

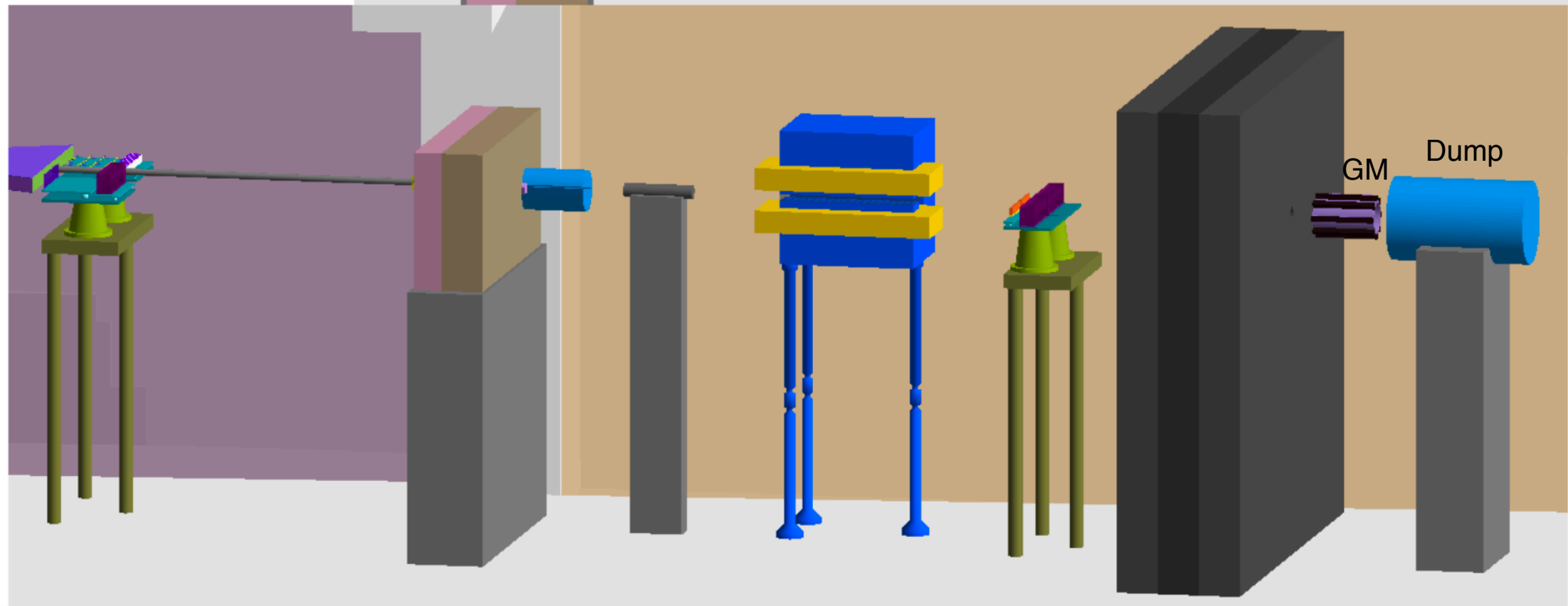
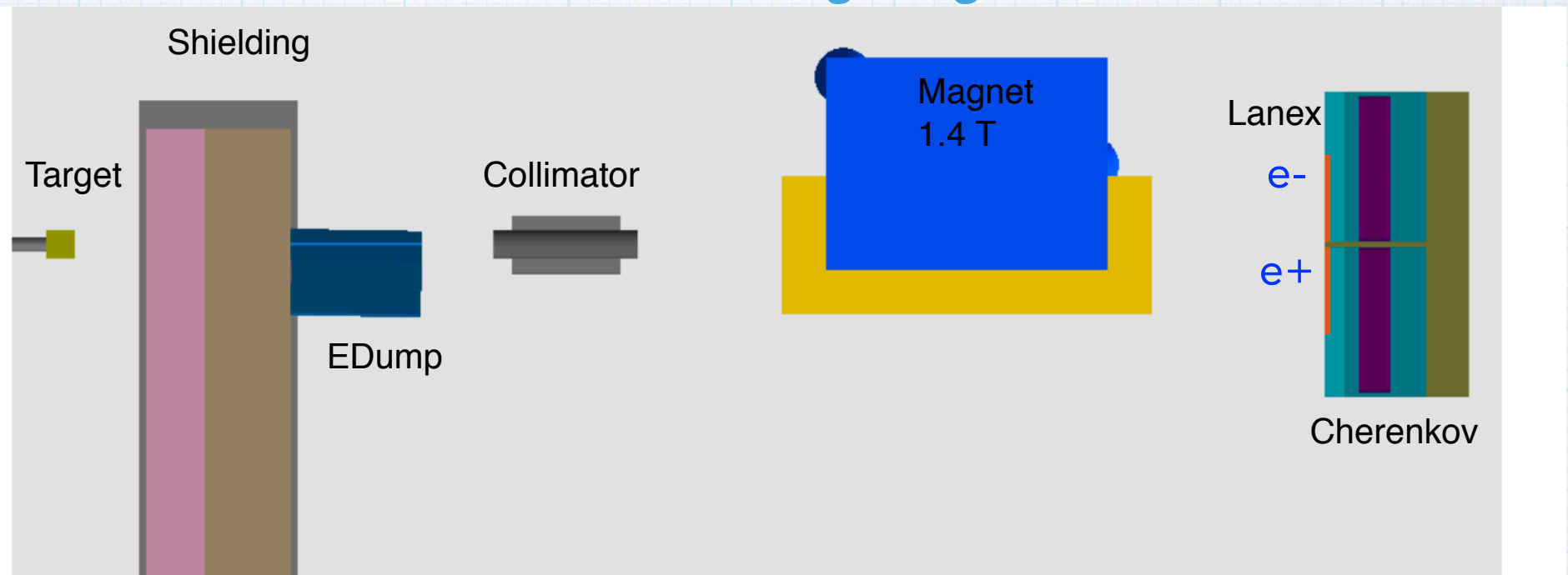
# FDS performance

Borysova Maryna (KINR)  
05/11/20  
LUXE weekly technical meeting

**LUXE**

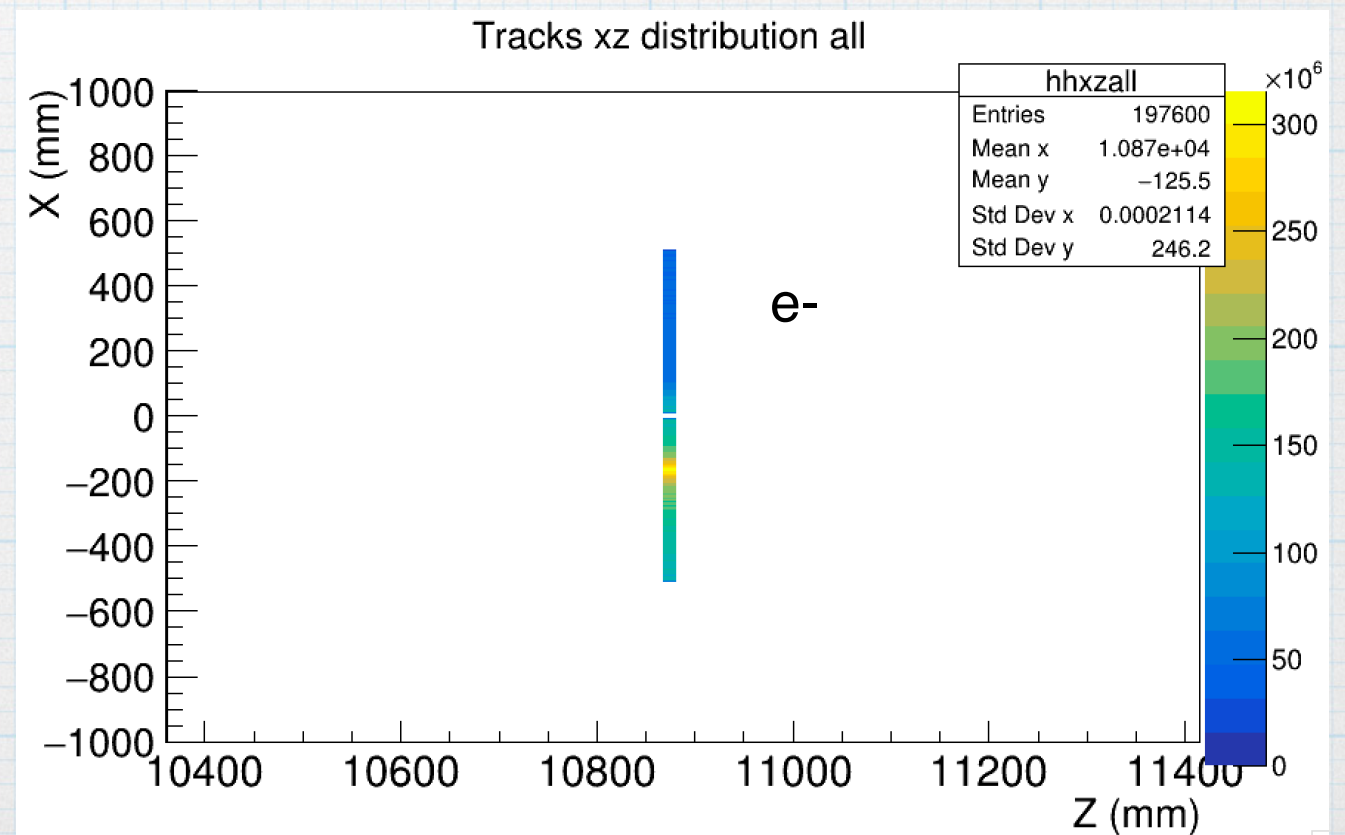
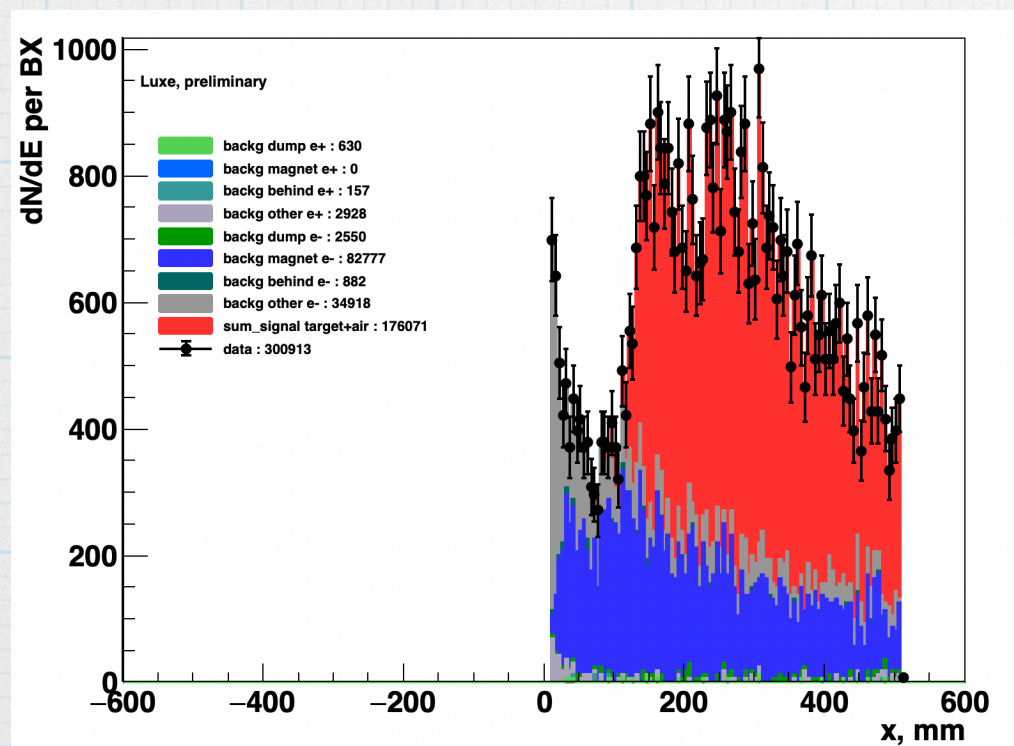
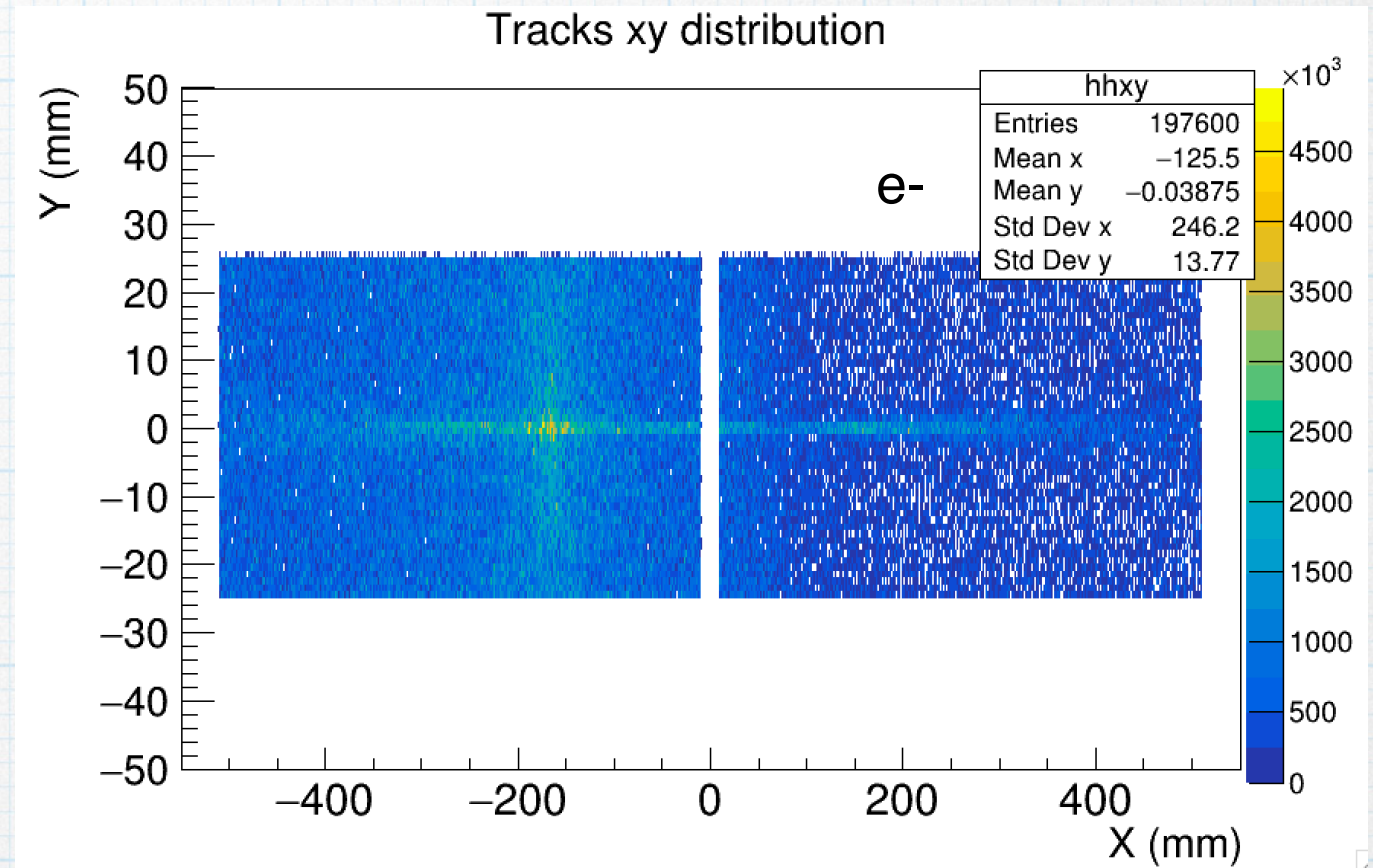
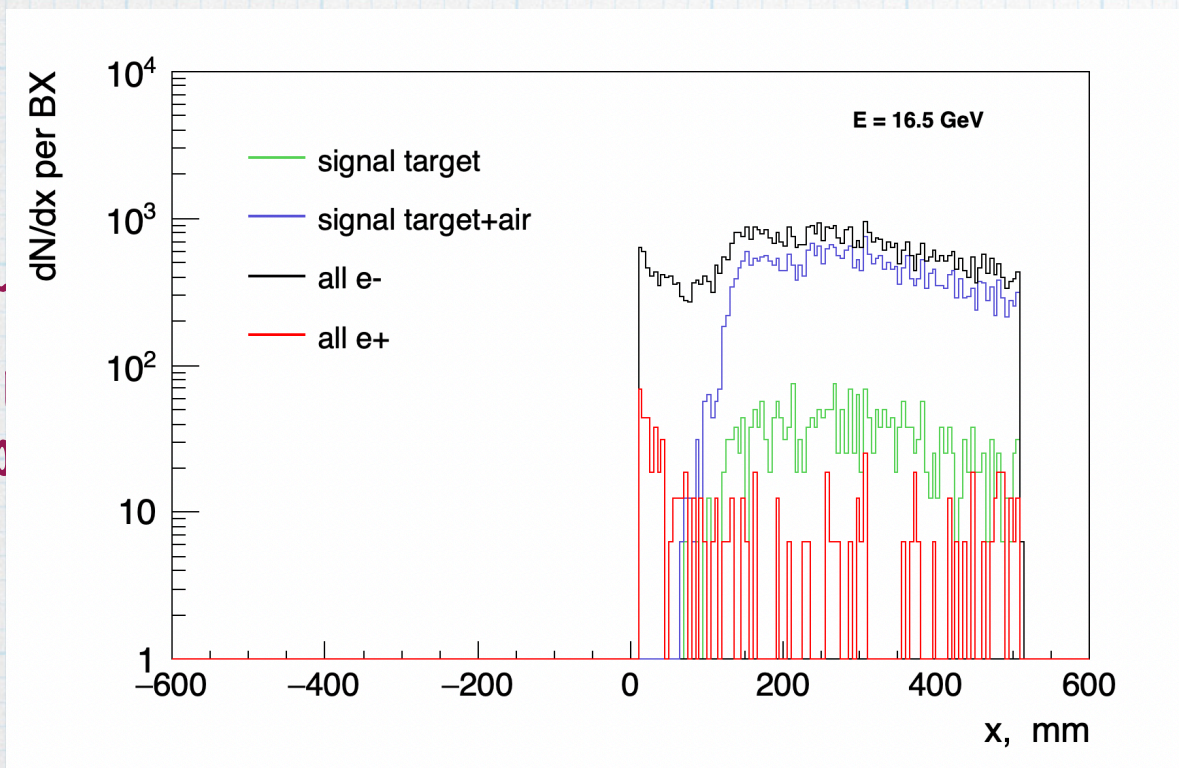


# Forward detector system w/o beam pipe



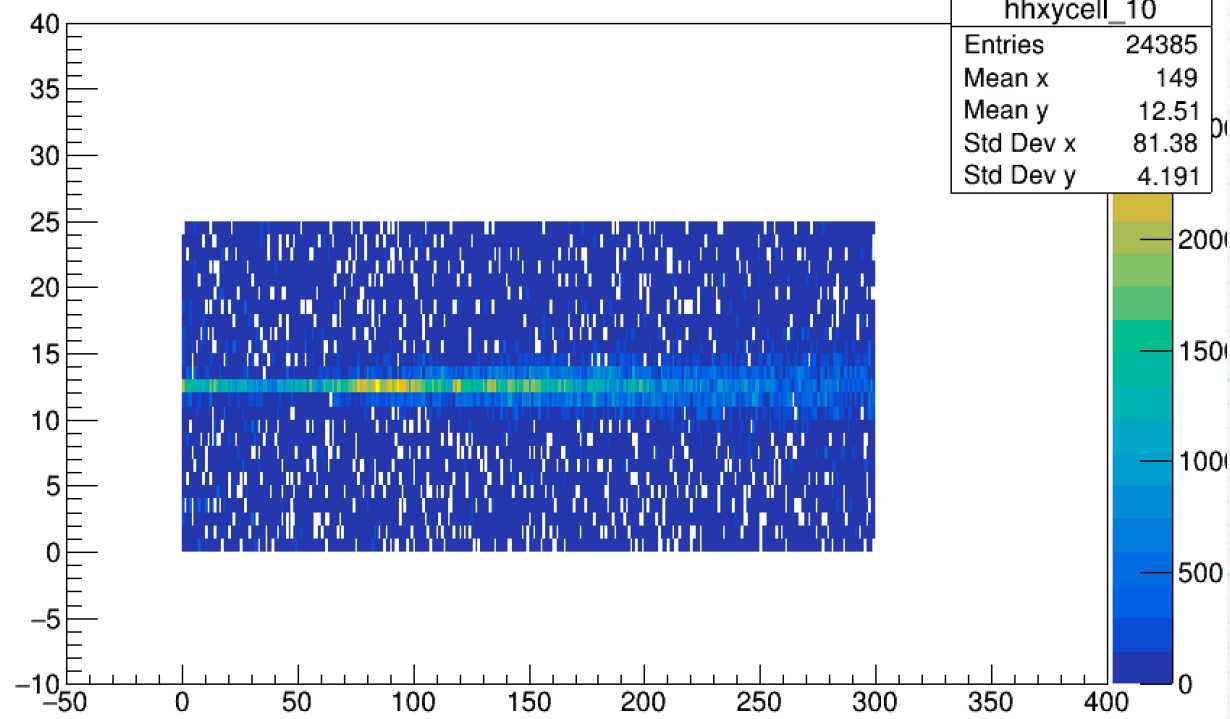


# \* Electron arm of Lanex Spectrometer

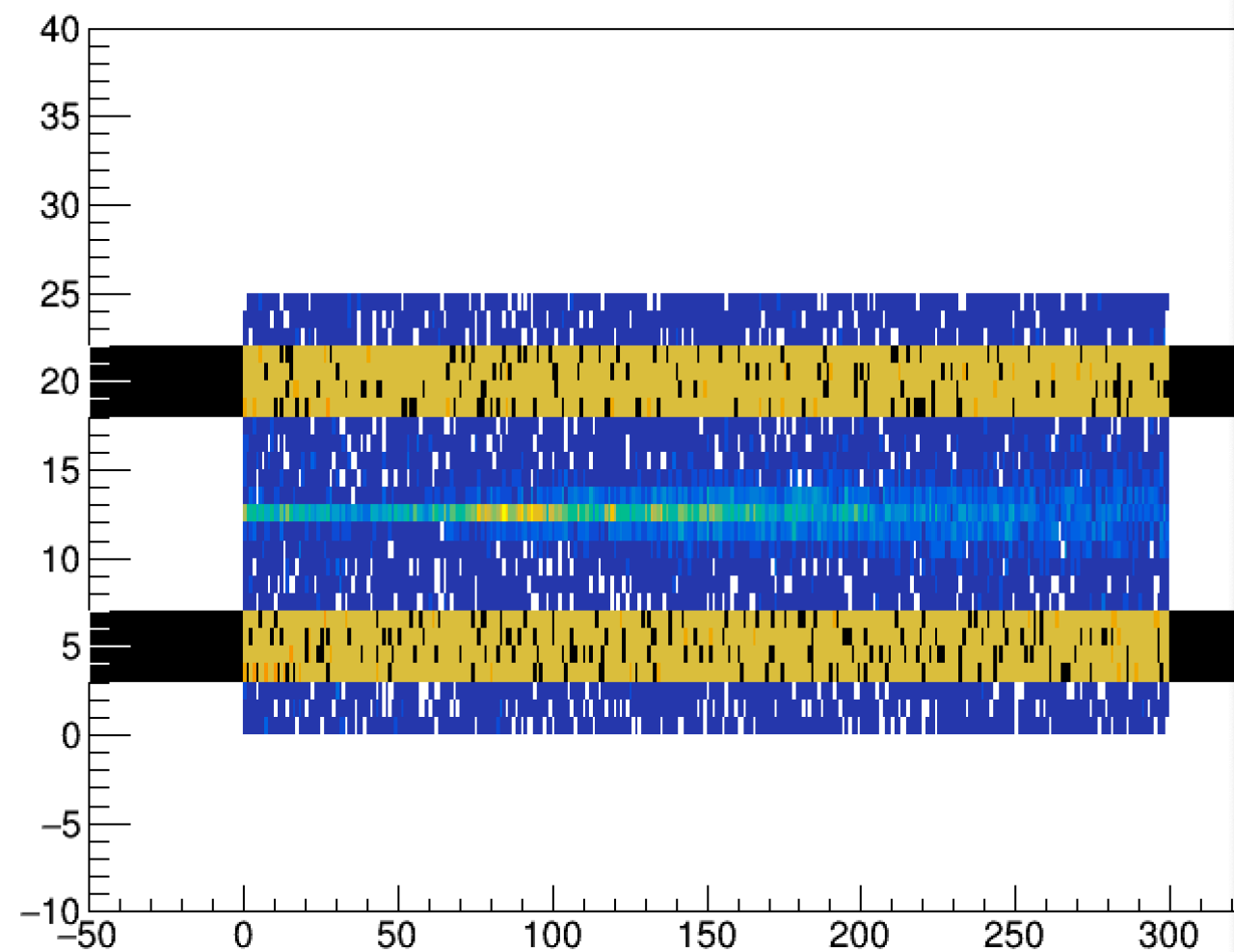
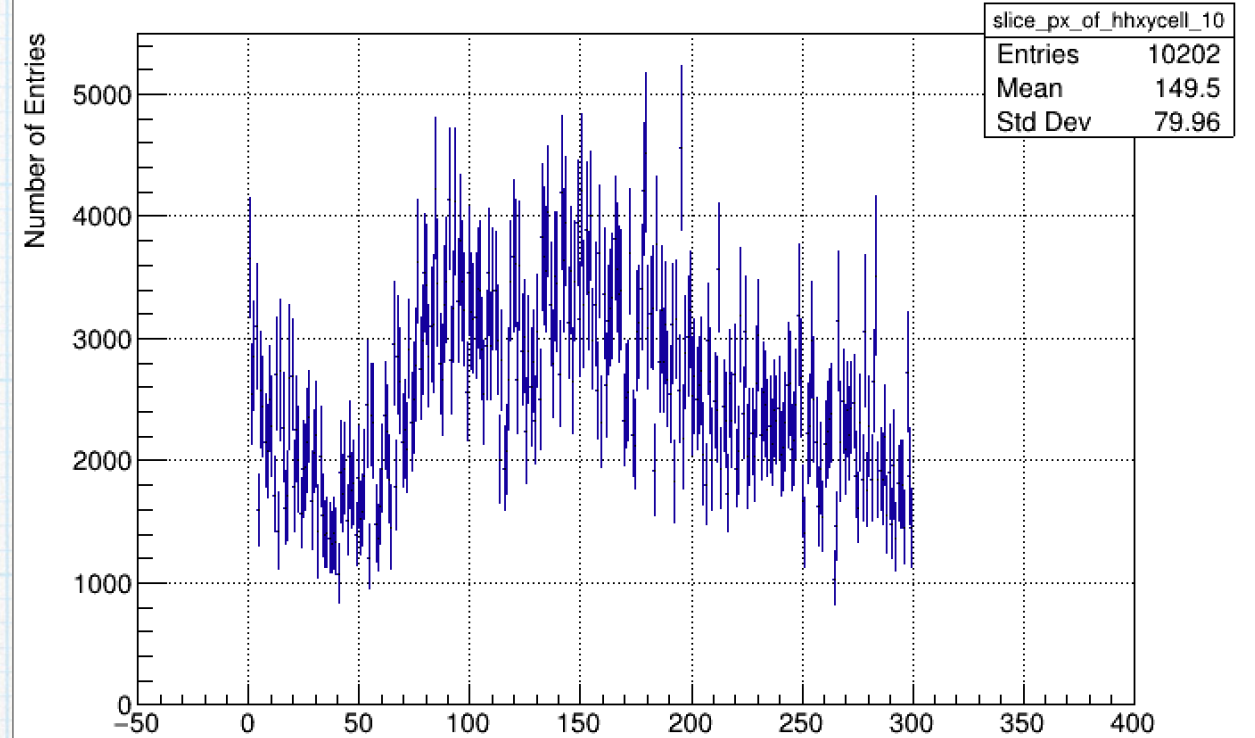




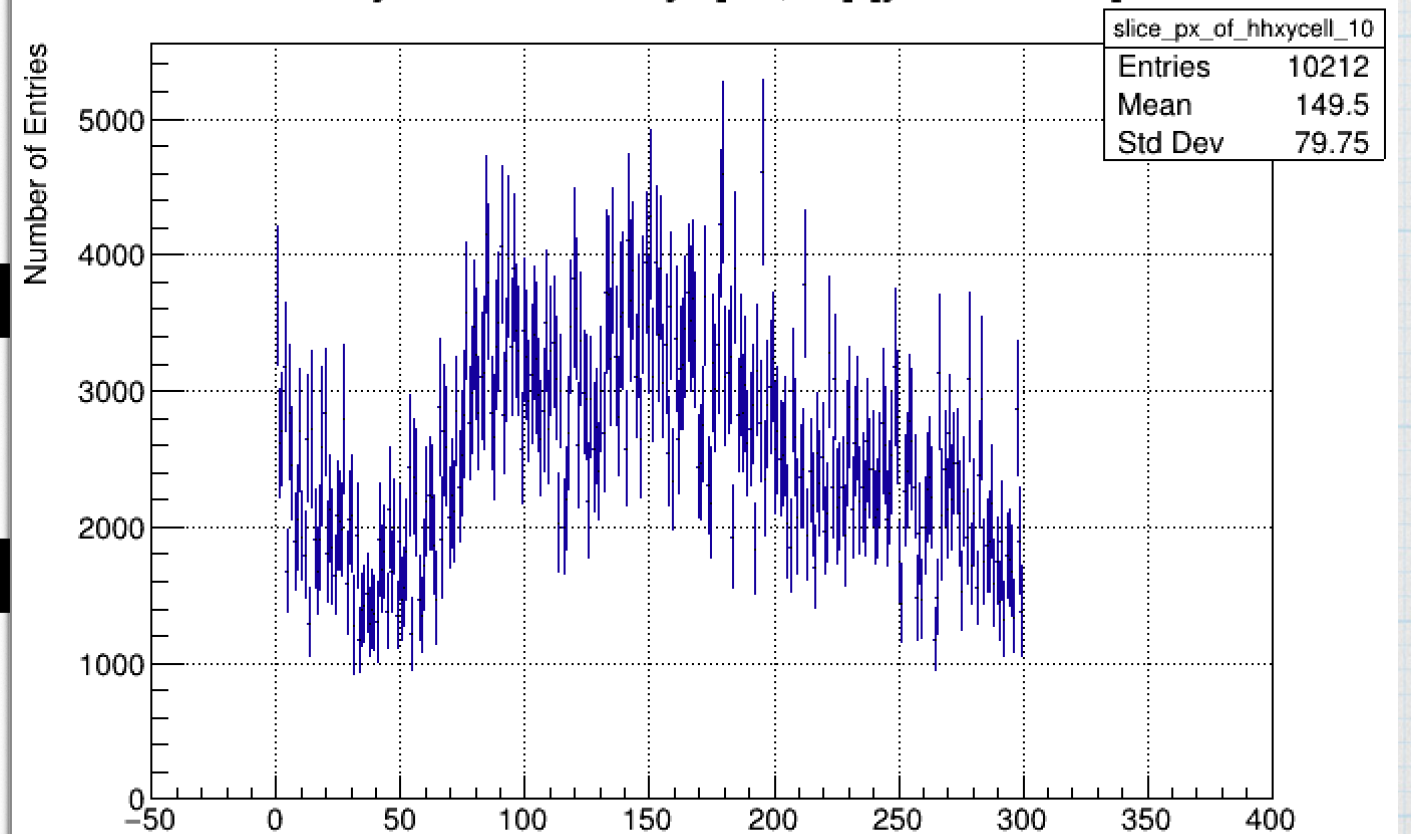
### hhxycell\_10



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

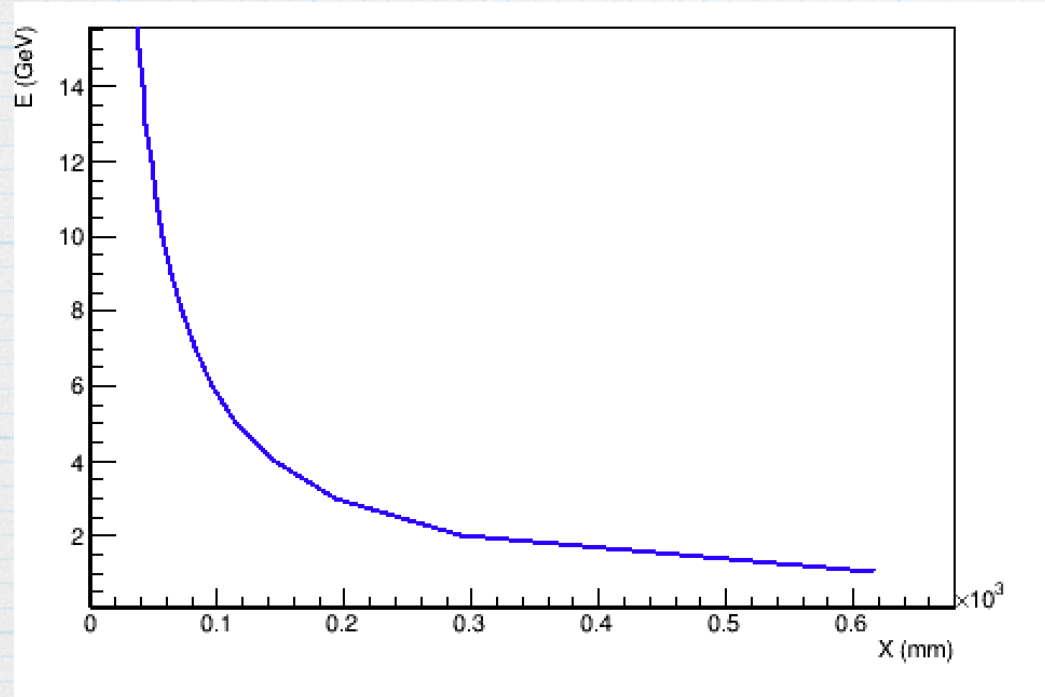


### ProjectionX of biny=[18,32] [y=7.0..22.0]

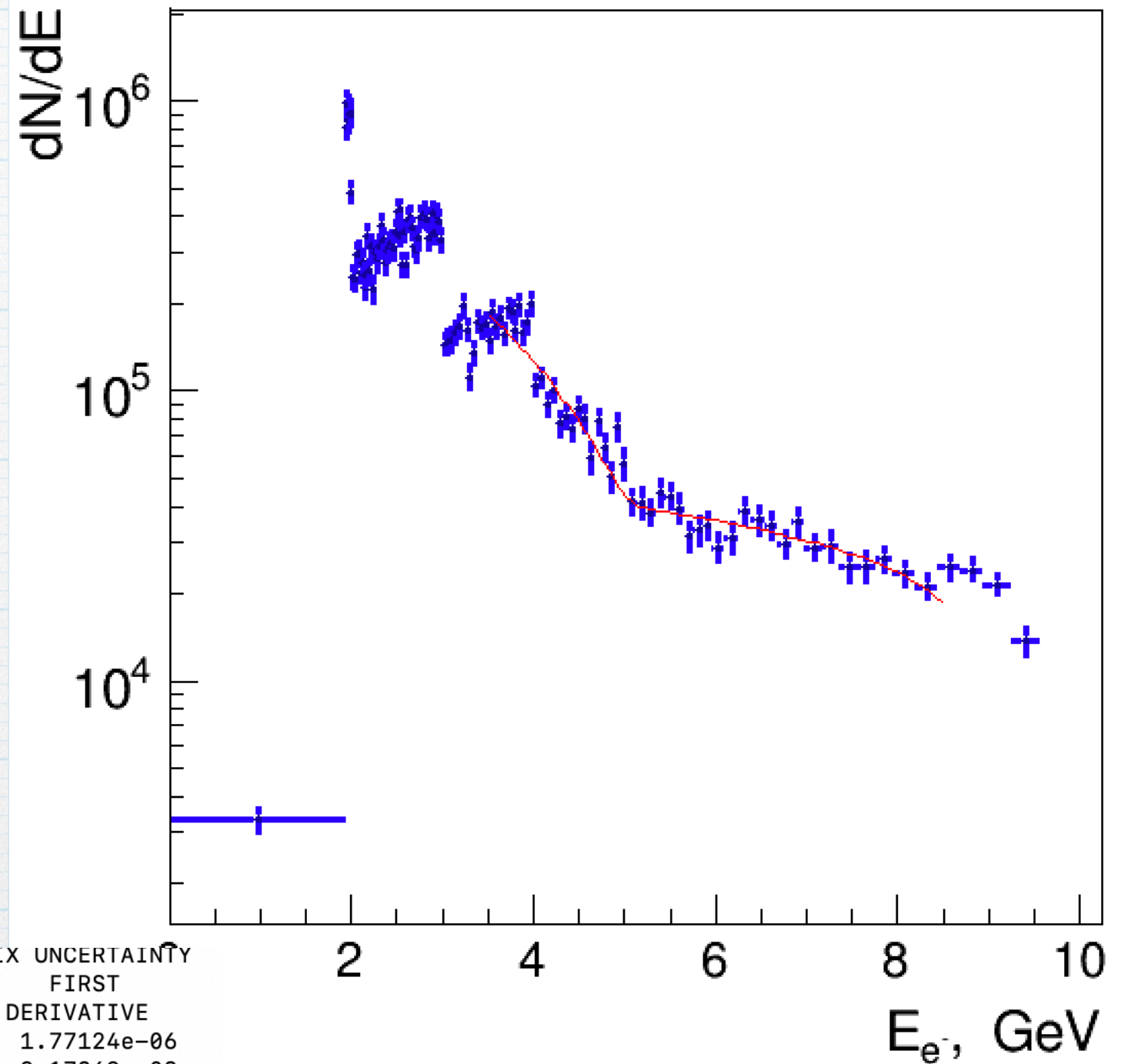




# Spectra reconstruction for the Lanex case



spectrum\_electron



EDM=3.45767 STRATEGY= 1 ERROR MATRIX UNCERTAINTY					
EXT	PARAMETER	APPROXIMATE		STEP	FIRST
NO.	NAME	VALUE	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



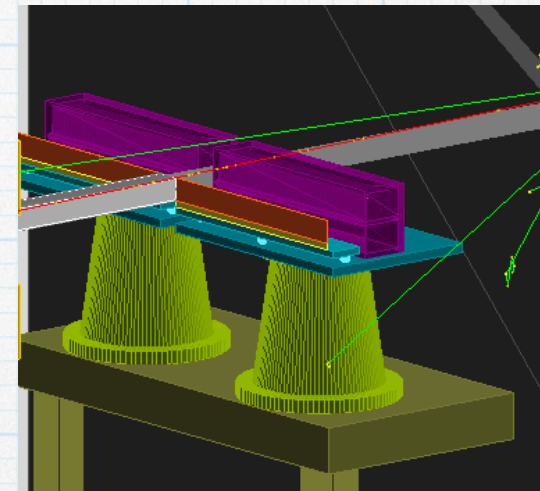
# Photon flux measurements



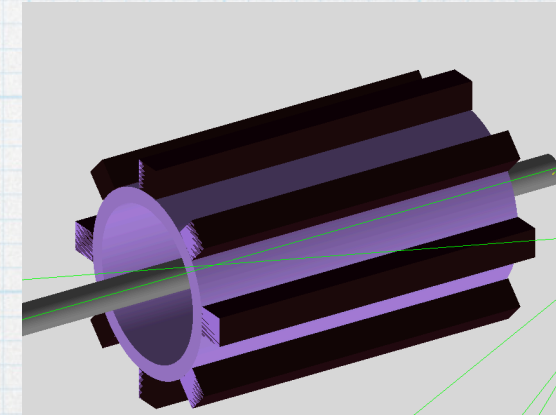
# Tasks

To measure total flux of photons above some threshold  
( $\sim$  MeV-GeV)

- the technologies:
  - a) conversion detector



- b) backscattering calorimeter



For the CDR

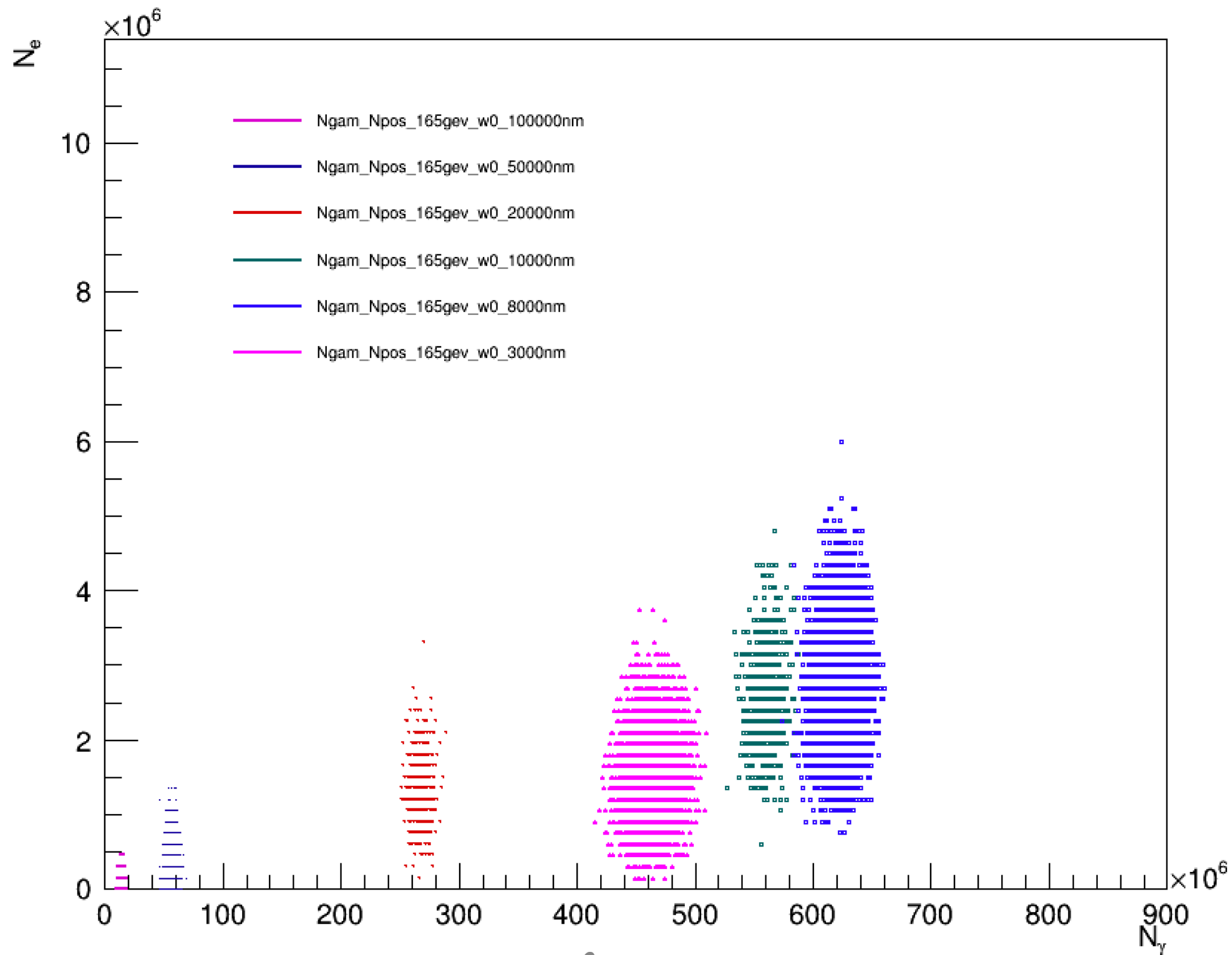
- a) quantify how well a) and b) can measure the flux and above which threshold  $\Rightarrow$

show relative resolution on photon flux of the two technologies as function of number of photons

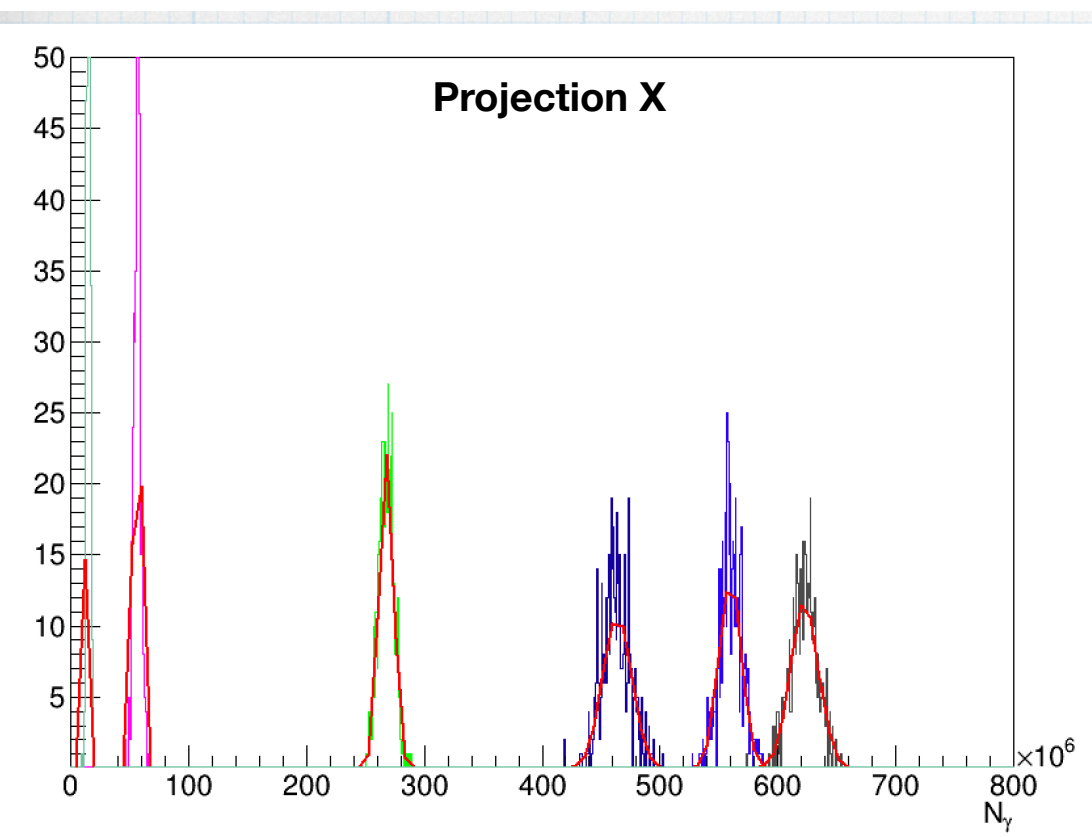
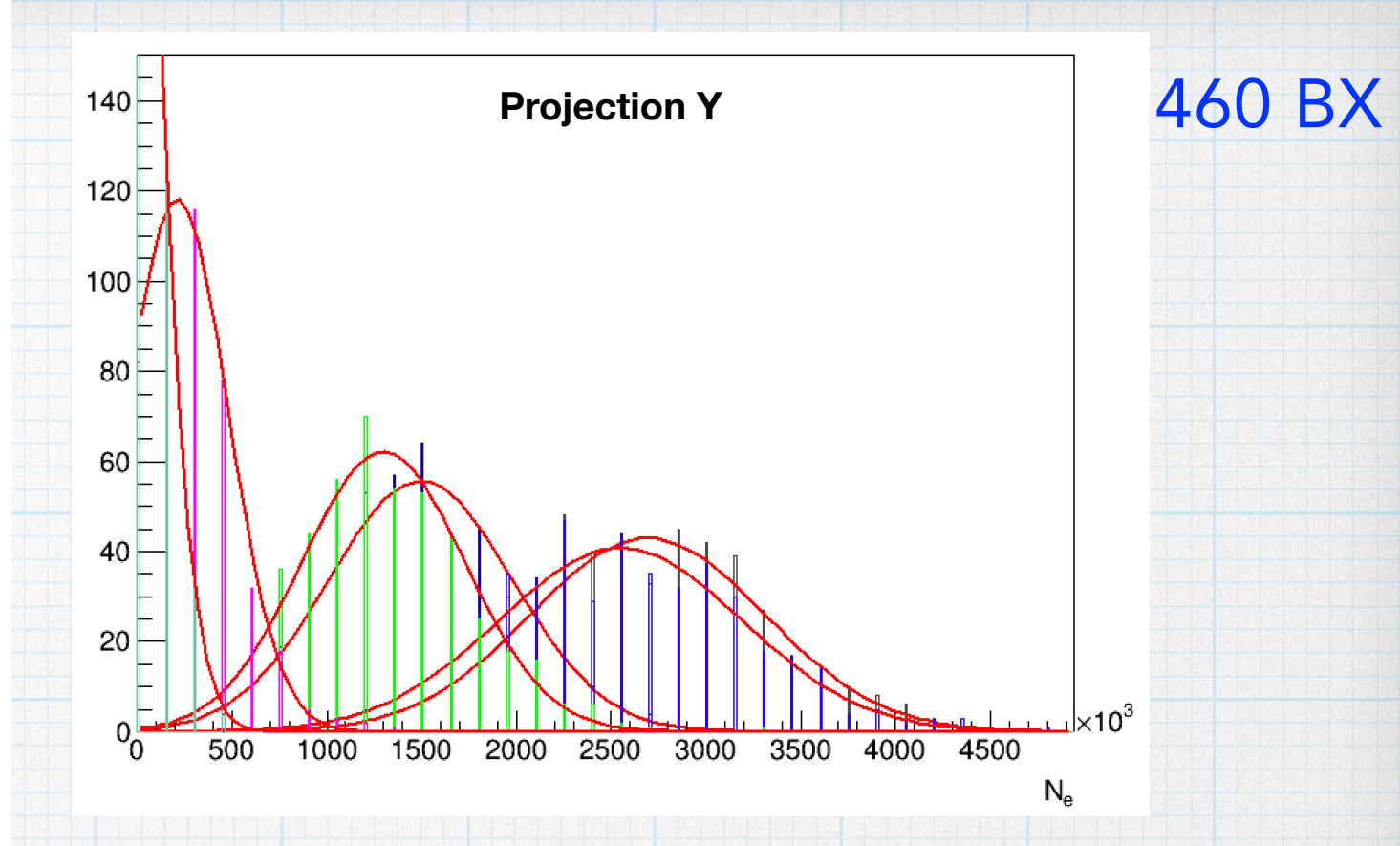
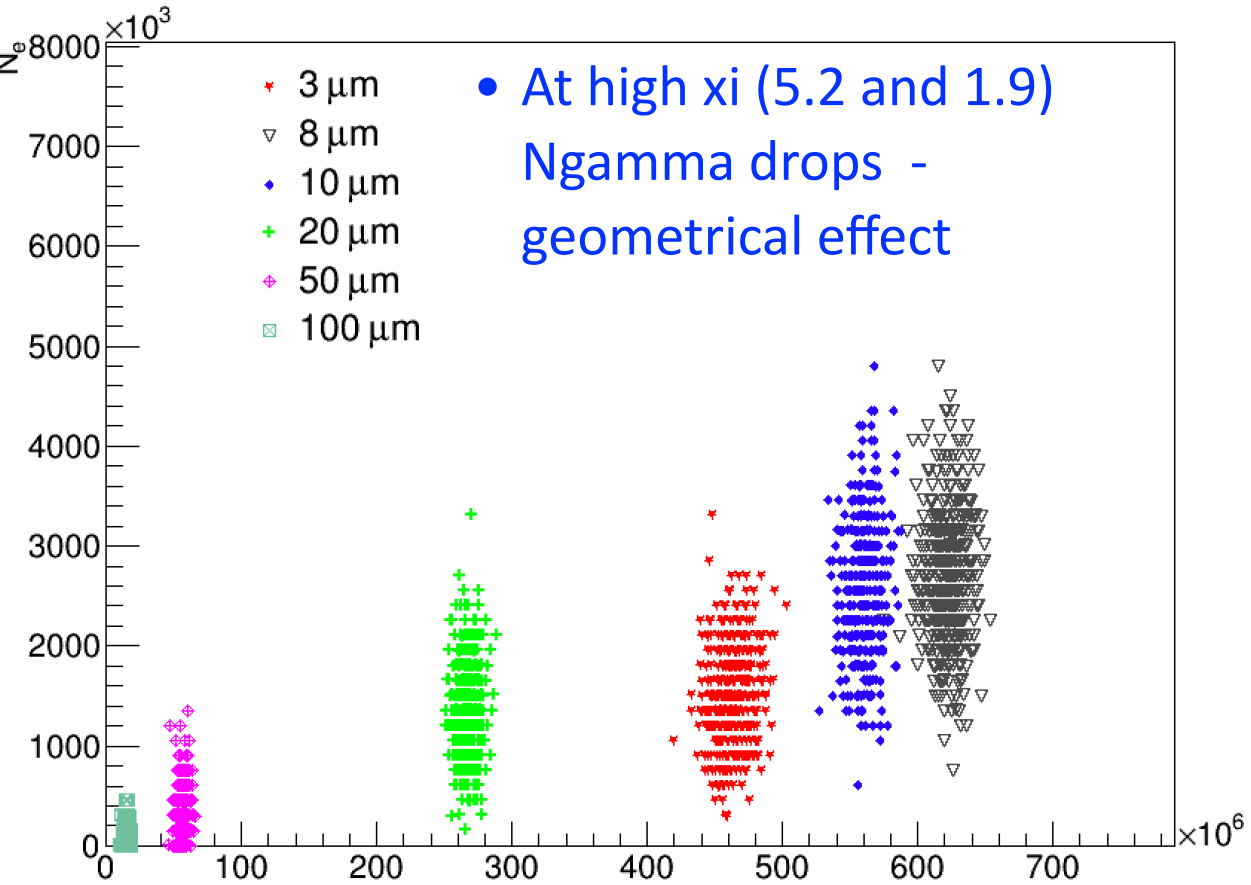


# number of pairs vs number of photons per BX for different xi in Lanex scrteens (setup w/o beam pipe)

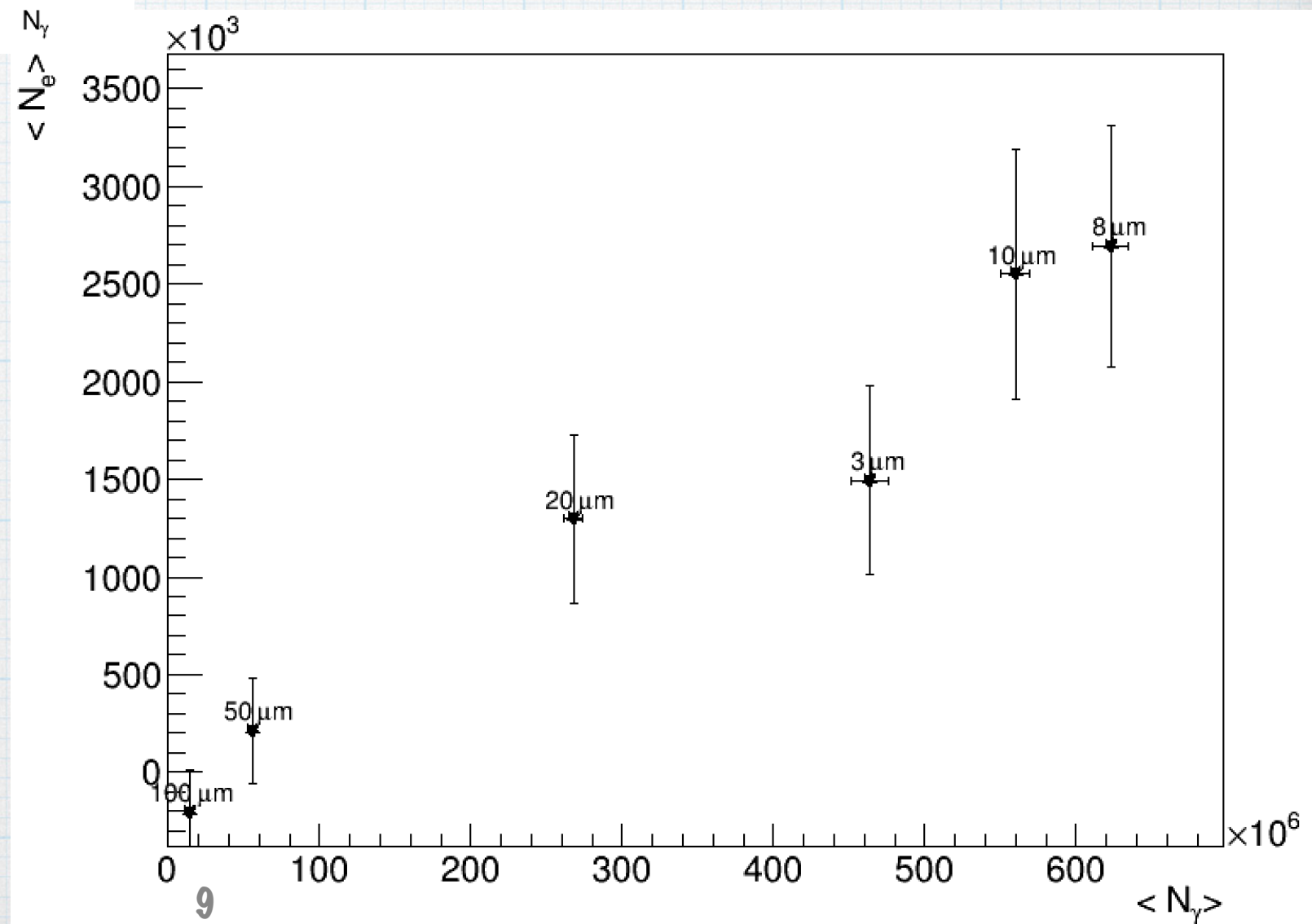
JETI40, 16.5 GeV, 50 um







• Spread in number of electrons is  
substantial  $\sim 25\text{-}30\%$





# Summary

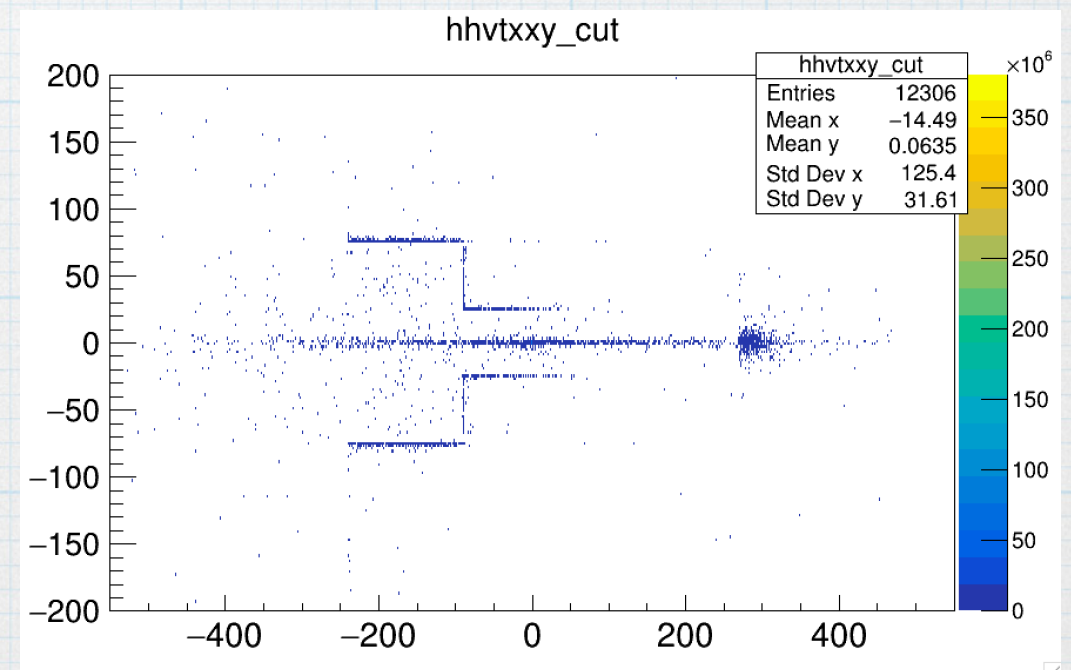
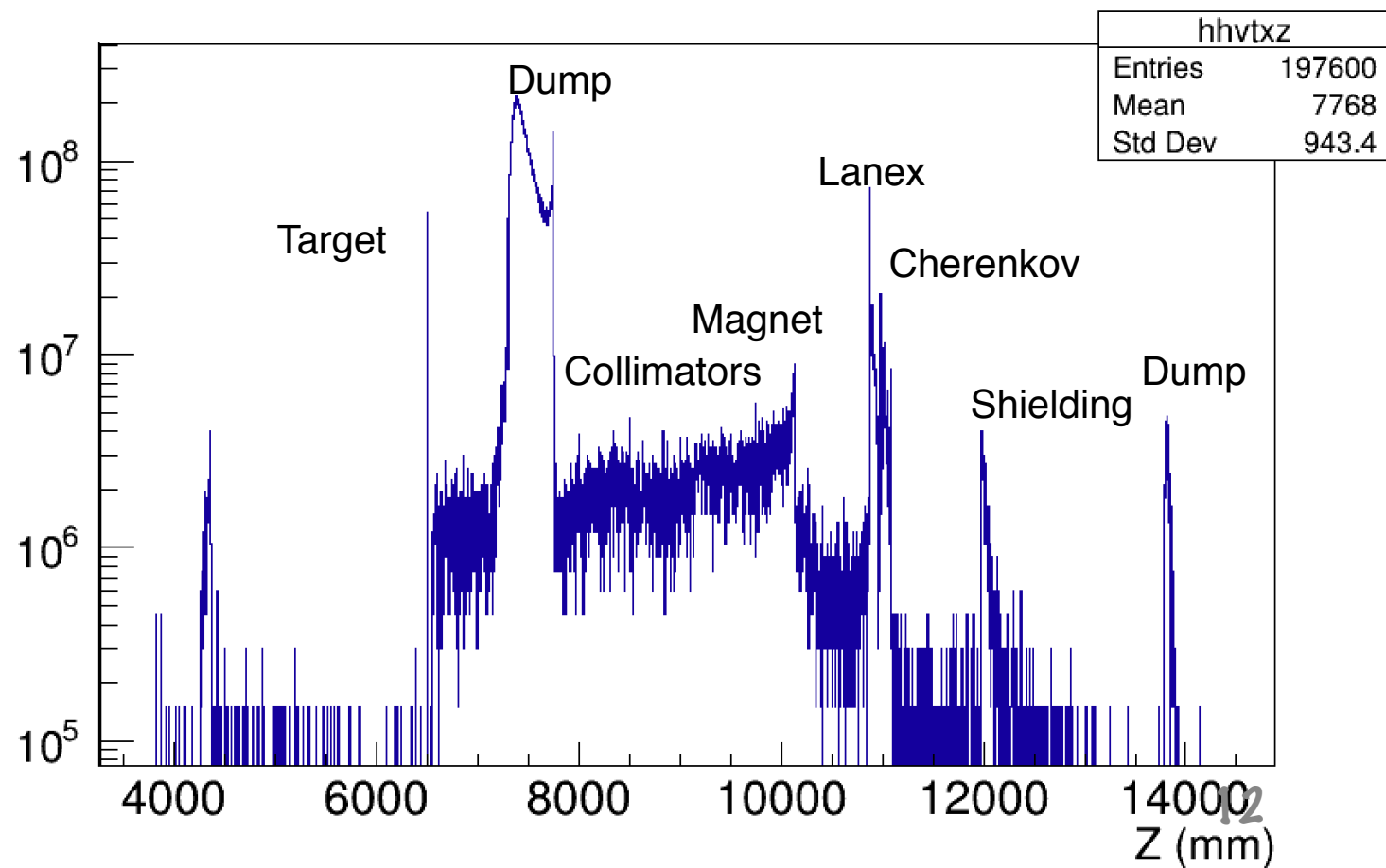
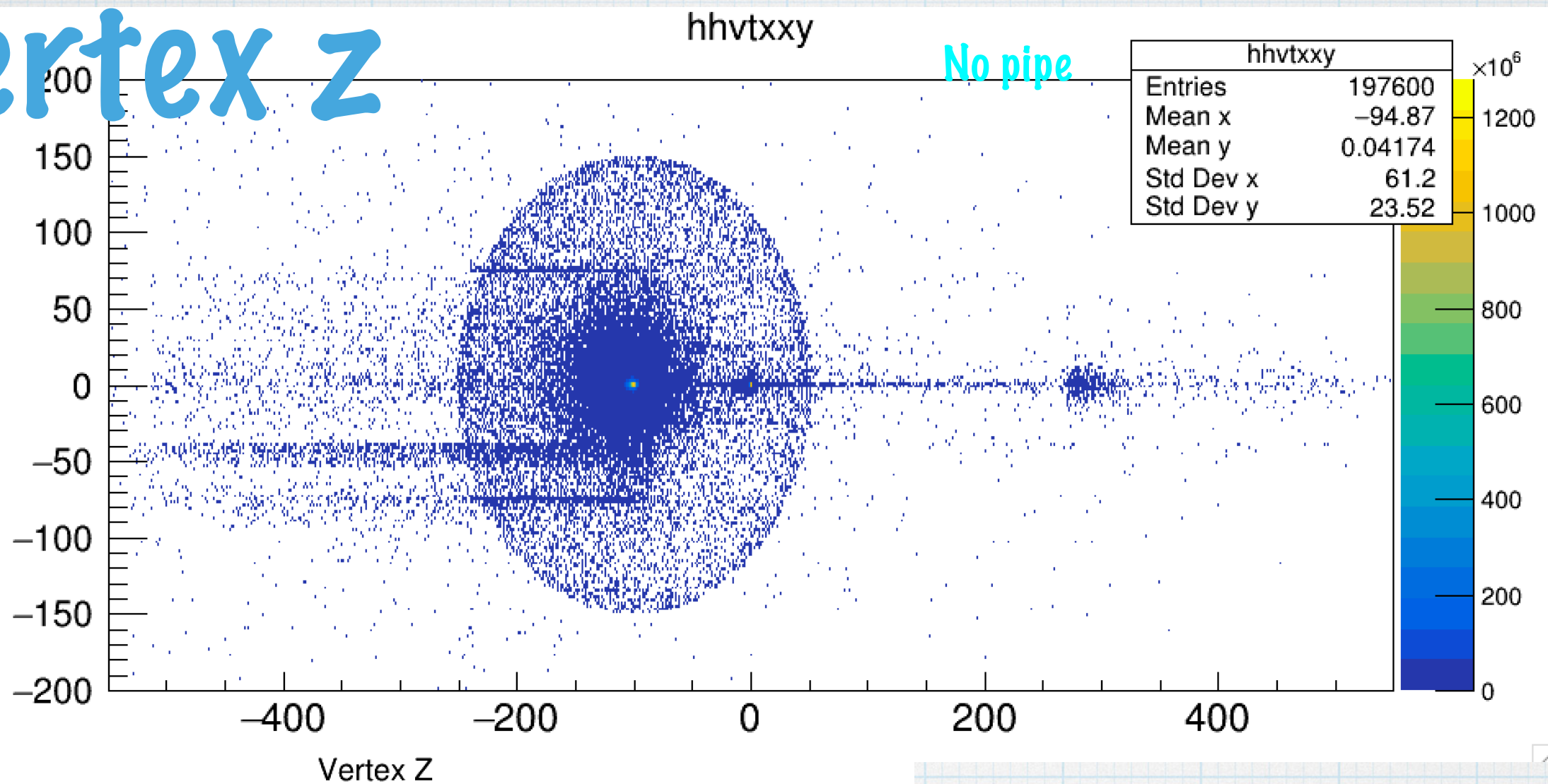
- \* The performance of FDS setup w/o beam pipe from the target to Compton detectors was studied
- \* electron spectrum look reasonable but positron is very contaminated
- \* Not sufficient Shielding w/ electron dump creates substantial background occupancy in Lanex detectors.
- \* Reconstruction in Lanex screens



Back up



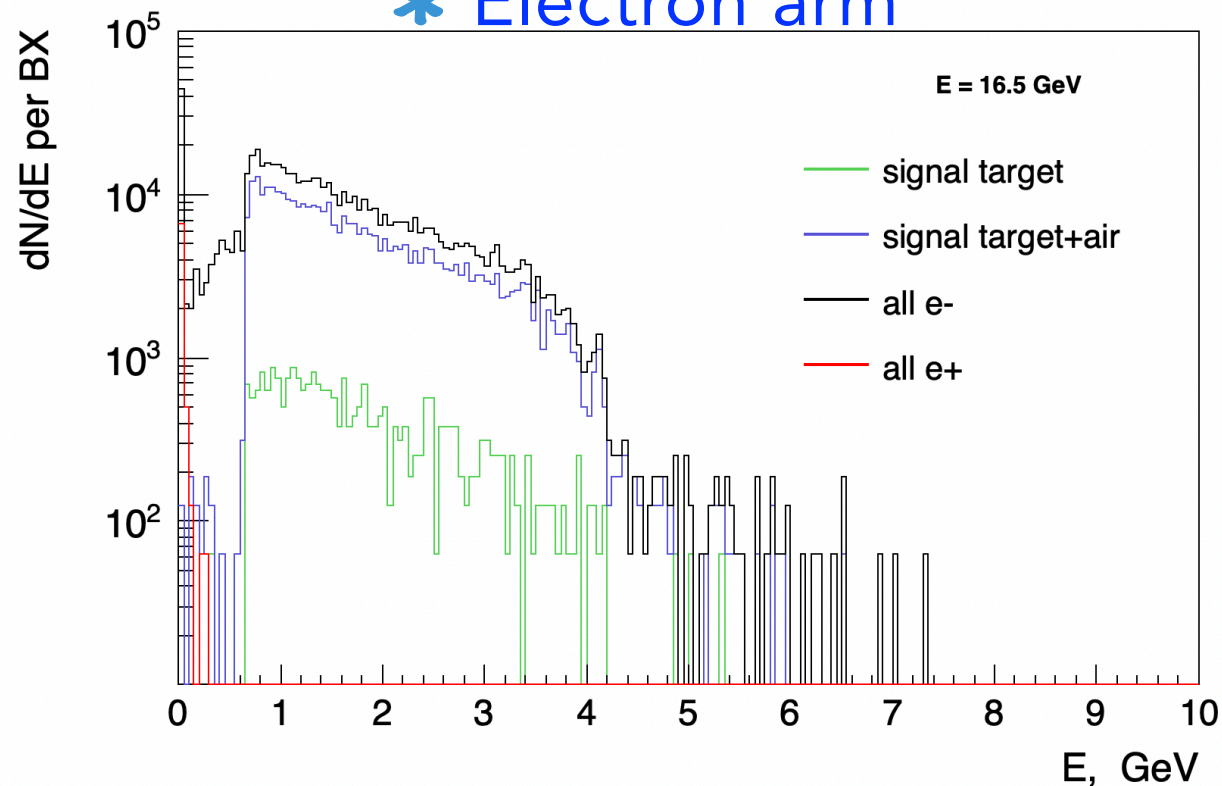
# Vertex z





# Lanex screens, Spectra

## \* Electron arm



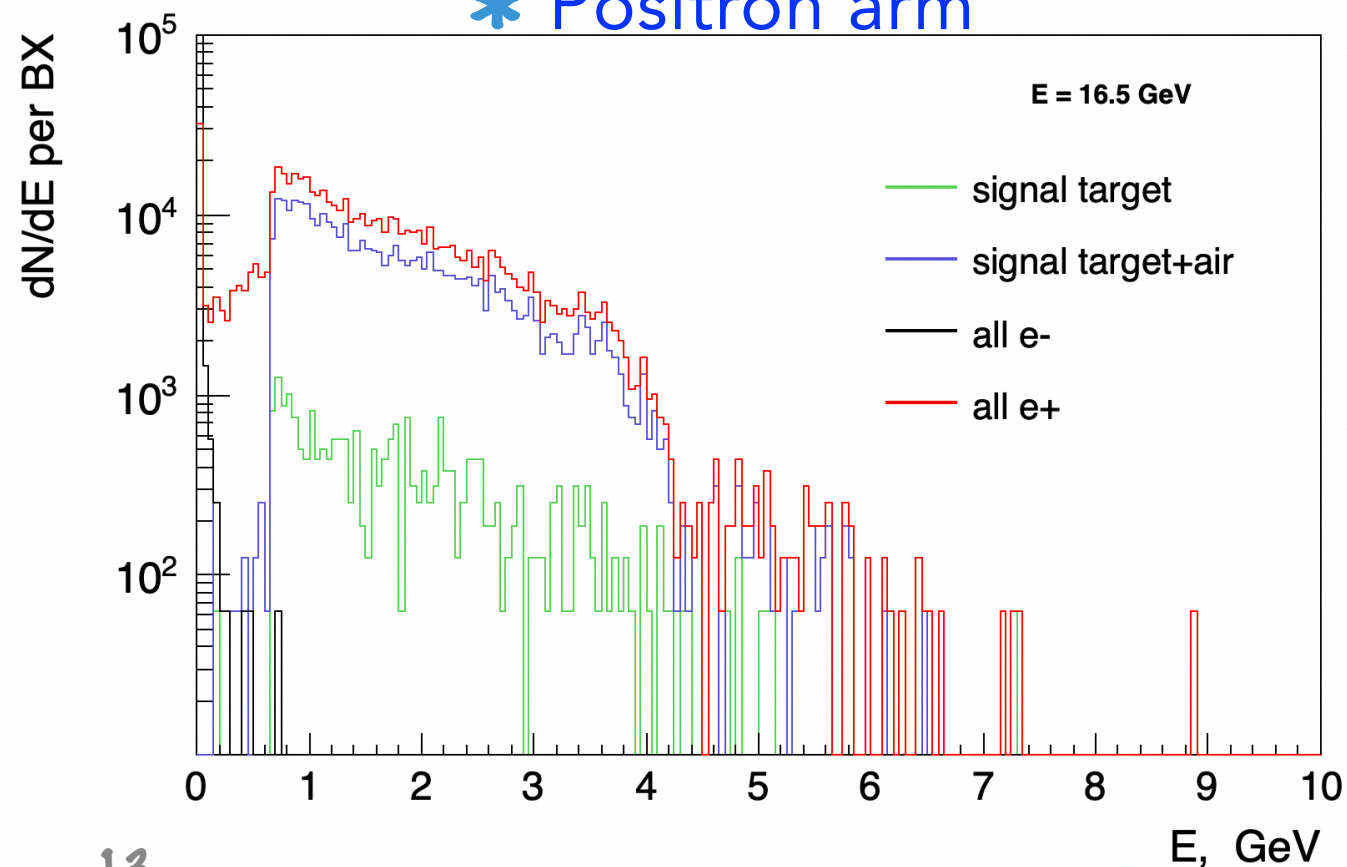
JETI40, 16.5 GeV, 50  $\mu\text{m}$

- 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  $\mu\text{m}$`
- `vtx z > 6.5m - 100 $\mu\text{m}$  && vtx z < 9m`

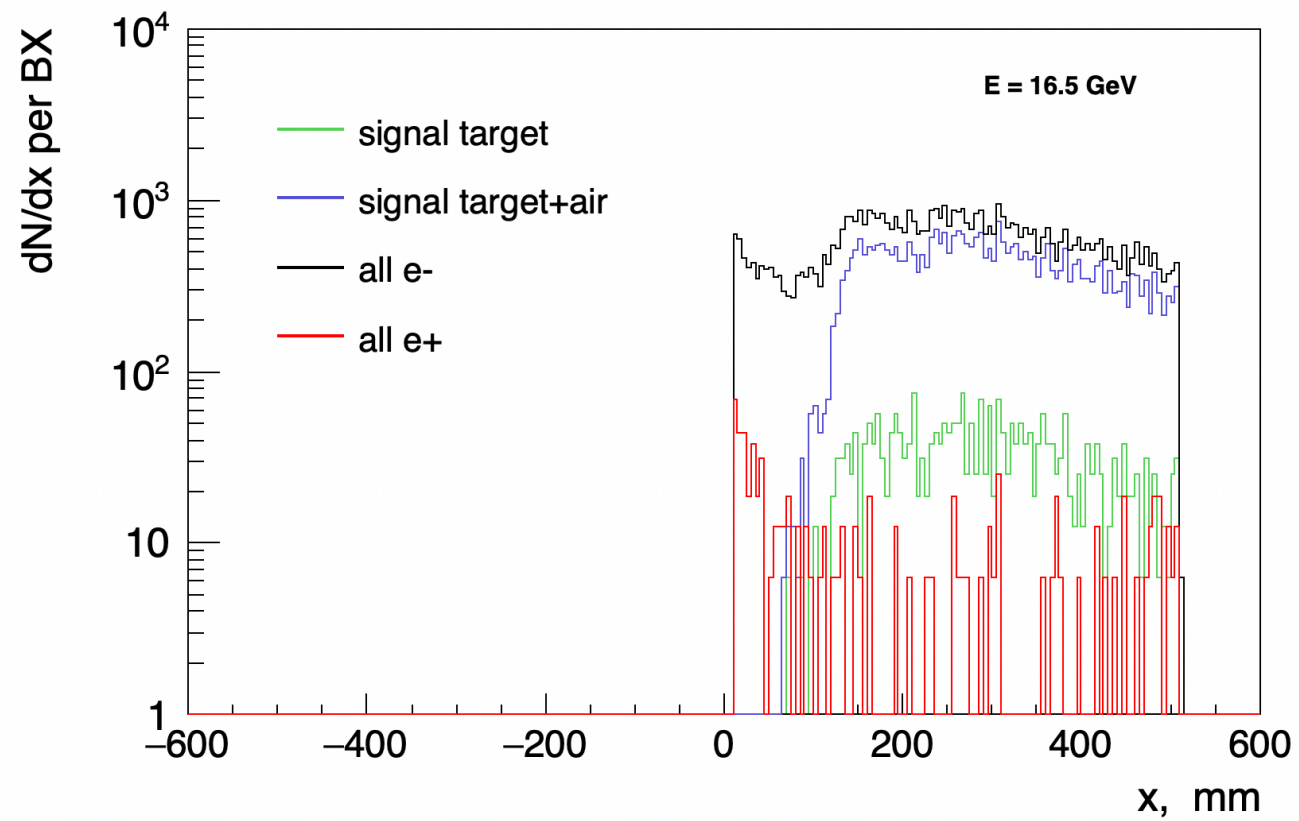
## \* Positron arm



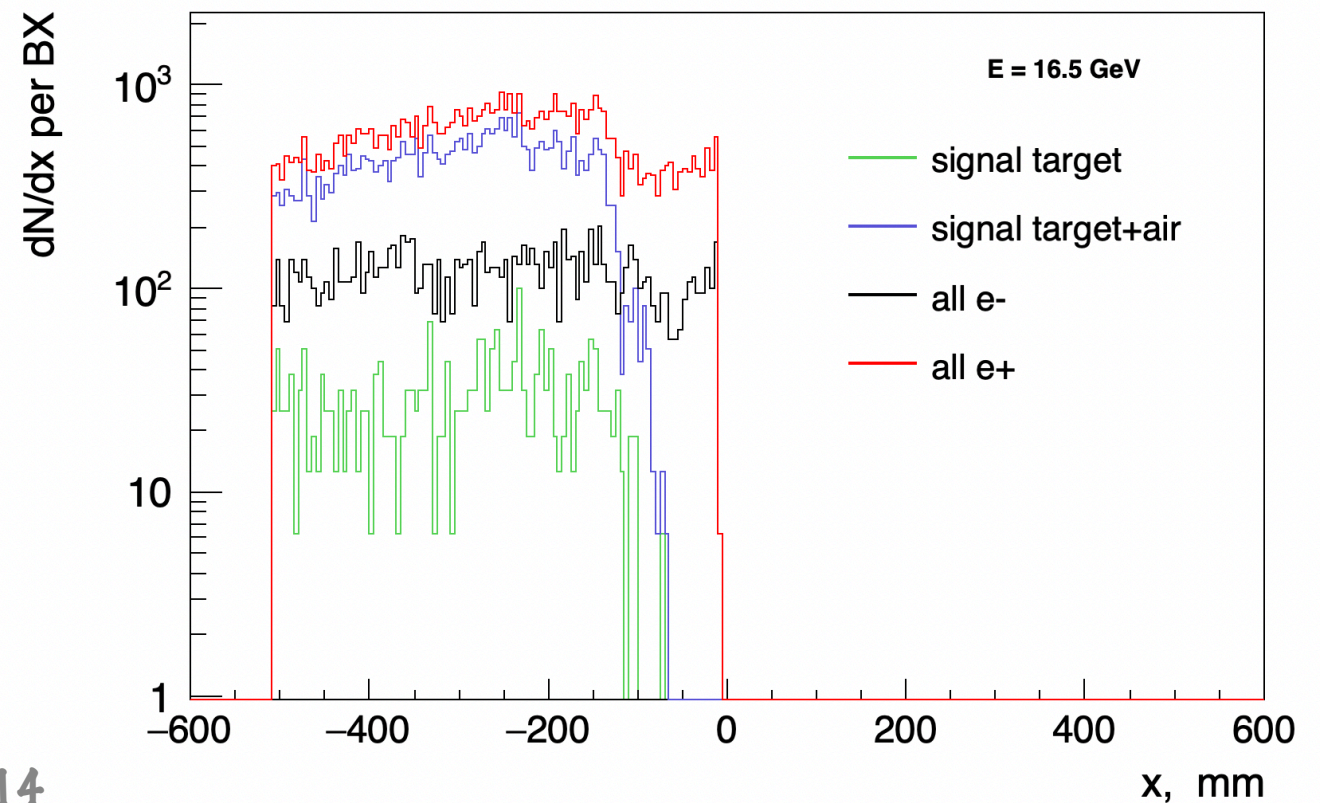


# Lanex screens, X-distributions

## \* Electron arm



## \* Positron arm

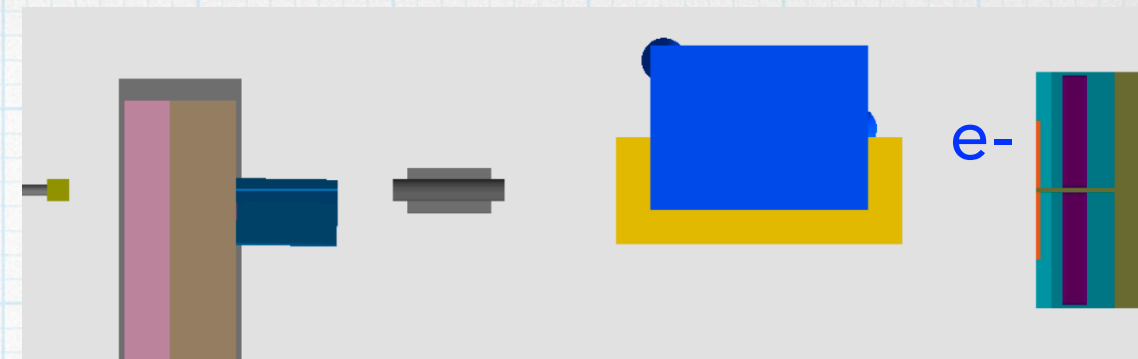


Material	X0,(cm)	Thickness	Fraction X0
Air	3.04E+04	350	1.15 %
Kapton	28.57	2.00E-02	0.07 %

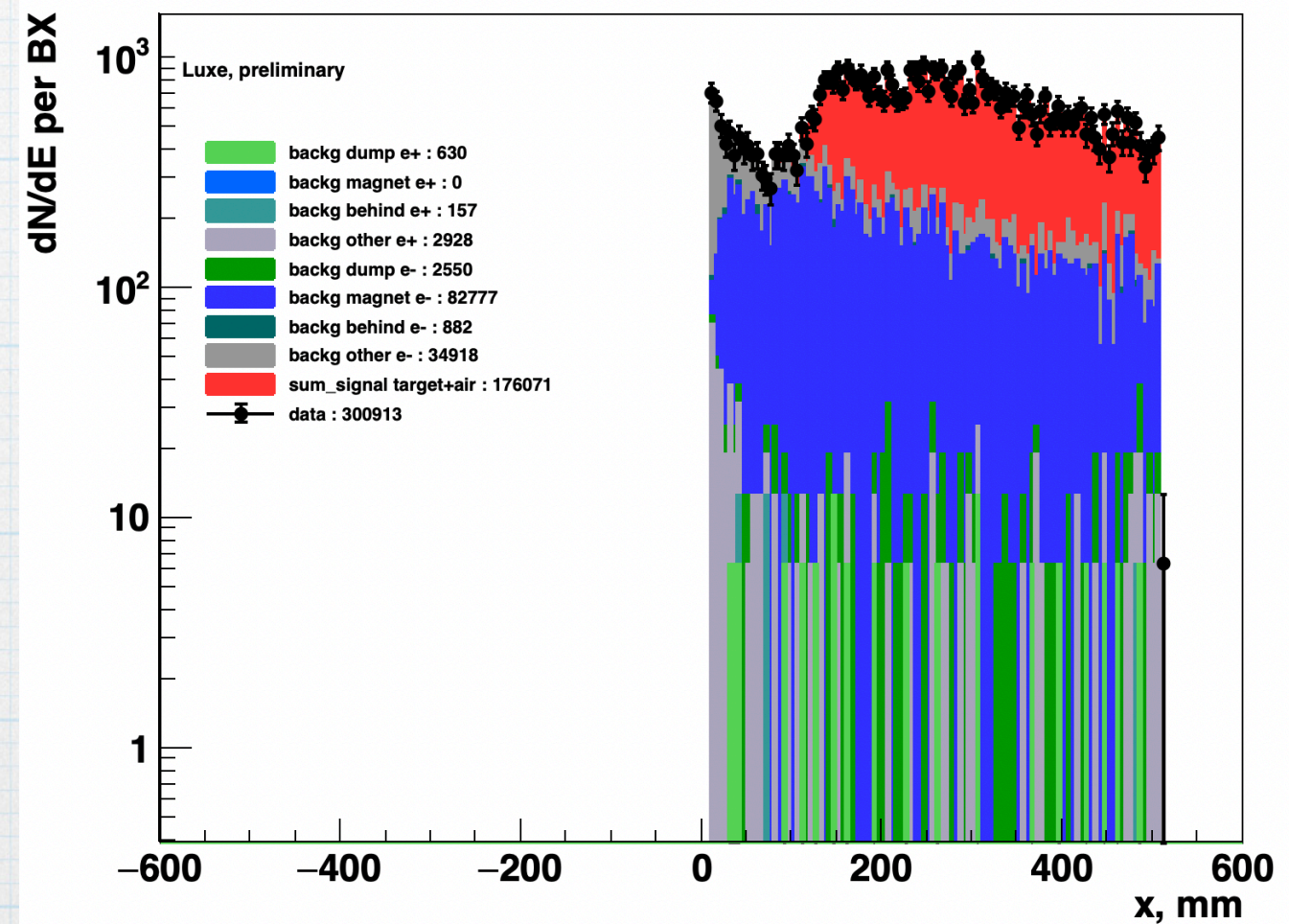
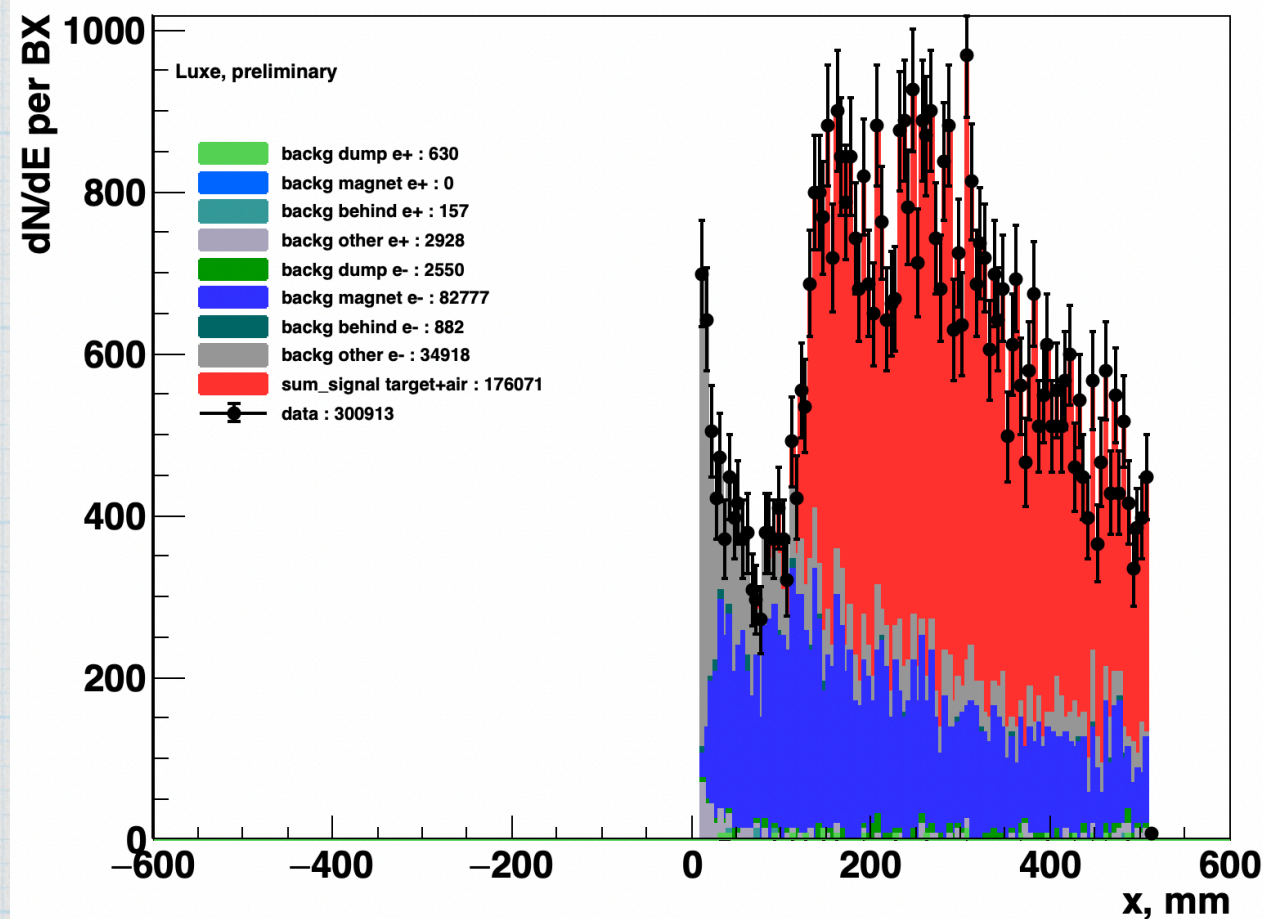


# Background

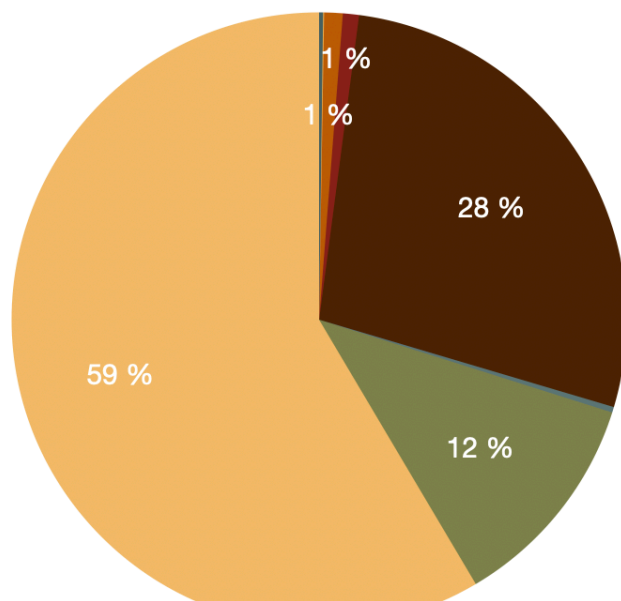
## \* Electron arm



JETI40, 16.5 GeV, 50  $\mu\text{m}$



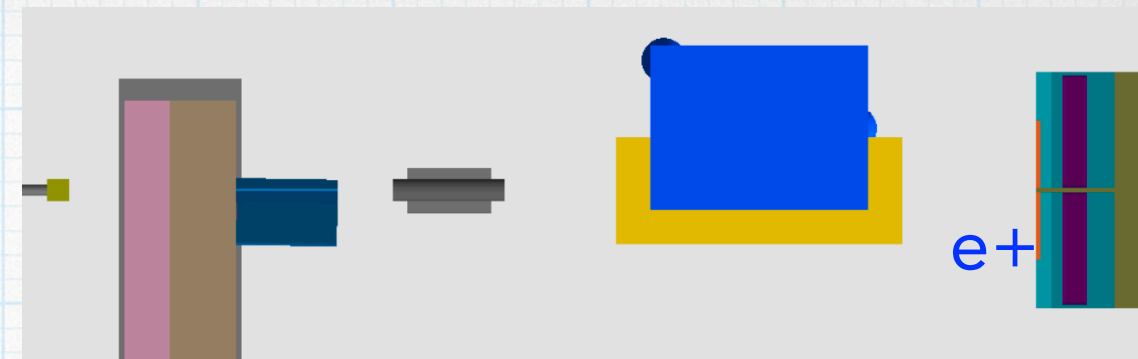
dump pos   magnet pos   behind pos   other pos   dump el  
 magnet el   behind el   other el   Signal



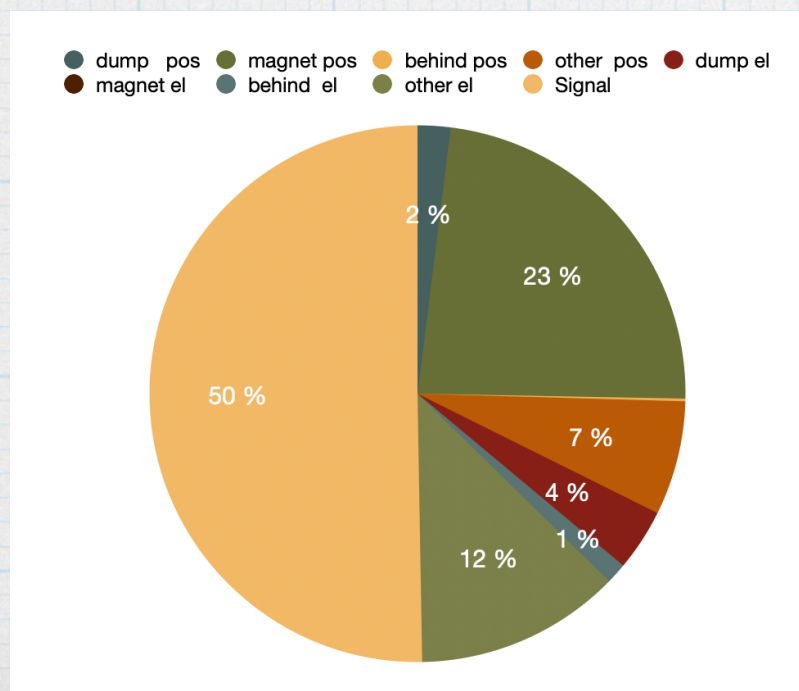
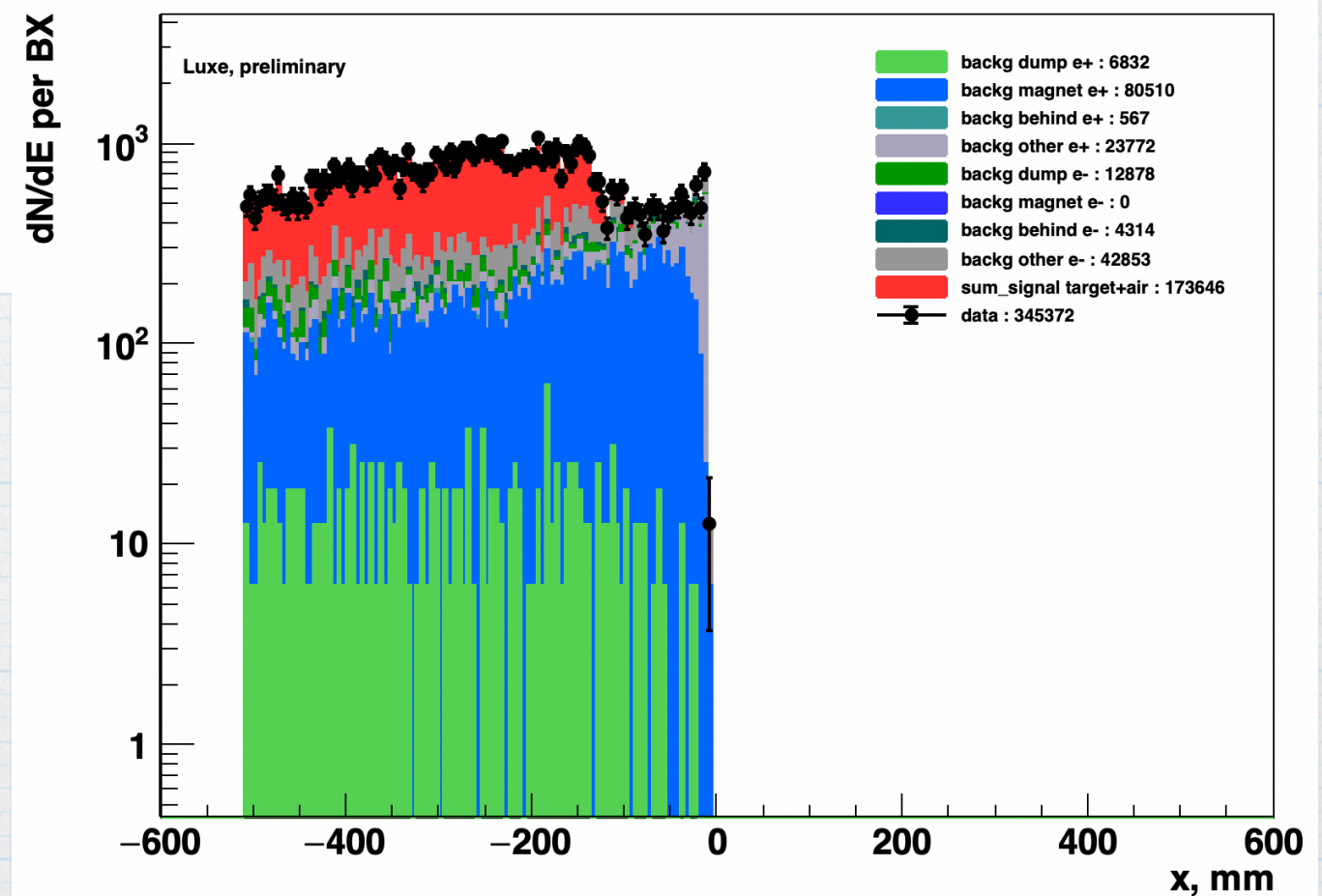
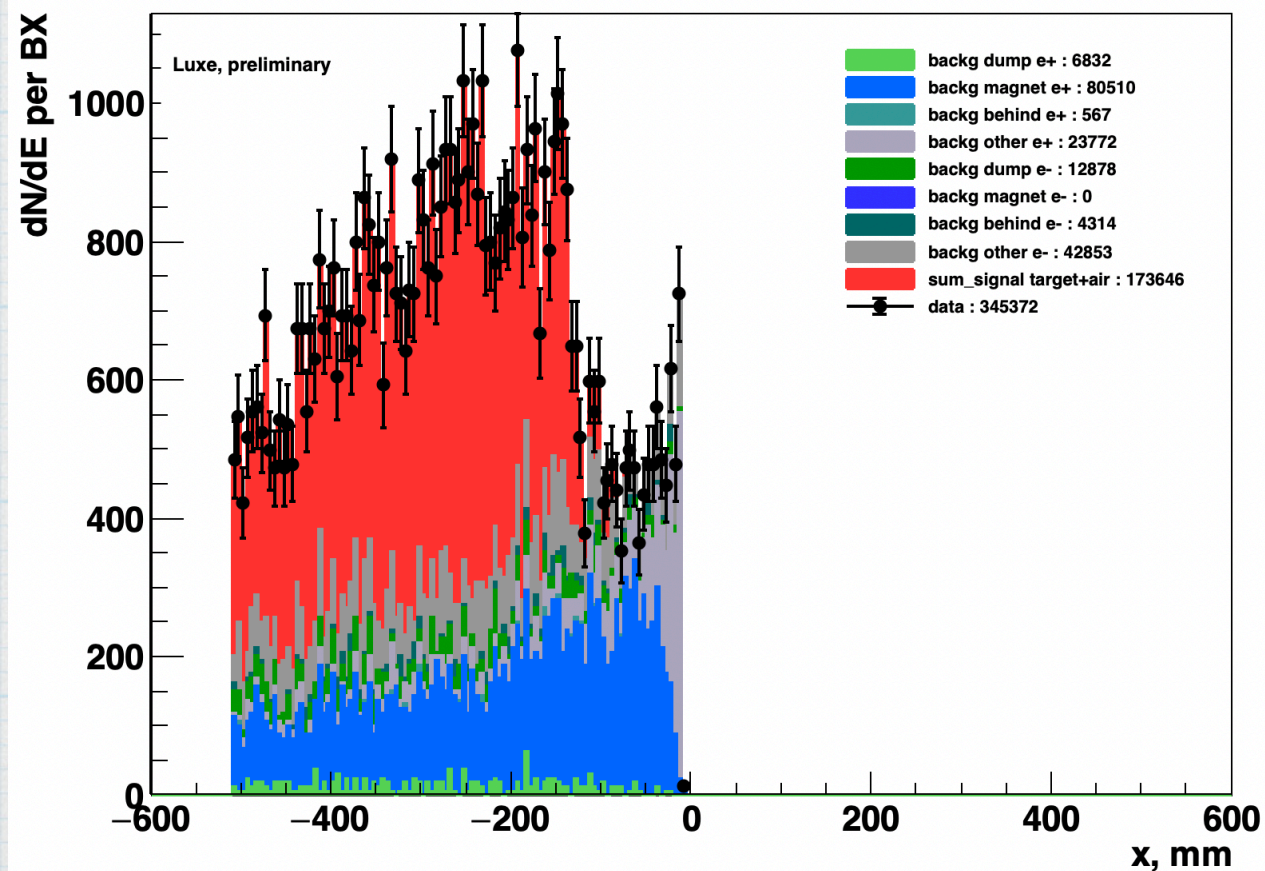


# Background

\* Positron arm

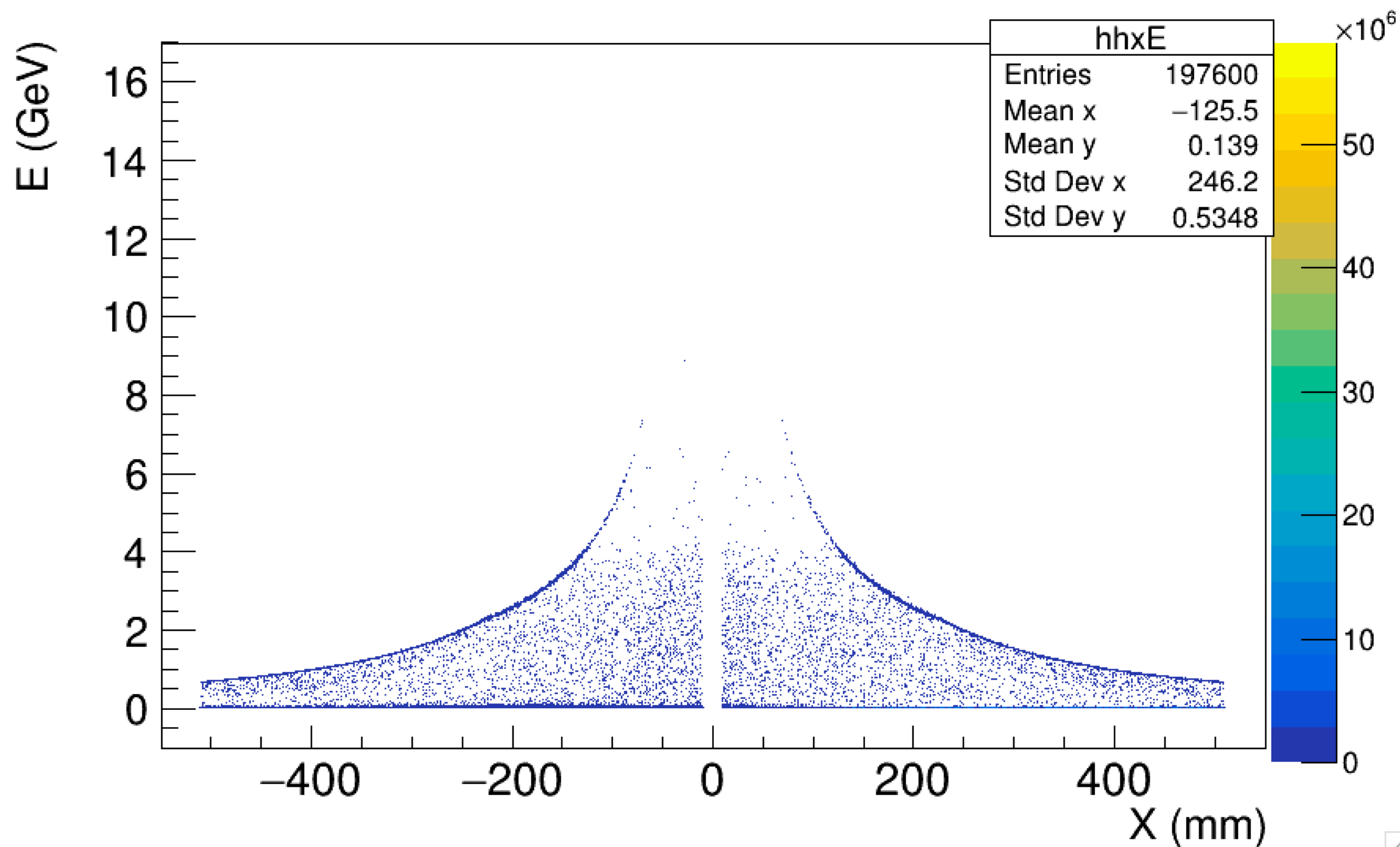


JETI40, 16.5 GeV, 50  $\mu\text{m}$



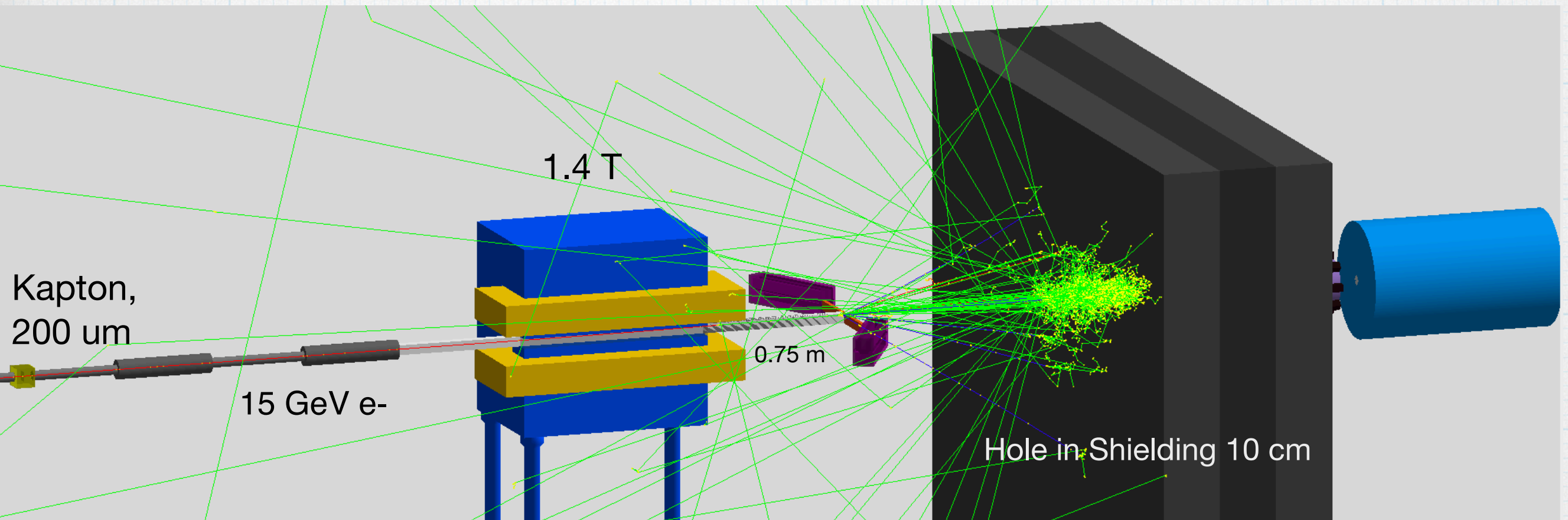


Tracks xE distribution





# FDS with LYSO calorimeters



## Aug 2020 Data Runs, bunch/pulse crossings completed

Experiment Config	$w_0 = 3\mu\text{m}$	$w_0 = 3.5\mu\text{m}$	$w = 0, 4.0\mu\text{m}$	$w_0 = 4.5\mu\text{m}$	$w_0 = 5.0\mu\text{m}$	$w_0 = 8.0\mu\text{m}$	$w_0 = 20.0\mu\text{m}$	$w_0 = 50.0\mu\text{m}$	$w_0 = 100.0\mu\text{m}$
peak SQED $\xi$	5.12	4.44	3.88	3.45	3.1	1.94	0.78	0.31	0.15
peak SQED $\chi$ (16.5 GeV)	0.9	0.79	0.69	0.61	0.55	0.34	0.138	0.055	0.028
JET140 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.

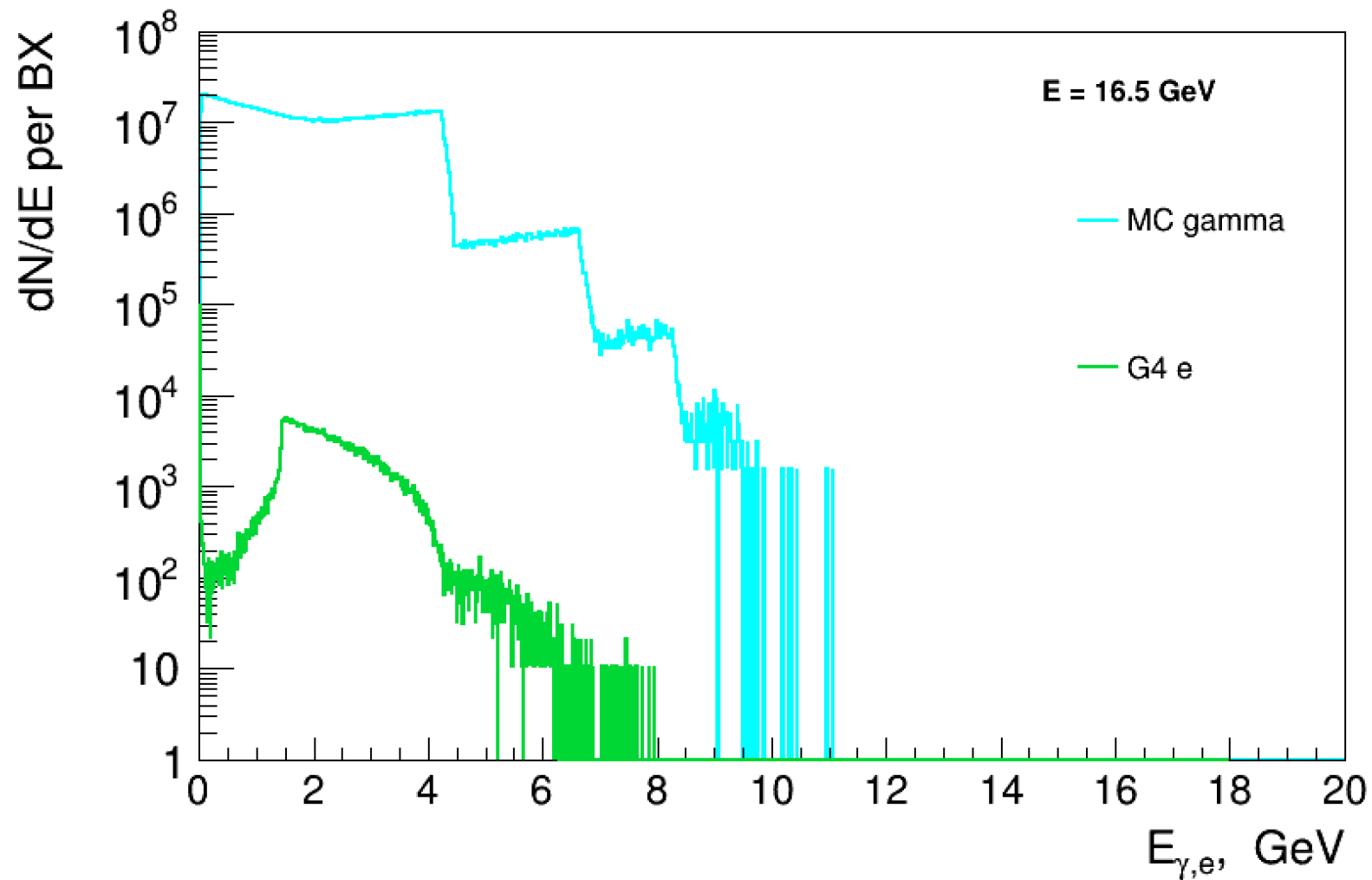
LYSO ( $\text{Lu}_{1.8}\text{Y}_{0.2}\text{SiO}_5$ )

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

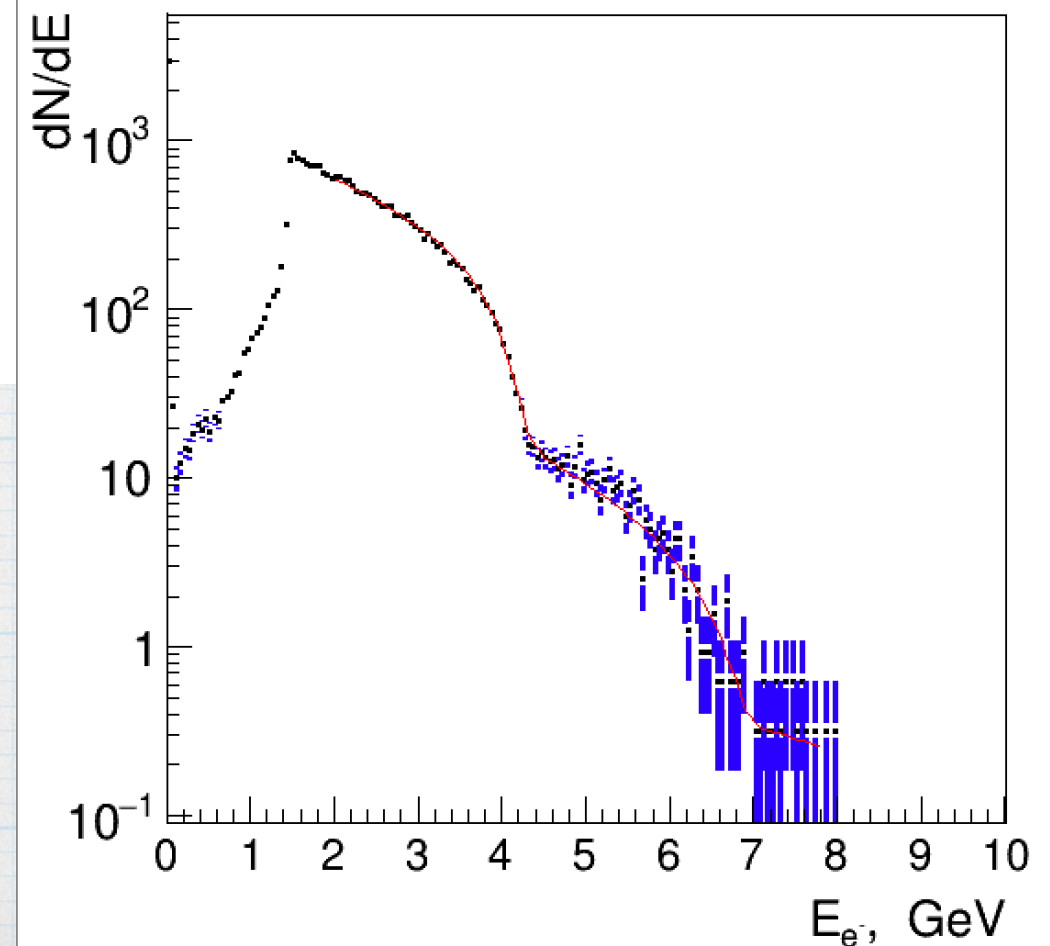


# Spectra MC vs G4

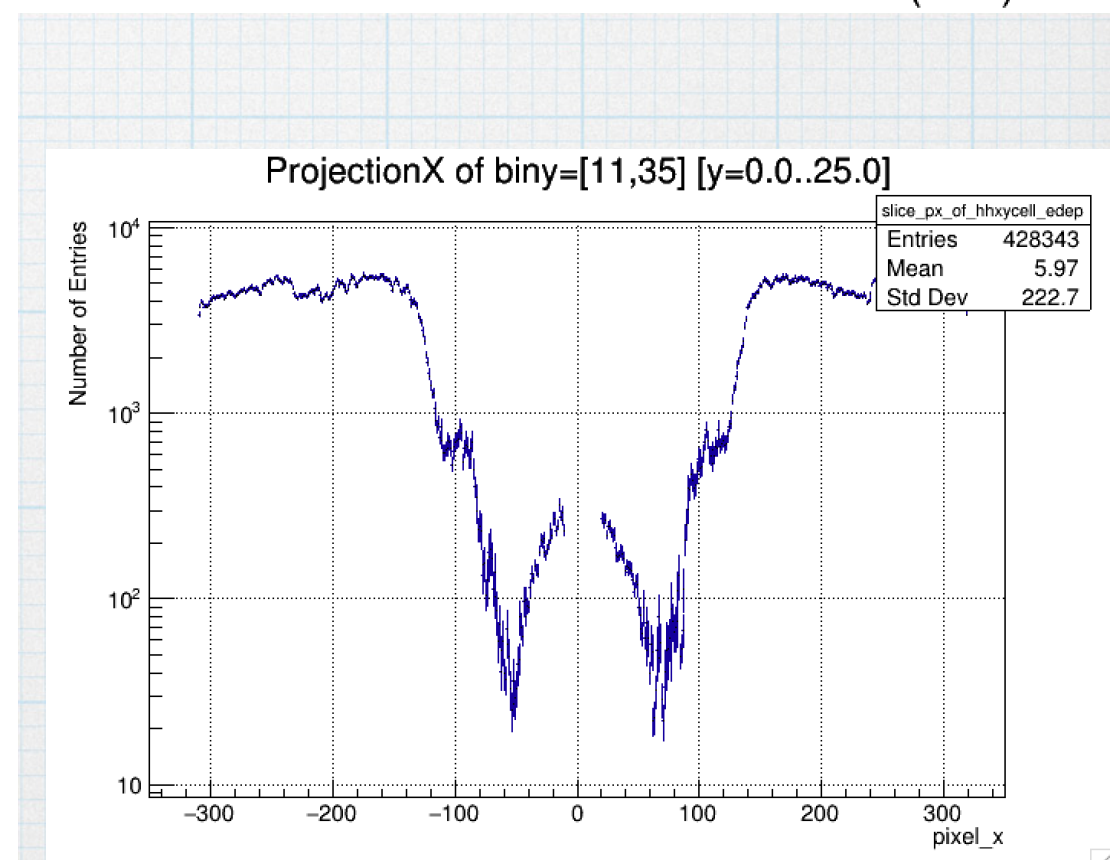
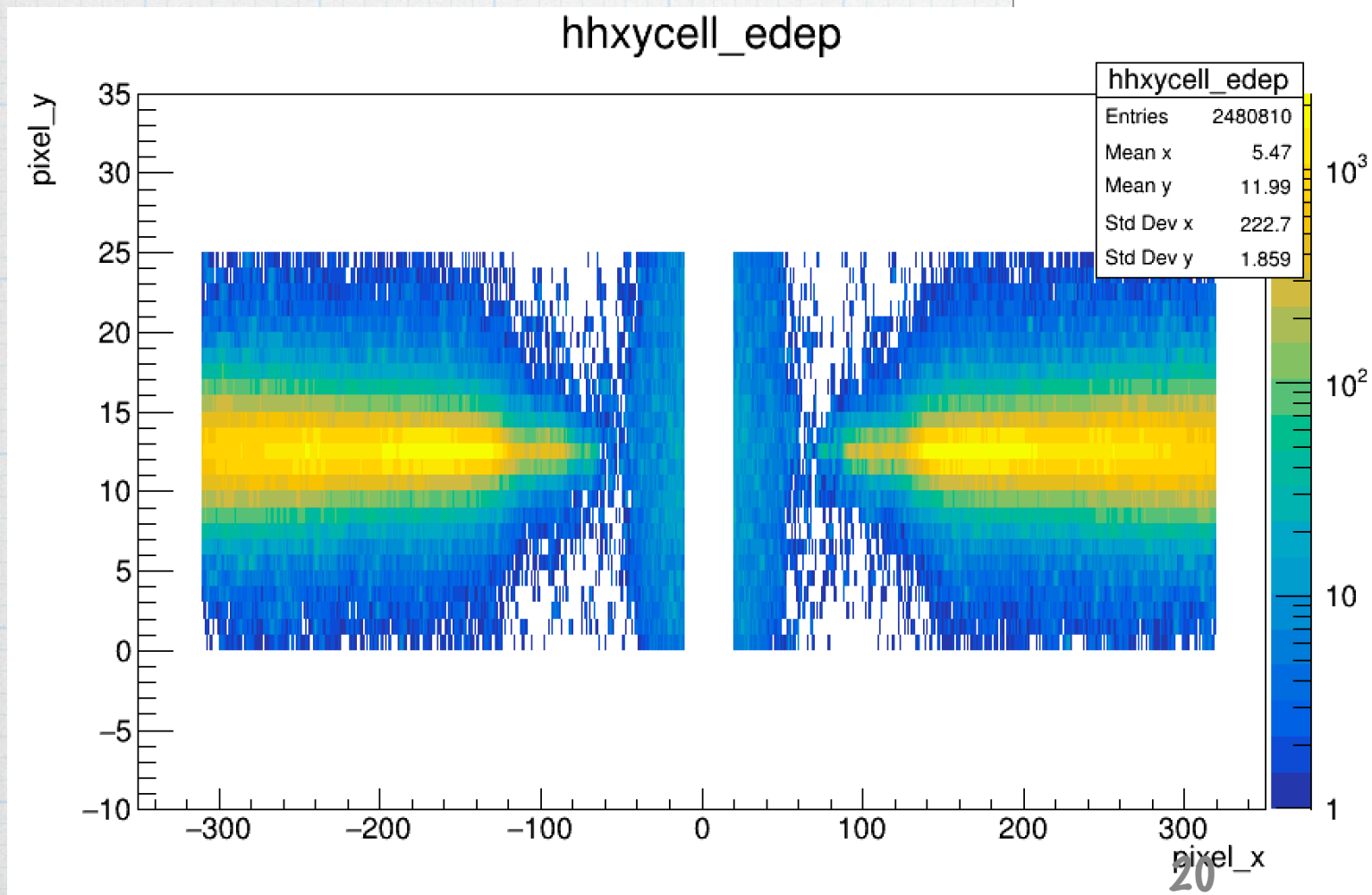
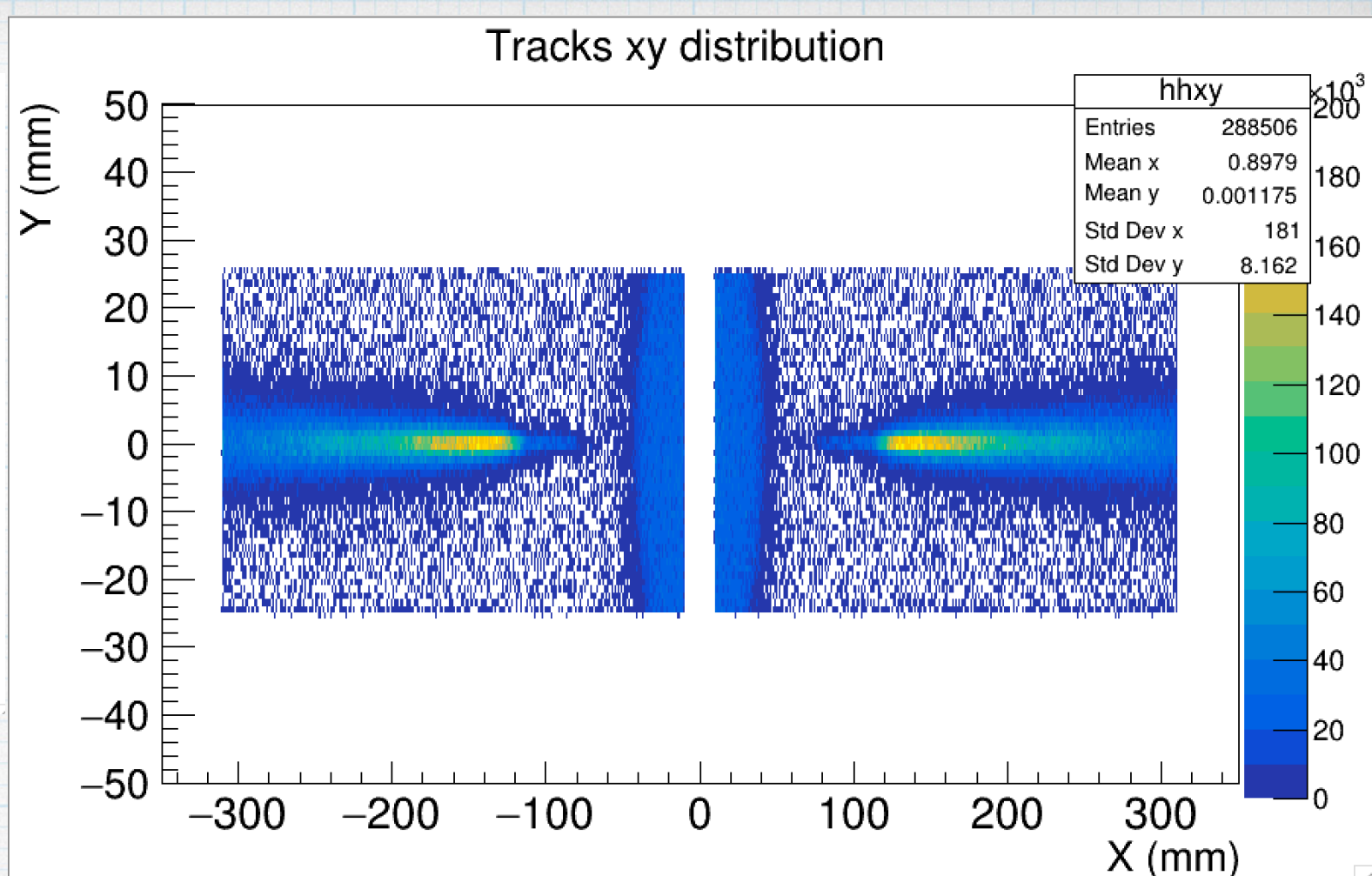
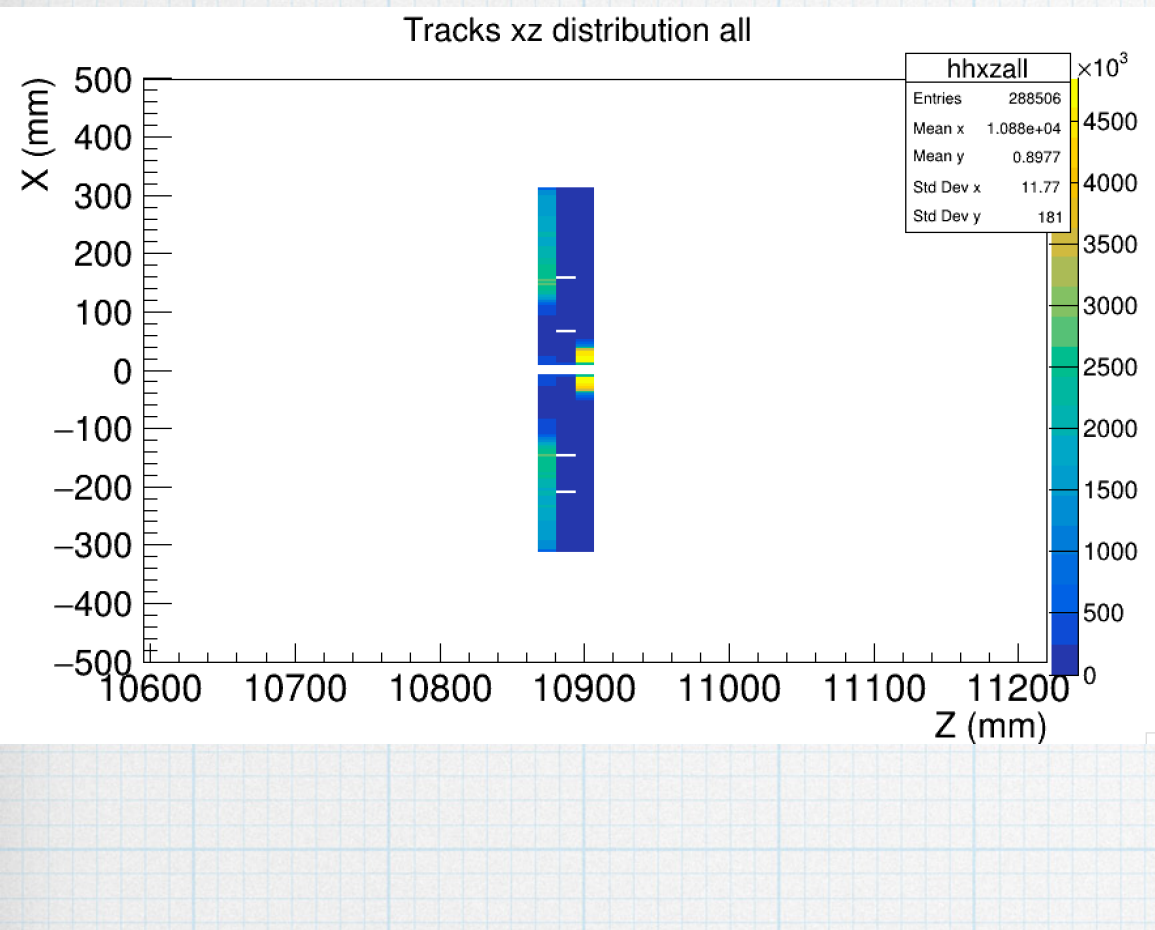
~4700BX out of 5000 BX at the laser intensity  $\xi = 0.3$  for 16.5 GeV electron beam



Energy spectrum

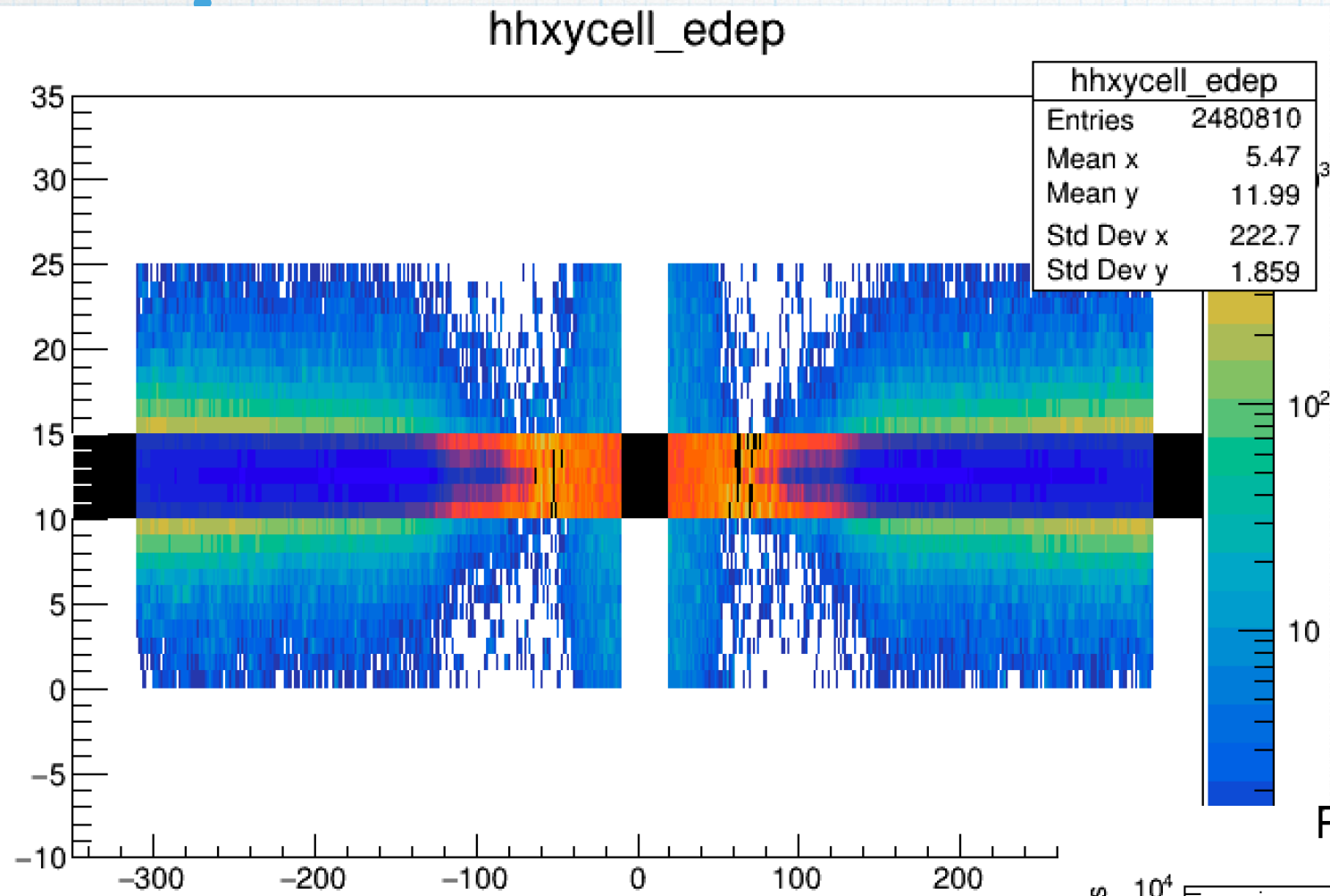




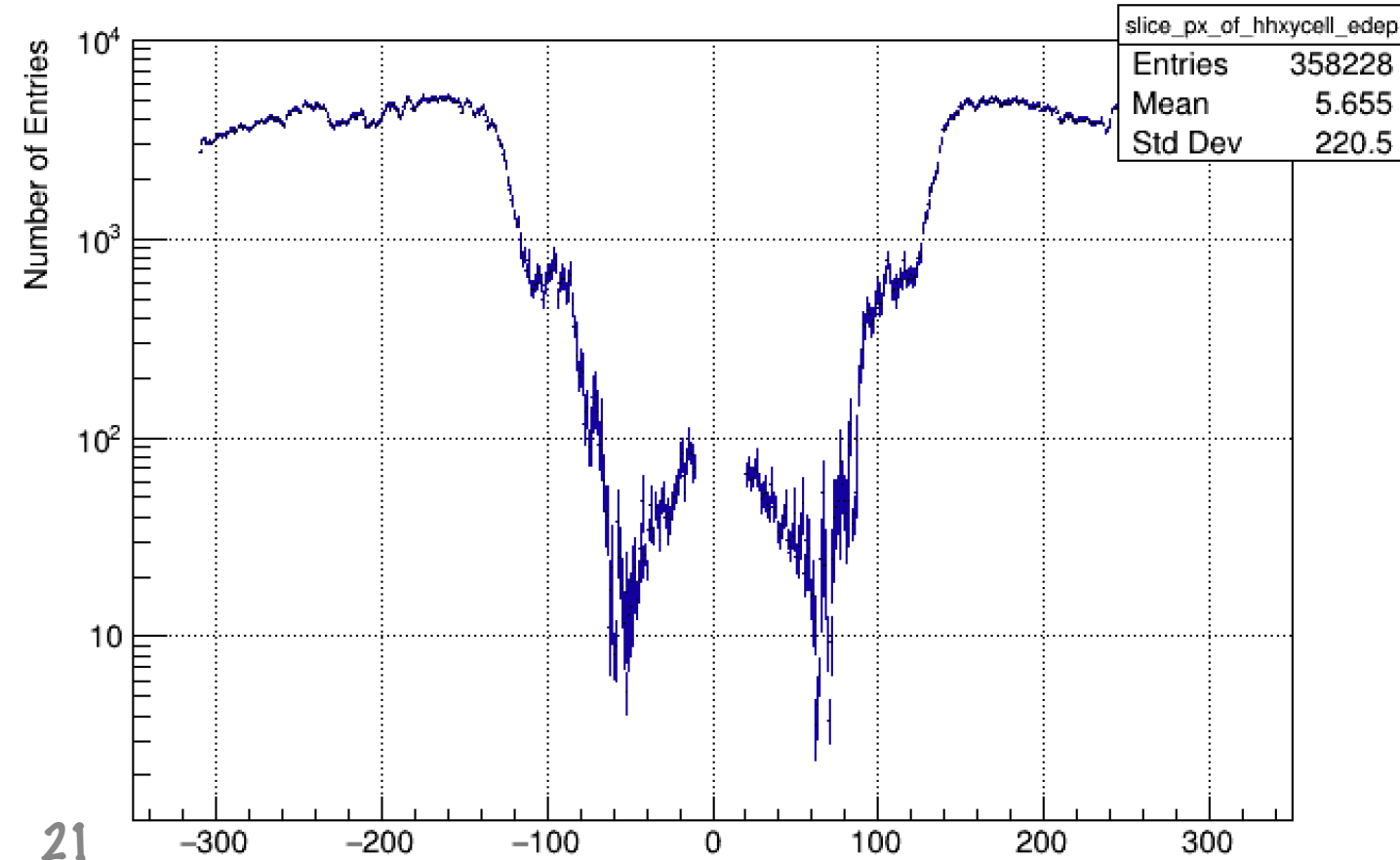




# Spectra reconstruction for the LYSO case

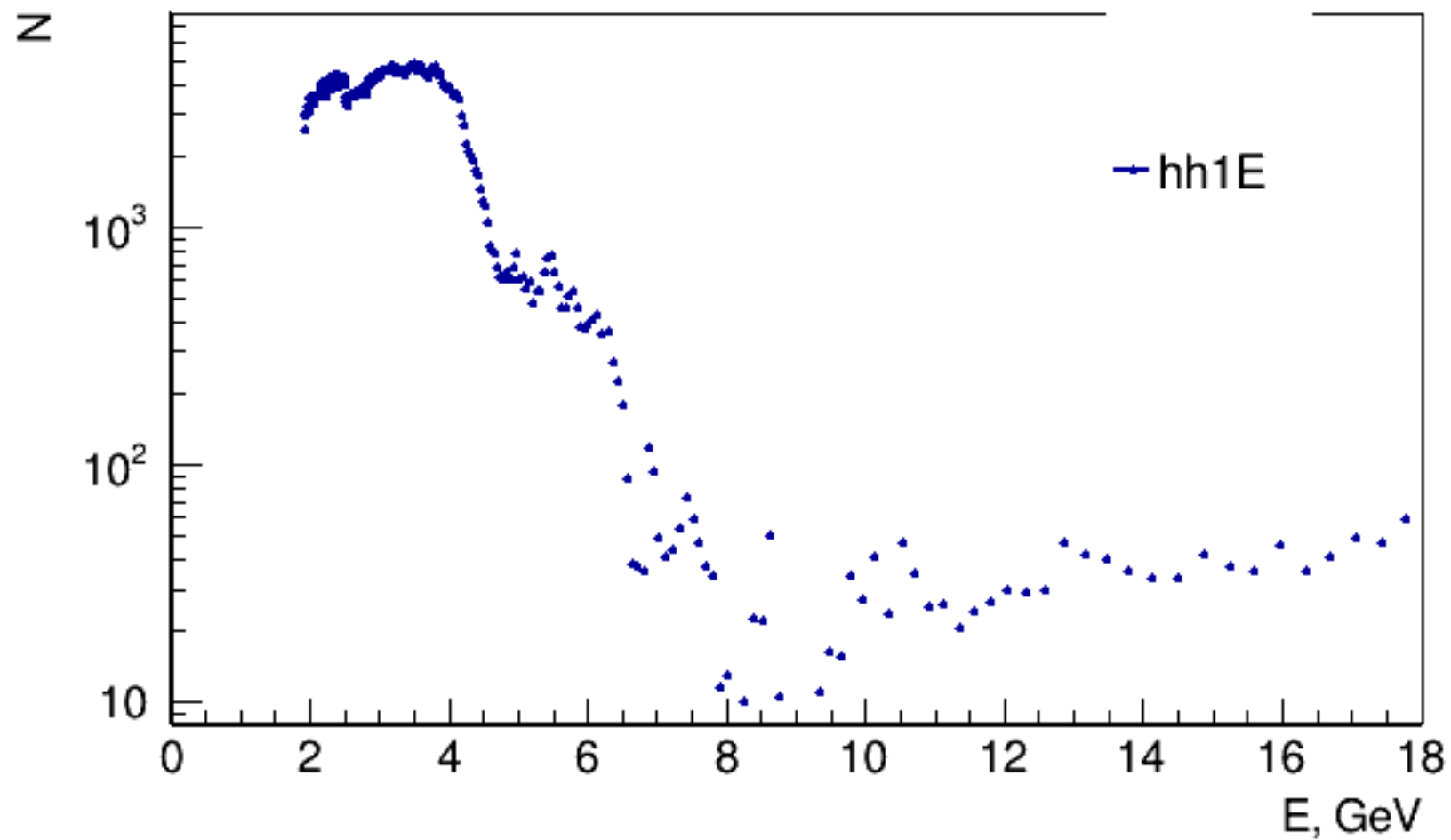
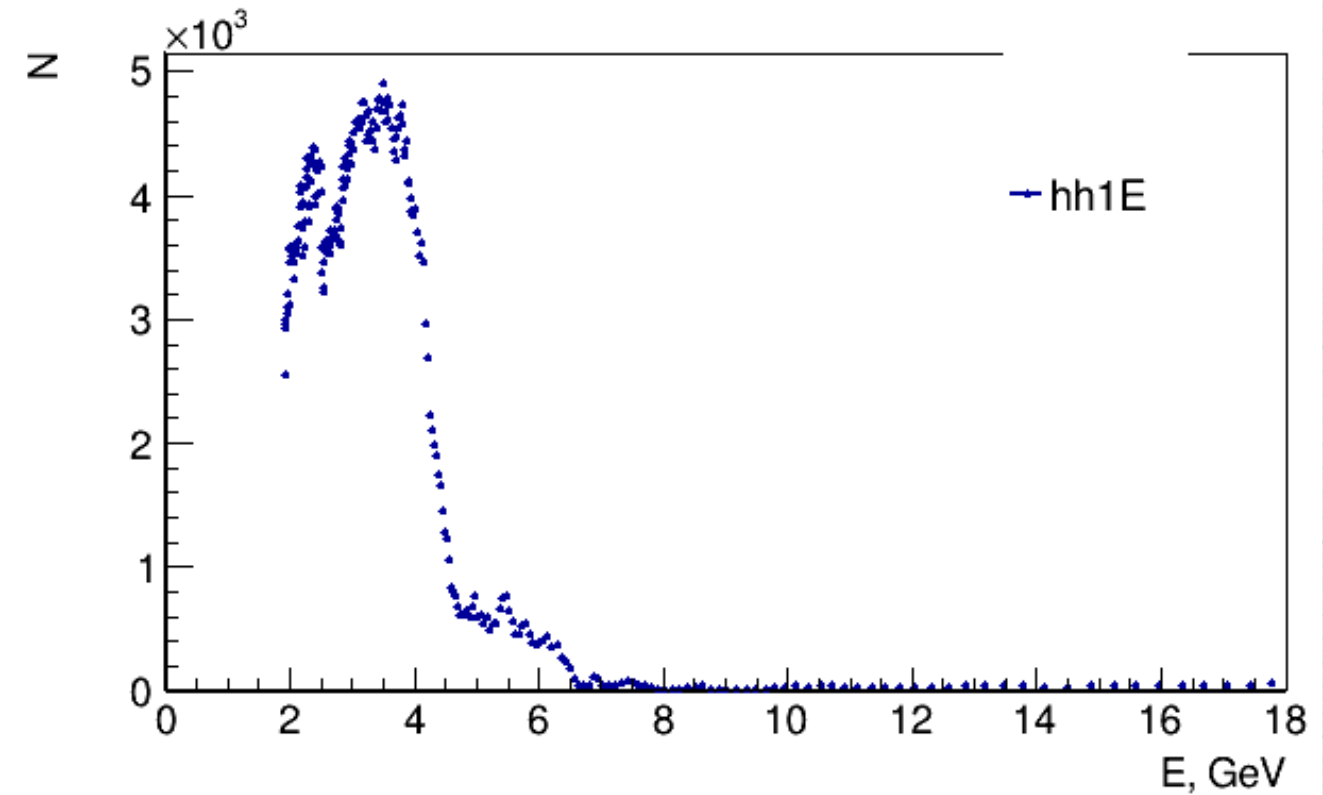
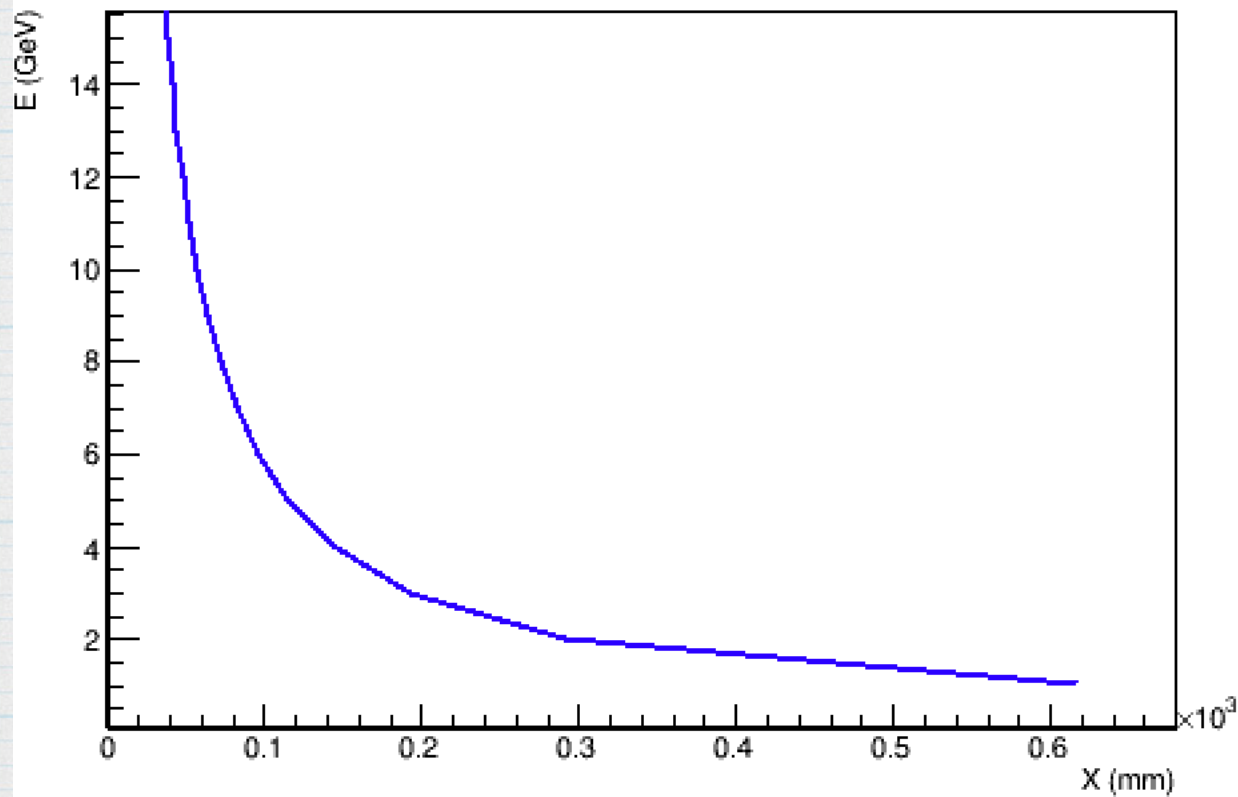


ProjectionX of biny=[21,25] [y=10.0..15.0]



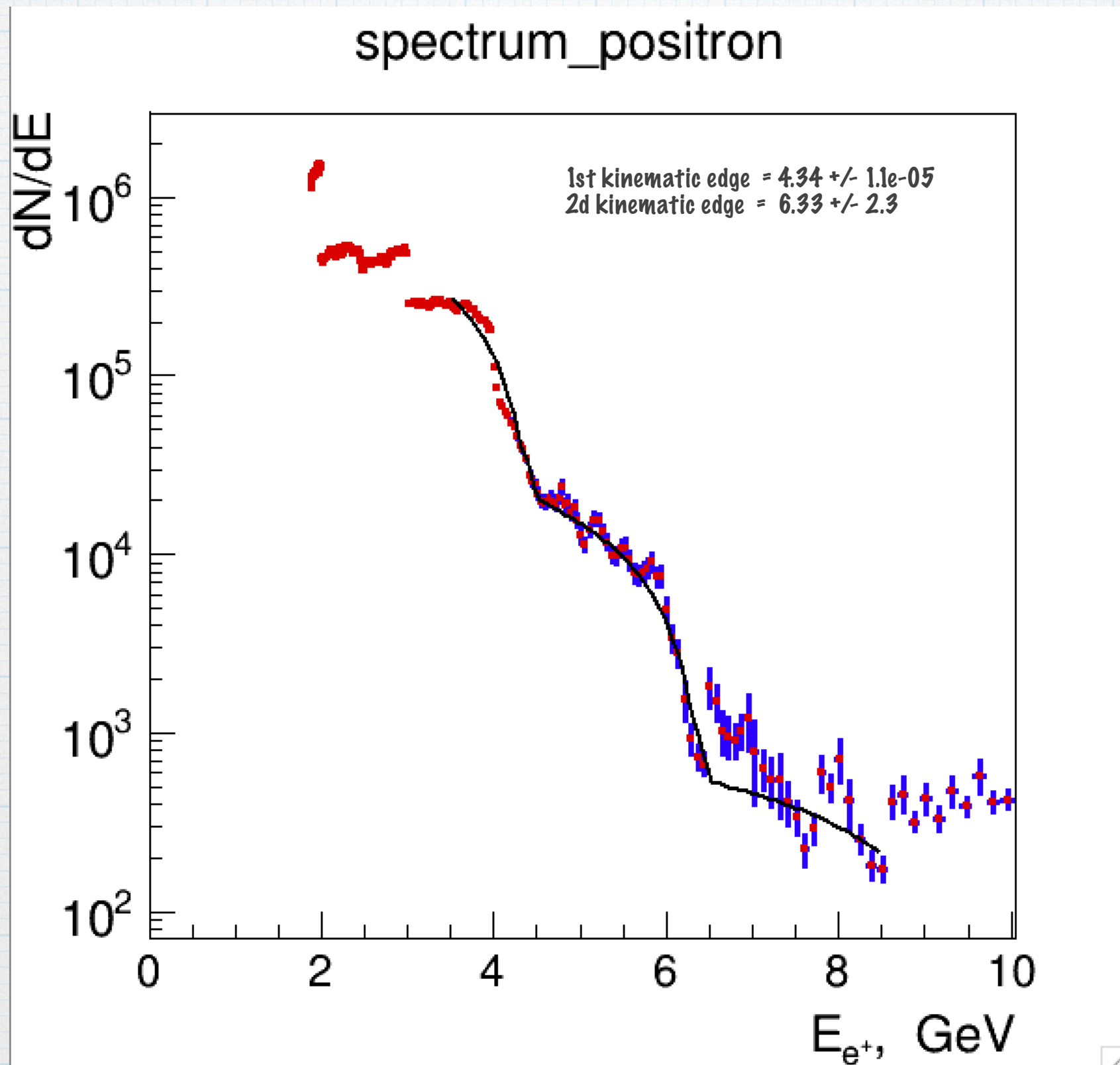


# Spectra reconstruction for the LYSO case

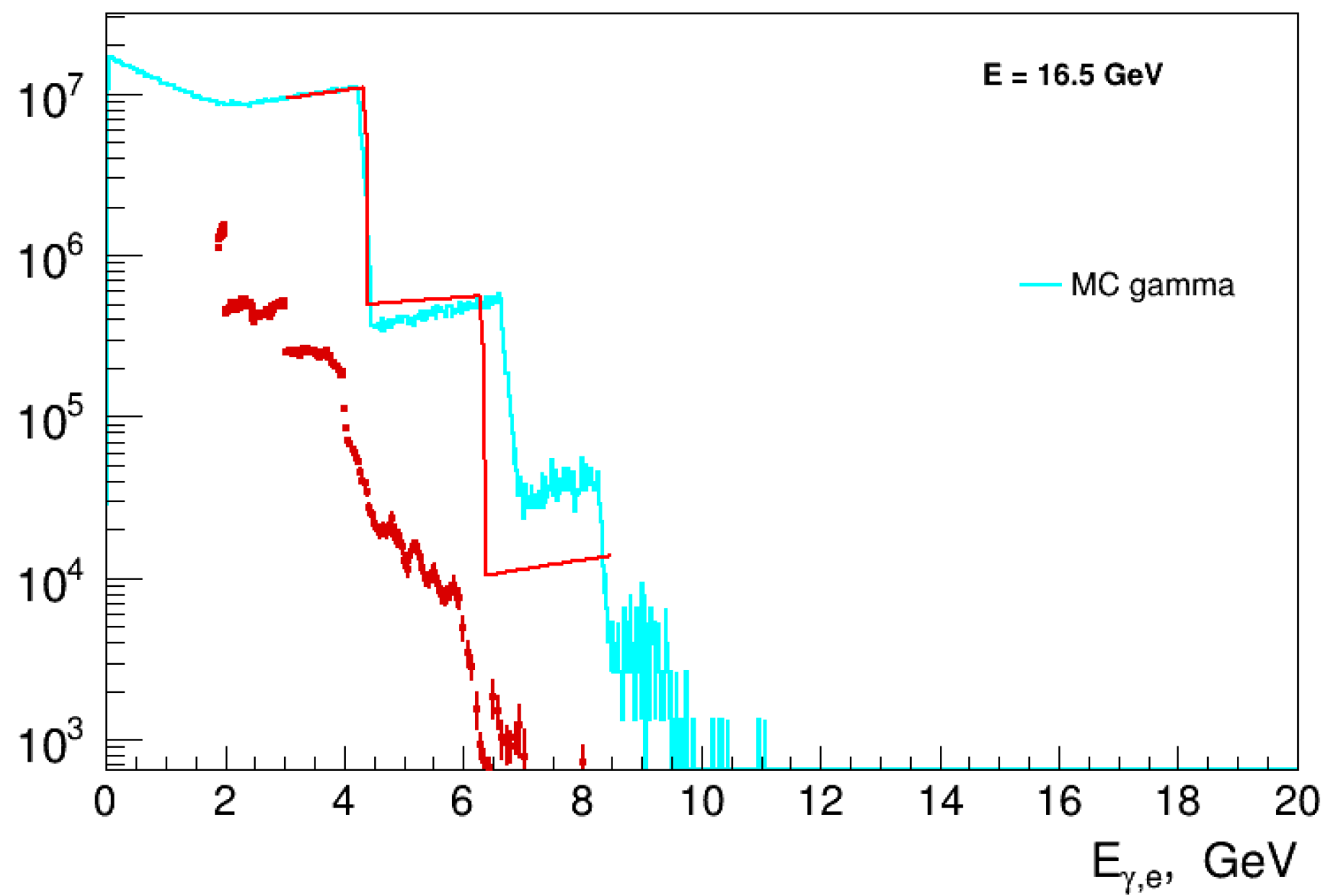
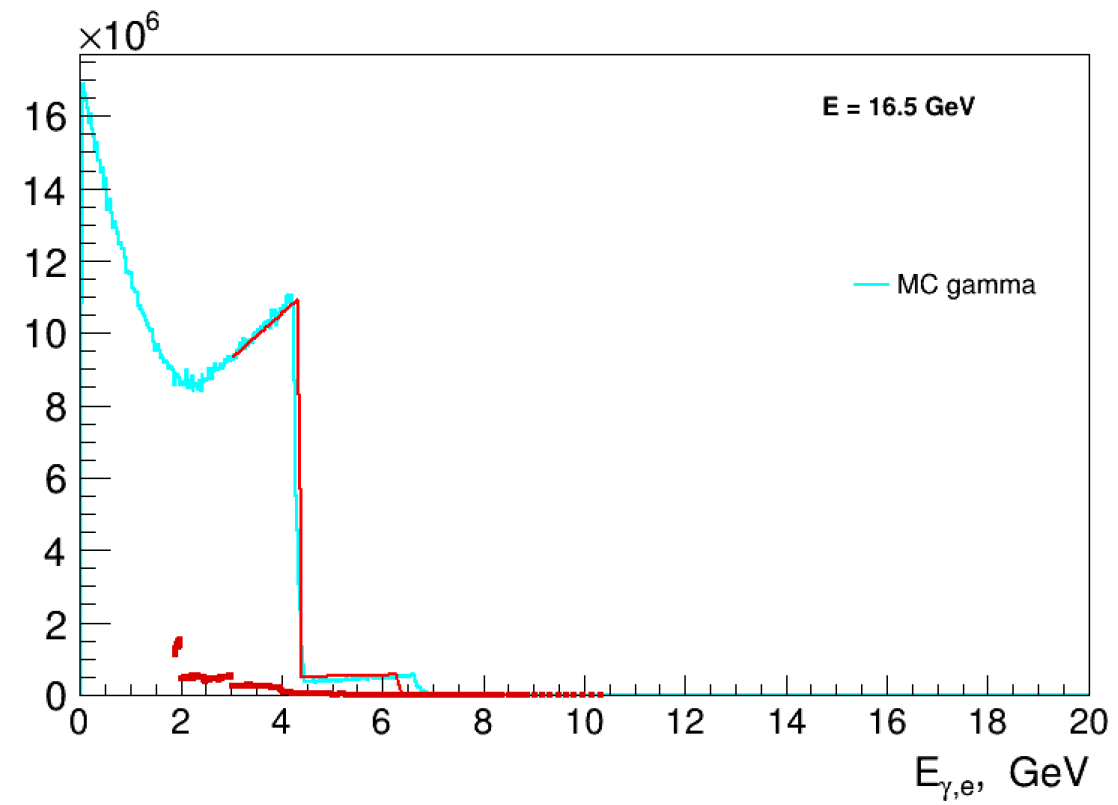




# Kinematic edges reconstruction



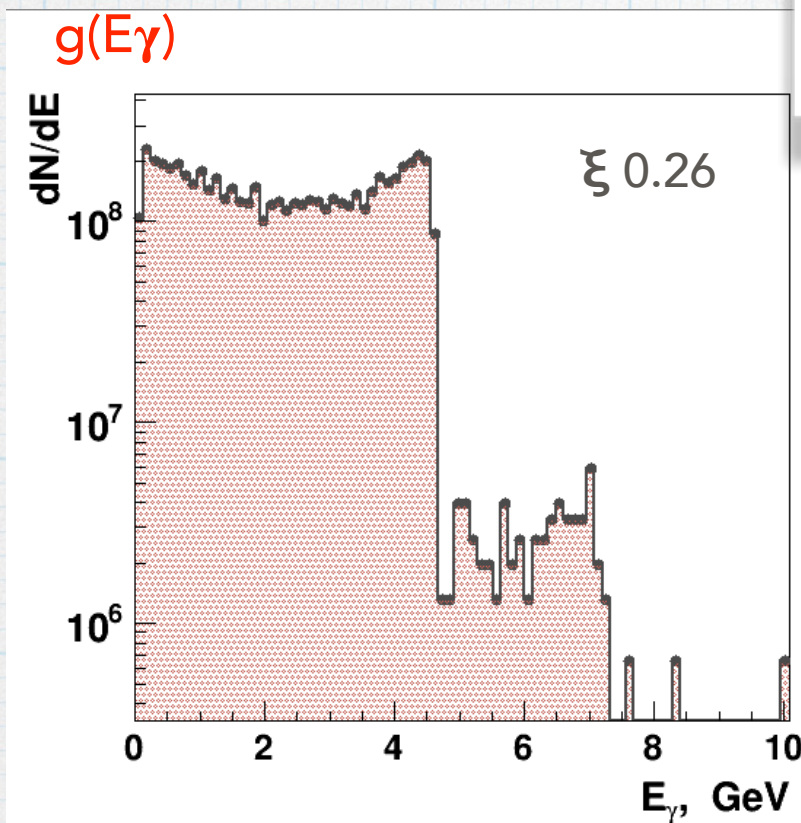




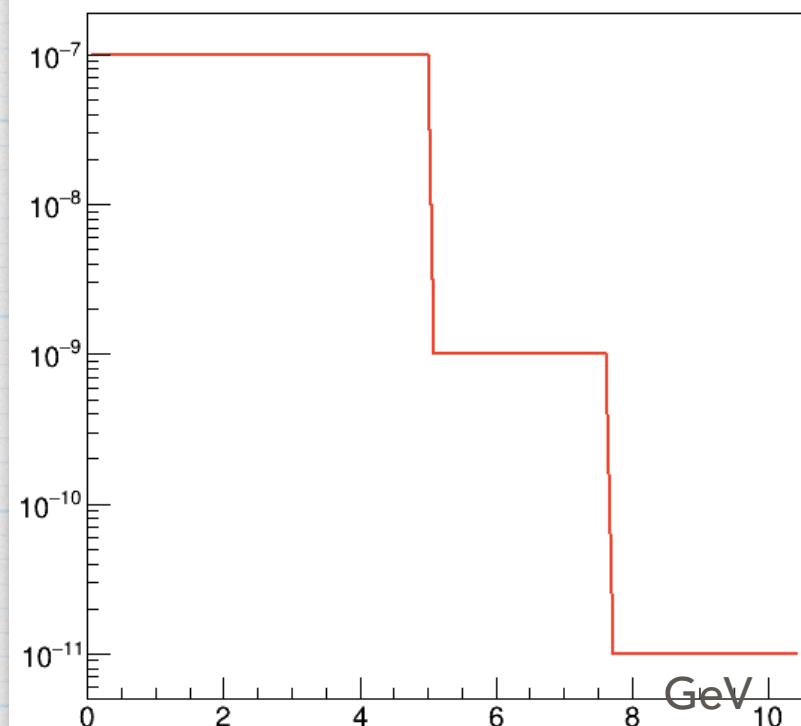


# Kinematic edges with accurate pair spectrum

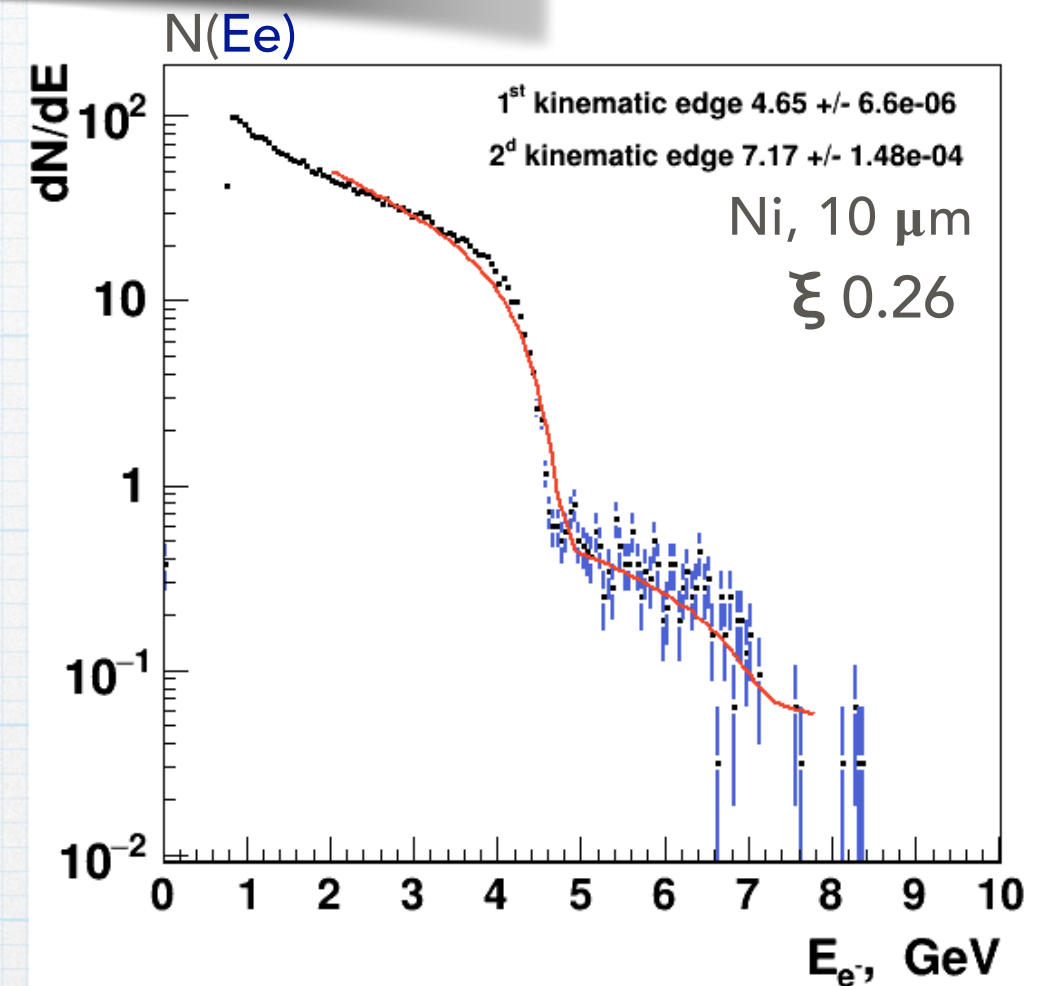
$$f(E_e) = \int \sigma(E_\gamma, E_e) g(E_\gamma) dE_\gamma$$



$g(E_\gamma, \text{pi})$  GammaSpectrumTest



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



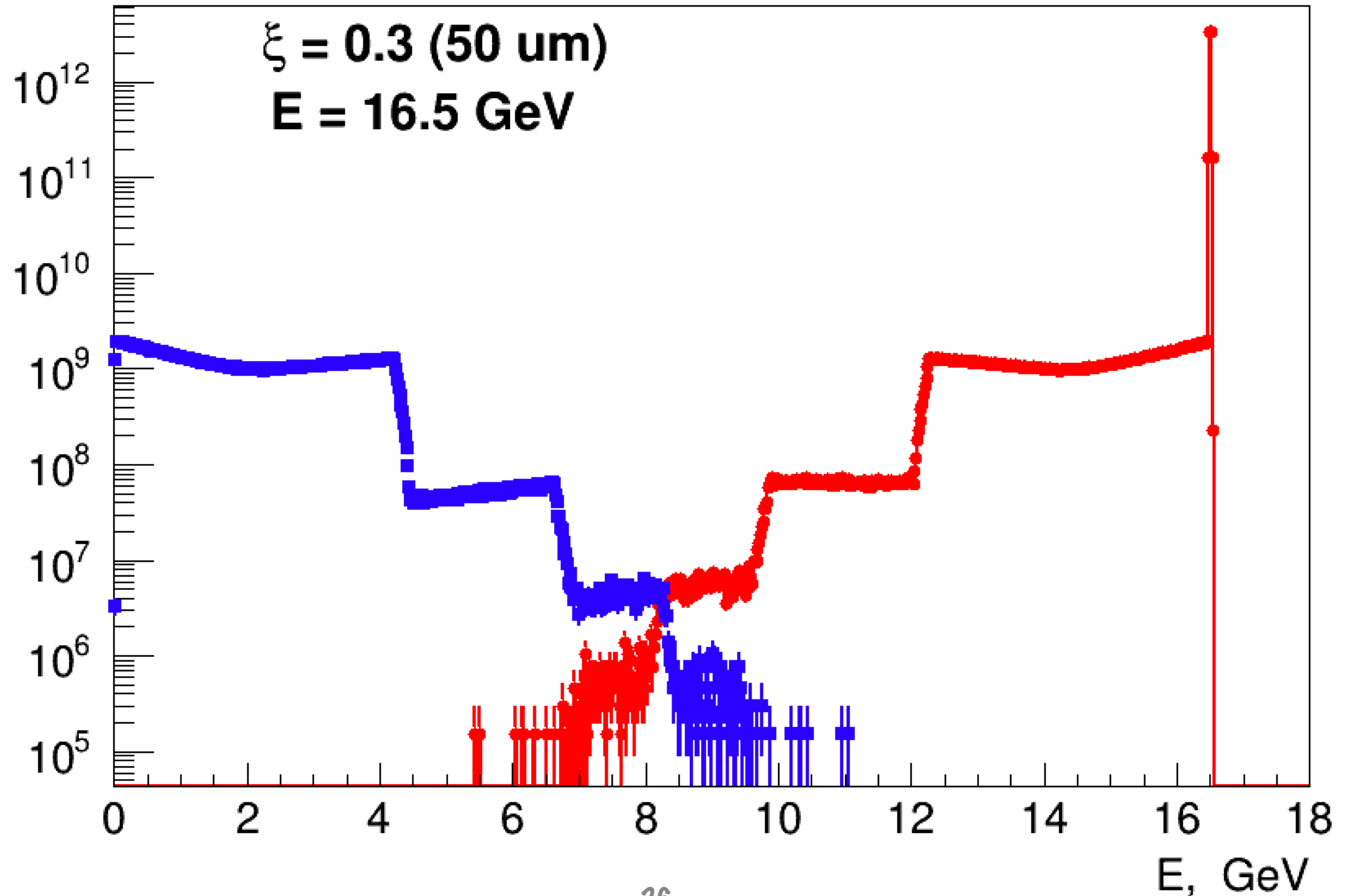
$$\int \sigma(E_\gamma, E_e) g(E_\gamma, p1, p2) dE_\gamma$$

fitting allows finding the kinematic edges quite well



# True electron/photon spectra

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)

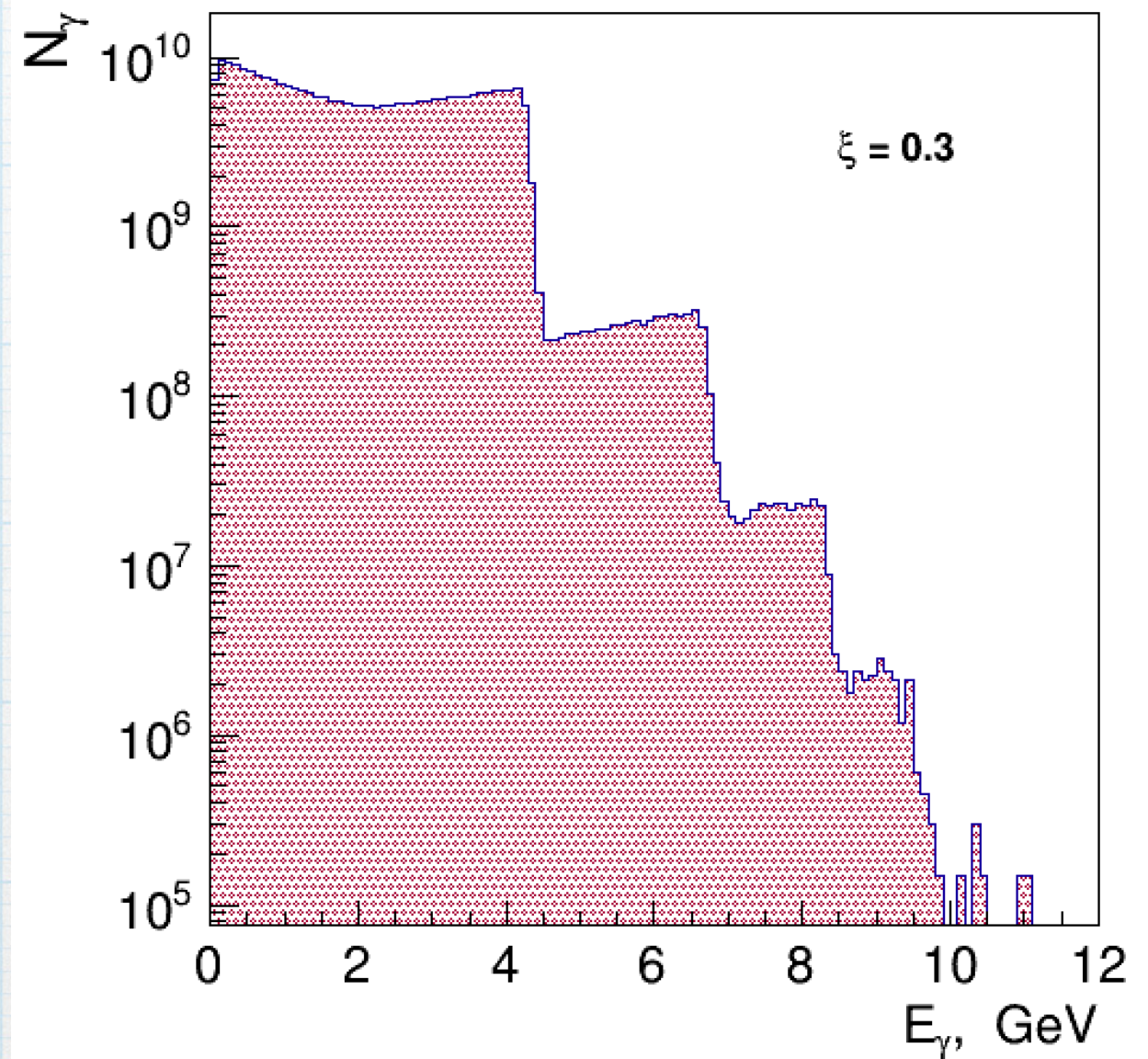
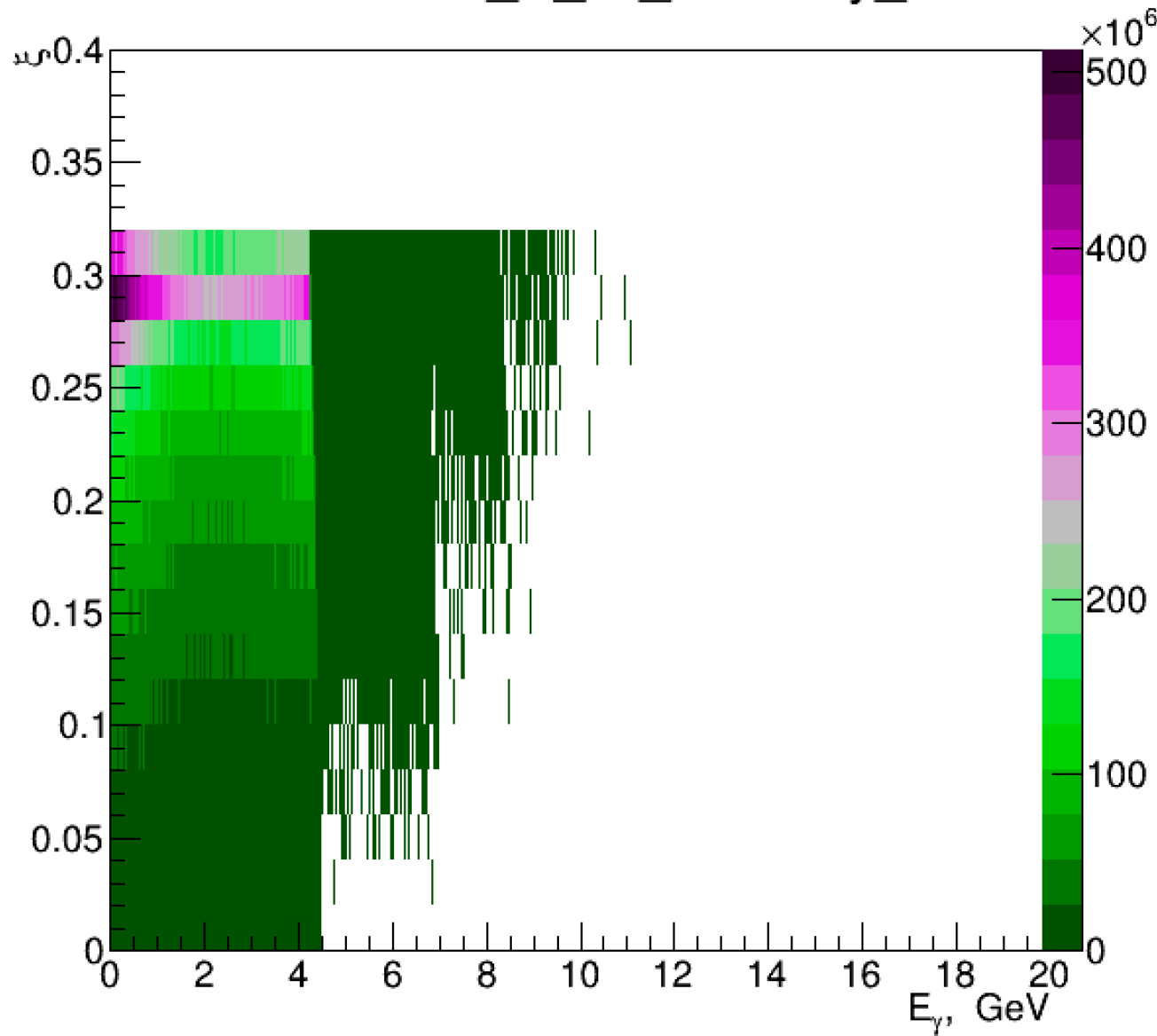




# $\xi$ vs photon energy in MC

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

Generated\_E\_vs\_Intensity\_2





# 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  $mc^2$

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

$$\sigma(E_\gamma, E_e) = \Phi(E_\gamma, E_e) * N_a \quad N_a - \text{Number of atoms}$$

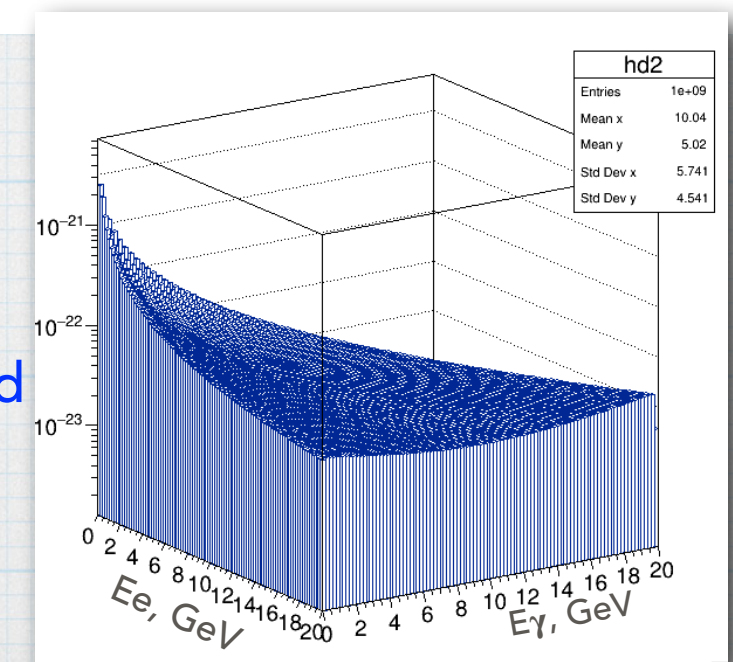
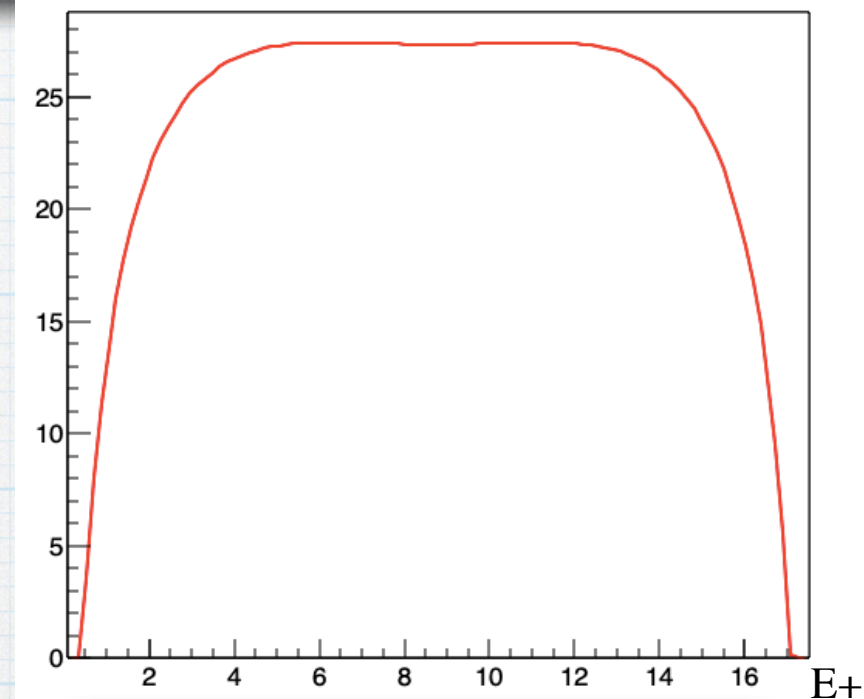
Photon spectra  $g(E_\gamma)$  can be reconstructed by fitting

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

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

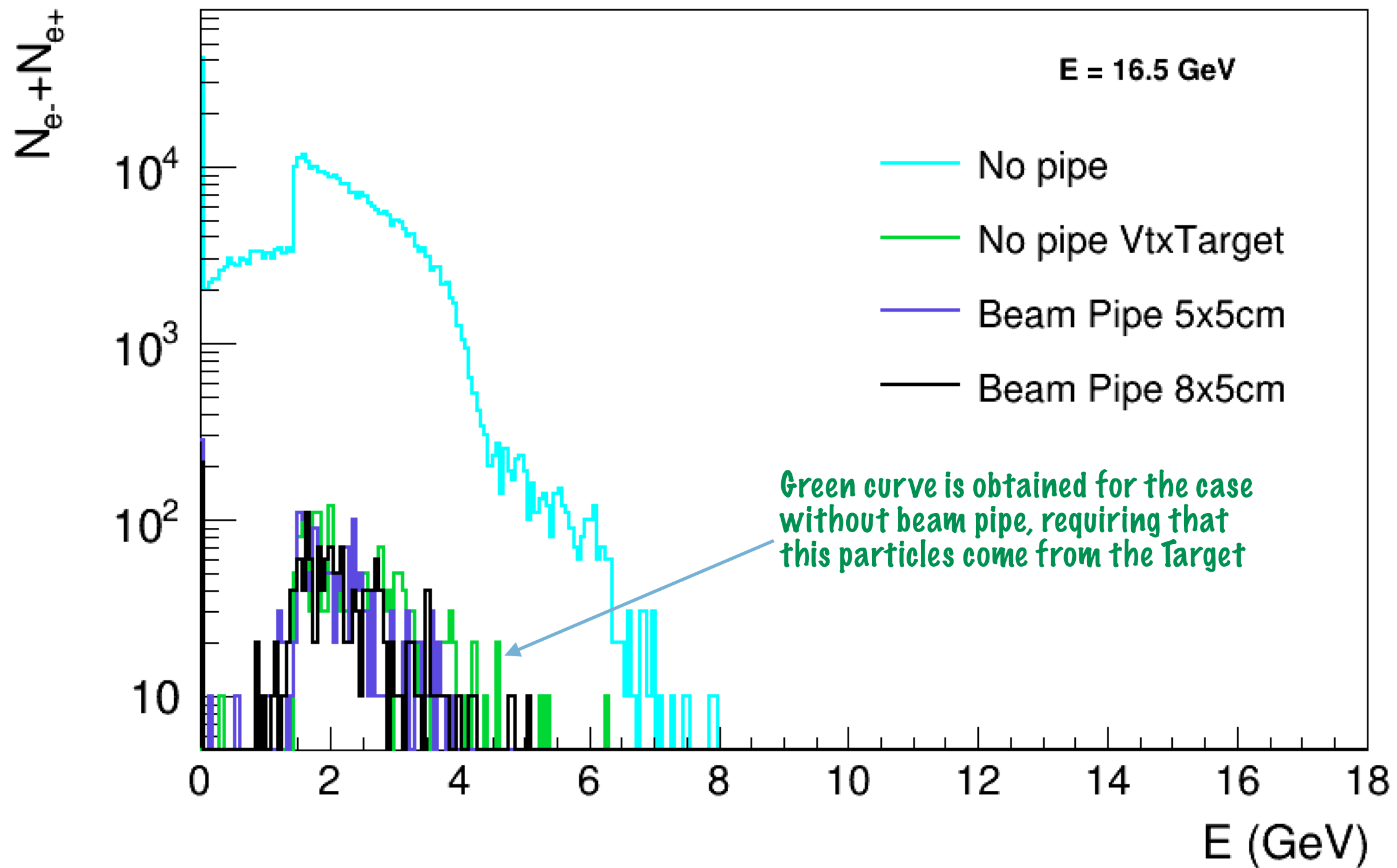
Since  $\sigma(E_\gamma, E_e)$  depends on number of scatters  $N_a$  defined by the thickness of the target the approach can be tested by using the thickness as fit parameter

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





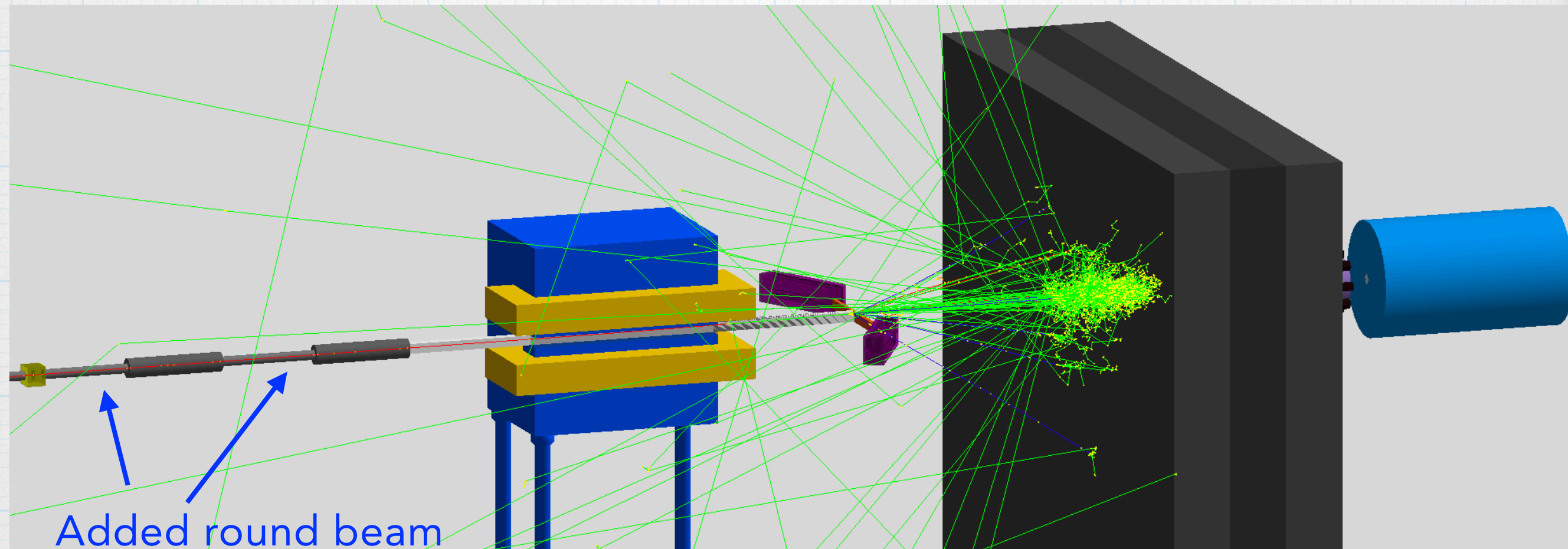
# Spectra



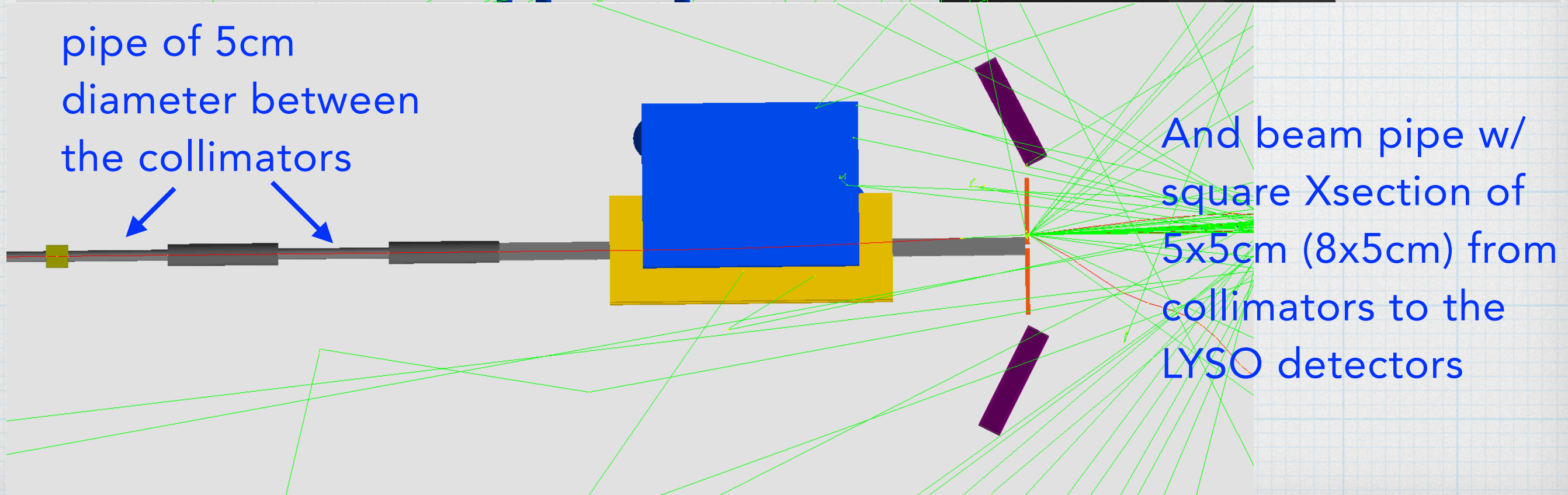
Without beam pipe we measure in Compton detectors a lot  $e^-/e^+$  pairs that were created in the air. Only 4%  $e^-/e^+$  are generated in the Target



# Setup with the beam pipe



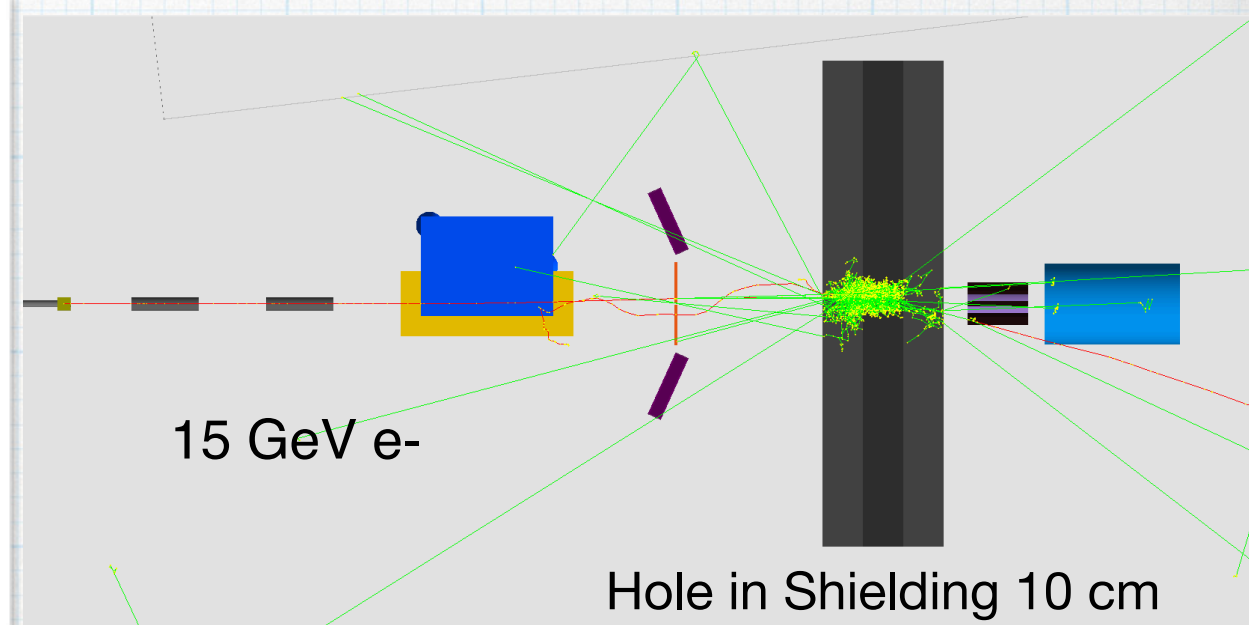
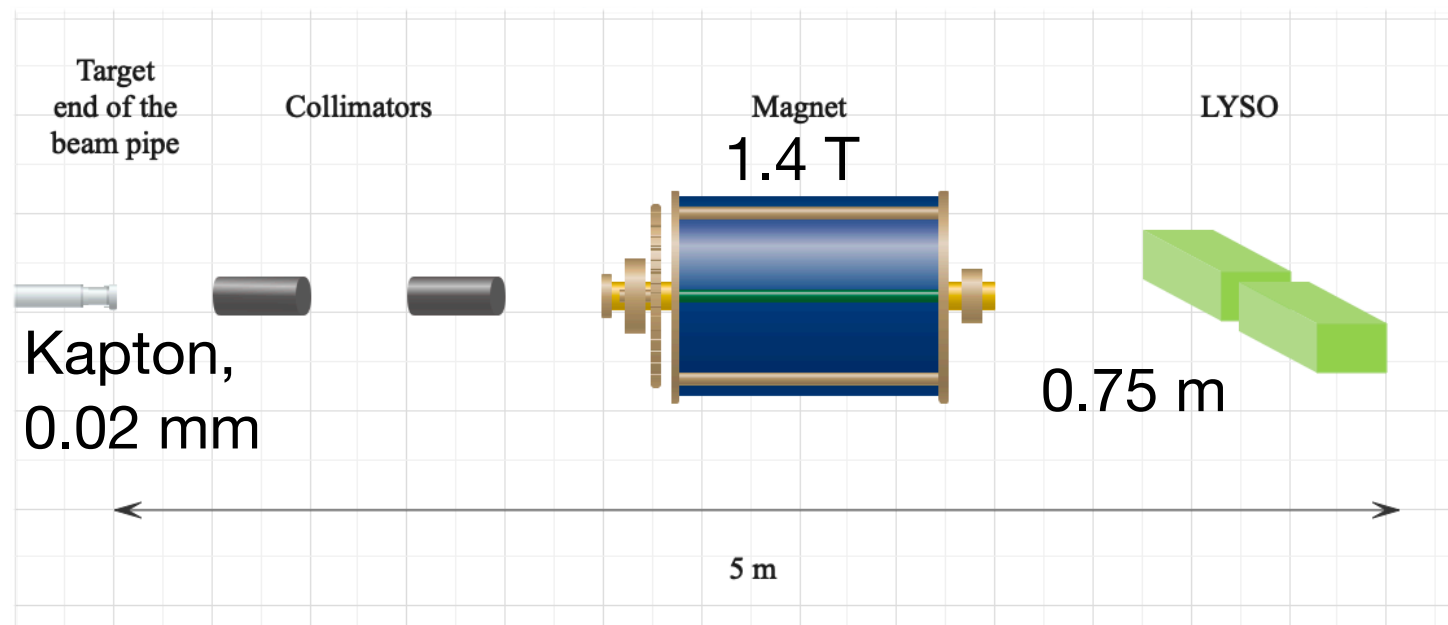
Added round beam  
pipe of 5cm  
diameter between  
the collimators



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



# FDS with LYSO calorimeters



## Aug 2020 Data Runs, bunch/pulse crossings completed

Experiment Config	$w_0 = 3\mu\text{m}$	$w_0 = 3.5\mu\text{m}$	$w = 0, 4.0\mu\text{m}$	$w_0 = 4.5\mu\text{m}$	$w_0 = 5.0\mu\text{m}$	$w_0 = 8.0\mu\text{m}$	$w_0 = 20.0\mu\text{m}$	$w_0 = 50.0\mu\text{m}$	$w_0 = 100.0\mu\text{m}$
peak SQED $\xi$	5.12	4.44	3.88	3.45	3.1	1.94	0.78	0.31	0.15
peak SQED $\chi$ (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

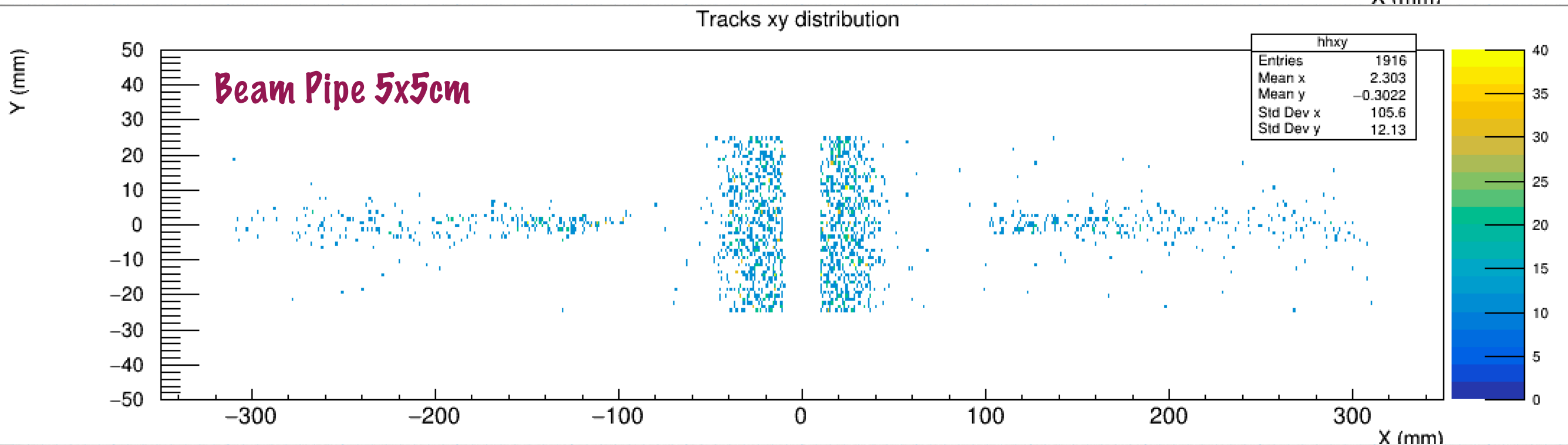
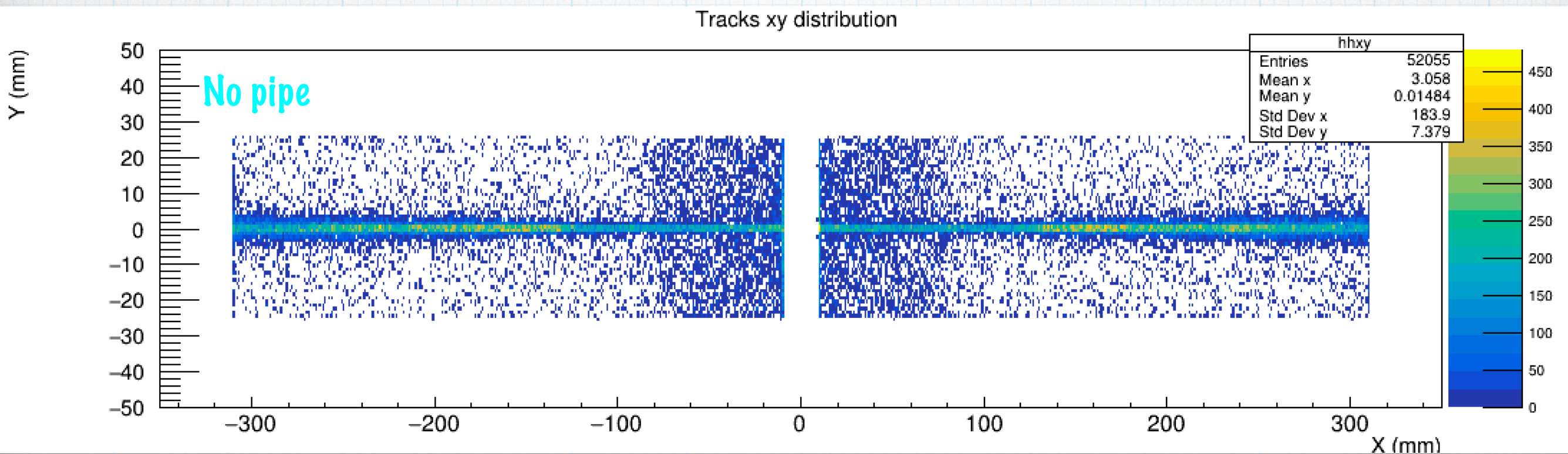
- \* The scintillators are modelled as a 15x5x2 cm (x:y:z) layer of lyso material
- \* The crystal (bin) size of the scintillators are 2 x 1 mm (finer segmentation in x; the deflection direction) giving 25 x 300 bins.

LYSO ( $\text{Lu}_{1.8}\text{Y}_{0.2}\text{SiO}_5$ )

All studies were performed with 100 BX at the laser intensity  $\xi = 0.3$  for 16.5 GeV electron beam



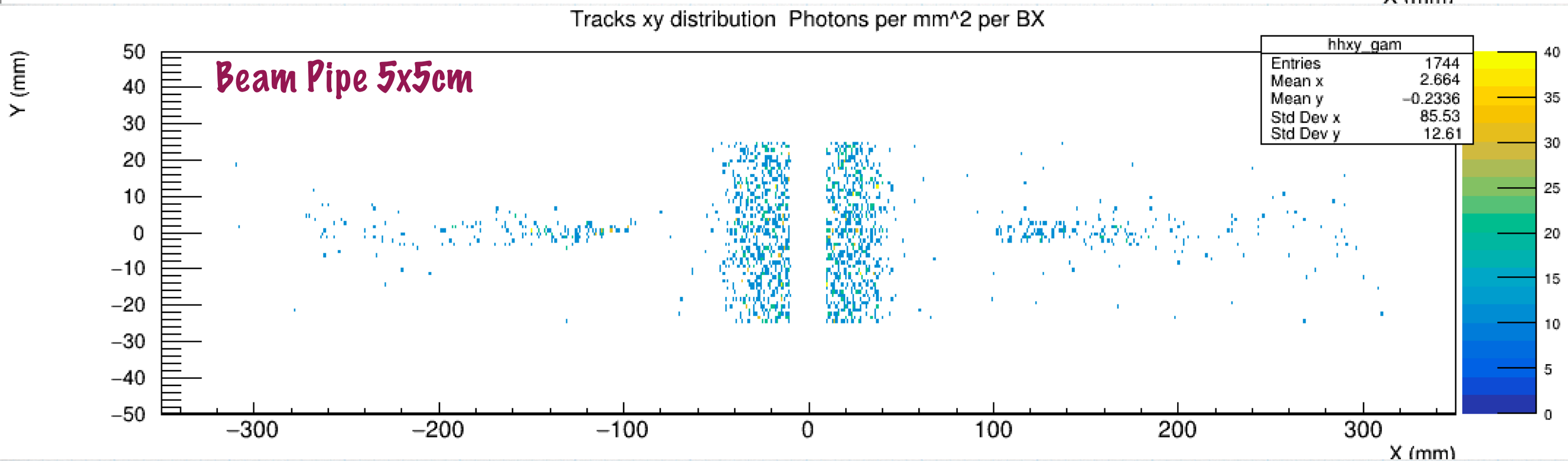
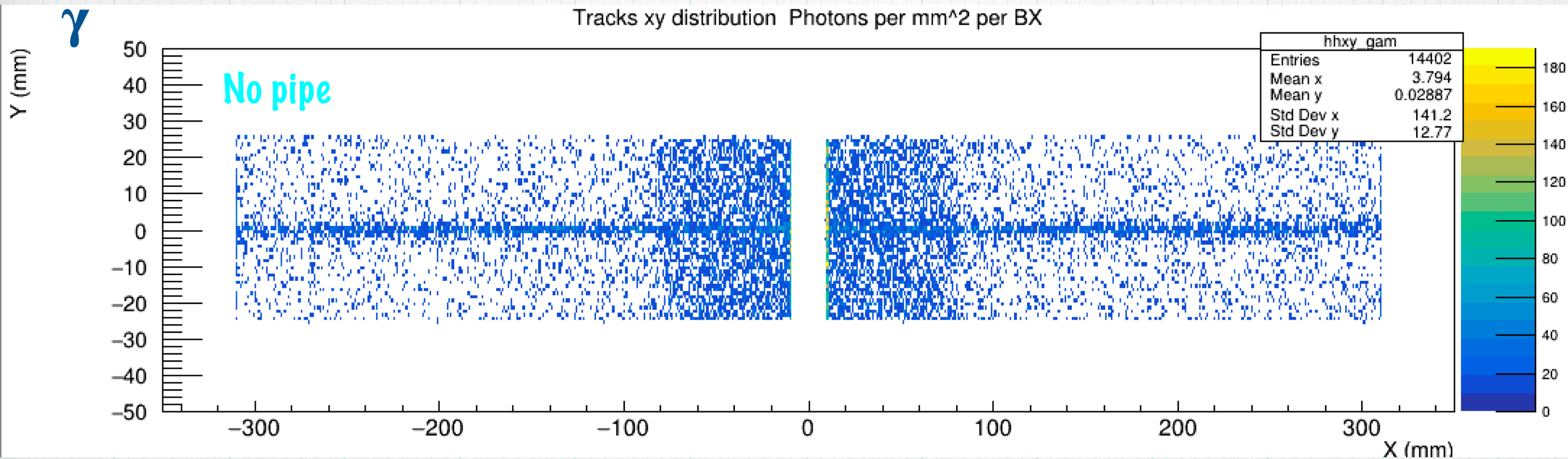
# Number of particles per BX per mm<sup>2</sup>, all particles



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

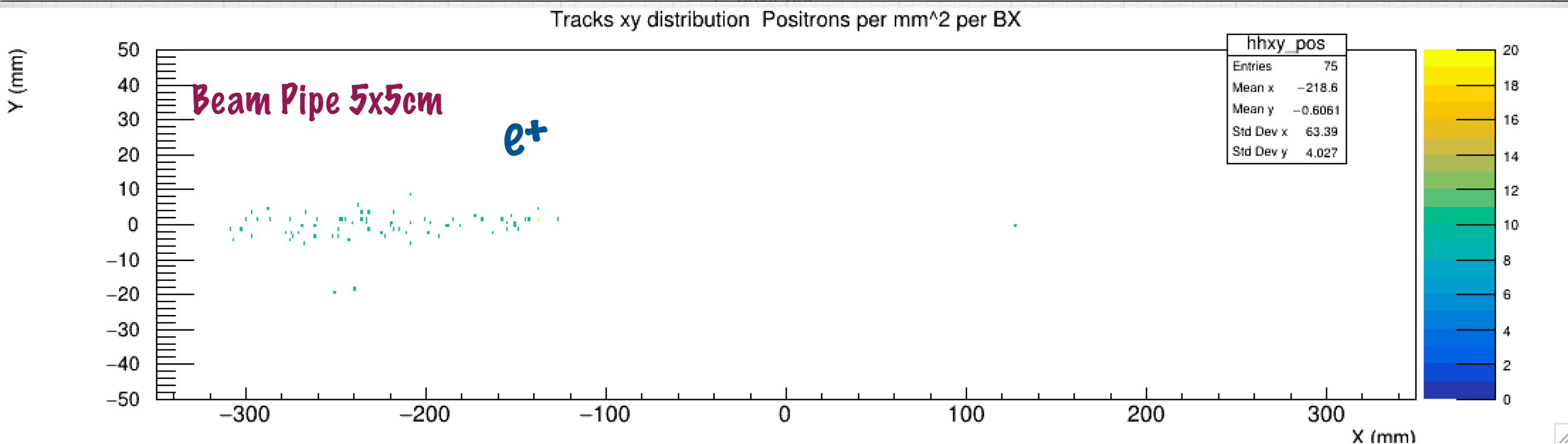
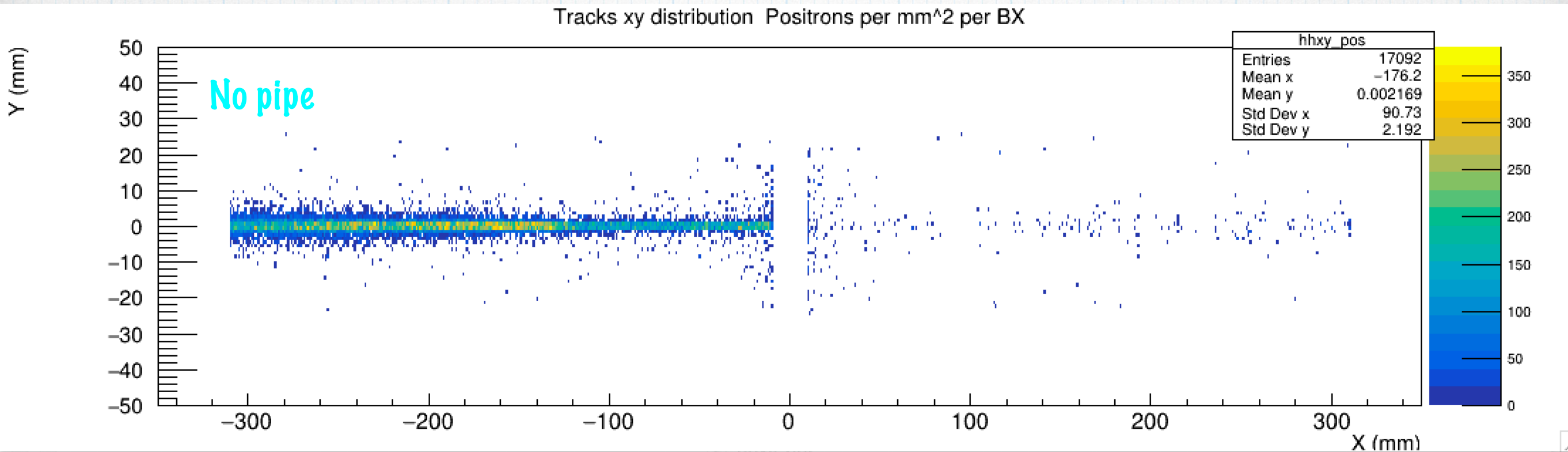


# Number of particles per BX per mm<sup>2</sup>, Photons



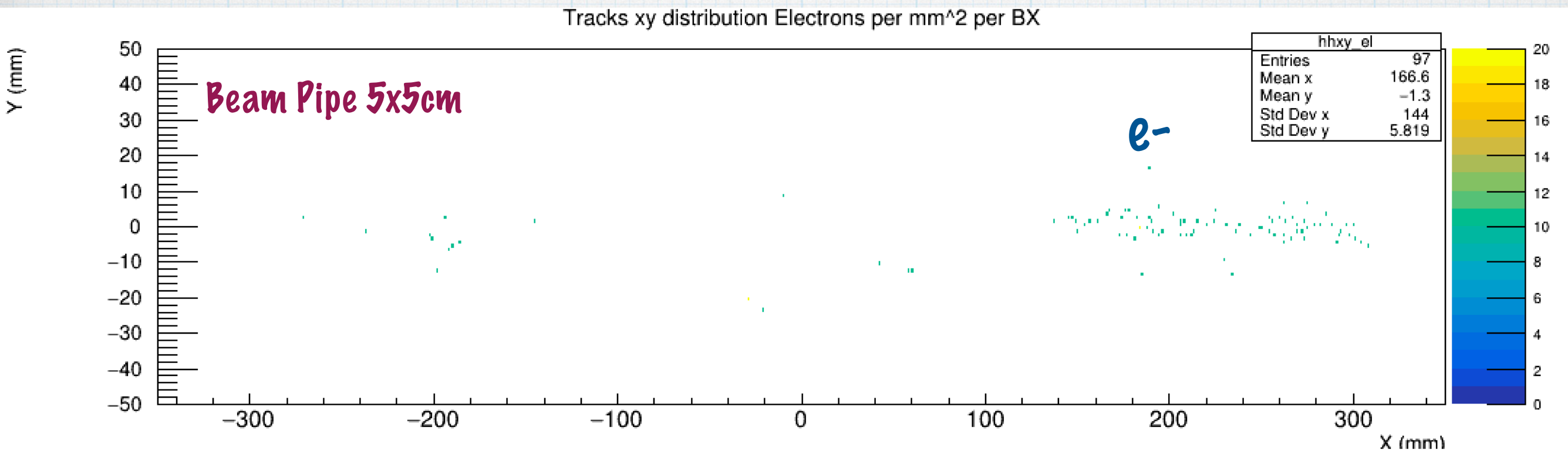
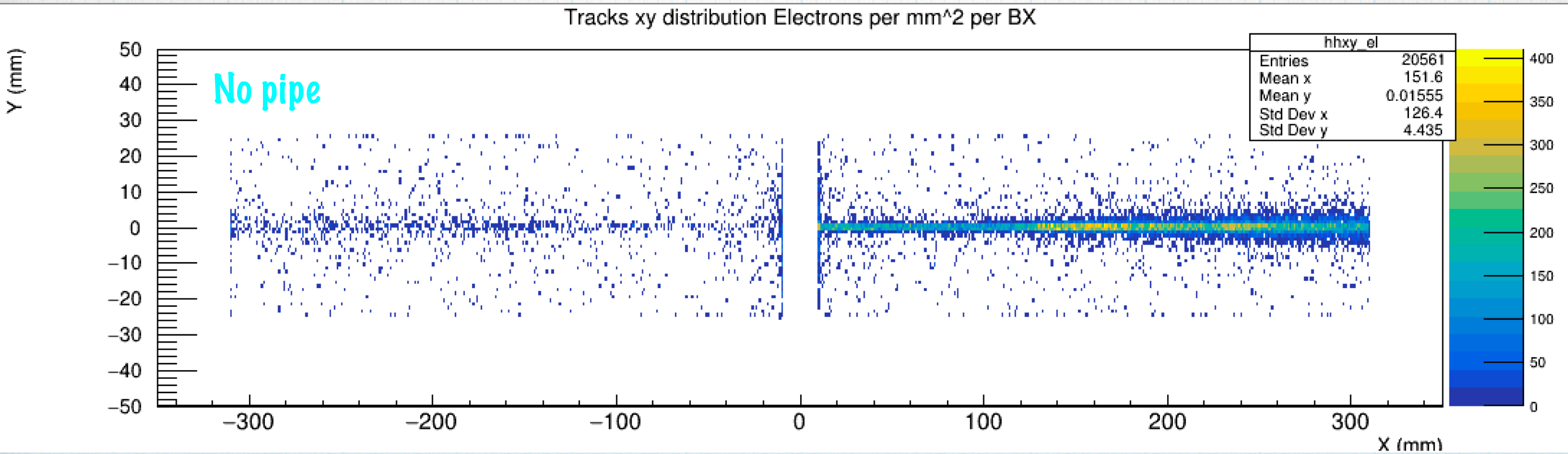


# Number of particles per BX per mm<sup>2</sup>, Positrons



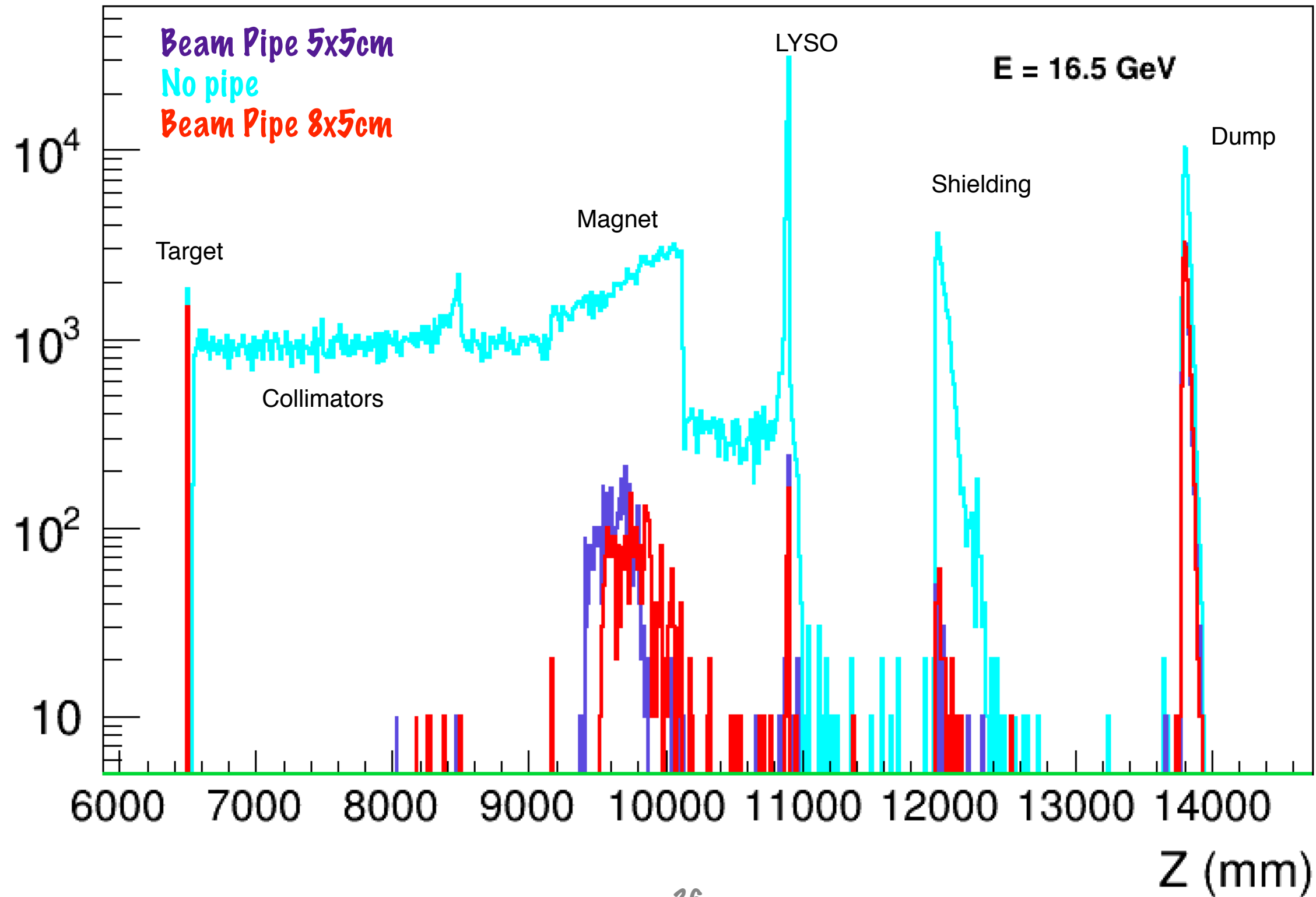
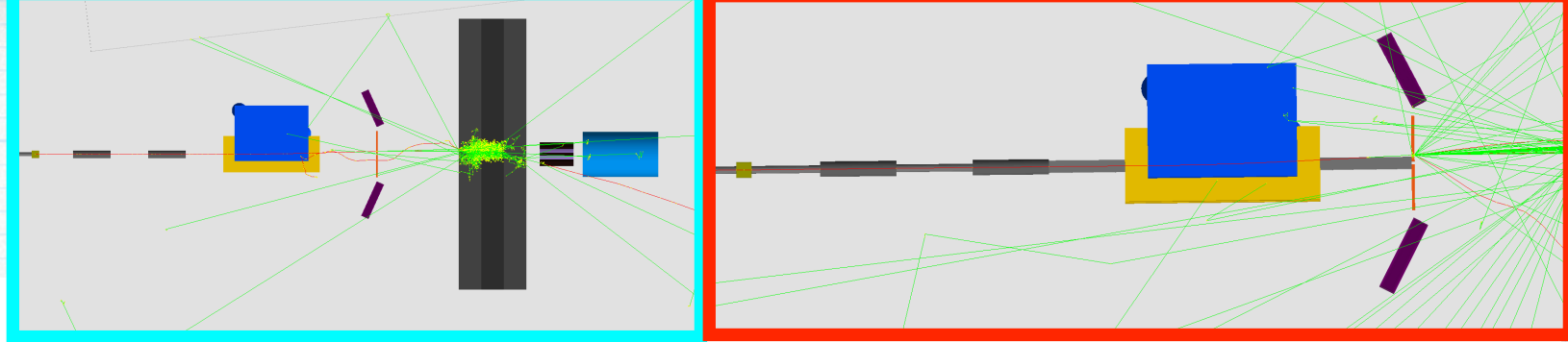


# Number of particles per BX per mm<sup>2</sup>, Electrons



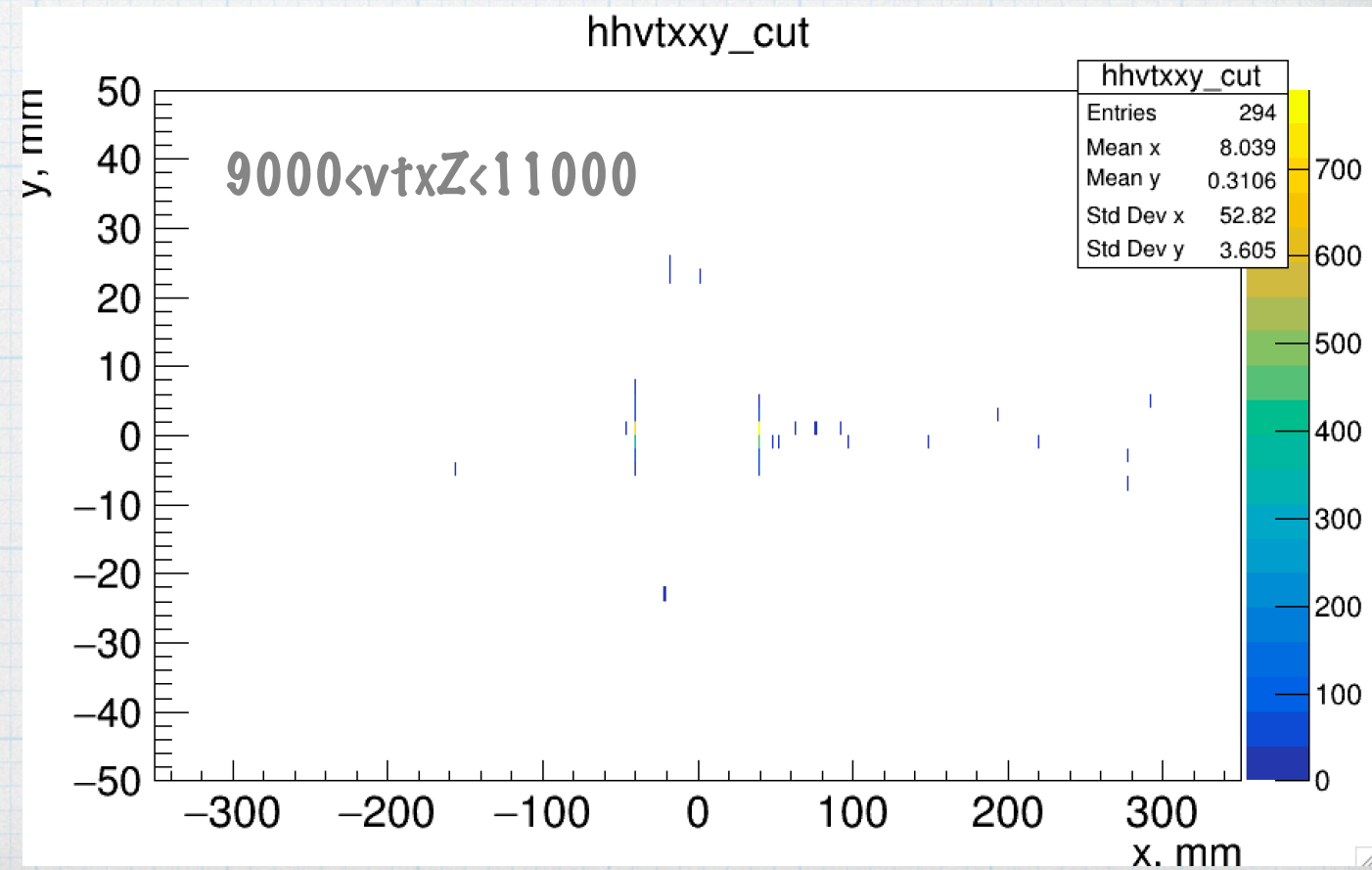
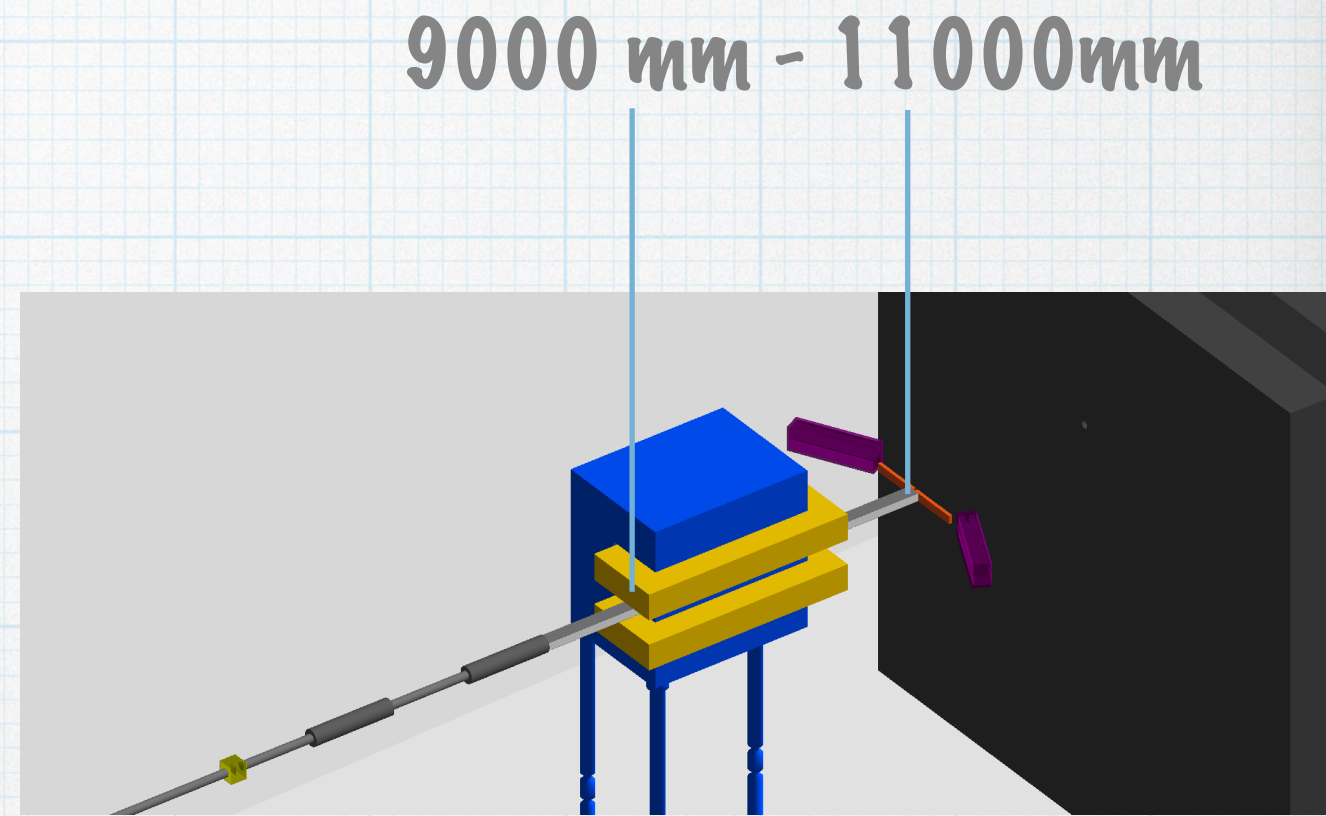
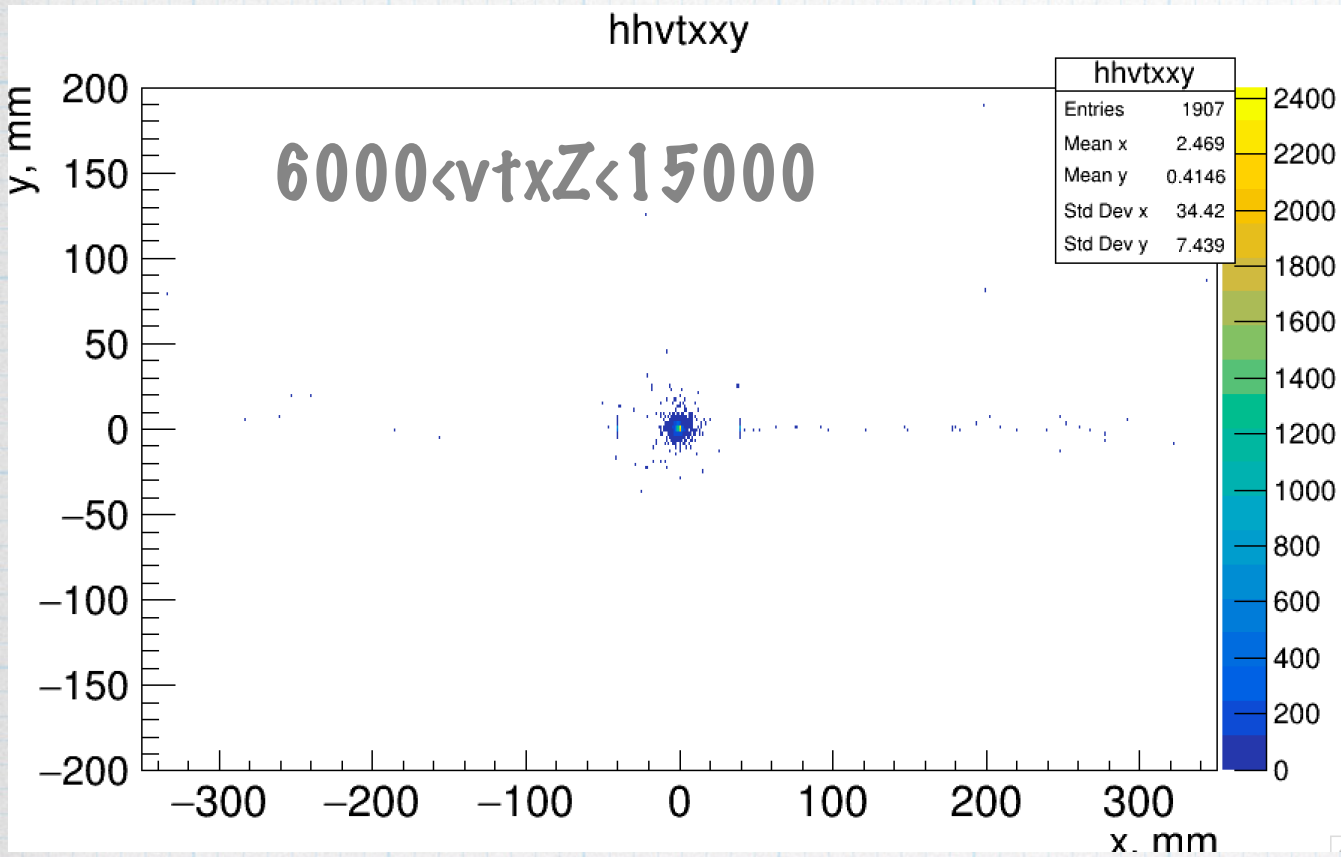


# Vertex z



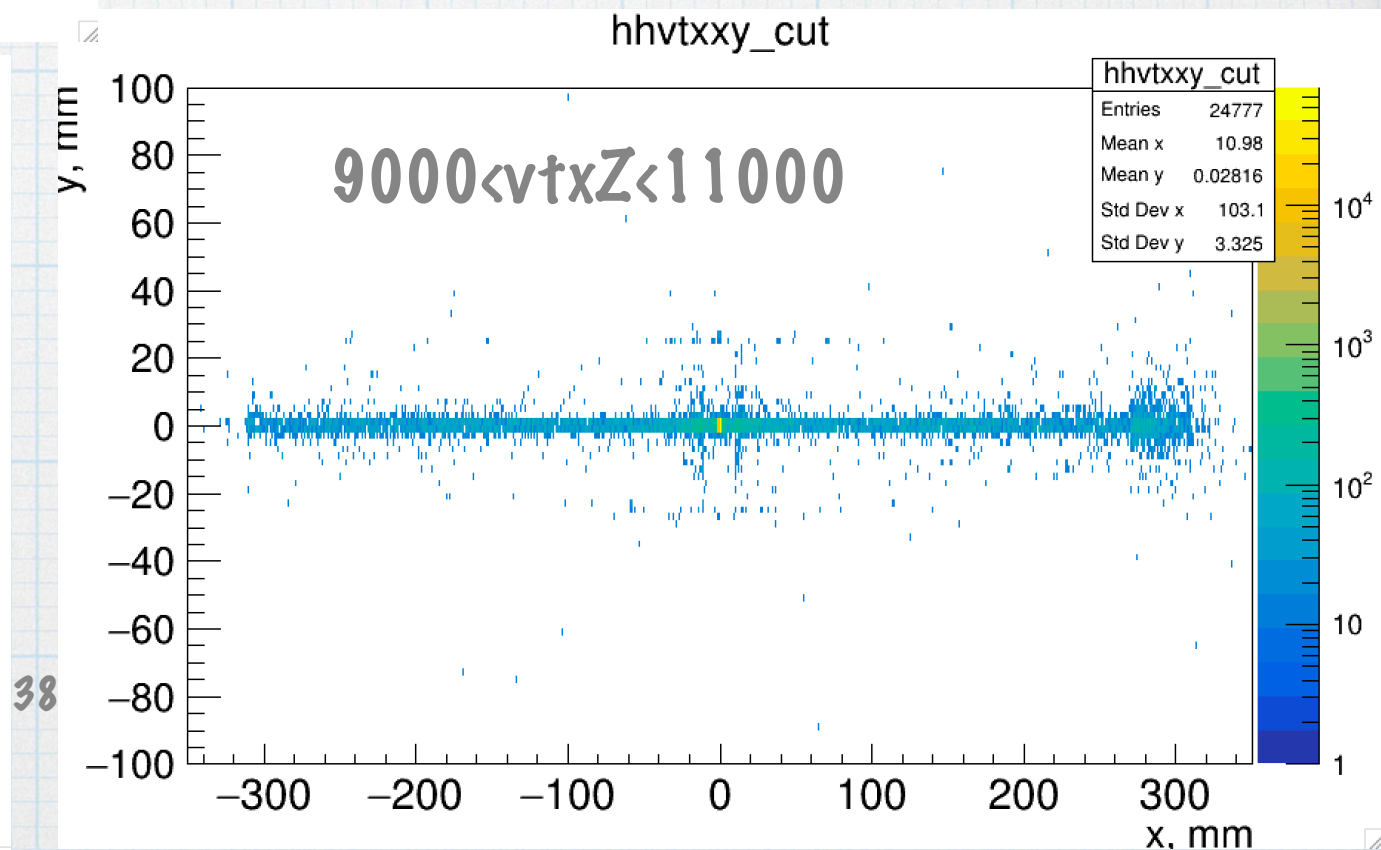
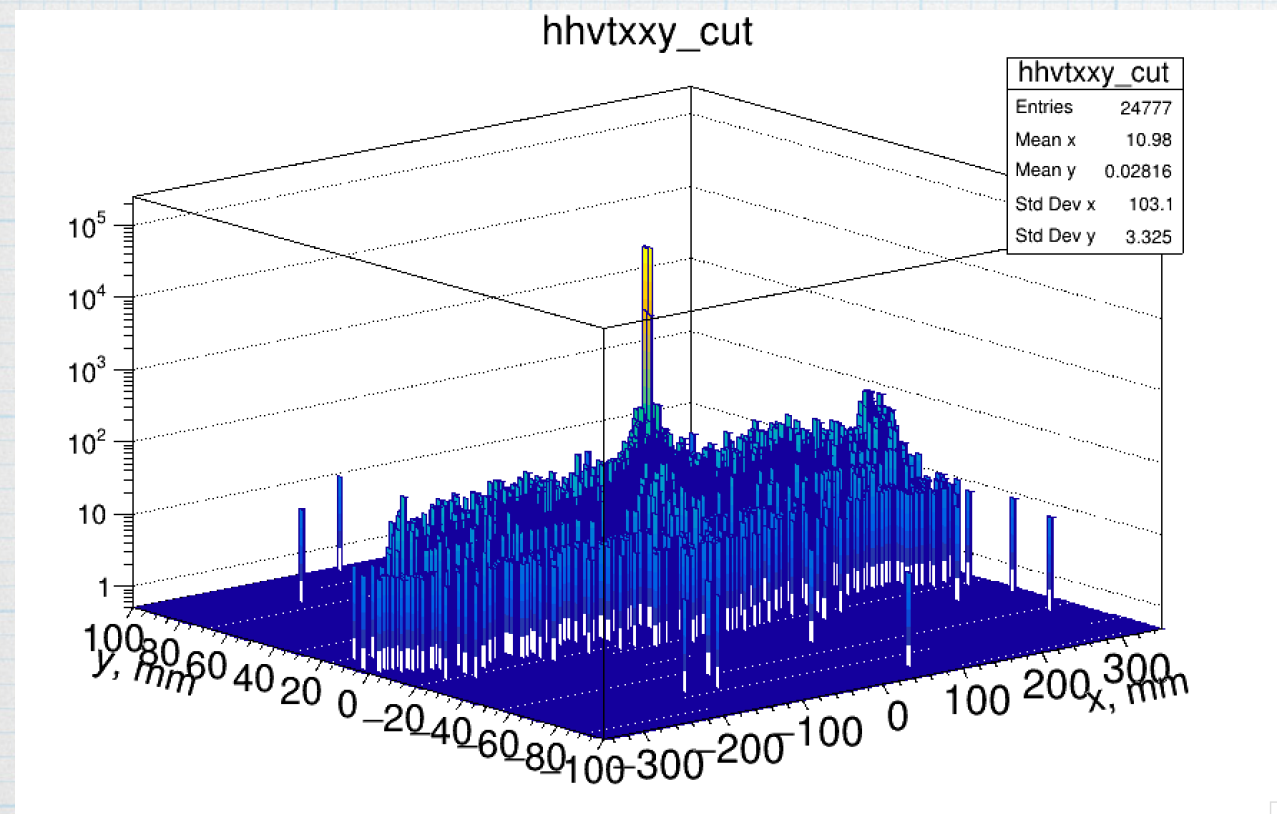
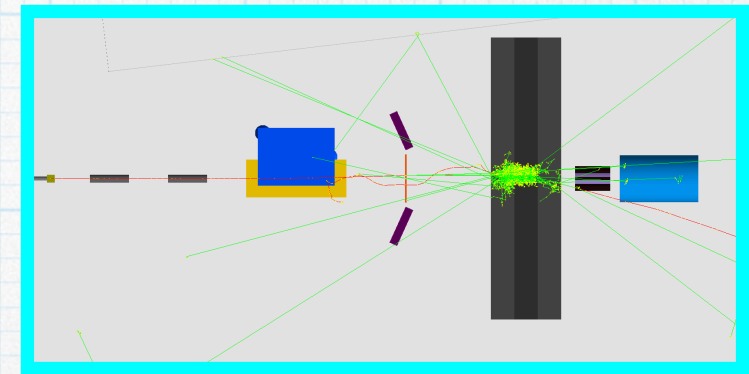
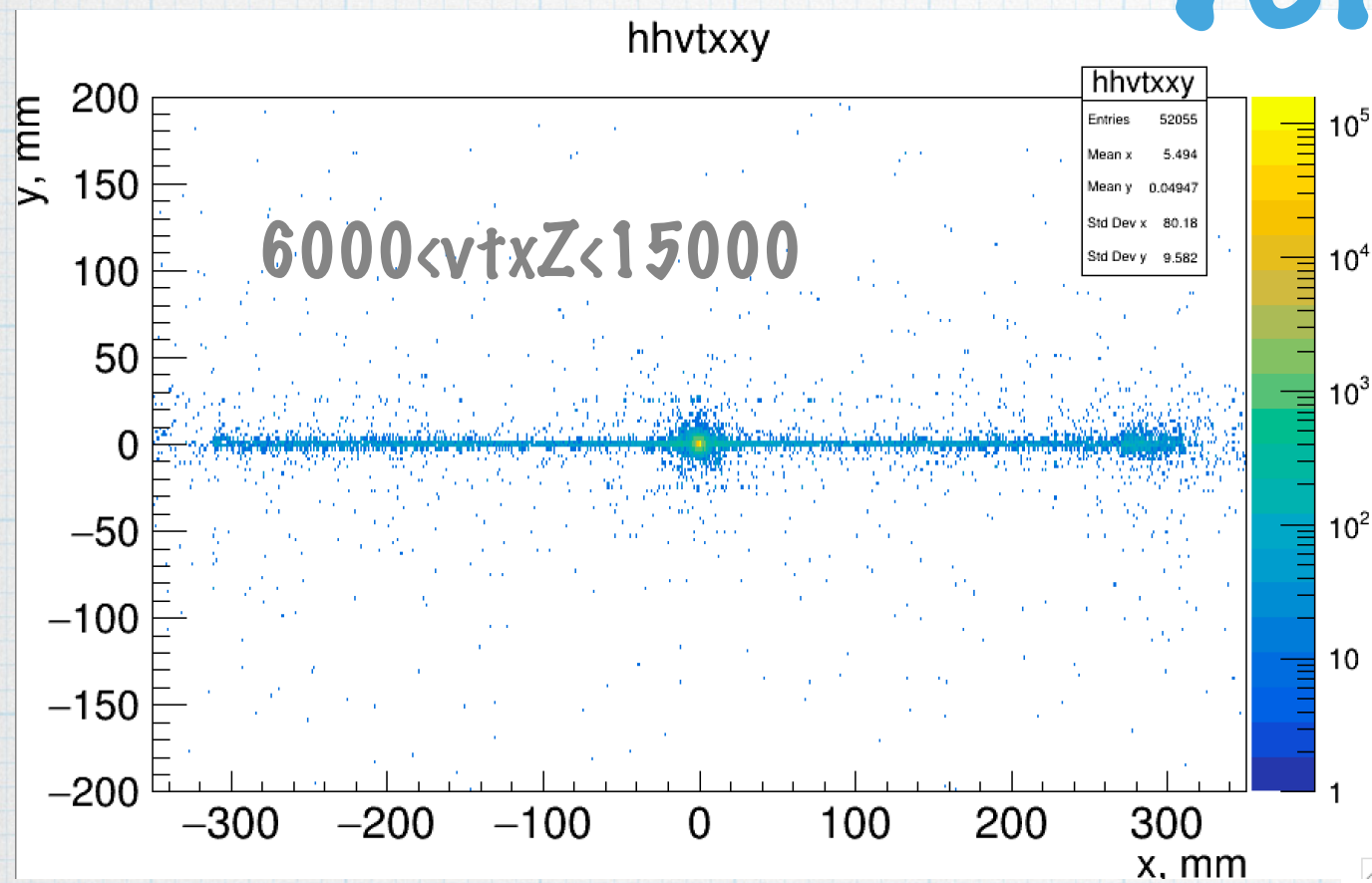


# Vertex x-y, beam pipe 8x5



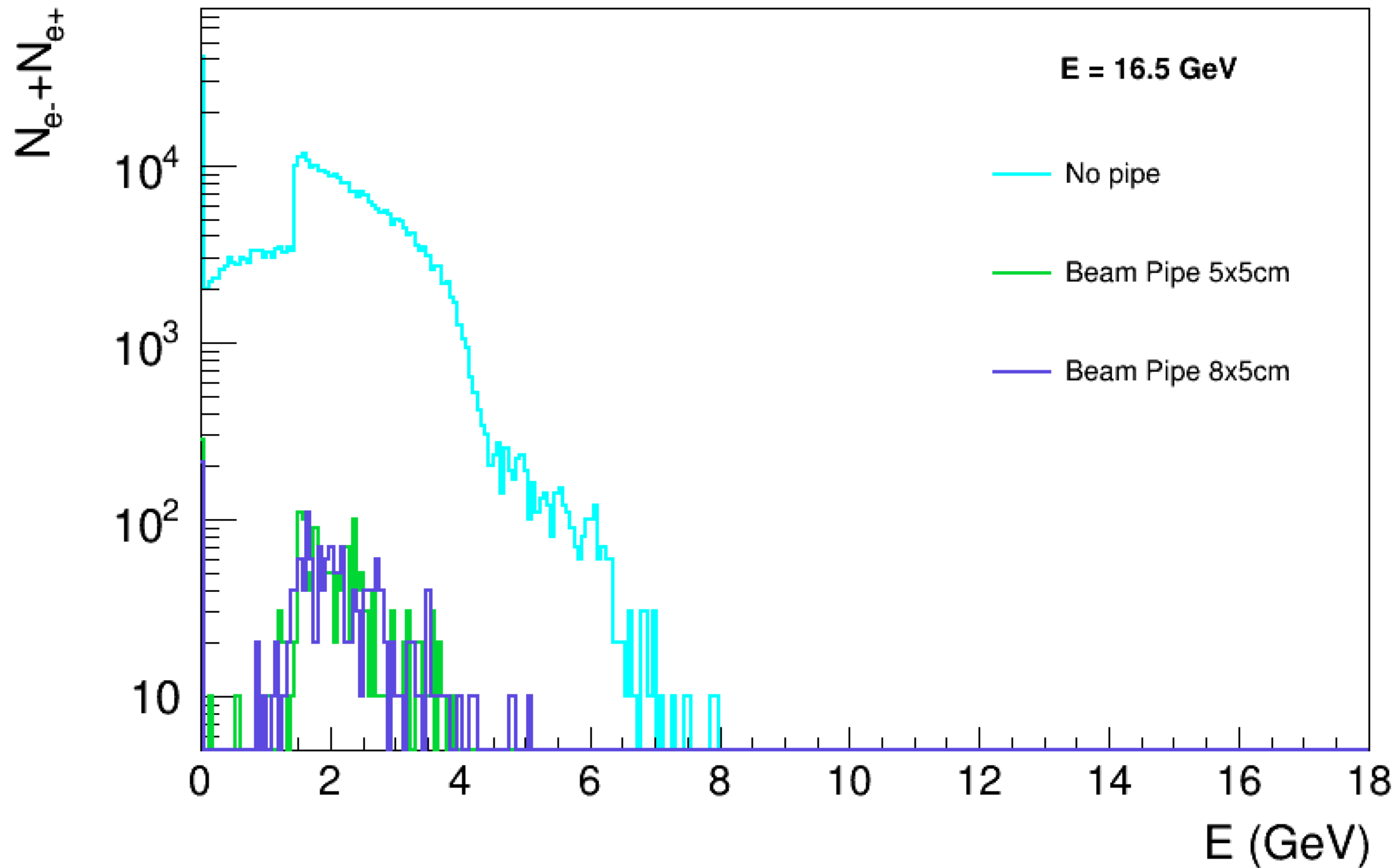


# Vertex x-y, no pipe





# Spectra

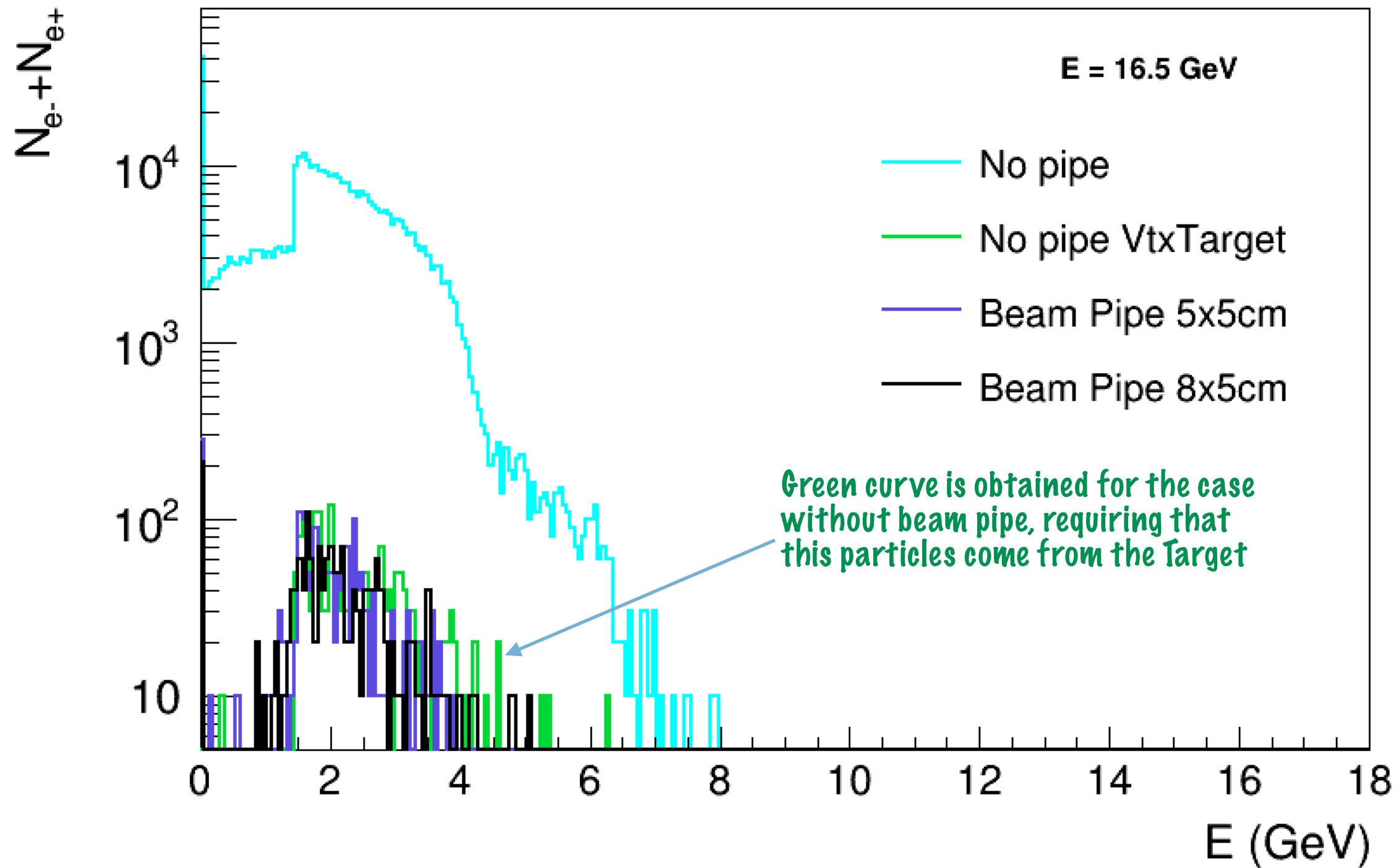


Without beam pipe we measure in Compton detectors a lot  $e^-/e^+$  pairs that were created in the air.  
Only 4%  $e^-/e^+$  come from the Target

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



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# Summary

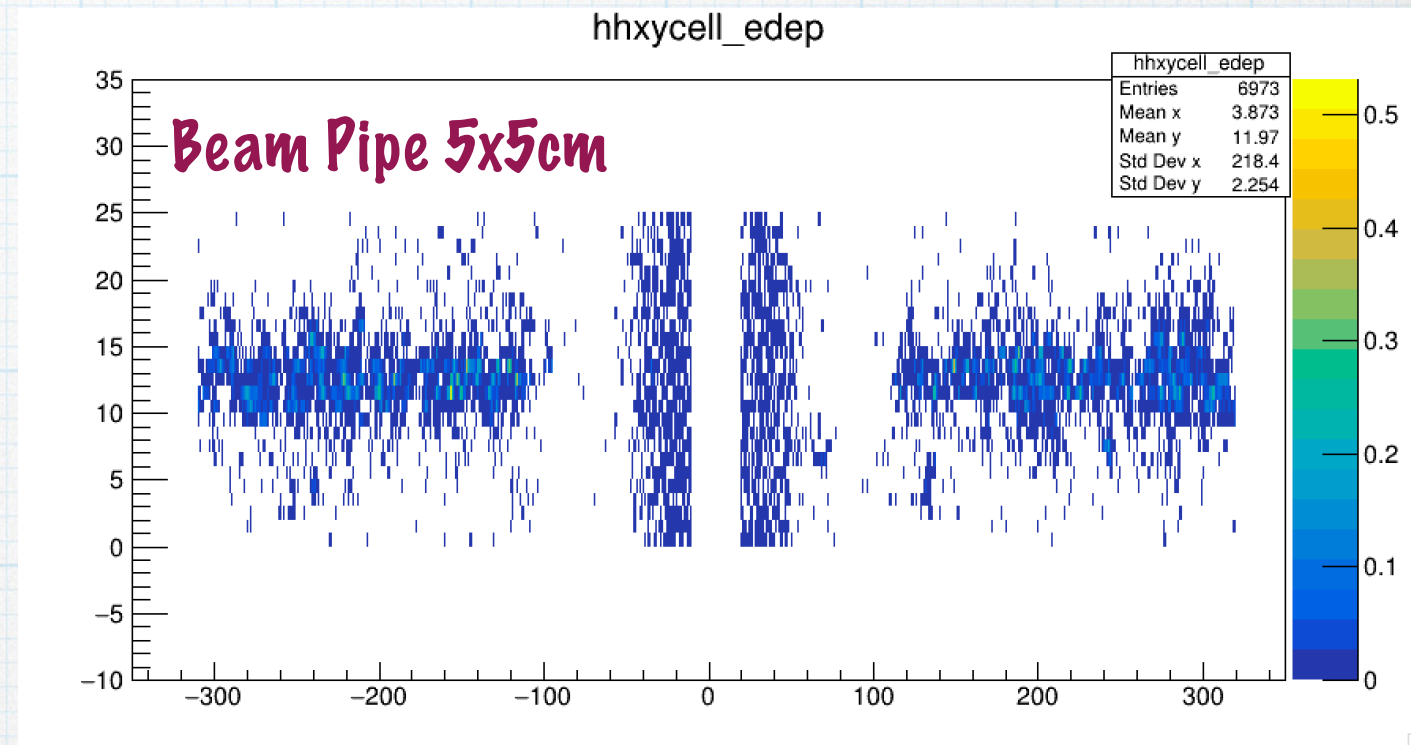
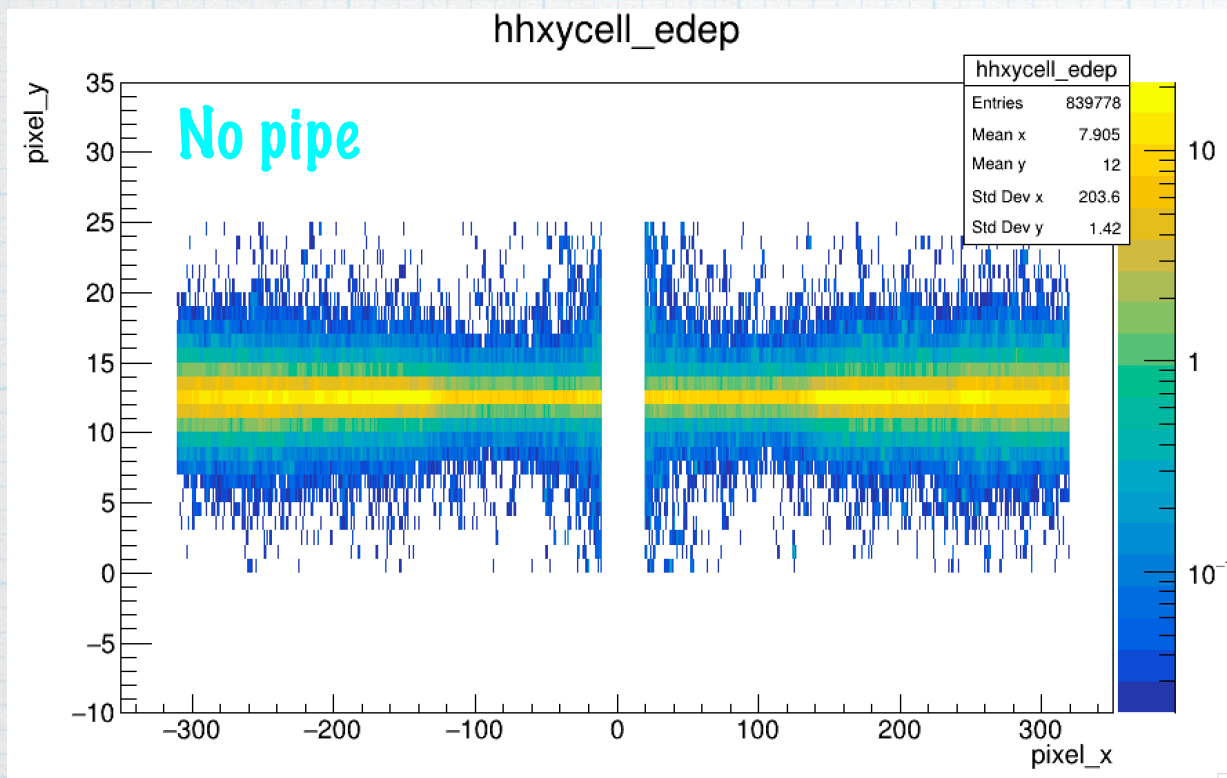
- \* The performance of FDS setup was compared with and without beam pipe from the target to Compton detectors
- \* Number of particles per BX hitting LYSO detector is 25 higher without beam pipe
- \* Big hole in the Shielding creates substantial background occupancy in LISO detectors.
- \* All extra 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



# 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  $\mu\text{m}$  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  $\sim 10$  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  $\text{g/cm}^3$ , volume  $0.1 \times 0.2 \times 2 = 0.04 \text{ cm}^3$ . Mass  $7.1 \times 0.04 = 0.284 \text{ g}$ .

Finally,  $5.6 \times 10^{-6}$  Gy per BX.

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



# Vertex z

