Shower Leakage Correction in a High Granularity Calorimeter

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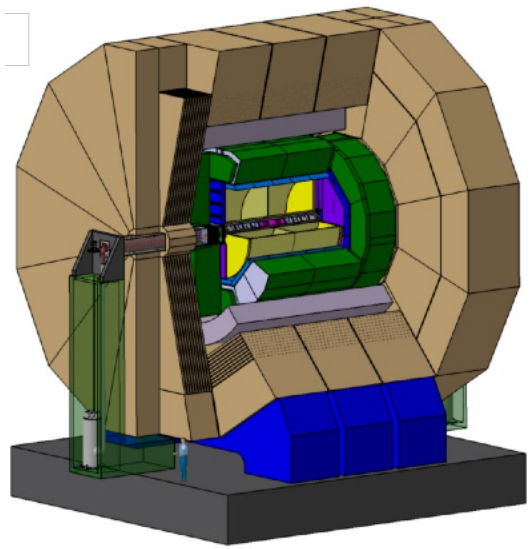
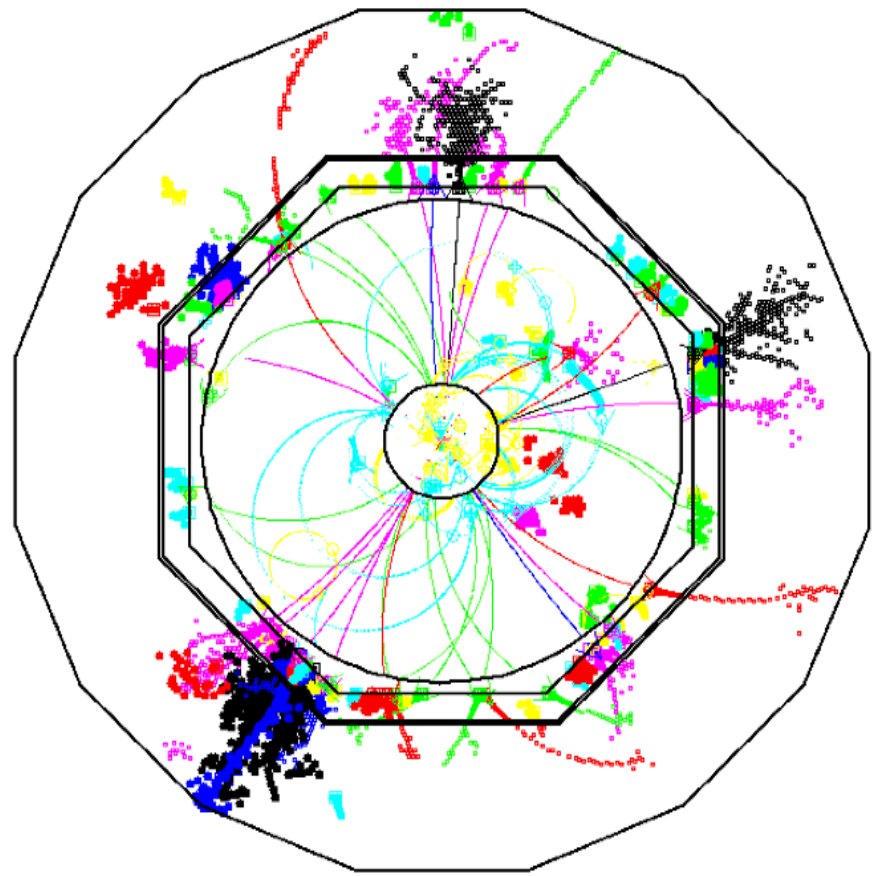
ILD: International Large Detector

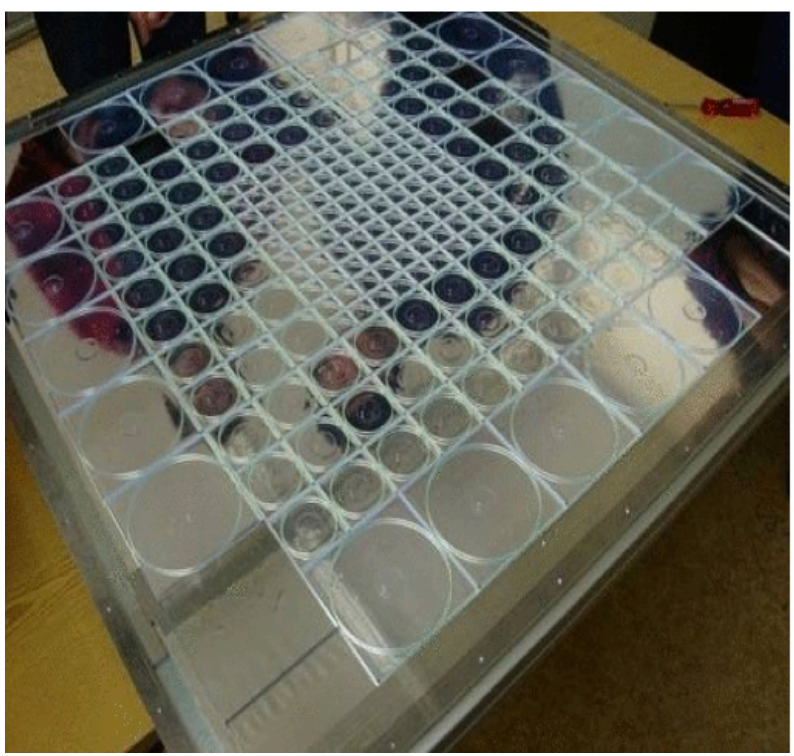




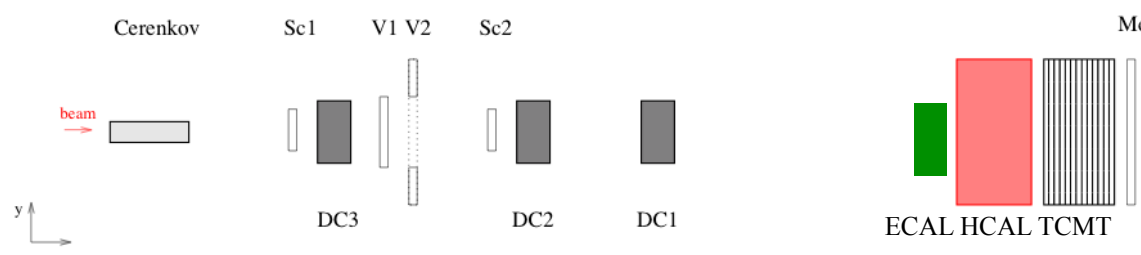
- In the ILD detector:
  - Hcal inside coil
  - Hcal ~5λ
  - Ecal ~1λ
  - 80 GeV, 95% containment
- Topological reconstruction of leakage

CALICE Test Beam

AHCAL size	~1m^3	channels	7608
materials	Steel -Scintillator	cell size (cm^2)	3x3 to 12x12
layers	38	light yield	~13 pixel/MIP
interaction length	4.3λ^{π}_{I}	S/N	~10
~1X$_0$/layer	~0.1λ^{π}_{I}/layer		

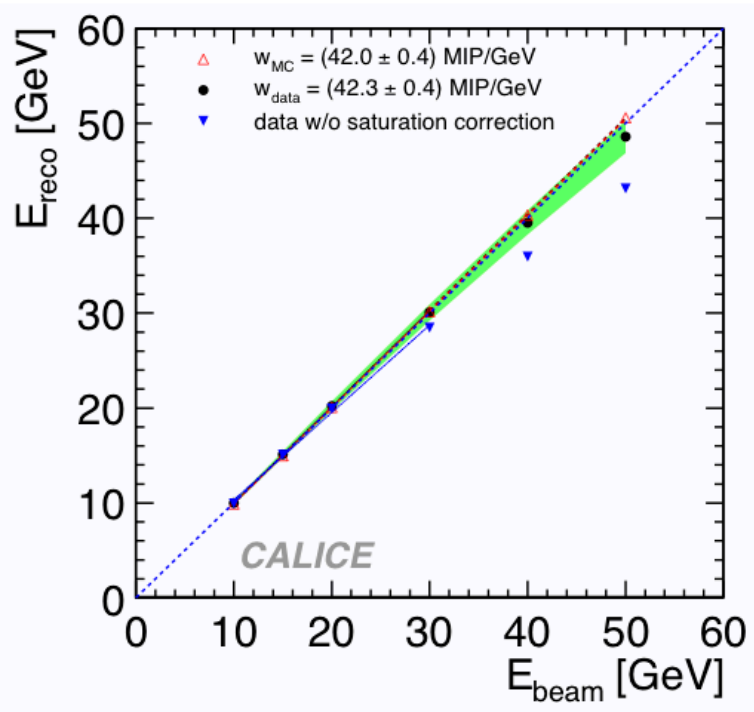


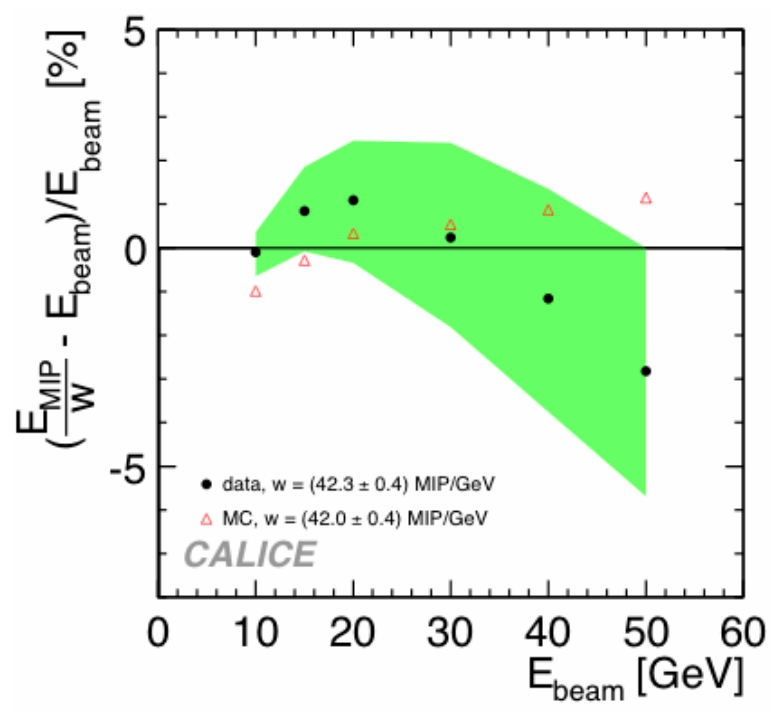
- CALICE collaboration is preparing/ performing large scale test beam
- A comprehensive set of data has been collected with the AHCAL
- Comparison with simulated data



Validation with e.m. Showers

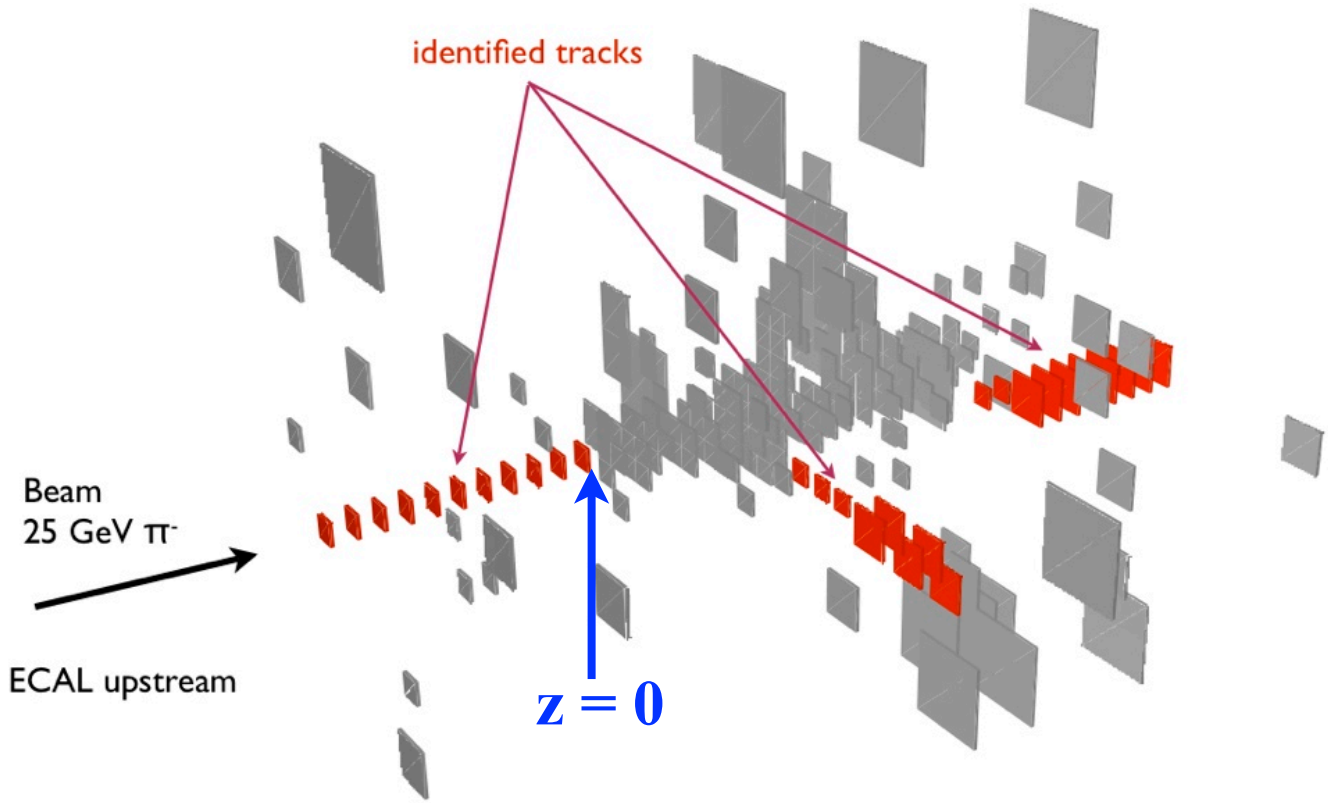
The CALICE collaboration *et al* 2011 *JINST* **6** P04003 doi:10.1088/1748-0221/6/04/P04003





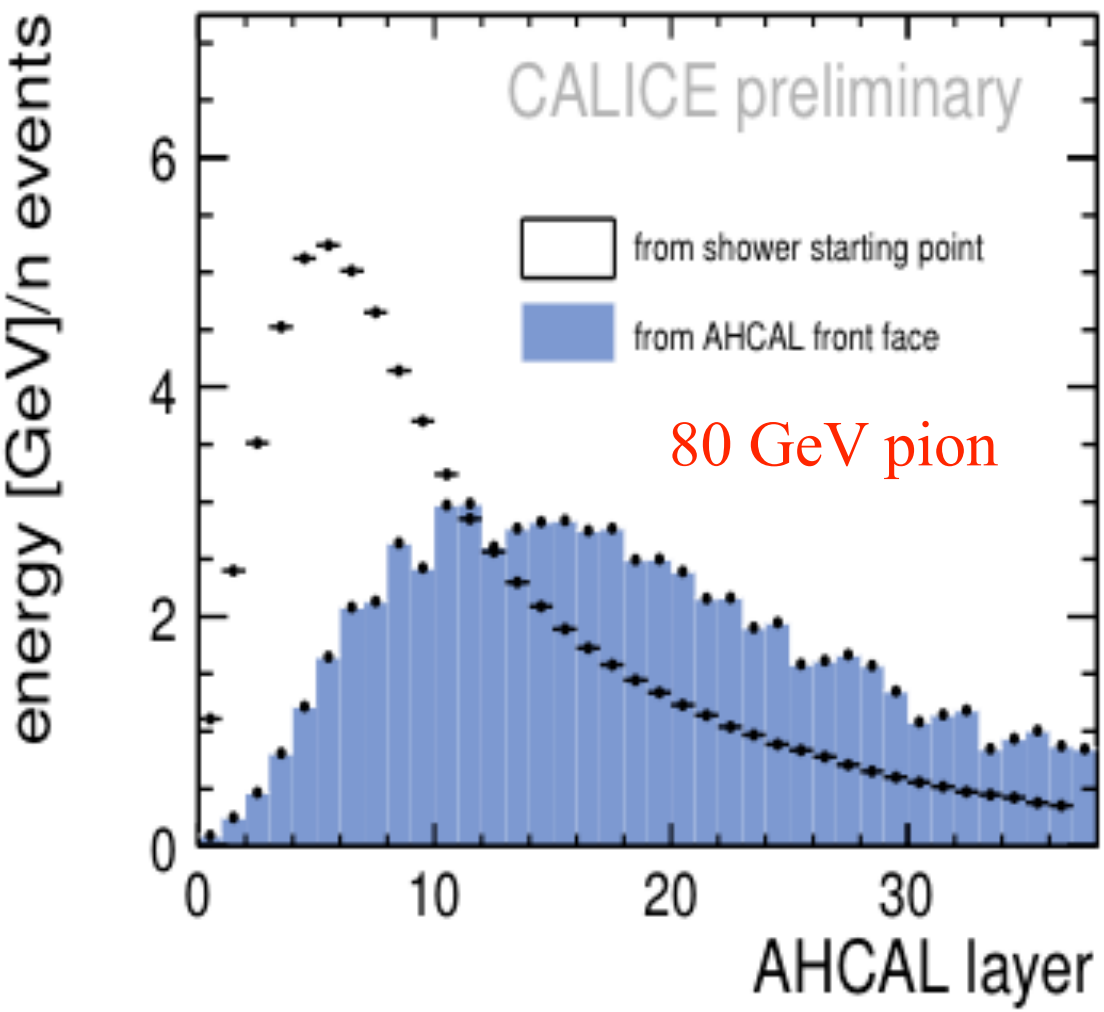
- Use positron data, without ECAL in front of AHCAL, to validate detector digitization and calibrations
- The calorimeter response to e.m. shower is linear to better than 3%.
- Energy density in hadron shower is smaller than e.m. shower
  - less sensitive to non-linearity of SiPM

Identification of Track Segments



- The high granularity of the calorimeter allows detailed 3D studies of the substructure of hadron showers
  - Minimum ionizing track segments can be identified
  - Detailed shower development information: shower starting point, energy fraction ...

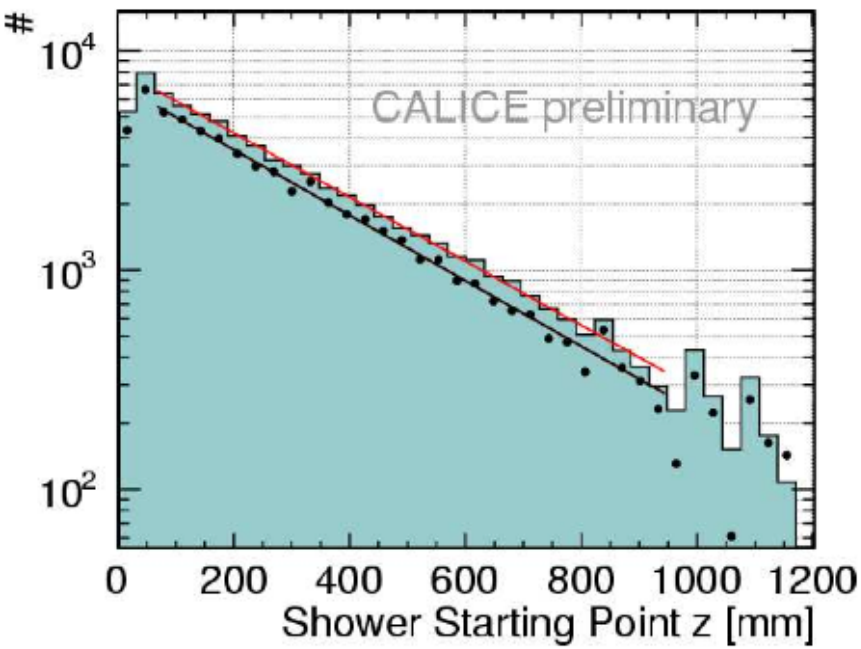
Longitudinal Shower Profile

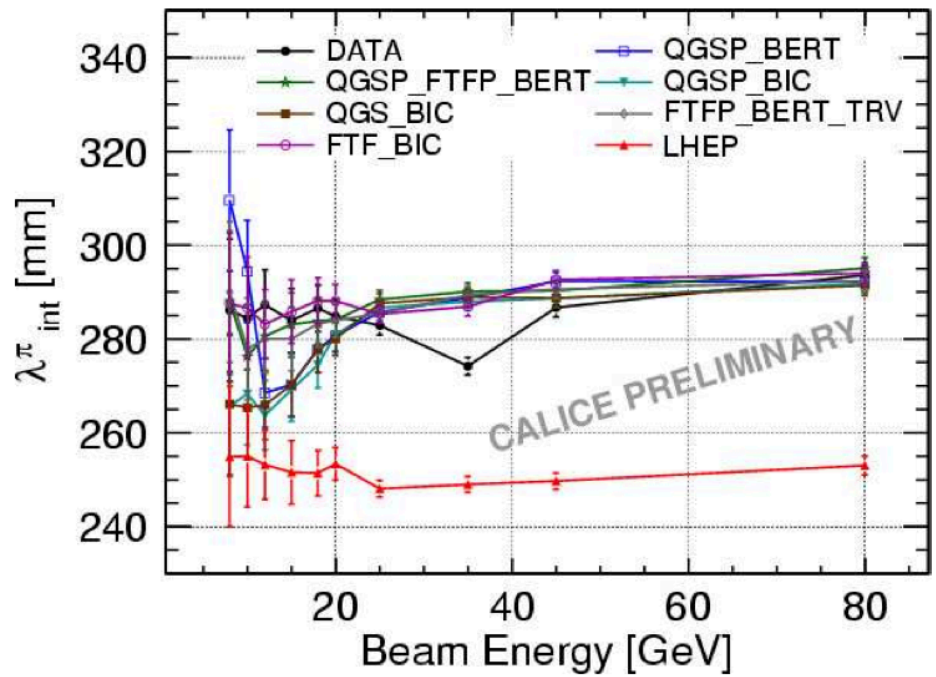


- Shower profile with/ without starting point alignment
  - Increased sensitivity with longitudinal shower profile from first nuclear interaction point, fluctuation ± 1Layer.

Hcal: z = 0, first identified nuclear interaction point

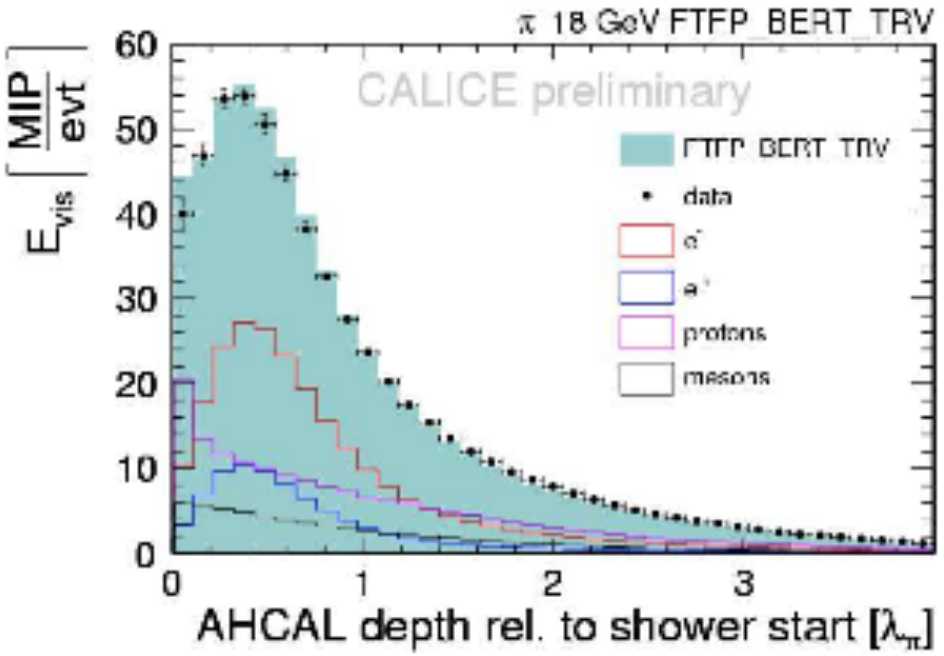
Cross Check of Interaction Length

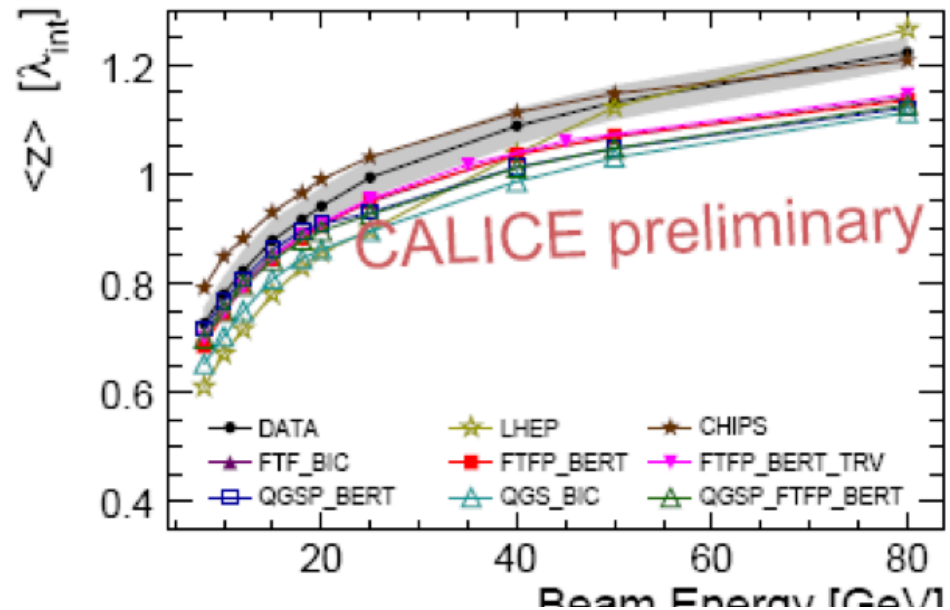


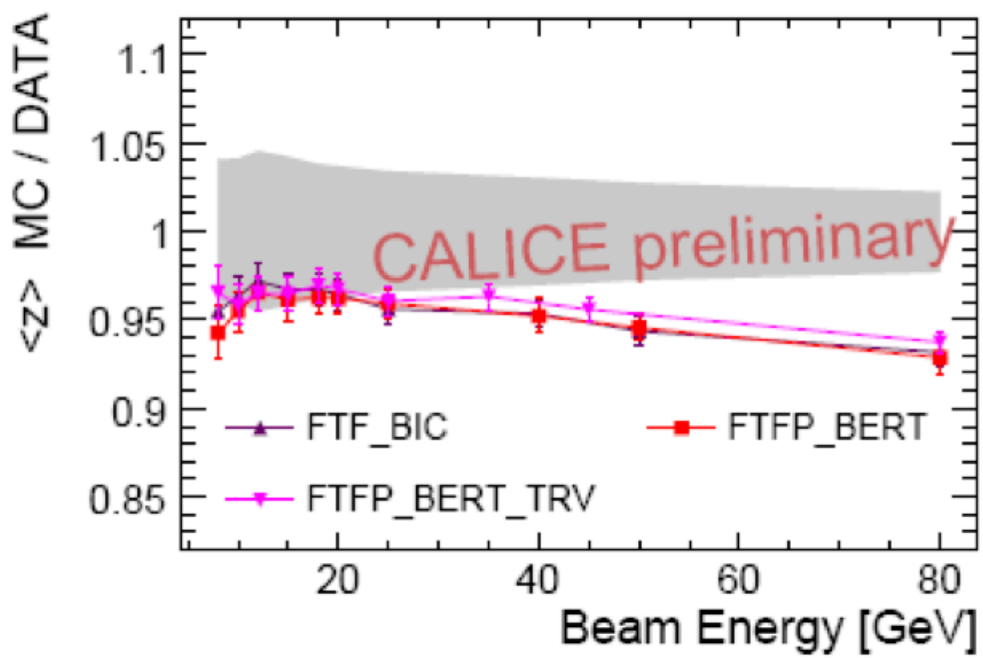


- Good agreement between simulation and data within uncertainty
- LHEP simulations a higher cross section than the other physics lists
  - results: lower interaction length compared to data

Longitudinal Shower Profile

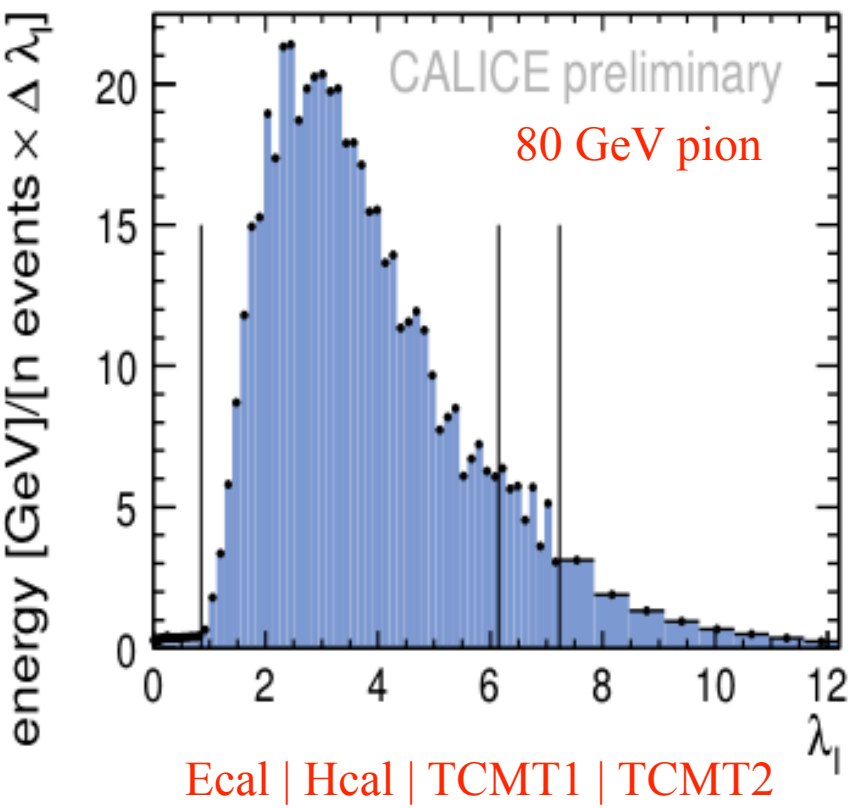






- Mean longitudinal extension
  - Agreement between MC and data within 5%
  - The shower from Monte Carlo is shorter
  - Validation of physics lists

Leakage Correction

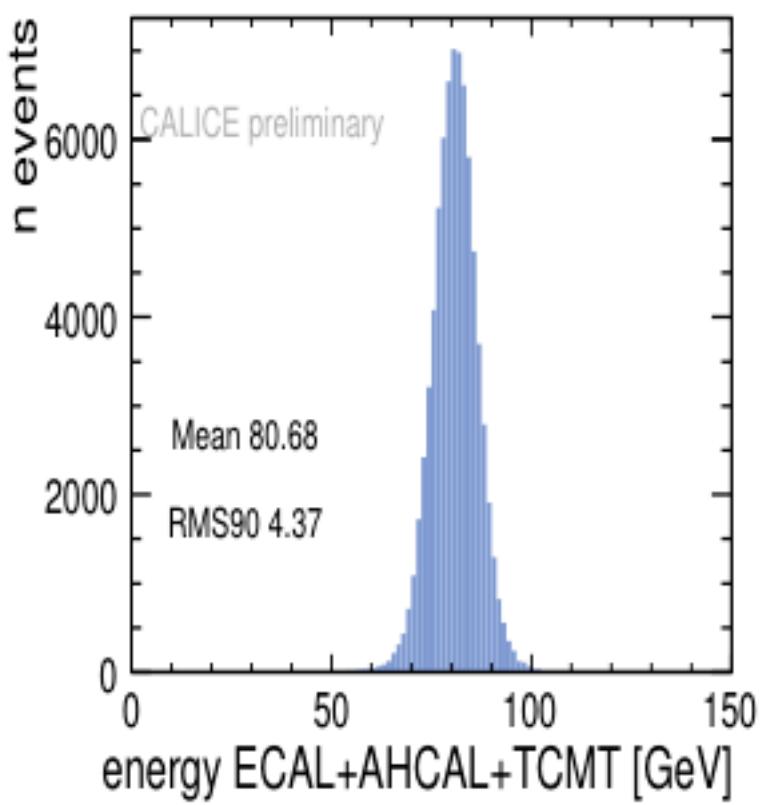


- Select pure pion events with shower starting point in the AHCAL:
- Behave as MIPs in the ECAL (track)
  - reduce systematics from combining ECAL and AHCAL
  - no lateral leakage from ECAL.
- Study a correction to the leakage from the AHCAL, relying only on the precise reconstruction of the shower shape by the AHCAL.

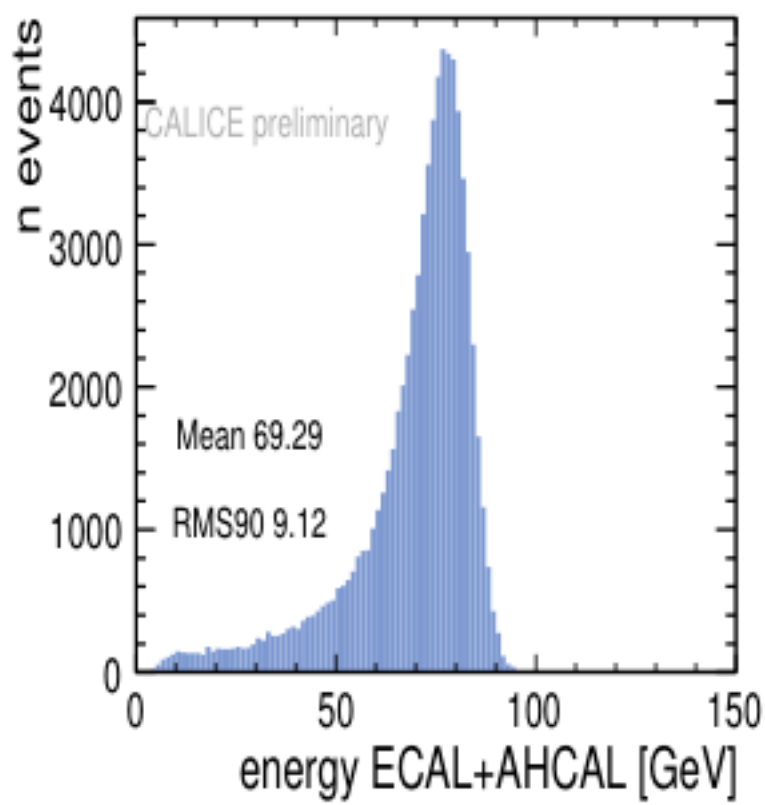
- The punch through pions, that start showering in the TCMT (<1%), are not considered.
- Apply correction without using the beam energy information.

Leakage Correction

- Total energy measured using the full calorimeter
- Energy measured by SiW-ECAL+AHCAL
  - Clear energy leakage can be seen
  - High granularity may provide a power to correct leakage



4.3 + 5.3 λ^{π}_{I} calorimeter



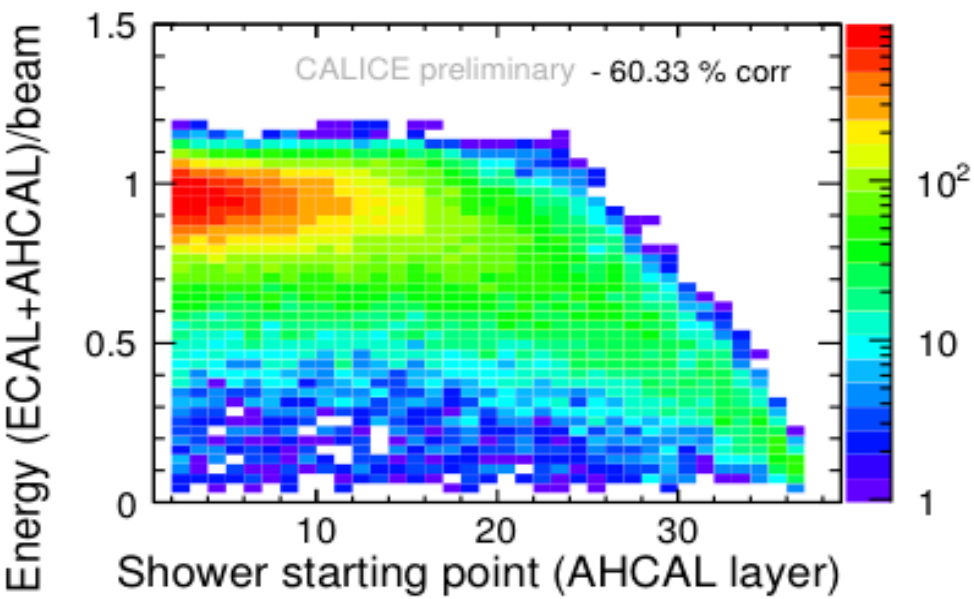
4.3 λ^{π}_{I} calorimeter

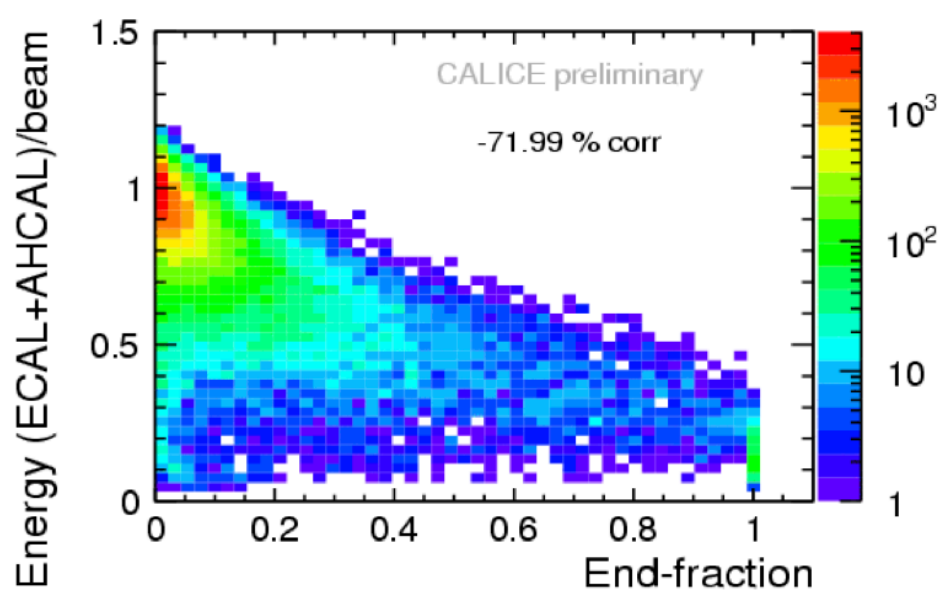
Leakage:shower start and end-fraction

End-fraction = fraction energy in last 4 AHCAL layers

- Two observation:
  - Early shower start./low end-fraction → shower (almost) concluded → low leakage.
  - Late shower start./high End-fraction → shower not concluded → high leakage.

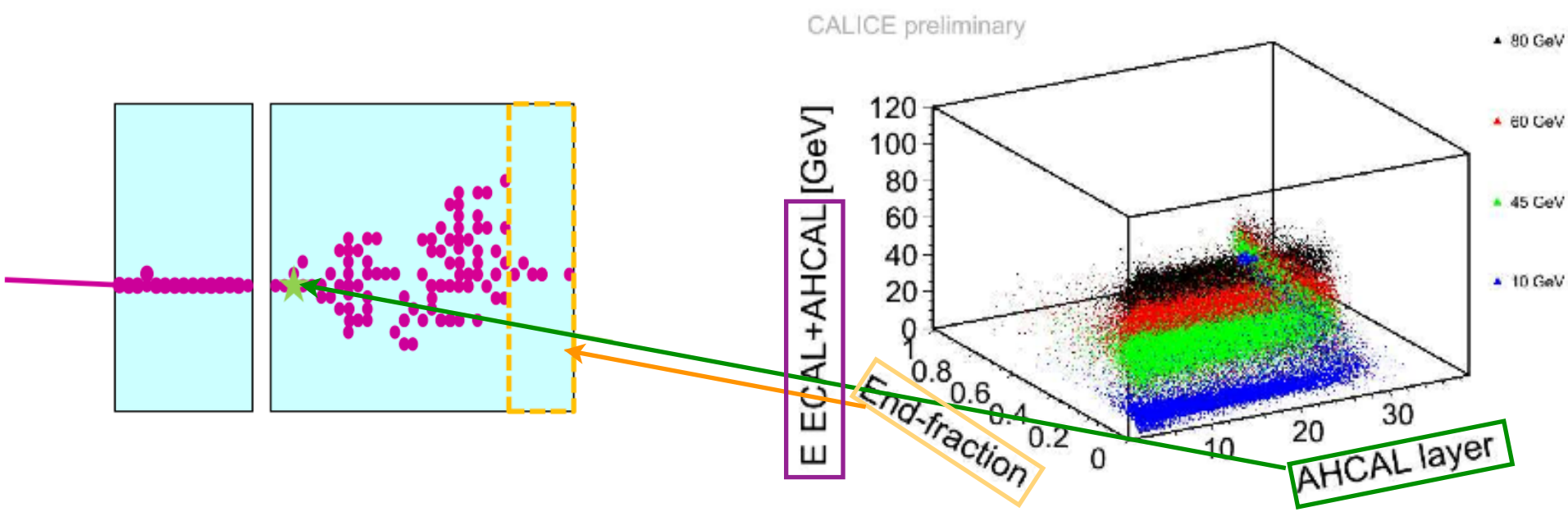
80 GeV pions





Creation of Lookup Tables

- Leakage correction factors from a multi-variable look-up tables
  - shower starting point, end-fraction and visible energy of sum SiW-ECAL and AHCAL
- Monte Carlo has been performed through 7.5 GeV to 100 GeV

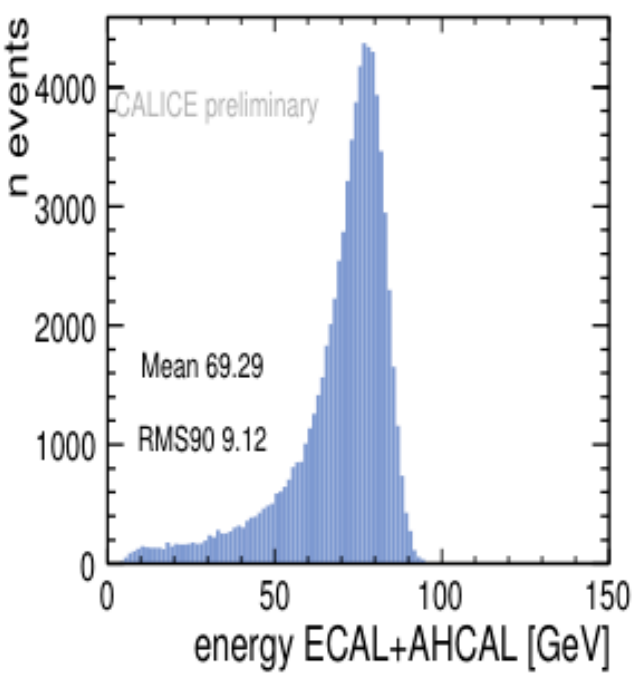


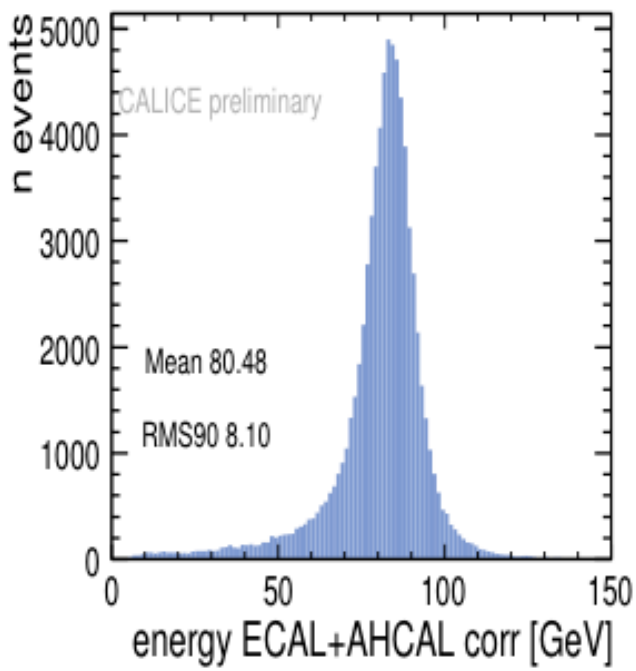
Application on 80 GeV pion

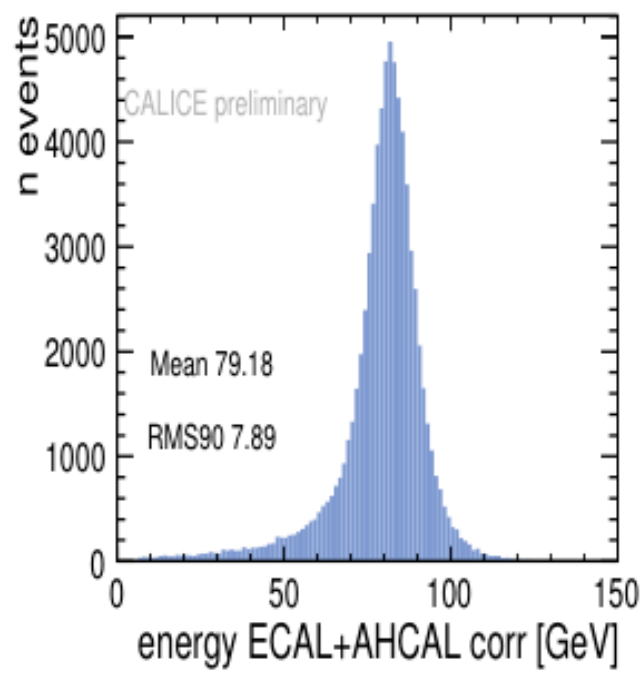
- Apply the correction on 80 GeV pion, from both data and MC.
- The correction reduces significantly the impact of the leakage

correction lookup tables from data

correction lookup tables from MC





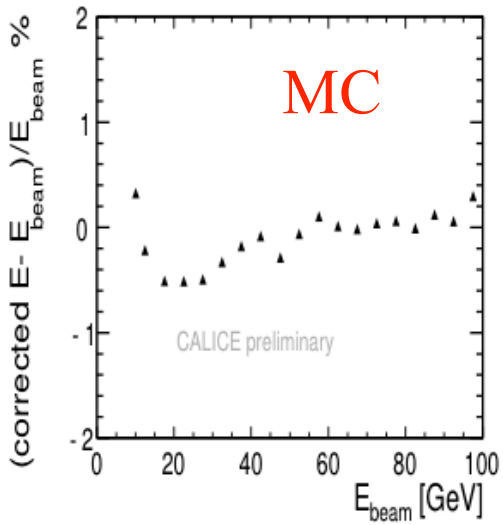


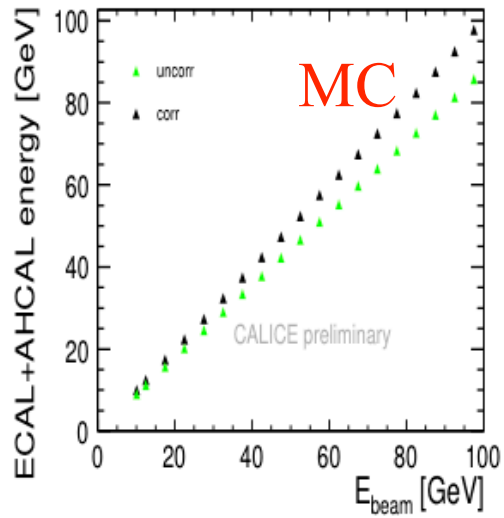
Before correction

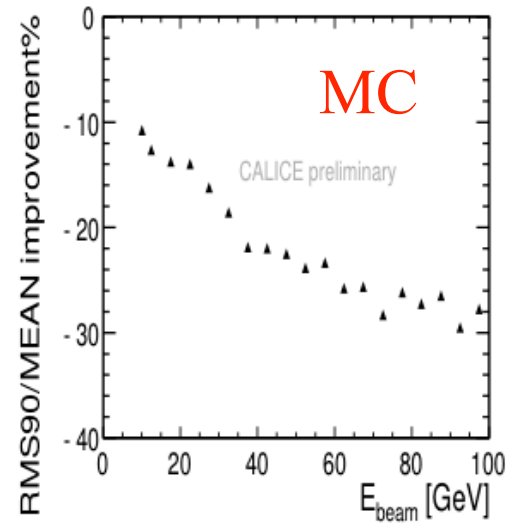
After correction

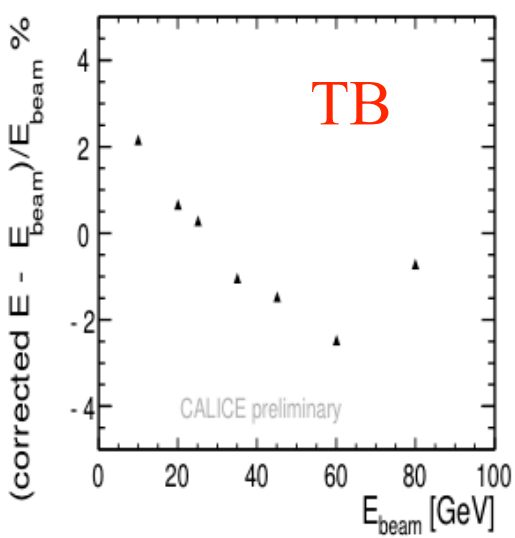
Leakage Correction

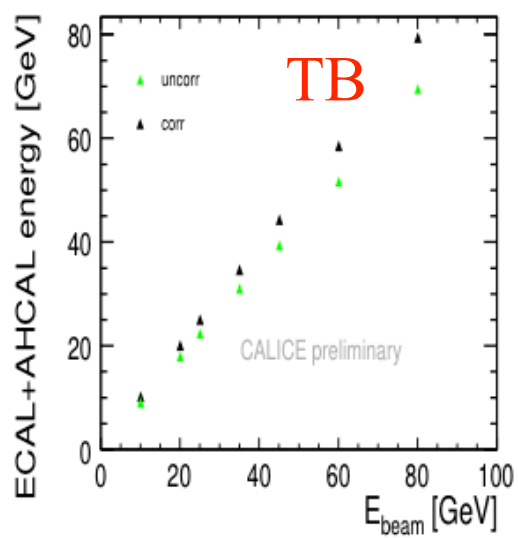
- Apply same lookup tables correction to MC and data

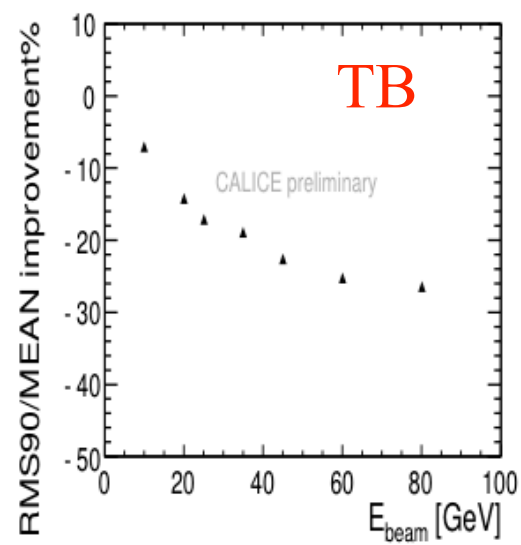












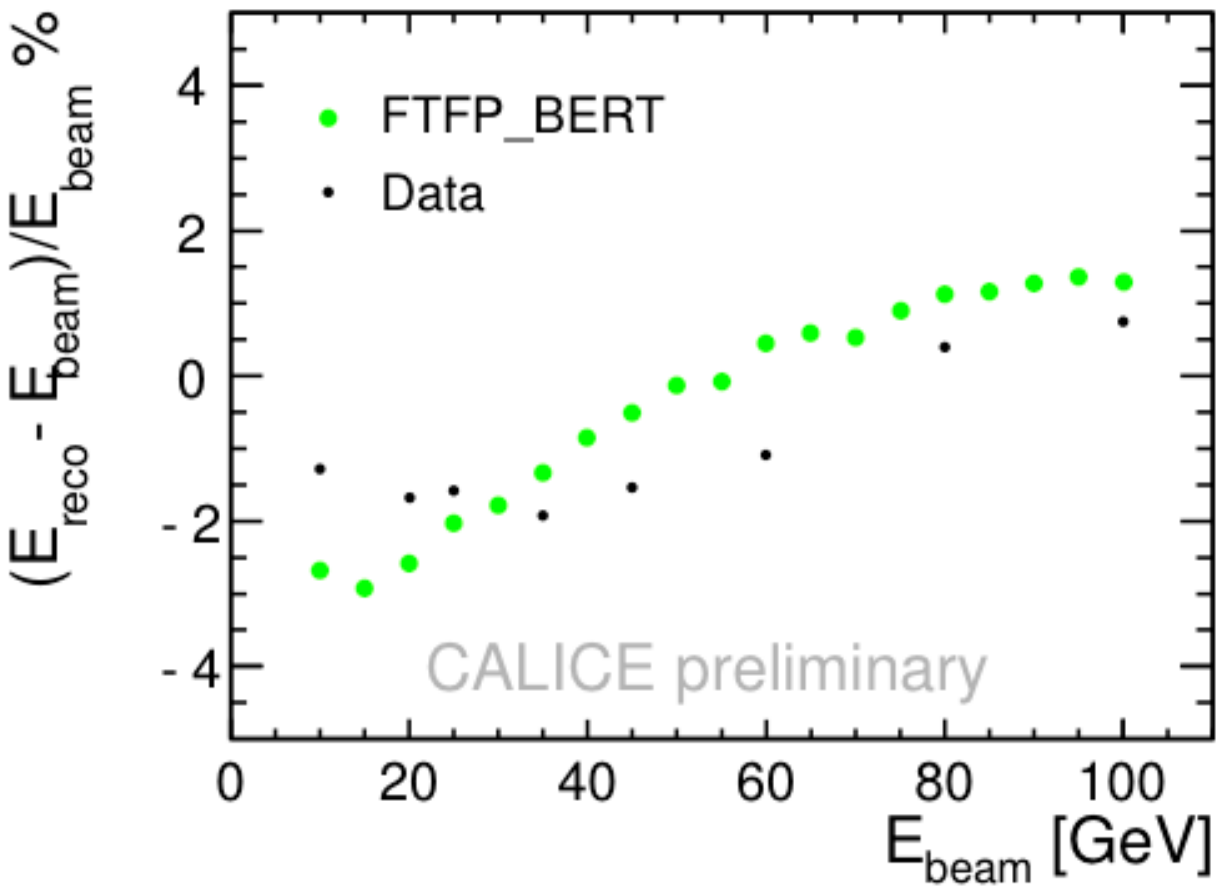
- Linearity of response recovered, improved the energy resolution.

Summary

- AHCAL Prototype - Testing the Concept
  - Operation of a 8000 channels system
  - Calibration established
  - Systematics established
- AHCAL Prototype - New Tool for Hadron Shower Physics
  - Developed method to identify the first hadron interaction
  - Developed method to estimate and correct longitudinal leakage
  - The correction method has been applied to simulation data and test beam data
  - The correction reduces significantly the impact of the leakage
- The tungsten HCAL data will come soon
  - W-AHCAL pions test beam start on November 2010
  - Allow new comparisons of simulation models with data

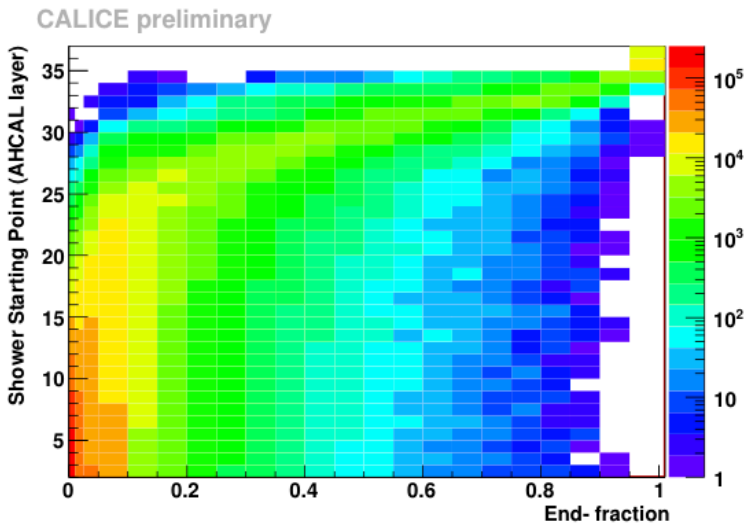
backup

Deviation



- Comparison of reconstructed energy in data and in MC
  - data larger below ~30GeV
  - data smaller when beam energy higher than 30GeV,
  - maximum different around ~60GeV after 30GeV

Detailed Shower Studies



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