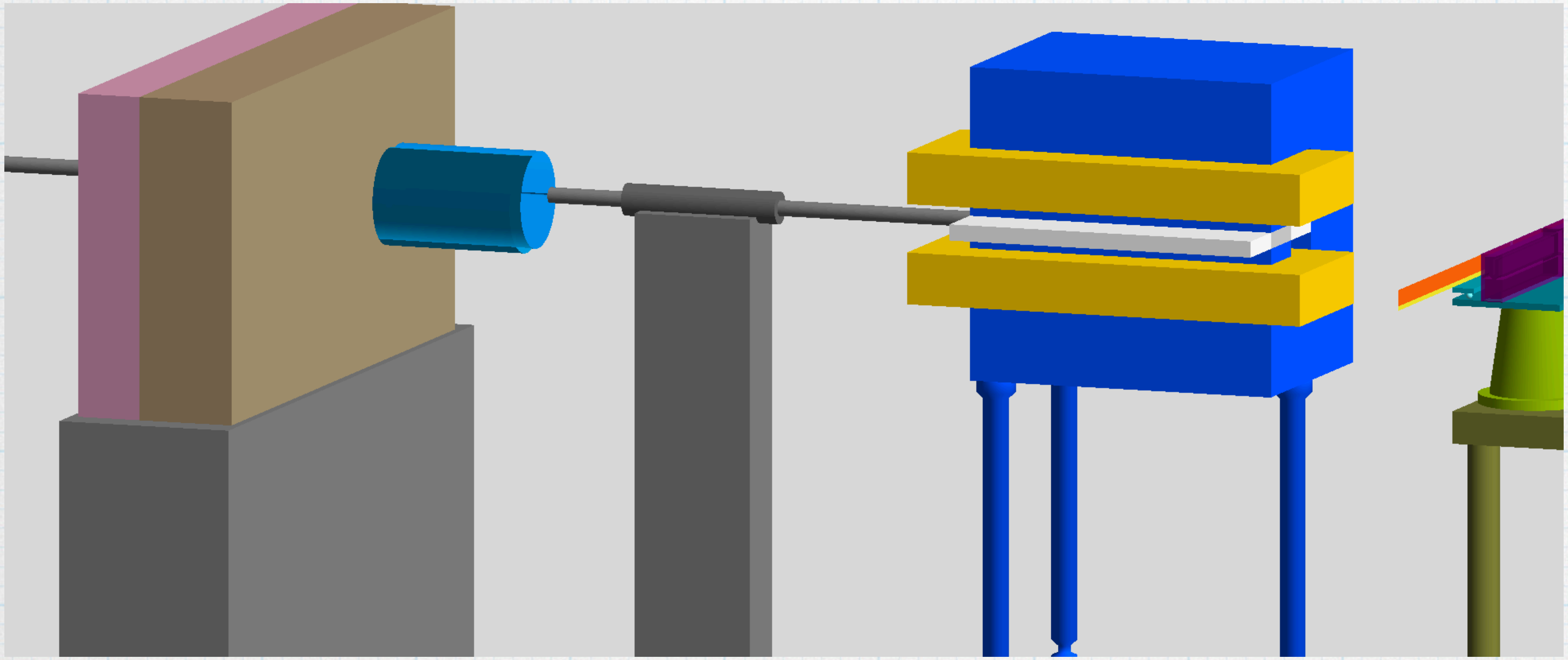
FDS performance
Beam pipe with chamber

Borysova Maryna (KINR)

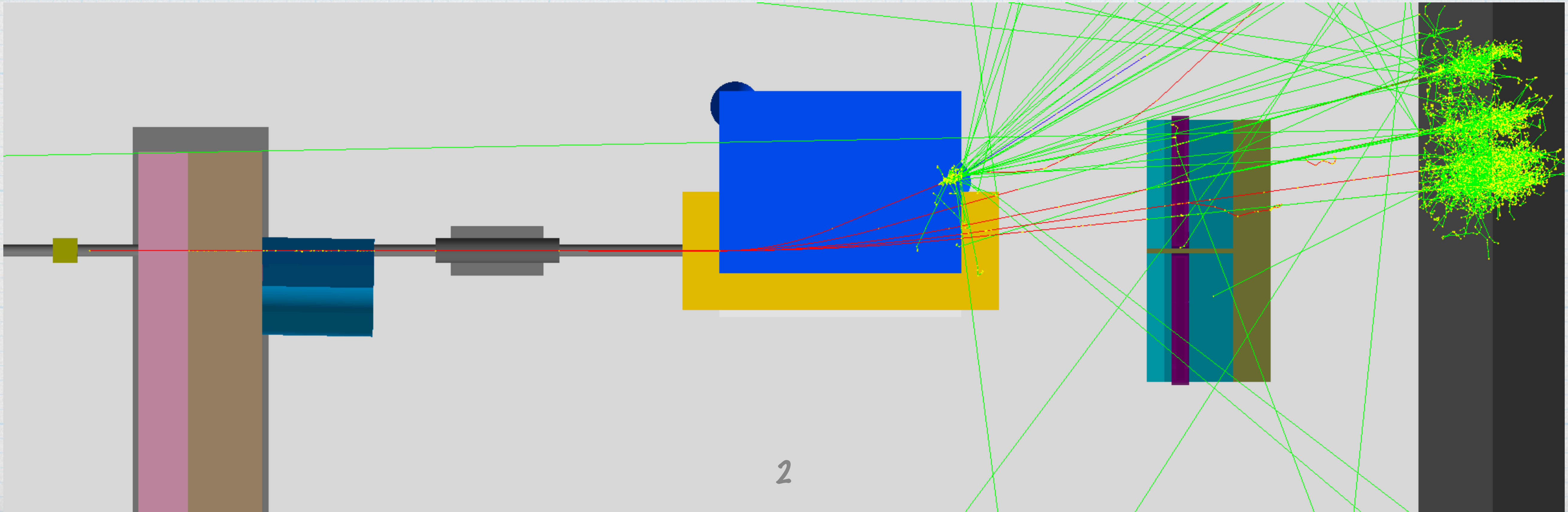
17/03/21
LUXE technical meeting

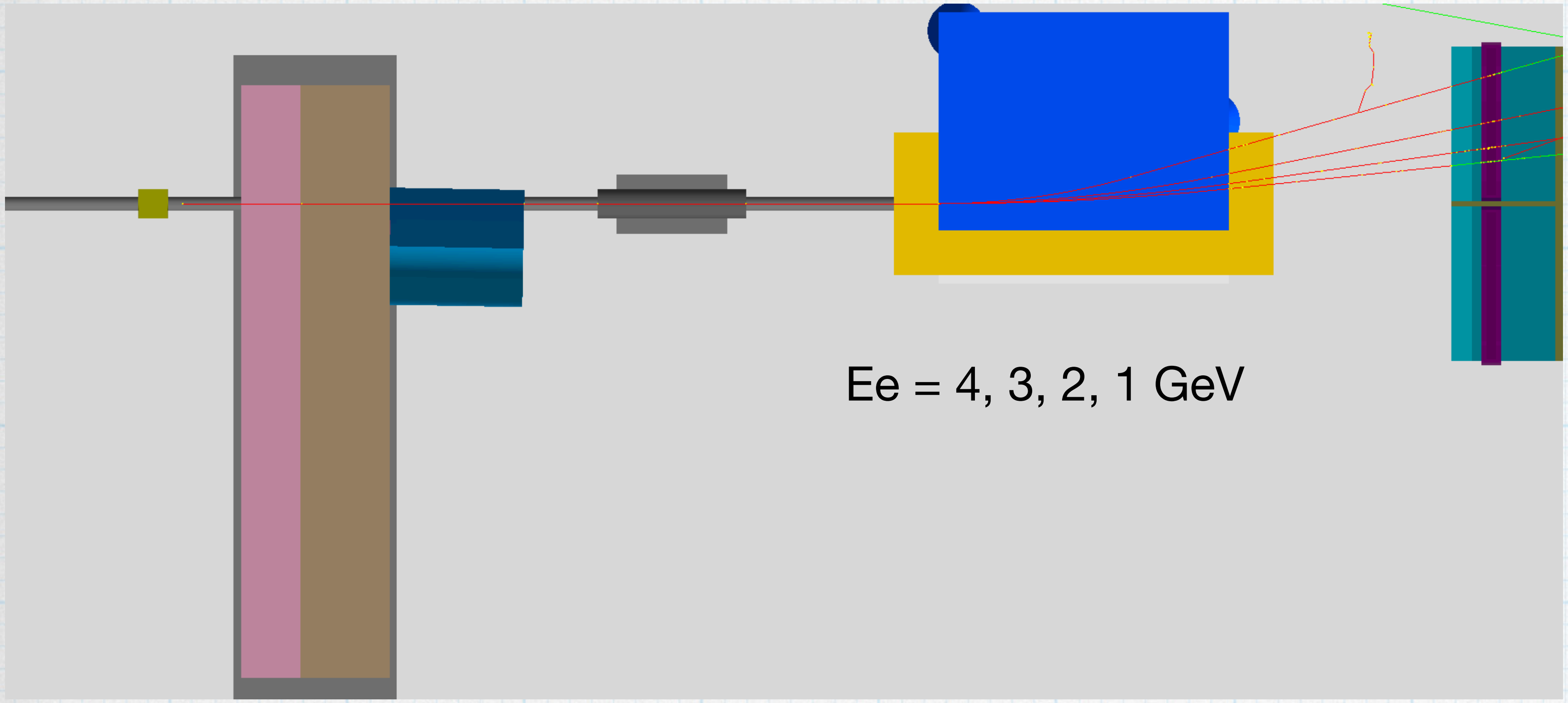
LUXE

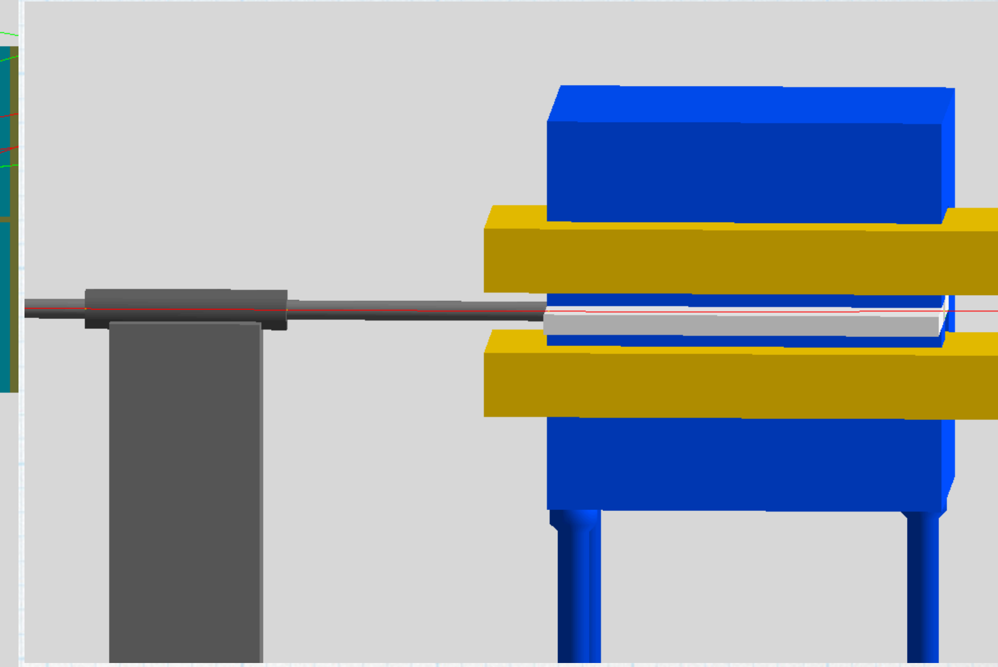
Forward detector system with beam pipe and short chamber

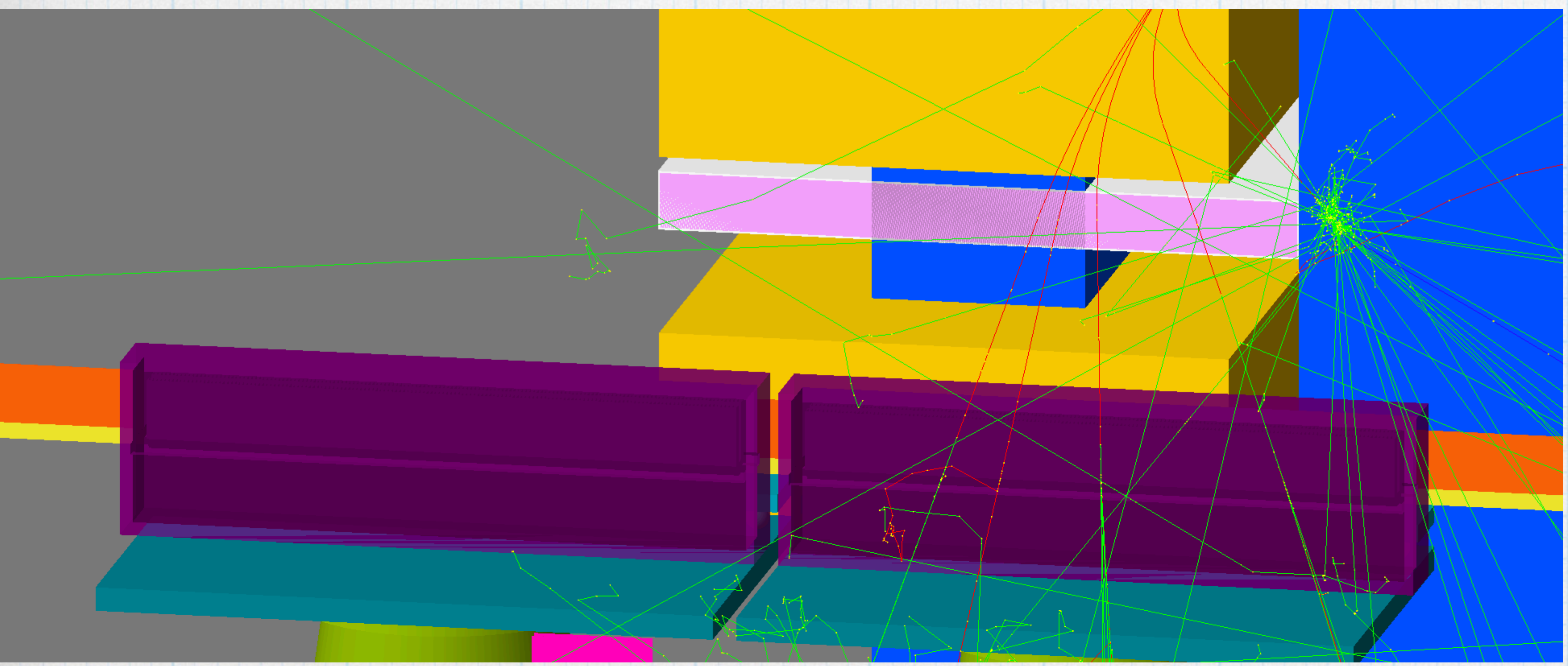


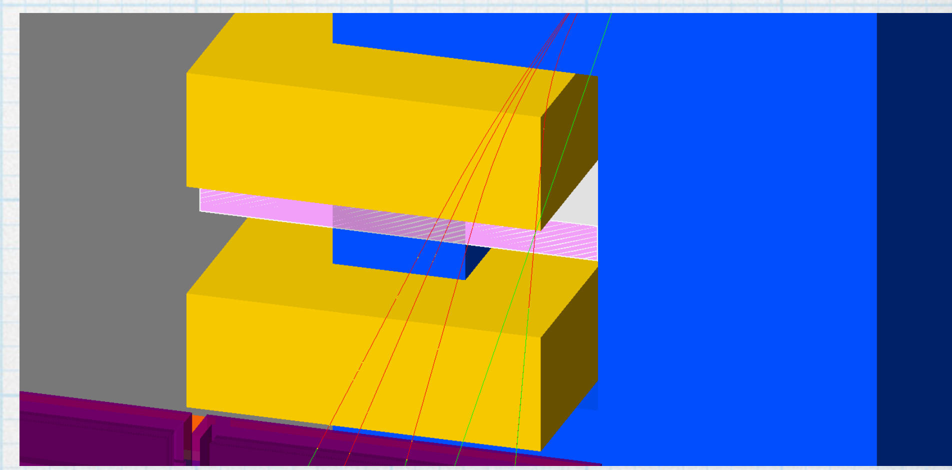
Ee = 4, 3, 2, 0.5 GeV



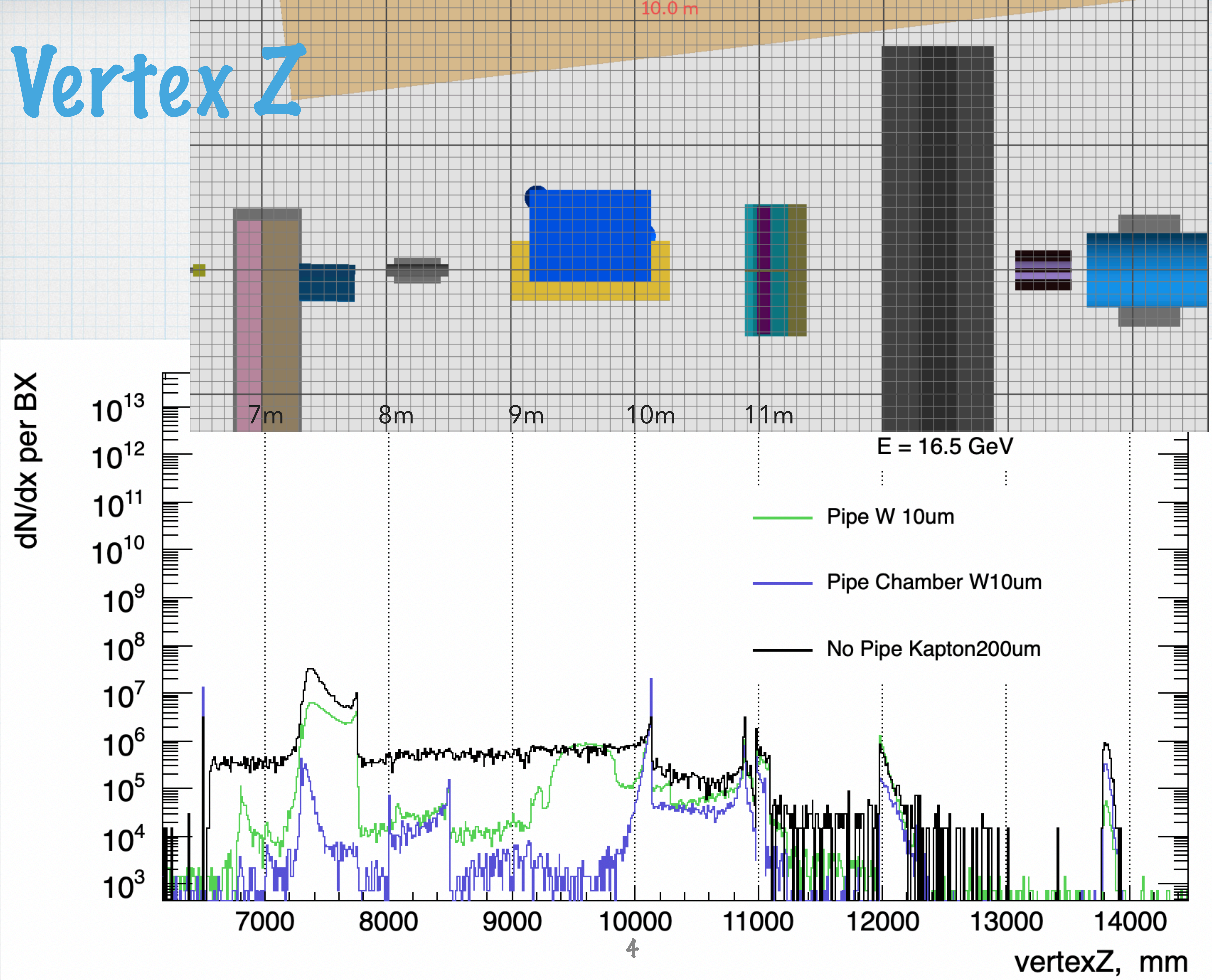

Ee = 4, 3, 2, 1 GeV





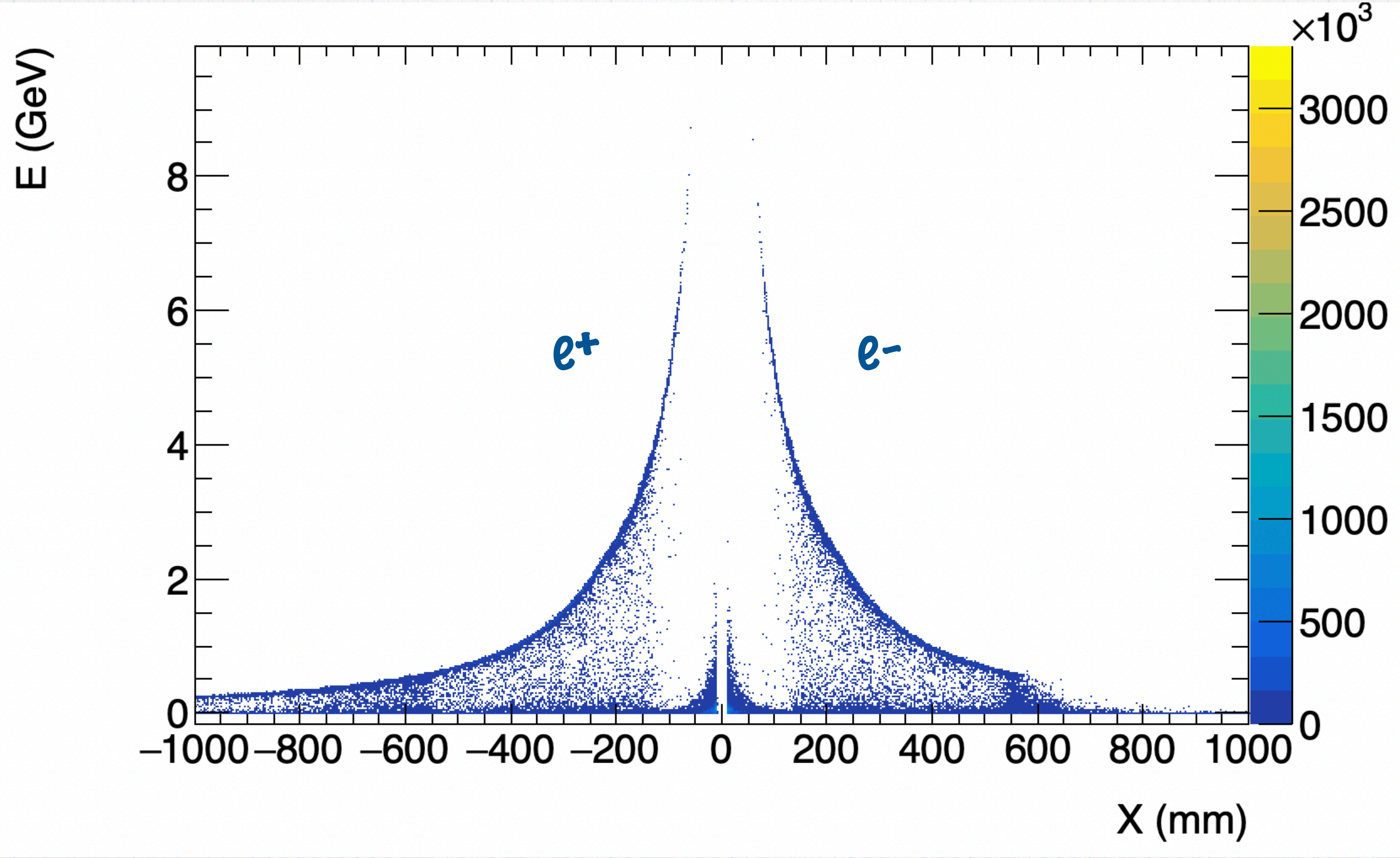


Vertex Z



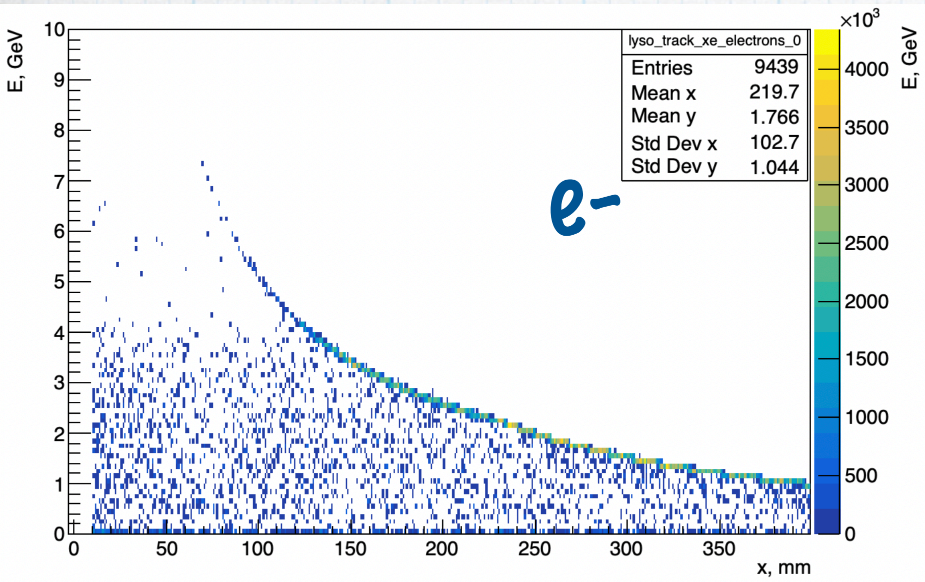
10.0 m
7m
8m
9m
10m
11m
E = 16.5 GeV
Pipe W 10um
Pipe Chamber W10um
No Pipe Kapton200um
dN/dx per BX
vertexZ, mm
7000
8000
9000
10000
11000
12000
13000
14000

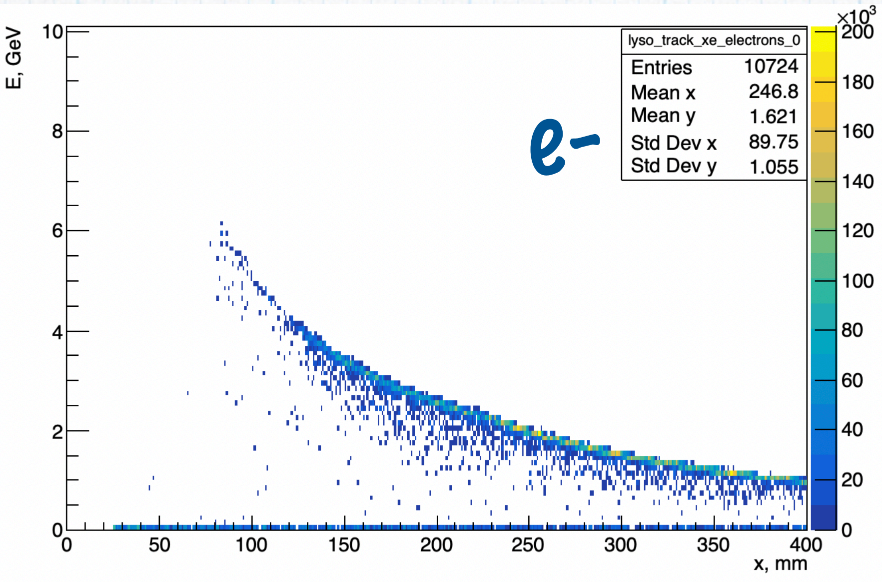
Energy vs position

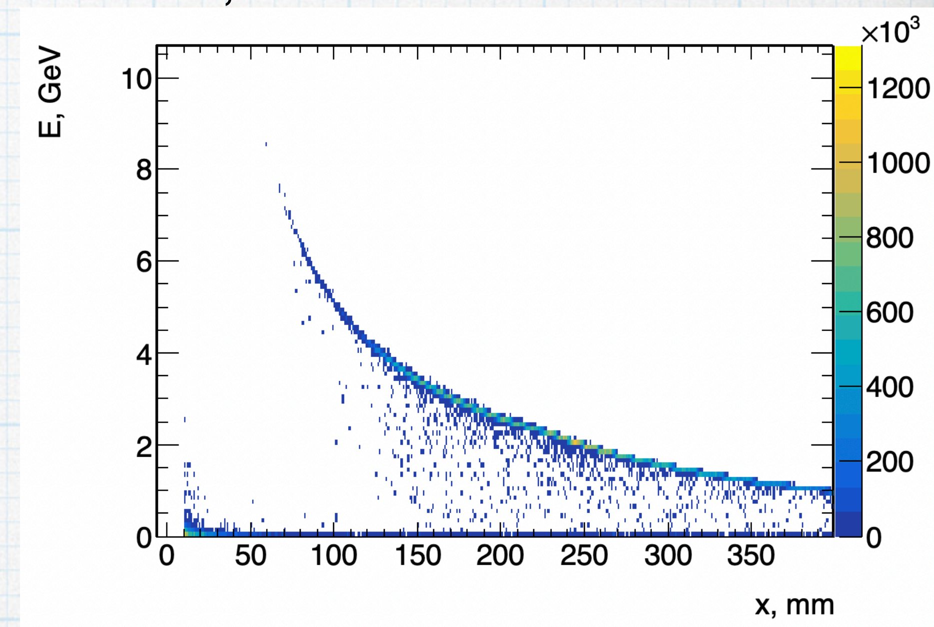


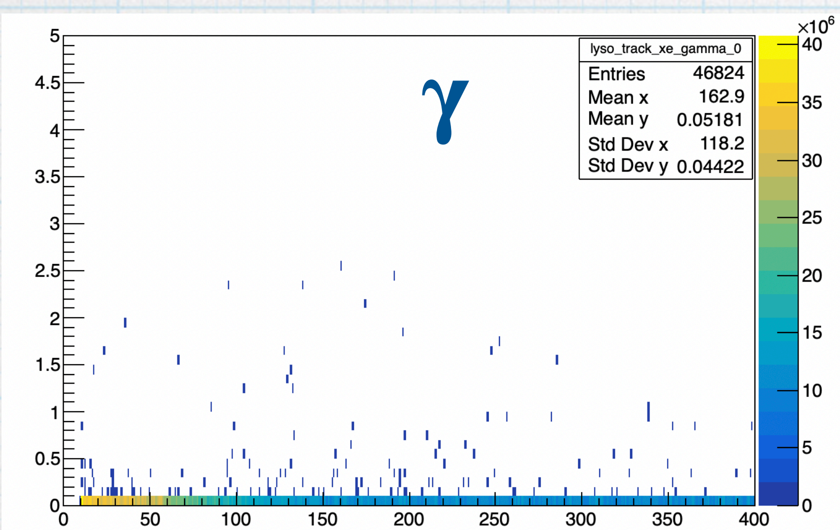
Energy vs position

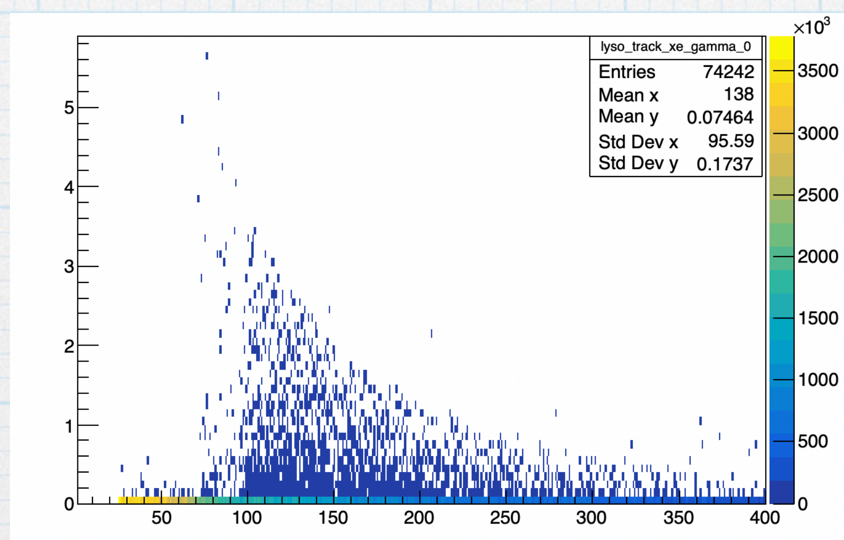
NO Beam Pipe Kapton, 200 um	Beam Pipe 5 cm W, 10 um	Beam Pipe 4.2 cm +chamber W, 10 um

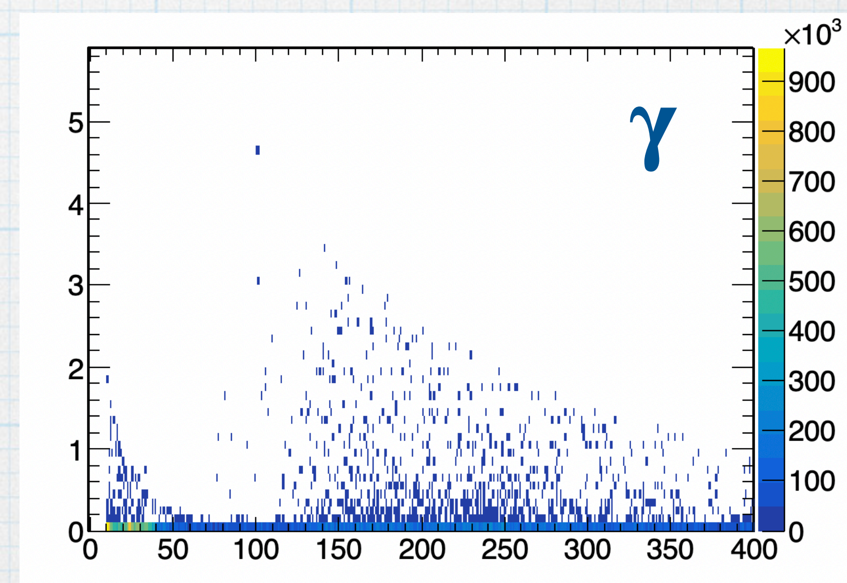








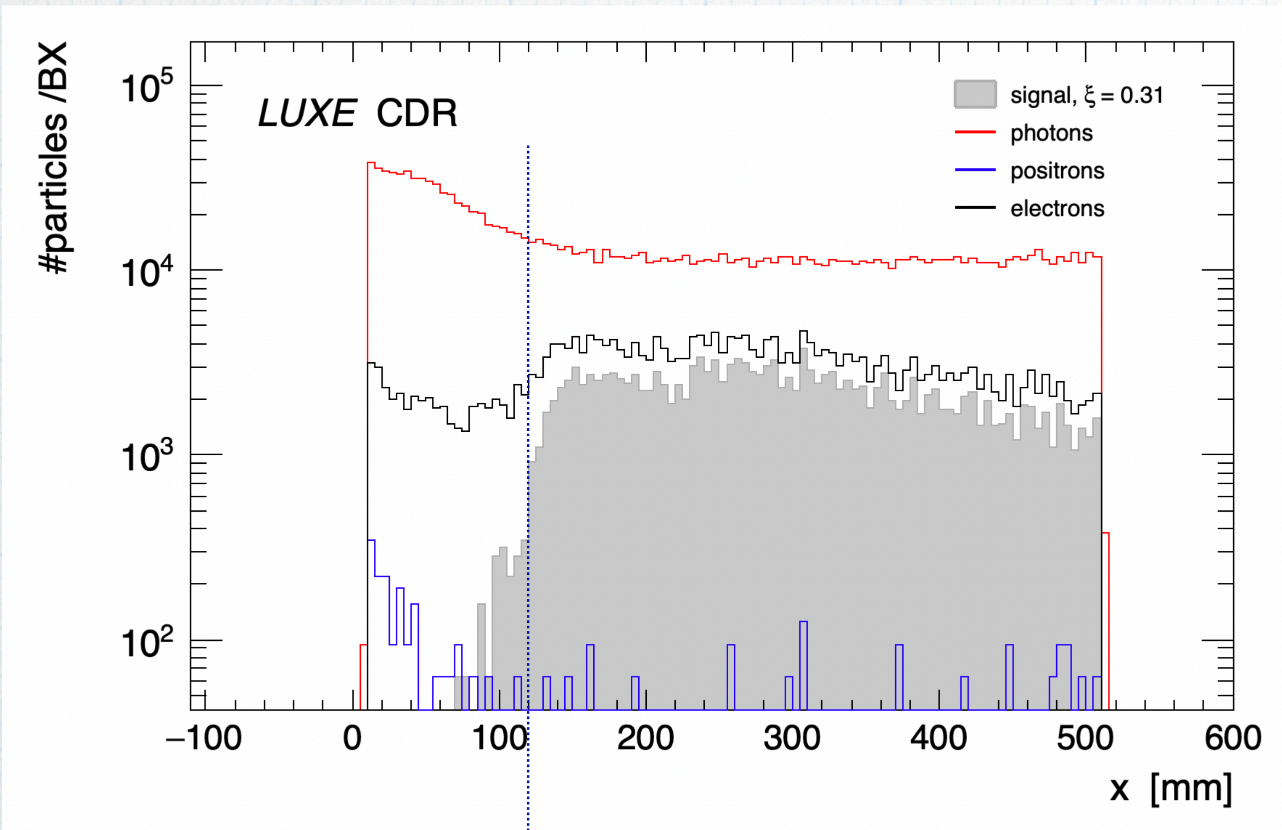




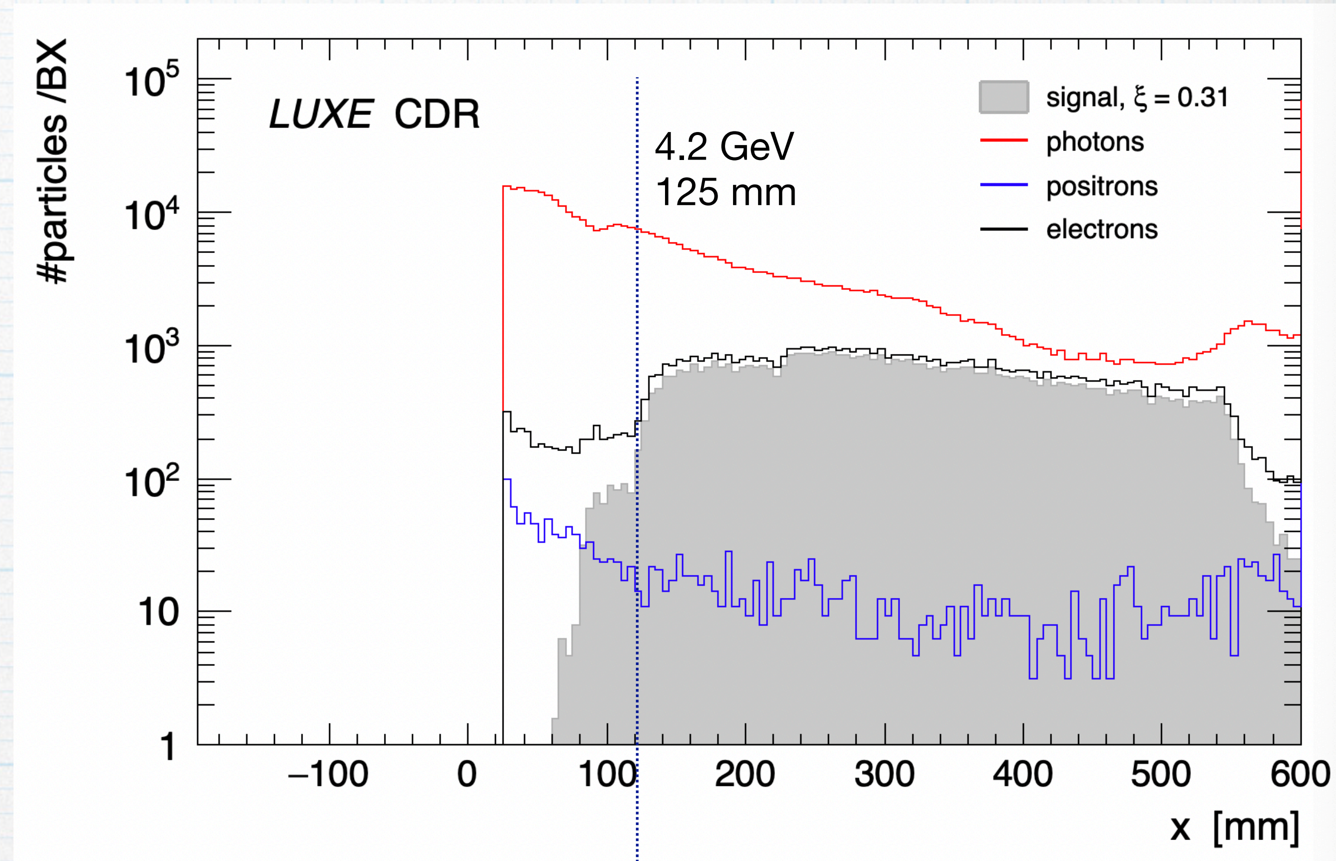
Electron Energy-position correlation is cleaner in case of beam pipe and photons distribution shows that they were produced after the electron direction was defined.

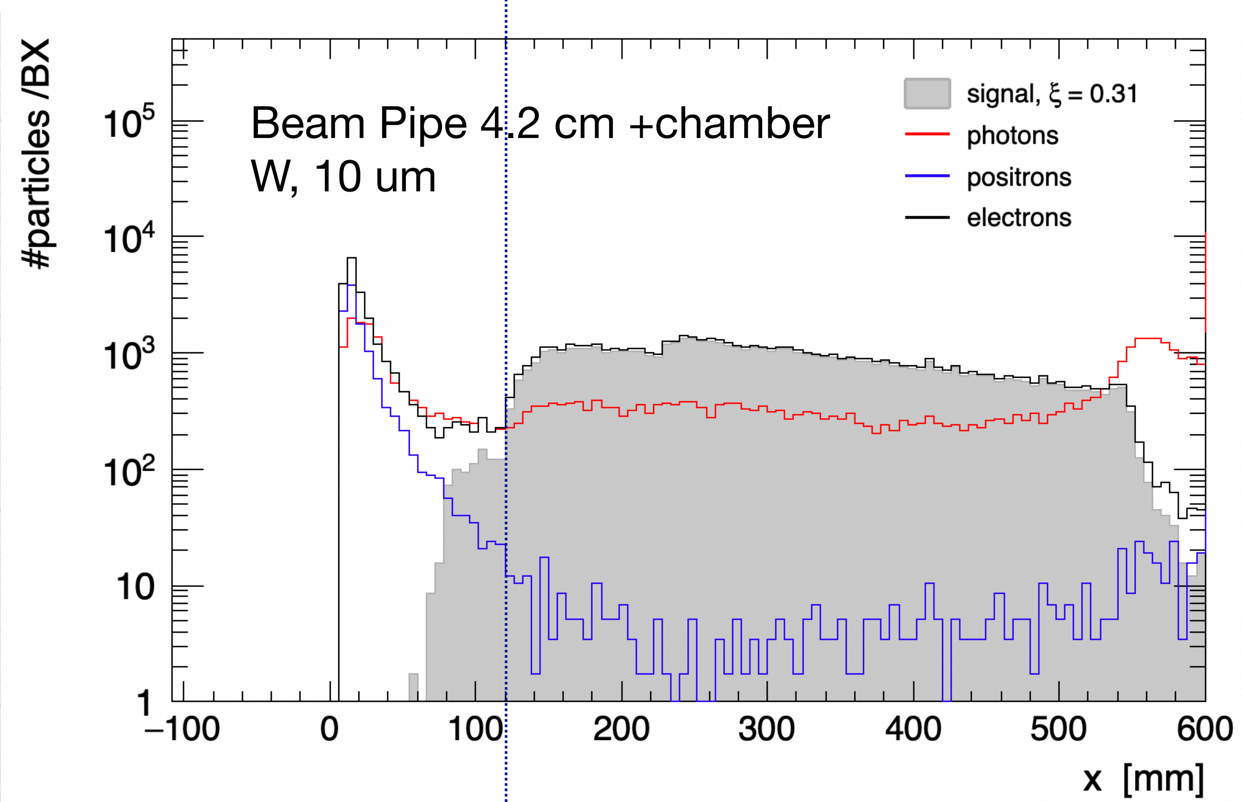
Particles in electron arm

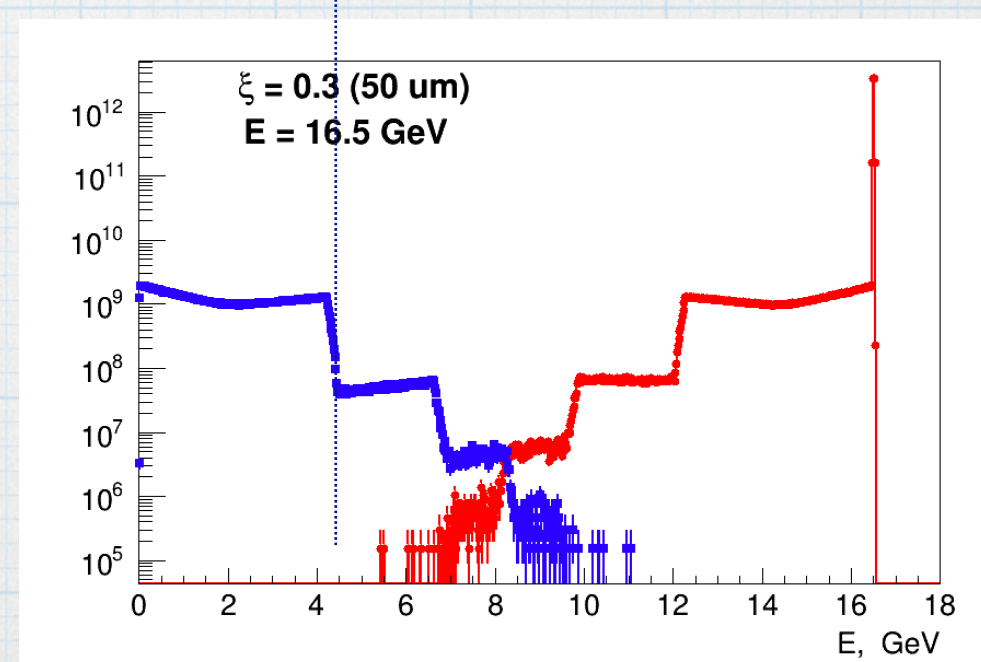
NO Beam Pipe
Kapton, 200 um

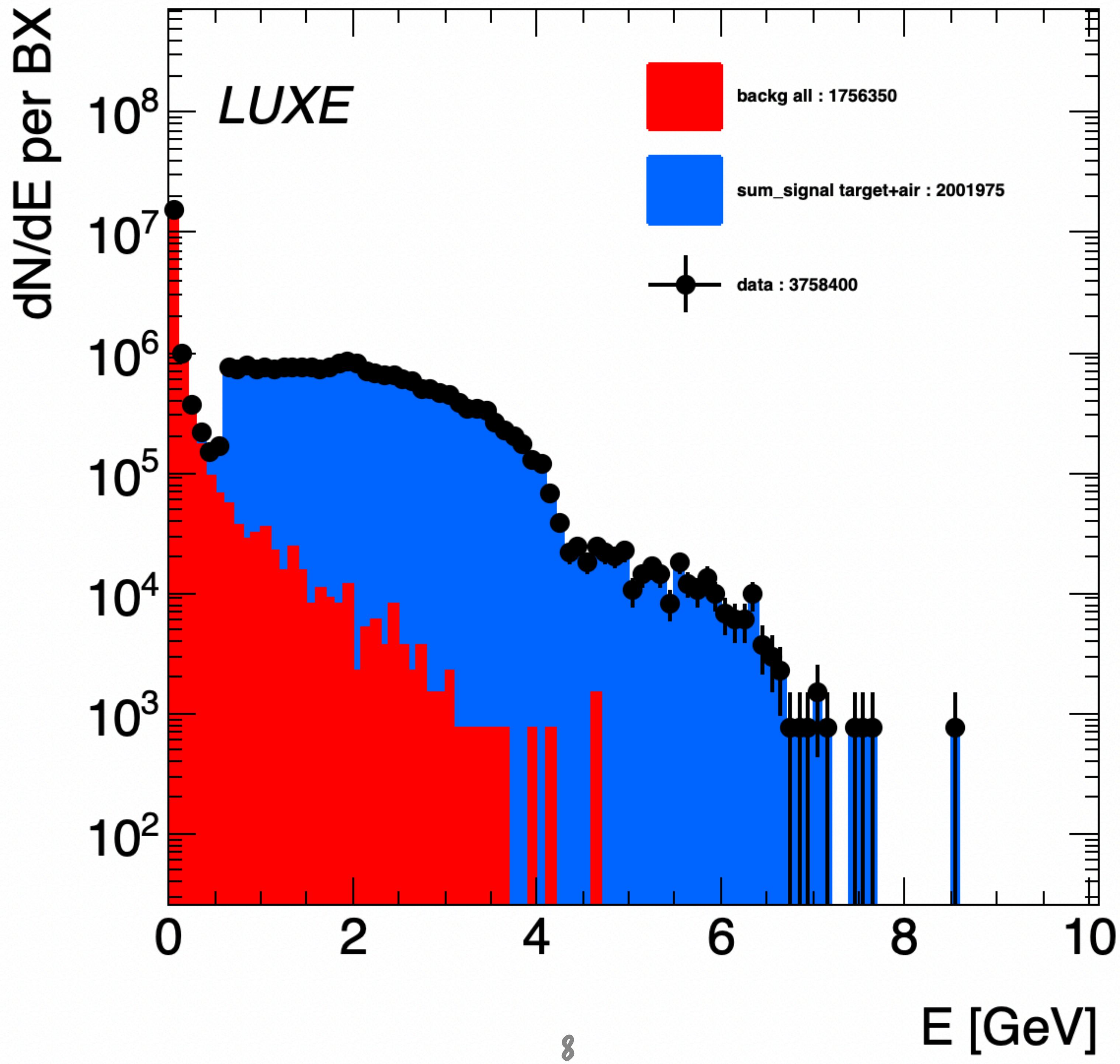


Beam Pipe 5 cm
W, 10 um



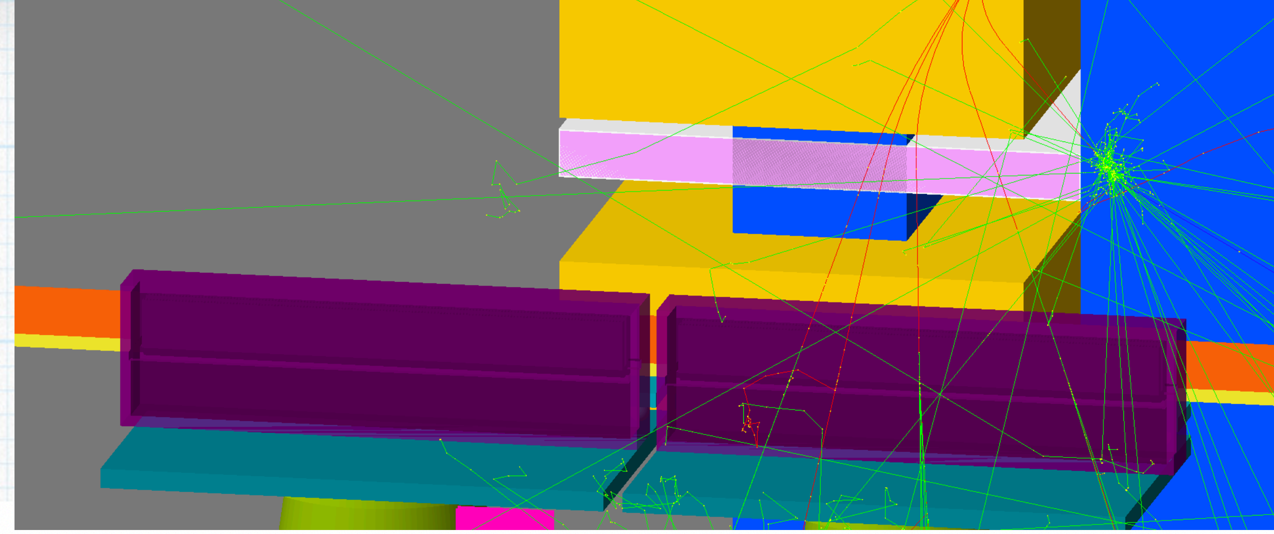


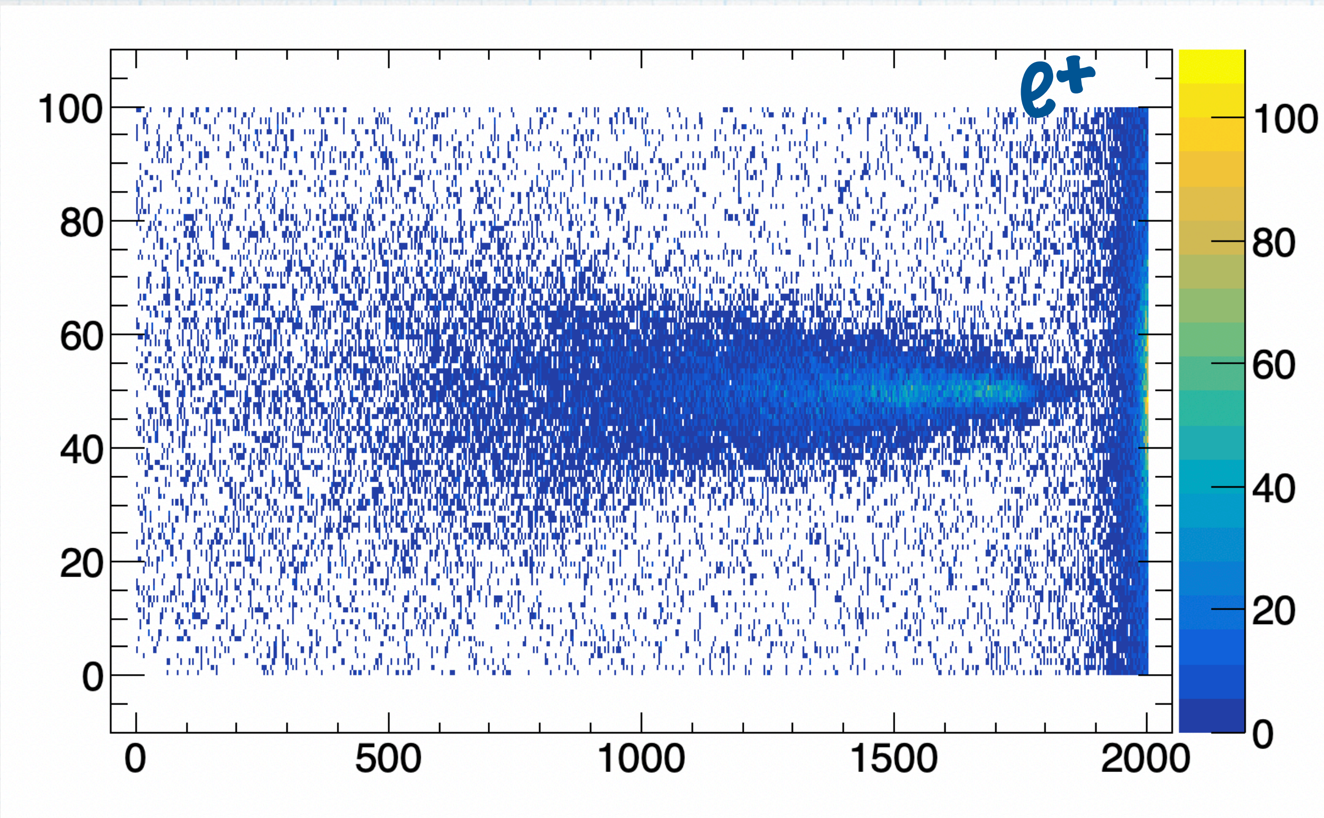


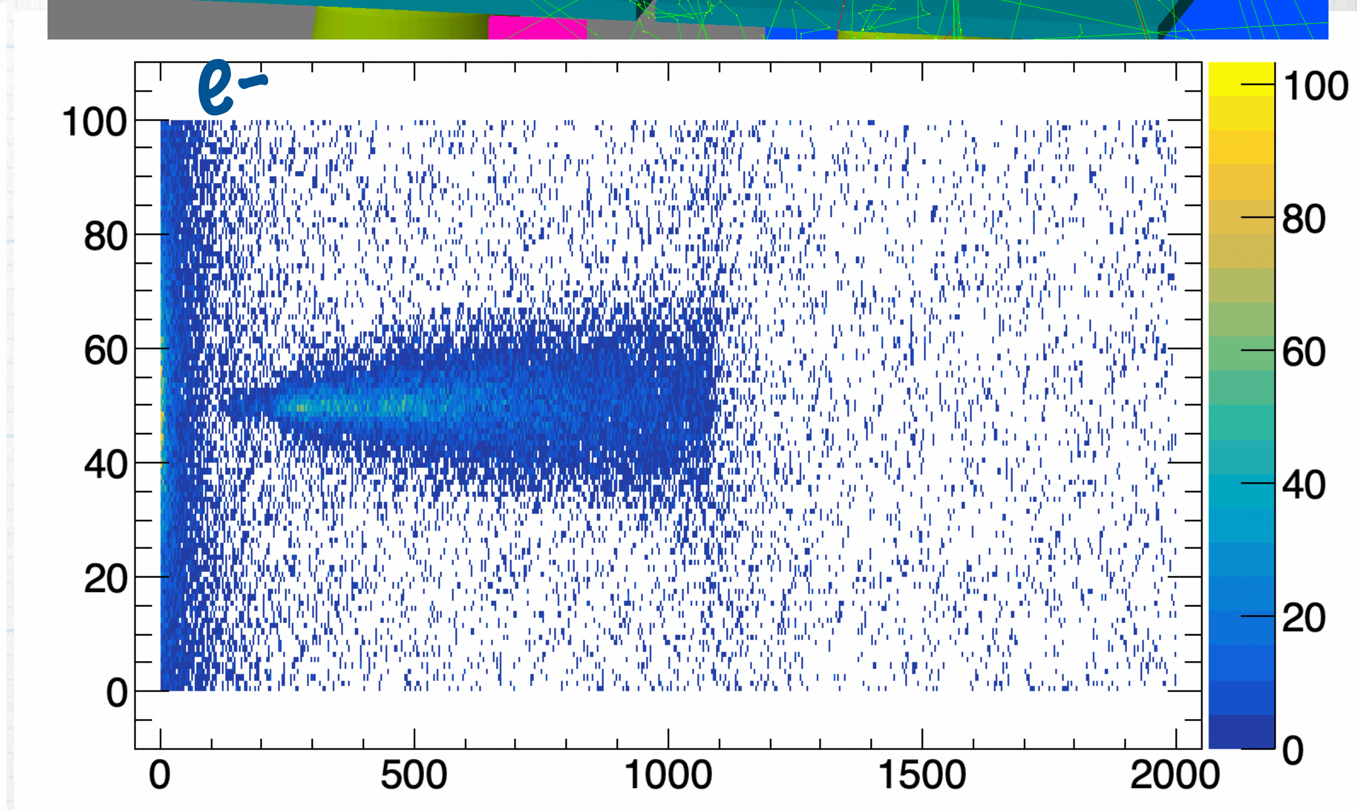


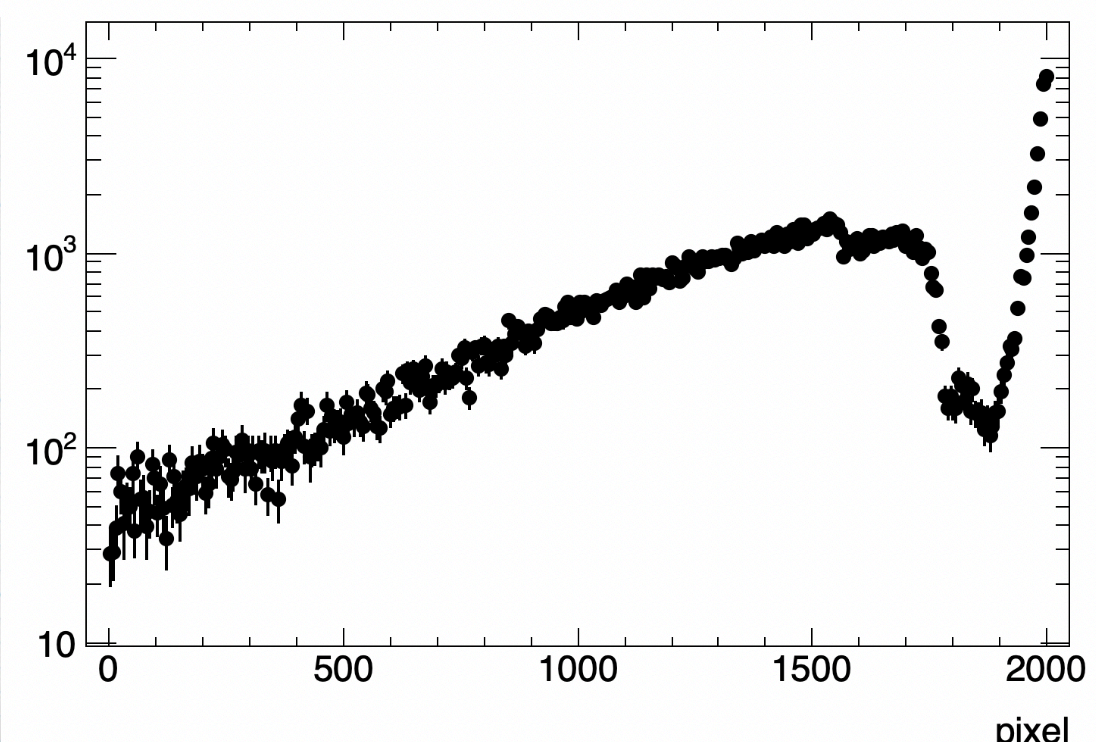
LUXE
backg all : 1756350
sum_signal target+air : 2001975
data : 3758400
dN/dE per BX
E [GeV]

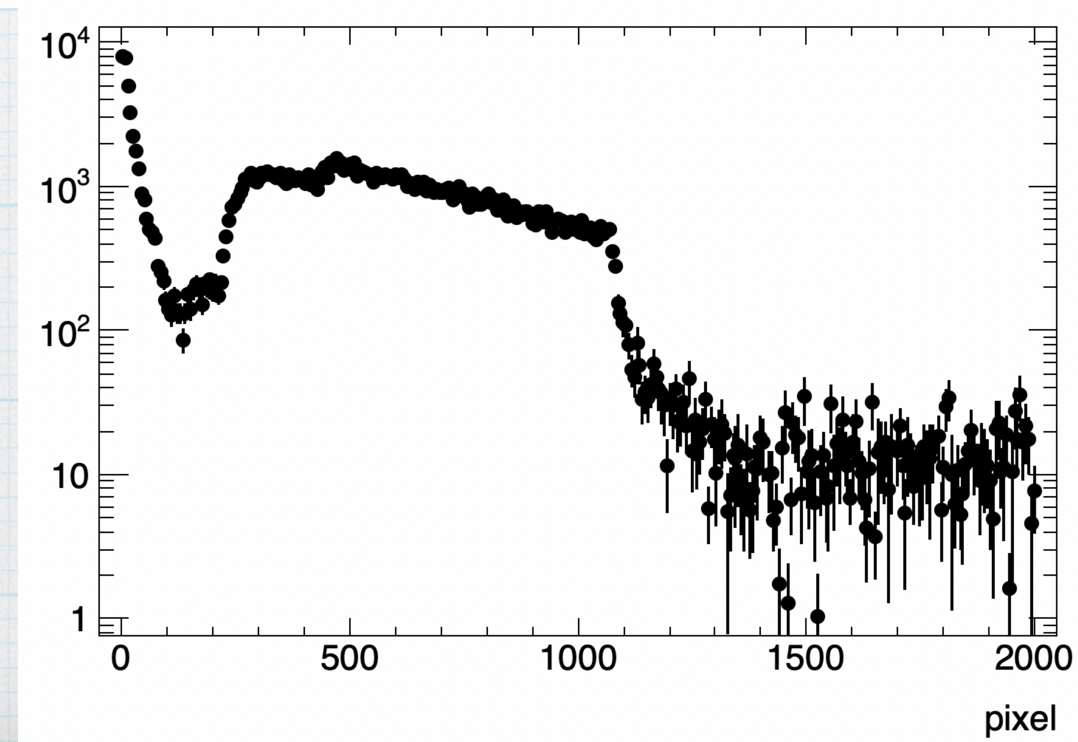
Deposited energy in Lanex, Beam pipe+chamber, ~4500 bx



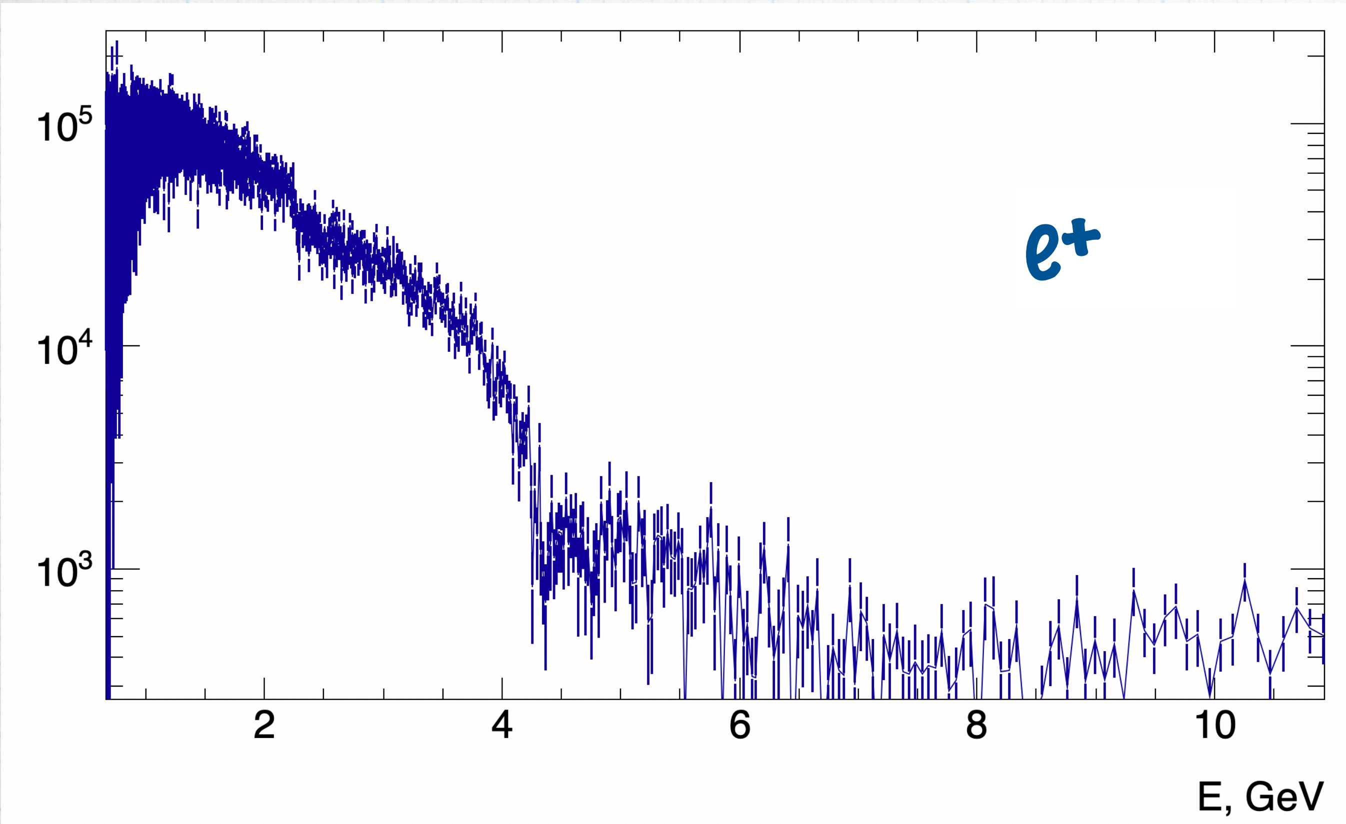


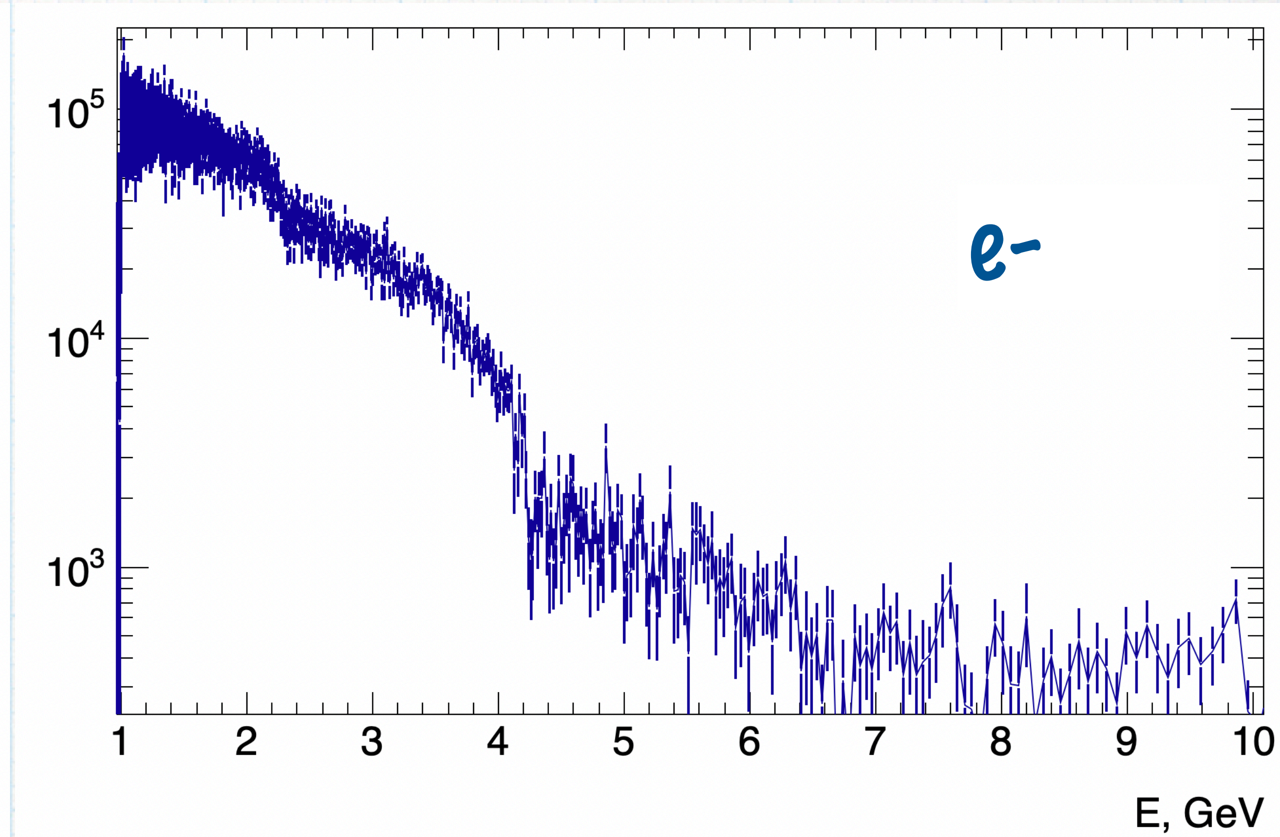


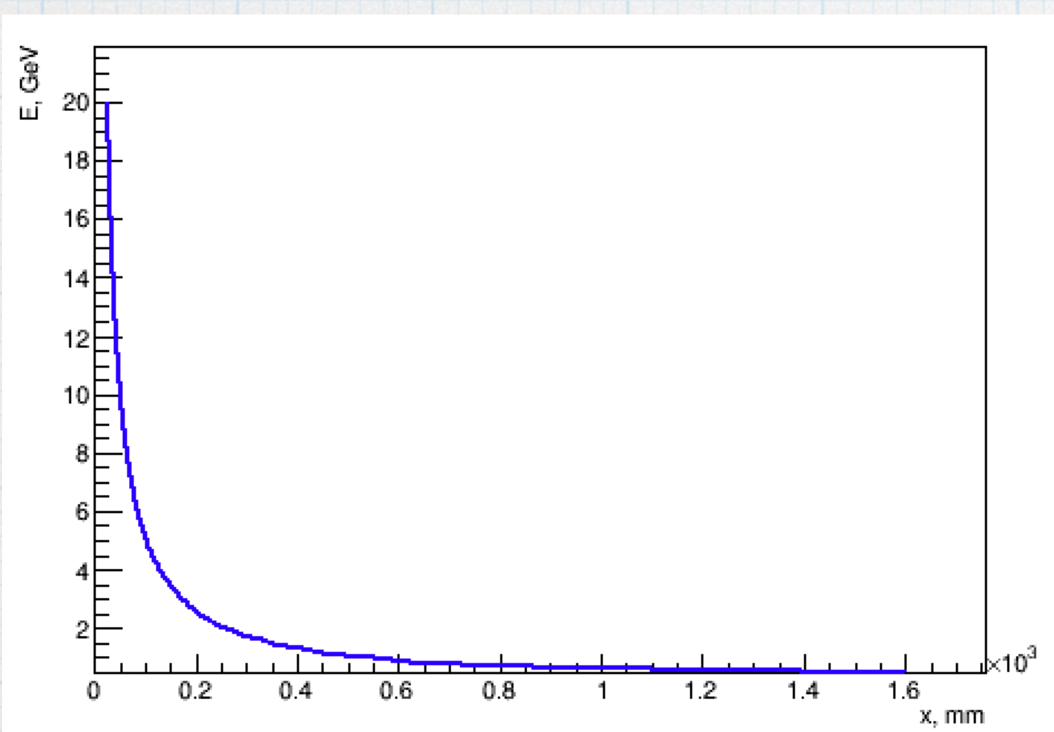


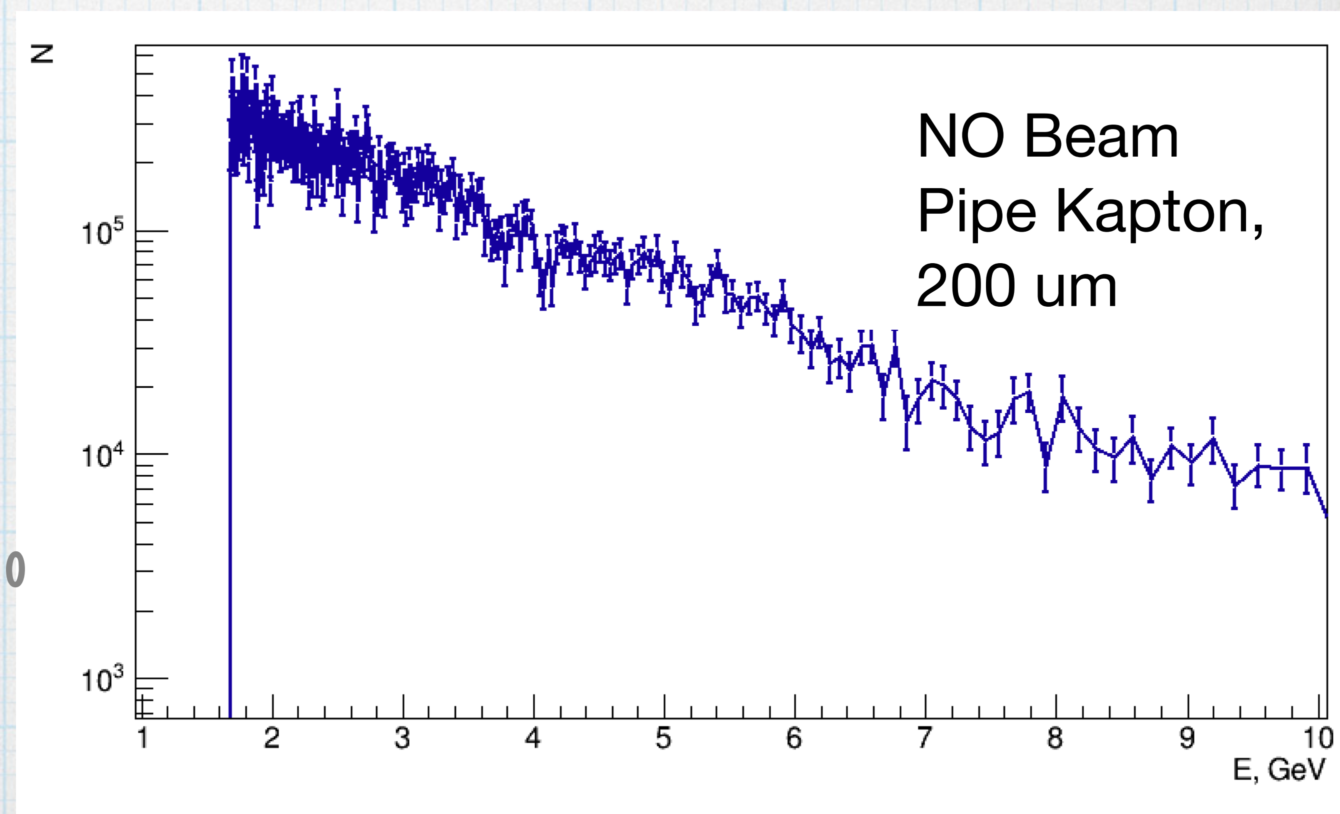


Reconstructed spectra

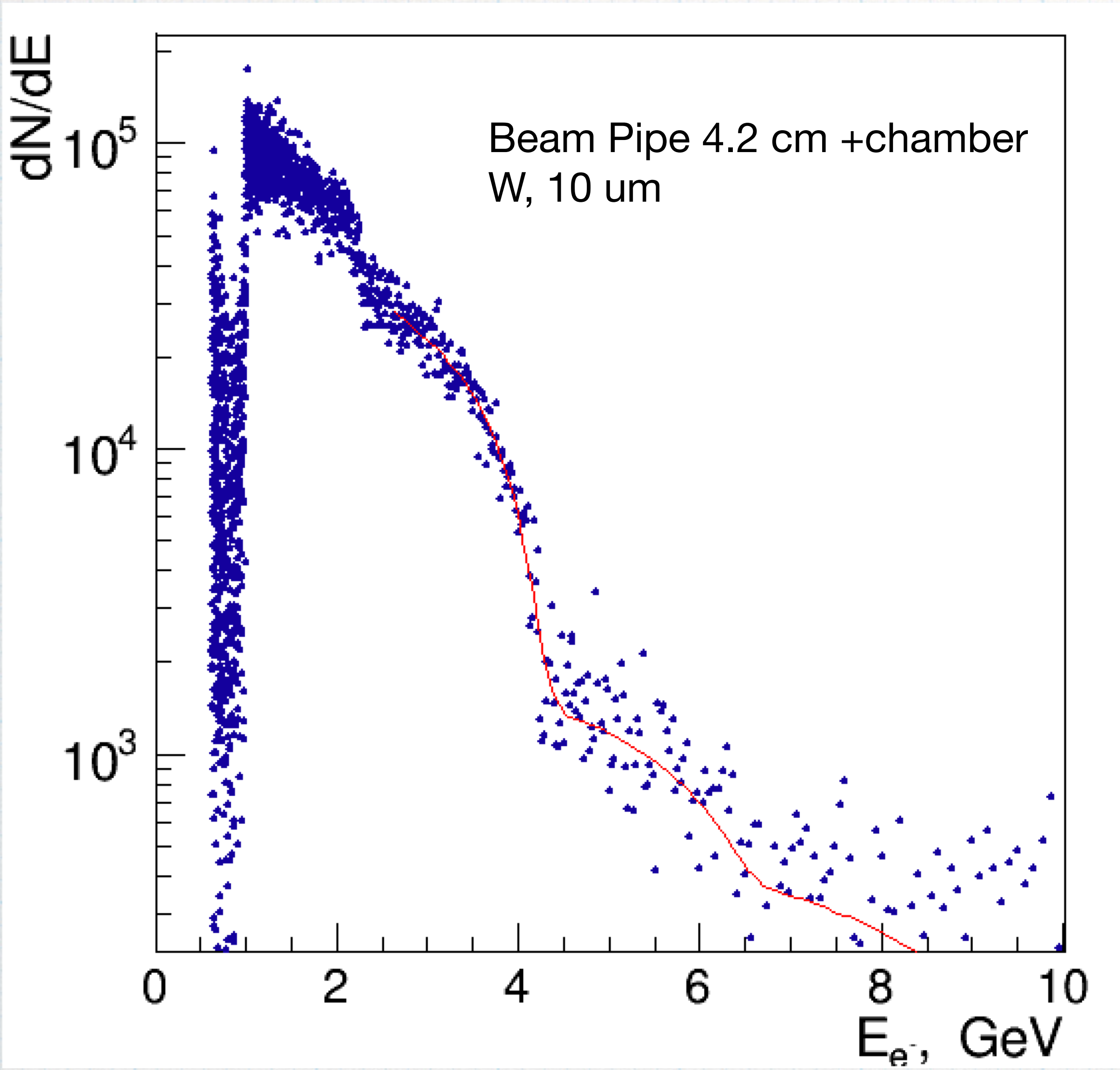


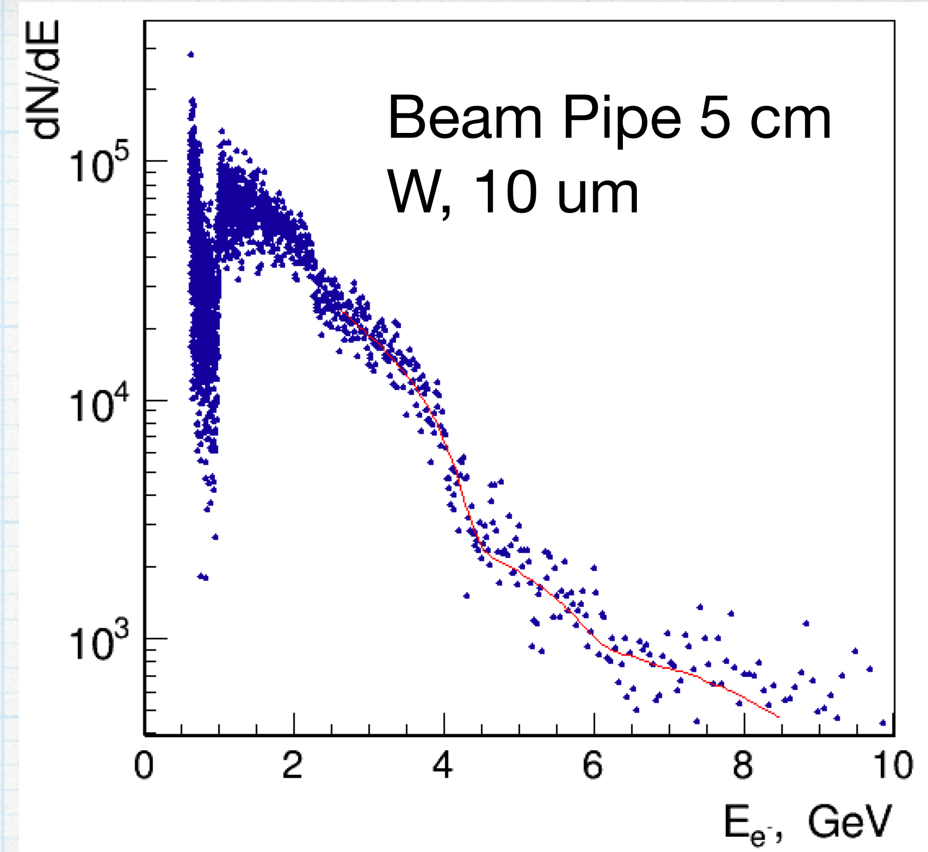


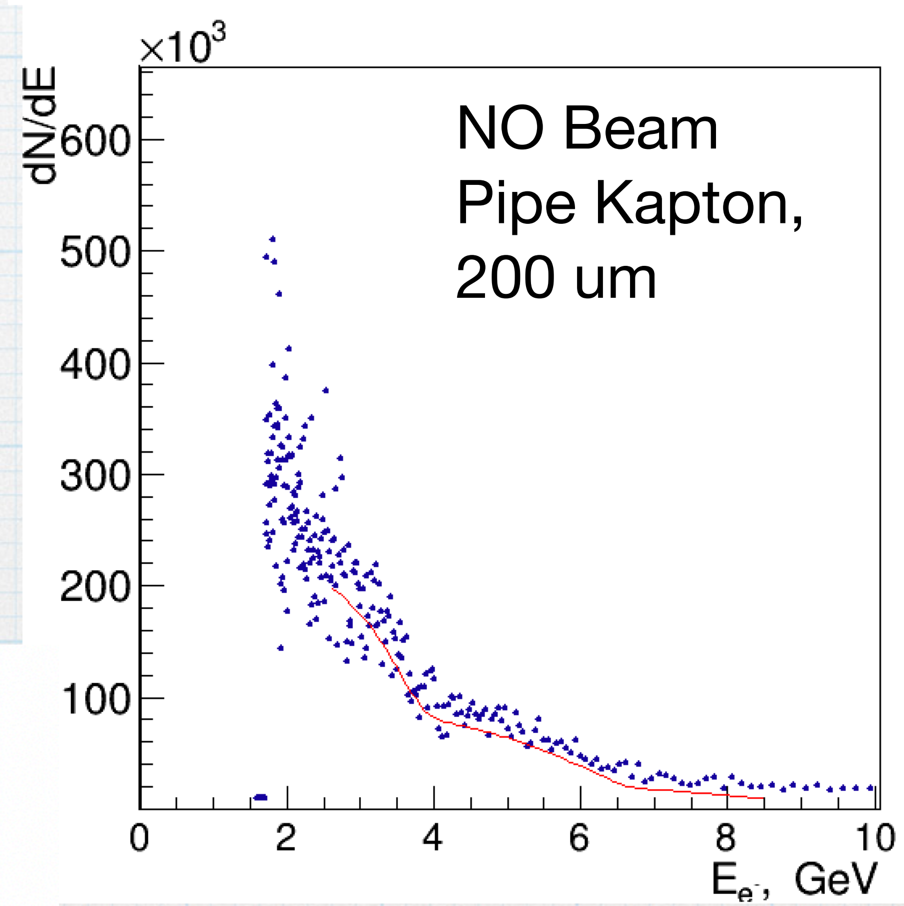




Reconstruction








```
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
```

Finite Impulses Response Filter (FIR)

method used by J. List et. al.

Finite Impulses Response Filter

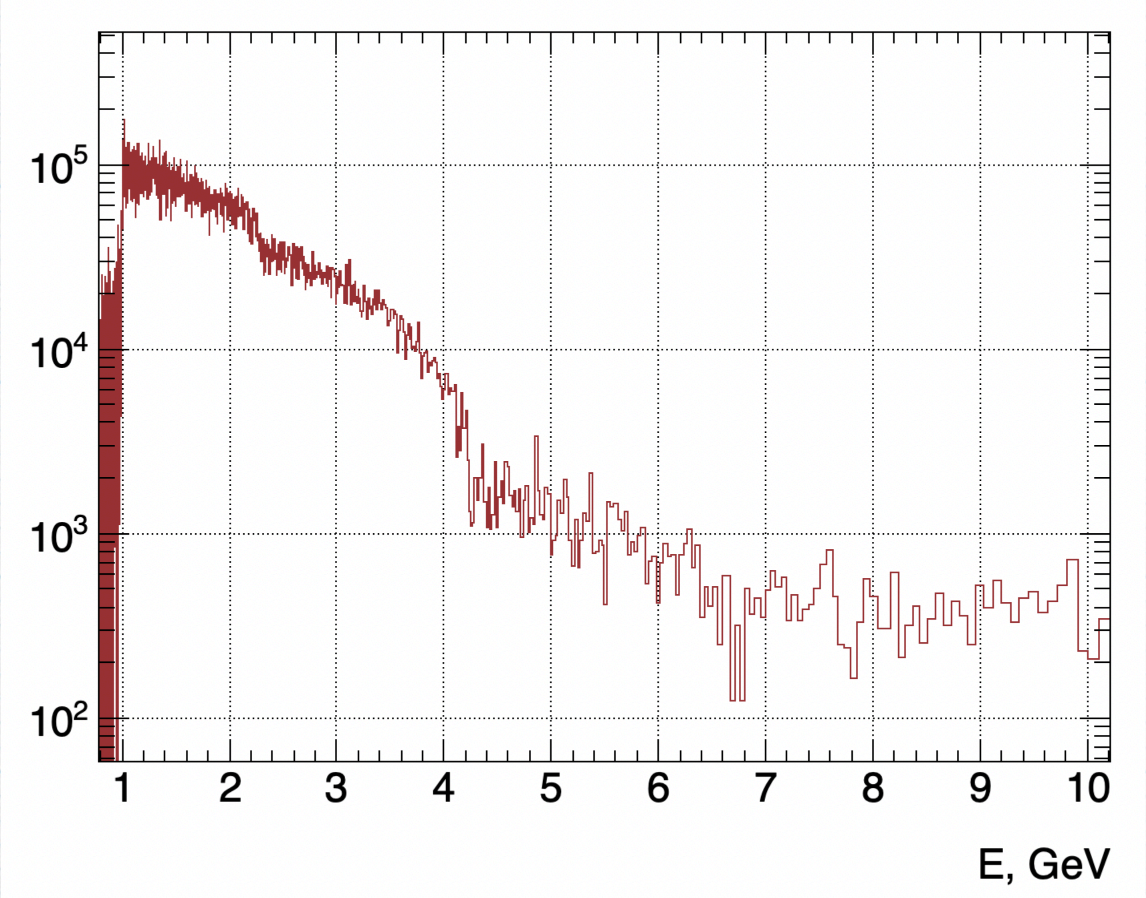
- edge-like features in function **g(x)** can be identified by maxima in the convolution **R(x)=h(x)∗g(x)** where **h(x)** is a matched filter
- **R(x)** is called the **Response**
- we have discrete data points **x=**$(x_0,\ldots,x_i)$, need discretized Response $R_d(i)$

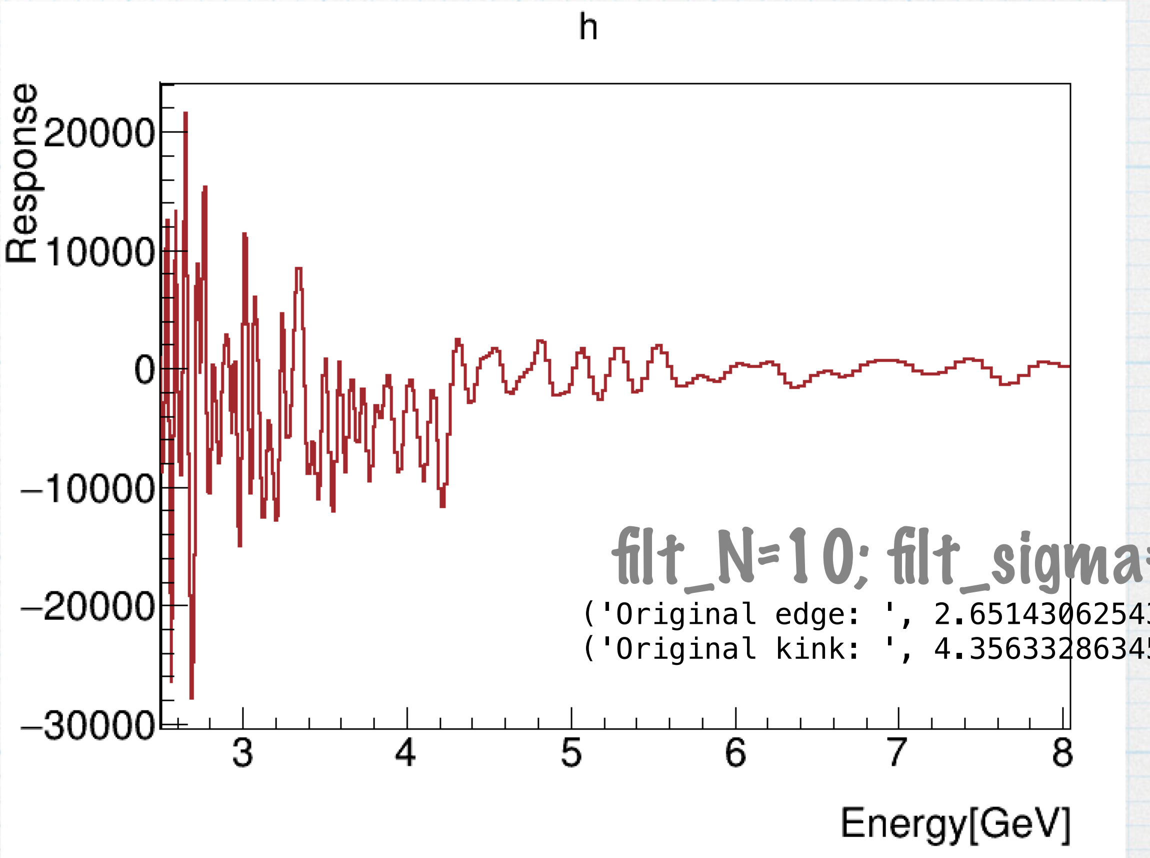
$$R_d(i) = \sum_{k=-N}^{N} h_d(k) \cdot g_d(i-k)$$

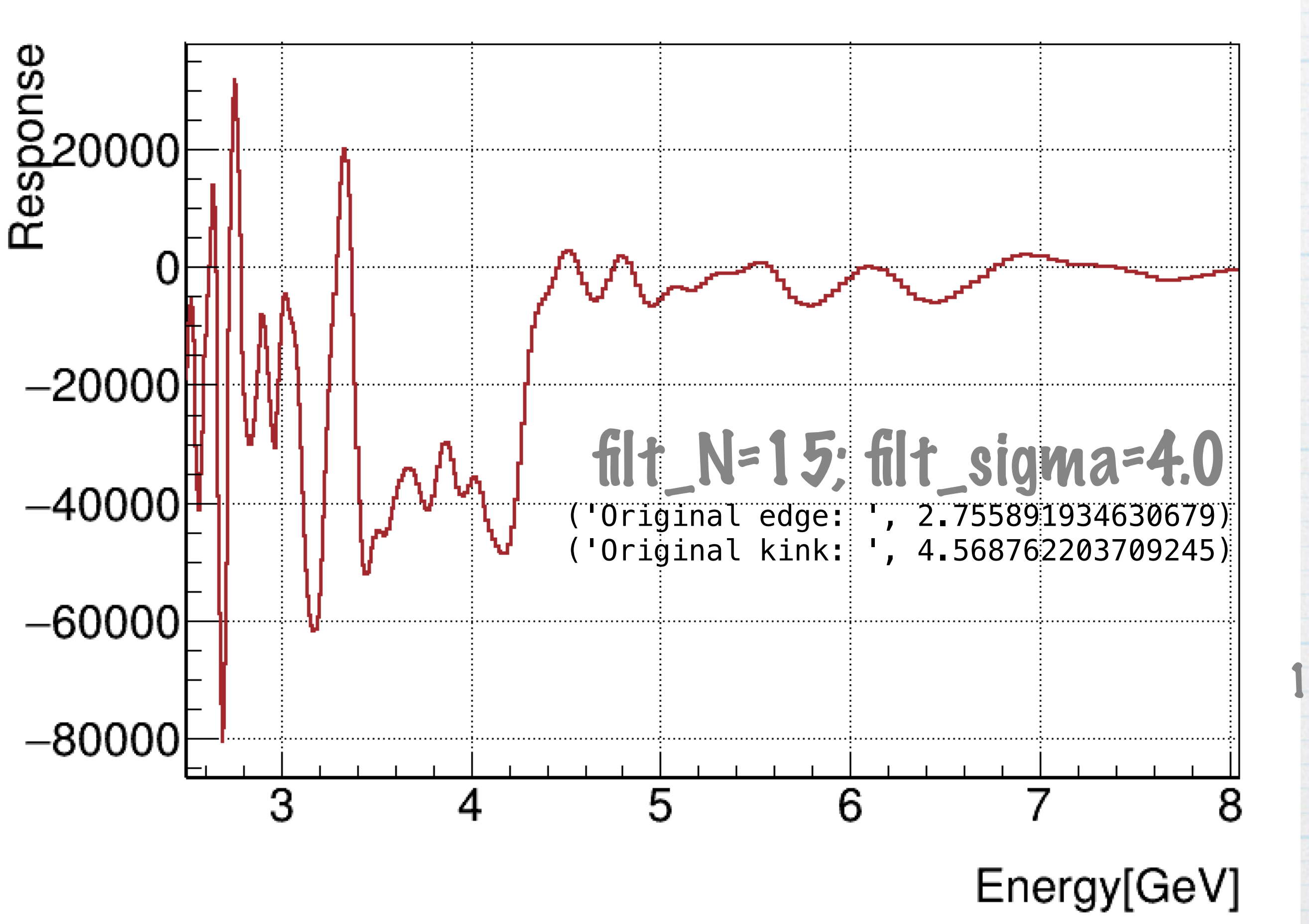
- different filters h_d available, optimal choice depends on the function g(x)
- Used here: **First derivative of a Gaussian (FDOG)**

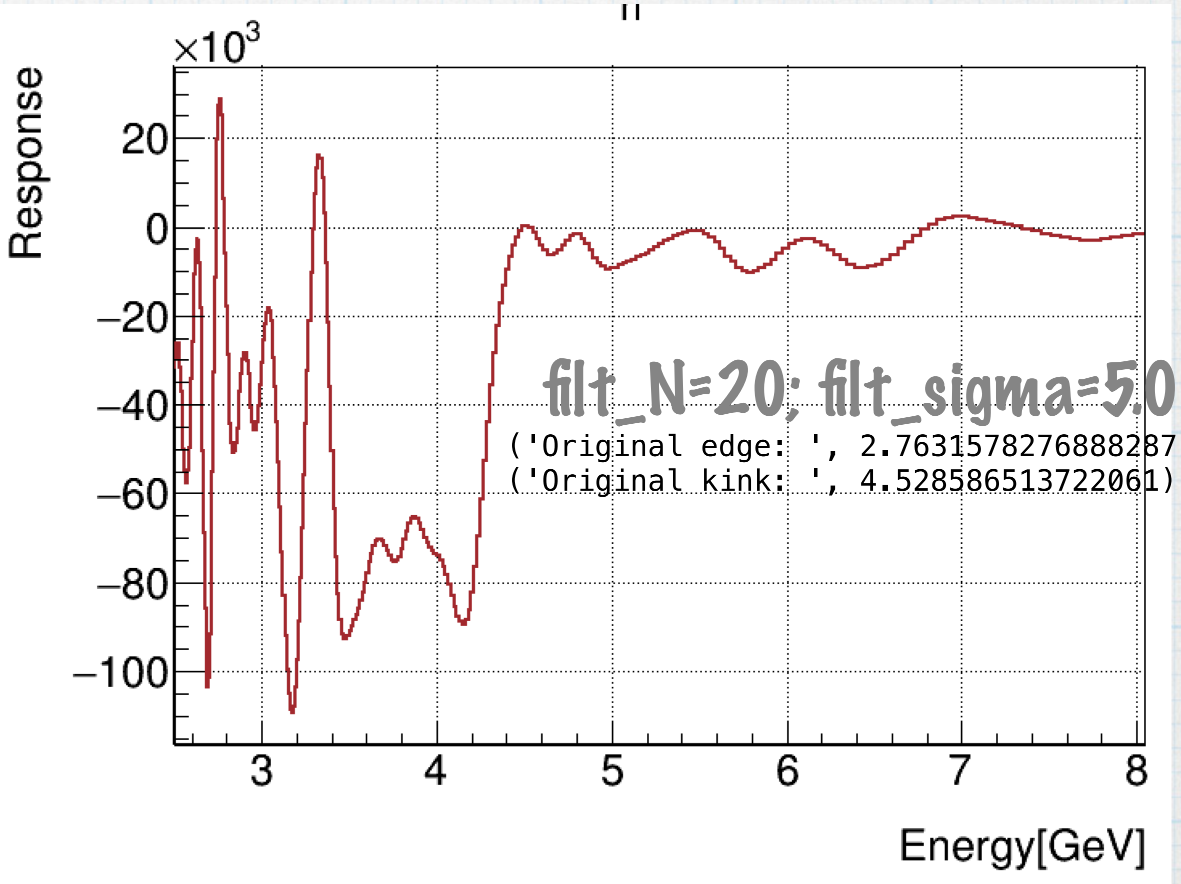
$$h_d(k) = -k \exp\left(-\frac{k^2}{2\sigma^2}\right) \text{ for } -N \le k \le N$$

Reconstruction with FIR









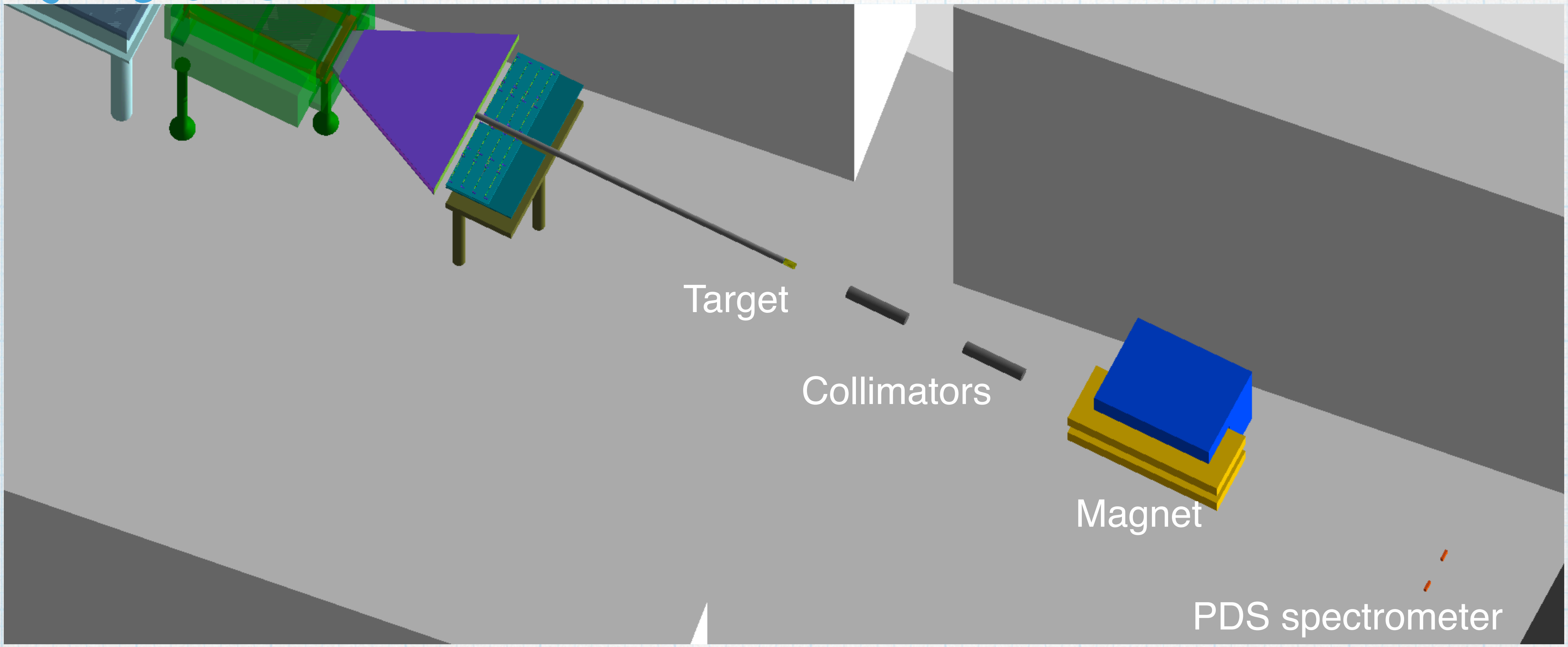
Summary

* The performance of FDS setup was compared with and without beam pipe from the target to Gamma spectrometer detectors
* Beam pipe with vacuum and target provide more clean signal formation
* Without beam pipe, air material thickness ~16 times bigger than Kapton target (window). More than 90% of e-/e+ pairs are generated in the air and about 30% of them in the magnet, so they experience shorter magnetic field and have wrong position in detector. It has a negative effect on spectrometer performance.
* Considering that bremsstralung rate is roughly the same as pair production, electrons and positrons will lose their energy in the air. It will also have negative impact on spectrometer measurements.
* 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. In this case they would not affect the signal in spectrometer.
* The first kinematic edge at 4.2GeV is clearly better observed in detector for the case with the pipe and pipe with chamber.
* Signal/Background is twice better for the case with the beam pipe

Back up

Intro

PDS - Photon Detector system



Direct electron-Beam Laser interaction

$e+n\omega \to e+\gamma$

Tasks at hand:

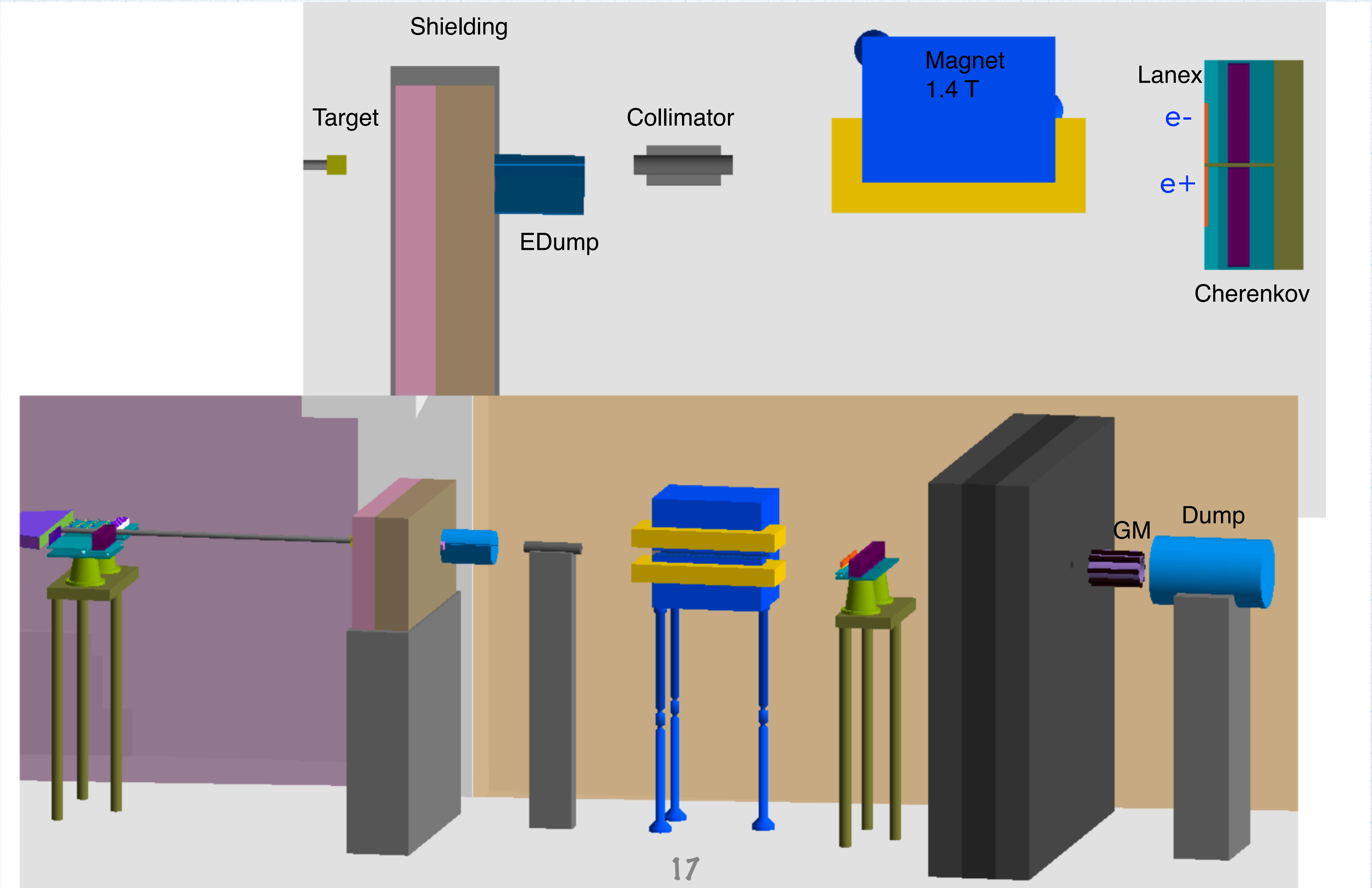
I measure HICS energy spectrum.

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

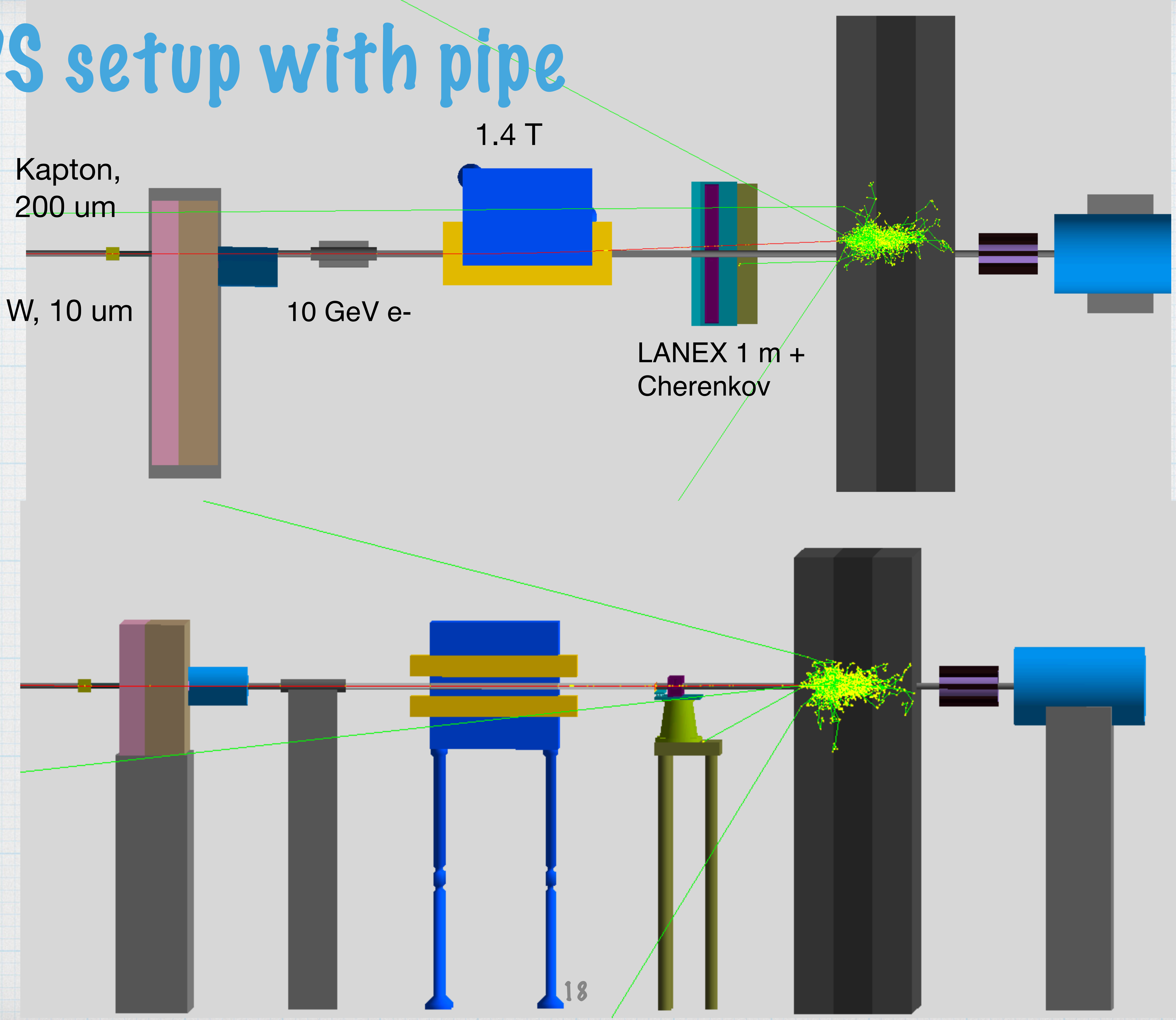
II measure absolute number of photons on event-by-event basis.

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

Forward detector system w/o beam pipe



FDS setup with pipe



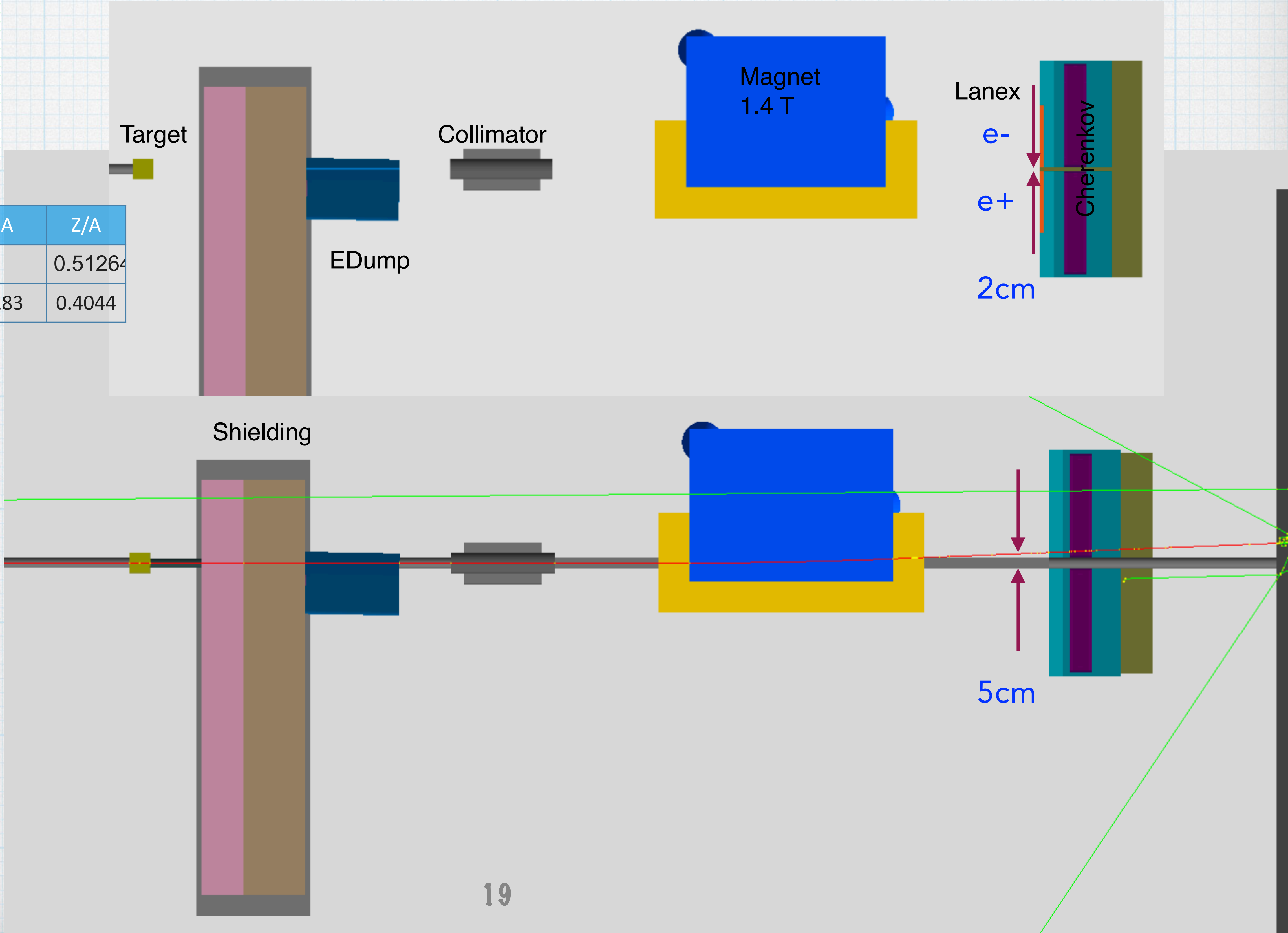
Forward detector system with & w/o beam pipe

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

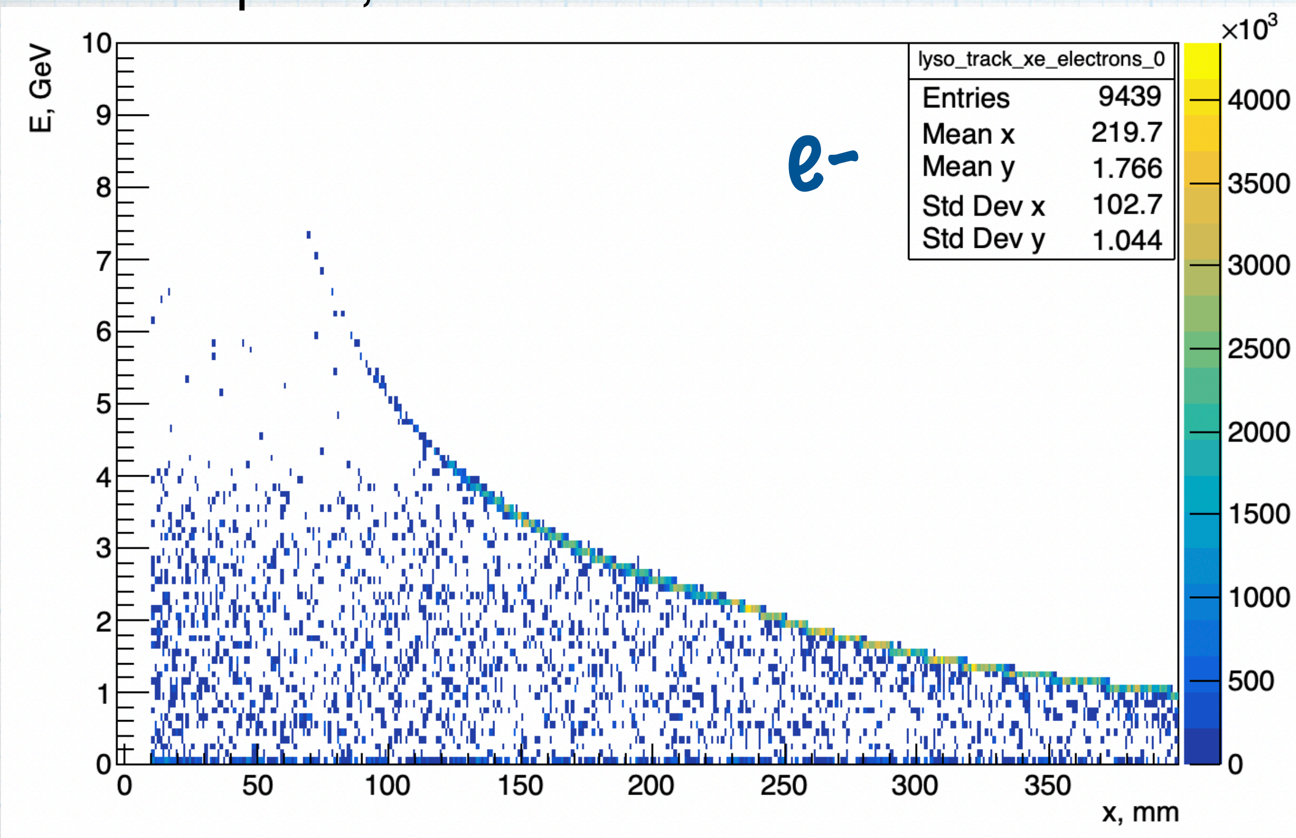
Material	X0,(cm)	Z	A	Z/A
Kapton	28.57			0.51264
Tungsten	0.35	74	183	0.4044

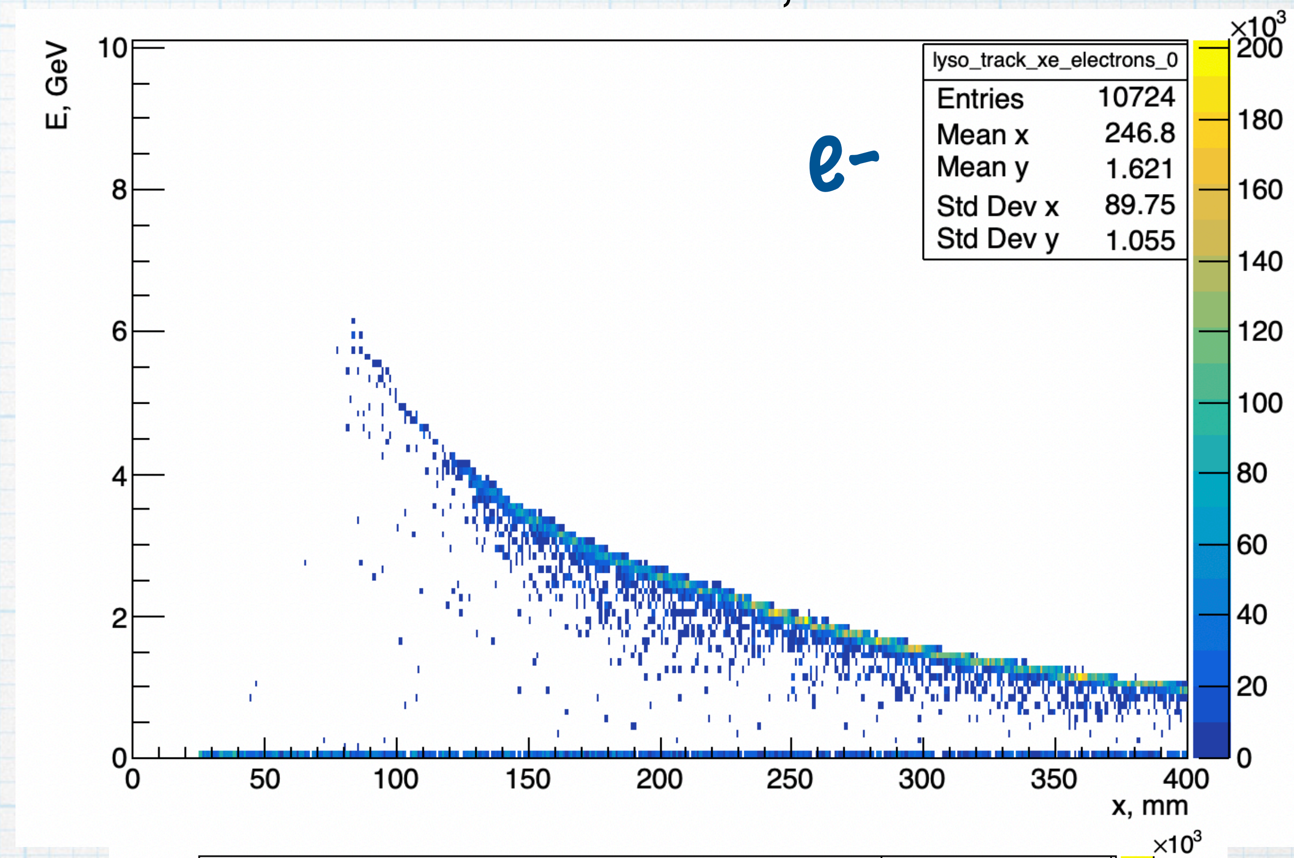


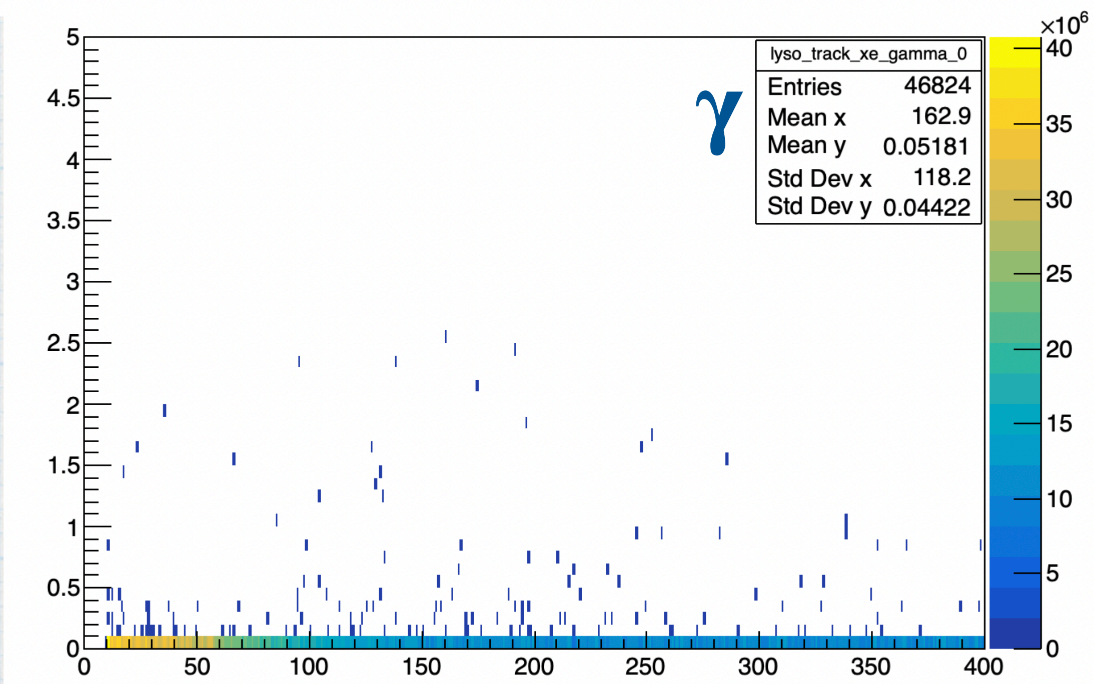
Energy vs position

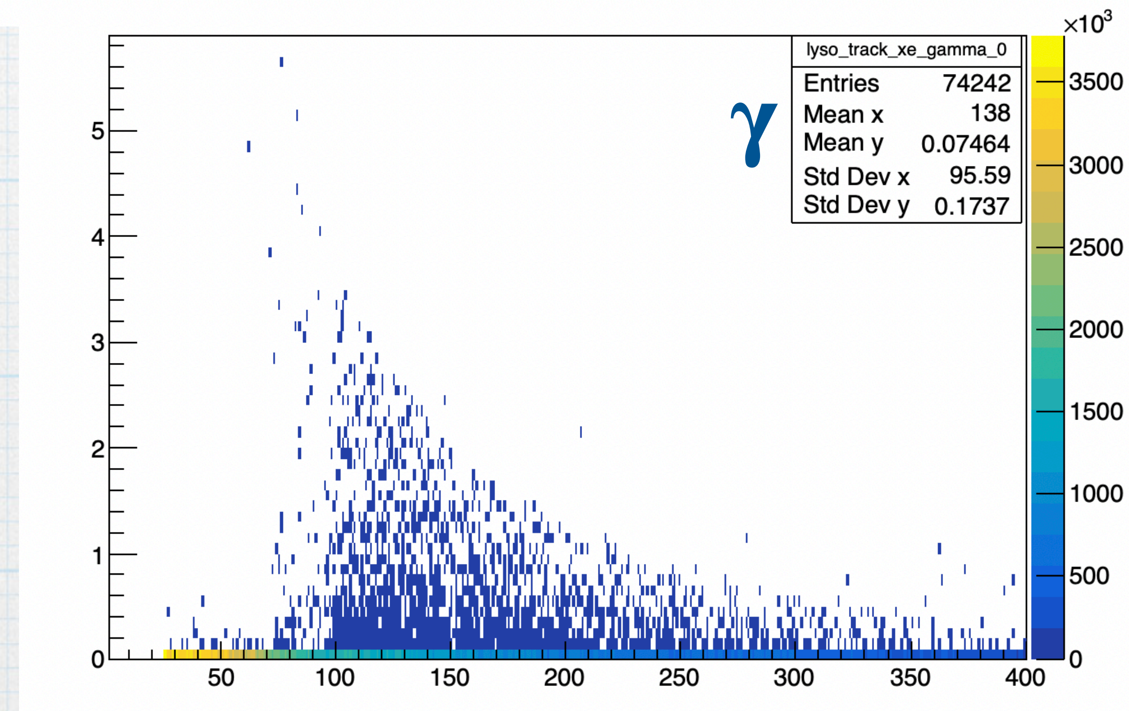
NO Beam Pipe
Kapton, 200 um

Beam Pipe 5 cm
W, 10 um





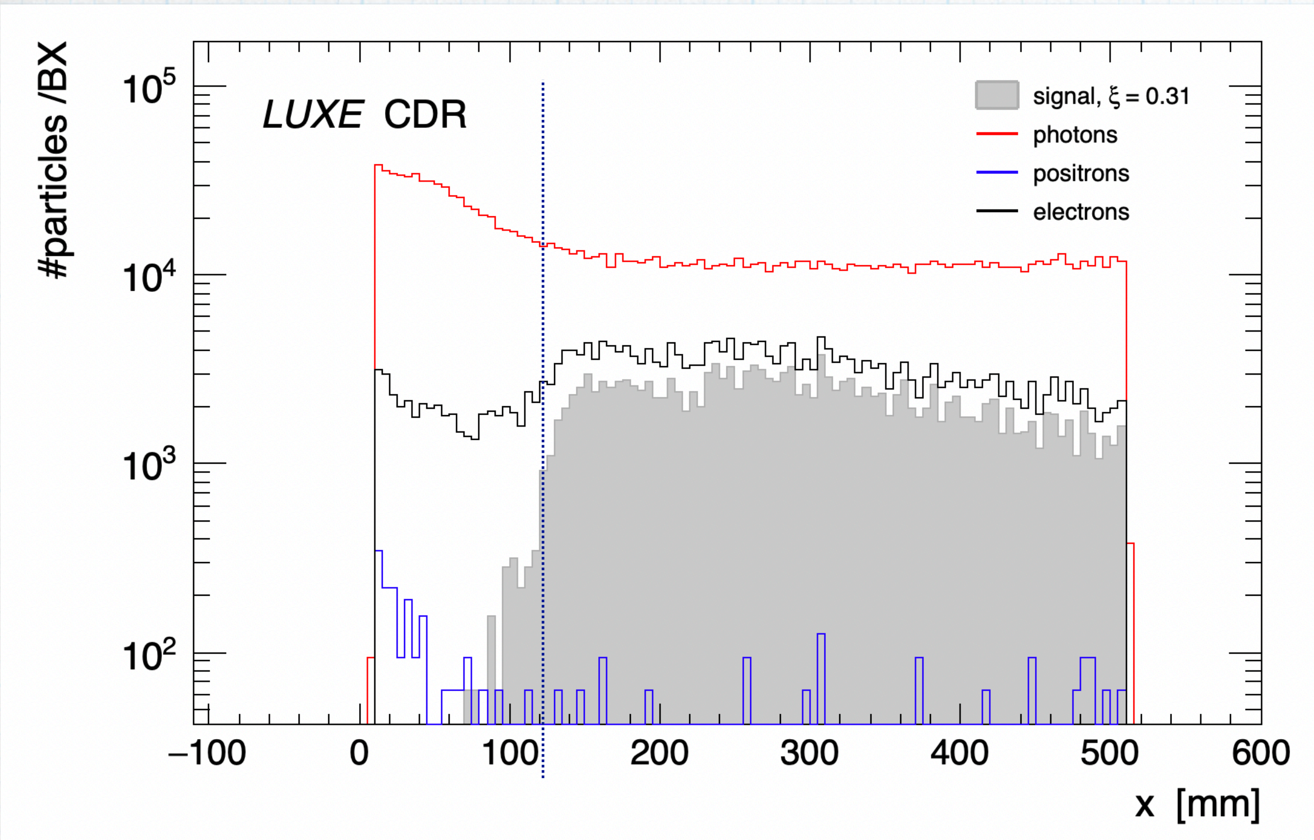




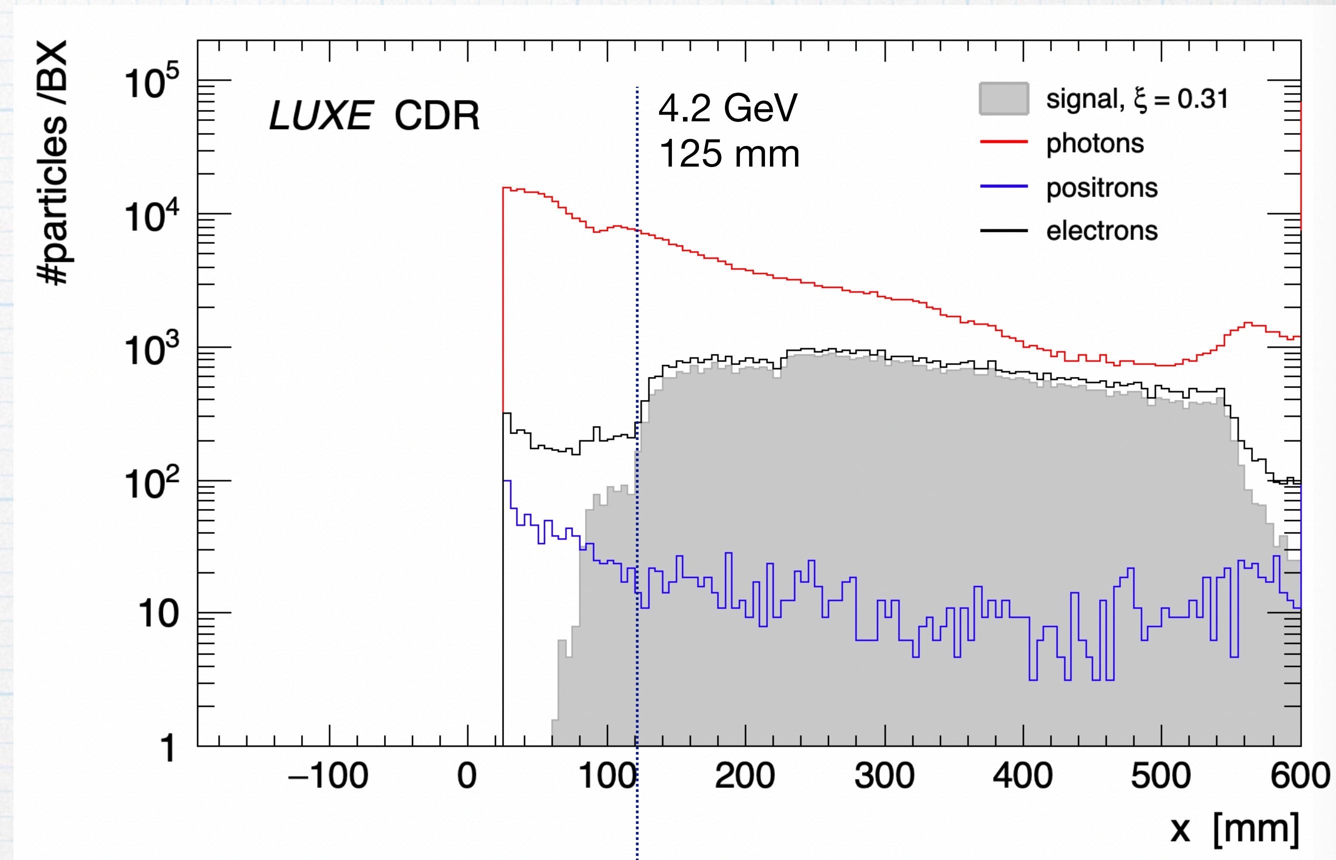
Electron Energy-position correlation is cleaner in case of beam pipe and photons distribution shows that they were produced after the electron direction was defined.

Particles in electron arm

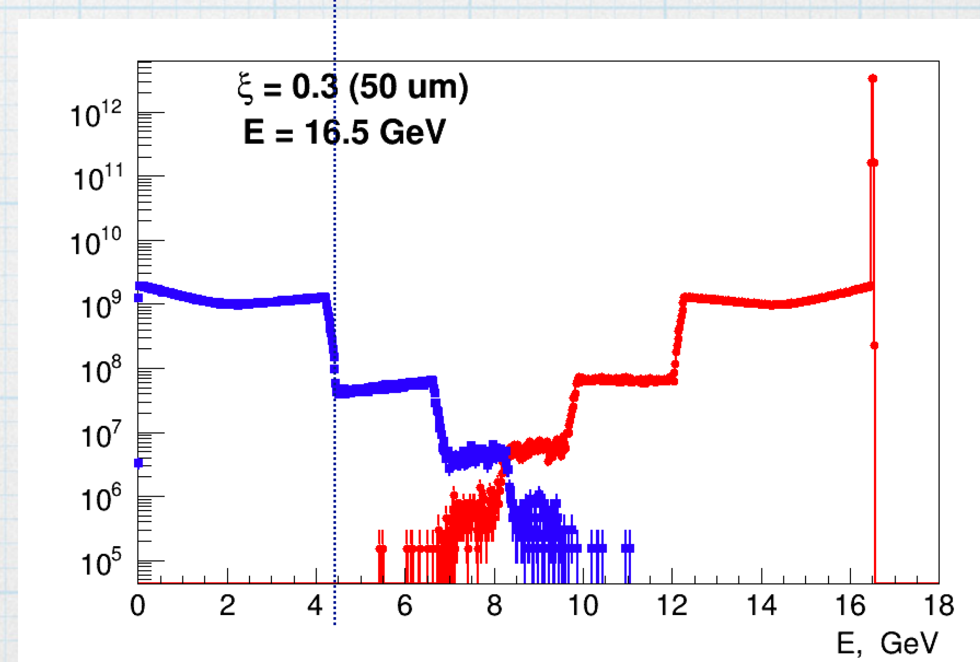
NO Beam Pipe
Kapton, 200 um



Beam Pipe 5 cm
W, 10 um



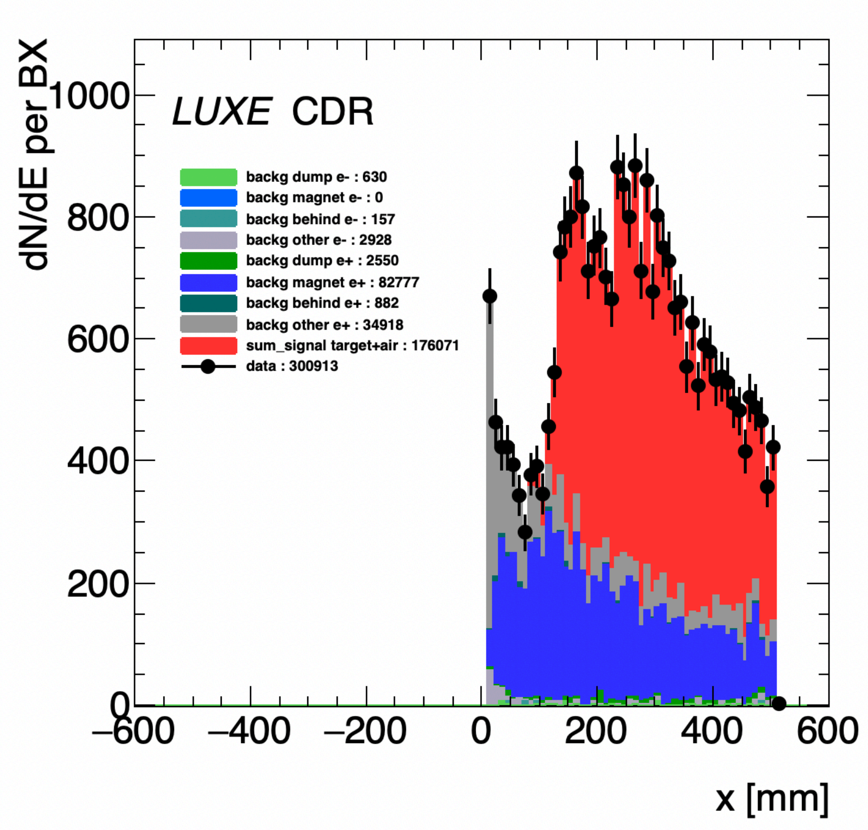
Material	X0,(cm)	Thickness	Fraction X0
Air	3.04E+04	350	1.15 %
Kapton	28.57	2.00E-02	0.07 %
Tungsten	0.35	1.00E-03	0.3%

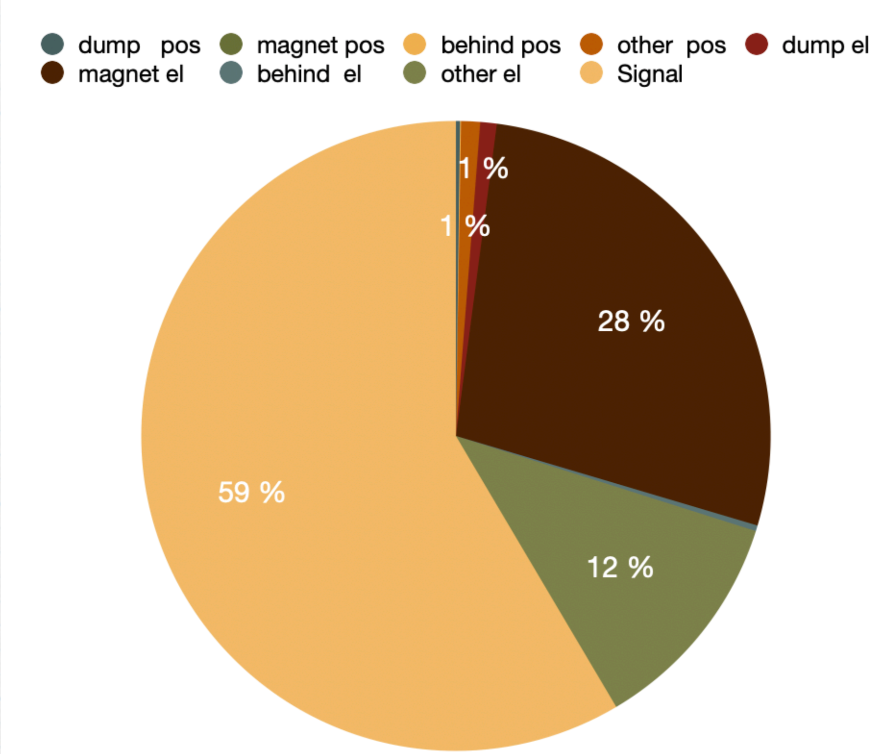


The first kinematic edge at 4.2GeV is clearly better observed in detector for the case with the pipe.

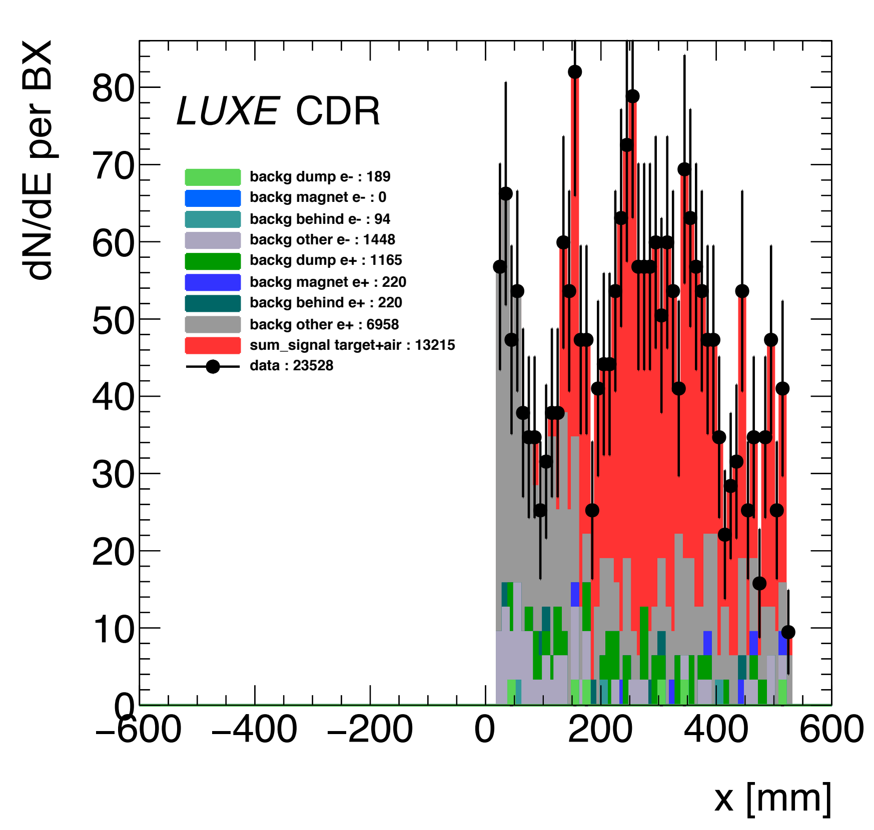
* S/B ratio: Electron arm of Lanex Spectrometer, x-distributions

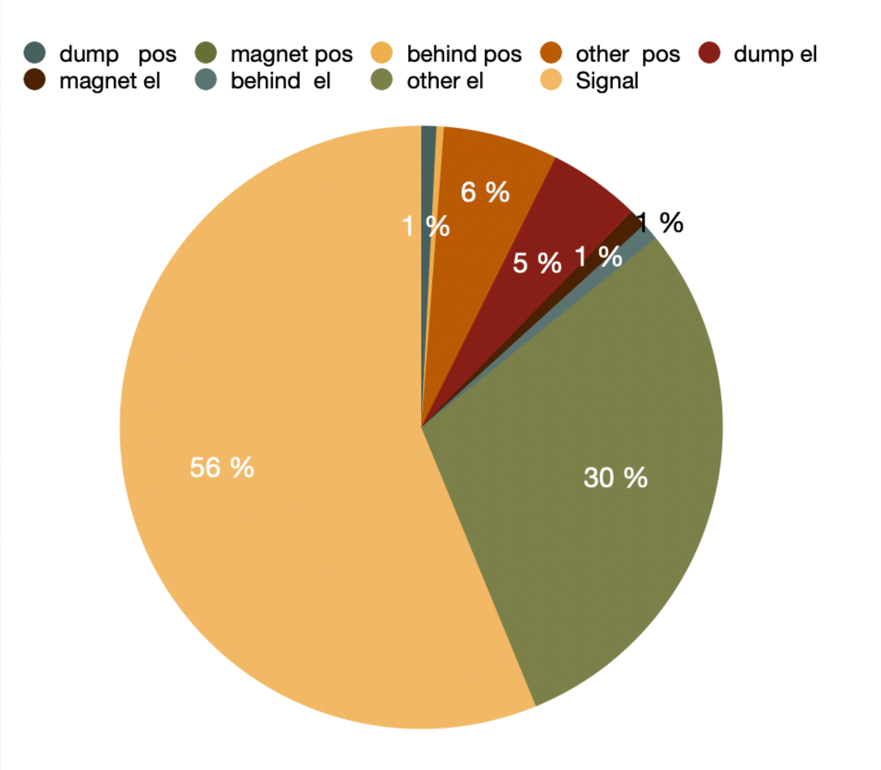
NO Beam Pipe
Kapton, 200 um



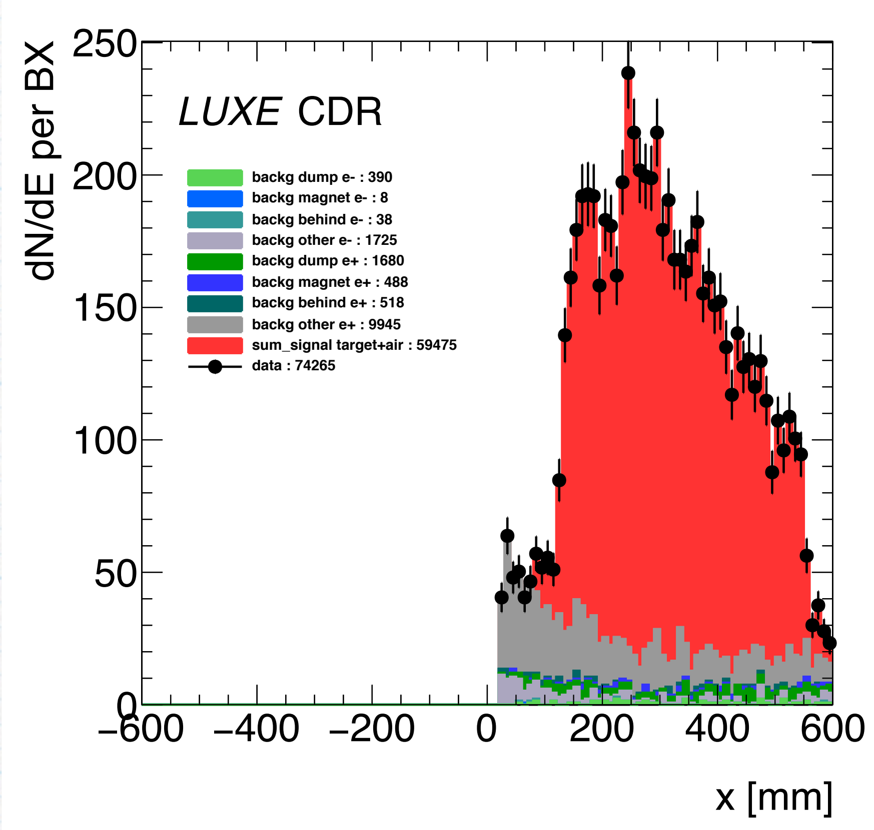


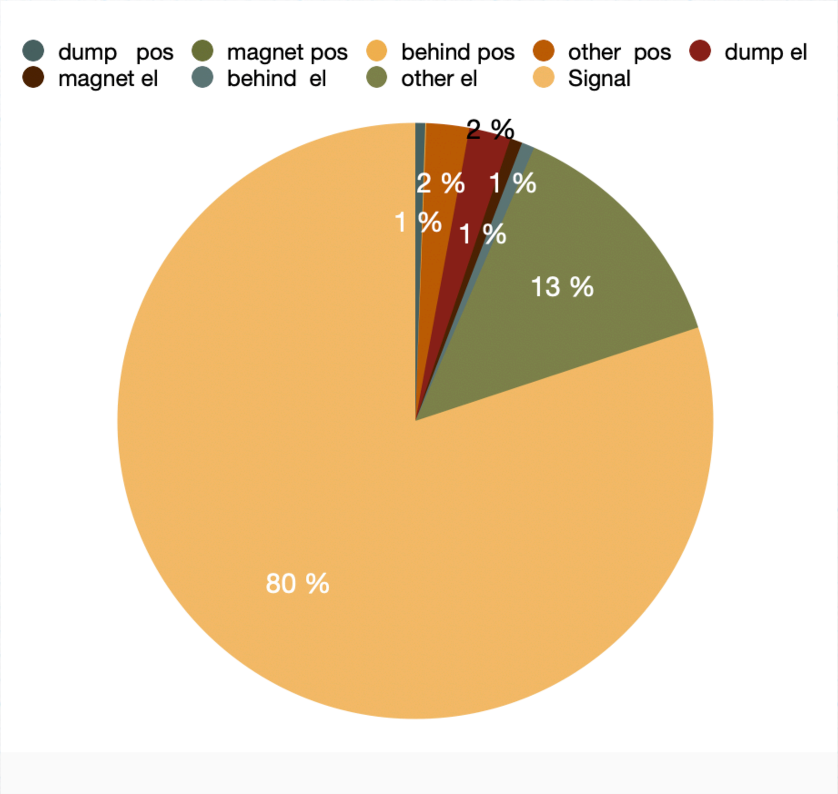
Beam Pipe 5 cm
Kapton, 200 um



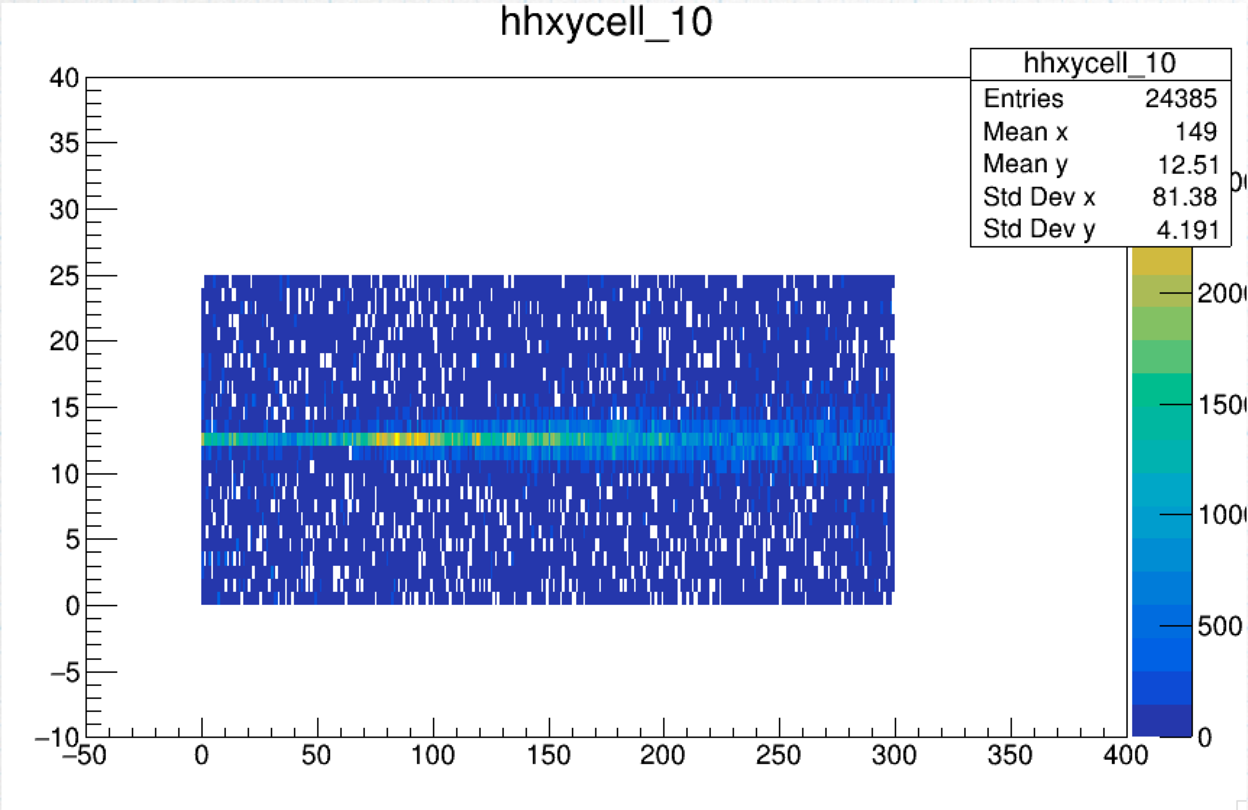


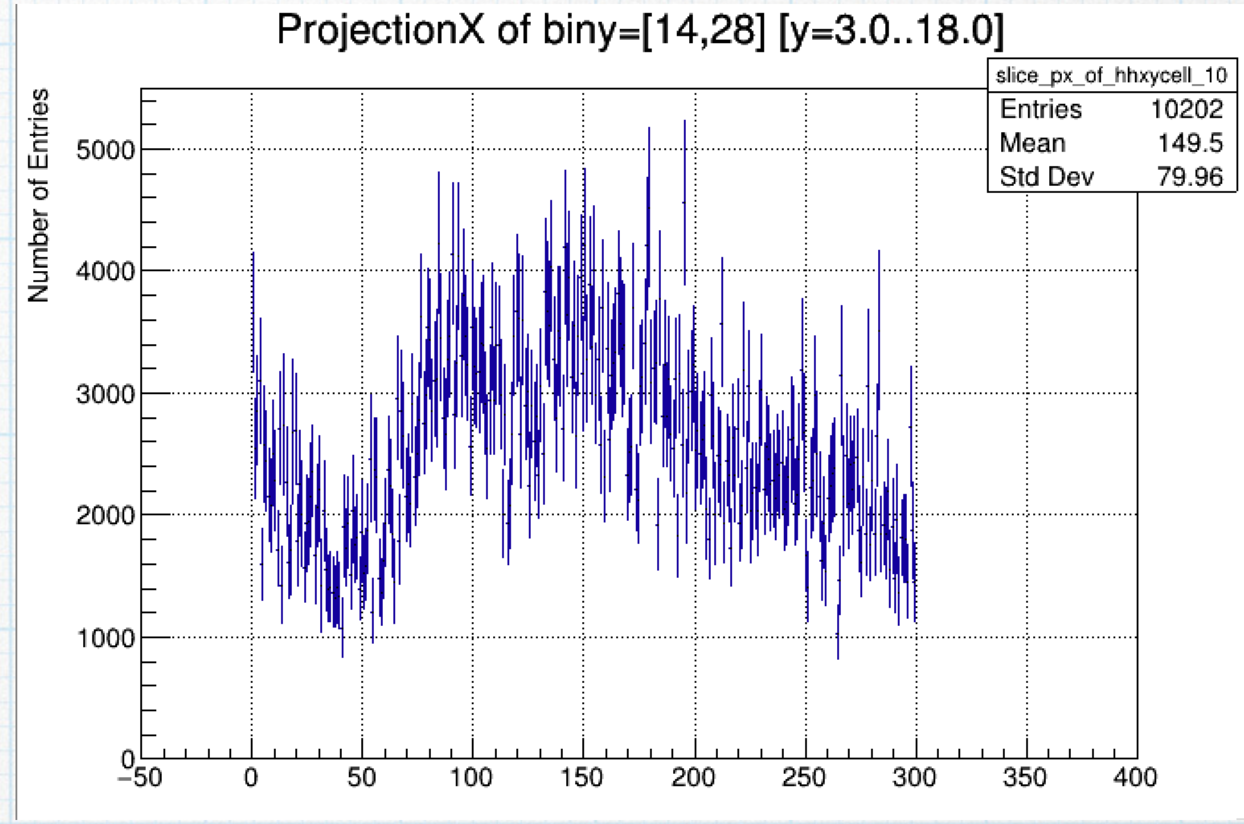
Beam Pipe 5 cm
W, 10 um

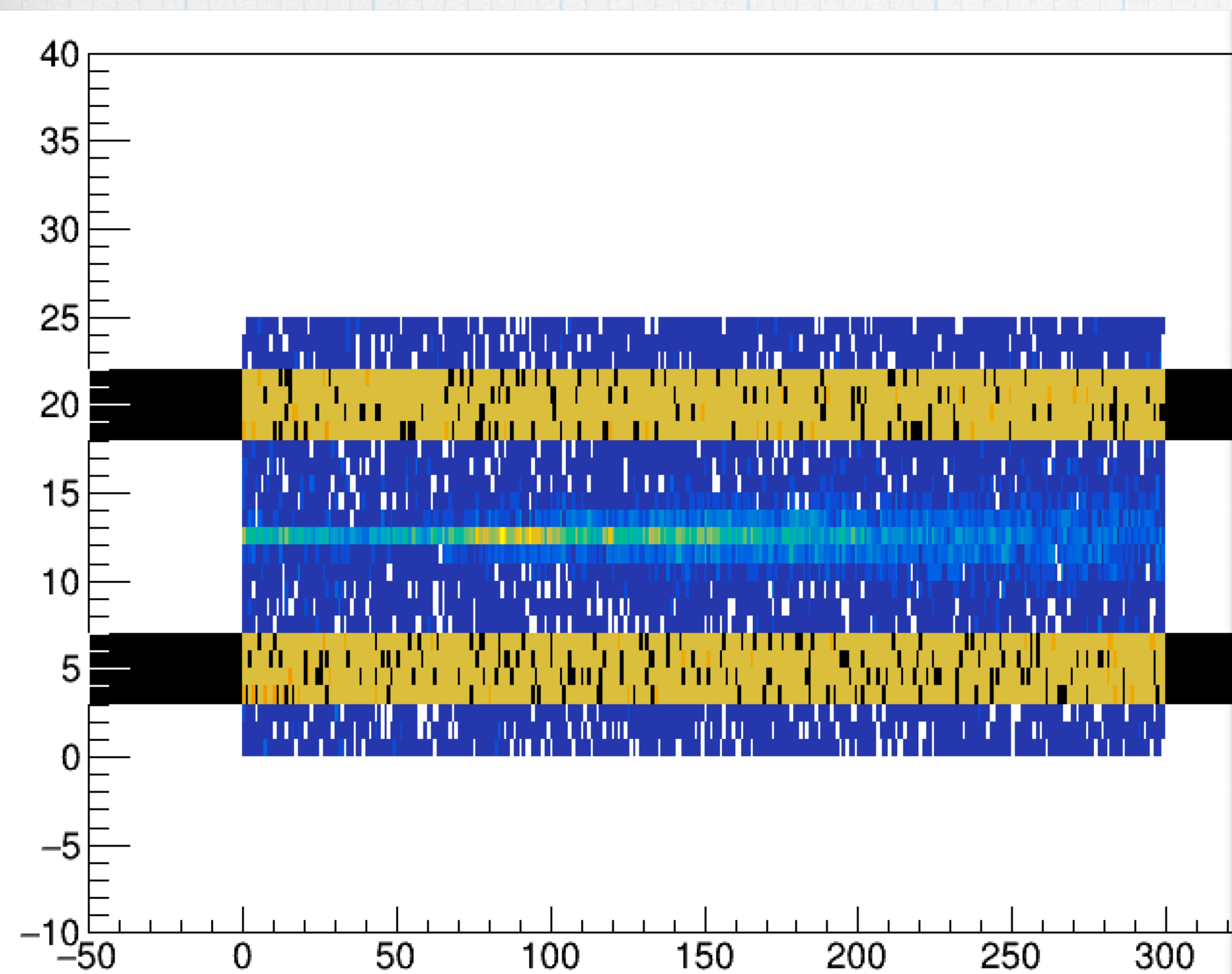


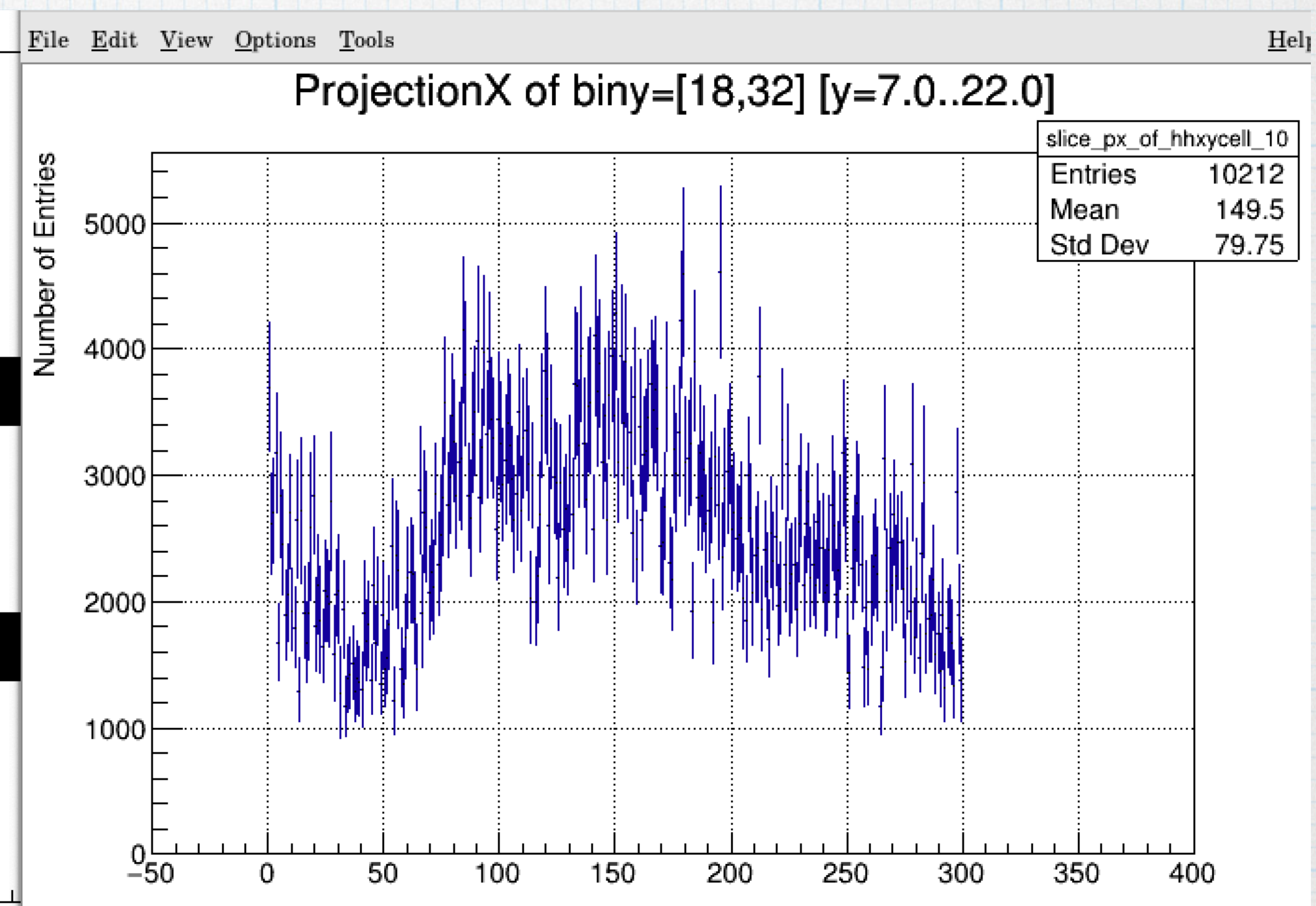


Reconstruction

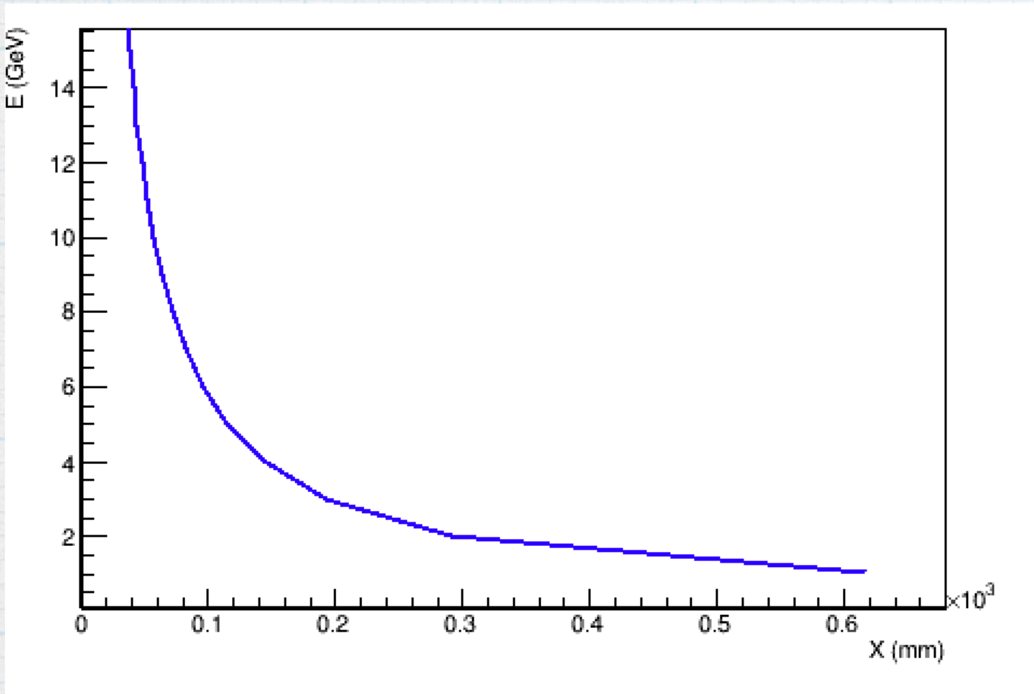

hhxycell_10
hhxycell_10
Entries 24385
Mean x 149
Mean y 12.51
Std Dev x 81.38
Std Dev y 4.191

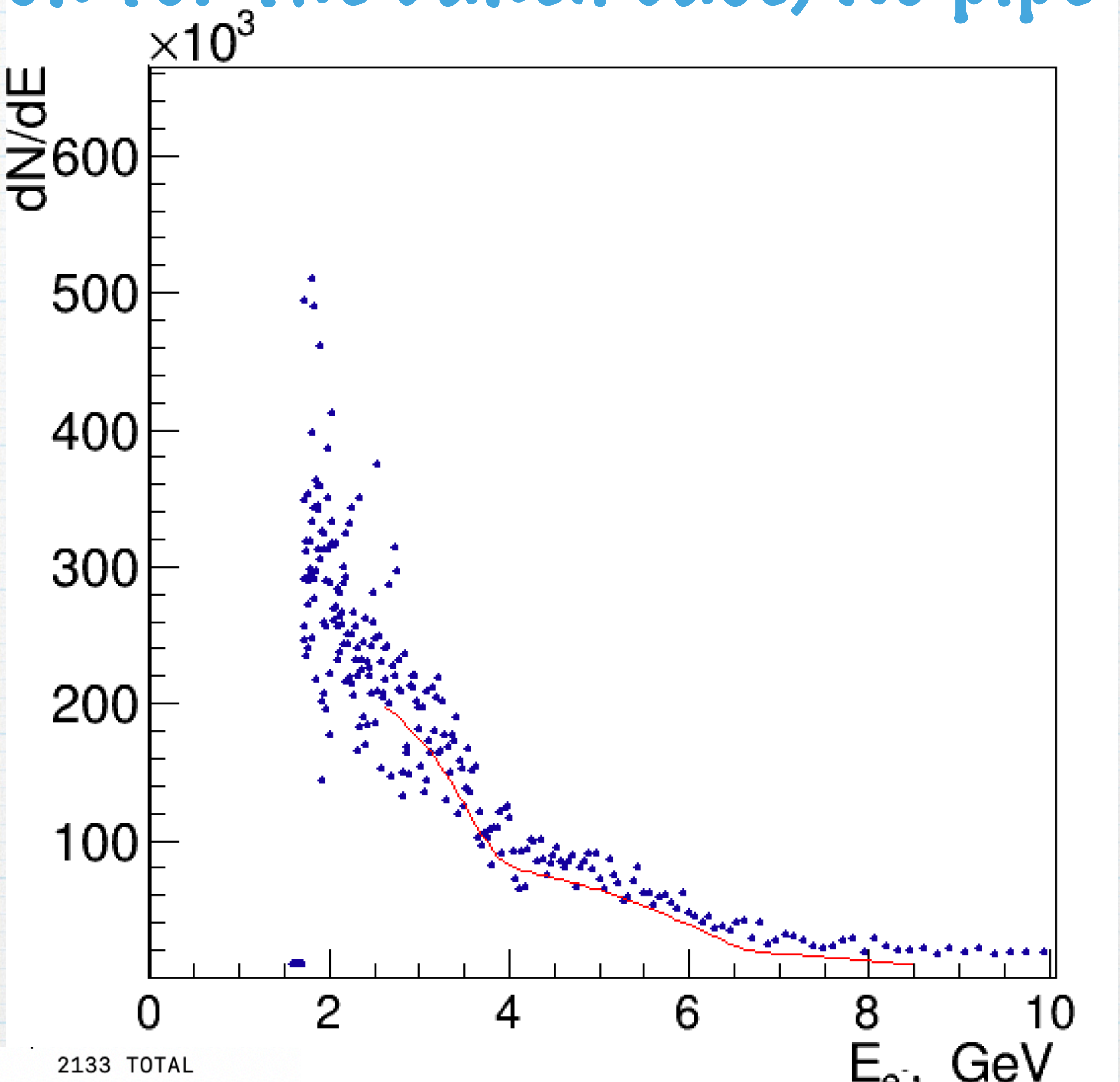

ProjectionX of biny=[14,28] [y=3.0..18.0]
slice_px_of_hhxycell_10
Entries 10202
Mean 149.5
Std Dev 79.96
Number of Entries




File Edit View Options Tools
ProjectionX of biny=[18,32] [y=7.0..22.0]
slice_px_of_hhxycell_10
Entries 10212
Mean 149.5
Std Dev 79.75
Number of Entries

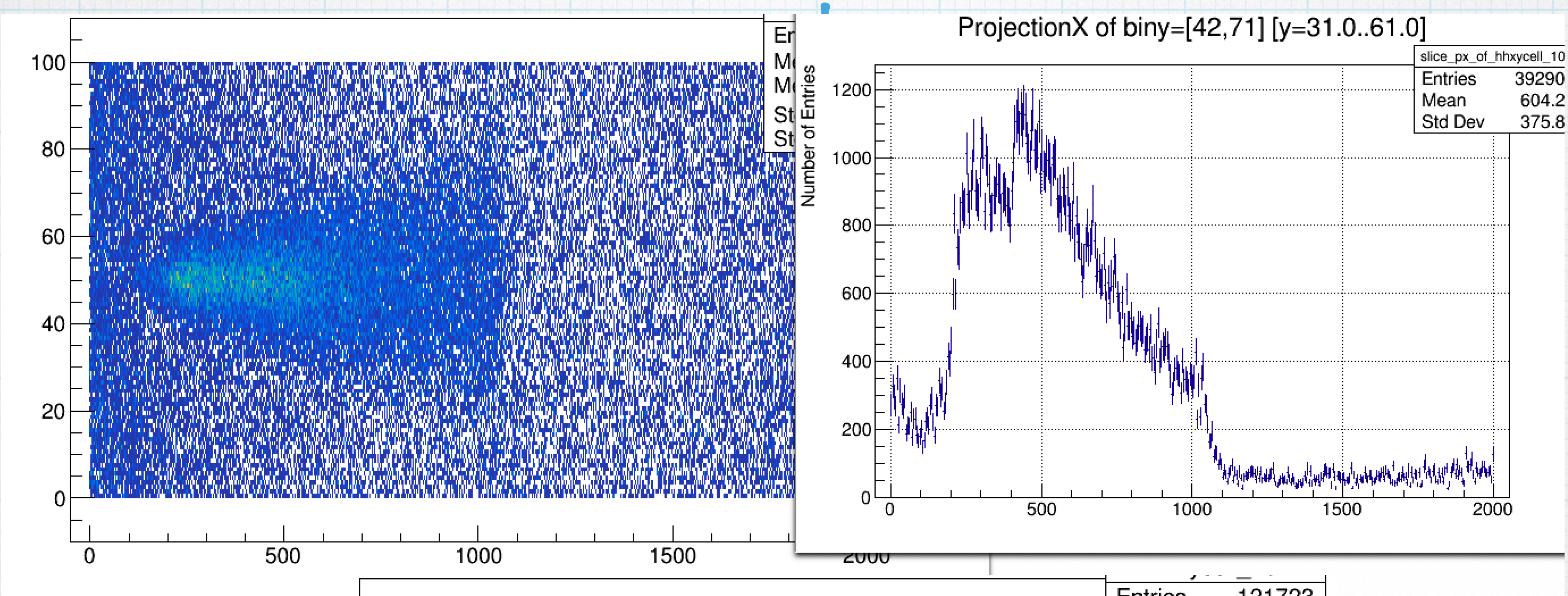
Spectra reconstruction for the Lanex case, No pipe

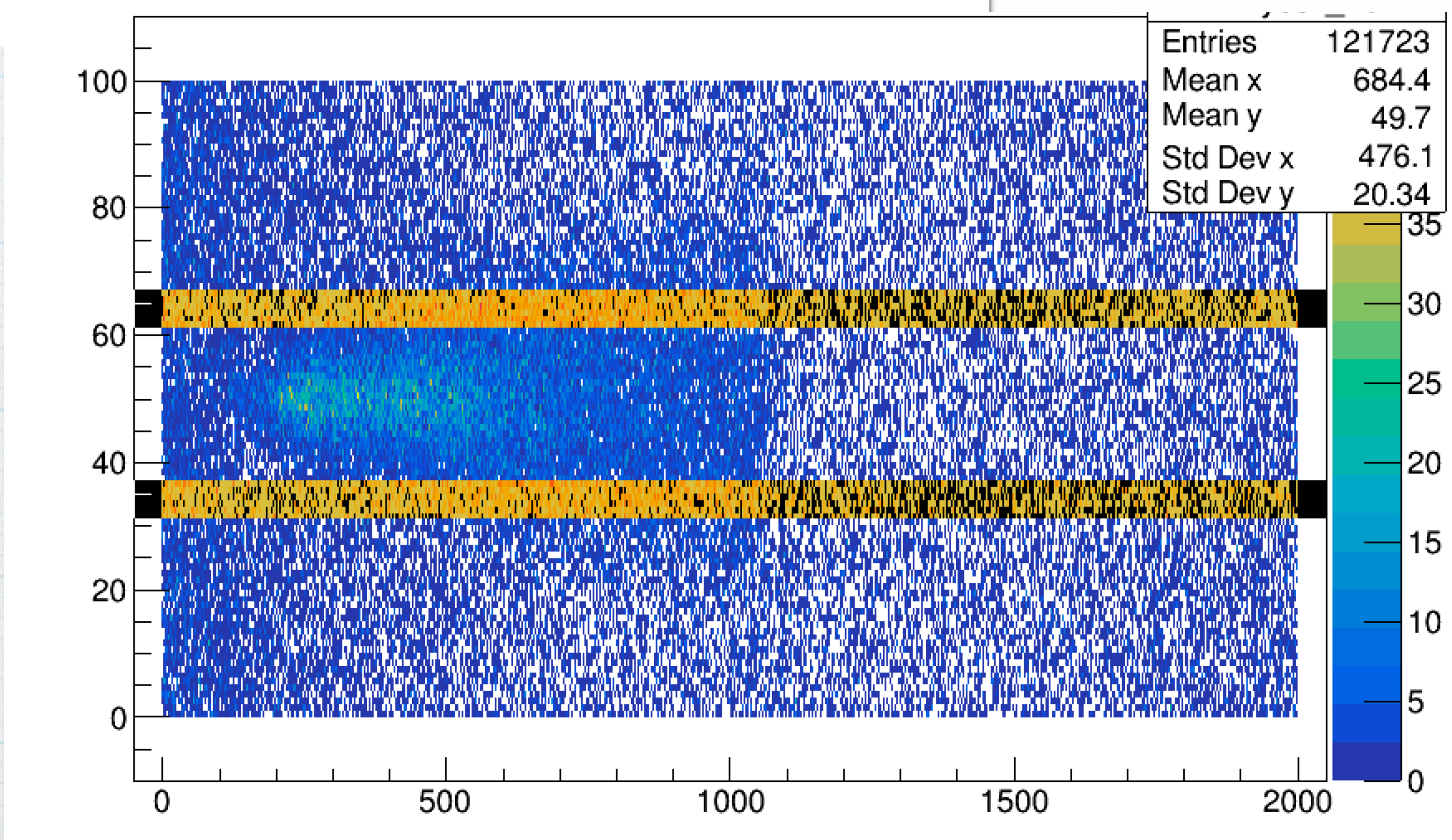




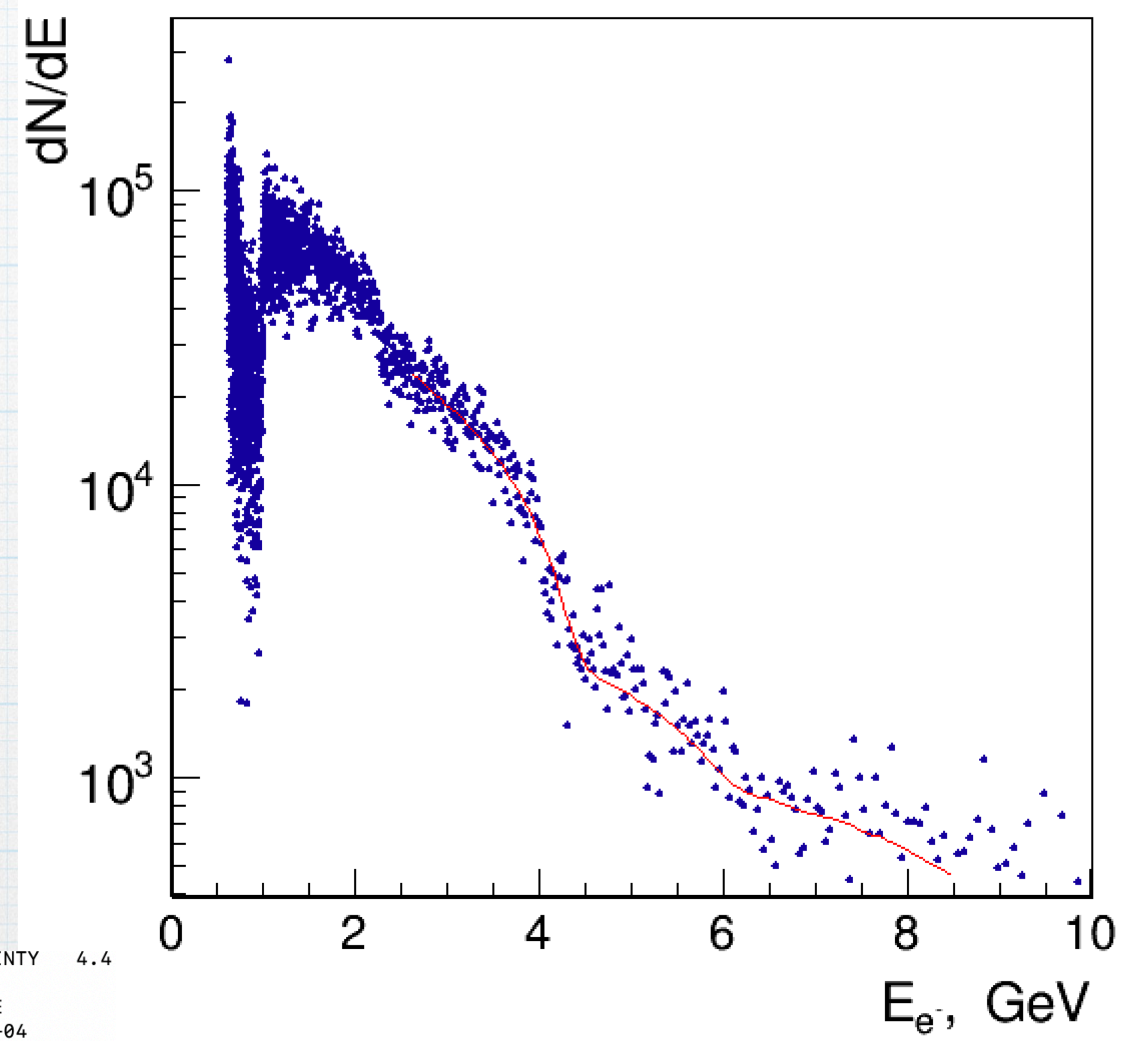

```
FCN=154.23 FROM MIGRAD    STATUS=CALL LIMIT    2132 CALLS       2133 TOTAL
                     EDM=0.000122625    STRATEGY= 1      ERR MATRIX NOT POS-DEF
 EXT PARAMETER                APPROXIMATE        STEP         FIRST
 NO.   NAME      VALUE            ERROR          SIZE      DERIVATIVE
  1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



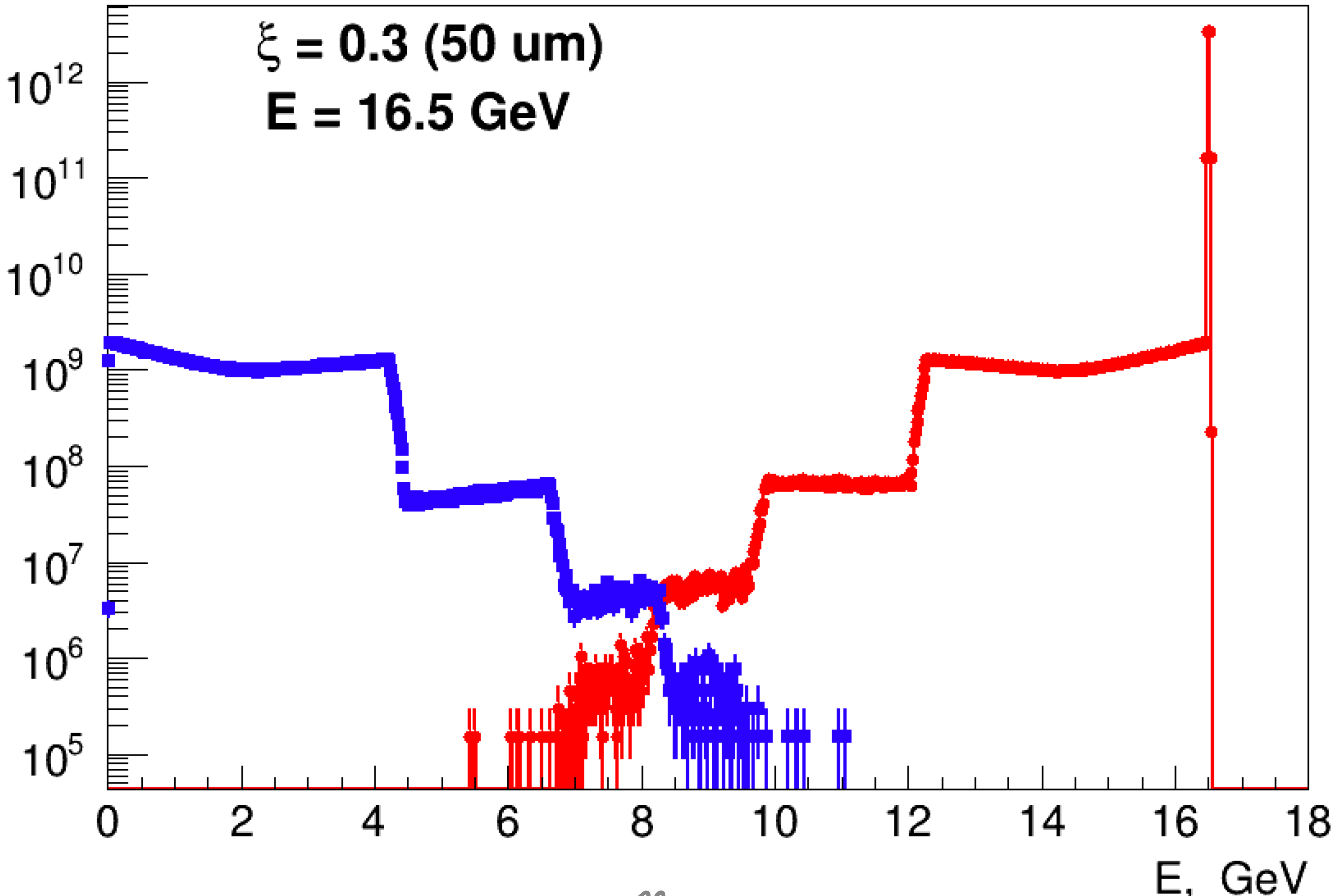
EDM=12.7612 STRATEGY= 1 ERROR MATRIX UNCERTAINTY 4.4

EXT 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

True electron/photon spectra

4764BX out of 5000 BX at the laser intensity xi = 0.3 for 16.5 GeV electron beam

(~5% of files have NaN so they are ignored)



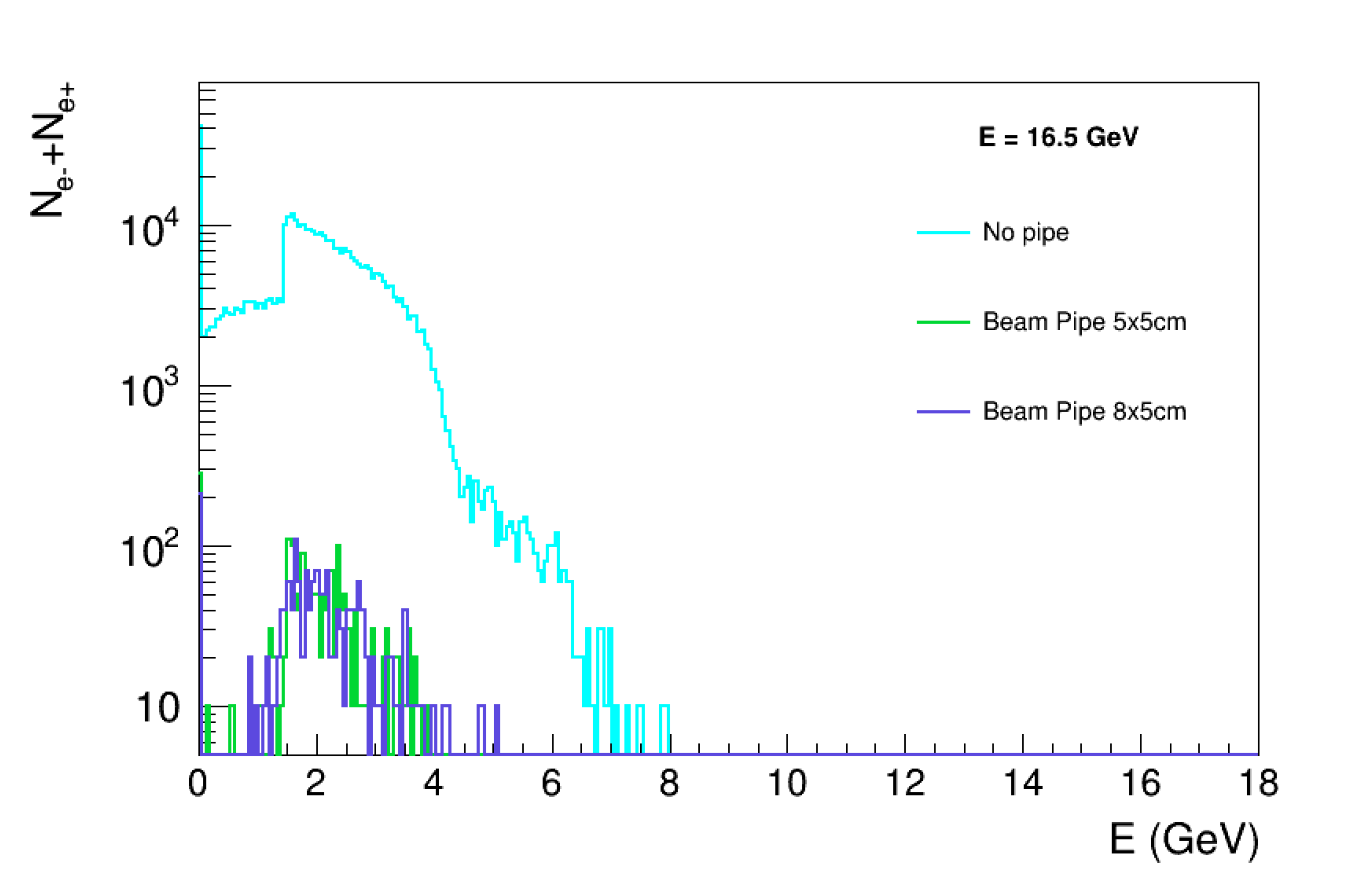
* Number of particles per BX hitting FDS spectrometers is 25 higher without beam pipe

* Without beam pipe we measure in Gamma spectrometer detectors a lot e-/e+ pairs that were created in the air. Only 4% e-/e+ pairs are generated in the Target

* All extra particles are generated in the air. Number of particles generated in the target is identical for Compton target with and without beam pipe.

* In the air the vertexes are distributed almost uniformly all the way from the target to the detectors in case of no pipe.

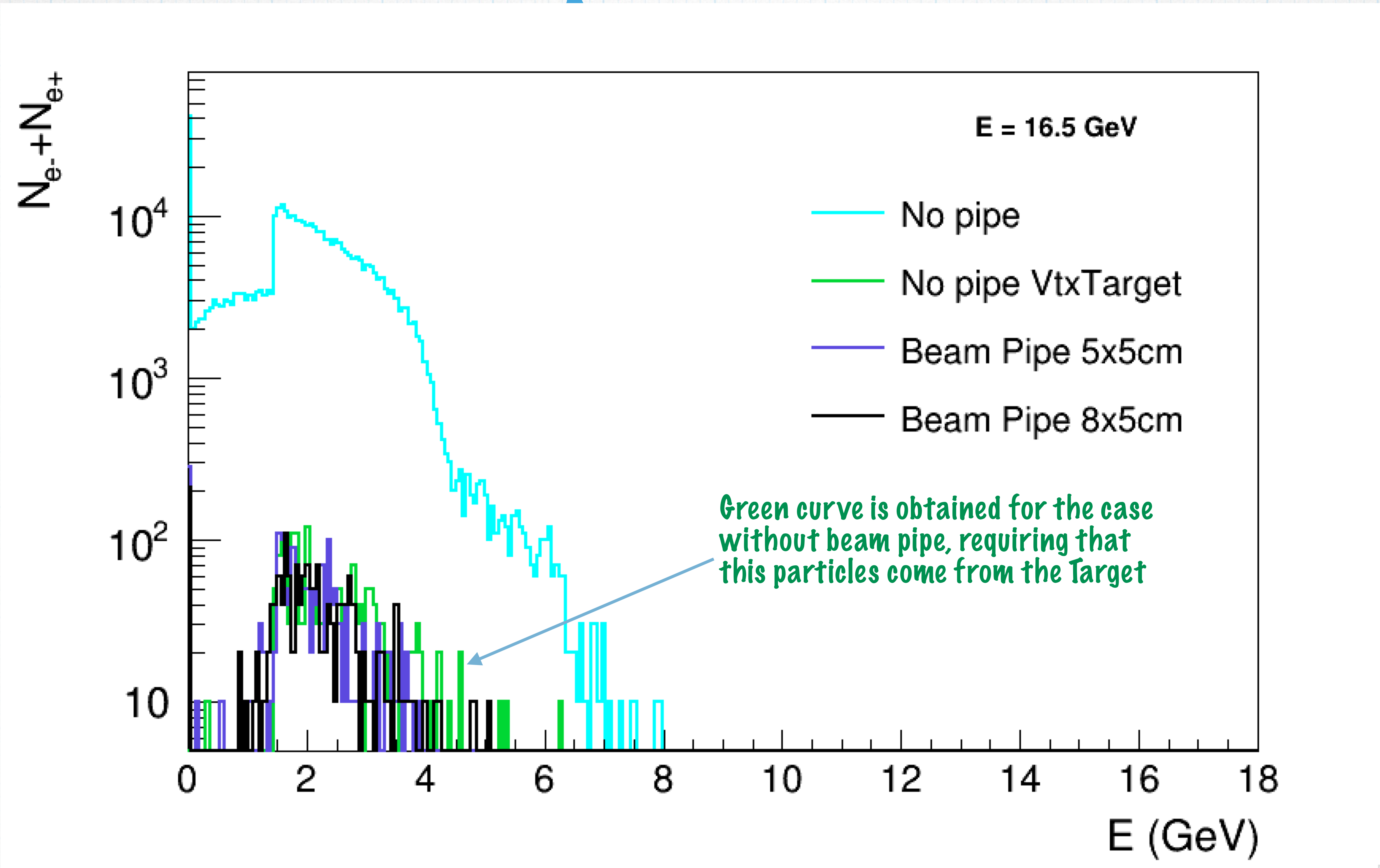
Spectra



Without beam pipe we measure in Compton detectors a lot e-/e+ pairs that were created in the air.
Only 4% e-/e+ come from the Target

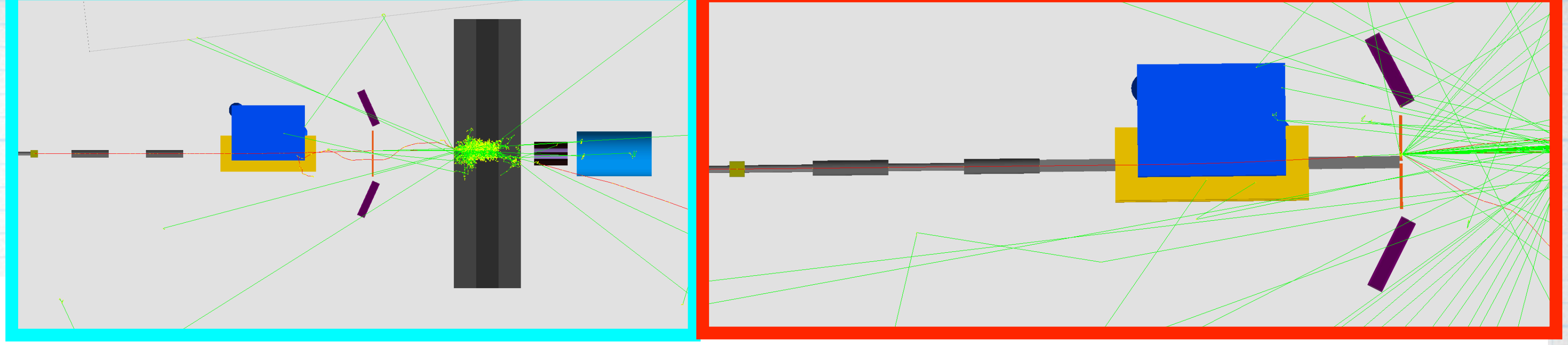
As the laser intensity is low (xi =0.3), to reconstruct spectra we need more statistics.

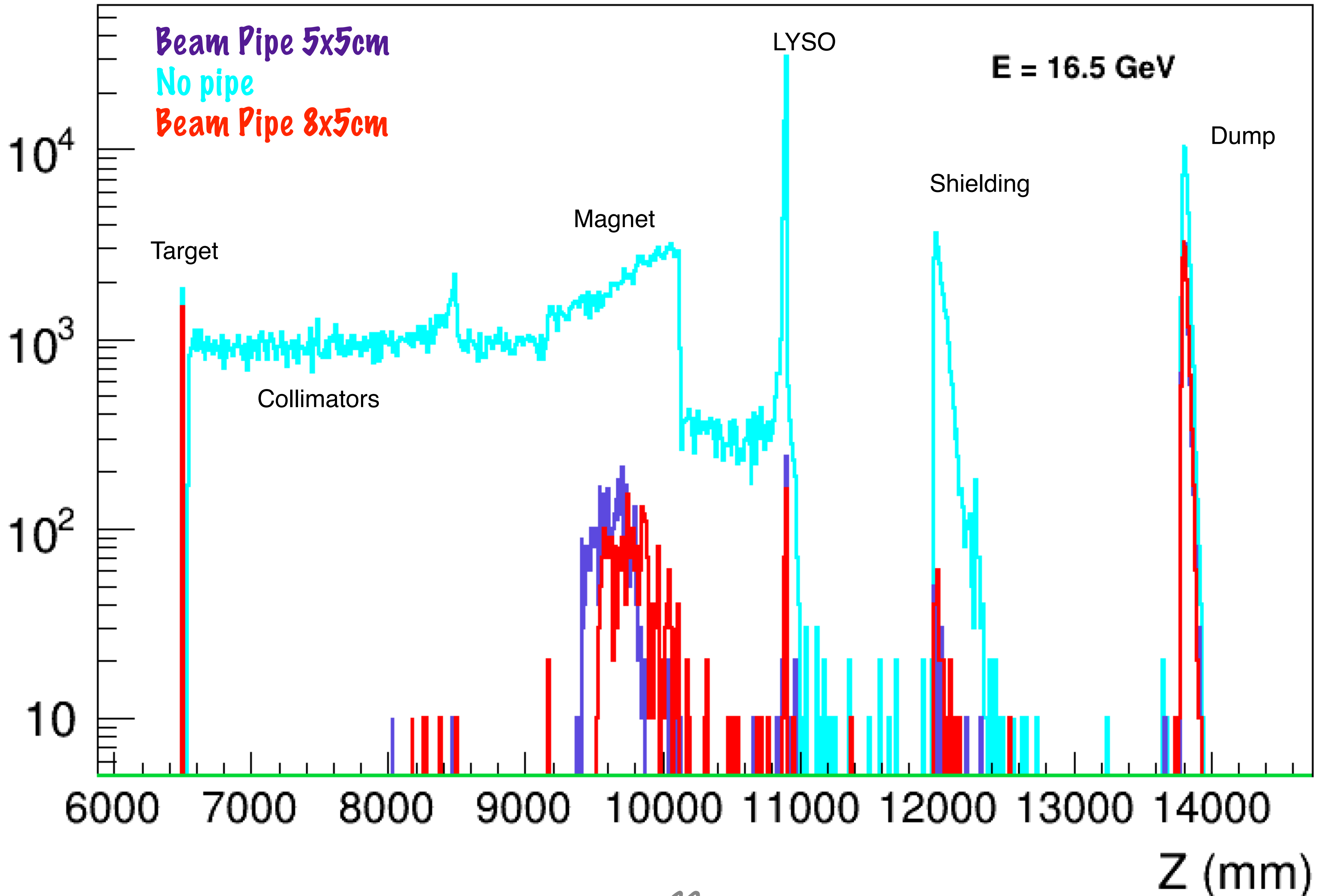
Spectra



Without beam pipe we measure in Compton detectors a lot e-/e+ pairs that were created in the air.
Only 4% e-/e+ are generated in the Target

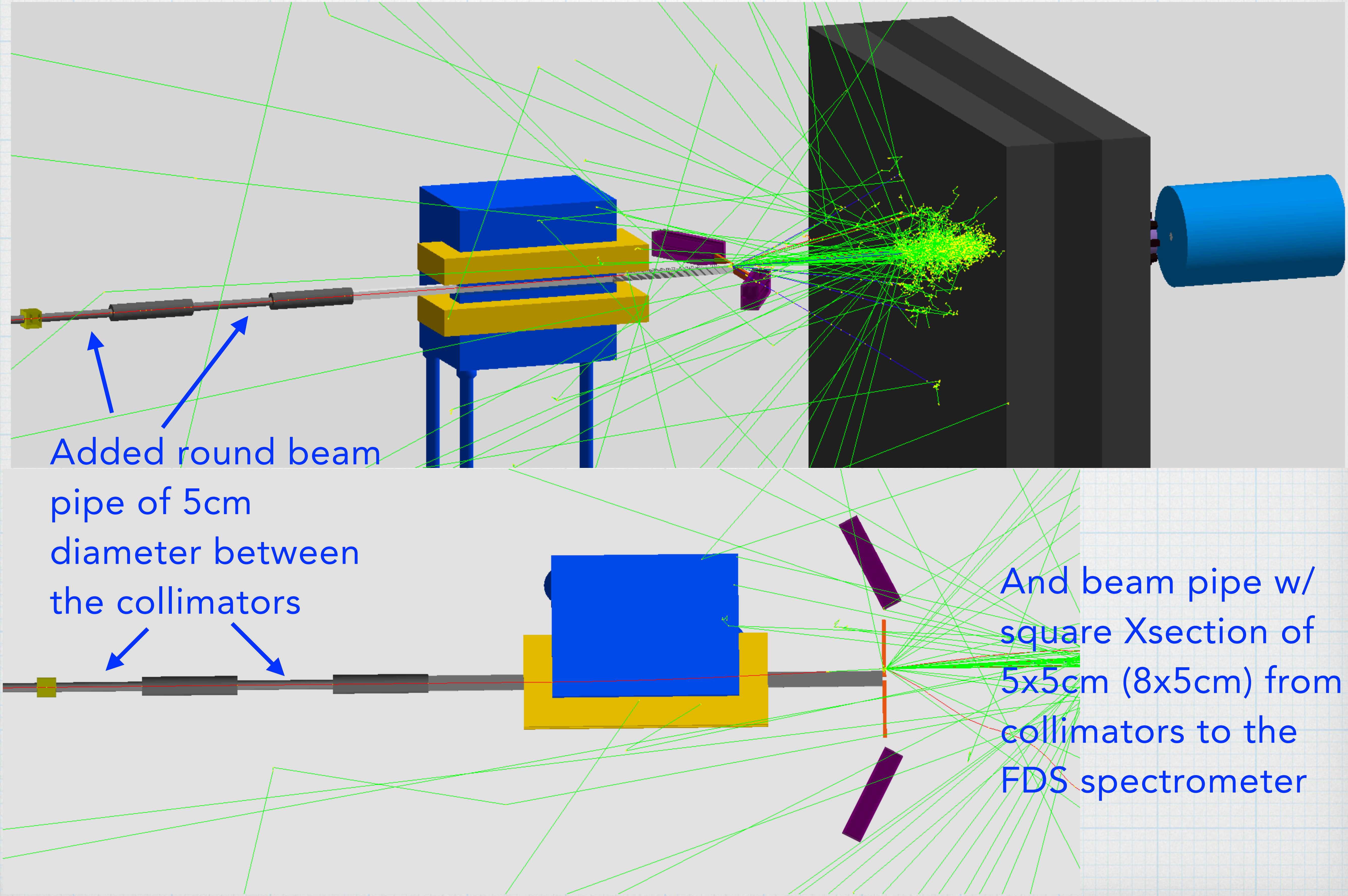
Vertex z



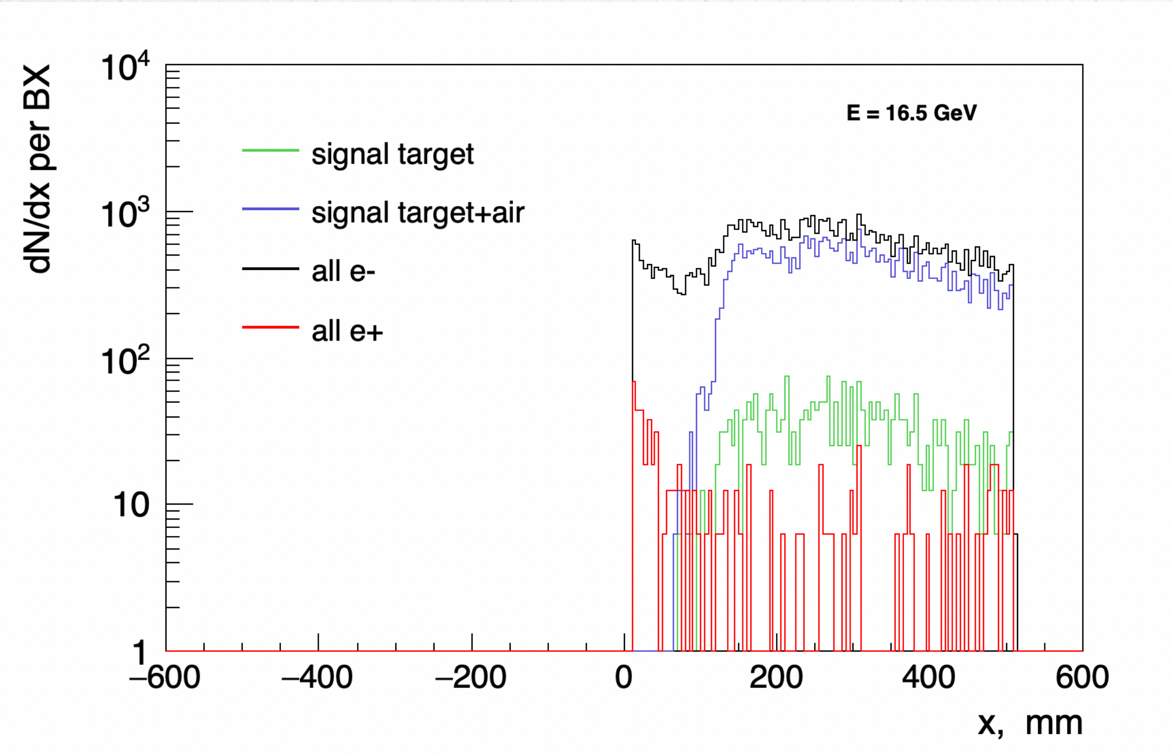


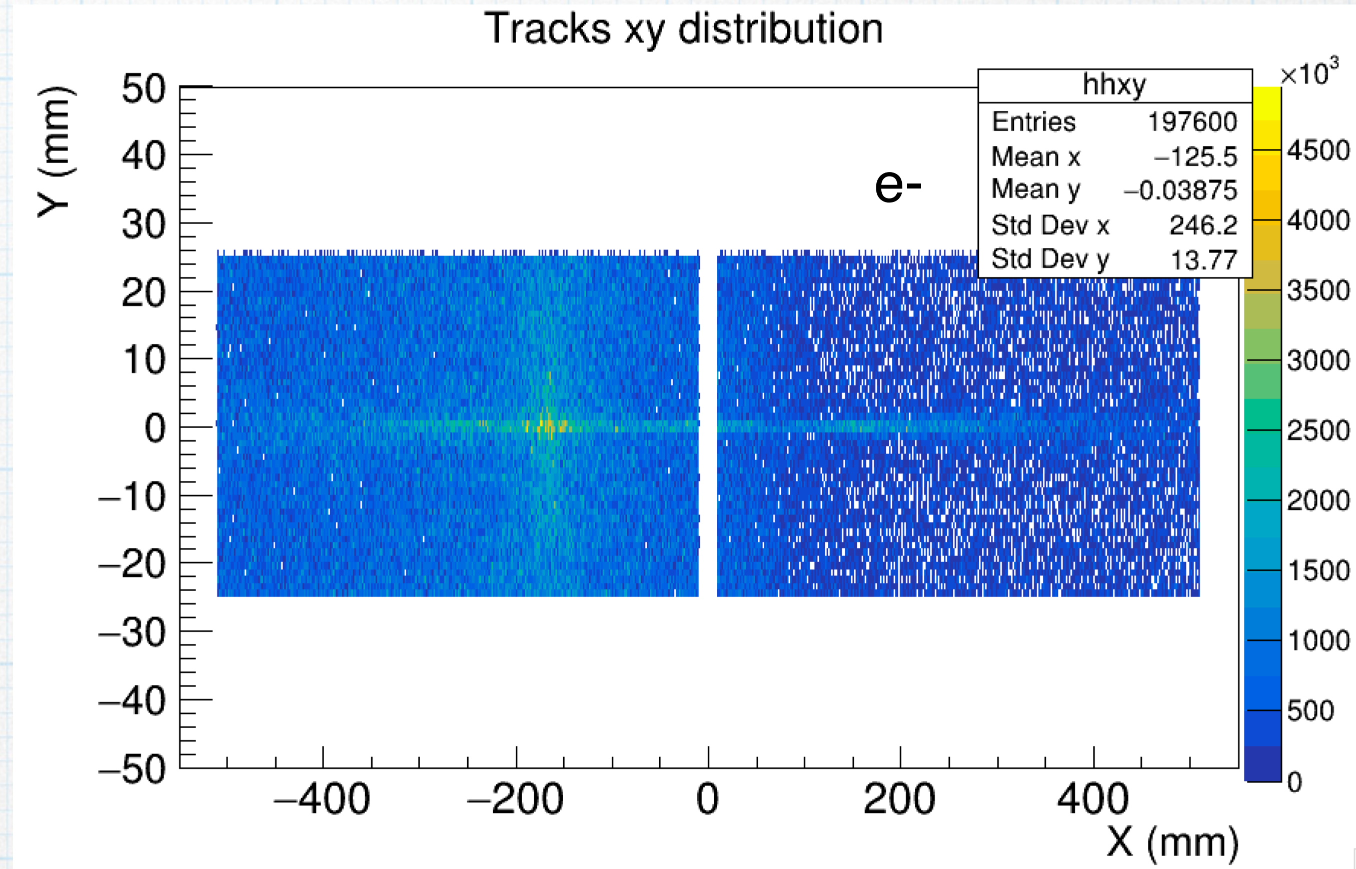
Beam Pipe 5x5cm
No pipe
Beam Pipe 8x5cm
E = 16.5 GeV
Target
Collimators
Magnet
LYSO
Shielding
Dump
10^4
10^3
10^2
10
6000 7000 8000 9000 10000 11000 12000 13000 14000
Z (mm)

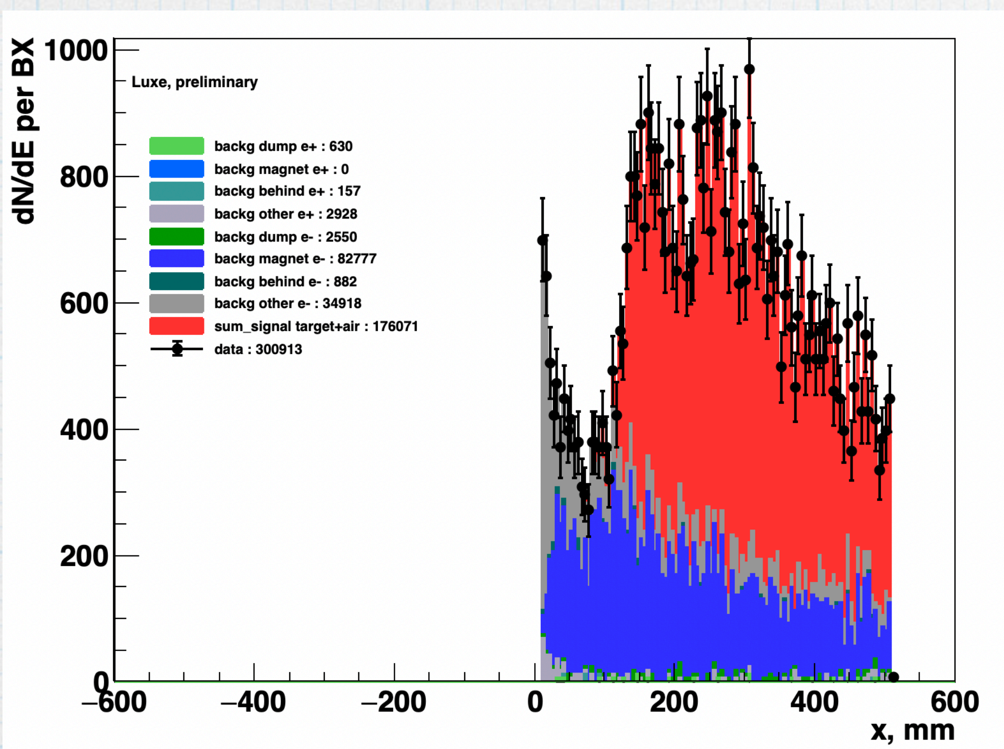
Setup with the beam pipe

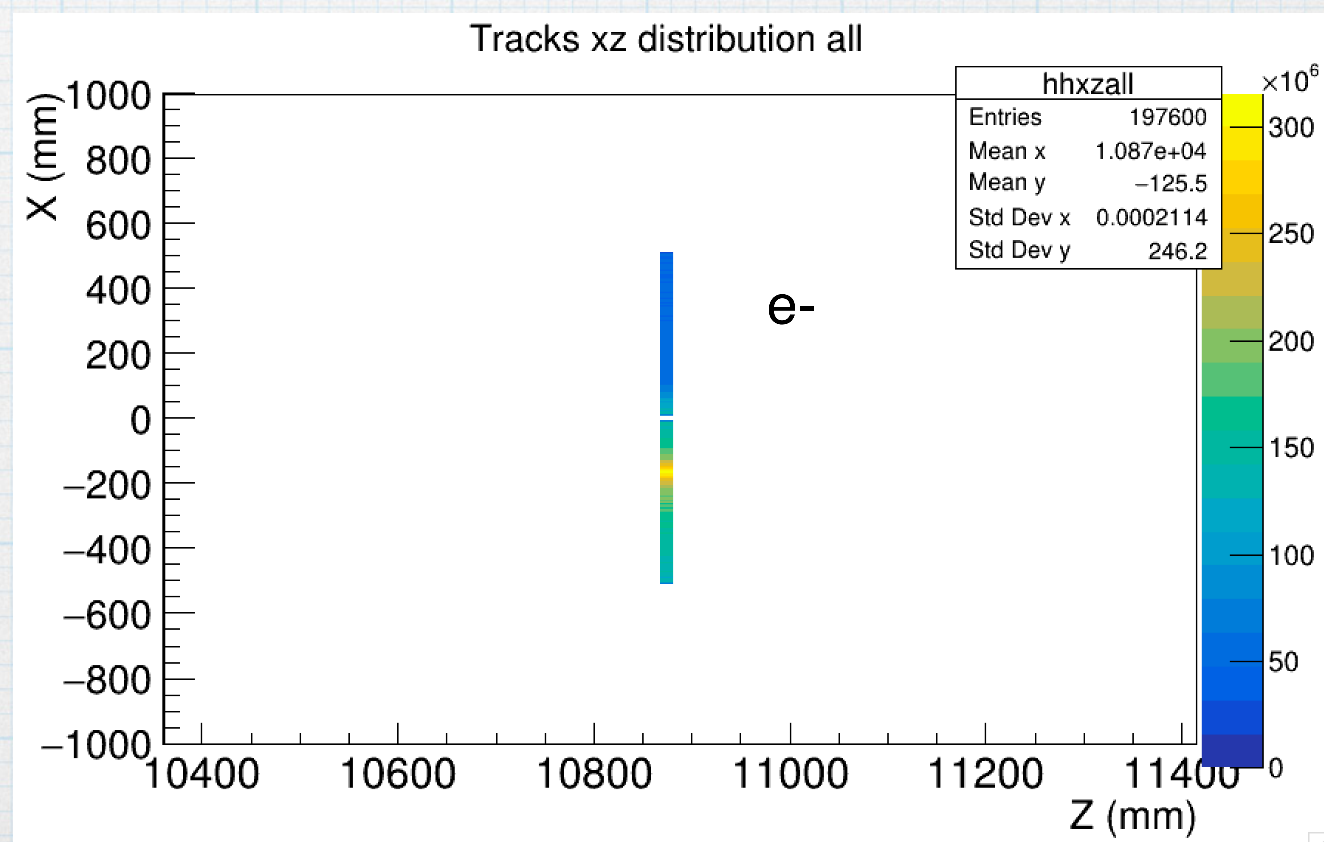


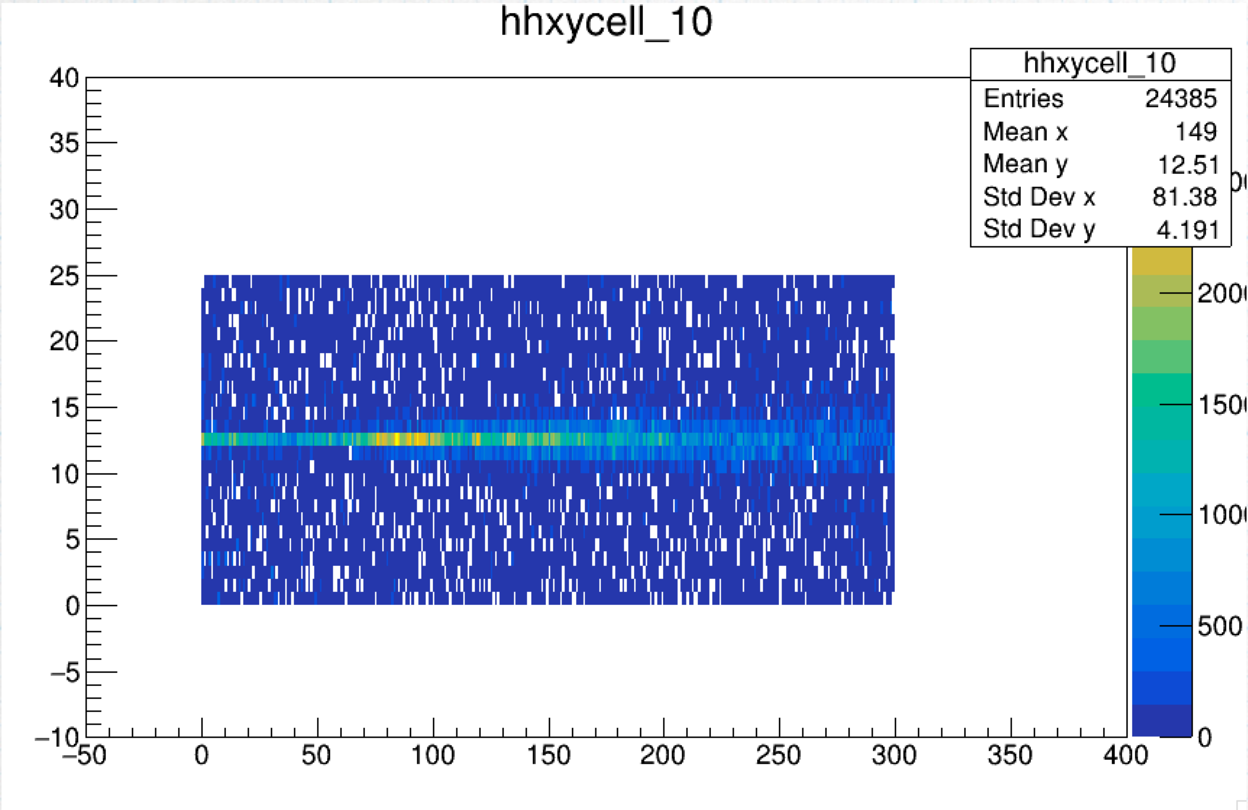
* Electron arm of Lanex Spectrometer

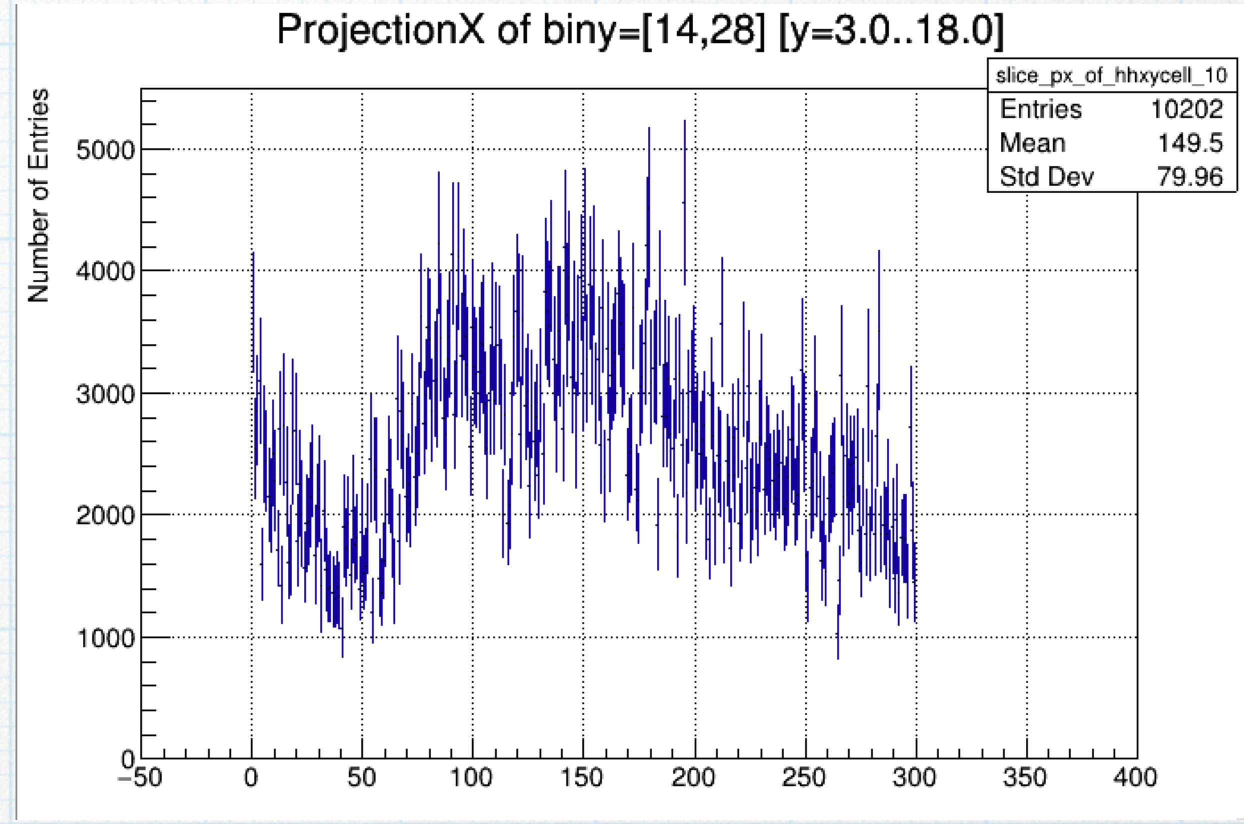


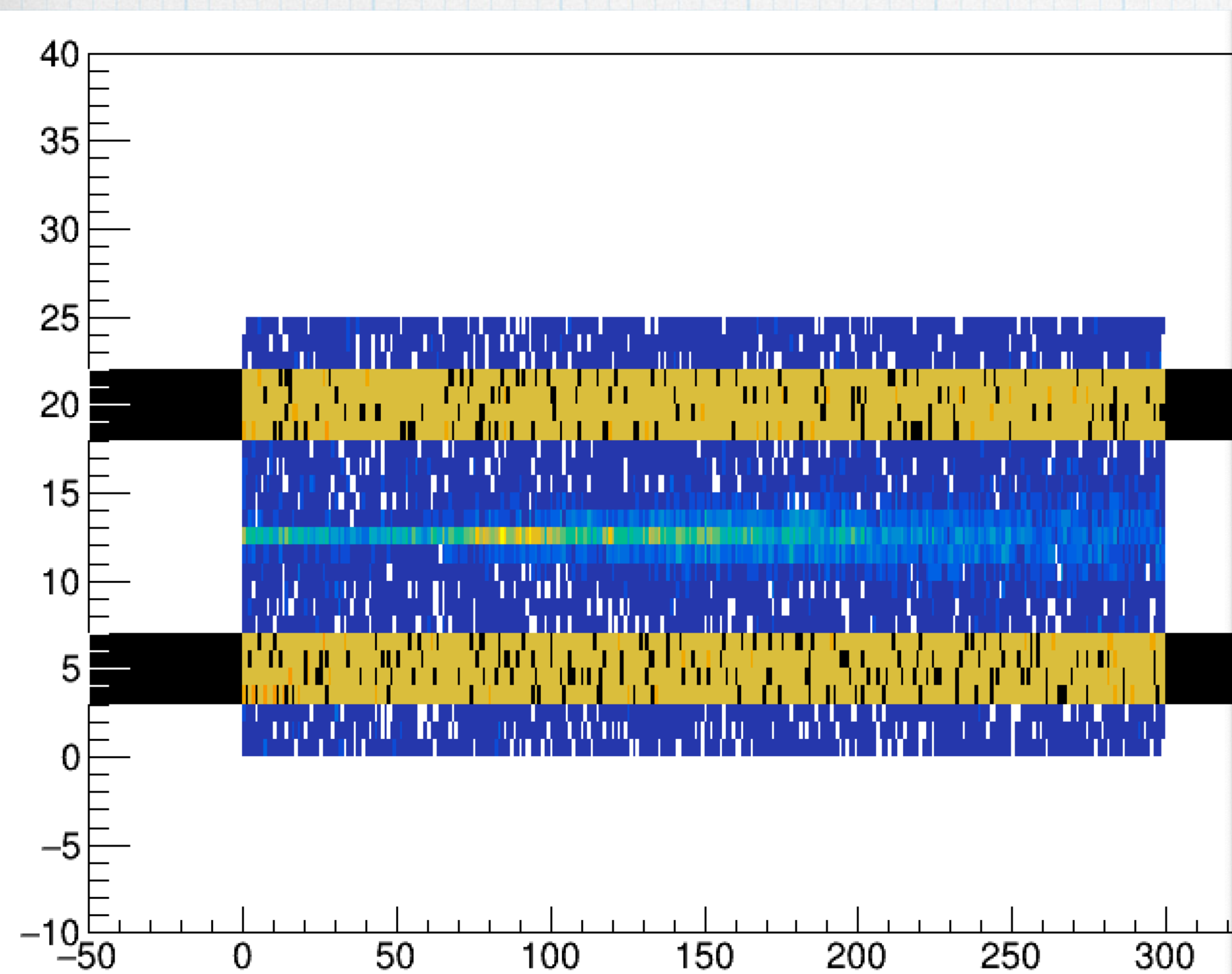


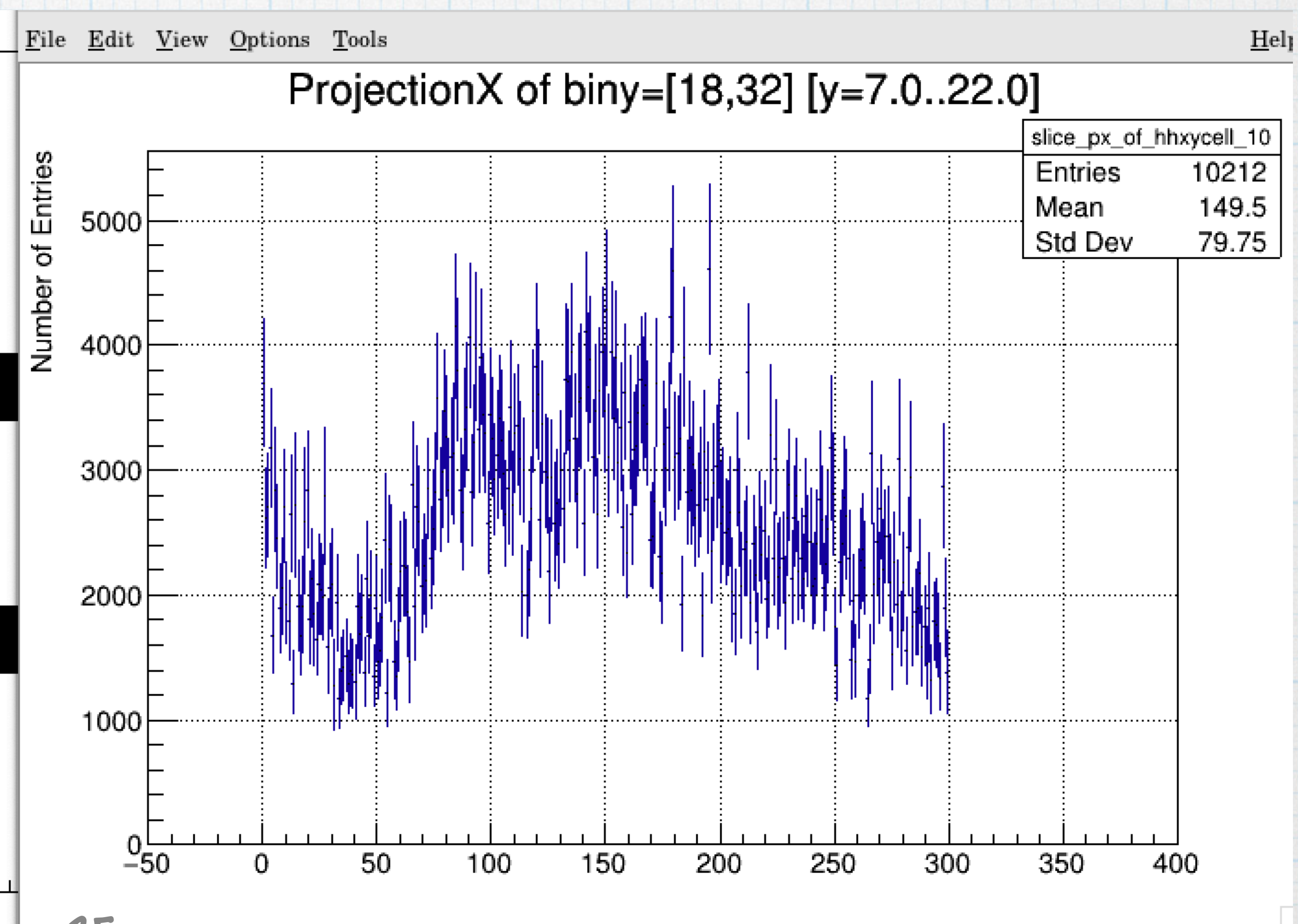




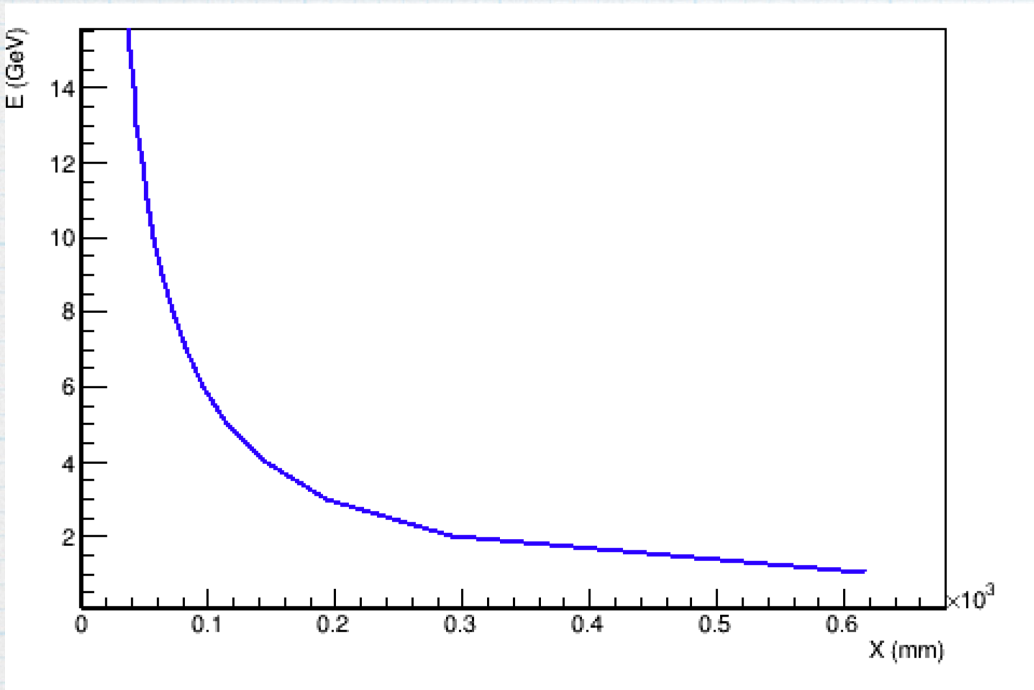

hhxycell_10
hhxycell_10
Entries 24385
Mean x 149
Mean y 12.51
Std Dev x 81.38
Std Dev y 4.191

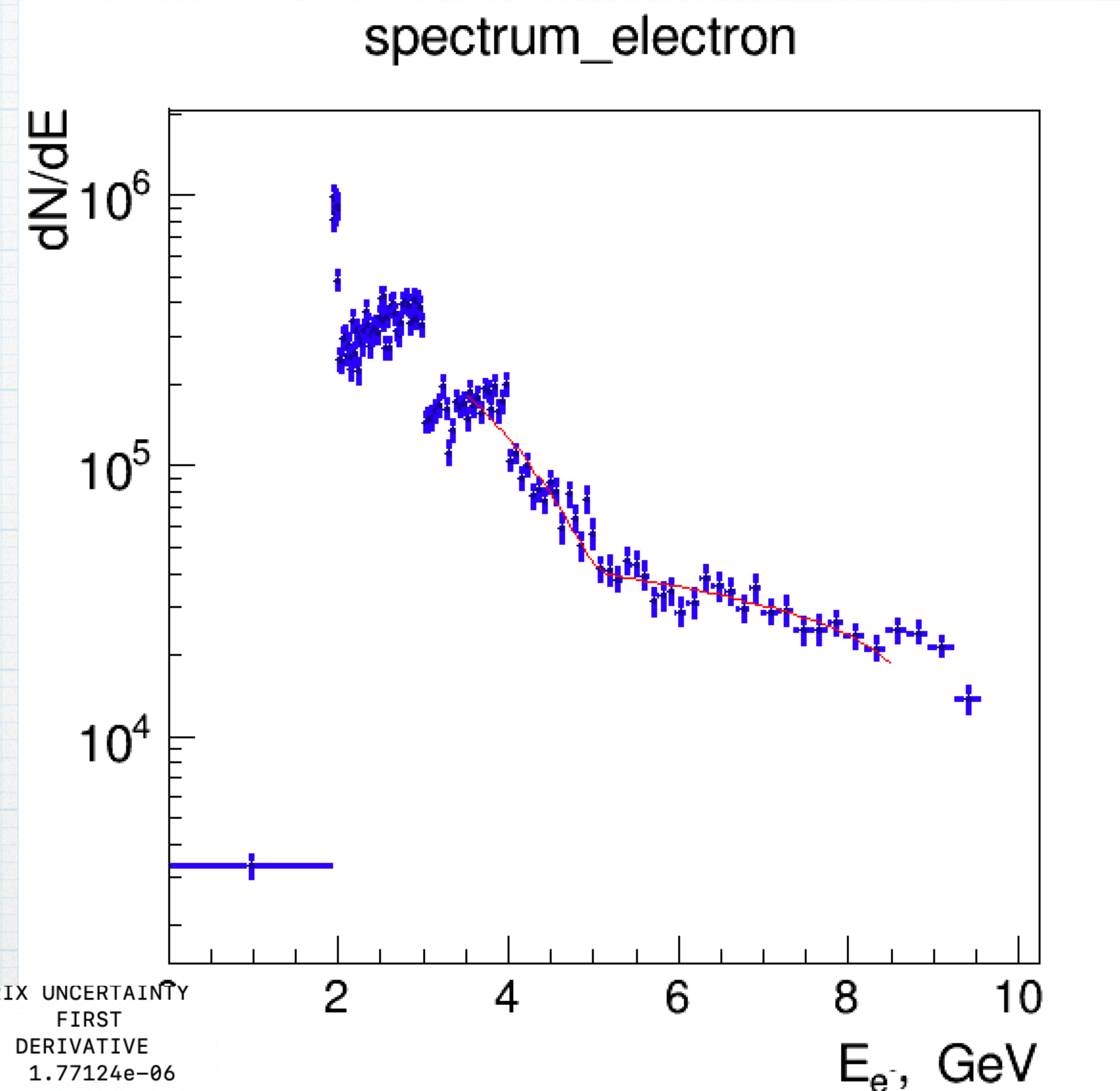

ProjectionX of biny=[14,28] [y=3.0..18.0]
slice_px_of_hhxycell_10
Entries 10202
Mean 149.5
Std Dev 79.96
Number of Entries




File Edit View Options Tools
ProjectionX of biny=[18,32] [y=7.0..22.0]
slice_px_of_hhxycell_10
Entries 10212
Mean 149.5
Std Dev 79.75
Number of Entries

Spectra reconstruction for the Lanex case





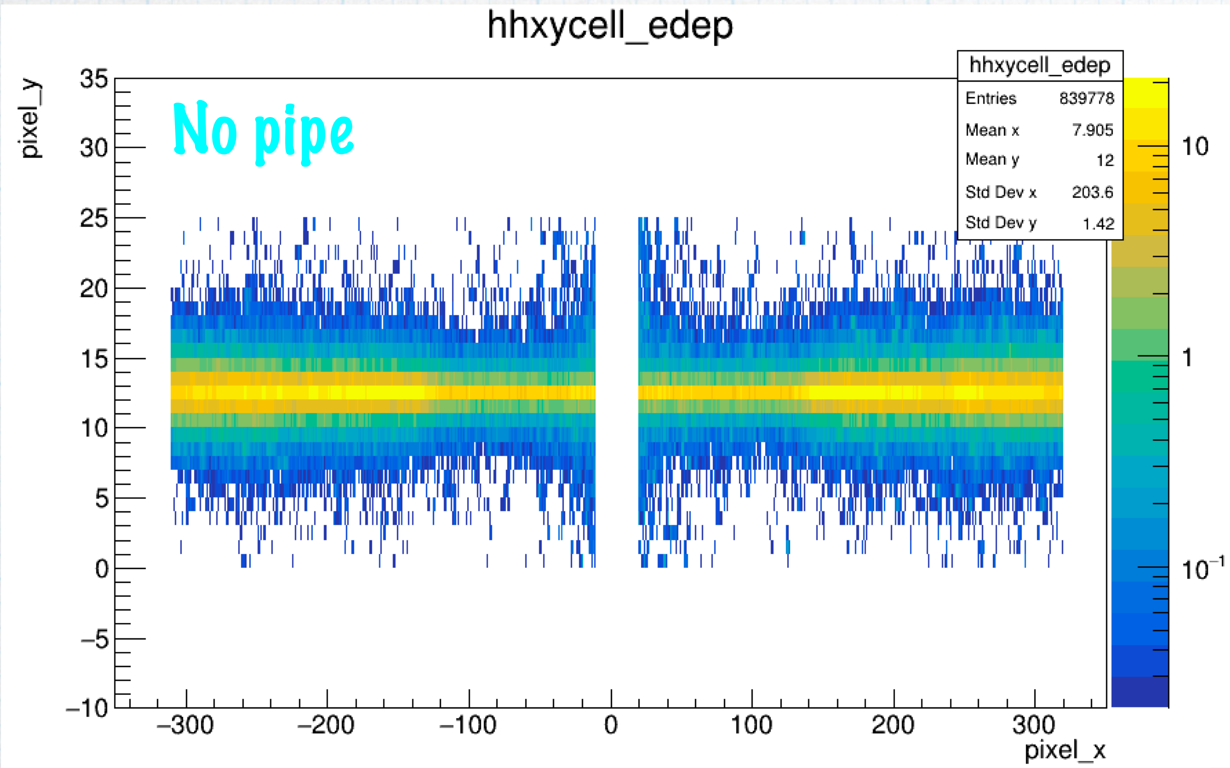
EDM=3.45767 STRATEGY= 1 ERROR MATRIX UNCERTAINTY

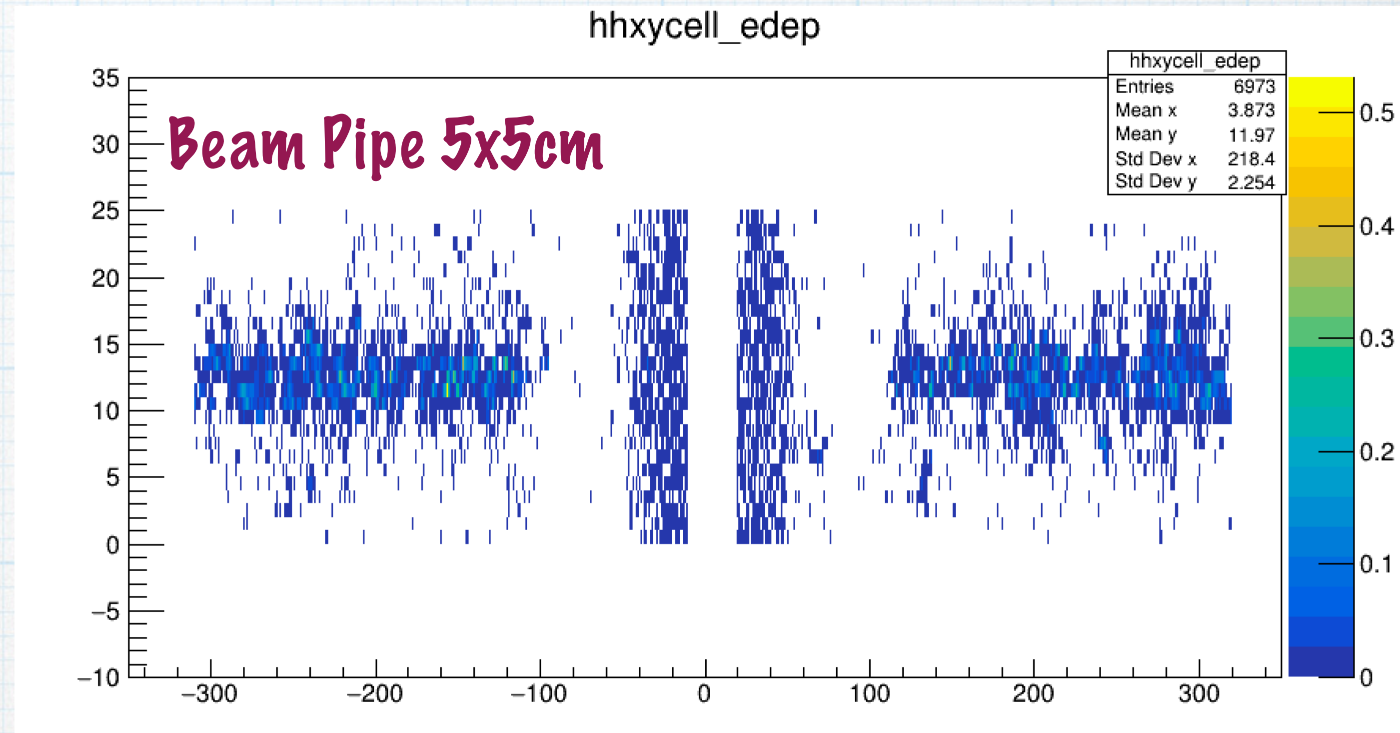
EXT NO.	PARAMETER NAME	VALUE	APPROXIMATE ERROR	STEP SIZE	FIRST DERIVATIVE
1	p0	-1.13129e+06	2.26562e+04	-2.47452e-02	1.77124e-06
2	p1	8.52709e+06	1.03972e+05	6.18410e-02	-9.17369e-08
3	p2	4.99979e+00	1.95217e-01	6.12022e-05	-2.60964e+00
4	p3	1.32018e+05	5.26539e+01	-5.57651e-06	2.62956e-05
5	p4	-3.82289e+05	6.92345e+03	3.70539e-03	-2.29557e-06
6	p5	8.42734e+00	1.79782e-01	-1.42424e-05	3.17284e+00
7	p6	1.86312e+05	2.00261e+00	-6.18804e-09	4.60353e-05
8	p7	9.31179e+00	4.96505e-01	4.46513e-05	-6.73901e-02
9	p8	0.00000e+00	1.48007e+00	-0.00000e+00	0.00000e+00

Deposited energy per cell

GeV per BX

- laser intensity $\xi = 0.32$





Compton MC2020 r for (xi=0.32), 16.5 GeV electrons. G4: Kapton foil of 20 um as a target, magnet 1.4T and 0.75m distance from magnet to LYSO .

If we take distribution of deposited energy the values around maximum are ~10 GeV.

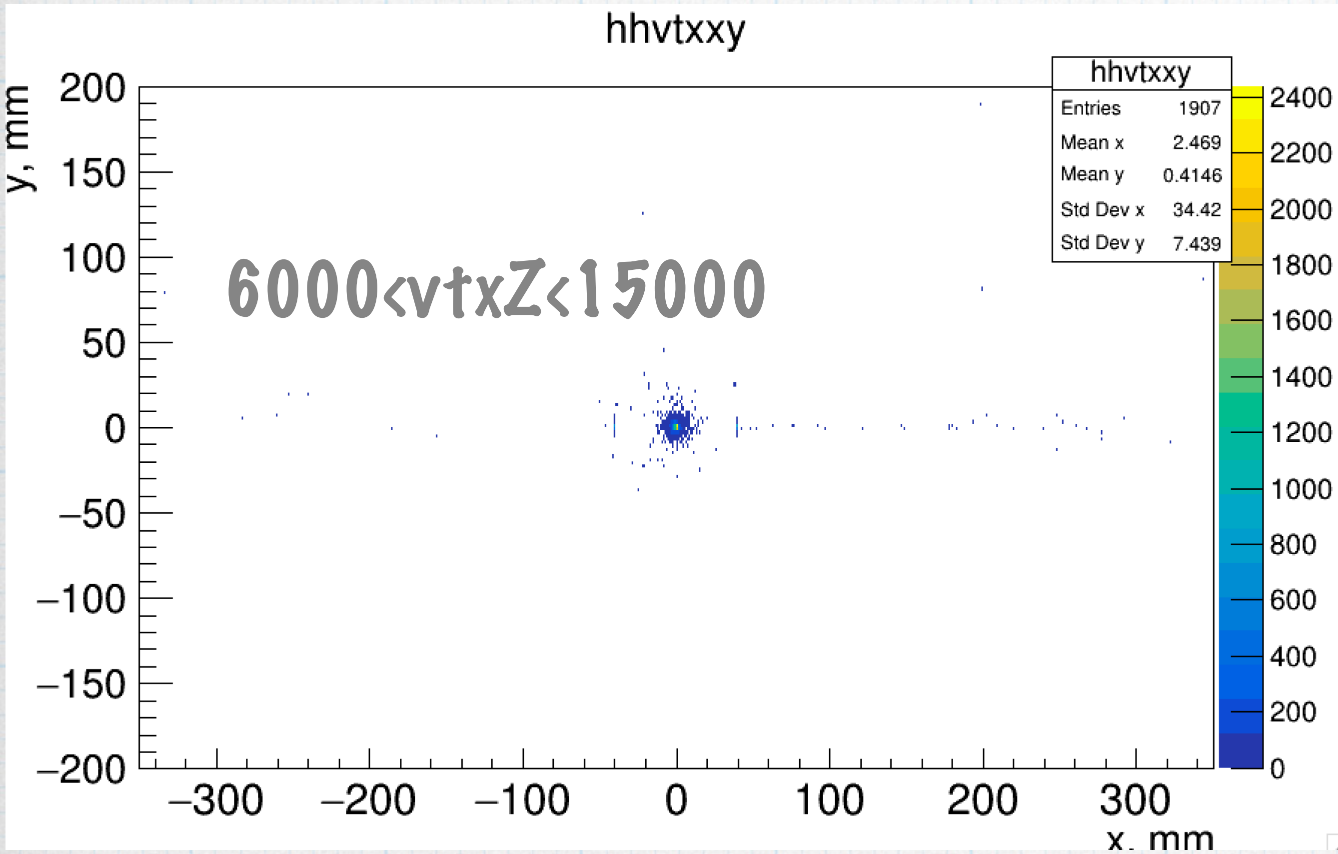
To convert it to Gy, convert it to J: ~1.6e-9J and then divide it to the mass of crystals in kg. Gy= J/kg

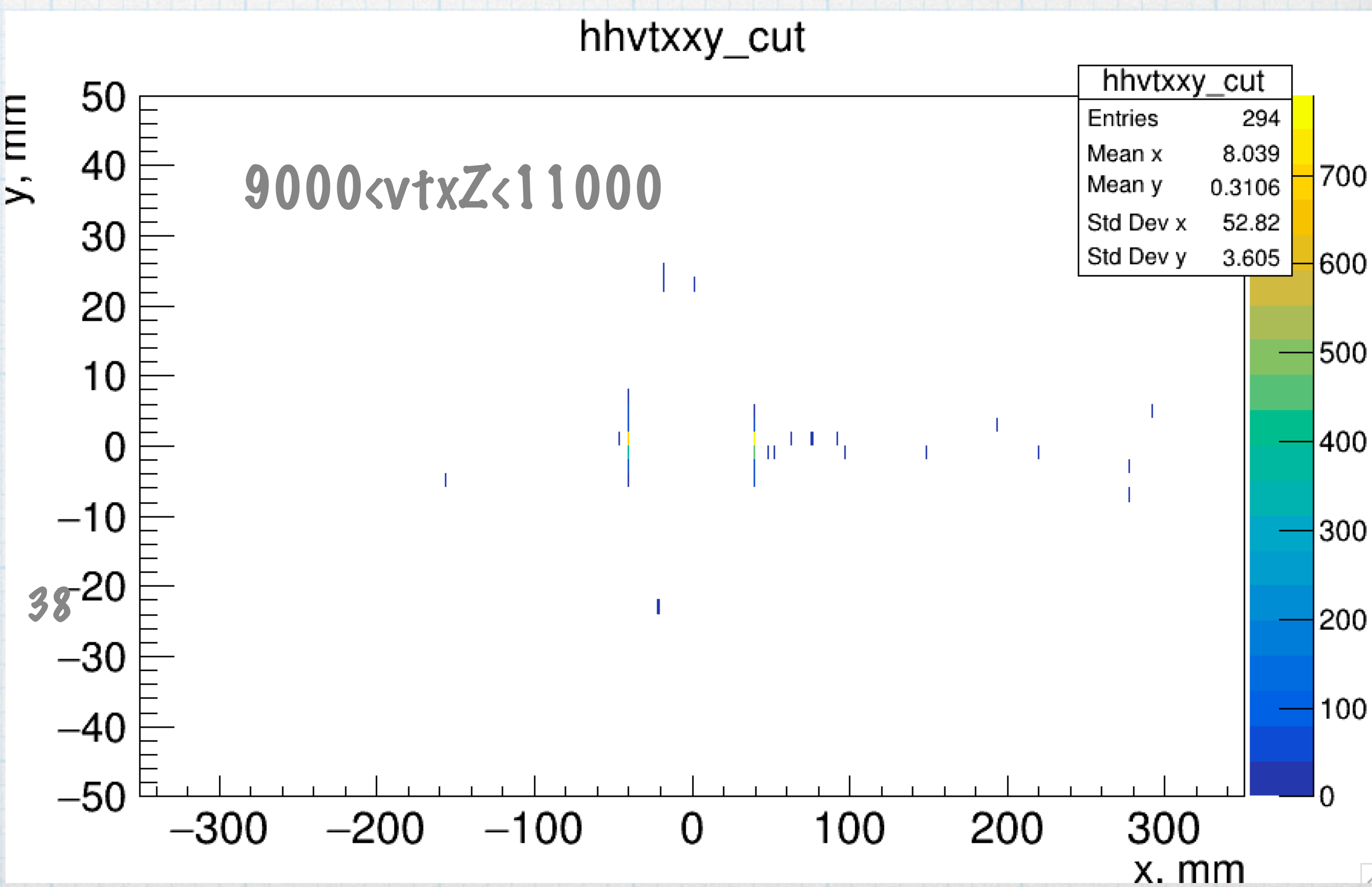
The density is 7.1 g/cm3, volume 0.1*0.2*2 = 0.04 cm3. Mass 7.1*0.04 = 0.284g.

Finally, 5.6e-6 Gy per BX.

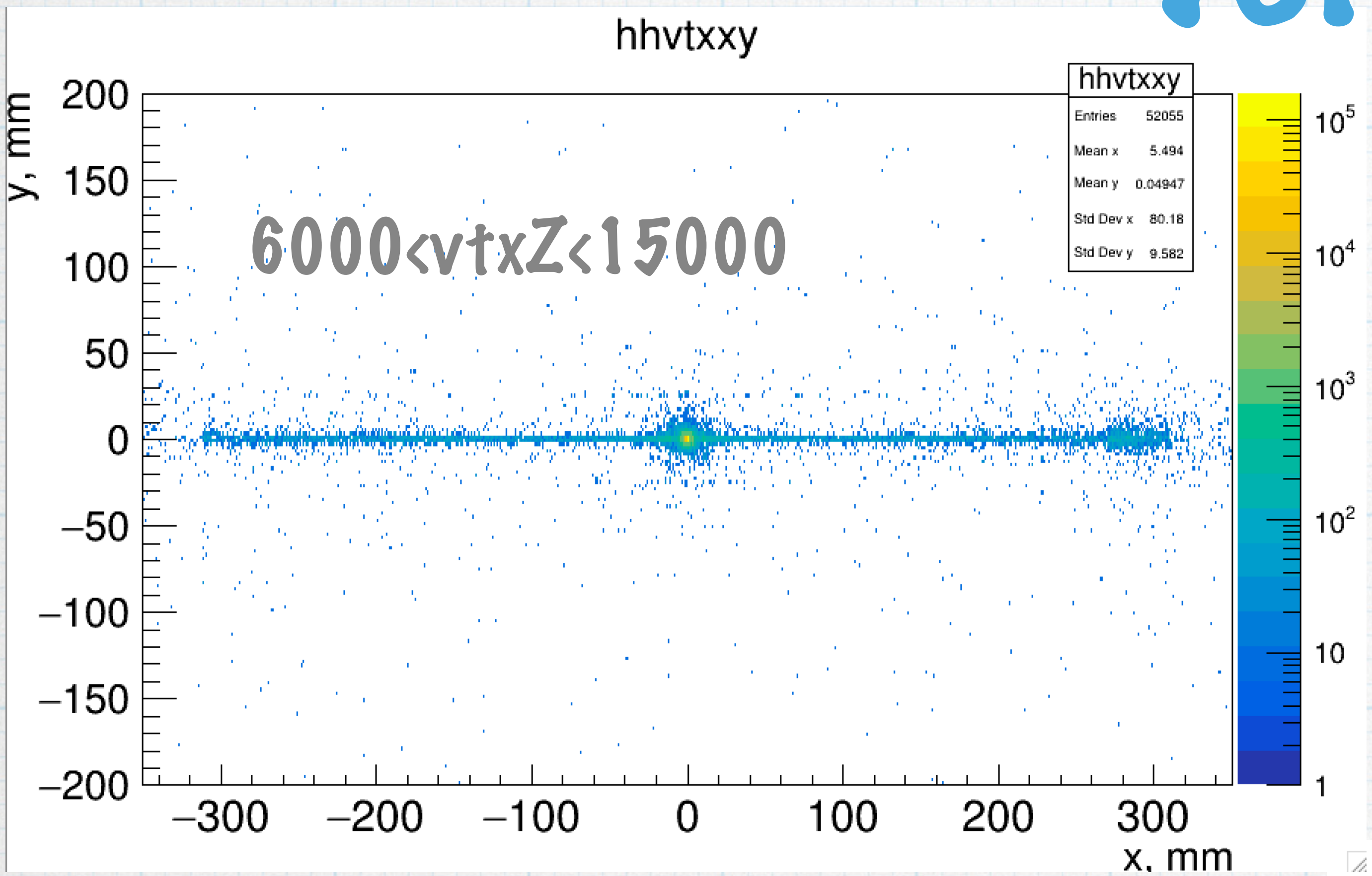
Assuming 1 Hz collisions rate we get the dose of 10 kGy in LYSO crystal in about 56 years.

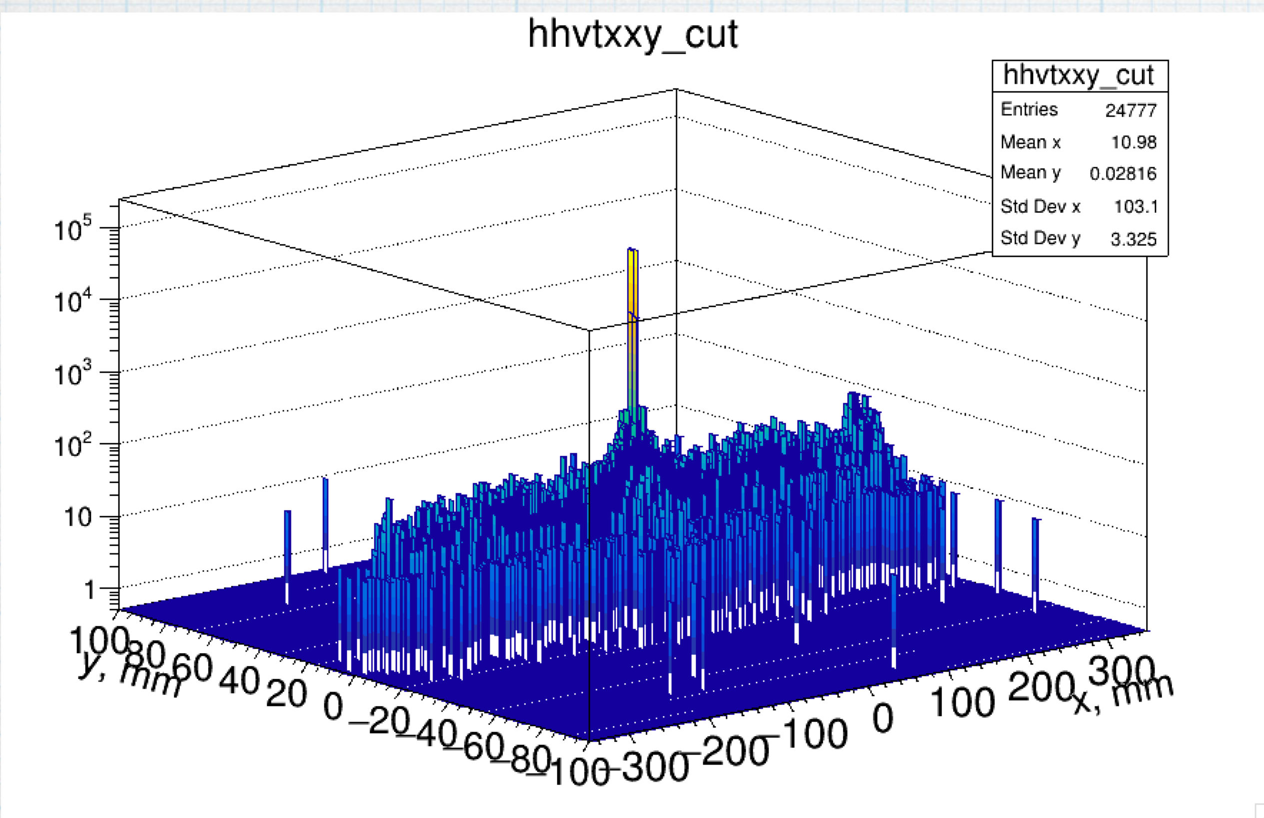
Vertex x-y, beam pipe 8x5

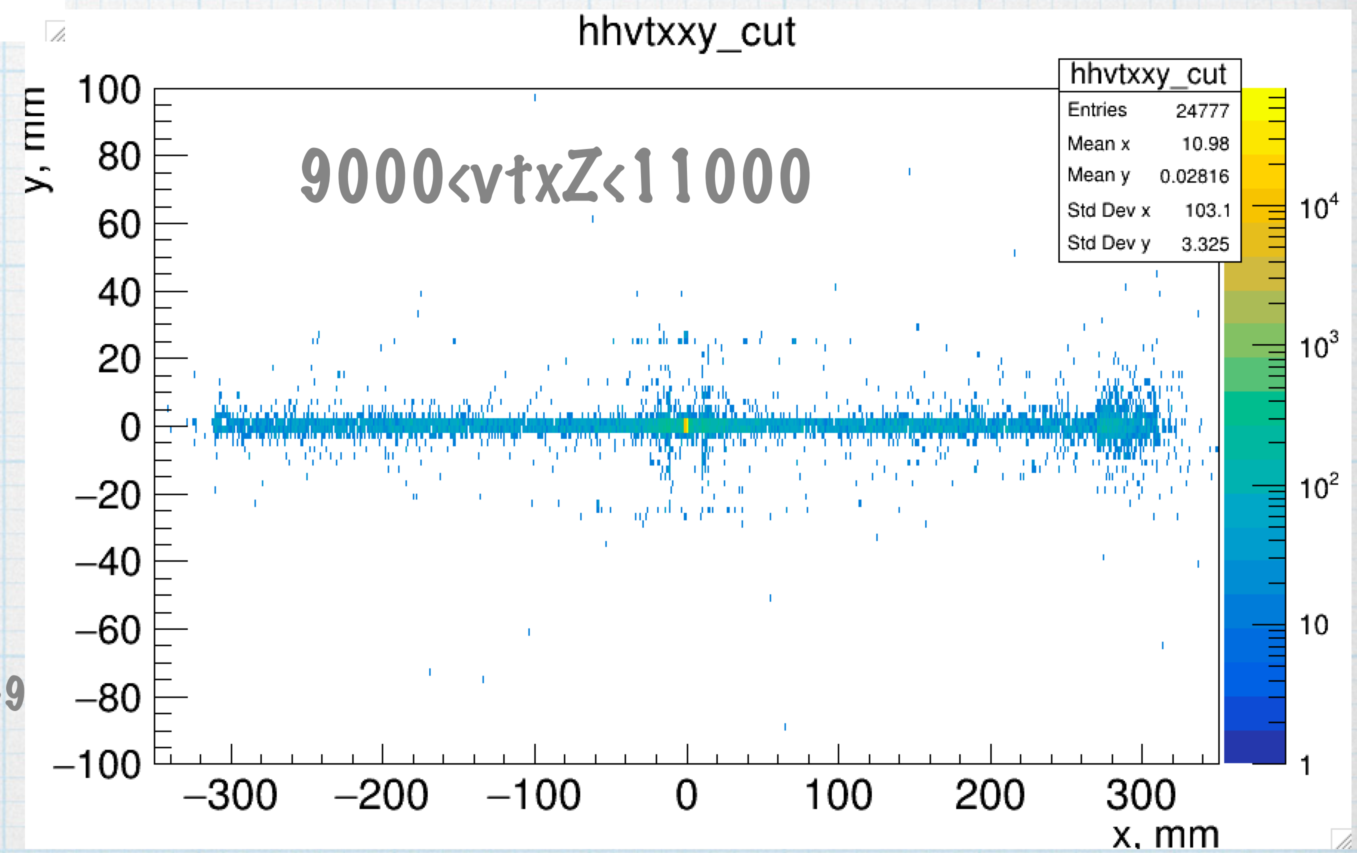




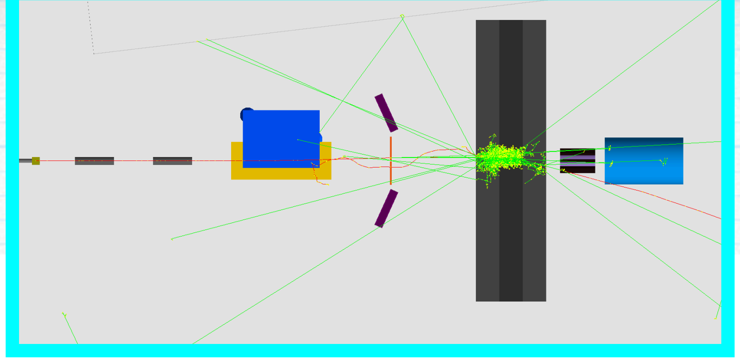
Vertex x-y, no pipe

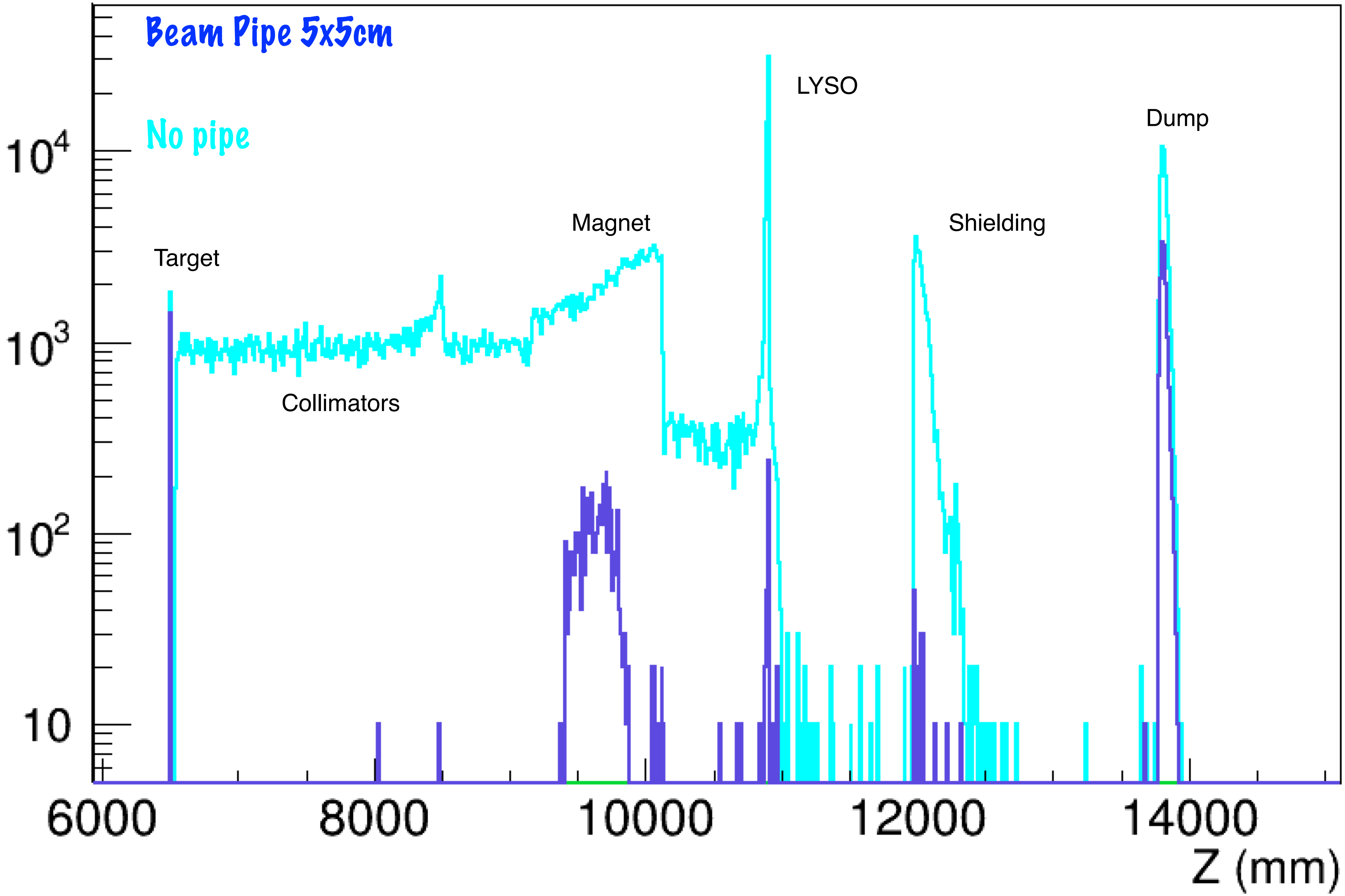






Vertex z





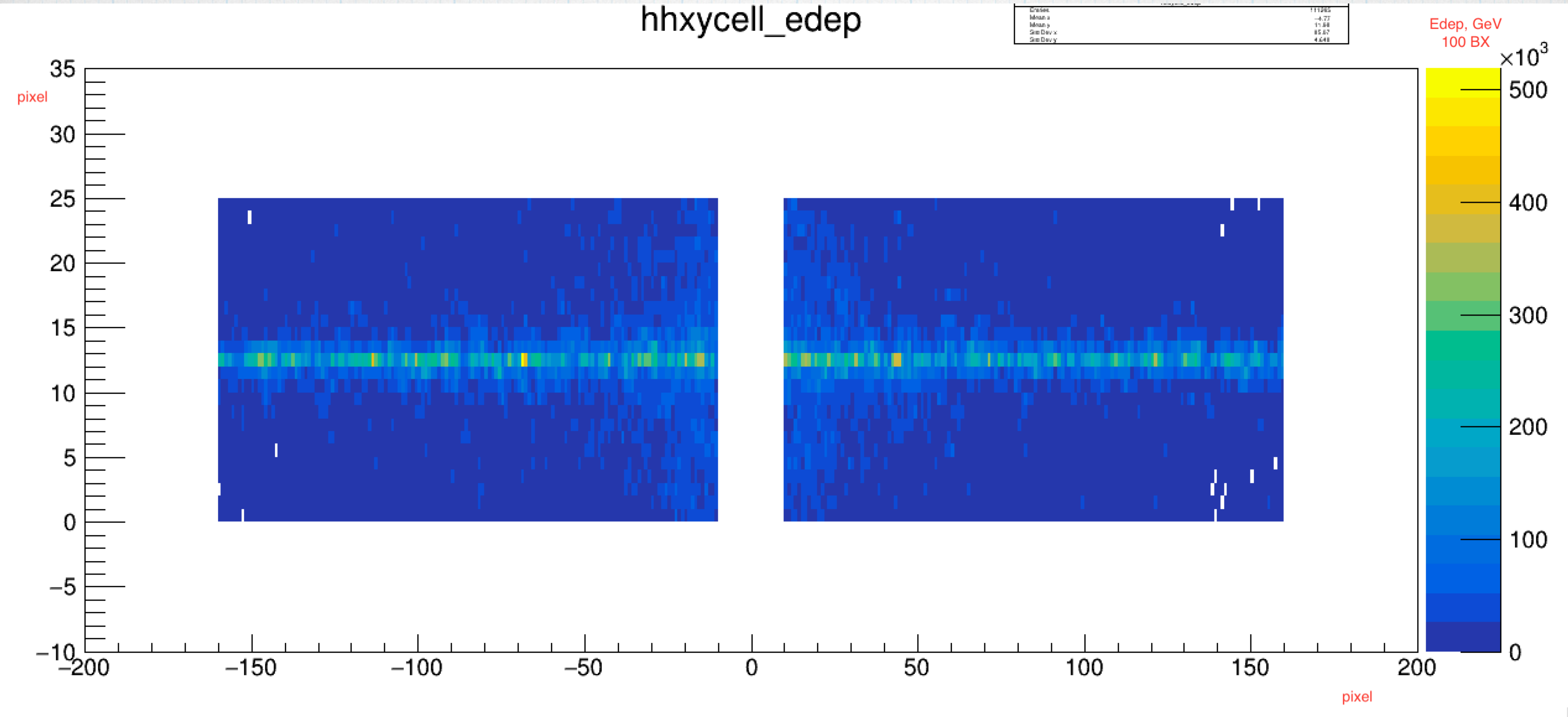
Beam Pipe 5x5cm
No pipe
Target
Collimators
Magnet
LYSO
Shielding
Dump
10^4
10^3
10^2
10
6000
8000
10000
12000
14000
Z (mm)

Profiler

Just simple estimation for GADOX (LANEX)
let's take photon beam of 10^10 photons of 10 GeV. The total energy is 10^11 GeV which is 16J.

If we consider the transverse size of the beam to be 0,4 mm and profiler thickness 5 cm (3.6 X0) with density~ 6,7 g/cm^3 the mass of irradiated area will be 0,042 g.
Specific heat capacity of gadolinium is 0,23 J/g K. Assuming 10% energy absorption (for 3.6 X0) that volume will heat by 165 degrees in one BX.
In 10 sec at 1Hz it will probably reach the melting point.

Of course I didn't account for heat dissipation, maybe the area of energy deposition will be wider and the constants for Gadox could be a bit different, but probably this won't work out: 5cm thick Gadox will burnt out in the center in seconds.
Lets forget the radiation damages...



Compton MC2019 r for 1J (xi=2.6), 17.5 GeV electrons. G4: tungsten foil of 10 um as a target, magnet 1T and 1.5m distance from magnet to LYSO .

If we take distribution of deposited energy the values around maximum are ~5e3 GeV.

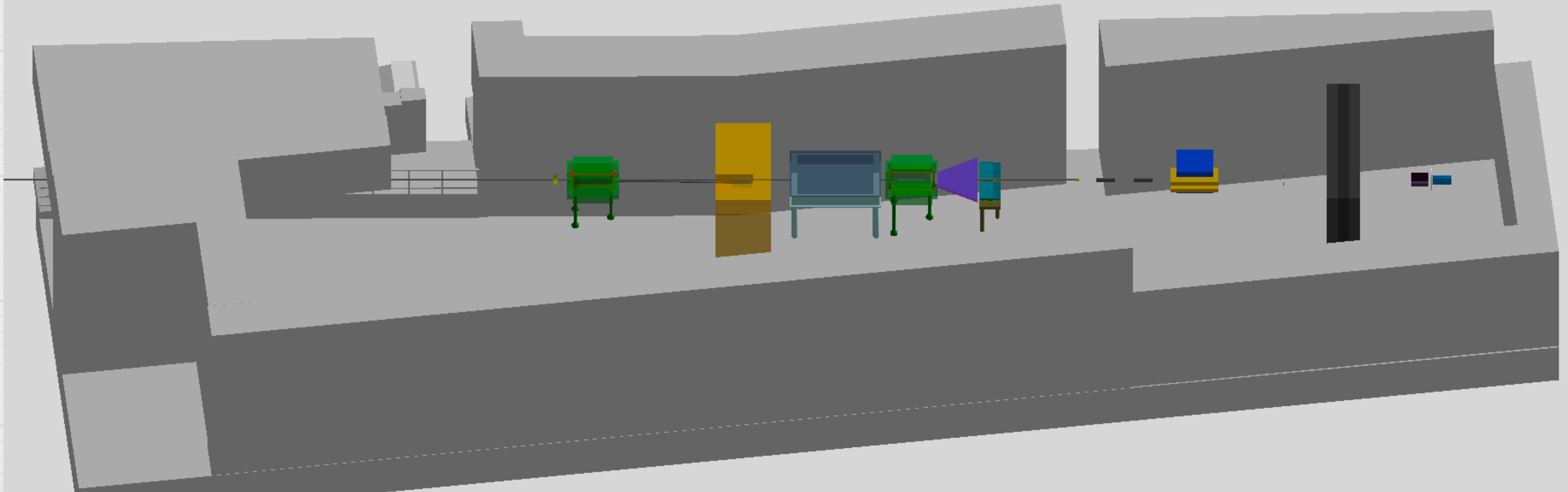
To convert it to Gy, convert it to J: ~8e-7 J and then divide it to the mass of crystals in kg. Gy= J/kg

The density is 7.1 g/cm3, volume 0.1*0.2*2 = 0.04 cm3. Mass 7.1*0.04 = 0.284g.

Finally 8e-7J/0.284e-3 = 2.8e-3 Gy per BX.

Assuming 1Hz collisions rate we get the dose of 10000Gy in LYSO crystal in about 1000/2.8e-3 = 3.6e6s which is 41,3 days.

Luxe Set-up



The distance between IP and Compton Target = 6.5 *m