Geometry Optimization in CEPC Hardronic Calorimeter

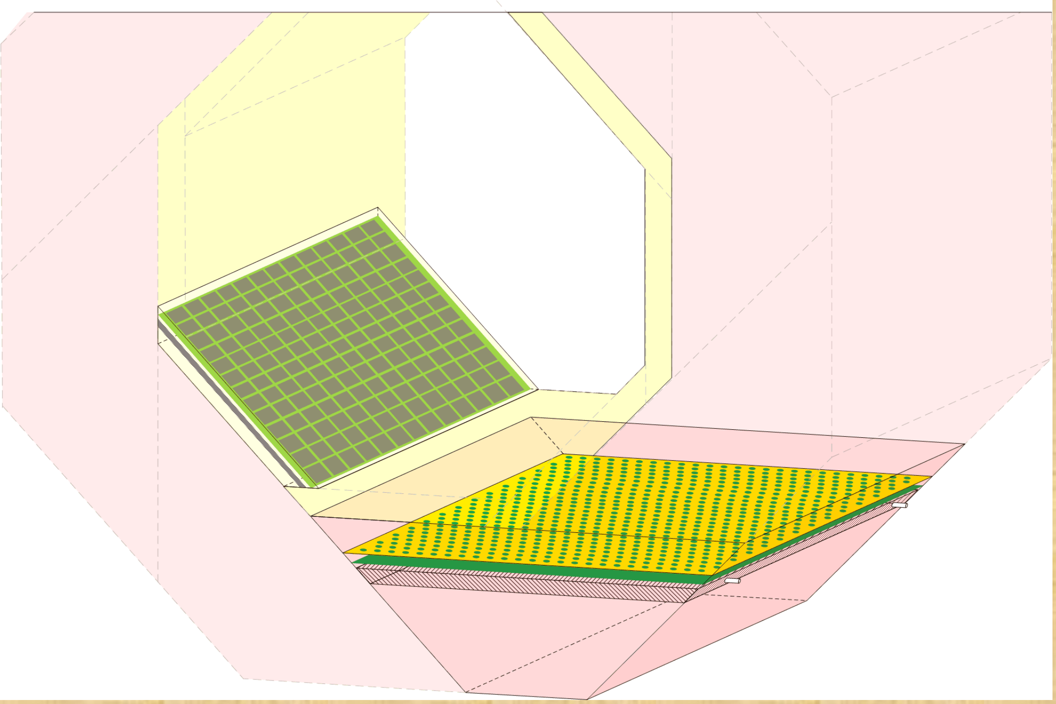
S.Chen

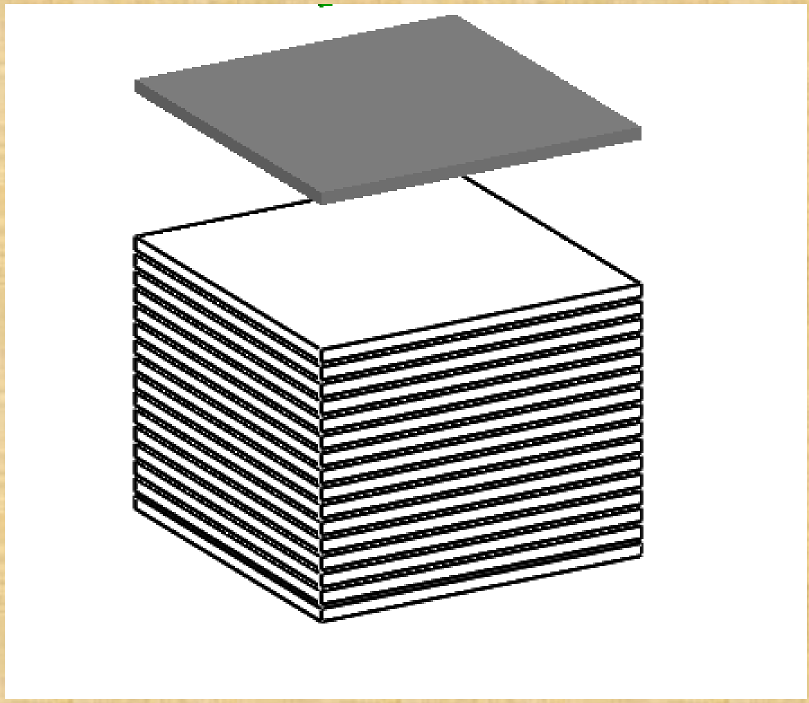
2016.8.29

Outline

1. Motivation
2. Hit Level
3. Cluster Level
4. Digitizer

Part1 Motivation





- HCAL in CEPC: Sample Calorimeter
- Structure: Thickness，Layers，Cell Size
- Change these parameter，compare the performance of HCAL
- Only HCAL Model by Mokka

Part2 Hit Level

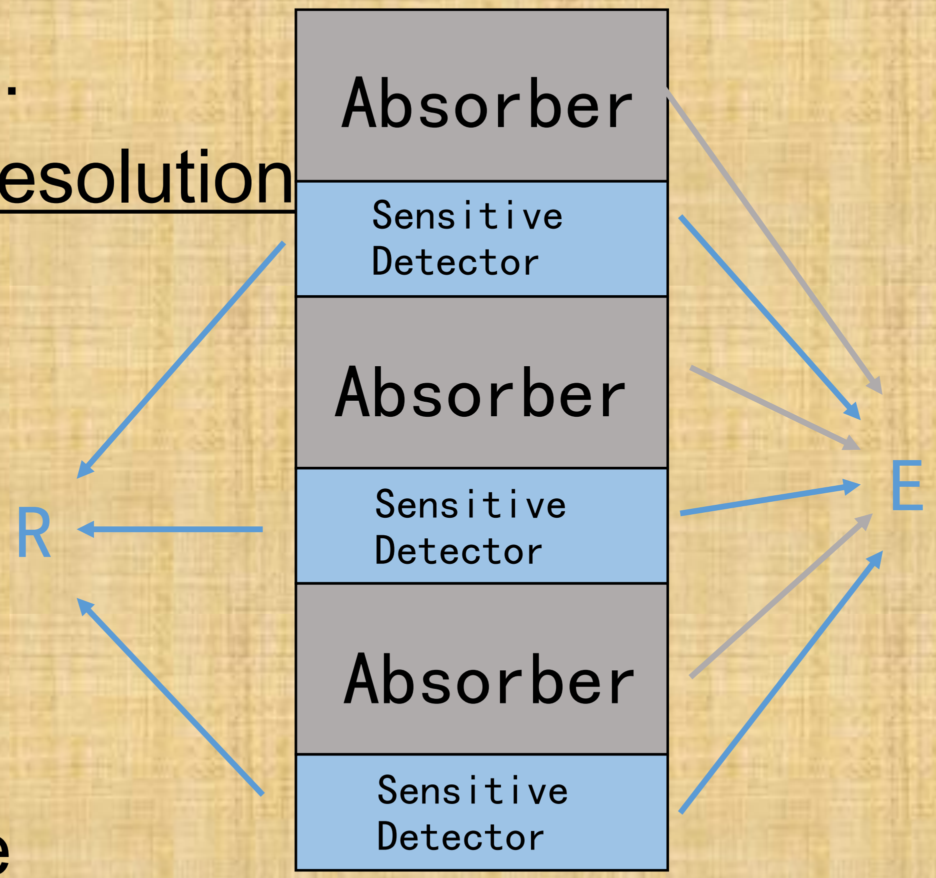
- Single Particle: Pion
- Scan: Layers, Cell Size, …
- Compare: the Linarity & Resolution

Energy Estimate

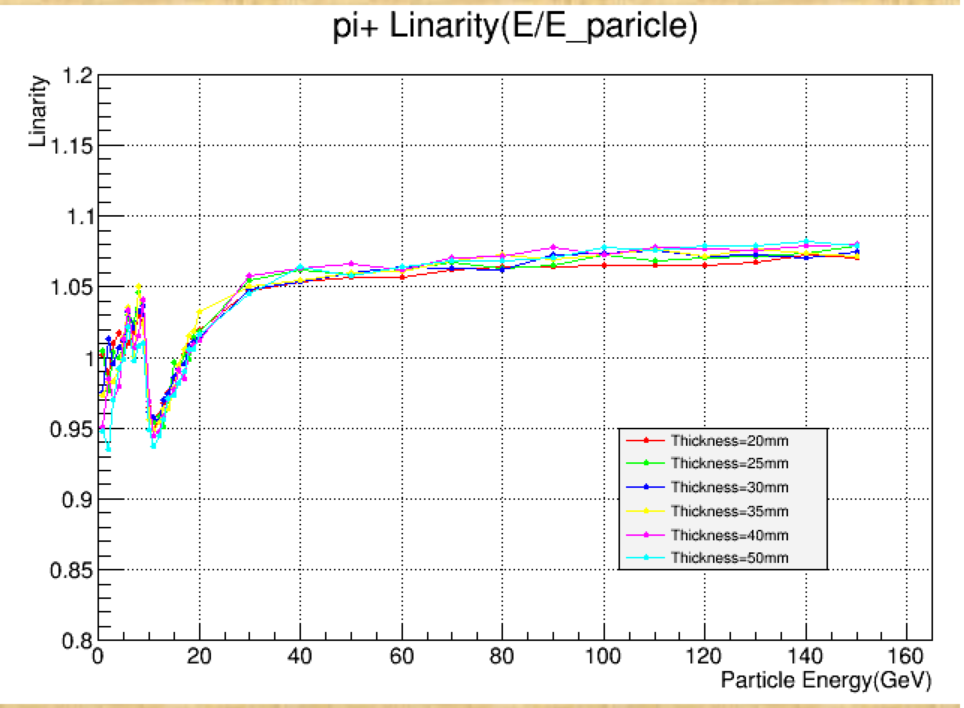
$$R = \varepsilon E$$

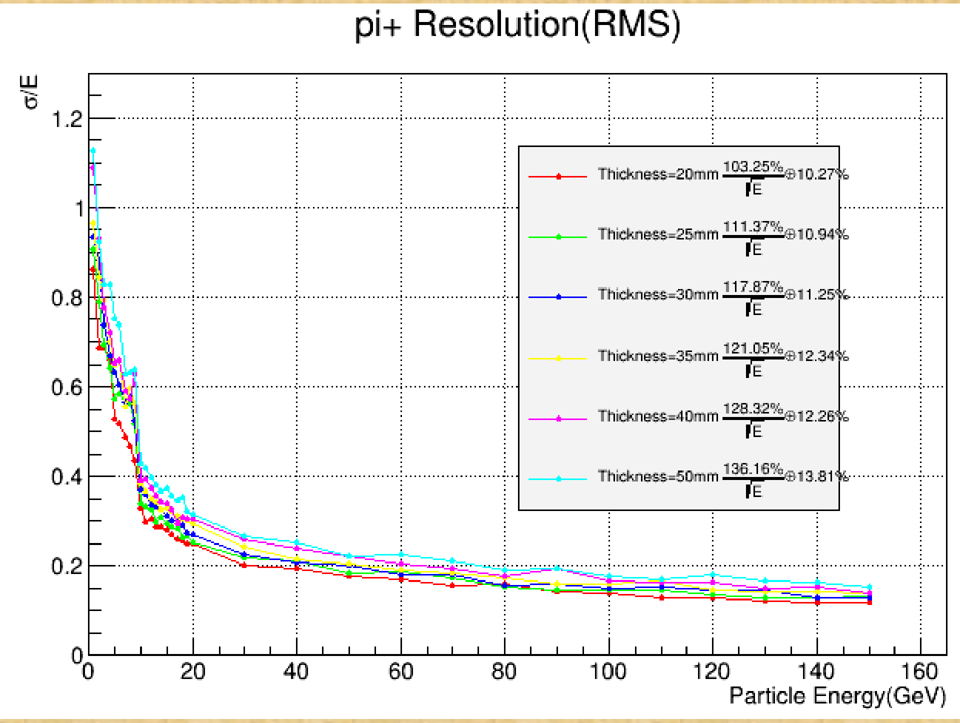
$$\rightarrow E = \frac{1}{\varepsilon} R = kR$$

- R: Calorimeter Response
- E: Estimated Energy



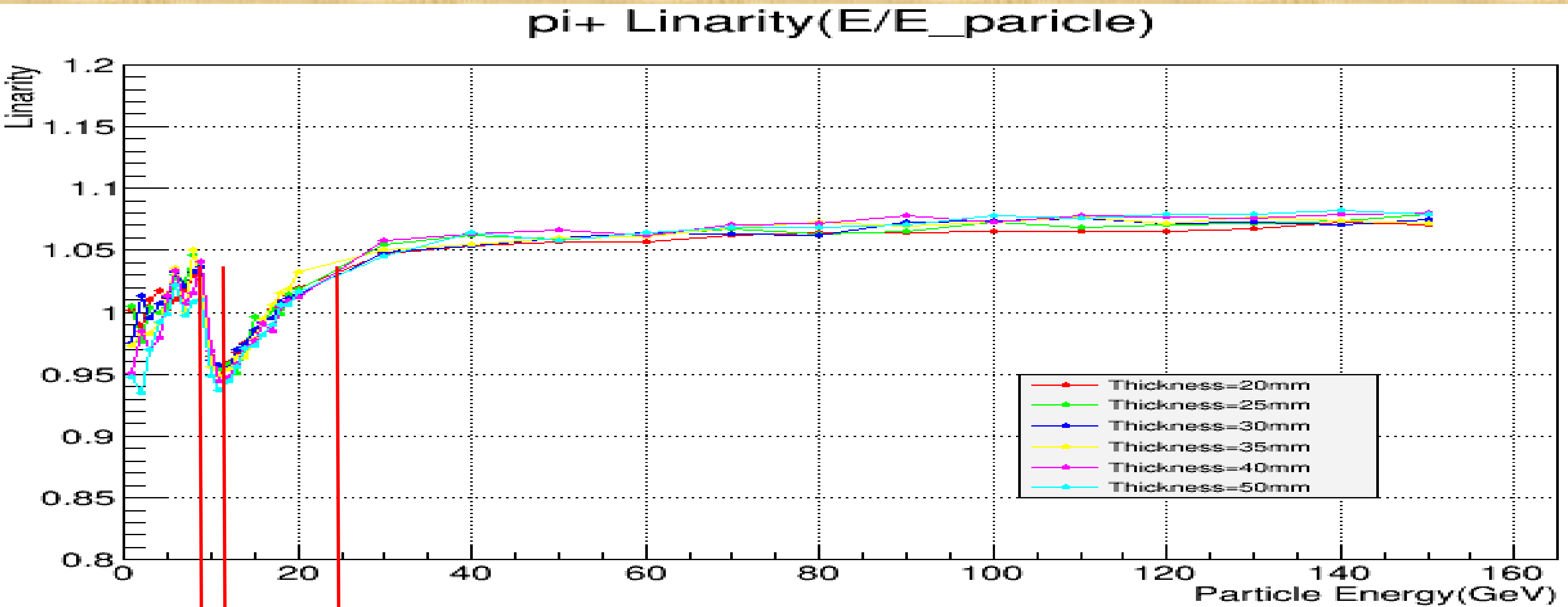
Energy Estimate

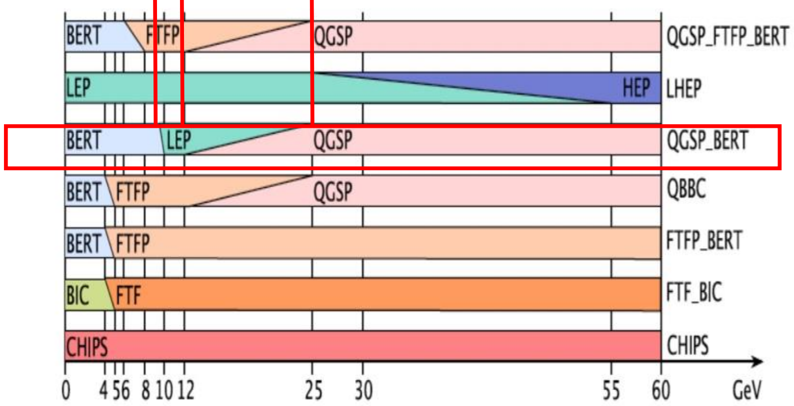


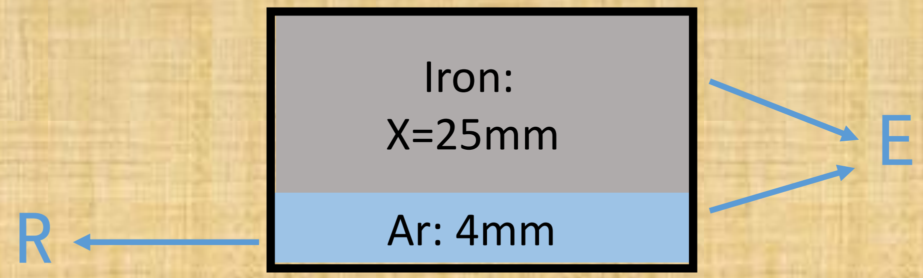


- 10GeV~30GeV

Energy Estimate(Physics List)







由$R=\varepsilon E$

则有 $\frac{1}{\varepsilon}=\frac{E}{R}=\frac{E_{iron}+E_{Ar}}{E_{Ar}}=1+\frac{E_{iron}}{E_{Ar}}$

而 $\frac{E_{iron}}{E_{Ar}}=\frac{(dE_{iron}/dx)\times X_{iron}\times\rho_{iron}}{(dE_{Ar}/dx)\times X_{Ar}\times\rho_{Ar}}$

考虑 $-\left(\frac{dE}{dx}\right)=4\pi N_a r_e^2 m_e c^2 z^2\left(\frac{Z}{A}\right)\left(\frac{1}{\beta^2}\right)\left[\ln\left(\frac{2m_e c^2\gamma^2\beta^2}{I}\right)-\beta^2-\frac{\delta}{2}\right]$ 假设 $\left[\ln\left(\frac{2m_e c^2\gamma^2\beta^2}{I}\right)-\beta^2-\frac{\delta}{2}\right]$ 项影响较小

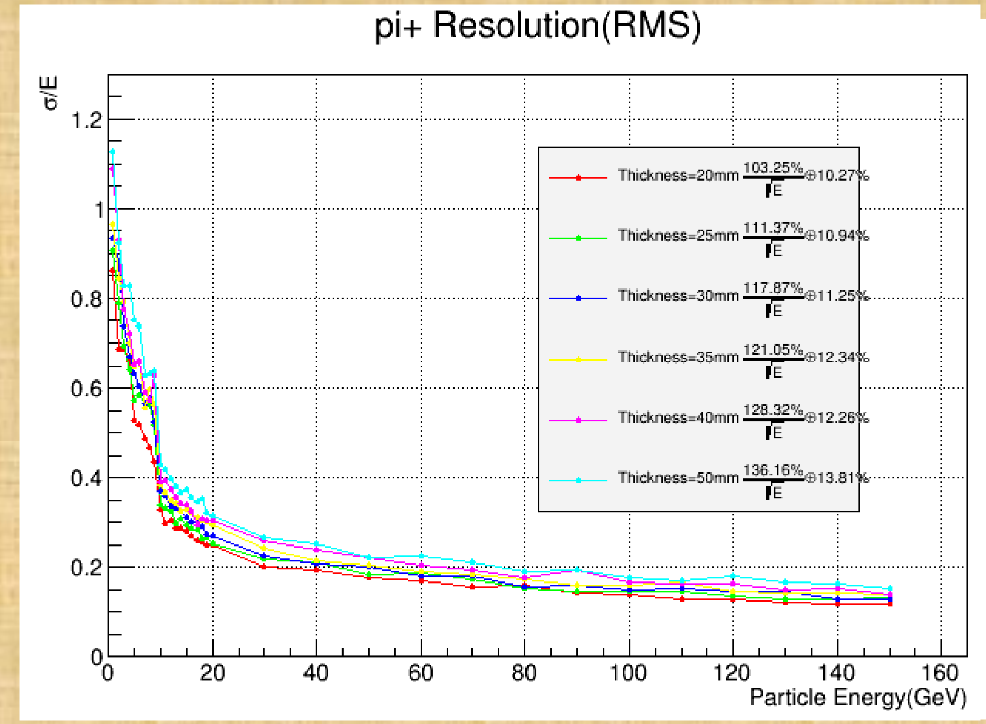
$\frac{(dE_{iron}/dx)}{(dE_{Ar}/dx)}=\frac{\frac{Z_{iron}}{A_{iron}}}{\frac{Z_{Ar}}{A_{Ar}}}=\frac{\frac{26}{56}}{\frac{19}{40}}$

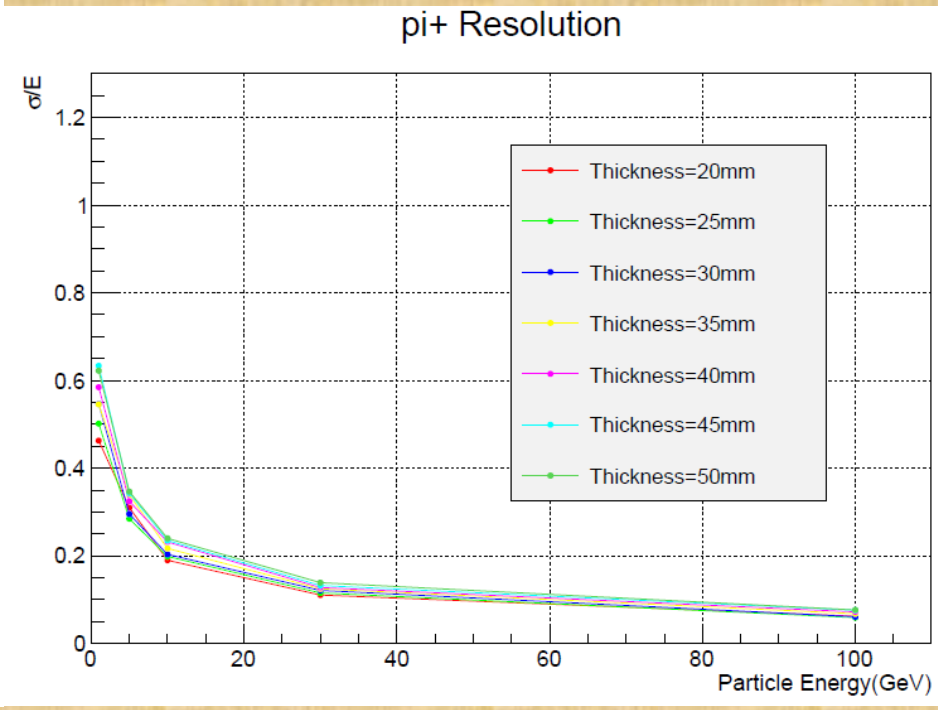
于是 $\frac{E_{iron}}{E_{Ar}}=\frac{26\times40\times2.5\times7.8}{56\times19\times0.4\times1.78\times10^{-3}}=2.68\times10^{4}$

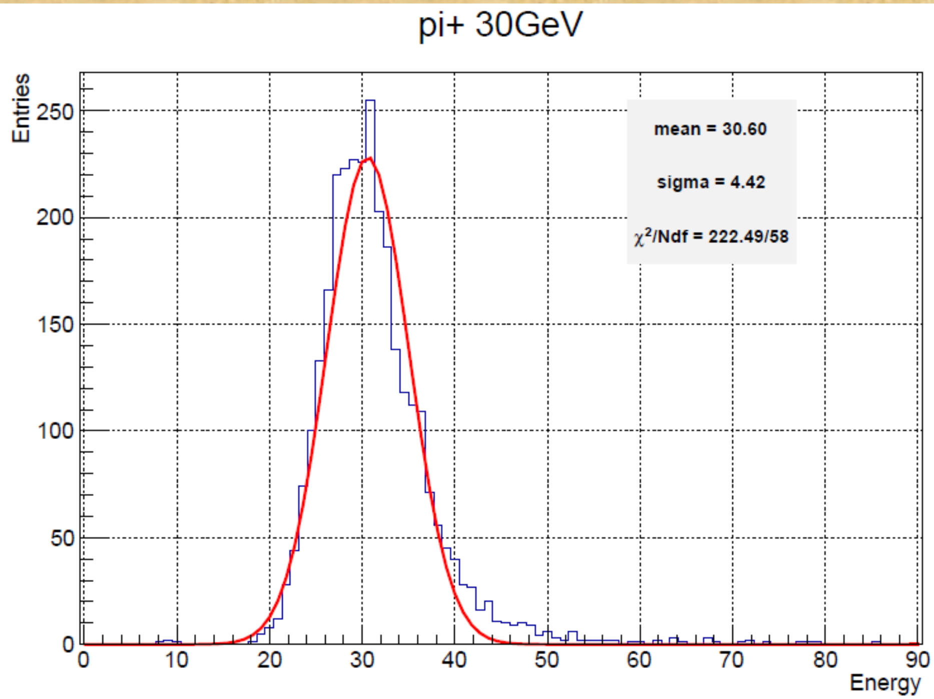
$\therefore\ k=\frac{1}{\varepsilon}=1+\frac{E_{iron}}{E_{Ar}}\approx2.68\times10^{4}$

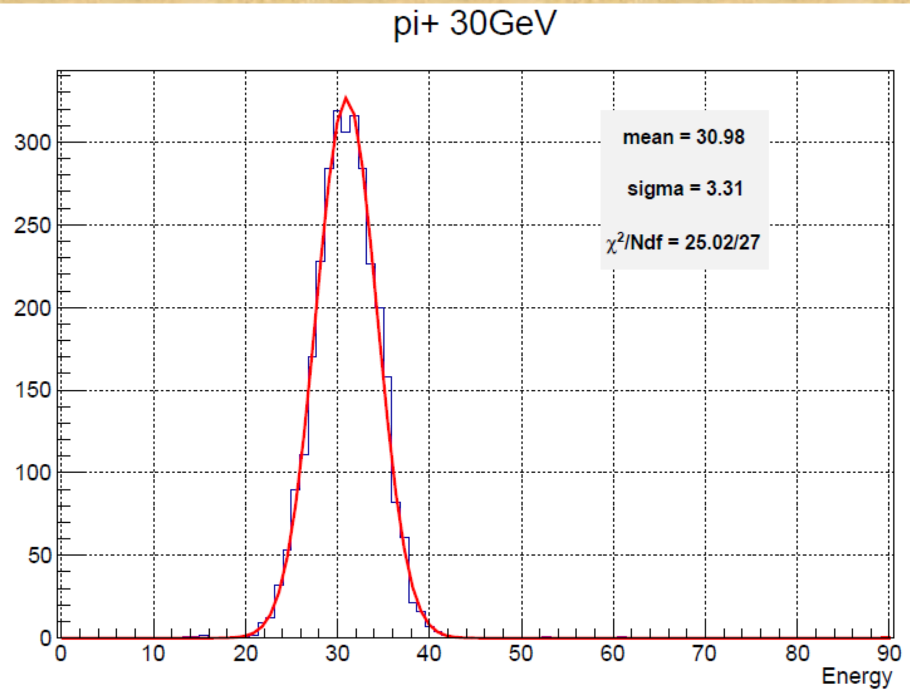
Simulation Result : 3.12×10^{4}

Digital Readout

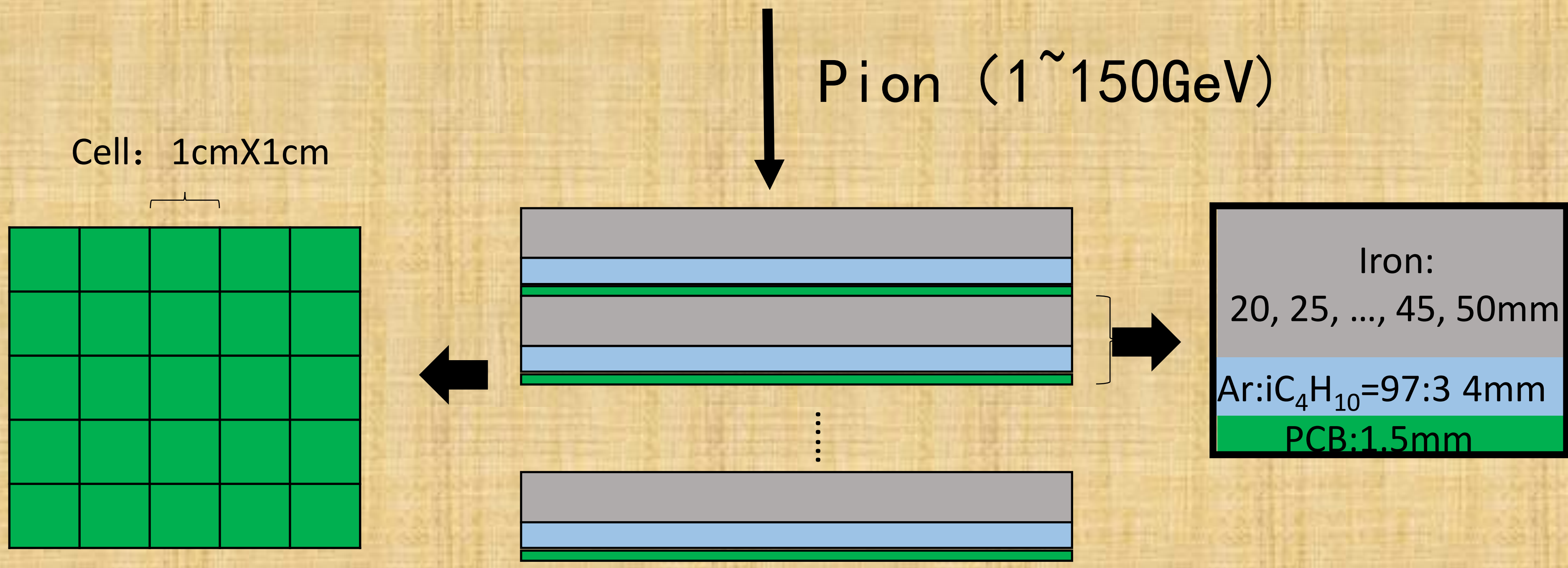





pi+ 30GeV
Entries
mean = 30.60
sigma = 4.42
χ^2/Ndf = 222.49/58
Energy

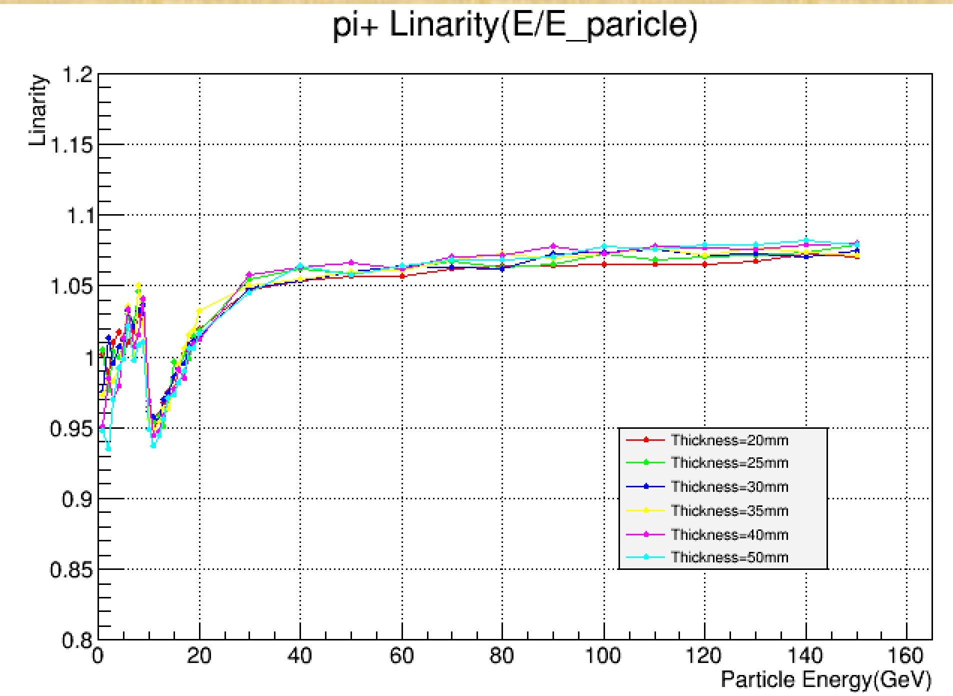

pi+ 30GeV
mean = 30.98
sigma = 3.31
χ^2/Ndf = 25.02/27
Energy

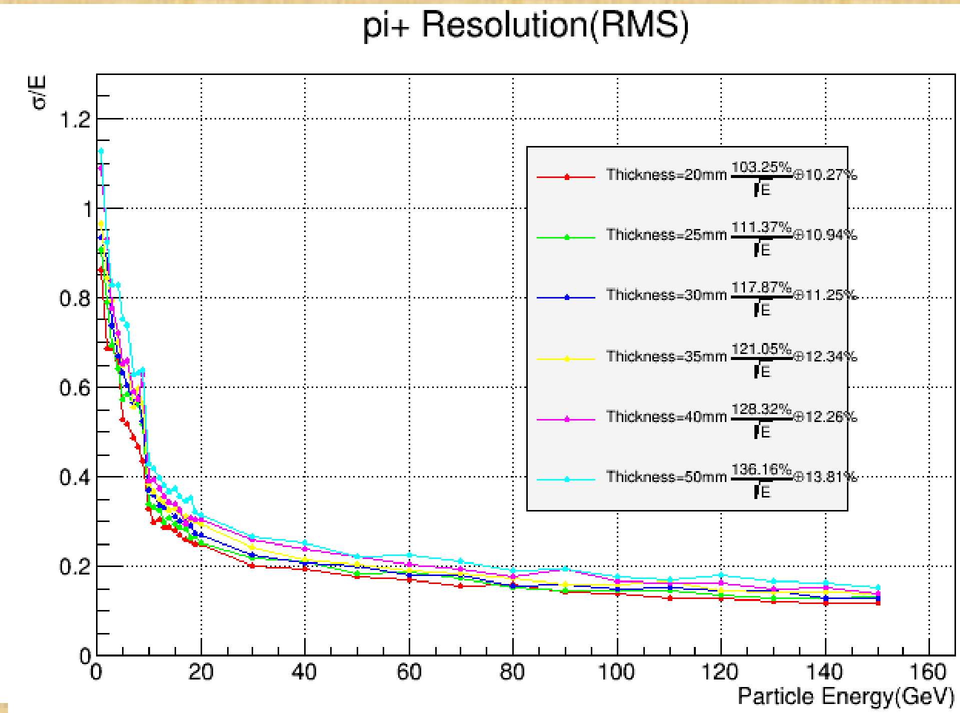
Thickness of Absorber



- Sensitive Region: Ar
- Keep the total thickness absorber :5000mm(30 λ_I, Fe: λ_I= 167.6mm)
- Thick enough to elimiate the effect of energy
- Change the thickness of iron(from 20 to 50mm)

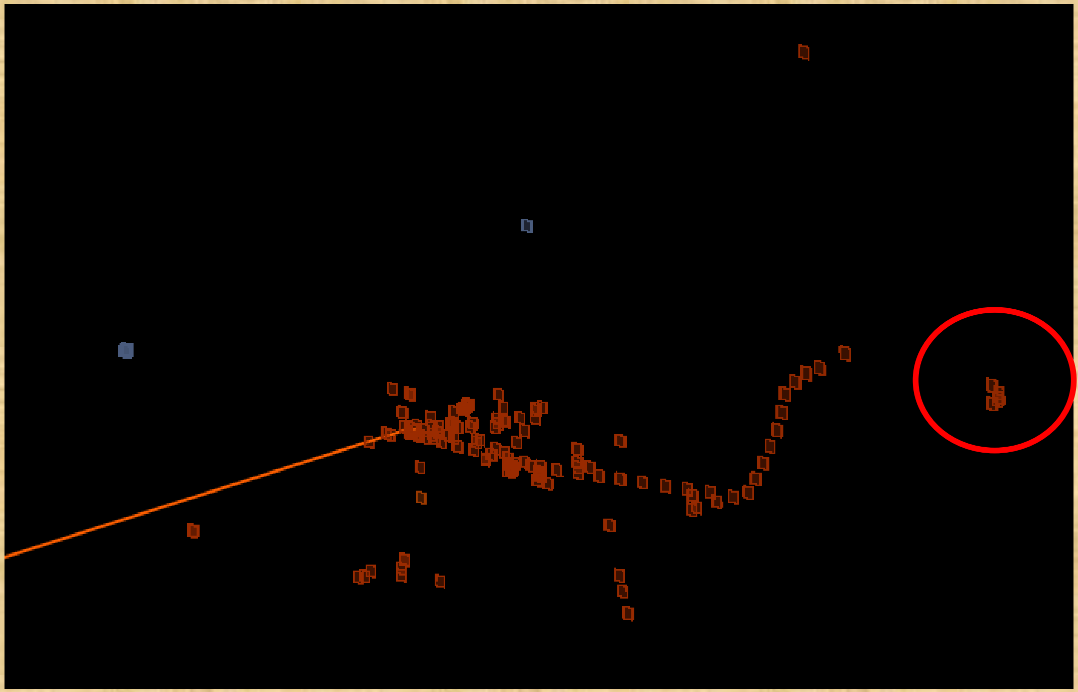
Thickness Result





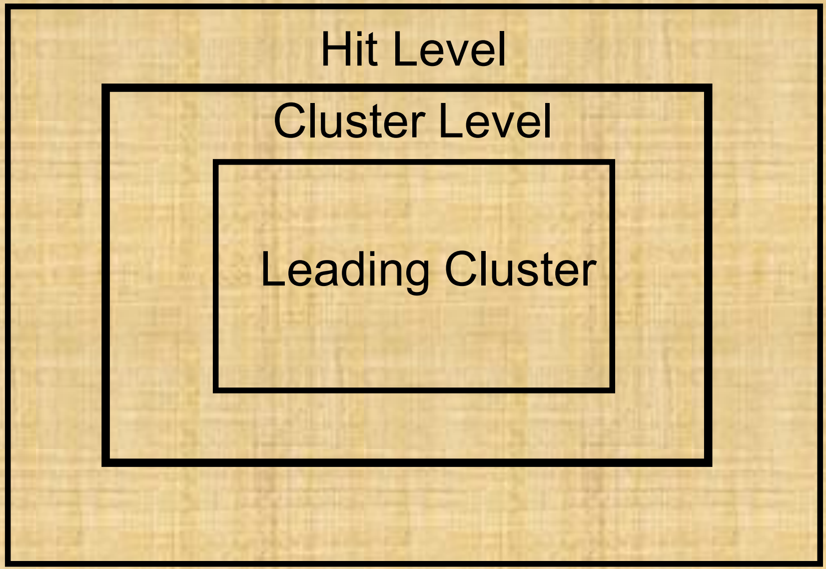
- Improve the energy estimator
- @cluster level || @digitization ---> ?

Part2. Cluster Level



- Check the efficiency of PFA

Benchmark of Cluster Level

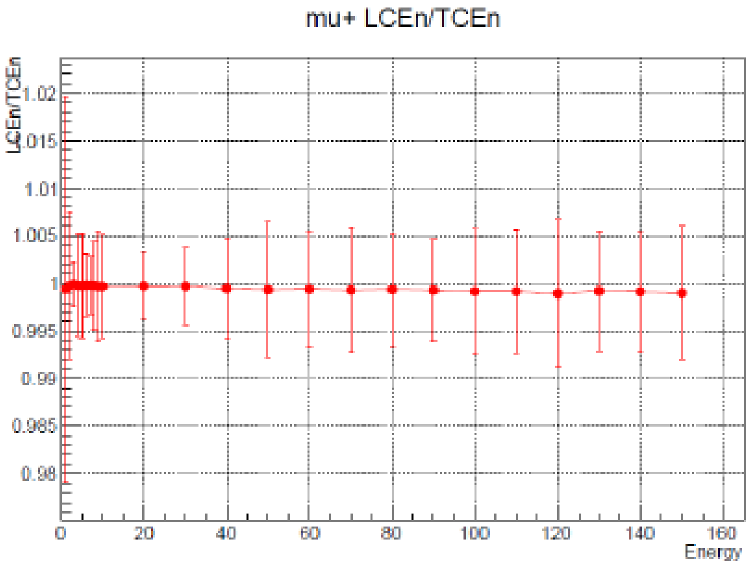


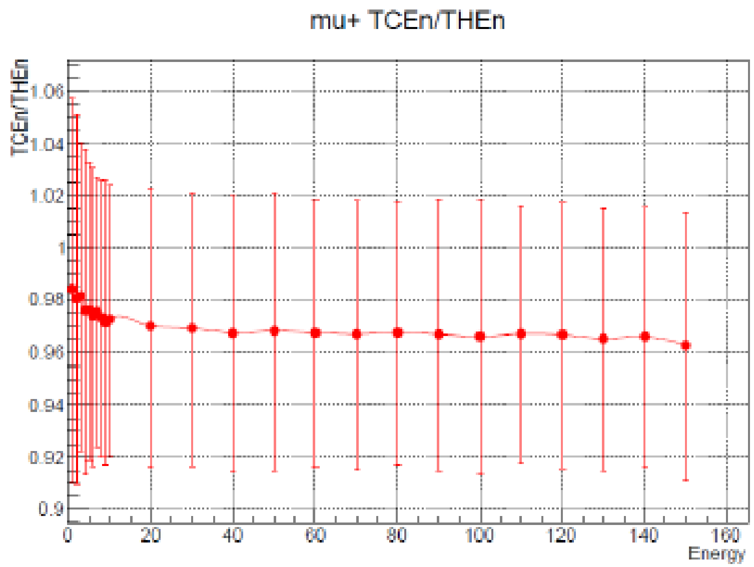
For single particle:

- Hit Level → Total Hit Energy → THEn
- Cluster Level → Total Cluster Energy → TCEn
- Leading Cluster → Leading Cluster → LCEn

- TCEn/THEn: PFA识别效率
- LCEn/TCEn，NClu

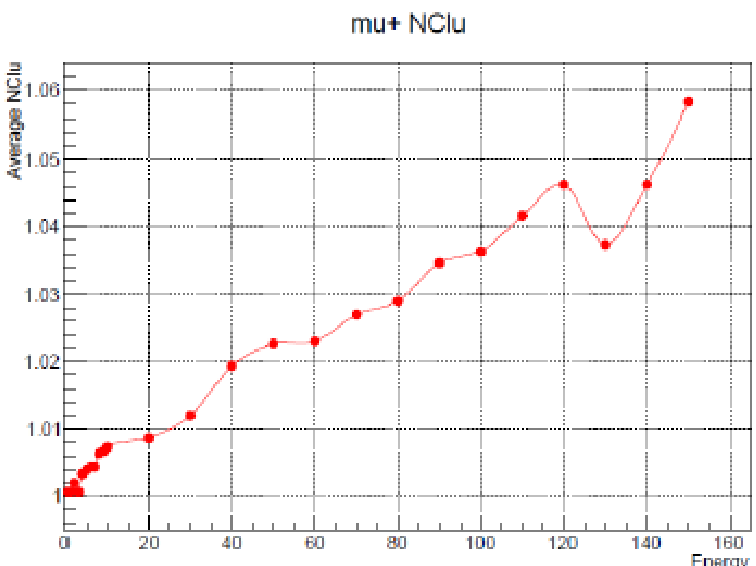
muon的Cluster Level的重建



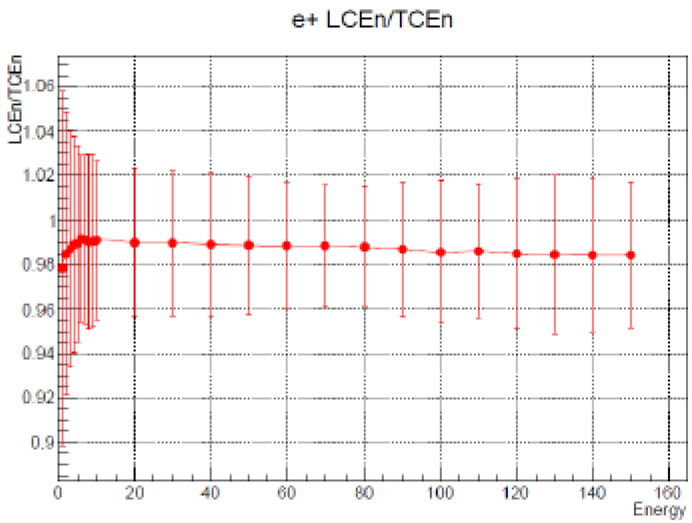


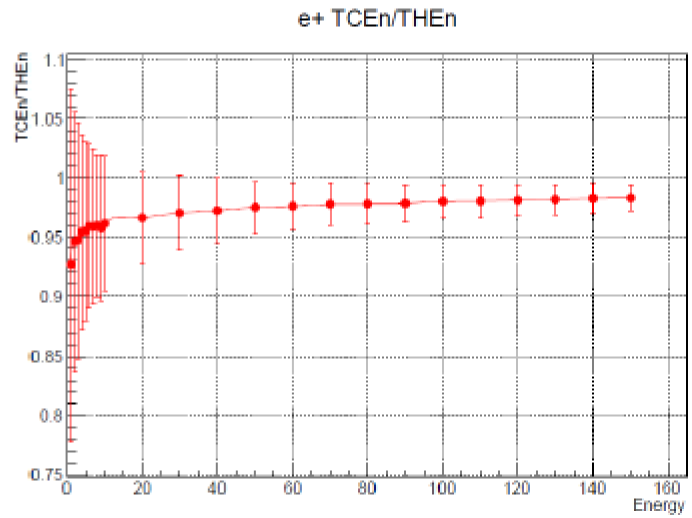
单粒子入射

LCEn: Leading Cluster的重建能量
TCEn: Cluster的总能量
THEn: Hit Level的总能量



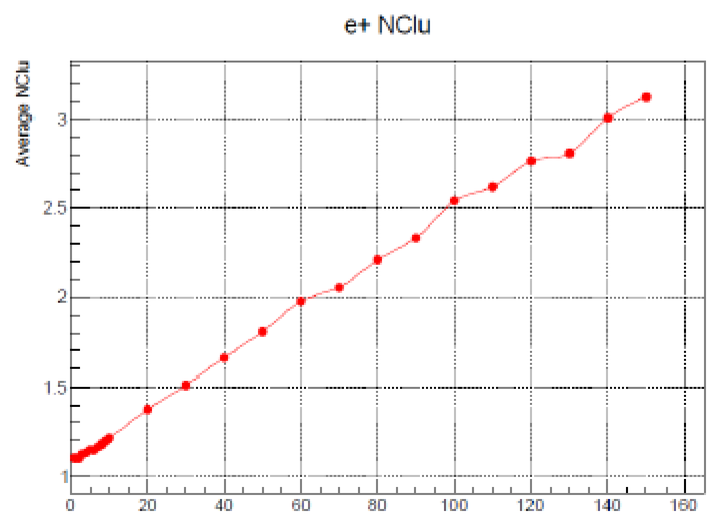
electron的Cluster Level的重建



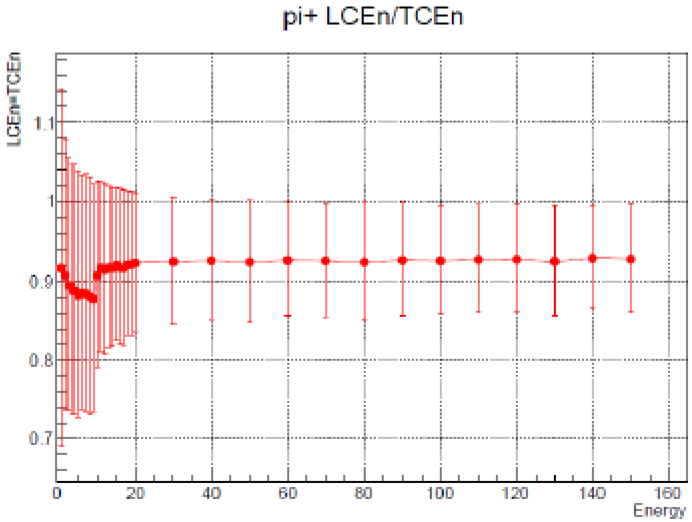


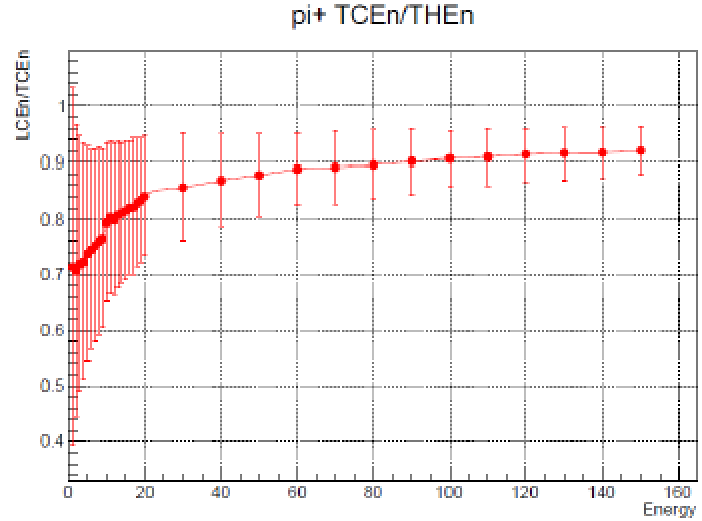
单粒子入射

LCEn: Leading Cluster的重建能量
TCEn: Cluster的总能量
THEn: Hit Level的总能量



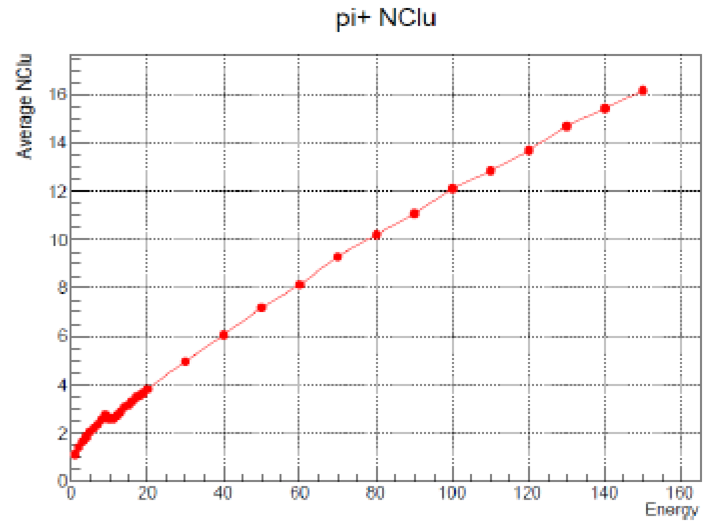
pion的Cluster Level的重建



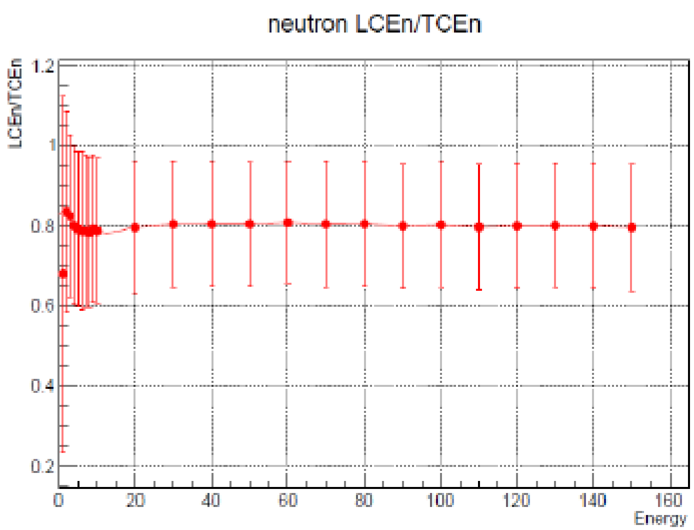


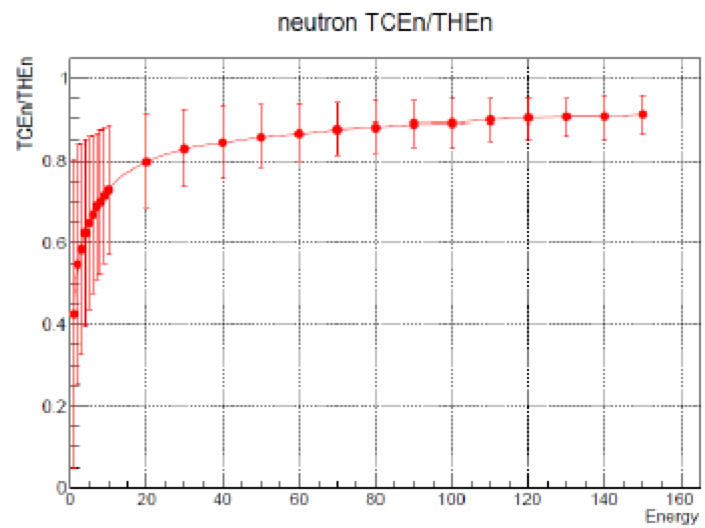
单粒子入射

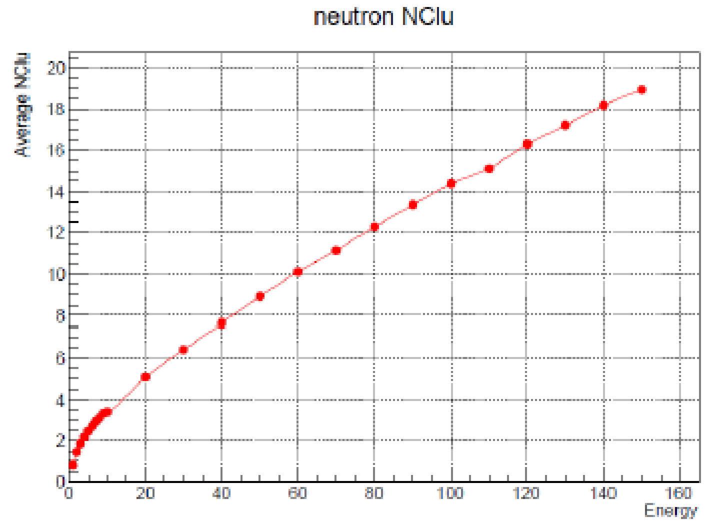
LCEn: Leading Cluster的重建能量
TCEn: Cluster的总能量
THEn: Hit Level的总能量



neutron的Cluster Level的重建





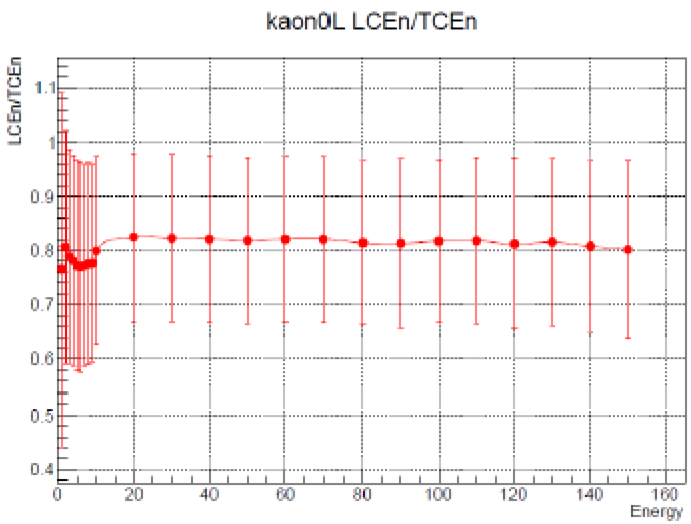


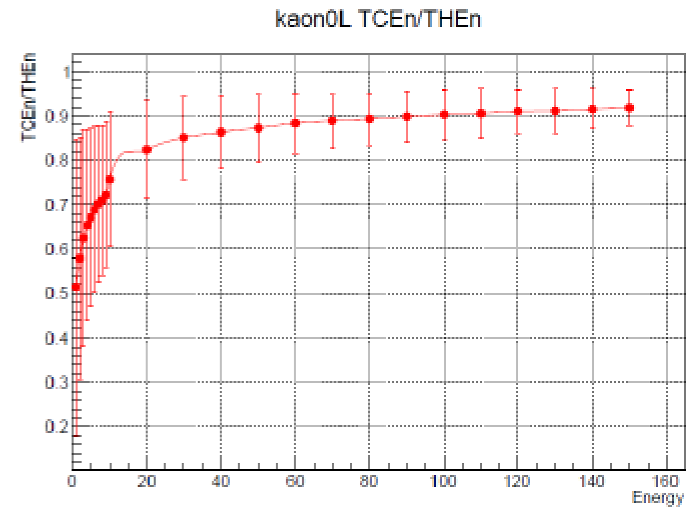
单粒子入射

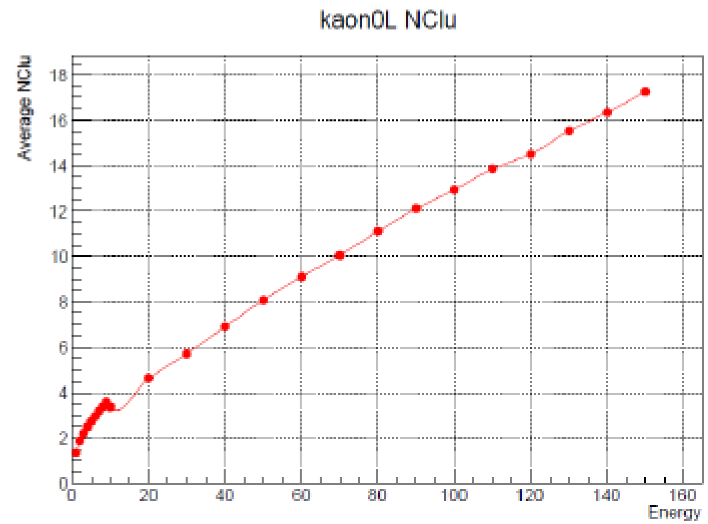
LCEn: Leading Cluster的重建能量
TCEn: Cluster的总能量
THEn: Hit Level的总能量

K0L的Cluster Level的重建

K_{0L}的Cluster Level的重建





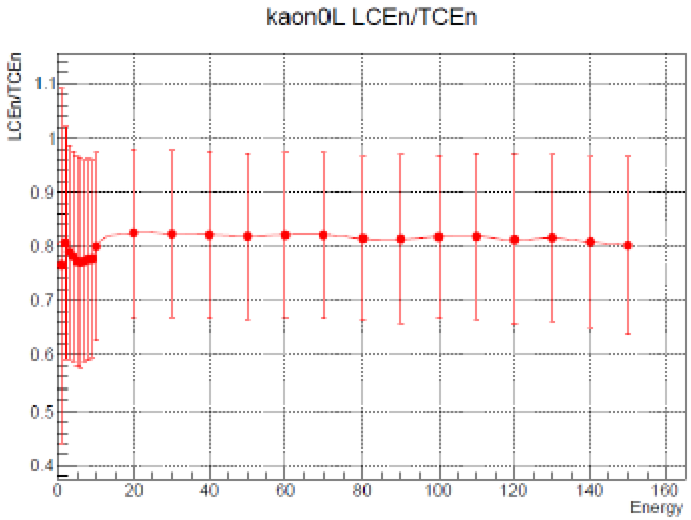


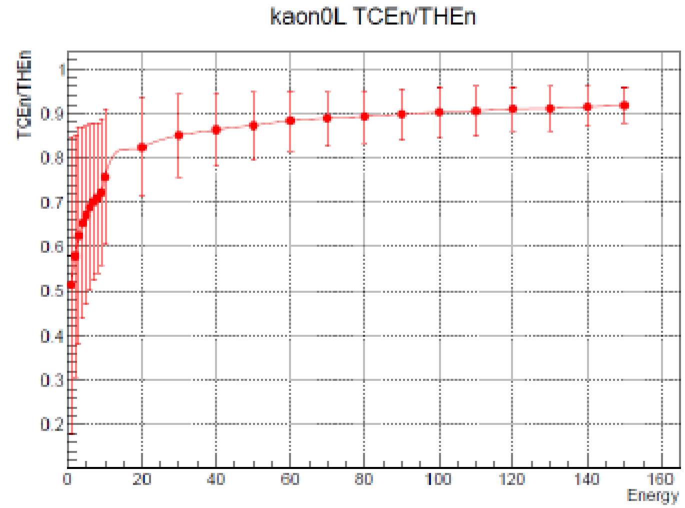
单粒子入射

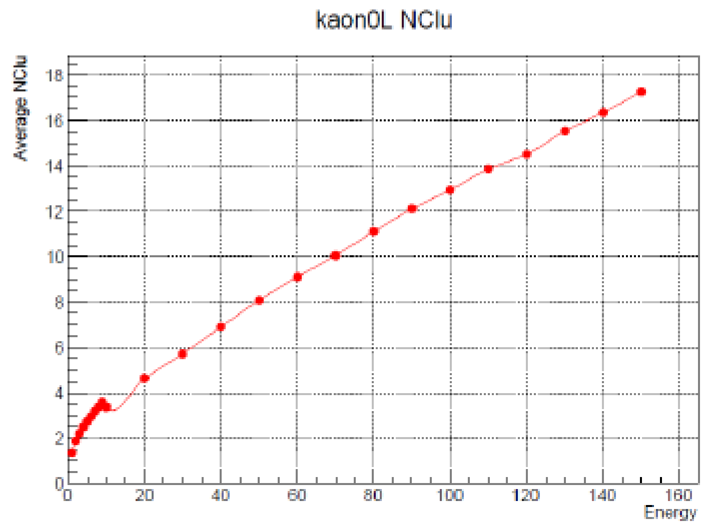
LCEn: Leading Cluster的重建能量
TCEn: Cluster的总能量
THEn: Hit Level的总能量

重建前后Linarity对比

K_{0L}的Cluster Level的重建



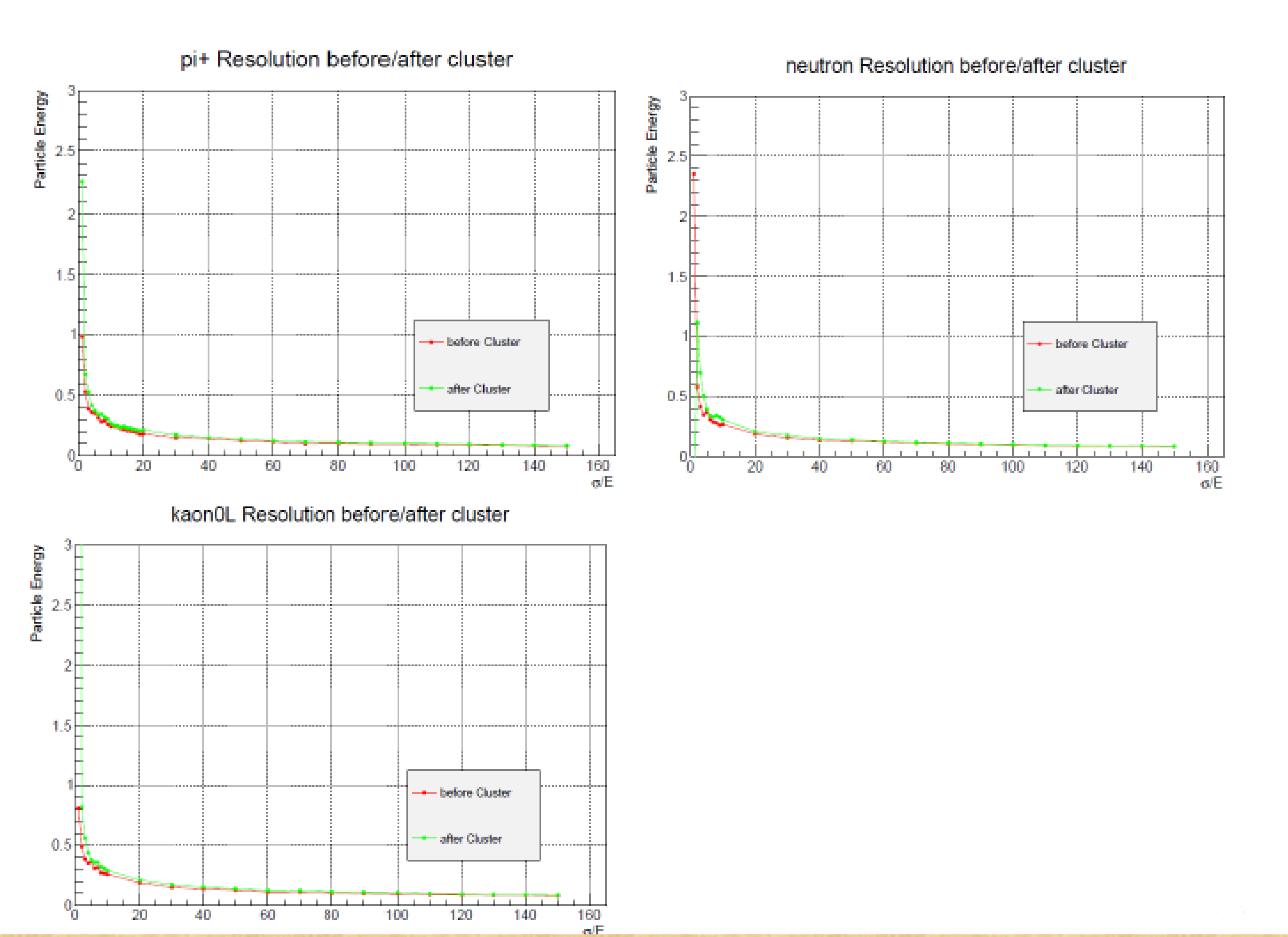




单粒子入射

LCEn: Leading Cluster的重建能量
TCEn: Cluster的总能量
THEn: Hit Level的总能量

重建前后Resolution对比

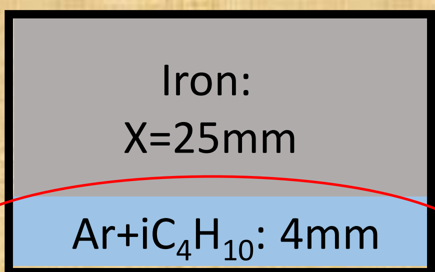


Part3.Digitizer

- 考虑实际的探测器性能
- 数字读出的量能器
- 探测效率的影响
- 探测器位置分辨的影响

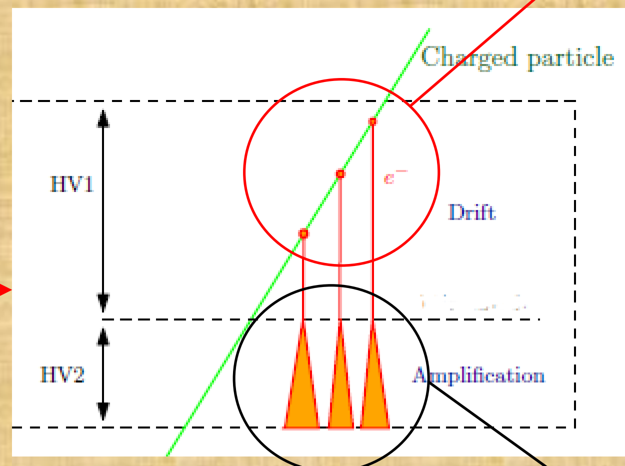
Principle of Gaseous Detector

1. Principle →Spatial Distribution



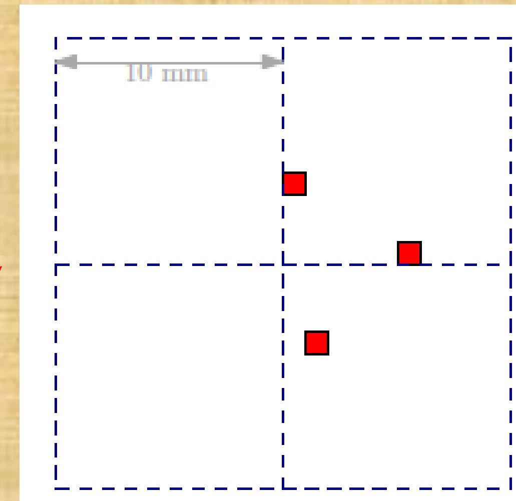
Simulation Detector：

Only gaseous layer



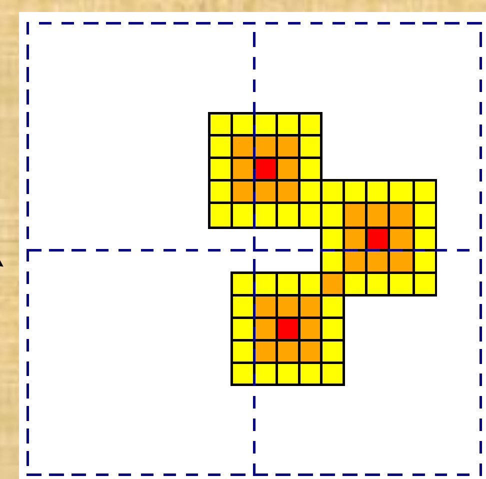
Real Detector：

Drift & Avalanche



Simulation Result：

Only primary ionization



Digitization Result：

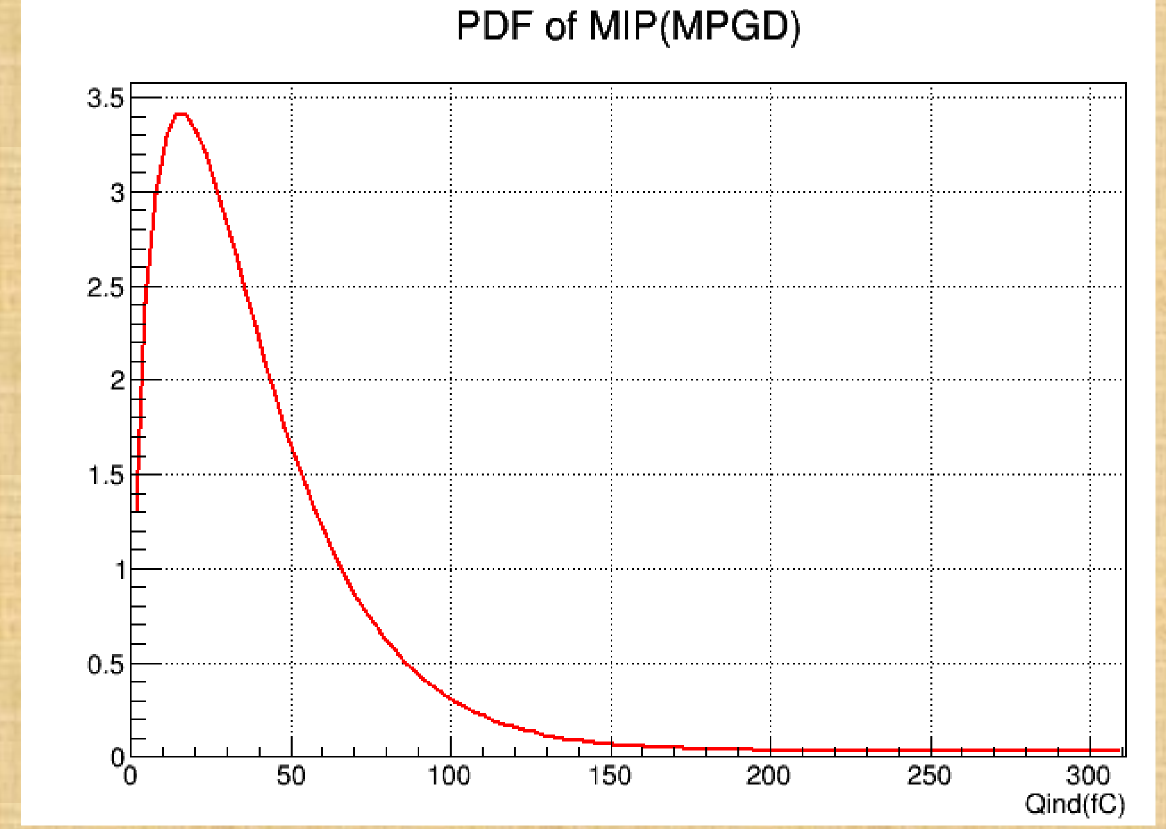
Spatial Distribution

2 Noise → Threshold →Efficiency

Distribution of charge

The Q spectrum of one MIP of induction can be estimated from the Polya PDF defined by:

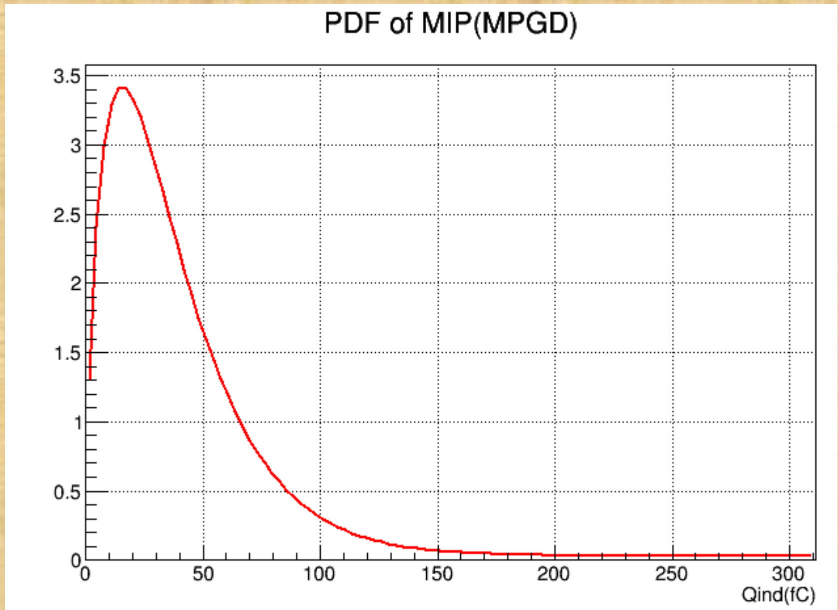
$$P(Q_{ind}; a, b, c) = {Q_{ind}}^{a} e^{-bQ_{ind}} + c$$

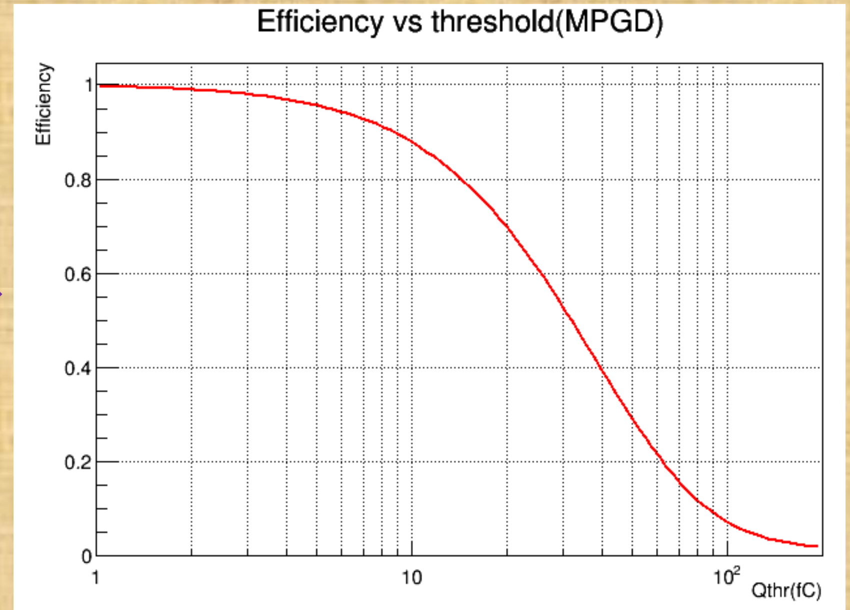


Distribution of charge

The efficiency as the function of threshold Qthr can be expressed by:

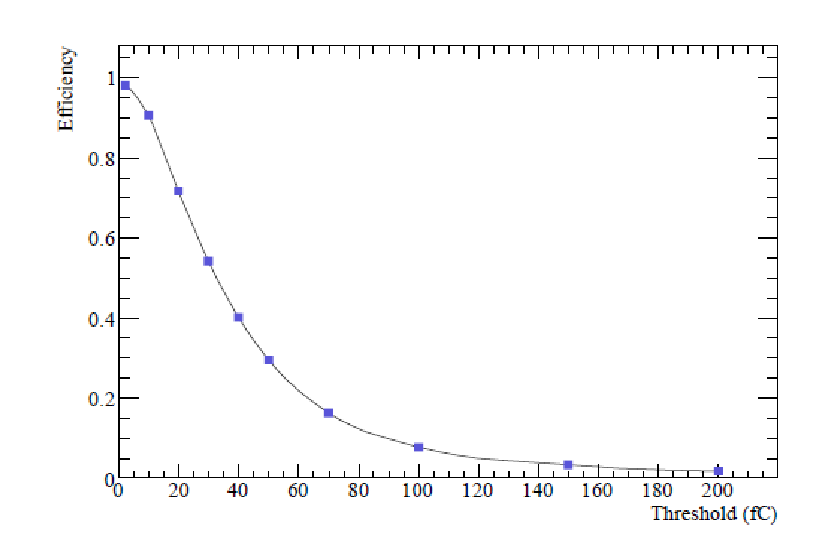
$$\varepsilon(Q_{thr}) = 1 - c\int_0^{Q_{thr}} P(Q_{ind}; a, b, c)\, dQ_{ind}$$

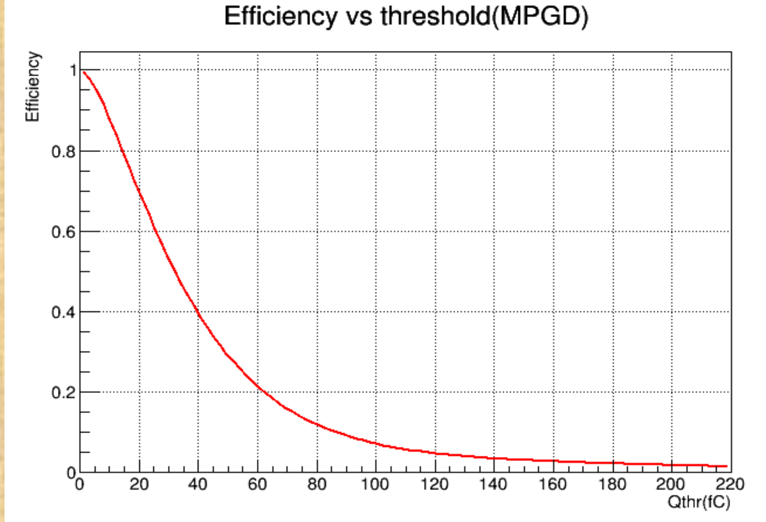




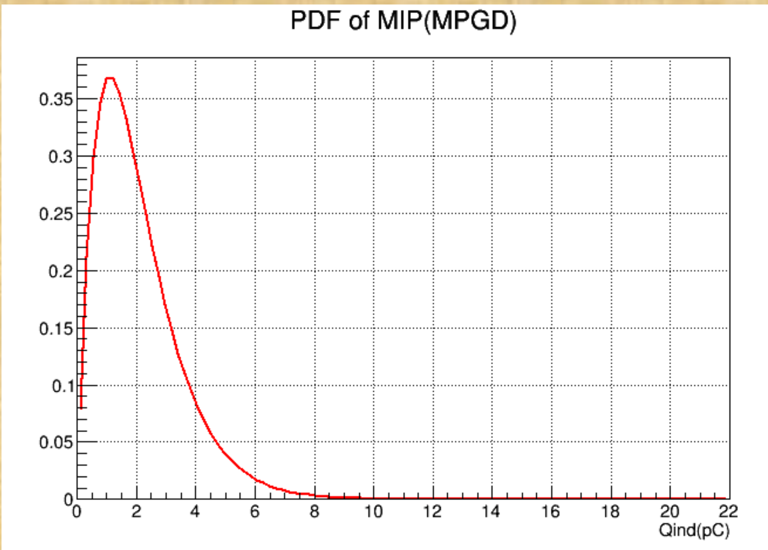
Charge of MPGD

Data from C. A. et al., JINST P11023,2009

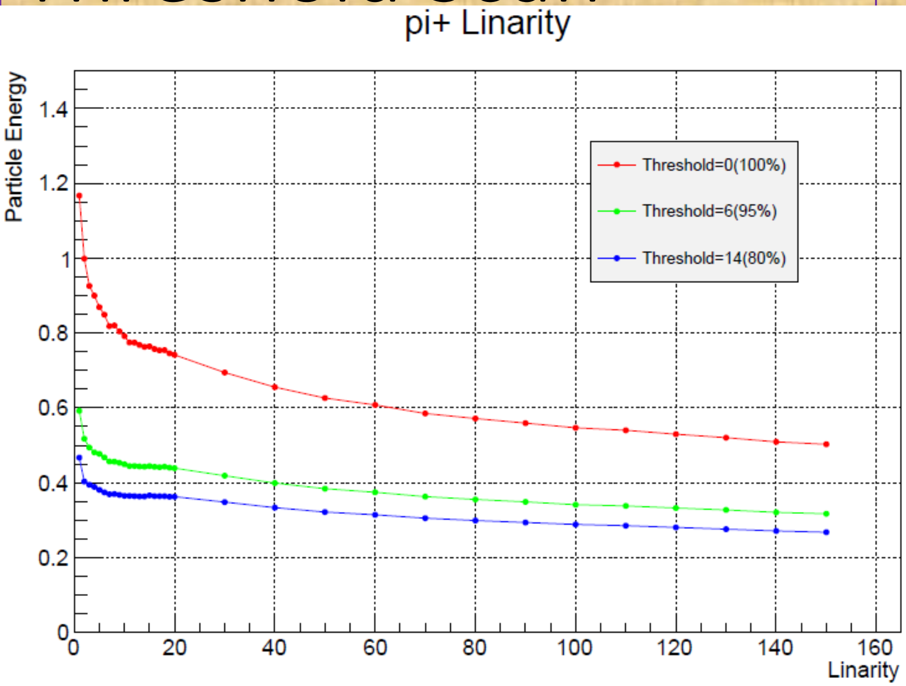


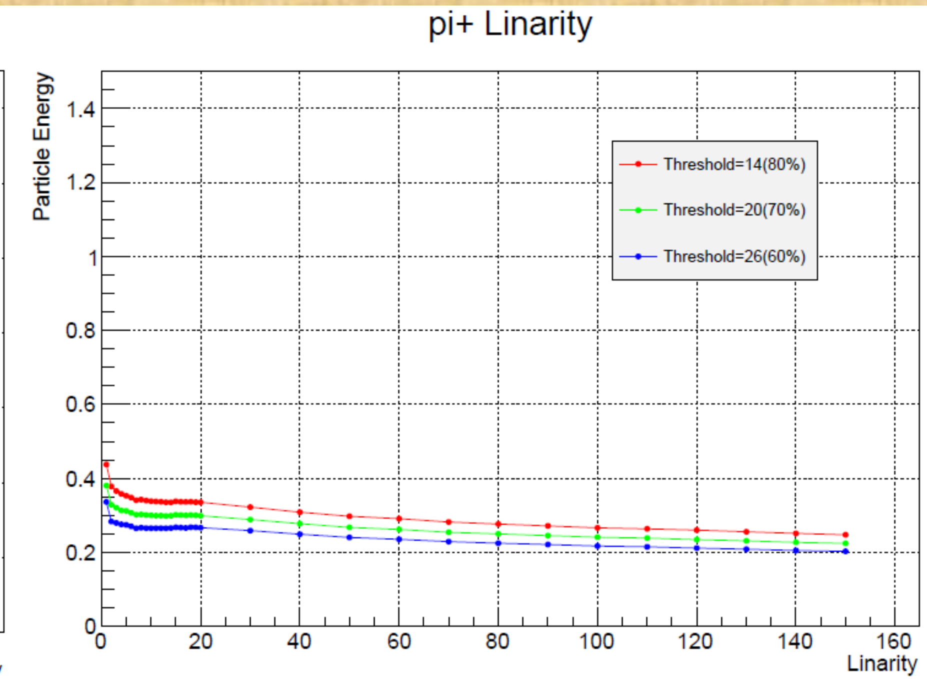


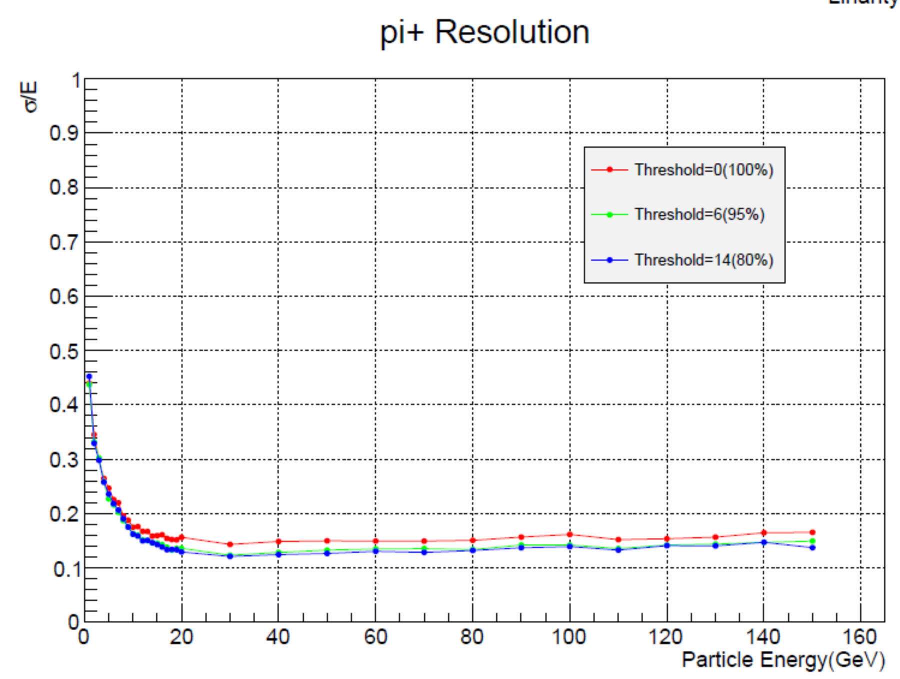
Charge of GRPC

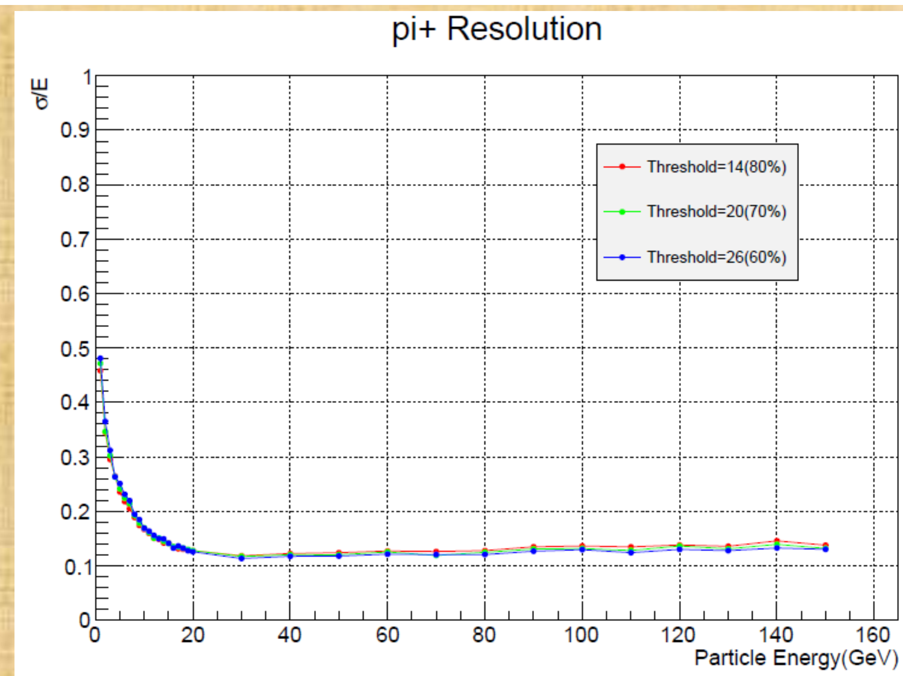


Threshold Scan

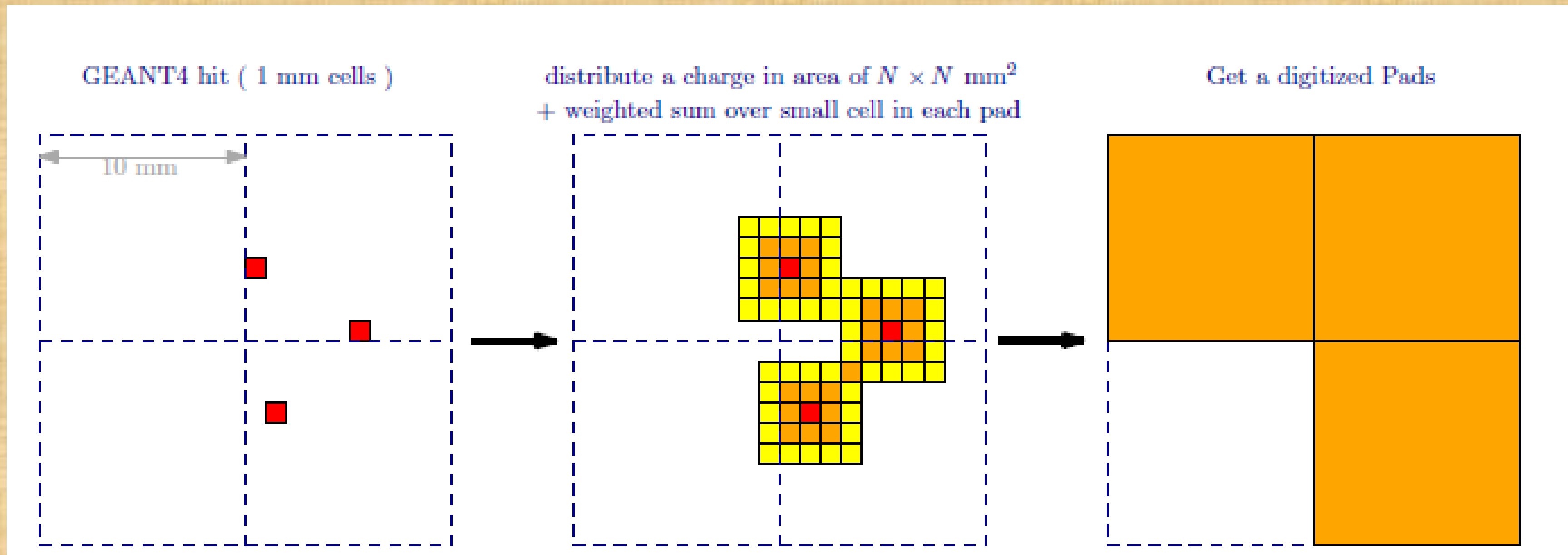


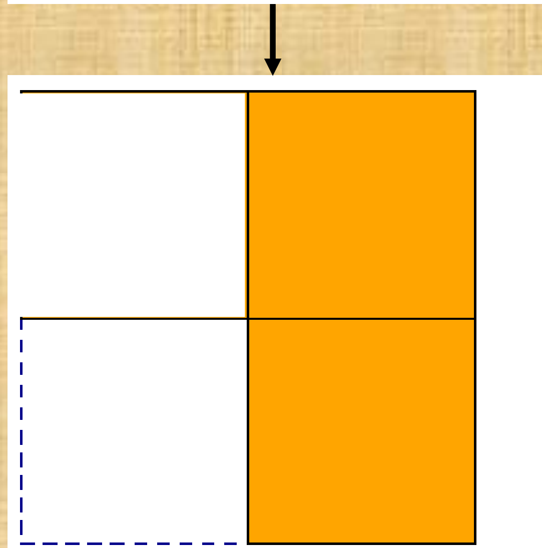






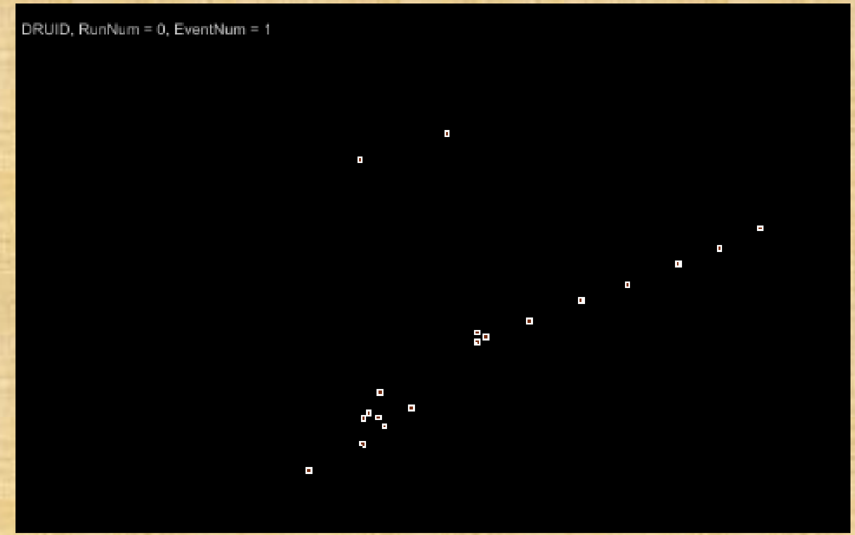
Spitial Distribution

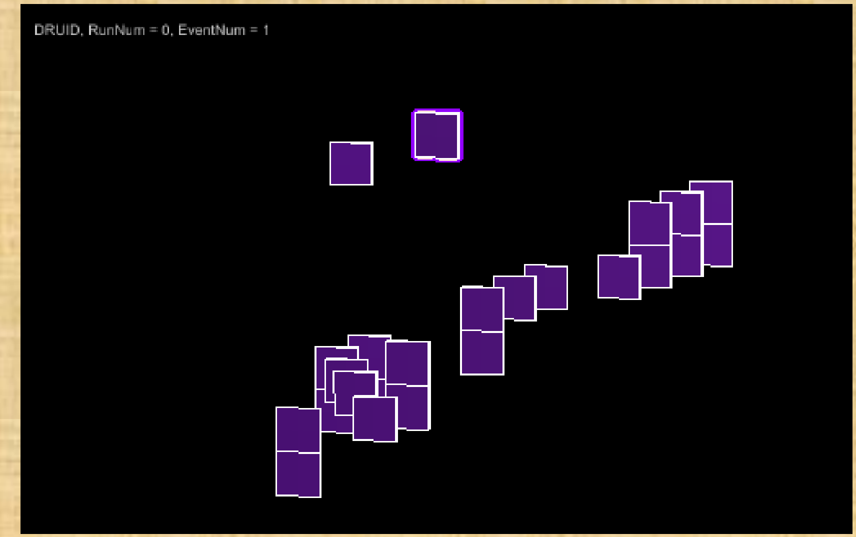


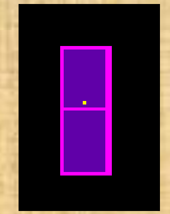


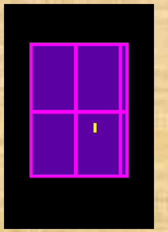
1. 1mmX1mm Cell Size模拟
2. 根据实验的Charge Distribution和Charge X-Y Distribution，将Hit能量转化为电荷量，并按比例分配到不同1cmX1cm格子内
3. 累加所有Hit的响应，每格给予相同能量值

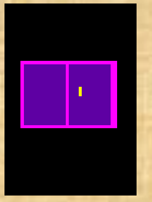
Spitial Distribution



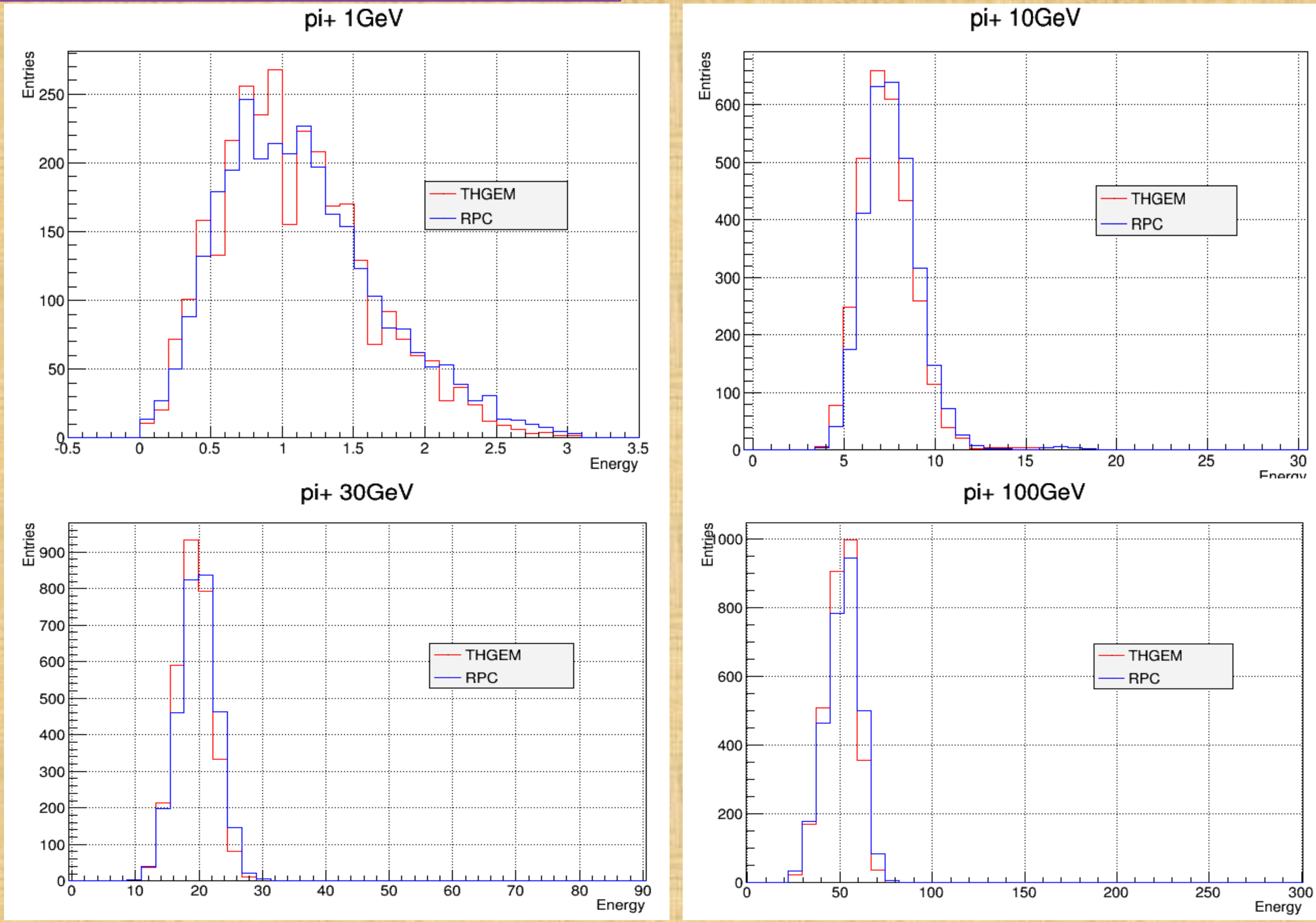






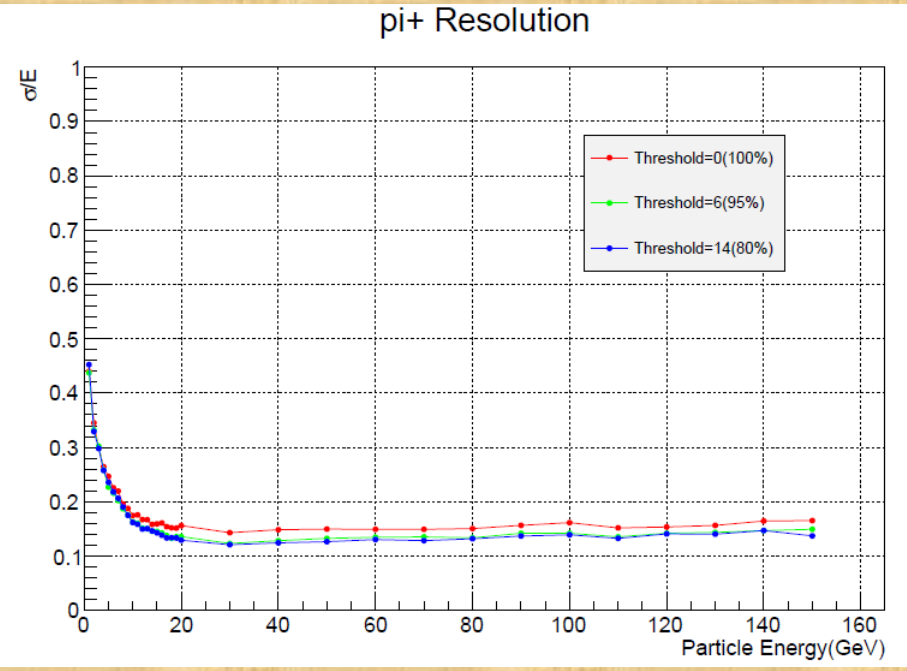


Compare E

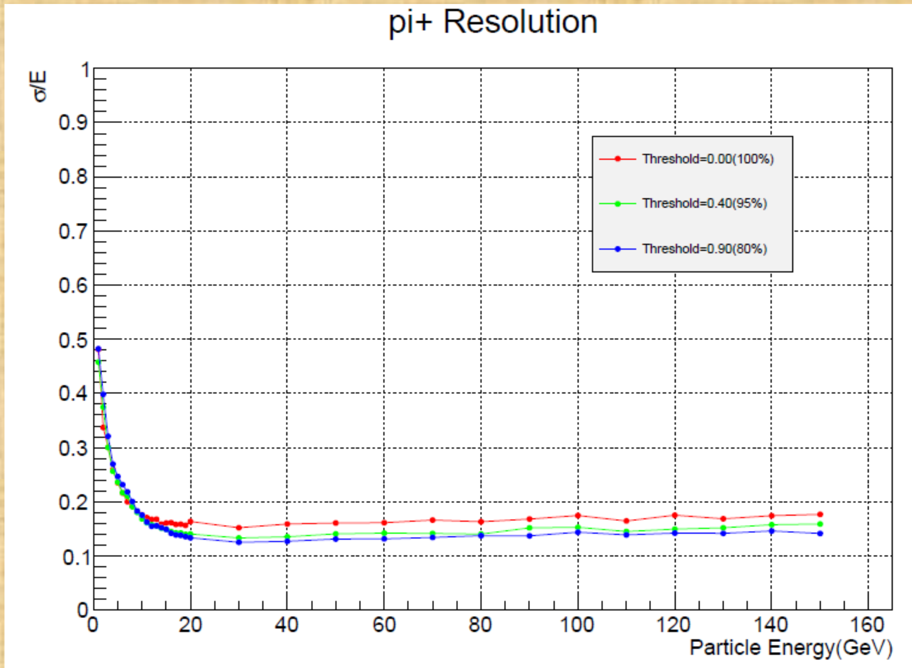


pi+ 1GeV
Entries
Energy
THGEM
RPC
pi+ 10GeV
Entries
THGEM
RPC
pi+ 30GeV
Entries
Energy
THGEM
RPC
pi+ 100GeV
Entries
Energy
THGEM
RPC

Compare R(THGEM)

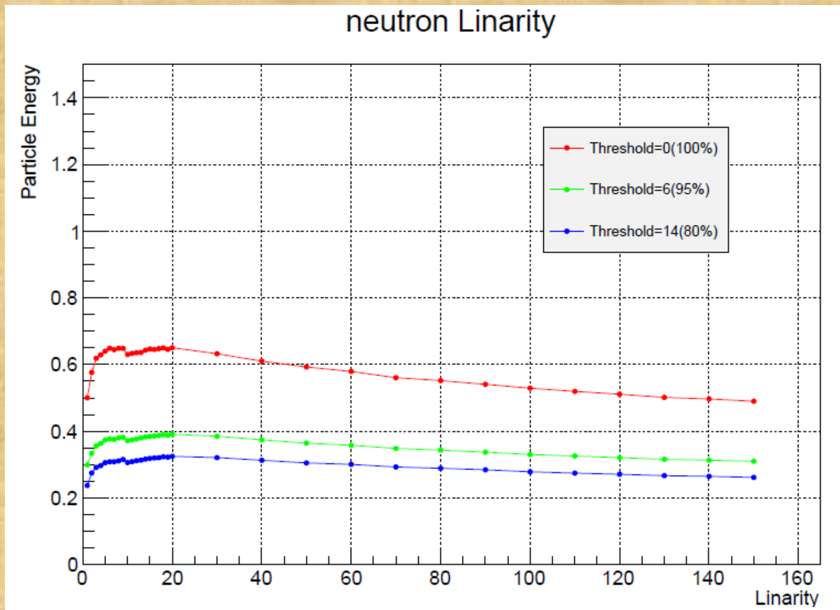


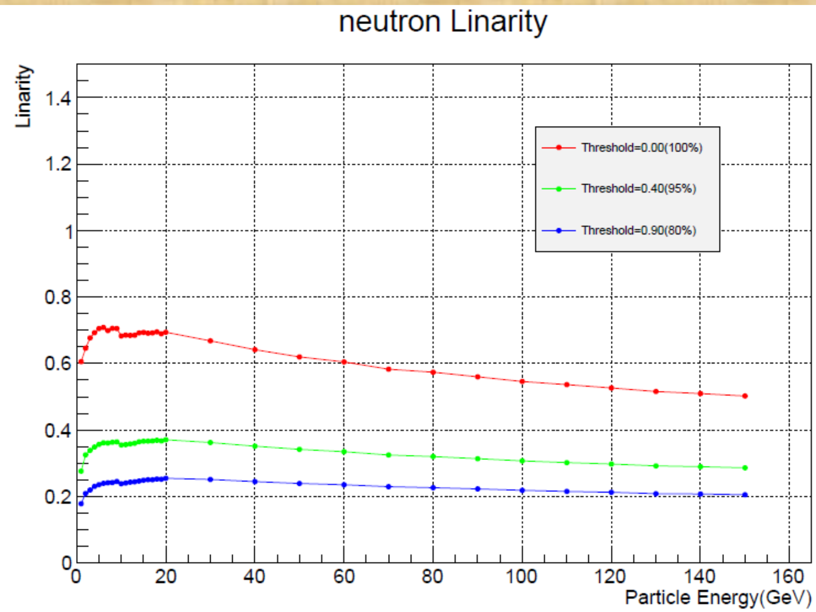
Compare R(GRPC)

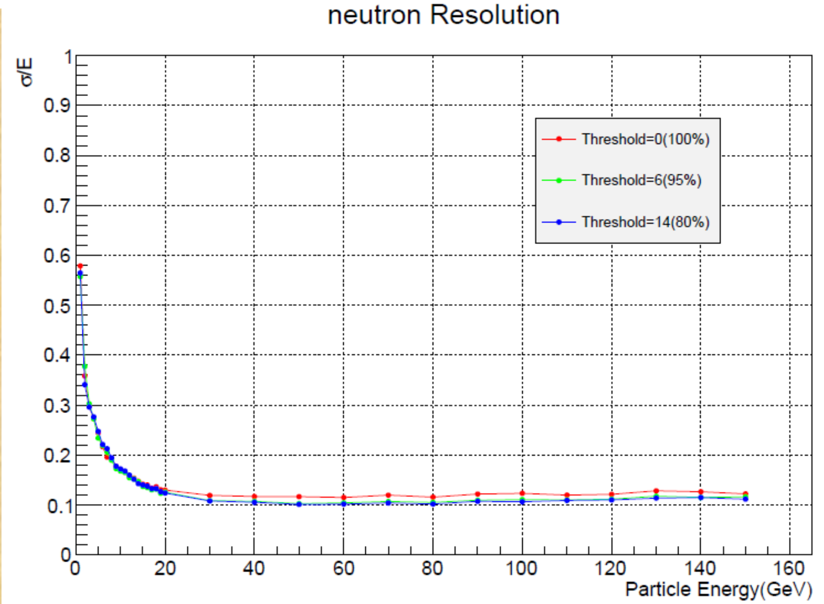


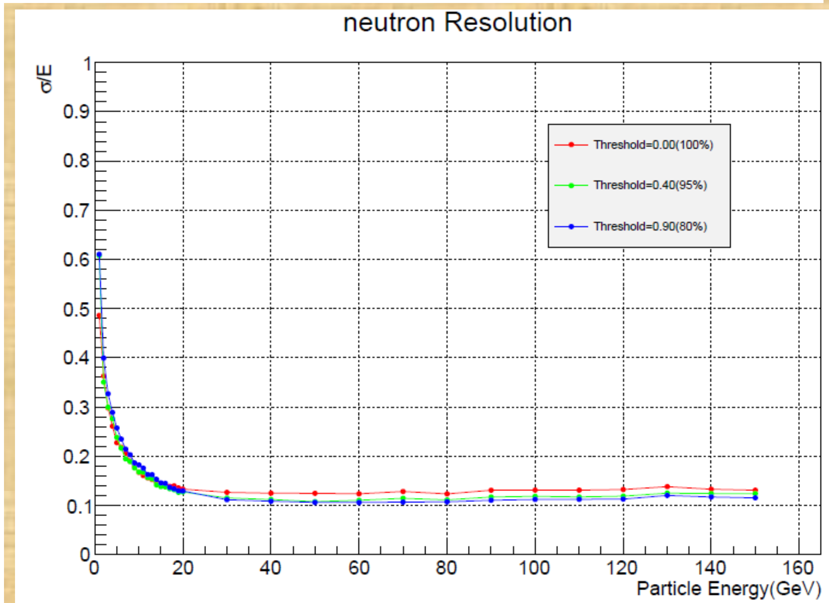
Neutron(THGEM)

Neutron(RPC)



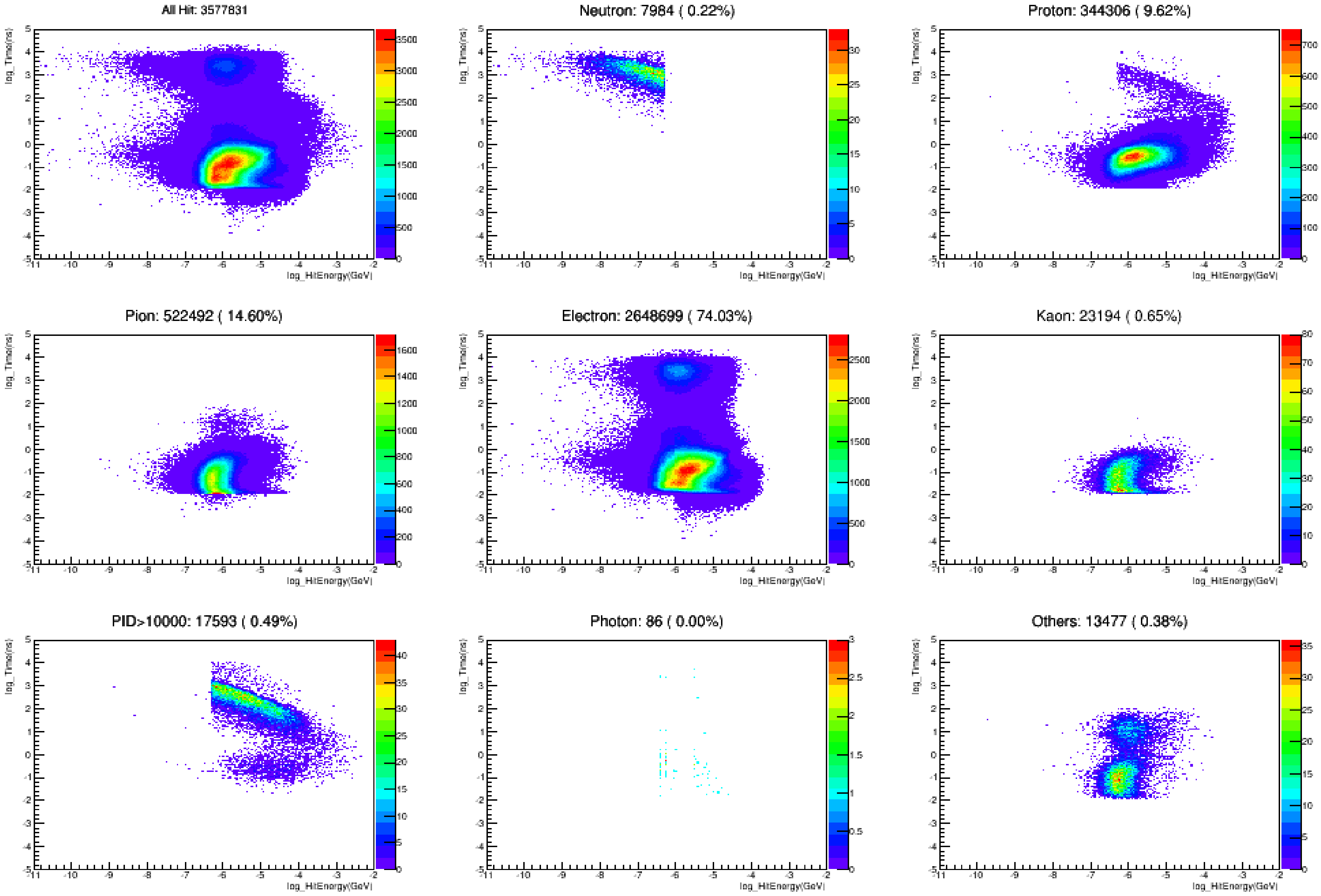




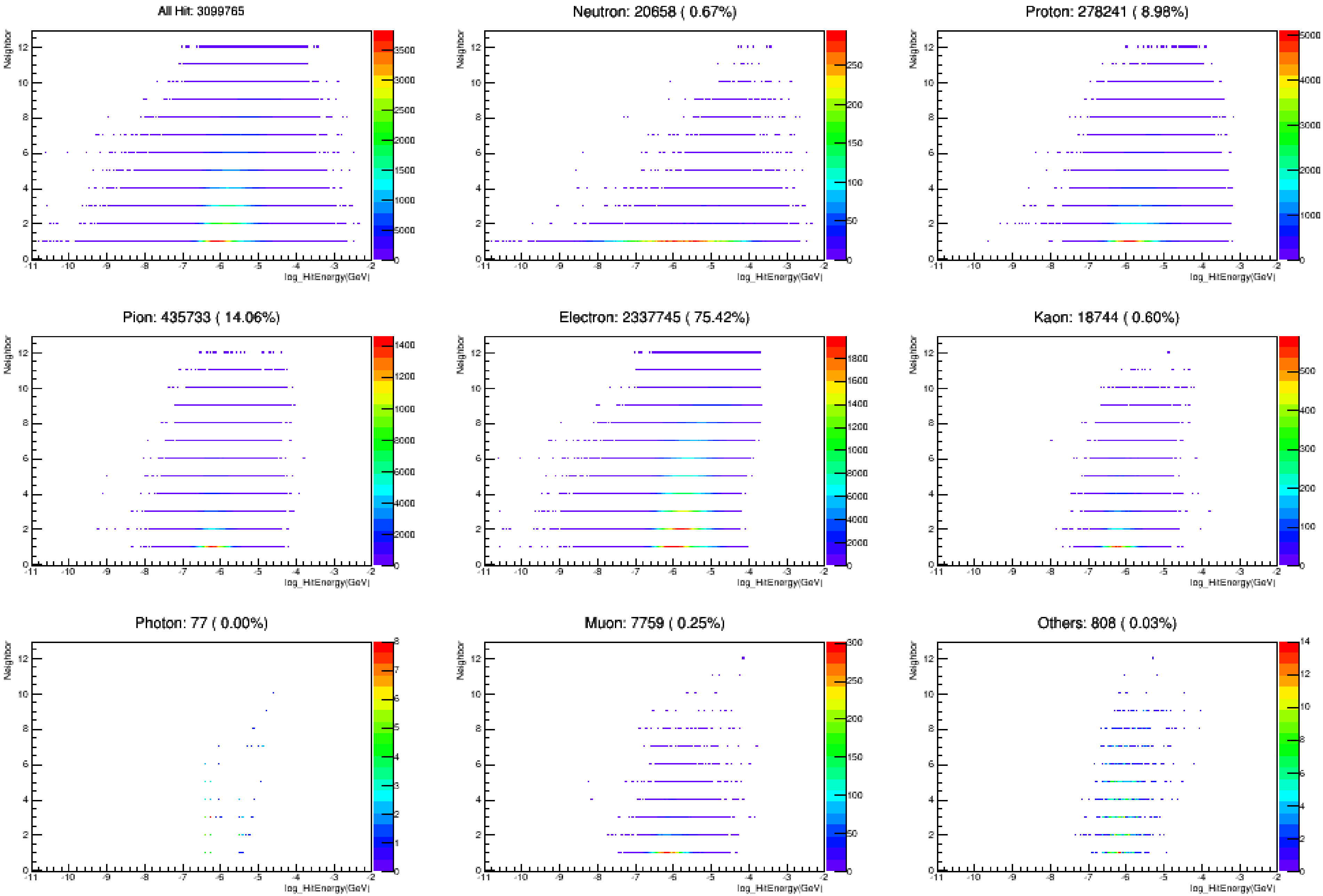


backup

Pion 150GeV 200Layers

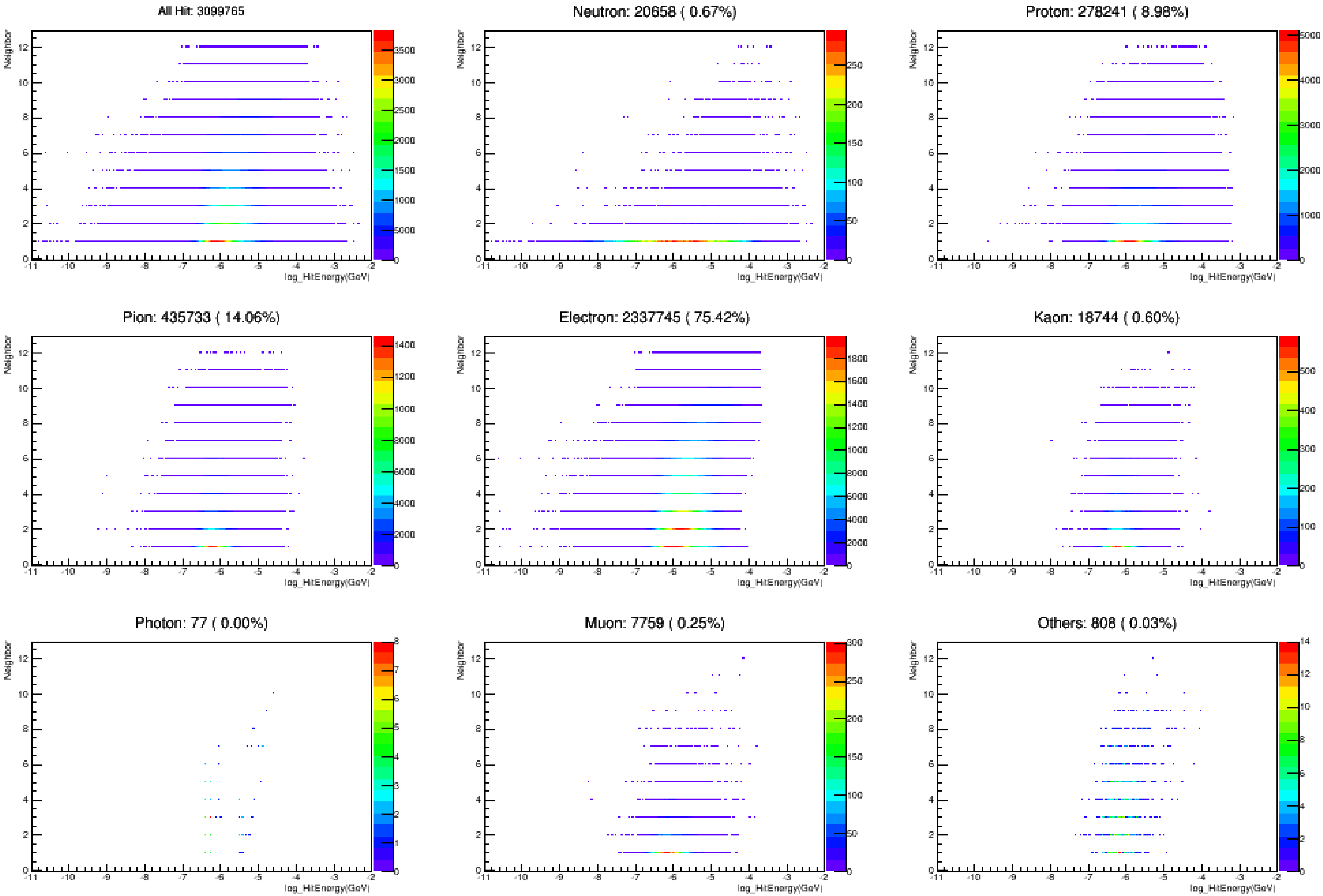


Neibohor



All Hit: 3099765
Neutron: 20658 (0.67%)
Proton: 278241 (8.98%)
Pion: 435733 (14.06%)
Electron: 2337745 (75.42%)
Kaon: 18744 (0.60%)
Photon: 77 (0.00%)
Muon: 7759 (0.25%)
Others: 808 (0.03%)
Neighbor
log_HitEnergy(GeV)

Neibohor


All Hit: 3099765
Neutron: 20658 (0.67%)
Proton: 278241 (8.98%)
Pion: 435733 (14.06%)
Electron: 2337745 (75.42%)
Kaon: 18744 (0.60%)
Photon: 77 (0.00%)
Muon: 7759 (0.25%)
Others: 808 (0.03%)
Neighbor
log_HitEnergy(GeV)