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Simulation Study in Various Configurations of ECAL

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ILD ECAL

- Fine granular detector is necessary for PFA

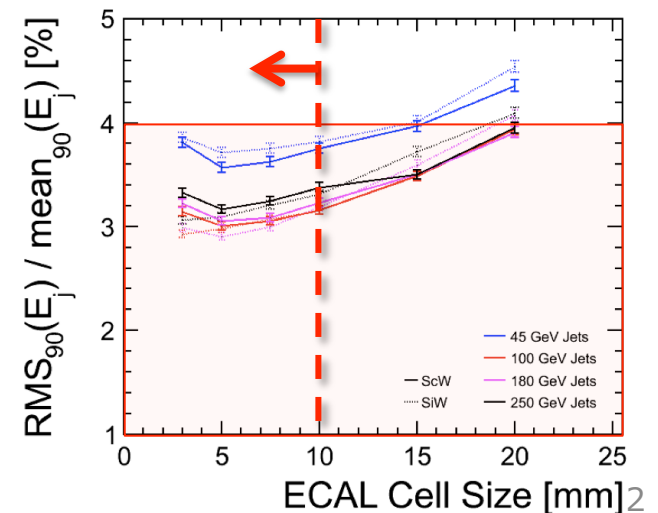
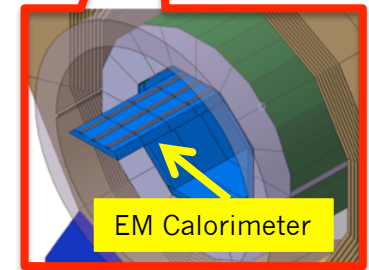
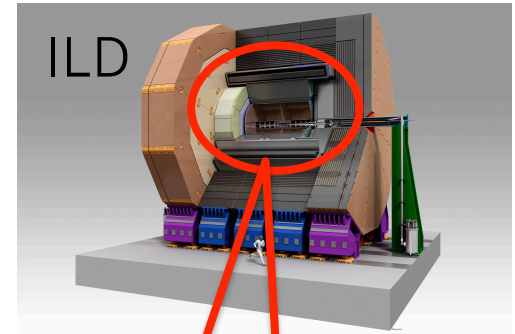


Requirement : pixel size $< 1\text{cm}^2$



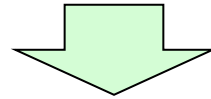
- ILD ECAL : Sampling calorimeter
 - Absorber : **Tungsten**
 - Candidates of sensitive detector
 - **Pixelized silicon**
 - **Scintillator-strip + MPPC**

$\rho_M : 9.3\text{mm}$
 $X_0 : 3.5\text{mm}$



Study Goal

**Study of parameter effects
by changing some parameters **independently****



Systematic optimization of calorimeter

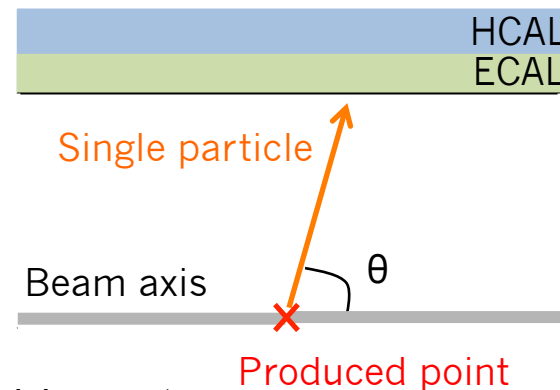
- **Longitudinal structure** mainly affects single particle resolution
 - thickness, the number of layers
- **Transverse structure** mainly affects confusion
 - pixel size, Si/Sc (or Hybrid) , overall size
- **Jet Energy Resolution depends on both structures**
 - : Subjects of the study this time

- **Conditions**

- Longitudinal thickness of absorbers are changed
 - Resolution of single particles
 - Resolution and confusion term of Jets
 - **Whole thickness of ECAL is adjusted to be almost equal for each configuration**
- Pixel size of Silicon is changed
 - Resolution and confusion term of Jets

- **Simulation : ilcsoft (v01-16-02)**

- number of events : 10,000 events
- Shot angle : $74.52^\circ < \theta < 104.48^\circ$ (photon and kaon),
All direction (Jets)



Confusion Term

- **Confusion term**

- is caused by the identification error of PFA
- is defined as the following equation

$$\text{Confusion term} = \sqrt{\text{JER}_{\text{PandoraPFA}}^2 - \text{JER}_{\text{PerfectPFA}}^2}$$

- **PerfectPFA**

- Use hits and track information of MC particles for clustering and particle-identification
- Can lead energy resolution without the identification error

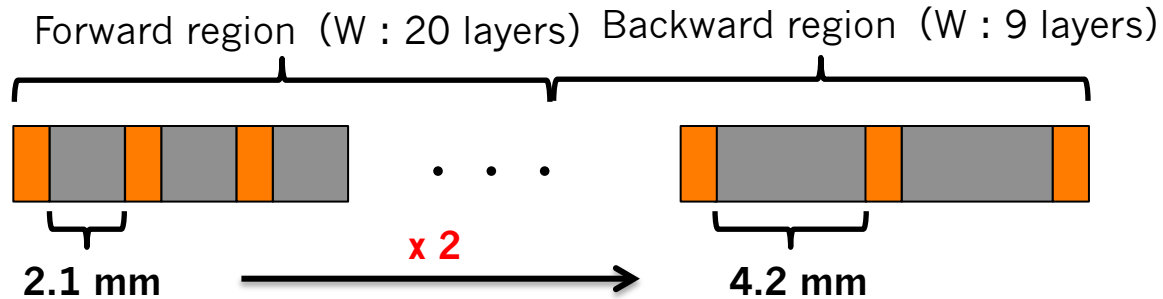
Absorber Thickness

- Configurations

※ Si : 0.5mm

Default

Whole thickness : $22.8X_0$



All absorbers have the same thickness

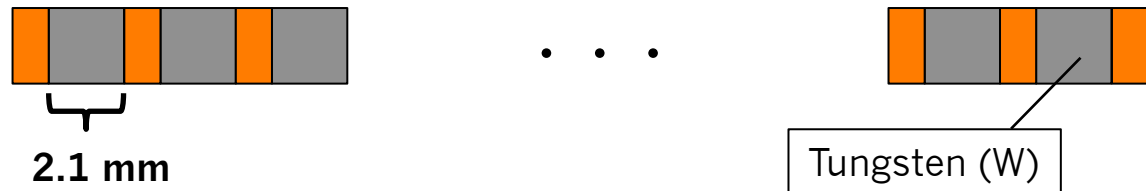
W_33 layers x 2.48 mm

Whole thickness : $23.38X_0$



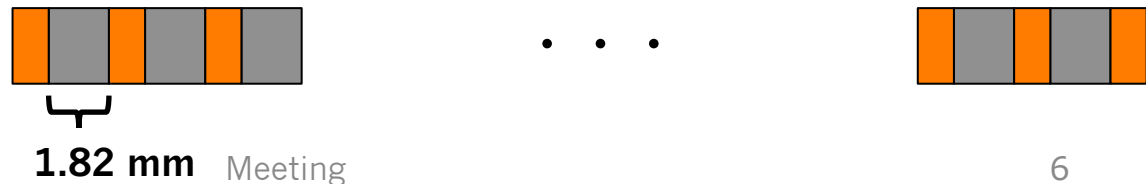
W_39 layers x 2.1 mm

Whole thickness : $23.4X_0$

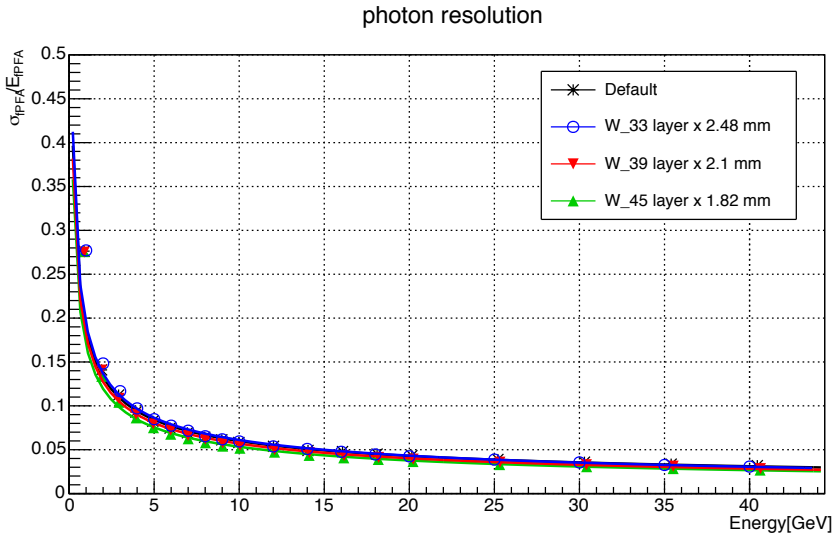


W_45 layers x 1.82 mm

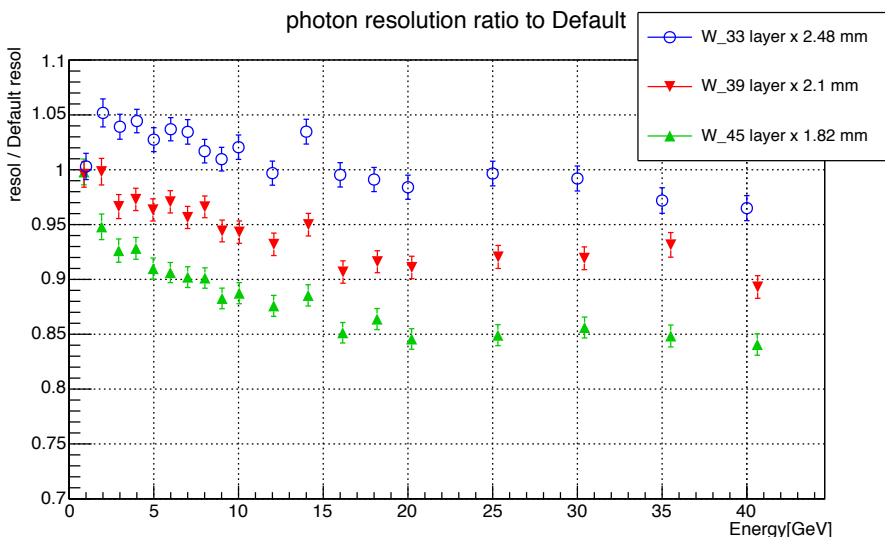
Whole thickness : $23.4X_0$



Energy Resolution of Single Photon



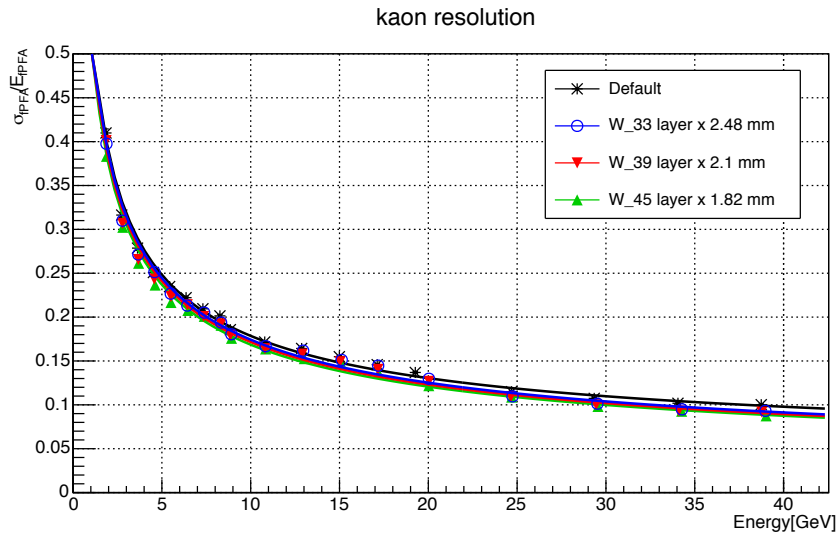
	stoch. [%]	const. [%]
Default	17.18±0.06	1.80±0.04
W_33 x 2.48	18.88±0.07	0.73±0.11
W_39 x 2.1	17.53±0.06	0.72±0.09
W_45 x 1.82	16.44±0.06	0.51±0.12



Fit function :
$$\frac{\sigma}{E} = \sqrt{\frac{(\text{stoch.})^2}{E} + (\text{const.})^2}$$

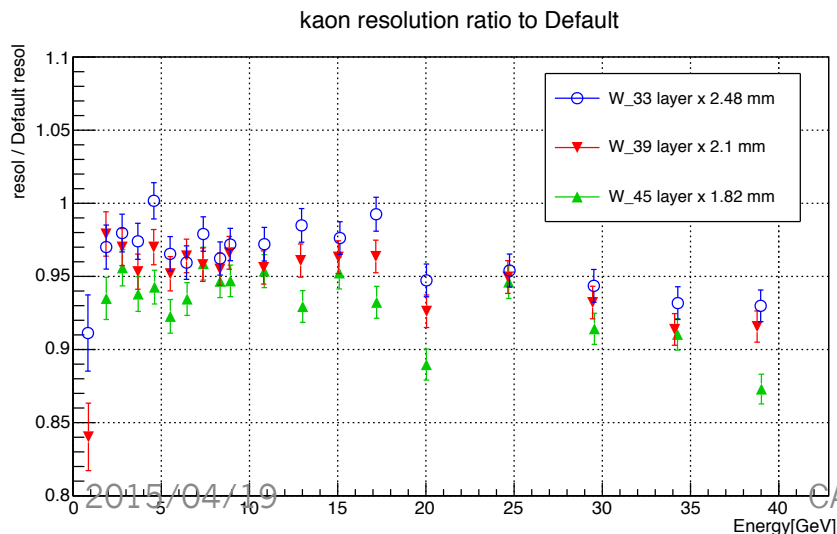
- improvement of const. term
 → **Resolutions are better than default value at high energy (maximum 16%)**

Energy Resolution of Single K^0_L



	stoch. [%]	const. [%]
Default	54.14±0.21	4.84±0.14
W_33 x 2.48	53.83±0.20	3.42±0.17
W_39 x 2.1	53.00±0.19	3.29±0.17
W_45 x 1.82	52.23±0.19	3.04±0.18

Fit function :
$$\frac{\sigma}{E} = \sqrt{\frac{(\text{stoch.})^2}{E} + (\text{const.})^2}$$



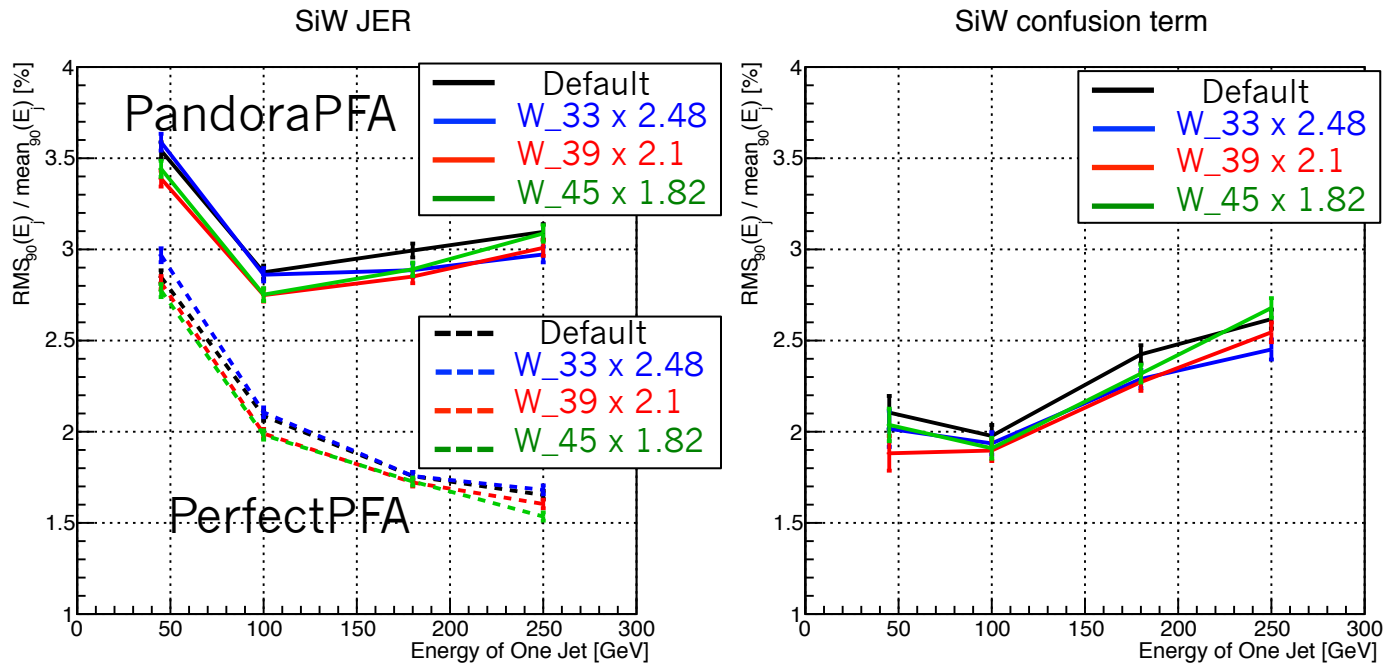
➤ Improvement of resolution can be caused by the number of absorber in backward region

➤ The ratio of Energy deposit

ECAL : HCAL = 4 : 6

Jet Energy Resolution

➤ di-jet ($e^+e^- \rightarrow Z \rightarrow q\bar{q}$)

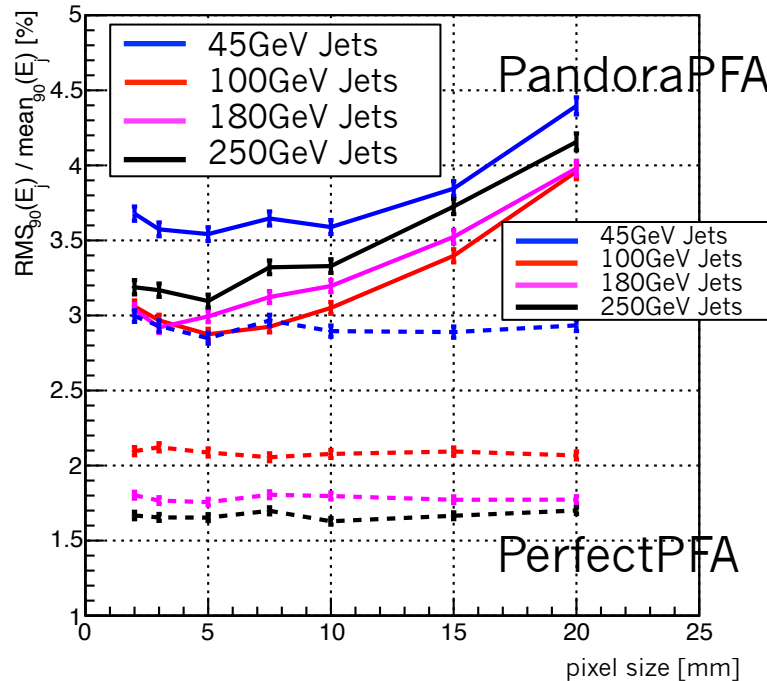


- No significant differences between three configurations except Default can be seen for Jet Energy Resolution
- Confusion terms between all configurations are almost equal

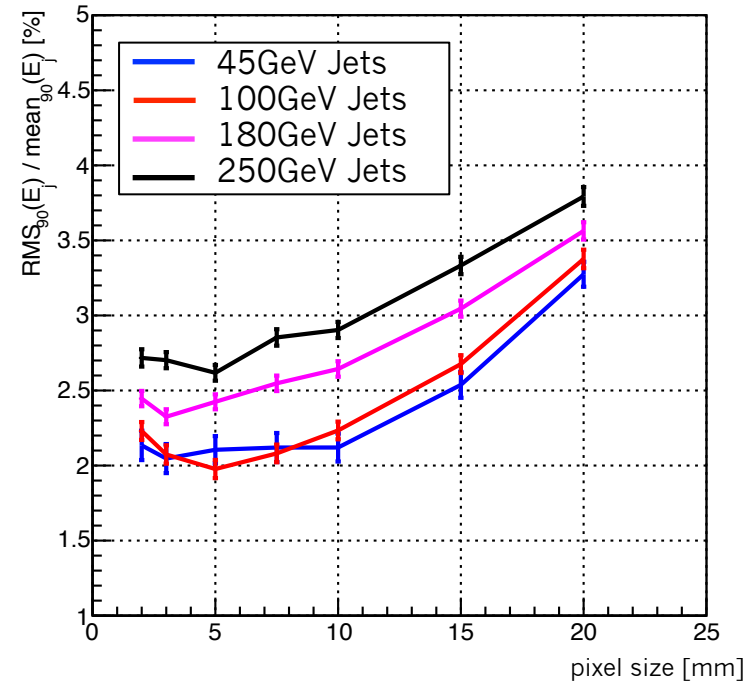
Pixel Size

- Pixel size : 2.0, 3.0, 5.0, 7.5, 10.0, 15.0, 20.0 mm
- Configuration : Default
- In previous study, the resolution at 3.0mm was worse than that of 5.0mm

SiW JER vs. ECAL pixel size



SiW confusion term vs. ECAL pixel size



- This result is the almost same as previous result
- Clustering area was optimized for 2.0 and 3.0 mm
- The degradation should be improved using other parameters

Summary and Outlook

- **Optimization of Si ECAL**

- Longitudinal thickness of absorbers
 - Jet Energy Resolution : No significant difference can be seen (except default)
 - Confusion terms : All configurations have the almost same values
- Pixel size of Si
 - The misclustering in PFA is suggested to lead the degradation of resolution at 2.0 and 3.0mm

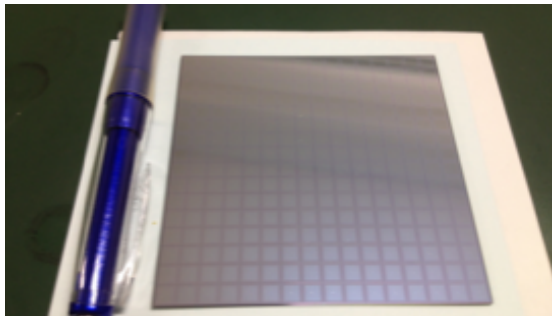
- **Outlook**

- Changing silicon to scintillator in backward region of ECAL
- Different pixel sizes between forward and backward region of ECAL
- Optimization of calorimeter including HCAL

BACKUP

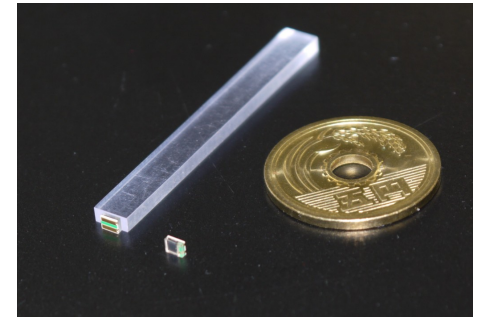
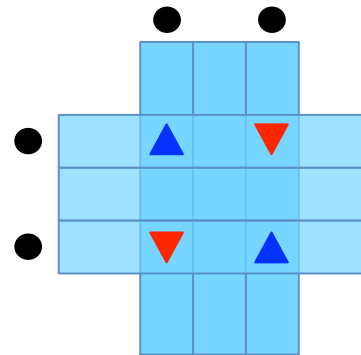
ILD ECAL

Silicon



- ✓ Pixel size : 5.5mm x 5.5mm
- ✓ Multi pixels → Good advantage for PFA
- ✓ Expensive

Scintillator + MPPC

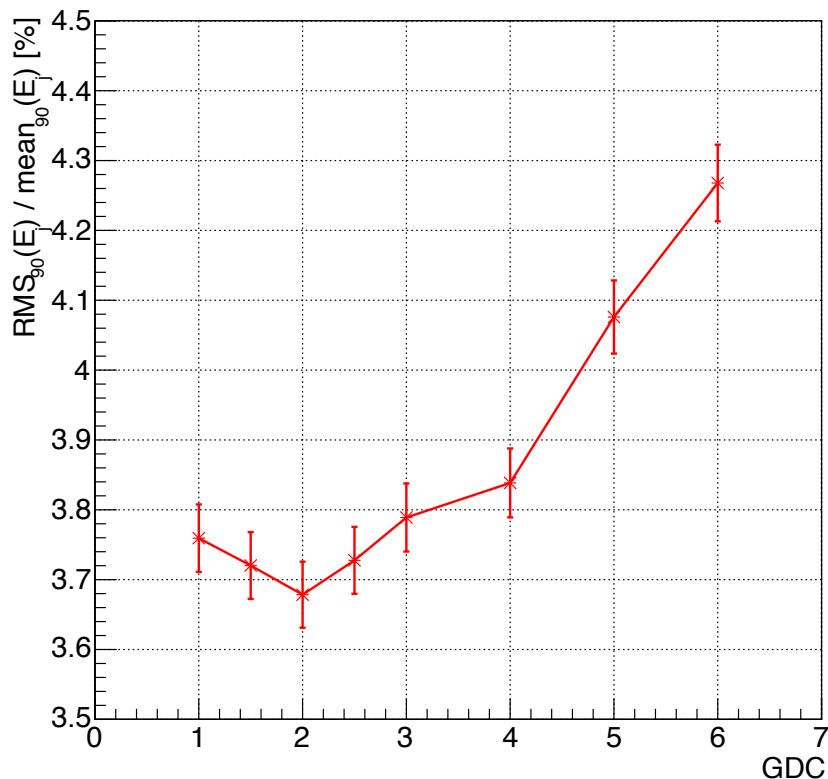


- ✓ Cross arrangement of 45mm x 5mm strip
→ Position resolution of 5mm x 5mm
- ✓ Relatively low cost
- ✓ Ghost hits which make the precision worse

Generic Distance Cut

Using 91 GeV di-Jets

Pixel 2.0mm JER vs. GDC



Pixel 3.0mm 91GeV JER vs. GDC

