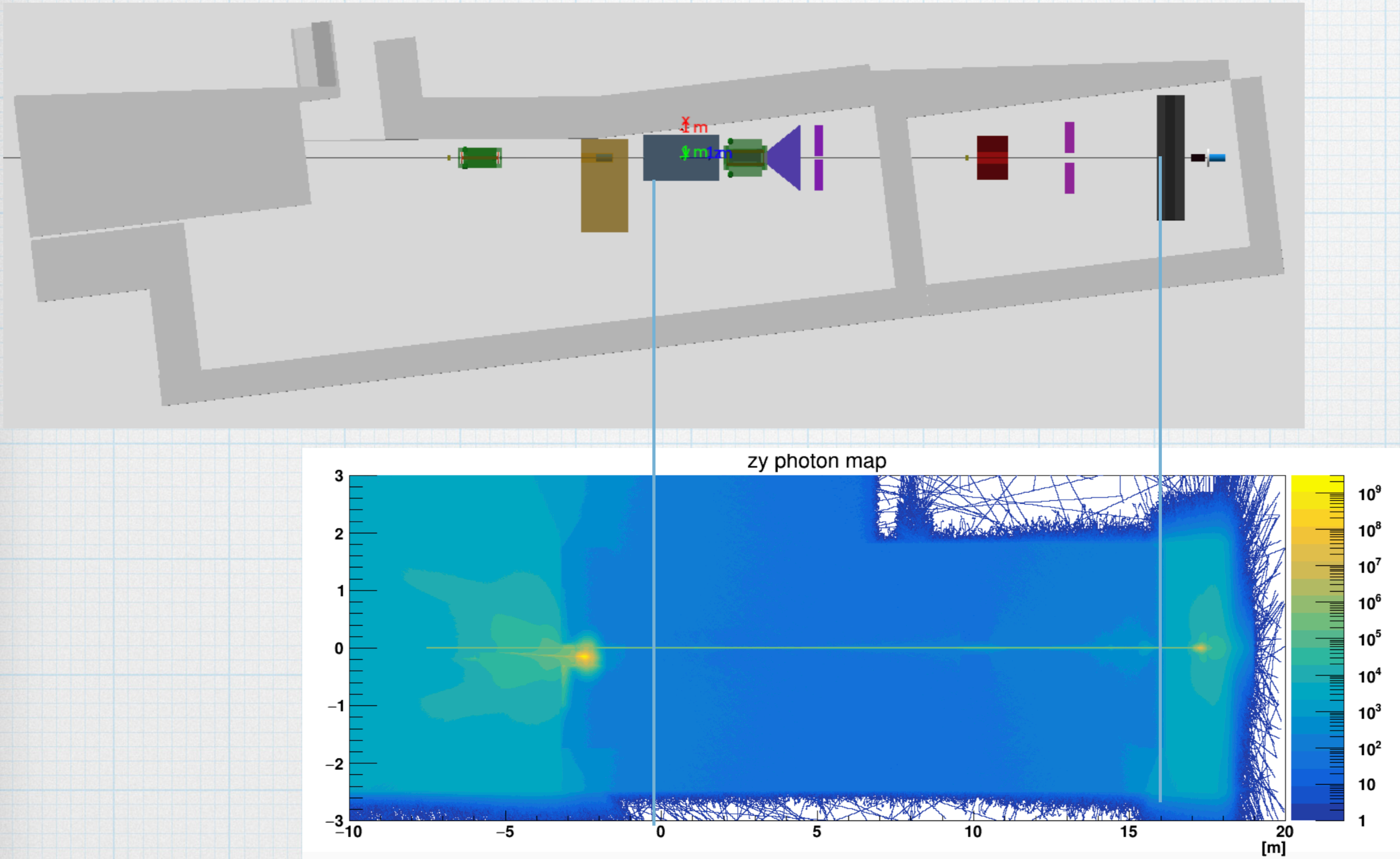
Gamma Monitor

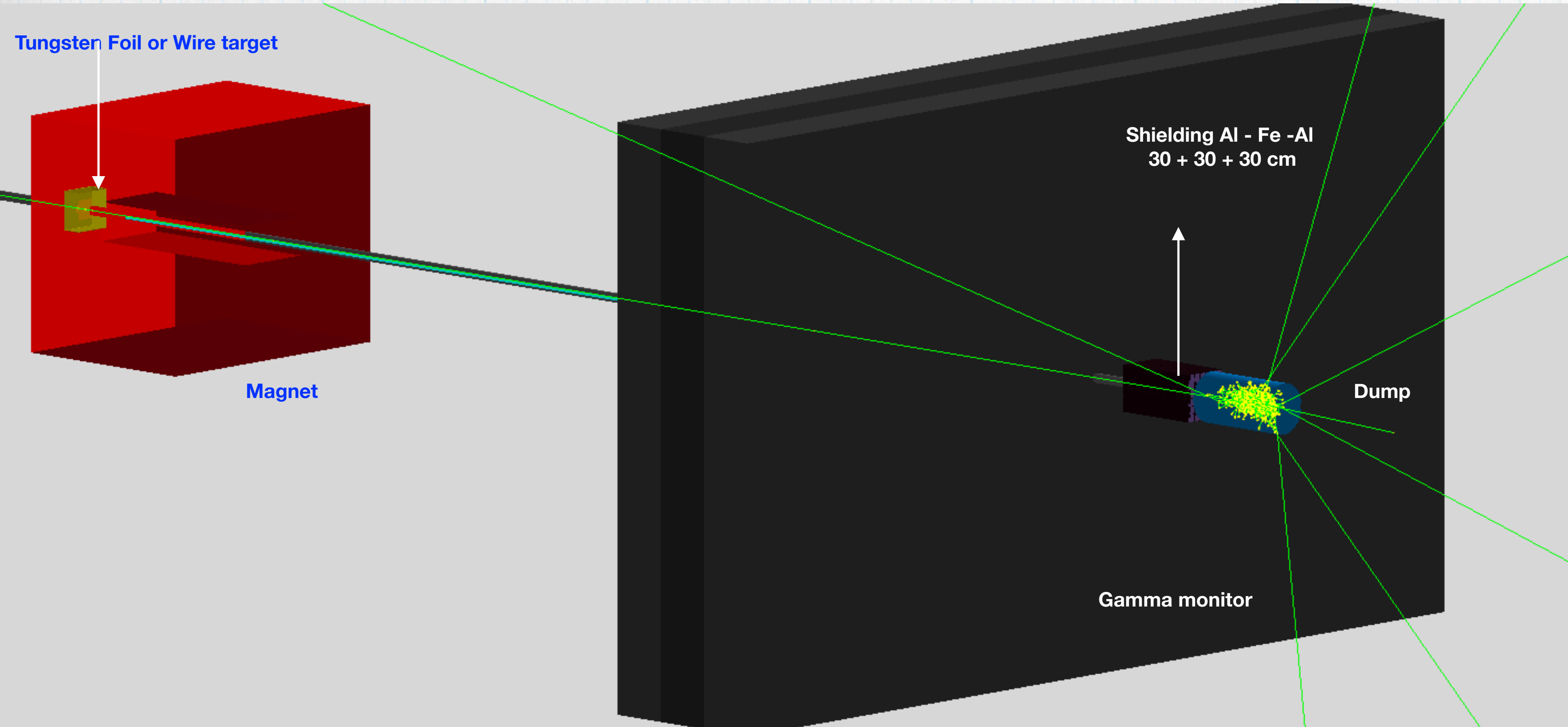
Borysova Maryna (KINR)
06/08/20
LUXE weekly technical meeting

LUXE

Photon fluxes in Geant 4 setup

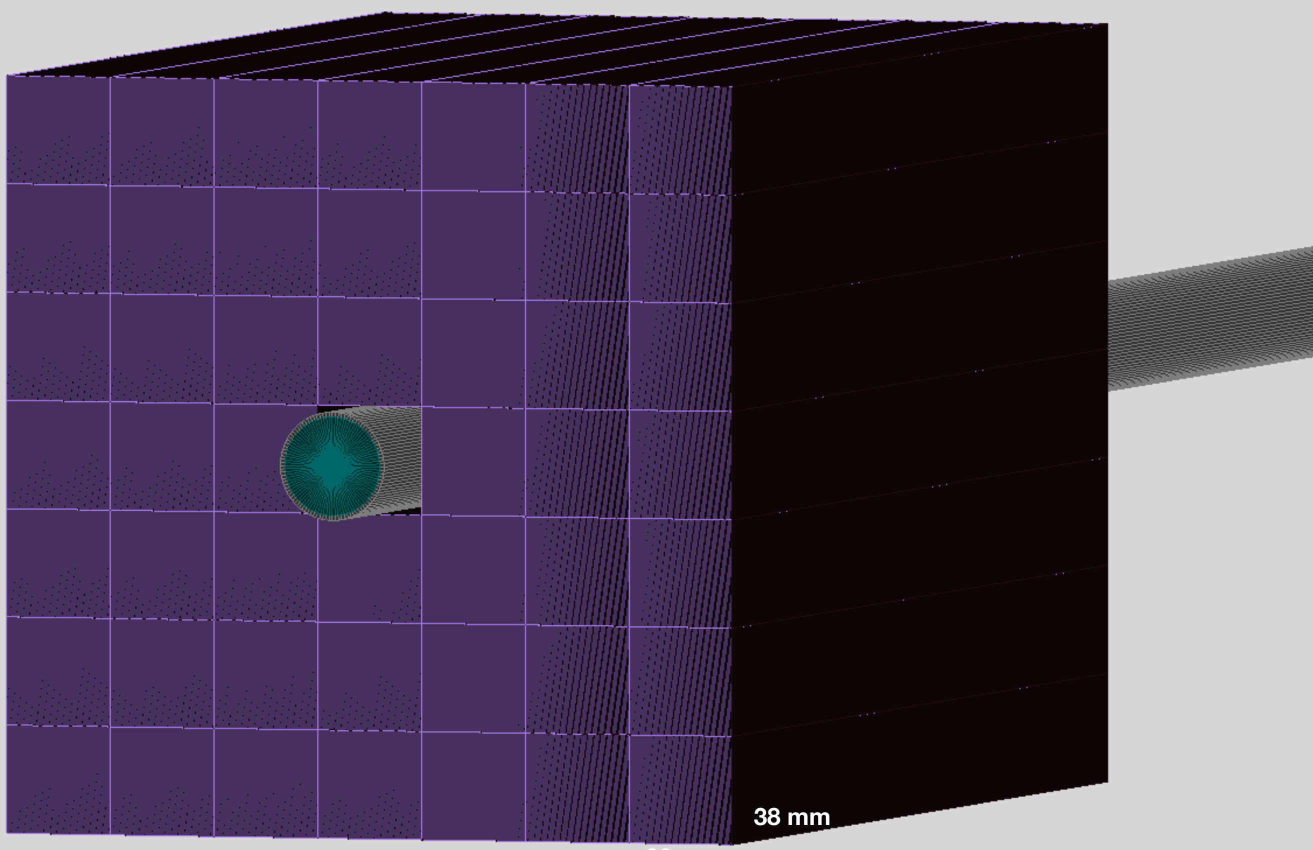


Gamma Monitor

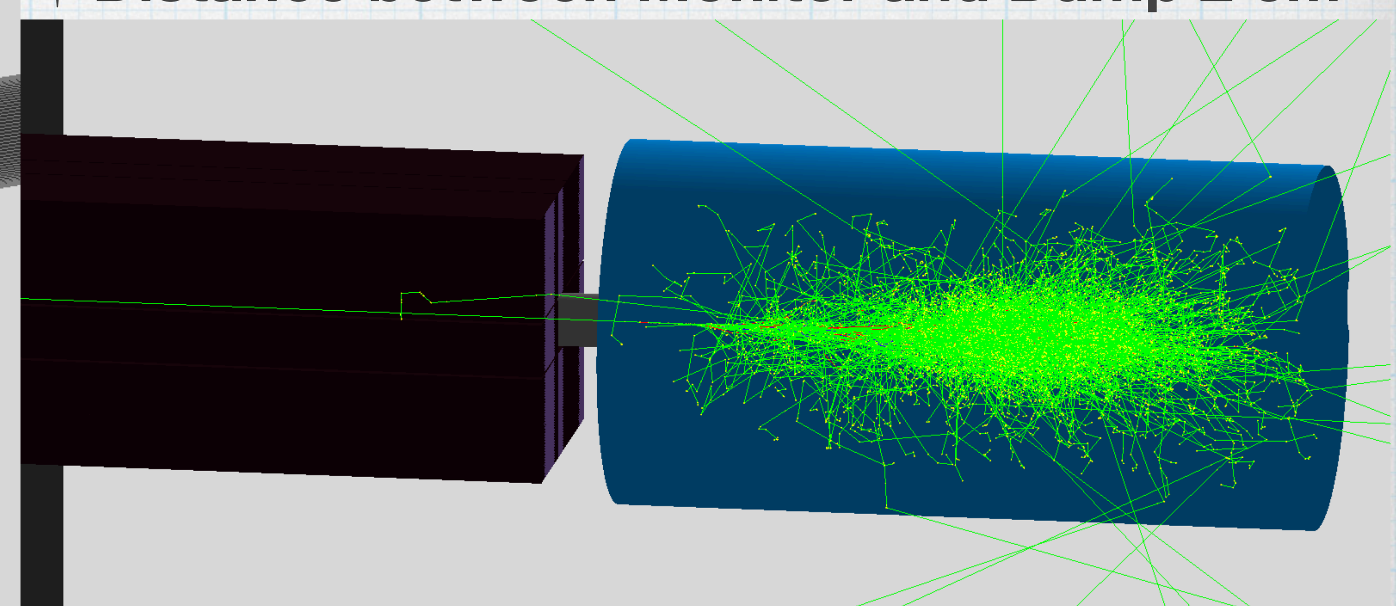


- The implementation of FDS in Luxe geometry with the LG Gamma Monitor made of new LG blocks in front of Al-Cu Dump,
- LG w/ measures 3.8 × 3.8 cm^2, length is 45 cm
- Wrapped with Aluminium foil of 0.016 mm (typical household foil; no account for air)

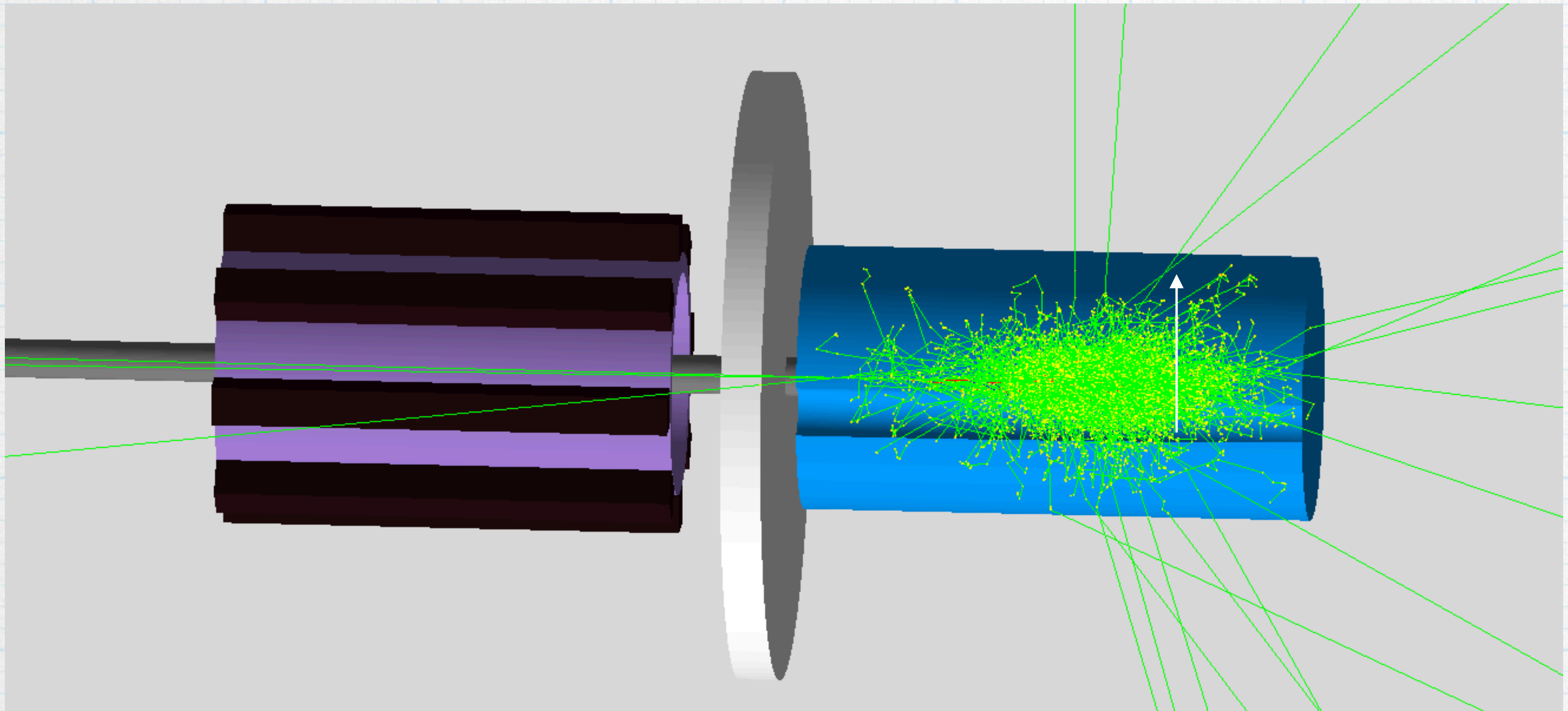
Beam Pipe , R =19.0 *mm, thickness = 1.65 mm



- Distance between Monitor and Dump 2 cm



Gamma Monitor: new design



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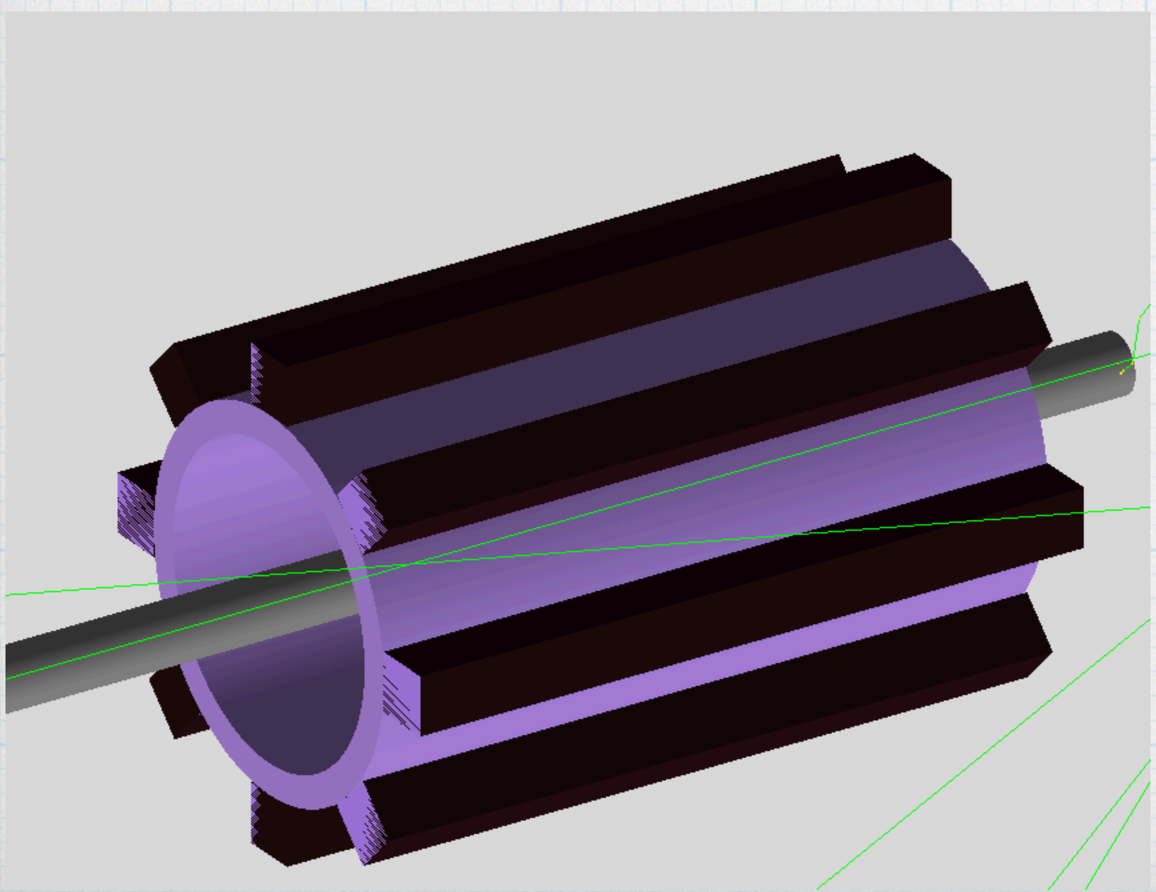
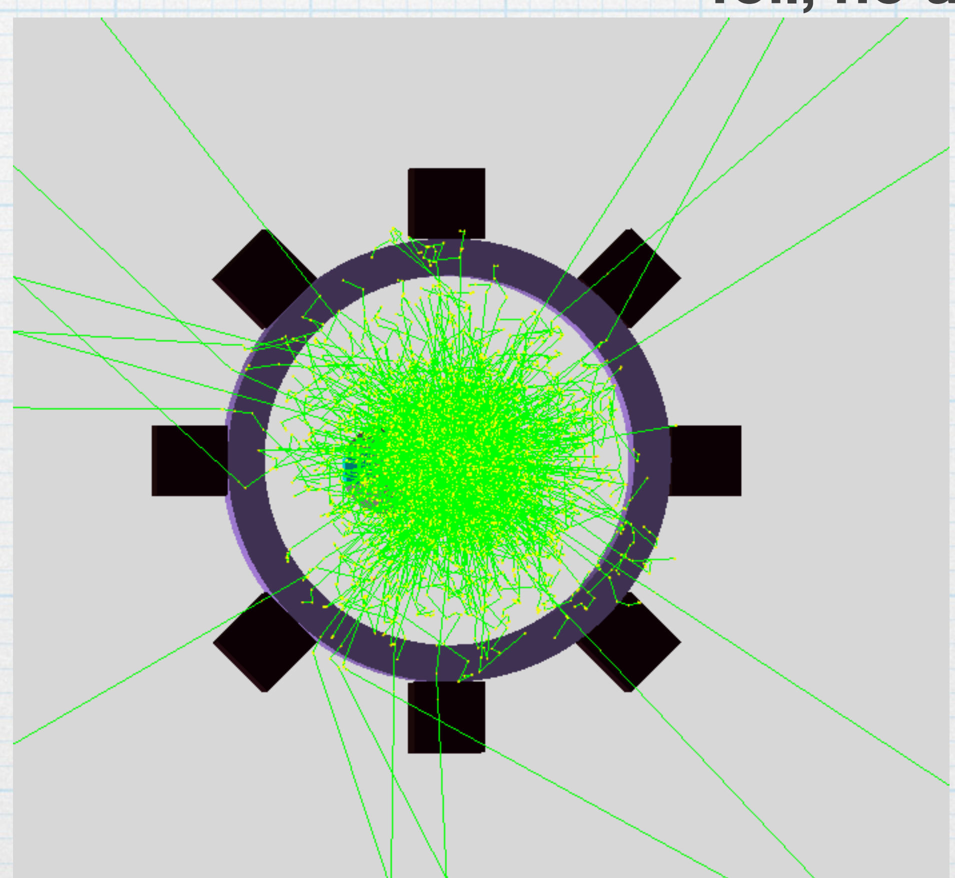
- LG w/ measures 3.8 × 3.8 cm^2, length is 45 cm
- Wrapped with Aluminium foil of 0.016 mm (typical household foil; no account for air)

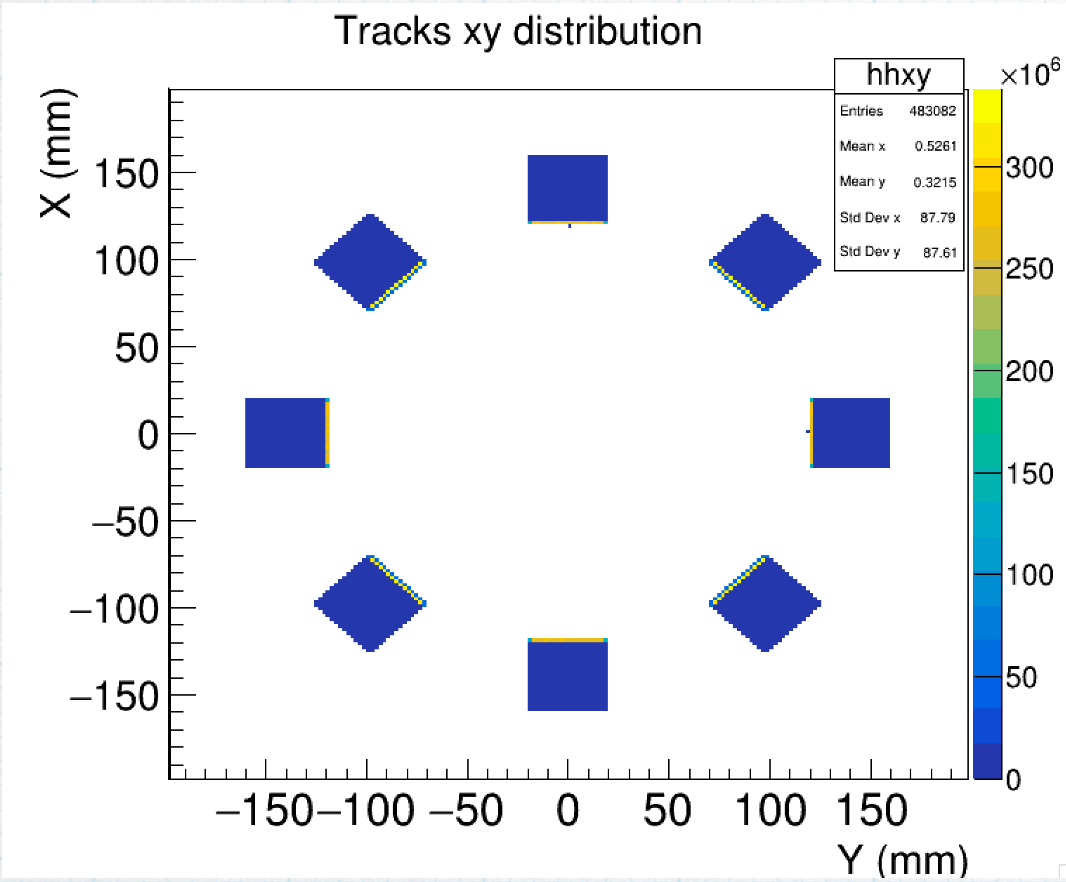
- Distance between Monitor and Dump 10 cm

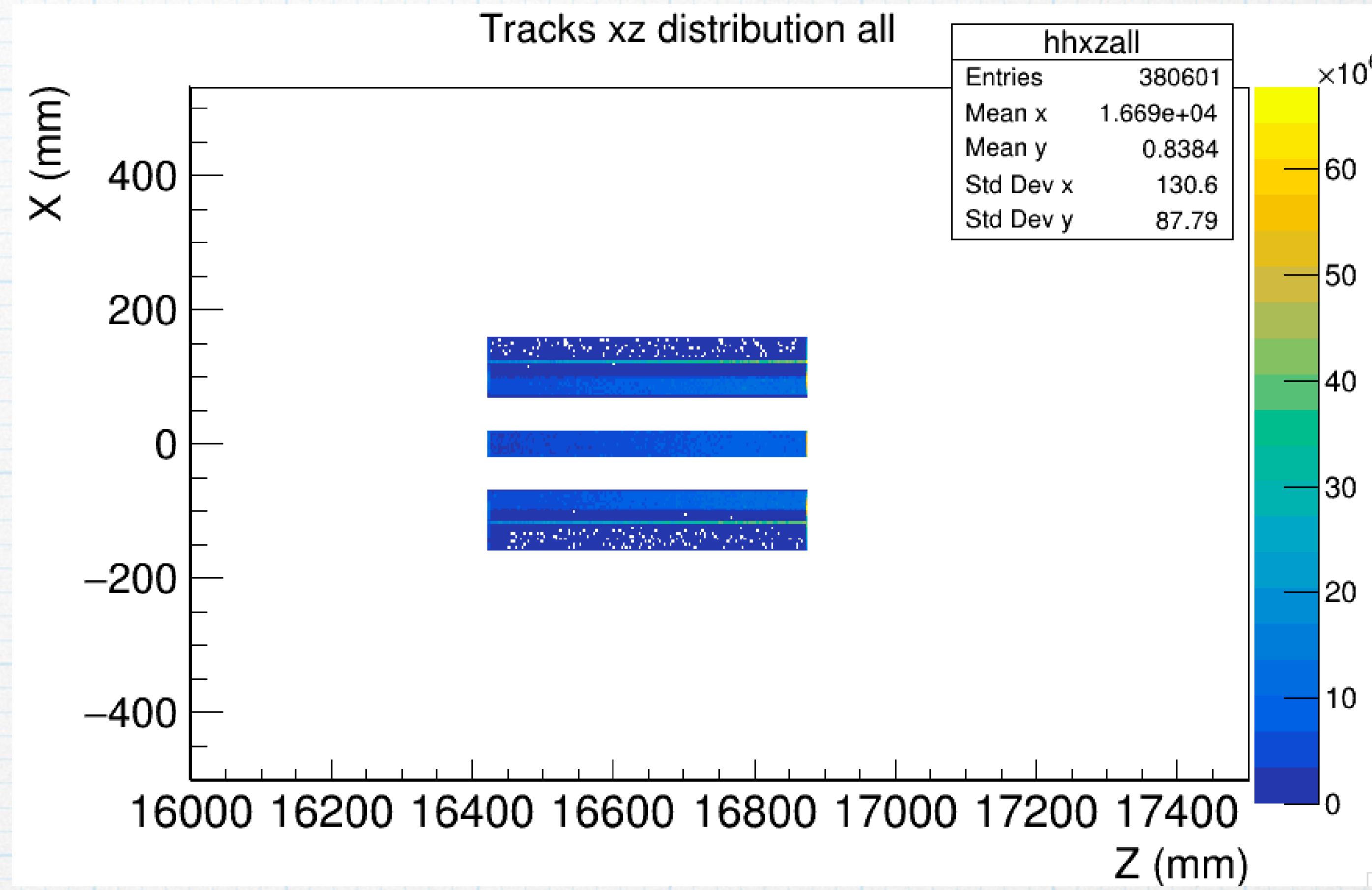
Beam Pipe , R =19.0 *mm, thickness = 1.65 mm

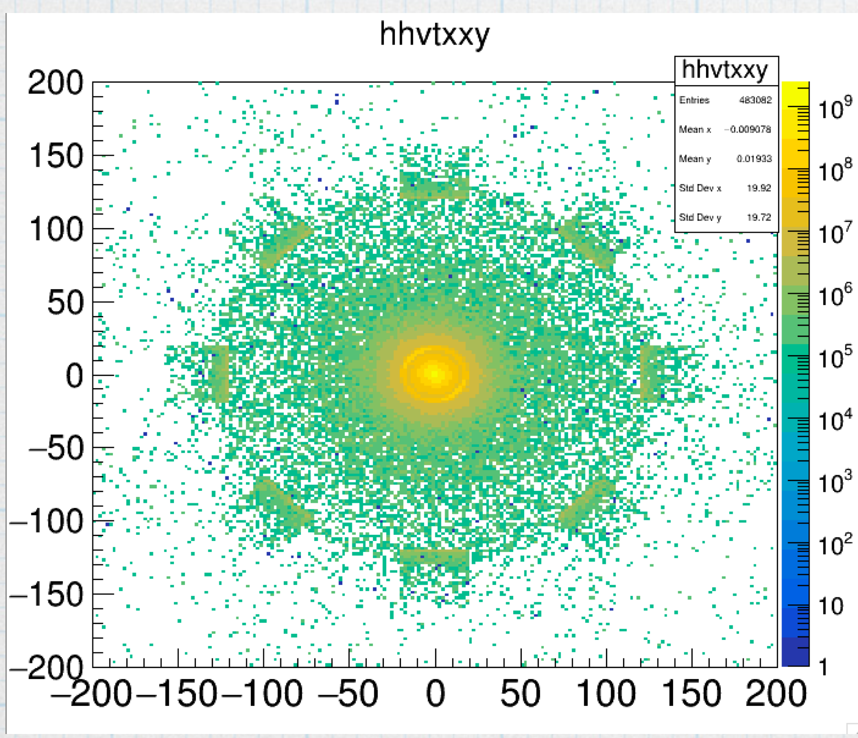


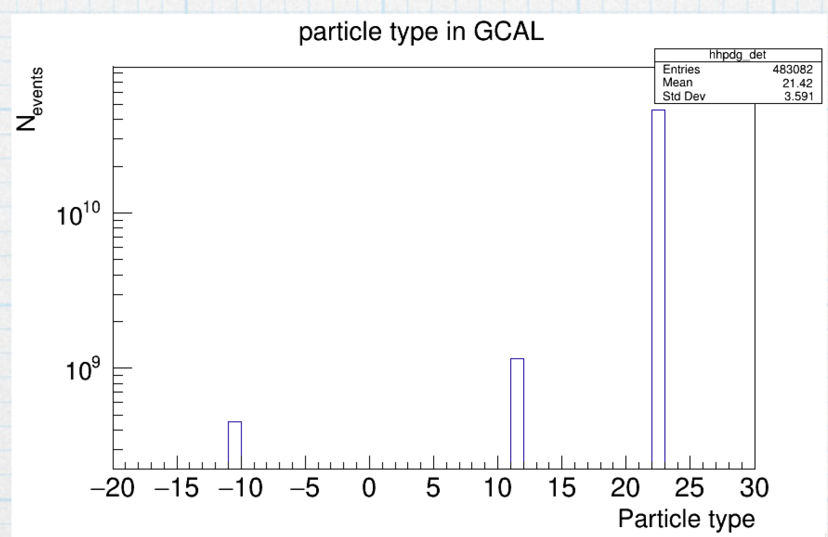


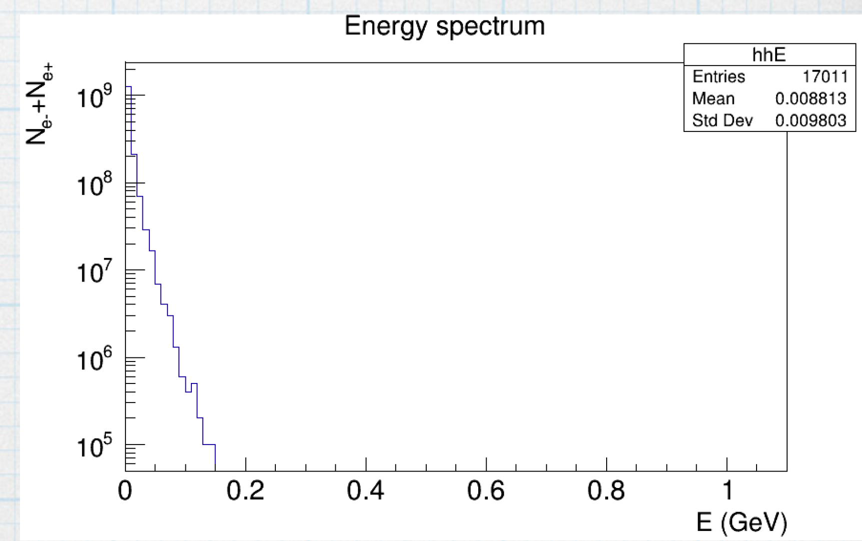
Simulation and Performance



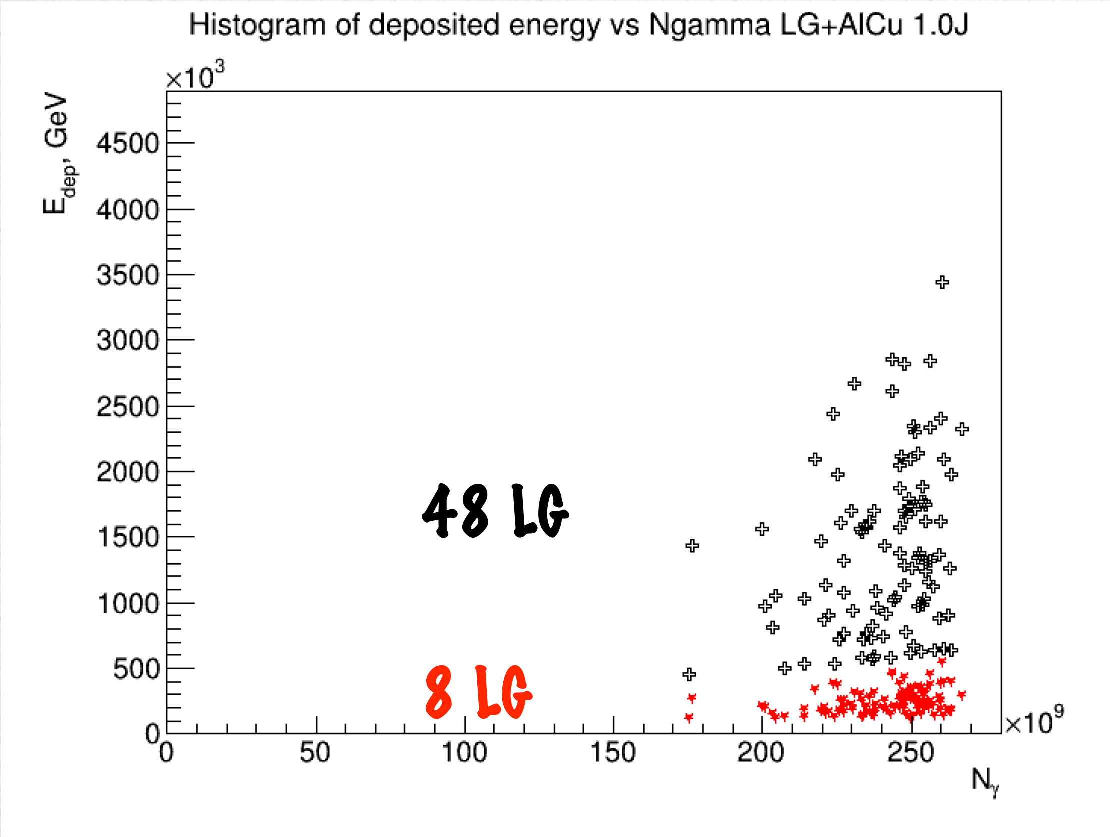


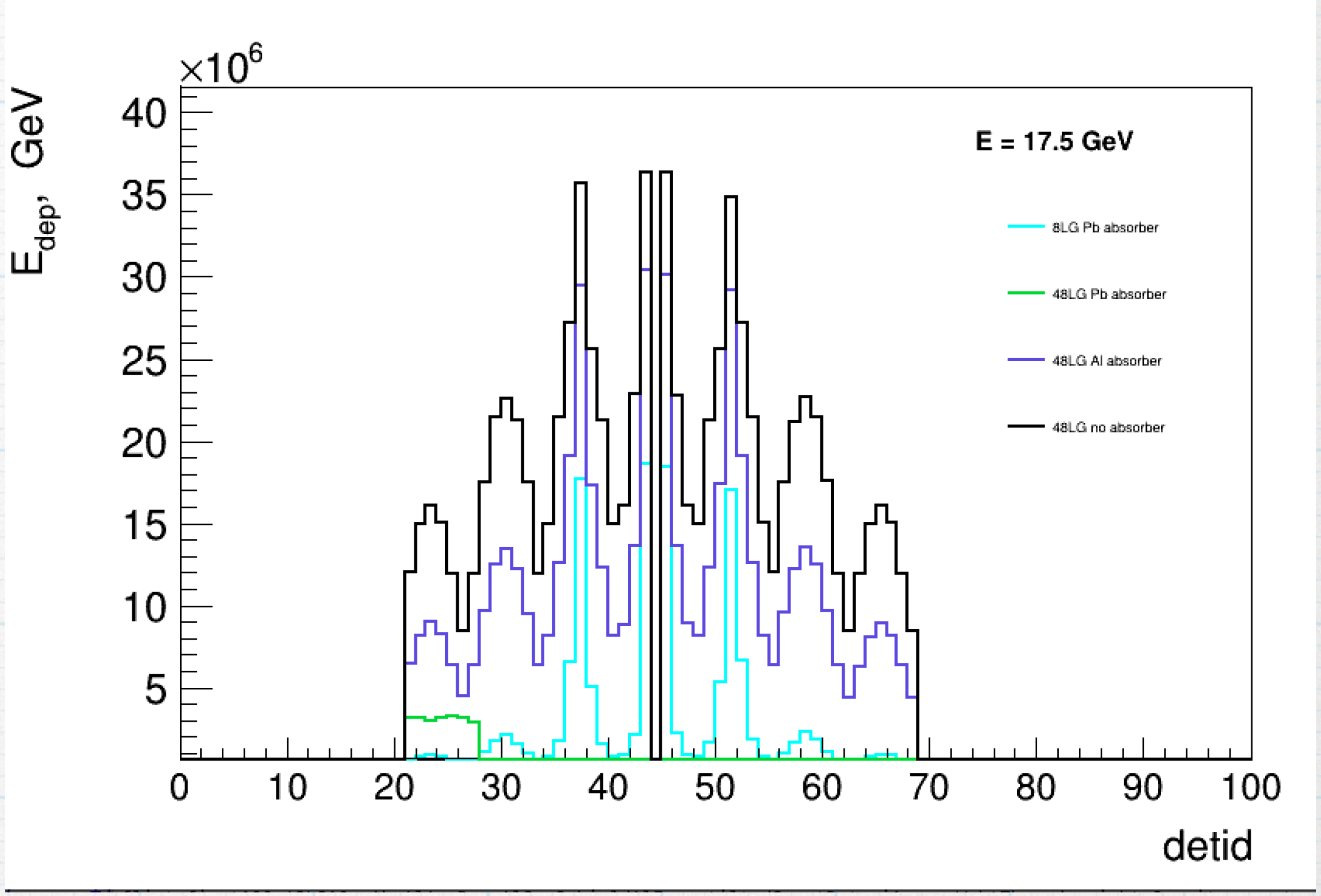


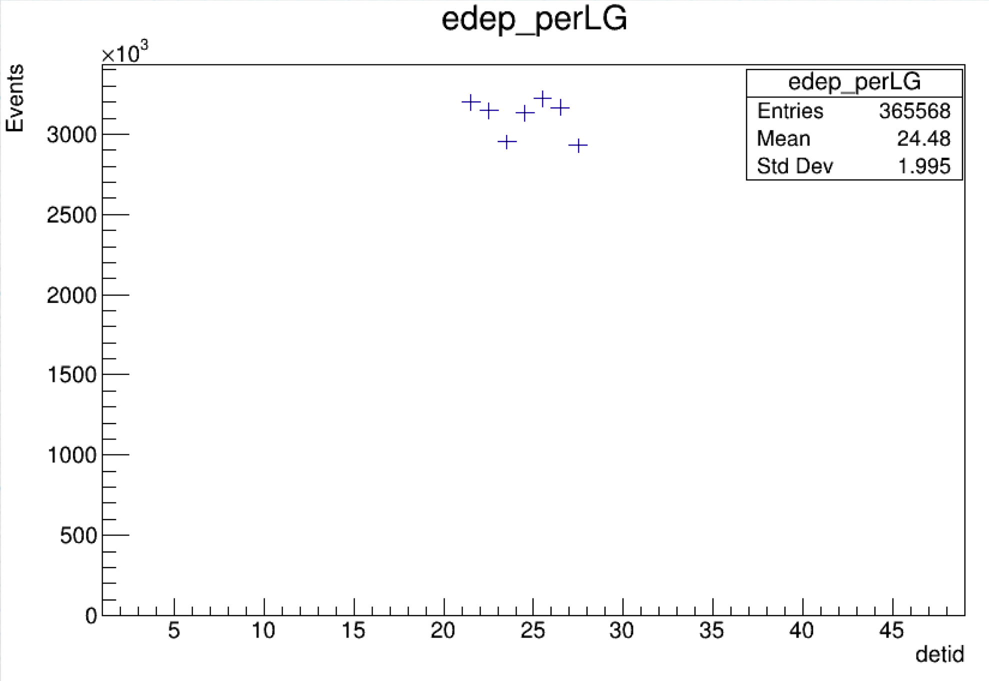




Simulation and Performance







* Depending on exact chemical composition of LG blocks max acceptable dose could be in the range of 5-100 Gy, which roughly means 75-1500 hours of usage on a distance of 10 cm with lead absorber from the beam pipe.

* Air support was used; using the real support made from Al(?) could further improve the performance

Outcomes

* Energy measured in GM of back-scattering particles is 4-6 orders of magnitude smaller than initial beam energy. Initial flux ~10^{12} GeV in GM depending on geometry ~10^6- 10^8 GeV

* Considering the high energy deposit in the inner layer of the GM, it is reasonable to have only one layer with LG blocks placed around beam pipe in a circle.

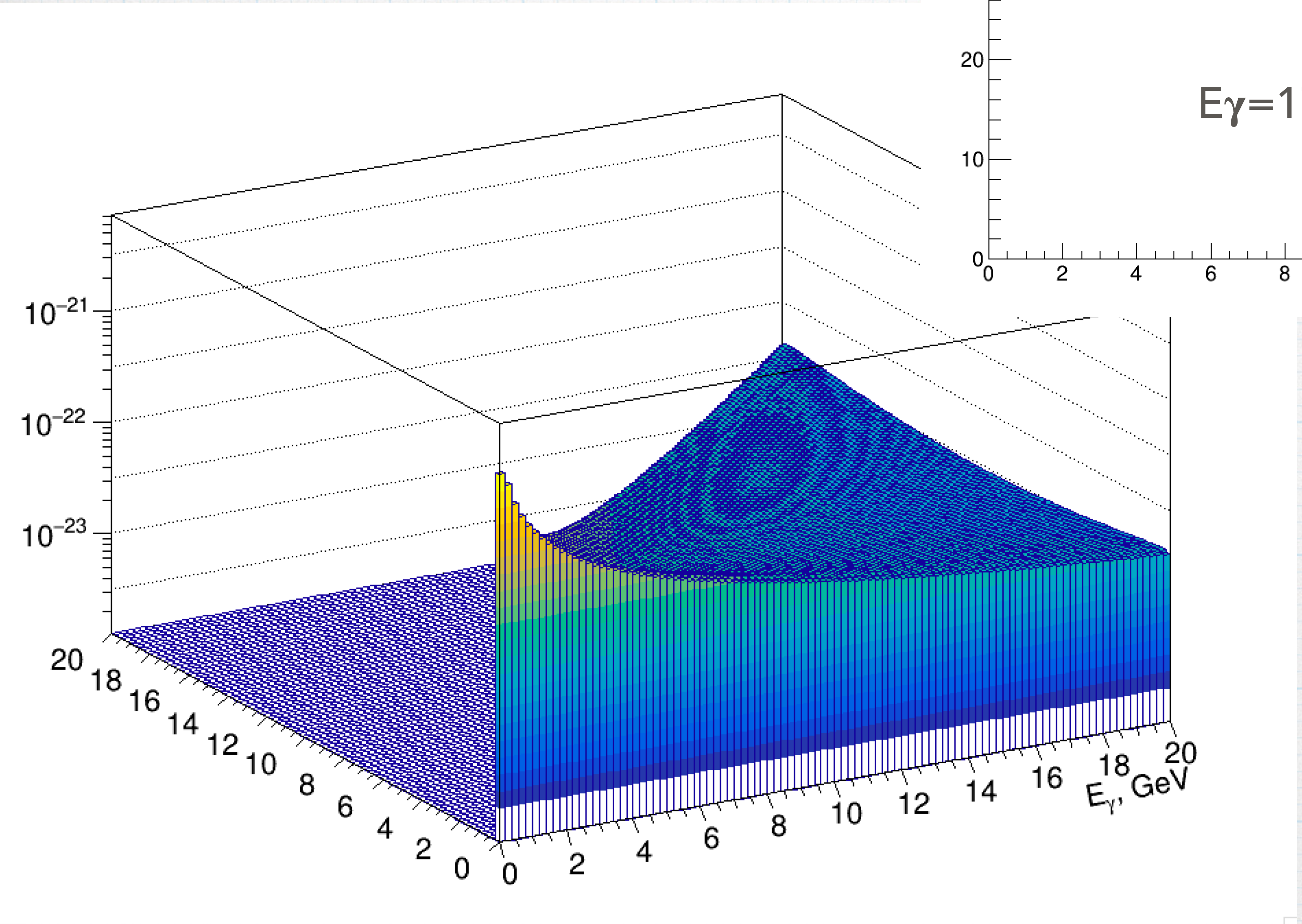
    - Possible sensitivity to the beam asymmetry
    - Uniform radiation load
    - Several replacements sets of LG blocks (6*8 =48)

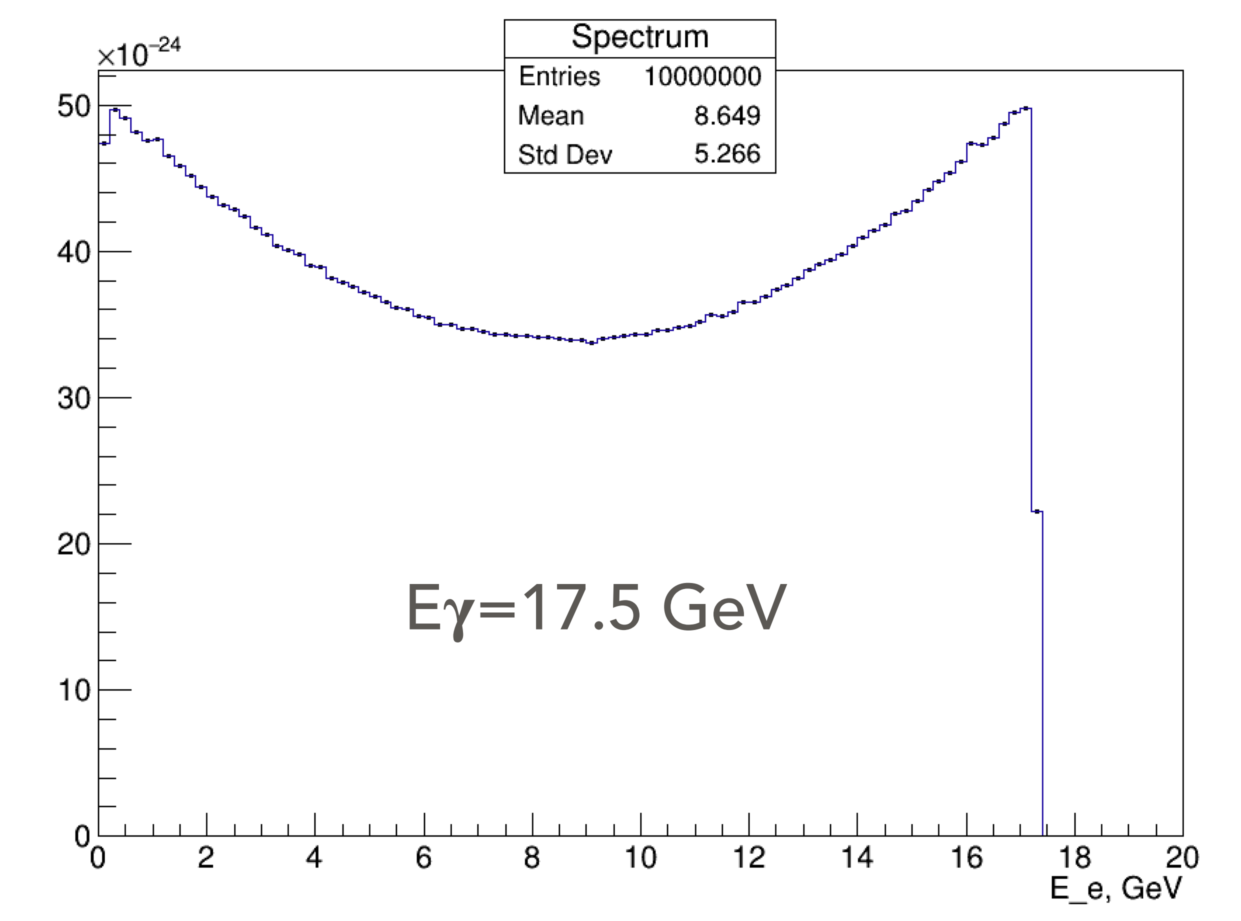
* Depending on exact chemical composition of LG blocks max acceptable dose could be in the range of 5-100 Gy, which roughly means 200-4000 hours of usage on a distance of 10 cm from the beam pipe.

* Considering the fact that no actual beam dump is foreseen and beam will be dumped into the wall, we can consider to design dump/reflector with needed properties

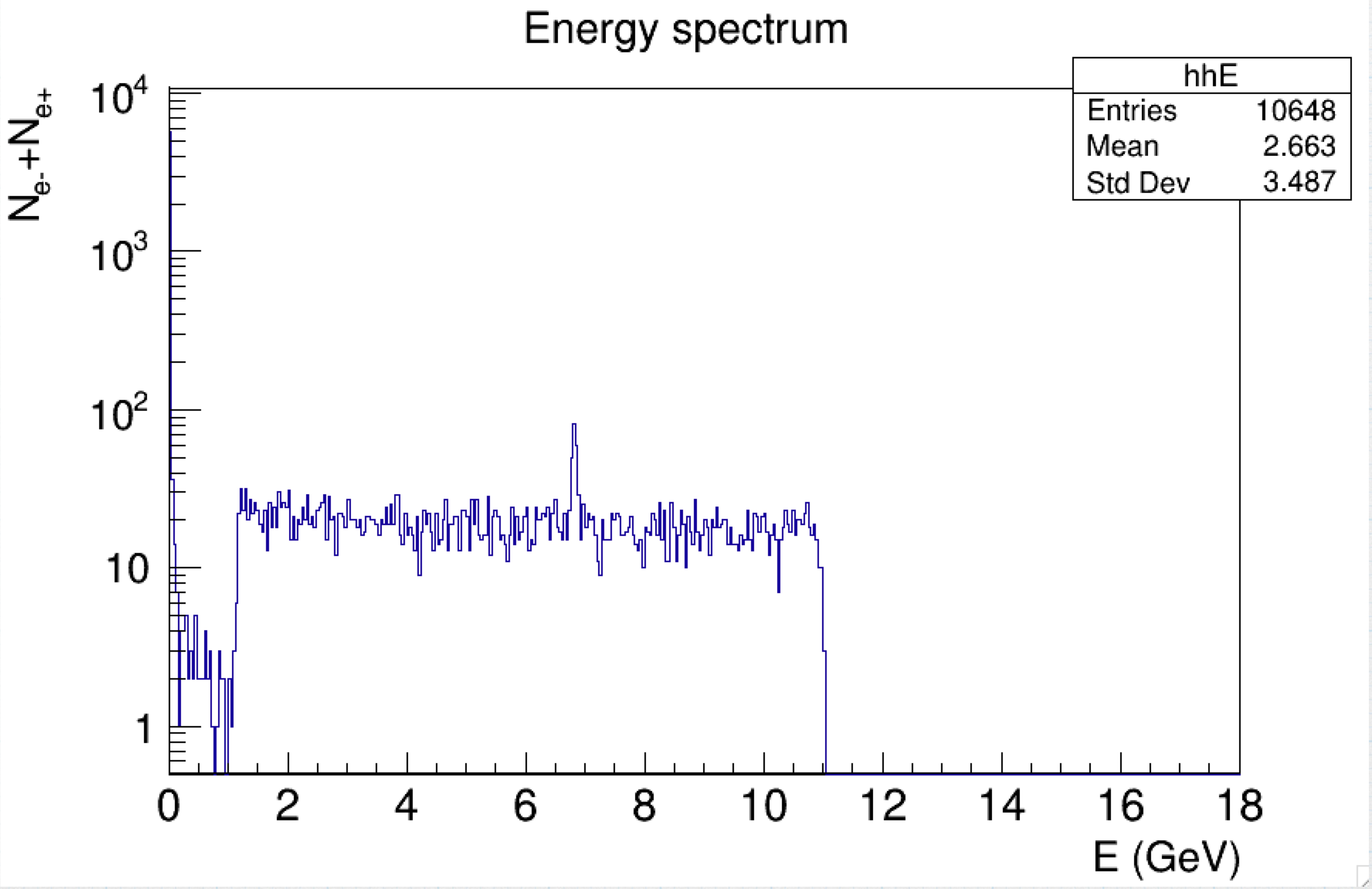
Back up

Photon spectrum from Geant4

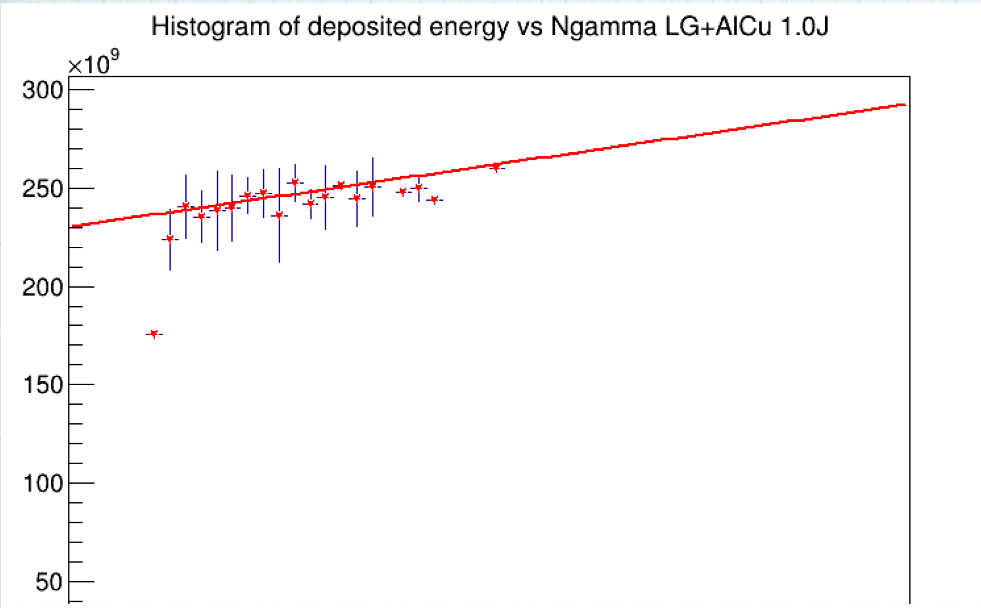




At the detector plane



Uncertainties estimation

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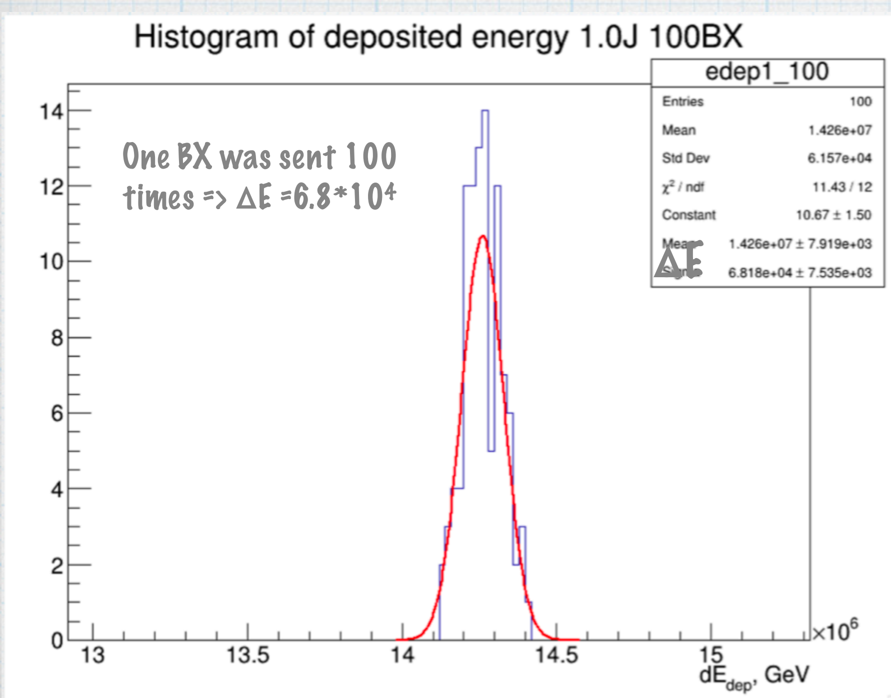
****************************************
Minimizer is Linear
Chi2                      =      4.02143
NDf                       =           13
p0                        =  2.30176e+11   +/-   9.80548e+09
p1                        =        57763   +/-   28404.7
*
Minimizer is Linear
Chi2                      =      49.2879
NDf                       =           13
p0                        =  6.79976e+10   +/-   3.97264e+09
p1               ∂N/∂E    =      12940.5   +/-   282.483
```

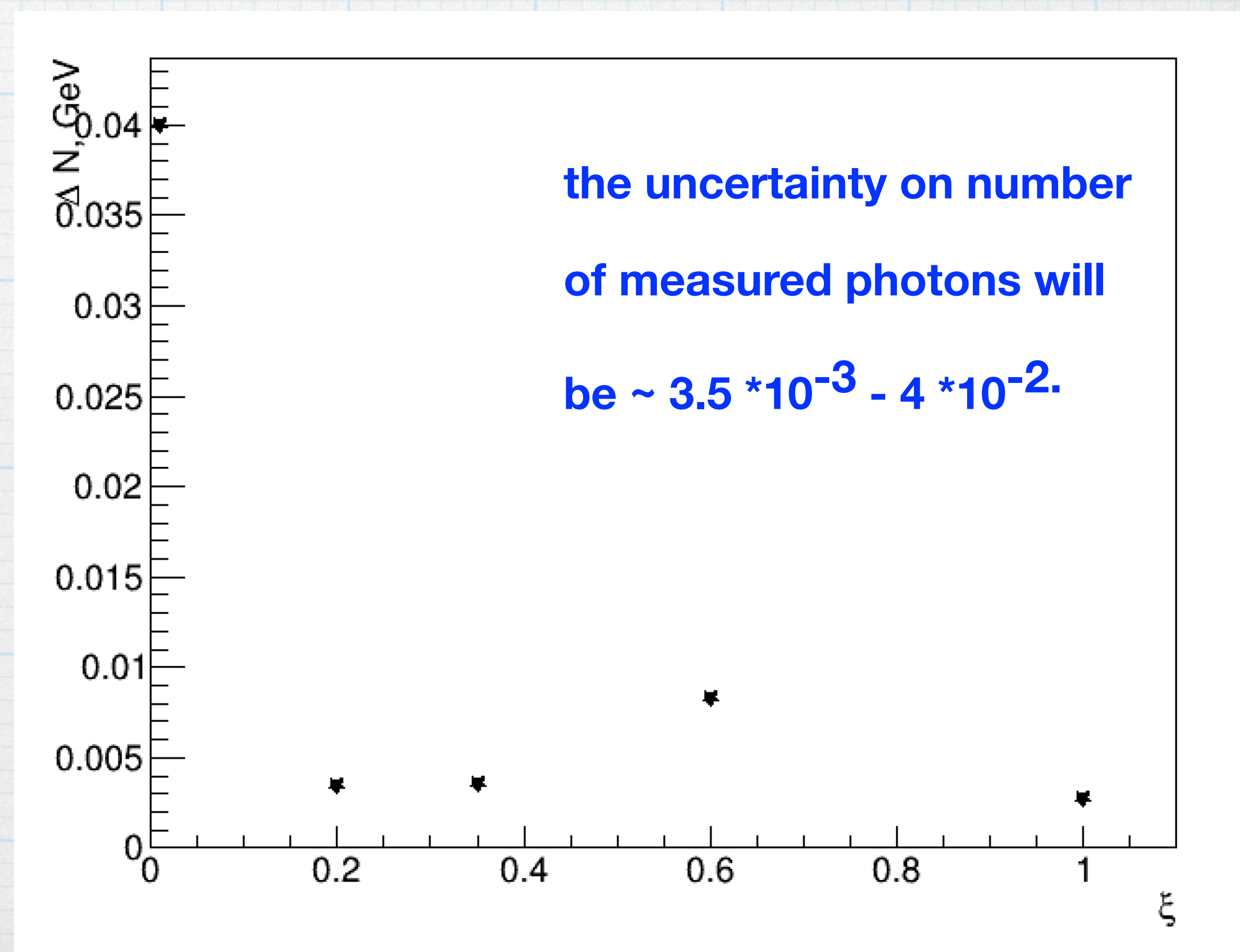


N(E) number of photons

$$\Delta N = \frac{\partial N}{\partial E}\Delta E \quad \Rightarrow \quad \frac{\Delta N}{N} = \frac{1}{N}\frac{\partial N}{\partial E}\Delta E$$

$N = 2.5 \cdot 10^{11}$ $\partial N/\partial E = 57763$

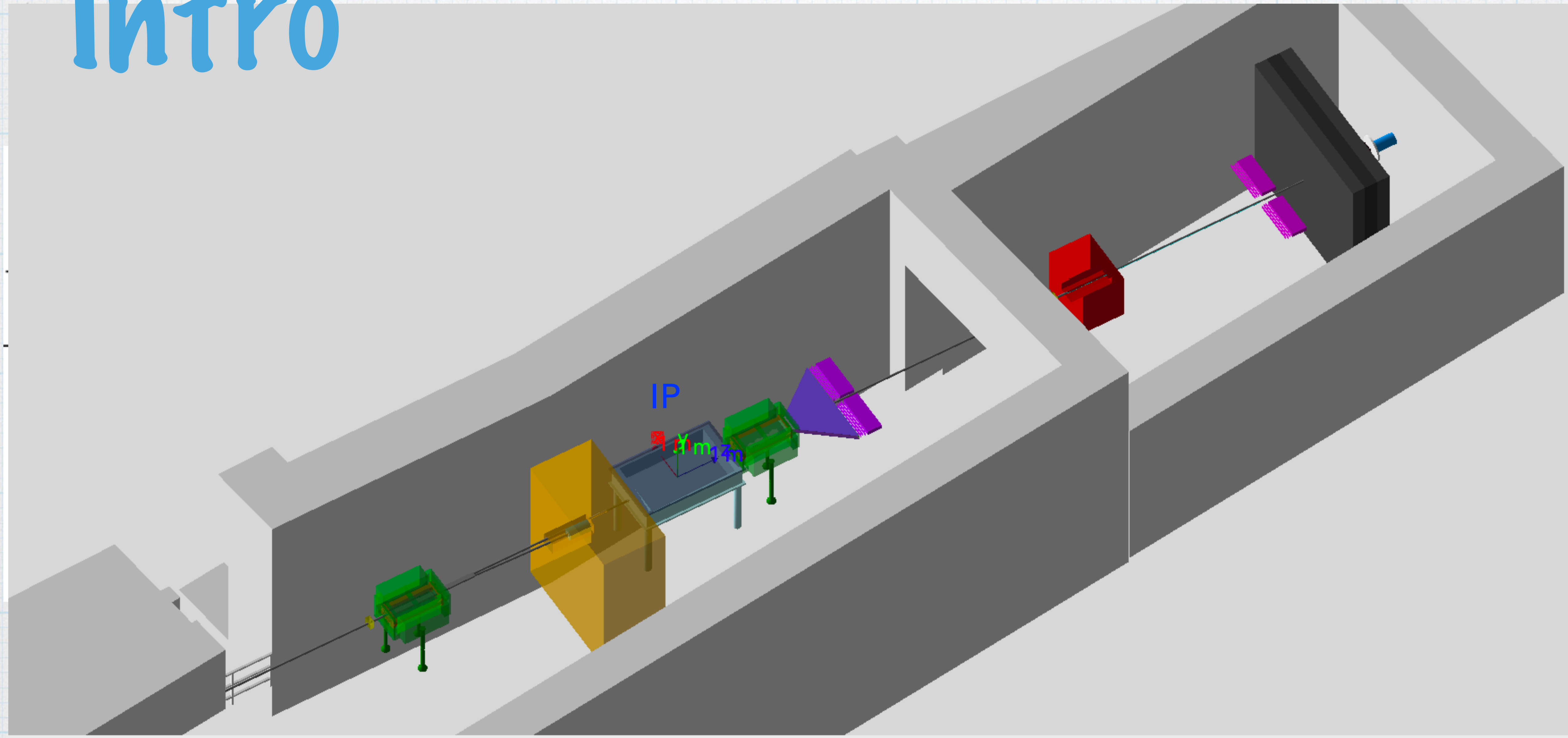
$$\frac{\Delta N}{N} = \frac{1}{N}\frac{\partial N}{\partial E}\Delta E = 6.8 \cdot 10^{4} \cdot 1.3 \cdot 10^{4} / 2.5 \cdot 10^{11} = 3.5 \cdot 10^{-3}$$



Outline

* Intro
* Experiment layout in GEANT4
* Simulation results
  - deposited energy on number of incoming photons
  - uncertainties estimation
  - degradation of optical properties studies

Intro



I measure HICS energy spectrum.

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

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

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

Inputs

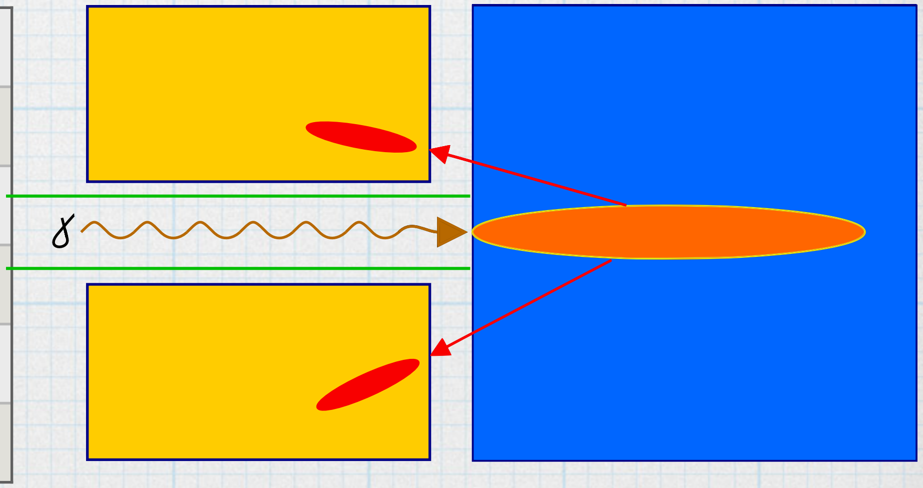
- MC for HICS + trident to model $e + n\omega \rightarrow e + \gamma$ process (A. Hartin)
- Ee = 14 and 17.5 GeV
- Different laser intensities ξ

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

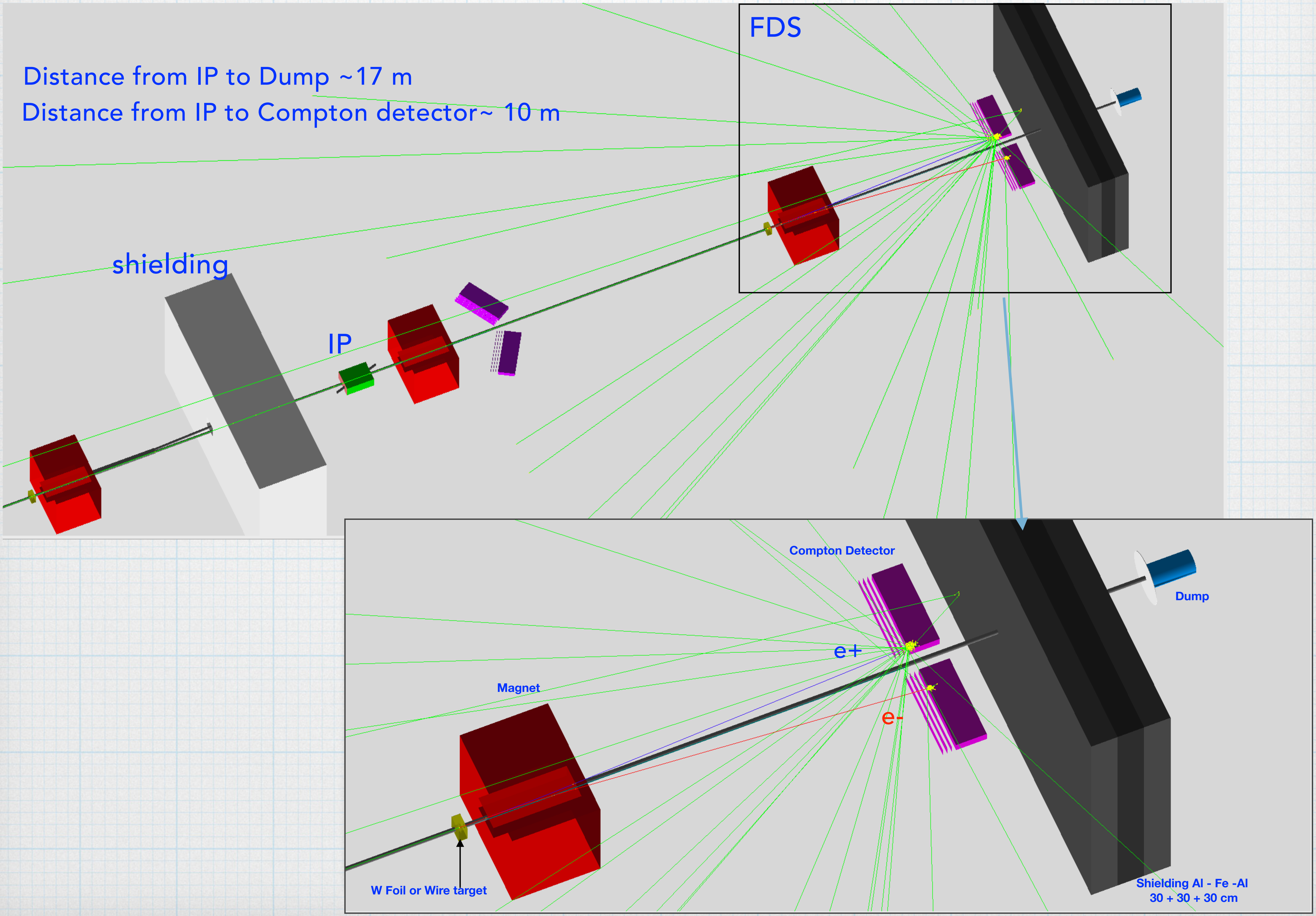
- the estimated rates of electrons, positrons and photons in the various detector regions for e-laser setup and Ee =17.5 GeV

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	γ	**2.4e+11**	**3.8e+07**
Photon	e+ and e–	**2.3e+07**	**4.2e+04**
Photon	e+ and e–	**5.8e+5**	**3.8e+03**

The Idea:



Experimental setup in GEANT4

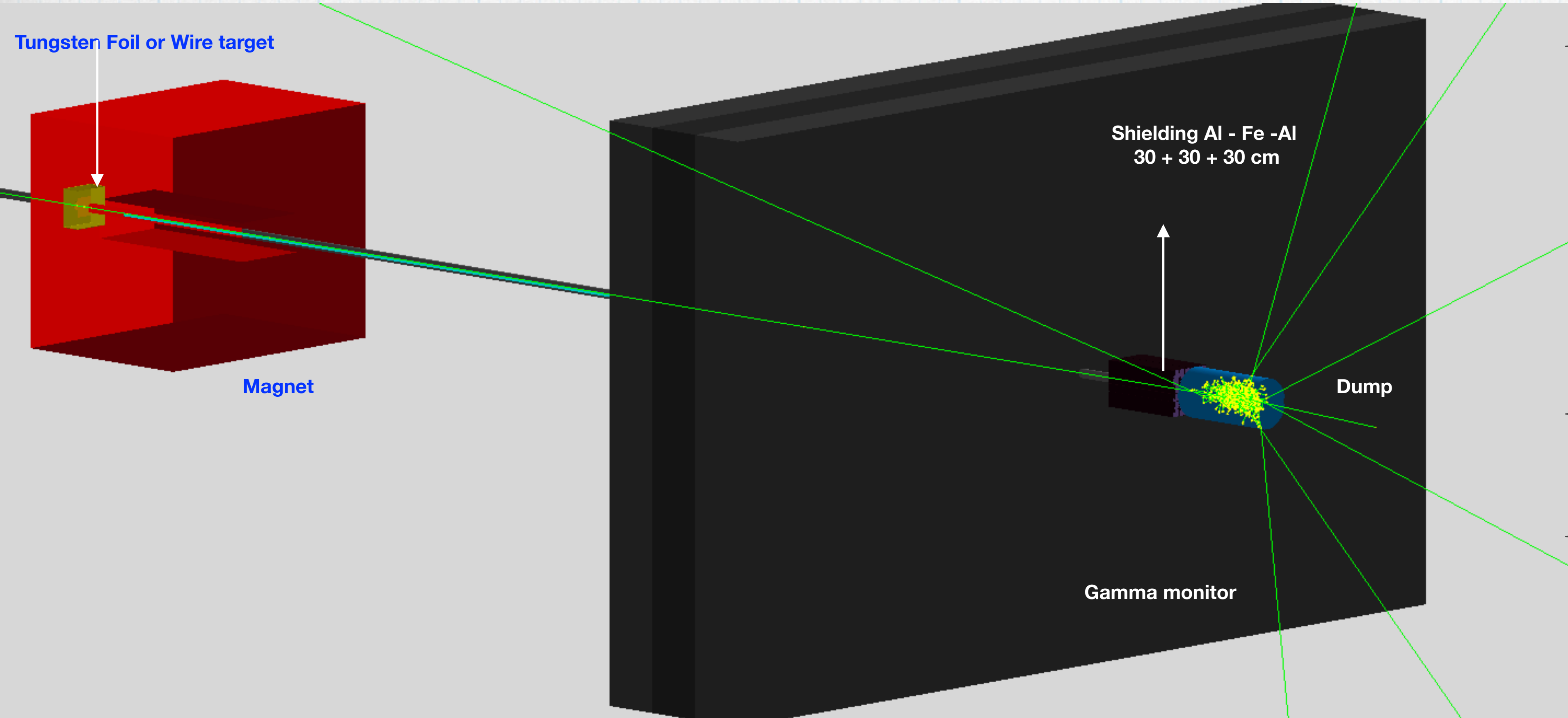


Lead glass blocks found in Hera West @DESY

- New TF-1 LG blocks! Not irradiated, w/ measures 3.8 × 3.8 cm^2, 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

Gamma Monitor



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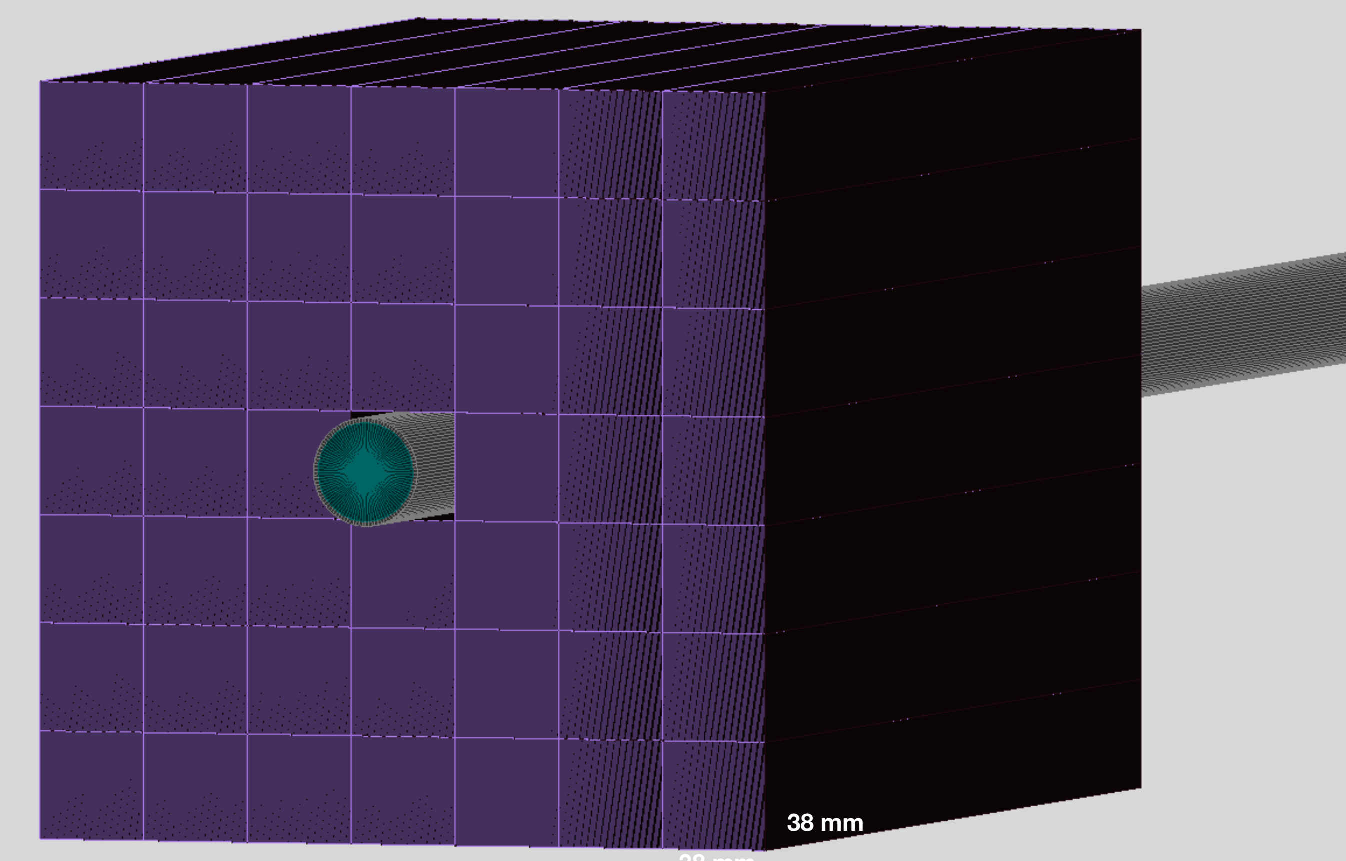

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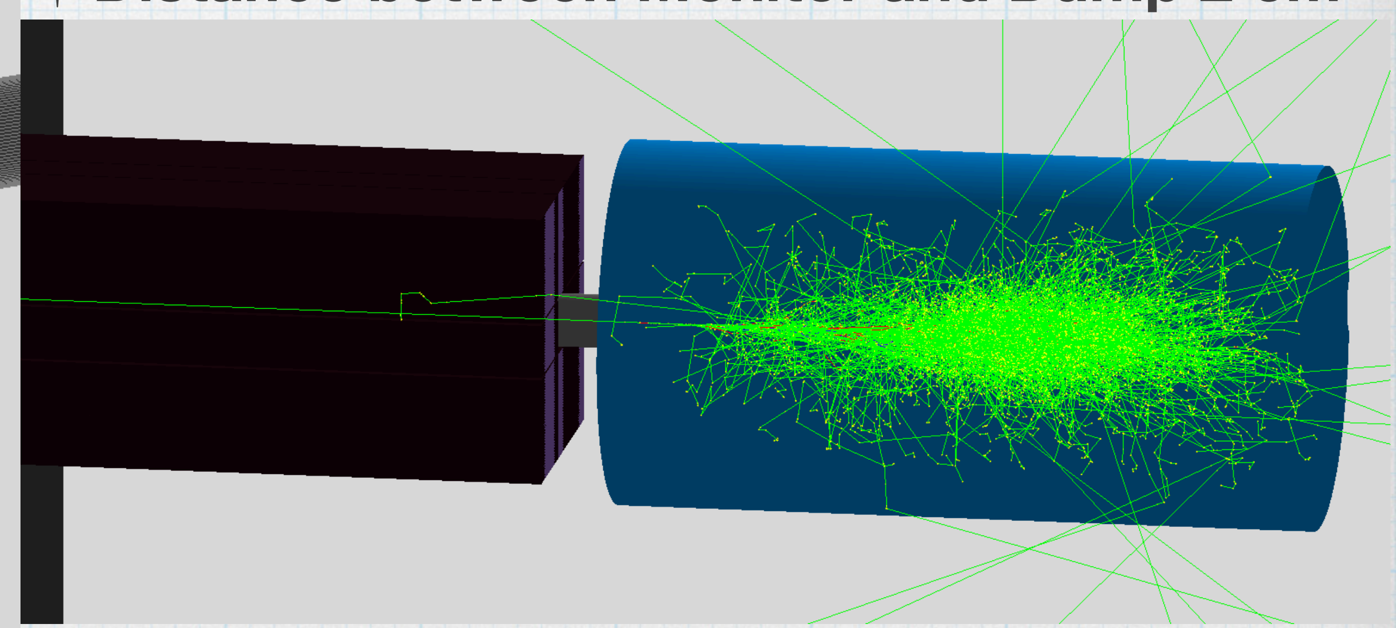
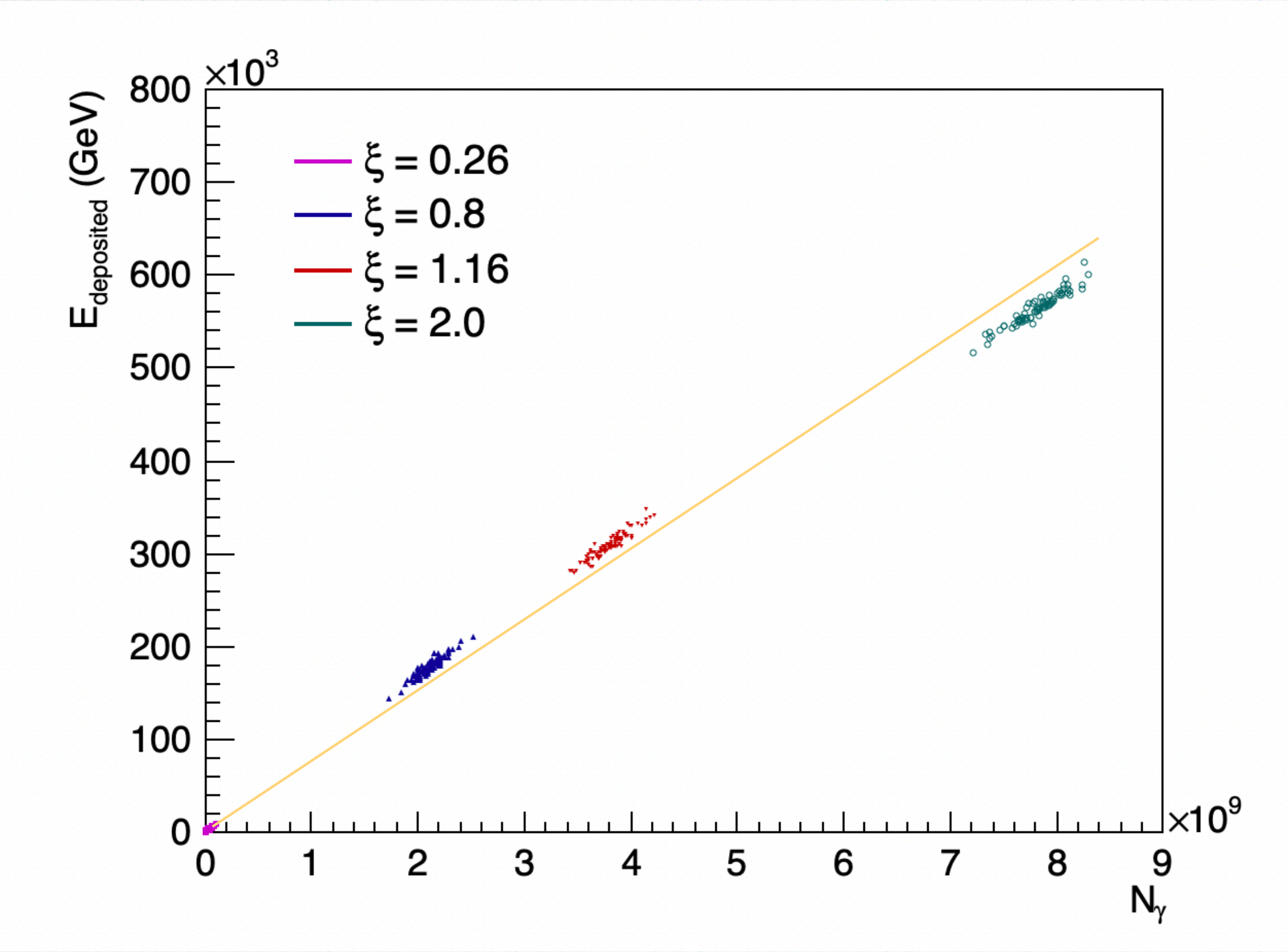
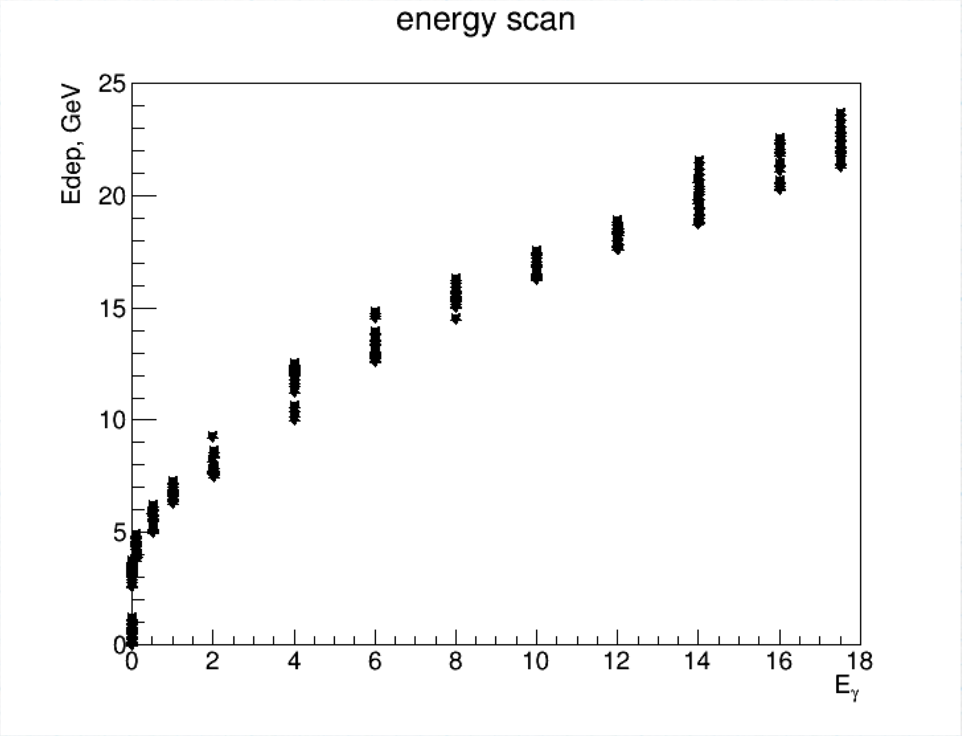


Simulation and Performance

Deposited energy versus true number of photons. Each point is one BX



- The (almost) linear dependence of deposited energy on number of incoming photons in GM allows the usage of backscatters for monitoring the photon flux
- For small ξ the HICS spectrum is softer and soft photons produce less back-scatters. This is the reason of small deviation from linearity in Edep on Eγ dependence



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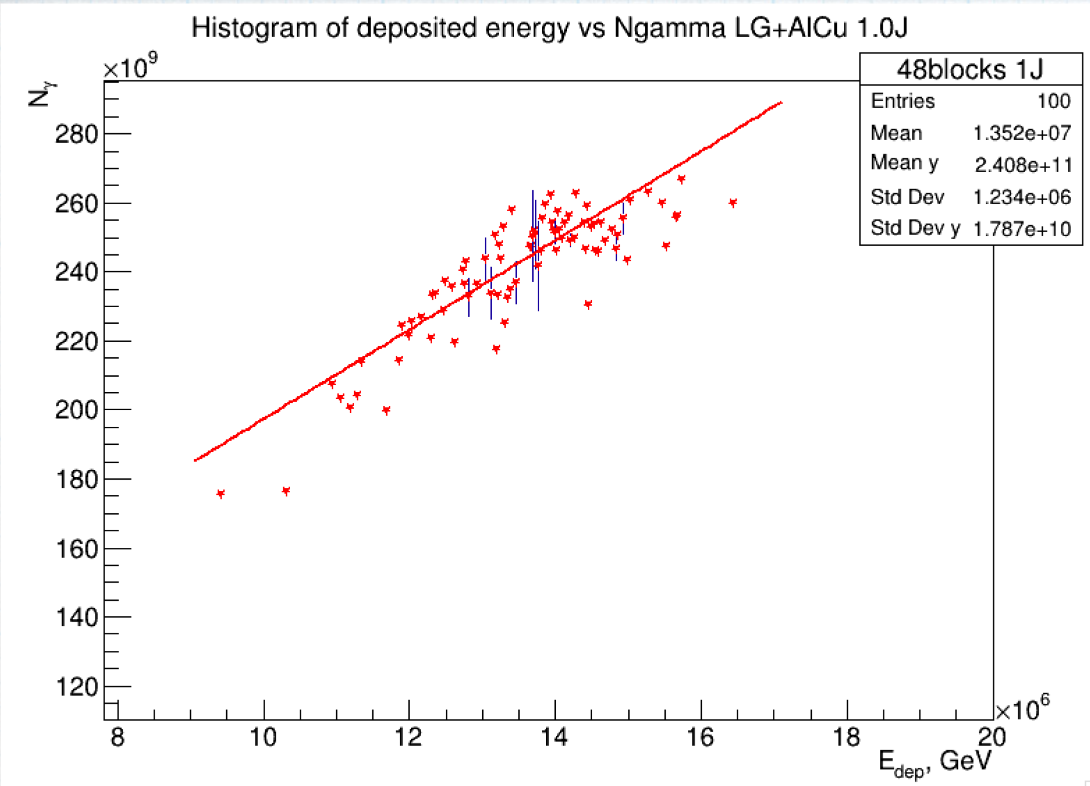

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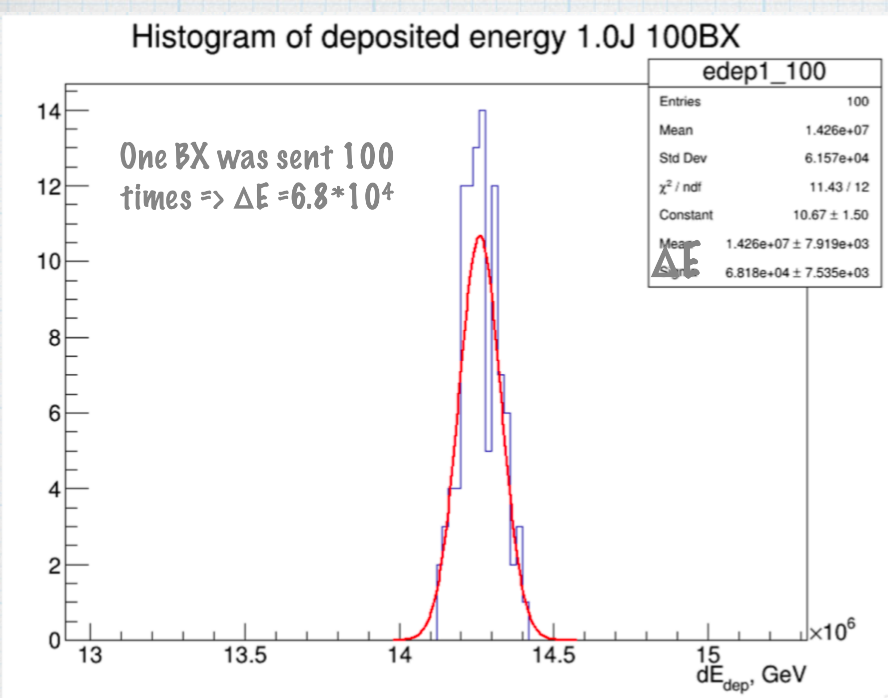
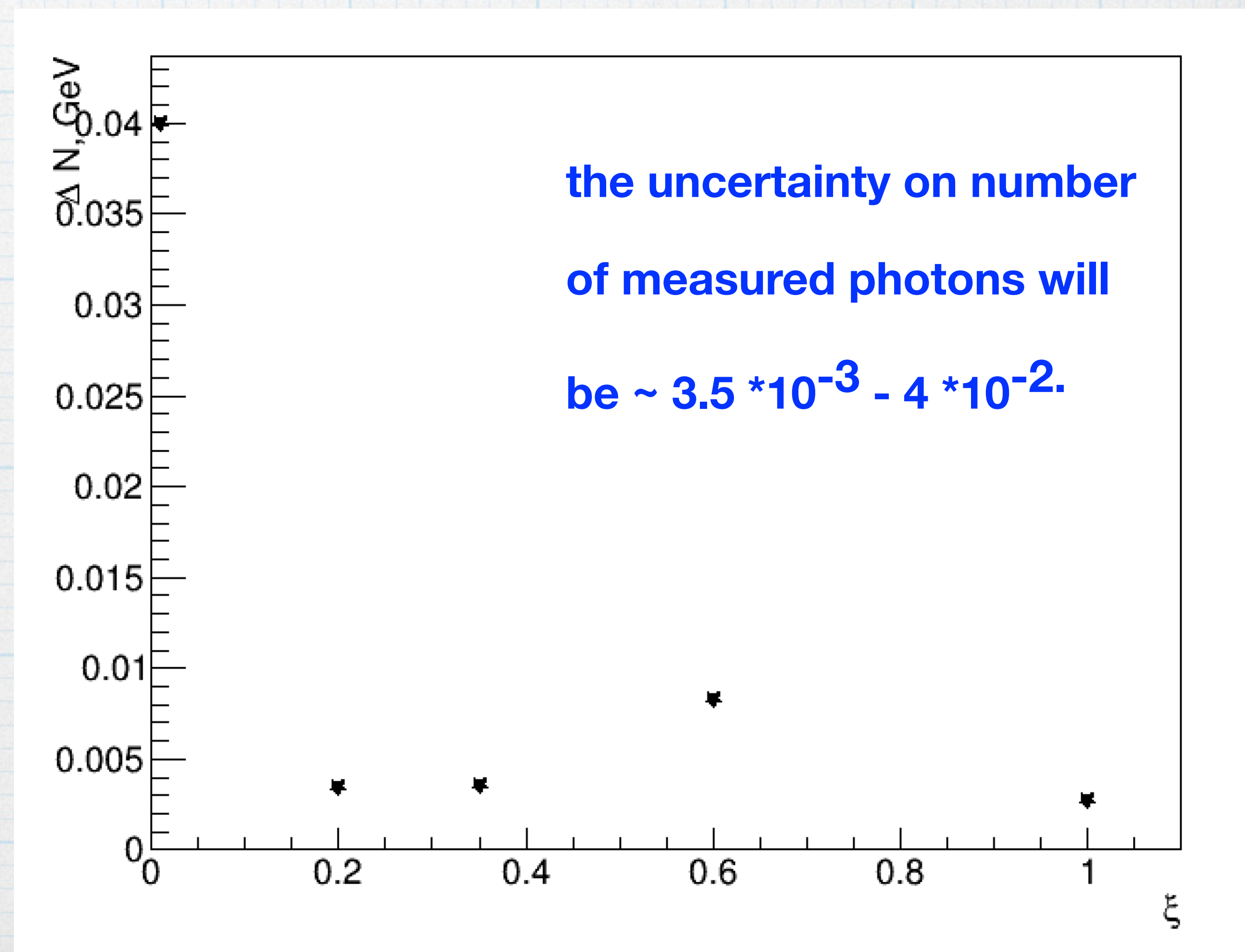
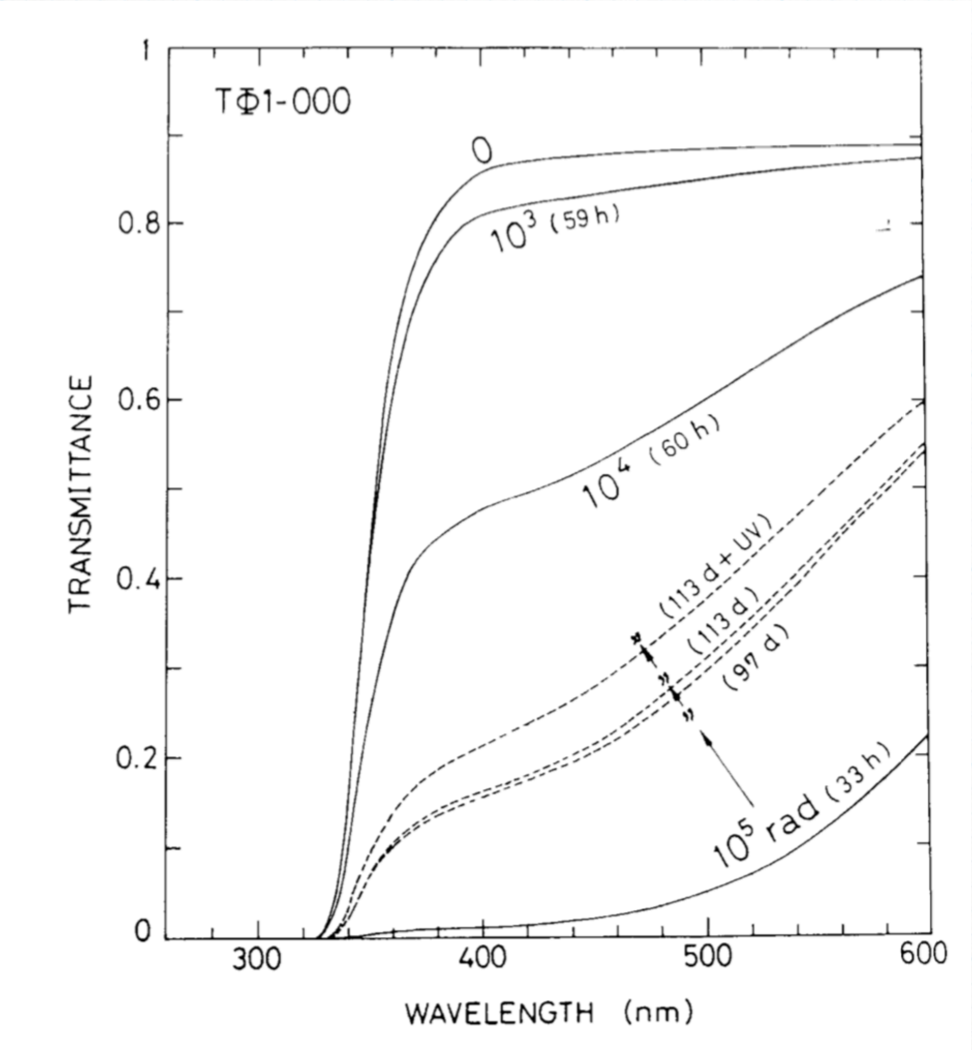
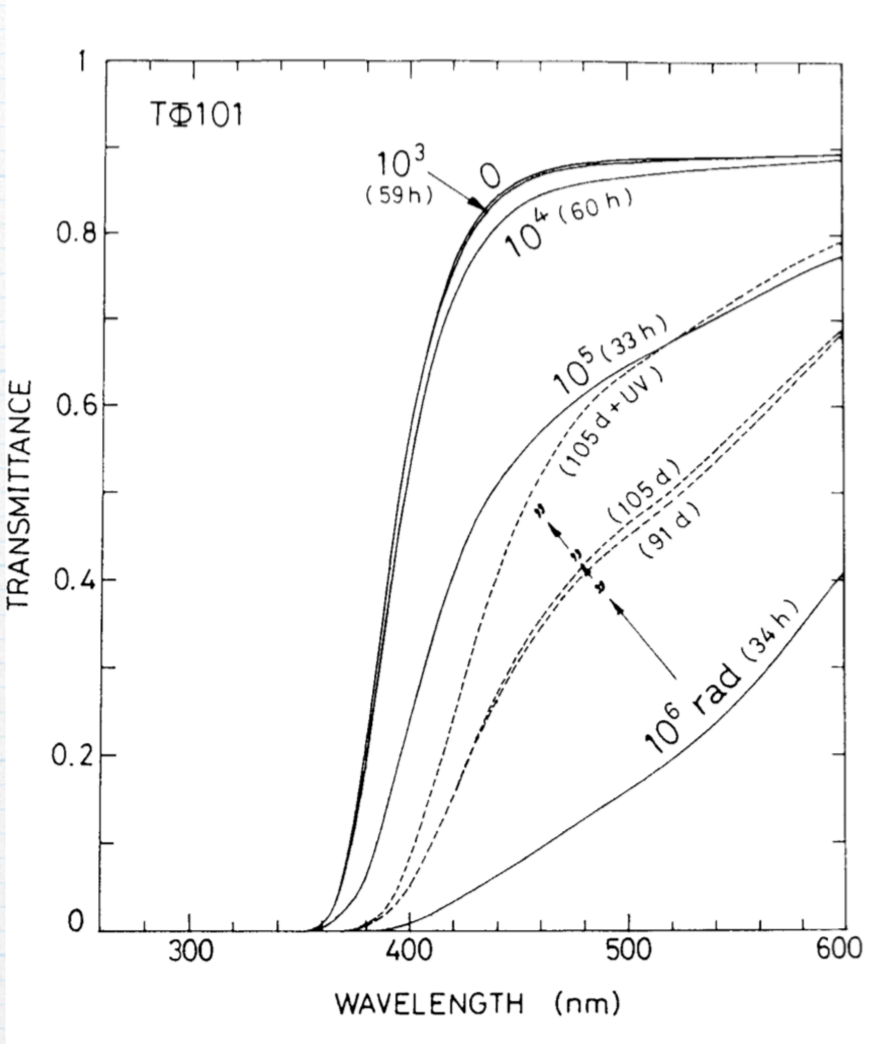




Degradation of the optical properties of the lead glass (TF1& TF101) by radiation





1rad= 0.01 Gy

TF101 - radiation hardened with addition of 0.2% cerium

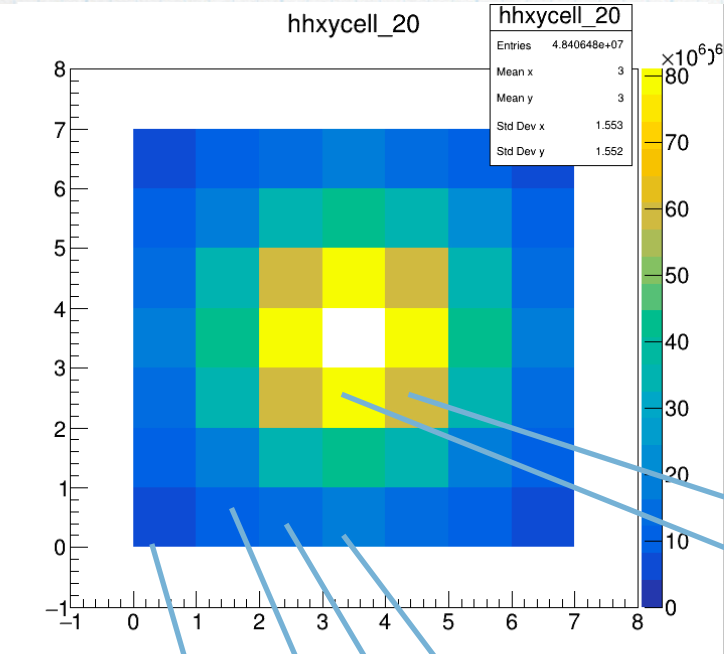
https://doi.org/10.1016/0168-9002(94)90990-3

If, we require the decrease of transmission over the detector depth of 45 cm LG block to be less than 1/e, the tolerable accumulated dose in TF101 should be about 10^4 rad = 100 Gy or a little higher.

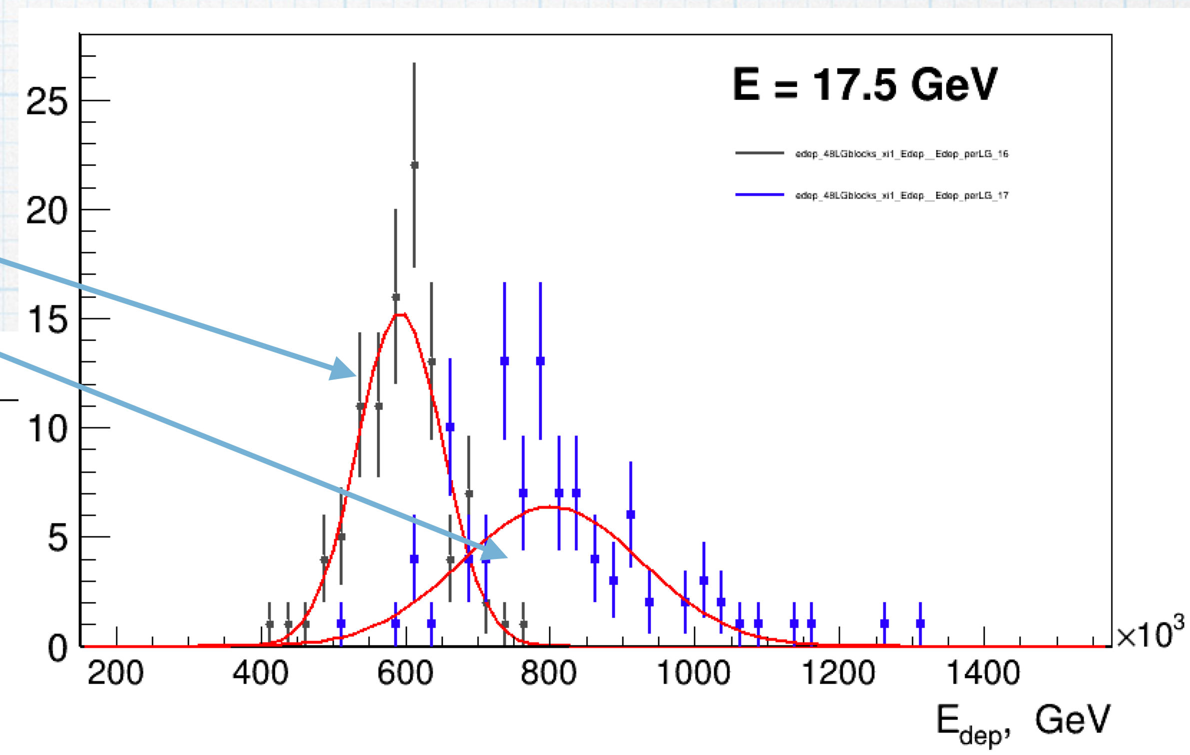
(=> 5* 10^2 rad = 5Gy In TF1)

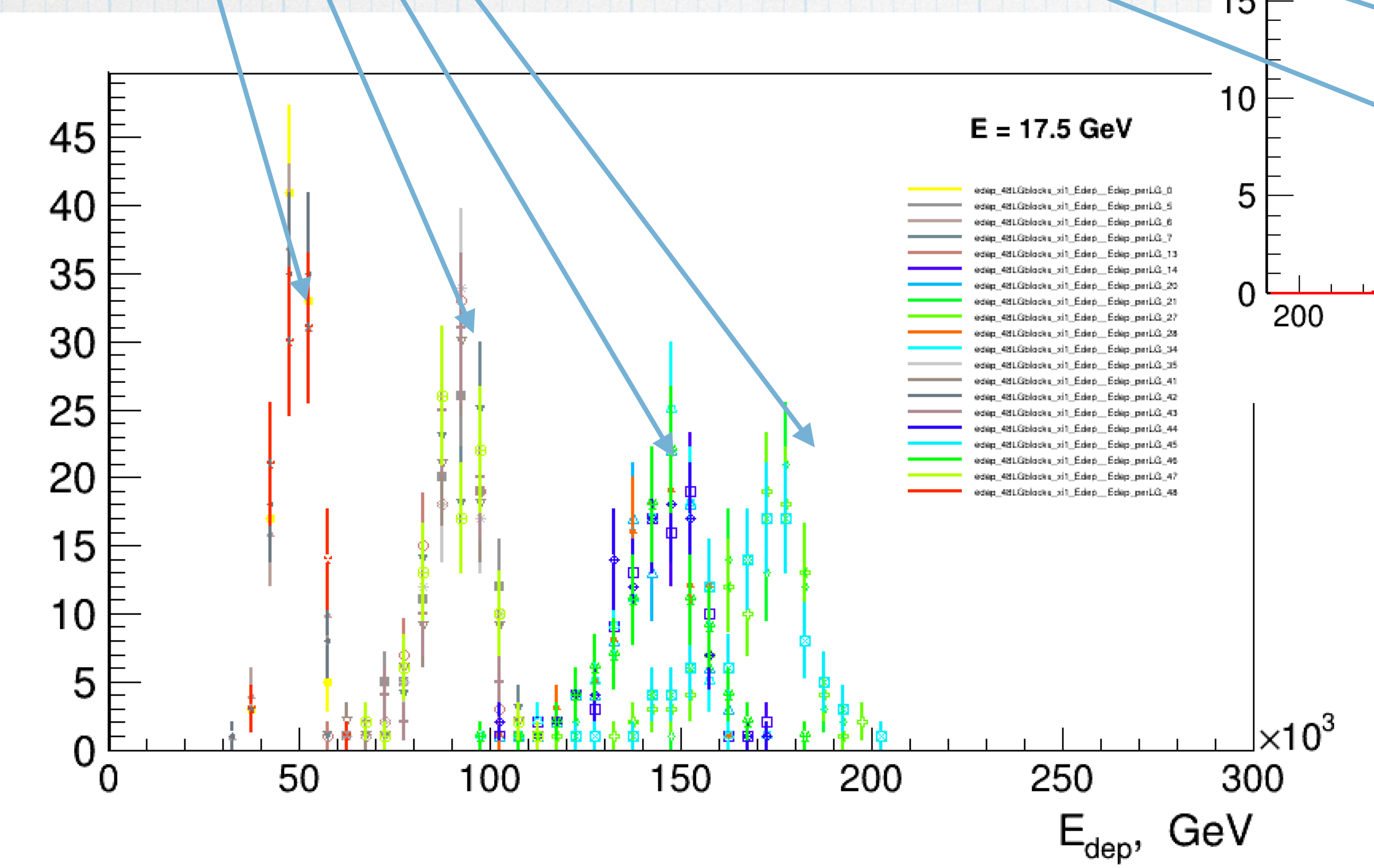
tolerable accumulated doses in the individual blocks

✶At high laser intensities ξ =2.6 (1J)



	Edep(100BX),GeV	Edep(1BX),GeV	Edep(1BX), J	Edep(1BX), J/kg (x0)=Gy	Edep(1BX), J/(2.5kg block)=Gy	Edep(1BX), Gy/sec(2.5kg block)	sec	hours
Inner layer	8.02E+07	8.02E+05	1.28E-04	9.22E-04	5.12E-05	5.12E-04	9.76E+03	2.71
	5.92E+07	5.92E+05	9.49E-05	6.81E-04	3.78E-05	3.78E-04	1.32E+04	3.67
Middle layer	4.40E+07	4.40E+05	7.05E-05	5.06E-04	2.81E-05	2.81E-04	1.78E+04	4.94
	3.50E+07	3.50E+05	5.61E-05	4.03E-04	2.24E-05	2.24E-04	2.24E+04	6.21
	2.00E+07	2.00E+05	3.21E-05	2.30E-04	1.28E-05	1.28E-04	3.91E+04	10.87
Outer layer		1.70E+05	2.72E-05	1.95E-04	1.08E-05	1.08E-04	4.61E+04	12.81
		1.44E+05	2.30E-05	1.65E-04	9.18E-06	9.18E-05	5.45E+04	15.13
		9.13E+04	1.46E-05	1.05E-04	5.83E-06	5.83E-05	8.57E+04	23.82
		4.86E+04	7.78E-06	5.59E-05	3.10E-06	3.10E-05	1.61E+05	44.76

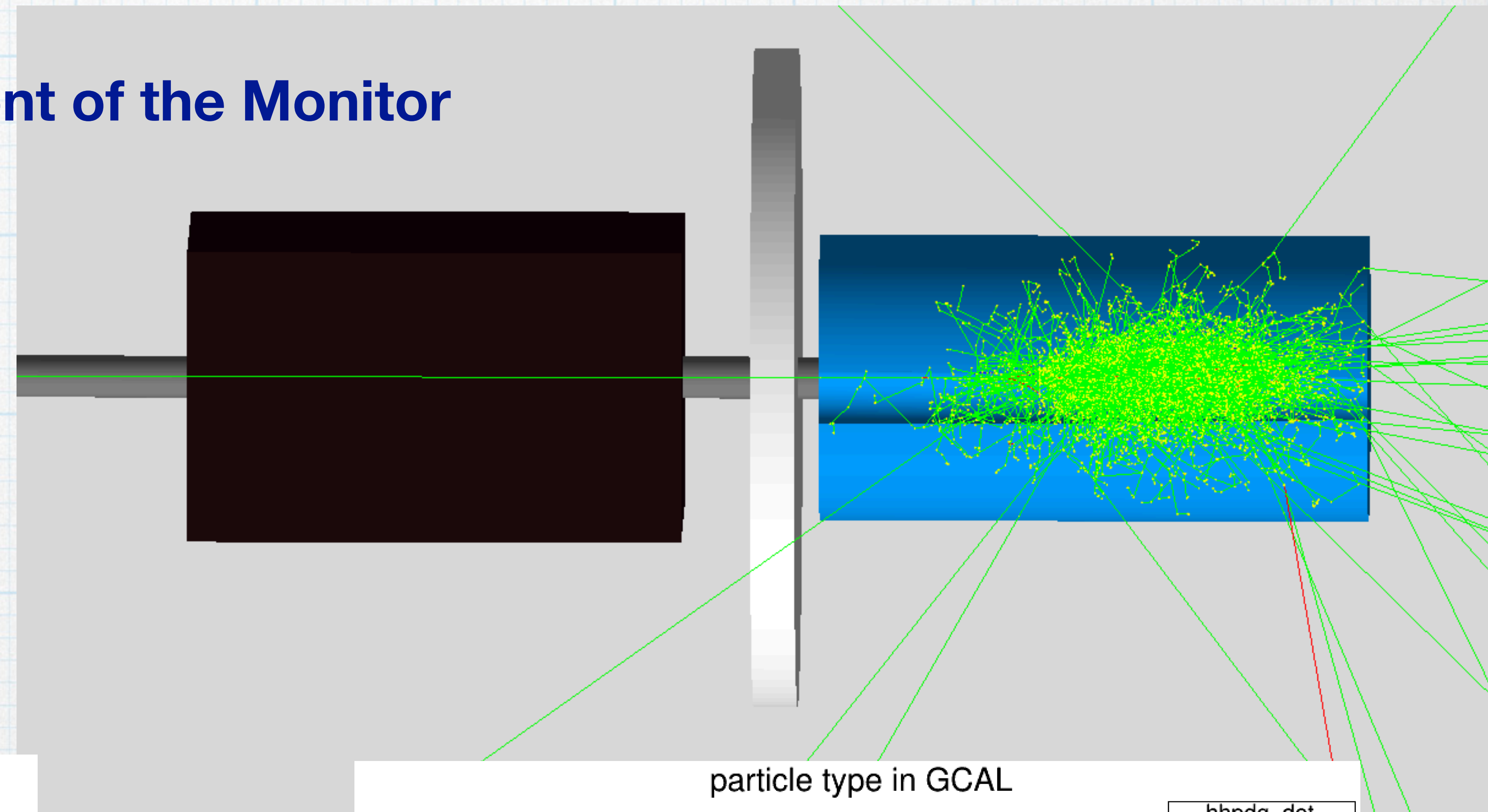


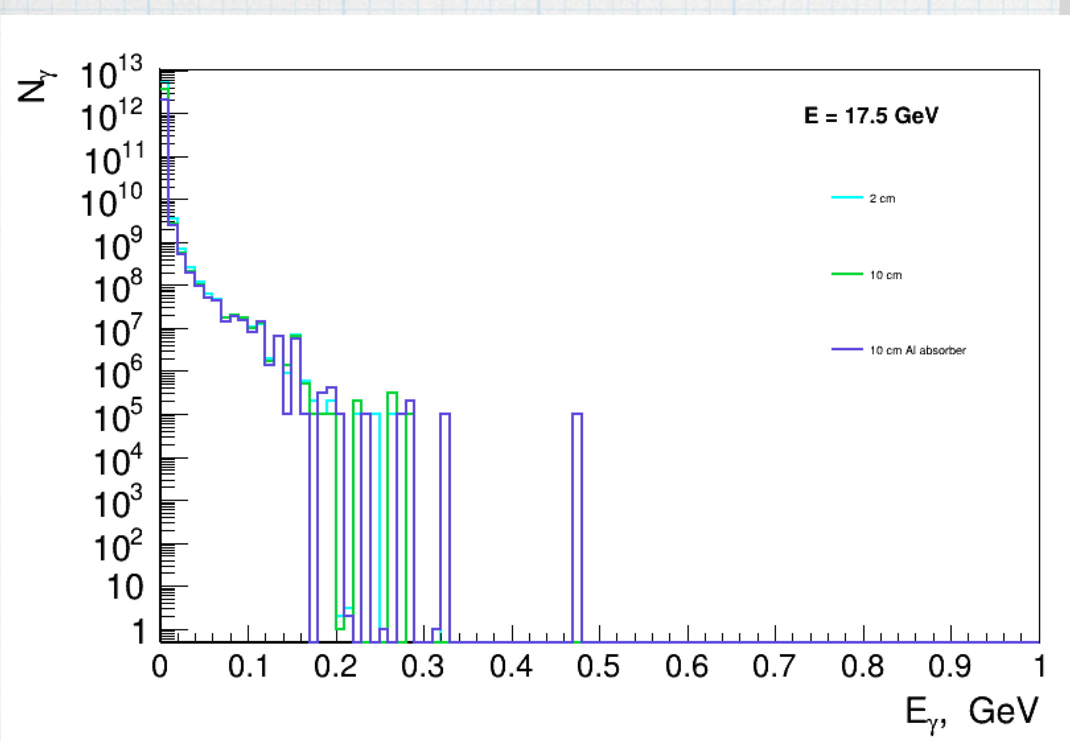


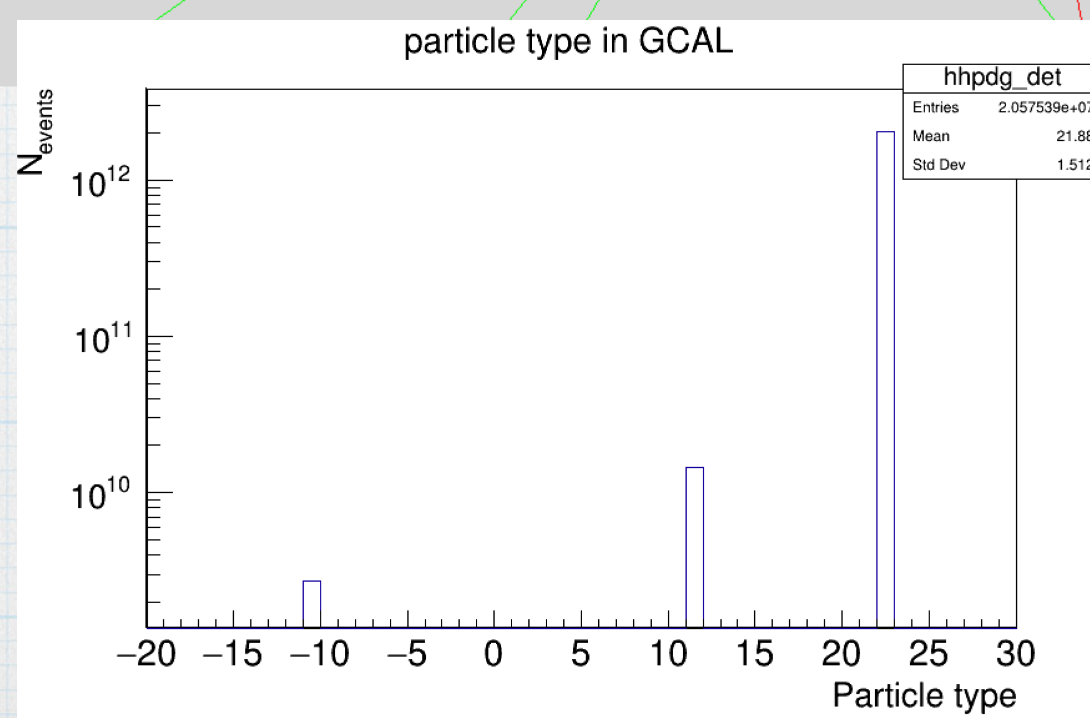
At 10 Hz rate the energy deposition accumulates the dose of 5 Gy in the whole TF1 block which ranges from 3 hours up to 45 hours

Adding absorber

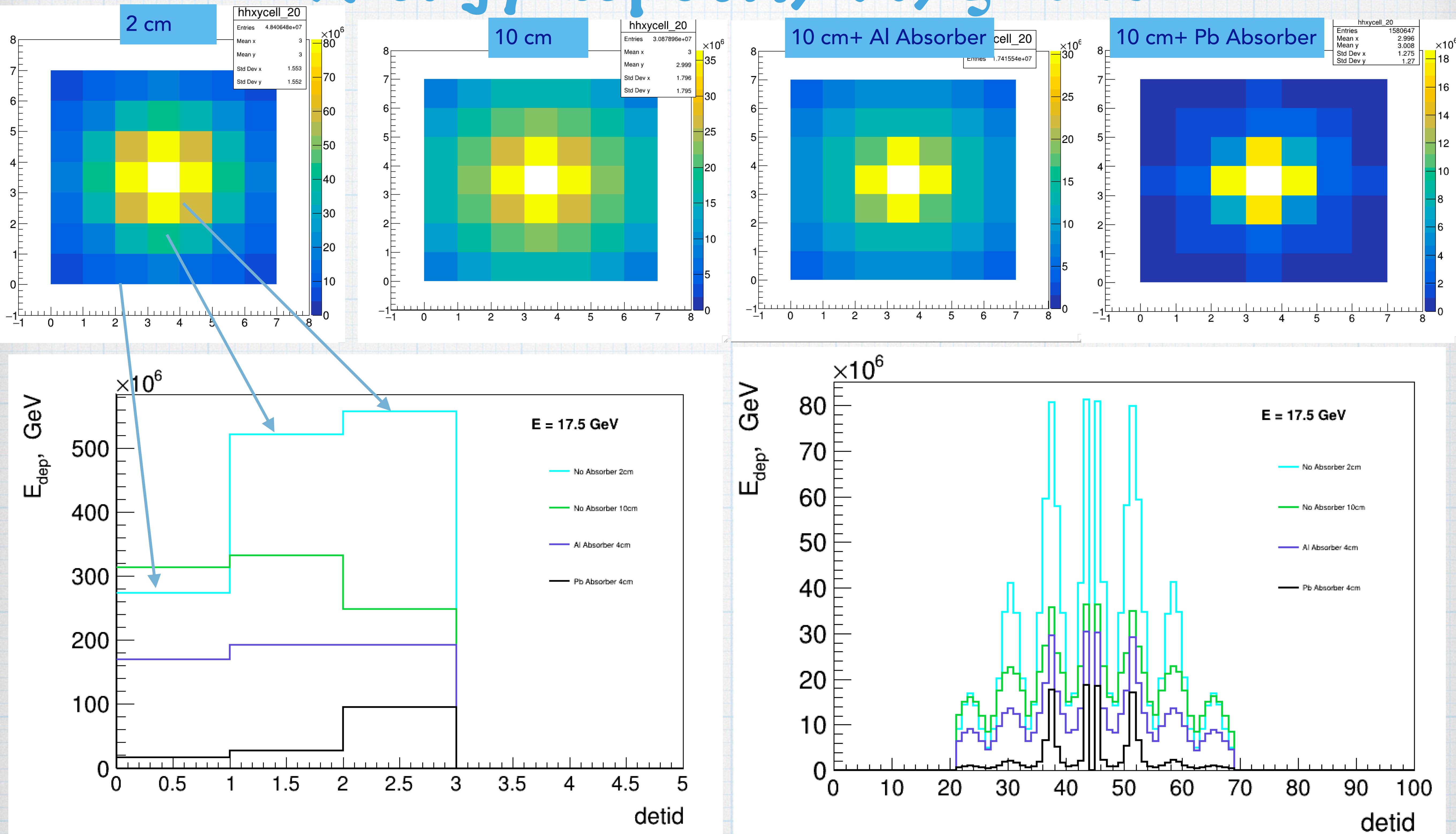
- ✳ 2Months ~1460 hours
- ✳ To try:
  - ✓ absorber (Al or Pb, 4 cm) in front of the Monitor







Energy deposit, 48, ξ =2.6



- ✶ **Moving further from the dump the deposit in inner layer twice less, which prolonged the usage of inner layer up to 7 hours**
- ✶ **Adding 4 cm Al absorber between dump and monitor prolongs up to 10 hours for the inner layer**

Summary

- ☑ Measuring total energy of back-scattering particles can be used to monitor the flow of incoming photons. Existing (@DESY 4free) lead glass blocks might be a good choice for the calorimeter.
- ☑ The estimated uncertainty on number of measured photons is ~ 10^{-3} - 10^{-2} in case of HICS.
- ☑ Can be used also for bremsstrahlung using the convolution of response function with the spectrum.
- ☑ If we consider the usage of existing (@DESY 4free) lead glass blocks the radiation degradation could be an issue but it could be mitigated.
- ☐ Degradation of optical properties studies
- ☐ Use more realistic LUXE geometry which has been partly implemented and consider specific (or different) detector techniques implementation.

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