



Energy measurement with the SDHCAL prototype

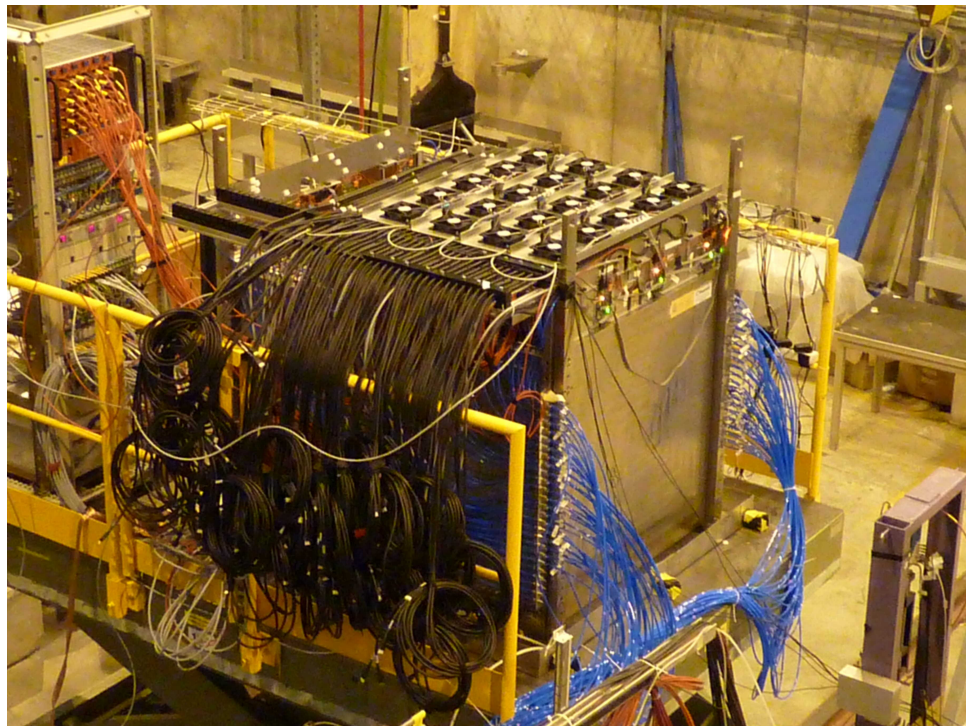
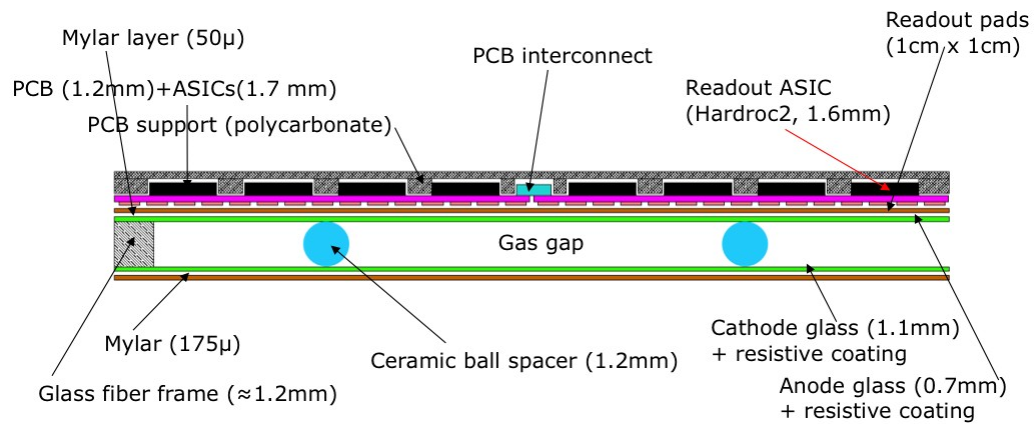
Alexey Petrukhin
CNRS, IPNLyon, ITEP Moscow

TIPP 2014, Amsterdam

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



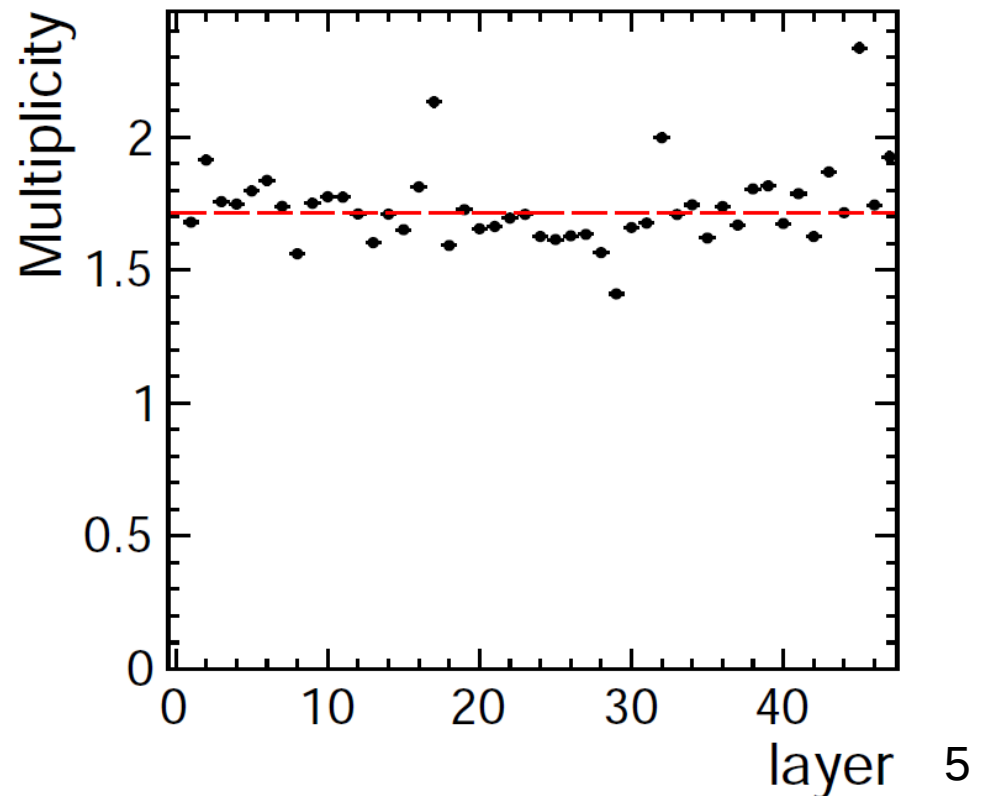
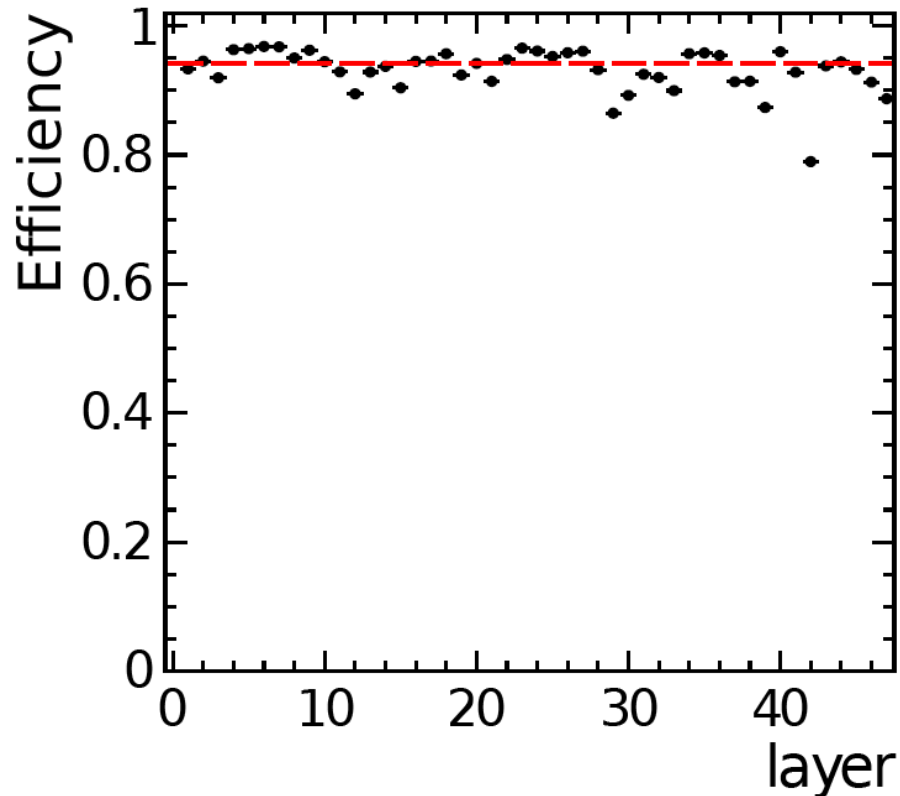
- 48 active GRPC layers, $1 \times 1 \times 1.3 \text{ m}^3$
- Self-supporting stainless steel mechanical structure
- Operates at 6.9 kV
- 440000 electronic channels
- Power-pulsing mode
- 3 thresholds semi-digital readout: better treatment of saturation at high energy, better understanding of hadronic shower

CERN SPS data

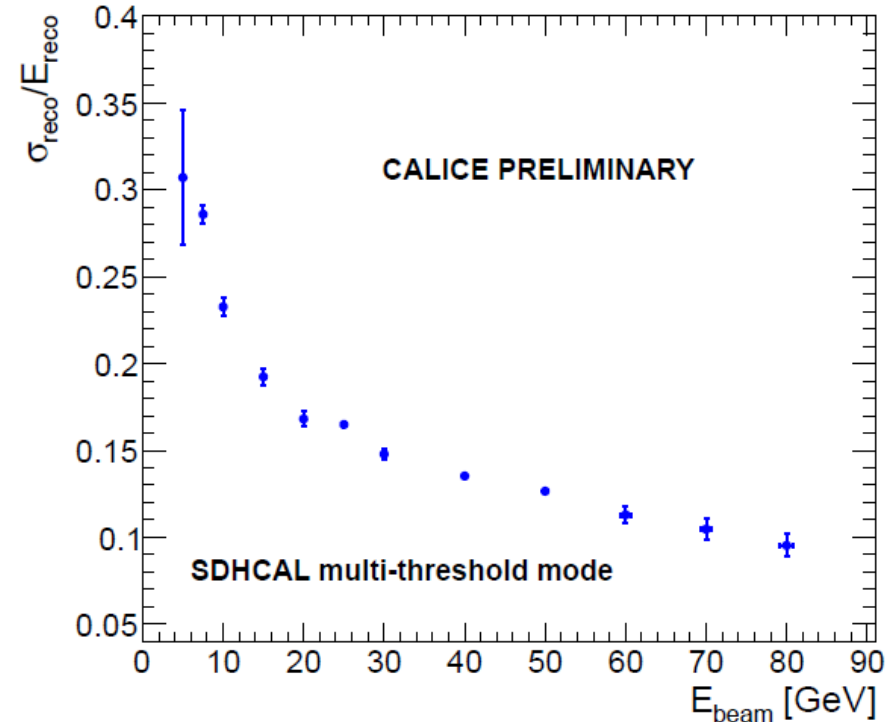
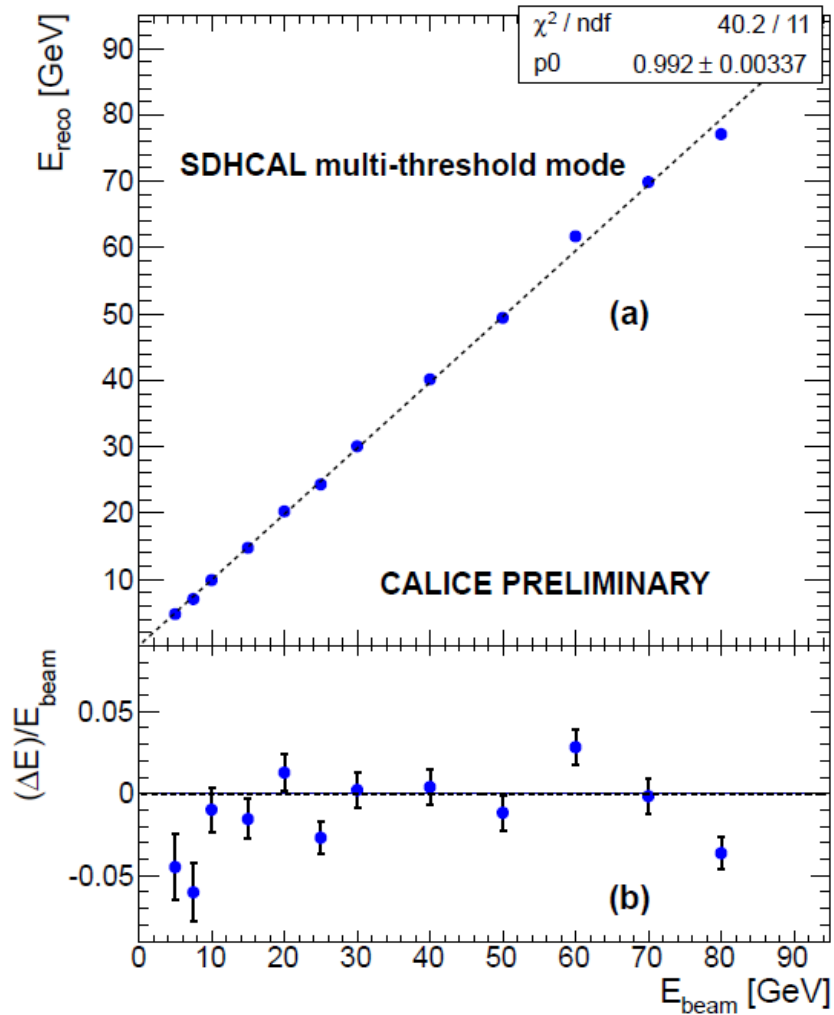
- May 2012 on H2 line for 2 weeks
- August-September 2012 on H6 line for 2 weeks
- November 2012 on H2 line (1 week)
- 48 layers in avalanche mode at 6.9 kV
- Gas: 93% TetraFluoroEthane, 5% CO₂, 2% SF₆
- Large beam size, low particle rate <1000 particle/spill -> good eff.
- Triggerless acquisition: stopped if 1 ASIC is full, readout all data recorded. ASIC internal clock: 200 ns. No gain correction
- 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, $\bar{\varepsilon} \sim 95\%$
- Multiplicity: hits number in cluster around track impact, $\bar{\mu} \sim 1.7$



Former results



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

Event selection

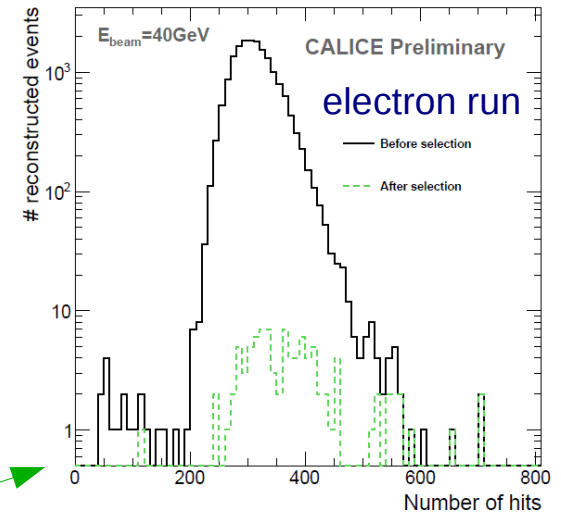
- No Cherenkov counter:
 - Needs more effective electron rejection:
shower start > 4 or $N_{\text{layer}} > 30$

- Muon rejection:

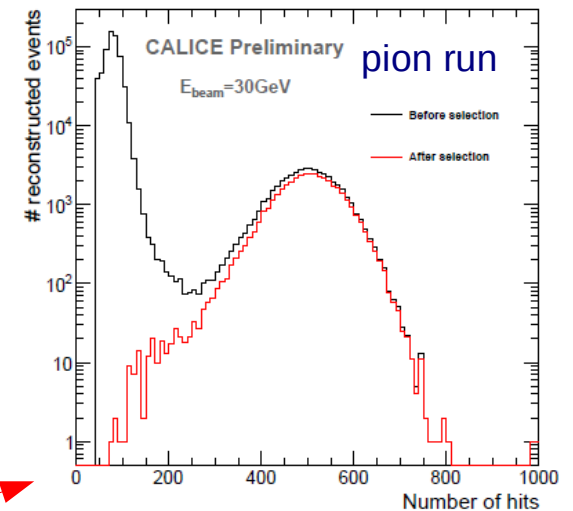
- $N_{\text{hit}} / N_{\text{layer}} > 2.2$

- Neutral:

- N_{hit} in first 5 layers > 4



Reject electrons

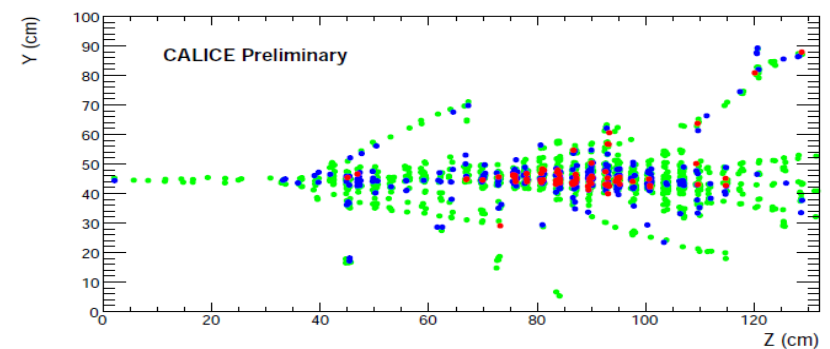
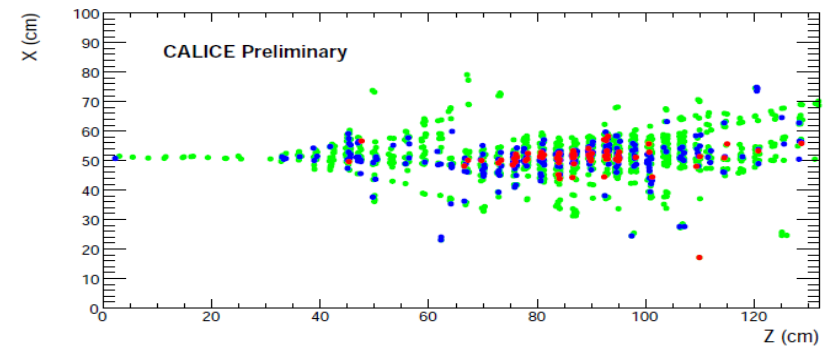
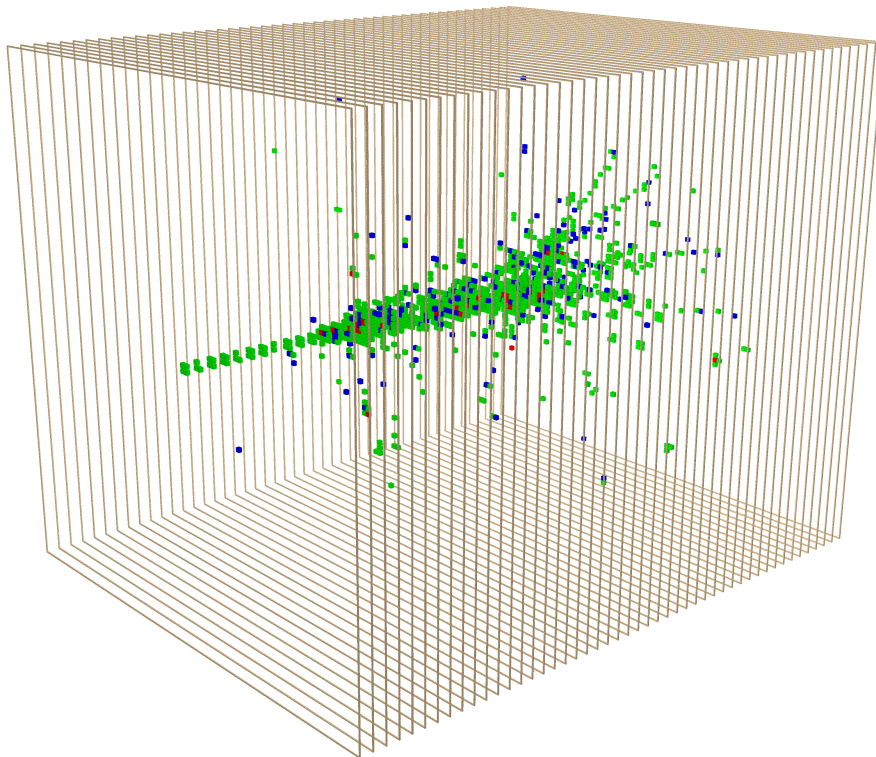


Full selection applied

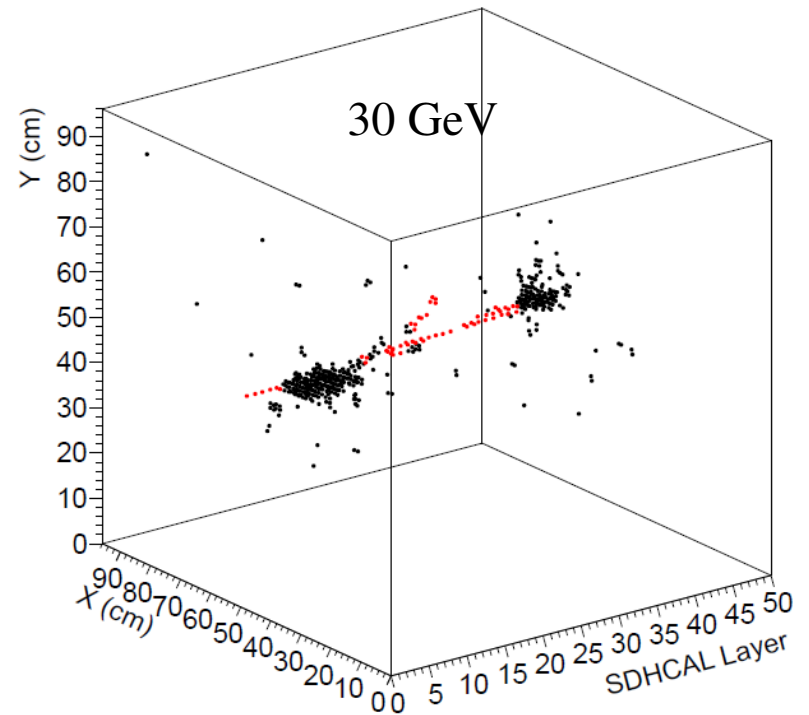
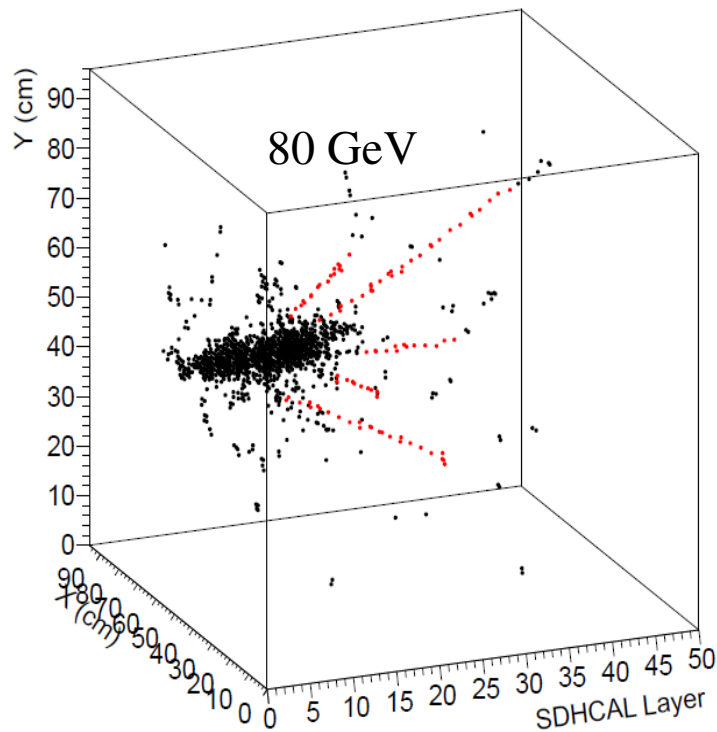
Energy reconstruction

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

- 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 $\chi^2 = \sum_{i=1}^{N_{ev}} \frac{(E_{beam}^i - E_{reco}^i)^2}{E_{beam}^i}$



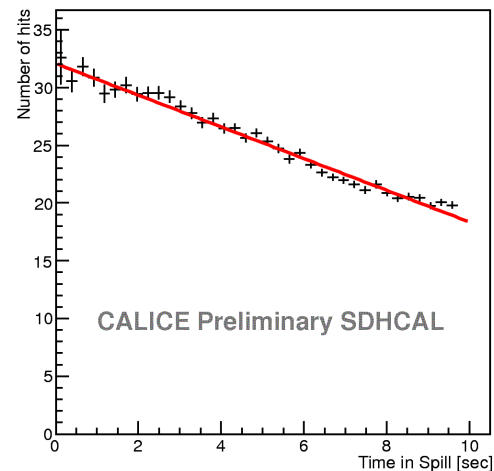
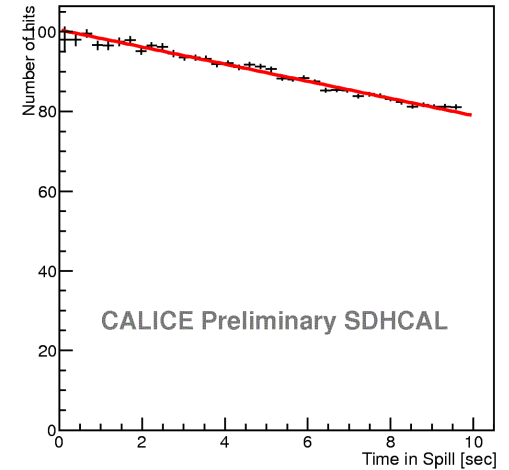
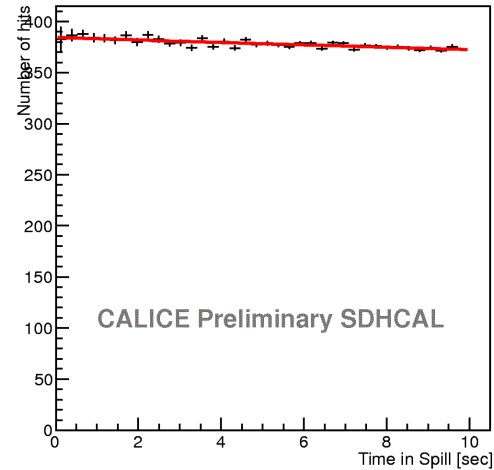
HT tracks



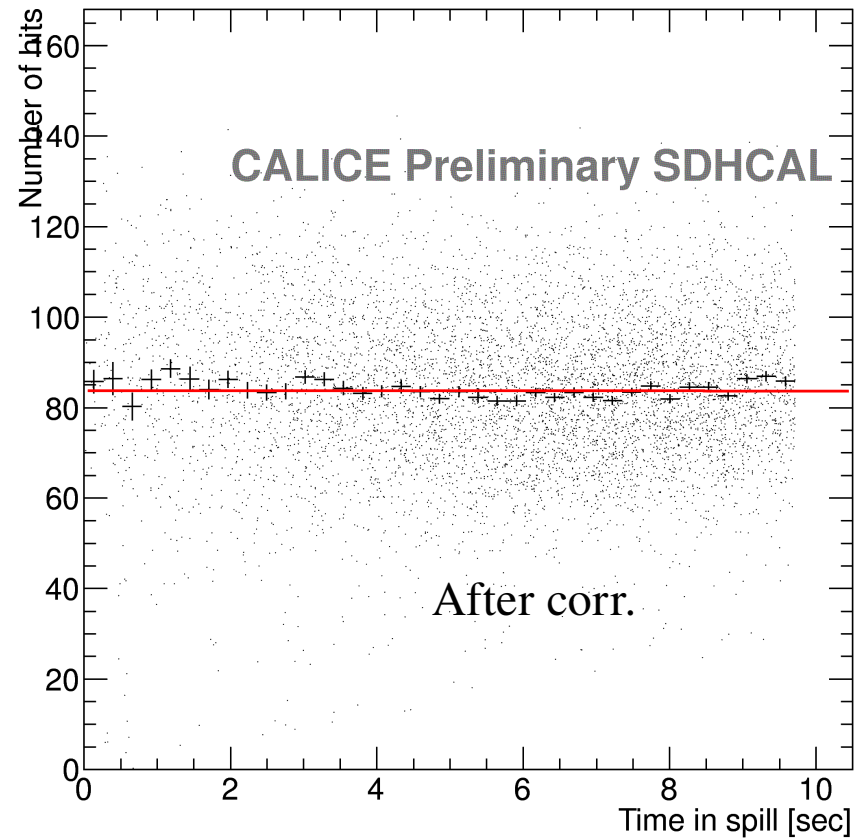
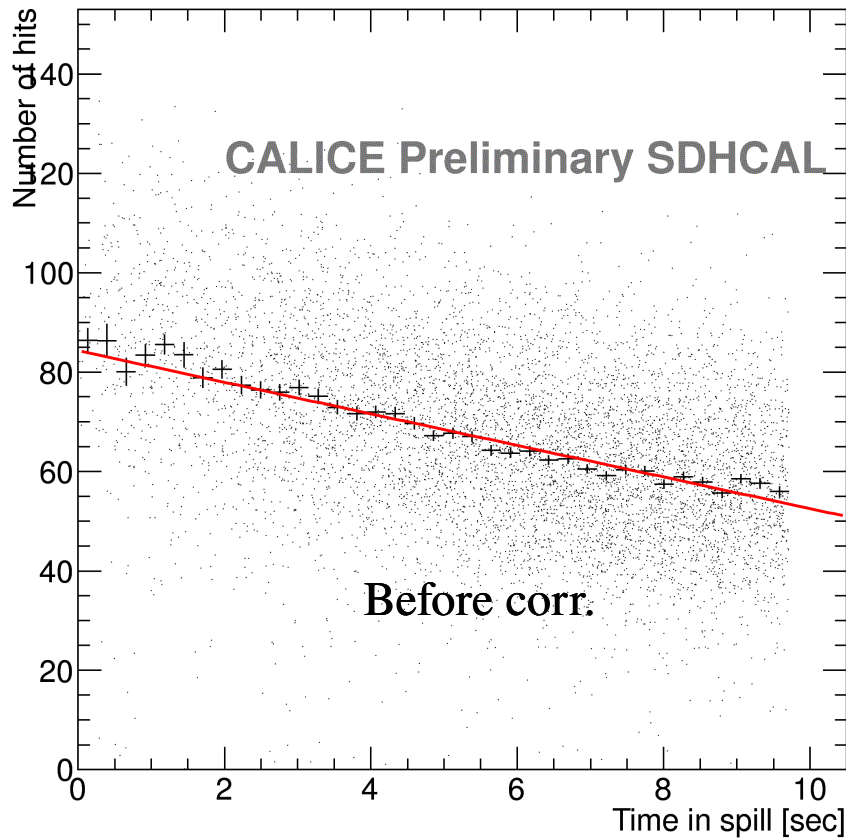
- Hough Transform tracks help to better understand the hadronic shower structure and improve on the energy resolution
- Hits belonging to HT tracks/mips should not be treated as those of the hadronic shower core

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



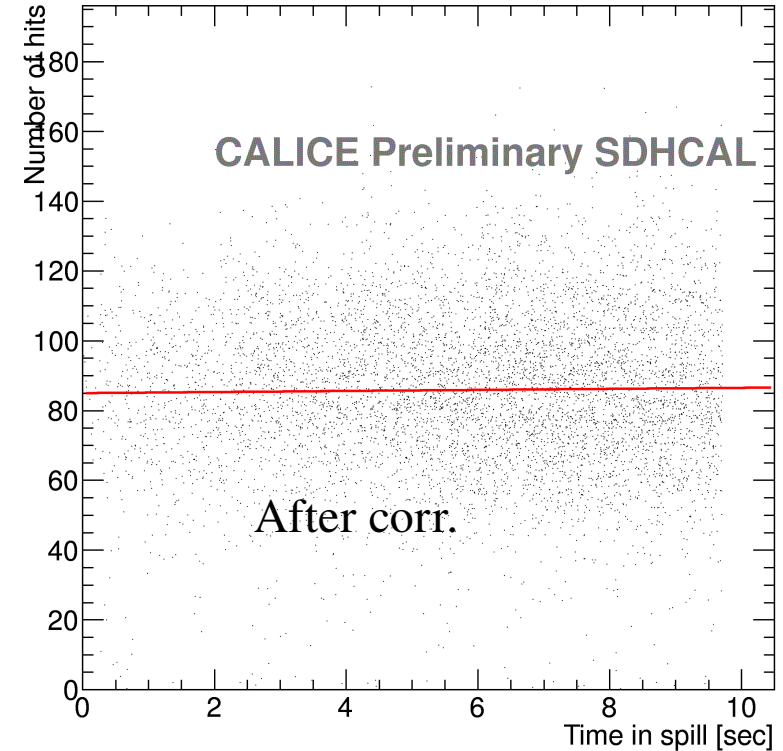
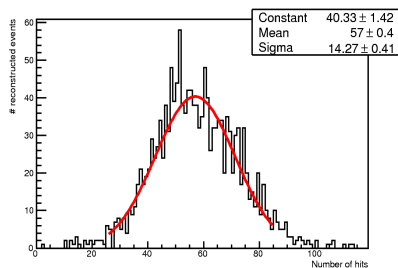
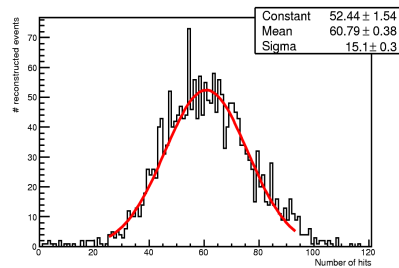
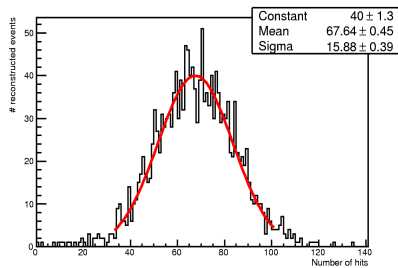
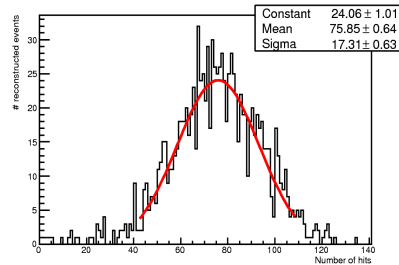
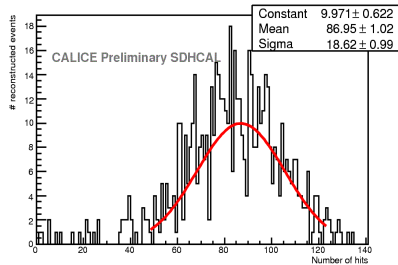
Linear fit calibration



- Fit by straight line the time evolution in spill, extract 'slope'

- Correct N_{hit} for each threshold, each run:
$$N_{corr} = \sum_{i=1}^3 N_{hit}_i - slope_i \cdot TimeInSpill$$

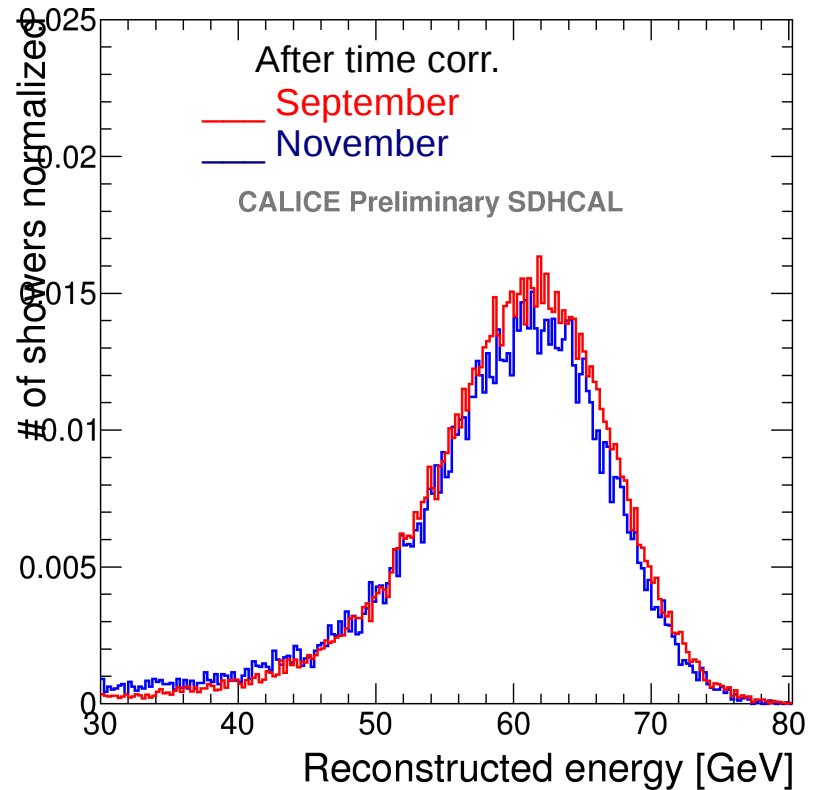
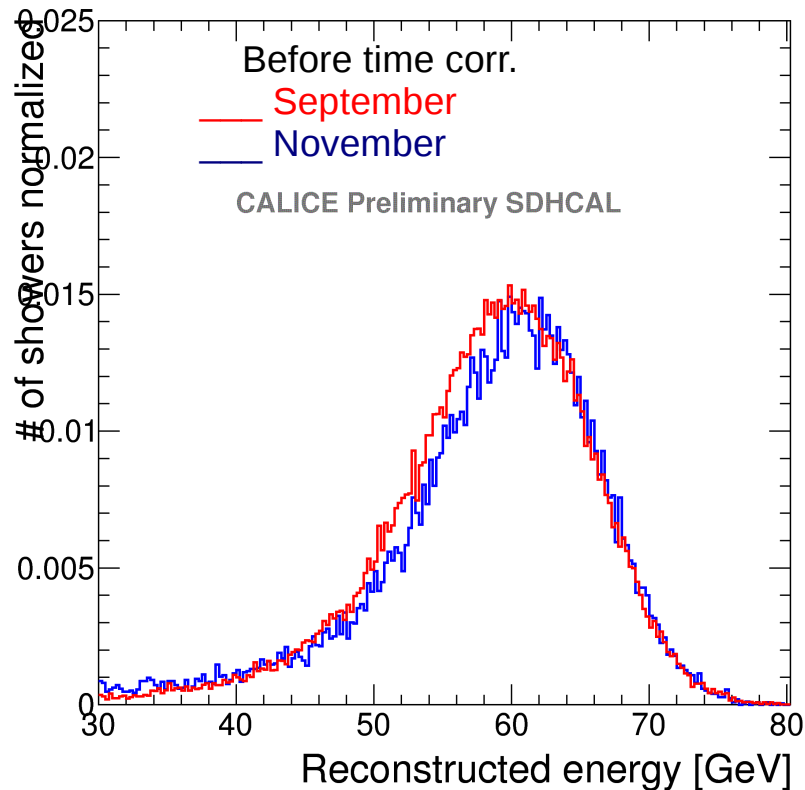
Time slots calibration



Procedure:

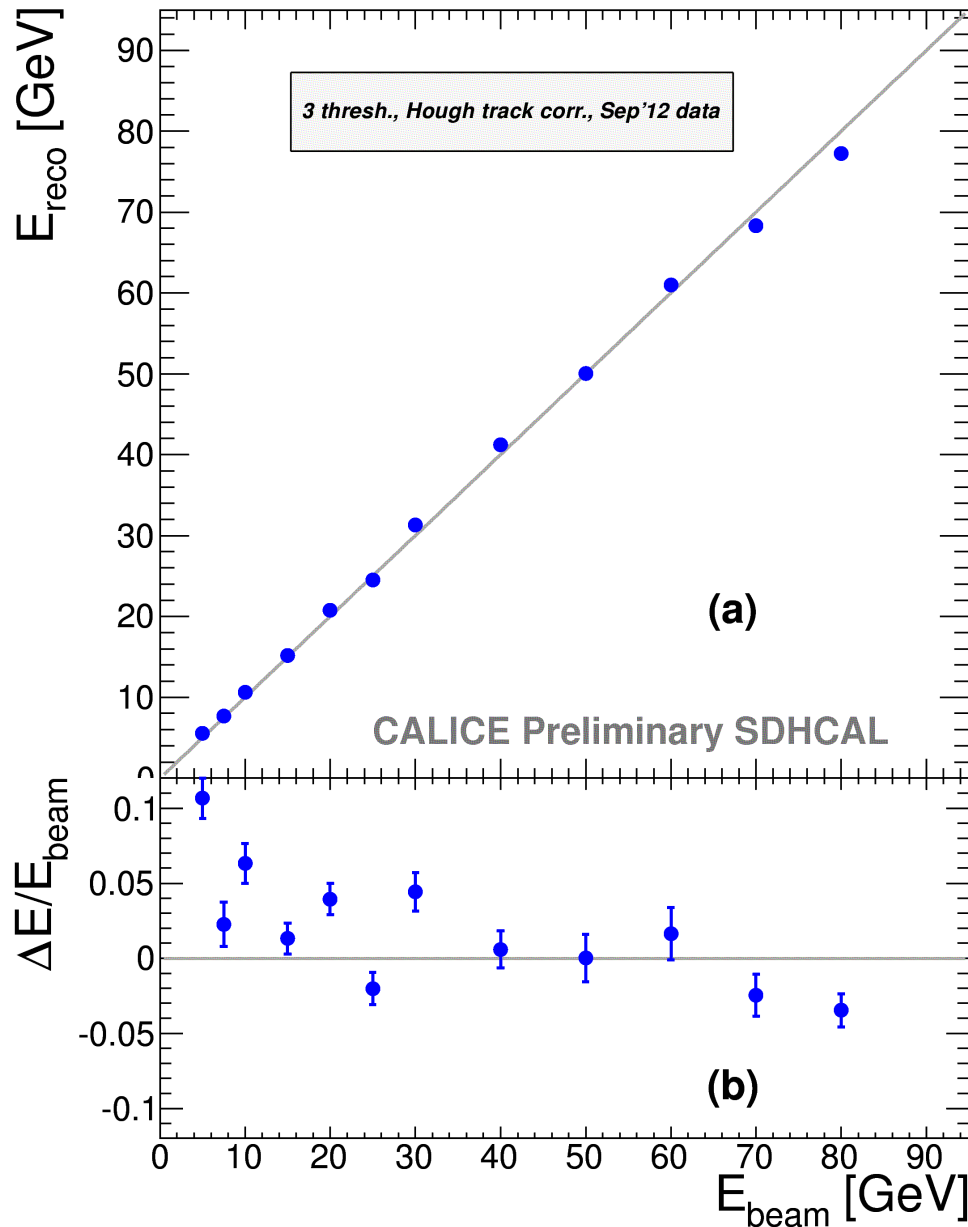
- Define 5 time slots in spill for every run
- Fit each N_{hit_i} and derive parameters for 3 thr.
- Mean of first distribution – reference. $Coeff_i = \frac{Mean_1}{Mean_i}$
- Apply calibration const to analysis job for each thr. $N_{corr} = \sum_{i=1}^5 N_{hit_i} \cdot Coeff_i$

Stability in time



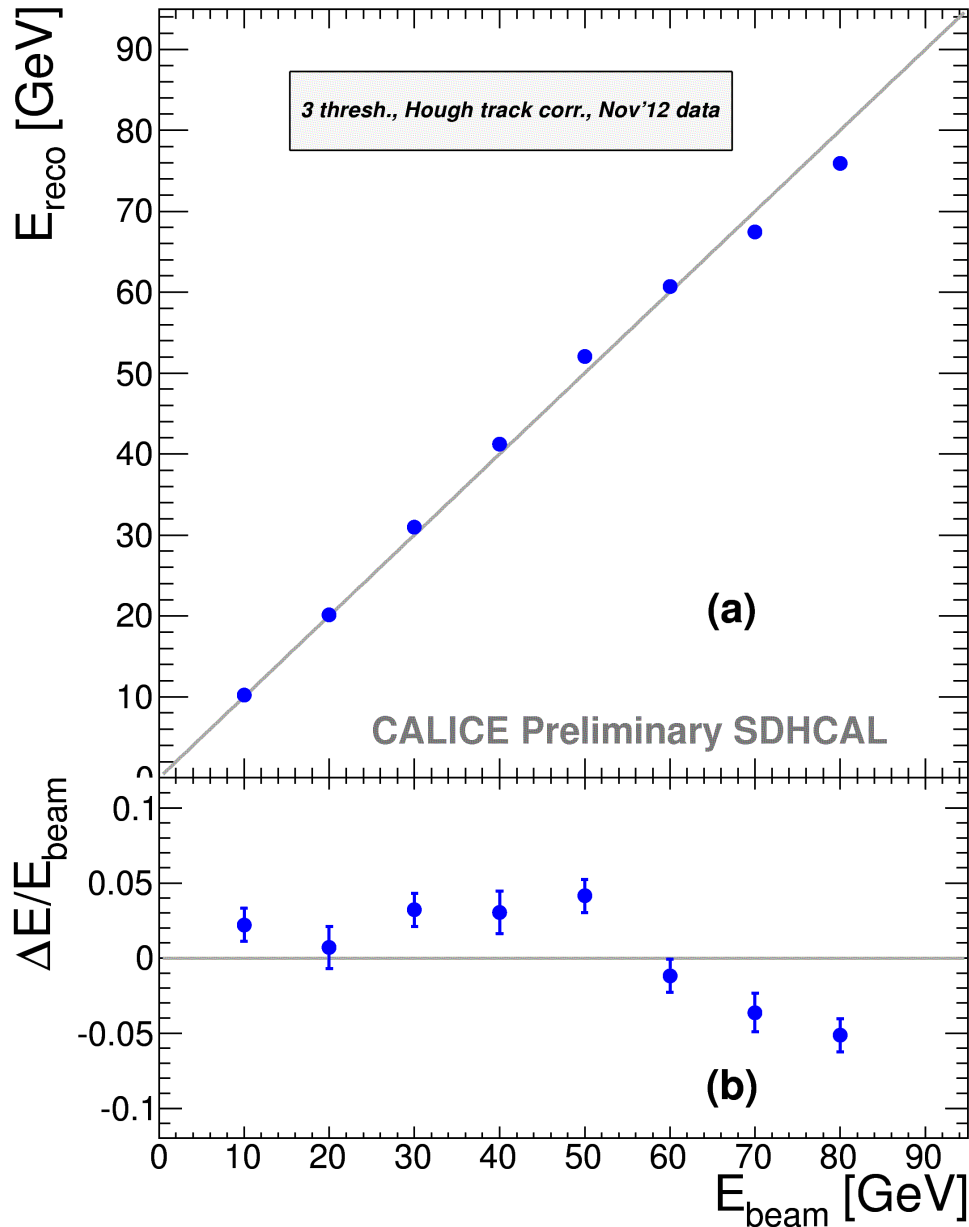
- Parameters from part of September -> November data
- Good agreement between two data sets
- Remarkable stability of SDHCAL prototype

Results on linearity Sept.



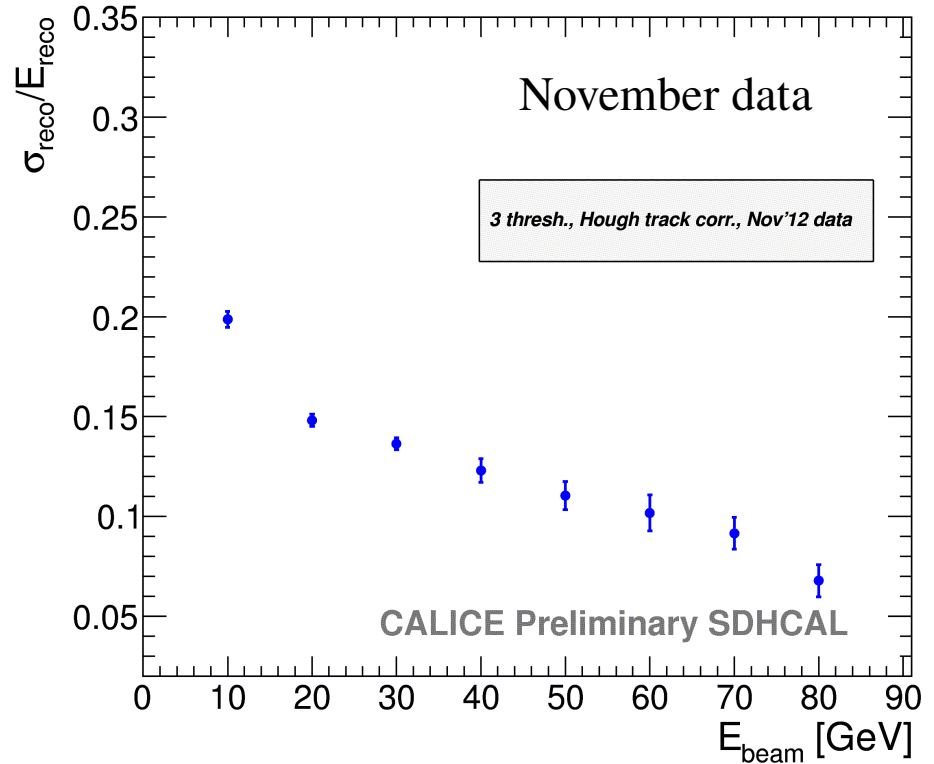
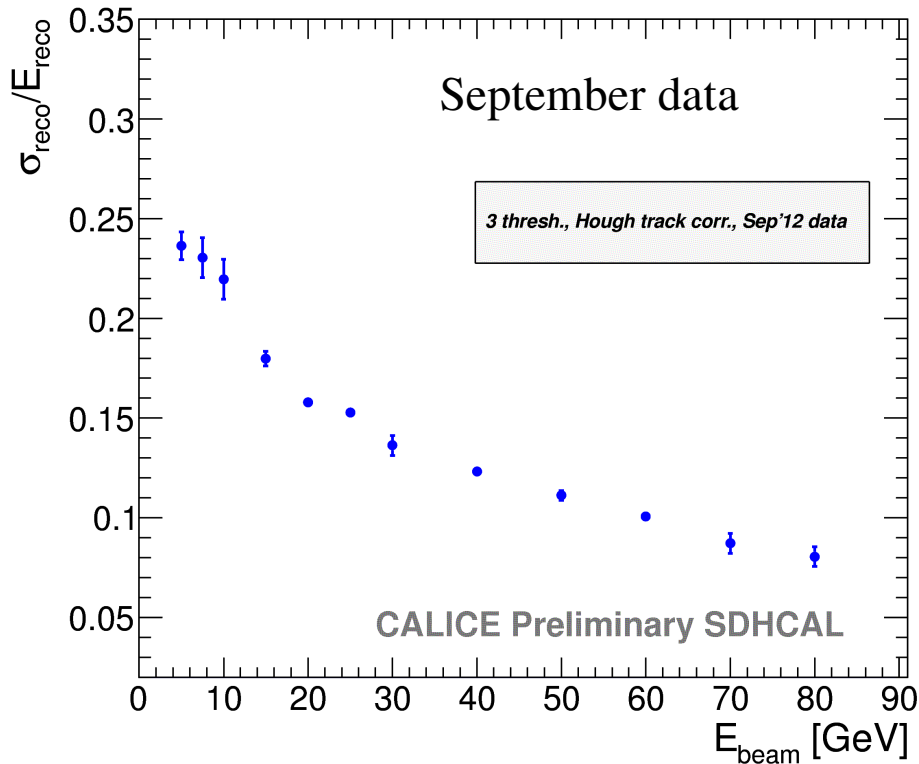
- E_{reco} obtained from $\pm 1.5\sigma$ Gaussian fit
- Good linearity in wide energy range: $\frac{(E_{\text{reco}} - E_{\text{beam}})}{E_{\text{beam}}} \leq 5\%$

Results on linearity Nov.



- E_{reco} obtained with parameters from September data
- Linearity inside $\pm 5\%$ for all energy points

Results on resolution



- September and November SDHCAL data with parameters from September
- Reasonable agreement between two data sets
- No gain correction applied
- Reconstructed energy resolution $<7\%$ at high energy after calibration

Highlights

- SDHCAL prototype with 48 layers was successfully tested on CERN SPS beam lines
- Good data quality and stability were observed
- New selection and parametrization are shown
- Two spill time correction methods are presented
- Reconstructed energy resolution reaches $<7\%$ at 80 GeV with satisfactory linearity
- More ideas
 - New analysis involving shower density approach are ongoing
 - Neural Network technique