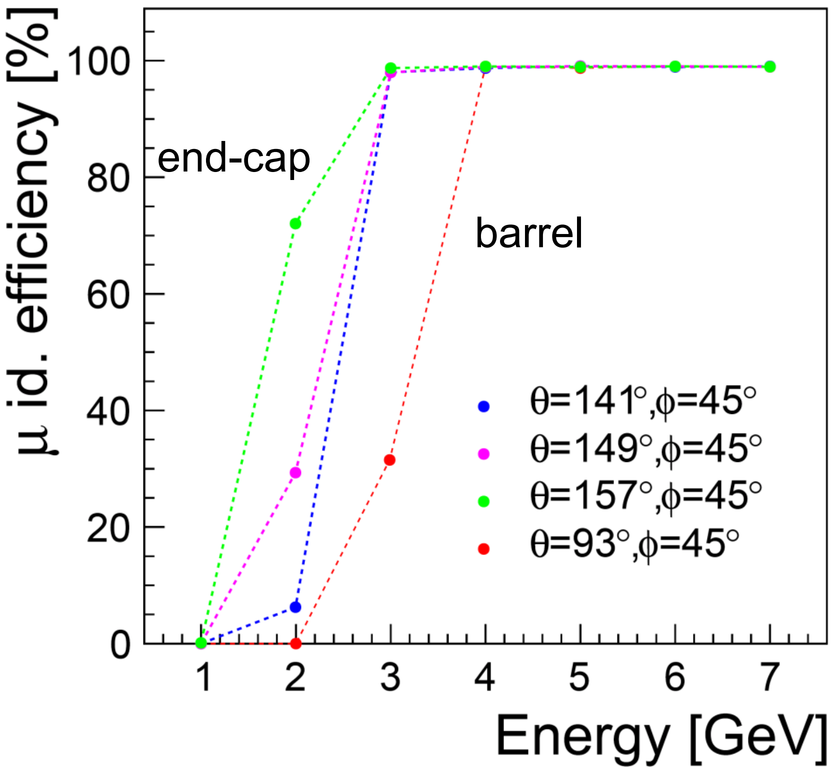


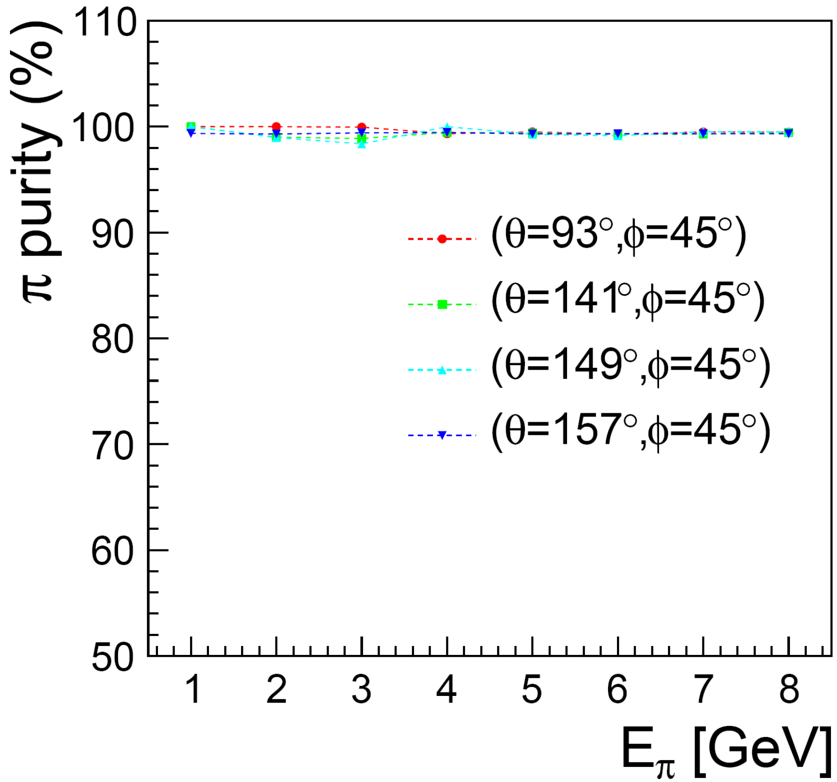


PFA algorithm inefficient in the connection between mip-like stubs in calorimeters and in the muon detector at low energy due to the curvature of the tracks (20% PFA muon reconstruction efficiency)

Good reconstruction and identification of low energy pions

Muon Identification and μ/π Separation

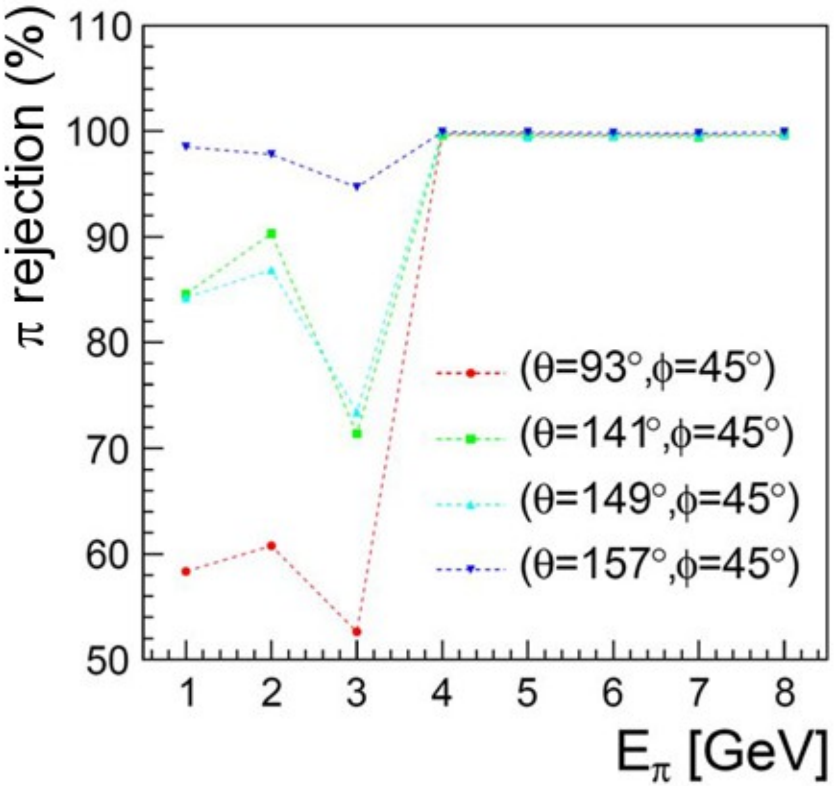




Effect of the coil in the end-cap region for soft muons:
the μ-id based only on the muon system is weak for energy lower than 4 GeV.

Angular dependence of mu-id

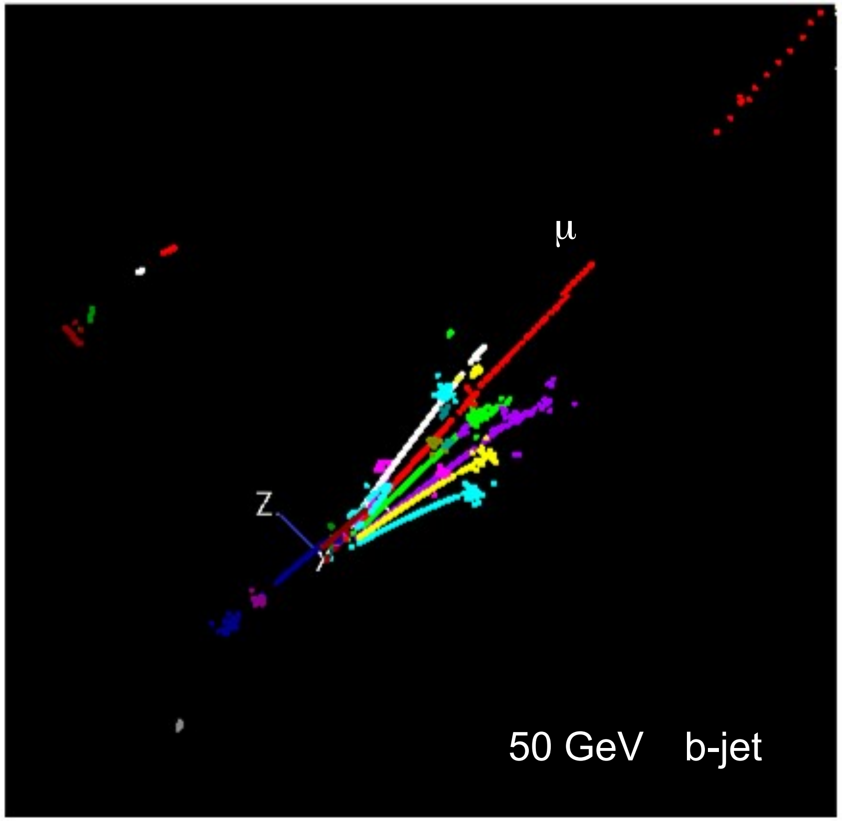
Muon Identification and μ/π Separation

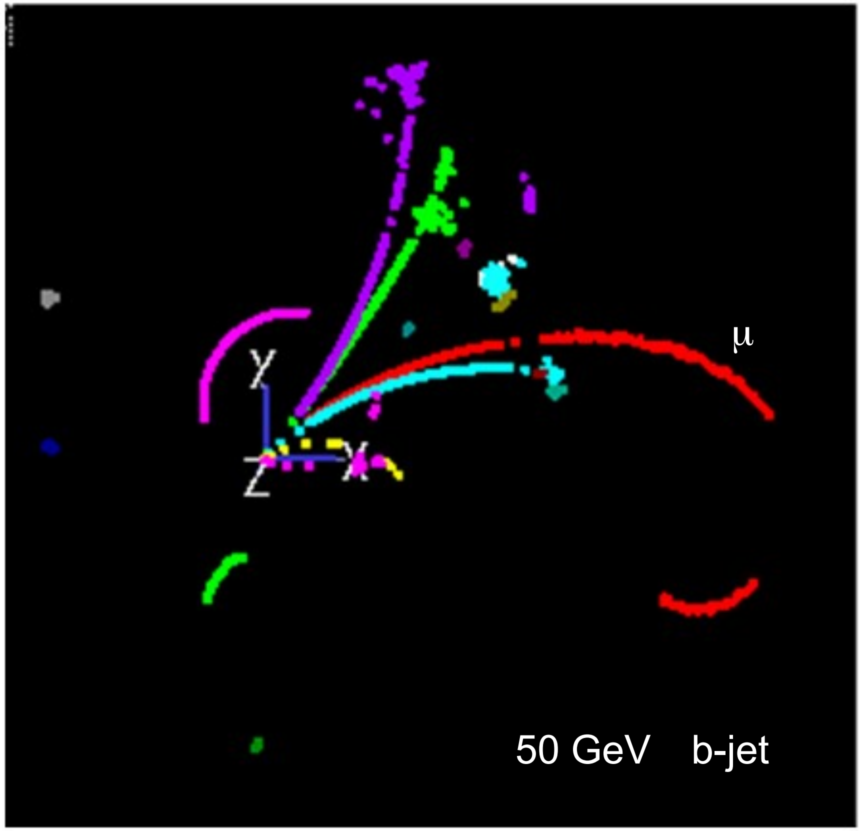


95% muon identification efficiency

Pion rejection about 100% at energy more than 4 GeV.
Low energy region needs dedicated analysis

Muon Identification in b-jets





50 GeV single b-jet directed in the barrel simulated in ILD detector
PFA reconstruction

Now running statistics for efficiency analysis

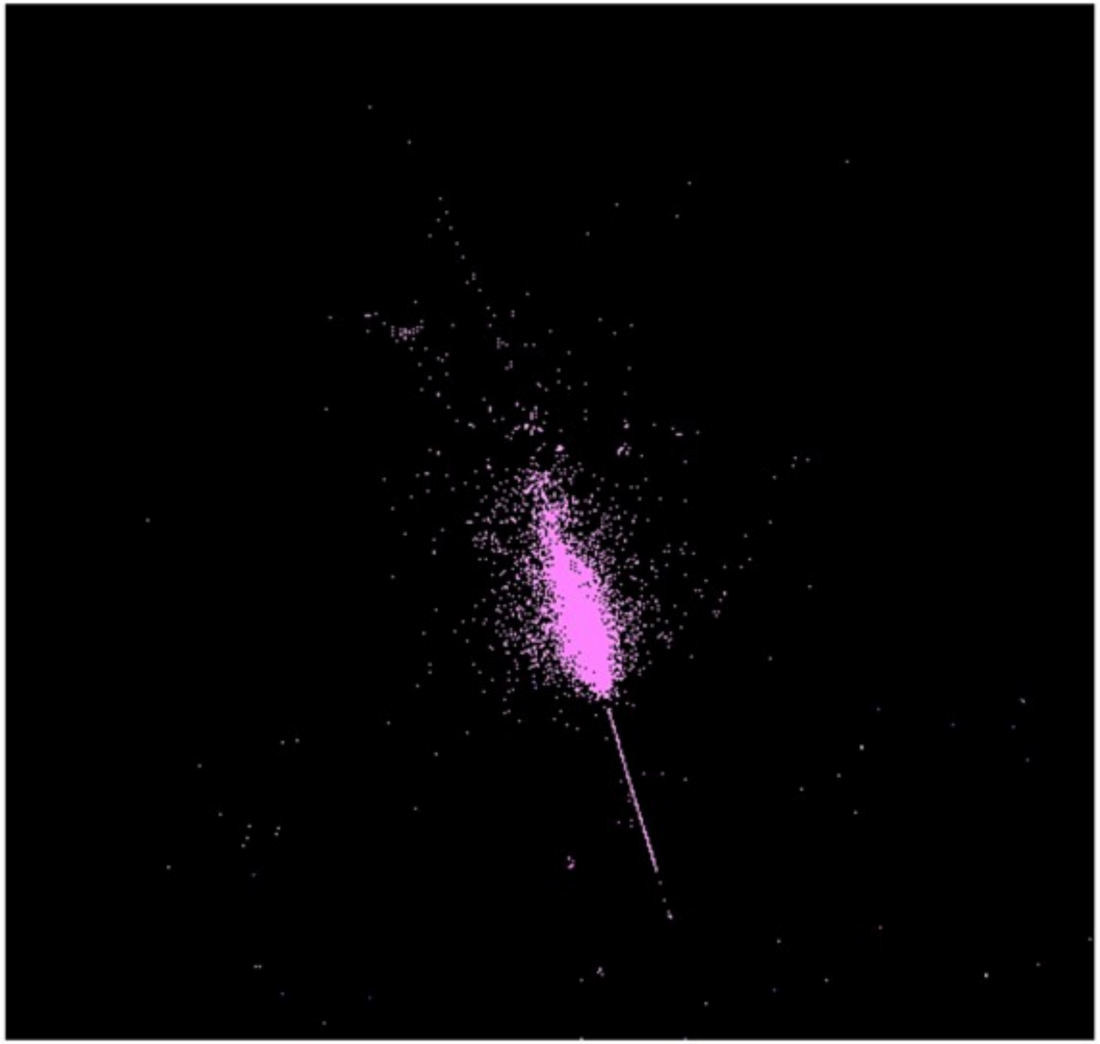
Muon System and Tail Catcher

- Good particle flow calorimetry requires calorimeter positioned within the detector solenoid.

- To allow for uncertainties in the simulation of the longitudinal development of hadronic showers, and to ensure the detector is appropriate for collisions at 1 TeV, a 48 layer (~6 λ) HCAL was chosen for ILD (LOI).

- One way to improve the performance with min (optimal) HCAL thickness could relays on the possible use of the instrumented return yoke (the Muon System) to correct for leakage of high energy showers out of the HCAL.

Hadron Processes in ILD

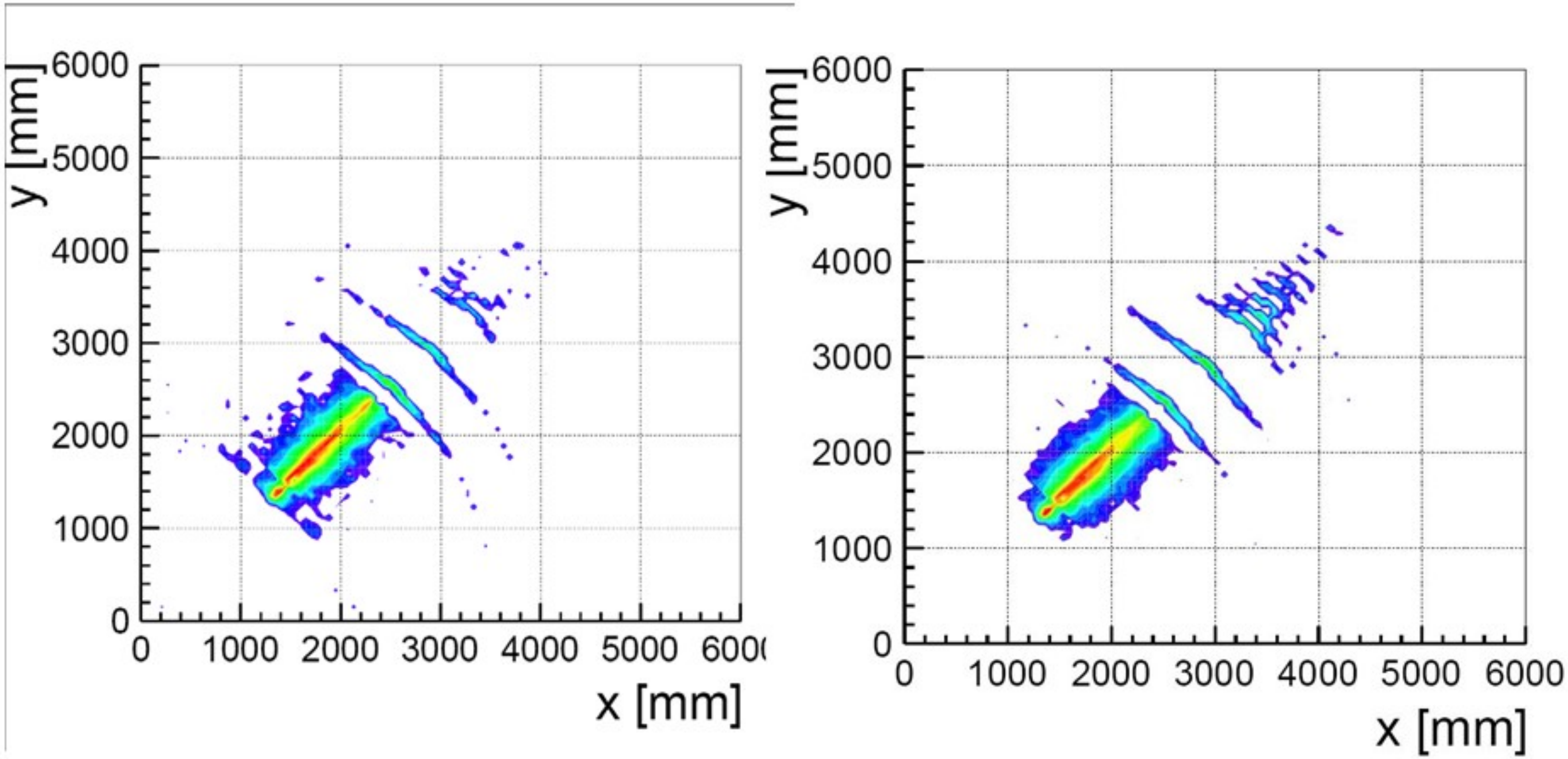


Simulated pi- shower with energy 100 GeV in the Barrel part of ILD, the main activity in the ECAL and HCAL

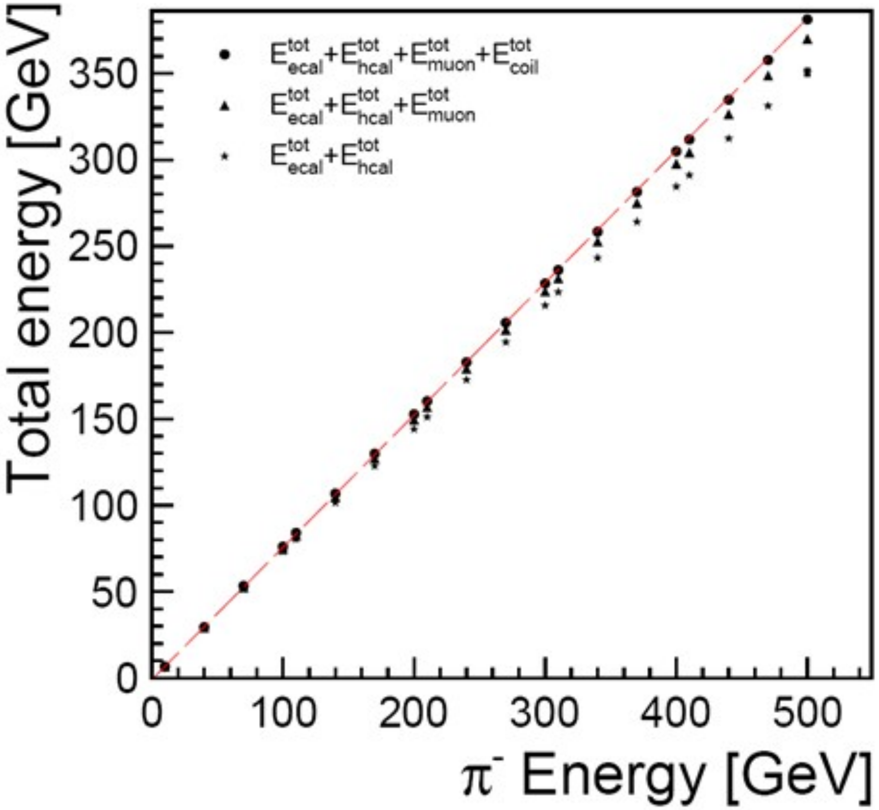
(Barrel Region)

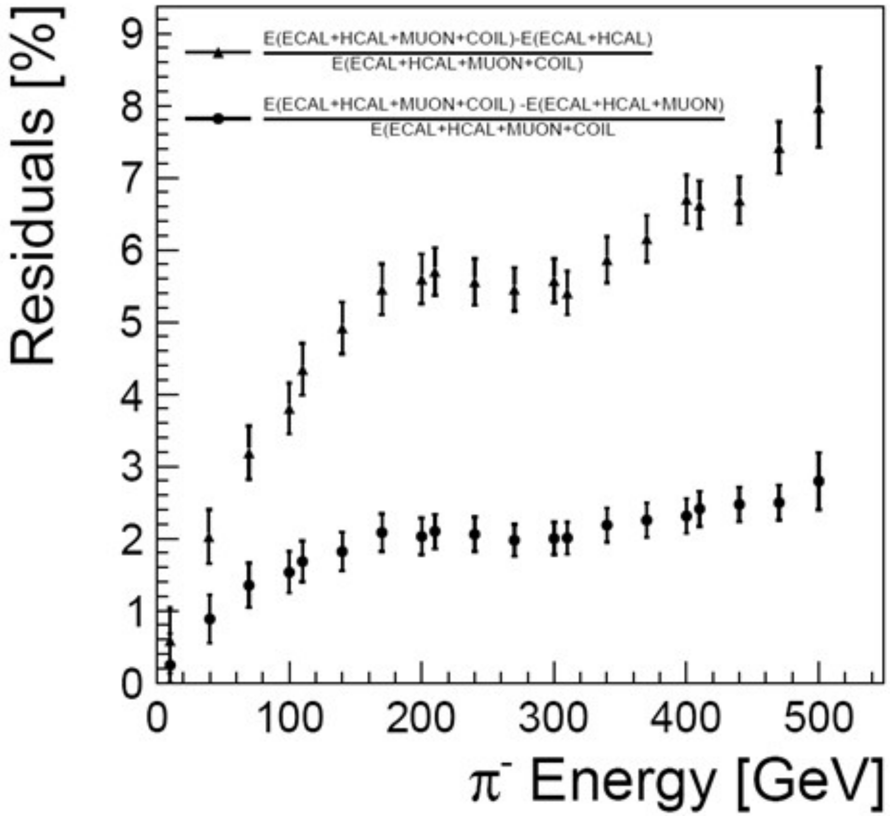
Analysis of Muon System for Hadron Processes

Pions Shower in the ILD with energy 140 GeV and 350 Gev (Barrel Region)



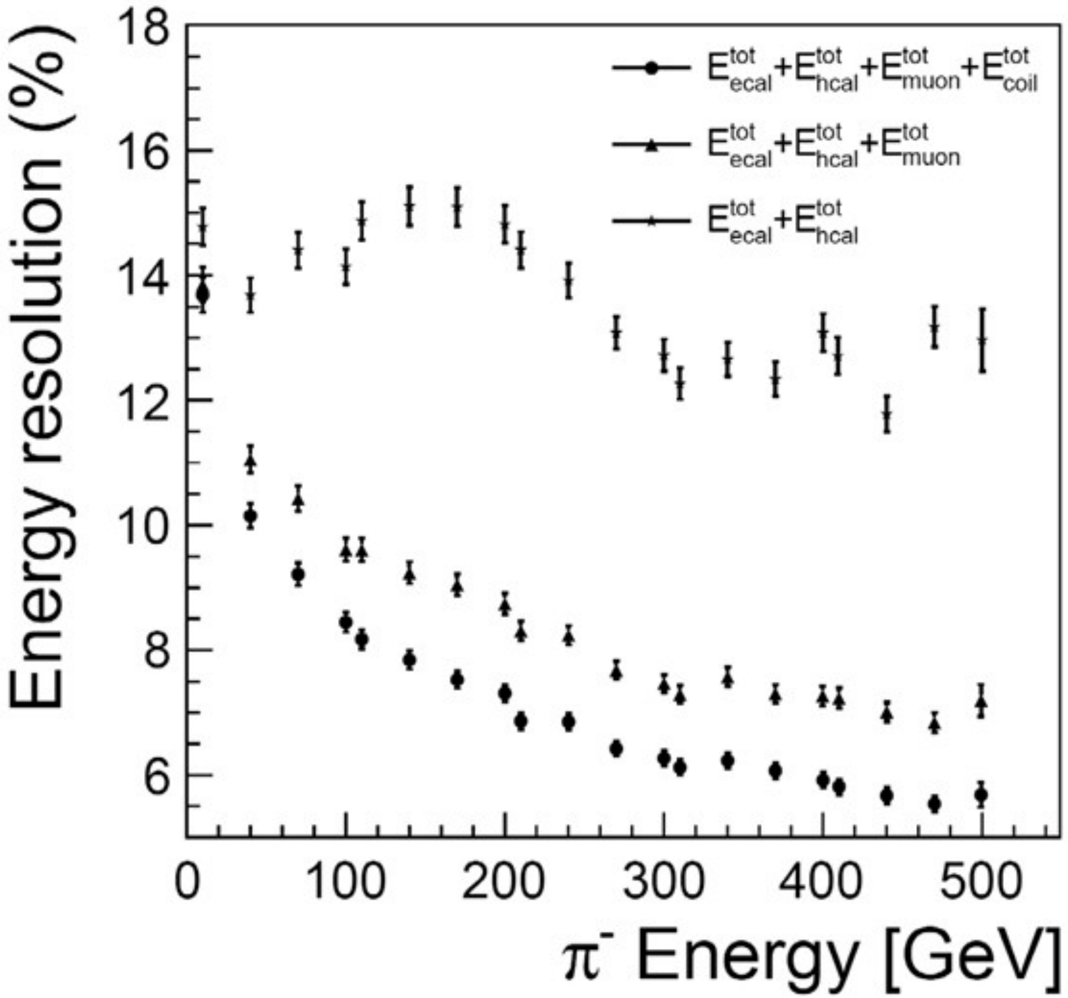
Estimation of pion shower energy





True MC
Pion showers in the Barrel Region of ILD

Performance of Muon System as Tail Catcher



ecal + hcal

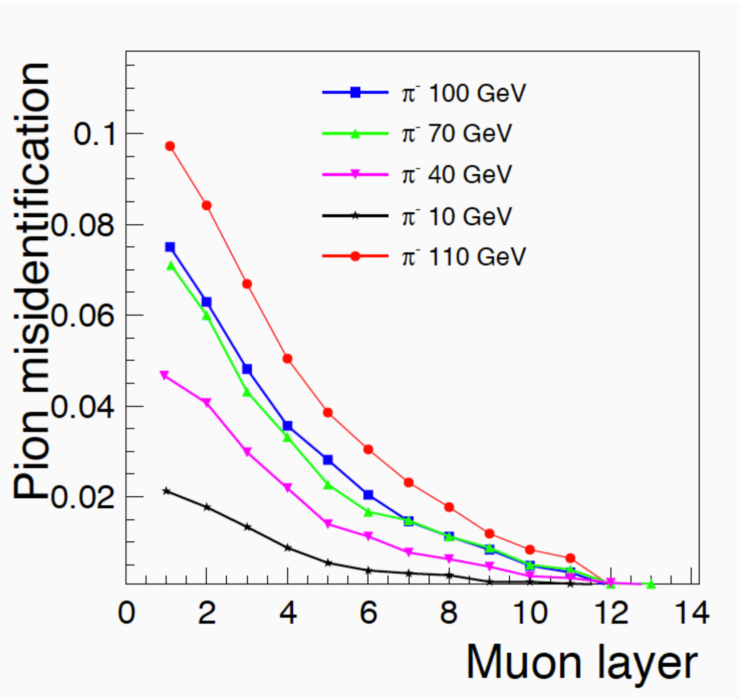
+ muon

+ muon + coil

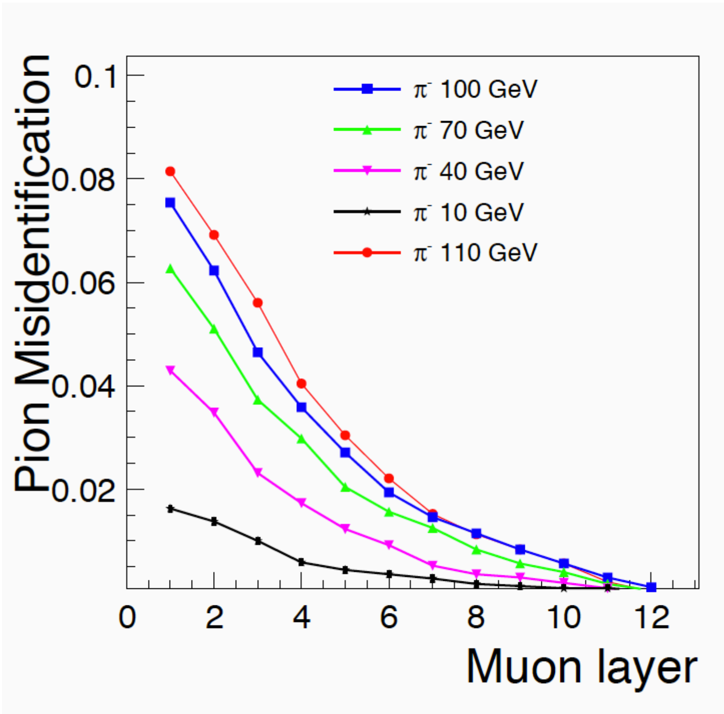
TRUE MC
Pion showers in the barrel region of ILD

Pion Misidentification in Muon System

Pions hits in muon system (selection by muons hypothesis) during the detection of the pions with different energy



Barrel



End-cap

Decay channel pion to muon is not excluded

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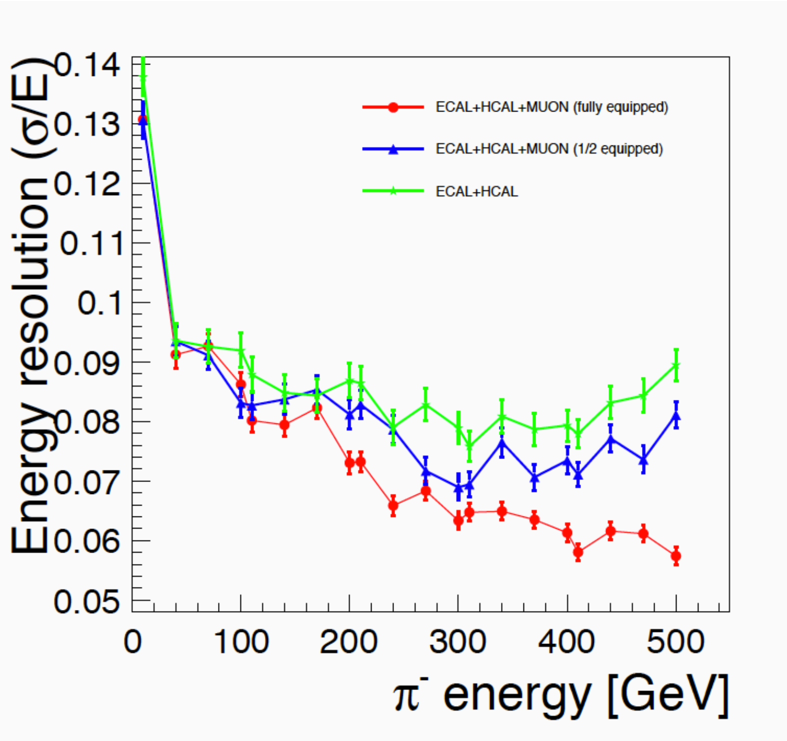

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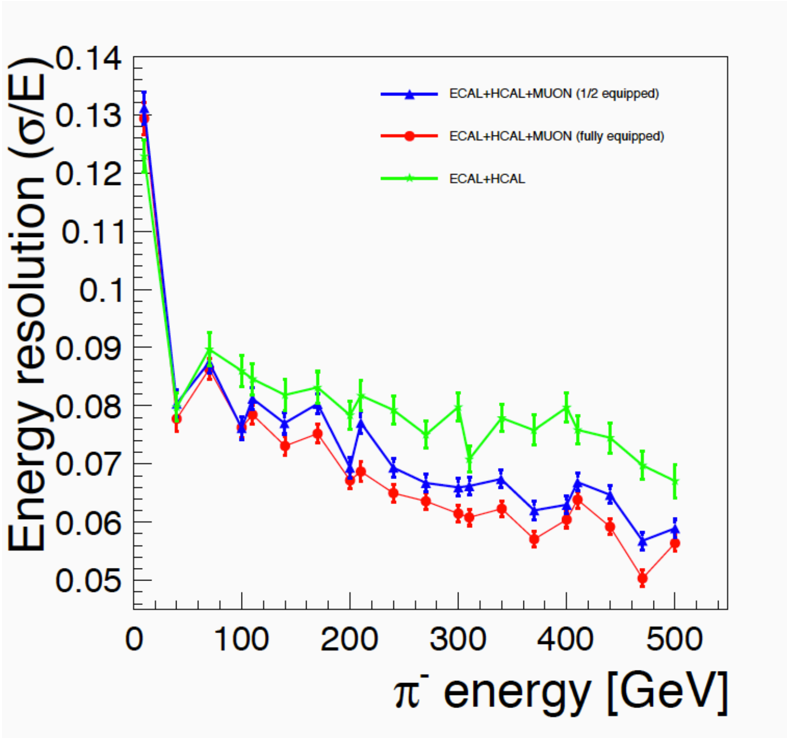

End-cap

The channel of pion decay to muon is not excluded

Conclusions and Outlook

- New geometry of the coil and the muon system for ILD introduced in MOKKA and tested
- Muon reconstruction in the ILD detector:
  - $\delta(1/pt) = 2.3\ 10\text{-}5$ GeV-1
  - $\delta(D0) = 2.5\ \mu m$
- Muon identification and μ/π separation:
  - ~95% μ-identification efficiency and correspondingly about 99% π rejection at energy >4 GeV
  - Lower pion rejection for muon energy < 4GeV. Needs dedicated analysis
- Muon system for hadronic processes:
  - Endcap region equipment of muon system as tail catcher reasonable
  - Performance of barrel region limited by the large coil
  - For high energy jets useful to improve performance, especially resolution
- Detailed simulation of element of muon system

- All tools now ready for detailed studies

Preliminary Conclusions for Yoke Design

Tail-catcher

- Improves energy resolution. In particular at high energies
- Full thickness 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 chamber layer on the very outside.
  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)
- Increasing iron plate thickness from 10 to 20cm probably fine at low energies (low statistics so far), but significant degradation at high energies

Instrumented coil

- Small improvement of energy resolution
- Might be useful for low energy hadrons and muons