

# ECAL Studies based on Remoll - 1

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For SoLID weekly Meeting

# ECAL Simulation Summary

- Baffles : babar\_more1
  - Kryptonite
- Wiser DIS e- and  $\pi$ - inputs
- No backgrounds incorporated (next step)
- Full EM calorimeter included

# Calorimeter Geometry

- Hexagonal lead blocks
  - Block side is 6.4 cm ( $A \sim 104 \text{ cm}^2$ )
- Each block in shower has,
  - 0.05 cm Pb
  - 0.15 cm scintillator Material
  - 0.024 cm air gap
- There are 194 layers of these blocks along the z-directions
- In x-y plane,  $R_{in} = 118 \text{ cm}$   $R_{out} = 261 \text{ cm}$
- Ionization Energy deposited on scint. material is recorded for each block

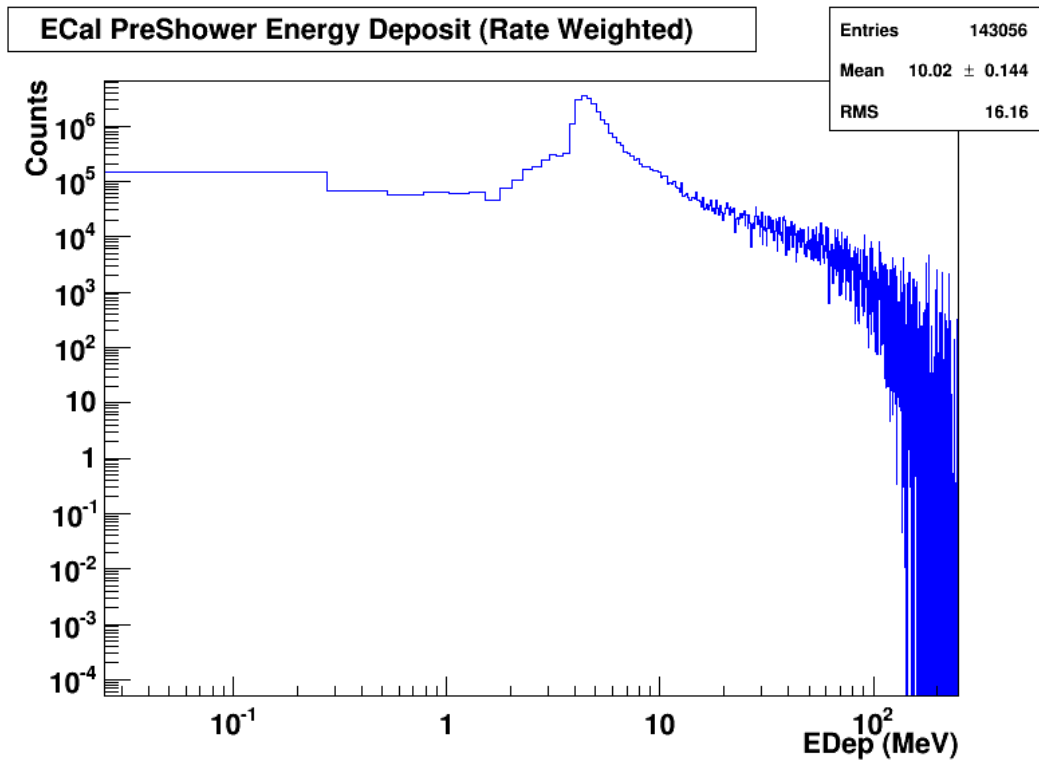
# Analysis Goals

- Compare Jin's standalone simulation results
- Get DIS and Pion Trigger rates from the full ecal (shower)
- Ultimately, get total trigger rates when backgrounds are incorporated – ongoing work

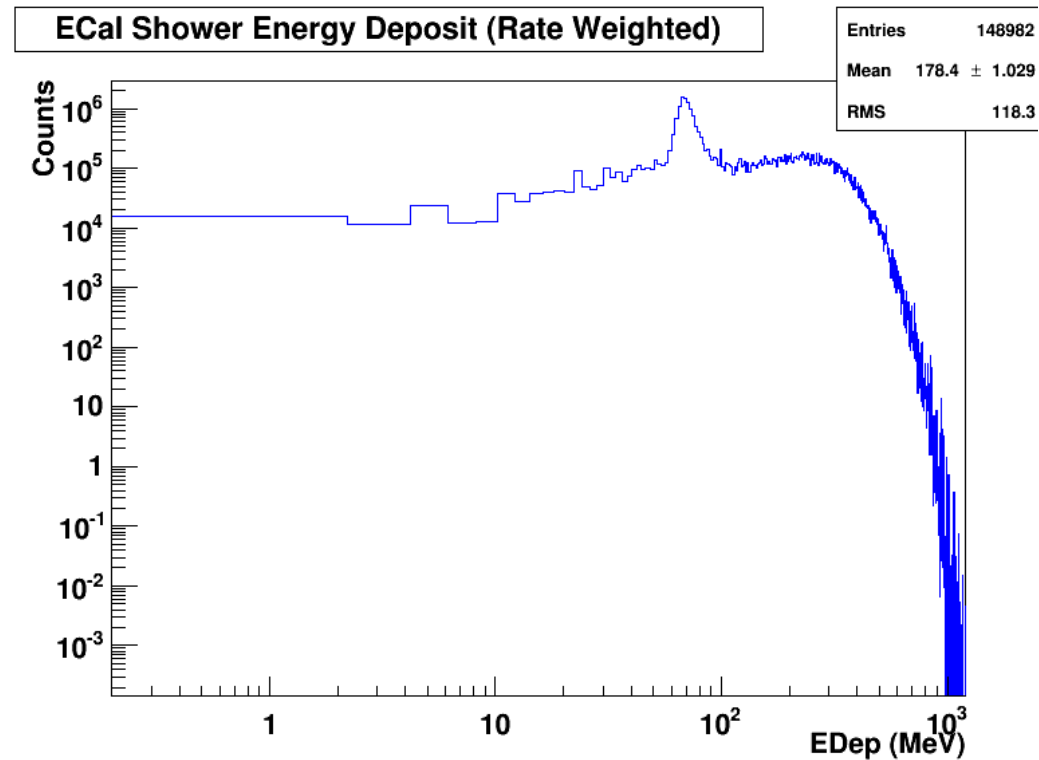
# Definitions

- Cuts applied at last GEM to select primary  $\pi^-$  and  $e^-$
- For each ecal block at given x,y the energy deposit is summed over all the layers:
  - **$Edep(x,y) = \sum Edep(x,y,z)$**
- By looping over  $Edep(x,y)$  blocks for each  $\pi^-$  or  $e^-$  event,
  - Using  $Edep(x,y)$ , 6+1 or 2+1 clusters can be computed
  - Maximum 6+1 sum and 2+1 sum are selected for each primary event ( $e^-$  or  $\pi^-$ ) :
    - **$Edep(6+1)$  and  $Edep(2+1)$**
  - Total energy deposit in the ecal for each primary event:
    - **$TotalEdep = \sum Edep(x,y)$**
- Further computed quantities at event level,
  - **$Edep\text{ fraction} = Edep(6+1)/TotalEdep$  and  $Edep(2+1)/TotalEdep$**
  - **$2+1/6+1\text{ ratio} = Edep(2+1)/Edep(6+1)$**

# Pre-Shower/Shower Edep : $\pi$ -

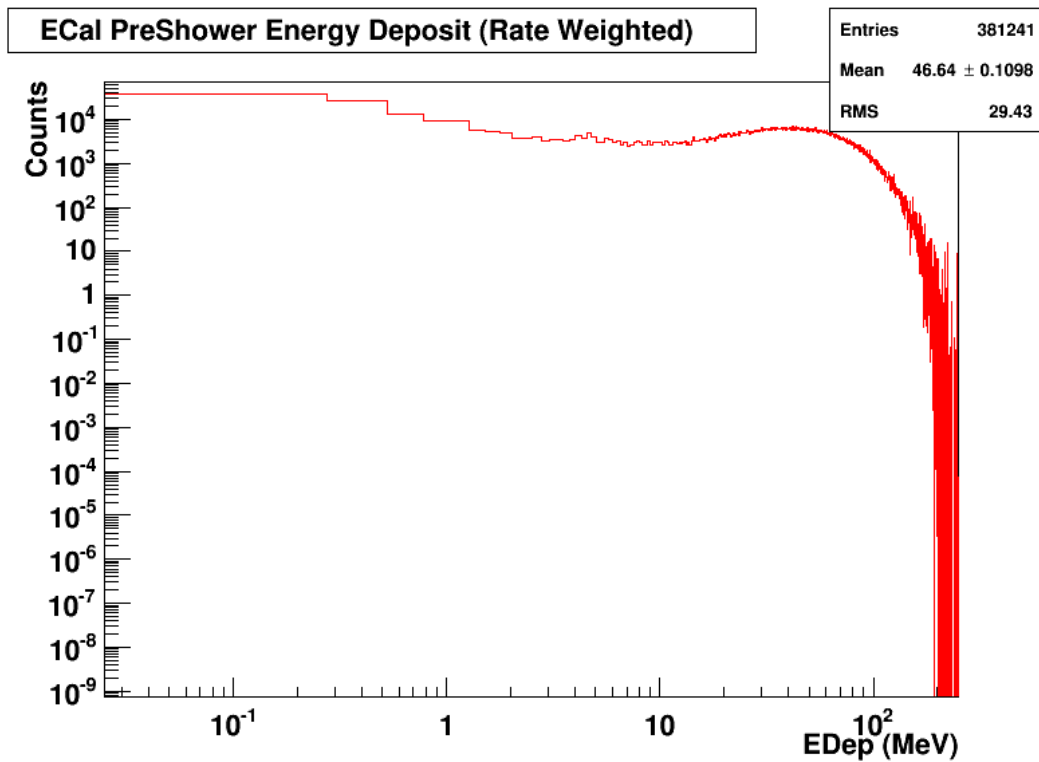


Pre-Shower Edep distribution

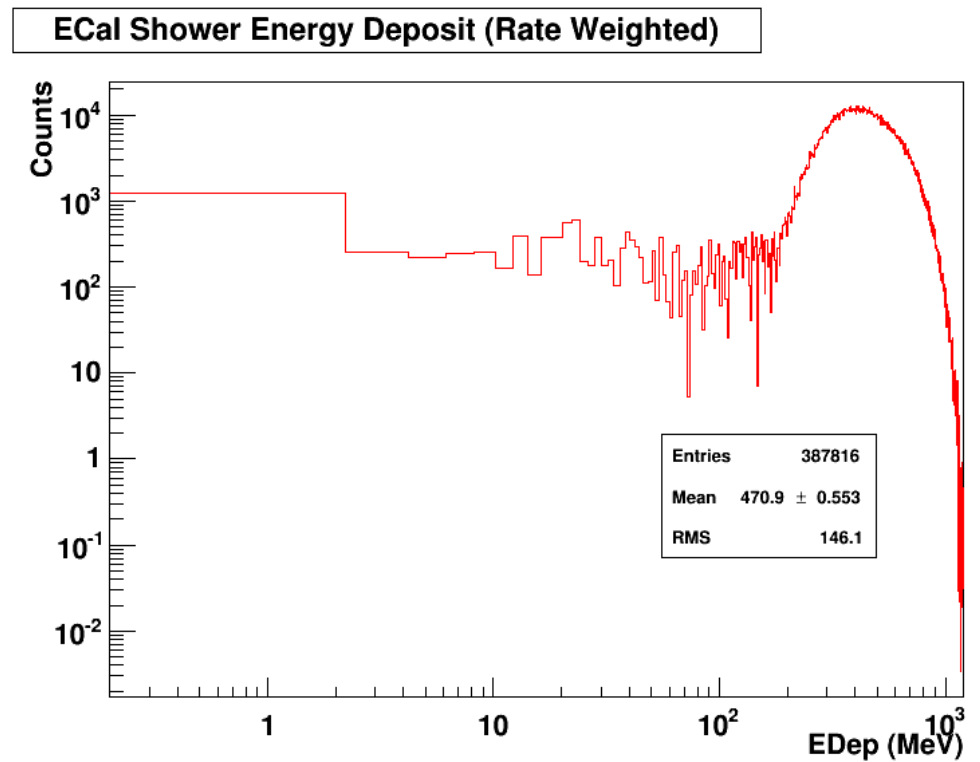


Shower Edep distribution

# Pre-Shower/Shower Edep : e-

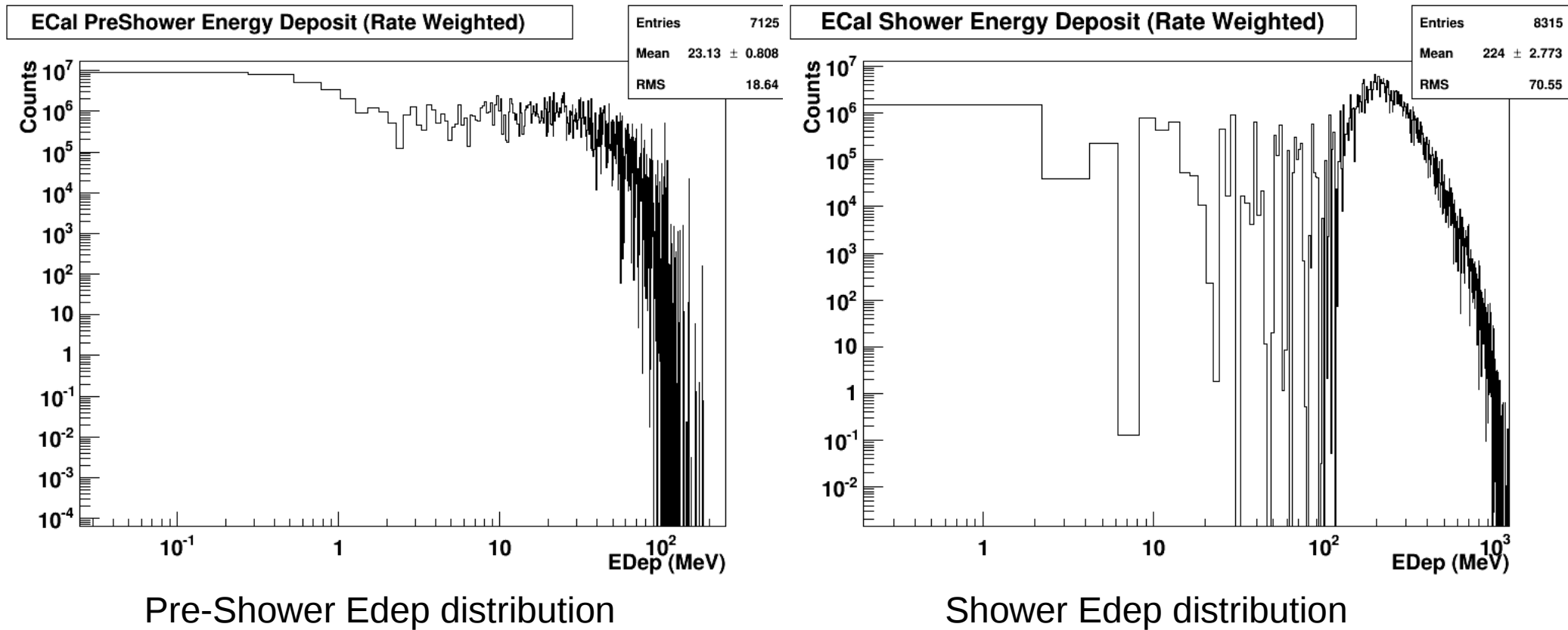


Pre-Shower Edep distribution



Shower Edep distribution

# Pre-Shower/Shower Edep : $\pi^0/\gamma$



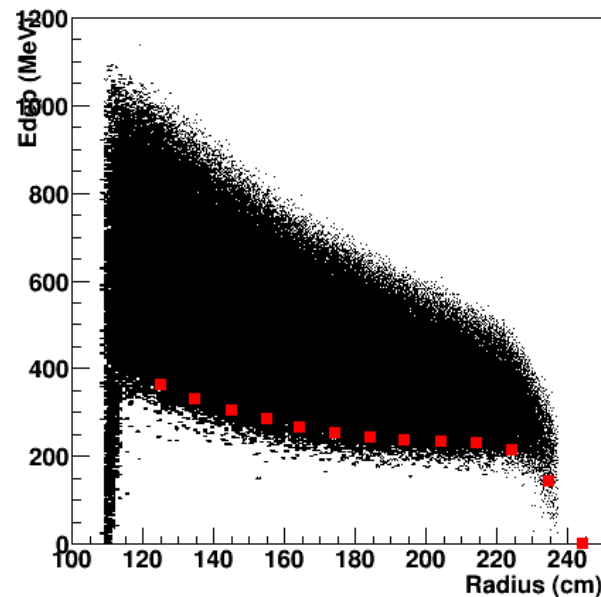


# Edep vs. ECAL Radius

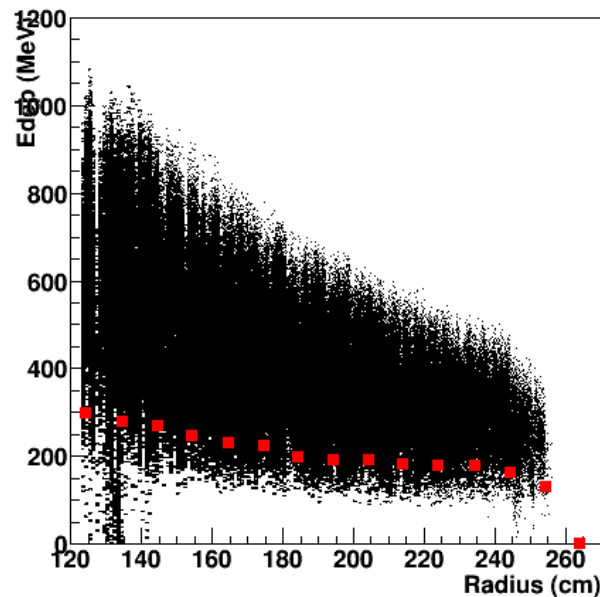
- For DIS electrons
  - $0.3 < x < 0.8$
  - $W^2 > 4 \text{ GeV}^2$
- For  $\pi^-$ 
  - Only primary tracks

# Threshold Set based on DIS

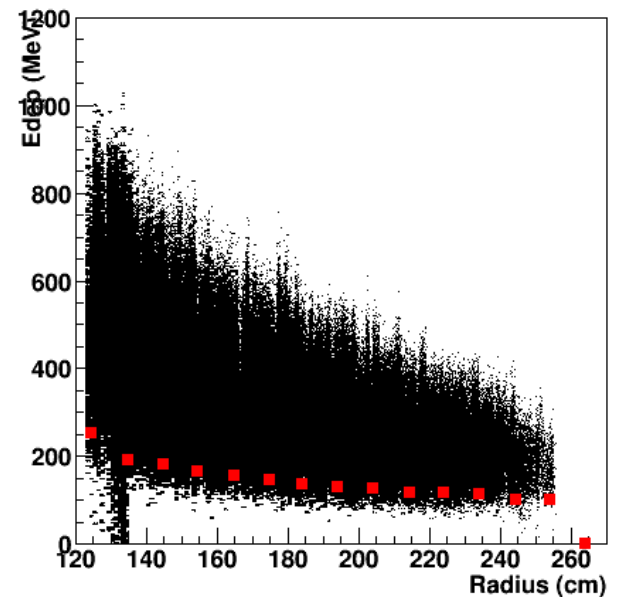
R vs. ECAL Shower Total Edep



R vs. ECAL Shower 6+1 Edep



R vs. ECAL Shower 2+1 Edep

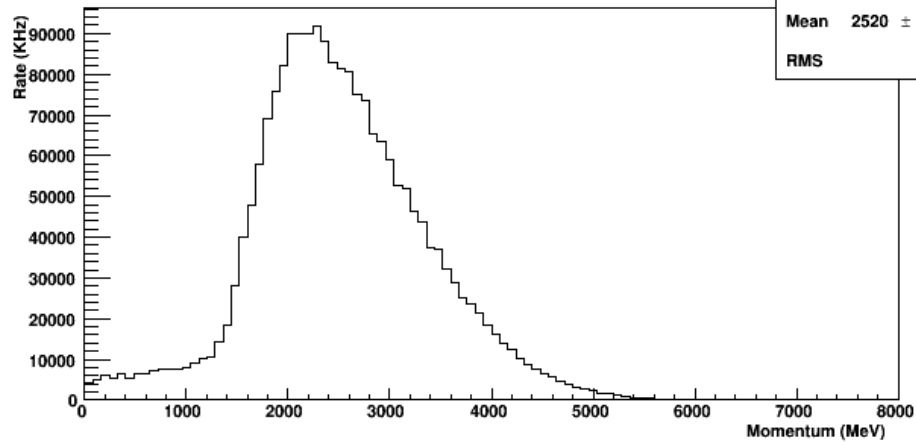


For DIS electrons

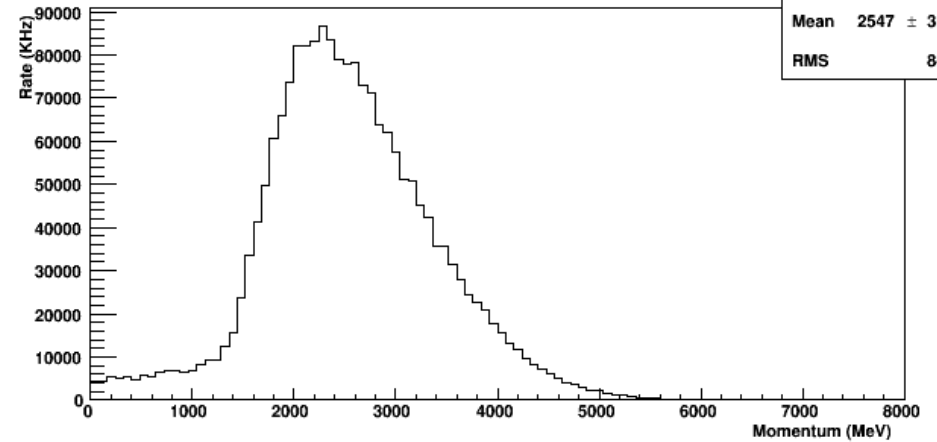
- $0.3 < x < 0.8$  and  $W^2 > 4 \text{ GeV}^2$

# Total Rate vs Trigger Rates : DIS

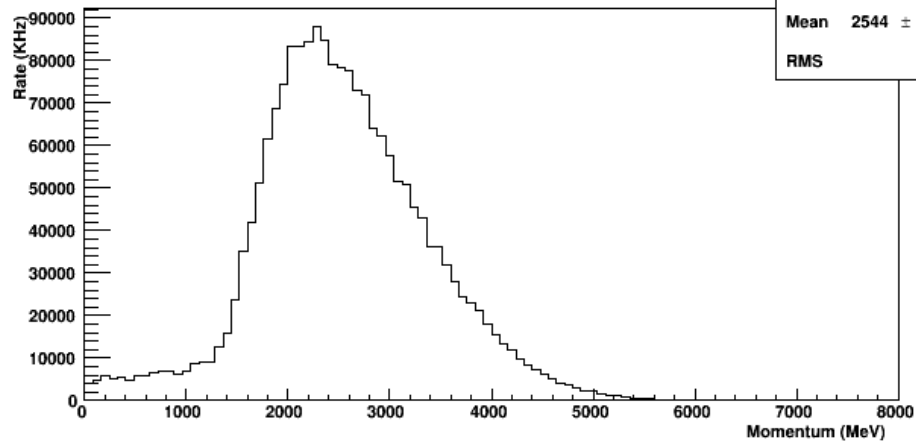
Last GEM Primary Track Momentum



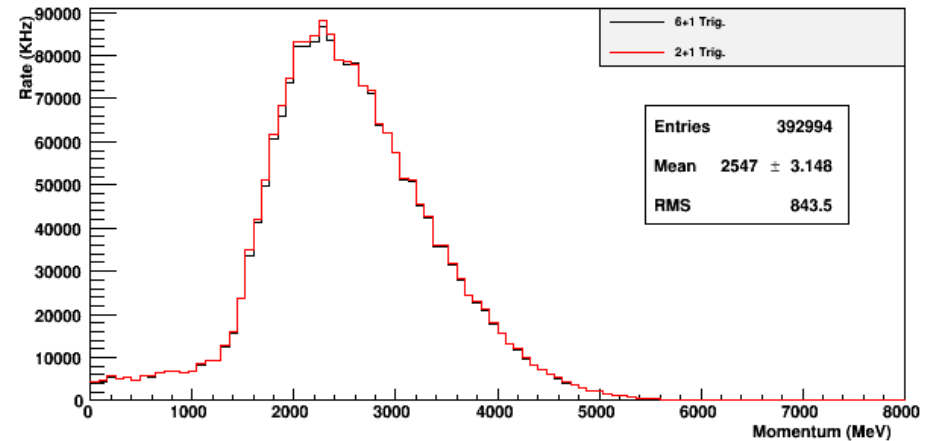
Last GEM Primary Track Momentum (6+1 Triggered)



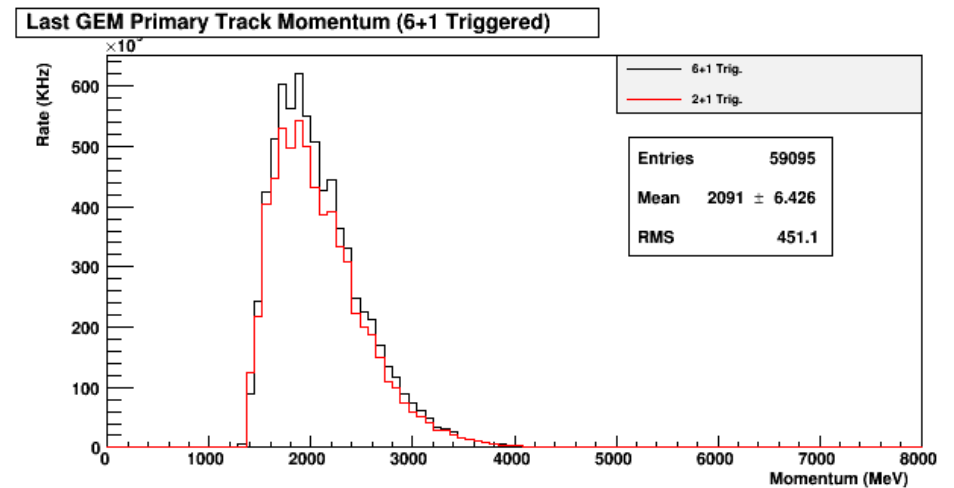
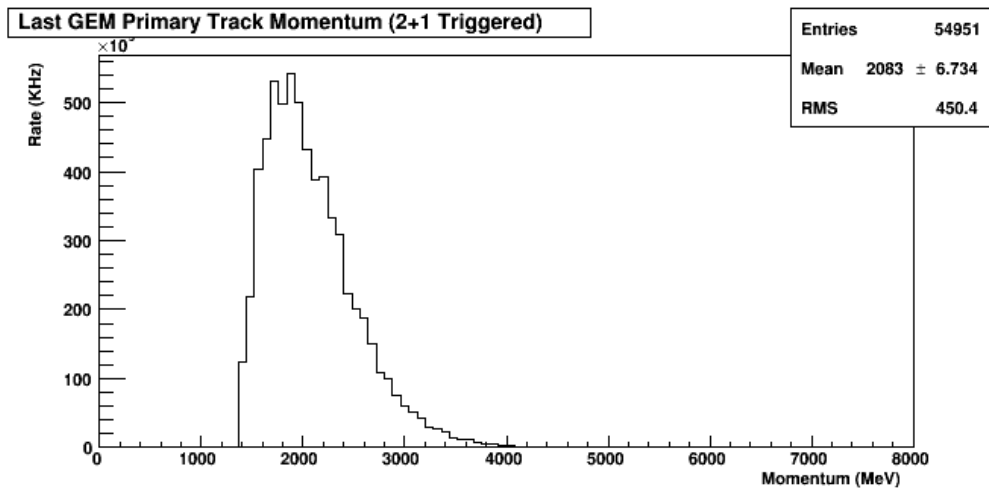
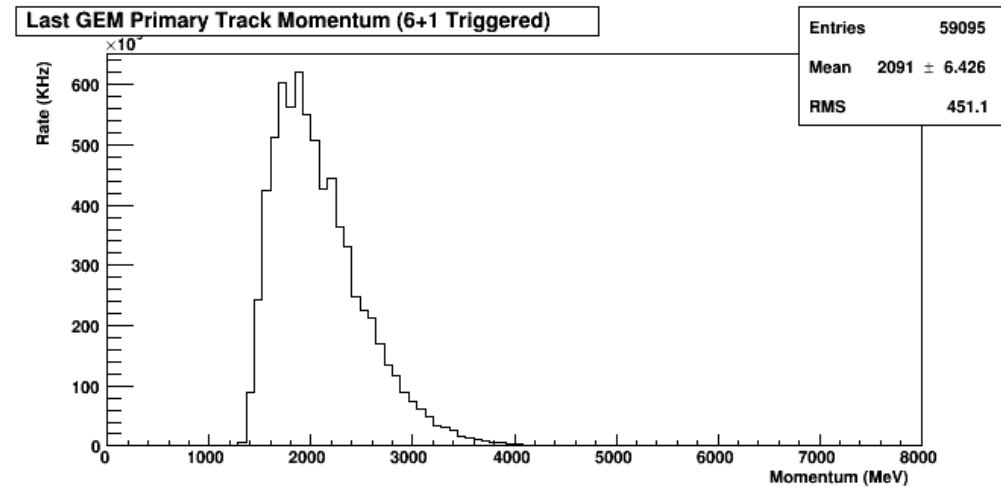
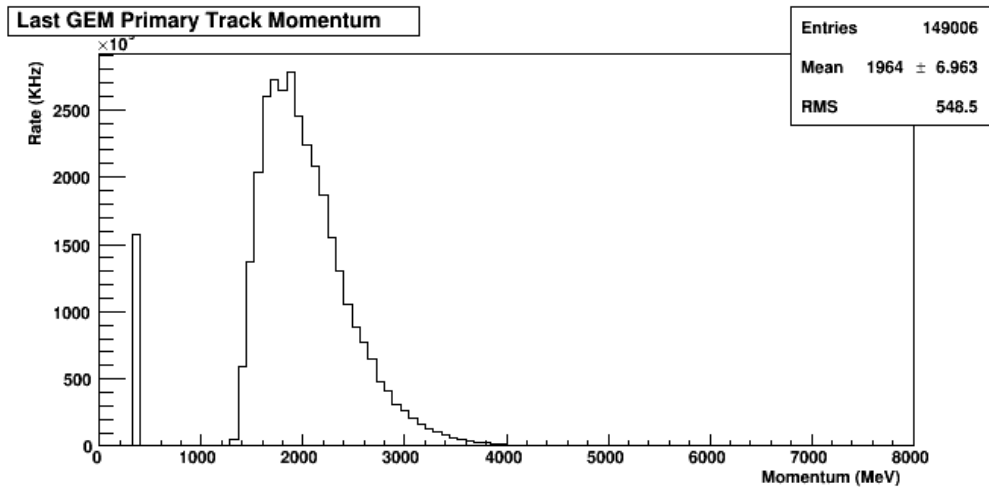
Last GEM Primary Track Momentum (2+1 Triggered)



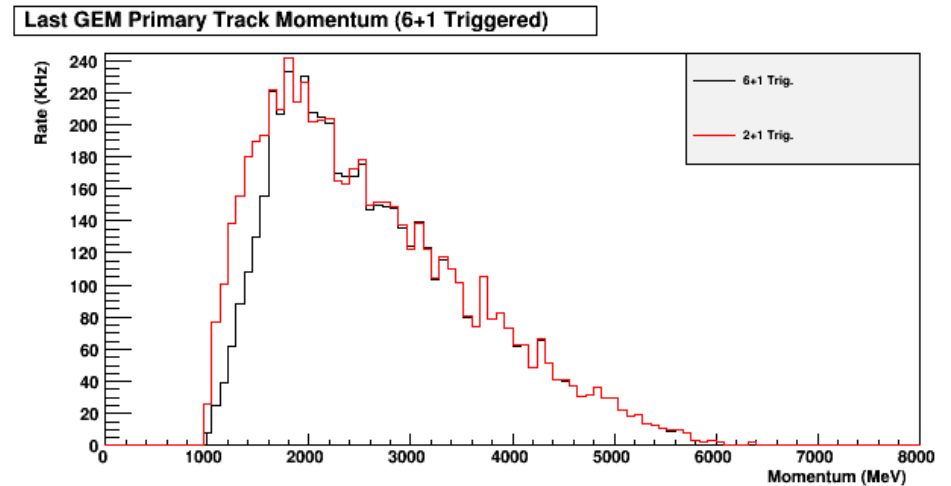
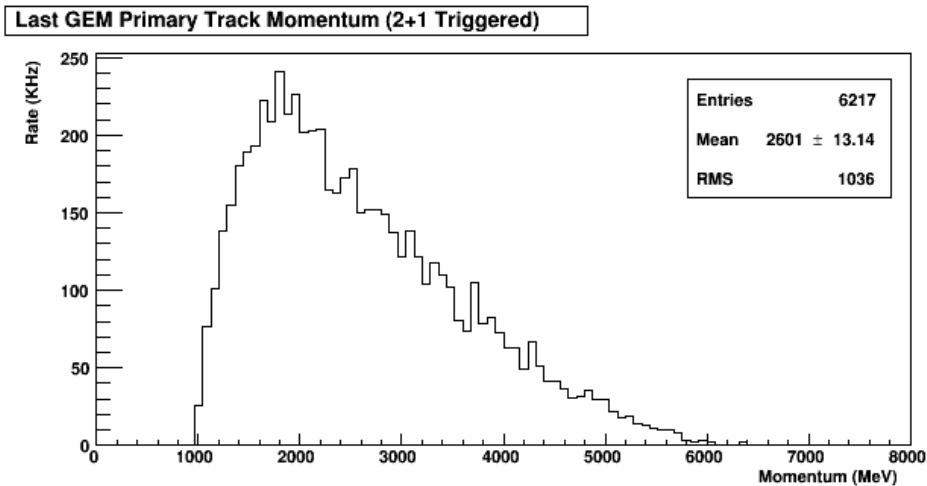
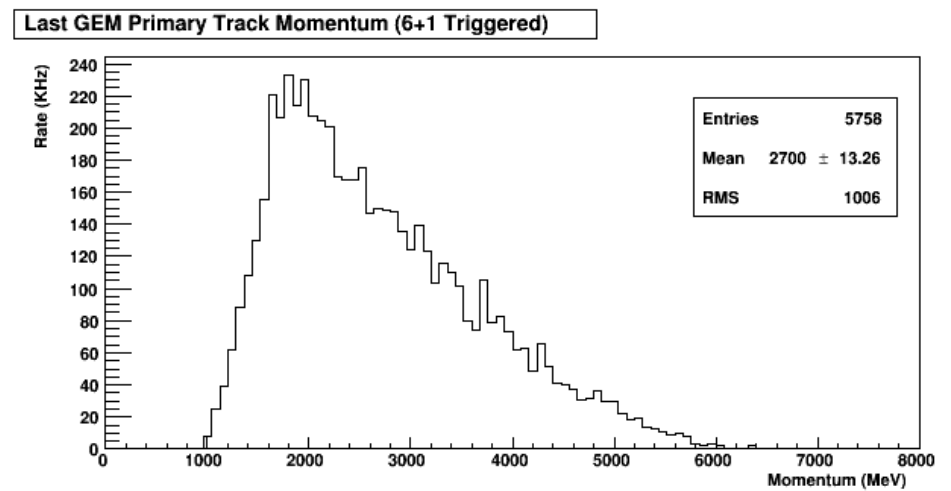
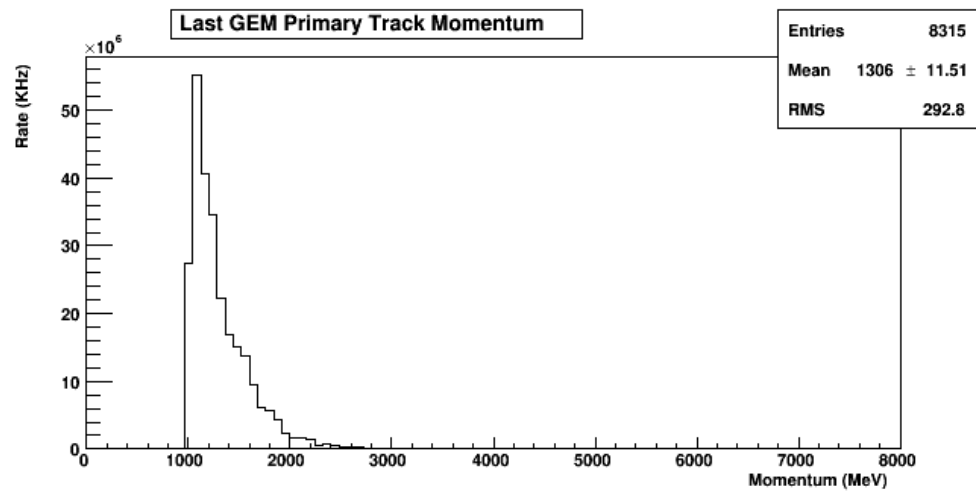
Last GEM Primary Track Momentum (6+1 Triggered)



# Total Rate vs Trigger Rates : $\pi^-$



# Trigger Rates : $\pi^0/\gamma$



# 6+1 vs 2+1 Preliminary Trigger Rate

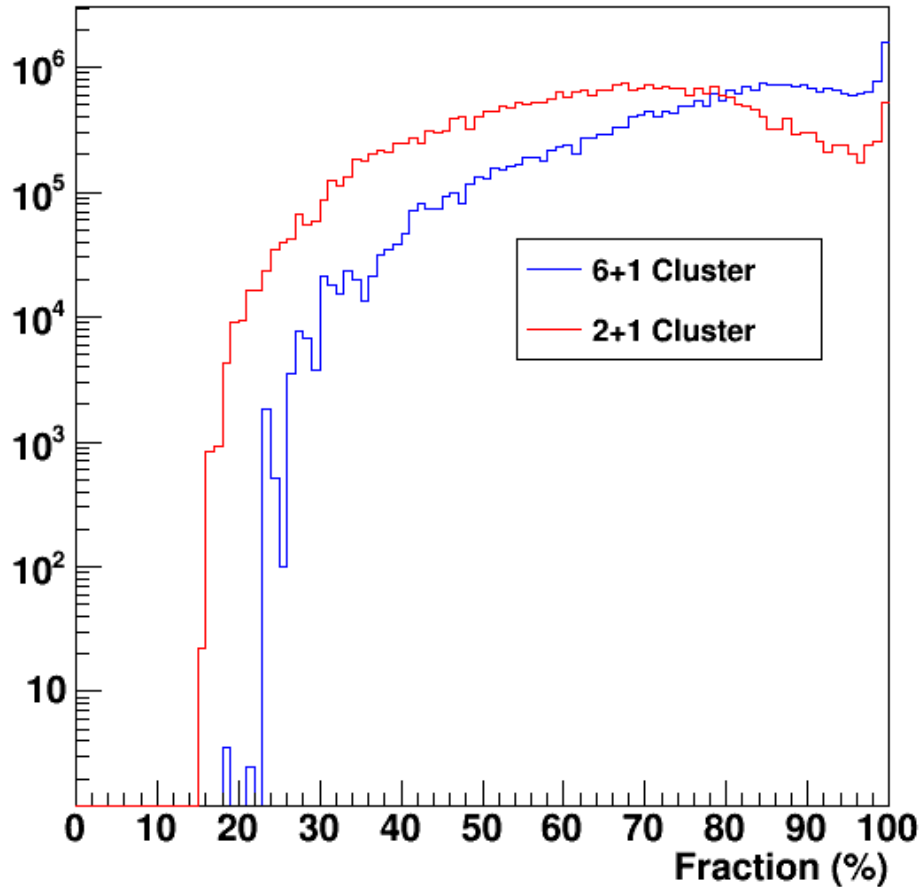
- This is by just using universal edep threshold as trigger to compare 6+1 vs 2+1
- About 10% reduction in  $\pi^-$  rate by using 2+1 clusters

|                | Total Rate | Trigger Rate |         |
|----------------|------------|--------------|---------|
|                |            | 6+1 Sum      | 2+1 Sum |
|                | (kHz)      | (kHz)        | (kHz)   |
| DIS            | 420.4      | 392.6        | 397.1   |
| $\pi^-$        | 33673.7    | 7235.4       | 6465.0  |
| $\pi^0/\gamma$ | 10504838.7 | 1328.4       | 2646.7  |

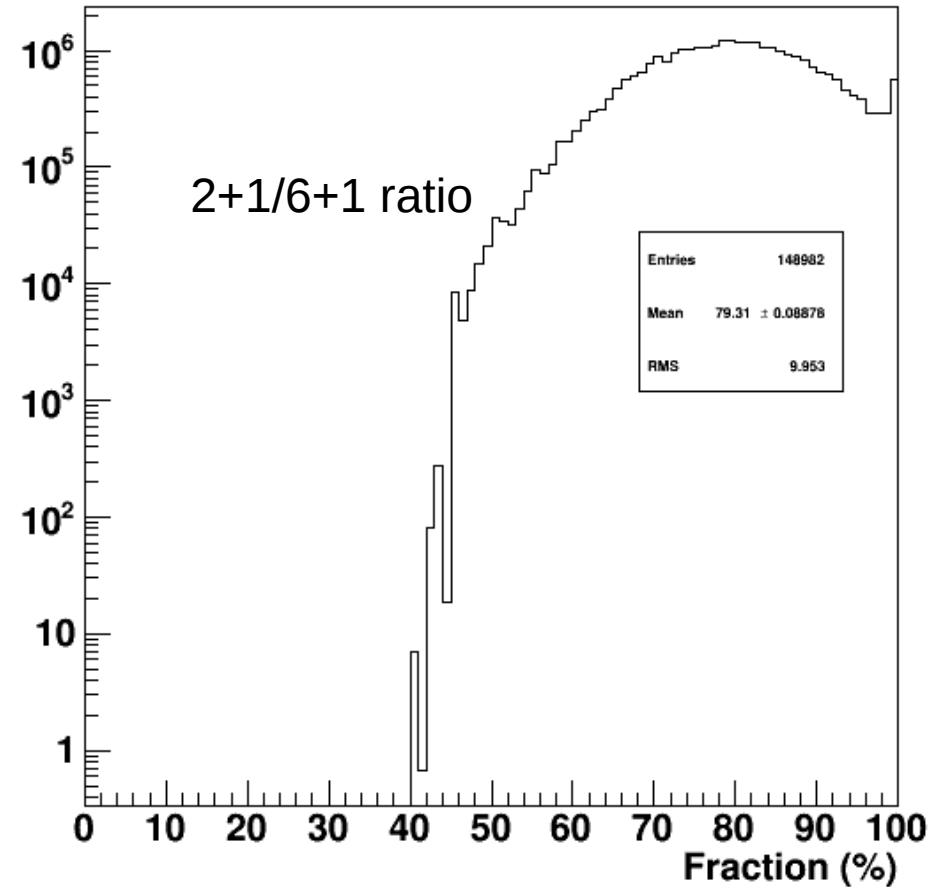
# 6+1 vs 2+1 Clusters in the Shower

# Shower : $\pi^-$

Primary Track EDEP Fraction in the Cluster (Rate Weighted)



2+1 over 6+1 Cluster EDEP Ratio (Rate Weighted)

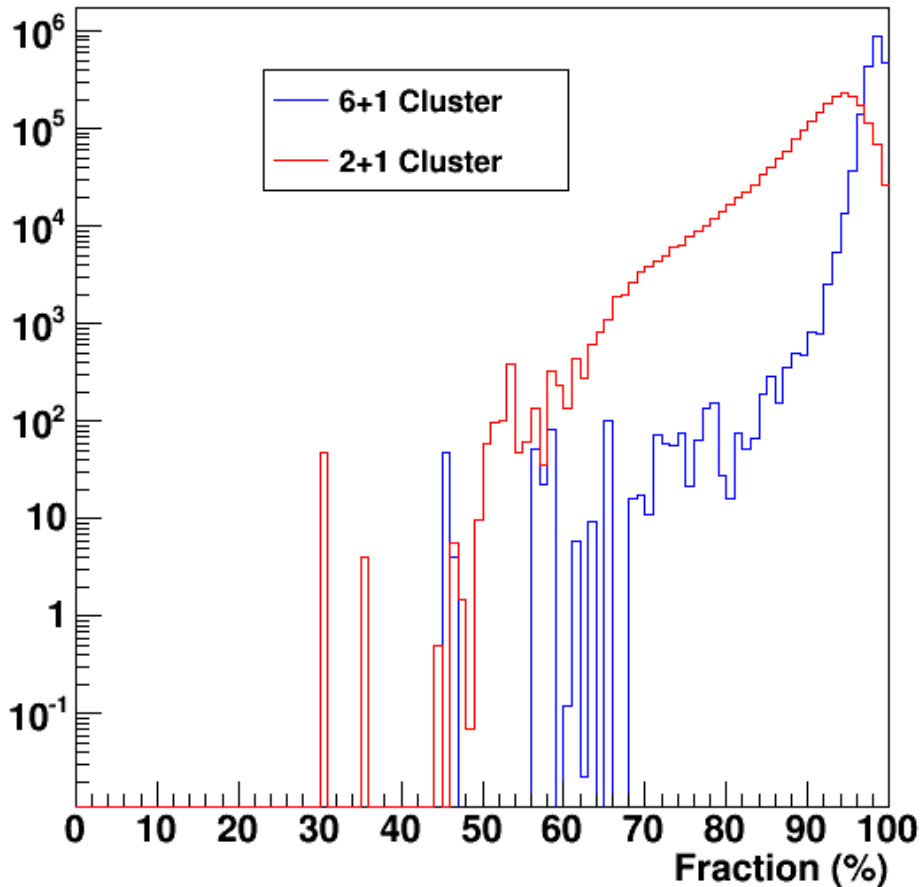


- Edep fraction =  $\text{Edep}(6+1)/\text{TotalEdep}$  and  $\text{Edep}(2+1)/\text{TotalEdep}$
- 2+1/6+1 ratio =  $\text{Edep}(2+1)/\text{Edep}(6+1)$

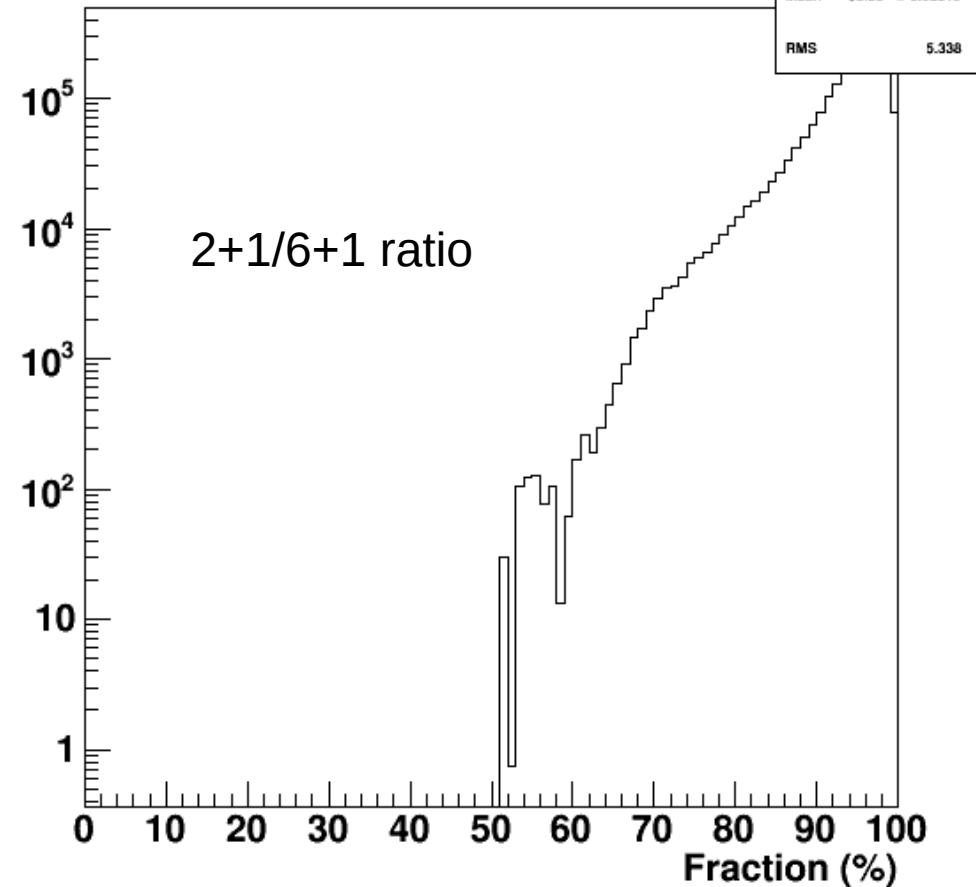


# Shower :e-

Primary Track EDEP Fraction in the Cluster (Rate Weighted)

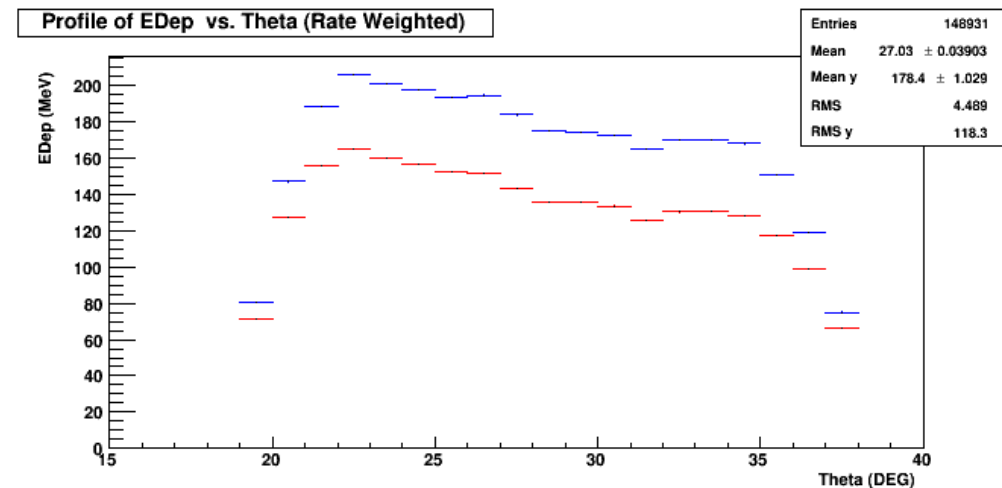
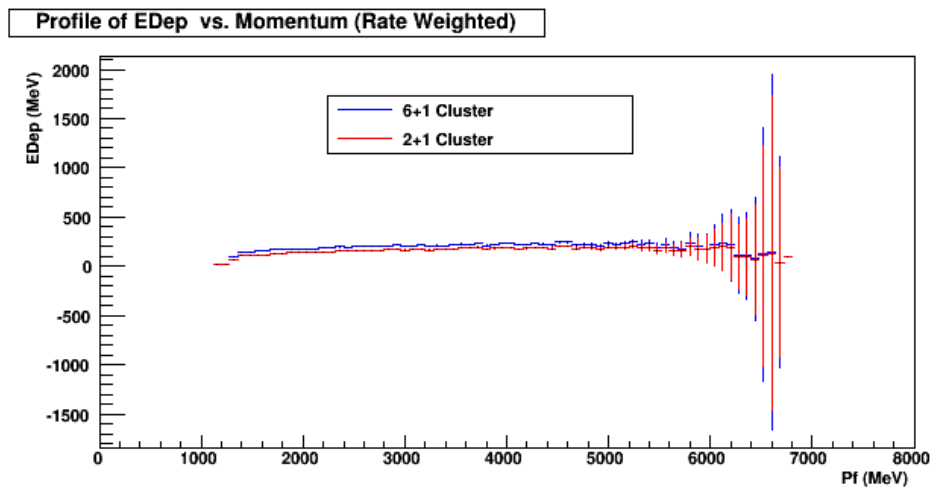
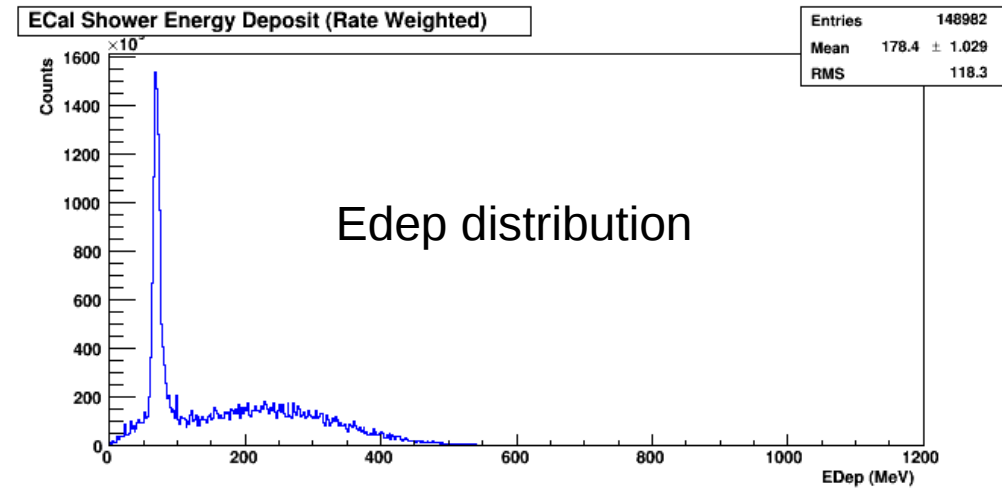
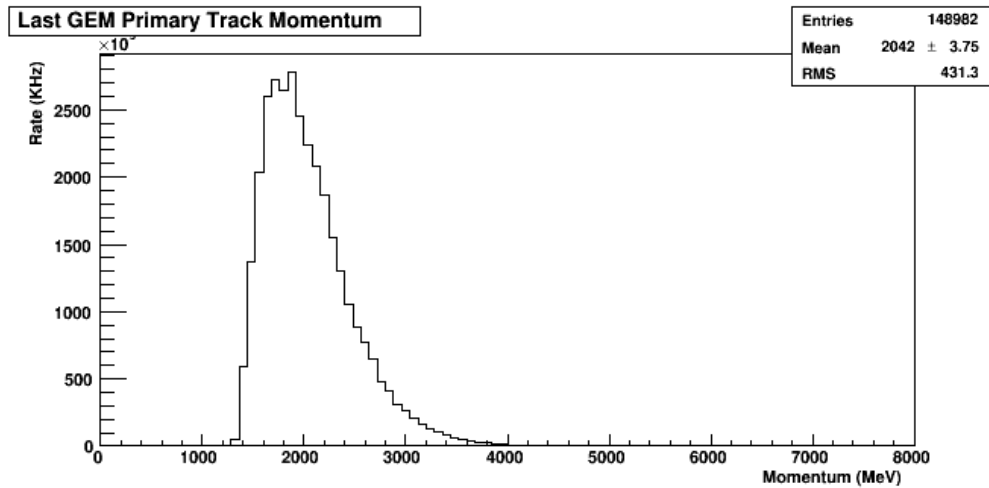


2+1 over 6+1 Cluster EDEP Ratio (Rate Weighted)



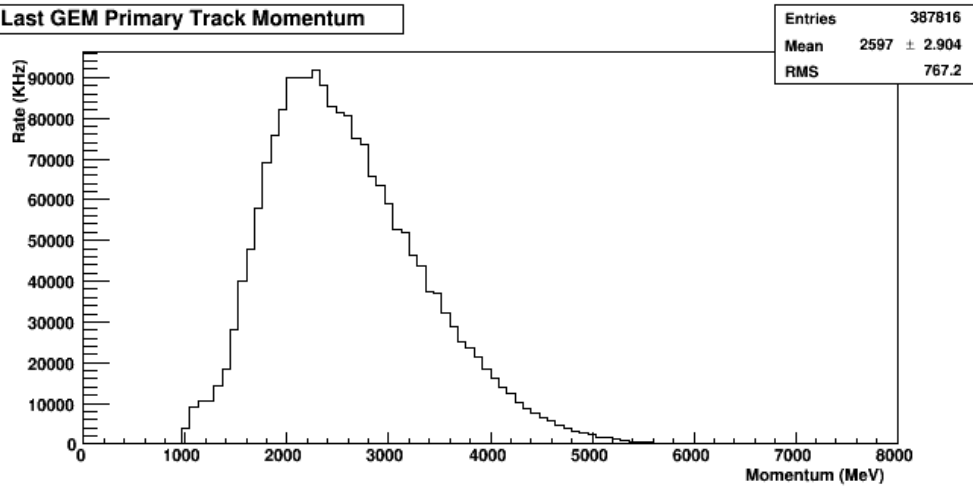
- Edep fraction =  $\text{Edep}(6+1)/\text{TotalEdep}$  and  $\text{Edep}(2+1)/\text{TotalEdep}$
- 2+1/6+1 ratio =  $\text{Edep}(2+1)/\text{Edep}(6+1)$

# Shower : $\pi^-$

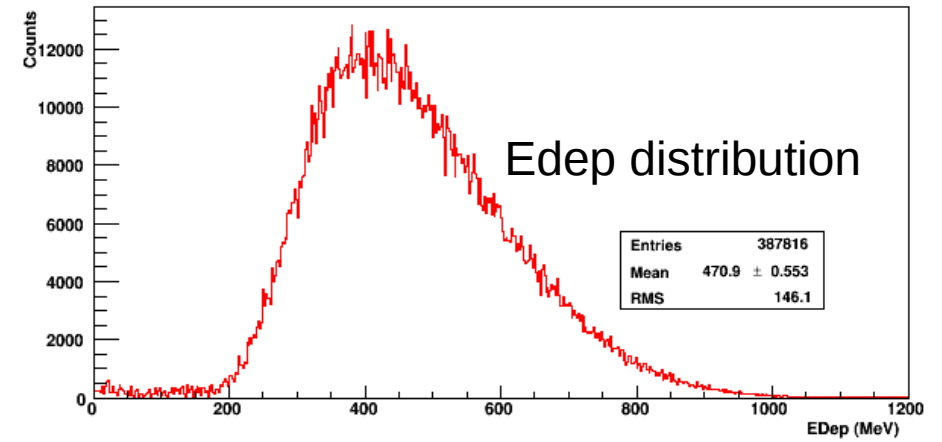


# Shower : e-

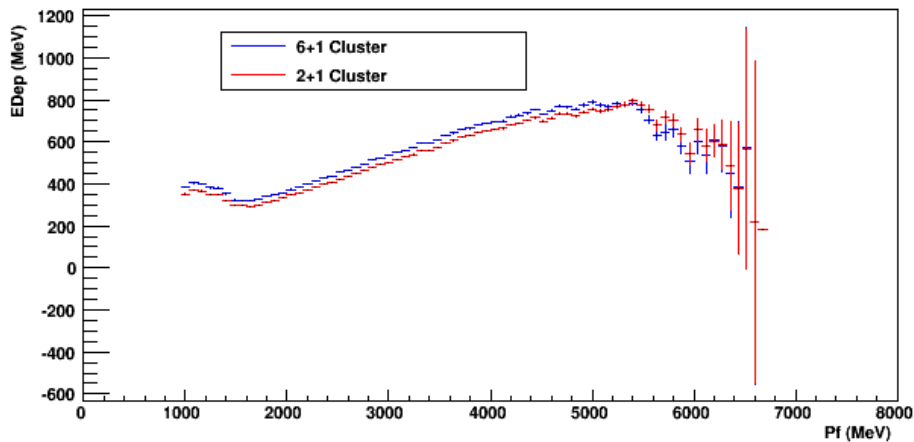
Last GEM Primary Track Momentum



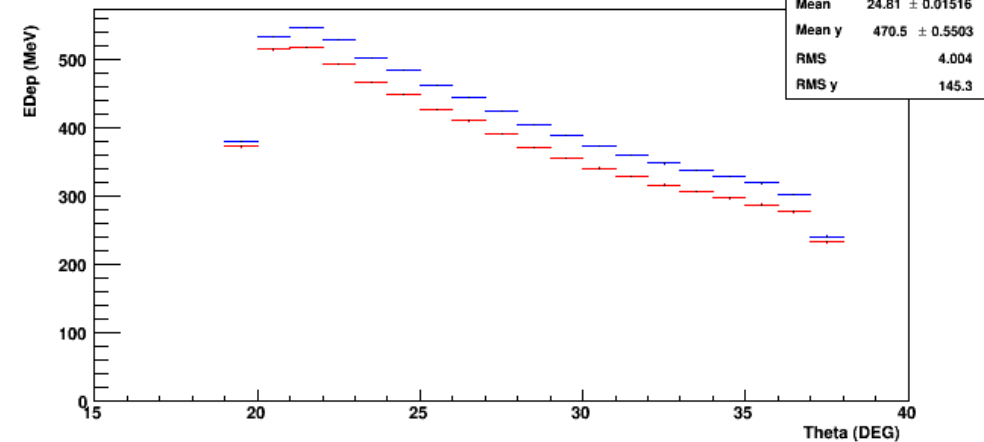
Ecal Shower Energy Deposit (Rate Weighted)



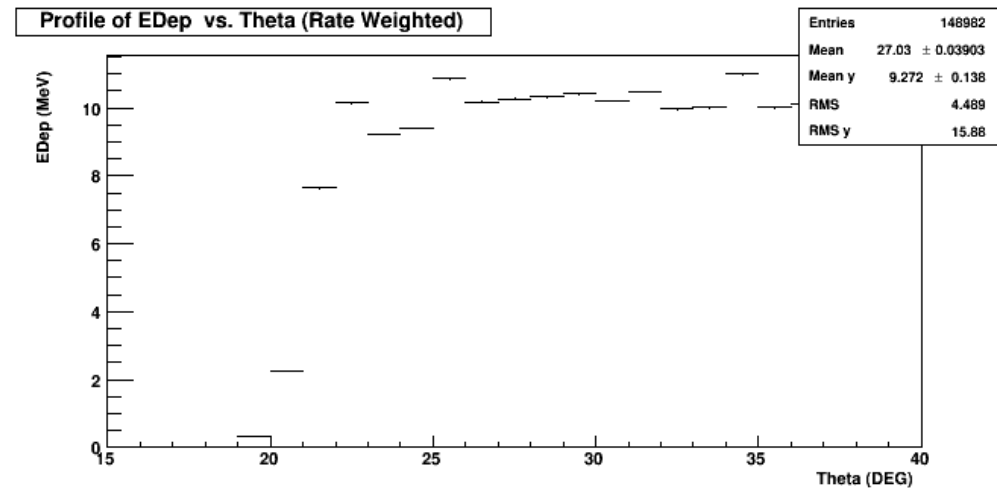
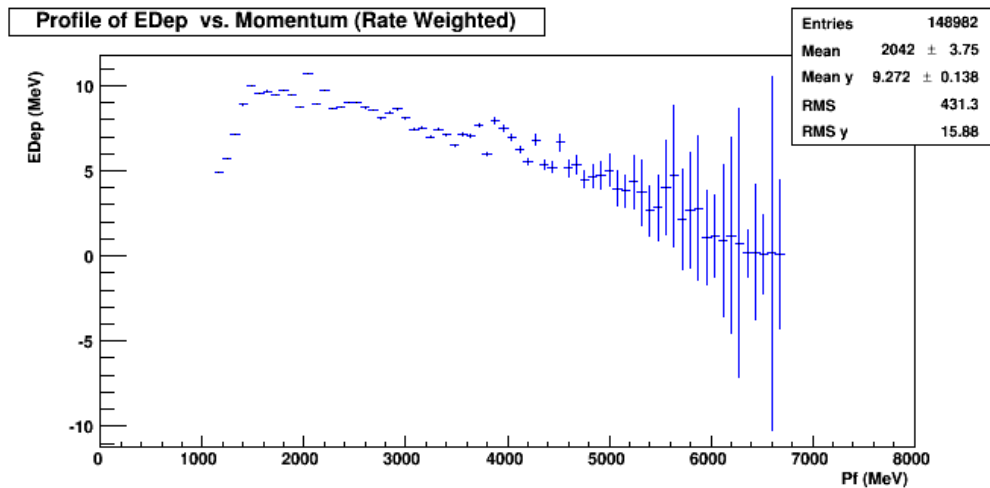
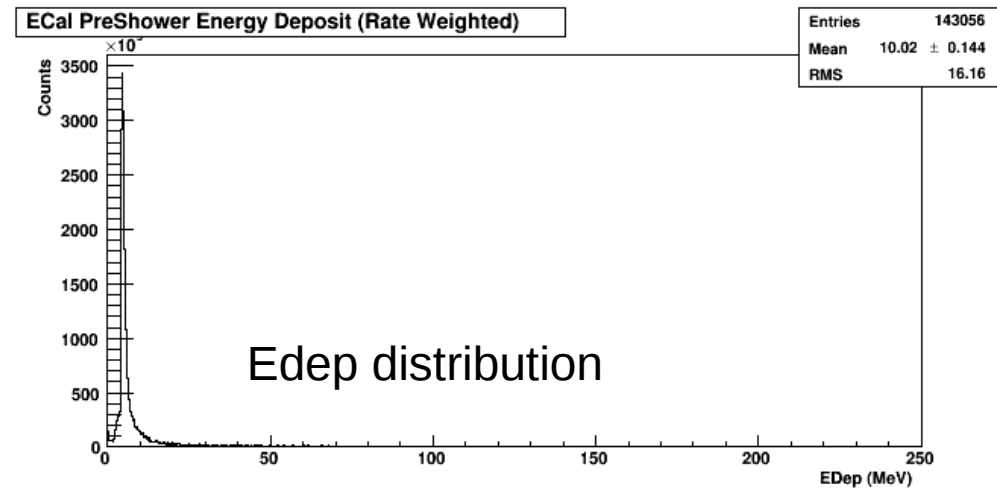
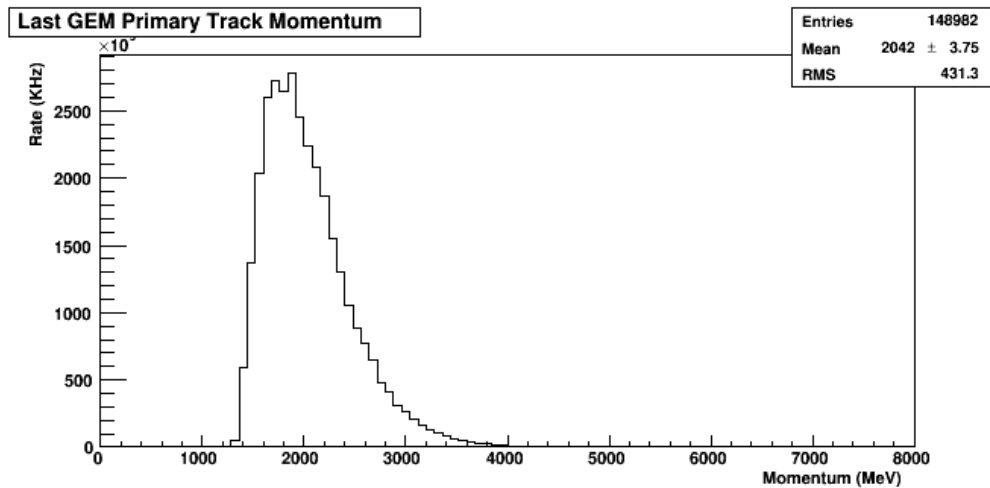
Profile of EDep vs. Momentum (Rate Weighted)



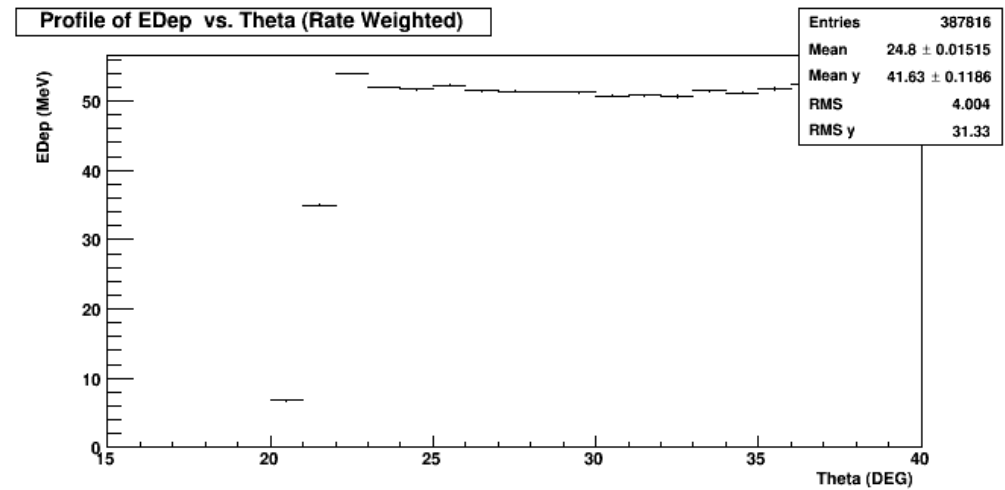
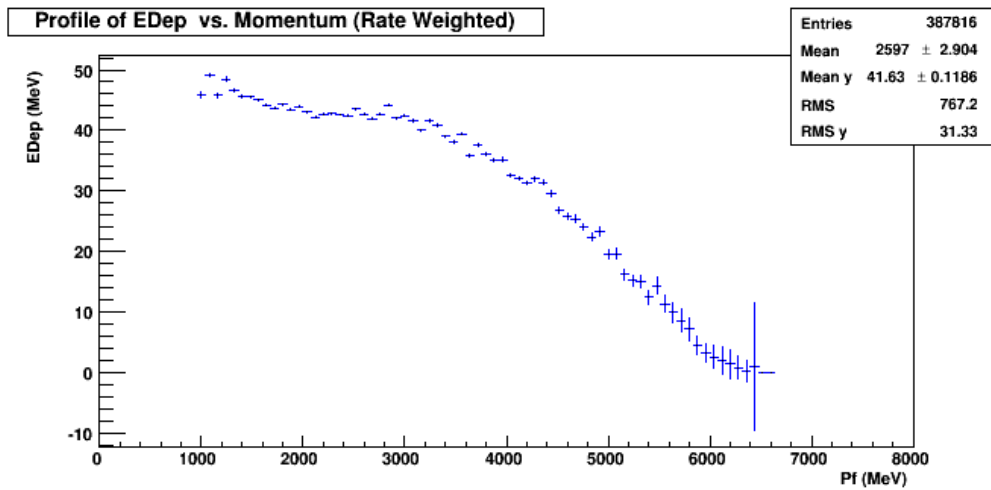
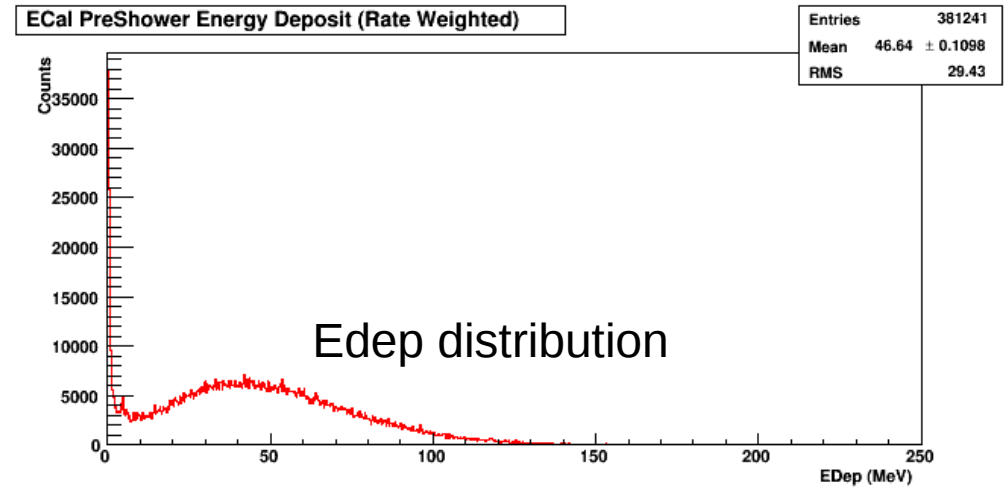
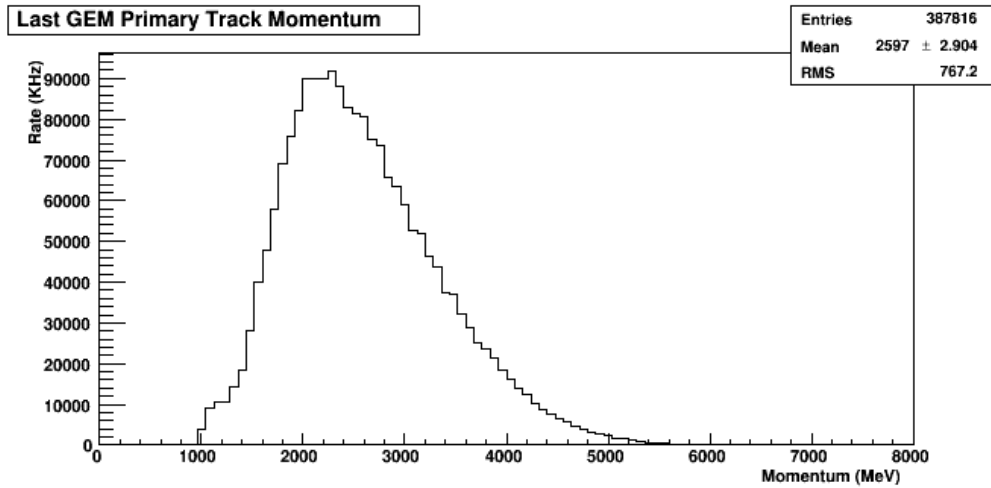
Profile of EDep vs. Theta (Rate Weighted)



# Pre-Shower : $\pi^-$



# Pre-Shower : e-

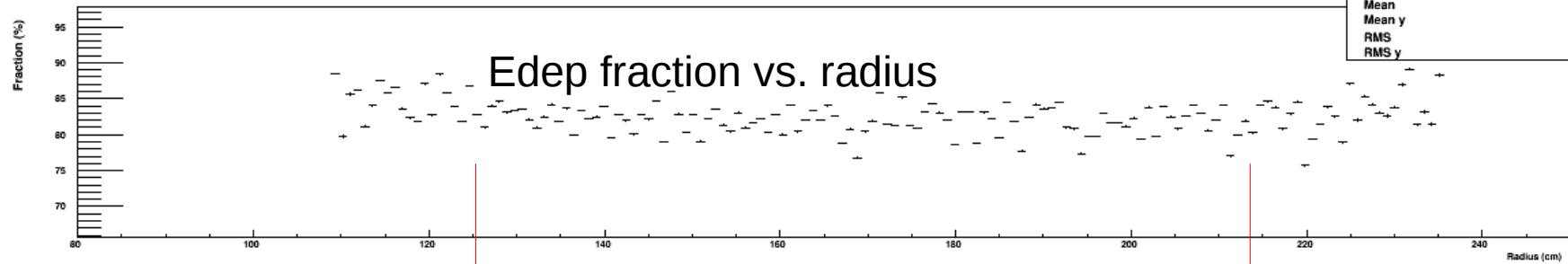


# Supplementary

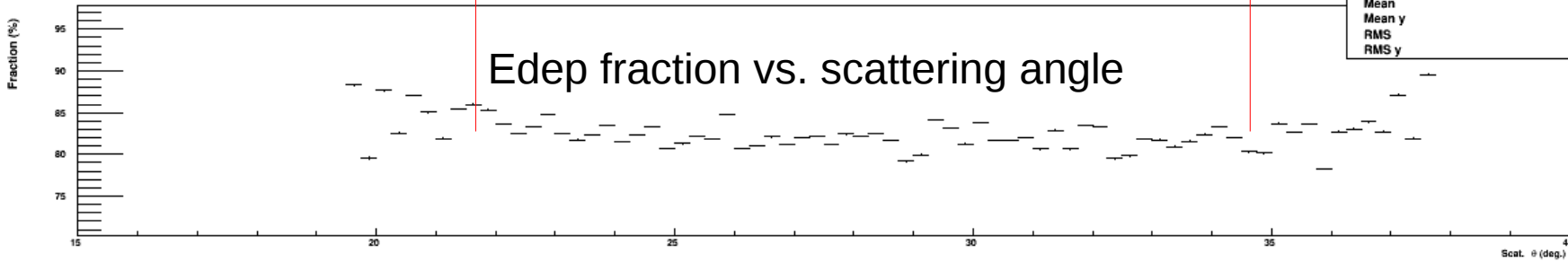
# Fraction of Energy Deposit on Pre-Shower Blocks and Shower Cluster

# Pre-Shower : $\pi^-$

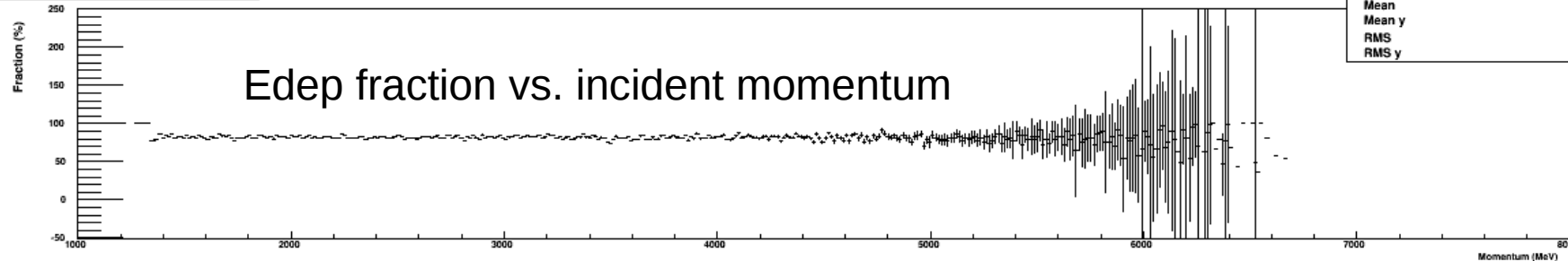
Profile of EDep Fraction vs. Ecal Radius



Profile of EDep Fraction vs. Scat. Angle



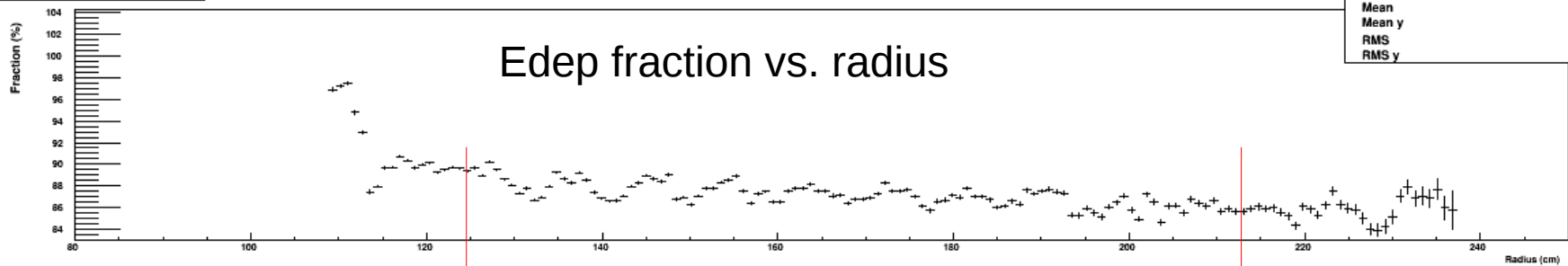
Profile of EDep Fraction vs. Incident Momentum



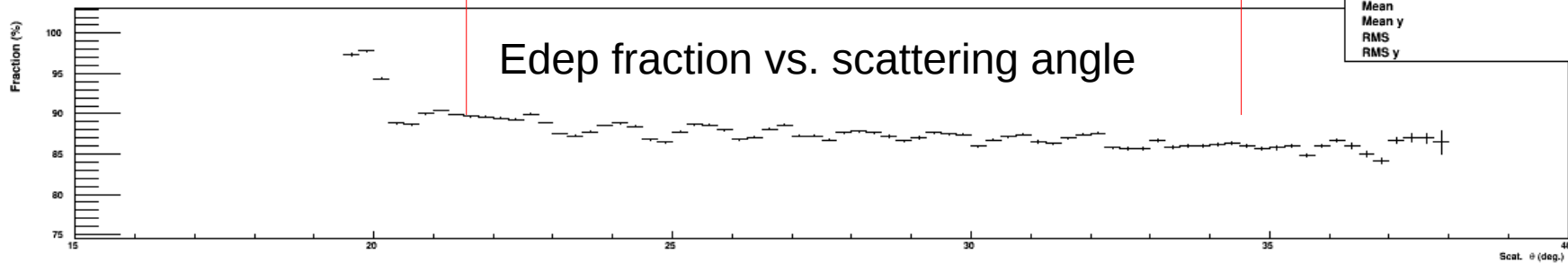


# Pre-Shower :e-

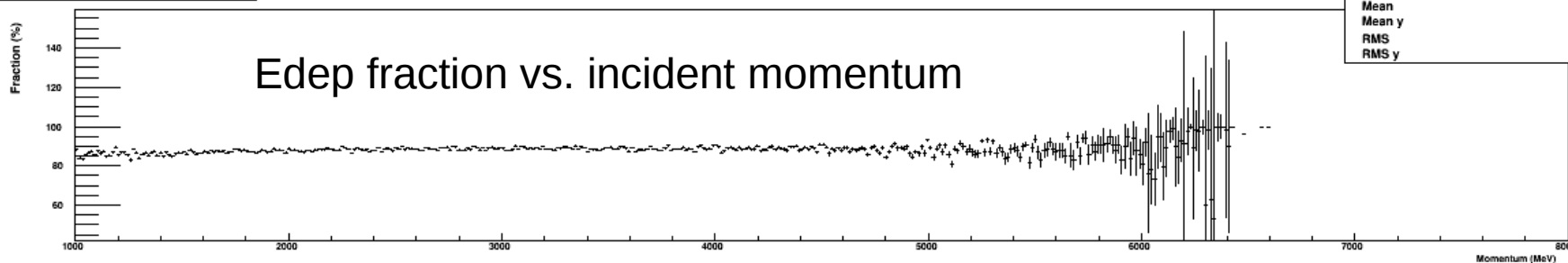
Profile of EDep Fraction vs. Ecal Radius



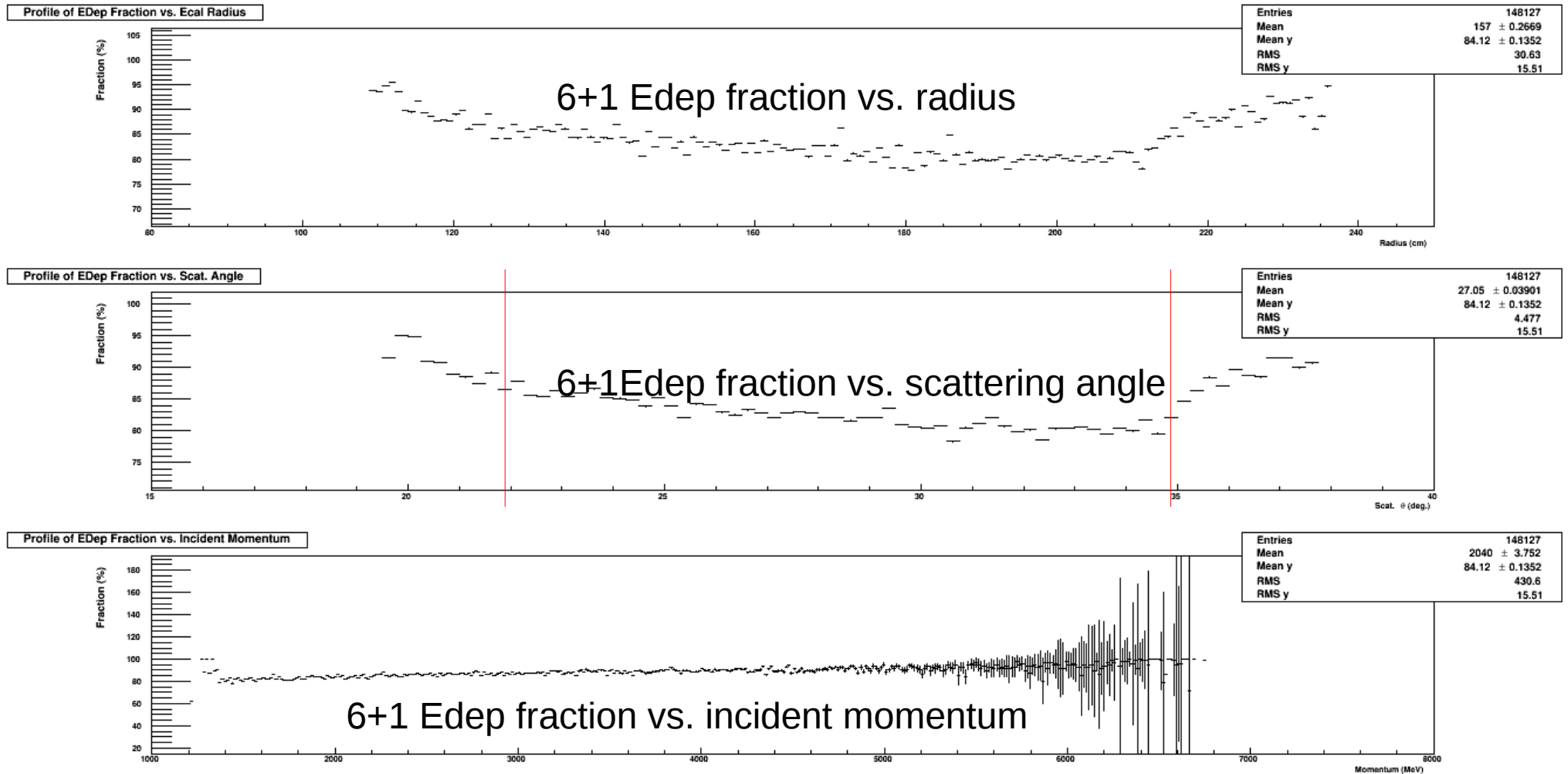
Profile of EDep Fraction vs. Scat. Angle



Profile of EDep Fraction vs. Incident Momentum

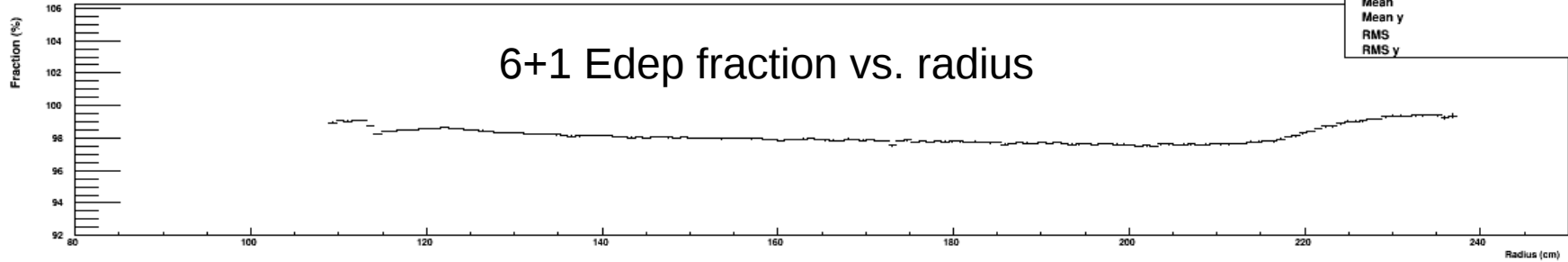


# Shower : $\pi^-$

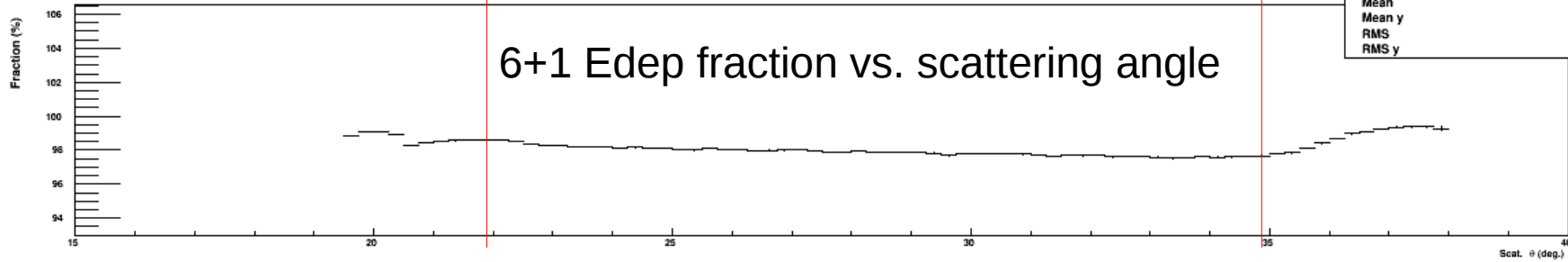


# Shower :e-

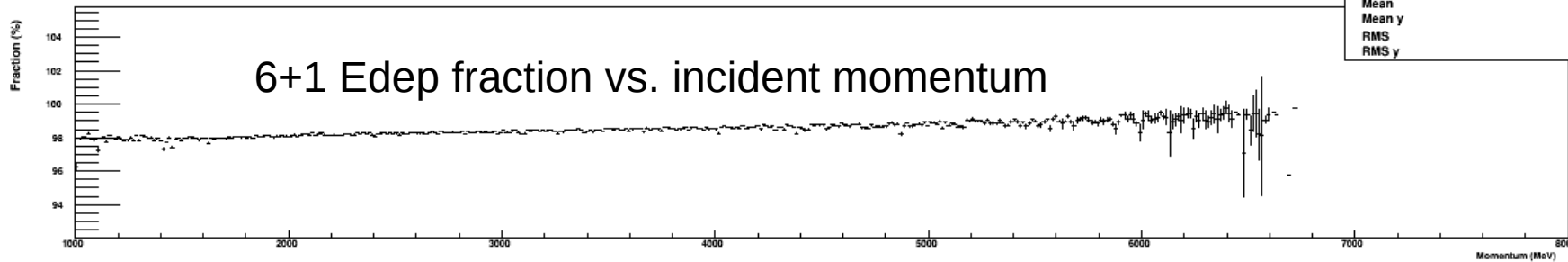
Profile of EDep Fraction vs. Ecal Radius



Profile of EDep Fraction vs. Scat. Angle



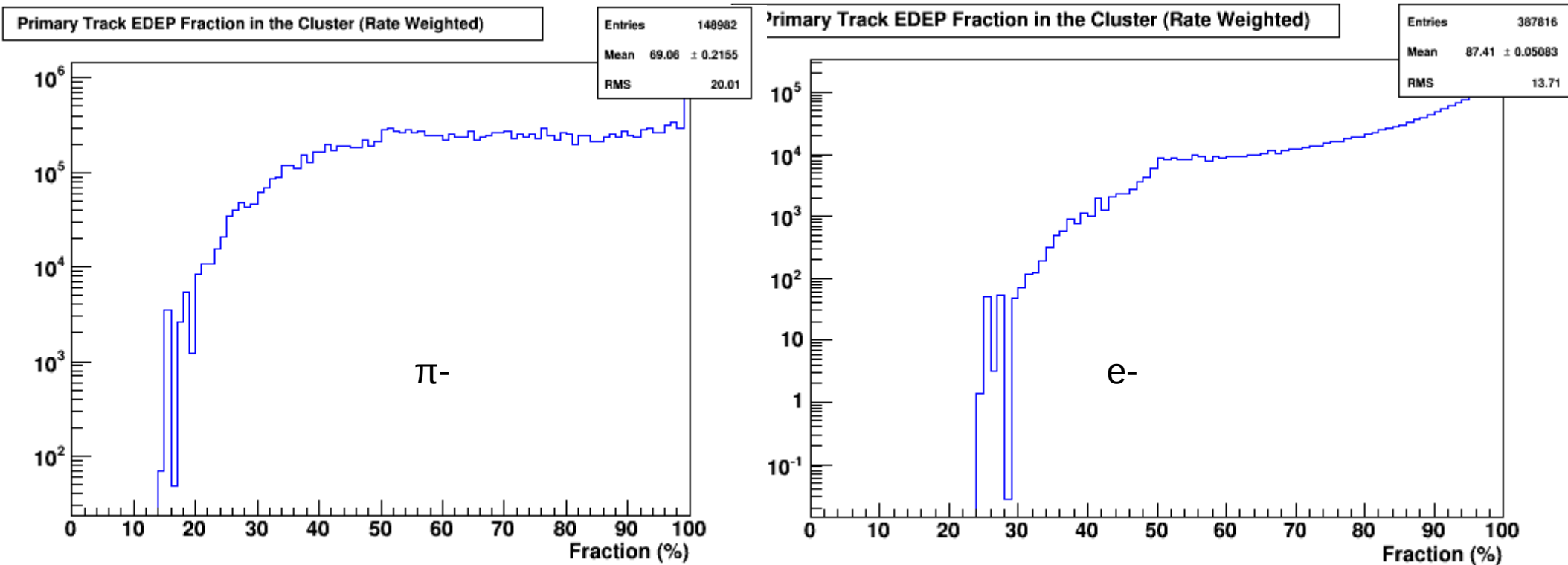
Profile of EDep Fraction vs. Incident Momentum



# Definitions

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- For each ecal block at given x,y the energy deposit is summed over all the layers:
  - **$Edep(x,y) = \sum Edep(x,y,z)$**
- By looping over  $Edep(x,y)$  blocks for each  $\pi^-$  or  $e^-$  event,
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  - Total energy deposit in the ecal for each primary event:
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- Further computed quantities at event level,
  - **$Edep\text{ fraction} = Edep(6+1)/TotalEdep$  and  $Edep(2+1)/TotalEdep$**
  - **$2+1/6+1\text{ ratio} = Edep(2+1)/Edep(6+1)$**

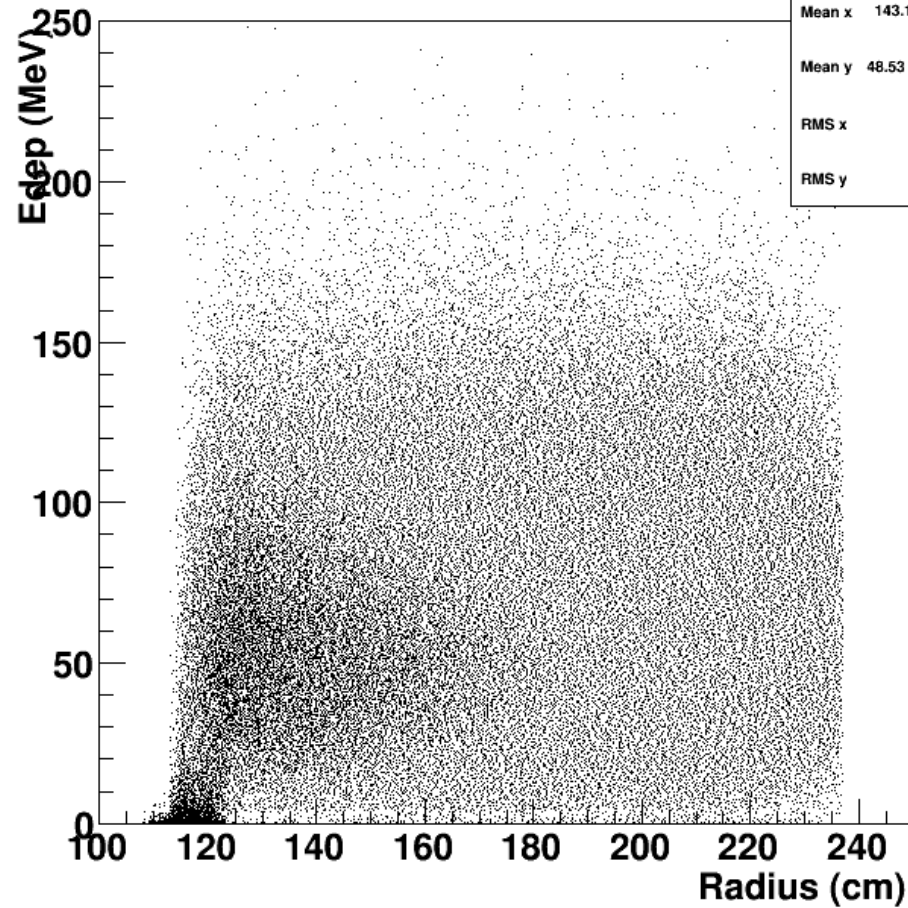
# Pre-Shower : $\pi^-$ vs $e^-$



$$\text{Edep fraction} = \text{PS\_Edep\_single\_block} / \text{PS\_TotalEdep}$$

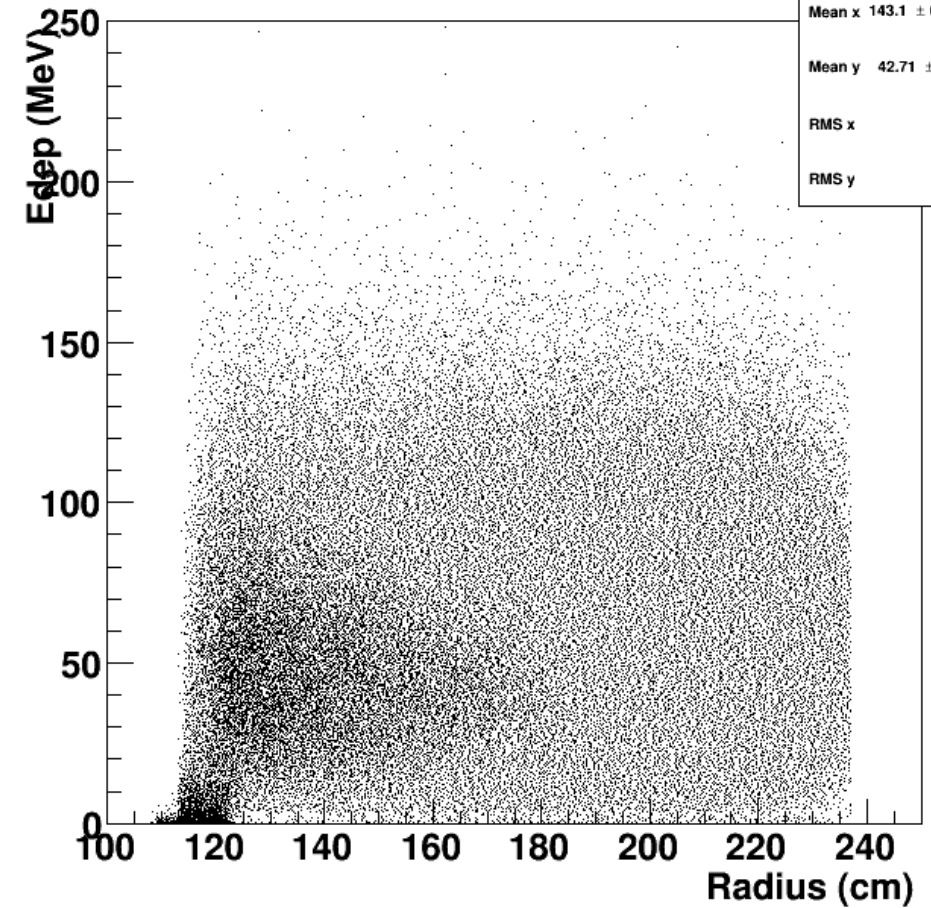
# Pre-Shower :e-

R vs. ECAL Pre-Shower Total Edep



|         |                    |
|---------|--------------------|
| Entries | 299996             |
| Mean x  | 143.1 $\pm$ 0.096  |
| Mean y  | 48.53 $\pm$ 0.1232 |
| RMS x   | 26.99              |
| RMS y   | 34.65              |

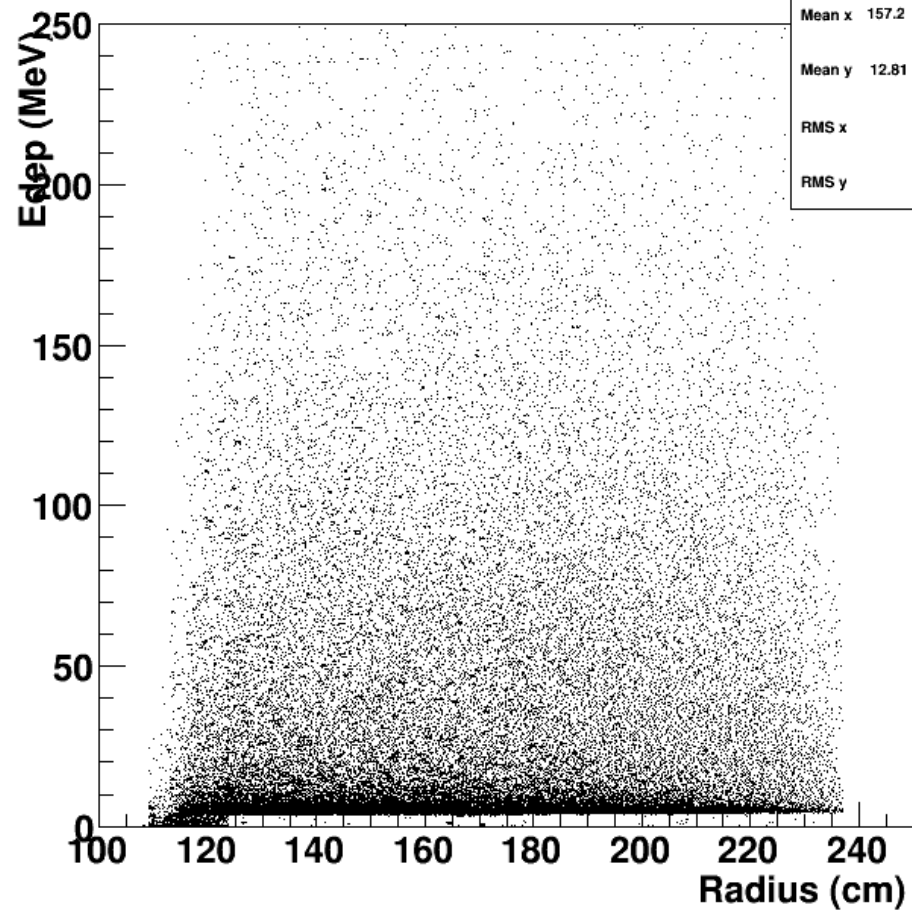
R vs. ECAL Pre-Shower Block Edep



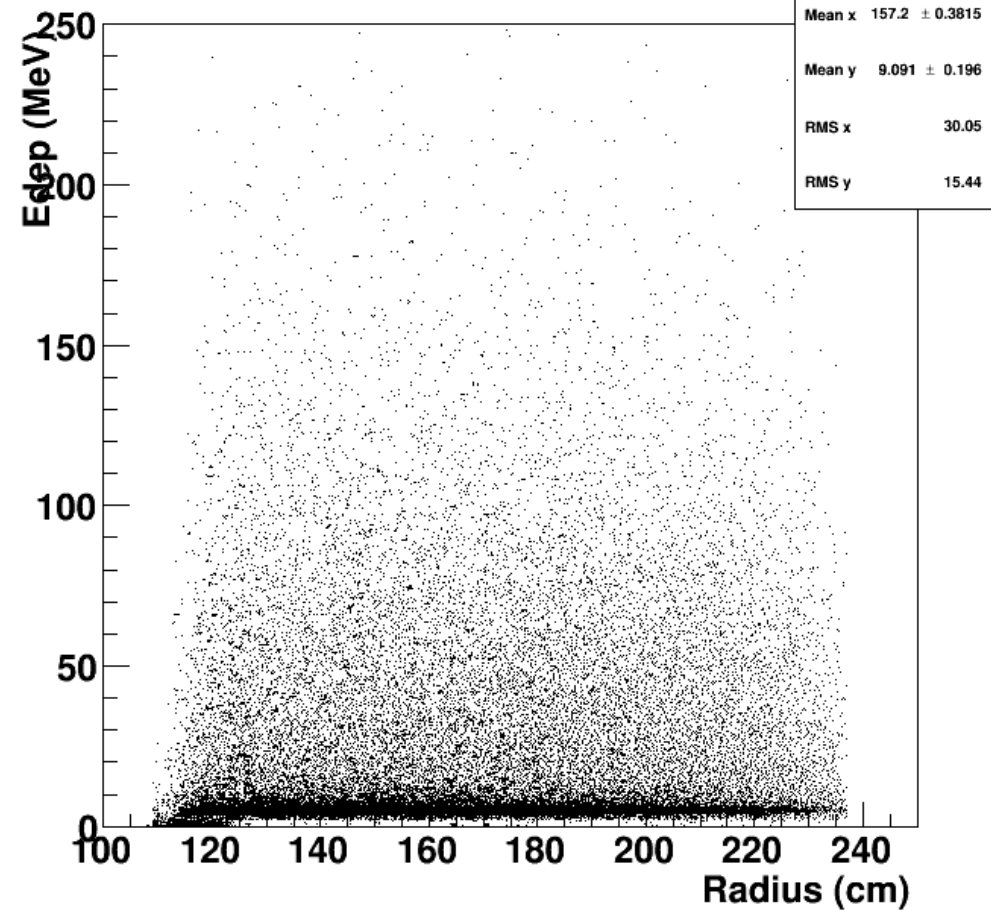
|         |                     |
|---------|---------------------|
| Entries | 299996              |
| Mean x  | 143.1 $\pm$ 0.09599 |
| Mean y  | 42.71 $\pm$ 0.1109  |
| RMS x   | 26.99               |
| RMS y   | 31.19               |

# Pre-Shower : $\pi^-$

R vs. ECAL Pre-Shower Total Edep



R vs. ECAL Pre-Shower Block Edep



# Single Events



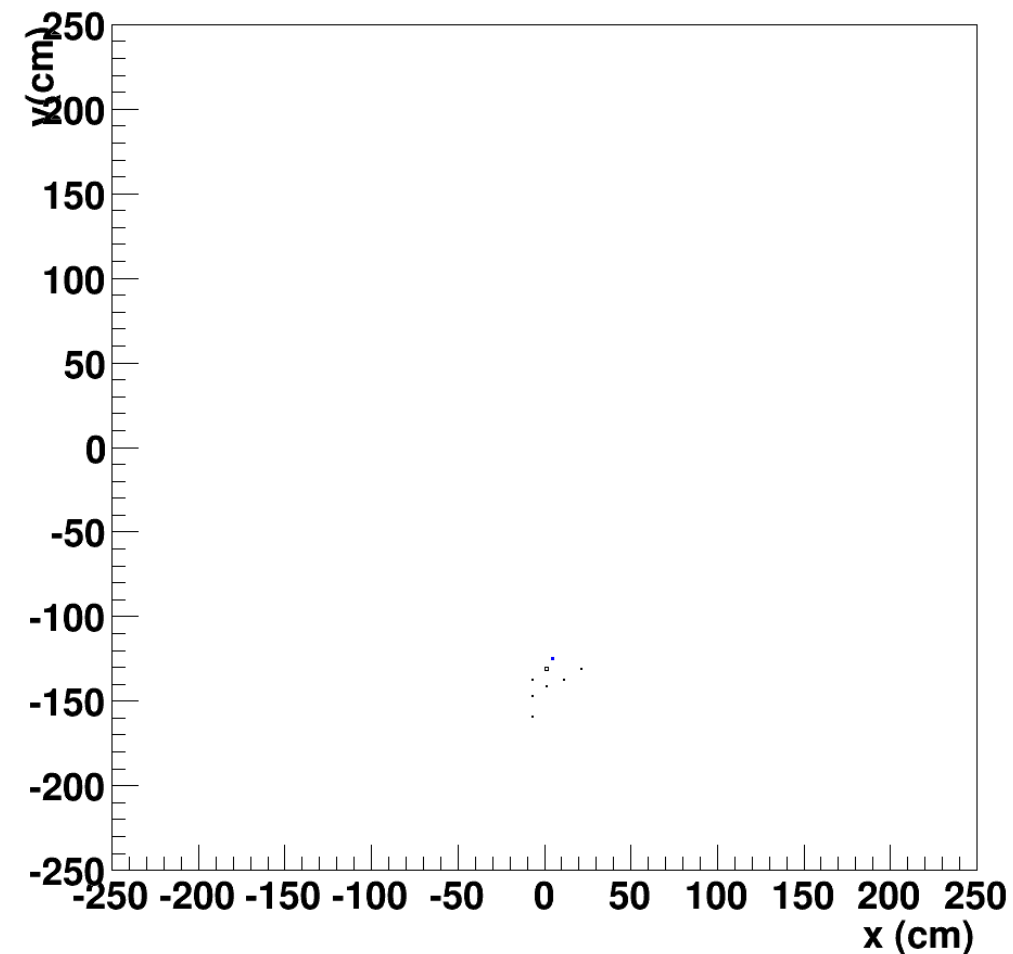
# Electron event - 1

|        |          |       |        |
|--------|----------|-------|--------|
| GEM    |          |       |        |
| Rate   | Momentum | Angle | Radius |
| (kHz)  | (MeV)    | (deg) | (cm)   |
| 0.3303 | 3882.21  | 22.15 | 124.19 |

|              |          |            |              |          |            |              |          |            |
|--------------|----------|------------|--------------|----------|------------|--------------|----------|------------|
| ECAL         |          |            | SC block sum | SC Total |            | SC block sum | SC Total |            |
| PS block sum | PS Total | percentage | 6+1          |          | percentage | 2+1          |          | percentage |
| (MeV)        | (MeV)    | (%)        | (MeV)        | (MeV)    | (%)        | (MeV)        | (MeV)    | (%)        |
| 137.88       | 140.24   | 98.3       | 710.72       | 717.64   | 99.0       | 693.77       | 717.64   | 96.7       |

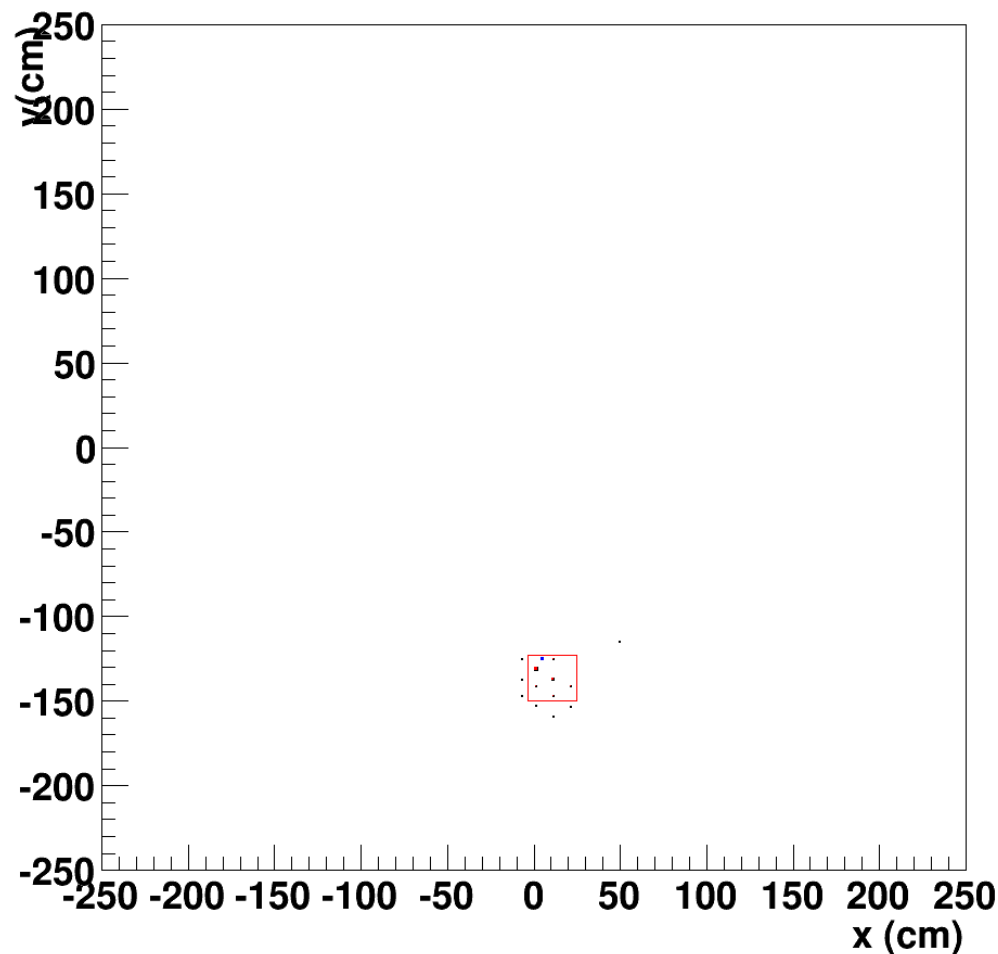
# Electron event – 1 : ECAL Hit Map

ECAL Blocks Hit Map (GEM hit in Blue)



Pre-Shower

ECAL Blocks Hit Map (GEM hit in Blue)

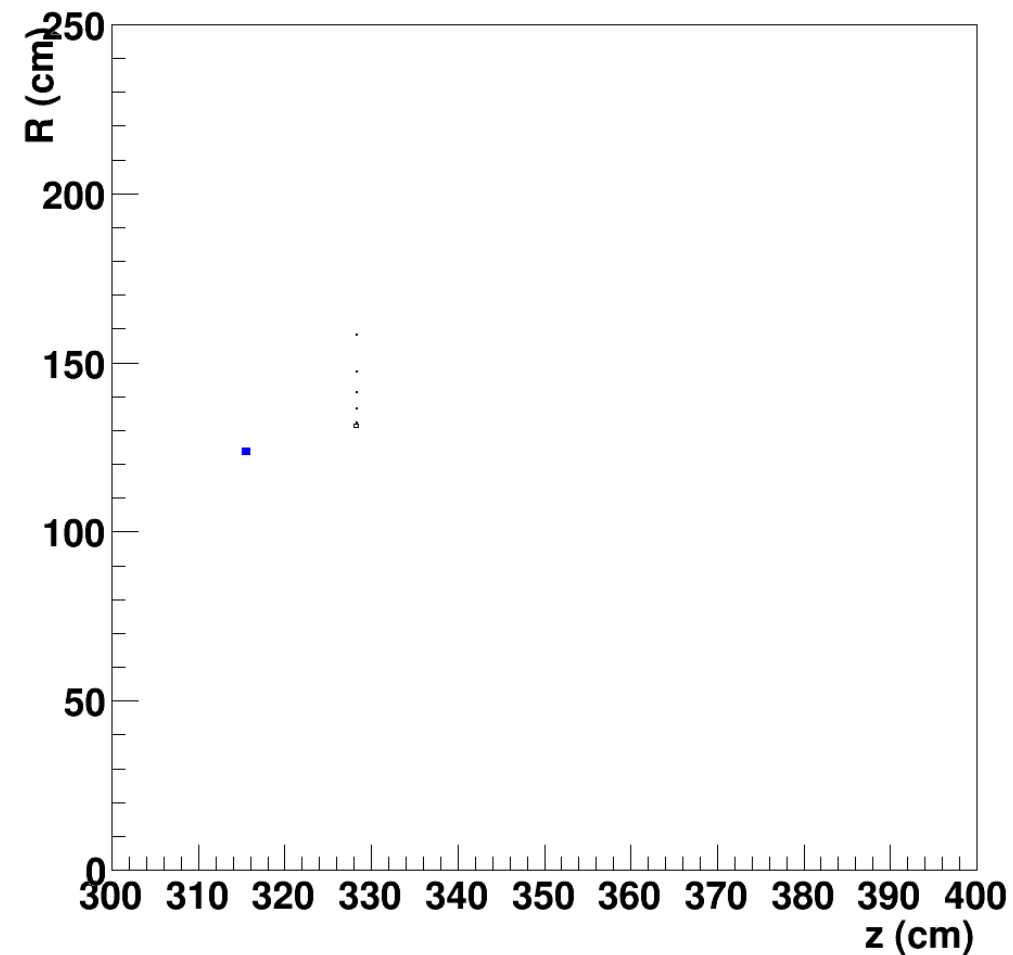


Shower

■ Hit location on the GEM  
6+1 blocks are within the box

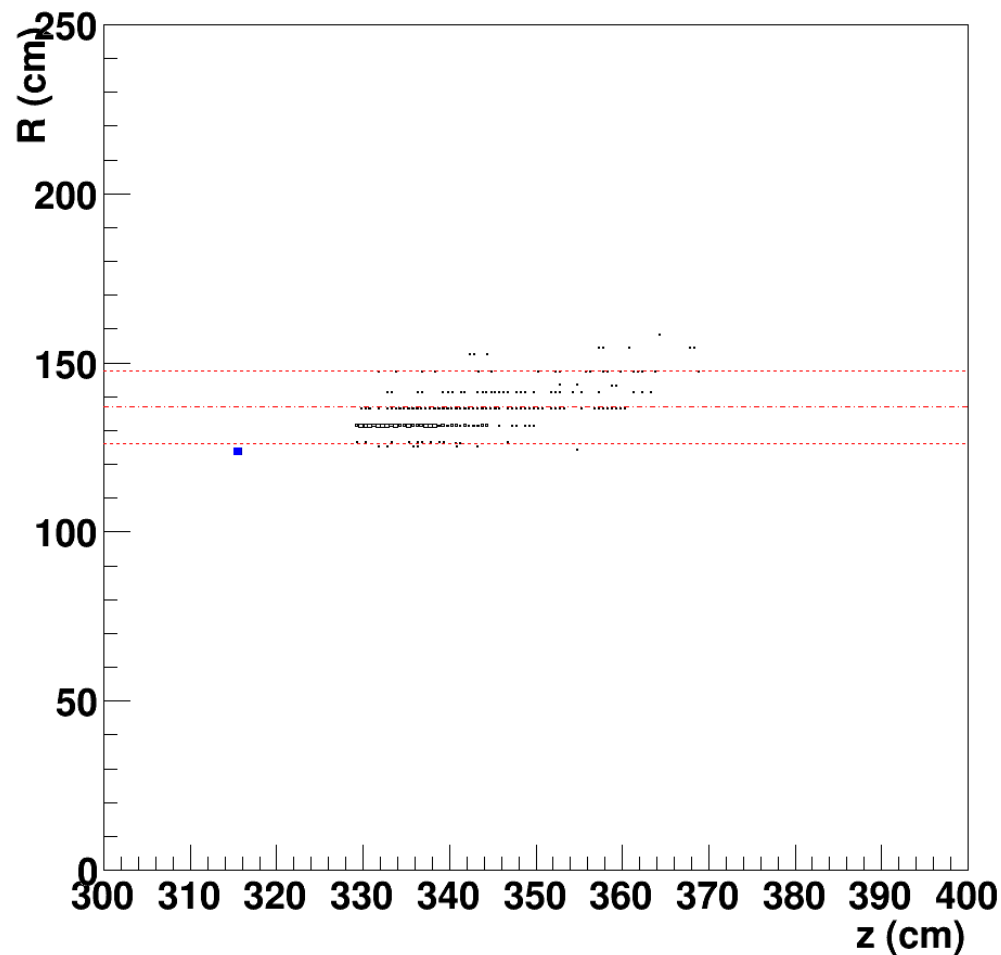
# Electron event – 1 : ECAL Hit Map

ECAL Blocks Hit Map (GEM hit in Blue)



Pre-Shower

ECAL Blocks Hit Map (GEM hit in Blue)



Shower

■ Hit location on the GEM

Radius of the center block of the 6+1 cluster

$R_{\min}$  and  $R_{\max}$  of the 6+1 cluster

# Electron event – 1 : ECAL Hit Map

| GEM       |           |           | PS        |           |          | Shower    |           |          |
|-----------|-----------|-----------|-----------|-----------|----------|-----------|-----------|----------|
| Hit Det X | Hit Det Y | Hit Det Z | Hit Det X | Hit Det Y | Edep     | Hit Det X | Hit Det Y | Edep     |
| (cm)      | (cm)      | (cm)      | (cm)      | (cm)      | (MeV)    | (cm)      | (cm)      | (MeV)    |
| 4.37      | -124.12   | 315.03    | -7.9      | -147.34   | 0.8377   | 10.9      | -147.34   | 8.0682   |
|           |           |           | 20.2      | -131.1    | 0.4855   | 48.4      | -114.86   | 0.7473   |
|           |           |           | -7.9      | -158.16   | 0.127    | 20.2      | -152.75   | 1.4062   |
|           |           |           | 1.5       | -131.1    | 137.8833 | -7.9      | -136.51   | 0.206    |
|           |           |           | -7.9      | -136.51   | 0.0974   | 1.5       | -141.93   | 16.9797  |
|           |           |           | 1.5       | -141.93   | 0.2047   | 1.5       | -152.75   | 0.1432   |
|           |           |           | 10.9      | -136.51   | 0.6073   | -7.9      | -147.34   | 1.371    |
|           |           |           |           |           |          | 10.9      | -158.16   | 0.2848   |
|           |           |           |           |           |          | 1.5       | -131.1    | 546.9128 |
|           |           |           |           |           |          | -7.9      | -125.69   | 2.7543   |
|           |           |           |           |           |          | 10.9      | -125.69   | 4.8246   |
|           |           |           |           |           |          | 10.9      | -136.51   | 129.8757 |
|           |           |           |           |           |          | 20.20     | -141.93   | 4.06     |

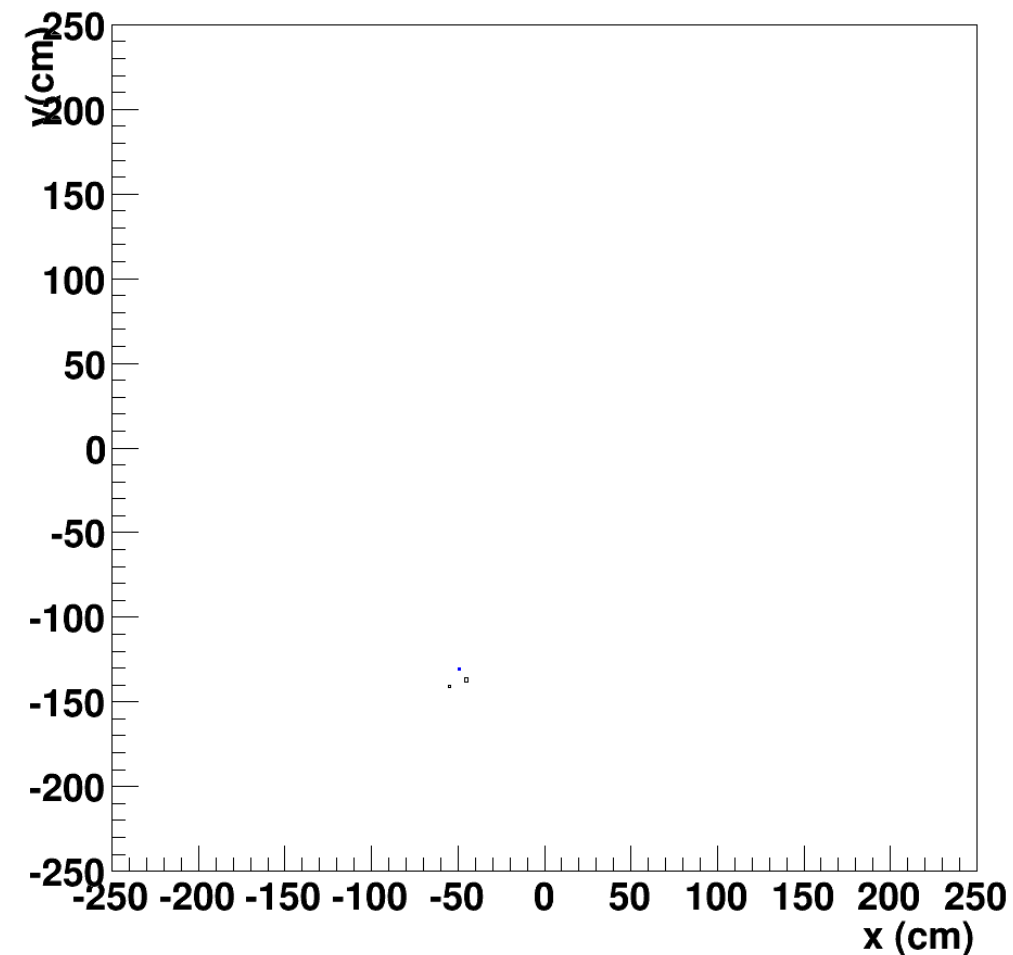
# Electron event - 2

|        |          |       |        |
|--------|----------|-------|--------|
| GEM    |          |       |        |
| Rate   | Momentum | Angle | Radius |
| (kHz)  | (MeV)    | (deg) | (cm)   |
| 1.3884 | 2685.05  | 24.7  | 140.29 |

|              |          |            |              |          |            |              |          |            |
|--------------|----------|------------|--------------|----------|------------|--------------|----------|------------|
| ECAL         |          |            | SC block sum | SC Total |            | SC block sum | SC Total |            |
| PS block sum | PS Total | percentage | 6+1          |          | percentage | 2+1          |          | percentage |
| (MeV)        | (MeV)    | (%)        | (MeV)        | (MeV)    | (%)        | (MeV)        | (MeV)    | (%)        |
| 17.13        | 25.94    | 66.0       | 537.75       | 551.9    | 97.4       | 477.56       | 551.9    | 86.5       |

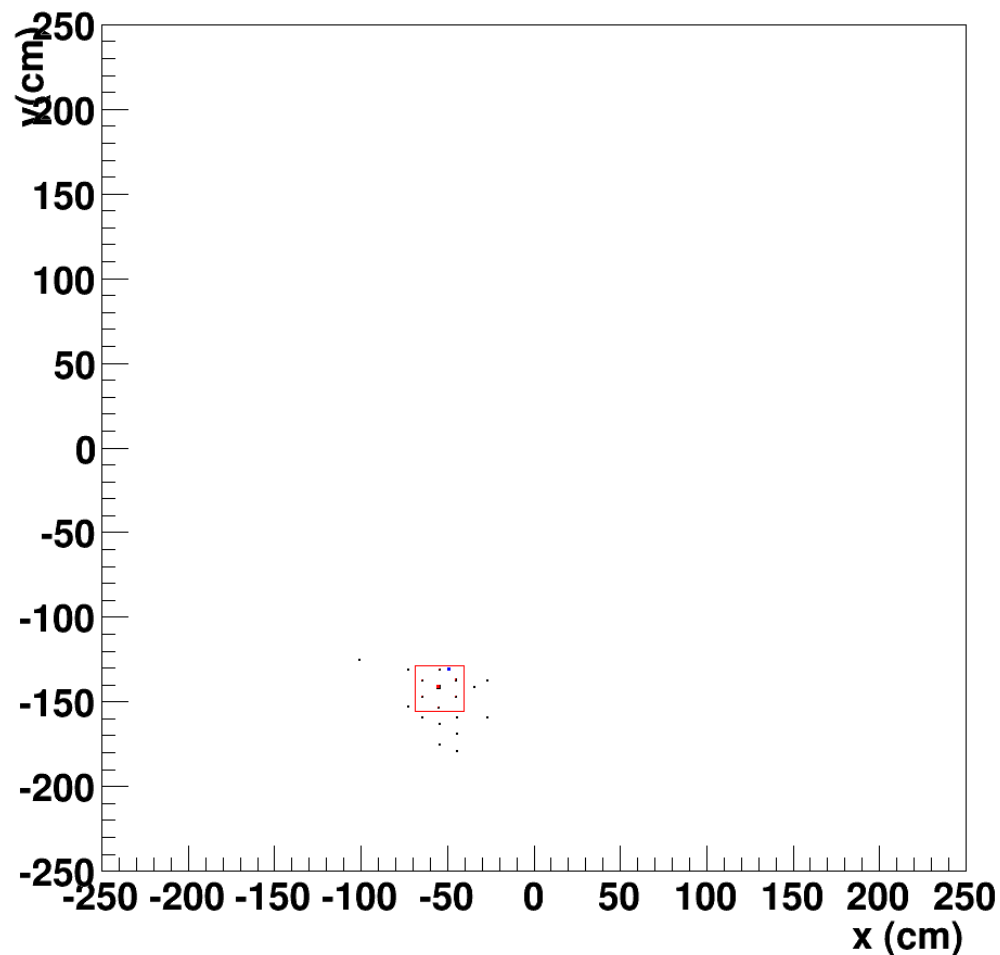
# Electron event – 2 : ECAL Hit Map

ECAL Blocks Hit Map (GEM hit in Blue)



Pre-Shower

ECAL Blocks Hit Map (GEM hit in Blue)



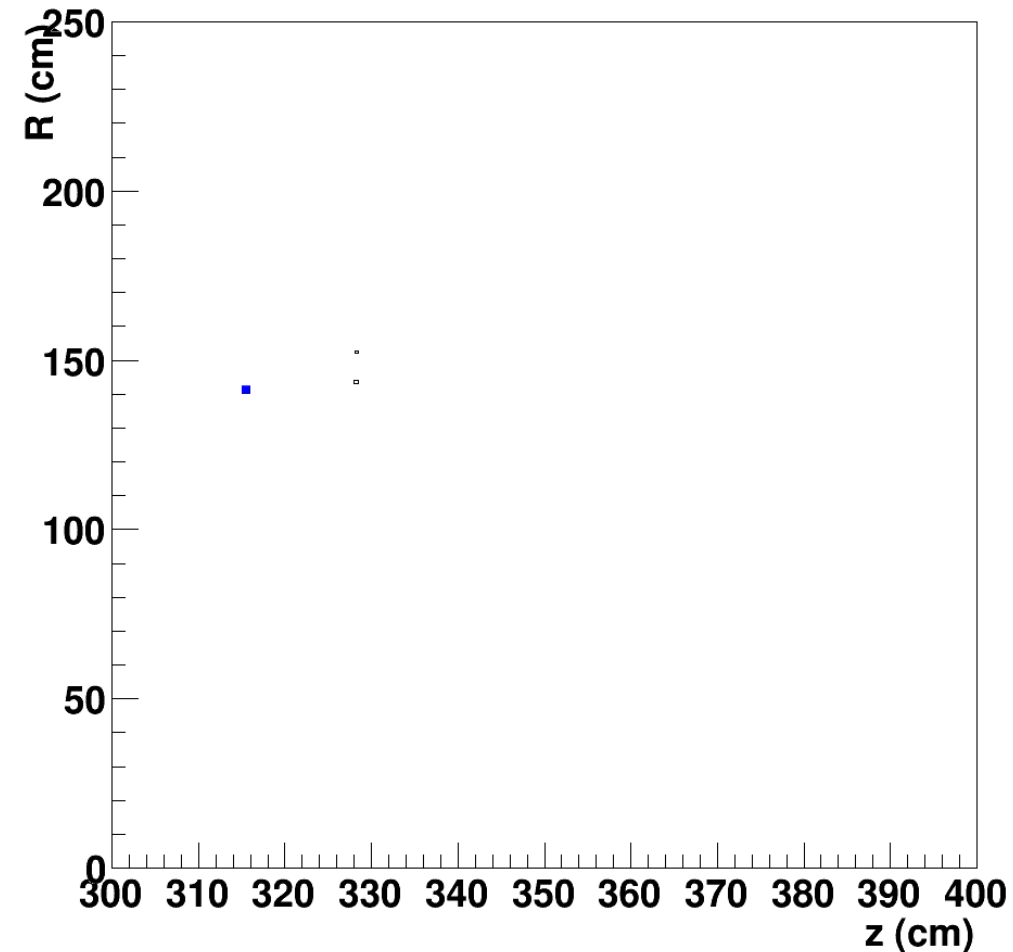
Shower

■ Hit location on the GEM

6+1 blocks are within the box

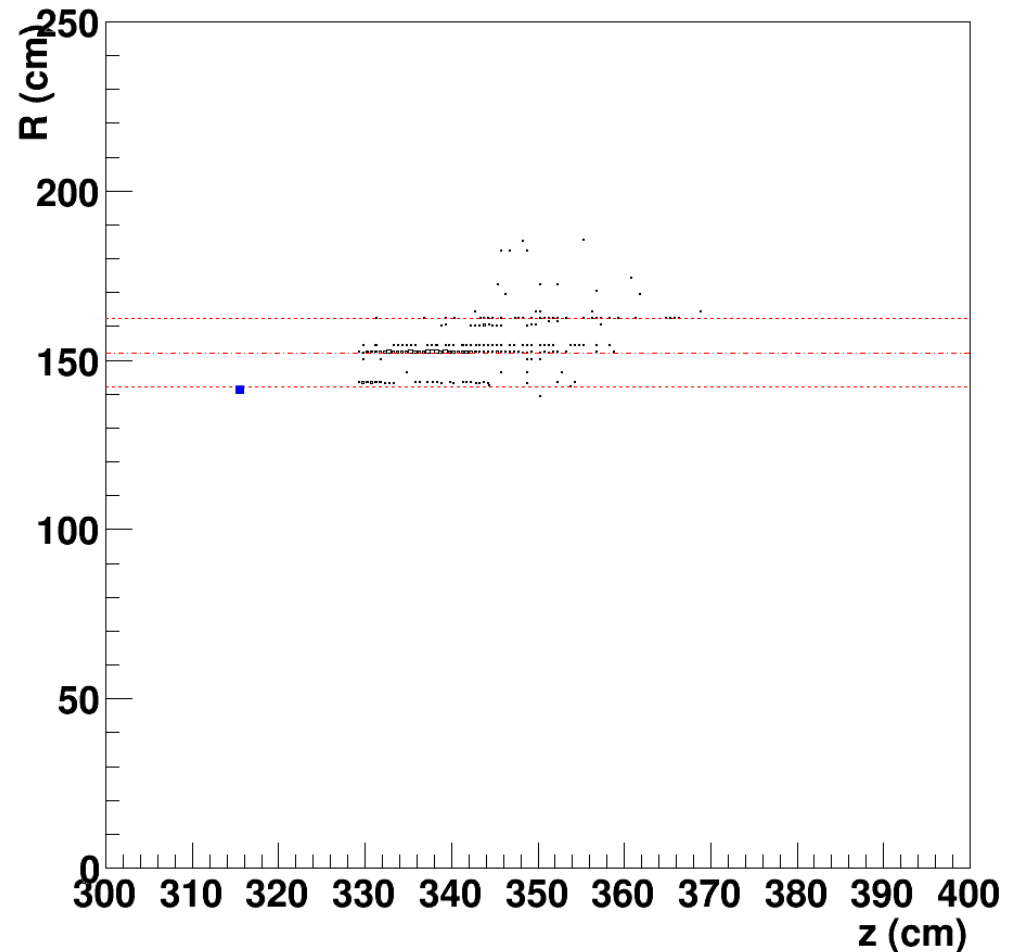
# Electron event – 2 : ECAL Hit Map

ECAL Blocks Hit Map (GEM hit in Blue)



Pre-Shower

ECAL Blocks Hit Map (GEM hit in Blue)



Shower

■ Hit location on the GEM

■ Radius of the center block of the 6+1 cluster

$R_{\min}$  and  $R_{\max}$  of the 6+1 cluster

# Electron event – 2 : ECAL Hit Map

| GEM       |           |           | PS        |           |       | Shower    |           |        |
|-----------|-----------|-----------|-----------|-----------|-------|-----------|-----------|--------|
| Hit Det X | Hit Det Y | Hit Det Z | Hit Det X | Hit Det Y | Edep  | Hit Det X | Hit Det Y | Edep   |
| (cm)      | (cm)      | (cm)      | (cm)      | (cm)      | (MeV) | (cm)      | (cm)      | (MeV)  |
| -48.08    | -131.79   | 315.03    | -54.80    | -141.93   | 8.81  | -101.60   | -125.69   | 2.43   |
|           |           |           | -45.40    | -136.51   | 17.13 | -26.60    | -136.51   | 0.20   |
|           |           |           |           |           |       | -45.40    | -168.99   | 0.19   |
|           |           |           |           |           |       | -54.80    | -141.93   | 386.51 |
|           |           |           |           |           |       | -54.80    | -174.40   | 0.70   |
|           |           |           |           |           |       | -45.40    | -158.16   | 3.49   |
|           |           |           |           |           |       | -45.40    | -136.51   | 45.03  |
|           |           |           |           |           |       | -45.40    | -147.34   | 65.52  |
|           |           |           |           |           |       | -64.10    | -158.16   | 0.59   |
|           |           |           |           |           |       | -36.00    | -141.93   | 3.94   |
|           |           |           |           |           |       | -54.80    | -131.10   | 0.20   |
|           |           |           |           |           |       | -73.50    | -152.75   | 0.40   |
|           |           |           |           |           |       | -54.80    | -163.57   | 0.73   |
|           |           |           |           |           |       | -64.10    | -136.51   | 0.56   |
|           |           |           |           |           |       | -26.60    | -158.16   | 0.00   |
|           |           |           |           |           |       | -64.10    | -147.34   | 14.40  |
|           |           |           |           |           |       | -54.80    | -152.75   | 25.53  |
|           |           |           |           |           |       | -45.40    | -179.81   | 0.34   |
|           |           |           |           |           |       | -73.50    | -131.10   | 1.12   |



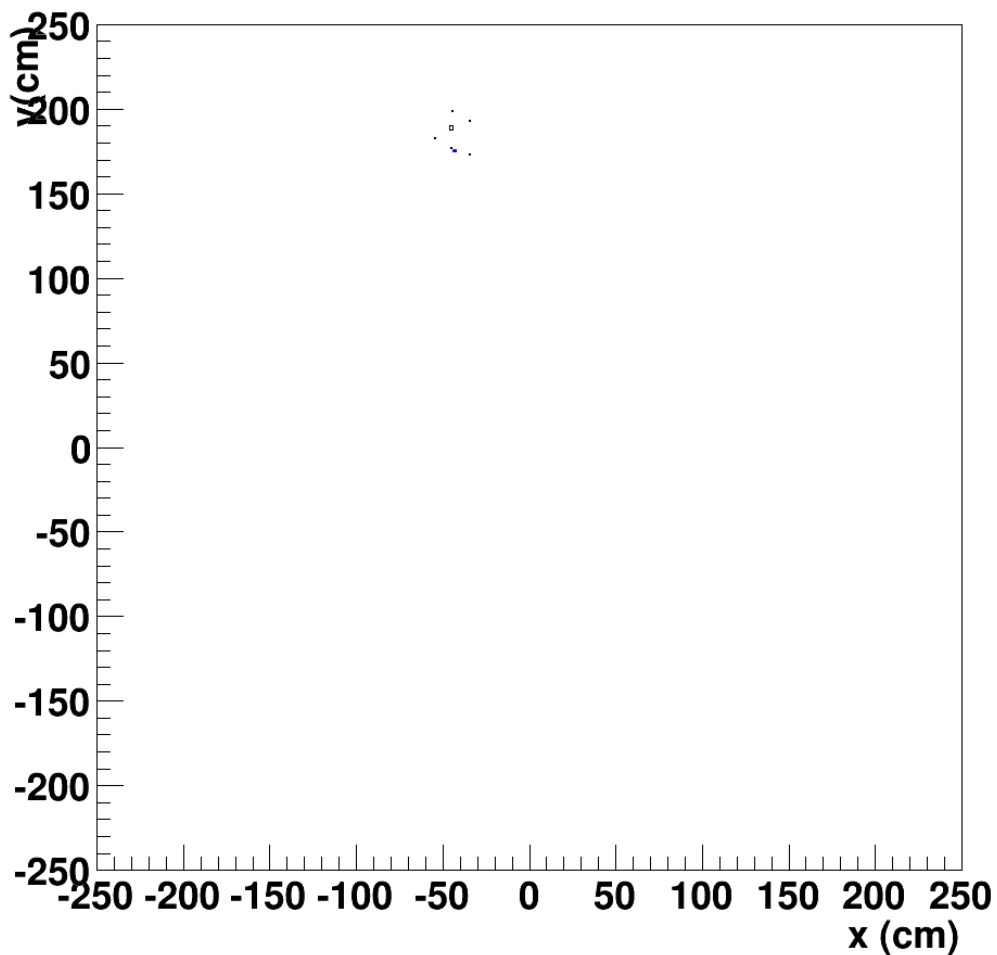
# Electron event - 3

|        |          |       |        |
|--------|----------|-------|--------|
| GEM    |          |       |        |
| Rate   | Momentum | Angle | Radius |
| (kHz)  | (MeV)    | (deg) | (cm)   |
| 0.0122 | 1193.33  | 30.67 | 180.89 |

|              |          |            |              |          |            |              |          |            |
|--------------|----------|------------|--------------|----------|------------|--------------|----------|------------|
| ECAL         |          |            | SC block sum | SC Total |            | SC block sum | SC Total |            |
| PS block sum | PS Total | percentage | 6+1          |          | percentage | 2+1          |          | percentage |
| (MeV)        | (MeV)    | (%)        | (MeV)        | (MeV)    | (%)        | (MeV)        | (MeV)    | (%)        |
| 76.17        | 89.53    | 85.1       | 615.56       | 624.45   | 98.6       | 565.18       | 624.45   | 90.5       |

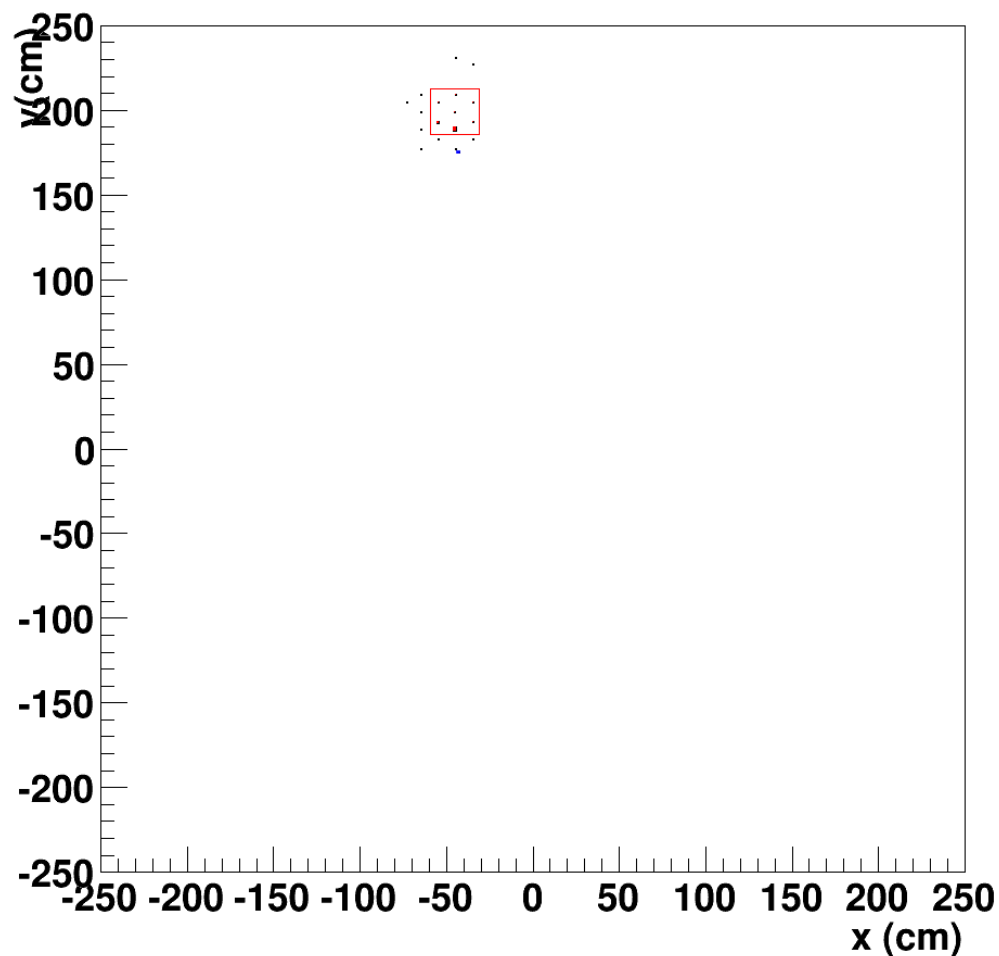
# Electron event – 3 : ECAL Hit Map

ECAL Blocks Hit Map (GEM hit in Blue)



Pre-Shower

ECAL Blocks Hit Map (GEM hit in Blue)



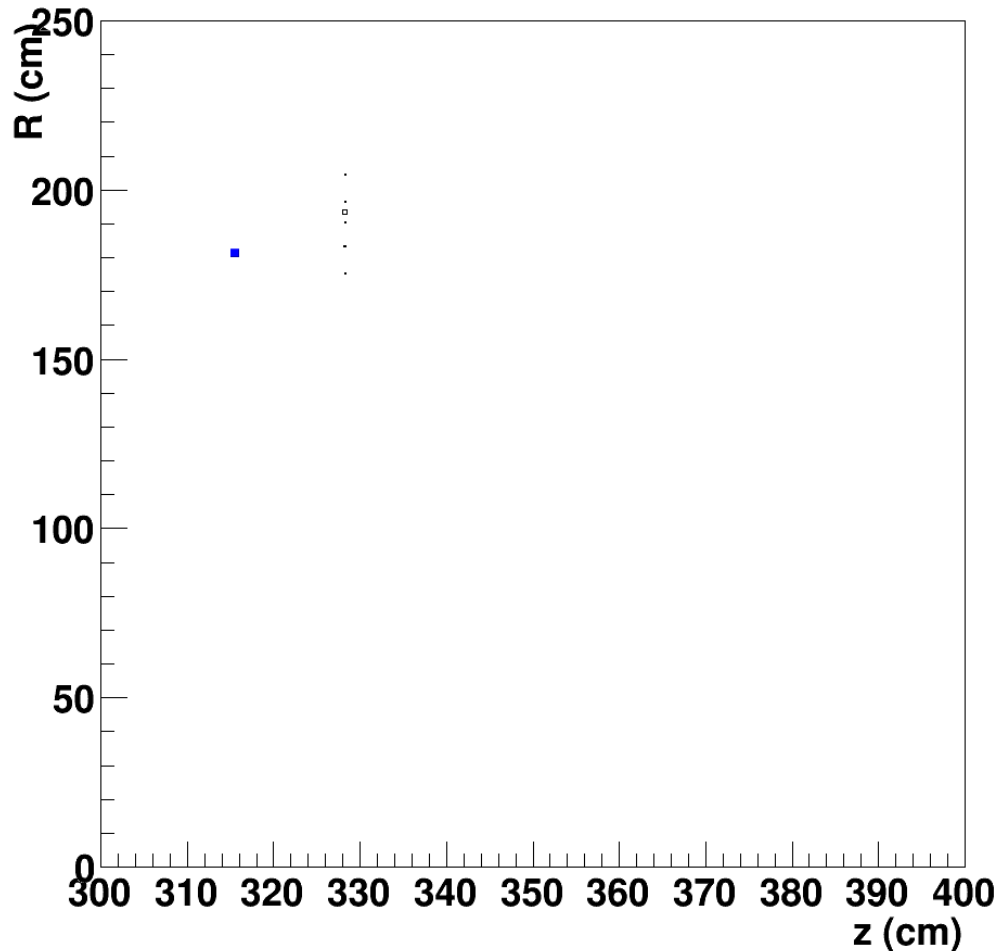
Shower

■ Hit location on the GEM

6+1 blocks are within the box

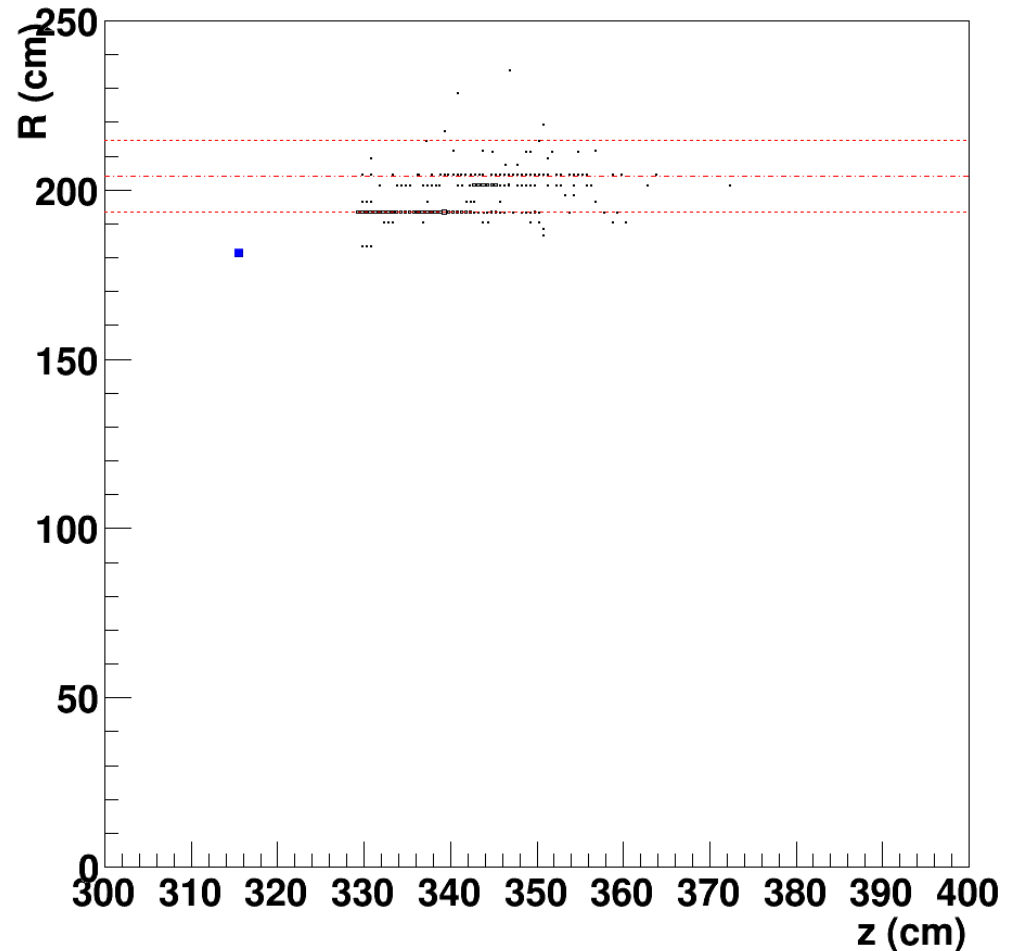
# Electron event – 3 : ECAL Hit Map

ECAL Blocks Hit Map (GEM hit in Blue)



Pre-Shower

ECAL Blocks Hit Map (GEM hit in Blue)



Shower

■ Hit location on the GEM

Radius of the center block of the 6+1 cluster

$R_{\min}$  and  $R_{\max}$  of the 6+1 cluster

# Electron event – 3 : ECAL Hit Map

| GEM       |           |           | PS        |           |       | Shower    |           |        |
|-----------|-----------|-----------|-----------|-----------|-------|-----------|-----------|--------|
| Hit Det X | Hit Det Y | Hit Det Z | Hit Det X | Hit Det Y | Edep  | Hit Det X | Hit Det Y | Edep   |
| (cm)      | (cm)      | (cm)      | (cm)      | (cm)      | (MeV) | (cm)      | (cm)      | (MeV)  |
| -43.43    | 175.60    | 315.03    | -36.00    | 193.65    | 0.69  | -45.40    | 199.06    | 43.07  |
|           |           |           | -45.40    | 199.06    | 0.40  | -36.00    | 204.47    | 1.14   |
|           |           |           | -36.00    | 172.00    | 0.31  | -45.40    | 188.24    | 441.65 |
|           |           |           | -45.40    | 177.41    | 11.84 | -73.50    | 204.47    | 0.83   |
|           |           |           | -45.40    | 188.24    | 76.17 | -54.80    | 193.65    | 118.65 |
|           |           |           | -54.80    | 182.82    | 0.11  | -64.10    | 177.41    | 0.06   |
|           |           |           |           |           |       | -64.10    | 199.06    | 0.67   |
|           |           |           |           |           |       | -45.40    | 209.89    | 1.76   |
|           |           |           |           |           |       | -36.00    | 193.65    | 5.00   |
|           |           |           |           |           |       | -36.00    | 182.82    | 0.26   |
|           |           |           |           |           |       | -64.10    | 209.89    | 0.38   |
|           |           |           |           |           |       | -45.40    | 231.54    | 0.03   |
|           |           |           |           |           |       | -36.00    | 226.12    | 0.07   |
|           |           |           |           |           |       | -54.80    | 204.47    | 4.30   |
|           |           |           |           |           |       | -45.40    | 177.41    | 0.88   |
|           |           |           |           |           |       | -64.10    | 188.24    | 0.84   |
|           |           |           |           |           |       | -54.80    | 182.82    | 4.89   |

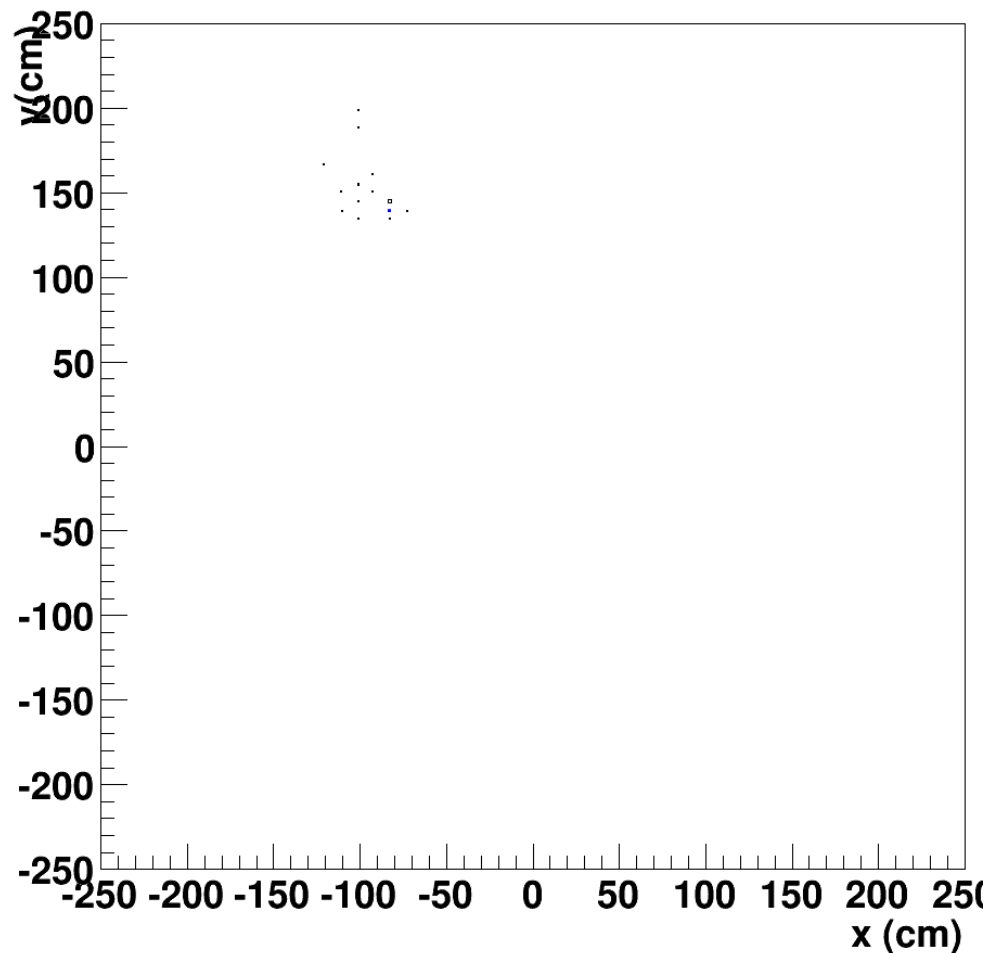
# $\pi$ - event - 1

|         |          |       |        |
|---------|----------|-------|--------|
| GEM     |          |       |        |
| Rate    | Momentum | Angle | Radius |
| (kHz)   | (MeV)    | (deg) | (cm)   |
| 14.1405 | 2321.19  | 27.91 | 161.58 |

|              |          |            |              |          |            |              |          |            |
|--------------|----------|------------|--------------|----------|------------|--------------|----------|------------|
| ECAL         |          |            | SC block sum | SC Total |            | SC block sum | SC Total |            |
| PS block sum | PS Total | percentage | 6+1          |          | percentage | 2+1          |          | percentage |
| (MeV)        | (MeV)    | (%)        | (MeV)        | (MeV)    | (%)        | (MeV)        | (MeV)    | (%)        |
| 24.29        | 37.38    | 65.0       | 379.29       | 514.82   | 73.7       | 291.05       | 514.82   | 56.5       |

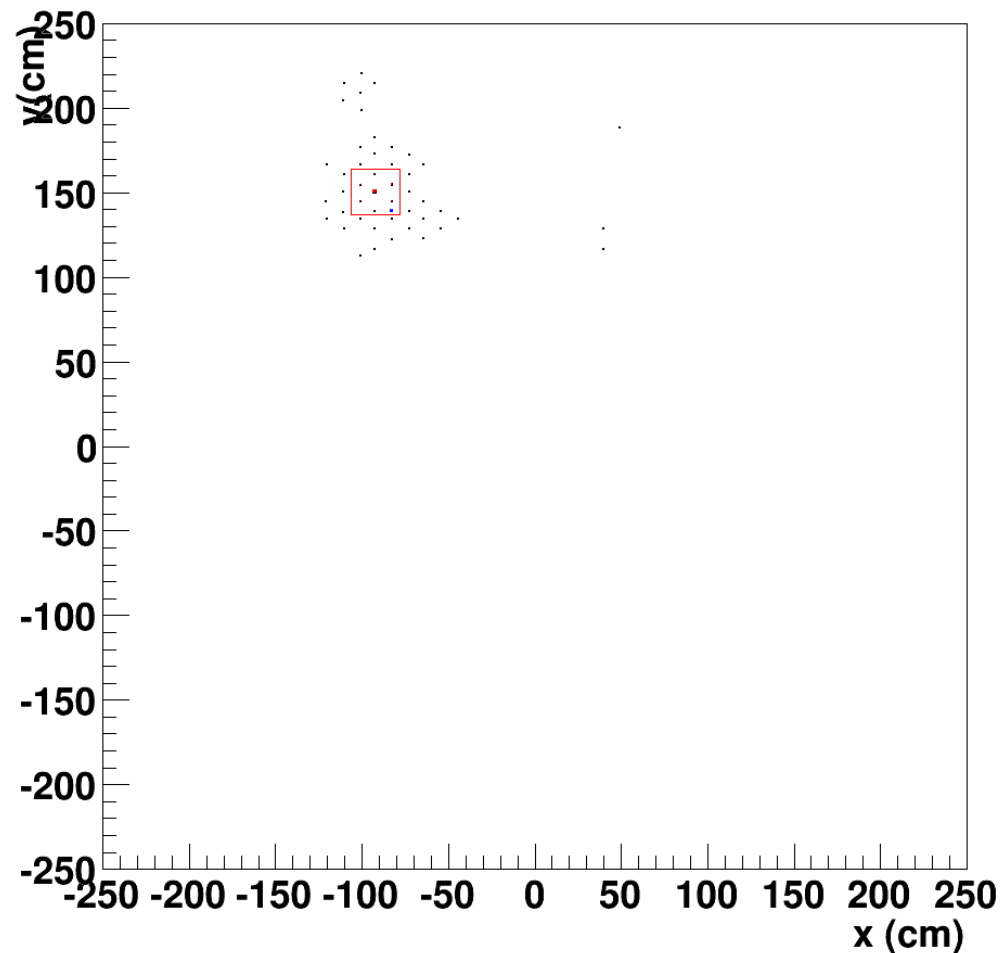
# $\pi$ - event – 1 : ECAL Hit Map

ECAL Blocks Hit Map (GEM hit in Blue)



Pre-Shower

ECAL Blocks Hit Map (GEM hit in Blue)

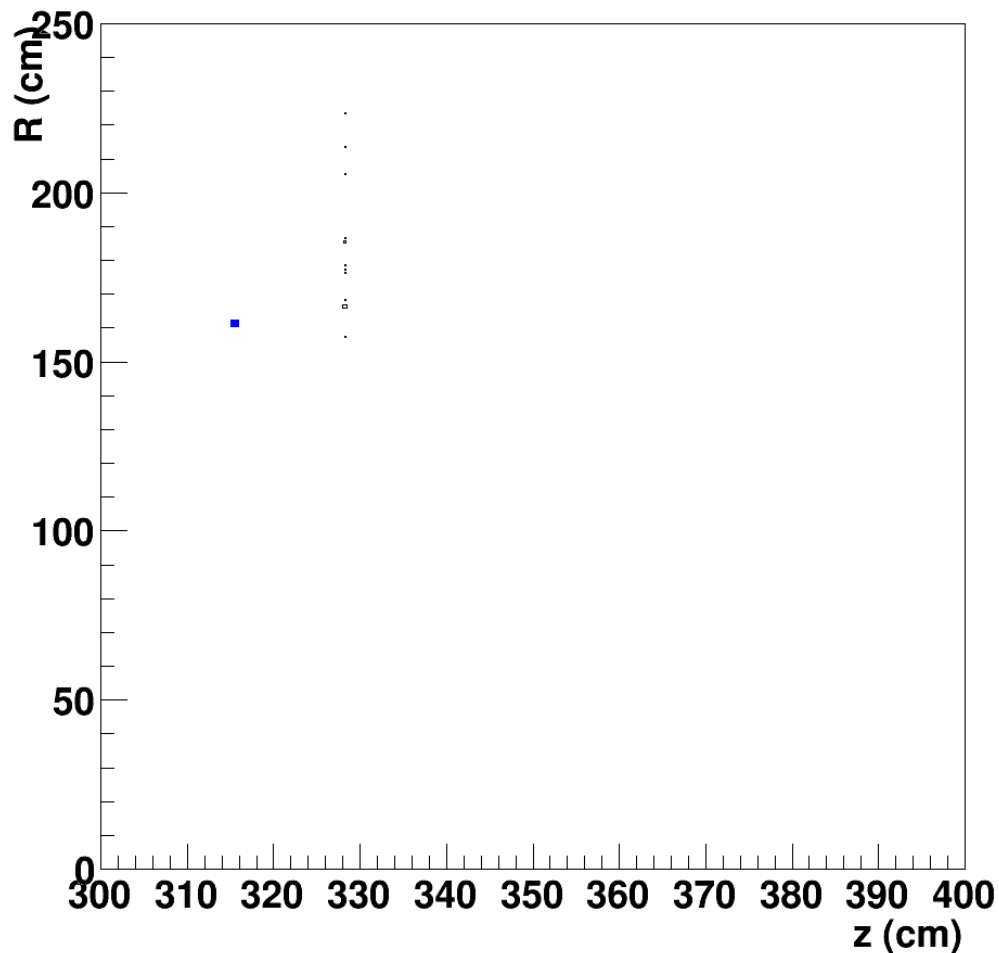


Shower

■ Hit location on the GEM  
6+1 blocks are within the box

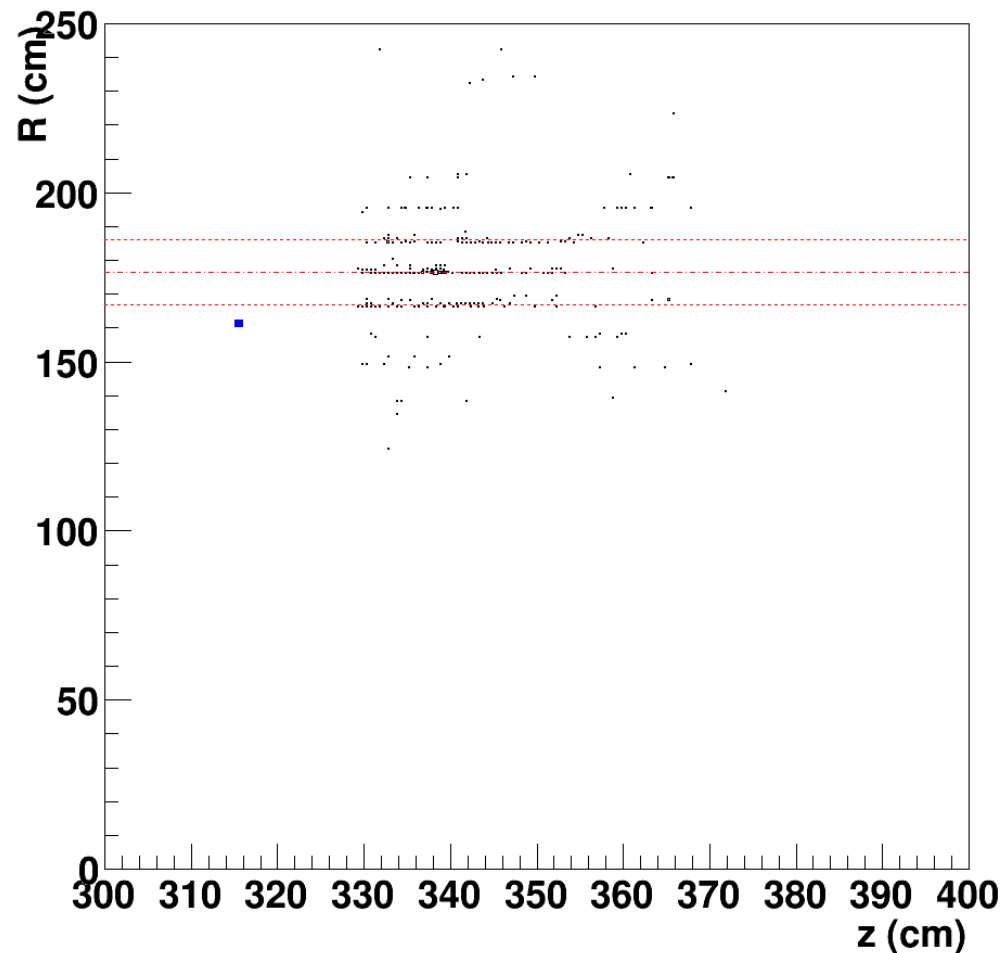
# $\pi^-$ event – 1 : ECAL Hit Map

ECAL Blocks Hit Map (GEM hit in Blue)



Pre-Shower

ECAL Blocks Hit Map (GEM hit in Blue)



Shower

■ Hit location on the GEM

Radius of the center block of the 6+1 cluster

$R_{\min}$  and  $R_{\max}$  of the 6+1 cluster

# $\pi^-$ event – 1 : ECAL Hit Map

[illegible]



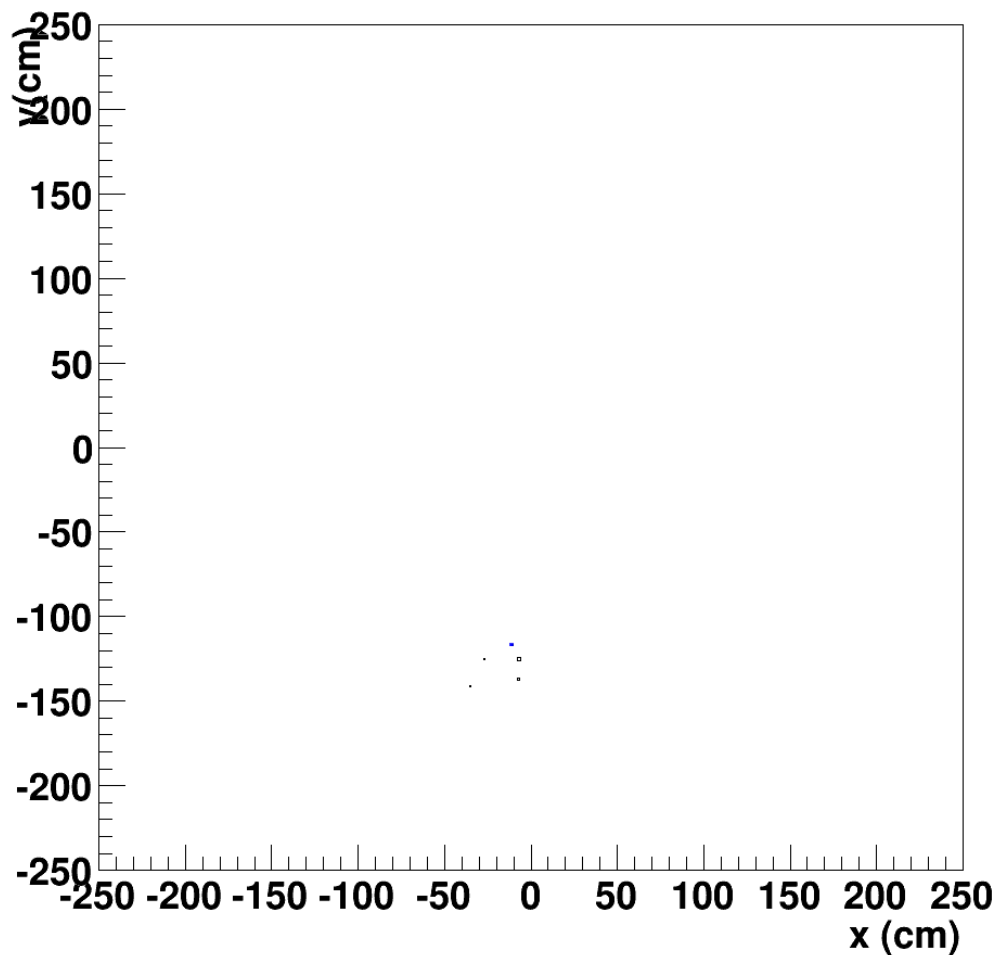
# $\pi$ - event - 2

|         |          |       |        |
|---------|----------|-------|--------|
| GEM     |          |       |        |
| Rate    | Momentum | Angle | Radius |
| (kHz)   | (MeV)    | (deg) | (cm)   |
| 54.5284 | 2624.51  | 21.07 | 117.54 |

|              |          |            |              |          |            |              |          |            |
|--------------|----------|------------|--------------|----------|------------|--------------|----------|------------|
| ECAL         |          |            | SC block sum | SC Total |            | SC block sum | SC Total |            |
| PS block sum | PS Total | percentage | 6+1          |          | percentage | 2+1          |          | percentage |
| (MeV)        | (MeV)    | (%)        | (MeV)        | (MeV)    | (%)        | (MeV)        | (MeV)    | (%)        |
| 4.91         | 7.37     | 66.6       | 604.79       | 642.11   | 94.2       | 563.7        | 642.11   | 87.8       |

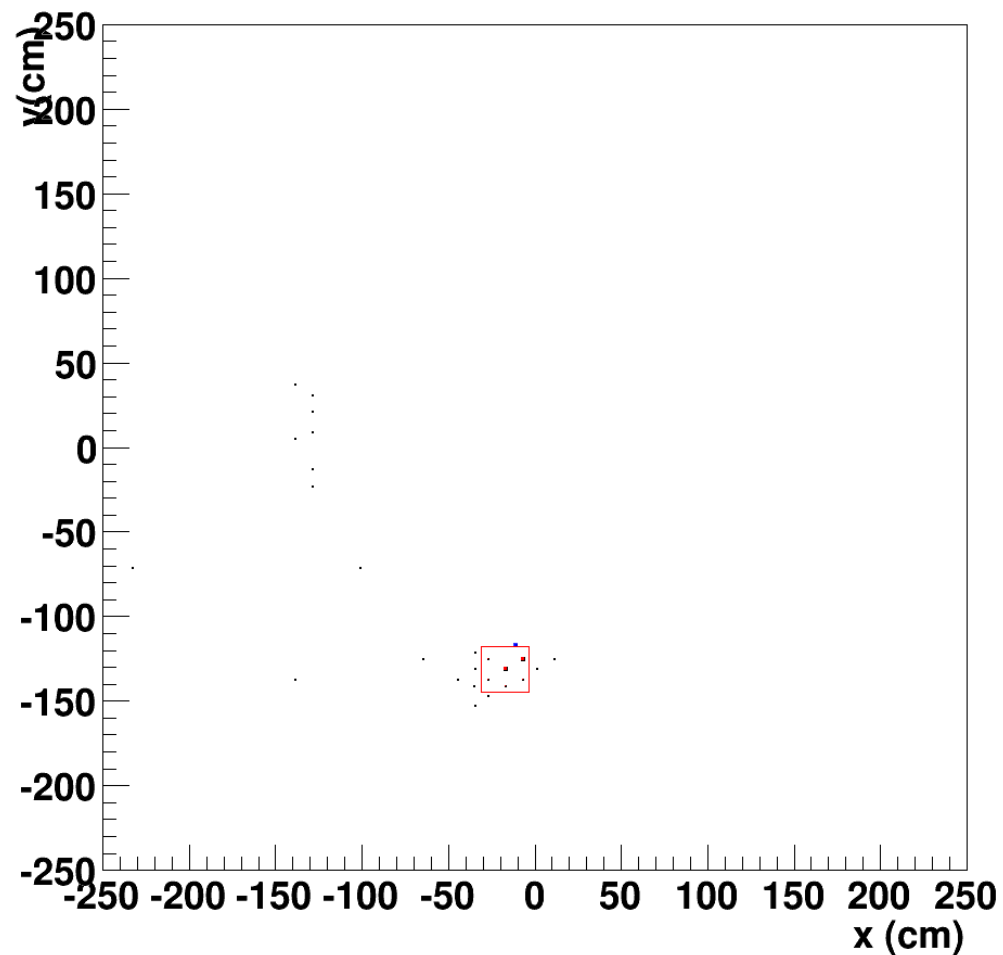
# $\pi$ - event – 2 : ECAL Hit Map

ECAL Blocks Hit Map (GEM hit in Blue)



Pre-Shower

ECAL Blocks Hit Map (GEM hit in Blue)

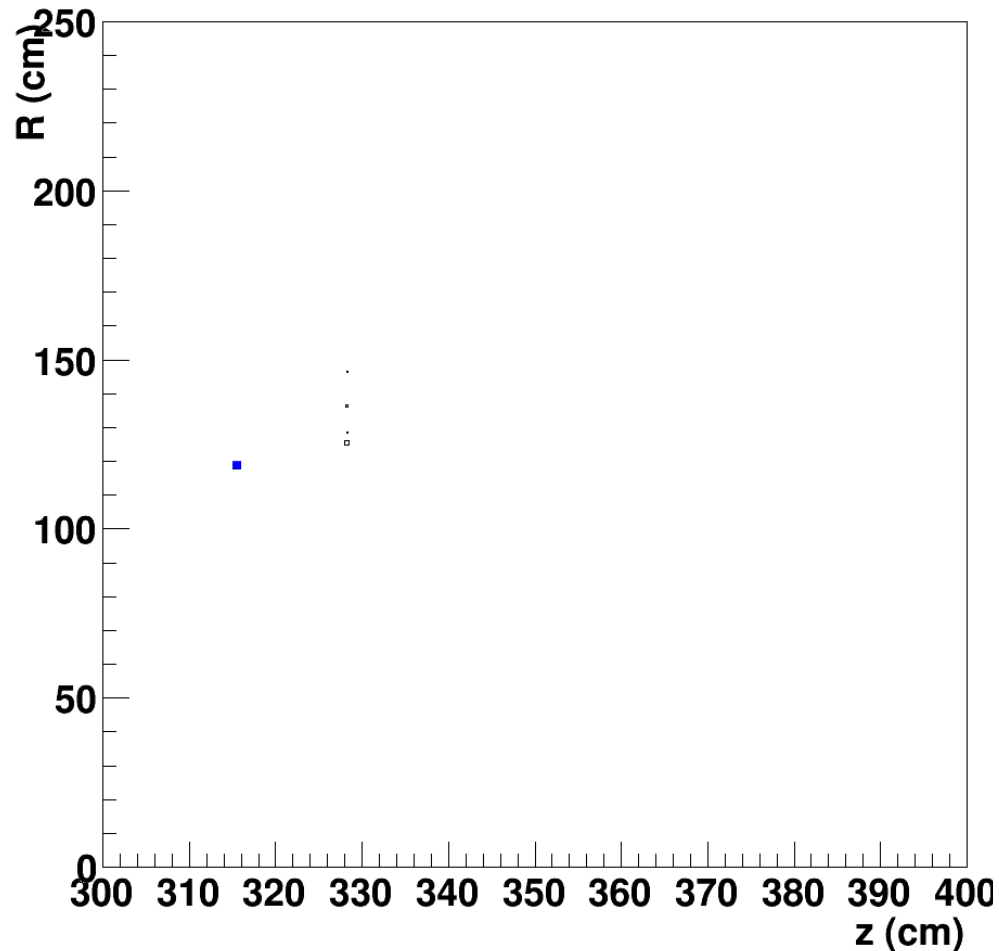


Shower

■ Hit location on the GEM  
6+1 blocks are within the box

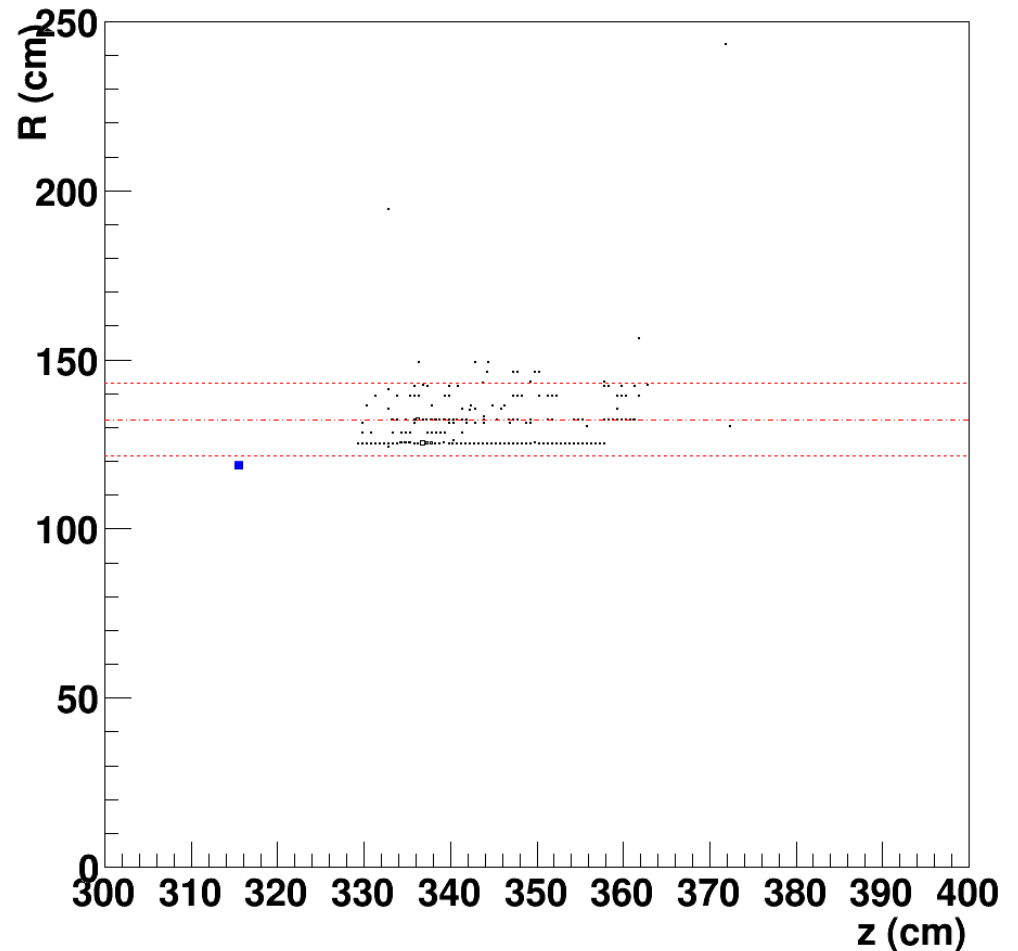
# $\pi$ - event – 2 : ECAL Hit Map

ECAL Blocks Hit Map (GEM hit in Blue)



Pre-Shower

ECAL Blocks Hit Map (GEM hit in Blue)



Shower

■ Hit location on the GEM

Radius of the center block of the 6+1 cluster

$R_{\min}$  and  $R_{\max}$  of the 6+1 cluster

# $\pi$ - event – 2 : ECAL Hit Map

| GEM       |           |           | PS        |           |       | Shower    |           |        |
|-----------|-----------|-----------|-----------|-----------|-------|-----------|-----------|--------|
| Hit Det X | Hit Det Y | Hit Det Z | Hit Det X | Hit Det Y | Edep  | Hit Det X | Hit Det Y | Edep   |
| (cm)      | (cm)      | (cm)      | (cm)      | (cm)      | (MeV) | (cm)      | (cm)      | (MeV)  |
| -11.77    | -116.95   | 315.03    | -7.90     | -125.68   | 4.91  | -129.80   | 31.28     | 0.04   |
|           |           |           | -36.00    | -141.92   | 0.37  | -36.00    | -141.92   | 7.99   |
|           |           |           | -7.90     | -136.51   | 2.01  | 10.90     | -125.68   | 2.06   |
|           |           |           | -26.60    | -125.68   | 0.08  | -36.00    | -152.75   | 0.24   |
|           |           |           |           |           |       | -129.80   | -22.84    | 0.81   |
|           |           |           |           |           |       | -36.00    | -120.27   | 2.66   |
|           |           |           |           |           |       | -129.80   | -12.02    | 1.74   |
|           |           |           |           |           |       | -139.10   | -136.51   | 0.51   |
|           |           |           |           |           |       | -129.80   | 9.63      | 3.16   |
|           |           |           |           |           |       | -139.10   | 4.22      | 0.37   |
|           |           |           |           |           |       | -45.40    | -136.51   | 0.61   |
|           |           |           |           |           |       | -7.90     | -125.68   | 362.88 |
|           |           |           |           |           |       | -7.90     | -136.51   | 7.14   |
|           |           |           |           |           |       | -17.30    | -131.10   | 200.82 |
|           |           |           |           |           |       | -129.80   | 20.46     | 0.15   |
|           |           |           |           |           |       | -26.60    | -125.68   | 7.76   |
|           |           |           |           |           |       | -36.00    | -131.10   | 5.82   |
|           |           |           |           |           |       | -232.90   | -71.56    | 0.23   |
|           |           |           |           |           |       | -101.60   | -71.56    | 0.74   |
|           |           |           |           |           |       | 1.50      | -131.10   | 5.06   |
|           |           |           |           |           |       | -64.10    | -125.68   | 0.50   |
|           |           |           |           |           |       | -26.60    | -147.33   | 0.81   |
|           |           |           |           |           |       | -139.10   | 36.70     | 3.80   |
|           |           |           |           |           |       | -17.30    | -141.92   | 8.37   |
|           |           |           |           |           |       | -26.60    | -136.51   | 17.82  |

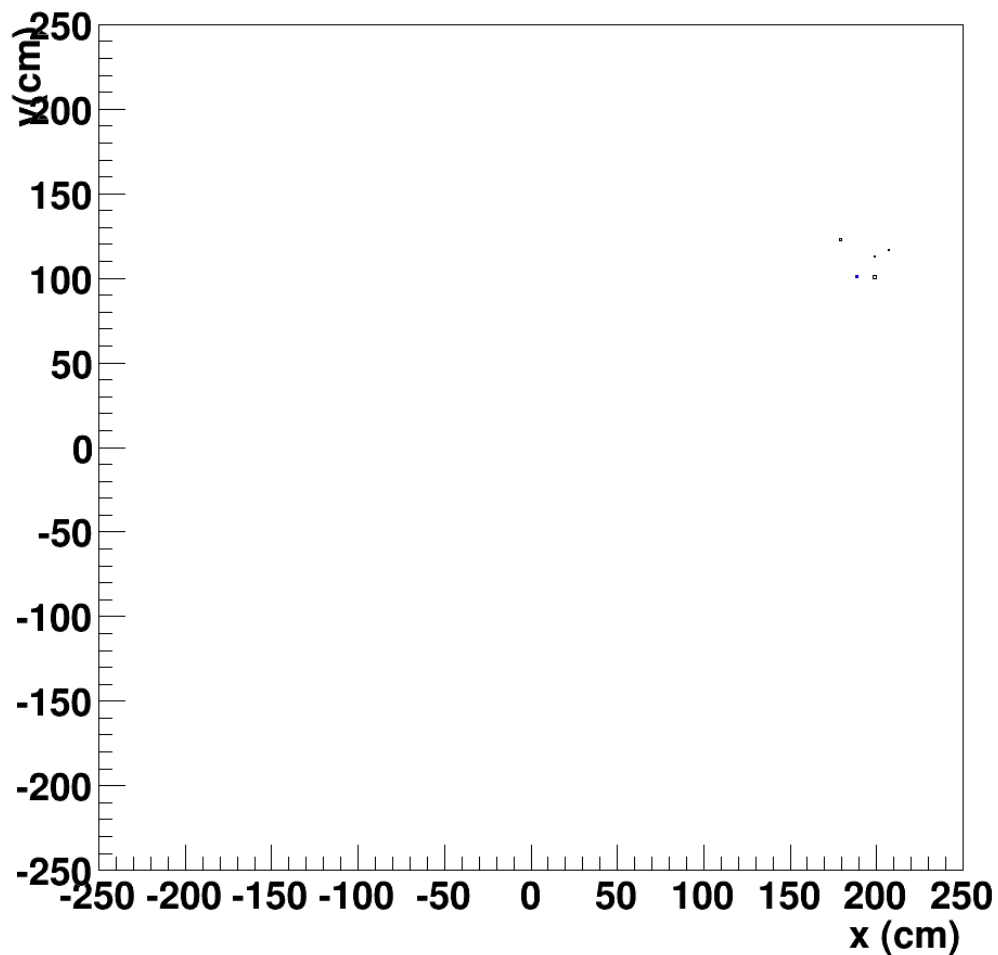
# $\pi$ - event - 3

|         |          |       |        |
|---------|----------|-------|--------|
| GEM     |          |       |        |
| Rate    | Momentum | Angle | Radius |
| (kHz)   | (MeV)    | (deg) | (cm)   |
| 30.8663 | 1618.3   | 35.12 | 214.52 |

|              |          |            |              |          |            |              |          |            |
|--------------|----------|------------|--------------|----------|------------|--------------|----------|------------|
| ECAL         |          |            | SC block sum | SC Total |            | SC block sum | SC Total |            |
| PS block sum | PS Total | percentage | 6+1          |          | percentage | 2+1          |          | percentage |
| (MeV)        | (MeV)    | (%)        | (MeV)        | (MeV)    | (%)        | (MeV)        | (MeV)    | (%)        |
| 8.44         | 11.65    | 72.4       | 257.51       | 377.08   | 68.3       | 154.65       | 377.08   | 41.0       |

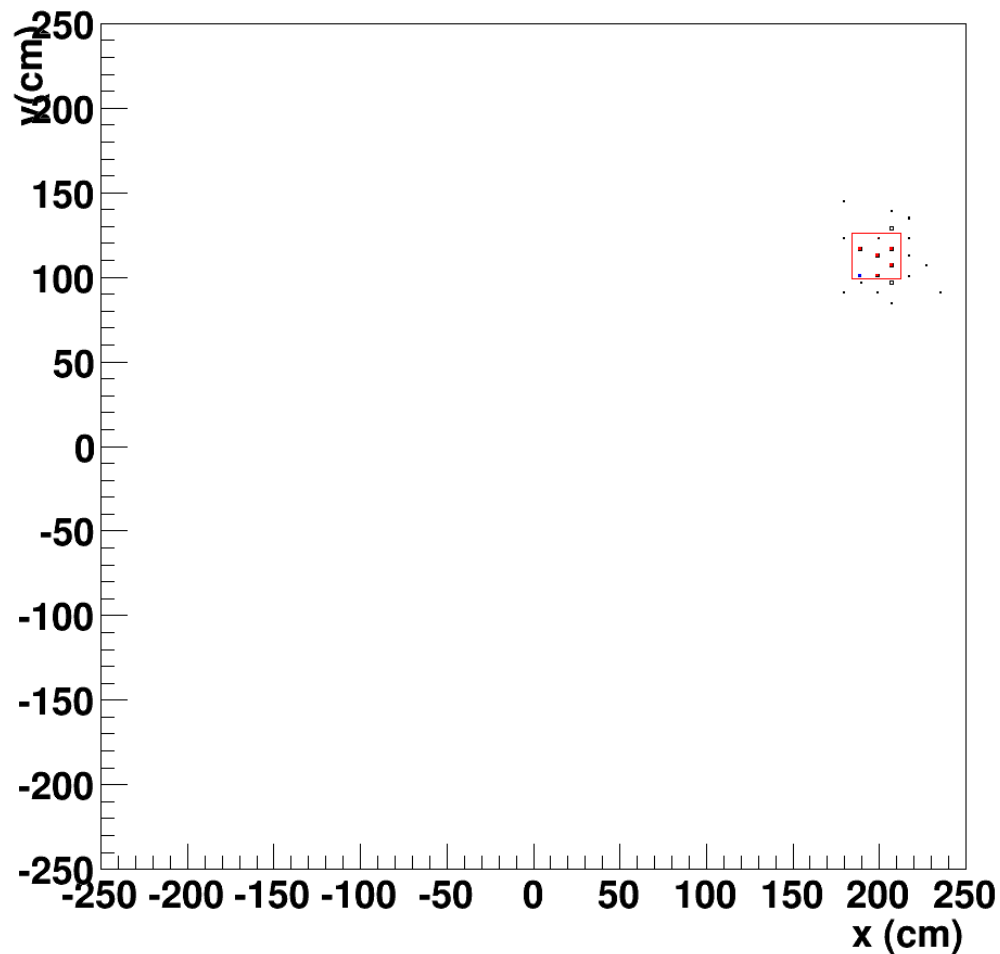
# $\pi$ - event – 3 : ECAL Hit Map

ECAL Blocks Hit Map (GEM hit in Blue)



Pre-Shower

ECAL Blocks Hit Map (GEM hit in Blue)



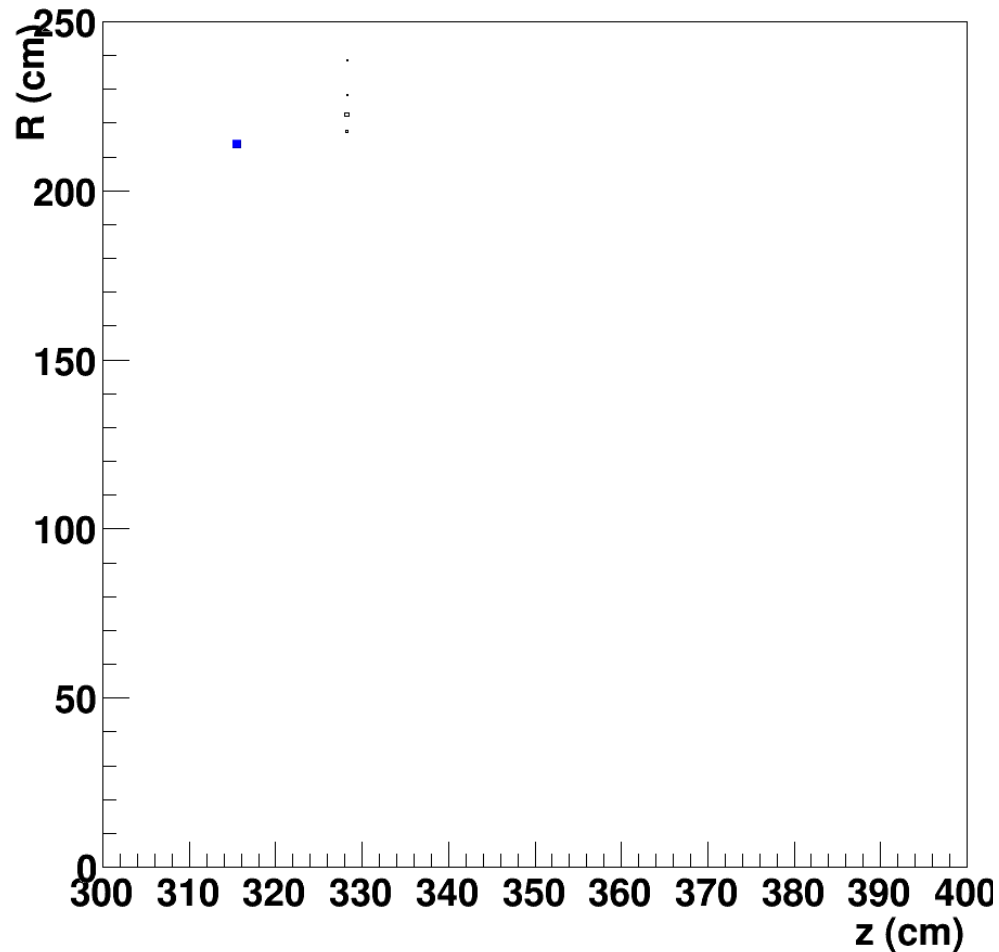
Shower

■ Hit location on the GEM

6+1 blocks are within the box

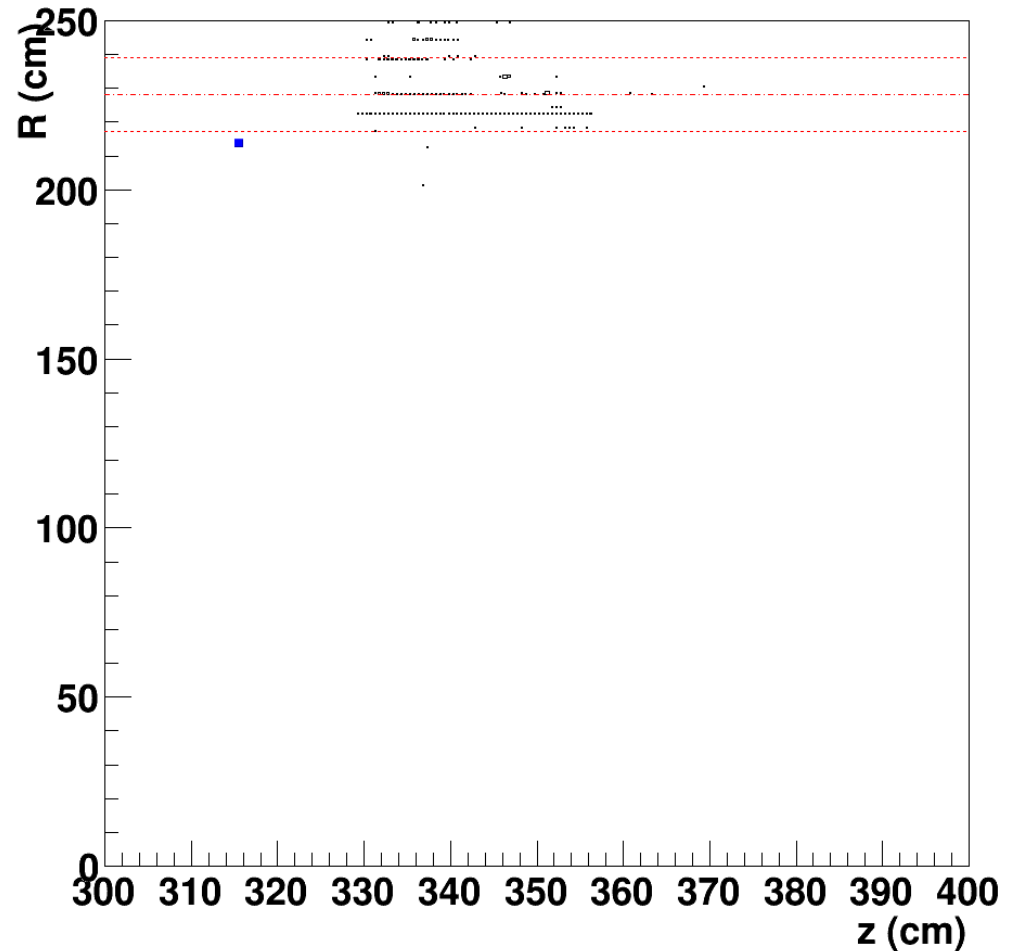
# $\pi^-$ event – 3 : ECAL Hit Map

ECAL Blocks Hit Map (GEM hit in Blue)



Pre-Shower

ECAL Blocks Hit Map (GEM hit in Blue)



Shower

■ Hit location on the GEM

Radius of the center block of the 6+1 cluster

$R_{\min}$  and  $R_{\max}$  of the 6+1 cluster

# $\pi$ - event – 3 : ECAL Hit Map

| GEM       |           |           | PS        |           |       | Shower    |           |       |
|-----------|-----------|-----------|-----------|-----------|-------|-----------|-----------|-------|
| Hit Det X | Hit Det Y | Hit Det Z | Hit Det X | Hit Det Y | Edep  | Hit Det X | Hit Det Y | Edep  |
| (cm)      | (cm)      | (cm)      | (cm)      | (cm)      | (MeV) | (cm)      | (cm)      | (MeV) |
| 189.56    | 100.44    | 315.03    | 207.70    | 117.89    | 0.14  | 198.4     | 112.47    | 54.40 |
|           |           |           | 198.40    | 101.65    | 8.44  | 207.7     | 85.41     | 1.97  |
|           |           |           | 179.60    | 123.30    | 2.96  | 217.1     | 101.65    | 1.04  |
|           |           |           | 198.40    | 112.47    | 0.10  | 179.6     | 90.82     | 0.06  |
|           |           |           |           |           |       | 198.40    | 90.82     | 6.25  |
|           |           |           |           |           |       | 189.00    | 96.24     | 0.19  |
|           |           |           |           |           |       | 235.90    | 90.82     | 0.18  |
|           |           |           |           |           |       | 207.70    | 139.54    | 0.28  |
|           |           |           |           |           |       | 226.50    | 107.06    | 0.85  |
|           |           |           |           |           |       | 207.70    | 117.89    | 54.53 |
|           |           |           |           |           |       | 198.40    | 123.30    | 0.05  |
|           |           |           |           |           |       | 217.10    | 134.12    | 13.38 |
|           |           |           |           |           |       | 217.10    | 123.30    | 9.40  |
|           |           |           |           |           |       | 189.00    | 117.89    | 48.28 |
|           |           |           |           |           |       | 179.60    | 144.95    | 0.88  |
|           |           |           |           |           |       | 198.40    | 101.65    | 43.99 |
|           |           |           |           |           |       | 207.70    | 96.24     | 46.44 |
|           |           |           |           |           |       | 179.60    | 123.30    | 0.37  |
|           |           |           |           |           |       | 217.10    | 112.47    | 0.54  |
|           |           |           |           |           |       | 207.70    | 128.71    | 37.73 |
|           |           |           |           |           |       | 207.70    | 107.06    | 56.26 |