CALCE Scintillator-based ECAL Test beam Results at FNAL

25th / April KILC12

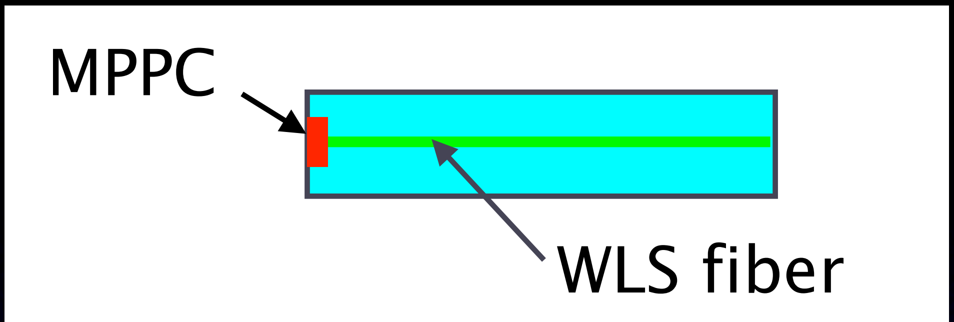
on behalf of CALICE-ASIA group
Katsushige Kotera
Shinshu University
for CALICE and CALICE-ASIA

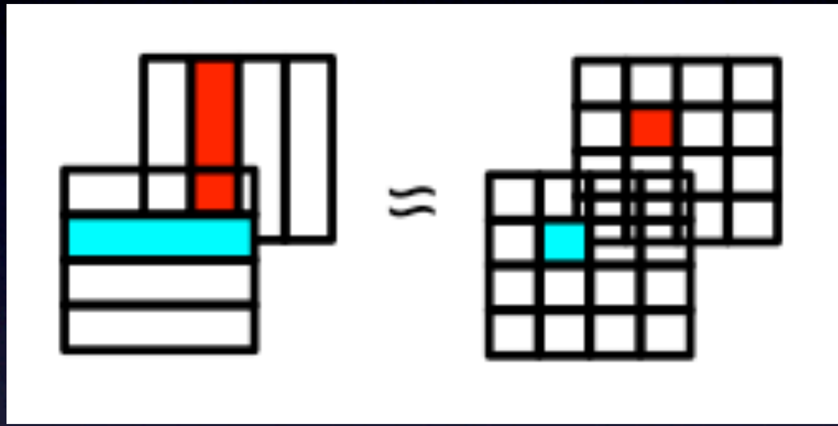
Out line

- Introduction of physiics prototype of Scintillator-based ECAL,
- CALICE FNAL TB in Sep. 2008 and May 2009,
- Temperature condition in 2009,
- ADC/MIP conversion factor (ADC/MIP.conv.factor) depending on temperature,
- Results: linearity and energy resolution of 2009 data,
- Discussion the constant term of energy resolution,
- Summary and plan.

Physics Prototype of Scintillator strip ECAL

- Requirments
  - energy resolution
  - linearity
  - uniformity
  - granularity
  - Robustness
  - Low cost
  - Magnetic field tolerance

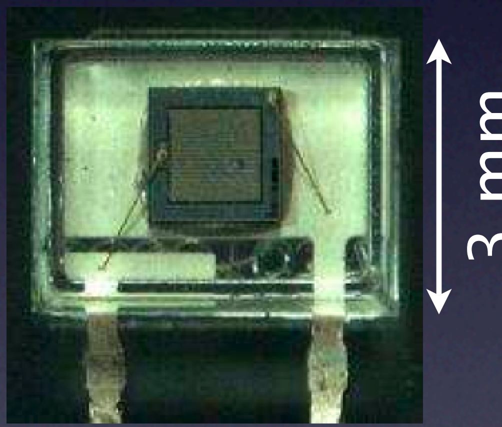


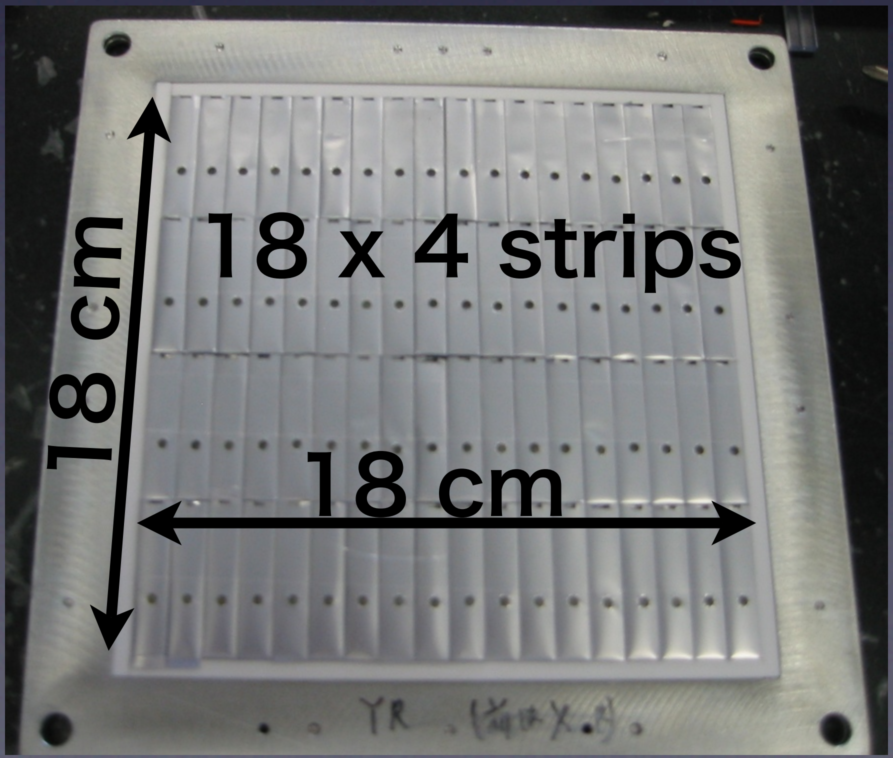


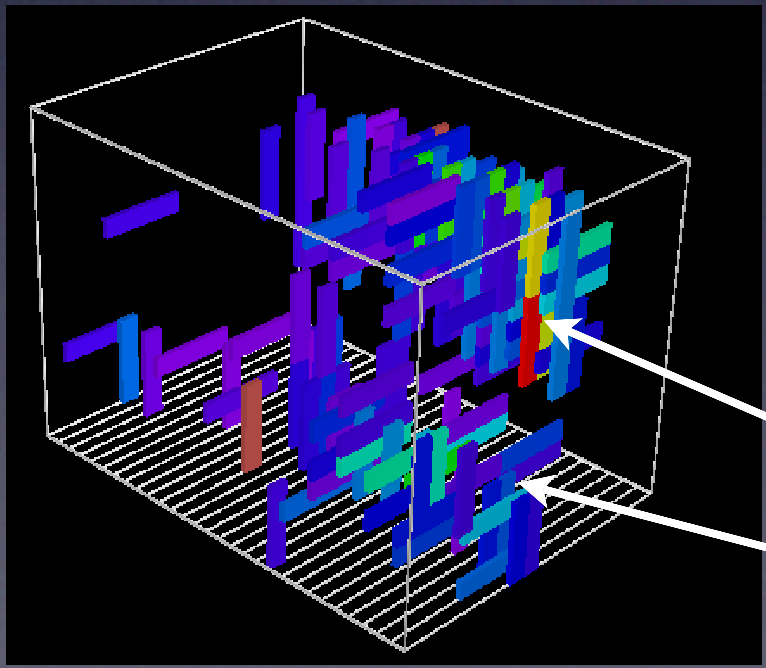
plastic scintillator 10mm x 45 mm x 3mm

1mmΦ WLS fiber

Hamamatsu
1600 pixel
1 x 1 mm
PPD = MPPC
in Plastic
package







$\pi^0 \rightarrow \gamma\gamma$

CALICE ScECAL FNAL Test beams

Sep 2008 → **7.5 months** → May 2009

Energy scan

e^- Uniform: 1,3,6,12,16,25,32 GeV
Center: 1,3,6,12,16,25,32 GeV

π^- Center: 3,6,12,16,25,32 GeV

e^- Center:
1,2,4,8,12,15,20,30,32 GeV

π^- Center:
2,4,12,15,20,32,60$^{(+)}$ GeV

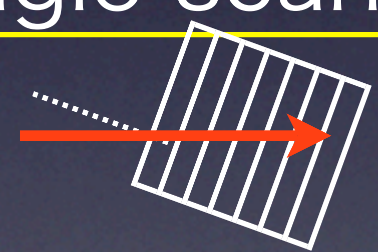
Position scan

$e^-\pi^-$ mixed 32 GeV

e^- 15 GeV

Tilt angle scan

10°: e^- 1,3,6,16,25,32 GeV
π^- 3,6,16,25,32 GeV



20°: e^- 2,4,8,15,20,32 GeV
π^- 8,15,32 GeV

π^0 run

π^- 16, 25, 32 GeV

π^+ 60 GeV

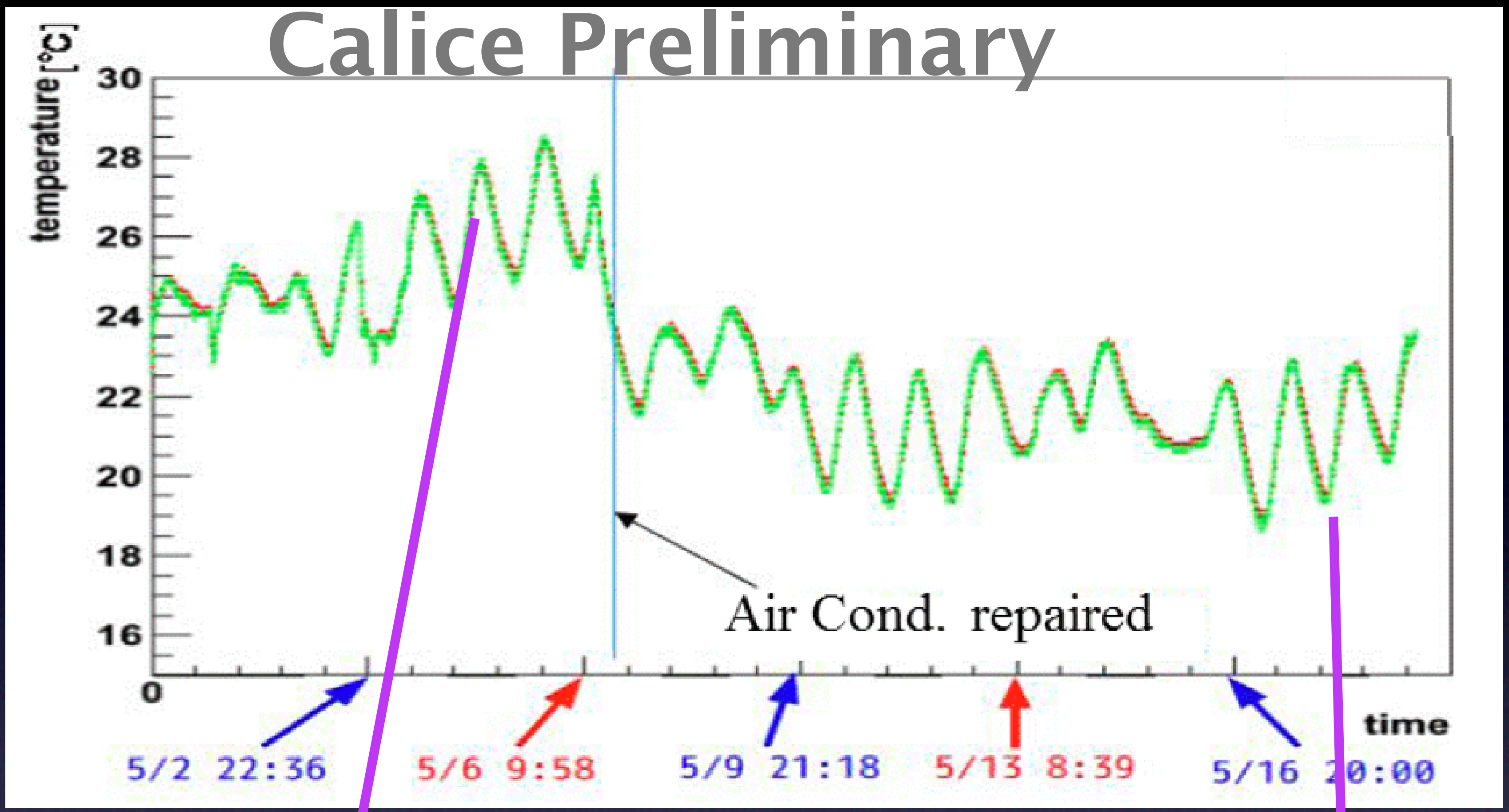
-cluster separation
-π^0 kinema. cut

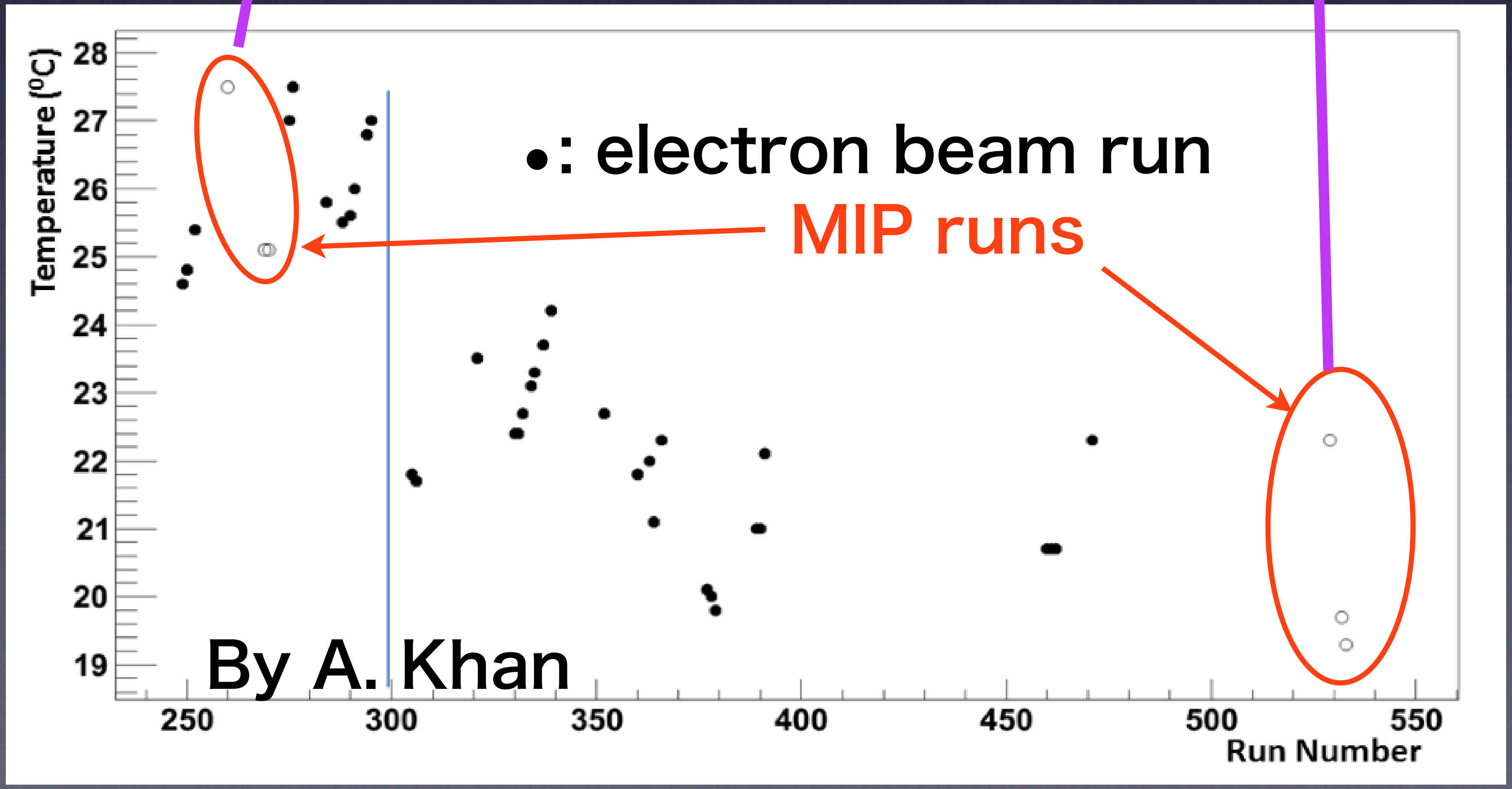
32GeV μ MIP calibration

~ @ 20℃

@ 20℃, 25℃,
Tilt angle 20° @ 20℃

May 2009 : Large Temperature fluctuation

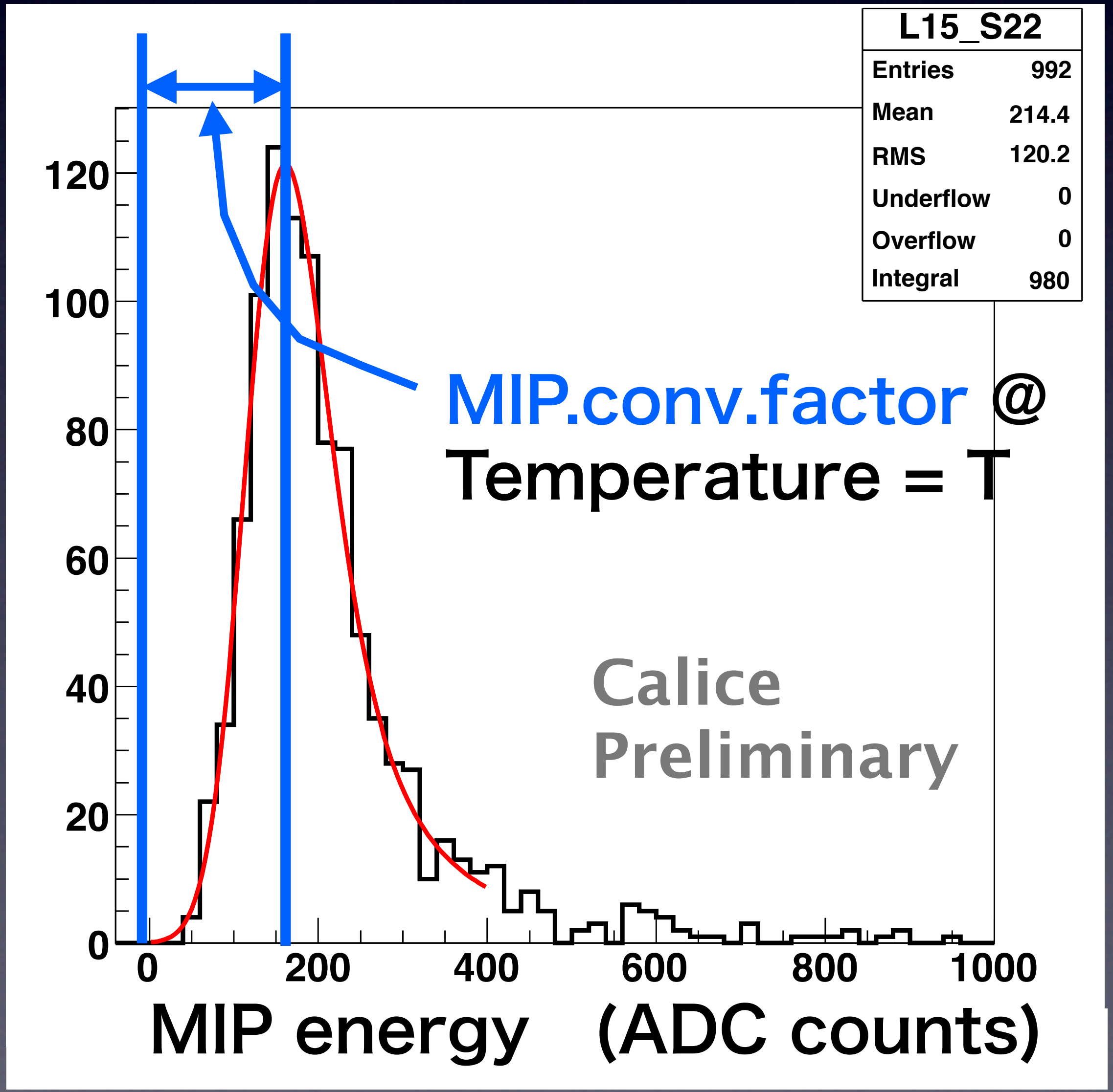


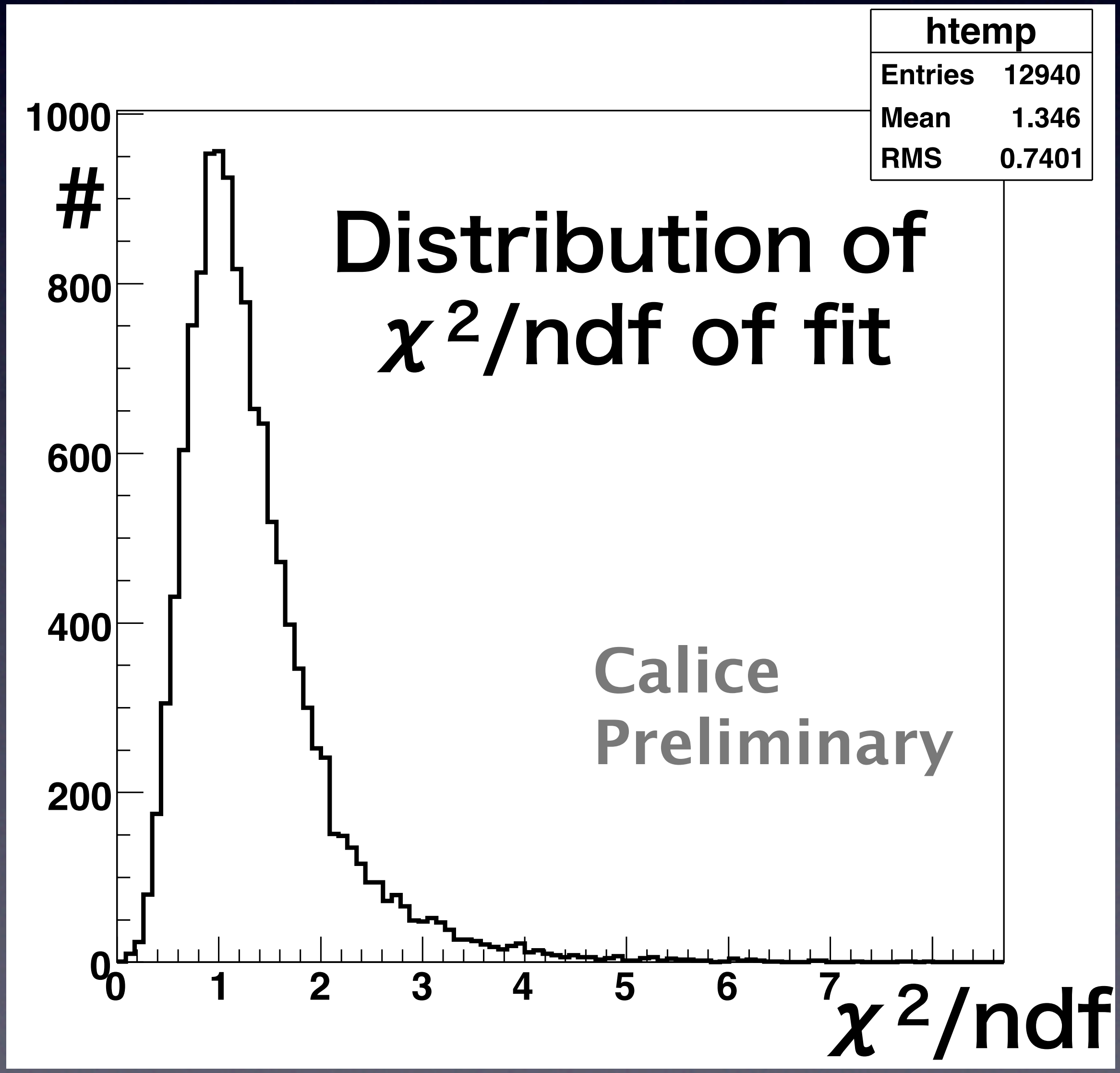


- Temperature varied 19℃ ~ 28℃,
- Chance to study temperature effect,
- First order temperature correction applied in this study is done by using ADC/ MIP.conv.factor for each channel.

ADC/MIP.conv.factor

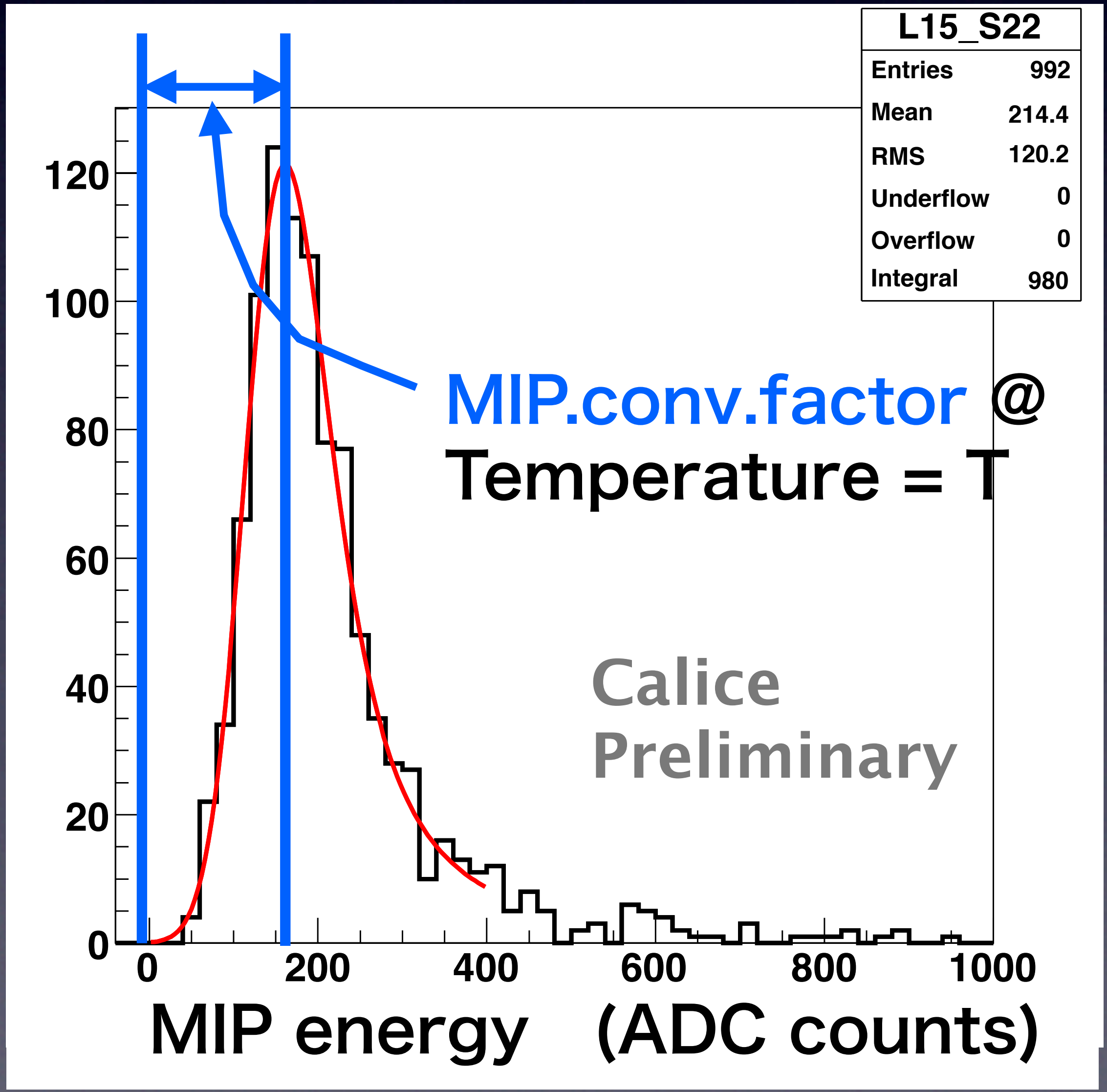
- To calibrate each channel, muon beams are used,
- ADC/MIP.conv.factor = “ADC counts”/“MIP”,

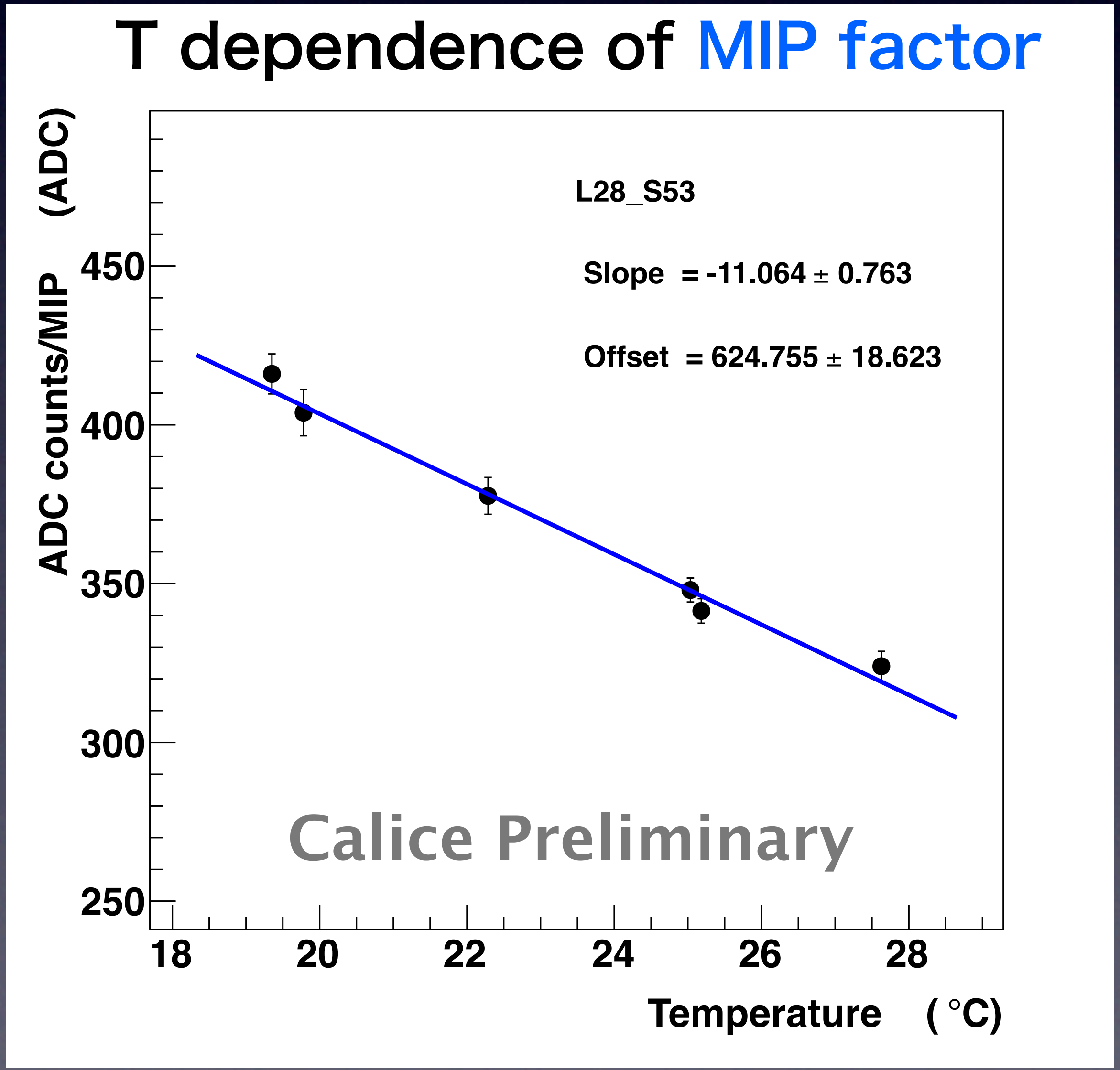




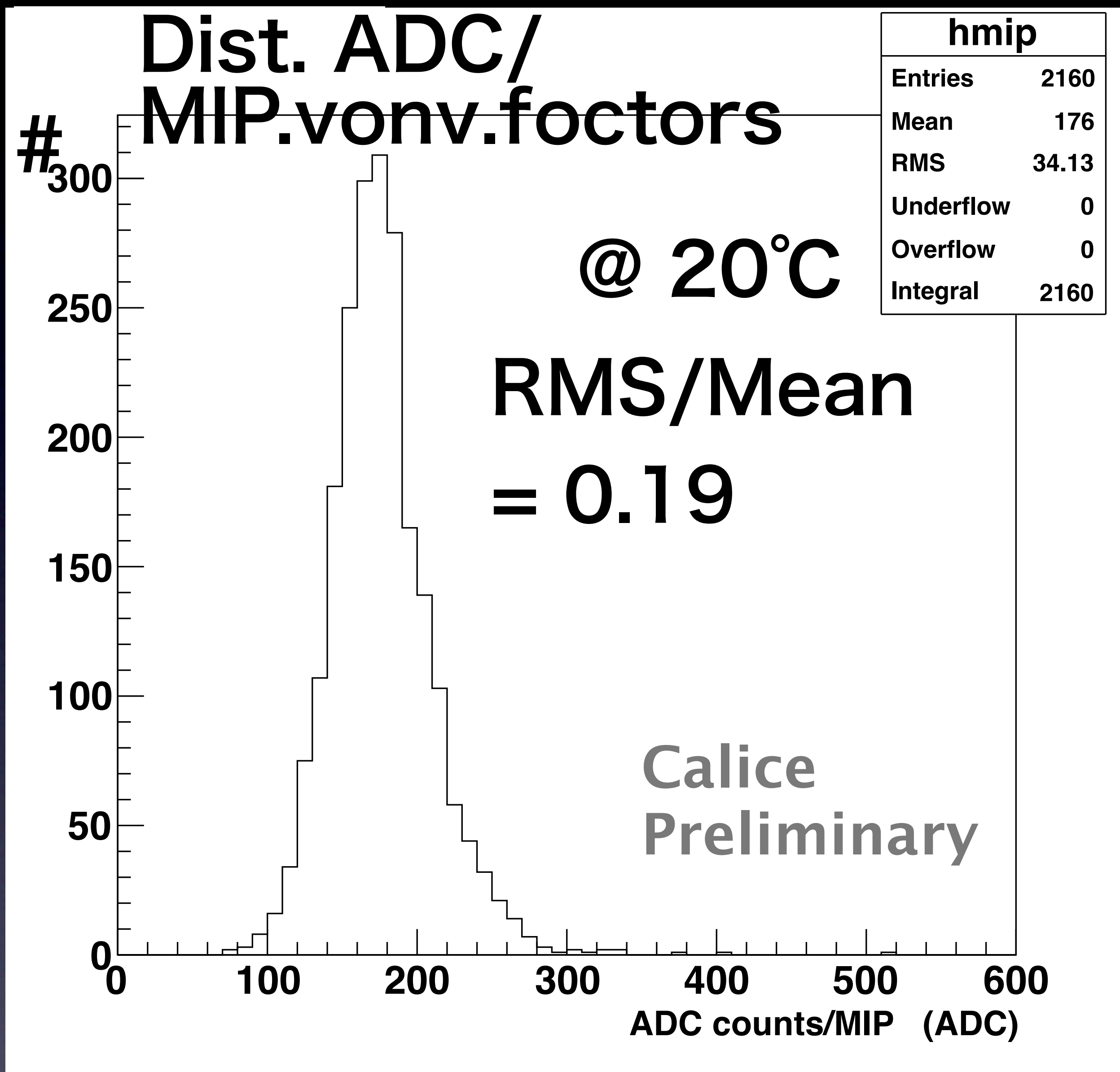
ADC/MIP.conv.factor

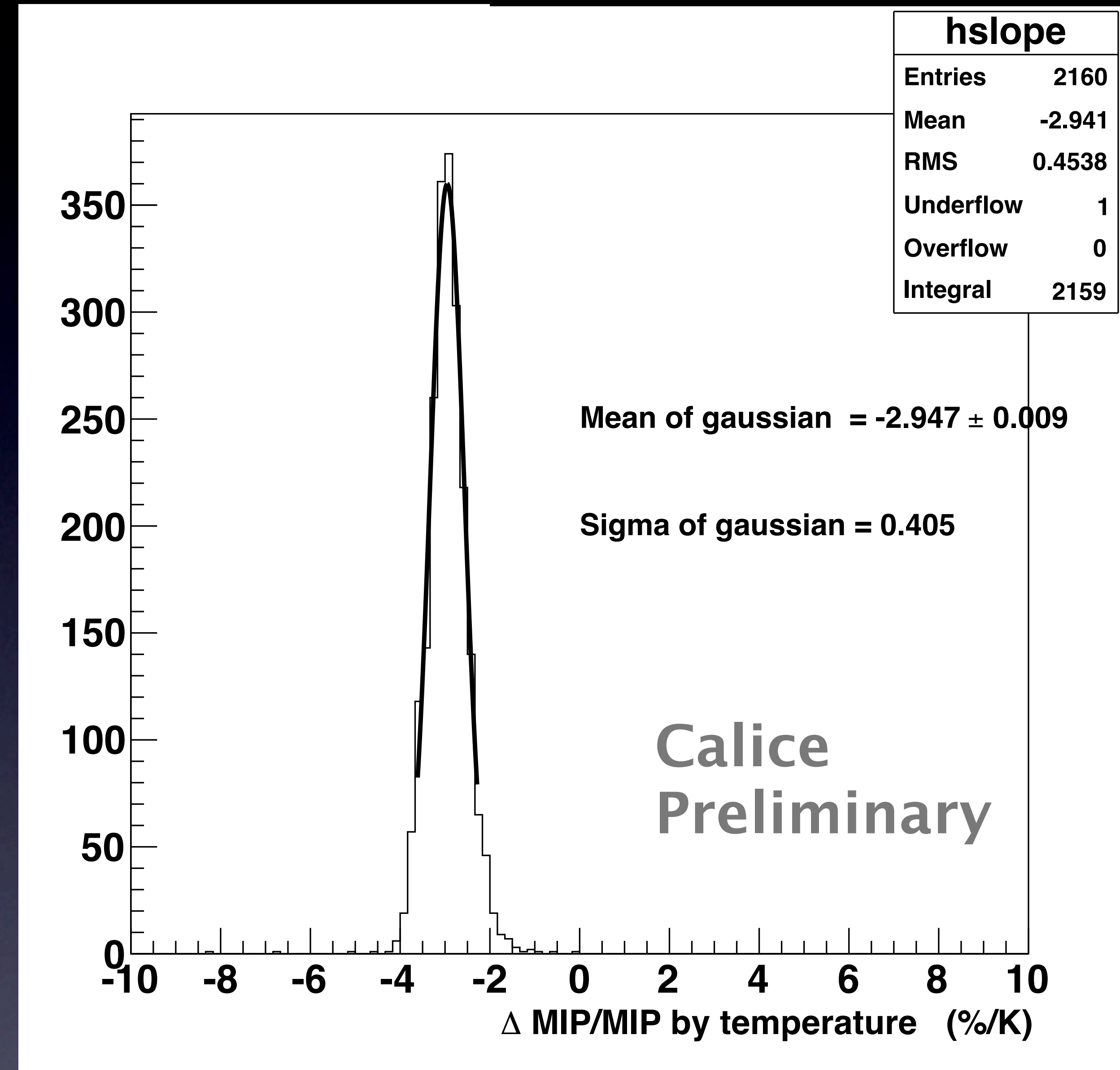
- To calibrate each channel, muon beams are used,
- ADC/MIP.conv.factor = "ADC counts"/"MIP",
- Temperature dependence of ADC/MIP.conv.factor is the same as the energy deposition by other particles,





Distribution of ADC/ MIP.conv.factors and slopes





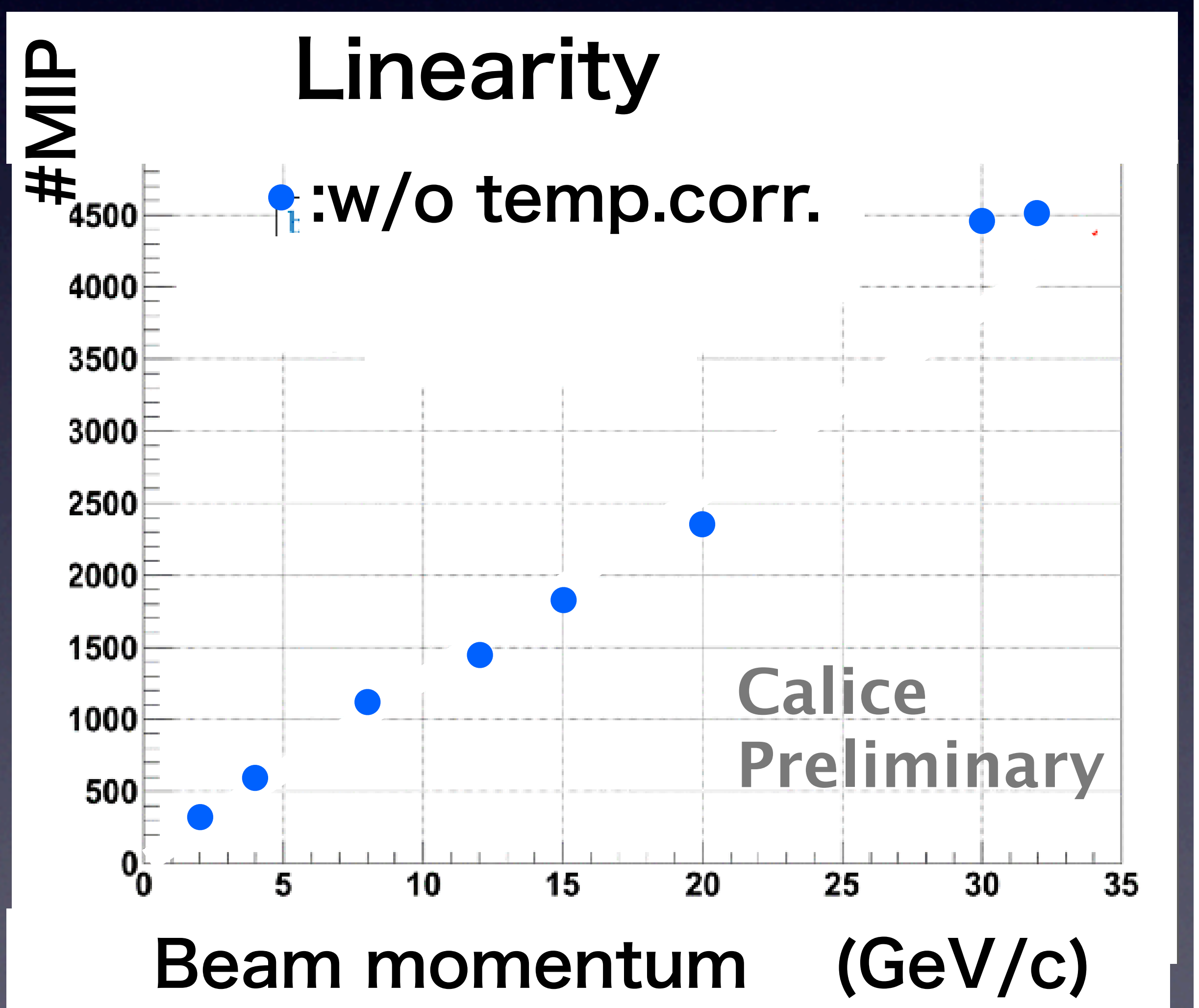
- Variation of ADC/MIP.conv.factor is 19%, ▶ This comes from Scintillator WLS fiber system (variations of scintillator quality, MPPC fiber miss matching and so on.) ∵ Variation of MPPC gains is less than a few%
- except 3 channels(noisy), slopes of ADC/MIP conversion factor of 2157 channels are in this narrow distribution

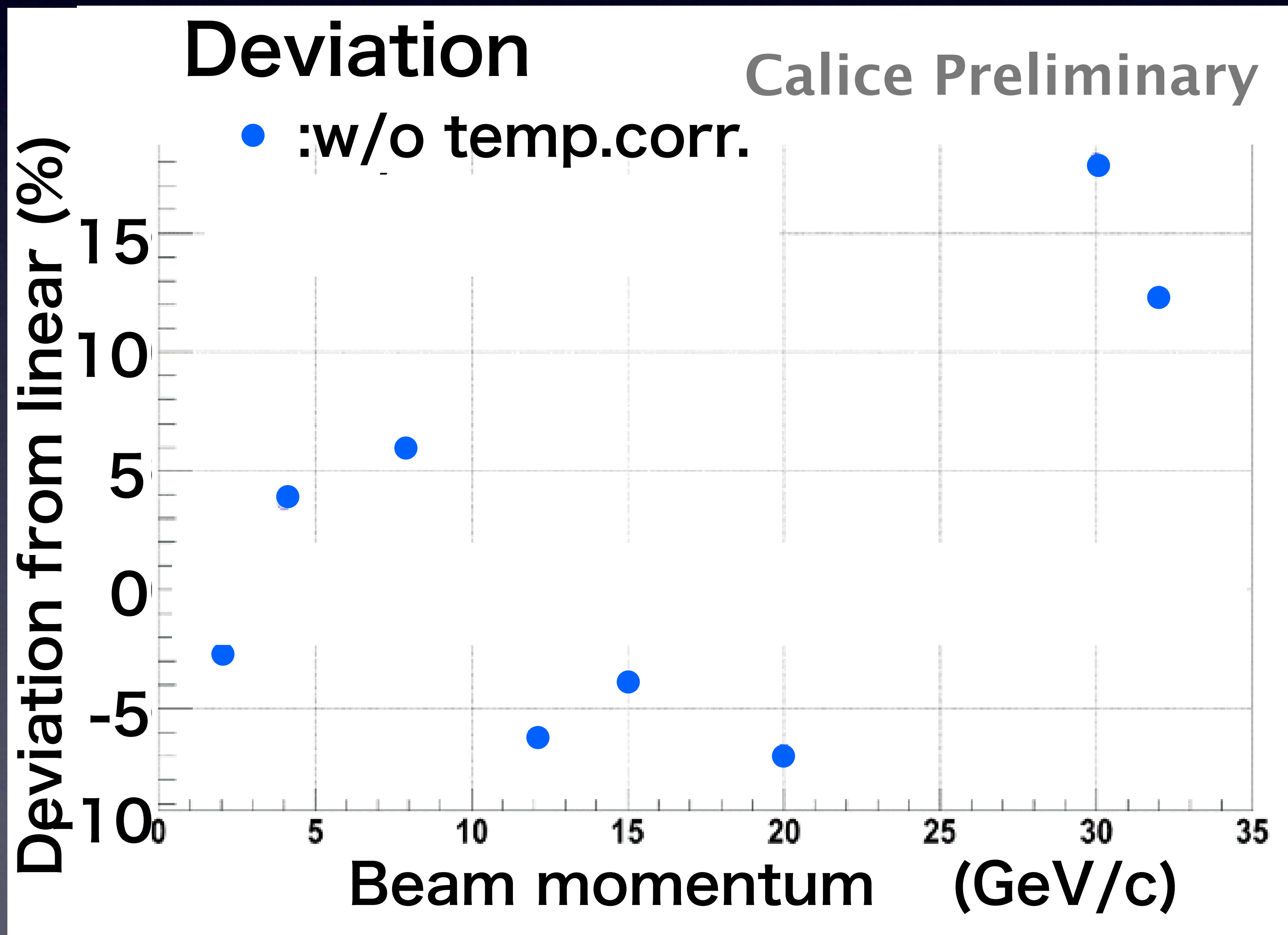
Electron energy response (2009)

First order temperature correction

Don't care temperature

energy sum expressed in # MIP $= \Sigma \frac{\text{ADCs by a hit on a channel at Temp.}}{\text{ADC/MIP.conv.factor of a channel}}$



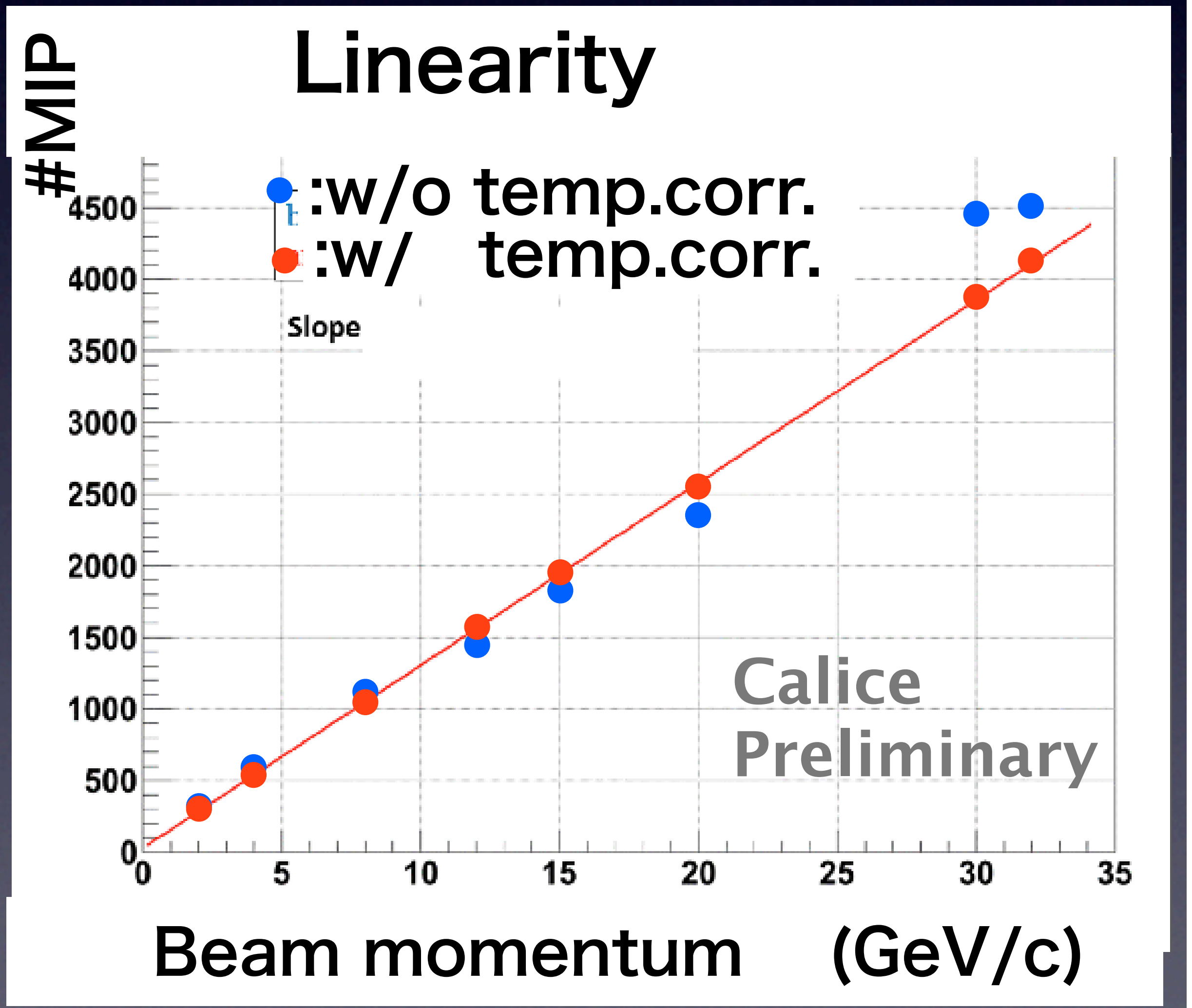


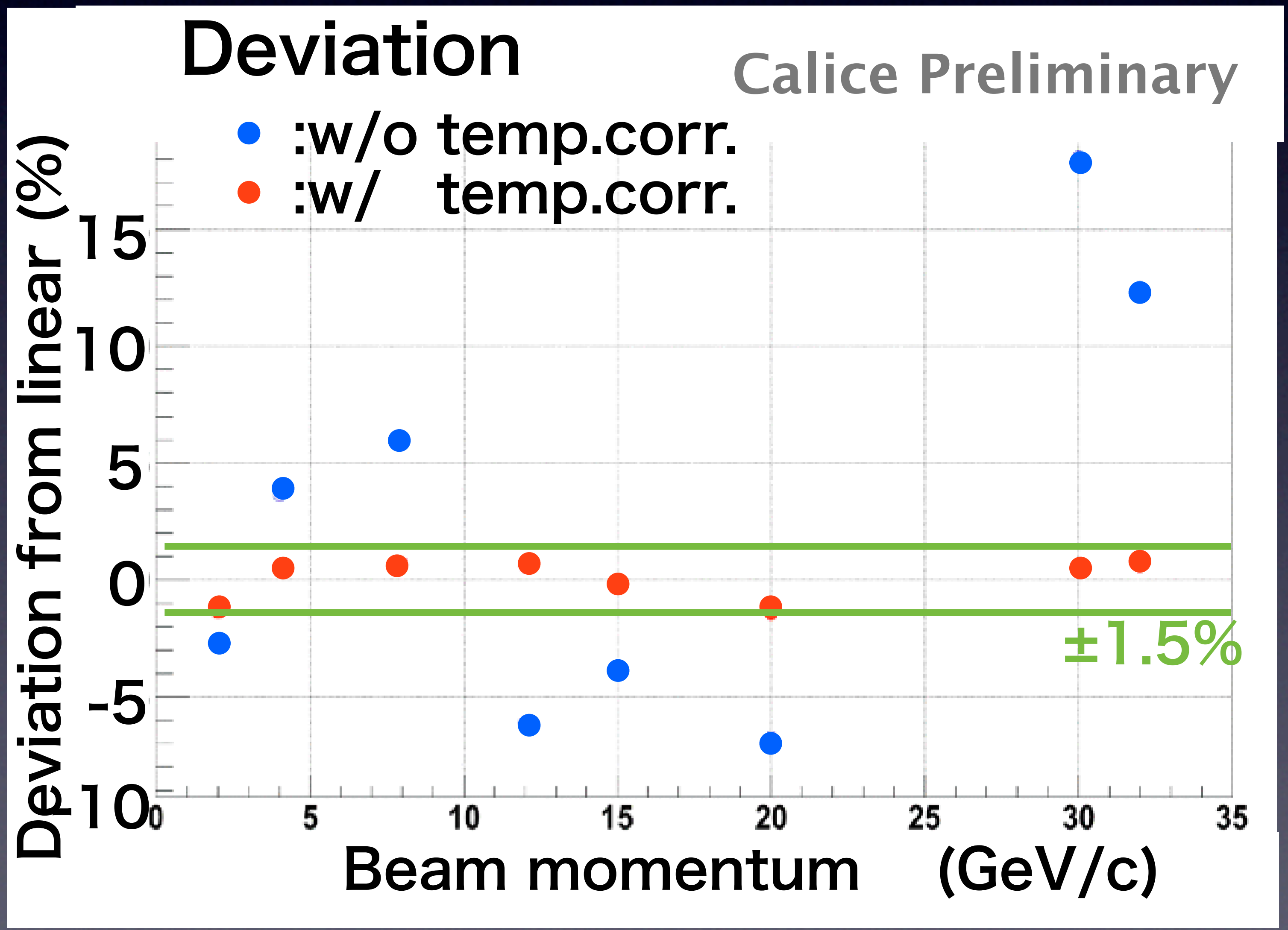
Electron energy response (2009)

First order temperature correction

Using the same temperature

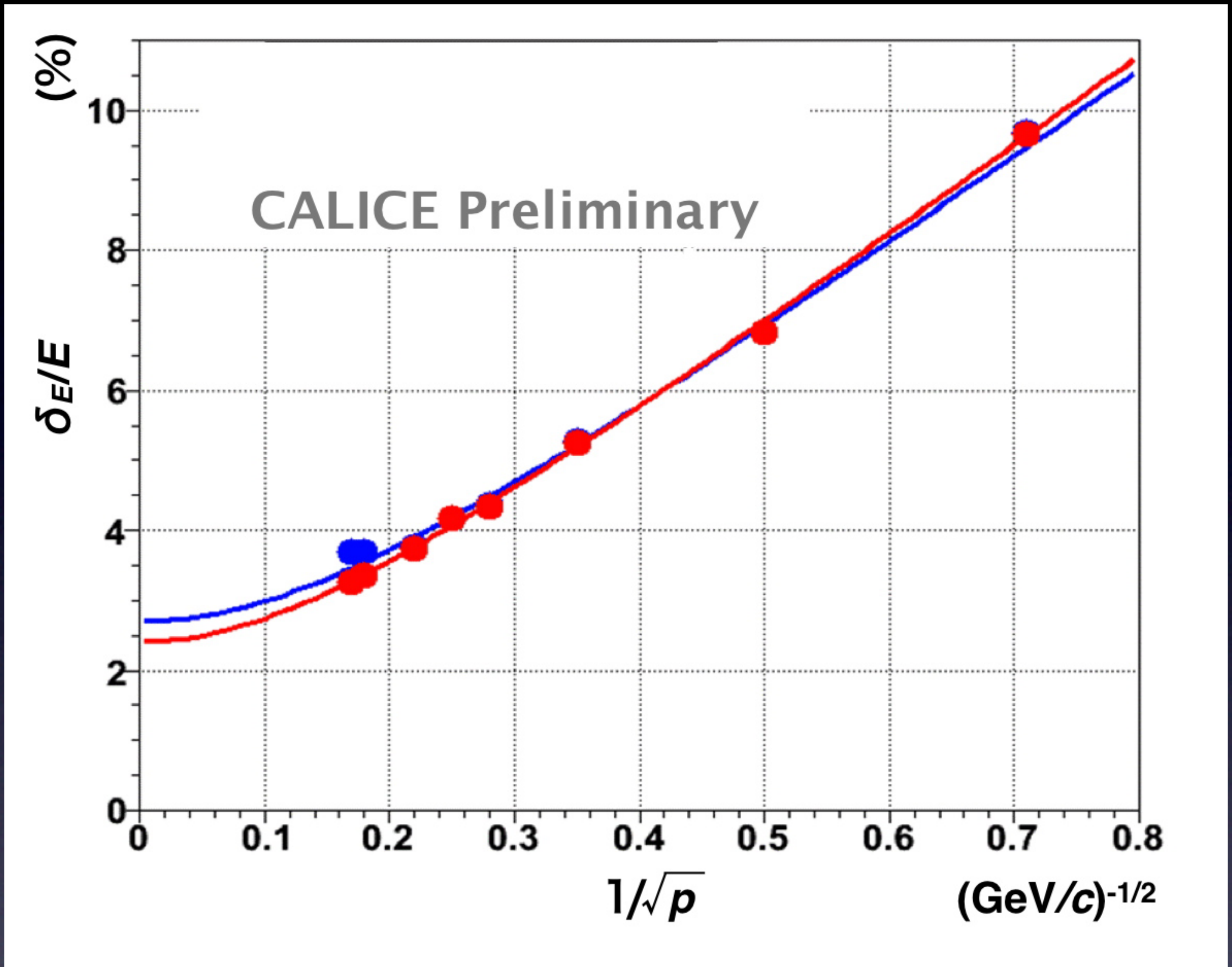
$$\text{Temp. corrected energy sum expressed in \# MIP} = \sum \frac{\text{ADCs by a hit on a channel at Temp.}}{\text{ADC/MIP.conv.factor of a channel (Temp.)}}$$





Temperature correction drastically improves linearity

Energy resolution (2009)



- Calice preliminary

constant term	2.32±0.02%
stochastic term	13.16±0.05%

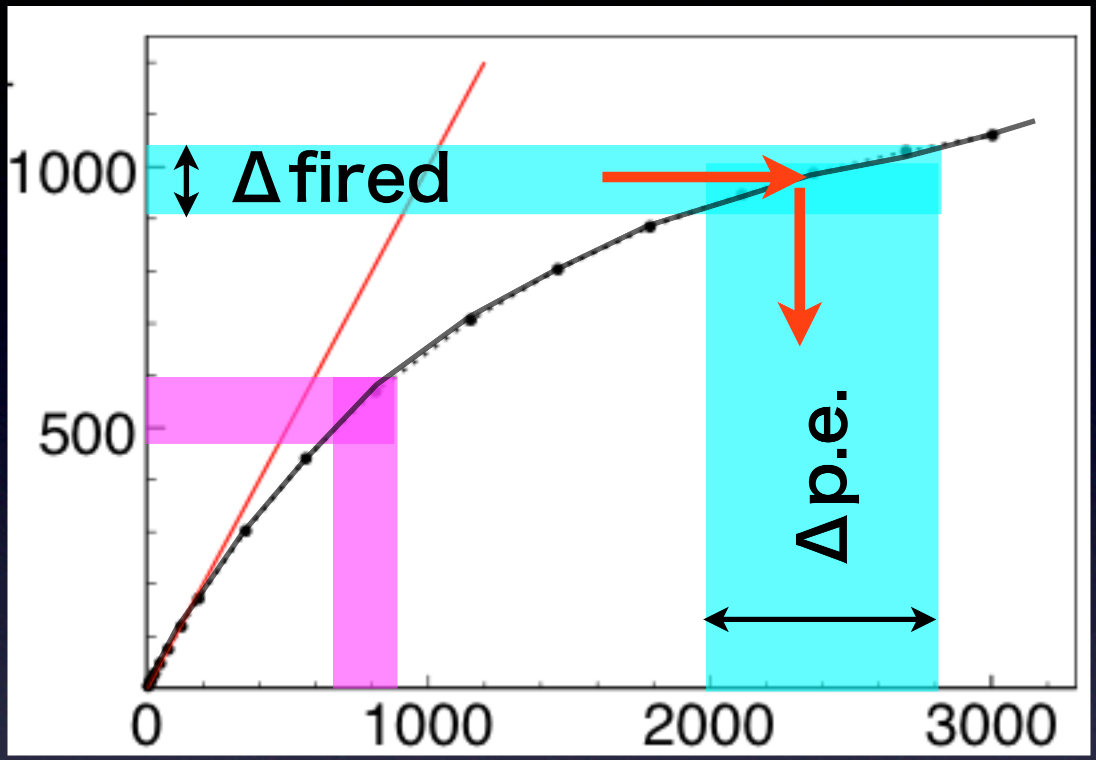
* only statistic errors

- Temperature correction improves energy resolution,
in this case, temperature during data taking of 32 GeV and 30 GeV is very different than temperature of MIP runs.

- Constant term is rather large ▶ study with MC

Discussion on constant term(1)

- Effect of PPD saturation correction on the constant term.



Fired = Npix [(1-exp(-Np.e./Npix)]

$$\text{factor}: \frac{\text{Npix}}{\text{Npix - Fired}}$$

is implemented in MC

	constant term(%)	stochastic term(%)
w/o saturation effect(MC)	1.61±0.08	12.6±0.2
w/ saturation effect(MC)	1.70±0.08	12.8±0.2
data (2009)	2.32±0.02	13.16±0.04

Effect of PPD saturation is small enough.

Discussion on constant term(2)

- Effect of beam mom. spread on the constant term of energy resolution

		constant term(%)	stochastic term(%)
MC	+ 0% beam mom. spread	1.27±0.09	12.5±0.2
MC	+ 1% beam mom. spread	1.61±0.08	12.6±0.2
MC	+ 2% beam mom. spread	2.27±0.07	12.8±0.2

- We can see the effect of beam momentum spread on the resolution.
- According to some discussion with Fermilab TB beam control, the momentum spread of beam is around 2%.

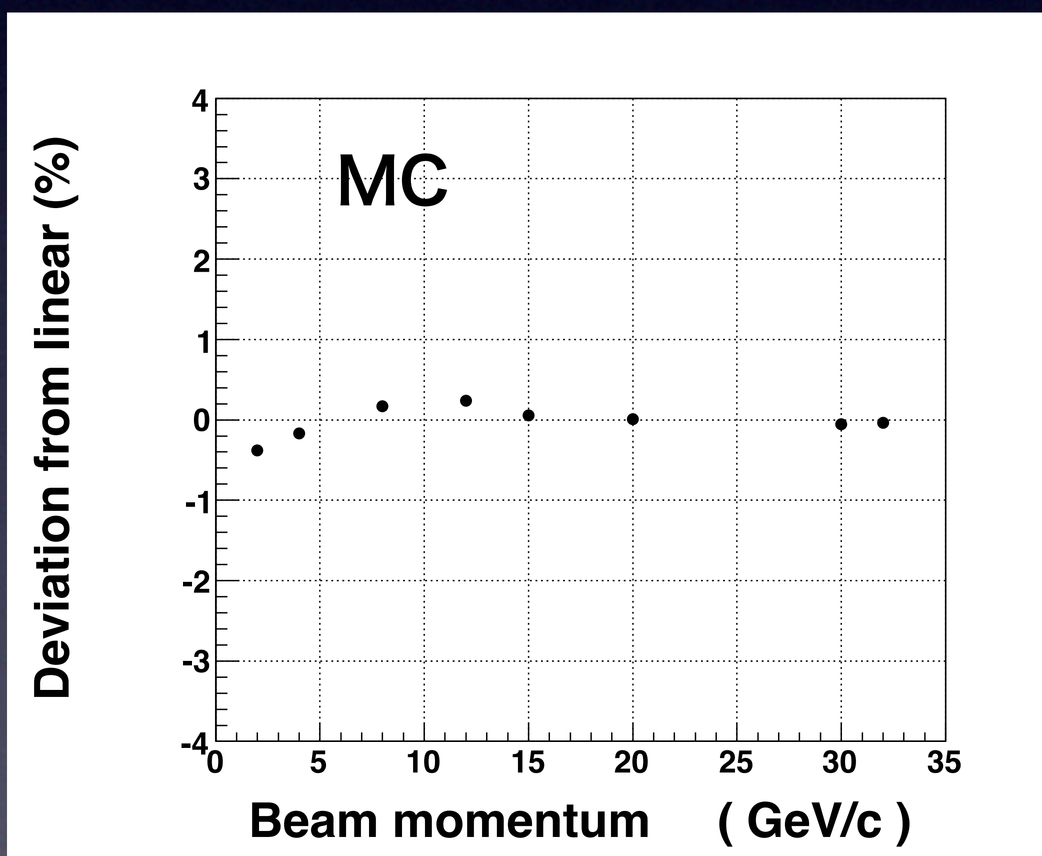
data (2009)	2.32±0.02	13.16±0.04
data (2009) - 2% beam mom. spread	1.17±0.03	13.13±0.03

- constant term of real data agree with MC with 2% beam momentum spread and 2% subtracted data agree with MC with no beam momentum spread ➡ main contribution of constant term?

Remaining source in const. term

With non-beam momentum spread, ScECAL prototype still has 1.2% constant term, according to MC simulation.

We want to understand the sources of this non-zero constant term.



- We already see: dead volume from PPD, reflector is small.

- linearity indicates some energy leakage for large energy

- Prototype module has larger air gap between layers.

▼

Plan: to see the effect of above issues by comparing with ideal detector in MC.

Summary

- ScECAL, May 2009 @ FNAL data was analyzed,
- First order temperature correction has been done,
- Temperature correction drastically improves linearity of energy response,
- Preliminary Energy resolution

Stochastic term	(13.16±0.05)%
Constant term	(2.32±0.02)%

uncertainties are only statistical

- Constant term was discussed.
  - Effect of PPD saturation correction is enough small.
  - Intrinsic momentum spread of beam is candidate of main source of the constant term.
  - Need more precise estimation of beam momentum spread.

Plane

- Estimation of systematic uncertainties are half way.
- More precise comparisons between MC and data
    - linearity, energy resolution,
    - lateral and longitudinal projection of energy dep.
- ECAL-AHCAL-TCMT combined analysis of pion,
- Analysis of effect of tilt incident angle,
- Precise incident beam position dependence,
- pi0 reconstruction
- .....

Backup