Preliminary hadron analysis for the CALICE AHCAL

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I. Event selection impact on the energy resolution and linearity

II. New method of software compensation for HCAL

Data and software

DATA: CERN 2007 test beam runs with complete CALICE setup

π^- 10, 12, 15, 18, 35, 80 GeV

π^+ 30, 40, 50, 60, 80 GeV

the newest official reconstruction software as of April 2010

MC: QGSP BERT and LHEP physics lists

π^- 10 GeV

π^+ 30, 50, 80 GeV (thanks to Lars Weuste)

official Mokka and digitization software as of April 2010

Event selection stages

Before any analysis:

Apply 0.5-MIP cut to both ECAL and HCAL hits

⇓

Identify muons using 2D histogram $E^{dep}_{ECAL} + E^{dep}_{HCAL}$ vs. E^{dep}_{TCMT} (Vasily's method)

⇓

Identify trash and multiparticle events

⇓

Separate electrons from π^- (Čerenkov counter)

Separate protons from π^+ (Čerenkov counter)

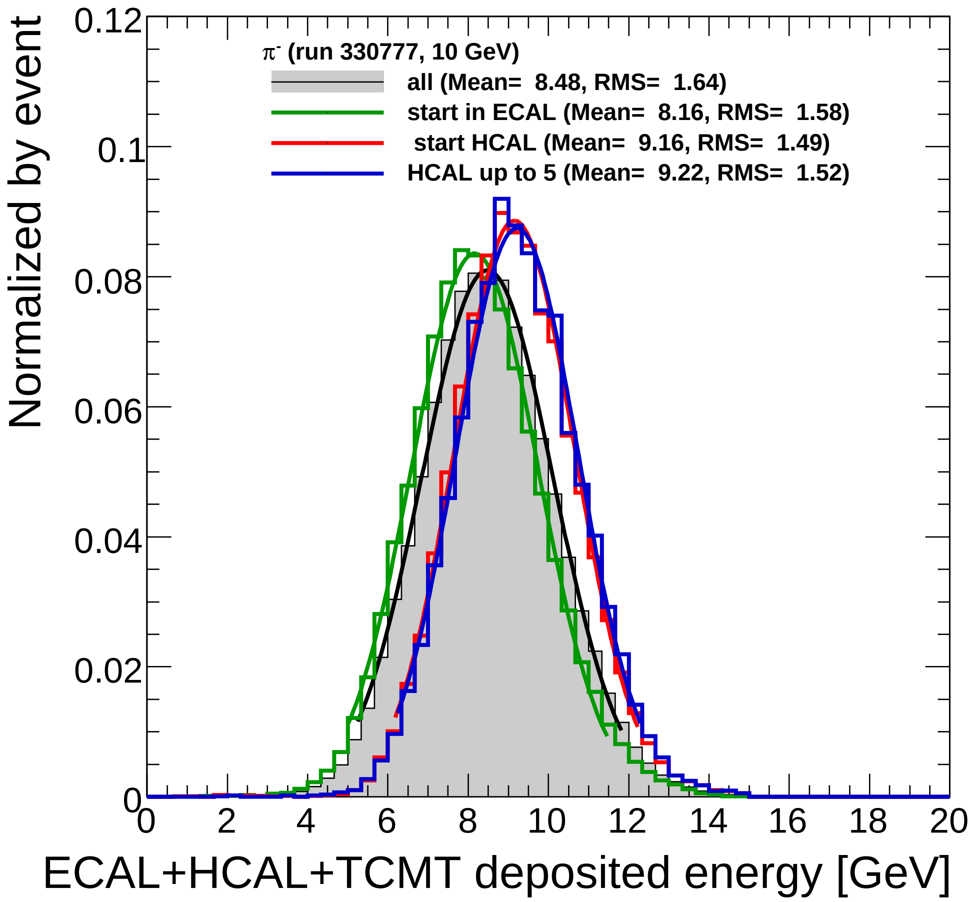
For analysis:

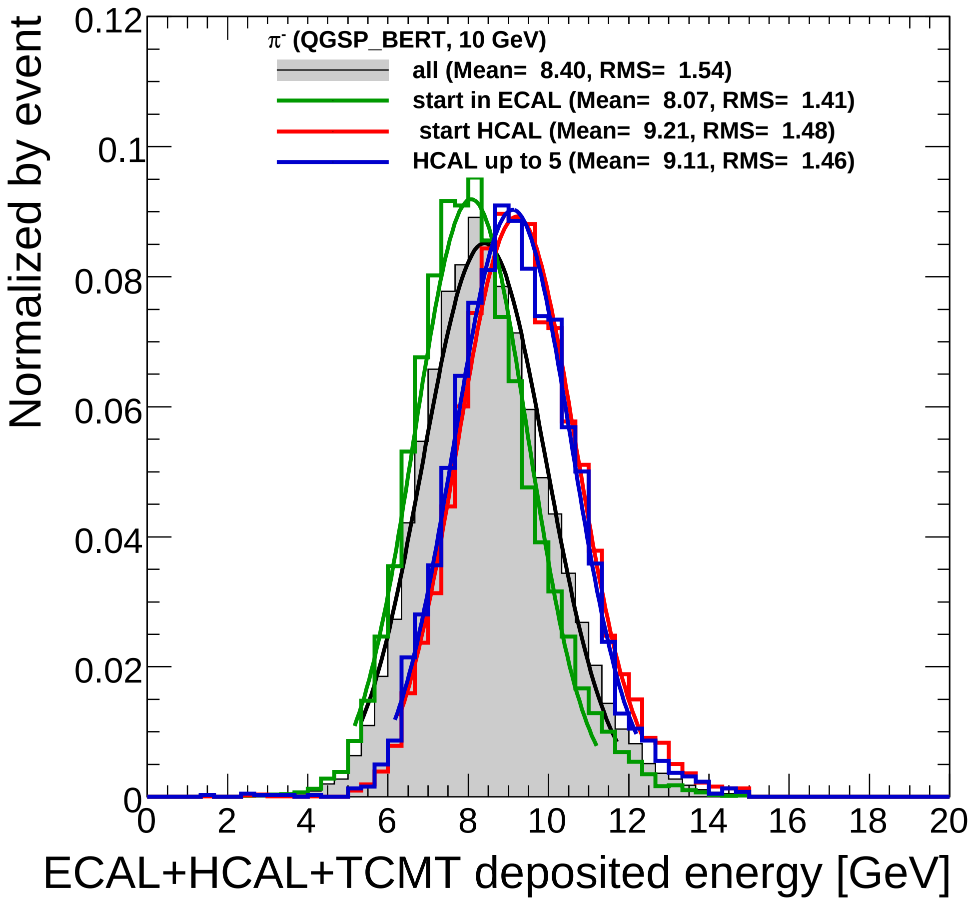
Find shower start position (using PrimaryTrackFinder)

⇓

Select events by shower start position: in ECAL, in HCAL, in first 5 HCAL layers

Event selection: energy distributions for 10-GeV π^-

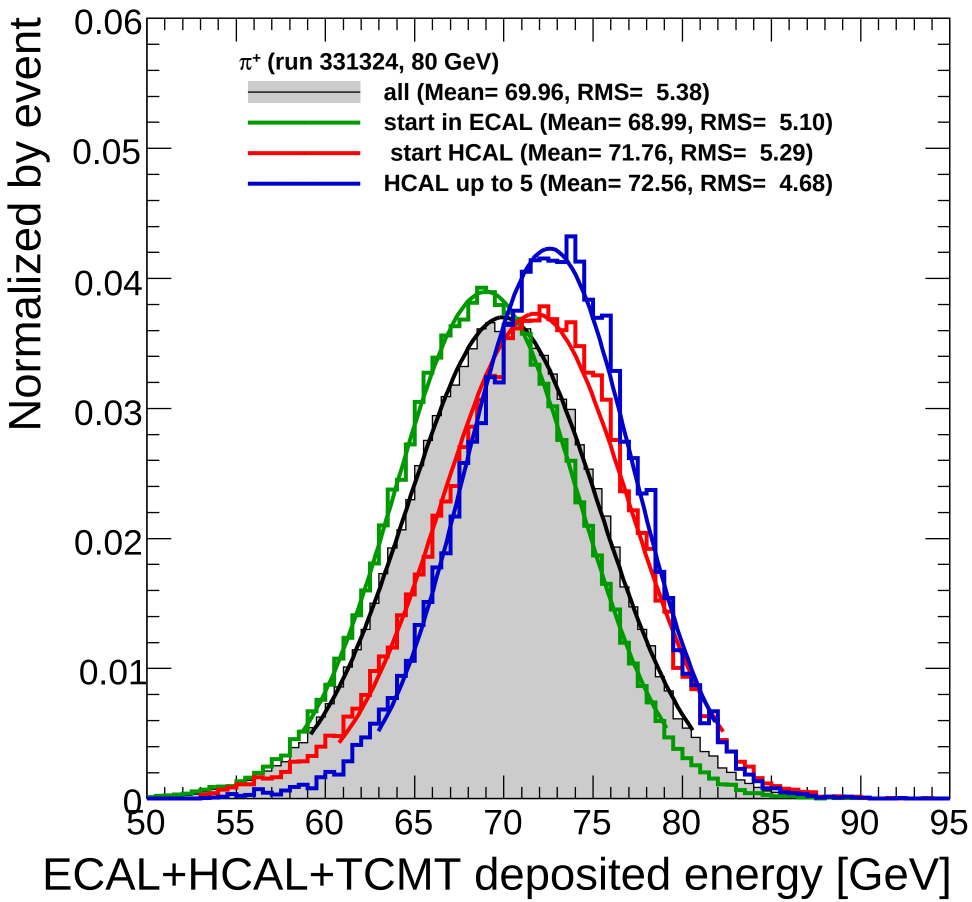


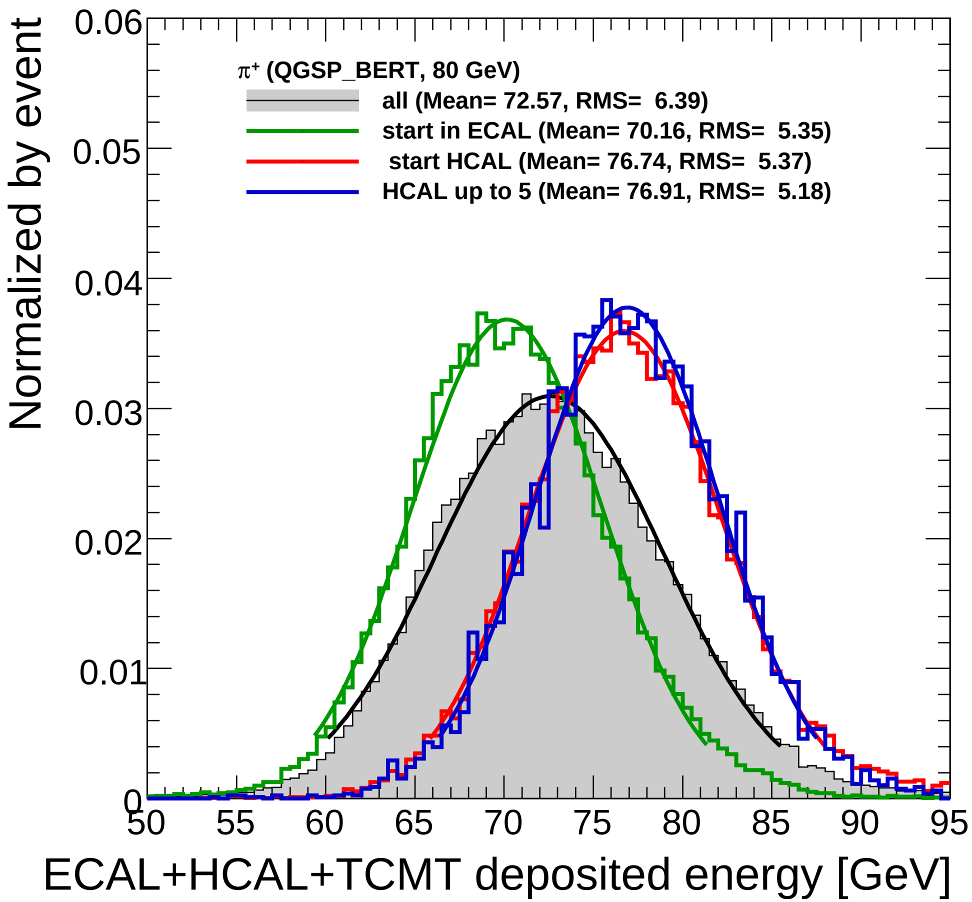


ECAL: $(\frac{GeV}{MIP})^{ecal}_{vis}$ **= 0.000147;** S_{ecal} **= 25.57; ECAL$_1$:ECAL$_2$:ECAL$_3$ = 1:2:3 (from CAN-008)**

HCAL: $(\frac{GeV}{MIP})^{hcal}_{vis}$ **= 0.000816;** S_{hcal} **= 31.22**

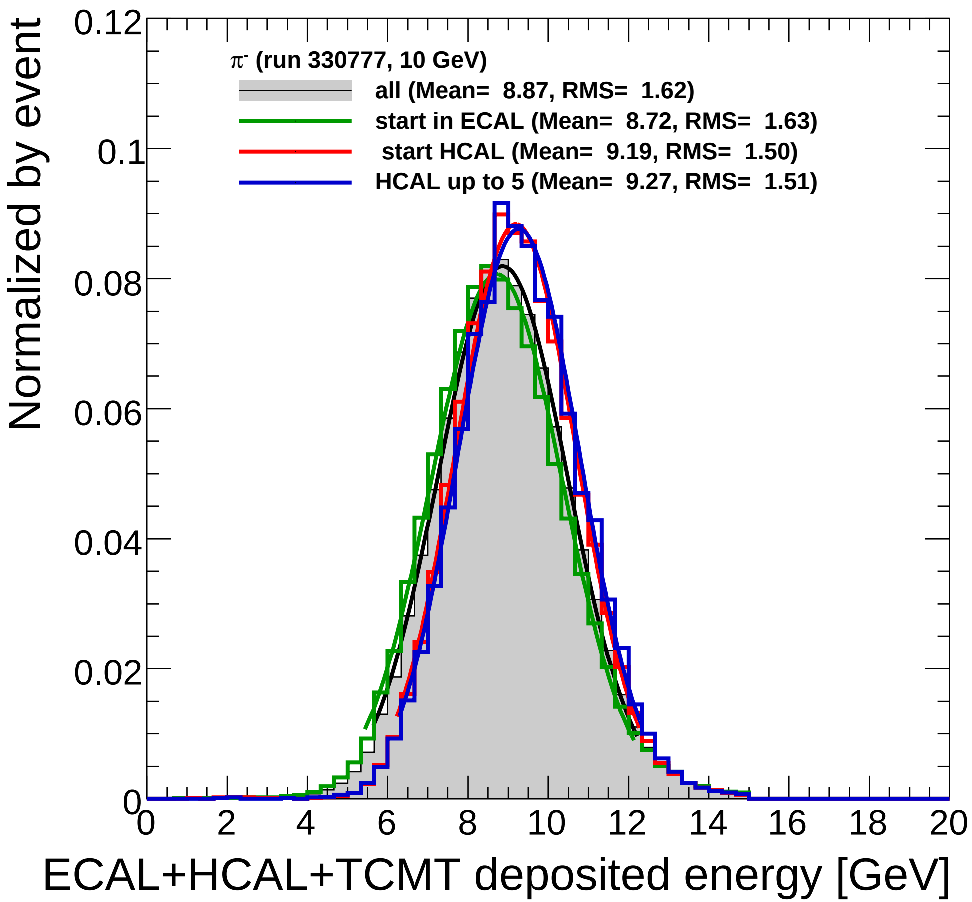
Event selection: energy distributions for 80-GeV π^+

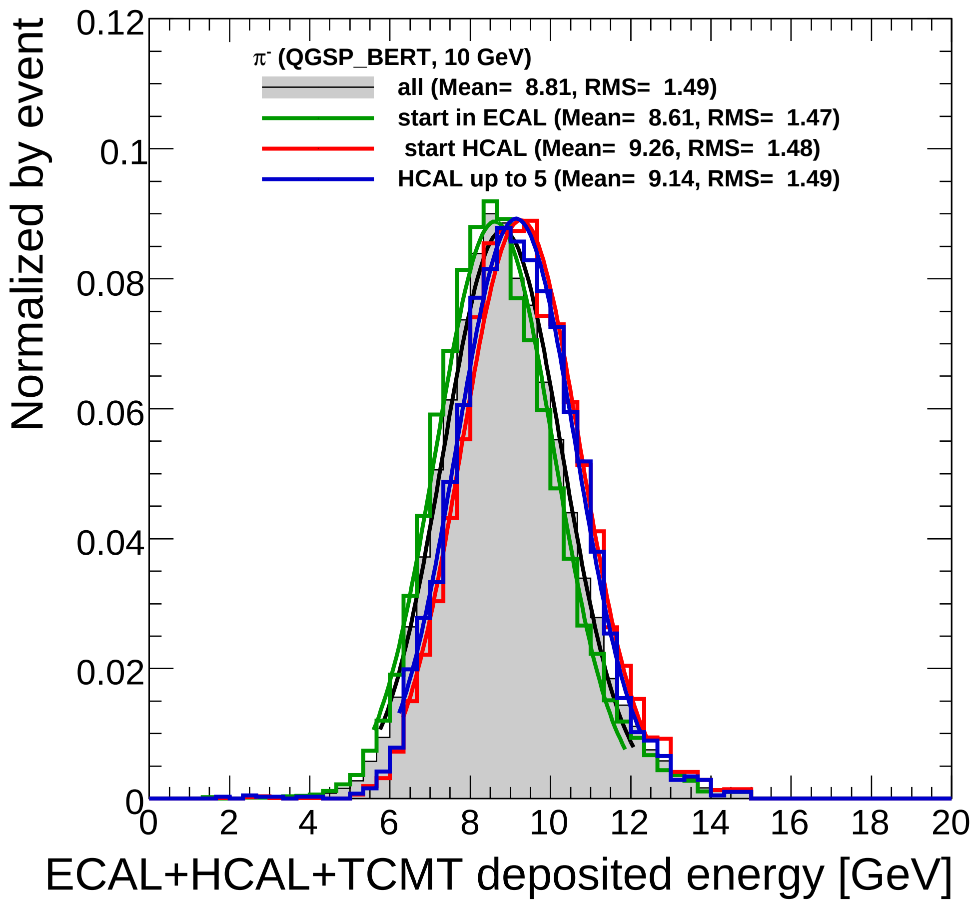




The same sampling factors and coefficients as in the previous slide.

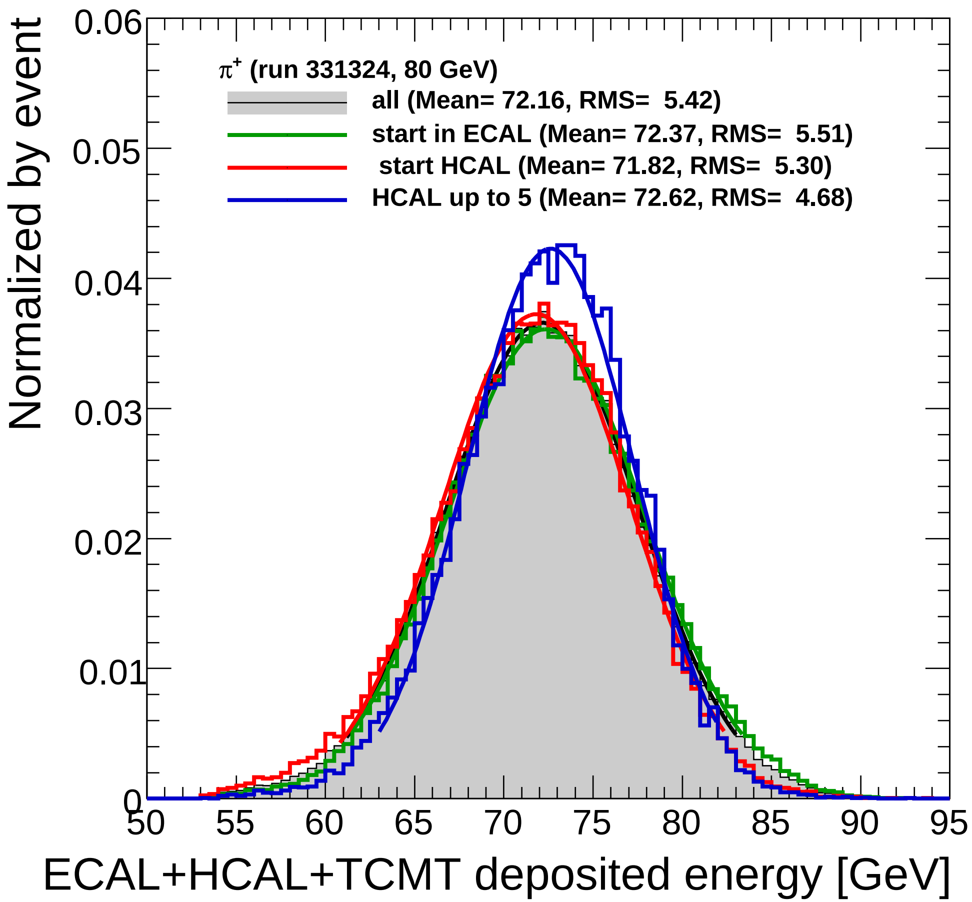
Event selection: energy distributions for 10-GeV π^-

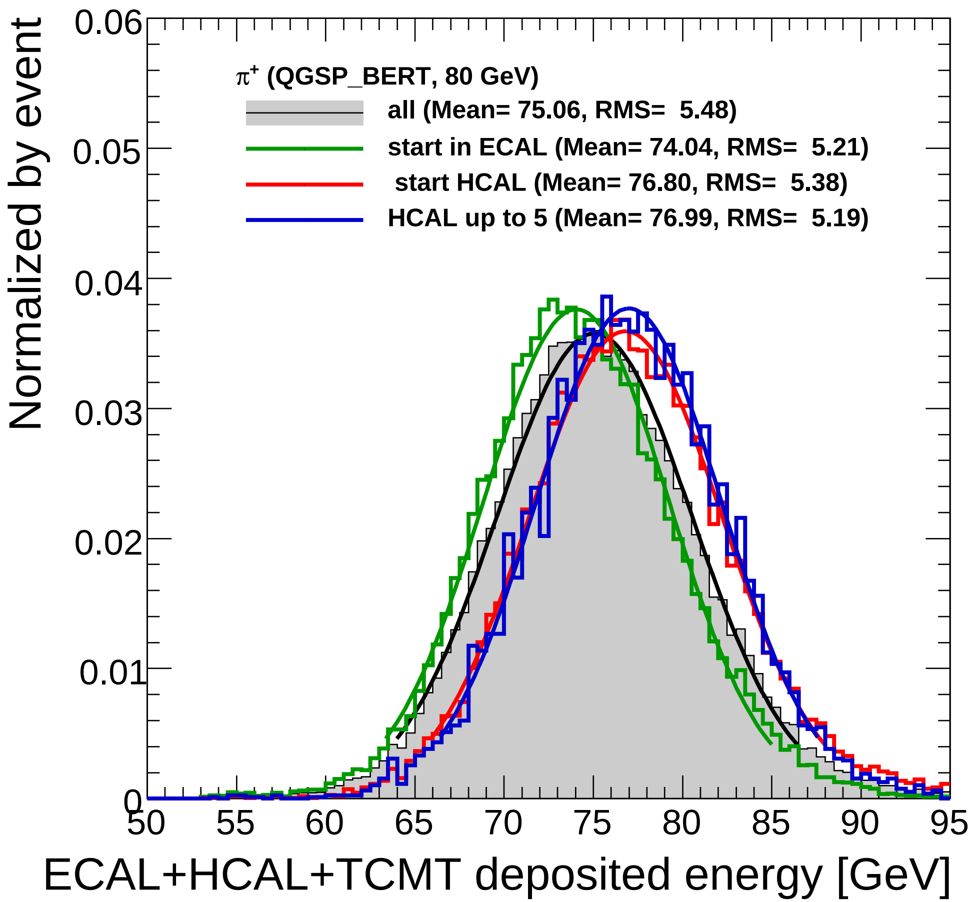




S_{ecal} = 29.2. For data, the selection of events with shower start in HCAL improves energy resolution and shifts the mean value up by $\sim$5%. The shift predicted by QGSP_BERT model is of the same order of magnitude.

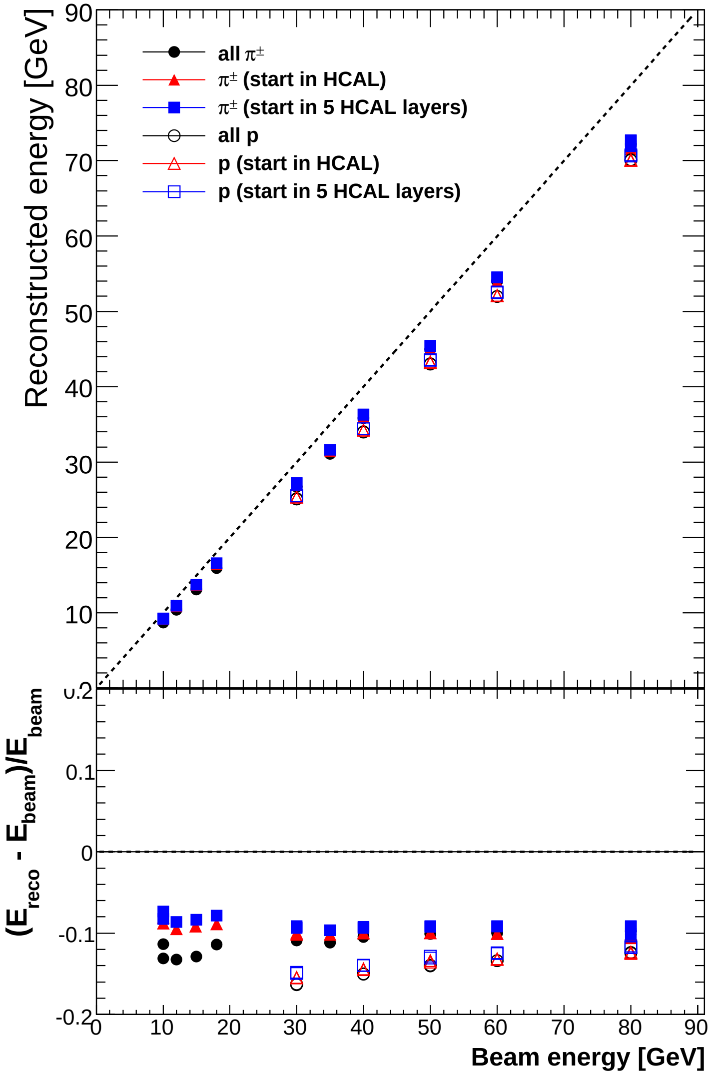
Event selection: energy distributions for 80-GeV π^+



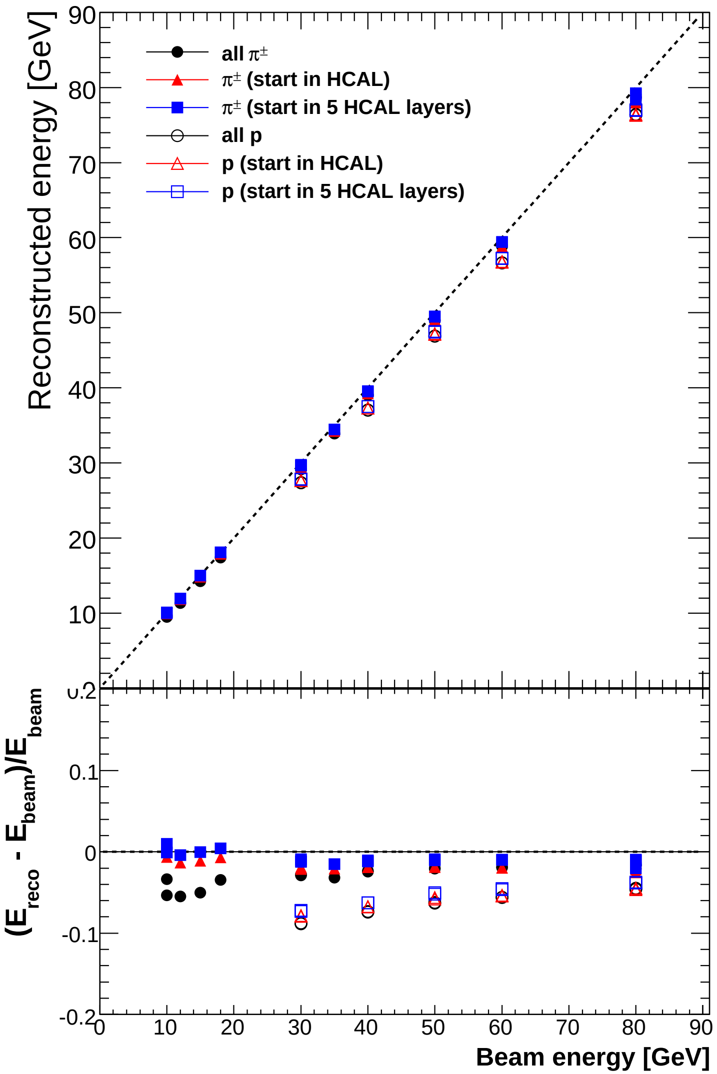


S_{ecal} = 29.2. The mean value shift predicted by QGSP_BERT is ∼5% as for 10 GeV while for 80-GeV data no such a shift is observed. The more significant RMS improvement can be seen for data than for QGSP_BERT.

Event selection: linearity

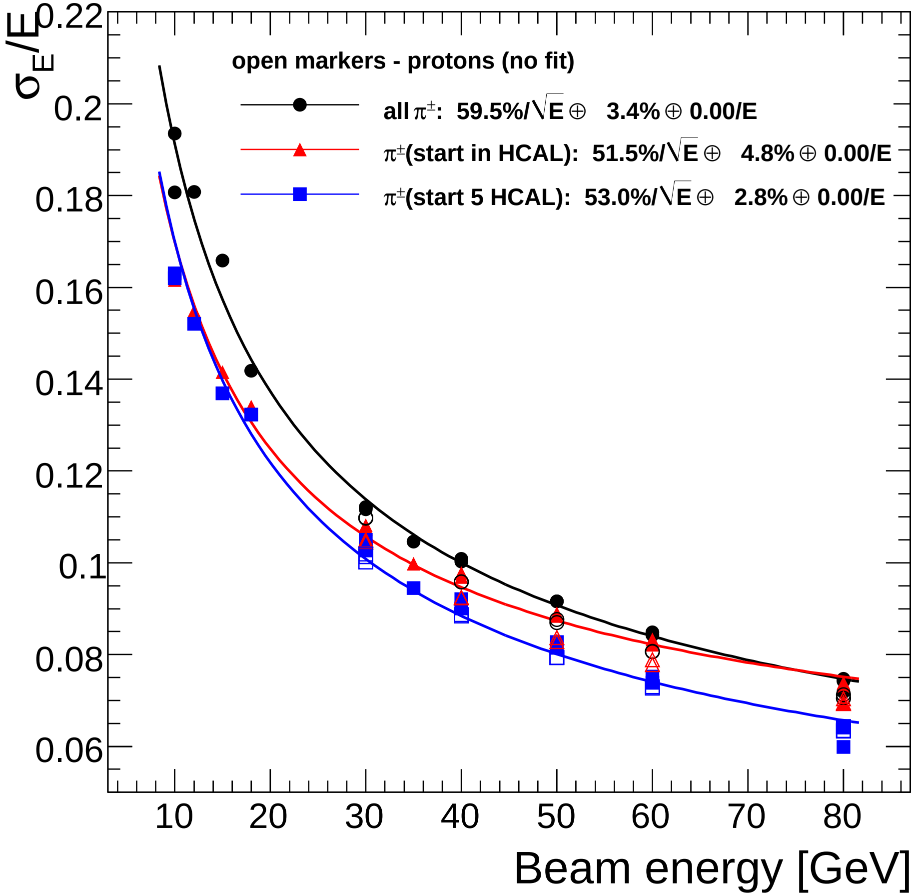


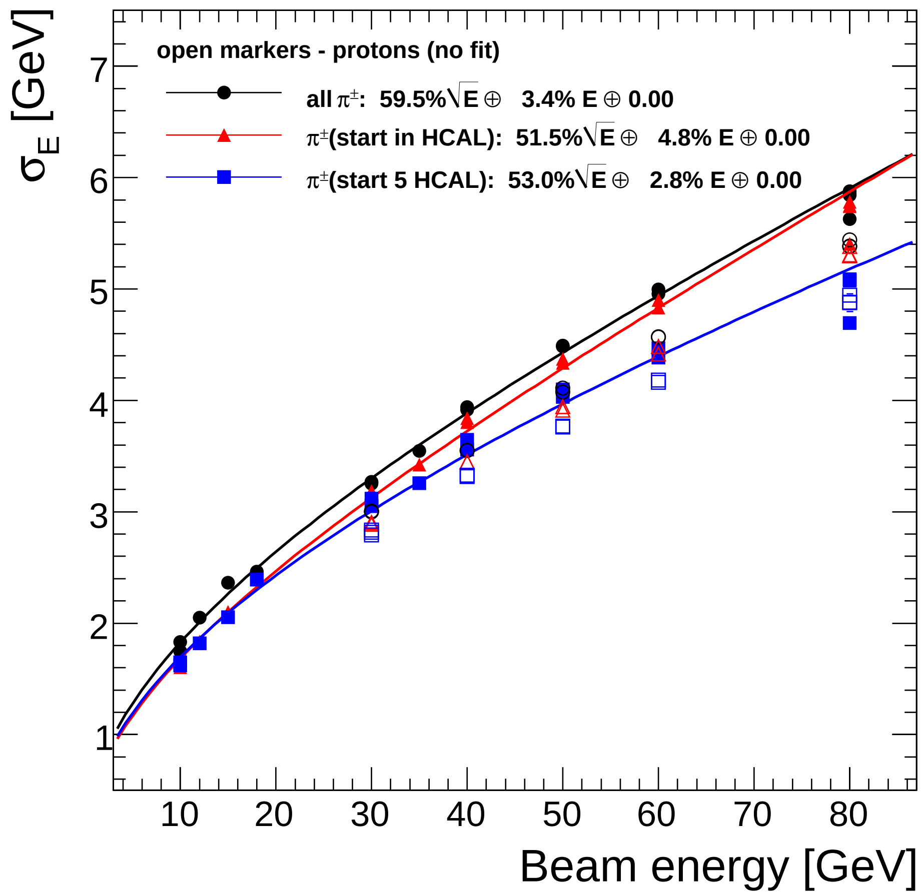
No scaling



E_{reco} **multiplied by 1.09 (e/π ratio)**

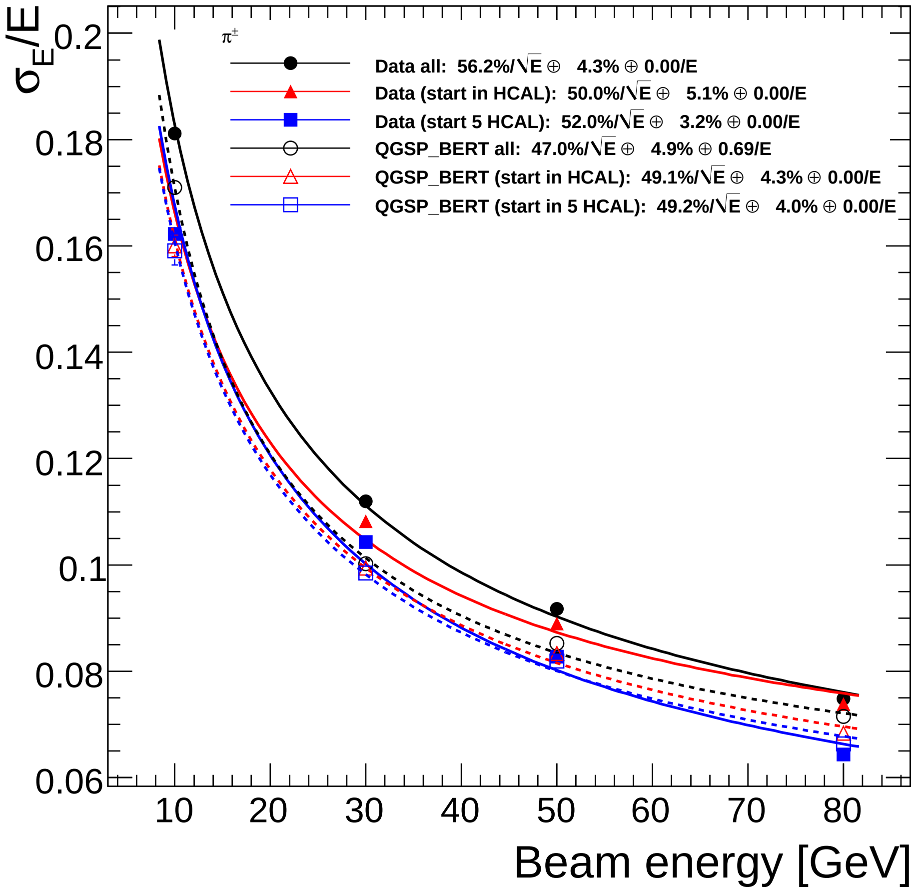
Event selection: energy resolution for data



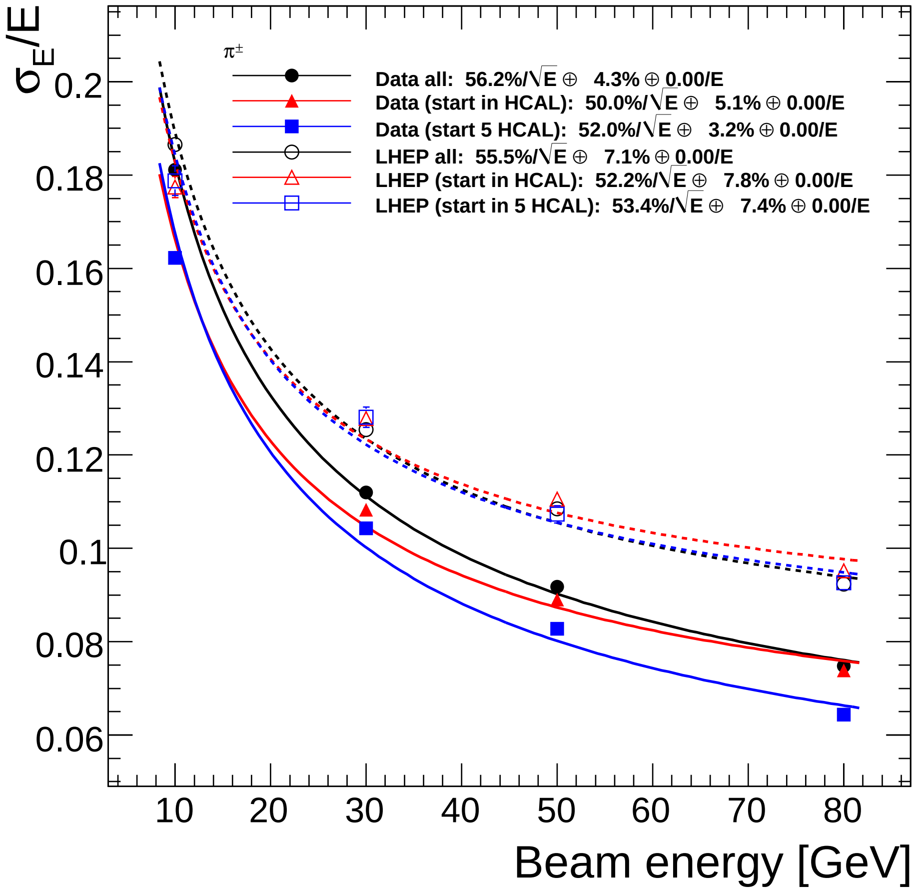


The increase of difference between start anywhere in HCAL and start in first 5 HCAL layers with increasing beam energy is due to higher probability of leakage for higher energies.

Event selection: energy resolution for MC



QGSP_BERT



LHEP

Event selection: summary

calibration inconsistency (ECAL size?) $\Rightarrow$ resolution $\downarrow\downarrow$ by $\sim$8% @ low energies

shower leakage into TCMT$\uparrow\uparrow$ $\Rightarrow$ resolution$\downarrow\downarrow$ by $\sim$8% @ high energies

How to avoid? Select events with shower start in the first 5 HCAL layers

$\Downarrow$

$$\frac{\sigma_E}{E} = \frac{(53.0 \pm 0.2)\%}{\sqrt{E/GeV}} \oplus (2.8 \pm 0.1)\% \oplus \frac{0.00 \pm 0.05}{E/GeV}$$

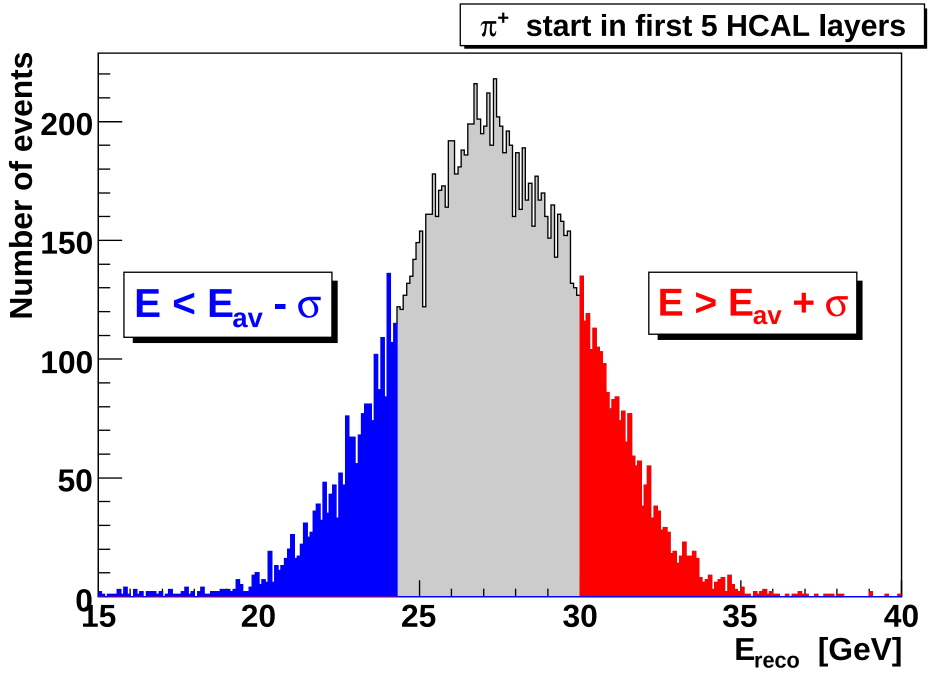
linearity $\sim$2% for π, while $\sim$8% for protons

For the CALICE AHCAL $e/\pi \approx 1.09$ for 10÷80 GeV

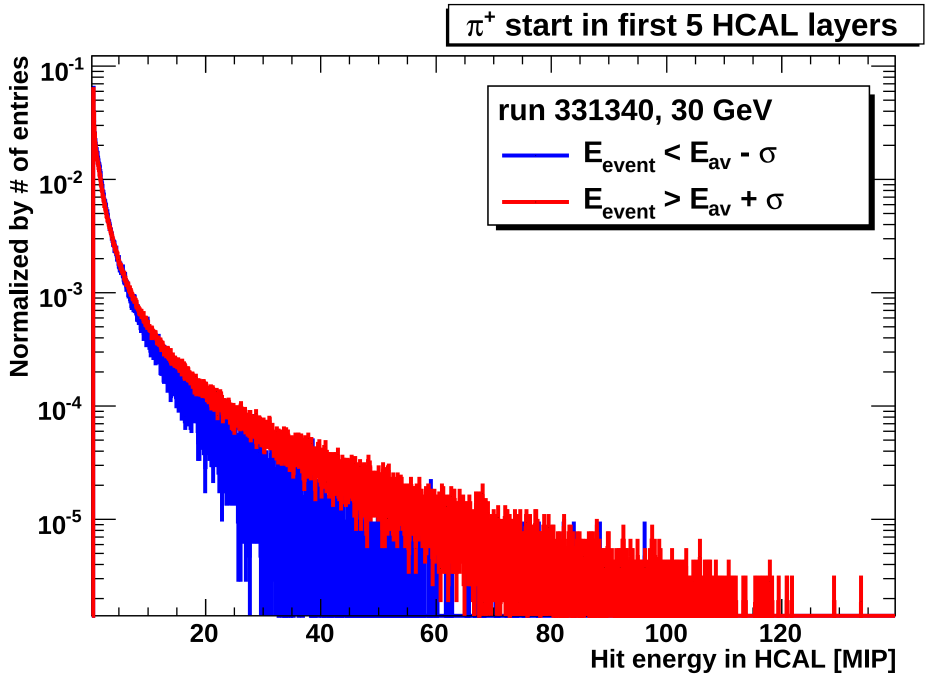
Software compensation: approach

based on hit spectrum analysis ⇒ only events with shower start in first 5 HCAL layers will be analyzed

Energy distribution for 30-GeV π^+

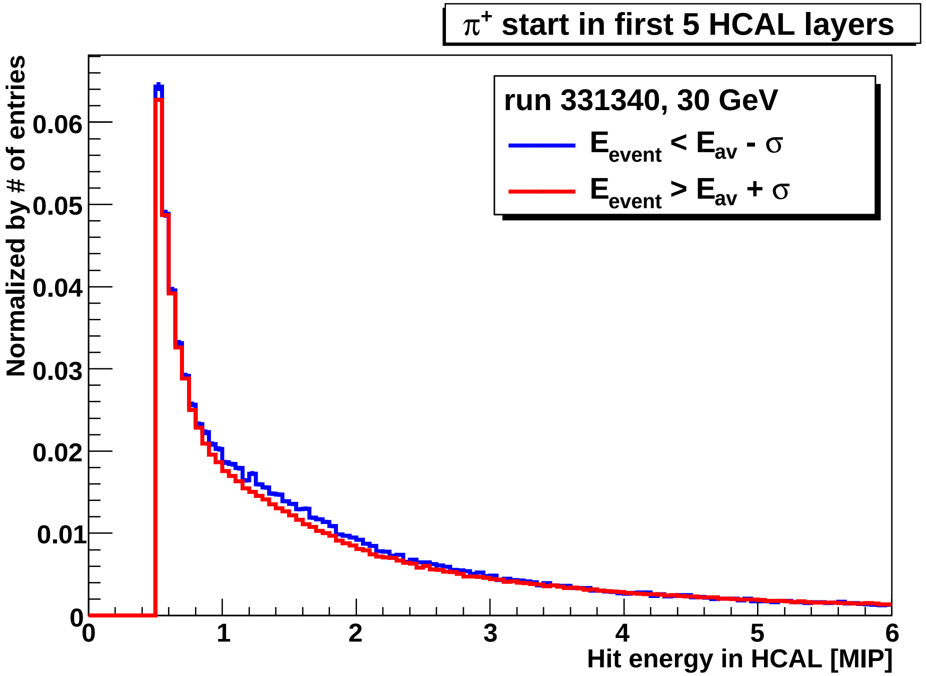


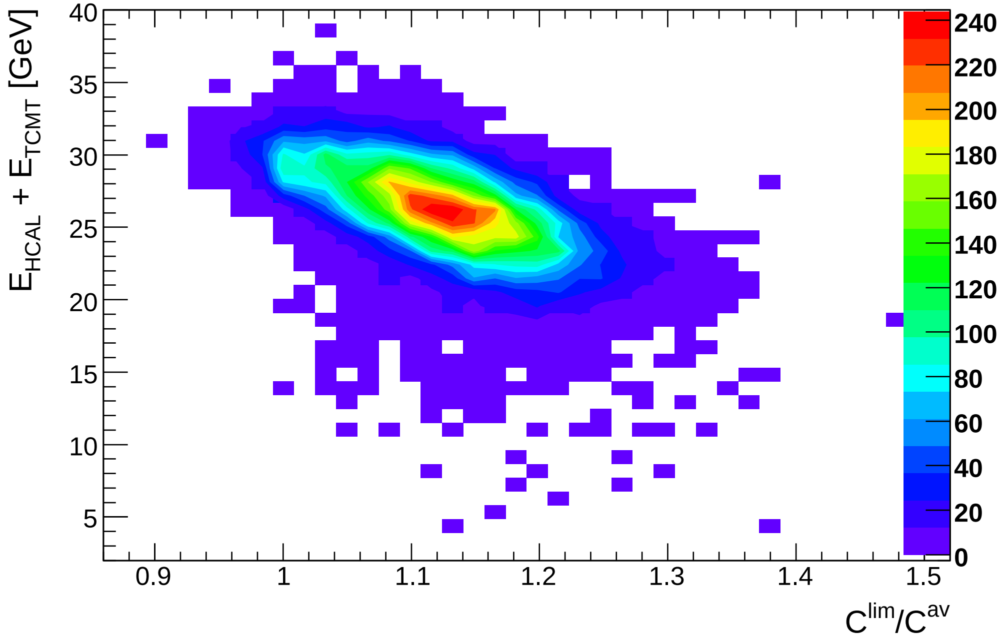
Hit spectra for energy distribution tails



The technique proposed in CAN-015 and also based on hit spectrum analysis includes individual hit weighting in 8 regions of hit spectrum and 6 parameters to correct energy dependence.

Software compensation: integral spectrum characteristics





The following integral values can characterize a hit spectrum $h_i(e)$ of the i-th event:

$$C_i^{lim} = \int_0^{e_{limit}} h_i(e)de \quad \textbf{and} \quad C_i^{av} = \int_0^{e_i^{av}} h_i(e)de$$

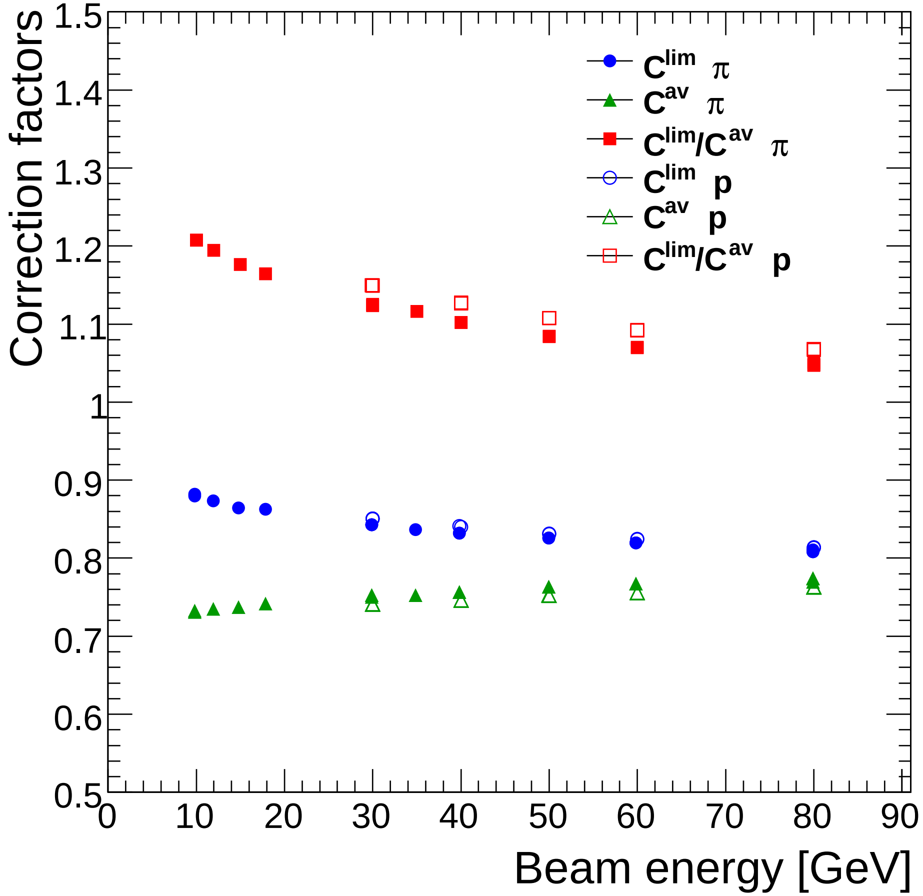
where $e_{limit} = 5.5$ **MIPs** **and** $e_i^{av} = \int_0^{e_{max}} eh_i(e)de$

The ratio $\frac{C_i^{lim}}{C_i^{av}}$ is inversely correlated with the energy deposited in the event.

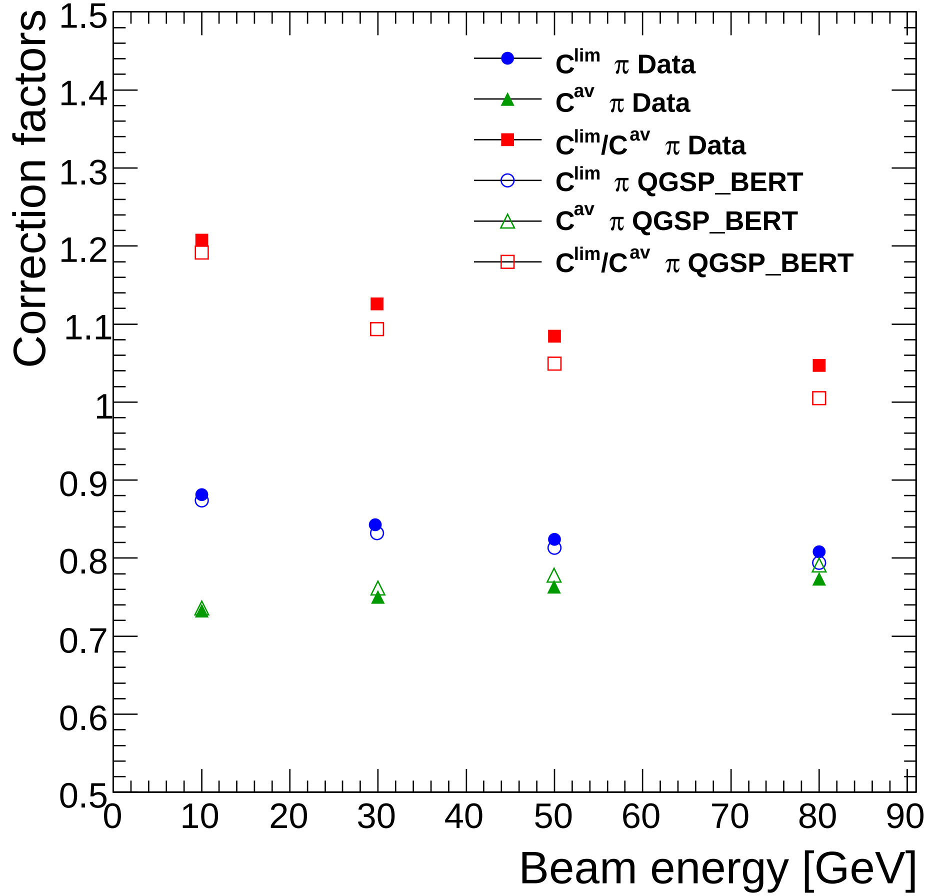
Software compensation: correction factor behavior

The mean value of the correction factor $\frac{C^{lim}}{C^{av}}$ exhibits a relatively weak but visible energy dependence

Data π^+ and Data p



Data π^+ and QGSP_BERT π^+



This dependence can be fitted by linear or parabolic function.

Software compensation: correction procedure for i-th event

Calculate uncorrected deposited energies E_i^{HCAL}, E_i^{ECAL}, and E_i^{TCMT}

$\Downarrow$

Calculate correction factors C_i^{lim} and C_i^{av}

$\Downarrow$

Correct HCAL energy: $E_i^{cor} = E_i^{HCAL} \cdot \frac{C_i^{lim}}{C_i^{av}}$

$\Downarrow$

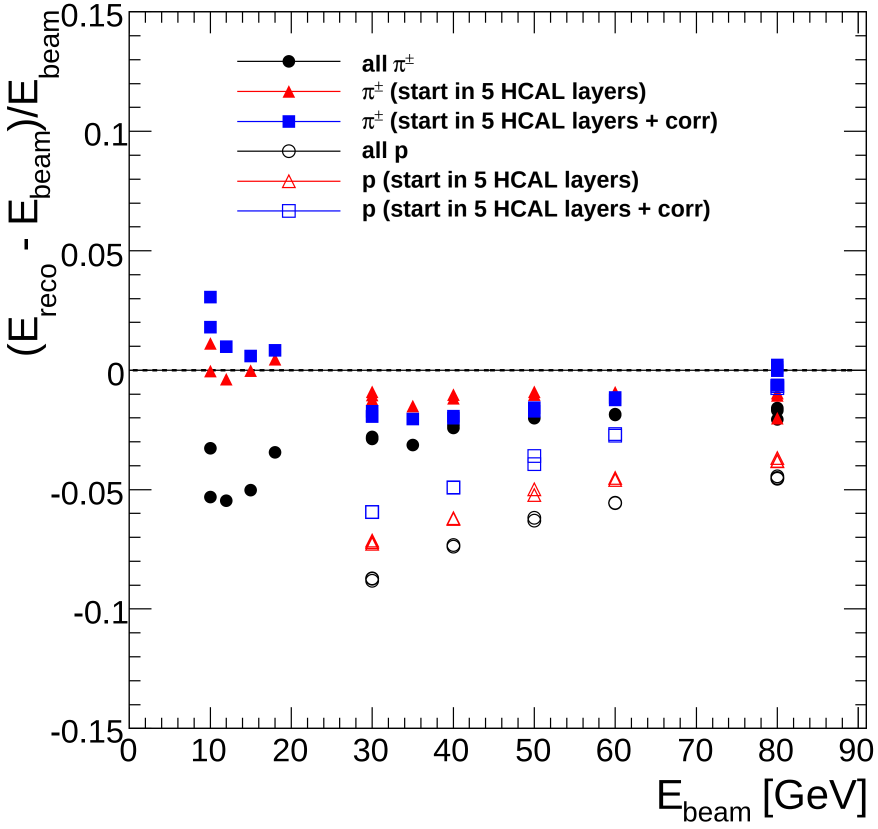
Calculate total energy: $E_i^{dep} = E_i^{ECAL} + E_i^{cor} + E_i^{TCMT}$

$\Downarrow$

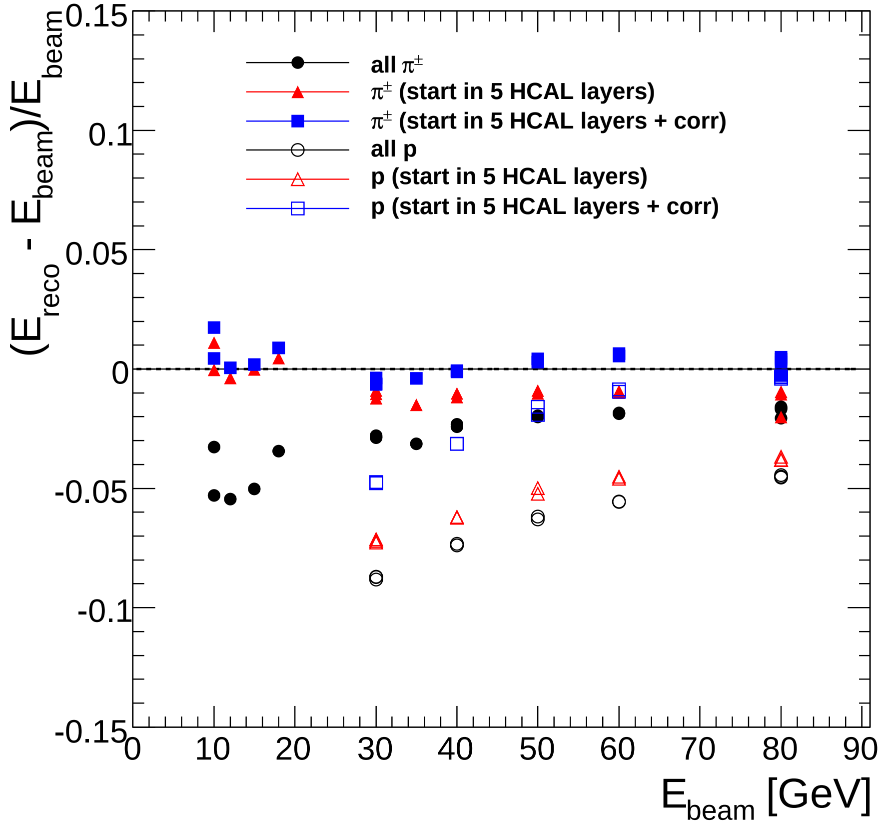
Correct energy dependence $E_i^{reco} = E_i^{dep}(a_1 + a_2 E_i^{dep})$, $a_1 = 0.91$, $a_2 = 0.002$ **GeV**$^{-1}$ **or**
$E_i^{reco} = E_i^{dep}(a_1 + a_2 E_i^{dep} + a_3 (E_i^{dep})^2)$, $a_1 = 0.876$, $a_2 = 0.0043$ **GeV**$^{-1}$ **and** $a_3 = -2.4 \cdot 10^{-5}$ **GeV**$^{-2}$

Only 3 (or 4) parameters and no adjustment of ranges in hit spectra

Software compensation: linearity after correction

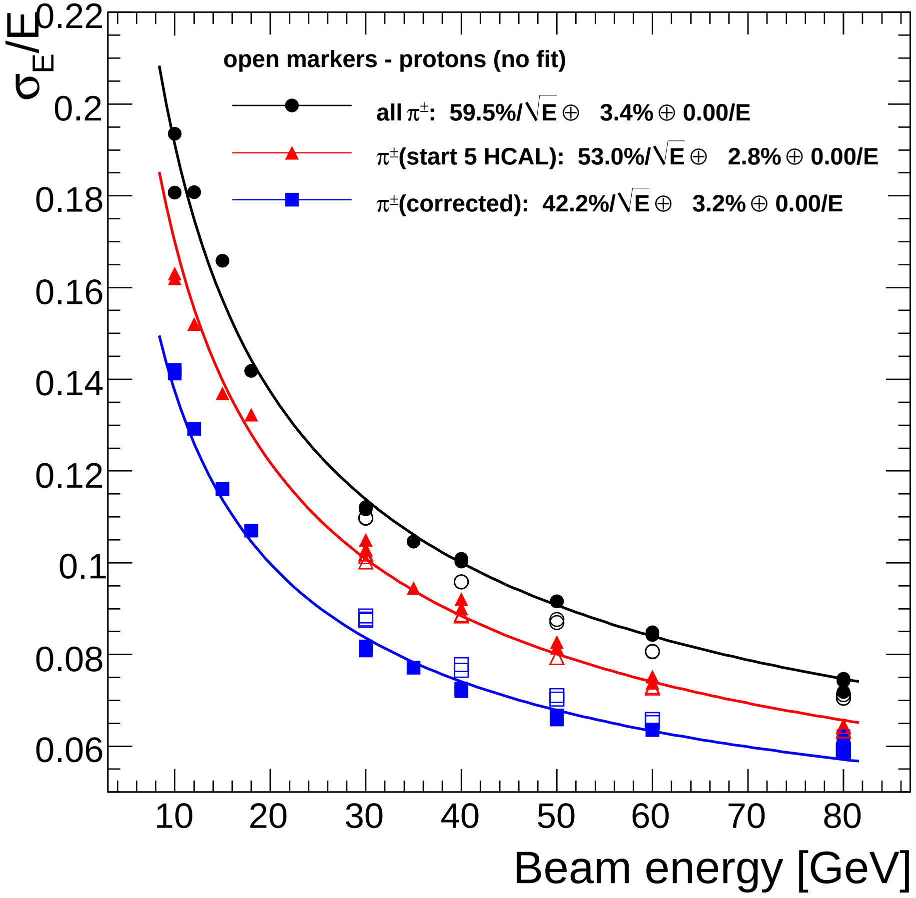


Linear

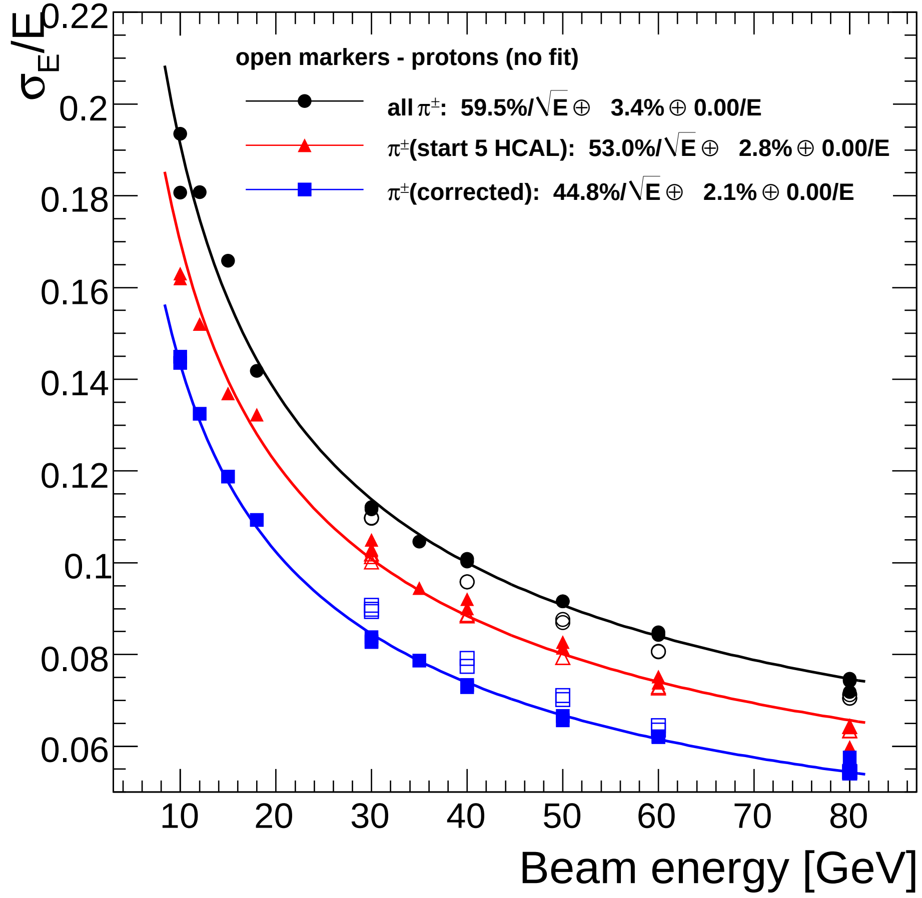


Parabolic

Software compensation: resolution after correction

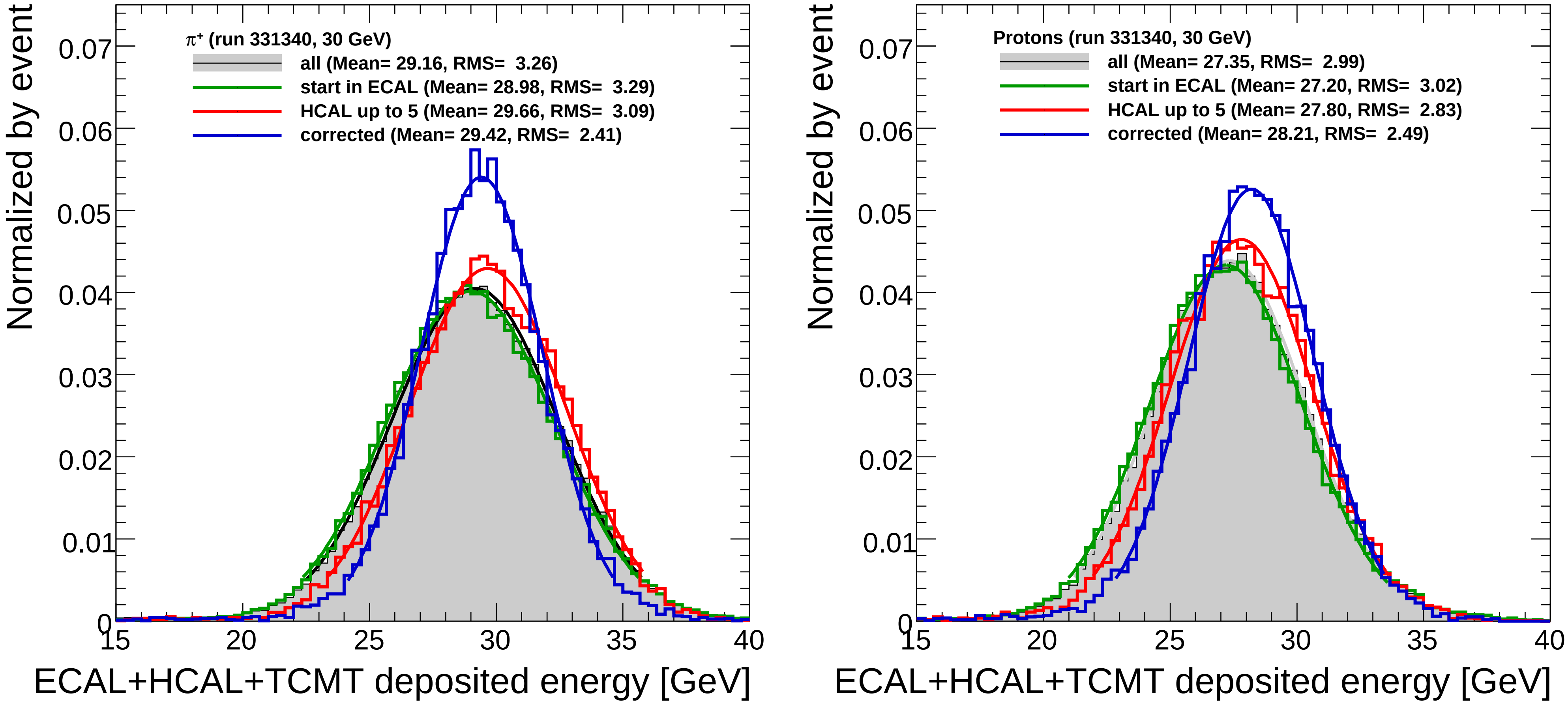


Linear



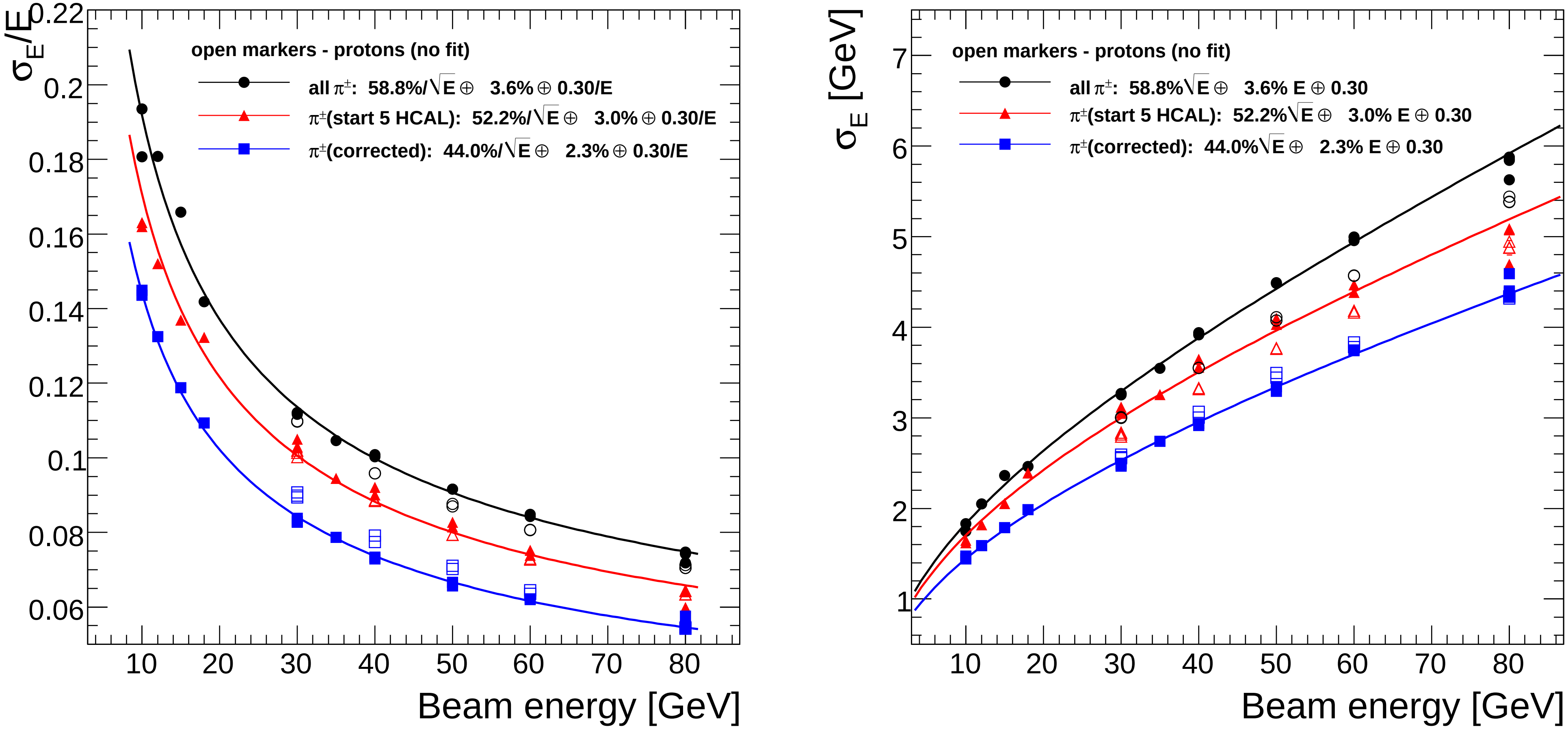
Parabolic

Software compensation: energy distributions after correction



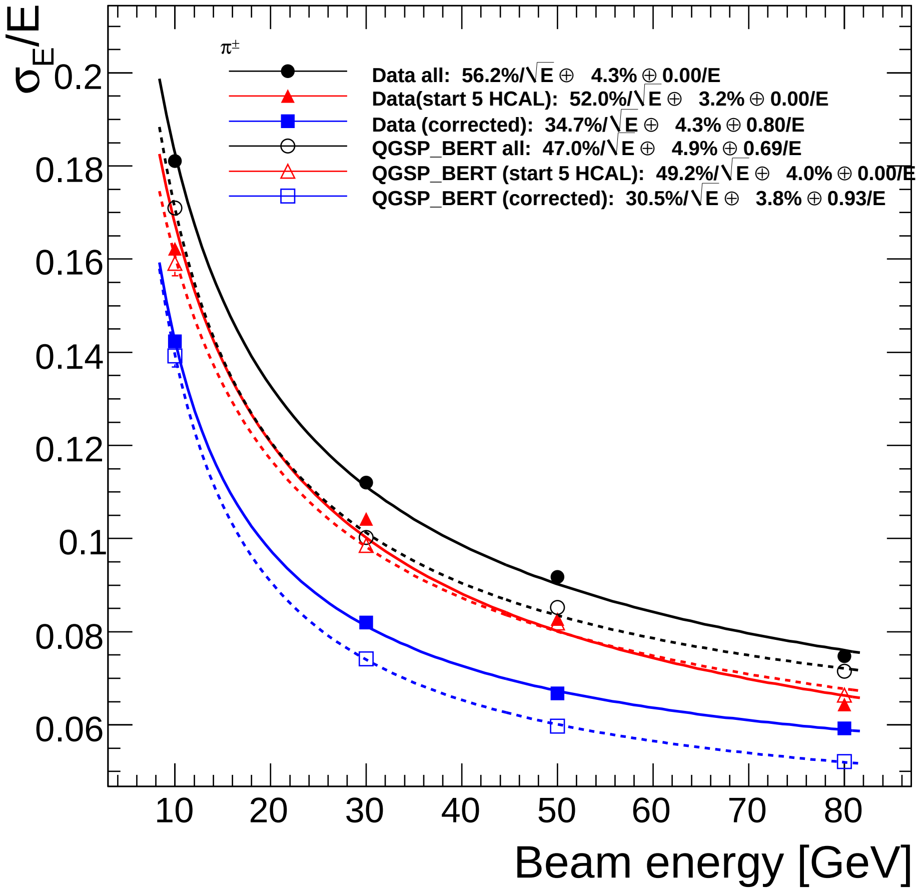
π^+ **proton**

Software compensation: fit with fixed σ_{noise}

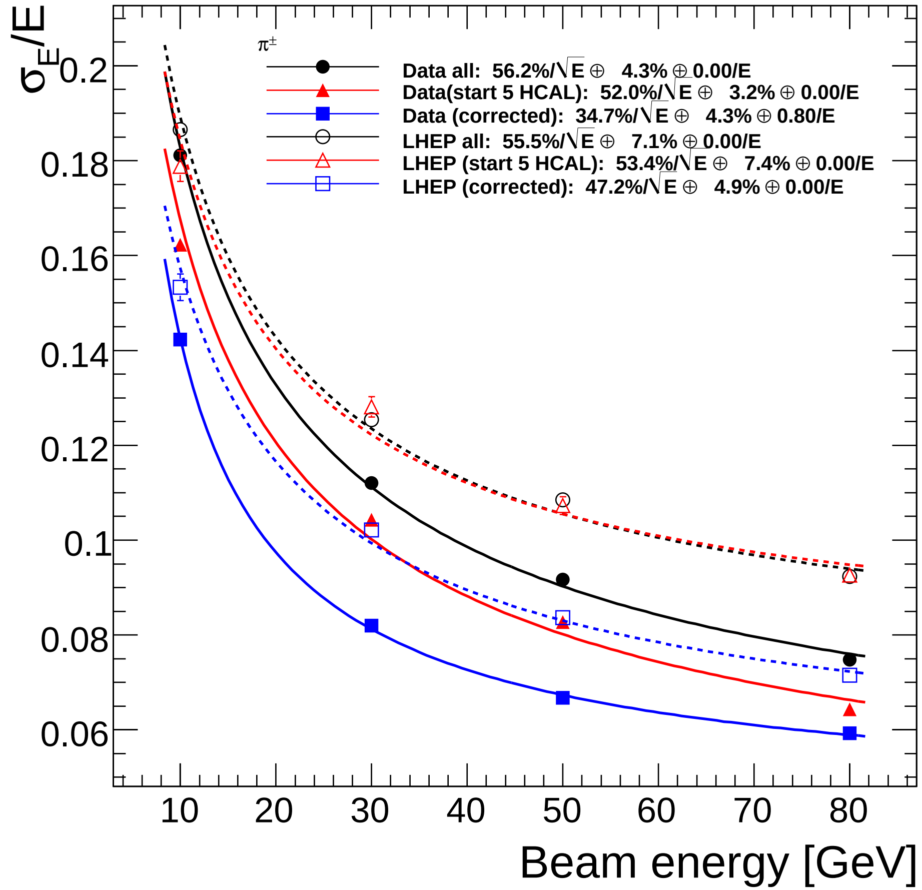


$$\frac{\sigma_E}{E} = \frac{(44.0 \pm 0.2)\%}{\sqrt{E/GeV}} \oplus (2.3 \pm 0.1)\% \oplus \frac{0.3}{E/GeV}$$

Software compensation: MC resolution after correction

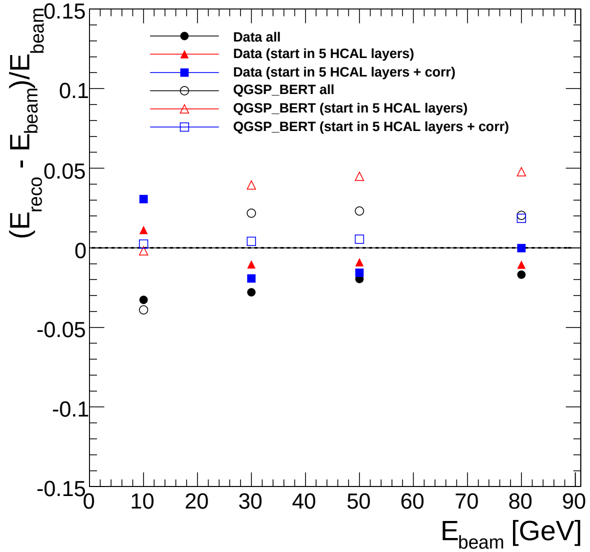


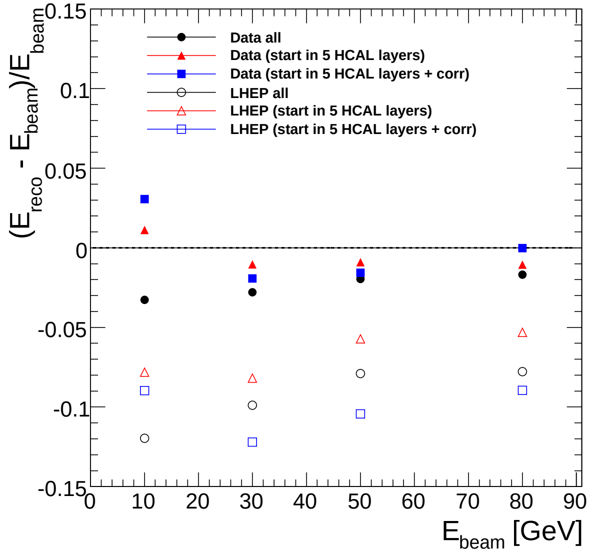
QGSP_BERT



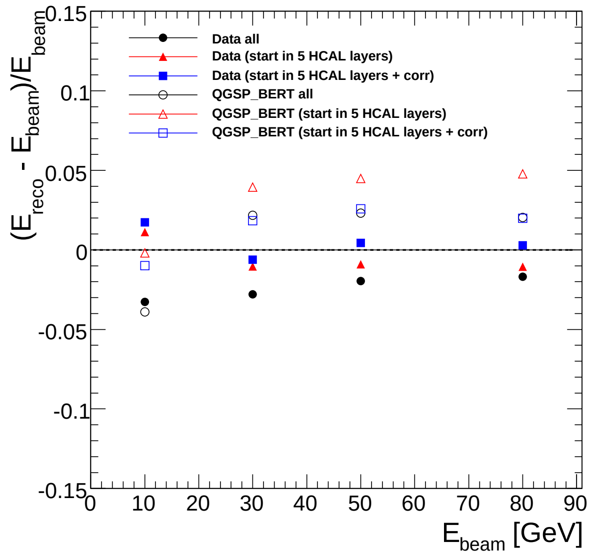
LHEP

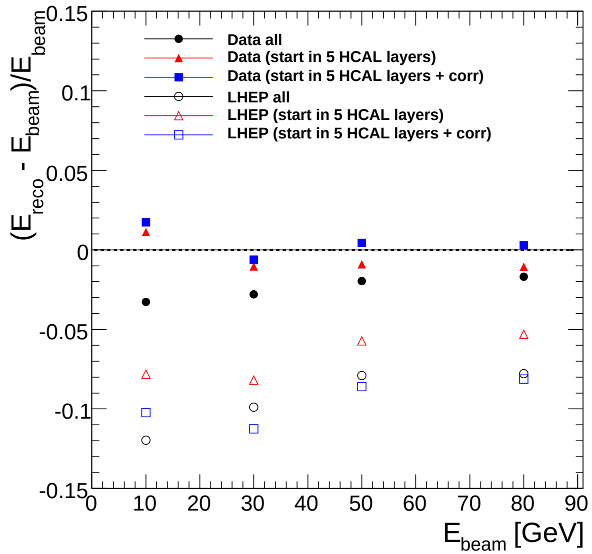
Software compensation: MC linearity after correction





Linear





QGSP_BERT **LHEP** **Parabolic**

Software compensation: summary

Proposed method of software compensation enables to improve resolution by $\sim$10%

Advantages	Problems
3 (or 4) parameters only	full hit spectrum necessary
weak energy dependence	energy range extension
similar behavior of MC resolution	distortion of MC linearity

TO DO:

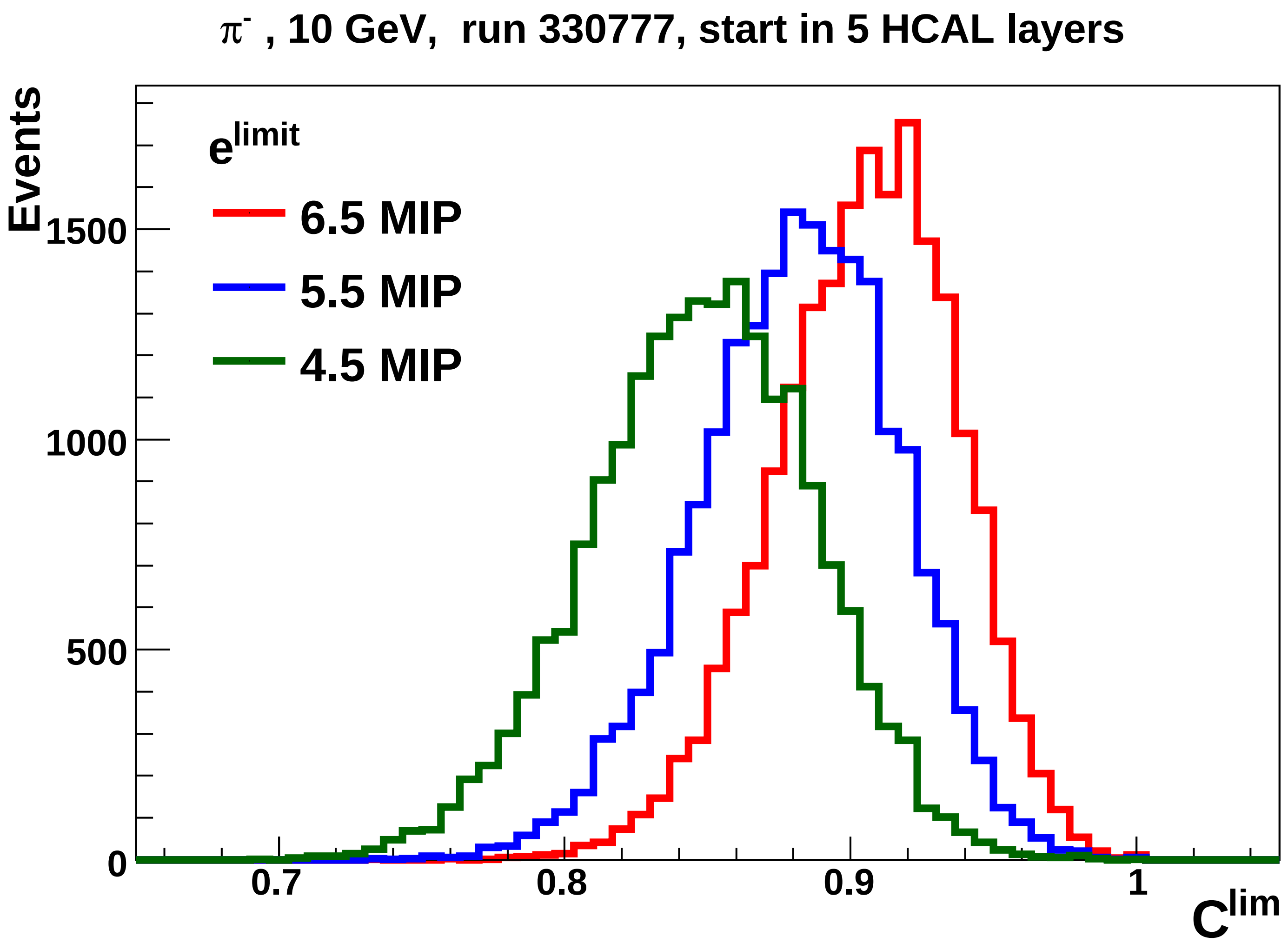
Hadron selection procedure for lower energies

More energy points and simulated MC physics lists

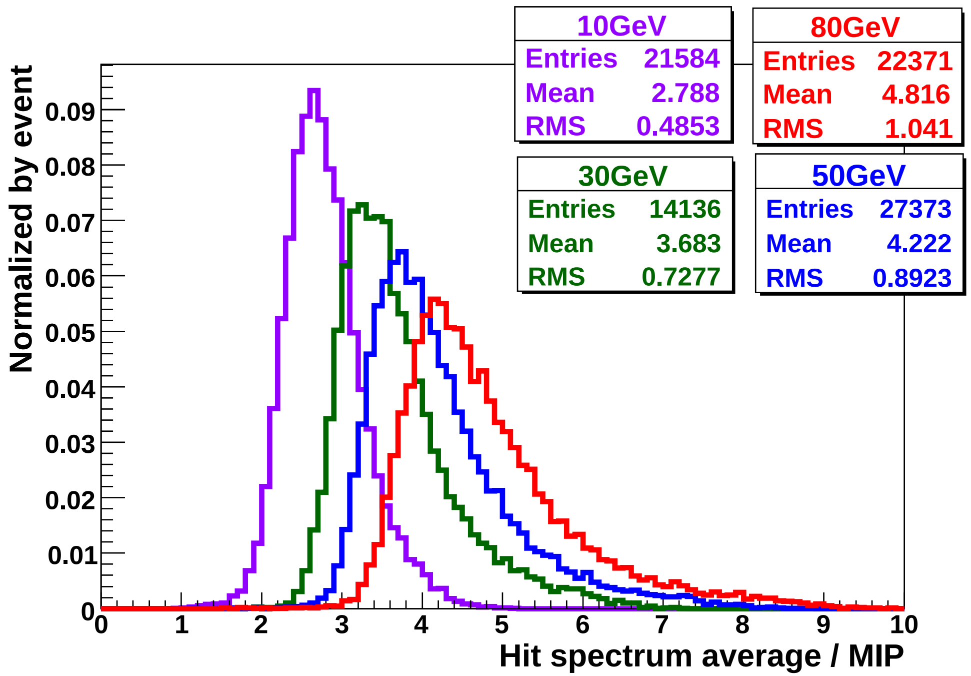
Energy range expansion

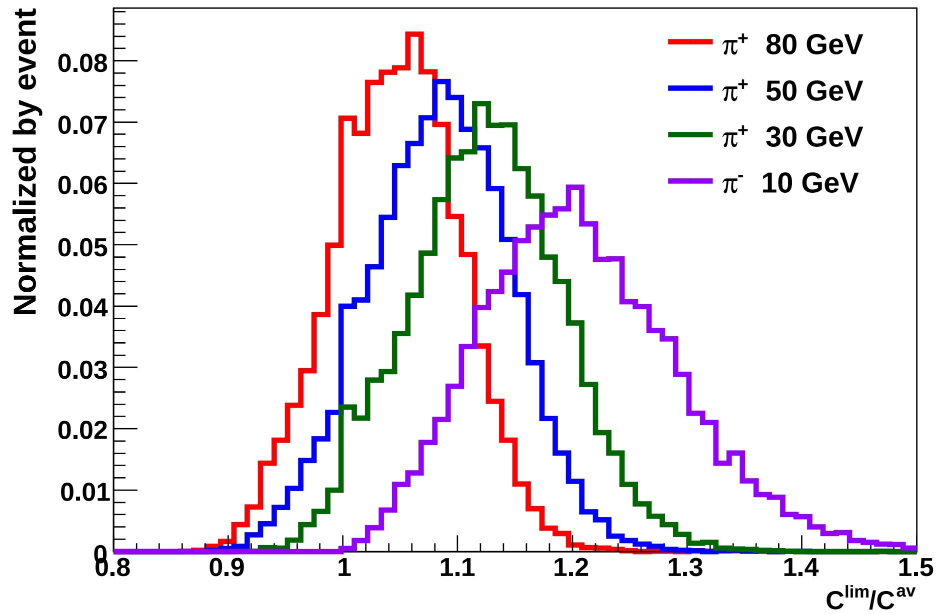
Backup slides

Software compensation: correction factor behavior



Software compensation: correction factor behavior





Software compensation: correction factor behavior