# Single Cell Software Compensation - Update

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# Software Compensation

Improvement of the energy reconstruction and
energy resolution of hadrons by...

- Single Cell Weighting Software Compensation Technique (CAN-15, Feb 2009)
- Cluster Weighting Software Compensation Technique (CAN-21, March 2010)
- Cluster based Neural Network Technique (CAN-21, March 2010)

In this talk:

- Single Cell Software Compensation Technique based on the 3D energy density of every hit
  - Data Selection
  - Method
  - Results for data and Monte Carlo
- Single Cell Software Compensation and PandoraPFANew

# Data Sets and Selection

Input:

- Data: $\pi^{-/+}$ runs from 10-80 GeV from CERN2007
  $\Rightarrow$ for extraction of weights
- Data: $\pi^{-}$ runs from 10-80 GeV from CERN2007
  $\Rightarrow$ for application of weights
- MC: $\pi^{-}$ events from 10-80 GeV with physics list FTF_BIC and QGSP_BERT
- Reconstruction and digitization done with calice software version v04-01

Cuts:

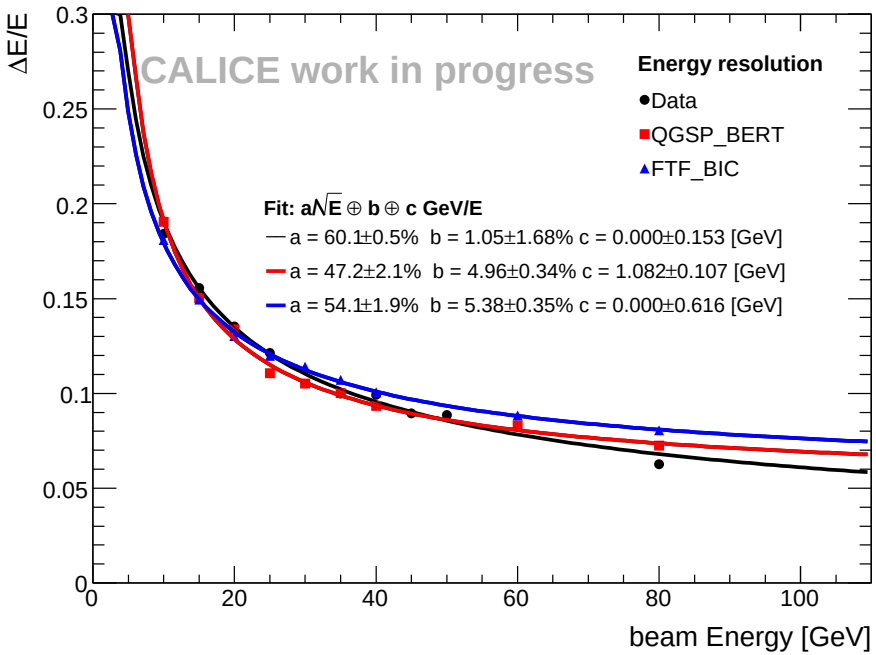
- $E_{hit} > 0.5$ MIP
- Cherenkov cut to eliminate electron/proton contamination
- Multiplicity counter cut for the $\pi^{+}$ runs.
- Shower has to start in layer 1-5 of HCAL

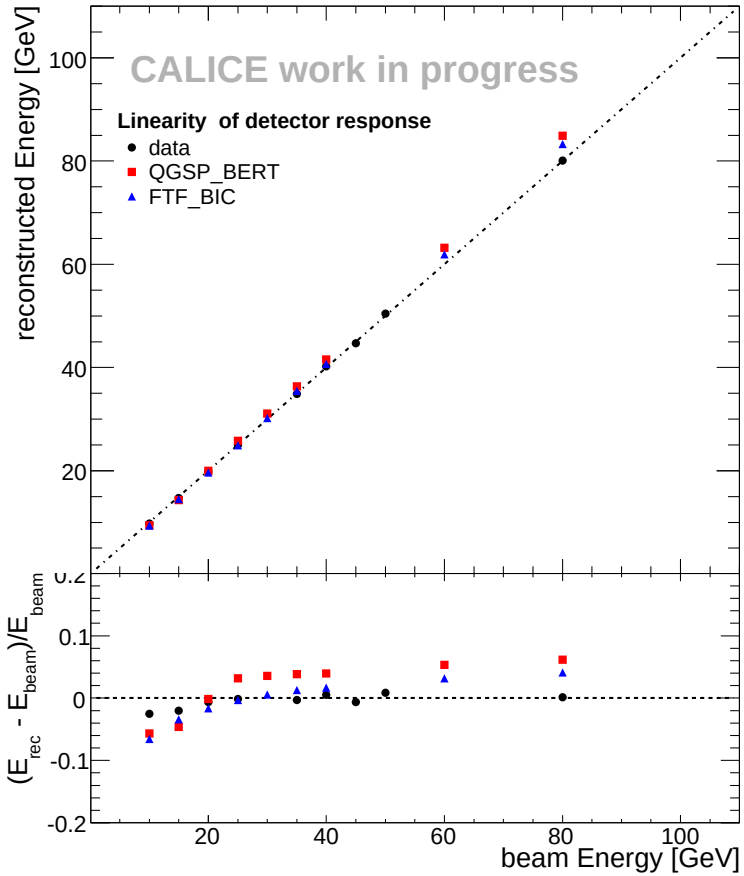
Initial reconstructed event energy:

$$E_{\mathrm{rec}}[GeV] = E_{\mathrm{hcal}}[GeV] + E_{\mathrm{tcmt}}[GeV]$$
$$E_{\mathrm{hcal}}[GeV] = E_{\mathrm{hcal}}[MIP] \cdot 0.03$$
$$E_{\mathrm{tcmt}}[GeV] = E_{\mathrm{tcmt}}[MIP] \cdot 0.03$$

# No software compensation

Drop of linearity for low energies due to ECAL treatment.
Energy deposition in ECAL is set to 200 MeV for every event.
MC energy resolution worse than data energy resolution for high energies.



# Software compensation technique

Technique similar to CAN-15 - single cell software compensation
$\Rightarrow$ every hit is multiplied with a different weight

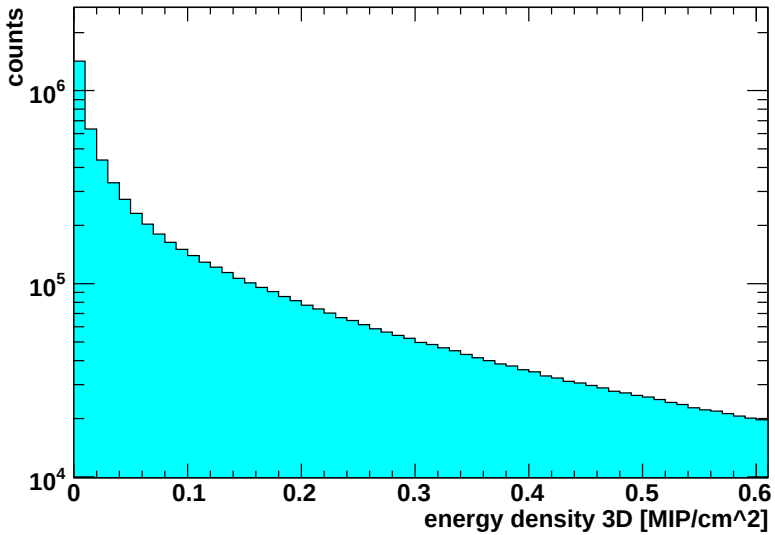
- corrected energy: $E_{\mathrm{rec}}[GeV] = E_{\mathrm{hcal}}[GeV] + E_{\mathrm{tcmt}}[GeV]$
  $E_{\mathrm{hcal}}[GeV] = \sum_{\mathrm{hits}} E_{\mathrm{hit}}[MIP] \cdot \omega$
  $E_{\mathrm{tcmt}}[GeV] = E_{\mathrm{tcmt}}[MIP] \cdot 0.03$
- Weight $\omega$ for each hit depends on initial reconstructed energy and '3D'-energy density of the hit
- Weight energy density dependence: $\omega = a \cdot exp(b \cdot ED) + c$; the higher the energy density the lower the weight $\omega$
- '3D'-energy density $ED$ is calculated from all neighboring cells ($ED = \frac{\sum E_{\mathrm{hit}}}{\sum A_{\mathrm{hit}}}$)
- Energy dependence of $\omega$ in functions for a, b, c
- A separation into different energy density bins was used to extract the weights

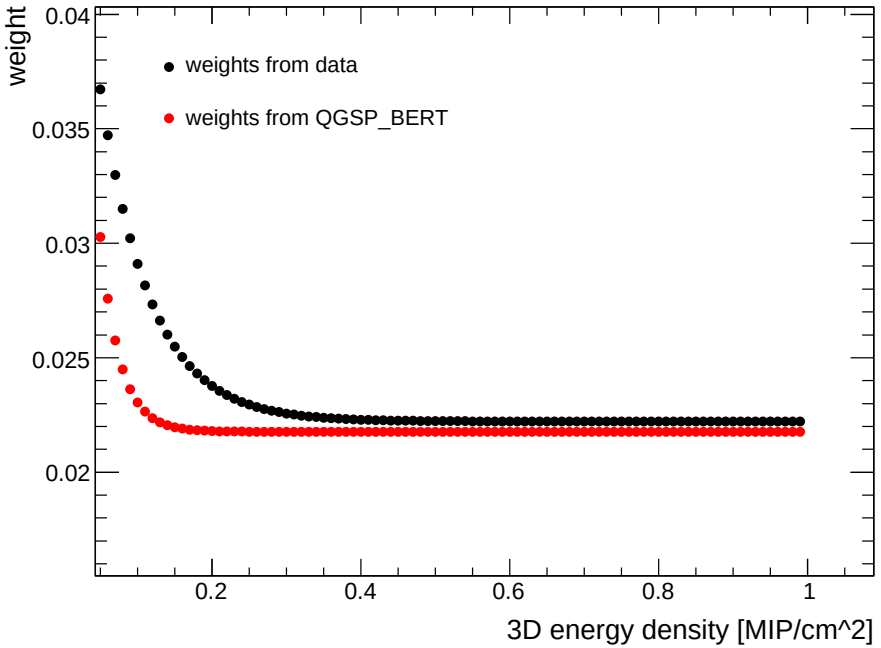
# Application of Software Compensation

- No energy density bins division is used, but minimal energy density if fixed to avoid extremely high weights for low energy densities

Different weights sets:

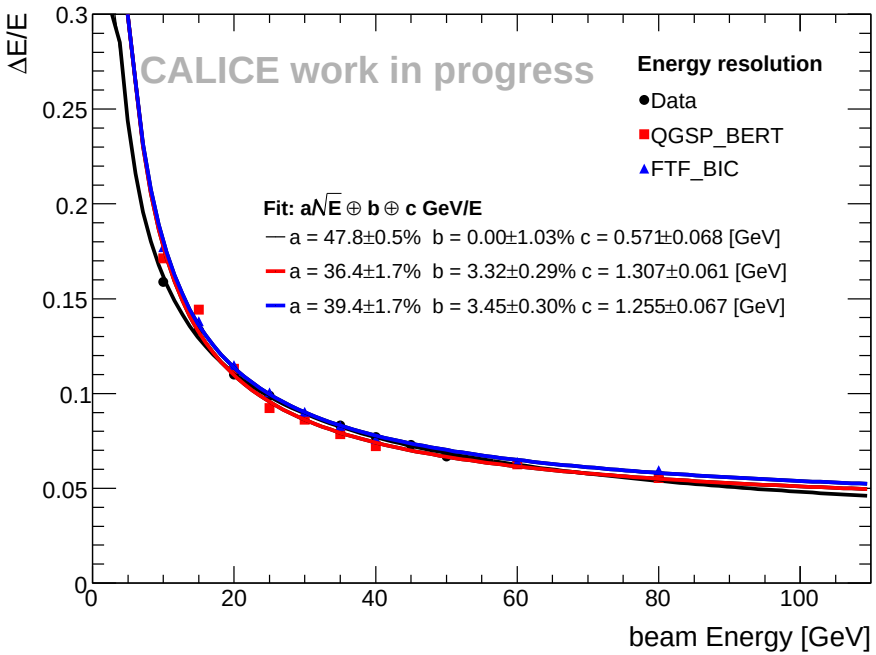
- Weights extracted from data
- Weights extracted from simulation with physics list QGSP_BERT

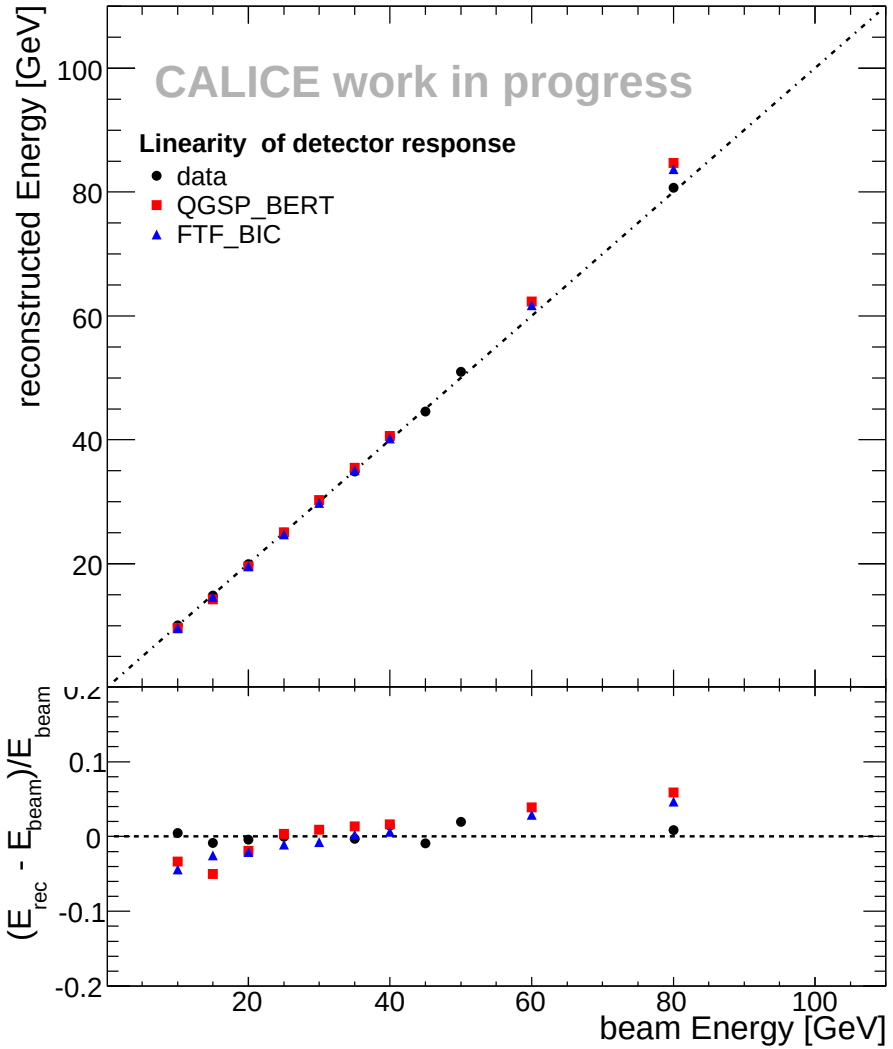


# Software compensation

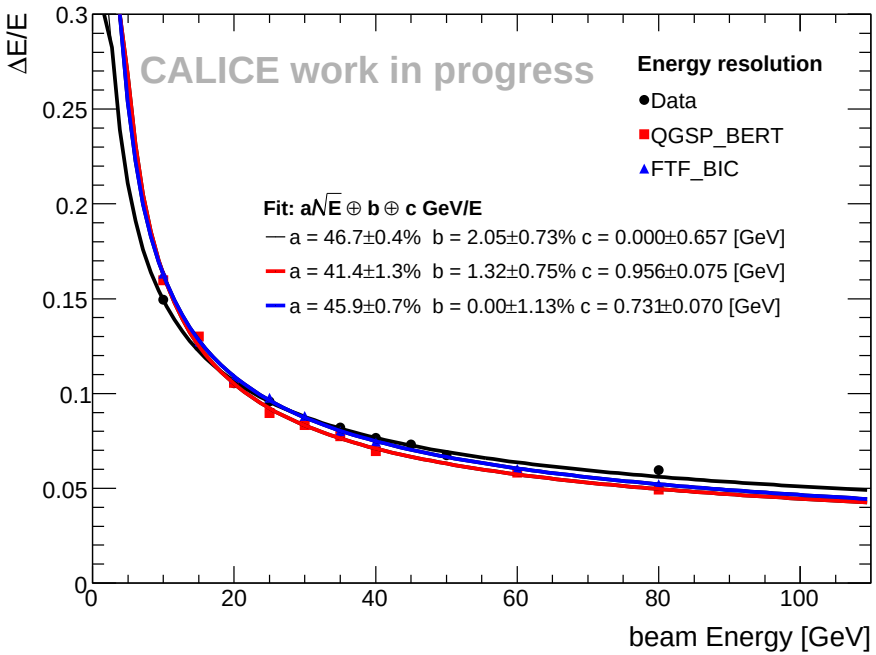
## Weights extracted from data

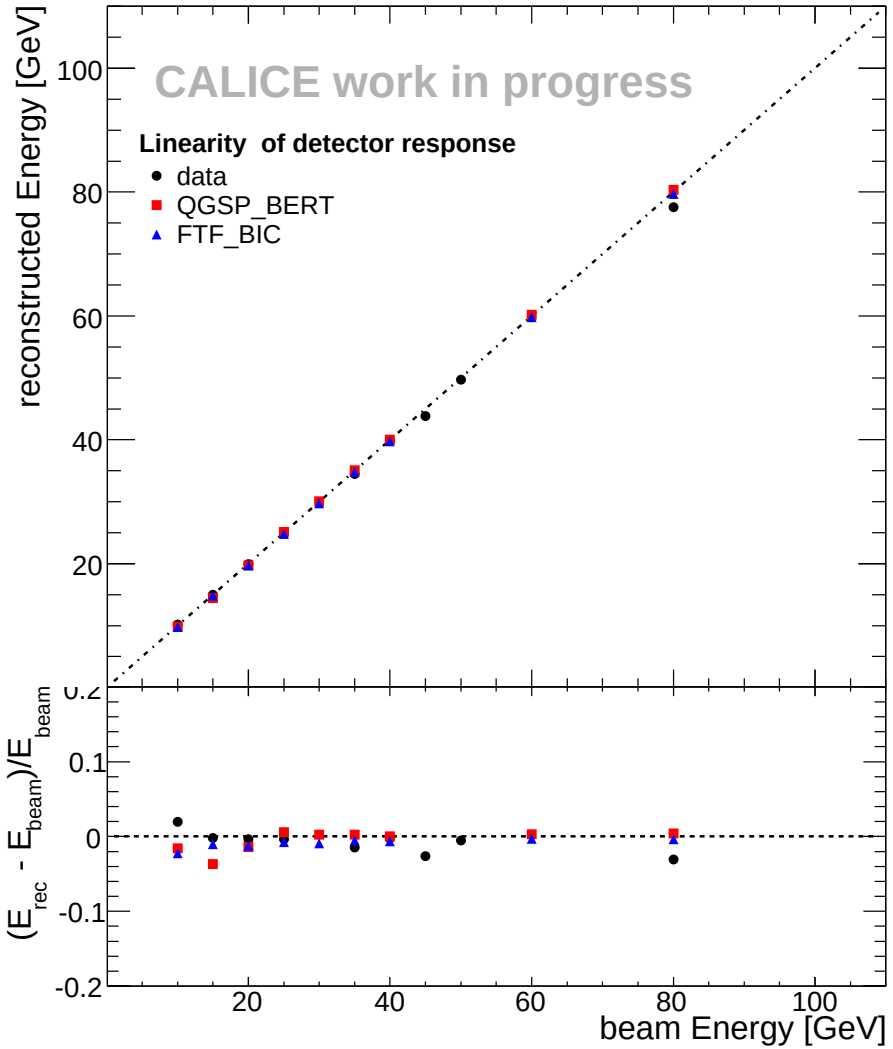


# Software compensation

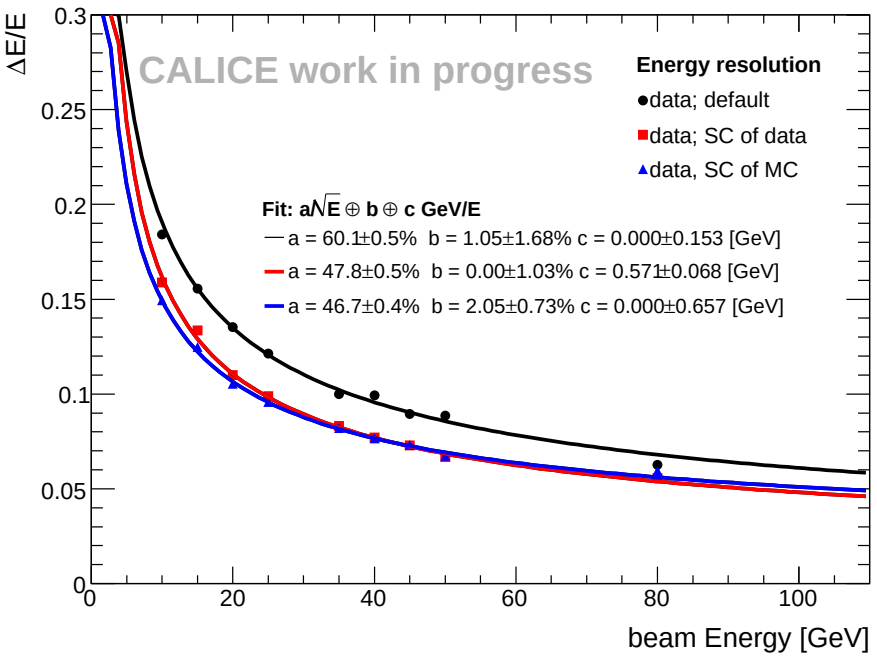
## Weights extracted from QGSP_BERT

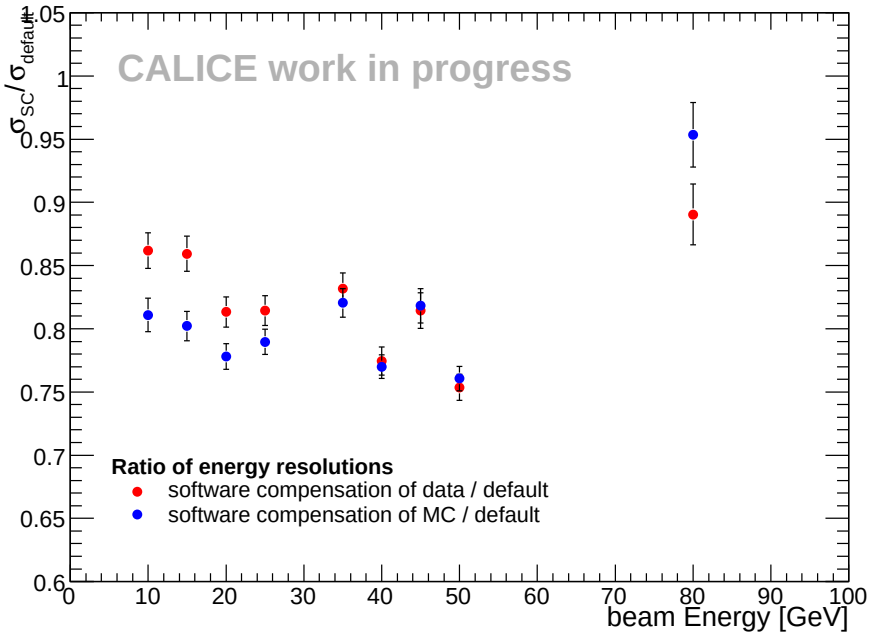


# Improvement of data energy resolution

- Improvement approximately 15-20 % for energies below 80 GeV
- Better performance of resolution for MC weights
- Better performance of linearity for data weights



# Summary of CALICE data analysis

- Idea: updated CAN-15 results - better Monte Carlo, better calibration
- Changes in weights extraction and application ('3D' energy density, no bin division in application,..)
- Improvement of energy resolution similar to CAN-015
- Software compensation works for data with weights extracted from Monte Carlo (QGSP_BERT)

To do:

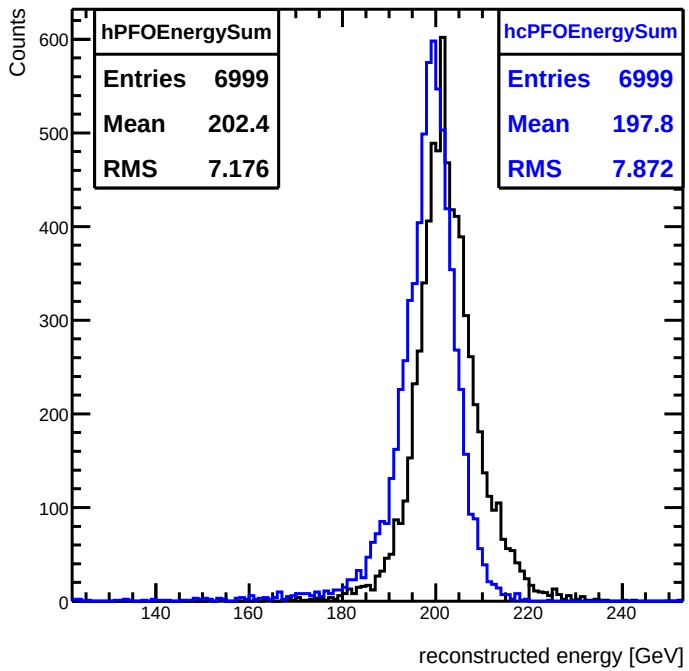
- Redo exact analysis of CAN-15
- Compare results with energy density of single cell and 3D energy density

# Software Compensation in PandoraPFANew

- Implementation of single cell software compensation technique into the PandoraPFANew framework
- Software Compensation will be implemented at two stages
  - inside reclustering algorithm as an energy correction function
    → applied to all hadronic clusters
    → helps to identify clusters hits
  - after particle flow object creation
    → applied to neutral hadronic particle flow objects without associated tracks
    → improves energy reconstruction of neutral hadrons

Status:

- Discussion with Mark Thomson and John Marshall about implementation
- To do: automatize weight extraction; test of technique robustness due to calibration changes, physics list changes, clustering algorithm changes



# Software Compensation in PandoraPFA

Resolution of the total reconstructed energy. Improvement compared to default settings. ($Z \rightarrow uds$)
Obtained improvement partially too good $\Rightarrow$ Events simulated with QGSP_BERT, calibration values for LCPhys

| $E_{cms}$[GeV] | 90 | 200 | 360 | 500 |
|---|---|---|---|---|
| Default | | | | |
| $E_{rec}$ [GeV] | 91.61±0.04 | 202.3±0.08 | 366.81±0.13 | 512.00±0.19 |
| RMS90/$E_{cms}$ [%] | 2.86+±0.02 | 2.46±0.02 | 2.64±0.02 | 2.82±0.02 |
| SC | | | | |
| $E_{rec}$ [GeV] | 90.4 ±0.04 | 199.58±0.07 | 360.59±0.12 | 502.27±0.18 |
| RMS90/$E_{cms}$ [%] | 2.8±0.02 | 2.26±0.02 | 2.5±0.02 | 2.69±0.02 |
| Improvement [%] | 2 | 8 | 5 | 5 |
| SC-EC | | | | |
| $E_{rec}$ [GeV] | 90.40±0.04 | 198.88±0.07 | 356.82±0.12 | 493.01±0.18 |
| RMS90/$E_{cms}$ [%] | 2.8±0.02 | 2.2±0.02 | 2.36±0.02 | 2.59±0.02 |
| Improvement [%] | 2 | 11 | 7 | 8 |

**Thank you!**

Left: Weights for 10 GeV beam energy
Right: Weights for 80 GeV beam energy