Study of the response of the CALICE Si-W ECAL physics-prototype to positrons

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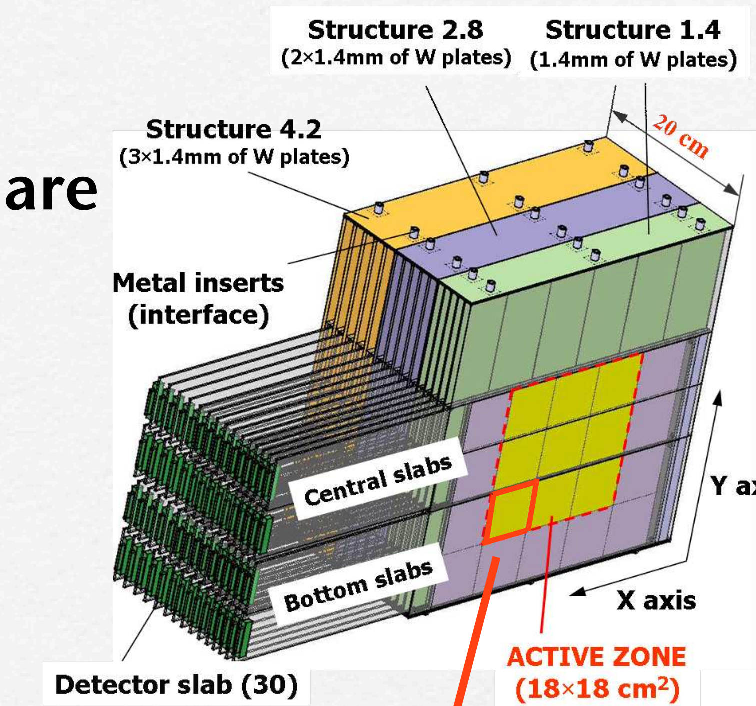
Motivation

- The CALICE Si-W ECAL physics prototype was constructed and tested with electron and positron beams at FNAL in 2008.
- We evaluated the performance of the response of the linearity and the energy resolution with collected positron data (4 - 20 GeV).
- We will compare the result of this analysis with that of previous TB analysis at CERN in 2006.

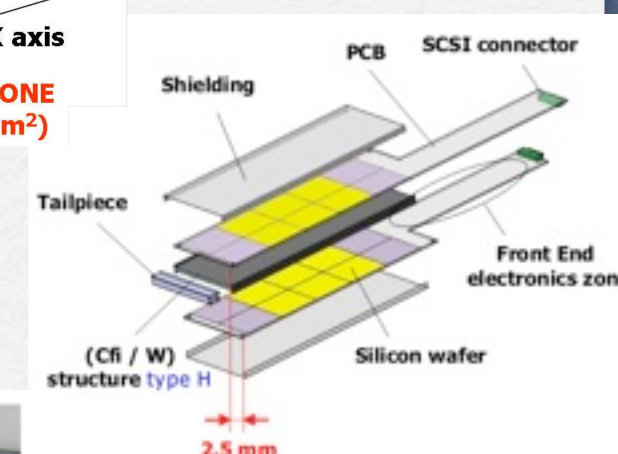
Prototype Design

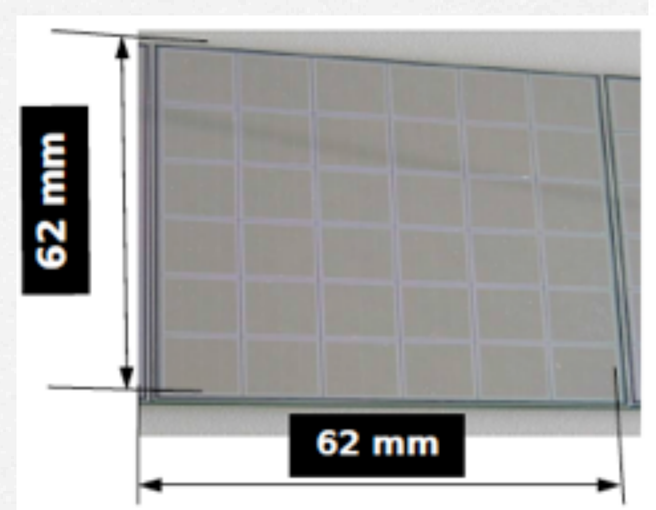
- The physics prototype consists of thirty sensitive layers and absorber layers and are divided into three structures.
  - sensitive layer : silicon
    - 6×6 pixels for one module
    - 3×3 modules in a layer (18×18 cm^2)
    - ➡ Total 9720 channels
  - absorber layer : tungsten
    - Structure 1.4 : 1〜10 : 1.4 mm (0.4X_0)
    - Structure 2.8 : 11〜20 : 2.8 mm (0.8X_0)
    - Structure 4.2 : 21〜30 : 4.2 mm (1.2X_0)
    - ➡ Total 24X_0

Prototype Design



Detector slab





Silicon module

Event Selection

- The total energy deposited on ECAL

$$E_{\text{raw}} = \sum_{i=0}^{i=9} E_i + 2\sum_{i=10}^{i=19} E_i + 3\sum_{i=20}^{i=29} E_i$$

- Event Selection

1. set the energy window.

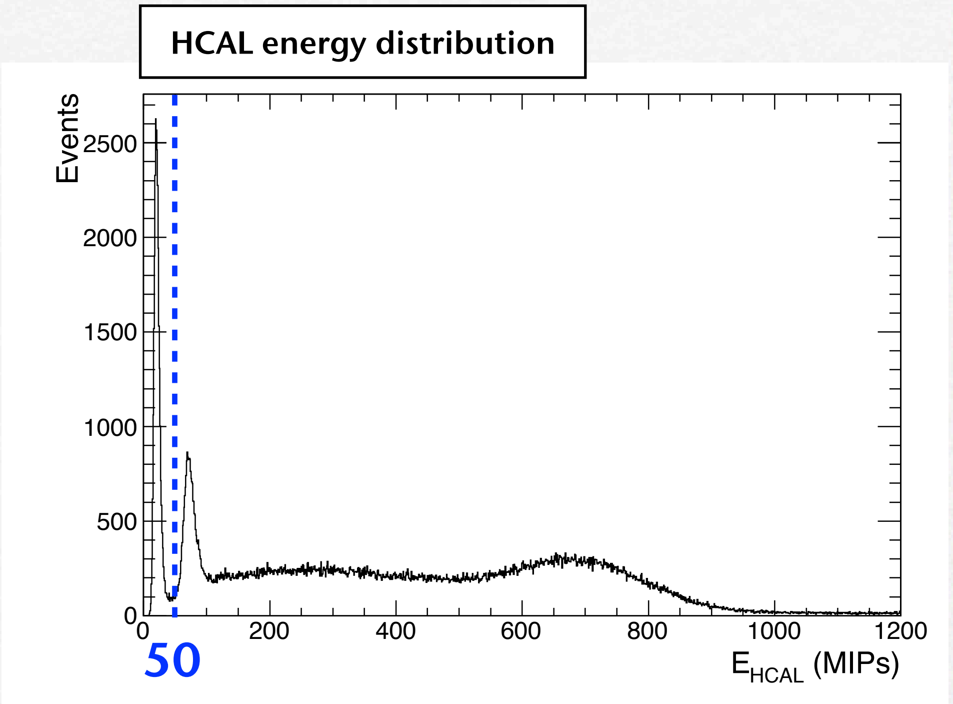
$$125 < \frac{E_{\text{raw}}\,(\text{MIPs})}{E_{\text{beam}}\,(\text{GeV})} < 375$$

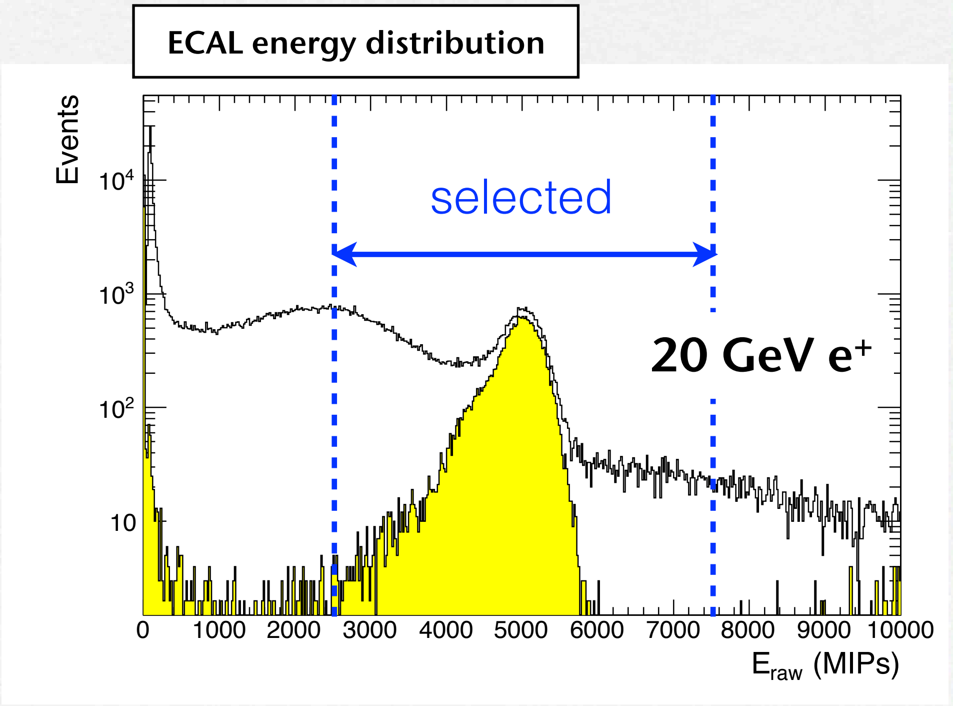
2. reject pion contamination by using HCAL information.

$$E_{\text{HCAL}} < 50\ \text{MIPs}$$

3. reject the event that the shower maximum layer is in the first five layers or the last five layers.

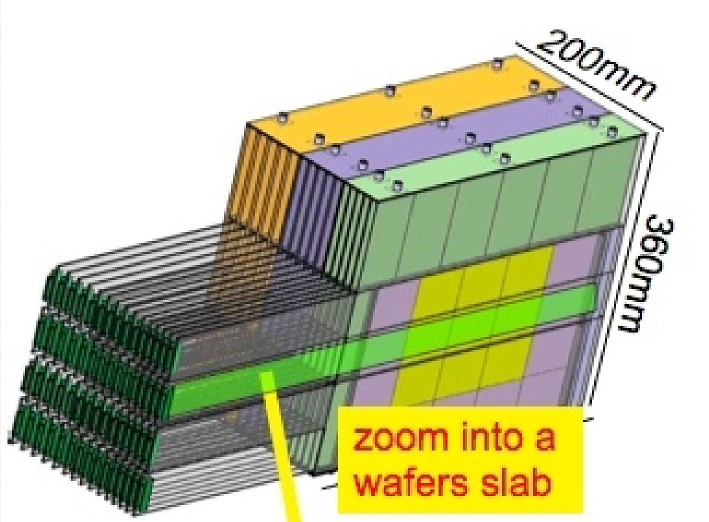
$$4 < L_{\text{max}} < 25$$

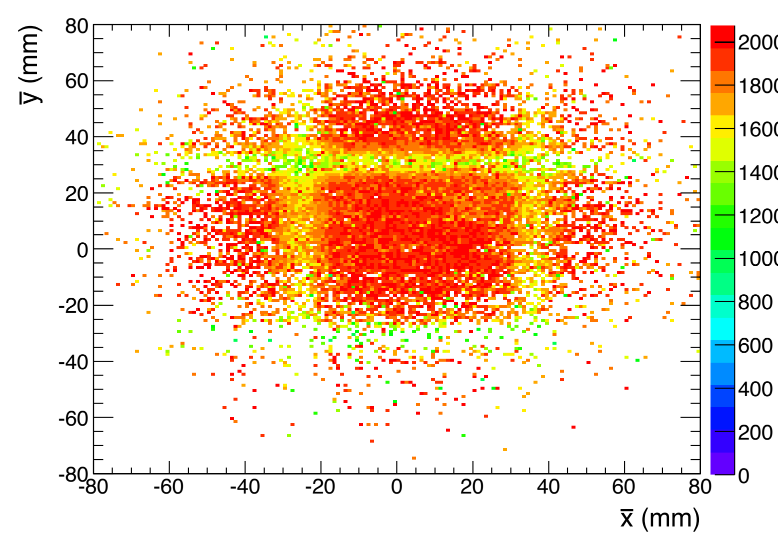




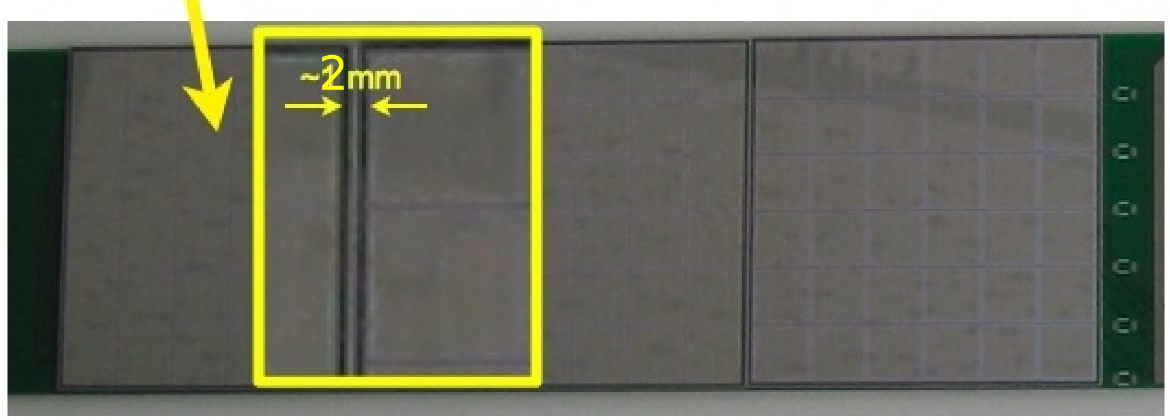
Gap Effect

- Each silicon wafer has 1 mm guard ring which makes non-active region.
  - ➡ There are 2 mm interwafer gaps.
  - ➡ They represents dominant source of the non-uniformity.





E_{mean} (MIPs)



shower barycenter

$$(\bar{x},\bar{y}) = \left(\sum_i E_i x_i, \sum_i E_i y_i\right) / \sum_i E_i$$

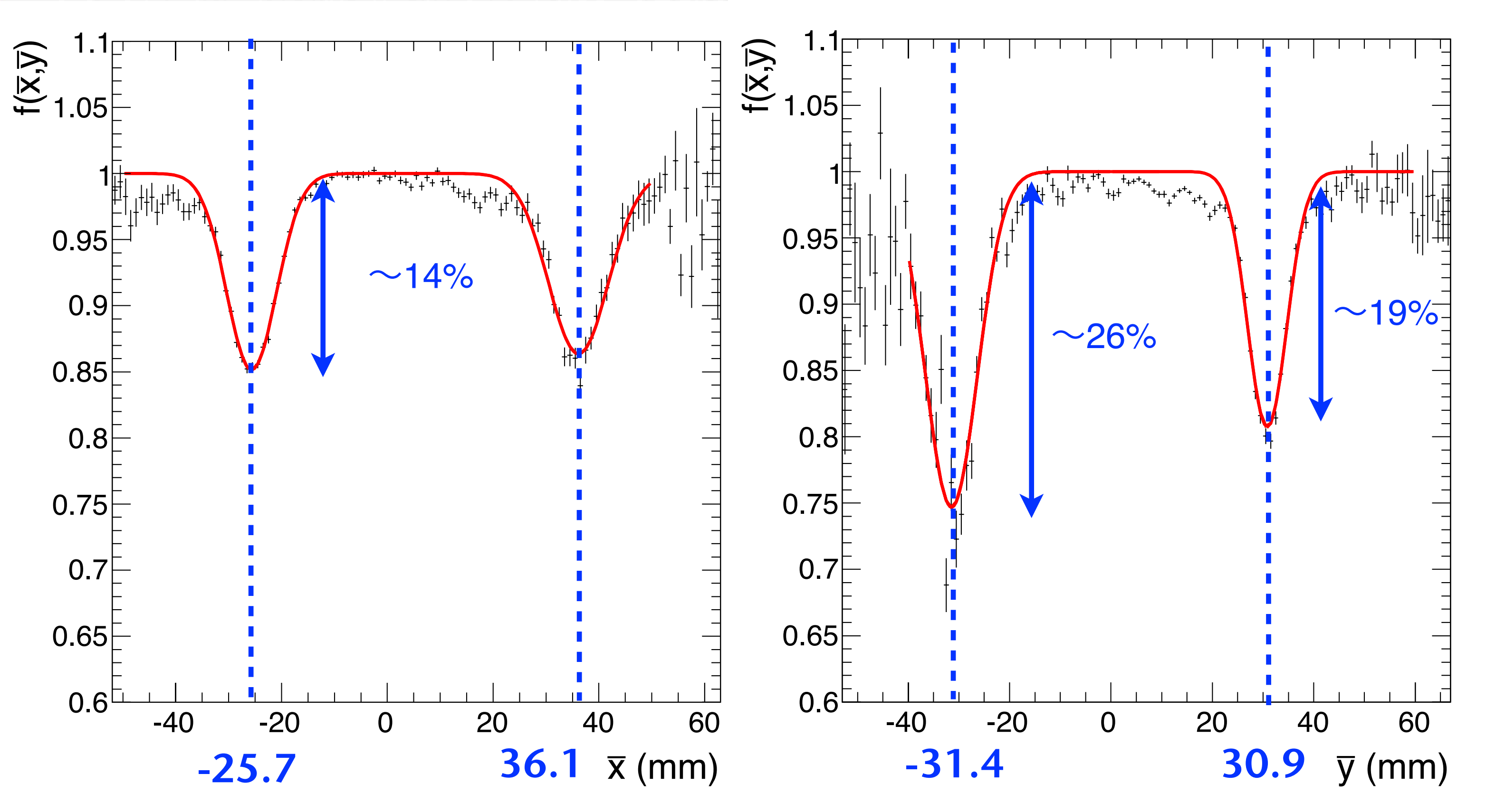
Need to correct the response of the calorimeter

Gap Correction

- The response around the interwafer gaps was fitted with the Gaussian.

$$f(\bar{x},\bar{y}) = \left(1 - a_x \exp\left(-\frac{(\bar{x}-x_{gap})^2}{2{\sigma_x}^2}\right)\right)\left(1 - a_y \exp\left(-\frac{(\bar{y}-y_{gap})^2}{2{\sigma_y}^2}\right)\right)$$

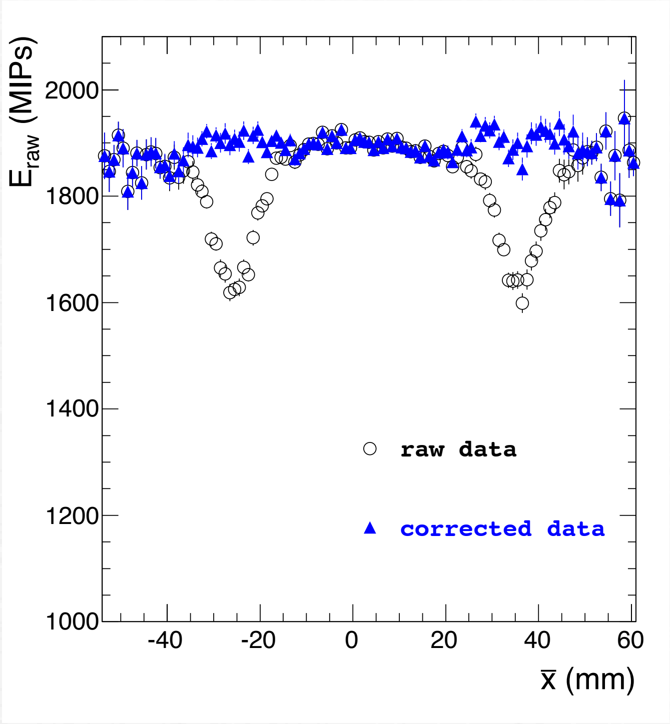
- The value of the parameters a_x, x_{gap}, σ_x, a_y, y_{gap} and σ_y was extracted from the results of the fits.

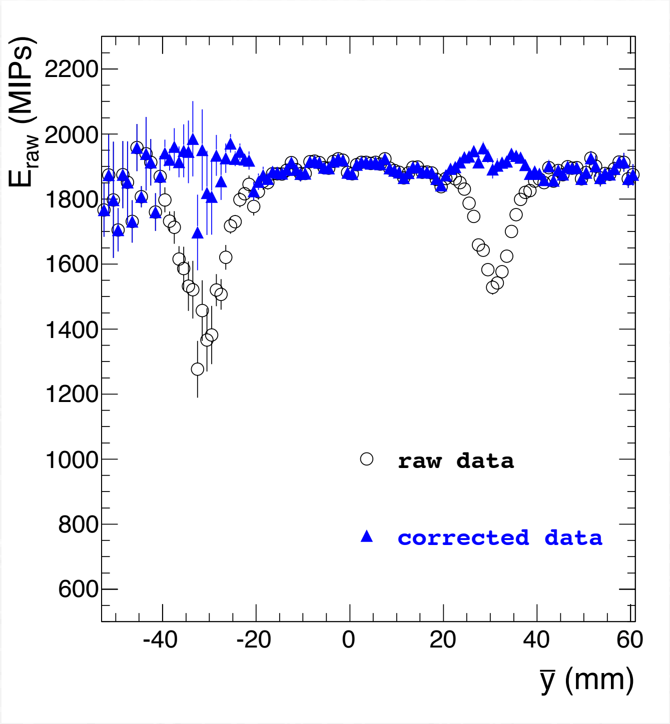


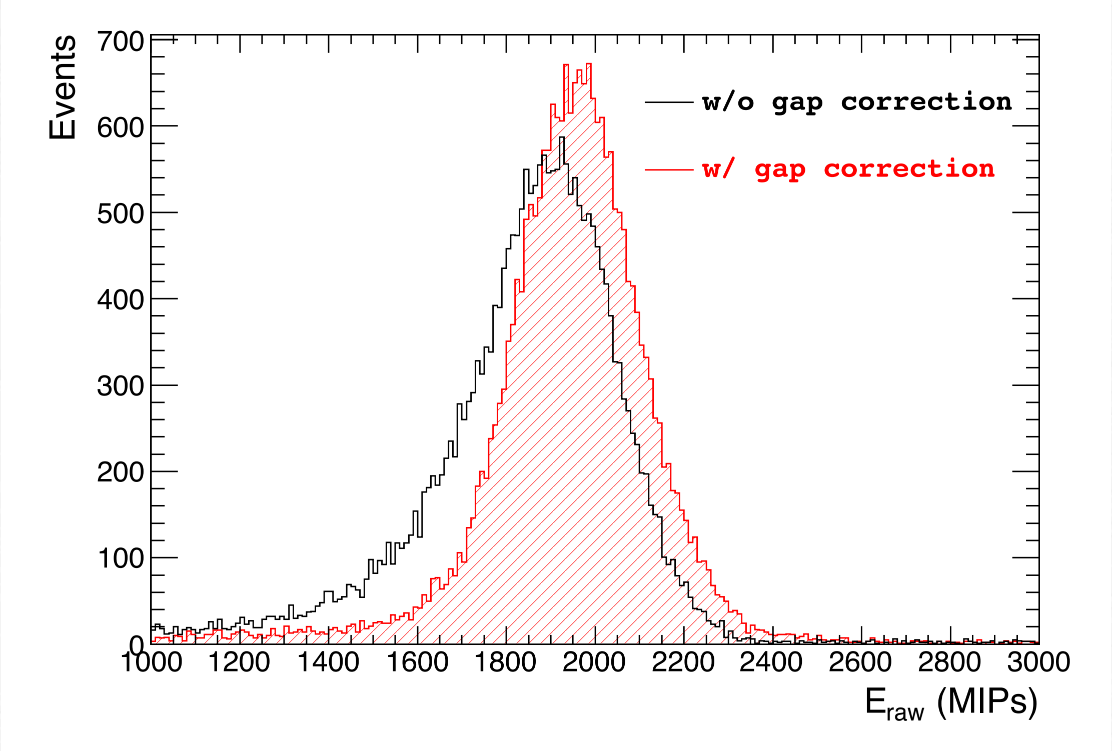
The results of the gaussian fit

	a_x, a_y	x_{gap}, y_{gap}	σ_x, σ_y
$\bar{x}$	0.14, 0.15	-25.7, 36.1	5.63, 4.74
$\bar{y}$	0.26, 0.19	-31.4, 30.9	5.17, 3.92

Gap Correction



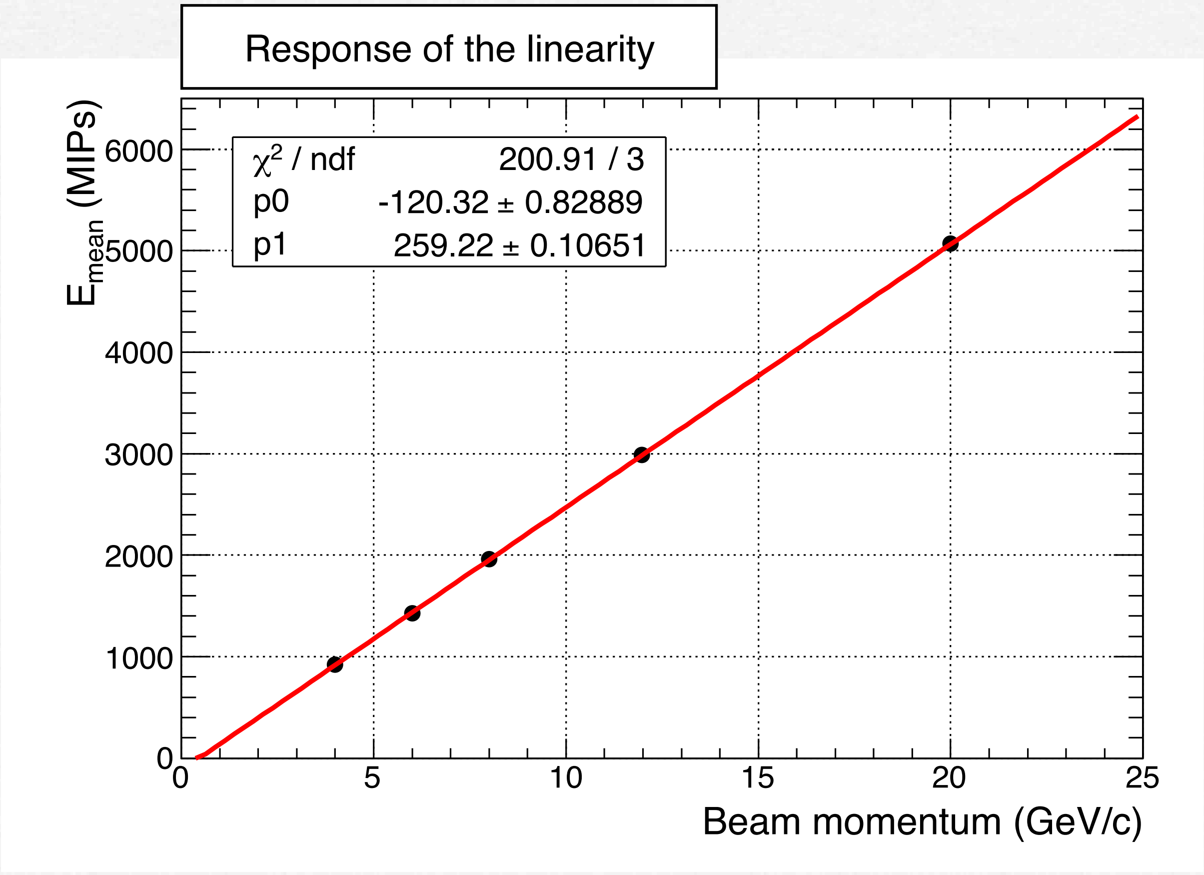


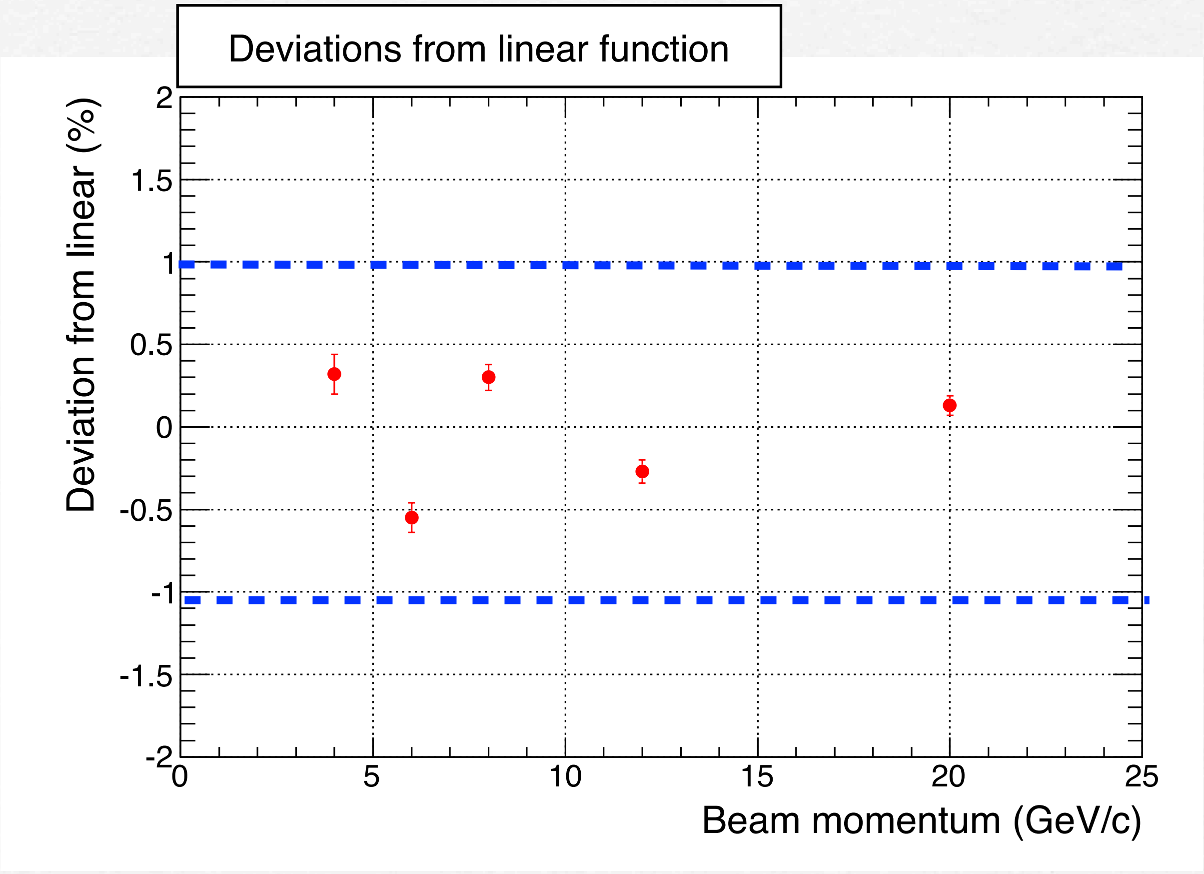


- The energy loss in the interwafer gaps can be corrected by applying 1/f correction factor.
- The shape of the energy distribution becomes more symmetric after gap correction.

Performance (Linearity)

- We checked the response of the linearity and energy resolution after gap correction.

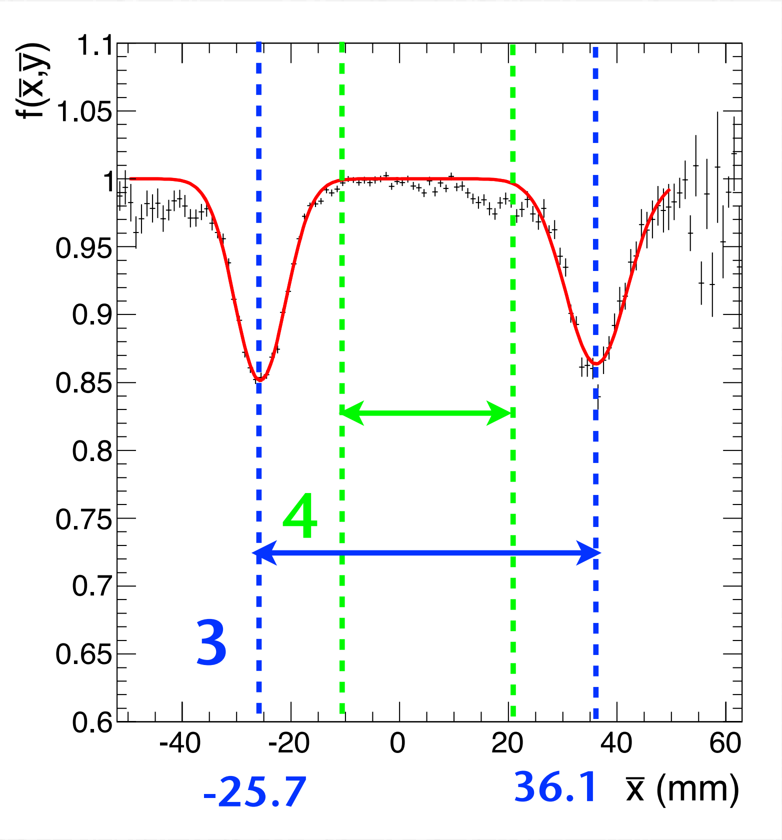


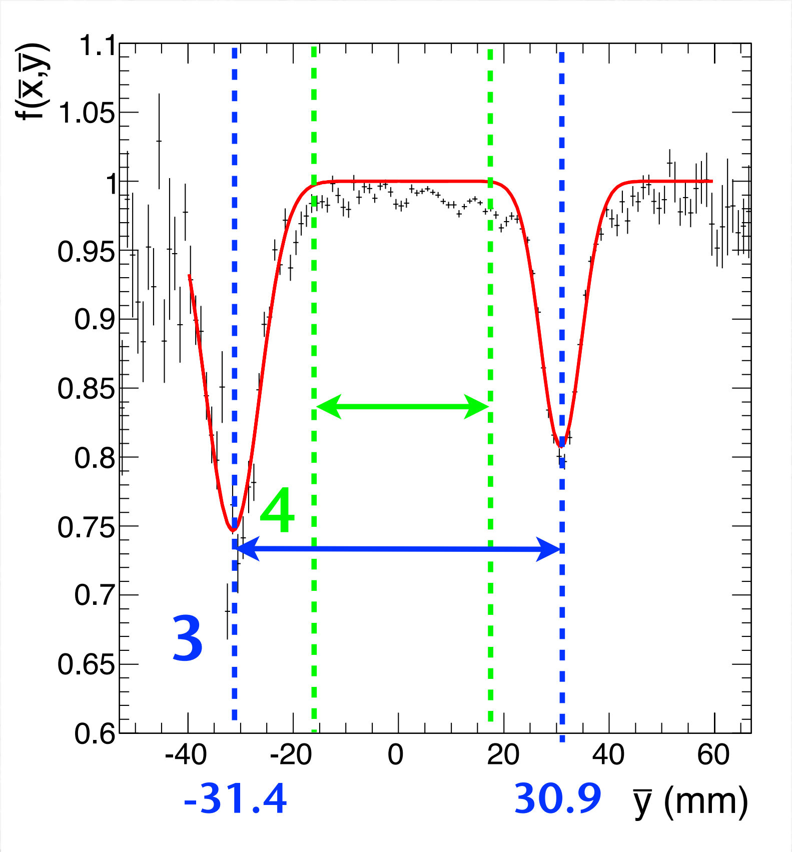


The deviations from linear are less than 1%

Performance (Energy Resolution)

- We classified the energy resolution into four situations and compared with each situation.
    1. "no correction" : not applied gap correction
    2. "gap correction" : applied gap correction for all region
    3. "center region w/ gap" : selected the event in the center region which includes gaps
    4. "center region w/o gap" : selected the events in the center region without gap





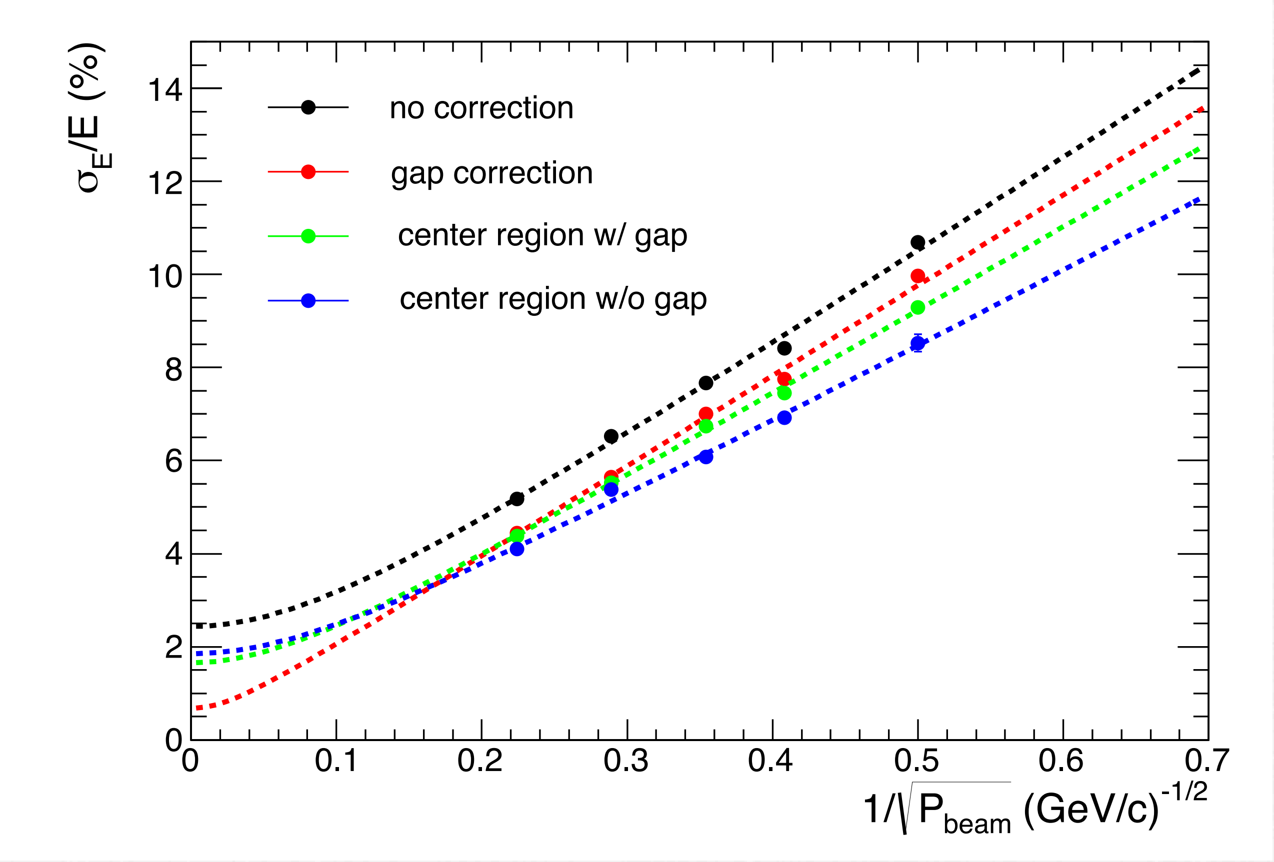
Performance (Energy Resolution)

- We checked the energy resolution in four situations.
- Resolution curve :

$$\frac{\sigma_E}{E} = \frac{\sigma_{\mathrm{stoc}}(\%)}{\sqrt{E}} \oplus \sigma_{\mathrm{const}}(\%)$$

Compared with CERN data, there is around 3% difference on the stochastic term for “gap correction” category.

We need to improve the method of the gap correction.



	stochastic	constant
no correction	20.47±0.21%	2.44±0.17%
gap correction	19.48±0.20%	0.68±0.52%
center region w/ gap	18.16±0.17%	1.66±0.15%
center region w/o gap	16.54±0.31%	1.85±0.23%
2006 CERN data	16.69±0.13%	1.09±0.06%

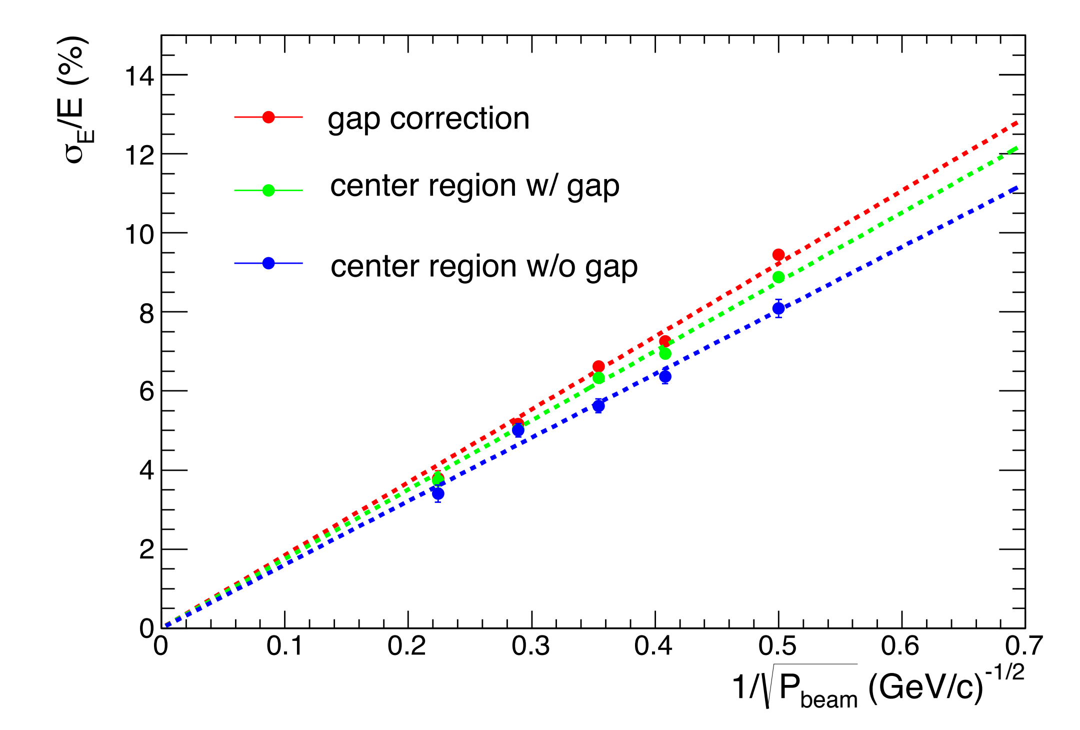
Momentum Spread

- The beam momentum spread at FNAL

  2.7 ± 0.3 % for 2-4 GeV, 2.3 ± 0.3 % for 8-32 GeV

- Taking into account the beam momentum spread, the intrinsic energy resolution is described by

$$\frac{\sigma_{\rm int}}{E} = \sqrt{\left(\frac{\sigma_{\rm obs}}{E}\right)^2 - (\sigma_{\rm fluc})^2}$$



	stochastic	constant
gap correction	18.45±0.15%	0.00±0.56%
center region w/ gap	17.52±0.17%	0.00±0.93%
center region w/o gap	16.07±0.23%	0.00±1.41%

Constant term becomes 0.
The reason is now under investigation.

Summary

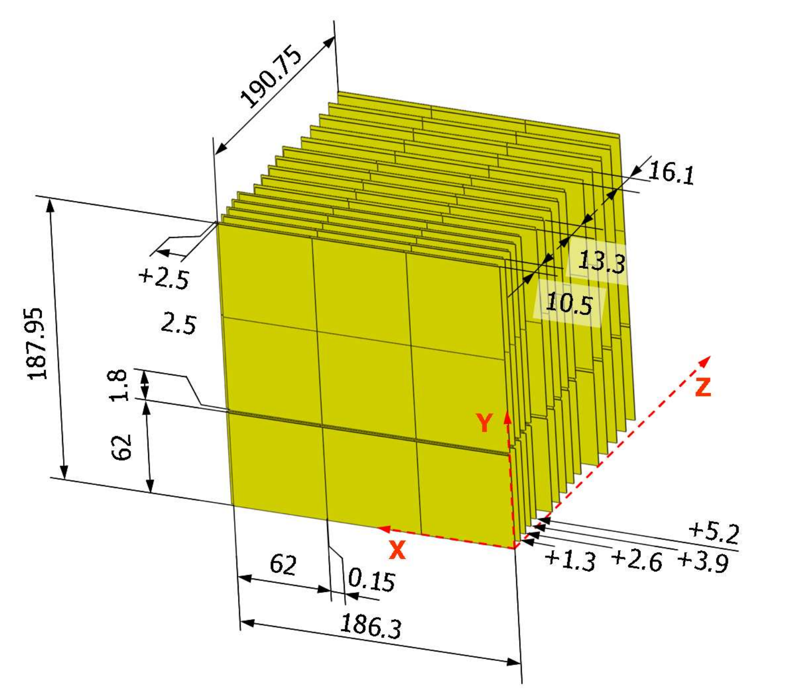
- We analyzed CALICE ECAL physics prototype test beam data taken in 2008 at FNAL and checked the response of the linearity and the energy resolution.

- Linearity
  - The response has good linearity
  - Deviations from linear function are less than 1%

- Energy resolution
  - The energy resolution has a stochastic term of 19.48±0.20% and constant term of 0.68±0.52% for “gap correction”.
  - In comparison with TB 2006 analysis, the result is not consistent.
  - In the case of the “center region w/o gap”, the energy resolution is consistent with TB 2006.

Future Prospects

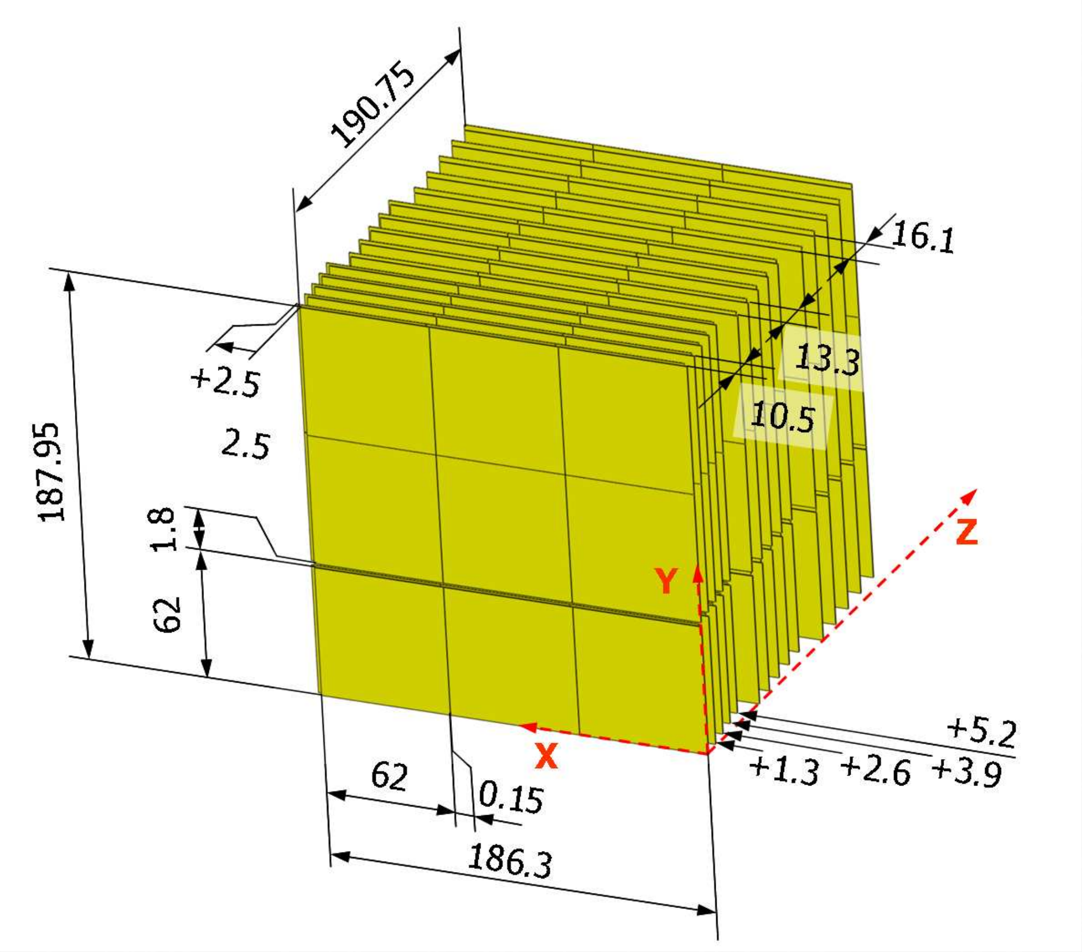
- try to improve the method of the gap correction.
  - to create the correction factor structure by structure
  - roughening the binning 1 mm to 2 mm on creating the correction factor
- start the simulation study to understand our analysis.
- estimate the systematic uncertainties on the energy resolution.



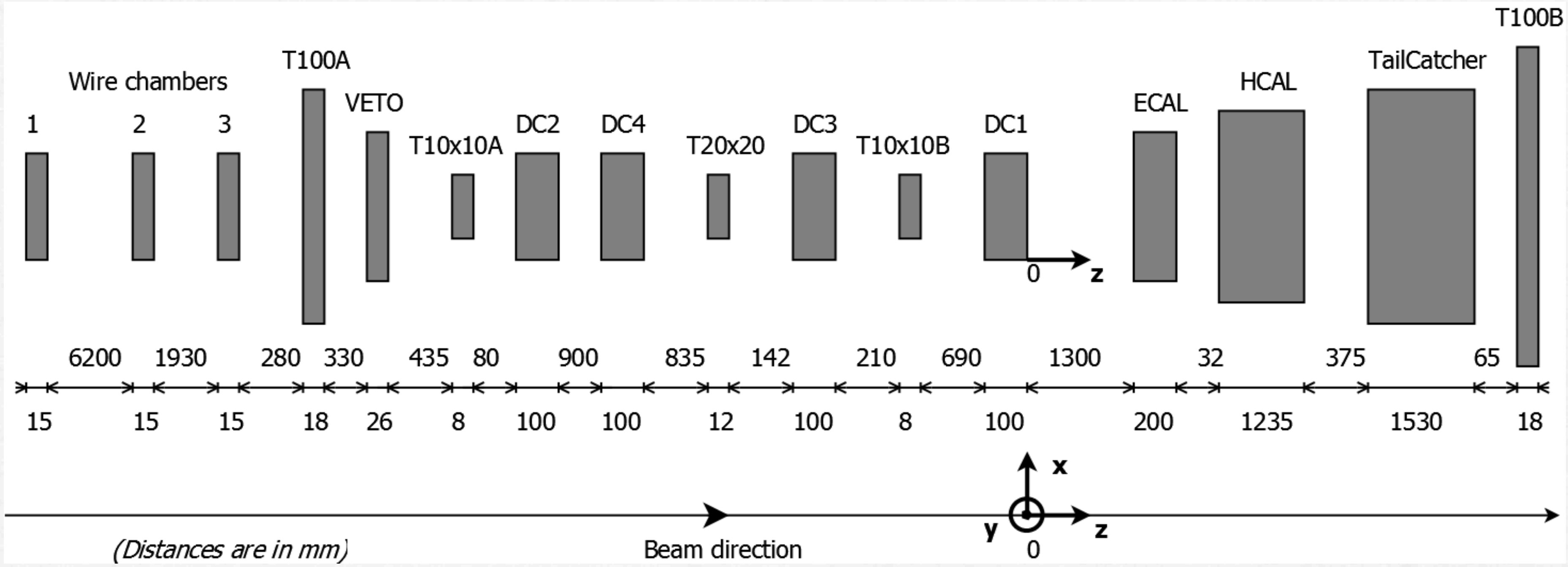
back up

Details of the passive area and offsets

- The passive area between modules is mainly due to two 1mm wide guard rings around the modules.
- A large passive area is located between the central and bottom slabs.



Test Beam @ FNAL



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