AHCAL answers IDAG

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On behalf of AHCAL analysis team

Strategy to answer IDAG

The IDAG question:

``Give an outline of the plan for calibrating the energy response of your calorimeter, both from test beams or monitoring signals and in situ running. What level of precision is required? How is it obtained? How do you monitor and maintain it? If operation at the Z pole is part of your strategy, how much data is required?''

The AHCAL approach to answer:

1) Simulation of ILD detector ➔ how statistical and systematic mis-calibration affect resolution for single hadrons and jet energy resolution

2) test beam data ➔ treat FNAL campaign as ``pre-installation test beam'' and CERN as ``collider physics run''. Transport calibration sets to CERN conditions and repeat main analyses.

from both studies ➔ we conclude whether the required precision can be obtained in ILD

1) Simulation

Simulate 4 possible mis-calibration scenarios:

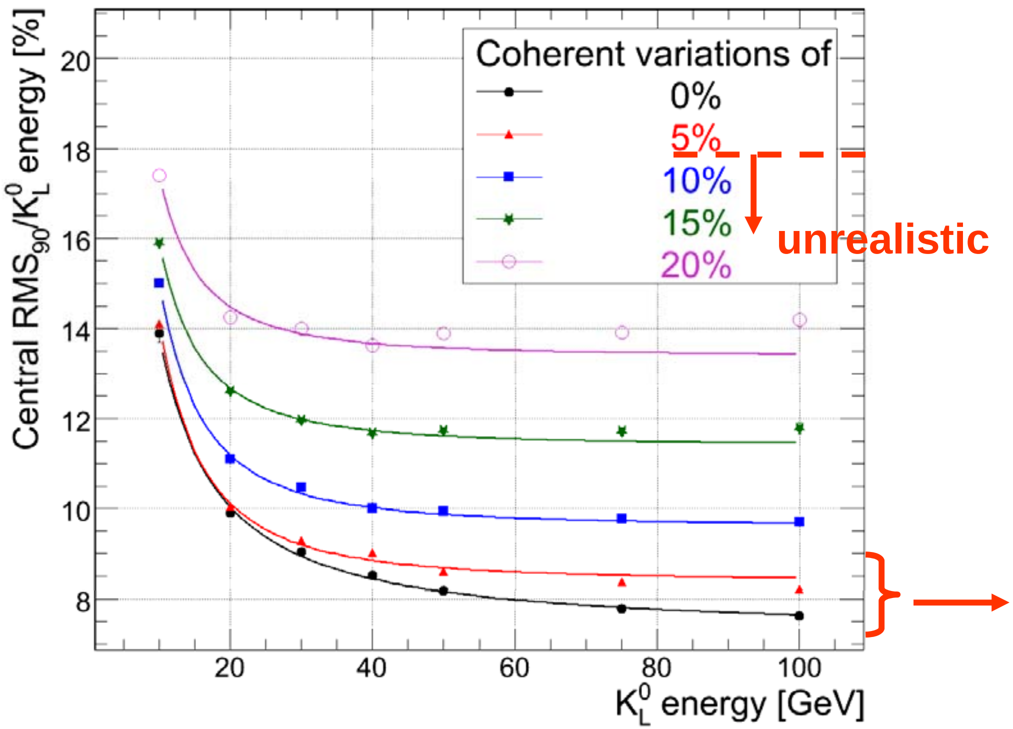
	Effect	Cause
i)	spread from event to event same for all cells	= temperature variations
ii)	spread from layer to layer	= voltage change
iii)	spread from cell to cell	= statistical variations
vi)	constant factor shift for all cells	= for reference our study

Analysis using Pandora PFA:

- Reconstruction of K_L^0
- Reconstruct di-jet invariant mass at 91 GeV and 500 GeV energy

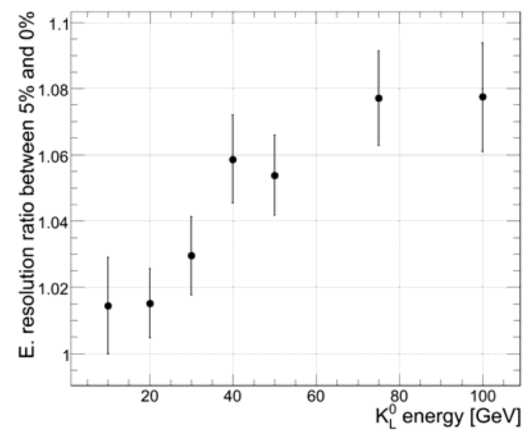
Single hadron resolution

Shoot K_L^0 in ILD detector and reconstruct E sum in ECAL+HCAL for different
i) spread from event to event, same for all cells



Worse realistic case:

2 deg T variation
~4%/K SiPM response
<5% RMS spread event by event
➔ ~8% worse single particle resolution at 100 GeV



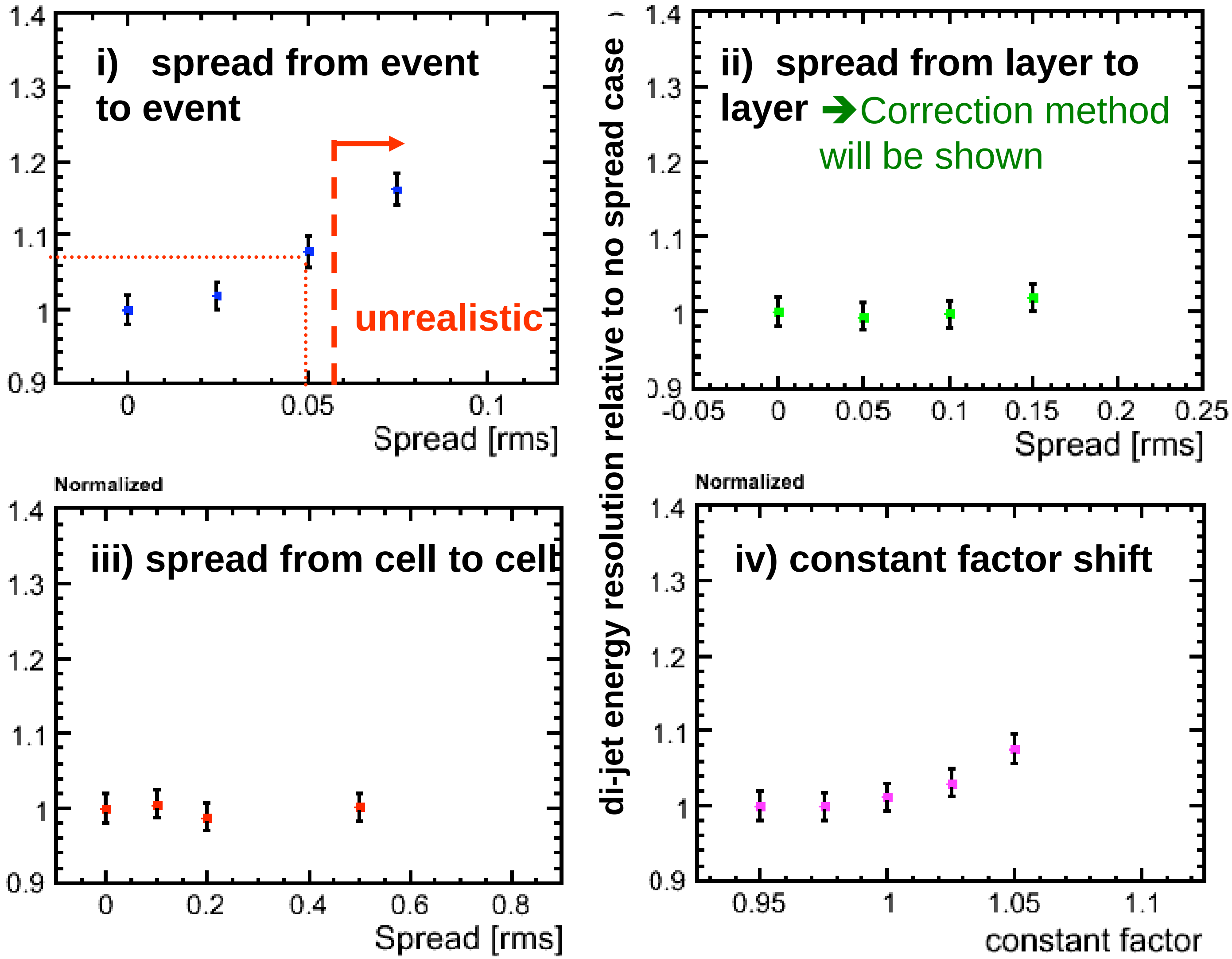
for K_L^0 fully contained in the HCAL the additional spread adds in quadrature to the constant term (14% with 5% spread)

Jet energy resolution

absolute di-jet energy res. at 500 GeV ~51%/ $E^{-1/2}$

i) worst case:

2 deg T variation
~4%/K SiPM response
➔<5% RMS spread event by event
➔10% worse di-jet energy resolution



- no significant effect from test ii) and iii)

- constant factor shift iv) can be recalibrated in-situ with LED system or MIP stab in hadronic showers (next)

Same results available for 91 GeV di-jet energy, same behavior, smaller effect

Test beam data

- Use FNAL MIP calibration to inter-calibrate calorimeter cells
- no MIP calibration available during “collider run” (CERN)
- 2 methods to transport MIP calibration from FNAL to CERN conditions:

1) $$A(T_1,U_1) = A(T_2,U_2) + \frac{dA}{dT}(T_1 - T_2) + \frac{dA}{dU}(U_1 - U_2)$$

T and U calibration

2) $$A(T_1,U_1) = A(T_2,U_2) + \frac{dA}{dG}(G(T_1,U_1) - G(T_2,U_2))$$

Gain calibration

Compare to CERN MIP calibration only used as reference

Caveat:
Between the running periods at CERN and FNAL the calorimeter was un-cabled and dis-assembled, shipped by road, rail and sea from Switzerland to the US. About 10% of the front end cards were replaced. And ~50% of the calorimeter cells are operated at a different voltage. Method 1) contains an explicit voltage correction, while method 2) corrects for both voltage and temperature changes using the change of SiPM gain

Transport of the MIP calibrations

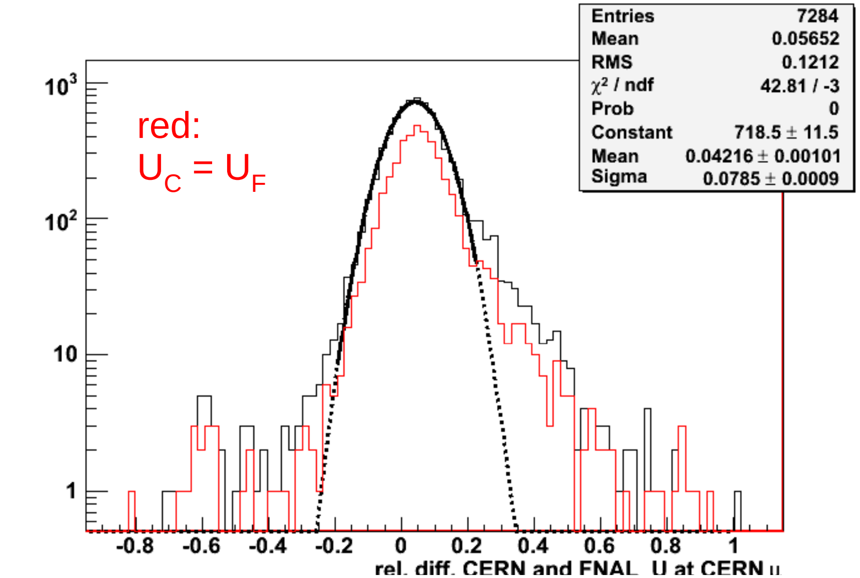
Comparison between T-U calibrated FNAL and reference CERN sample

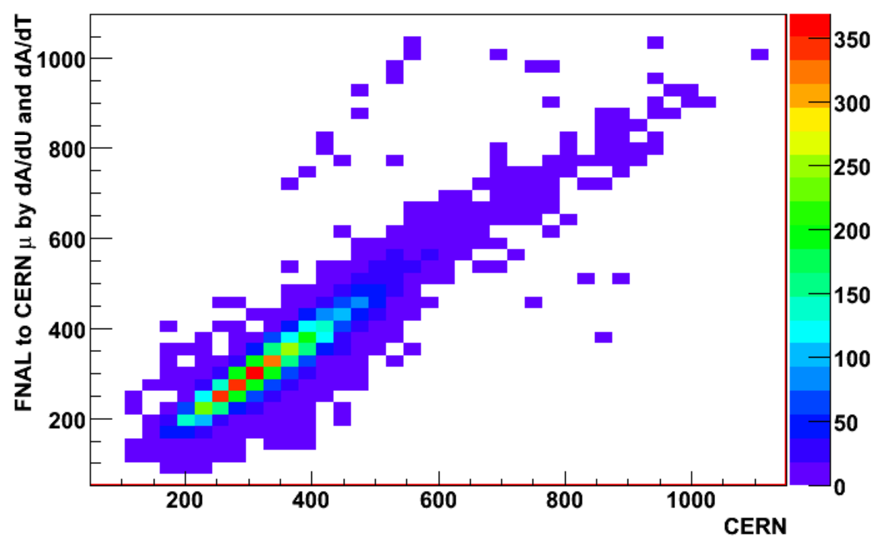
Remaining 4% offset due to different muon beam energy 30GeV @ FNAL / 80GeV @ CERN

8% spread comes from the MIP calibration uncertainty (~3% on both samples) + uncertainty on transport method ~6%

~7280 ch / 7600 ch: 260 dead/noisy + 60 missing calib

Same for G calibrated FNAL sample



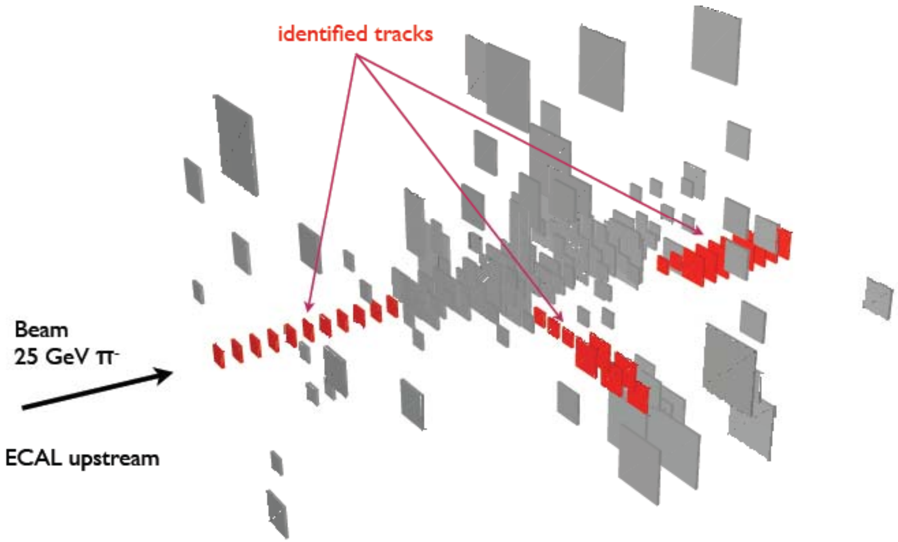


Use MIP stab to recalibrate layers

- Collect all MIP stab in pion runs to fit a layer by layer correction to the MIP calibration after transportation

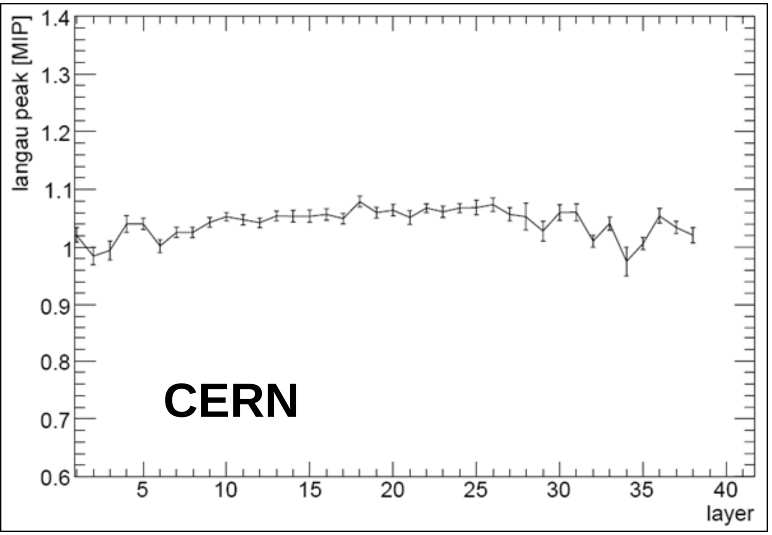
➔ Layer by layer needed due to low statistics with MIP stubs

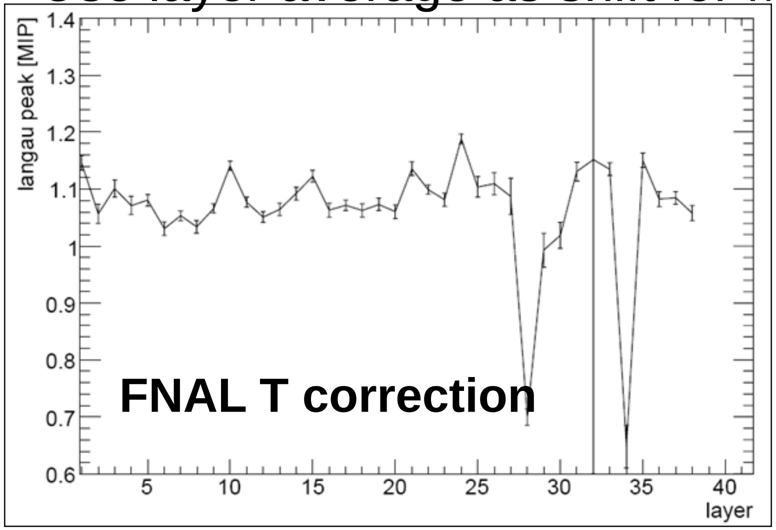
➔ This method is applicable to ILD



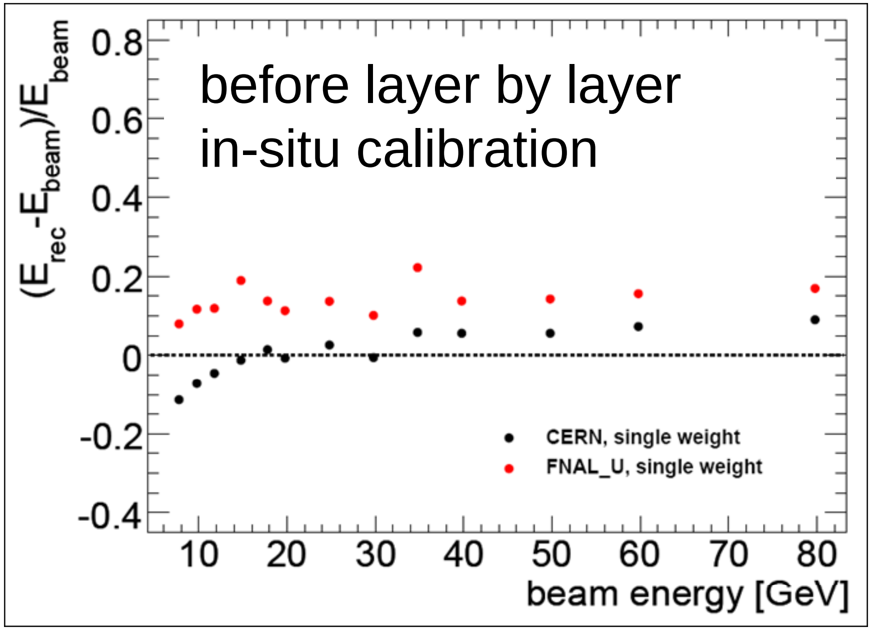
CERN reference sample defines the accuracy of the method

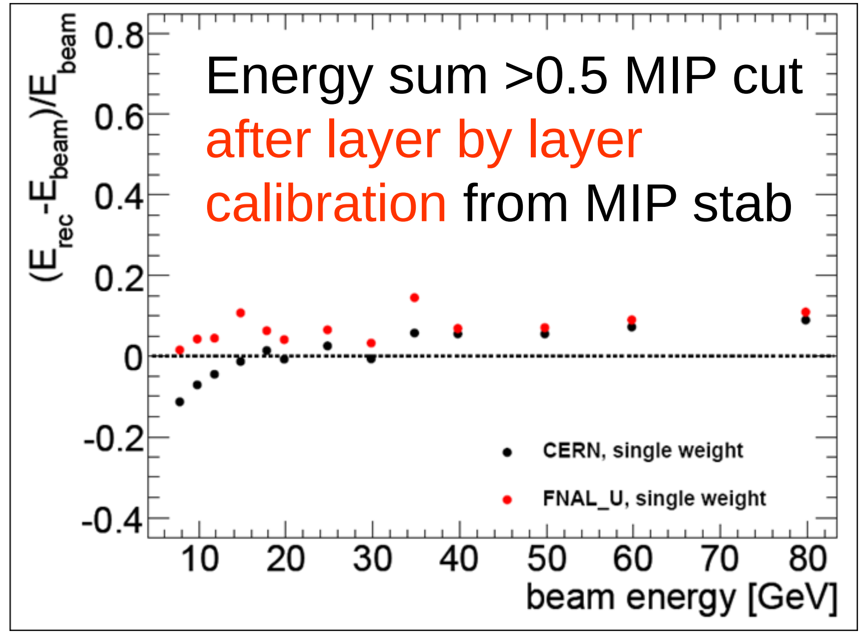
~5-10% offset observed in FNAL T-transported calibrations
Use layer average as shift for MIP calib.





Impact on hadron analysis





~10% shift E dependent (20% at low E)

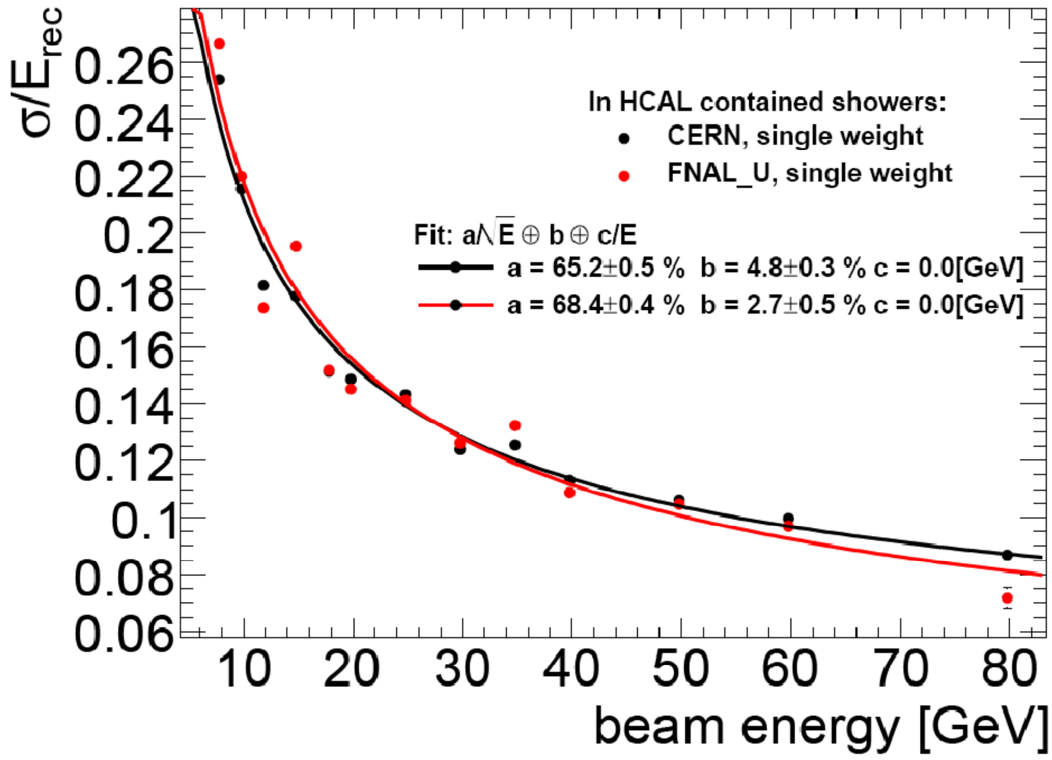
➔ Corrected by the in-situ layer-by-layer calibration using MIP stabs from pion showers

➔ Remaining effects at low energy are being investigated (MIP stab correction on CERN data + cleaning of ~80 bad channels)

Effect on E resolution: increase of stochastic term 65%→68%

Impact on hadron analysis

Energy sum >0.5 MIP cut after layer by layer calibration from MIP stab



Effect on E resolution: increase of stochastic term 65%→68%

Use MIP stab correction @ ILD

IDEA: find MIP stabs in jets and use them to define a MIP correction layer by layer

First look into simulation:
~5 pb^{-1} needed at Z^0 pole for all layers,
~30 fb^{-1} at 500 GeV

Test on one HCAL layer in ILD (MOKKA)

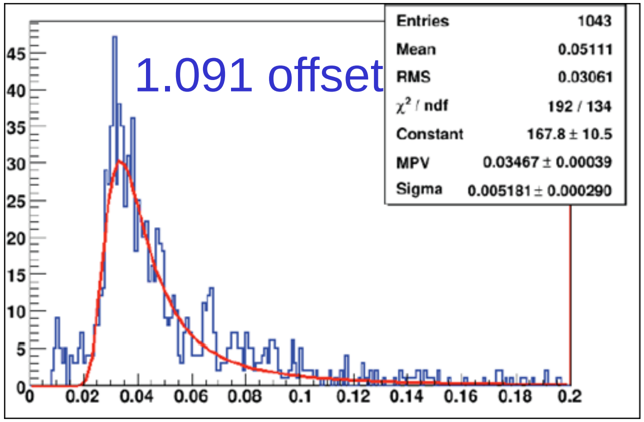
Introduce calibration offset by 1.091

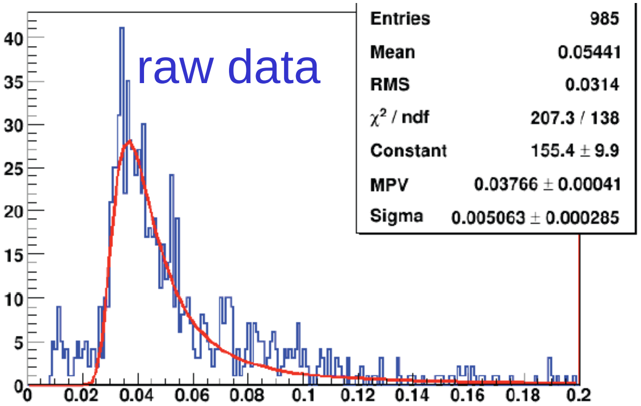
- MPV_Layer = 0.03766
- MPV_raw = 0.03467
- MPV_layer / MPV_raw = 1.086

➔Deviation: (1.091 - 1.086) / 1.091 = 0.458%

The calibration offset has been measured with an accuracy of 0.5%

collected MIP stabs in one layer





Conclusions

From simulation of ILD detector we learn:

- Worse case scenario = uncorrected temperature variation during data taking ➔ simulated as event by event shift constant for all cells with a max RMS of 5%
- Effect on single particle energy resolution: max 10% worsening
- Effect on di-jet energy resolution: max 10% (5%) worse @ 500 (91) GeV

From test beam data we learn:

- Inter-calibration for calorimeter cells can be obtained during test beam runs and transported to the operation condition of the “collider run”
- At present ~6% uncertainty with both tested transport methods
- Calibration offsets layer-by-layer are measured using MIP stab in hadron showers (also applicable at ILD)
- Impact on hadron analysis : ~4.5% worse energy resolution

➔ Possible improvements:

refine extraction of calibration constants

backup

FNAL_G vs CERN

3% offset ➔ 4% difference in muon energy

8% spread ➔ 3% uncertainty of MIP calibration for both sets +
~6% uncertainty from the method