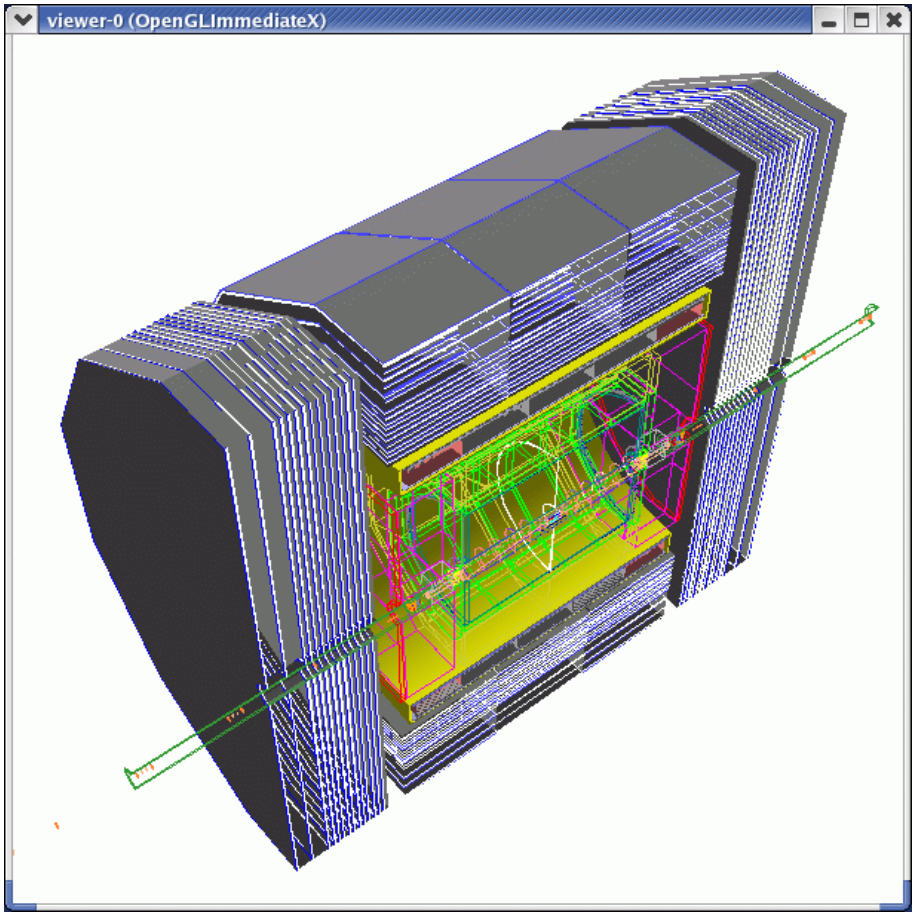
Muon reconstruction and identification in the ILD detector

N. D'Ascenzo, V.Saveliev
National Research Nuclear University

U.Schneekloth
DESY

The magnet and muon system for ILD



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

- EndCup: 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

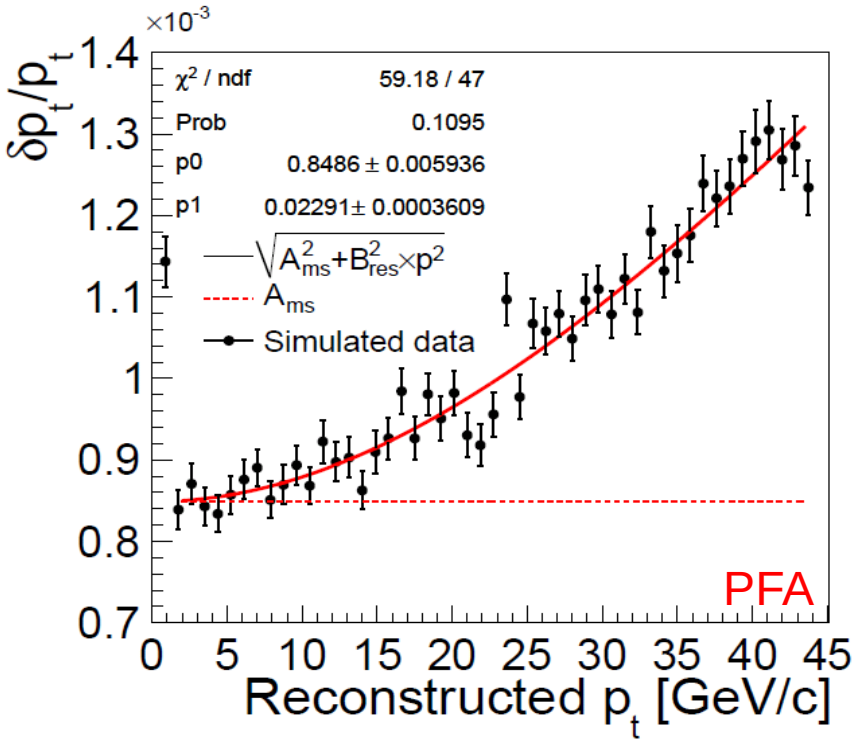
Muon Detector System:

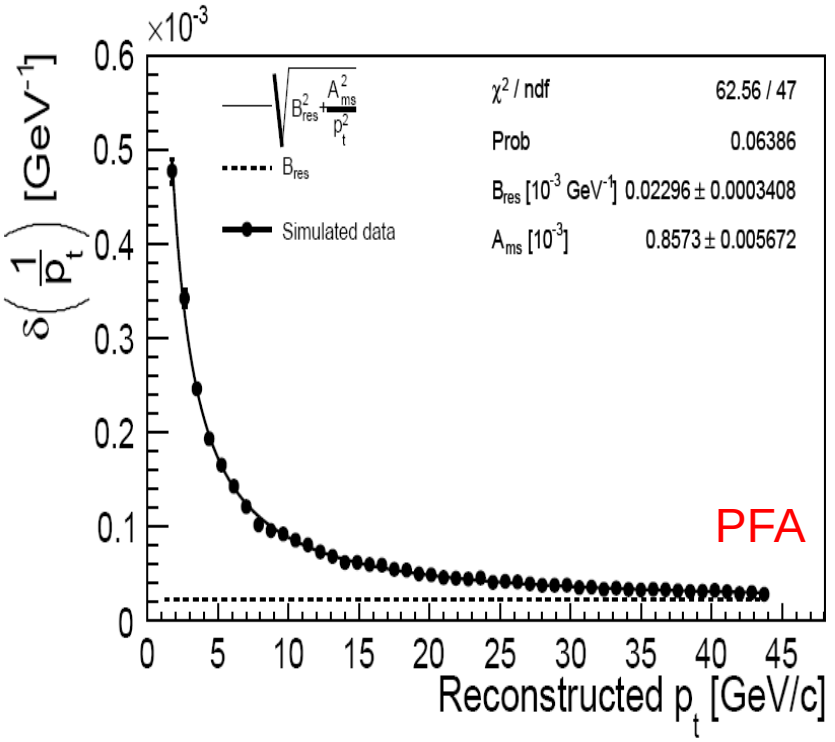
- Scintillator Double Sensitive Layers in the Yoke Gaps (1cm + 1cm scintillator)

Analysis and tools

- Tasks of the muon system:
  - Identification of muons and tracking (PFA segment)
  - Tail catcher for HCAL
- Topics of analysis:
  - Study of the muon reconstruction (muon momentum, impact parameter)
  - Study of the 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 (endcap). 5000 events per point are simulated.

Muon momentum resolution study





Gluckstern parameterization:

Multiple scattering:

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

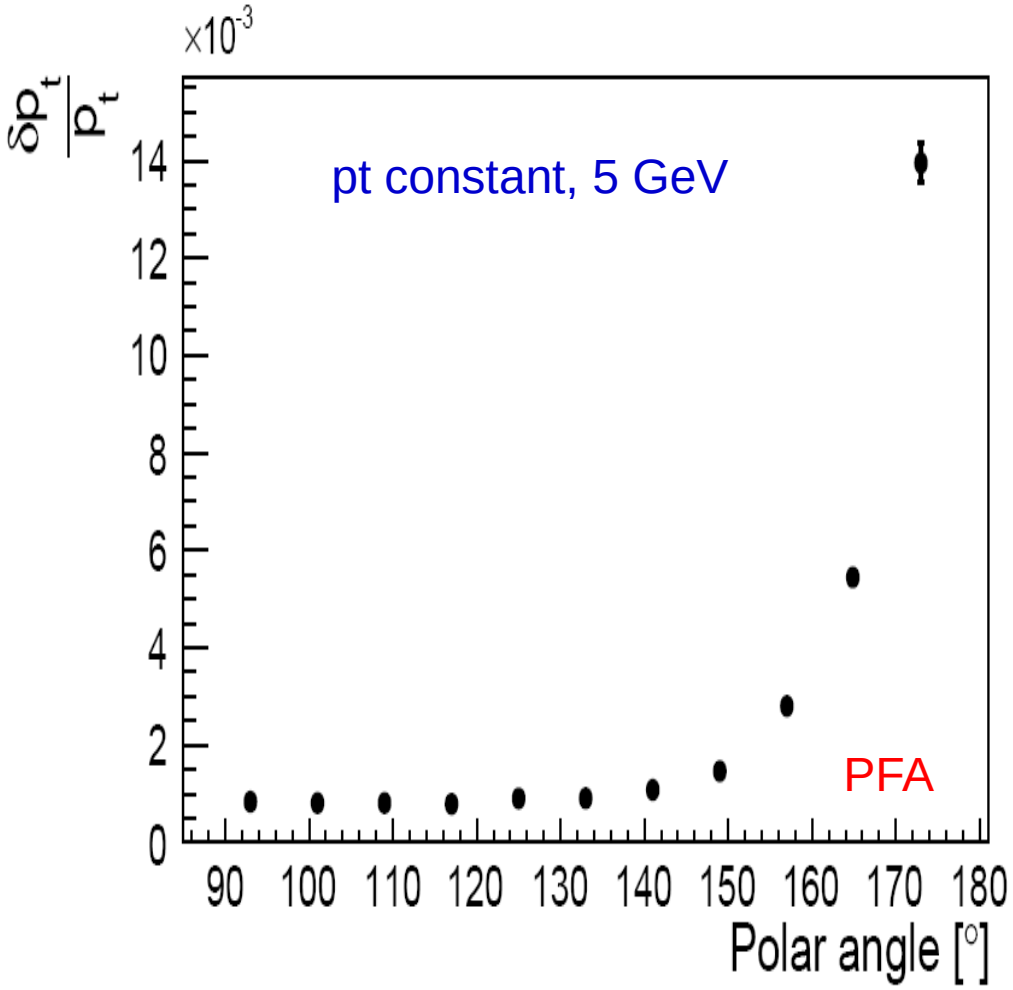
Detector resolution:

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

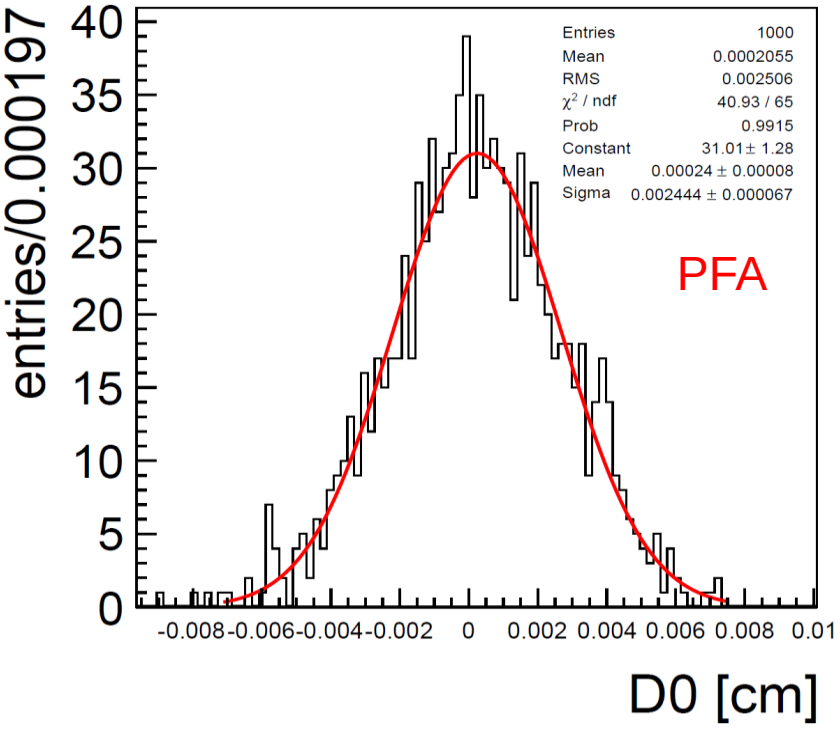
$$A_{ms} = 0.85 \cdot 10^{-3}$$

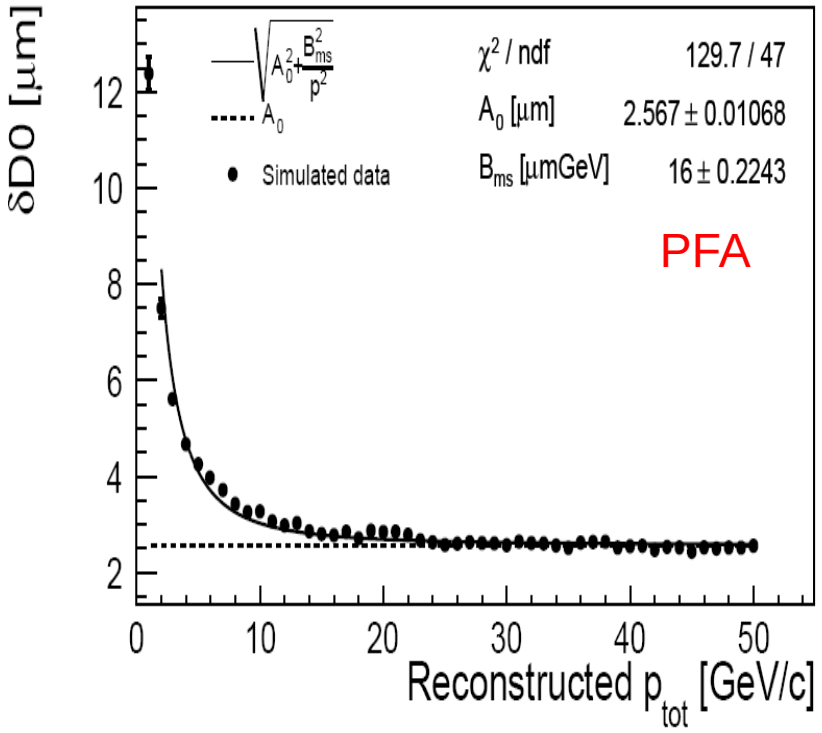
$$B_{res} = 2.3 \cdot 10^{-5} GeV^{-1}$$

Angular dependence of the momentum resolution



Impact parameter resolution





(Data quality check 50 GeV)

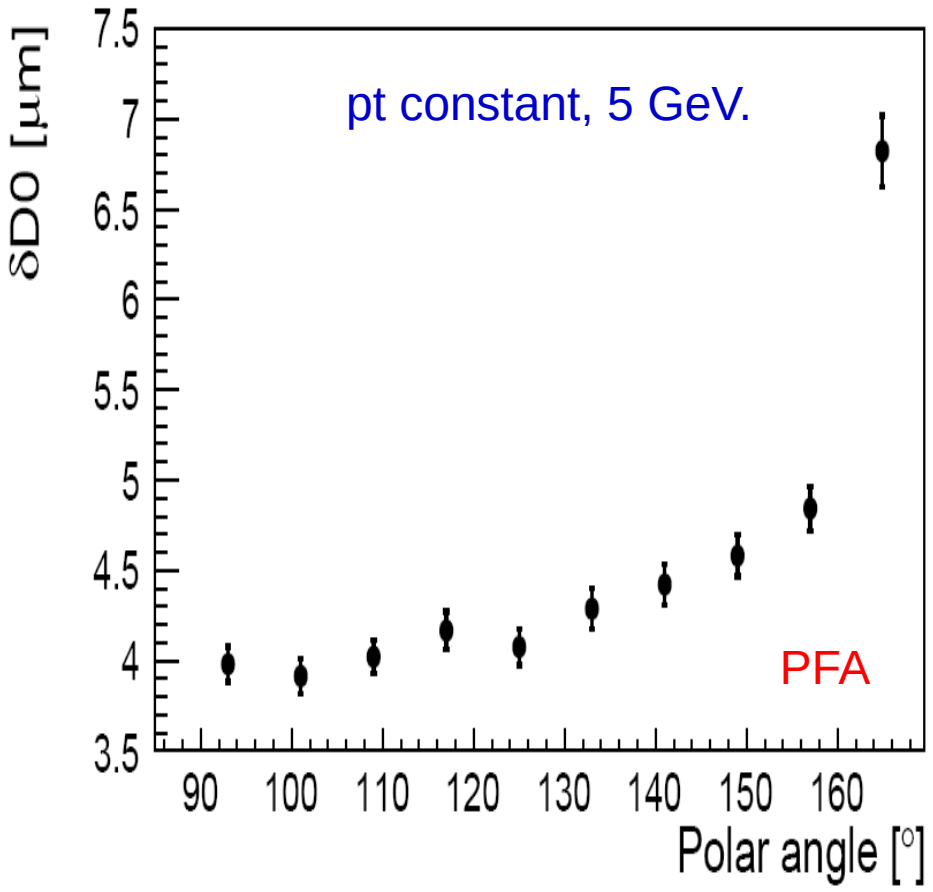
$$\delta D_0 = \sqrt{A_0^2 + \frac{B_{ms}}{p^2}}$$

A_0: finite detector resolution term,

B_{ms}: multiple scattering term.

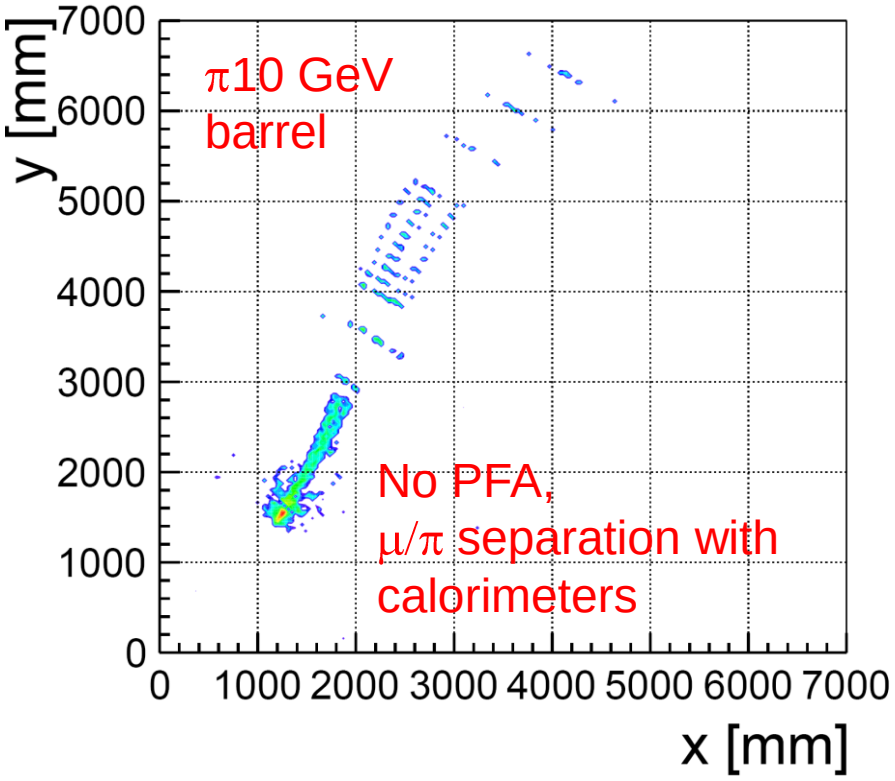
$$A_0 = 2.5\mu m$$

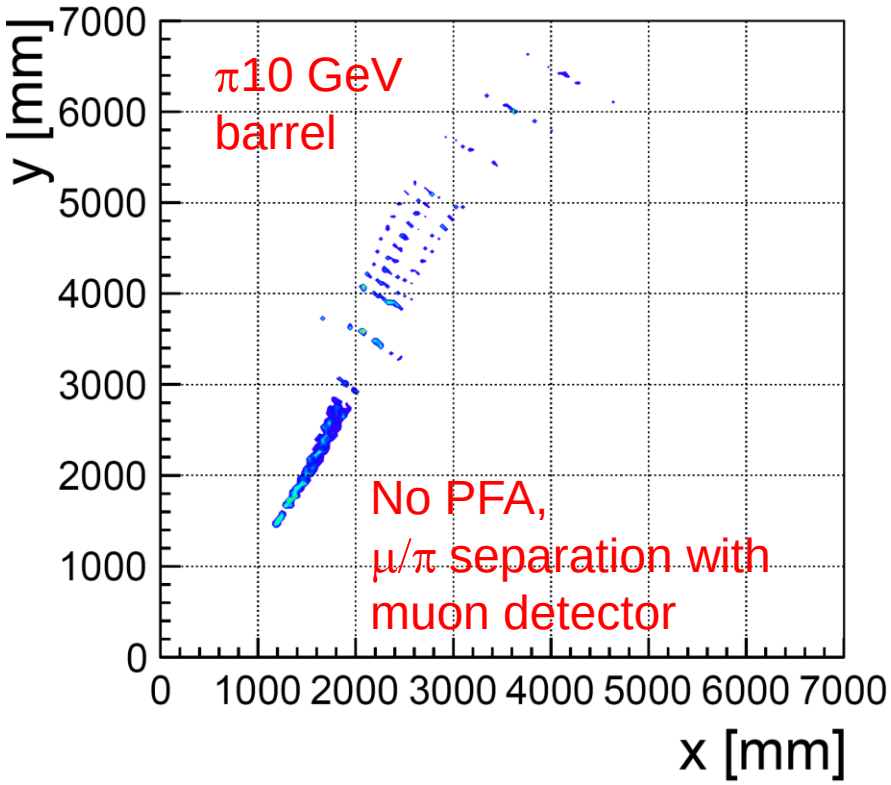
Impact parameter resolution study



In the very forward region, for θ=173°, the impact parameter resolution deteriorates up to 70 μm

μ–id and μ/π separation E=10 GeV

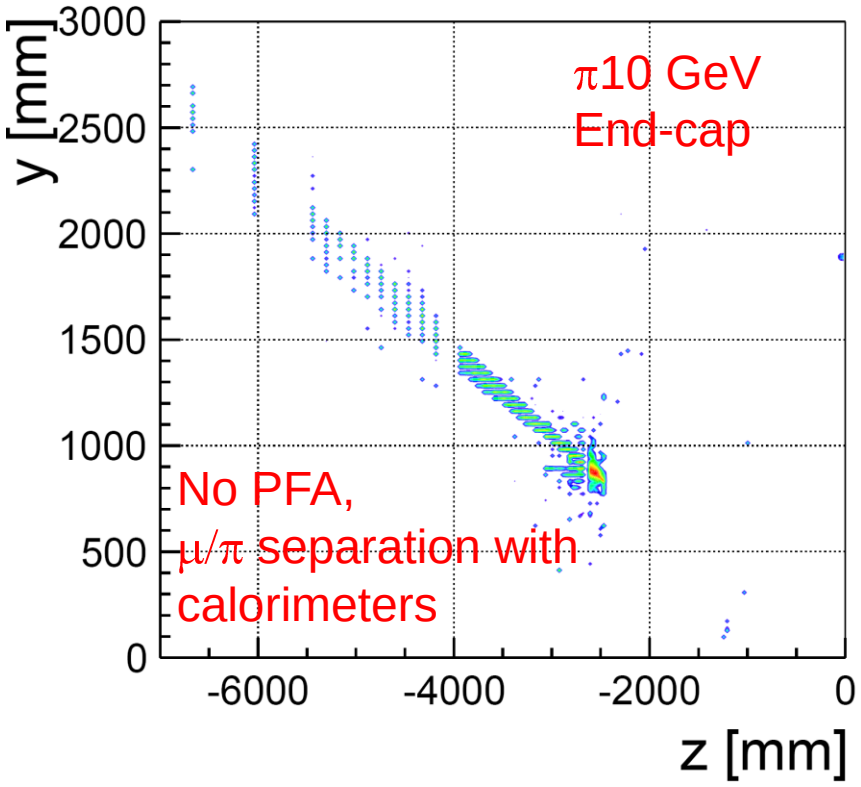


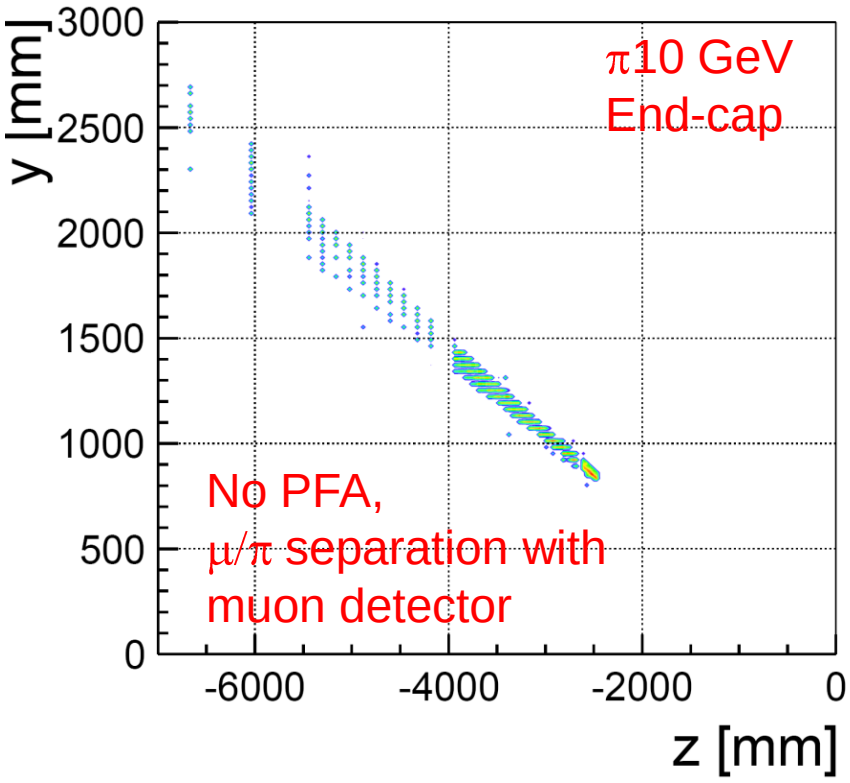


Selection based on visible energy in the calorimeters and in the muon detector

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

μ–id and μ/π separation E=10 GeV

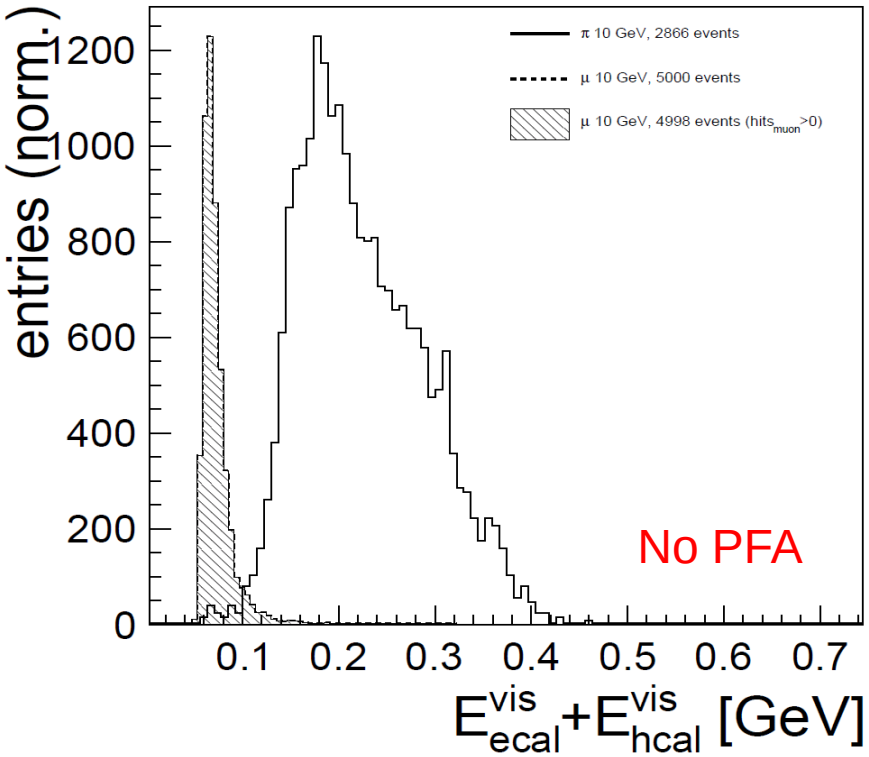


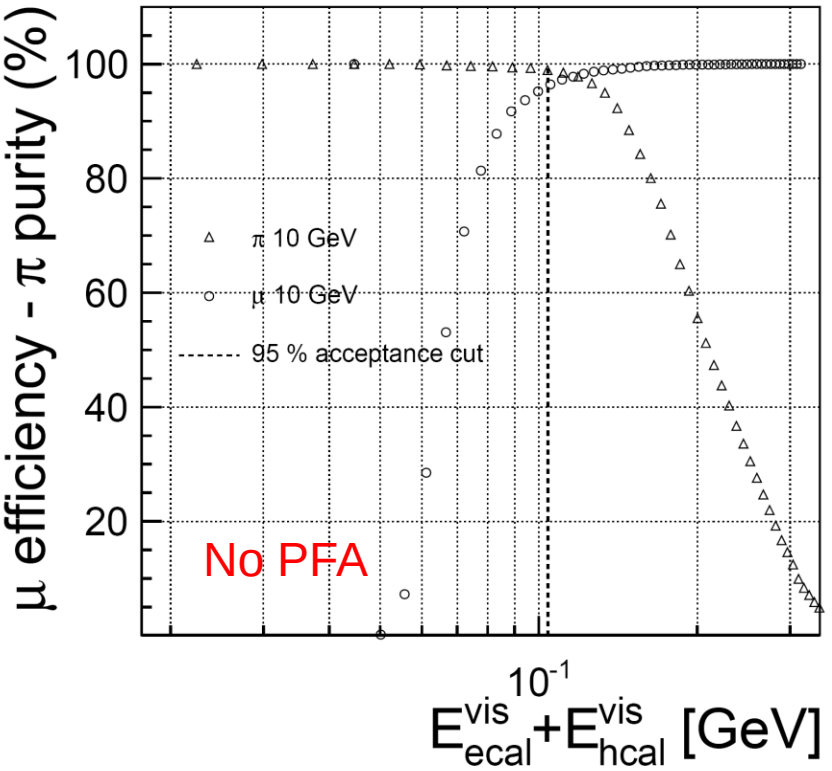


Selection based on visible energy in the calorimeters and in the muon detector

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

μ/π separation in calorimeters (E=10 GeV)

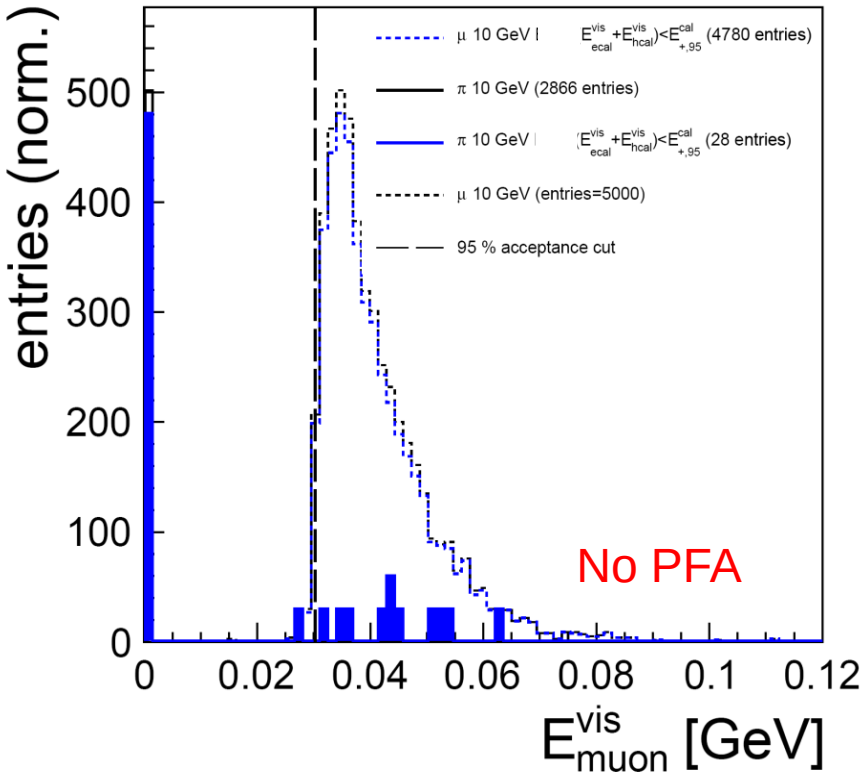




$$\alpha_{\mu}^{cal} = \int_{0}^{E_{+,95}} h_{\mu}(E)dE = 95\% \qquad \beta_{\pi}^{cal} = \int_{E+,95}^{\infty} h_{\pi}^{cal}(E)dE$$

95 % muon efficiency acceptance cut.
(98.98 0.18)% pion purity

μ/π separation in muon detector (E=10 GeV)



95 % efficiency acceptance

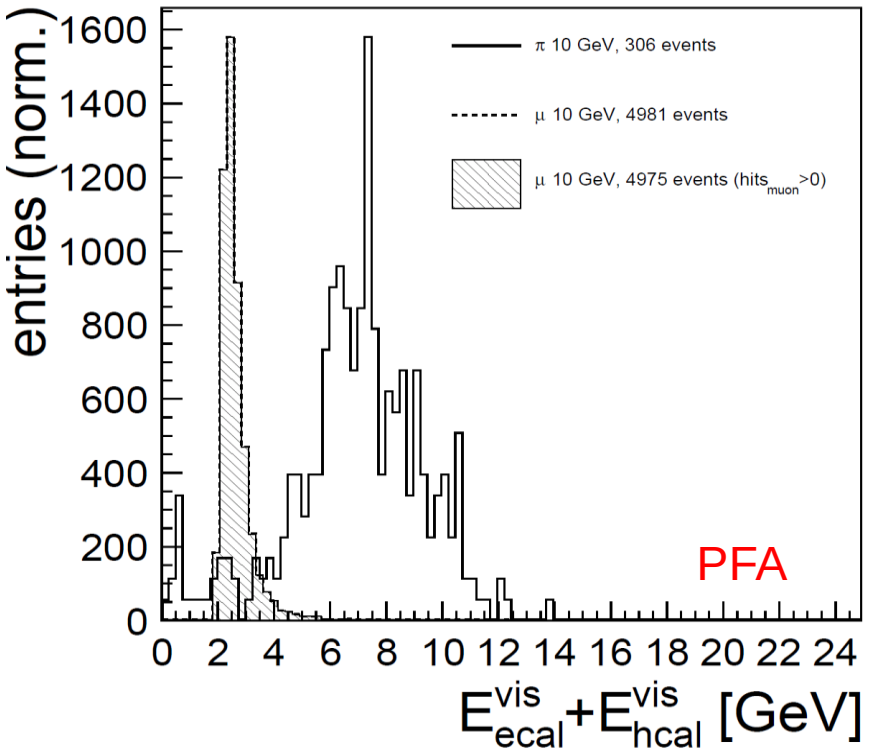
(99.62 0.12)% pion purity

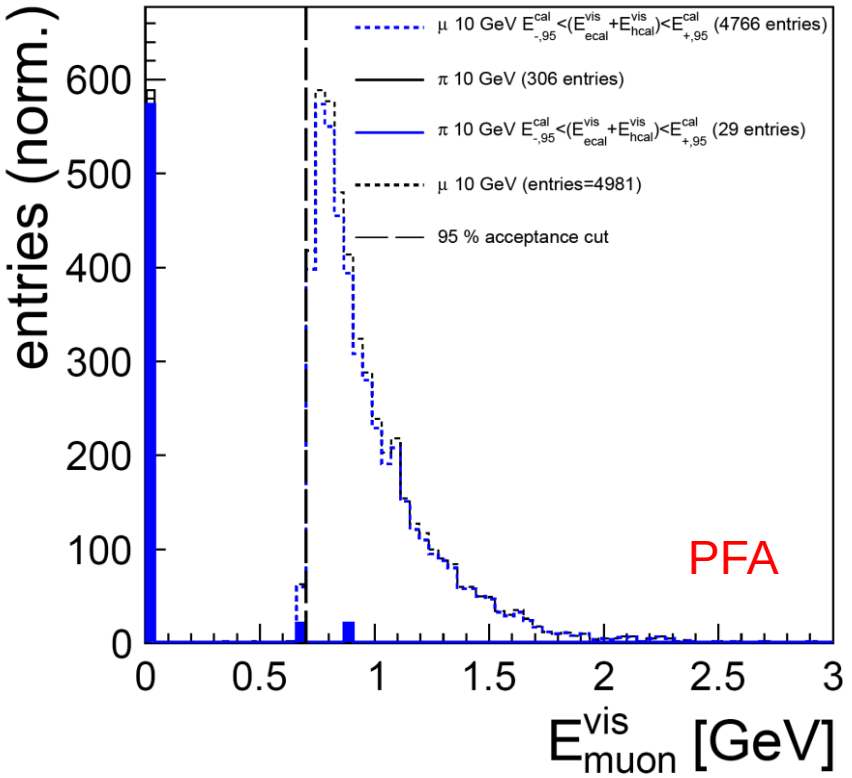
$$\alpha_{\mu}^{muon} = \int_{E_{+,95}}^{\infty} h_{\mu}(E)dE = 95\%$$

$$\beta_{\pi}^{muon} = \int_{0}^{E_{+,95}} h_{\pi}^{cal}(E)dE$$

Muons with initial momentum higher than 10 GeV are identified with efficiency of about 95% and the corresponding pion contamination is always less than 1%

μ–id and μ/π separation E=10 GeV (PFA)

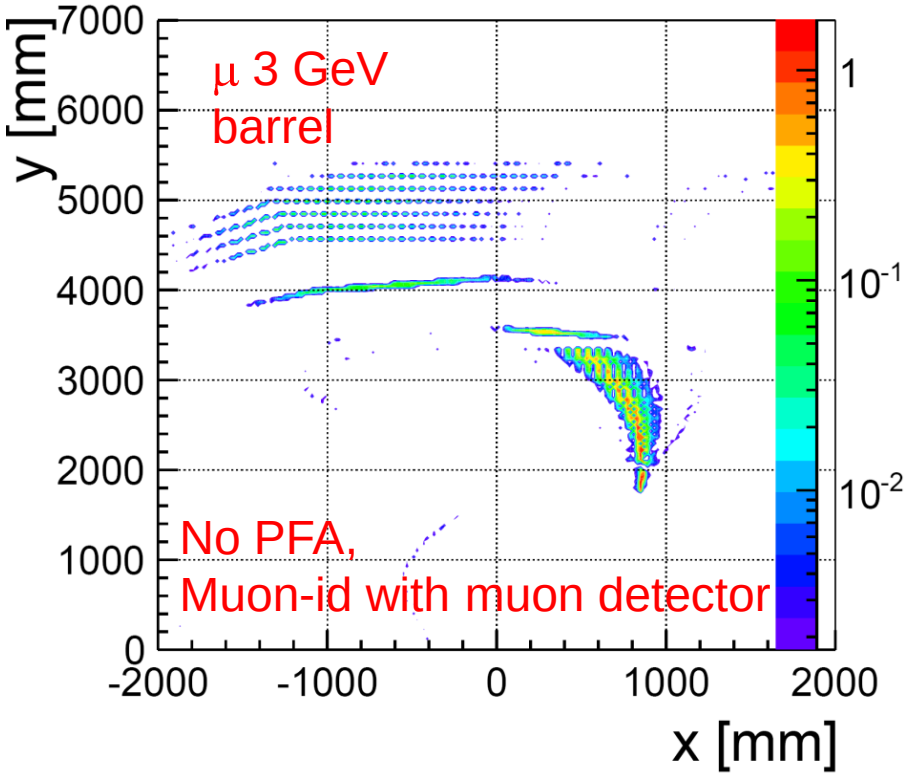


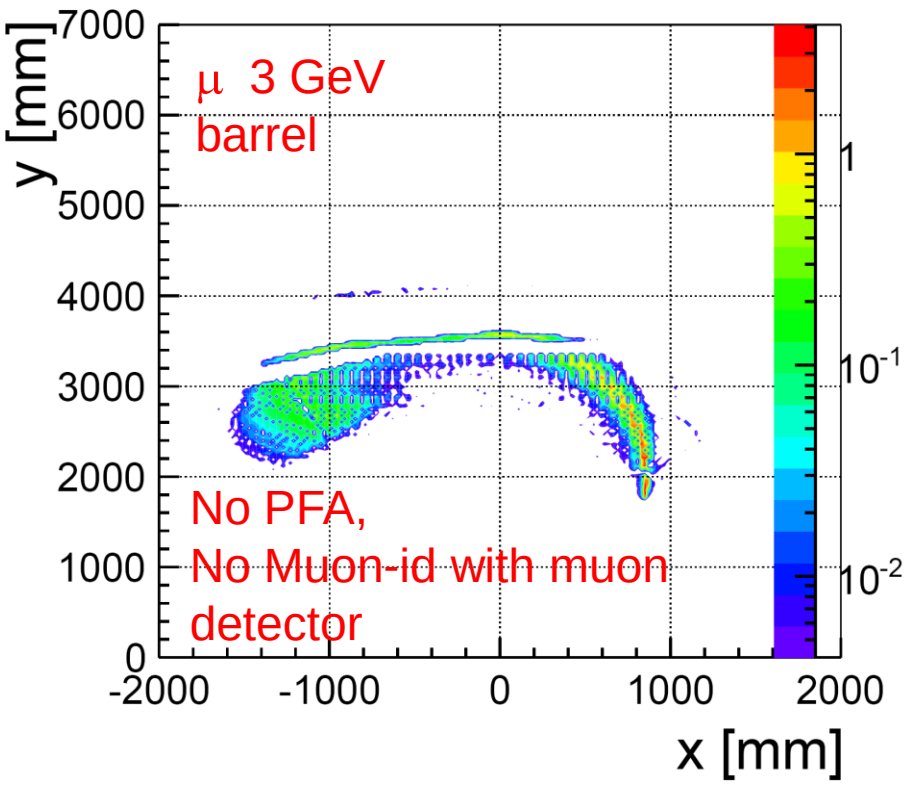


Low efficiency of single π identification in PFA algorithm (about 20%).

For 95% muon-id, pion purity very low

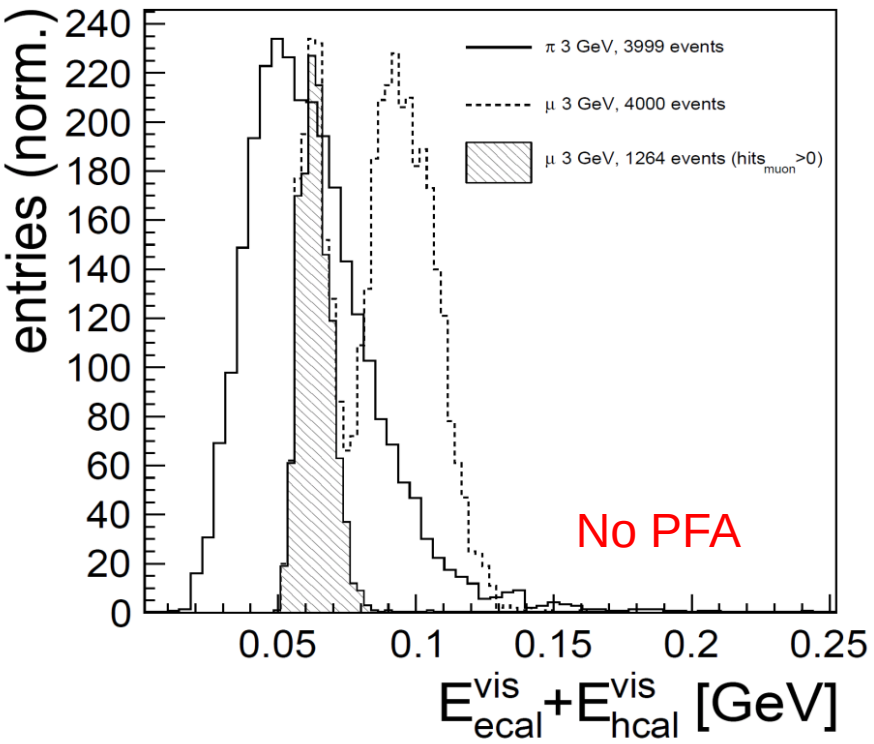
μ–id and μ/π separation E=3 GeV

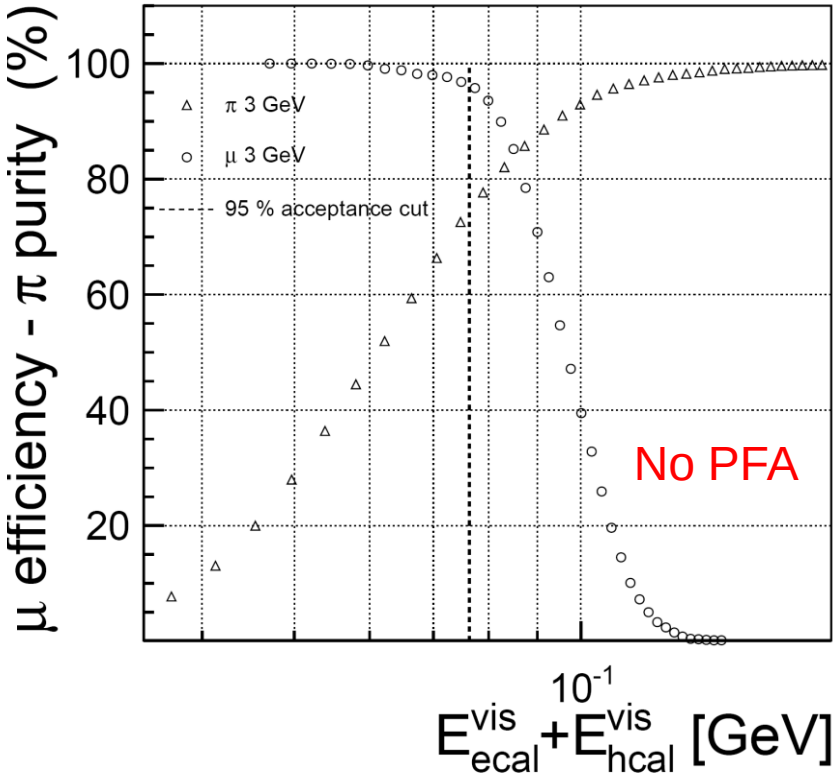




Impact of the coil material on the muon identification

Problem in μ–id and μ/π separation at low energy



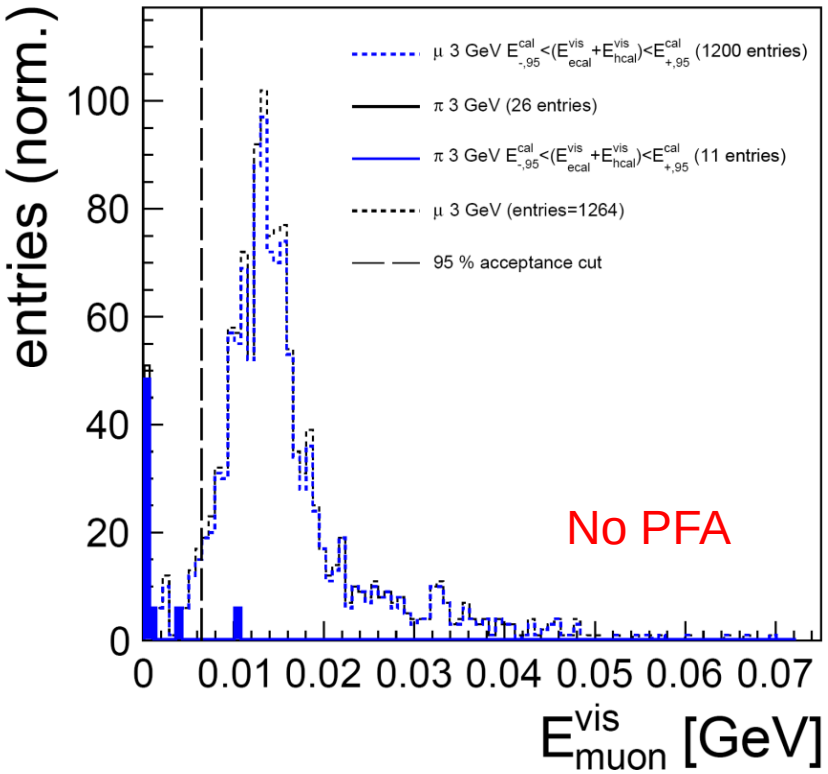


Low energy pions deposit energy mainly in ECAL

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

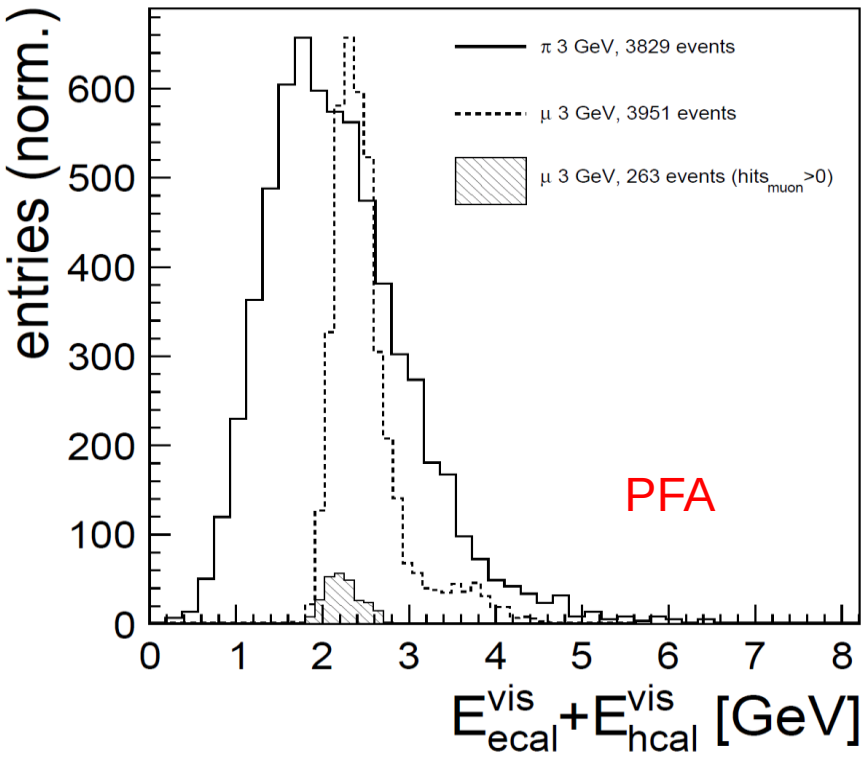
Necessary special analysis method

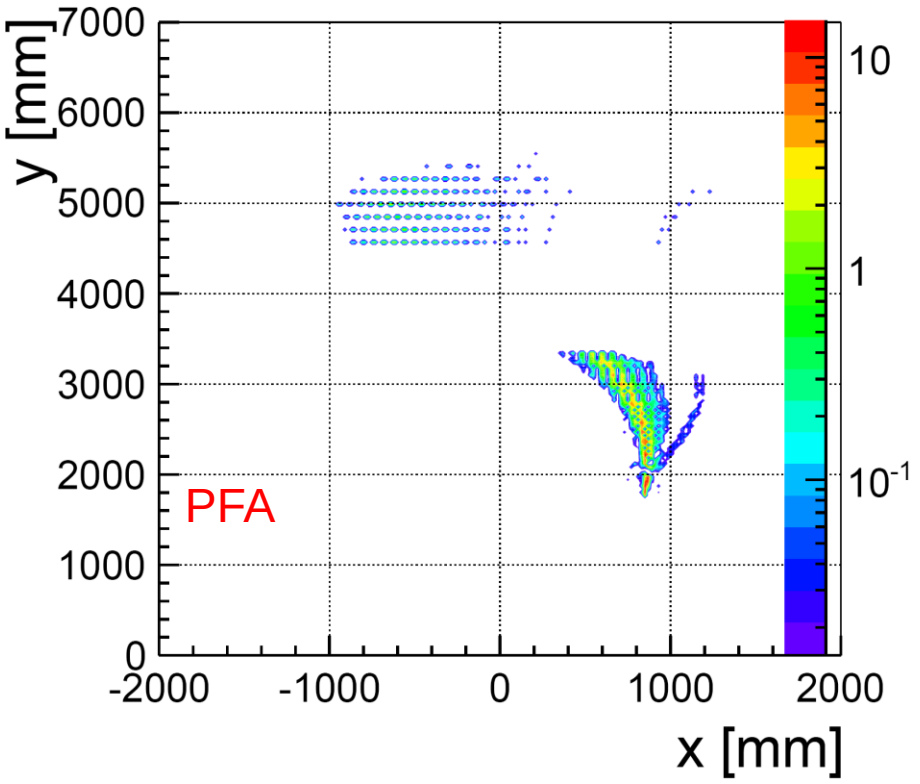
μ–id and μ/π separation with muon system at low energy



For muons which are identified by the muon system, estimation for 95 % muon efficiency, pion purity (96 5)%

μ–id and μ/π separation in PFA (E=3 GeV)

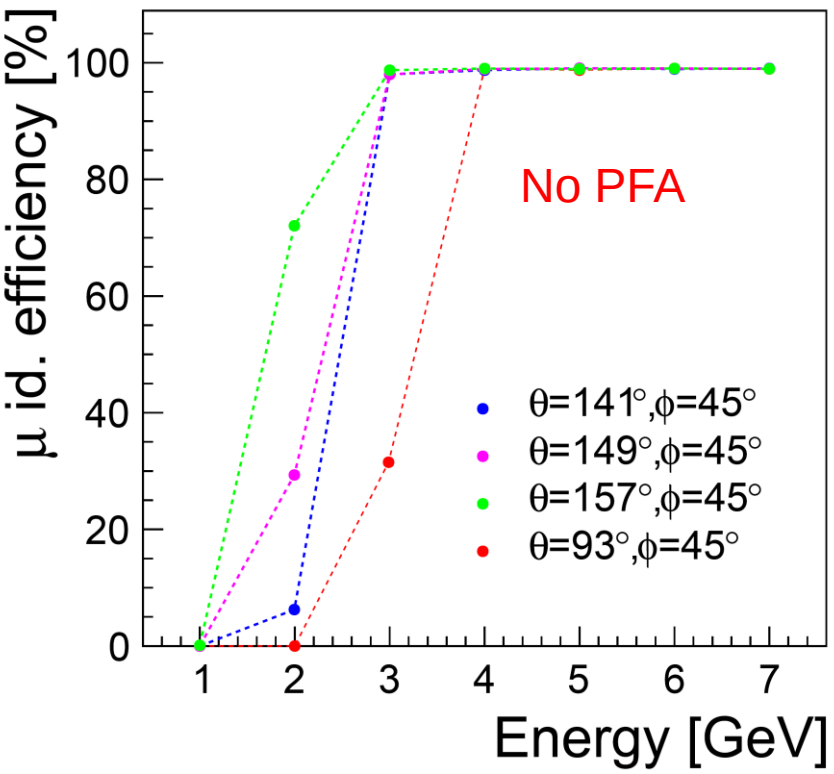


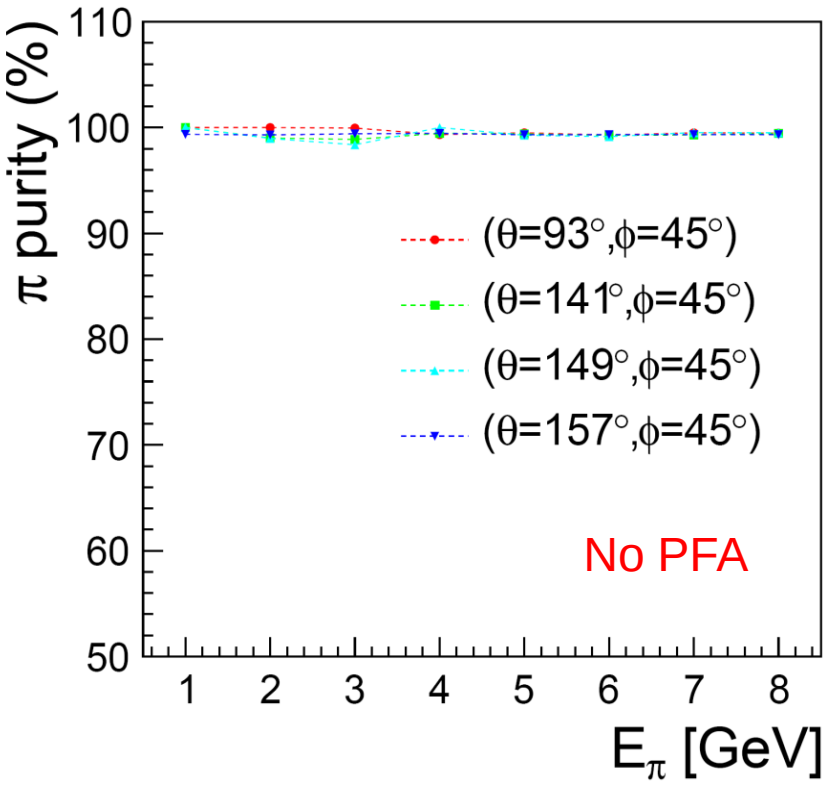


PFA algorithm unefficient in the connection between mip-like stubs in calorimeters and in the muon detector at low energy due to the curvature of the tracks (20% PFA muon reconstruction efficiency)

Good reconstruction and identification of low energy pions

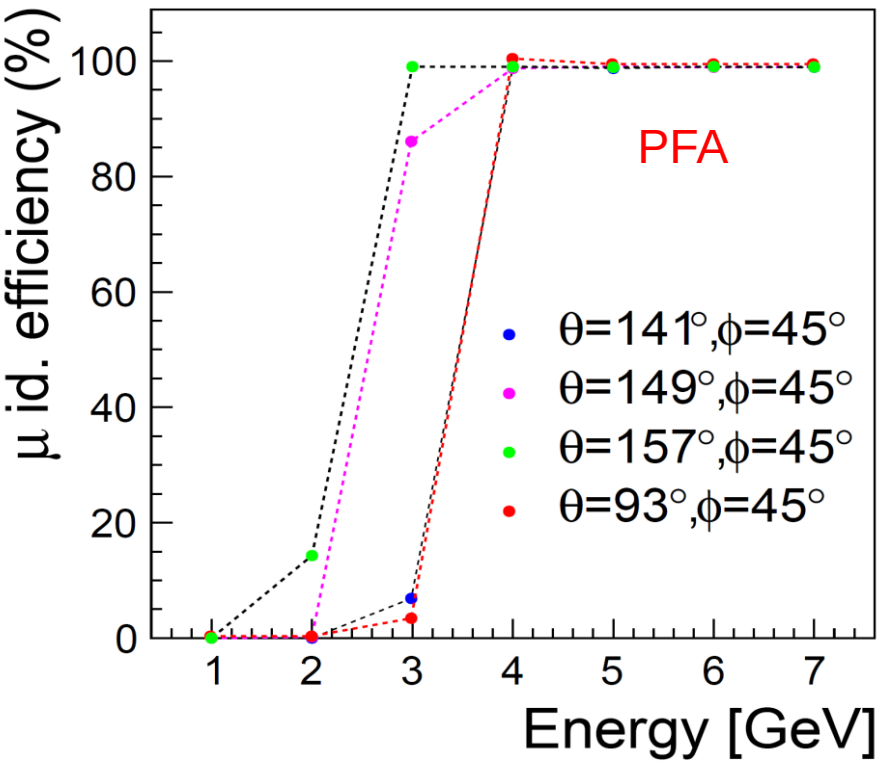
μ–id and μ/π separation with muon detector

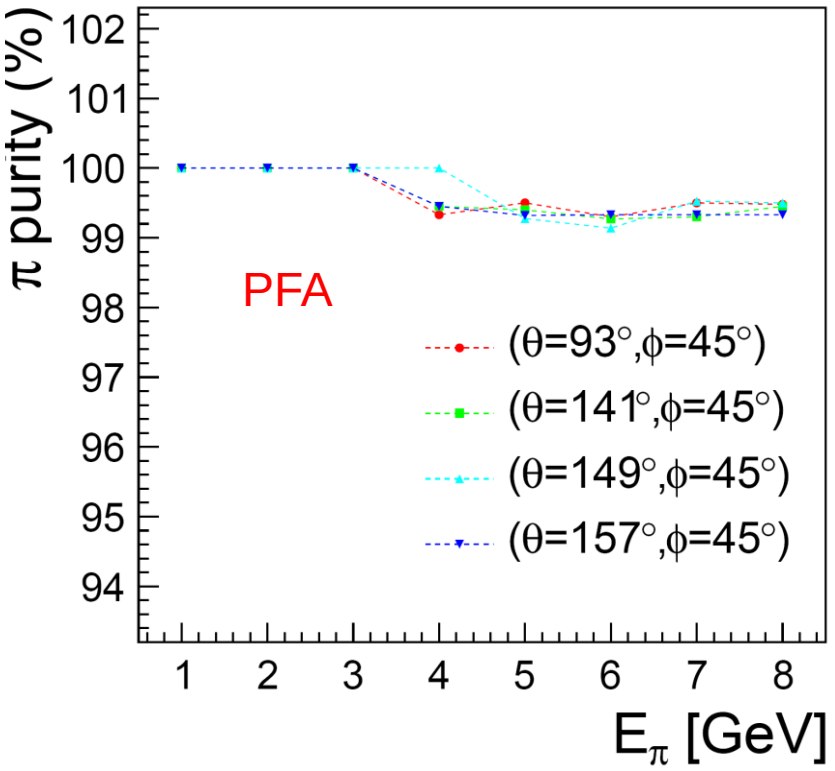




Effect of the coil in the end-cap region for soft muons:
the μ-id based only on the muon system is weak for energy lower than 4 GeV.

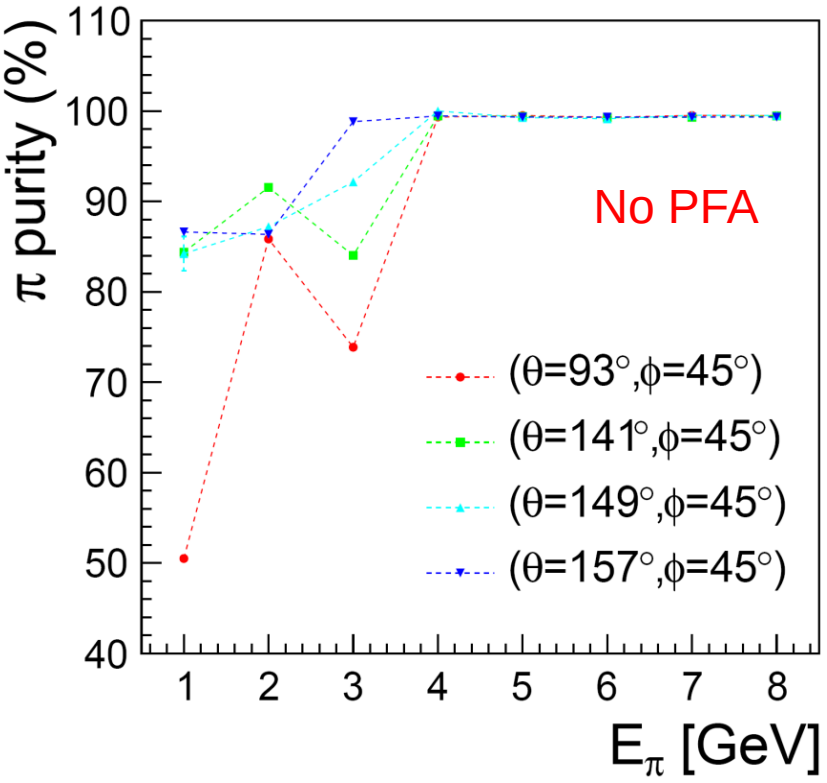
μ–id and μ/π separation with muon detector (PFA)

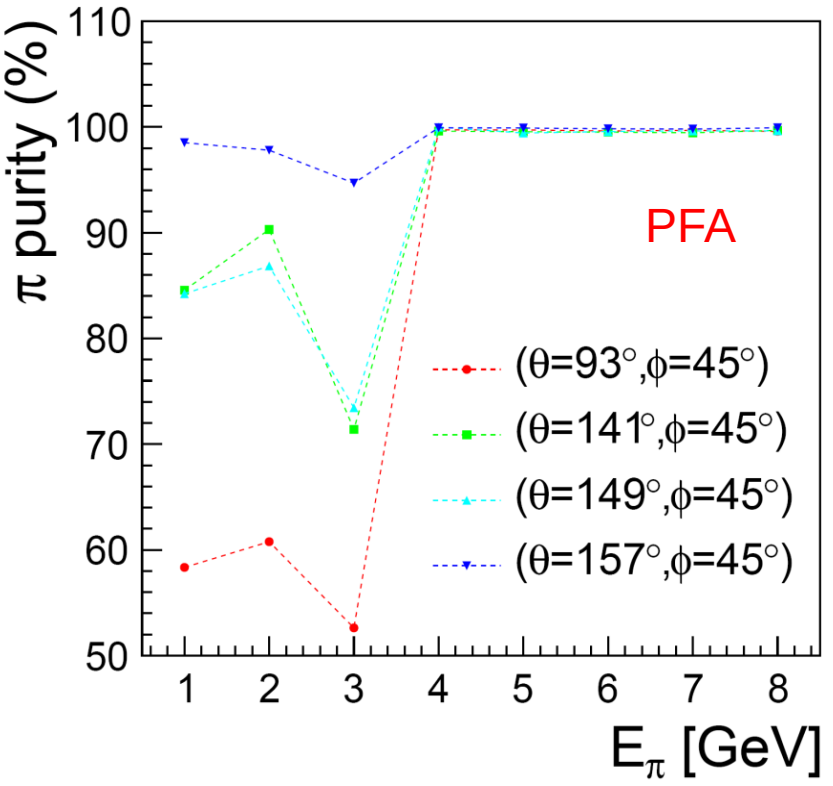




Effect of the coil in the end-cap region for soft muons:
the μ-id based only on the muon system is weak for energy lower than 4 GeV.

μ–id and μ/π separation (muon det. + calorimeters)





95% muon identification efficiency

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

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:
  - $\delta(1/pt) = 2.3\ 10^{-5}\ GeV^{-1}$
  - $\delta(D_0) = 2.5\ \mu m$
- Muon identification and μ/π separation:
  - ~95% μ-identification efficiency and correspondingly about 99% π purity at energy >4 GeV
  - Lower purity for muon energy < 4GeV. Needs dedicated analysis