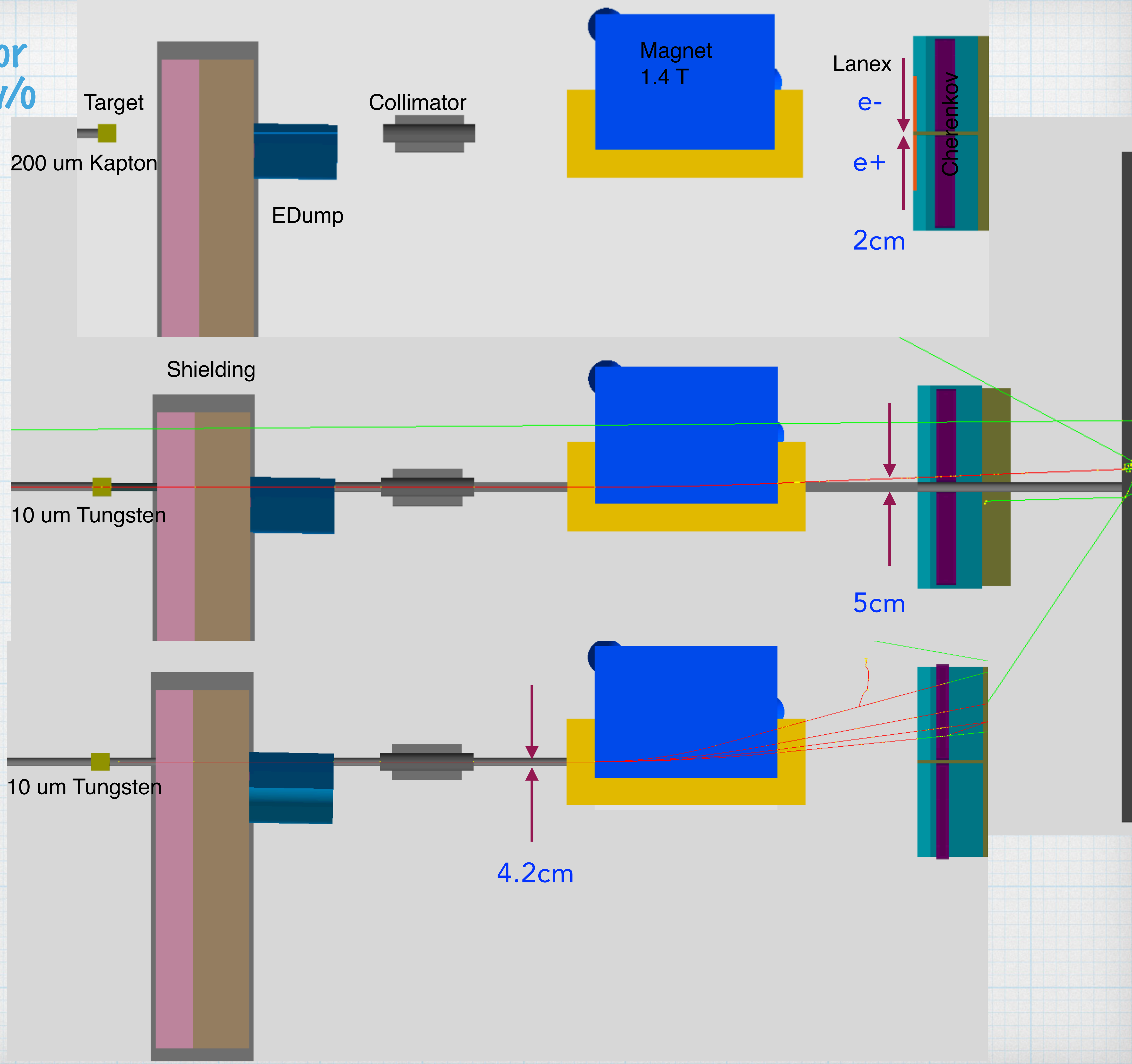
# FDS performance
# Beam pipe with chamber

Borysova Maryna (KINR)
04/04/21
LUXE S&A meeting

LUXE

# Forward detector system with & w/o beam pipe

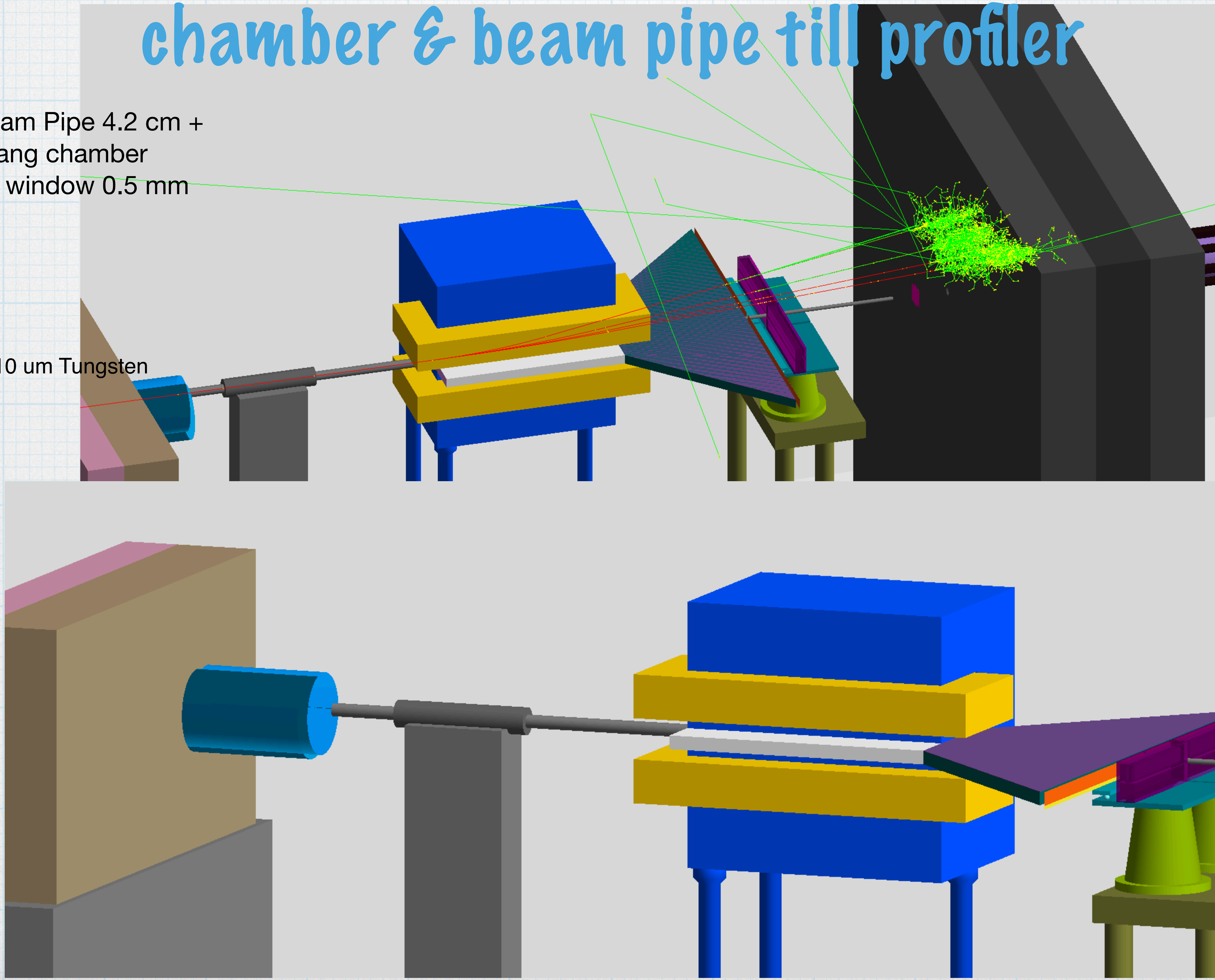
No Beam Pipe
Kapton, 200 um

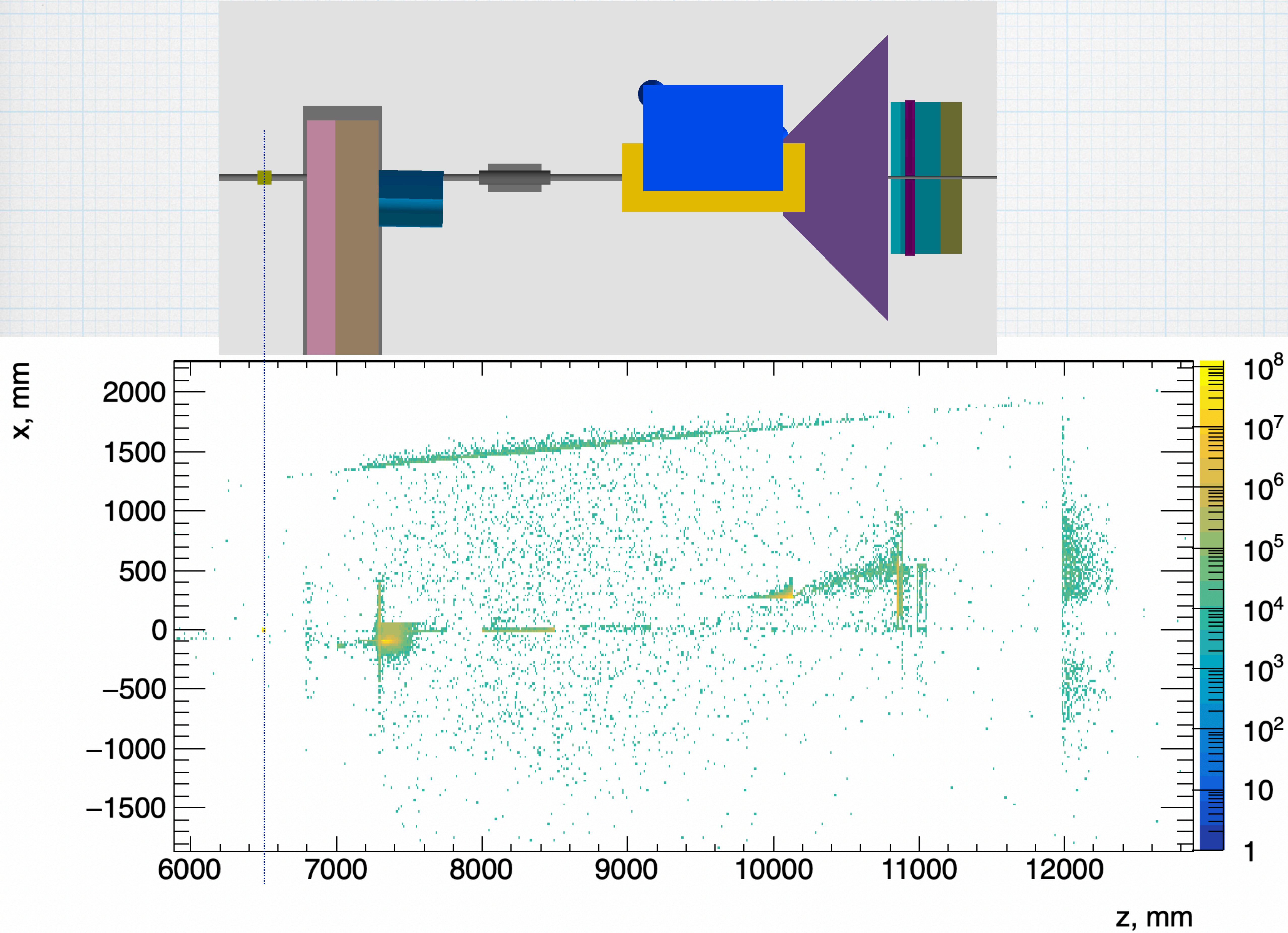



Beam Pipe 5 cm
W, 10 um

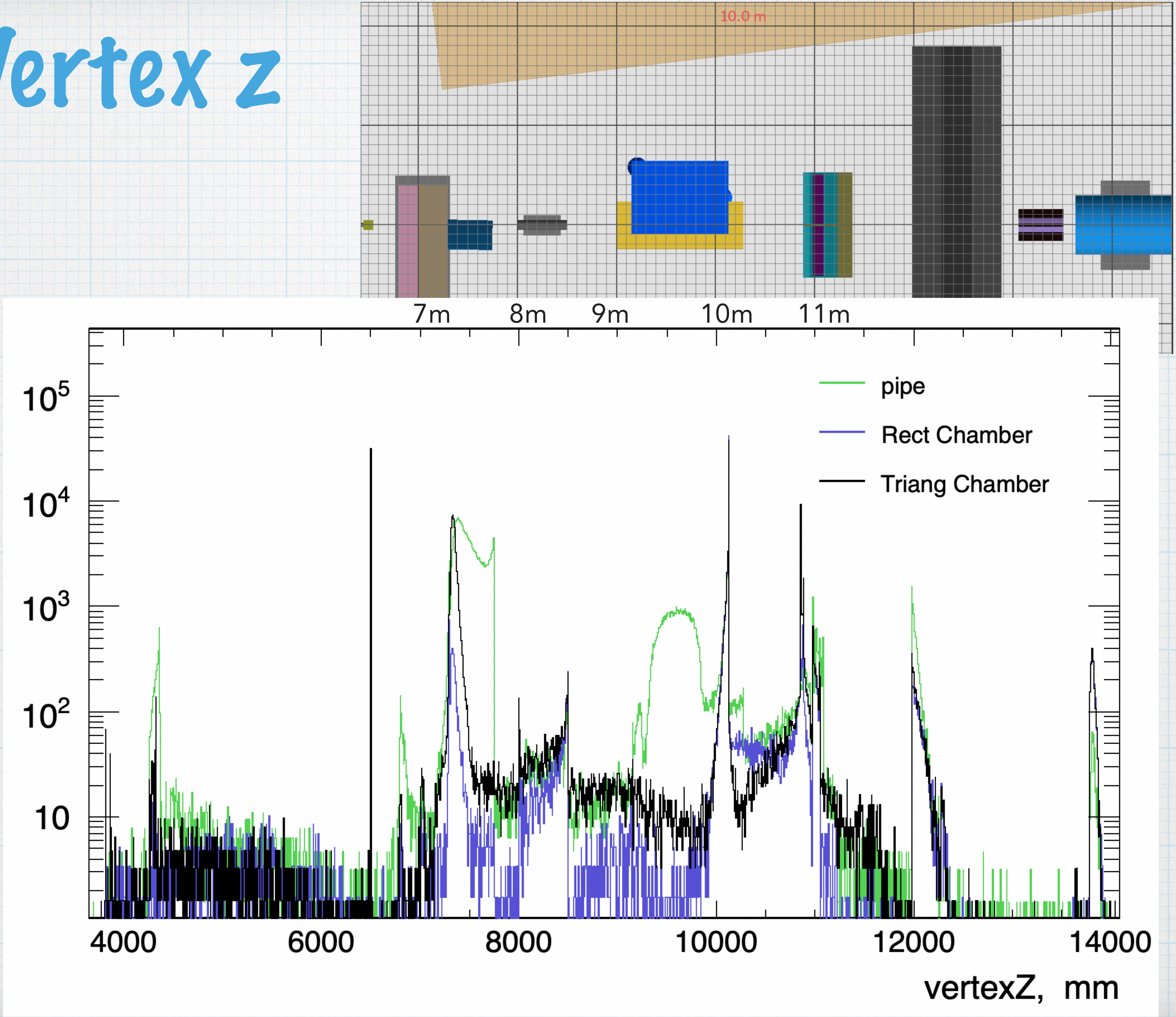
Beam Pipe 4.2 cm
+chamber
W, 10 um

# Forward detector system with triangular chamber & beam pipe till profiler

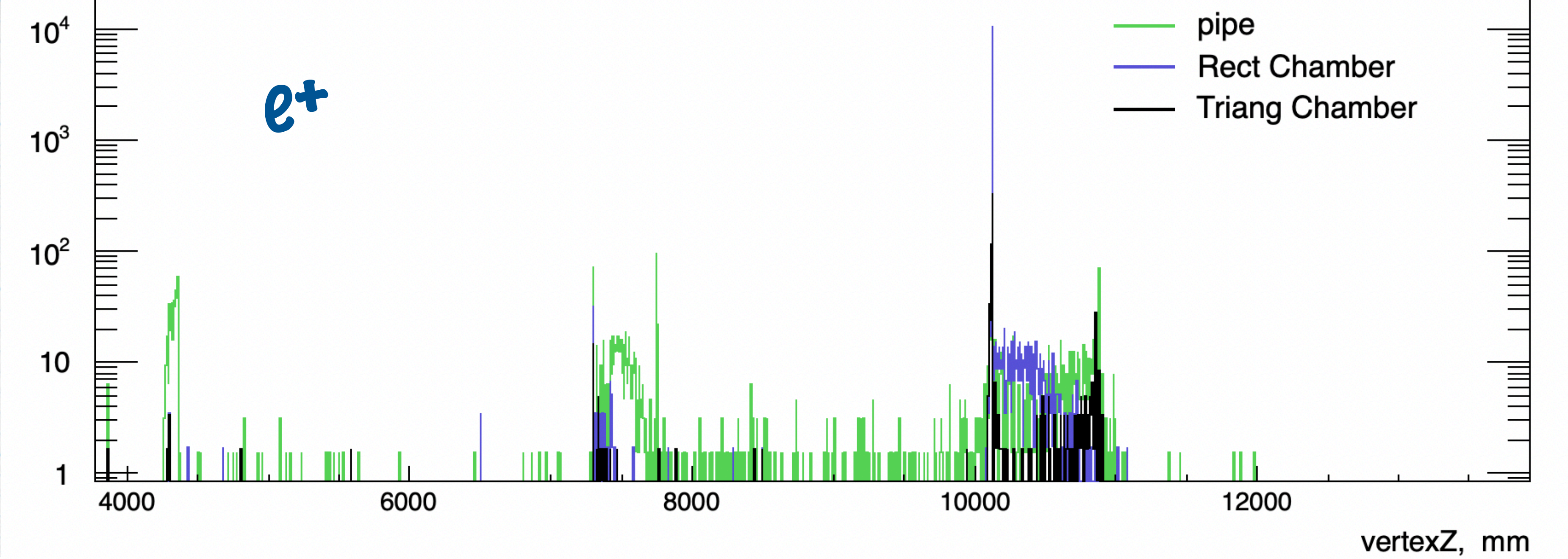


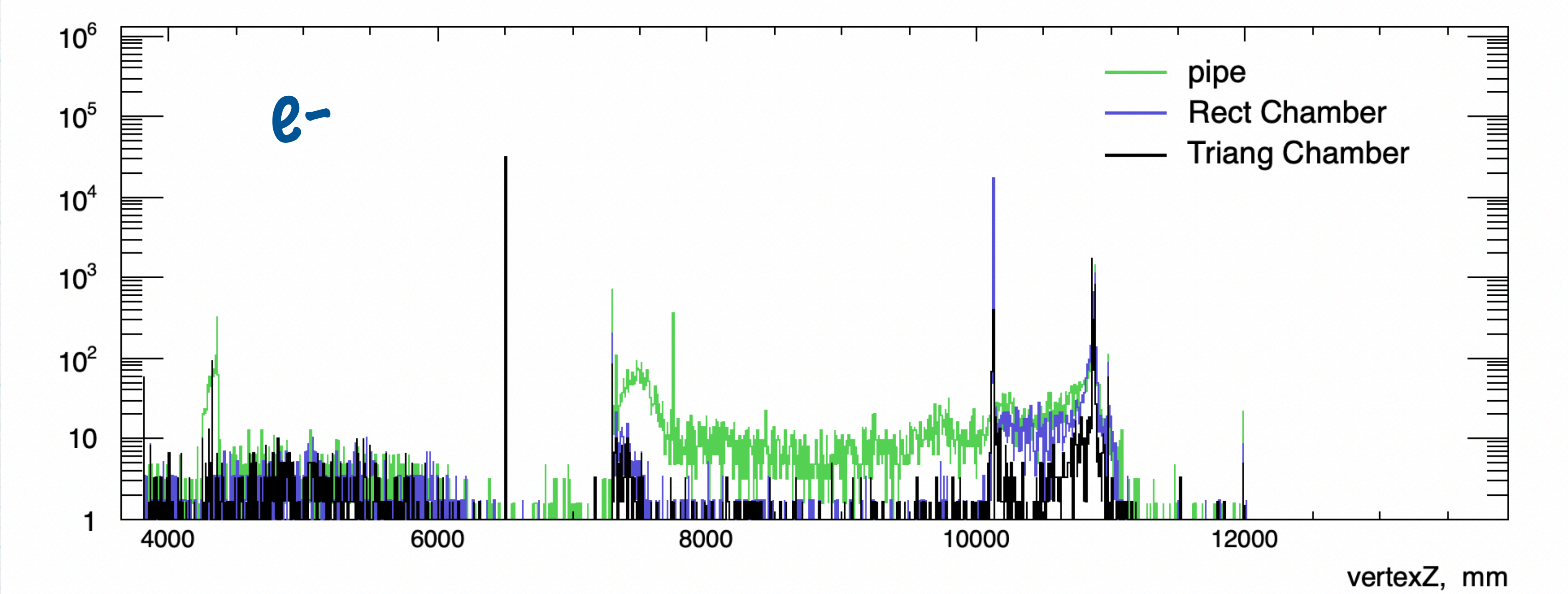

x, mm
2000
1500
1000
500
0
−500
−1000
−1500
6000
7000
8000
9000
10000
11000
12000
z, mm
$10^8$
$10^7$
$10^6$
$10^5$
$10^4$
$10^3$
$10^2$
10
1

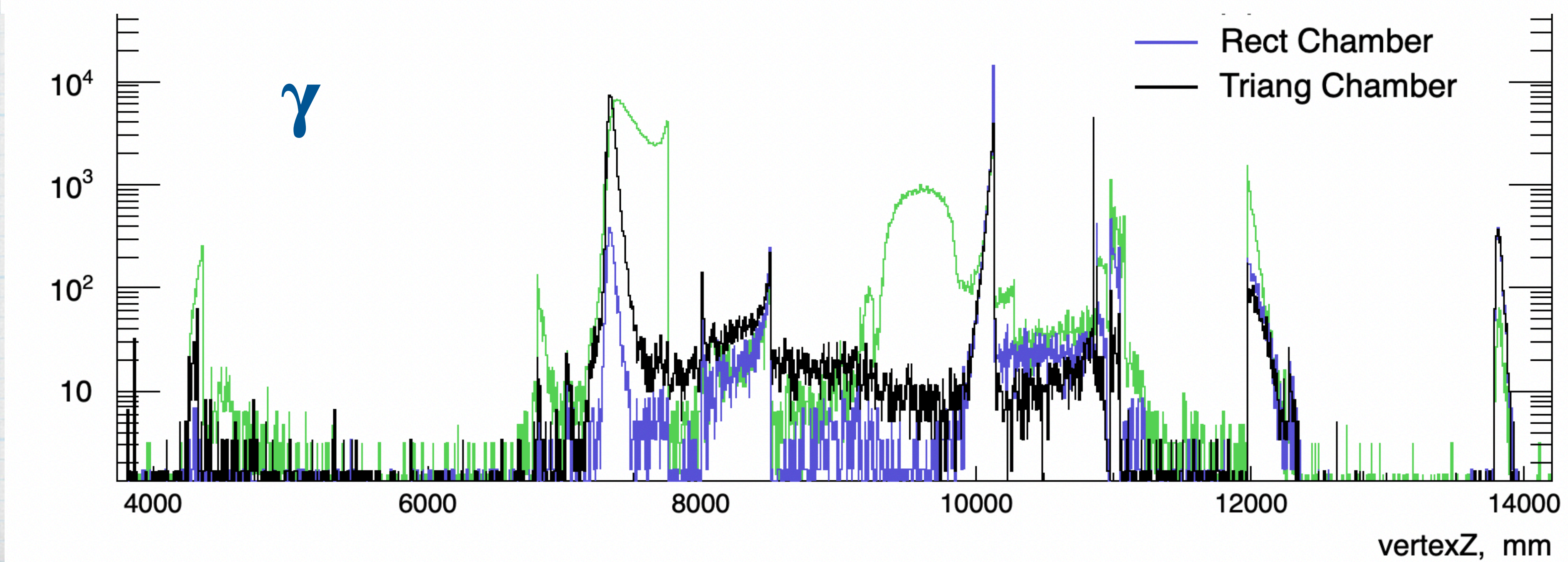
# Vertex z



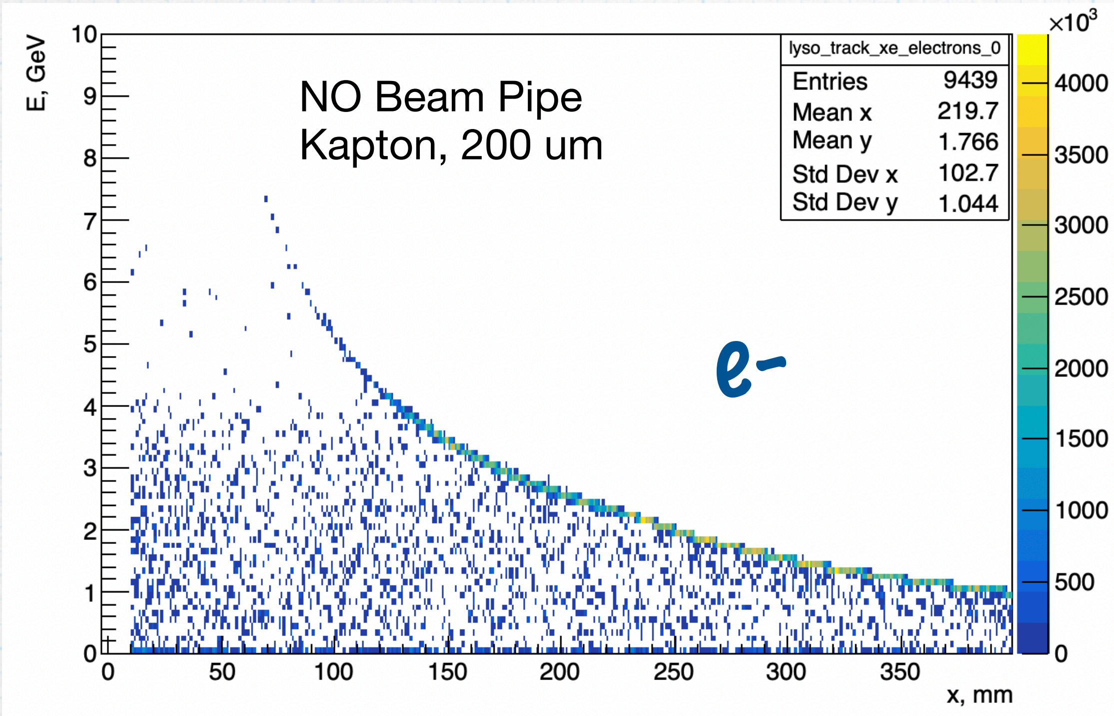
10.0 m
7m
8m
9m
10m
11m
pipe
Rect Chamber
Triang Chamber
$10^5$
$10^4$
$10^3$
$10^2$
10
4000
6000
8000
10000
12000
14000
vertexZ, mm

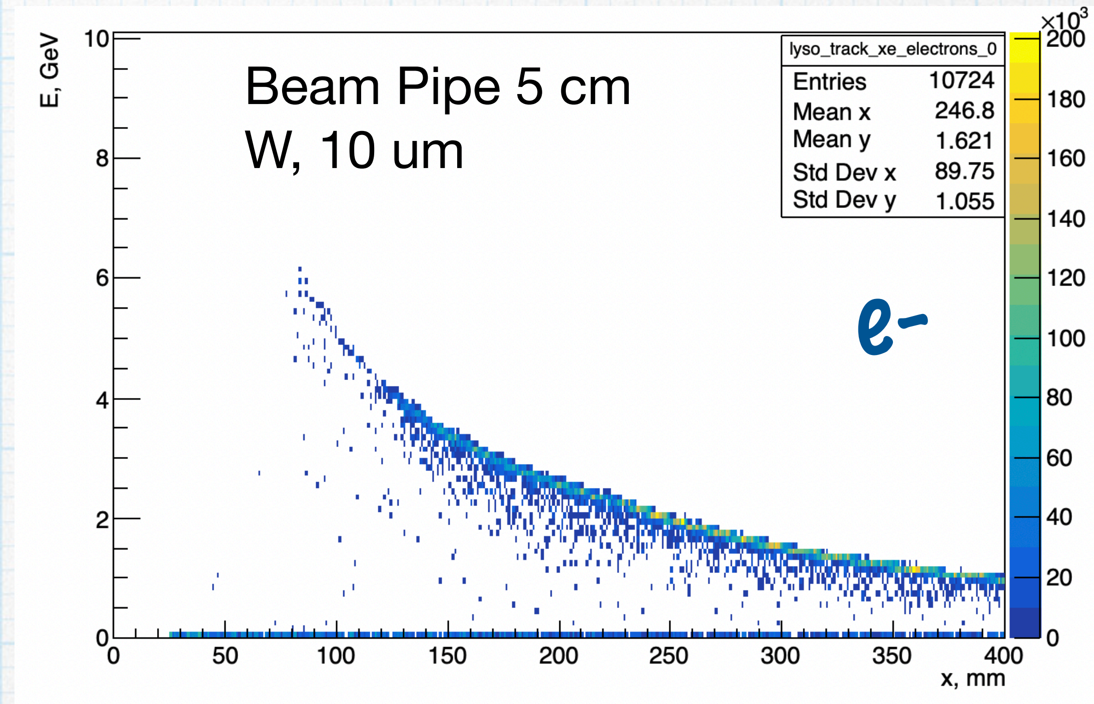

e+
pipe
Rect Chamber
Triang Chamber
$10^4$
$10^3$
$10^2$
10
1
4000
6000
8000
10000
12000
vertexZ, mm

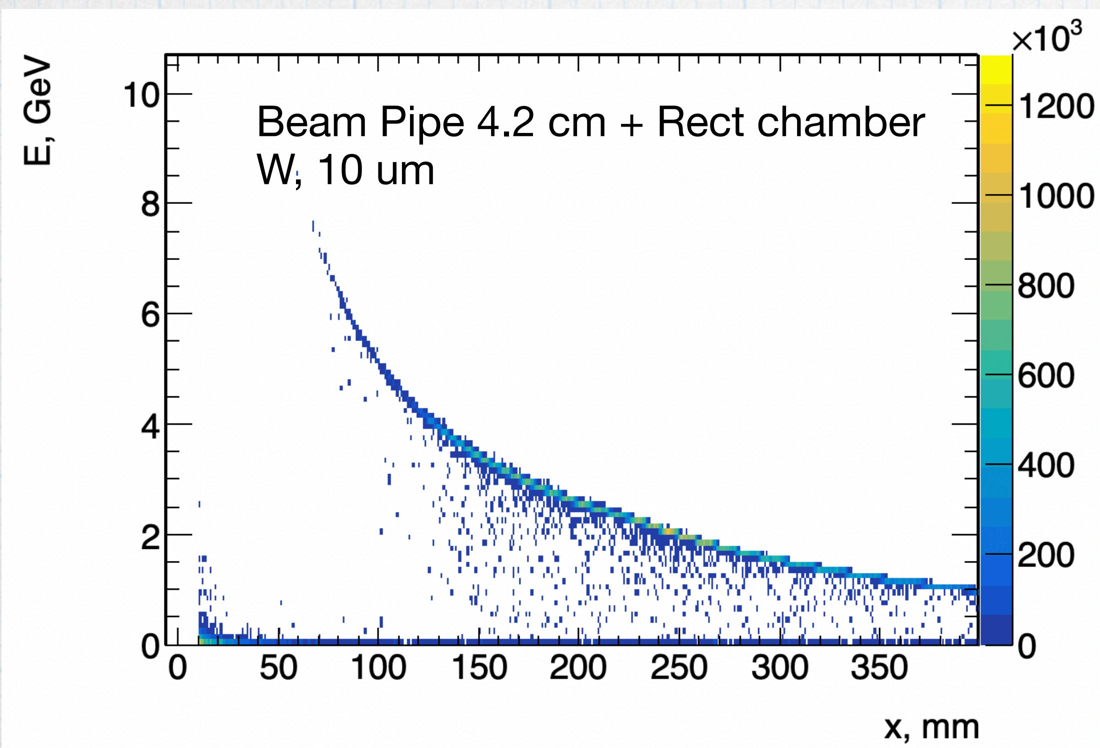

e-
pipe
Rect Chamber
Triang Chamber
$10^6$
$10^5$
$10^4$
$10^3$
$10^2$
10
1
4000
6000
8000
10000
12000
vertexZ, mm

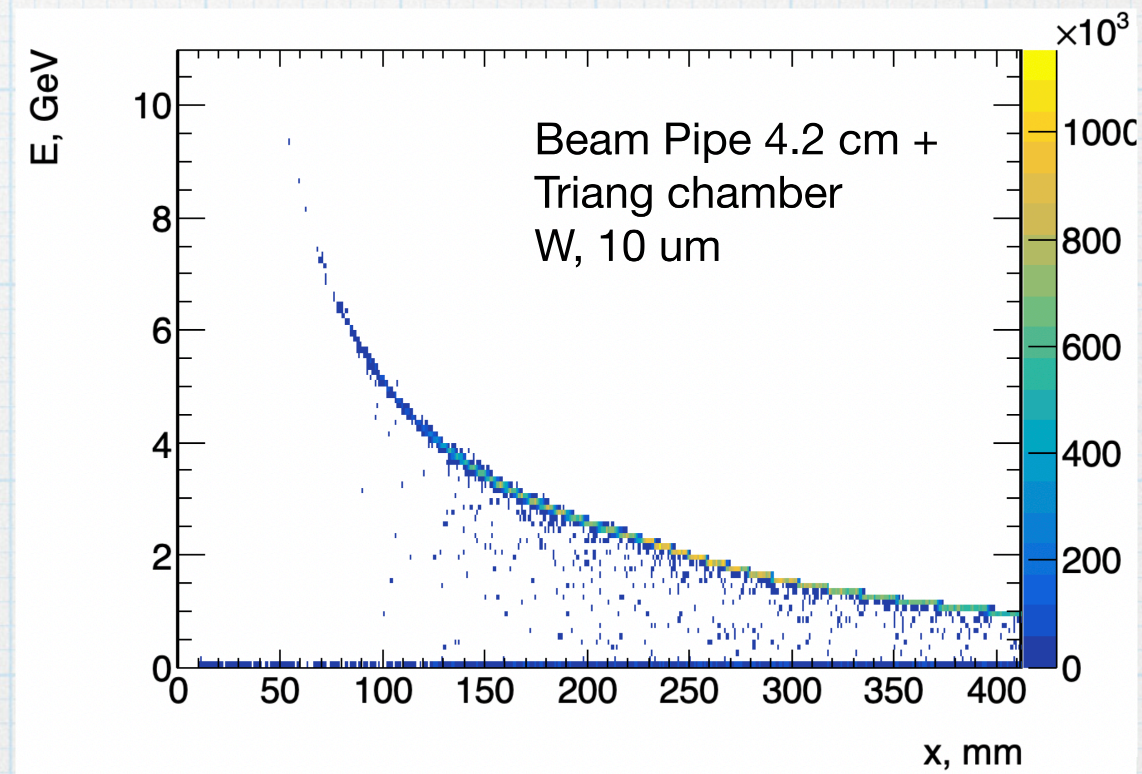

γ
Rect Chamber
Triang Chamber
$10^4$
$10^3$
$10^2$
10
4000
6000
8000
10000
12000
14000
vertexZ, mm

# Energy vs position: electrons



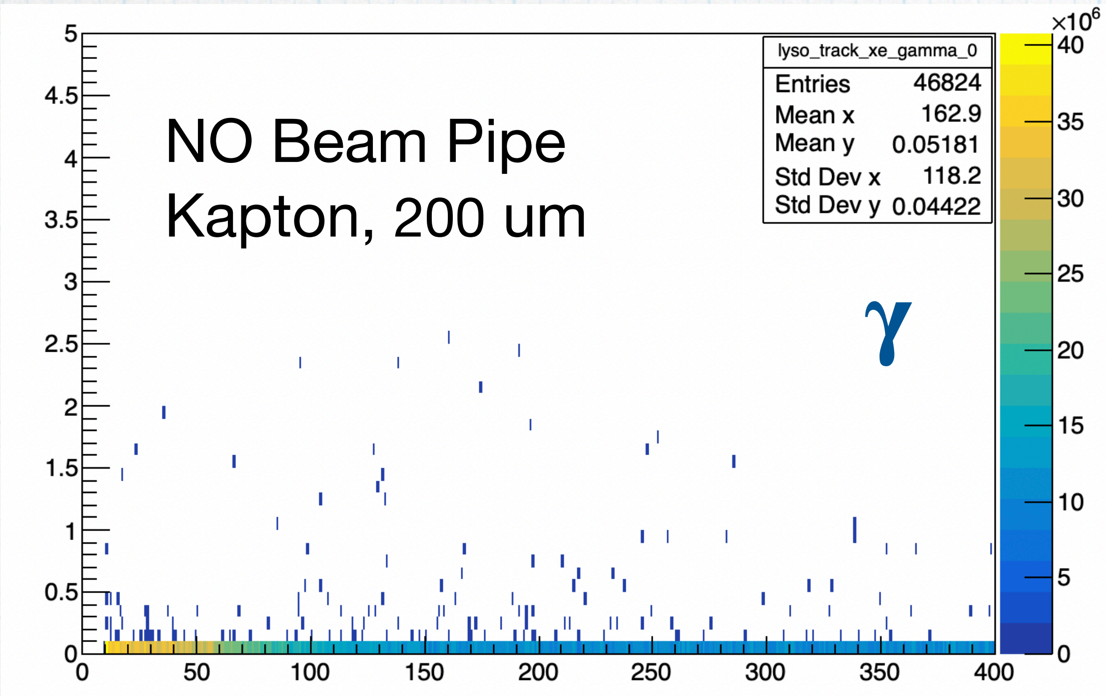



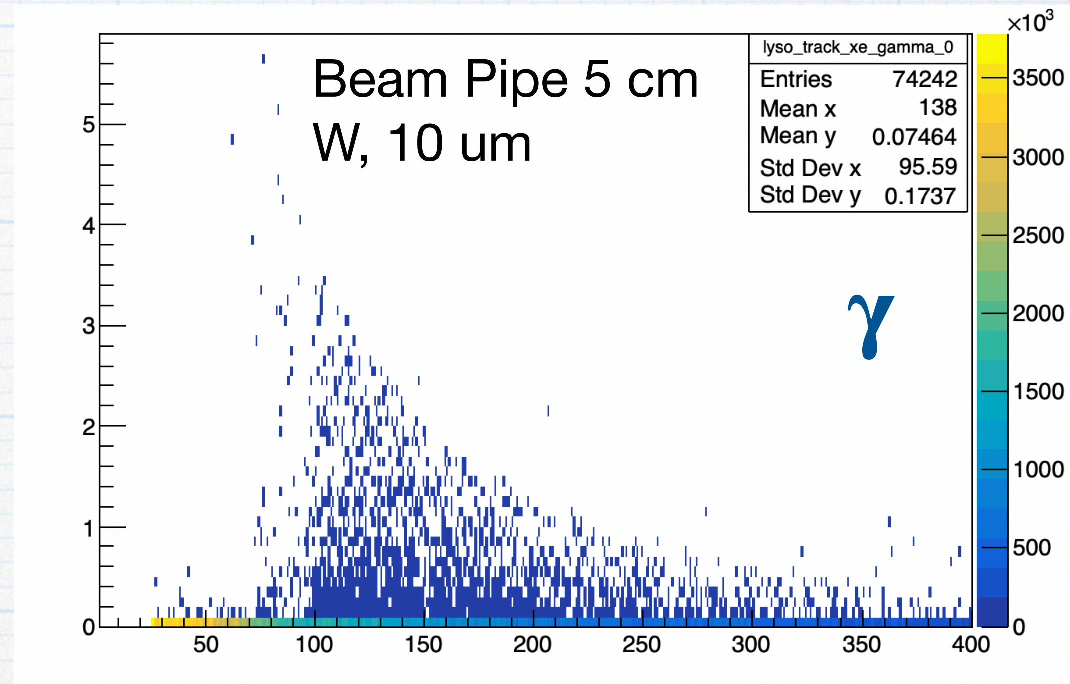



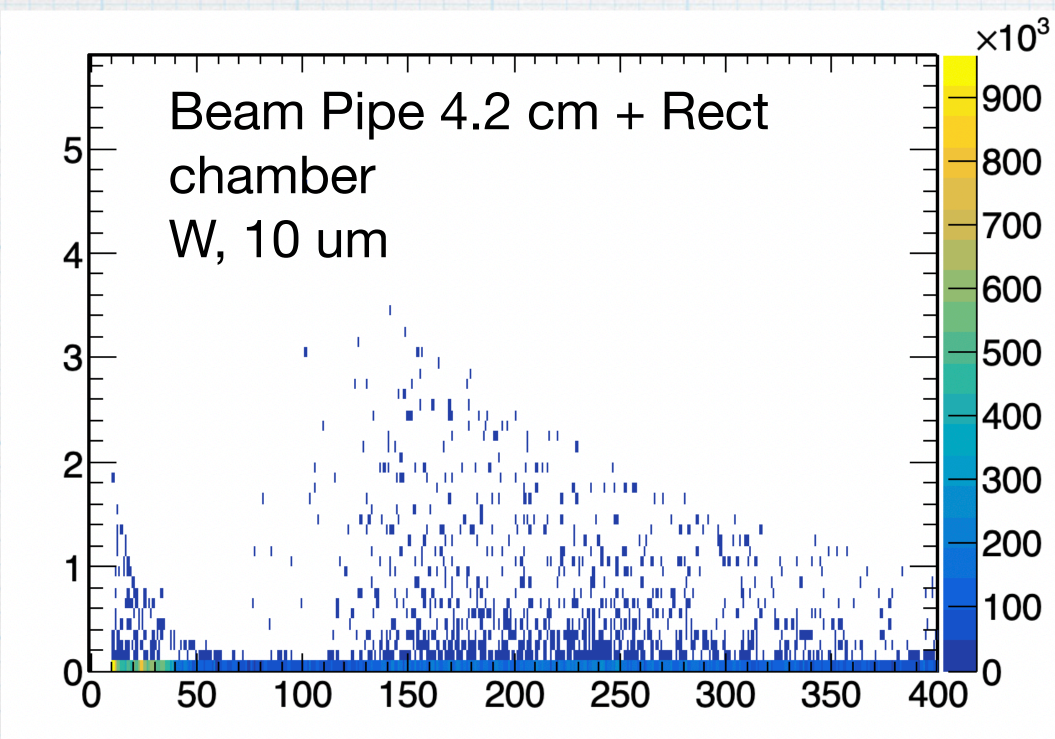



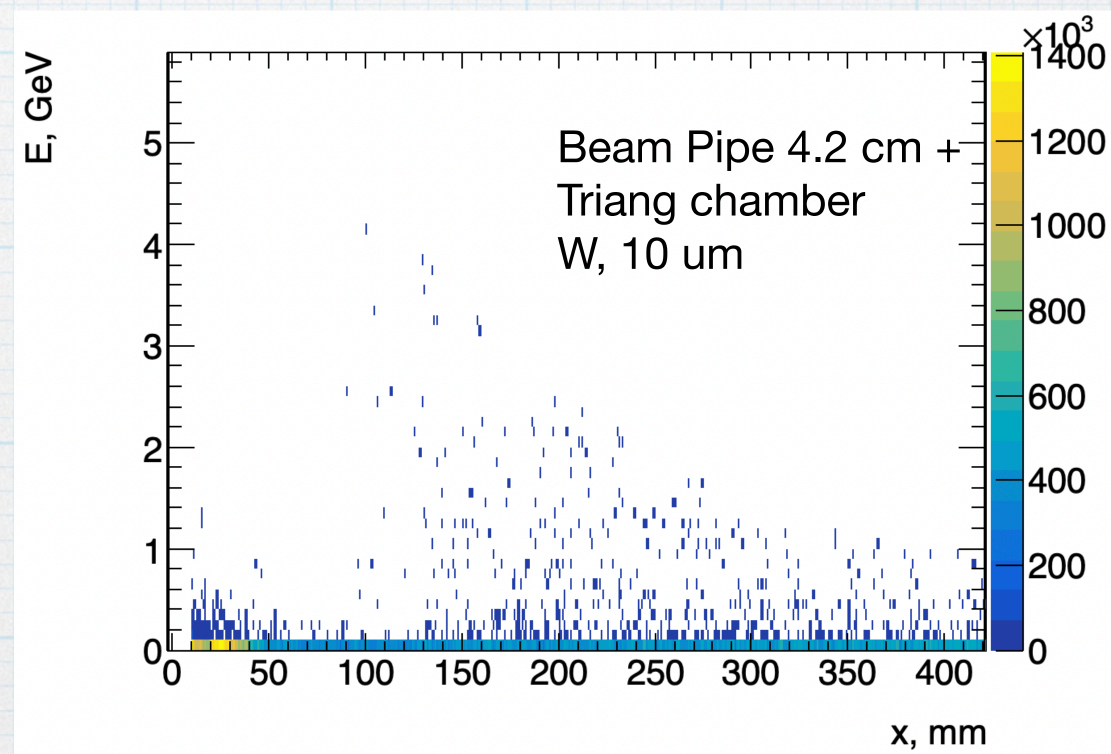

Electron Energy-position correlation is cleaner in case of beam pipe

# Energy vs position: photons



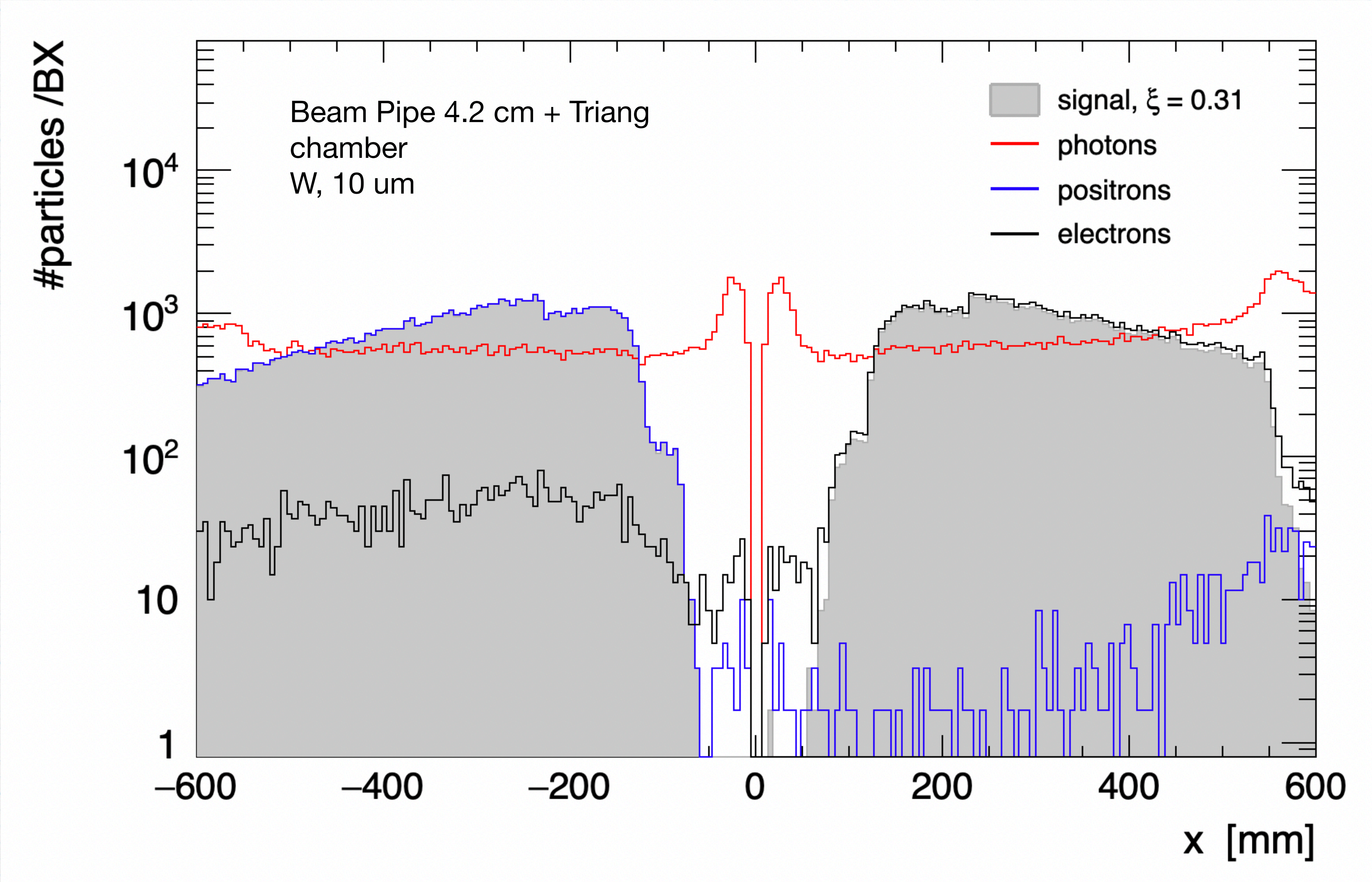




Energy-position correlation is cleaner in case of beam pipe and photons distribution shows that they were produced after the electron direction was defined.

# Tracks

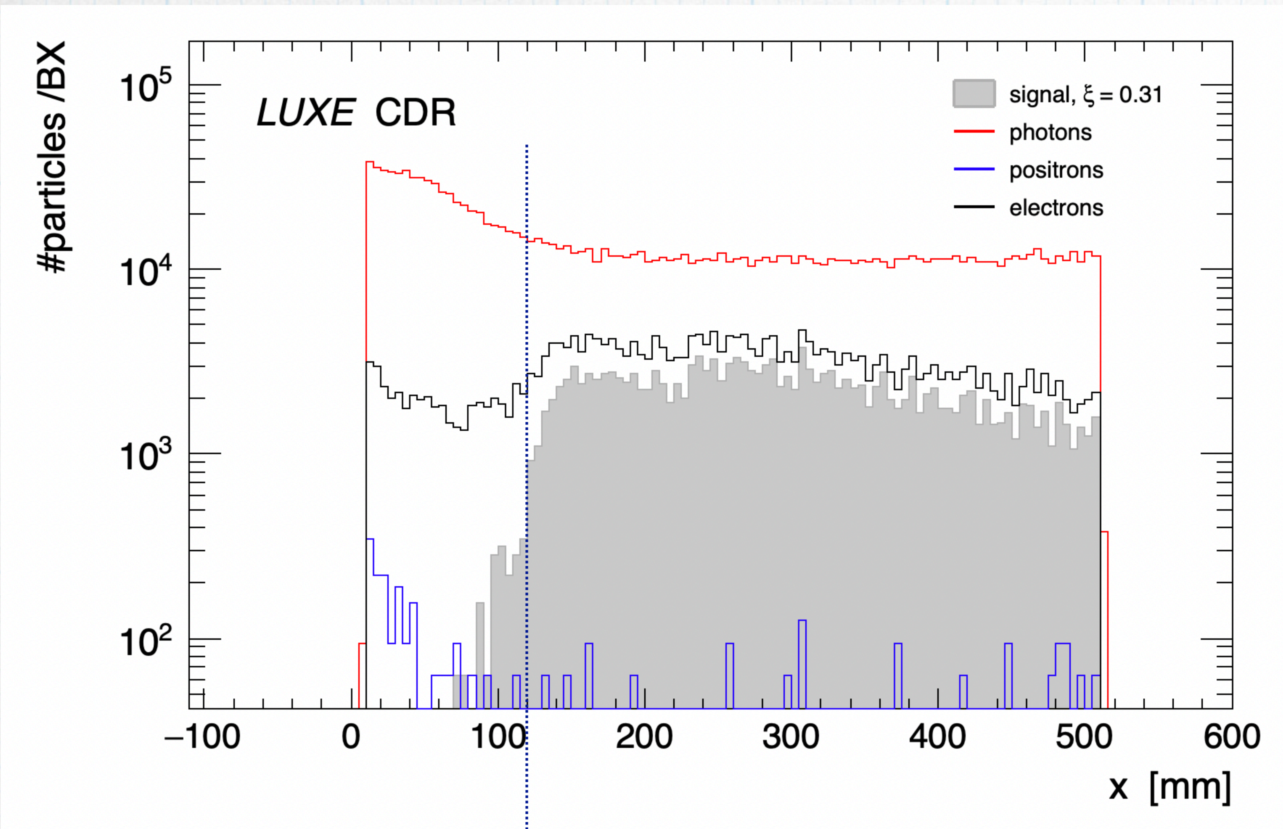


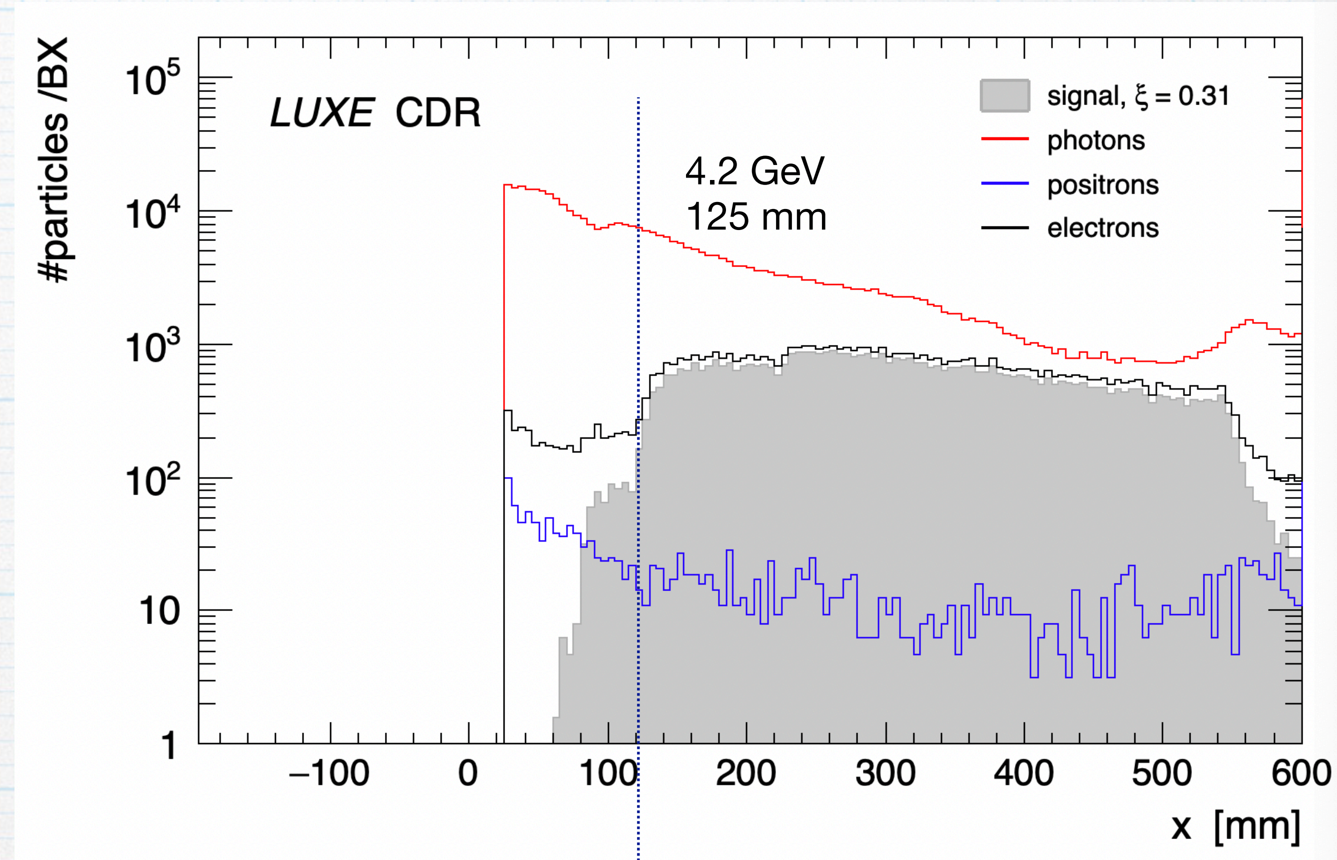
#particles /BX
Beam Pipe 4.2 cm + Triang
chamber
W, 10 um
signal, ξ = 0.31
photons
positrons
electrons
$10^4$
$10^3$
$10^2$
10
1
−600
−400
−200
0
200
400
600
x [mm]

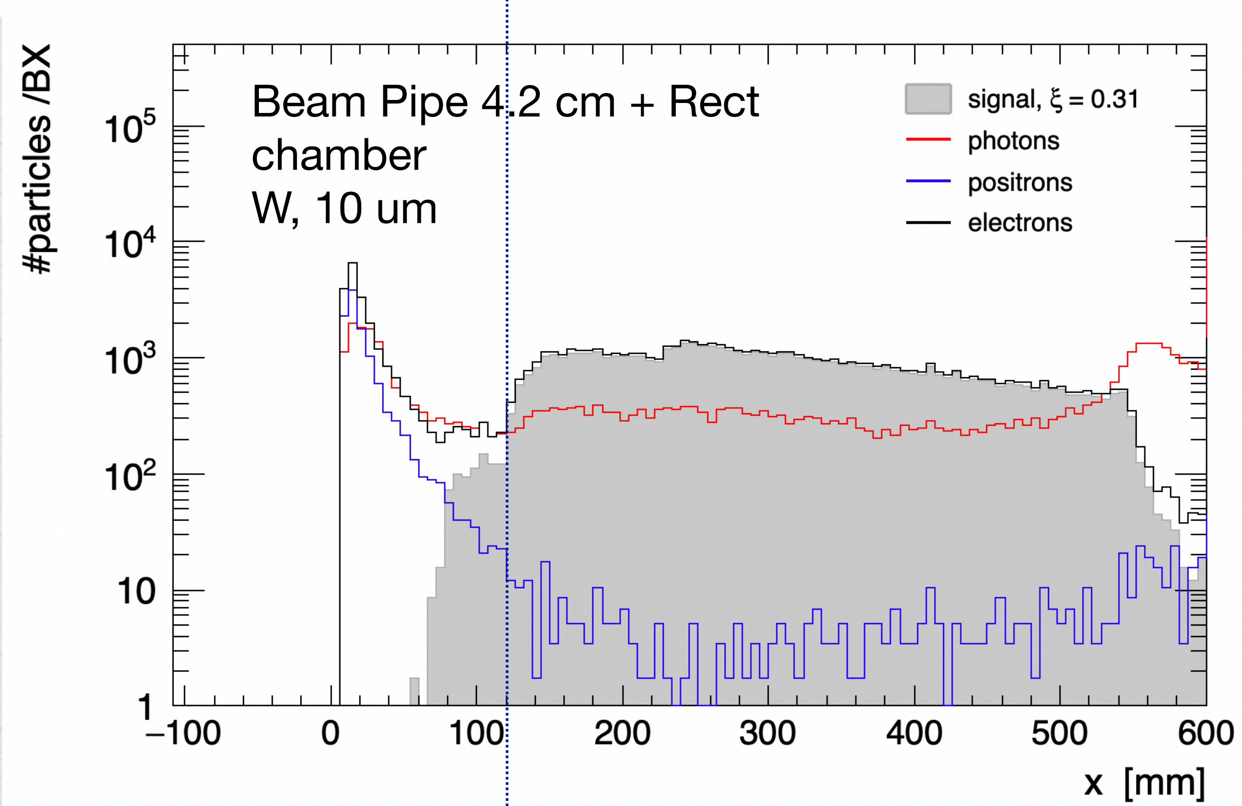
# Particles in electron arm

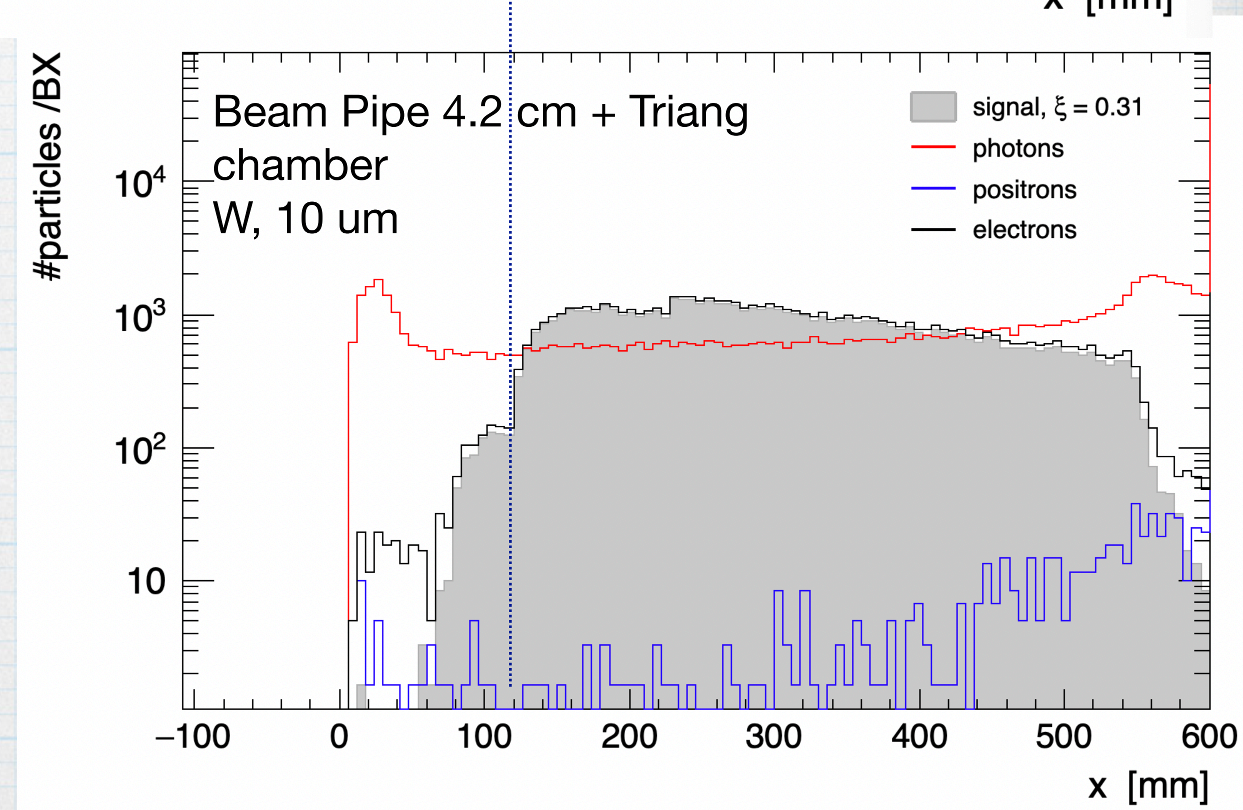
NO Beam Pipe
Kapton, 200 um

Beam Pipe 5 cm
W, 10 um



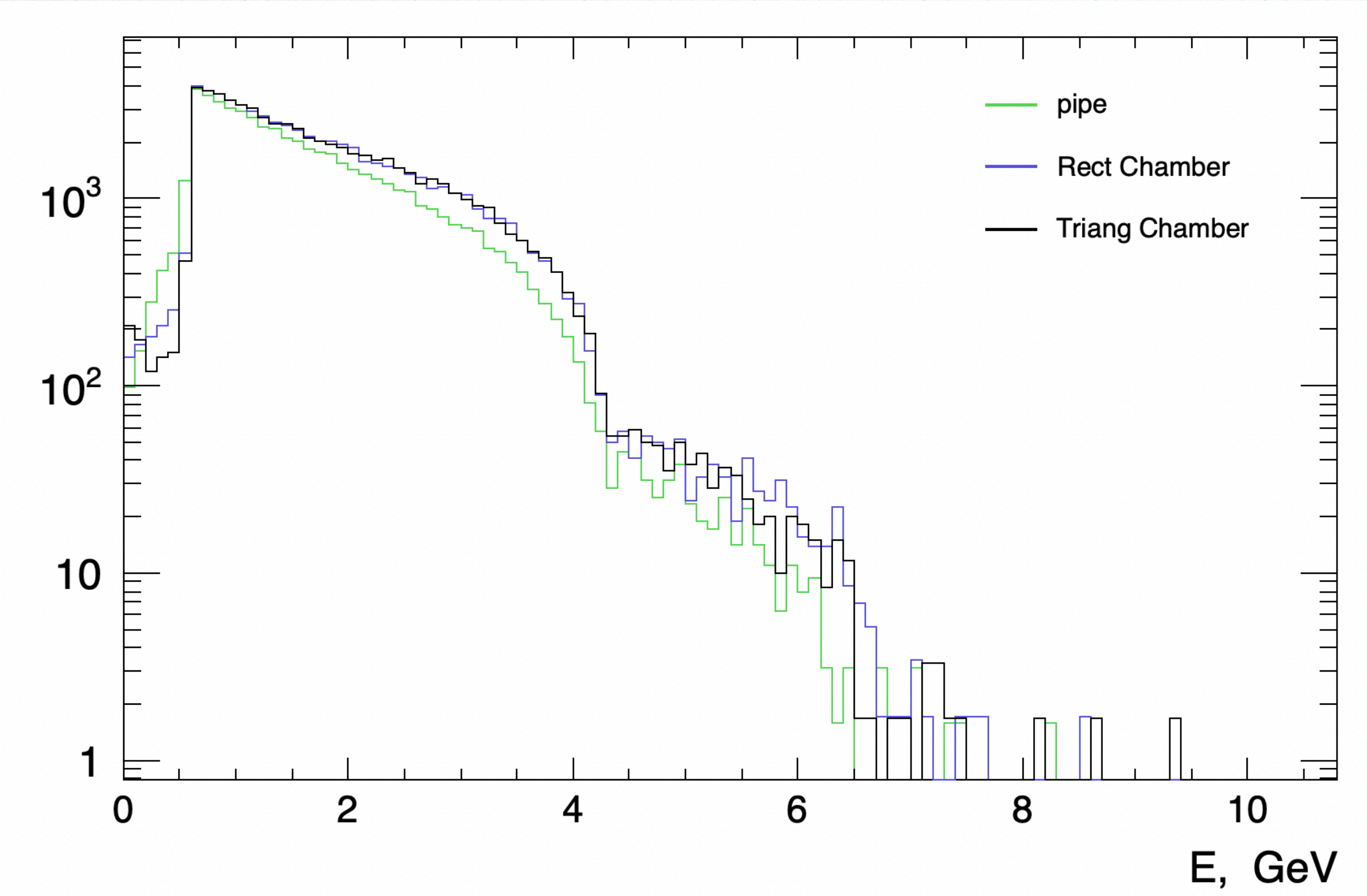



# "True" spectra

JETI40, 16.5 GeV, 50 um



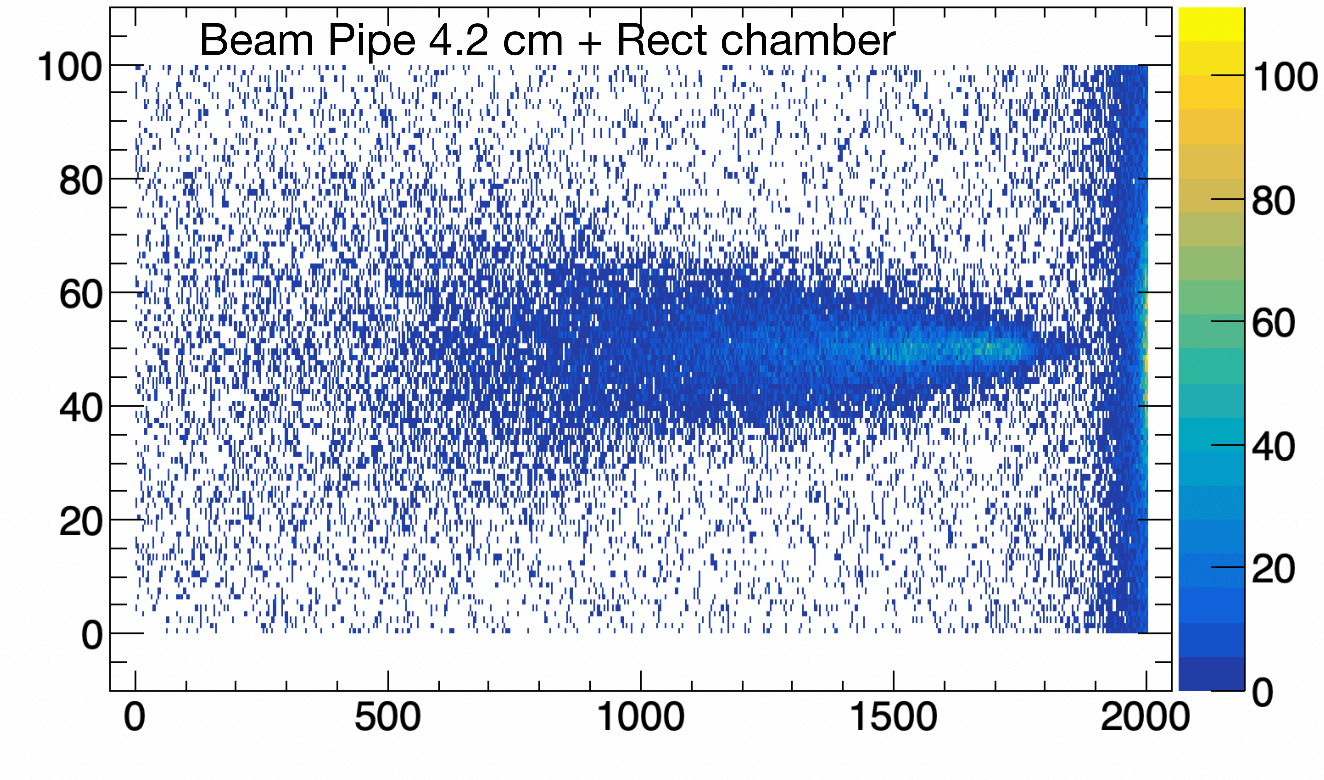

- Electrons/positrons generated in target by primary photon and which are hitting Lanex screens
- Consider air before the magnet as a target too

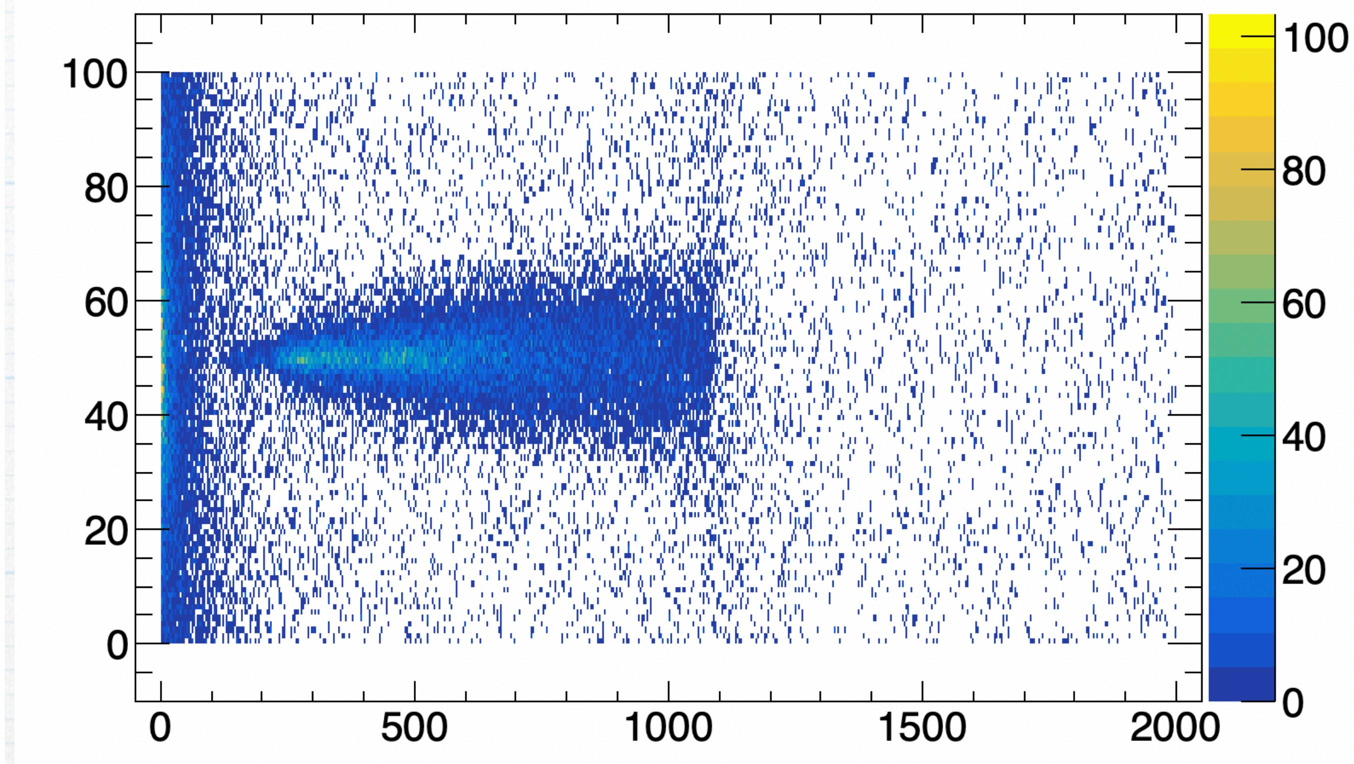
* Selection
- detid == 3000/3001
- pdg ==11/-11
- Parent pdg ==22
- Parent == primary
- Primary pdg ==22
- |vtx x,y |<25 mm
- |vtx z - 6.5 m |< 100 um
- vtx z > 6.5m -100um && vtx z < 9m

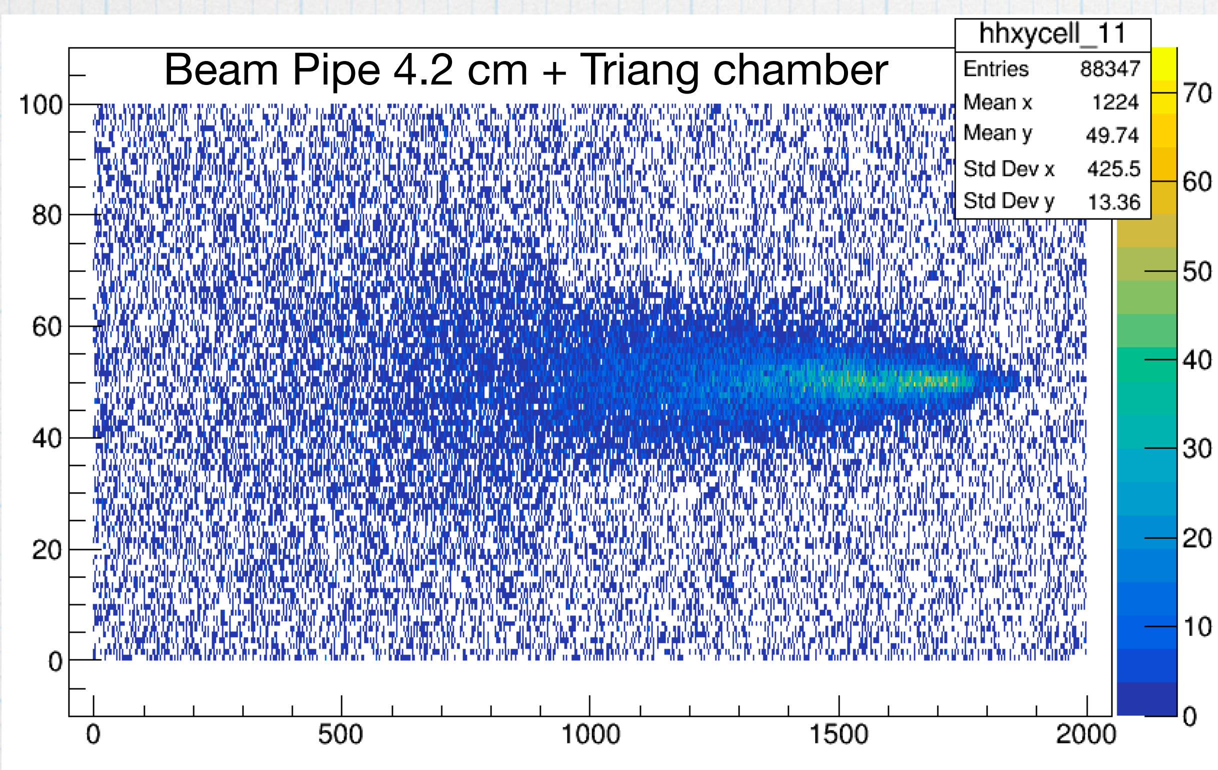
# Deposited energy in Lanex, Beam pipe+chamber, ~4500 bx

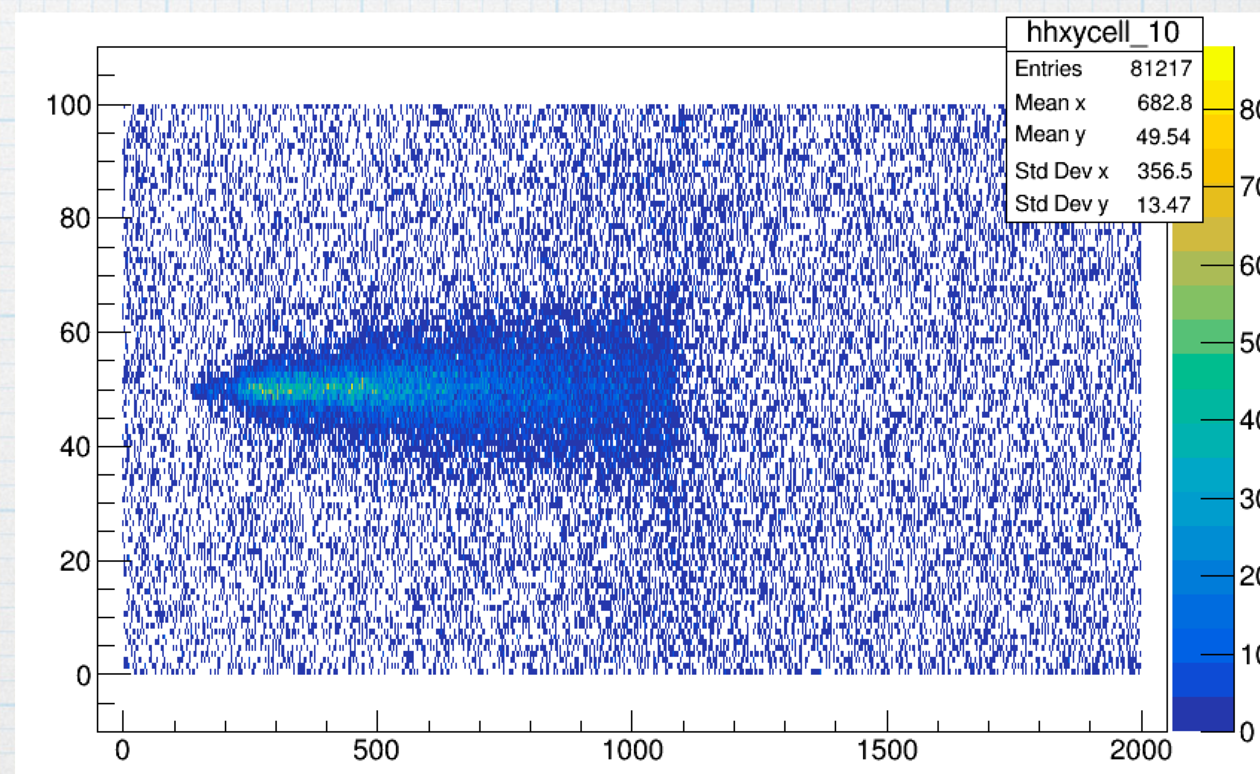
## Positron arm

## Electron arm

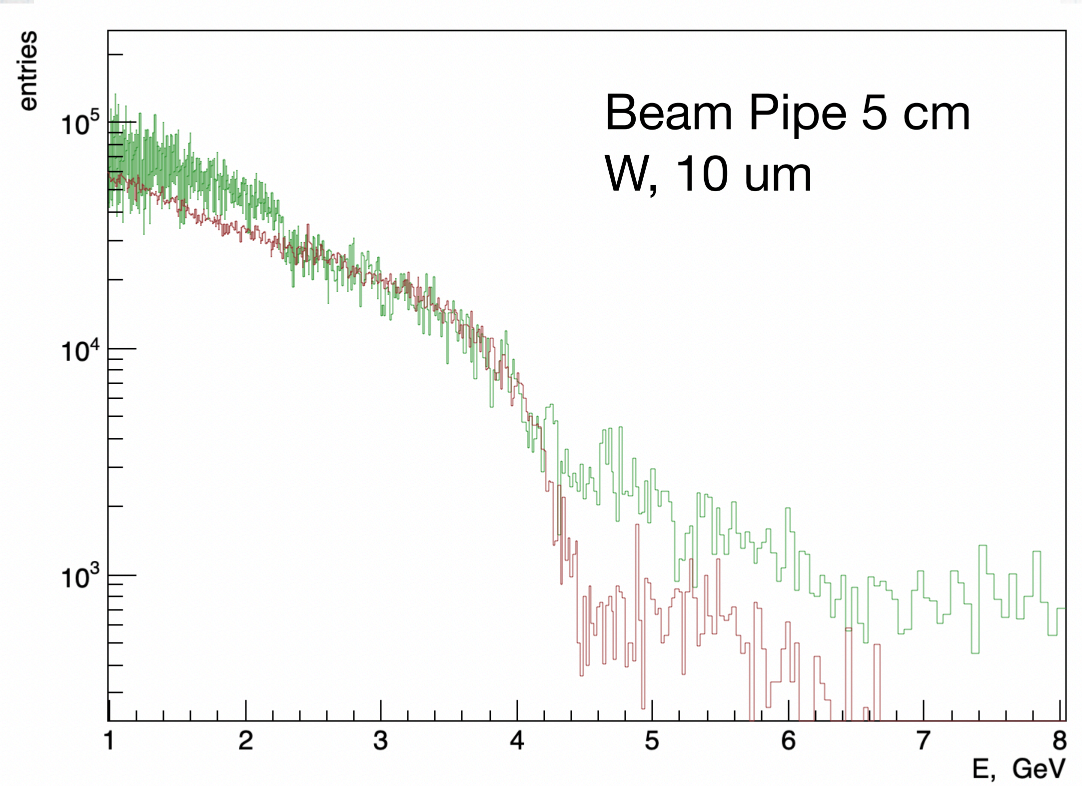


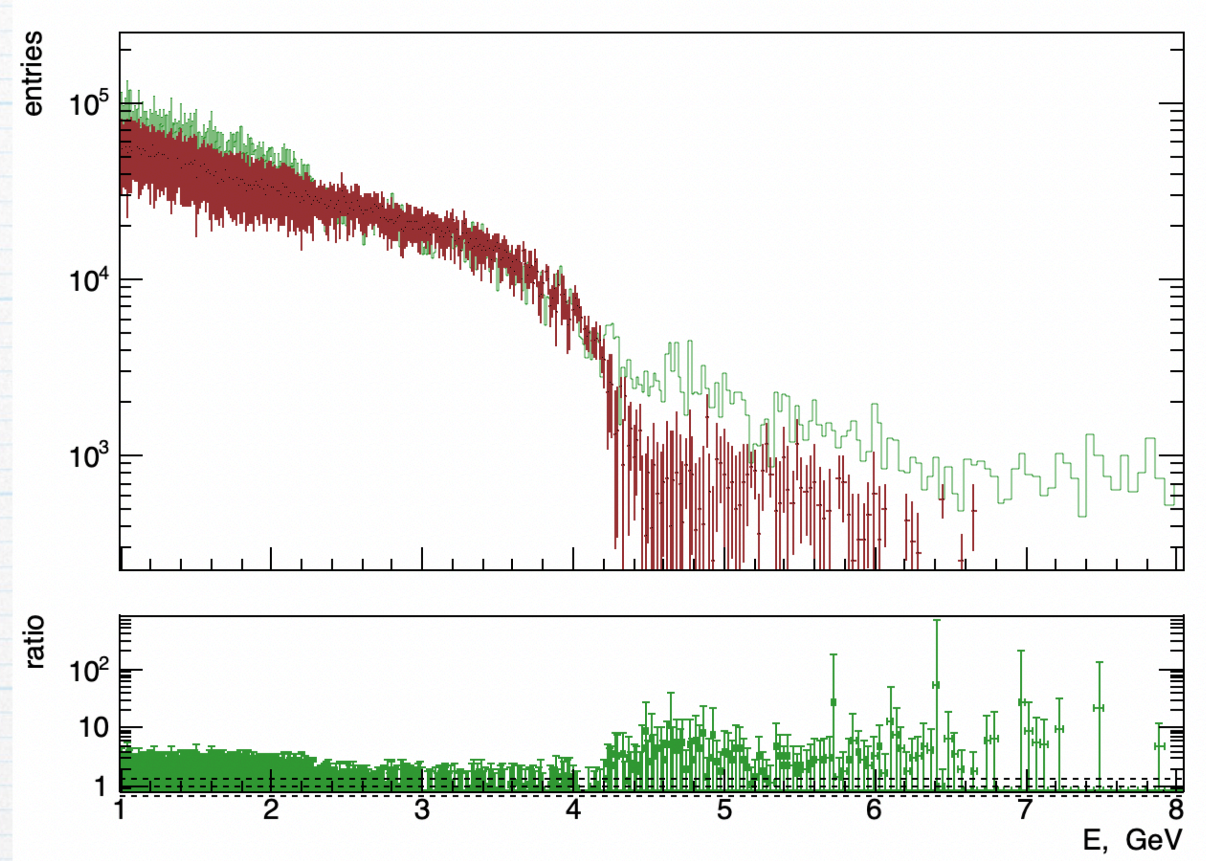



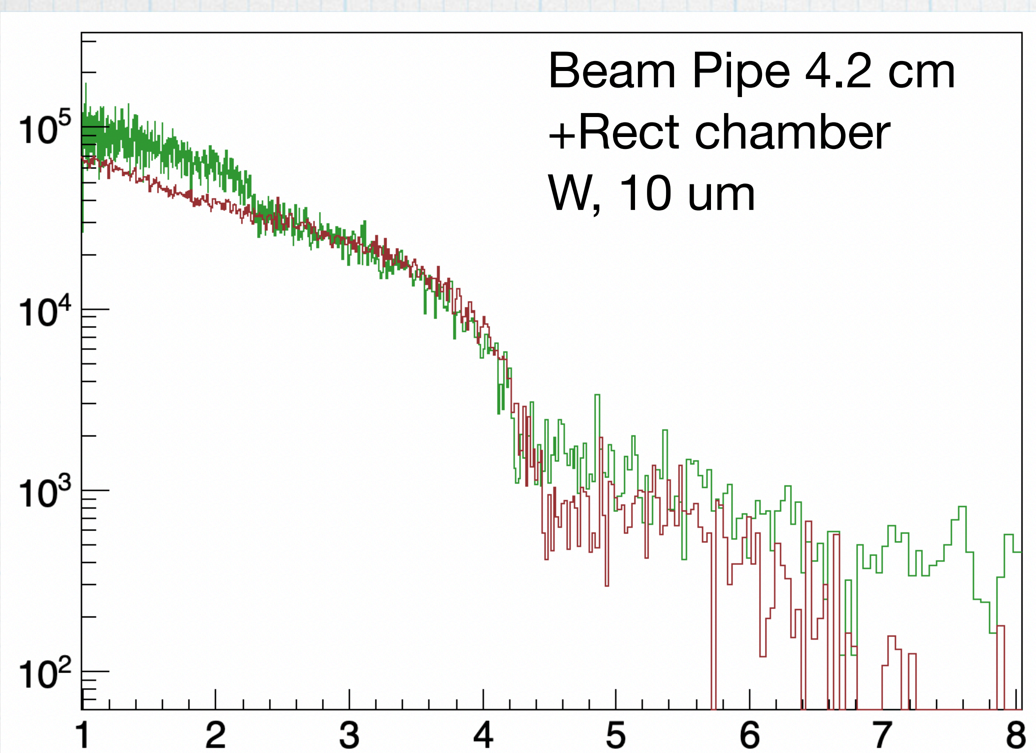



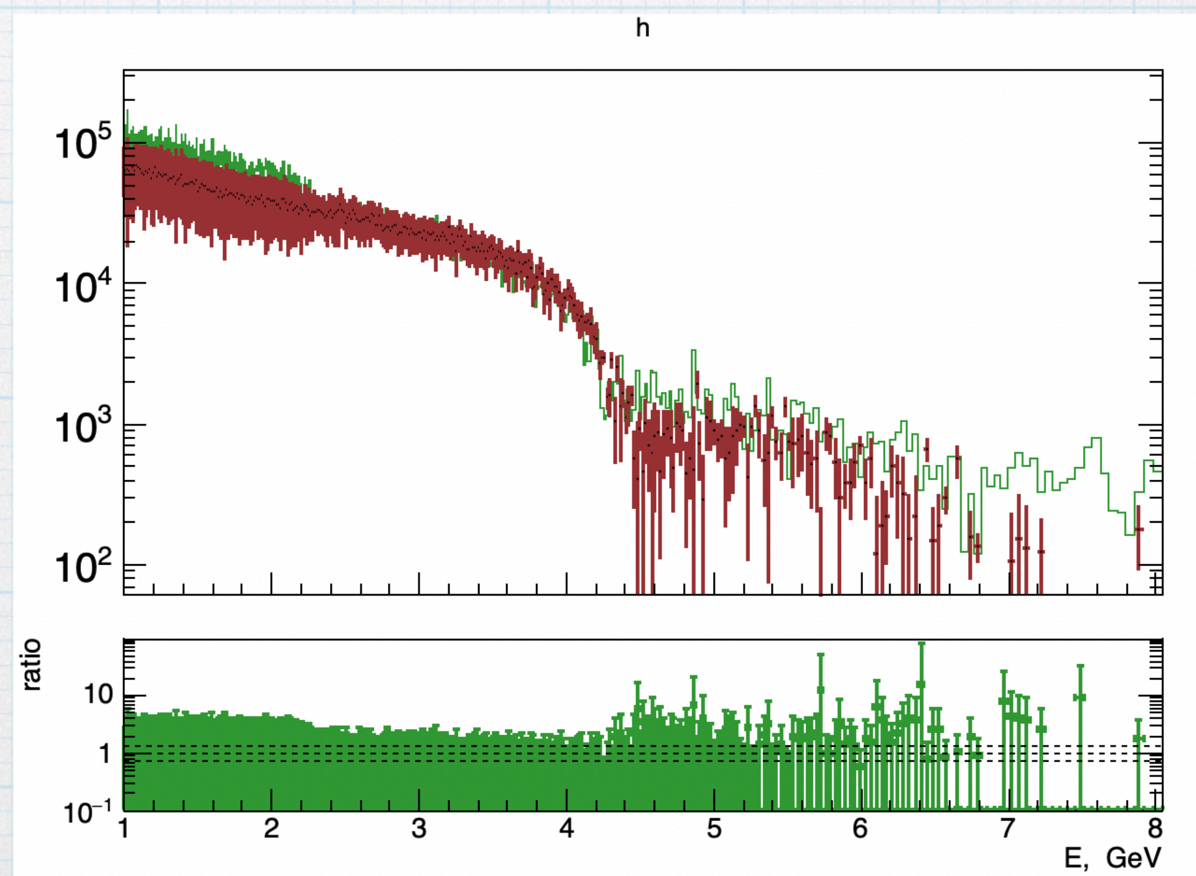



# True vs Reconstructed

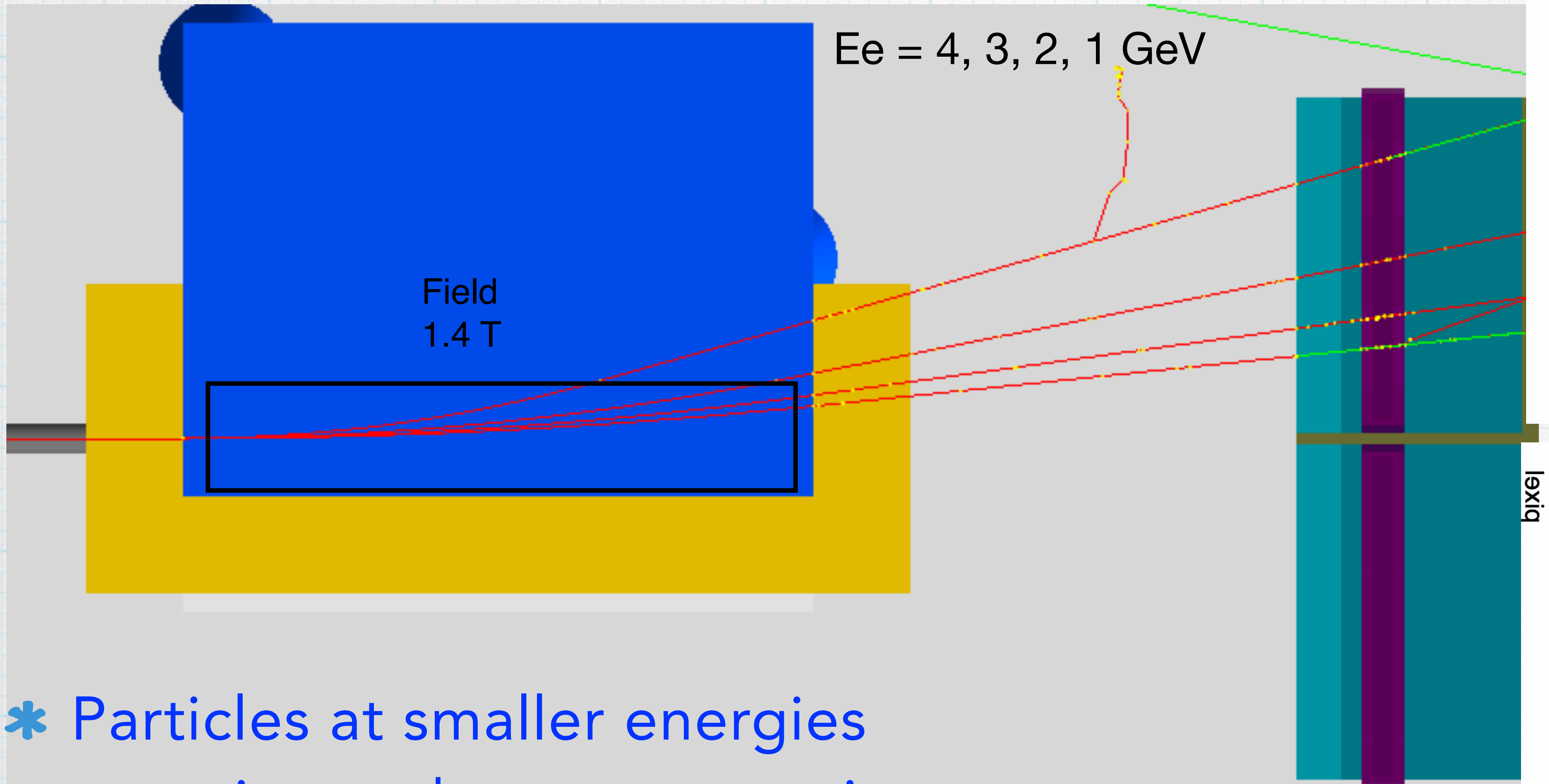


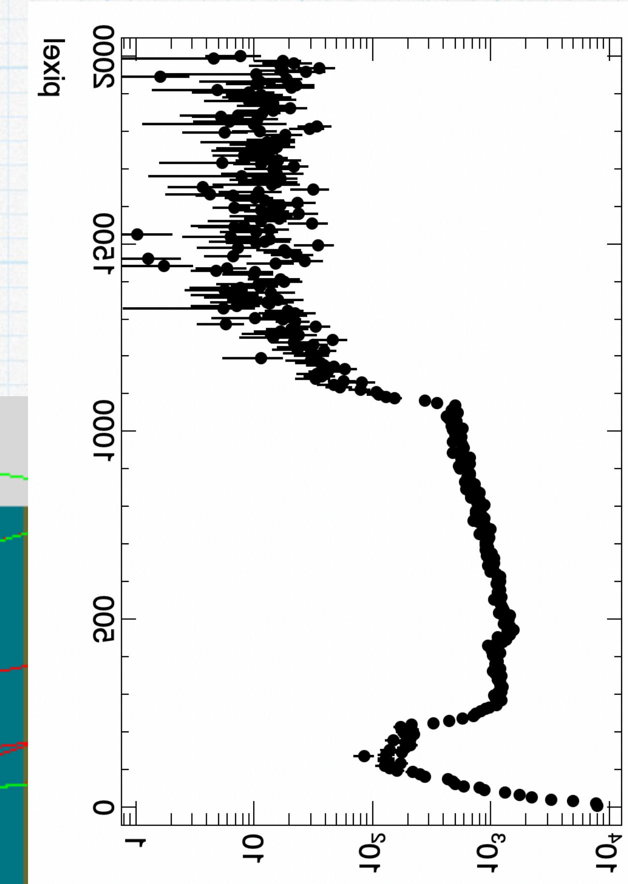



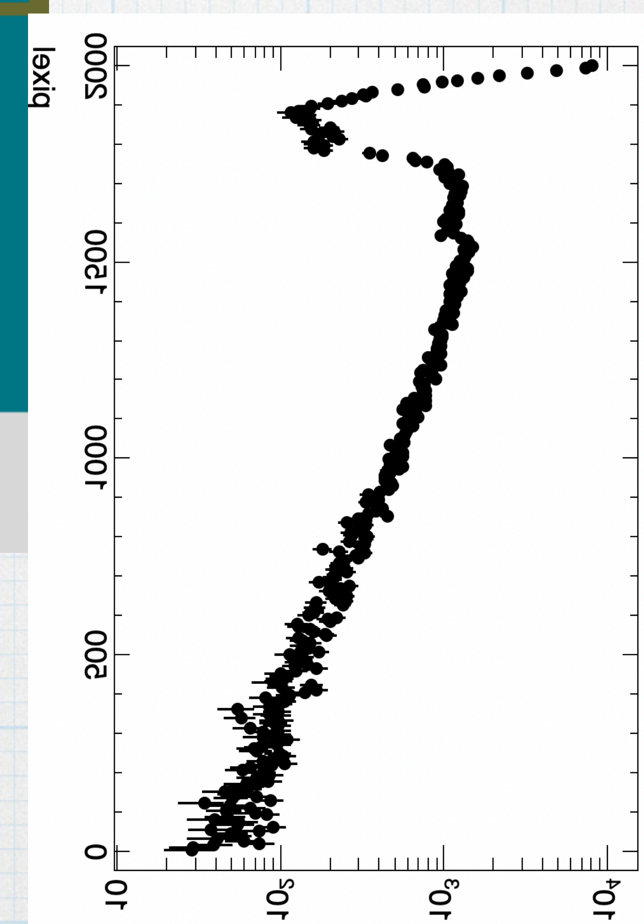



# The reason for substructure at low E in reconstructed spectra



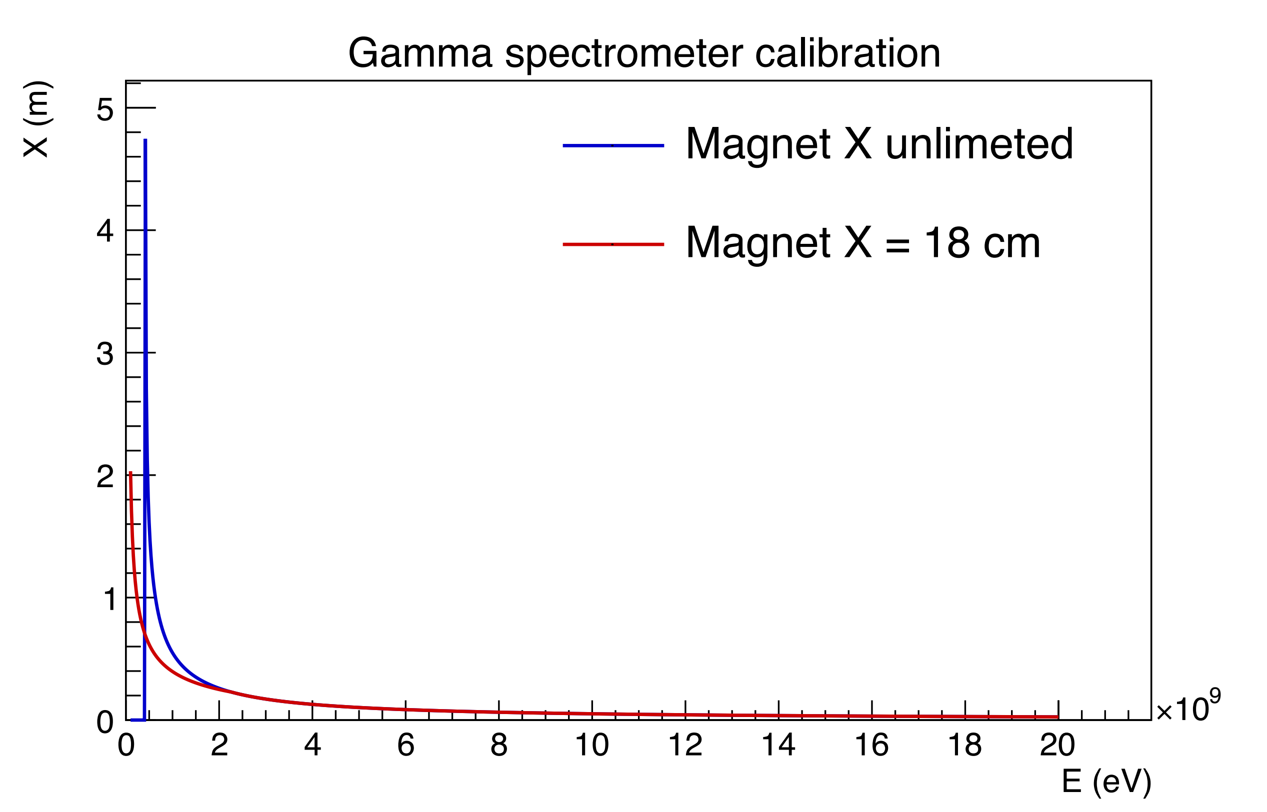



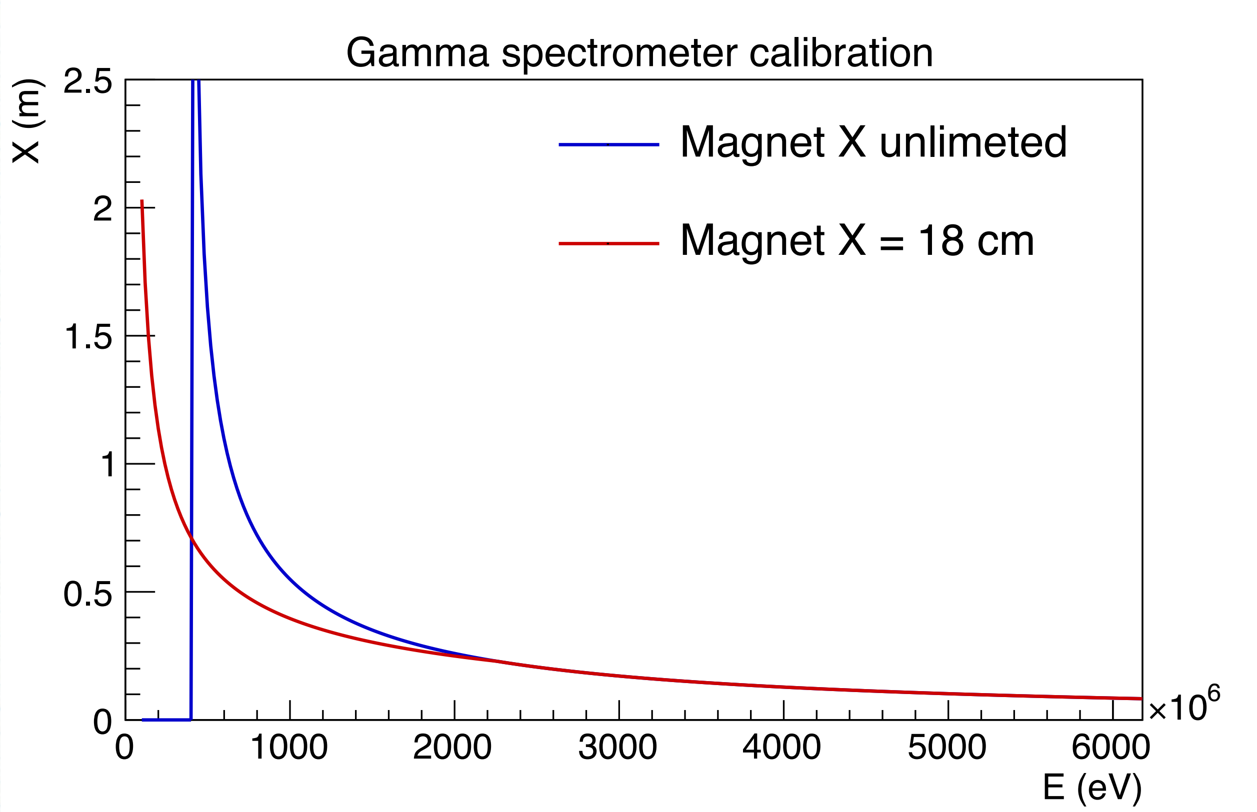



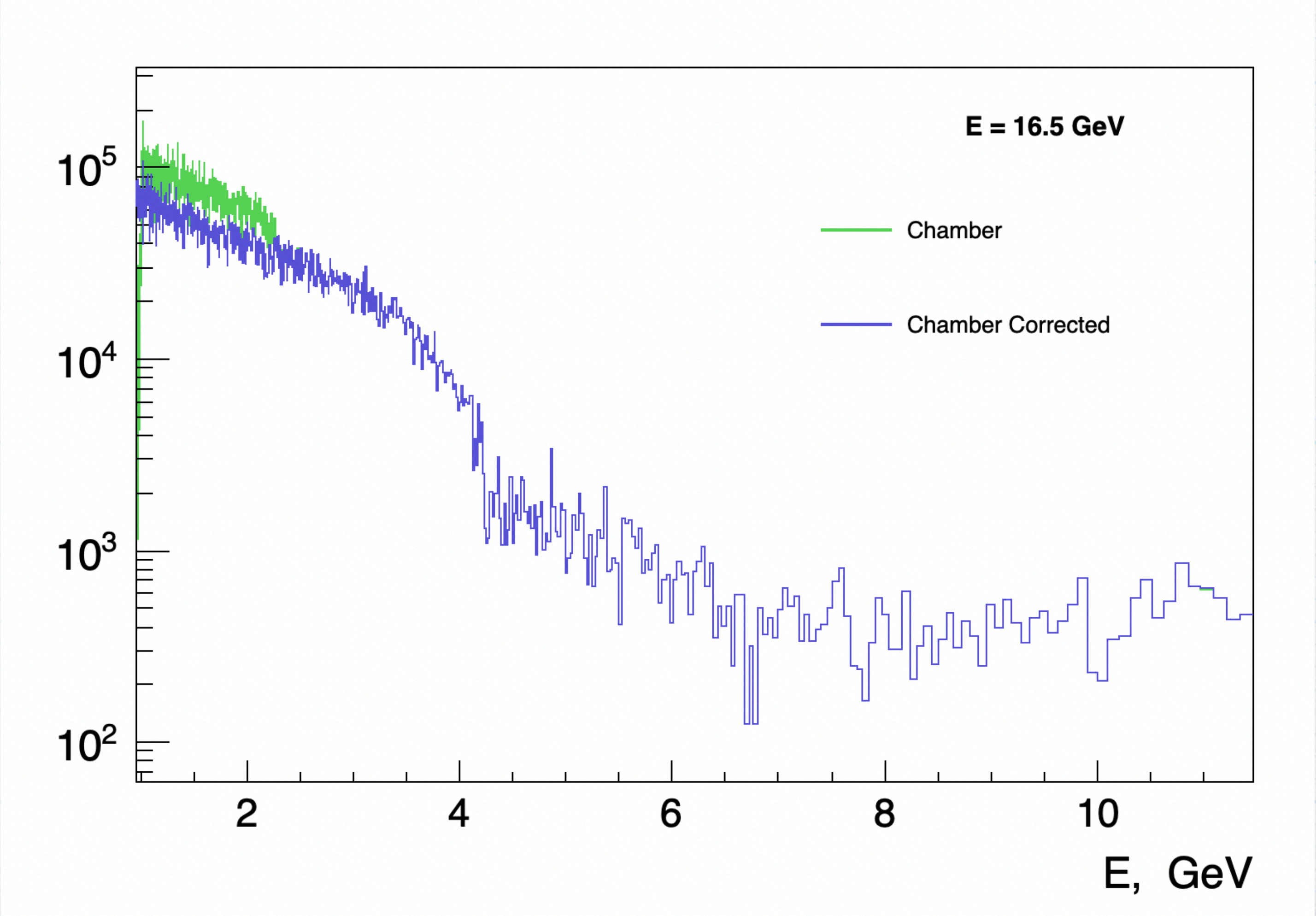

* Particles at smaller energies experience shorter magnetic field

* Should be counted for in calibration, converting x-distributions into energy spectra

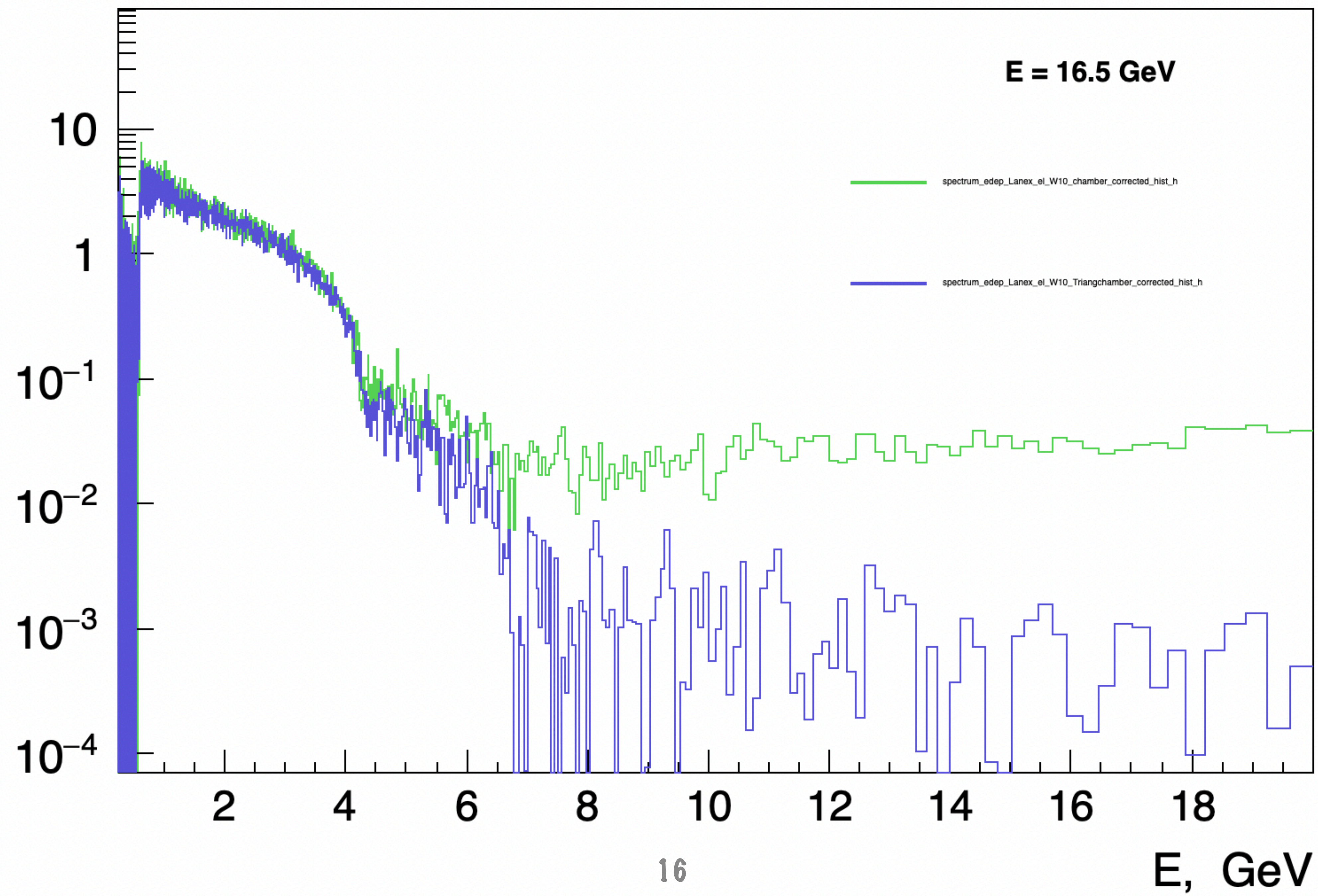
# Corrected calibration



# Reconstructed spectra: Rectangular vs Rectangular chamber



# Summary

* The performance of FDS setup was compared with pipe, with pipe and two types of chambers and without beam pipe from the target to Gamma spectrometer detectors

* Beam pipe with chamber and target provide more clean signal formation

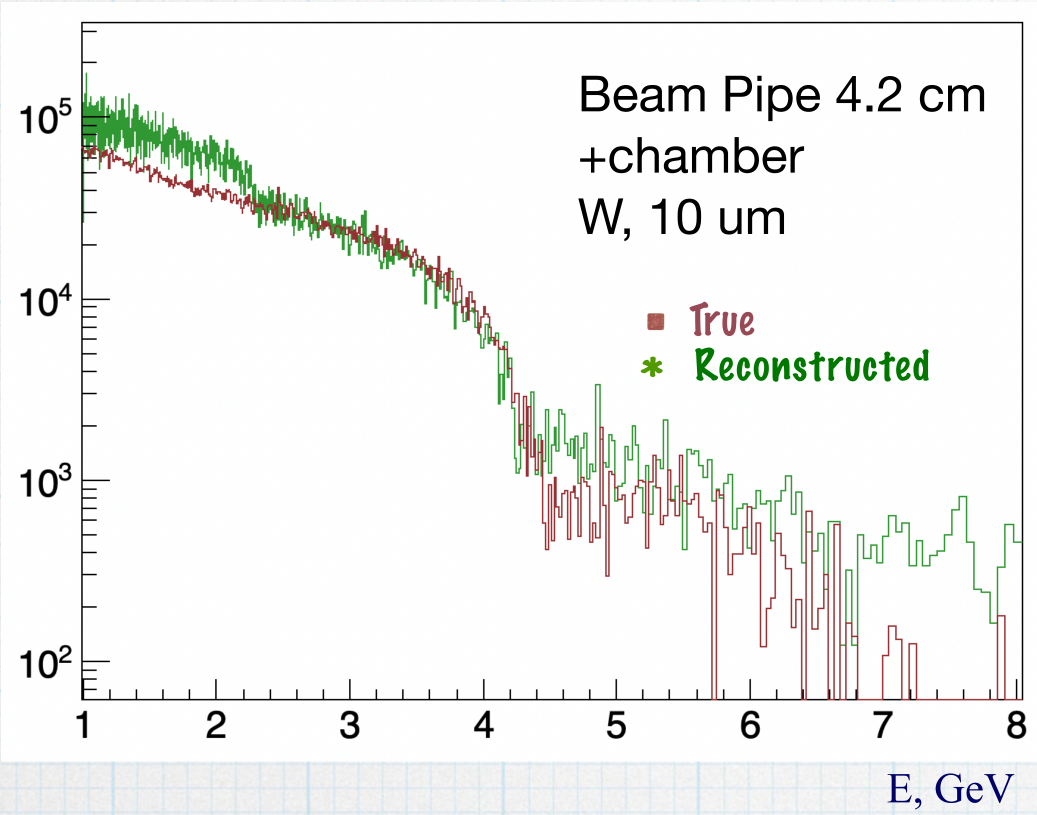
* Even with shorter chamber where particles cross the window almost perpendicular to the window, the first edge is clearly seen and could be reconstructed

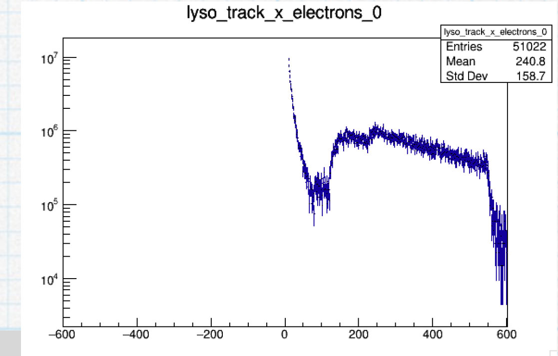
* Corrected calibration

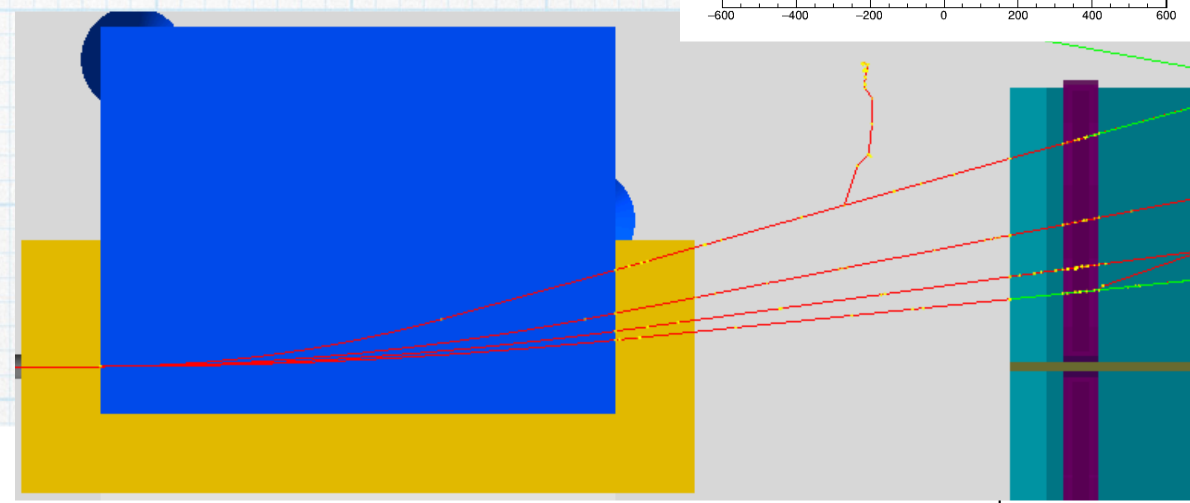
* Reconstruction

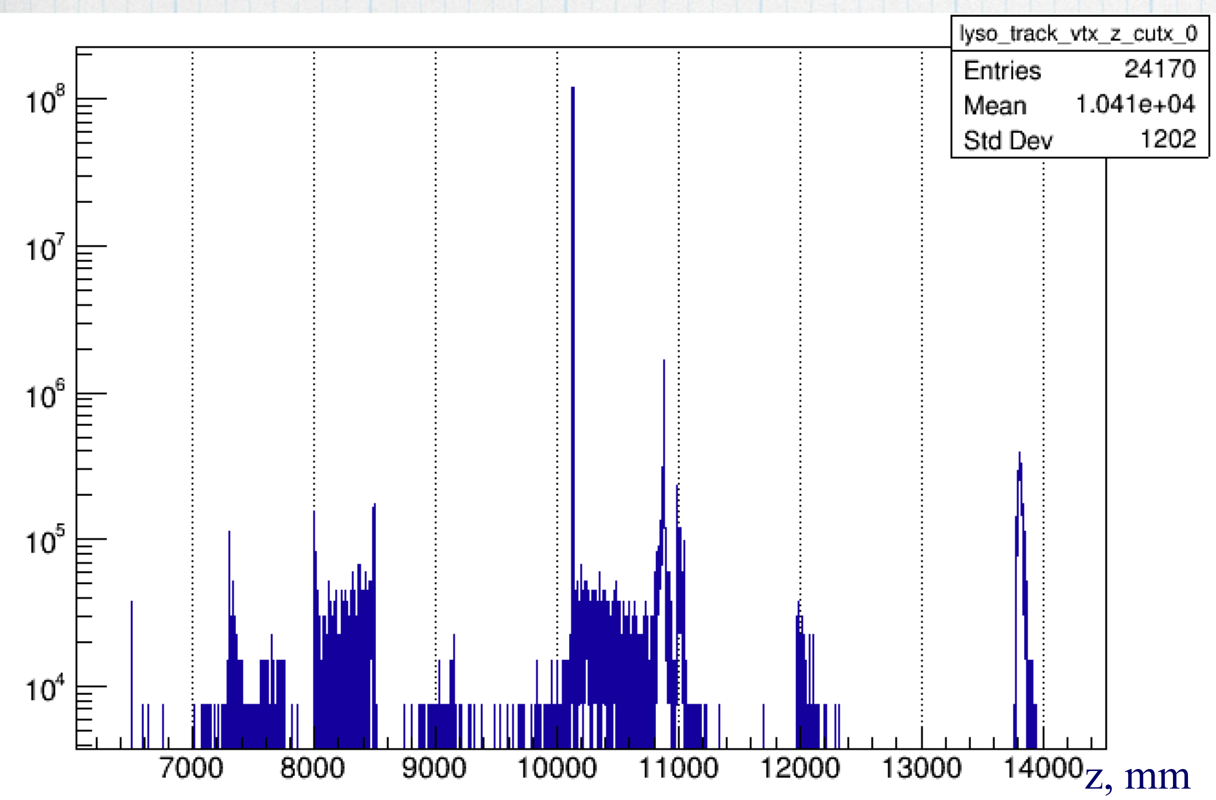
# Back up

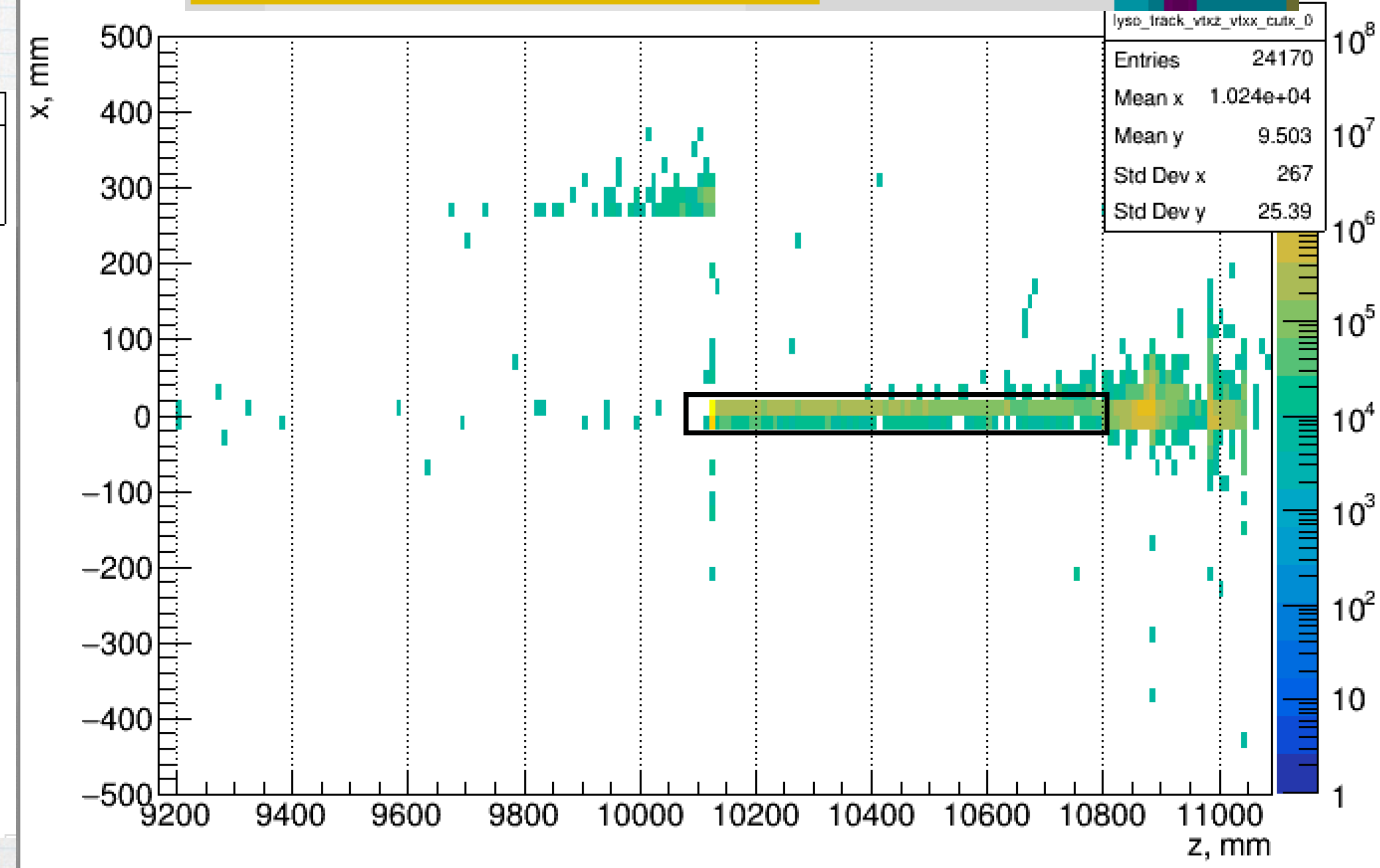
# The reason for substructure at low E in reconstructed spectra



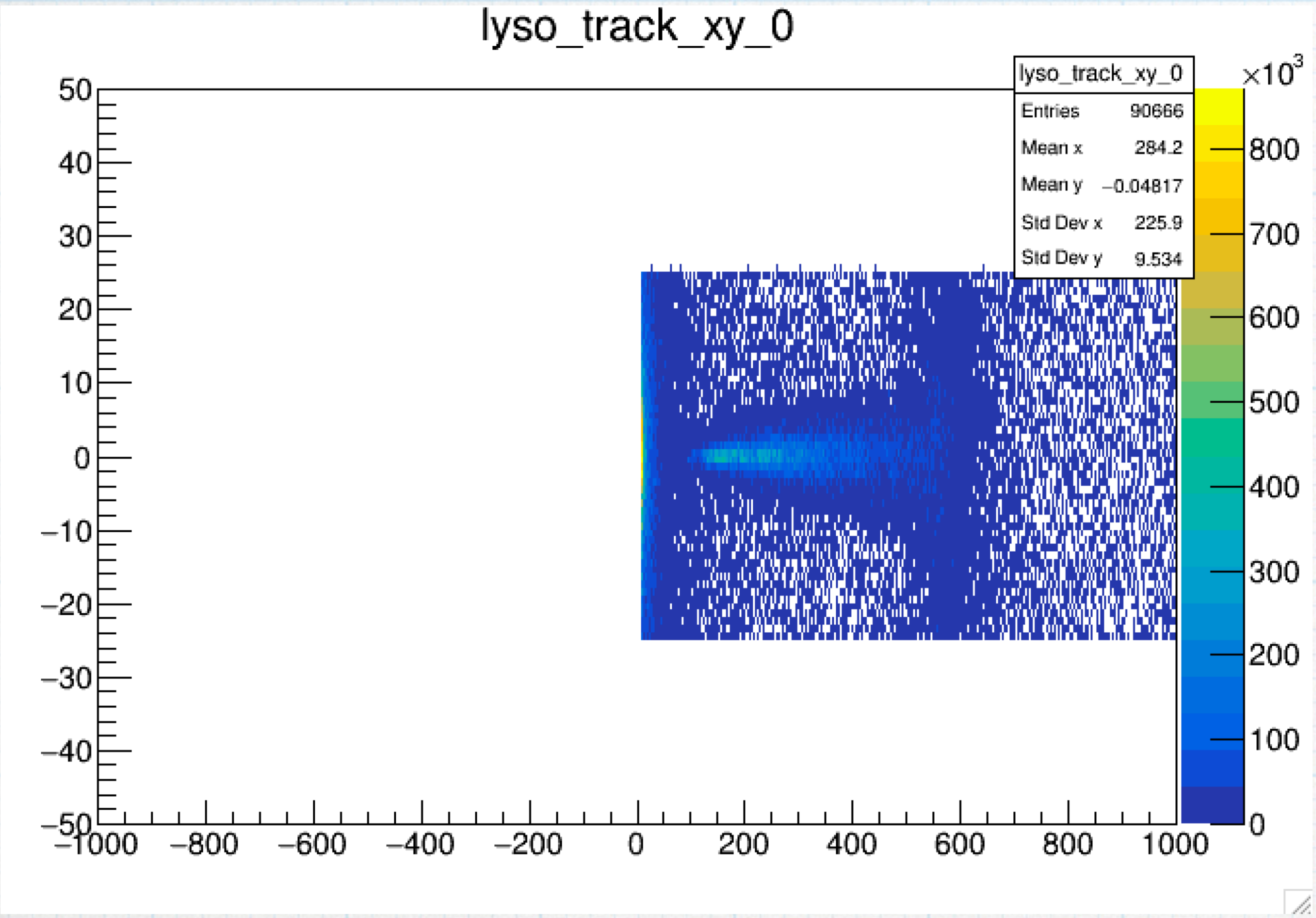



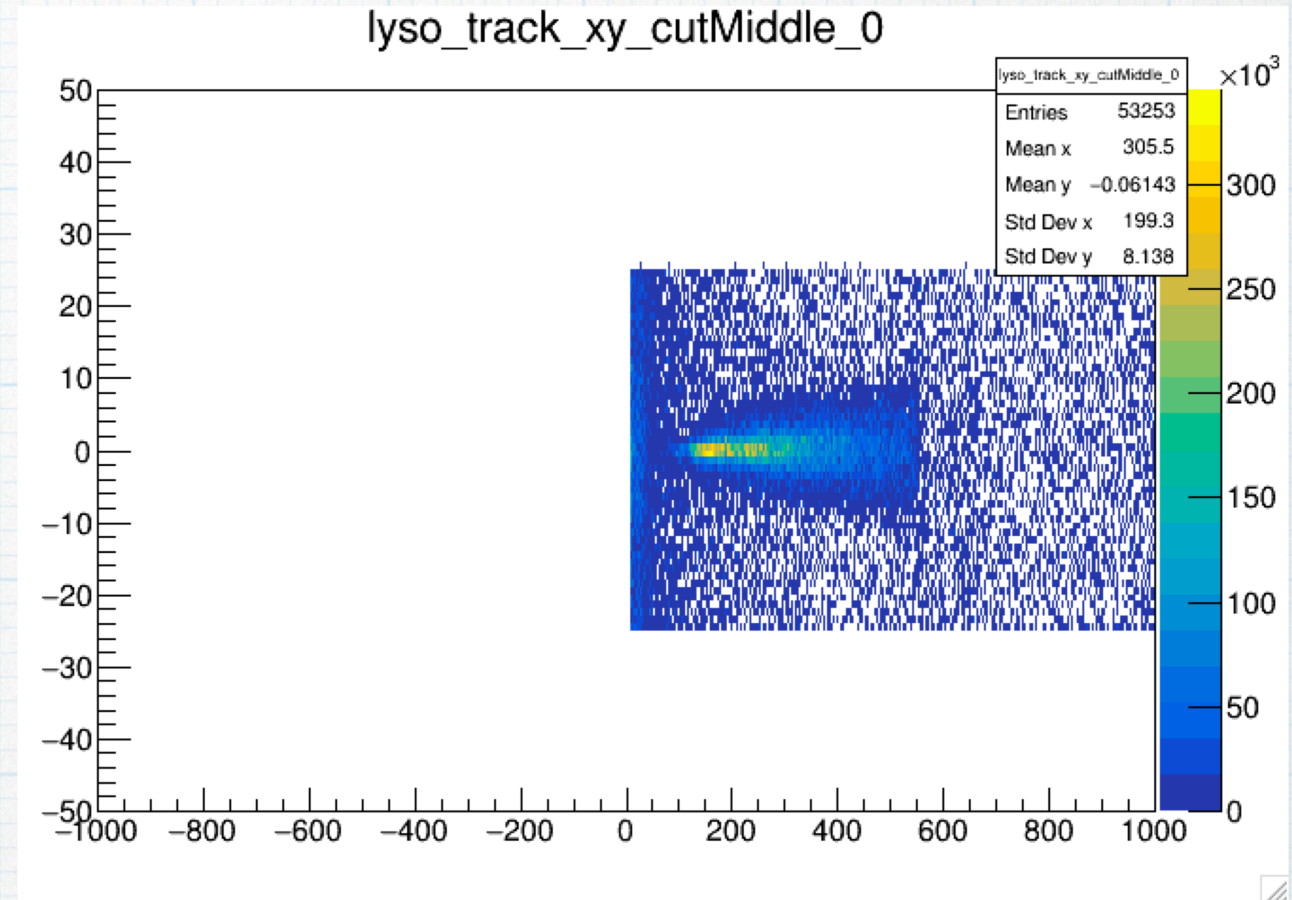



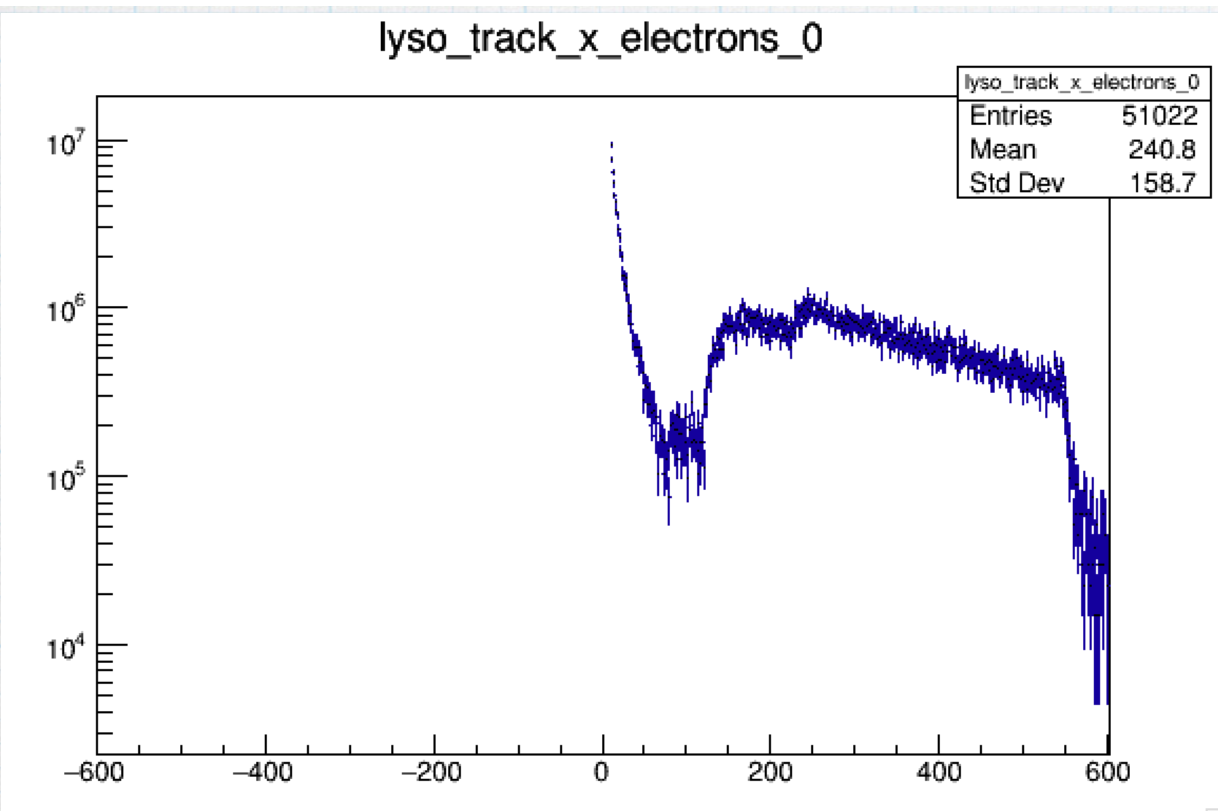


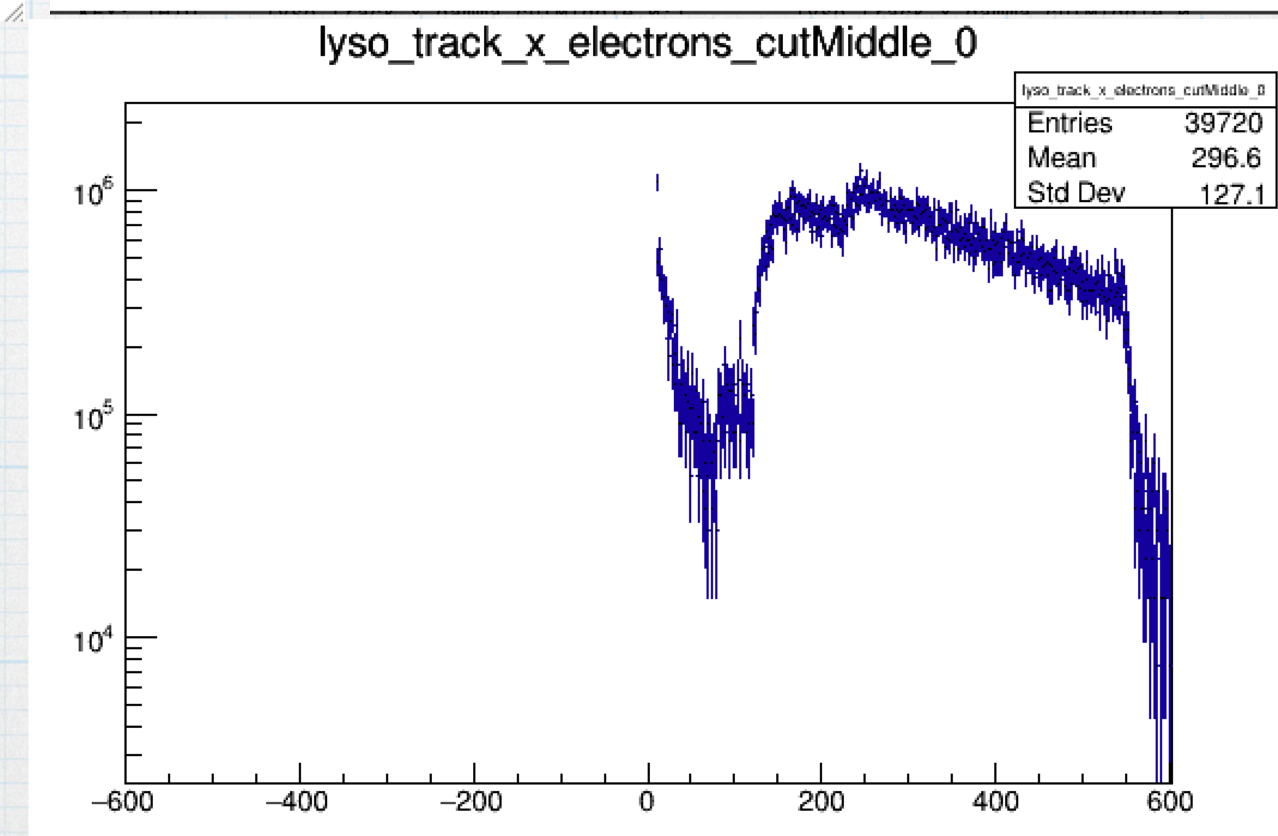



# xy and x track distributions



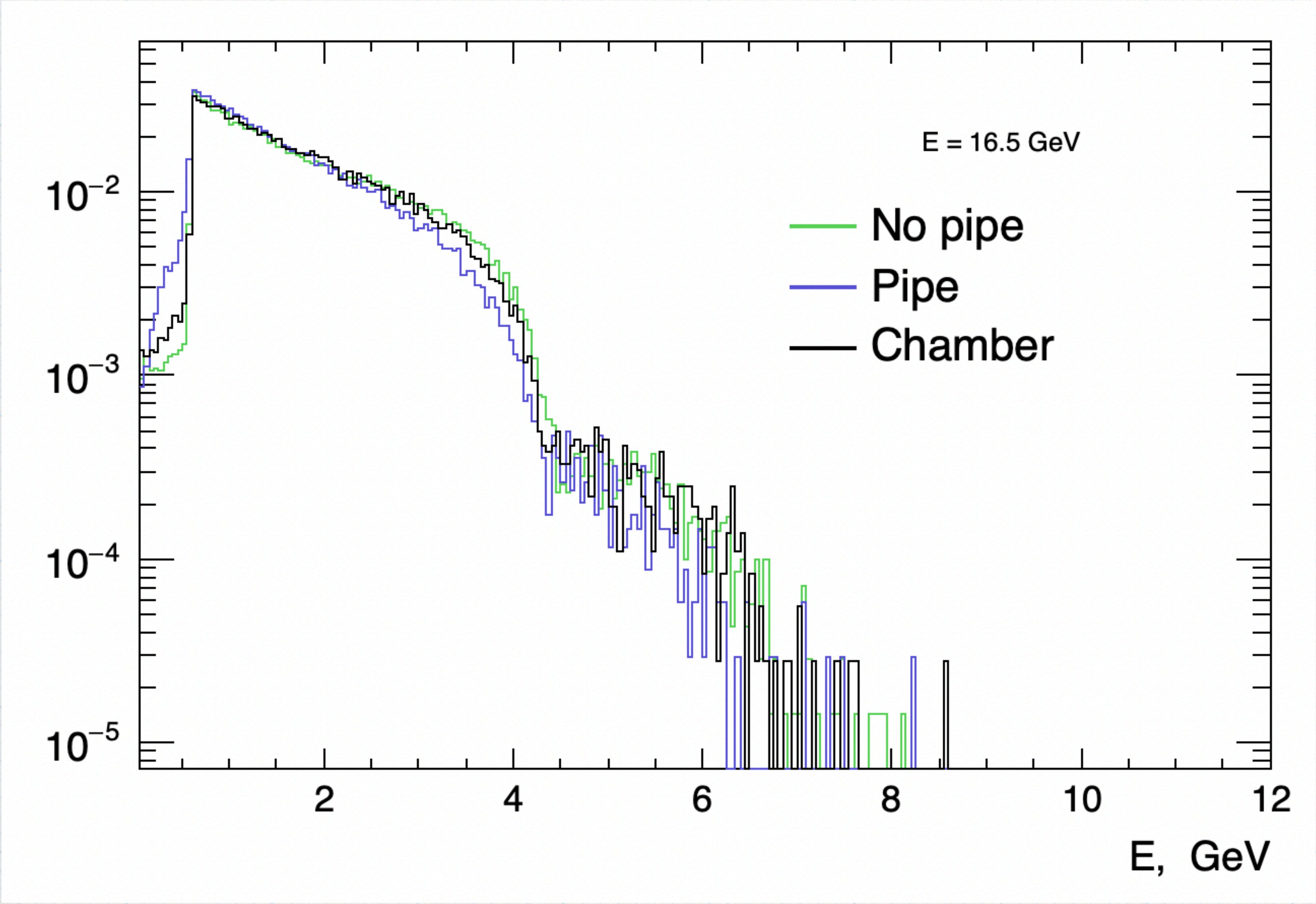




- Beam pipe from chamber till Gamma profiler is necessary

# "True" spectra

JETI40, 16.5 GeV, 50 um




- Electrons/positrons generated in target by primary photon and which are hitting Lanex screens
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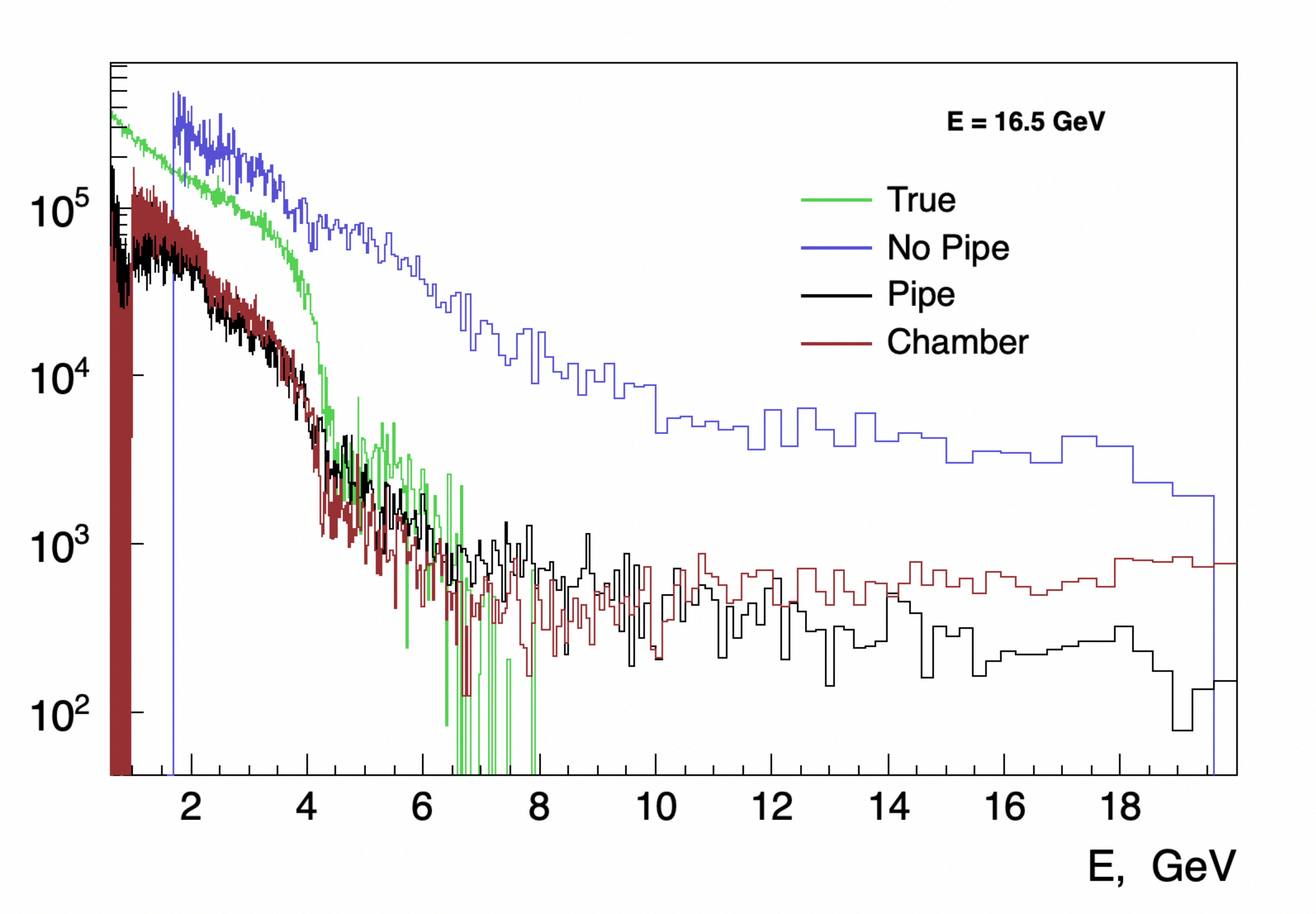
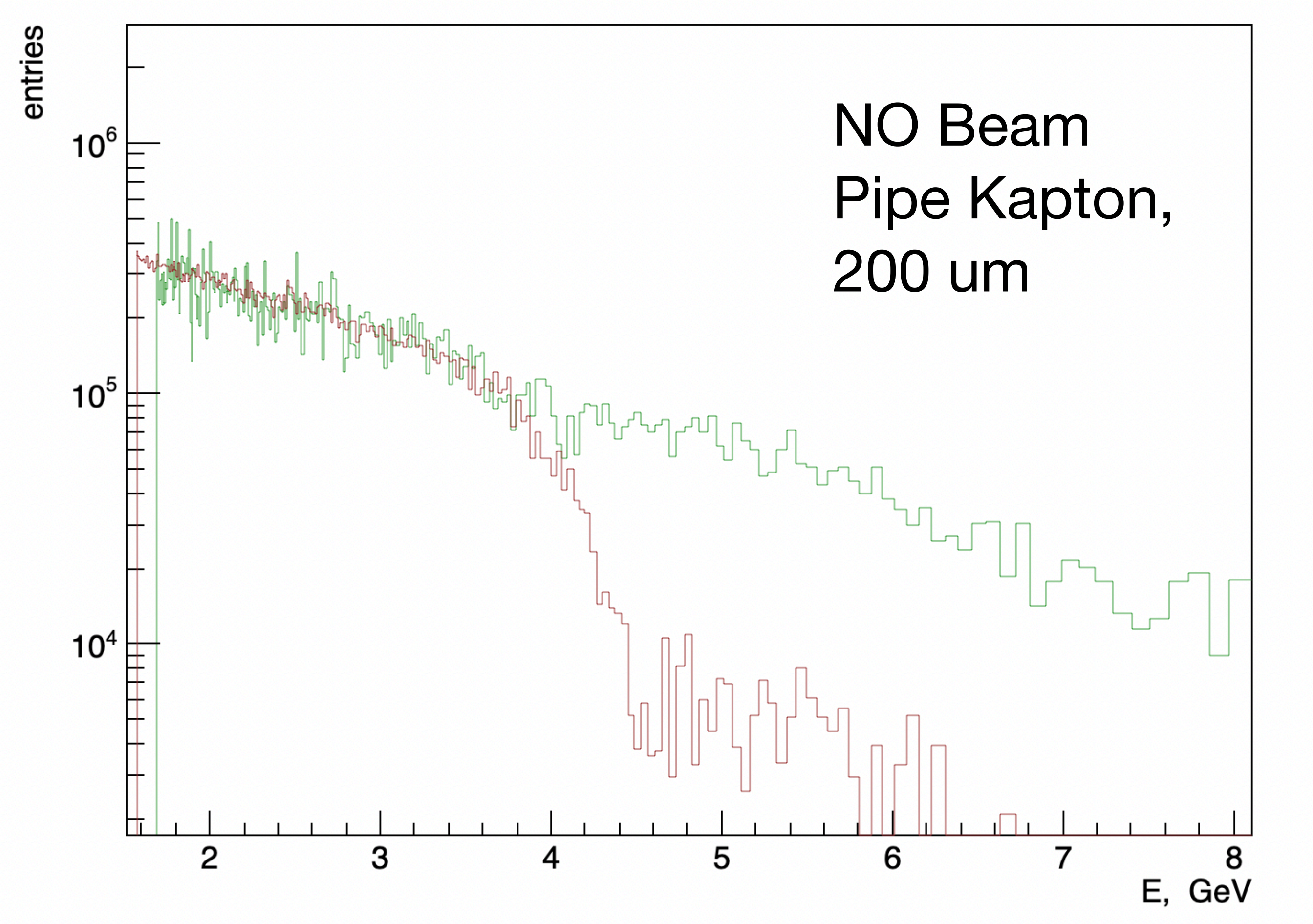
- Parent == primary
- Primary pdg ==22
- |vtx x,y |<25 mm
- |vtx z - 6.5 m |< 100 um
- vtx z > 6.5m -100um && vtx z < 9m

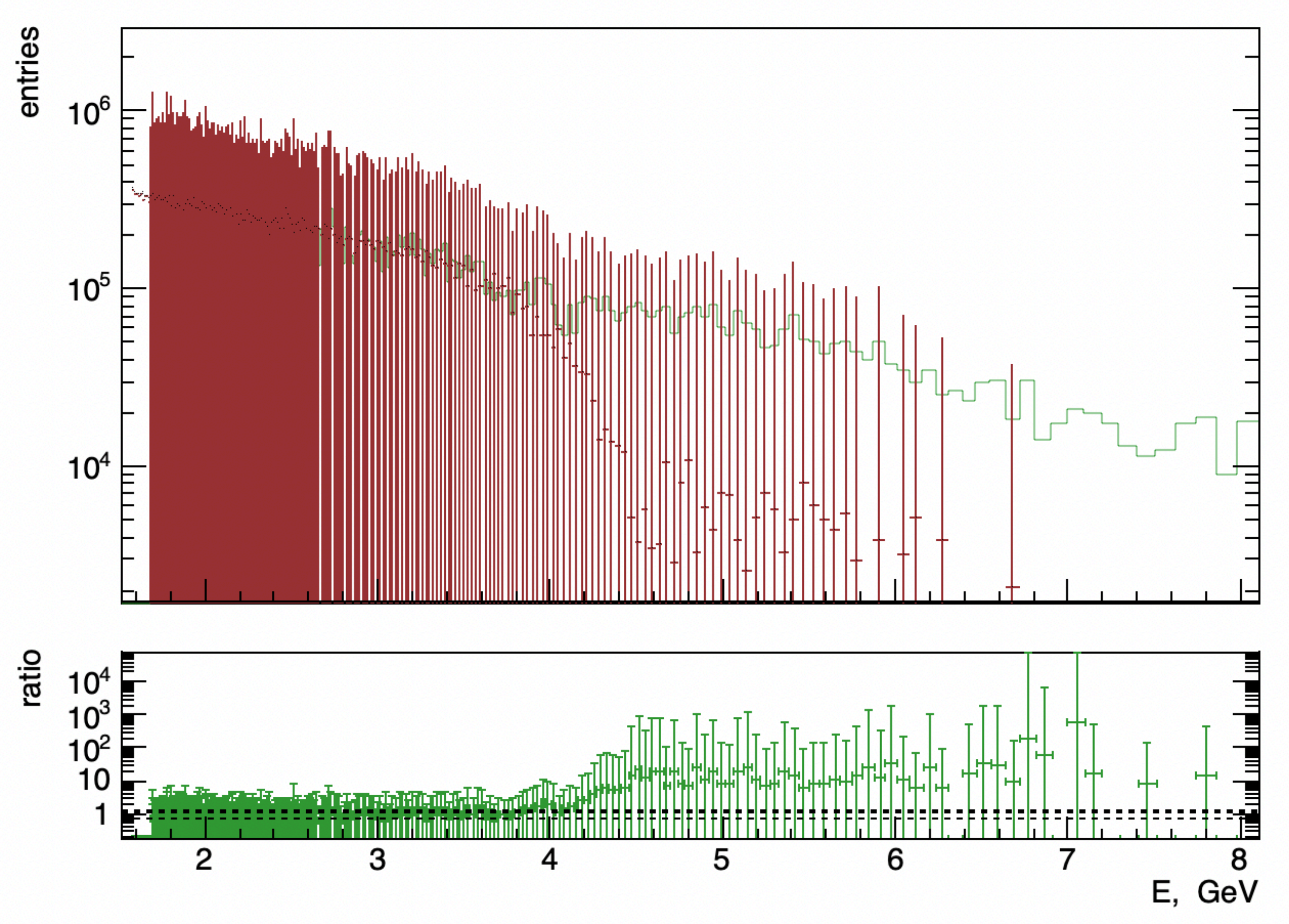
# Reconstructed spectra

Not normalised



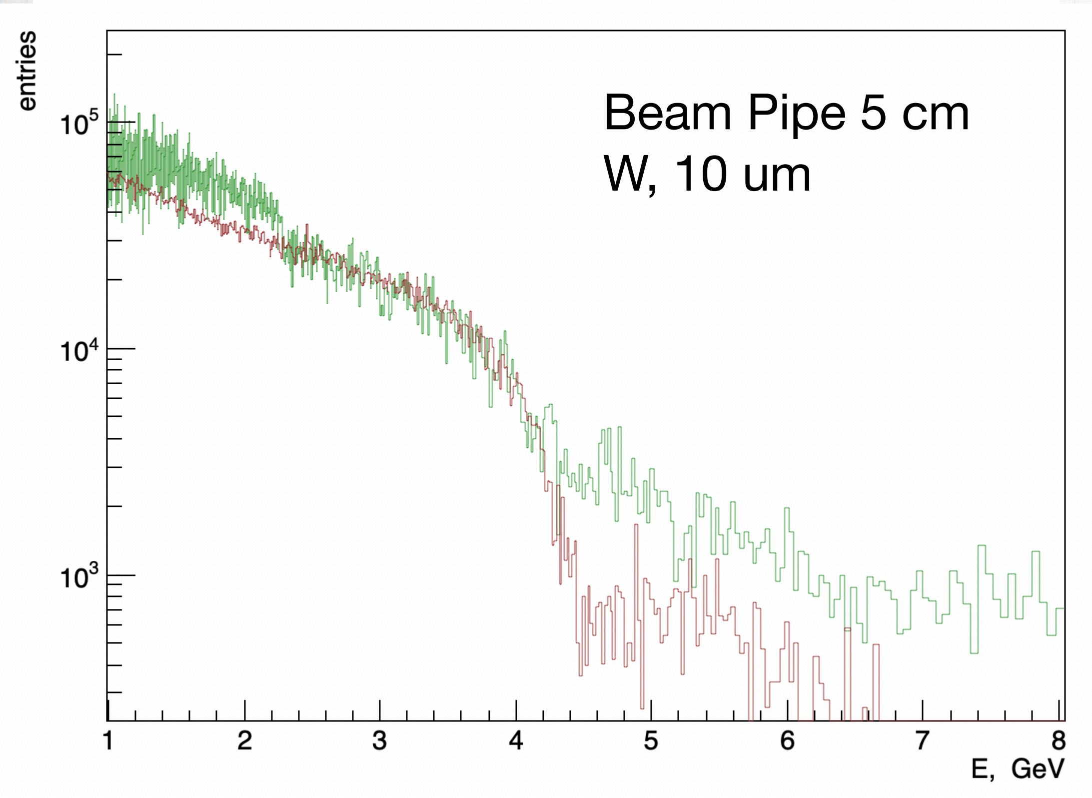
# True vs Reconstructed

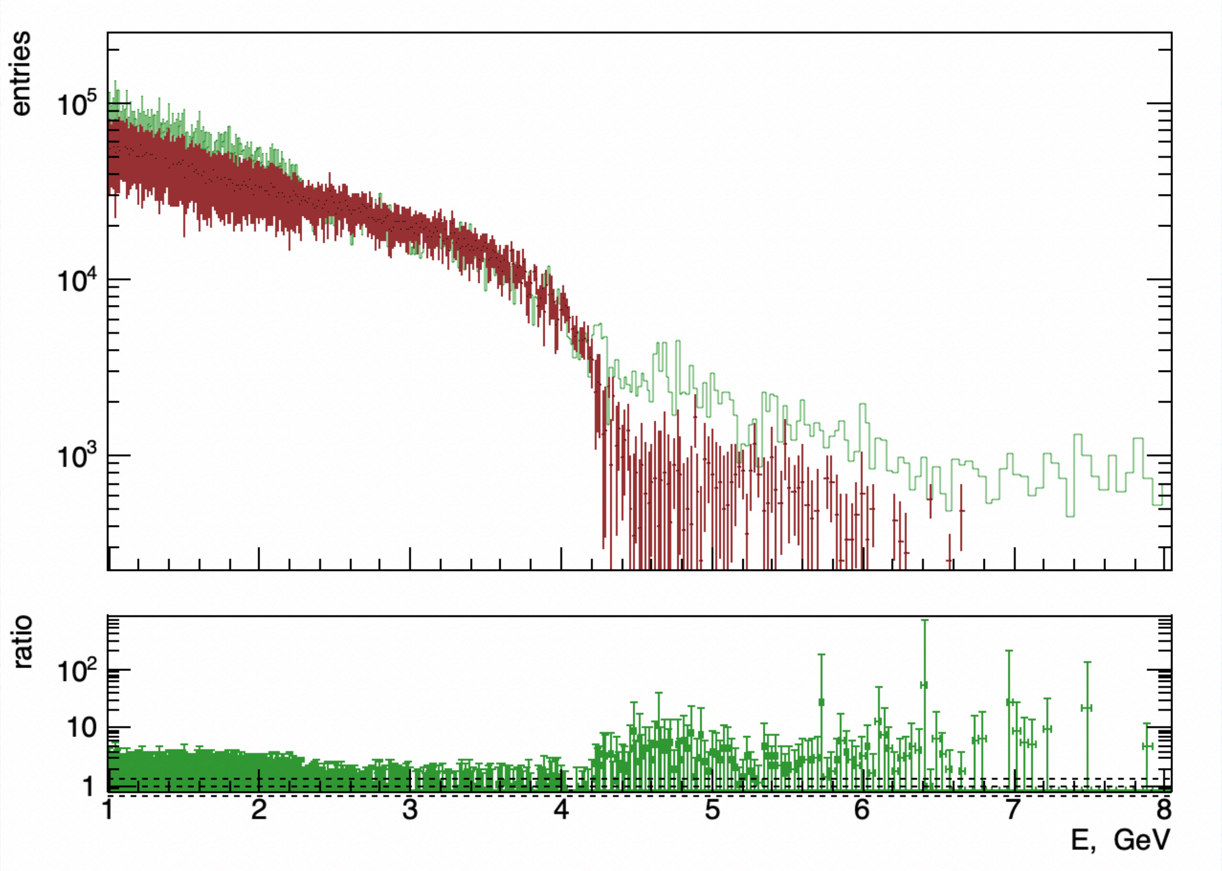


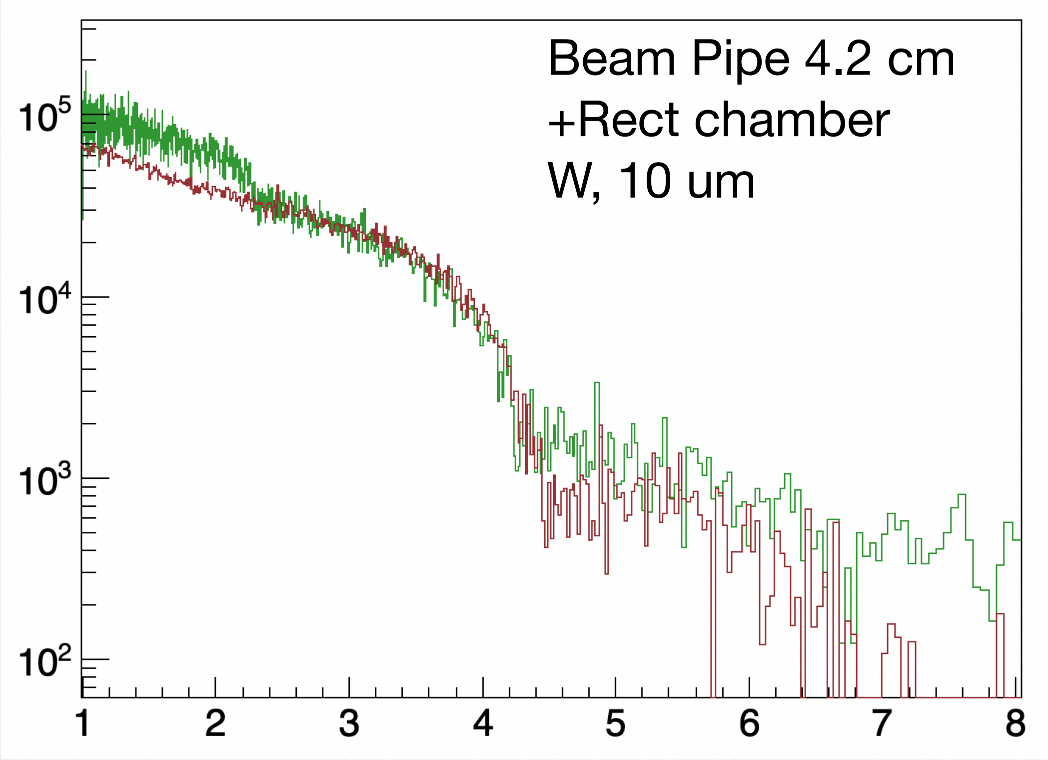



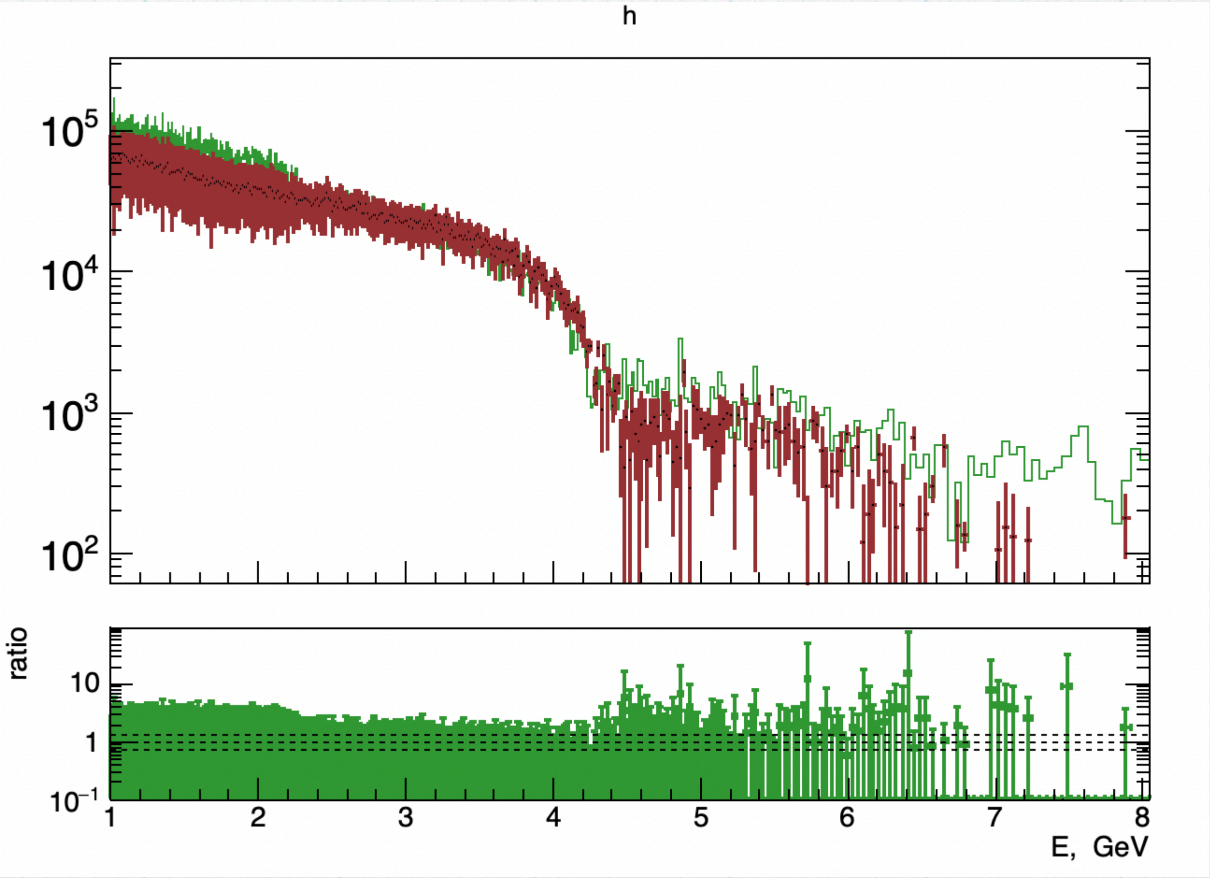

* Spectra were normalised on integral in E range of [2.5; 3]

# True vs Reconstructed

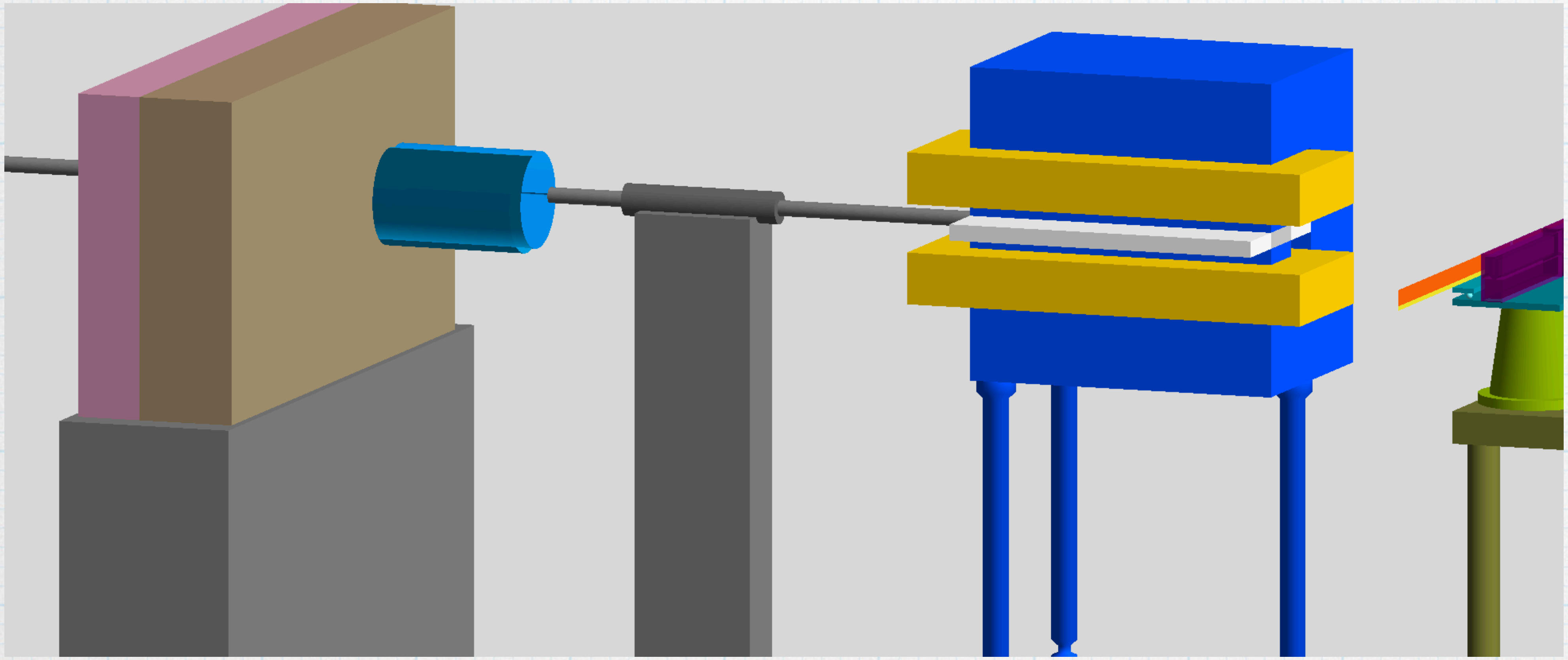


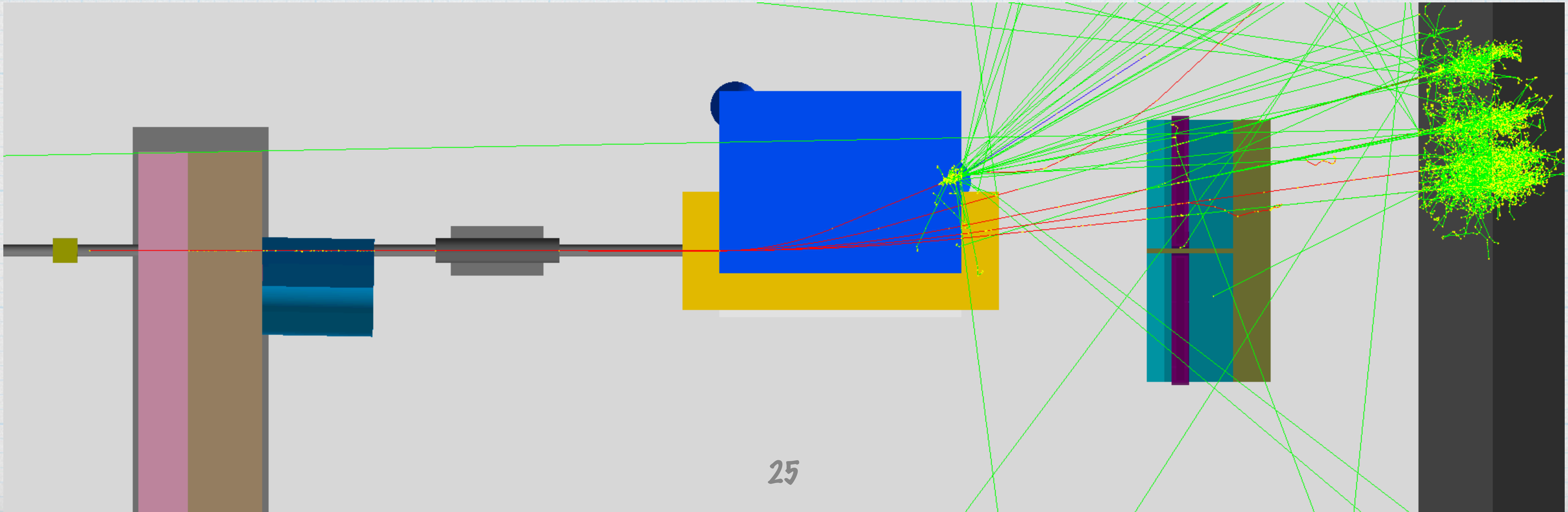



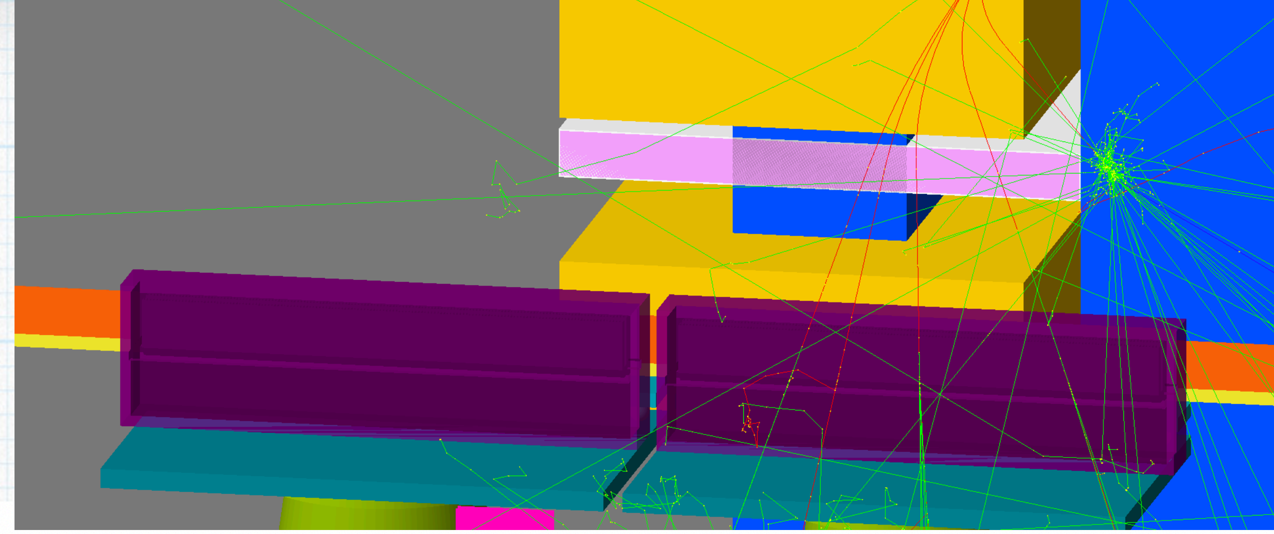
# Forward detector system with beam pipe and short chamber

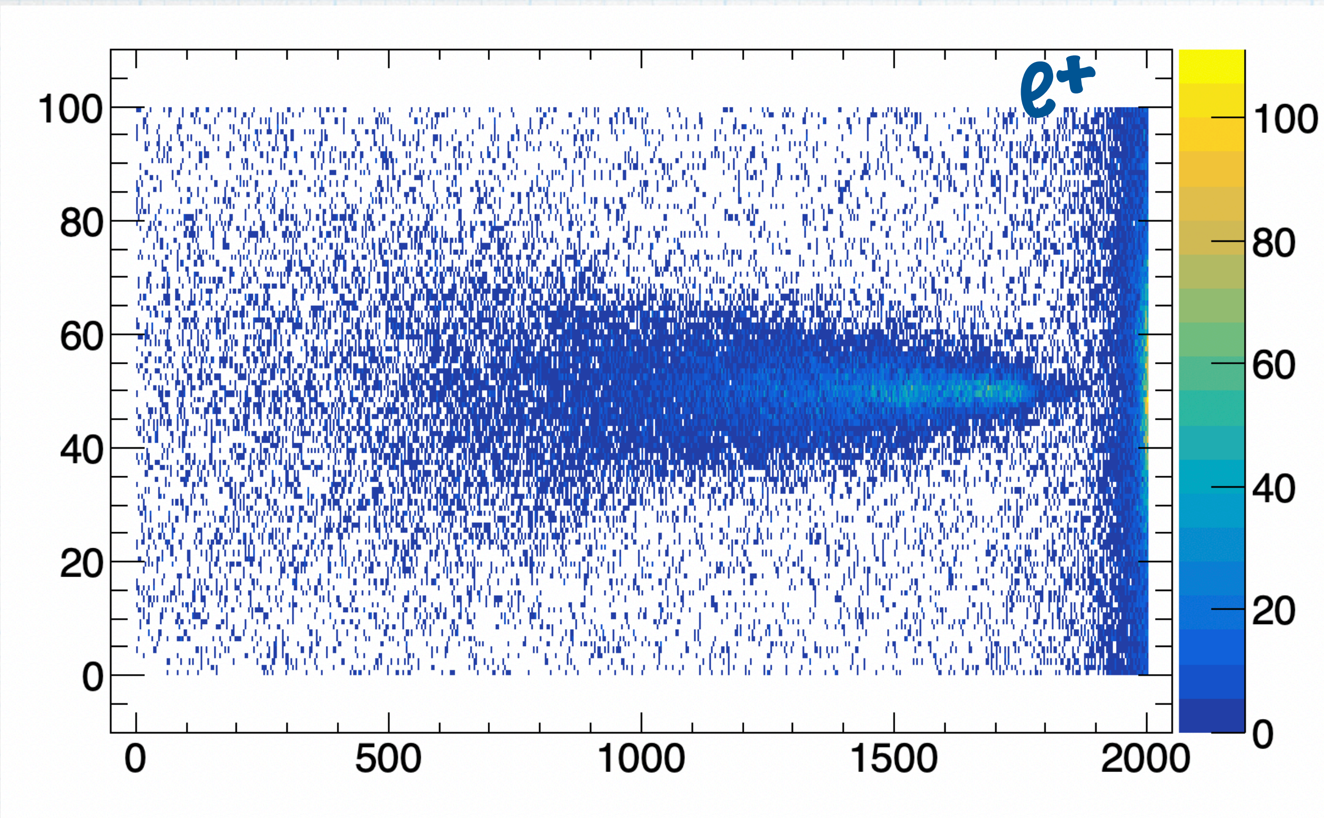


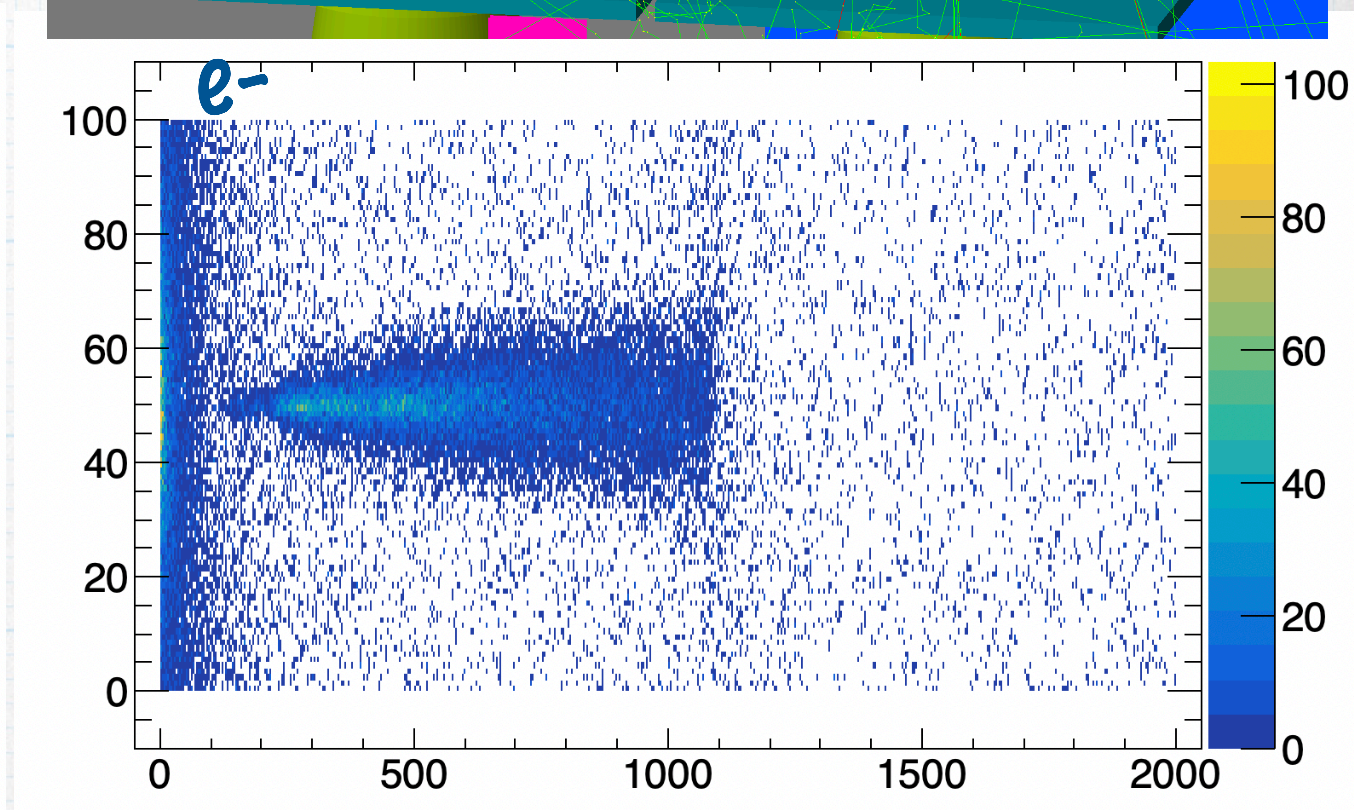
Ee = 4, 3, 2, 0.5 GeV

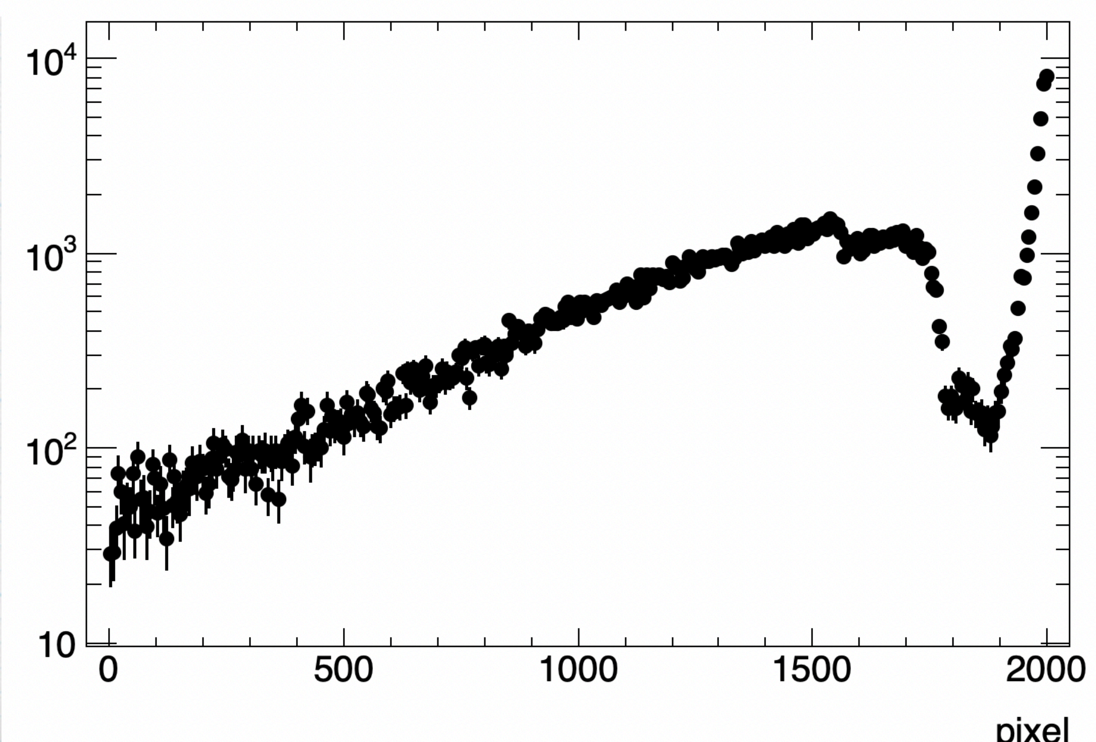


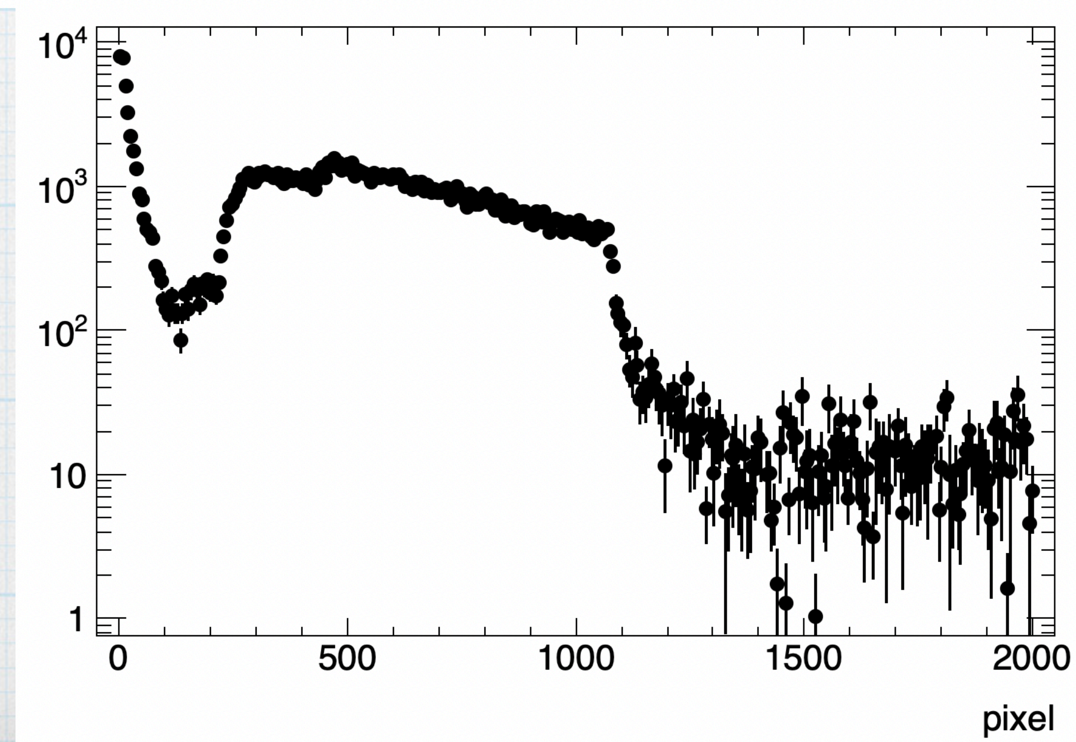
# Deposited energy in Lanex, Beam pipe+chamber, ~4500 bx



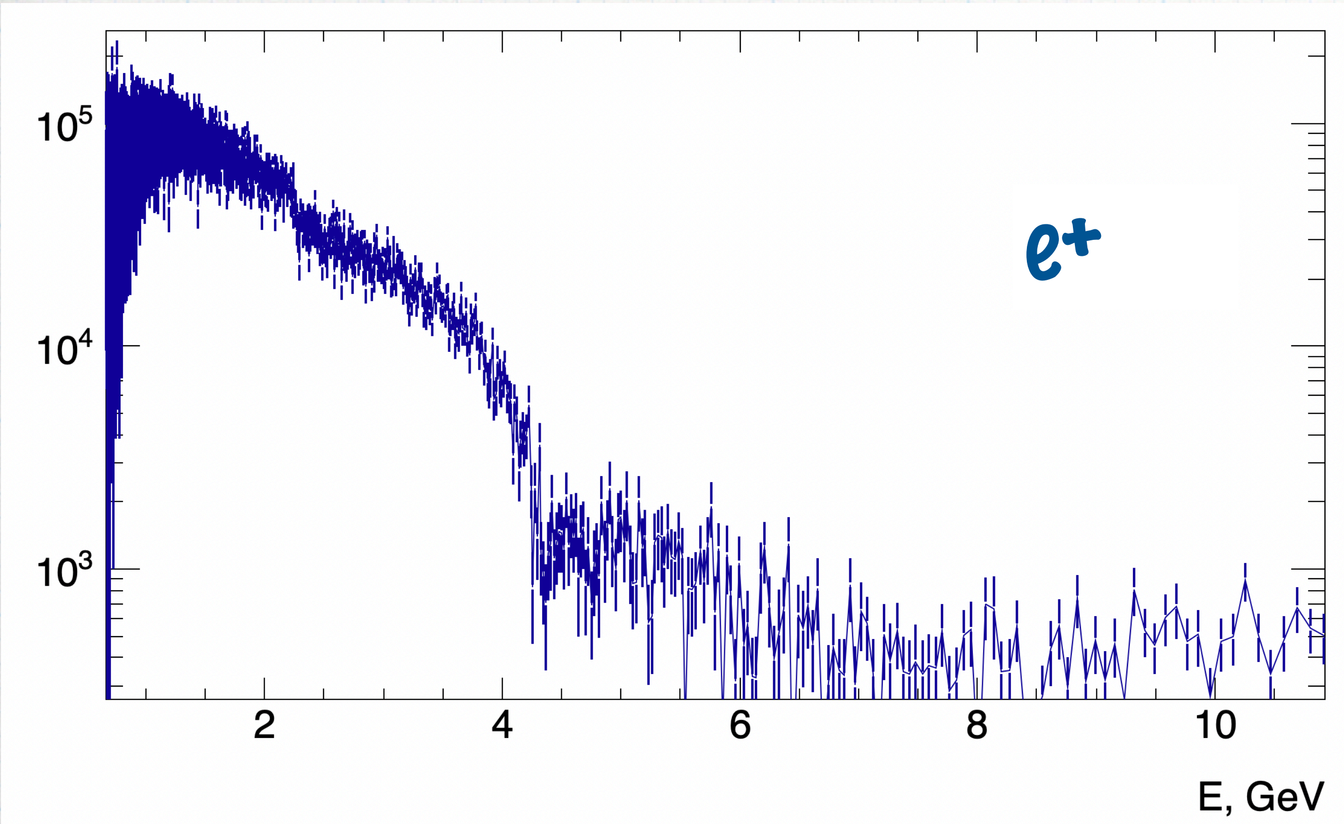


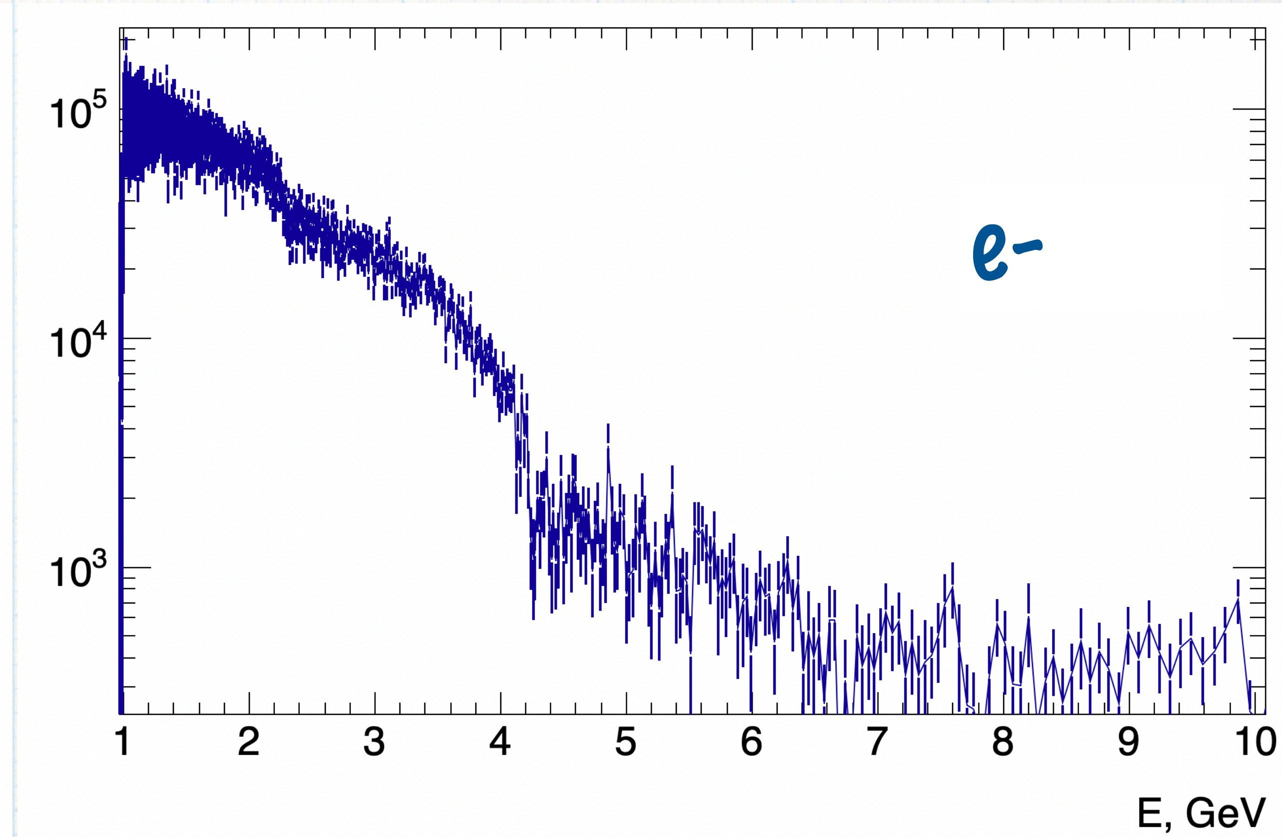



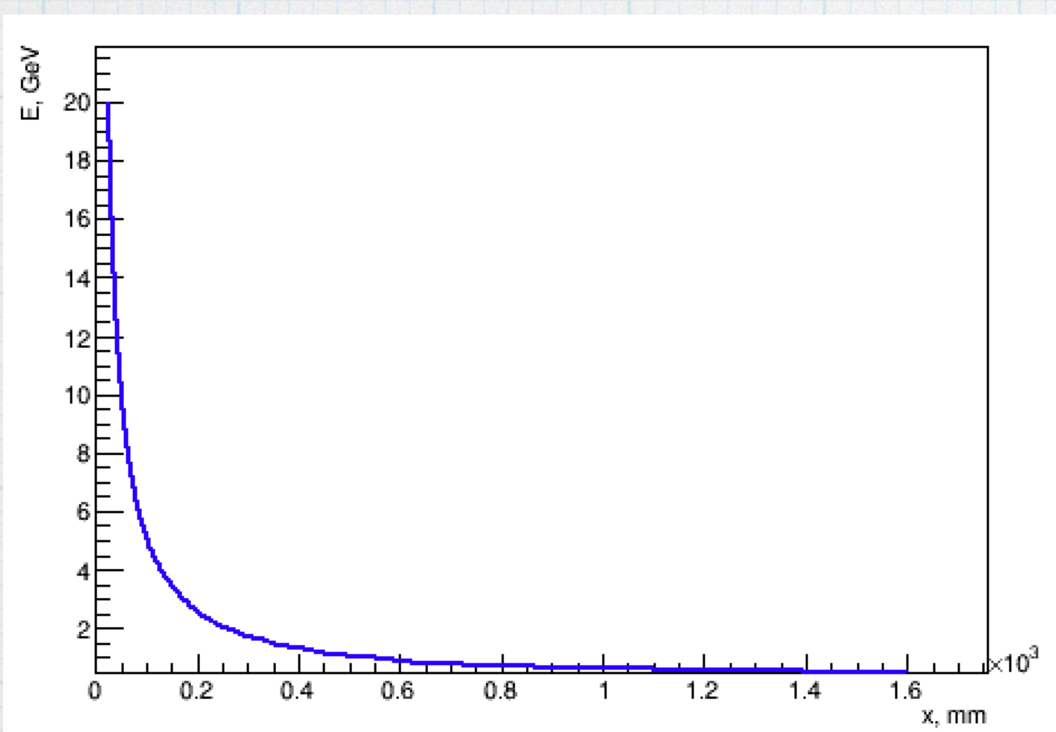



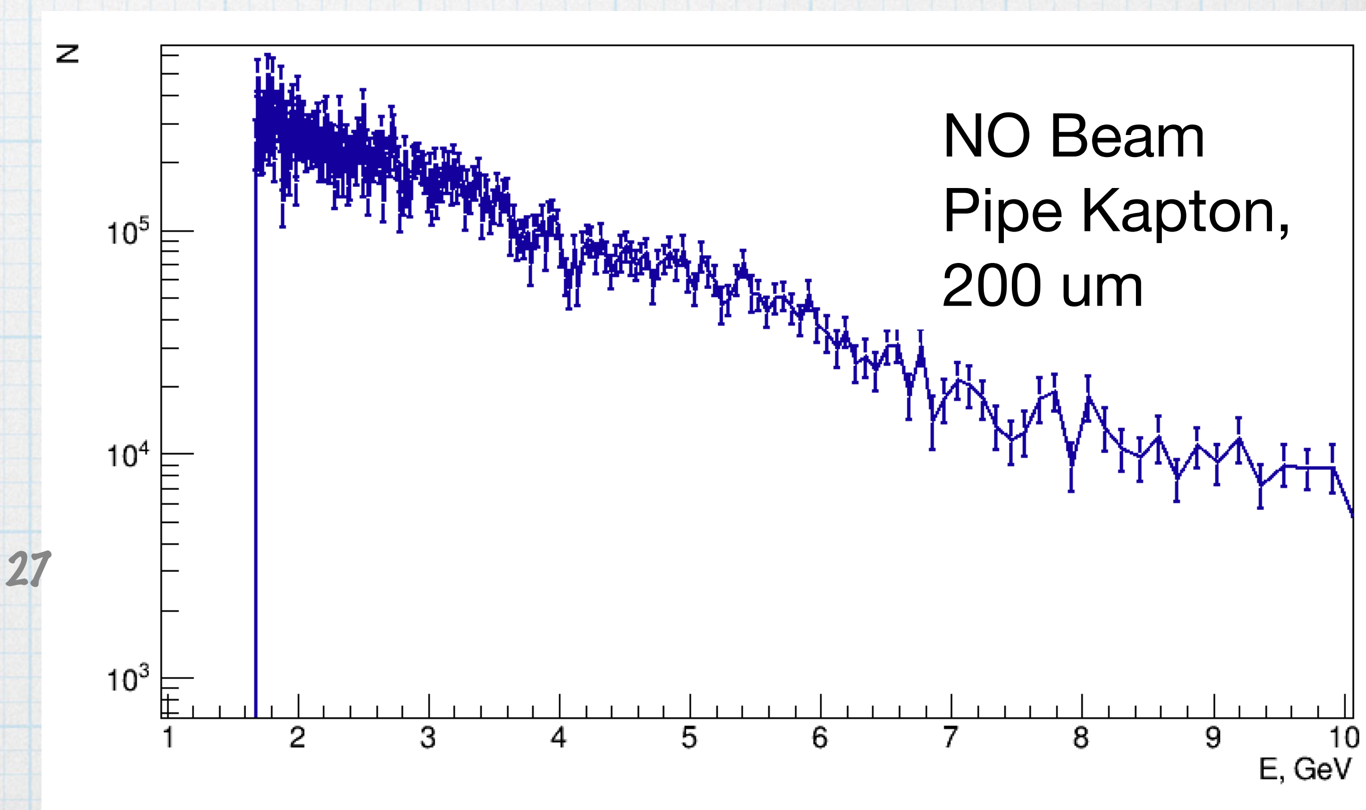



# Reconstructed spectra

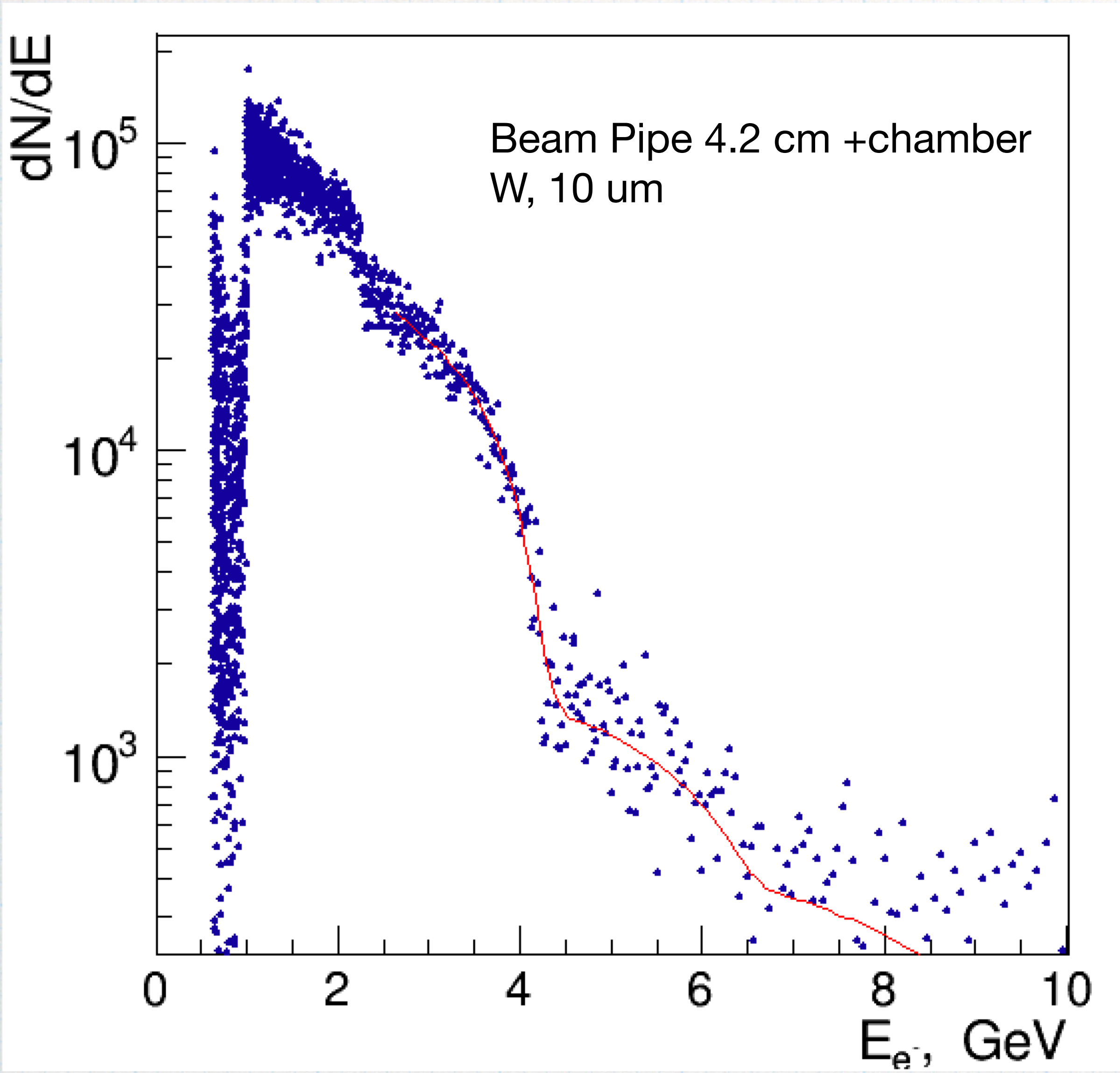


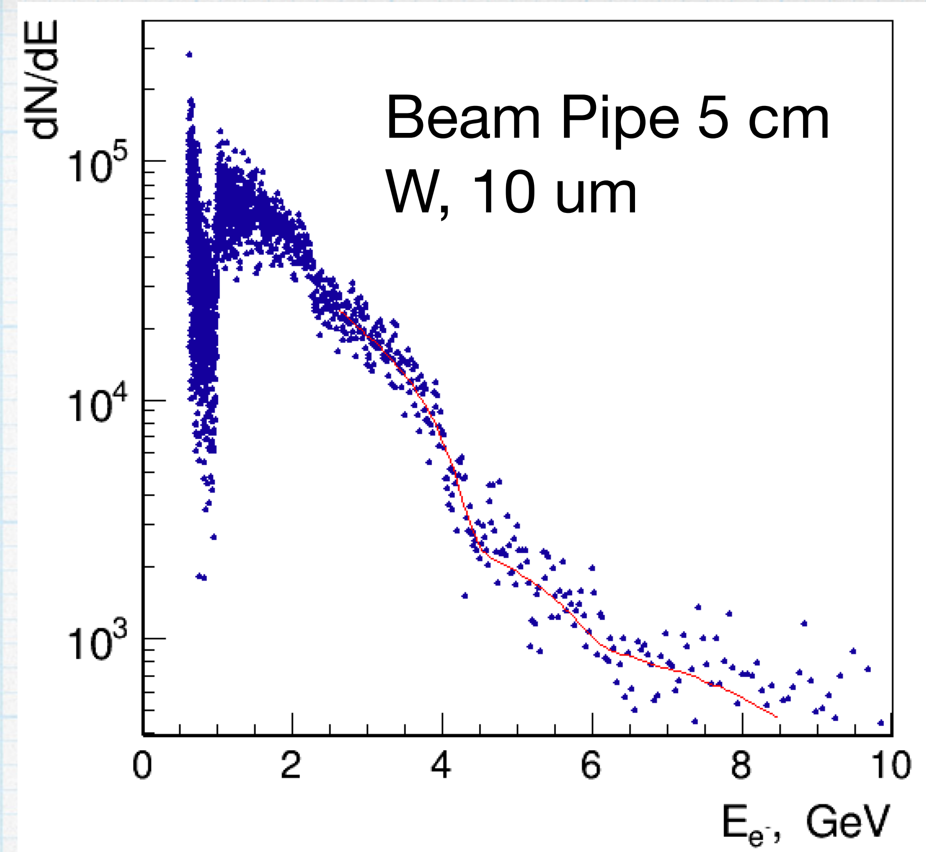



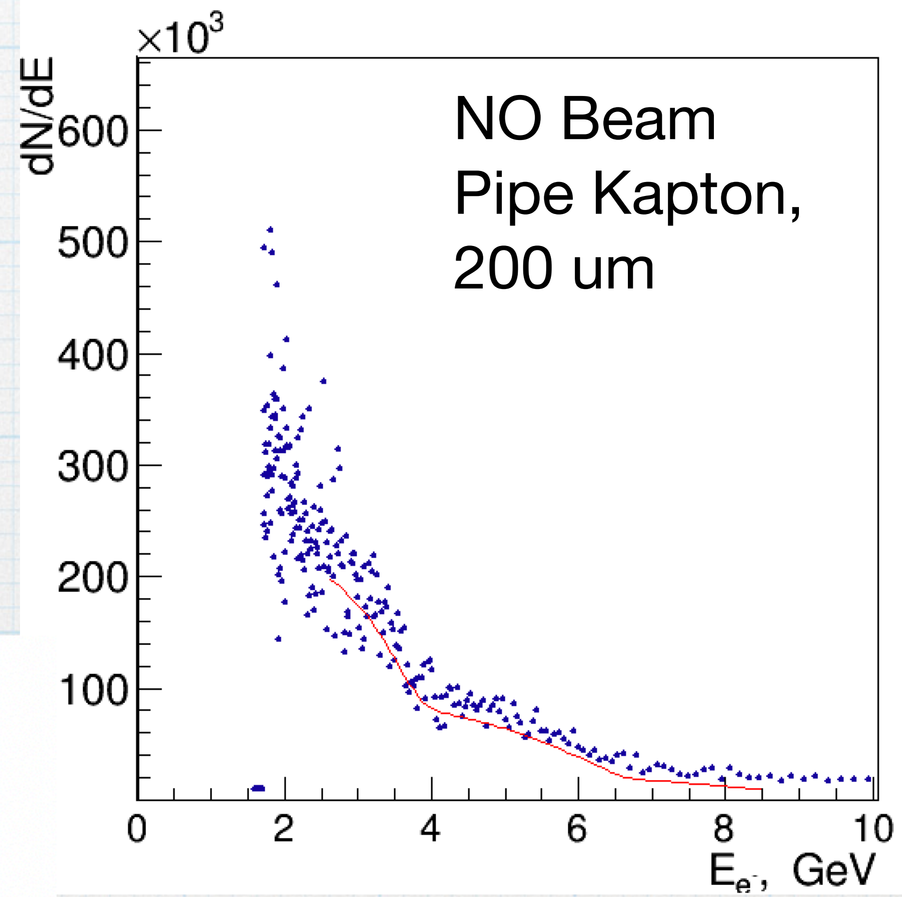



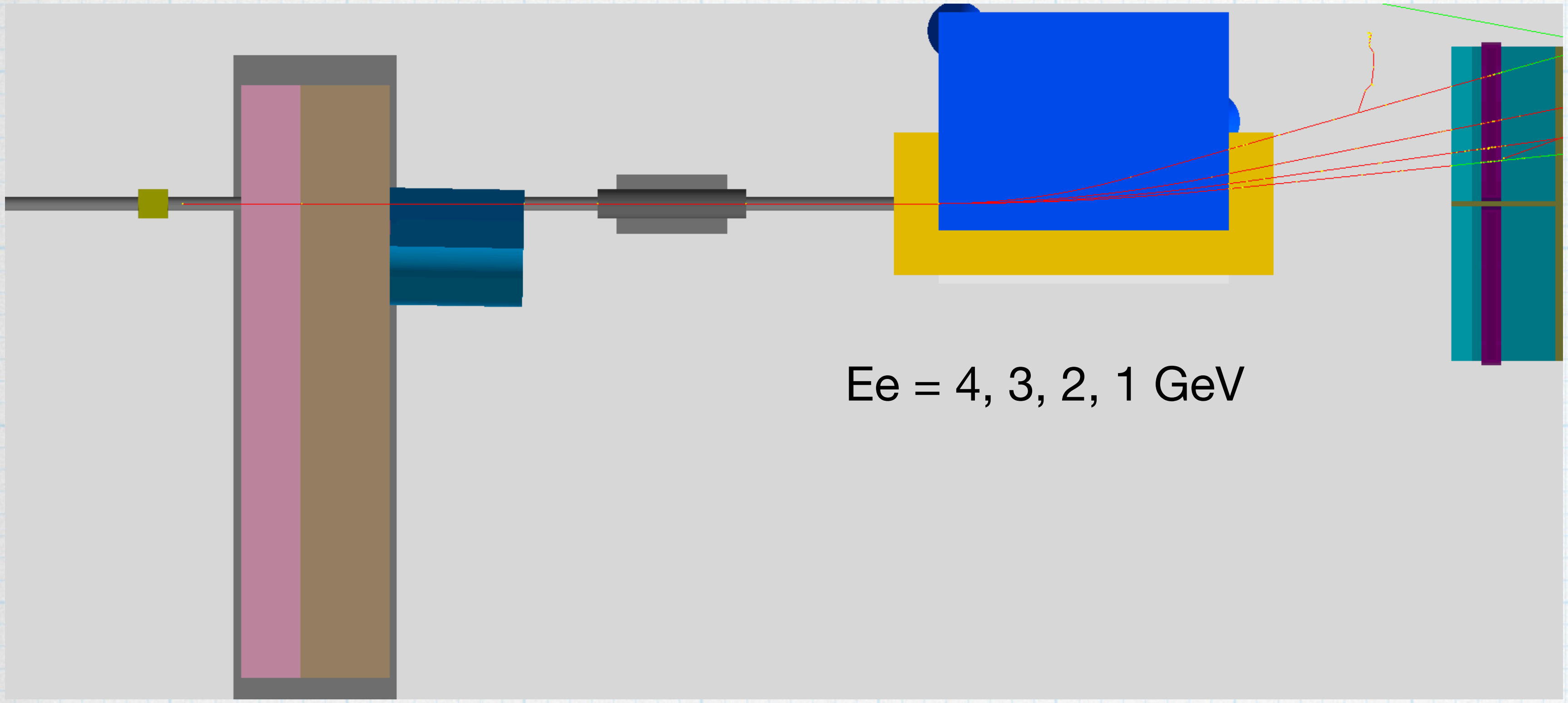
# Reconstruction

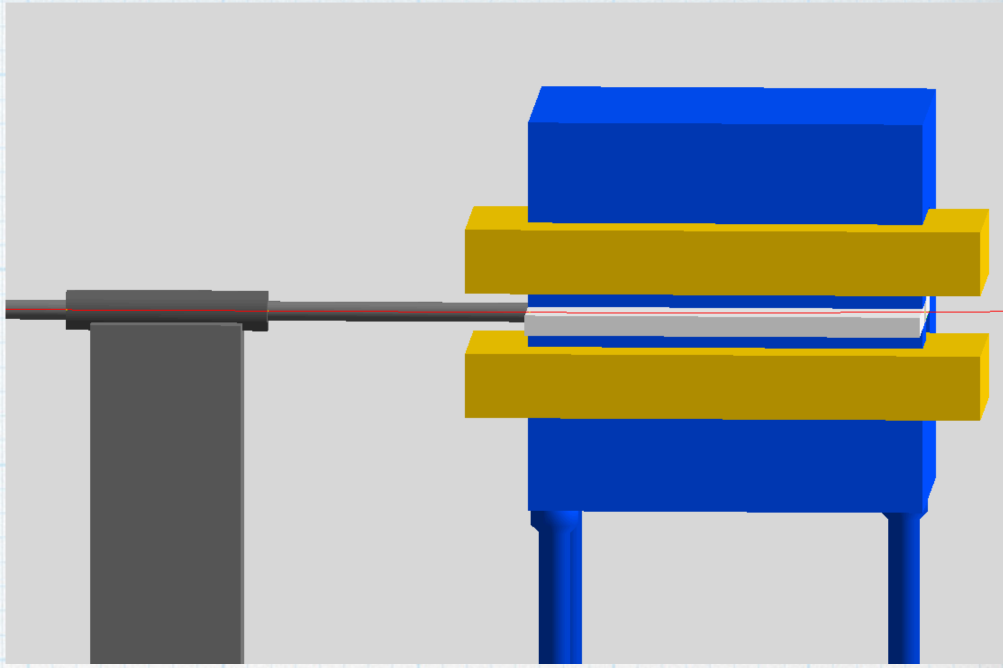


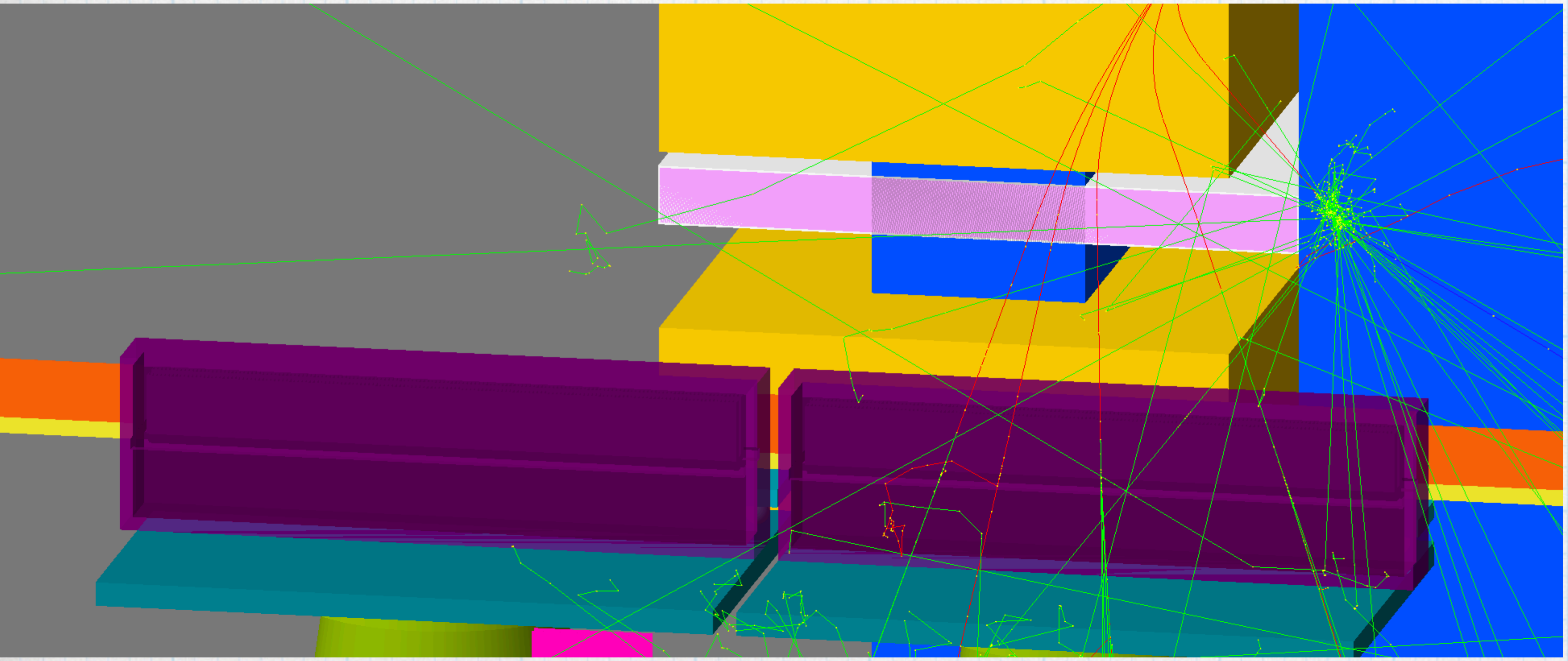



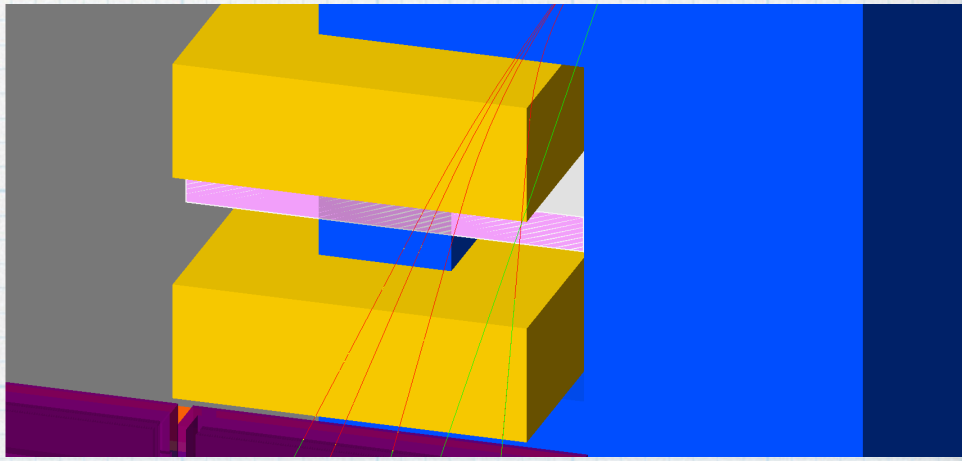




```
FCN=286.962 FROM MIGRAD    STATUS=CONVERGED     1542 CALLS        1543 TOTAL
                 EDM=7.91701e-07    STRATEGY= 1  ERROR MATRIX UNCERTAINTY   2.8 per cent
 EXT PARAMETER                                   STEP         FIRST
 NO.   NAME      VALUE            ERROR          SIZE      DERIVATIVE
  1  p0           3.18016e+07   1.00975e+07   1.10980e+02   1.45240e-09
  2  p1           1.31744e+06   3.47969e+07  -3.38722e+02   2.74221e-10
  3  p2           4.23333e+00   2.49577e-02  -1.03029e-06   1.09203e-01
  4  p3           1.45899e+06   1.28757e+06   4.96121e+00   5.80110e-09
  5  p4          -2.87851e+06   7.30678e+06  -2.23974e+01   2.87624e-09
  6  p5           6.55447e+00   3.61566e-02   1.22269e-06  -5.93120e-01
  7  p6           1.87125e+05   1.34326e+04  -2.19133e-02   3.06250e-08
  8  p7           1.04984e+01   3.18584e-03  -3.06284e-06  -2.29524e-01
```

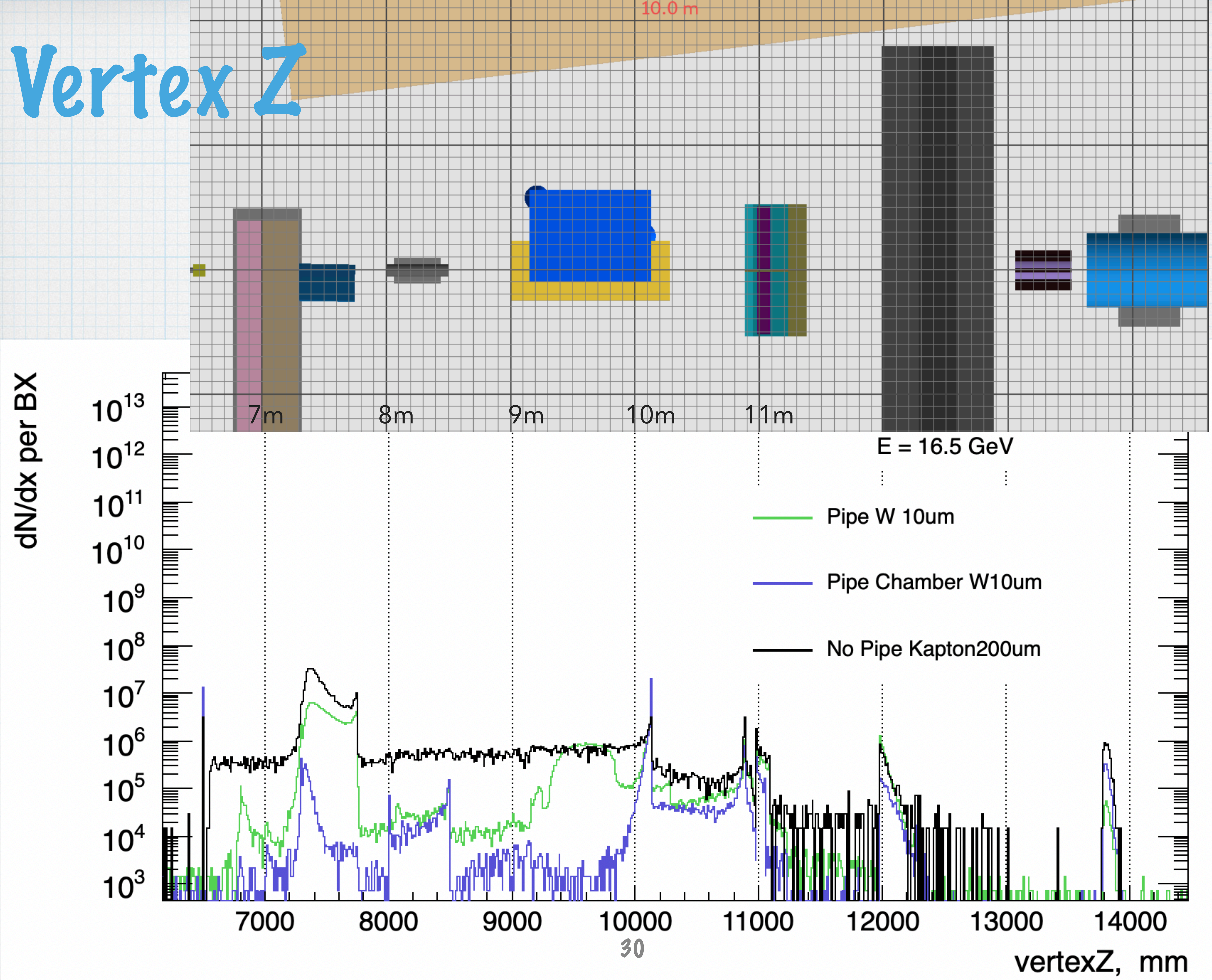

Ee = 4, 3, 2, 1 GeV







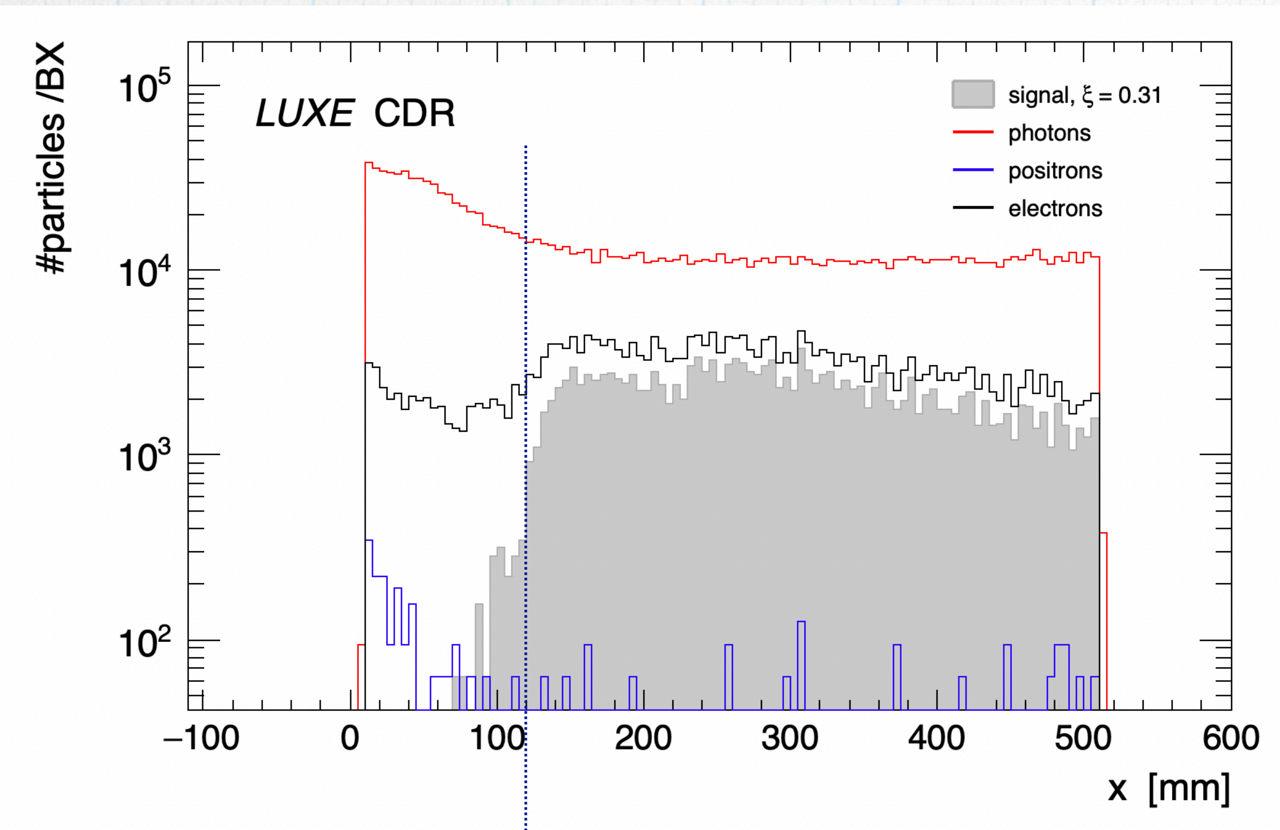
# Vertex Z



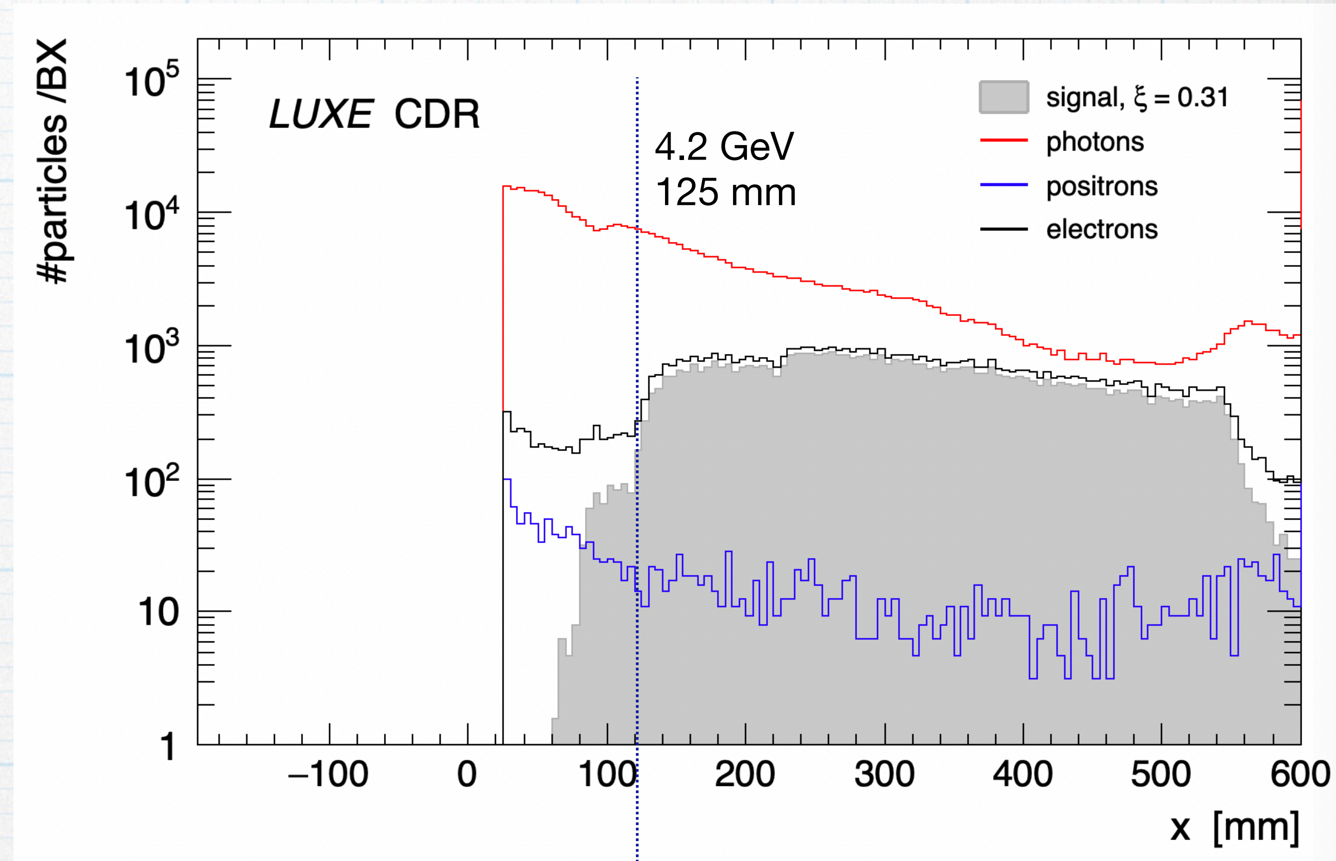
10.0 m
7m
8m
9m
10m
11m
E = 16.5 GeV
dN/dx per BX
Pipe W 10um
Pipe Chamber W10um
No Pipe Kapton200um
vertexZ, mm

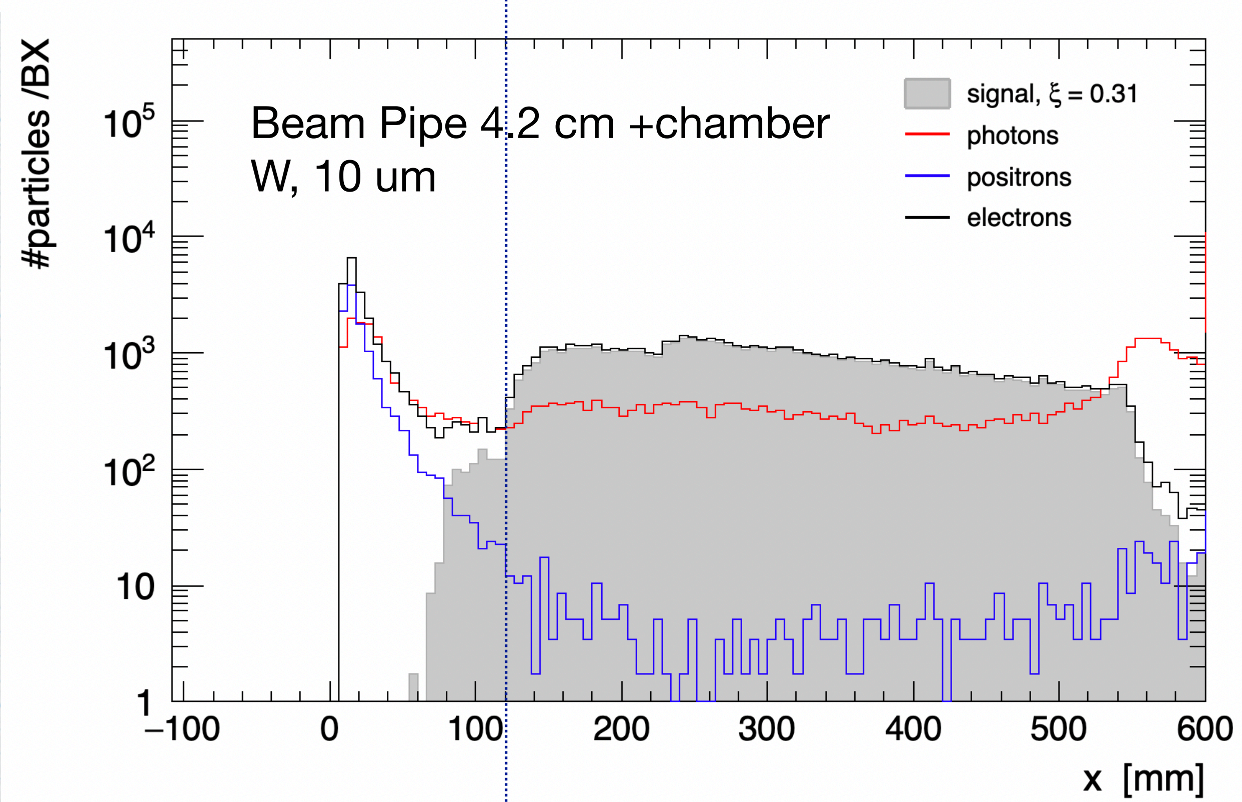
# Particles in electron arm

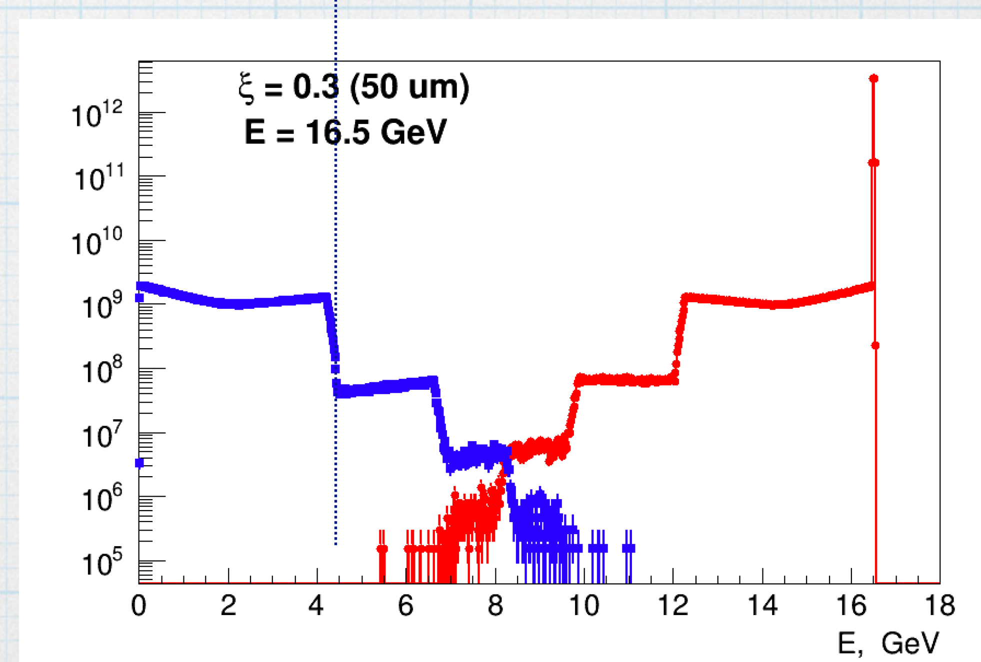
NO Beam Pipe
Kapton, 200 um




Beam Pipe 5 cm
W, 10 um



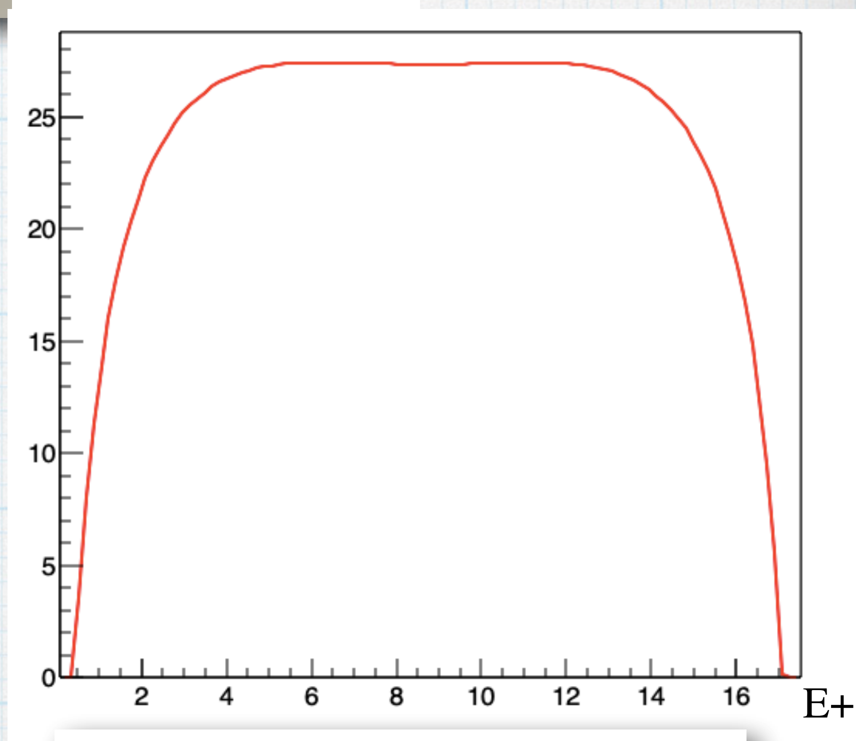
# Photon spectra reconstruction using Bethe-Heitler pair spectrum

The classical Bethe-Heitler formula (H.Bethe, W.Heitler, Proc.Roy.Soc.A146 (34)83)

$$\Phi\,(E_0)\,dE_0 = \frac{Z^2}{137}\left(\frac{e^2}{mc^2}\right)^2 4\,\frac{E_0^{\,2}+E_+^{\,2}+\frac{2}{3}E_0E_+}{(h\nu)^3}\,dE_0\left(\log\frac{2E_0E_+}{h\nu mc^2}-\frac{1}{2}\right).$$

energies involved are large compared with $mc^2$

$\Phi(E+, E_0=E\gamma)$




$\sigma(E\gamma, Ee) = \Phi(E\gamma, Ee)*N_a$ $N_a$ - Number of atoms

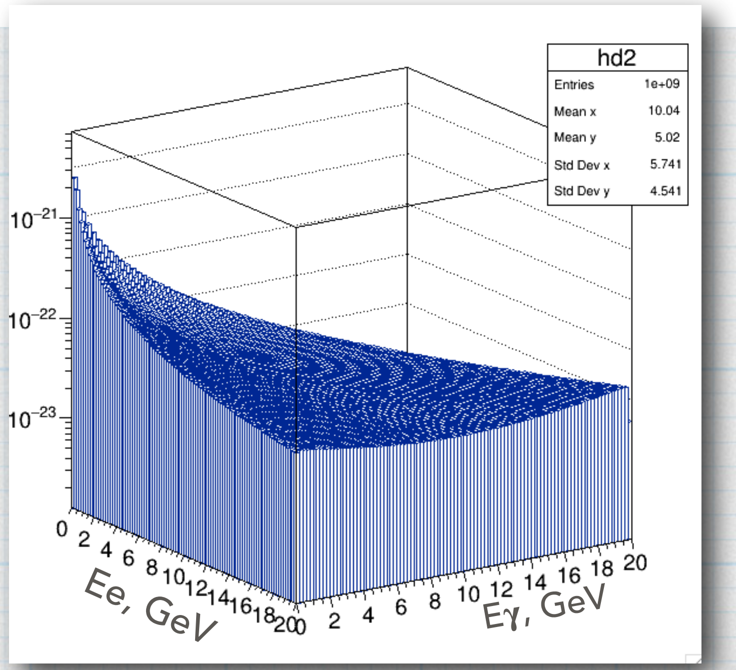
- Photon spectra $g(E\gamma)$ can be reconstructed by fitting

  $N(Ee)=\int \sigma(E\gamma, Ee)g(E\gamma)dE\gamma$

  Where N(Ee) positron/electron spectra measured in detector after the conversion.

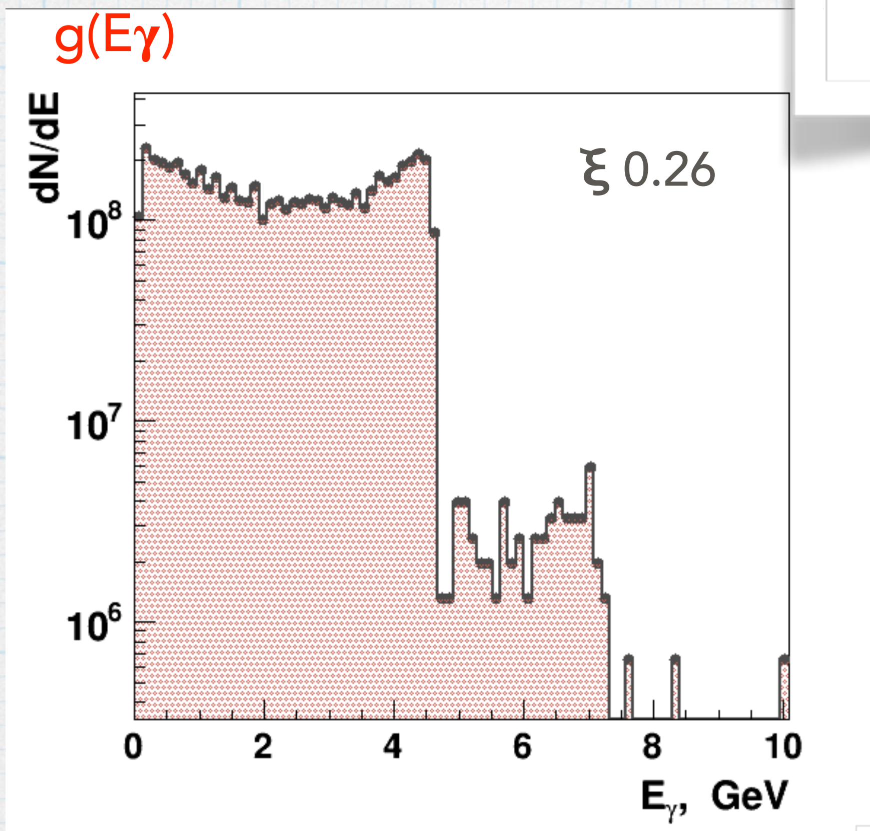
- Since $\sigma(E\gamma, Ee)$ depends on number of scatters $N_a$ defined by the thickness of the target the approach can be tested by using the thickness as fit parameter

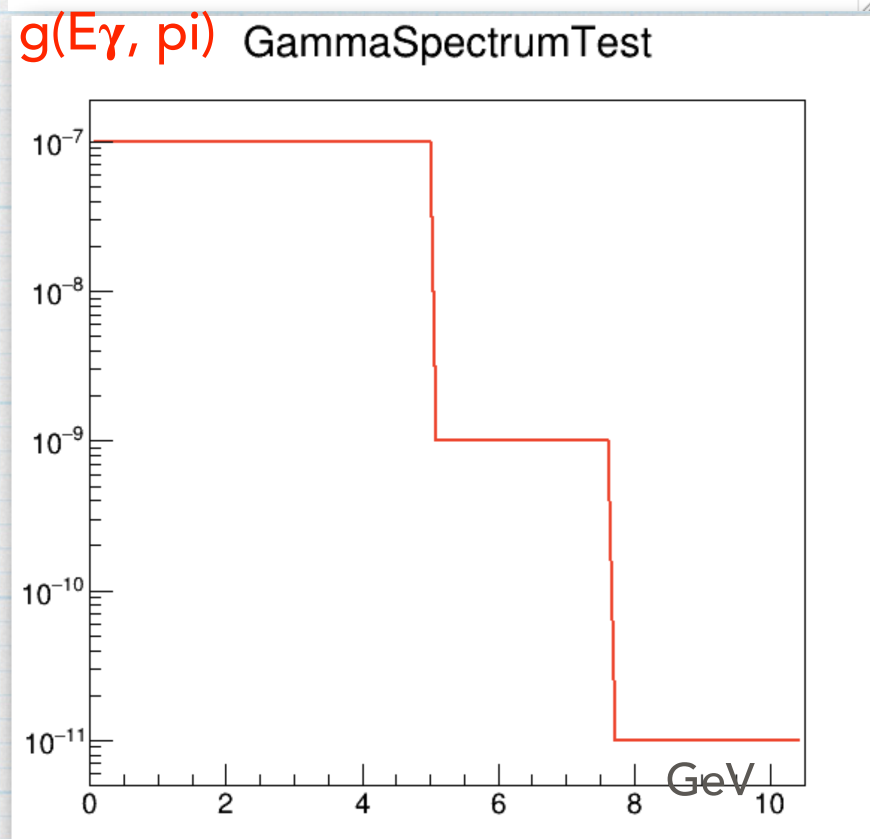
- Used Bethe-Heitler class from Geant4, with corrections and extended for various effects (the screening, the pair creation in the field of atomic electrons, correction to the Born approximation, the LPM suppression mechanism, etc.) to calculate differential cross-section



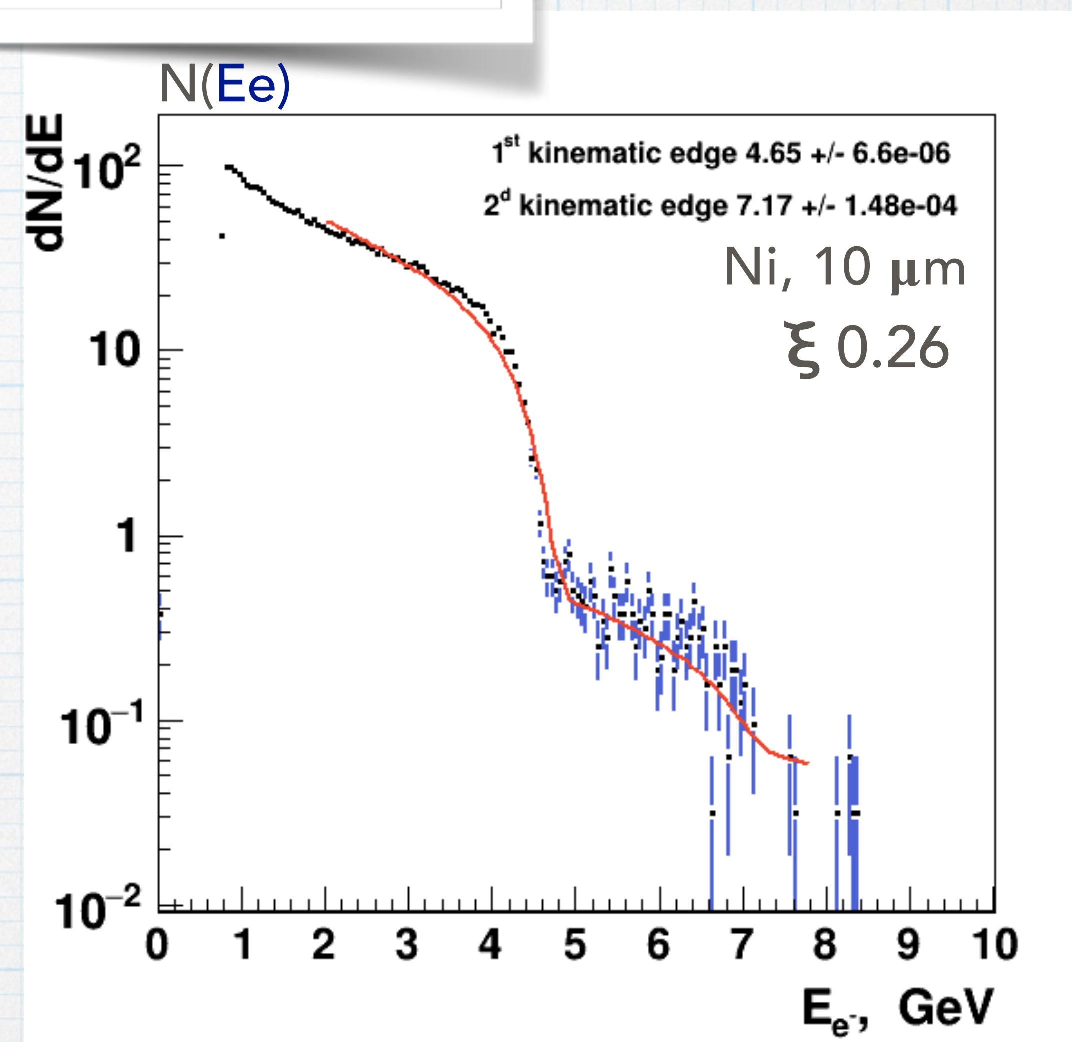
# Kinematic edges with accurate pair spectrum

$$f(Ee) = \int \sigma(E\gamma, Ee)\, g(E\gamma)\, dE\gamma$$




The single-particle spectrum obtained in GEANT4 is compared to a **model spectrum** calculated by convolving the trial **photon spectrum** with the **Bethe-Heitler cross section**

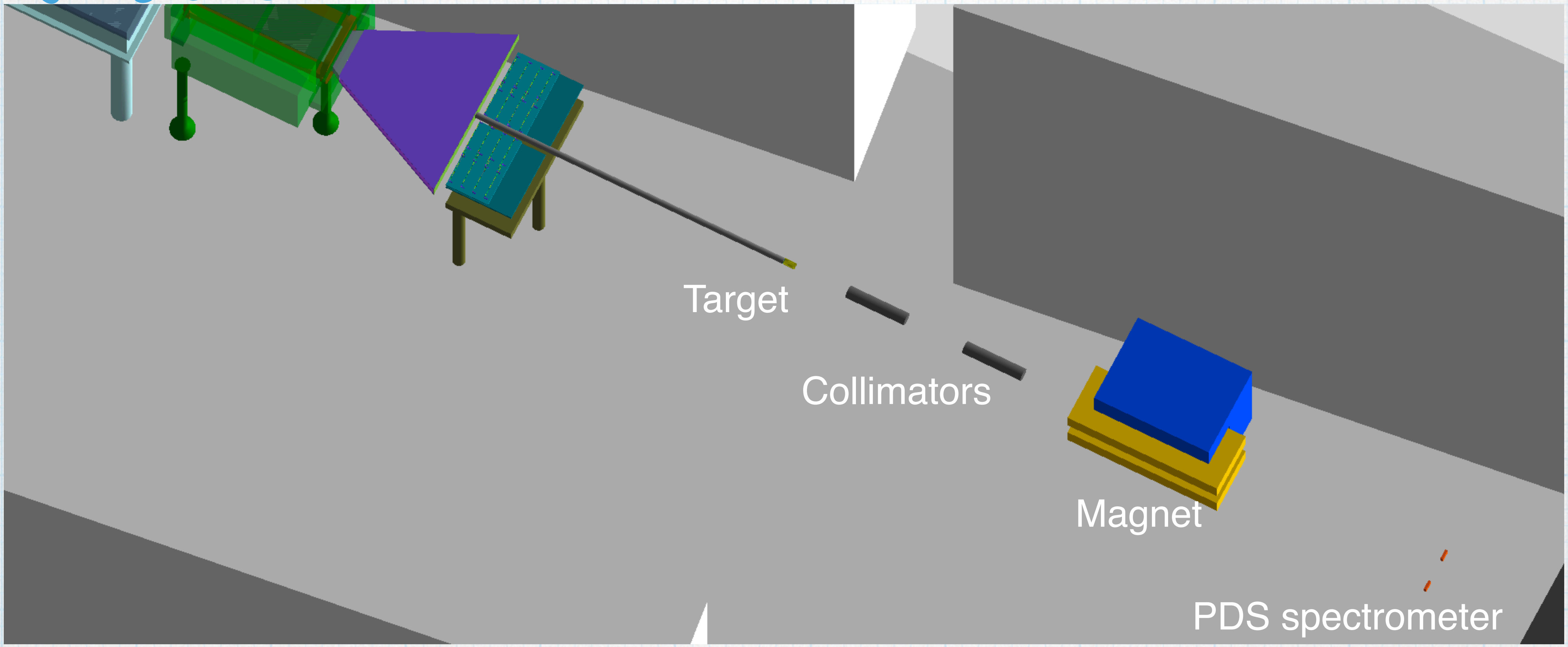



$$\int \sigma(E\gamma, Ee)\, g(E\gamma, p1, p2)\, dE\gamma$$

fitting allows finding **the kinematic edges** quite well

# Intro

PDS - Photon Detector system




Tasks at hand:

**Direct electron-Beam Laser interaction**

$e+n\omega \rightarrow e+\gamma$

I measure HICS energy spectrum.

- Use low X0 target (~1e-6 X0) for gamma to electrons/positrons conversions followed by spectrometer;
- determine kinematic edges;
- detailed shape.

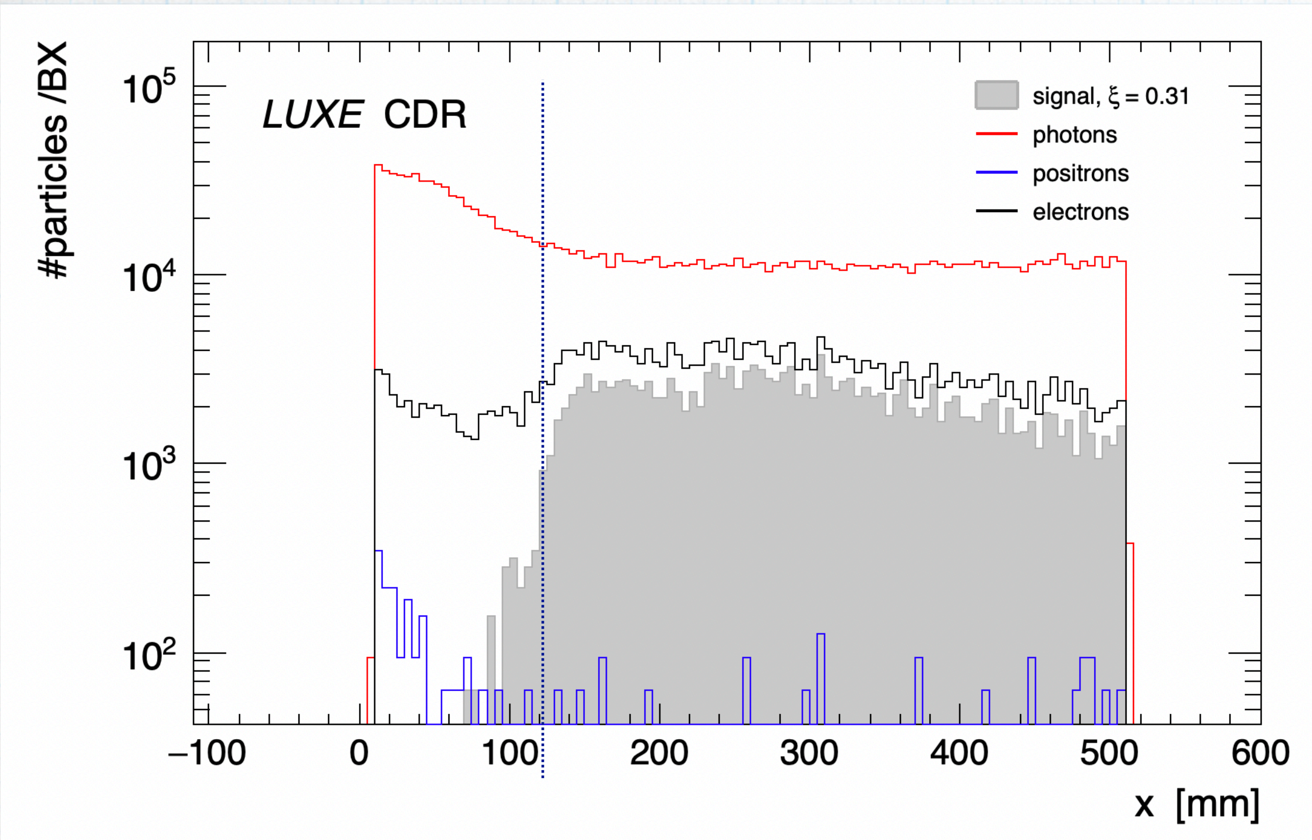
II measure absolute number of photons on event-by-event basis.

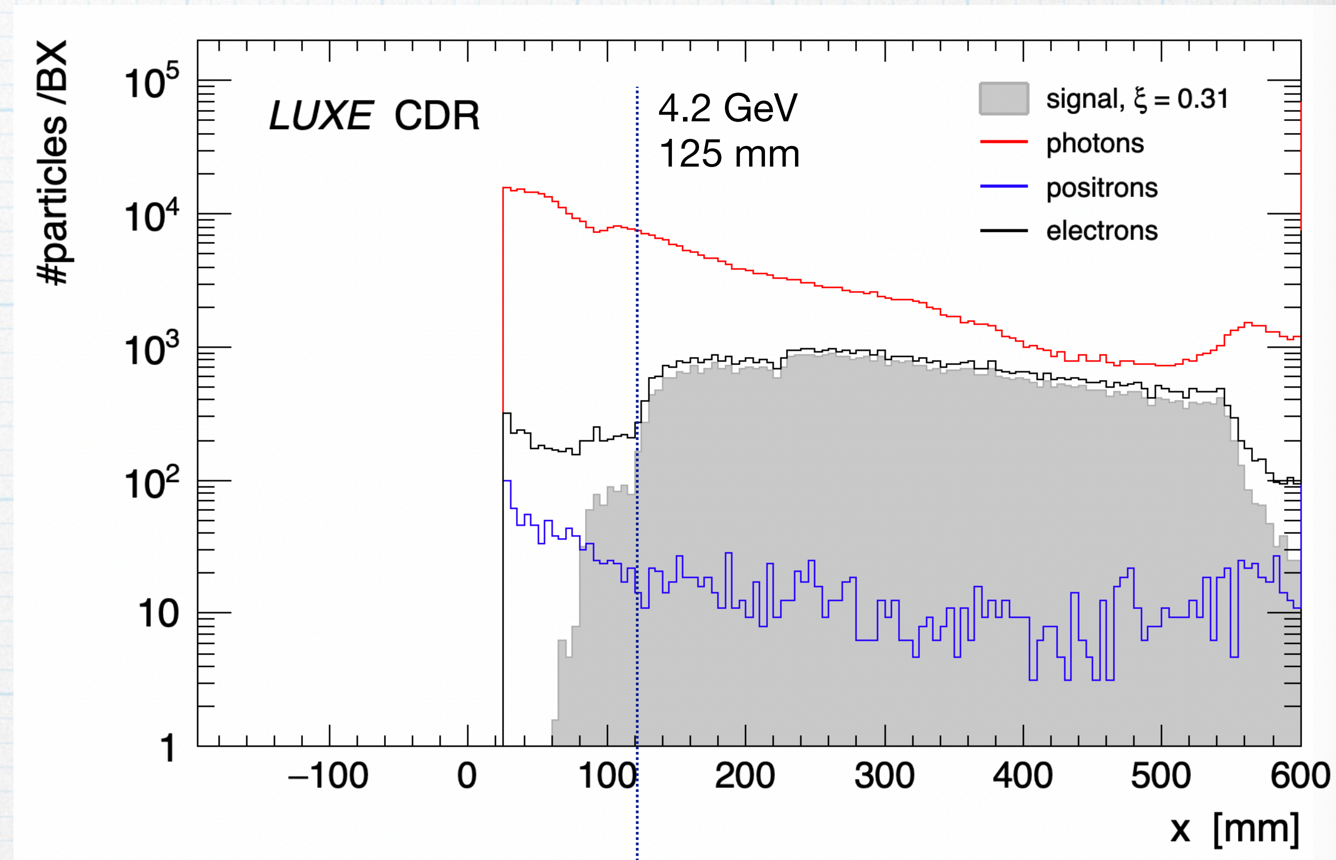
- Spectra normalisation;
- Be sensitive to angular distribution of HICS photons (if possible)

# Particles in electron arm

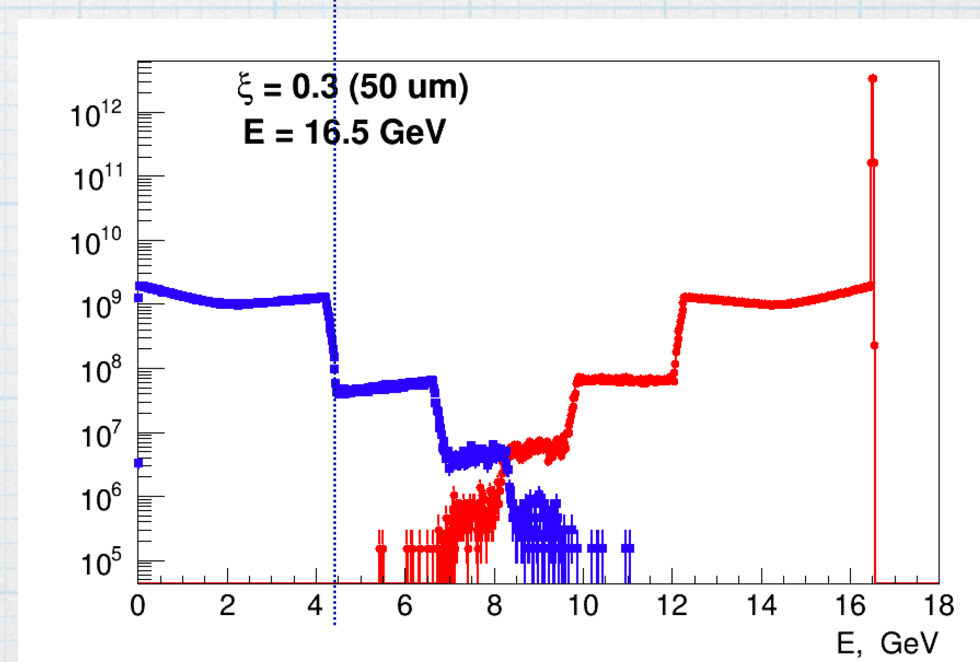
NO Beam Pipe
Kapton, 200 um

Beam Pipe 5 cm
W, 10 um




| Material | X0,(cm) | Thickness | Fraction X0 |
|---|---|---|---|
| Air | 3.04E+04 | 350 | 1.15 % |
| Kapton | 28.57 | 2.00E-02 | 0.07 % |
| Tungsten | 0.35 | 1.00E-03 | 0.3% |





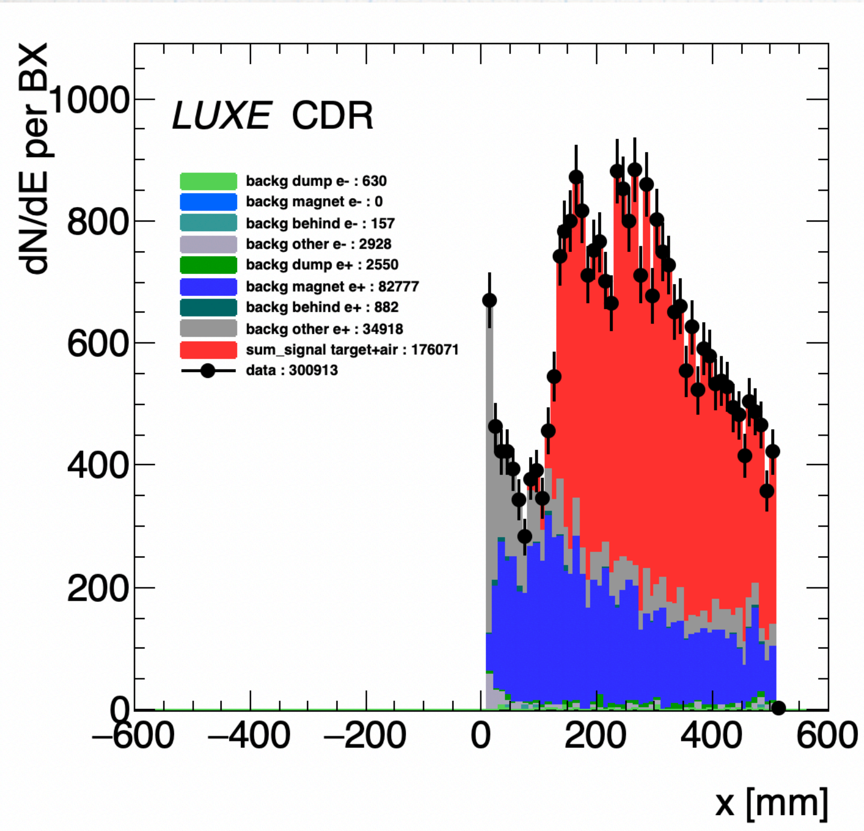

The first kinematic edge at 4.2GeV is clearly better observed in detector for the case with the pipe.

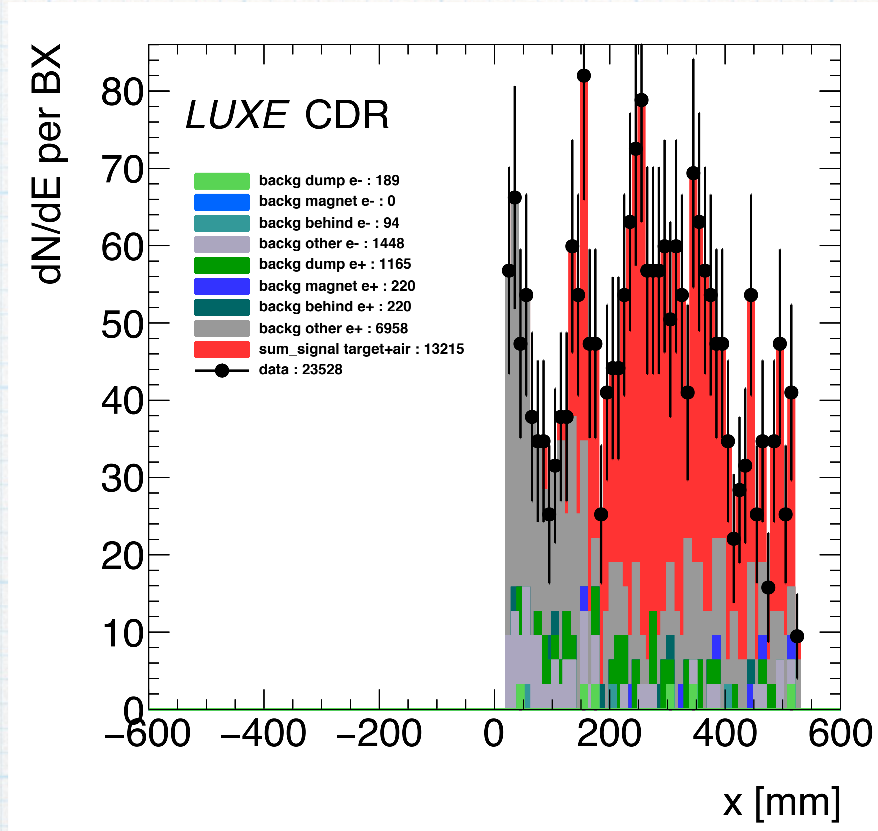
# * S/B ratio: Electron arm of Lanex Spectrometer, x-distributions

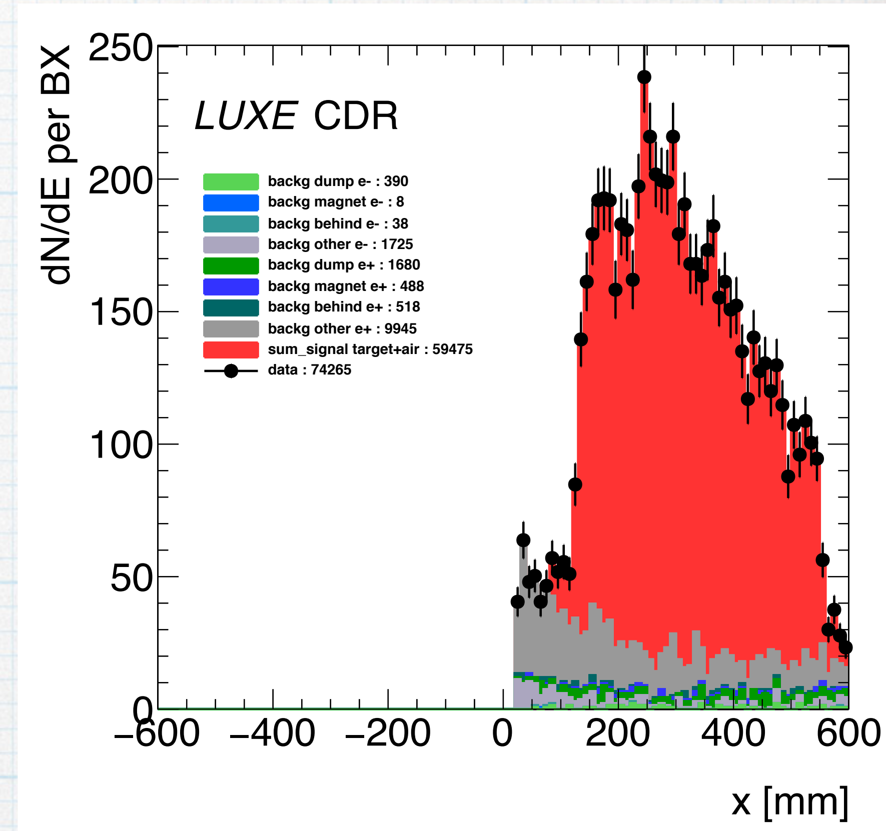
**NO Beam Pipe**
**Kapton, 200 um**

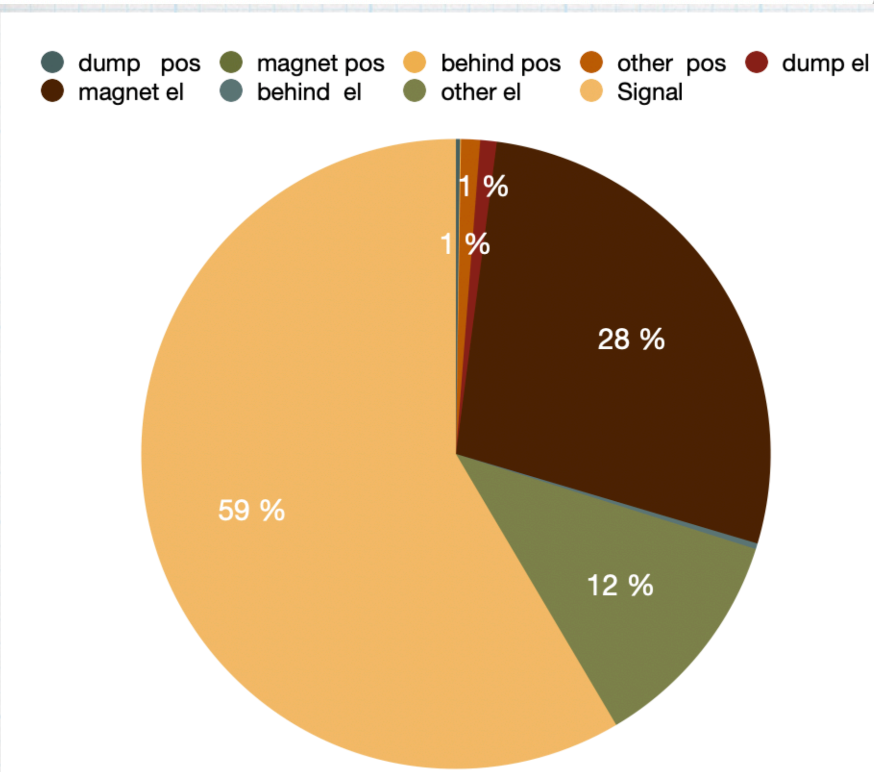
**Beam Pipe 5 cm**
**Kapton, 200 um**

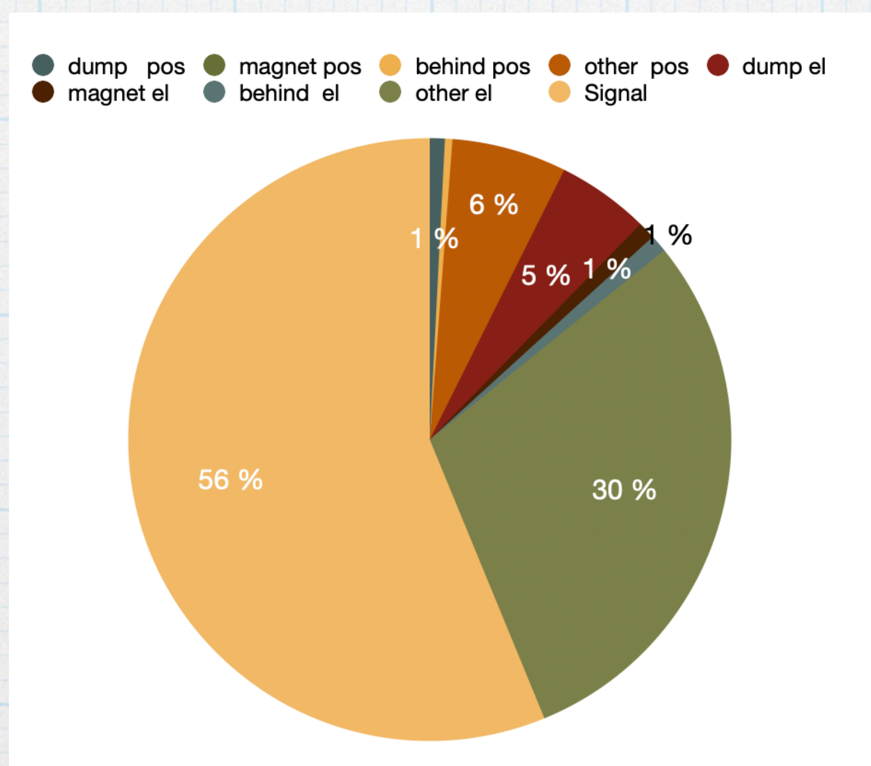
**Beam Pipe 5 cm**
**W, 10 um**

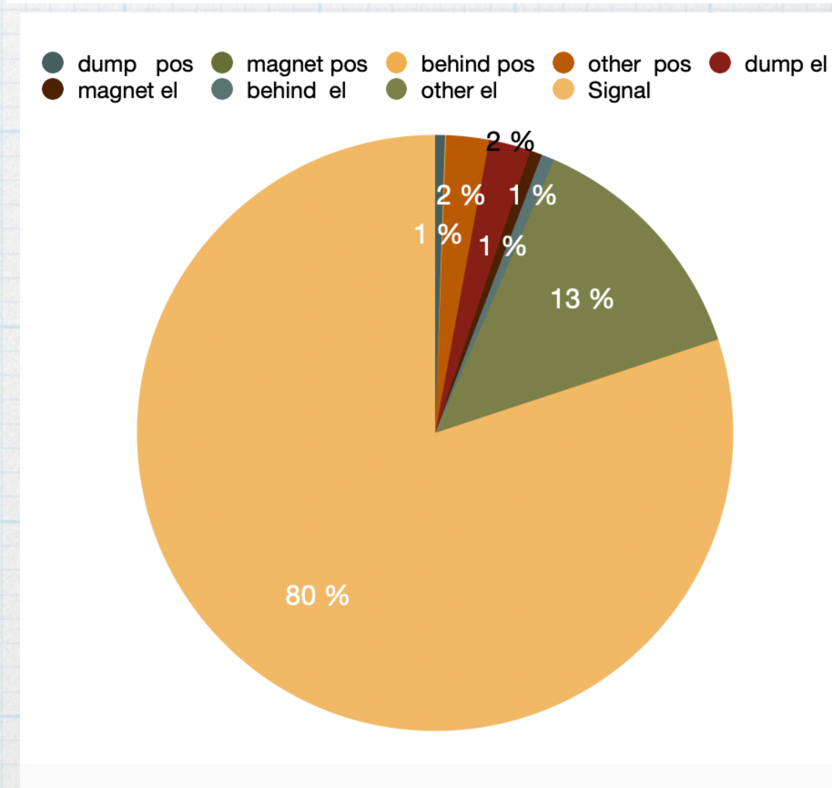


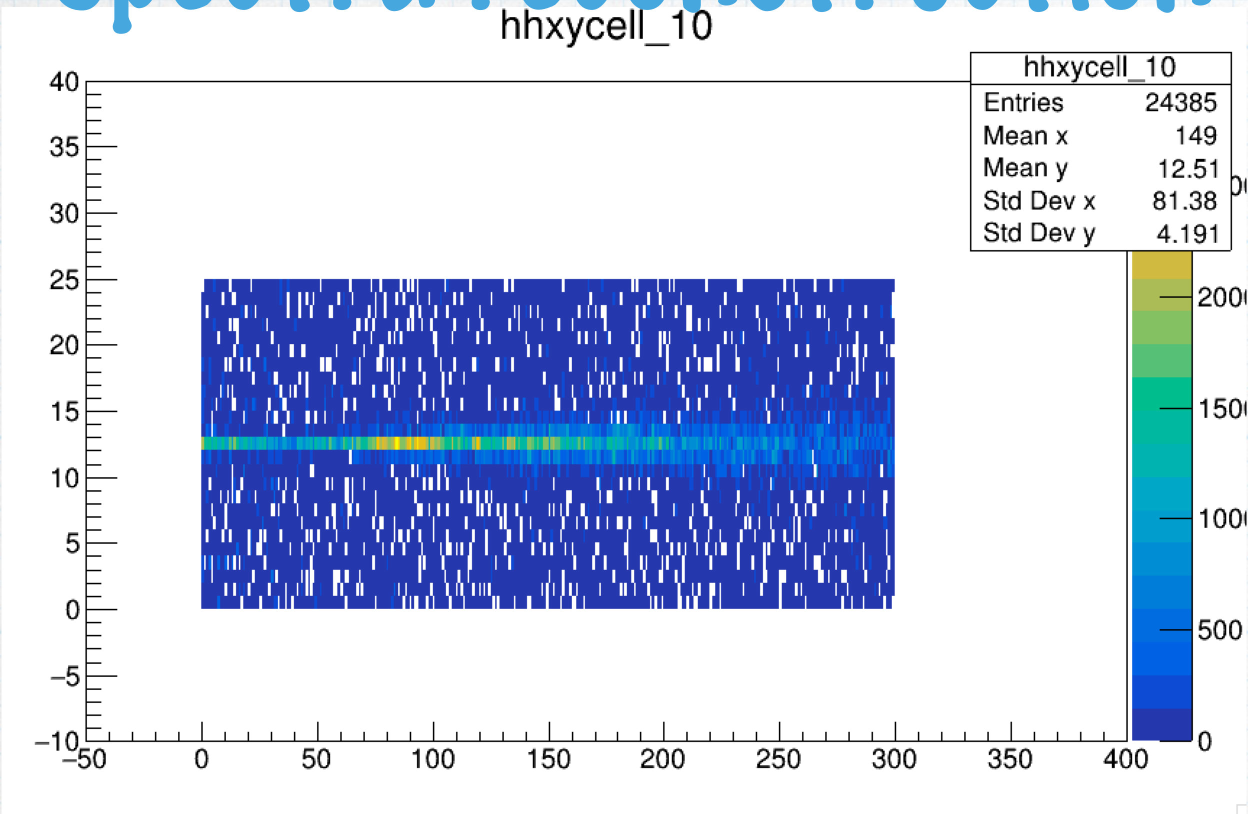



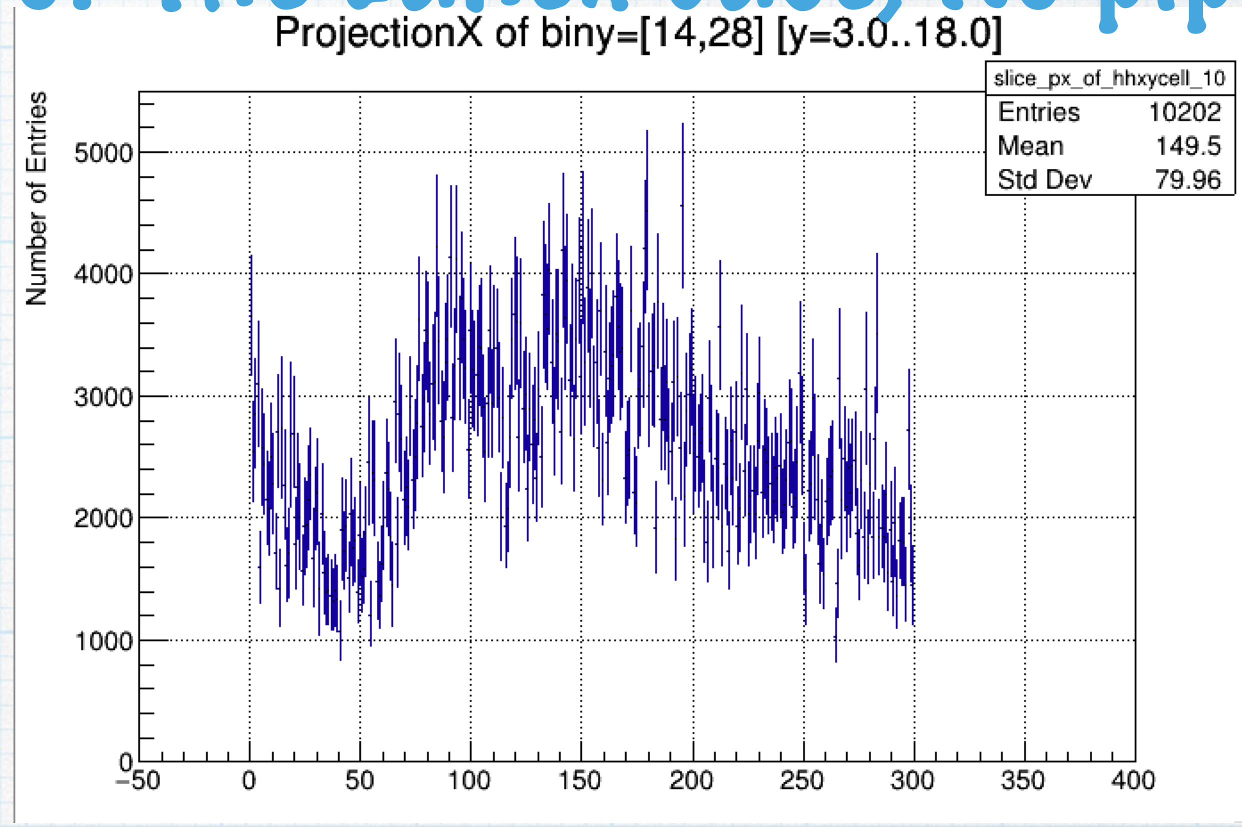



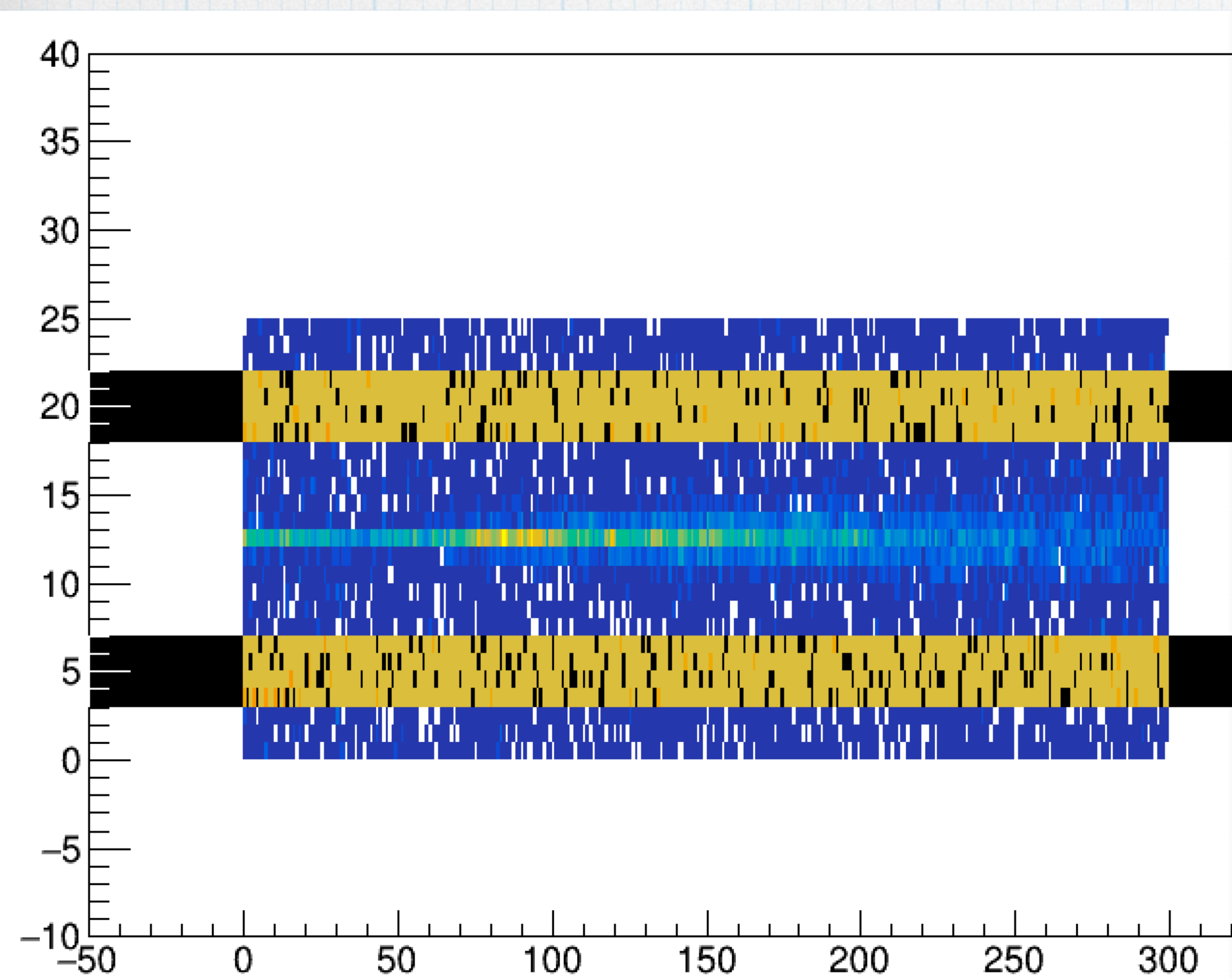



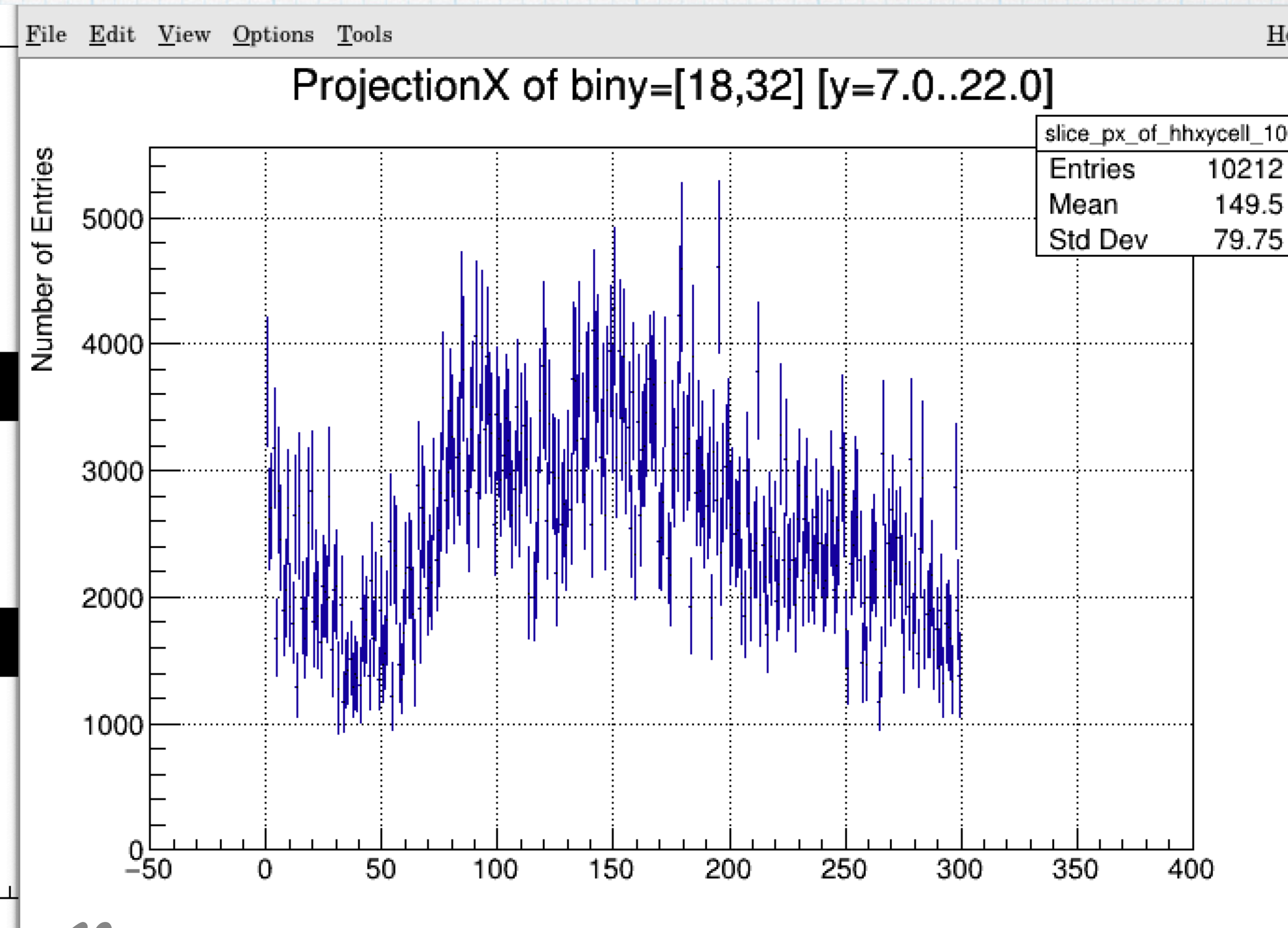
# Reconstruction

# Spectra reconstruction for the Lanex case, No pipe

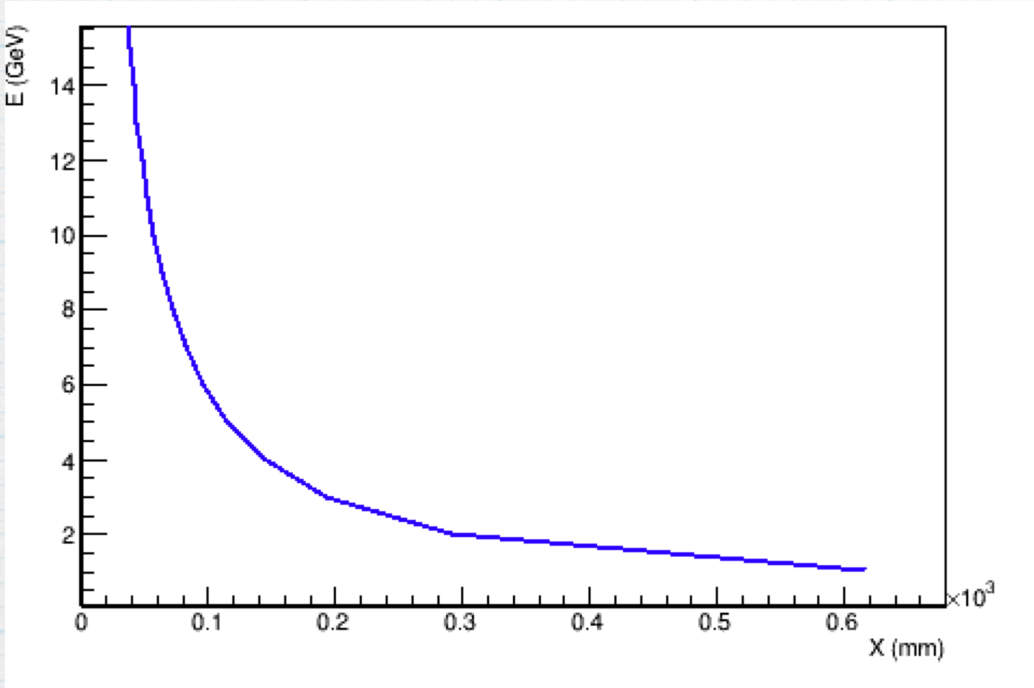


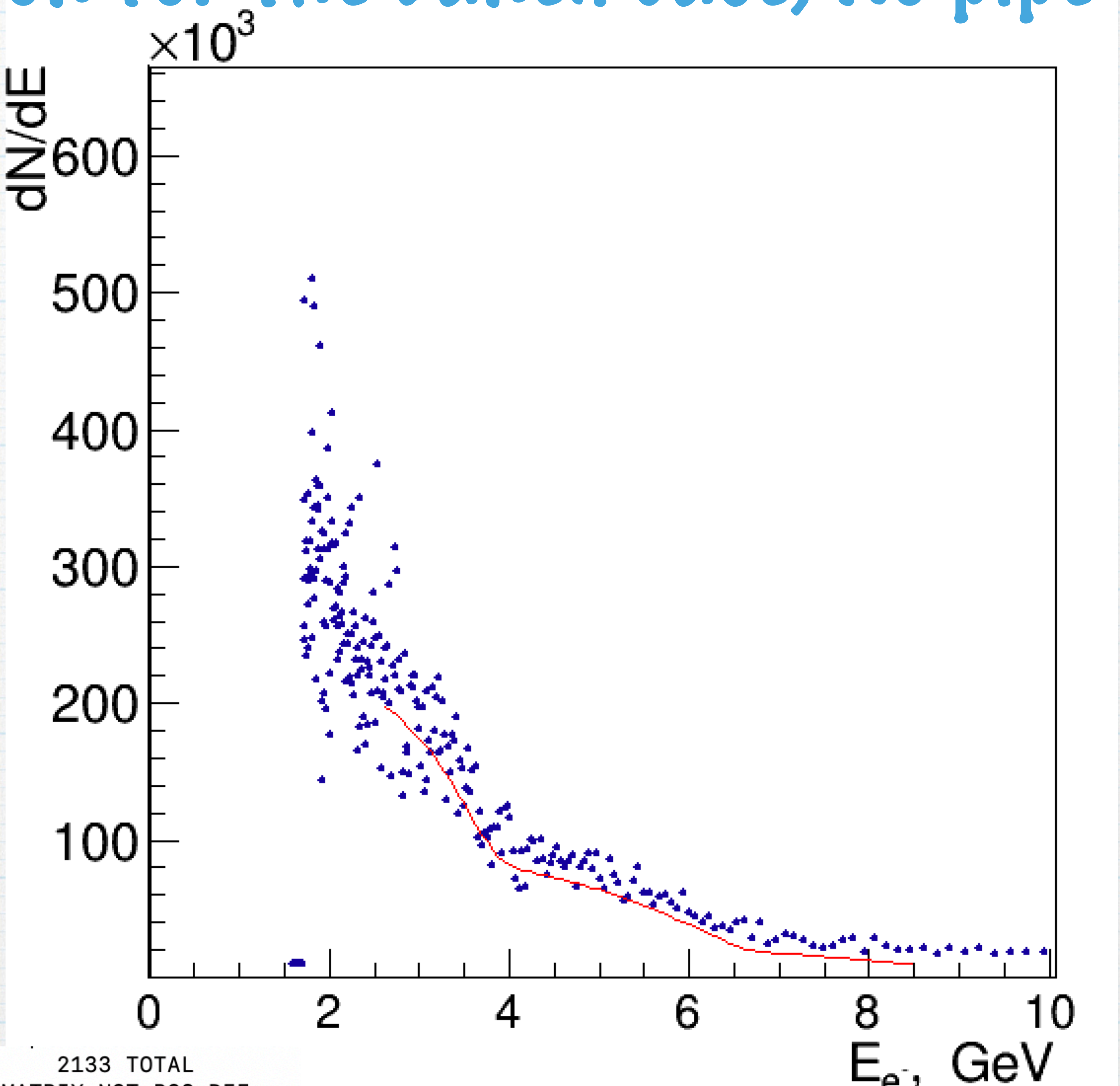





# Spectra reconstruction for the Lanex case, No pipe

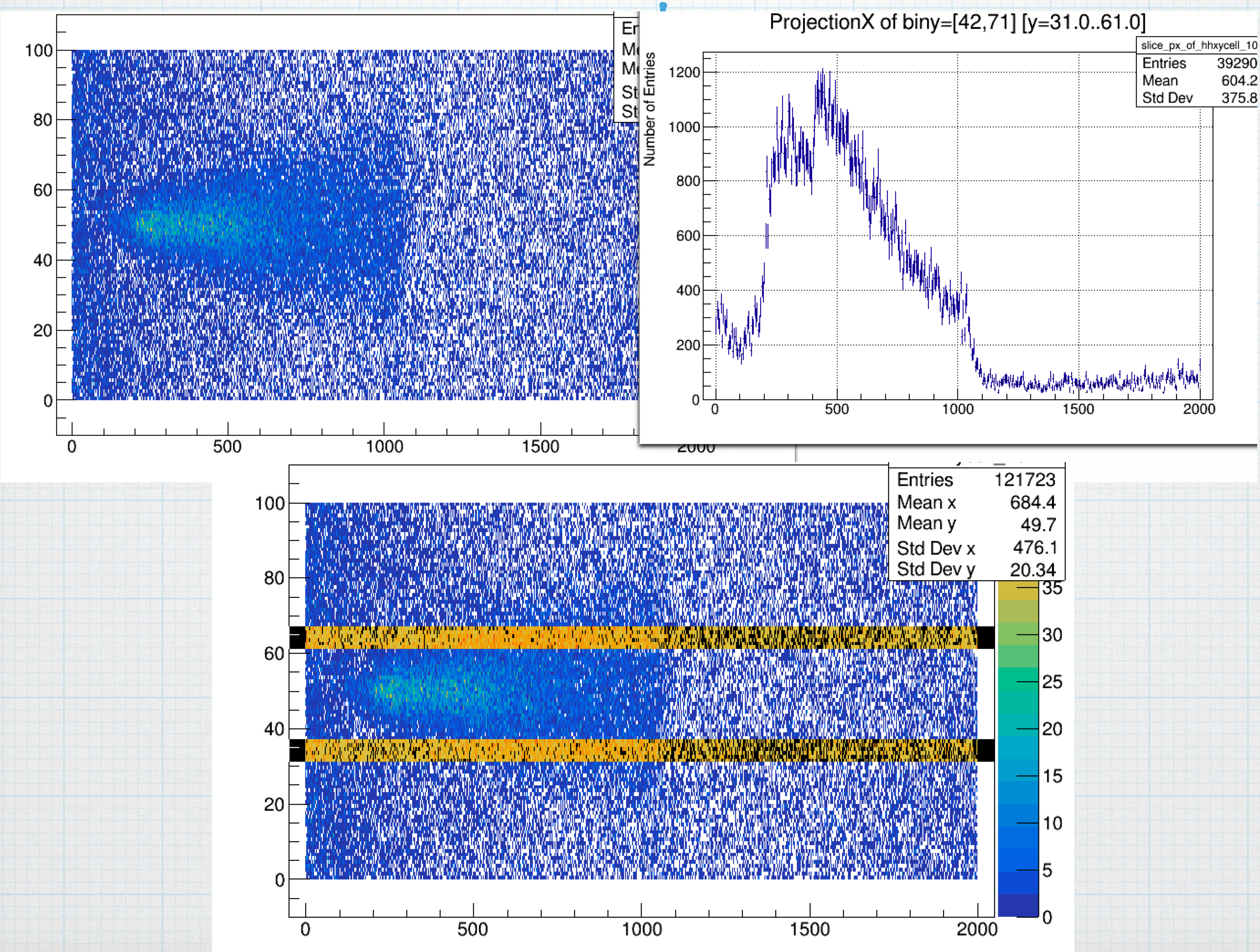


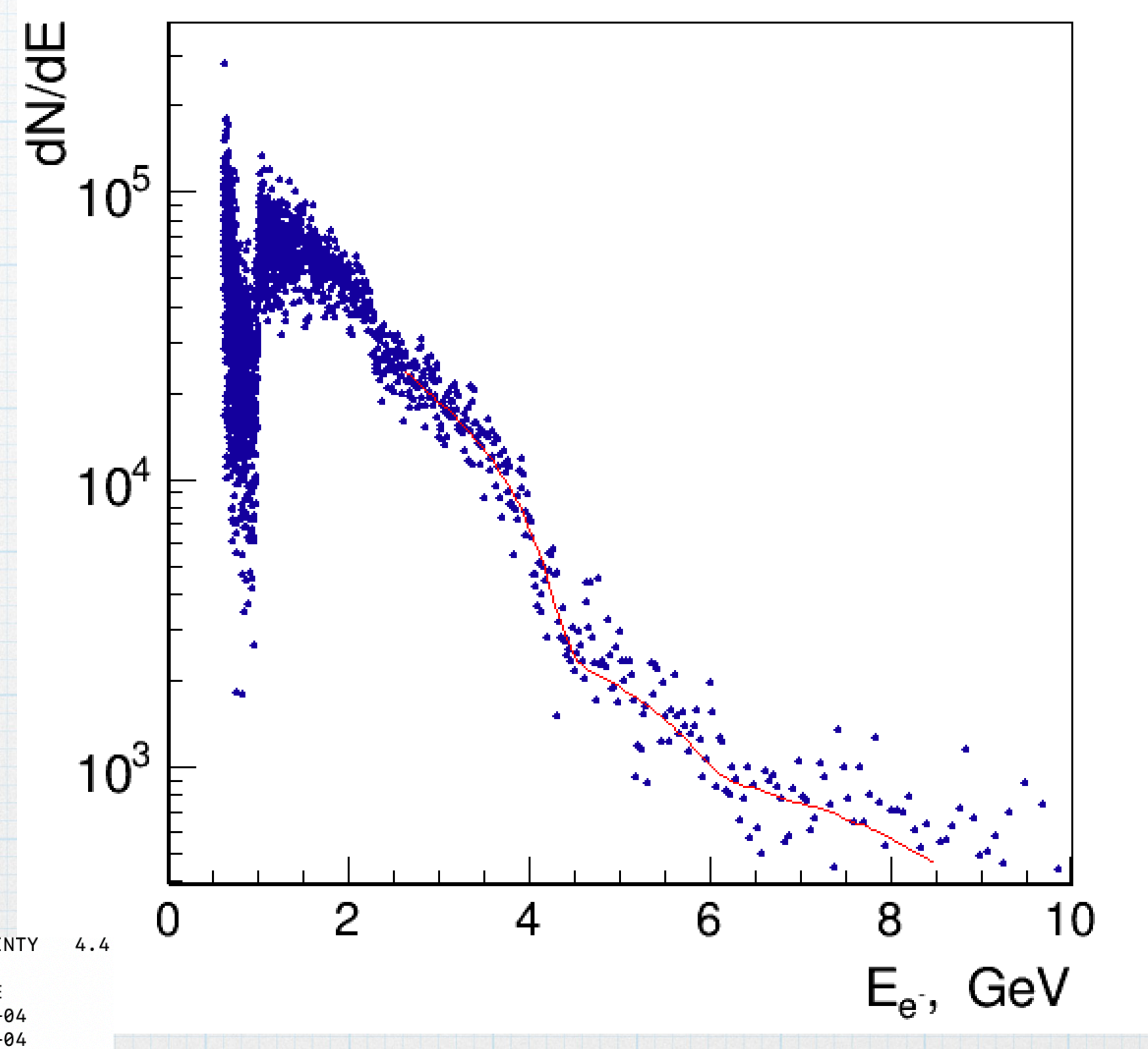

FCN=154.23 FROM MIGRAD STATUS=CALL LIMIT 2132 CALLS 2133 TOTAL
EDM=0.000122625 STRATEGY= 1 ERR MATRIX NOT POS-DEF

| EXT NO. | PARAMETER NAME | VALUE | APPROXIMATE ERROR | STEP SIZE | FIRST DERIVATIVE |
|---|---|---|---|---|---|
| 1 | p0 | 4.54727e+08 | 2.01770e+08 | -2.17984e+01 | 3.87807e-11 |
| 2 | p1 | -8.58055e+08 | 6.67723e+08 | 5.11001e+01 | 1.23214e-11 |
| 3 | p2 | 3.86233e+00 | 1.22372e-02 | -2.76617e-08 | 6.41855e-03 |
| 4 | p3 | 8.36369e+07 | 1.90351e+07 | -2.82335e+01 | -2.98255e-09 |
| 5 | p4 | -1.83334e+08 | 9.97231e+07 | 1.60226e+02 | -6.98724e-10 |
| 6 | p5 | 6.63088e+00 | 1.09126e-02 | -1.70609e-08 | -3.00232e-02 |
| 7 | p6 | 1.11186e+07 | 5.76344e+05 | -2.06107e-01 | 2.11536e-09 |
| 8 | p7 | 9.92678e+00 | 3.08289e-02 | -4.52970e-08 | -1.28762e-02 |

# Deposited energy in Lanex, electron arm, Beam pipe, ~4500 bx



# Spectra reconstruction for the Lanex in case of the Beam Pipe




EDM=12.7612 STRATEGY= 1 ERROR MATRIX UNCERTAINTY 4.4

| EXT NO. | PARAMETER NAME | VALUE | APPROXIMATE ERROR | STEP SIZE | FIRST DERIVATIVE |
|---|---|---|---|---|---|
| 1 | p0 | 5.98903e+04 | 2.68674e+03 | 0.00000e+00 | 2.12079e-04 |
| 2 | p1 | 2.70945e+05 | 1.75589e+04 | 0.00000e+00 | 1.40484e-04 |
| 3 | p2 | 4.22613e+00 | 1.42109e-02 | 0.00000e+00 | -2.05537e+00 |
| 4 | p3 | 3.33463e+03 | 9.87207e+01 | 0.00000e+00 | -1.83814e-02 |
| 5 | p4 | 3.18507e+04 | 1.51429e+03 | 0.00000e+00 | -3.93684e-04 |
| 6 | p5 | 6.20470e+00 | 2.56398e-03 | 0.00000e+00 | -2.13886e+03 |
| 7 | p6 | 2.04507e+03 | 7.80814e+01 | 0.00000e+00 | 2.56788e-04 |
| 8 | p7 | 1.03181e+01 | 1.71342e-01 | -0.00000e+00 | -1.72980e+00 |
| 9 | p8 | 0.00000e+00 | 4.26209e-01 | -0.00000e+00 | 0.00000e+00 |

# Finite Impulses Response Filter (FIR)

method used by J. List et. al.

**Finite Impulses Response Filter**

- edge-like features in function **g(x)** can be identified by maxima in the convolution **R(x)=h(x)∗g(x)** where **h(x)** is a matched filter
- **R(x)** is called the **Response**
- we have discrete data points **x=**$(x_0,\ldots,x_i)$, need discretized Response $R_d(i)$

$$R_d(i) = \sum_{k=-N}^{N} h_d(k) \cdot g_d(i-k)$$

- different filters $h_d$ available, optimal choice depends on the function g(x)
- Used here: **First derivative of a Gaussian (FDOG)**

$$h_d(k) = -k\exp(-\frac{k^2}{2\sigma^2}) \quad \text{for} \quad -N \leq k \leq N$$

# Reconstruction with FIR