Hadronic Energy Reconstruction
- Update -

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MPI for Physics & Excellence Cluster 'Universe'
Munich, Germany

CALICE Collaboration Meeting, Lyon, France, September 2009

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

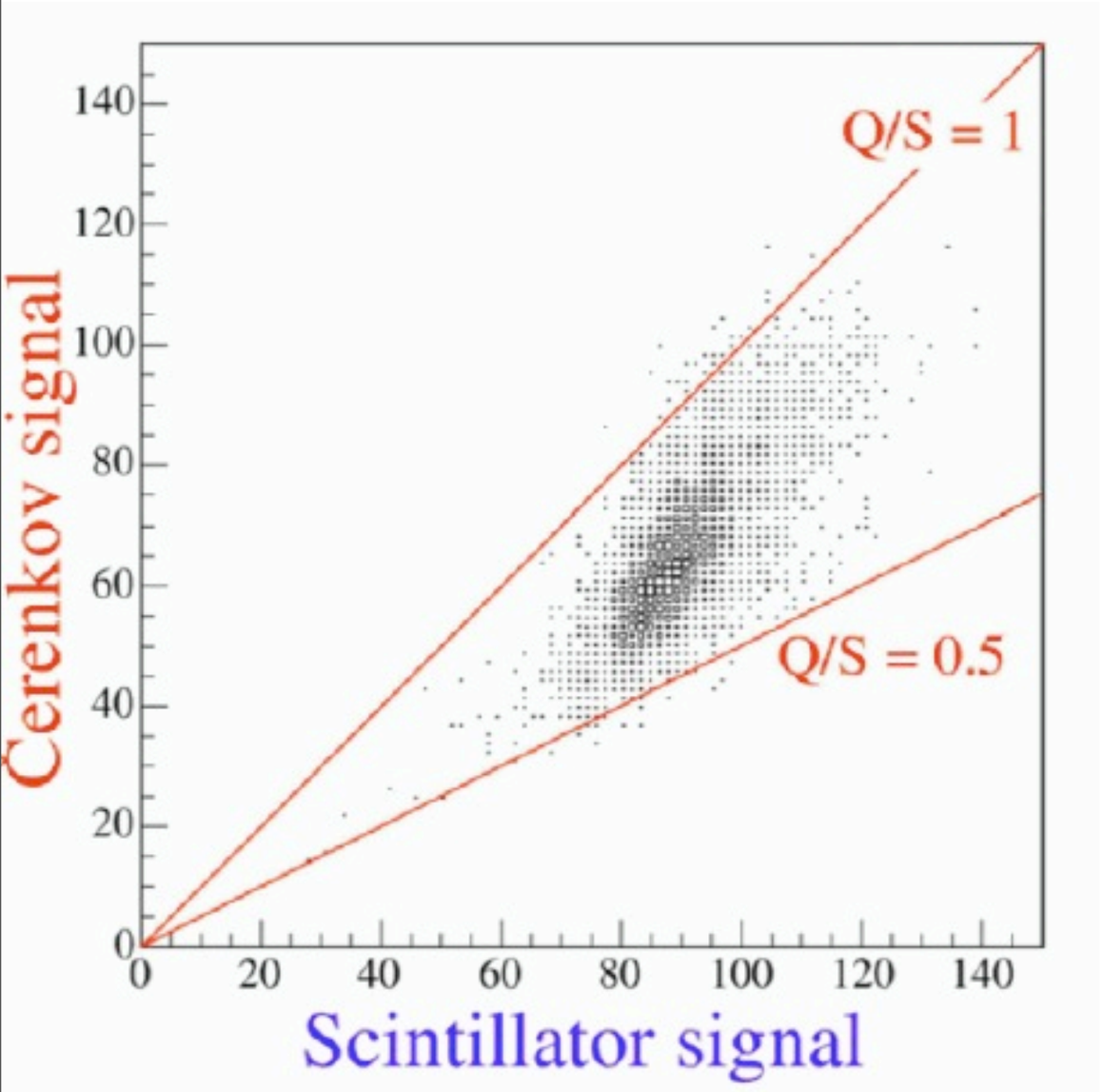
Calorimeter for ILC

Excellence Cluster Universe

Overview

- Reminder: Where we are
- Clustering in hadronic showers
- New Ideas: Neural Networks
- Broadening the Horizon: FNAL Data
- Summary / Outlook

DREAMing of Compensation



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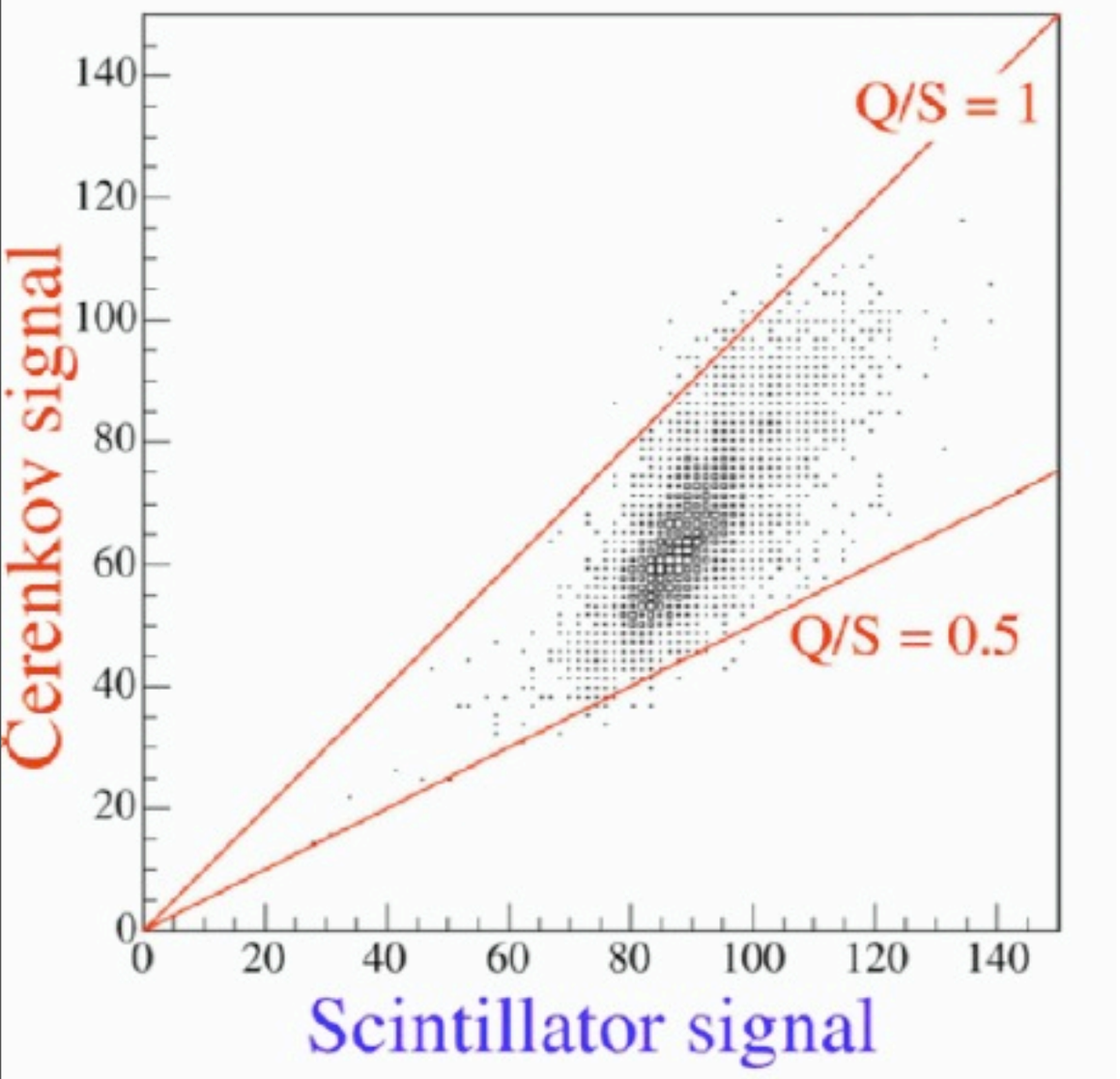

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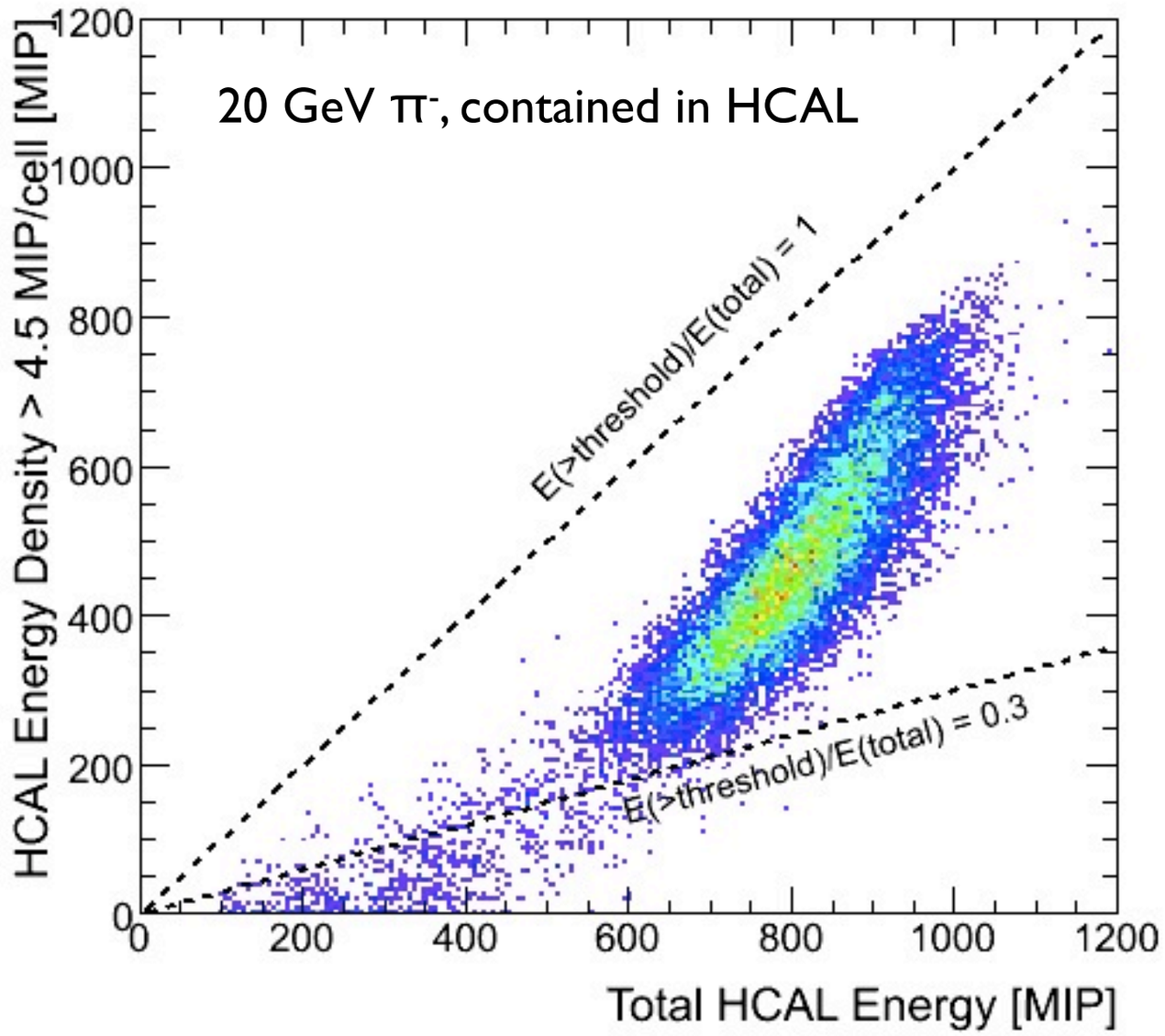


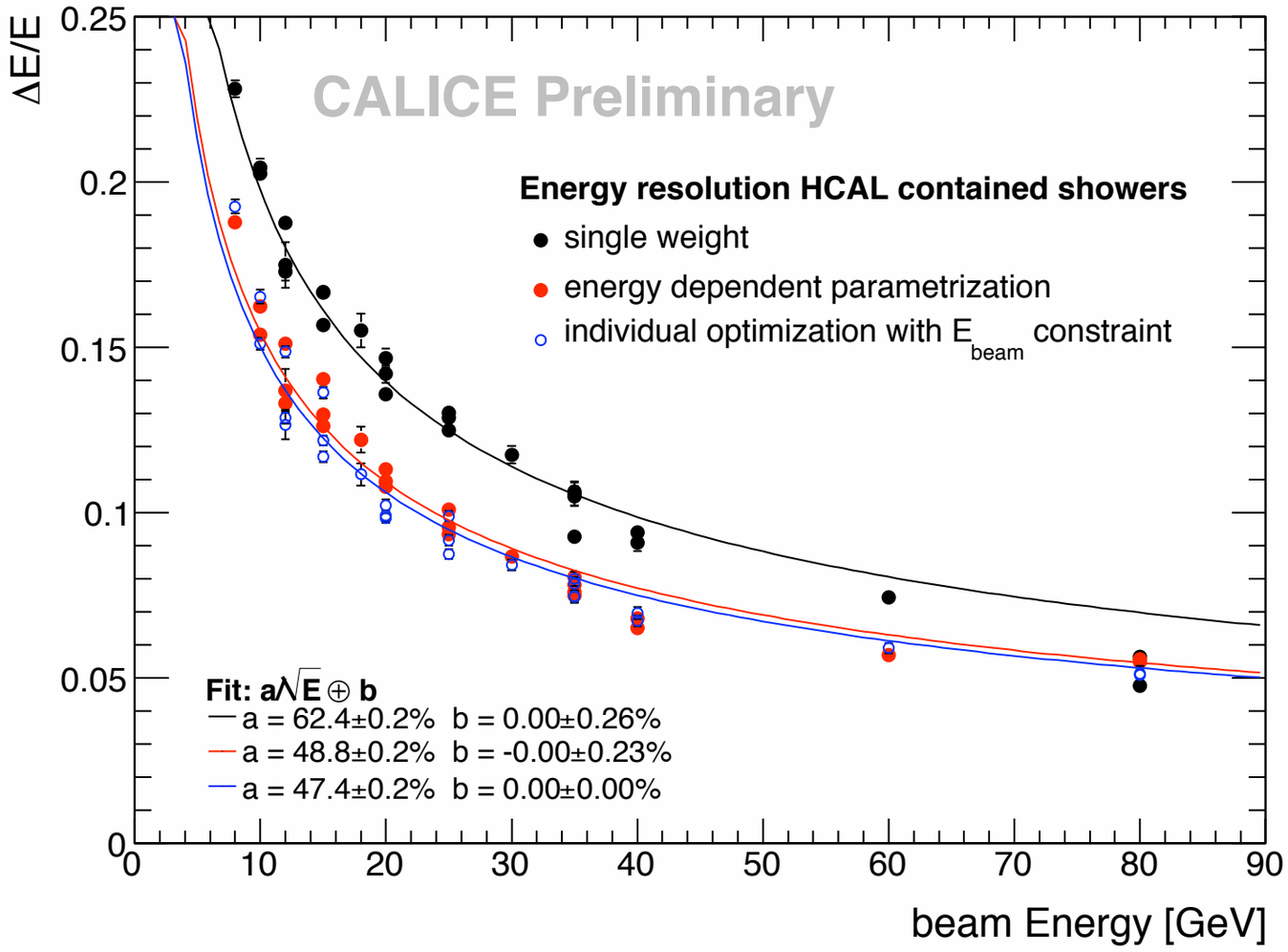
Local energy density works pretty much the same: events with a low total energy have a lower fraction of high density cells, this information can be used to improve the resolution: We can "DREAM", too...

Reminder: HCAL only Resolution

Software compensation with weighting, based on the energy in each cell, works!

3 ways to reconstruct the energy:

- One conversion factor per detector, no density dependent weighting
- Density dependent weighting, using a beam energy constraint
- Density dependent weighting using an energy dependent parametrization of the weights, the weights are selected event by event using the first energy estimate obtained with one factor per detector: prior knowledge of beam energy not necessary!



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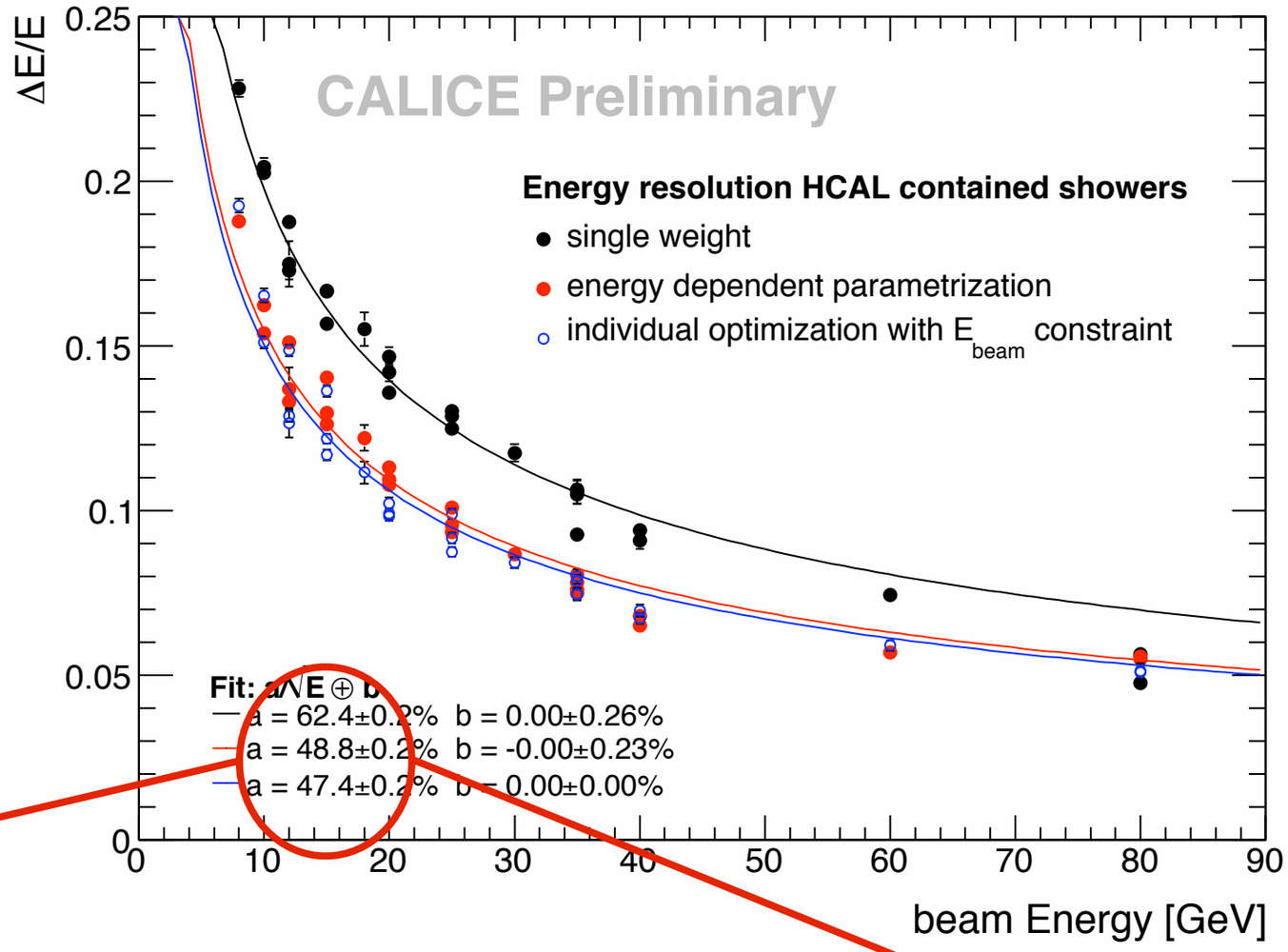
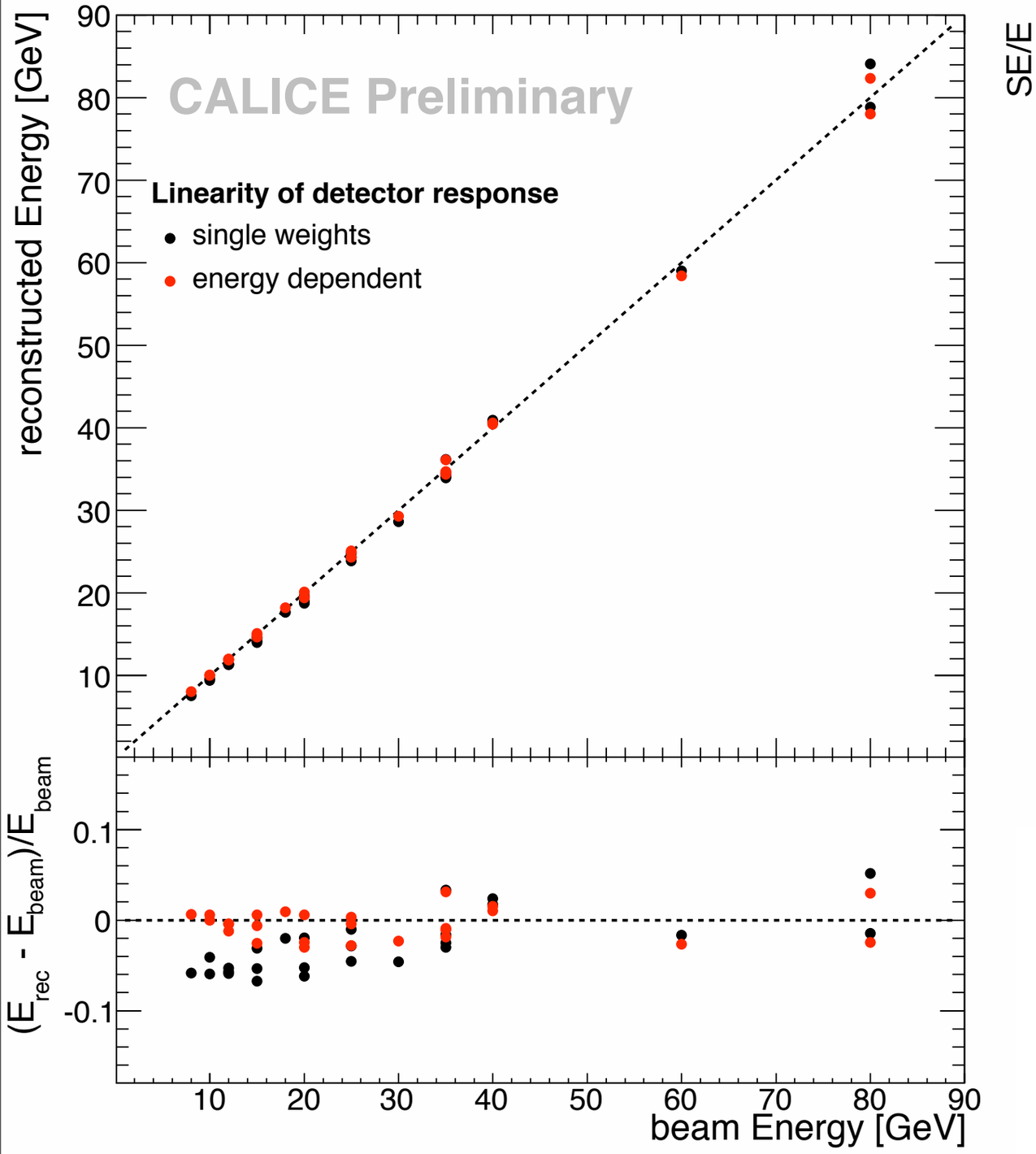
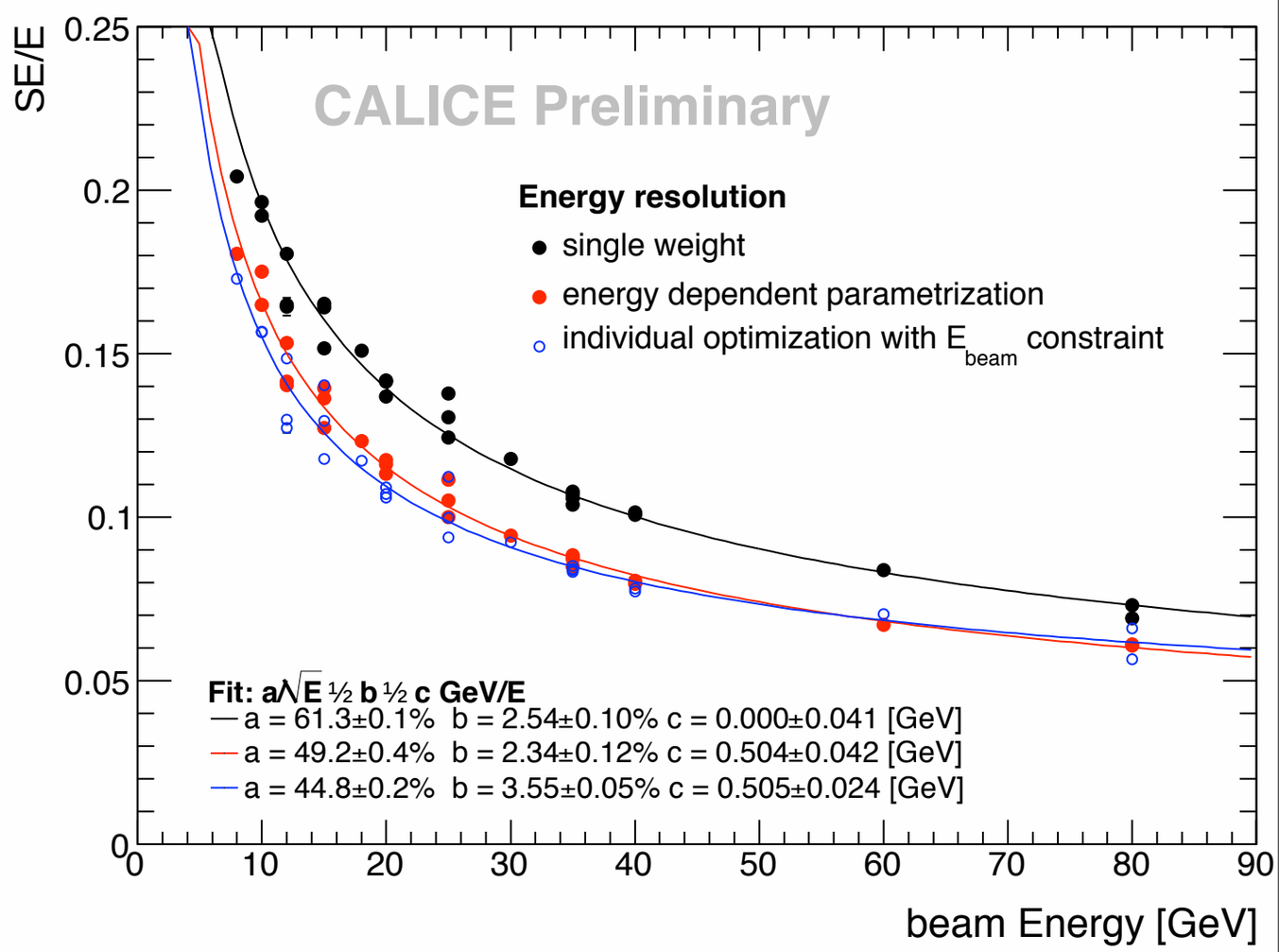


stochastic term w/o weighting: 62.4%, with parametrized weighting 48.8%

Reminder: Full Setup Energy Resolution & Linearity





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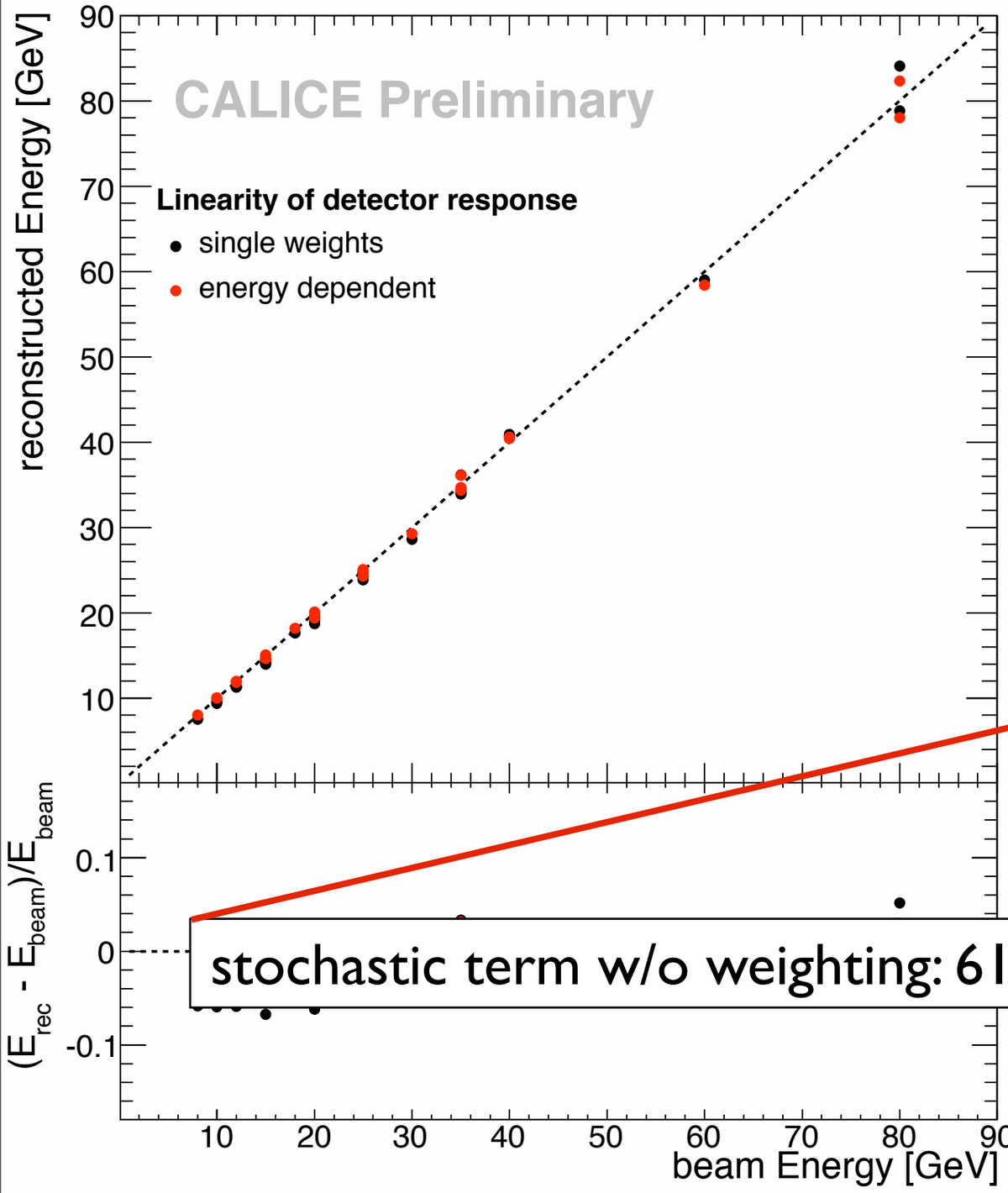
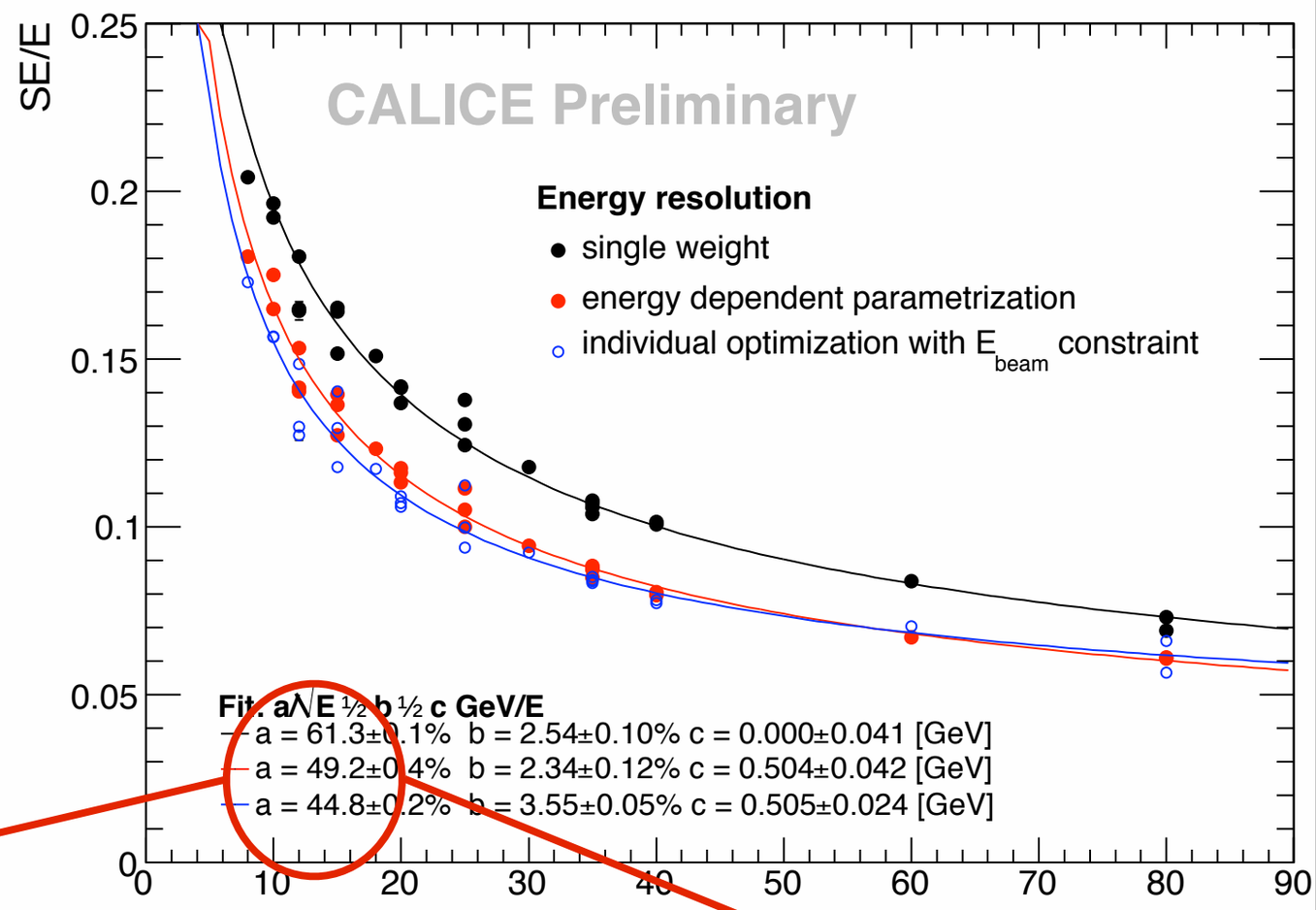
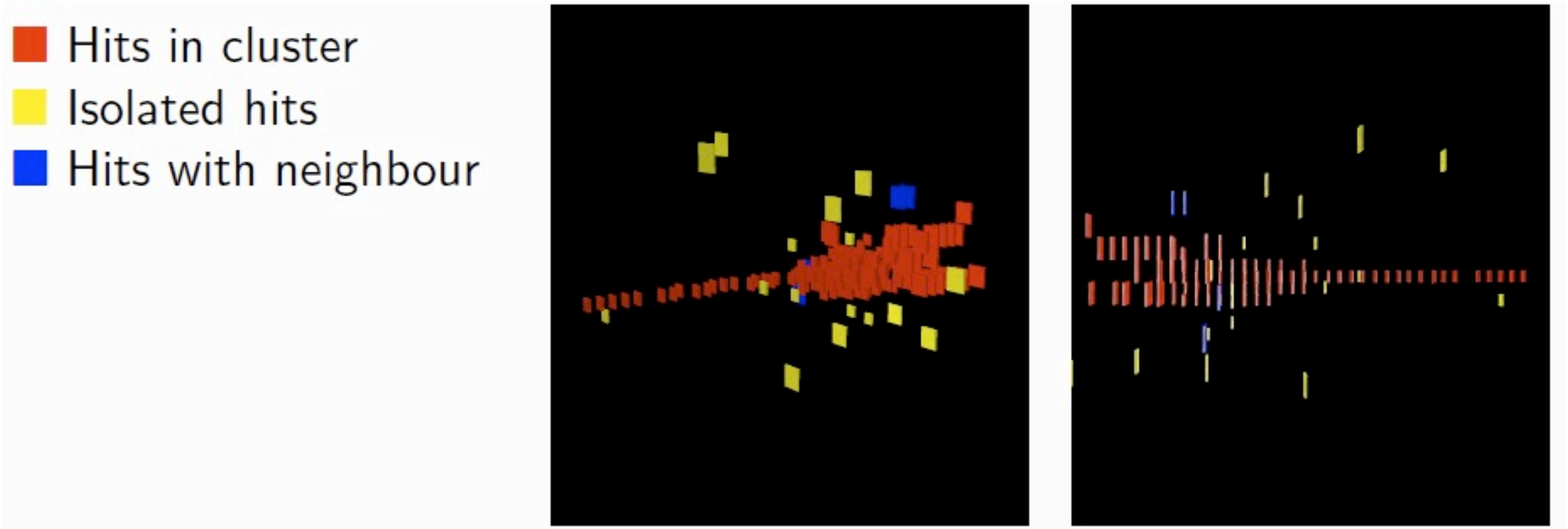




stochastic term w/o weighting: 61.3%, with parametrized weighting 49.2%

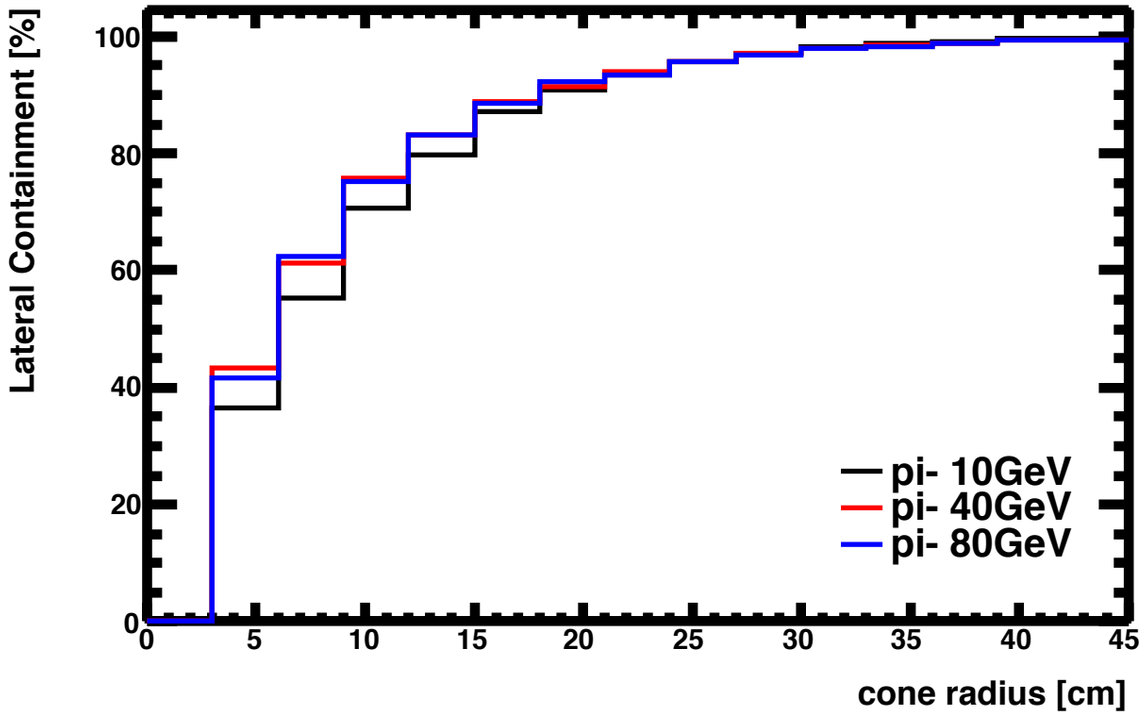
Alternative Approach: Cluster-based Weighting

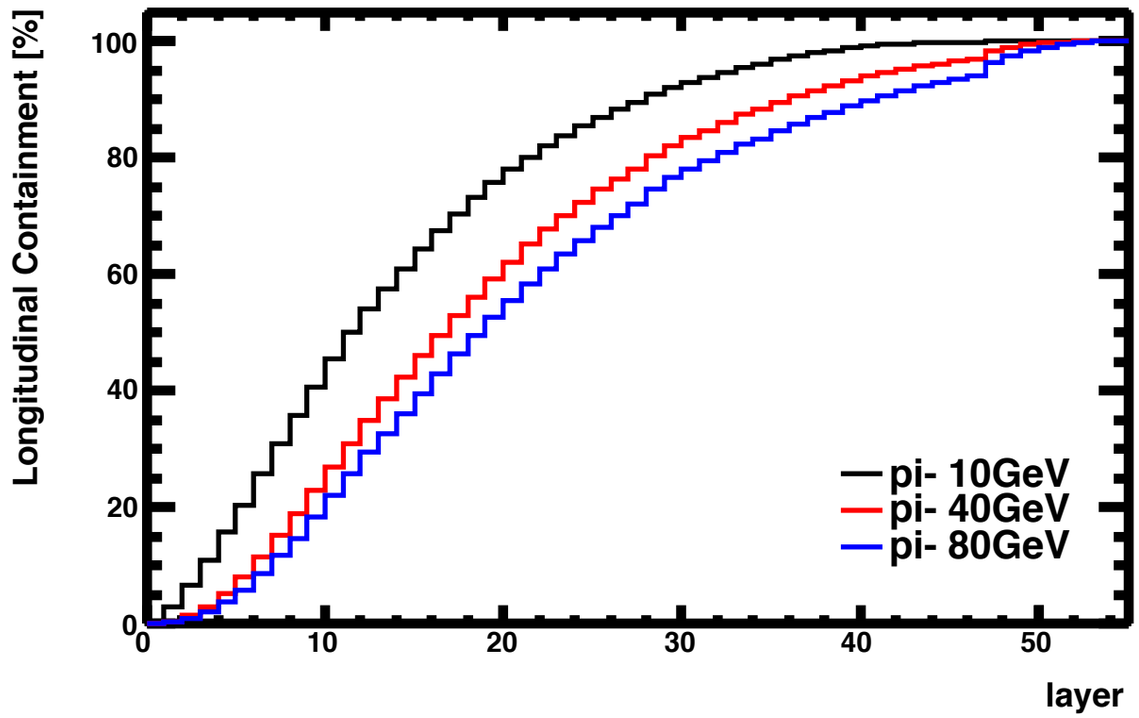
- Identify all hits belonging to a shower (first simple approach)
  - project shower on the front face of the HCAL, find maximum as shower axis
  - in each layer expand from the axis until energy does not grow significantly



- includes the track leading to the shower
  - separate identification of the shower start: increased energy deposit, multiple hits

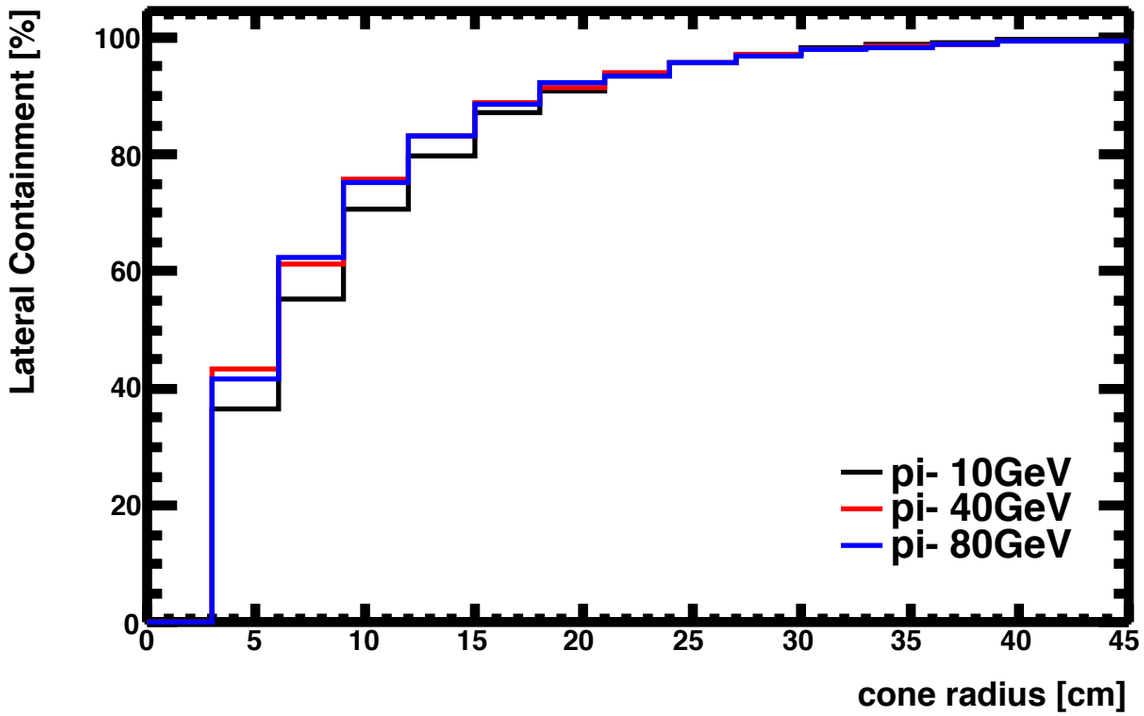
Cluster Properties: Containment

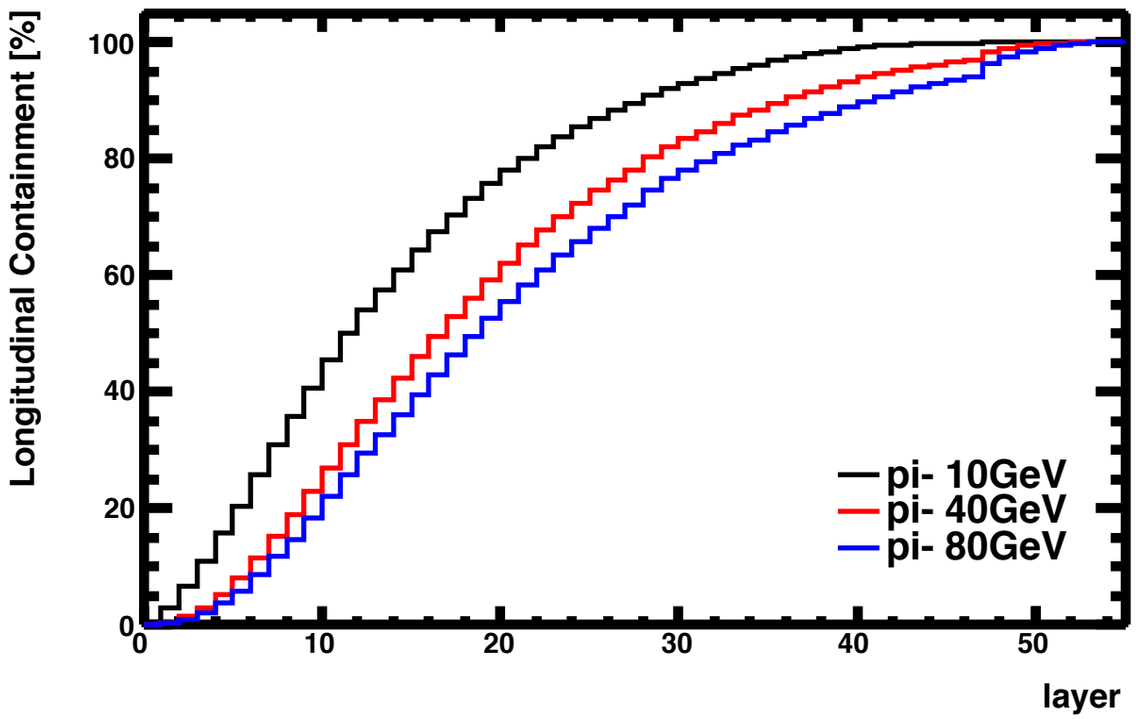


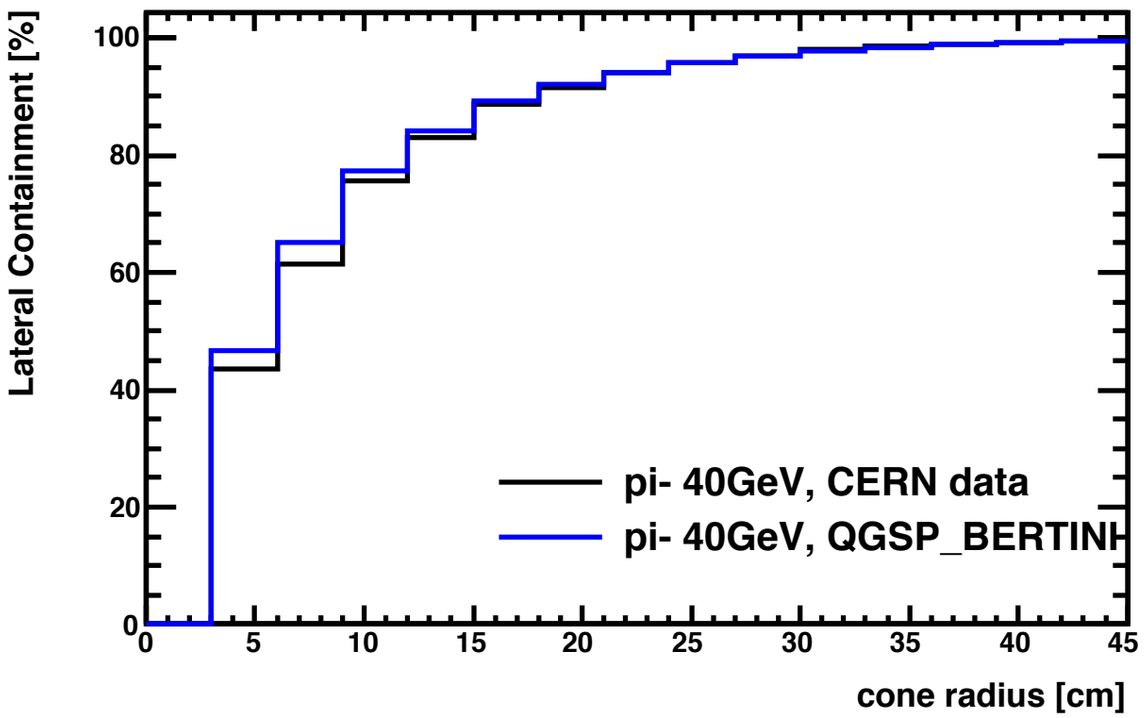


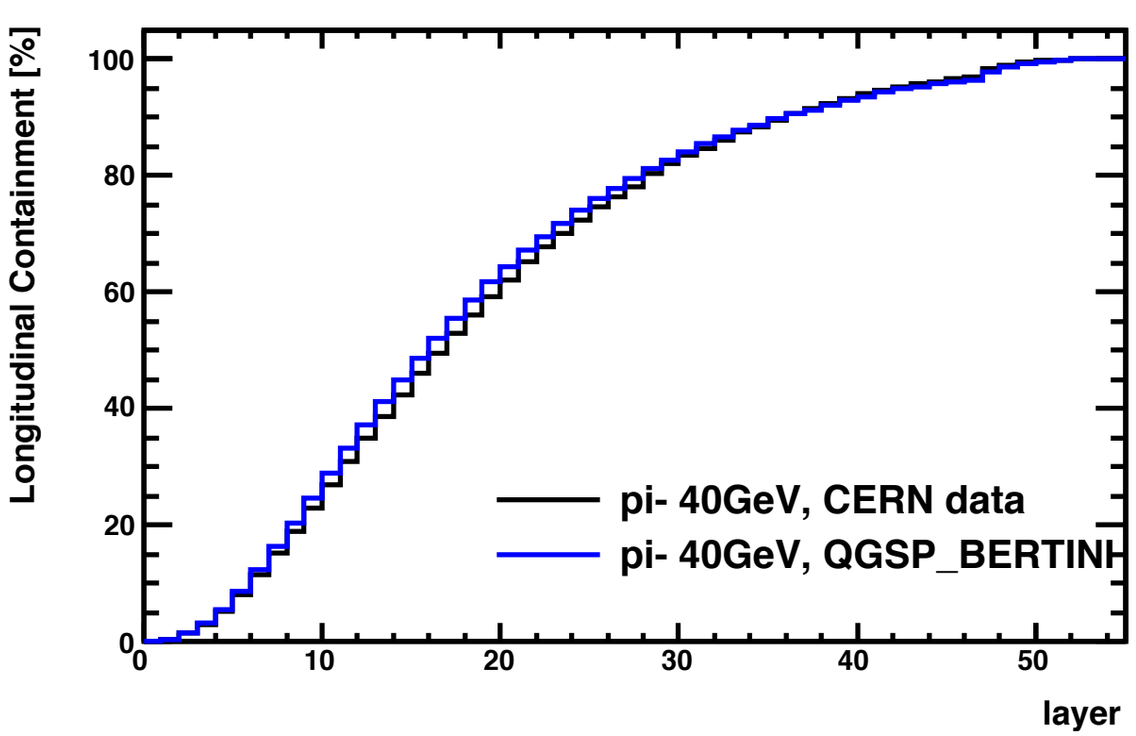
- Energy contained in the cluster depending on depth and radius

Cluster Properties: Containment

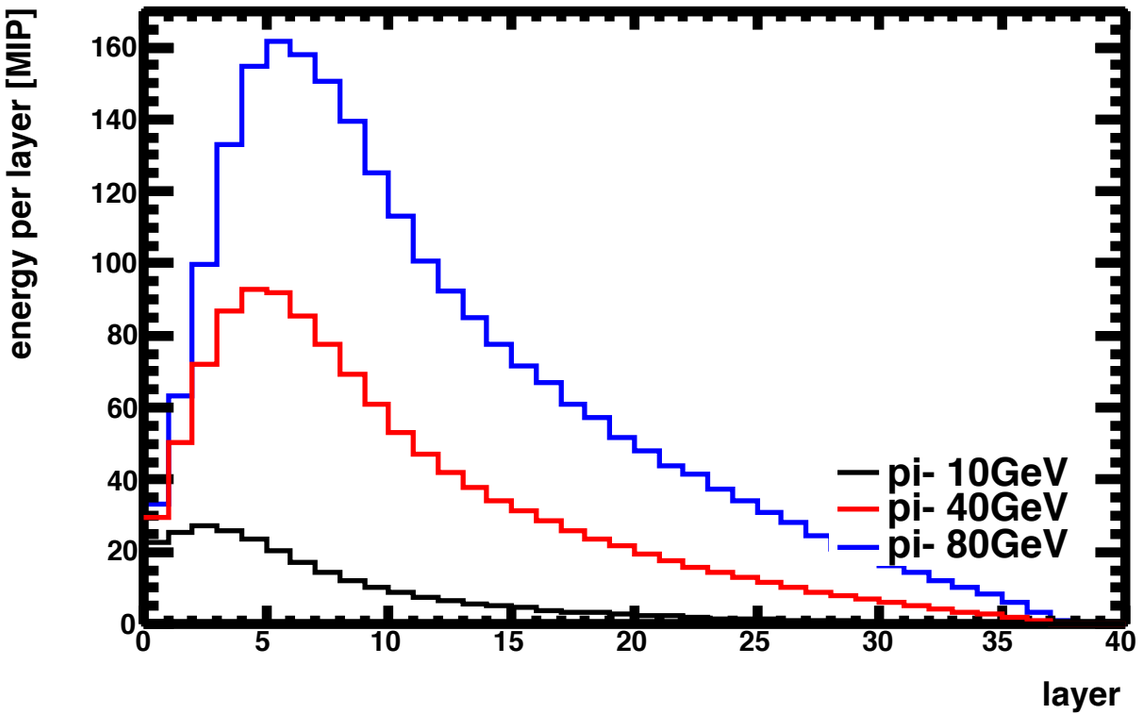


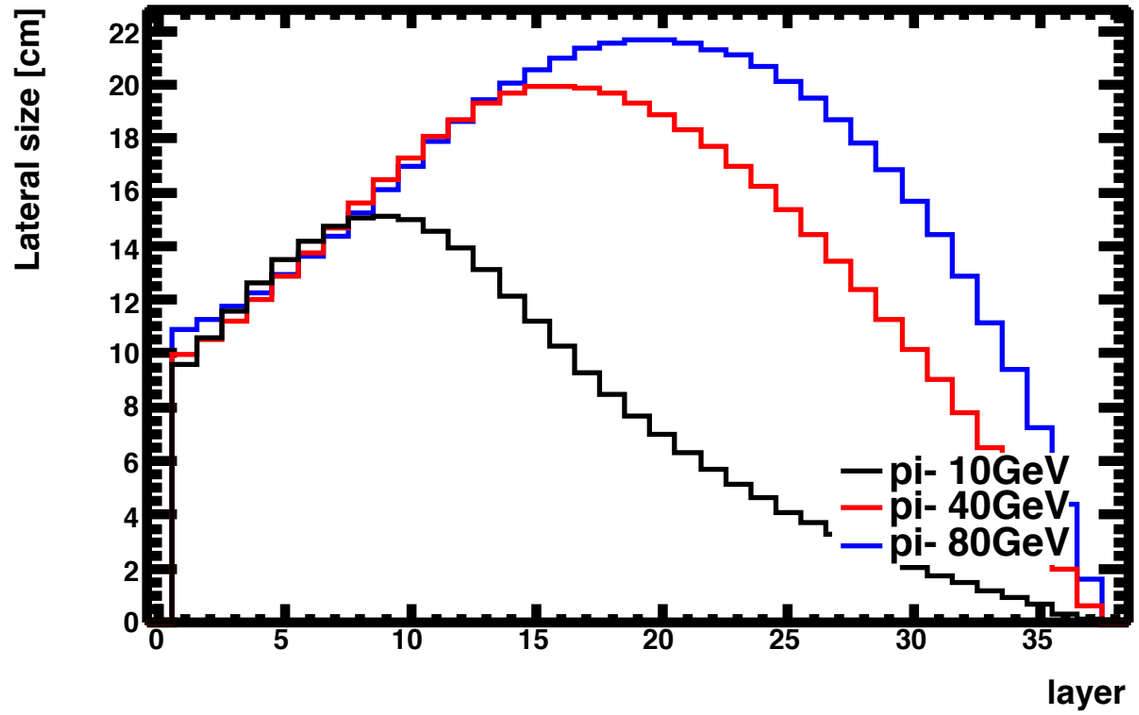






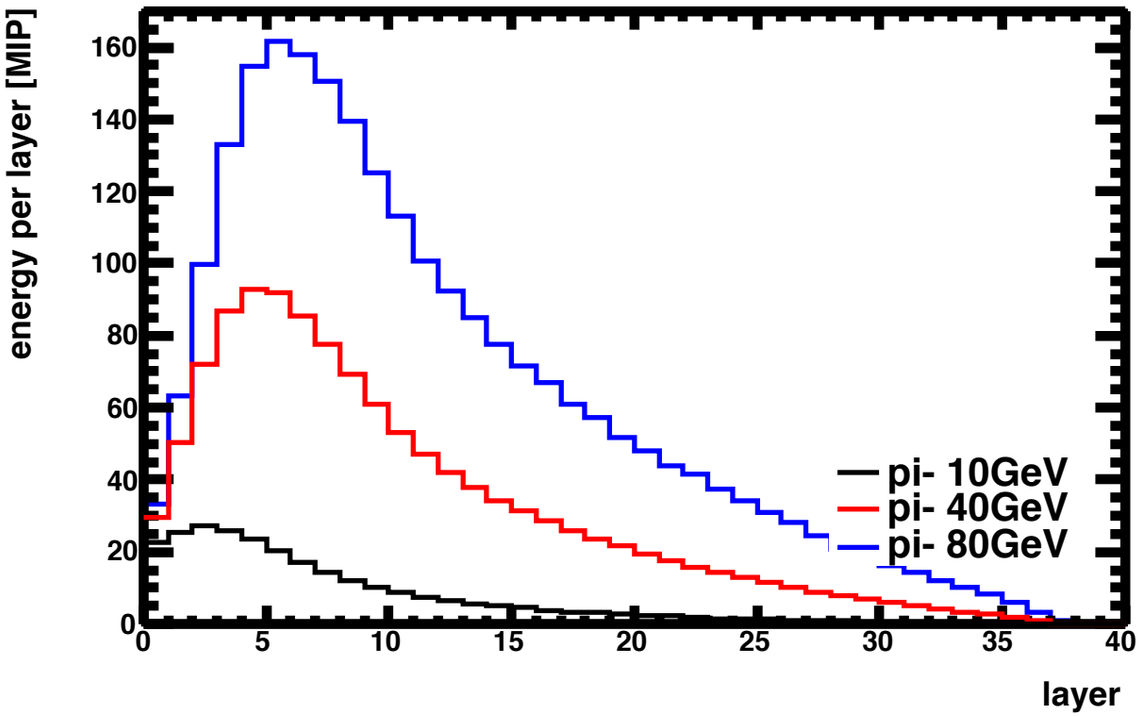
Cluster Properties: Size

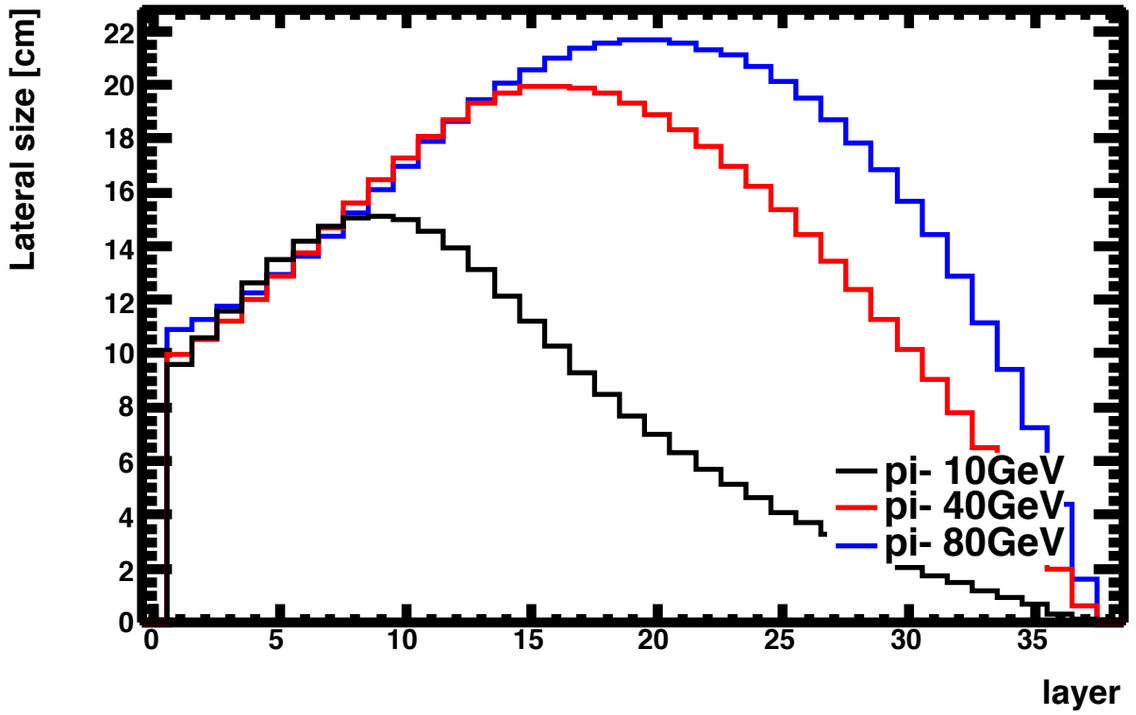


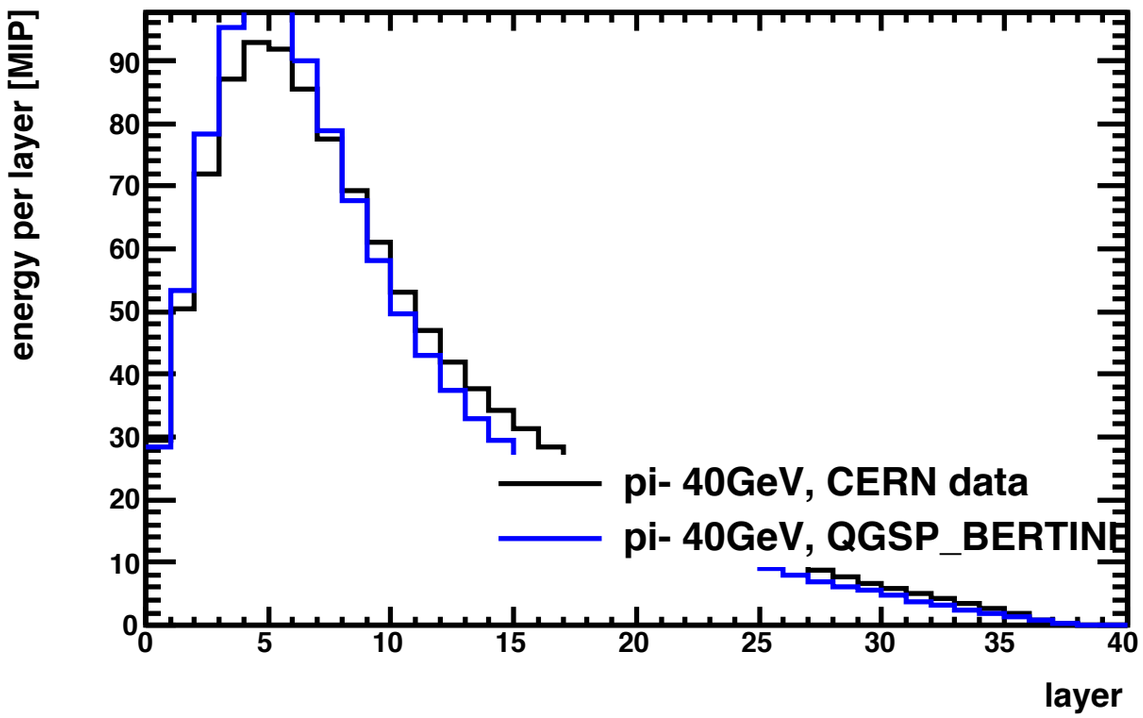


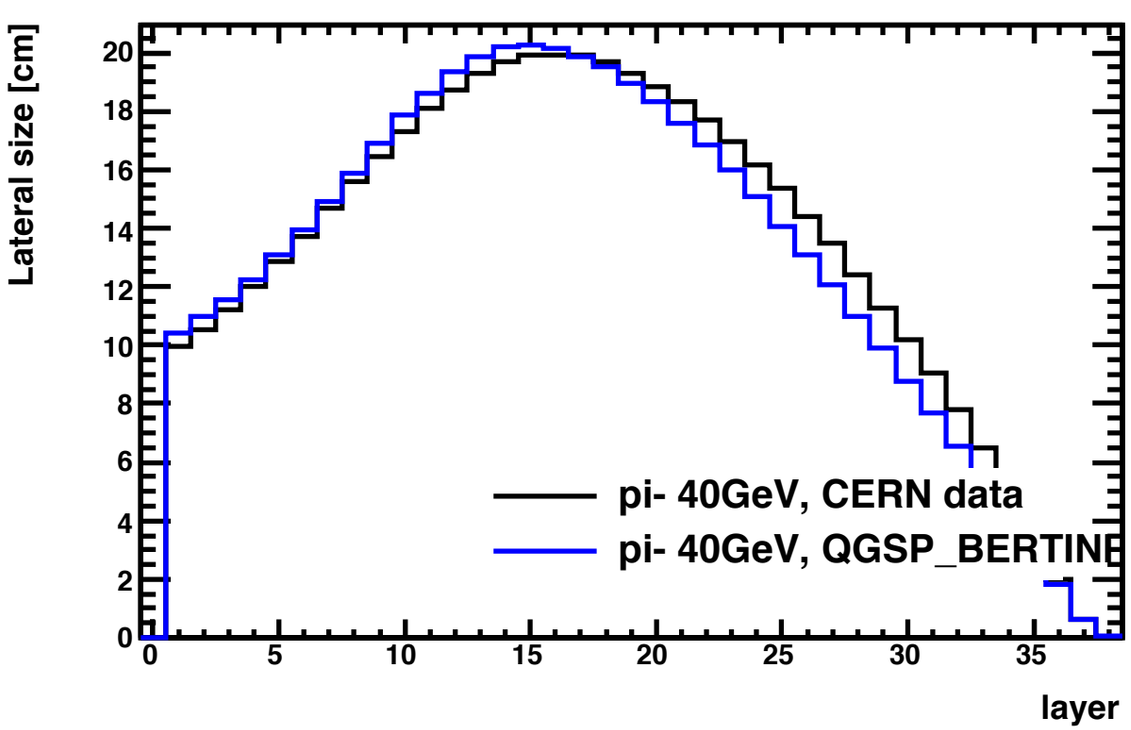
- Energy per layer from cluster start

Cluster Properties: Size

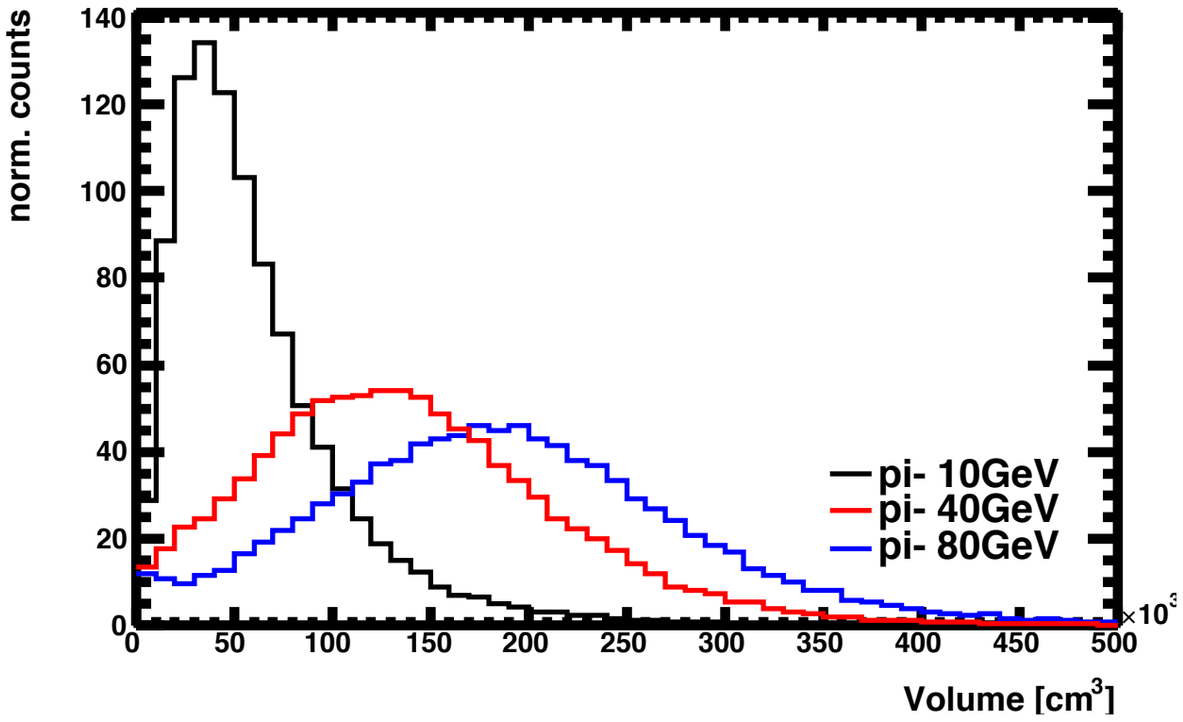


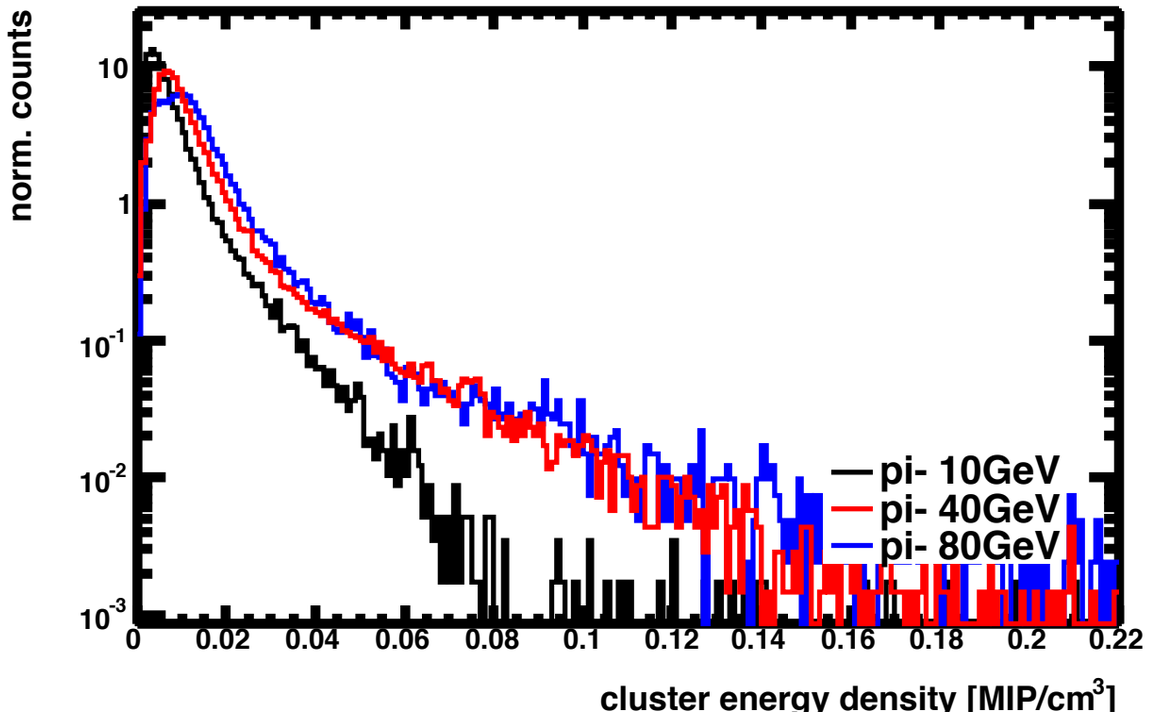






Cluster Properties: Volume & Density





- Cluster Volume: The sum of the volumes of the layer-wise cylinders in the cluster
  - In the TCMT, the same shower radius as in the last HCAL layer is assumed (if the cluster extends into the TCMT)
- Energy density is given by the total cluster energy divided by volume

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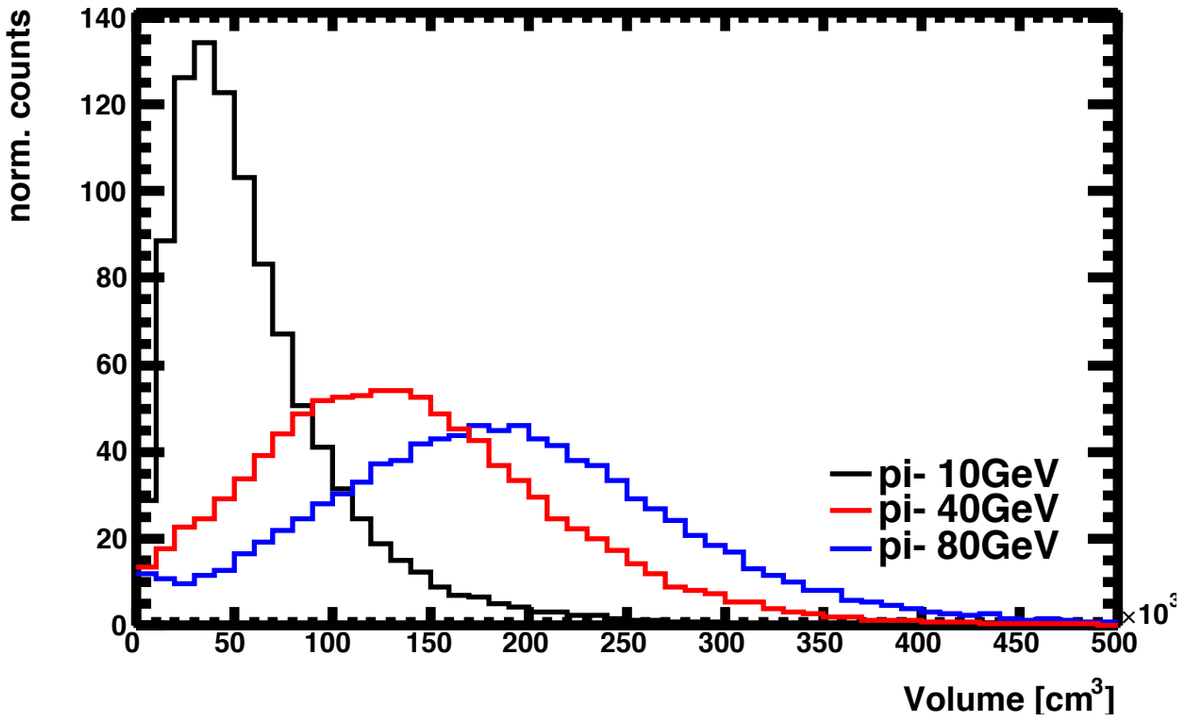

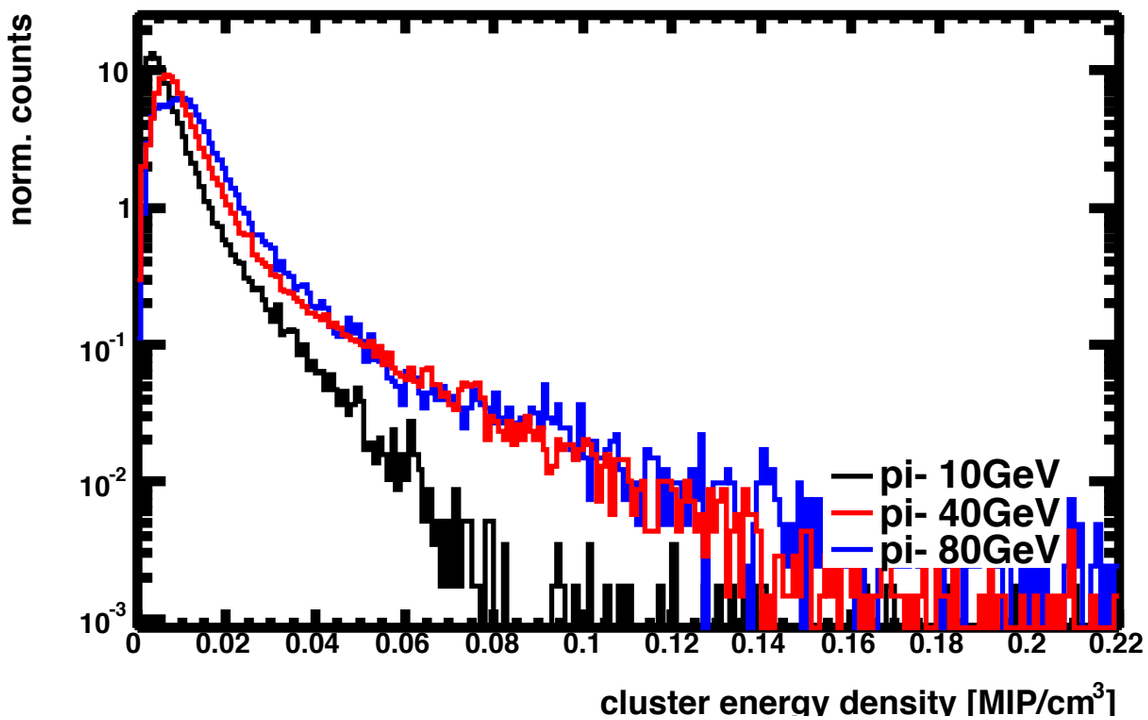

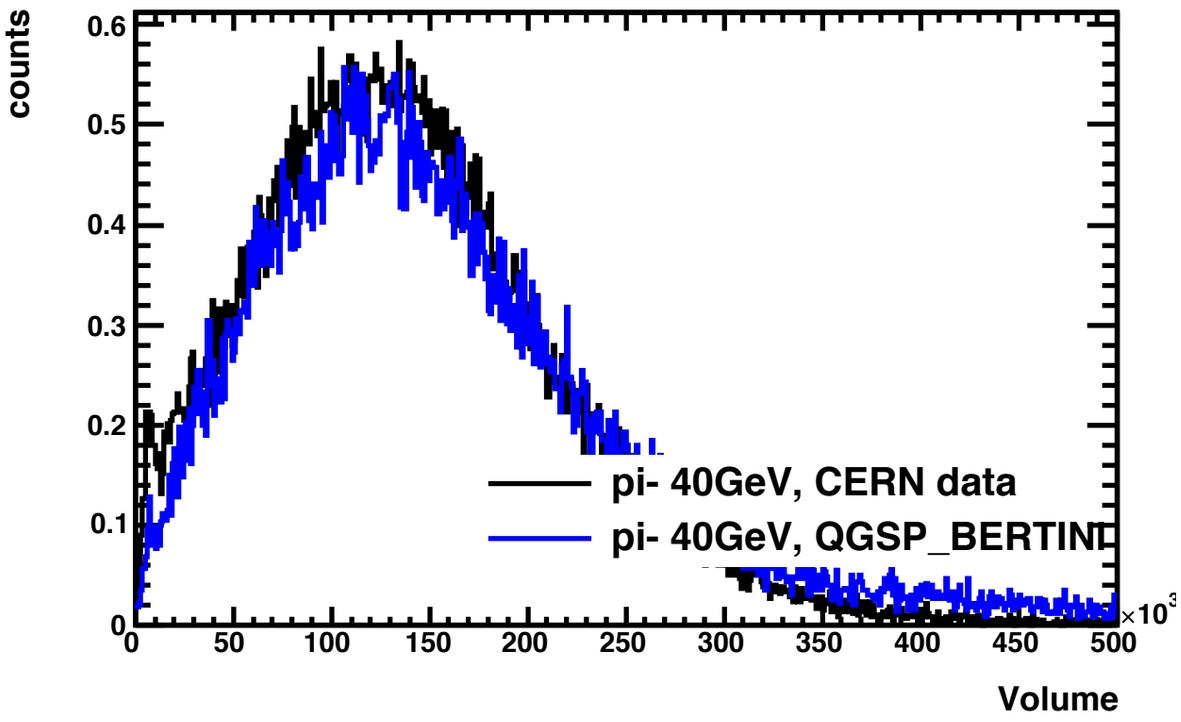

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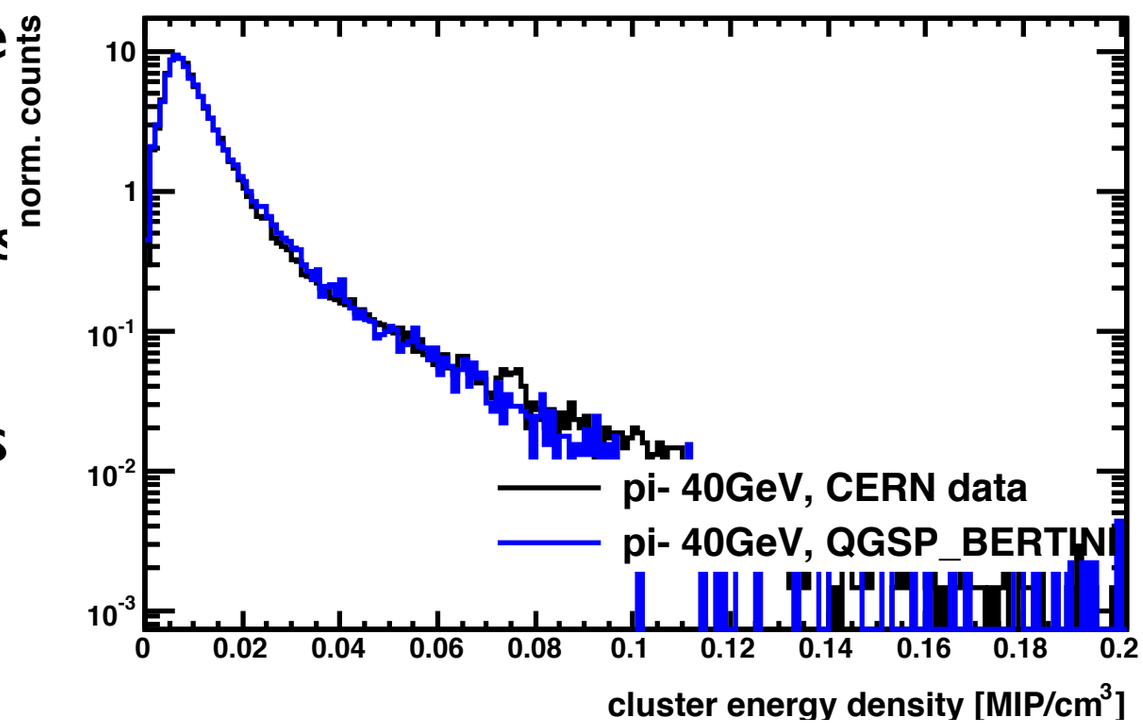

Clusters and Weighting

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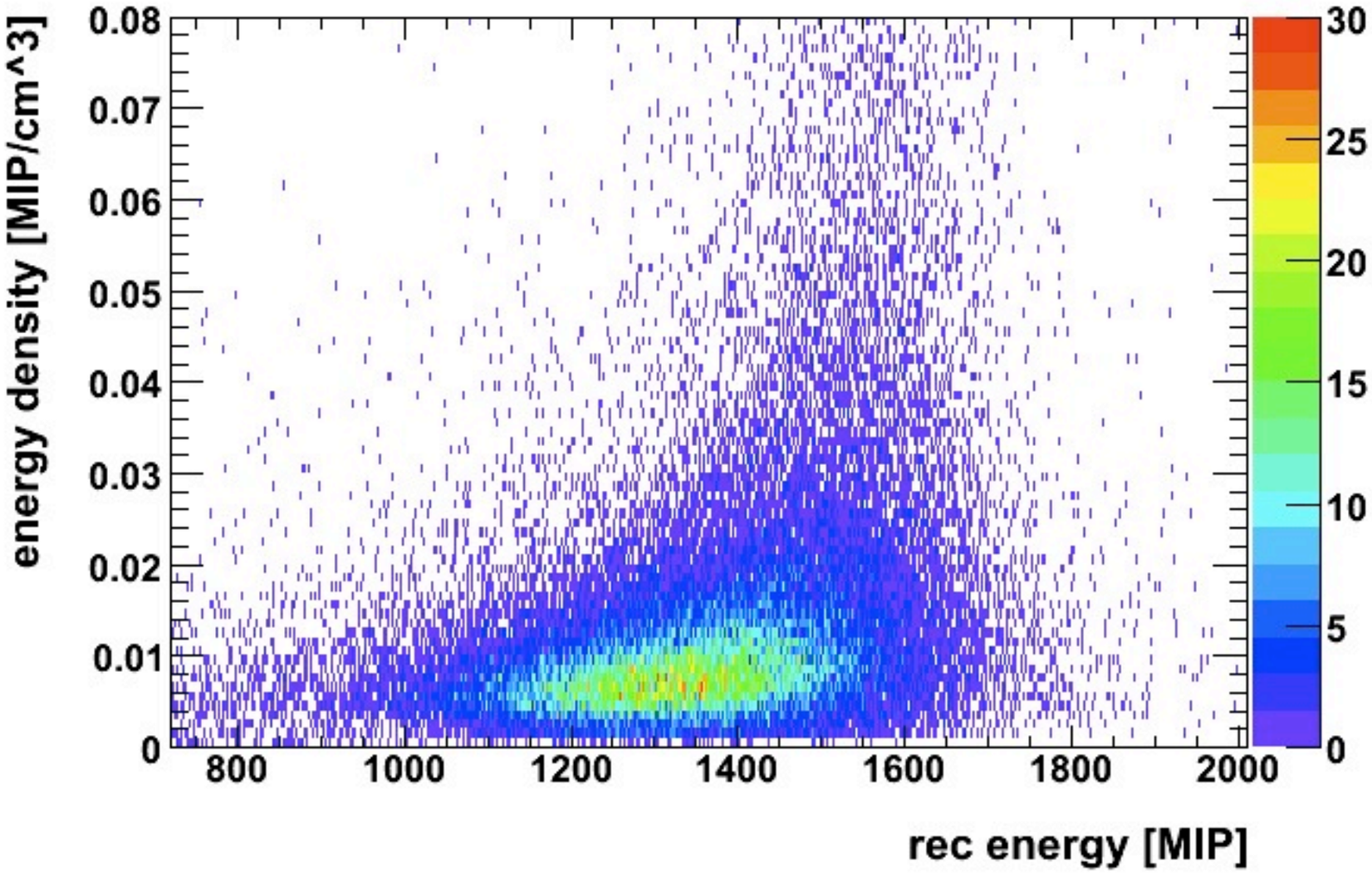
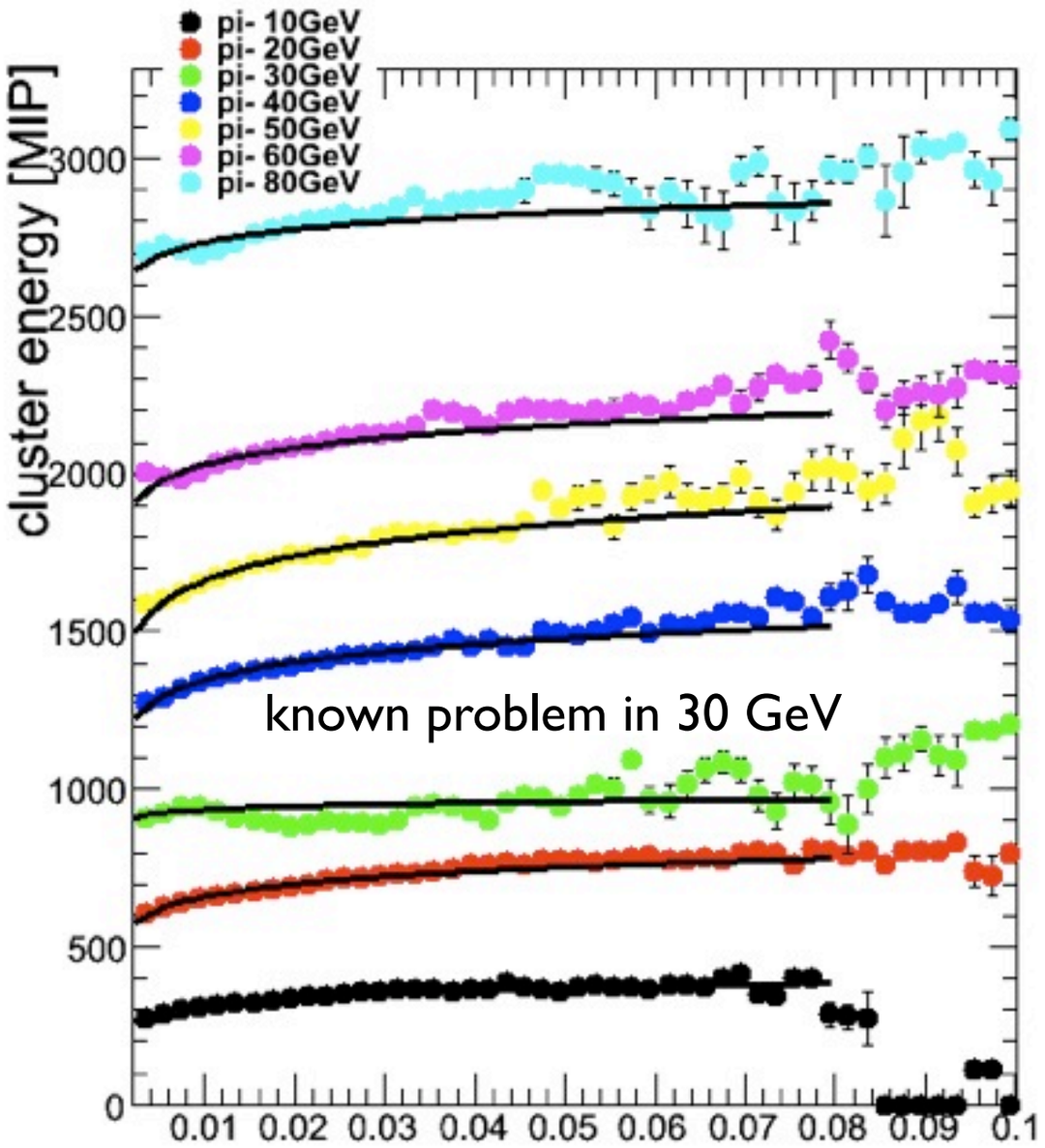
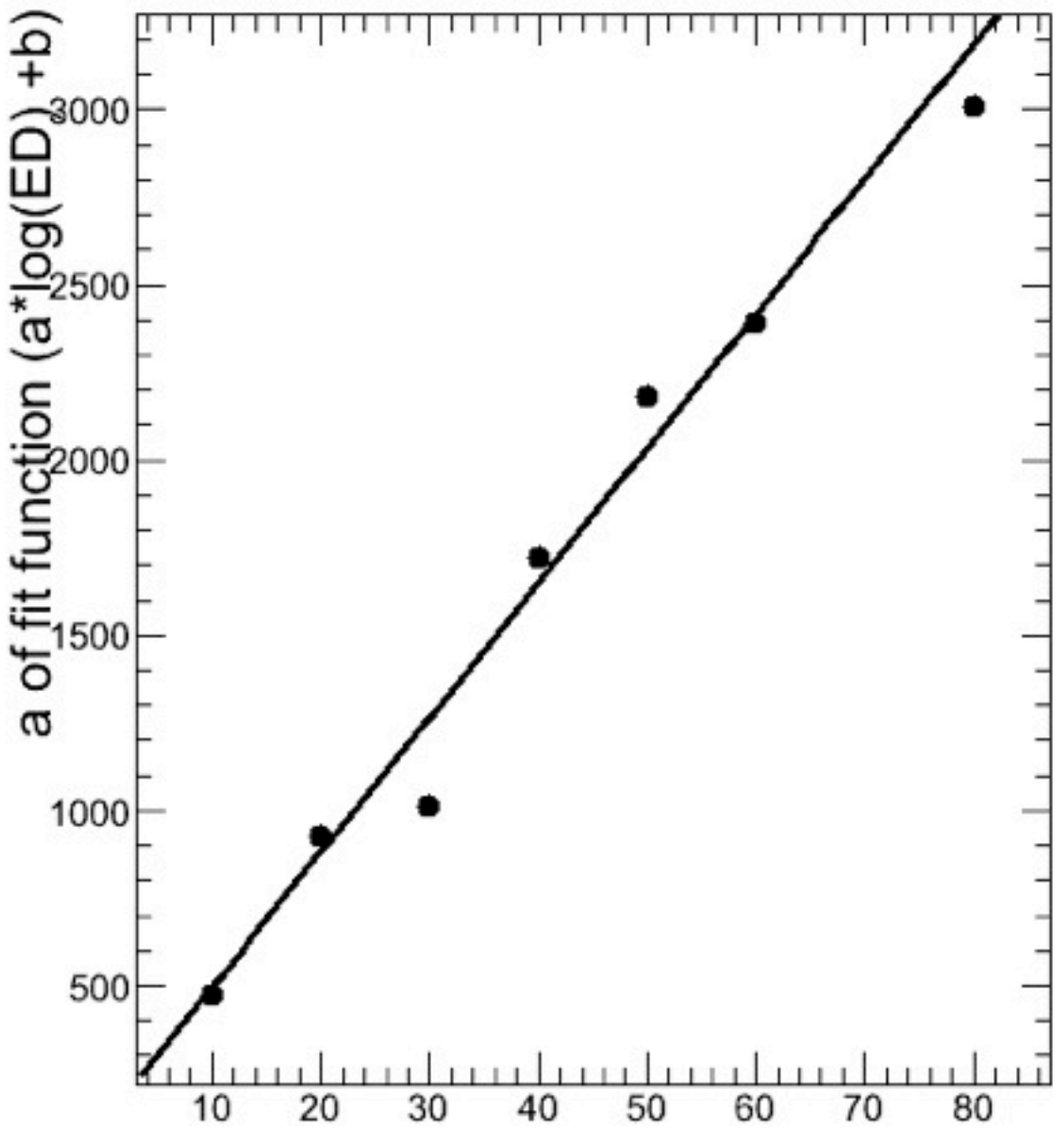


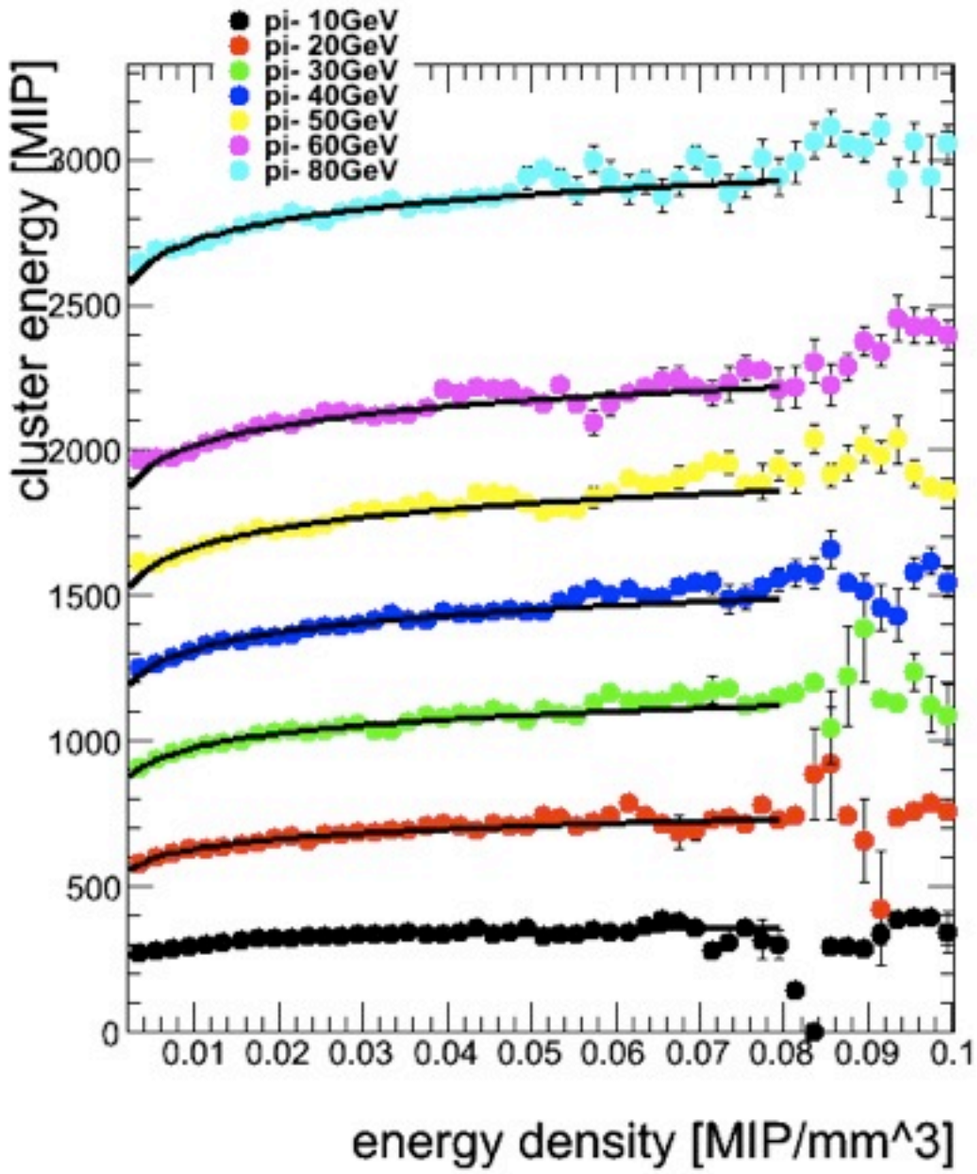
Cluster Density: A Closer Look

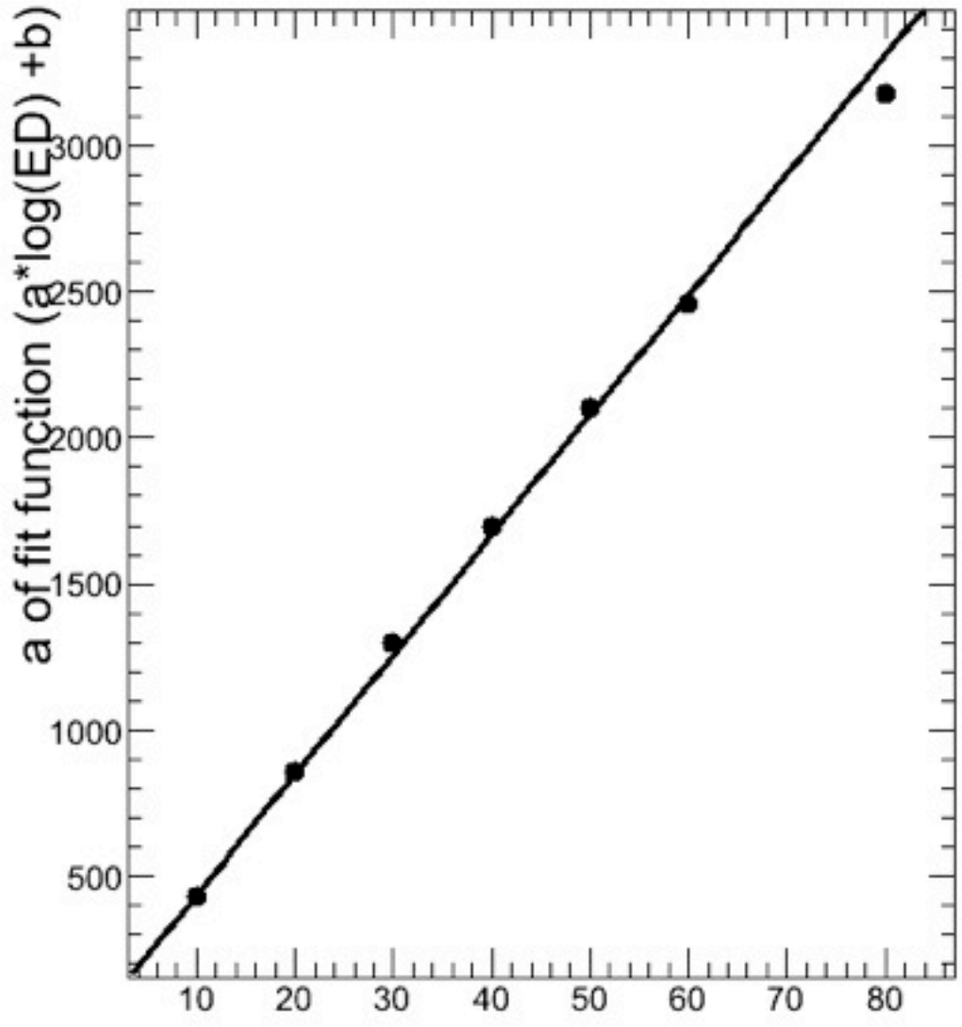
- Reconstructed energy as a function of cluster density: clear correlation





Cluster Density: Agrees with MC





- Next steps: See if this can be used to improve the energy resolution and the linearity of the detector response
  - Further ahead: Identification of sub-clusters for more detailed weighting options

An Alternative: Neural Networks

- Study the possibility use Neural Networks to improve energy resolution and linearity
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A challenge:

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- Use TMVA

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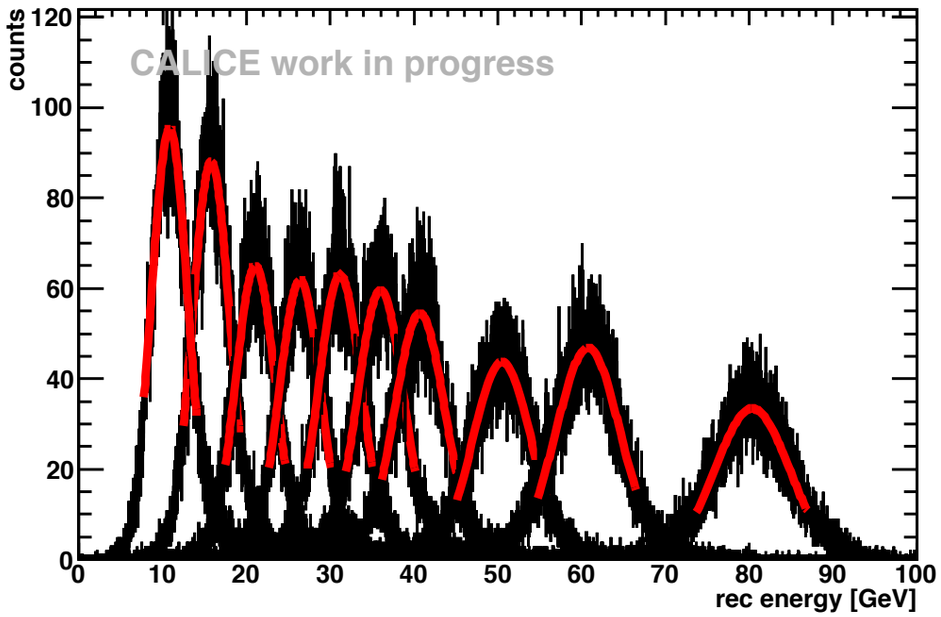
- ▸ Use MC events, simulated in small energy steps (QGSP_BERT)

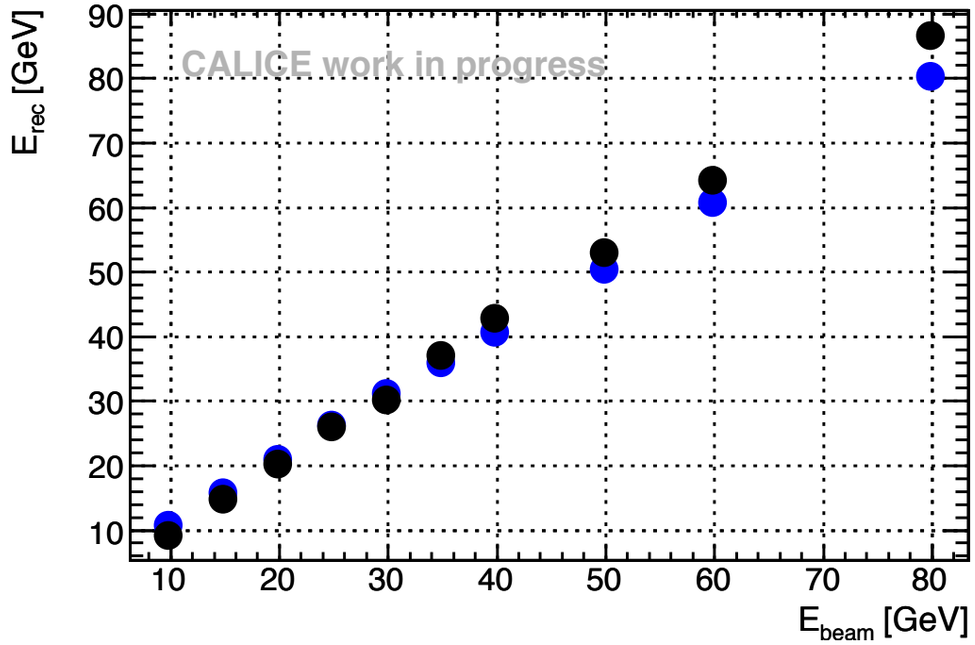
- ▸ Use TMVA

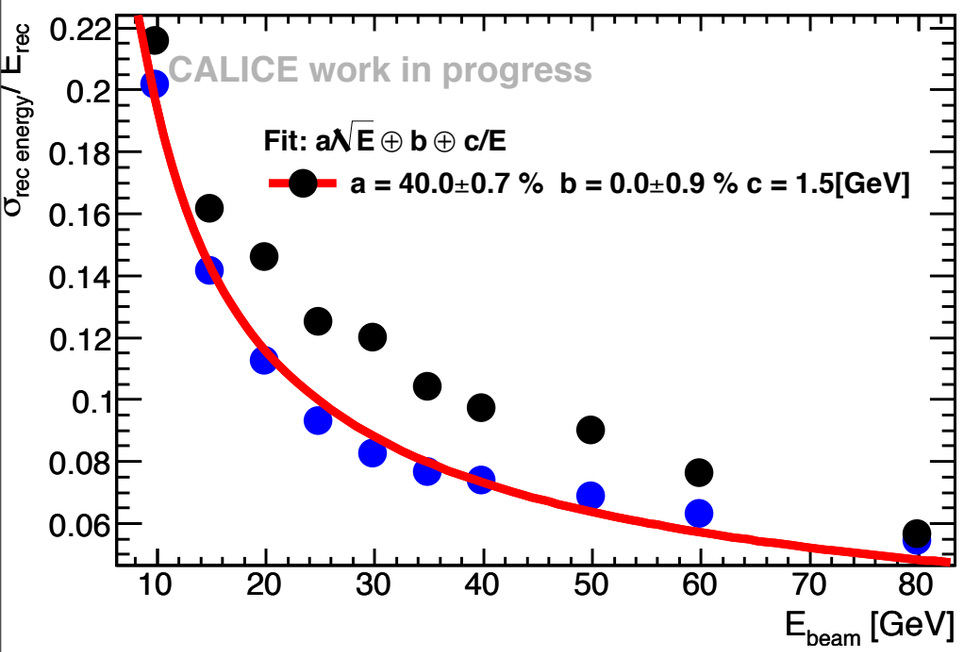
- Then apply this trained network to
  - simulated data, energies as in test beam
  - real data

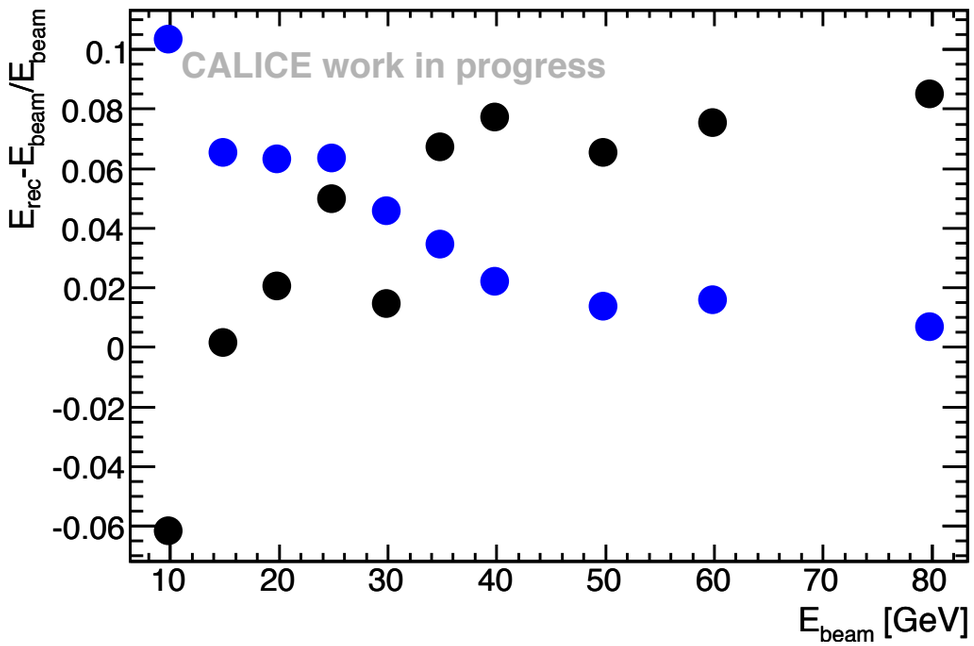
- Here always: No cut on the TCMT, TCMT energy is included in the analysis

NN: Preliminary Results: MC



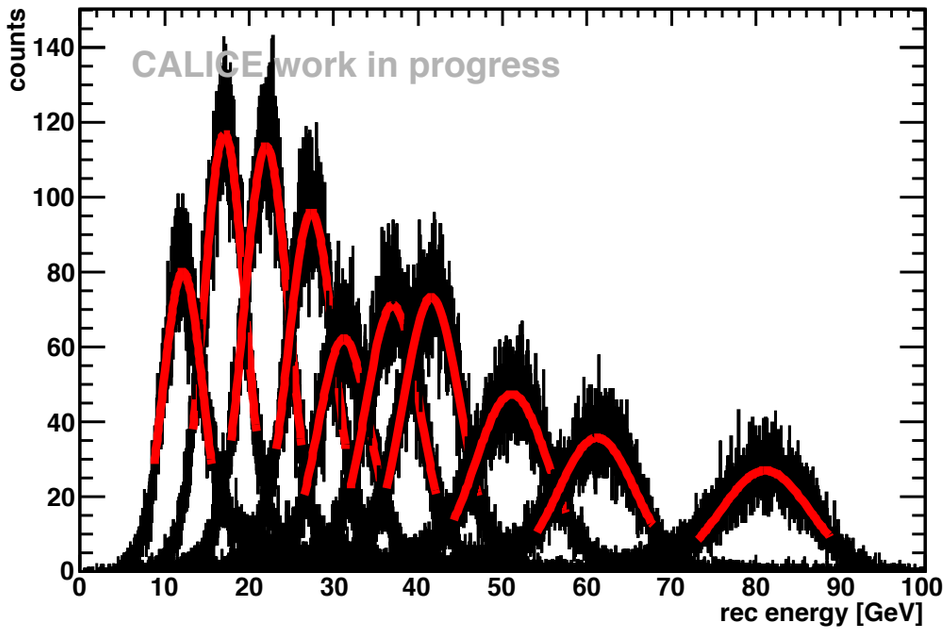


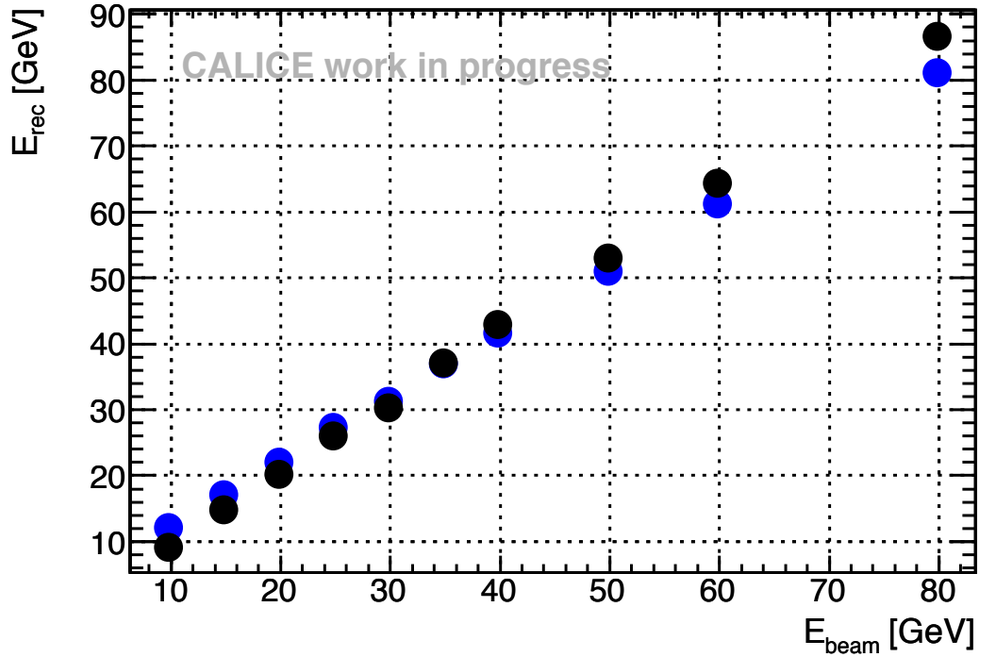




- Improvement in resolution, but still problems with linearity

NN: Preliminary Results: Data





- Slight improvement of resolution, severe problems with linearity

Broadening the Horizon: FNAL Data

- A LOT of good data is out there, that has not really been looked at yet...
  - Large overlap with existing data: Cross-Check of methods in different datasets
  - Added energy points, in particular at low energy

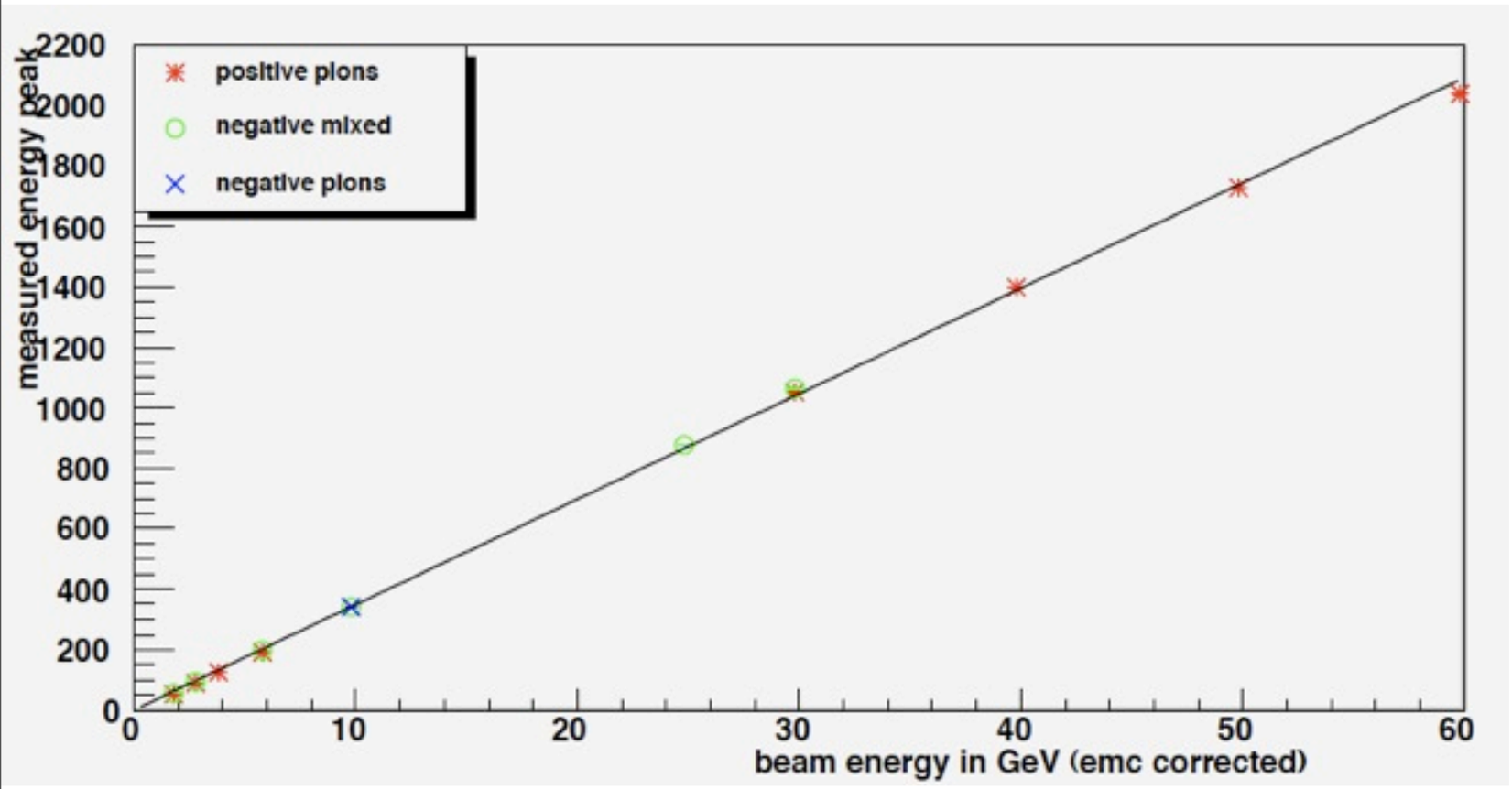
Data from May 2009: Combined runs SiW ECAL + AHCAL + TCMT

- No final calibration yet: Using existing preliminary calibration, used also for fast offline QA
- As a first shot: Using the fast offline bigtree for analysis
- Crosscheck with own data reconstruction (still using the same preliminary calibration)

Runs in the range from 500236 to 500410 used (pion and mixed runs)

Study in HCAL only: MIP in ECAL (30 to 60 MIP), nothing in TCMT (< 12 MIP)

A First Look at FNAL Data: BigTree



Good linearity, different runs at the same energy agree!

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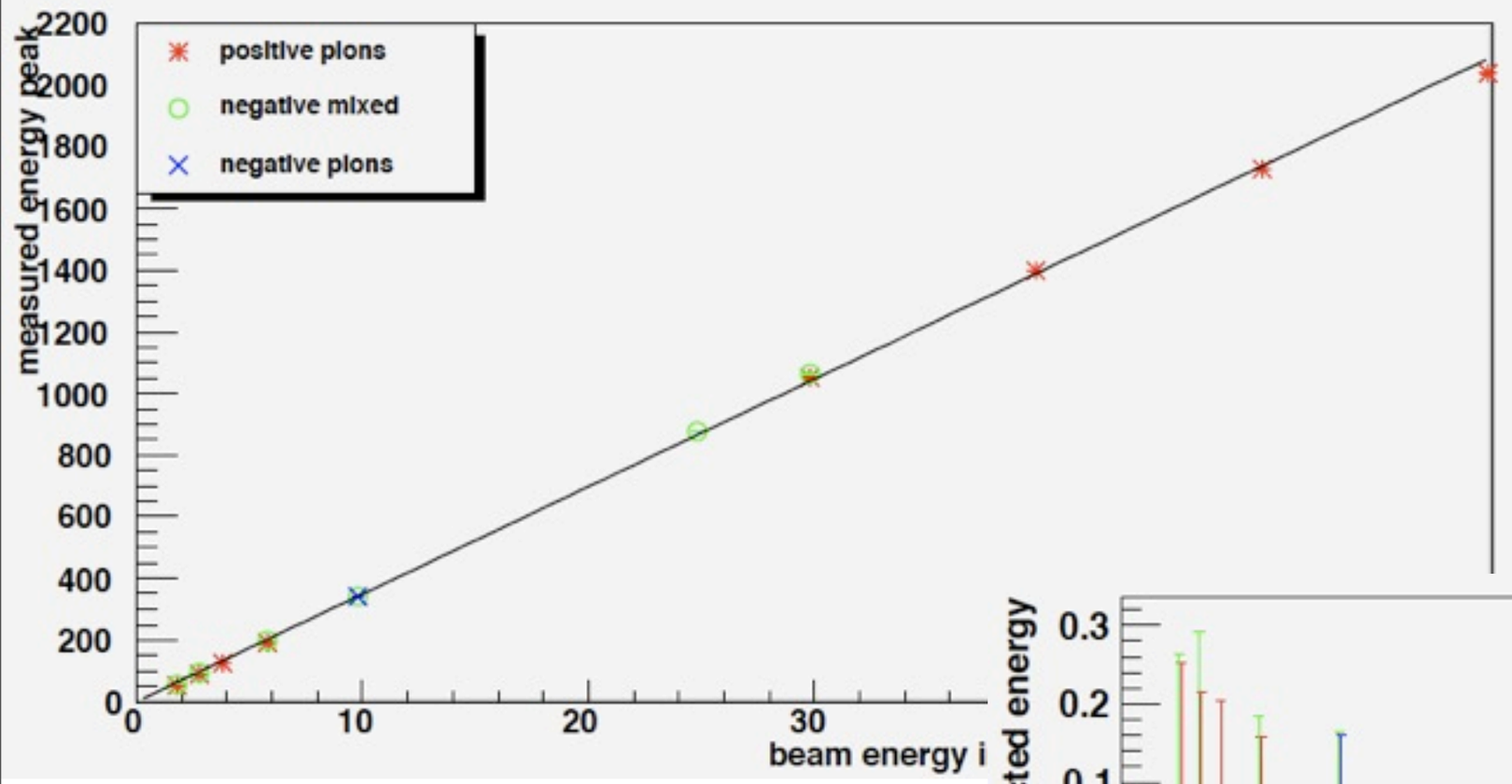

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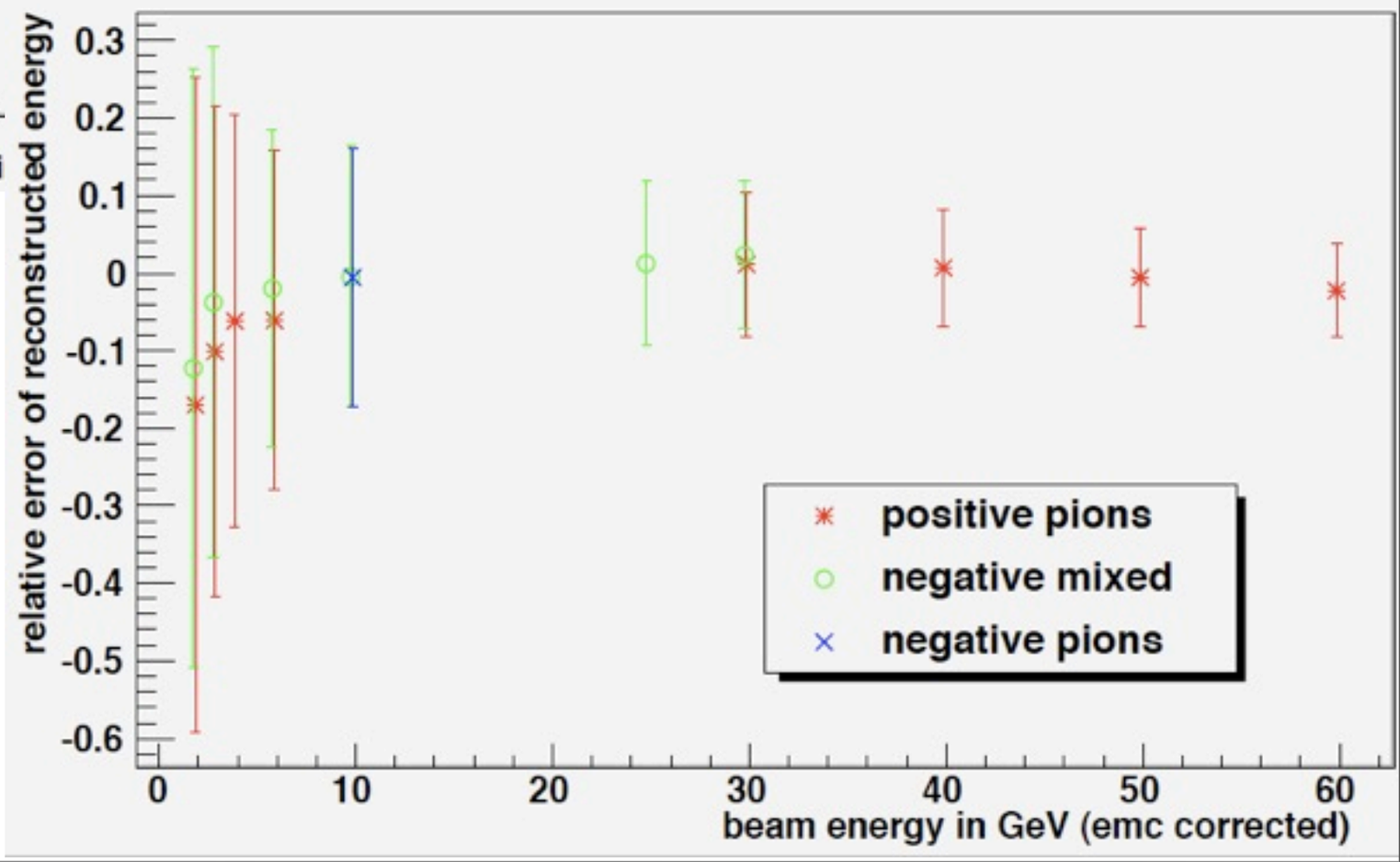

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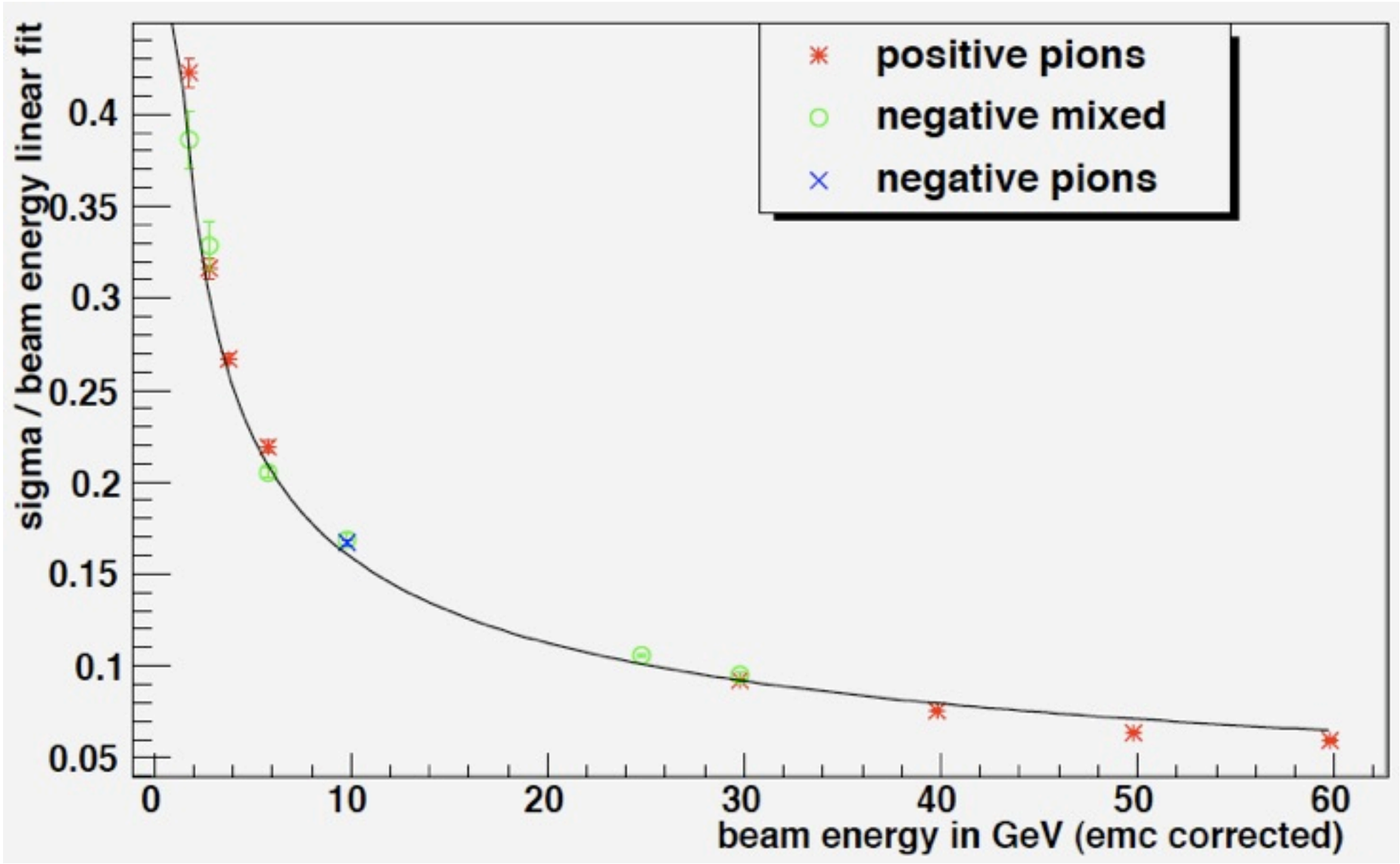

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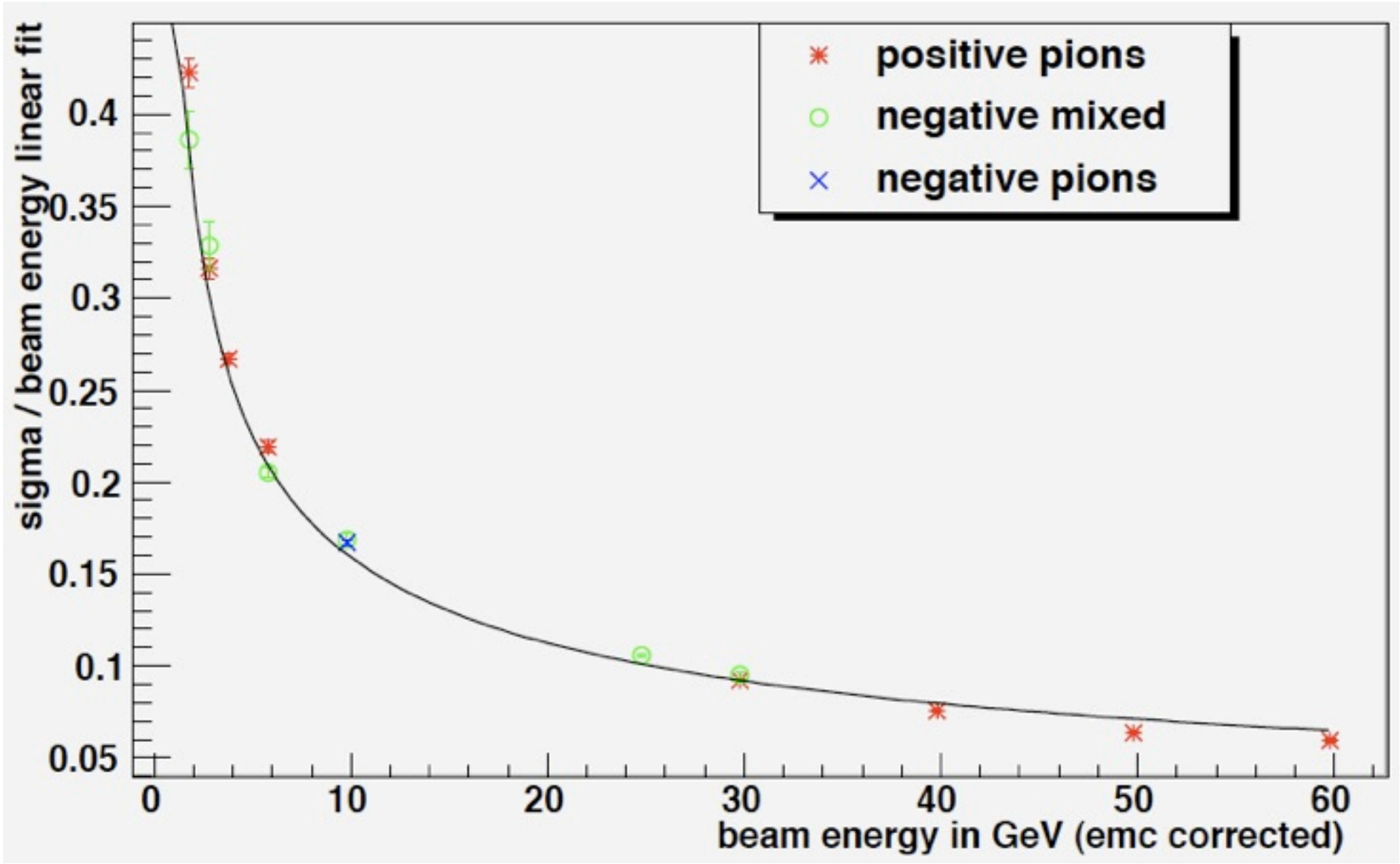

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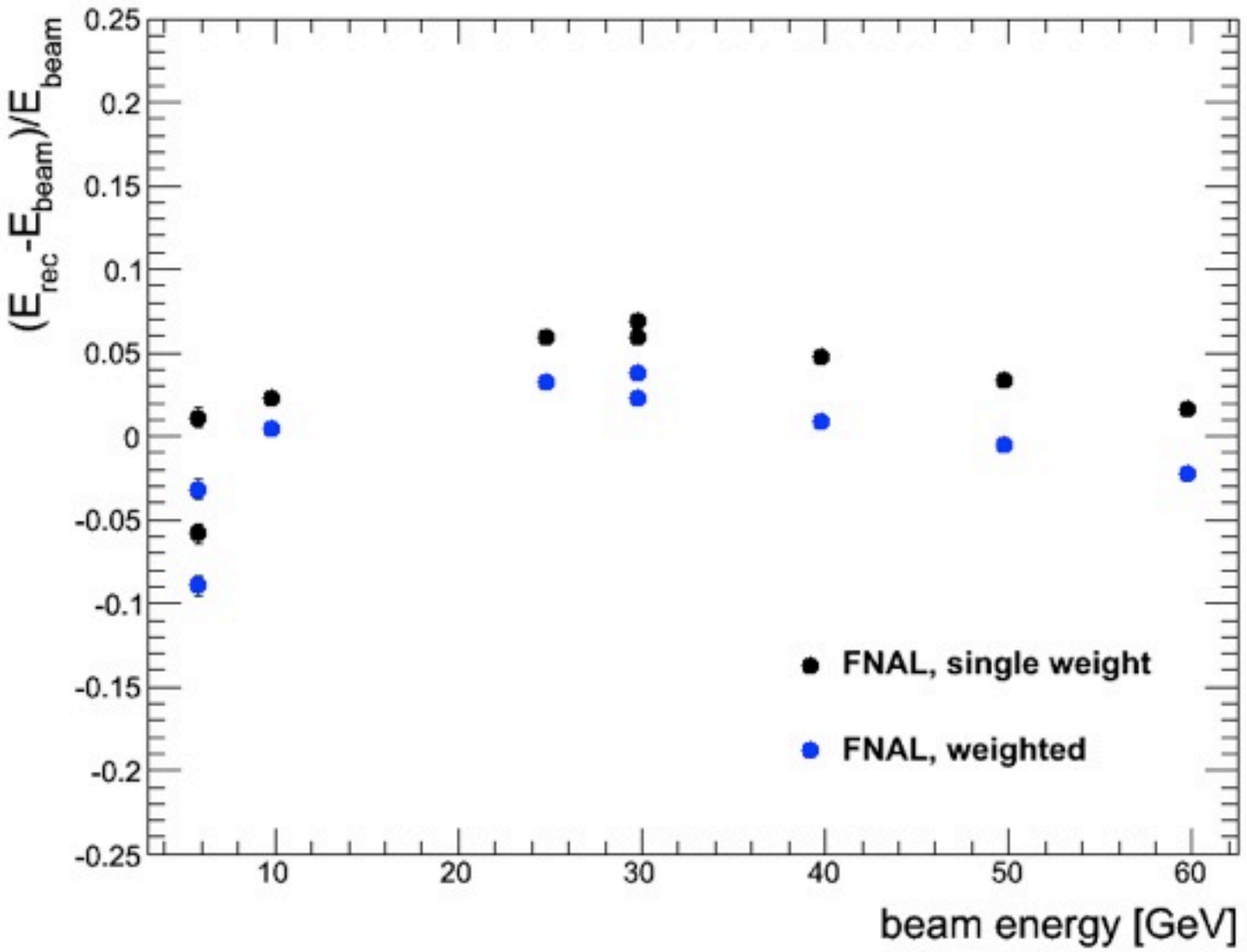
... almost as good as CERN data with weighting!

FNAL Data: The Cross-Check

- Using reconstructed data with our standard analysis, applying weights derived from the CERN data



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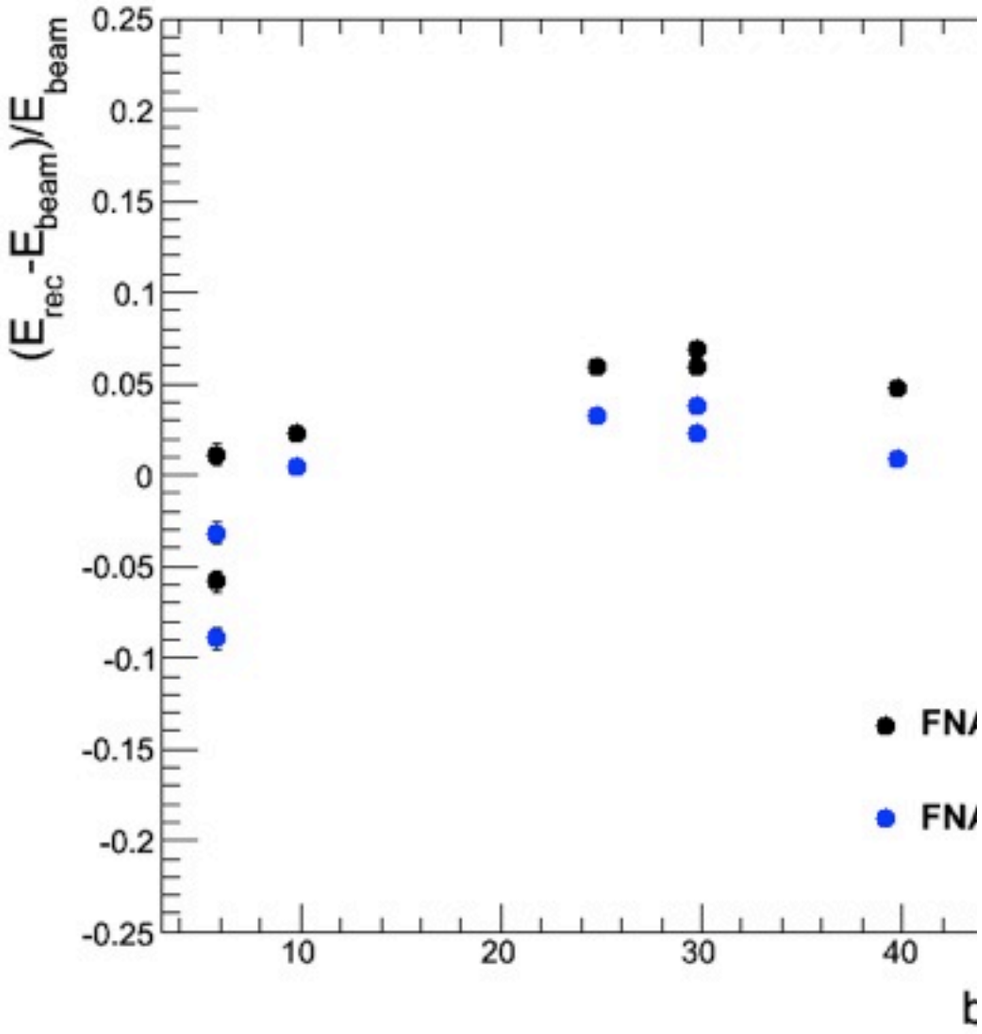

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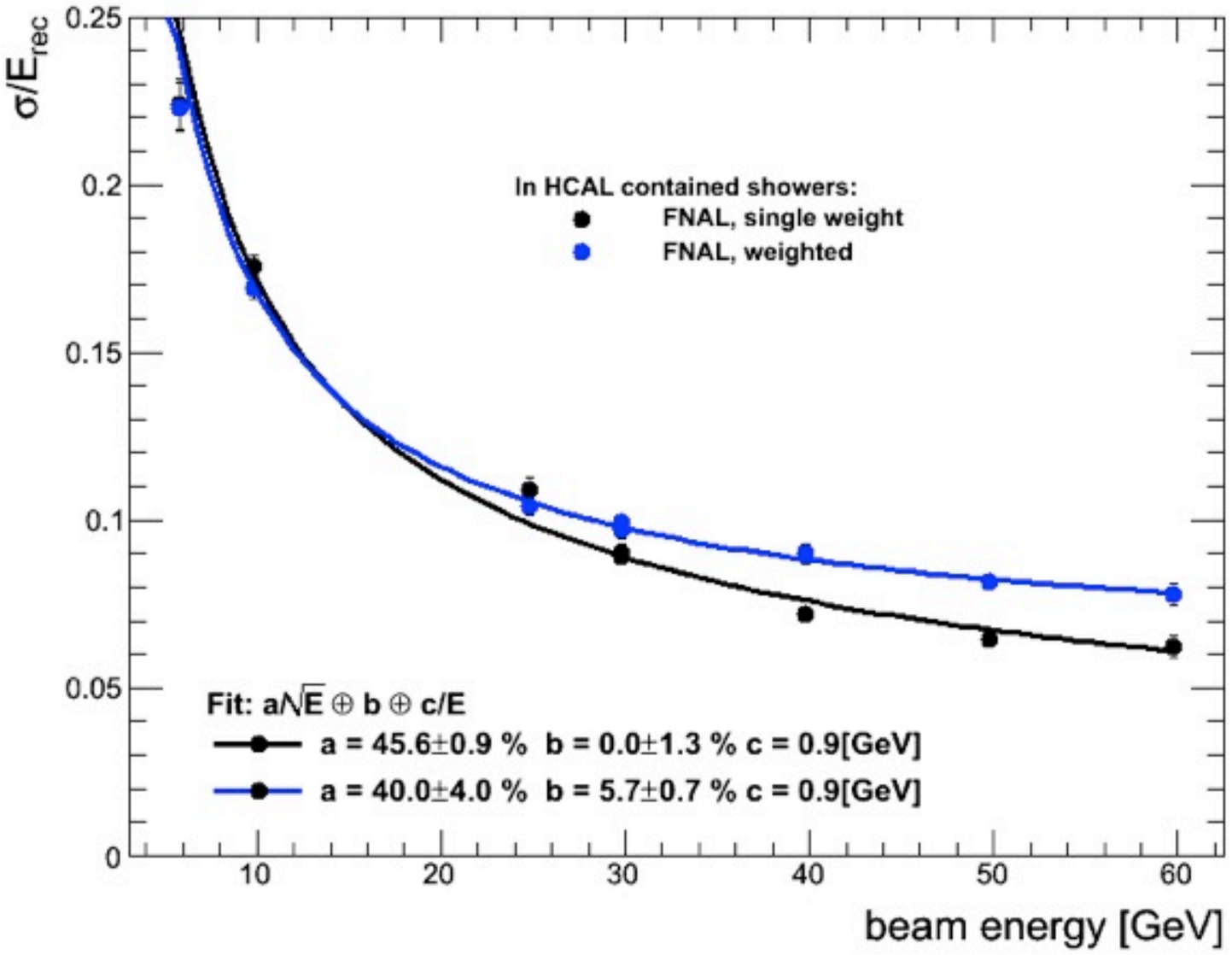

... but the weighting breaks the energy resolution at higher energies! Further studies needed...

Summary, Outlook

- Initial study of weighting methods based on local shower density to improve the energy resolution for hadrons
  - Improvement of the resolution of ~ 20% is reached for the full CALICE setup and for the HCAL alone

- Investigation of clusters
  - Currently using a simple clustering algorithm
  - Total energy density in cluster might be suited for weighting procedures
  - Possibility to use Neural Networks: Work ongoing

- New data: FNAL 2008
  - Surprisingly good energy resolution, but problems with weighting: Reasons probably in the method of data reconstruction, will be investigated