The Next Generation Scintillator-based Electromagnetic Calorimeter Prototype and Test Beam Result on Temperature Correction

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CALICE Collaboration Meeting
March 5th -7th , 2012
Shinshu University, Matsumoto, Japan

March 5th , 2012

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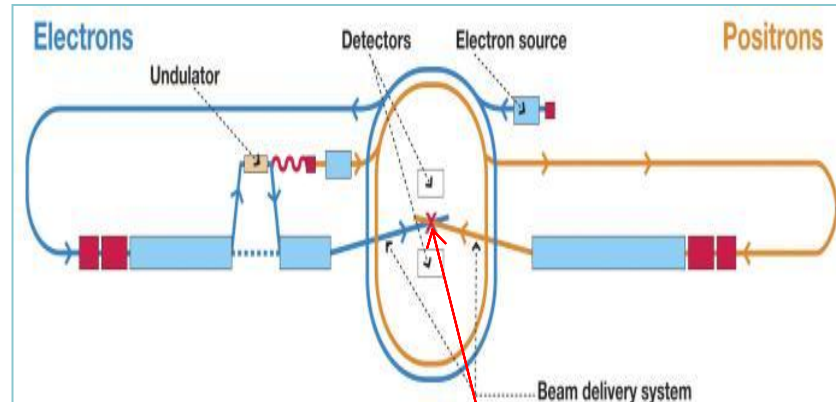
Particle Flow Algorithm (PFA) at International Large Detector

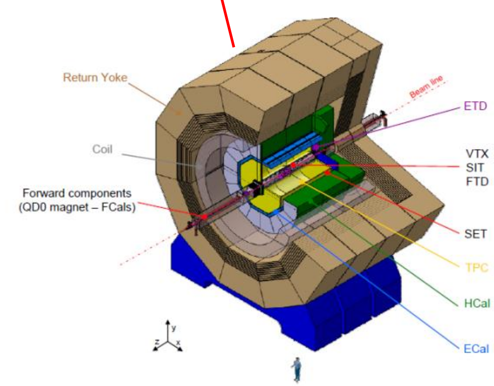
- International Linear Collider (ILC) is a next generation project designed to smash electron and positron at center of mass energy 0.5~1TeV



- At the ILC experiment, measuring the quark-jet energy is one of the key issue :

  $e^+e^- \longrightarrow$ *H*, *W*, *Z*, *tt*, SUSY,
  any massive particles decay to multi-jets

- The Particle Flow Algorithm (PFA) is proposed to improve the jet energy resolution significantly. Actual break down of a jet is :
  - Charged particles (Kaon, pion, electron) .. 65%
  - Photon (gamma) … 25%
  - Neutral hadron（$K_L{}^0$） … 10%



- The idea of PFA is to measure the energy of each particle in a jet, By using the PFA, jet energy resolution can be improved from 60% to 30%.

- Therefore it is necessary to separate each particles in a jet by calorimeter signal.

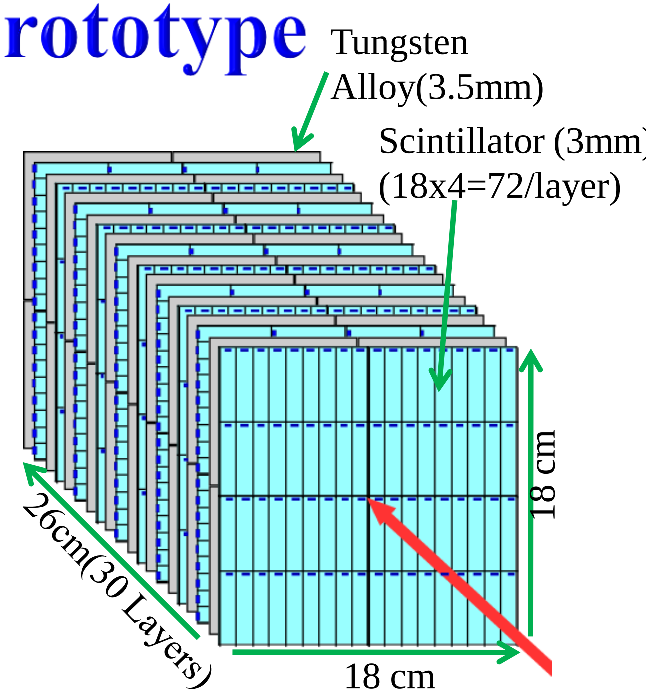
⟶ Need very finely segmented calorimeter

The Scintillator-ECAL Prototype

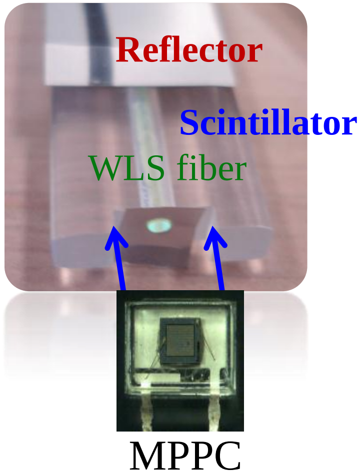
- The ScECAL prototype is built to establish a scintillator-based ECAL technology

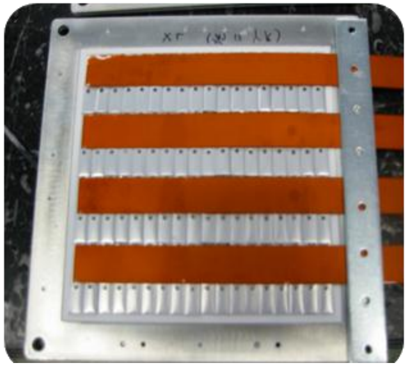
  (18 x 18 cm^2, 30 layers, 21.3X_0)

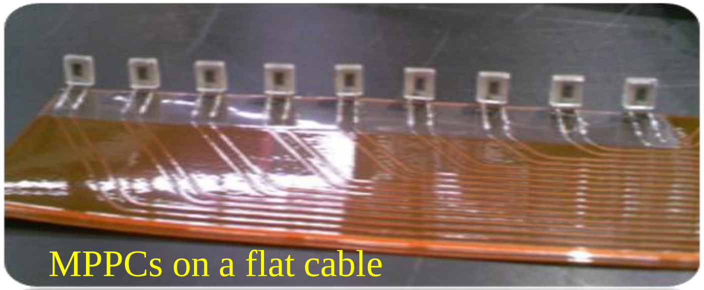
- **2160** readout channels
- MPPC gain monitoring system is implemented



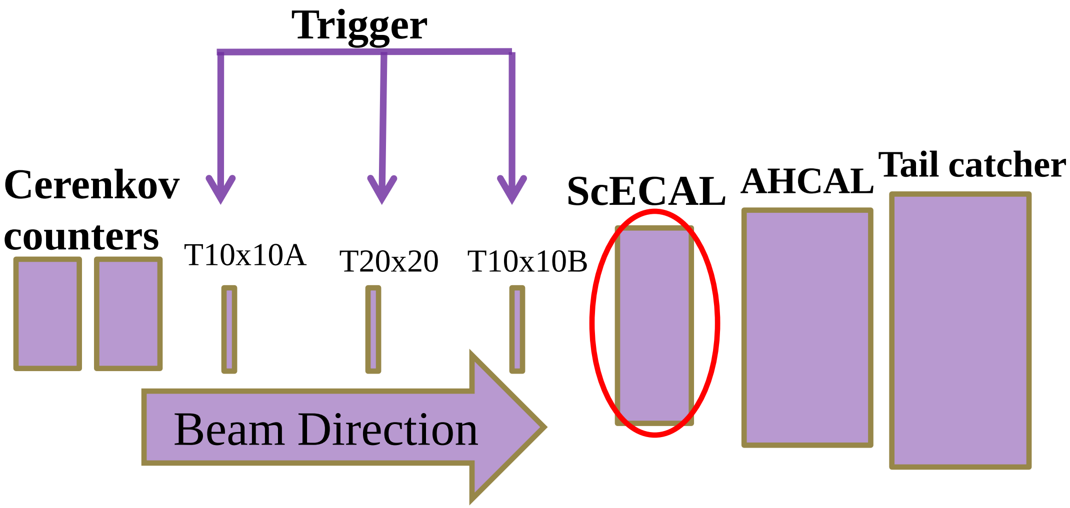
Scint. Strip : 1 cm x 0.3 cm x 4.5 cm

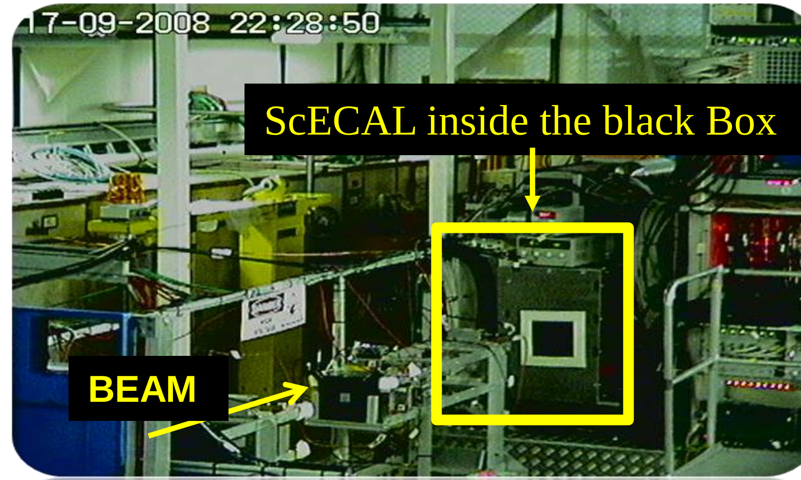






Beam Test at Fermilab Meson Beam Test Line





- Cerenkov counter available to discriminate electron or pion
- We performed Beam Test in 2008 and 2009 for different configurations .
- Beam Test combined with AHCAL and Tail catcher has done.

2008	
Electron	1, 3, 6, 12, 16, 15, 32 GeV
Pion (center region)	3, 6, 12, 16, 25, 32 GeV
Mixed beam	32 GeV
Tilt angle 10 deg	Electon : 1, 3, 6, 25, 32 GeV Pion : 3, 6, 16, 25, 32 GeV
π^0	16, 25, 32 GeV
Muon	32 GeV

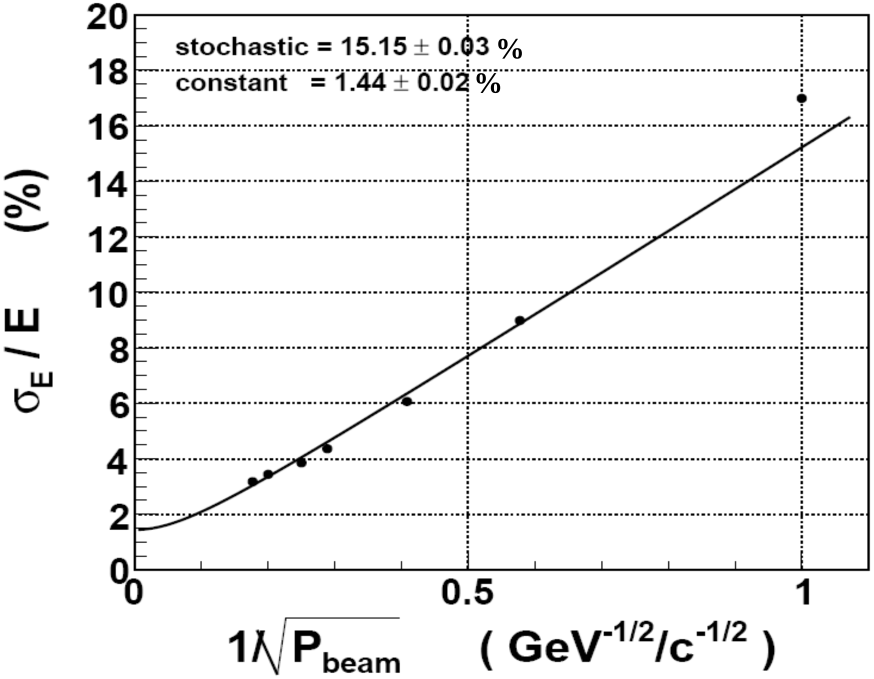
2009	
Electron	1, 2 , 4, 8, 12, 15, 20, 30, 32 GeV
Pion (center region	2, 4, 12, 15, 20, 30,GeV
Position Scan	15 GeV
Tilt angle 20 deg	Electon : 2, 4, 8, 15, 20, 32GeV Pion : 8, 15, 32 GeV
π^0	60 GeV
Muon	32 GeV @ 20 ^{0}C and 25 ^{0}C

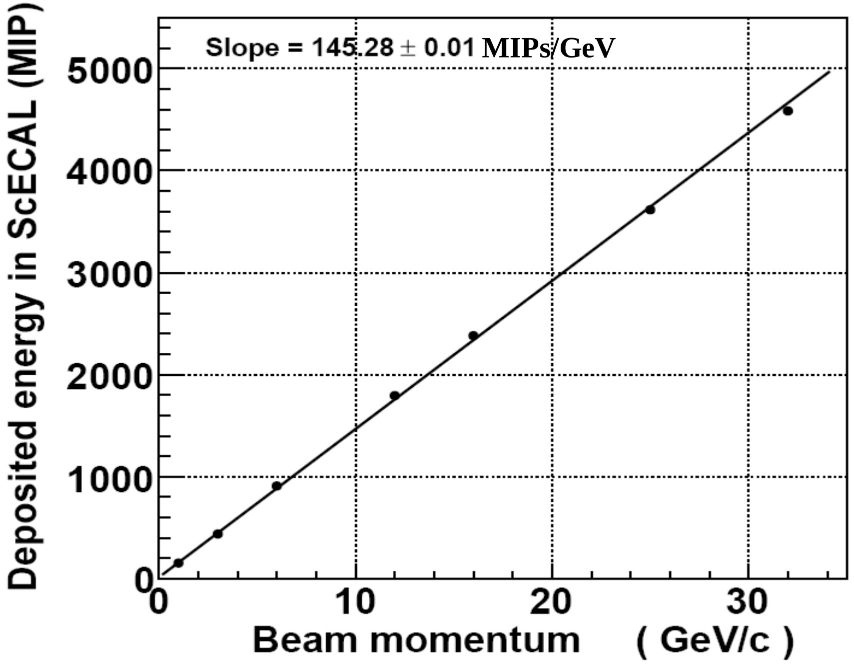
September 2008, Linearity & Resolution

[*"Performance of the ScECAL Prototype for the ILC " (CALOR 2010) 012070]*

➢ For Energy Resolution The line is the fitting result with a function of :

$$\frac{\sigma}{E} = \sigma_{constant} \oplus \sigma_{stochastic} \frac{1}{\sqrt{E}}$$





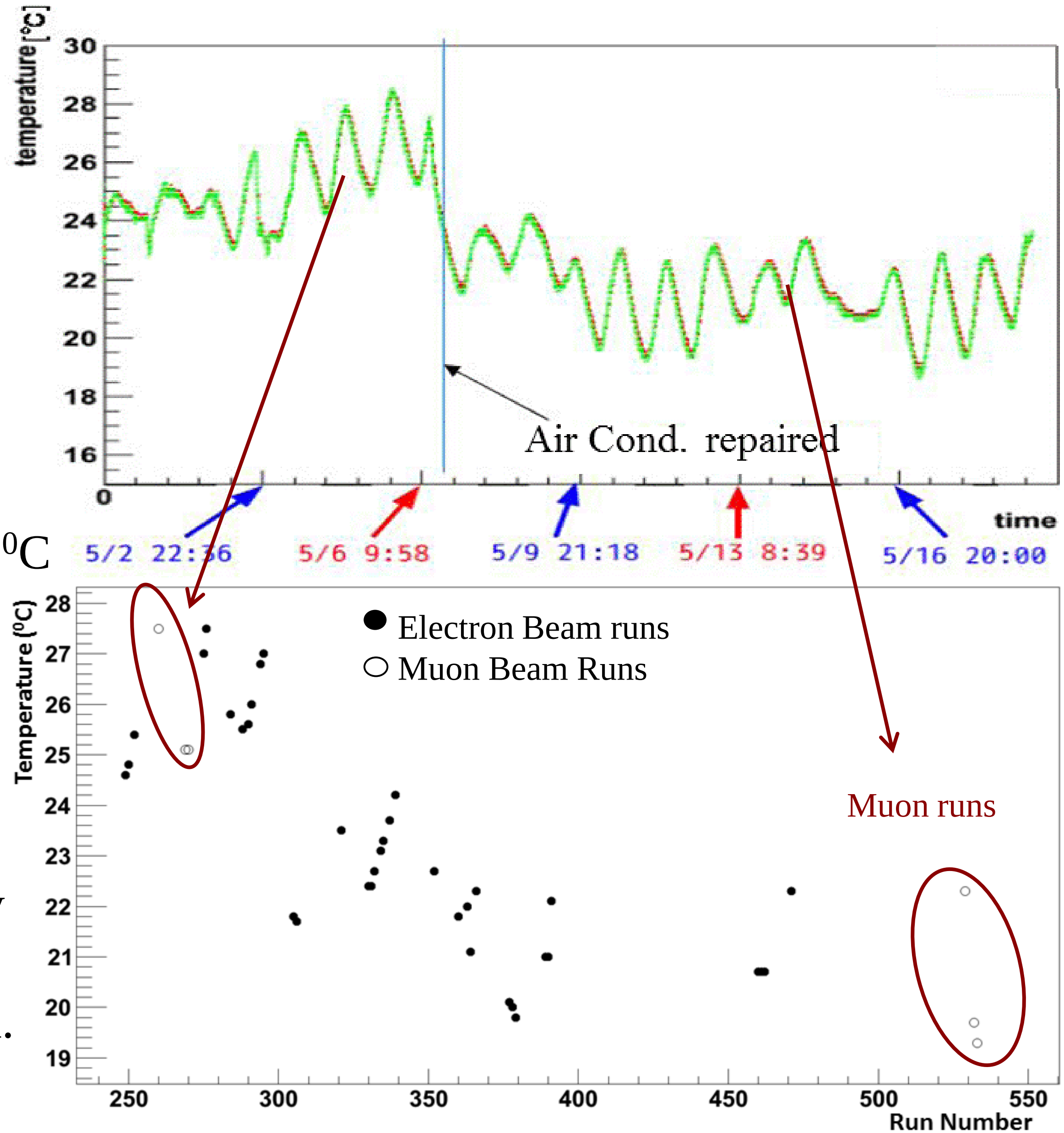
➢ The fluctuation of the Deviation from Linear Fitting is less than 6%.

Constant term	1.44 ± 0.02%
Stochastic term	15.15±0.03%

* The Errors are only statistical

Temperature variation During 2009 Beam Test

- Temperature variation during whole period of Beam test 2009.
- Higher and lower temperature region are separated by a vertical line.
- Temperature varied 19 ^{0}C~27 ^{0}C
- During beam test there was temperature change about 5 ^{o}C .
- Temperature effects is clearly appear on the behavior of the muon & electron energy scan.



MIP Conversion Factor and Temperature Dependence

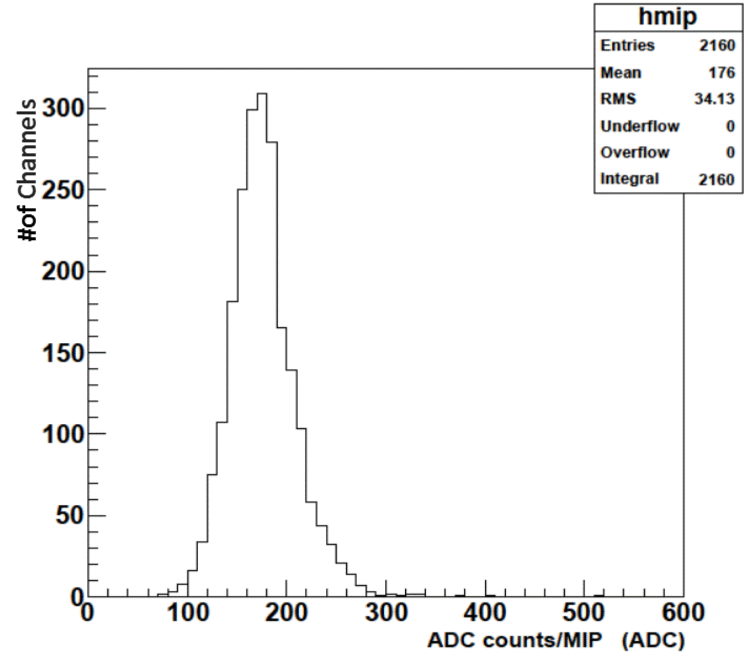
- Muon Beam used for the detector calibration

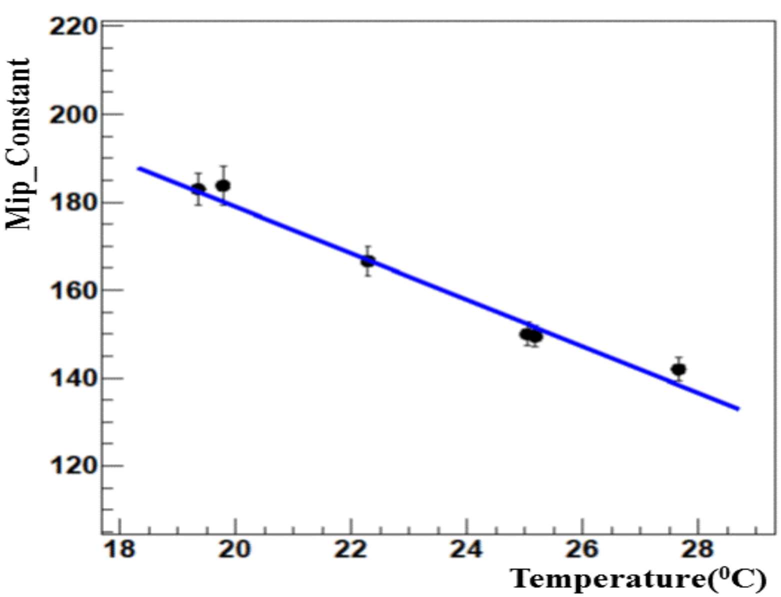
Total 6 Runs of Muon were used

Temperature varied 19 ^{0}C~27 ^{0}C

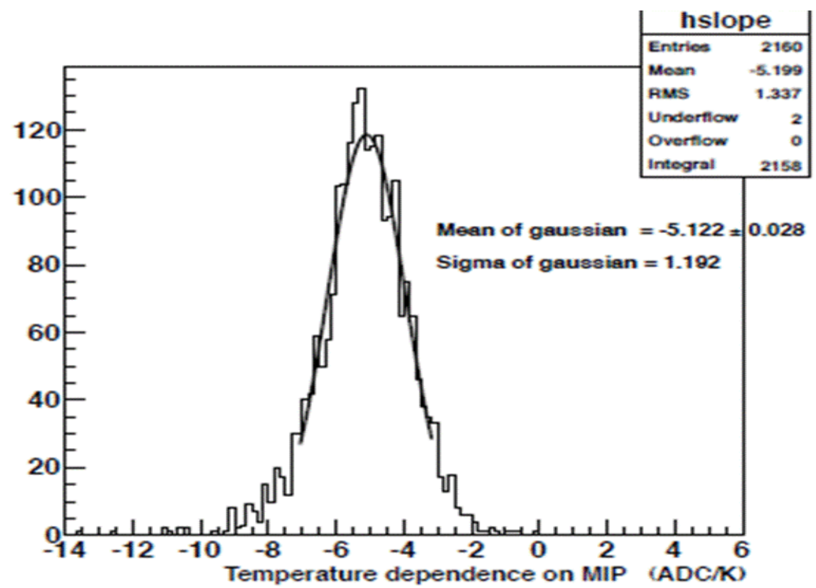
The Average MIP conversion factor is about ~ 176.0 ADC counts/MIP

Good Linear correlation between ADC/MIP and Temperature.





Temperature dependence of the MIP calibration constant



Distribution of the slope factor for all the ScECAL channels

Events Selection

Electron events are selected based on particle- shower shape information

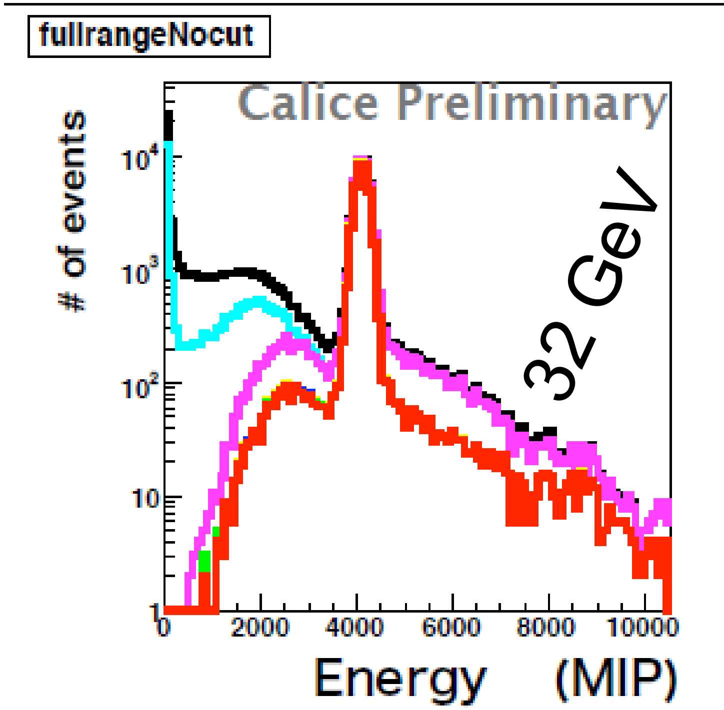
1. Shower maximum is required to be in the first part of ScECAL in order to reject Pions , muon and shower leakage.

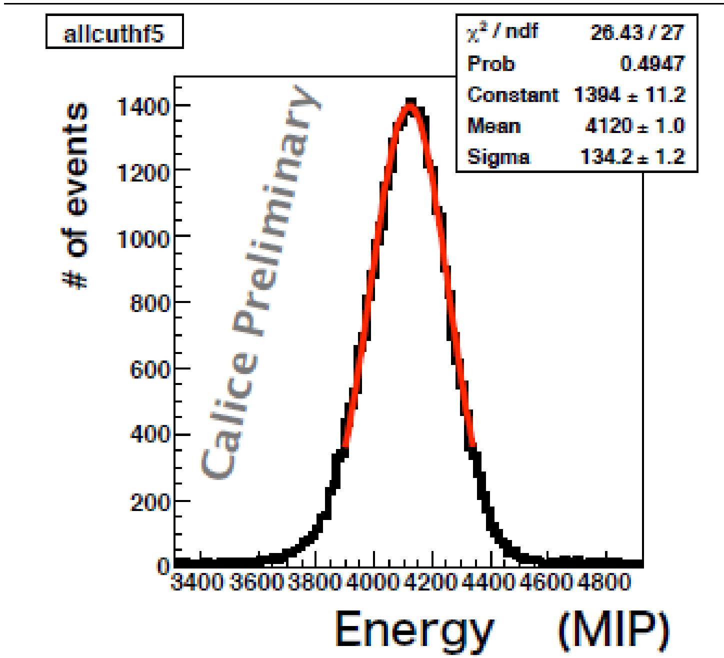
2. To reject Pion, Maximum energy deposit in the shower is to be consistent with electron event depending on the beam energy .

3. To reject the event with the large signal in AHCAL to avoid Pions, the deposited energy in AHCAL should be less than 20 MIPS .

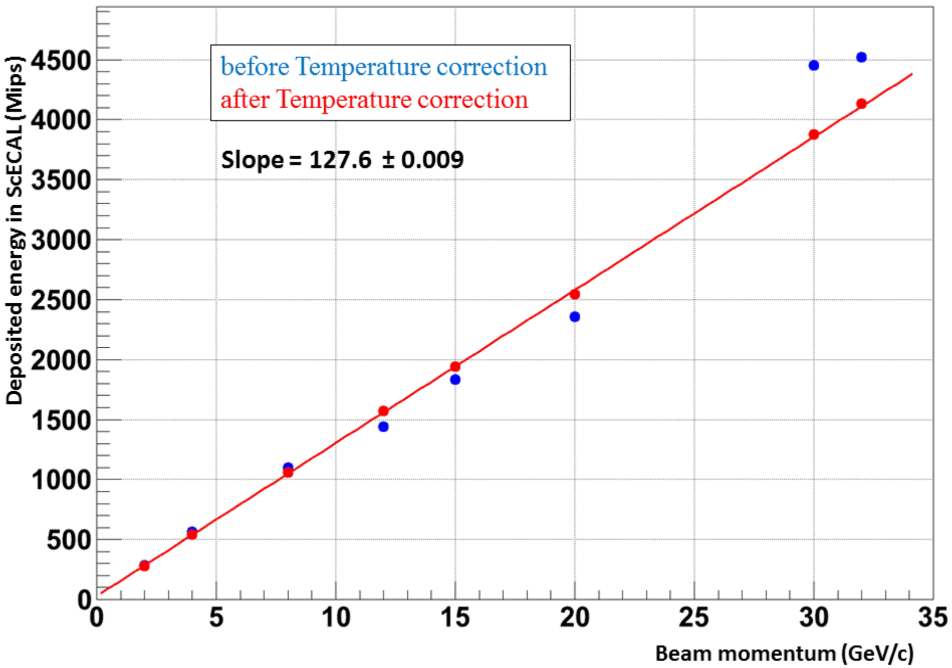
4. Energy in last layer of AHCAL must be consistent with zero to reject Muon.

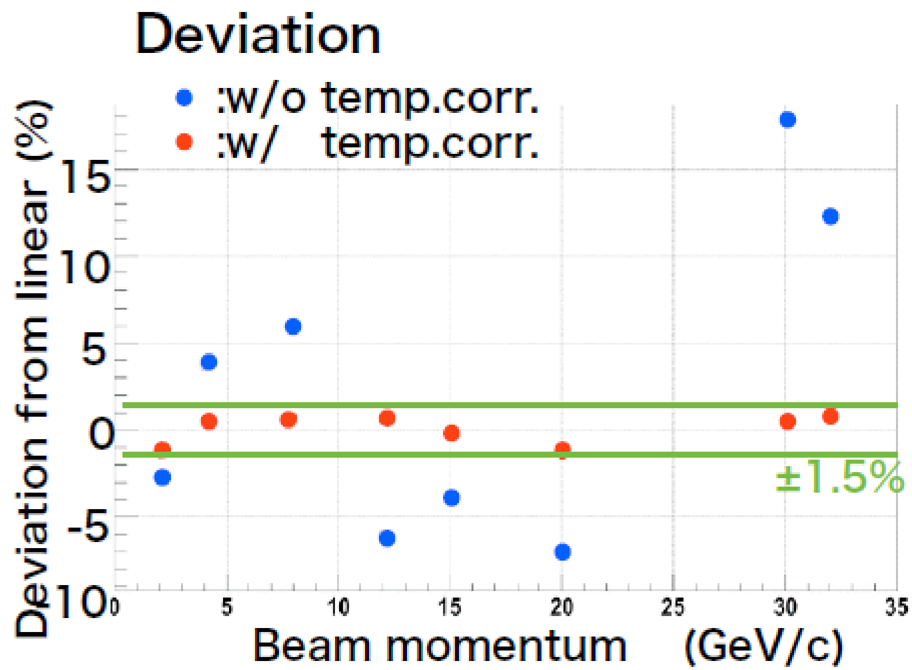
5. Center of the shower must be consistent with ScECAL center, to reject the events which have shower leakage to the side surface of the detector.





Electron Energy Response (2009)

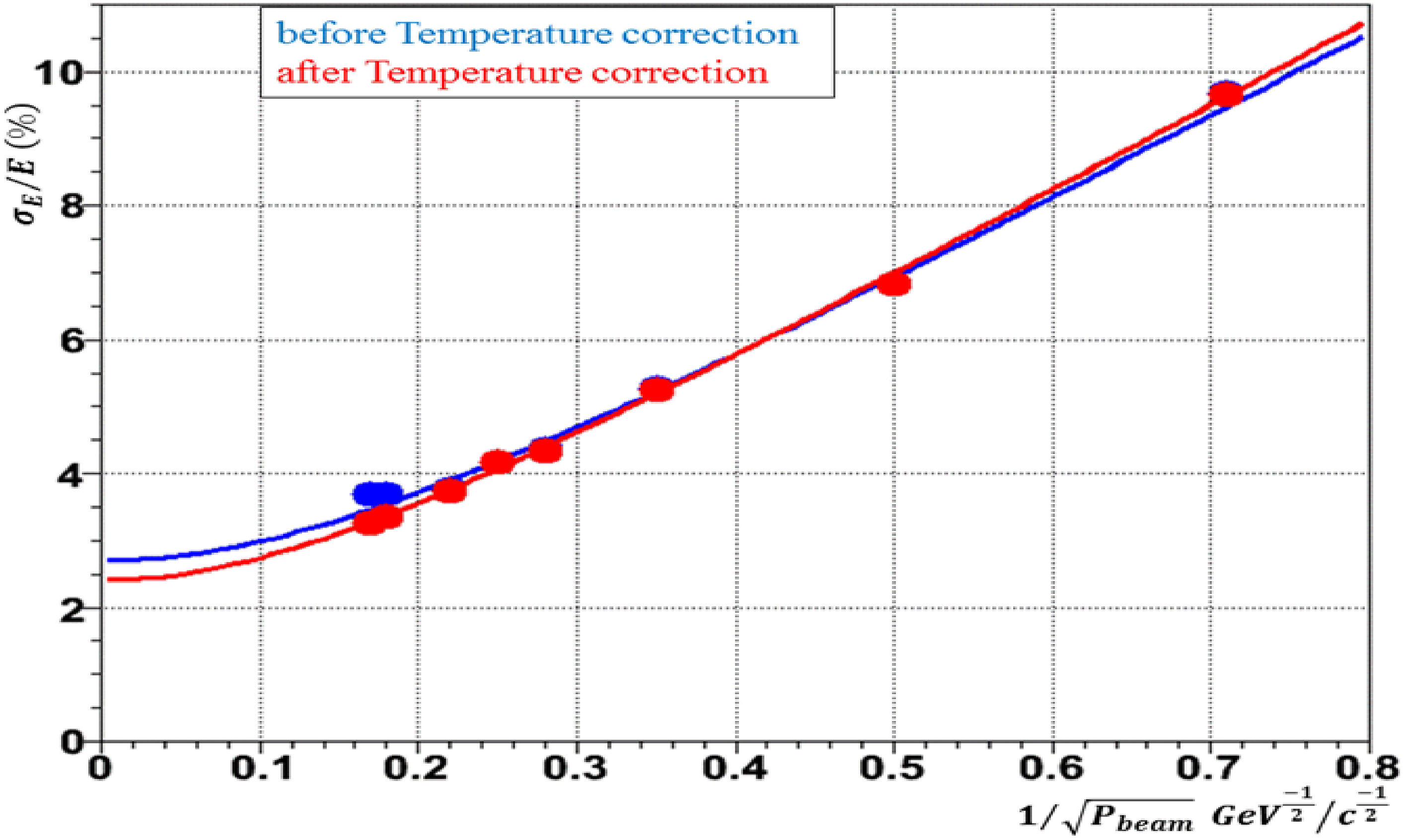




- Temperature correction applied through ADC/MIP.con.factors for each channel
- Linearity improved after temperature correction.
- Deviation from linearity is about 1.5%

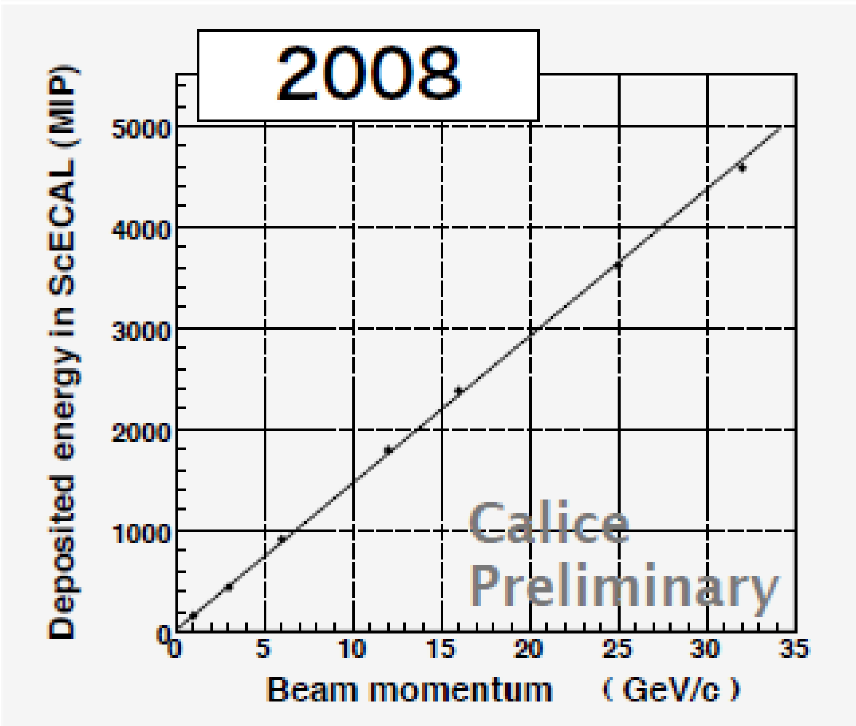
Energy Resolution (2009)

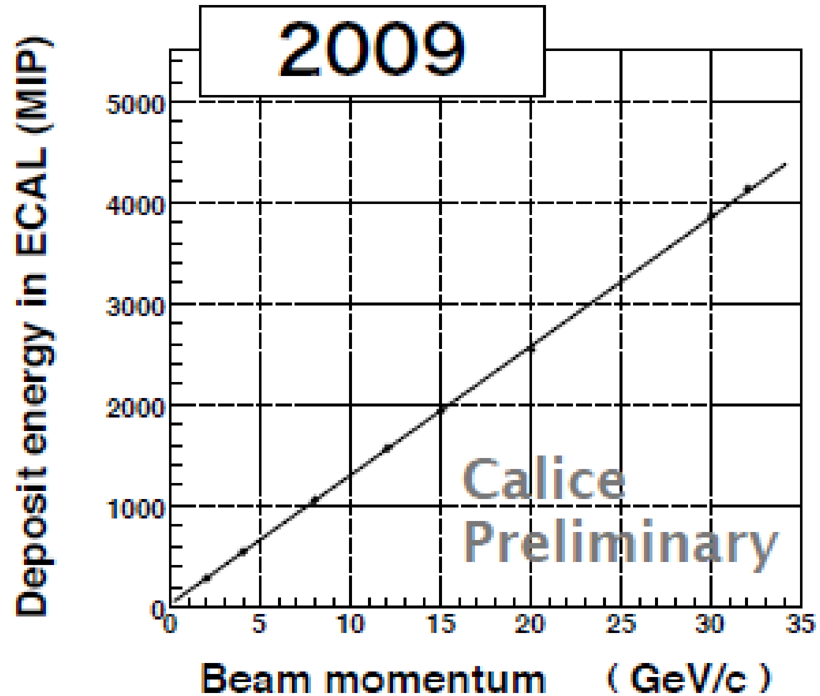
- Temperature Correction has clear effect on Energy Resolution



Energy Resolution (%)		
	Before Temperature Correction	After Temperature Correction
$\sigma_{constant}$	2.69 ± 0.01	2.41 ± 0.01
$\sigma_{stochastic}$	12.78 ± 0.03	13.13 ± 0.03

Comparison of MIP/GeV between 2008 and 2009





MIP/GeV -> 2008 : 145.3MIP/GeV , and 2009 : 127.6 MIP/GeV

2009 :

Temperature of (electron data taking) – Temperature of ADC/MIP.factor(corrected) =0

2008 :

Temperature of (electron data taking) – Temperature of ADC/MIP.factor(corrected) ≠0

Estimated temperature : Muon data 23.4 ^{0}C, Electron data 19.1 ^{0}C

Summary

- For the ILC the calorimeter is required to have high energy resolution and high spatial resolution to identify the jet.
- The Plastic Scintillator-based electromagnetic calorimeter prototype has been fabricated and tested at Fermilab beam.

Beam test at FNAL Sep. 2008 and 2009

- Less than 6% deviation from linearity is observed (for 2008 data)
- $\sigma_{\mathbf{constant}}$ ~ 1.44±0.02% & $\sigma_{\mathbf{stochastic}}$ ~ 15.15±0.03% (for 2008 data)

- Less than 1.5% deviation from linearity is observed (for 2009 data)
- $\sigma_{\mathbf{constant}}$ ~ 2.41±0.01% & $\sigma_{\mathbf{stochastic}}$ ~ 13.13±0.03% (for 2009 data)

- Preliminary selection cuts for the electron has been set to purify the beam data.
- Temperature dependence of MIP conversion was measured, and have a stable linear function.
- Temperature Correction improves linearity of energy response and also effect the energy resolution

Plan

- Temperature correction – photo-sensor gain is sensitive to temperature change.
- MPPC saturation correction – MPPC response is not linear with light input.
- Utilize detailed information of shower shape - selection by signal on beam line devices.
- Estimation of Systematic Uncertainty.

Thanks