SCECAL Beam Test Results

TILC09 @ Epochal Tsukuba

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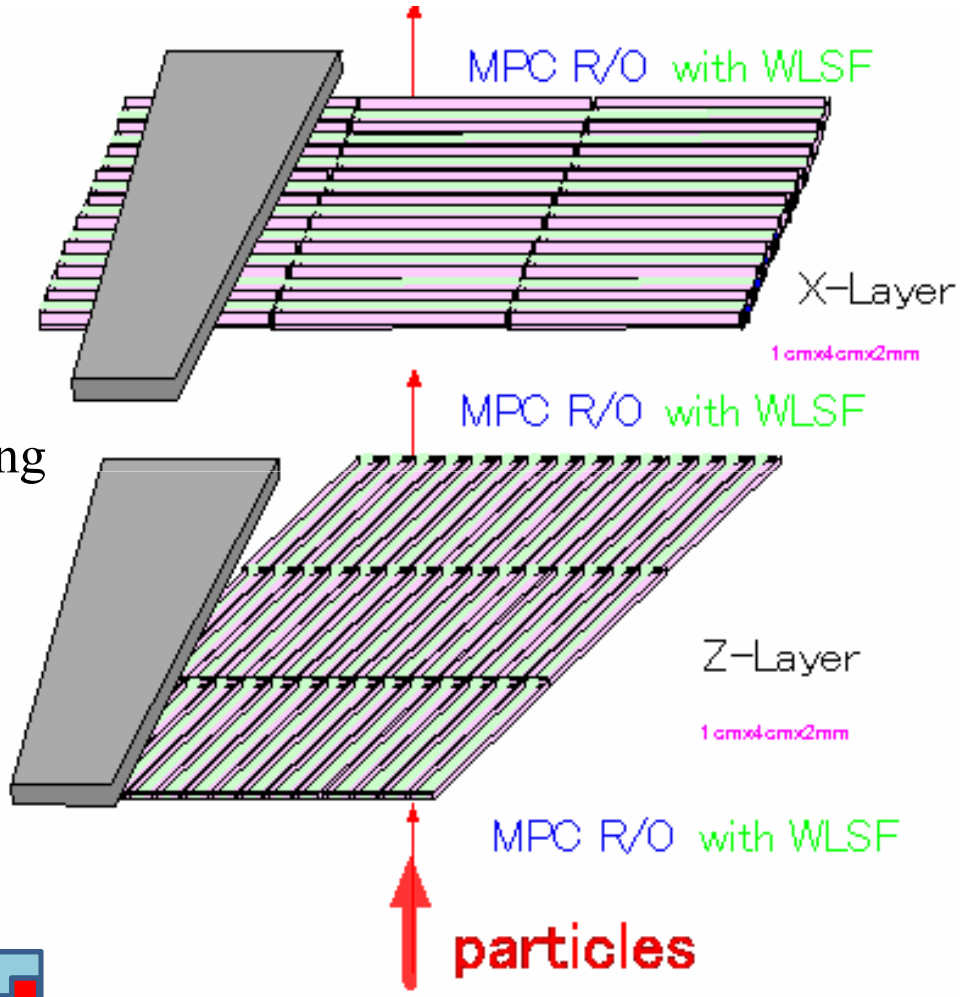
for the GLDCAL Group / CALICE Collaboration

The Scintillator-Strip Electromagnetic Calorimeter

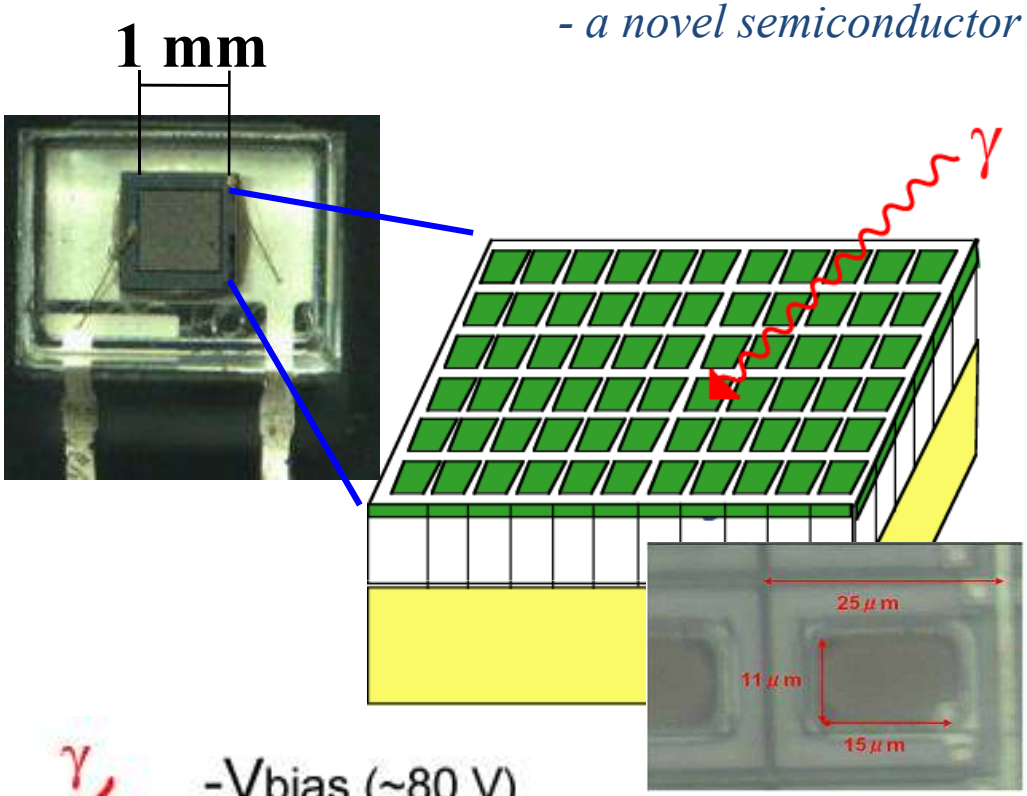
- Sampling calorimeter with Tungsten-scintillator sandwich structure.
- Scintillator strip technology adopted to achieve fine granularity.
- Huge Number of channels (~5M for ECAL).
- Need to solve many challenging issues
  - Establish the components while keeping low production costs
  - Stability & Robustness
- **First need to establish the feasibility!**



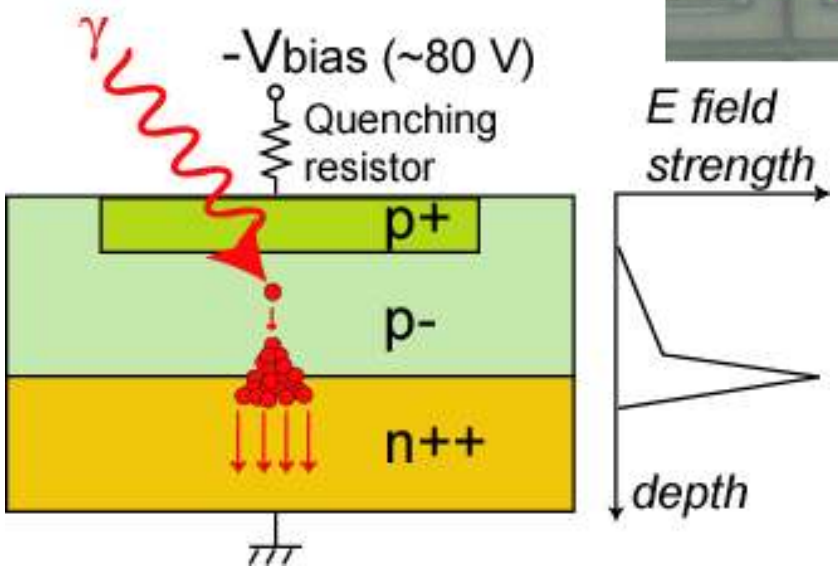
Scintillator strip
(4.5 x 1 x 0.2 cm)

Development of the Multi-Pixel Photon Counter (MPPC)

- a novel semiconductor photo-sensor -

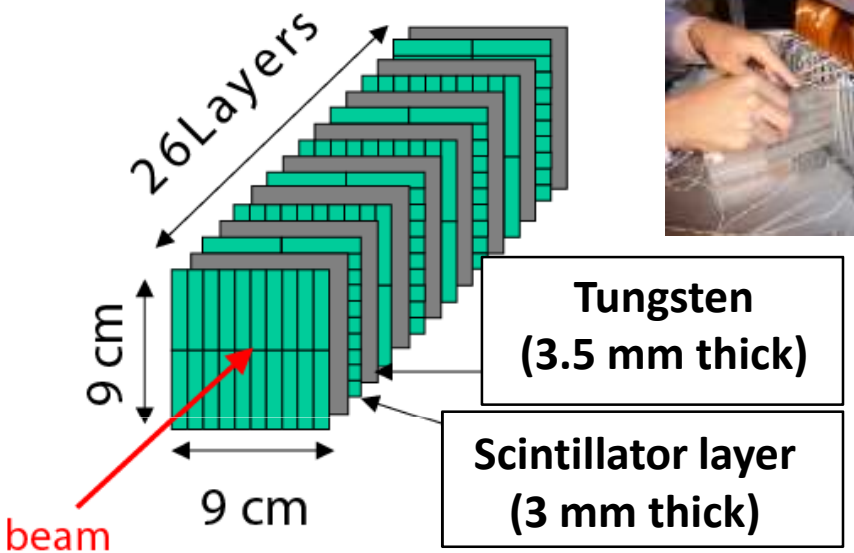


- Consists of Geiger-mode APD pixel matrix.
- High Gain (10^5~10^6)
- Enough Photon Detection Efficiency (~15% with 1600 pixel)
- Compact (package size ~ a few mm)
- Low Cost
- Insensitive to magnetic field
- Dark noise exists (~100 kHz)
- Input vs output is non-linear

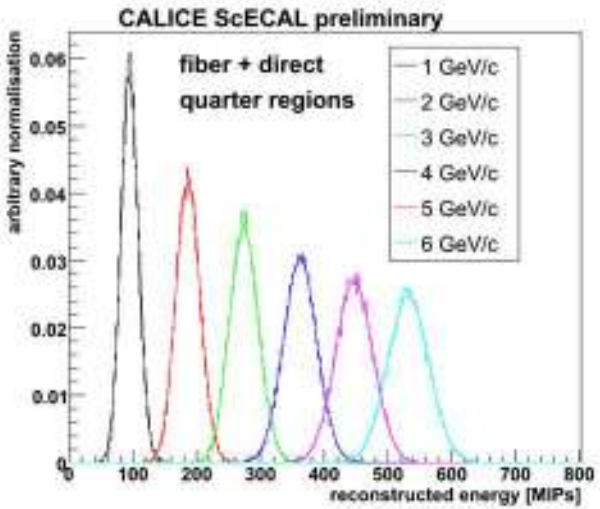


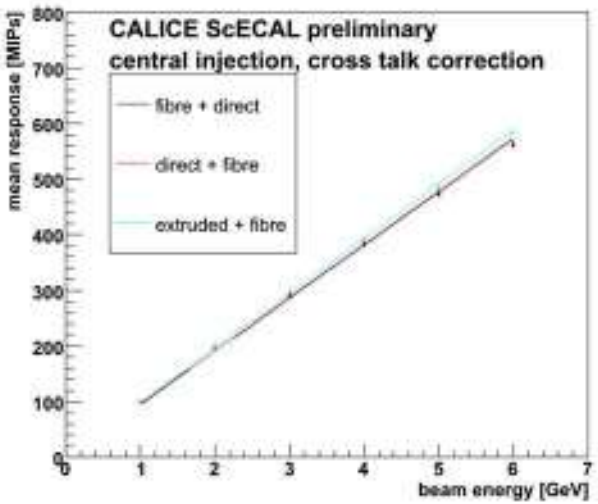
- We are developing and studying the MPPC with Hamamatsu Photonics / KEKDTP group.
- Reasonably good performance has been achieved so far for Sci-Strip readout.

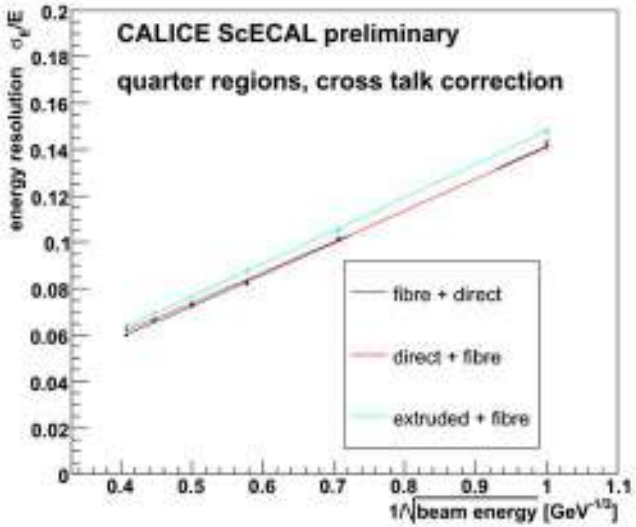
1st small prototype performance (tested in 2007 at DESY, 1-6 GeV e^+)



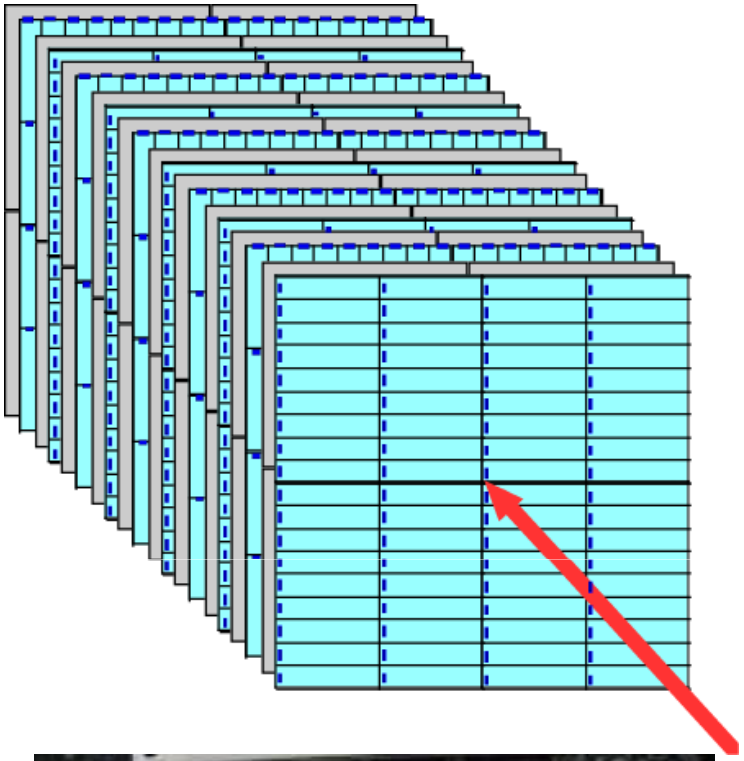
- The 1st prototype tested at DESY electron synchrotron.
- Results show sufficient feasibility in 1-6 GeV e^+ energy.

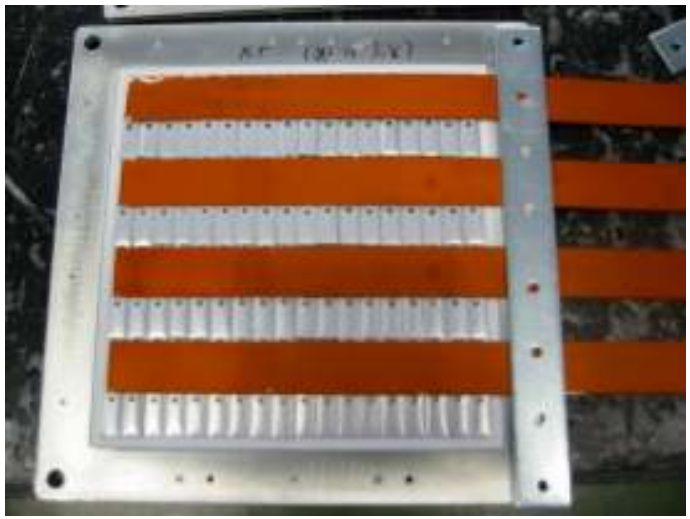






The ScECAL 2nd Test Module

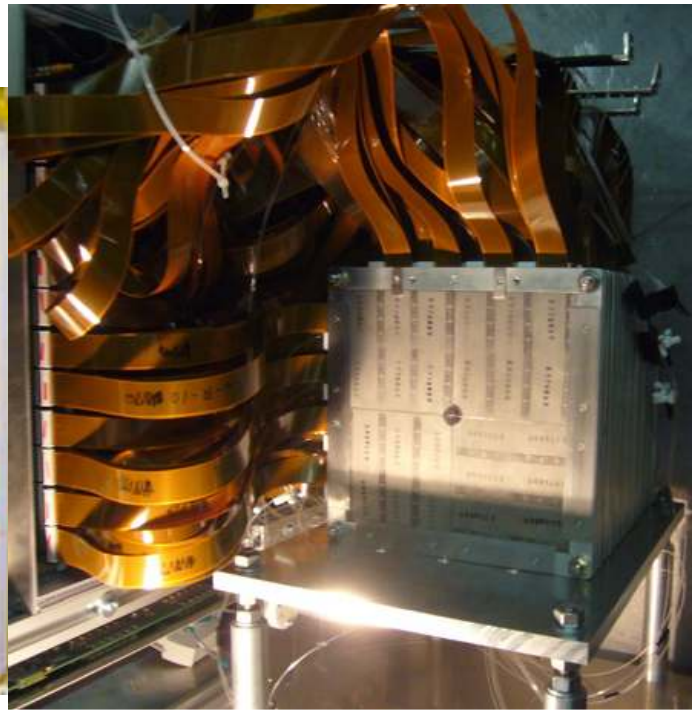




- The final test module to establish the ScECAL feasibility.
- Sandwich structure with scintillator-strips (3 mm) and tungsten layers (3.5 mm).
- Extruded scintillator and new generation photon sensor (MPPC) are fully adopted.
- Strips are orthogonal in alternate layers.
- 72 strips x 30 layers = 2160 channels.
- Overall size ~ 20 x 20 x 25 cm.

Beam Test in Sep 2008 @ MTBF

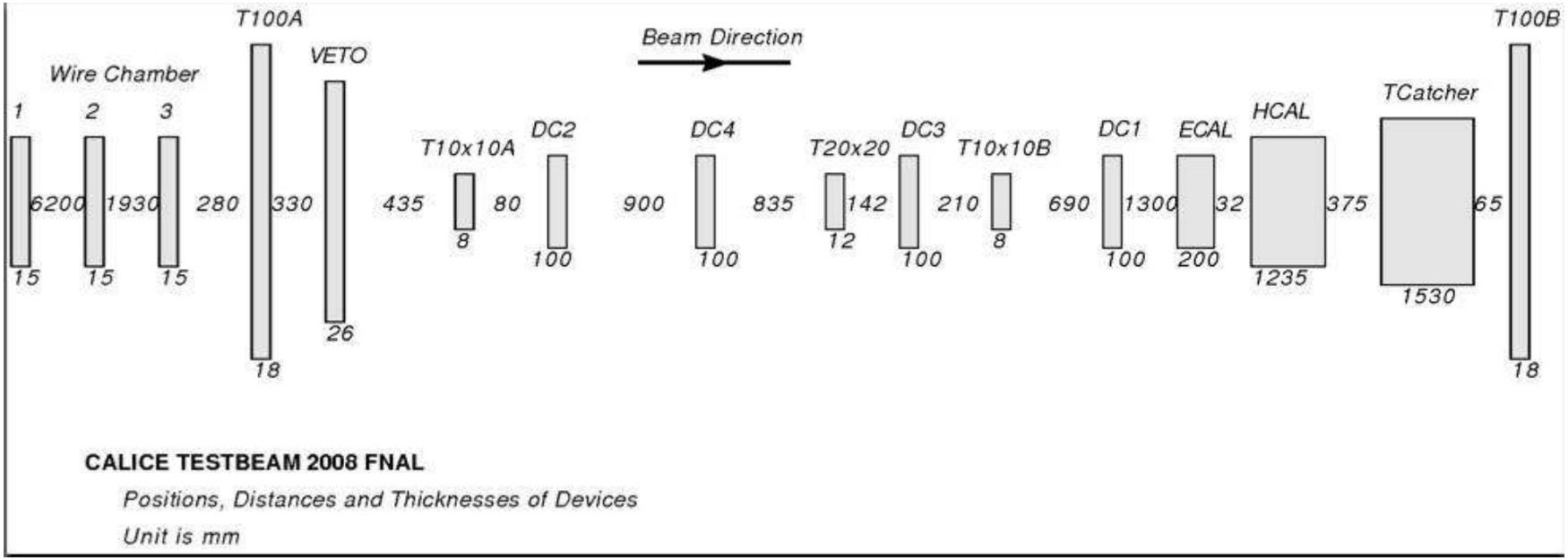
- Objective : Establish the feasibility of Scintillator-ECAL + Analog HCAL with various types of beams in wide energy range.
  - Energy resolution, Linearity for electrons and pions.
  - Position and angular scan.
  - π^0 reconstruction ability of the Scitillator-ECAL
- Beam running during Sep 3rd – 29th 2009 at FNAL Meson Test Beam Facility.



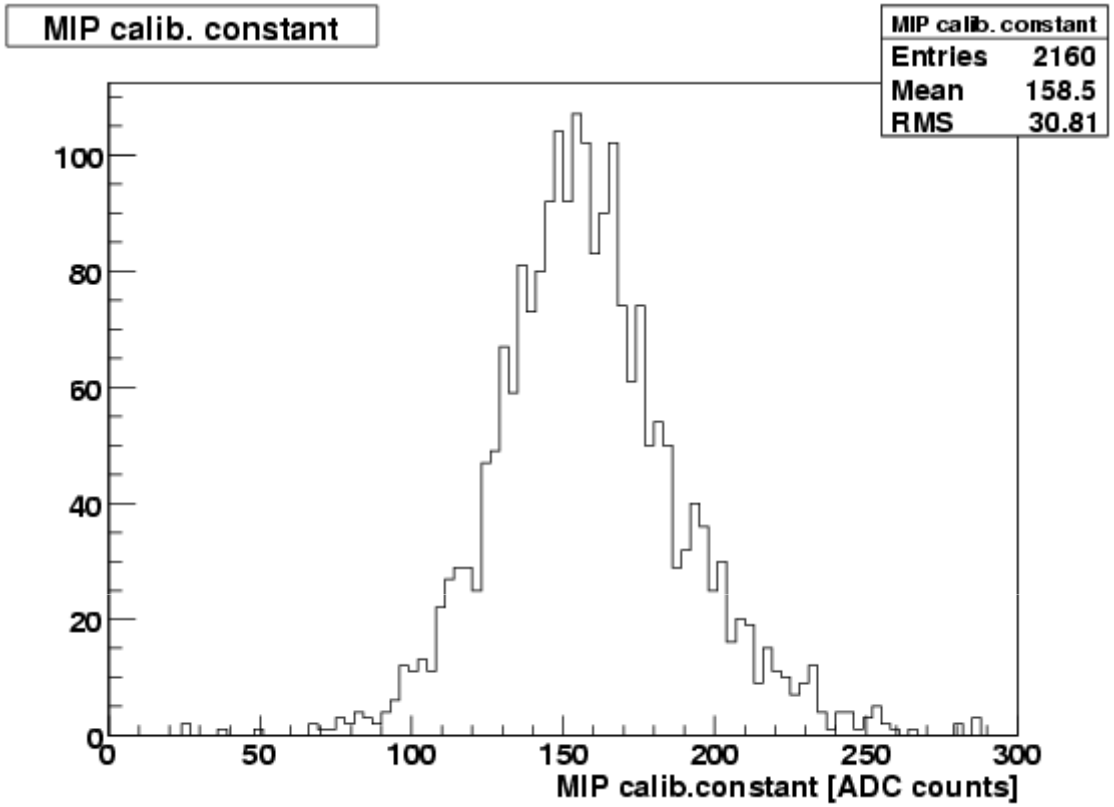
The Fermilab Meson Test Beamline

Various types of beams available

- 1-32 GeV electrons
- 1-60 GeV pions
- 32 GeV muons
- 120 GeV protons
- Cerenkov counter available to discriminate electron or pion.

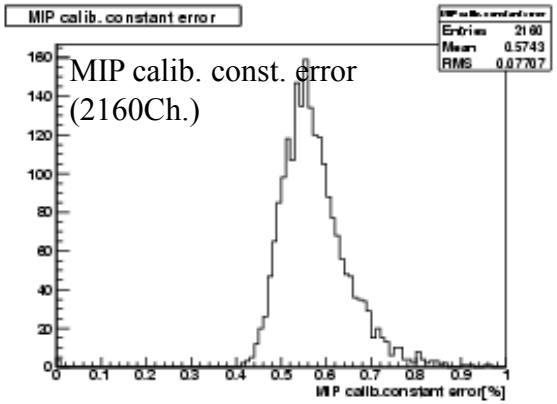


MIP calibration constants

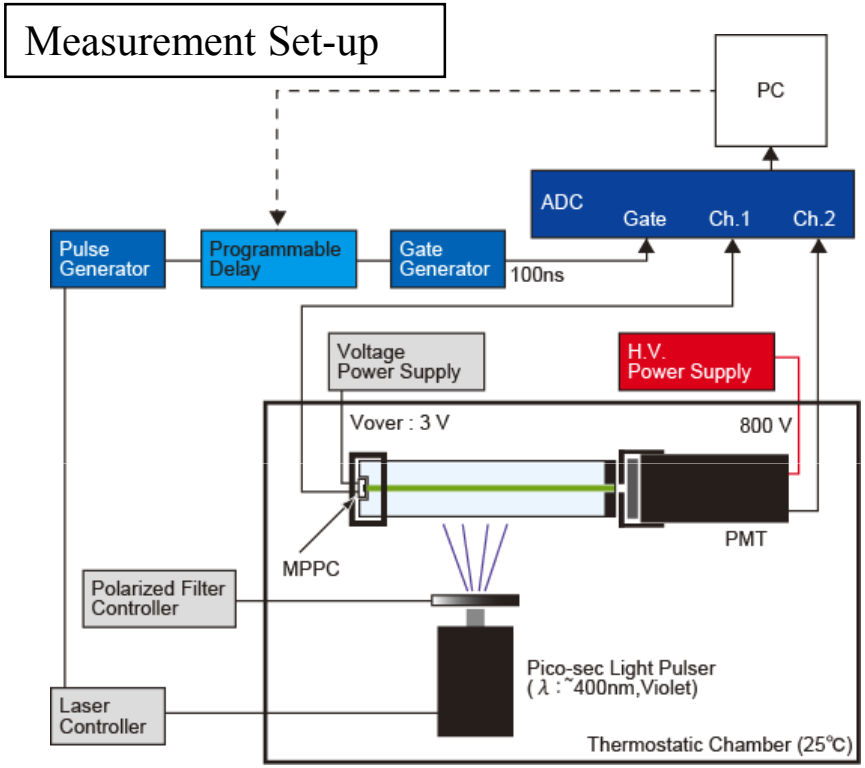


(5 channels were dead.)

The average is about 160 ADC counts / MIP, and the average of the errors is about 0.5%. For the 2160 channels, the deviation is about 20 % (30 ADC counts).



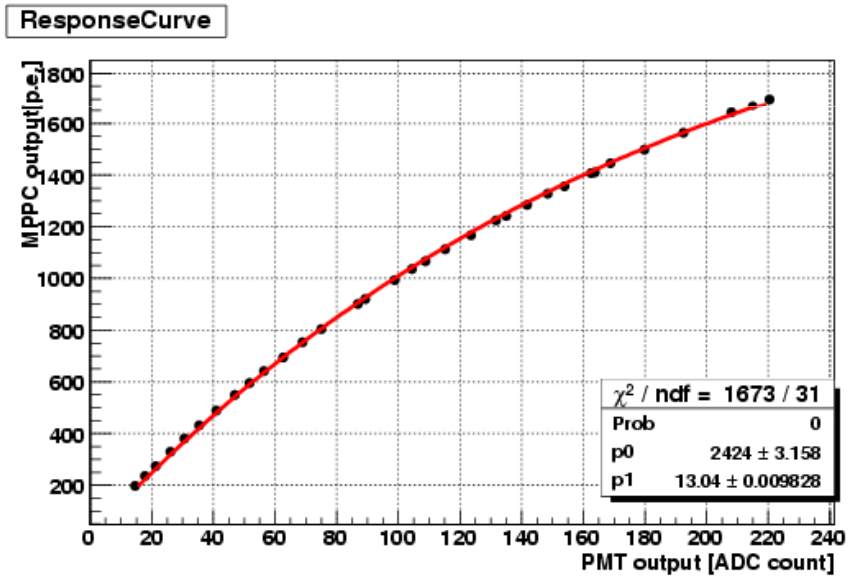
The response curve measurement



$$N_{fired} = N_{pix}\left(1-\exp\left(\frac{N_{true}}{N_{pix}}\right)\right)$$

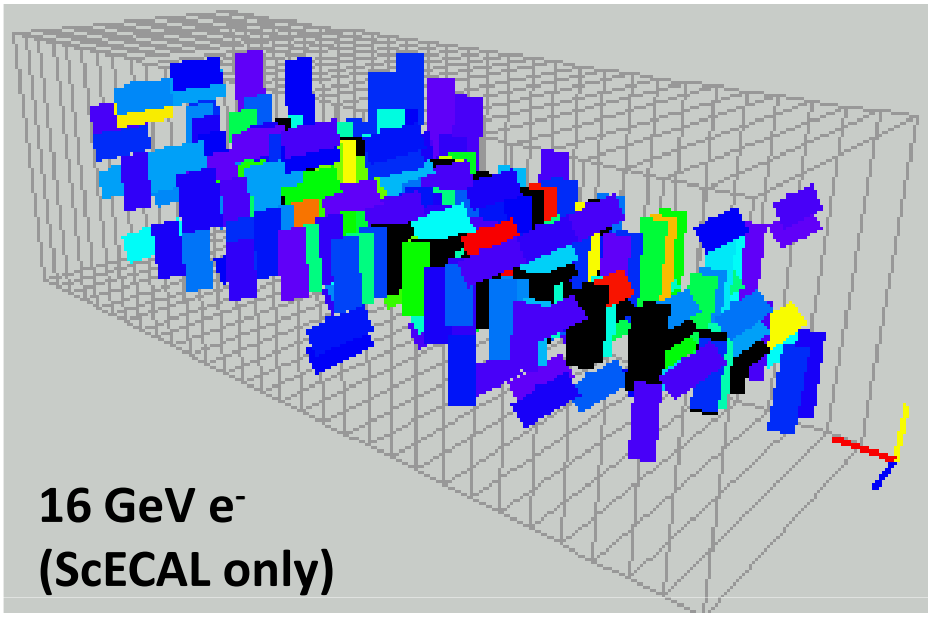
Fit function

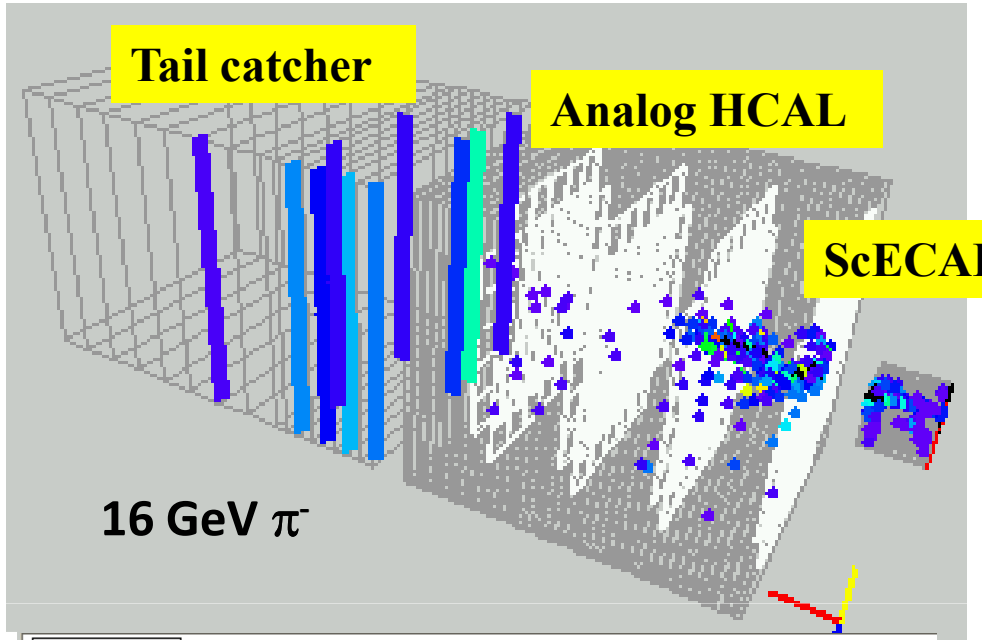
$$Output_{MPPC} = \mathrm{p0}\left(1-\exp\left(\frac{\mathrm{p1}\times Output_{PMT}}{\mathrm{p0}}\right)\right)$$

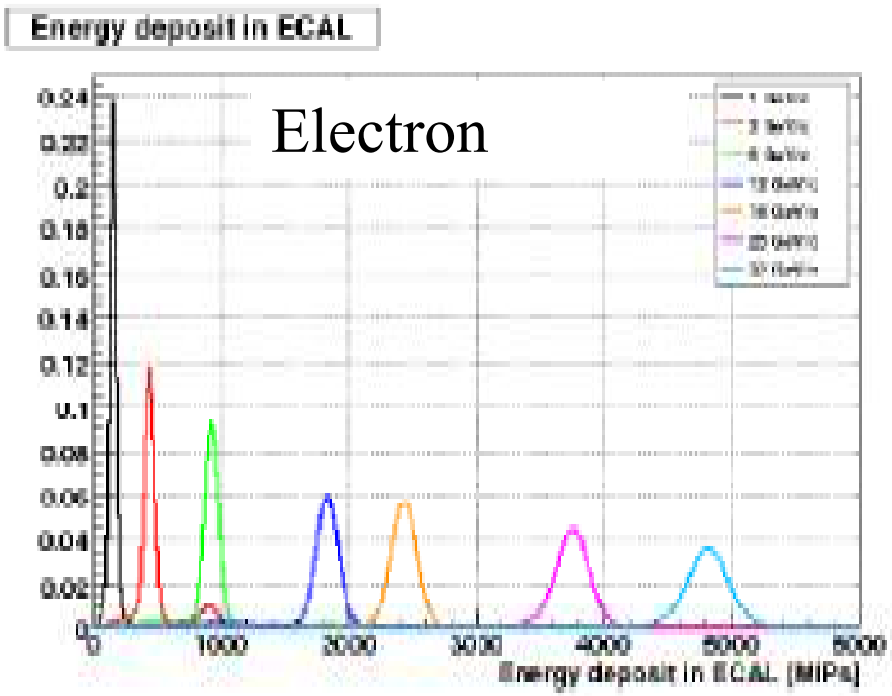


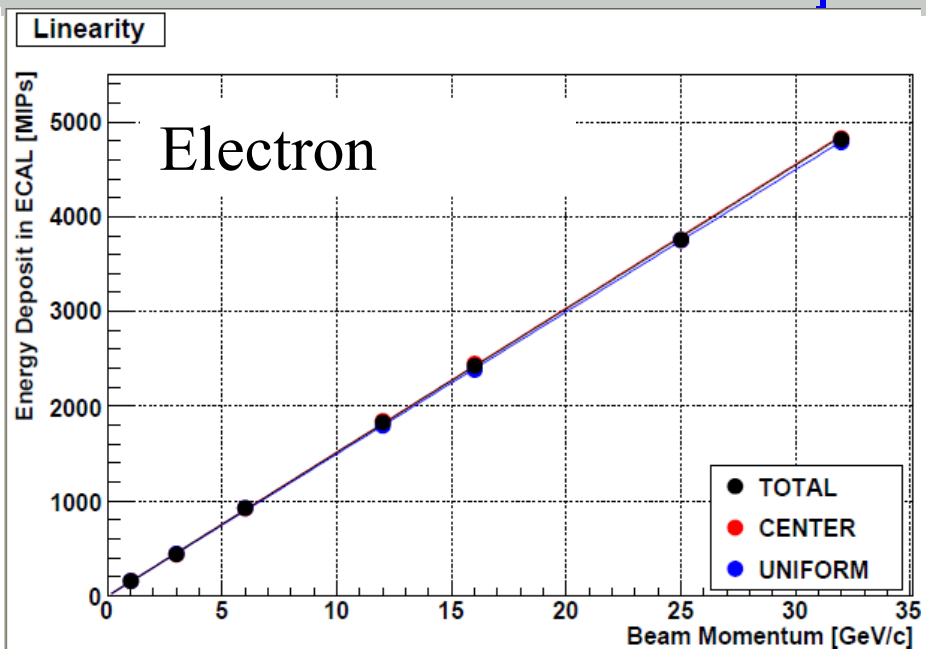
Result : N_{pix}=2424 ± 3

Very Preliminary Results





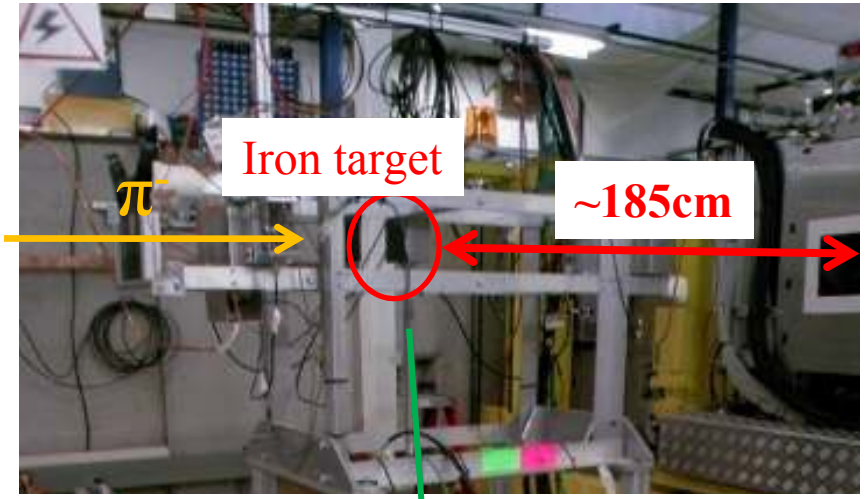


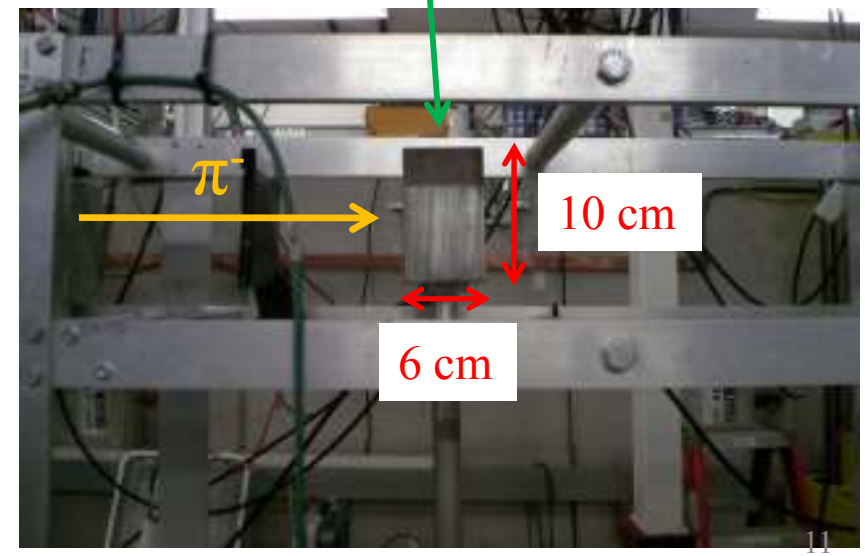


Setting for production of π^0

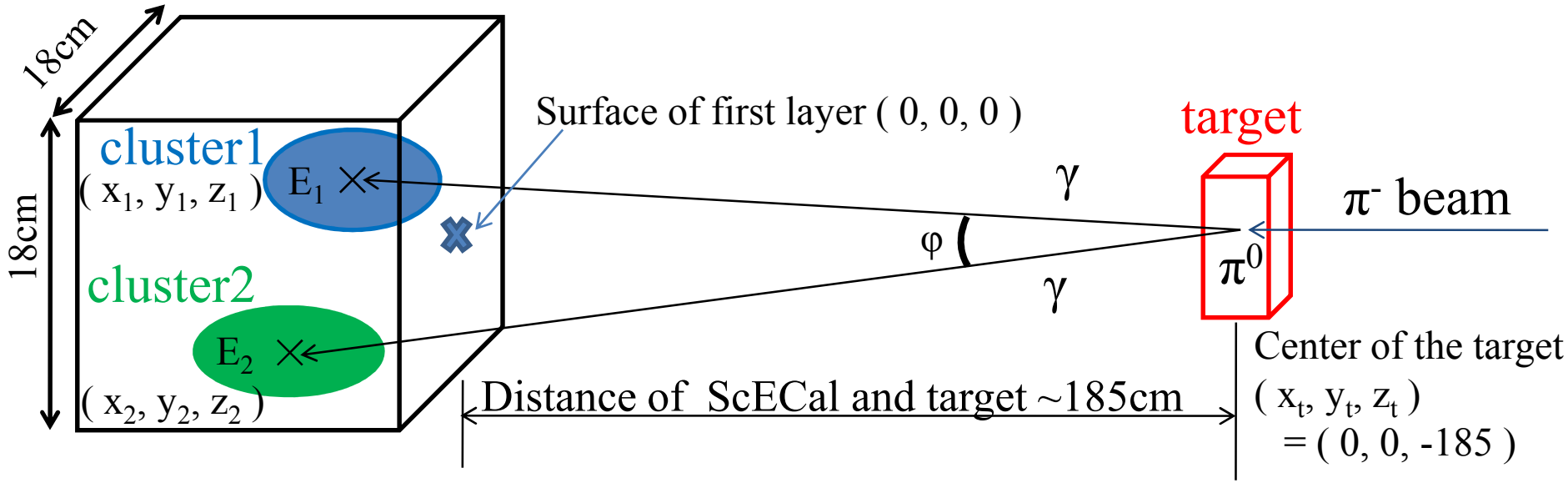
- To produce π^0, π^- beam (16, 25, 32 GeV) was injected into Iron target.
- Size of the Iron target : 10x10 cm^2, thickness 6 cm
- The Iron target was put in ~185 cm upstream of ScECal.

(The distance of EMCAL from interaction point is 185 cm.)





Reconstruction of Invariant Mass in 2 γ system



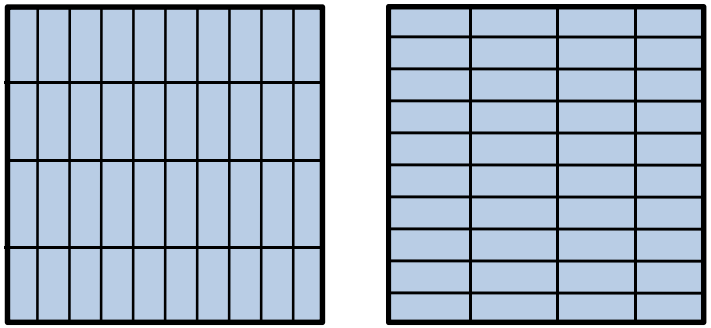
$$(\text{Invariant Mass}) = \text{sqrt}(2*E_1*E_2*(1-\cos(\varphi)))$$

In case two gammas have equal energy,

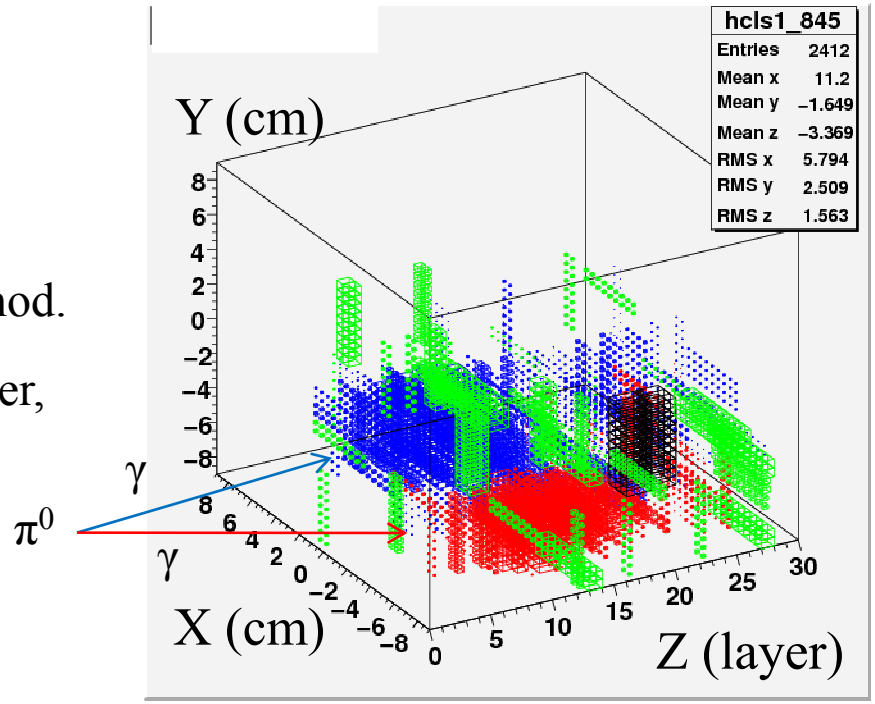
Energy of π^0 (GeV)	3	4	5	10	15
Distance of two clusters (cm)	16.7	12.5	10.0	5.0	3.3

Strip Clustering

1. Define X and Y layers according to strips orientation.
2. Select a strip which has the largest output in X layers. The strip is called seed strip.
3. Connect seed strip and the neighbor strips (upper, lower, left, right, forward and backward) (E of neighbor strip <= 1.2*(E of seed strip))
4. Connected strips are defined as new seeds. Repeat 3 until no more neighbor strip remains.
5. Using other strips, repeat 2 – 4.
6. For Y layers, make clusters using the same method.
7. Finally, the Y cluster is connected to the X cluster, in case energy center of a cluster in Y layers is located within +- 2.85 cm in X and Y from energy center of a cluster in X layers.



X layer Y layer

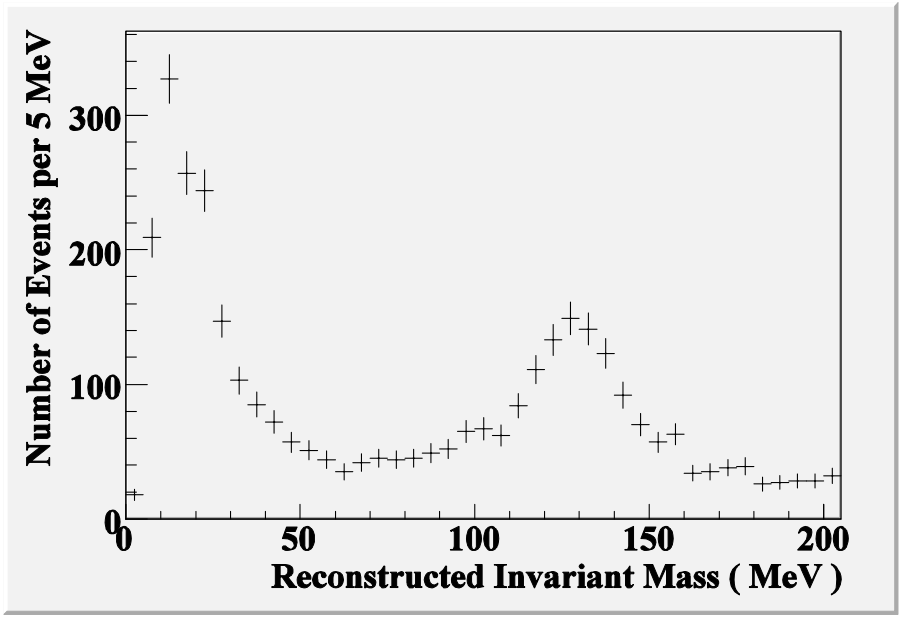


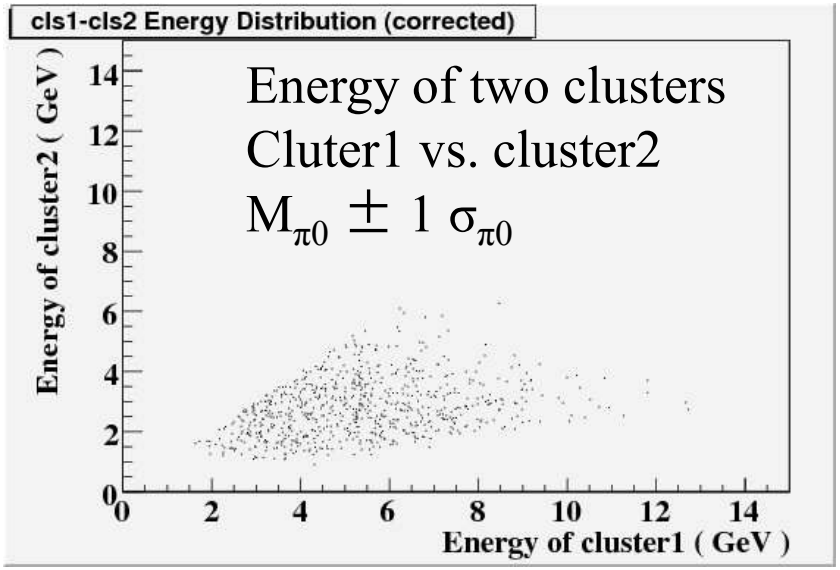
** This strip clustering is not the official algorithm for ScECal.

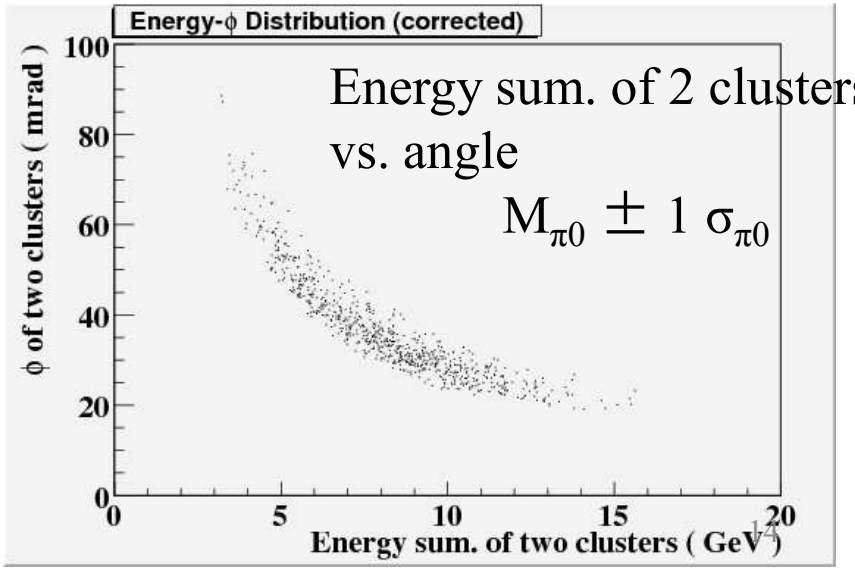
Reconstructed Invariant Mass from 2 Clusters

Very preliminary results of π^0 mass reconstruction

π^0 detection is successful !







Next Beam Test

Additional beam test for ScECal second prototype will be started on 20 April (to 28 May).

Motivation

- energy scan at more energy points
  - 1, 2, 3, 4, 6, 8, 10, 12, 15, 16, 20, 25, 30, 32 GeV
  - Both positive and negative beams available
- Take more π^0 data at more energy points
- Position dependence of resolution / linearity
- Tilt angle scan (20, 30 degrees)
- higher energy pion (up to 60 GeV) data taking

Summary

- Study of the Scintillator-strip ECAL is extensively underway in CALICE collaboration.
- Development of base components (strip + MPPC) is in good shape and almost done.
- Beam Test has been performed to establish feasibility of the ScECAL.
  - Observing event shape with the fine granular calorimeter.
  - Energy resolution, Linearity comparable with expectation.
  - First trial of π^0 reconstruction with the ScECAL is successful.
- Next step : Further improvement of base component and simulation study.
- Additional ScECal beam test will be started on 20 April to 28 May at FNAL.