CALICE calorimeter R&D at CIEMAT

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IX Jornadas LC-Spain
IFIC Valencia, 18-19 Dec 2012

Calorimetry @ ILC

Challenge**: Improve the present energy resolution by a factor 2**

How**: Using particle flow algorithms**

Measure the charged particles only in the tracker. Almost perfect resolution
Measure photons in ECAL
Measure neutral particles in HCAL

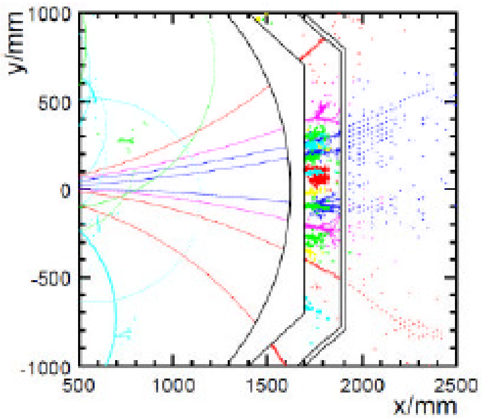
Requirements**:**

Good calorimeter resolution but mainly tracking capabilities
➔Extremely fine calorimeter segmentation transversal and longitudinally
(hundred of millions of read-out channels).
Important technological challenges.

Particle Flow Algorithm

Physics@ILC → a lot multi-jet final states

Particle flow → measure each particle in a jet



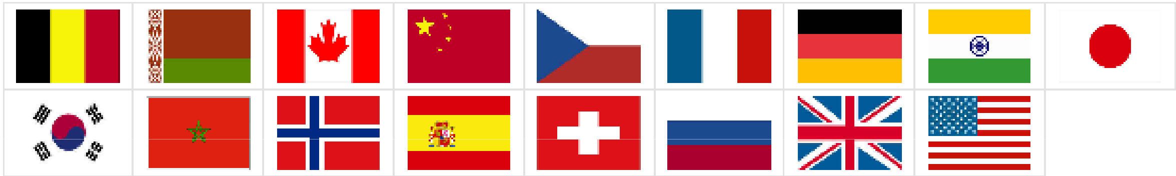
Charged } ⟶ { Trackers
Neutral } ⟶ { Calorimeters

Confusion

- High B field
- Large radius
- Calorimeters with fine granularity

CALICE – Calorimeter for ILC

The CALICE Collaboration



336 physicists/engineers from 57 institutes and 17 countries coming from the 4 regions (Africa, America, Asia and Europe)

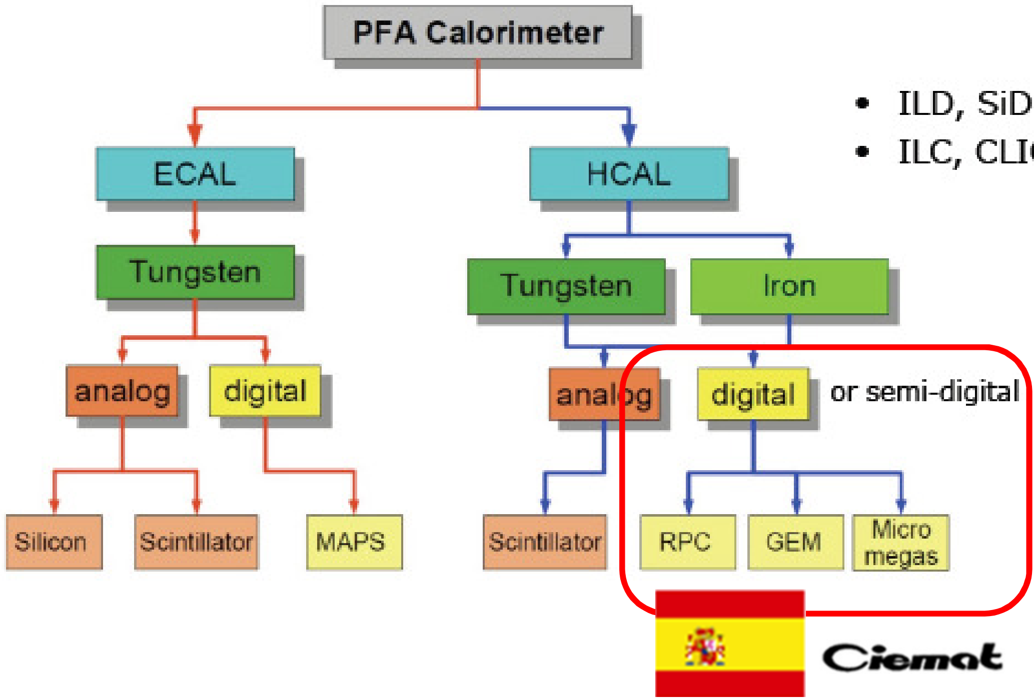
Goal:
Develop highly granular calorimeters optimized for the particle flow measurement of multi-jet final states at Linear Colliders

R & D on different technologies.

Two different **prototype concepts:**

Physics Prototypes:
Aim: Proof of physic principle, test of models, reconstruction algorithms.

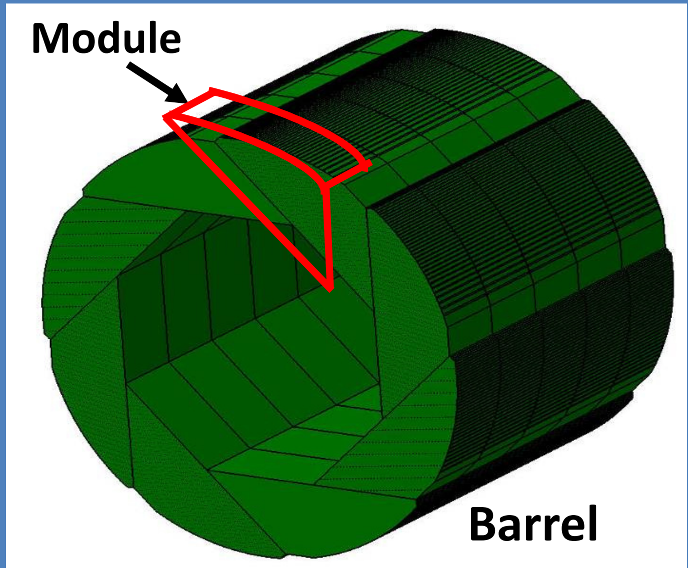
Technical prototypes
Aim: Realistic, scalable to final design

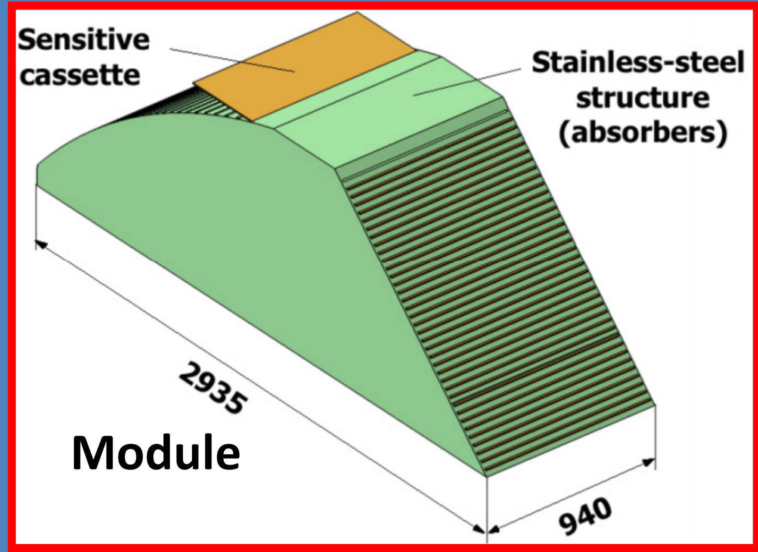


- ILD, SiD
- ILC, CLIC

Towards a SHDCAL Technological Prototype

ILD - SDHCAL
LOI design





The technological prototype

We intend to validate the SDHCAL concept by building a prototype which is as close as possible to the proposed SDHCAL for ILD to understand key issues of integration and operation

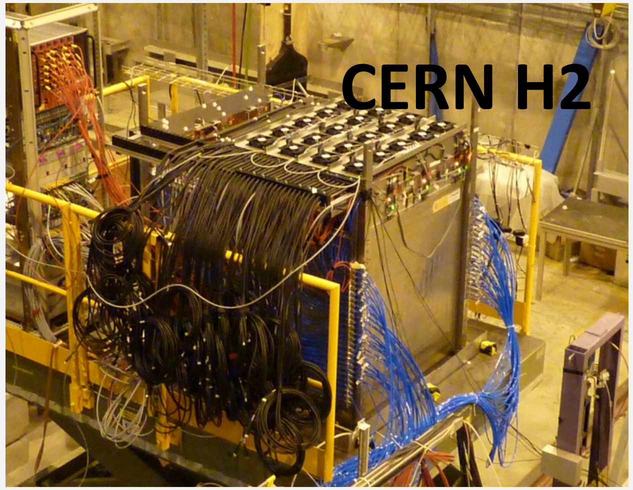
1- Large detector with almost no dead zones
2- Large and embedded electronics board
4- One-side services: HV, LV, gas, readout
5- Self-supporting mechanical structure
6- Power-pulsed electronics
7- New generation of DAQ system

Size: 51 stainless steel plates + 50 detector cassettes ~ 1m^3 ~500K channels

The SDHCAL technological prototype

51 stainless steel plates + 50 detector cassettes
~1x1 m^2 48 GRPC + 2 MICROMEGAS

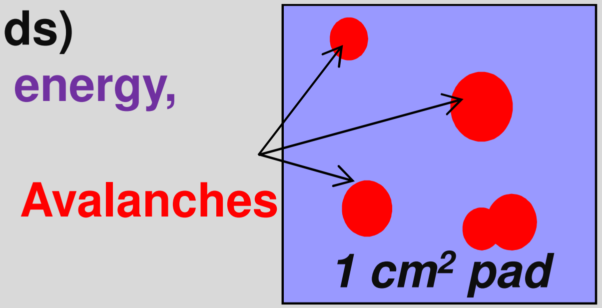
1x1 cm^2 readout pads
2 cm absorber between detectors
~ 1m^3 ~500K channels *A Tracking device !!!*



Gaseous detectors like *GRPC* (Glass Resistive Plate Chambers) are homogenous, cost-effective, and allow high longitudinal and transverse segmentation.

Readout : 1x1cm^2 pads Semidigital readout (2-bits, 3 Thresholds)
It uses number of hits instead of deposited energy,
how many & which pads over thresholds

At high energy the shower core is very dense
➔ 2-bit readout reduces saturation effects at E > 30GeV



Test beams at CERN 2011-2012

2011

Test beam SPS CERN June

Unfortunately the new DAQ generation wasn´t yet ready by June .

But by using the USB DIF readout we were able to take a very small amount of data

USB readout is not designed for the prototype:

- ➔ Extra cabling
- ➔ Synchronization very difficult
- ➔ Very slow readout

Test beam @ PS & SPS CERN Sep-Oct

- ➔ **Commissioning of the new DAQ**
- ➔ **First tests for physics**

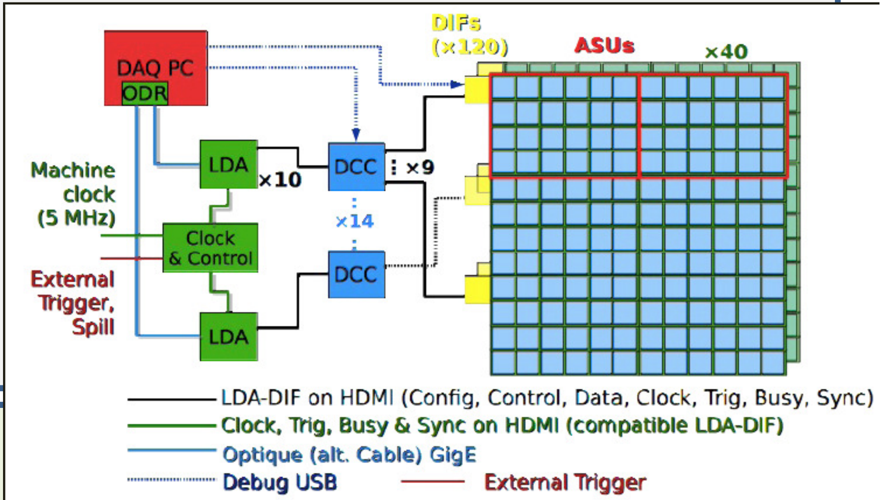
But not enough to perform a study.

Still some problems with the DAQ

An improved (and provisional) version of the DAQ:

HDMI used for synchronization and control

USB used for the readout of data



DAQ system scheme

2012

Test beam@CERN: PS - April SPS (H2,H6) May, Aug-Sep, Nov

A lot of data taken:

cosmics, muons from beam, pions and electrons at different Energies

One CALICE note published recently and more analysis going on

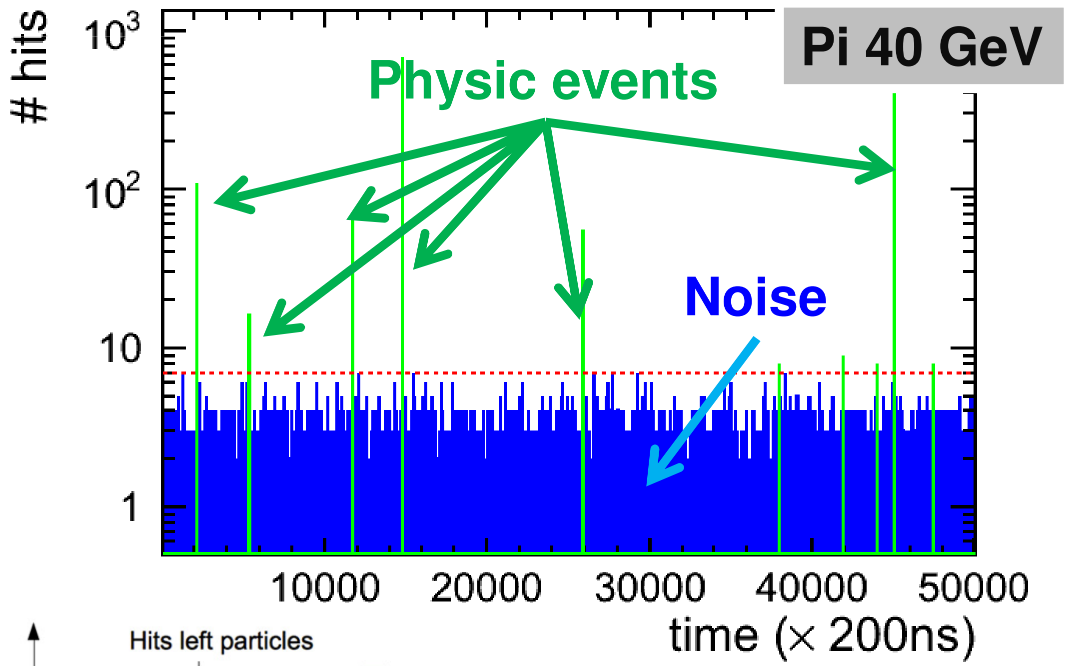
Noise

Power pulsed and trigger less acquisition:

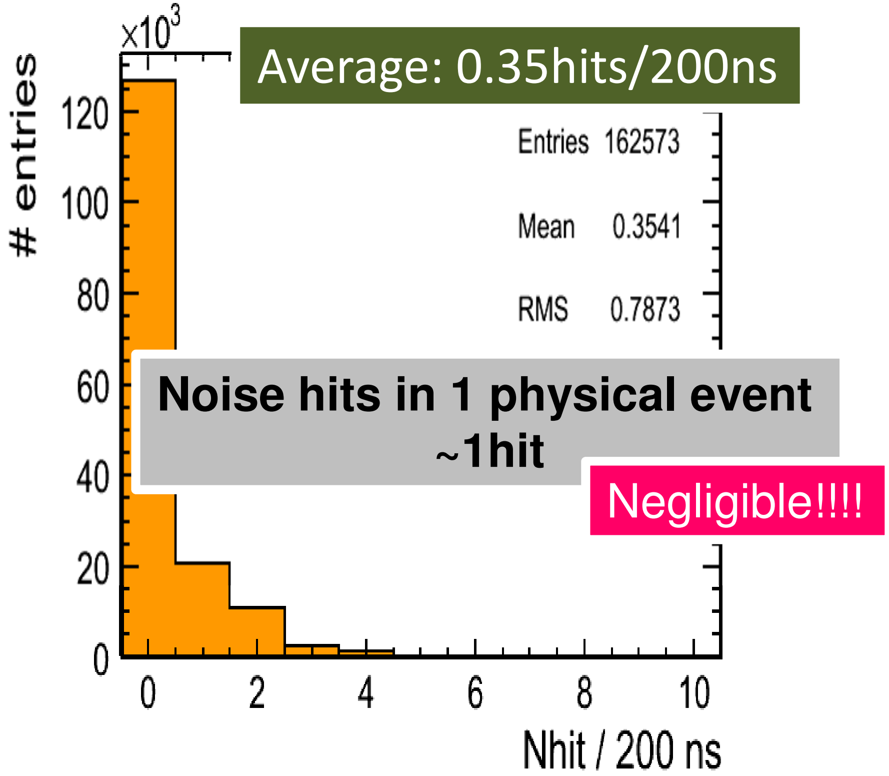
Switch on when spill arrives, off at the end of spill and record events until memory is full

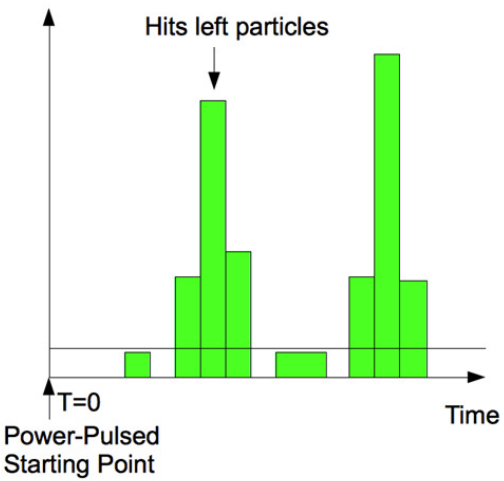
➔ The run contains also noise

Hit time distribution for a single spill



Noise hits in a time slot of 200ns

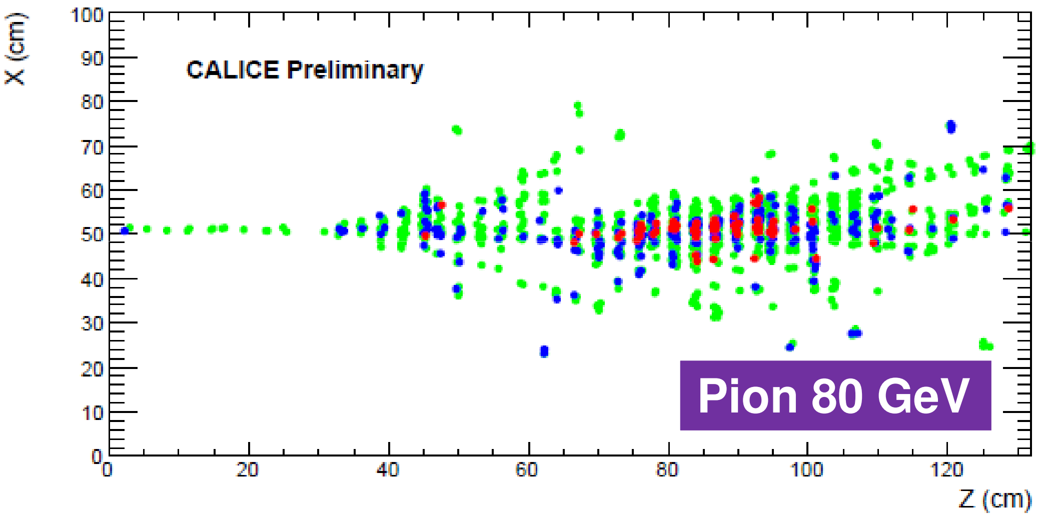


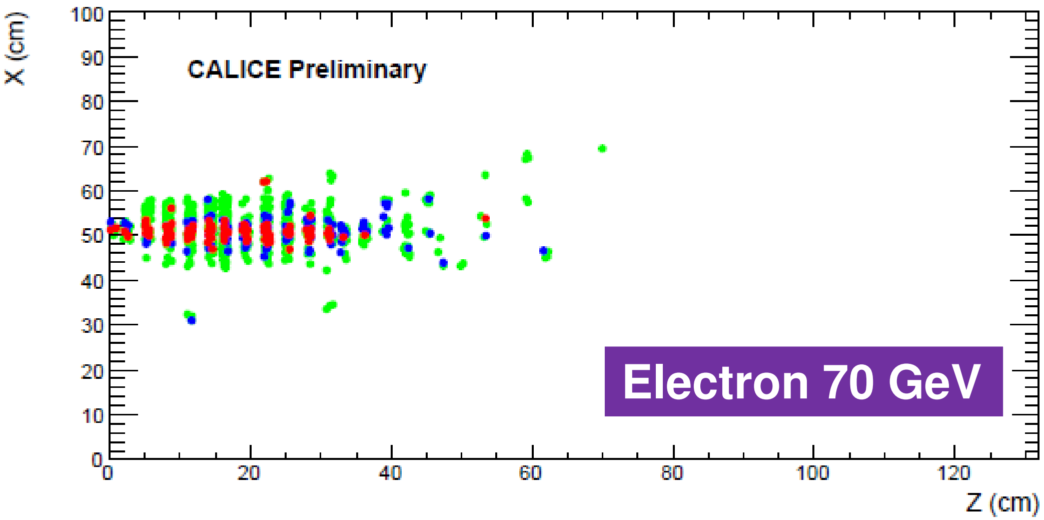


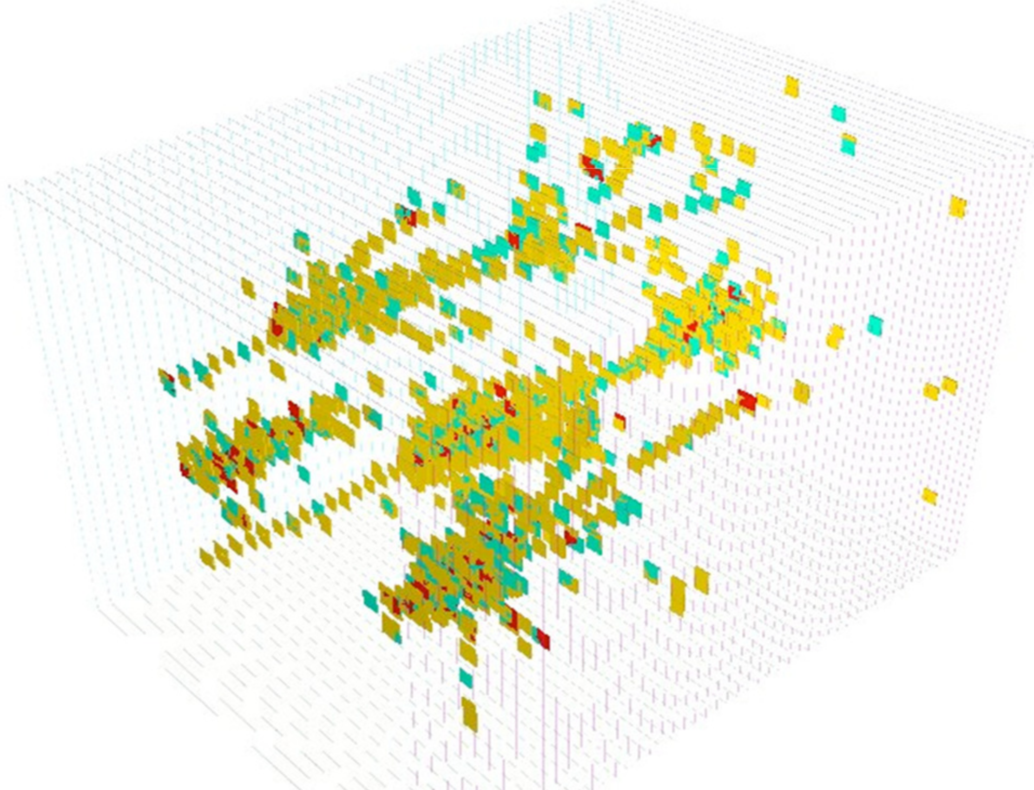
Bin=electronic clock tick: 200ns

1 Physic Event = 3 clock ticks

Event Displays – Raw Data







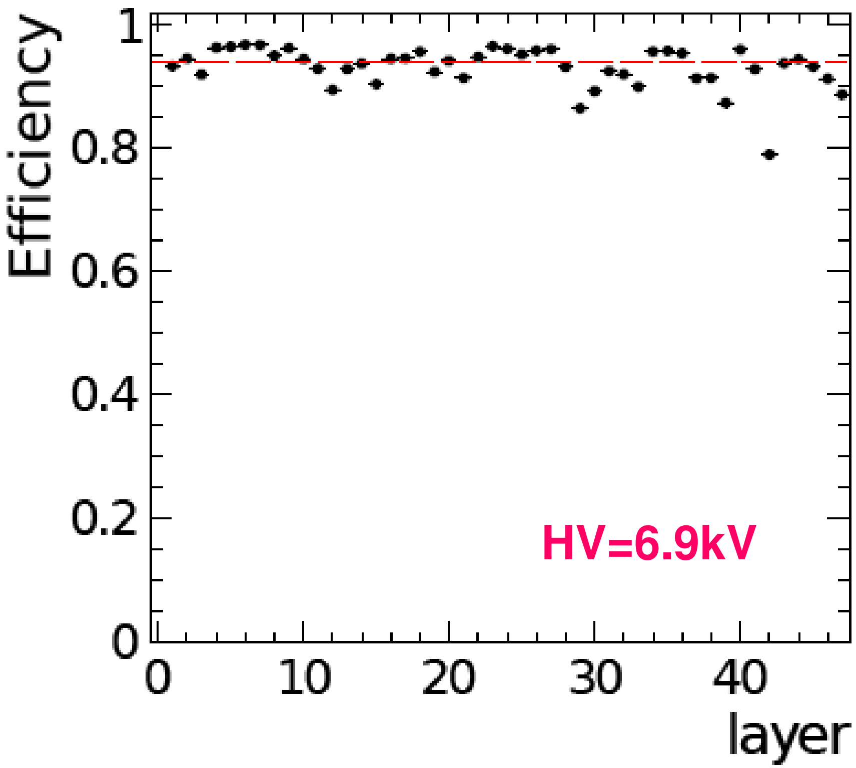
Nice separation of close-by hadronic showers

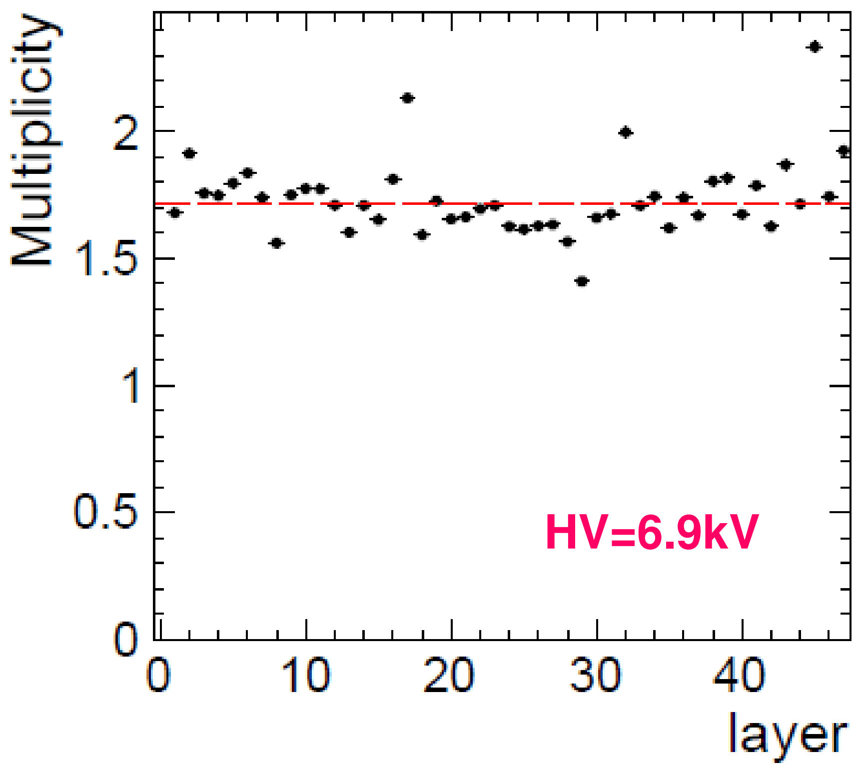
- **First threshold (114 fC ~ 0.1 mip)**
- **Second threshold (5pC ~ 4 mip)**
- **Third threshold (15 pC ~12.5 mip)**

Efficiency & Multiplicity

Muons are used to compute the efficiency and multiplicity.
To compute efficiency the track must have cluster signals in at least seven layers (the muons cross the full detector, 48 GRPC Layers) and chi2<20.

A chamber is considered efficient if it has a hit at a distance of less than 3cm around the expected position (The hits in the layer under study are not used to compute the track)





Gas: TetraFluoroEthane (TFE) (93%), CO_2 (5%), SF_6 (2%)

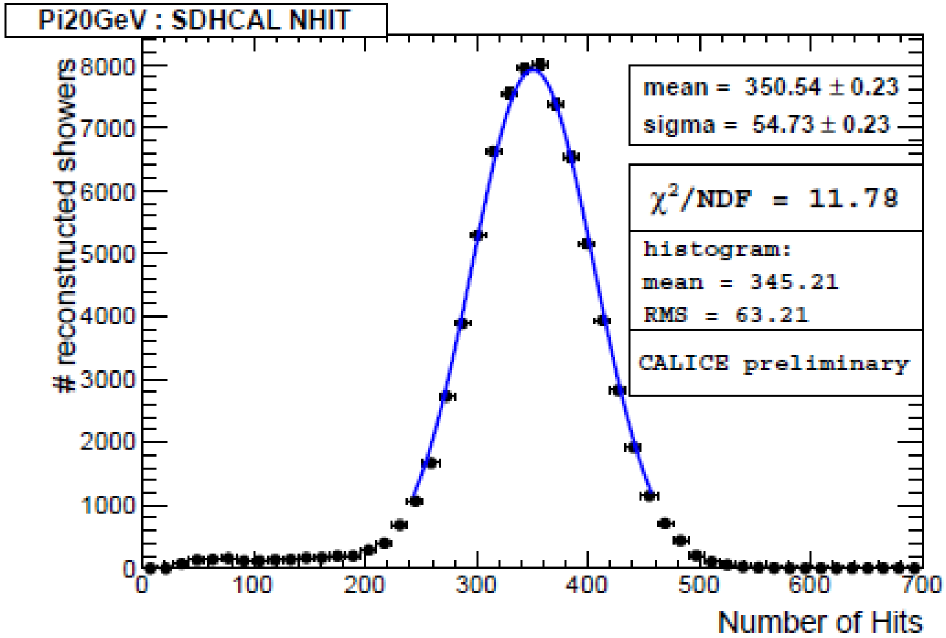
Hit Distribution – Binary mode

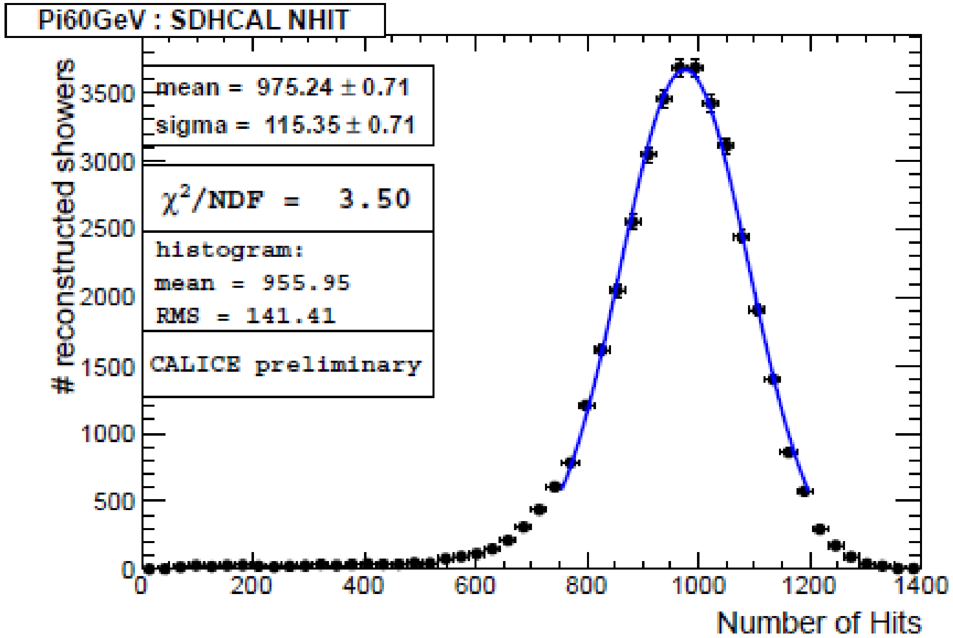
Counting the total number of hits (without taking into account which threshold was fired)

Uncalibrated – No gain corrections

Cuts applied:

- **First plate should be one of the first four plates to remove showers induced by cosmics**
- **Interaction occurs in the first 15 planes to remove late interacting hadrons**
- **The ratio of hits in the last 7 planes to the number of hits in the first 30 should be < 0.15**



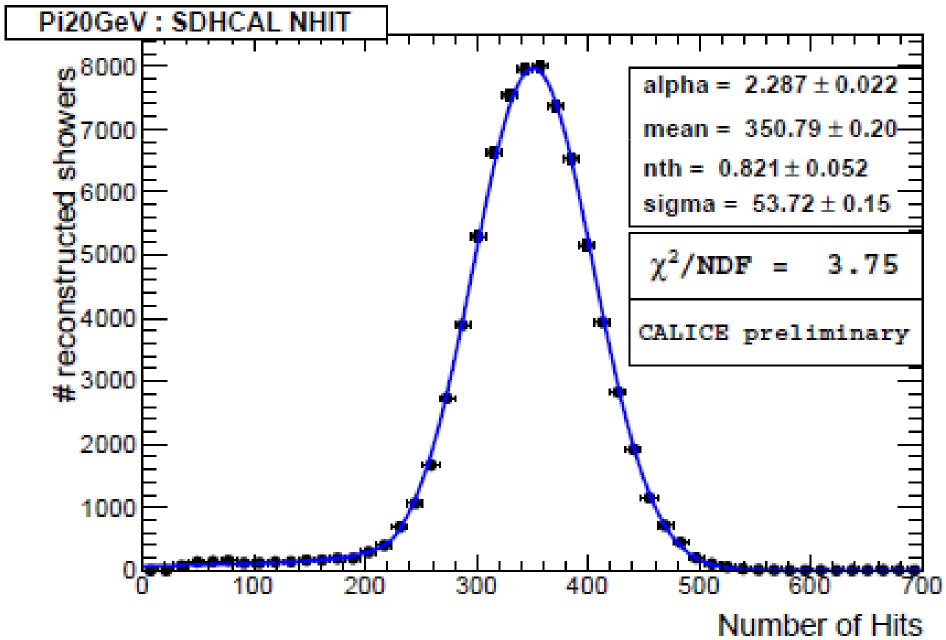


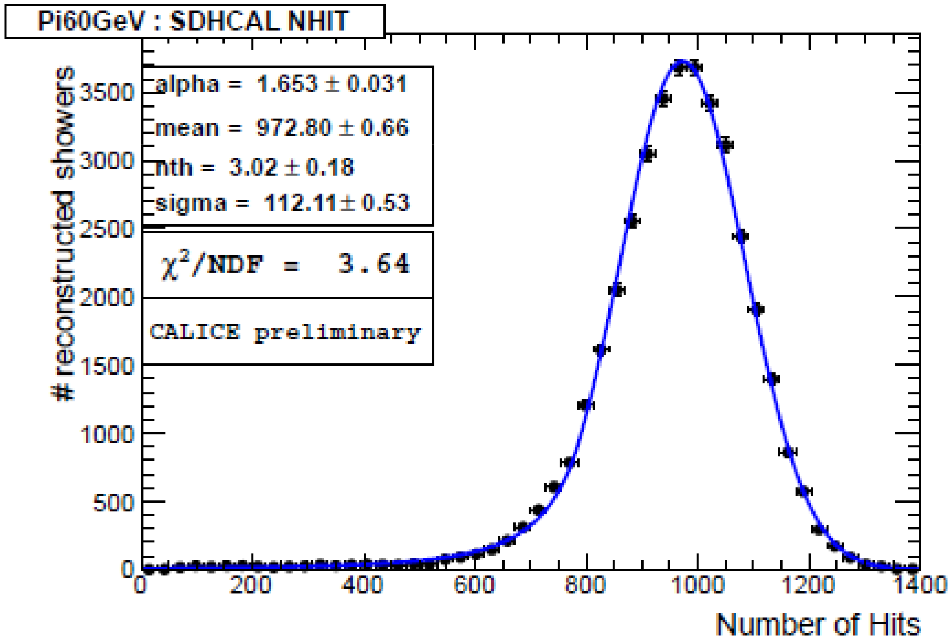
Gaussian Fit in the range of 2 standard deviations around the mean value

To take into account the tails we have used also a Crystal Ball function (next slide)

Hit Distribution – Binary mode

Counting the total number of hits (without taking into account which threshold was fired)





Crystal Ball function

Gaussain core and a power-law low-end tail, below a certain threshold

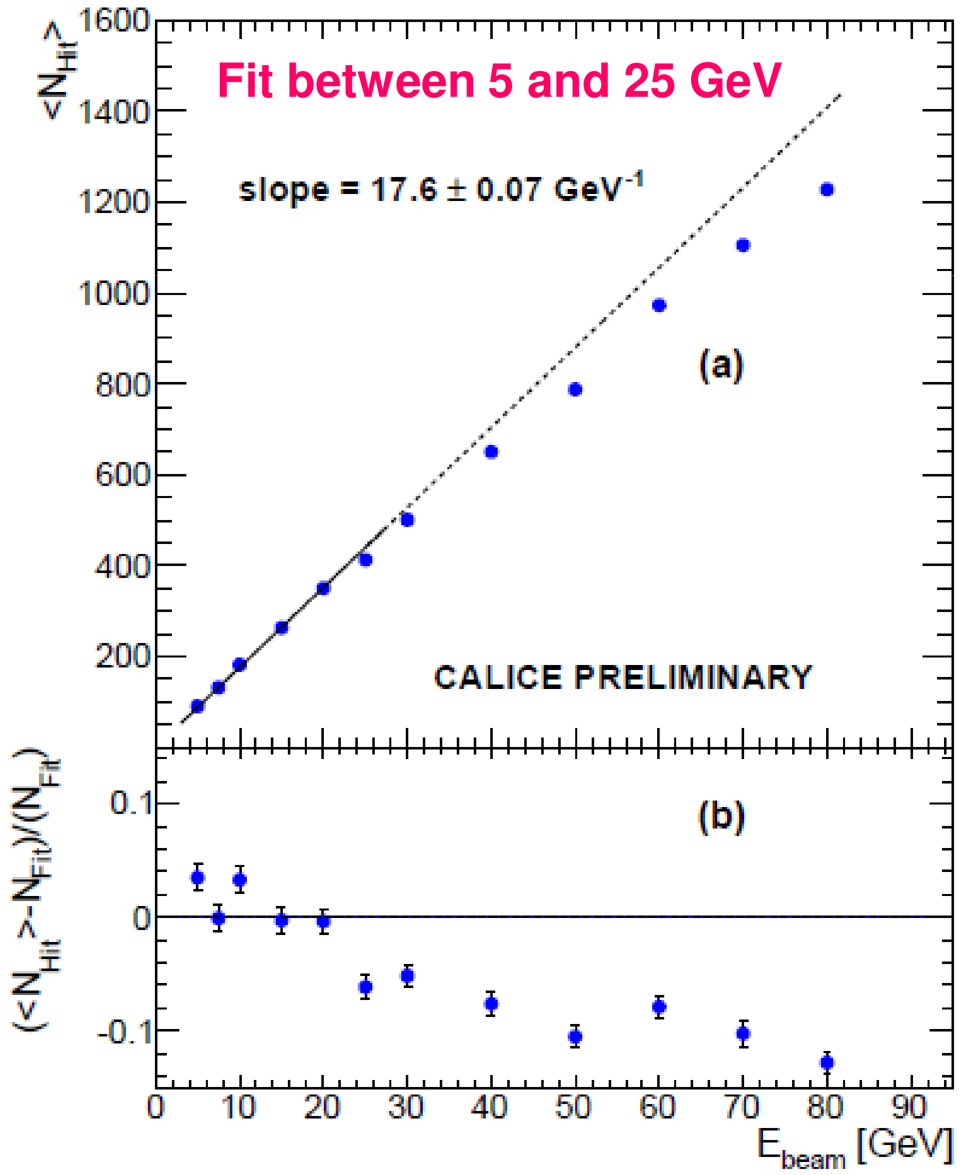
$$f(x;\alpha,nth,\bar{x},\sigma) = N \cdot \begin{cases} \exp(-\frac{(x-\bar{x})^2}{2\sigma^2}) & \text{for } \frac{x-\bar{x}}{\sigma} > -\alpha \\ A \cdot (B - \frac{x-\bar{x}}{\sigma})^{-nth} & \text{for } \frac{x-\bar{x}}{\sigma} \leq -\alpha \end{cases}$$

$$A = \left(\frac{nth}{|\alpha|}\right)^{nth} \cdot \exp\left(-\frac{|\alpha|^2}{2}\right)$$

N= normalization factor

$$B = \frac{nth}{|\alpha|} - |\alpha|$$

Number of hits (binary) vs Energy



$E = C \times Nhit$

Deviation from linearity at higher energies suggest to replace the constant C by a linear function C + D x Nhit

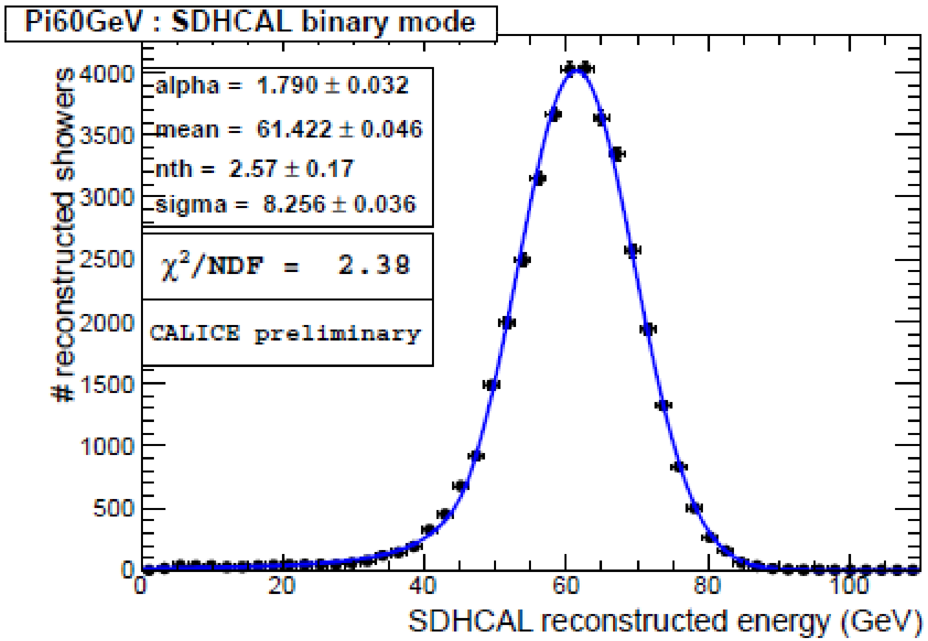
$E = (C + D \times Nhit) \times Nhit$

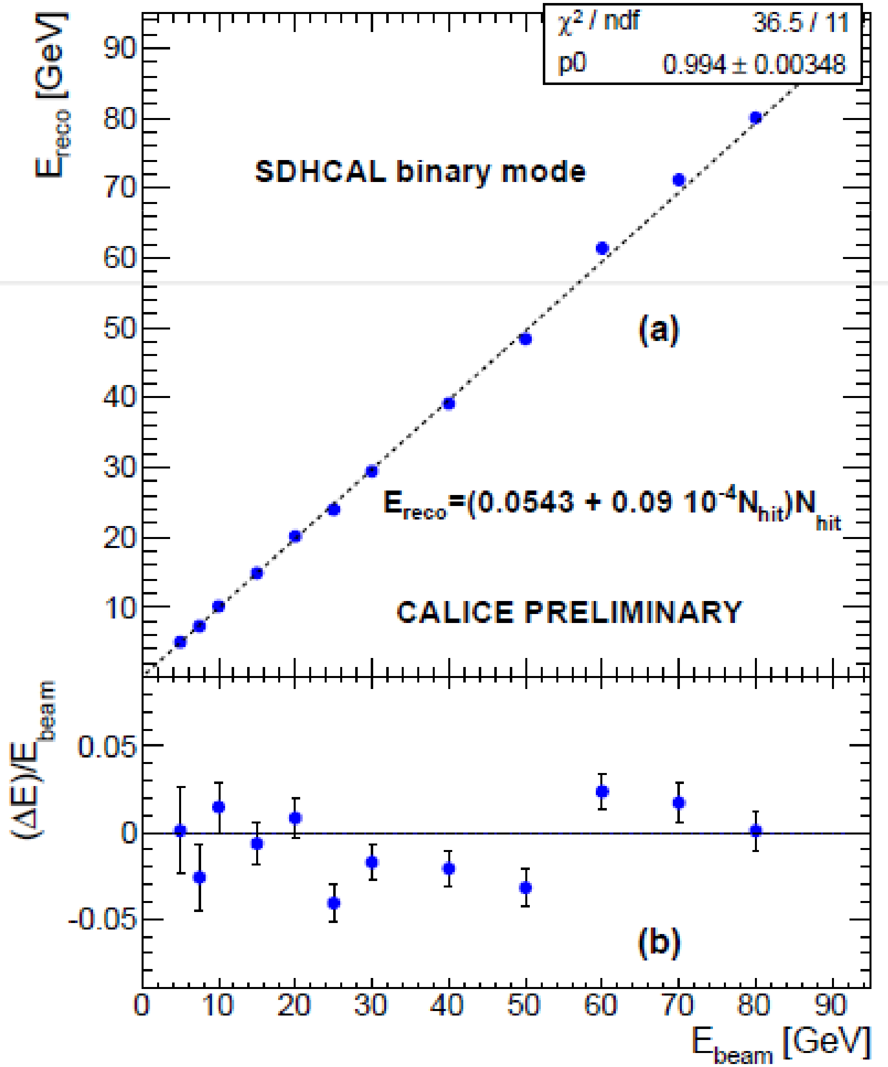
C=0.0543, D=0.09x10^{-4}

Reconstructed Energy (Binary mode)

E = (C + D x Nhit) x Nhit

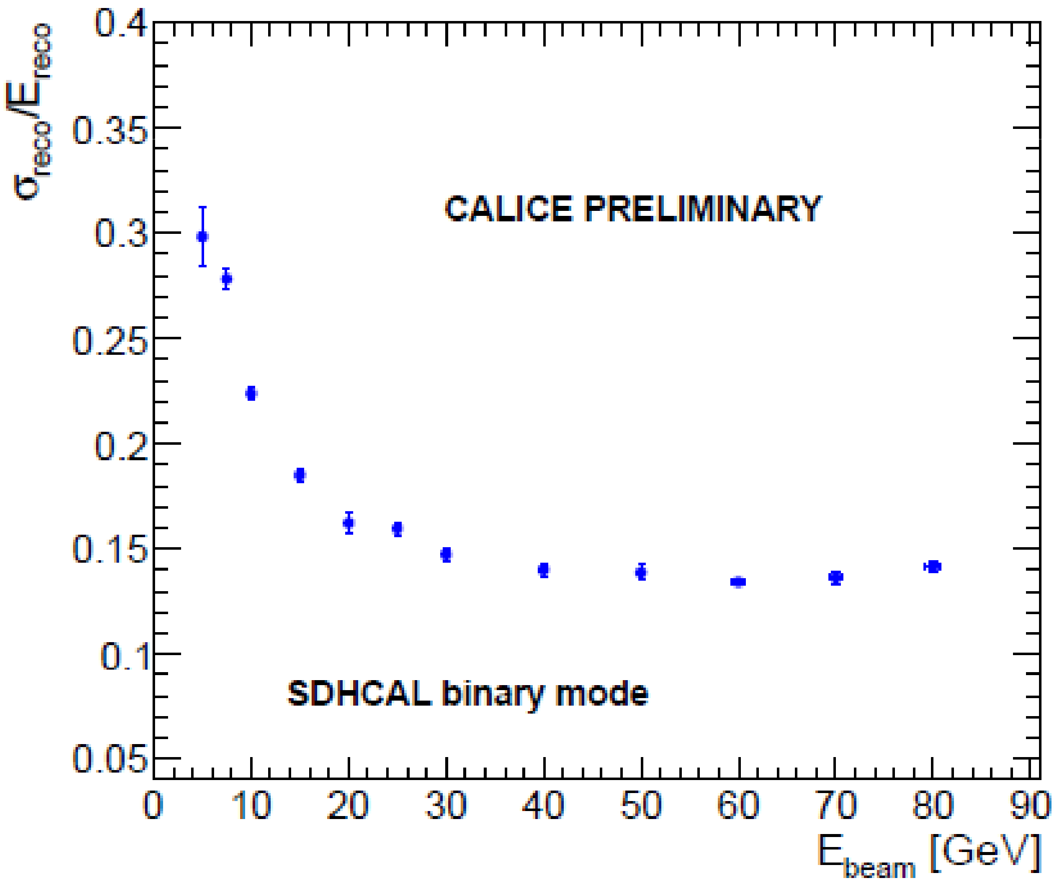
C=0.0543, D=0.09x10^{-4}





As expected, this method of shower energy resolution restores linearity

Resolution vs Energy – Binary mode



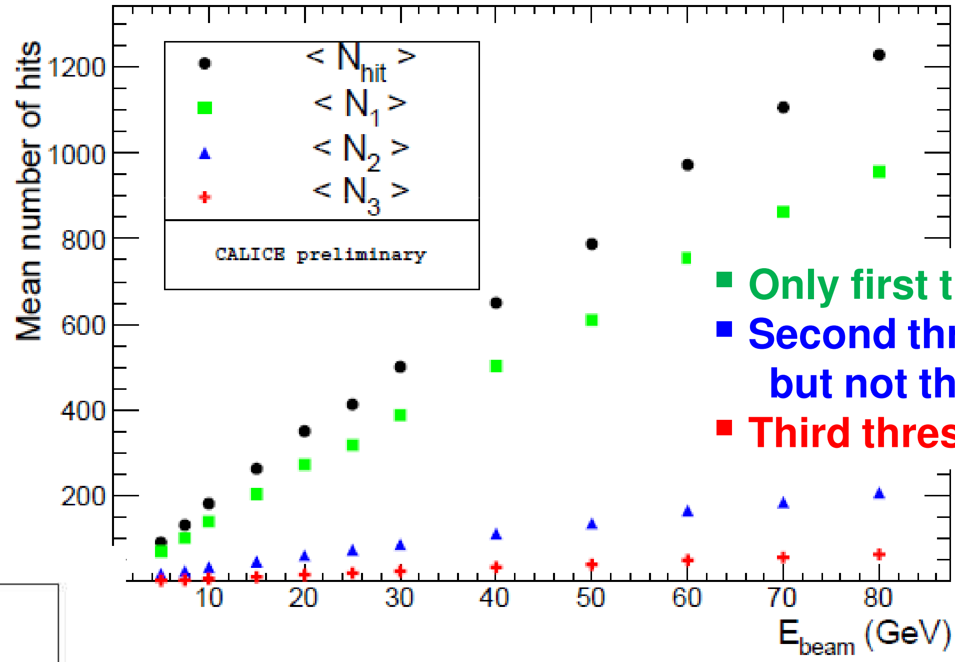
Energy reconstruction using different threshold

$E_{rec} = \alpha N1 + \beta N2 + \gamma N3$

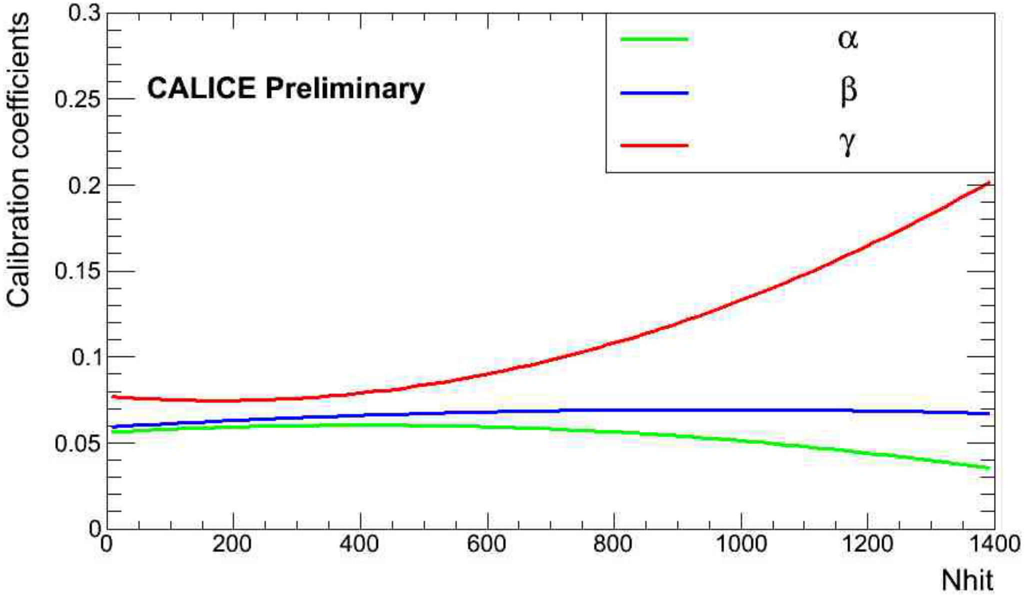
α, β, γ depends on the Energy.
It can be parametrized as a funcion of Nhit (=N1+ N2 +N3)
Different functions of Nhit were tested.
Trying to minimize:

$$\chi^2 = \Sigma_{i=1}^{N} \frac{(E^i_{\rm true} - E^i_{\rm rec})^2}{E^i_{\rm true}}$$

Average number of hits for each threshold



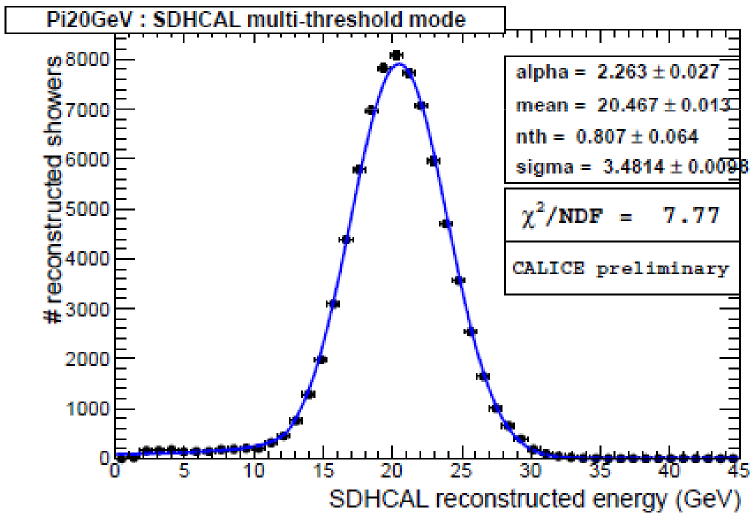
- **Only first threshold**
- **Second threshold but not third one**
- **Third threshold**

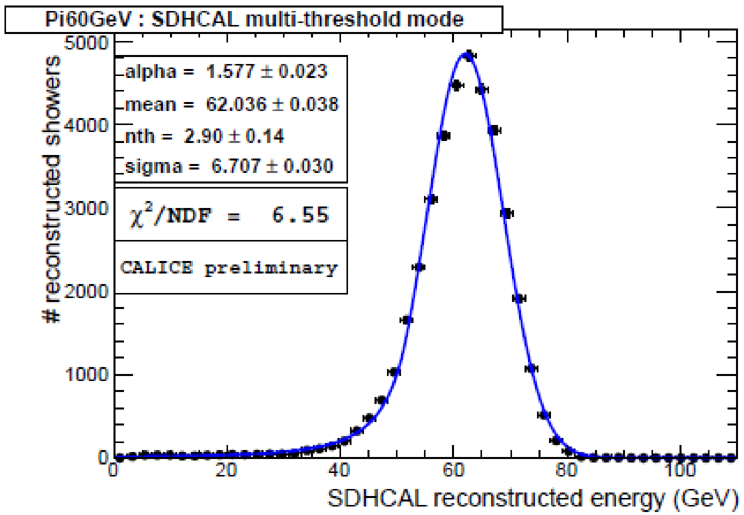


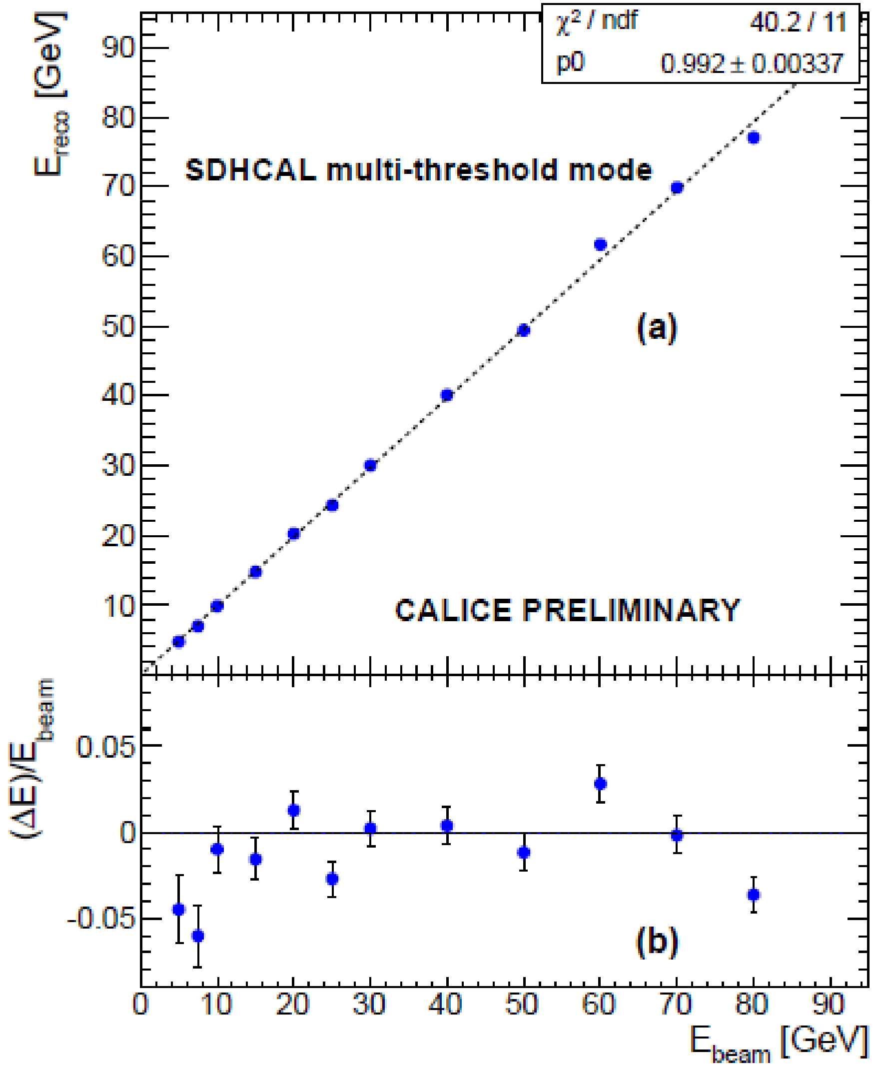
Parametrization of α, β, γ as a function of Nhit

Energy Reconstruction Multi-threshold mode

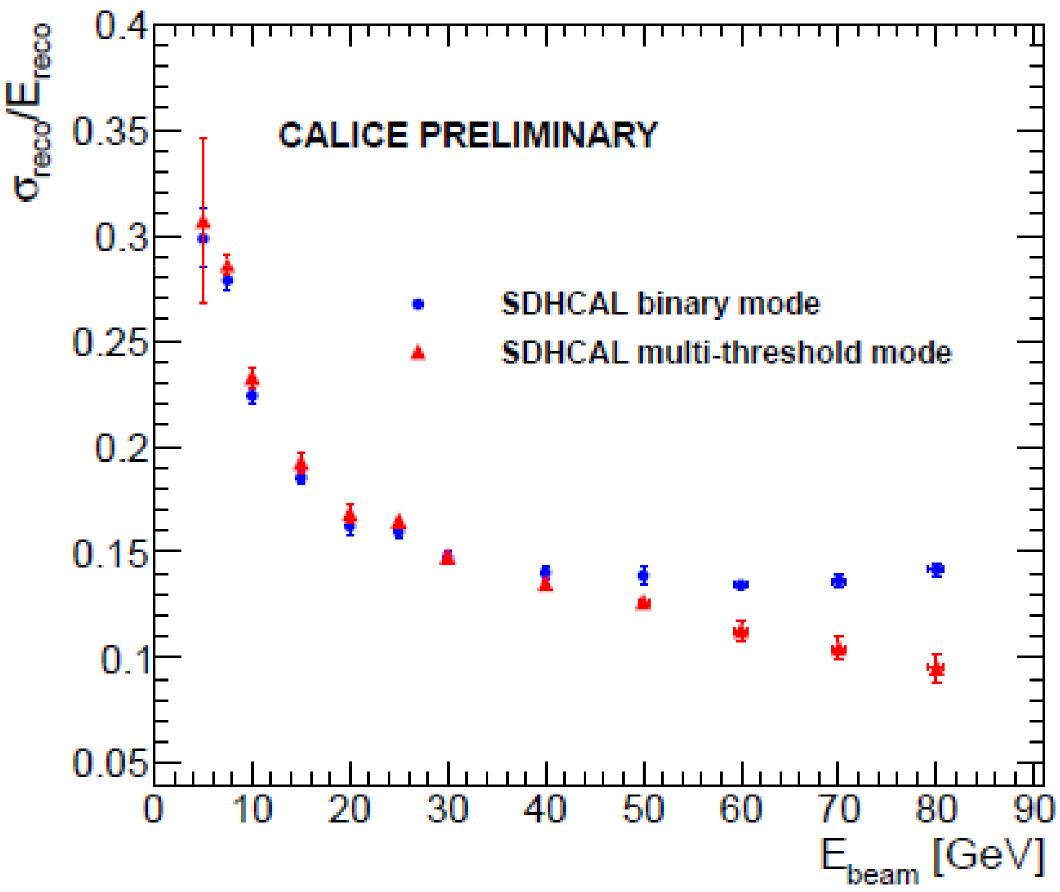
$$E_{rec} = \alpha N1 + \beta N2 + \gamma N3$$

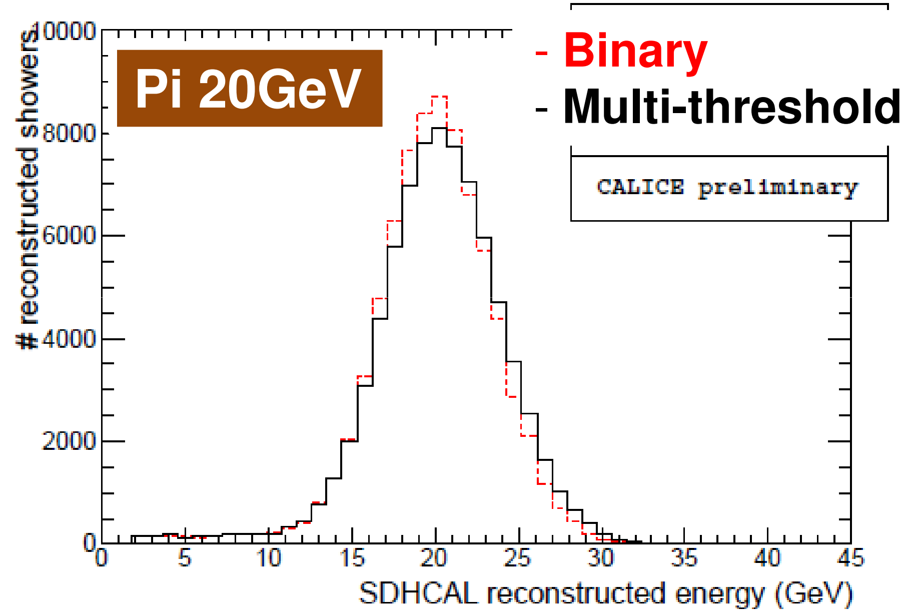


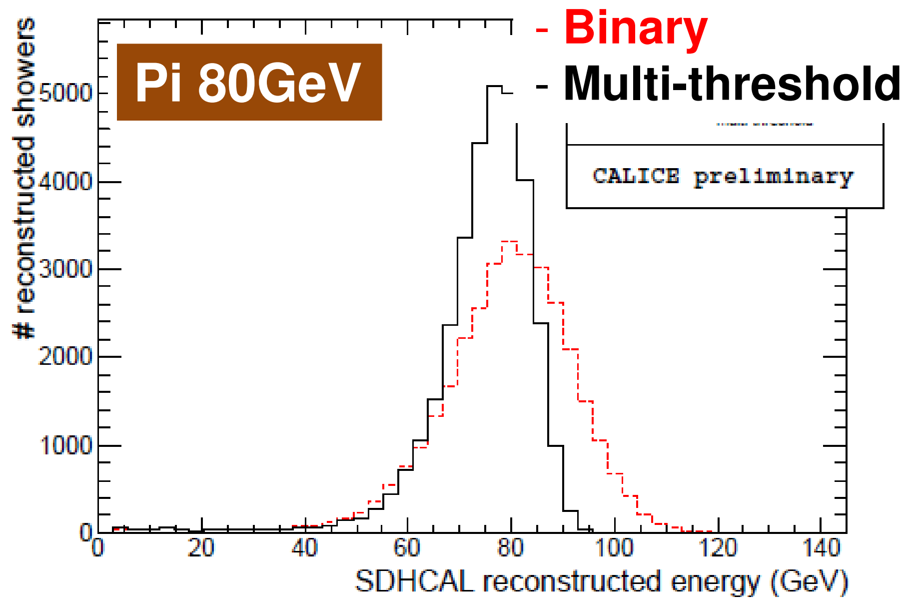




Resolution vs Energy.
Binary & Multi-threshold mode







Muti-threshold improves resolution for high energy

Summary

A **SDHCAL technological prototype** has been **built** and **successfully tested** in different test beam campaigns at PS and SPS at CERN

The **DAQ worked well** in **trigger less** and power **pulsing mode**

First analysis show a good performance has been obtained even without a calibration

The use **of multi-threshold** information **improves** the **resolution** for energies > 30-40 GeV

More studies (in **short term**) still pending and **more data** to be analyzed.

In particular

- Apply gain corrections, local calibrations
- Response to electrons
- The last test beam data with 4 Micromegas used as tail catcher still to be analyzed
- Comparisons with simulation

Ciemat group has an important contribution in all this work:

- Mechanics design and construction of the prototype
- Final assembly at CERN
- Participation in the different test beam data periods
- Data Analysis

And now starting the design of a new DIF (Detector InterFace) card