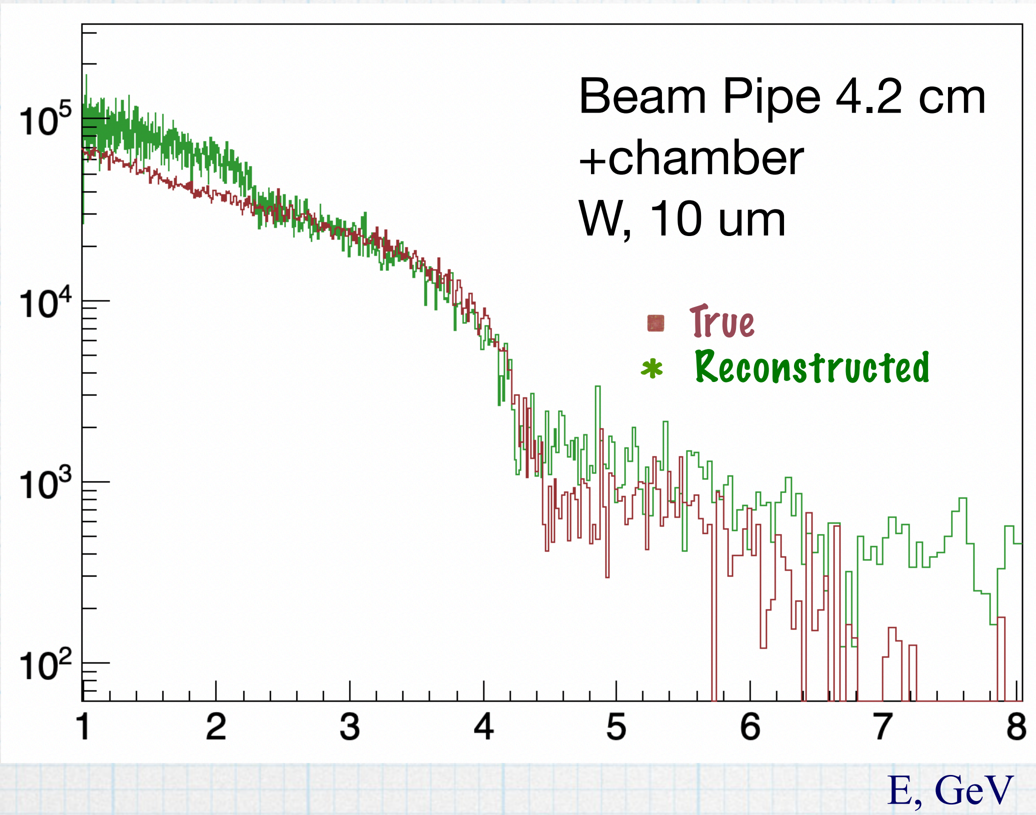
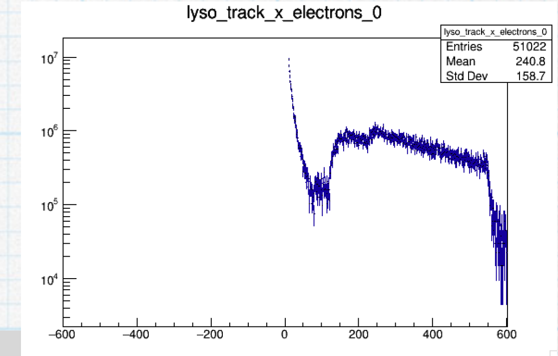
FDS performance
Beam pipe with chamber

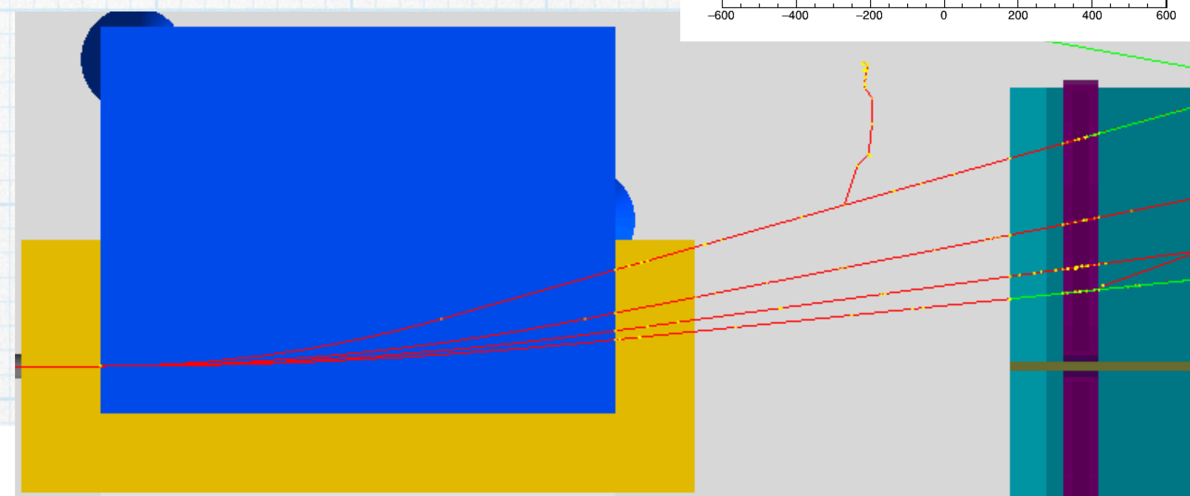
Borysova Maryna (KINR)
31/03/21
LUXE technical meeting

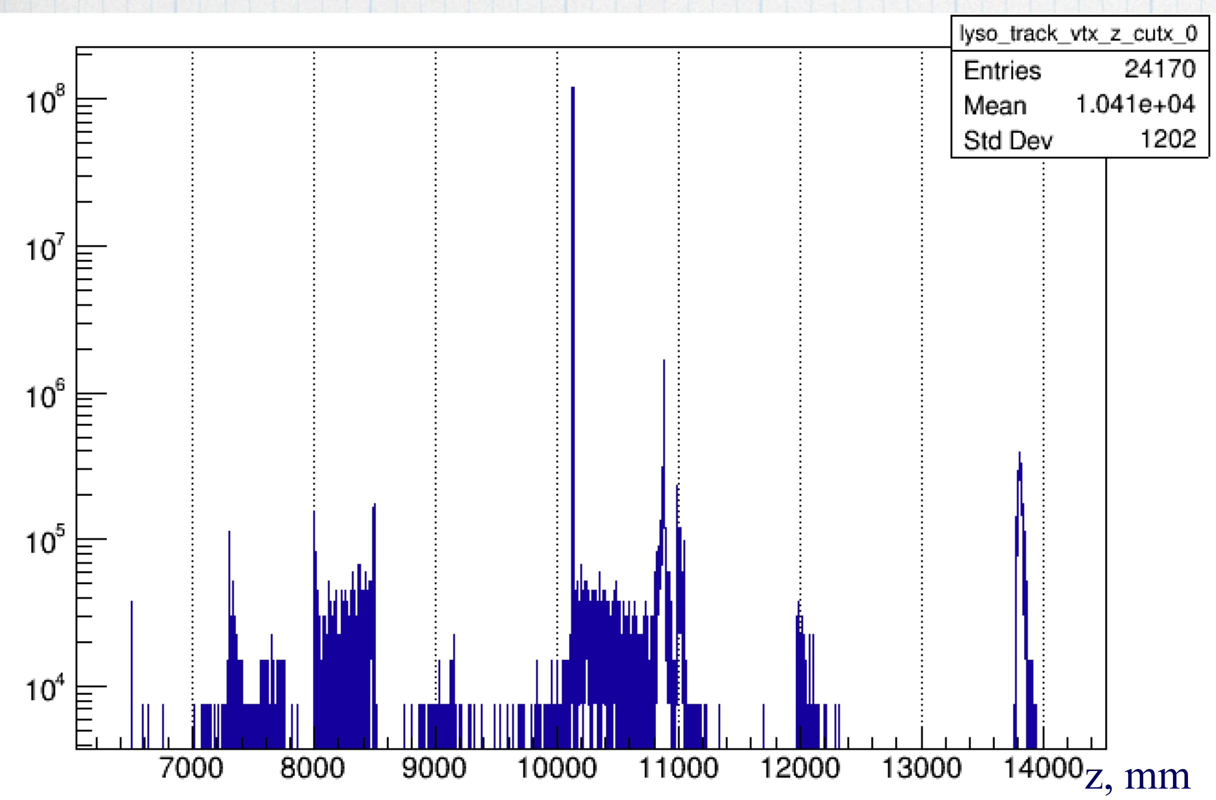
LUXE

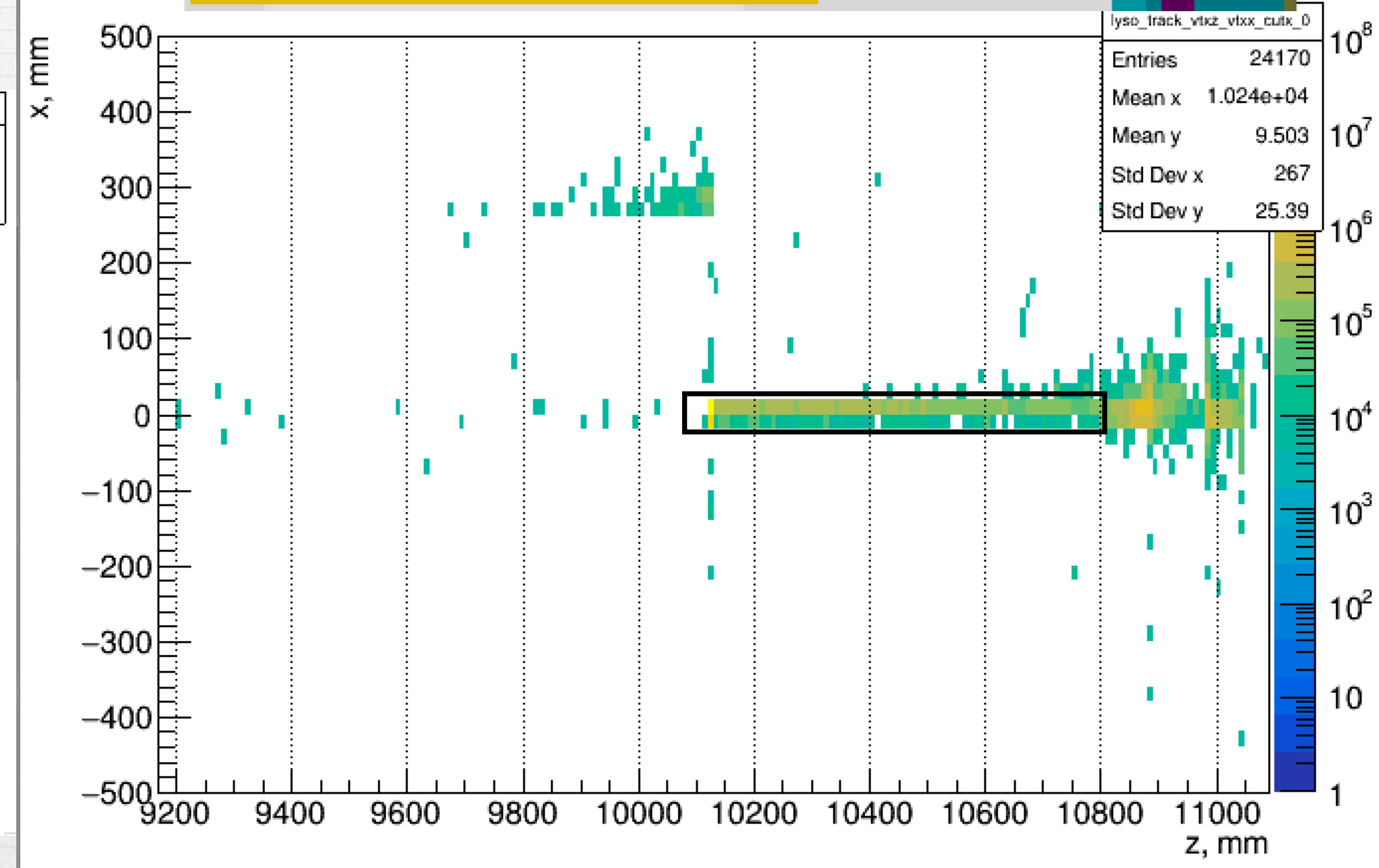
The reason for substructure at low E in reconstructed spectra



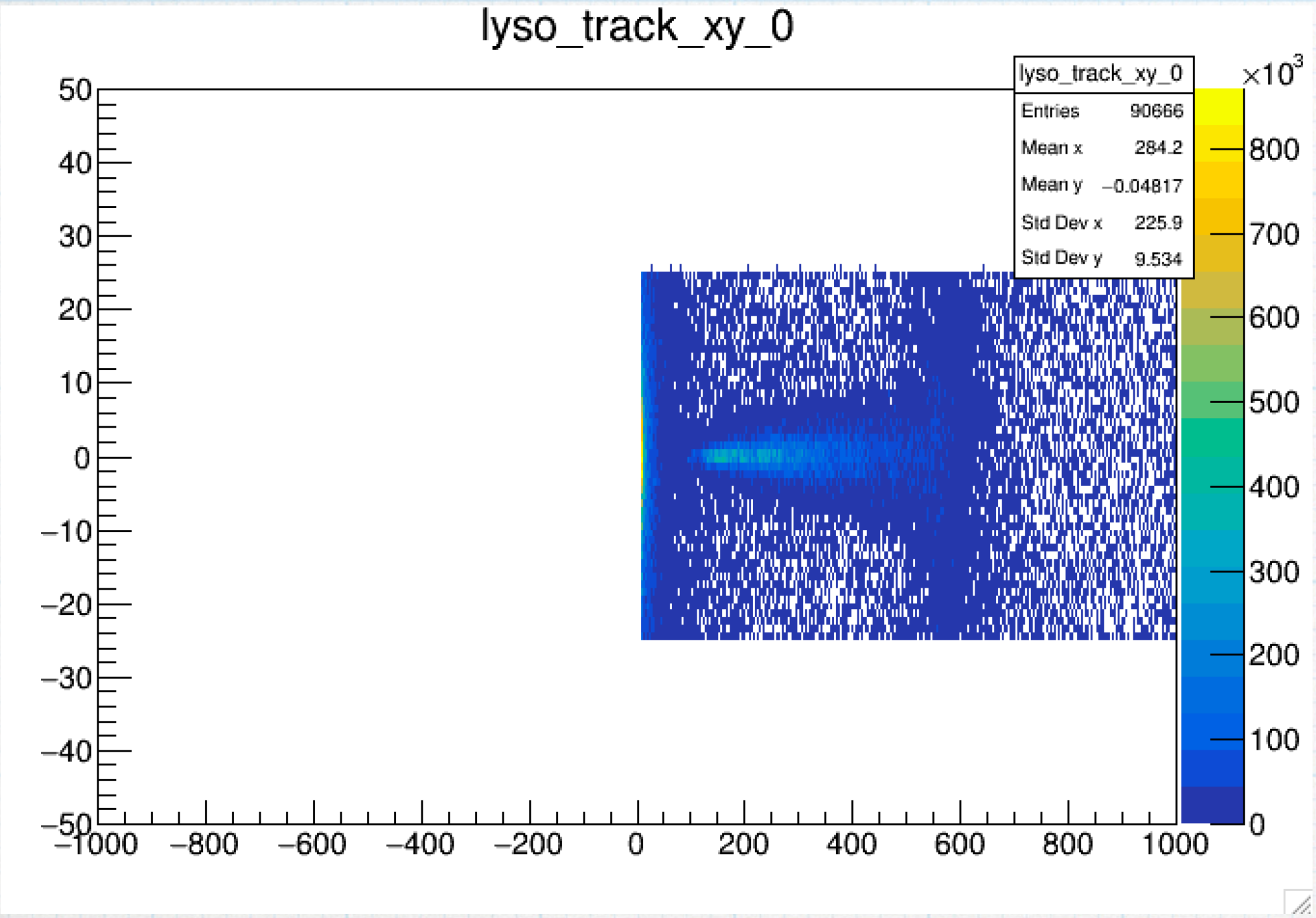


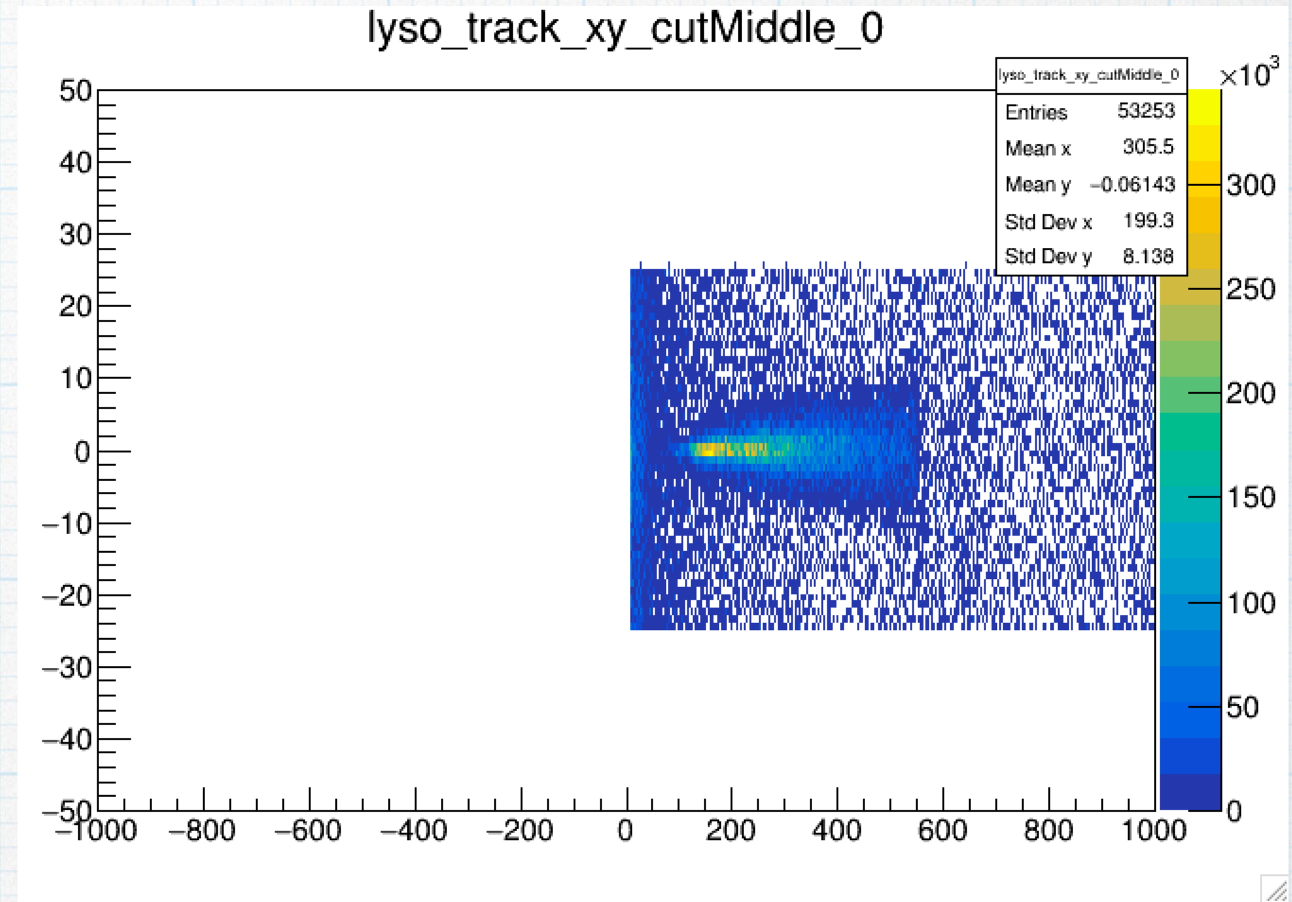


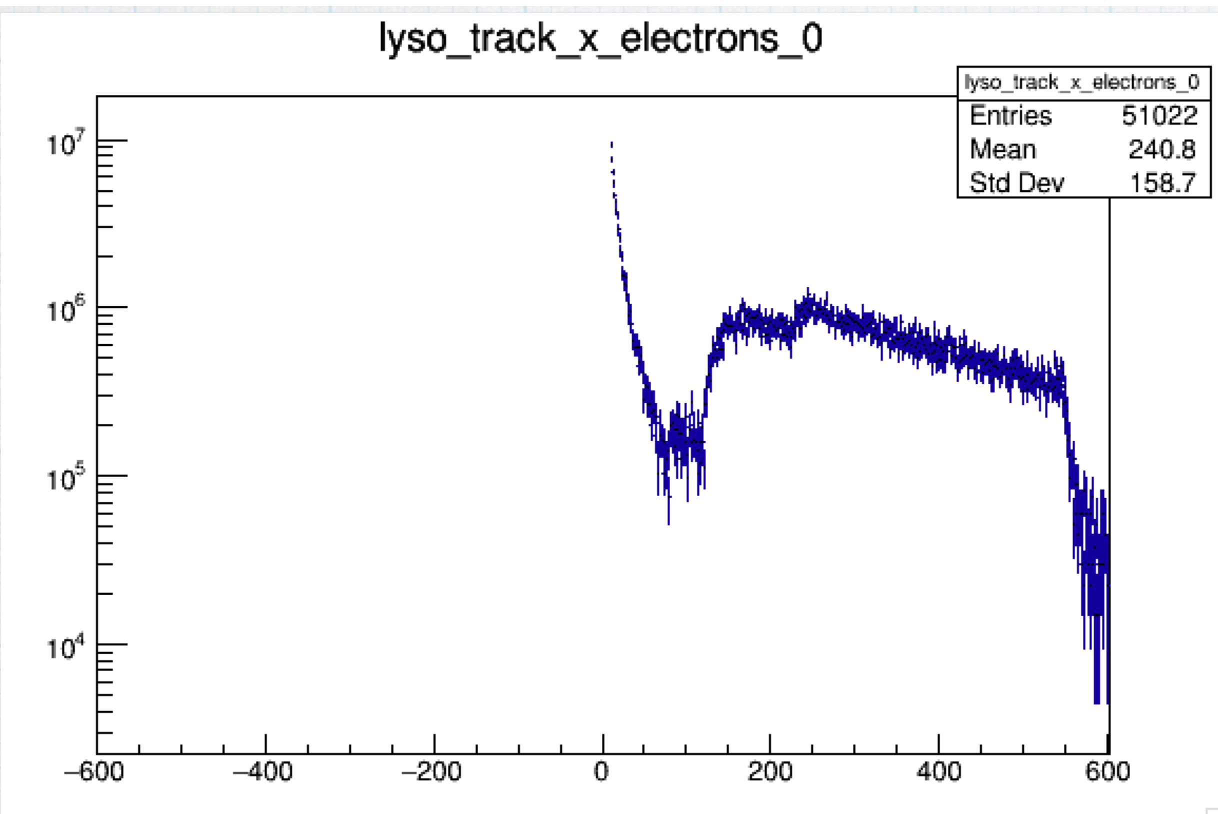


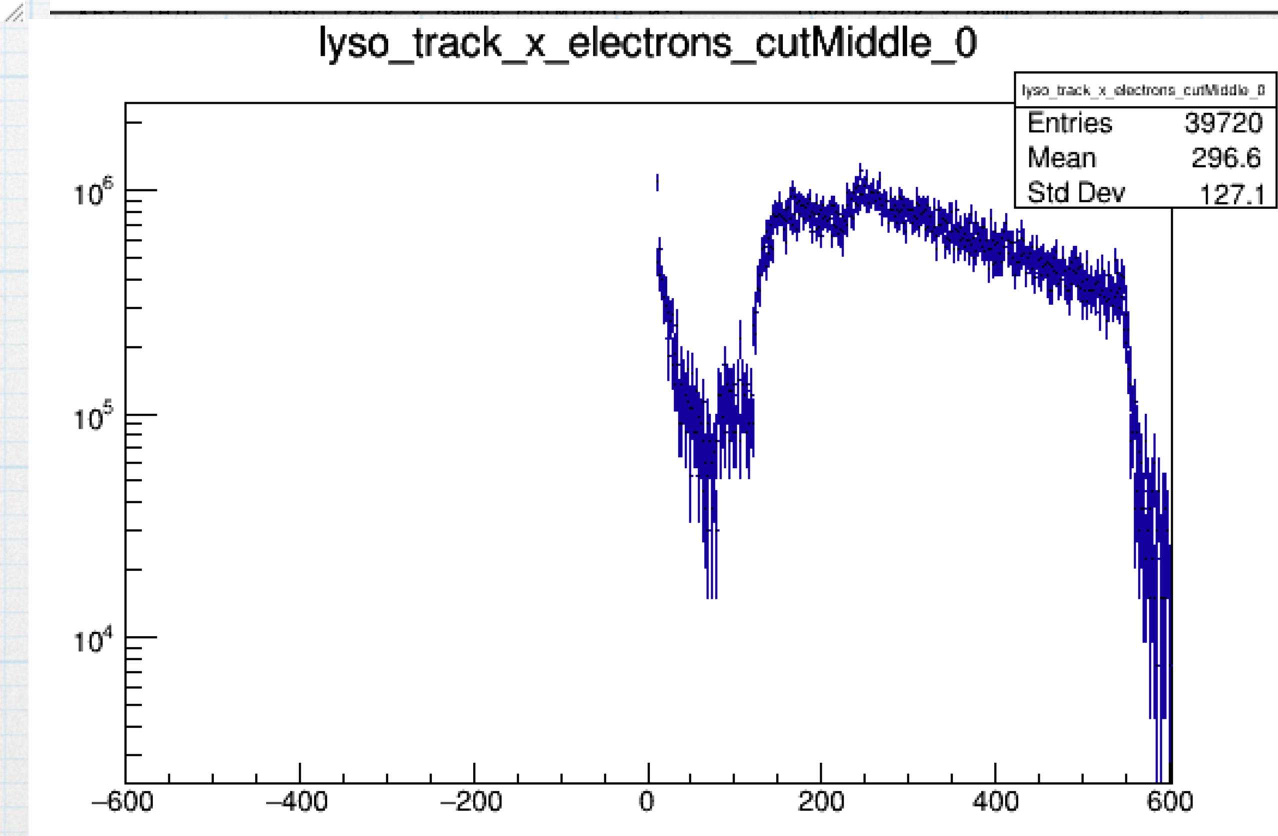


xy and x track distributions



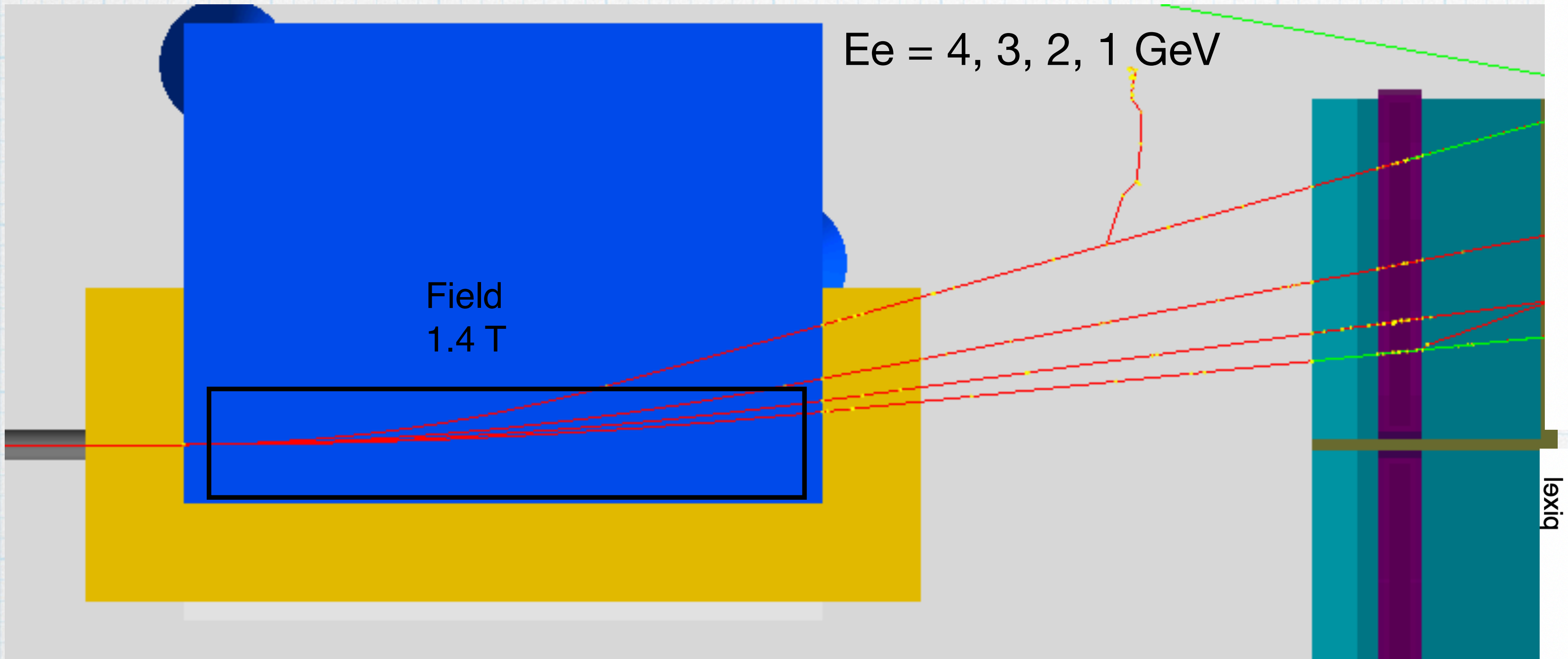


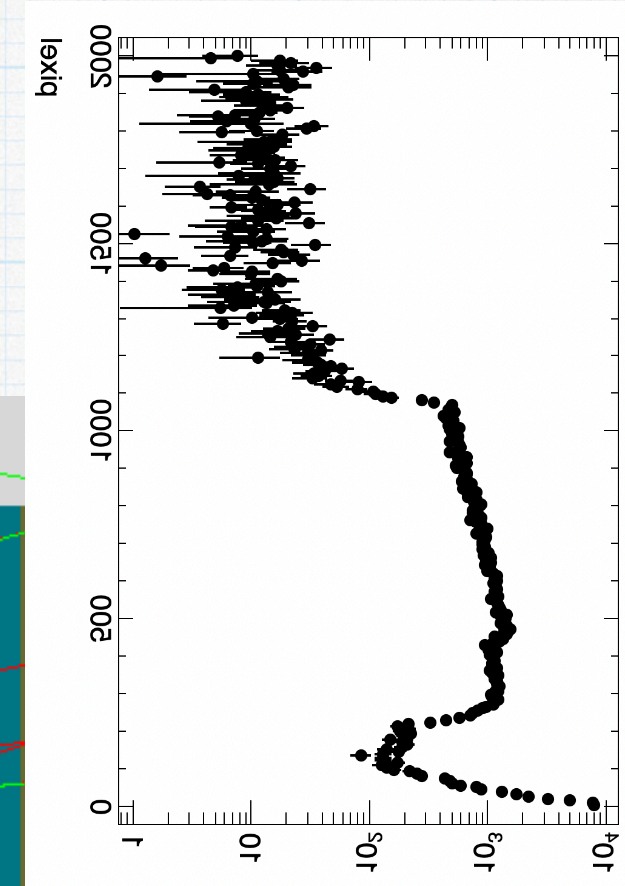


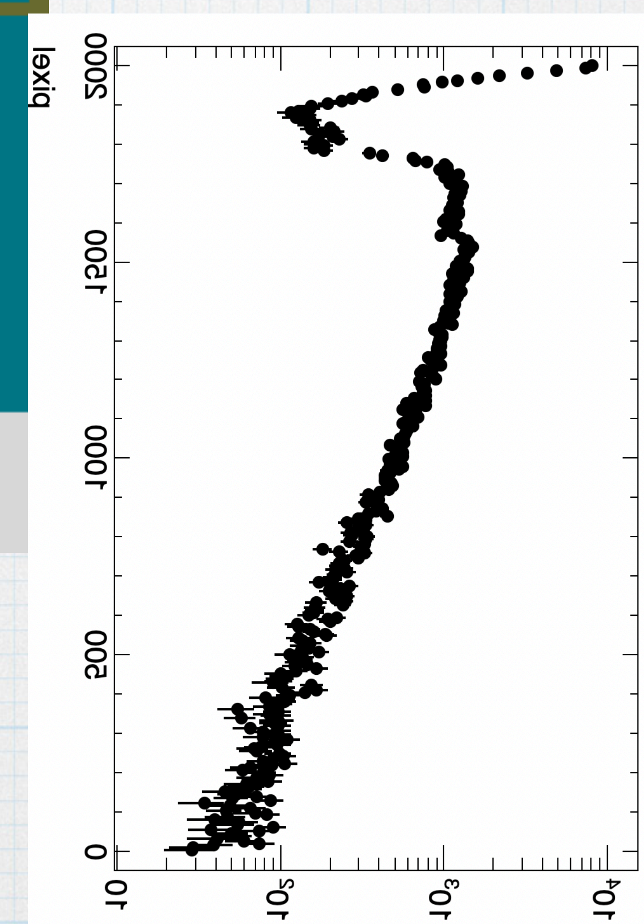


- Beam pipe from chamber till Gamma profiler is necessary

The reason for substructure at low E in reconstructed spectra

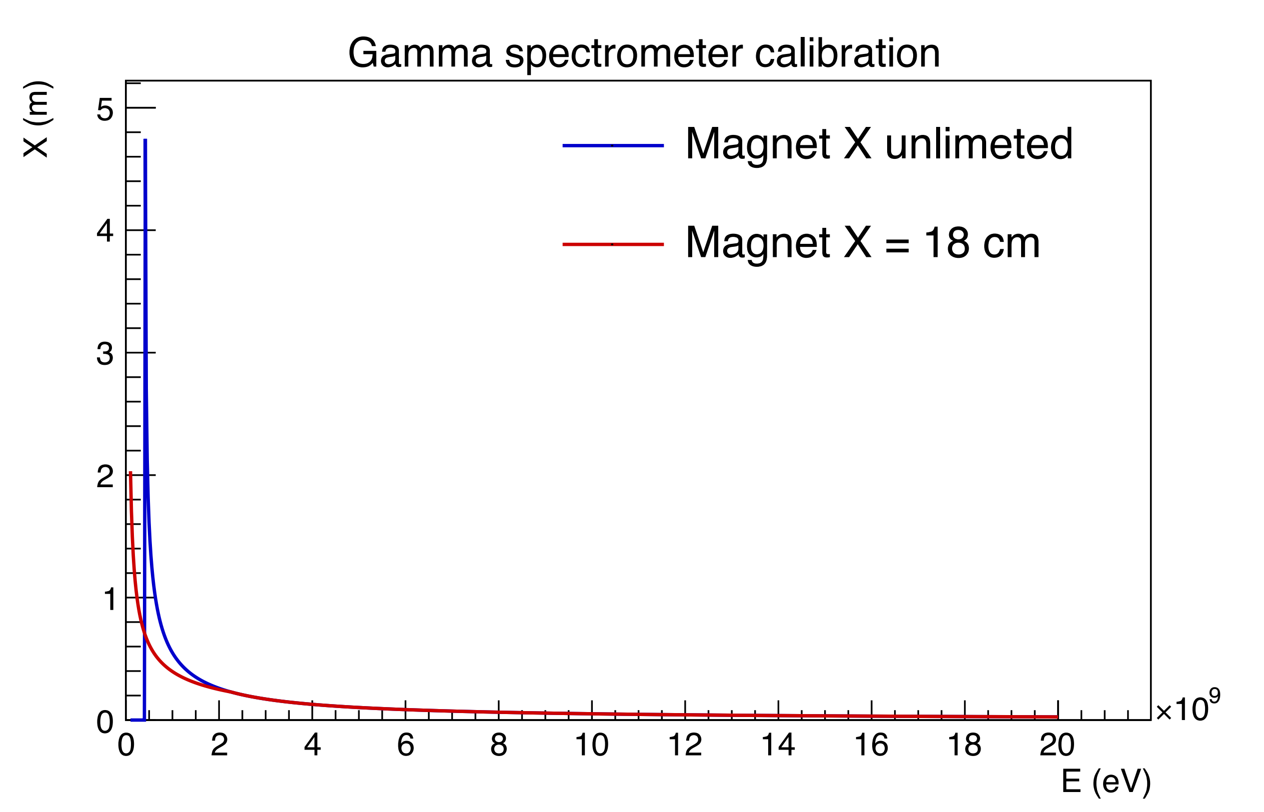


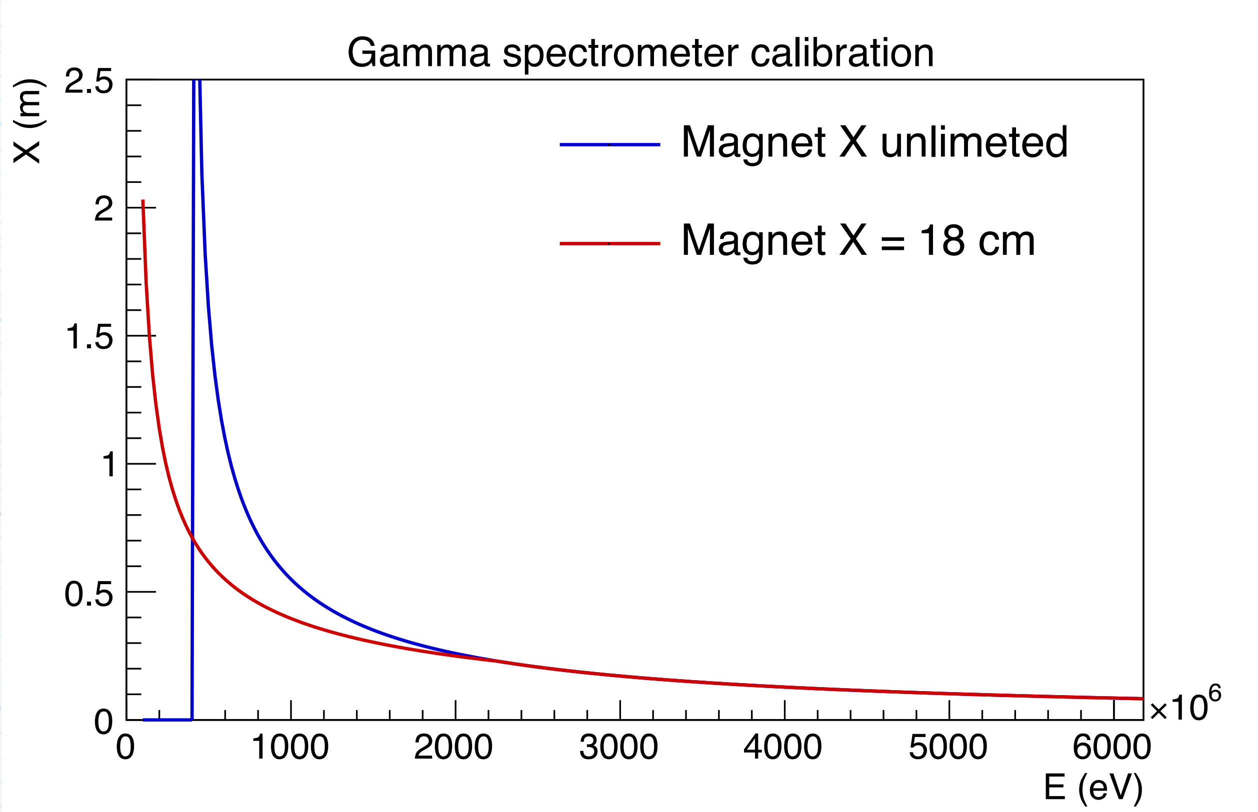


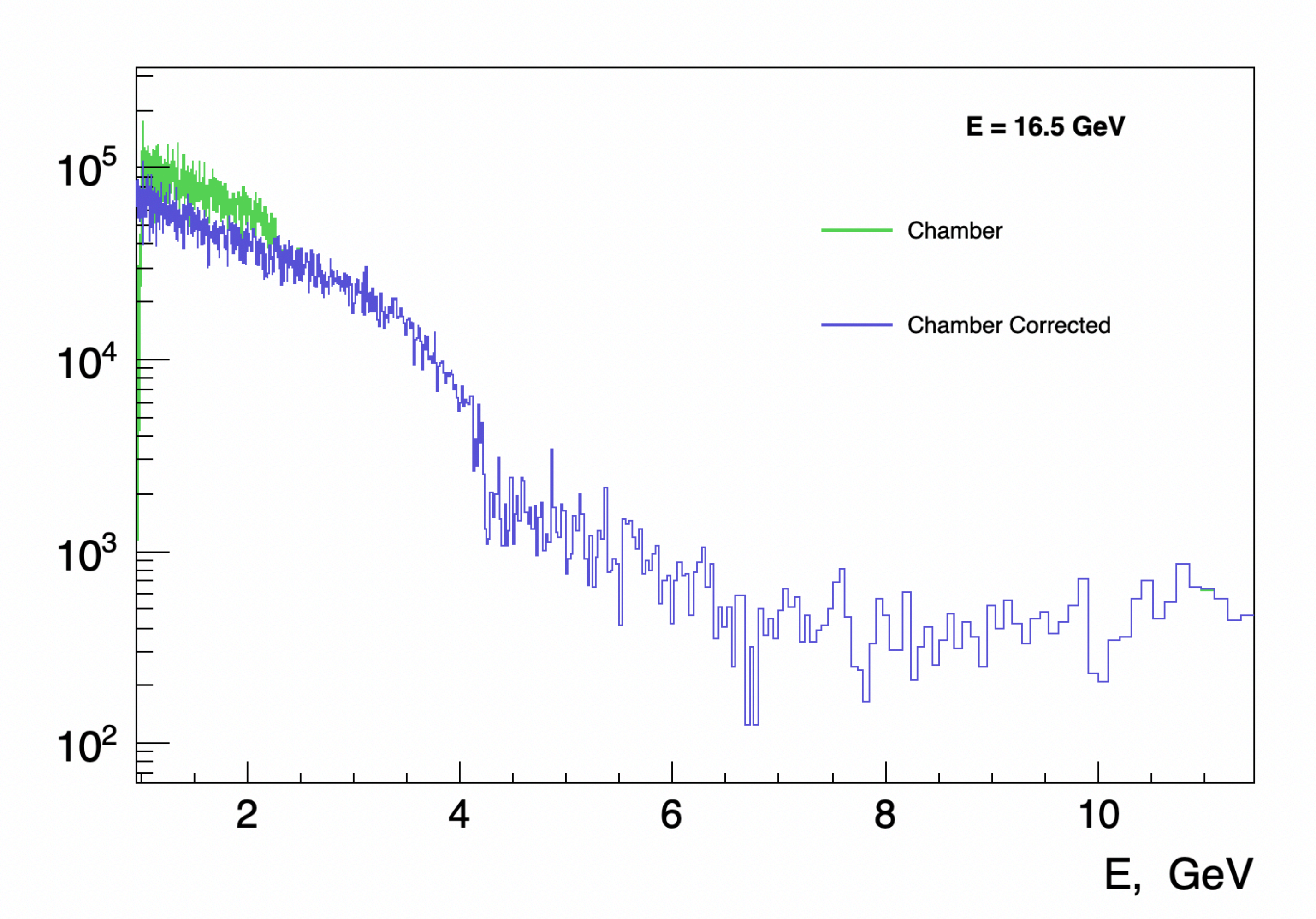


- Particles at smaller energies experience shorter magnetic field
- Should be counted for in calibration, converting x-distributions into energy spectra

Corrected calibration







Summary

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

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

* Beam pipe from chamber till Gamma profiler is necessary

* Corrected calibration

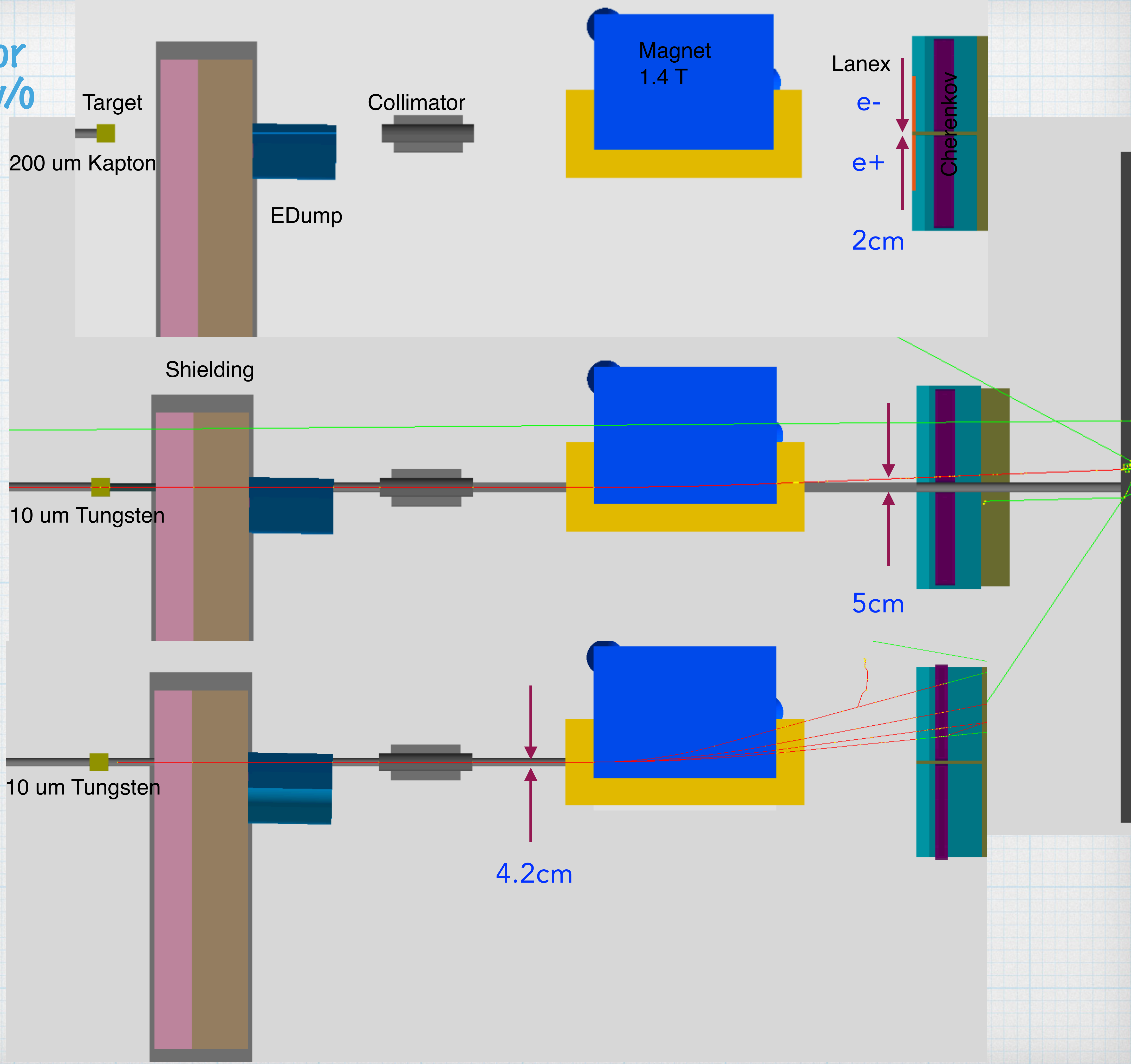
Back up

Forward detector system with & w/o beam pipe

No Beam Pipe
Kapton, 200 um

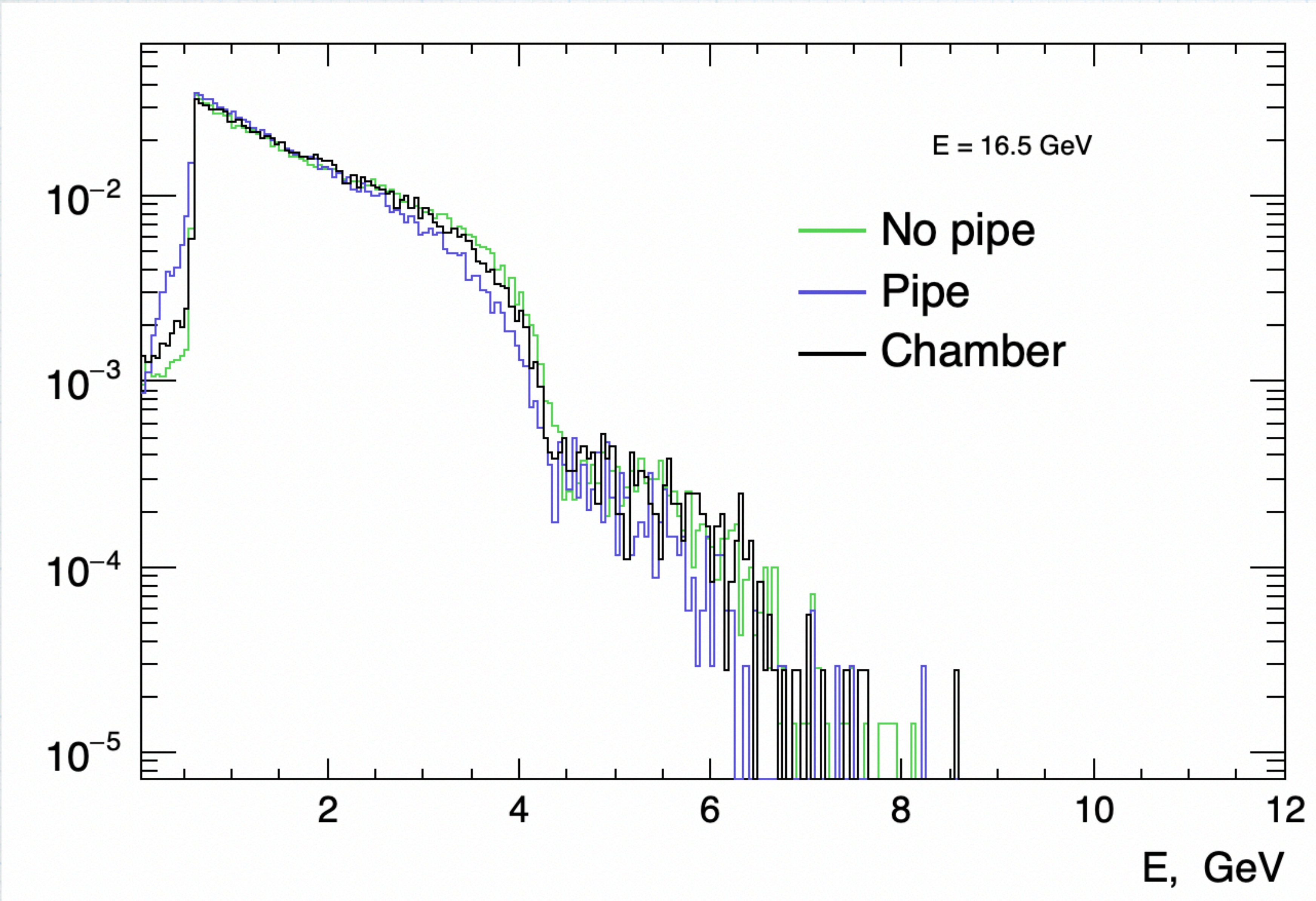
Beam Pipe 5 cm
W, 10 um

Beam Pipe 4.2 cm
+chamber
W, 10 um



"True" spectra

JETI40, 16.5 GeV, 50 um

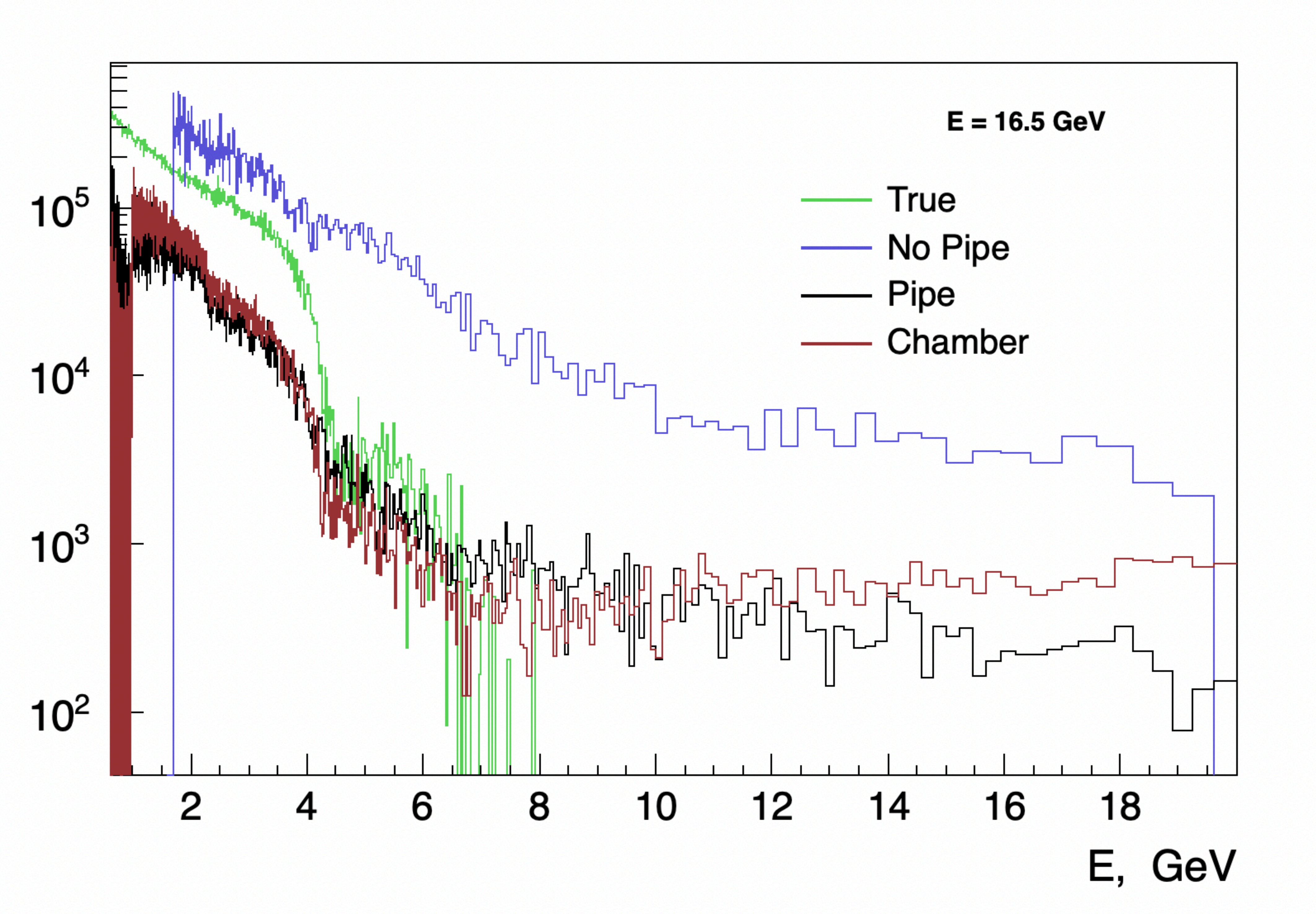


- Electrons/positrons generated in target by primary photon and which are hitting Lanex screens
- Consider air before the magnet as a target too

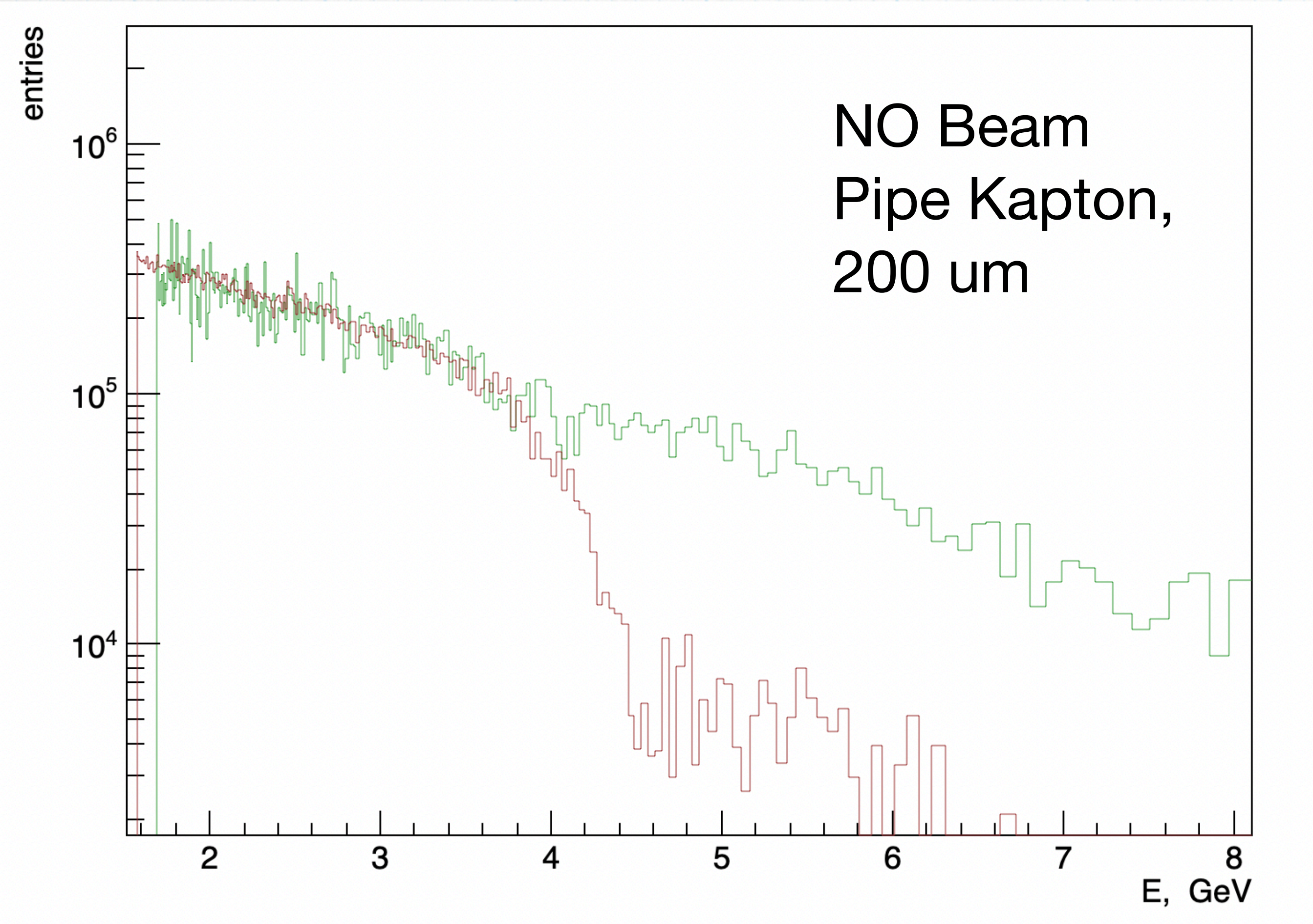
* Selection
- detid == 3000/3001
- pdg ==11/-11
- Parent pdg ==22
- Parent == primary
- Primary pdg ==22
- |vtx x,y |<25 mm
- |vtx z - 6.5 m |< 100 um
- vtx z > 6.5m -100um && vtx z < 9m

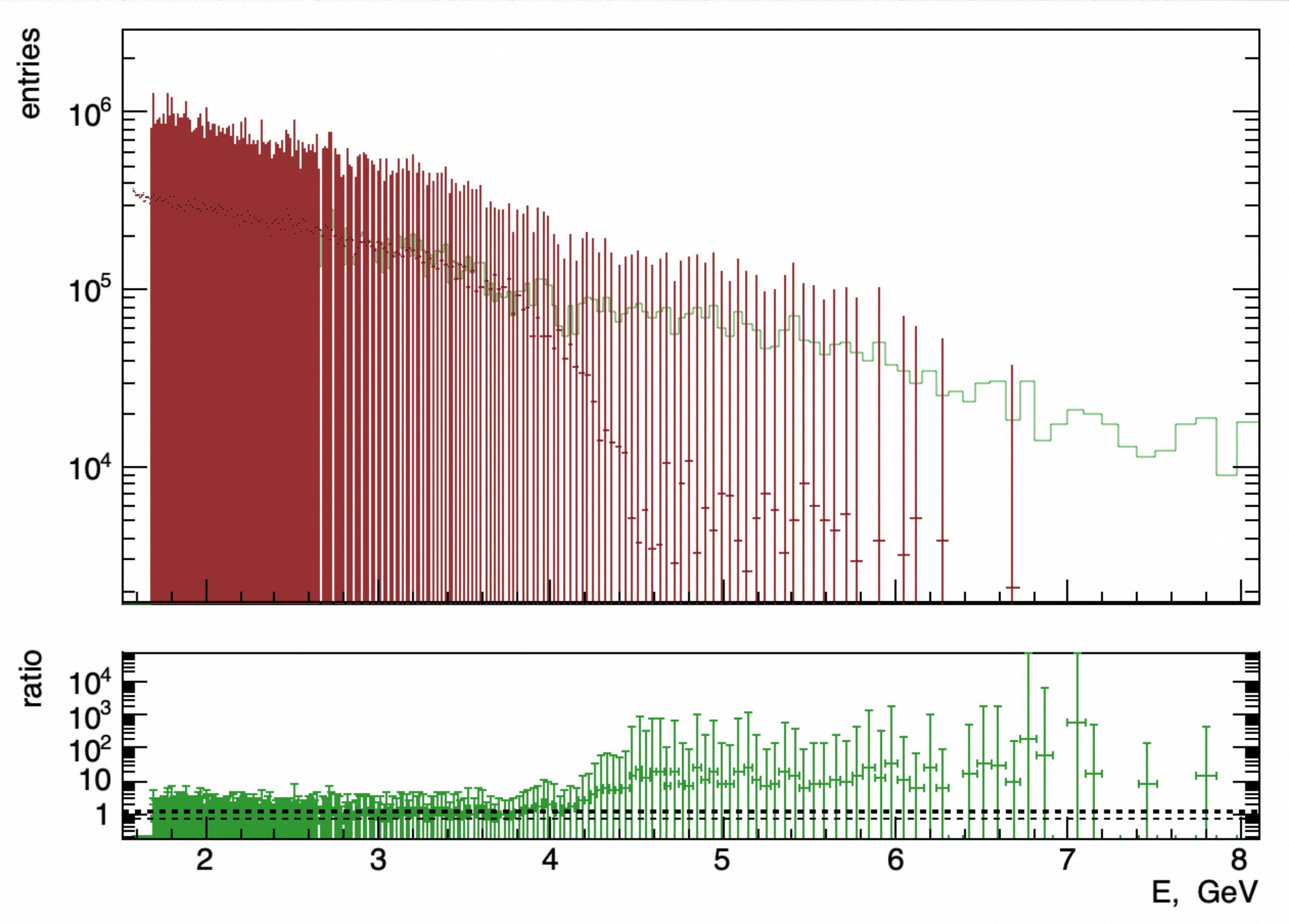
Reconstructed spectra

Not normalised



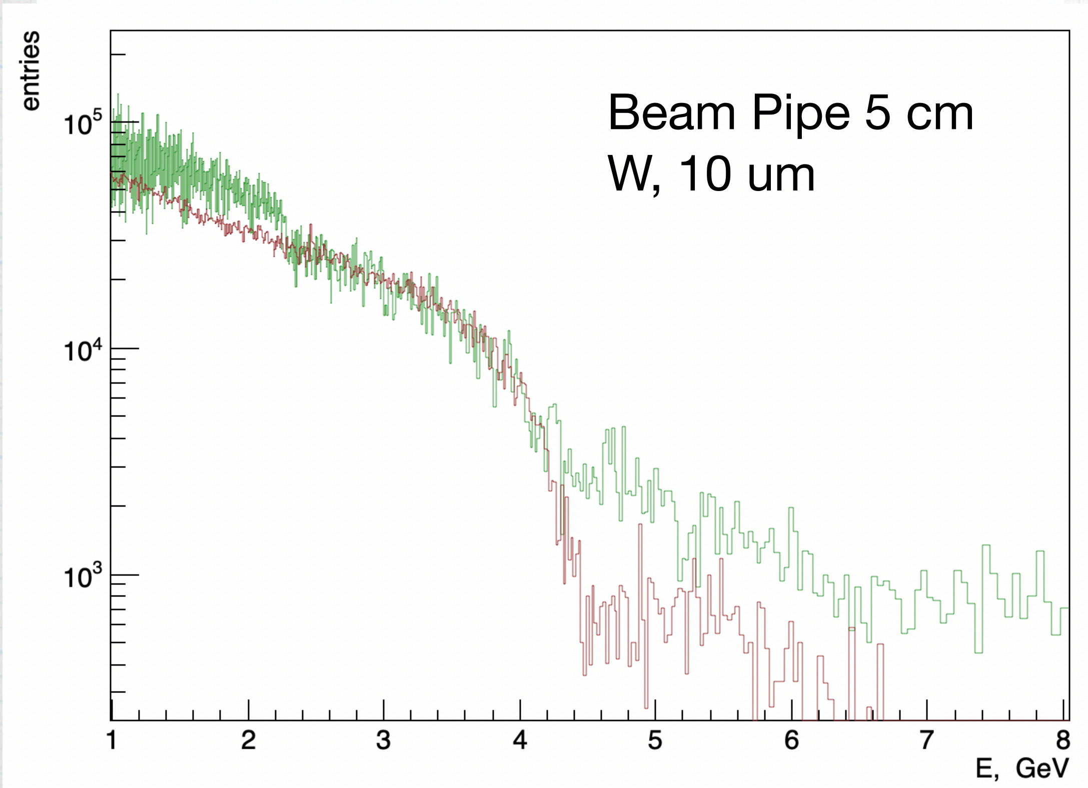
True vs Reconstructed

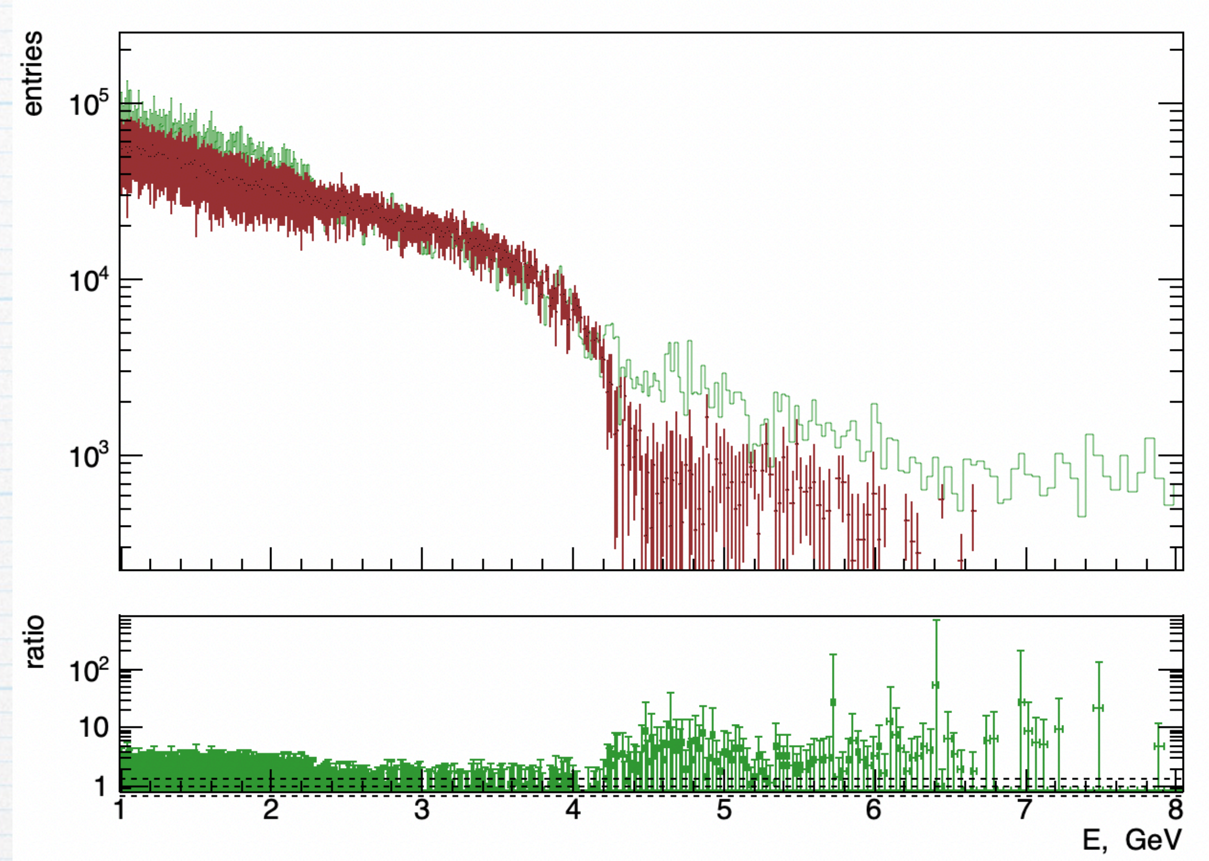


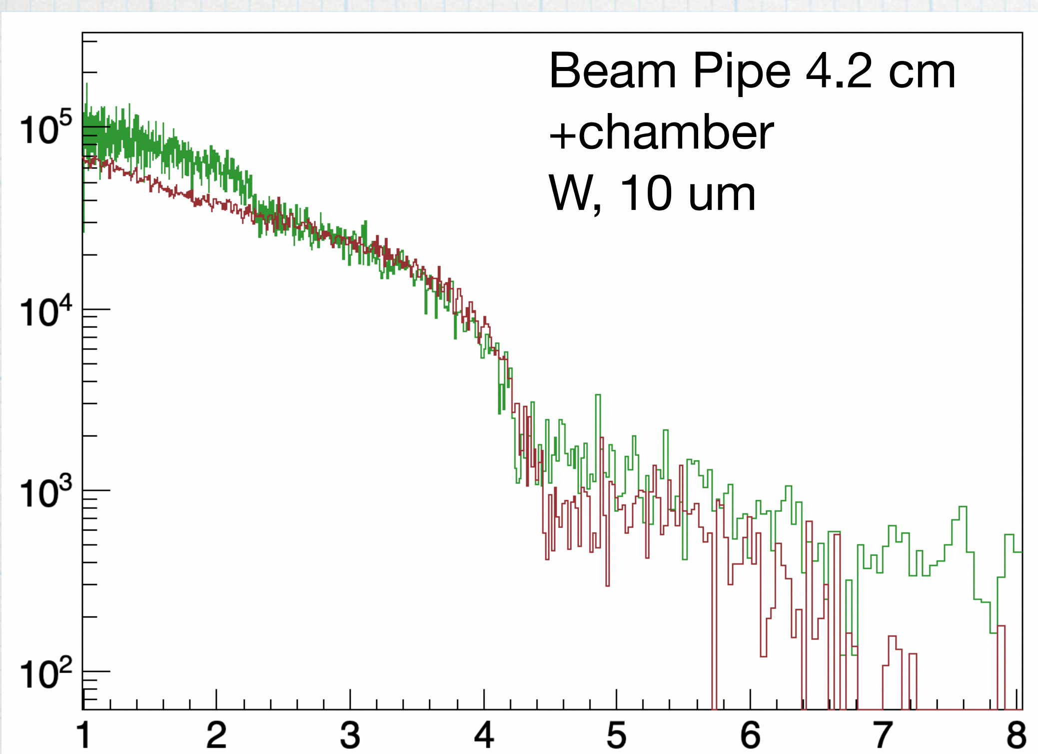


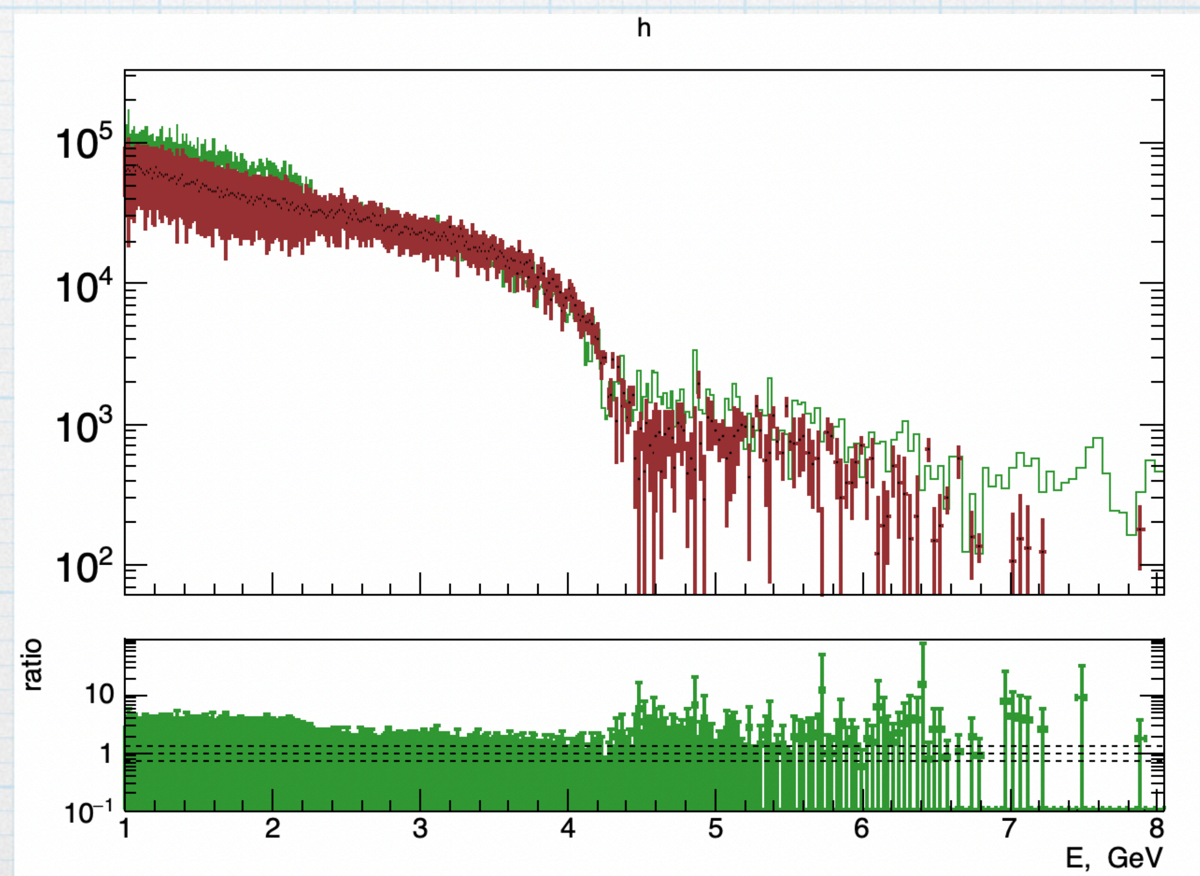
* Spectra were normalised on integral in E range of [2.5; 3]

True vs Reconstructed

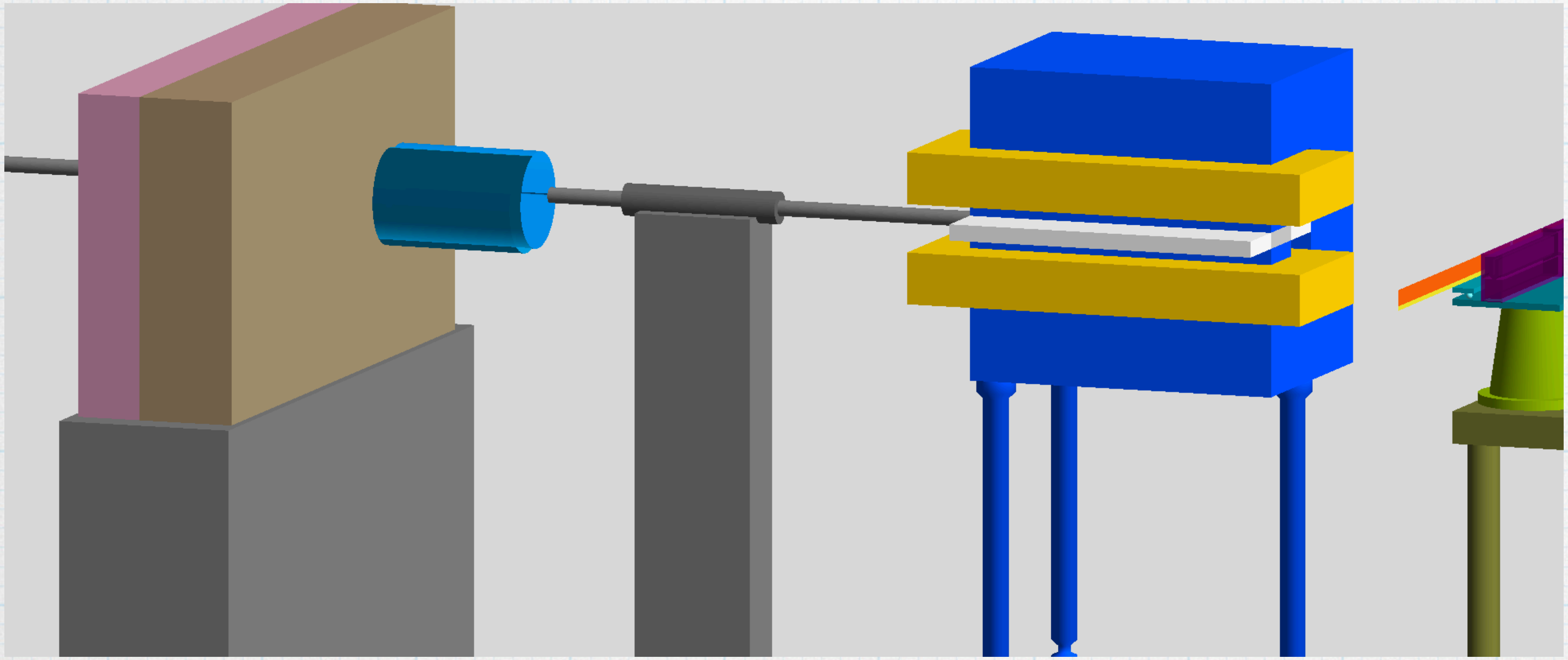




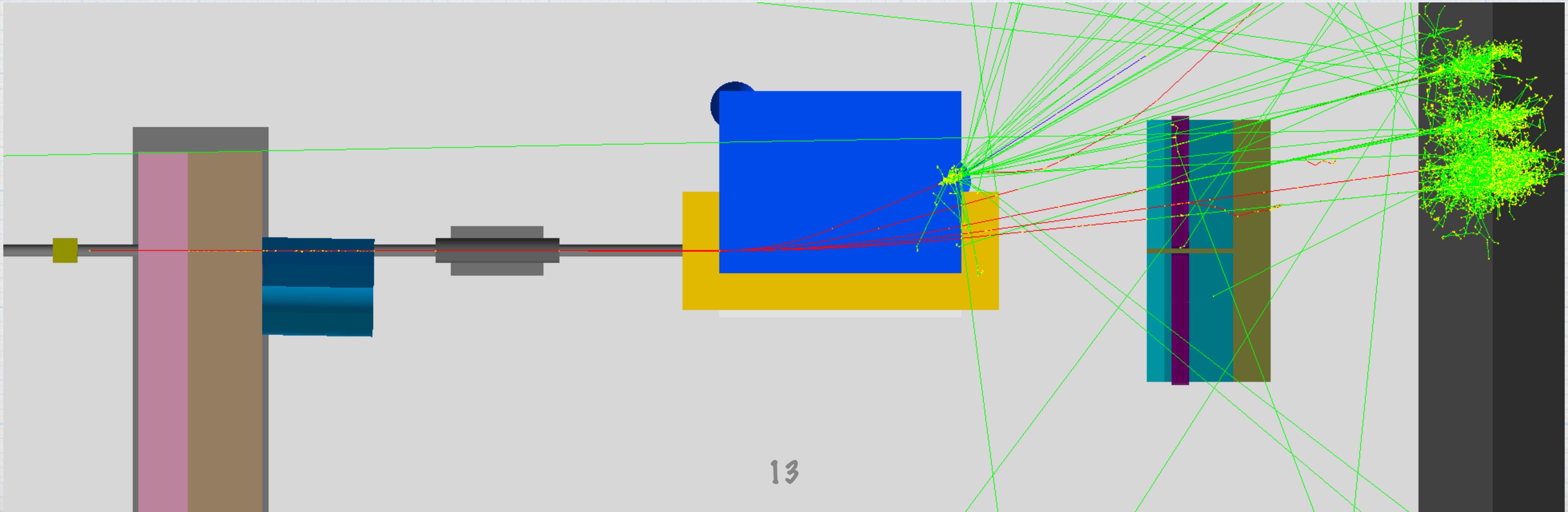




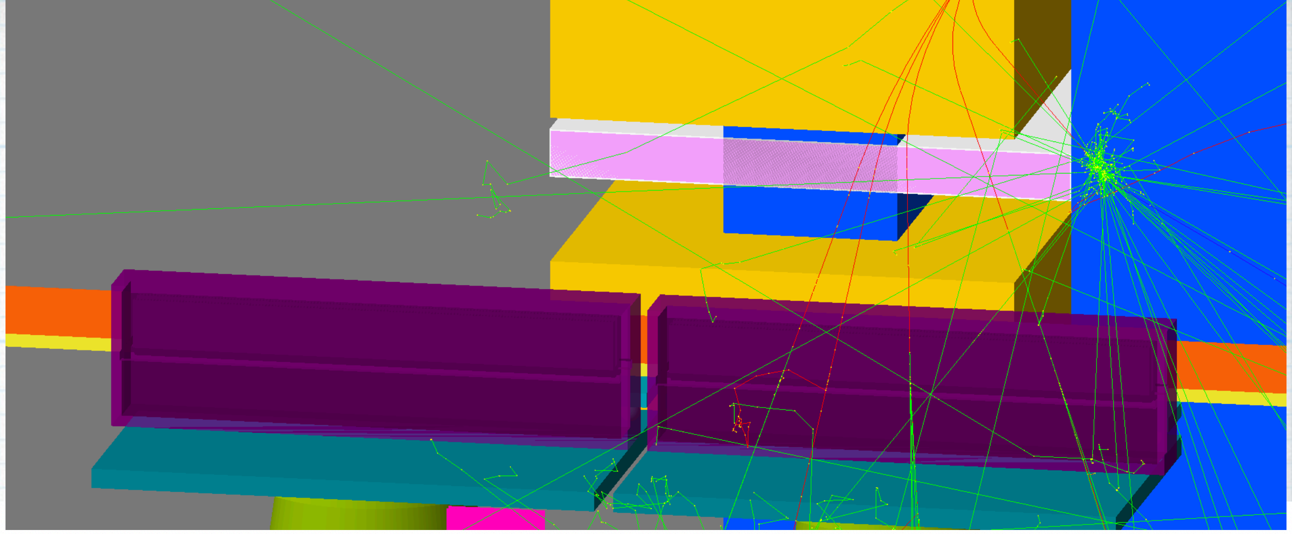
Forward detector system with beam pipe and short chamber

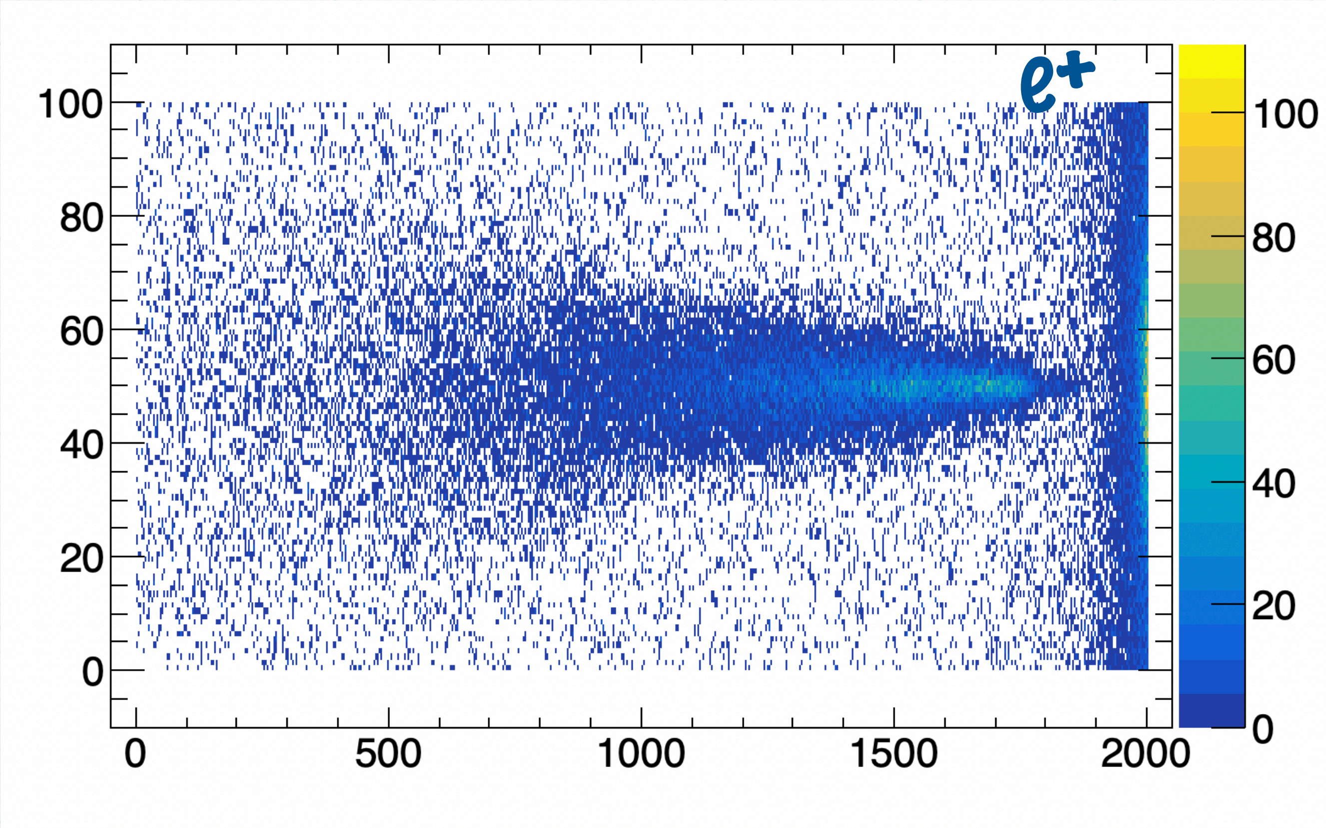


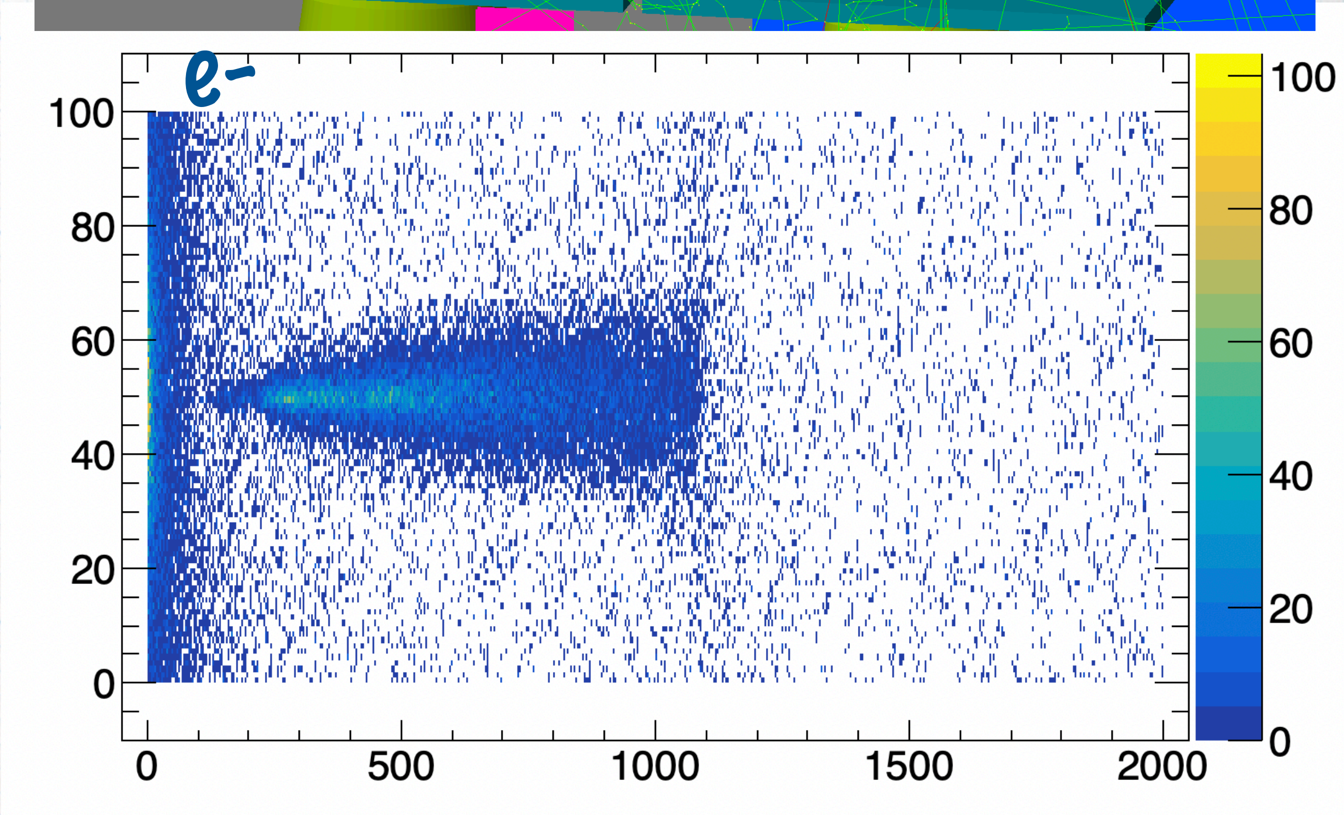
Ee = 4, 3, 2, 0.5 GeV

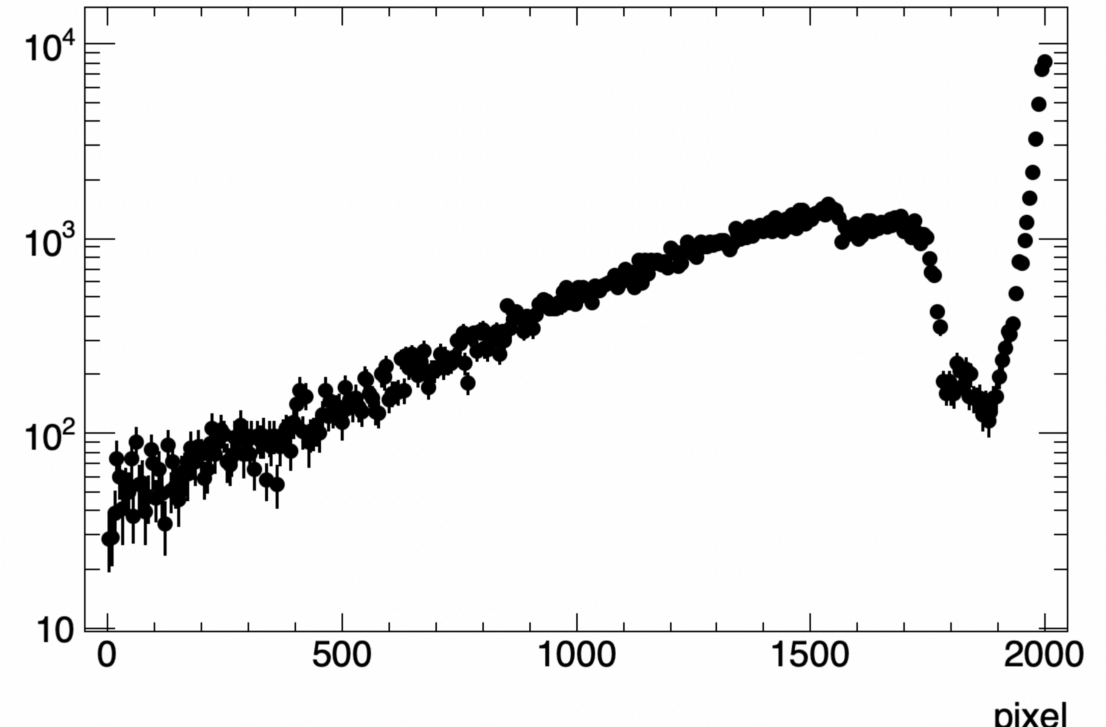


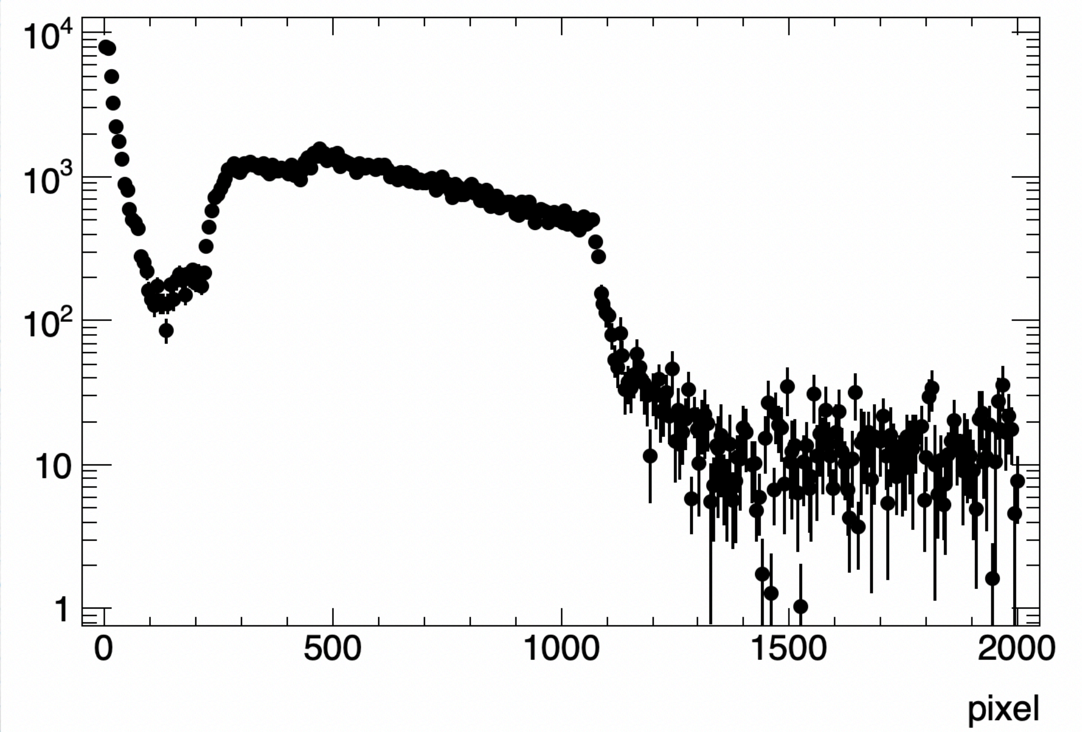
Deposited energy in Lanex, Beam pipe+chamber, ~4500 bx



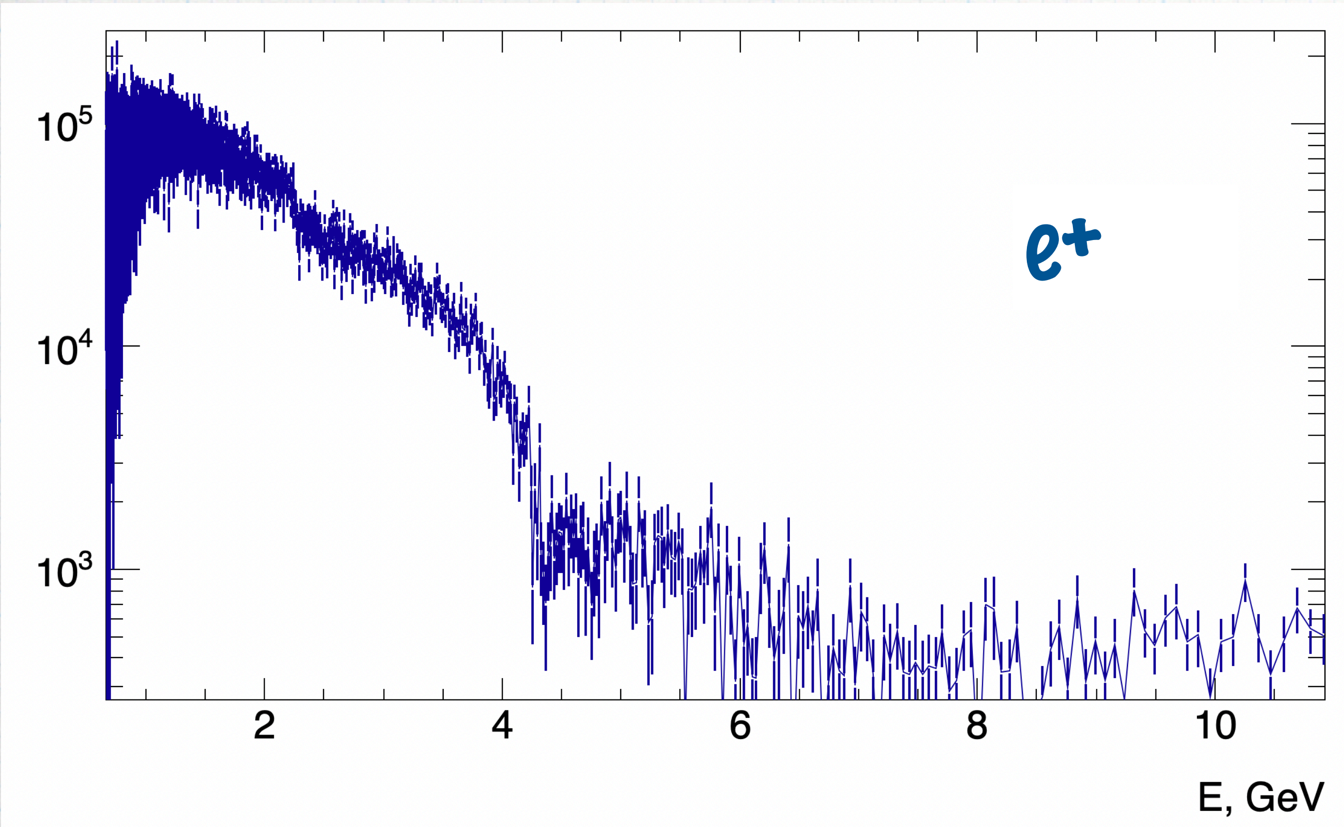


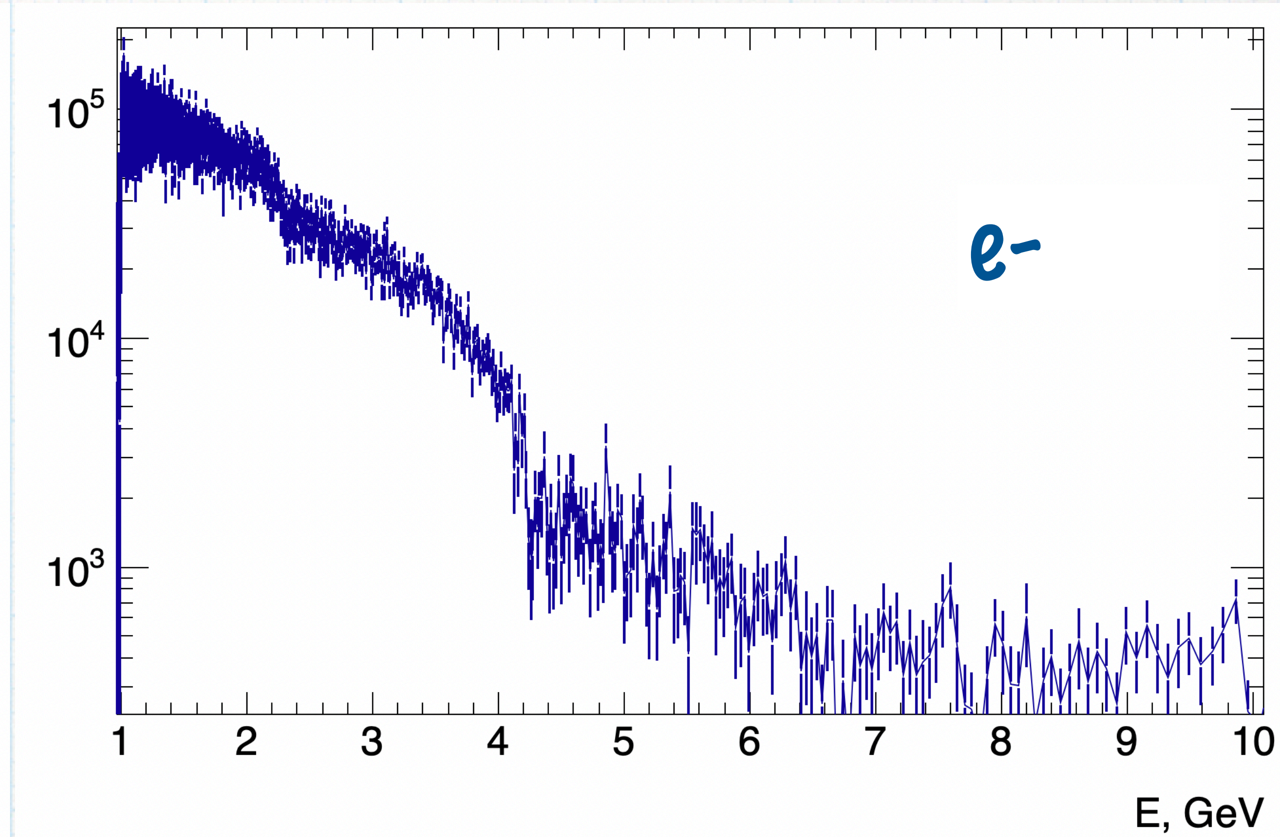


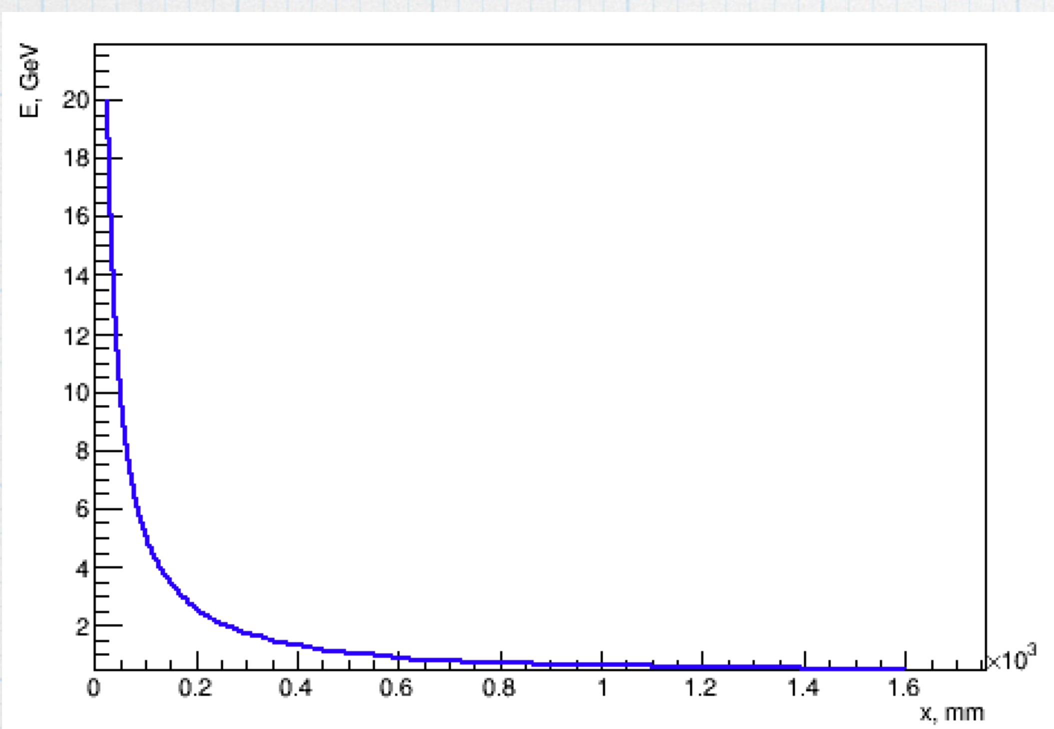


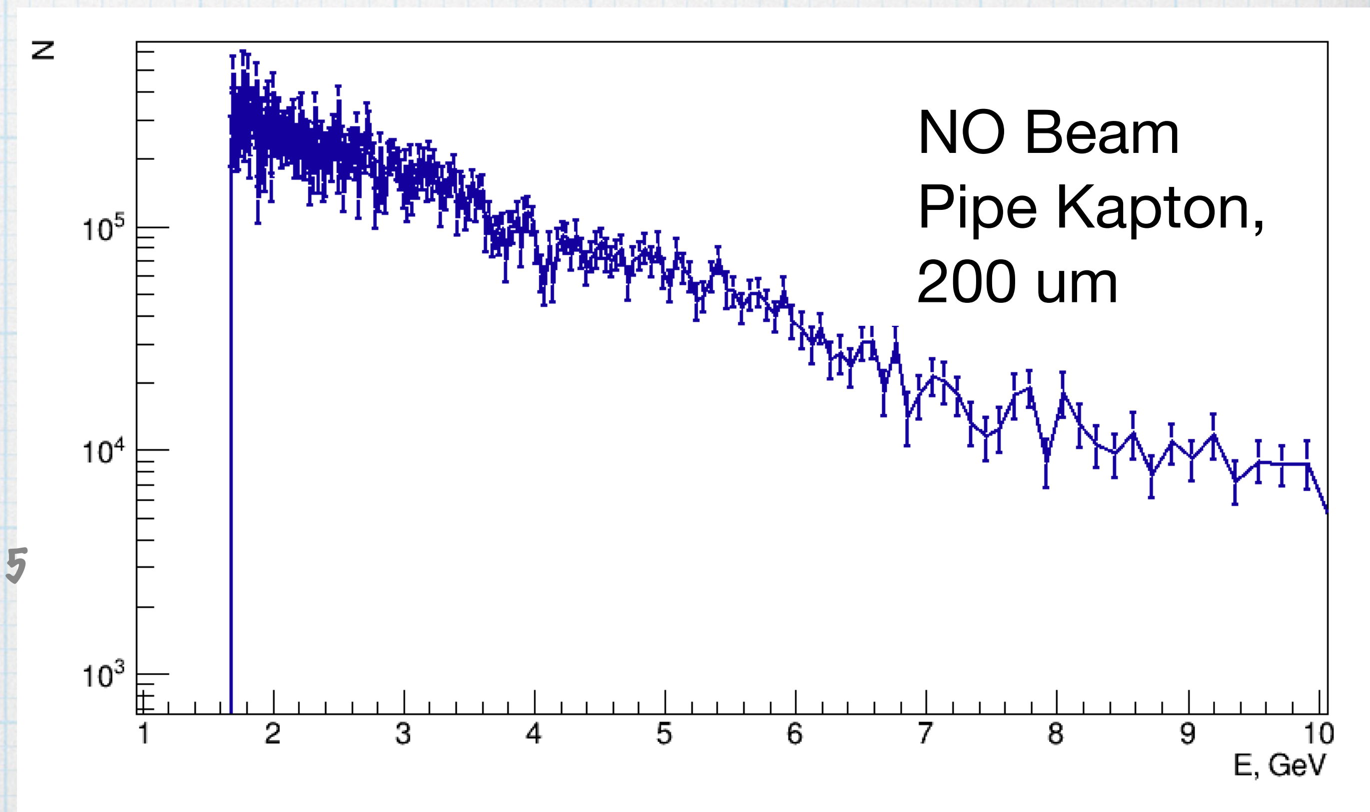


Reconstructed spectra

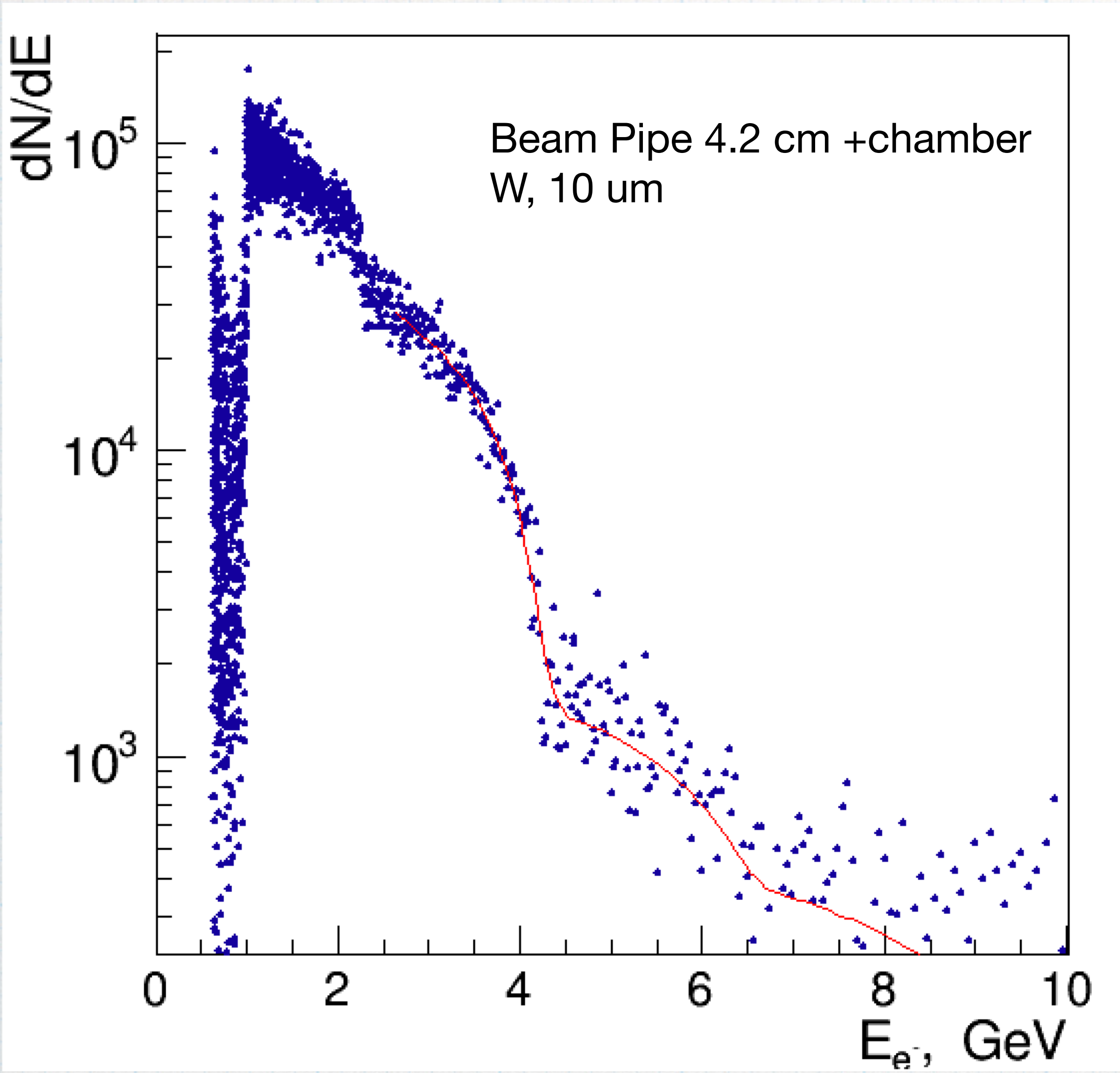


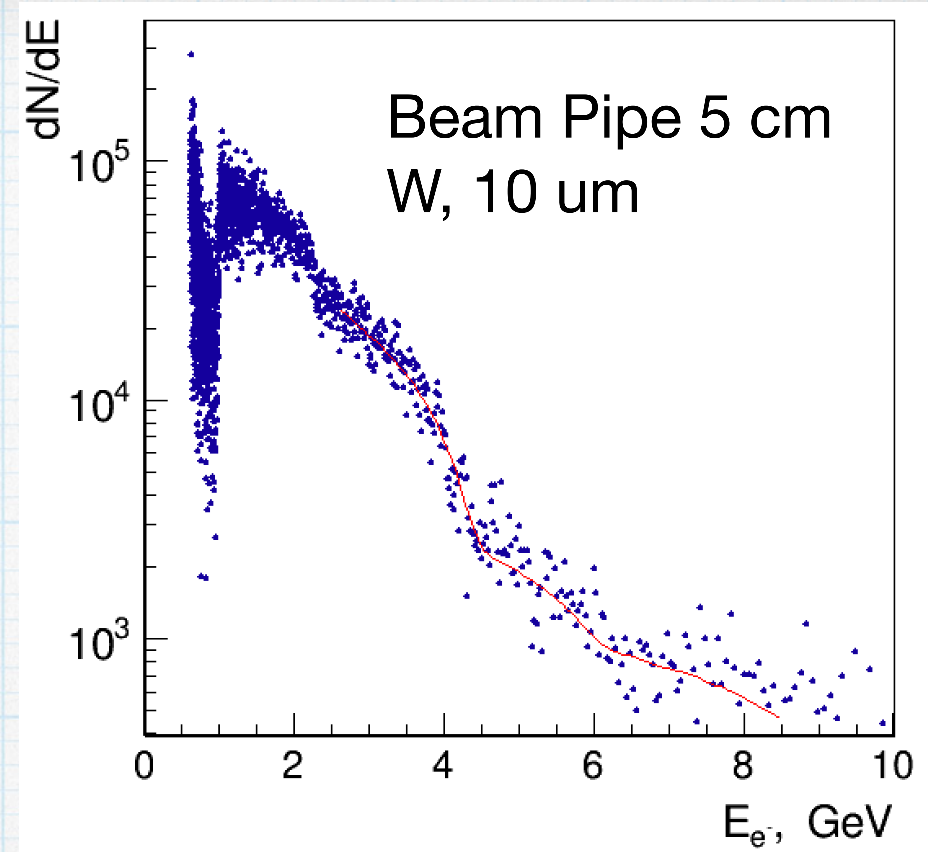


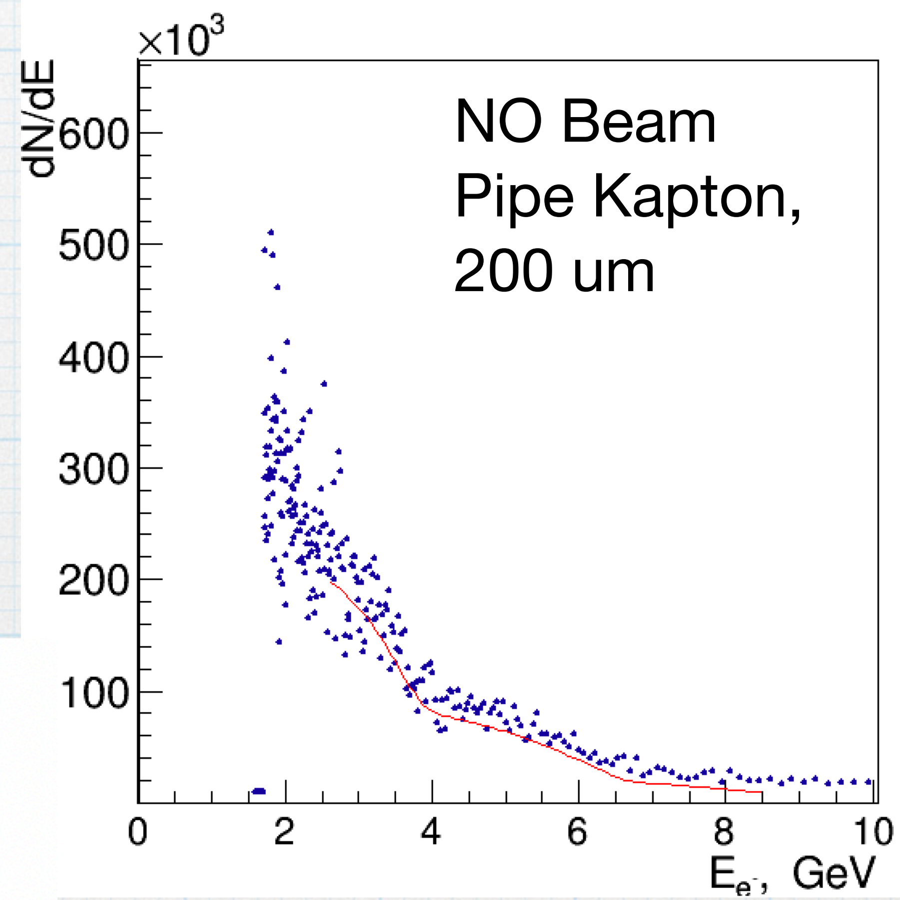




Reconstruction





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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
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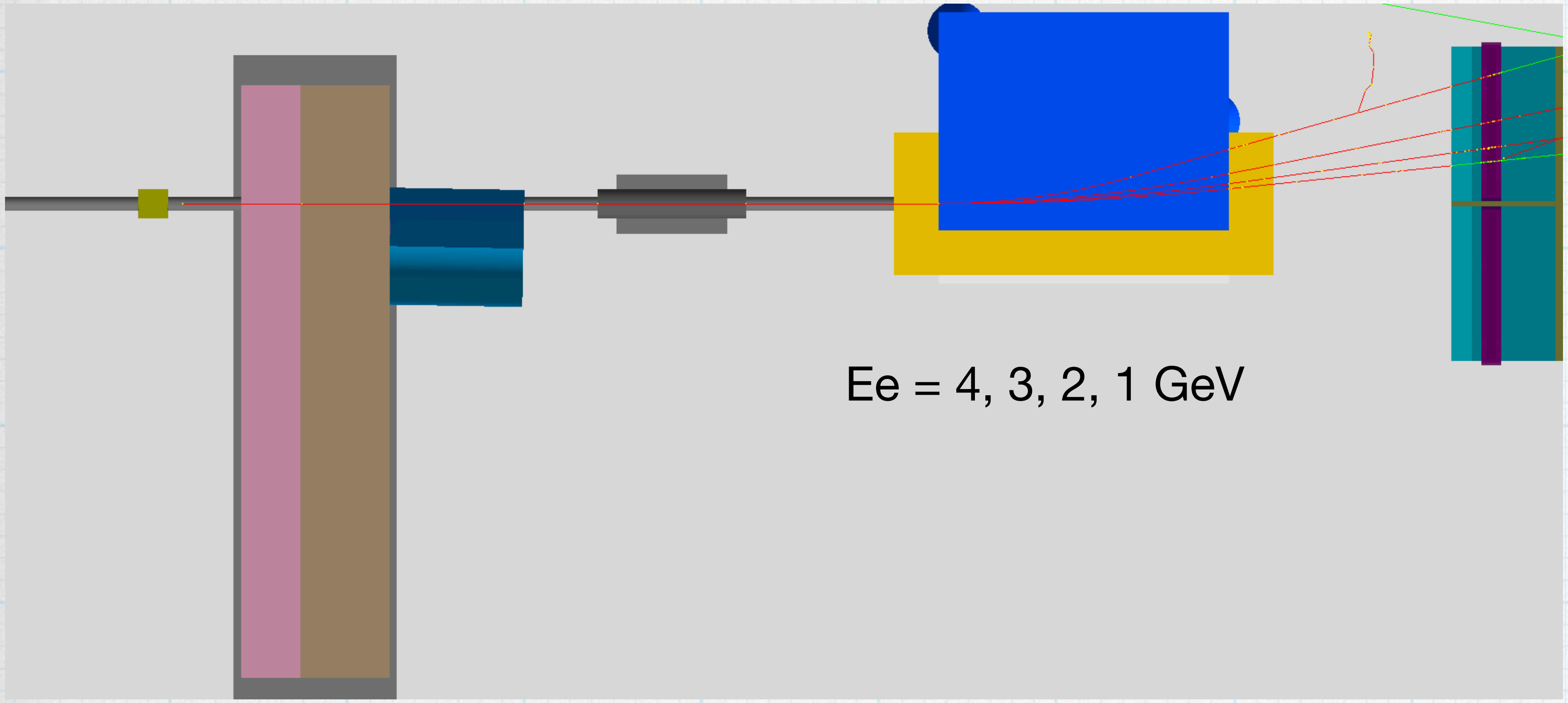
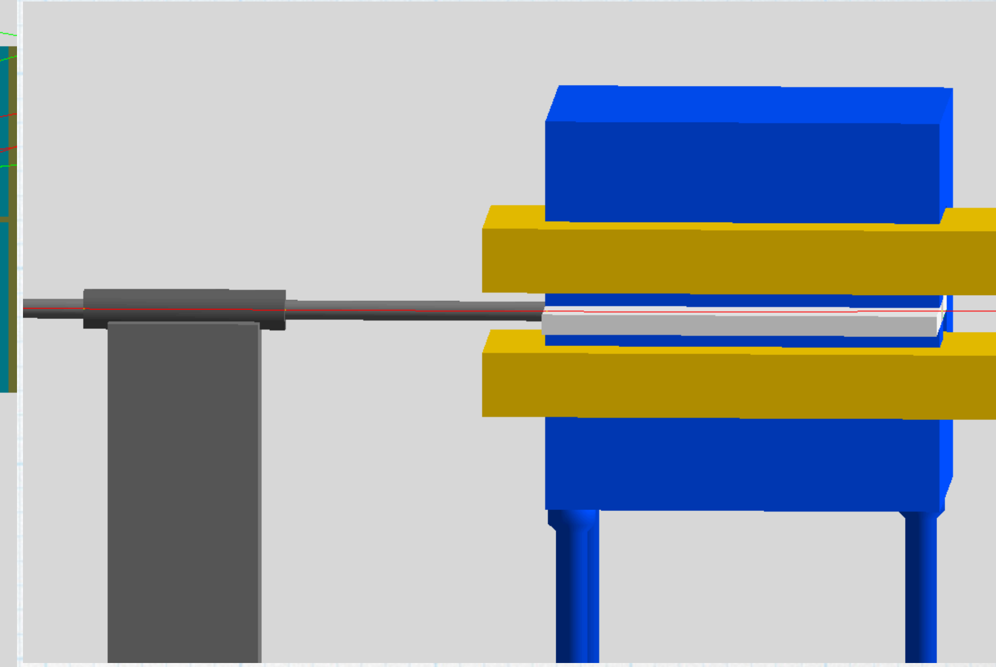
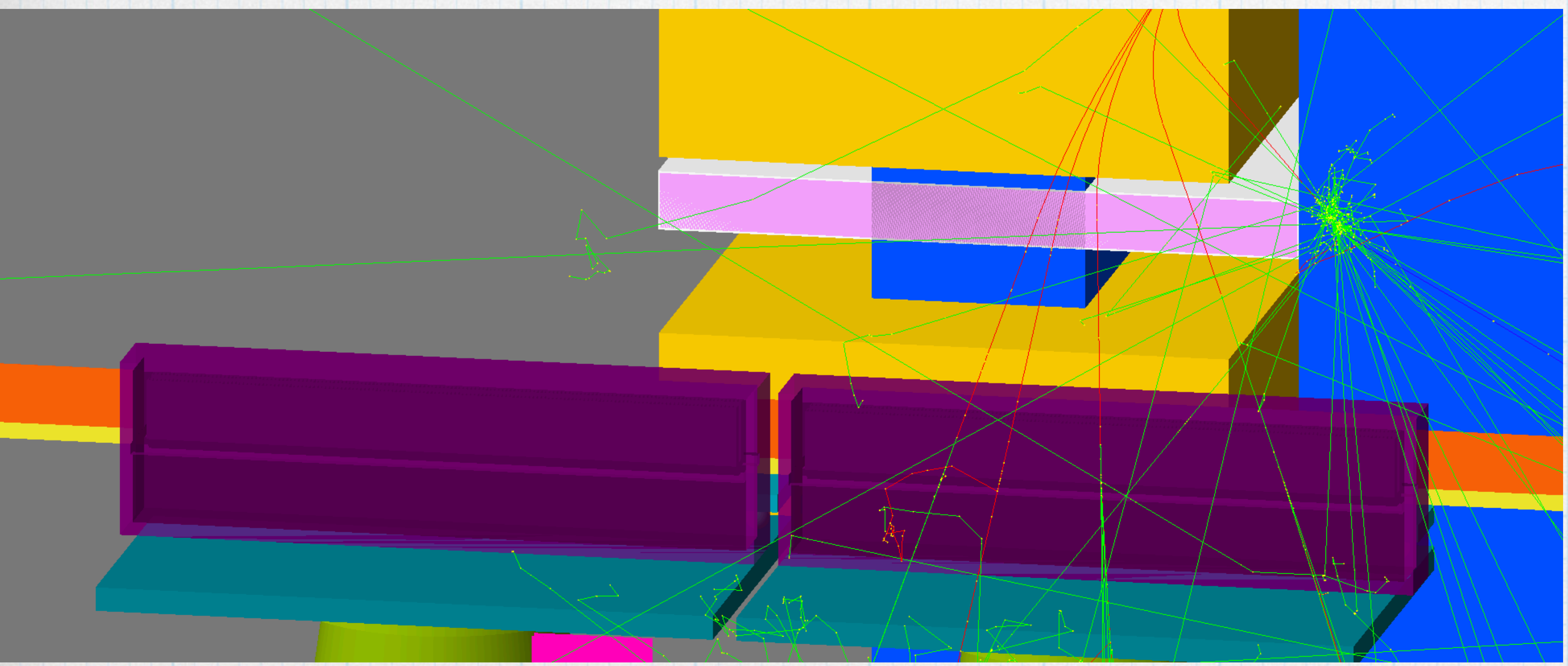
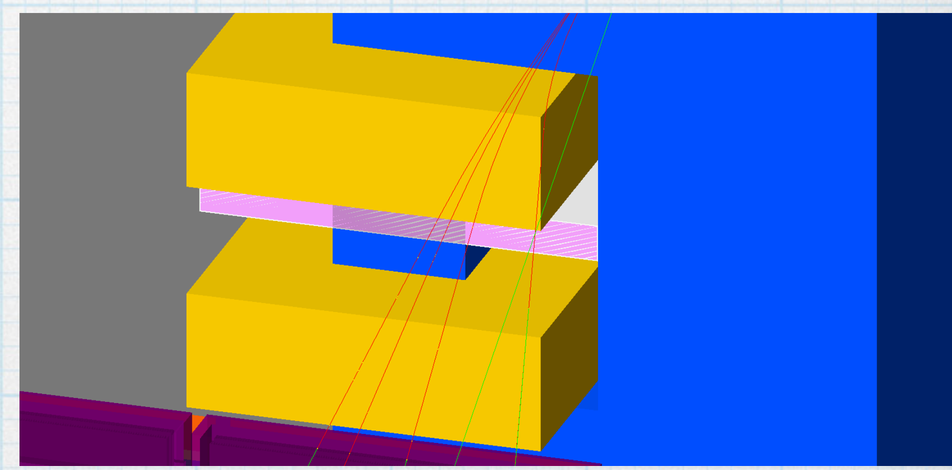

Ee = 4, 3, 2, 1 GeV







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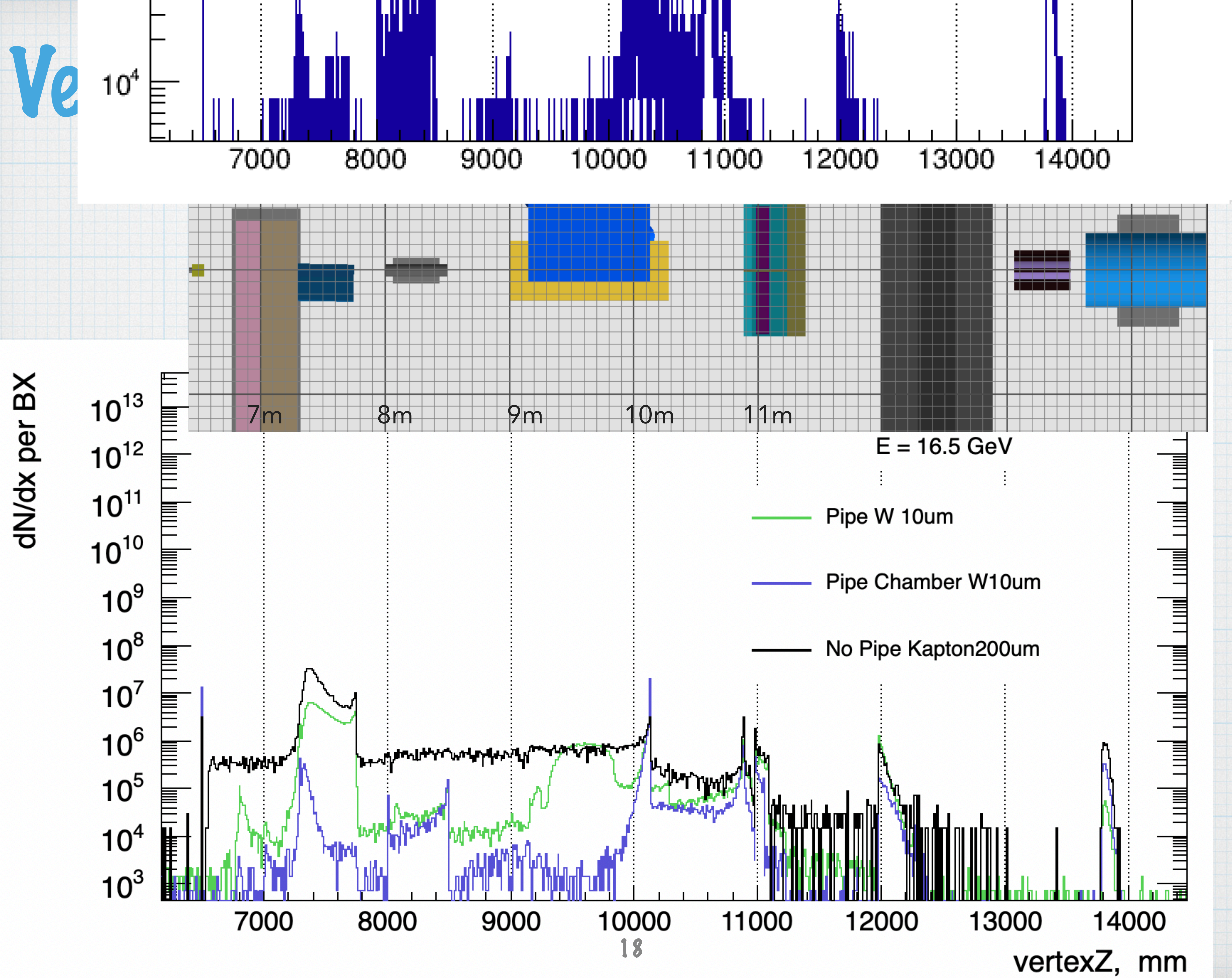
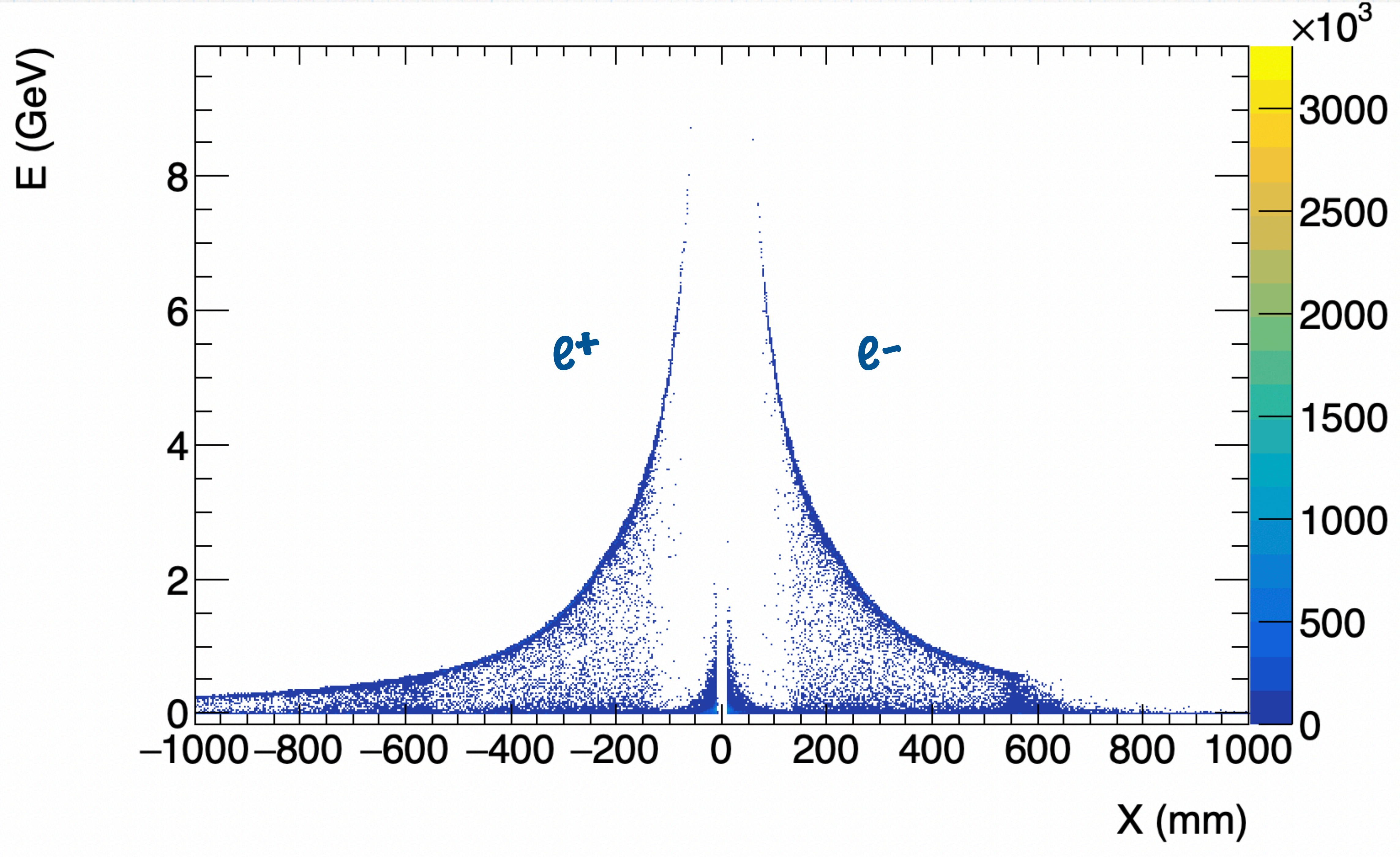


10^4
7000
8000
9000
10000
11000
12000
13000
14000
7m
8m
9m
10m
11m
E = 16.5 GeV
dN/dx per BX
10^{13}
10^{12}
10^{11}
10^{10}
10^9
10^8
10^7
10^6
10^5
10^4
10^3
Pipe W 10um
Pipe Chamber W10um
No Pipe Kapton200um
vertexZ, mm

Energy vs position

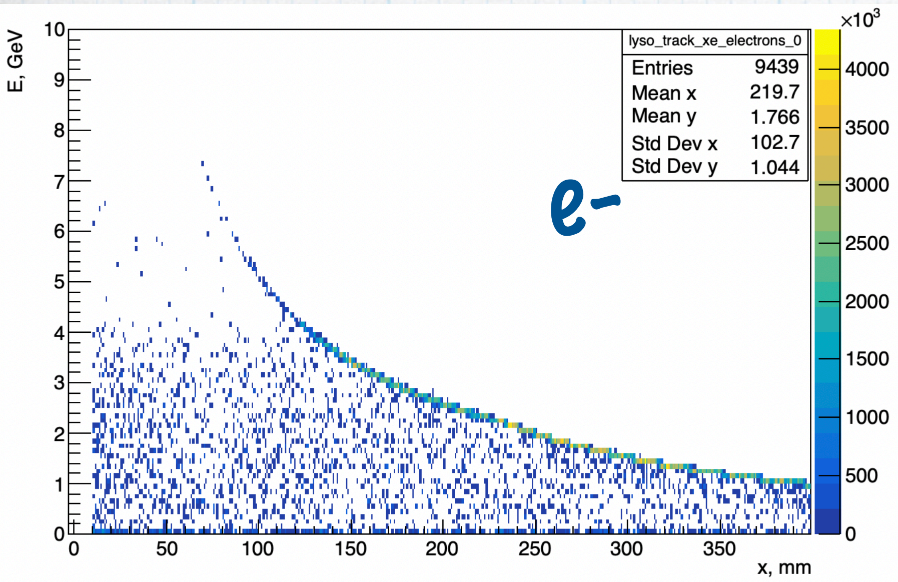


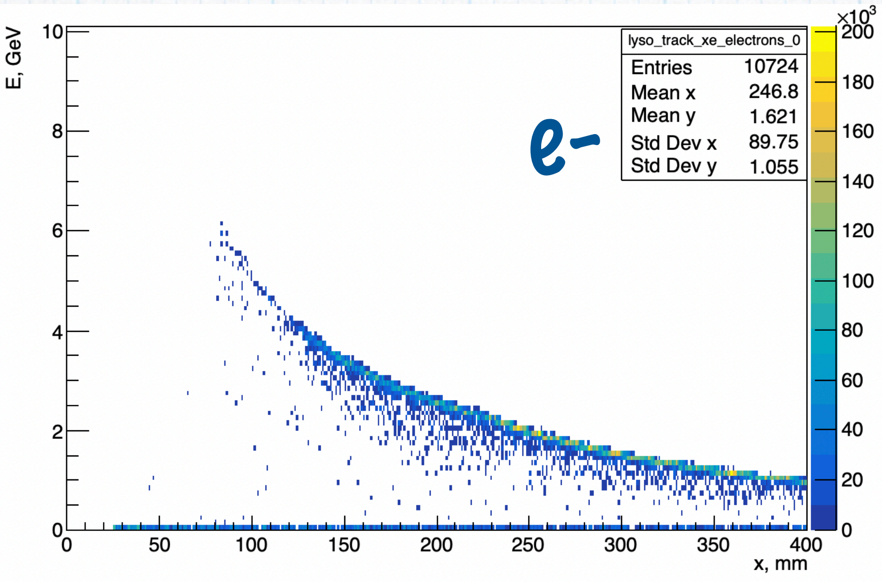
Energy vs position

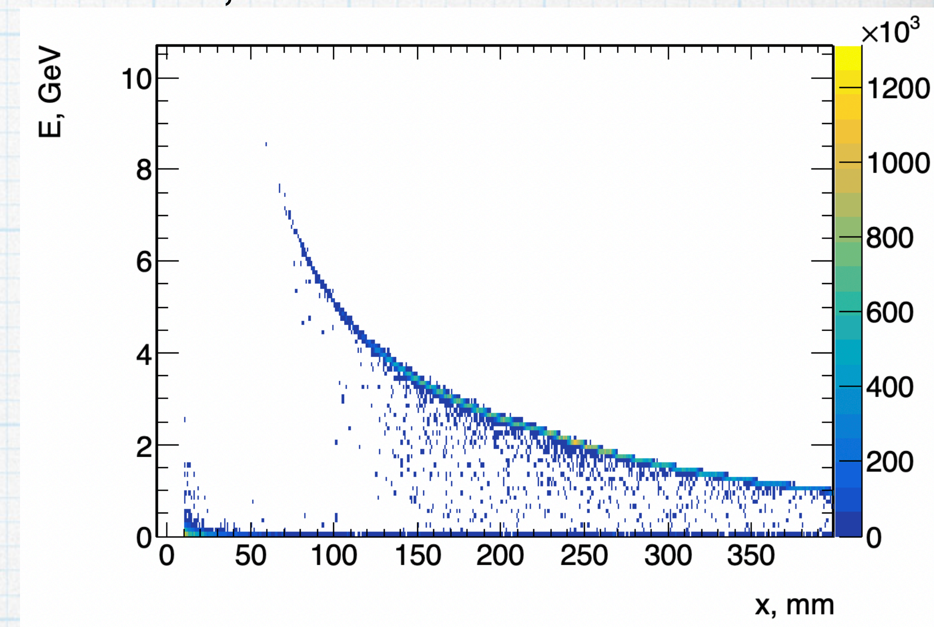
NO Beam Pipe
Kapton, 200 um

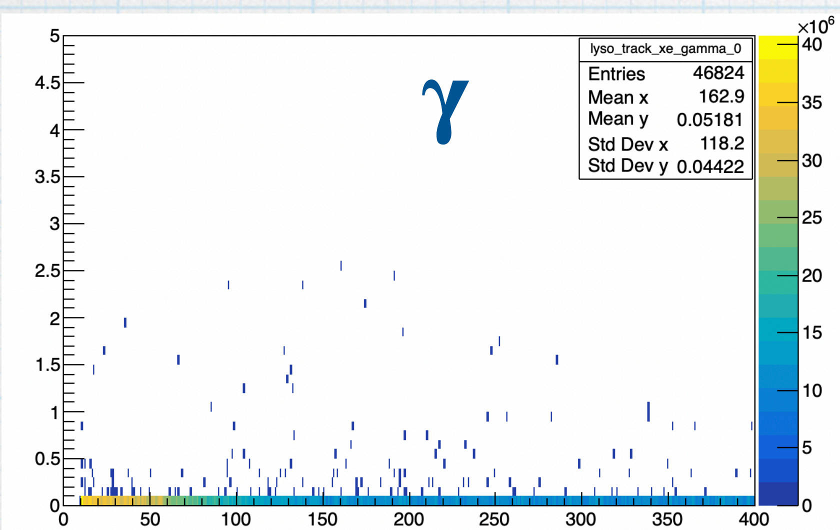
Beam Pipe 5 cm
W, 10 um

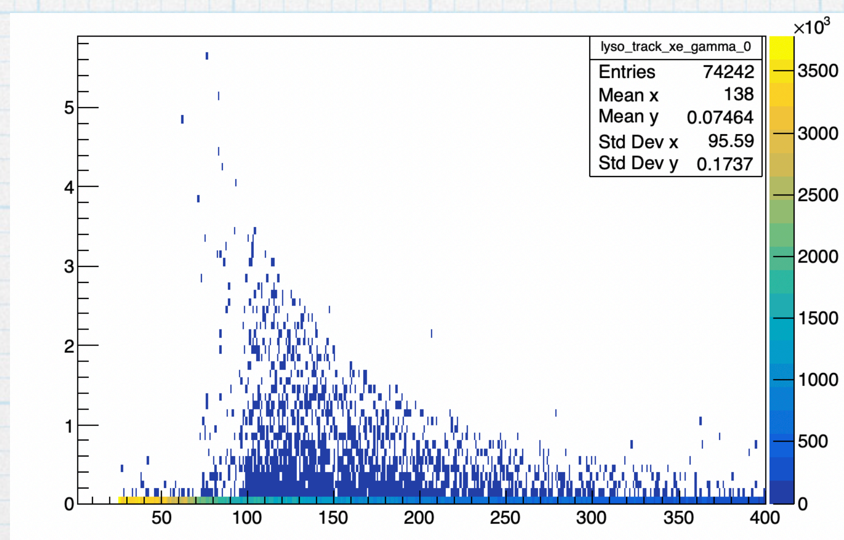
Beam Pipe 4.2 cm +chamber
W, 10 um

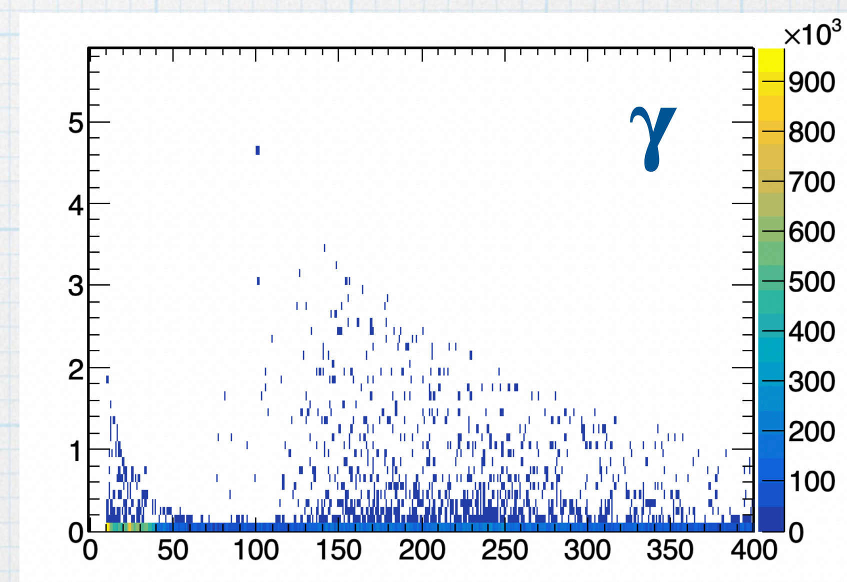








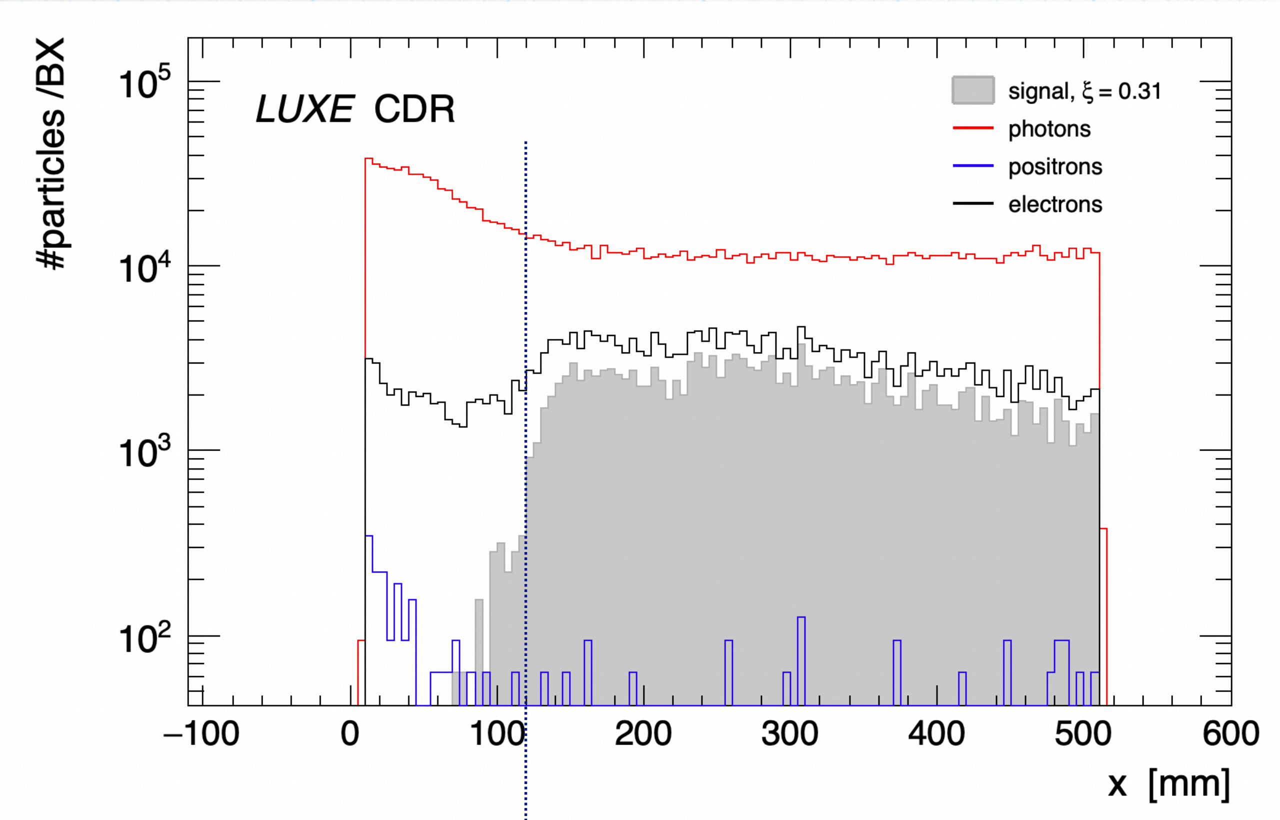




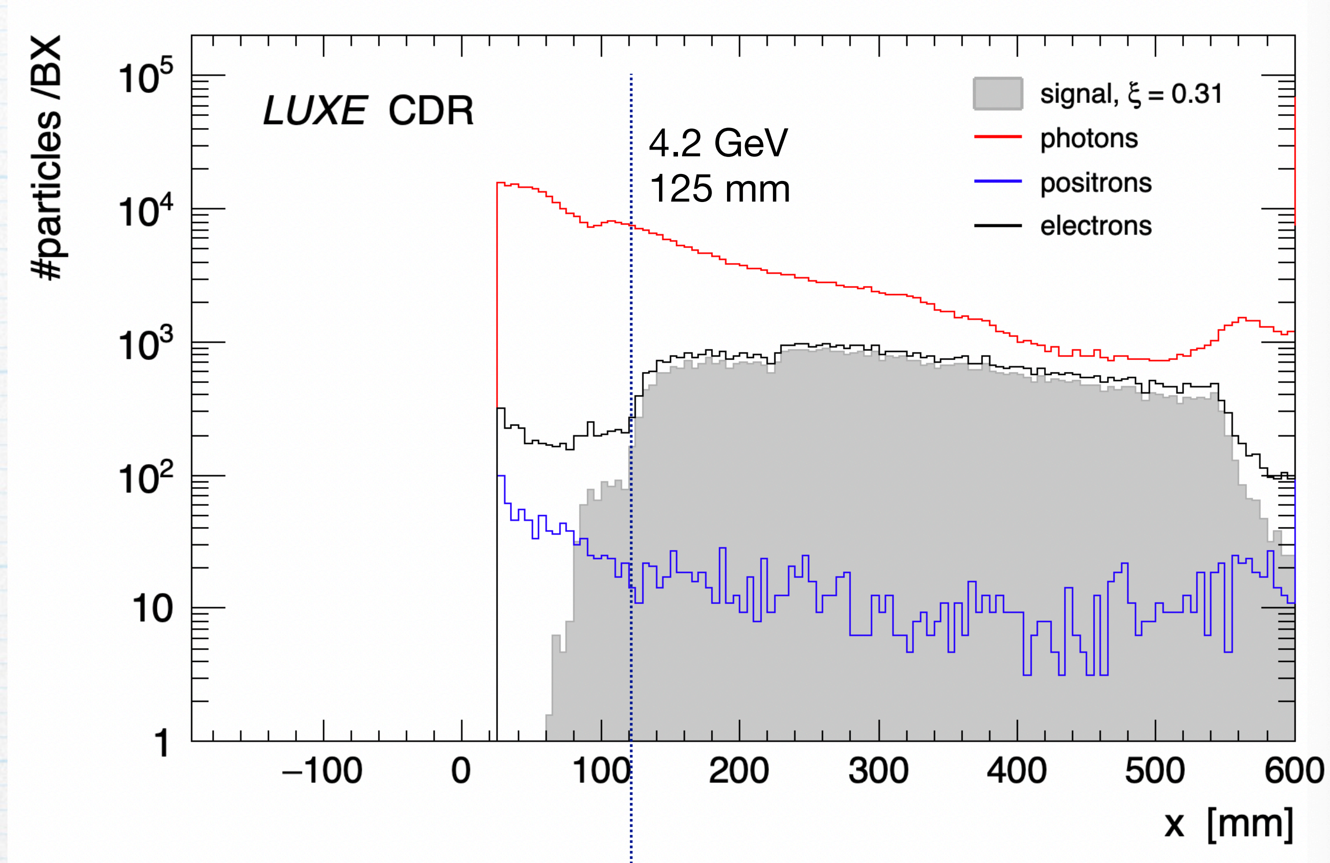
Electron Energy-position correlation is cleaner in case of beam pipe and photons distribution shows that they were produced after the electron direction was defined.

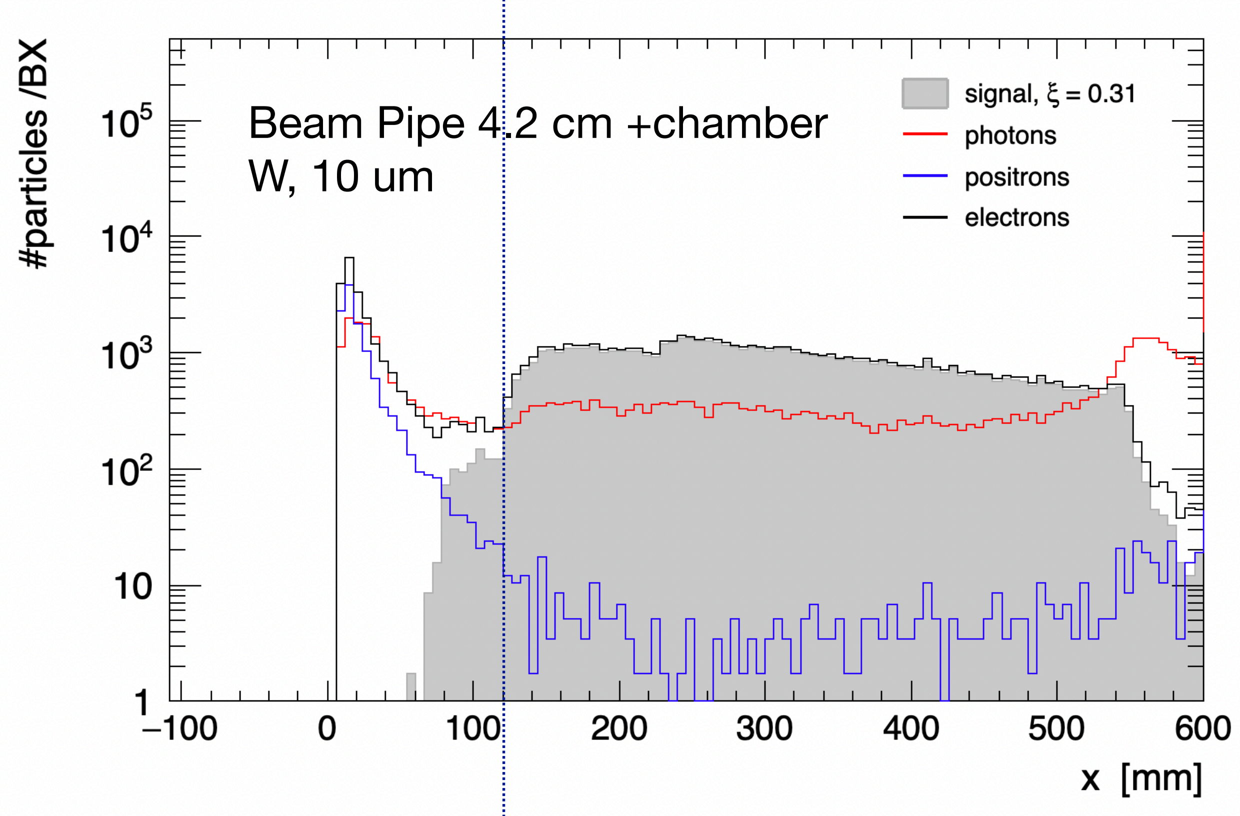
Particles in electron arm

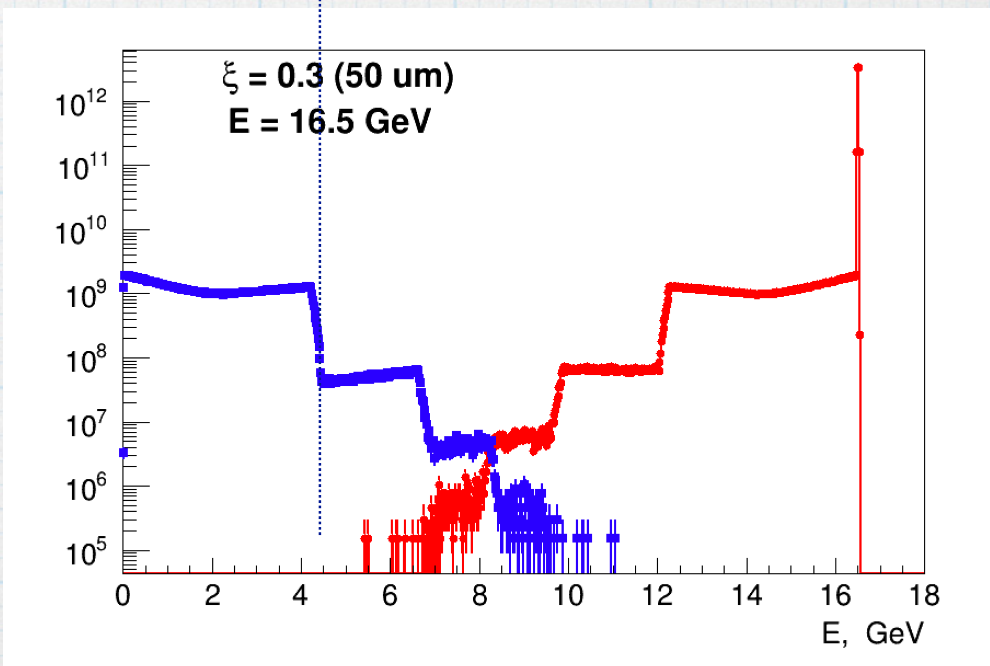
NO Beam Pipe
Kapton, 200 um

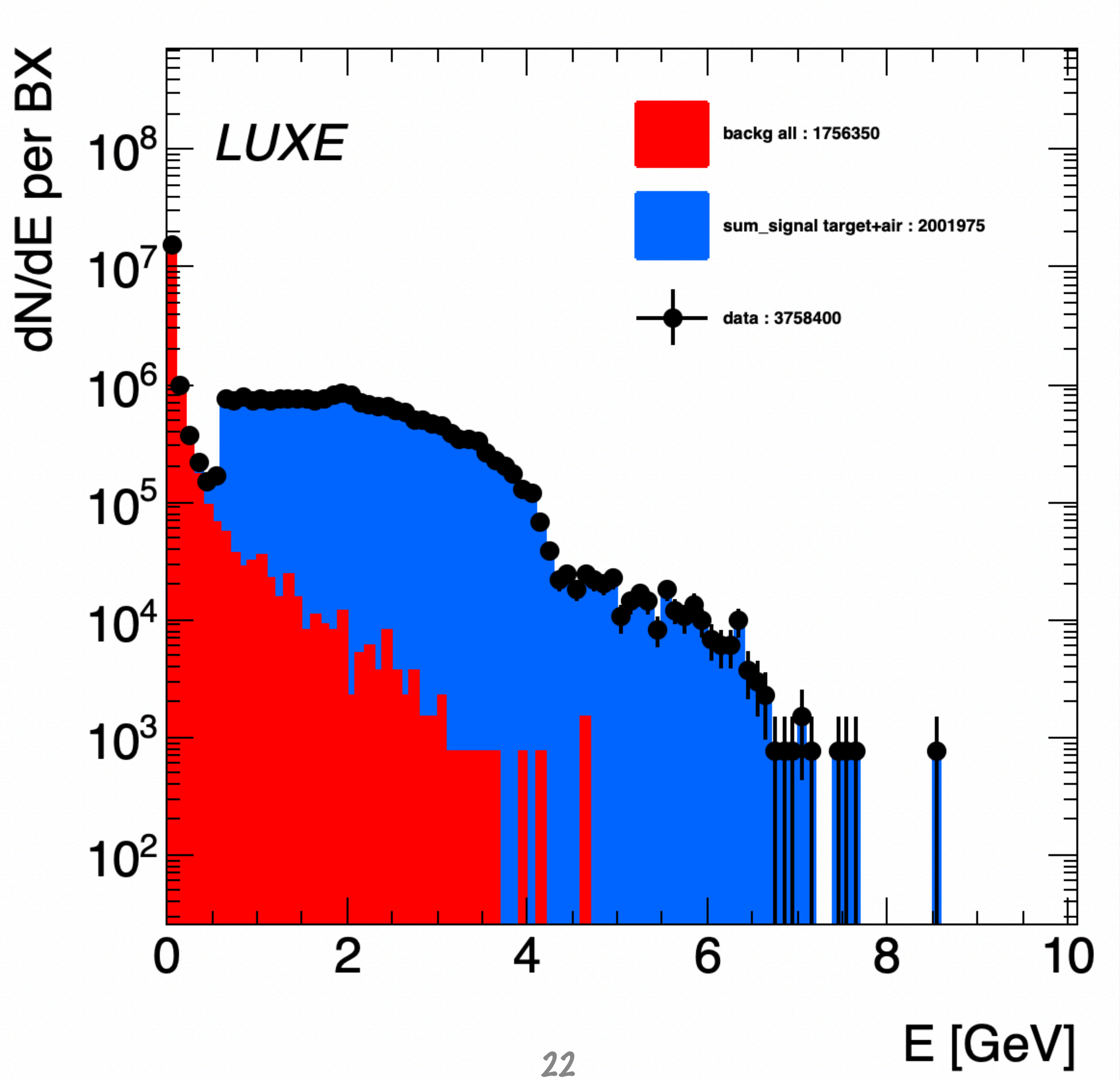


Beam Pipe 5 cm
W, 10 um








LUXE
backg all : 1756350
sum_signal target+air : 2001975
data : 3758400
dN/dE per BX
E [GeV]
0
2
4
6
8
10
10^2
10^3
10^4
10^5
10^6
10^7
10^8

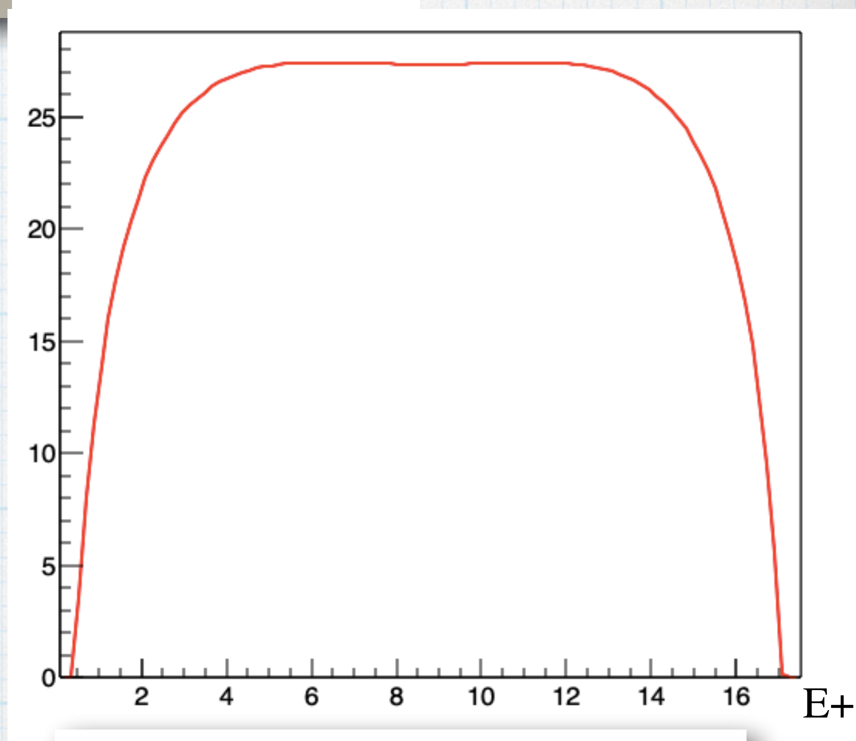
Photon spectra reconstruction using Bethe-Heitler pair spectrum

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

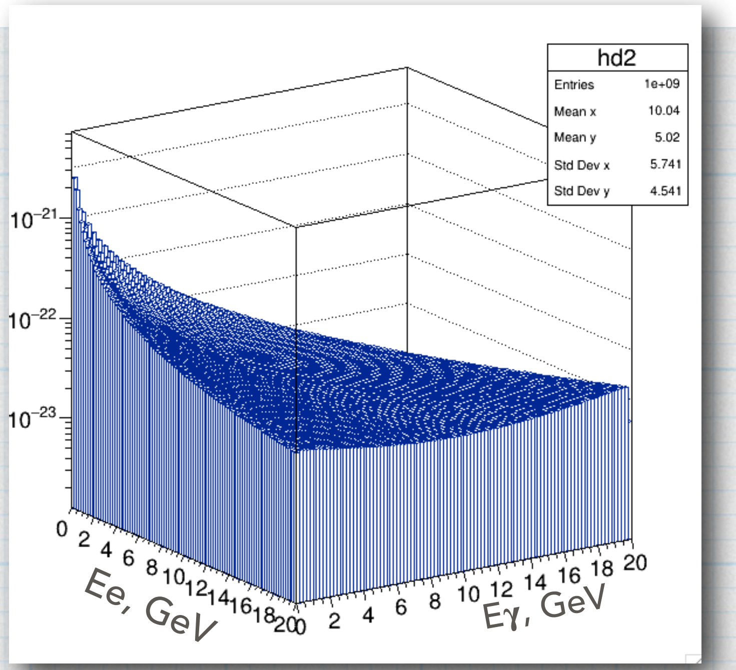
- Photon spectra $g(E\gamma)$ can be reconstructed by fitting

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

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

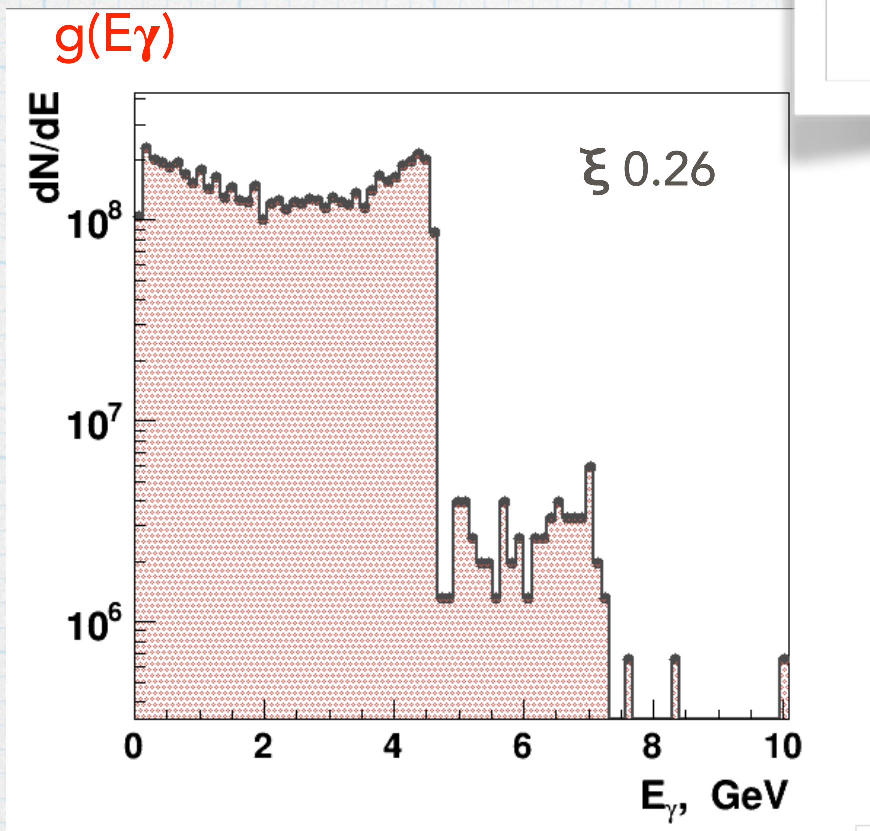
- Since $\sigma(E\gamma, Ee)$ depends on number of scatters N_a defined by the thickness of the target the approach can be tested by using the thickness as fit parameter

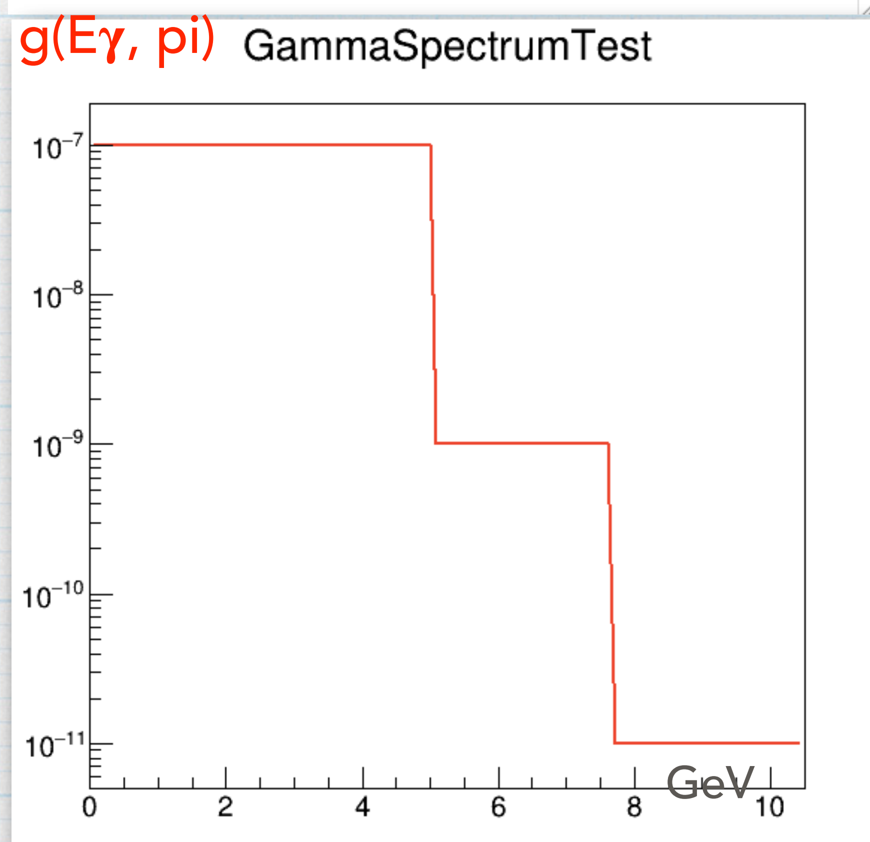
- Used Bethe-Heitler class from Geant4, with corrections and extended for various effects (the screening, the pair creation in the field of atomic electrons, correction to the Born approximation, the LPM suppression mechanism, etc.) to calculate differential cross-section



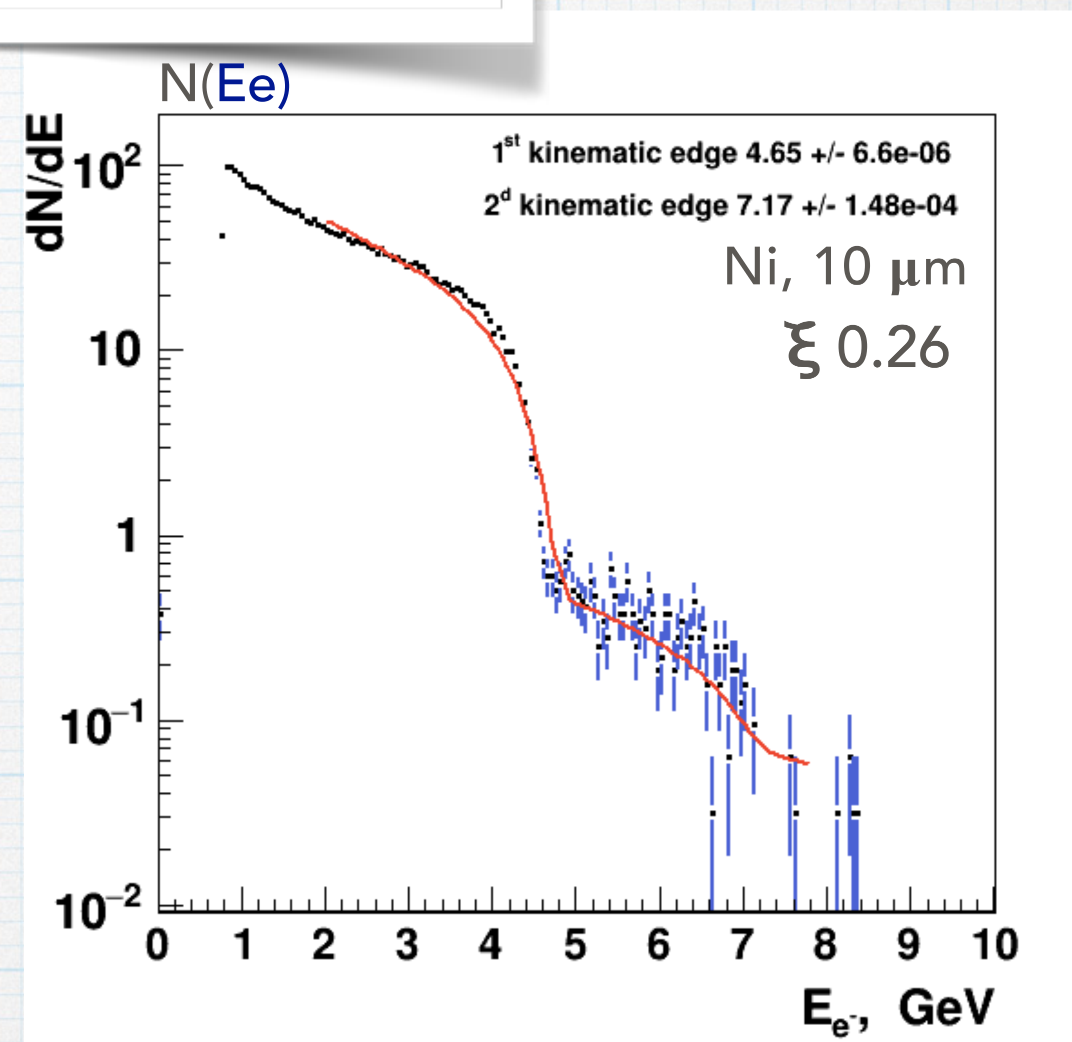
Kinematic edges with accurate pair spectrum

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





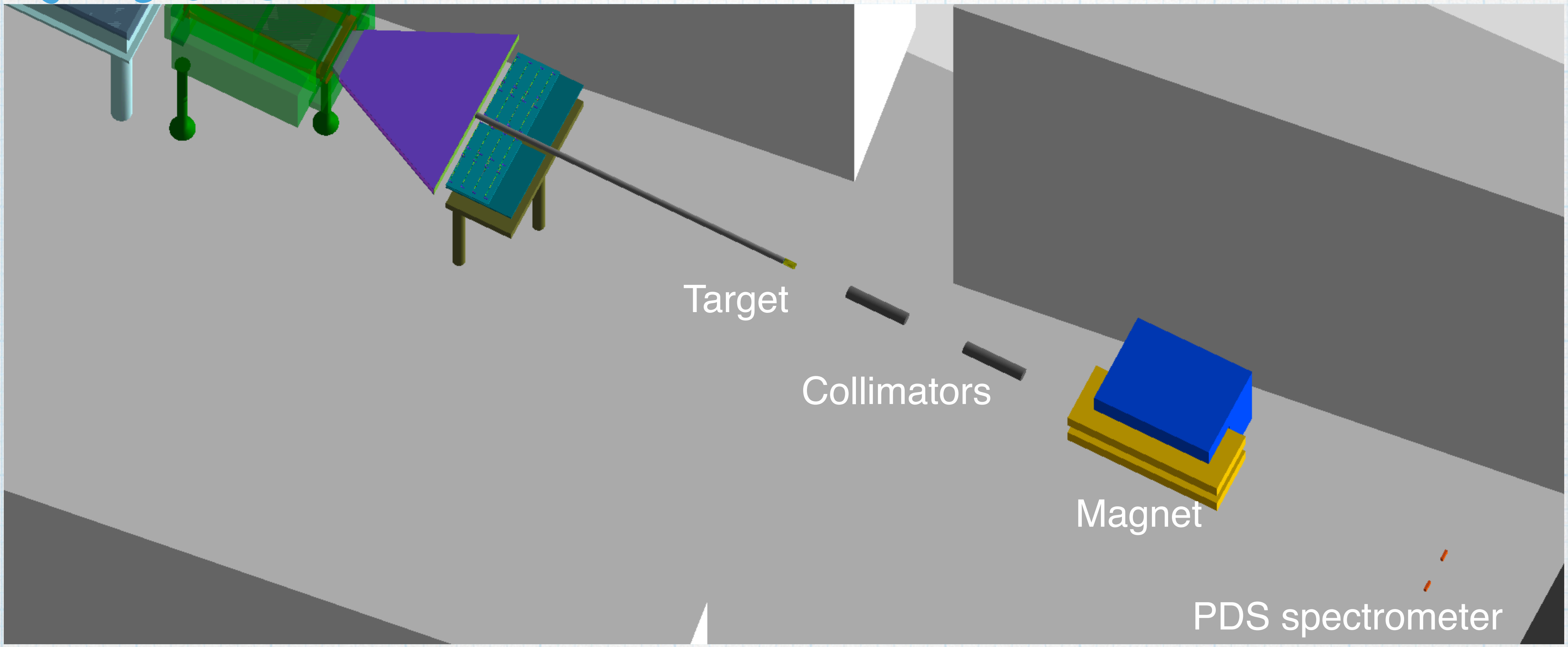
The single-particle spectrum obtained in GEANT4 is compared to a **model spectrum** calculated by convolving the trial **photon spectrum** with the **Bethe-Heitler cross section**



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

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

Intro



Tasks at hand:

Direct electron-Beam Laser interaction
$e + n\omega \rightarrow e + \gamma$

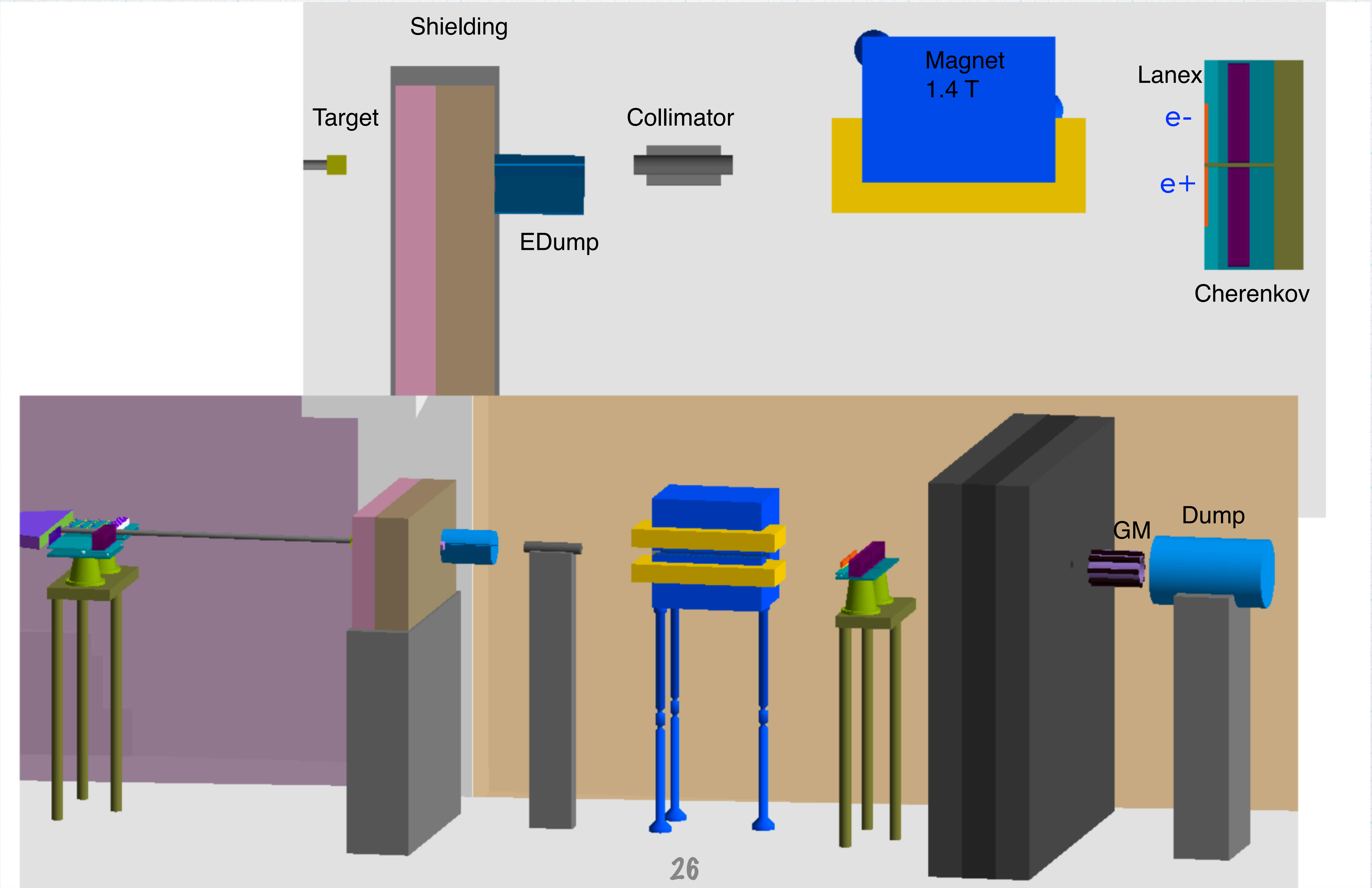
I measure HICS energy spectrum.

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

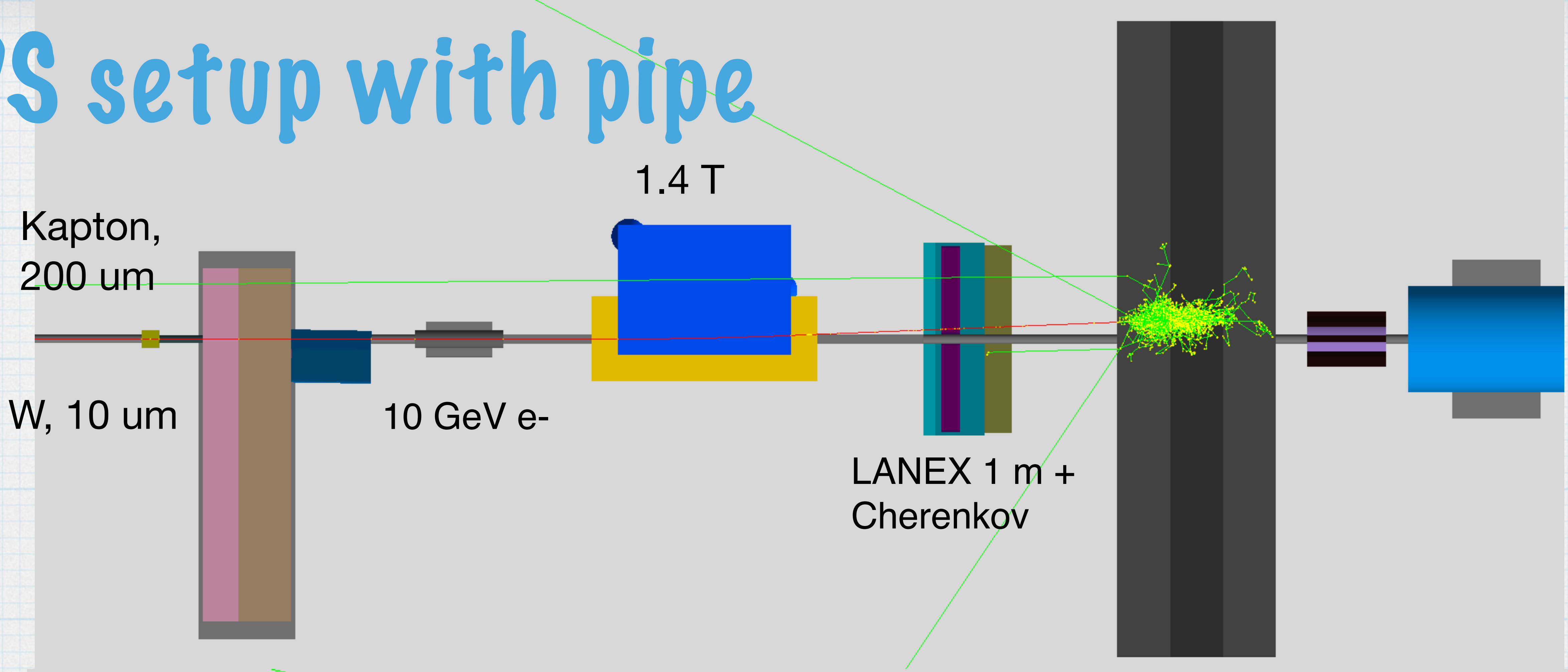
II measure absolute number of photons on event-by-event basis.

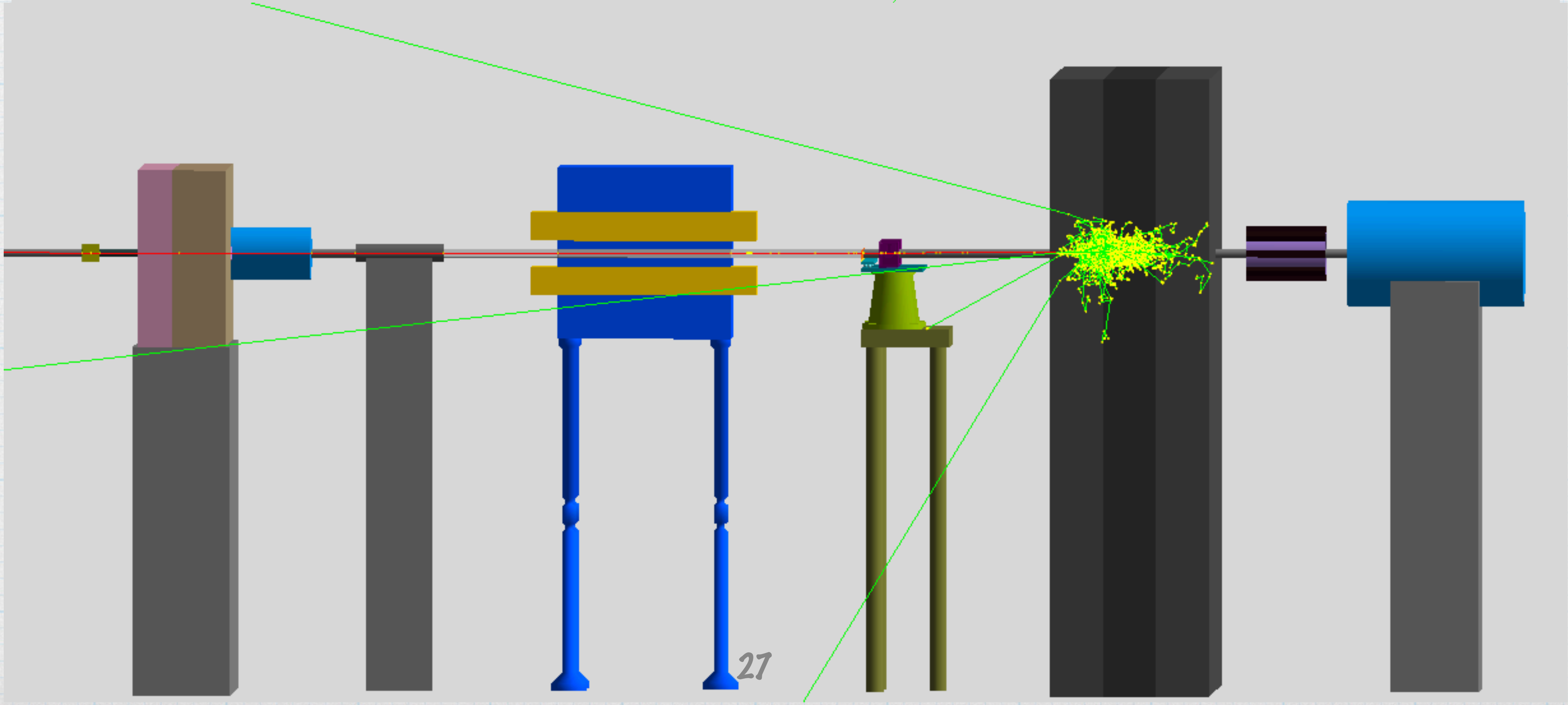
- Spectra normalisation;
- Be sensitive to angular distribution of HICS photons (if possible)

Forward detector system w/o beam pipe



FDS setup with pipe





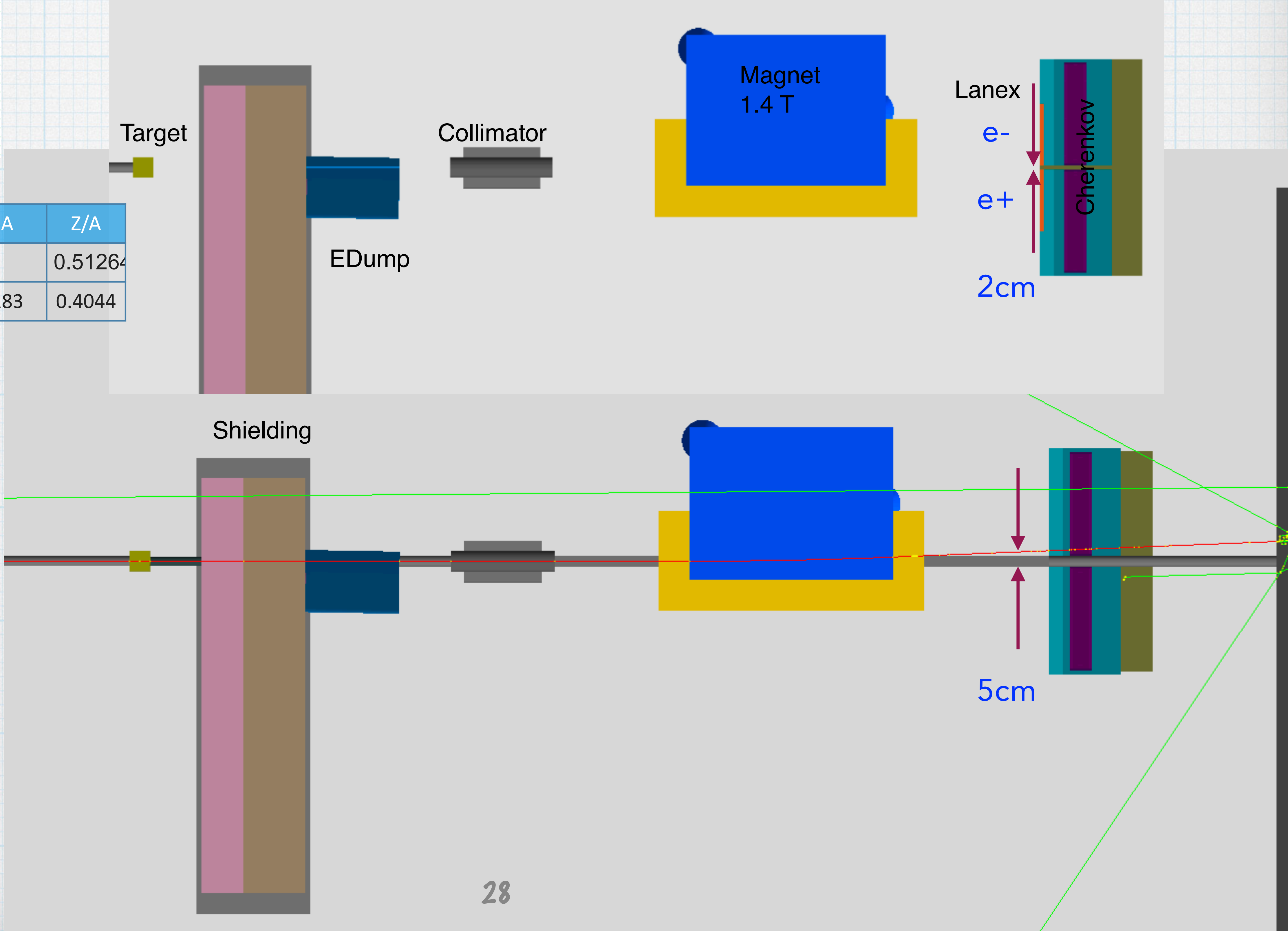
Forward detector system with & w/o beam pipe

Kapton :Polyimide film $[C_{22}H_{10}N_2O_5]_n$

Composition:

Elem	Z	Atomic frac*	Weight frac
H	1	10.000000	0.026362
C	6	22.001366	0.691133
N	7	2.000071	0.073270
O	8	5.000195	0.209235

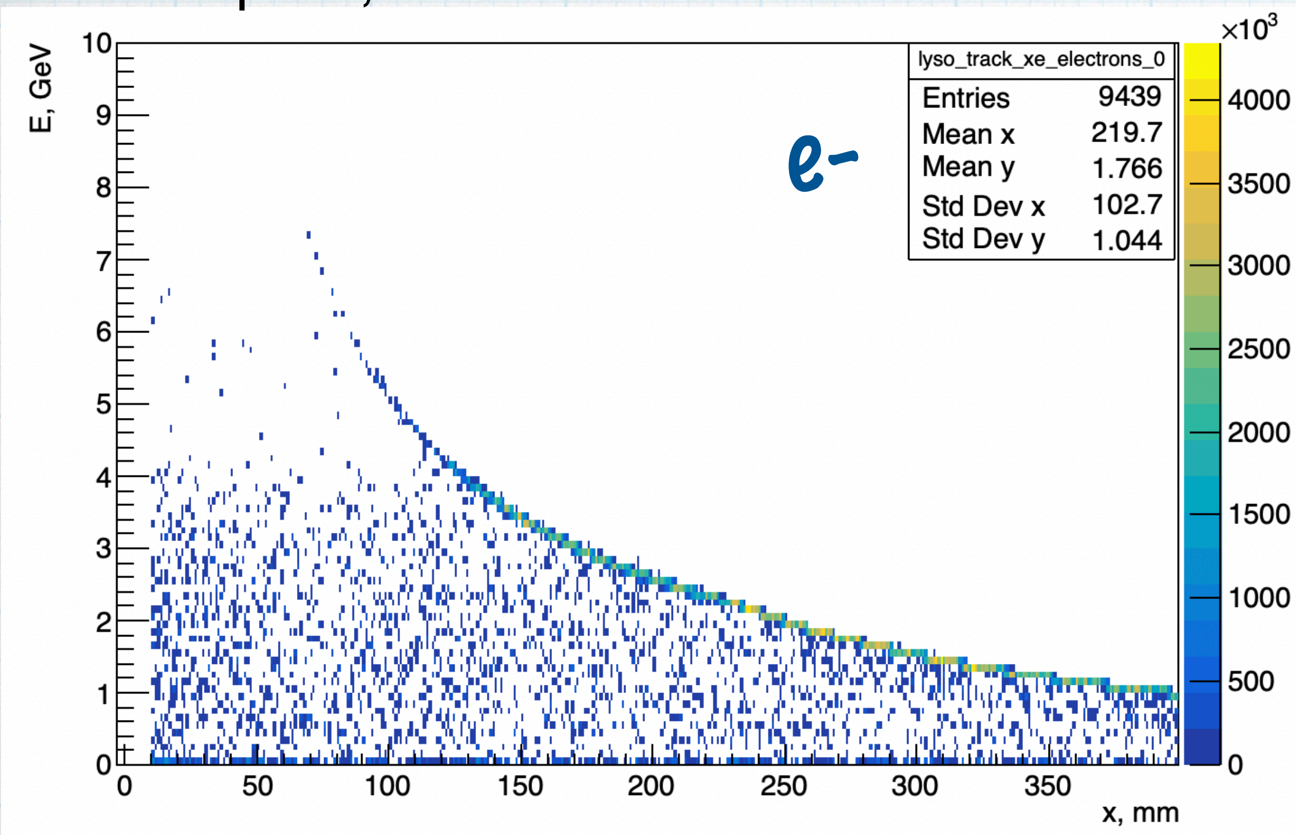
Material	X0,(cm)	Z	A	Z/A
Kapton	28.57			0.51264
Tungsten	0.35	74	183	0.4044

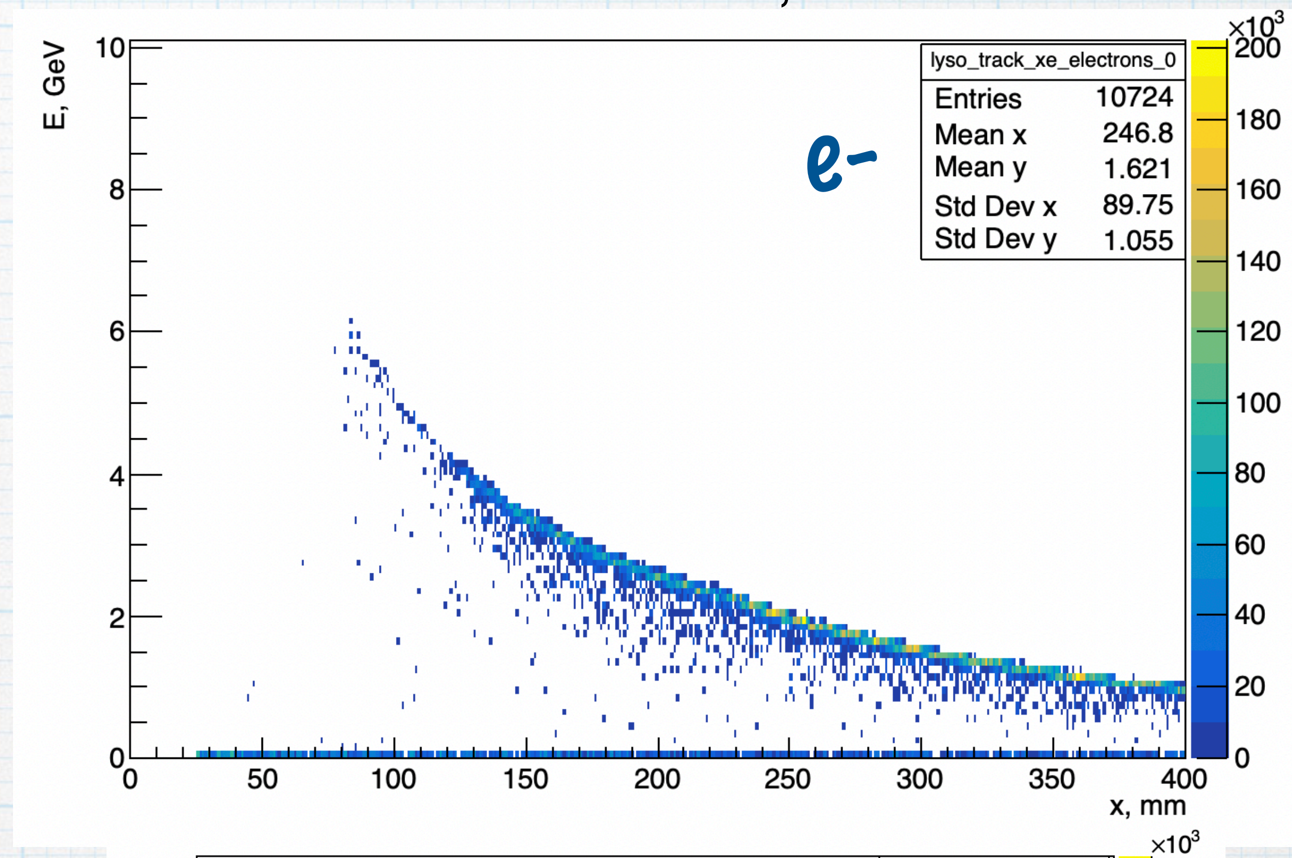


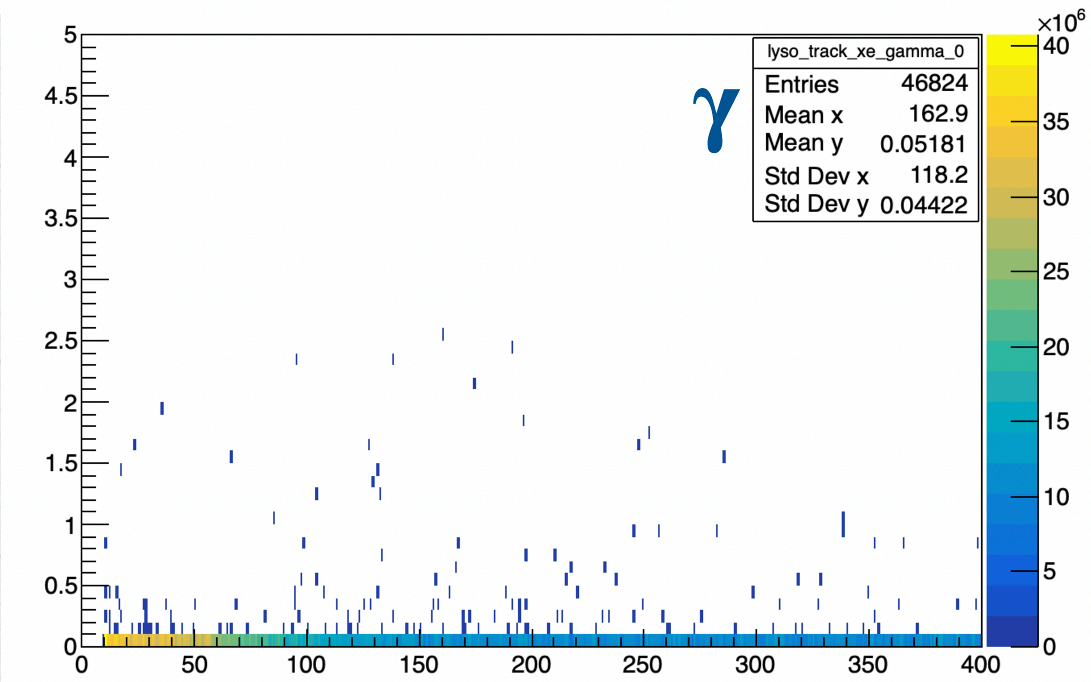
Energy vs position

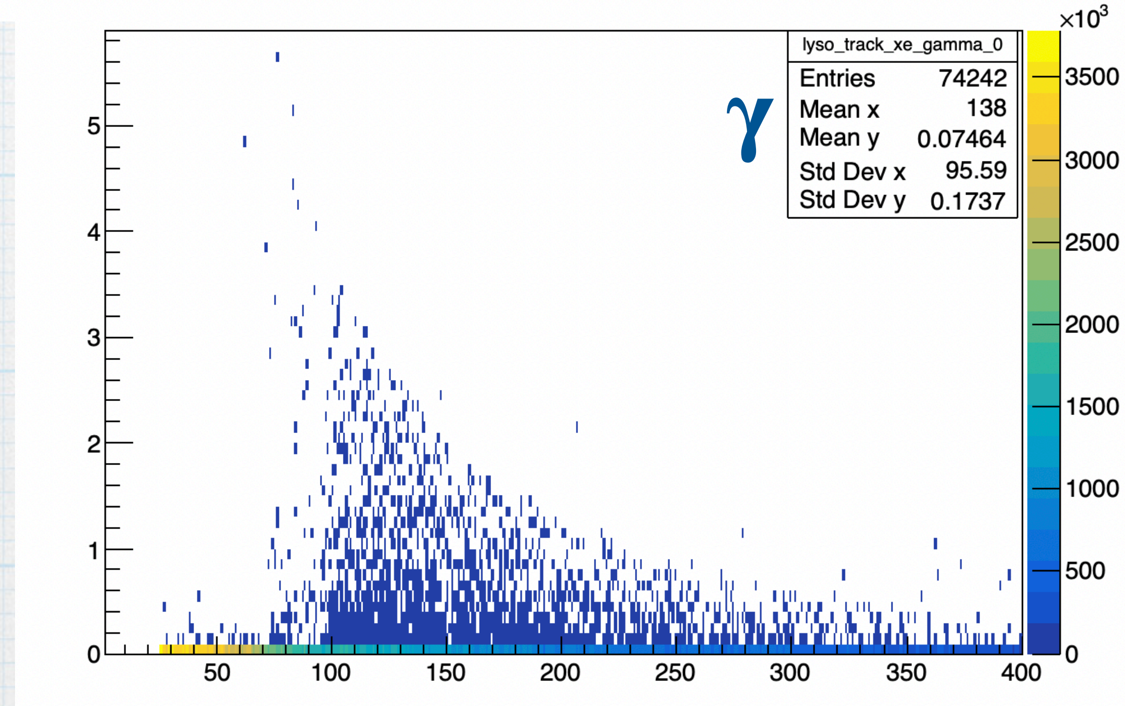
NO Beam Pipe
Kapton, 200 um

Beam Pipe 5 cm
W, 10 um







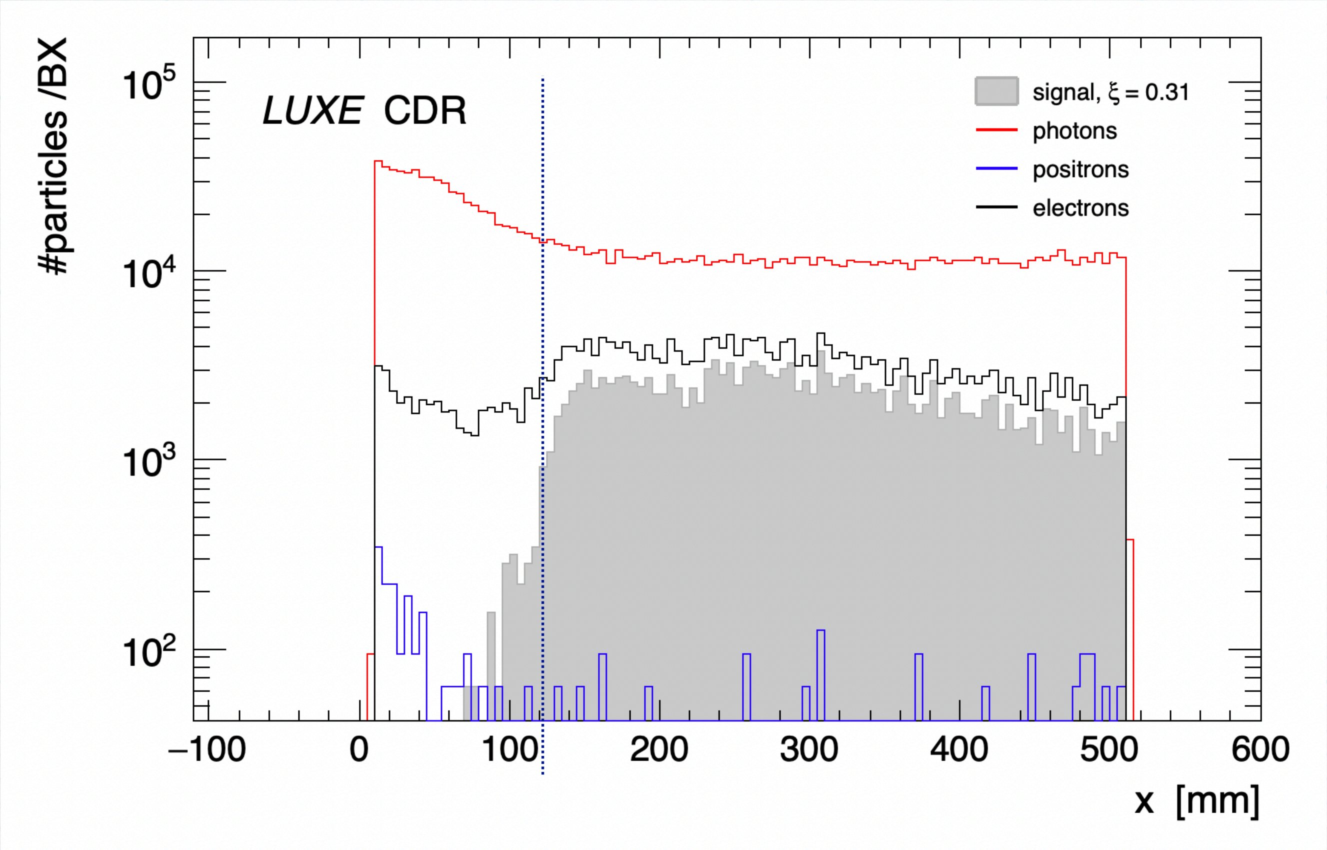


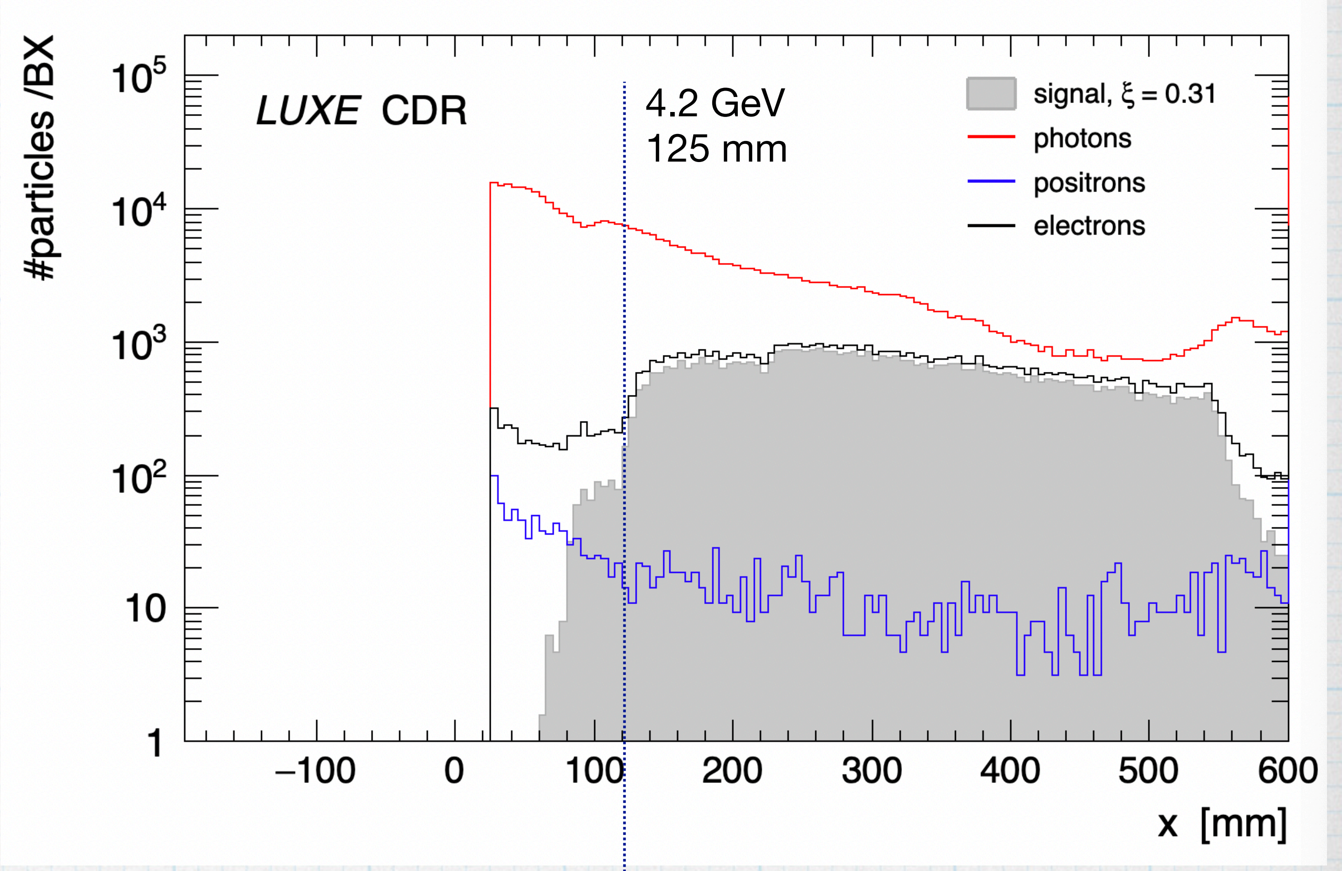
Electron Energy-position correlation is cleaner in case of beam pipe and photons distribution shows that they were produced after the electron direction was defined.

Particles in electron arm

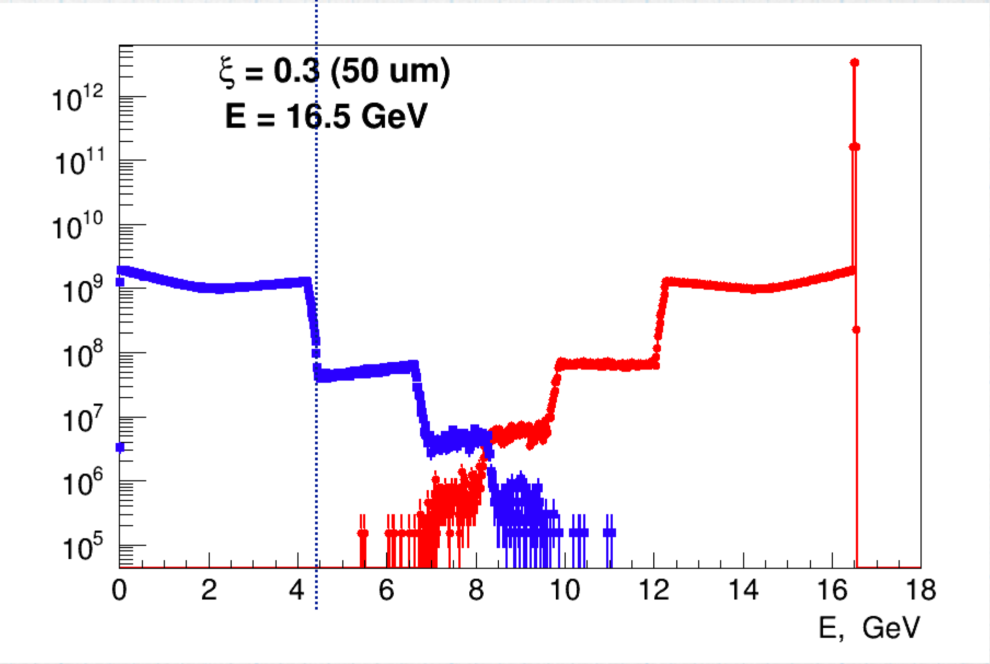
NO Beam Pipe
Kapton, 200 um

Beam Pipe 5 cm
W, 10 um





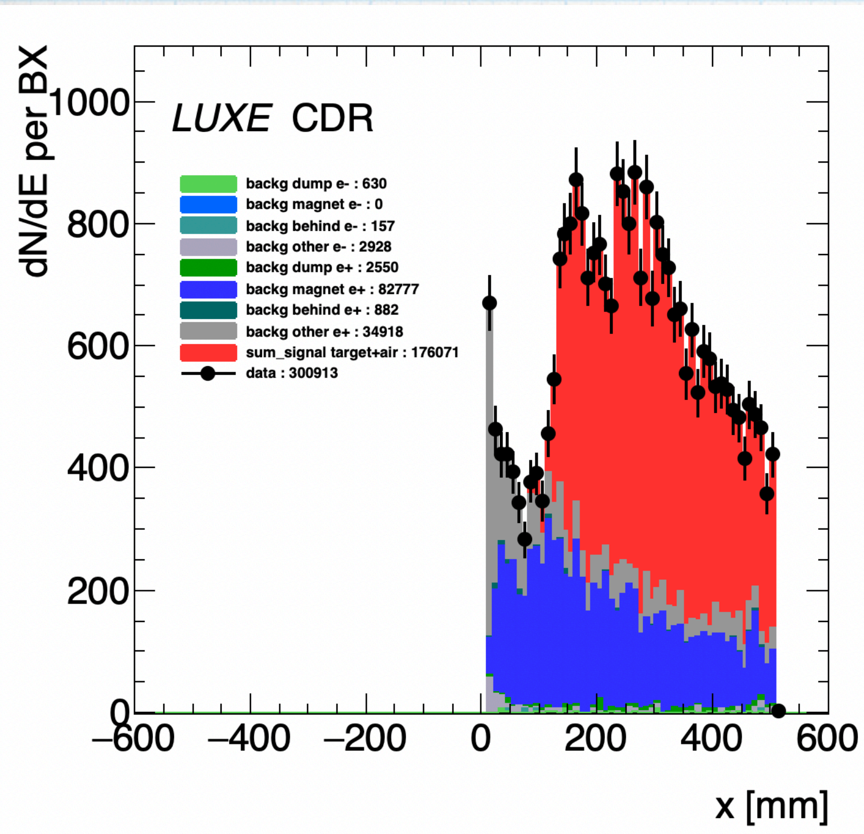
Material	X0,(cm)	Thickness	Fraction X0
Air	3.04E+04	350	1.15 %
Kapton	28.57	2.00E-02	0.07 %
Tungsten	0.35	1.00E-03	0.3%

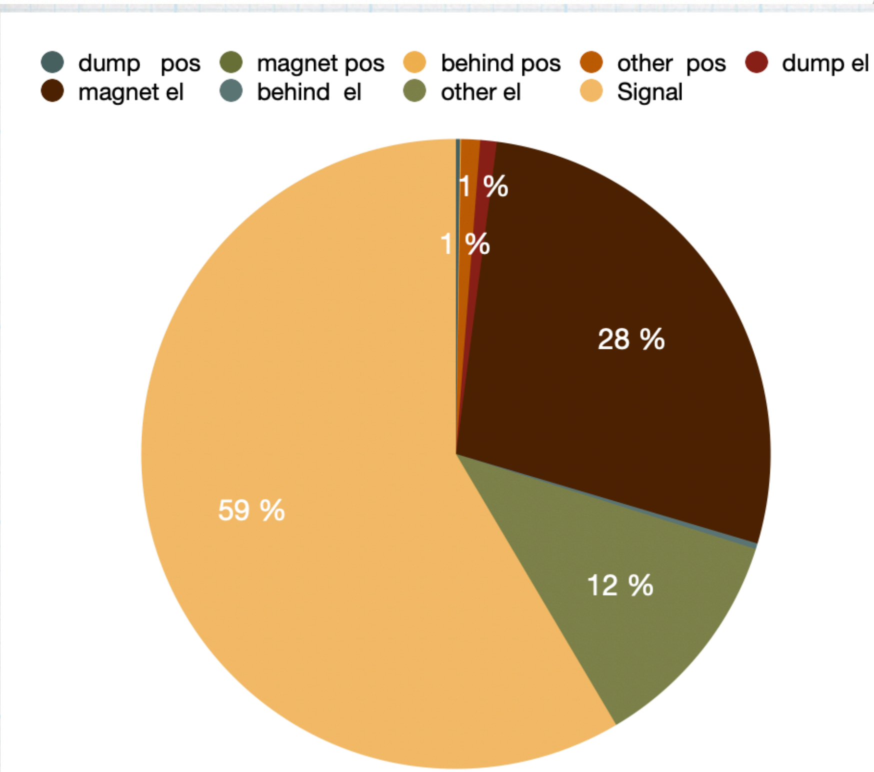


The first kinematic edge at 4.2GeV is clearly better observed in detector for the case with the pipe.

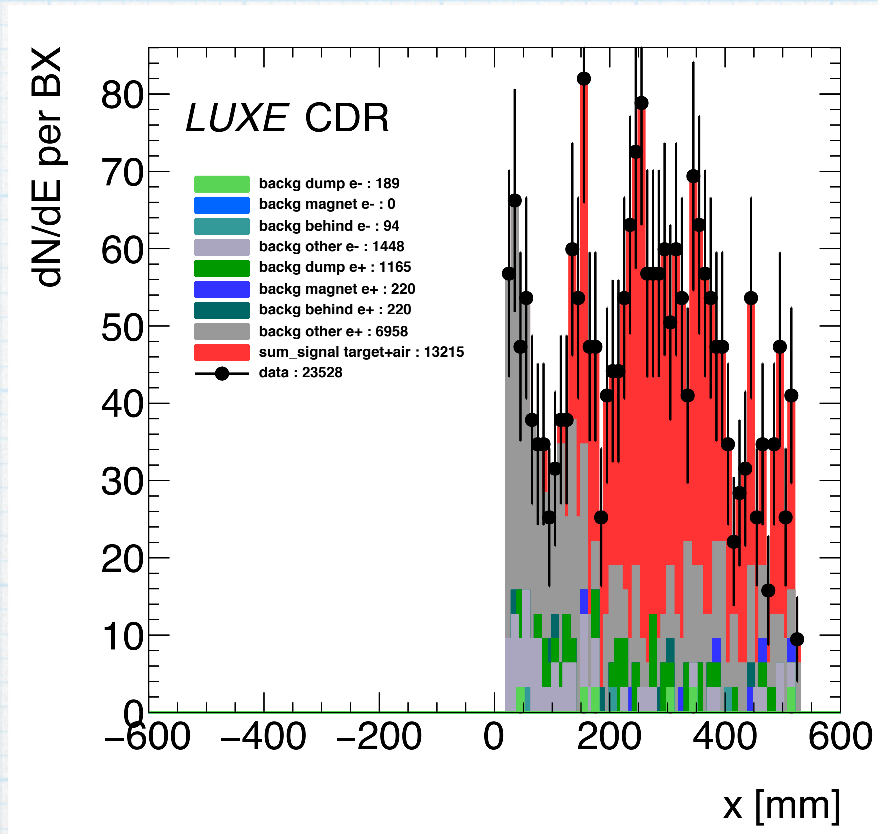
* S/B ratio: Electron arm of Lanex Spectrometer, x-distributions

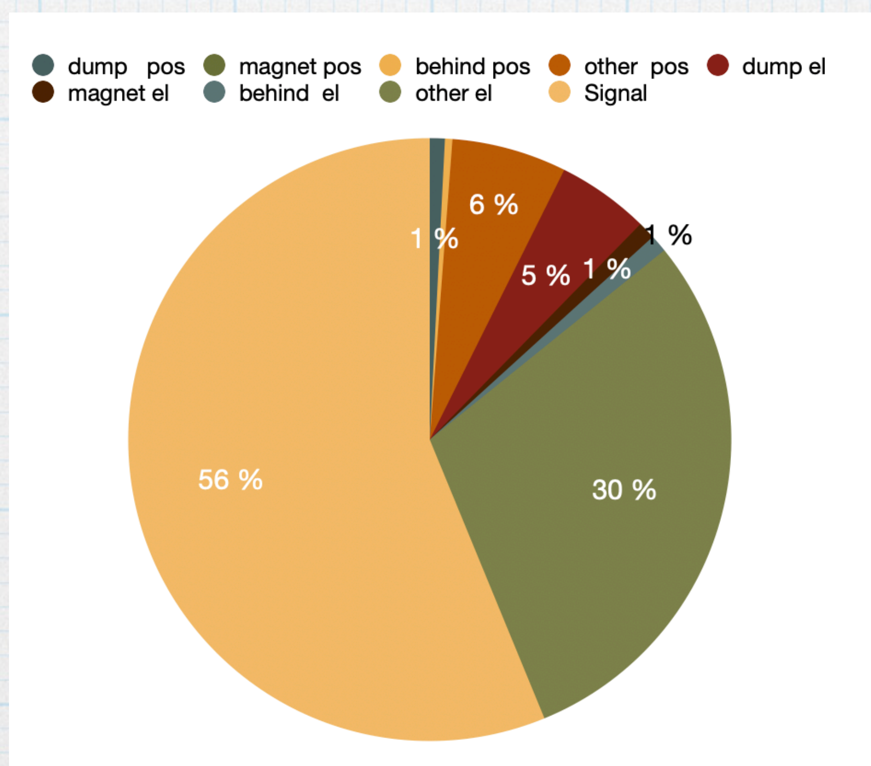
NO Beam Pipe
Kapton, 200 um



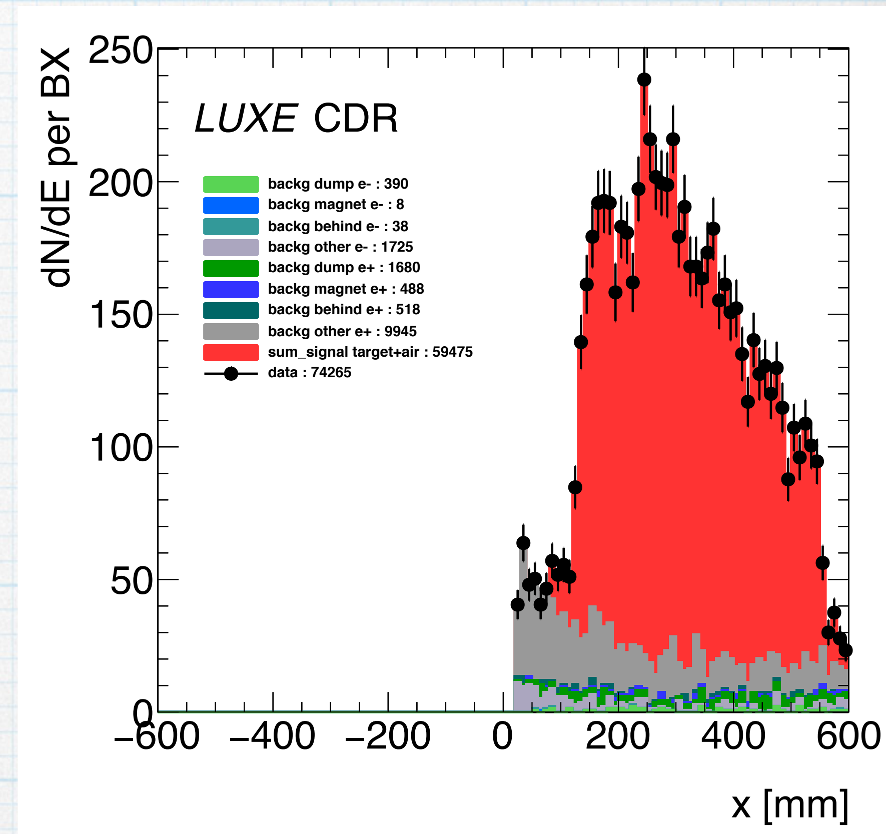


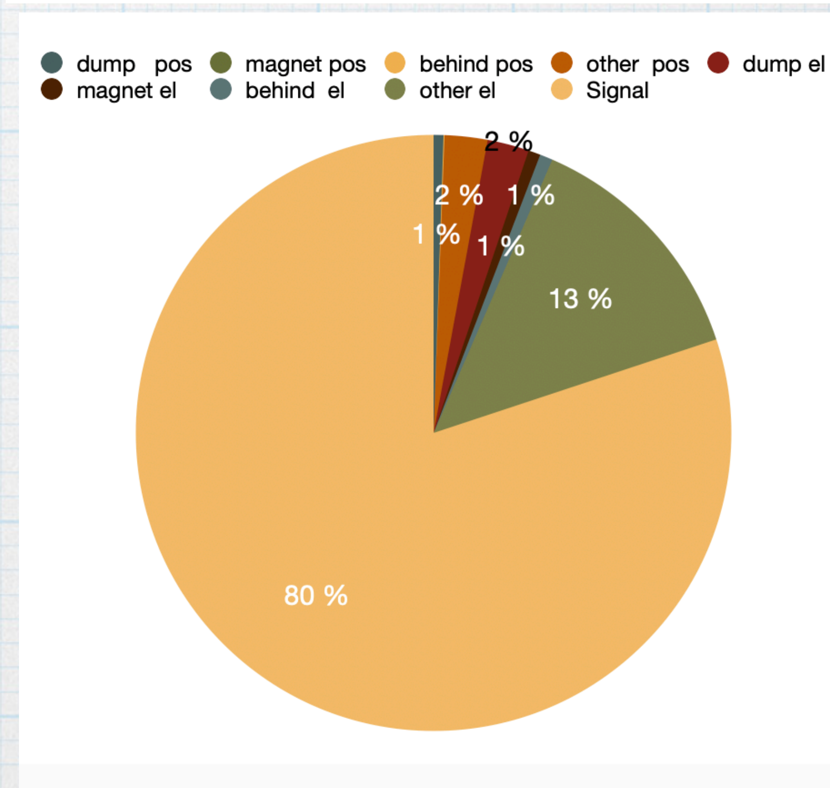
Beam Pipe 5 cm
Kapton, 200 um





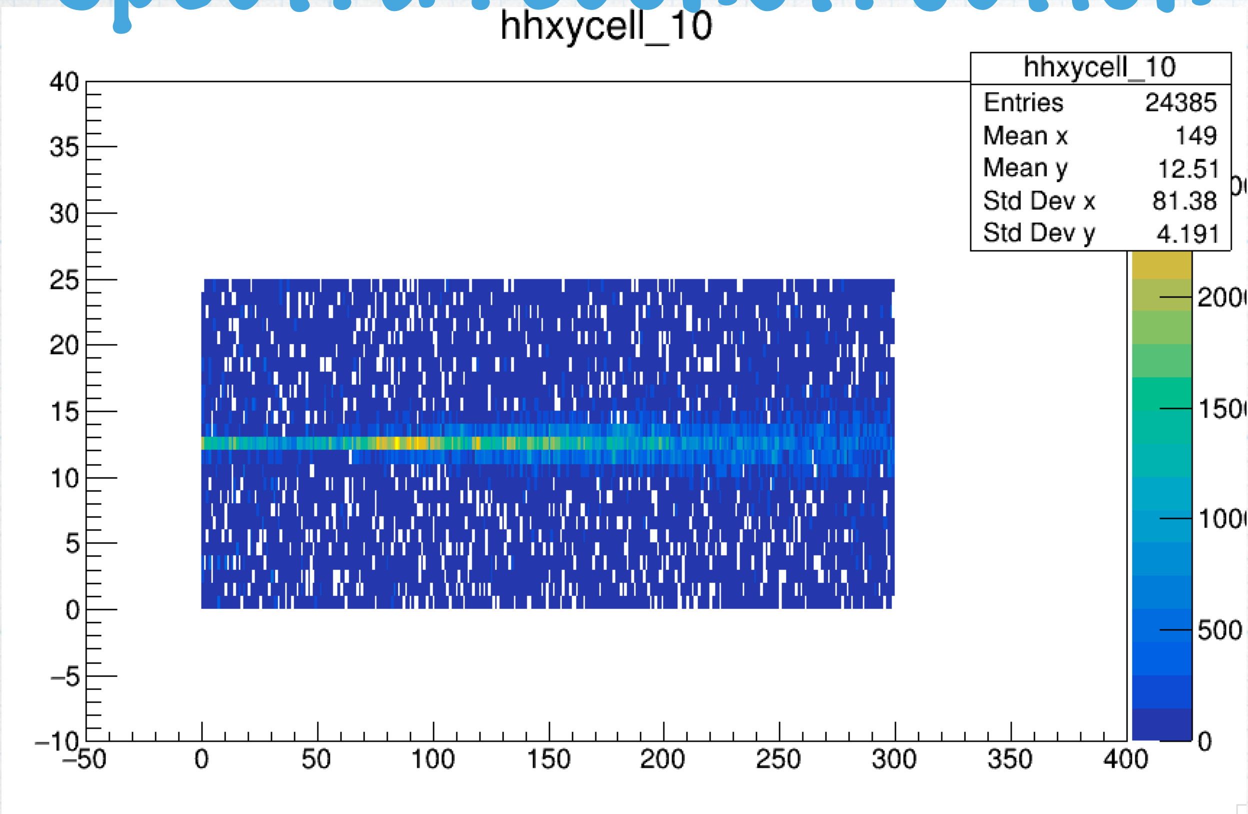
Beam Pipe 5 cm
W, 10 um

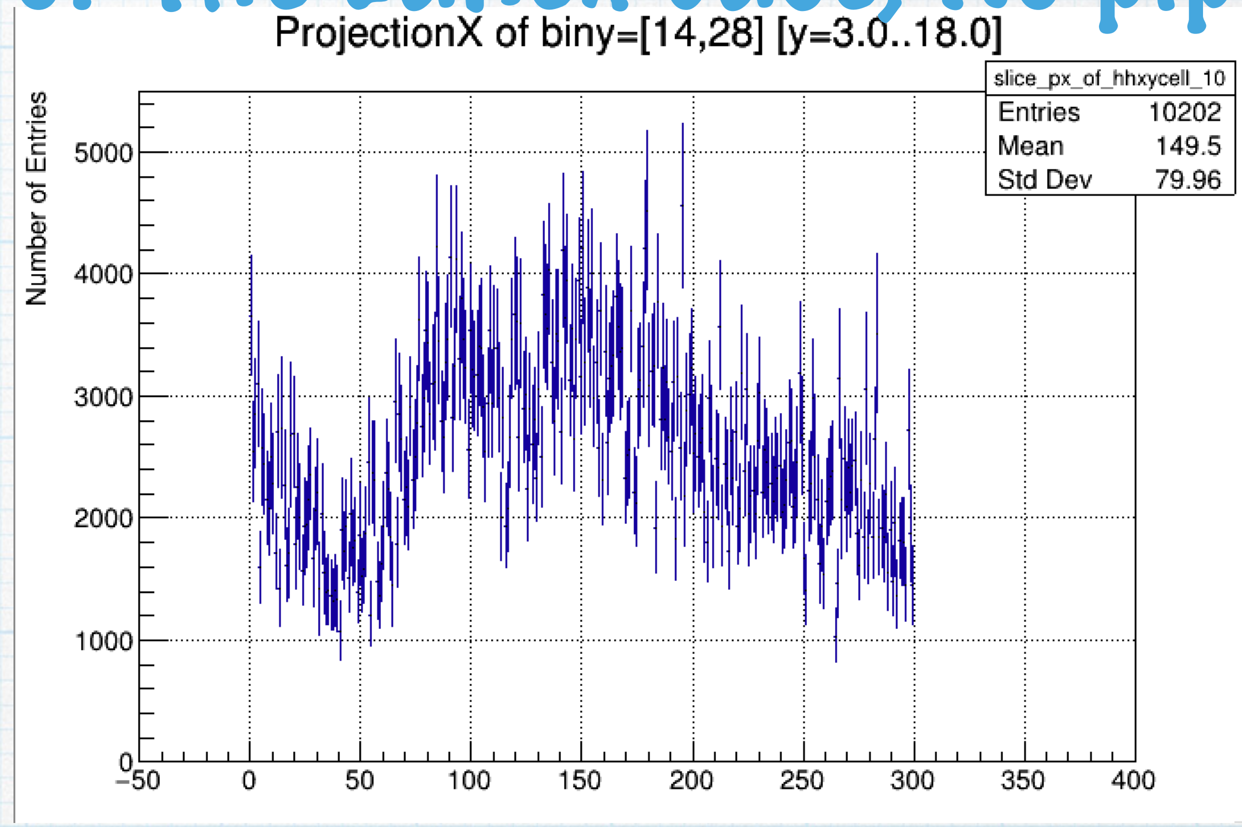


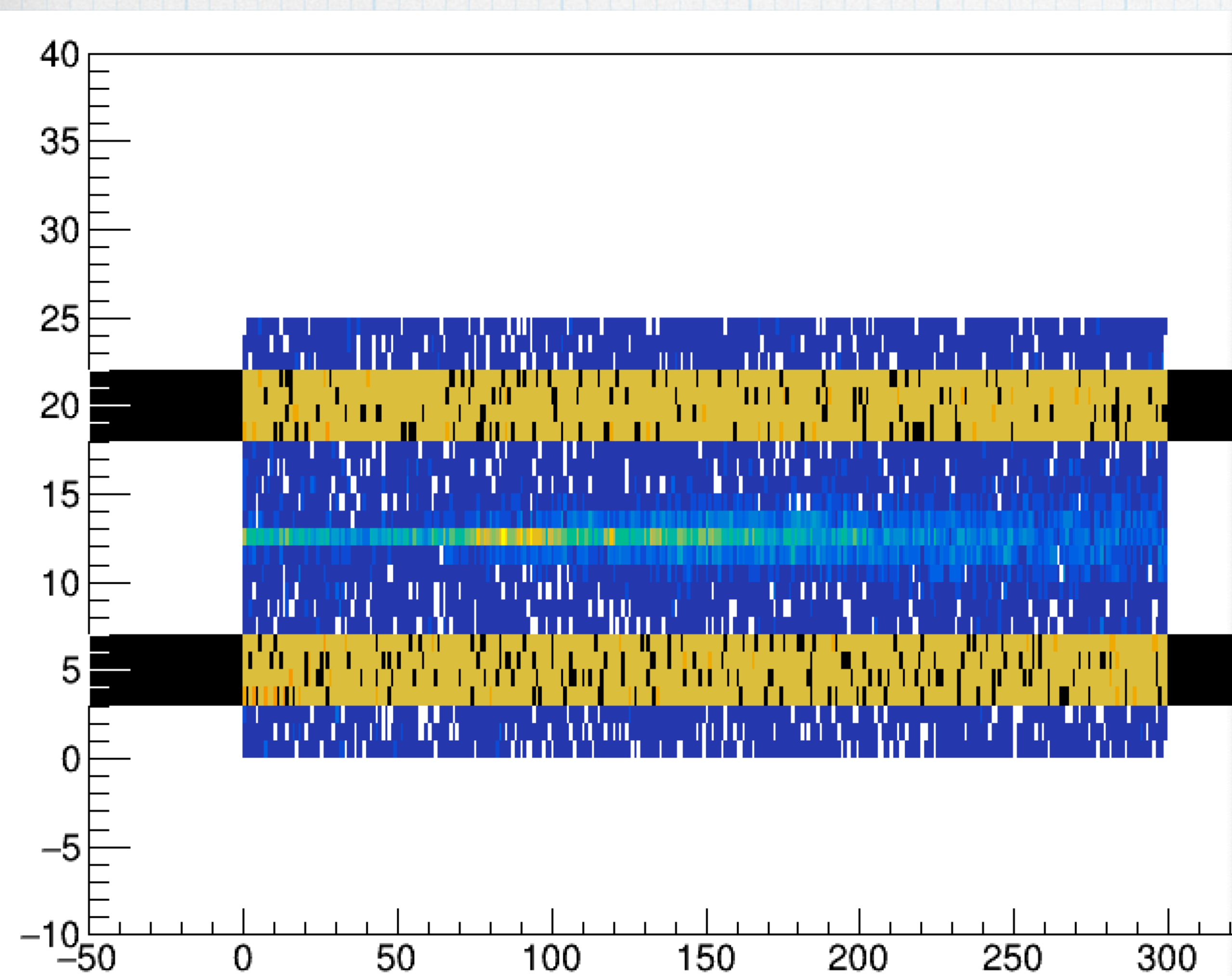


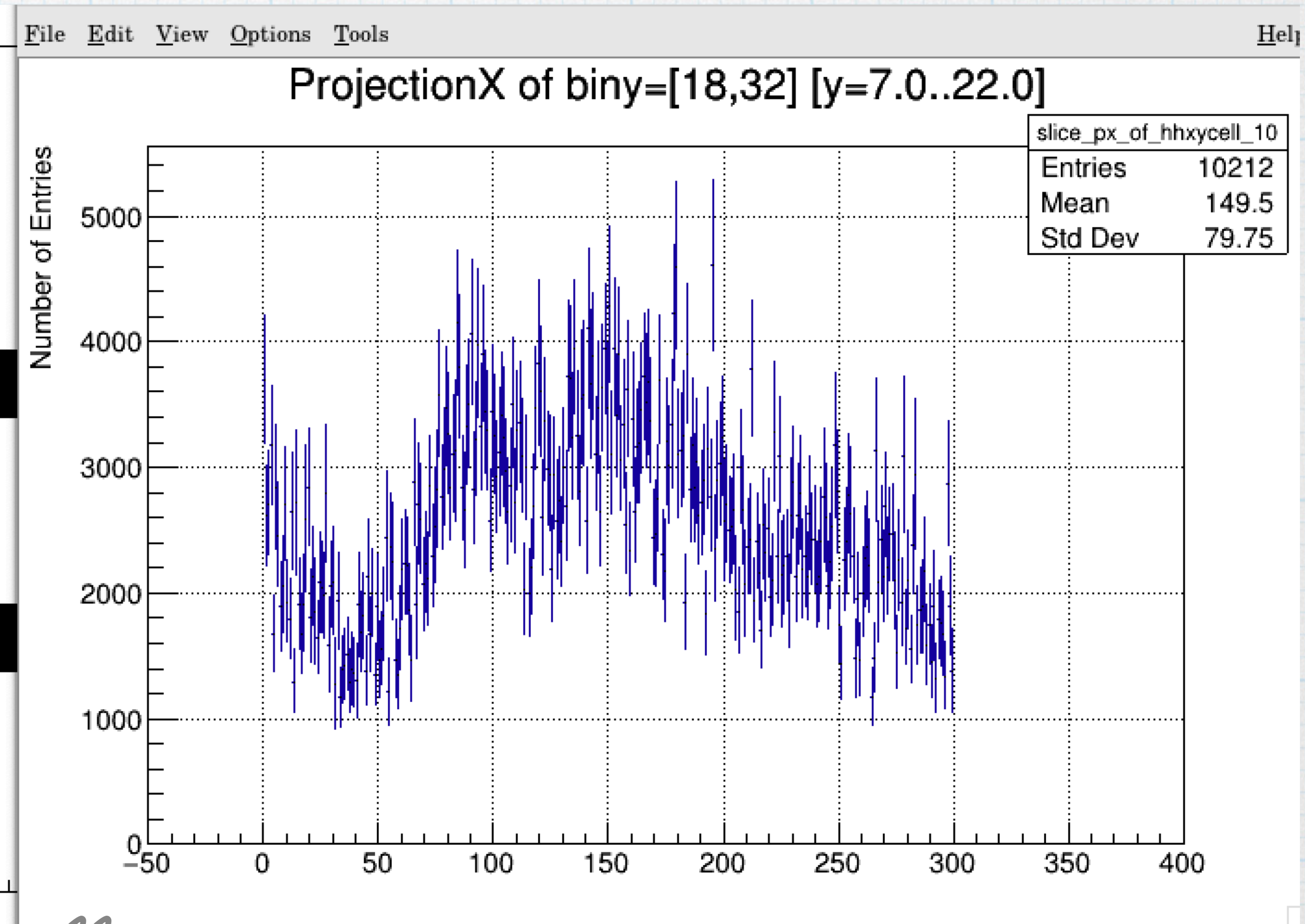
Reconstruction

Spectra reconstruction for the Lanex case, No pipe

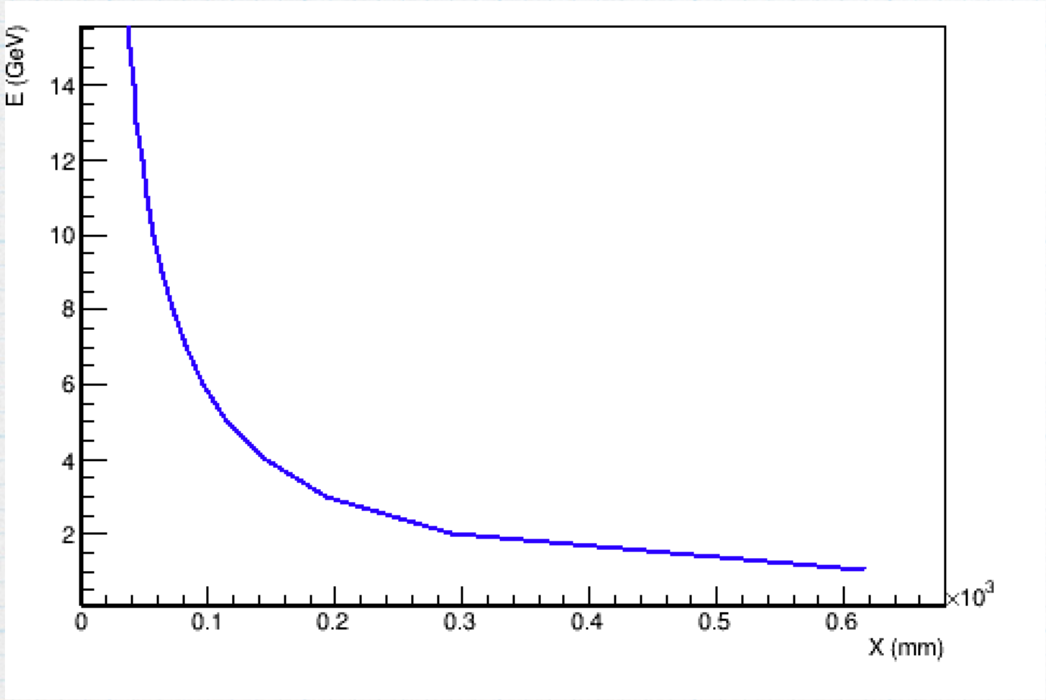


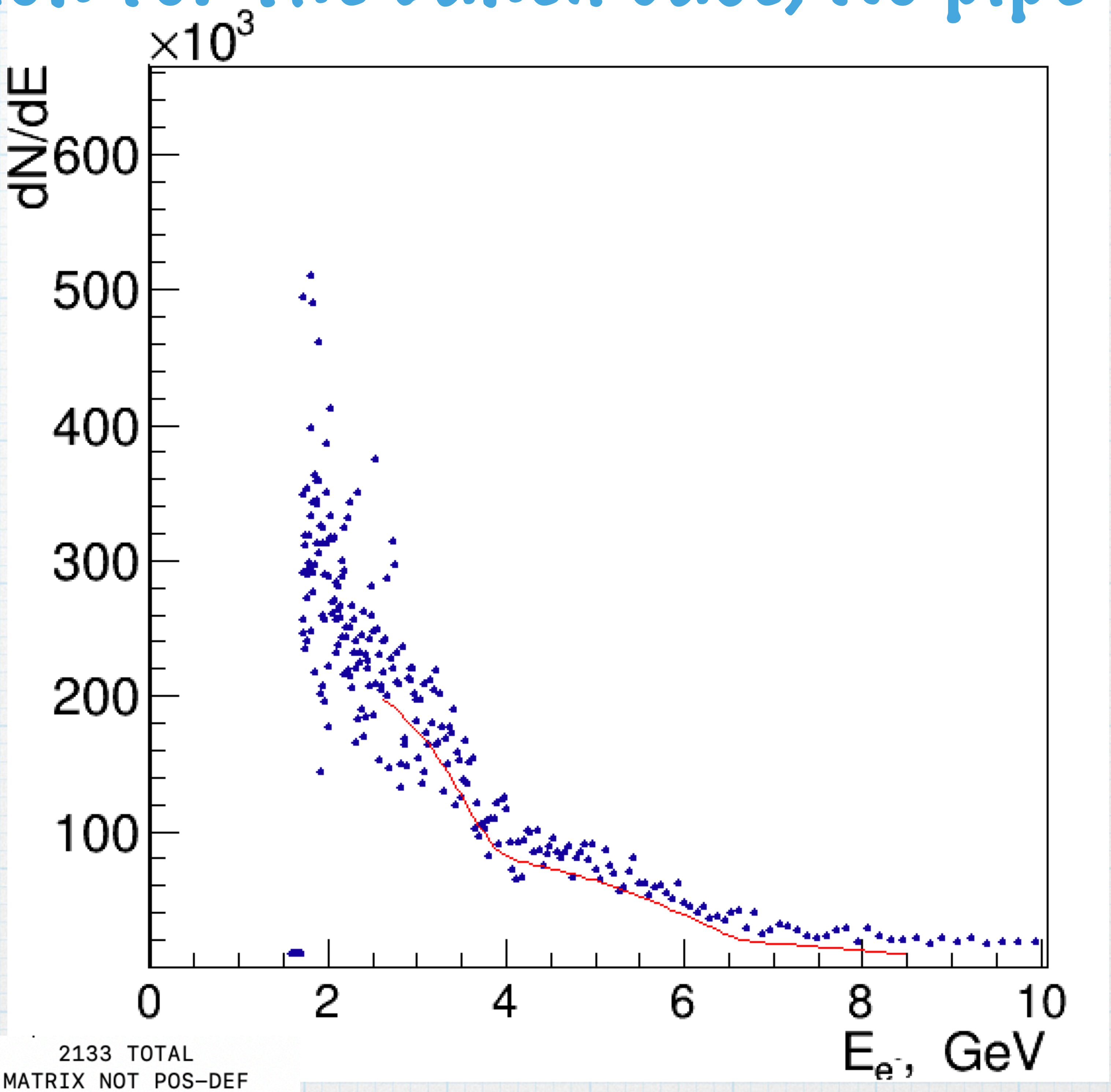






Spectra reconstruction for the Lanex case, No pipe



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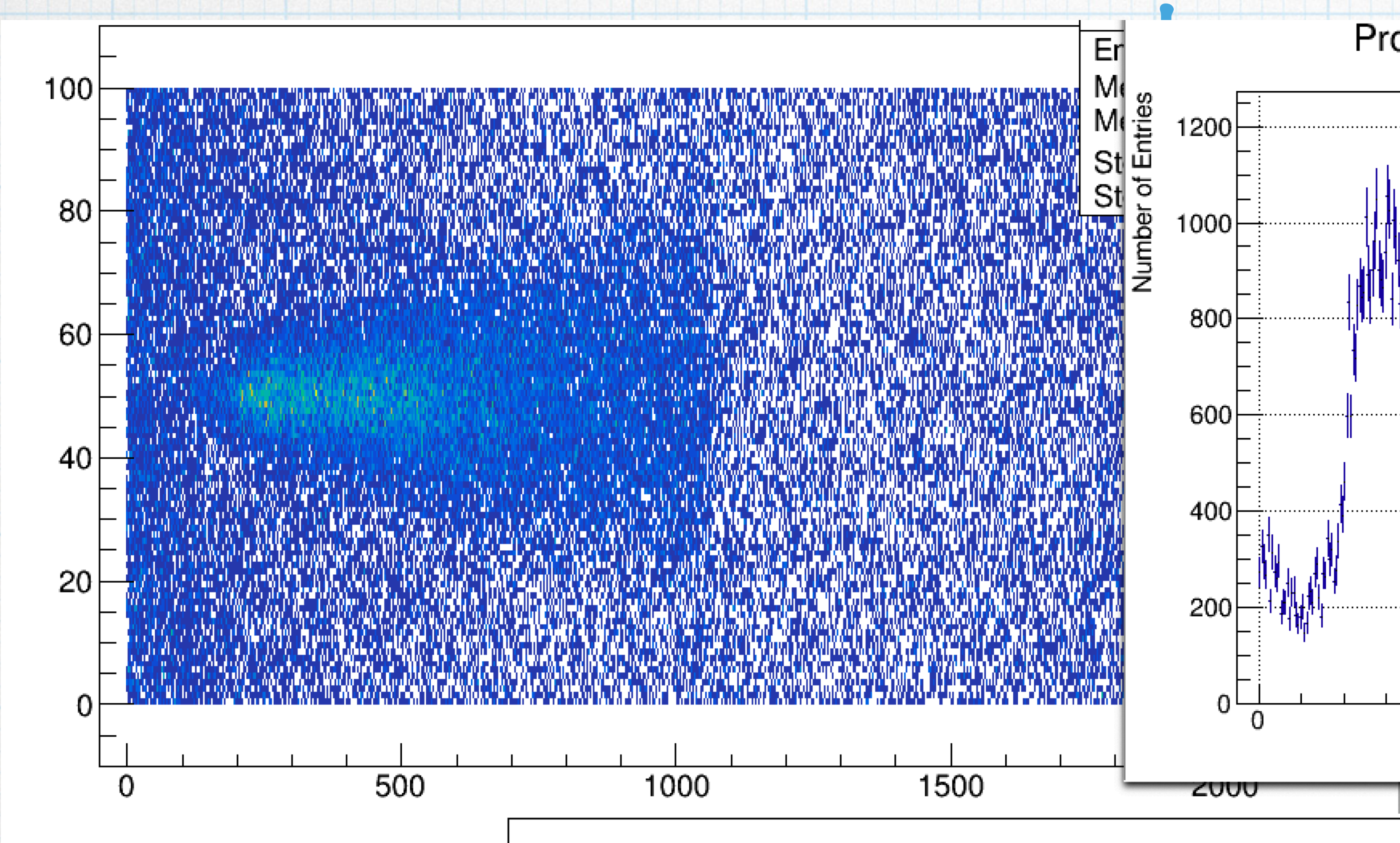
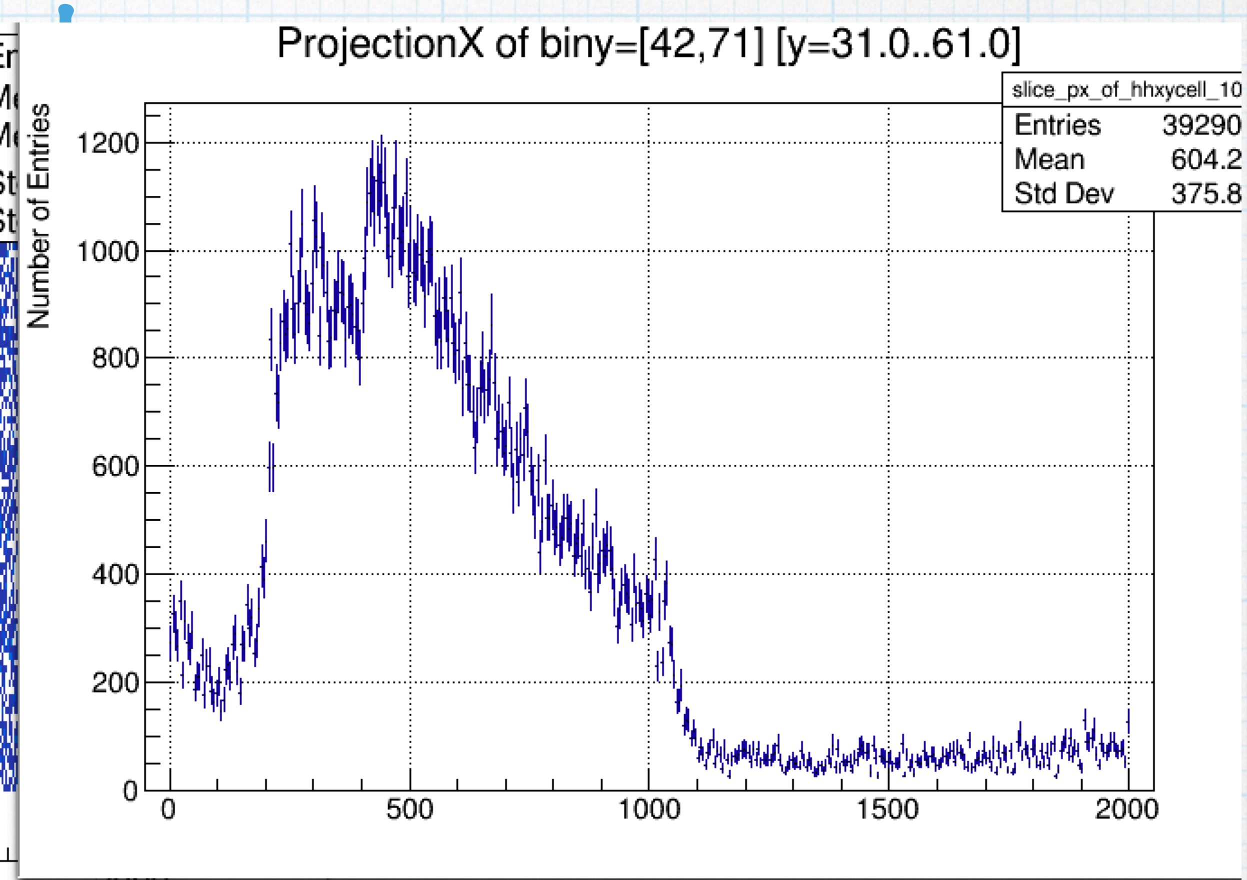
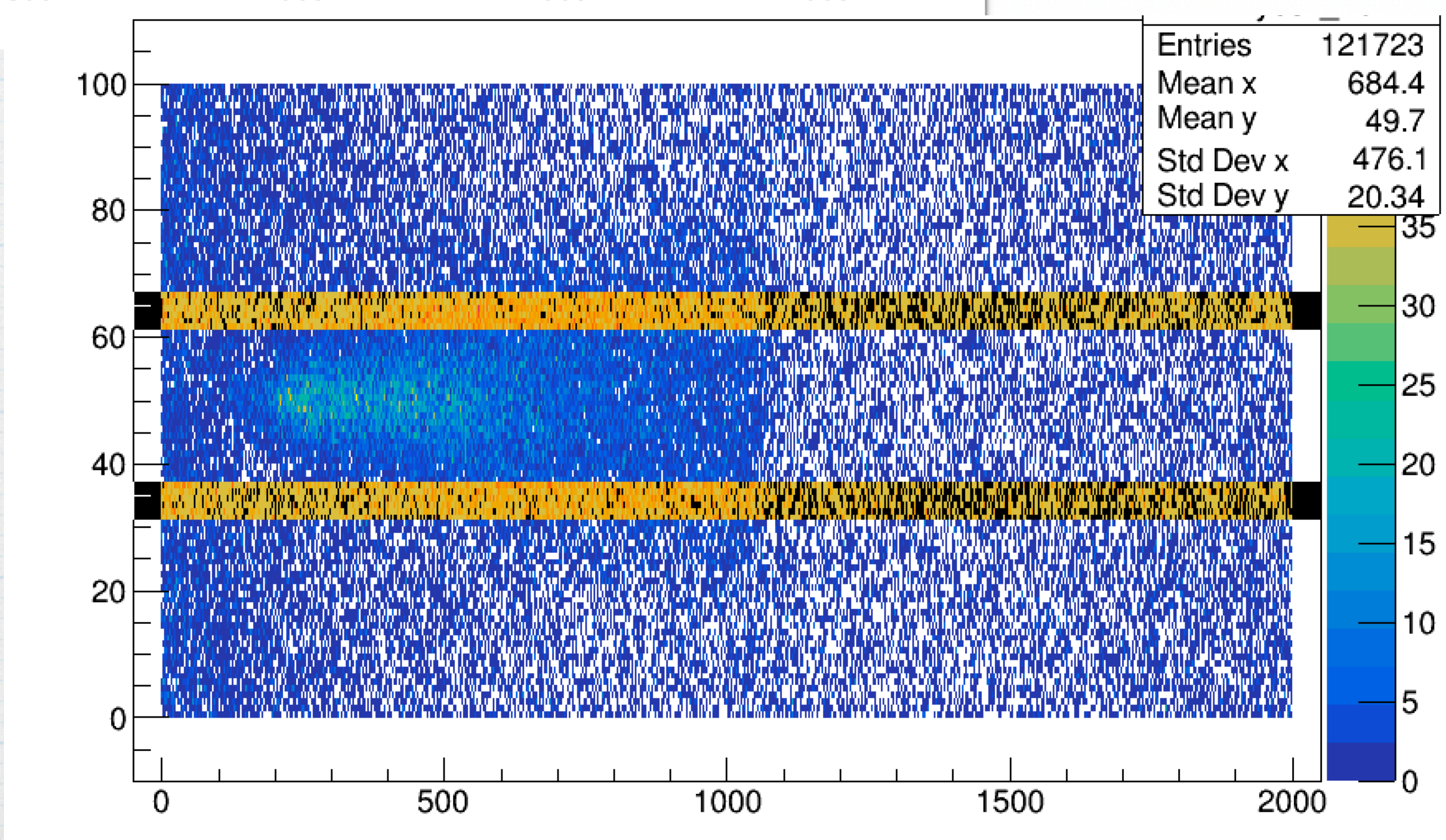
FCN=154.23 FROM MIGRAD    STATUS=CALL LIMIT    2132 CALLS        2133 TOTAL
                     EDM=0.000122625    STRATEGY= 1      ERR MATRIX NOT POS-DEF
 EXT PARAMETER                APPROXIMATE        STEP         FIRST
 NO.   NAME      VALUE            ERROR          SIZE      DERIVATIVE
  1  p0           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
```

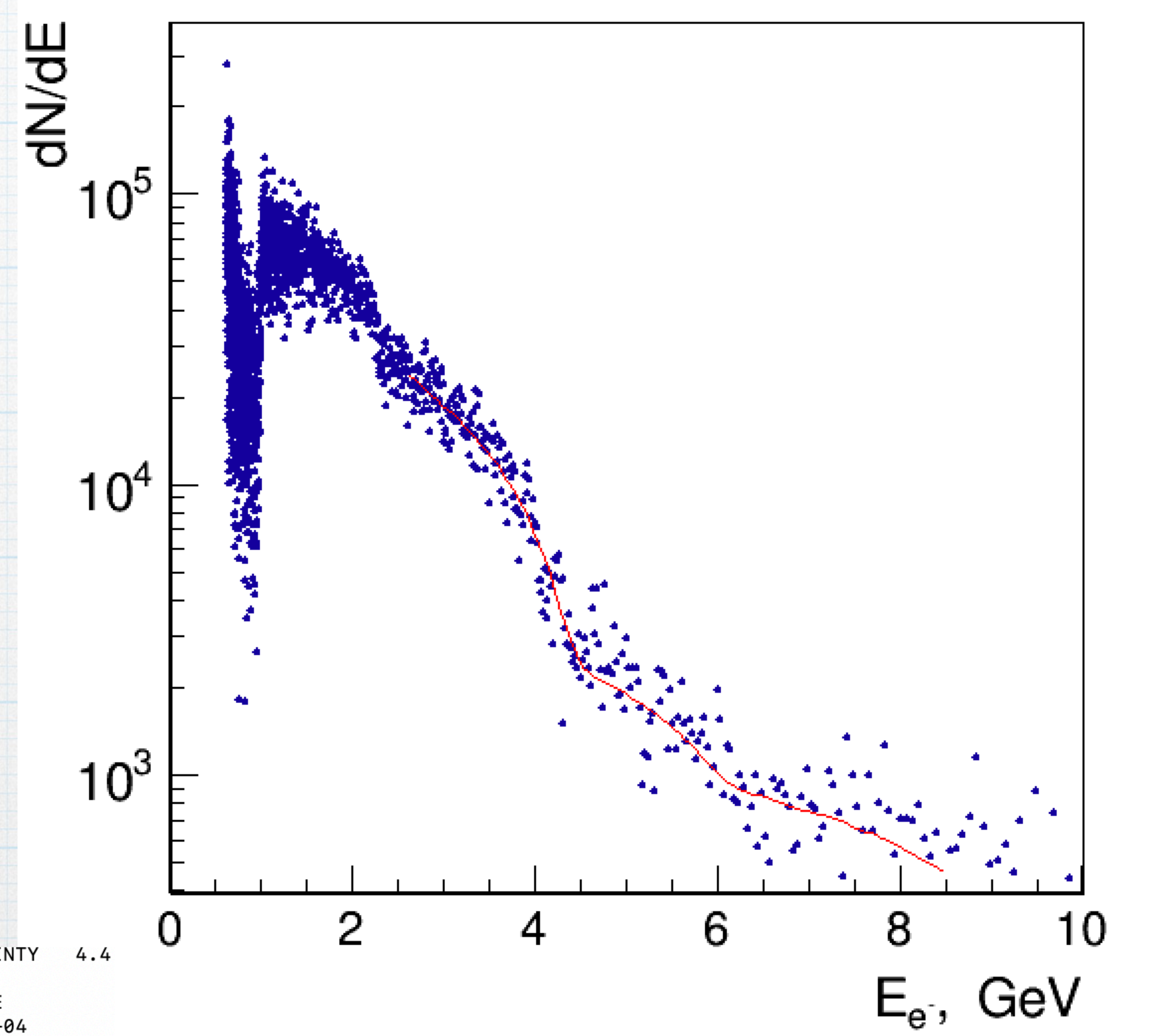
Deposited energy in Lanex, electron arm, Beam pipe, ~4500 bx







Spectra reconstruction for the Lanex in case of the Beam Pipe




```
             EDM=12.7612     STRATEGY= 1  ERROR MATRIX UNCERTAINTY   4.4
EXT PARAMETER                    APPROXIMATE        STEP         FIRST
NO.   NAME        VALUE            ERROR          SIZE       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=**$(x_0,\dots,x_i)$, 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)**

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

Reconstruction with FIR