Hadron resolution analysis for the CALICE AHCAL

M. Chadeeva, M. Danilov, O. Markin and V. Morgunov

ITEP, Moscow

Plan

- Updates of the PandoraPFA test results from CAN-024
  - improved mapping from CALICE to ILD geometry
  - more sophisticated treatment of isolated hits
  - results
- Software compensation approach
  - idea
  - correction factor from hit energy spectrum
  - correction procedure
  - results

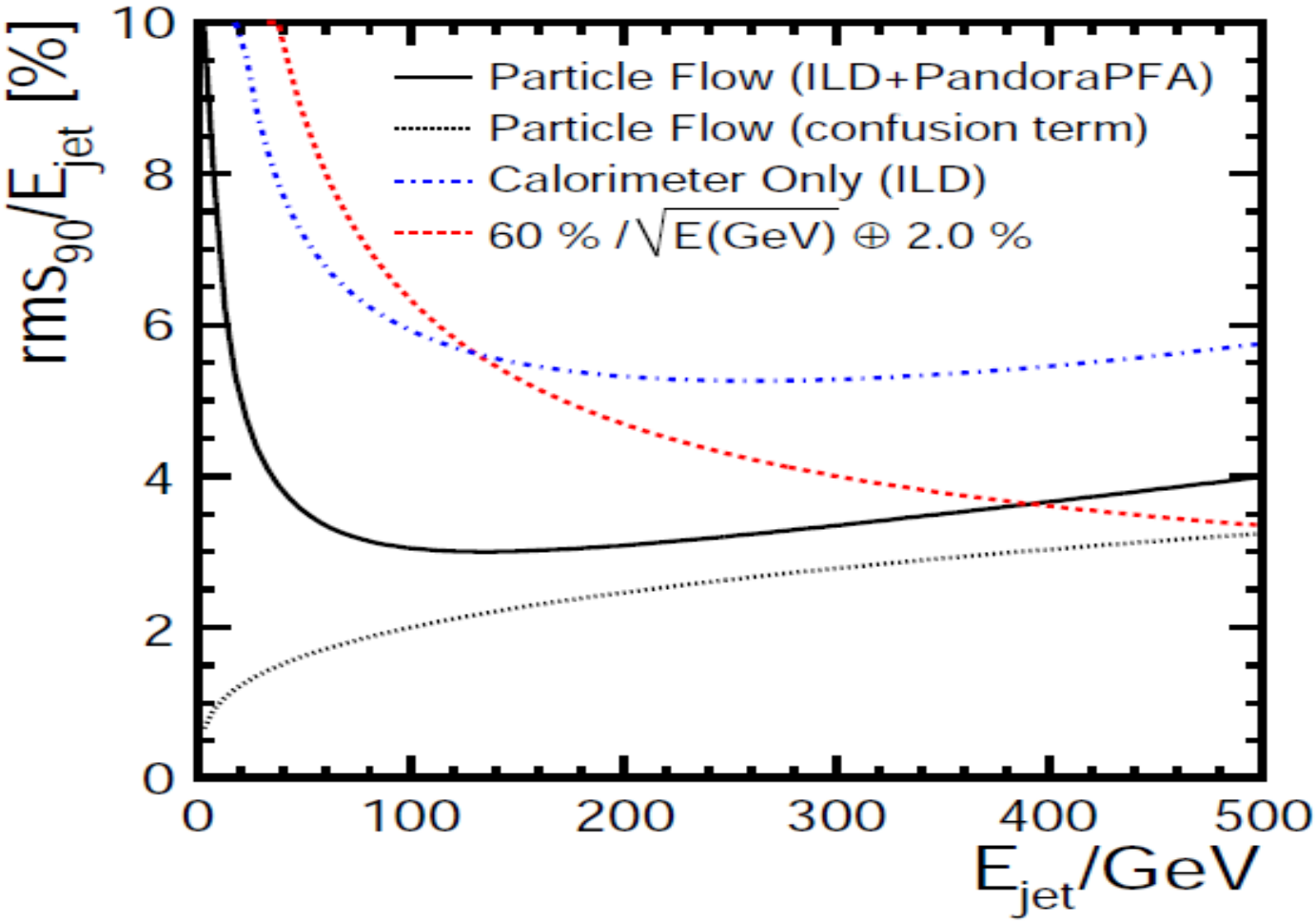
Data and Software

- CERN 2007 test beam data taken with complete setup
  - pions in the energy range from 10 to 80 GeV
  - pion event selection includes:
    - muon identification
    - electron or proton separation (Cherenkov counter)
    - selection by shower starting layer
  - reconstruction software as of April 2010, ECAL and HCAL em calibrations for MIP to GeV conversion
- MC samples for QGSP_BERT, FTFP_BERT, FTF_BIC and LHEP phys. lists from GEANT4 9.2 (Mokka v07-00, detector model TBCern0707_p0709)

Particle Flow Analysis approach

PFA approach: only neutral particle energies are derived in a calorimeter whereas the energies of charged particles are reconstructed in a tracker.

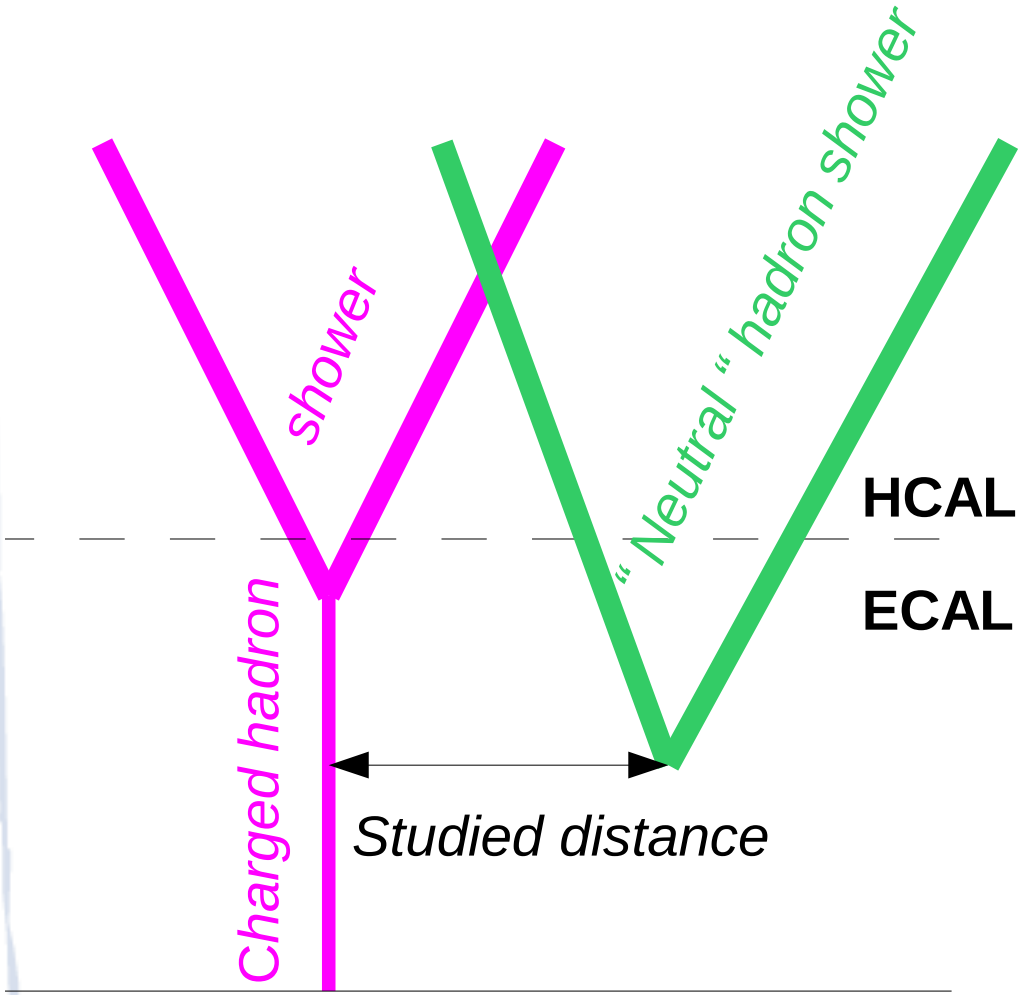
The confusion term is a result of shower overlapping, when the reconstructing program mixes up hits from showers created by charged and neutral hadrons.



M. A. Thomson, NIM A611:25-40,2009

PandoraPFA test: shower overlapping

Two pion showers from test beam data are overlaid, mapped into ILD geometry and passed to PandoraPFA processor.

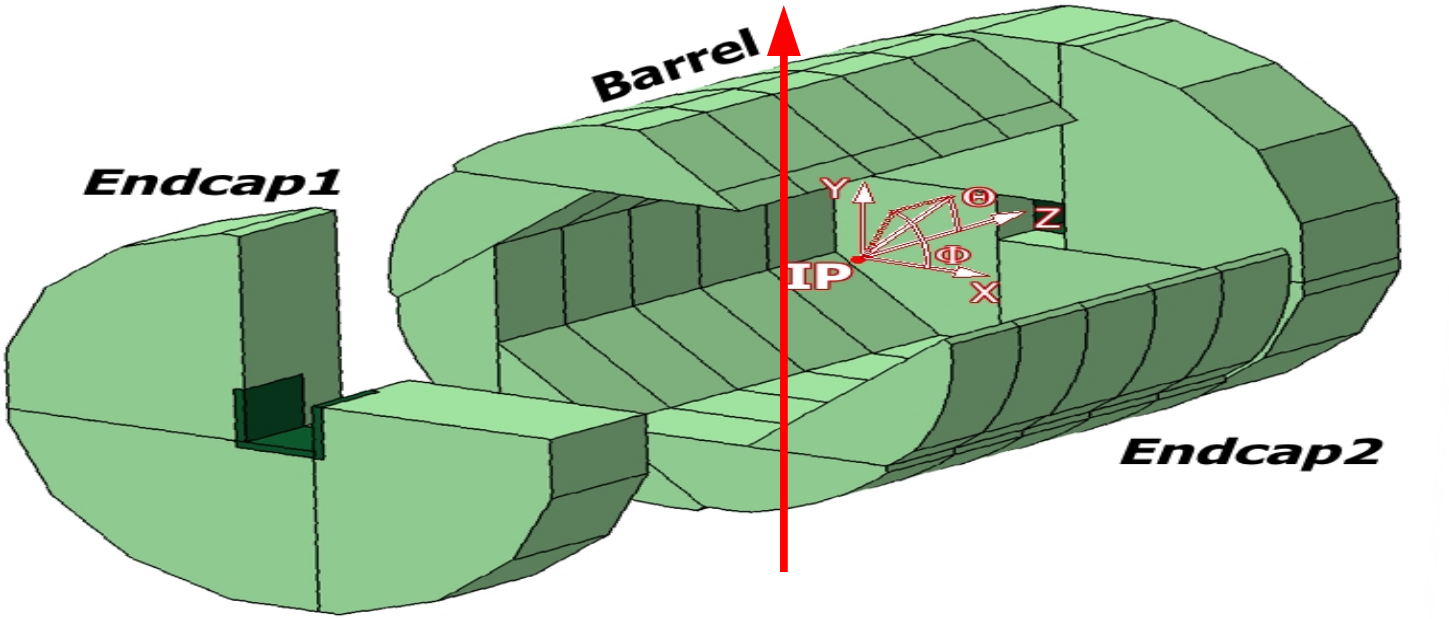


To emulate a neutral hadron, all hits before shower start are removed. Remained hits of this emulated "neutral" are shifted w.r.t. charged pion hits at a studied transverse distance.

The studied distances vary from 5 cm to 30 cm that are typical for 100 GeV jets in a 4 T magnetic field.

PandoraPFA test: updates

Improved mapping: hits of both showers are mapped into the detector similar to ILD, but with layer and absorber thicknesses equal to those of the CALICE prototypes -> improvement in confusion term ~5%

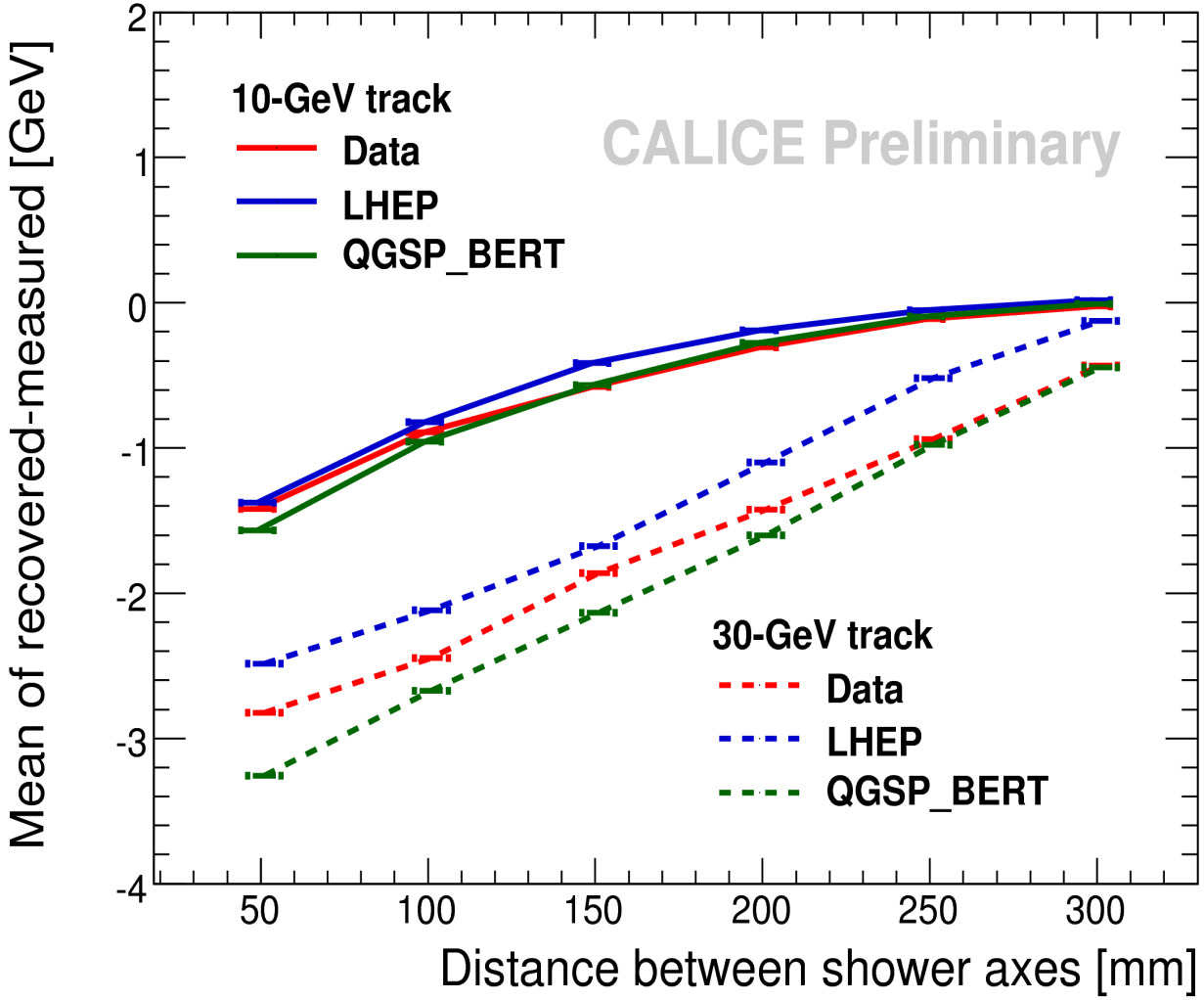


CALICE test beam

New treatment of isolated hits: the energy of unused isolated hits and small (< 5 hits) clusters was divided between charged and neutral proportionally to their reconstructed energies -> significant changes in RMS (up to 50%)

PandoraPFA test: mean of deviation

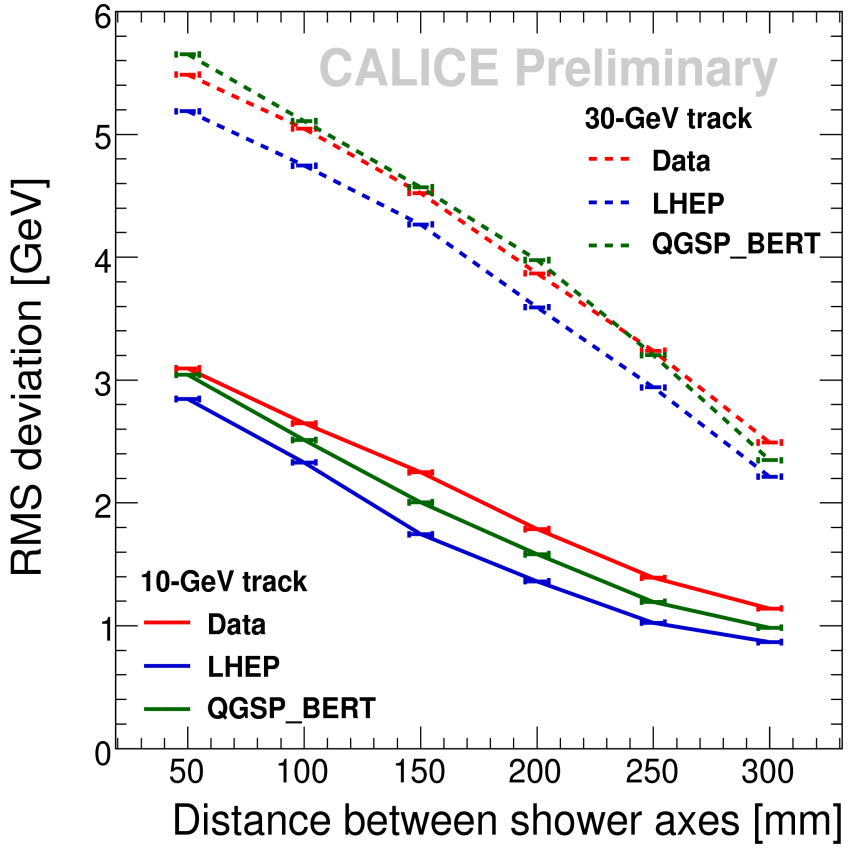
The energy of 10-GeV neutral hadron recovered by PandoraPFA processor is compared with that measured by CALICE calorimeter.

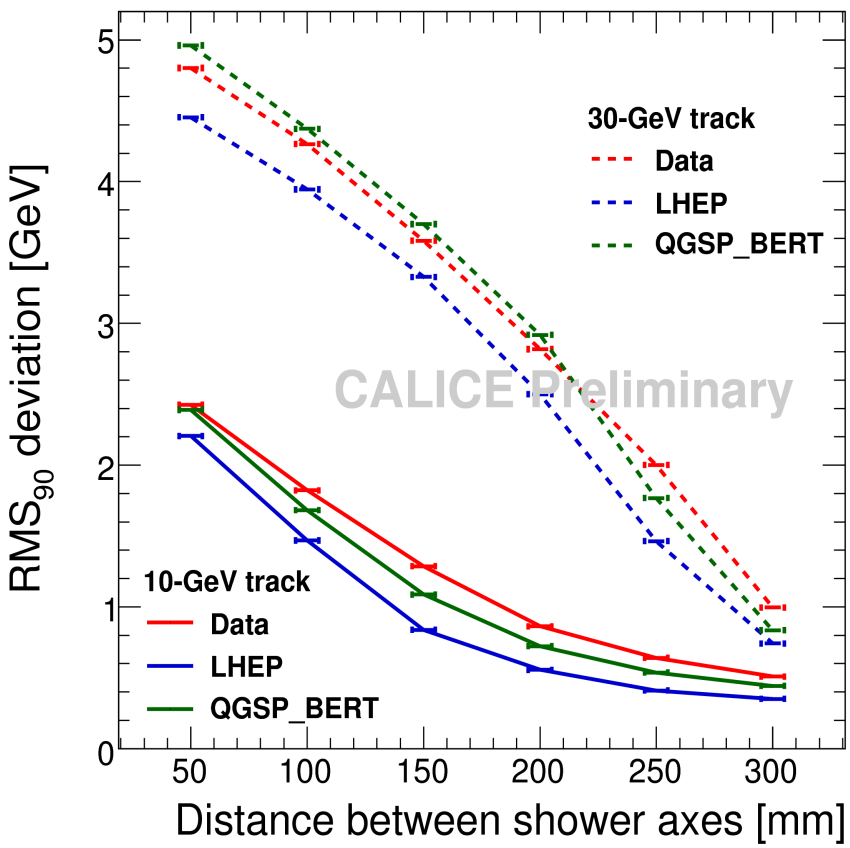


Updates in the treatment of isolated hits and small clusters results in zero mean value at large distances.

Due to more compact and narrower showers in LHEP, it predicts smaller confusion than that observed for data.

PandoraPFA test: confusion term





The RMS deviation of the *recovered* energy of 10-GeV neutral hadron from its energy *measured* in the calorimeter can be interpreted as a confusion error. Updates result in significant RMS_{90} improvement at 20÷30 cm.

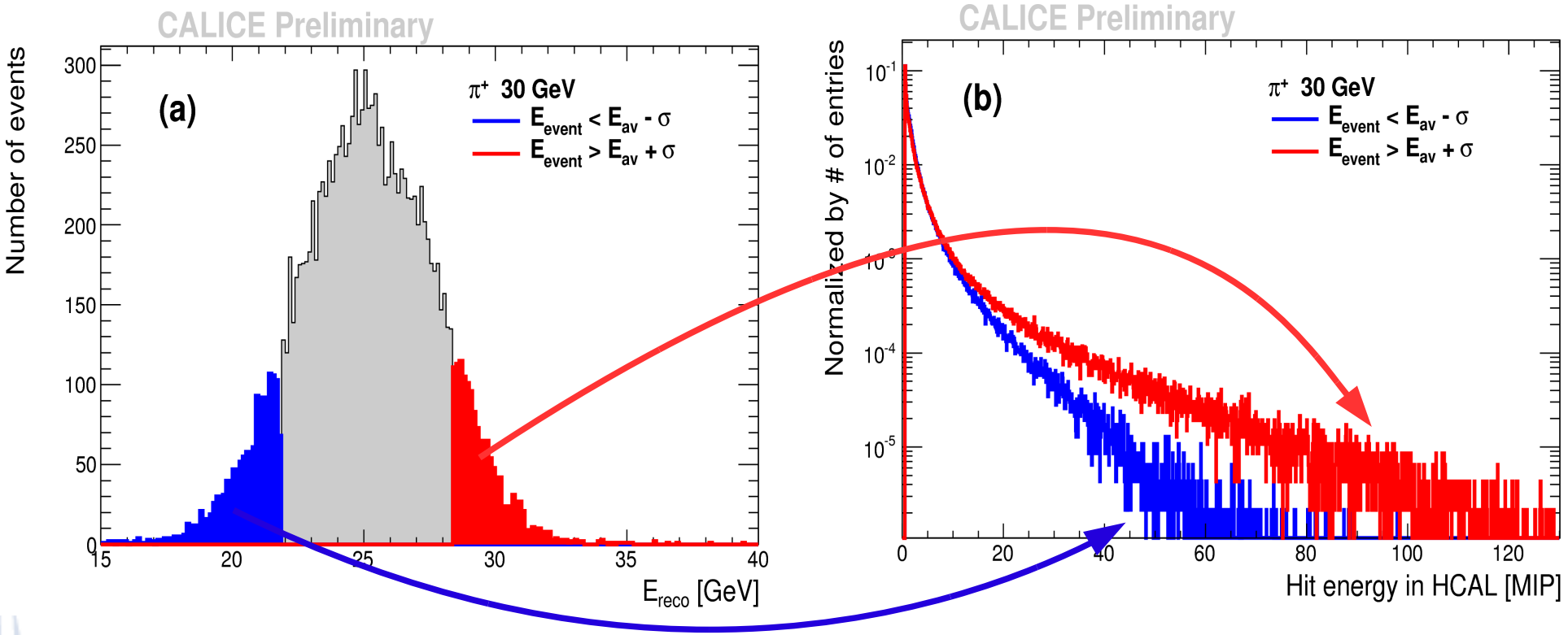
PandoraPFA test: summary

- CALICE test beam data were used to test the PandoraPFA algorithm.
- Improved procedures for mapping and isolated hit treatment were implemented.
- The modifications resulted in reducing RMS_p deviation of the recovered energy from the measured energy for the case that determines the confusion error for 100 GeV jets in a 4 T magnetic field (i.e. for the distance of about 25 cm between 10-GeV neutral and 10-GeV charge hadrons).
- The modifications keep a good agreement between test beam data and MC simulation.

Software compensation: idea

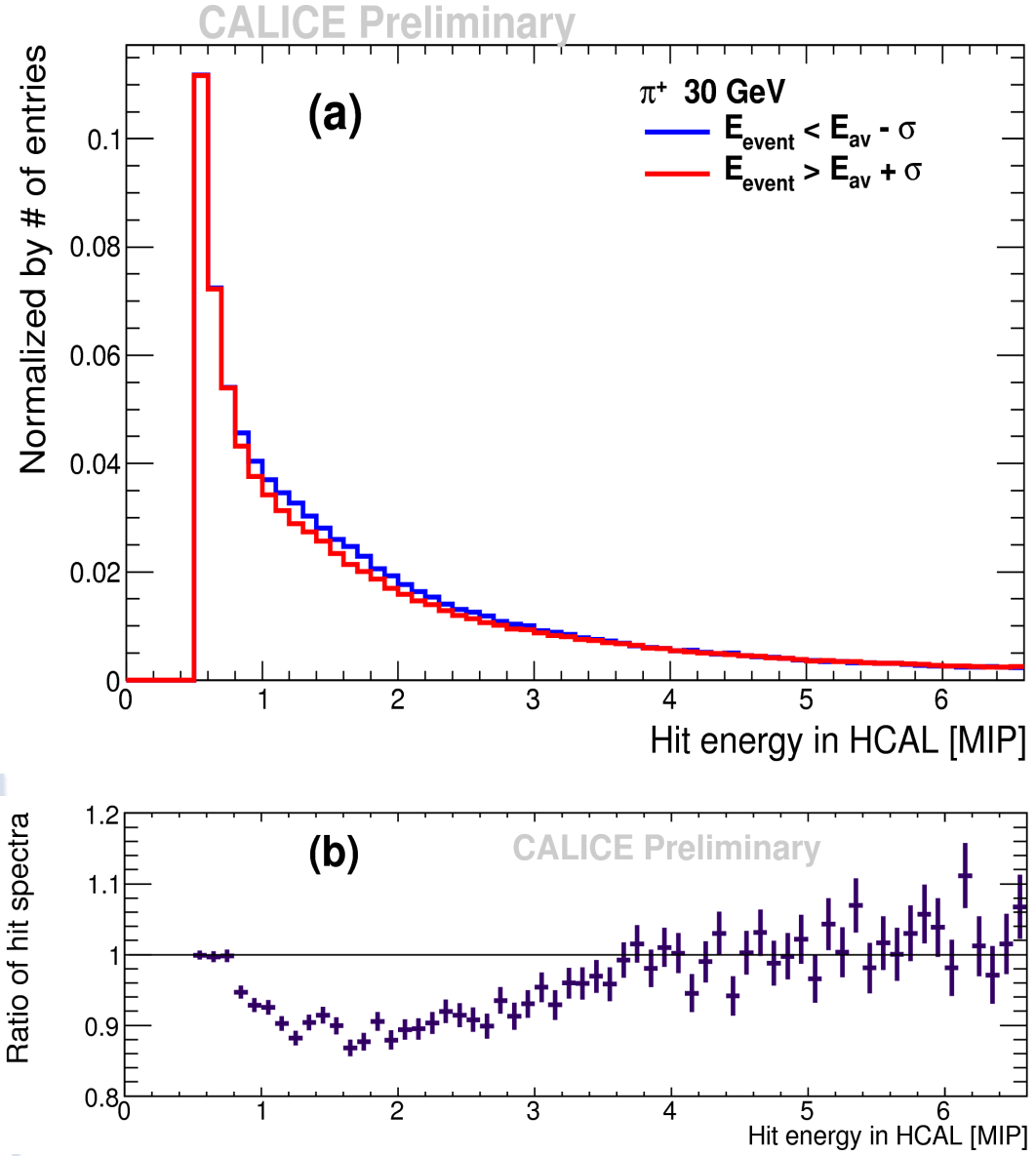
Non-compensating calorimeter -> response depends on em fraction

Hit energy spectrum shapes are different for high and low detected response -> spectrum shape is related to the amount of em fraction



Events with shower start in first 5 HCAL layers are analyzed (most fully contained in HCAL)

Software compensation: hit spectrum shape



Hit spectrum shape of the event can be described by the following variables:

$C_{lim} = N(e<e_{lim})/N_{all}$

$C_{av} = N(e<e_{av})/N_{all}$

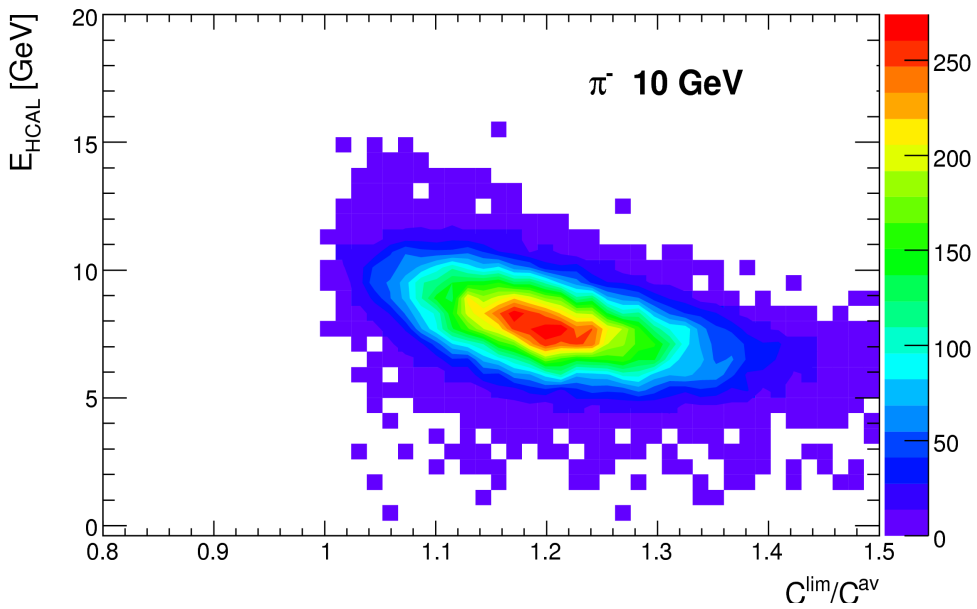
e - hit energy (MIPs)

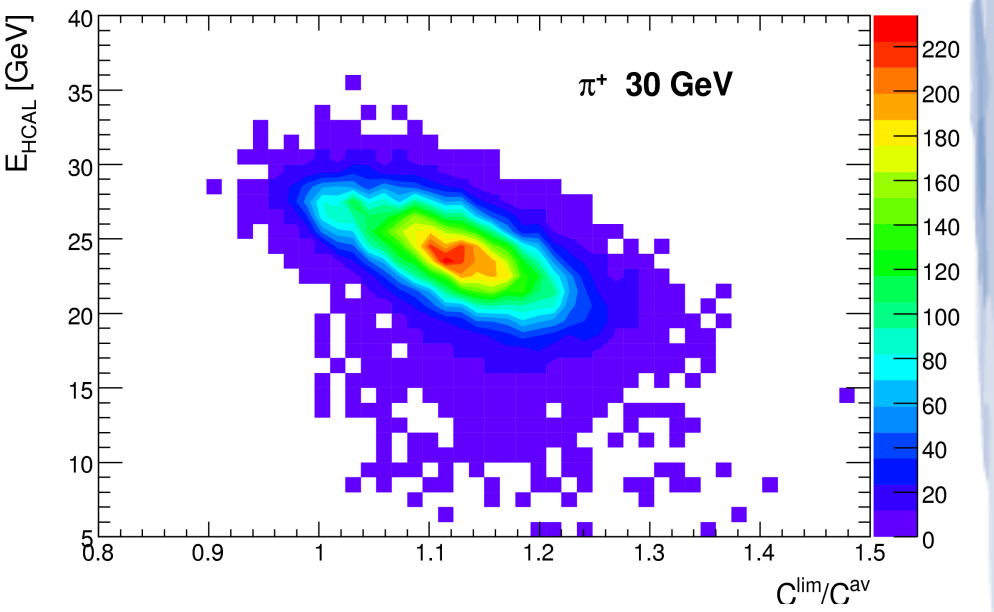
e_{lim} = 5.5 MIPs

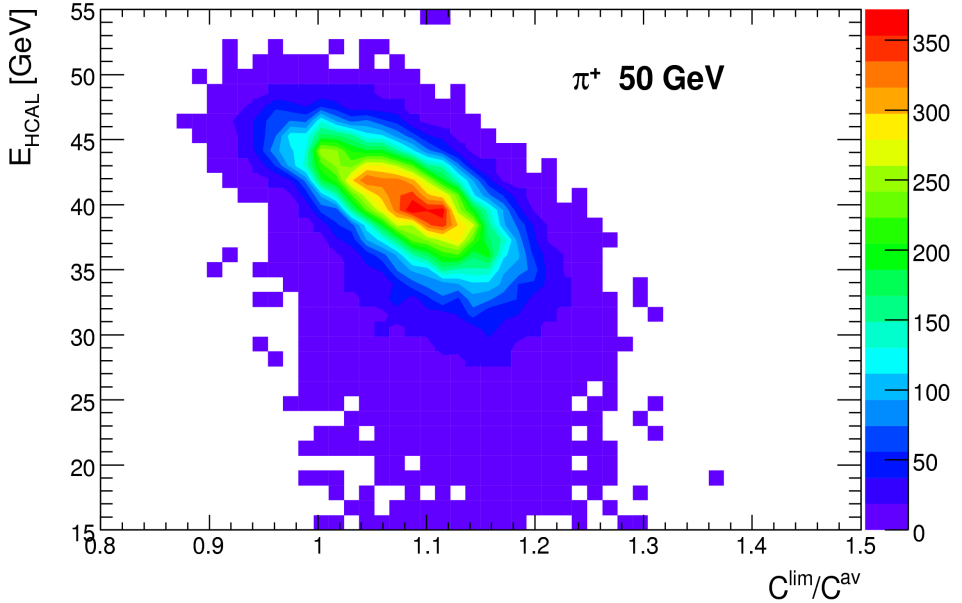
e_{av} - spectrum mean

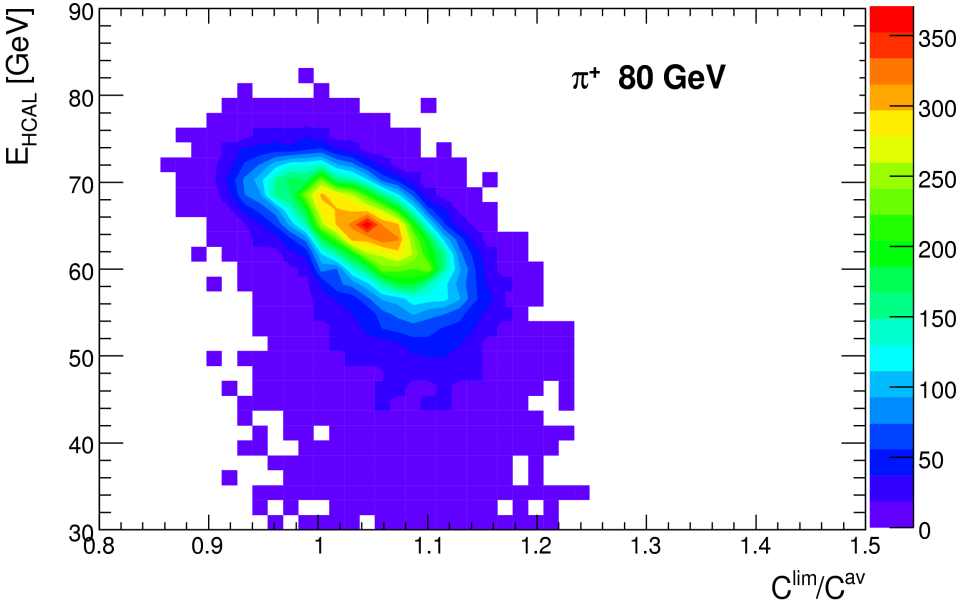
N_{all} - full number of hits

Software compensation: correlation









The ratio C_{lim}/C_{av} is inversely correlated with the HCAL deposited energy

Software compensation: correction procedure for the i-th event

I

corrected HCAL energy: $E_{cor} = E_{HCAL} \times C_{lim} / C_{av}$

corrected shower energy: $E_{sh} = E_{cor} + E_{TCMT}$

1st step reconstructed energy: $E_I = E_{sh} + E_{ECAL}$

II

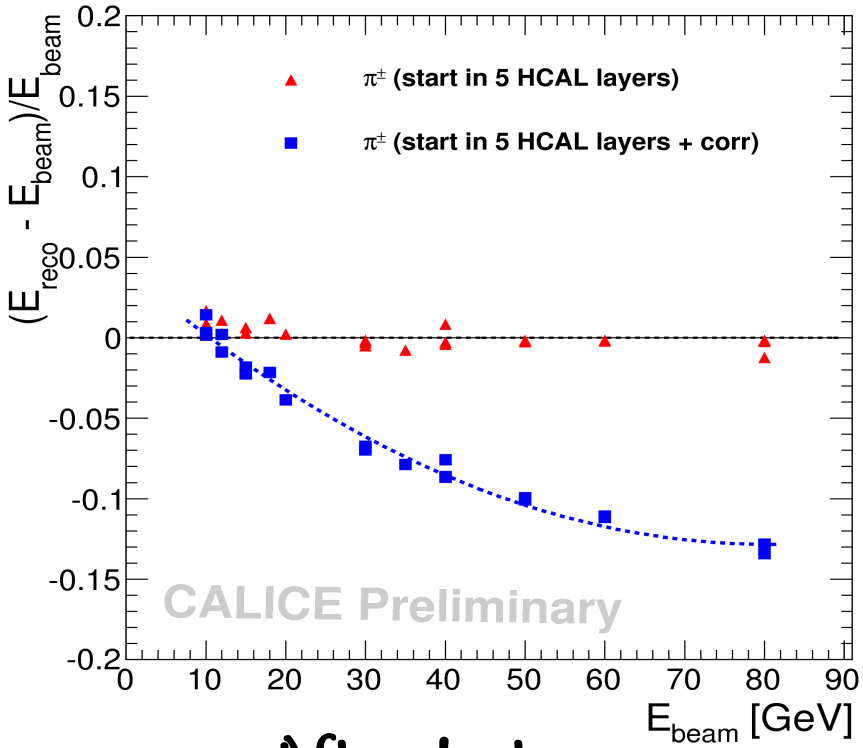
additional polynomial correction to keep linearity:

$$E_{reco} = E_{sh} (a_1 + a_2 E_{sh} + a_3 E_{sh}^2) + E_{ECAL}$$

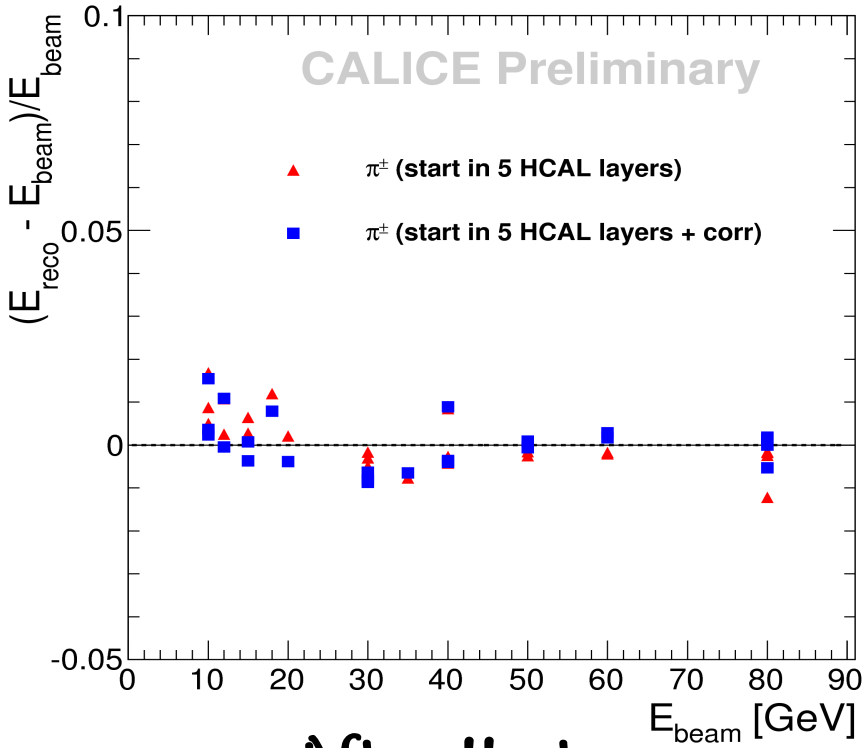
coefficients from fit of $(E_{beam} - \langle E_{ECAL} \rangle)$ vs. $\langle E_{sh} \rangle$

Software compensation: linearity

Residuals to linearity for events with shower start in first 5 HCAL layers, without and with energy correction applied



After I step

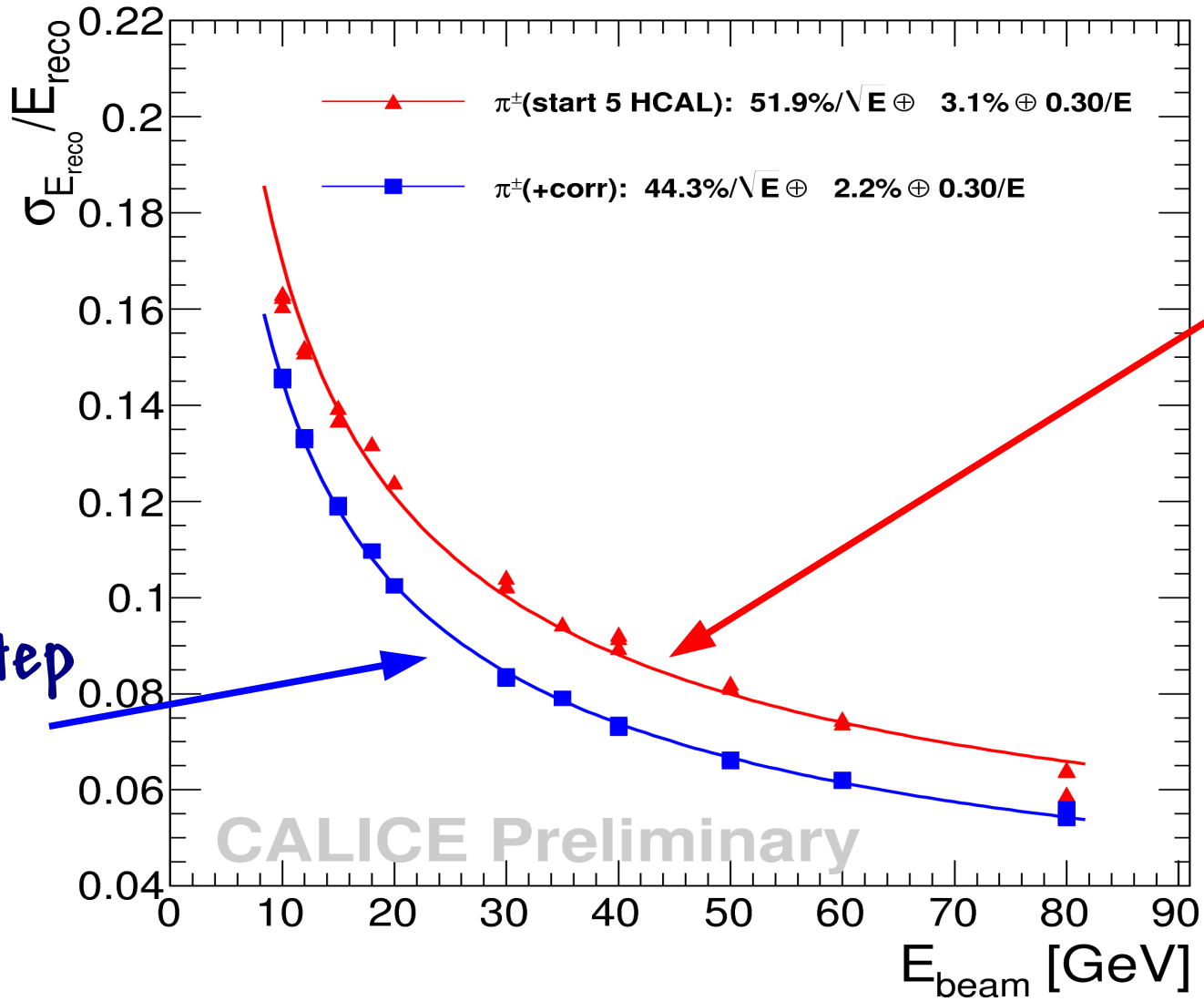


After II step

Without correction: energy sum is multiplied by 1.19 (e/π ratio)

With 2-step correction: a_1=0.958 a_2=0.0047 GeV^{-1} a_3=-2.8x10^{-5} GeV^{-2}

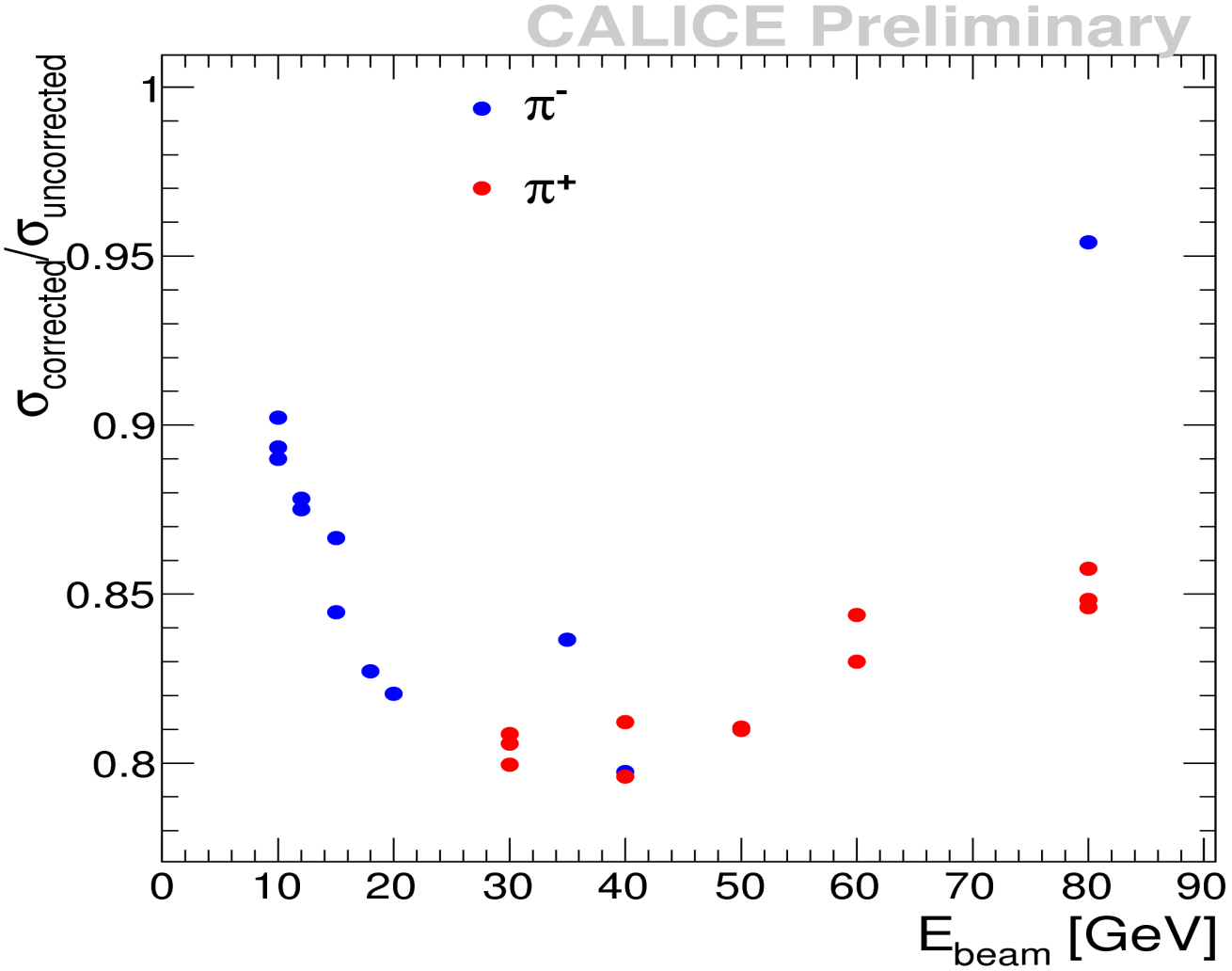
Software compensation: relative resolution



Before correction

After 2-step correction

Software compensation: relative improvement

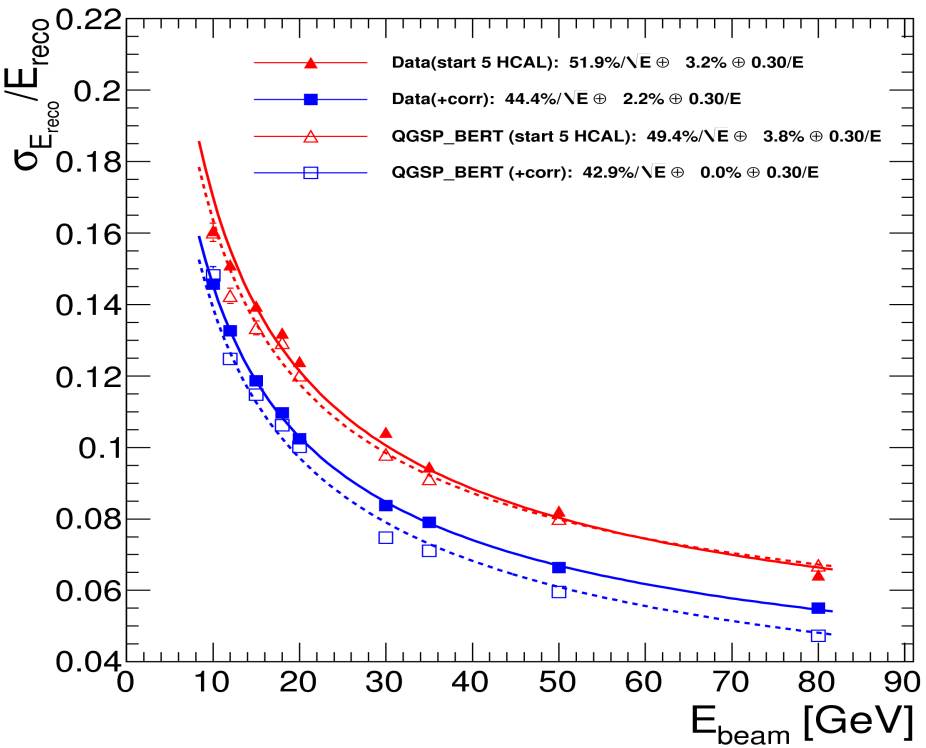


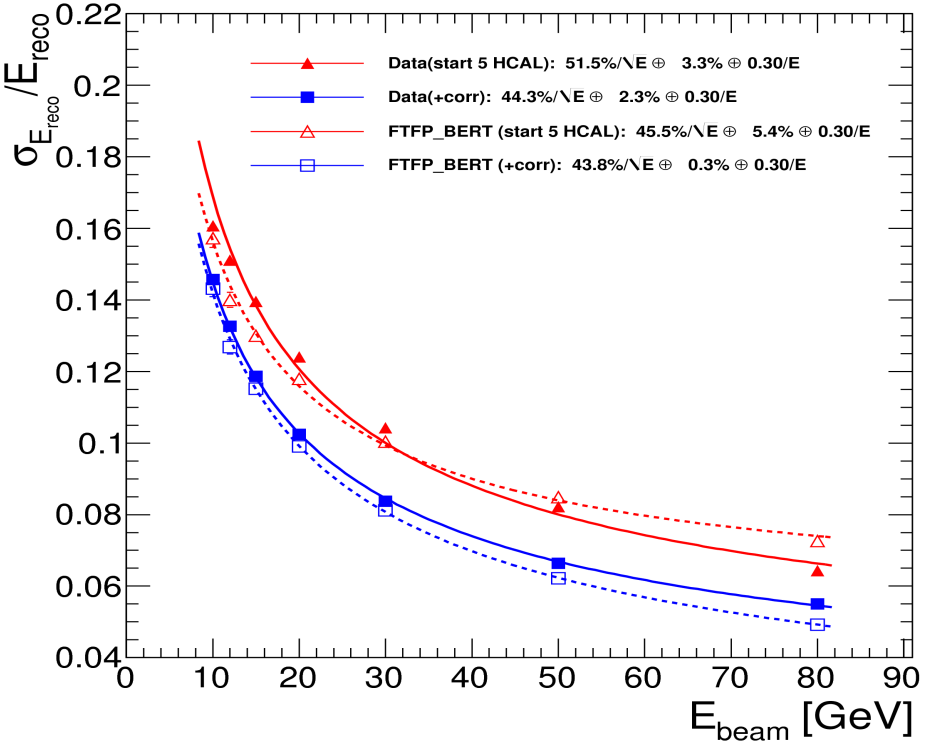
by 5% ÷ 20% for π^- (12 runs 10÷80 GeV)

by 15% ÷ 20% for π^+ (12 runs 30÷80 GeV)

Software compensation: data and MC

The same mip2gev coefficients from em calibration and e/π ratio are applied to MC samples as to data.





Before correction QGSP_BERT is in better coincidence with data than FTFP_BERT (FTF_BIC behavior is similar to that of FTFP_BERT).

Both physics lists predict better resolution after correction for higher energies.

The correction procedure does not change the MC linearity behavior.

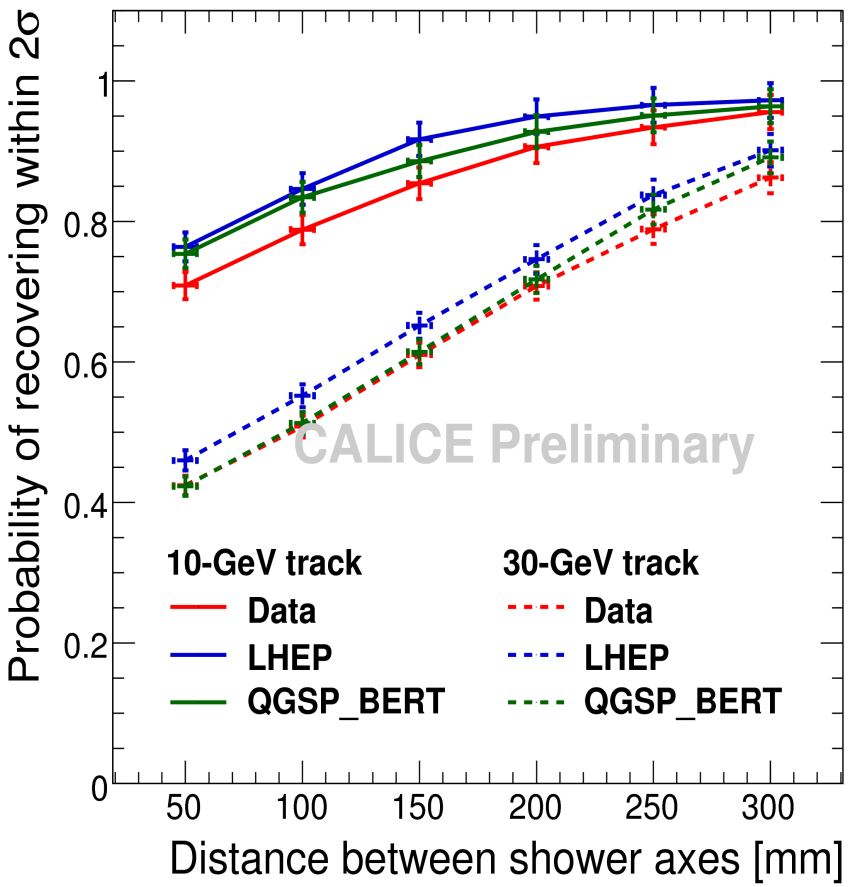
Software compensation: summary

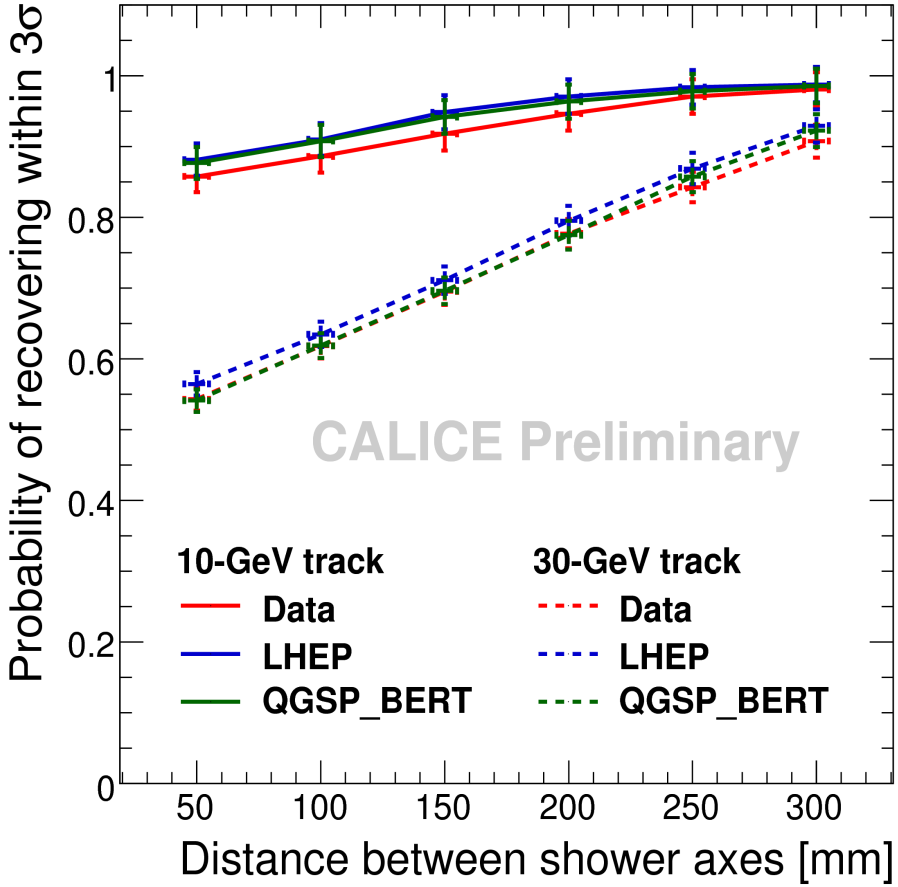
- The software compensation approach based on hit spectrum shape analysis is proposed which includes one correction factor for HCAL deposited energy.
- The proposed 2-step software compensation procedure allows to improve pion energy resolution by ~10% ÷ 20% in the energy range from 10 to 80 GeV, while keeping the linearity within 2%.
- QGSP_BERT, FTFP_BERT and FTF_BIC physics lists predict more significant resolution improvement after correction comparing to data.
- TO DO: expand energy range, study more physics lists, include more runs (especially high energy π-), invoke ECAL

Backup slides

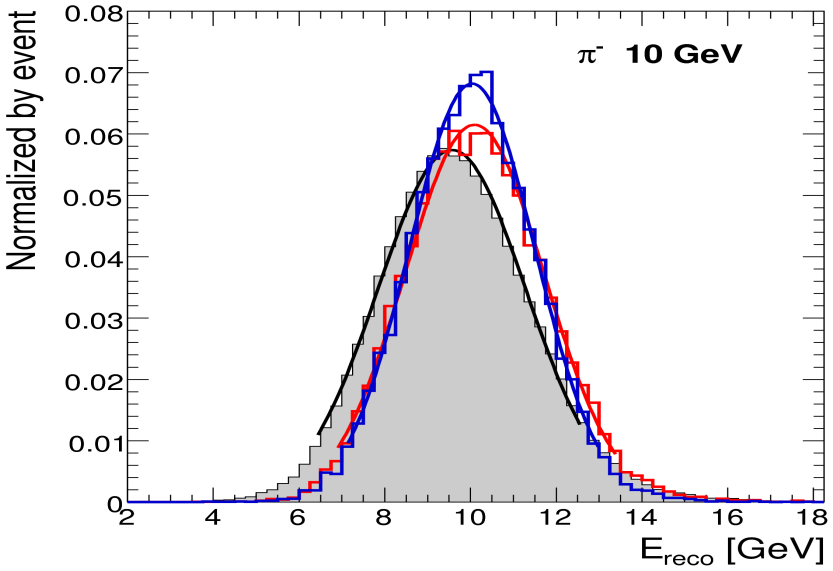
PandoraPFA test: efficiency

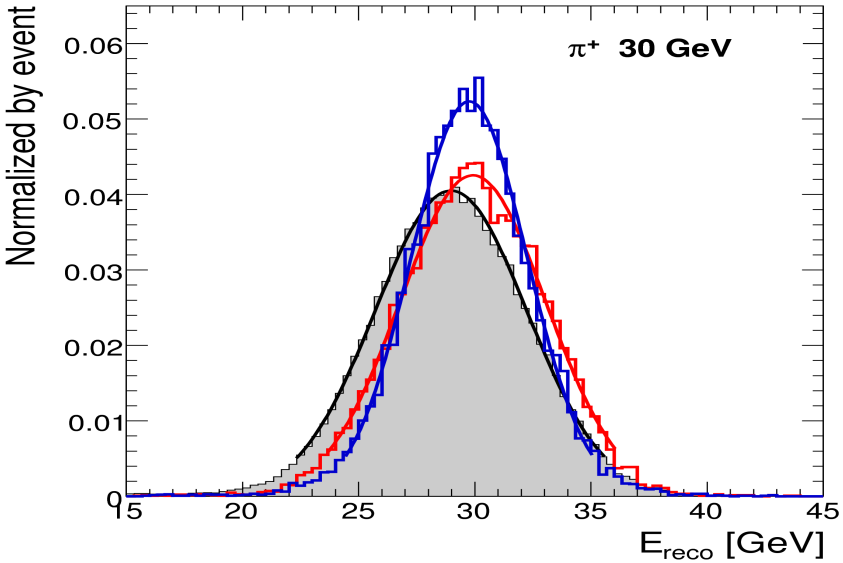
The probability to recover the 10-GeV neutral hadron energy within 2 and 3 standard deviations from its real energy versus its distance from 10-GeV (continuous lines) and 30-GeV (dashed lines) charged pion

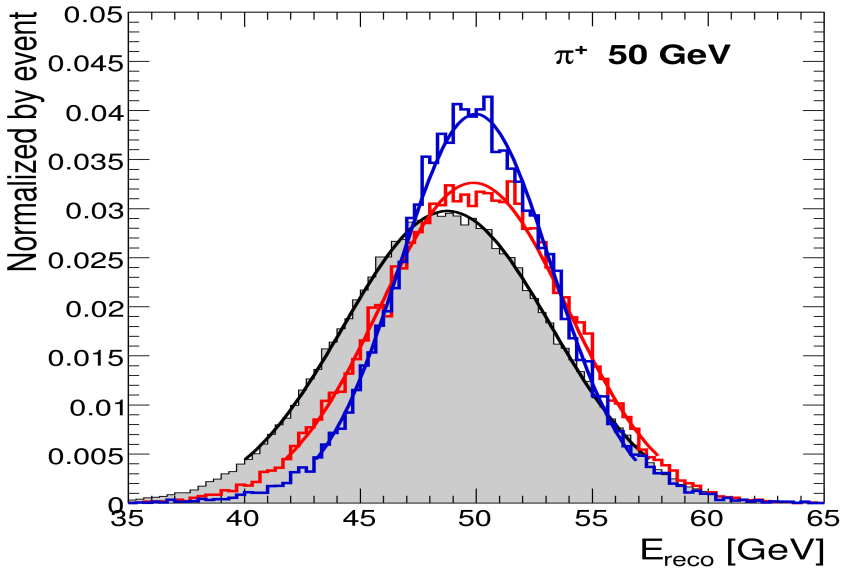


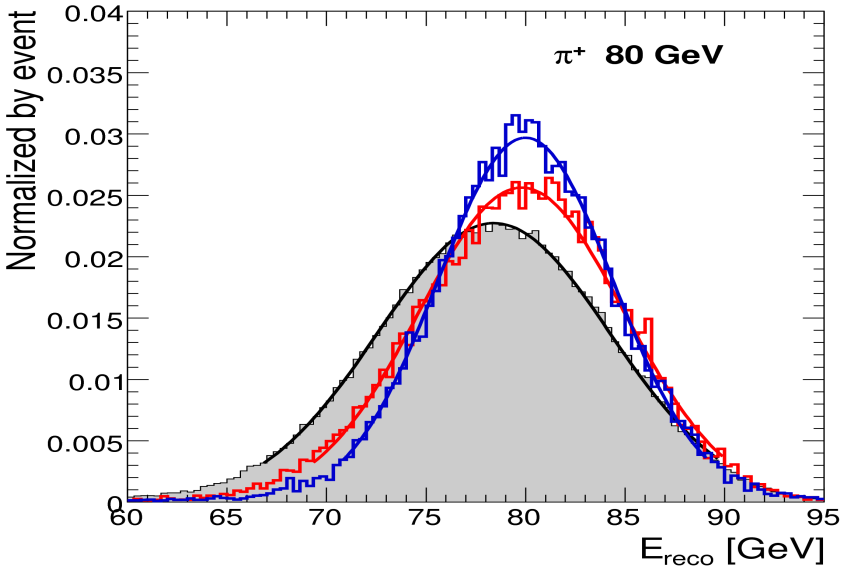


Software compensation: energy distributions









w/o selection by starting layer; start in 5 HCAL layers; +correction