

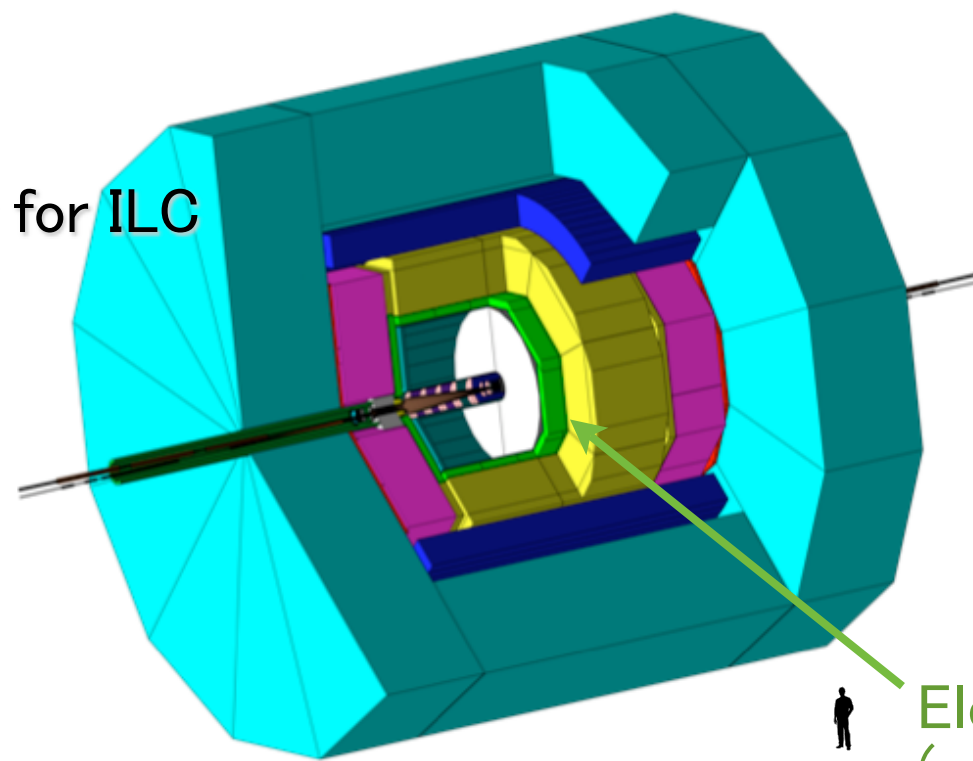
Study of the Granular Electromagnetic Calorimeter with PPDs and Scintillator Strips for ILC

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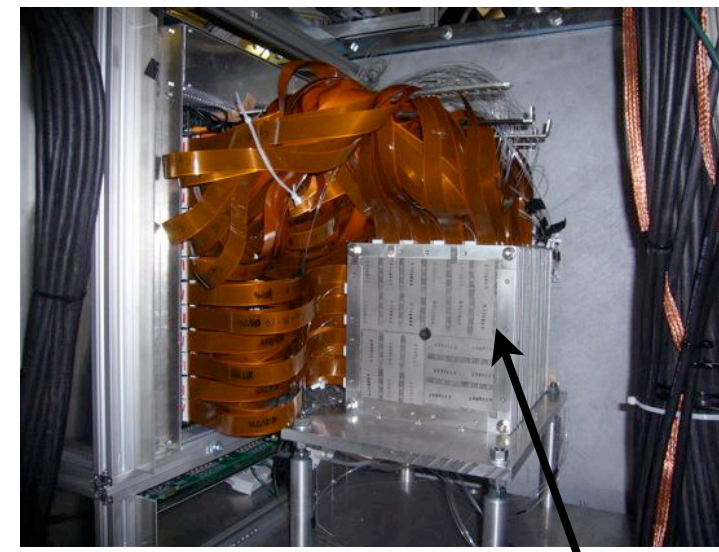
CALICE
CALORimeter for the LInear Collider Experiment
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@VCI201

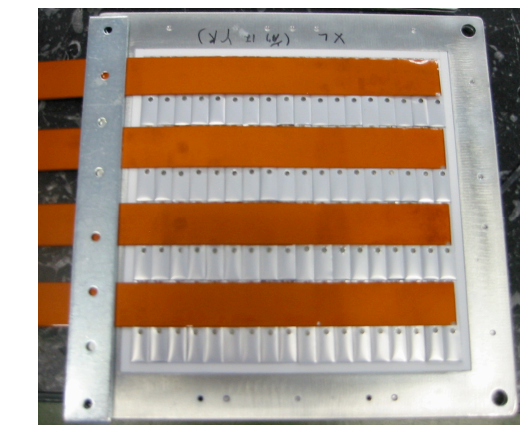
ILD detector for ILC



Electromagnetic calorimeter (green part) in ILD and the prototype module of Scintillator strip ECAL



One of the 30 layers of prototype module with readout cables



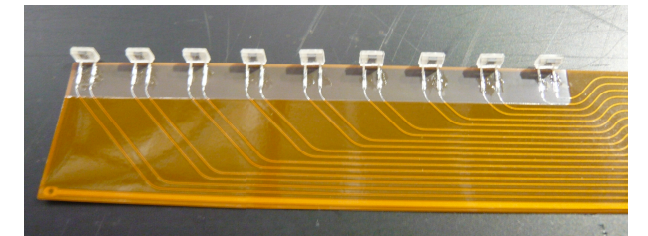
For ILD, the number of those channels will be $\sim 10^7$

Abstract and summary

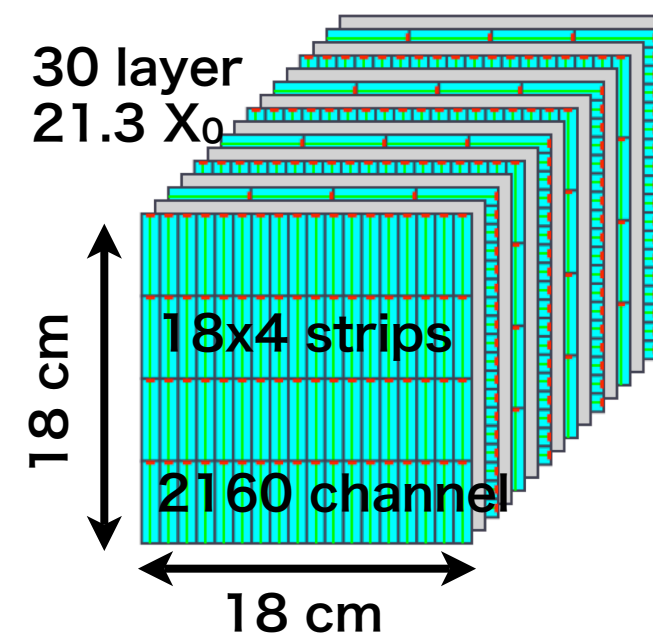
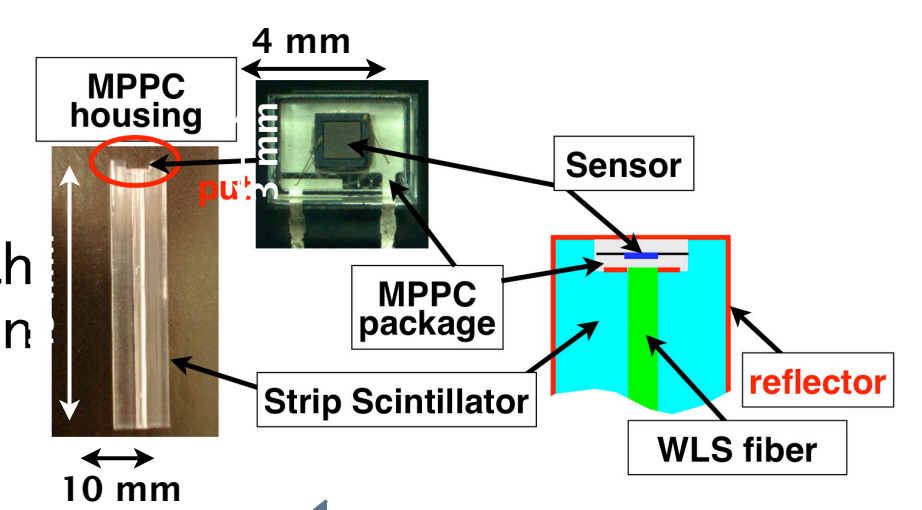
In the CALICE collaboration we are developing the granular electromagnetic calorimeter using the Pixelated Photo Detector and scintillator strips for the ILC detector. A prototype of ECAL has been constructed. In order to achieve the 1 cm x 1 cm lateral segmentation the scintillator strips of dimension 1 cm x 4.5 cm x 0.3 cm was adopted. These strips in odd layers are orthogonal with respect to those in the even layers. The scintillation lights in each strip are readout with the PPD. The transverse size of the prototype is 18 cm x 18 cm and the depth is 30 layers in 26 cm, then total number of readout channels is 2160. Each layer is paired with a tungsten absorber with thickness of 3.5 mm. The prototype was tested with 1 - 32 GeV electrons at Fermilab in Sep. 2008 and May 2009. The summary of the preliminary results are;

- Energy resolution for 1 - 32 GeV electrons for 2008 data; $\sigma/E = (1.44 \pm 0.22)\% \oplus (15.15 \pm 0.03)\% / \sqrt{E(\text{GeV})}$,
 - Deviation from the linearity: $< 6\%$, uncertainties are only statistics.
- We are still trying to improve the performance.

PPDs (1600 pixel 1 mm² MPPC by Hamamatsu K.K.) arranged on a readout cable. Properties of 2160 MPPCs were measured before mounting.



MPPC is mounted on each scintillator strip. Scintillator strips are hermetically wrapped with reflector film made by KIMOTO Co. Scintillation light is gathered through WLS fiber.

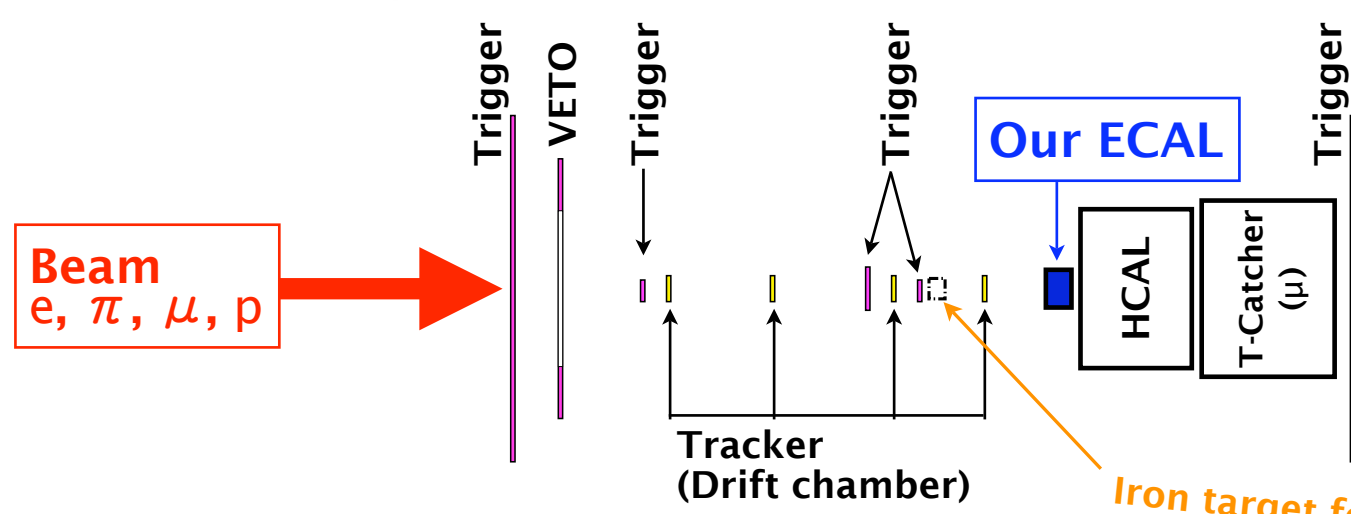


LED light distributed through notches of clear fibers to each strip through small hole of reflector for calibration purpose.

Kyungpook National University in Korea studies extrude method to produce low cost scintillator strips.

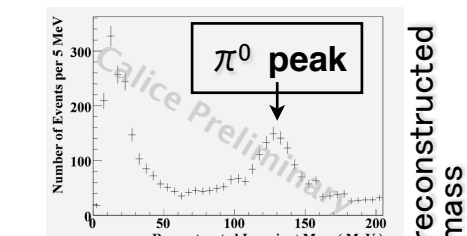
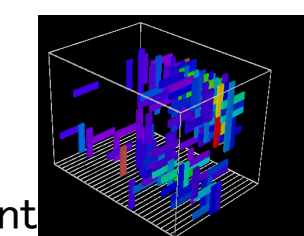
BEAM TEST @ Fermilab MesonTBF

Fermilab provides 1-60 GeV e, π, μ mixed beams with 0.2% momentum spread



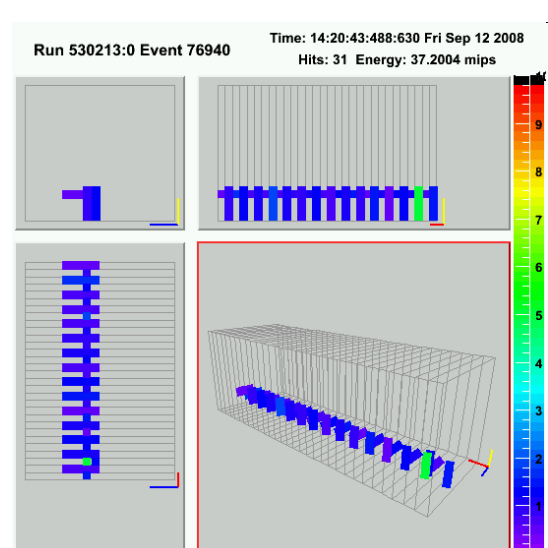
- Beam test periods: September 2008 and May 2009
- Energy range: e⁻ 1 - 32 GeV, π⁻ 2 - 32 GeV and π⁺ 60 GeV
- Cerenkov counter upstream of experimental hall is used to separate π⁻ and e⁻
- Precise position scan on a strip
- Tilt incidental angle scan: 10° 20°
- 16 - 60 GeV π⁰ run

a typical π⁰ event

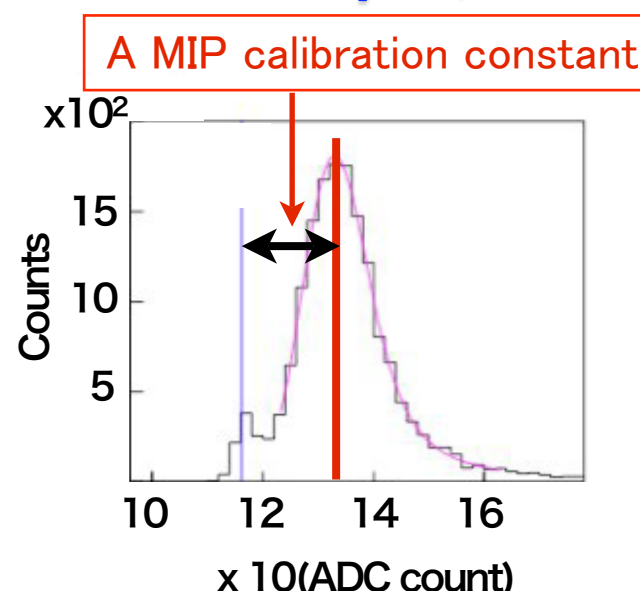


reconstructed mass

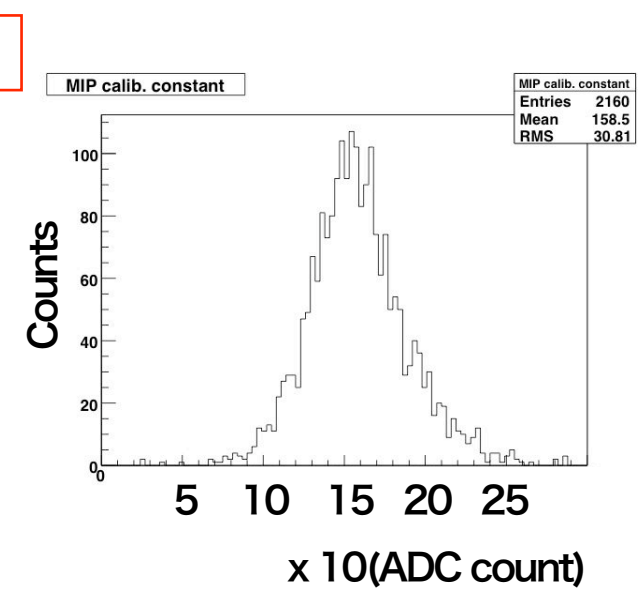
MIP calibration (32 GeV μ⁺)



A typical MIP event on the ECAL.

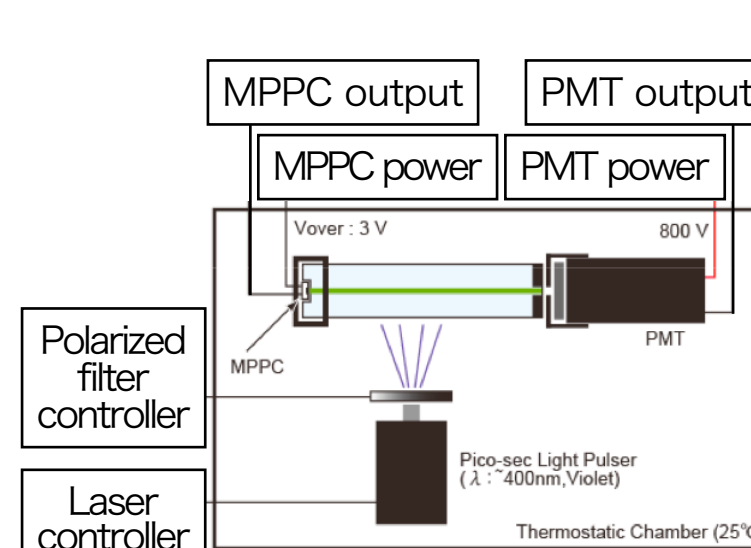


A typical deposited energy distribution of MIPs on a strip.

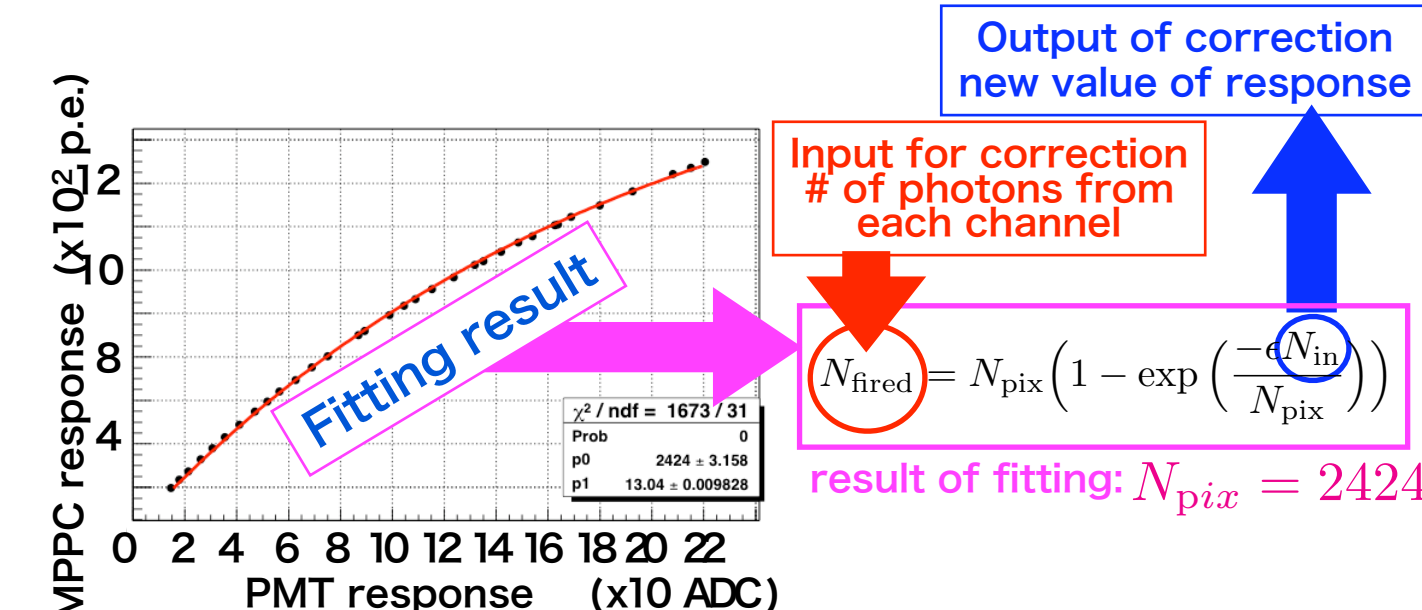


Distribution of MIP calibration constant of 2160 strips.

MPPC saturation correction

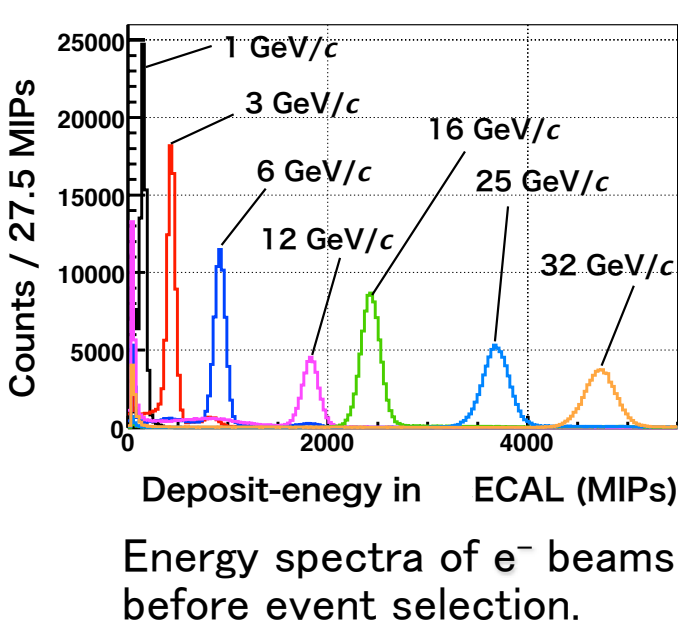


MPPC saturation is studied comparing with PMT.

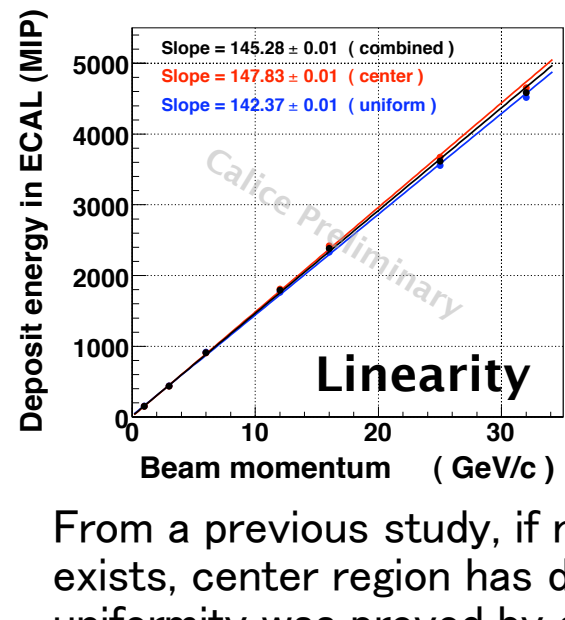


For each strip in each event, MPPC response is put into the reverse of above function.

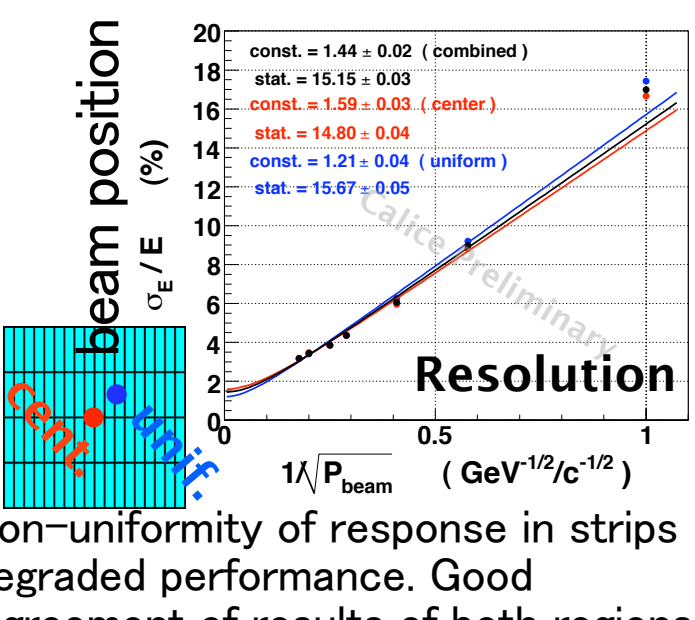
Linearity and Resolution for electrons



Energy spectra of e⁻ beams before event selection.



From a previous study, if non-uniformity of response in strips exists, center region has degraded performance. Good uniformity was proved by agreement of results of both regions.



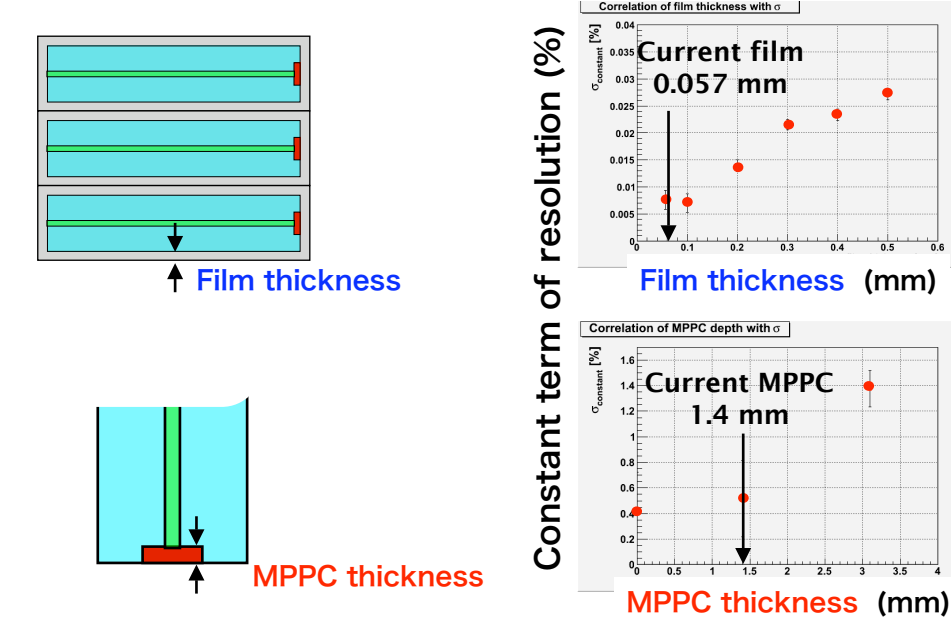
Calice Preliminary

constant term	1.44±0.02%
stochastic term	15.15±0.03%

Study of non-negligible constant term is ongoing, possible reasons can be;

- temperature fluctuation,
- imperfect MPPC saturation correction,
- energy leakage,
- dead volume.

Effect of dead volume



Simulation studies (Geant4 base) on dead volume due to reflector and MPPC indicate that; the dead volume is not the cause of the constant term in the current detector design.

Next steps

10 mm → 5 mm

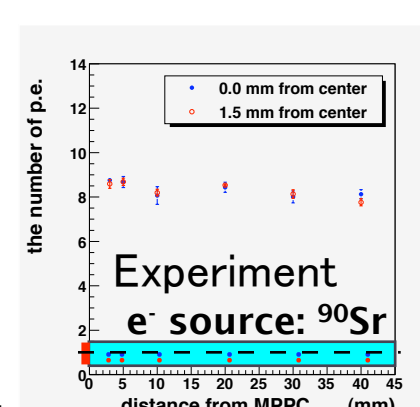
According to recent study, 5 mm x 5 mm segmentation is desirable than 10 mm x 10 mm segmentation for the higher energy Jets; E_{Jet} > 200 GeV.

10 mm
5 mm
Smaller MPPC package is available

Current package 3 x 4 x 1.3 mm³ Hamamatsu, S10943-8585
2 x 2.5 x 0.85 mm³ Hamamatsu, S10362-11-025P

5 mm width scintillator strip has enough light yield and uniformity;

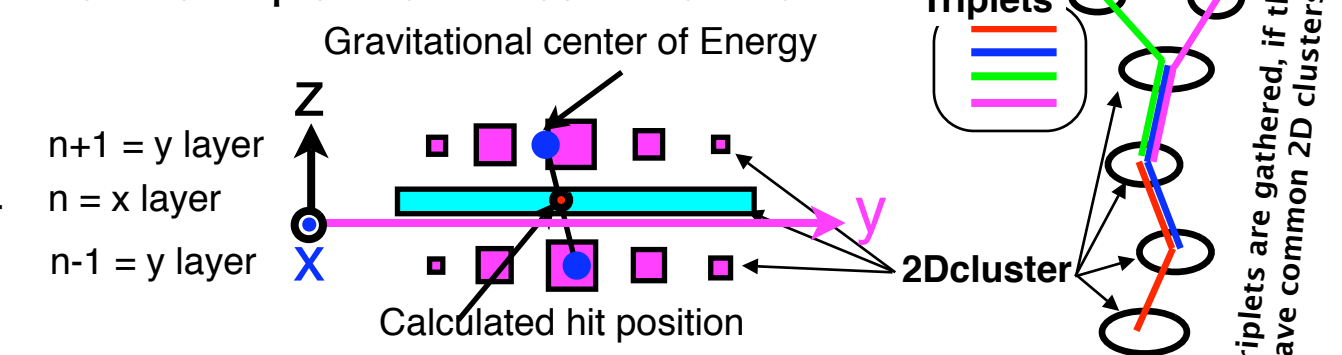
- without WLS,
- hermetically covered by reflector,
- a small hole on reflector opening only for the sensor.



Strip clustering

Study of the clustering algorithm to extract the best performance of the strip calorimeter is ongoing.

A cluster-triplet from three 2-D clusters.



Triples are gathered, if they have common 2D clusters