W-ScFi calorimeter design and simulation Study

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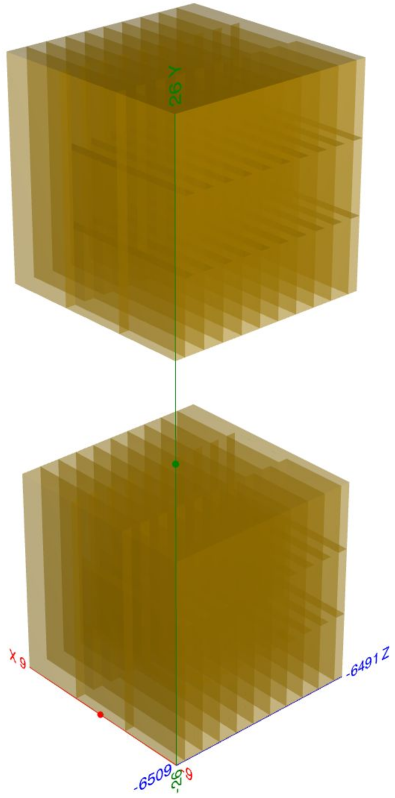
Ppt 1 (08/31/23) : Design - Energy Resolution - Sampling Frac Compare with 4:1 and 2:1 WScFi ratio
Ppt 2 (09/21/23) : Shower Profile Check with 4:1 - Position Resolution (X)
Ppt 3 (10/02/23) : Shower Profile Check with 4:1 - Angular Resolution

Ppt 1

08/31/23

W-ScFi calorimeter design

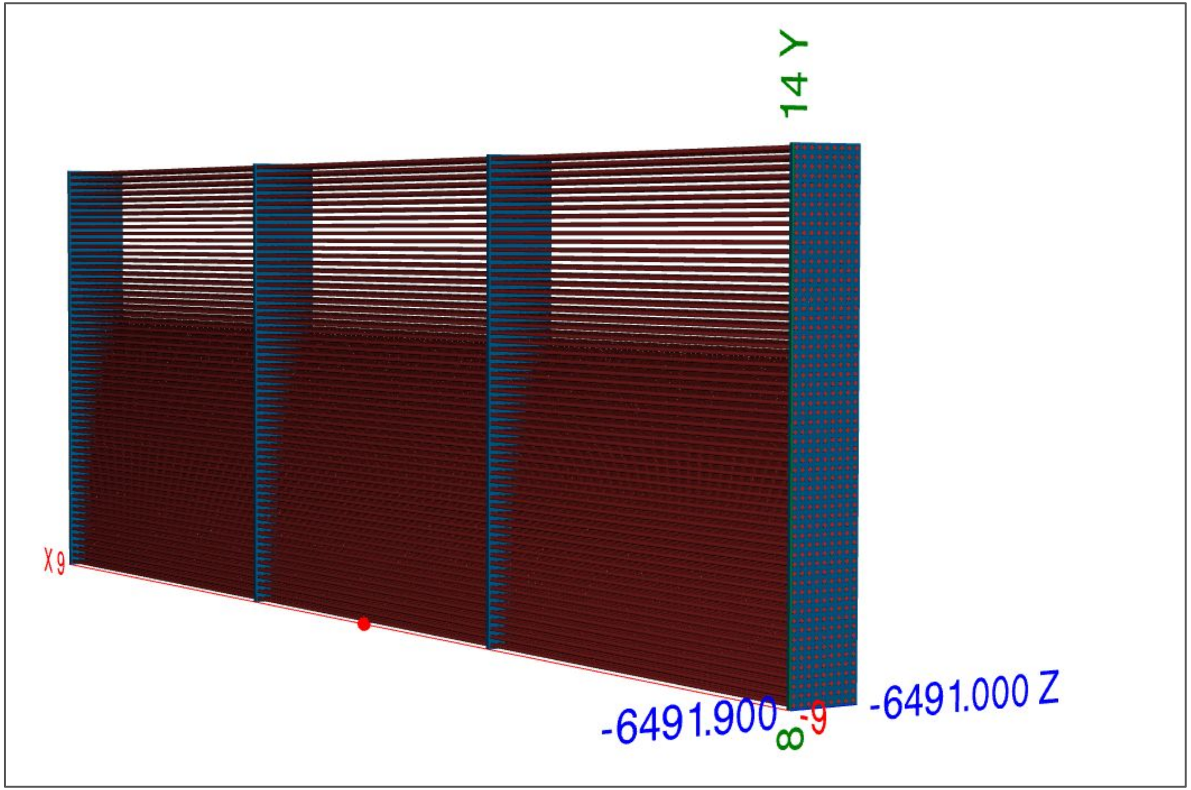


Alternating X || and Y || layers.

Detector Construction Details:

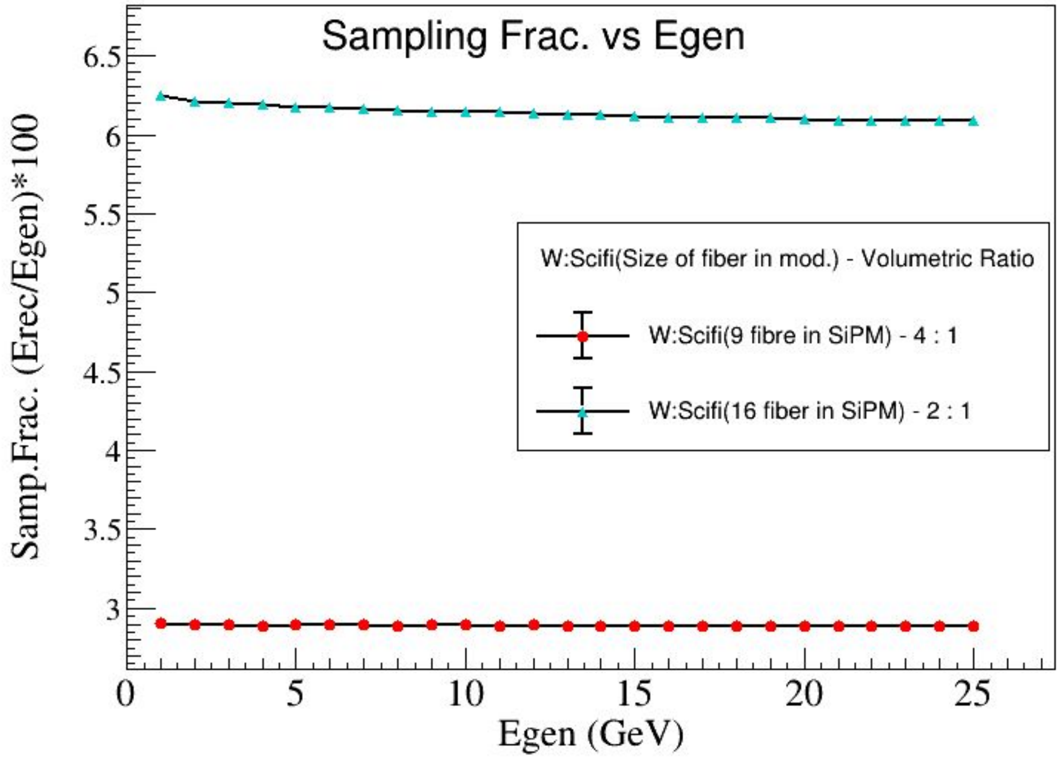
- Each Layer has 3 modules
- 20 layers, 10 X || and 10 Y || , alternating way
- Size of SiPM is soul for the detector construction size : 3x3 mm2
- #SiPM / Layer along width (Z) : 3
- #SiPM / Module along X (Y || layers)or Y (X || layers) : 20
- So Module Size : (3*3 mm) * (20*3 mm) *(20*3*3 mm) : 0.9 * 6*18 cm3
- Dimension of Fiber : radius 0.25 mm and length (20*3*3 mm) 18 mm
- Dimension of Brass Mesh (0.5*fiber spacing) :
  - 0.25 mm for 9 fiber in one SiPM readout - W:SiFi ratio 4:1
  - 0.125 mm for 16 fiber in one SiPM readout = W:SiFi ratio 2:1
- Total Brass meshes 4 along the length of fiber.

W-ScFi calorimeter design



Structure of X|| ScFi with Brass Mesh and without W powder

W-ScFi calorimeter simulation

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root [0]
Processing ErecbyEgenVsEgen.C...
Erec : 0.0290265 Egen : 1 ErecbyEgen : 2.90265
Erec : 0.0579124 Egen : 2 ErecbyEgen : 2.89562
Erec : 0.0868421 Egen : 3 ErecbyEgen : 2.89474
Erec : 0.115581 Egen : 4 ErecbyEgen : 2.88952
Erec : 0.144577 Egen : 5 ErecbyEgen : 2.89153
Erec : 0.173553 Egen : 6 ErecbyEgen : 2.89256
Erec : 0.202456 Egen : 7 ErecbyEgen : 2.89223
Erec : 0.23122 Egen : 8 ErecbyEgen : 2.89025
Erec : 0.260165 Egen : 9 ErecbyEgen : 2.89072
Erec : 0.28909 Egen : 10 ErecbyEgen : 2.8909
Erec : 0.317878 Egen : 11 ErecbyEgen : 2.8898
Erec : 0.346942 Egen : 12 ErecbyEgen : 2.89119
Erec : 0.375644 Egen : 13 ErecbyEgen : 2.88957
Erec : 0.404534 Egen : 14 ErecbyEgen : 2.88953
Erec : 0.433401 Egen : 15 ErecbyEgen : 2.88934
Erec : 0.46221 Egen : 16 ErecbyEgen : 2.88881
Erec : 0.491077 Egen : 17 ErecbyEgen : 2.88869
Erec : 0.519876 Egen : 18 ErecbyEgen : 2.8882
Erec : 0.548593 Egen : 19 ErecbyEgen : 2.88733
Erec : 0.57742 Egen : 20 ErecbyEgen : 2.8871
Erec : 0.606486 Egen : 21 ErecbyEgen : 2.88803
Erec : 0.635288 Egen : 22 ErecbyEgen : 2.88767
Erec : 0.664168 Egen : 23 ErecbyEgen : 2.88769
Erec : 0.692799 Egen : 24 ErecbyEgen : 2.88666
Erec : 0.721805 Egen : 25 ErecbyEgen : 2.88722
---------------------------------------------
Erec : 0.0624885 Egen : 1 ErecbyEgen : 6.24885
Erec : 0.124289 Egen : 2 ErecbyEgen : 6.21443
Erec : 0.185903 Egen : 3 ErecbyEgen : 6.19676
Erec : 0.247544 Egen : 4 ErecbyEgen : 6.1886
Erec : 0.308876 Egen : 5 ErecbyEgen : 6.17752
Erec : 0.370189 Egen : 6 ErecbyEgen : 6.16981
Erec : 0.431605 Egen : 7 ErecbyEgen : 6.16579
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Erec : 0.675631 Egen : 11 ErecbyEgen : 6.1421
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Erec : 1.15978 Egen : 19 ErecbyEgen : 6.10412
Erec : 1.2204 Egen : 20 ErecbyEgen : 6.102
Erec : 1.27861 Egen : 21 ErecbyEgen : 6.08863
Erec : 1.33987 Egen : 22 ErecbyEgen : 6.0903
Erec : 1.40055 Egen : 23 ErecbyEgen : 6.08935
Erec : 1.4605 Egen : 24 ErecbyEgen : 6.08541
Erec : 1.52177 Egen : 25 ErecbyEgen : 6.08706
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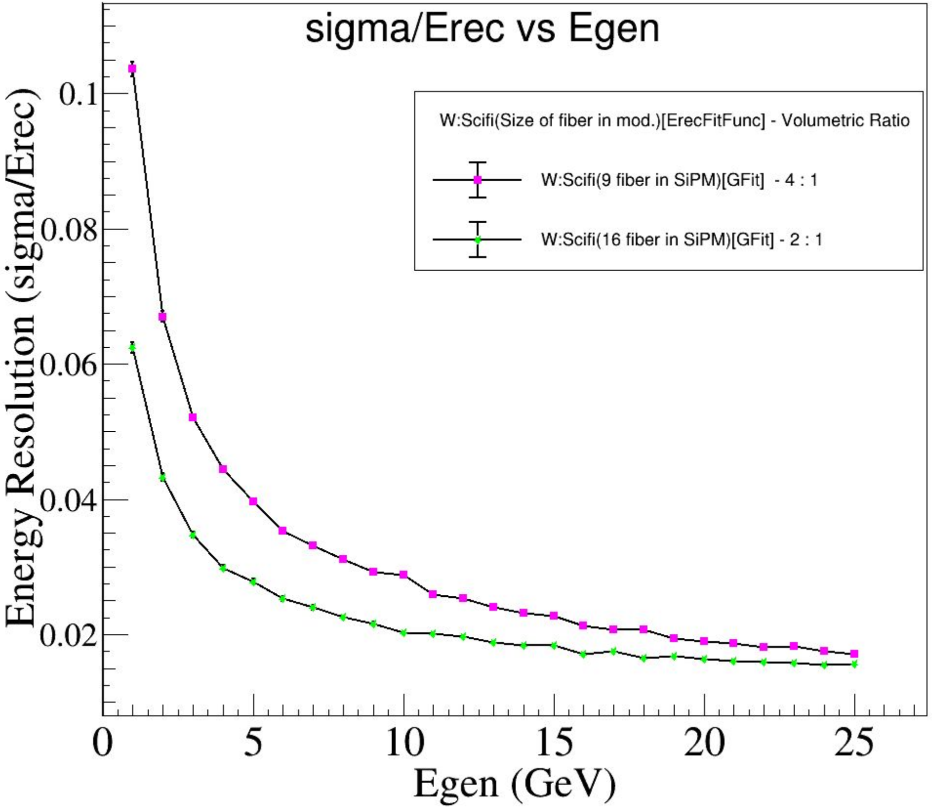
- Sampling fraction is more stable when W:ScFi is 4:1

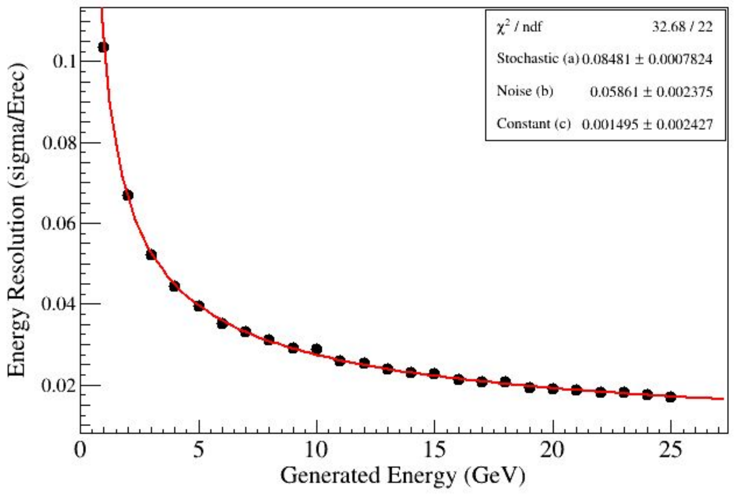
W-ScFi calorimeter simulation



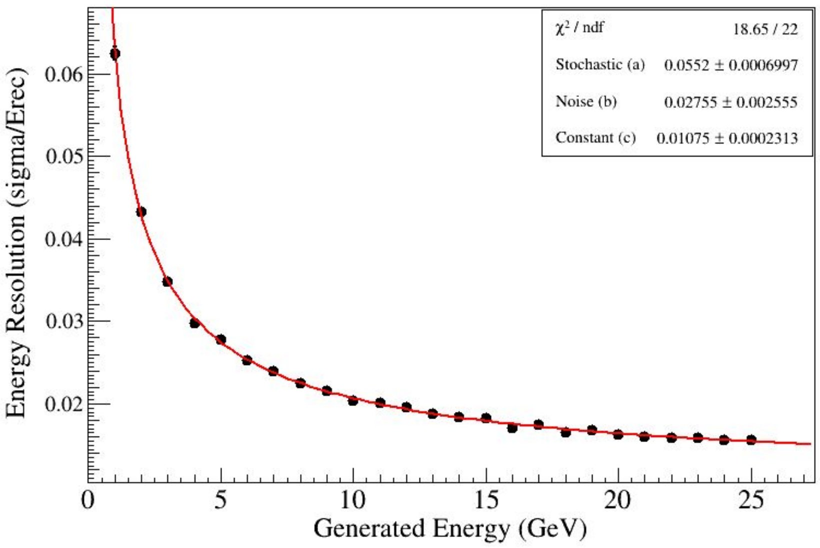
Result :

Energy Resolution is good for both of the cases. It was seen the linear behaviour of Erec with Egen for W:ScFi 4:1. So Choosing 9 fibers for a single readout of SiPm is good.

Back-Up



W:ScFi - 4:1



W:ScFi - 2:1

Ppt 2

09/21/23

W-ScFi - 4:1 | Ev-by-Ev avg. energy deposition profile

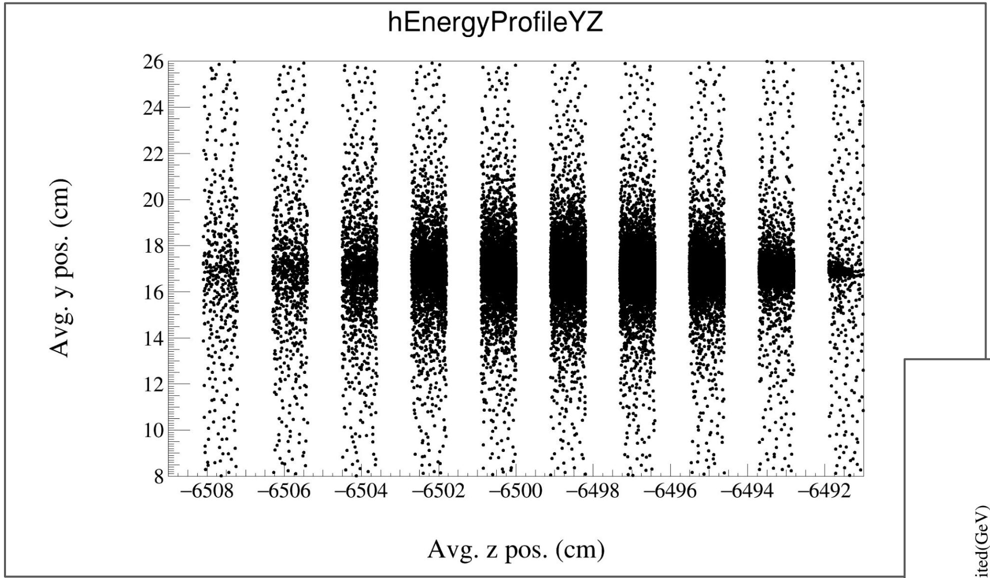
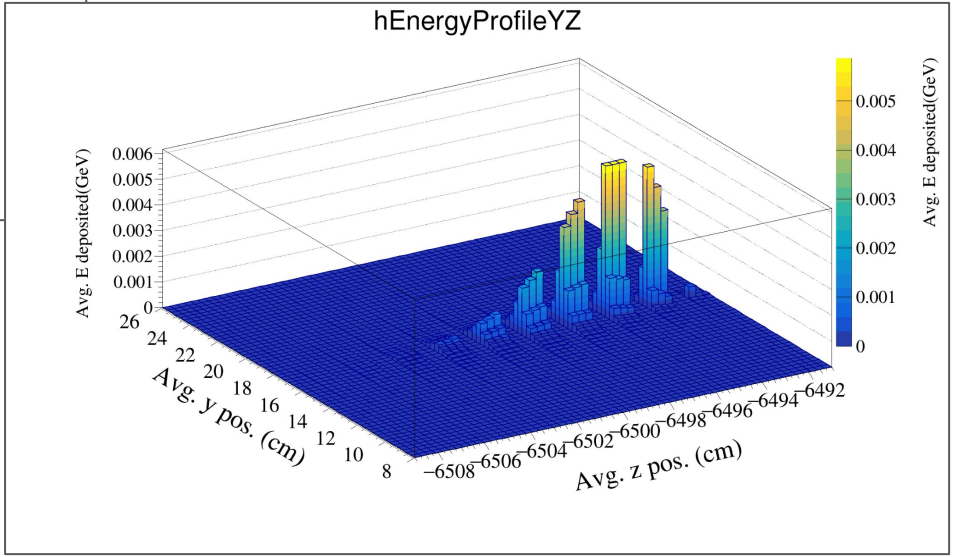


Fig.: 2D Profile from X|| Layers

Fig.: 3D Profile from X|| Layers



e- Position Resolution - Algorithm

- Total energy deposition (Edep_i) in 9 fibers of each SiPM is associated with a position, Pos_i
    - where i = {SiPMs}
- Depending on the layer Orientation, **Pos_i = {**
    - **x_i = SiPMs in Y|| layers,**
    - **y_i = SiPMs in X|| layers }**
- For each Layer Orientation,
    - **Pos_rec = sum_i pos_i*Edep_i / sum_i Edep_i**
    - Take the difference, (Pos_rec - Pos_gen),
    - Fit the histogram of Event-by-event difference with Gaussian Function
    - **The width of Gaussian fit is the corresponding resolution.**

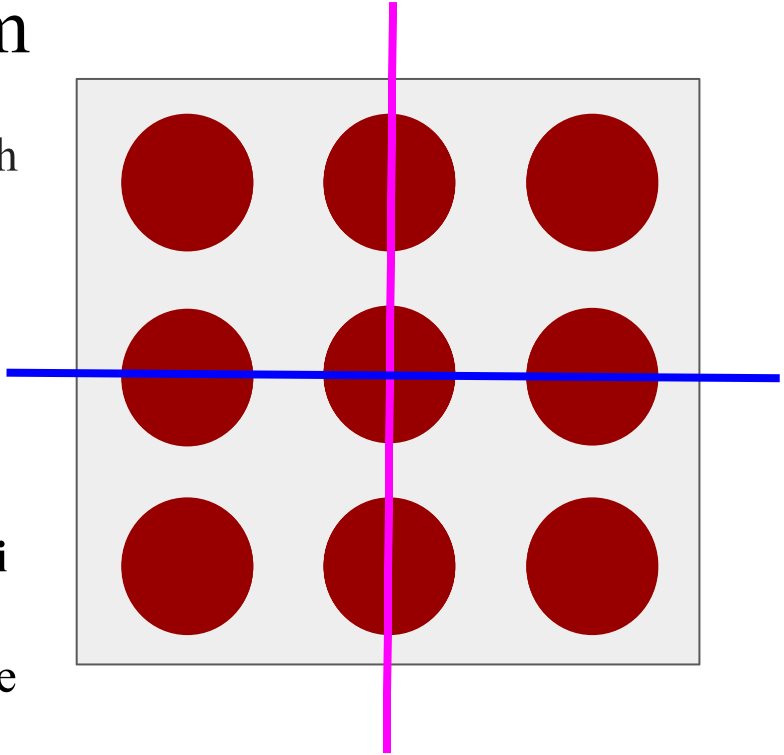
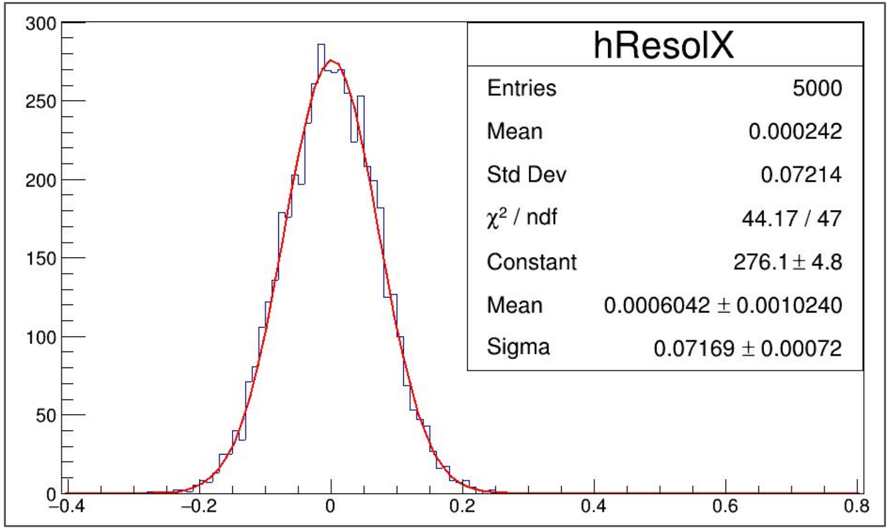


Fig.:Single SiPM with 9 fibers

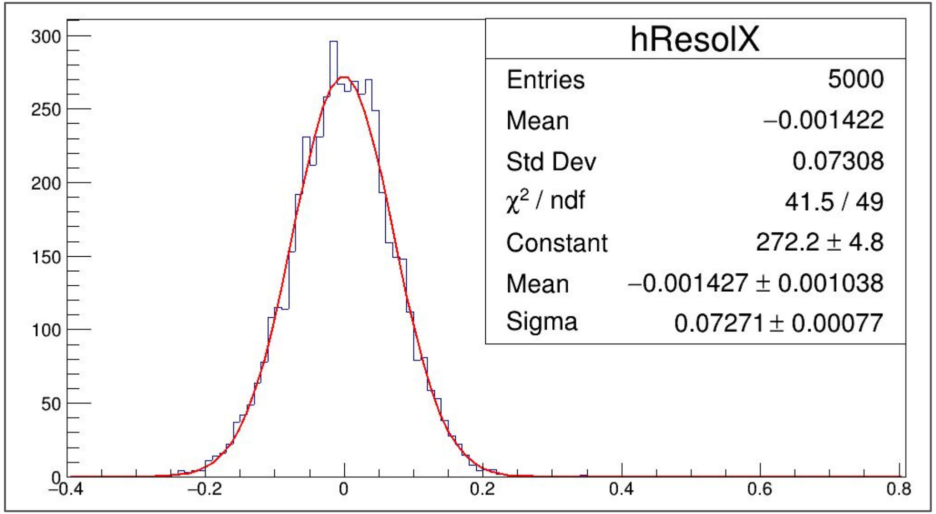
e- Position Resolution - Results

- Electron gun right in front of upper CAL (0.0, 17.0, 64.9) cm.
- Electron gen energy = 10 GeV
- Each event single electron shooted directly at CAL.

First Layer X || modules

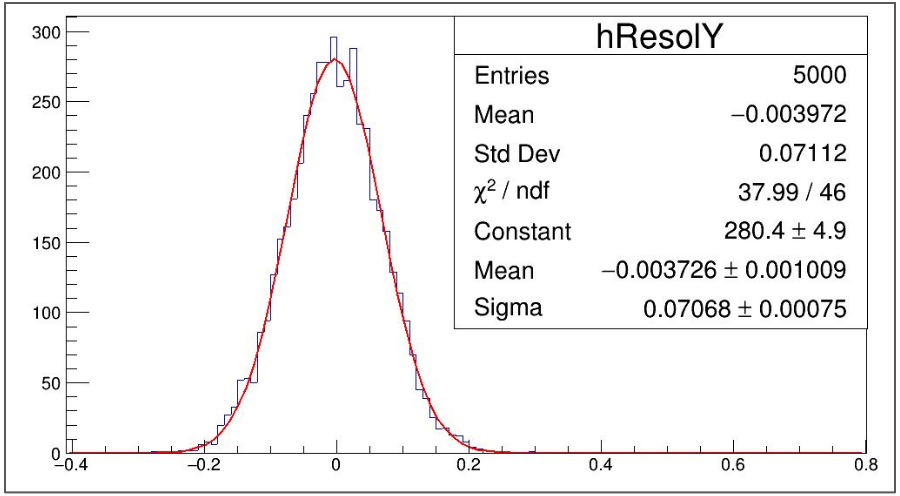


First Layer Y || modules

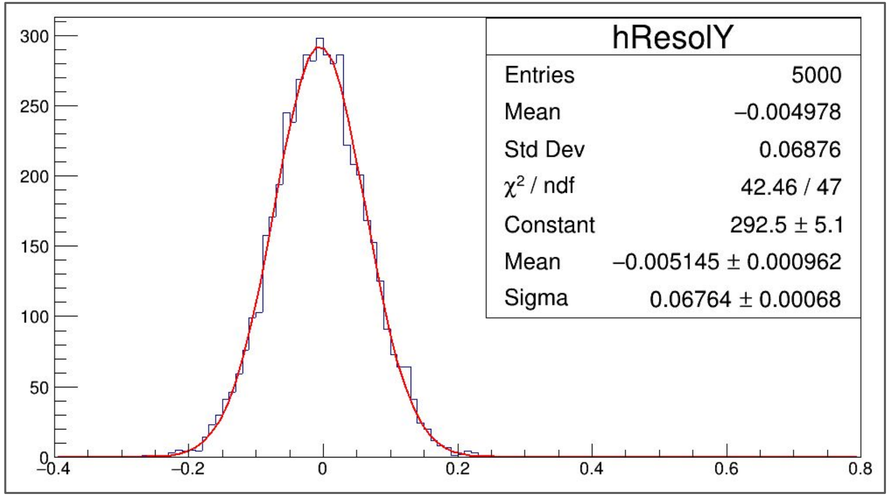


e- Position Resolution - Results

First Layer X || modules



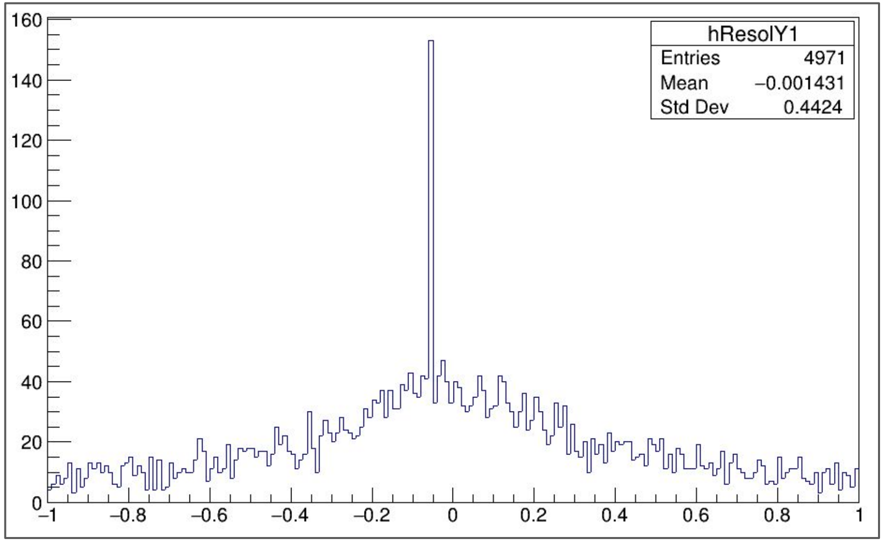
First Layer Y || modules



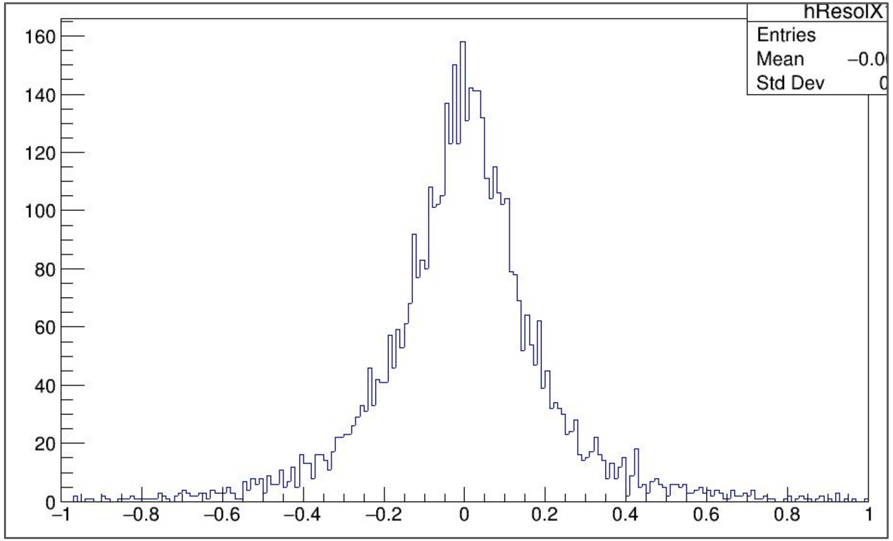
- The **(x,y) position resolution is approx. 0.7 mm** with slightly “lower” resolution for Y-coordinates of shower (reasons unknown).

e- Edep Shower Profile @ Every Layer

- All simulations are with x|| layer @ first (Sequentially in odd place)



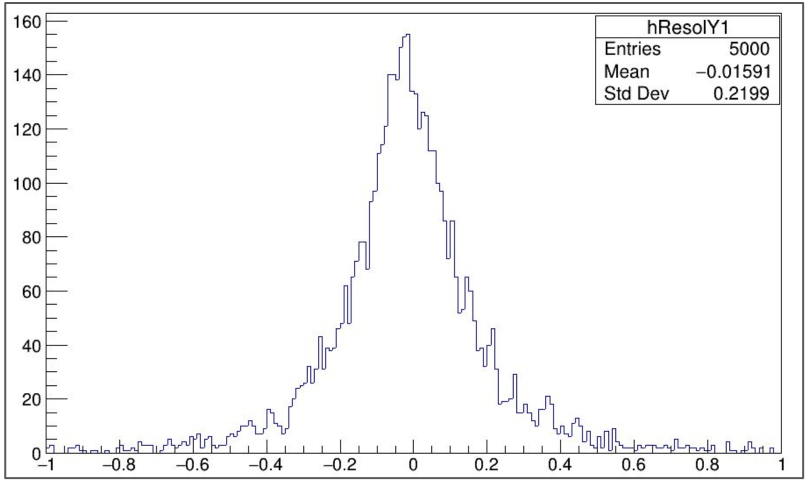
Layer 1



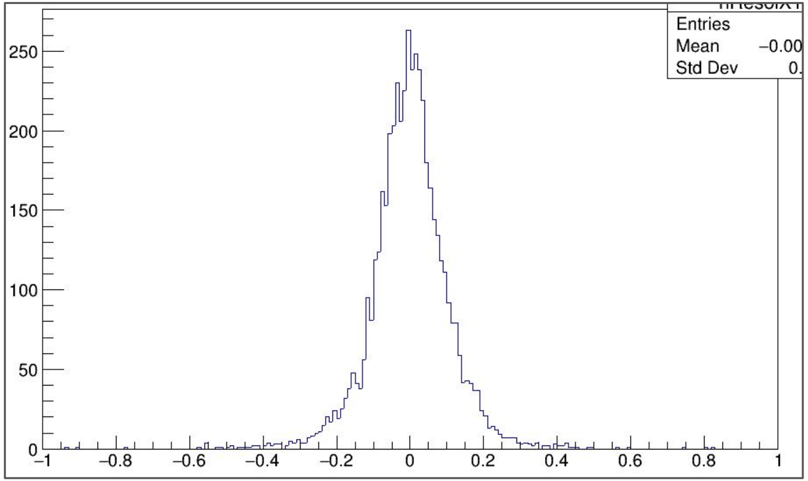
Layer 2

Ev-by-Ev avg. energy deposition profile @ Every Layer

- All simulations are with x|| layer @ first (Sequentially in odd place)
- A thick 0.9 cm tungsten plate is kept in front of calorimeter.



Layer 1



Layer 2

- **With addition of W layer, the shower develops before it reaches the layers.**

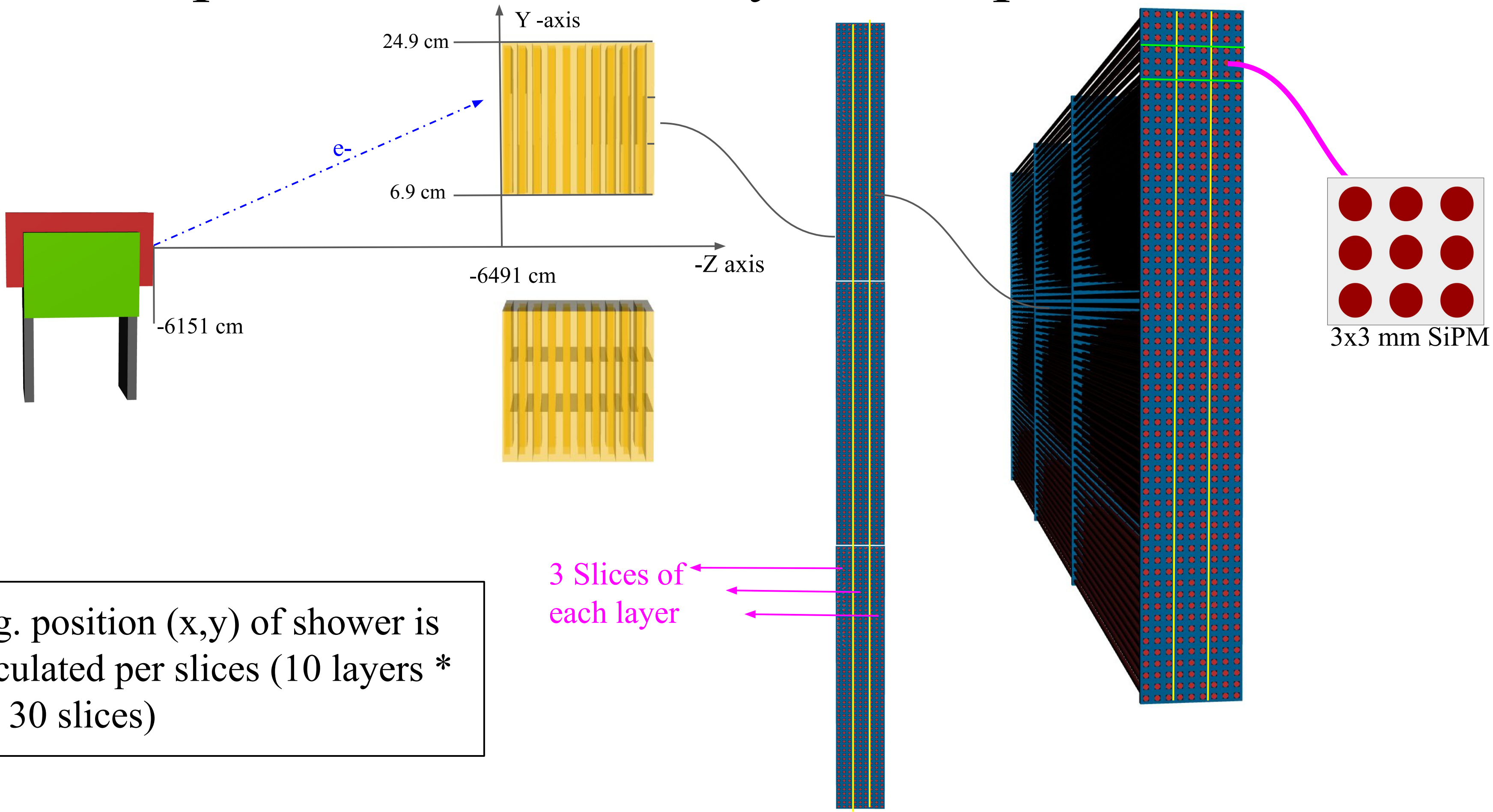
Next Steps

- To extract angle of e- hit from Edep shower profile from each layer.

Ppt 3

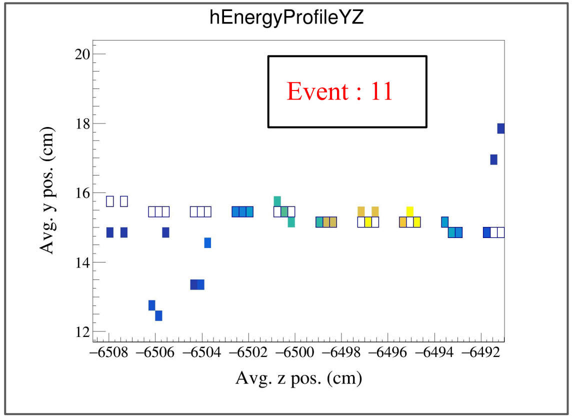
10/03/23

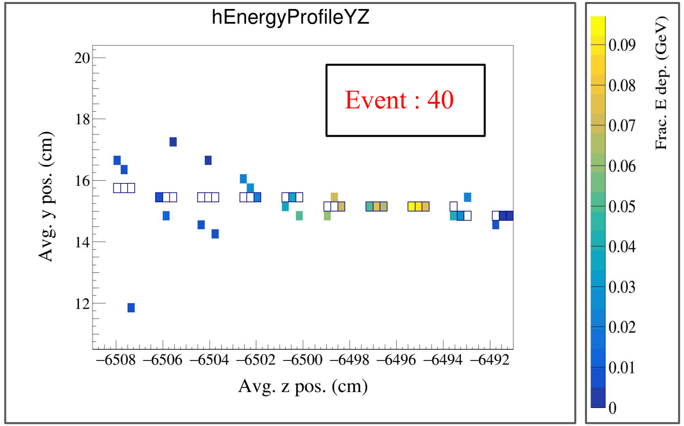
Pictorial representation of Analysis Setup



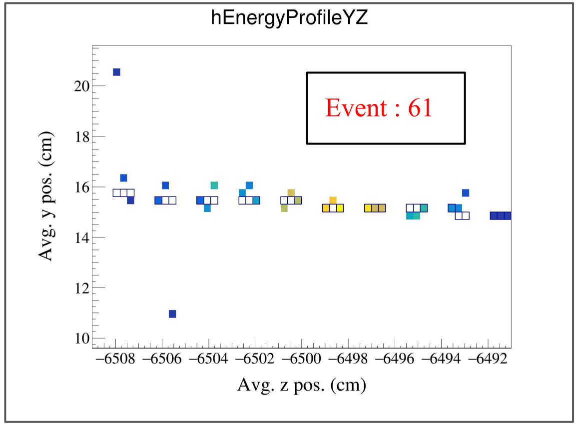
Avg. position (x,y) of shower is calculated per slices (10 layers * 3 = 30 slices)

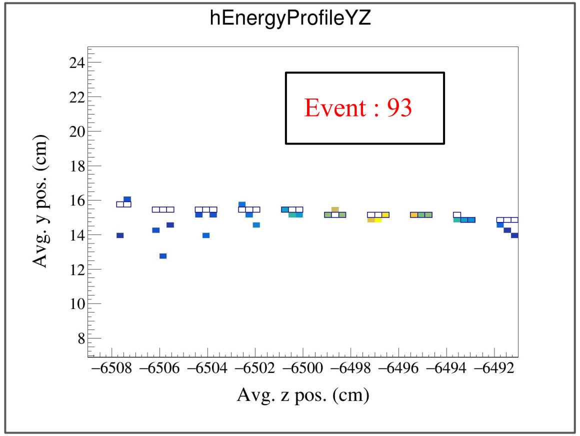
Event-by-Event shower fluctuations





m_gen : -0.0438

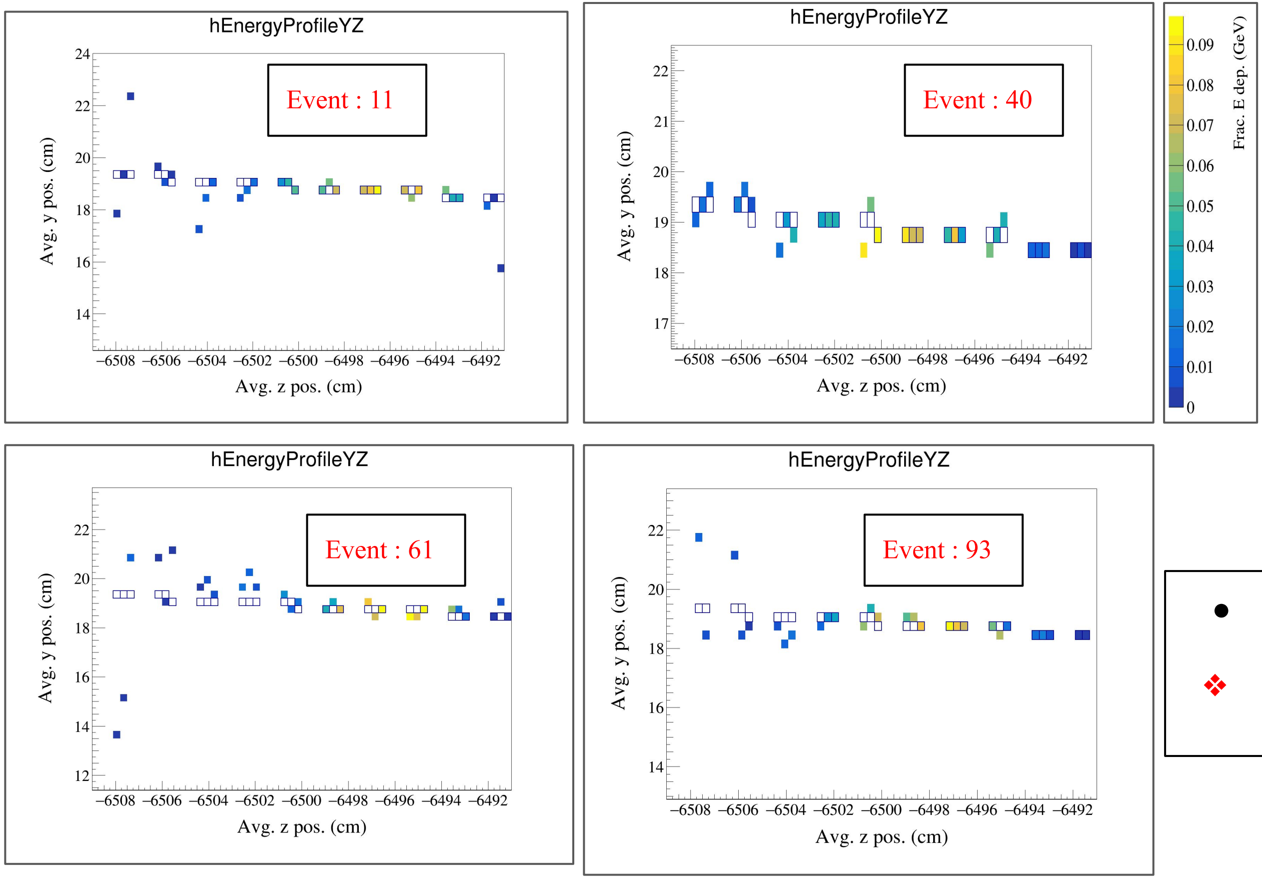




- Coloured columns represent avg. y_pos of energy deposition of shower.
- Hollow boxes : Ideal position of energy deposition (y_pos = z*m_gen + c_gen)
- All events have same m_gen.

❖ Event-by-event shower fluctuation is large.

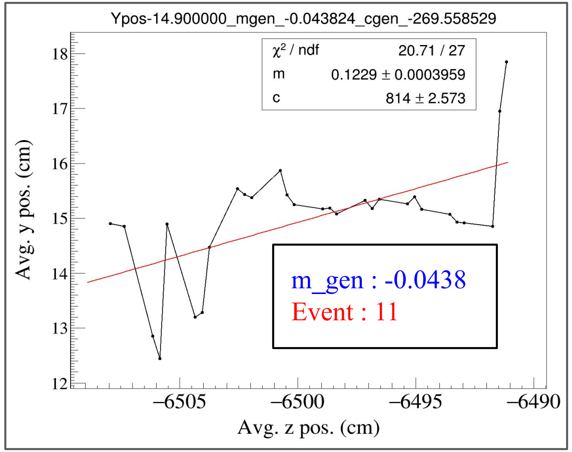
Event-by-Event shower fluctuations

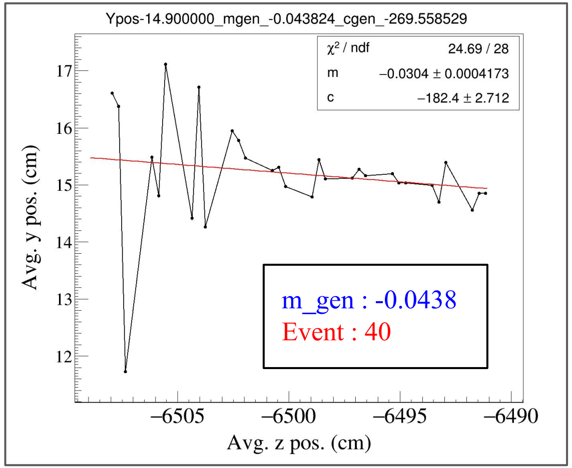


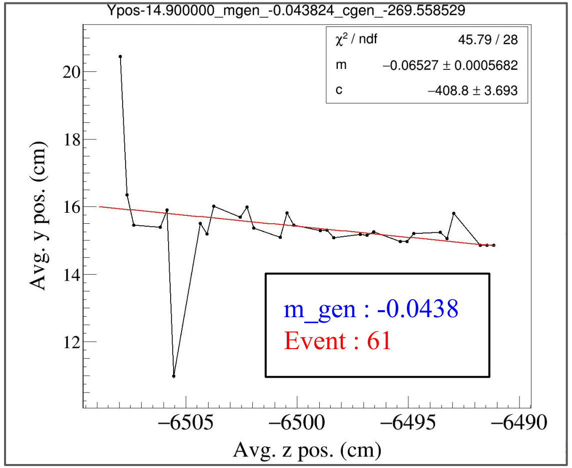
m_gen : -0.0541

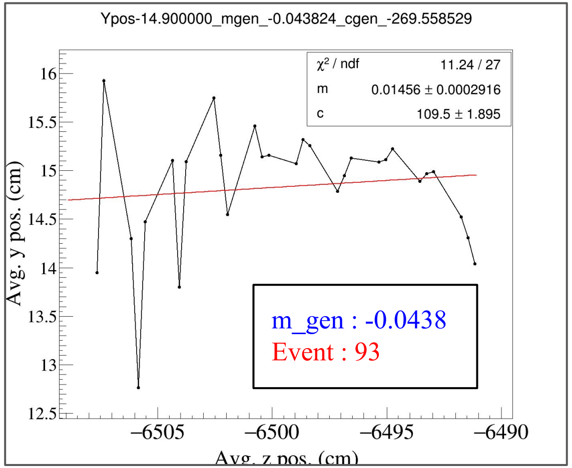
- Diff m_gen → Diff. hit location in CAL
- ❖ Event-by-event shower fluctuation is large.

Event-by-Event reconstructed angle fluctuations





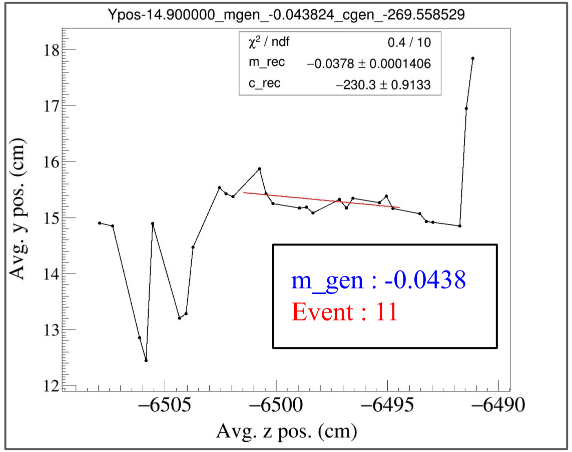


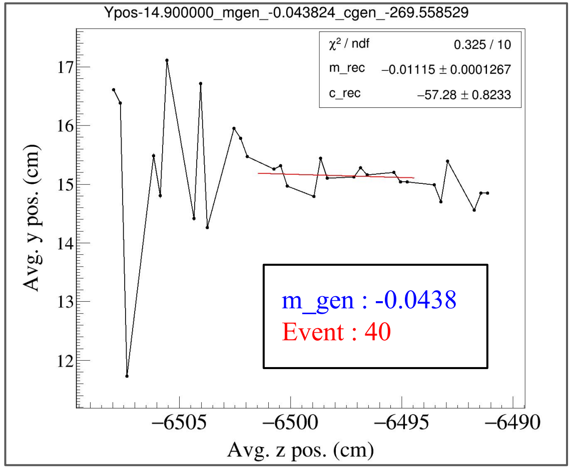


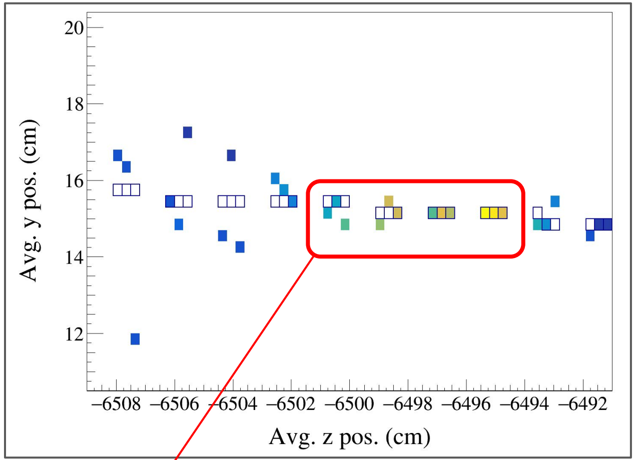
- All events have same m_gen.
- Data points are avg. y_pos

❖ Event-by-event shower fluctuation is large → large angle fluctuation

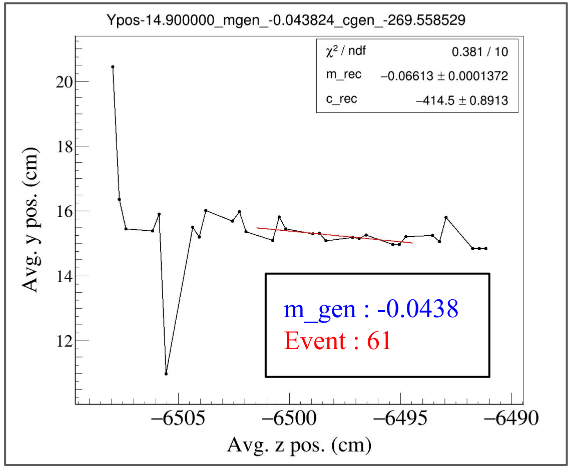
Event-by-Event reconstructed angle fluctuations

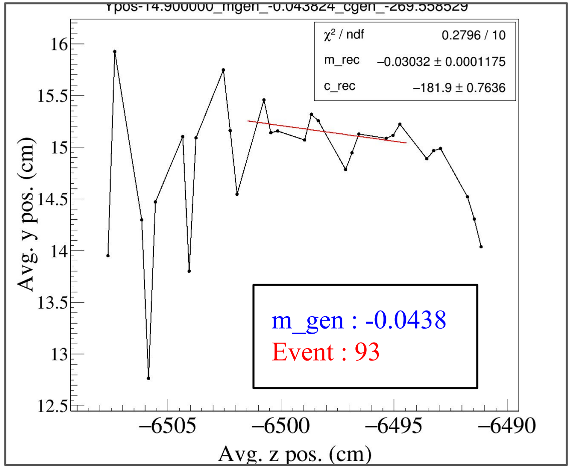






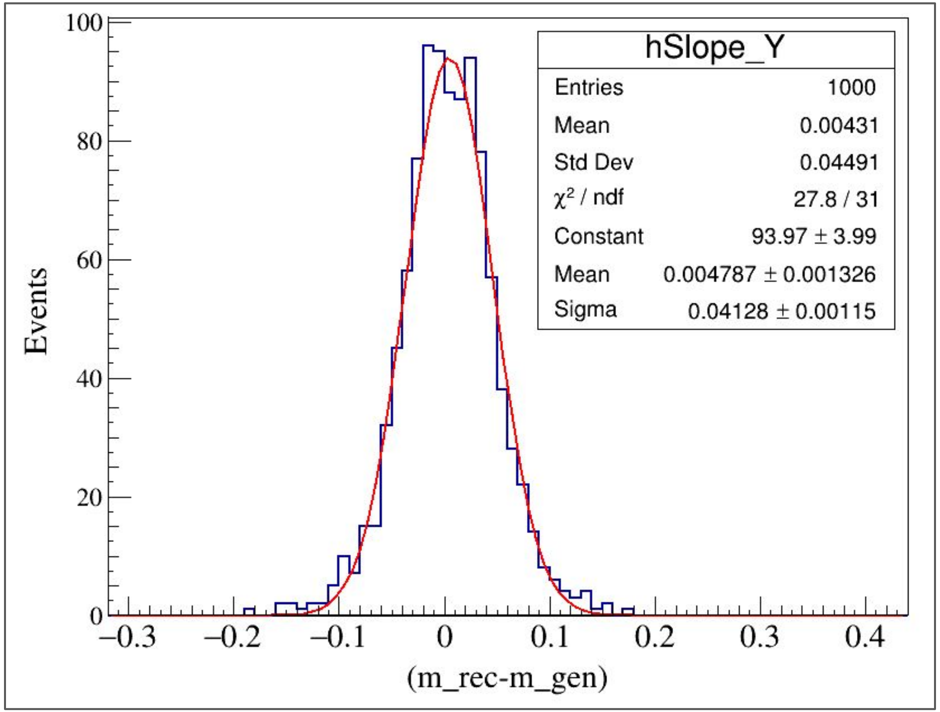
Only these 4 layers (4*3 slices) are considered for linear fit





- Event-by-Event angle fluctuation is now manageable.

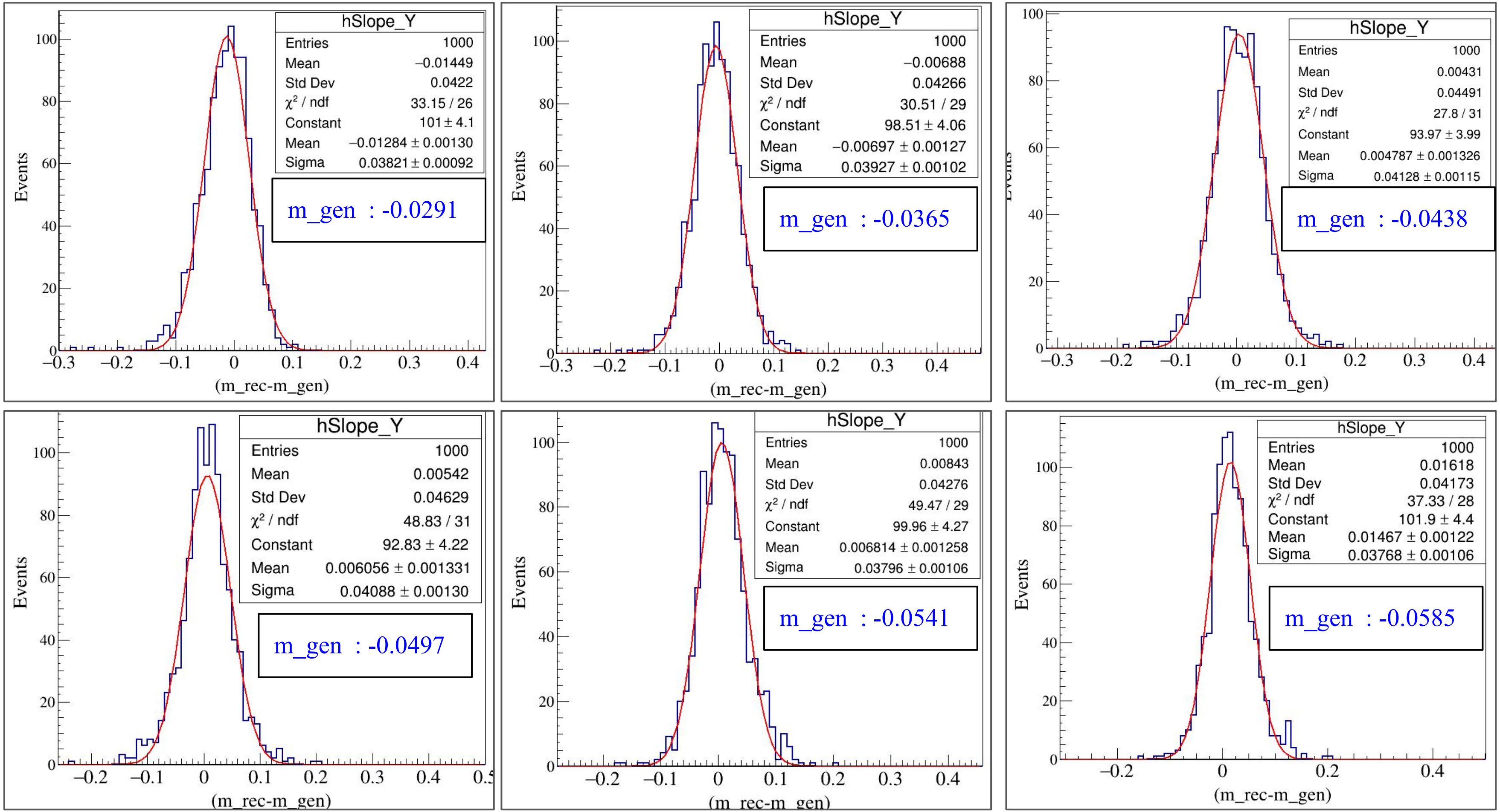
Angular Resolution at m_gen = -0.0438



- Slope for each event is extracted by 4 layers mention in previous slide.

❖ Resolution on slope is 0.0413

Angular Resolution at different slope



Summary

- Event-by-event large fluctuation in avg. Y_pos in slices with relatively lower energy deposition.
    - Resulting in large fluctuation in calculator of slope of e- hit.

- When slices only with relatively large energy deposition is considered then fluctuations in slope are manageable.
    - The resolution is slope then is around 0.04

- Dependence of Slope (angular) resolution is not seen with different shooting angle of e-