GLD PFA REVIEW

Snowmass 2005/08/17

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.....

Content

- **Cheated PFA**
  - **To understand the leading components of jet energy resolution**
  - **To know the ultimate jet energy resolution**

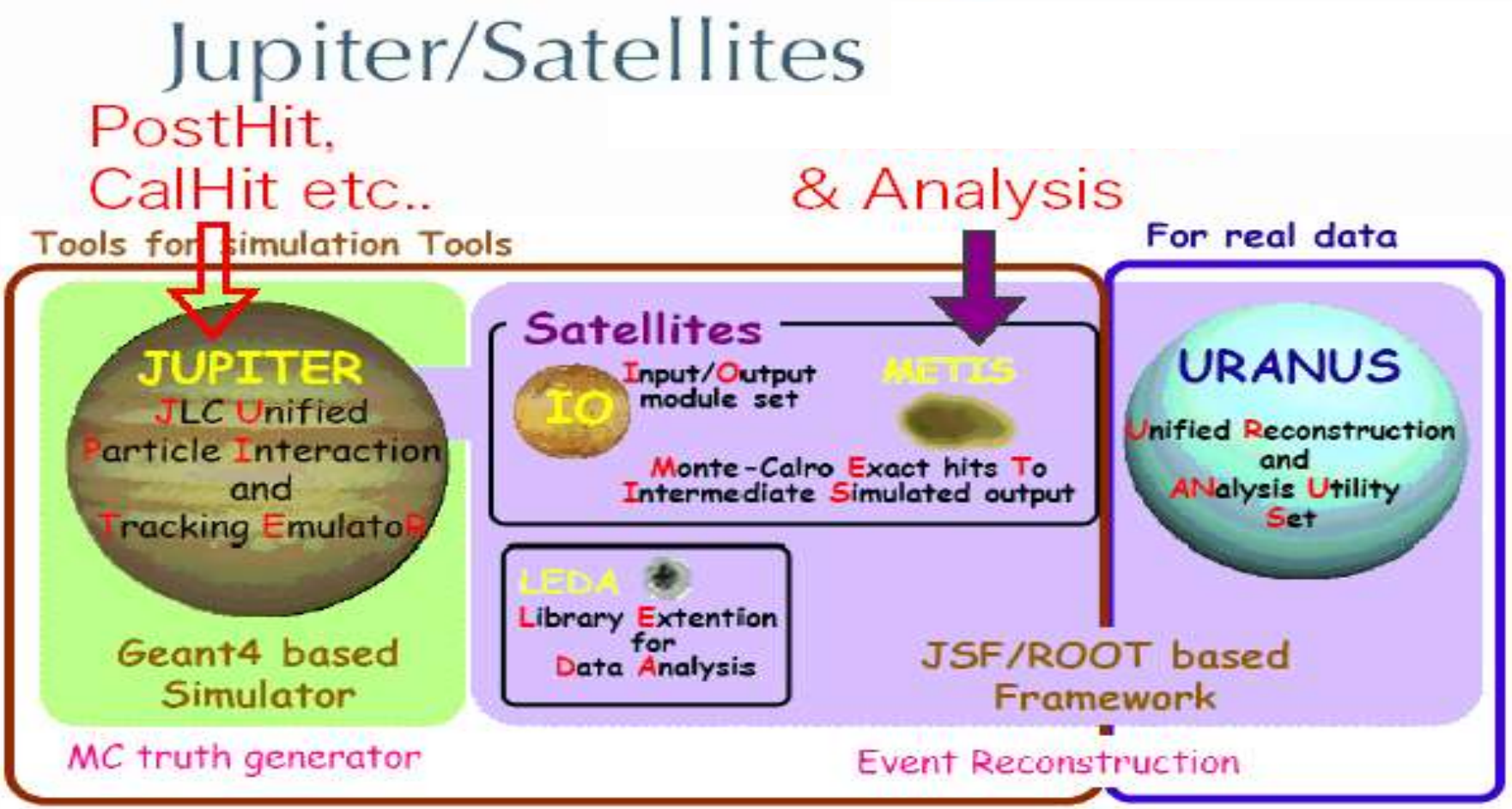
  (Based on the ACFA8 Talk, S. Yamamoto)

- **Realistic PFA**
  - **To optimize the PFA itself**

  (Based on the ACFA8 Talk, T. Yoshioka & T. Fujikawa)

- **Realistic PFA with MST clustering**
  - **In the very beginning status, no result yet (*A.L.C. Sanchez*)**
- **Plan in the Snowmass**

Simulation Tools

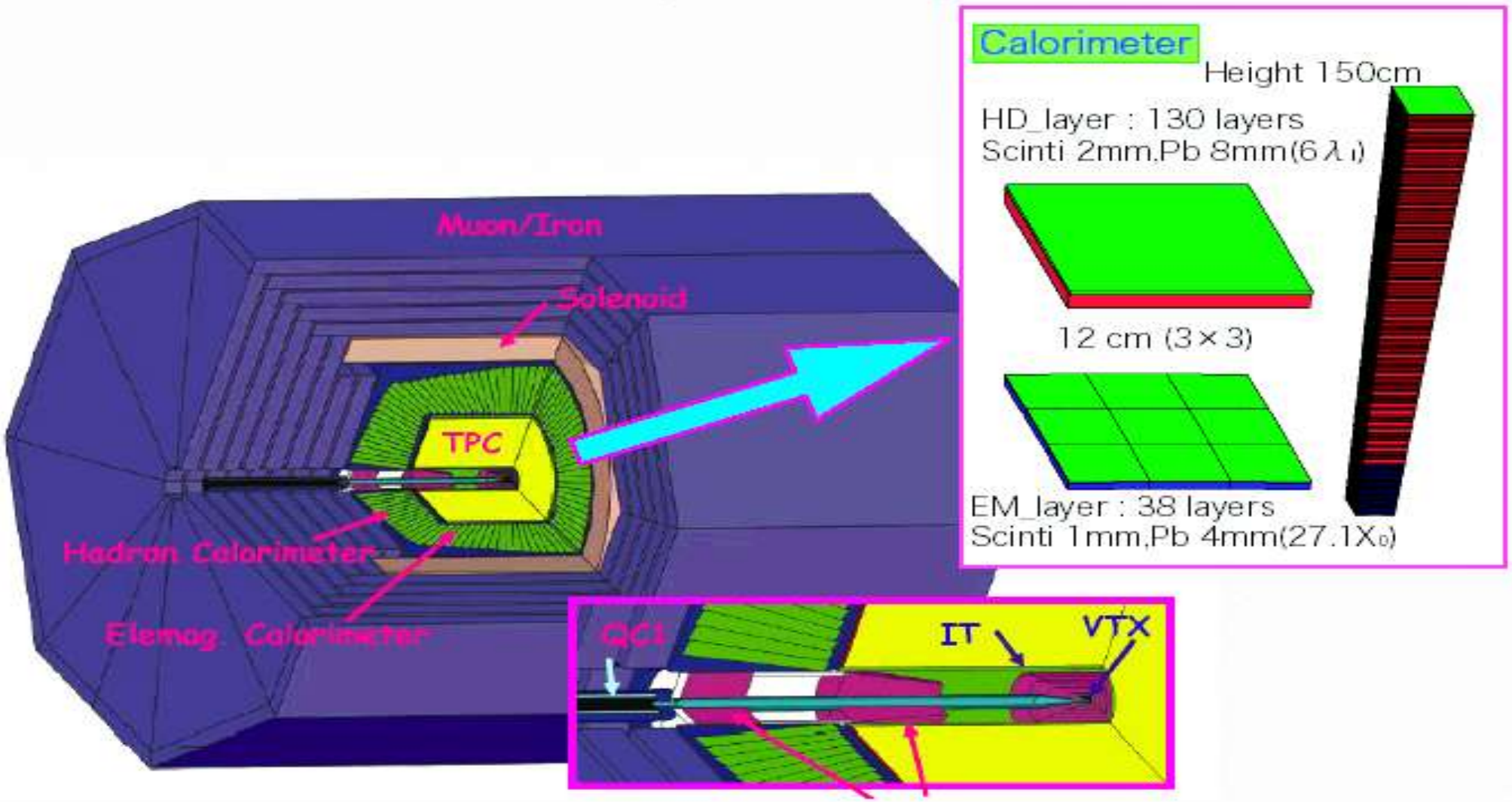


JSF: the analysis flow controller based on ROOT
The release includes event generators, Quick Simulator,
and simple event display

➡ Geant4.7.0.p01 & root_v4.04/02

Simulation Tools

Geometry



Cheated PFA

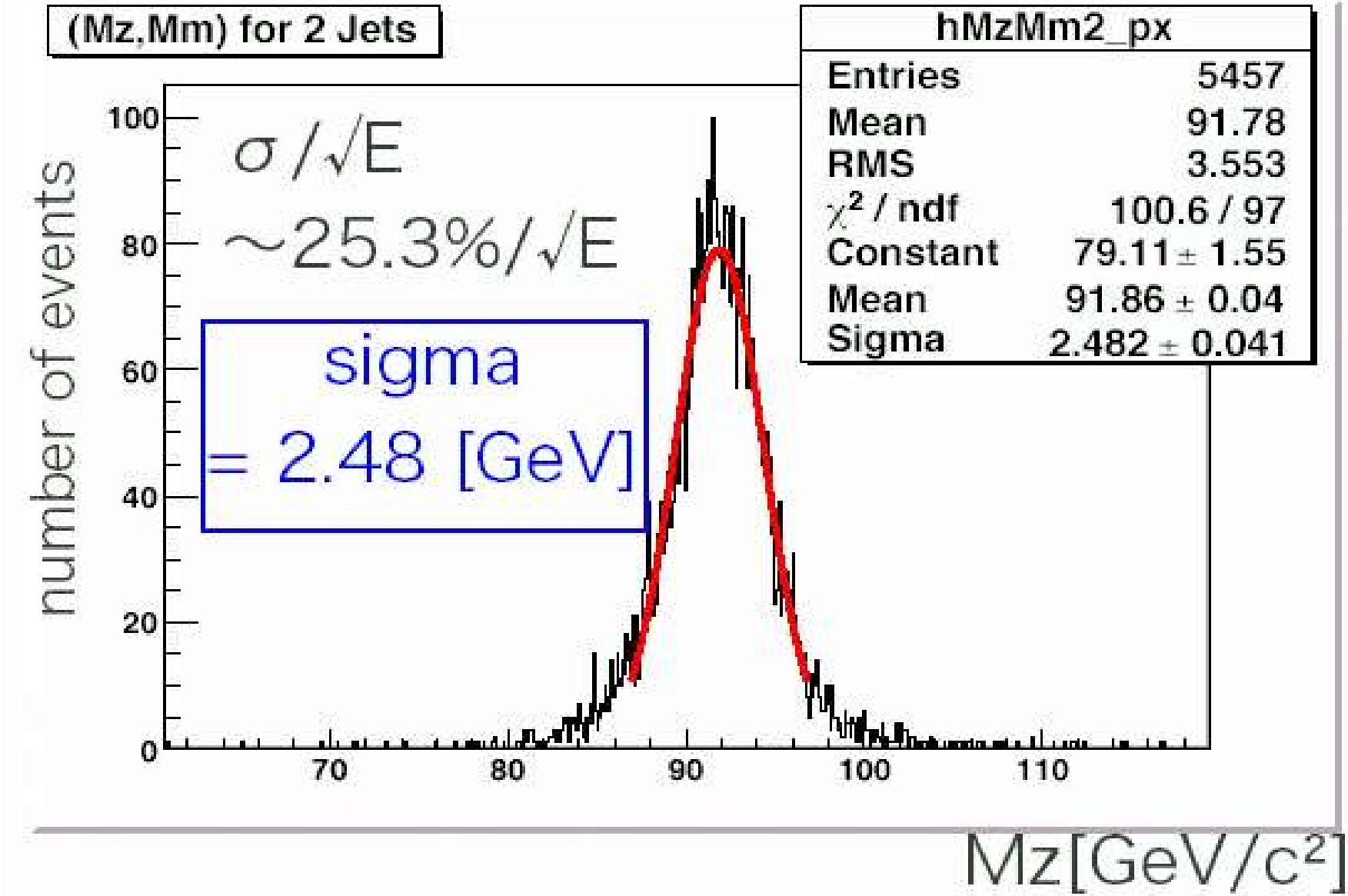
- **Some Jargons:**
  - **Particle Flow Object (PFO): a particle flow inside the detector from IP to CAL**
  - **Charged PFO: PFO with track-> a charged particle**
  - **Neutral PFO: PFO without track -> a neutral particle**
  - **PostHit (post TPC Hit): a virtual hit point which is created for any potential cluster parent (including neutrino) at the exiting point from the TPC gas volume.**

Cheated PFA

- **Possible candidates which may affect the Jet Energy Resolution:**
  - **Kink -- Done**
  - **CAL resolution and acceptance -- Done**
  - **Tracker resolution and acceptance -- Done**
  - **Calibration Method**
  - **Smearing**
  - **V0 (neutral particles decay into 2 charged particles, say, Ks and Λ)**
  - **Neutrino (invisible energy)**
  - **PID**
  - **…**

Cheated PFA

Z->q q-bar (q= u,d,s) @ 91.187 GeV



Cheated PFA

- **Status:**
  - **We have investigated various factors that contribute to jet energy resolution.**
  - **The unknown 1.16 GeV needs to be explained.**

	Sigma	Contribution
Total	2.48 GeV	100%
HD	1.70 GeV	48%
EM	1.36 GeV	30%
Track	0.00 GeV	0%
Unknown	1.16 GeV	22%

Realistic PFA

Procedure:

1.

Clustering (collect contiguous fired cells)

Gamma Finder (Separate gamma from e and hadron)

2.

Cluster-Track Matching (Separate charged particles from neutral particles)

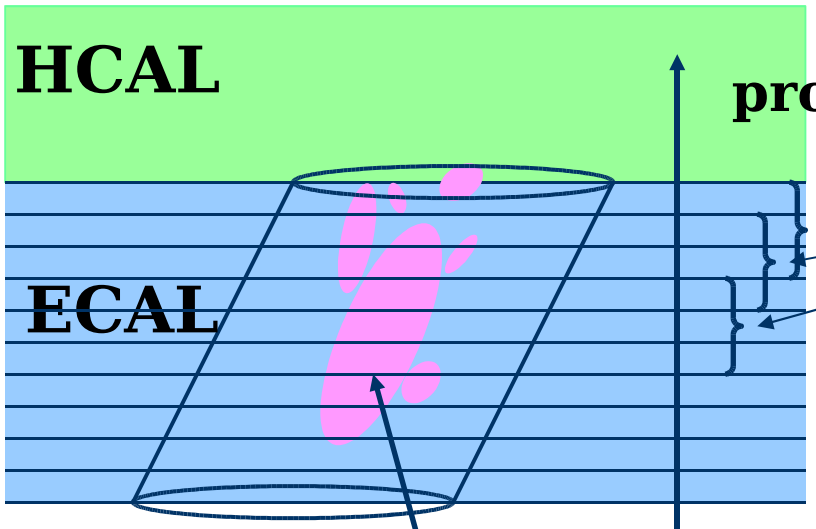
Note:

- → Cheating method is used for charged hadrons in the Endcap region.
- → Assuming the remaining clusters be neutral hadrons.

Realistic PFA

Gamma Finder

Choose the most energetic small cluster within ECAL region and make a small tube (R = 5cm) along to its thrust axis. Fit the longitudinal shower profile of the energy deposition within a tube as an electromagnetic cascade (gamma distribution function).



take an average of energy deposit for every 3-layers

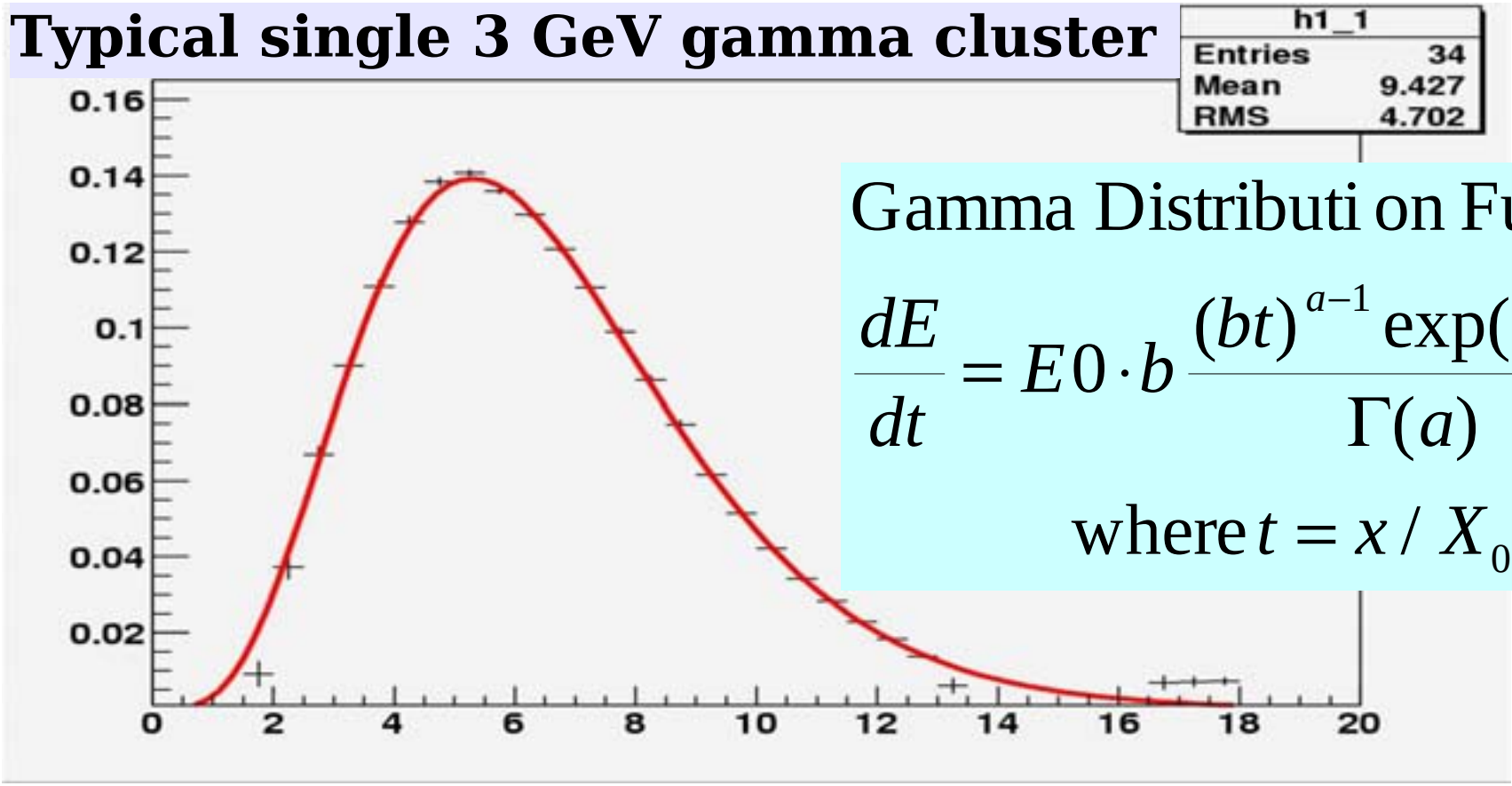
Energy deposit in three layers are averaged to reduce the fluctuations.

Realistic PFA

Gamma Finder

The small fitting Chisqure is the first requirement to separate the gamma from hadrons

Typical single 3 GeV gamma cluster



Gamma Distribution Function

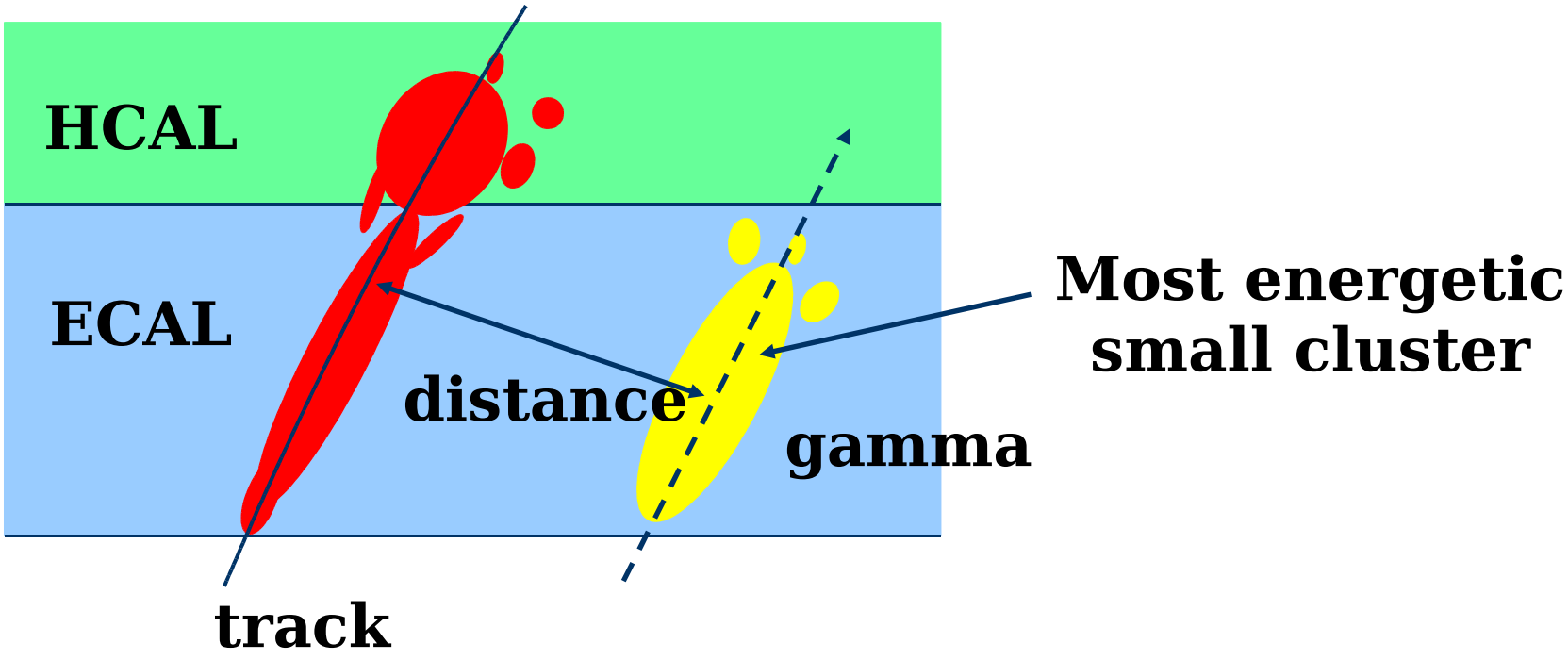
$$\frac{dE}{dt} = E0 \cdot b \frac{(bt)^{a-1} \exp(-bt)}{\Gamma(a)}$$

where $t = x / X_0, b \cong 0.5$

Realistic PFA

Gamma finder

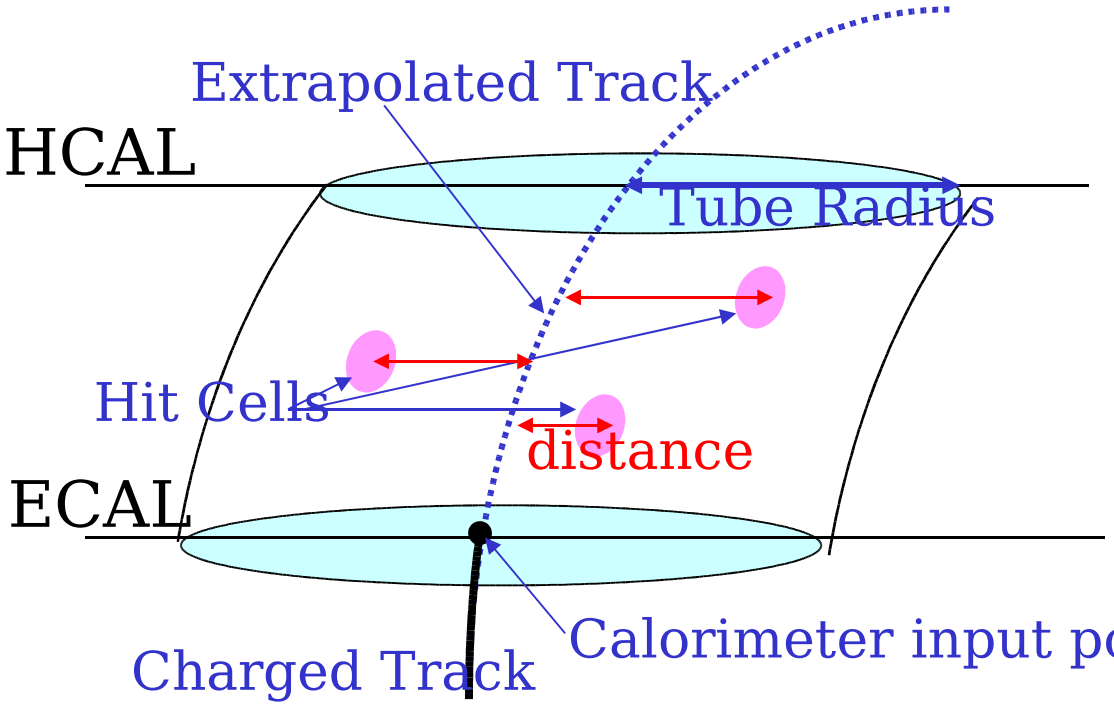
We calculate the distance between most energetic small cluster and its nearest track. The distance is used to separate gamma from charged particles.



Realistic PFA

Track Matching

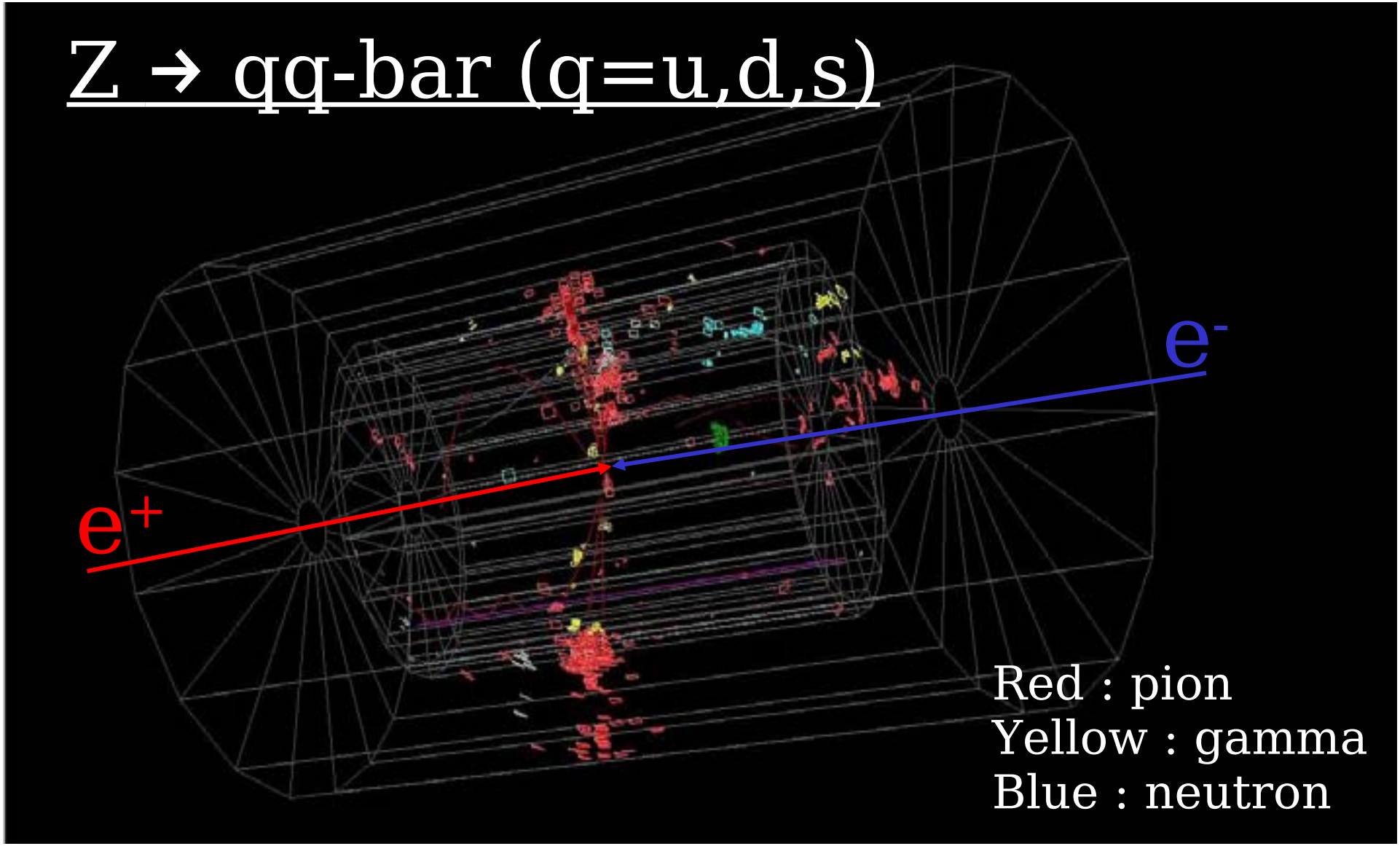
- **Basic Concept** :
  Extrapolate the charged track and calculate a distance between a calorimeter hit cell and the extrapolated track.
  Connect the cell that in a certain tube radius (clustering).



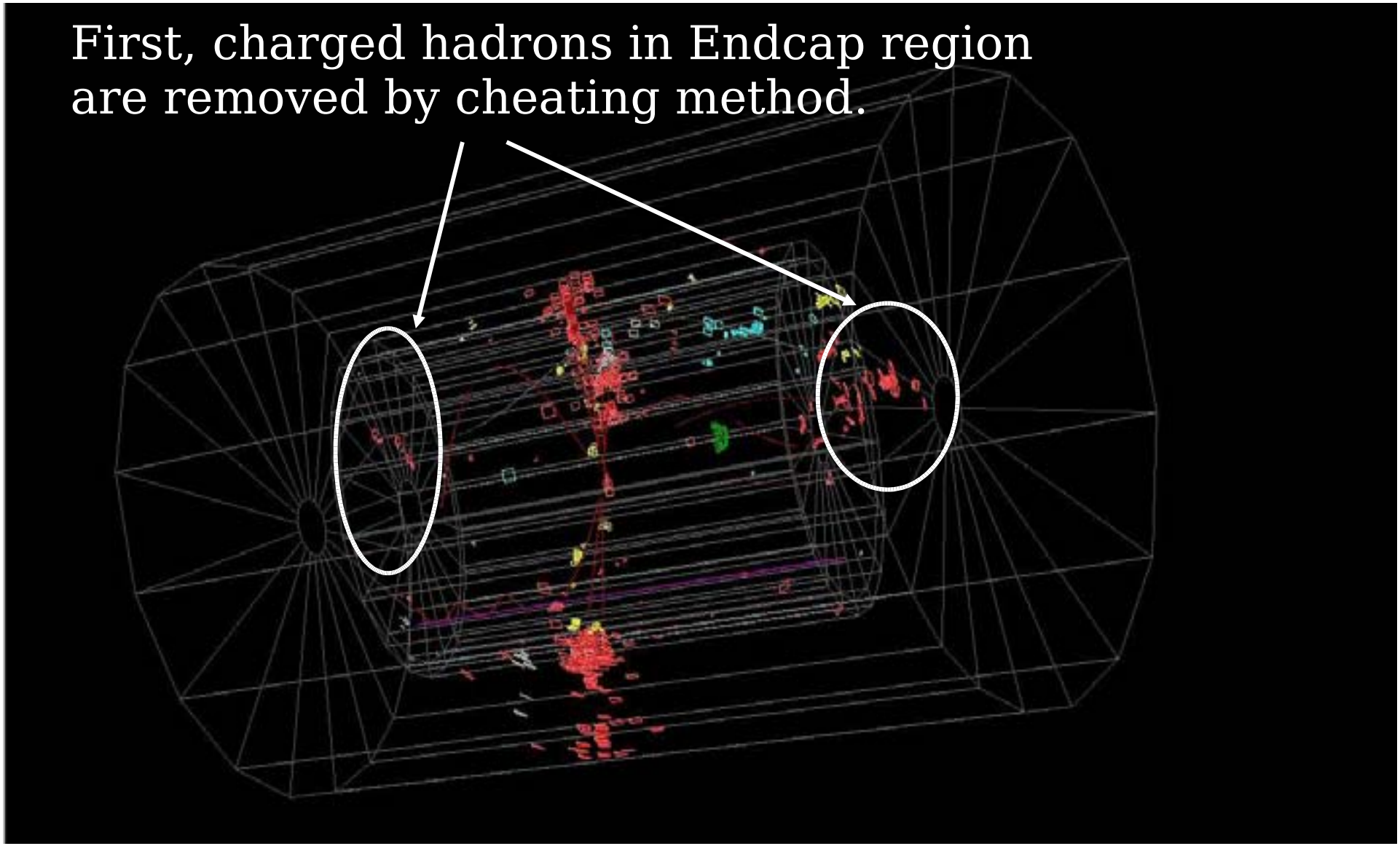
- Calculate the distance for any track/calorimeter cell combination.

- Tube radius for ECAL and HCAL can be changed separately.

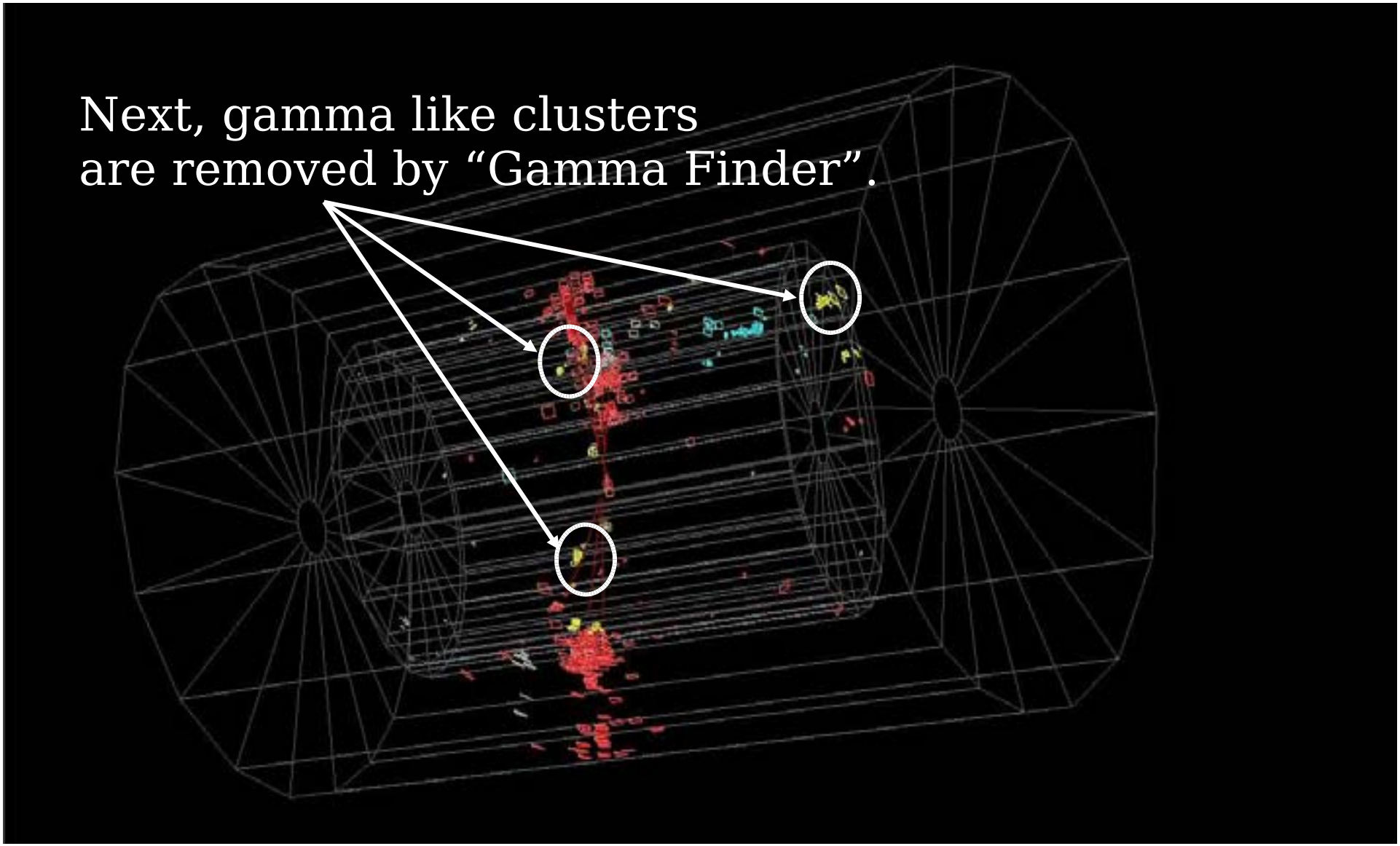
Realistic PFA



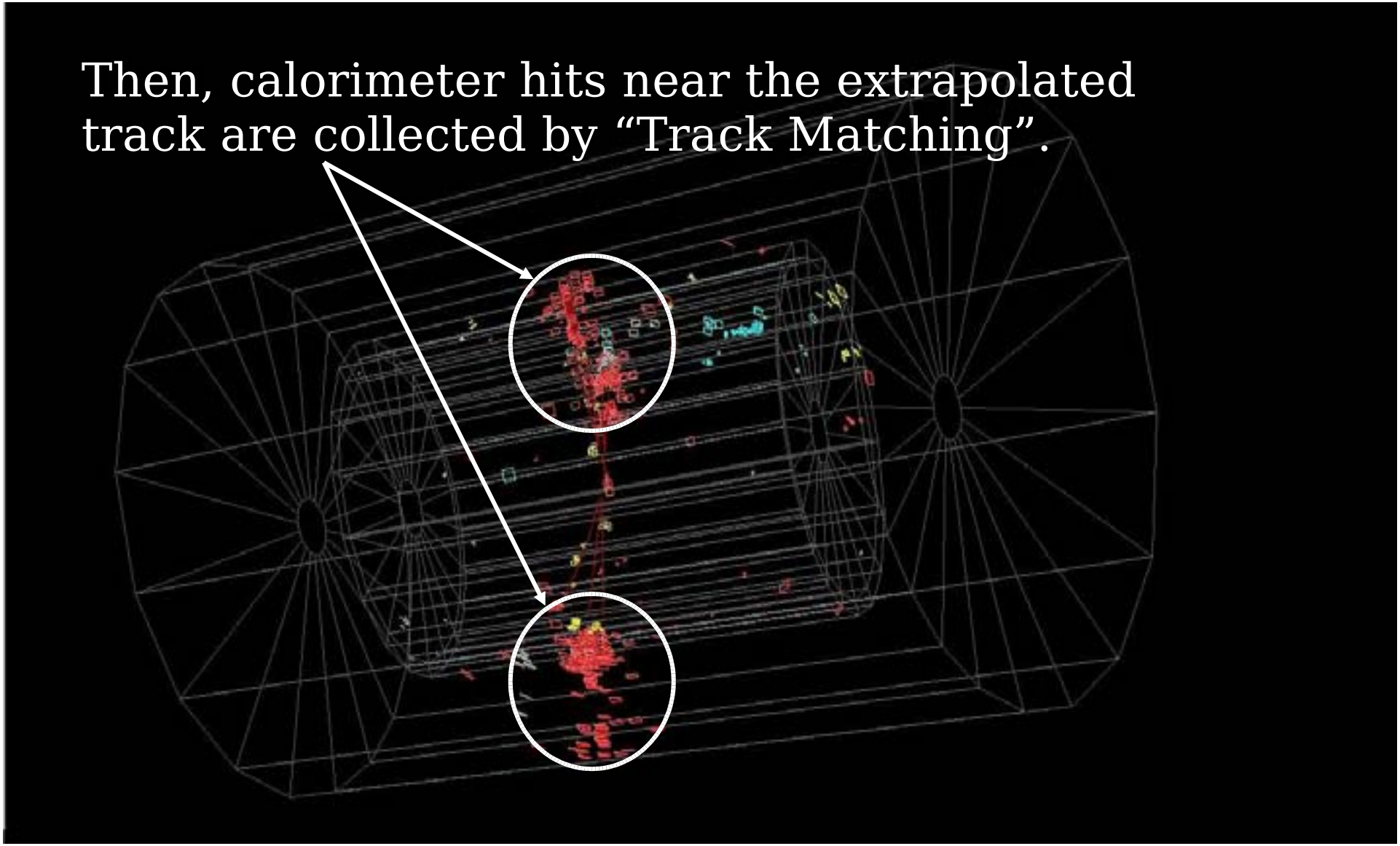
Realistic PFA



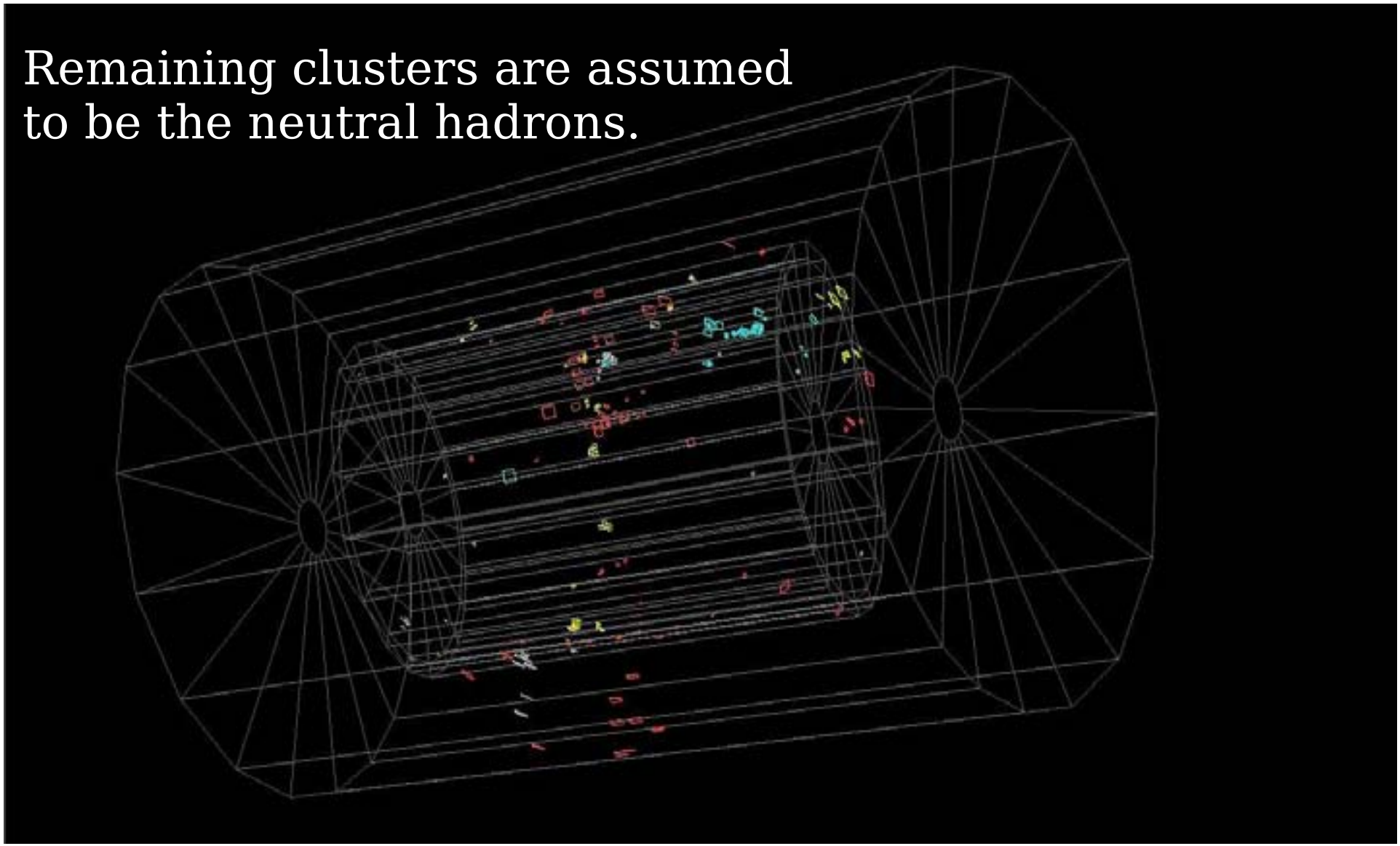
Realistic PFA



Realistic PFA

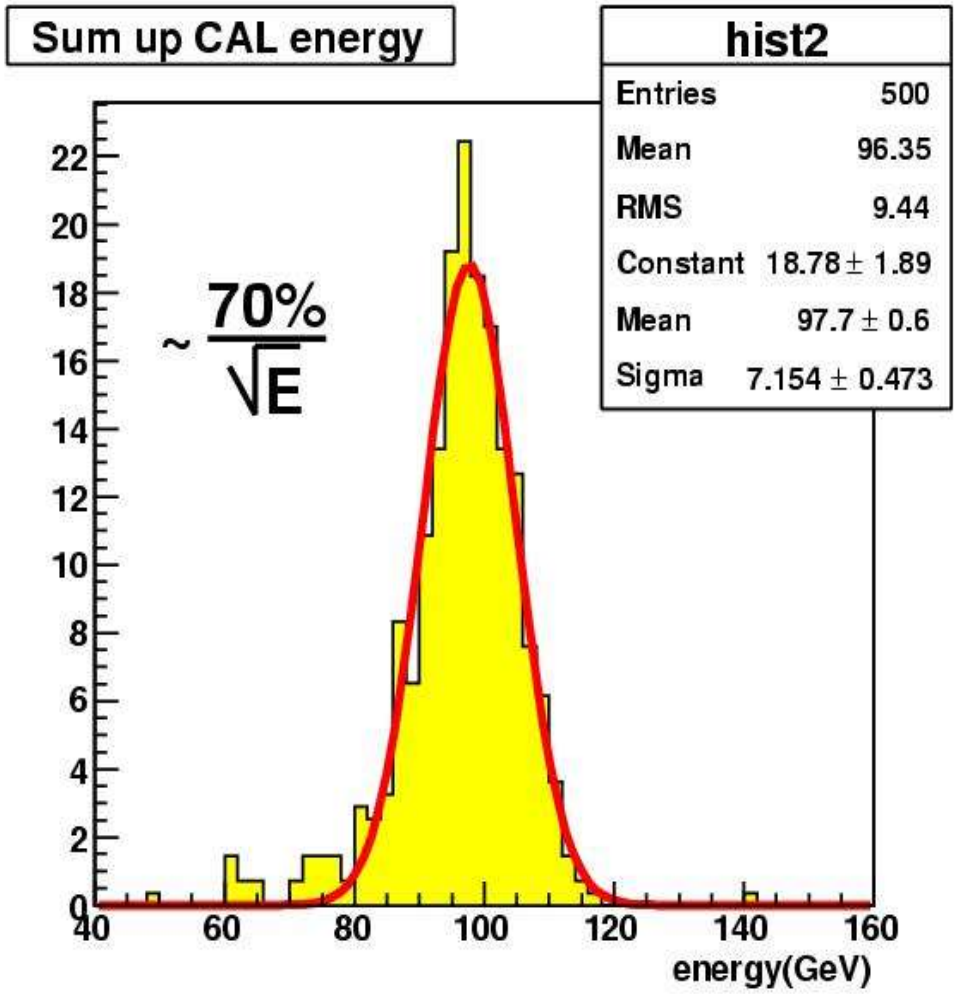


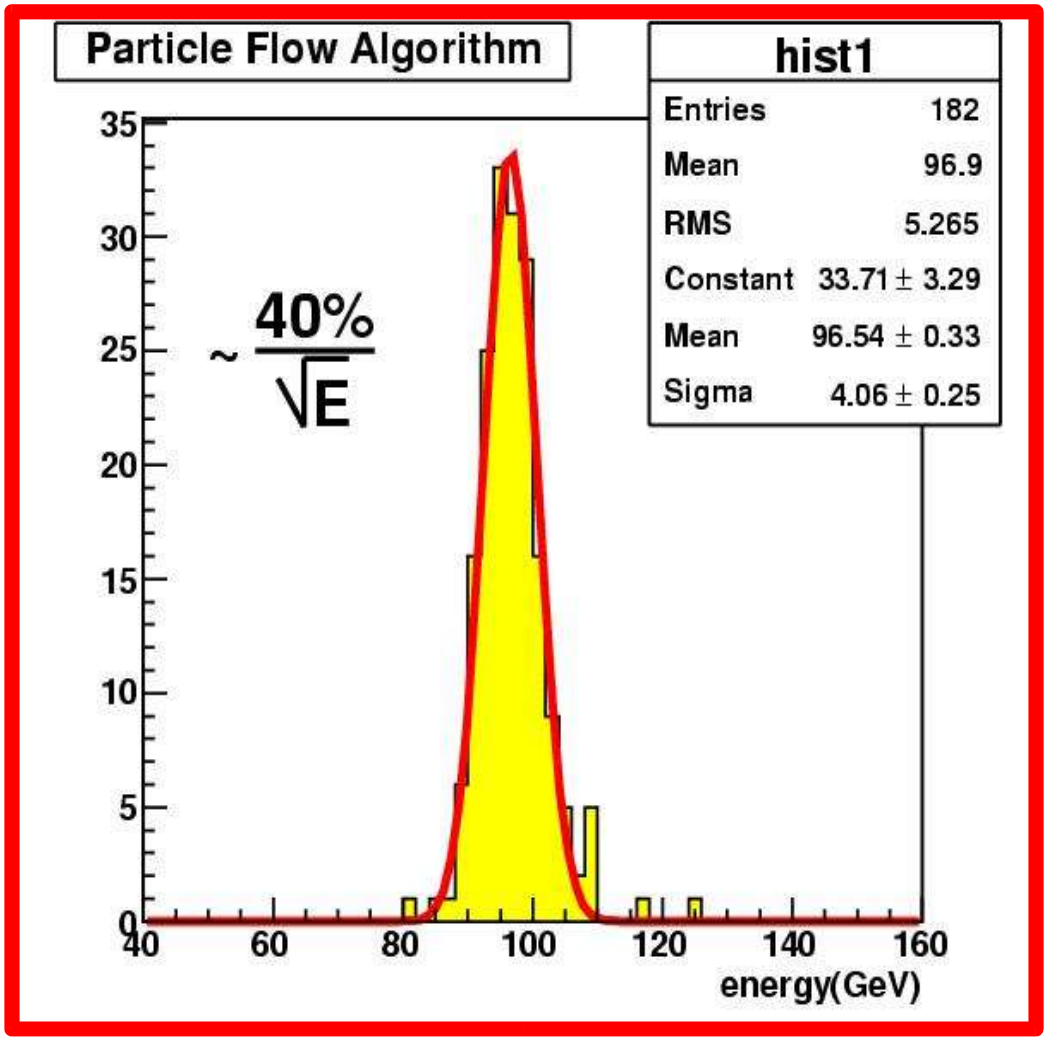
Realistic PFA



Realistic PFA

Z mass resolution





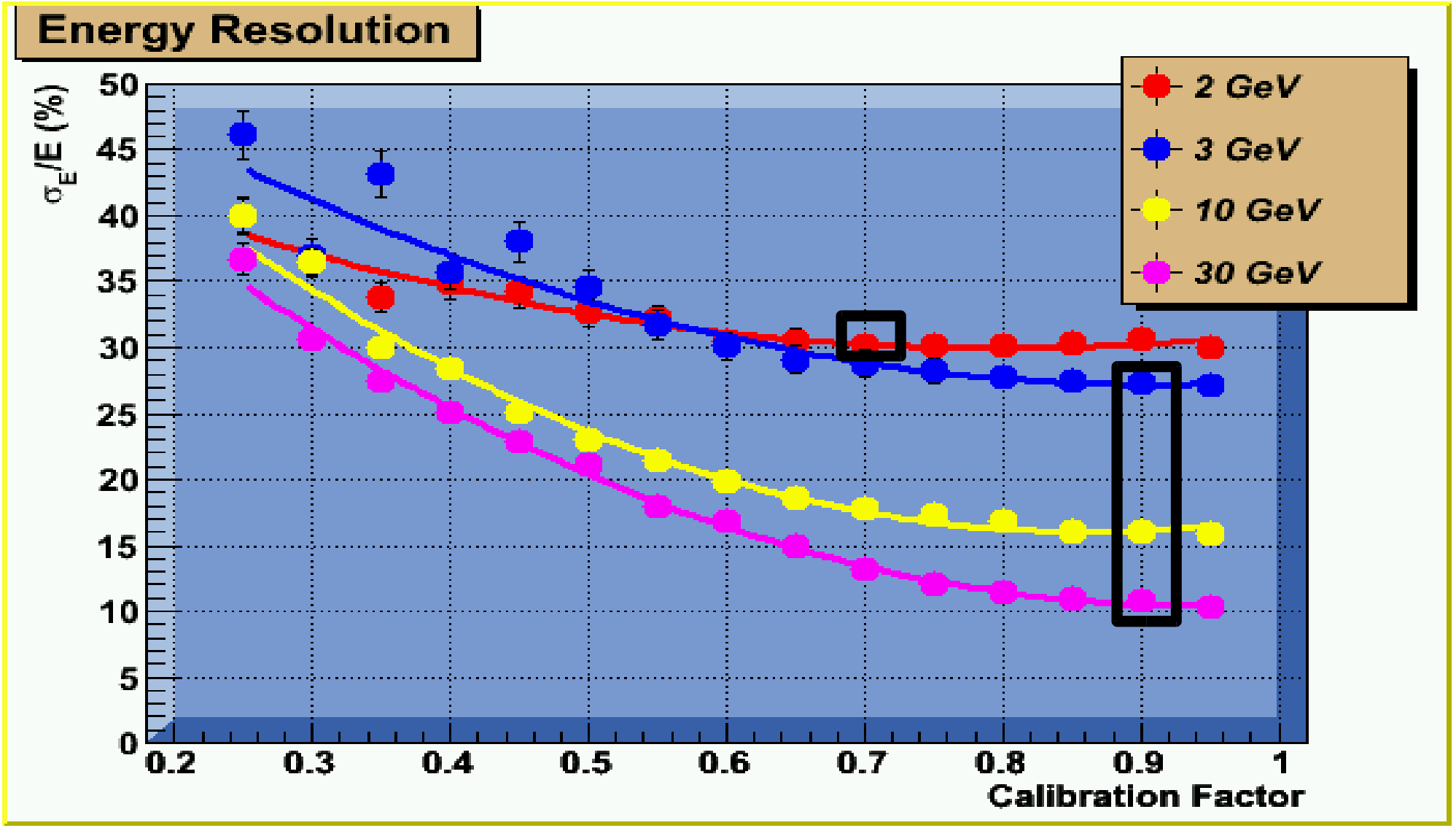
Sum up Calorimeter Energy **Particle Flow Algorithm**

Realistic PFA

- Summary
- Realistic Particle Flow Algorithm (PFA) for GLD is developed and the performance is checked.
  - Gamma Finder: Efficiency : 60%, Purity : 99%
  - Track Matching : Efficiency : 86%, Purity : 82%
  - Z mass resolution : 40%/sqrt(E)
- Goal : 30%/sqrt(E) of Z mass resolution.
  - Treat Endcap properly.
  - Improve gamma finder efficiency.
  - Optimize track matching parameters.

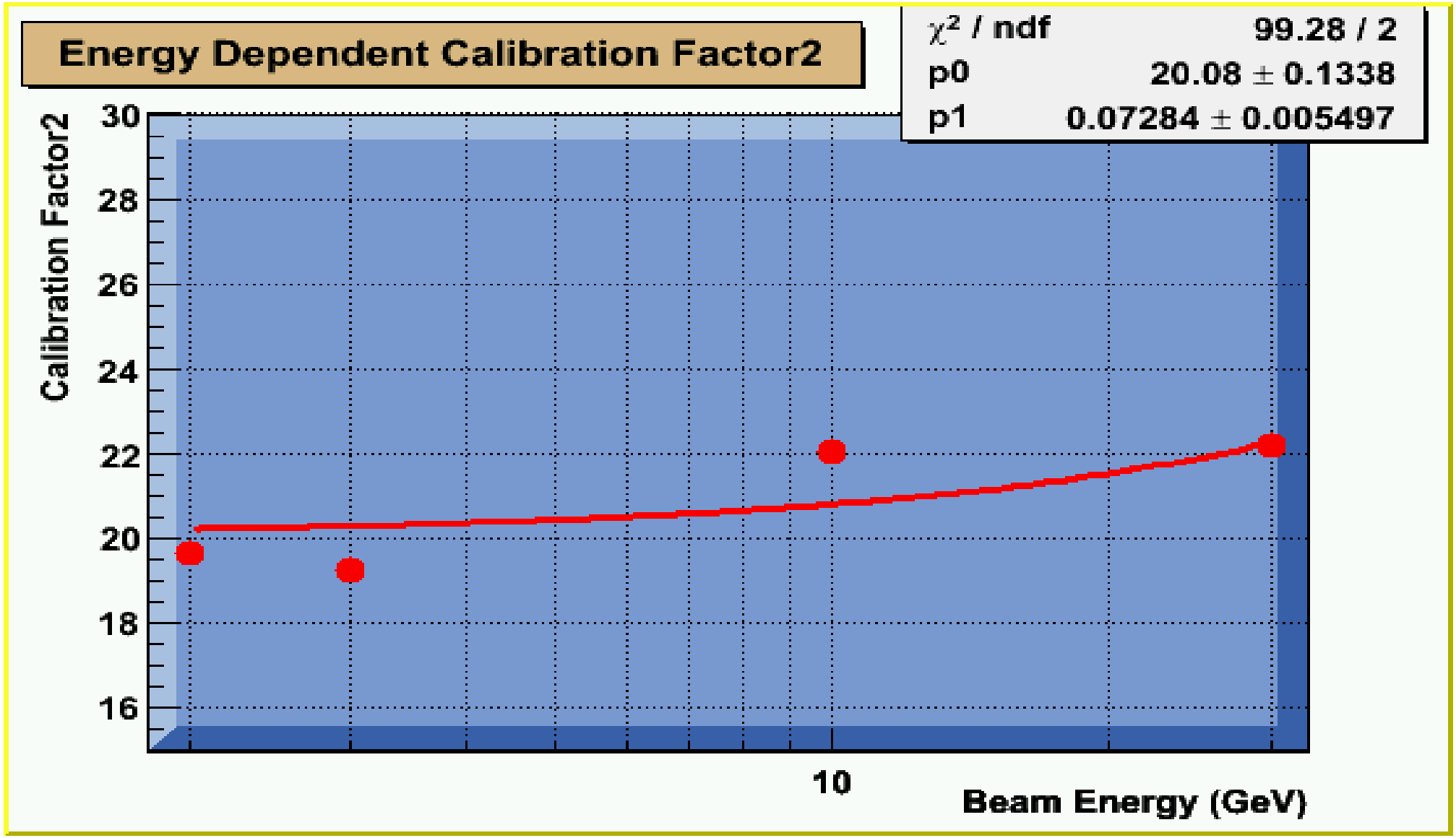
Calibration Factor

π- beam test, E_tot = E_ecal+ b*E_hcal



Calibration Factor

π- beam test, E_tot = a*(E_ecal+ b*E_hcal)



Calibration Factor

π- beam test, E_tot = a*(E_ecal+ b*E_hcal)

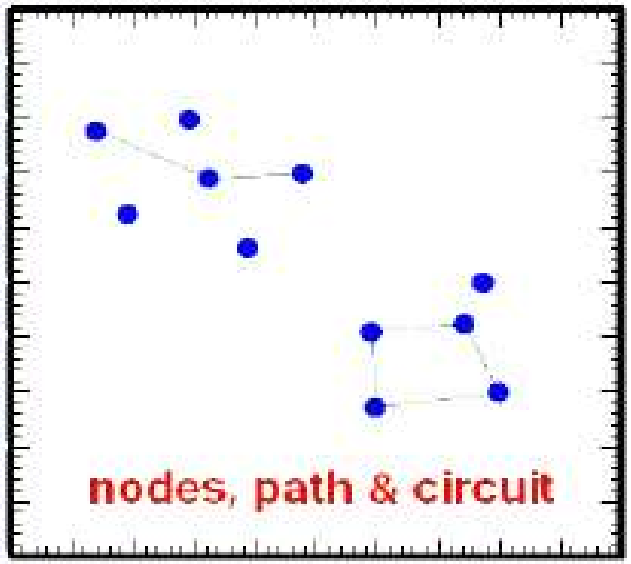
Summary:

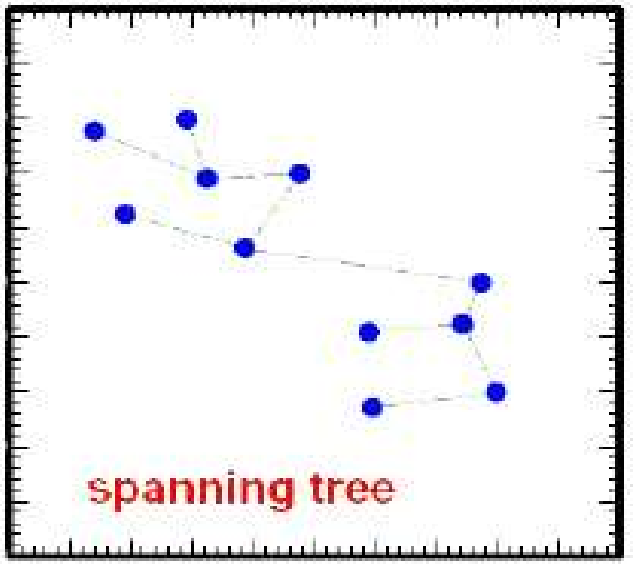
- **b=0.7 (2 GeV)**
- **b=0.9 (3 – 30 GeV)**
- **a=(20.08 ± 0.13)*E_beam + (0.07± 0.01)**
- **a=25.6 for e–/gamma**
- **Deviation from linearlity: <6%**
- **e/pi ratio: 1.15~1.35**

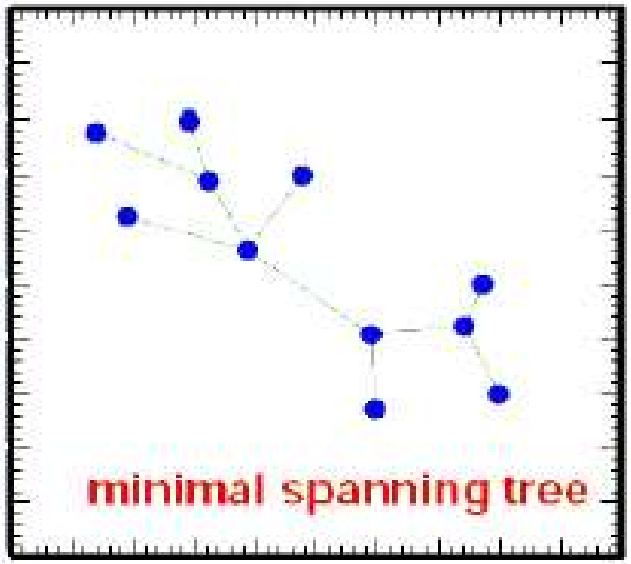
Realistic PFA with MST

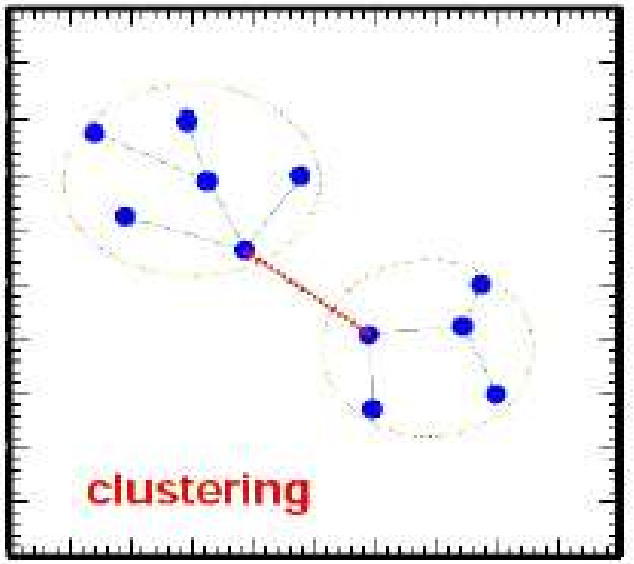
- Minimal Spanning Tree (MST)
- (no results yet)

A tree which contains **all nodes** with no circuits and of which the sum of weights of its edges is minimum









Realistic PFA with MST

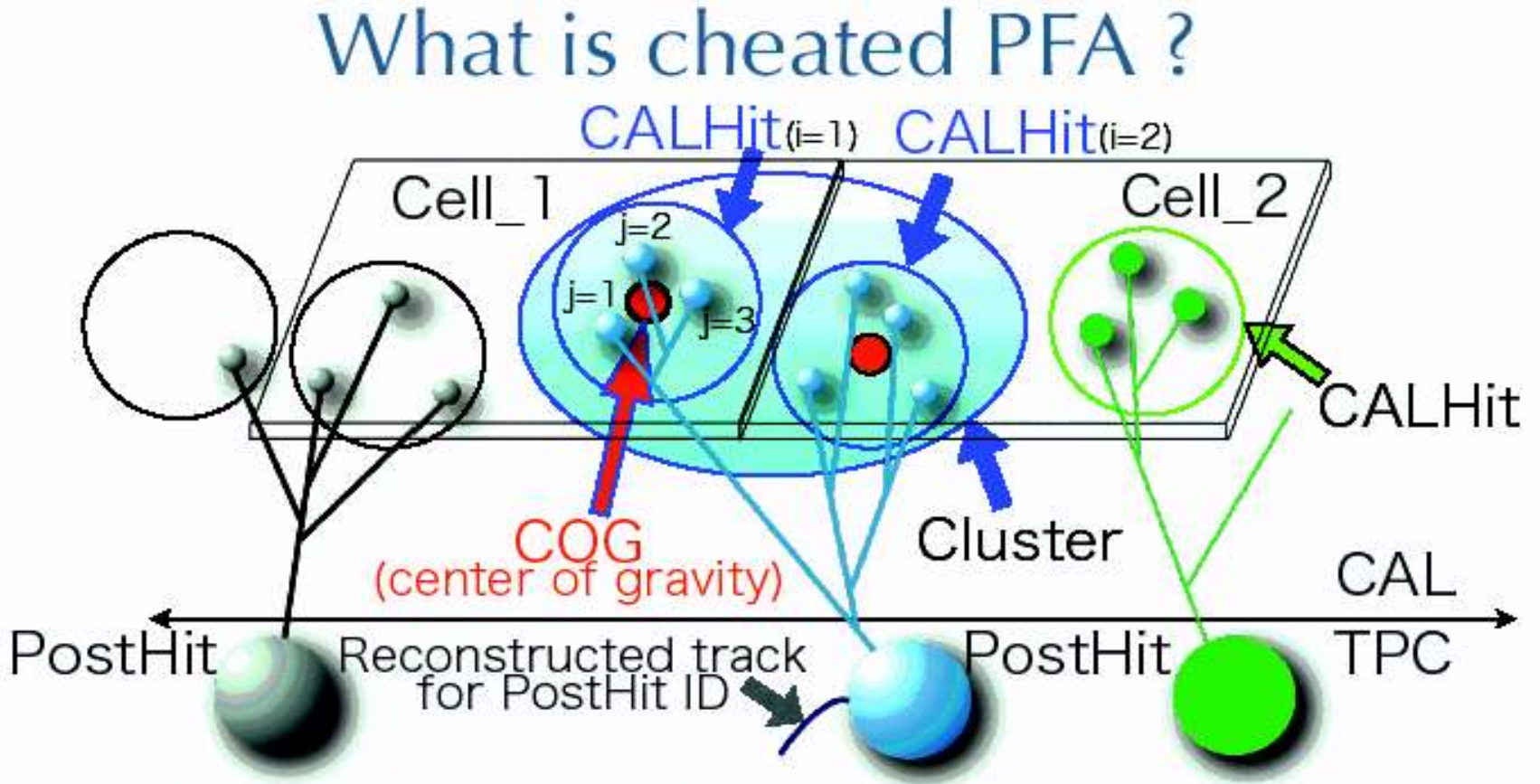
- **Realistic PFA with Minimum Spanning Trees (MST) for clustering**
  - **Status**
    - **Still under coding in Satellites...**
    - **New set of clustering classes (50% coding is finished)**

Plan in the Snowmass

- **Segmentation Effect (scintillator size, 1cm x 1cm/ 2cm x 2cm/ 4cm x 4cm/ 8cm x 8cm)**
- **Material Effect (Pb/Scinitillator; W/Scintillator)**
- **Calibration Factor (Recalculate this energy dependent calibration factor whenever the detector configuration is modified.)**
- **Communicate with people using other concepts**
- **Hadronic Shower Models (LCHadronPhysics? QGSP? ...)**

Backup

Cheated PFA



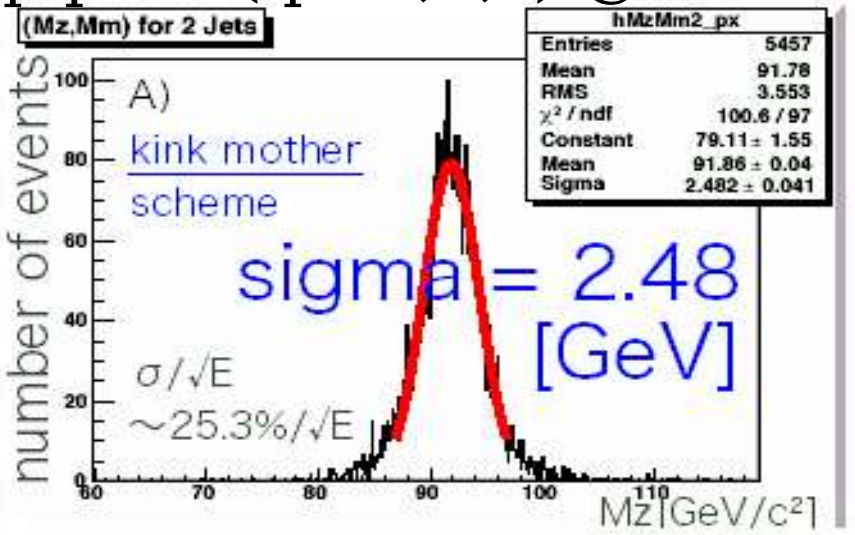
1. Different PostHits create different CALHits even in the same cell.
2. The CALHits have the centers of gravity as their hit positions instead of the cell center, then

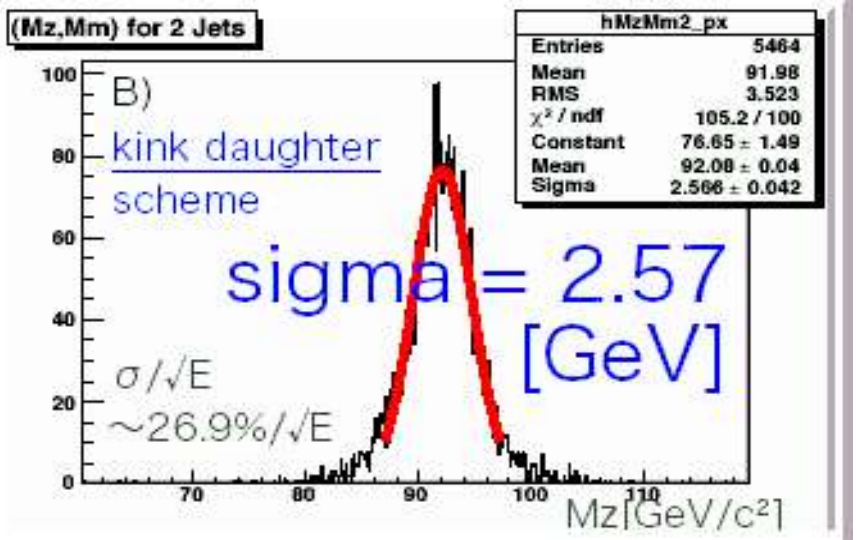
$$E^c = \sum_i E_i^c = \sum_{i,j} E_{i,j}^c \quad x^c = \sum_i E^{c_i} \cdot x_i^c / \sum_i E_i^c = \sum_{i,j} E_{i,j}^c \cdot x_{i,j}^c / \sum_{i,j} E_{i,j}^c$$

---> Equivalent to infinite segmentation.

Cheated PFA

Z->q q-bar (q= u,d,s) @ 91.187 GeV





A) 2.79^2 = (Kink mother treatment)^2 + (Other contributions)^2

(Other contributions)^2 = 2.79^2 - (Kink mother treatment)^2

The improvement in kink mother scheme is

$((2.79^2-2.48^2)^2/(2.79)^2 \sim 21.0\ \%)$

B) 2.79^2 = (Kink daughter treatment)^2 + (Other contributions)^2

(Other contributions)^2 = 2.79^2 - (Kink daughter treatment)^2

The improvement in kink daughter scheme is

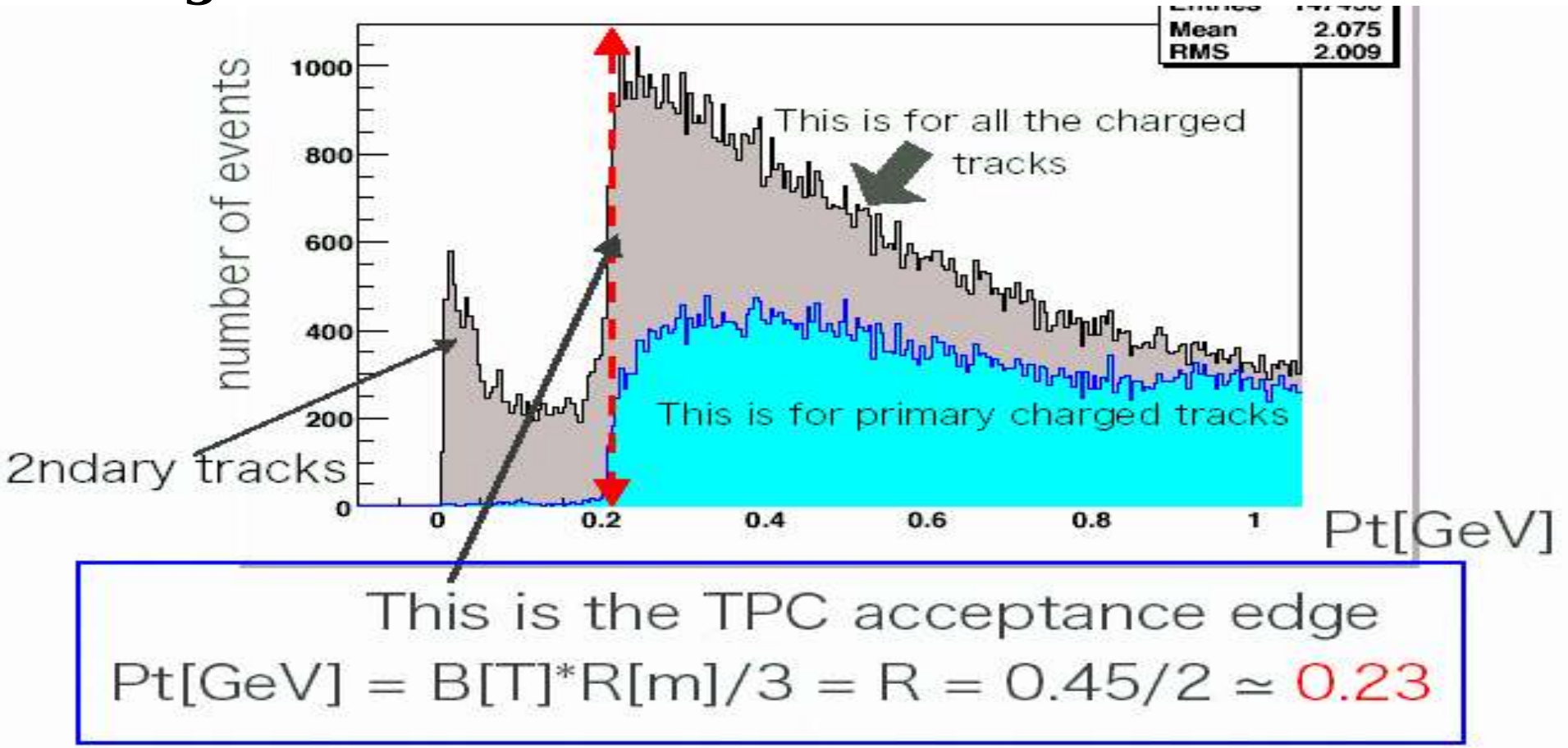
$((2.79^2-2.57^2)^2/(2.79)^2 \sim 15.1\ \%)$

In spite of double-counting of neutral kink daughters, **kink mother scheme** seems better than kink daughter scheme.

Cheated PFA

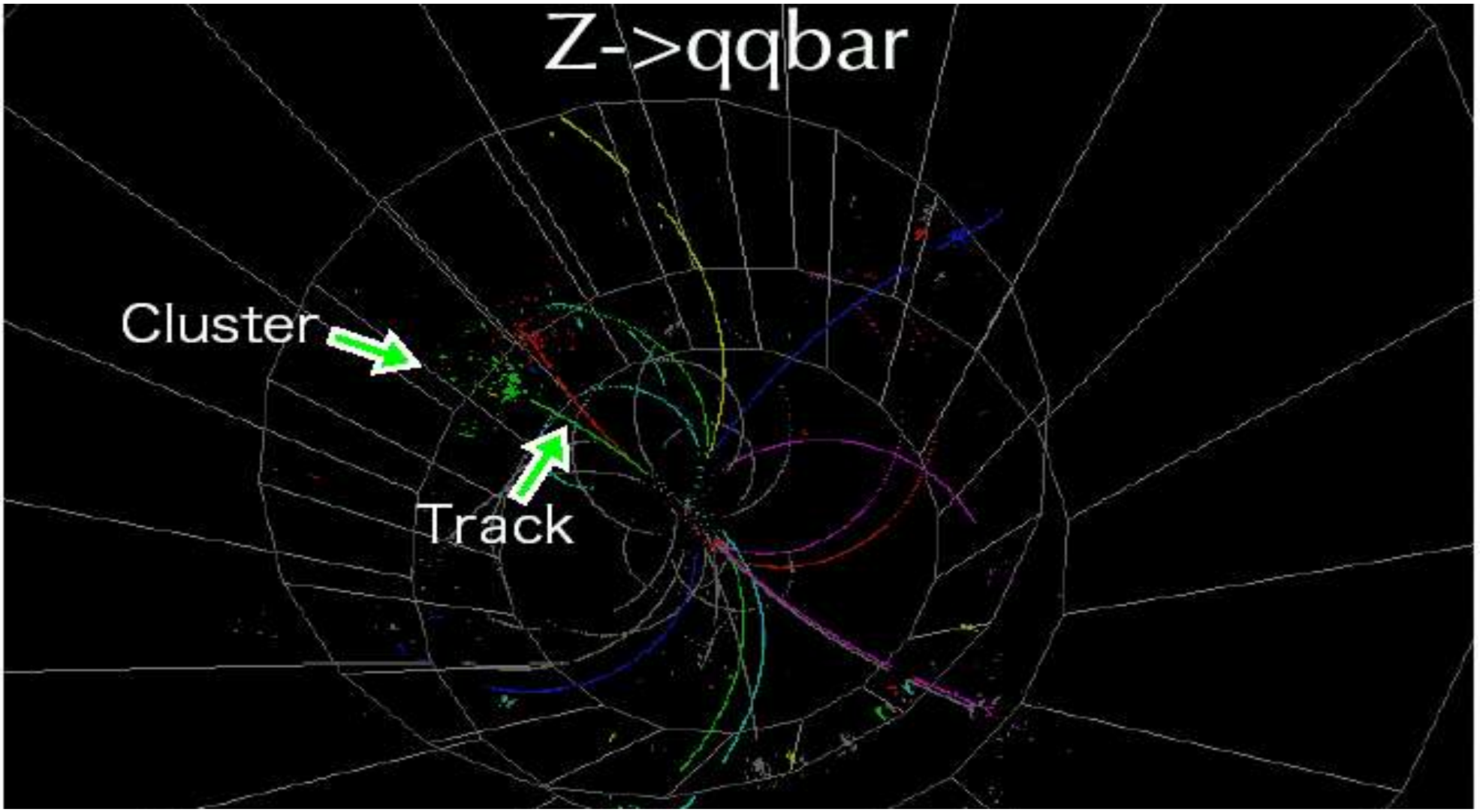
Z->q q-bar (q= u,d,s) @ 91.187 GeV

The lost primary tracks (due to low Pt, they do not make tracks in TPC) might be the main reason-> under investigation



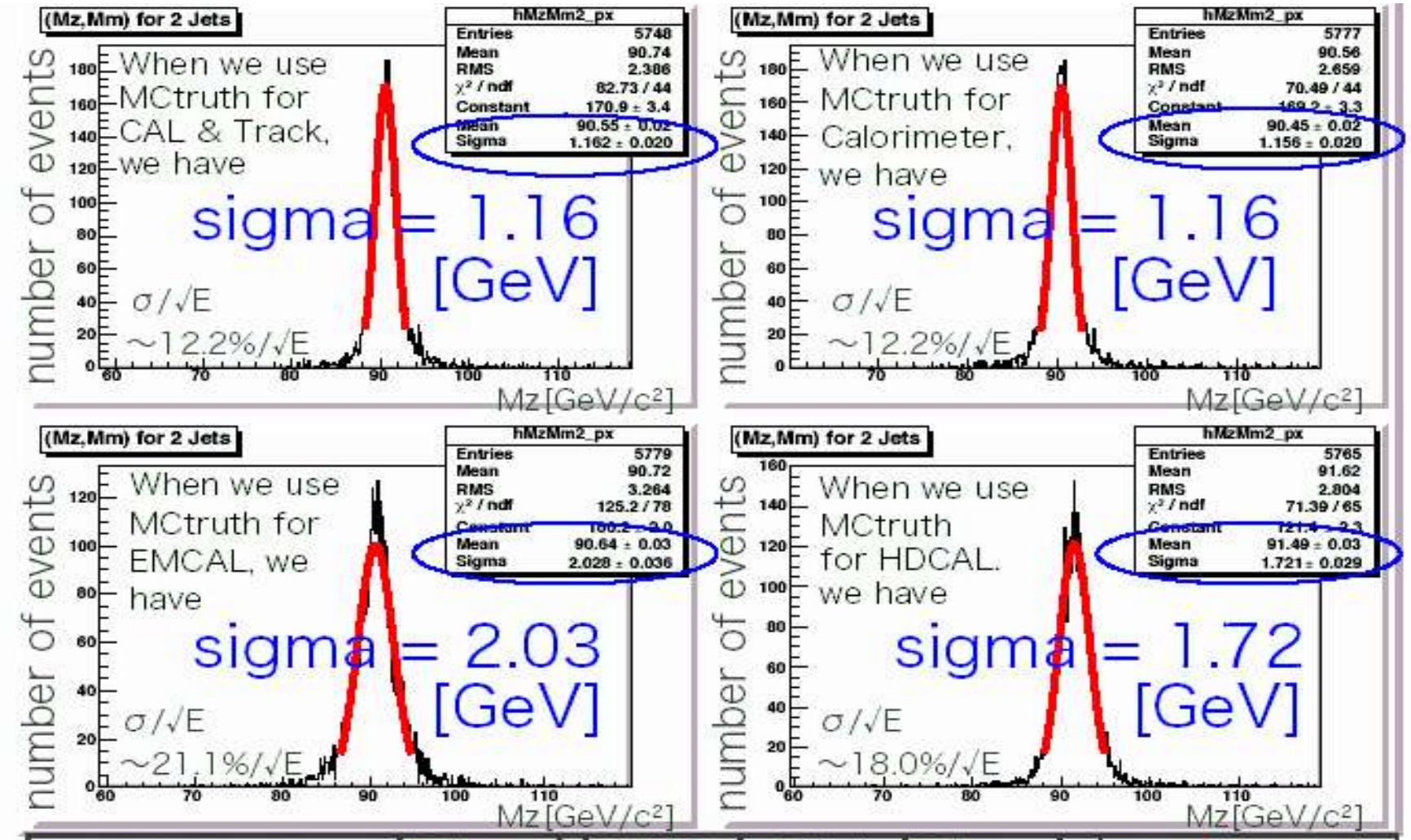
Cheated PFA

Event Display:
One Typical charged PFO was shown below.



Cheated PFA

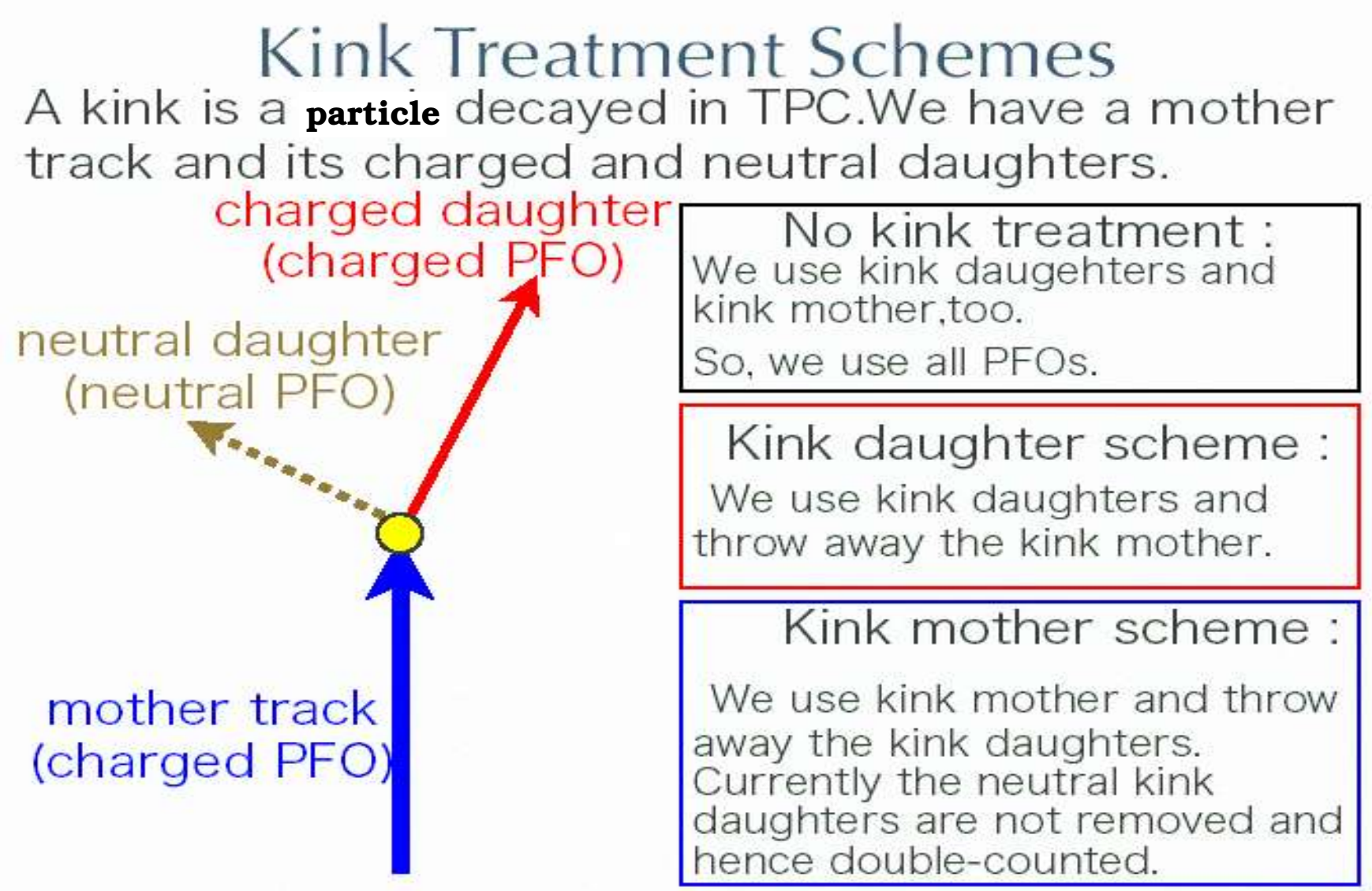
Z->q q-bar (q= u,d,s) @ 91.187 GeV



Contribution (%)	Total	HD	EM	Track	Unknown
	100	48	30	≃ 0	22 (1.16GeV)

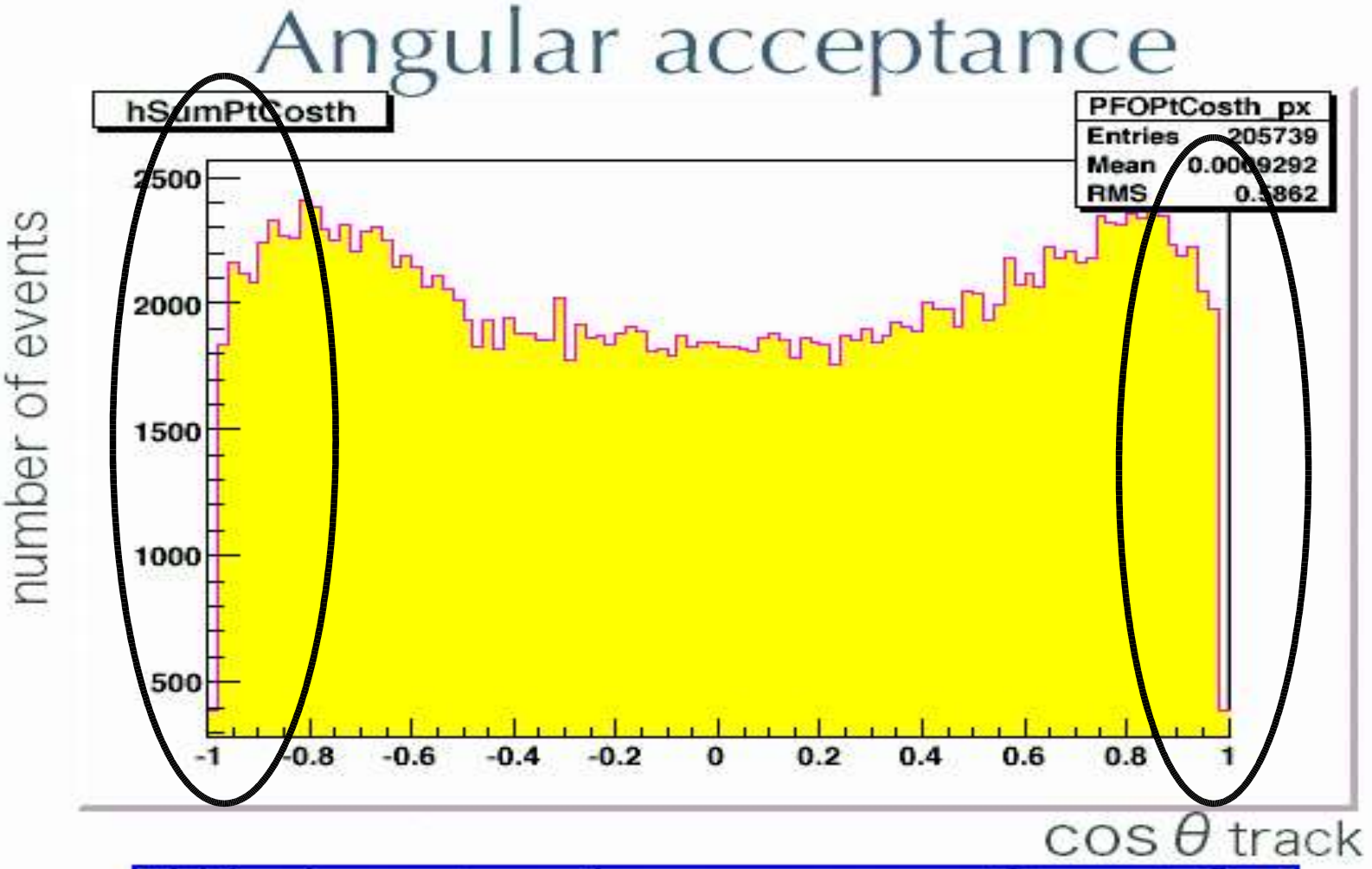
Cheated PFA

Z->q q-bar (q= u,d,s) @ 91.187 GeV



Cheated PFA

Z->q q-bar (q= u,d,s) @ 91.187 GeV

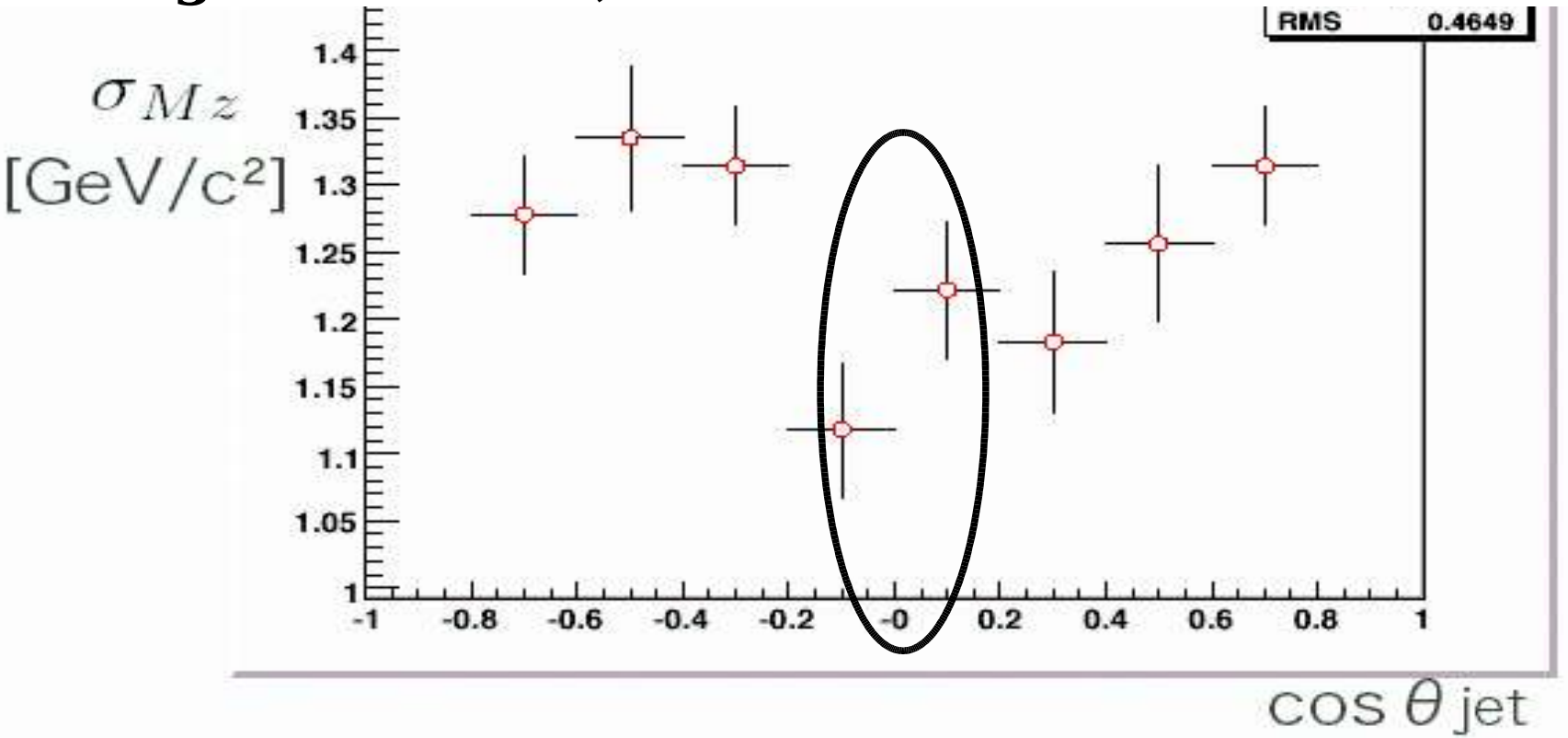


We lose tracks near $\cos\theta = \pm 1$.
-> Acceptance hole.

Cheated PFA

Z->q q-bar (q= u,d,s) @ 91.187 GeV

If energy lost in the very forward region (dead area) is the main reason, then in the barrel region, the σ_{Mz} should go down to 0, but it doesn't.

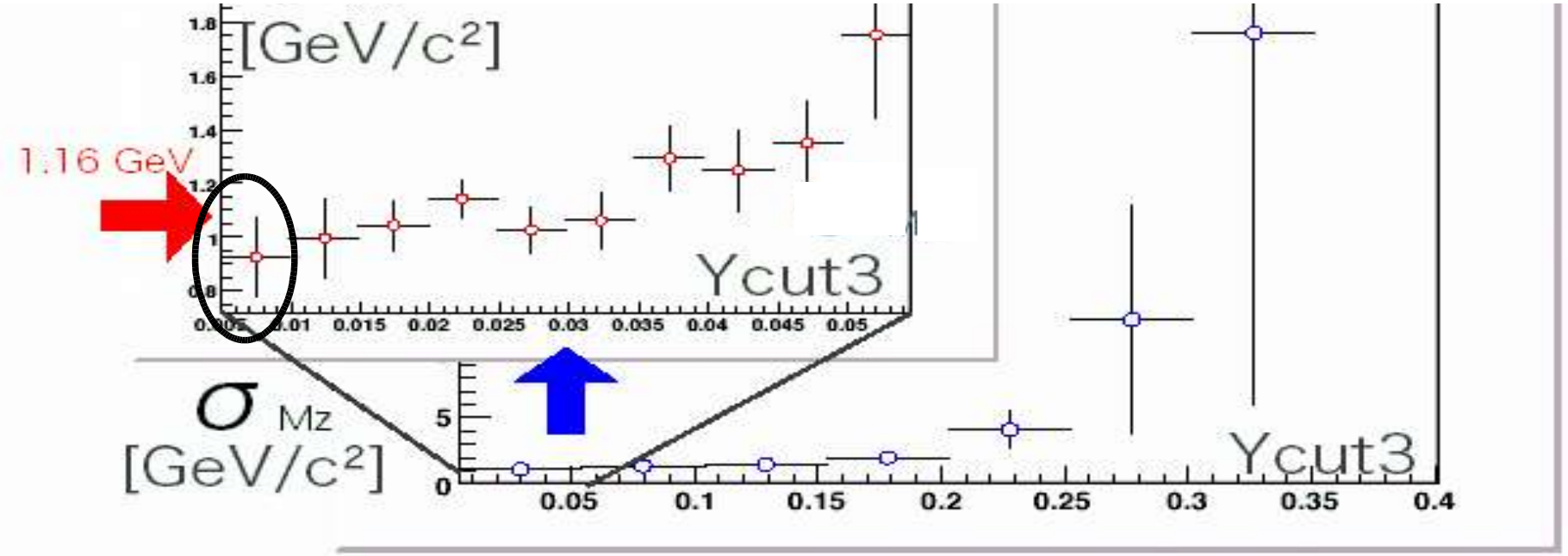


The remaining 1.16 GeV can't be explained by this.

Cheated PFA

Z->q q-bar (q= u,d,s) @ 91.187 GeV

If 3-jet events treated as 2-jet events due to the jet energy lost in the very forward region are the main reason, then in "very 2 jet-like" case, the σ_{Mz} should go down to 0, but it doesn't.



Ycut3: the topology changes from 3-jet to 2-jet