SDHCAL Energy Resolution

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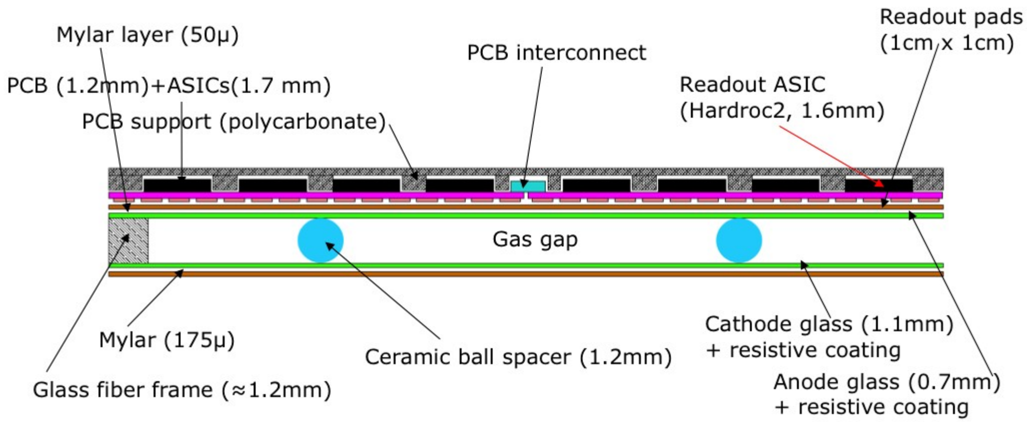
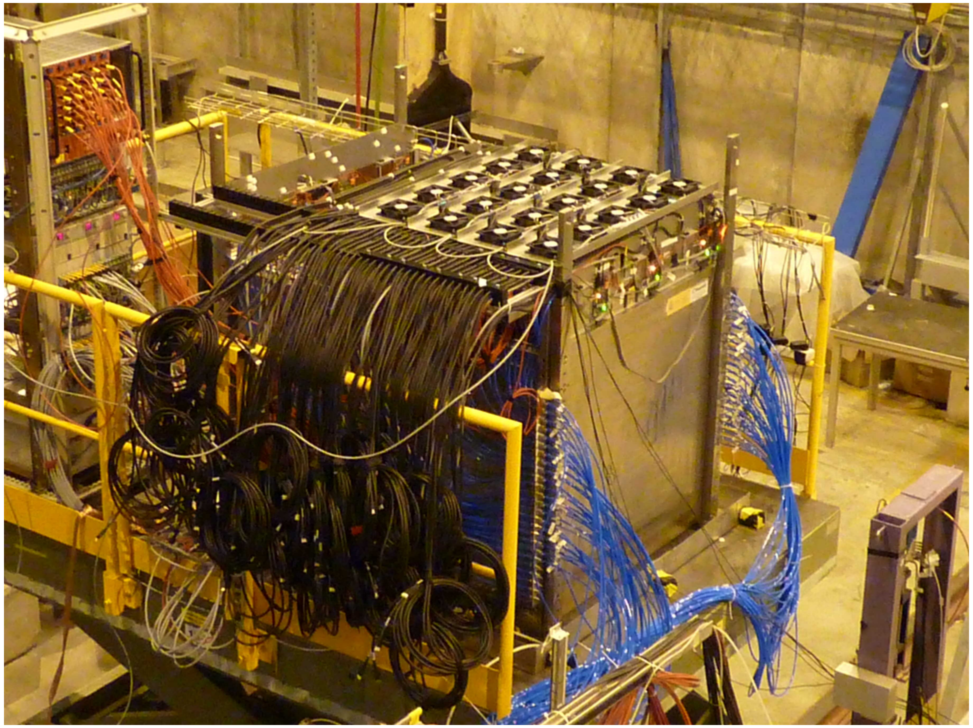
Motivation

- SDHCAL prototype – highly granular gaseous hadronic calorimeter
  - Good resolution of hadronic energy measurement
  - Excellent tracking for Particle Flow Algorithms (PFA)
  - Compatible with future ILC experiment requirements
    - High efficiency
    - Compactness
    - Low power consumption

Prototype description





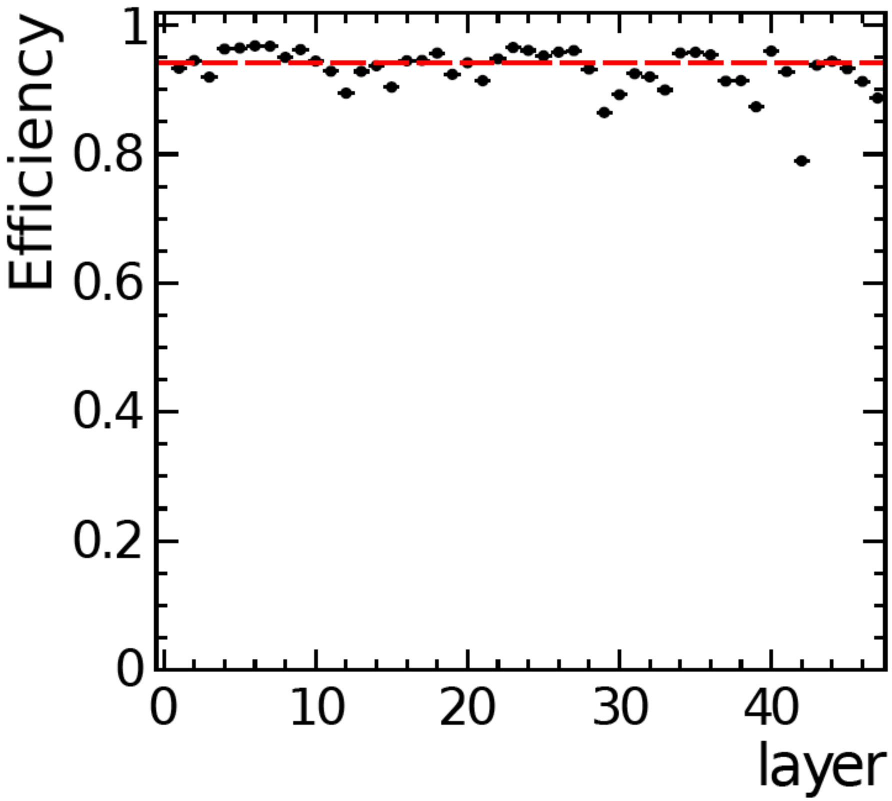
- 48 active GRPC layers, 1x1x1.3 m^3
- Self-supporting stainless steel mechanical structure
- Operates at 6.9 kV
- 440000 electronic channels
- Power-pulsing mode
- 3 thresholds semi-digital readout: better treatment of saturation at high energy, better understanding of hadronic shower

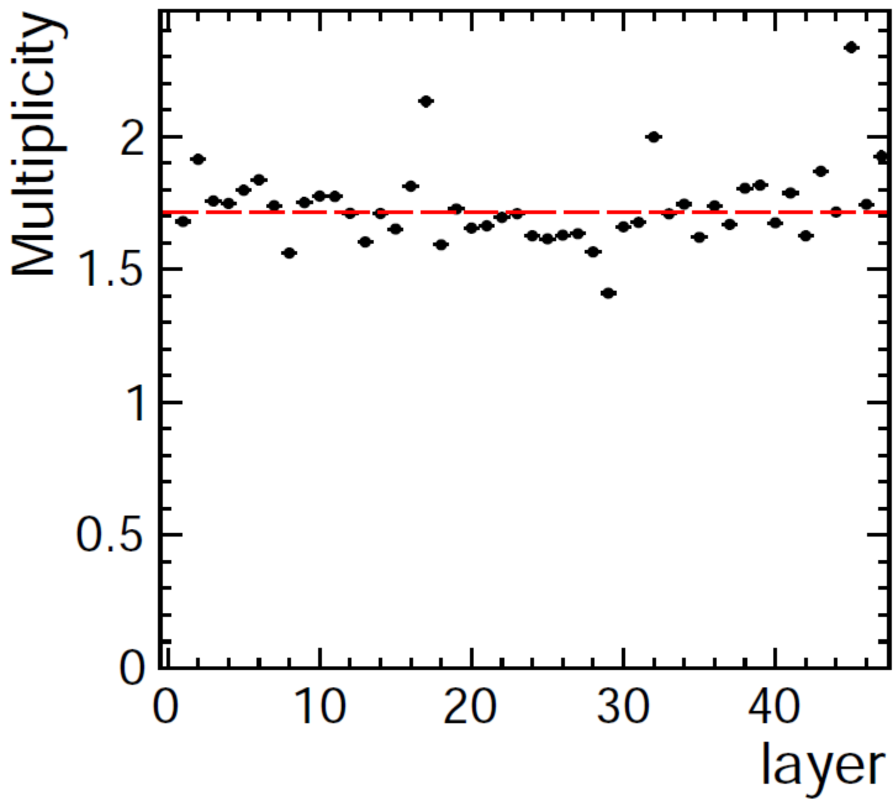
CERN SPS data

- May 2012 on H2 line for 2 weeks
- August-September 2012 on H6 line for 2 weeks
- November 2012 on H2 line (1 week)
- December 2014 on H6 (1 week)
- 48 layers in avalanche mode at 6.9 kV
- Gas: 93% TetraFluoroEthane, 5% CO_2, 2% SF_6
- Large beam size, low particle rate <1000 particle/spill -> good eff.
- Triggerless acquisition: stopped if 1 ASIC is full, readout all data recorded. ASIC internal clock: 200 ns.
- Power-pulsing: idle electronics between 2 beam spills. 9 vs 45 sec -> 1/5 of ASICs nominal consumption

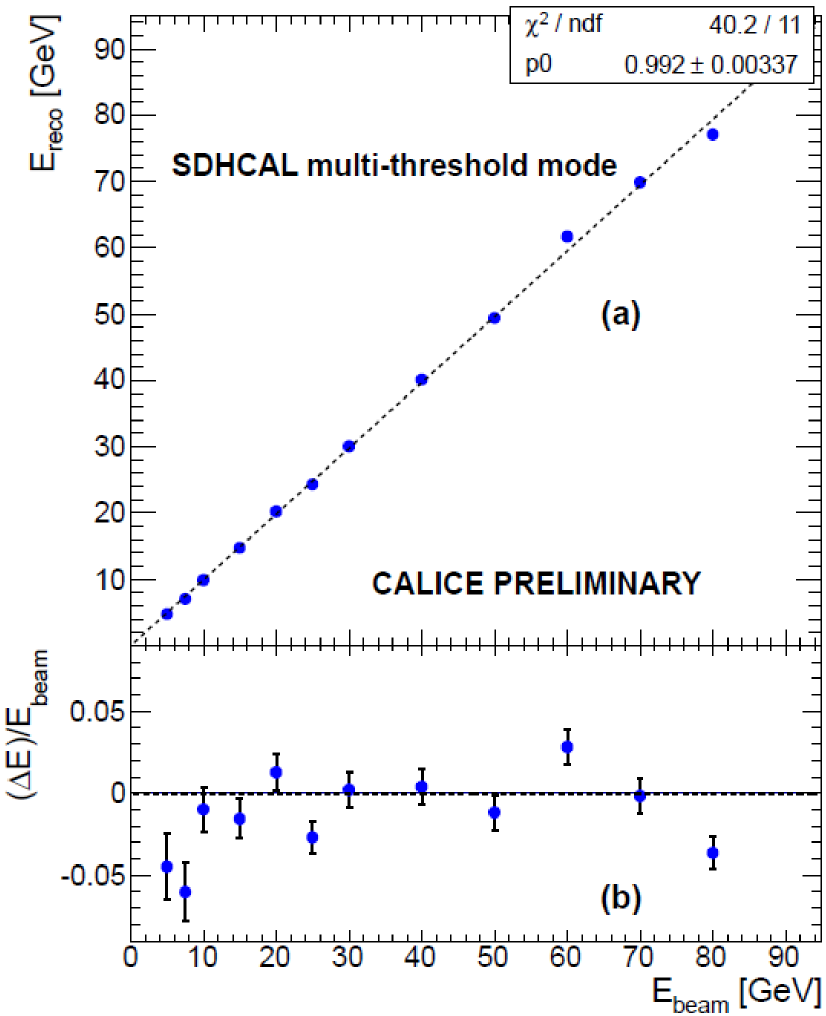
Data quality control

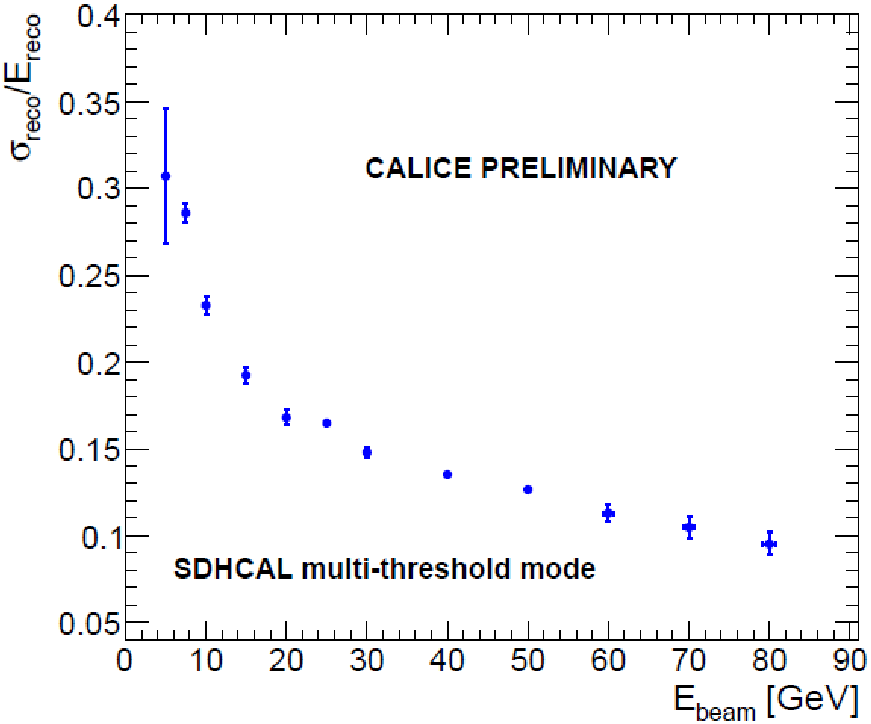
- Efficiency: tracks fraction for which ≥1 hit found at <3 cm around expected position at studied layer, $\bar{\varepsilon}$~95%
- Multiplicity: hits number in cluster around track impact, $\bar{\mu}$~1.7





Former results

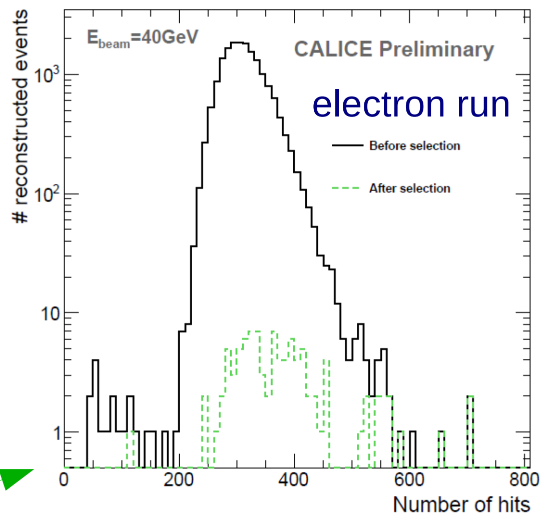




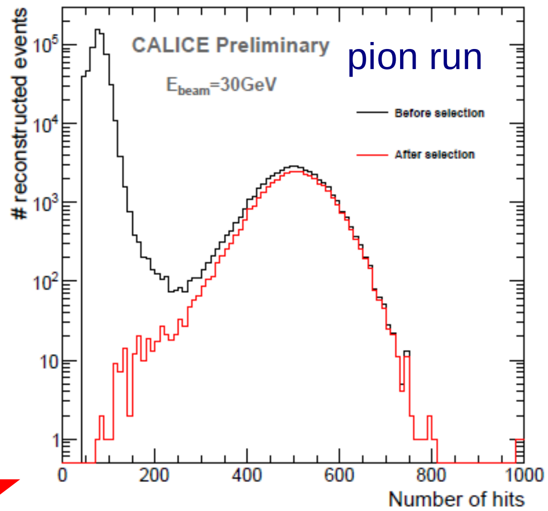
- CALICE Note CAN-037, Nov'12
- Reconstructed energy resolution < 10% at high energy

Event selection

- No Cherenkov counter (2012):
  - Needs more effective electron rejection: shower start > 4 or N_{layer} > 30
- Muon rejection:
  - $N_{hit}/N_{layer} > 2.2$
- Neutral:
  - N_{hit} in first 5 layers >4



Reject electrons

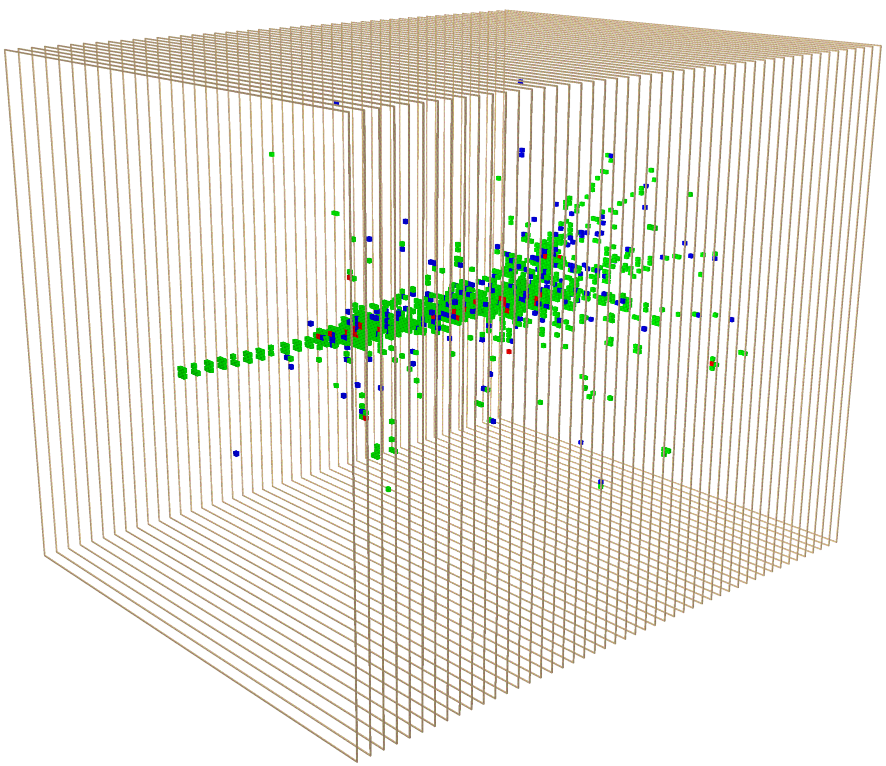


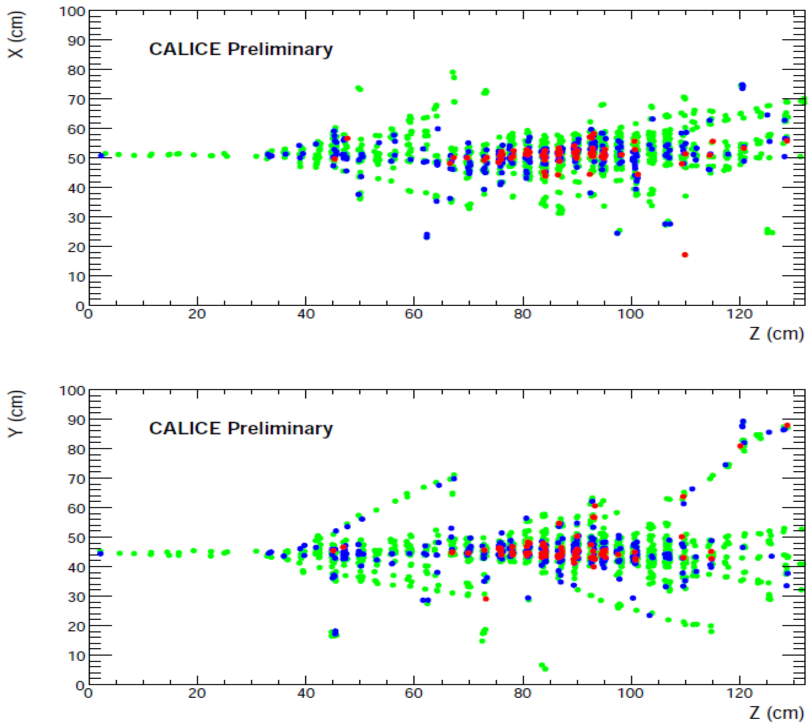
Full selection applied

Energy reconstruction

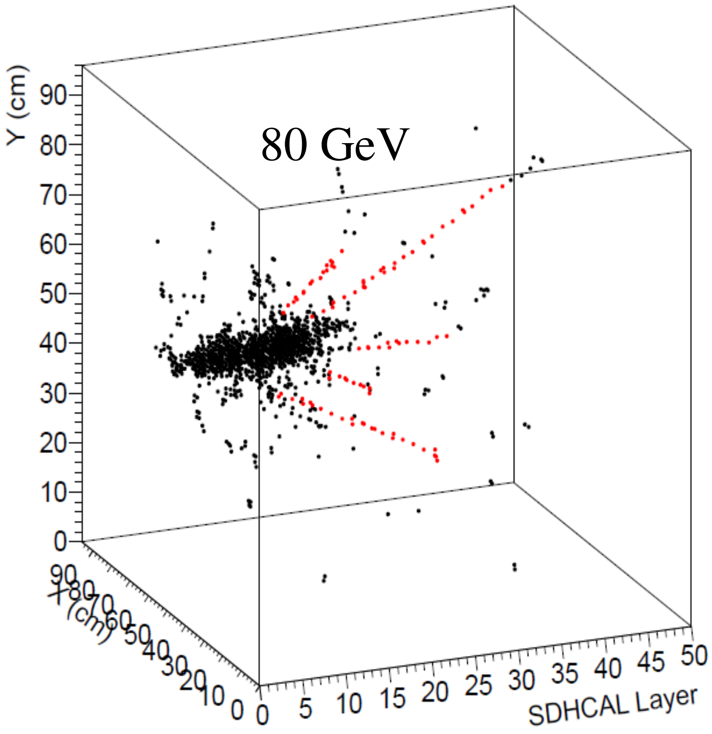
$$E_{reco} = \alpha(N_{tot})N_1 + \beta(N_{tot})N_2 + \gamma(N_{tot})N_3 + cN_{HT}$$

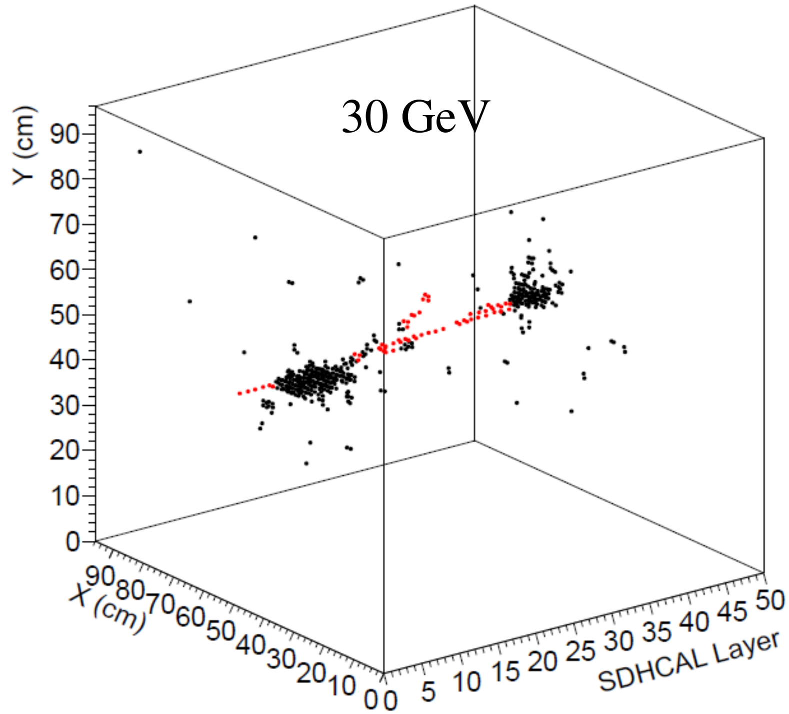
- α, β, γ – quadratic functions of N_{tot}, reconstruction with 10 parameters
- N_i – hits for threshold i
- N_{HT} – hits selected by Hough Transform method [CALICE analysis note CAN-047]
- α, β, γ from χ^2 minimization $\chi^2 = \sum_{i=1}^{N_{ev}} \frac{(E^i_{beam} - E^i_{reco})^2}{E^i_{beam}}$





HT tracks

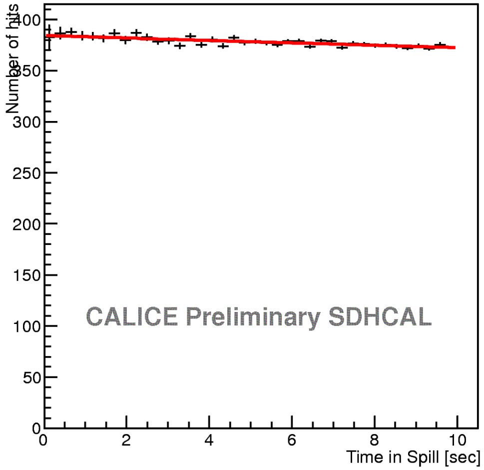


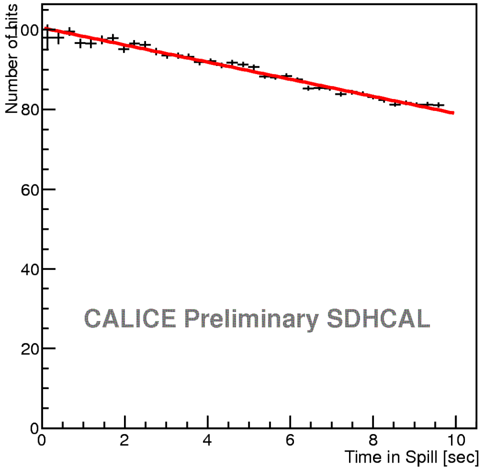


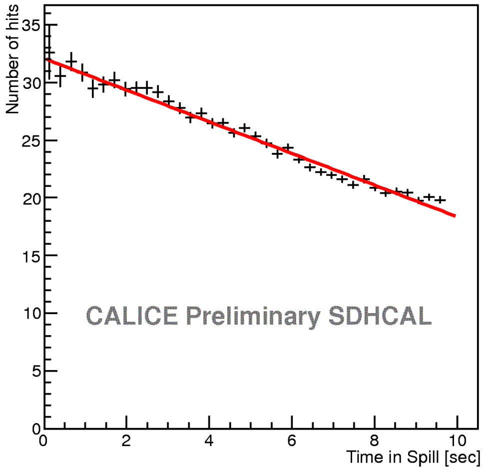
- Hough Transform tracks help to better understand the hadronic shower structure and improve on the energy resolution
- Hits belonging to HT tracks/mips should not be treated as those of the hadronic shower core

Hits in spill time

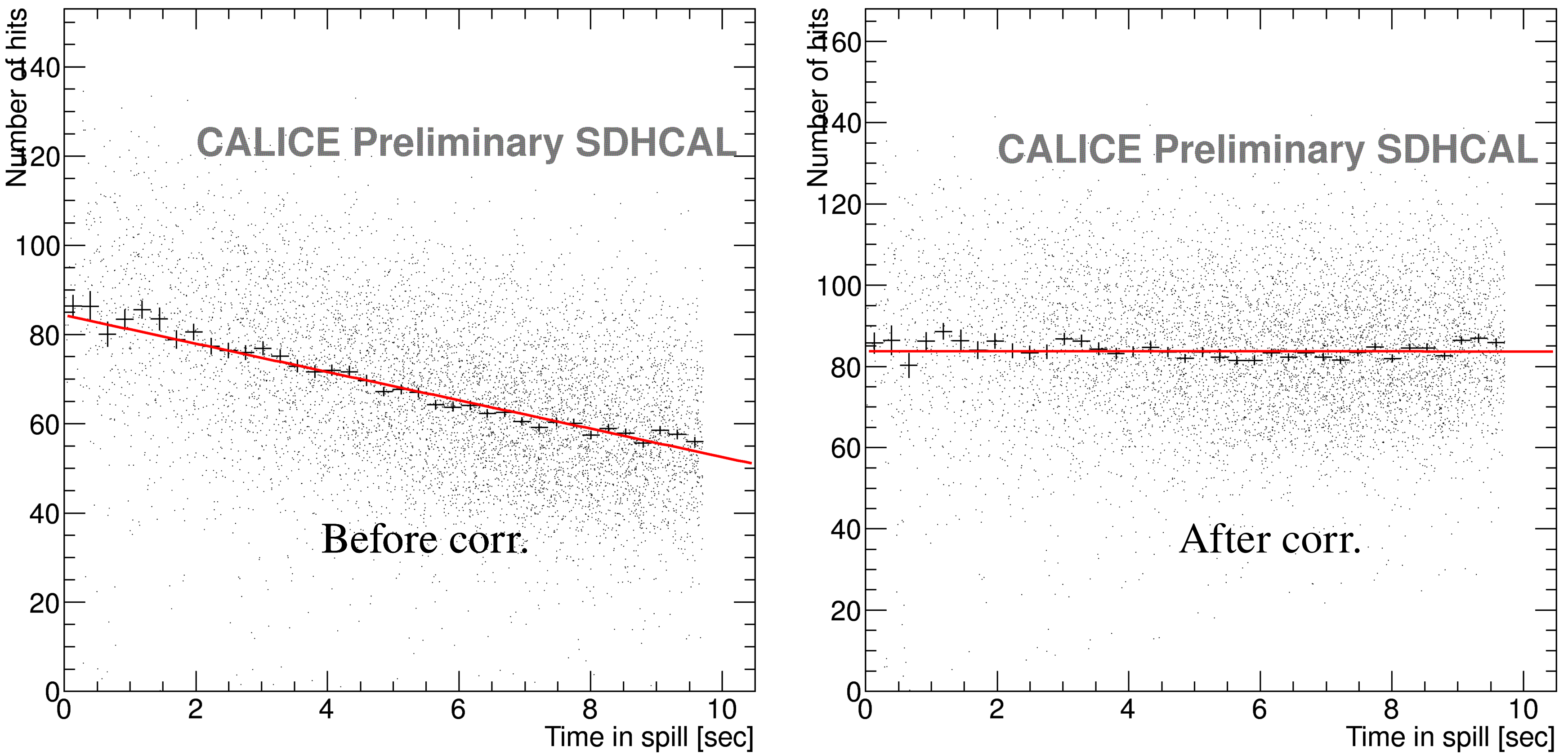
- Hadronic shower hits decrease during spill time
- Bigger effect for 2-3 thresholds at high energy
- Degradation of hadronic showers energy resolution!
- Needs to be calibrated





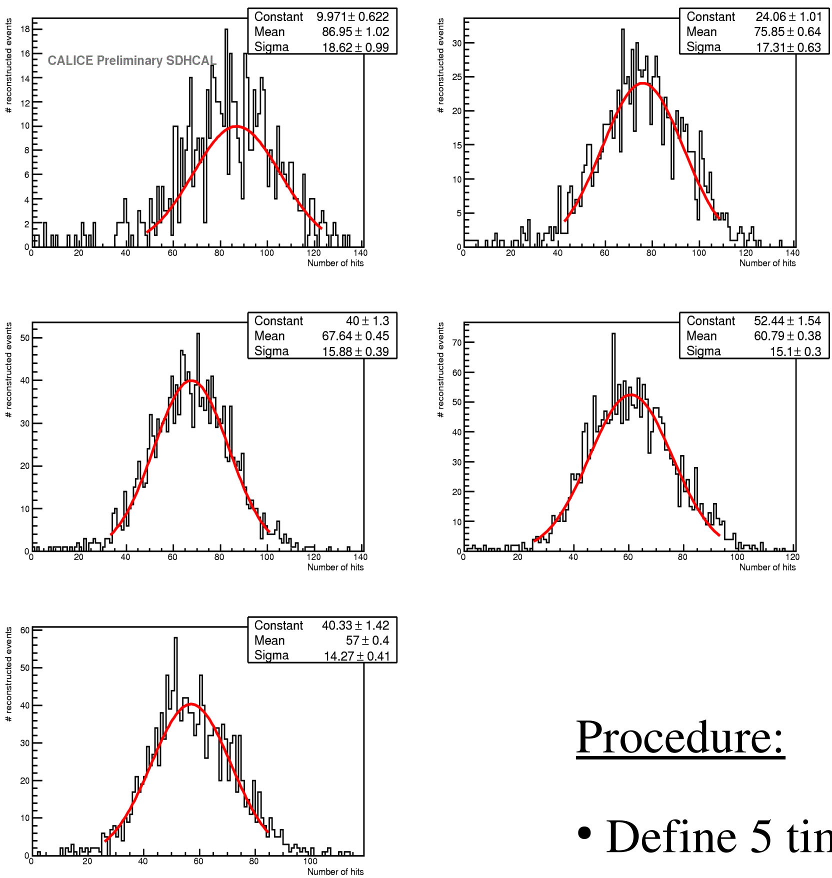


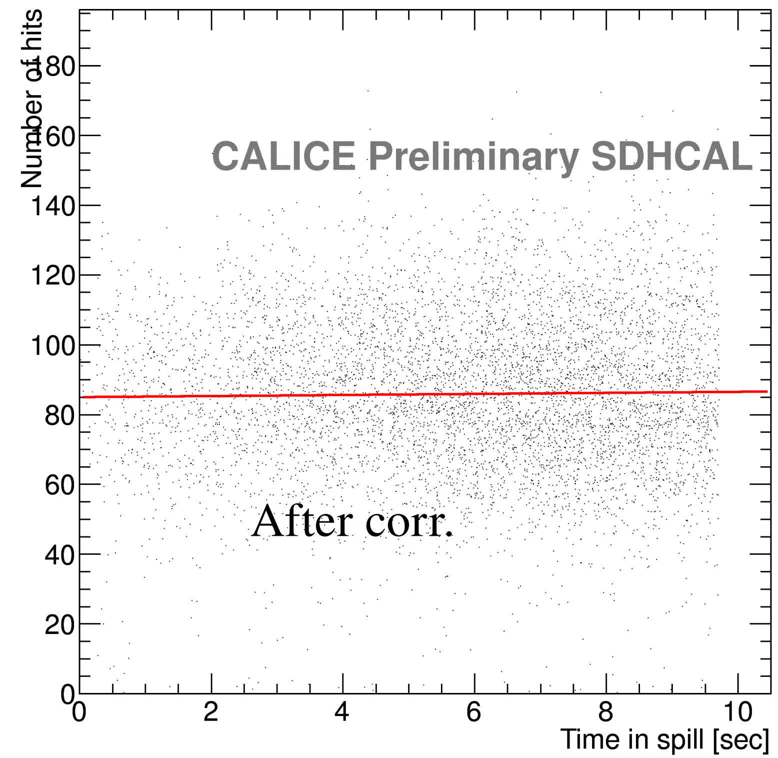
Linear fit calibration



- Fit by straight line the time evolution in spill, extract 'slope'
- Correct Nhit for each threshold, each run: $N_{corr} = \sum_{i=1}^{3} Nhit_i - slope_i \cdot TimeInSpill$

Time slots calibration

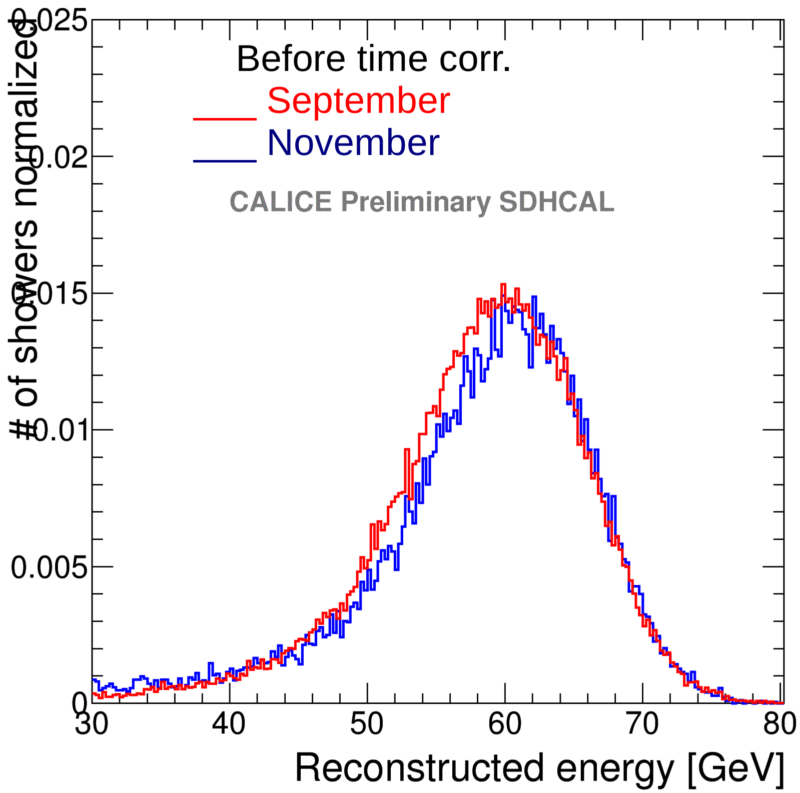


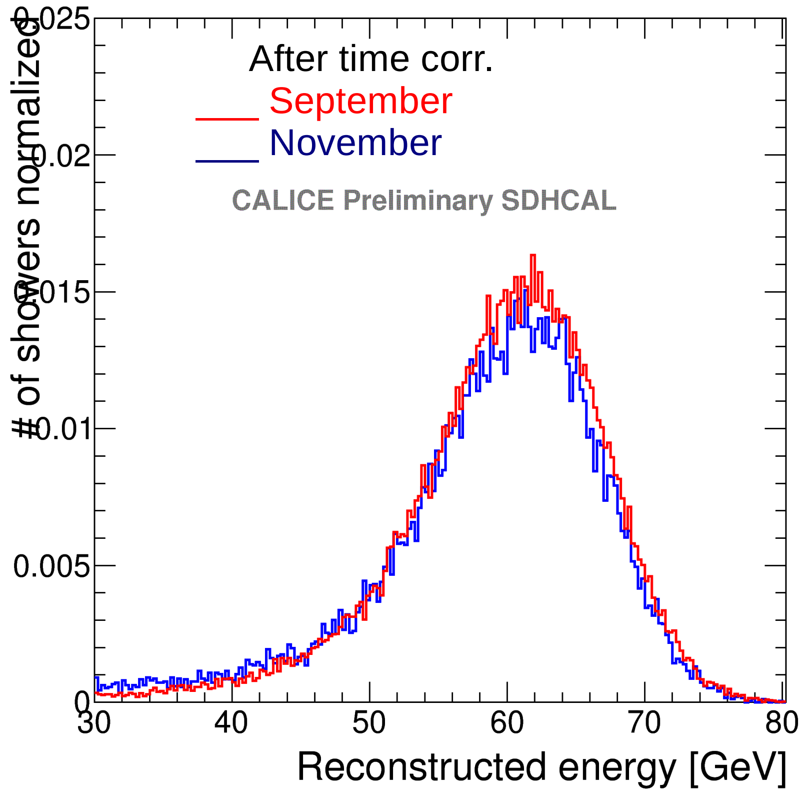


<u>Procedure:</u>

- Define 5 time slots in spill for every run
- Fit each $Nhit_i$ and derive parameters for 3 thr.
- Mean of first distribution – reference. $Coeff_i = \frac{Mean_1}{Mean_i}$
- Apply calibration const to analysis job for each thr. $N_{corr} = \sum_{i=1}^{5} Nhit_i \cdot Coeff_i$

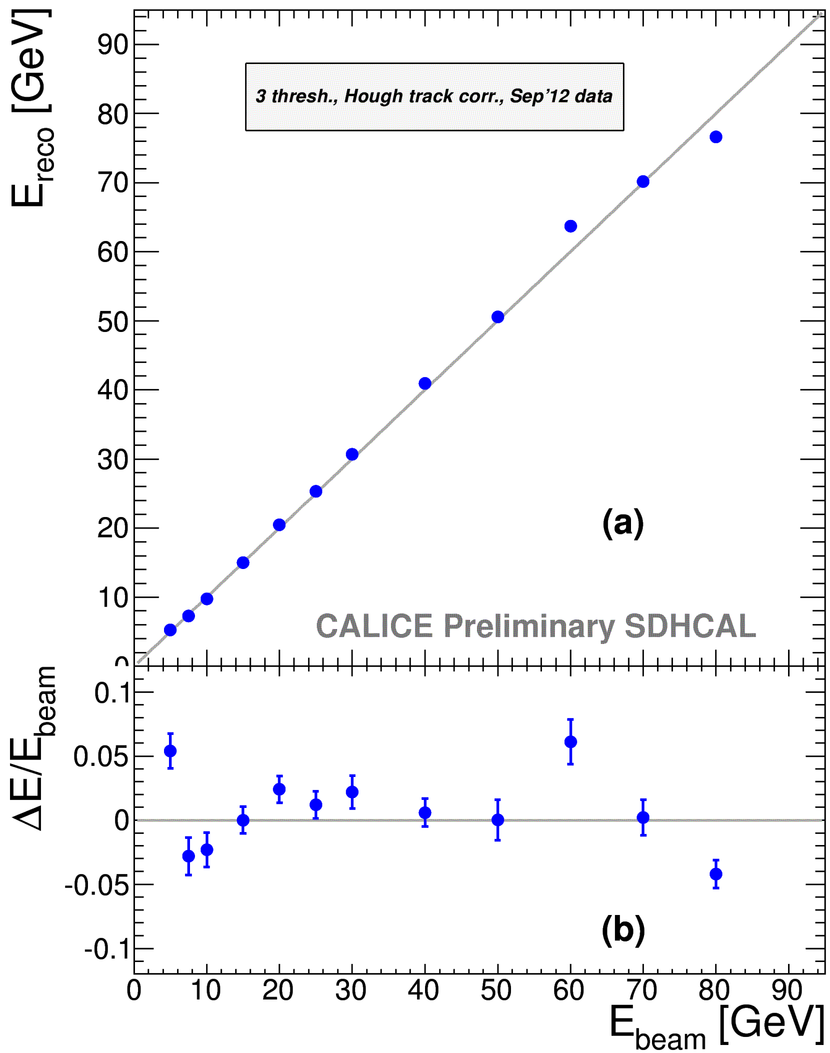
Stability in time

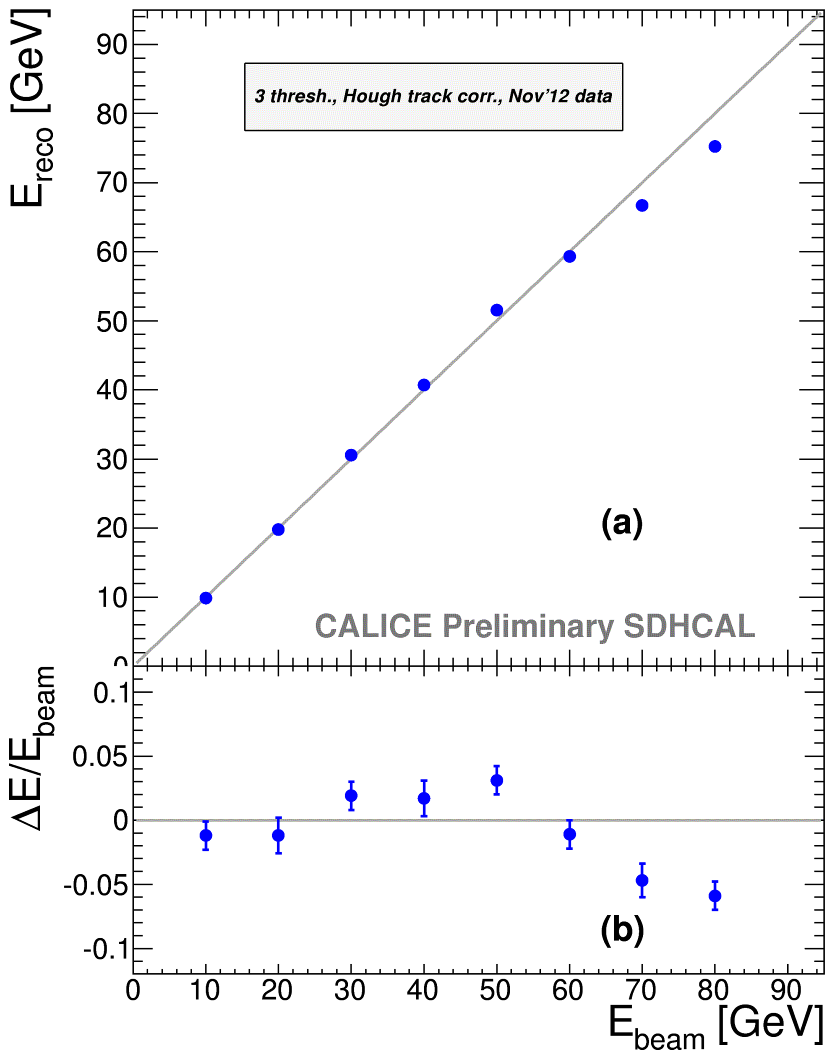




- Parameters from part of September -> November data
- Good agreement between two data sets
- Remarkable stability of SDHCAL prototype

Results on linearity '12

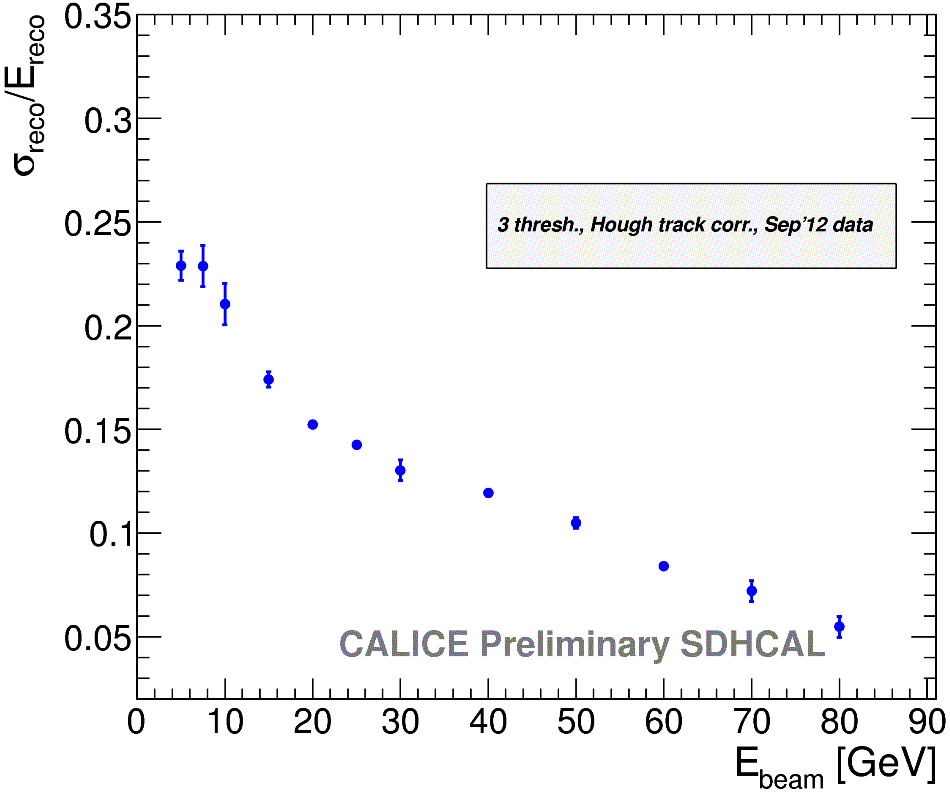


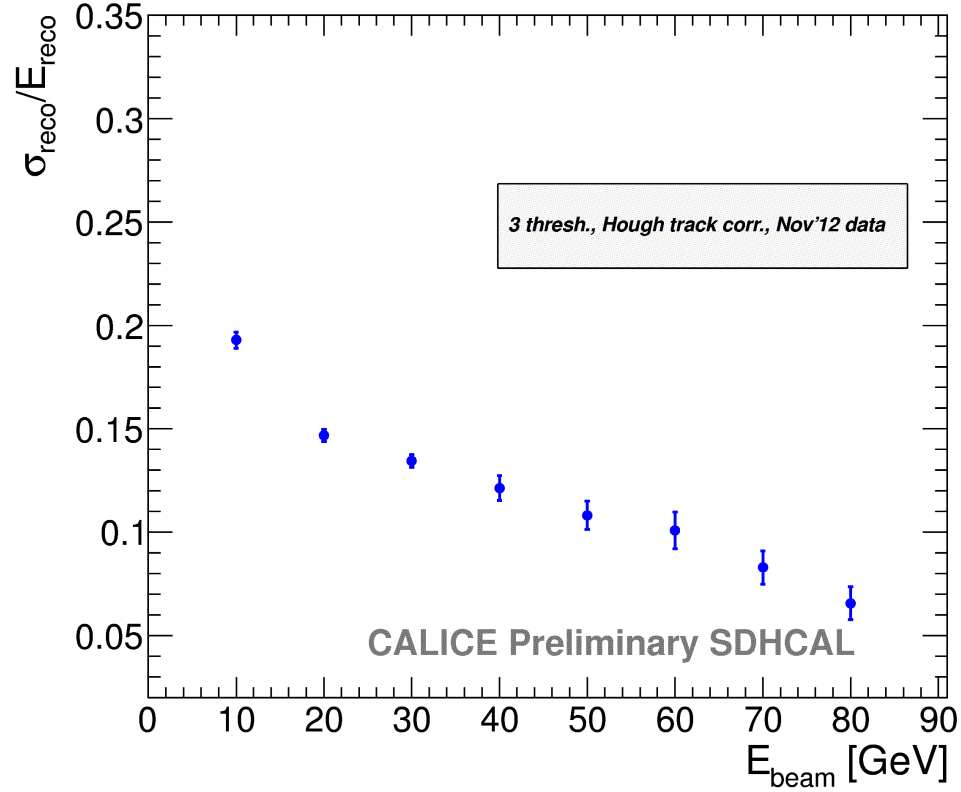


- E_{reco} obtained from ±1.5σ Gaussian fit
- Parametrization from September data

- Good linearity in wide energy range: $\frac{(E_{reco} - E_{beam})}{E_{beam}} \leq 5\%$

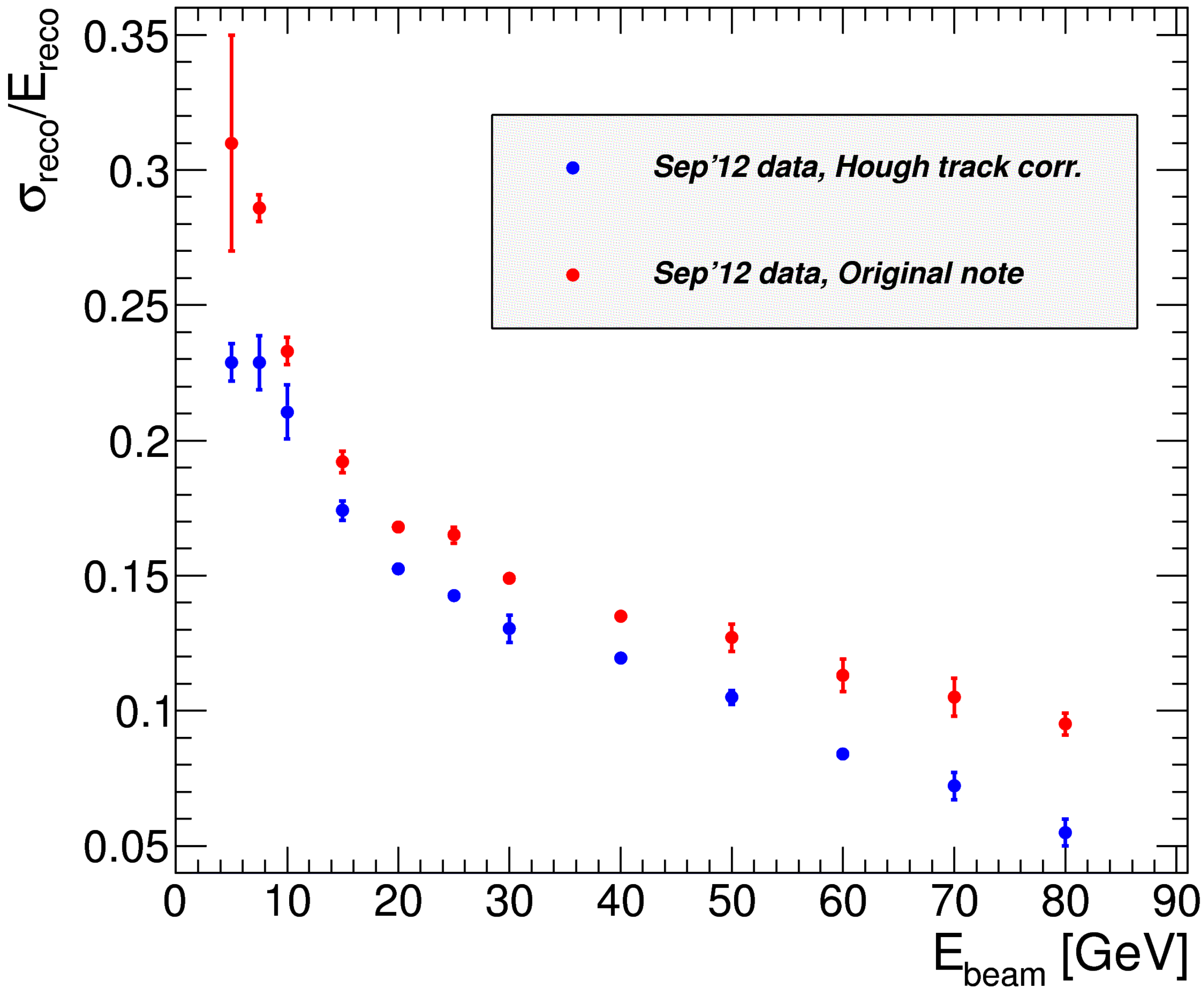
Results on resolution '12





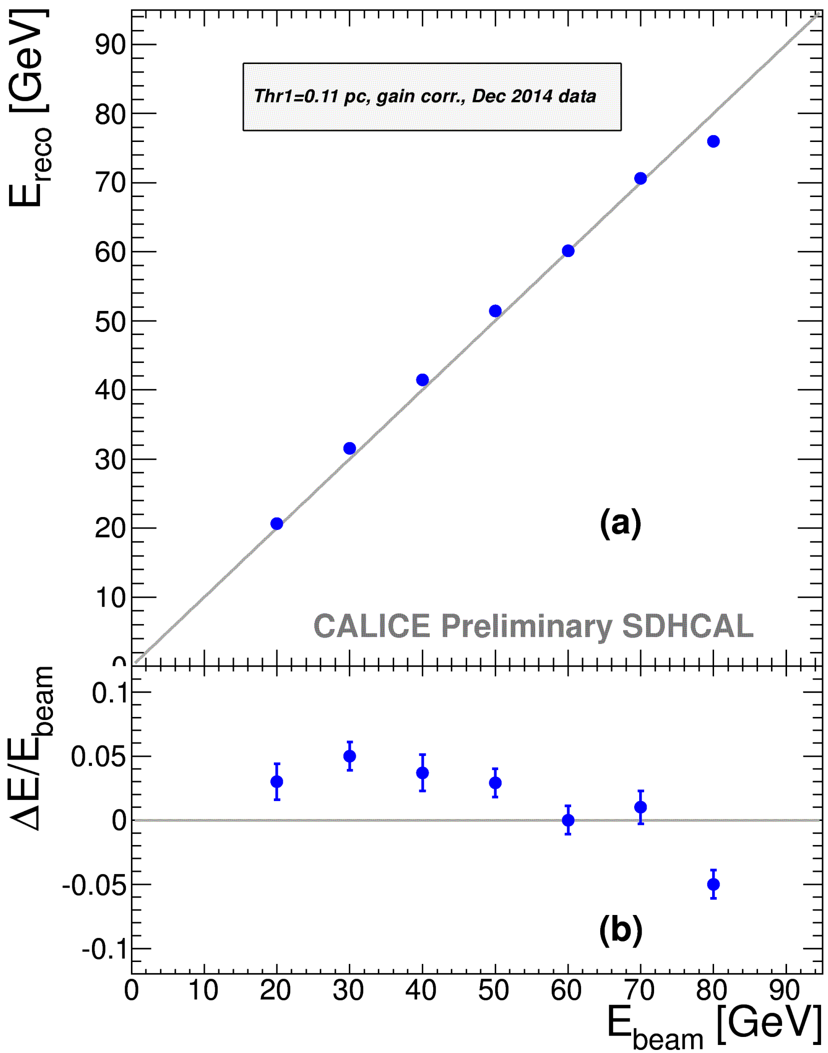
- September and November SDHCAL data with parameters from September
- Reasonable agreement between two data sets
- No gain correction applied
- Reconstructed energy resolution <6% at high energy after calibration

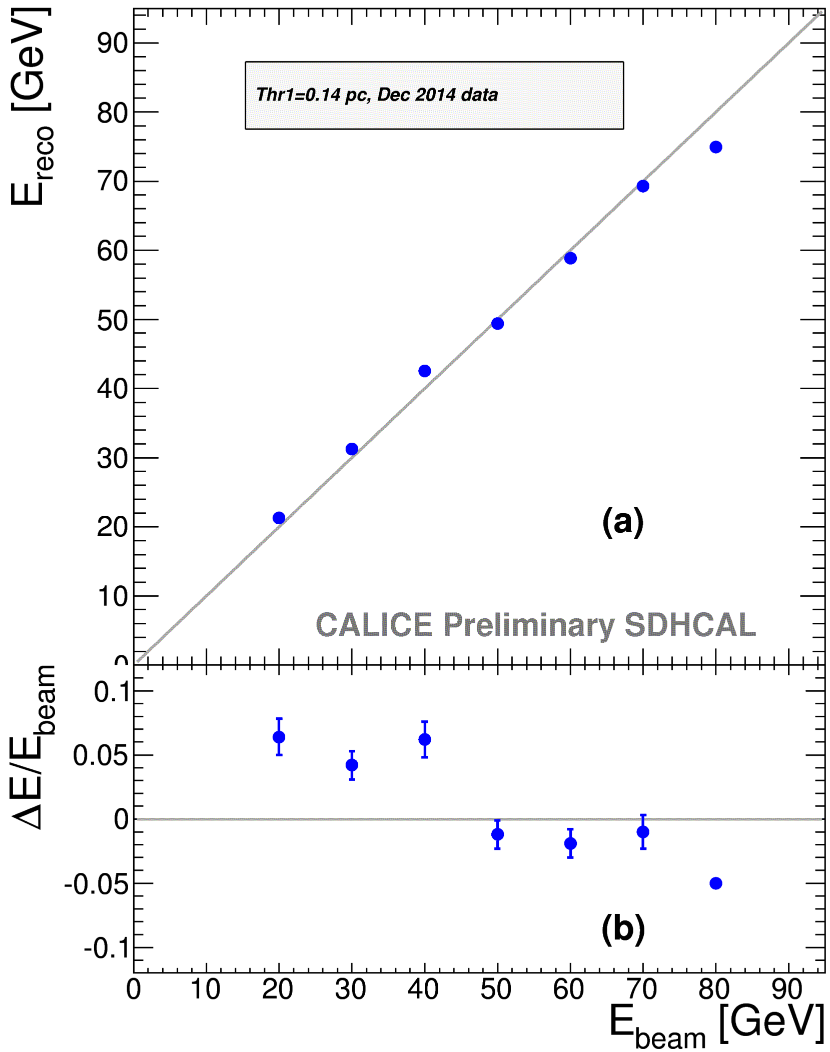
Summary 2012 data



- Clear improvement in resolution since November'12 !

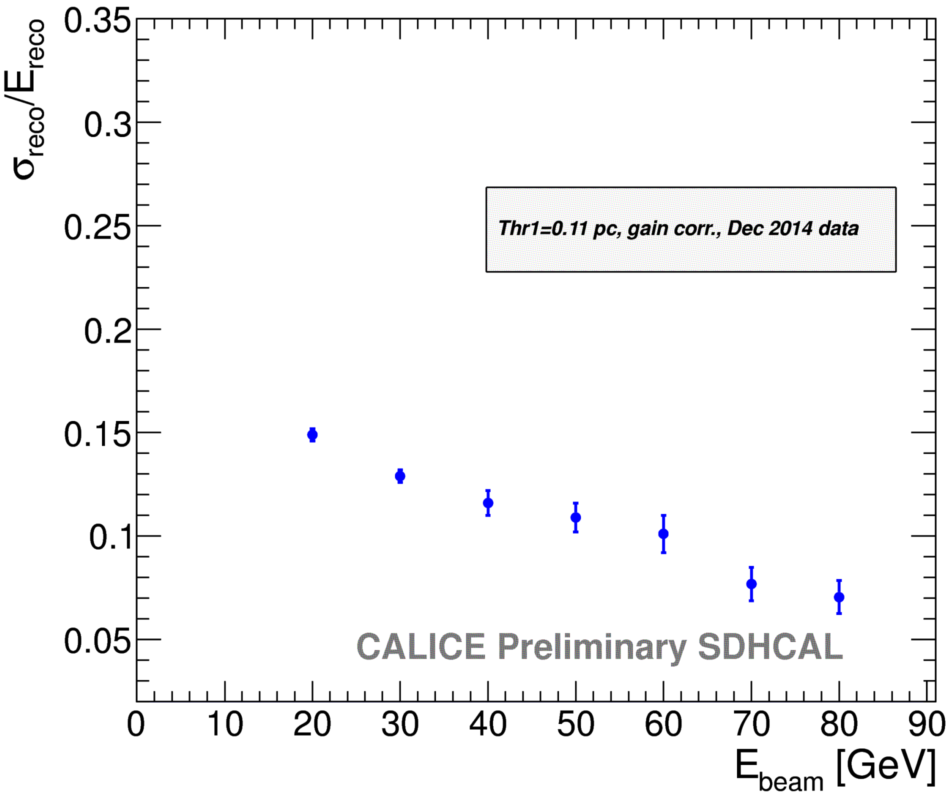
2014 data

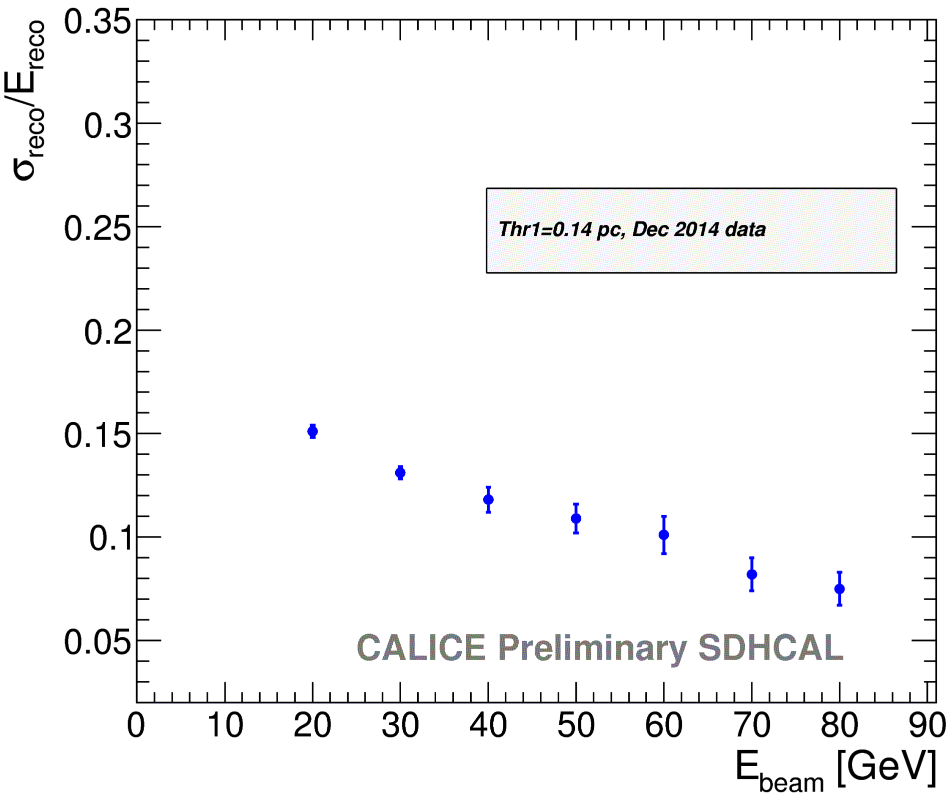




- Promising results with new TB data
- No HT tracks used

2014 data





- No HT tracks used
- Similar results with different thresholds
- More optimization is needed

Highlights

- SDHCAL prototype with 48 layers was successfully tested on CERN SPS beam lines in 2012, 2014
- Good data quality and stability were observed
- Reconstructed energy resolution in 2012 reaches <6% at 80 GeV with satisfactory linearity [CALICE analysis note CAN-037b], ready for publication ?
- 2014 data gives promising results
- More ideas
  - Neural Network technique, train with 2014 data (5 GeV step)