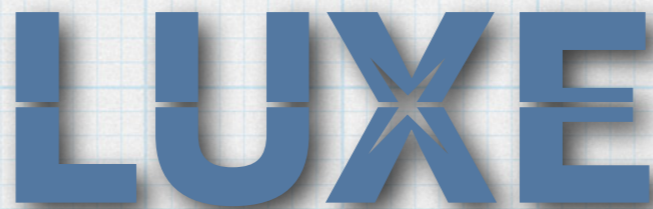


FDS performance Beam pipe vs Air

Borysova Maryna (KINR)

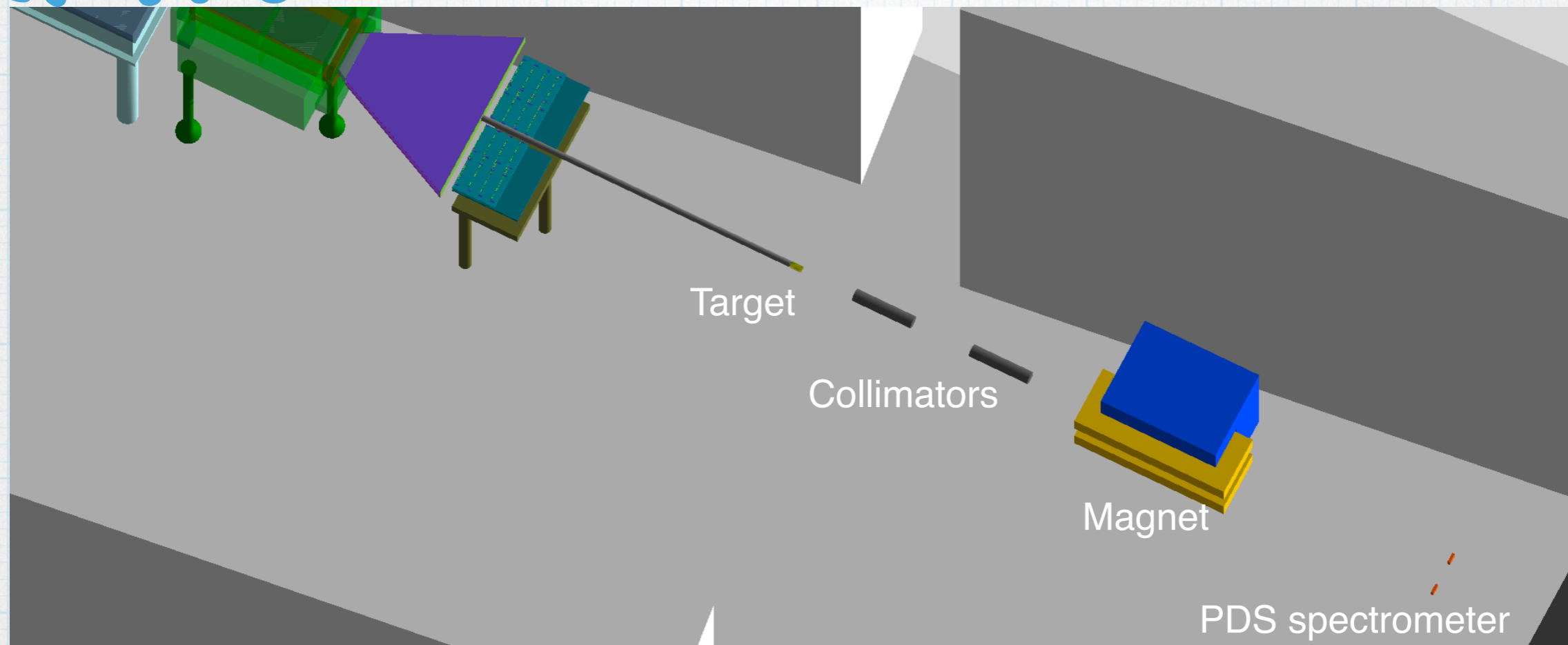
02/02/21

LUXE simulation meeting

The logo for the LUXE experiment, featuring the word "LUXE" in a bold, blue, sans-serif font. A stylized, multi-pointed star or asterisk is positioned behind the letter "X".

Intro

PDS - Photon Detector system



Tasks at hand:

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

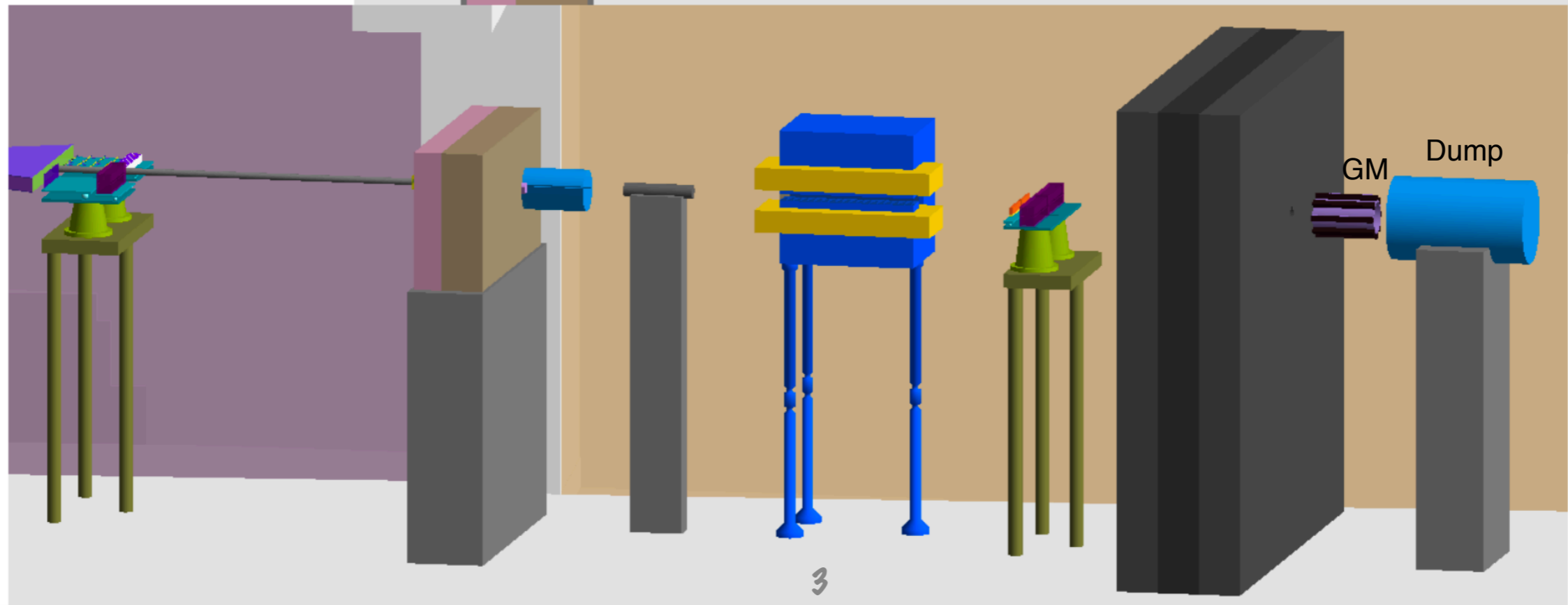
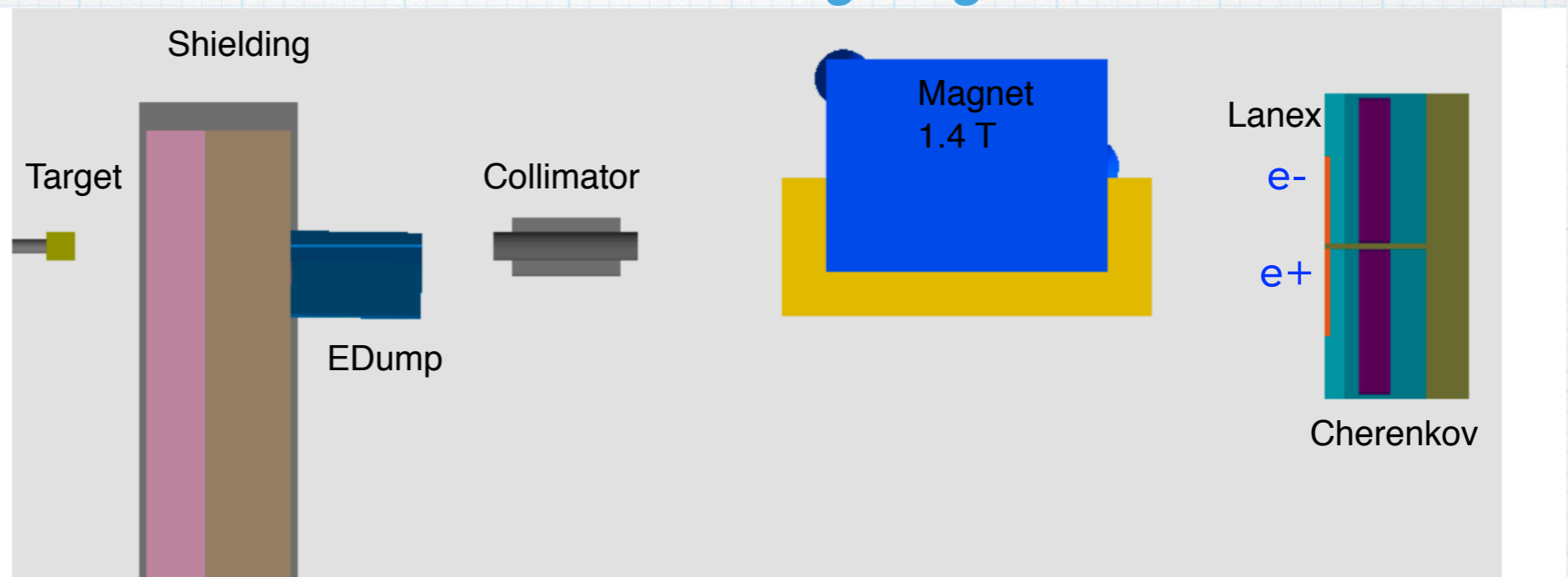
I measure HICS energy spectrum.

- Use low X_0 target ($\sim 10^{-6} X_0$) for gamma to electrons/positrons conversions followed by spectrometer;
- determine kinematic edges;
- detailed shape.

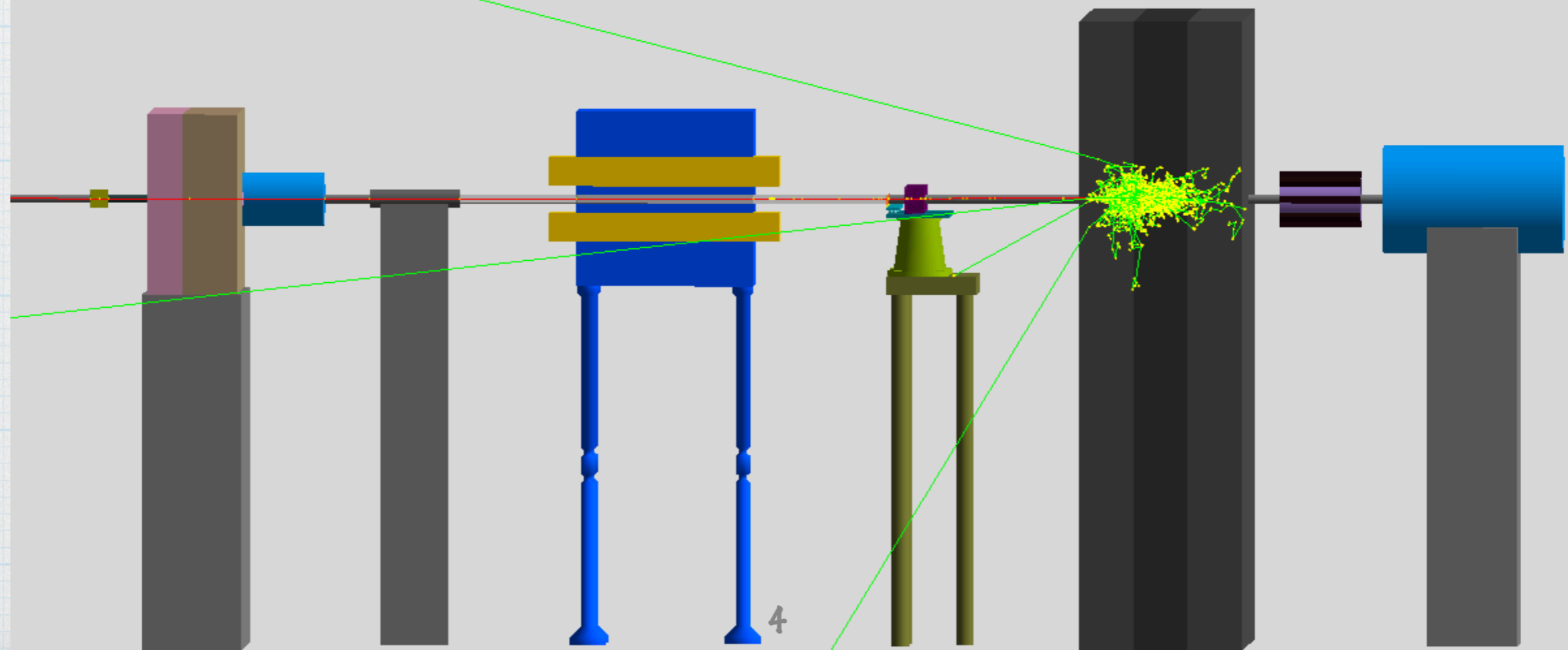
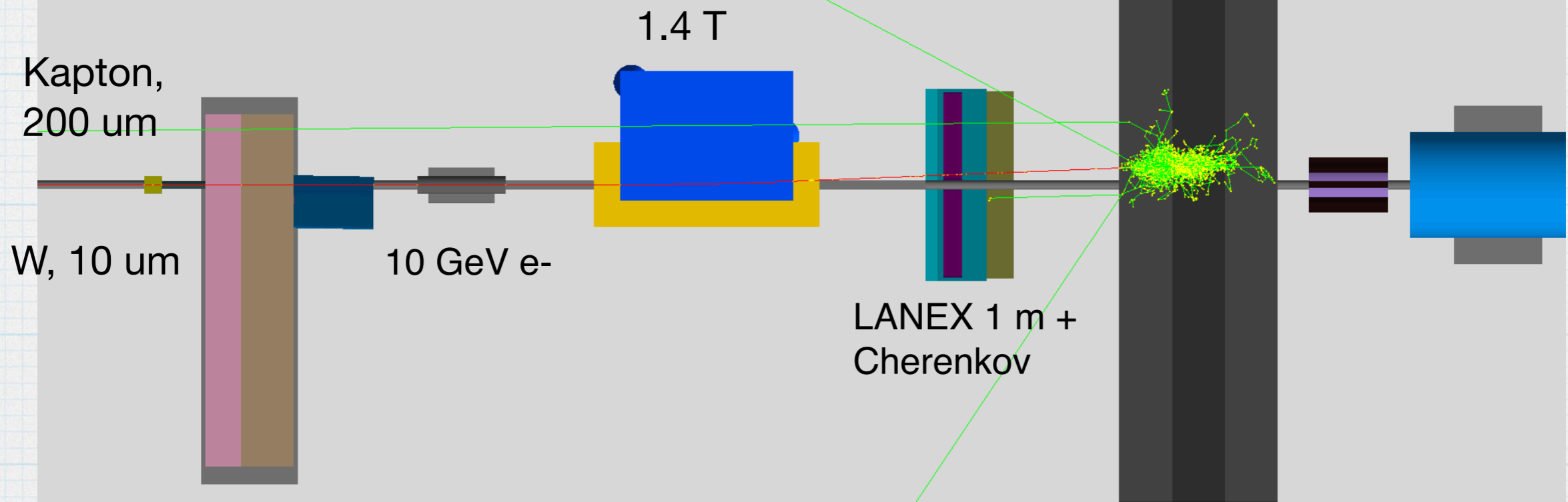
II measure absolute number of photons on event-by-event basis.

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

Forward detector system w/o beam pipe



FDS setup with pipe



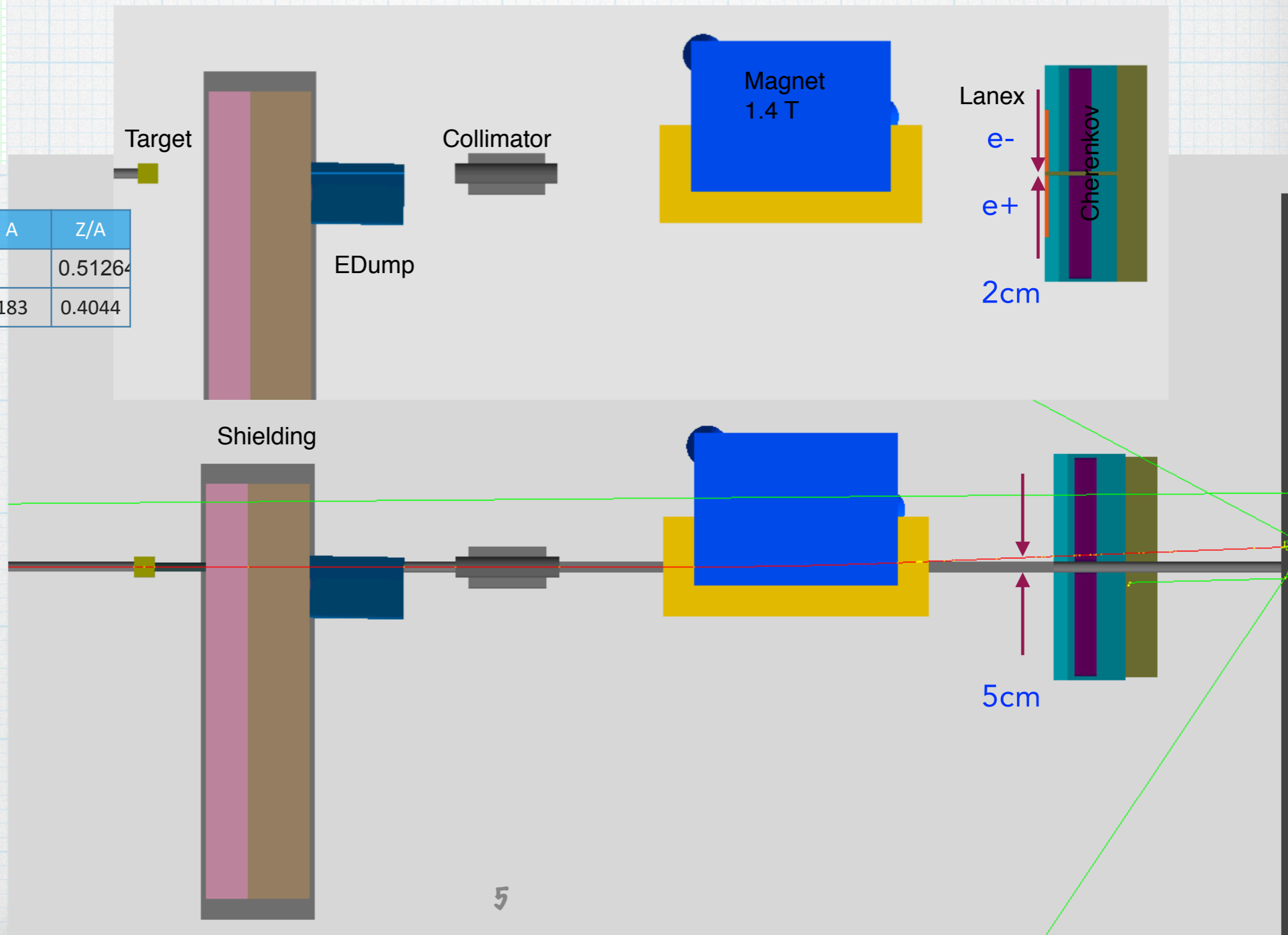
Forward detector system with & w/o beam pipe

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

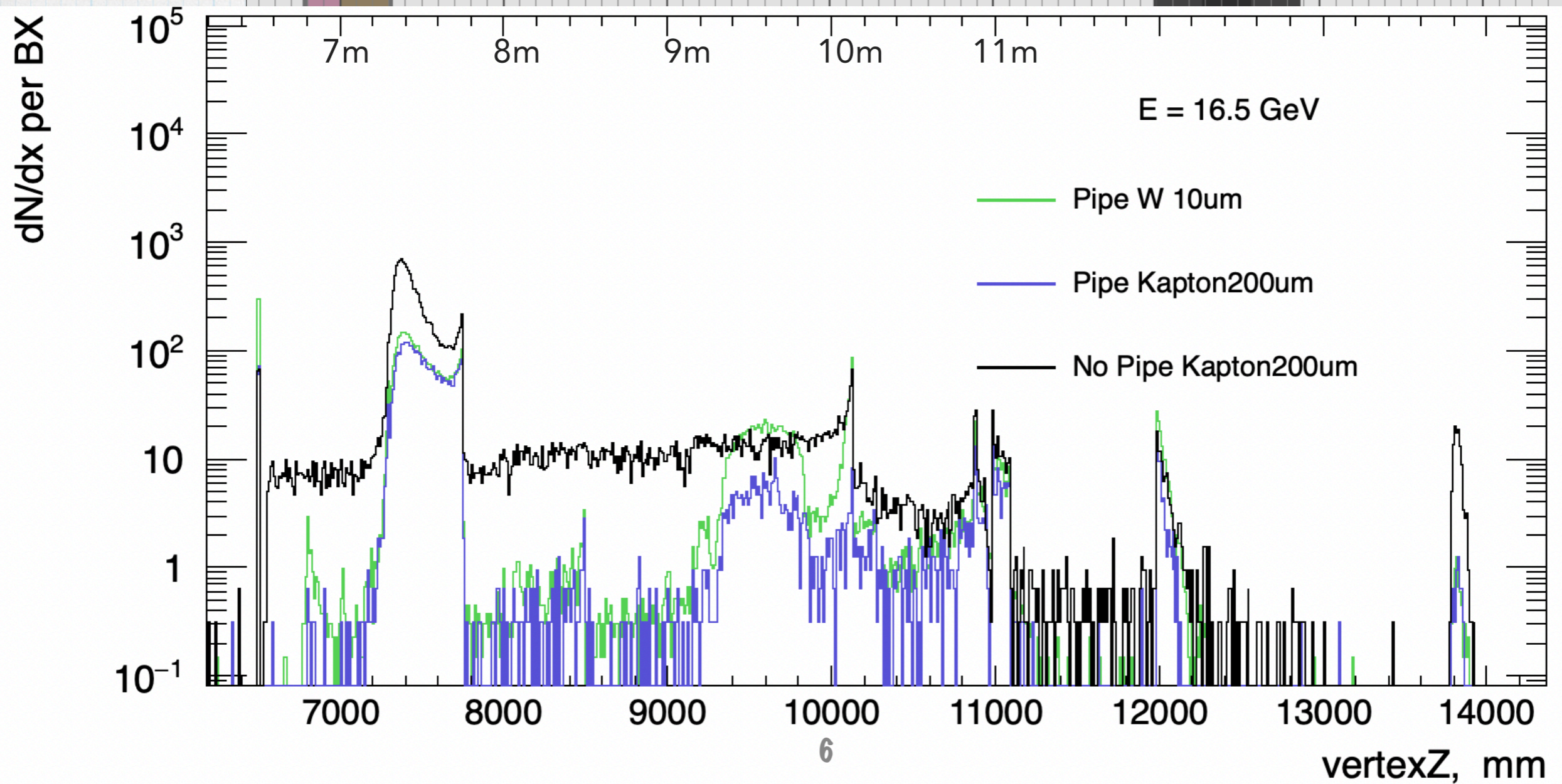
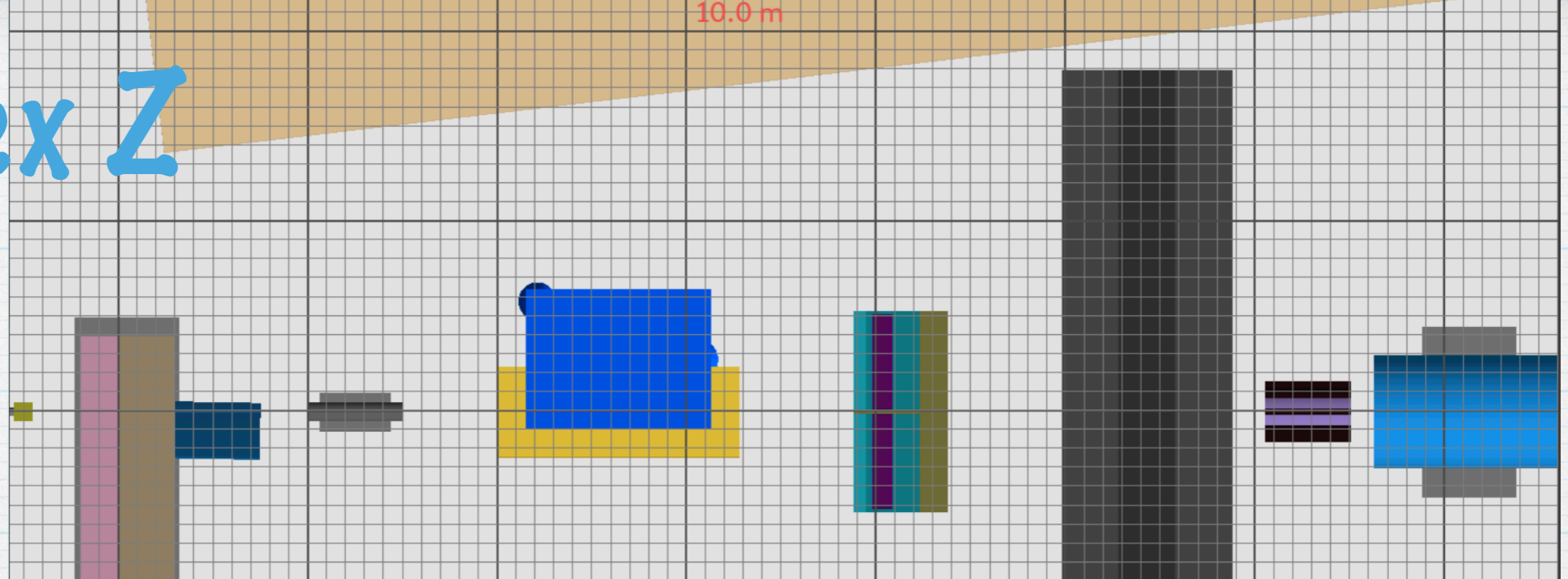
Composition:

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



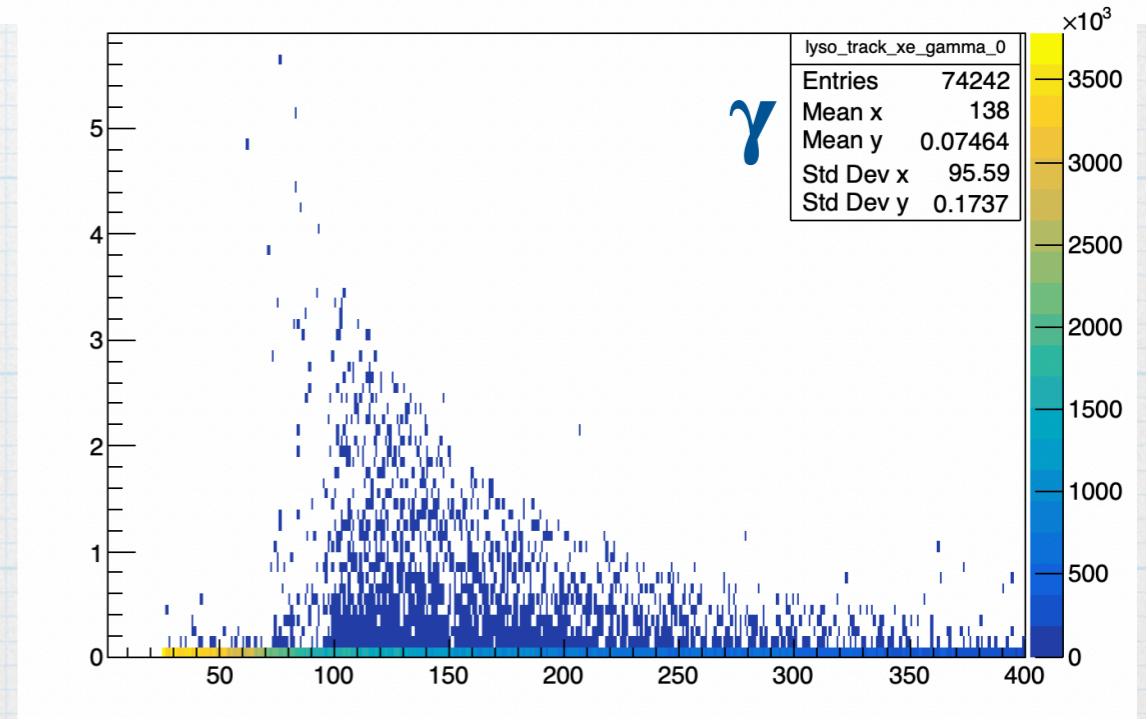
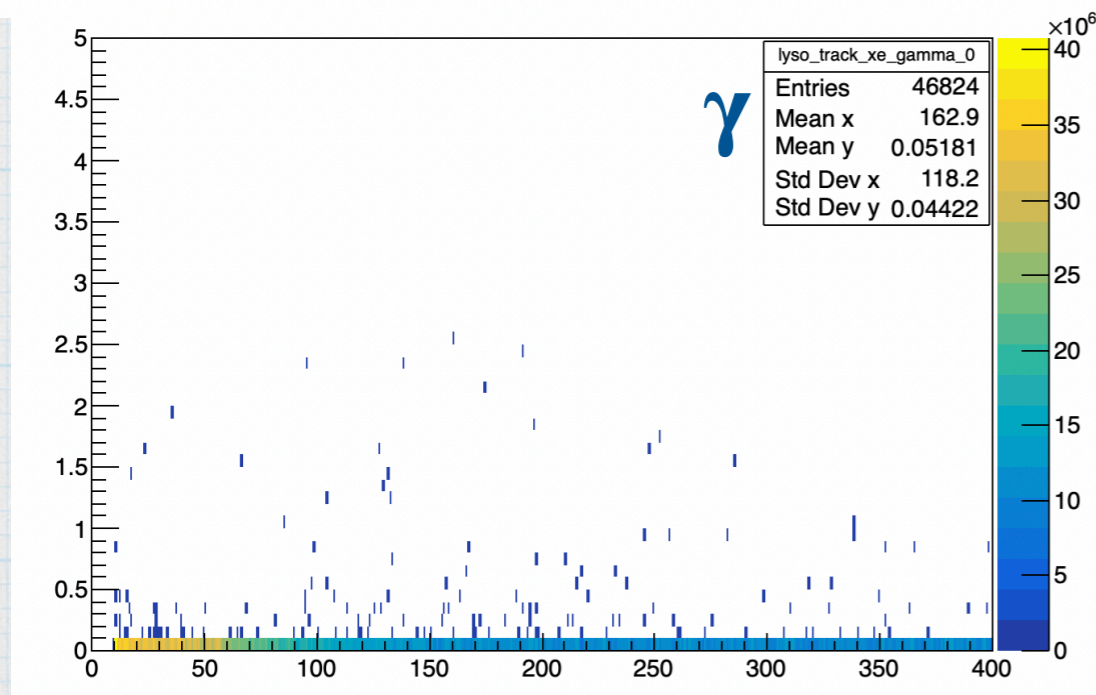
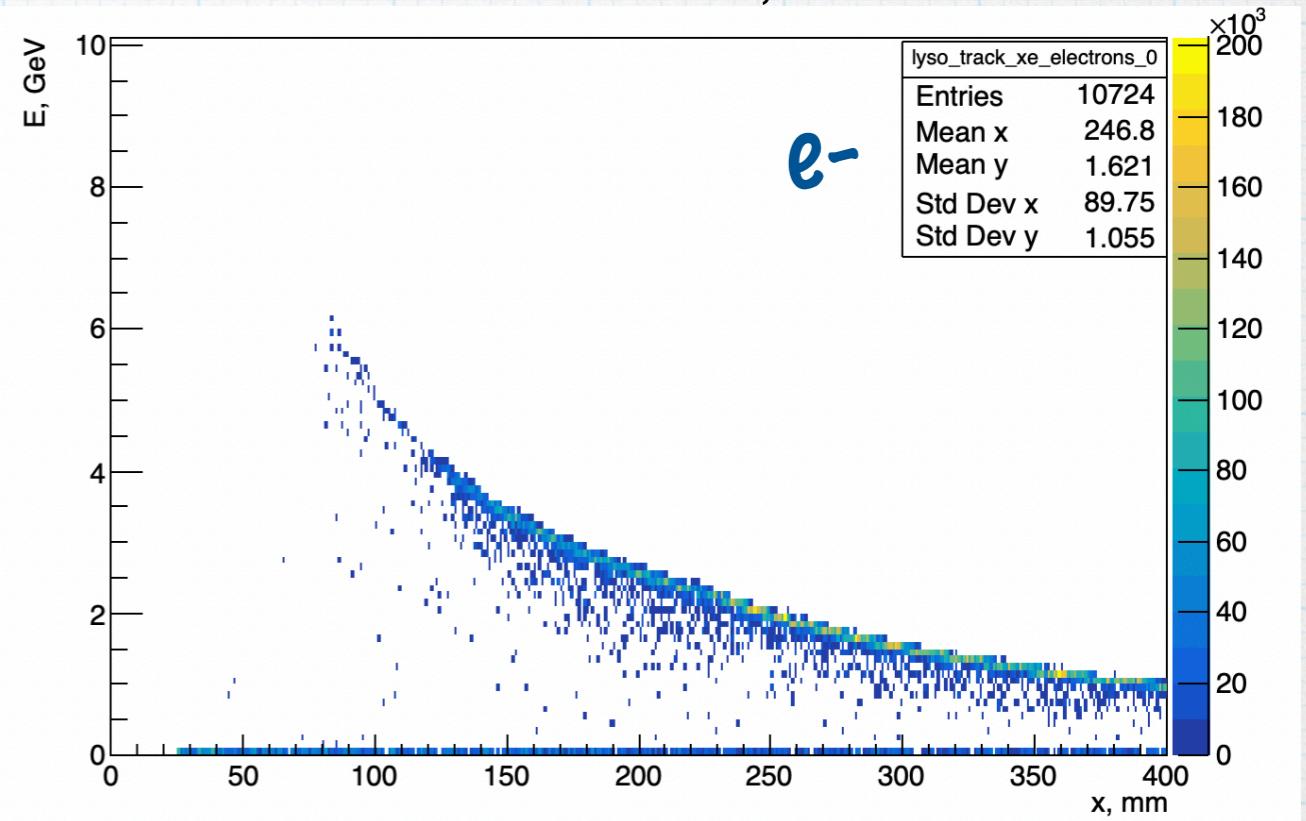
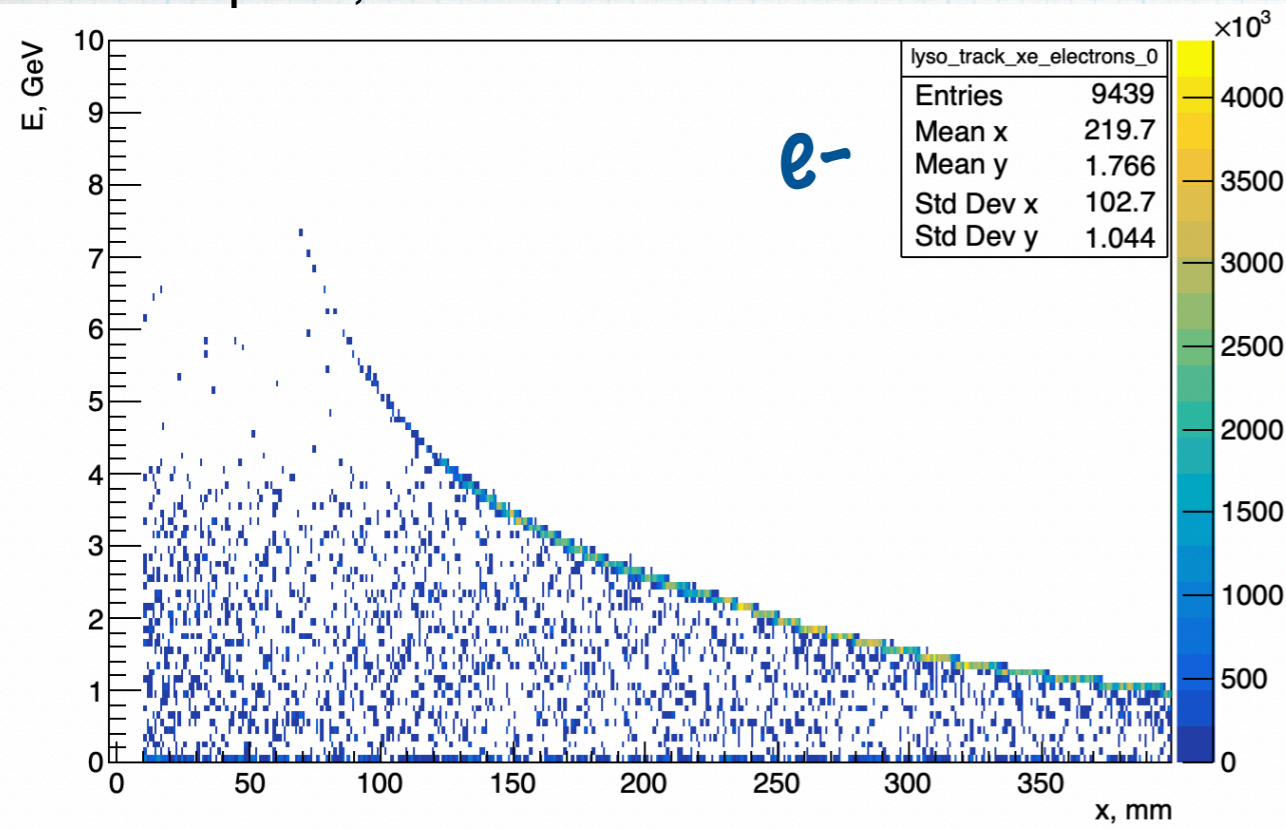
Vertex Z



Energy vs position

NO Beam Pipe
Kapton, 200 μm

Beam Pipe 5 cm
W, 10 μm



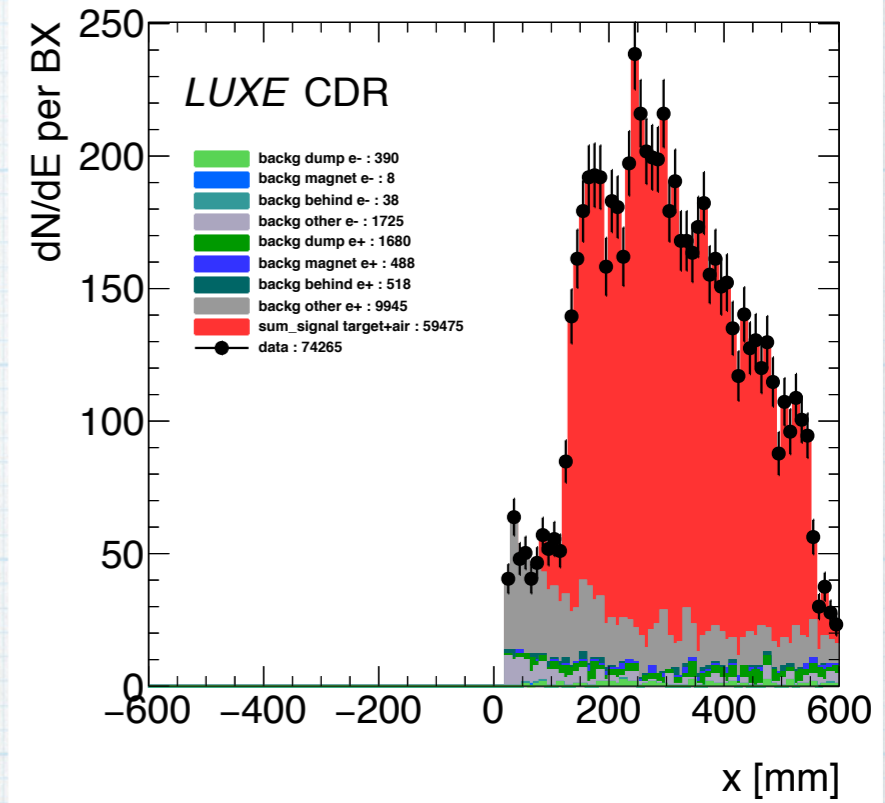
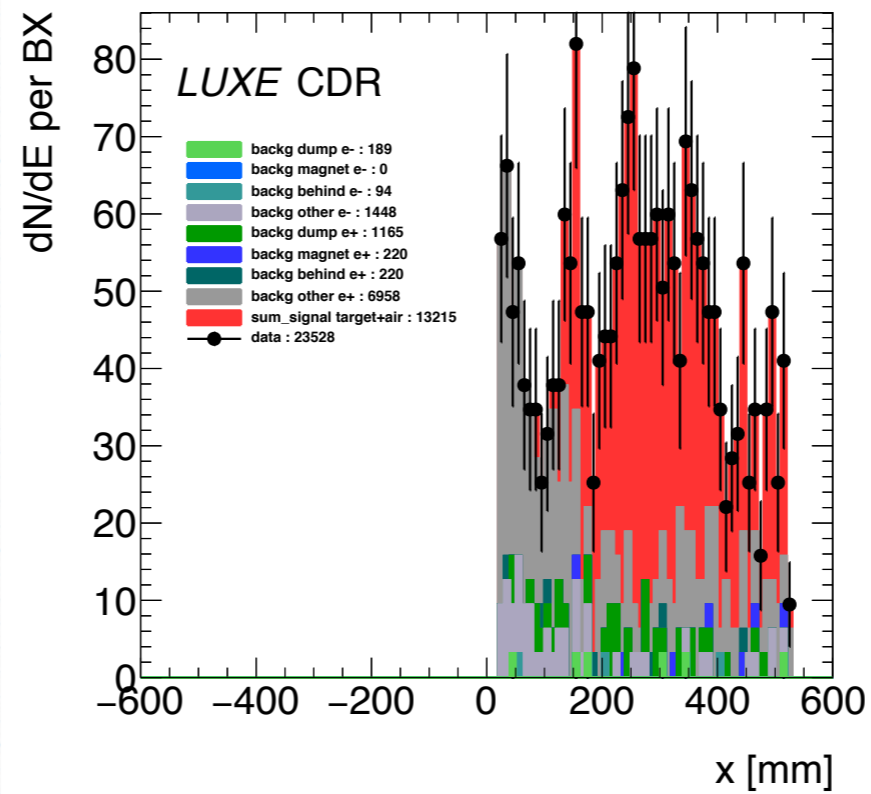
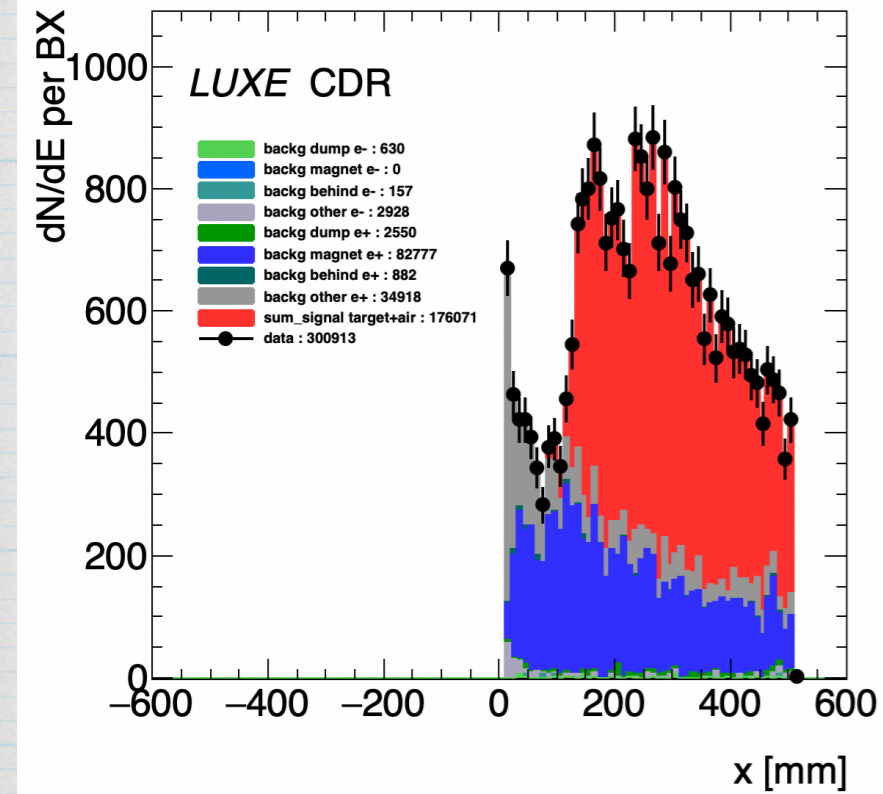
Electron Energy-position correlation is cleaner in case of beam pipe and photons distribution shows that they were produced after the electron direction was defined.

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

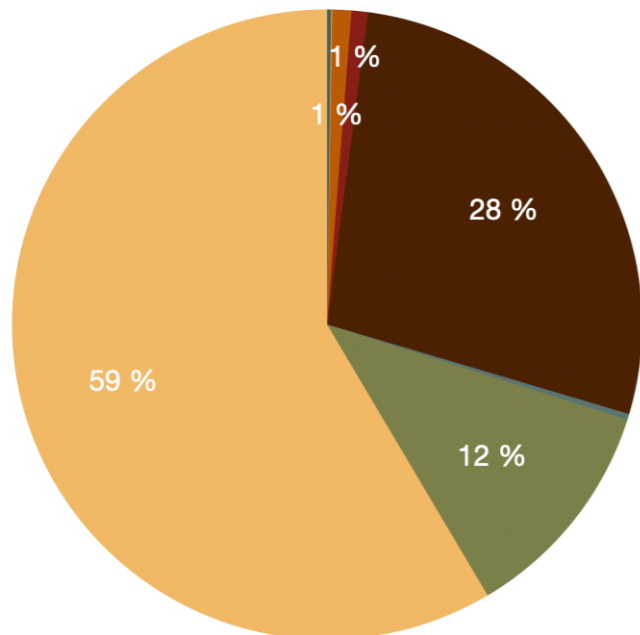
NO Beam Pipe
Kapton, 200 μ m

Beam Pipe 5 cm
Kapton, 200 μ m

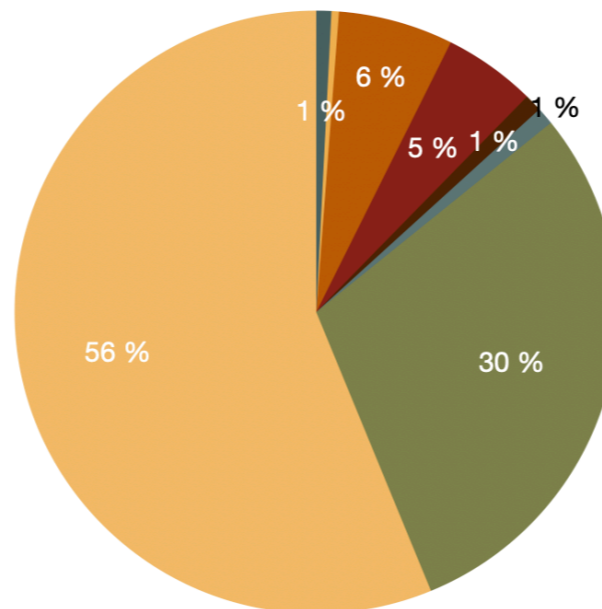
Beam Pipe 5 cm
W, 10 μ m



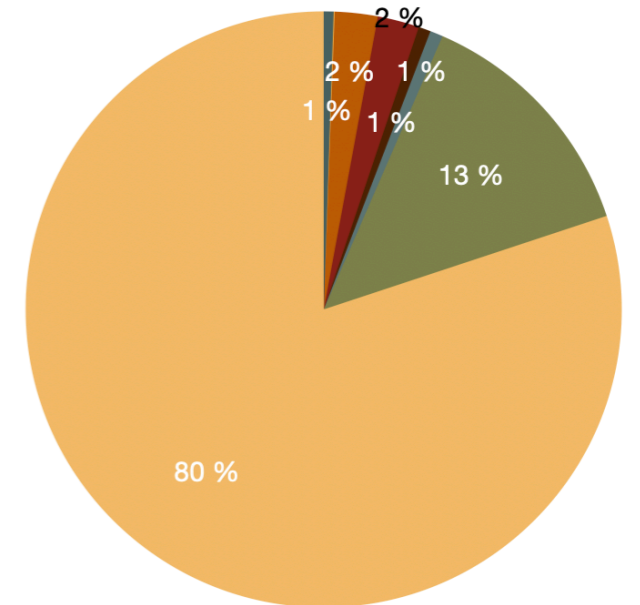
dump pos magnet pos behind pos other pos dump el magnet el behind el other el Signal



dump pos magnet pos behind pos other pos dump el magnet el behind el other el Signal

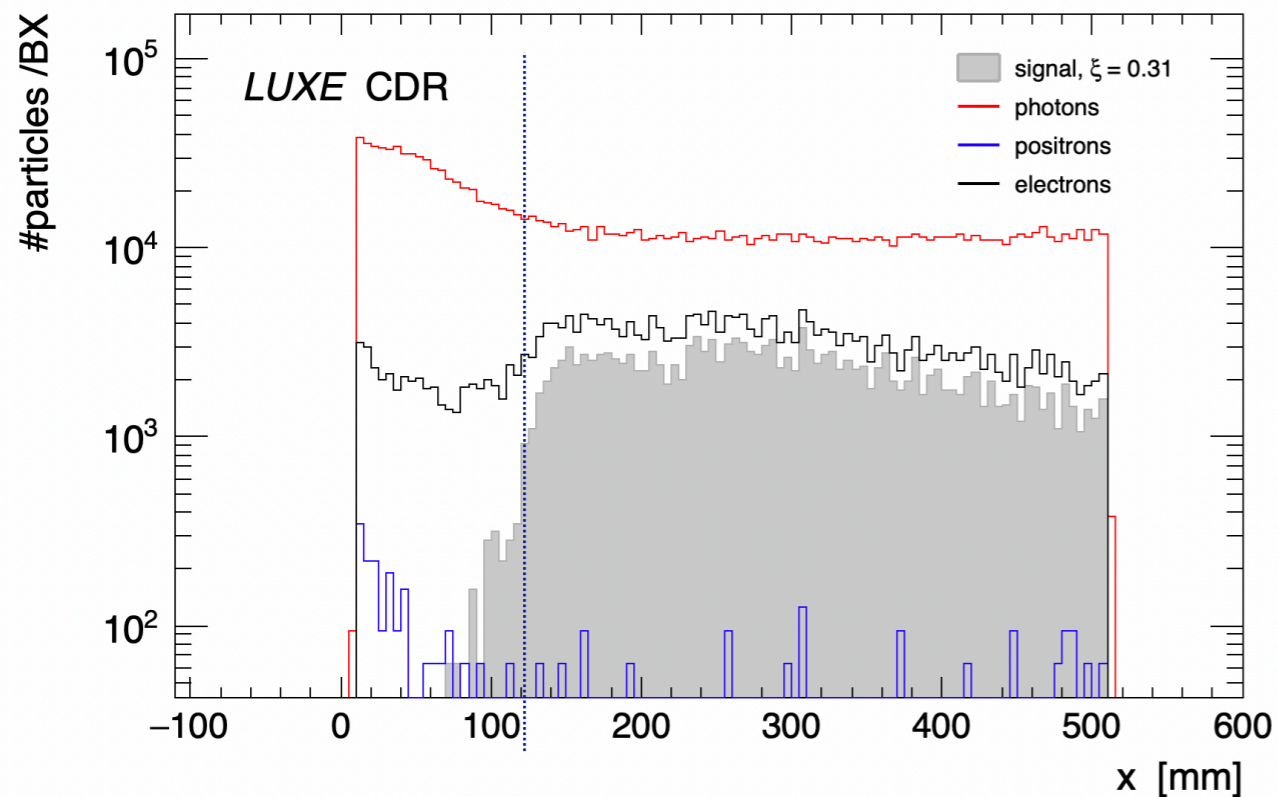


dump pos magnet pos behind pos other pos dump el magnet el behind el other el Signal

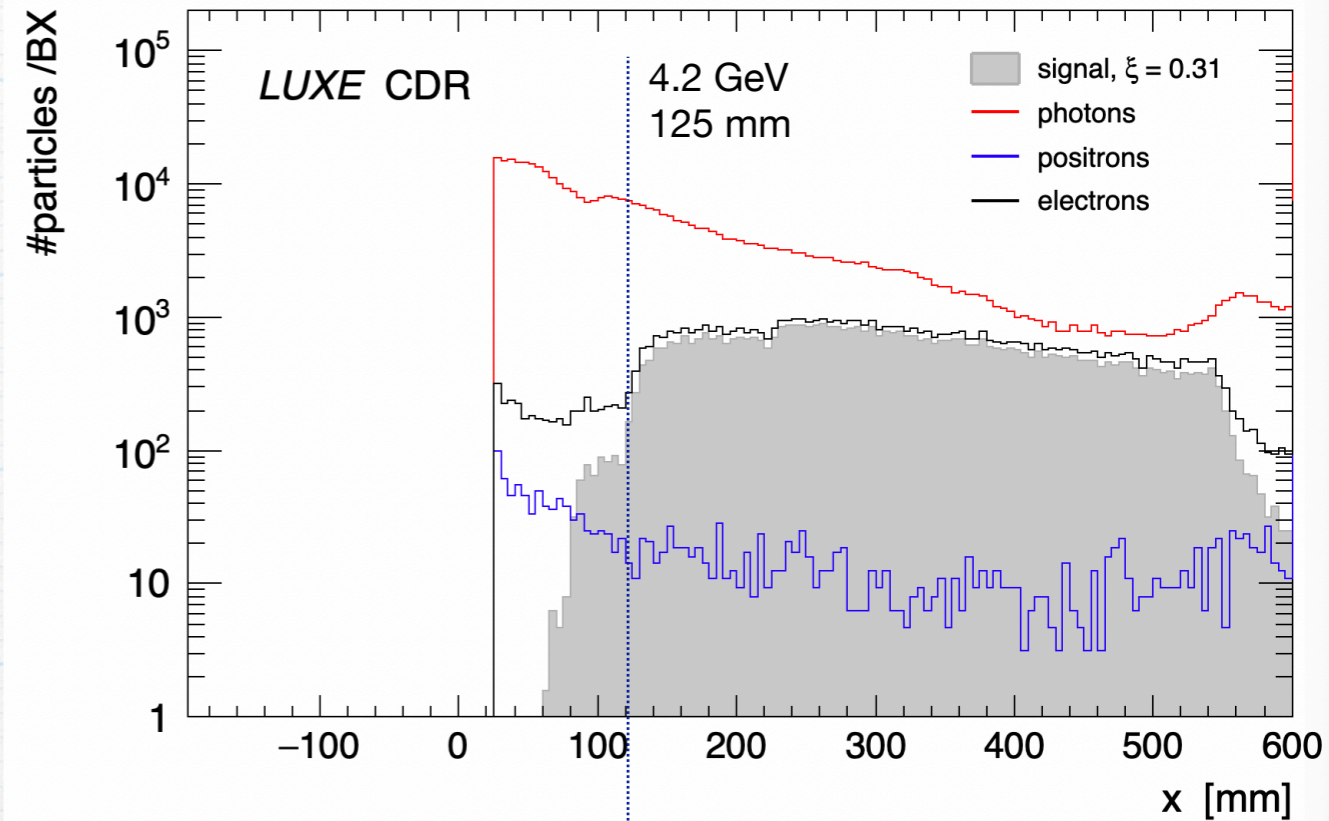


Particles in electron arm

NO Beam Pipe
Kapton, 200 μm



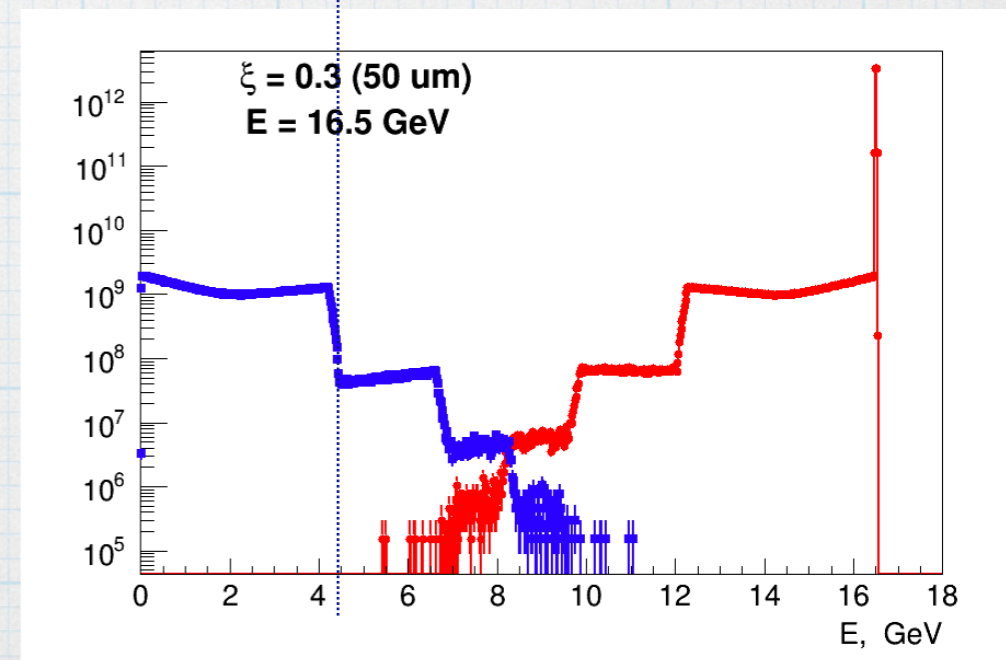
Beam Pipe 5 cm
W, 10 μm



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%

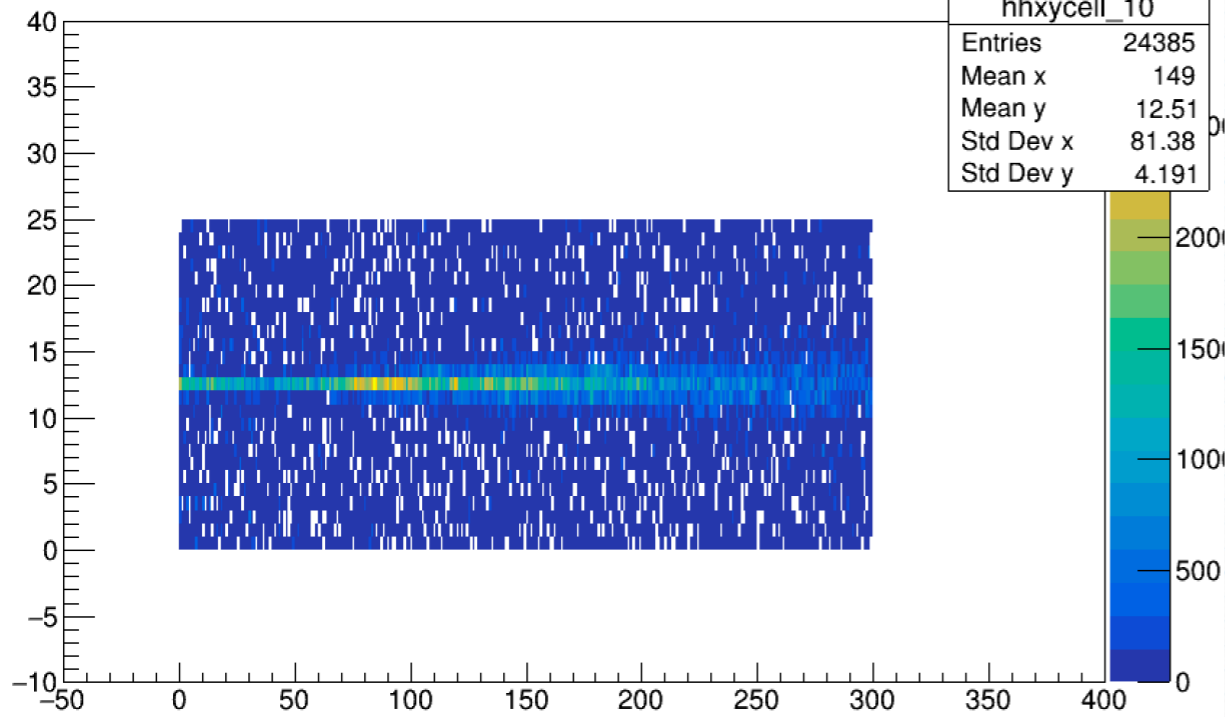
9

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

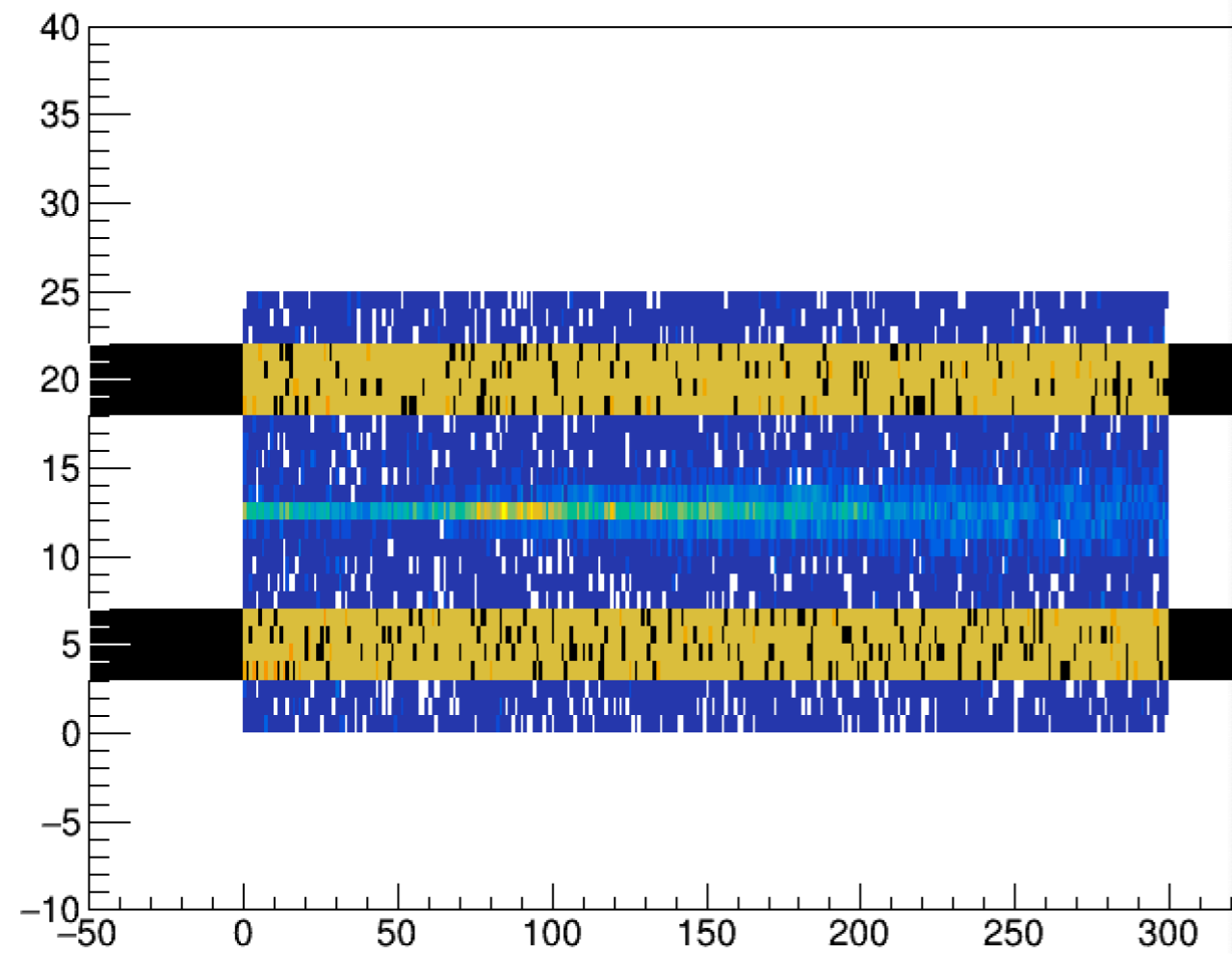
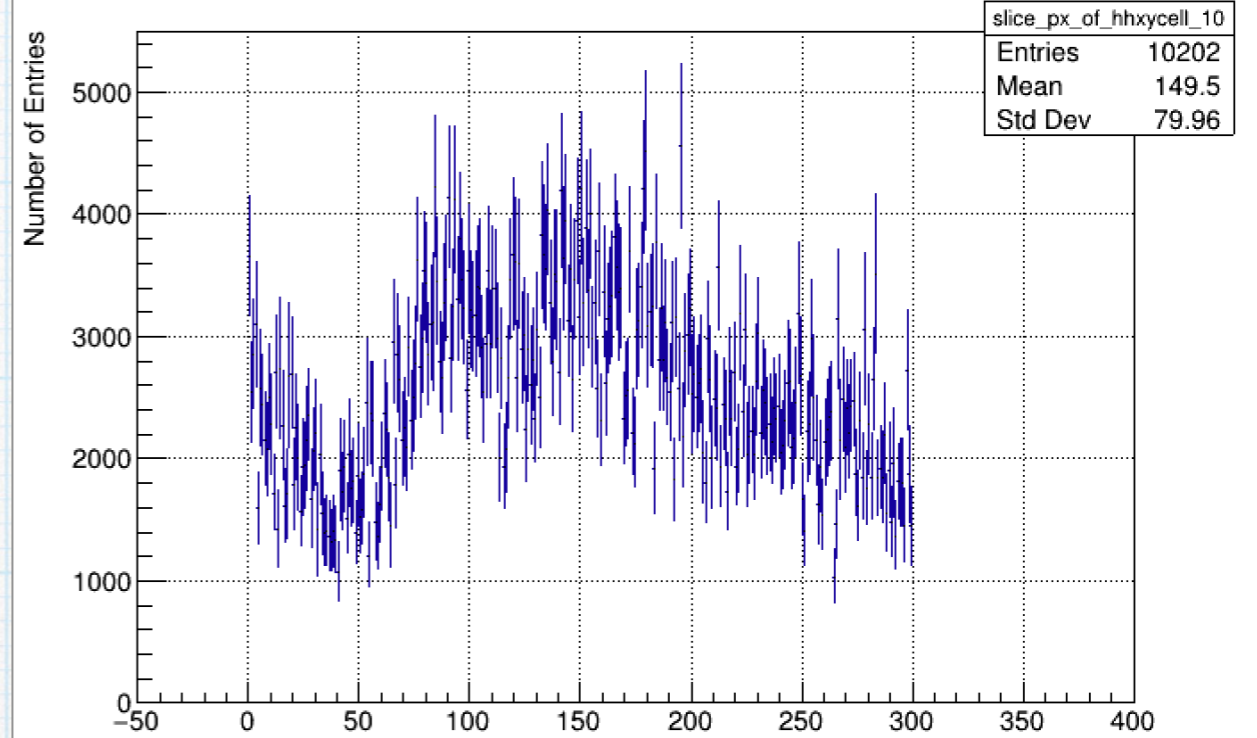


Reconstruction

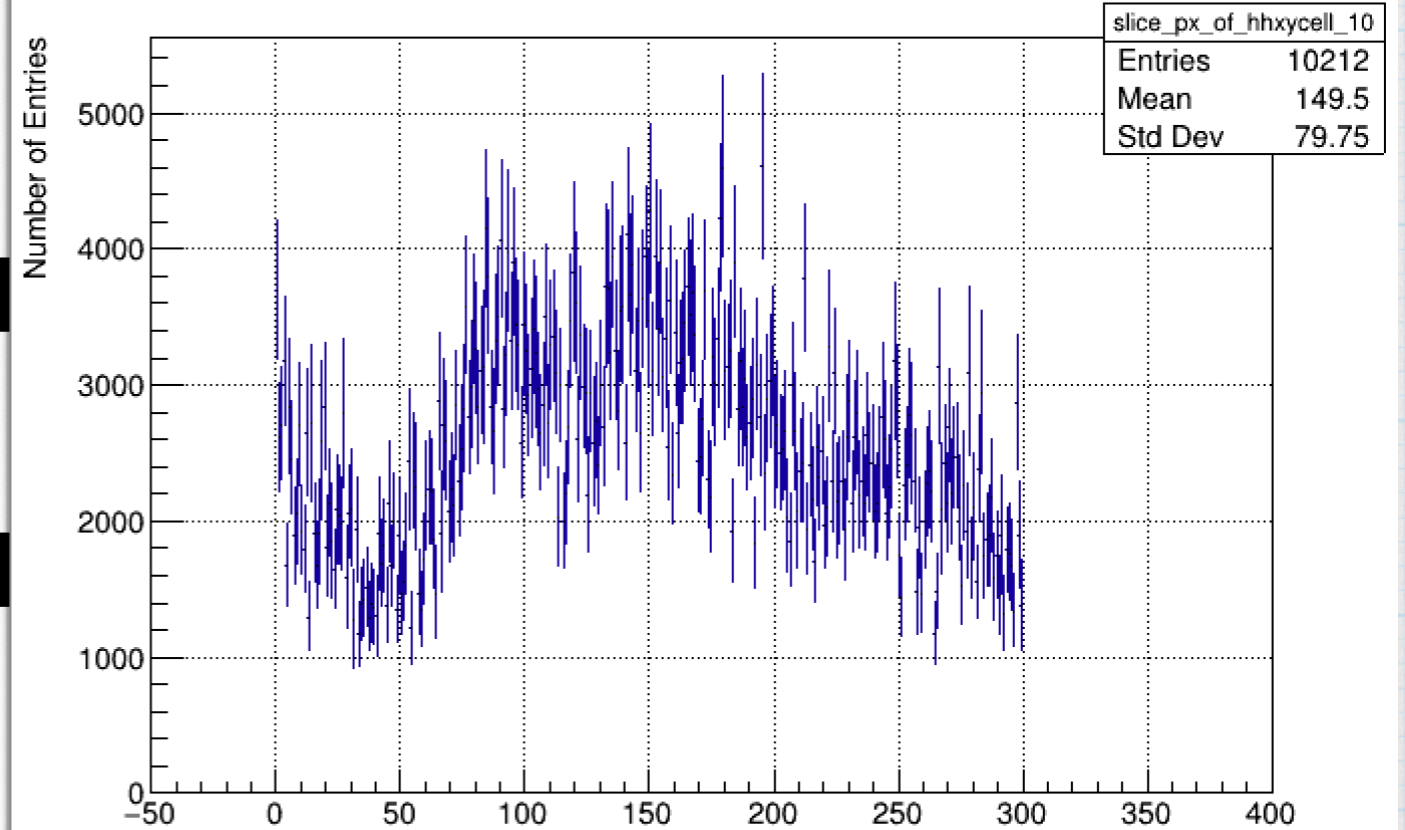
hhxycell_10



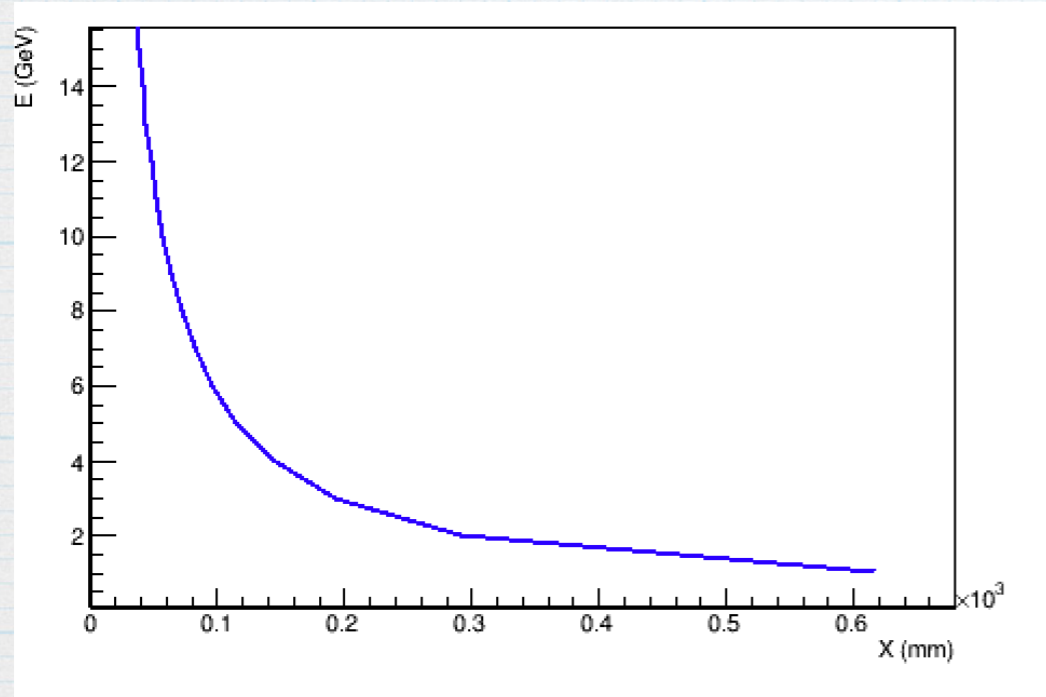
ProjectionX of biny=[14,28] [y=3.0..18.0]



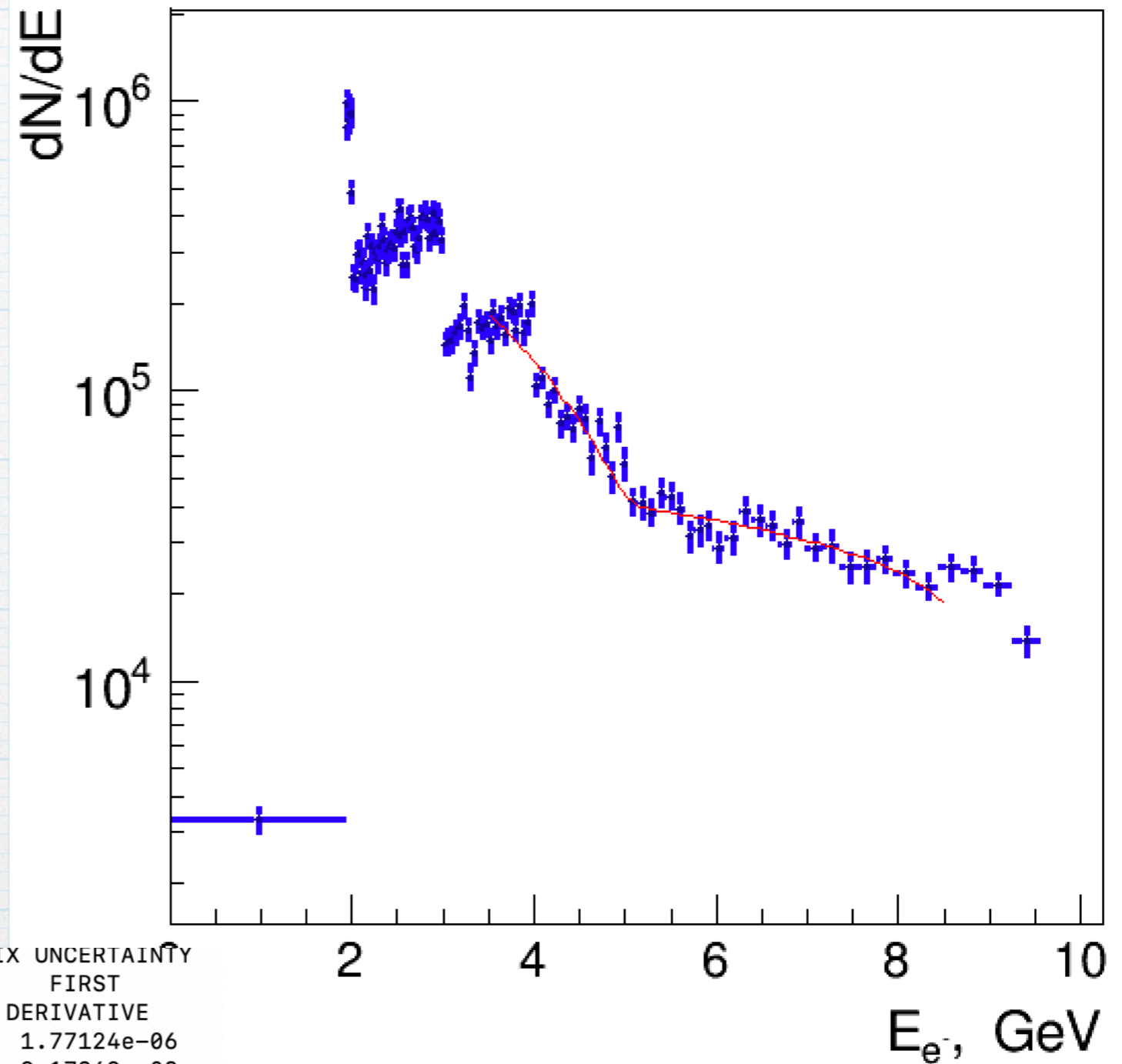
ProjectionX of biny=[18,32] [y=7.0..22.0]



Spectra reconstruction for the Lanex case

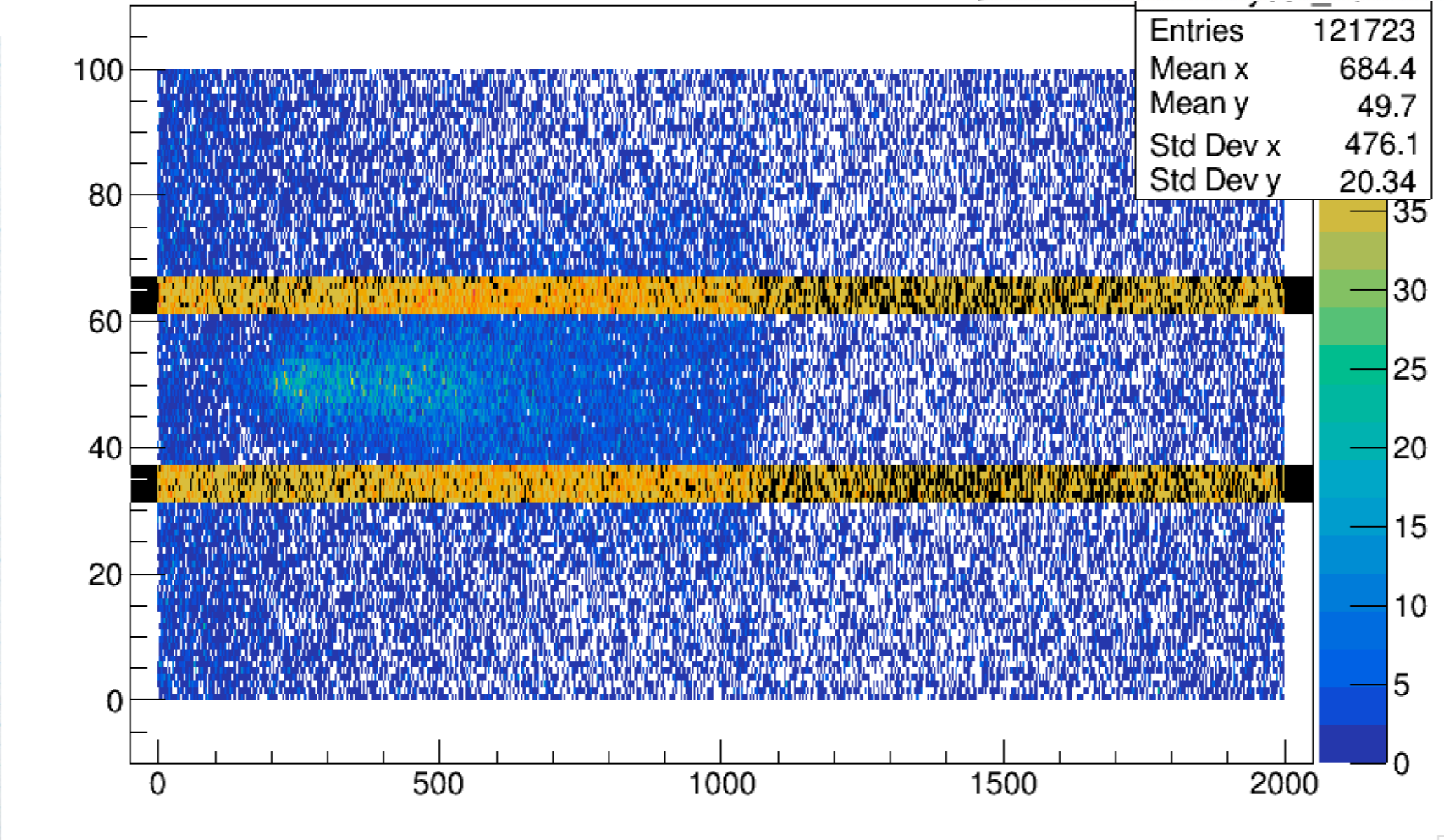
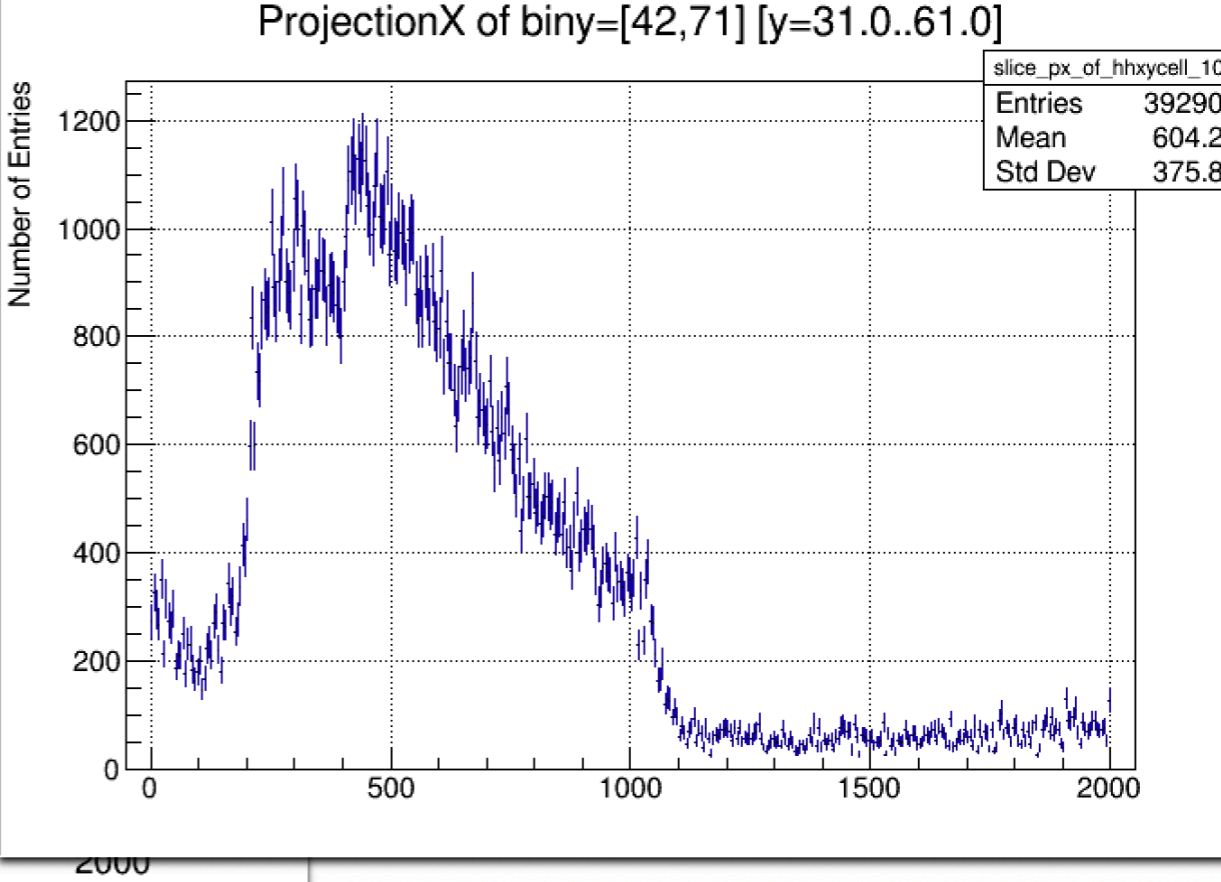
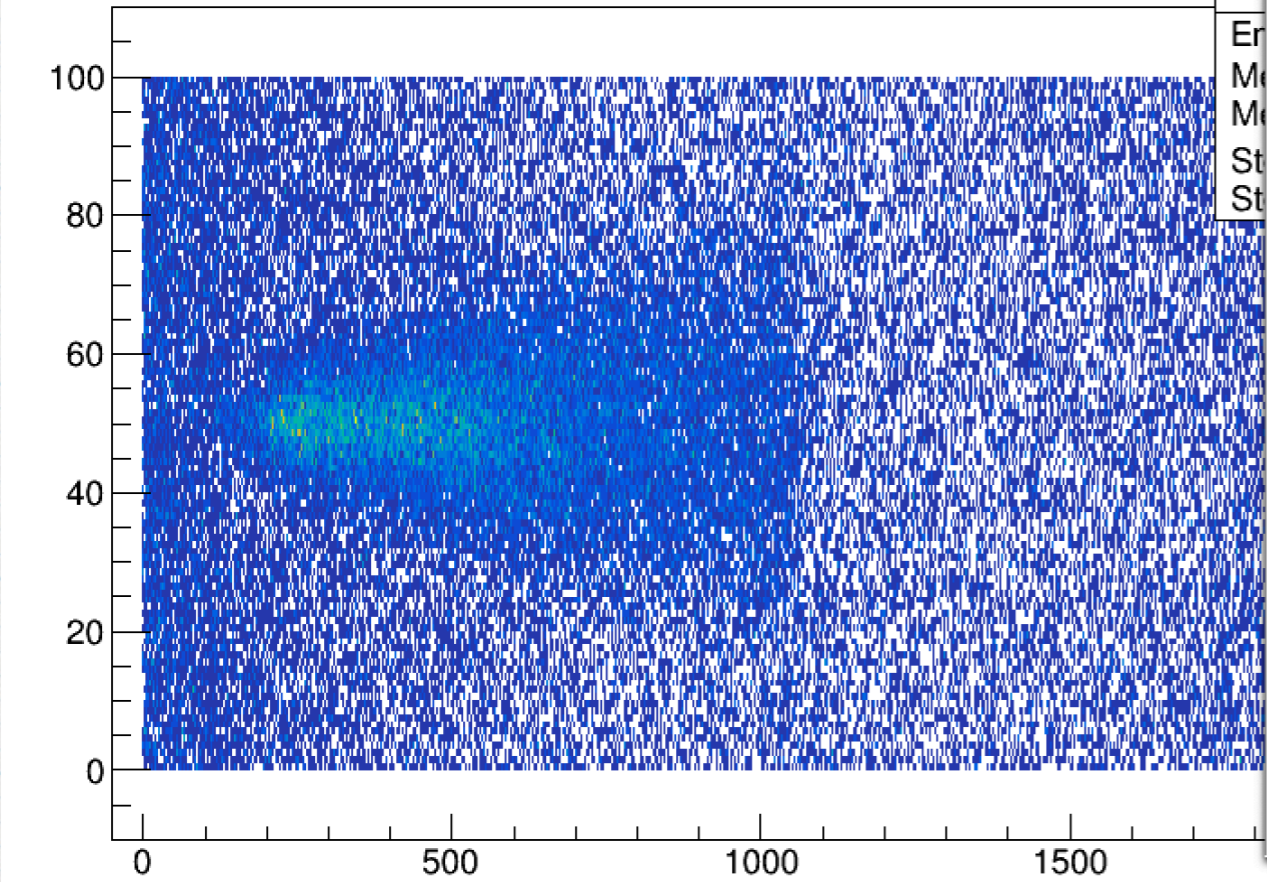


spectrum_electron

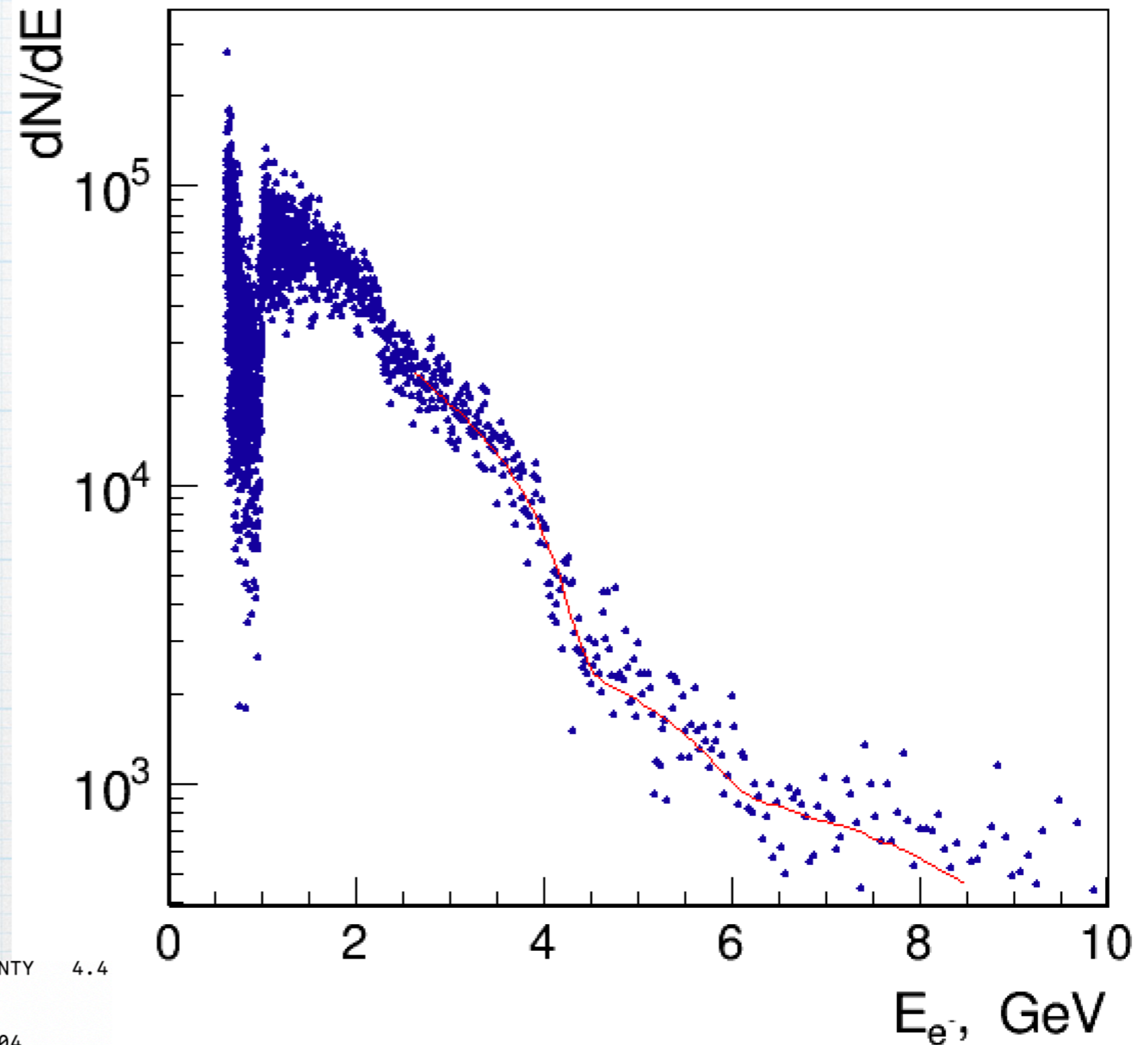


EDM=3.45767 STRATEGY= 1 ERROR MATRIX UNCERTAINTY					
EXT	PARAMETER	VALUE	APPROXIMATE	STEP	FIRST
NO.	NAME		ERROR	SIZE	DERIVATIVE
1	p0	-1.13129e+06	2.26562e+04	-2.47452e-02	1.77124e-06
2	p1	8.52709e+06	1.03972e+05	6.18410e-02	-9.17369e-08
3	p2	4.99979e+00	1.95217e-01	6.12022e-05	-2.60964e+00
4	p3	1.32018e+05	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 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	

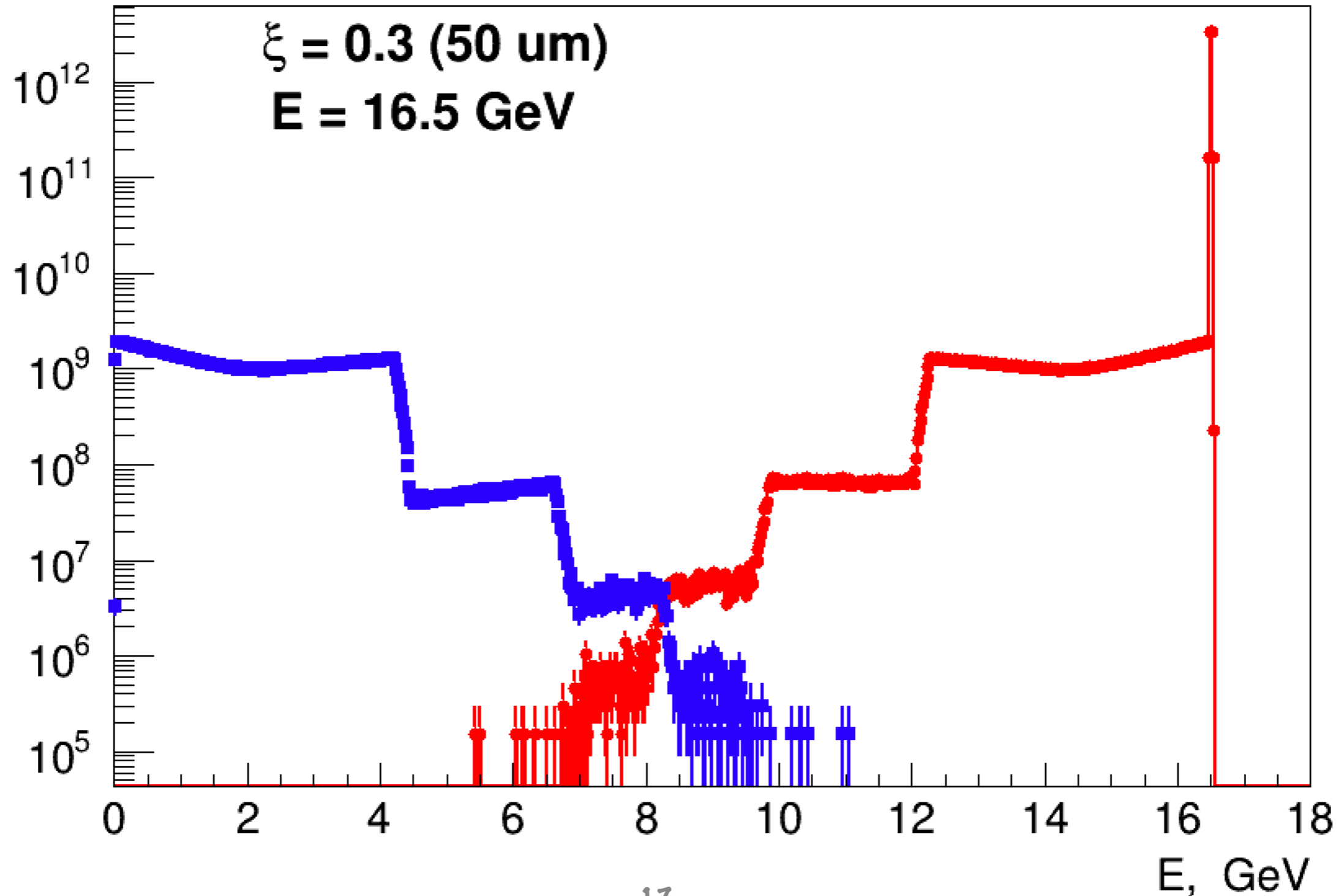
Summary

- * 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 bremsstrahlung 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 4.2 GeV is clearly better observed in detector for the case with the pipe.
- * Signal/Background is twice better for the case with the beam pipe

Back up

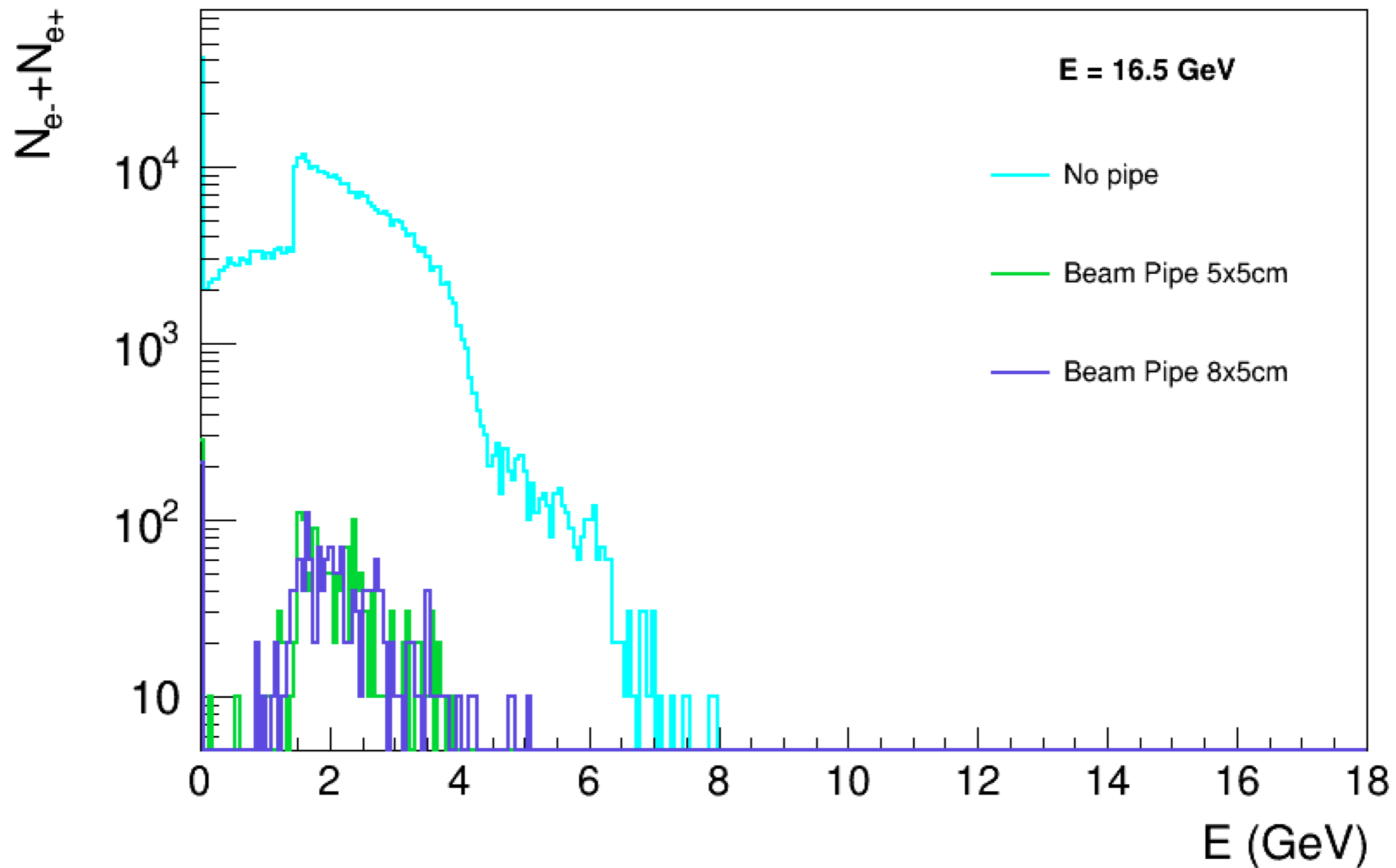
True electron/photon spectra

4764 BX 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.

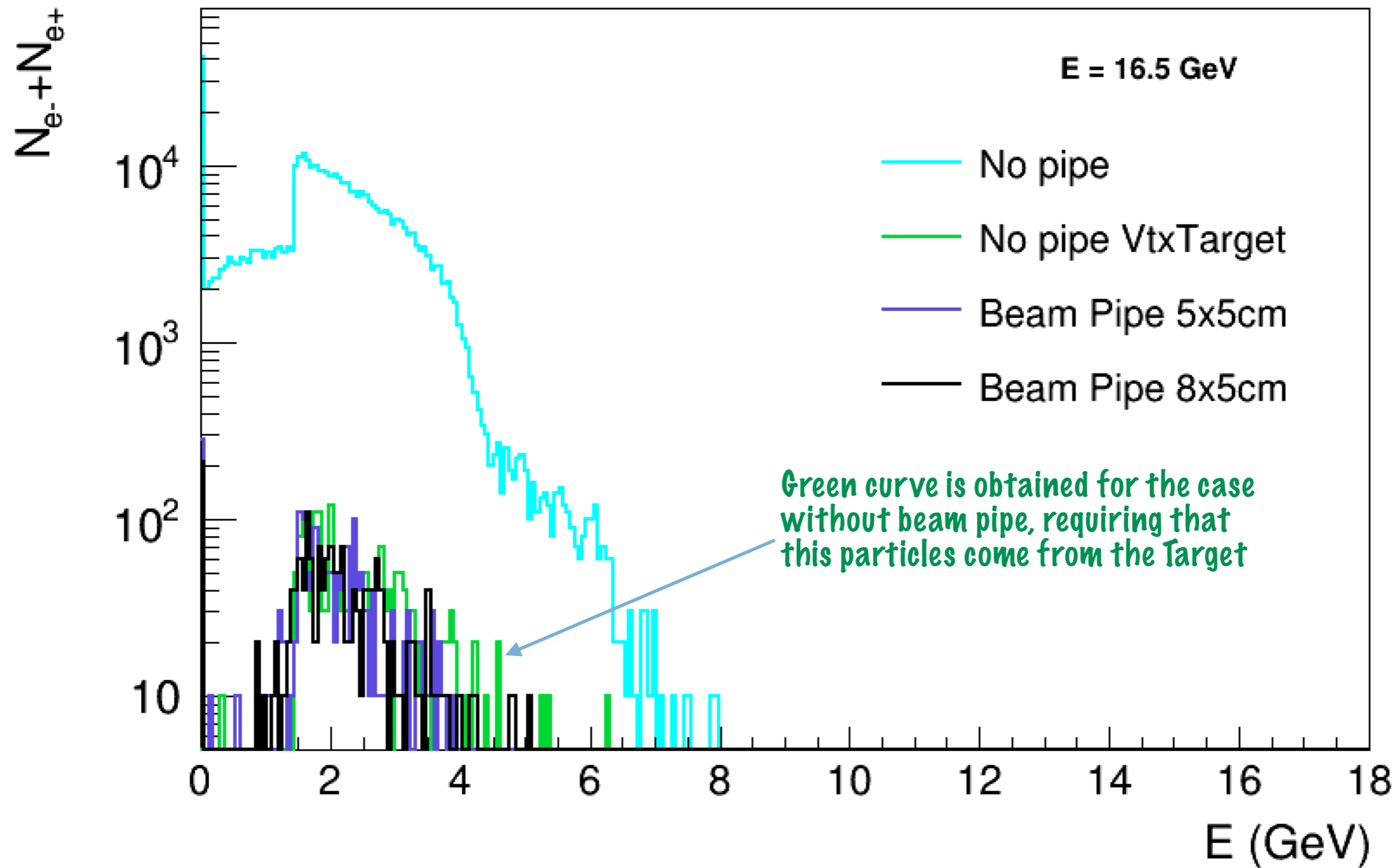
Spectra



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

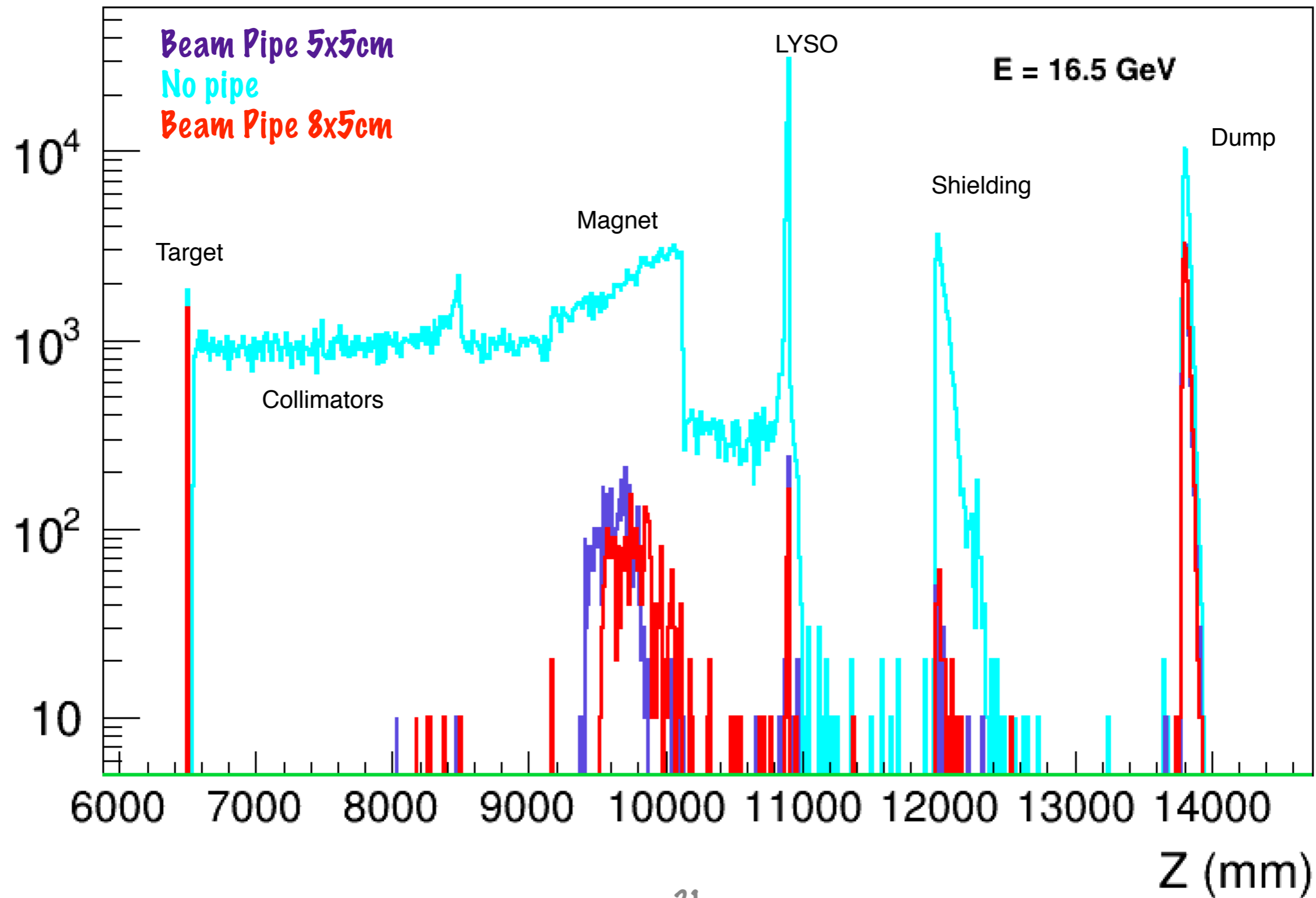
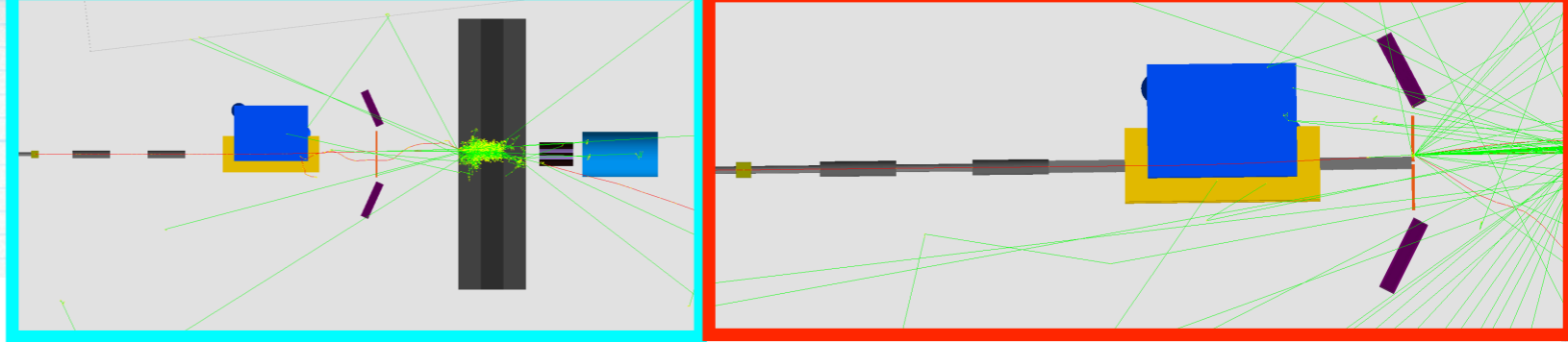
As the laser intensity is low ($\xi = 0.3$), to reconstruct spectra we need more statistics.

Spectra

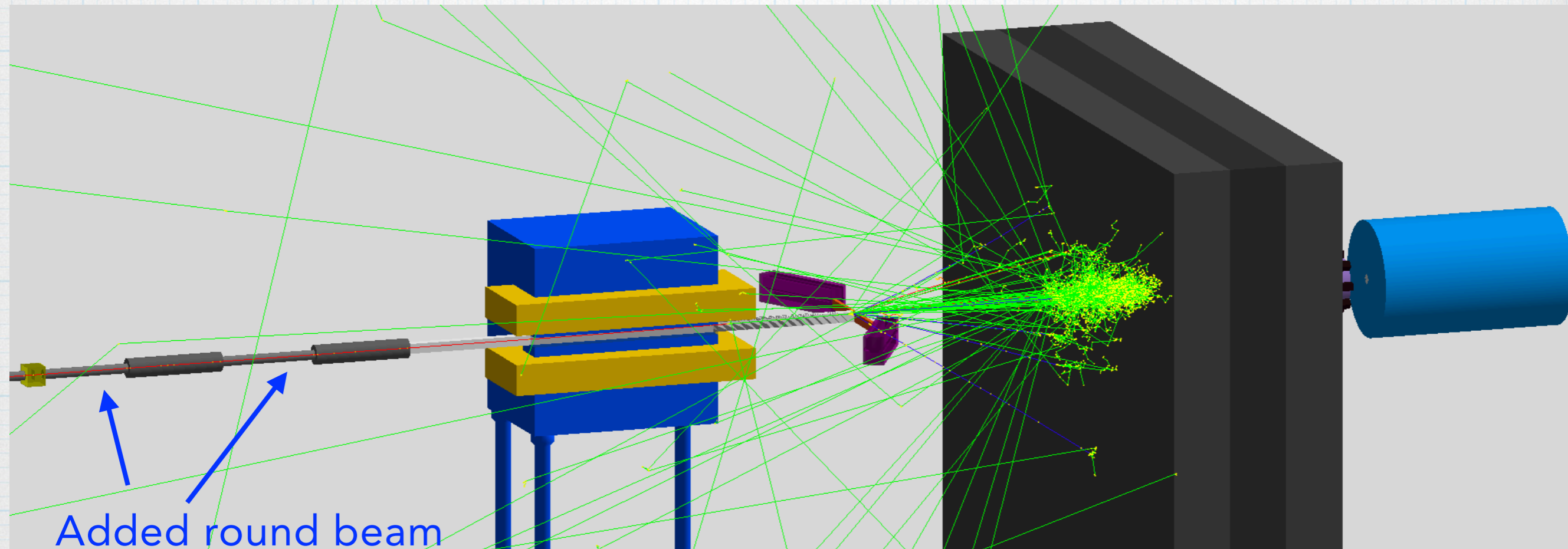


Without beam pipe we measure in Compton detectors a lot e^-/e^+ pairs that were created in the air. Only 4% e^-/e^+ are generated in the Target

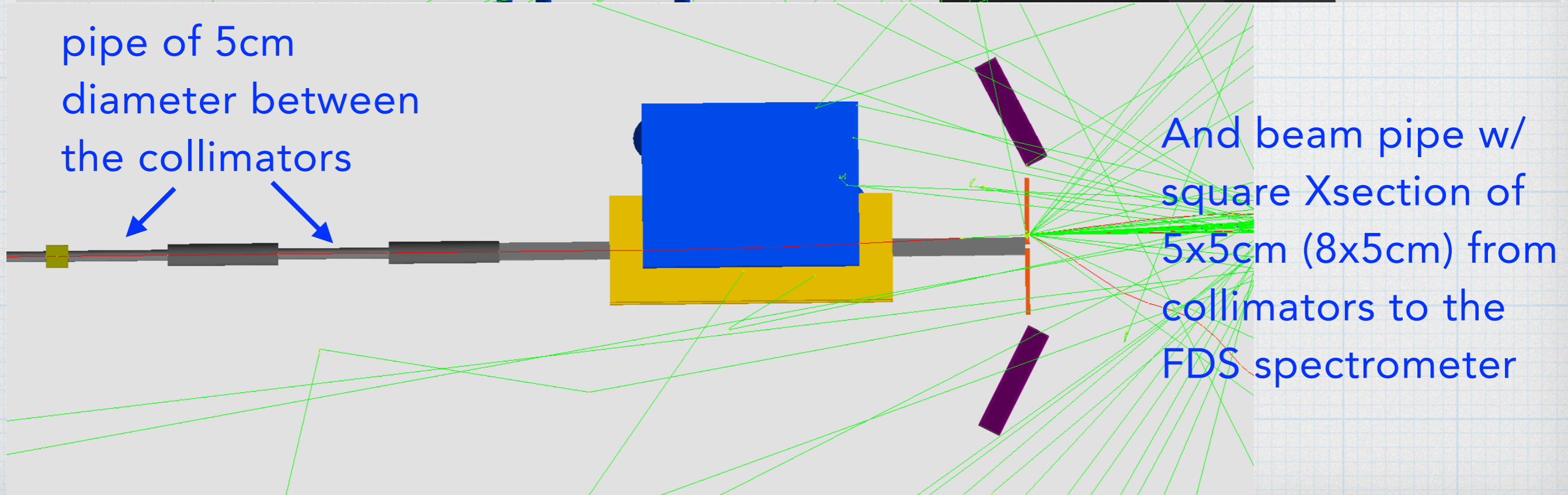
Vertex z



Setup with the beam pipe

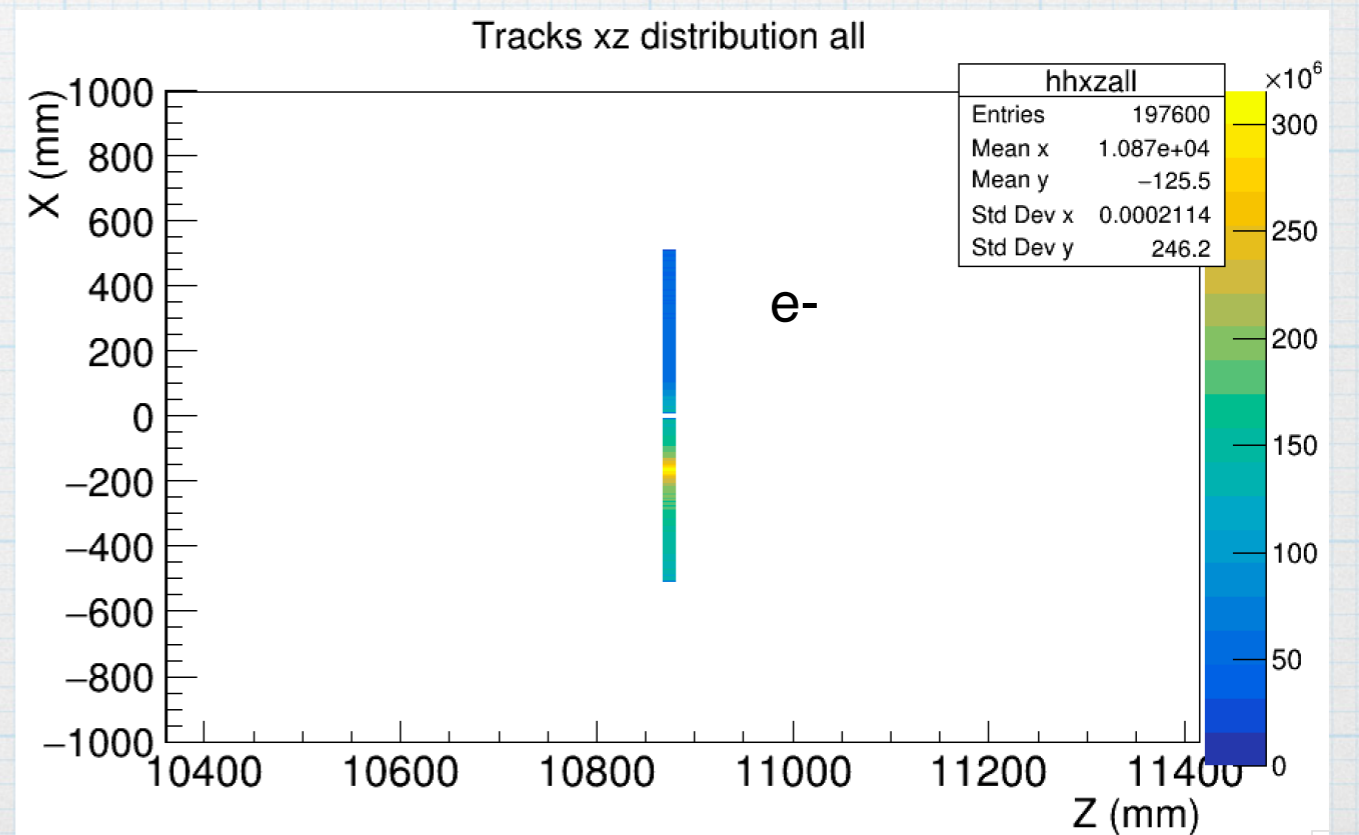
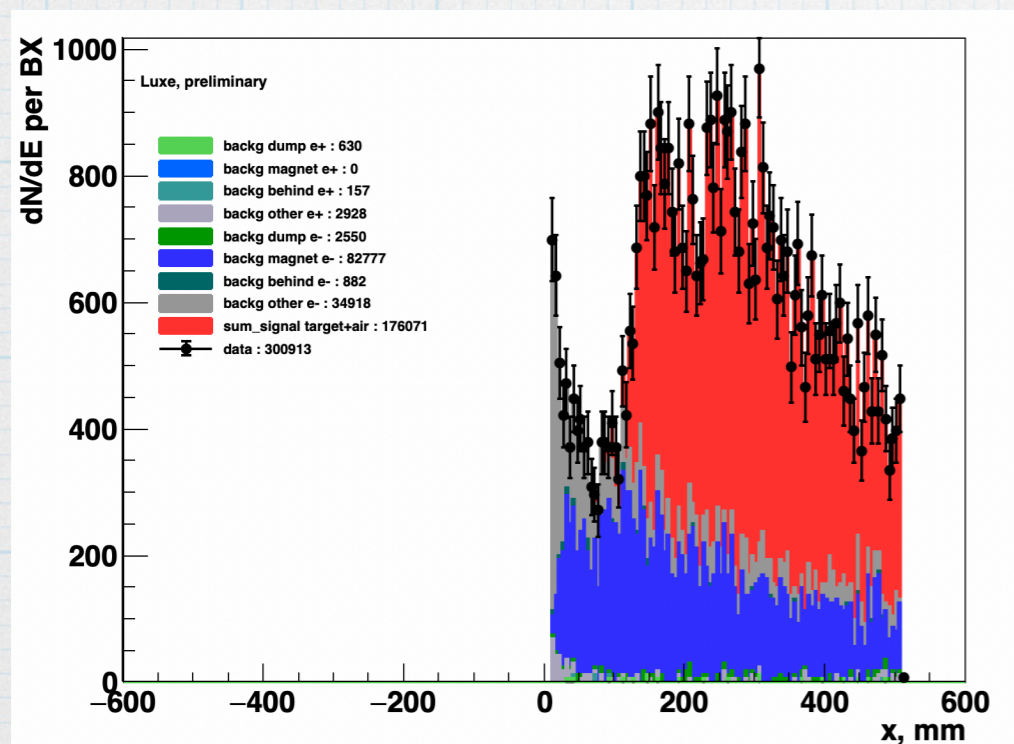
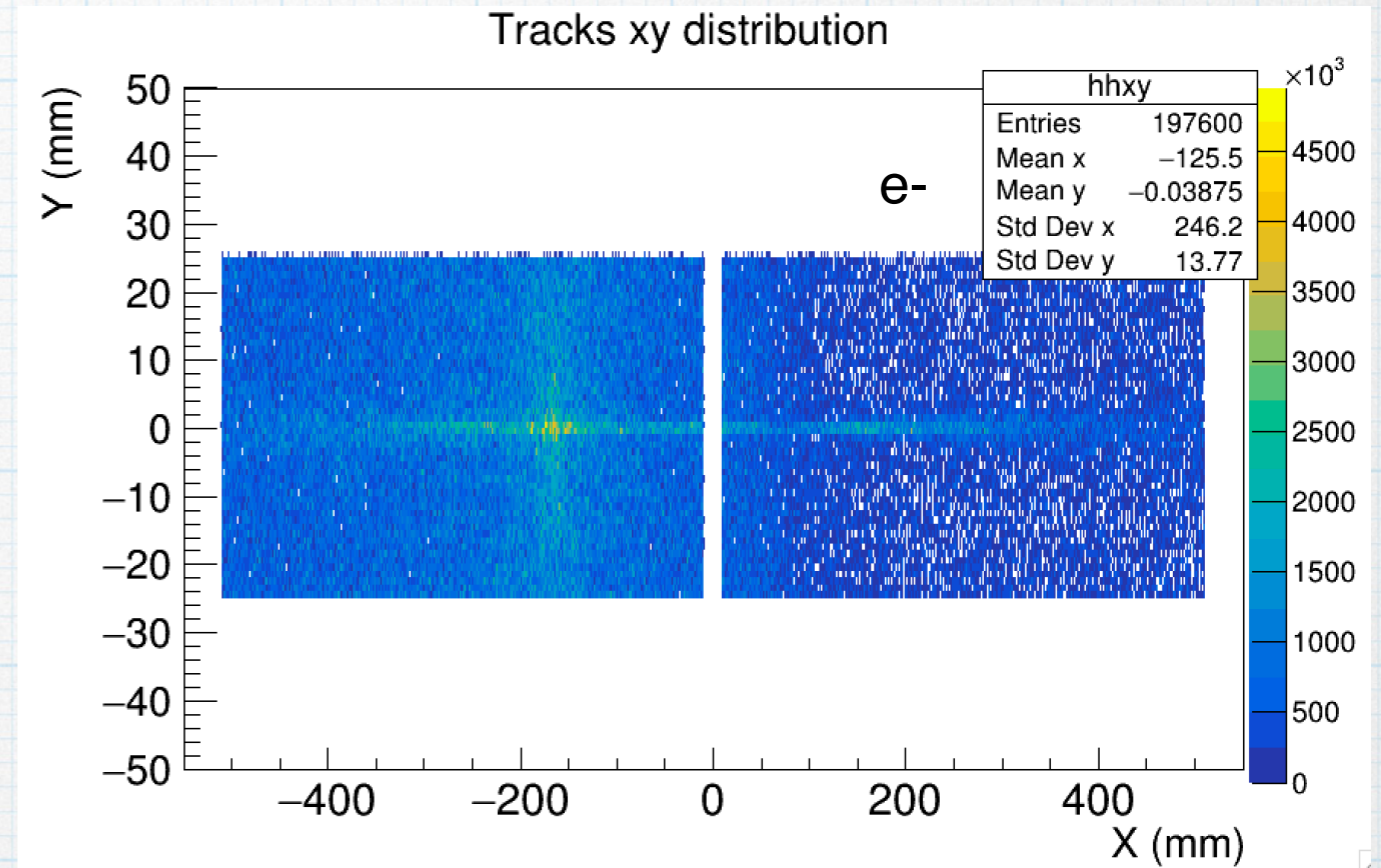
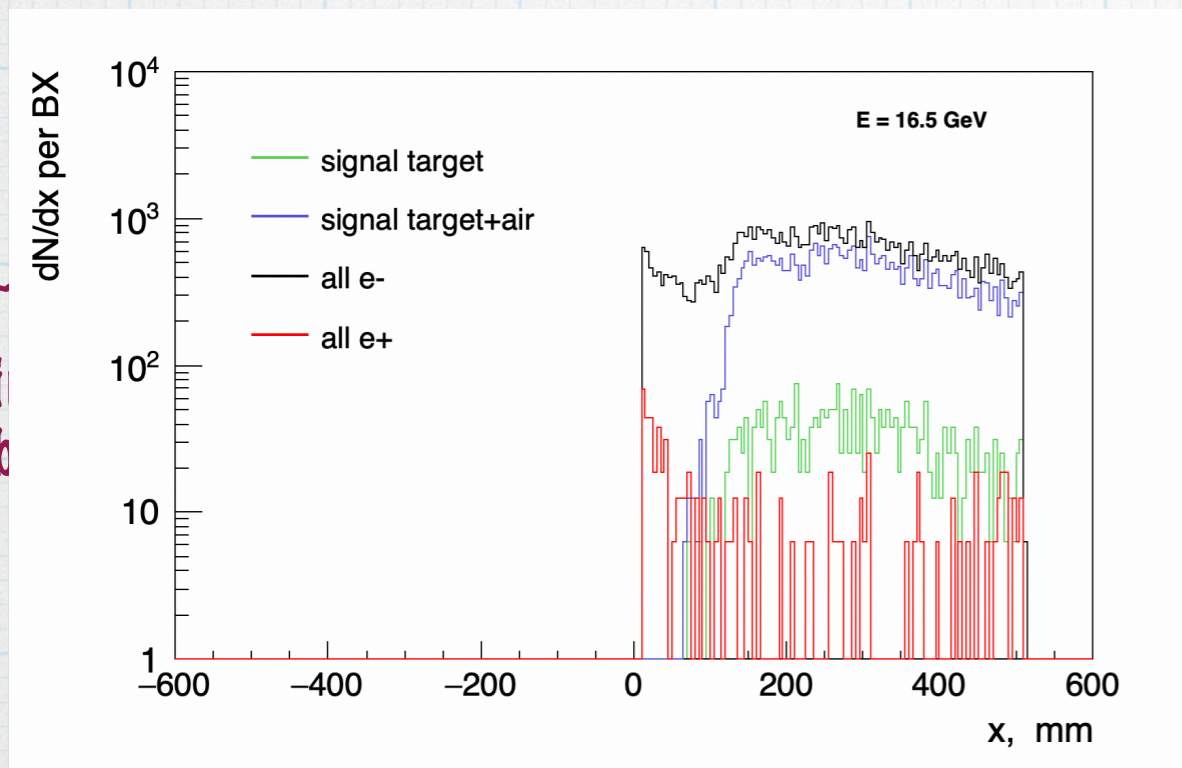


Added round beam
pipe of 5cm
diameter between
the collimators

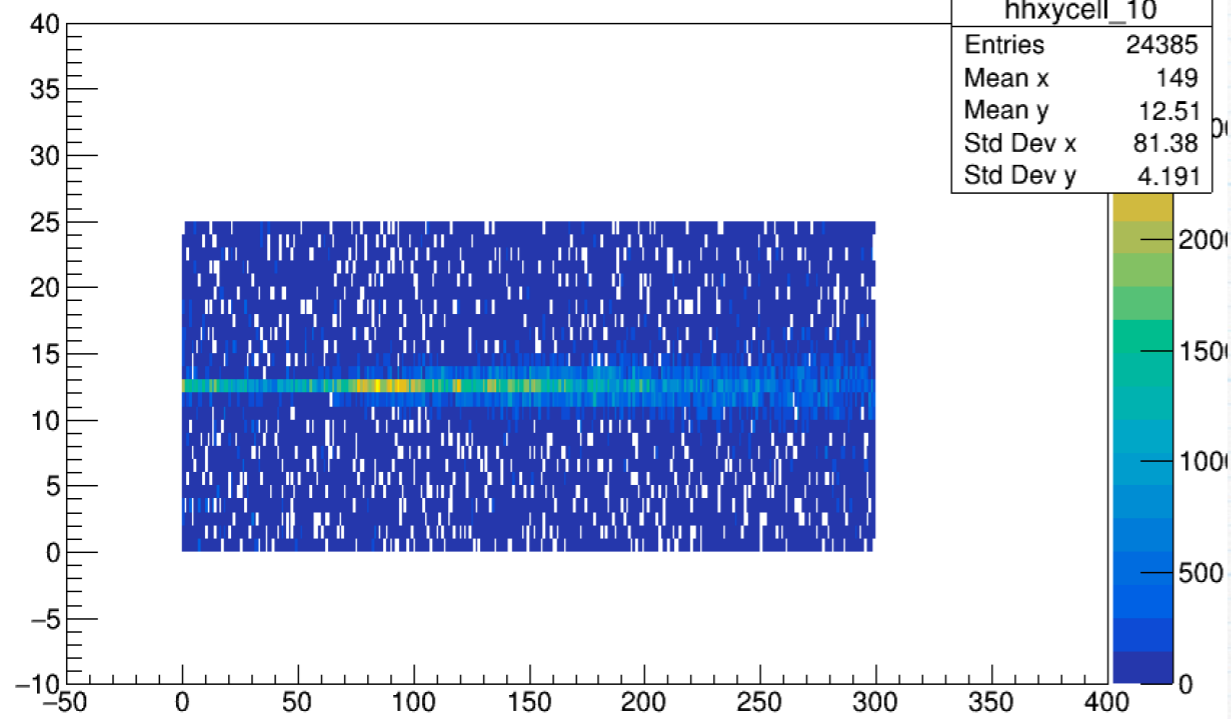


And beam pipe w/
square Xsection of
5x5cm (8x5cm) from
collimators to the
FDS spectrometer

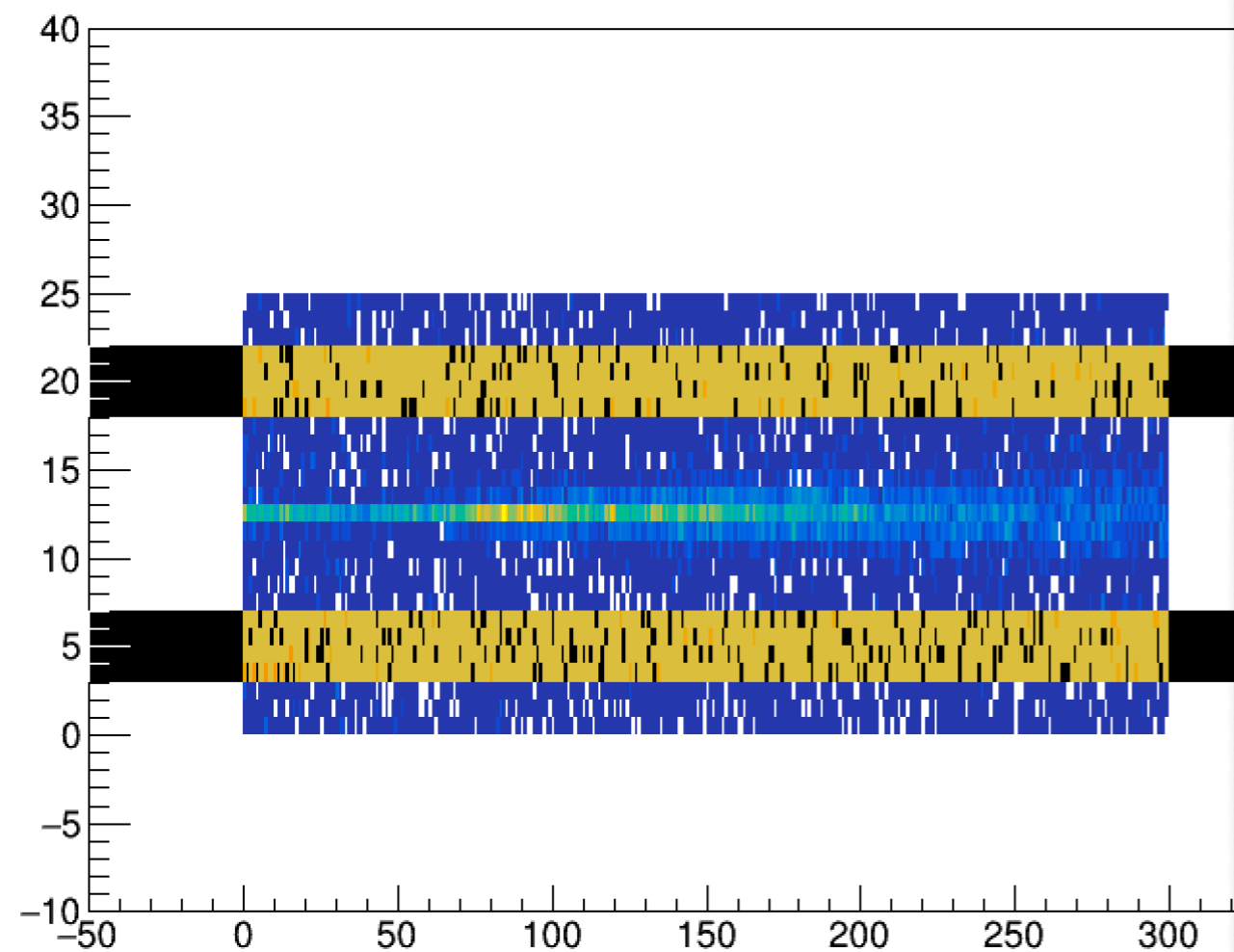
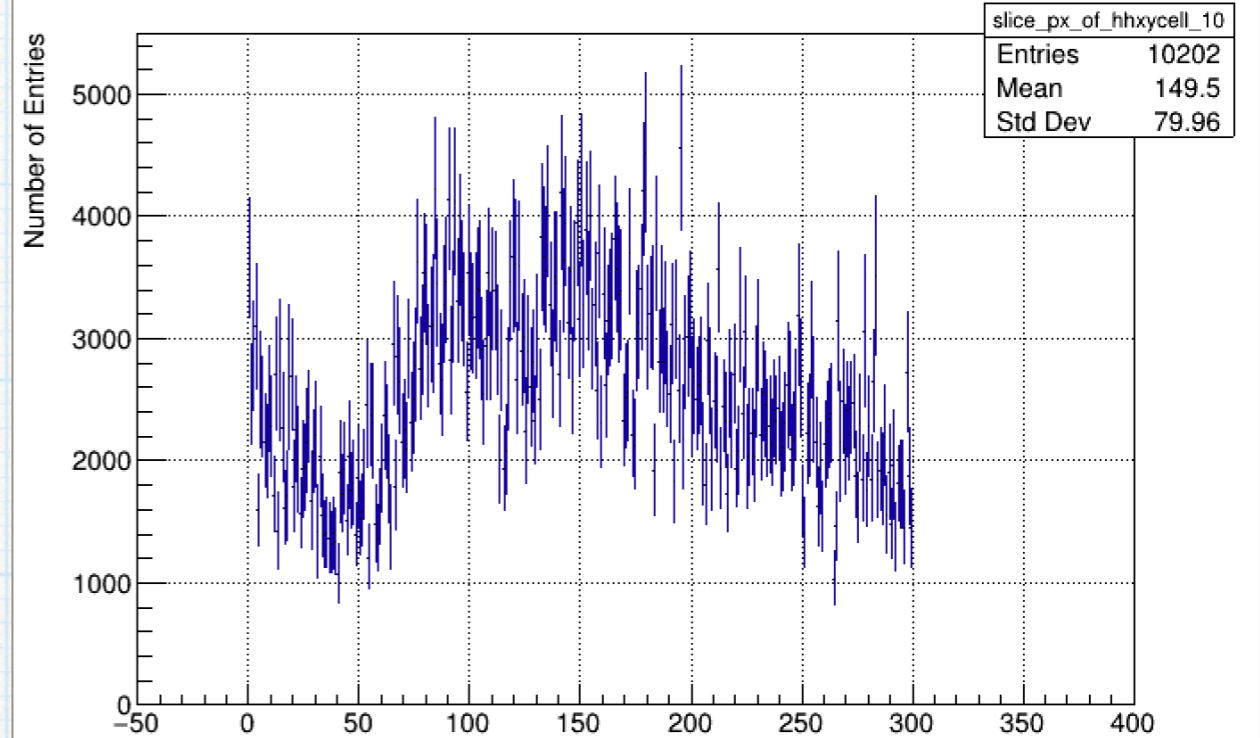
* Electron arm of Lanex Spectrometer



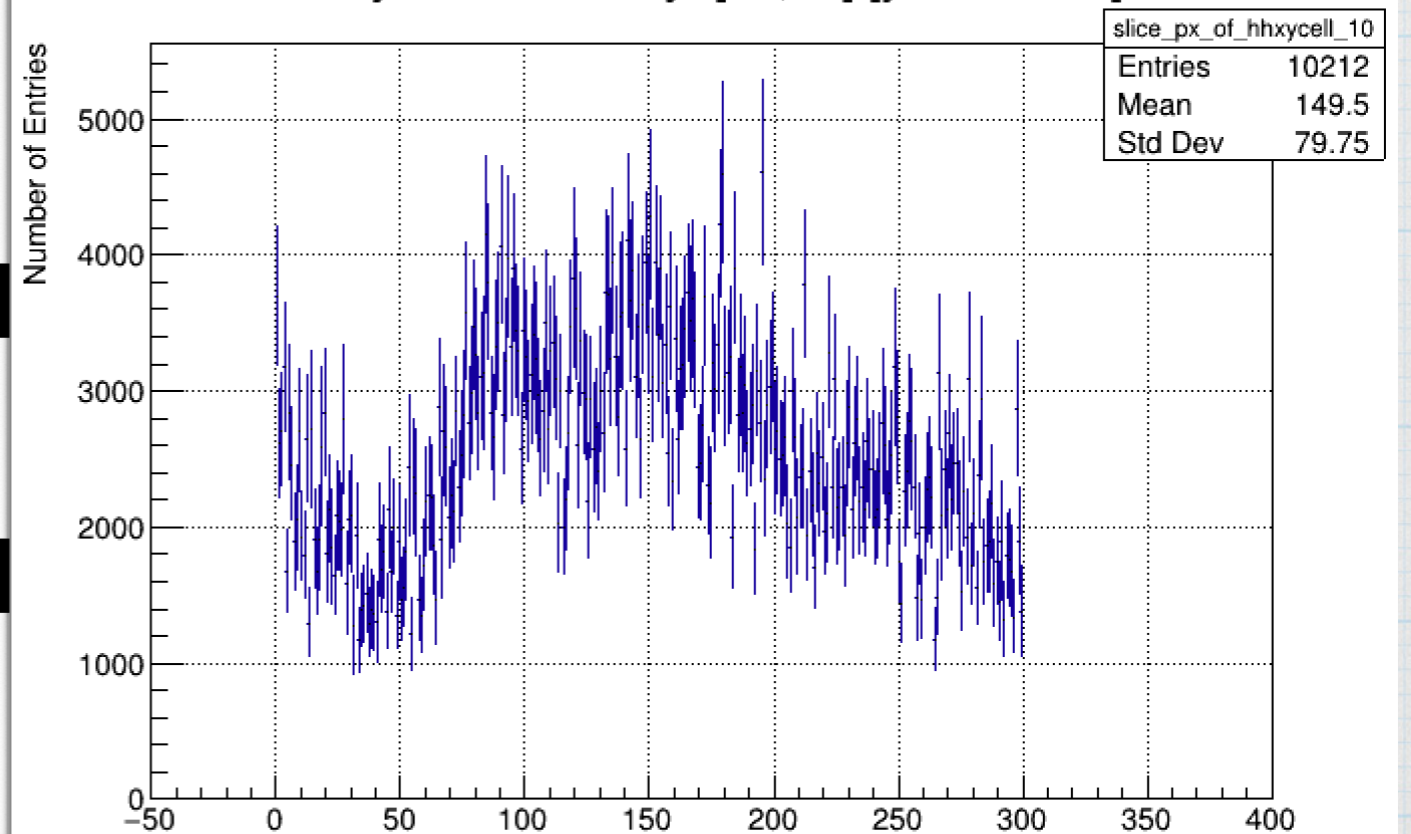
hhxycell_10



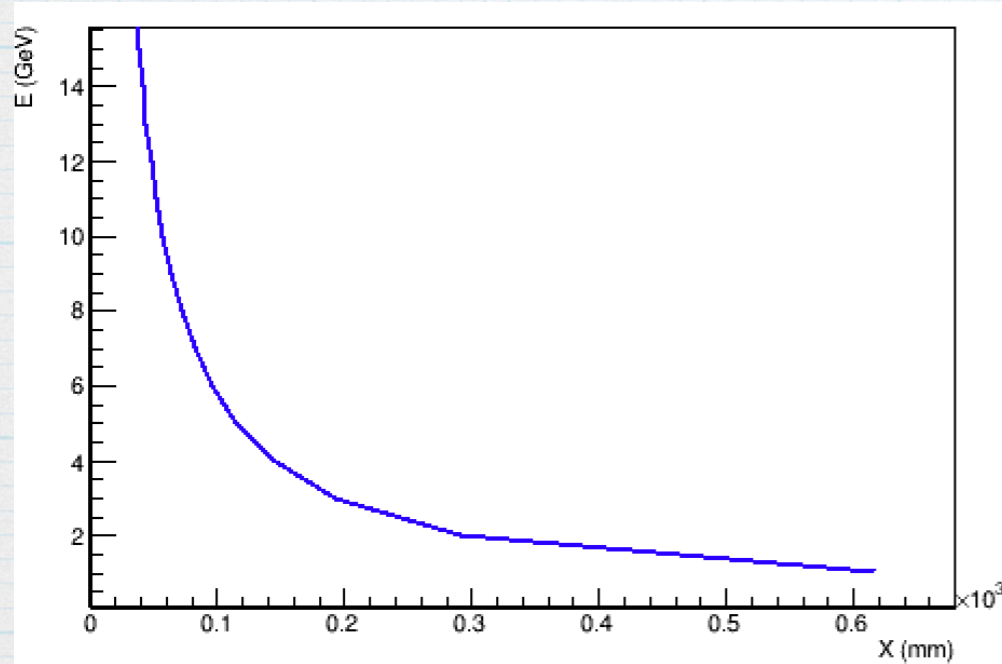
ProjectionX of biny=[14,28] [y=3.0..18.0]



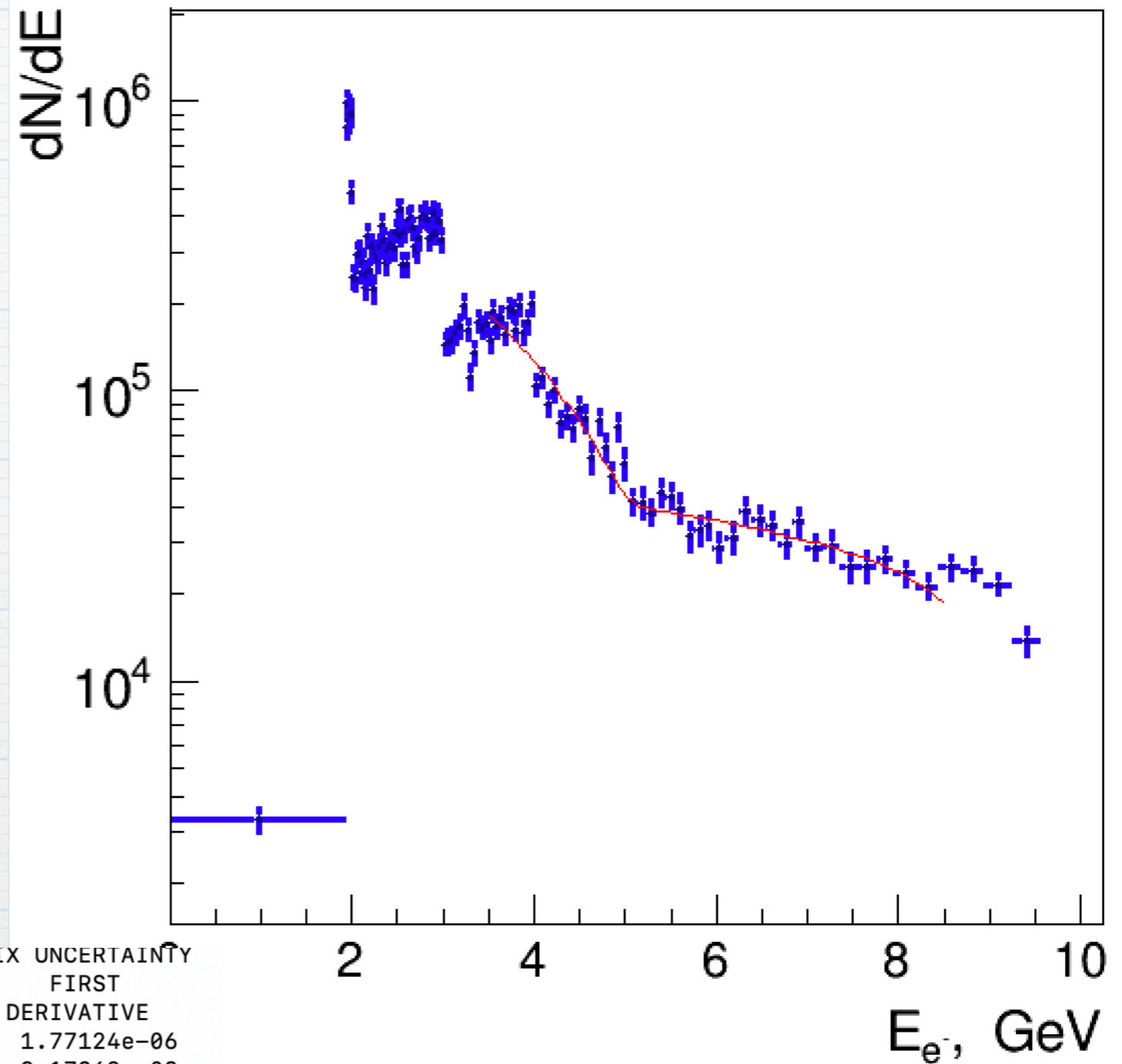
ProjectionX of biny=[18,32] [y=7.0..22.0]



Spectra reconstruction for the Lanex case



spectrum_electron

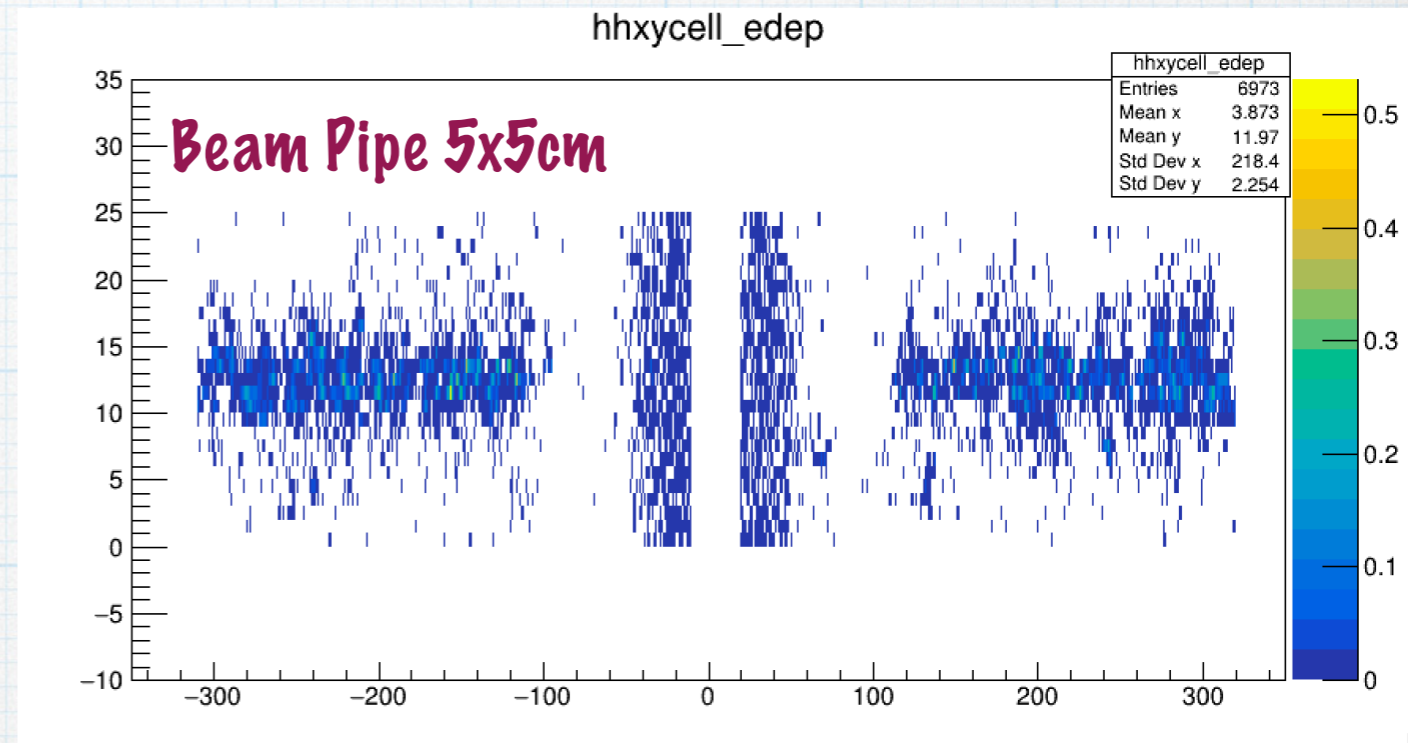
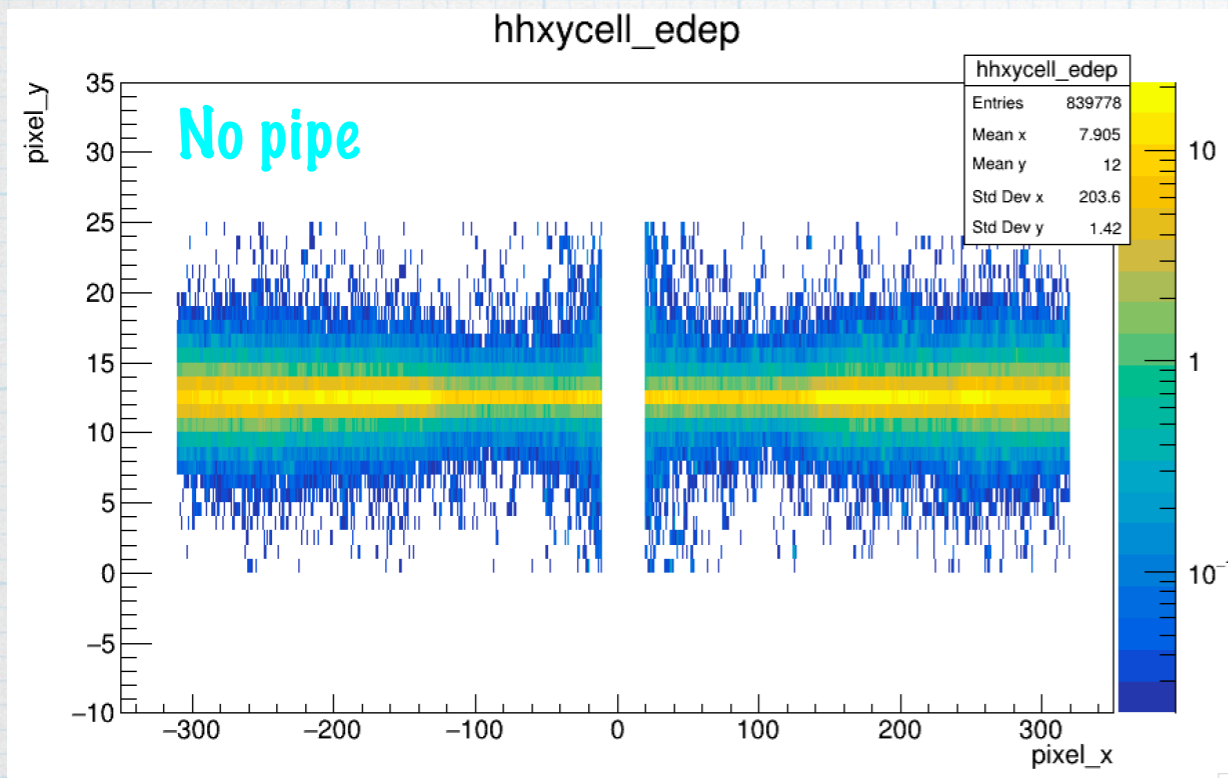


EDM=3.45767 STRATEGY= 1 ERROR MATRIX UNCERTAINTY					
EXT	PARAMETER	VALUE	APPROXIMATE	STEP	FIRST
NO.	NAME		ERROR	SIZE	DERIVATIVE
1	p0	-1.13129e+06	2.26562e+04	-2.47452e-02	1.77124e-06
2	p1	8.52709e+06	1.03972e+05	6.18410e-02	-9.17369e-08
3	p2	4.99979e+00	1.95217e-01	6.12022e-05	-2.60964e+00
4	p3	1.32018e+05	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 μm 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.

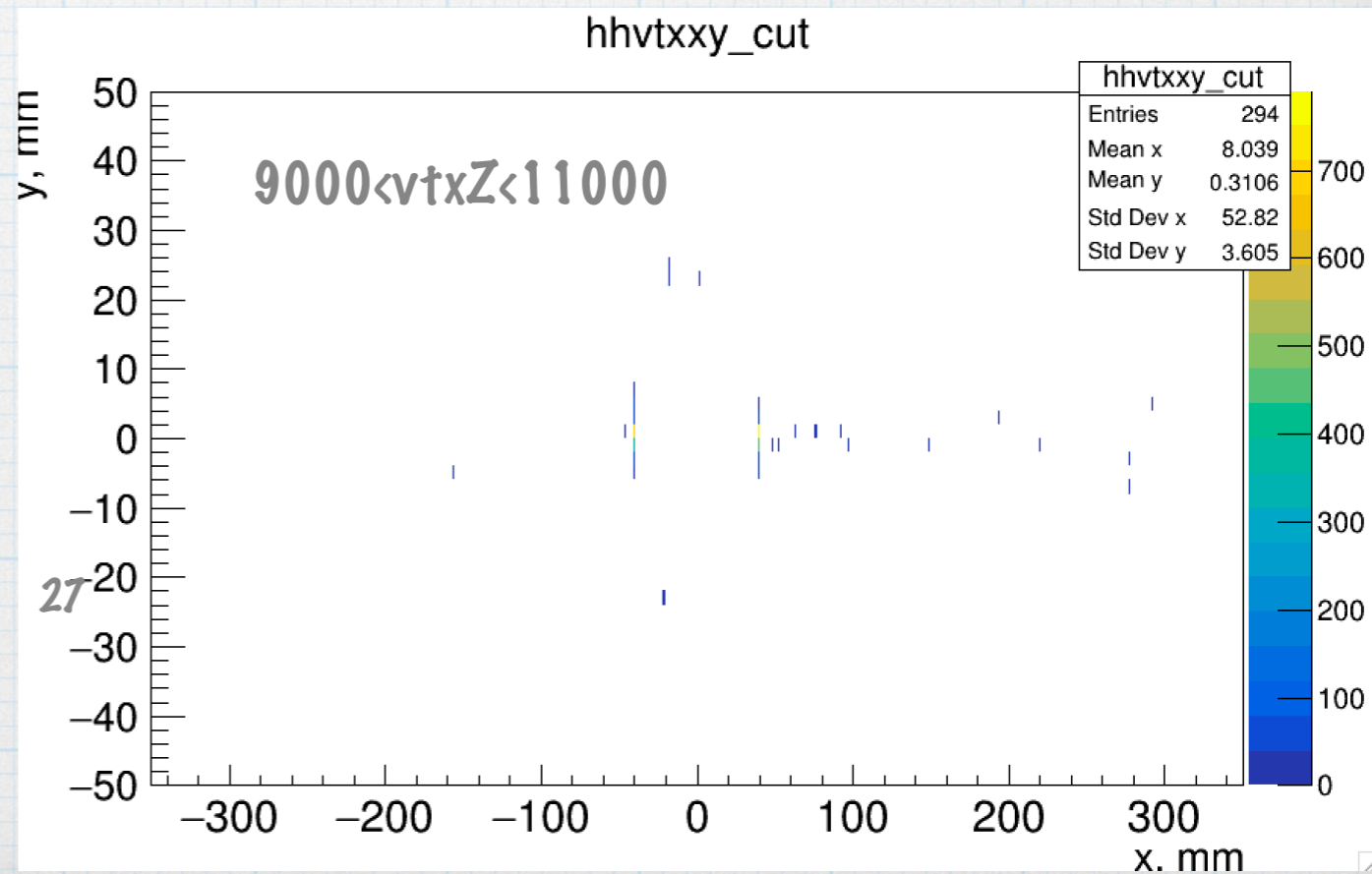
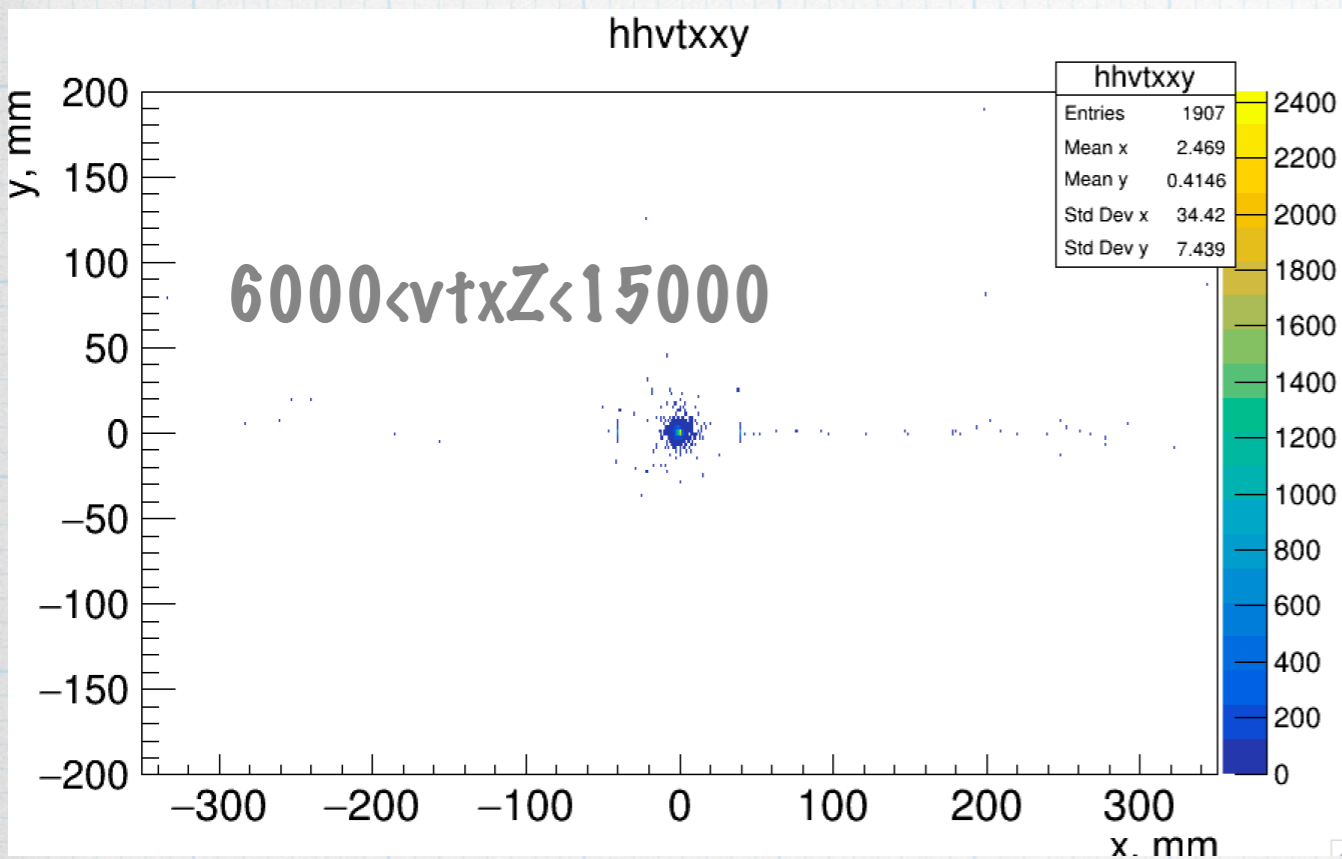
To convert it to Gy, convert it to J: $\sim 1.6 \times 10^{-9} \text{ J}$ and then divide it to the mass of crystals in kg. $\text{Gy} = \text{J/kg}$

The density is 7.1 g/cm^3 , volume $0.1 \times 0.2 \times 2 = 0.04 \text{ cm}^3$. Mass $7.1 \times 0.04 = 0.284 \text{ g}$.

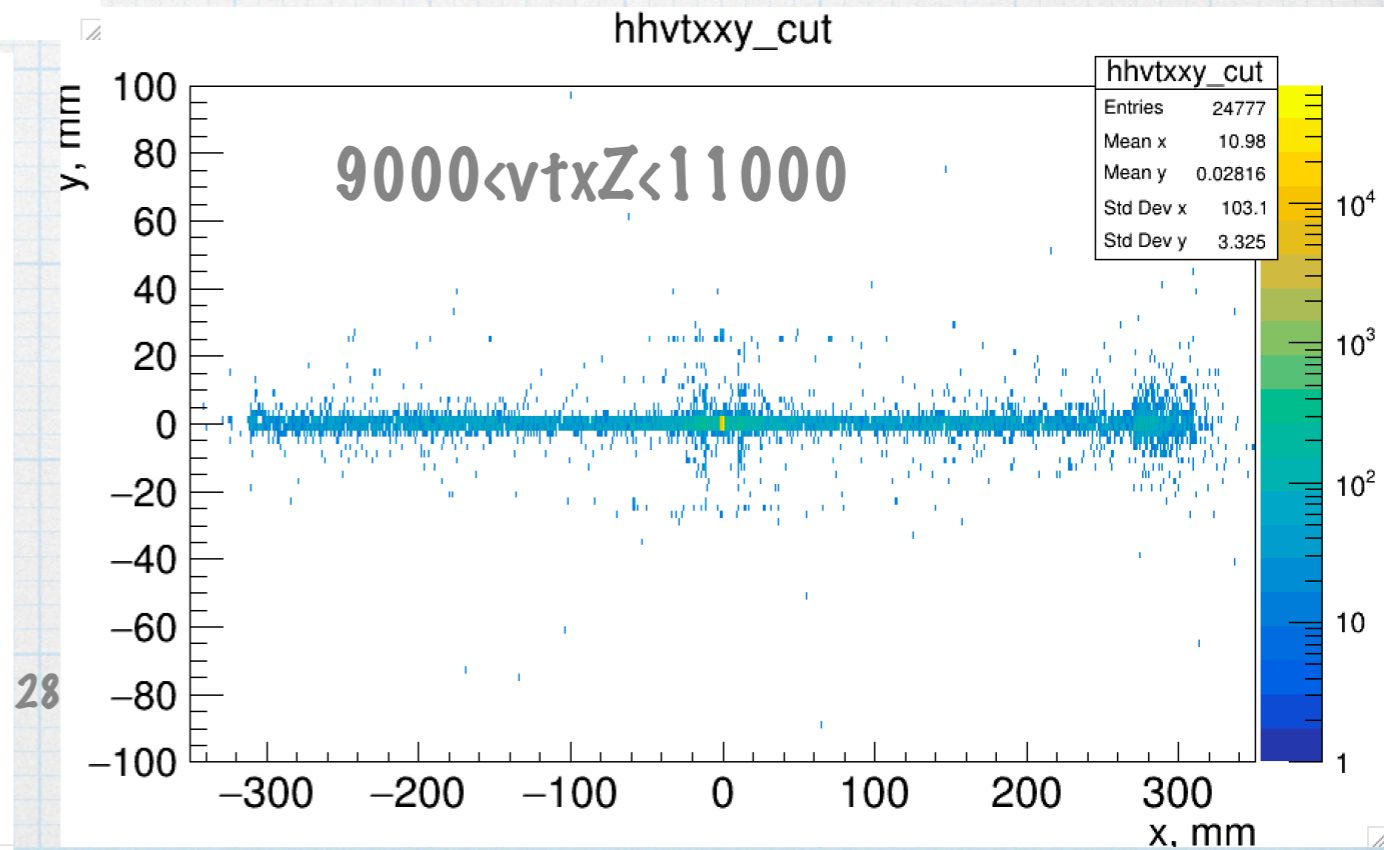
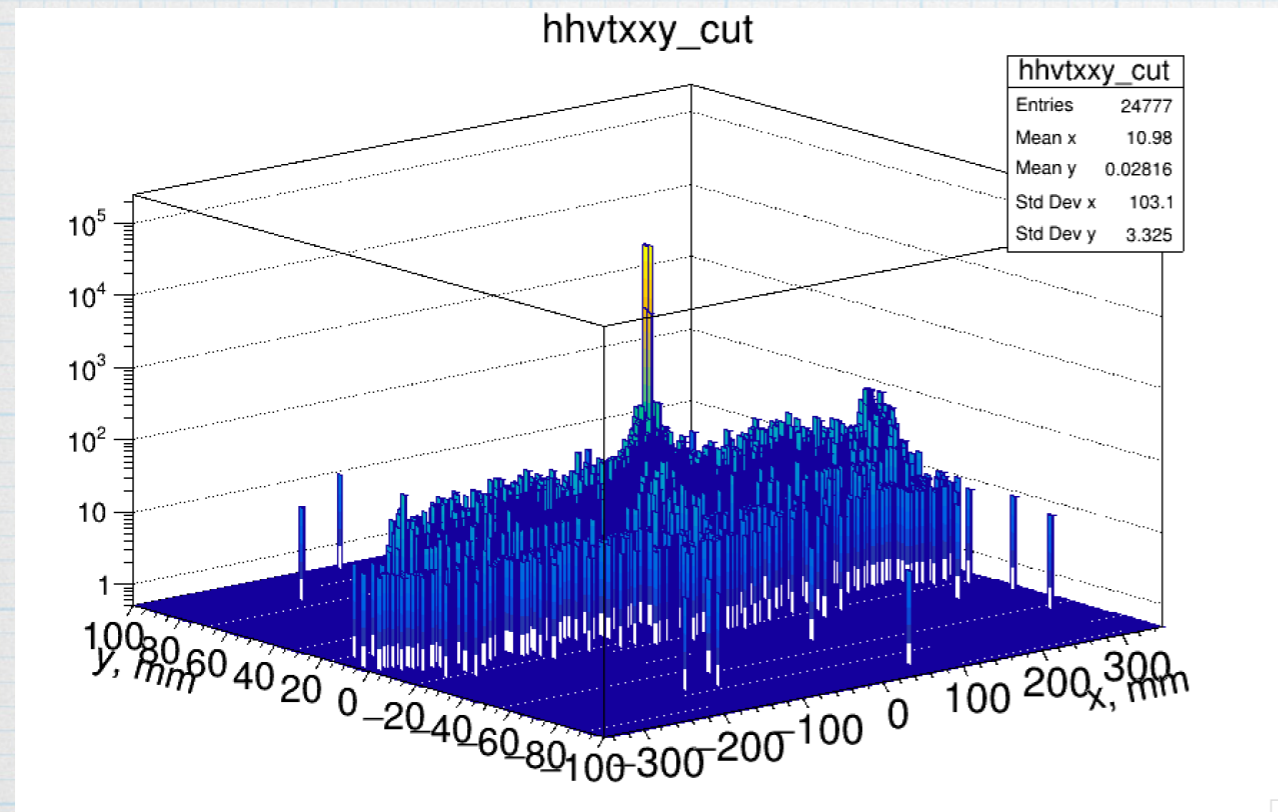
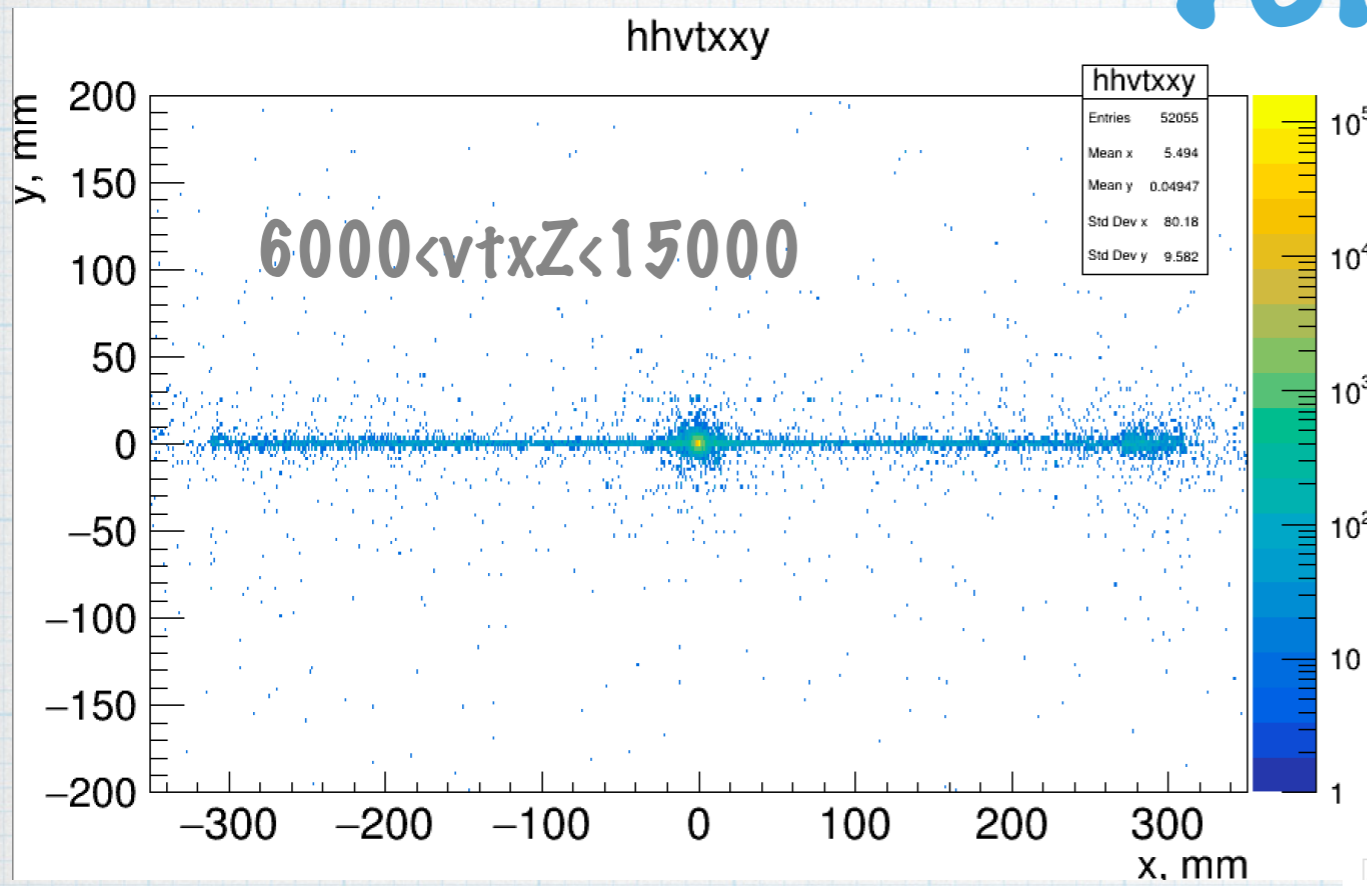
Finally, 5.6×10^{-6} Gy per BX.

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

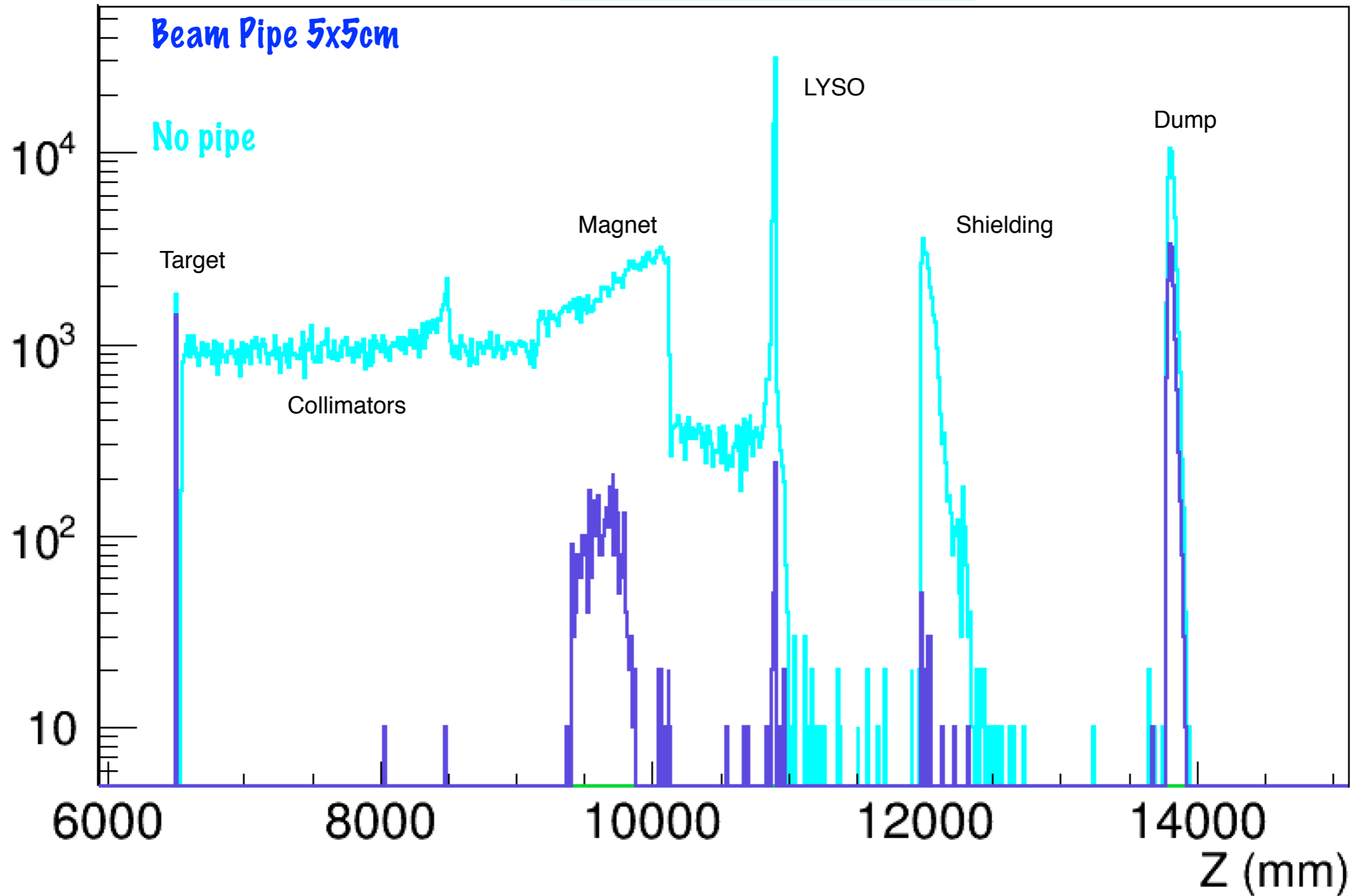
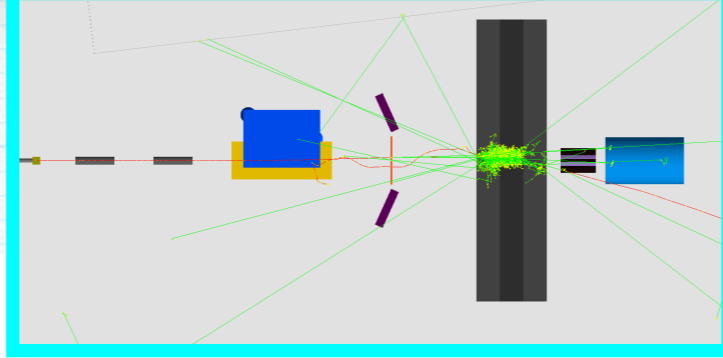
Vertex x-y, beam pipe 8x5



Vertex x-y, no pipe



Vertex z



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/cm³ 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...

hhxycell_edep

Crosses	111285
Mean x	-4.77
Mean y	11.84
Std Dev x	85.87
Std Dev y	4.448

Edep, GeV
100 BX

$\times 10^3$

500

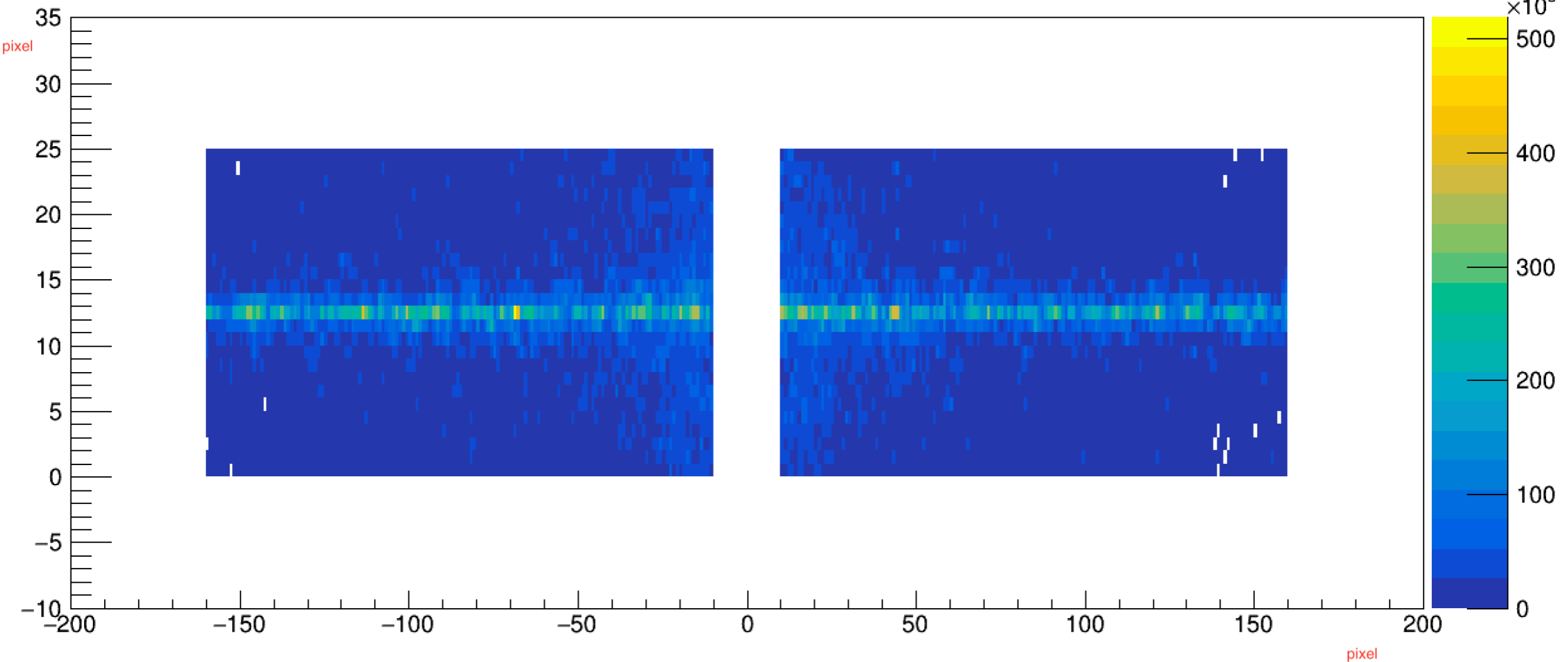
400

300

200

100

0



Compton MC2019 r for 1J ($\xi=2.6$), 17.5 GeV electrons. G4: tungsten foil of 10 μm 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 $\sim 5e3$ GeV.

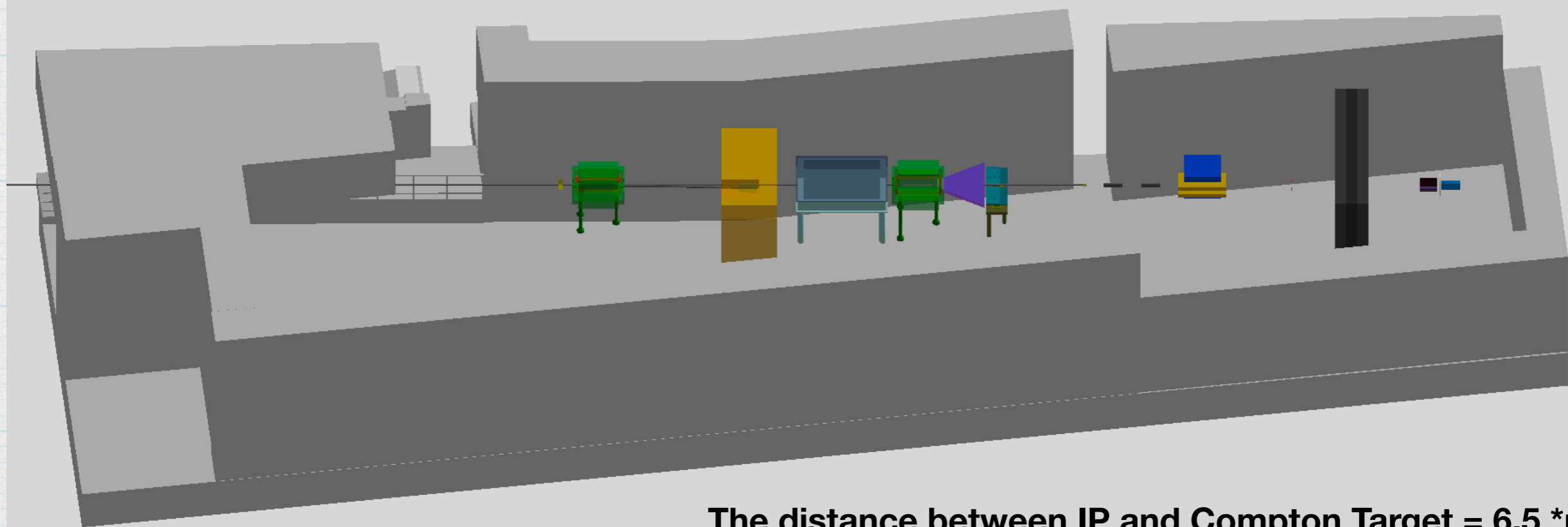
To convert it to Gy, convert it to J: $\sim 8e-7$ J and then divide it to the mass of crystals in kg. $\text{Gy} = \text{J/kg}$

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

Finally $8e-7\text{J}/0.284e-3 = 2.8e-3$ Gy per BX.

Assuming 1Hz collisions rate we get the dose of 10000Gy in LYSO crystal in about $1000/2.8e-3 = 3.6e6$ s which is 41,3 days.

Luxe Set-up



The distance between IP and Compton Target = 6.5 m

