Latest results of ScECAL FNAL-TB

; appearing in the paper for electron response

1st June 2016

CALICE day of ECFA in Santander

K. Kotera, Shinshu University/DESY

I hope this would be the final!

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Outline

1. a brief introduction to the physics prototype II.

2. major 5 updates (5 of many),

5

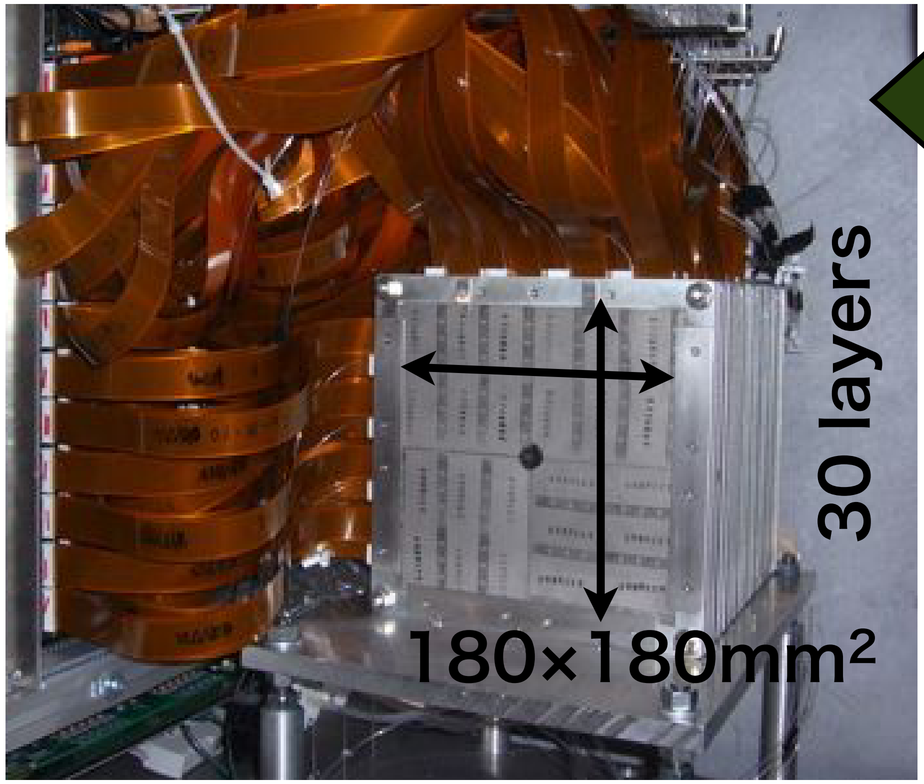
a) request from the CALICE editorial board;
Frank Simon, Lei Xia, Nigel Watson

b) our response

1) brief explanation for the calibration,
2) Cut value of Inter calibration,
3) explanation for systematic uncert. from cuts,
4) wave structure of deviation from liner,
5) realistic simulation.

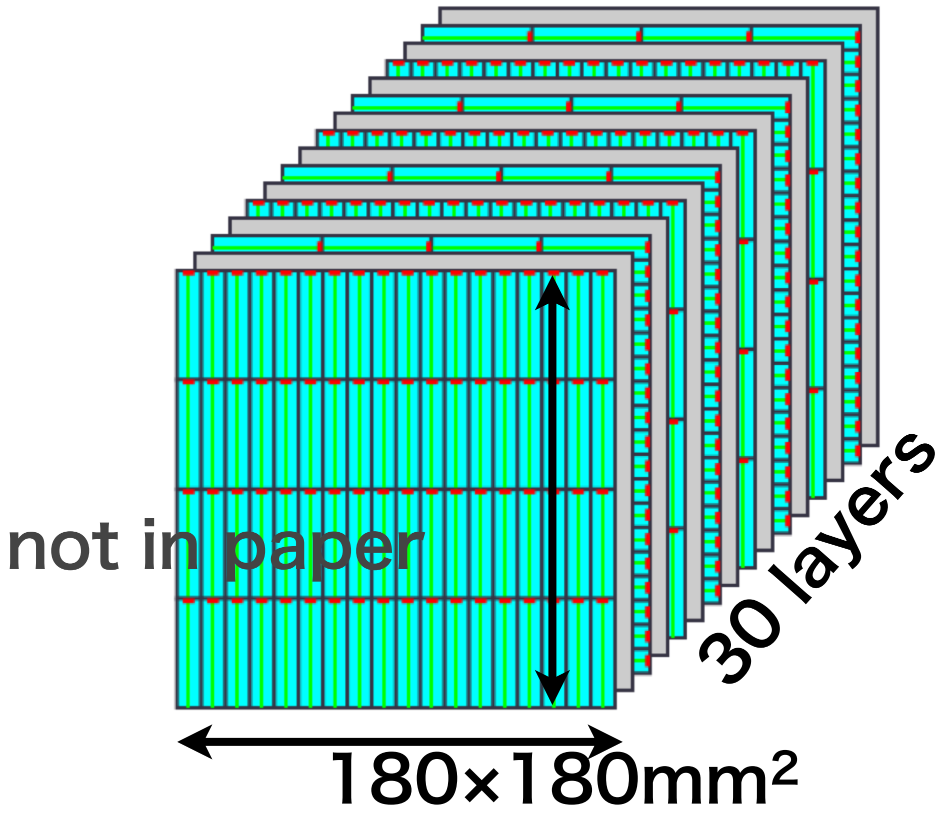
3. summary

ScECAL Physics Prototype



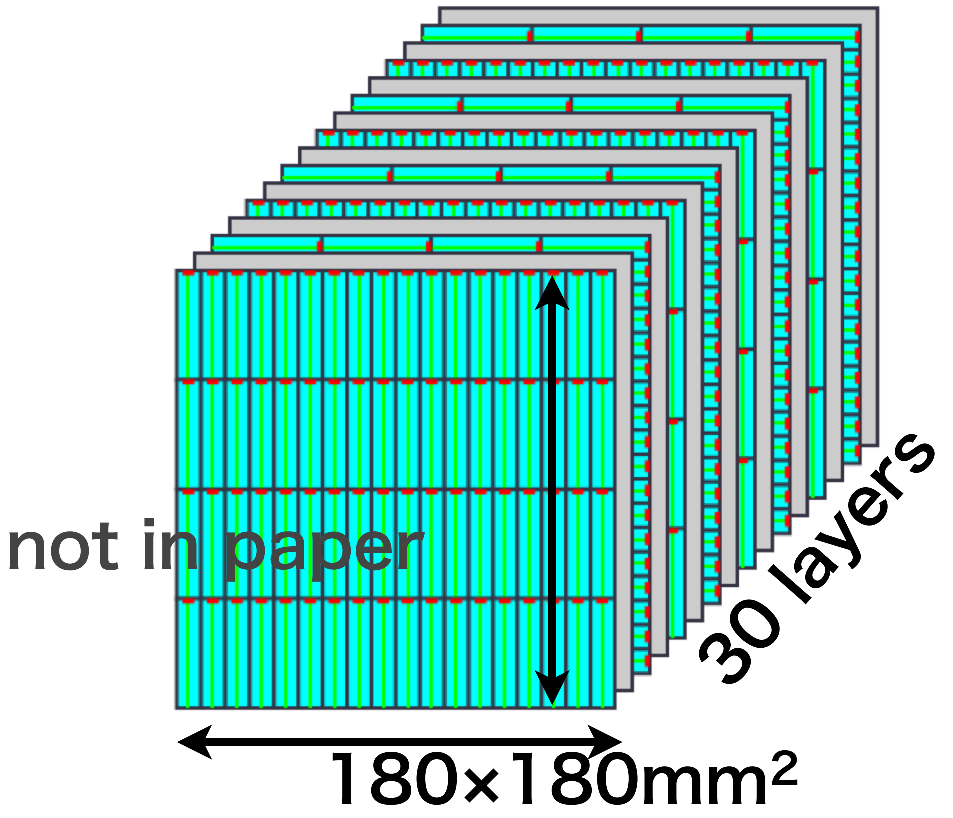
AHCAL front face

ScECAL Physics Prototype



- 3.5mm tungsten-C* abs.

ScECAL Physics Prototype



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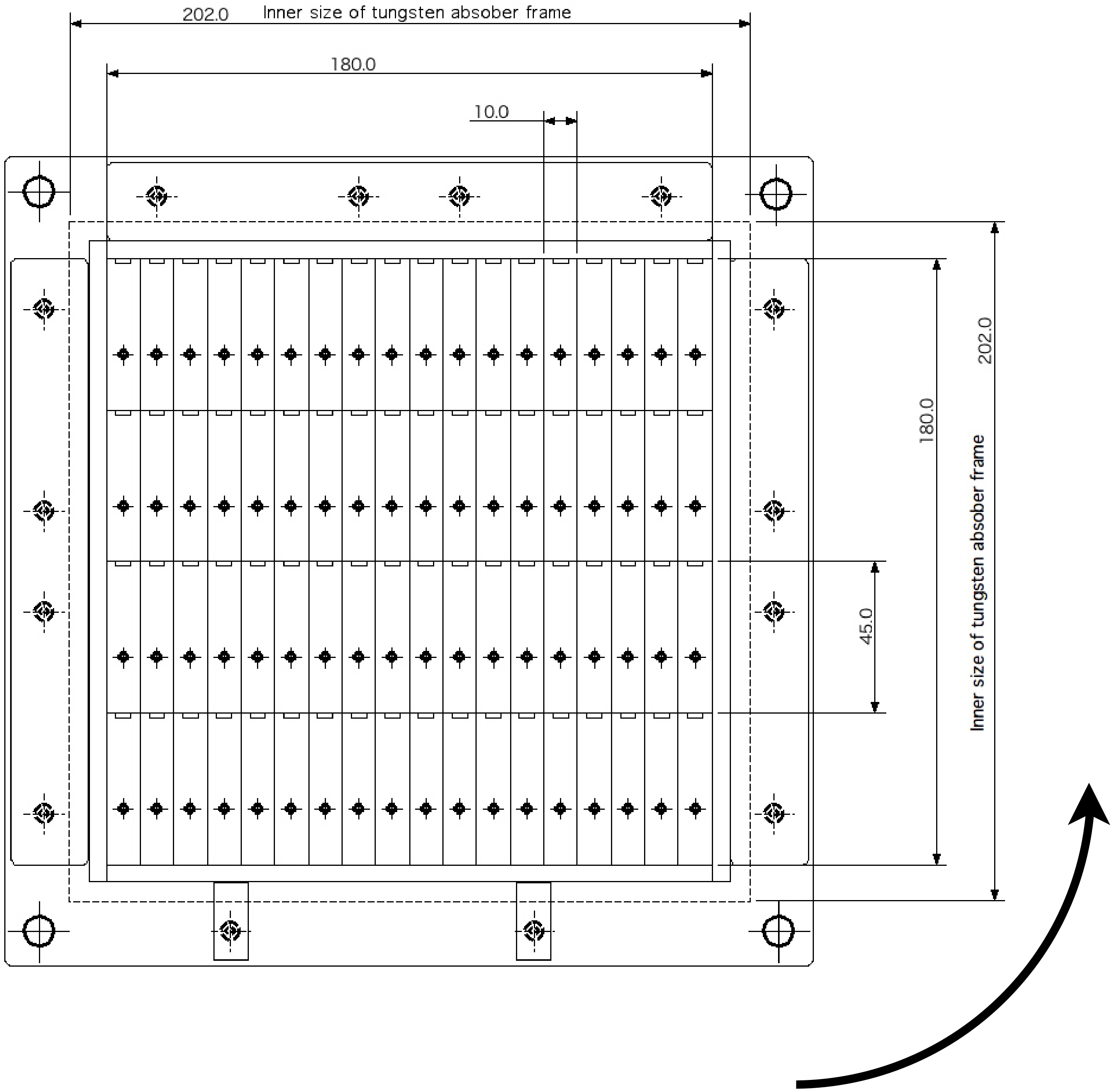
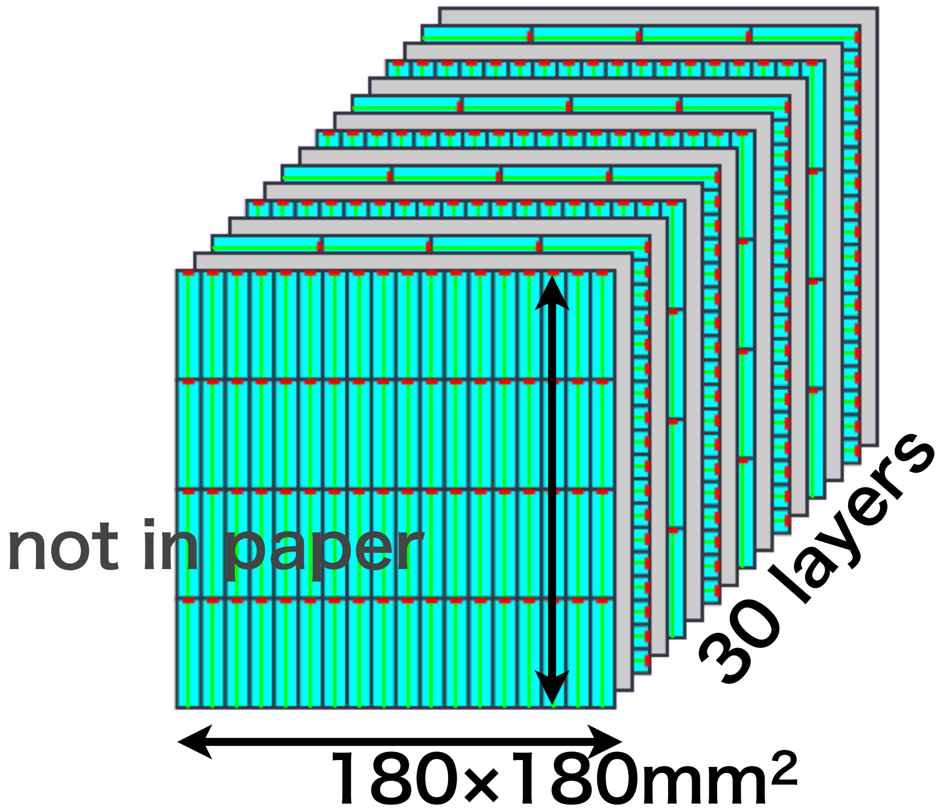


rotate 90° w.r.t. previous layer

ScECAL Physics Prototype



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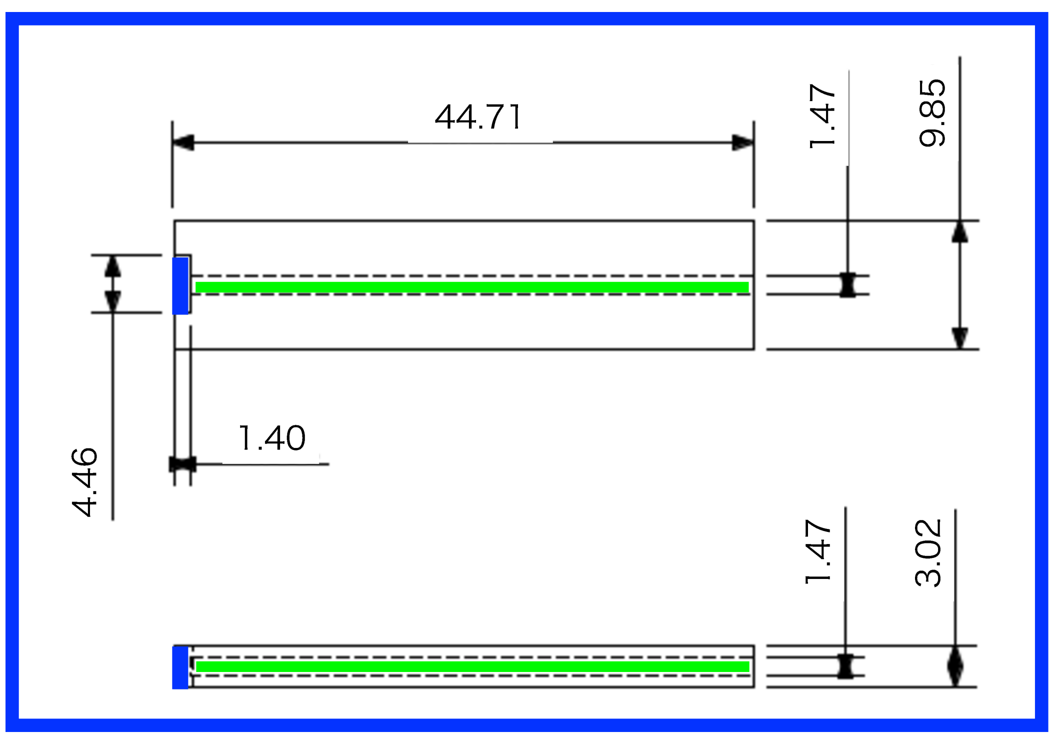

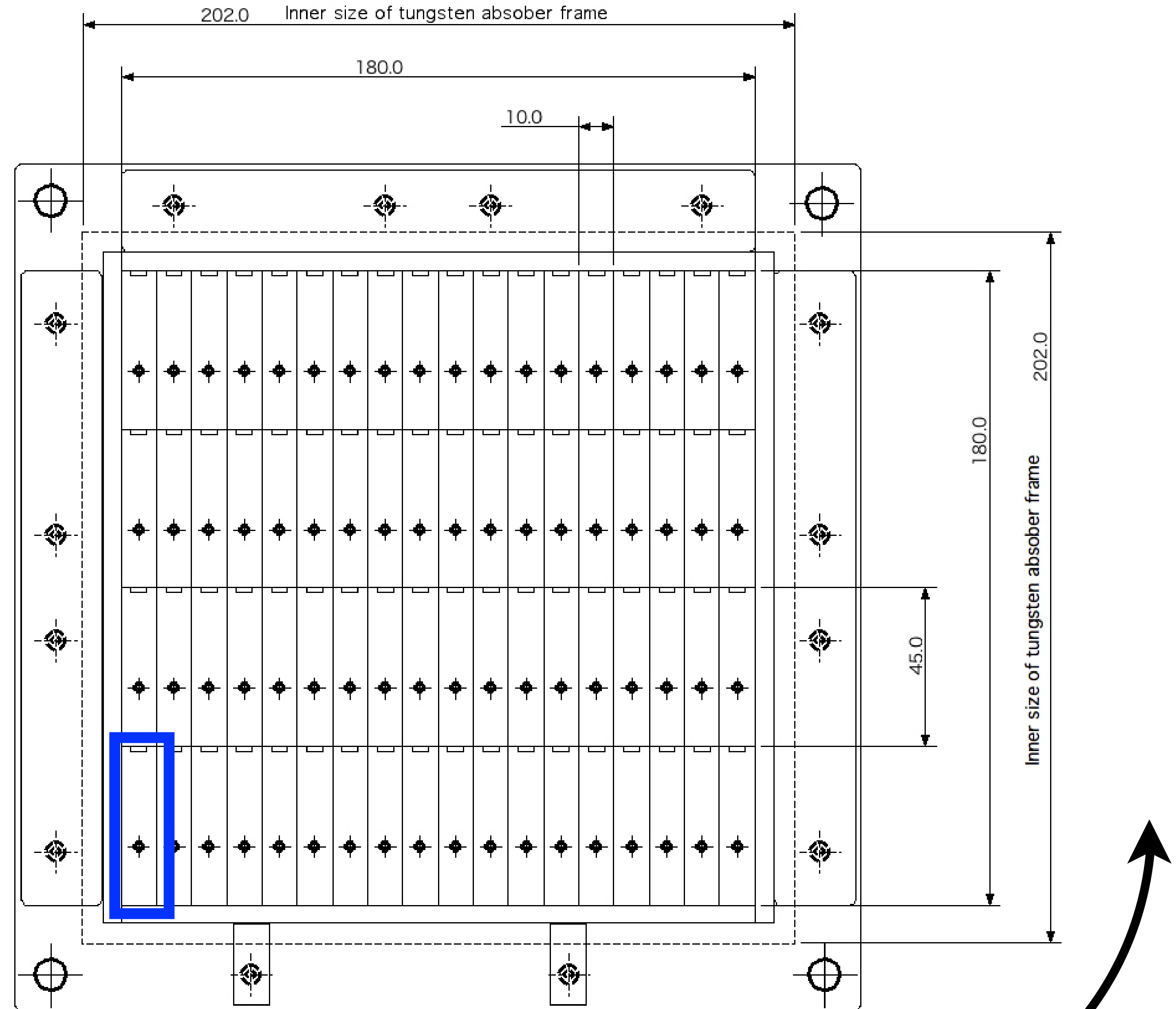

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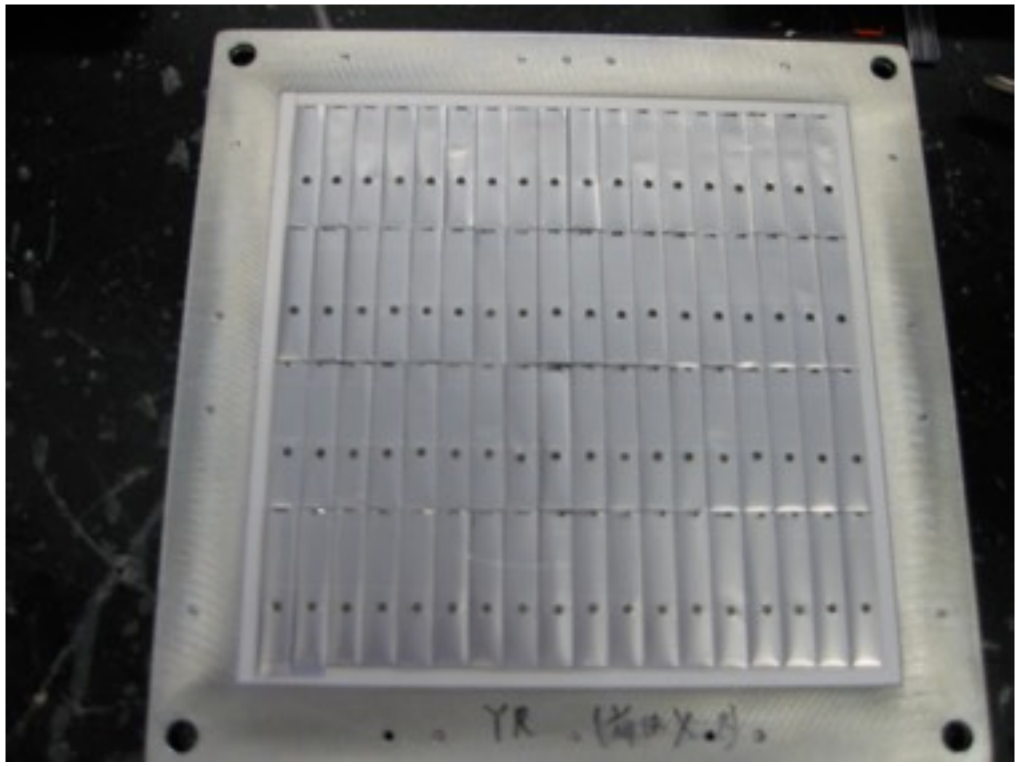
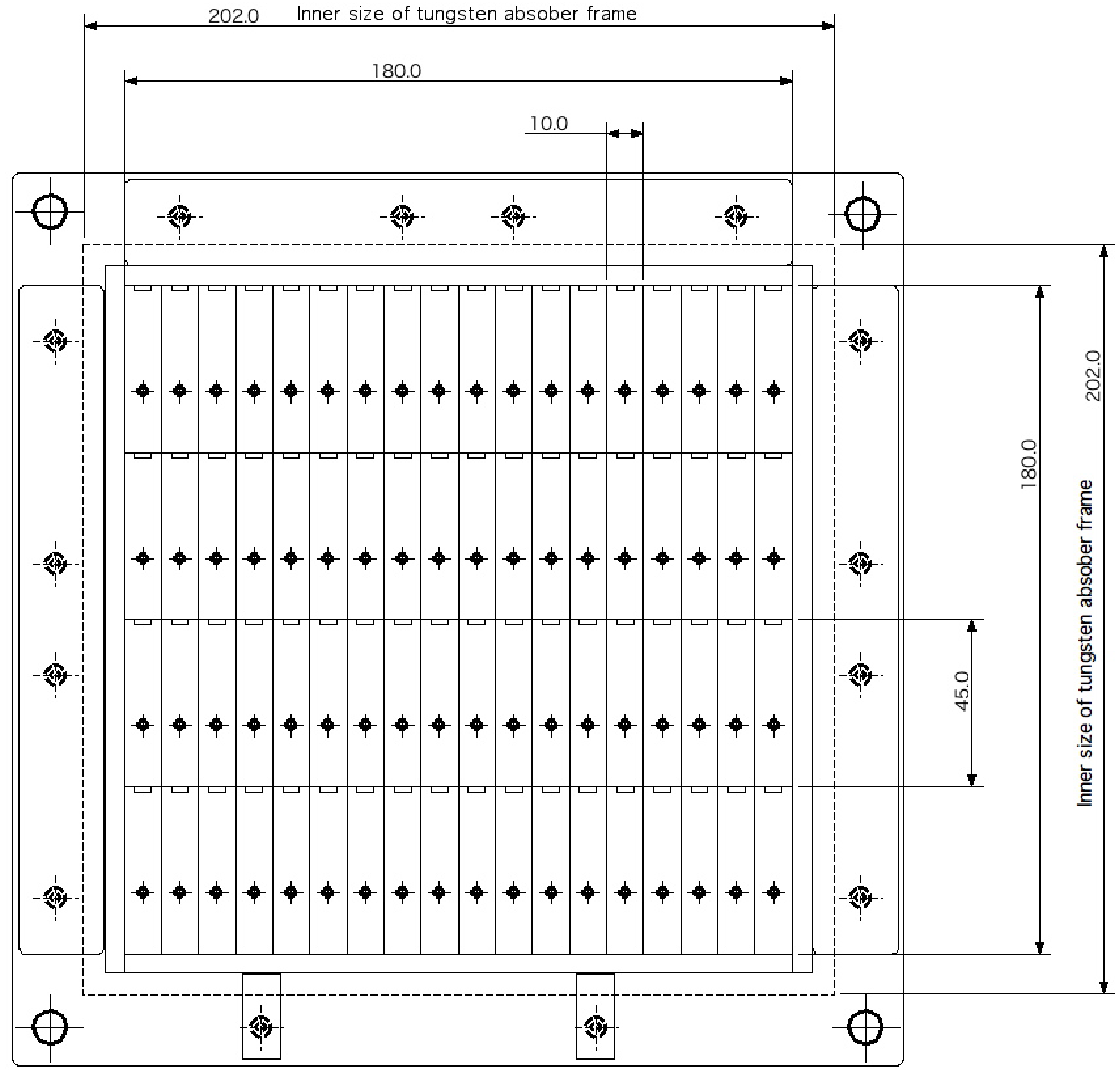
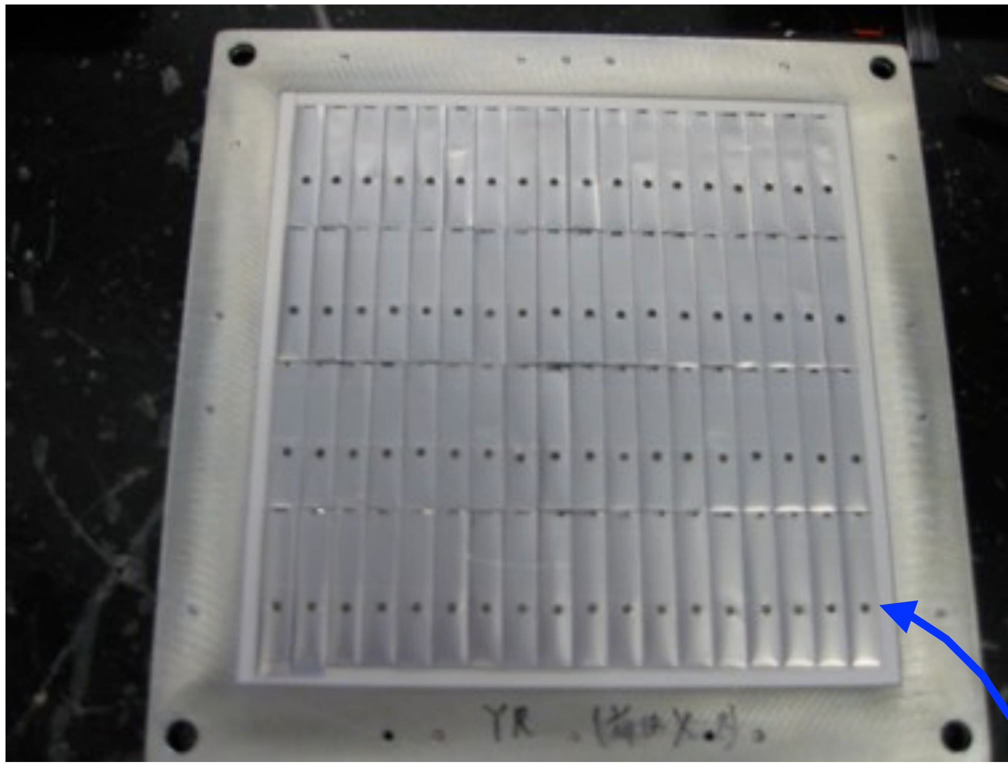


2500 strips were wrapped in reflector film.



ScECAL Physics Prototype



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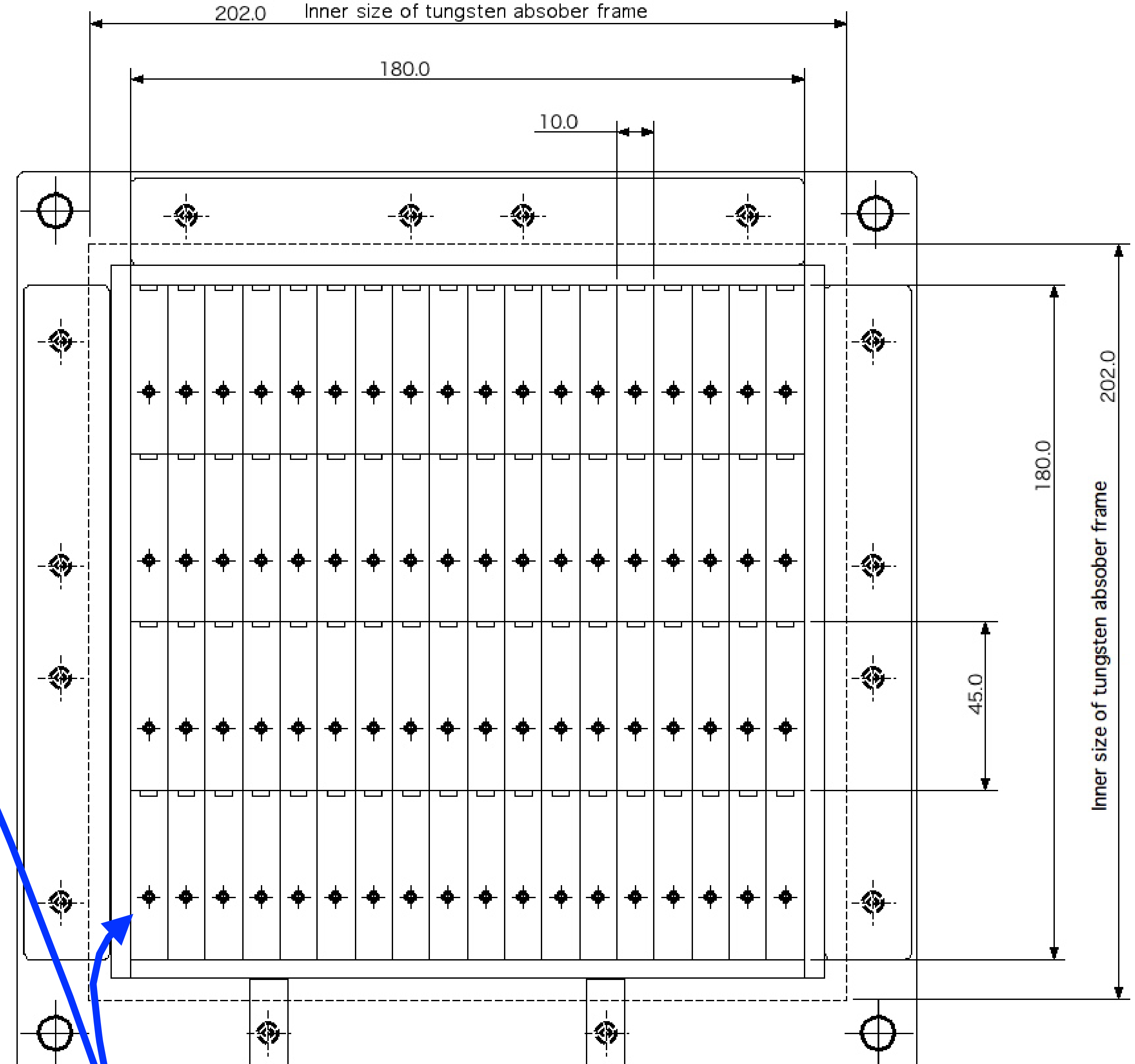
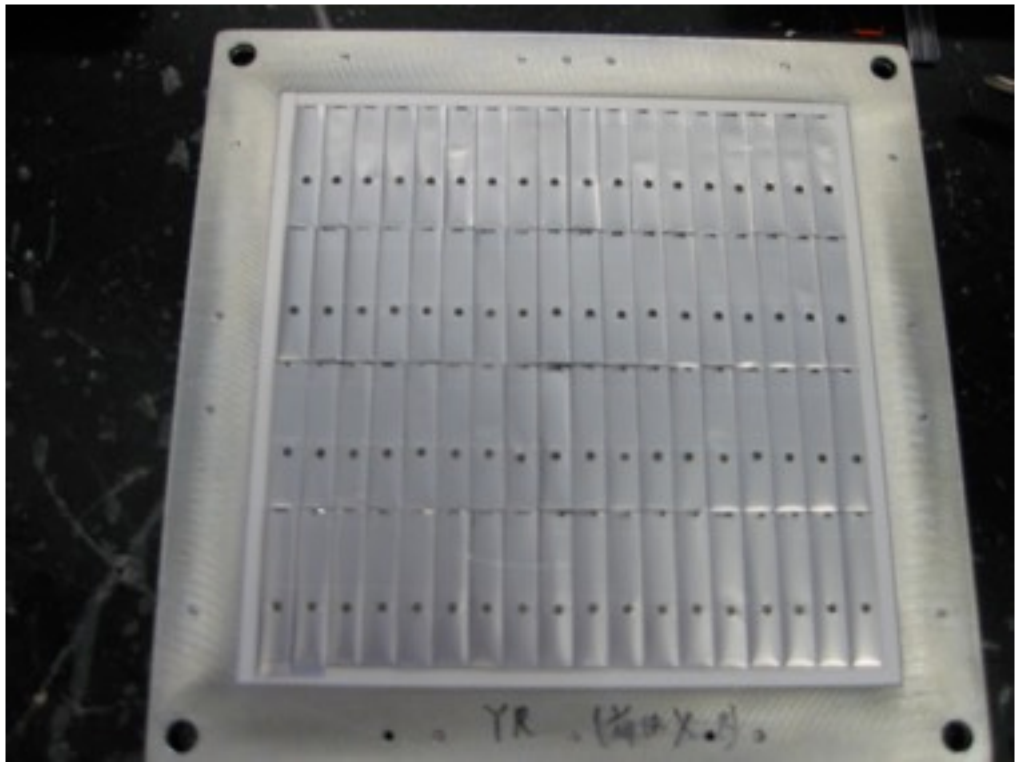
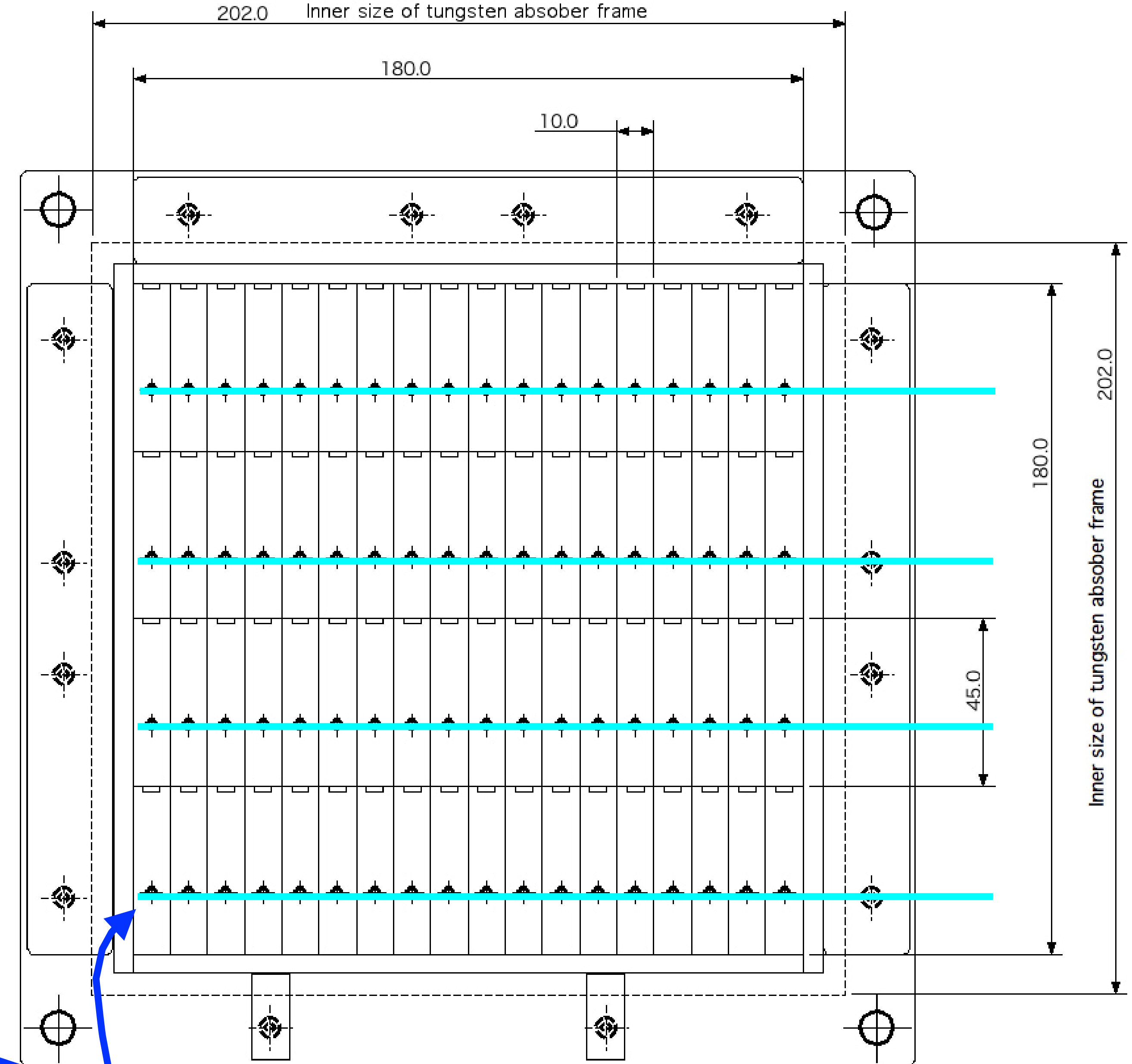
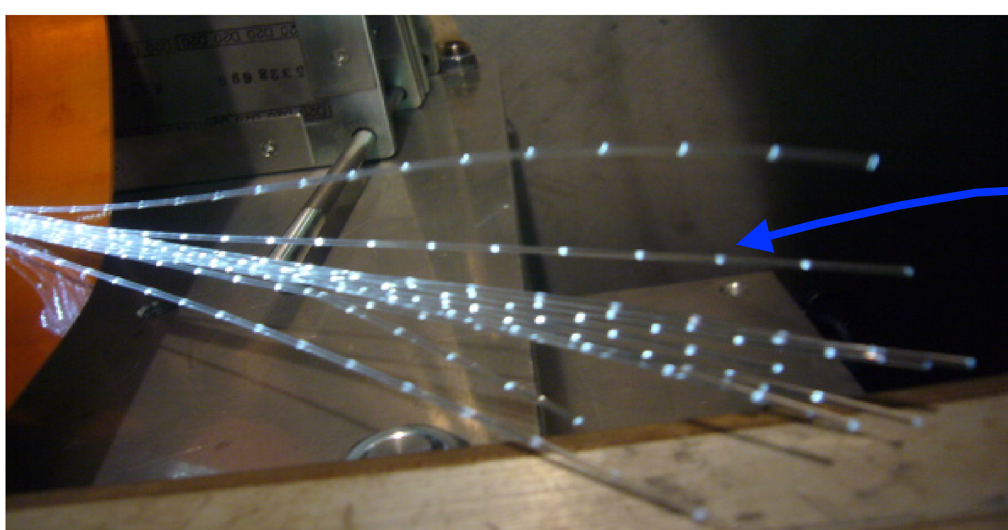


LED light went into strips for monitoring.

ScECAL Physics Prototype



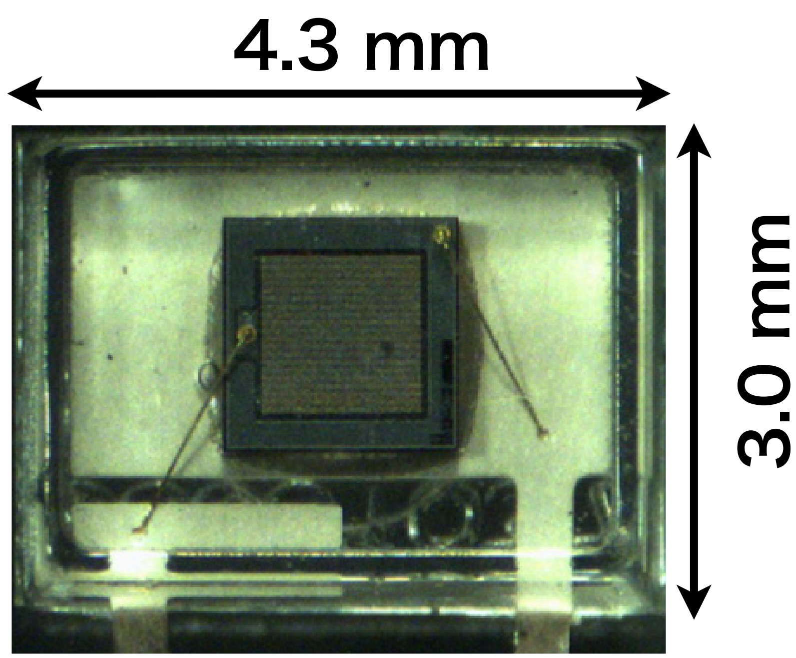


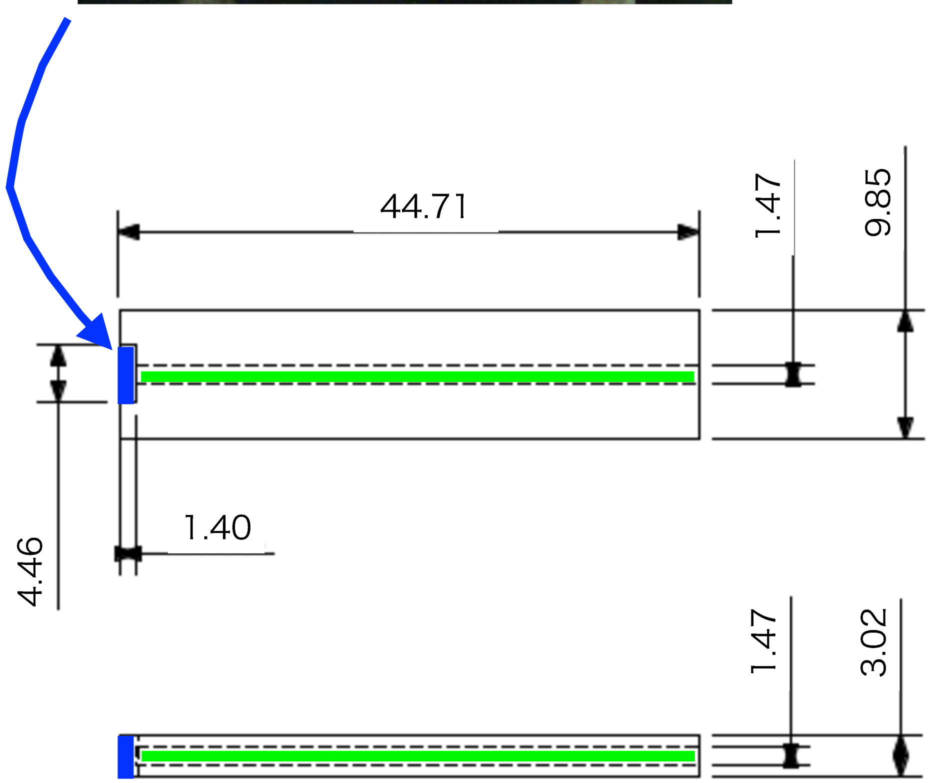


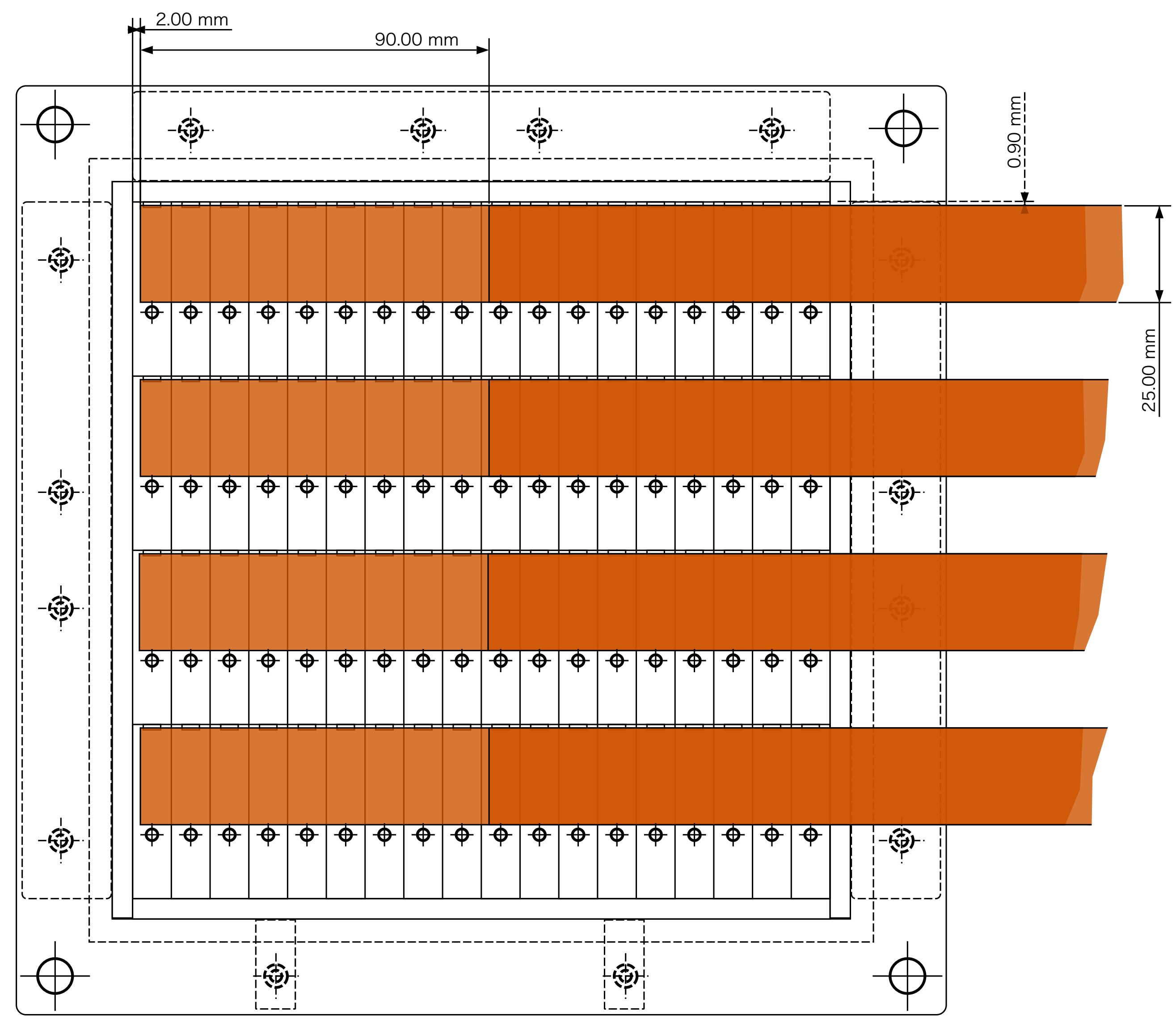
LED light was distributed via clear fibers

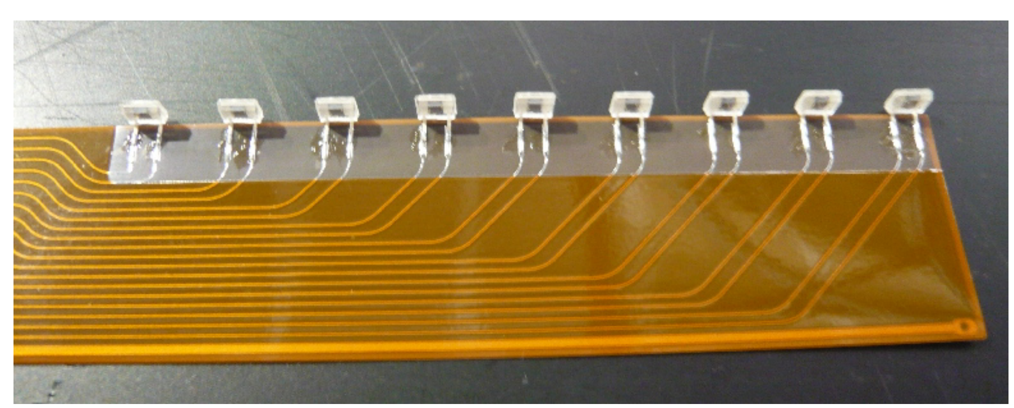
ScECAL Physics Prototype

25μm pitch 1600 pix in 1×1mm^2 MPPC





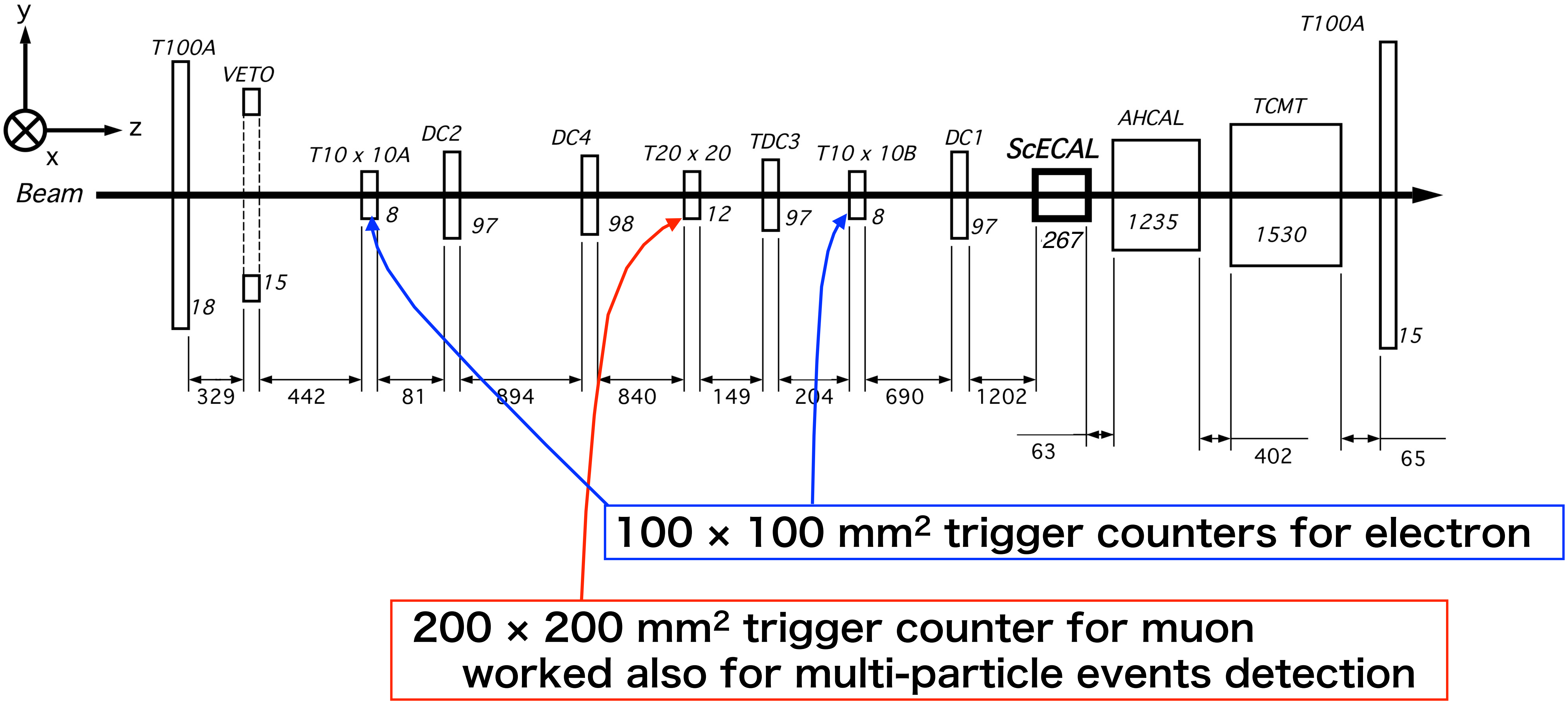




9 MPPCs on a cable

MT6 in Fnal Test Beam Facility

Sep 2008, May 2009



A differential Čerenkov counter was upstream : select particles

- DAQ system was the same as AHCAL phys. prototype.

Request 1

Calibration procedure is difficult to understand
for a person from the other fields;

add a section to entirely explain it.

↑

We added a dedicating subsection,

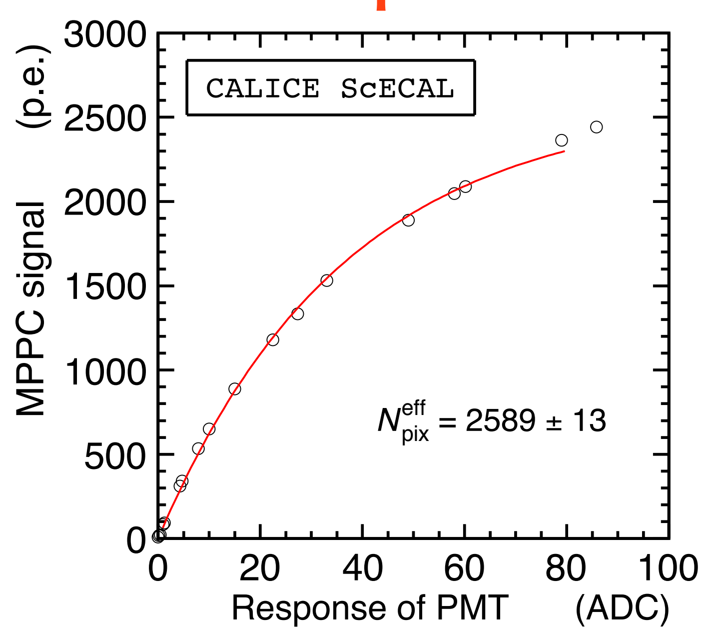
This is not update on the results, but better to give
you a brief explanation of our calibration procedure.

Calibration Procedure

1. MIP calibration; #ADCs corresponds to one MIP,
   for the channel by channel equalization,

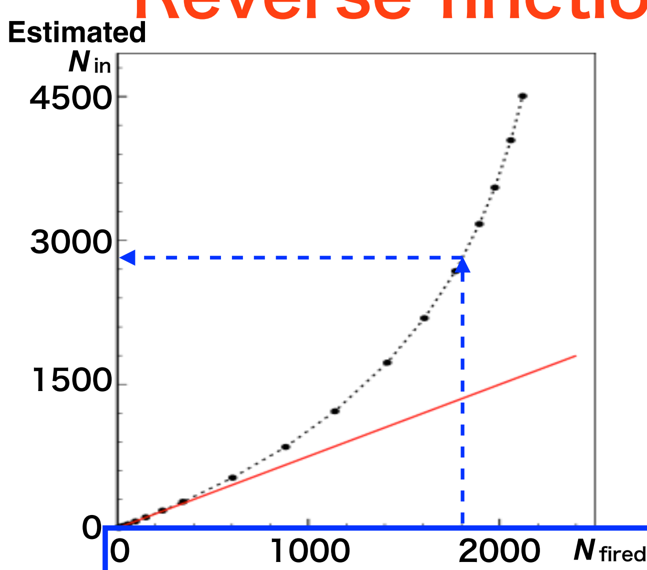
2. MPPC gain calibration; #ADCs corresponds to one p.e.,
   for i. gain monitoring,
   ii. MPPC saturation correction,

MPPC response curve: F



Use reverse of MPPC response F

Reverse finction: F^{-1}

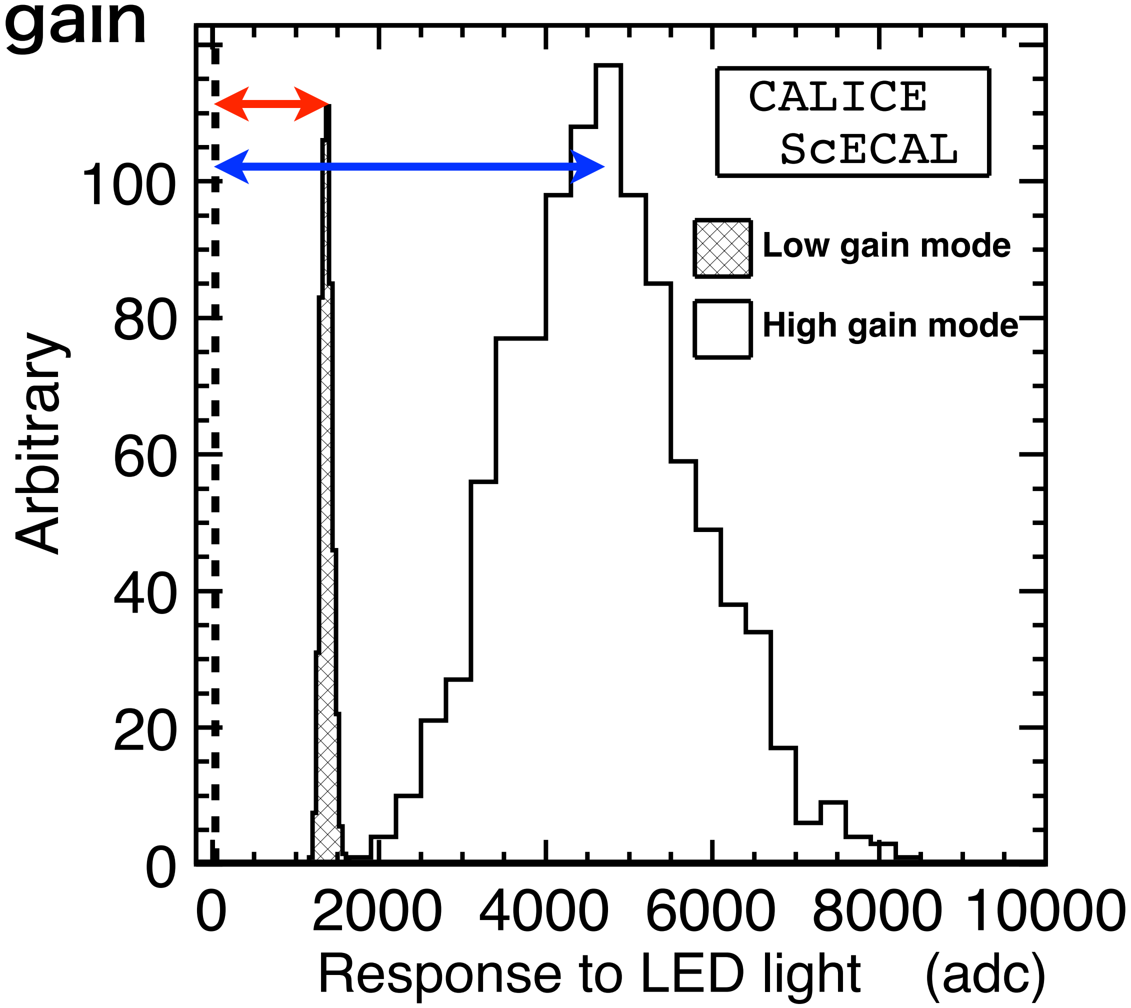


Input is # p.e.

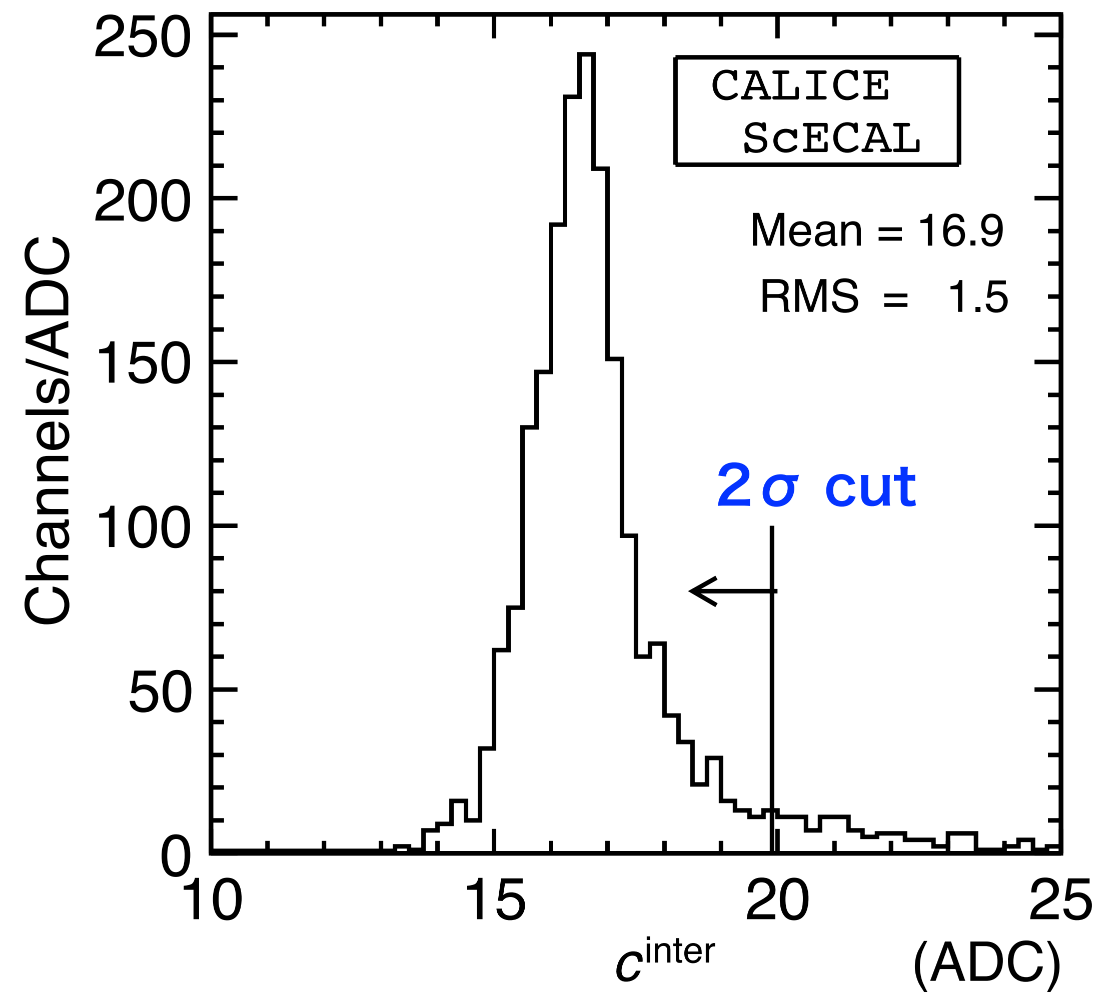
3. Inter calibration; ratio-response of high_gain/low_gain,
   for that
   ADC/p.e was measured with high gain
   Physics data was measured with low gain.

Inter-calibration

Response to a certain strength of LED light w/ Low and w/ High gain



Distribution of Inter-calibration constant $C^{inter} = \langle ADCs \rangle^{high} / \langle ADCs \rangle^{low}$



10% channels were suffered by noise from LED system (not occurs in physics runs)+ large tail

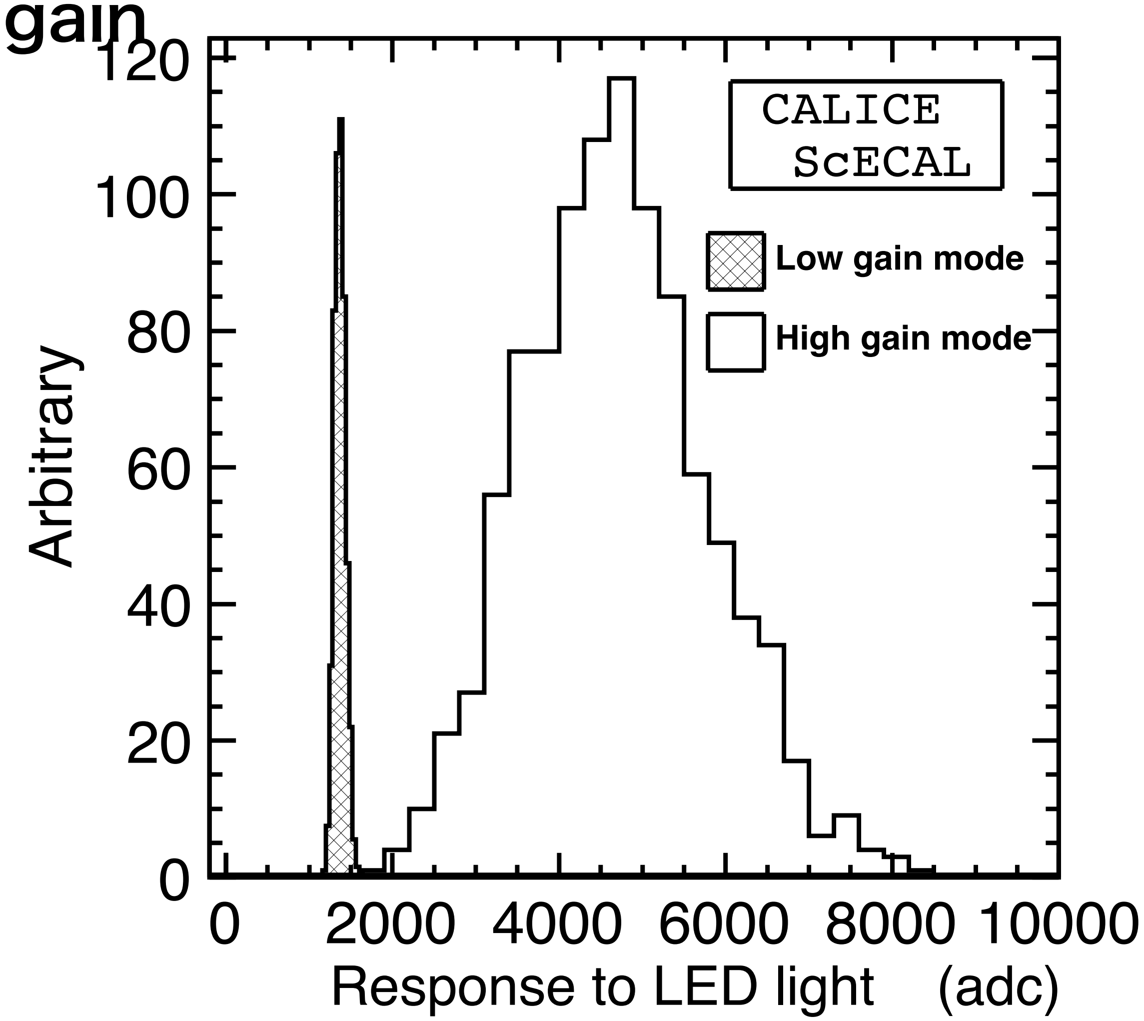
average of C^{inter} was applied for the failed channels.

Request 2

explain clear reason of cut value on the C^{inter}.

Inter calibration

Response to a certain strength of LED light w/ Low and High gain



Distribution of Inter calibration constant

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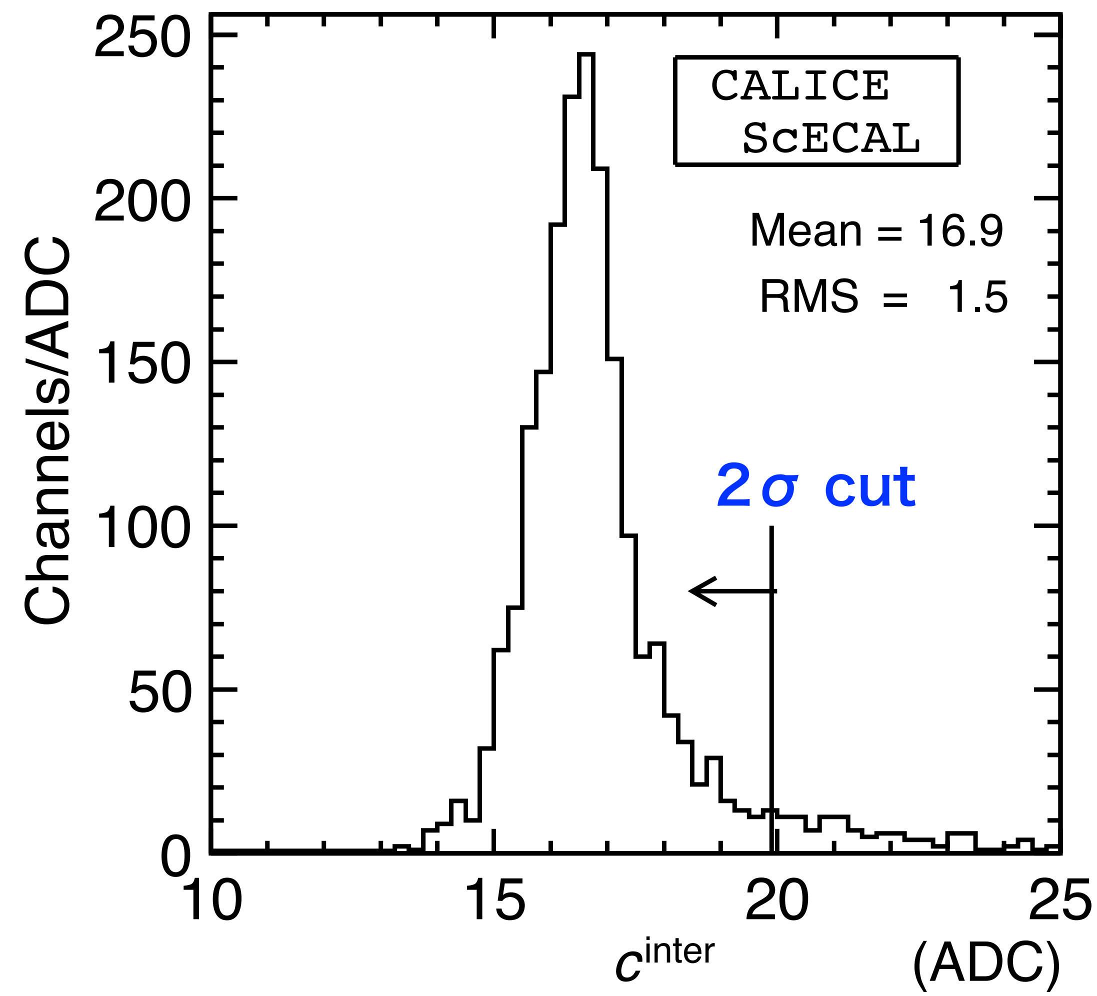


10% channels were suffered by noise from LED system (not occurs in physics runs)+ large tail

updated ➡

cut	effect on σE(%)
1σ	< 0.01
2σ	reference
3σ	< 0.01
no cut	< 0.1

Request 3

explain how to determine a systematic uncertainty comes from a cut value.

Electron event selections

0. Čerenkov counter

1. highest energy layer < 20th (to reduce π)

2. highest energy layer has energy >

15 MIPs for	2 GeV/c
27 MIPs for	4 GeV/c
54 MIPs for	8 GeV/c
80 MIPs for	12 GeV/c
95 MIPs for	15 GeV/c
125 MIPs for	20 GeV/c
200 MIPs for	> 30 GeV/c

3. highest energy layer in AHCAL < 20 MIPs (to reduce π)

4. most downstream layer of AHCAL < 0.4 MIP

5. (6). -40 mm < gravitational center energy < 40 mm in x (y)

updated ➡ 7. energy in multi-particle counter < 1.4 MIPs corresponds

thanks for Oskar

Electron event selections

0. Čerenkov counter

1. highest energy layer < 20th (to reduce π)

2. highest energy layer has energy >

15 MIPs for	2 GeV/c
27 MIPs for	4 GeV/c
54 MIPs for	8 GeV/c
80 MIPs for	12 GeV/c
95 MIPs for	15 GeV/c
125 MIPs for	20 GeV/c
200 MIPs for	> 30 GeV/c

3. highest energy layer in AHCAL < 20 MIPs (to reduce π)

4. most downstream layer of AHCAL < 0.4 MIP

example 5. (6). -40 mm < shower center-of-gravity < 40 mm in x (y)

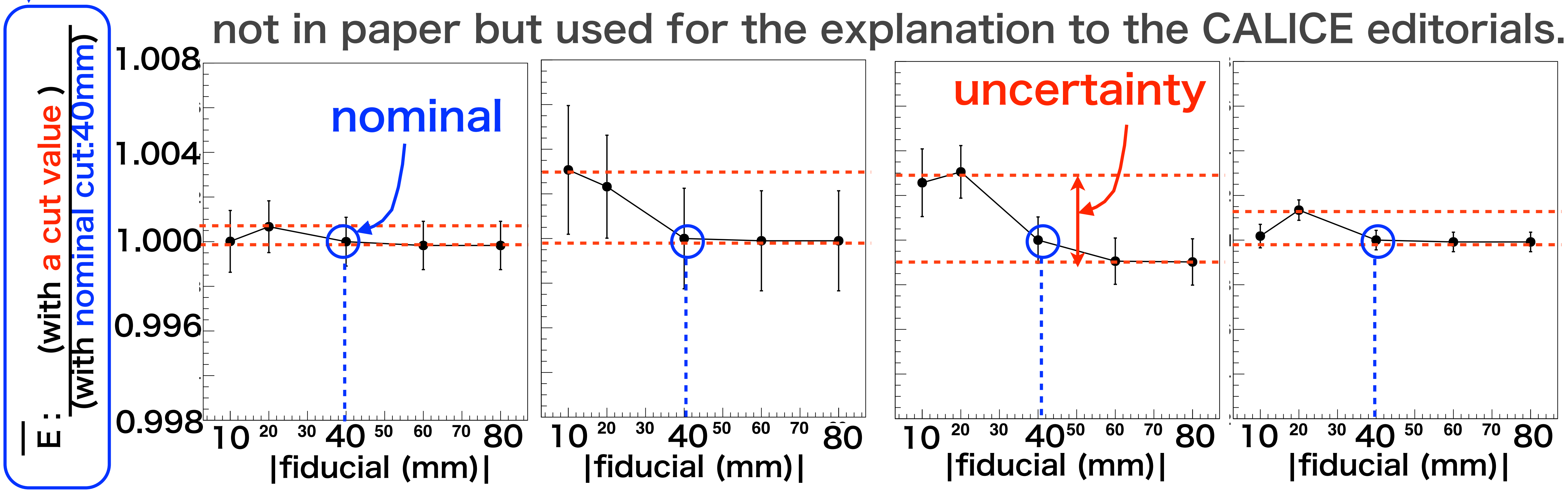
updated ➡ 7. energy in multi-particle counter < 1.4 MIPs corresponds

Cut variations on Shower center

Ratio Ē : (with a cut value) / (with nominal cut)

example: |center-of-gravity | < 40 mm in x; 20 GeV, 4 runs
fiducial volume

not in paper but used for the explanation to the CALICE editorials.

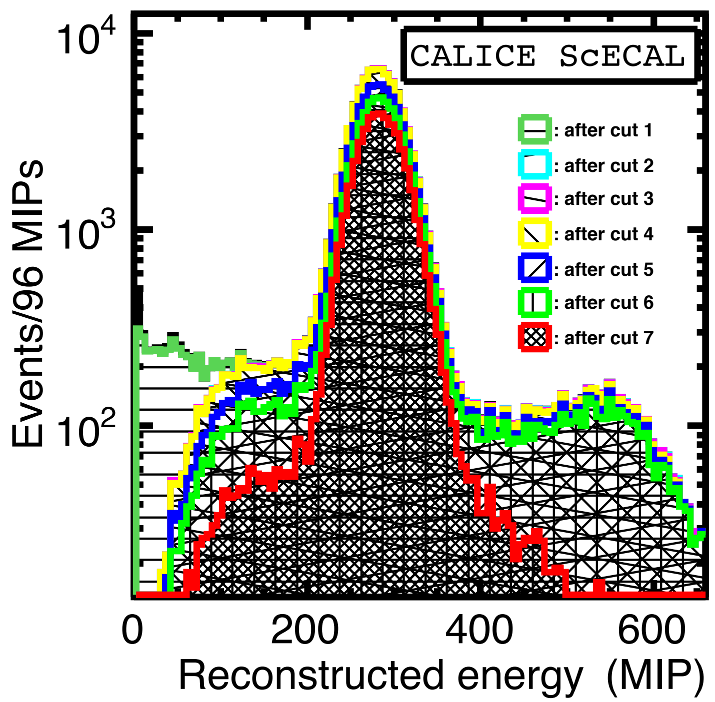


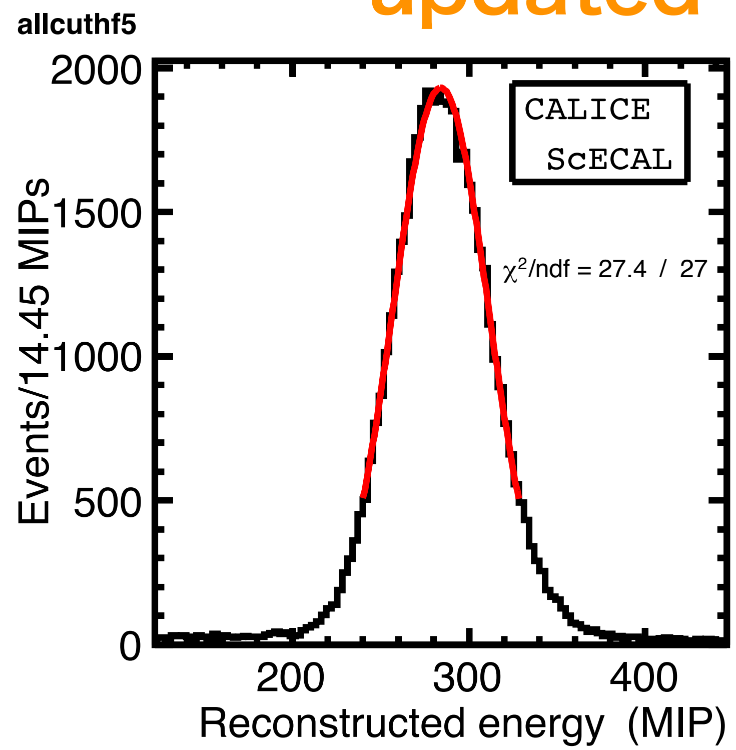
average of highest and lowest variations in runs is taken as a systematic uncertainty; variations were weighted with their uncertainty

Energy spectra after selection

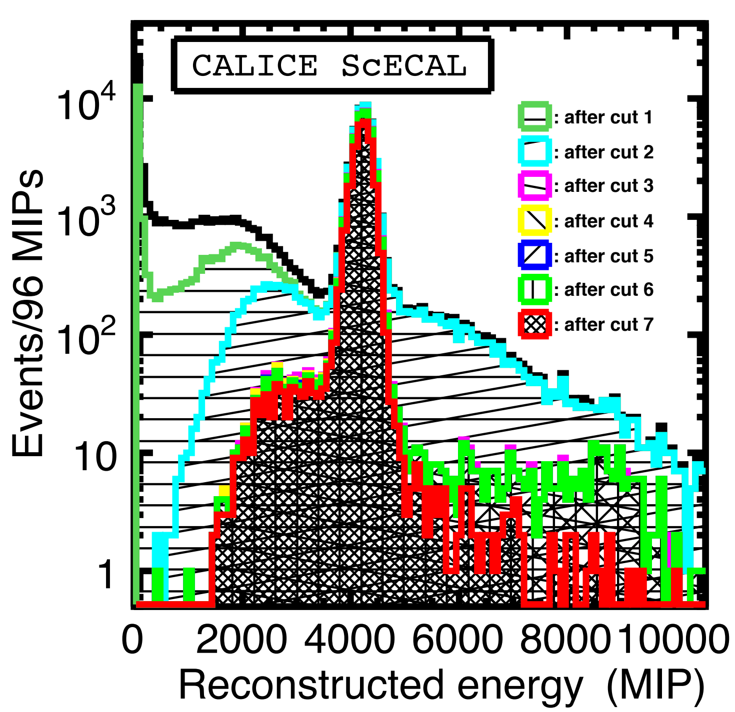
a run of 2 GeV

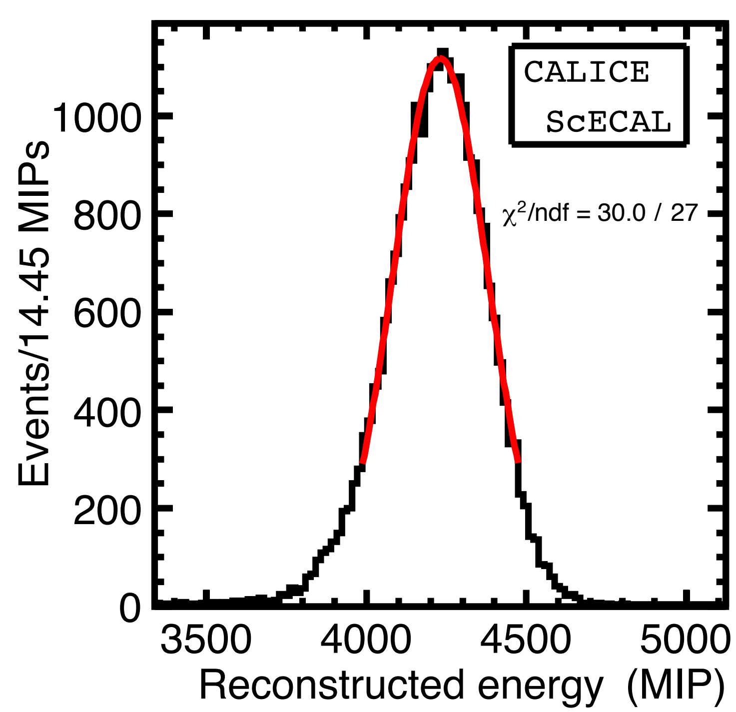
updated





a run of 32 GeV





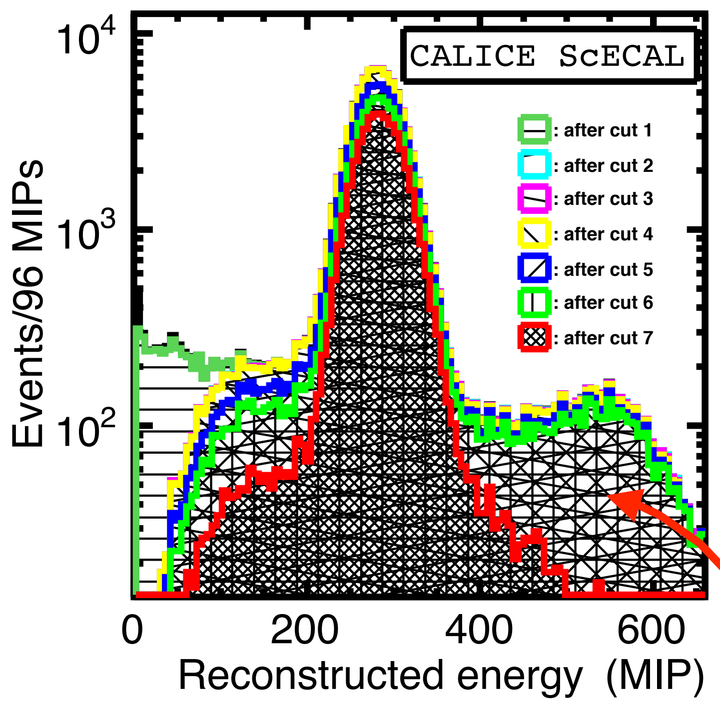
Gauss fitting area:
$\pm 1.6\sigma$ = 90% of area.

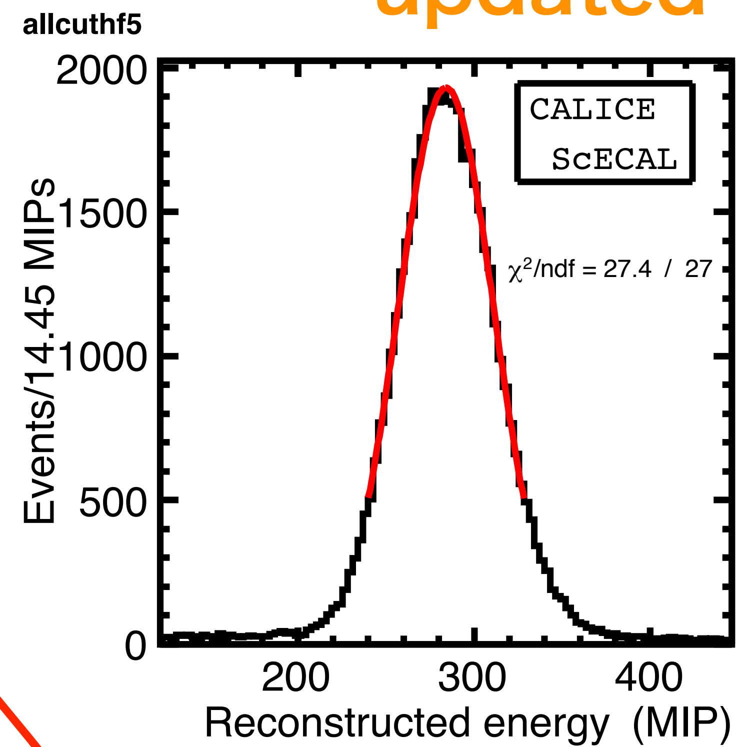
$0.9 < \chi^2/\mathrm{ndf} < 1.2$
for all runs

Energy spectra after selection

a run of 2 GeV

updated





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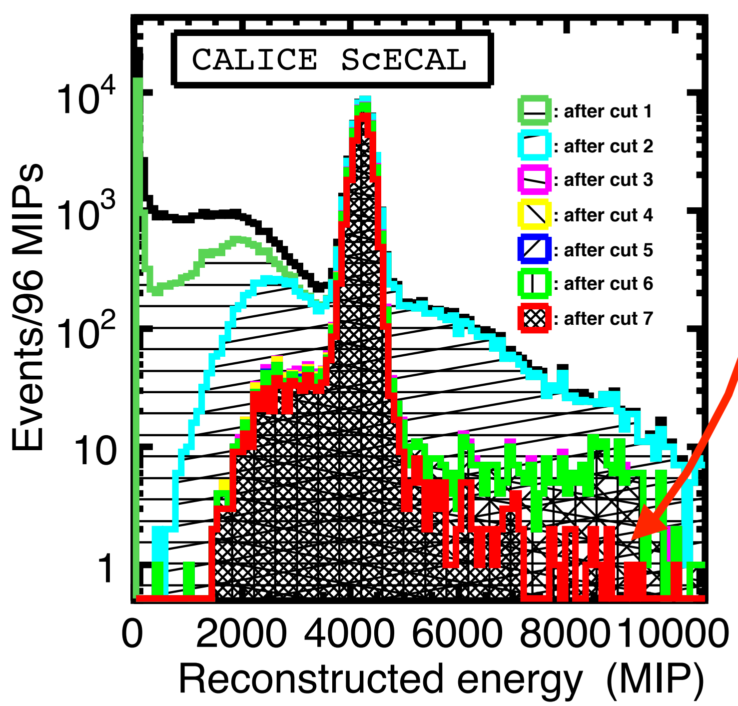
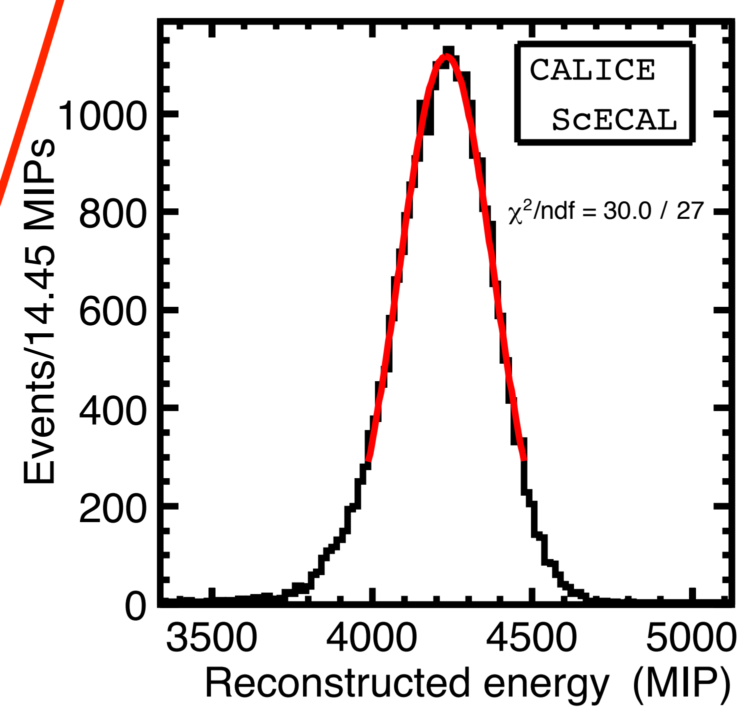
for all runs

a run of 32 GeV

Multi-particle event cut reduced double e^- event

updated

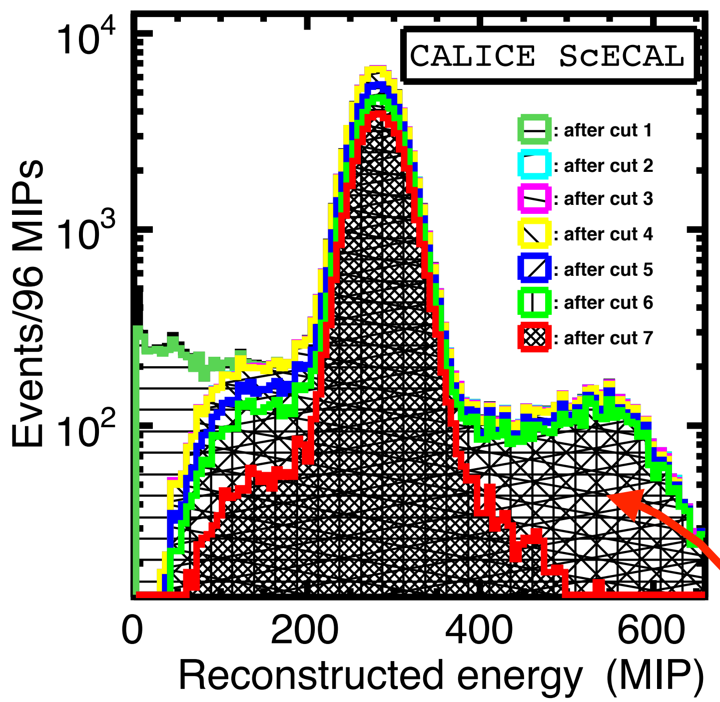


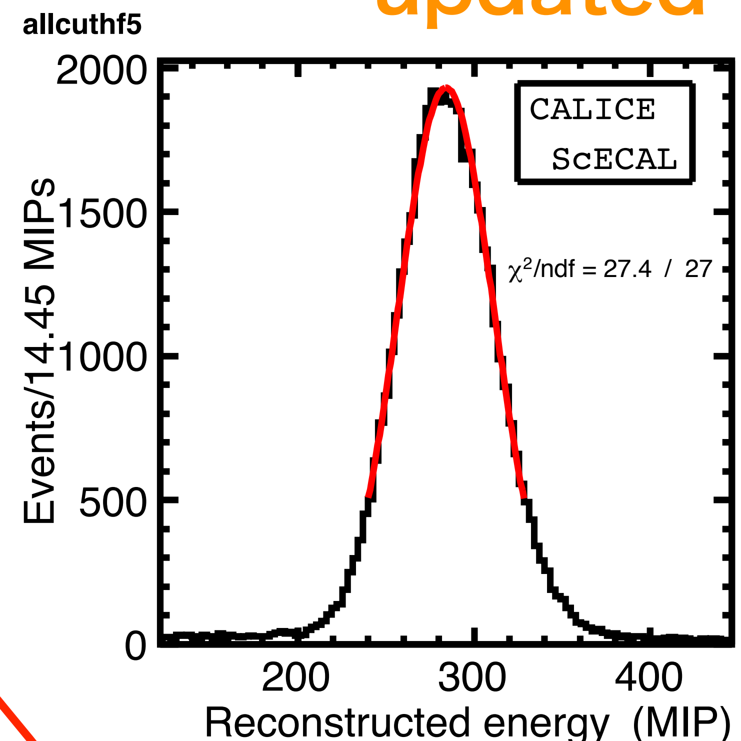


Energy spectra after selection

a run of 2 GeV

updated





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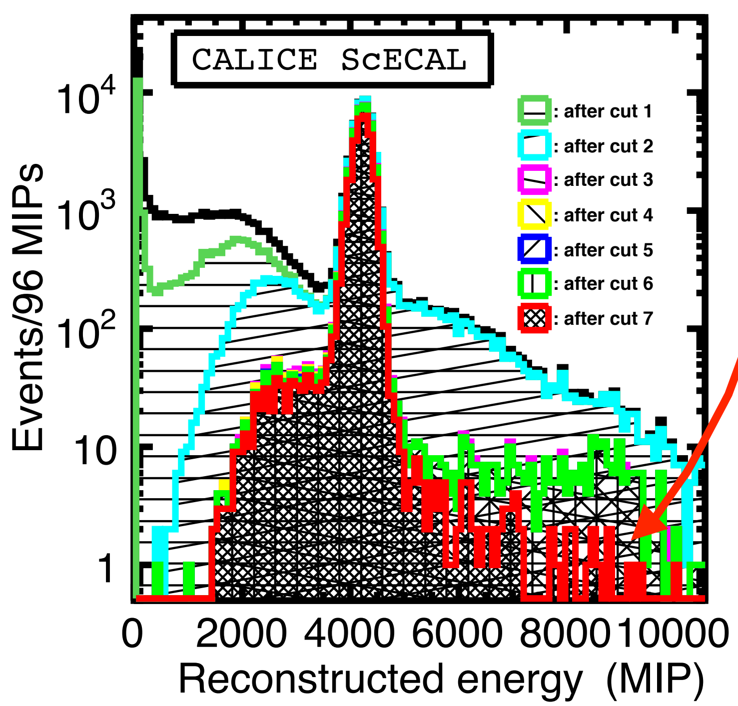
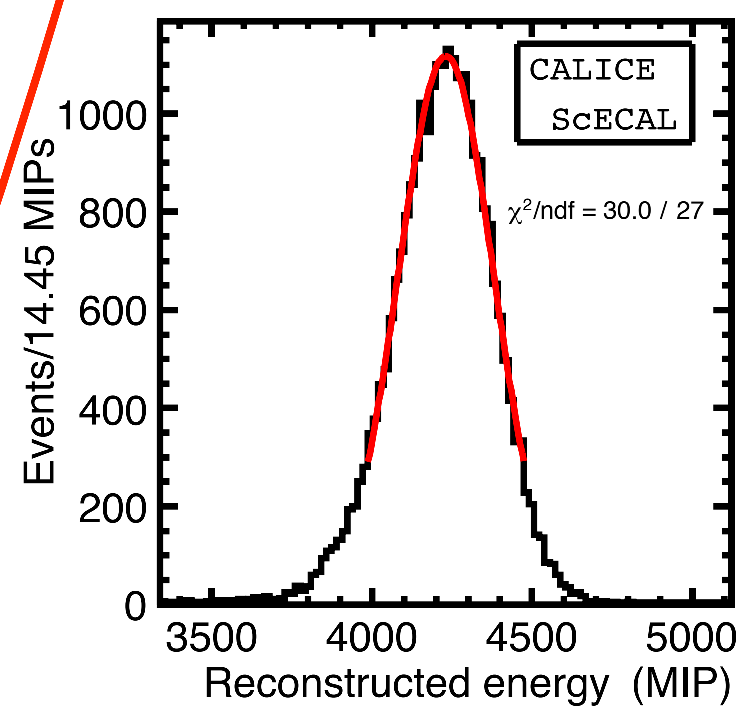
for all runs

a run of 32 GeV

Multi-particle event cut reduced double e⁻ event

updated





The mean and σ of the gaussian were taken as the energy mean and its resolution.

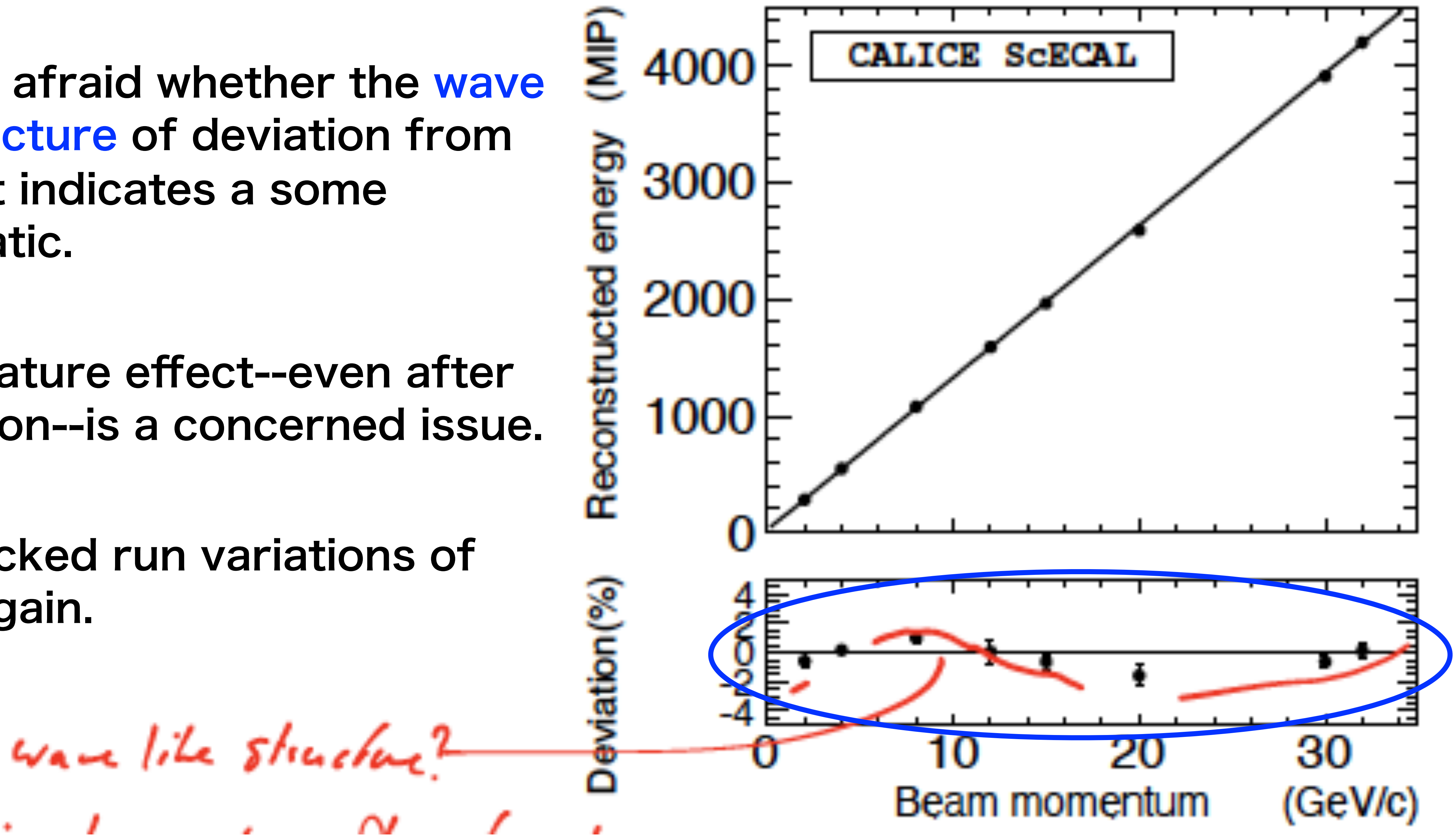
Request 4

Is there some systematics?

Frank is afraid whether the wave like structure of deviation from linear fit indicates a some systematic.

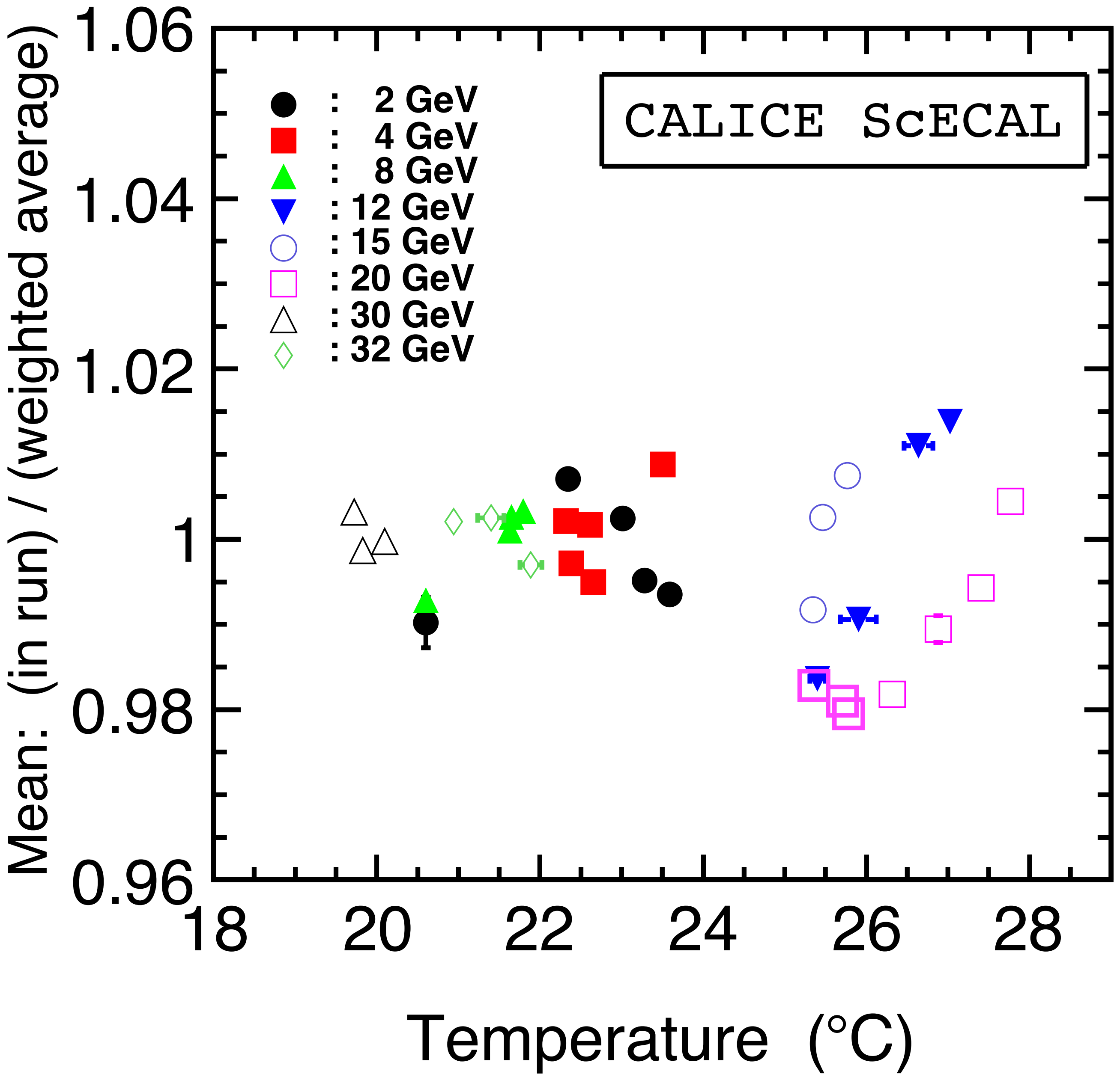
Temperature effect--even after correction--is a concerned issue.

We checked run variations of mean again.



Run variations

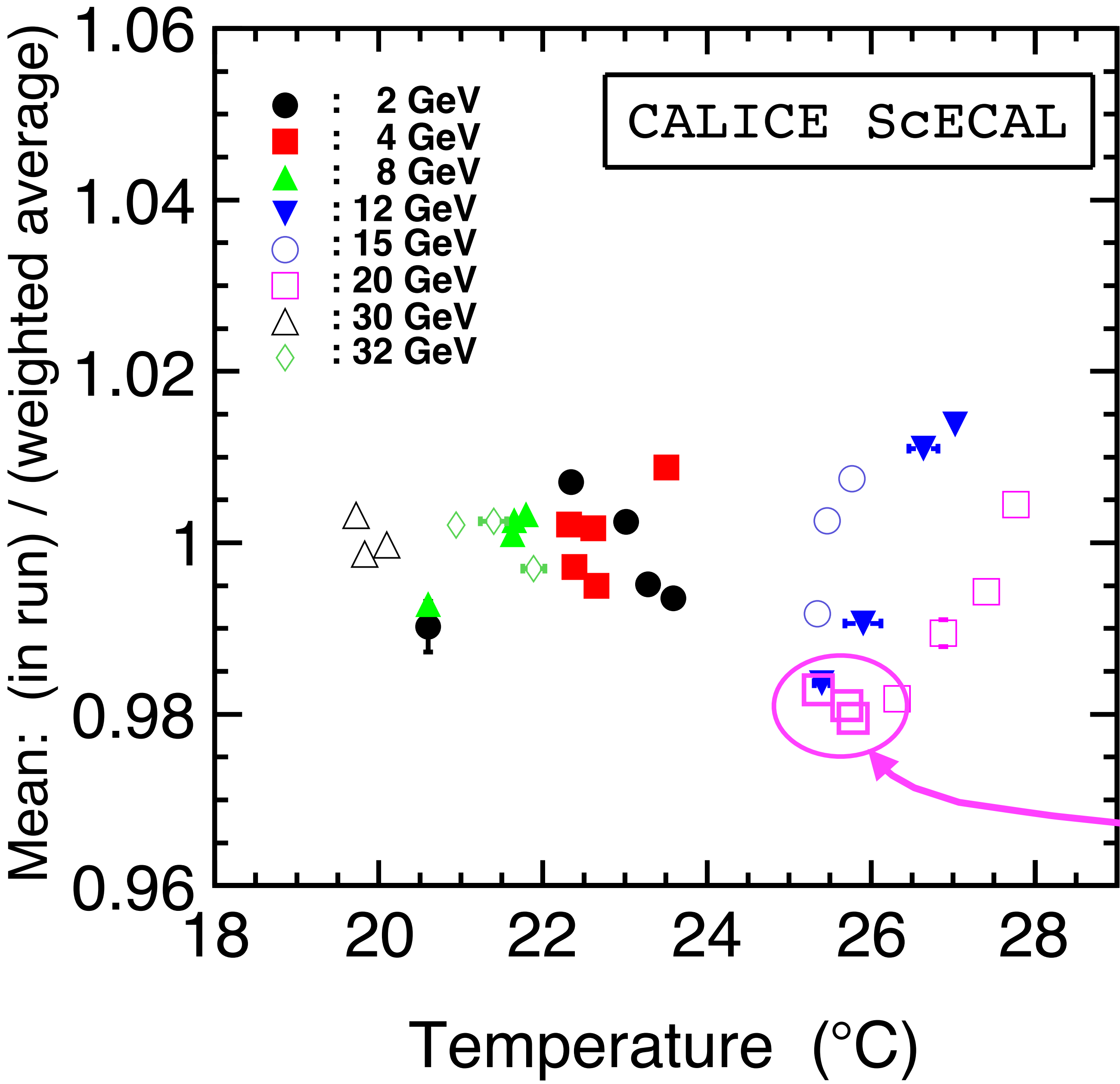
ratio of Energy mean
[a run / average] vs temperature



Unclear dependence on temperature,
except 20 GeV, 12 GeV

Run variations

ratio of Energy mean [run by run / average] vs temperature



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We found a Mail from MT6: collimator set was wrong for those three runs

Run variations

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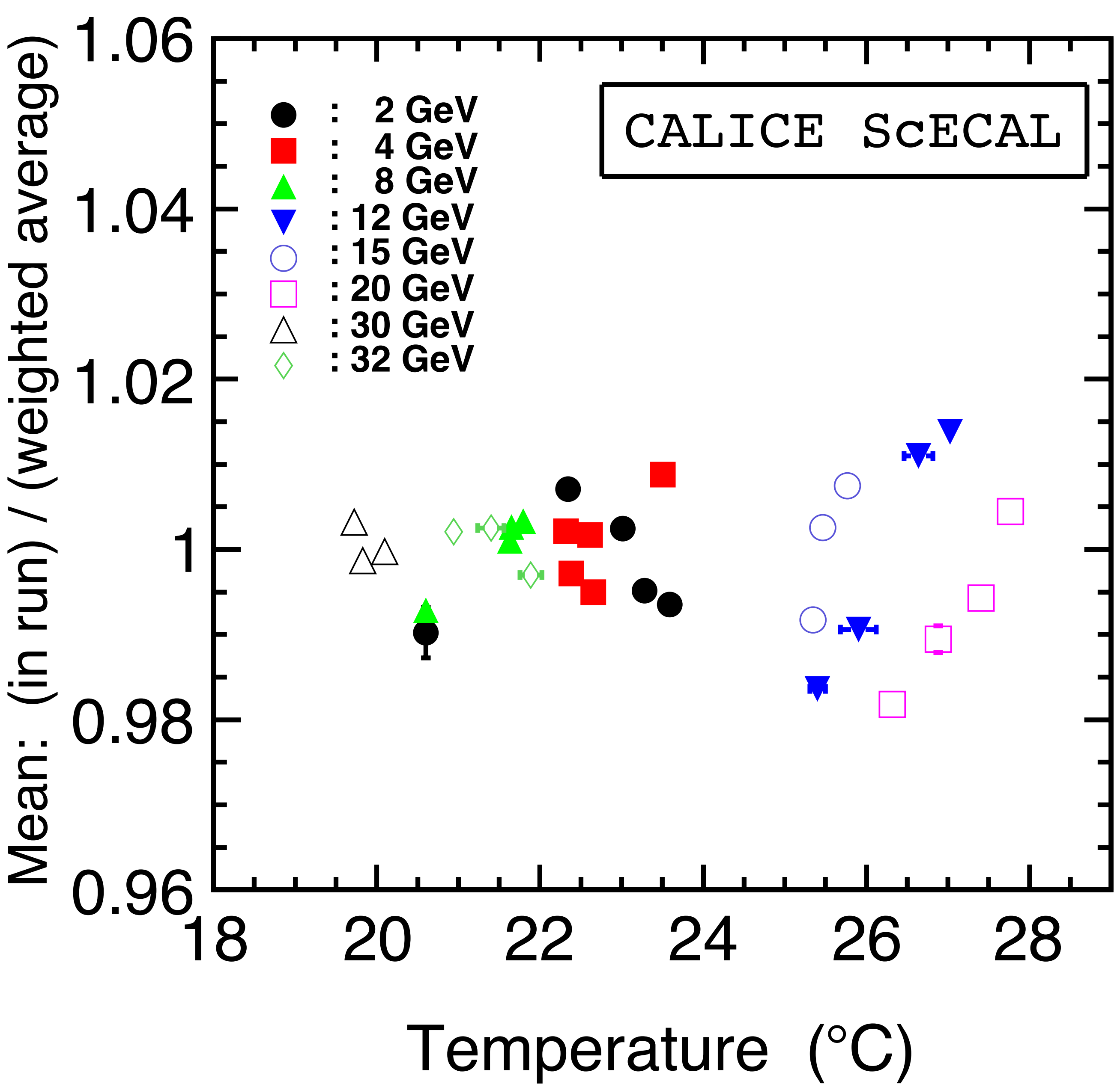

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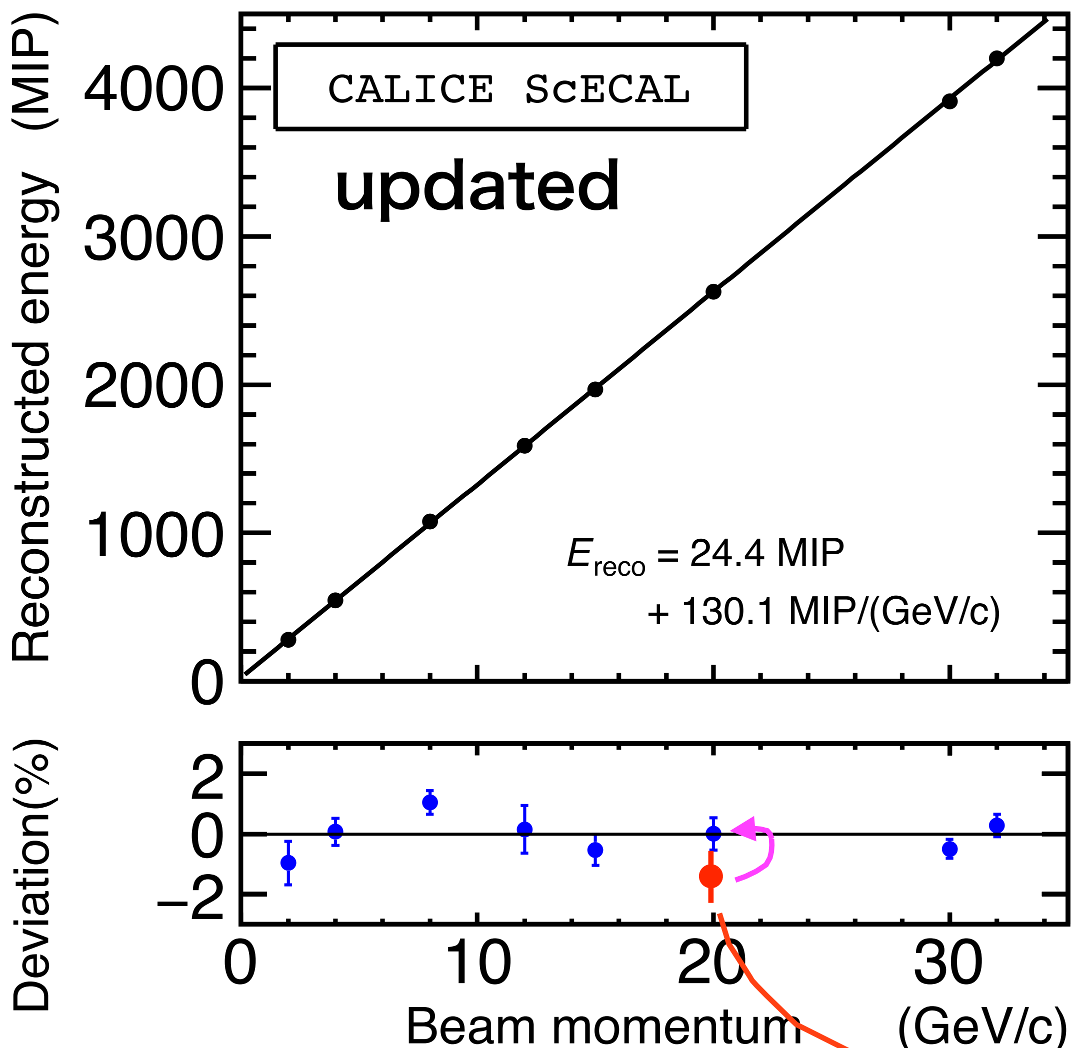
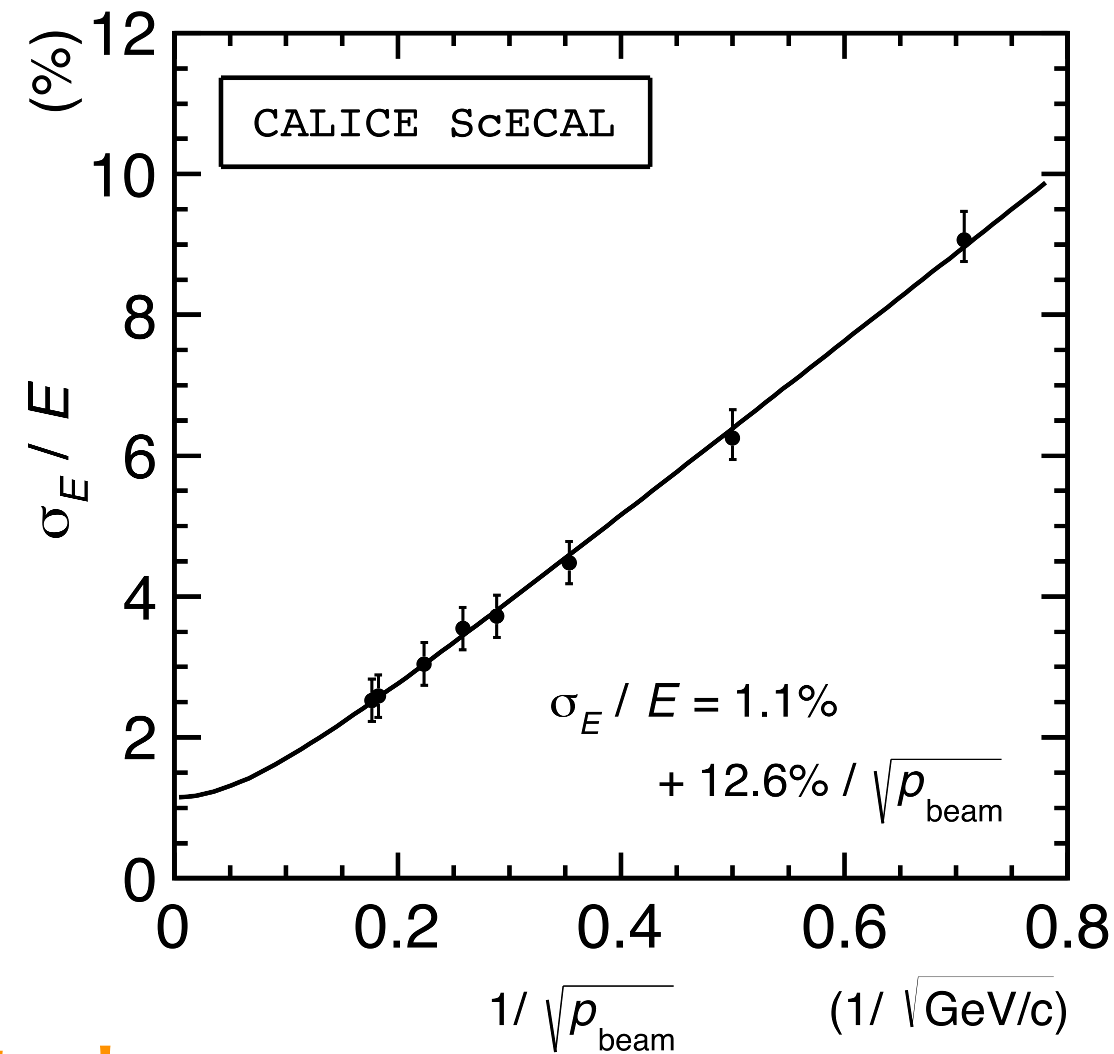
Linearity and resolution



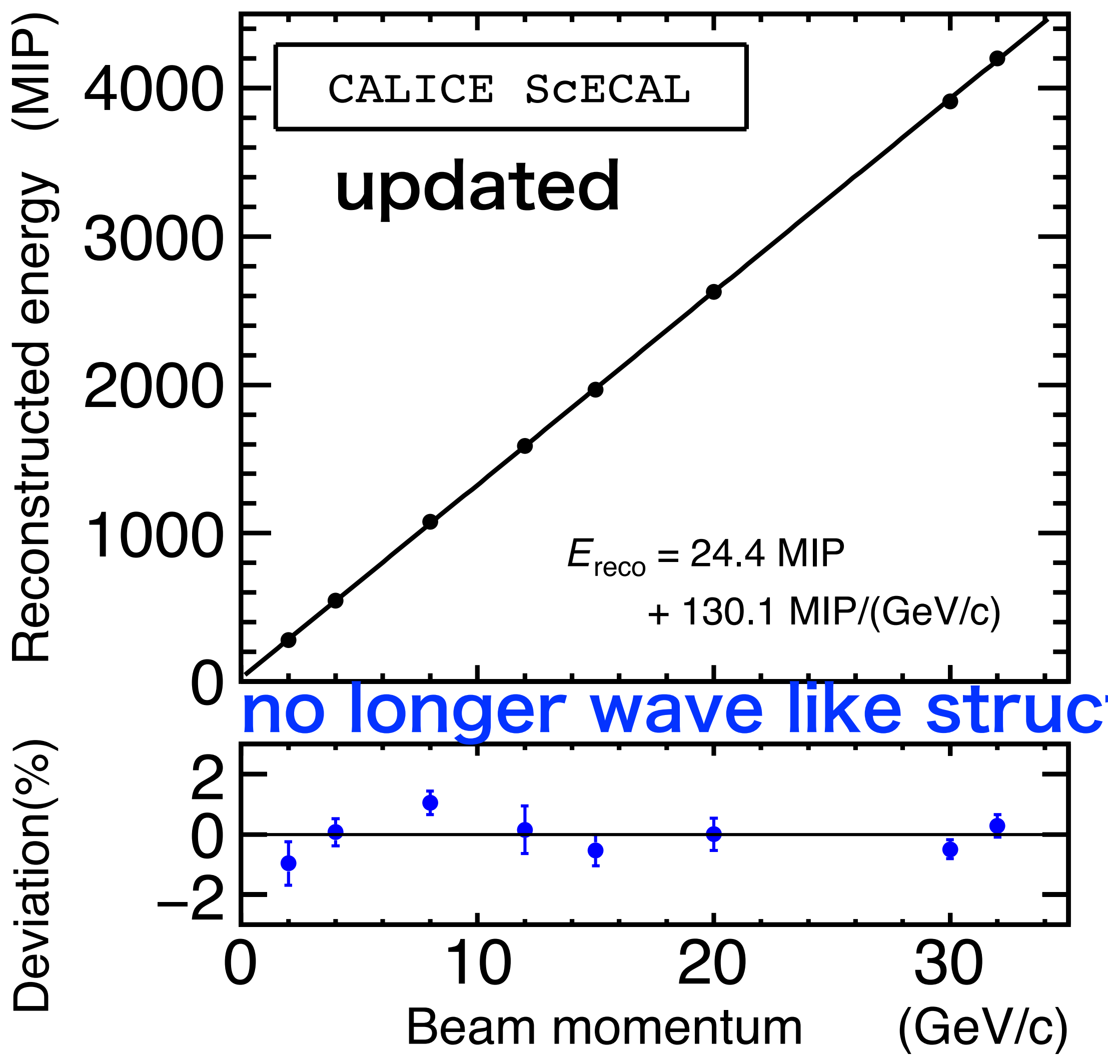


updated

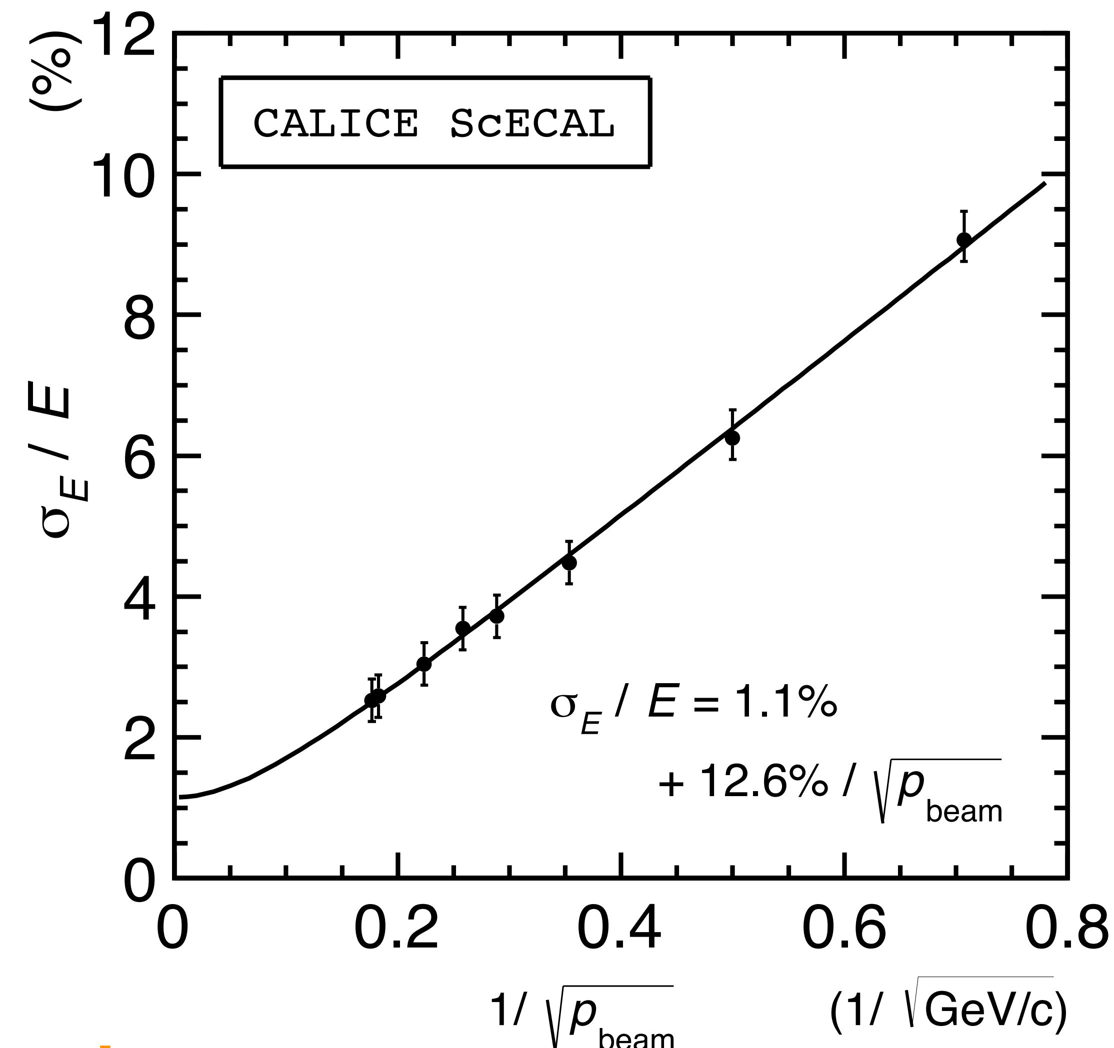
	response			resolution	
	offset (MIP)	slope (dMIP/dGeV)	dev.	constant(%)	stochastic(%)
CAN16c	22.5±1.4	130.44±0.30	<1.6	$1.0^{+0.5}_{-1.0}$	12.8±0.4
current	24.4±1.7	130.12±0.25	<1.0	$1.1^{+0.5}_{-0.7}$	12.6±0.4

Uncertainty: statistic ⊕ systematic

Linearity and resolution



no longer wave like structure



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Uncertainty: statistic ⊕ systematic

Request 5

Maybe most important request,

More realistic simulation!

More realistic simulation

implement realistic simulation: thanks Oskar Hartbrich

- binomial photon statistics was implemented,
    - MPPC saturation→ photon statistics → unfolding,
- photon yield variation for strip by strip, -- from data,
- gain for channel by channel -- from data,
- beam position spread -- from data (center-of-gravity),
- background overlay--from data (recycling),
- intrinsic momentum fluctuation,
- use the same analysis code as data analysis.

Data vs. MC

Longitudinal projection (20 GeV/c)

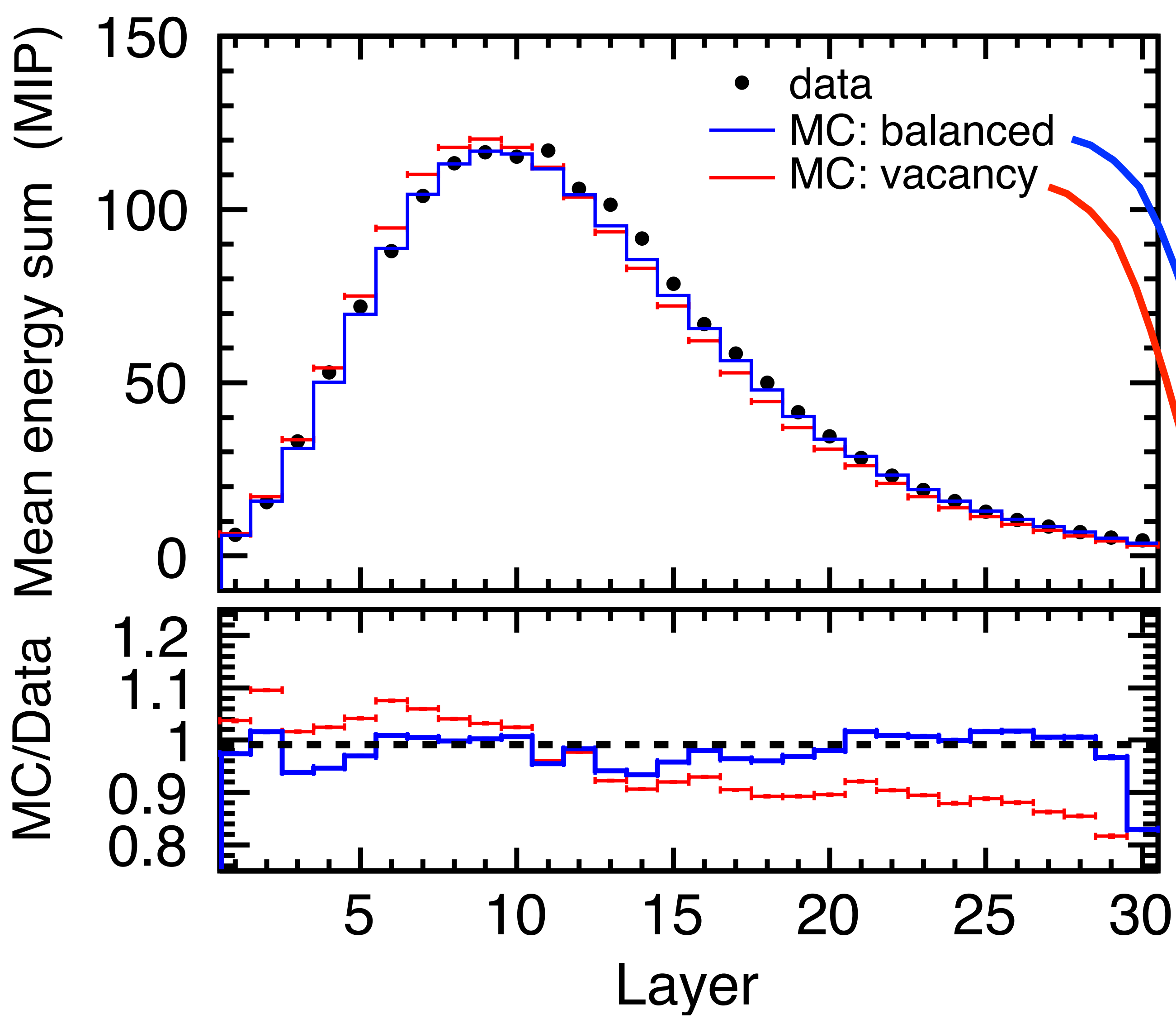
Absorber, WC + Co + Cr (measured with XRD)

We measure the density for geant4 in two method.

believable
see CIN-025

- weight/size meas. $14.25 g/cm^3$
- calc. from materials $14.76 g/cm^3$

Density conflict each other.



Two ways to adjust;

1. WC : Co ➡ decrease : increase.
2. assume vacancies in the abs.

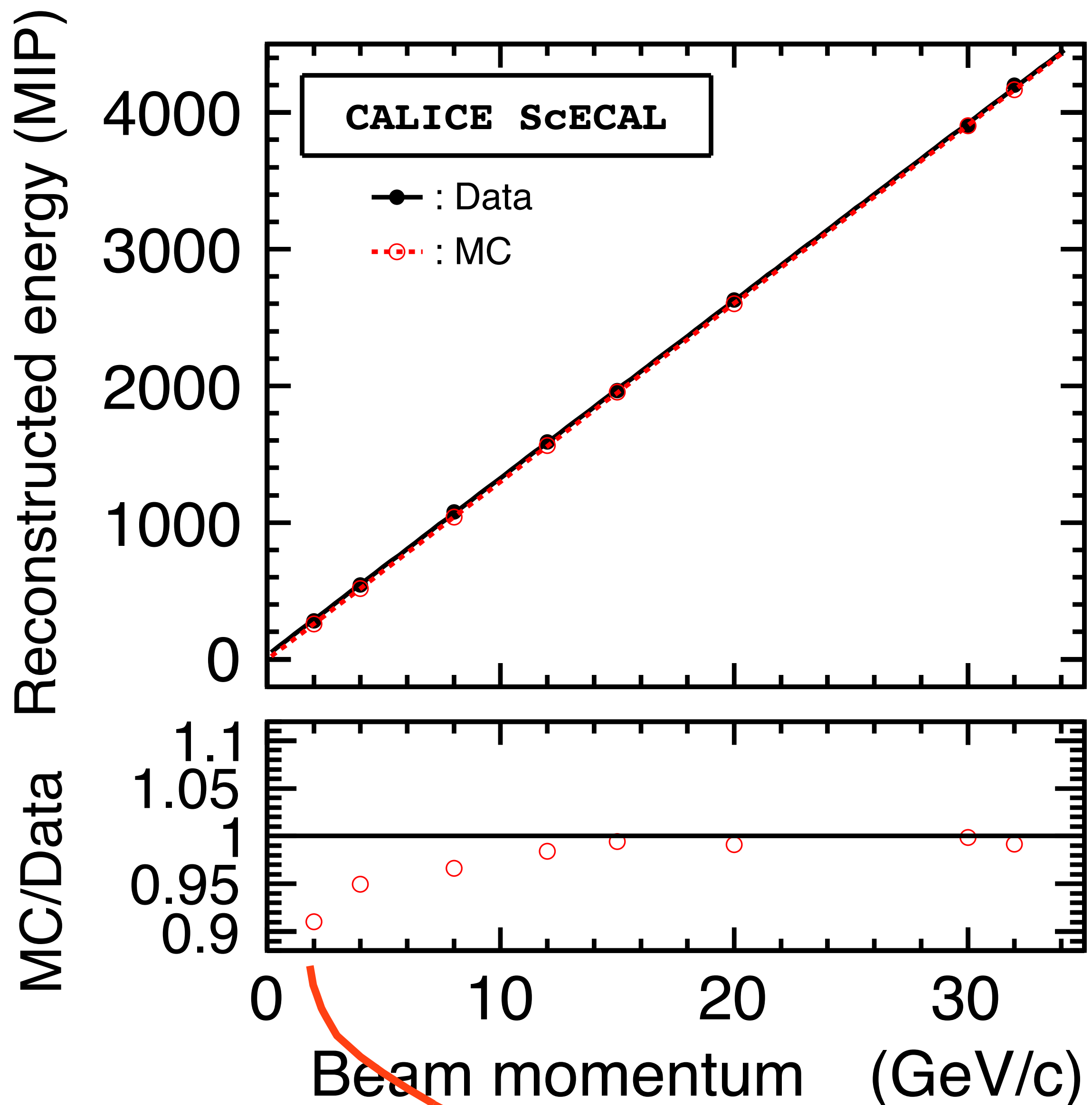
Case 1 has good agreement.

We take case 1 as default.

not change quantitative values
ex. dp/dMIP resolution etc.

Data vs. MC

Response



	offset (MIP)	slope (dMIP/dGeV)
data	24.4±1.7	130.1±0.3
MC	-3.0±0.1	130.3±0.1

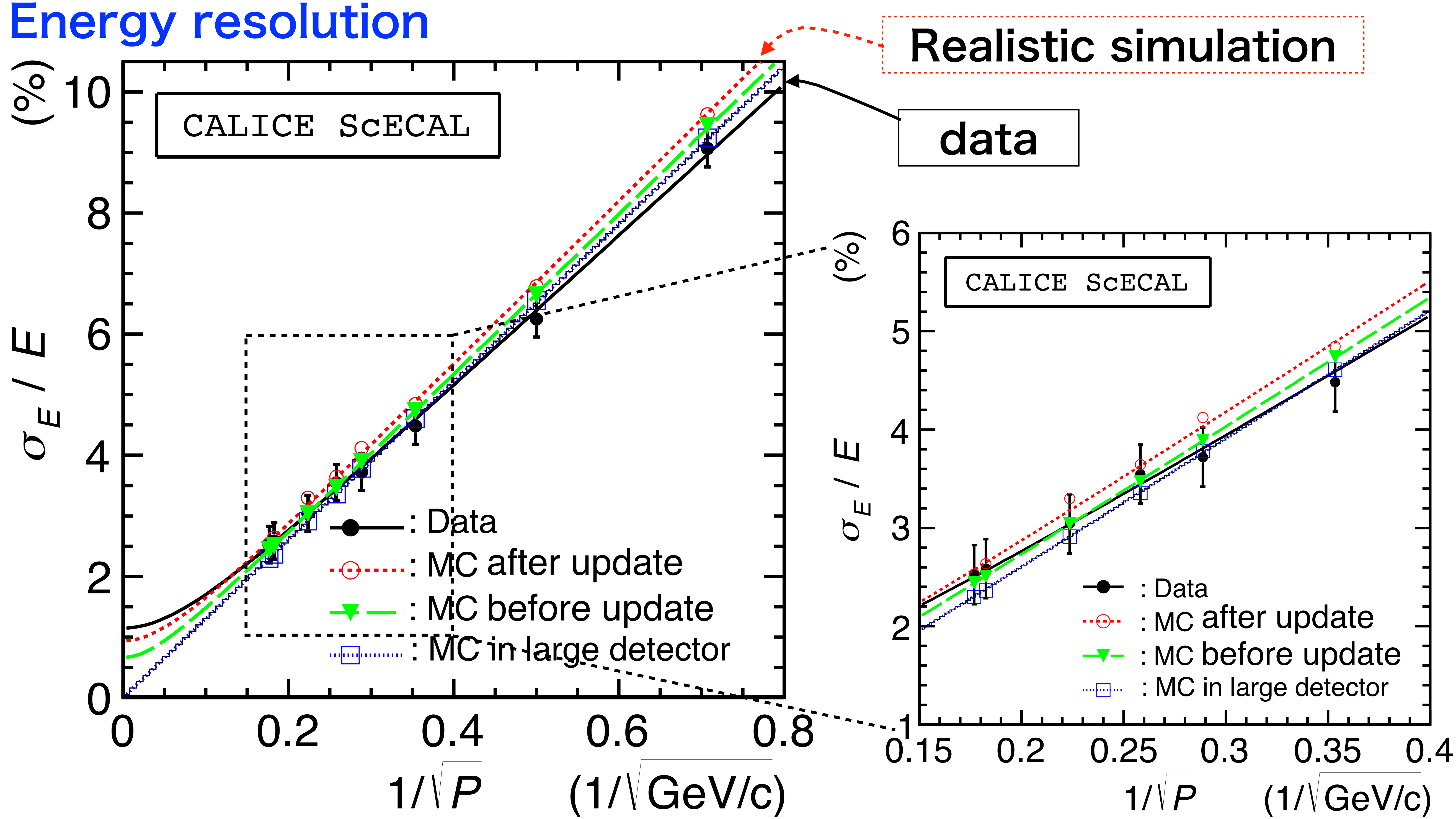
MC agrees on the slope of response.

MC failed to represent an offset. (note that BG was overlaid)

Although the ratio becomes clearly smaller as beam momentum becomes smaller, absolute difference corresponds to 0.18 ± 0.20(RMS) GeV/c, not so large.

Data vs. MC

Energy resolution



Realistic simulation agrees data within 1 uncertainty, except 2 GeV (1.6 uncertainties).

Summary

We've shown five modifications according to the requests from CALICE editorial board,

1. Calibration procedure should be entirely explain in a dedicating section.
   ➡ done.
2. Reason of cut on the inter calibration.
   ➡ done.
3. explain how to determine the systematic uncertainties come from selection cuts.
   ➡ done.
4. explain wave like structure of deviation plot from linear
   ➡ Wave like structure was disappeared.
5. more realistic simulation.
   ➡ done.

Next step:

Discuss with editorial board ➡ PUBLISH!!

Back up

Beam momentum fluctuation

Design of MT6 beam $\Delta p/p$ (1-60 GeV/c): 2%

Pb/glass calorimeter measurement (1-4 GeV/c): 2.7±0.3%

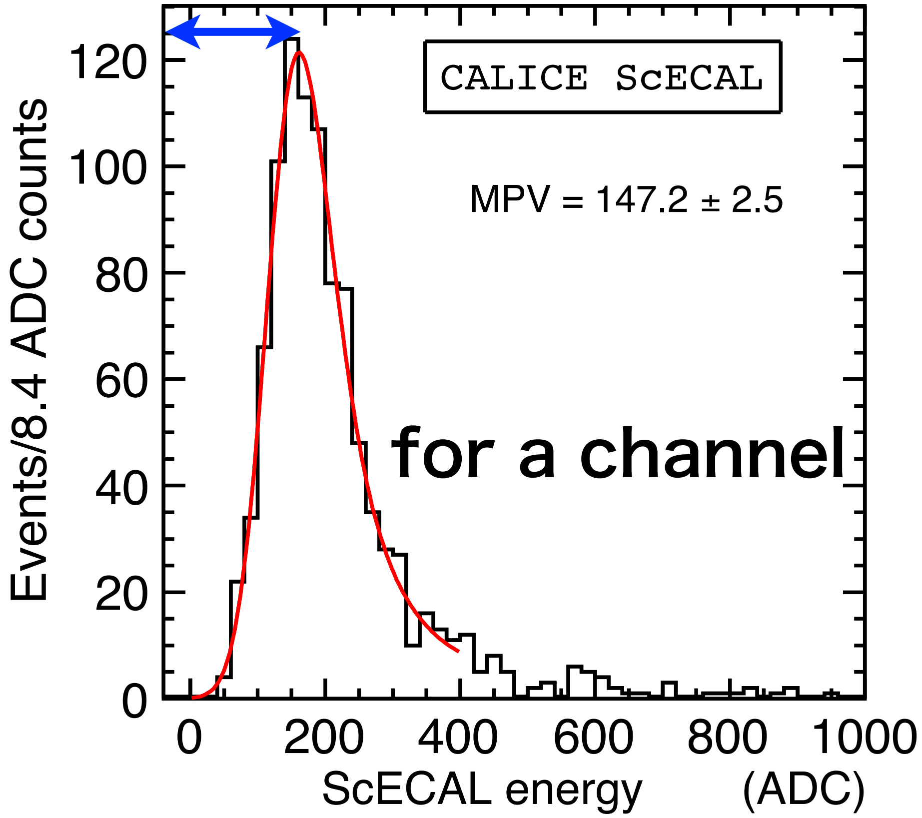
Pb/glass calorimeter measurement (8 GeV/c): 2.3±0.3%

Our limited / best knowledge:

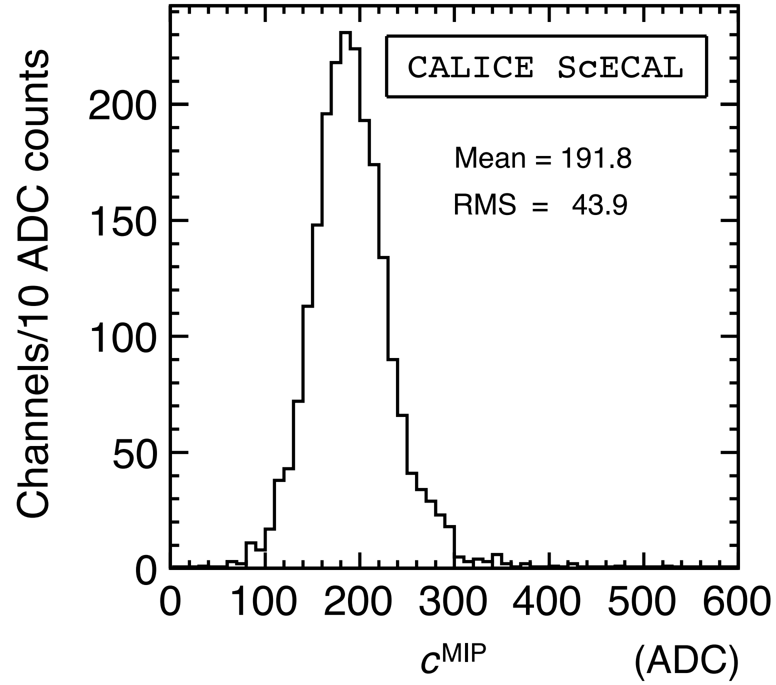
- 2 - 4 GeV/c : 2.7%, 4 GeV/c > 2.3% of intrinsic fluctuation
- systematic uncertainty : 0.3%

MIP calibration

MIP calibration factor(c^{MIP})

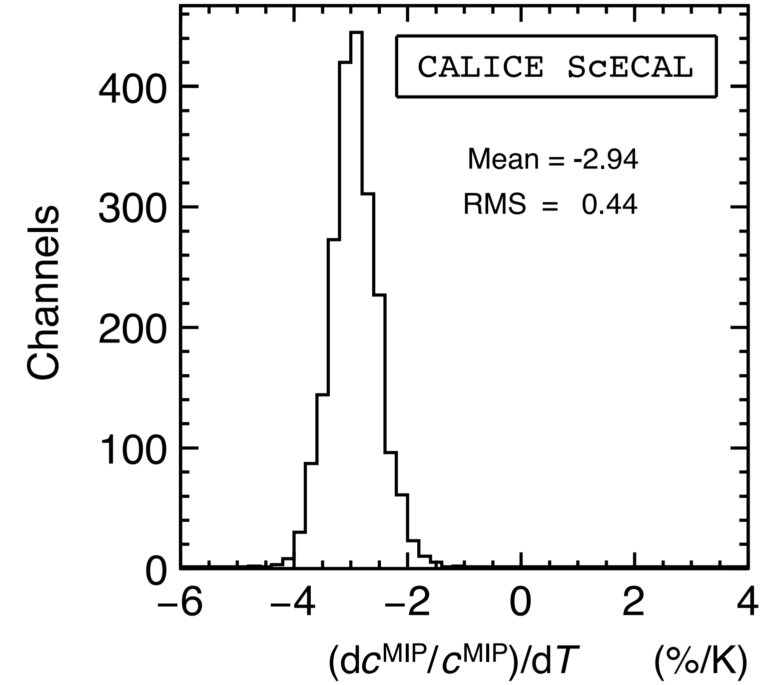


dist. c^{MIP} at 20℃

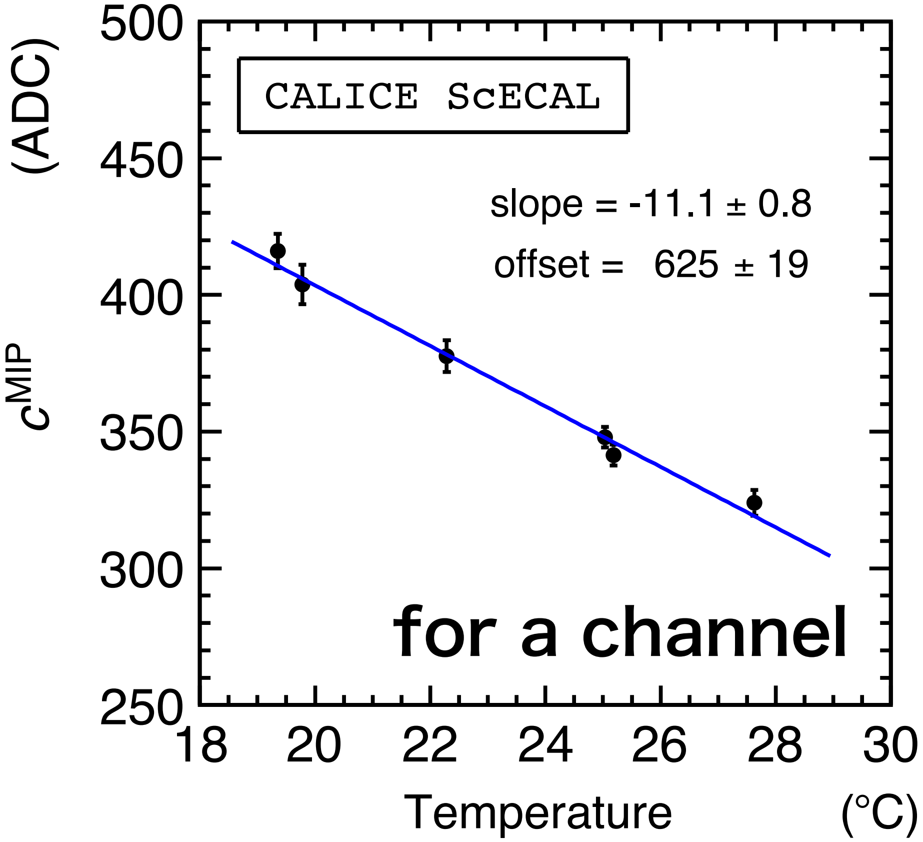


dist. slope

$(dc^{MIP}/c^{MIP})/dT$



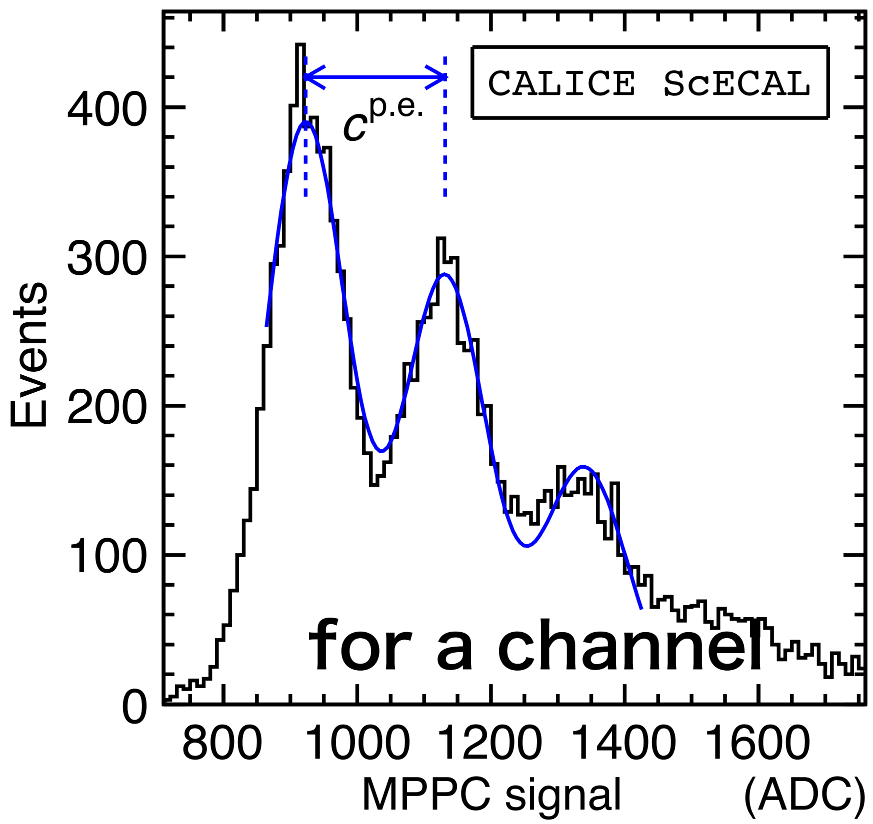
$c^{MIP}(T)$



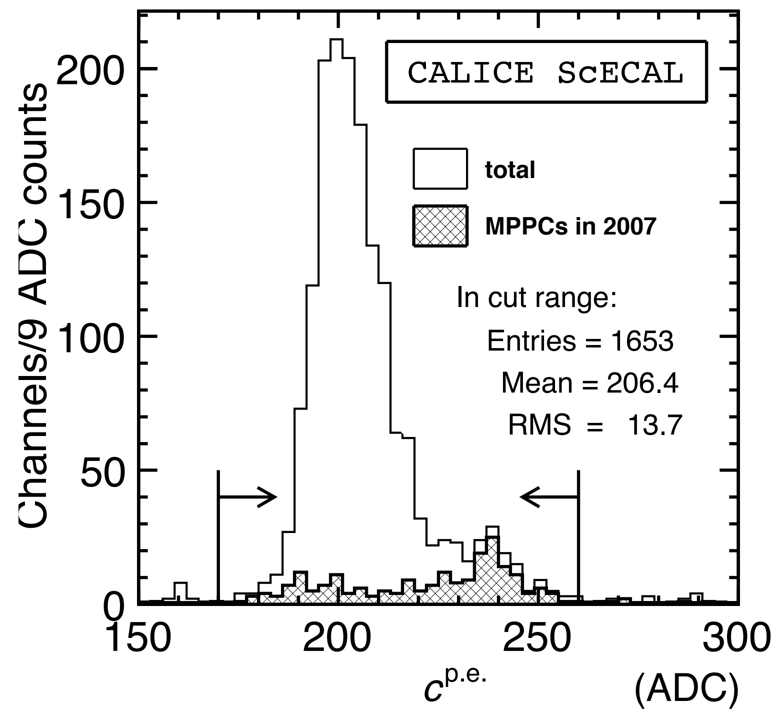
- MPV (c^{MIP})s of 7 temperature conditions were measured
- Each signal was converted in the # of MIPs using c^{MIP} at 20°C and slope $(dc^{MIP}/c^{MIP})/dT$
- $c^{MIP}(T)$ for every channel was determined except 2 dead channels.

MPPC Gain calibration

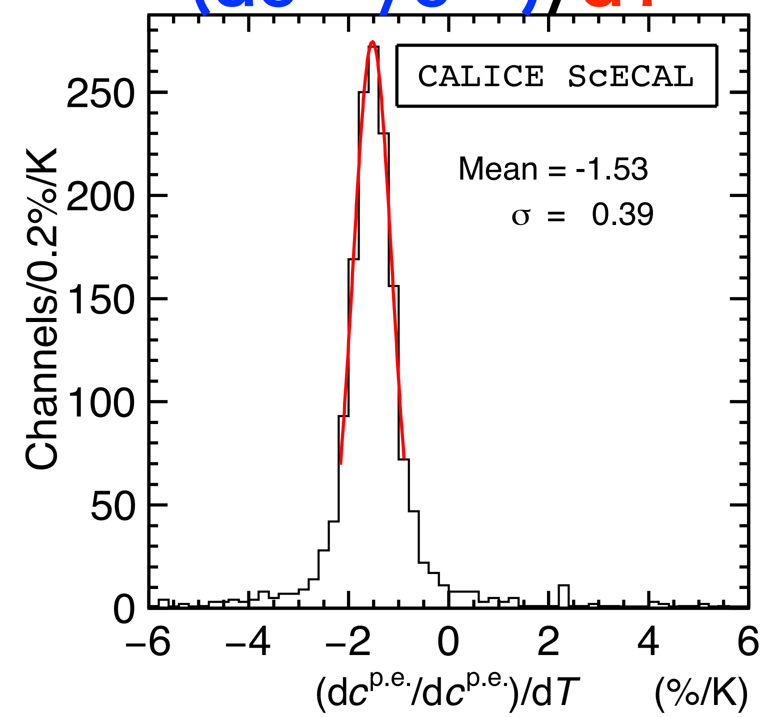
Gain calibration factor($c^{p.e.}$)



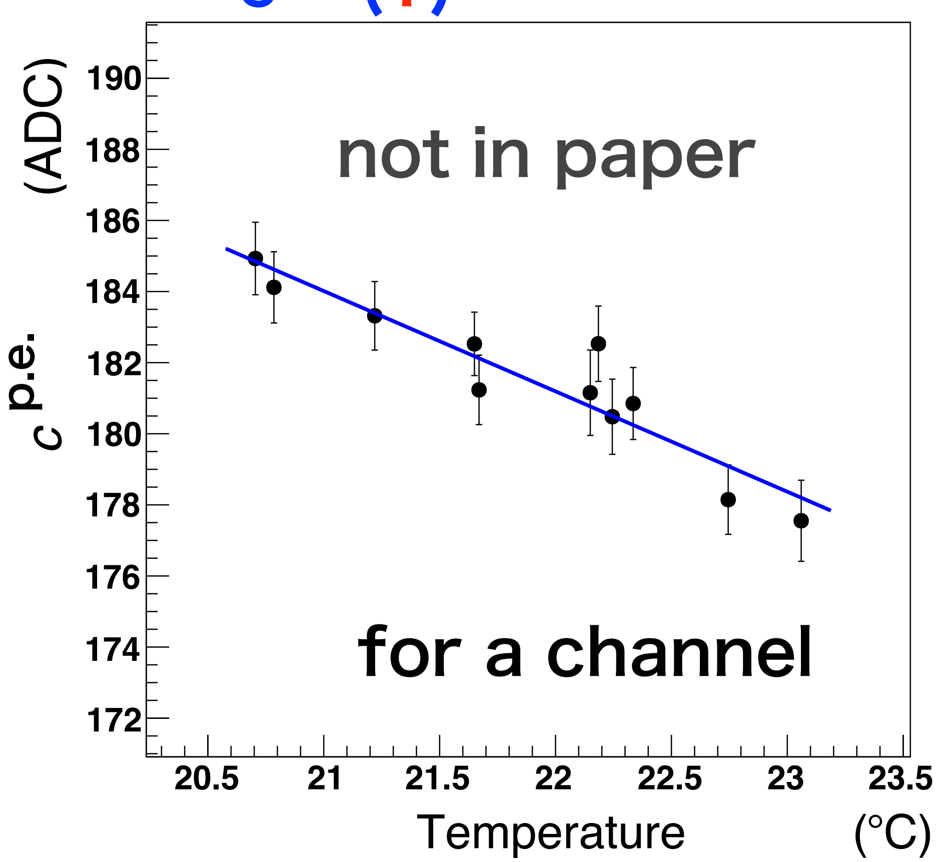
dist. $c^{p.e.}$ at 20℃



dist. slope $(dc^{p.e.}/c^{p.e})/dT$



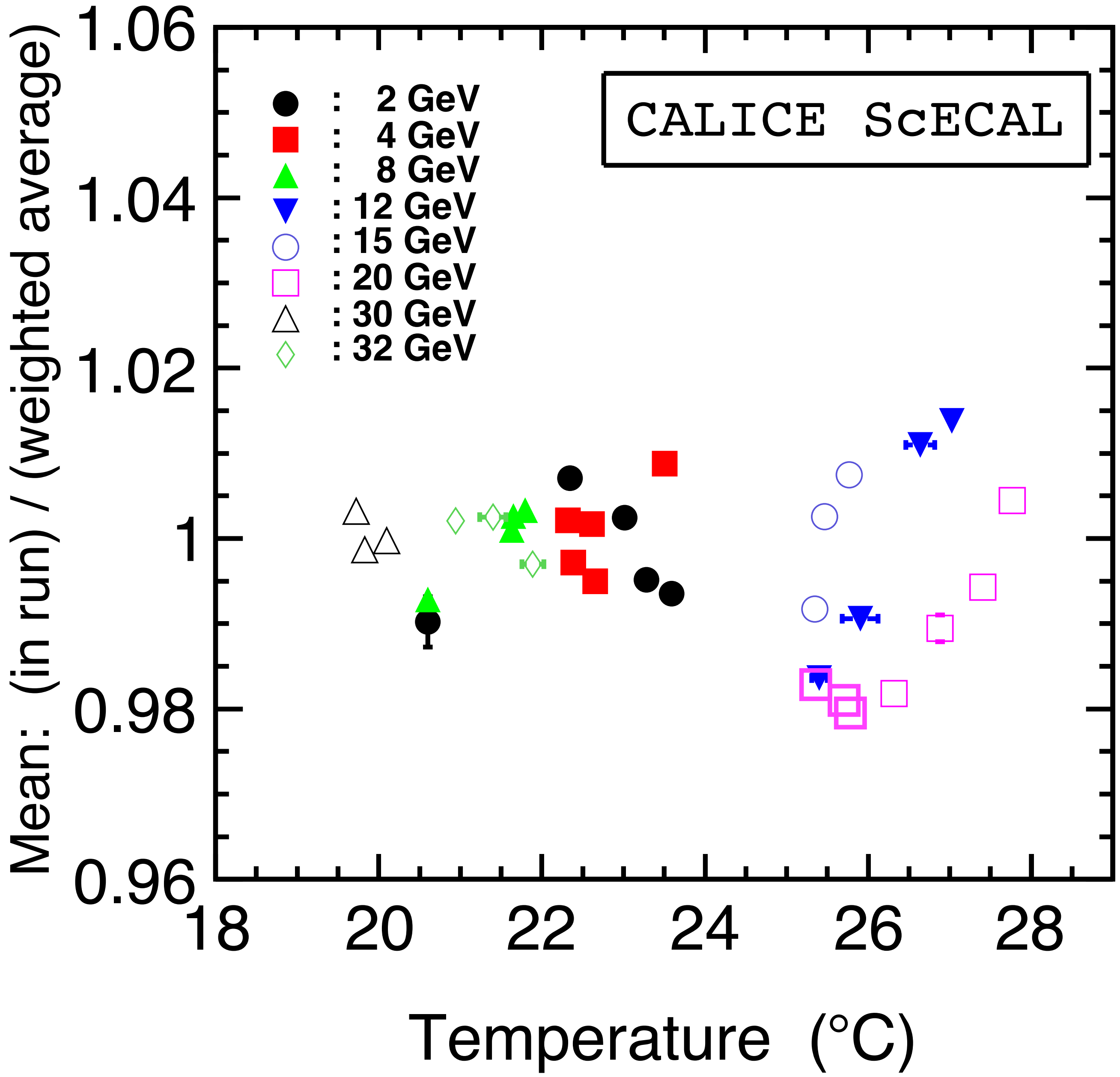
$c^{p.e.}(T)$



- Gain ($c^{p.e.}$)s of 11 temperature conditions were measured
- Each signal was converted in the # of p.e. using $c^{p.e.}$ at 20°C and slope $(dc^{p.e.}/c^{p.e.})/dT$
- $c^{p.e.}(T)$ for 76.5% of 2160 channels ware determined,
  - 20%: double-peak pedestal or no separation,
  - 3%: range cut--above plot.
- use average value of $c^{p.e.}$(20℃) and $(dc^{p.e.}/c^{p.e})/dT$ for failed channels.

Run variations

We had known that the run variations of E_{mean} is larger than their uncertainty



Plot shows
ratio of Energy mean
[run by run / average].

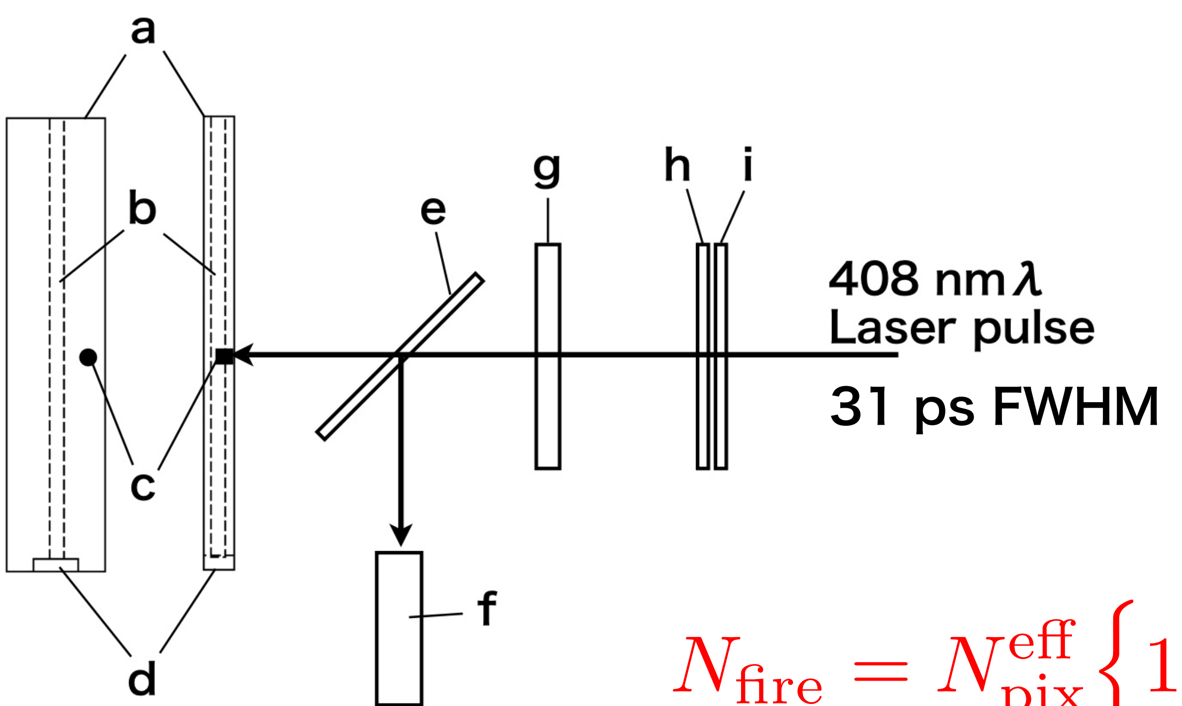
Unclear dependence on temperature.

$$\bar{x} \pm \delta\bar{x} = \frac{\sum_i \omega_i x_i}{\sum_i \omega_i} \pm \left(\sum_i \omega_i\right)^{-1/2}$$

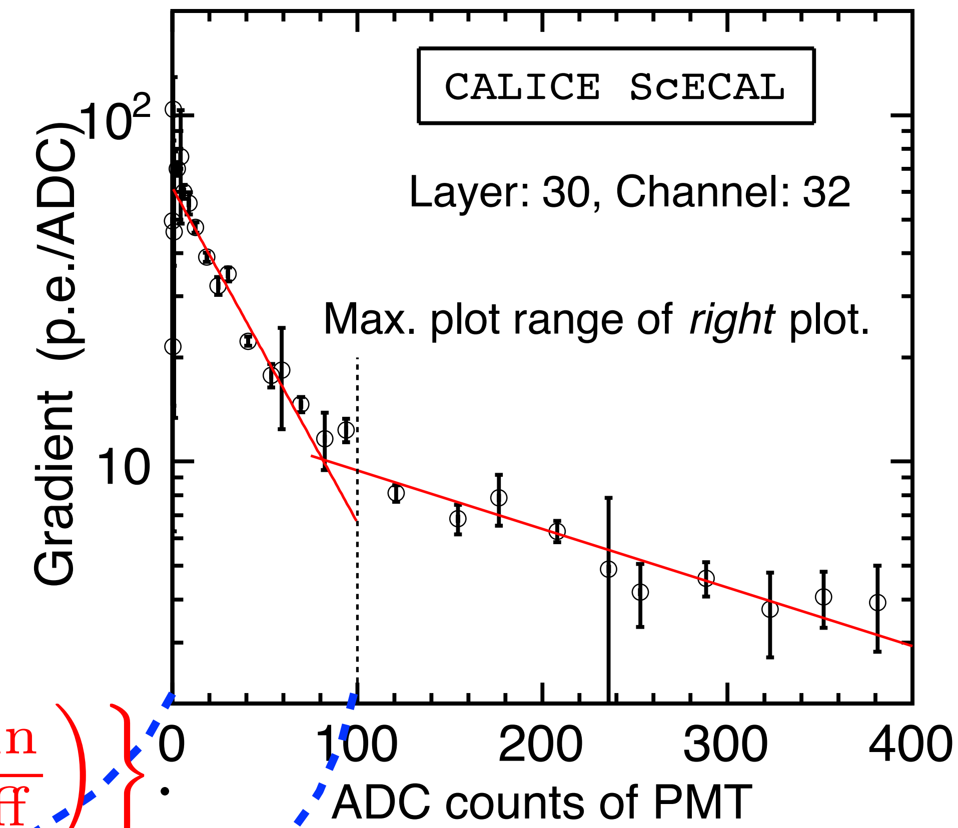
$$\omega_i = 1/(\delta x_i)^2$$

MPPC response function

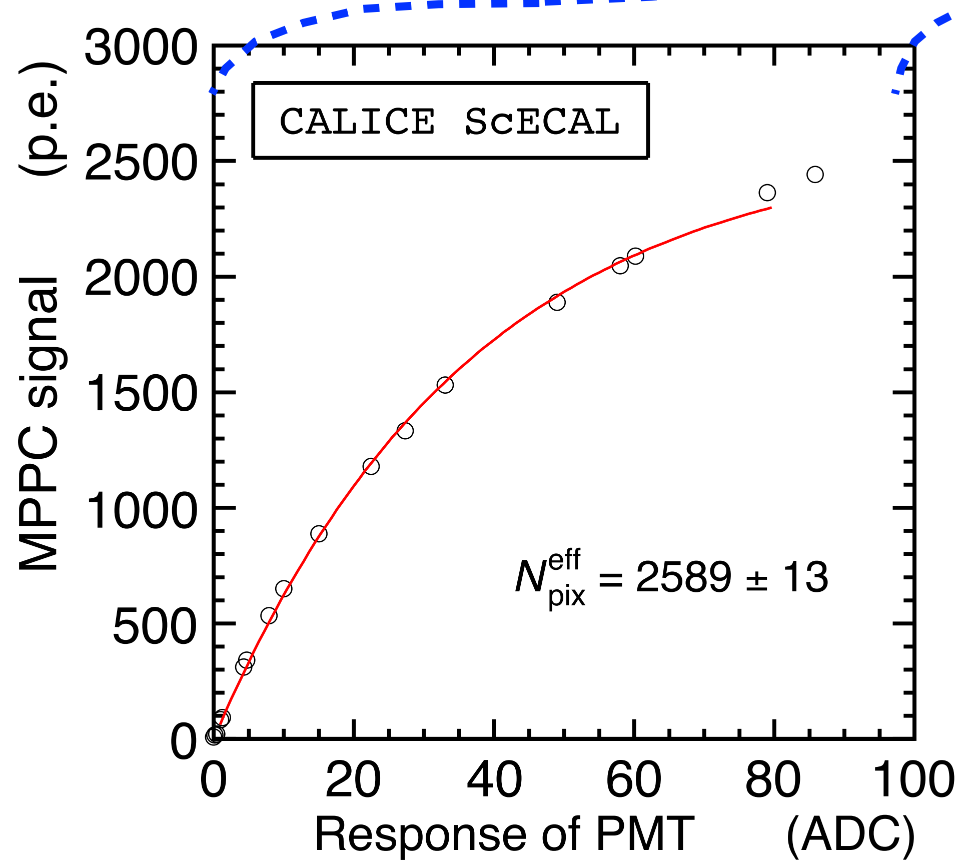
Samples are 72 channels in 30th layer.



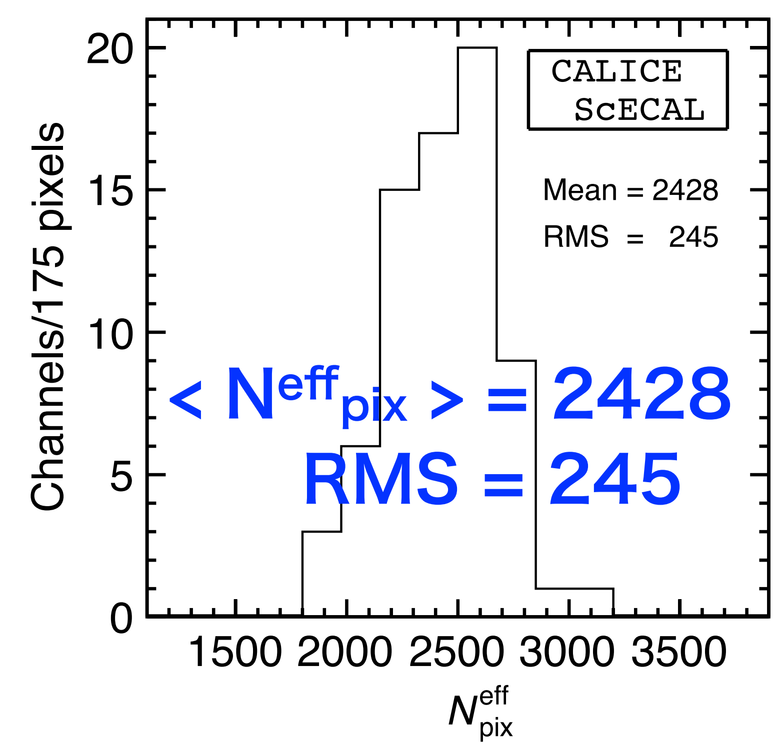
- a. scintillator
- b. WLS fiber
- c. hole on reflector
- d. MPPC
- e. half miller
- f. PMT
- g. lens
- h,i. polaroid



$$N_{\rm fire} = N_{\rm pix}^{\rm eff}\left\{1 - \exp\left(-\frac{\epsilon N_{\rm in}}{N_{\rm pix}^{\rm eff}}\right)\right\}.$$



Distribution of N^{eff}_{pix}

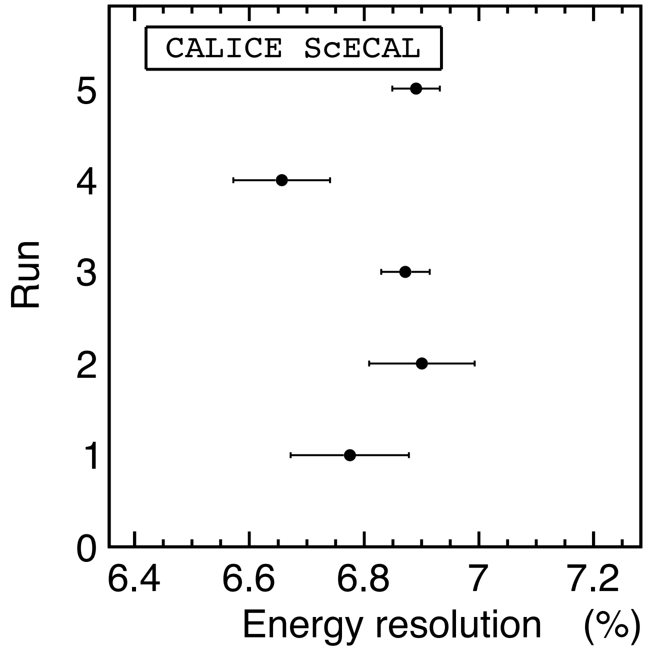


$< N^{eff}_{pix} > = 2428$

RMS = 245

Run variations

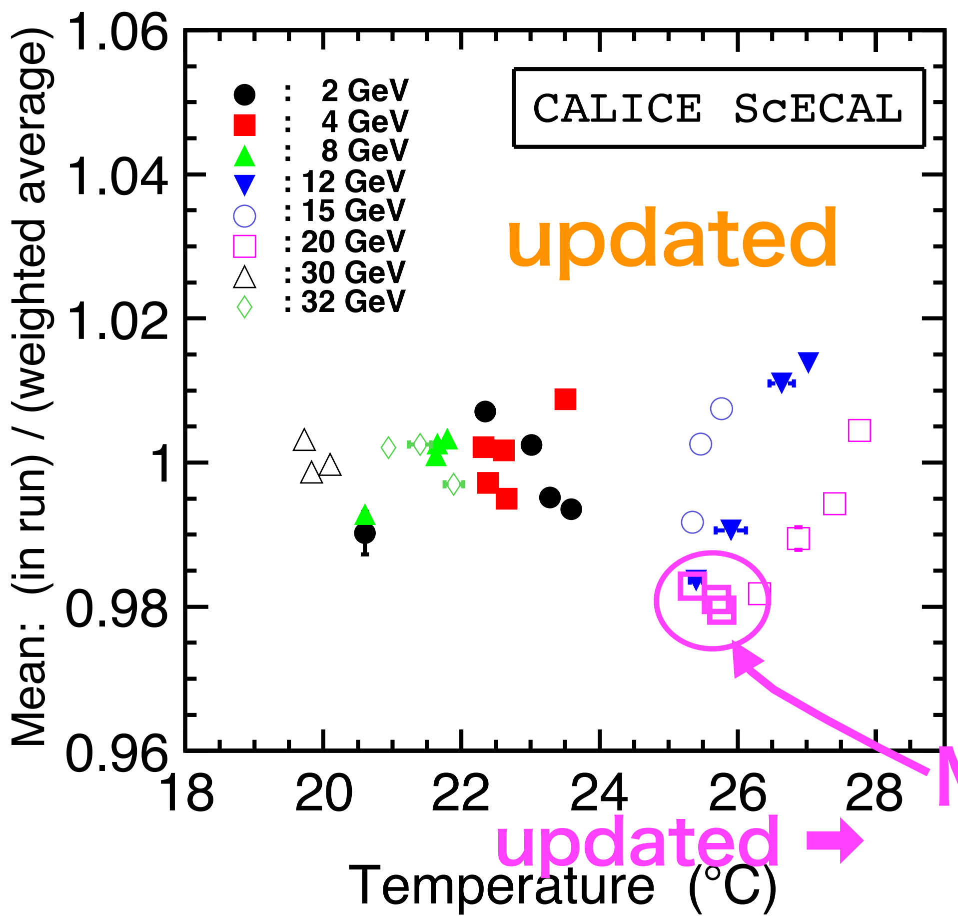
Energy resolution



Run variations in the energy resolution are reasonable w.r.t their uncertainties.

4 GeV/c as an example

Energy mean [mean(run)/ average]



Run variations are larger than that uncertainties.

Unclear dependence on temperature.

use Error weighted mean:

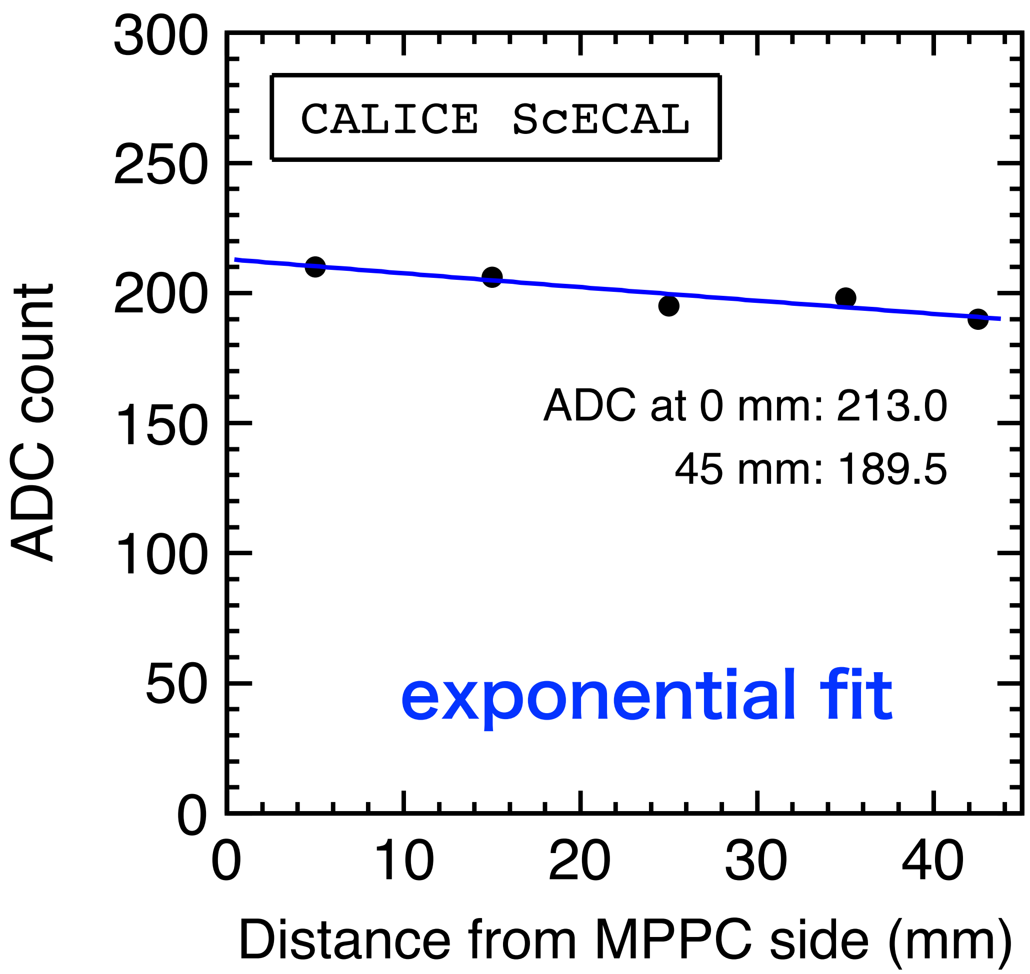
$$\bar{x} \pm \delta\bar{x} = \frac{\sum_i \omega_i x_i}{\sum_i \omega_i} \pm \left(\sum_i \omega_i\right)^{-1/2}$$

$$\omega_i = 1/(\delta x_i)^2$$

Response uniformities

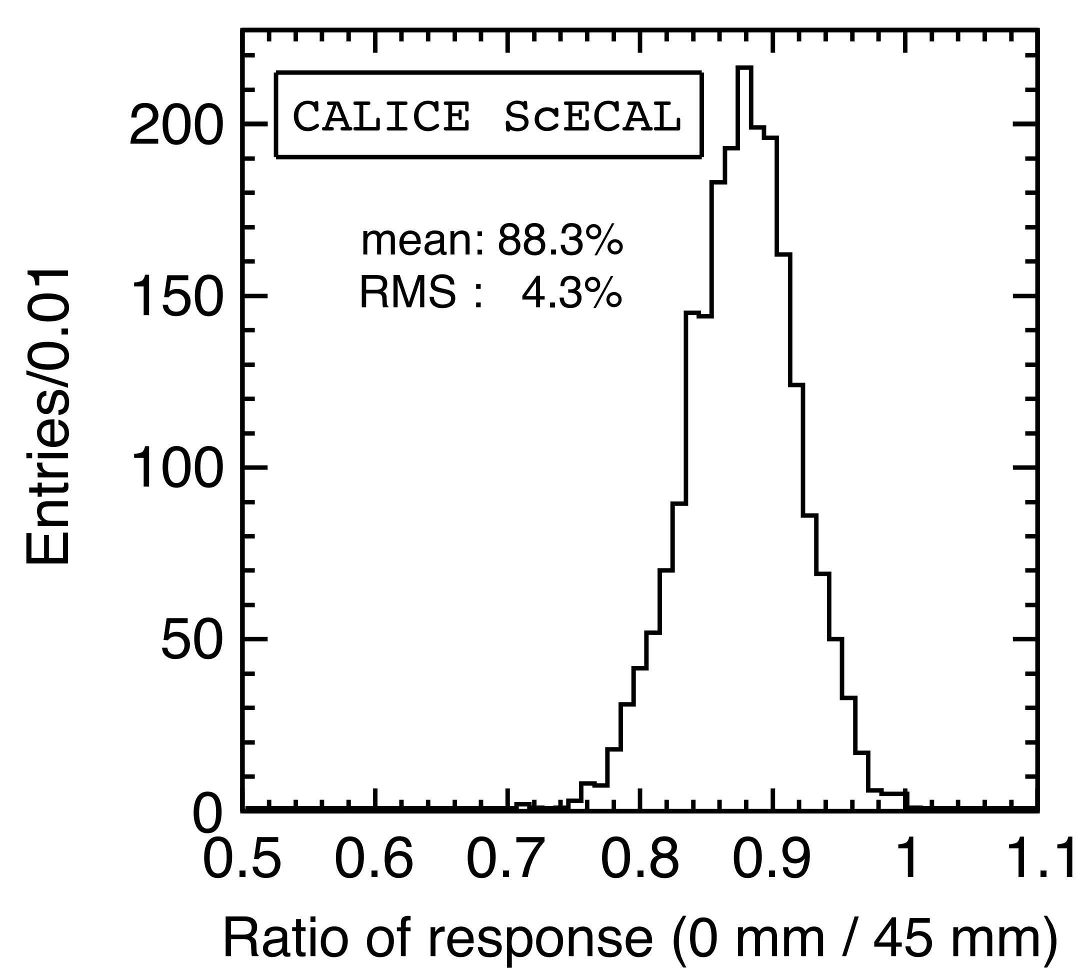
updated

Position dependence of response--the distance from MPPC--was determined by position information from hits on the orthogonal layers.



Distribution of ratio

$$\frac{\text{response at 45mm}}{\text{response at 0mm}}$$



MC ignores the effect of this non uniformity

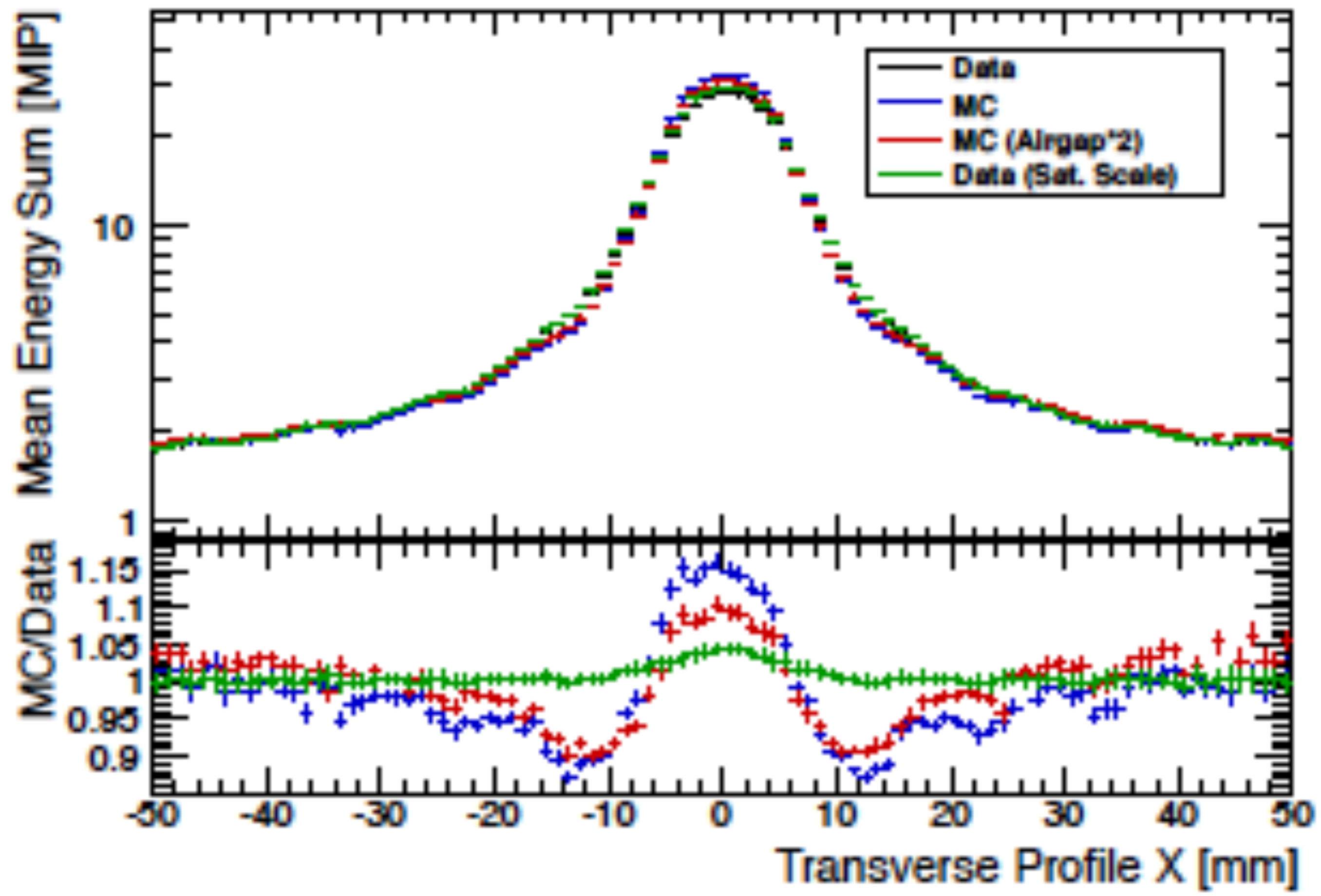
➡ 88.3% uniformity is enough.

Other properties

- DAQ system was the same as AHCAL phys. prototype,
- Scintillator strips were made with an extrusion method at KNU,
- Response uniformity of strip was improved than 1st prototype,

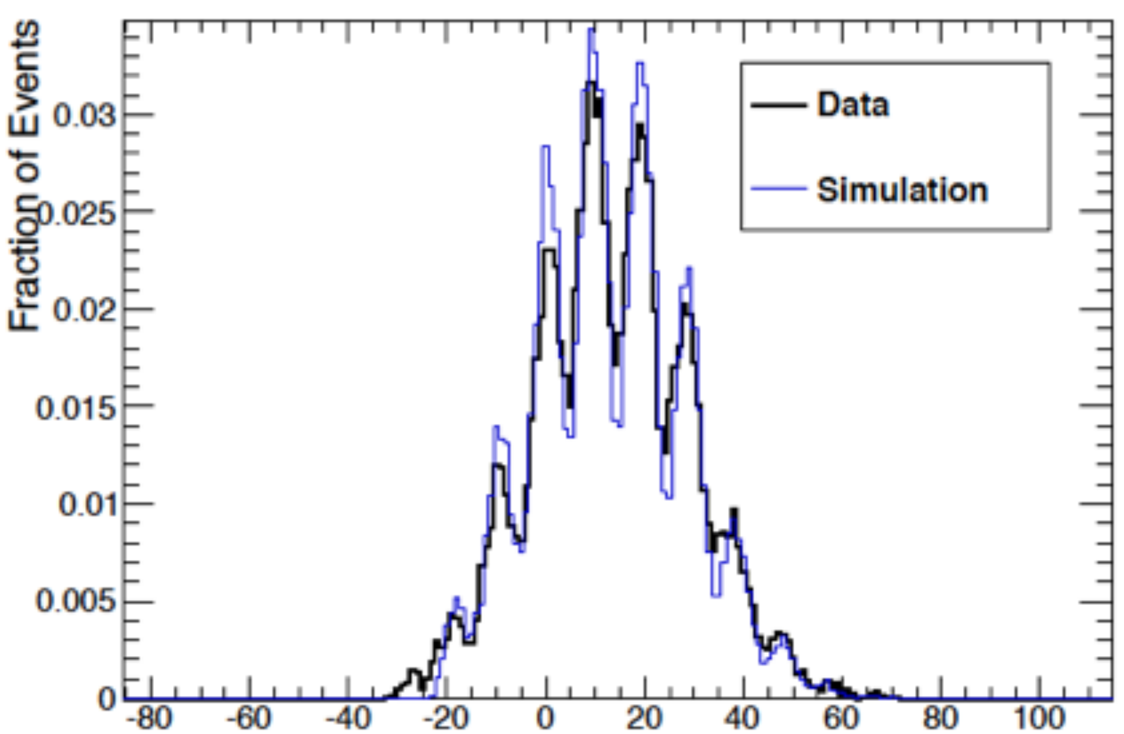
Data vs. MC

lateral projection (20 GeV/c)



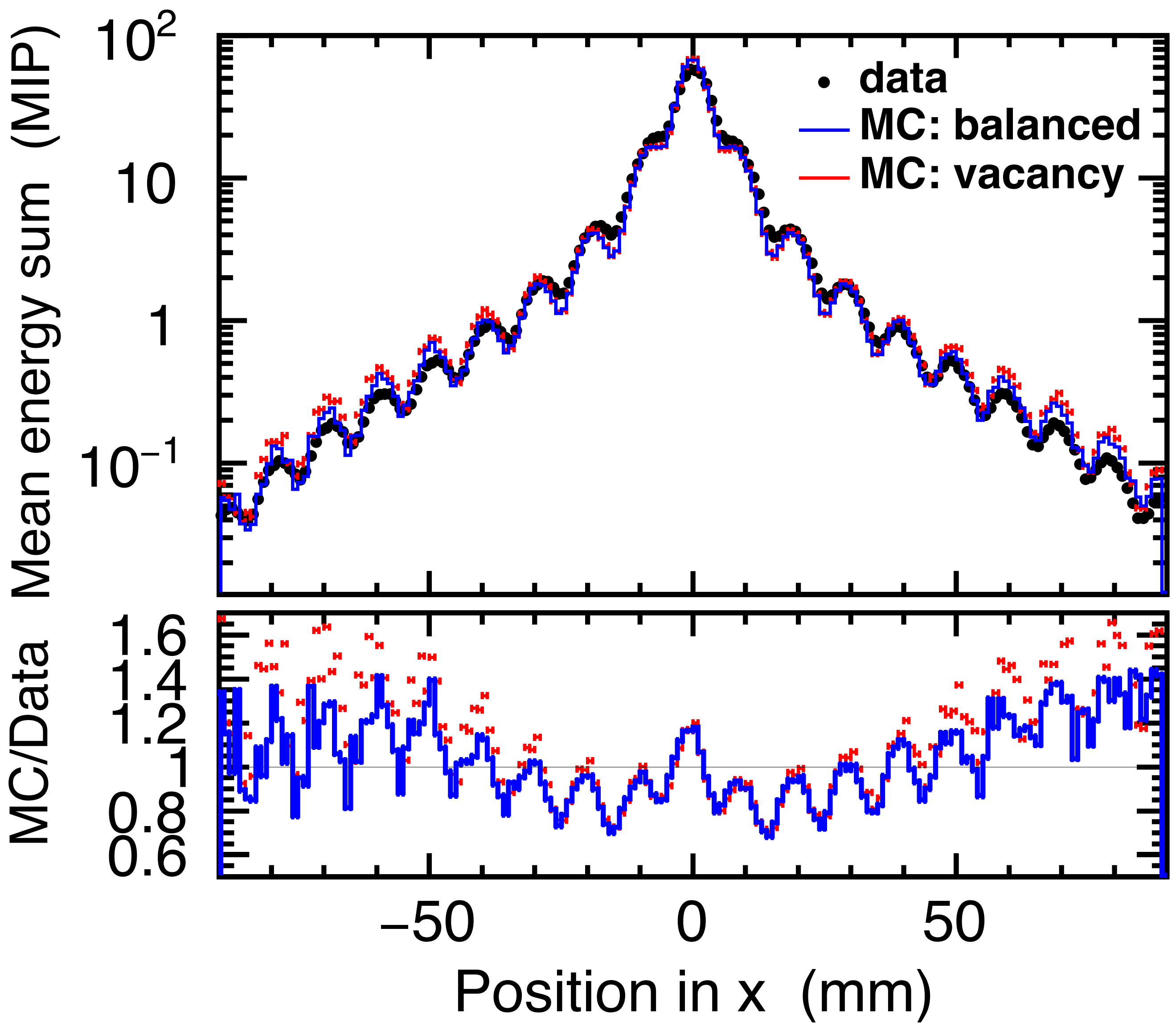
MC distribution is sharper than data.

Any assumptions failed to explain the phenomenon to date.



Data vs. MC

lateral projection (12 GeV/c)



Hit position - shower center c-o-g

10 mm structure was smeared by subtraction of C-o-G.

Totally good agreement.
Again balanced method has good agreement

Effect of difference of the distribution of C-o-G between MC and Data reflects the disagree here.

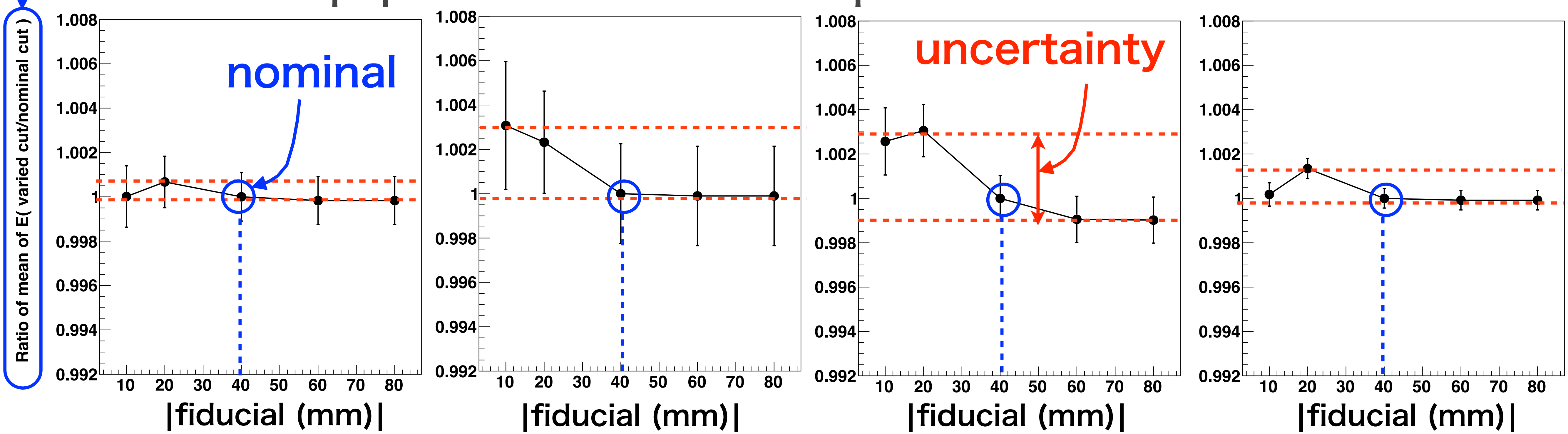
Cut variations on Shower center

Ratio Ē : (with a cut value) / (with nominal cut)

example: |center-of-gravity | < 40 mm in x; 20 GeV, 4 runs

fiducial volume

not in paper but used for the explanation to the CALICE editorials.



average of highest and lowest variations in runs is taken as a systematic uncertainty; variations were weighted with their uncertainty.