Analogue, Digital and Semi-Digital Energy Reconstruction in the CALICE AHCAL.

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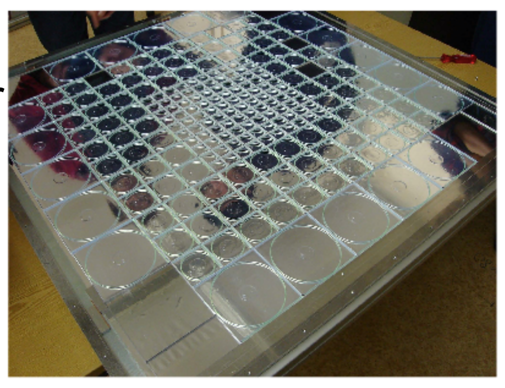
CALICE Hadron Calorimeters

Prototypes for an imaging calorimeter optimised for particle flow algorithm at the future International Linear Collider (ILC)

- SiPM scintillator tile hadron calorimeter with 12bit read-out (**AHCAL**), $(3cm)^2$ granularity
- Glass RPC hadron calorimeter with 1bit read-out (**DHCAL**), $(1cm)^2$ granularity
- Glass RPC hadron calorimeter with 2bit read-out (**SDHCAL**), $(1cm)^2$ granularity

One active AHCAL layer



$1m^3$ DHCAL physics prototype

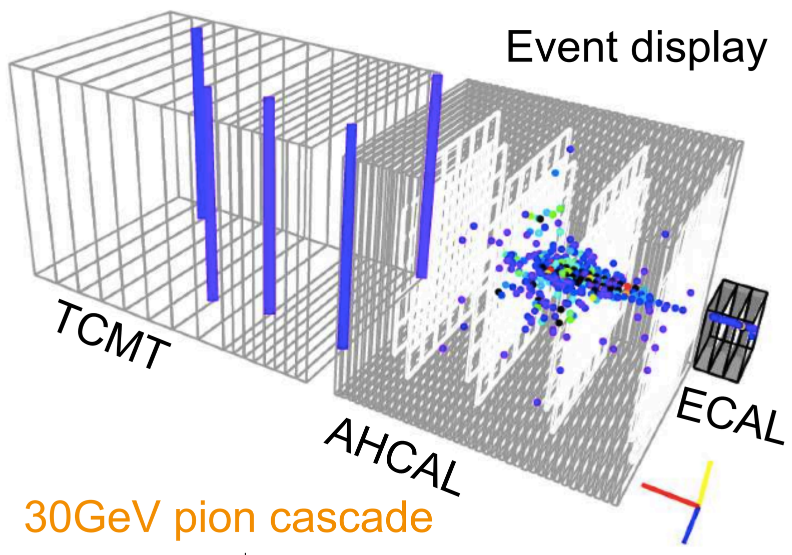
The AHCAL physics prototype

at CERN and FNAL 2006-2011

Test beam setup CERN 2007:

- Si-W ECAL (30 layers)
- Fe-AHCAL (38 layers, ~ 2cm steel absorber)
- Tail Catcher/Muon Tracker (16 layers)

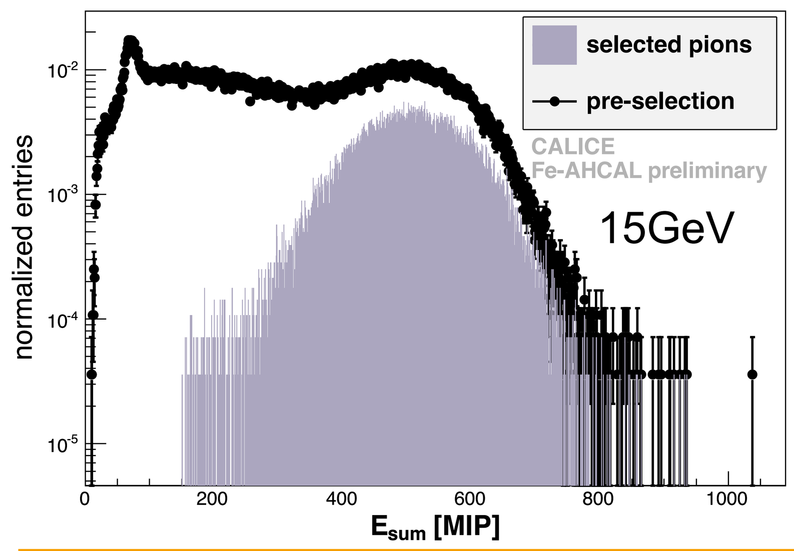
Event display



30GeV pion cascade

Measurement observables:

visible energy/ energy sum E_{sum} and the number of hits above 0.5MIP N_{hits} in the AHCAL



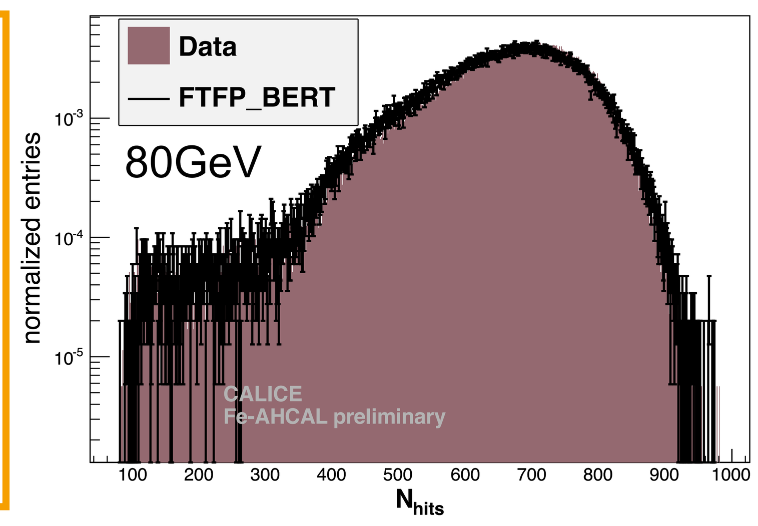
π^- event selection 10-80GeV

- Track in ECAL
- Shower start in first 5 AHCAL layers
- >150MIP in AHCAL

Simulation with GEANT4 9.6 patch 1 and Mokka v08_02 software packages

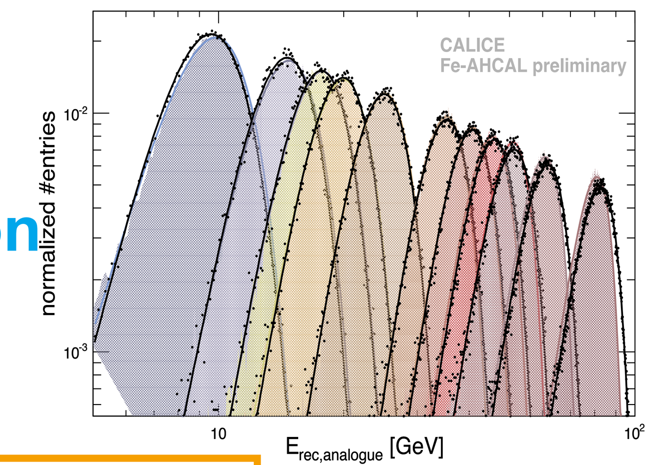
- Conversion coefficient 846keV/MIP
- Optical crosstalk 15%
- Physics list: FTFP_BERT

- ~20% of events per run selected
- At high energies E_{sum} distributions show energy leakage
- N_{hit} distributions show left hand side tail, due to particles traversing same cell, limited granularity
- MC data comparison: FTFP_BERT slightly overestimates the AHCAL response

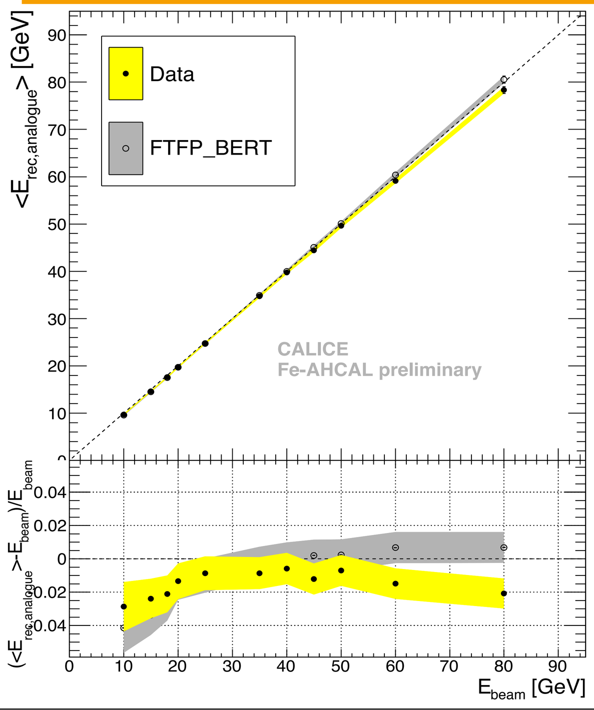


$\langle E_{sum}\rangle$ and $\langle N_{hits}\rangle$ taken from Mean and RMS of fitted Novosibirsk

Analogue Energy Reconstruction with E_{sum}



$$E_{rec,analog} = E_{ECAL,track} + \frac{e}{\pi} \cdot \omega \cdot E_{Sum}$$

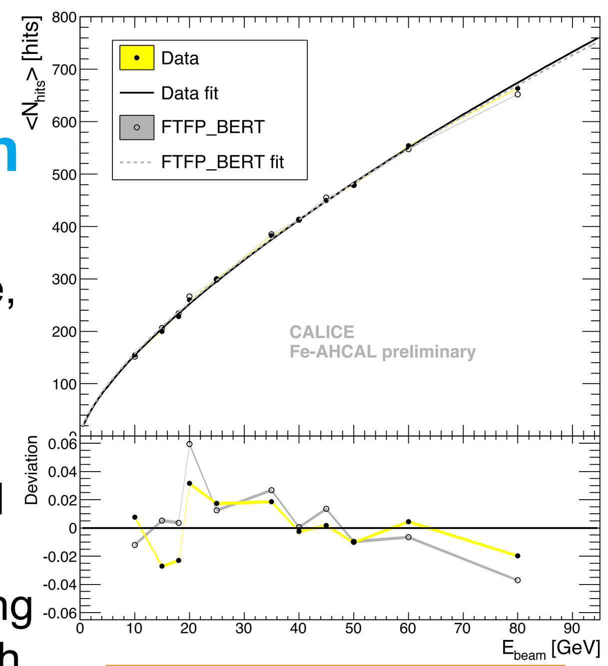


- e/π=1.19, higher response to electron than to pions
- ω=0.02364, electromagnetic calibration factor
- $E_{ECAL,track}$=0.381GeV
- Linear response, due to linearity of E_{sum}

Digital Energy Reconstruction with N_{hits}

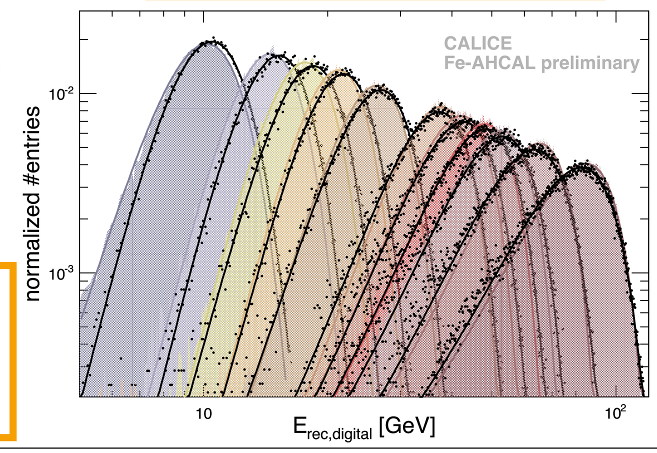
- Non-linear response, due to particles traversing same cell (not optimized granularity for digital read-out)
- Linearisation by fitting the mean of N_{hits} with a power law

$$\langle N_{hits}\rangle = a \cdot (E_{beam})^b$$



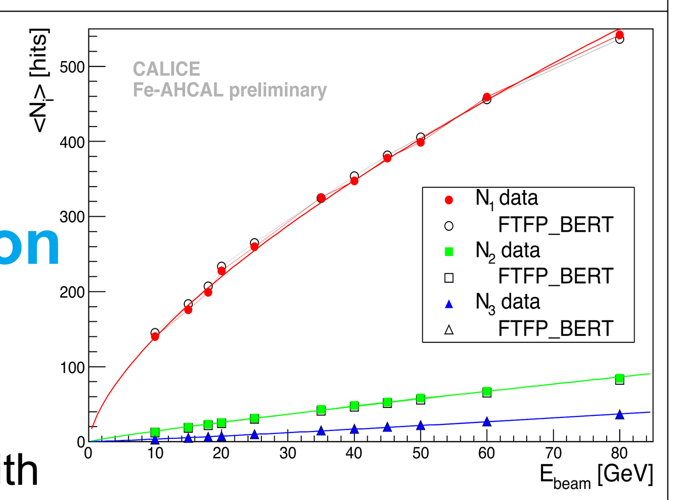
$$E_{rec,digital} = \sqrt[b]{\frac{N_{hits}}{a}}$$

- Reconstruction on event-by-event basis with fit parameters a & b



Systematic errors:
E_{sum}: beam energy, MIP→GeV conversion
N_{hits} : beam energy

Semi-digital Energy Reconstruction with $N_{hits} = N_1+N_2+N_3$

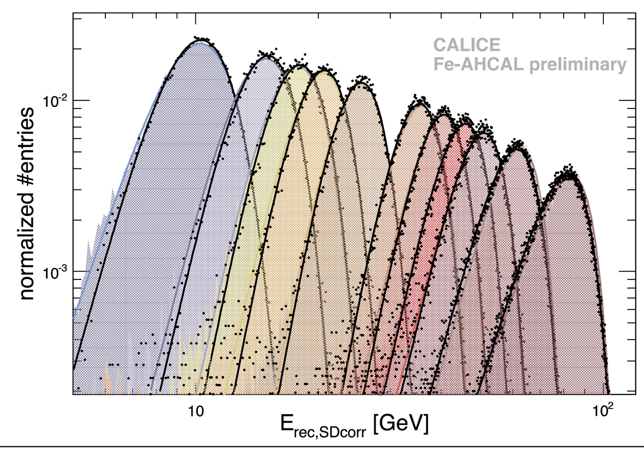


N_i = number of hits with

- N_1 : 0.5MIP<E_{hit}< 5MIP
- N_2 : 5MIP<E_{hit}<15MIP
- N_3 : 15MIP<E_{hit}
- α,β and γ: quadratic polynomials of N_{hits}
- Parameters calculated by minimising

$$E_{rec,SD} = \alpha N_1 + \beta N_2 + \gamma N_3$$

$$\chi^2 = \sum_{i=1}^{N} \frac{\left(E^i_{beam} - E^i_{rec,semi-digital}\right)^2}{E^i_{beam}}$$



- With an additional linearisation step, a non-linearity smaller than 3% is achieved
- Threshold values not optimised for AHCAL

Comparison between different reconstruction procedures

Investigating the advantages and disadvantages of the method in terms of relative energy resolution

- Resolutions shown after linearisation

Analogue:

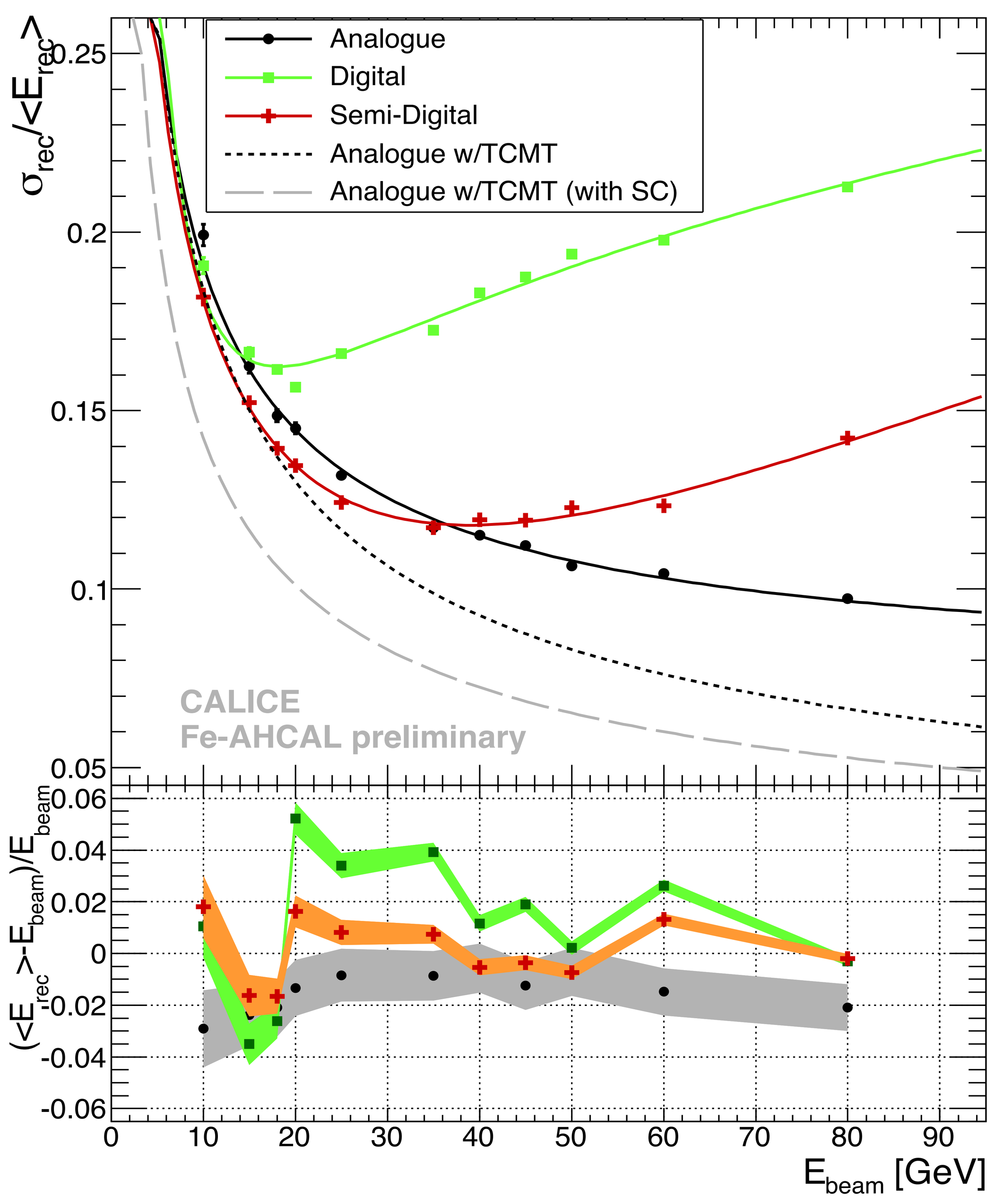
- Finest resolution at high energy, with software compensation superior at all energies
- Without energy deposits in TCMT, absolute degradation in resolution of max. 3% at 80GeV

Digital:

- Achieves 16% at 20GeV
- Resolution degrades at larger energies because of several particles traversing same cell

Semi-Digital:

- Achieves 12% at 30GeV
- At low energies better than simple analog reconstruction



- Software compensation algorithms weight high density areas of the shower differently from low density areas and improve the resolution
- The semi-digital energy reconstruction weights hits depending on their energy content and improves in that way the resolution

Future plans:

- MC describes data, can be used to study analogue, digital and semi-digital performance for $(1cm)^2$ scintillator tile sizes

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