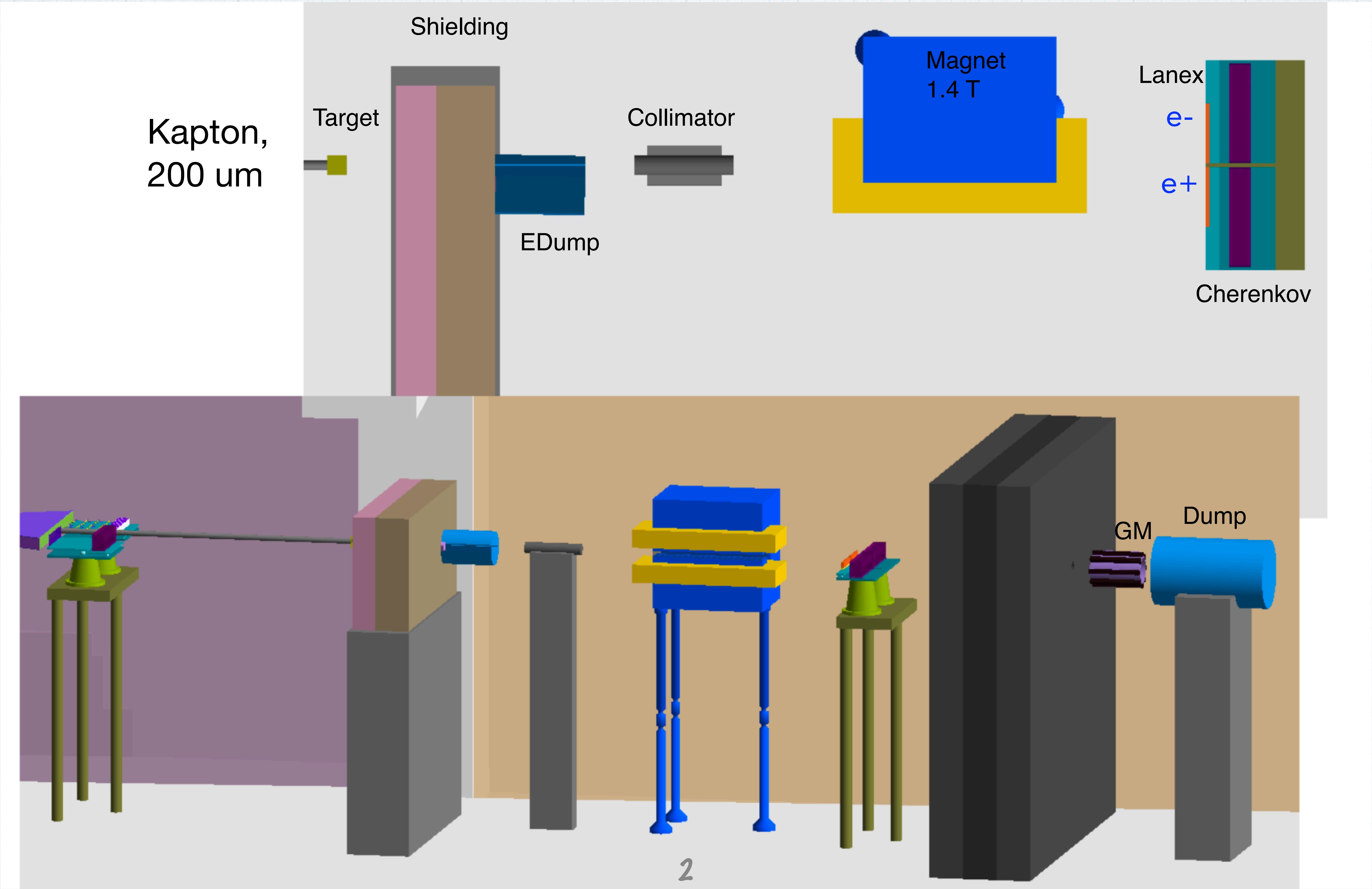
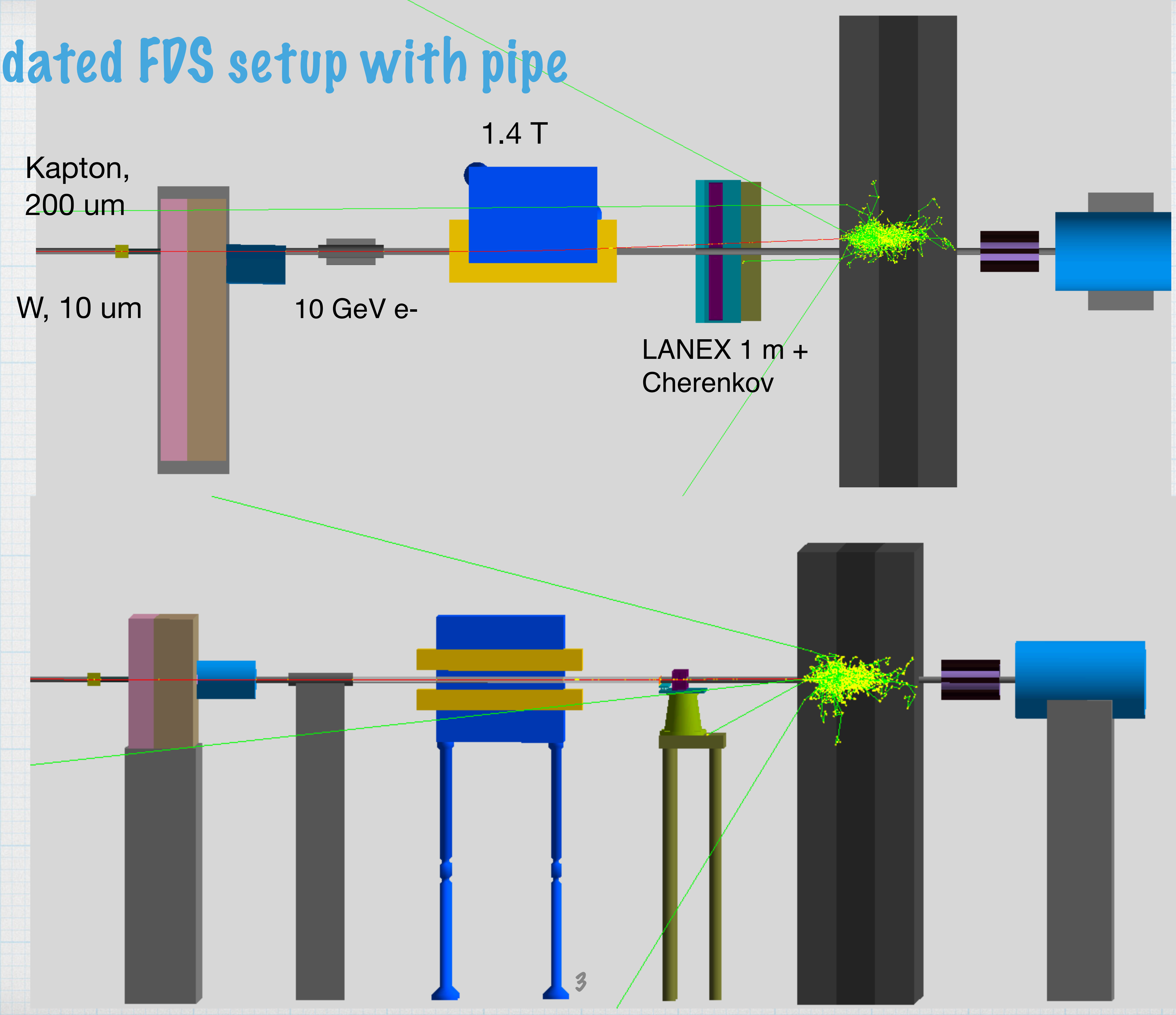
FDS performance: No pipe vs beam pipe

Borysova Maryna (KINR)
16/11/20
LUXE weekly technical meeting

Forward detector system w/o beam pipe

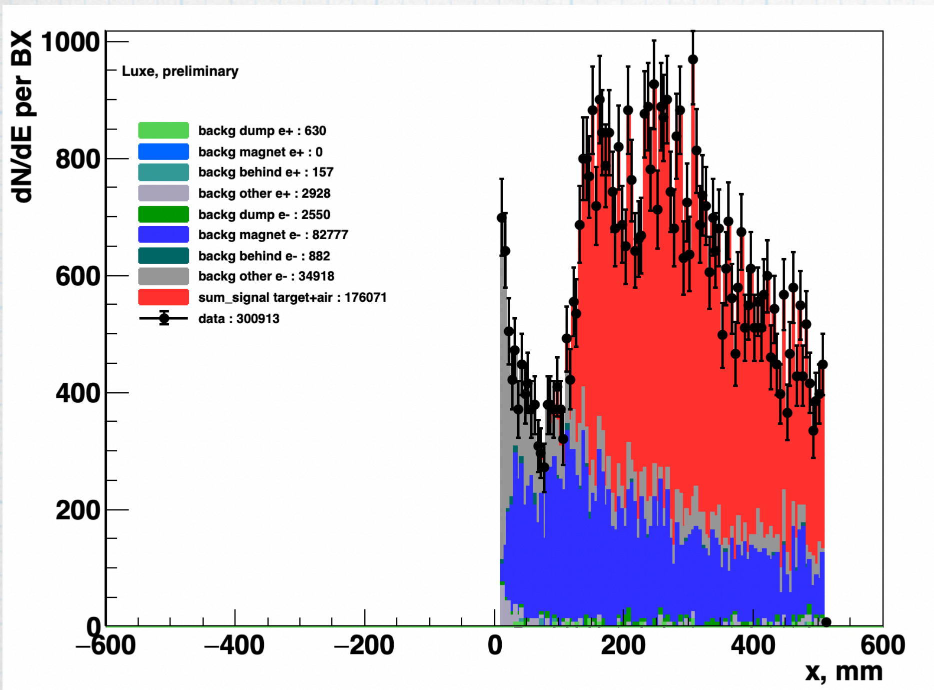


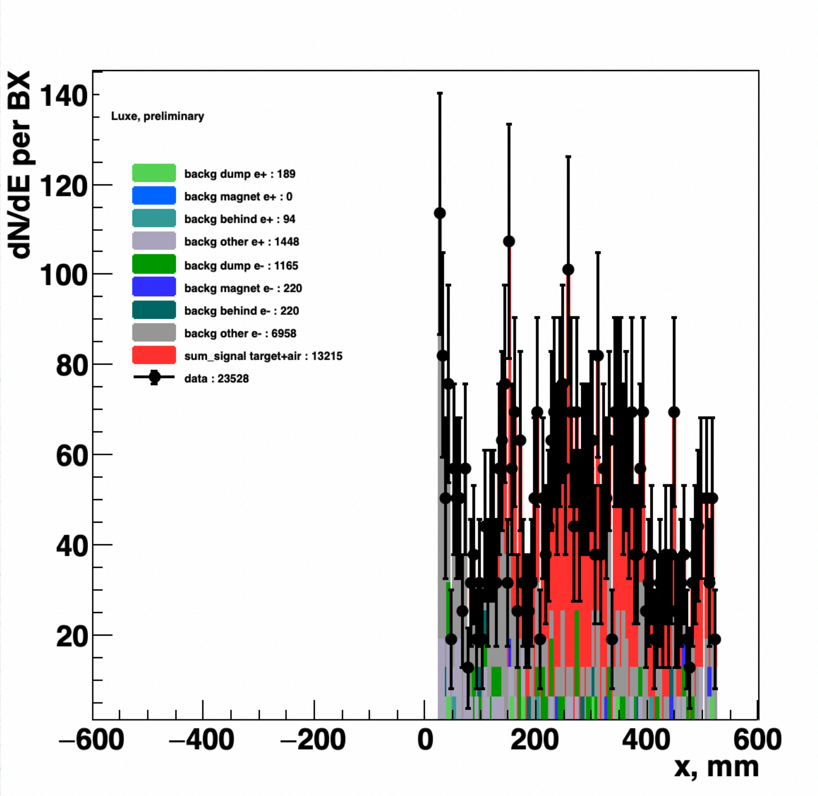
Updated FDS setup with pipe

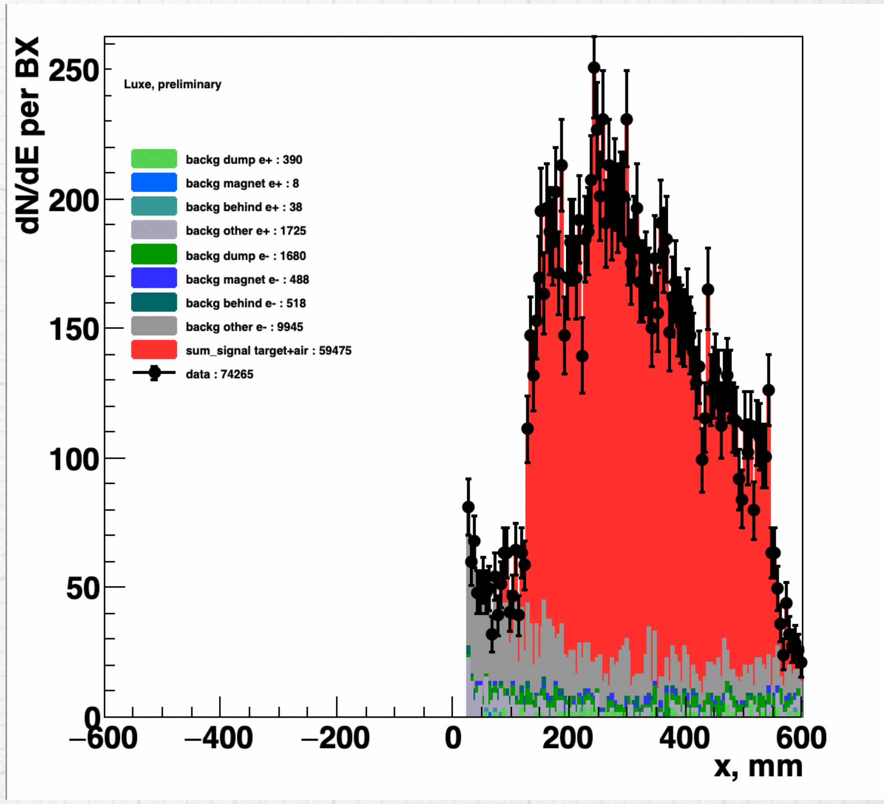


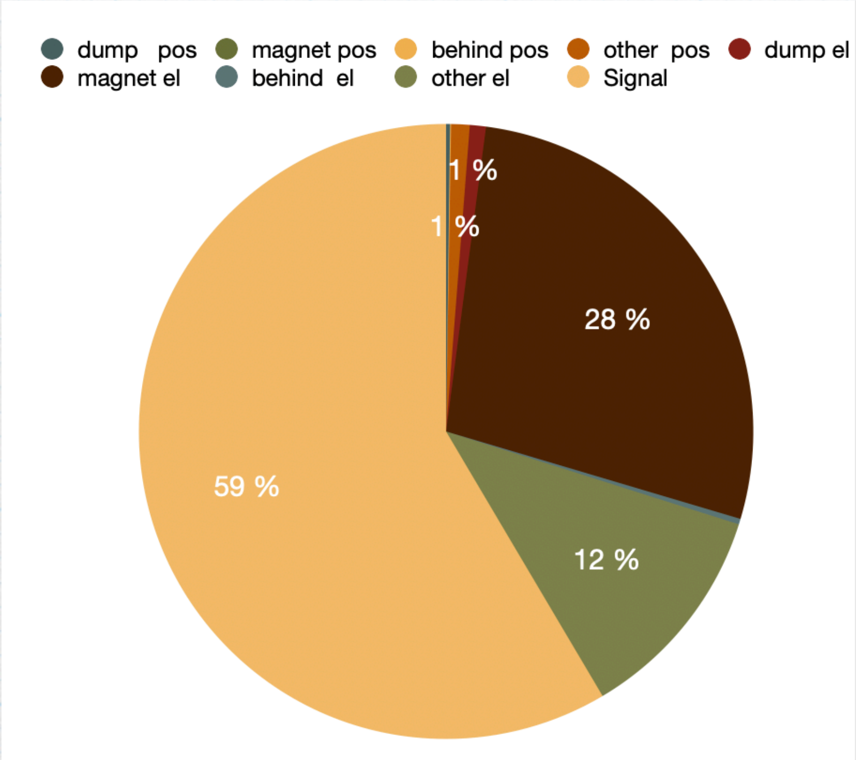
Electron arm of Lanex Spectrometer

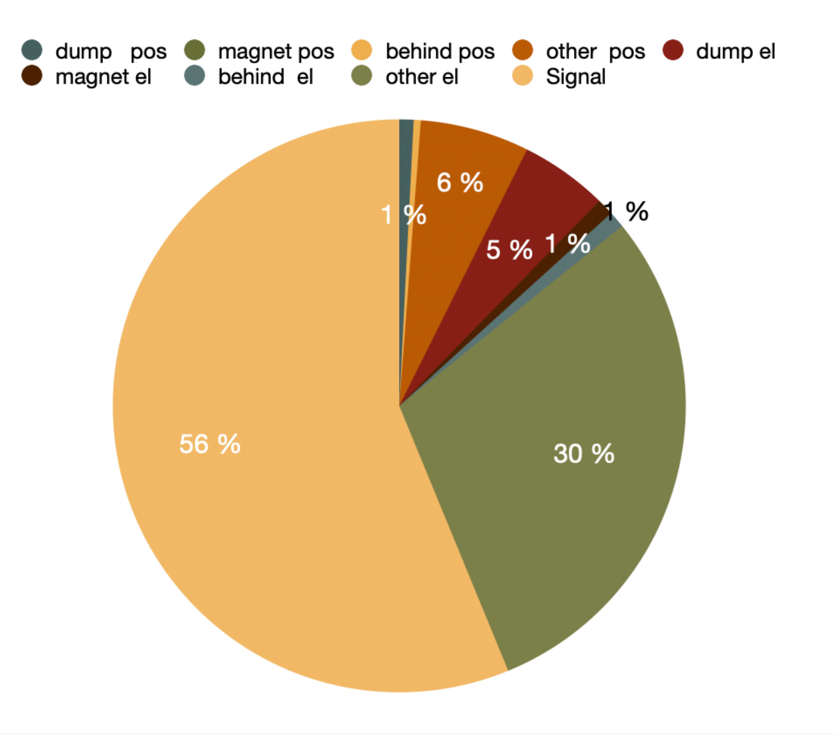
NO Beam Pipe Kapton, 200 um	Beam Pipe 5 cm Kapton, 200 um	Beam Pipe 5 cm W, 10 um

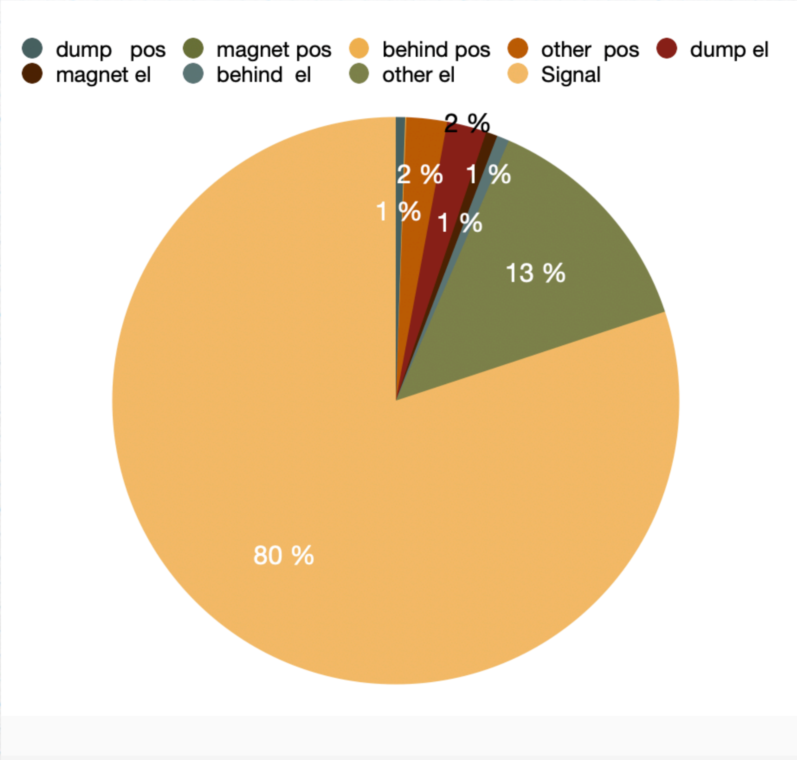






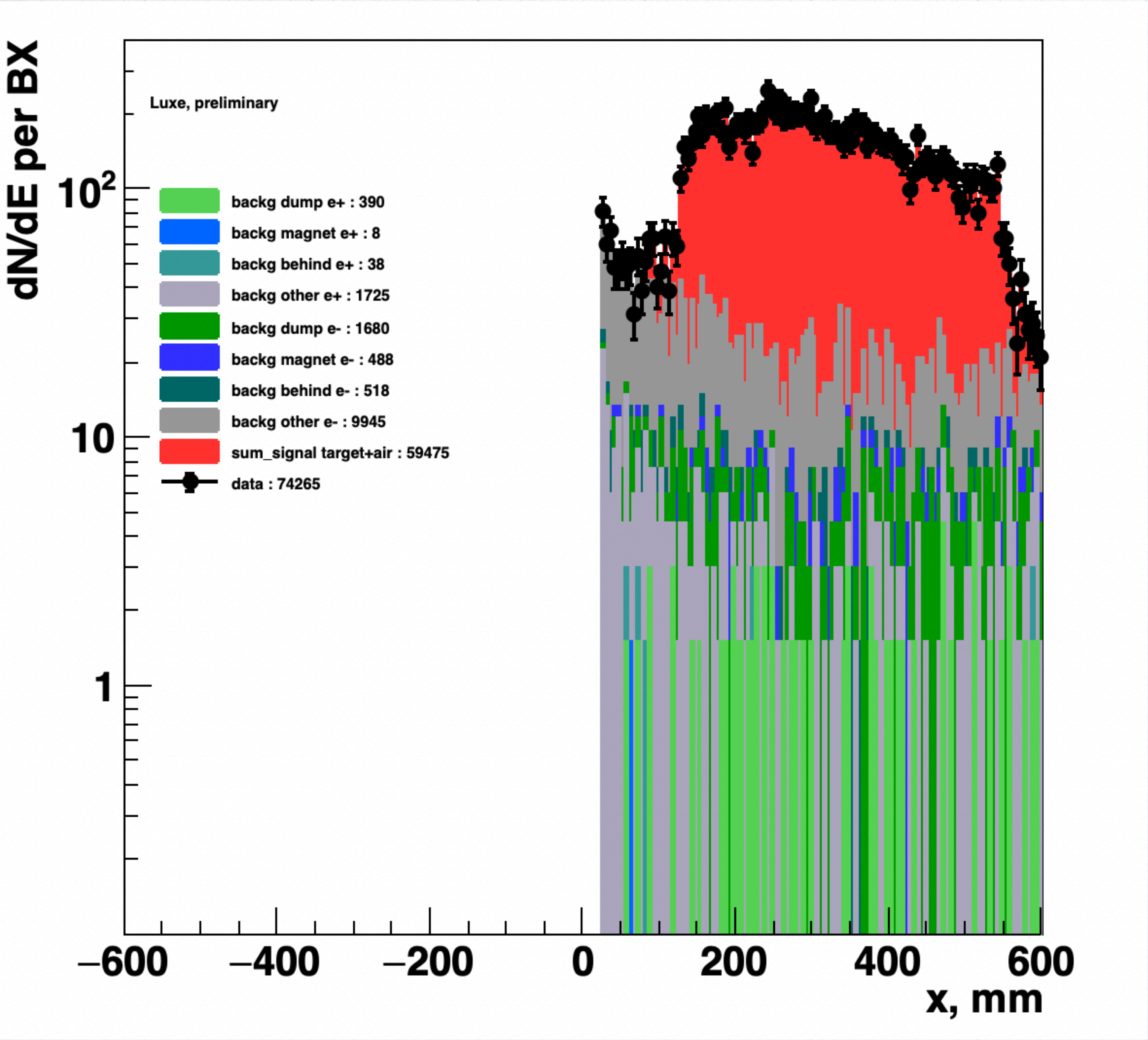




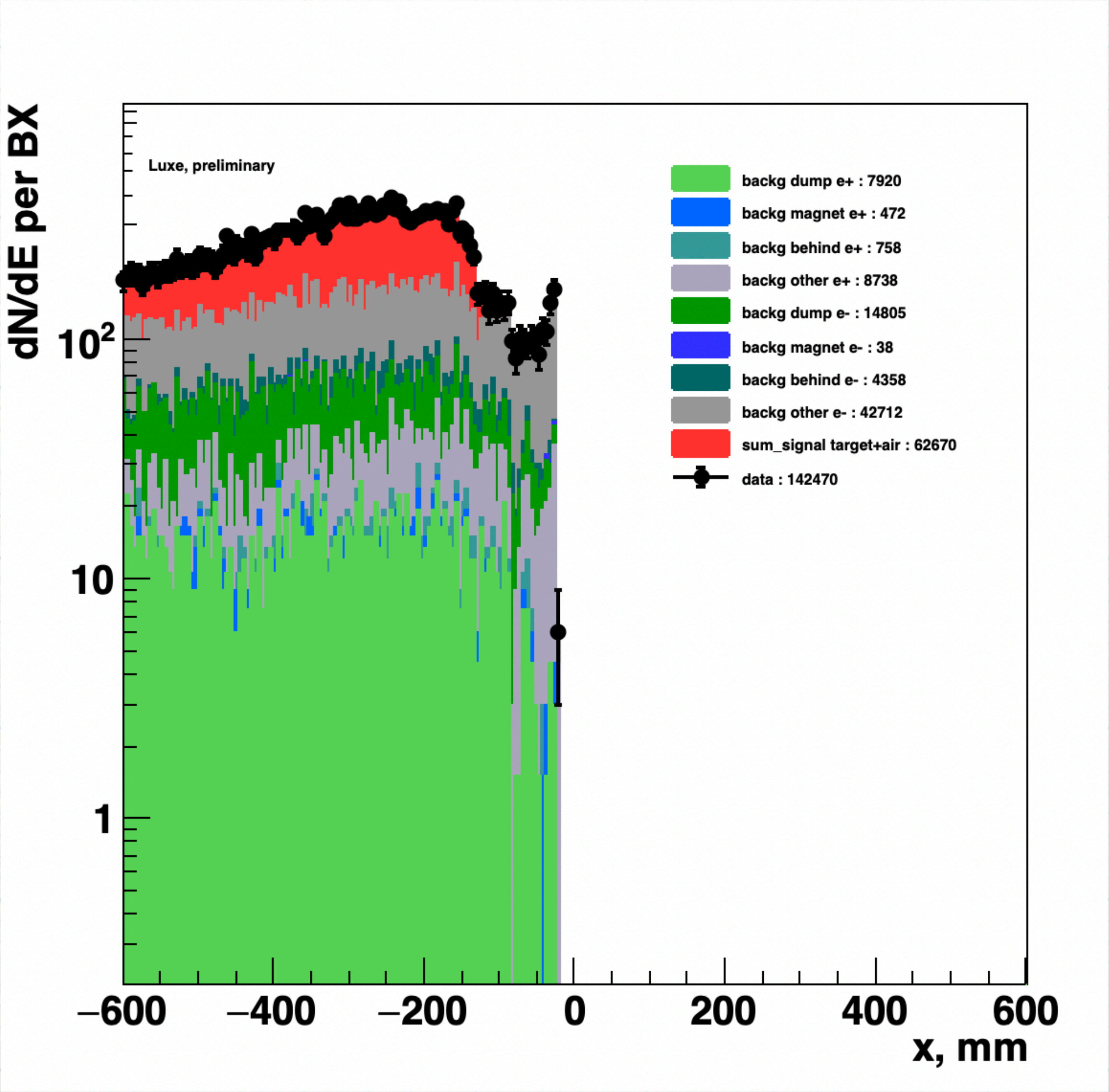


Background: Beam Pipe 5 cm ,W 10 um, log scale

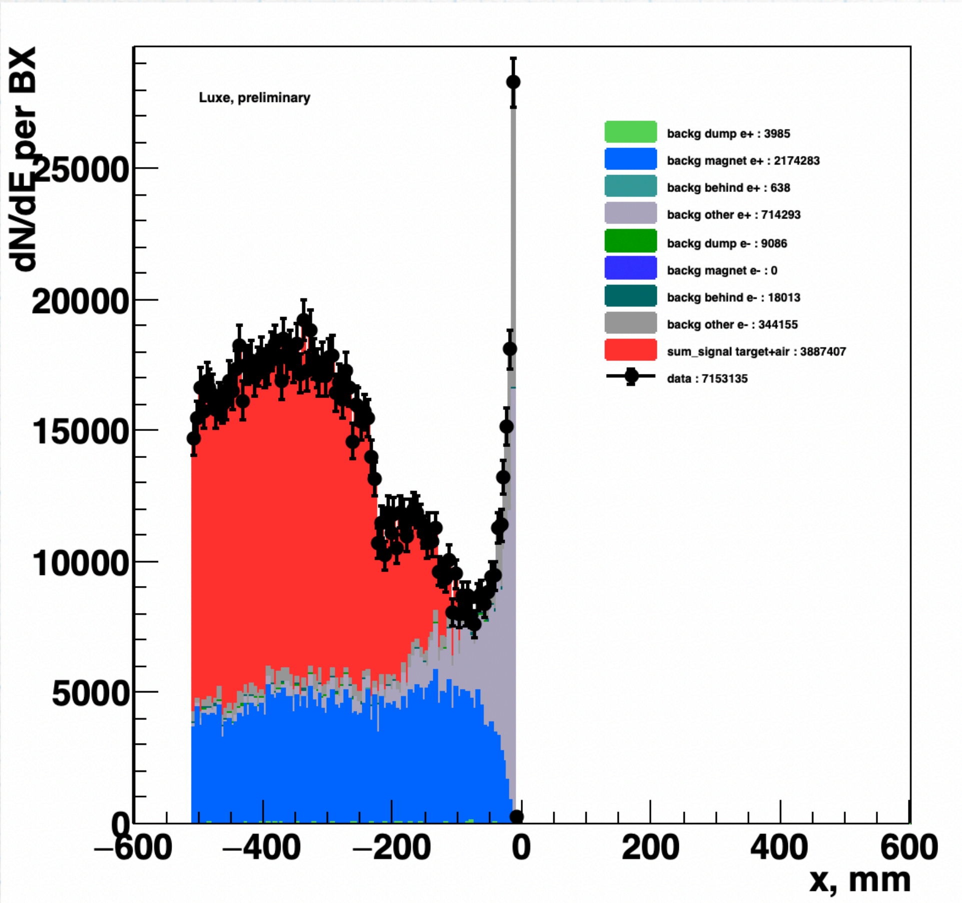
* Electron arm

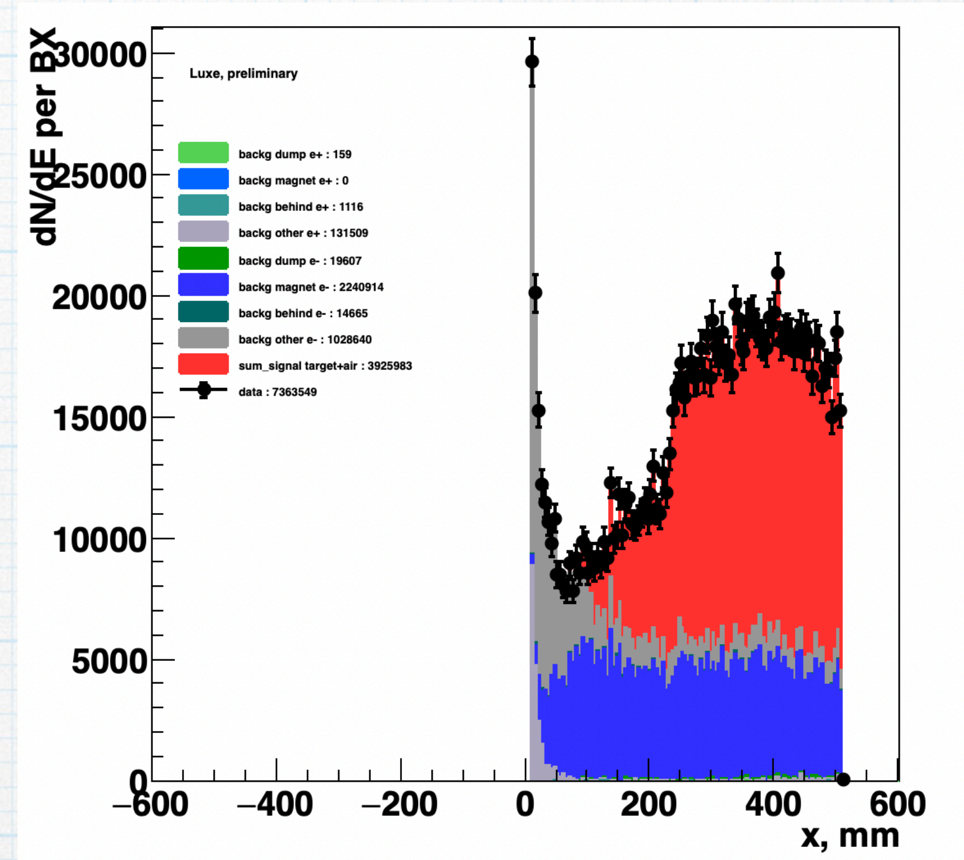


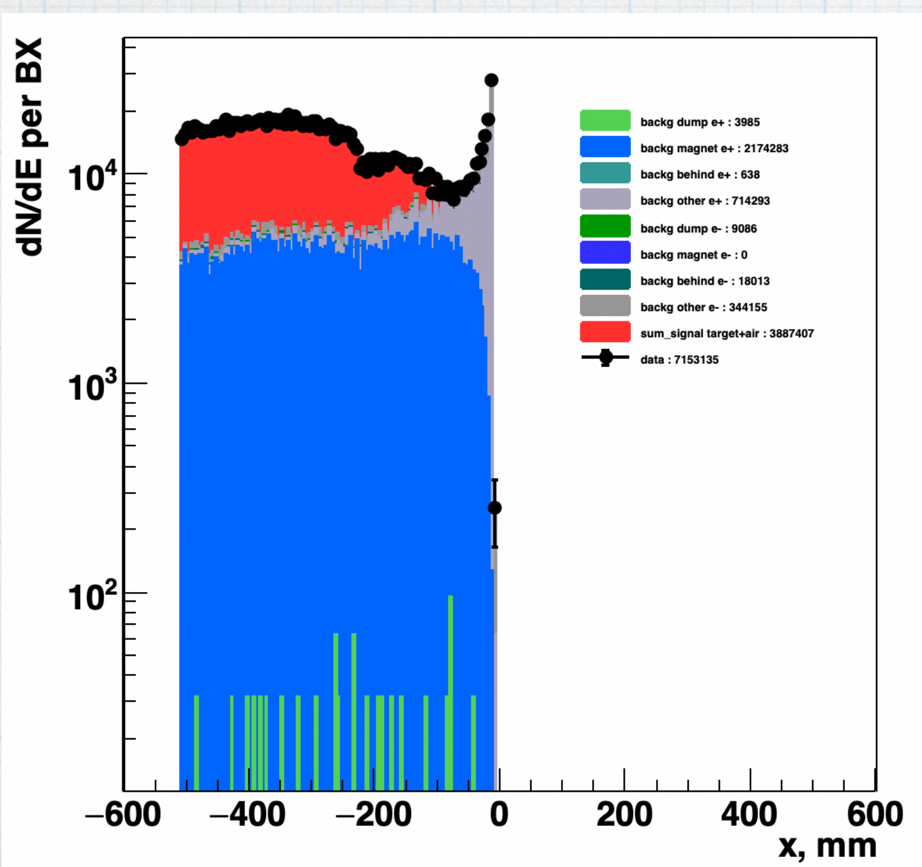
* Positron arm

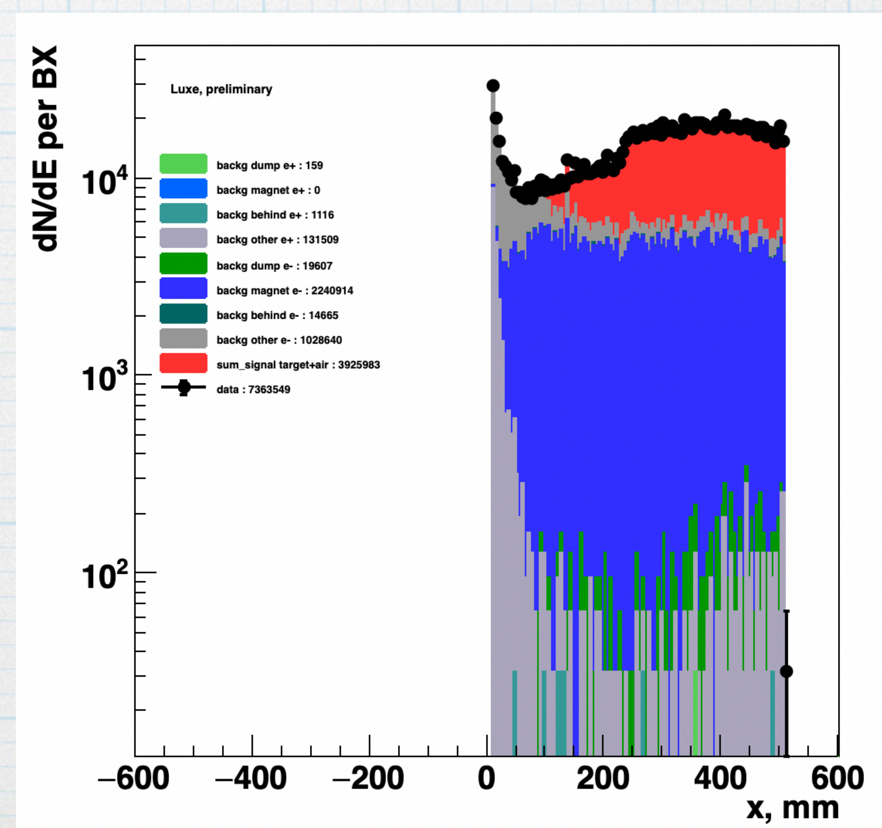


Phase II, 16.5 GeV, 8 um, 941 BX









Summary

* The performance of FDS setup with and w/o beam pipe from the target to the Gamma beam dump was studied

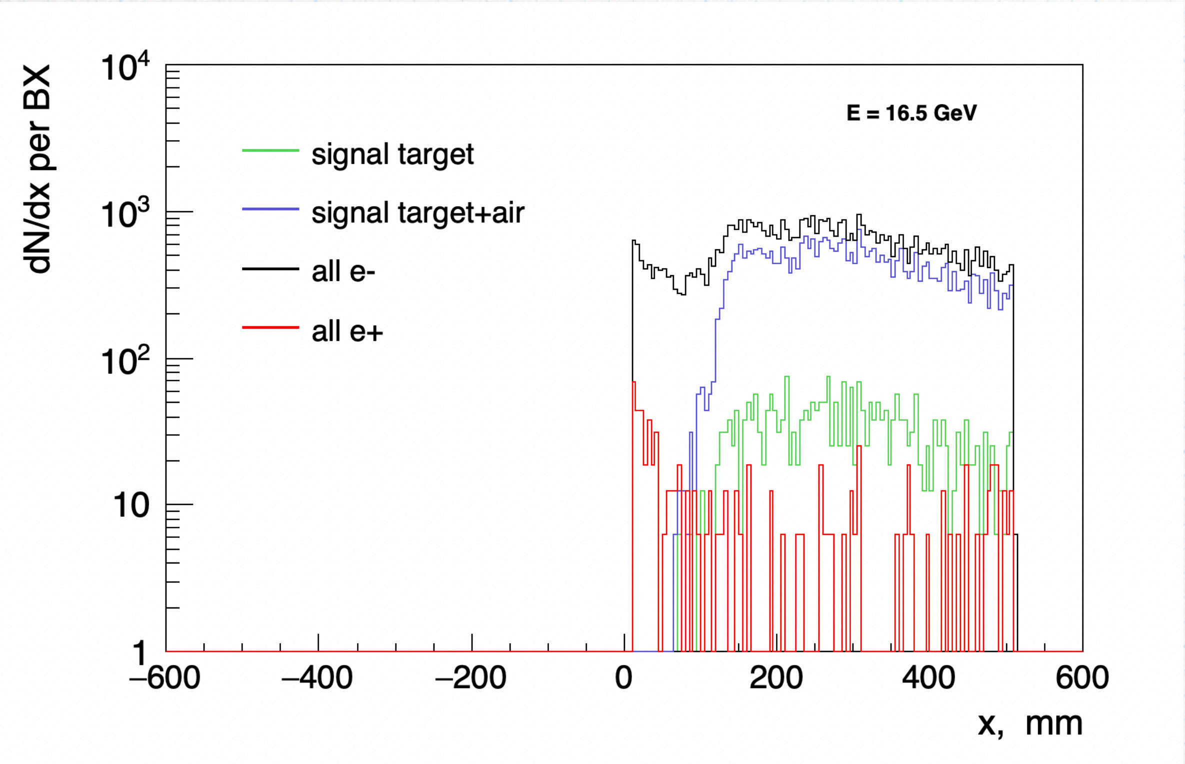
* Background estimation for the cases of no beam pipe and beam pipe and two types of targets (200 um Caption vs 10um W) in last case

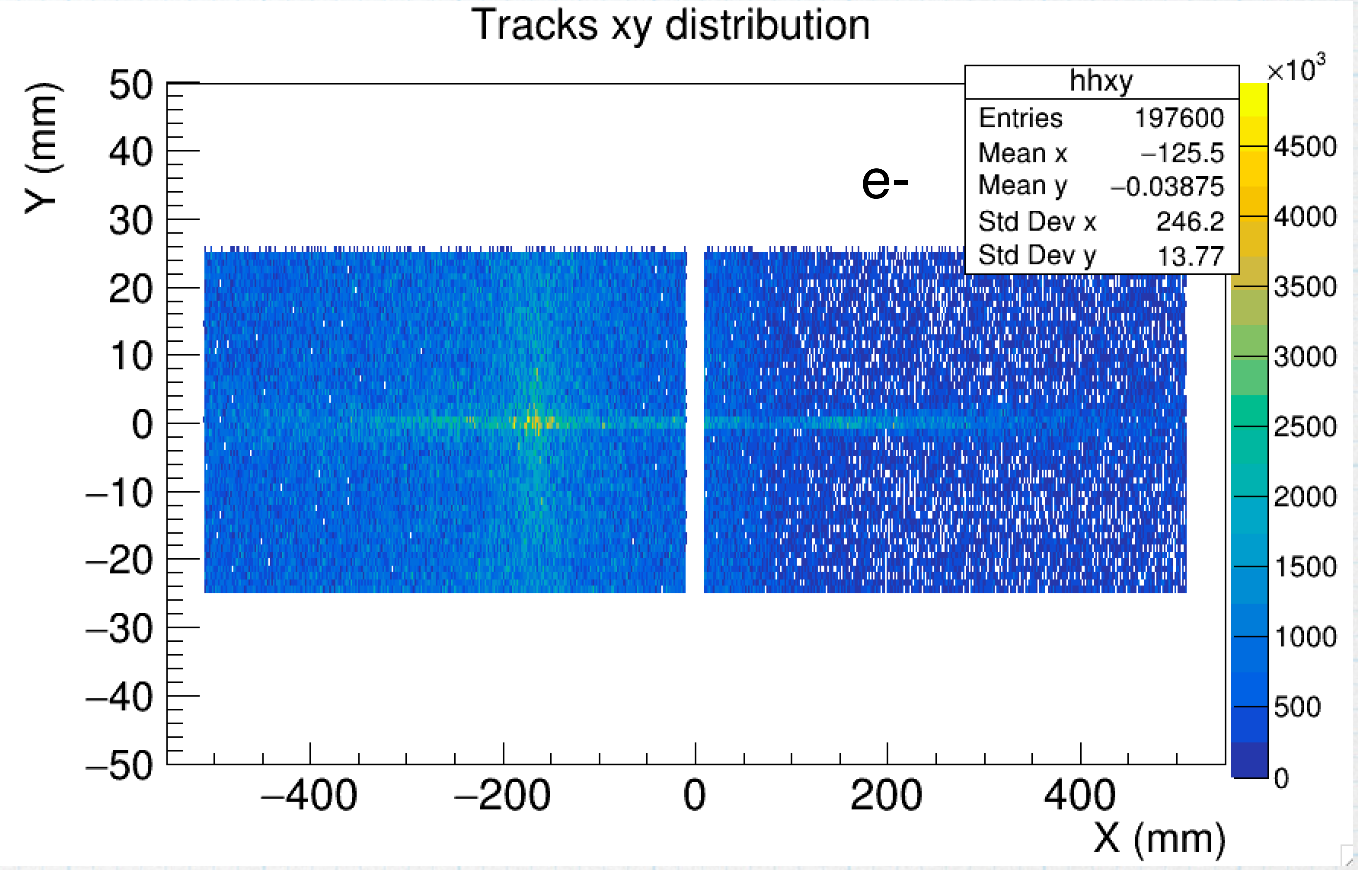
* electron spectrum look reasonable but positron is very contaminated

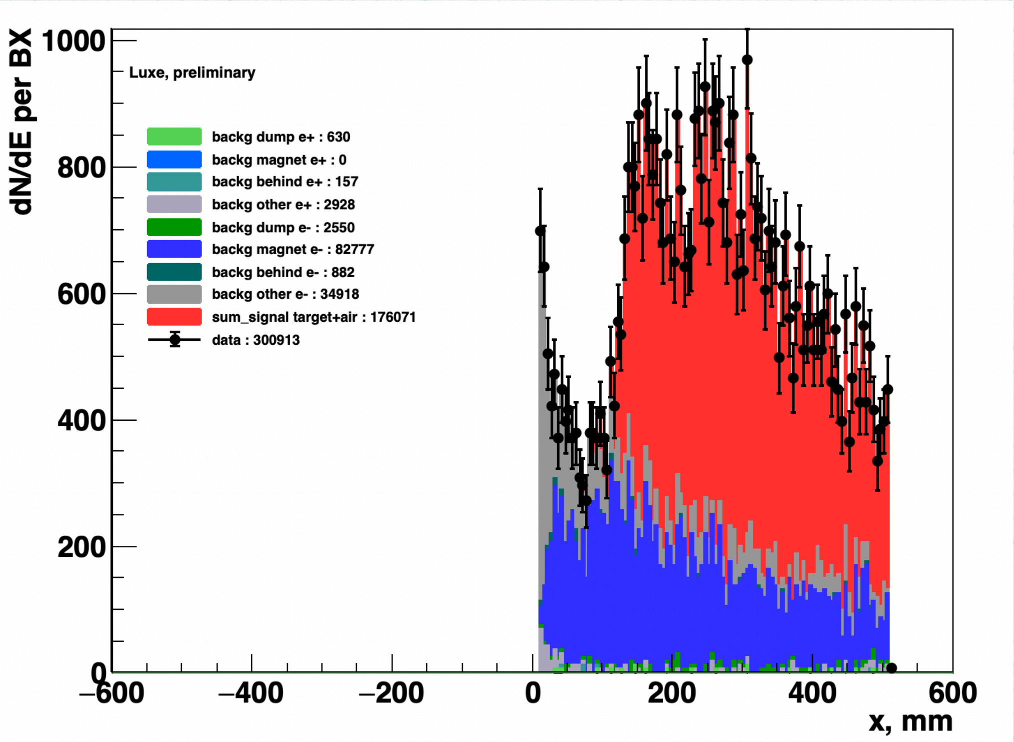
* Not sufficient Shielding w/ electron dump creates substantial background occupancy in positron arm of Lanex detector.

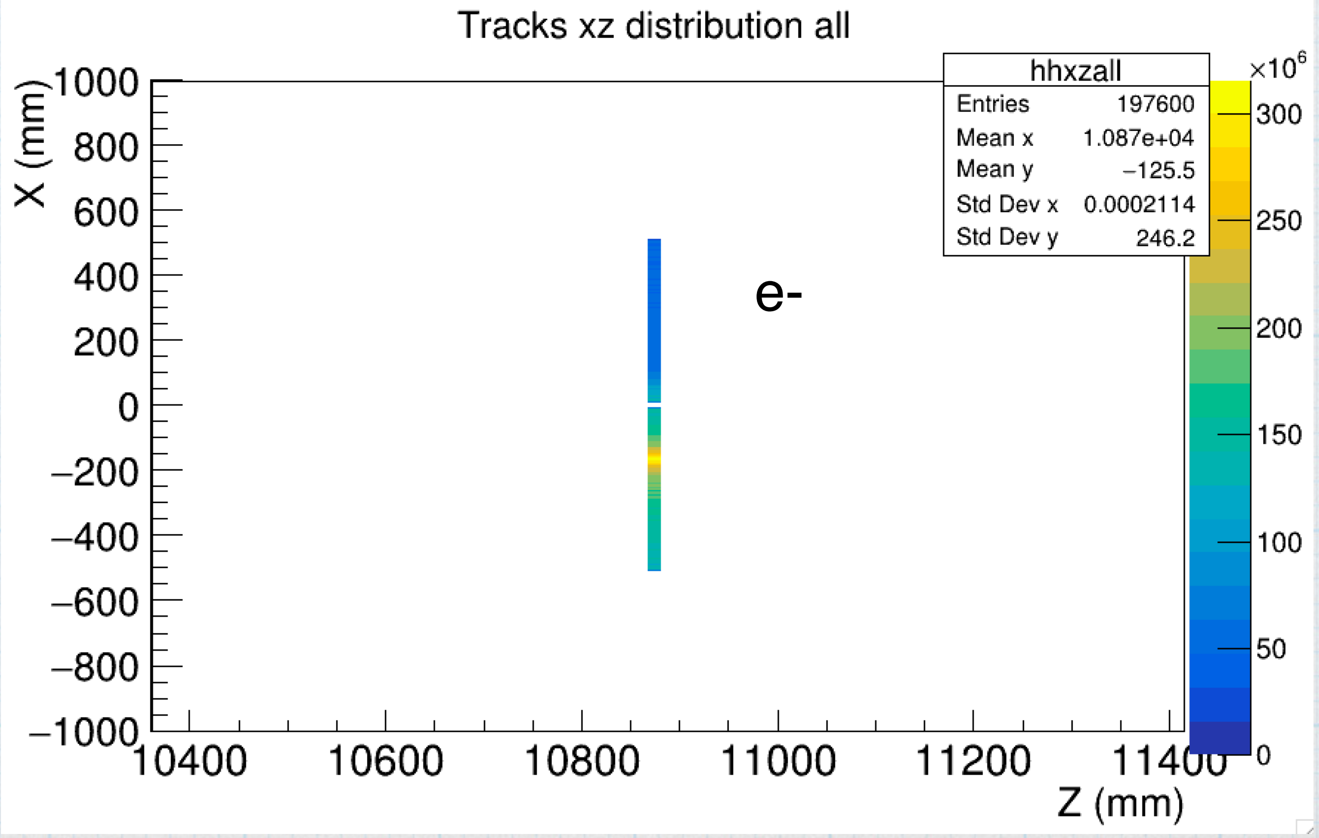
Back up

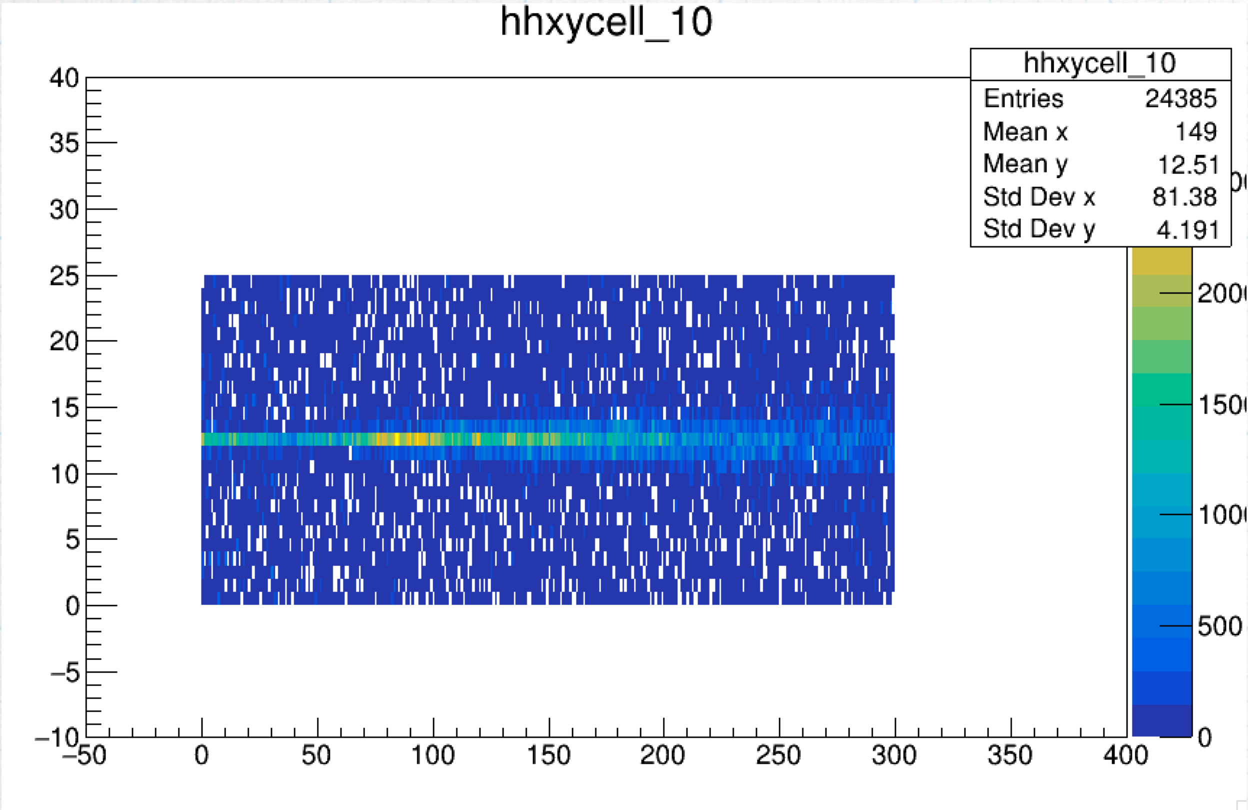
* Electron arm of Lanex Spectrometer

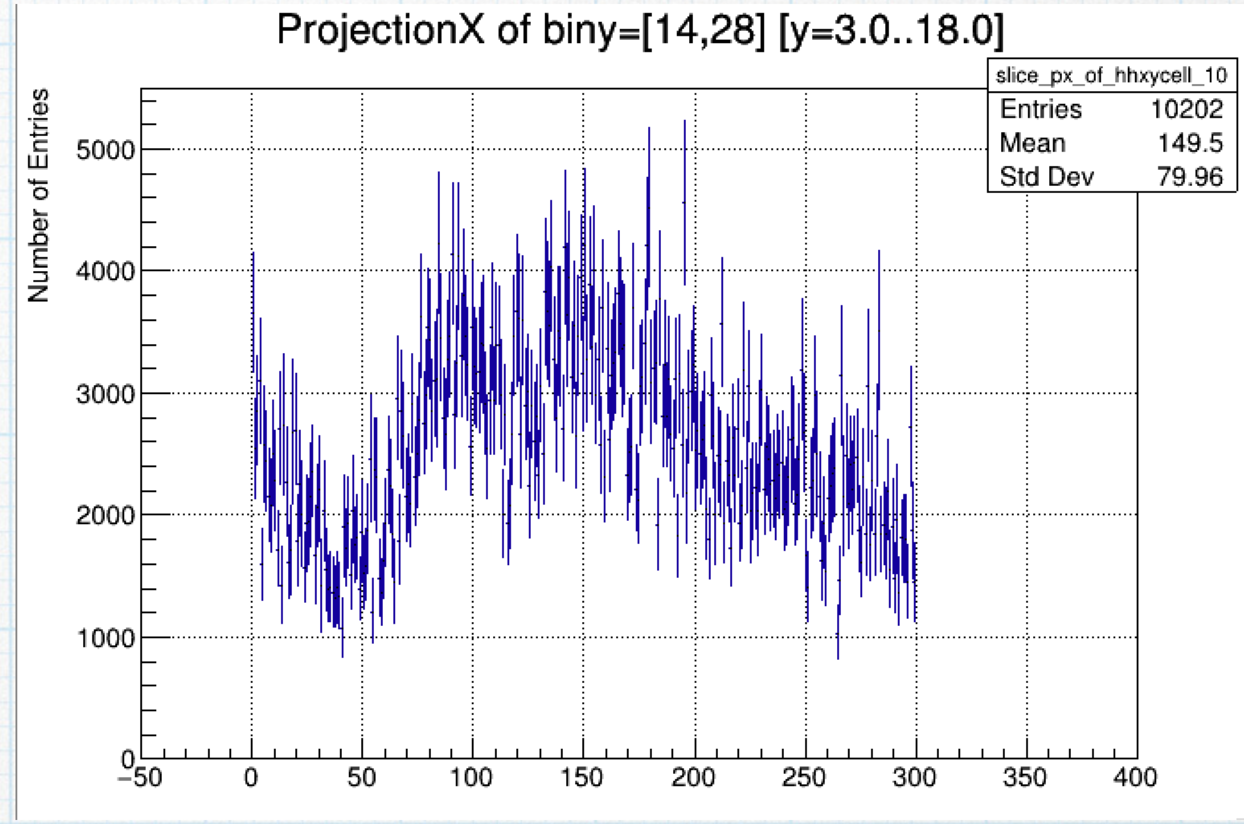


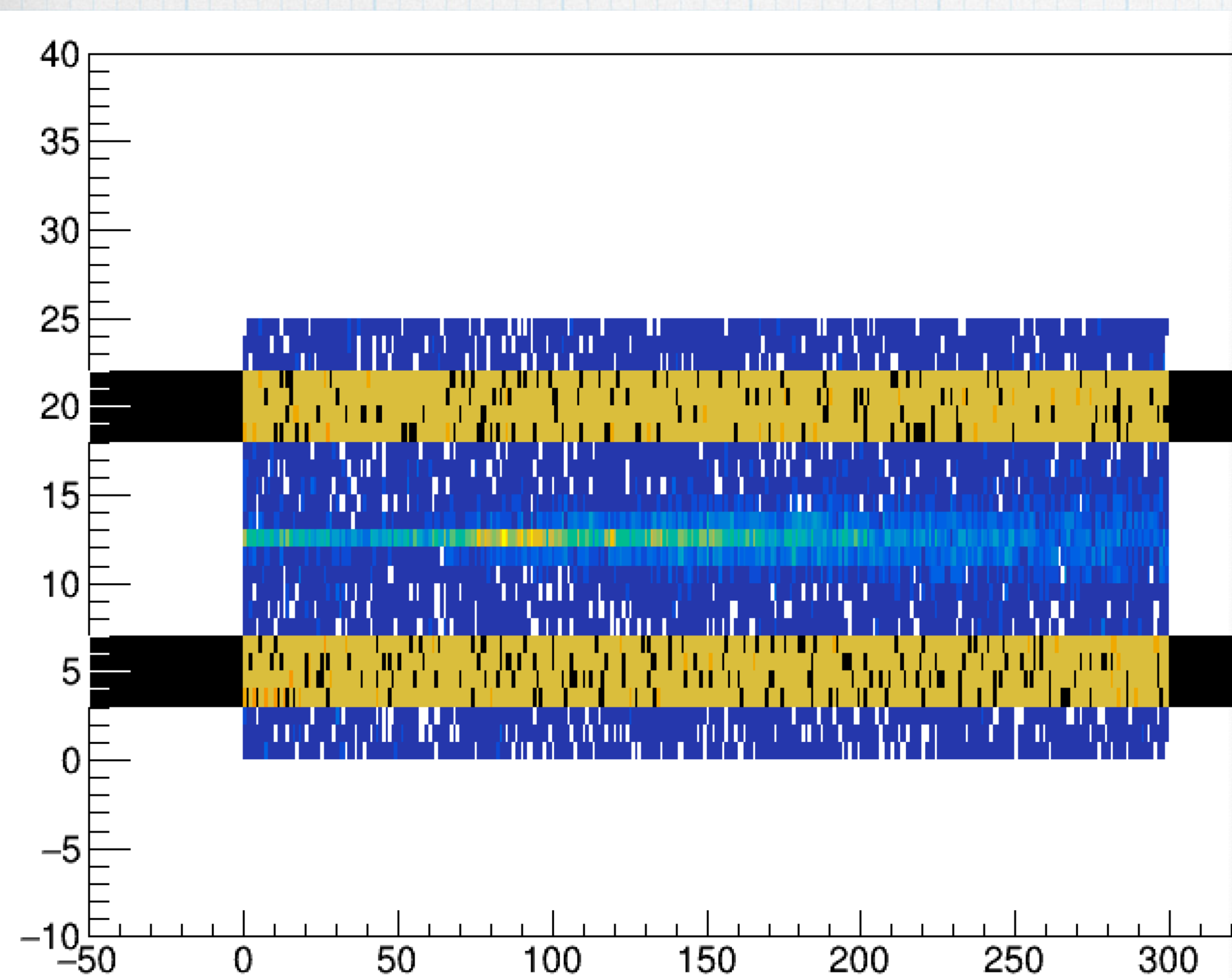


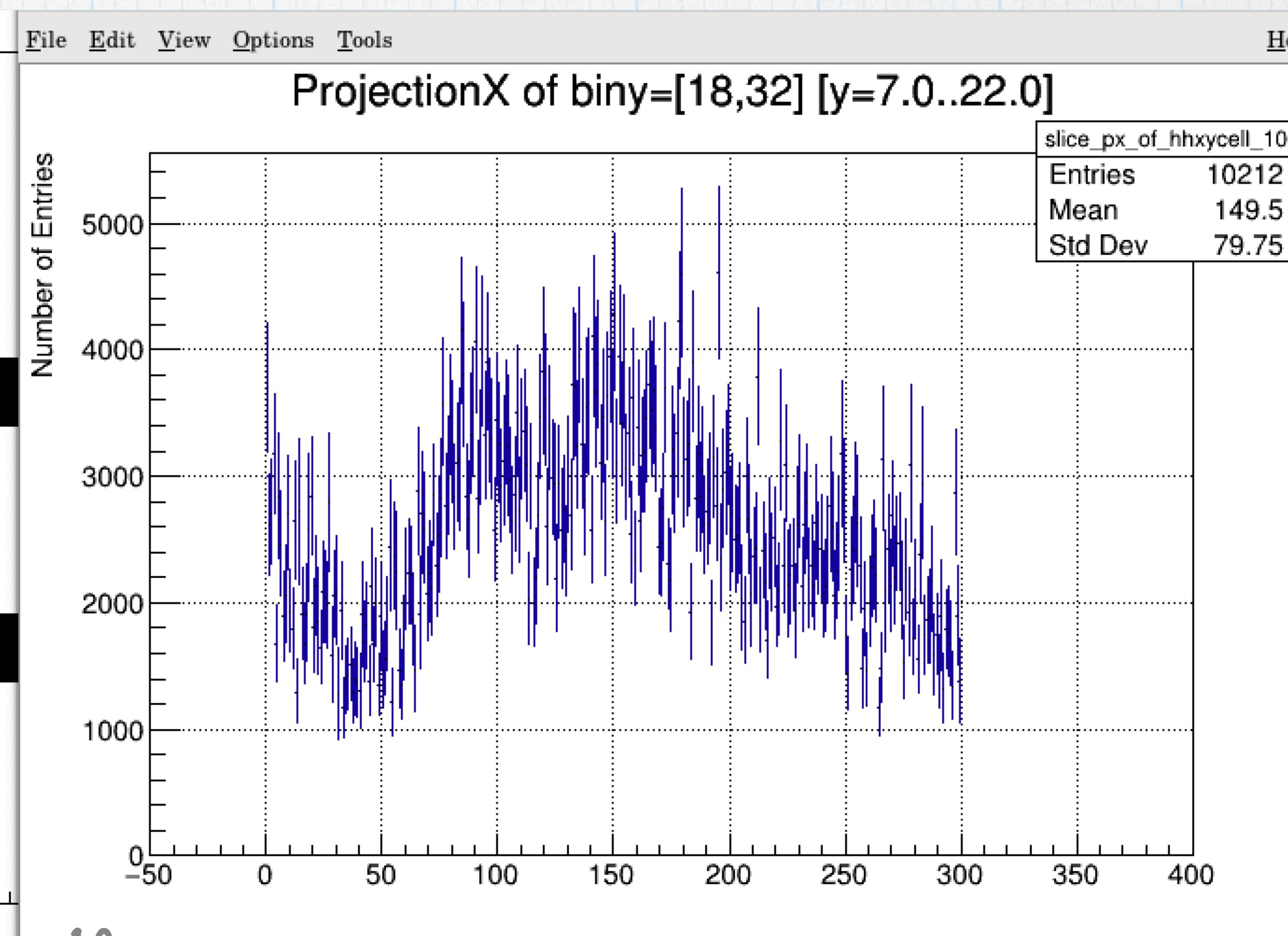




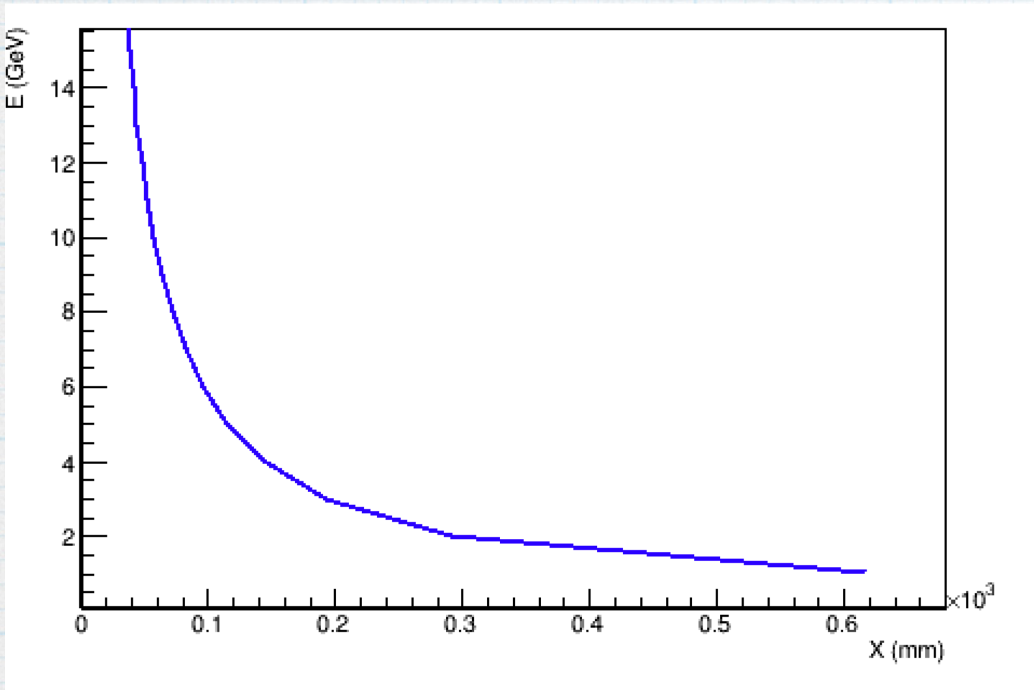

hhxycell_10
hhxycell_10
Entries 24385
Mean x 149
Mean y 12.51
Std Dev x 81.38
Std Dev y 4.191

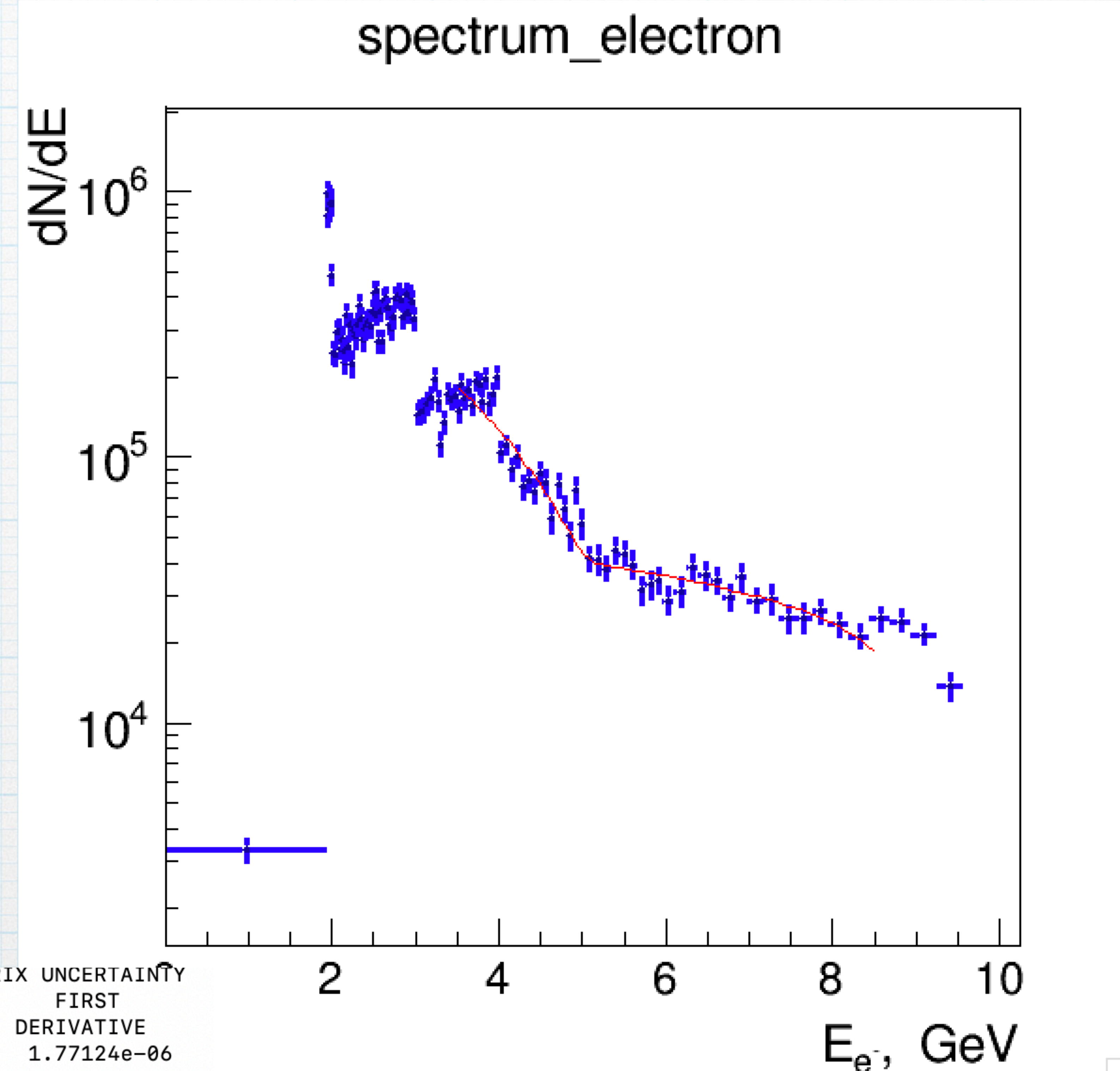

ProjectionX of biny=[14,28] [y=3.0..18.0]
slice_px_of_hhxycell_10
Entries 10202
Mean 149.5
Std Dev 79.96
Number of Entries




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





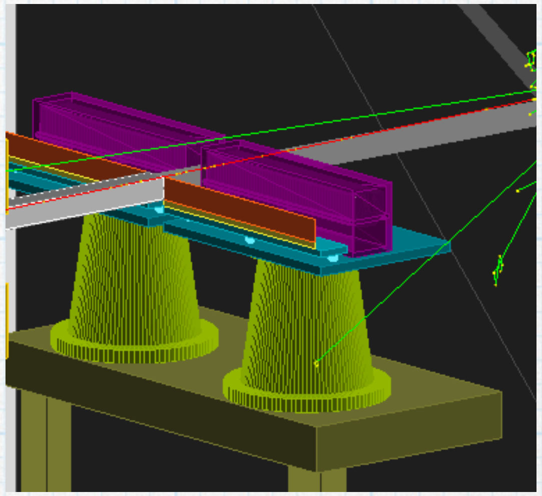
EDM=3.45767   STRATEGY= 1   ERROR MATRIX UNCERTAINTY

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

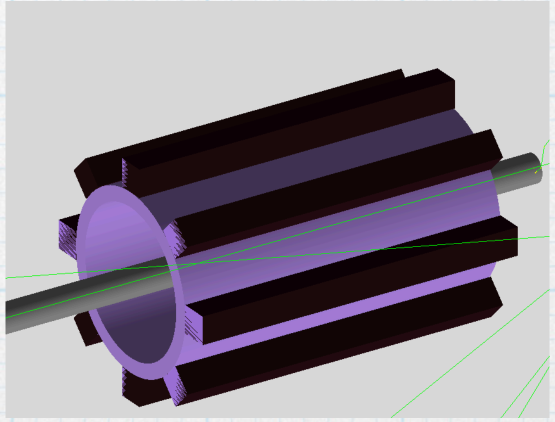
Photon flux measurements

Tasks

To measure total flux of photons above some threshold (~MeV-GeV)



- the technologies:
  a) conversion detector

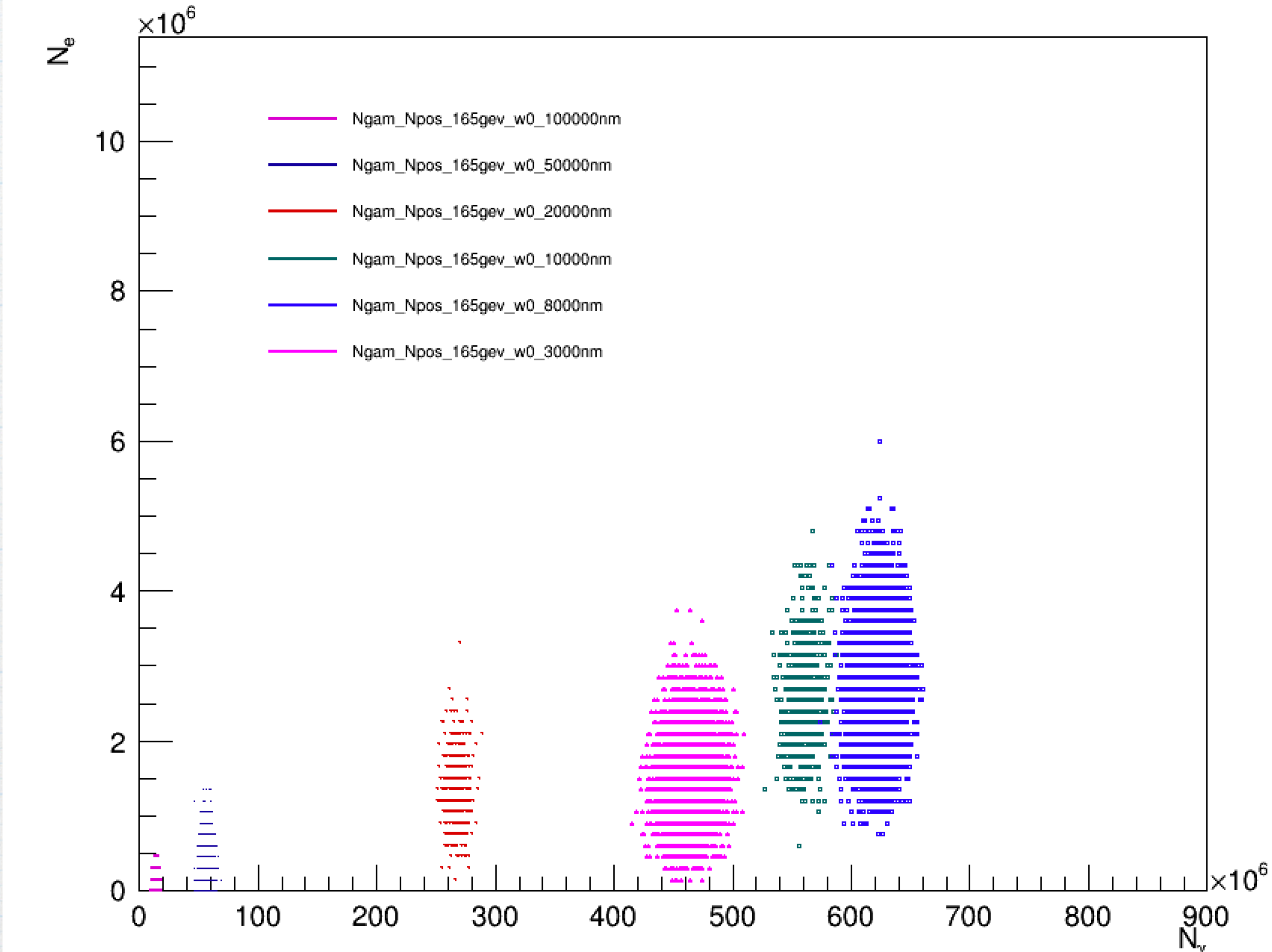


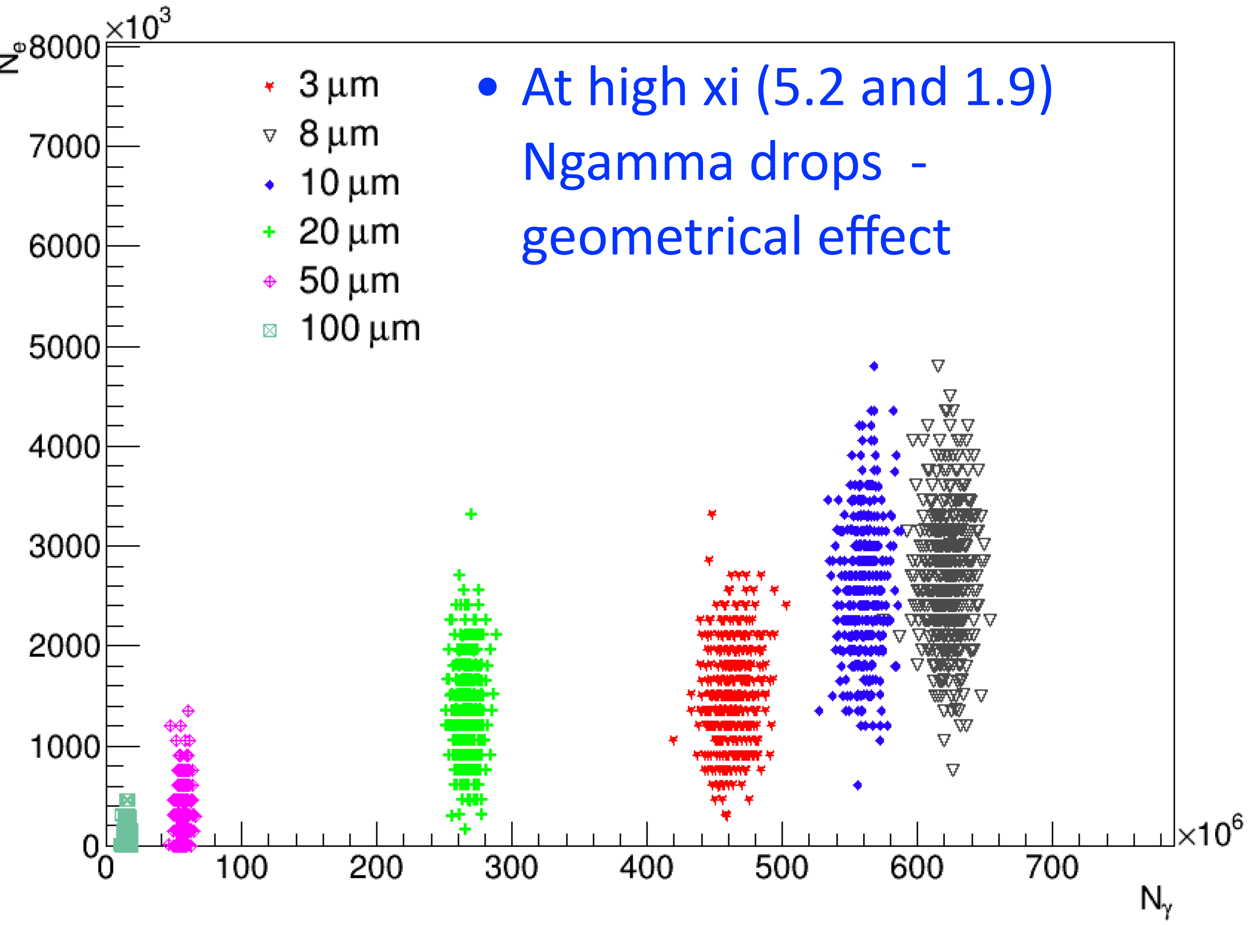
  b) backscattering calorimeter

For the CDR
a) quantify how well a) and b) can measure the flux and above which threshold =>
 show relative resolution on photon flux of the two technologies as function of number of photons

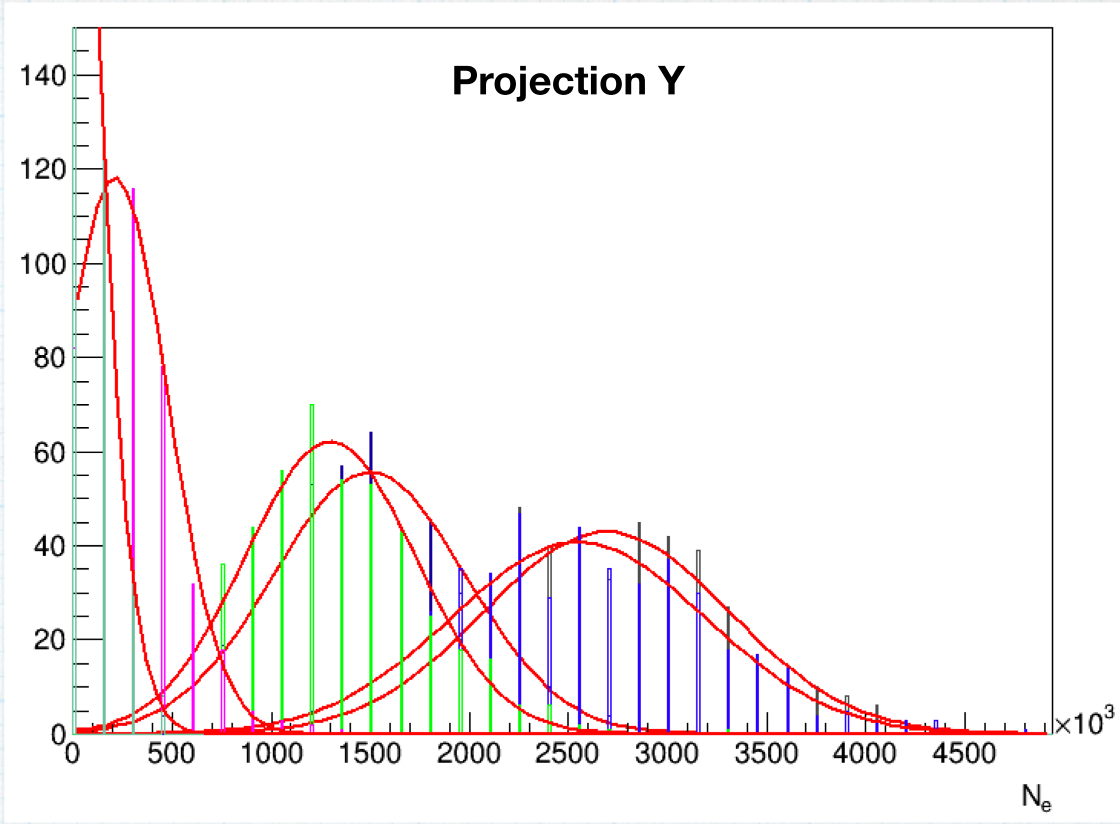
number of pairs vs number of photons per BX for different xi in Lanex scrteens (setup w/o beam pipe)

JETI40, 16.5 GeV, 50 um

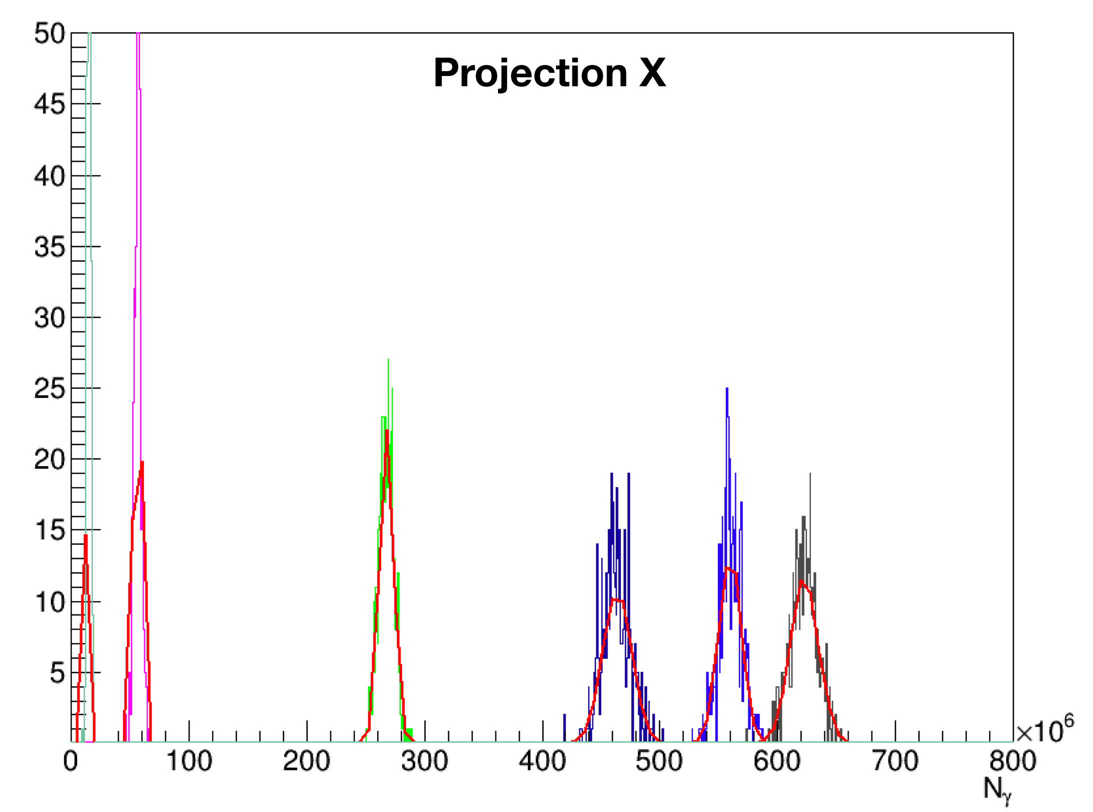


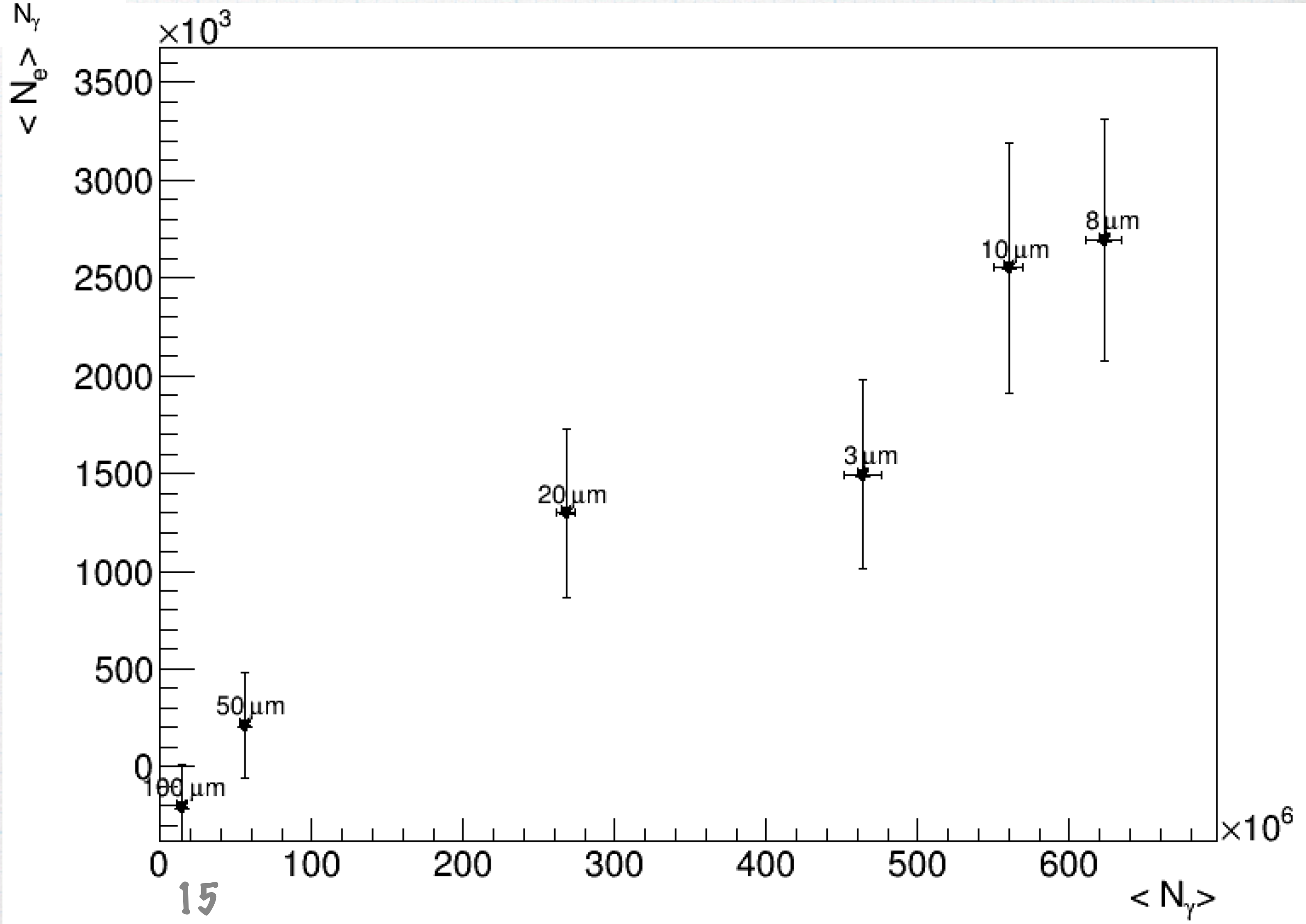


- At high xi (5.2 and 1.9) Ngamma drops - geometrical effect



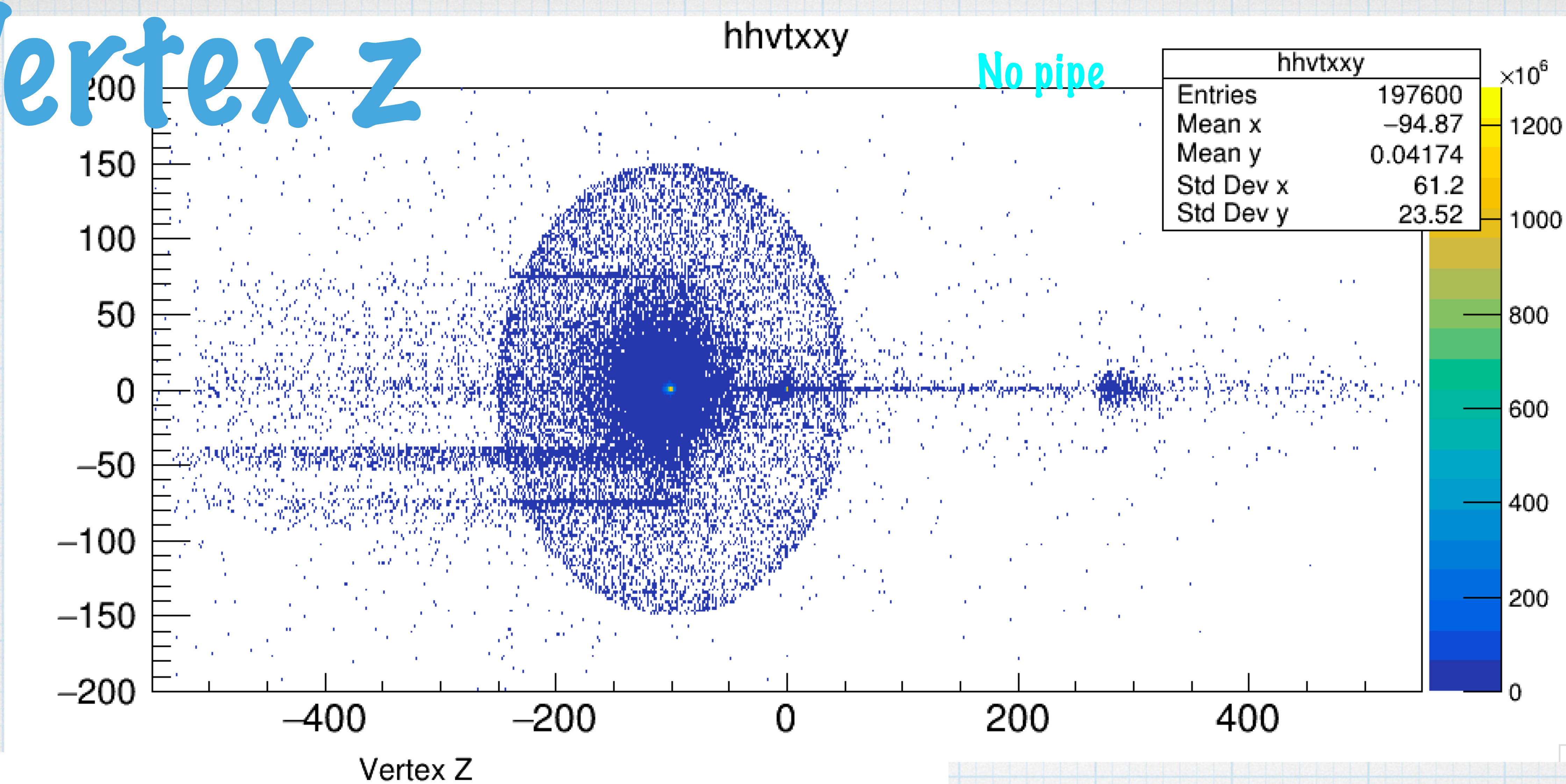
460 BX



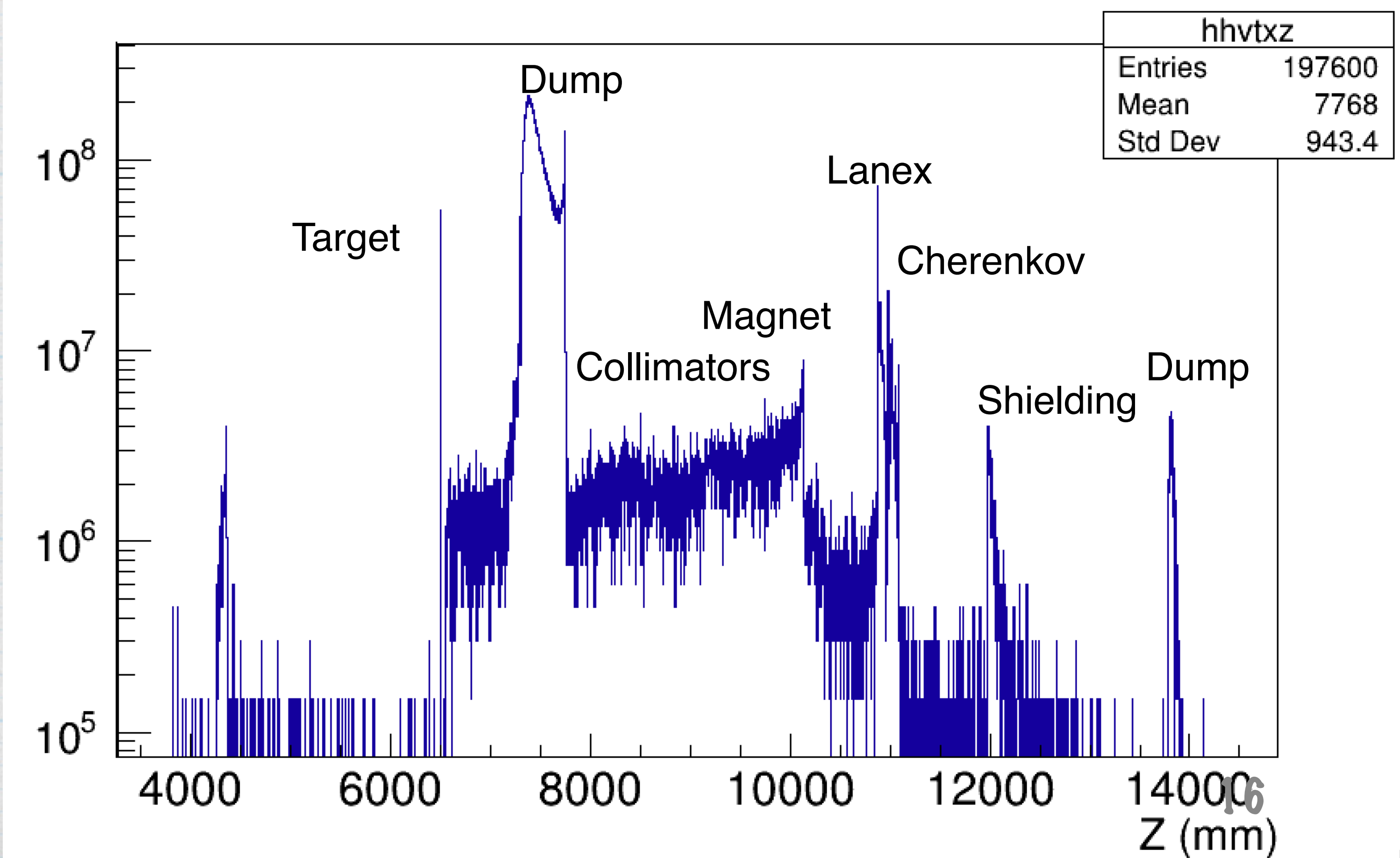


- Spread in number of electrons is substantial ~ 25-30%

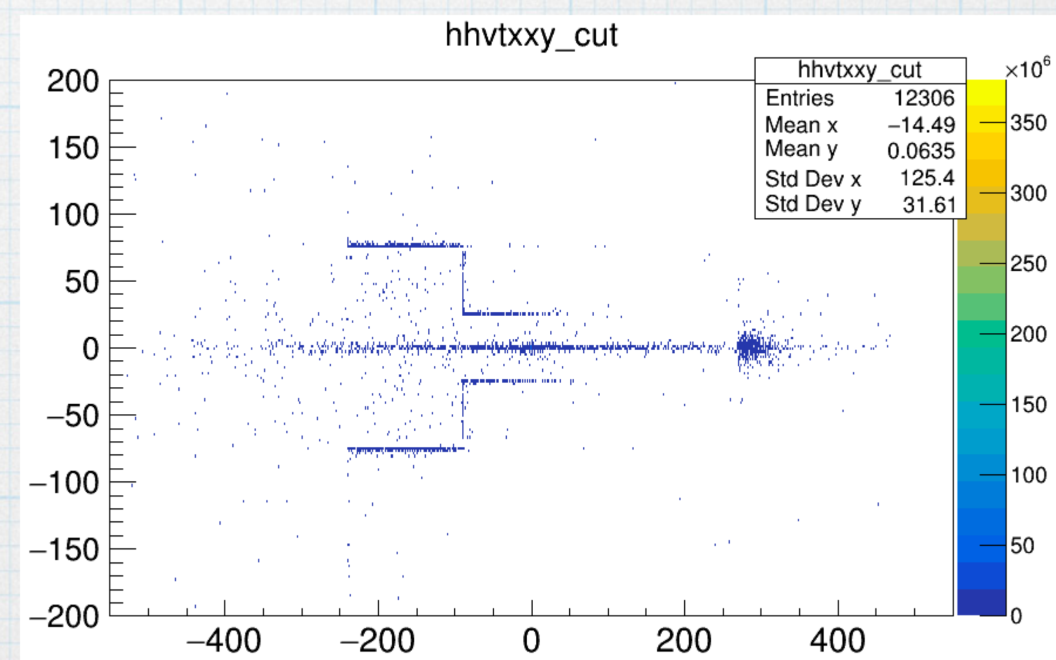
Vertex z



hhvtxxy
No pipe
hhvtxxy
Entries 197600
Mean x −94.87
Mean y 0.04174
Std Dev x 61.2
Std Dev y 23.52
×10^6
Vertex Z



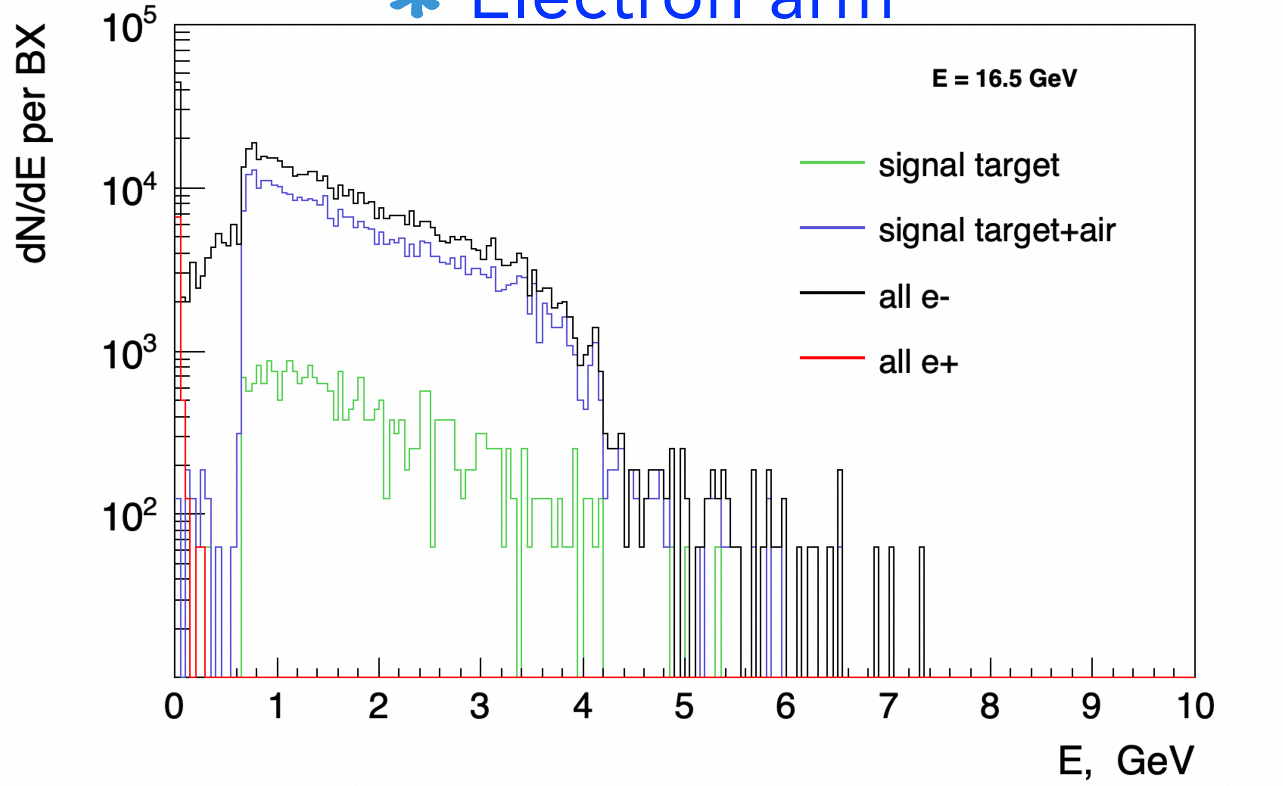
hhvtxz
Entries 197600
Mean 7768
Std Dev 943.4
Dump
Target
Lanex
Cherenkov
Magnet
Collimators
Shielding
Dump
Z (mm)



hhvtxxy_cut
hhvtxxy_cut
Entries 12306
Mean x −14.49
Mean y 0.0635
Std Dev x 125.4
Std Dev y 31.61
×10^6

Lanex screens, Spectra

* Electron arm



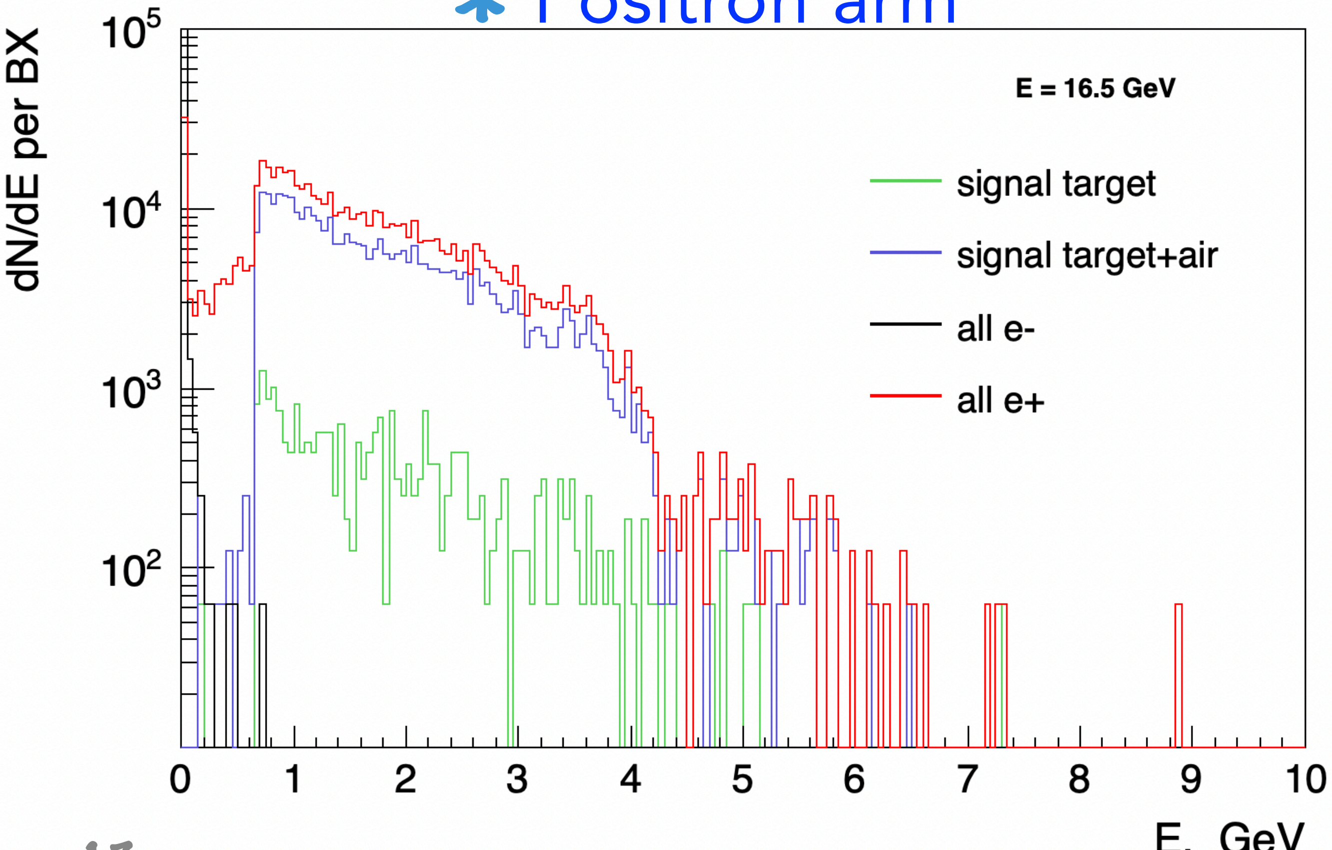
JETI40, 16.5 GeV, 50 um

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

* Selection

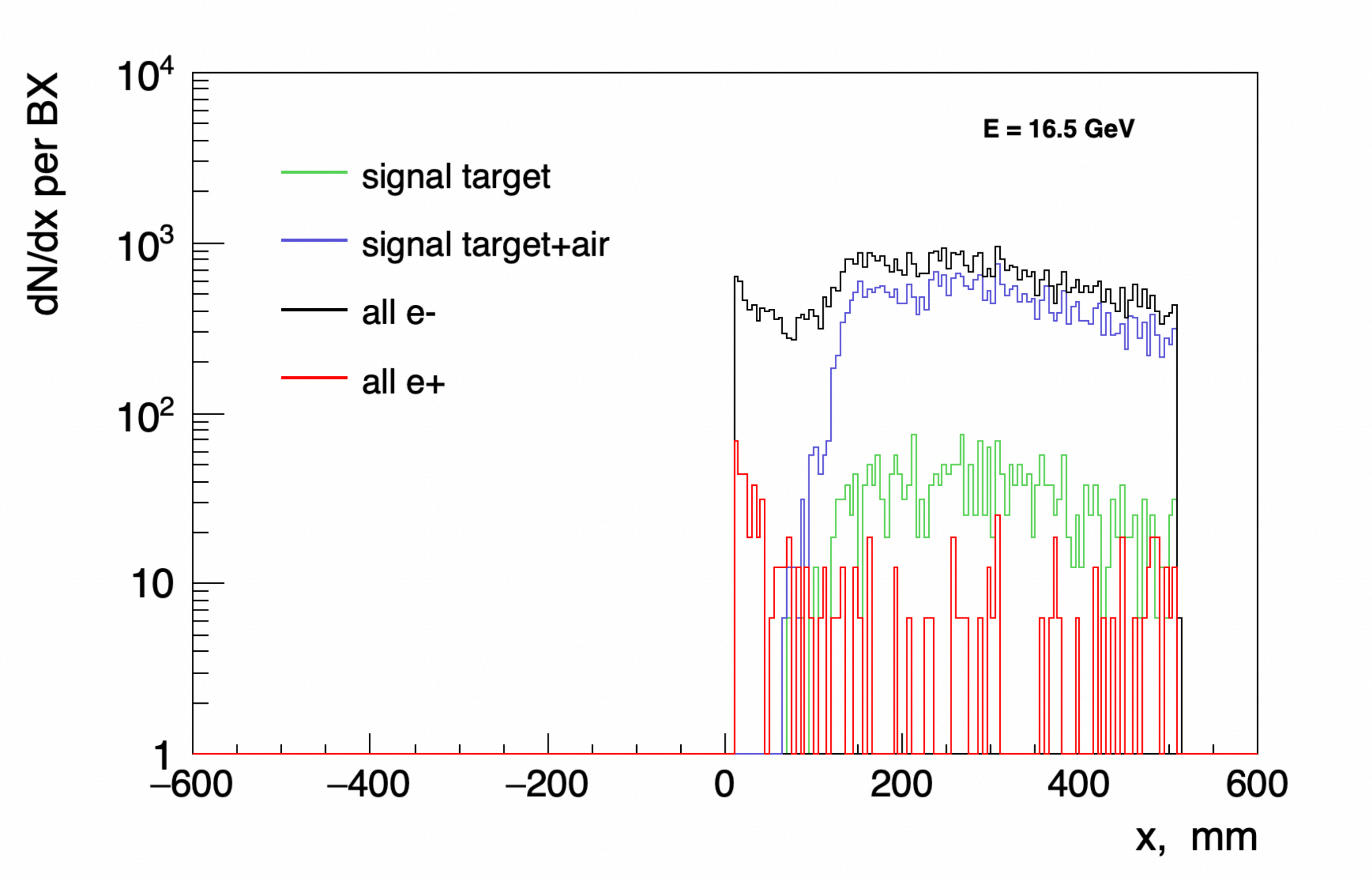
- detid == 3000/3001
- pdg ==11/-11
- Parent pdg ==22
- Parent == primary
- Primary pdg ==22
- |vtx x,y |<25 mm
- |vtx z - 6.5 m |< 100 um
- vtx z > 6.5m -100um && vtx z < 9m

* Positron arm



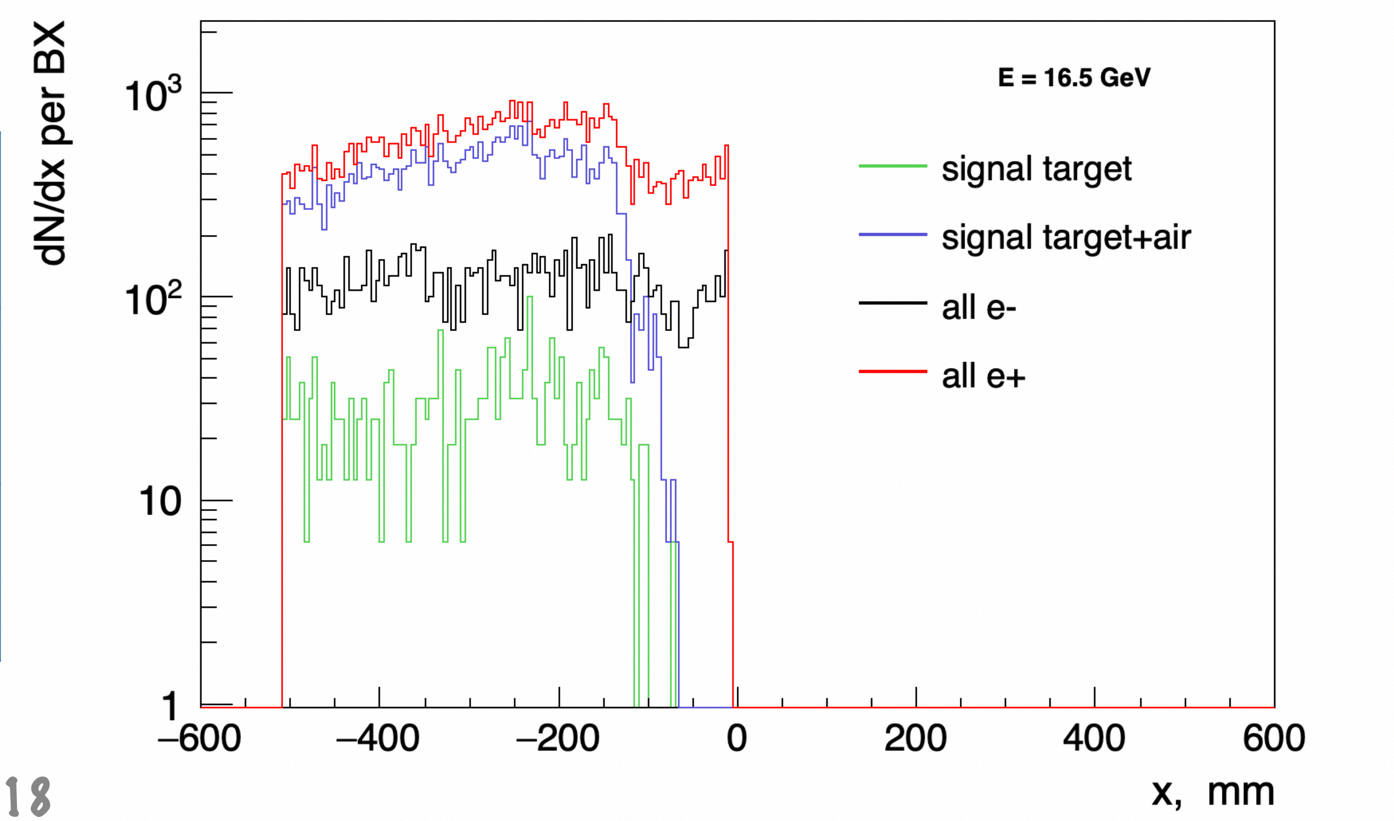
Lanex screens, X-distributions

* Electron arm



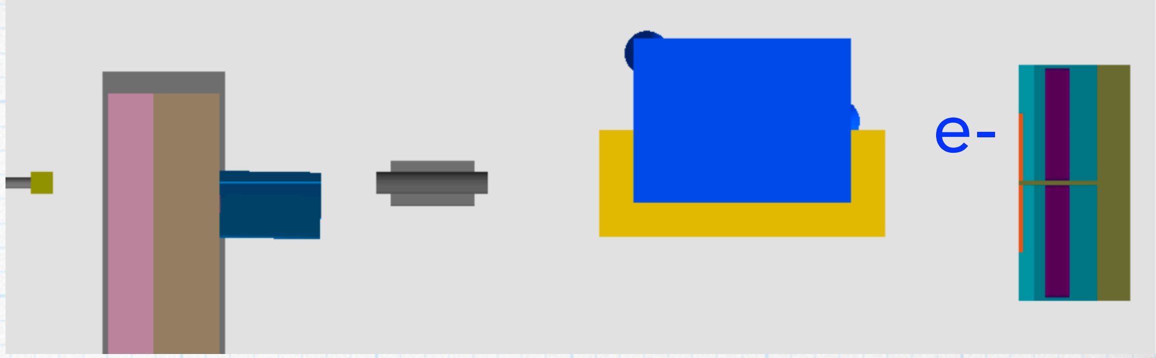
Material	X0,(cm)	Thickness	Fraction X0
Air	3.04E+04	350	1.15 %
Kapton	28.57	2.00E-02	0.07 %

* Positron arm

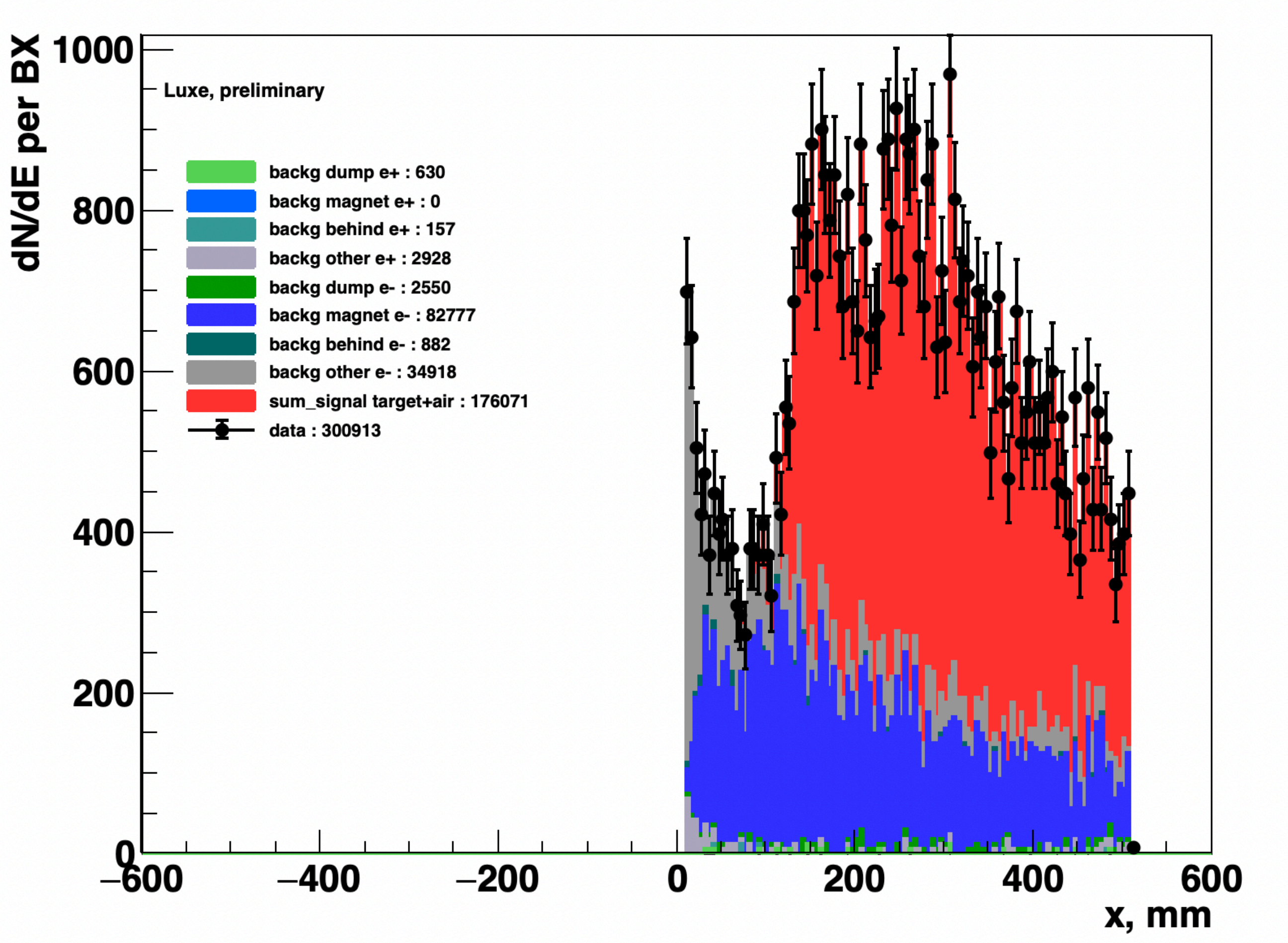


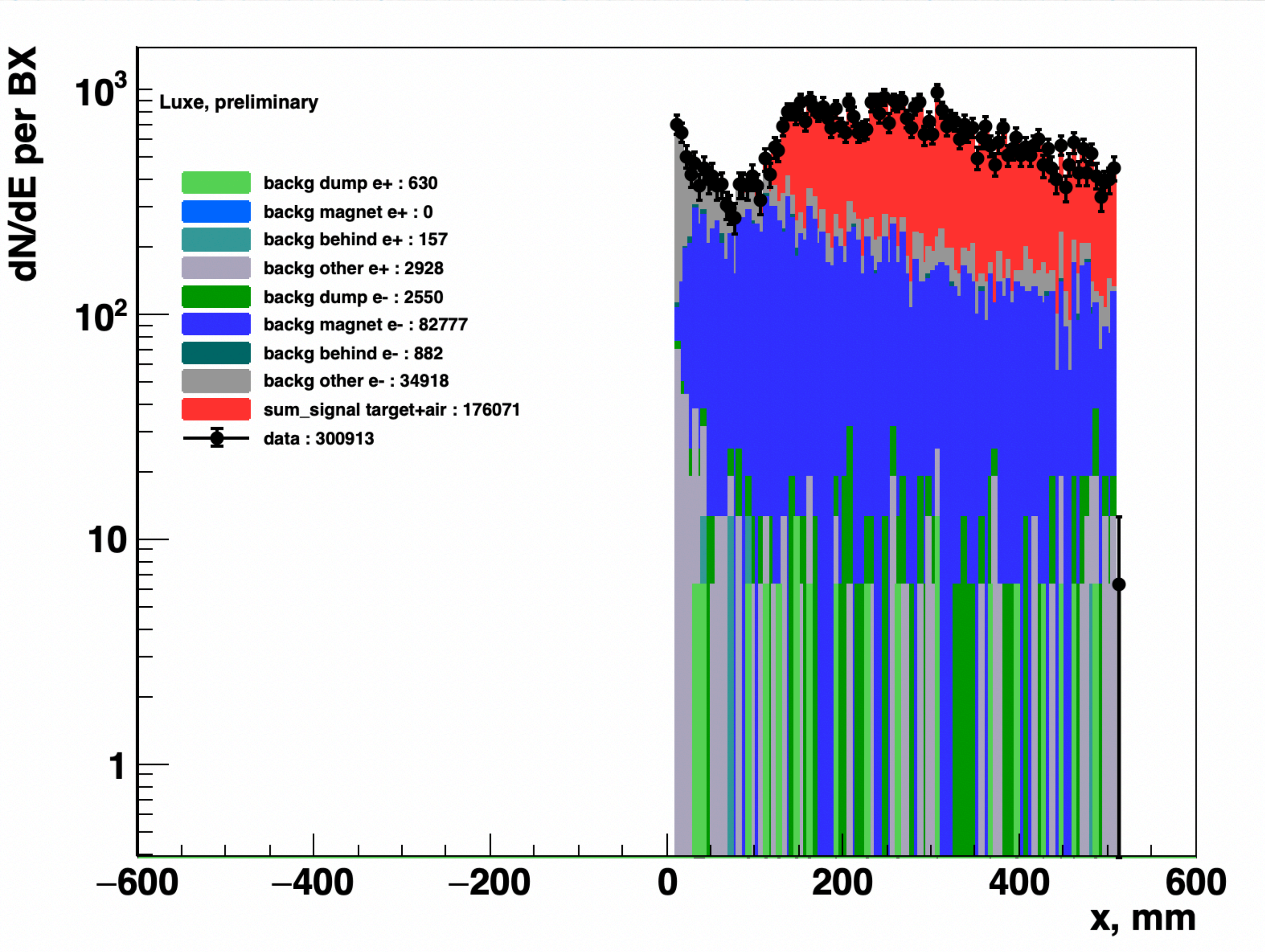
Background

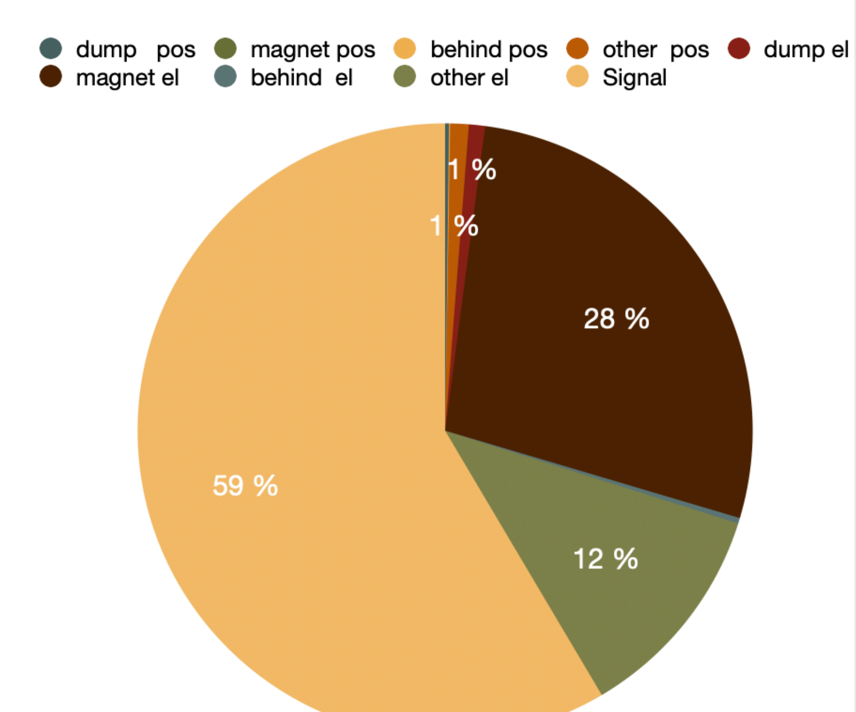
* Electron arm



JETI40, 16.5 GeV, 50 um

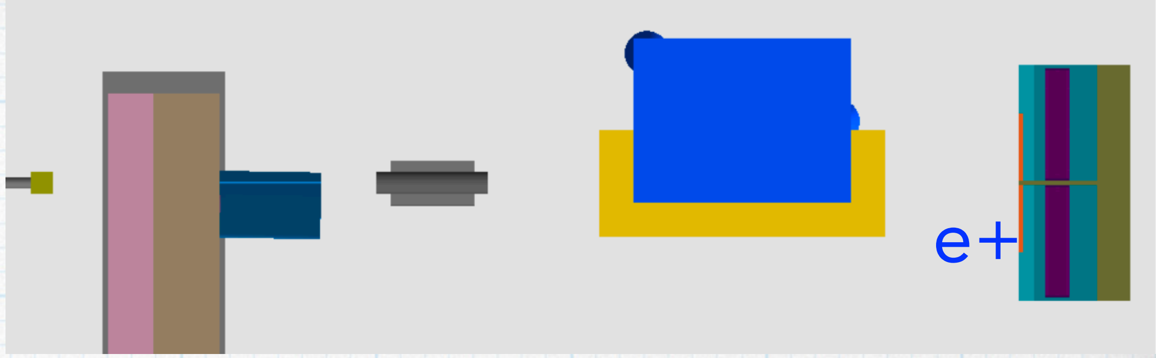




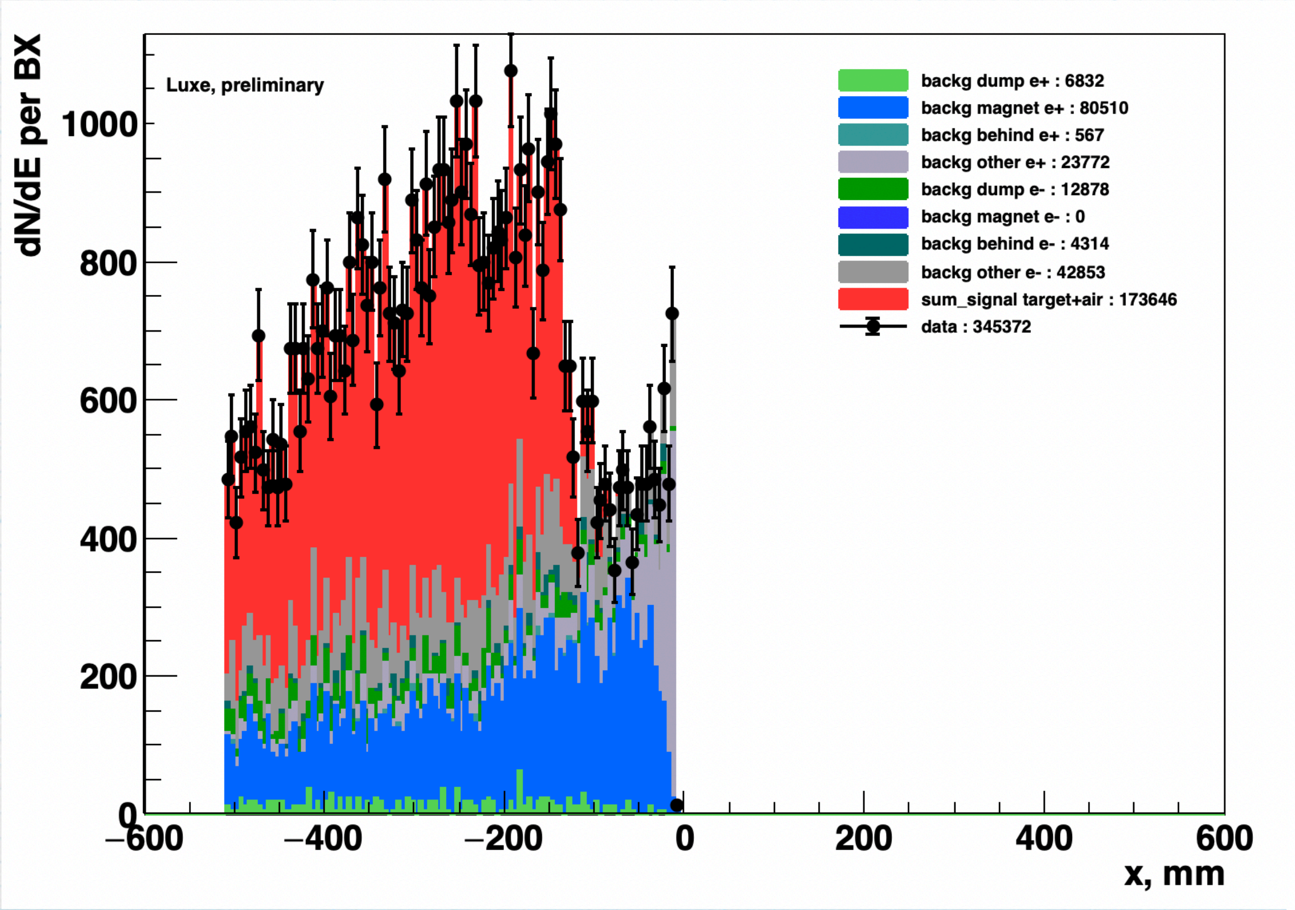


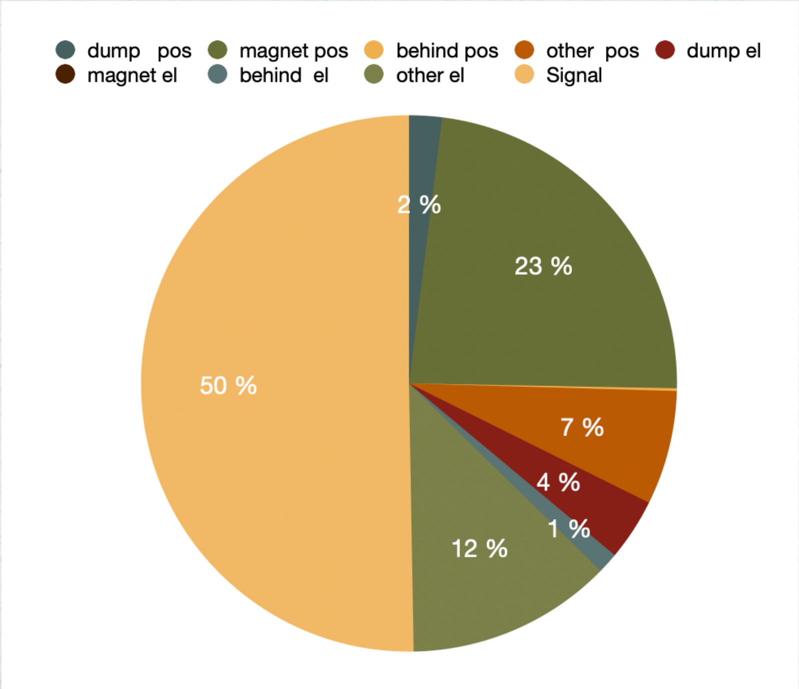
Background

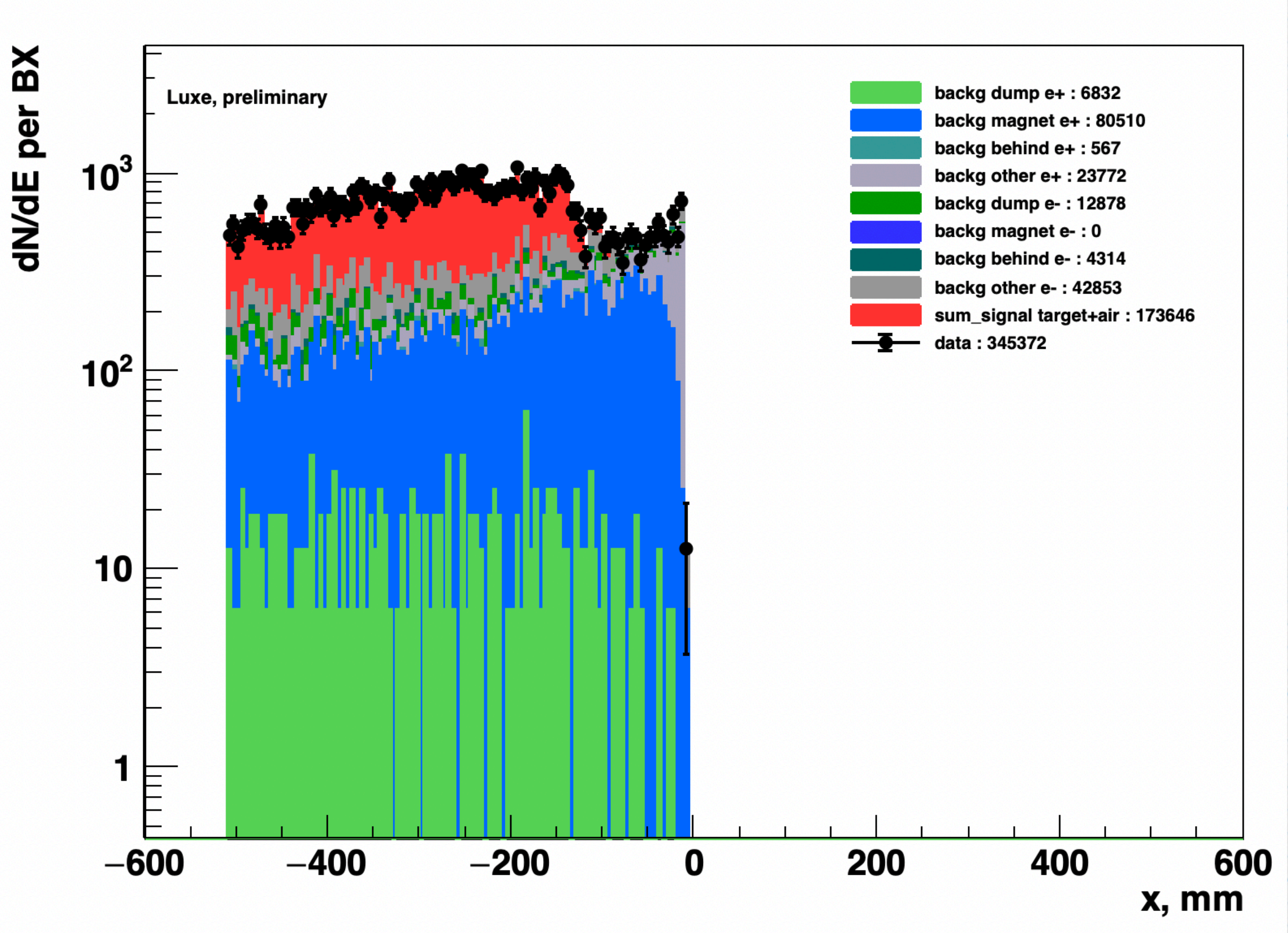
* Positron arm



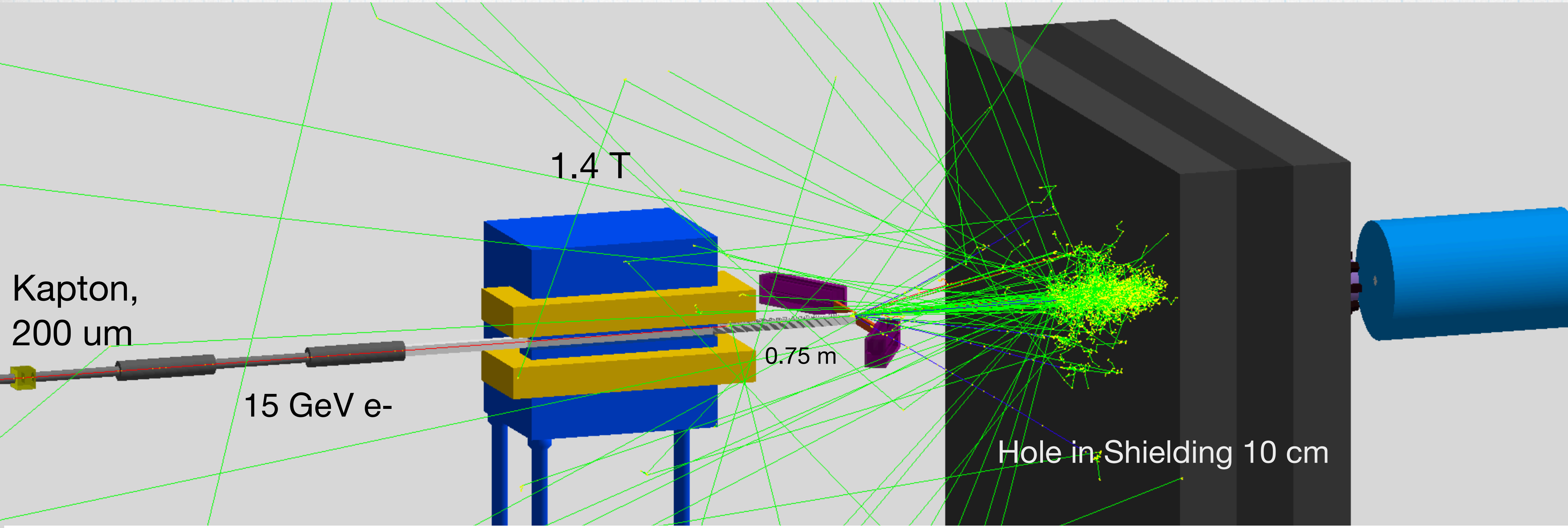
JETI40, 16.5 GeV, 50 um







FDS with LYSO calorimeters



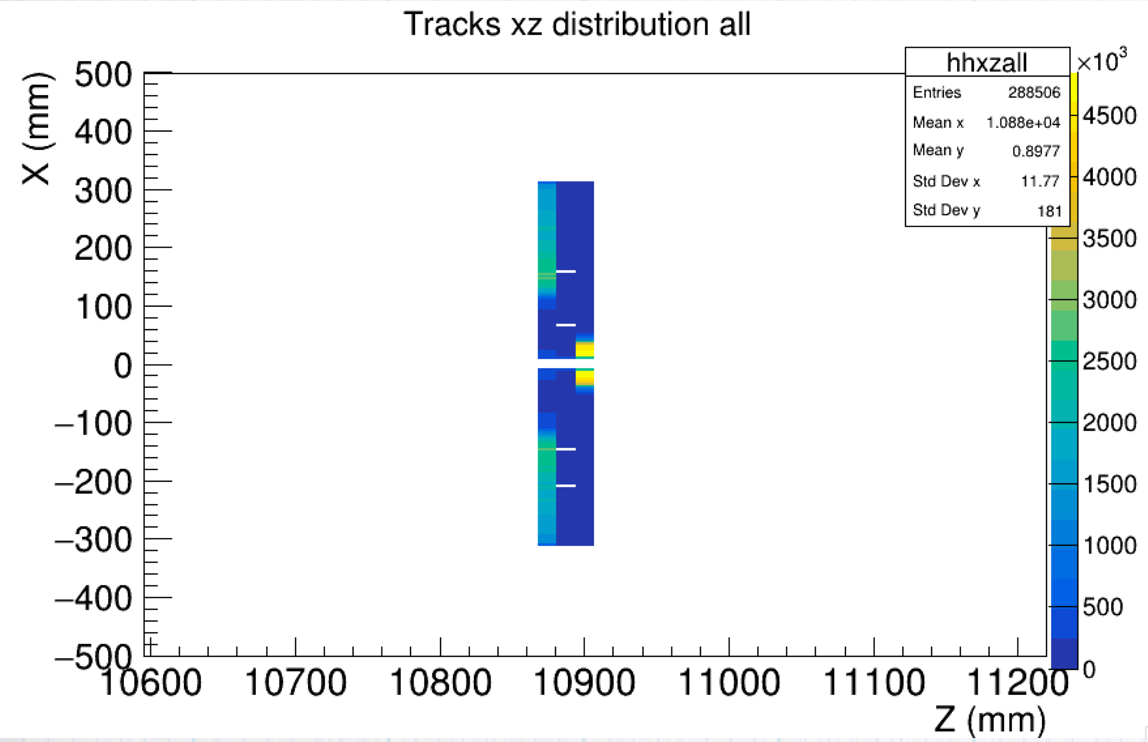
Aug 2020 Data Runs, bunch/pulse crossings completed

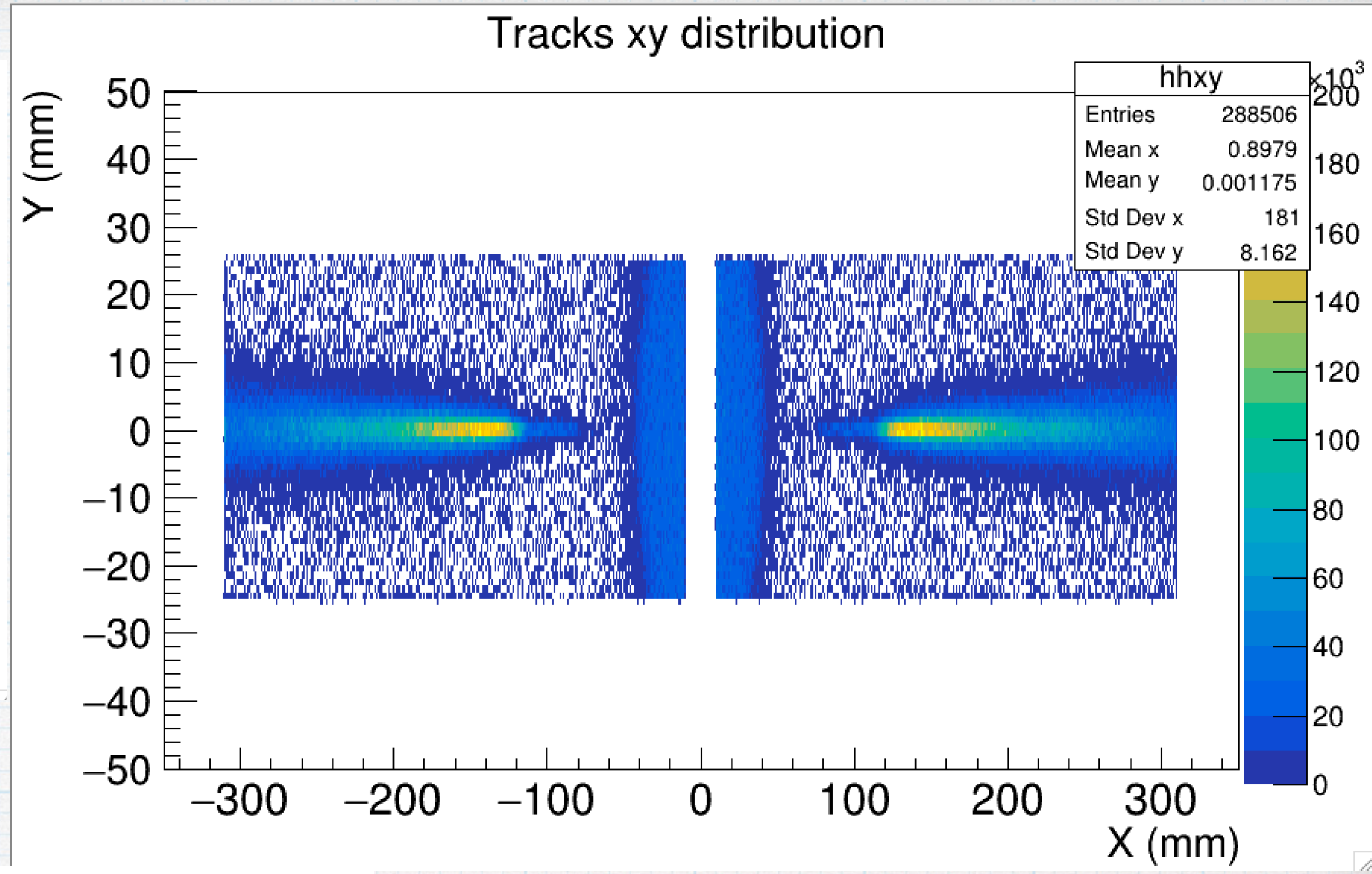
Experiment Config	$w_0 = 3\mu$m	$w_0 = 3.5\mu$m	$w = 0, 4.0\mu$m	$w_0 = 4.5\mu$m	$w_0 = 5.0\mu$m	$w_0 = 8.0\mu$m	$w_0 = 20.0\mu$m	$w_0 = 50.0\mu$m	$w_0 = 100.0\mu$m
peak SQED ξ	5.12	4.44	3.88	3.45	3.1	1.94	0.78	0.31	0.15
peak SQED χ (16.5 GeV)	0.9	0.79	0.69	0.61	0.55	0.34	0.138	0.055	0.028
JETI40 e-laser 16.5 GeV	10000	1000	1000	1000	1000	1000	500	5000	500

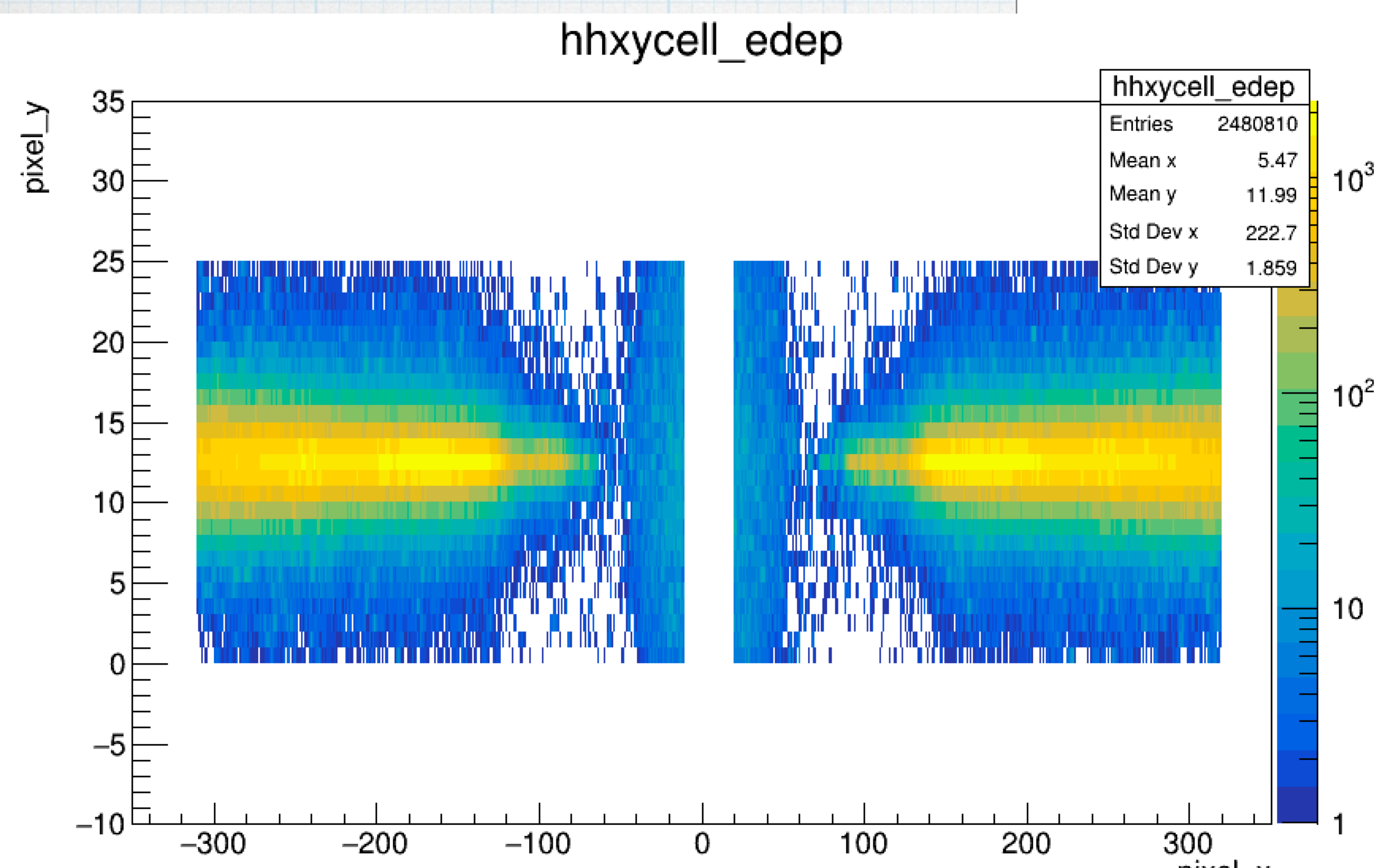
- The scintillators are modelled as a 15x5x2 cm (x:y:z) layer of lyso material
- The crystal (bin) size of the scintillators are 2 x 1 mm (finer segmentation in x; the deflection direction) giving 25 x 300 bins.

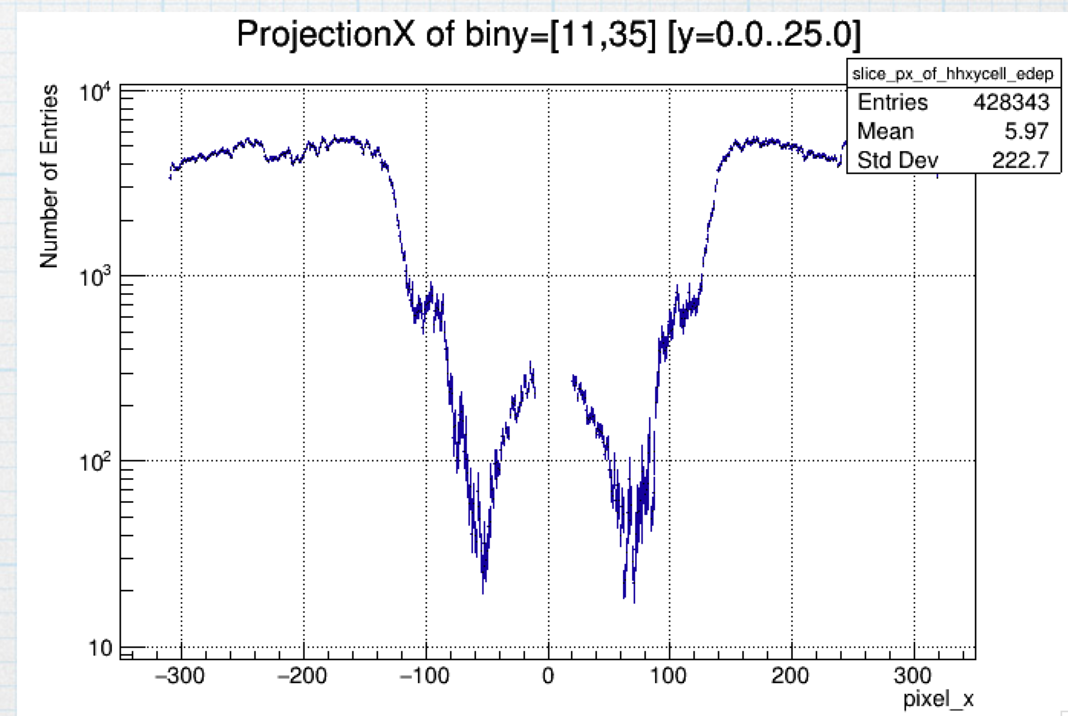
LYSO $(Lu_{1.8}Y_{0.2}SiO_5)$

All studies were performed with 5000 BX at the laser intensity xi = 0.3 for 16.5 GeV electron beam

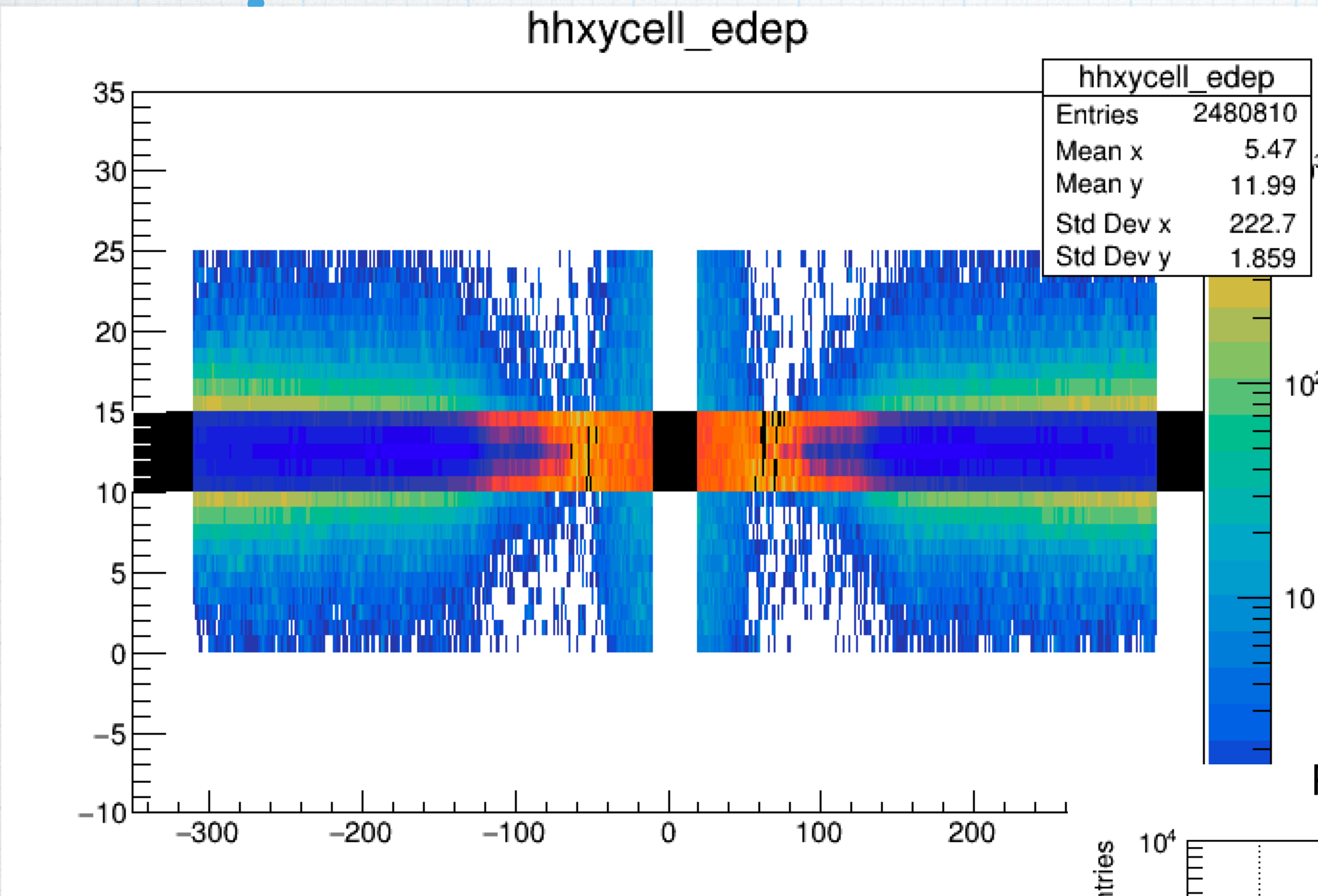

Tracks xz distribution all
hhxzall
Entries 288506
Mean x 1.088e+04
Mean y 0.8977
Std Dev x 11.77
Std Dev y 181
X (mm)
Z (mm)
×10³

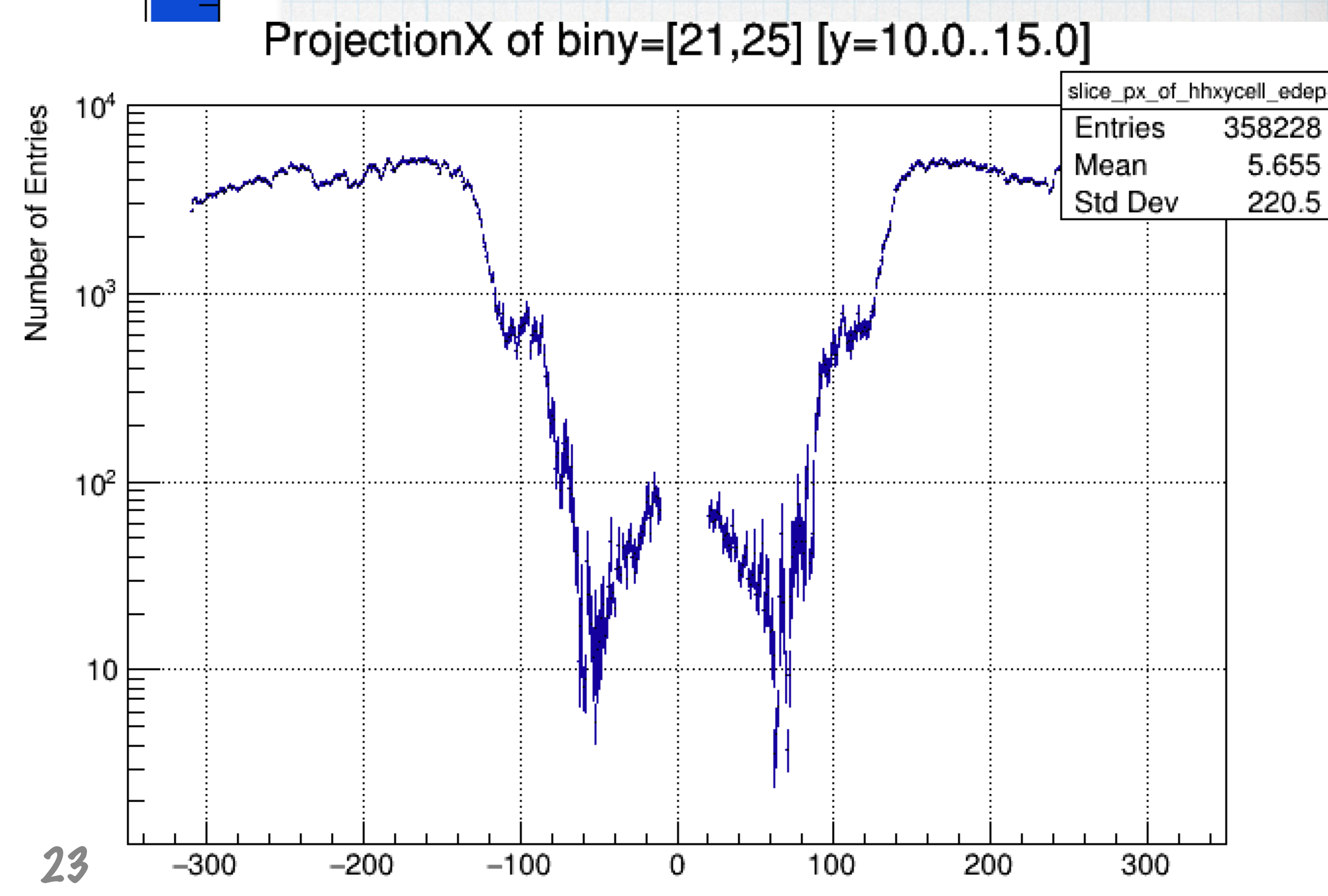

Tracks xy distribution
hhxy
Entries 288506
Mean x 0.8979
Mean y 0.001175
Std Dev x 181
Std Dev y 8.162
Y (mm)
X (mm)
×10³


hhxycell_edep
hhxycell_edep
Entries 2480810
Mean x 5.47
Mean y 11.99
Std Dev x 222.7
Std Dev y 1.859
pixel_y
pixel_x

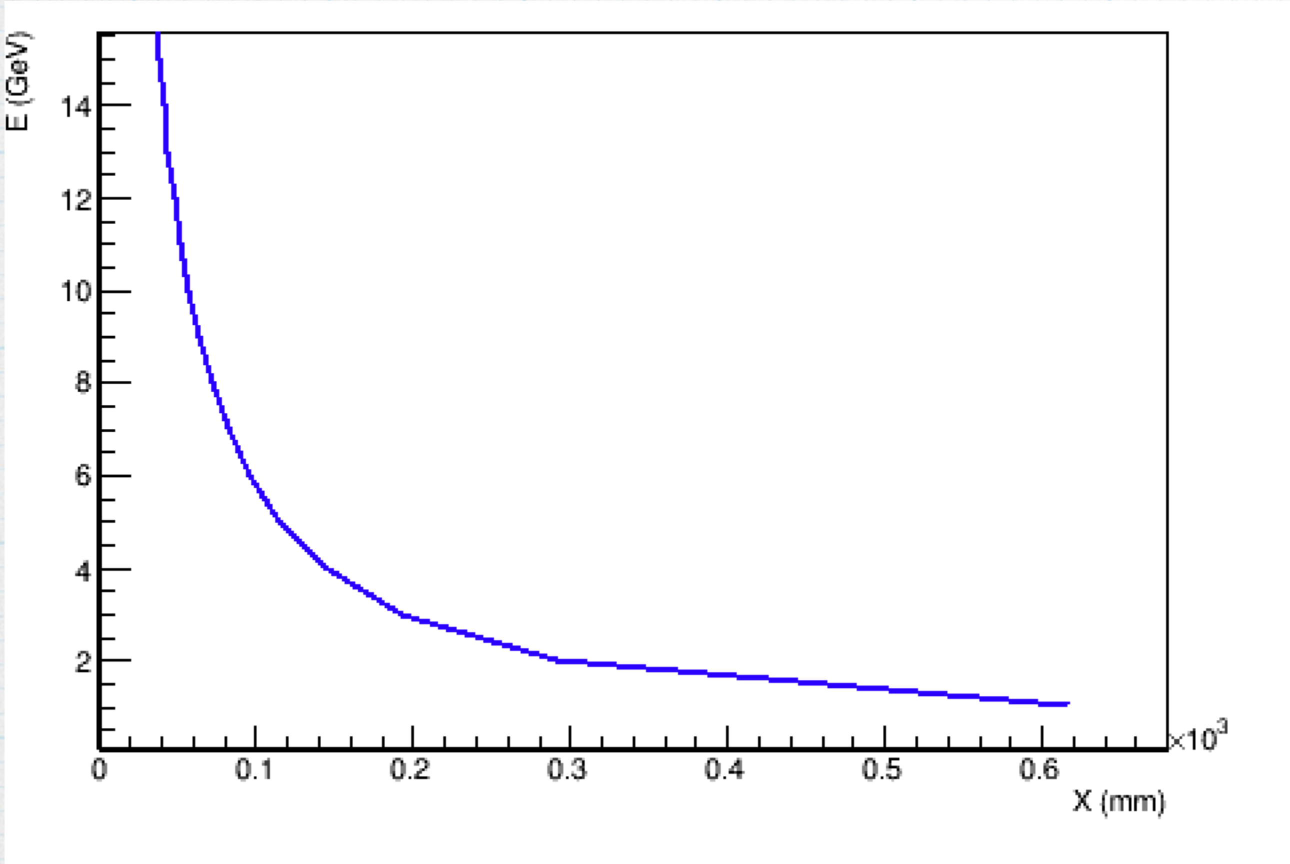

ProjectionX of biny=[11,35] [y=0.0..25.0]
slice_px_of_hhxycell_edep
Entries 428343
Mean 5.97
Std Dev 222.7
Number of Entries
pixel_x

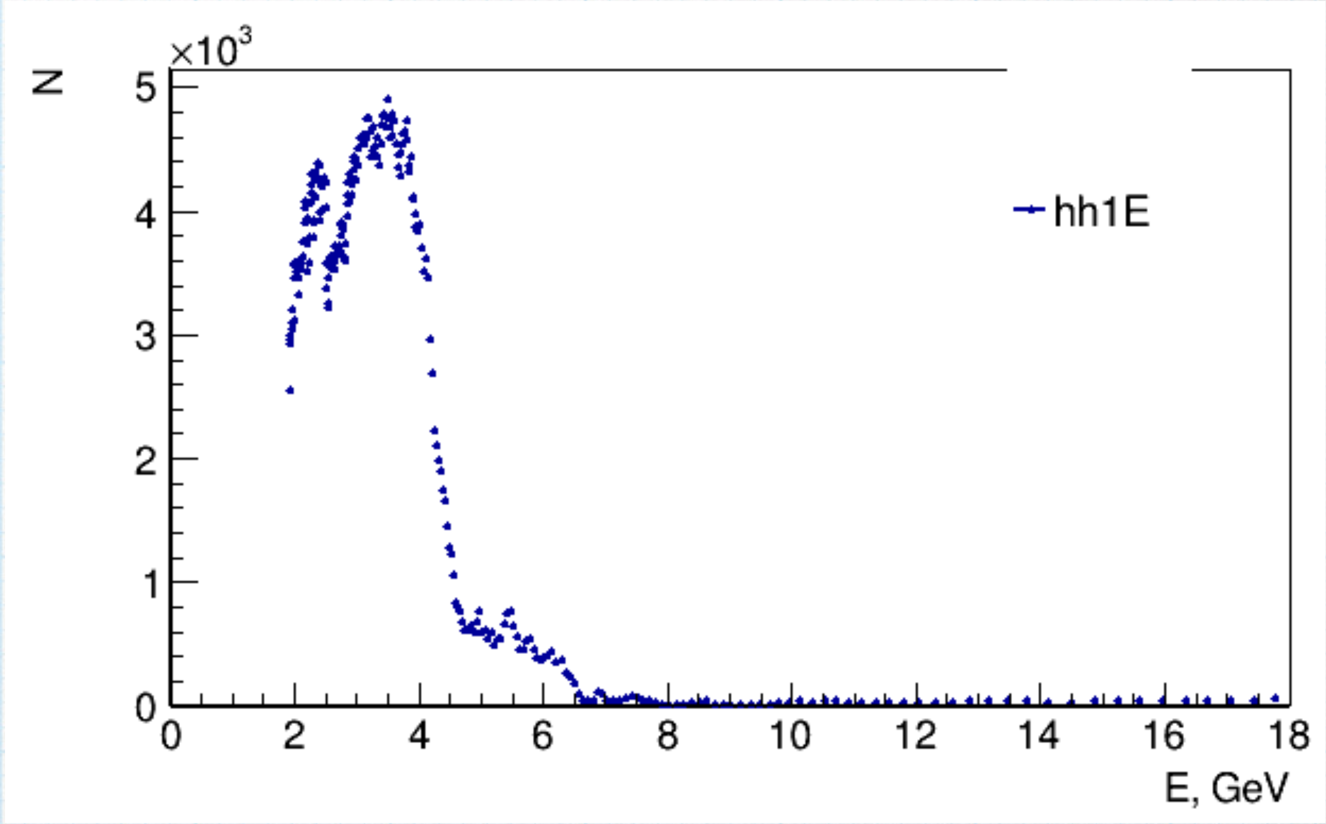
Spectra reconstruction for the LYSO case

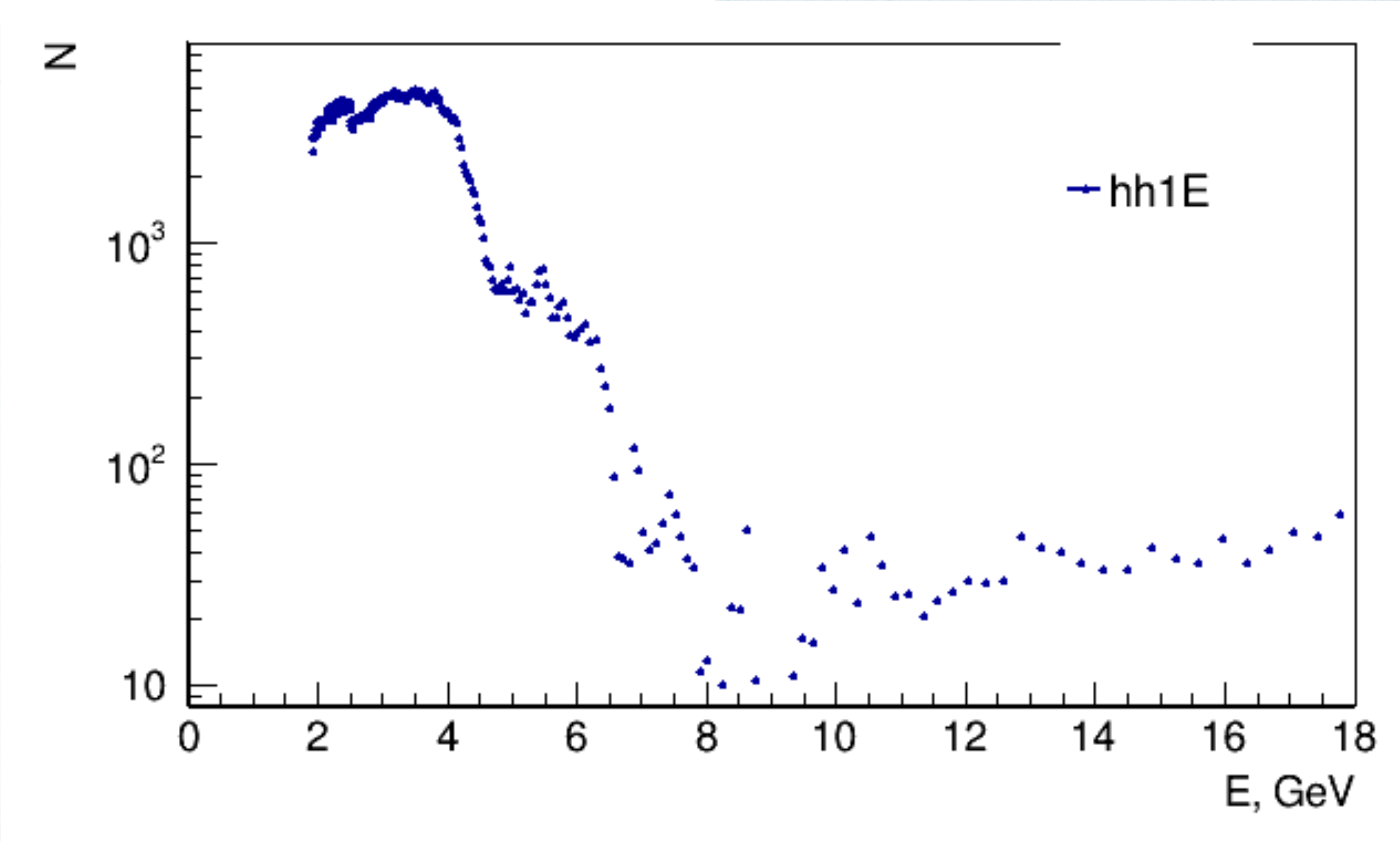




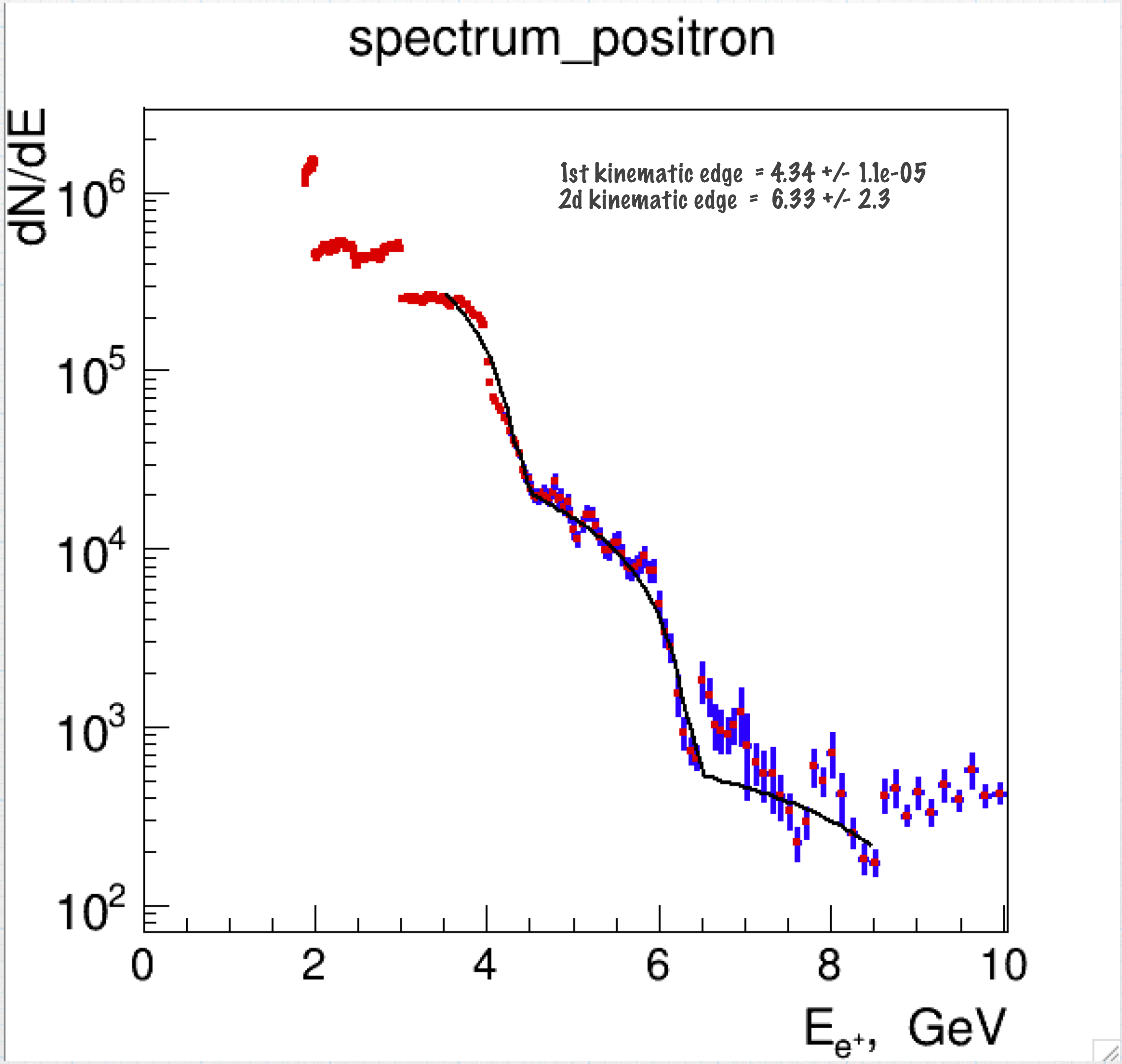
Spectra reconstruction for the LYSO case

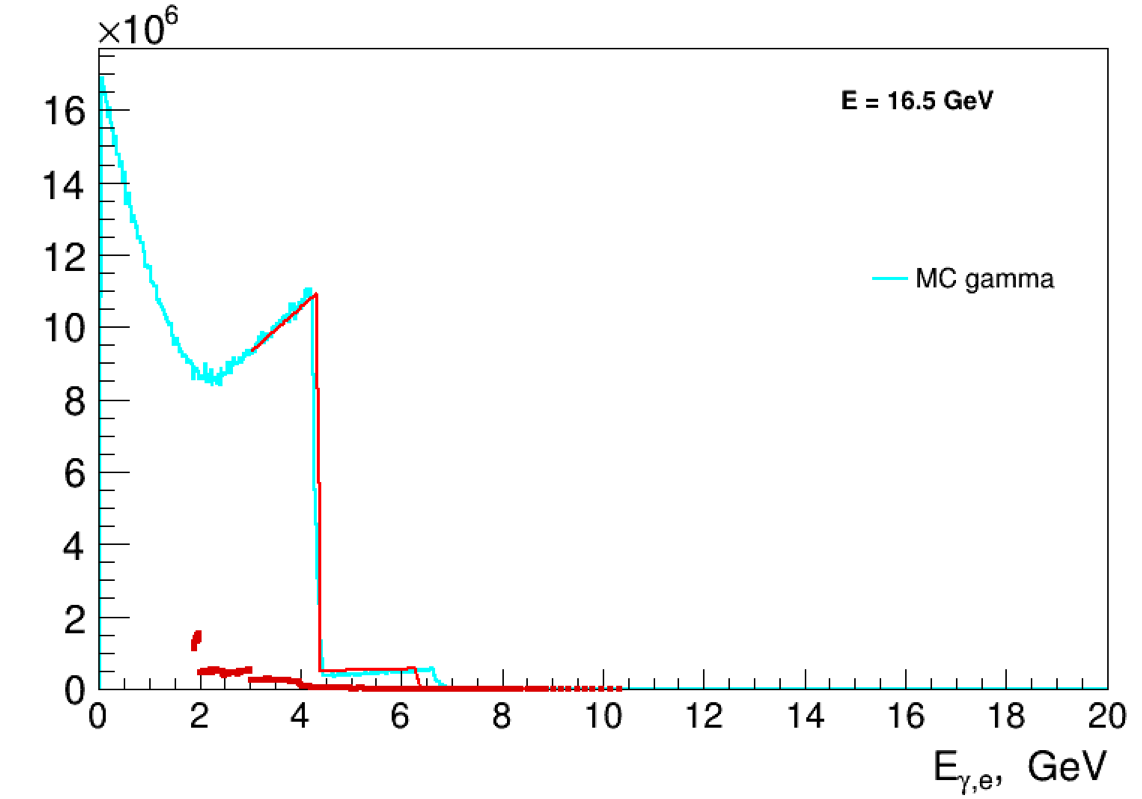




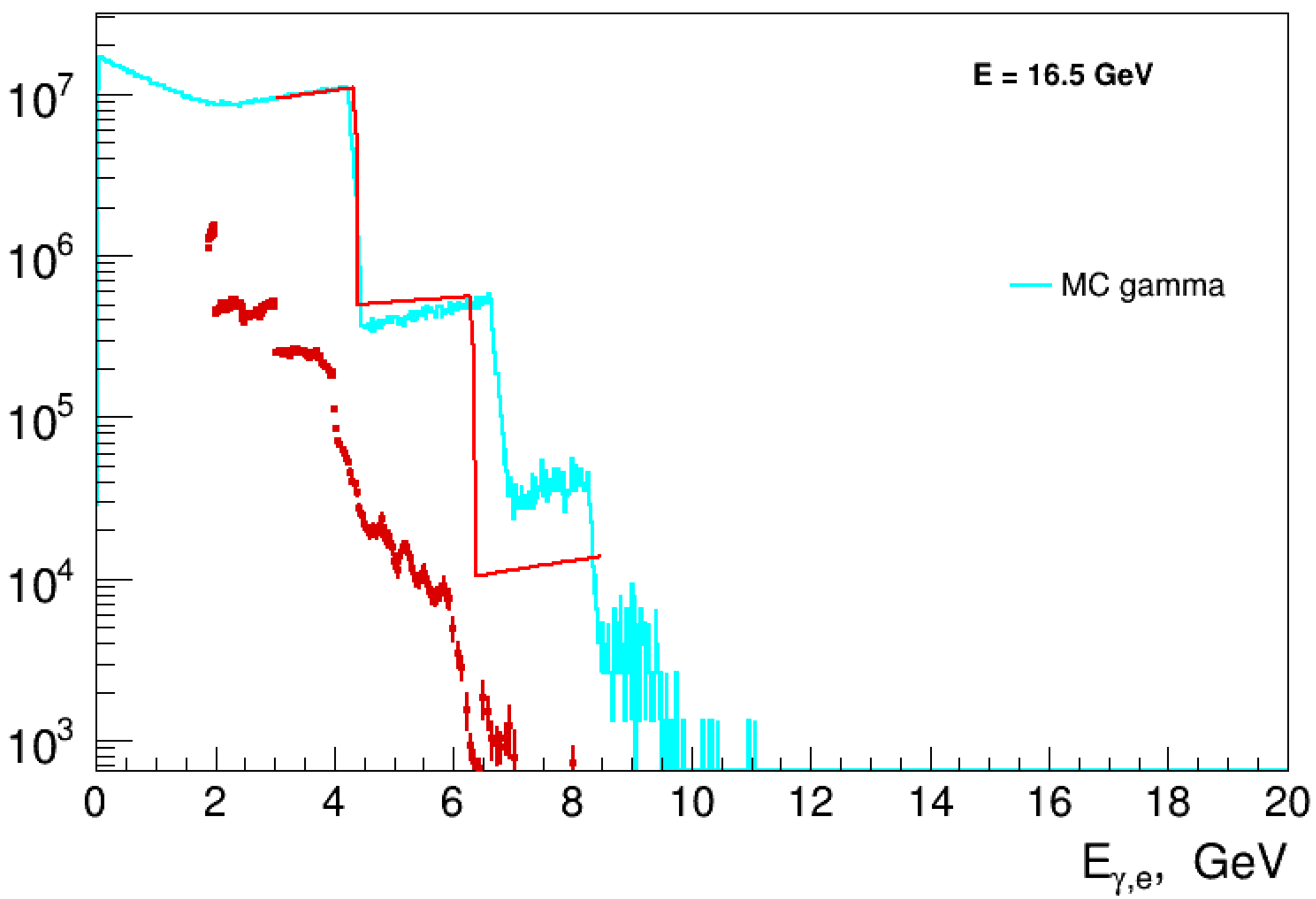


Kinematic edges reconstruction





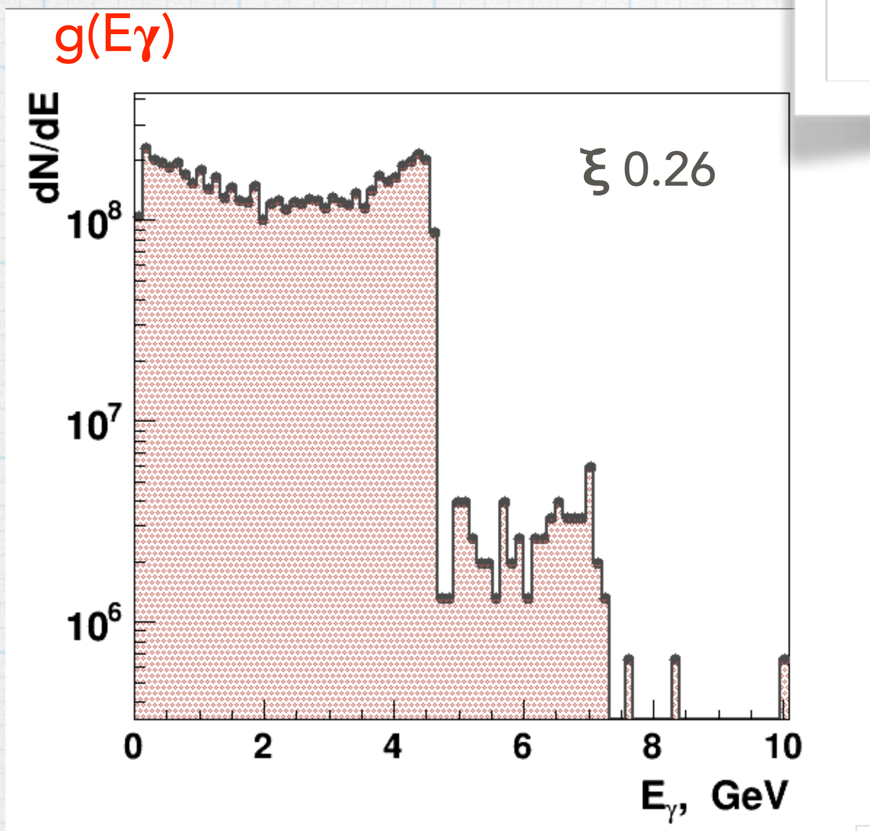
×10^6
E = 16.5 GeV
MC gamma
E_{γ,e}, GeV

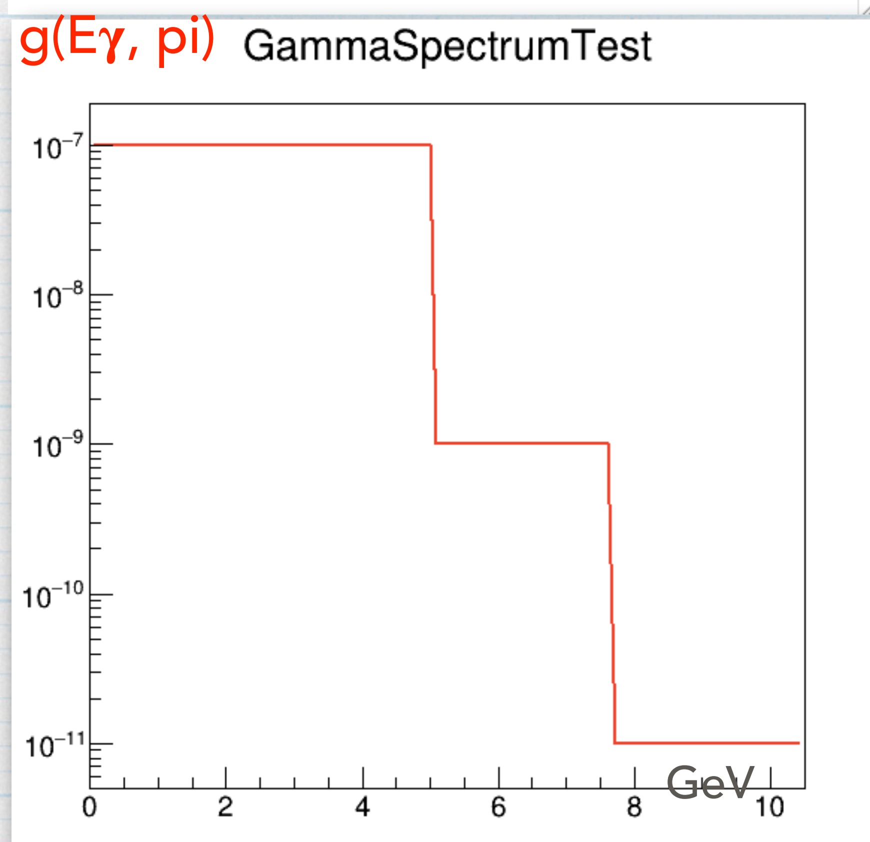


E = 16.5 GeV
MC gamma
E_{γ,e}, GeV

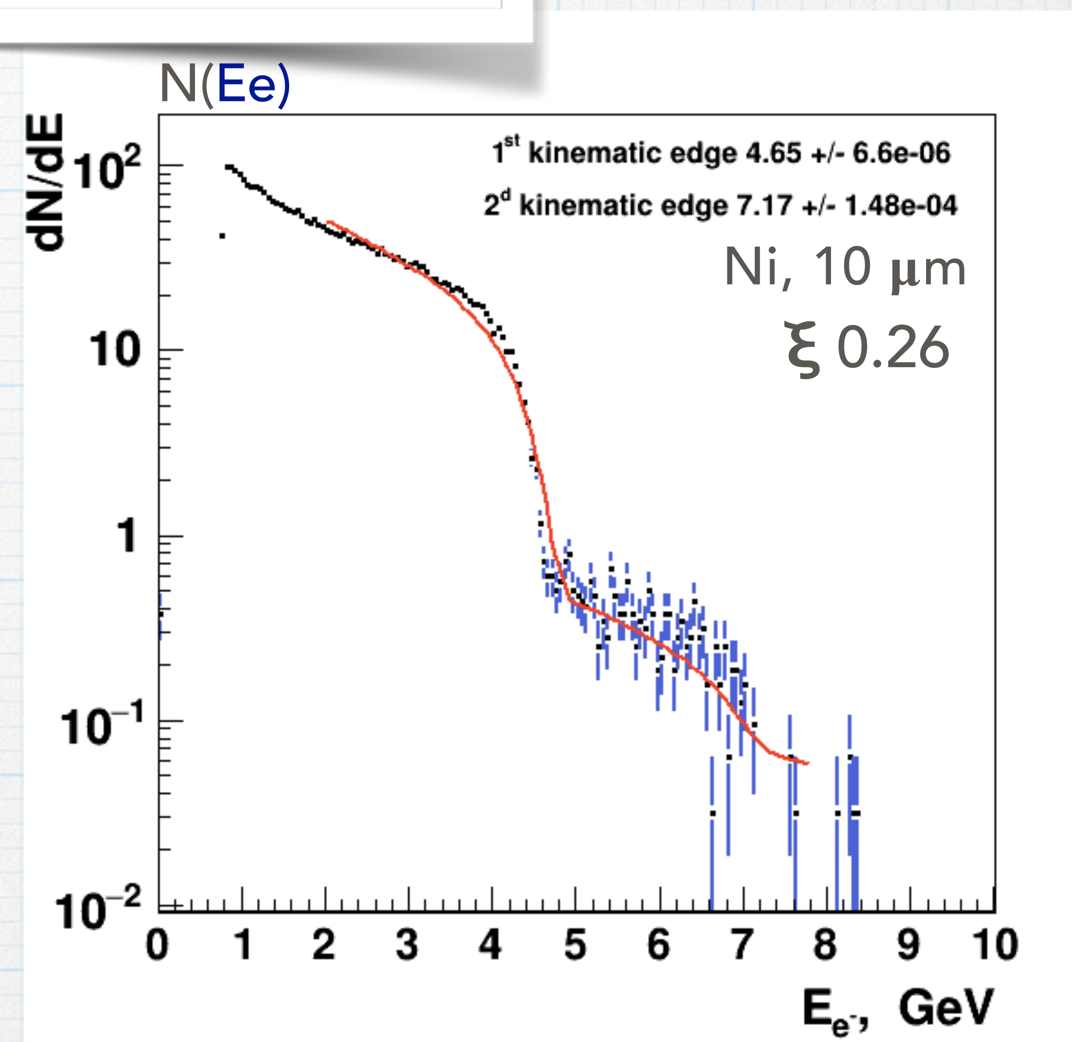
Kinematic edges with accurate pair spectrum

$$f(E_e)=\int \sigma(E_\gamma, E_e)\,g(E_\gamma)\,dE_\gamma$$





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**



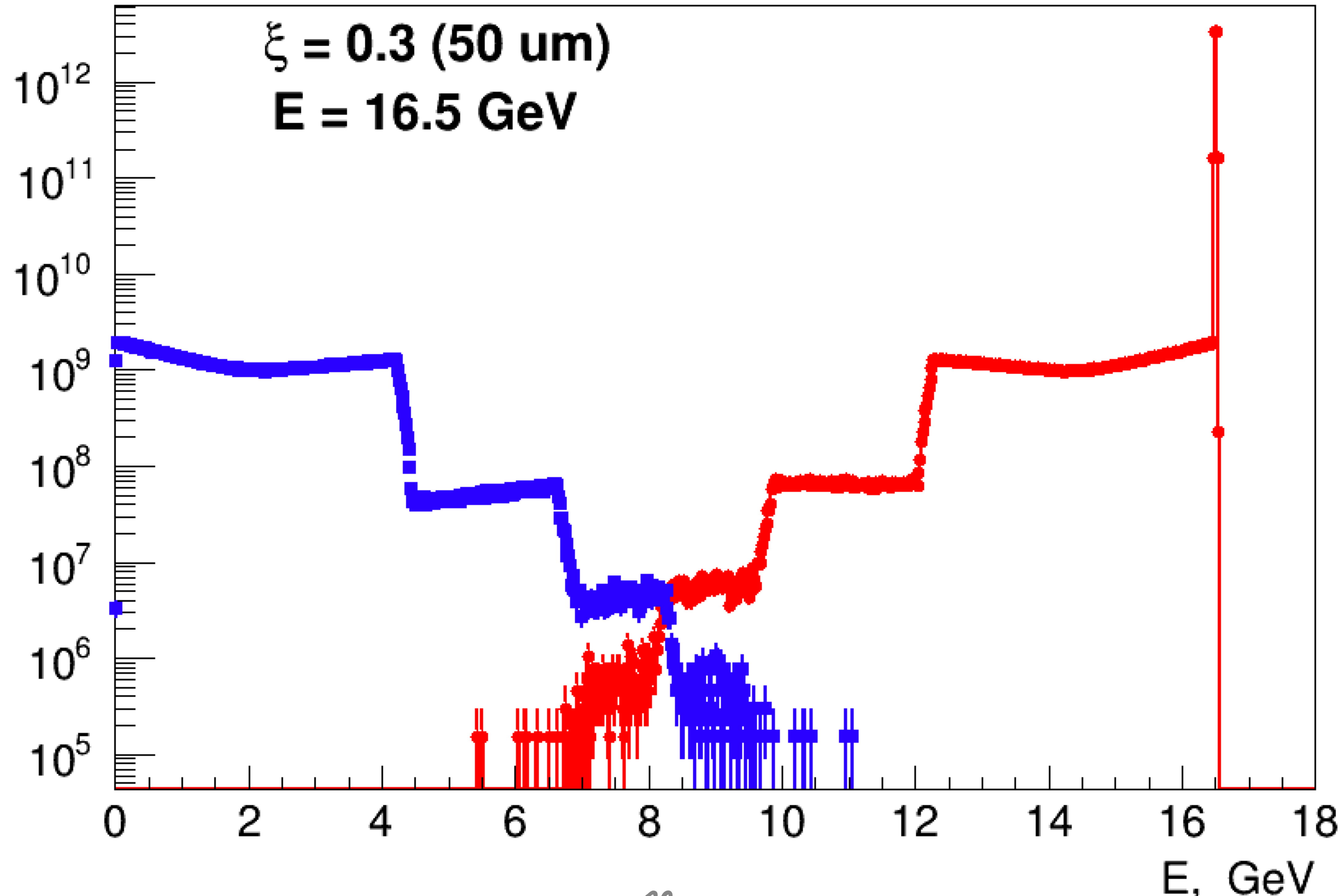
$$\int \sigma(E_\gamma, E_e)\,g(E_\gamma,p1,p2)\,dE_\gamma$$

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

True electron/photon spectra

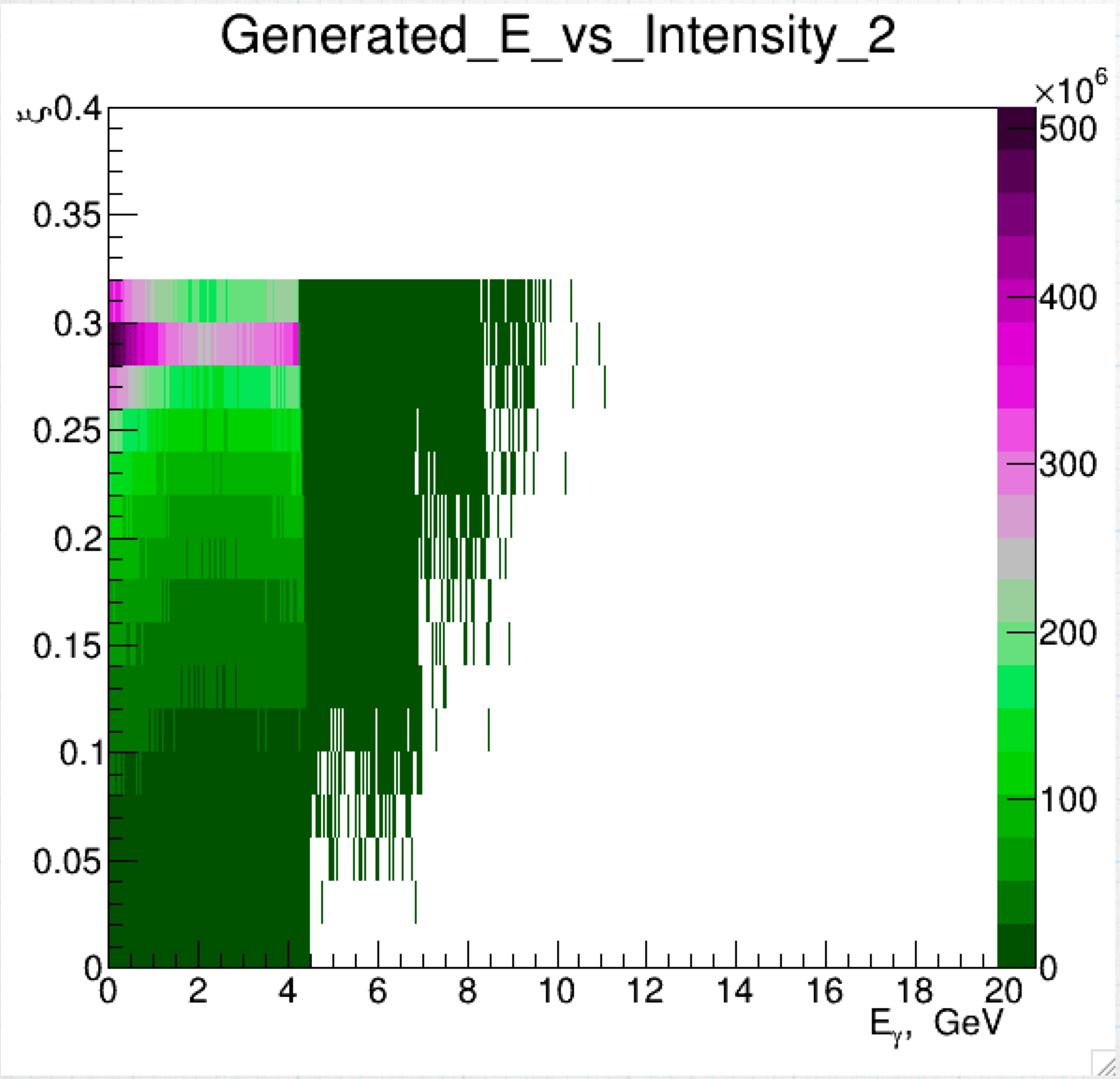
4764BX out of 5000 BX at the laser intensity xi = 0.3 for 16.5 GeV electron beam

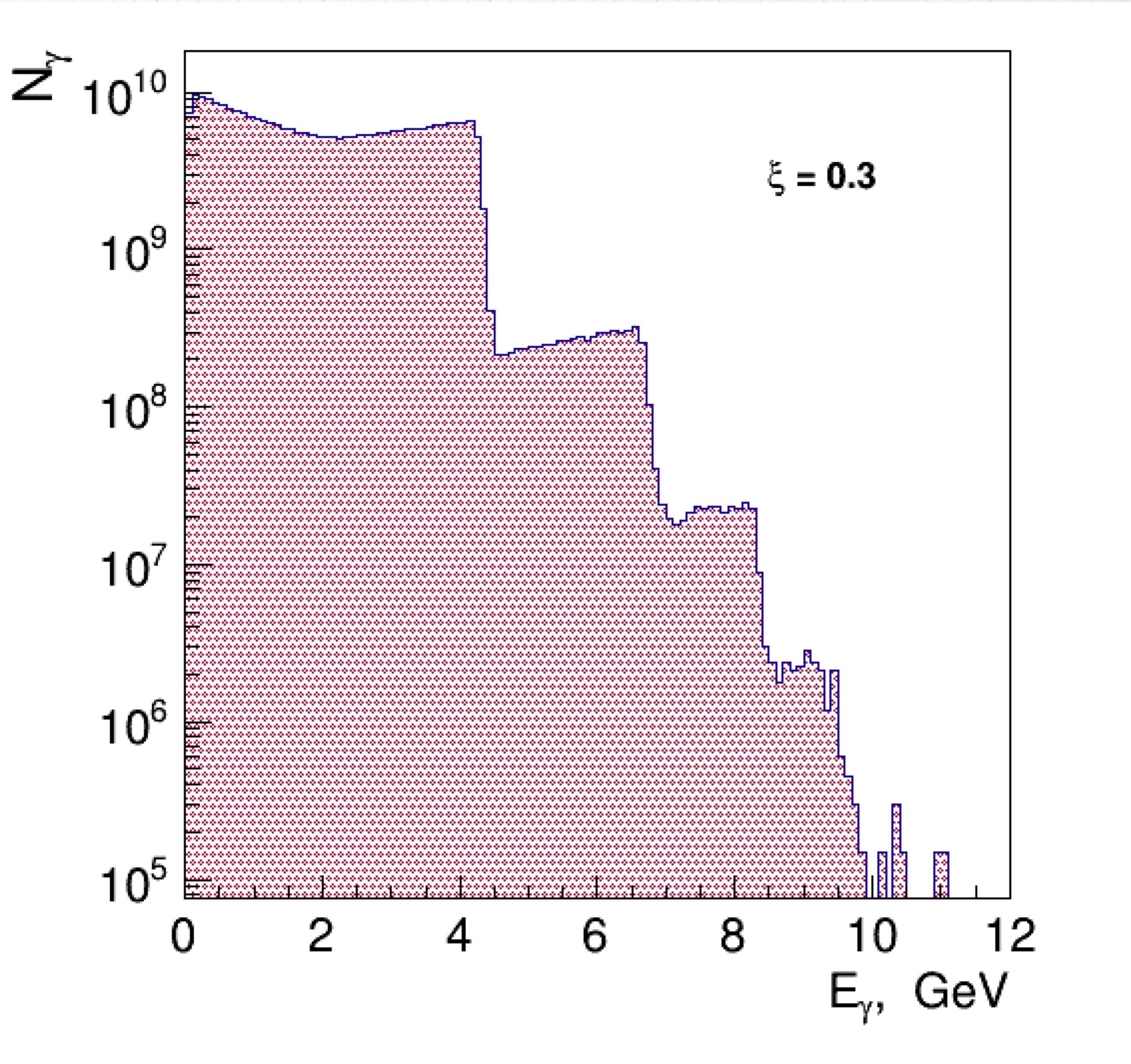
(~5% of files have NaN so they are ignored)



ξ vs photon energy in MC

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





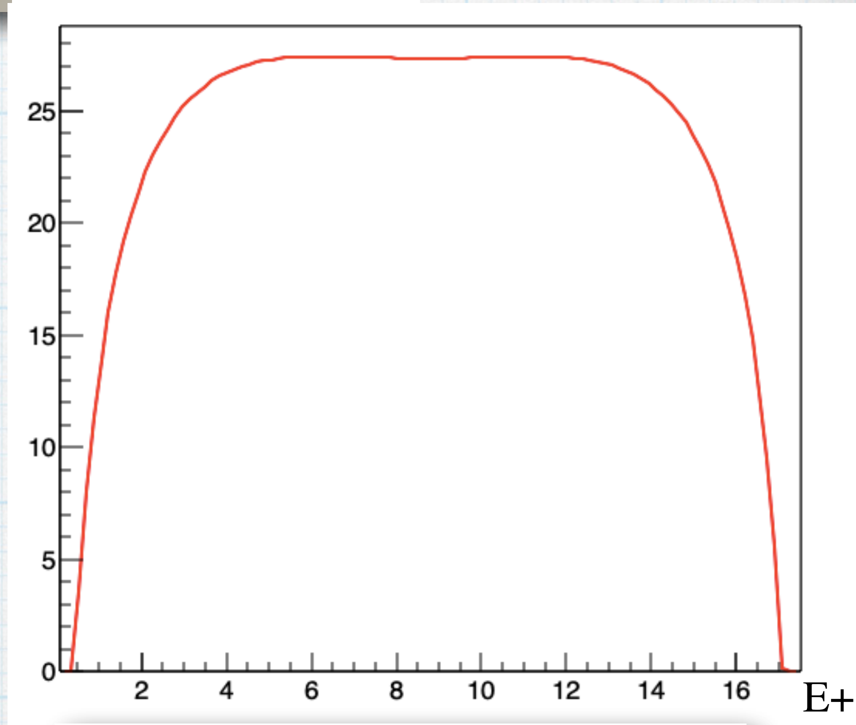
Photon spectra reconstruction using Bethe-Heitler pair spectrum

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

$$\Phi\,(E_0)\,dE_0 = \frac{Z^2}{137}\left(\frac{e^2}{mc^2}\right)^2 4\,\frac{E_{0+}{}^2E_+{}^2 + \frac{2}{3}E_0E_+}{(h\nu)^3}\,dE_0\left(\log\frac{2E_0E_+}{h\nu mc^2} - \frac{1}{2}\right).$$

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

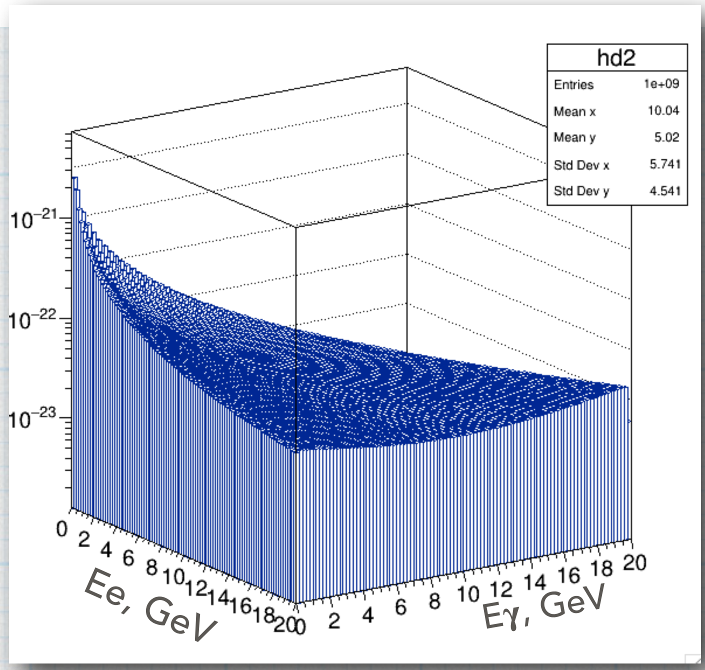
- Photon spectra $g(E\gamma)$ can be reconstructed by fitting

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

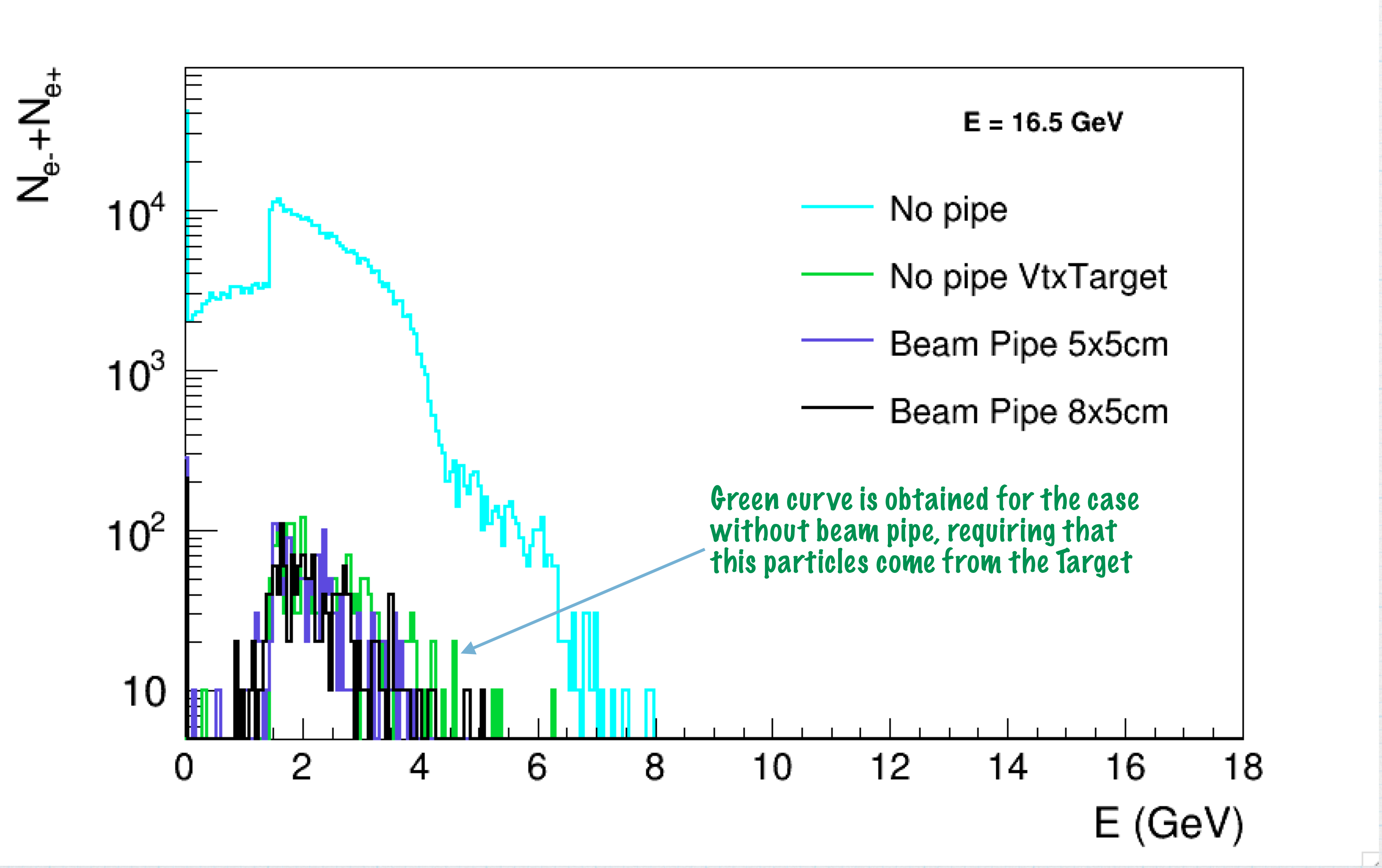
  Where N(Ee) positron/electron spectra measured in detector after the conversion.

- 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

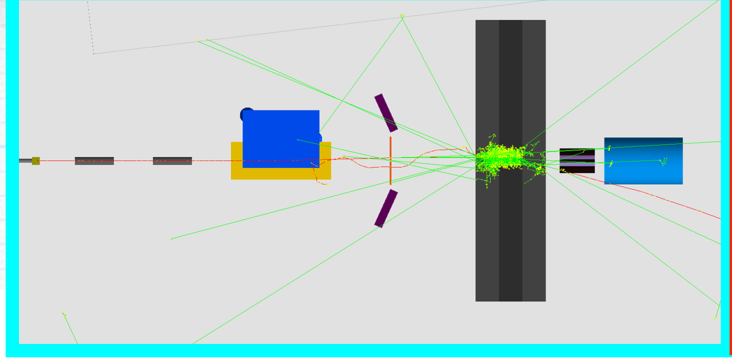


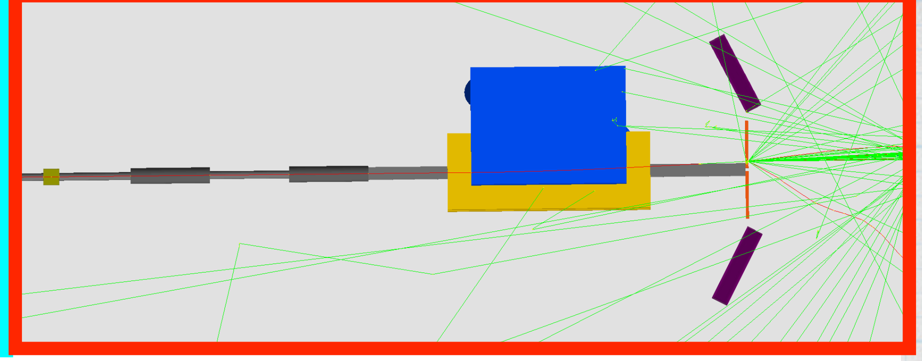
Spectra

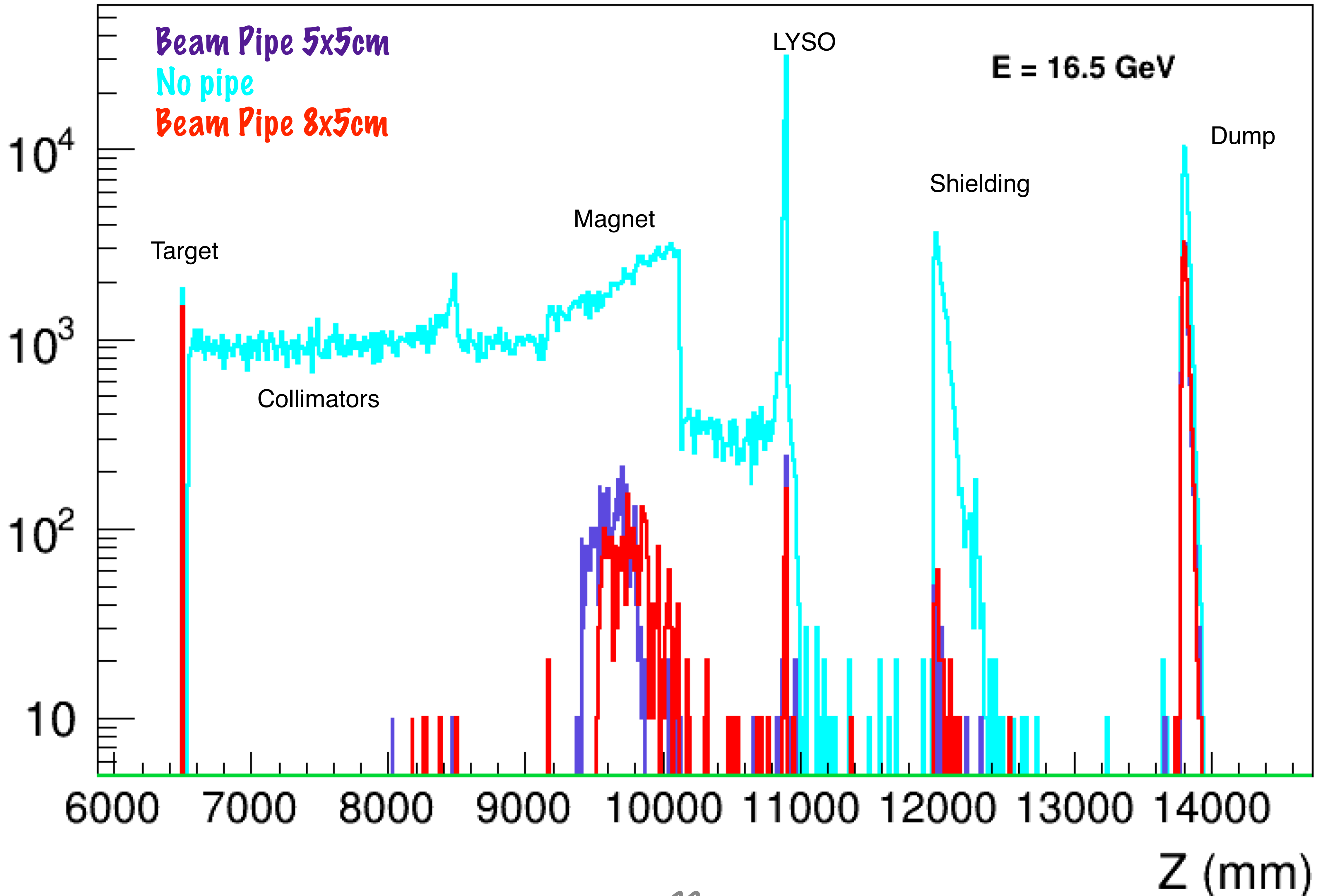


Without beam pipe we measure in Compton detectors a lot e-/e+ pairs that were created in the air.
Only 4% e-/e+ are generated in the Target

Vertex z

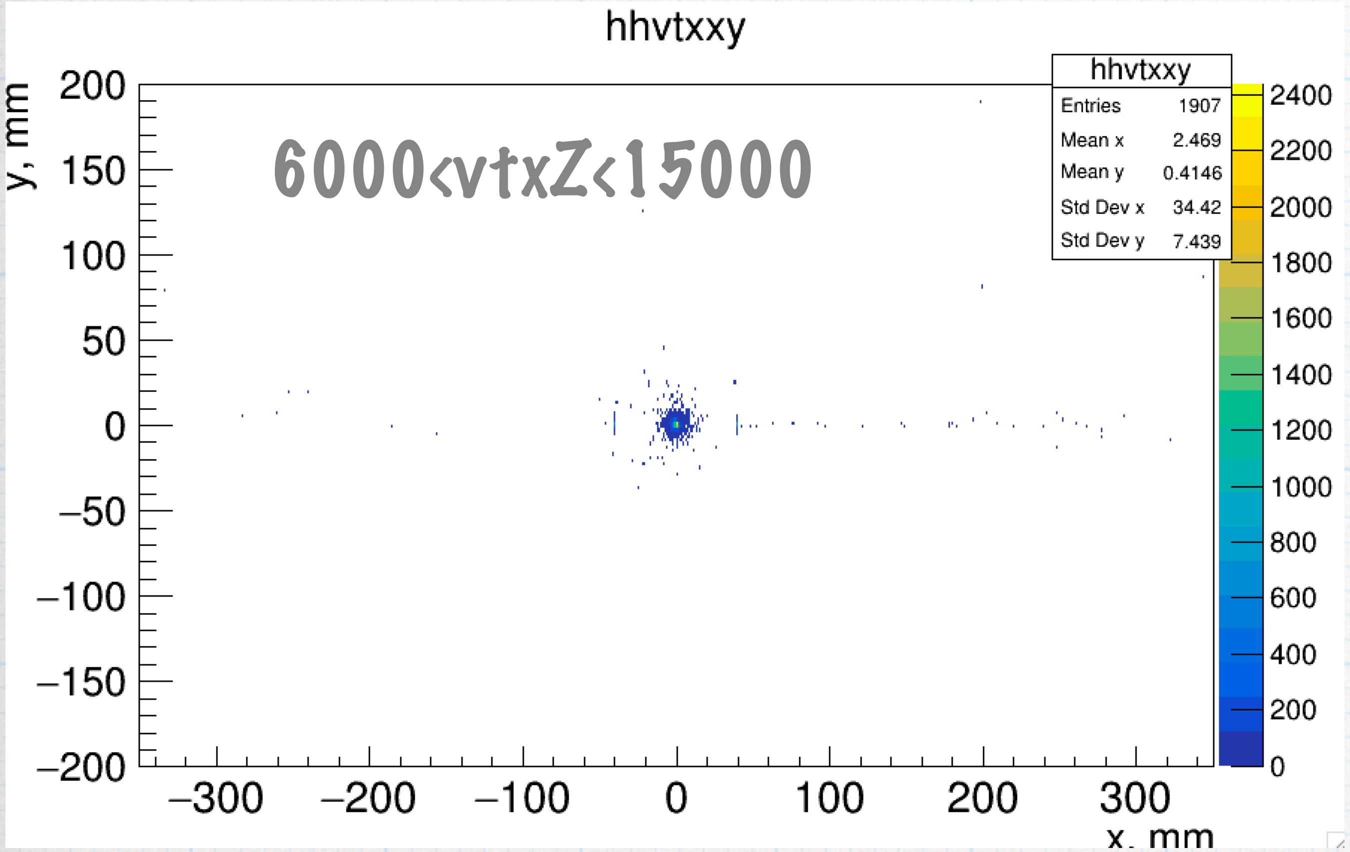




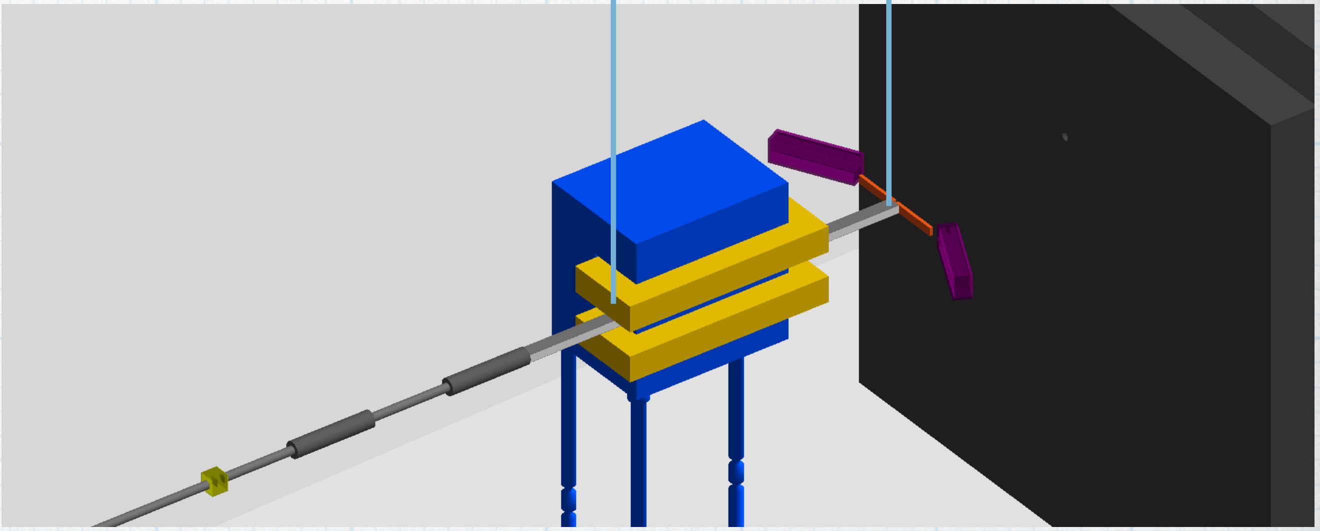


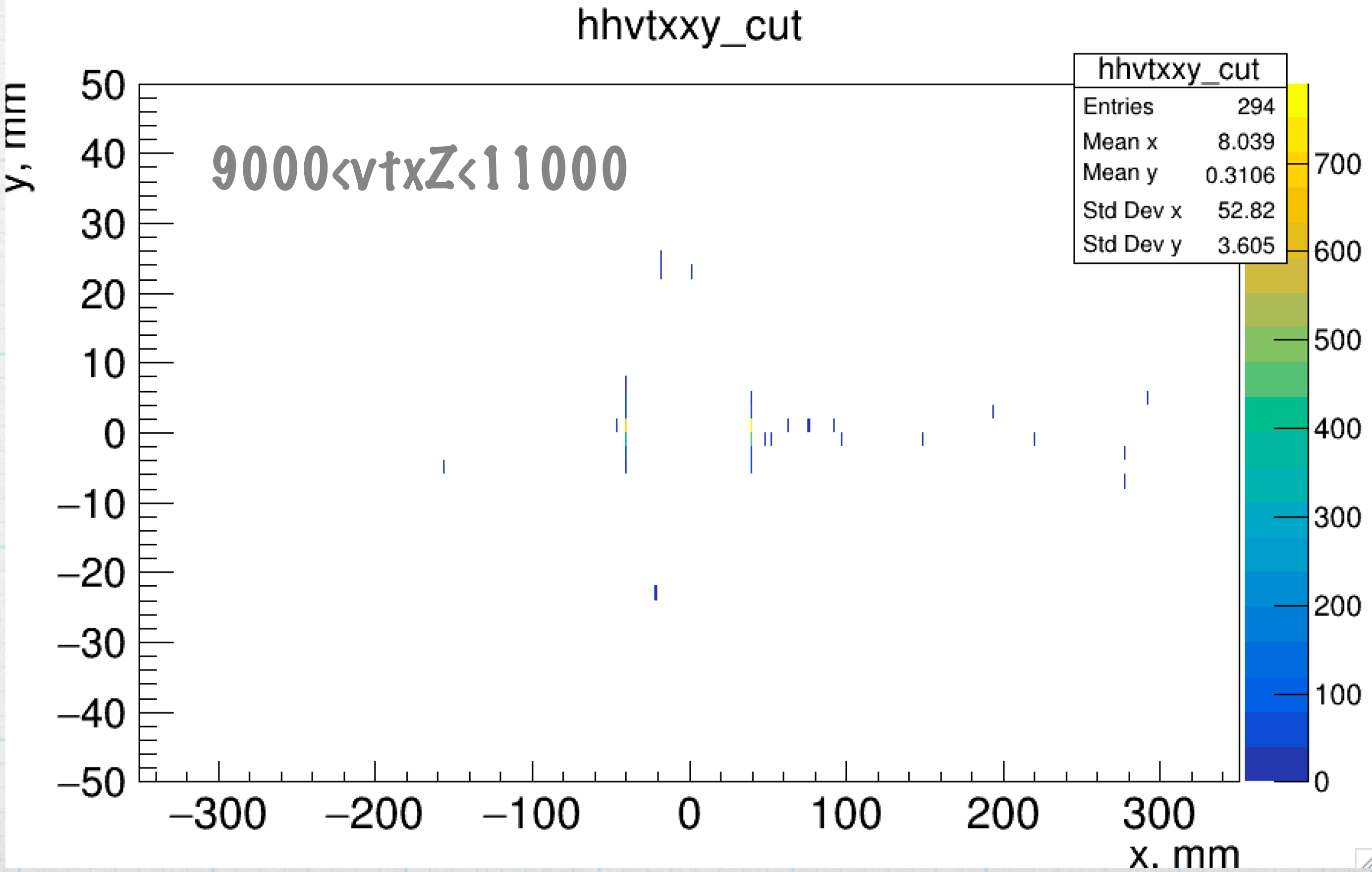
Beam Pipe 5x5cm
No pipe
Beam Pipe 8x5cm
E = 16.5 GeV
Target
Collimators
Magnet
LYSO
Shielding
Dump
10^4
10^3
10^2
10
6000 7000 8000 9000 10000 11000 12000 13000 14000
Z (mm)

Vertex x-y, beam pipe 8x5

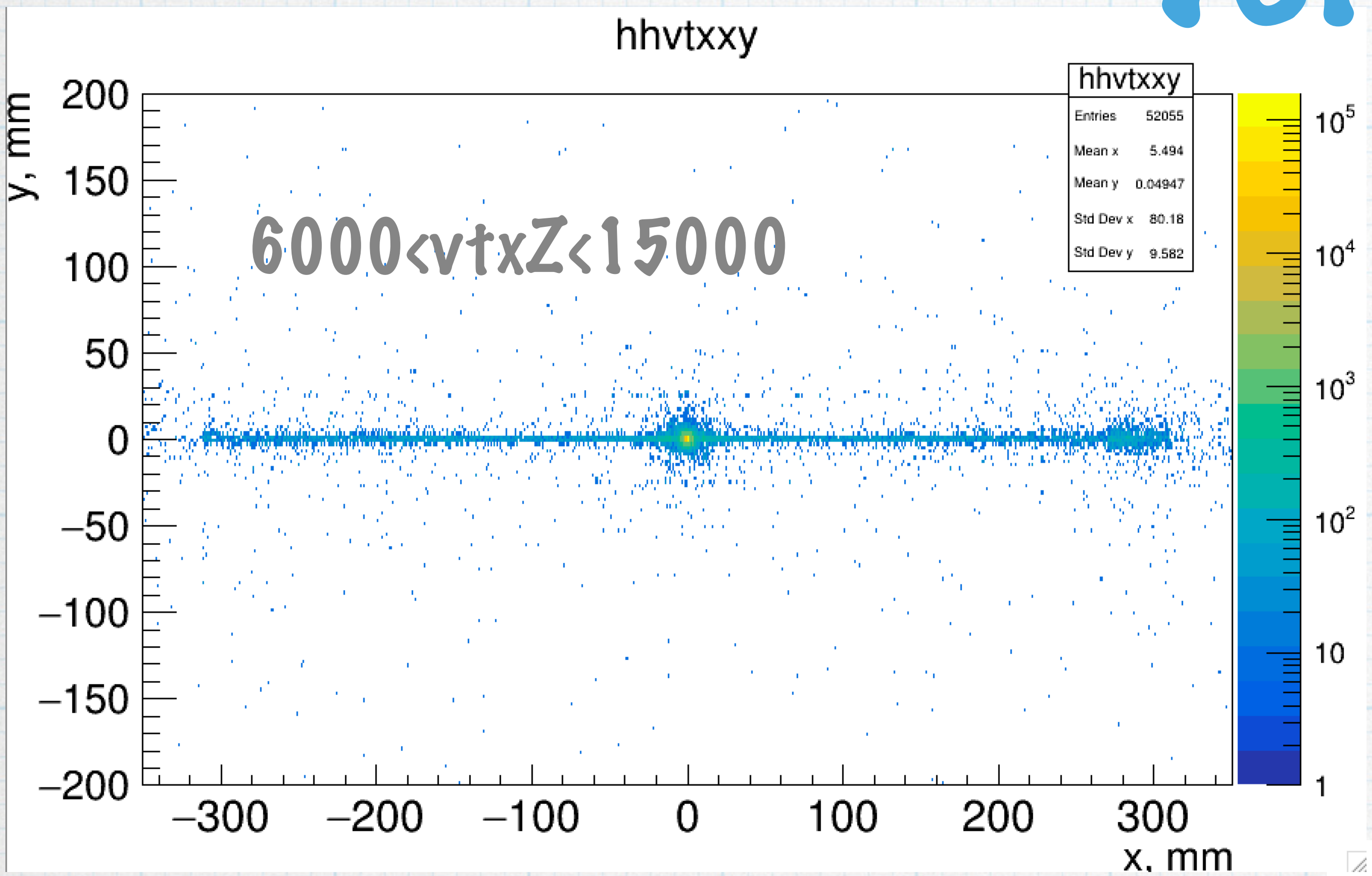


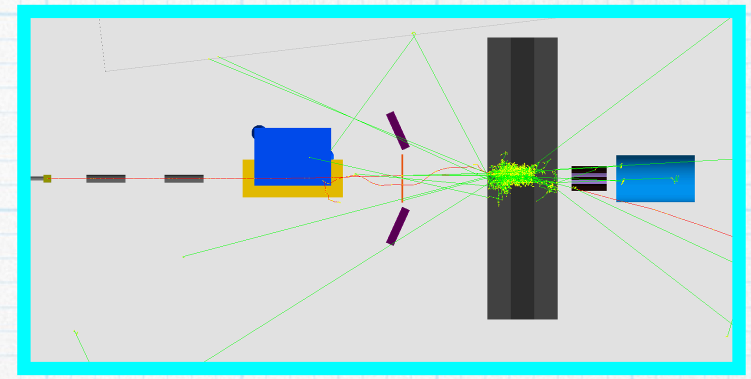
9000 mm - 11000mm

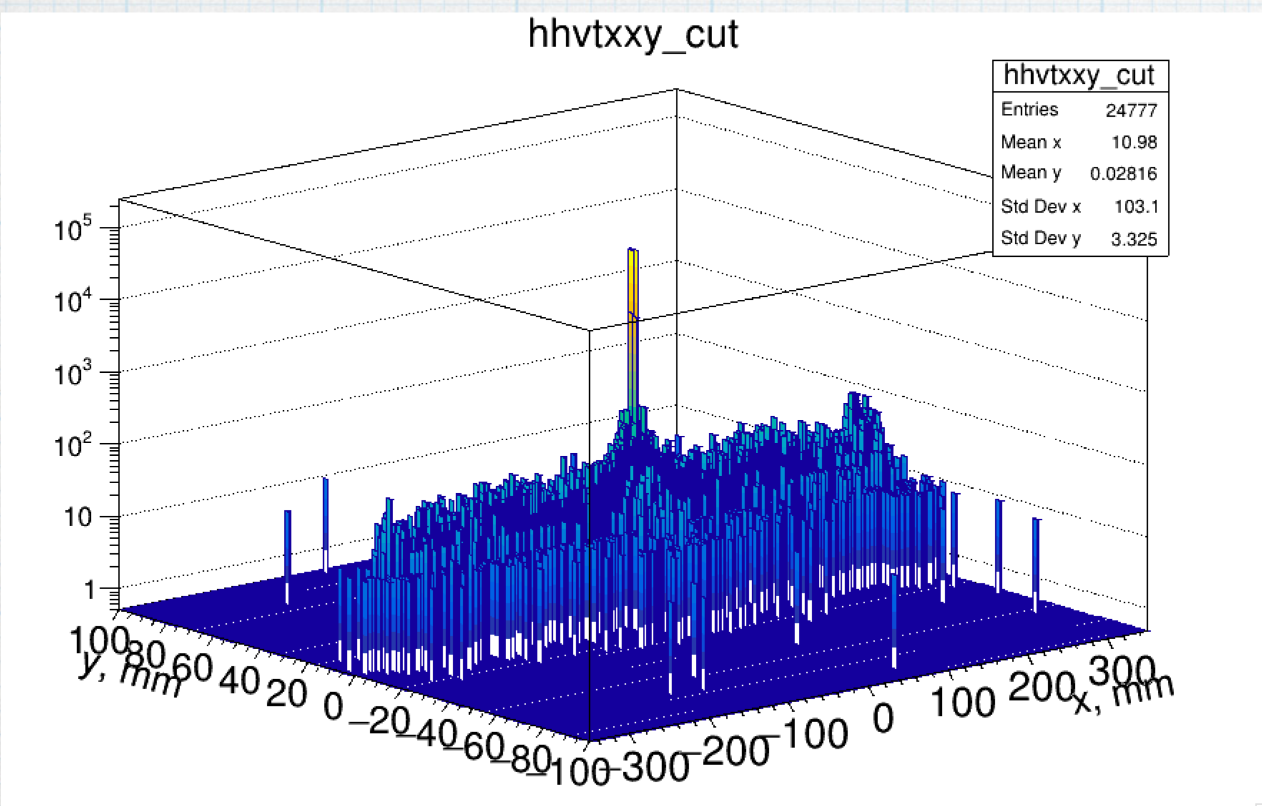


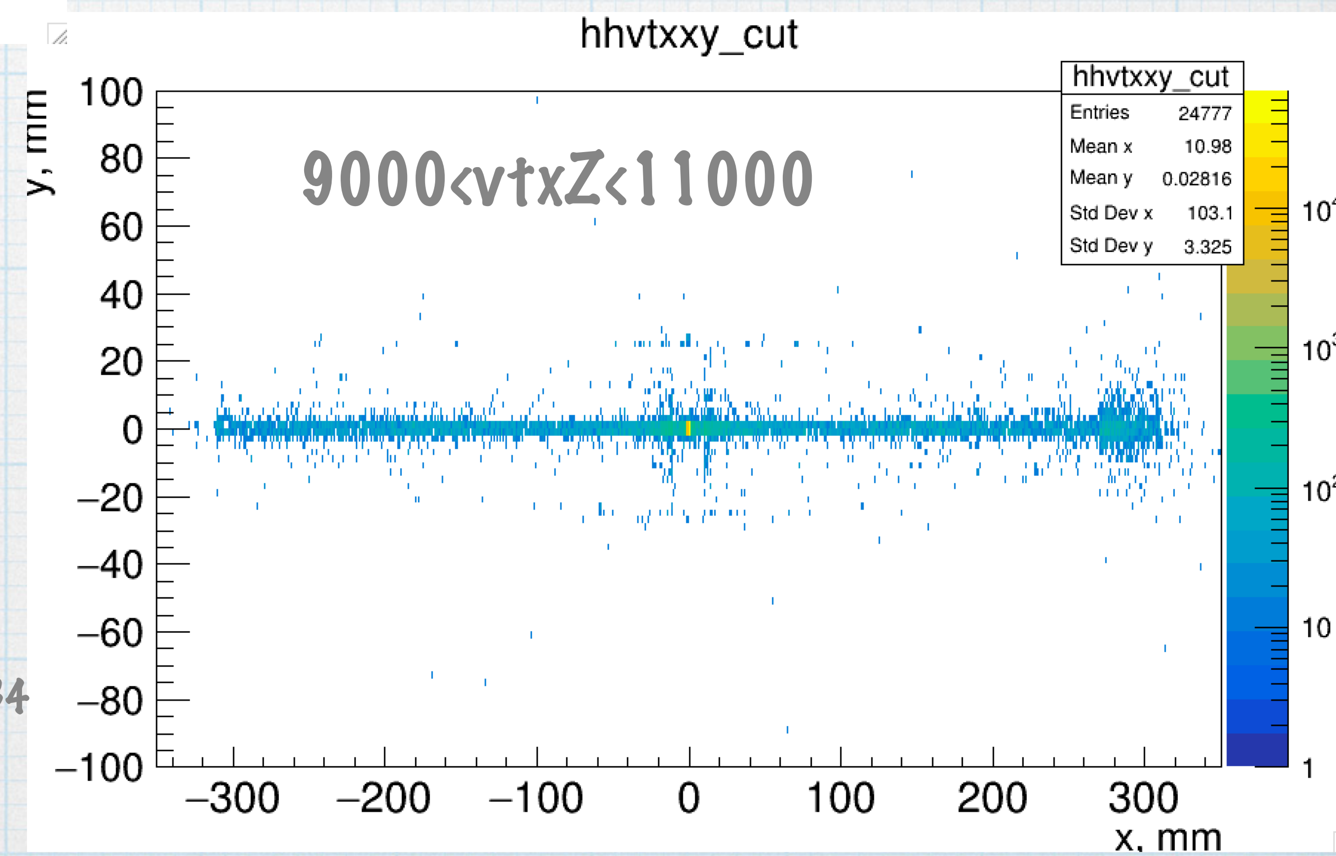


Vertex x-y, no pipe

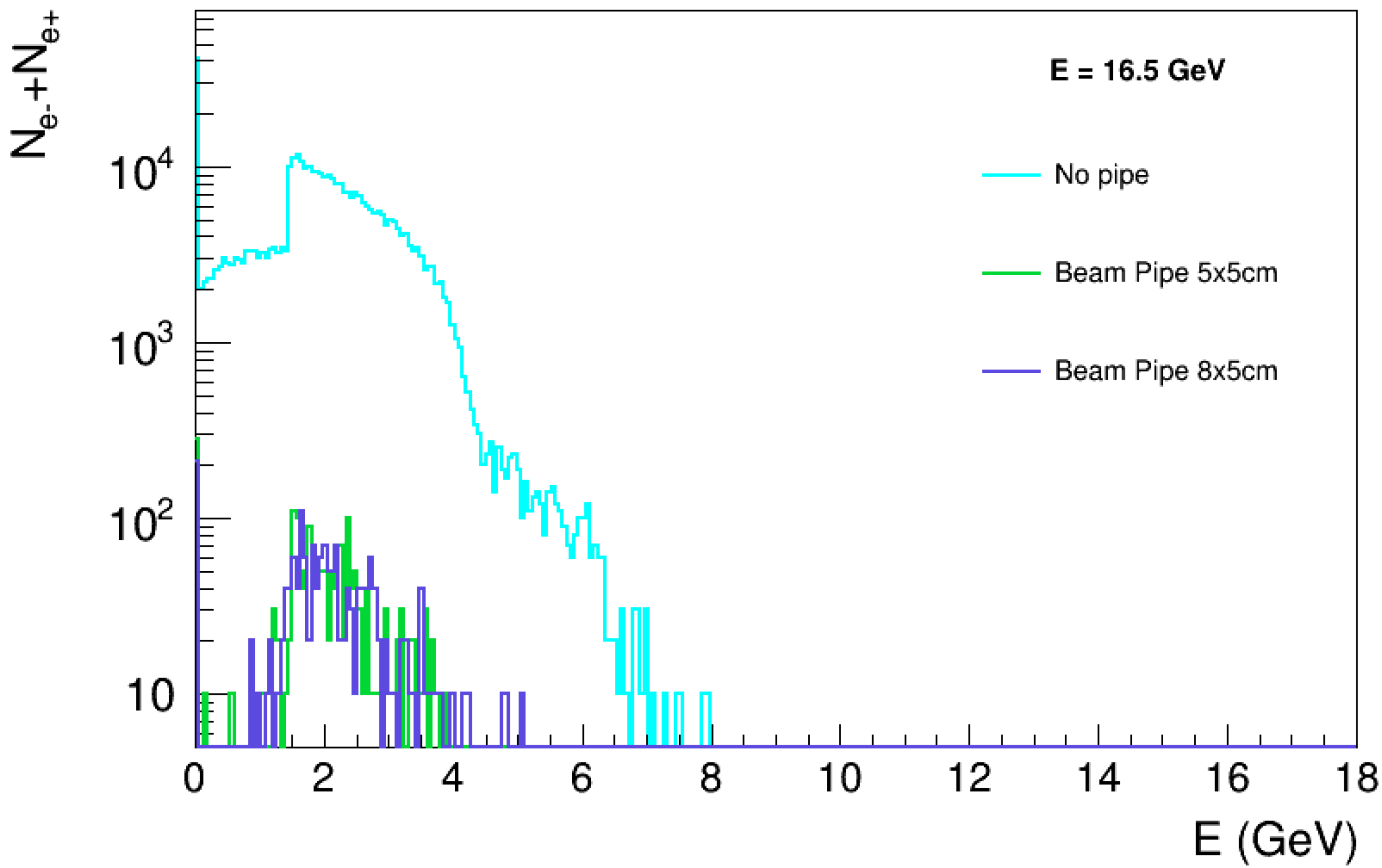








Spectra



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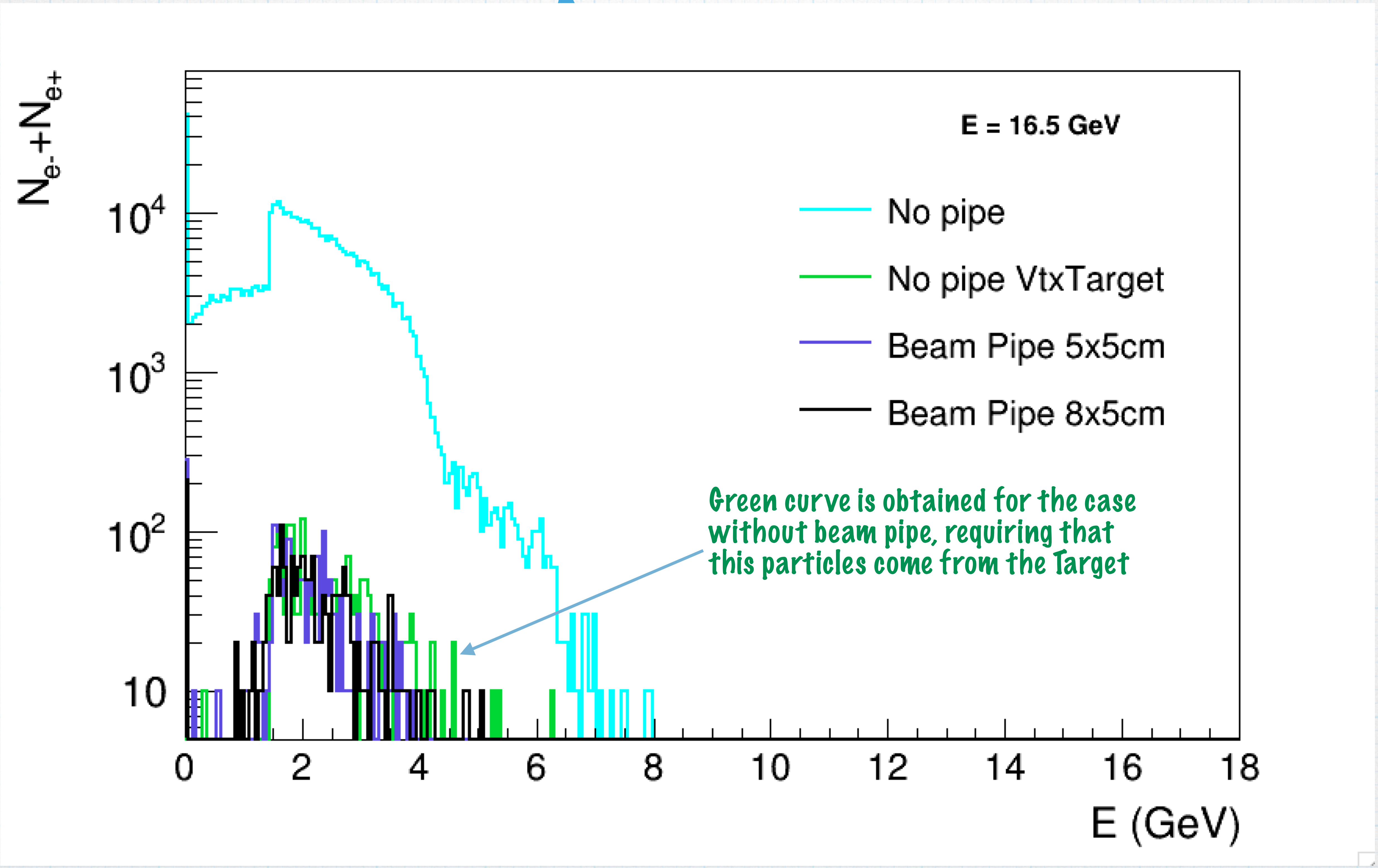
Only 4% e-/e+ come from the Target

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

Summary

* The performance of FDS setup was compared with and without beam pipe from the target to Compton detectors

* **Number of particles per BX hitting LYSO detector is 25 higher without beam pipe**

* **Big hole in the Shielding creates substantial background occupancy in LISO detectors.**

* **All extra particles are generated in the air. Number of particles generated in the target is identical.**

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

* **As the laser intensity is low (xi =0.3), to reconstruct spectra we need more statistics. Asked Anthony to produce more; he runs now 1000BX**