Updates on ZDC Simulation

June 20, 2023
Far-forward Weekly Meeting

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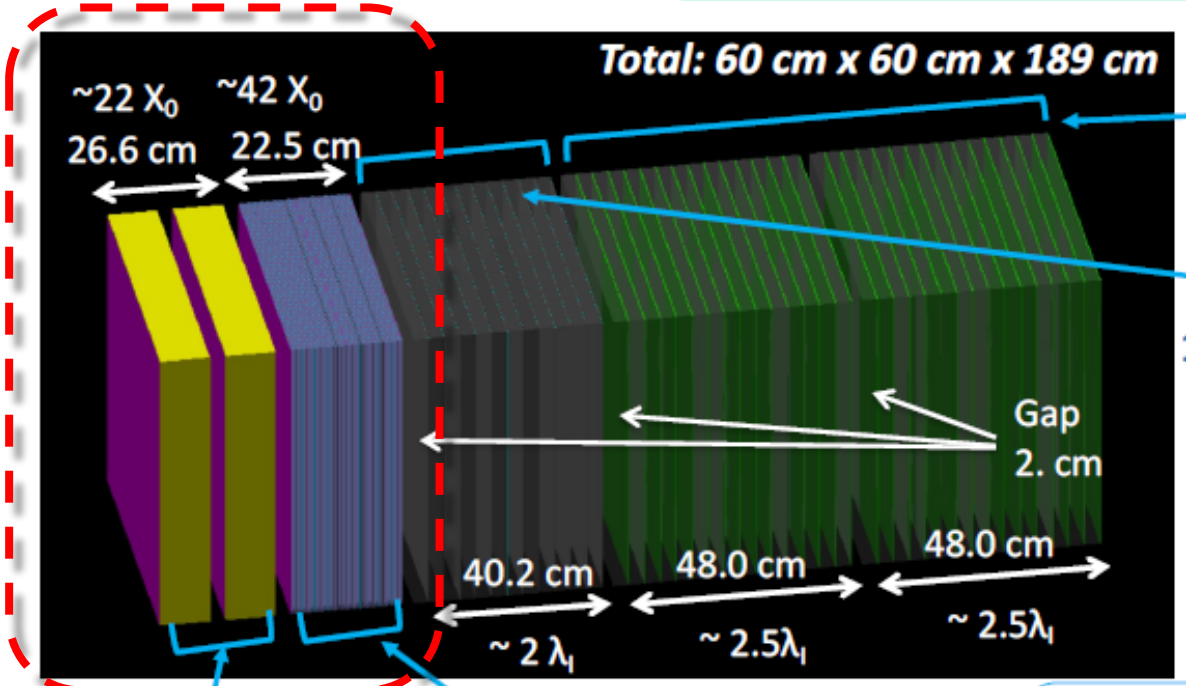
First ZDC design

Plots of energy deposition are in backup slides.



30 layers (15 layers x 2)

Pb 3cm Thickness
Scintilator
10 cm x 10 cm x 2 mm
Gap 0.0013 mm

12 layers

Pb 3cm Thickness
PET (Glue) 0.11 mm
Silicon
1 cm x 1 cm x 320 µm
PET (Glue, FPC) 0.41 mm
Gap 1. mm

2 layers

Silicon
3 mm x 3mm x 300 µm
PET (Glue, FPC) 0.39 mm
Gap 1.2mm
Crystal (PbWO4)
3cm x 3cm x 10 cm
Gap 3 cm

Si: 3 layers,
Si: 40 layers,
W: 42 layers

= **Si** + 2 x

20 layers +

Tungsten 3.5 mm Thickness
PET (Glue) 0.11 mm
Silicon 1 cm x 1 cm x 320 µm
PET (Glue, FPC) 0.41 mm, Gap 1.mm

1 layer

Tungsten 3.5 mm Thickness
PET (Glue) 0.11 mm
Silicon 3 mm x 3mm x 300 µm
PET (Glue, FPC) 0.39 mm, Gap 1.2mm

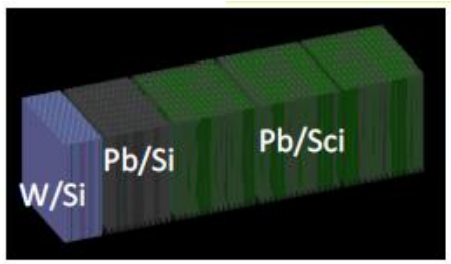
1st Version of ZDC Geometry – Shima's Approach

Parameters from fit

- The energy response in each detector looks quite linear.
- Extract parameters from fits:

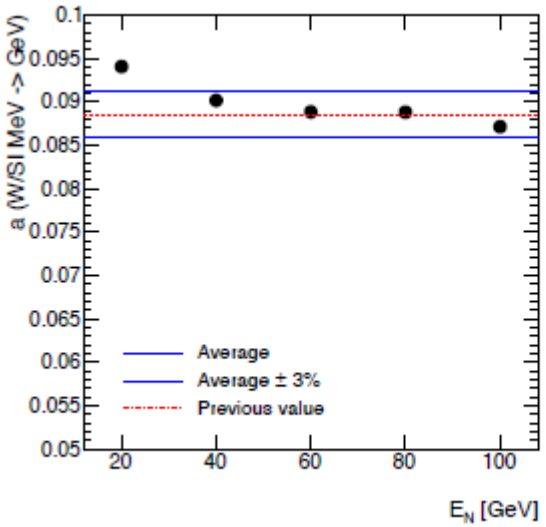
$$a \cdot E_{\mathrm{SI\ (W/SI)}} + b \cdot E_{\mathrm{SI\ (Pb/SI)}} + c \cdot E_{\mathrm{Sci}} = E_{\mathrm{N}}$$ (E_N = Neutron energy)

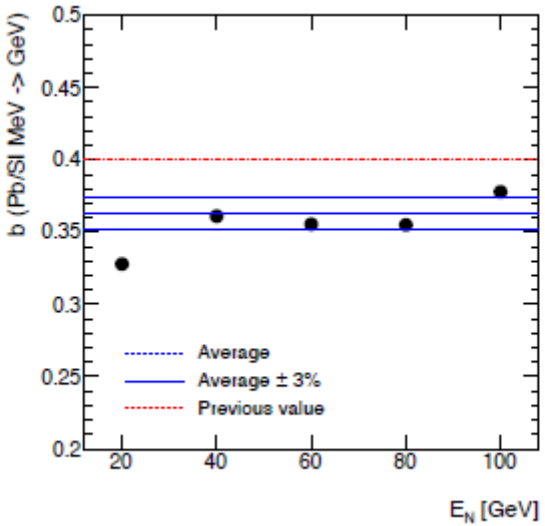
Fit is done for each energy sample (E_N= 20, 40, 60, 80, 100 GeV)

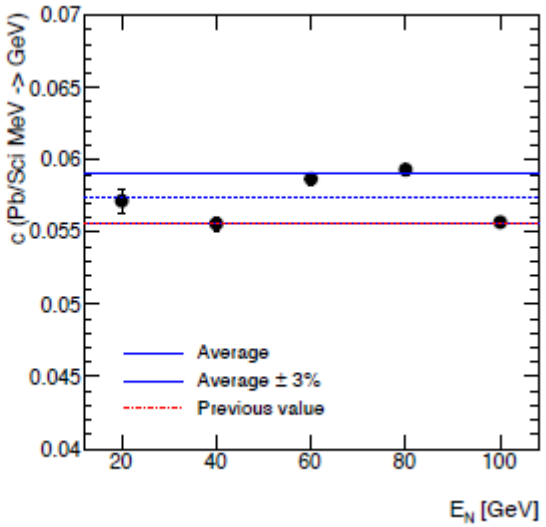


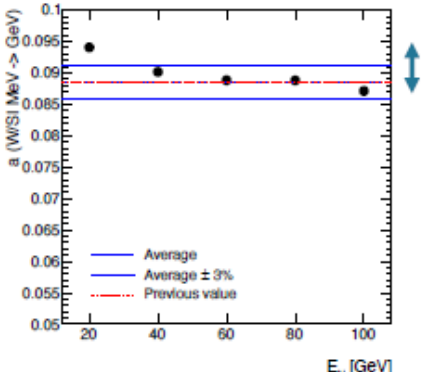
- W/SI: Average * (1-0.008*(E_{SI}-500)/1000)
- Pb/SI: Average * (1+0.04*(E_{SI}-50)/100)

Made-up slopes by eye. Optimisation is needed in future.

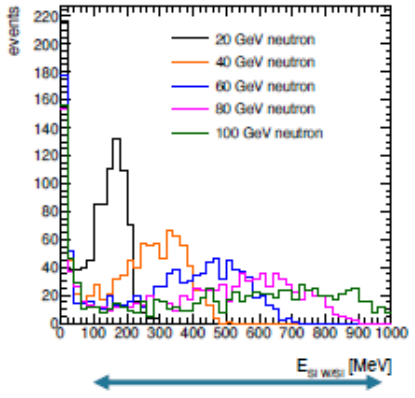








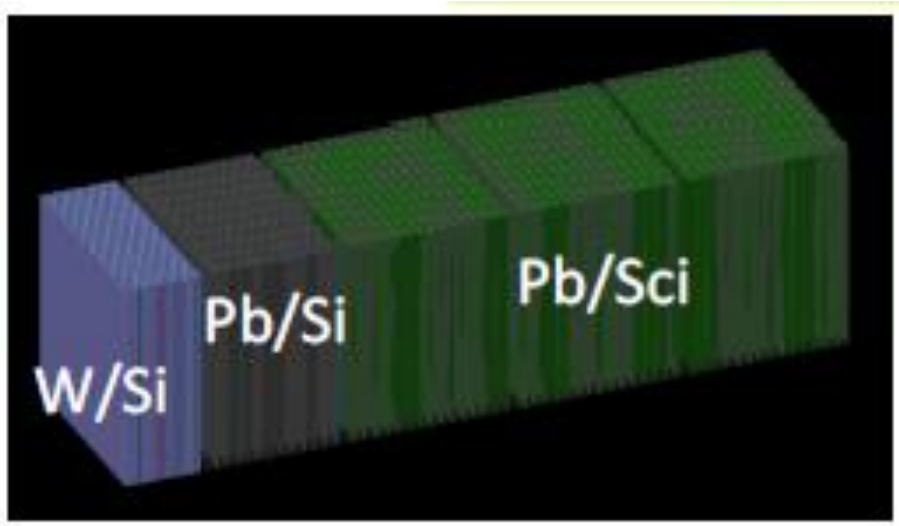
Δ~0.008



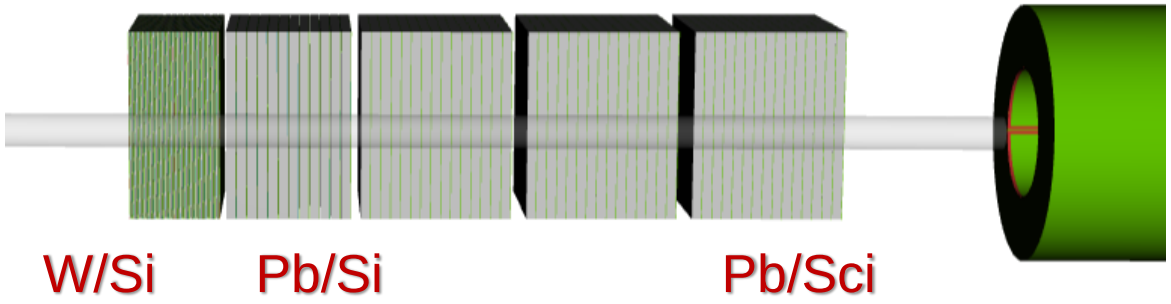
Leaver arm ~ 1000

1st Version of ZDC Geometry – 3 module test

Shima:



Current:

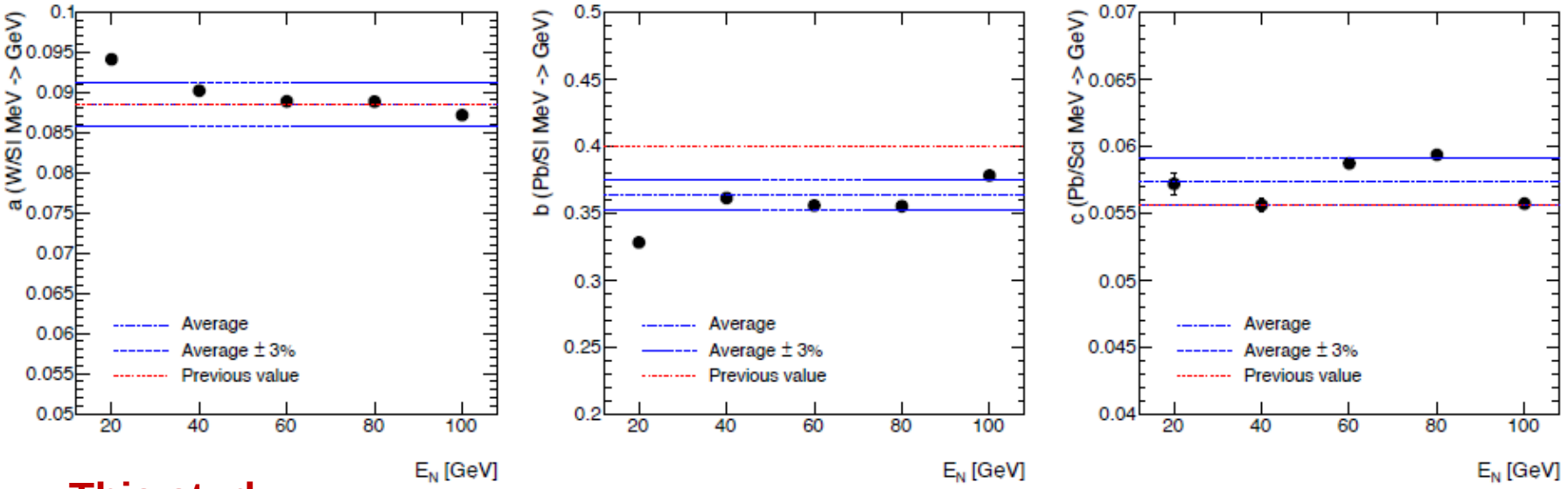


- Implementation of the 1st-version ZDC Geometry
  - Based on the slides that I have, should be similar enought, if not identical

- Try to reproduce the result of Shima with the first design.

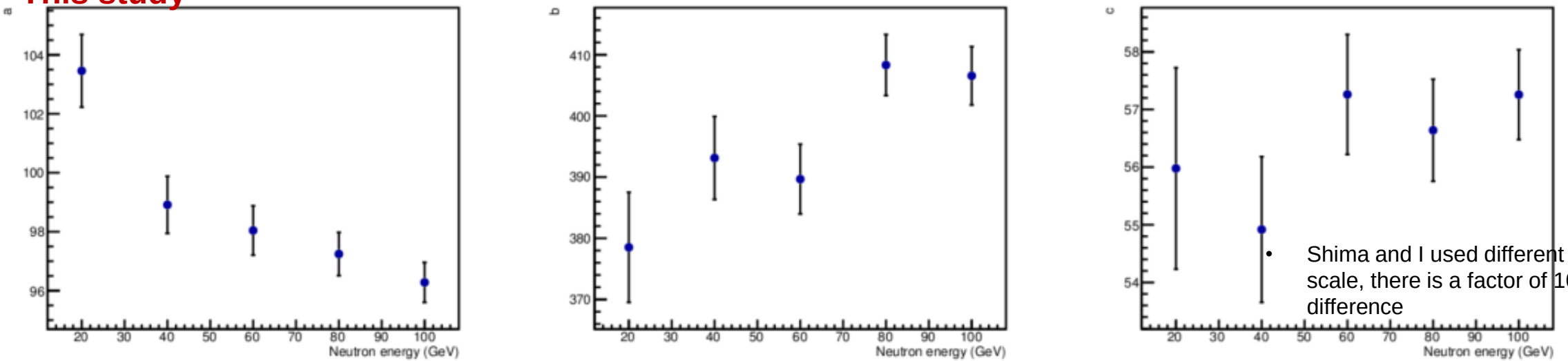
1st Version of ZDC Geometry – 3 module test

Result of Shima



- Similar trend of energy dependence is obseved
- The parameters I have is larger than what Shima got
- Will try energy dependent calibration like Shima

This study



- Shima and I used different energy scale, there is a factor of 1000 difference

1st Version of ZDC Geometry – All modules included

Shima's parameterization:

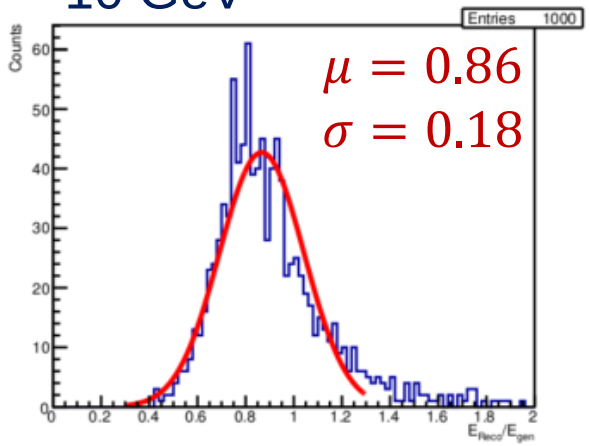
- W/SI: Average * (1-0.008*(E_{SI}-500)/1000)
- Pb/SI: Average * (1+0.04*(E_{SI}-50)/100)

Made-up slopes by eye. Optimisation is needed in future.

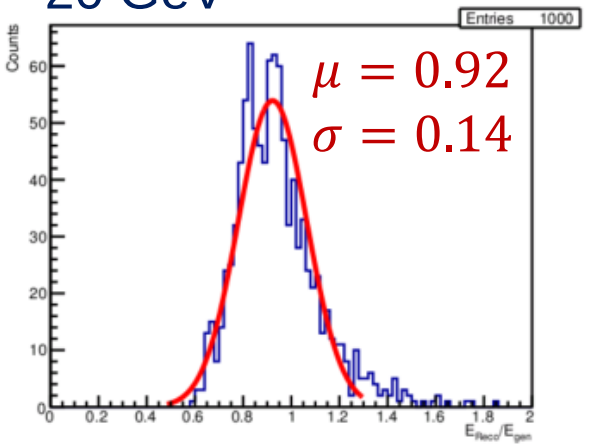
My parameterization:

- W/SI: 0.0988 * (1 - 0.007 * (E_{SI} - 500)/1000)
- Pb/SI: 0.3952 * (1 + 0.03 * (E_{SI} - 50)/100)

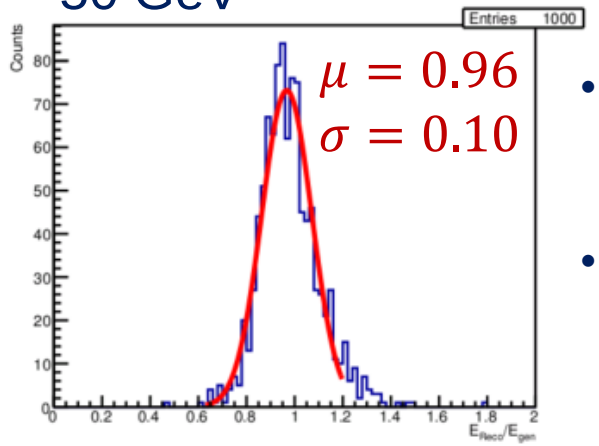
10 GeV



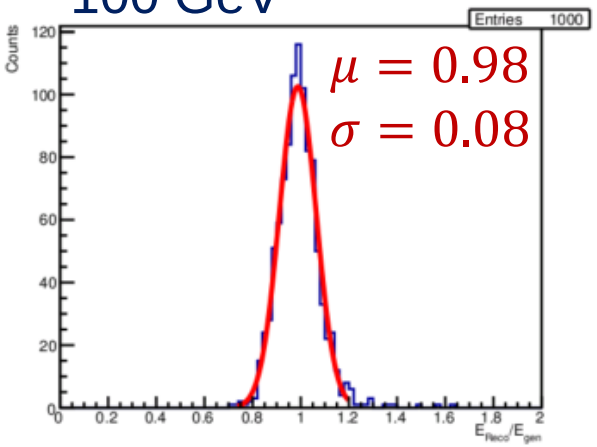
20 GeV



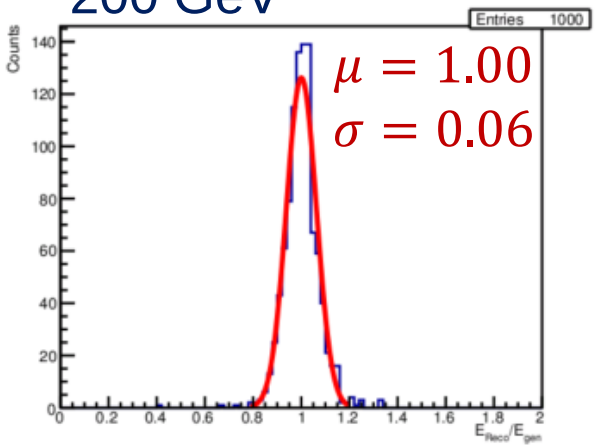
50 GeV



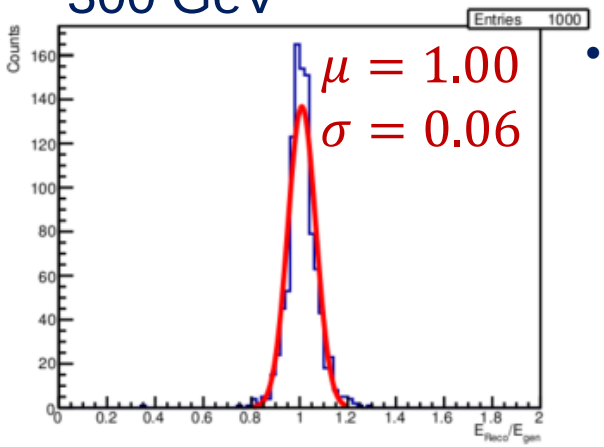
100 GeV



200 GeV

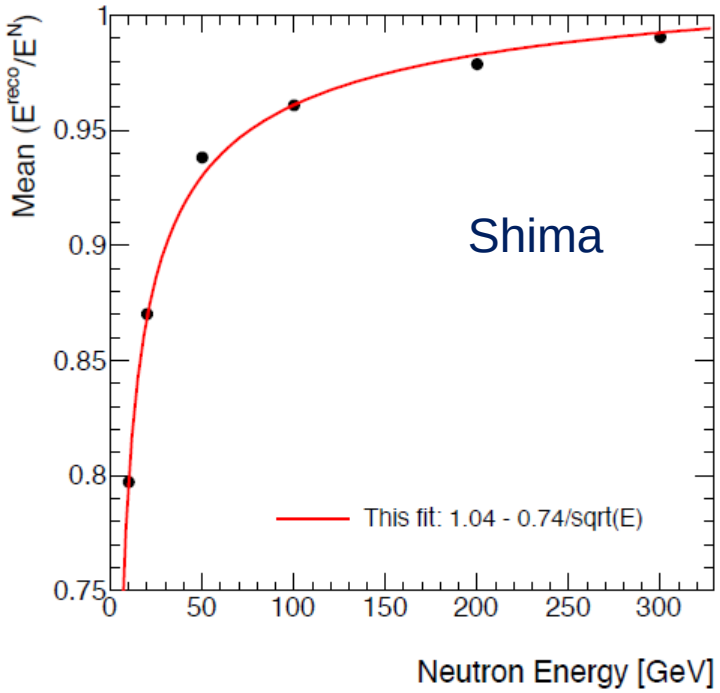


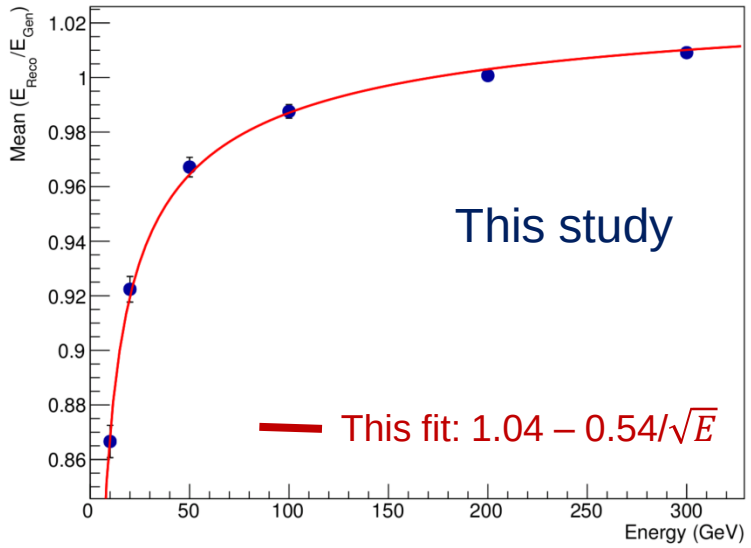
300 GeV

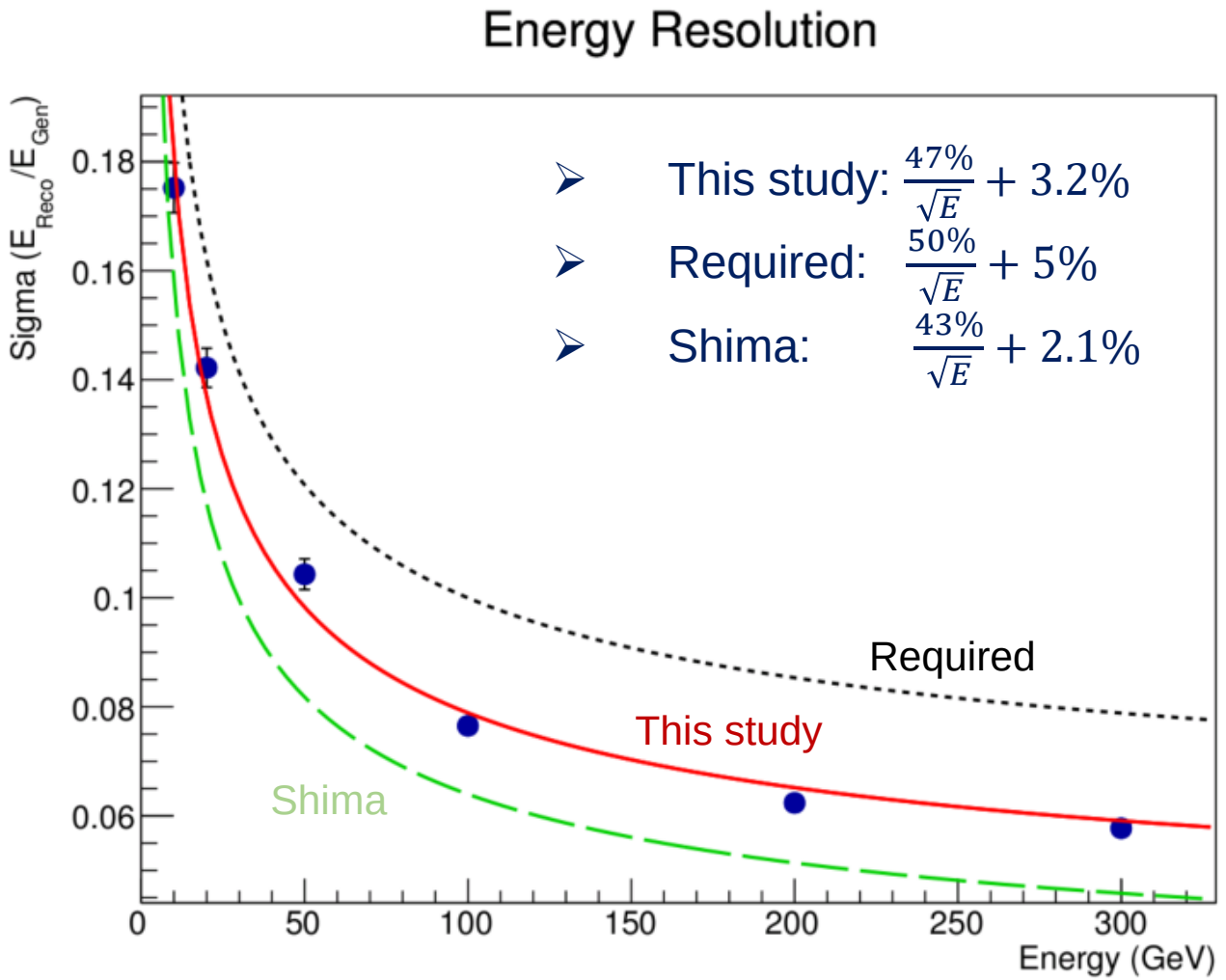


- Six energy settings (GeV): (10, 20, 50, 100, 200, 300)
- The energy deposited in the crystal is simply added to the calibrated energy from the other modules.
- Gaussian fit of E_{reco} / E_{Gen}

1st Version of ZDC Geometry – All modules included



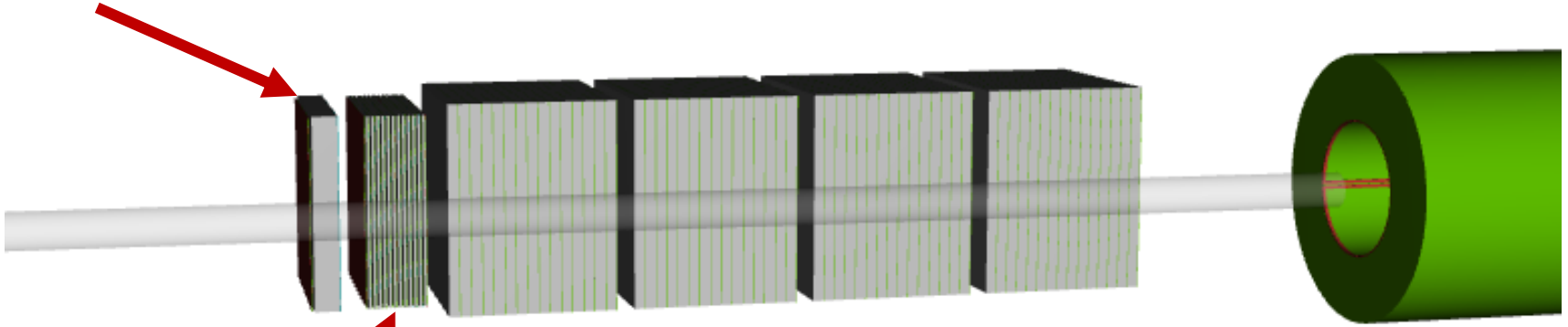


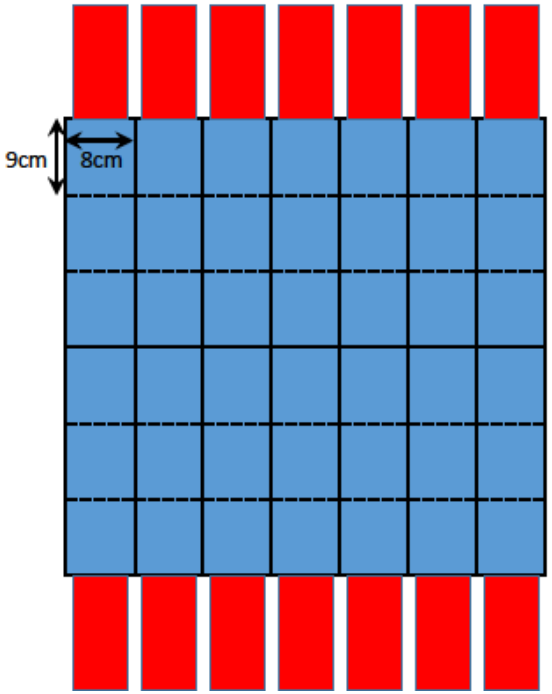


- Result not as good as what Shima had, but acceptable

New ZDC Geometry

- 1st Silicon & crystal calorimeter:
  - Smaller lateral dimension (x, y) = (56, 54) cm.
- Silicon Pixel lateral size (x, y) = (4, 3) mm

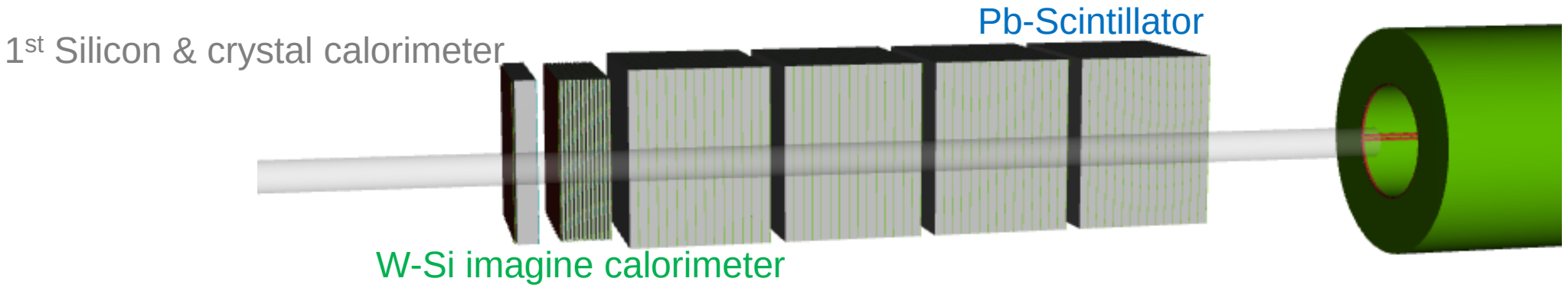




- W-Si imagine calorimeter
  - Smaller lateral dimension (x, y) = (56, 54) cm.
  - Smaller number of layers $1X_0 \times 22 \rightarrow 2X_0 \times 12$ layers

- Pb-Scintillator + fused silica
  - Towers of 10cm x 10cm x 48cm, each module is 60cm x 60cm x 48cm
  - 4 modules
  - Not yet have the implementation of fused silica – only scintillator now
- Pb-Si modules removed

New ZDC Geometry

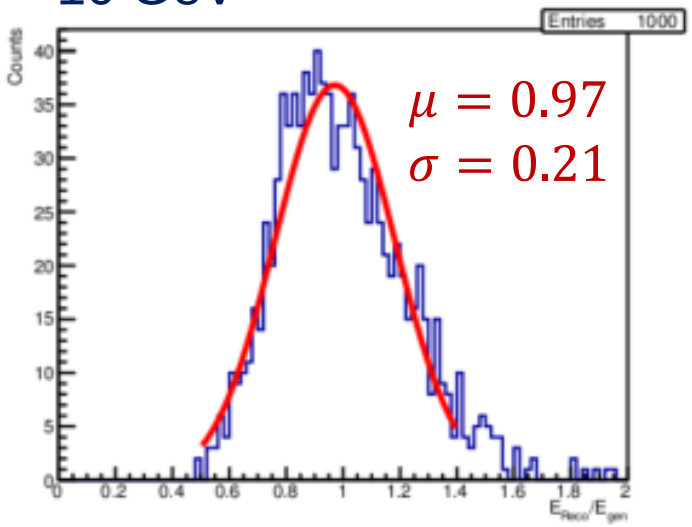


- Use particle gun to generate neutrons of different energy
  - Position at the front of ZDC, at angle along the ZDC center
  - Five different energy settings: (10, 20, 50, 100, 150) GeV
  - 1000 events for each setting
- Do calibration with linear fitter

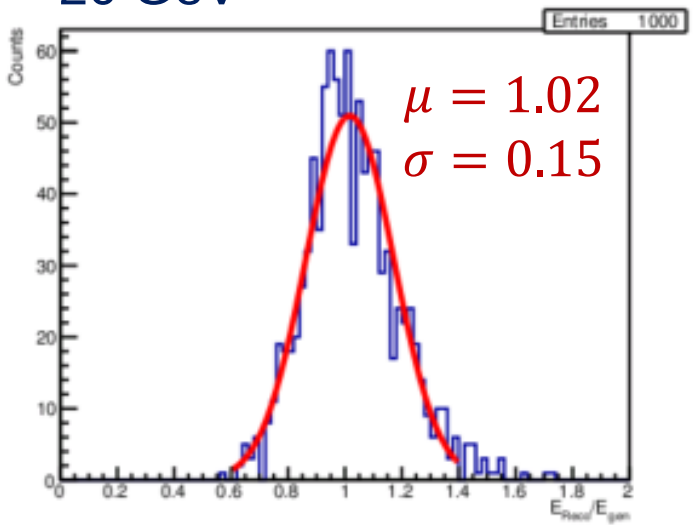
$$E_{rec.} = c_1 E_{SiPix} + c_2 E_{Crystal} + c_3 E_{WSi} + c_4 E_{PbScint} + \mathrm{b}$$

New ZDC Geometry

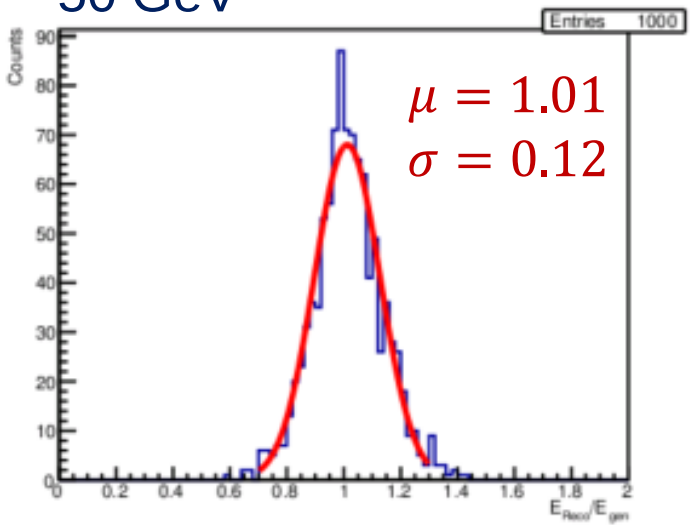
10 GeV



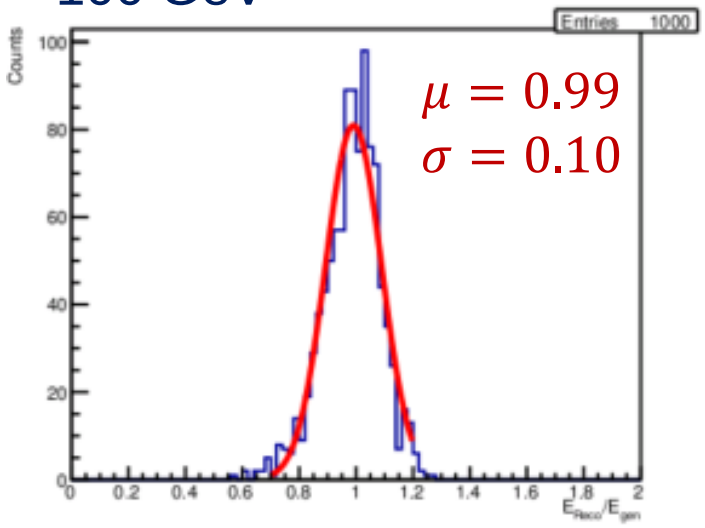
20 GeV



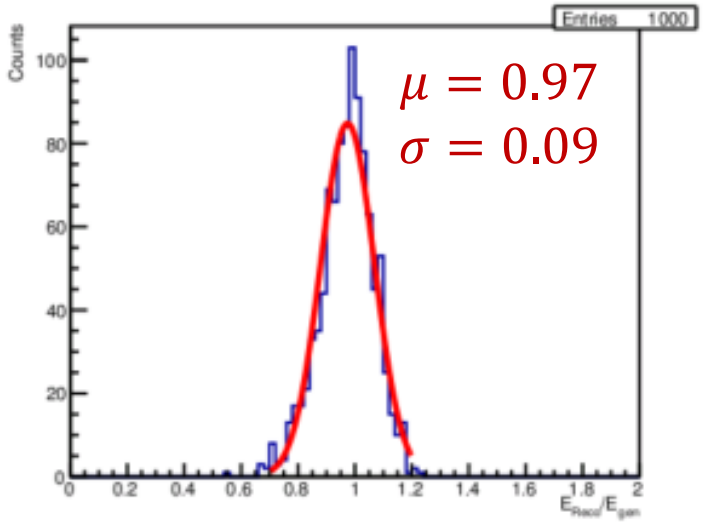
50 GeV



100 GeV

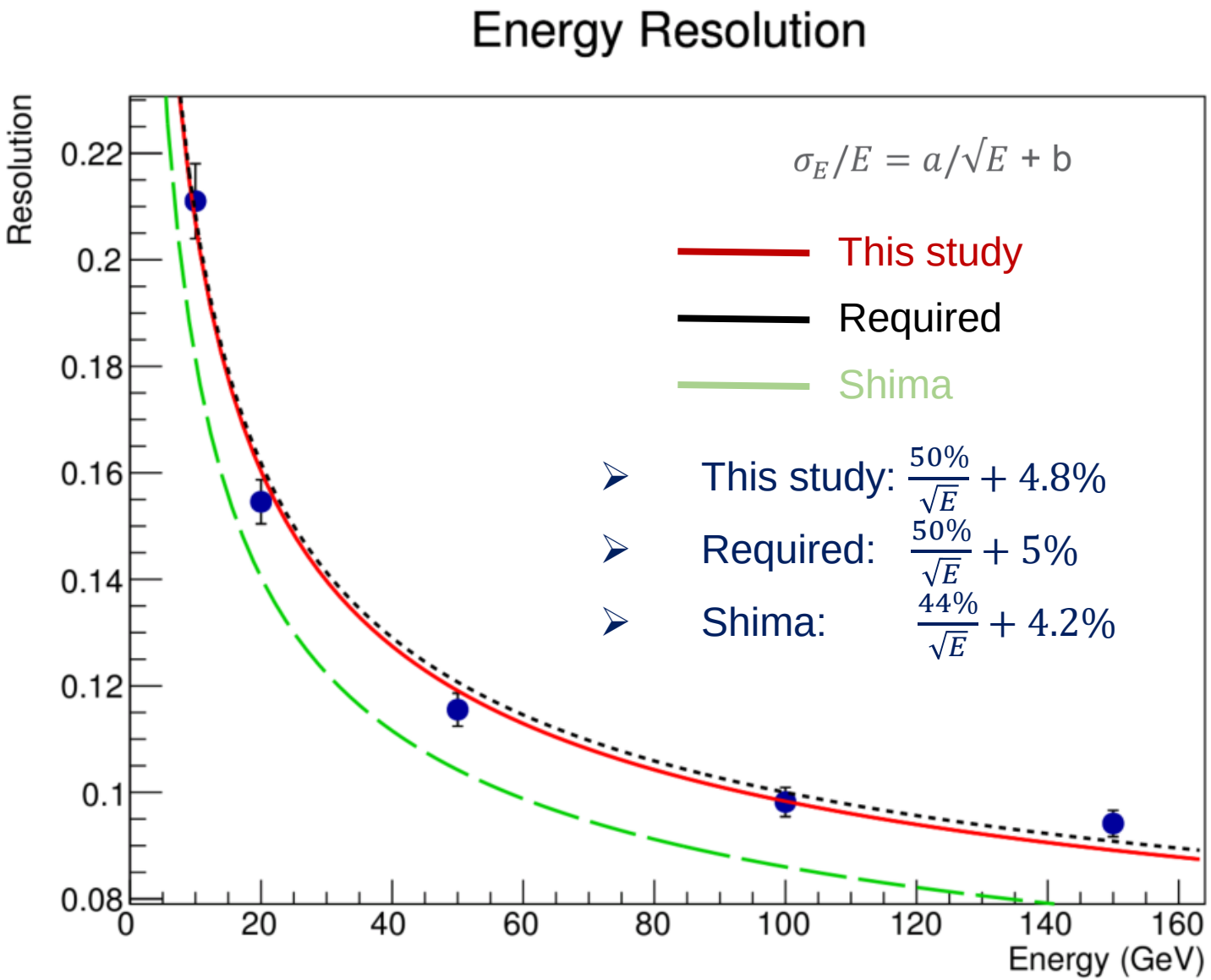


150 GeV



- Gaussian fits of E_{reco} / E_{Gen}

New ZDC Geometry



- With energy-independent calibration applied, the resolution of the new ZDC design is comparable to the minimum required value.
- Working on building framework for the position resolution study.