Gamma Monitor using backscatters

Borysova Maryna (KINR)

20/02/20

LUXE technical meeting

DESY Hamburg

Lead glass blocks found in Hera West

- **New TF-1 LG blocks! Not irradiated, w/ measures 3.8 × 3.8 cm², length is 45 cm , ~50**
- **Will give the possibility to determine precisely coordinates and energies**

- **Spare modules for GAMS Found in Hera West thanks to Sergey Schuwalow**
- **There is a preliminary agreement to move it to the LUXE Lab**

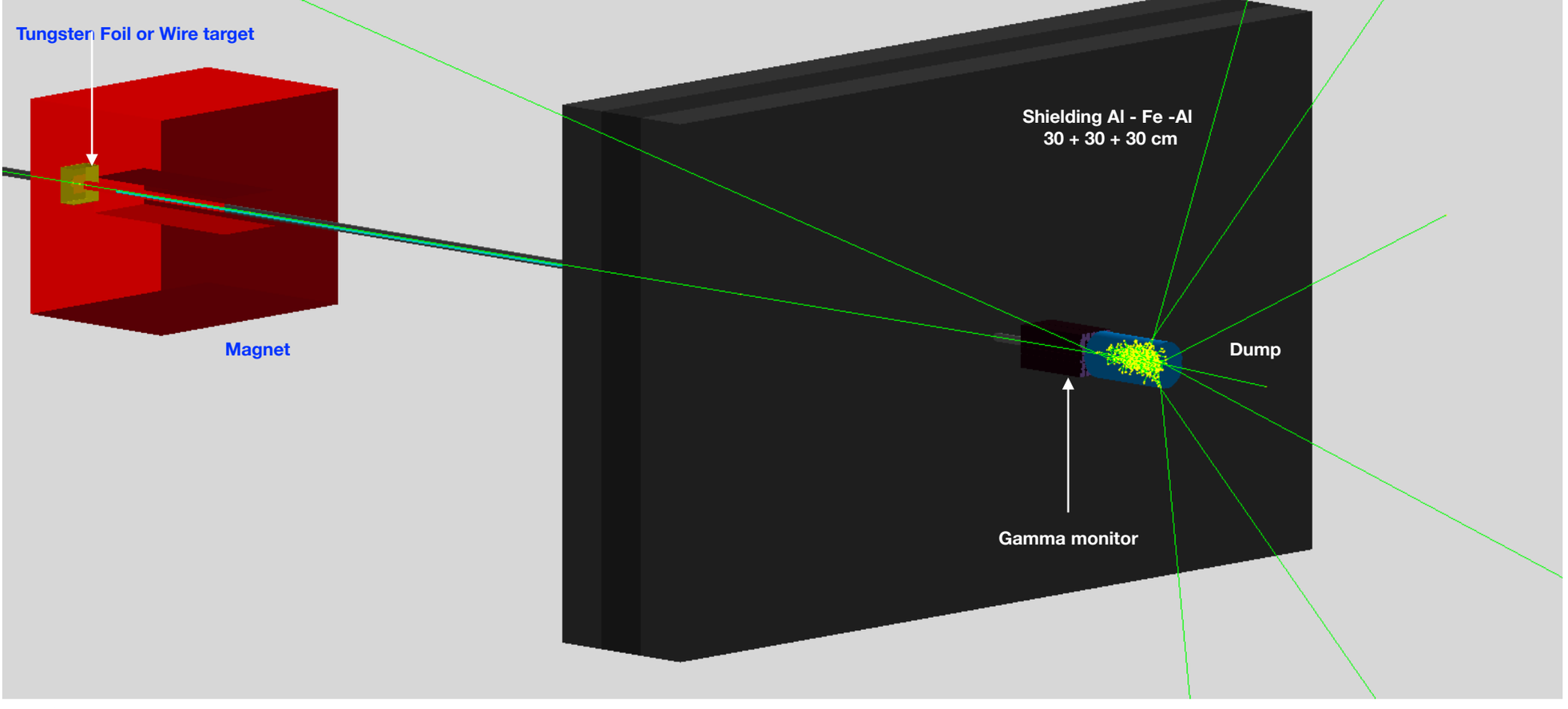
Chemical Composition of TF-1 LG

Table 1. Chemical composition and physical properties of the TF-1[10].

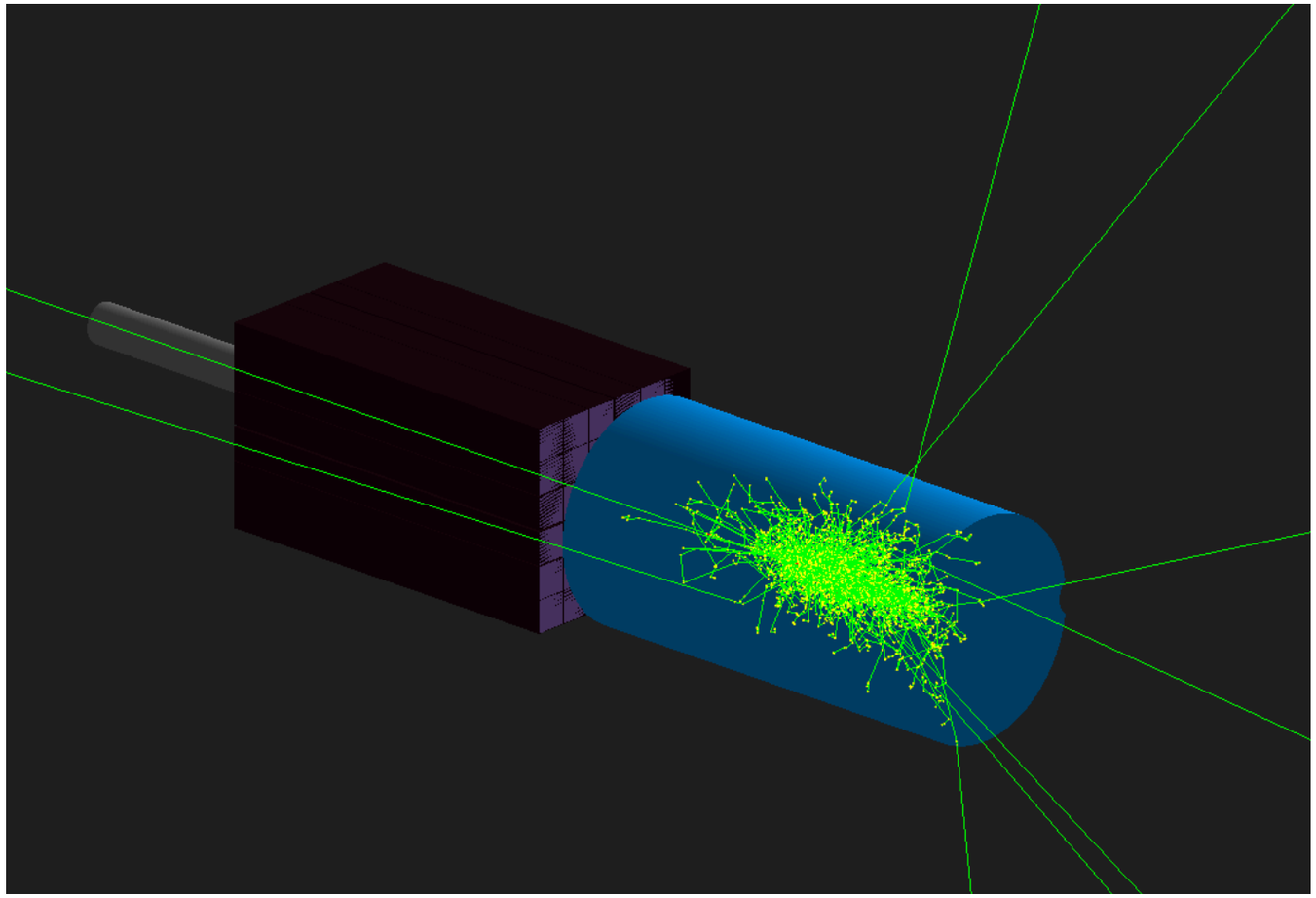
Chemical composition (weight %)		Fractions atomic units
PbO	51.2	Pb-0.082232
SiO_2	41.3	Si-0.246406
K_2O	3.5	0-0.608358
Na_2O	3.5	K-0.038057
As_2O_3	0.5	NA-0.023135
Radiation length (cm)	2.50	AS-0.001812
Density (g/cm^3)	3.86	
Critical energy (MeV)	15.57	
Refraction index	1.6476	

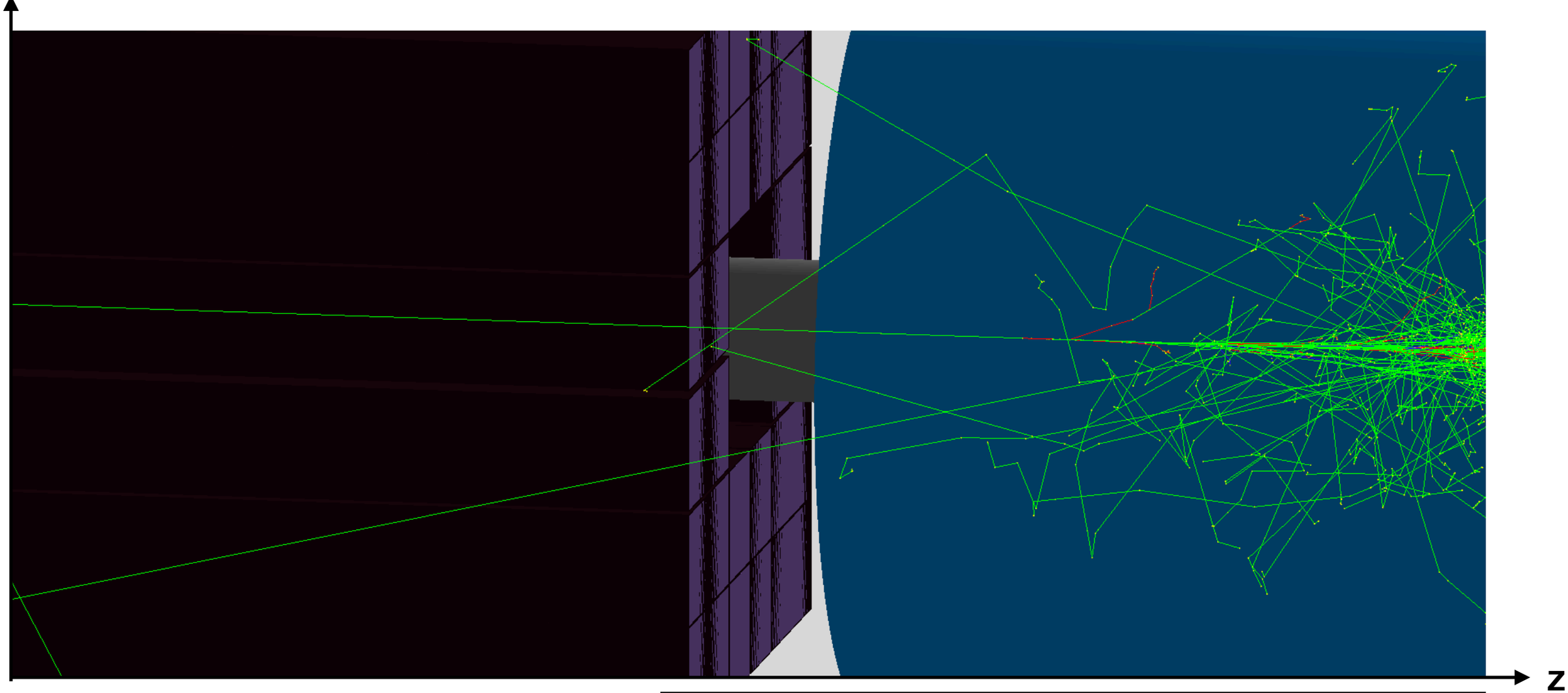
Used previously in
GAMS-2000 spectrometer (Serpuchov)
GAMS-4000 spectrometer (NA-12 experiment, CERN)

The measured energy resolution of the GAMS-4000 spectrometer for a single photon is $\sigma_E/E = 0.011 + 0.053 / \sqrt{E(GeV)}$.



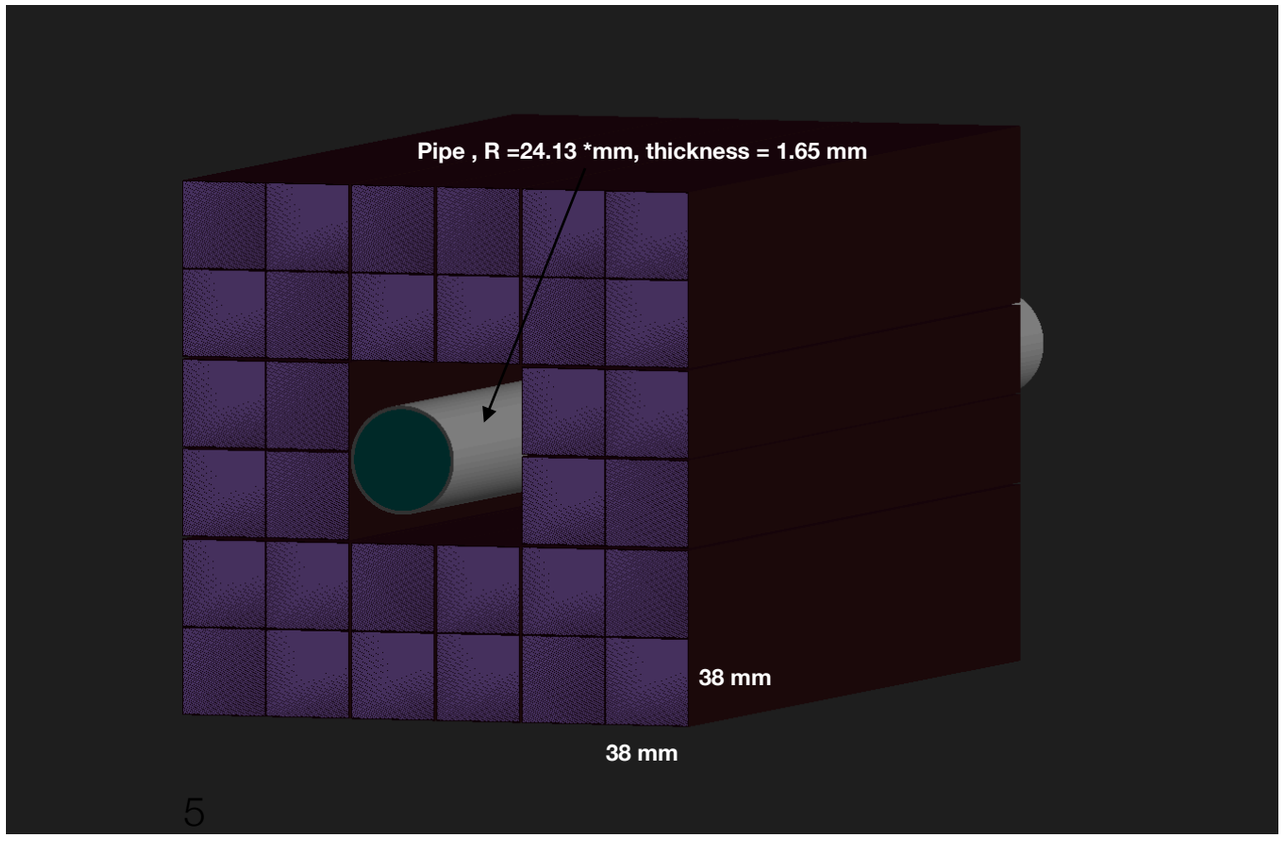
- The implementation of FDS in Luxe geometry with the LG Gamma Monitor made of 32 new LG blocks in front of Al-Cu Dump,
- LG w/ measures 3.8 × 3.8 cm^2, length is 45 cm
- Wrapped with Aluminium foil of 1 mm





- The implementation in Luxe geometry of the LG Gamma Monitor made of 32 new LG blocks in front of Al-Cu Dump(R(Cu) = 13.0 *cm; R(Al) = 6.5 *cm & L(Al)= 20 *cm)

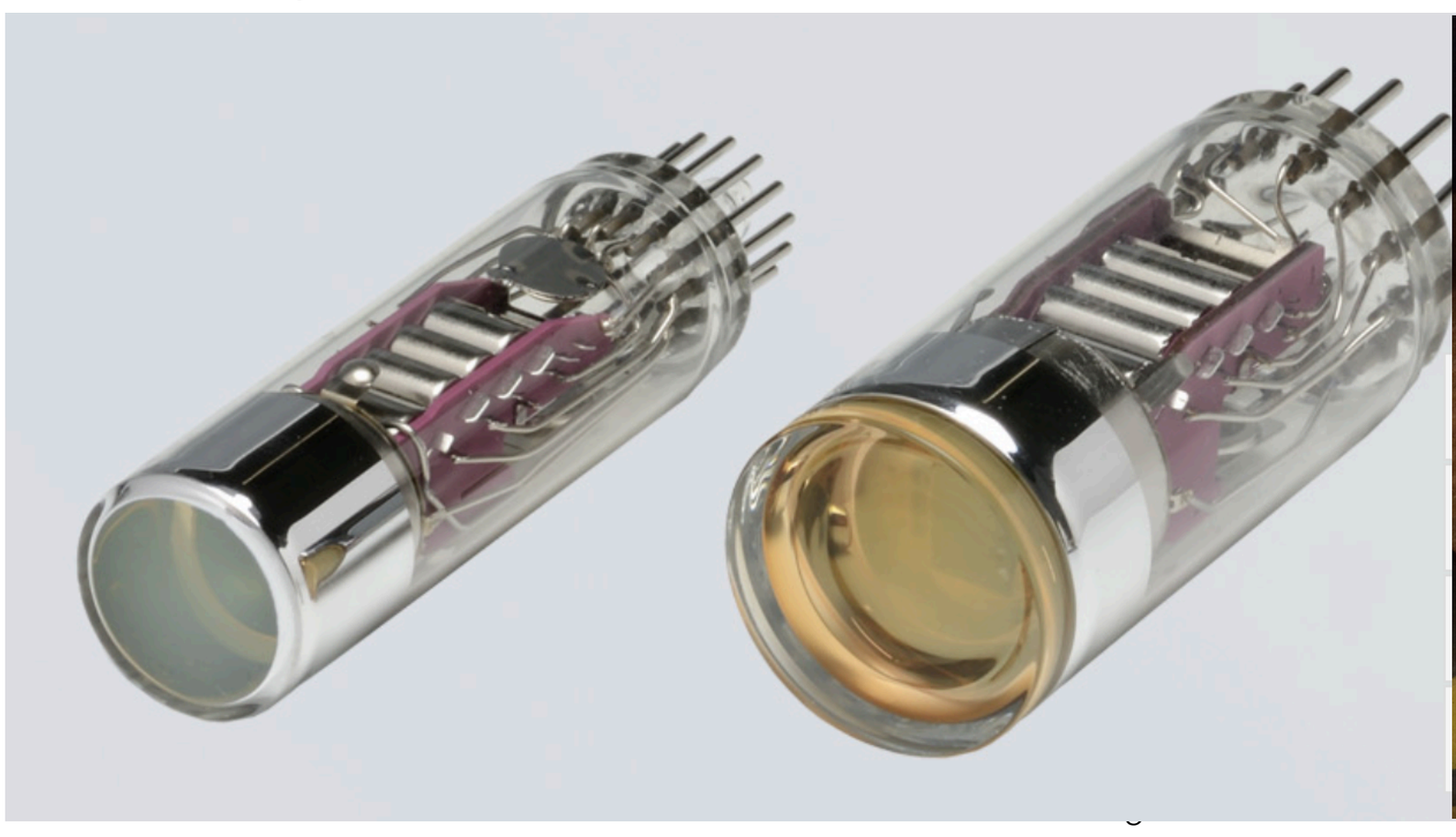
- 32 LG w/ measures 3.8 × 3.8 cm^2, length is 45 cm
- Each block is wrapped with Aluminium foil of 1 mm



Hamamatsu Photomultiplier tubes

Image	Data sheet	Part no.	Product name	Tube Size	Photocathode Area Shape	Photocathode Area Size	Wavelength (Short)	Wavelength (Long)	Wavelength (Peak)	[Cathode] Luminous Sensitivity Typ.	[Cathode] Radiant Sensitivity Typ.
		Sort / Filter	Sort / Filter	Sort / Filter	Sort / Filter	Sort / Filter	Sort / Filter	Sort / Filter	Sort / Filter	Sort / Filter	Sort / Filt
		R750	Photomultiplier tube	Dia.19 mm	Round	Dia.15 mm	185 nm	650 nm	420 nm	110 μA/lm	85 mA/W
	PDF	R821	Photomultiplier tube	Dia.19 mm	Round	Dia.15 mm	160 nm	320 nm	240 nm	--	28 (at 254 nm) mA/W
	PDF	R972	Photomultiplier tube	Dia.19 mm	Round	Dia.13 mm	115 nm	200 nm	140 nm	--	12 (at 121 nm) mA/W

Photomultiplier tube



Photomultiplier tubes.The head-on type, also called the end-on type, receives incident light through the end of the glass bulb.

Outlook

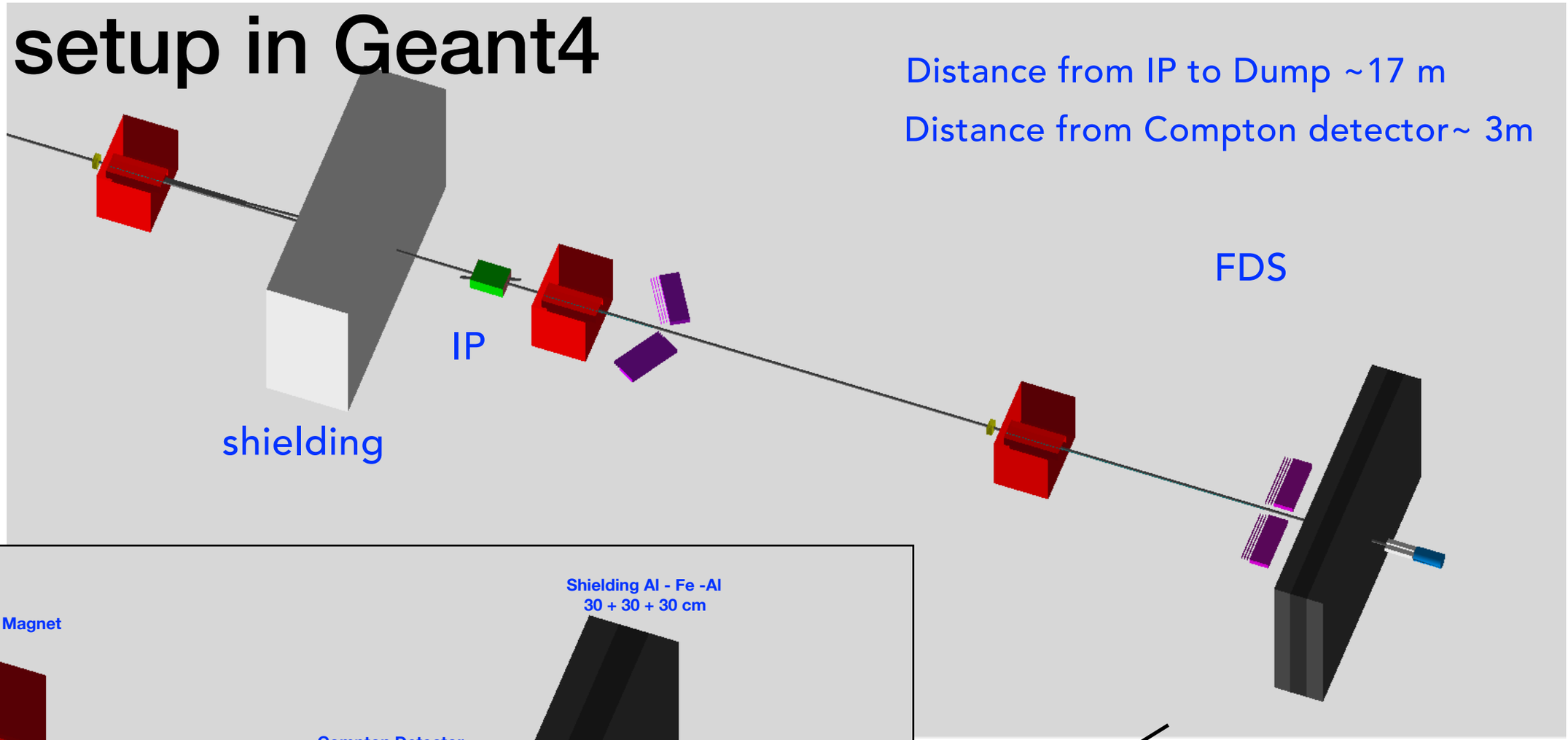
- **Gamma monitor studies:**

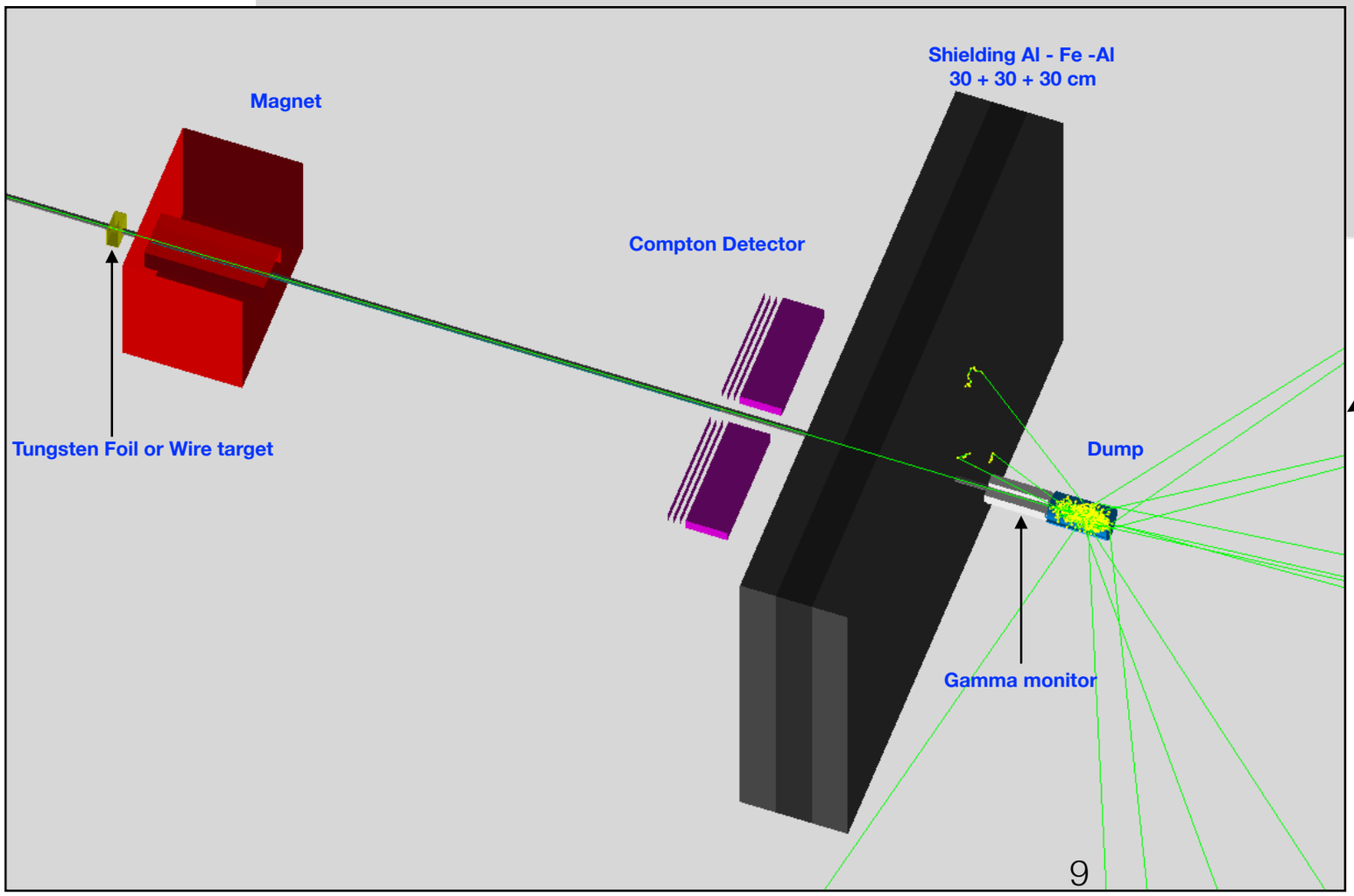
✴**New, irradiated LG block are found and could be wrapped and used for GM.**
✴**The implementation in Luxe geometry the LG Gamma Monitor made of 32 new LG blocks in front of Al-Cu Dump**
✴**Gamma Monitor was studied in GEANT4 w/ LG Monitor in front of Al-Cu Dump for the for mono beams with different energies**

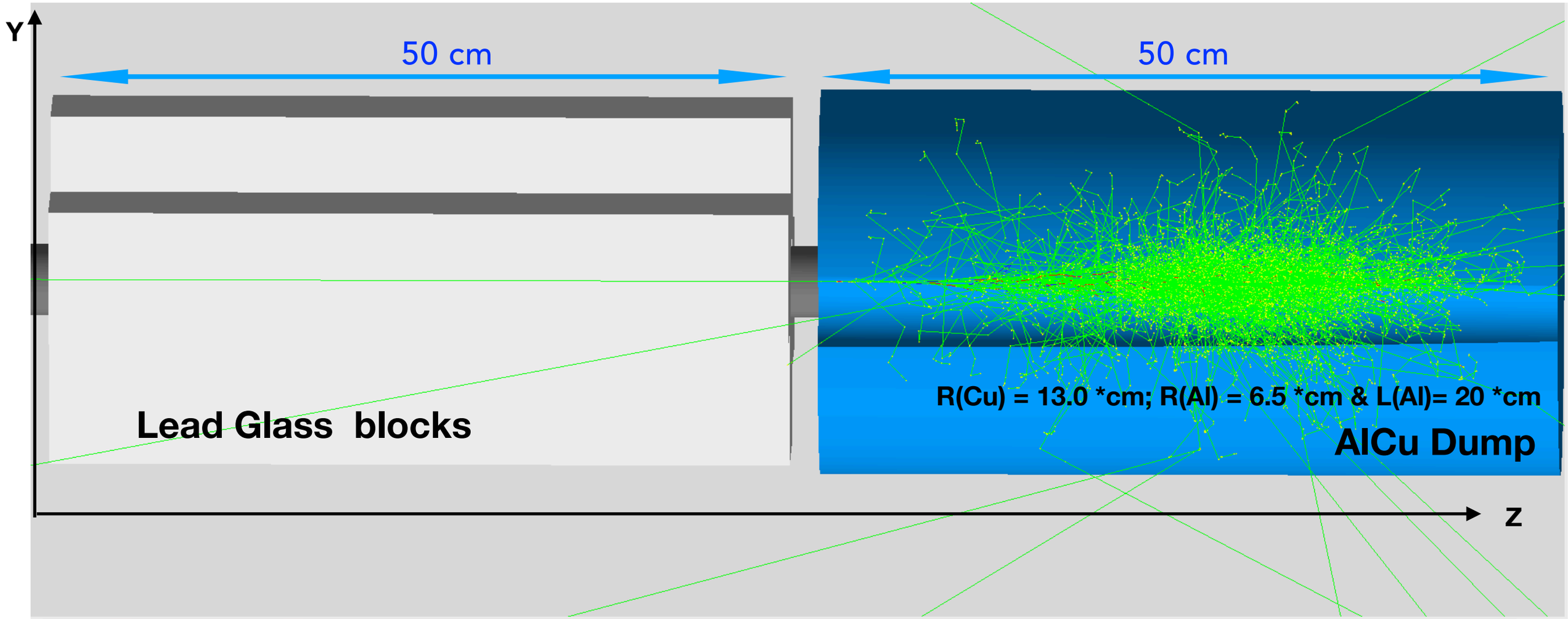
Further studies:
To run the simulation with new geometry implementation
To reduce the size of the beam pipe to be consistent with the blocks size, run the simulation and to compare to the previous one.

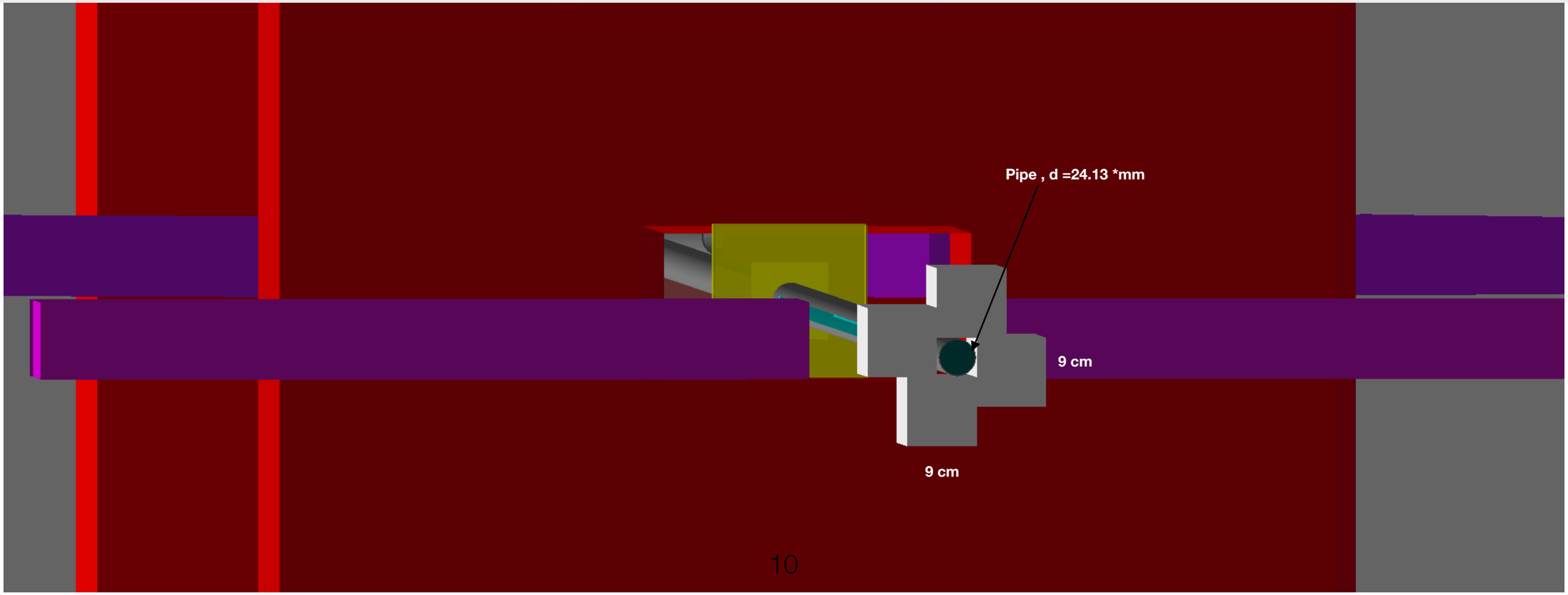
Back up

Gamma Monitor made of 4 Hermes LG blocks in Luxe setup in Geant4

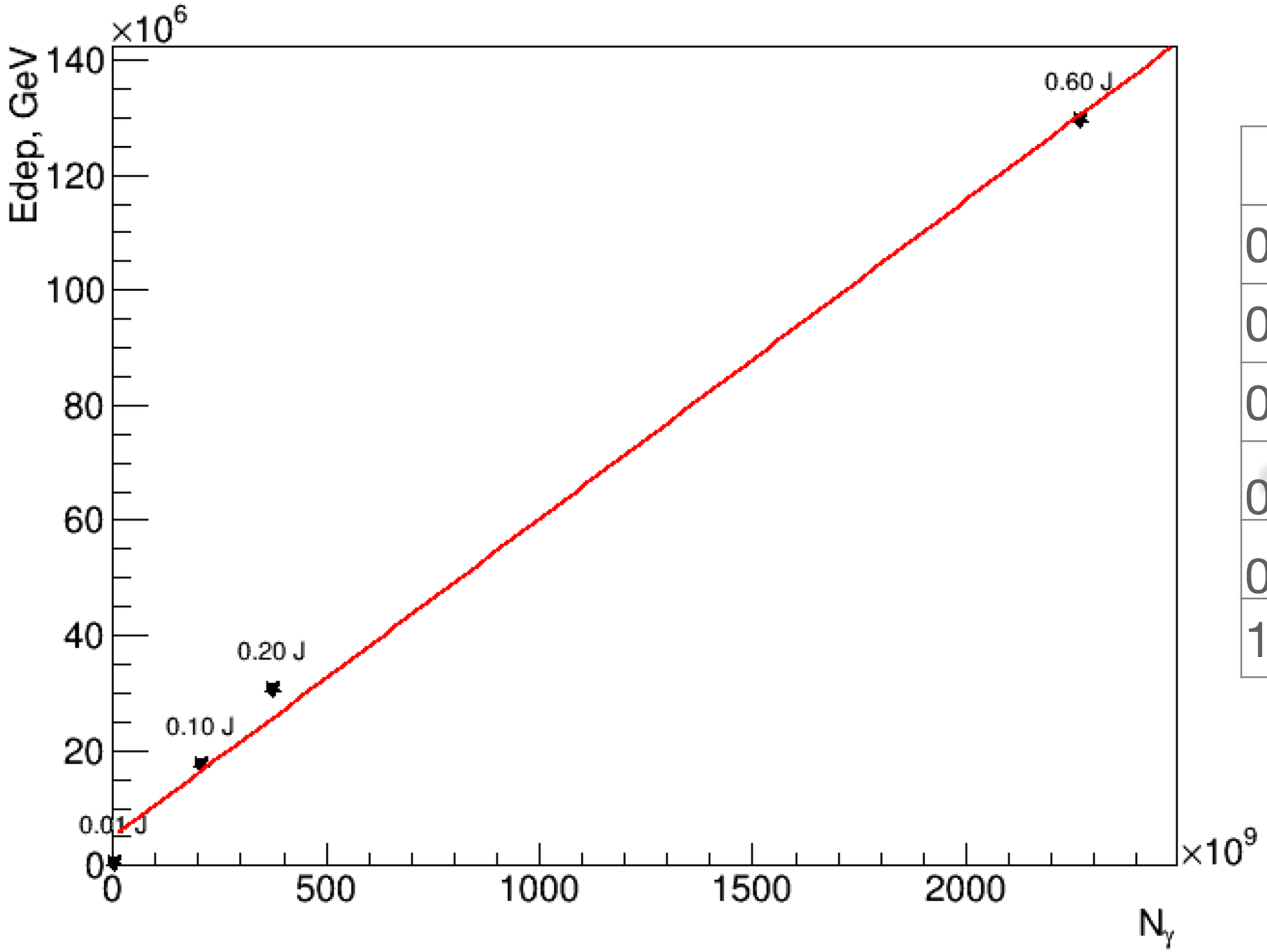





Y
50 cm
50 cm
Lead Glass blocks
R(Cu) = 13.0 *cm; R(Al) = 6.5 *cm & L(Al)= 20 *cm
AlCu Dump
Z


Pipe , d =24.13 *mm
9 cm
9 cm

The deposited energy of 100 BX for different laser intensities

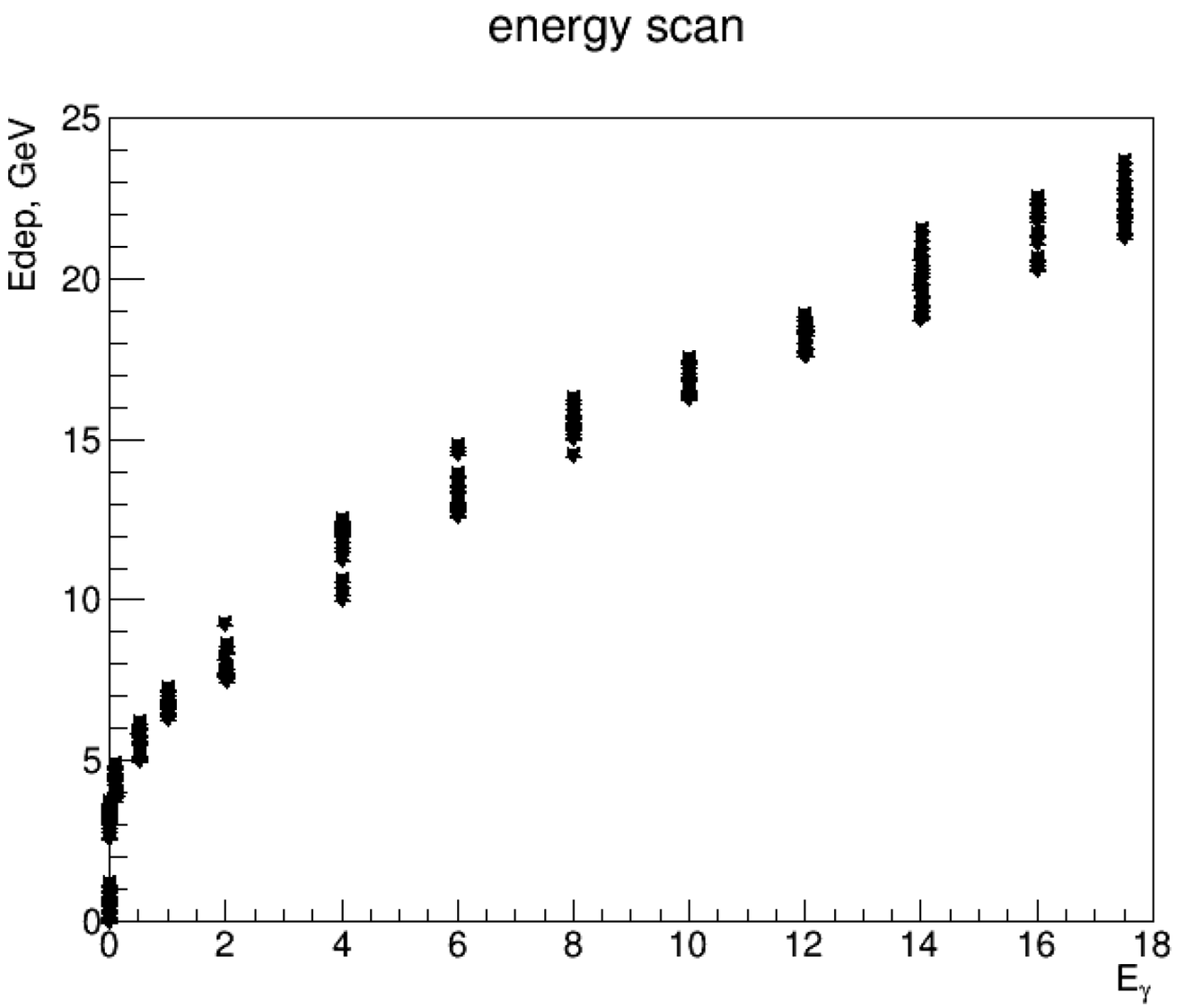


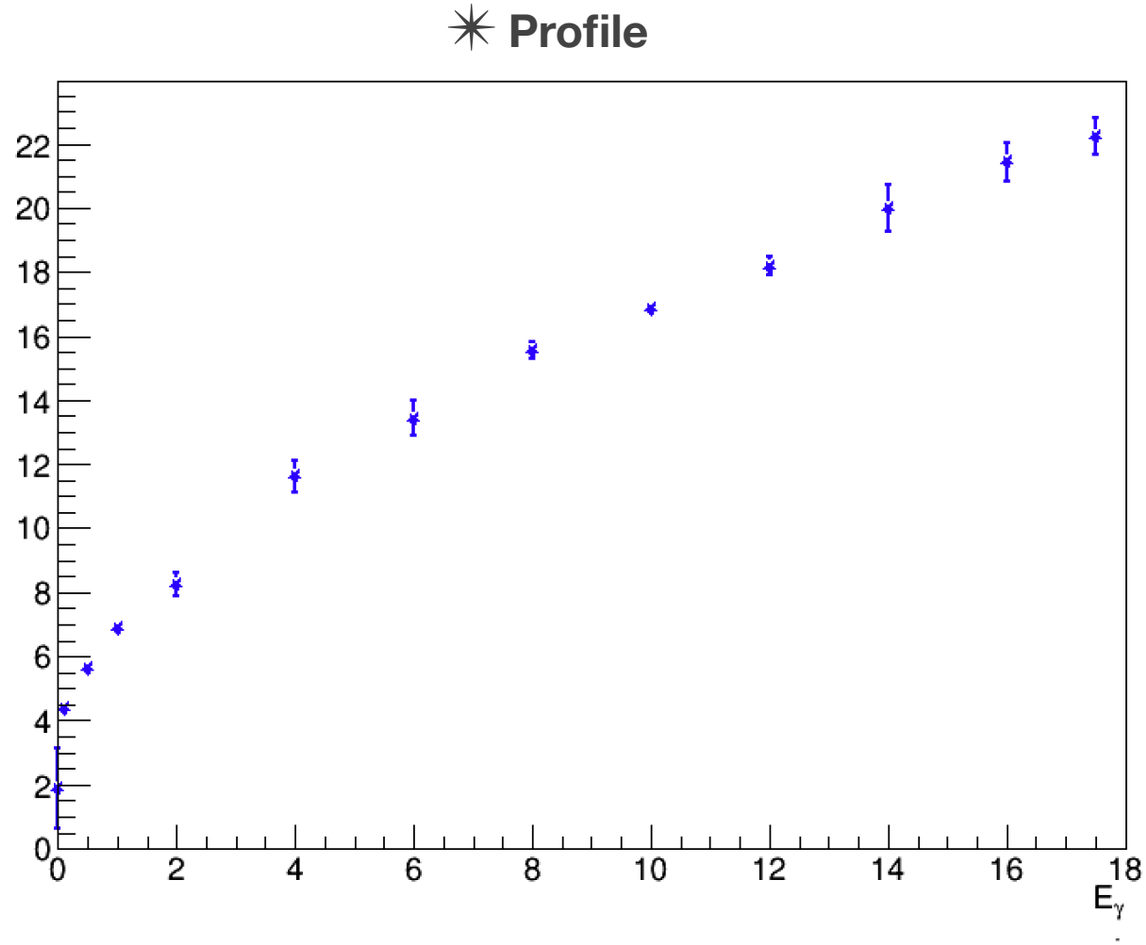
J	ξ
0.01	0.26
0.1	0.82
0.2	1.16
0.35	1.54
0.6	2.02
1.0	2.6

Energy dependence of deposited energy in Gamma monitor

20 Runs* 100000 photons with mono energies: 1,2,4,6,8,10,12,14,16 and 17.5 GeV

Added lower energies 0.0001, 0.1, 0.5 GeV





GODDeSS (G-eant4 O-bjects for D-etailed De-tectors with S-cintillators and S-iPMs)

OPEN ACCESS

GODDeSS: a Geant4 extension for easy modelling of optical detector components

E. Dietz-Laursonn, T. Hebbeker, A. Künsken, M. Merschmeyer, S. Nieswand and T. NiggemannJournal of Instrumentation, Volume 12, April 2017

GODDeSS is a Geant4-based package extending Geant4 by some useful object classes for scintillator tiles, optical fibres and photon detectors.

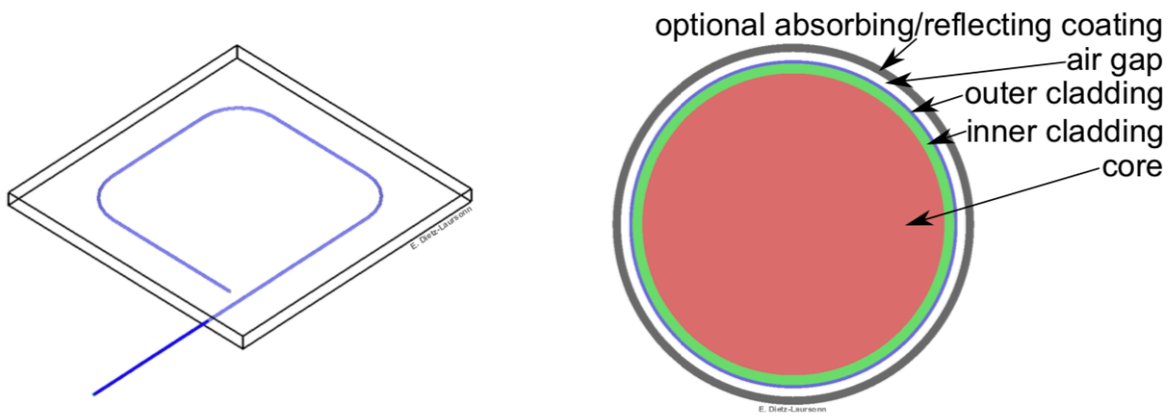
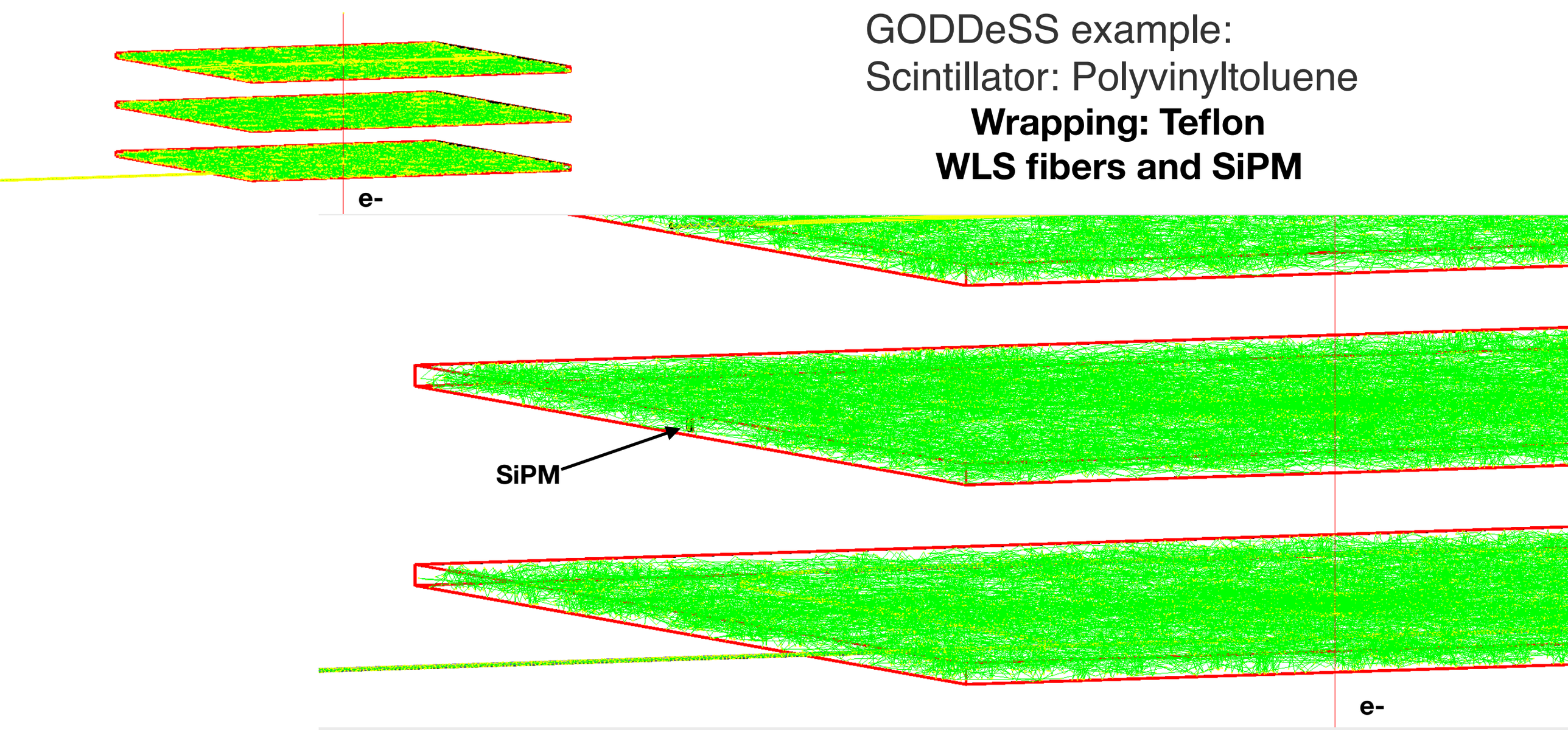


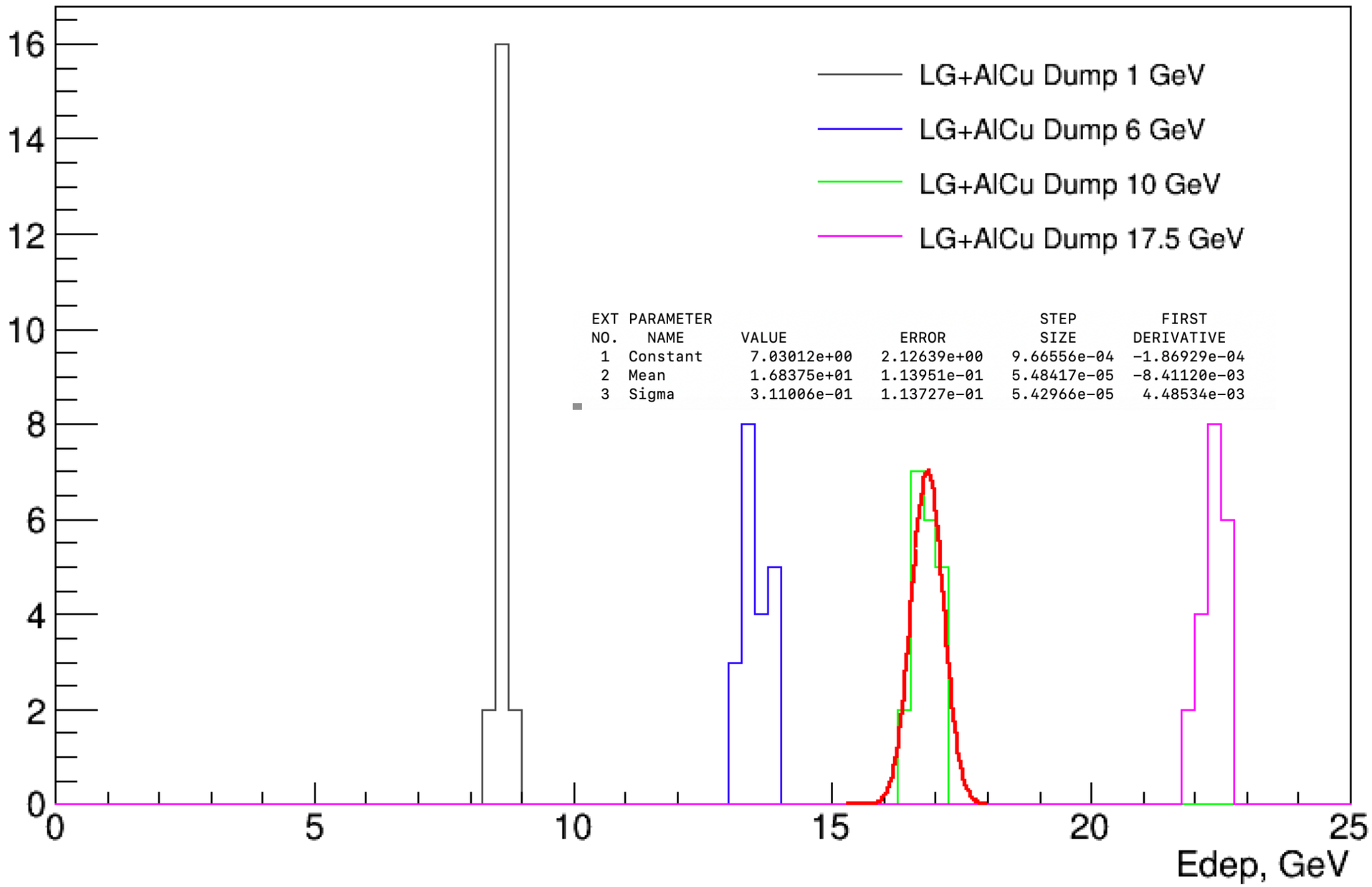
Figure 3. Left: scintillator tile with a complex fibre setup, the fibre protruding from the scintillator tile. If GODDeSS is used for the simulation, this setup can be generated by the user with 8 lines of code (one for the scintillator tile and one for each of the three bent and four straight fibre parts). Right: profile of a simulated round multi-cladding-fibre.

GODDeSS example:
Scintillator: Polyvinyltoluene
Wrapping: Teflon
WLS fibers and SiPM




```
------------------------------------------------------------------------------
EventID = 0
primary particles:                          e- (1)
primaryParticleID:                          11
primaryParticle_pos/mm:                                (0,100,0)
primaryParticle_momentum/MeV:               (0,-6981.12,4.2747e-13)
primaryParticle_PathLength/mm:              5
primaryParticle_E_depos/MeV:                0.888921
primaryParticle_hit_time/ns:                0.325225
primaryParticle_hit_pos/mm:                 (-0.00950988,2.5,0.022659)
primaryParticle_hit_momentum/MeV:           (-0.867265,-6979.74,3.00354)
secondary particles:                        opticalphoton (37452)
production processes:                       Cerenkov (2082); OpWLS (4588); Scintillation (30782)
Number of optical photons:
total:                  37452
by scintillation:       30782     (by primary: 30782    by secondary: 0)
by Cerenkov radiation:  2082      (by primary: 2082     by secondary: 0)
by WLS:                 4588
Number of optical photons absorbed:
total:           37448 (scintillation photon: 30780     Cerenkov photon: 2081  WLS photon: 4587)
in fibre:        4588  (scintillation photon: 4490      Cerenkov photon: 44    WLS photon: 54)
in SiPM:         595   (scintillation photon: 76        Cerenkov photon: 4     WLS photon: 515)
in scintillator, wrapping, optical cement,...: 32265    (scintillation photon: 26214      Cerenkov photon: 2033  WLS photon: 4018)
------------------------------------------------------------------------------
```

Energy deposit distributions for 1, 6, 10 and 17.5 GeV



Lead glass blocks from Hera

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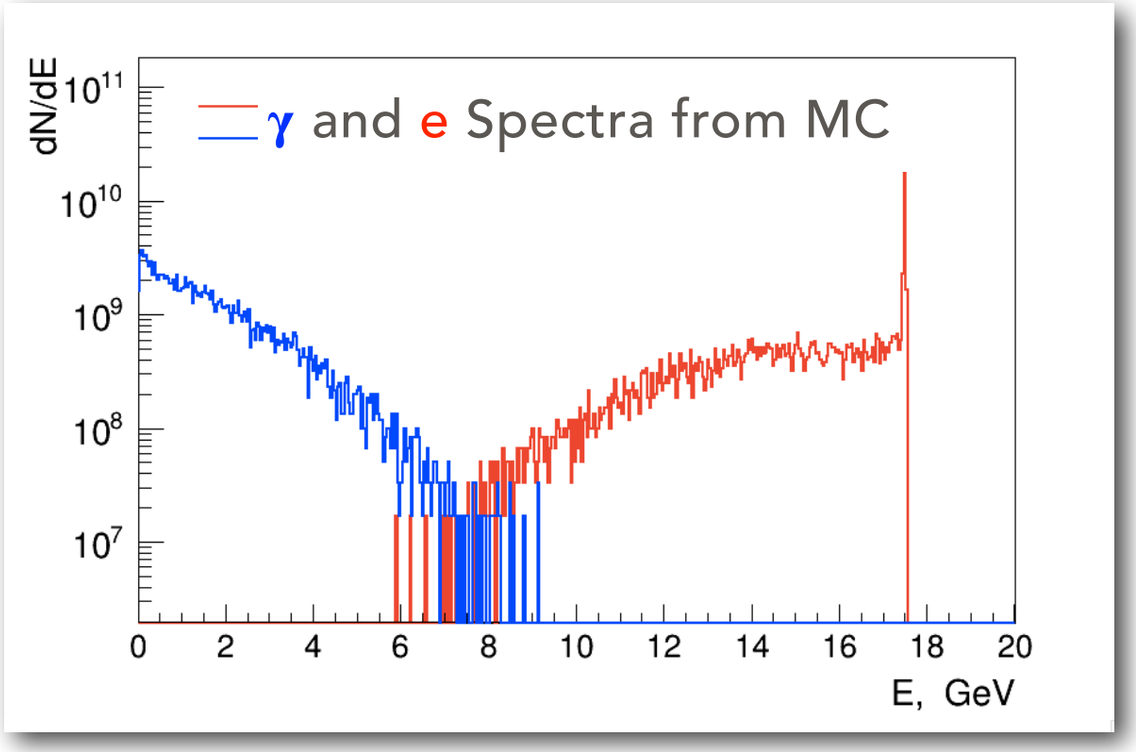
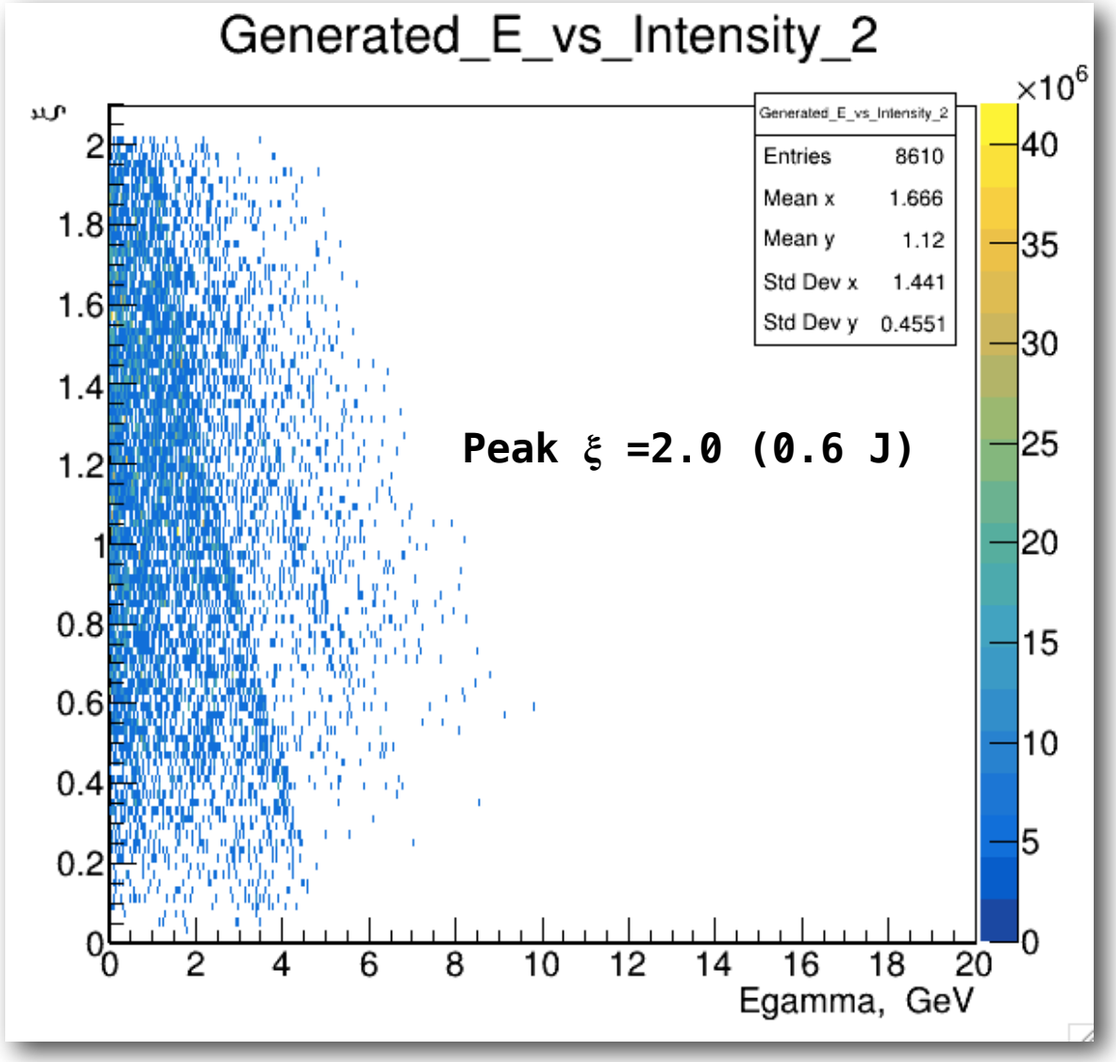
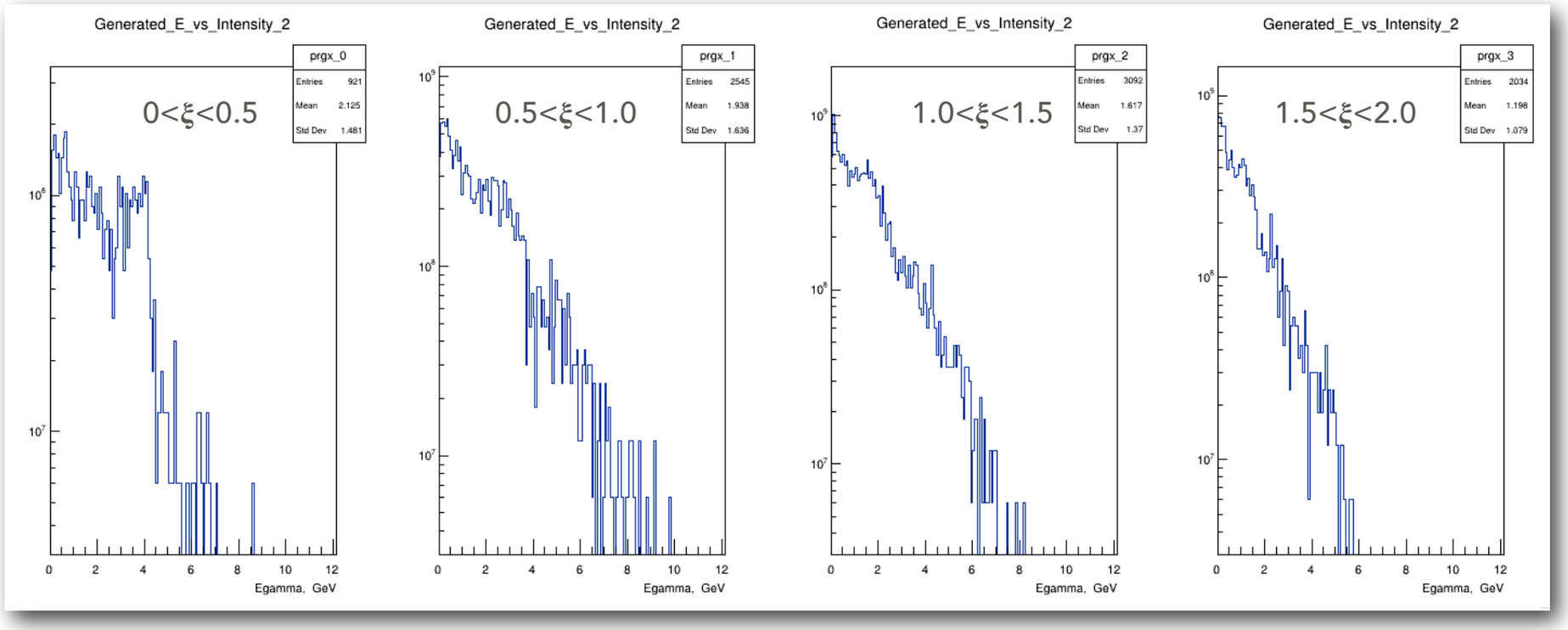
ξ vs Eγ FROM MC





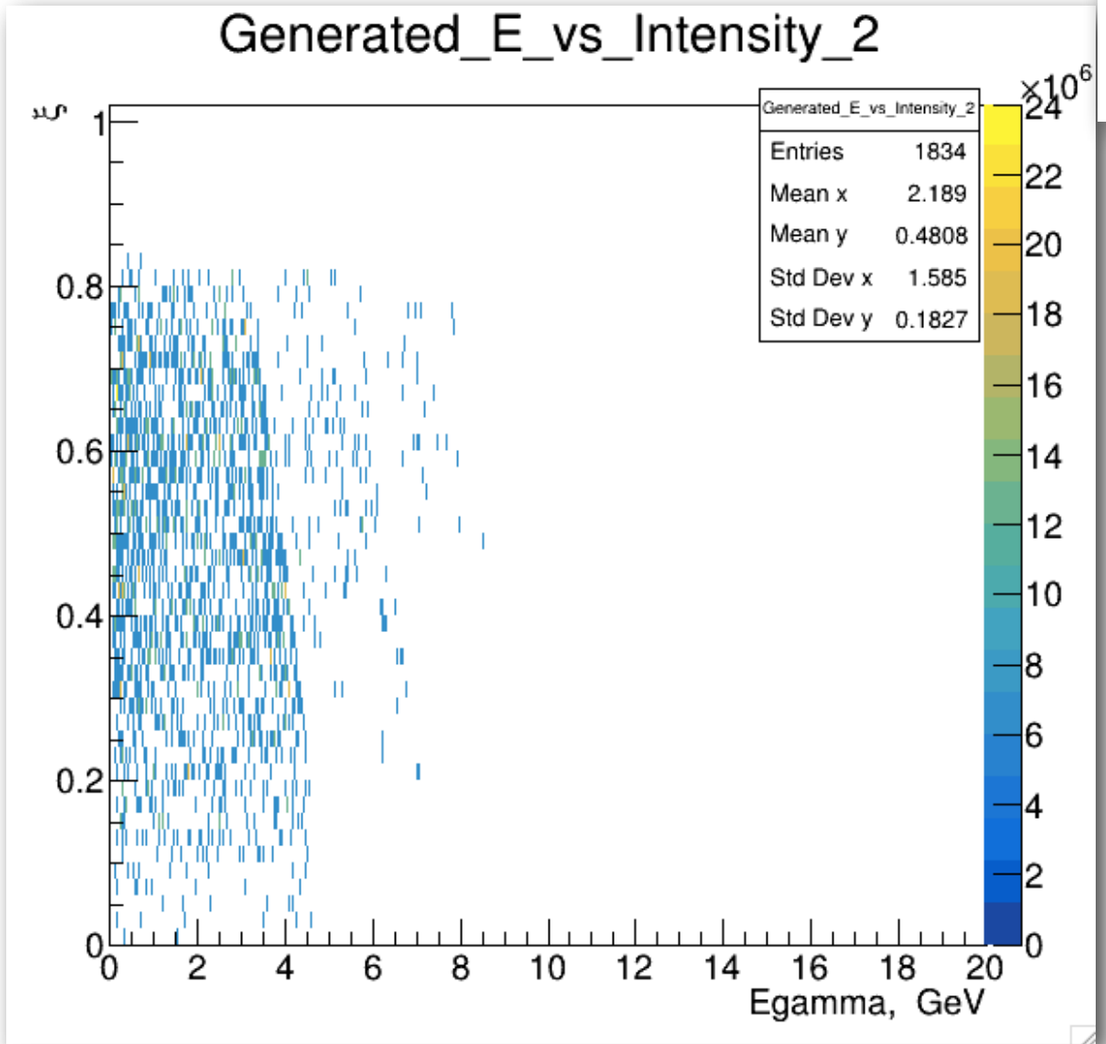
- Laser Intensity (ξ) is not uniform
- This makes the kinematic edges from different *n* not visible
- ξ distribution might be reconstructed by fitting measured spectra w/ convolution of HICS xsection & ξ trial distribution

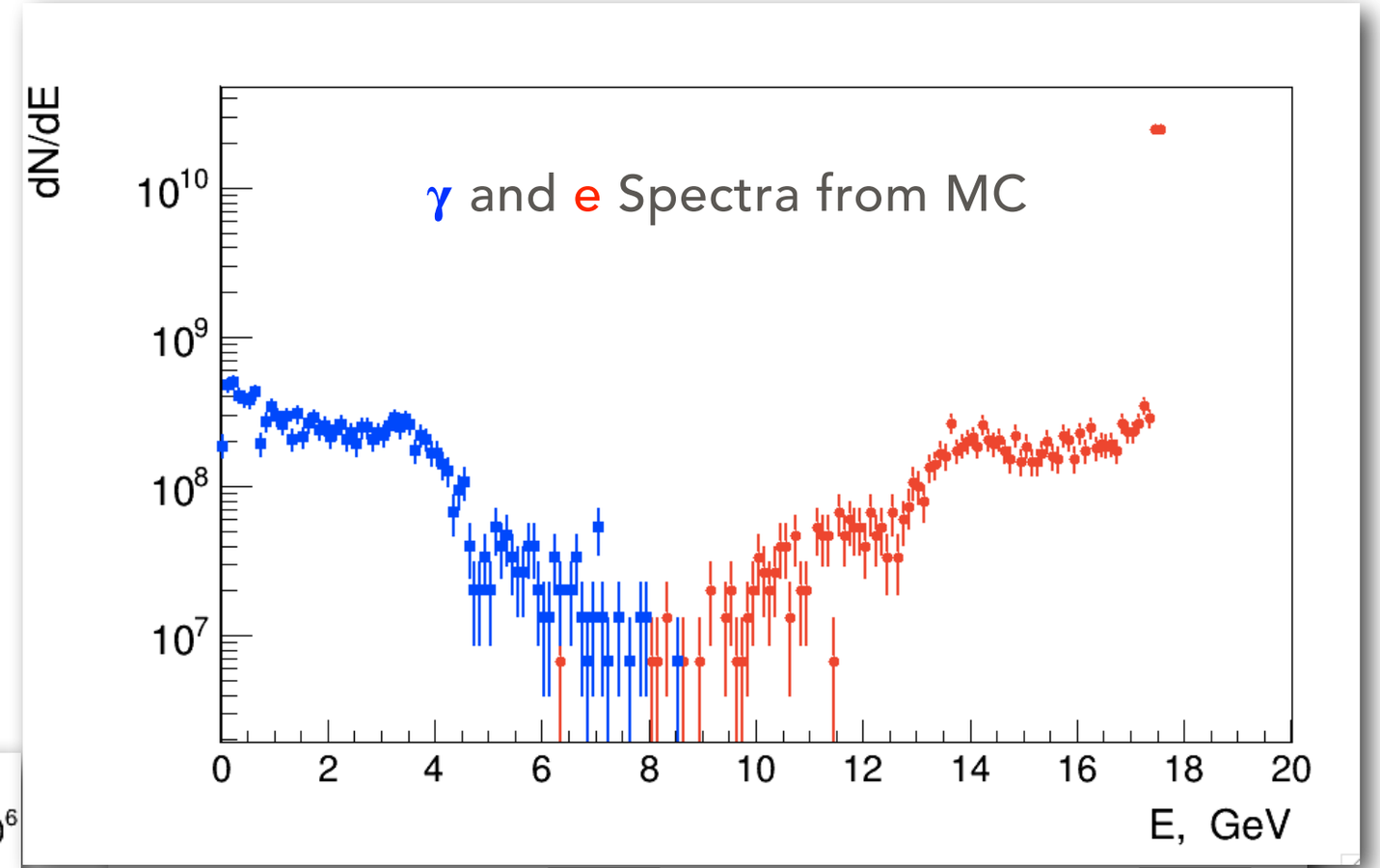


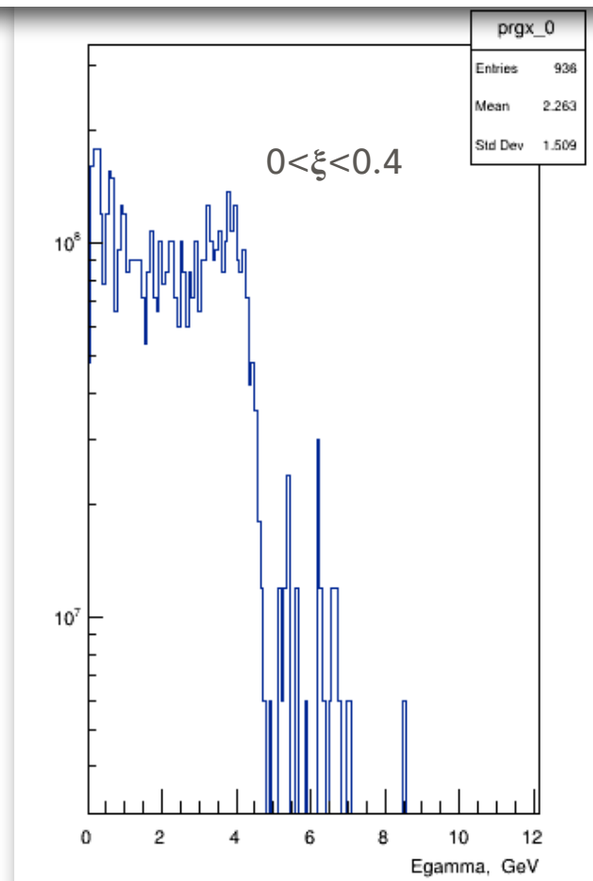
ξ vs Eγ FROM MC

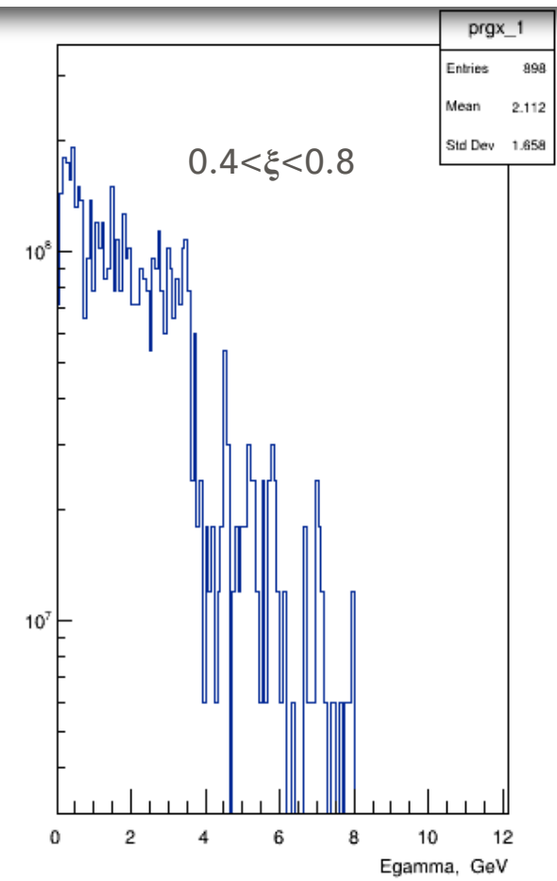
Peak ξ = 0.8 (0.1J)

The kinematic edges can be seen at the low intensity.

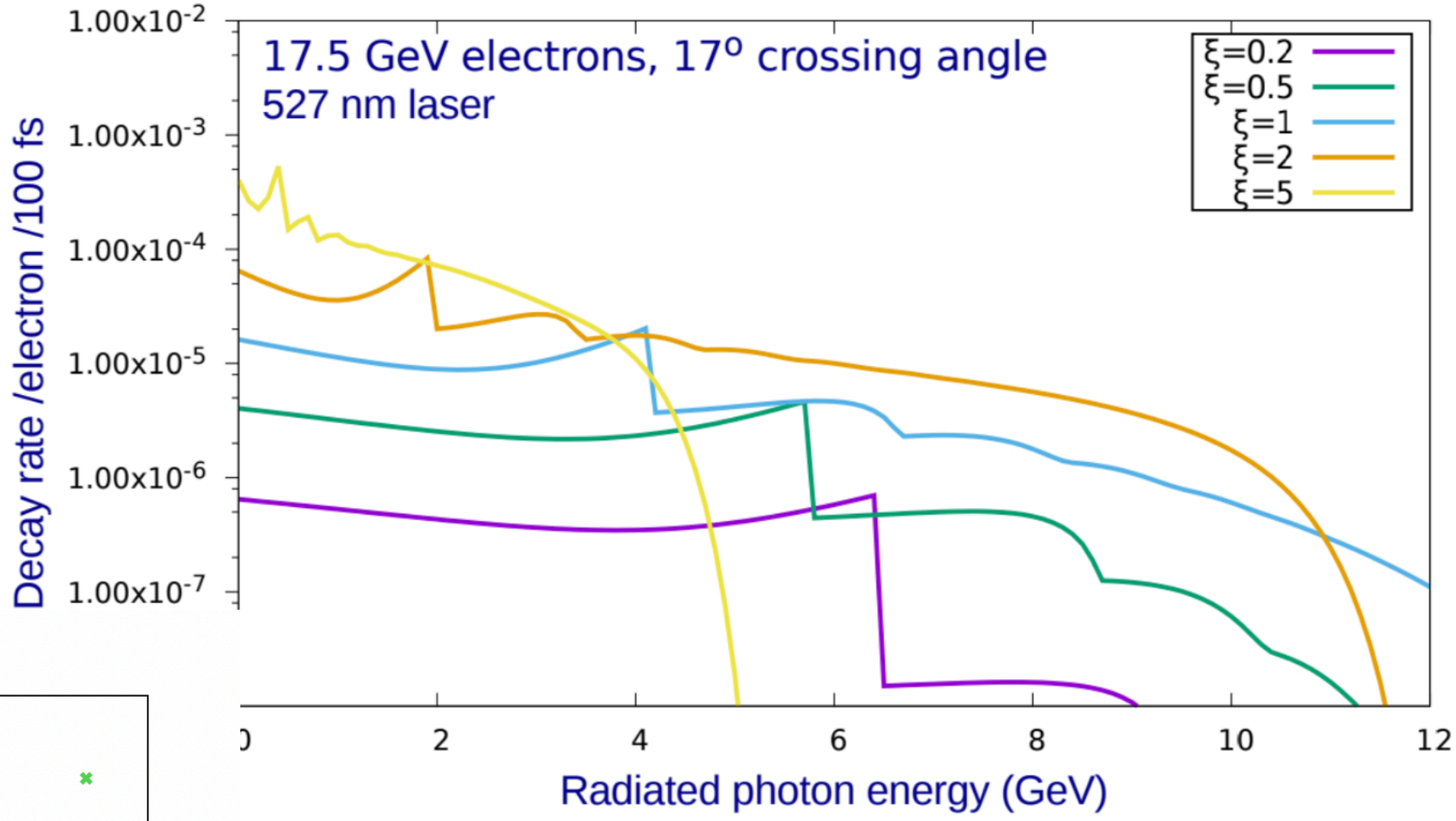


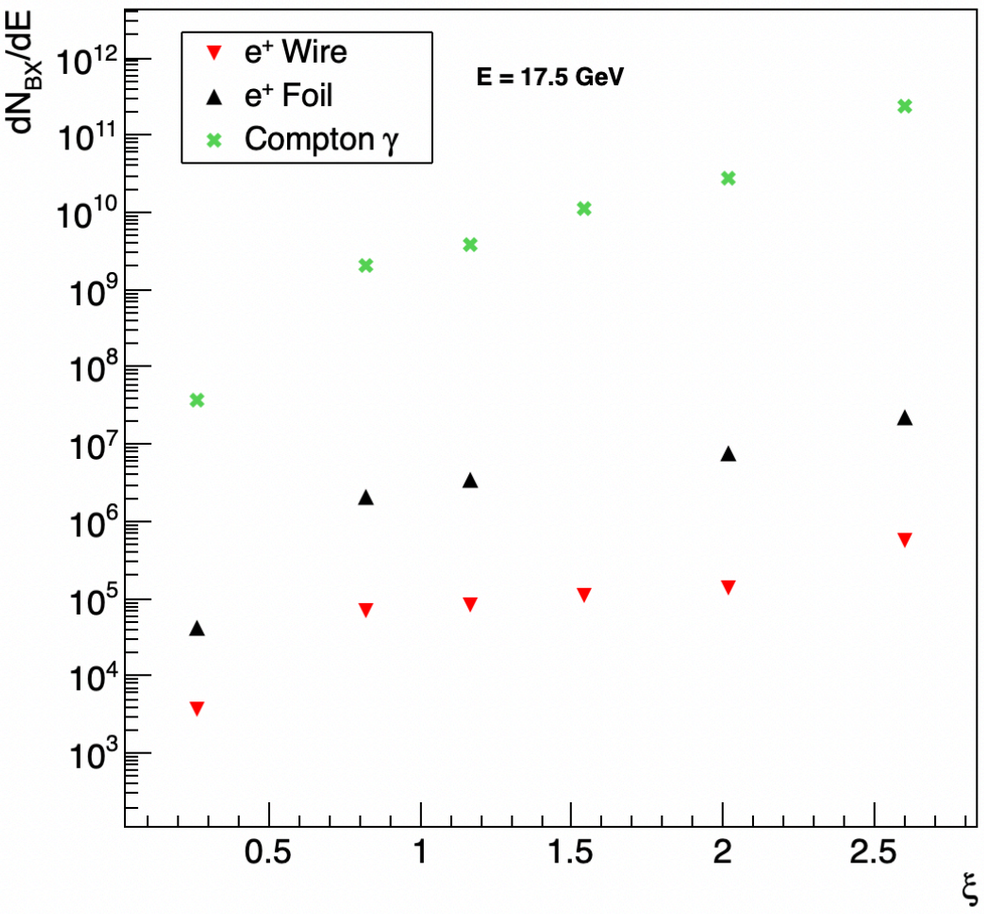




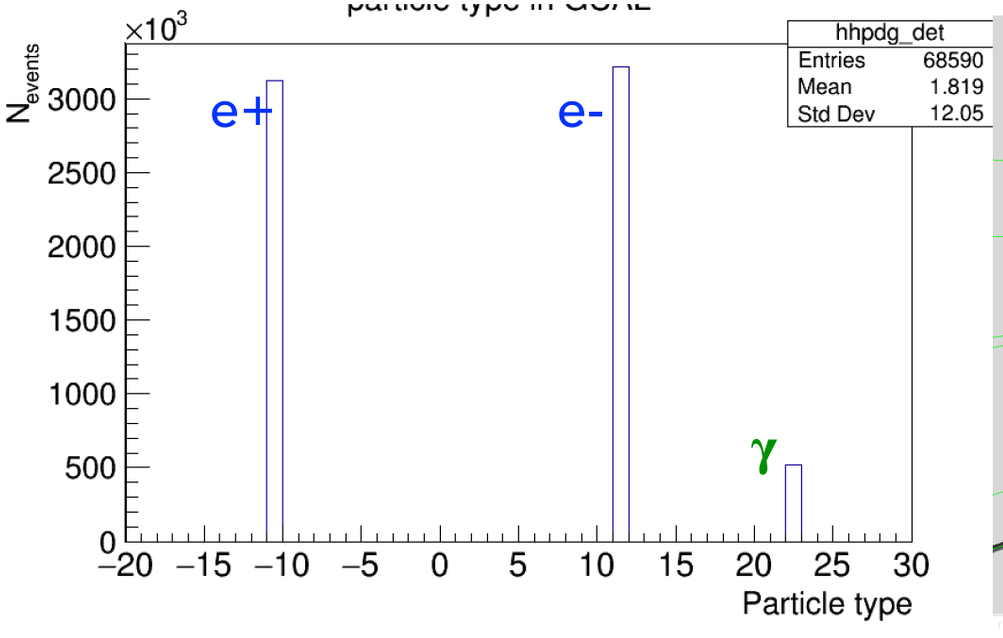


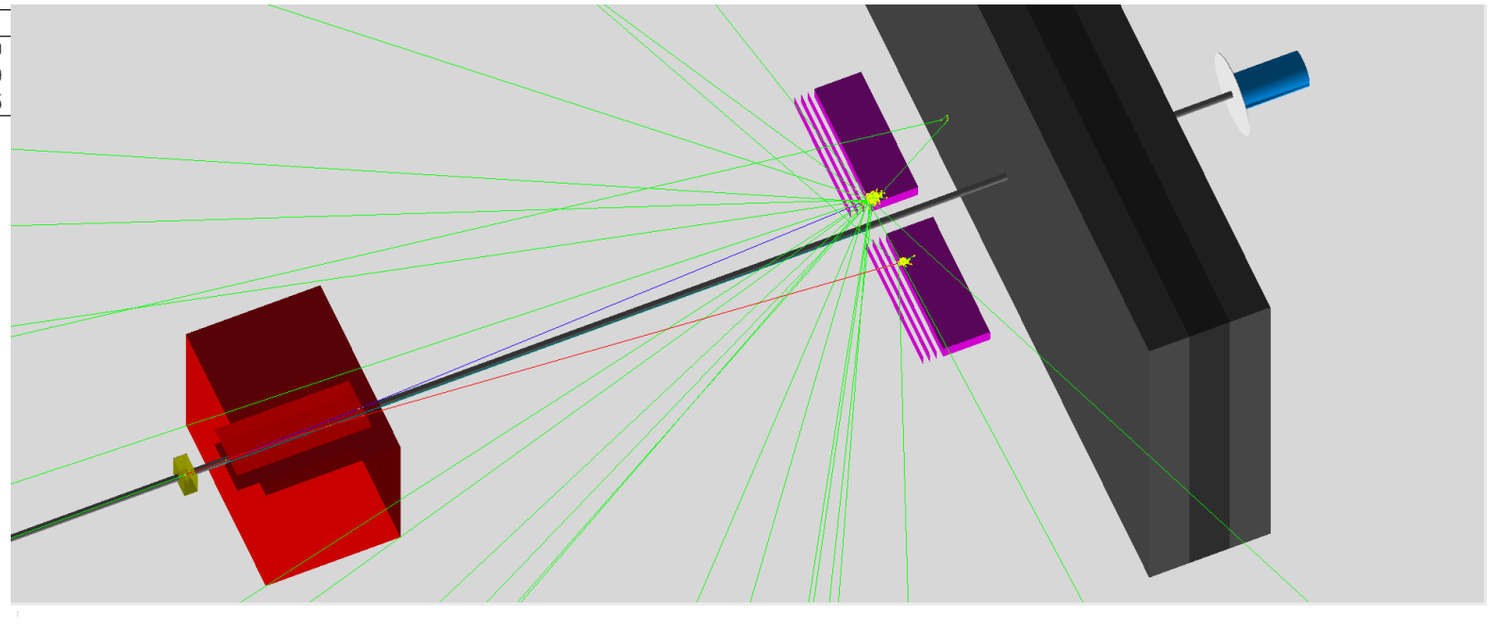
HICS for 17 GeV electrons, intensity sweep

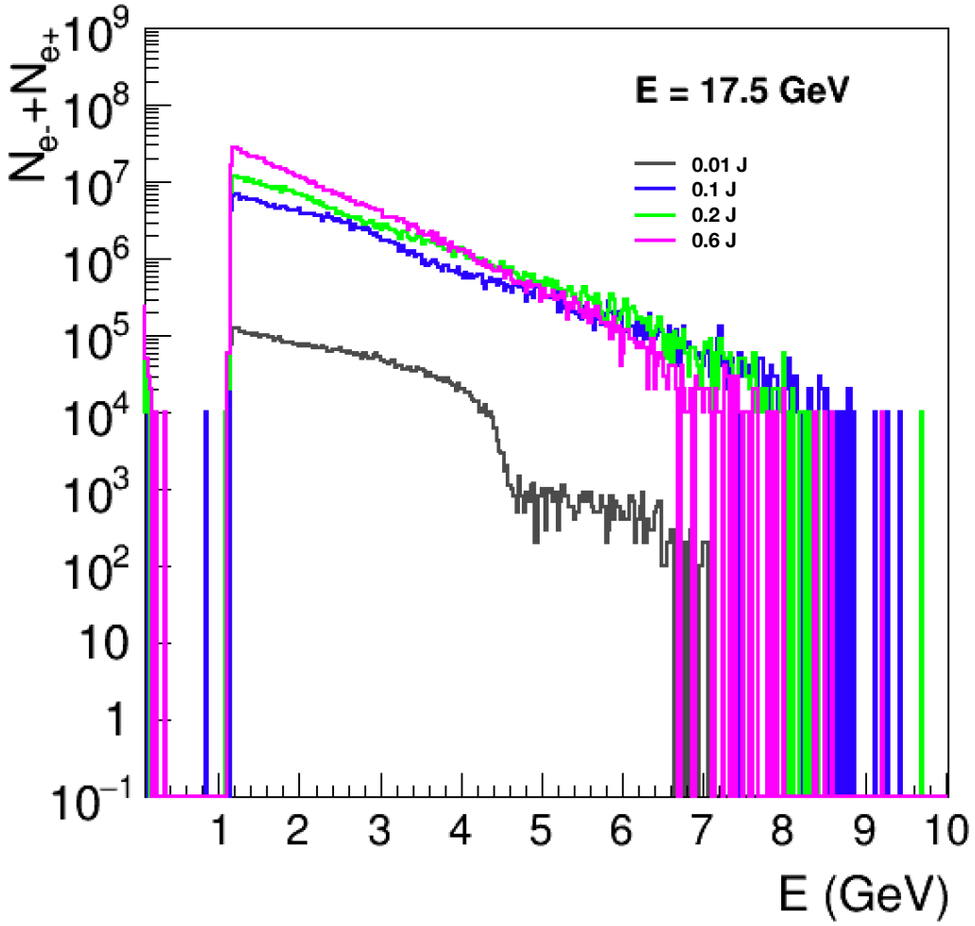


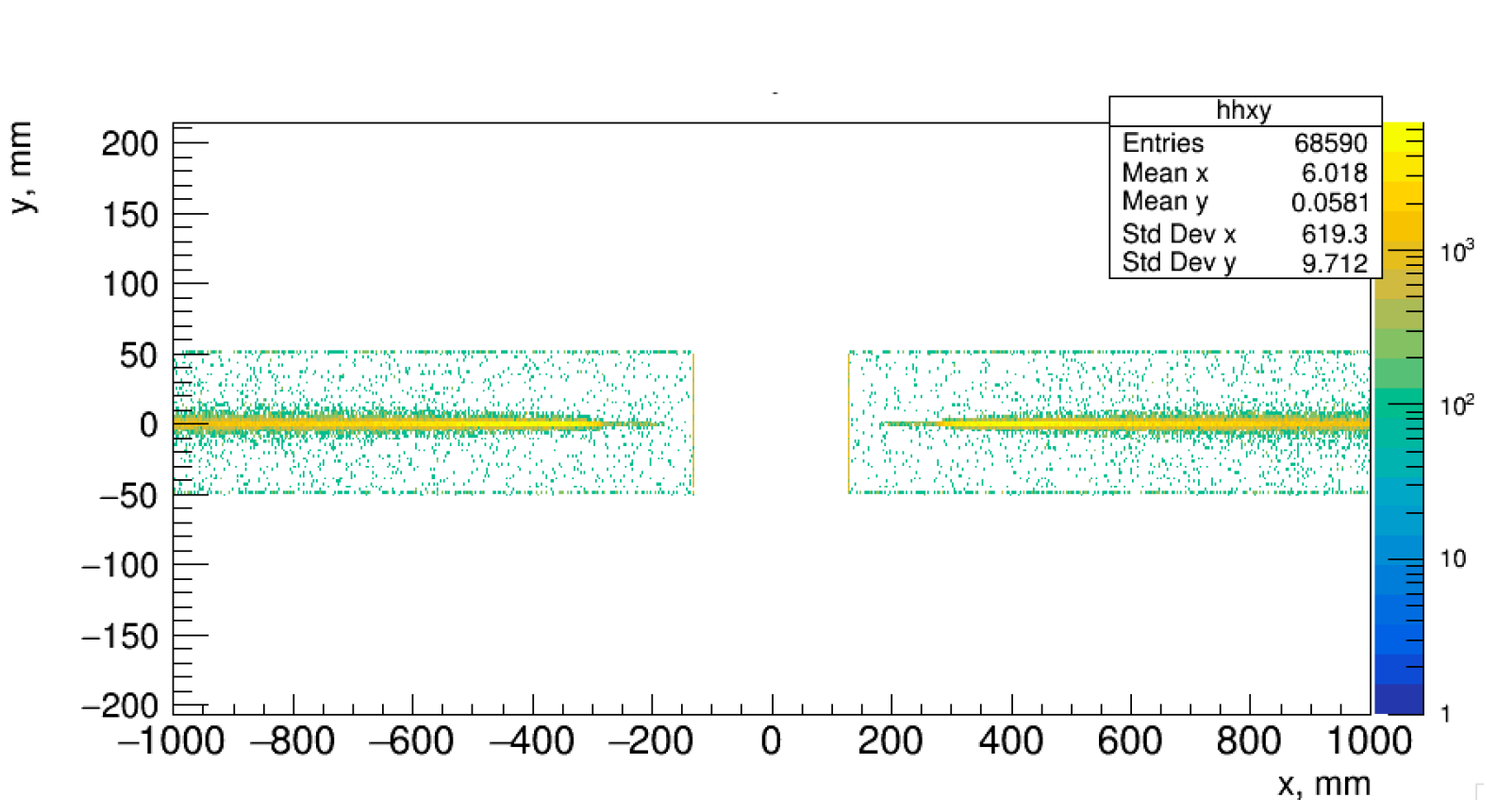


Compton detector

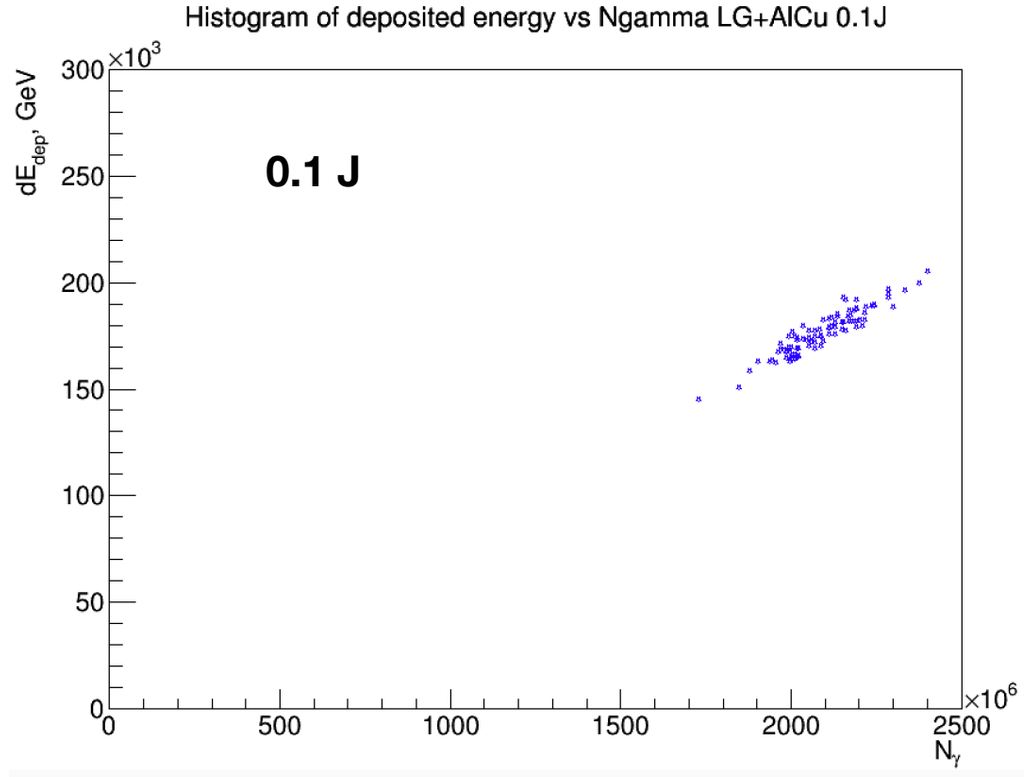


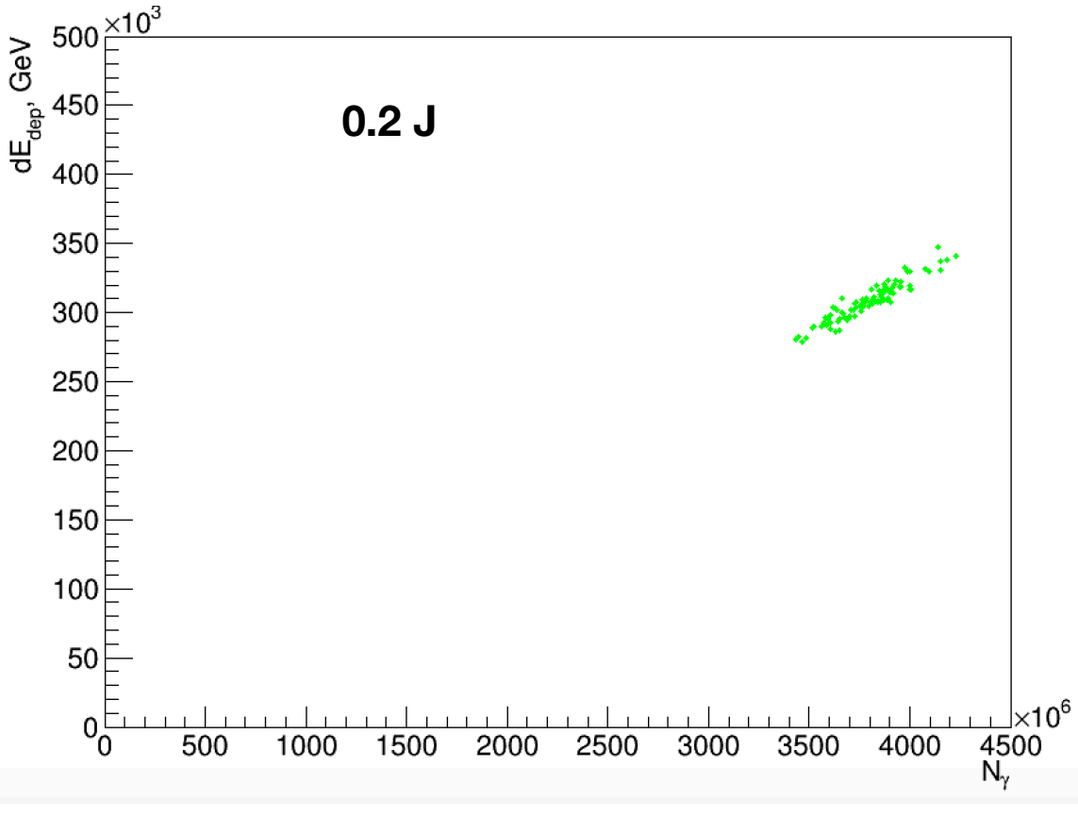


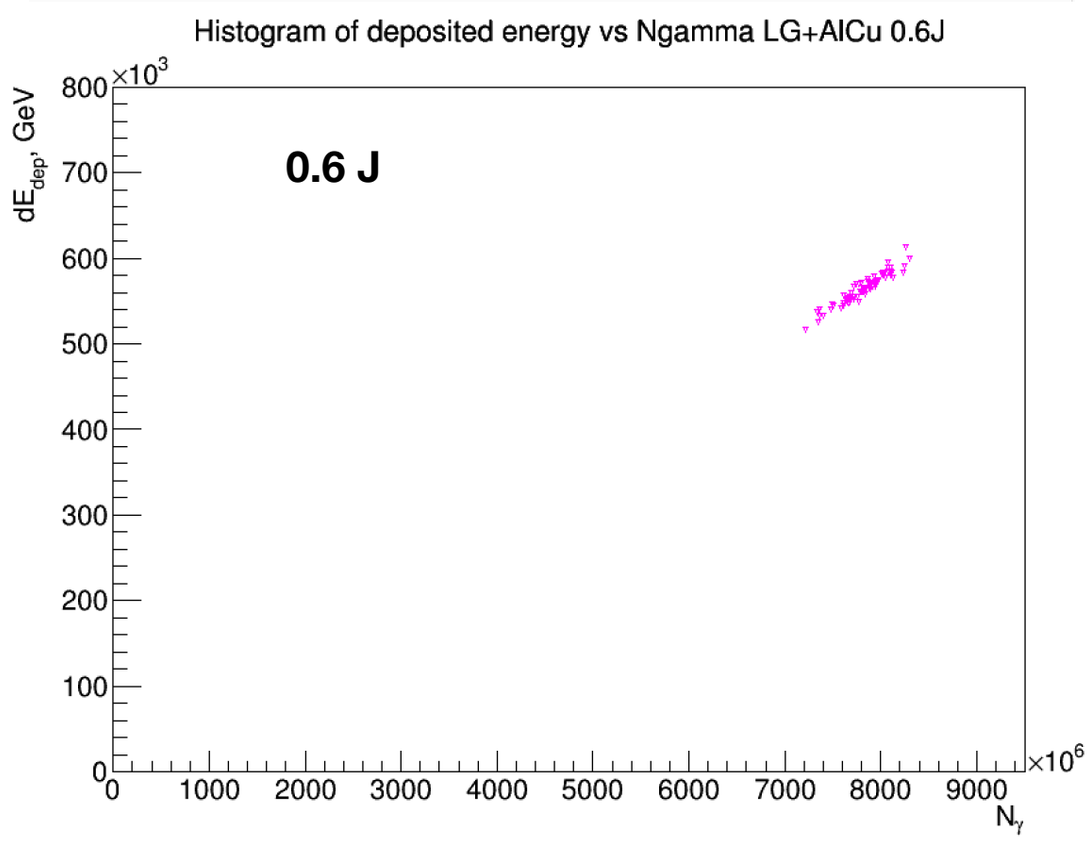




The dependence of deposited energy on number of incoming photons per BX for LG Gamma monitor and AlCu dump



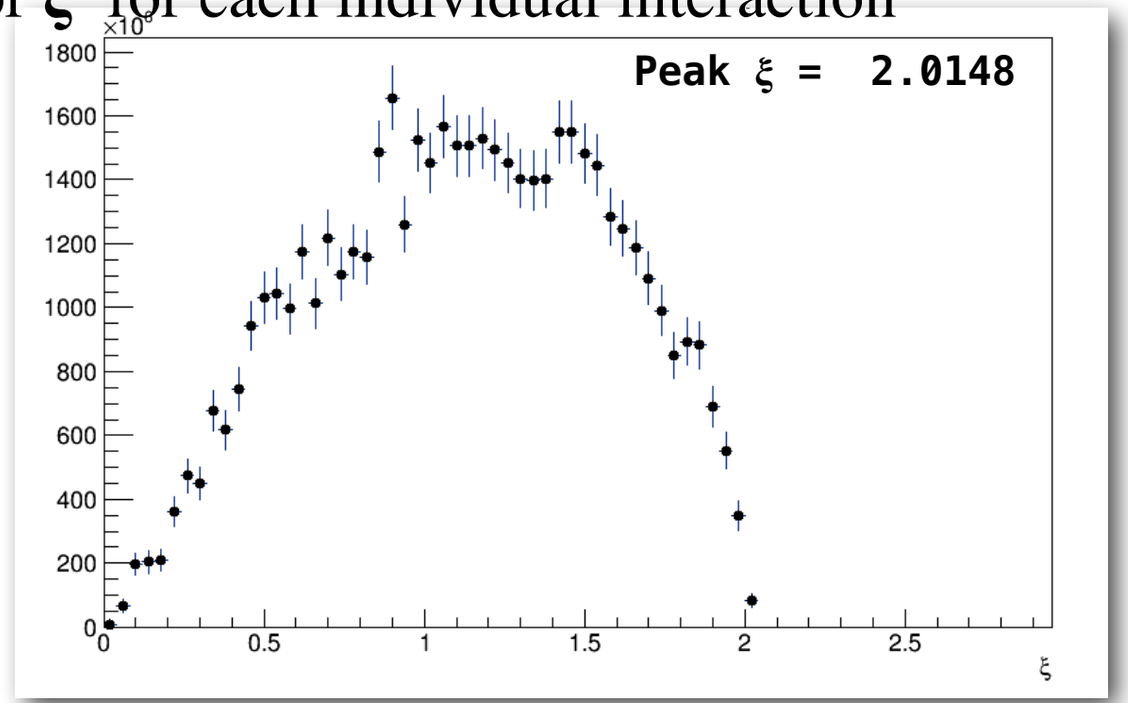


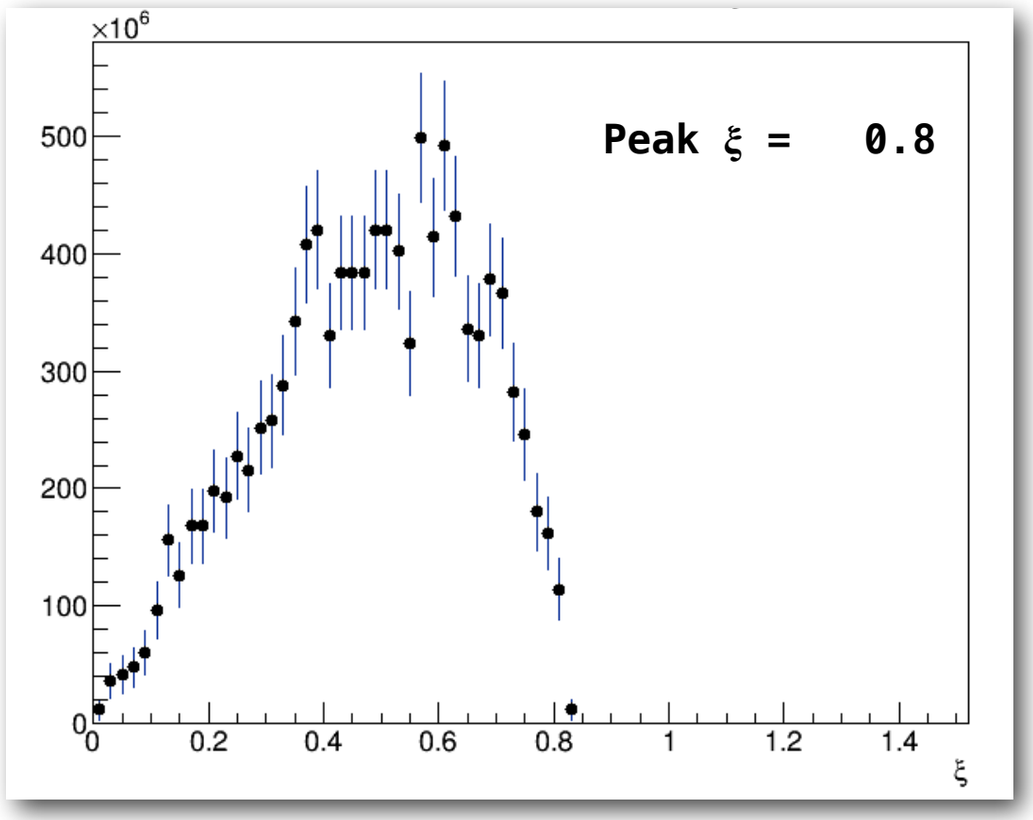


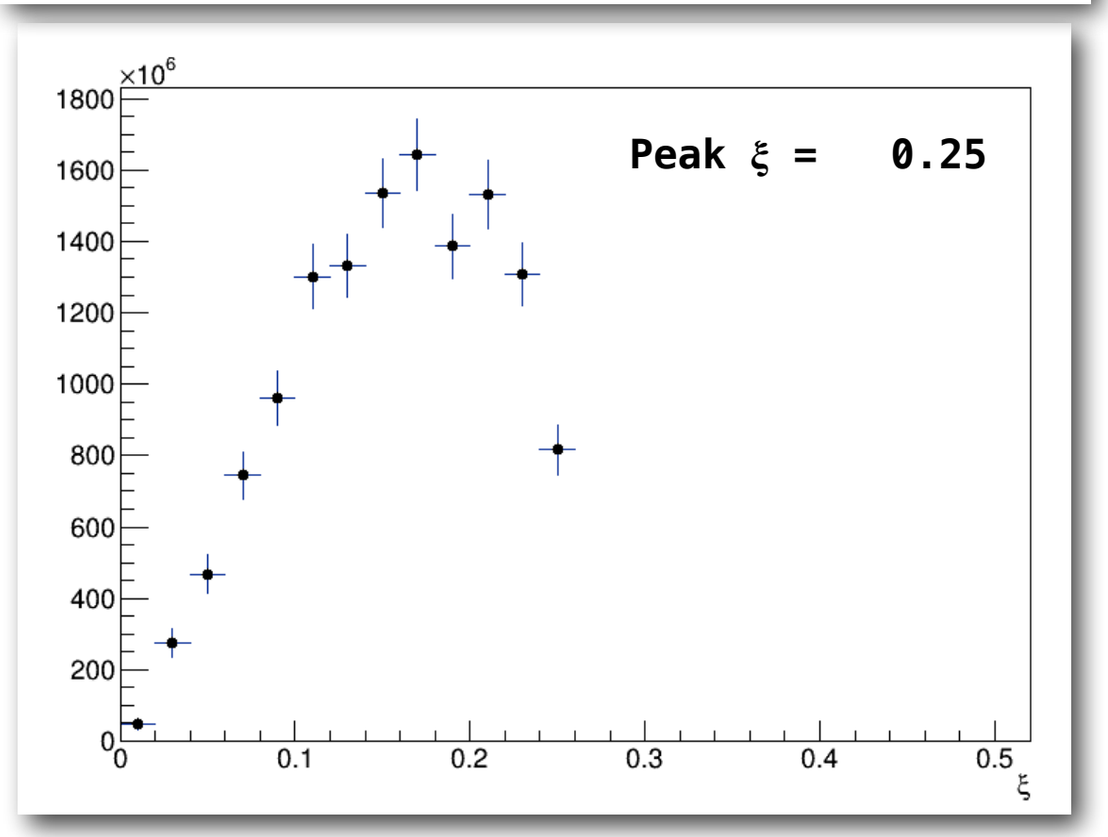
Laser Intensity

MC simulation provides information for ξ for each individual interaction

- Realistic simulation of laser pulse intensity distribution.
- The field is not the same across the laser pulse.



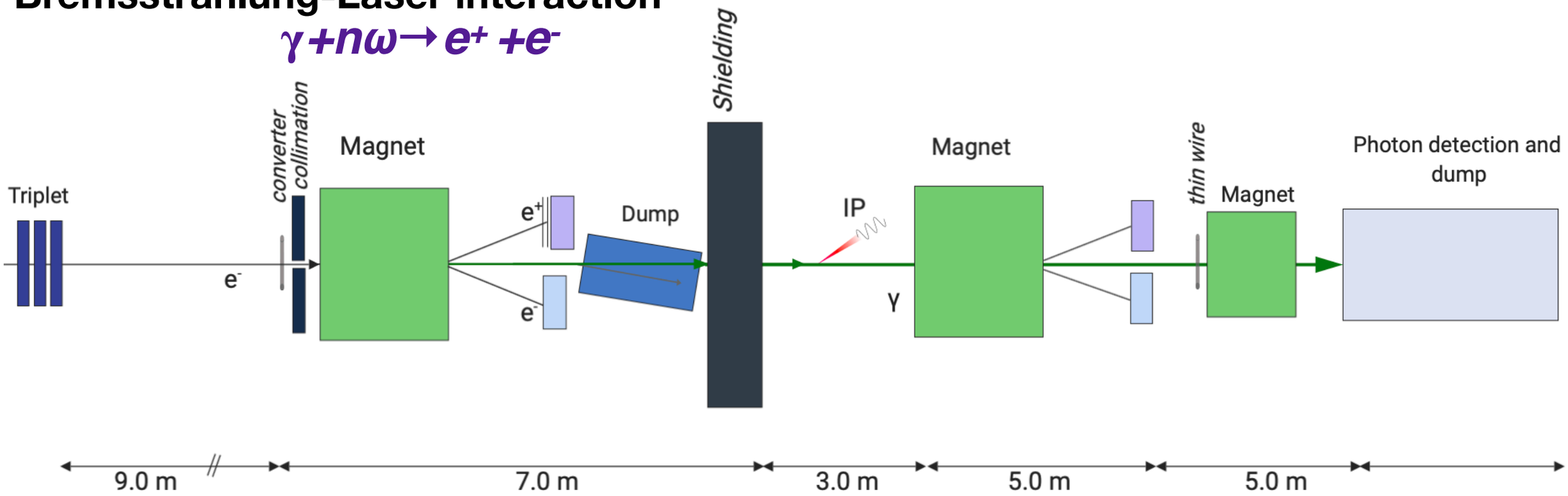




LUXE Set Up

Bremsstrahlung-Laser interaction

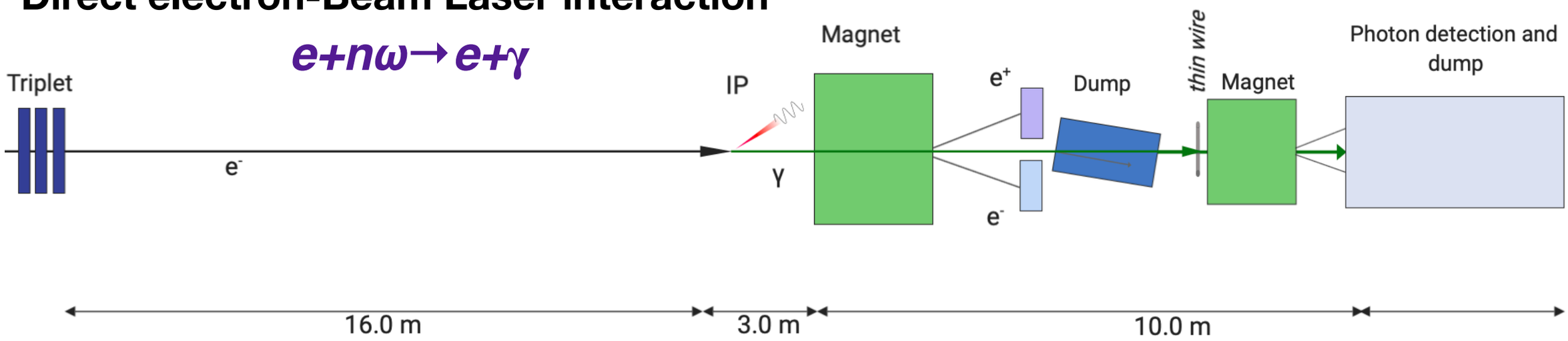
$\gamma + n\omega \rightarrow e^+ + e^-$



the non-linear pair-production process

Direct electron-Beam Laser interaction

$e + n\omega \rightarrow e + \gamma$



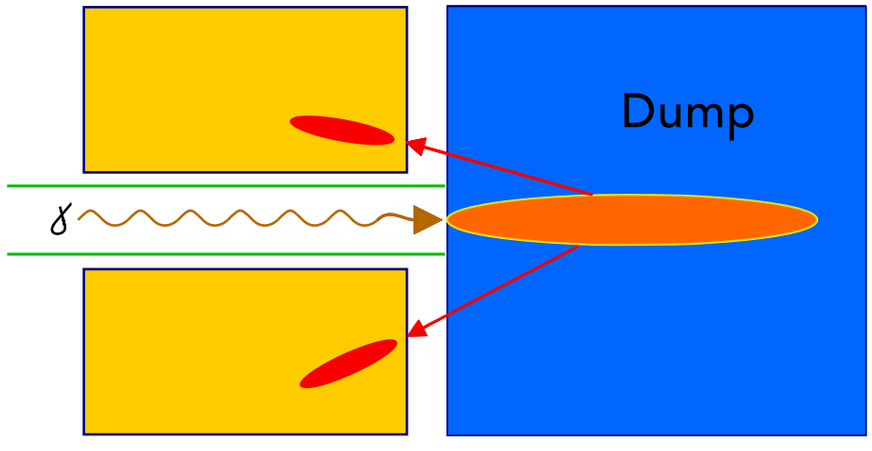
one-step and two-step trident
the non-linear Compton processes

Rates from LOI

For 6.0e9 electrons in BX w/ E= 17 GeV

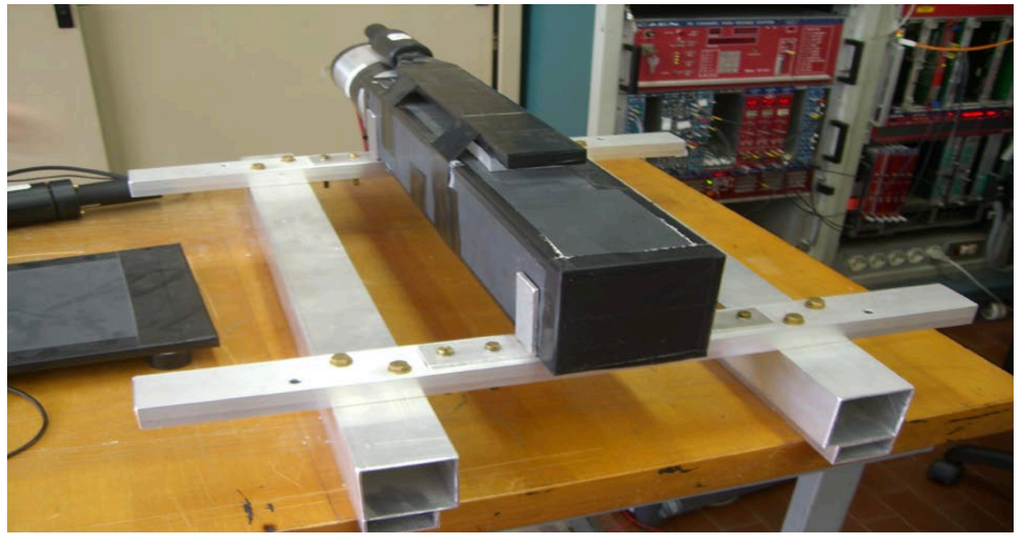
Location	particle type	rate for ξ=2.6	rate for ξ=0.26
e– detector	e–, E <16 GeV	**5.9e+9**	**2.4e+07**
e+ detector	e+	**61.07**	**0.0**
Photon detector	γ	**2.4e+11**	**3.8e+07**
Photon detector	e+ and e–	**2.3e+07**	**4.2e+04**
Photon detector	e+ and e–	**5.8e+5**	**3.8e+03**

The Idea:



Lead glass blocks from Hermes Experiment

Available: 6 calorimeter blocks w/ measures 9×9 cm^2, length is 50 cm



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K_2O	7.0
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Radiation length (cm)	2.78
Density (g/cm^3)	3.86
Critical energy (MeV)	17.97
Moliere radius (cm)	3.28
Refraction index	1.65
Thermal expansion coefficient (C^{-1})	$8.5 \cdot 10^{-6}$

Table 1: Chemical composition and physical properties of the F101 LG

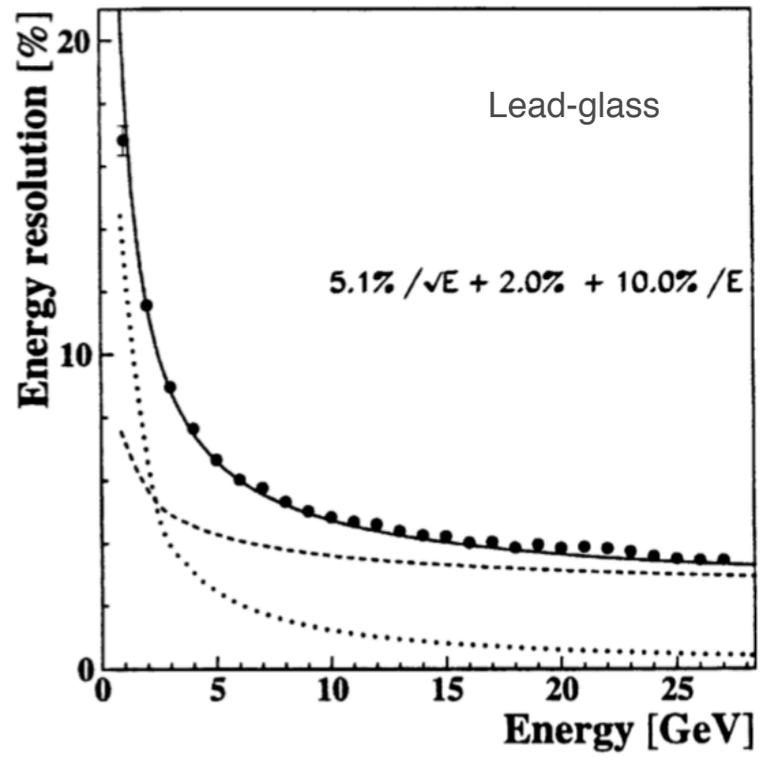
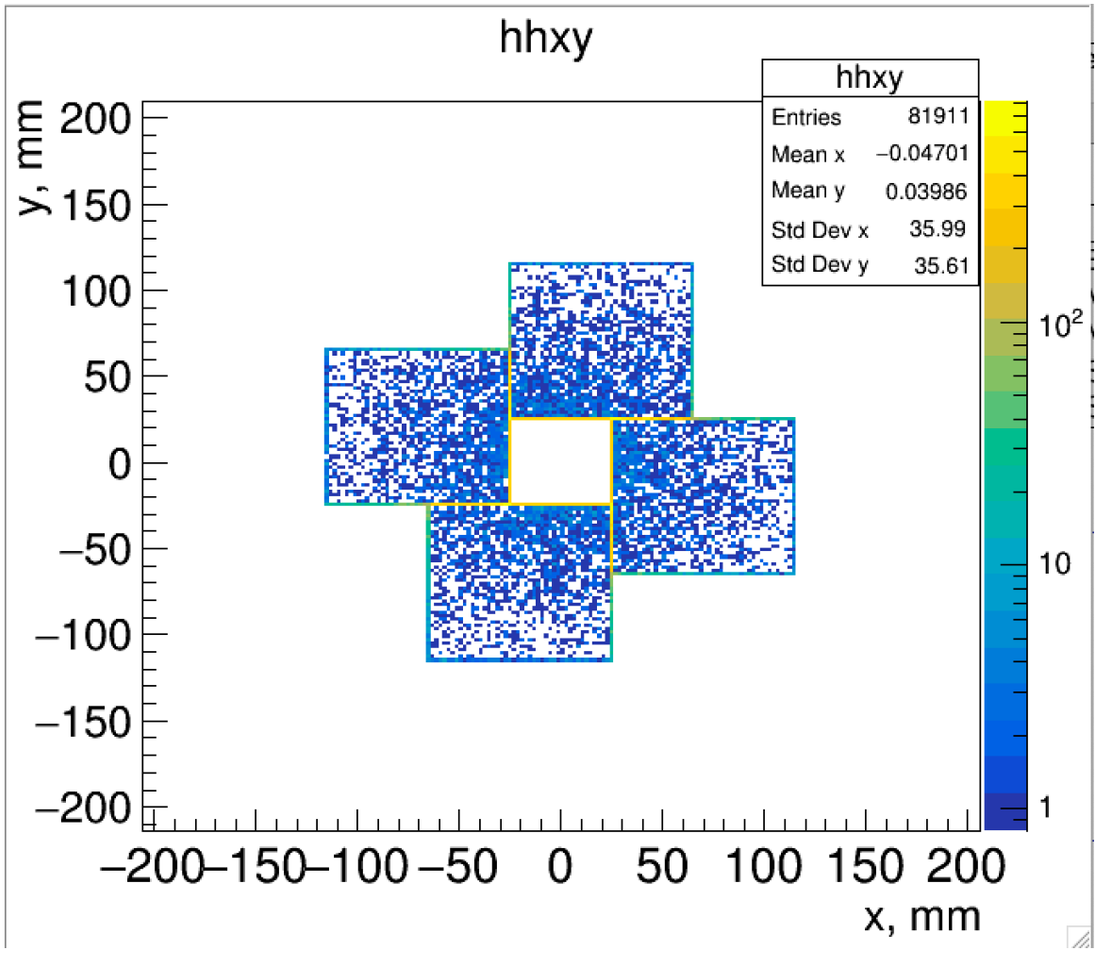
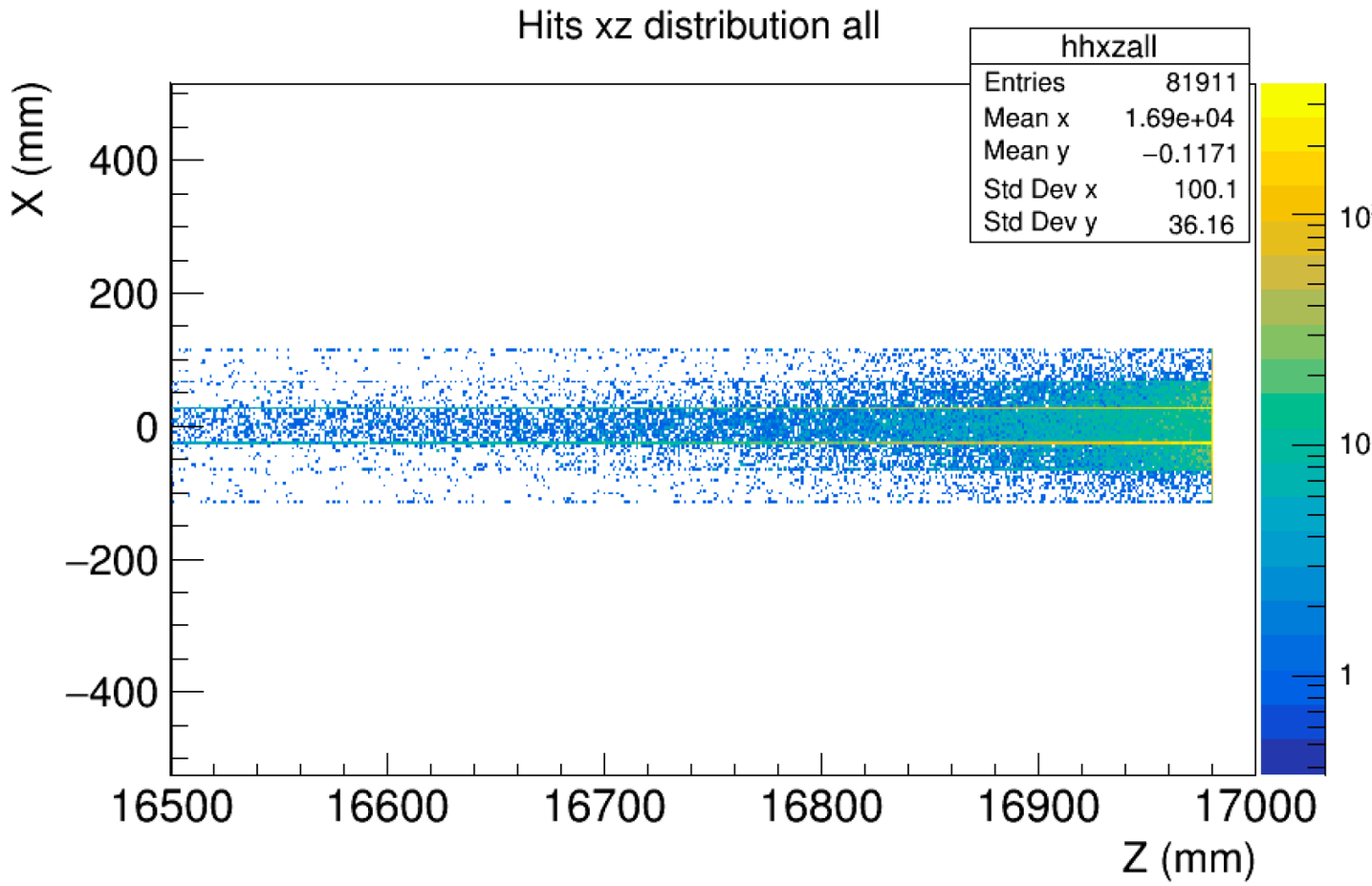
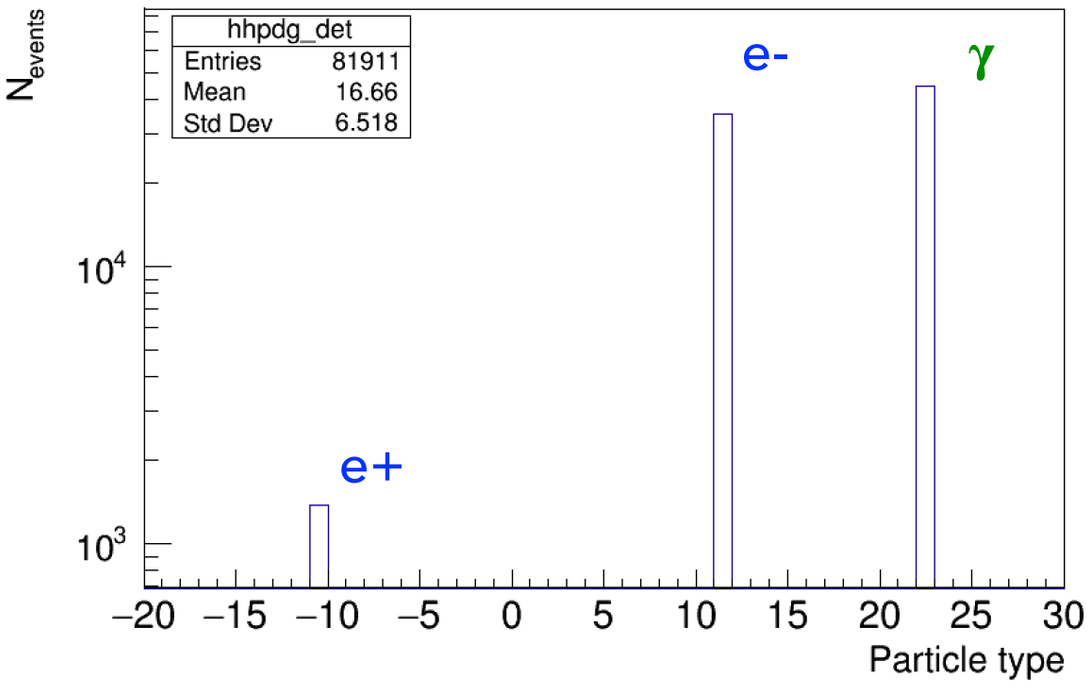


Fig. 5. Energy resolution of the calorimeter; the circles correspond to the 1996 data, the solid curve is the sum of the contributions from the lead-glass (dashed curve) and from the pre-shower (dotted curve) provided at test beam measurement [7].

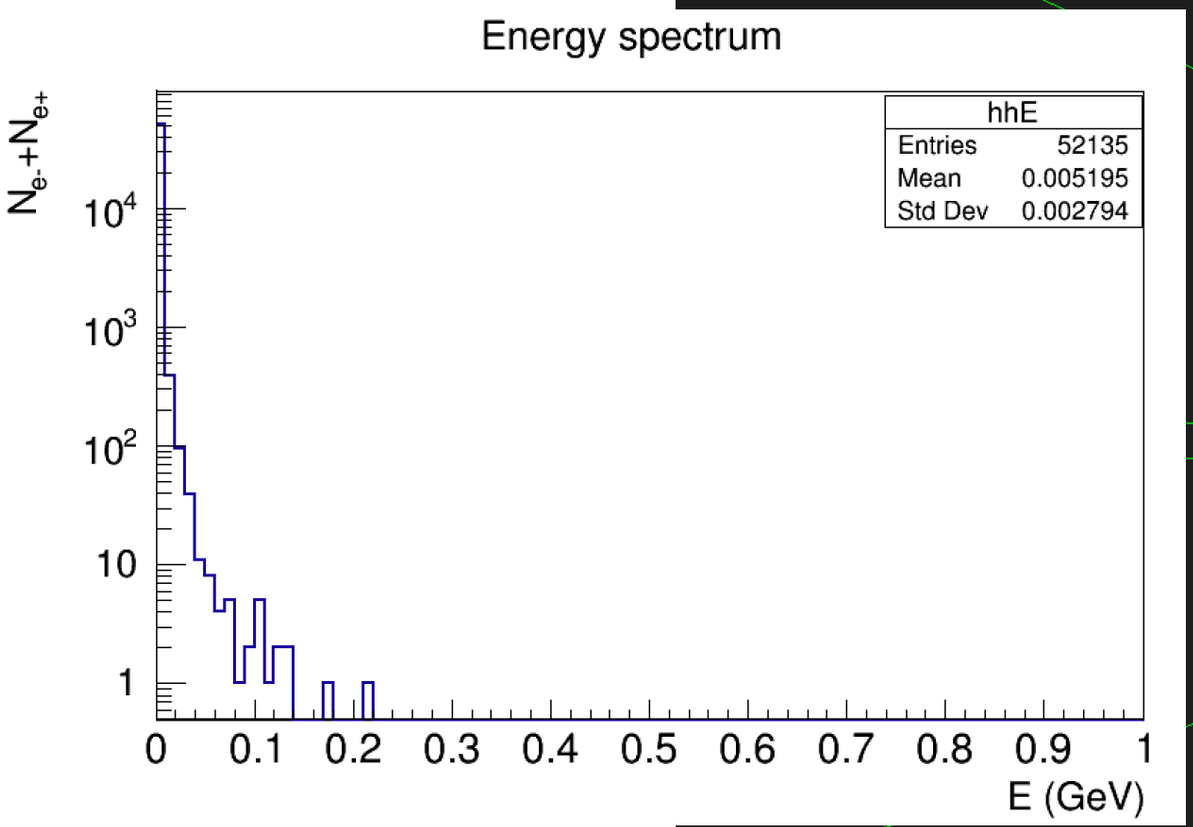
Control plots for LG monitor





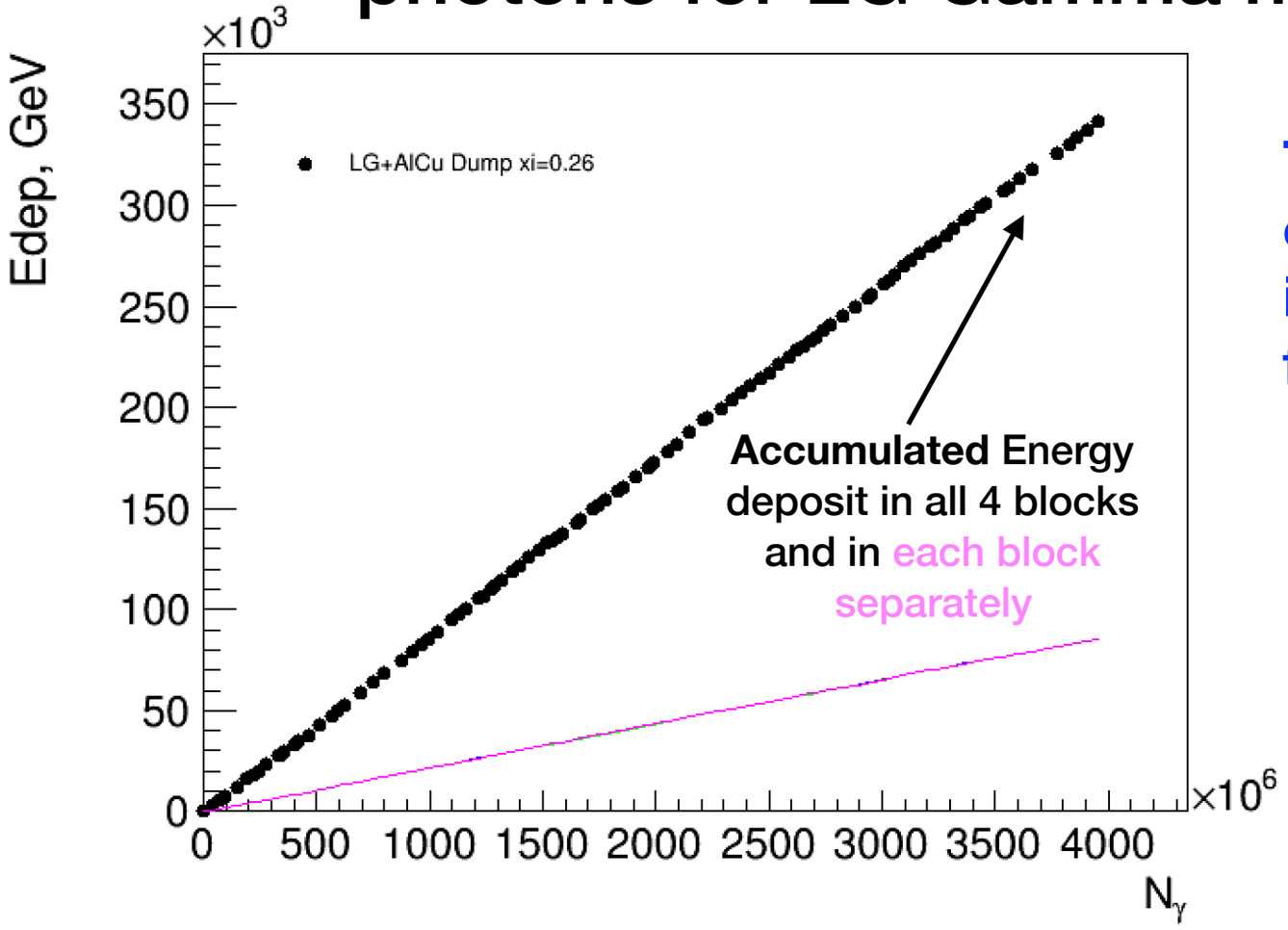


The distribution of hits of particles entering LG Gamma monitor in XY and XZ planes

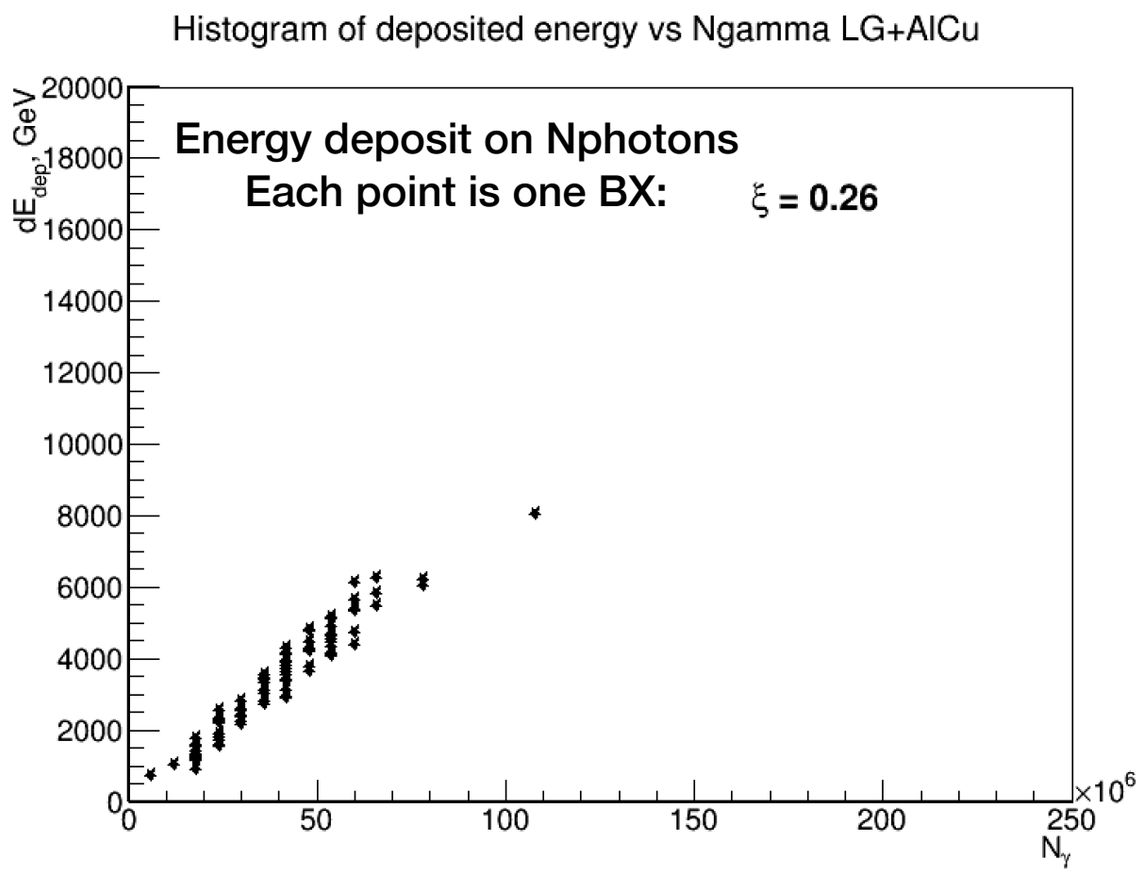

Energy spectrum
hhE
Entries 52135
Mean 0.005195
Std Dev 0.002794
$N_{e^-}+N_{e^+}$
10^4
10^3
10^2
10
1
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
E (GeV)

e- with 0.2 GeV

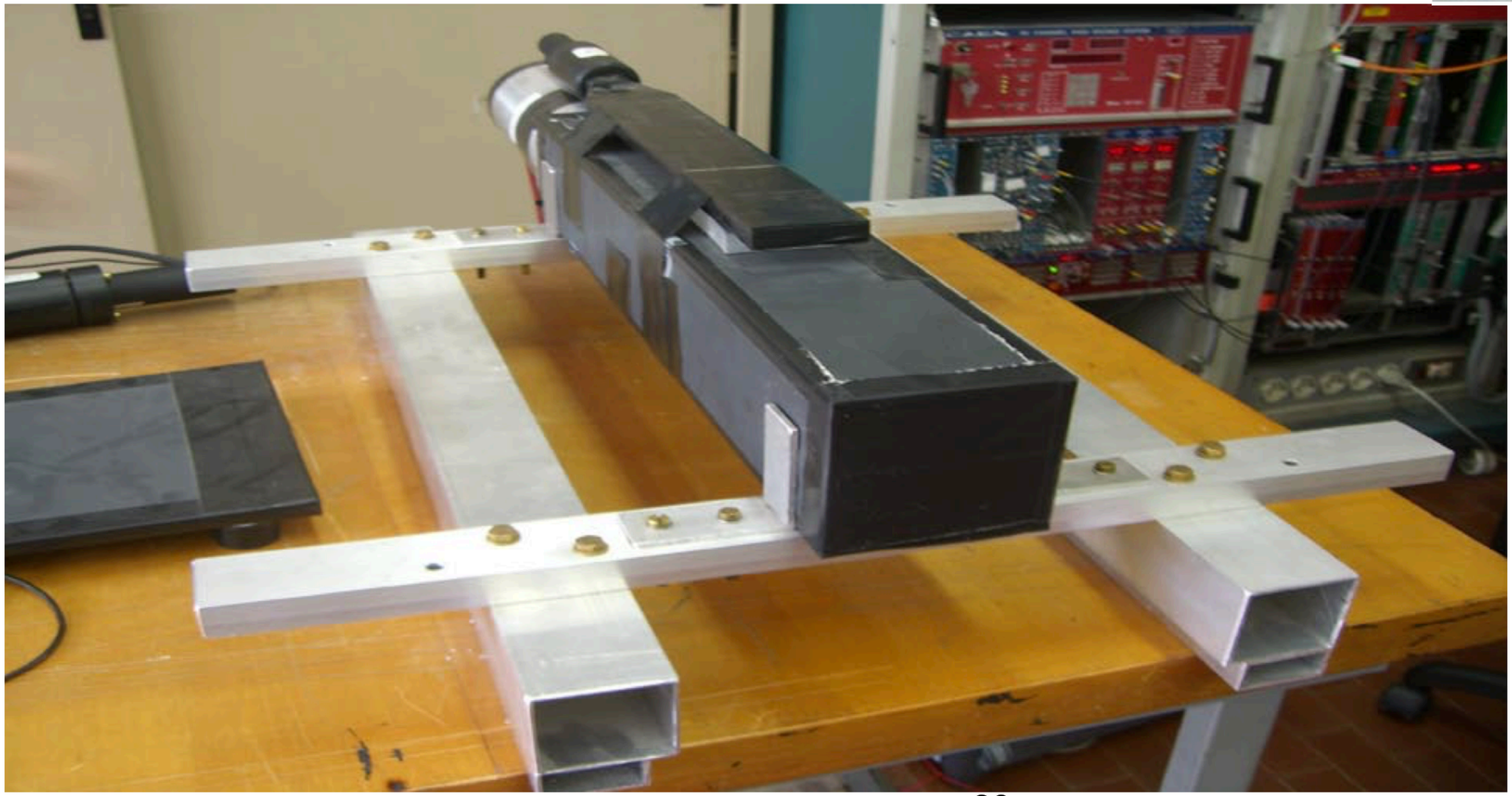
The dependence of deposited energy on number of incoming photons for LG Gamma monitor and AlCu dump



The linear dependence of deposited energy on number of incoming photons in LG allows the usage of backscatters for estimating the photon flux

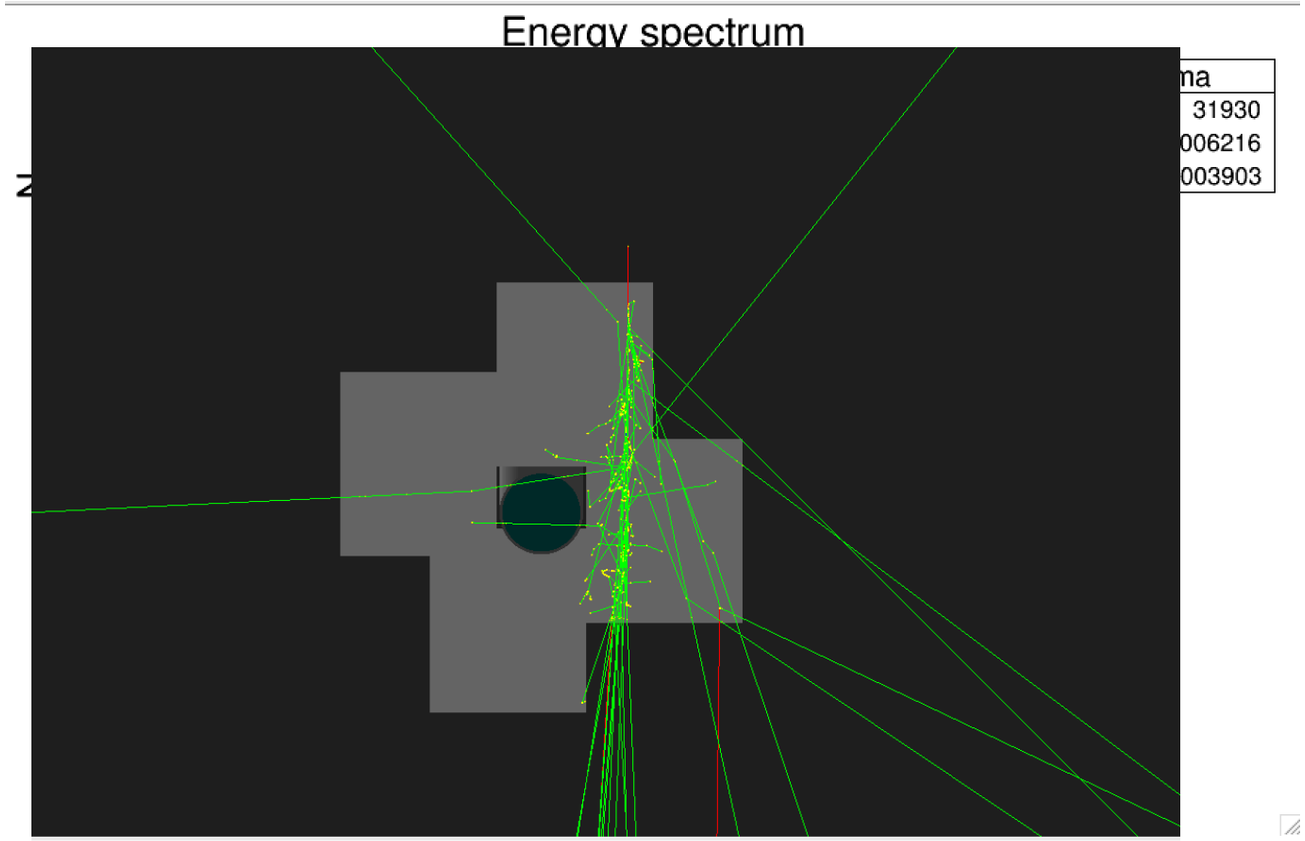


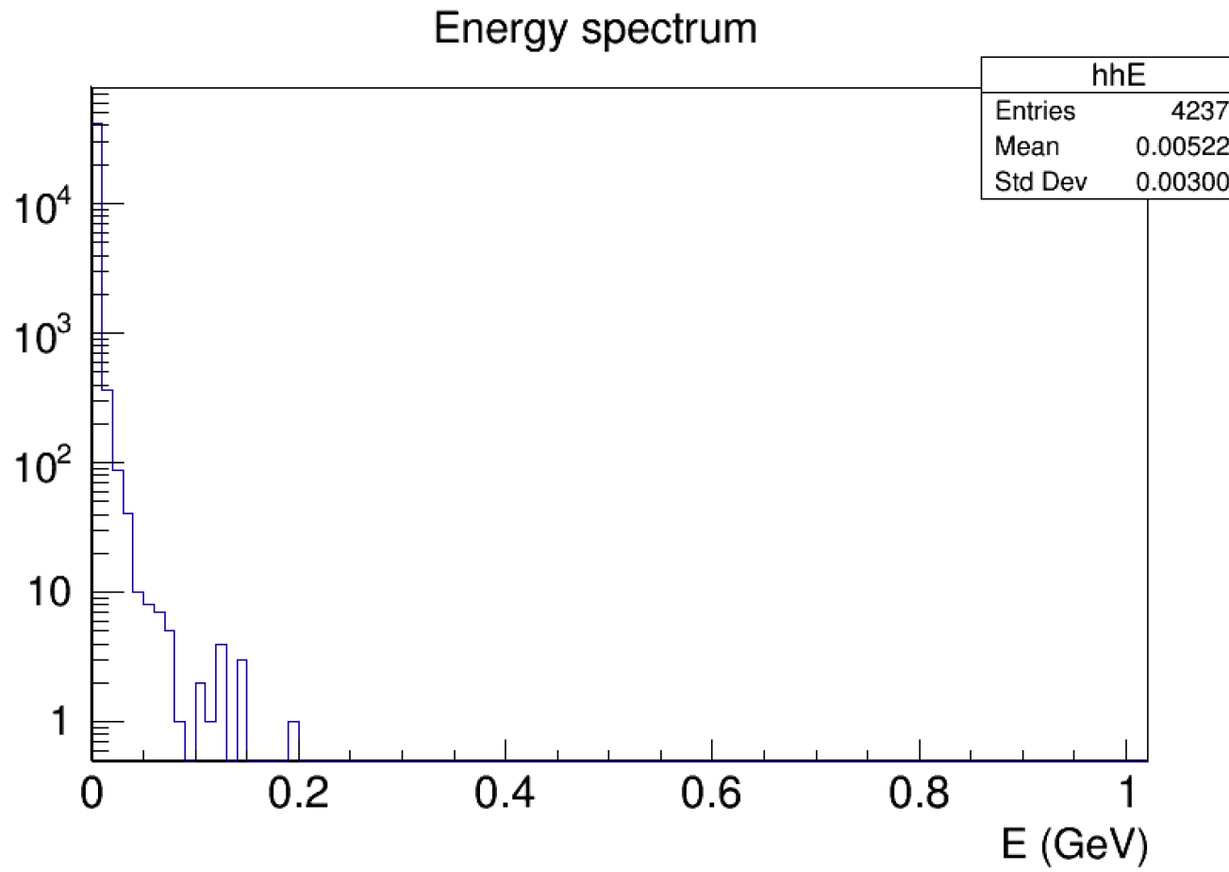
Wrapped LG block

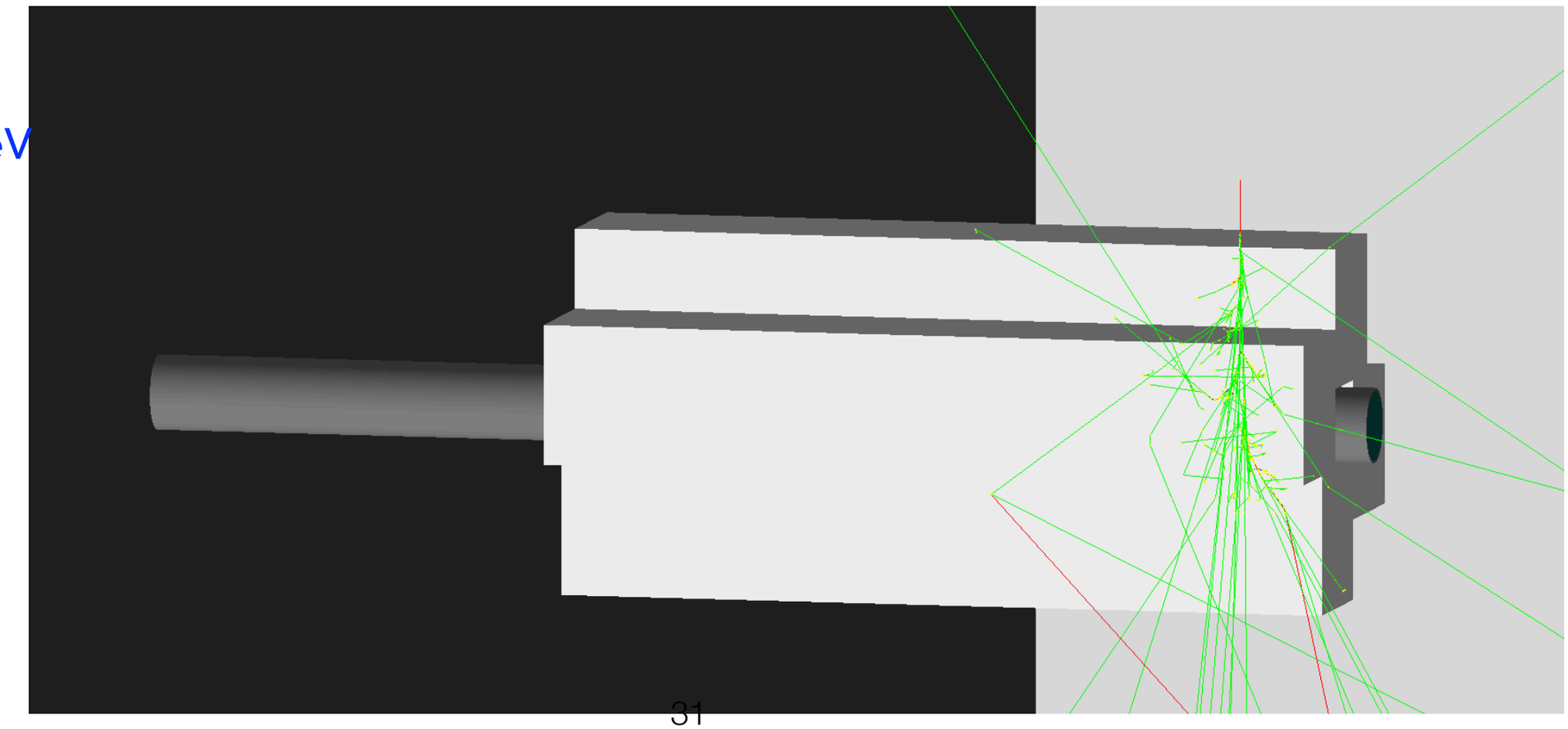


blocks are wrapped with an aluminized mylar foil to reflect the Cherenkov photons, and a tedlar foil to make the blocks light tight.

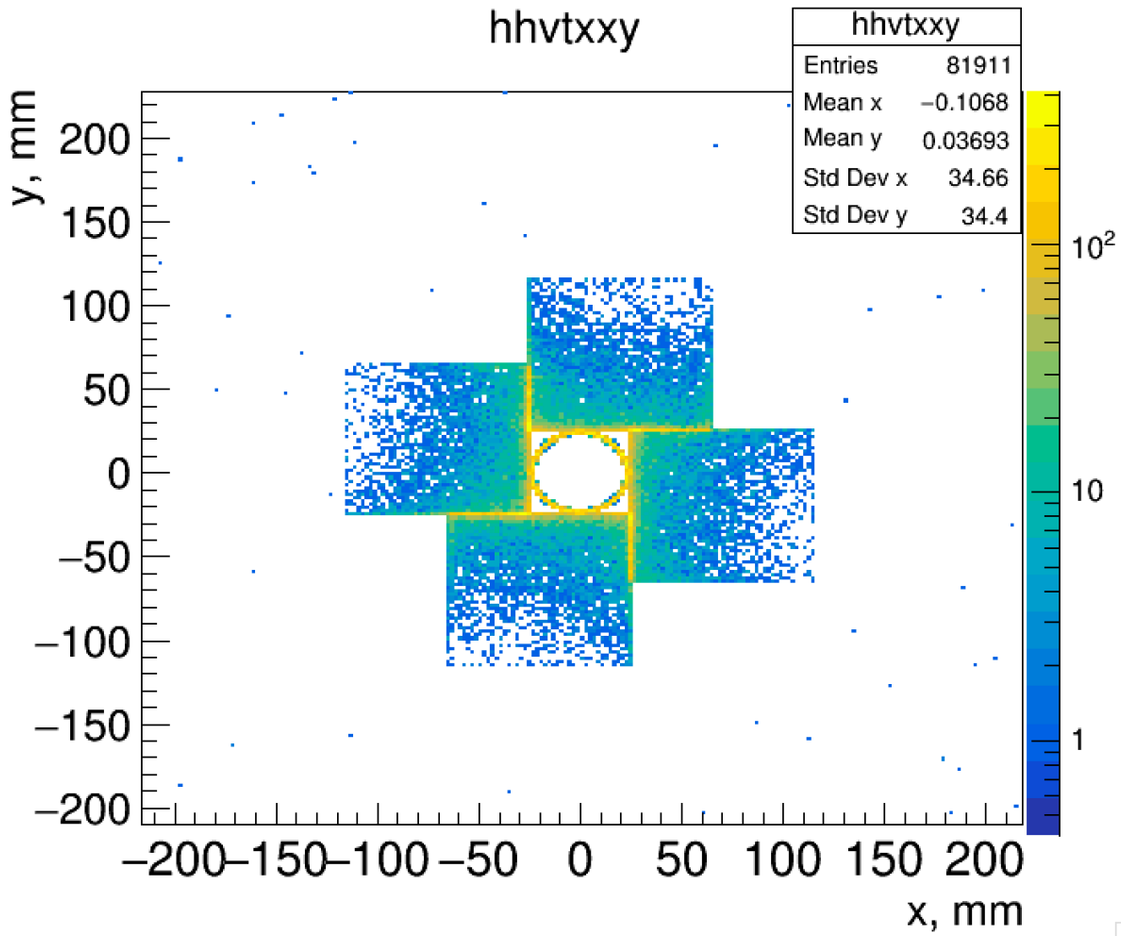
e- with 0.5 GeV

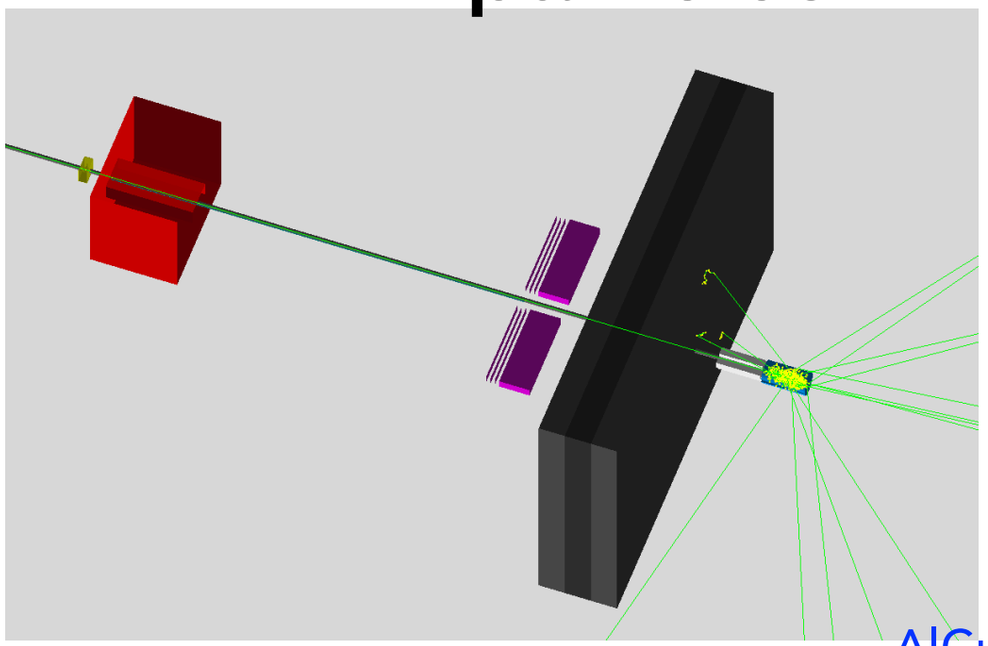

Energy spectrum
ma
31930
006216
003903


Energy spectrum
hhE
Entries 4237
Mean 0.00522
Std Dev 0.00300
10^4
10^3
10^2
10
1
0
0.2
0.4
0.6
0.8
1
E (GeV)



Vertexes of the particles

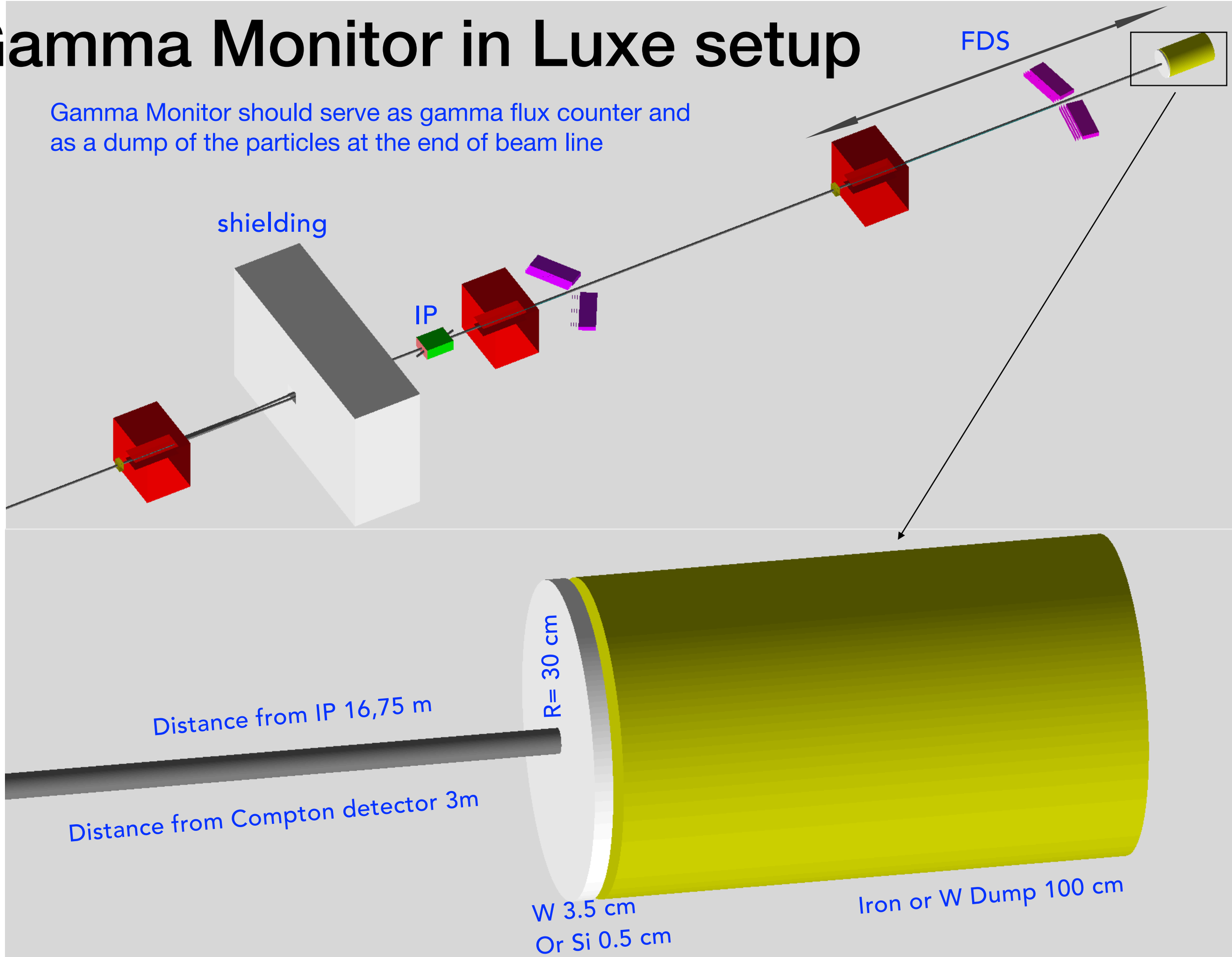




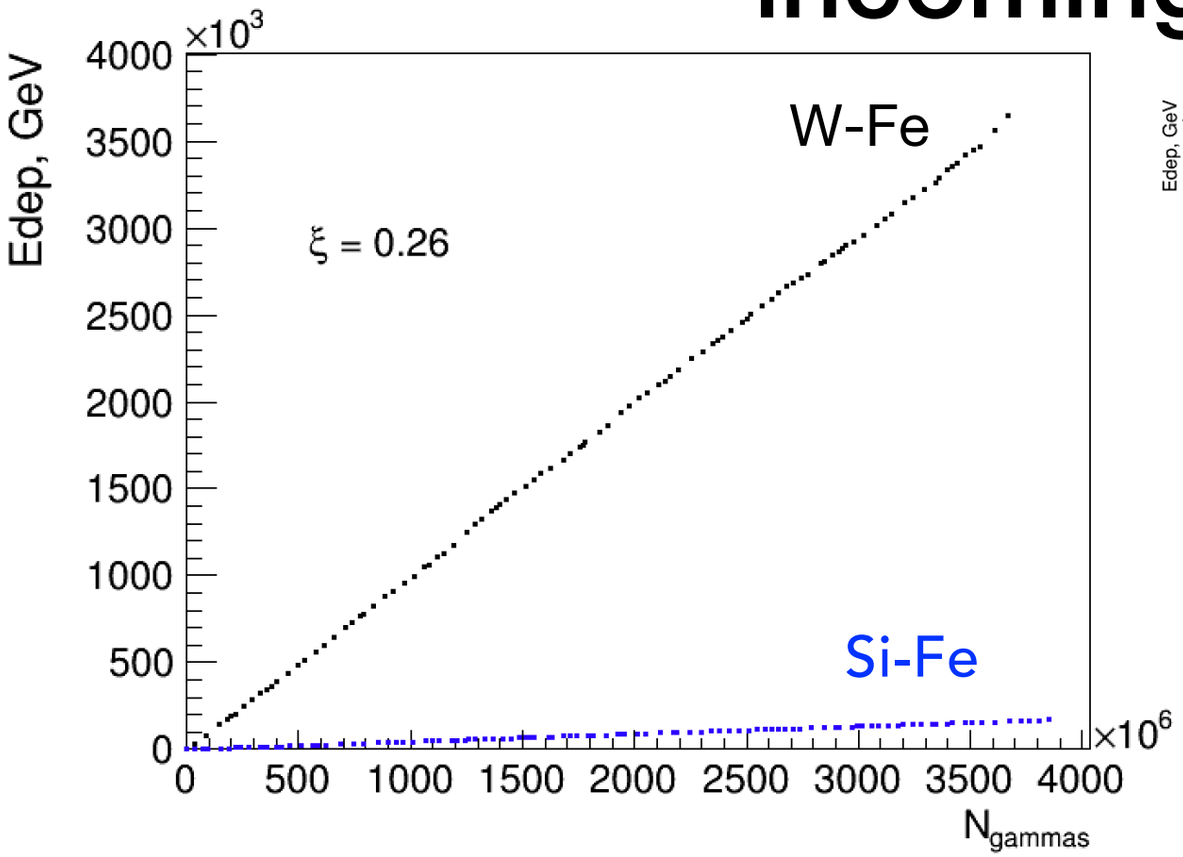
Vertex Z

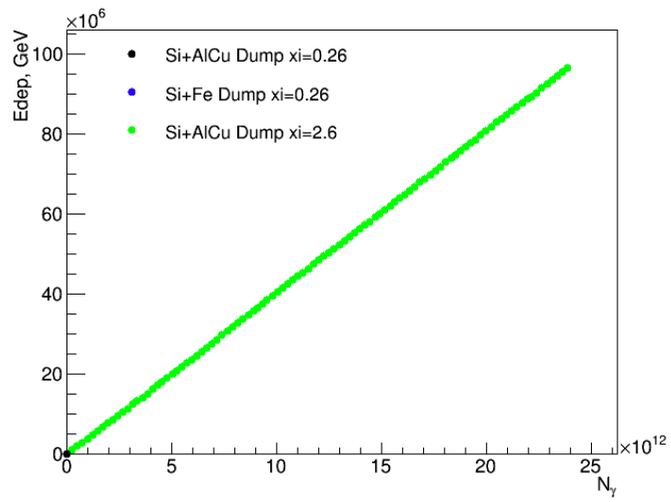
Gamma Monitor in Luxe setup

Gamma Monitor should serve as gamma flux counter and as a dump of the particles at the end of beam line

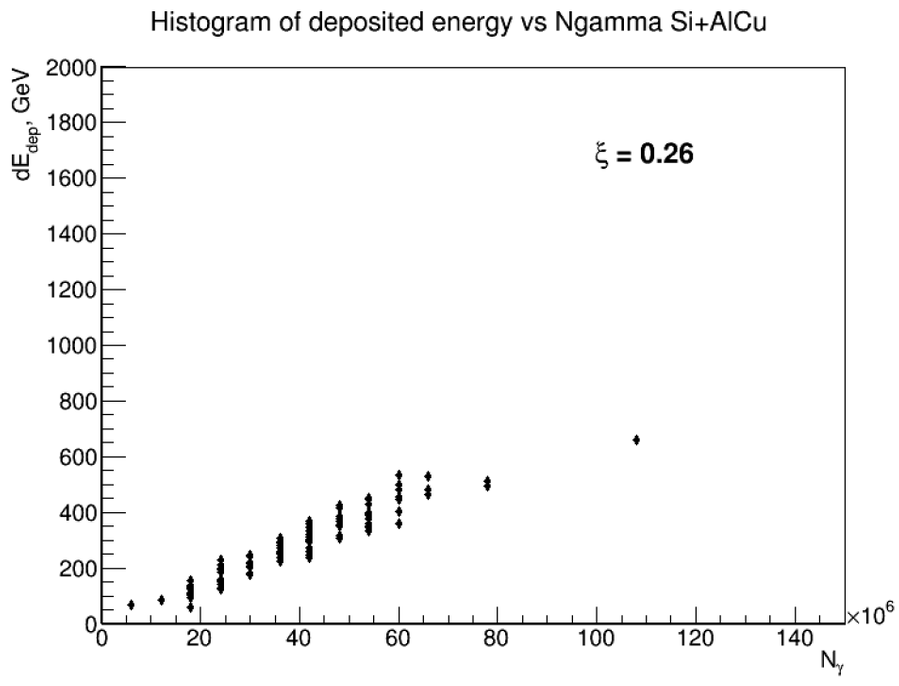


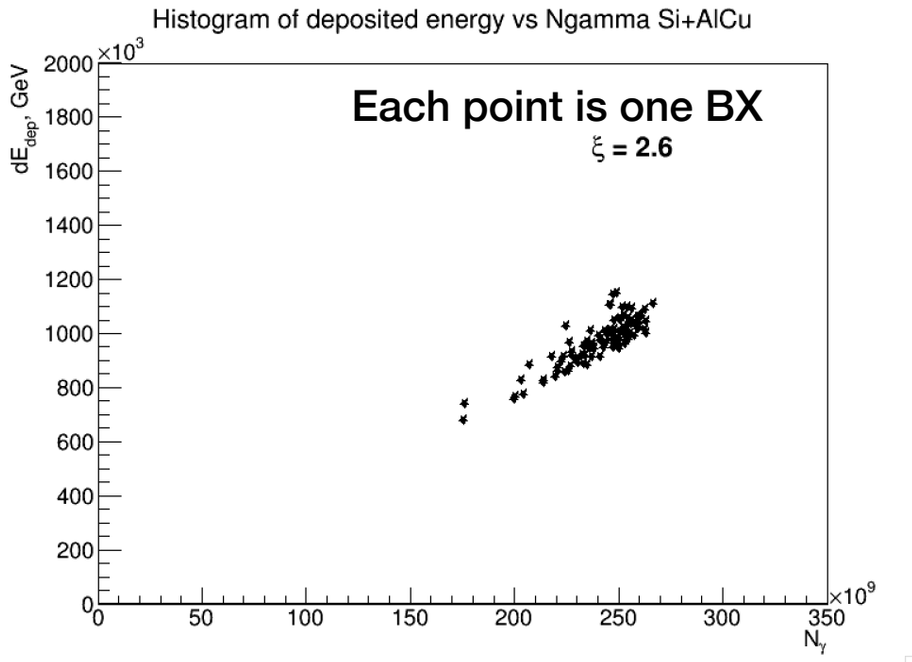
Energy dependence on number of incoming photons





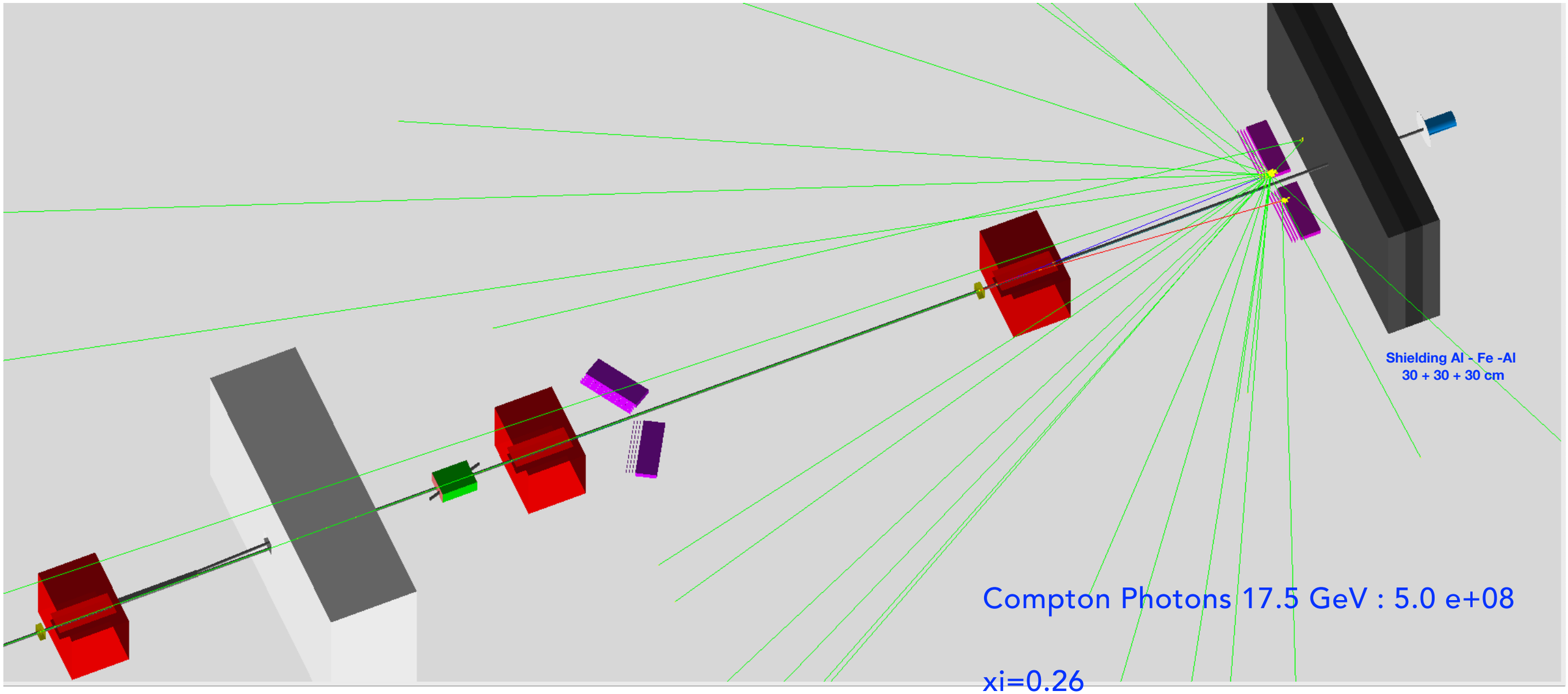
The linear dependence of deposited energy on number of incoming photons allows the usage of backscatters for estimating the photon flux



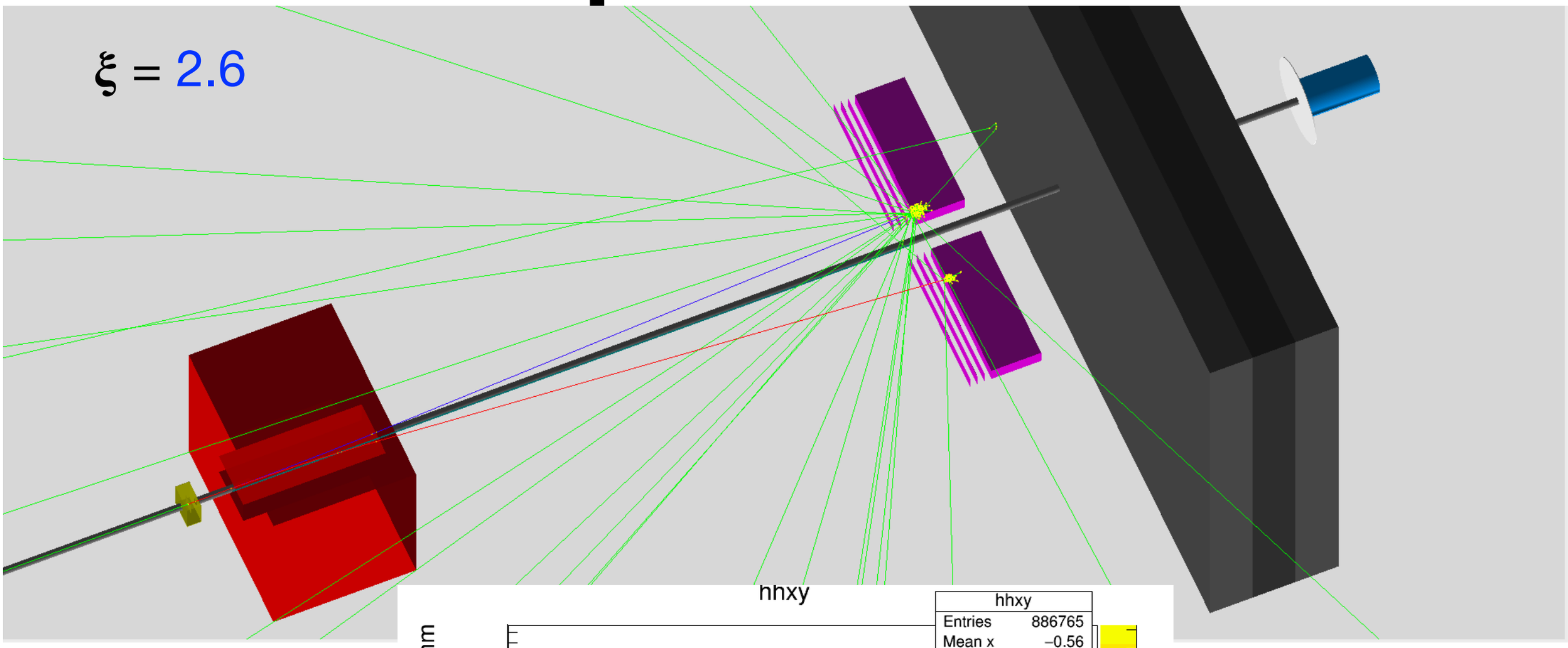


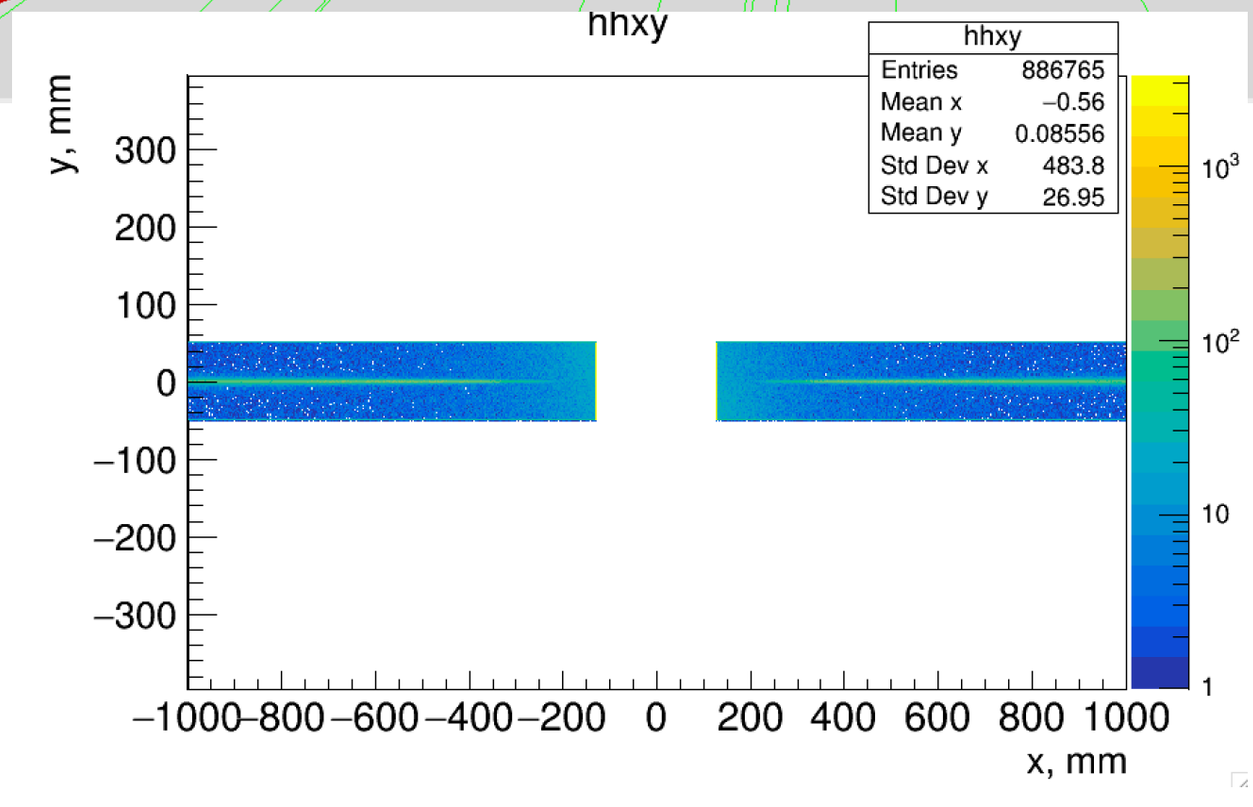
In average one γ deposits ~1 keV; w/ the sigma 0.2 keV

Luxe setup with non-tilted Compton Detector

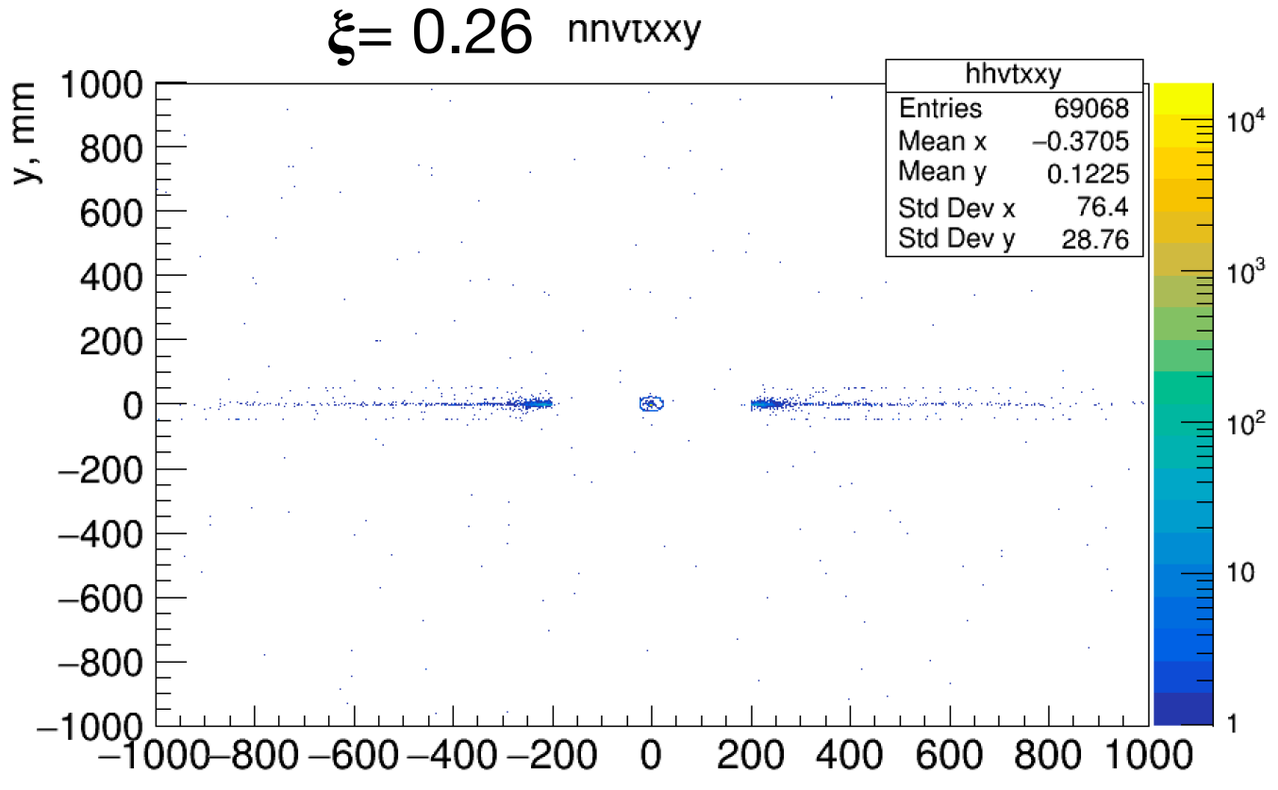


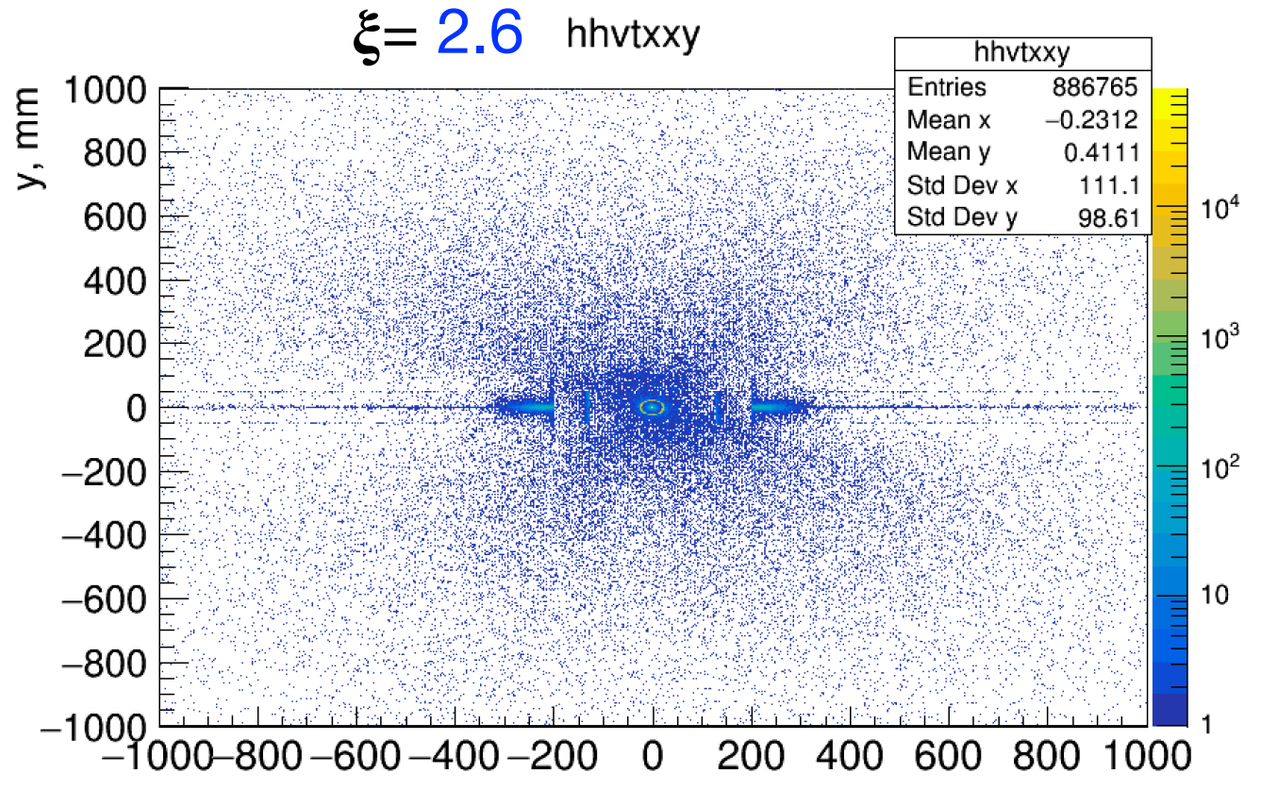
Compton detector

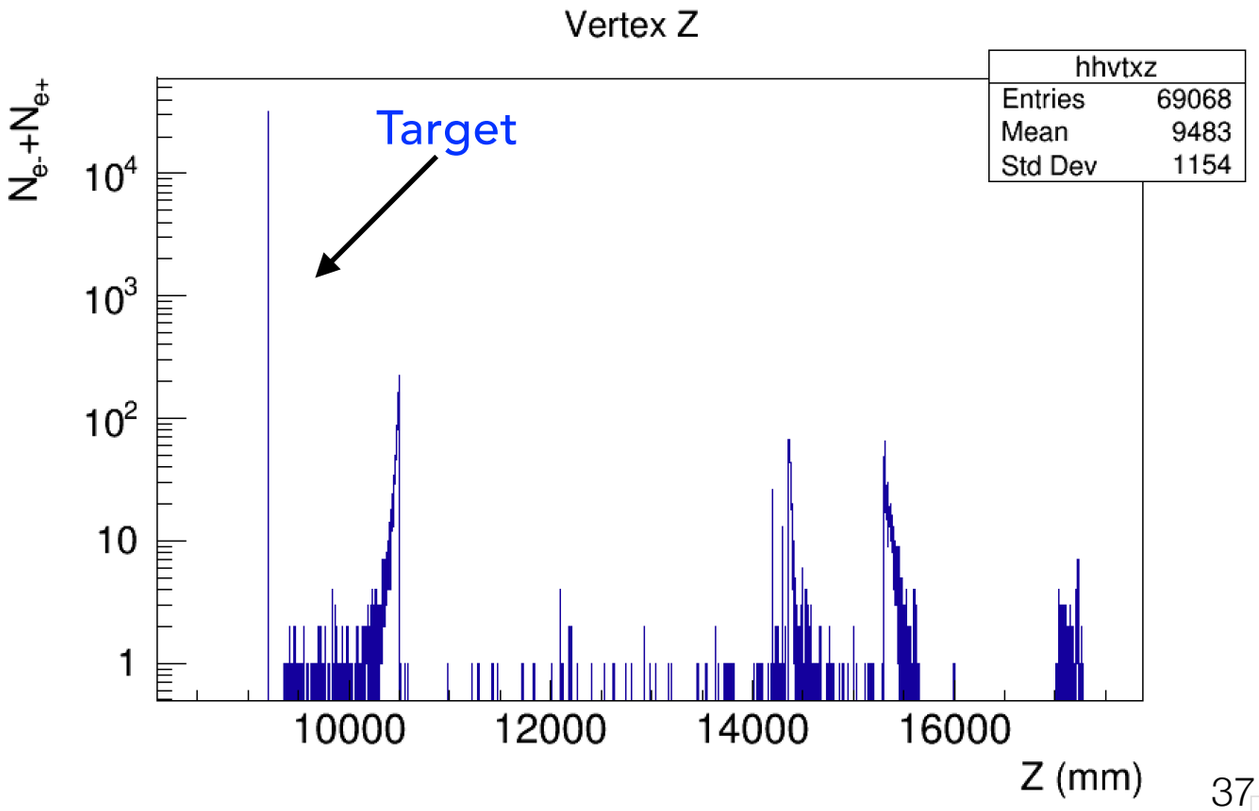


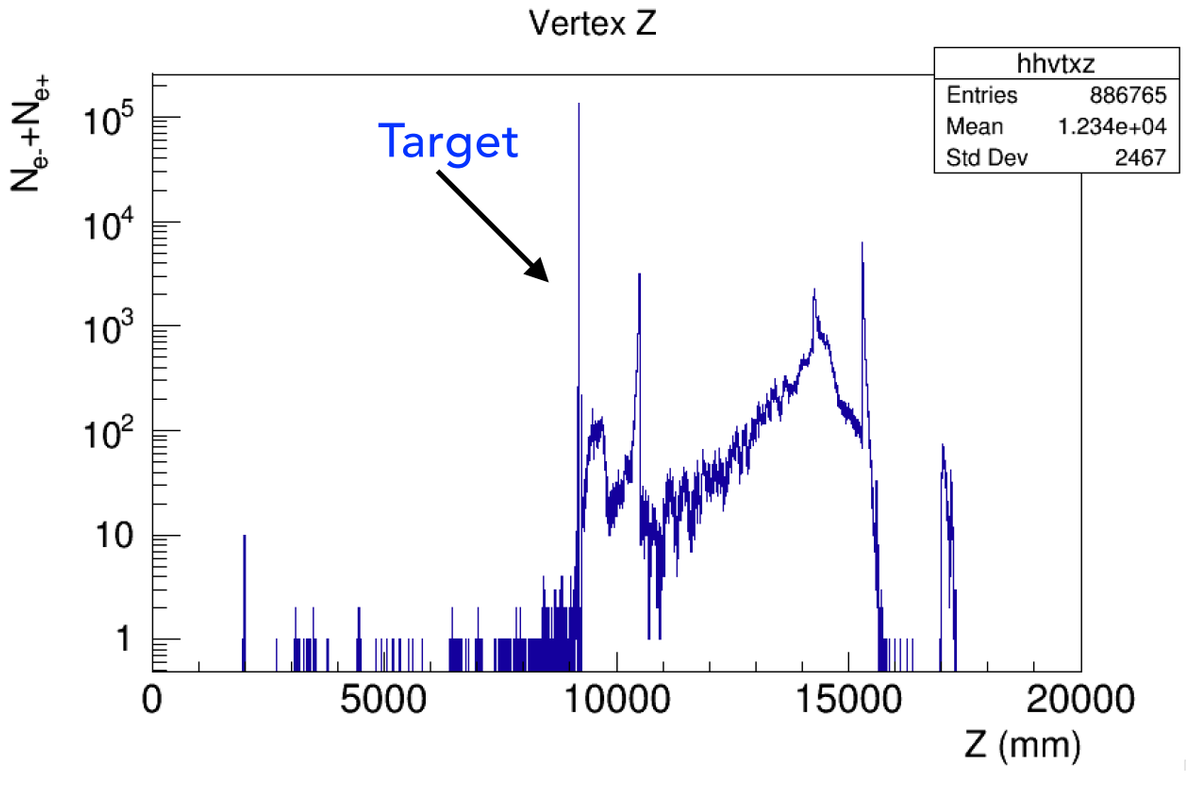


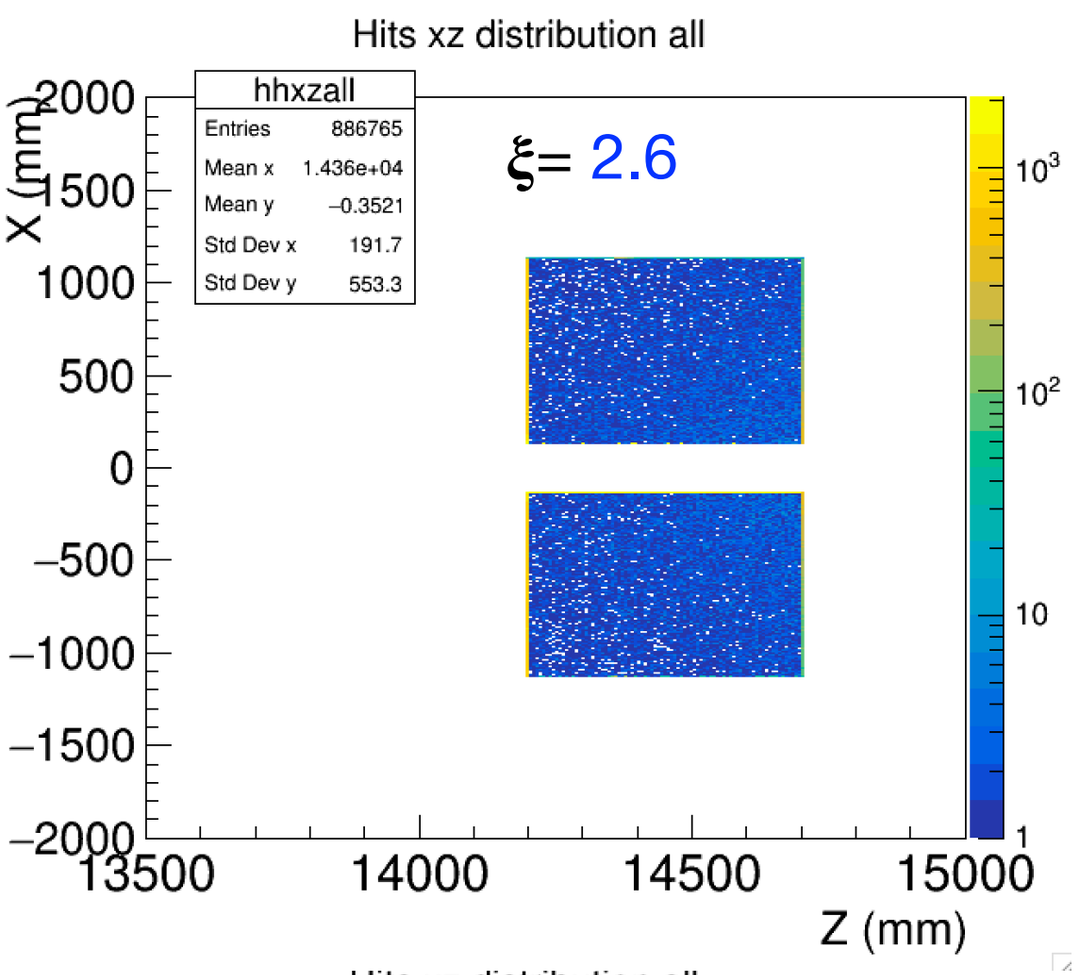
Vertexes in Compton detector

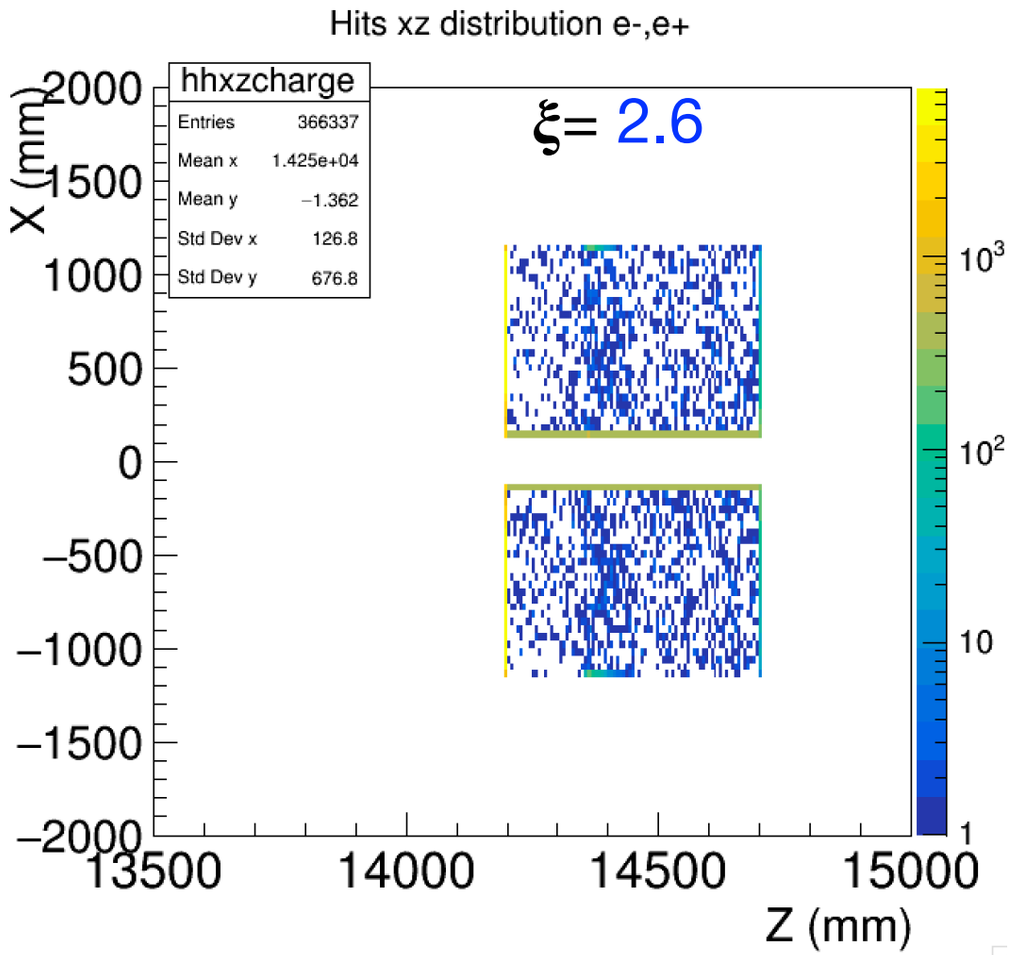


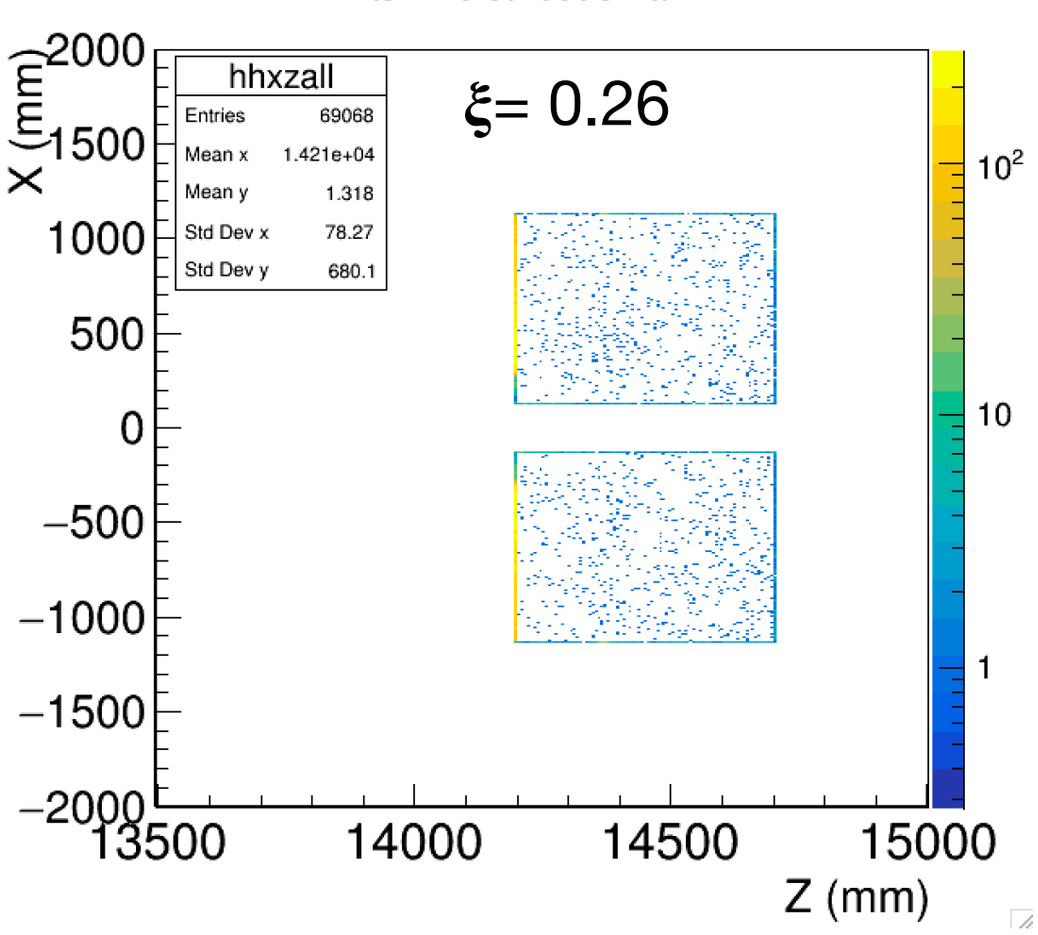


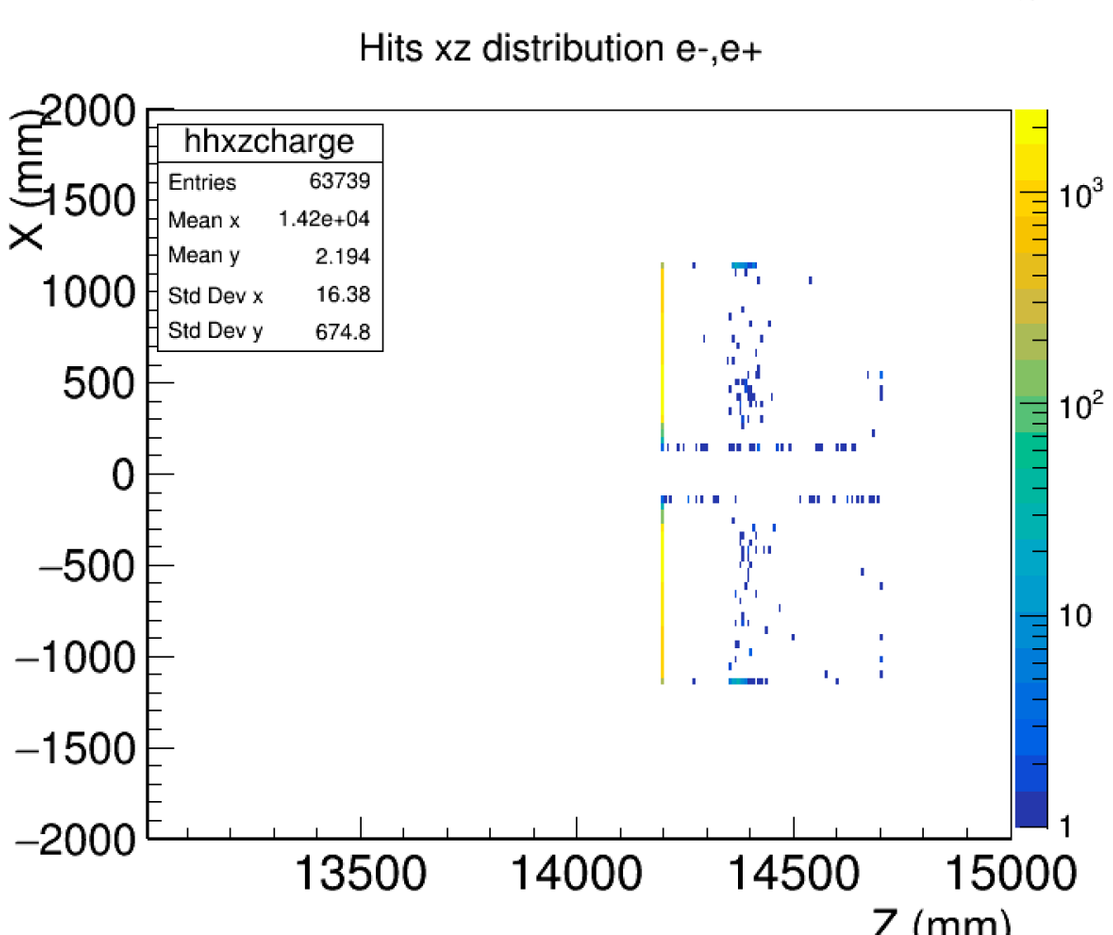




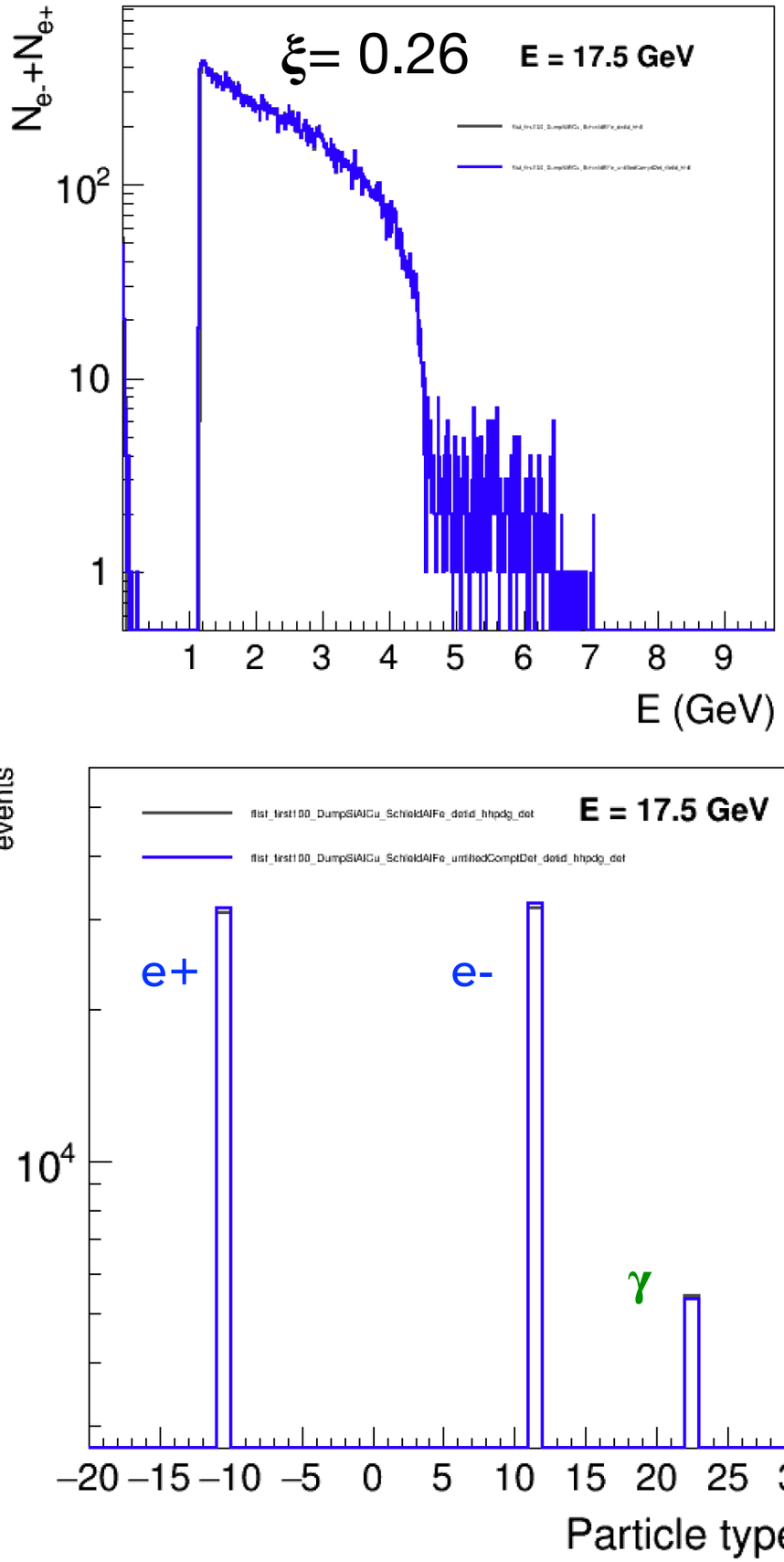

Hits xz distribution all
hhxzall
Entries 886765
Mean x 1.436e+04
Mean y −0.3521
Std Dev x 191.7
Std Dev y 553.3
ξ= 2.6
X (mm)
Z (mm)

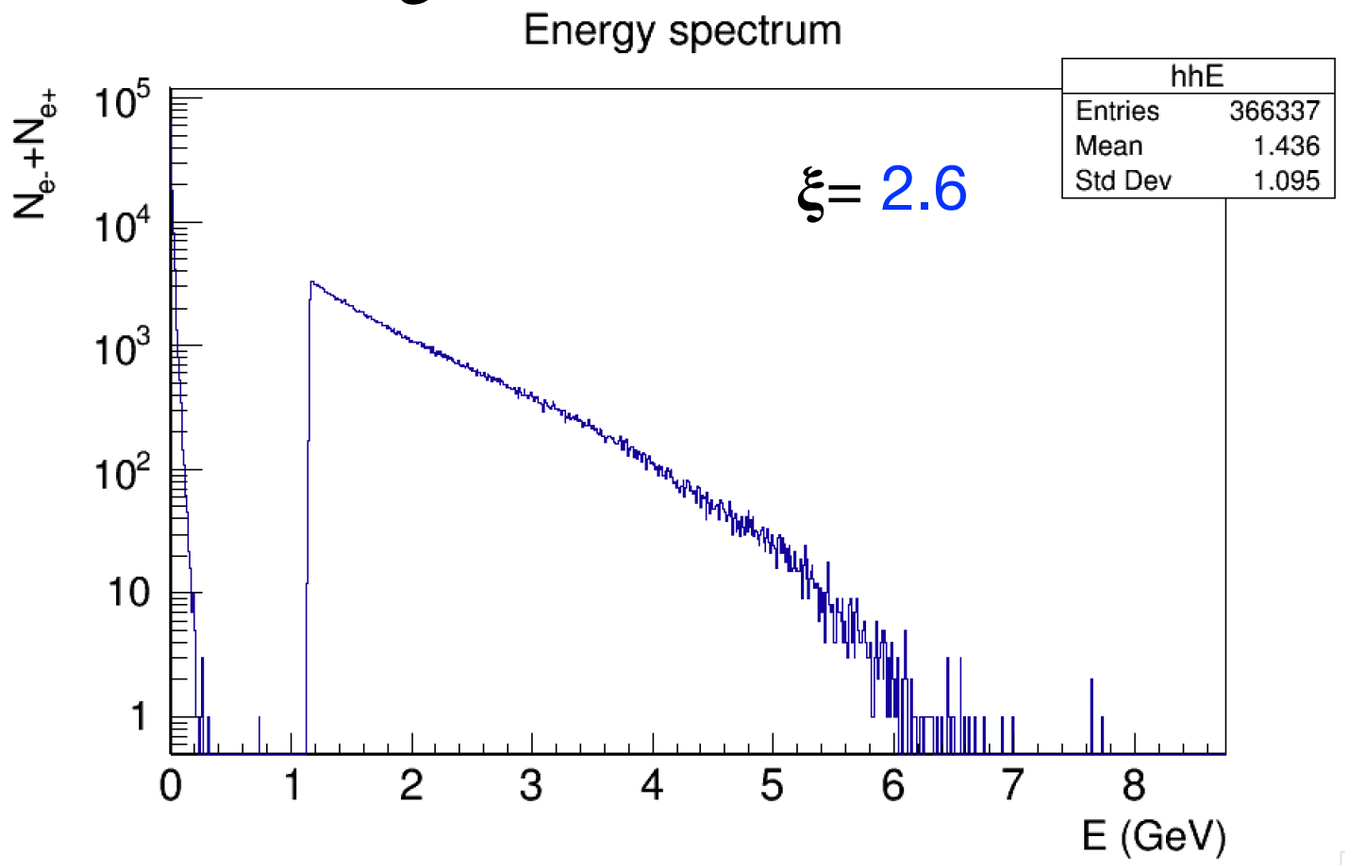

Hits xz distribution e-,e+
hhxzcharge
Entries 366337
Mean x 1.425e+04
Mean y −1.362
Std Dev x 126.8
Std Dev y 676.8
ξ= 2.6
X (mm)
Z (mm)


Hits xz distribution all
hhxzall
Entries 69068
Mean x 1.421e+04
Mean y 1.318
Std Dev x 78.27
Std Dev y 680.1
ξ= 0.26
X (mm)
Z (mm)


Hits xz distribution e-,e+
hhxzcharge
Entries 63739
Mean x 1.42e+04
Mean y 2.194
Std Dev x 16.38
Std Dev y 674.8
X (mm)
Z (mm)

Compton detector: ξ= 2.6 vs 0.26





Edep, GeV

$\times 10^6$

140
120
100
80
60
40
20
0

LG+AlCu Dump 0.6J
LG+AlCu Dump 0.1J
LG+AlCu Dump 0.2J
LG+AlCu Dump 0.01J

0
500
1000
1500
2000

$\times 10^9$

N_γ