Gamma Monitor using backscatters

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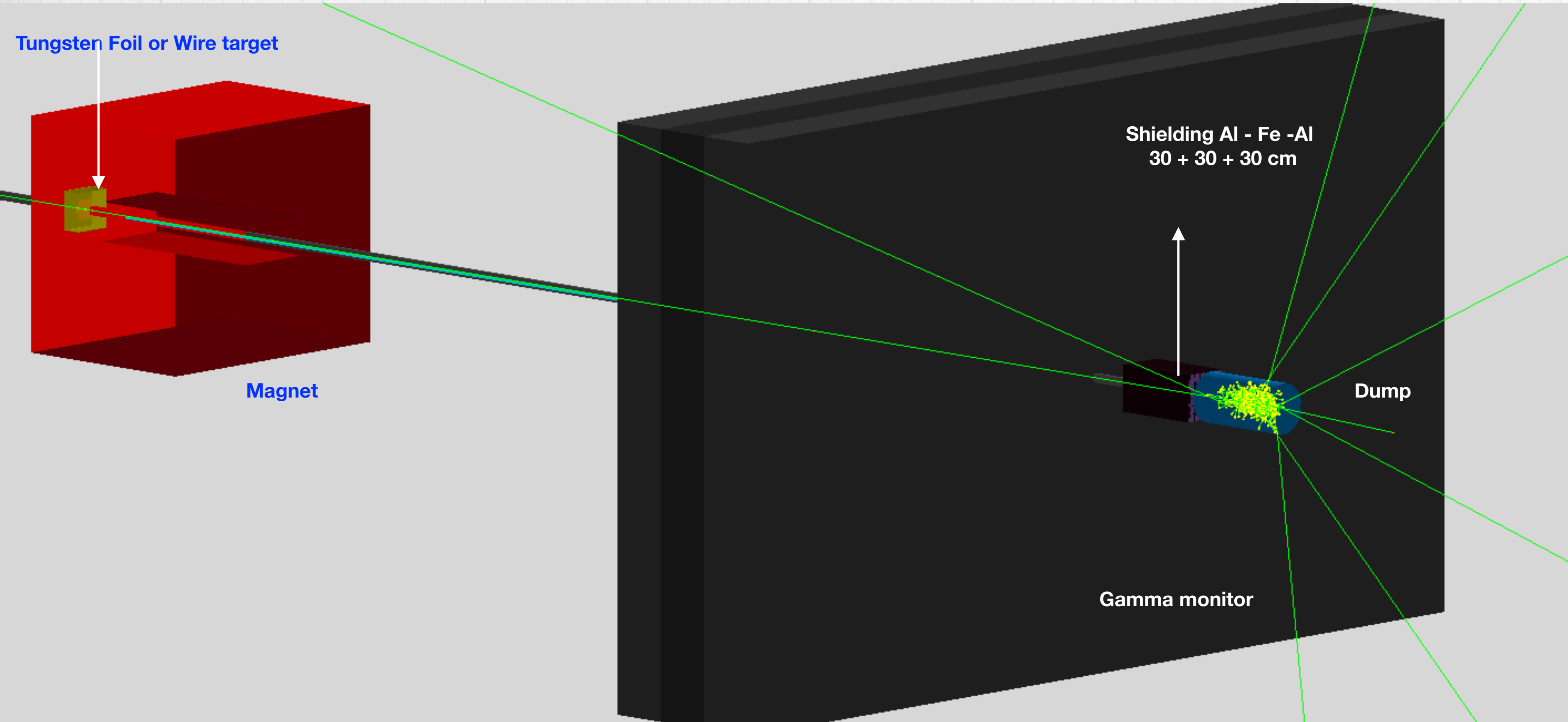
LUXE technical meeting

DESY Hamburg

23/04/20

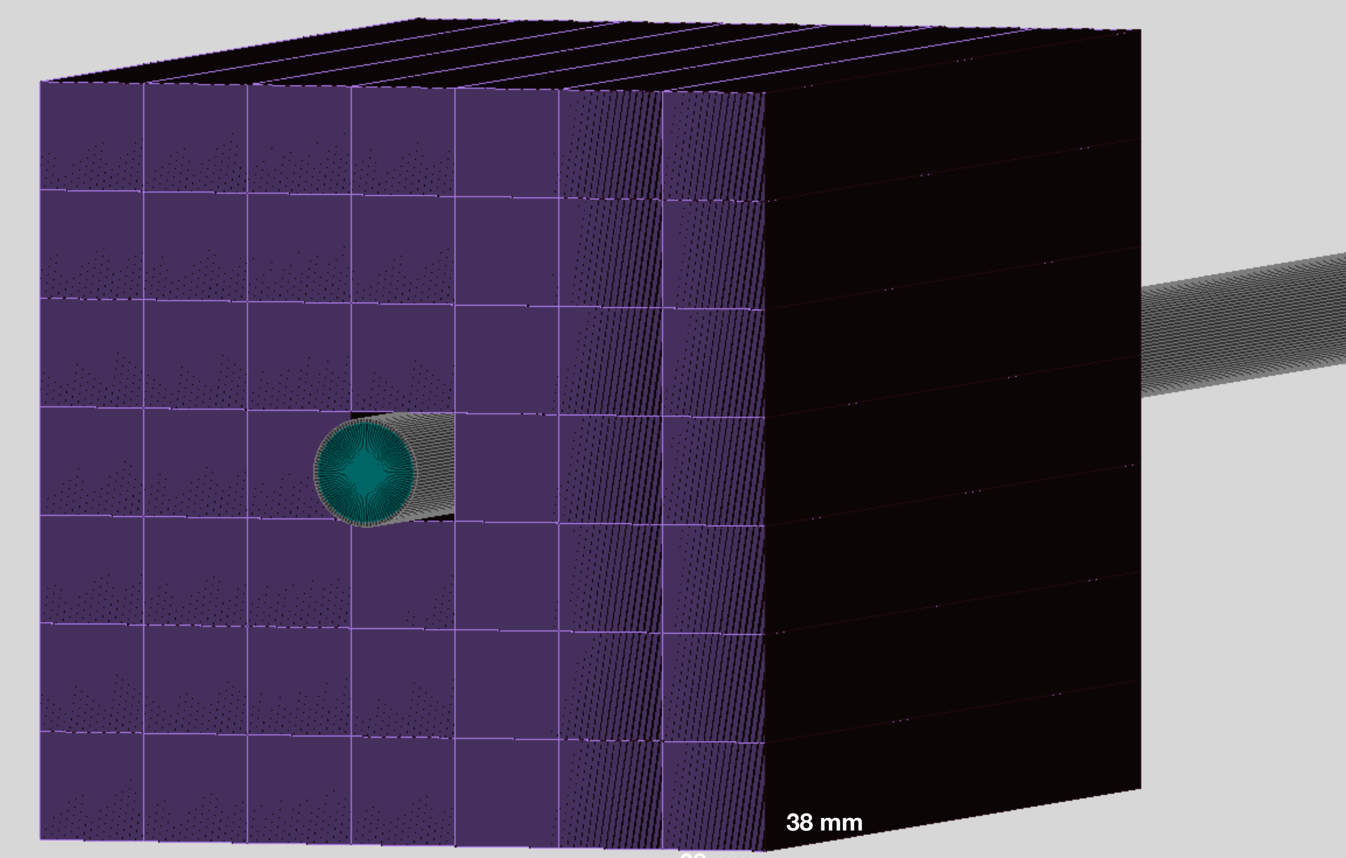
LUXE

Gamma Monitor

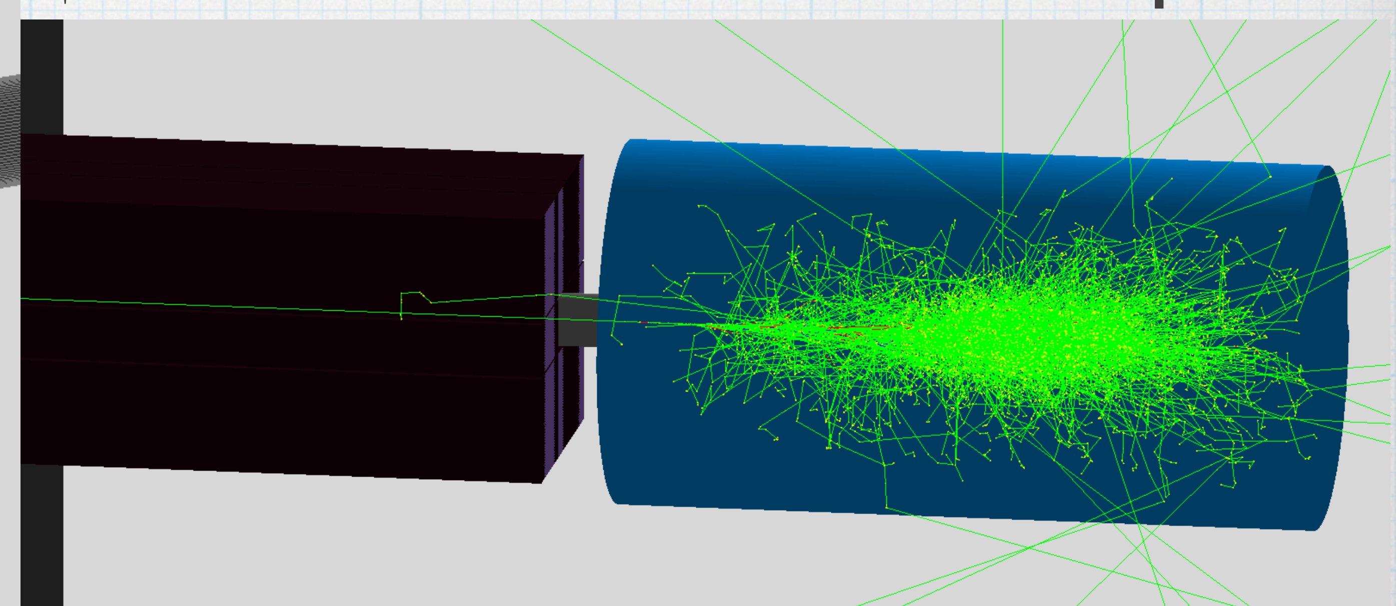


- The implementation of FDS in Luxe geometry with the LG Gamma Monitor made of new LG blocks in front of Al-Cu Dump,
- LG w/ measures 3.8 × 3.8 cm^2, length is 45 cm
- Wrapped with Aluminium foil of 0.016 mm (typical household foil; no account for air)

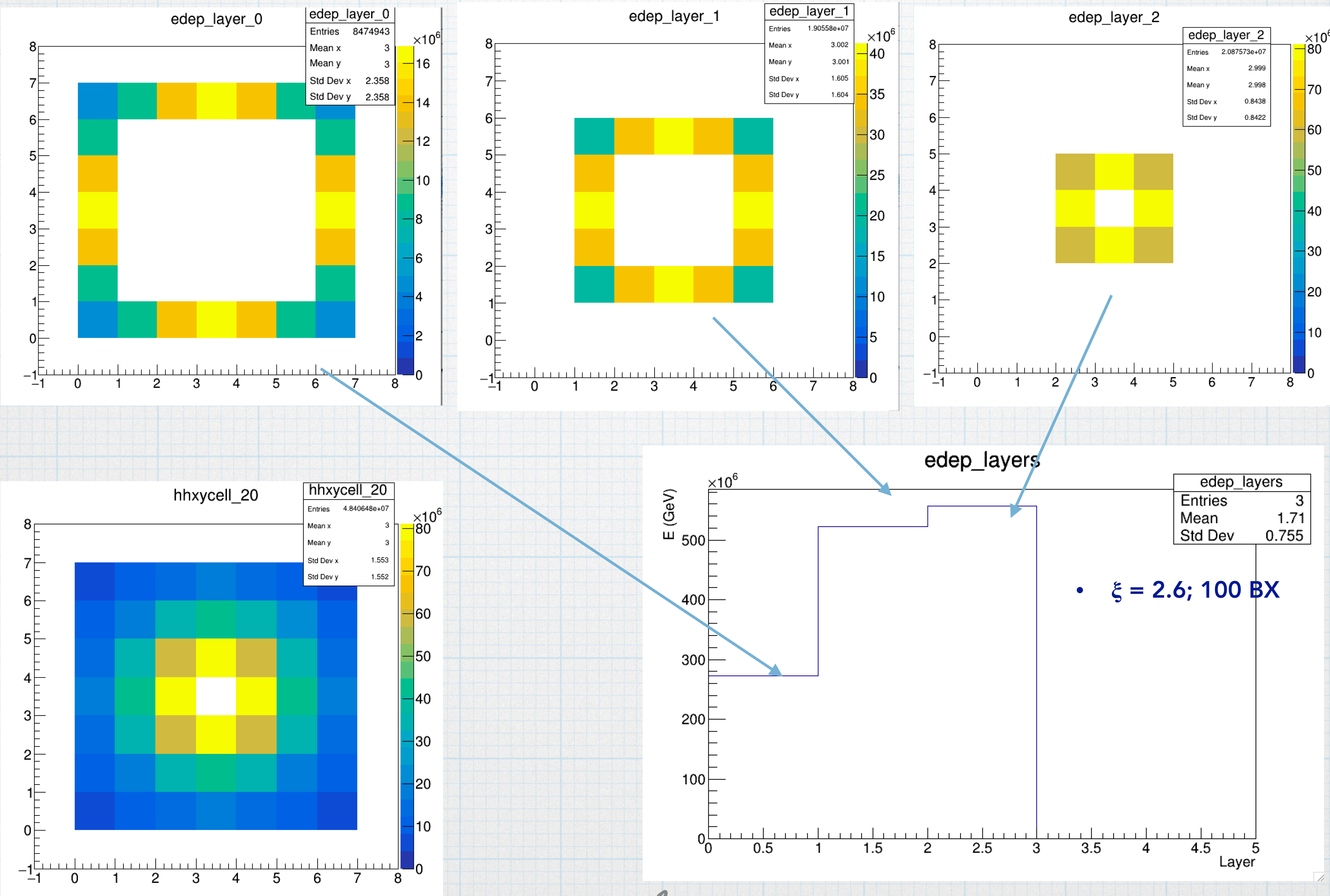
Beam Pipe , R =19.0 *mm, thickness = 1.65 mm



- Distance between Monitor and Dump 2 cm



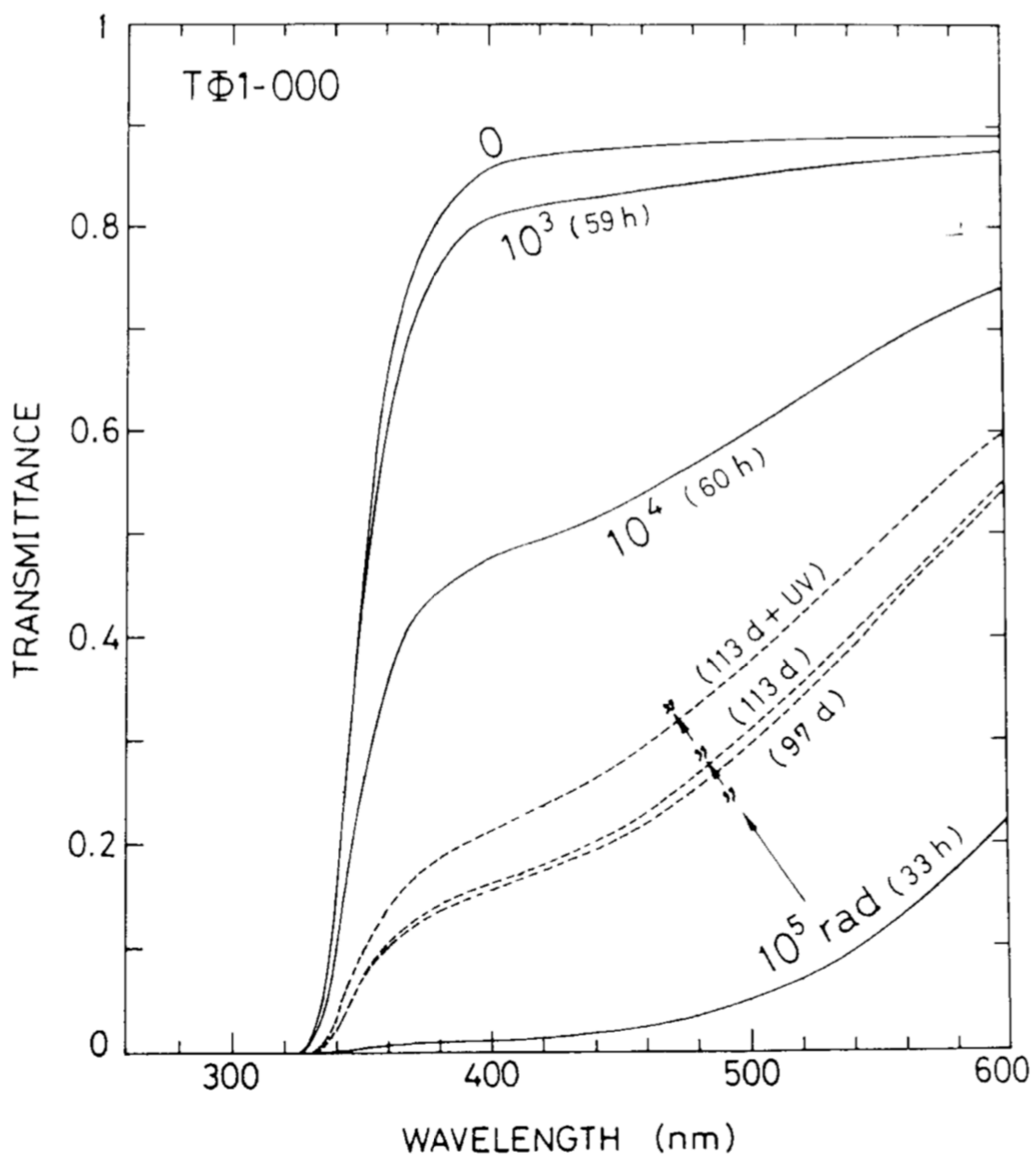
Energy deposition in layers, 48 LG blocks, ξ = 2.6 (1 J)



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

1 rad = 0.01 Gy

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



Irradiation by ^{60}Co γ -rays was carried out at Japan Atomic Energy Research Institute (JAERI). Four cycles of irradiation followed by transmission measurement were carried out to cover the accumulated dose* from 10^3 to 10^6 rad by increasing the accumulated dose by a factor of 10 per cycle. Each cycle (irradiation, measurement and mailing of samples between KEK and JAERI) took about a week. Each irradiation period took 10 minutes, 1 hour, 3 hours and 1 hour for the accumulated dose of 10^3, 10^4, 10^5 and 10^6 rad, respectively, by mounting the samples at different distances from a calibrated ^{60}Co source. Since recovery of radiation damage upon exposure to UV light is known in many materials such as PbF_2[4], CsI:Tl[5], BaF_2[6] and GSO:Ce[7], we paid attention for safety lest a sample should be exposed to strong UV light, including sunshine, during any course of the irradiation-measurement cycle. All the samples were wrapped in aluminum foil except during a short period of transmission measurement which took about 10 to 15 minutes per measurement per sample.

- Radiation hardness of TF1(GAMS) vs TF101(HERMES): TF101 because of 0.2% Cerium 20 times radiation harder

Degradation of light transmission

If we require the decrease of transmission to be less than 1% per unit radiation length X0 = 2.8 cm In detectors read out by photomultipliers with a bilalkali or a multilalkalli photocathode, the tolerable accumulated dose In TF101 should be about 2 x 10^3 rad. (=> 10^2 rad = 1Gy In TF1)

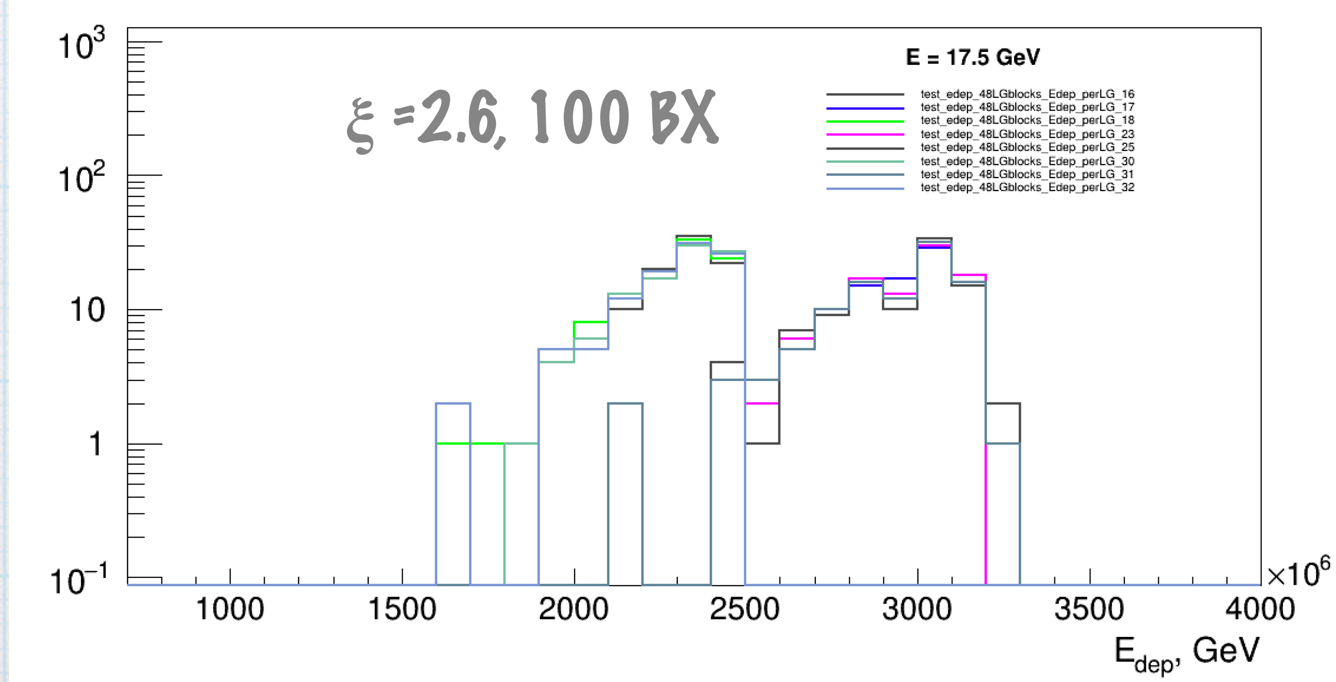
If, Instead, we require the decrease of transmission over the detector depth of 45 cm to be less than 1/e, the tolerable accumulated dose should be about 10^4 rad or a little higher. (~ (=> 5*10^2 rad = 5Gy In TF1))

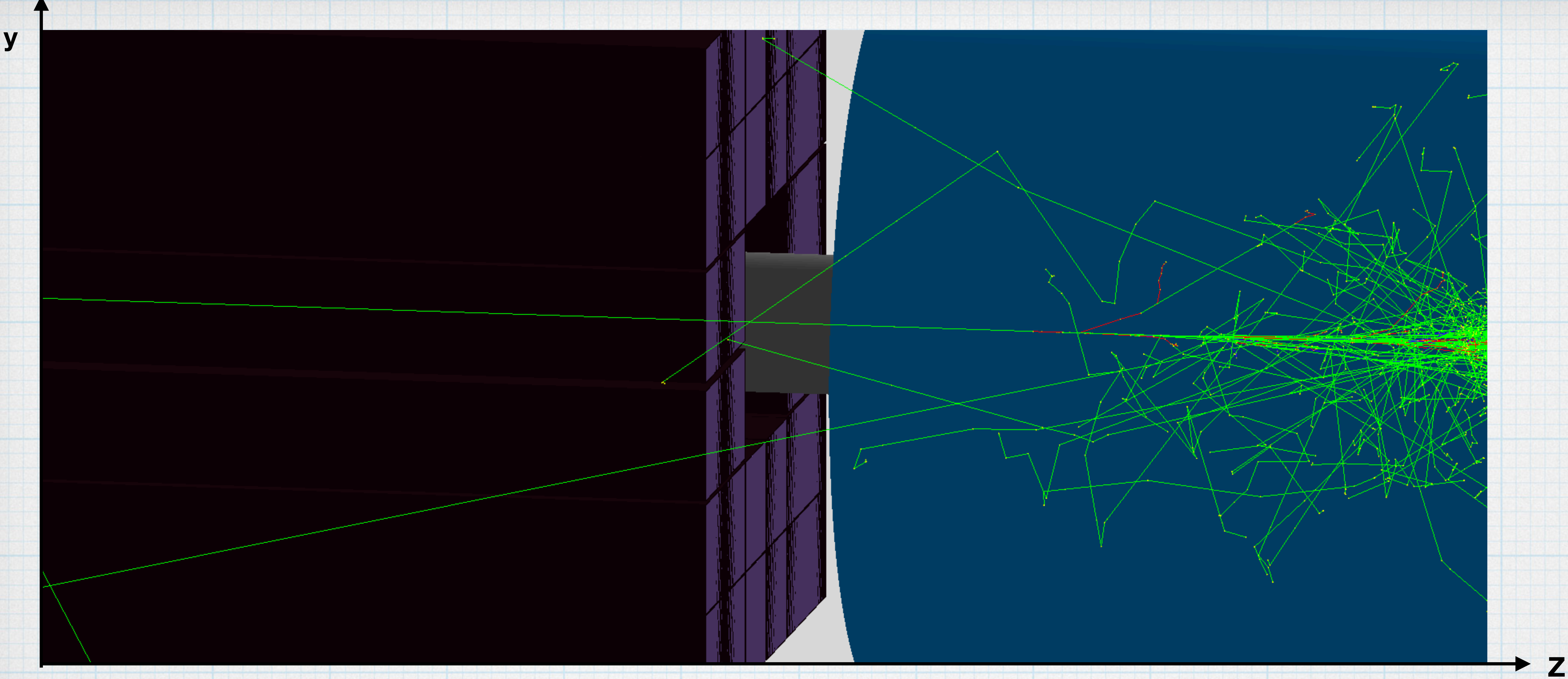
1J = 6,242e+9 GeV
1 rad = 0.01 Gy

1 Gy = 1 J/kg => for TF1 100BX 2-3Gy => In 1000 sec glass will be destroyed

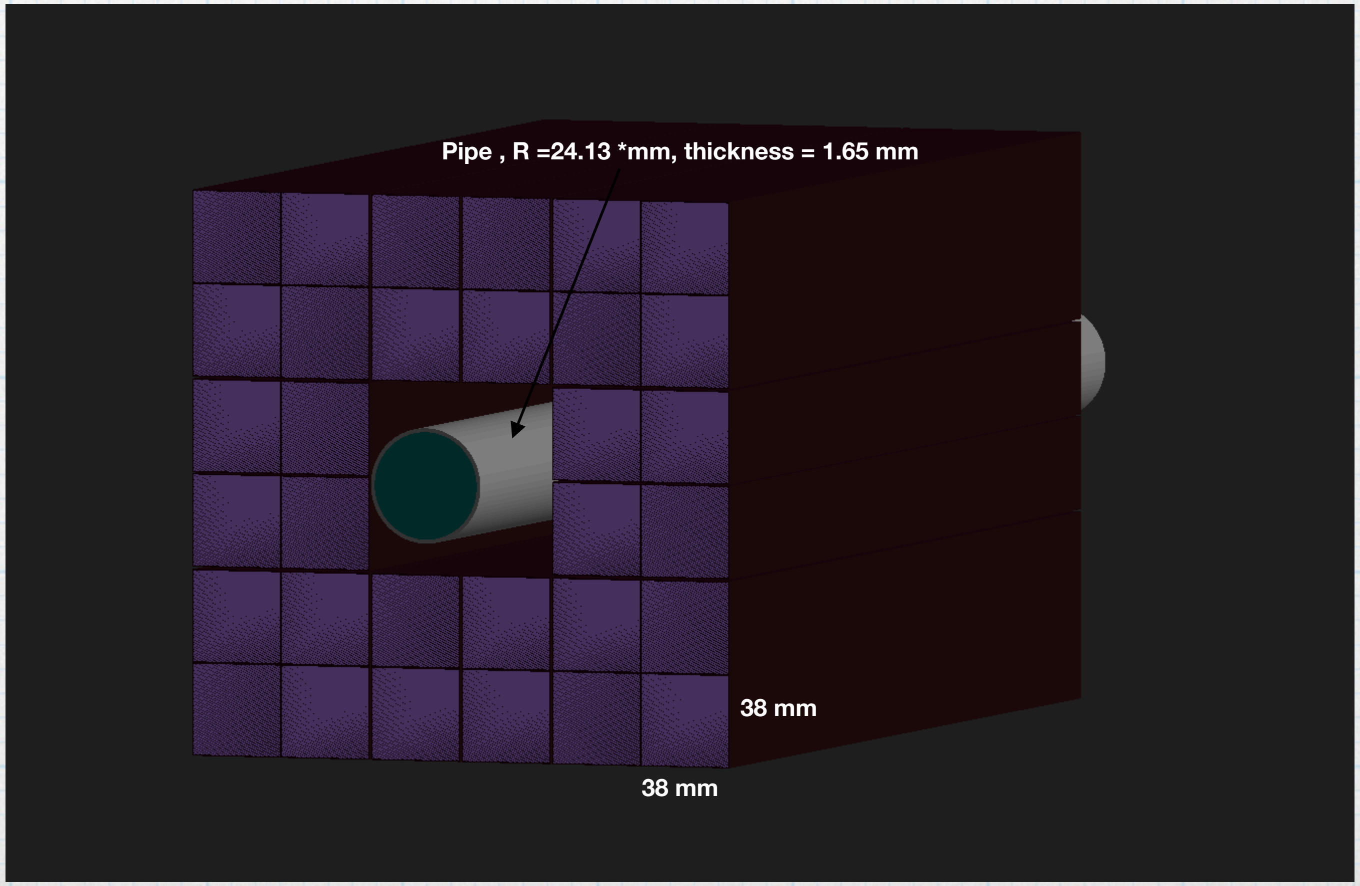
Table 1. Chemical composition and physical properties of the TF-1[10].

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	





- 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

Outlook

- Gamma monitor studies:

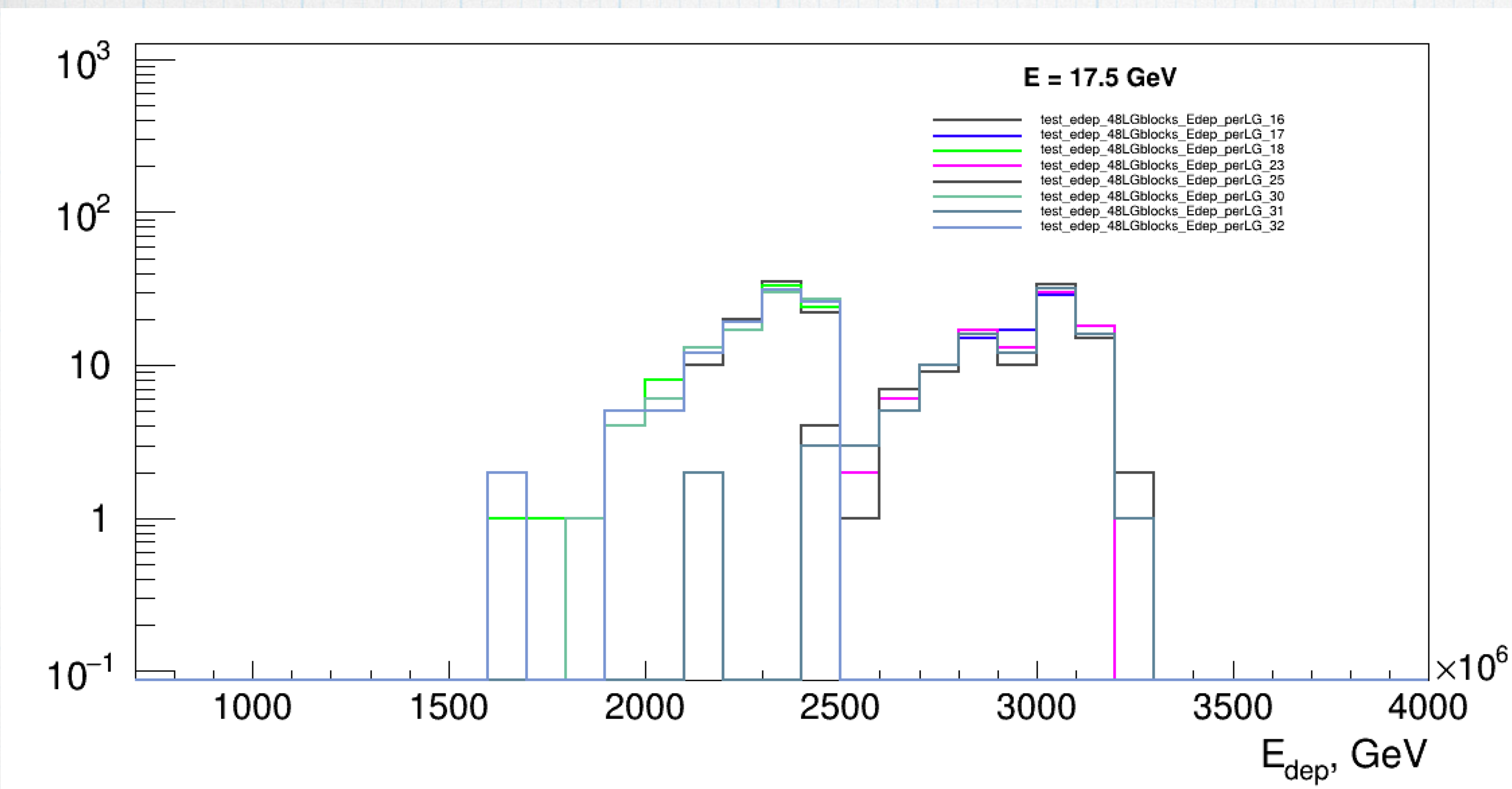
The study of the radiation hardness of LG

- ✳Radiation hardness of TF1(GAMS) vs TF101(HERMES): TF101 because of 0.2% Cerium 20 times radiation harder
- ✳the tolerable accumulated dose should be about 5*10^2 rad
- ✳At high laser intensities (1J) the blocks that closely surround the beam pipe will be damaged in 15 min at 10 Hz rate

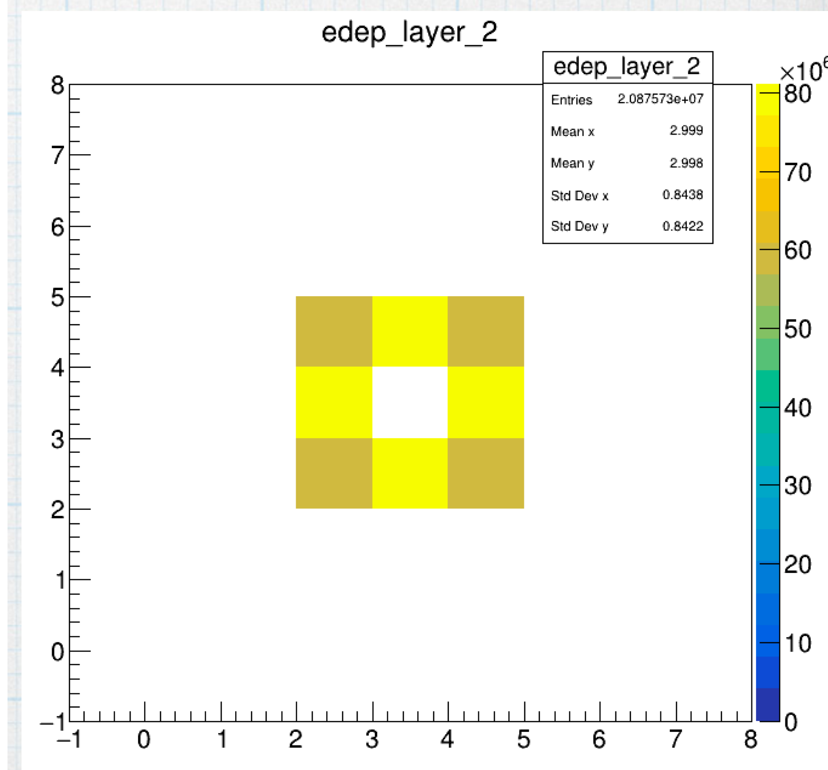
Back up

Deposited Energy in the inner layer

* The deposited energy per One BX
  - for ξ =2.6 Edep in the dump ~ 10^{11} ⇒ Edep in the GM ~ 10^{7}
  -

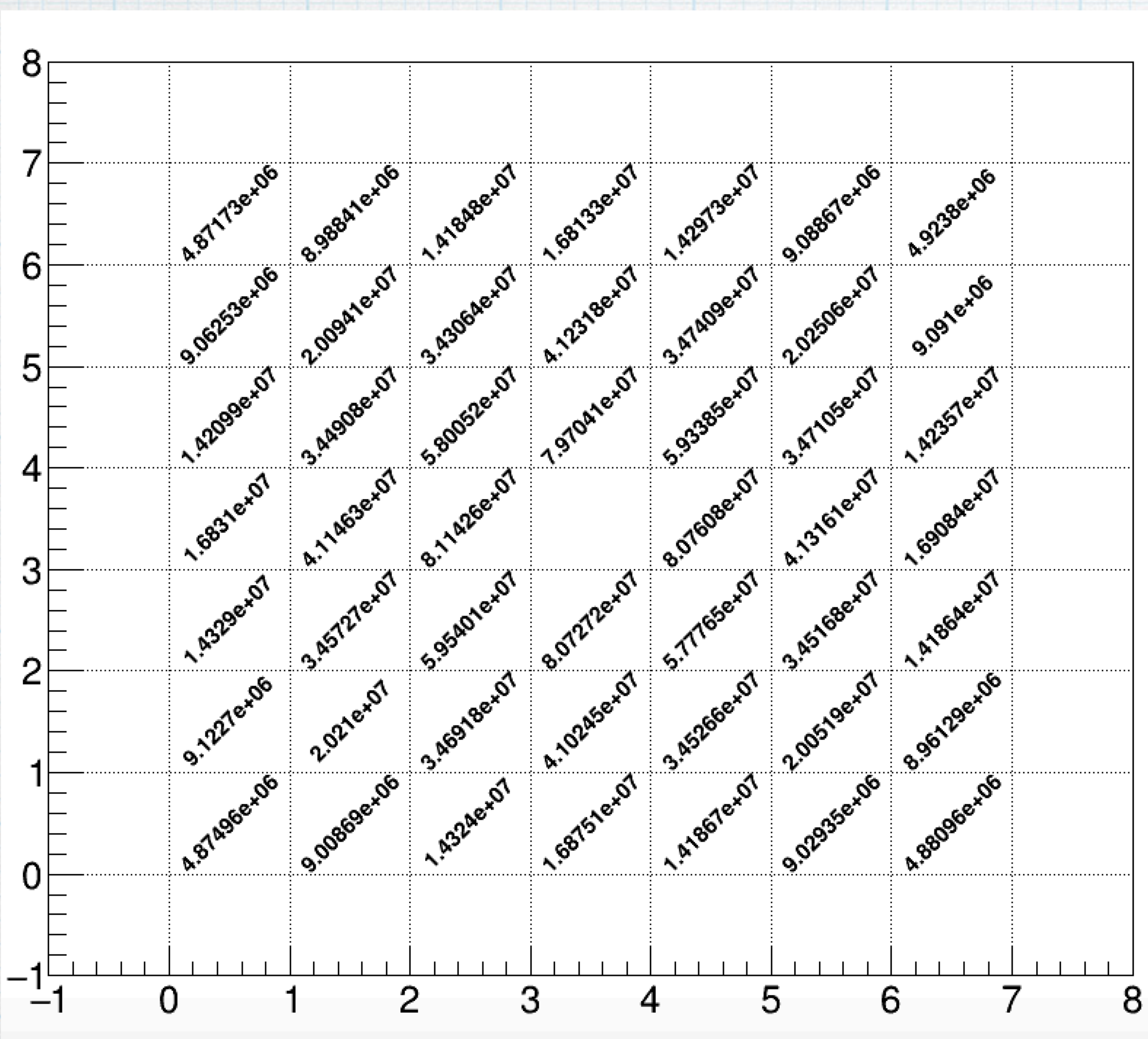


- for ξ =2.6, 100 BX

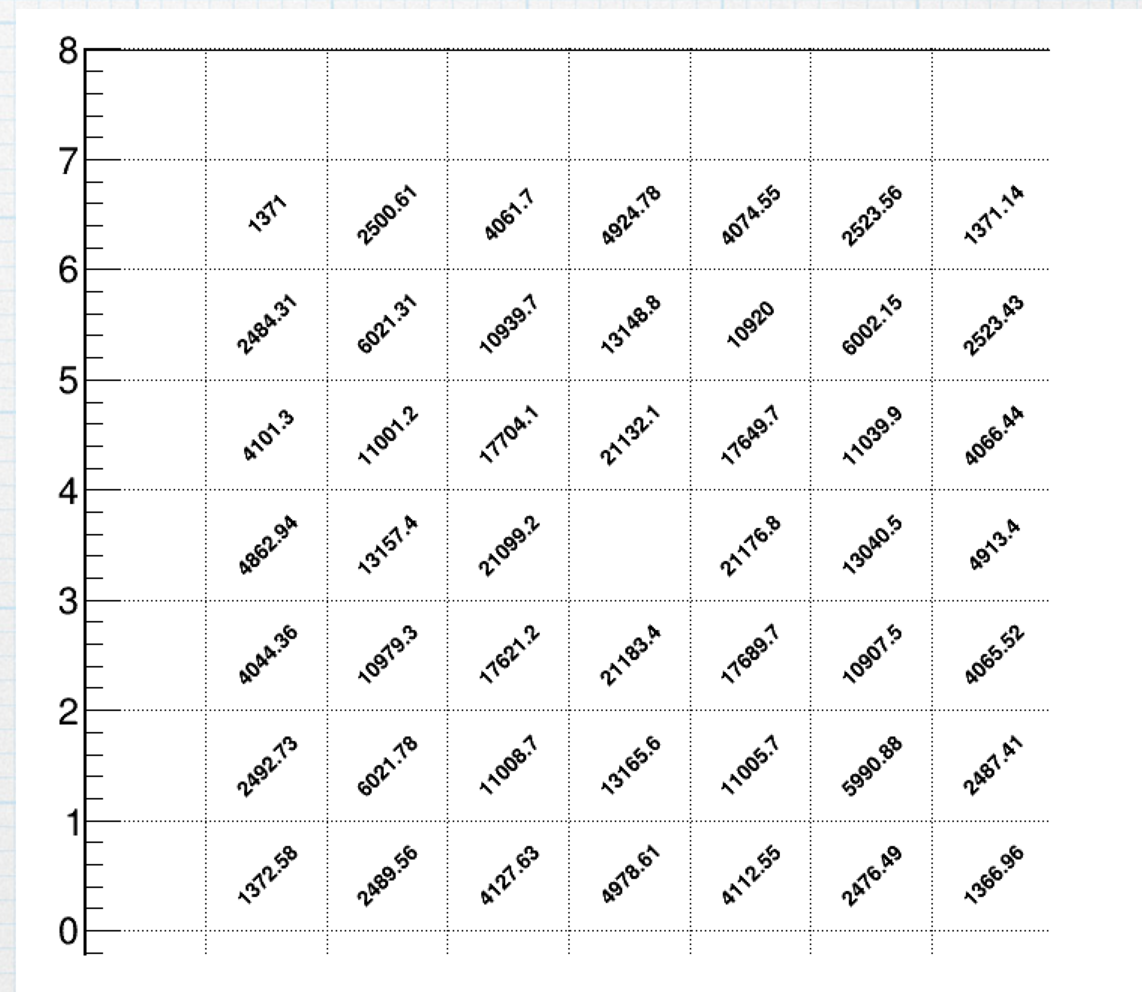


Previously raised issues:

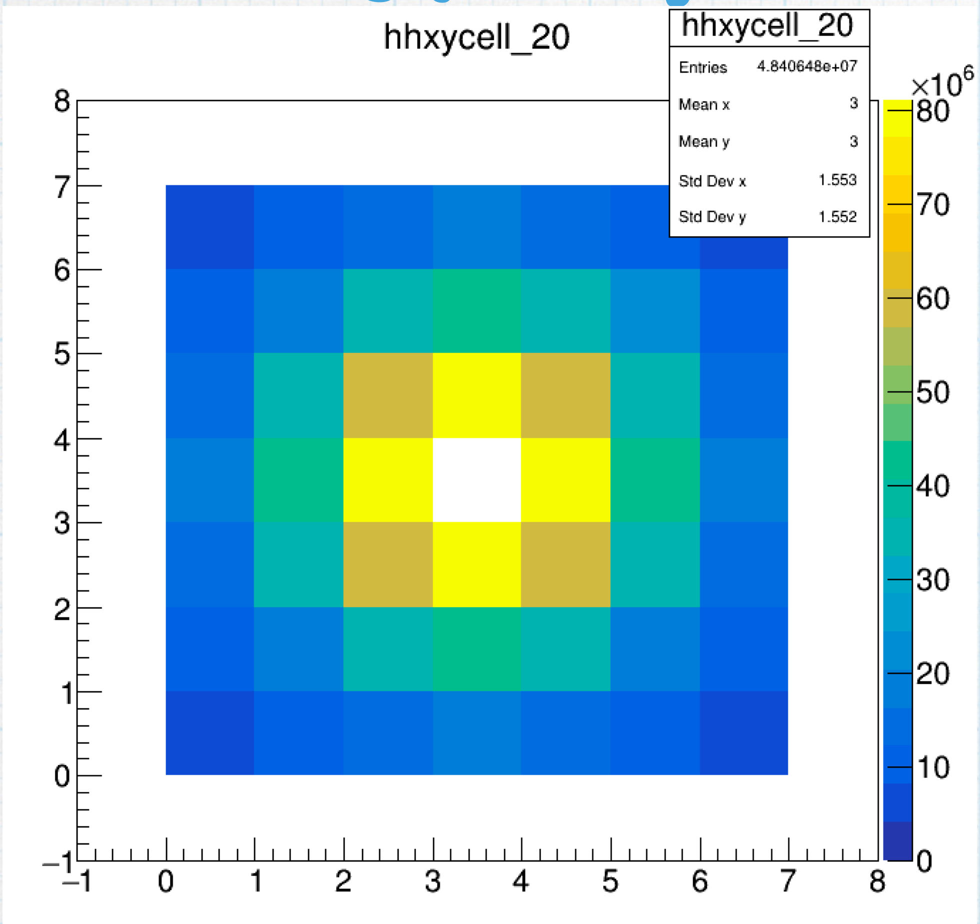
* The units are correct - GEV
* The number of particles entering each block per 100 BX
  - for ξ =2.6

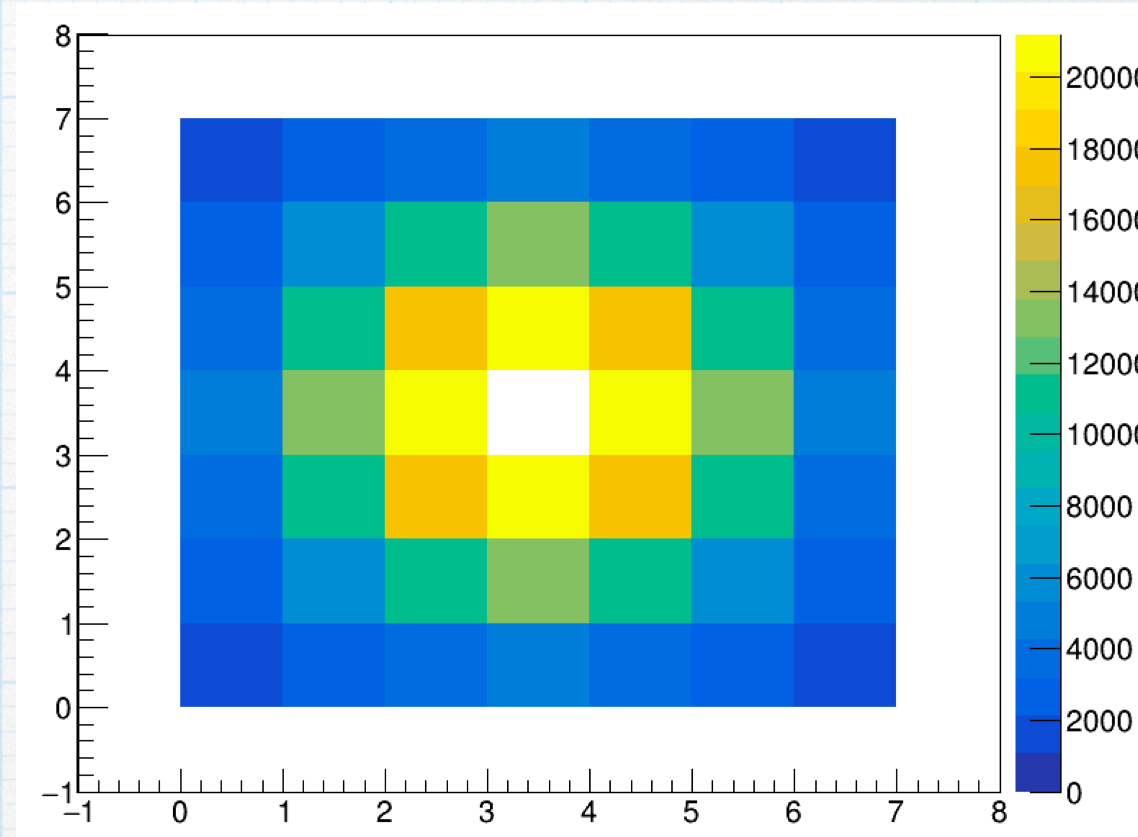


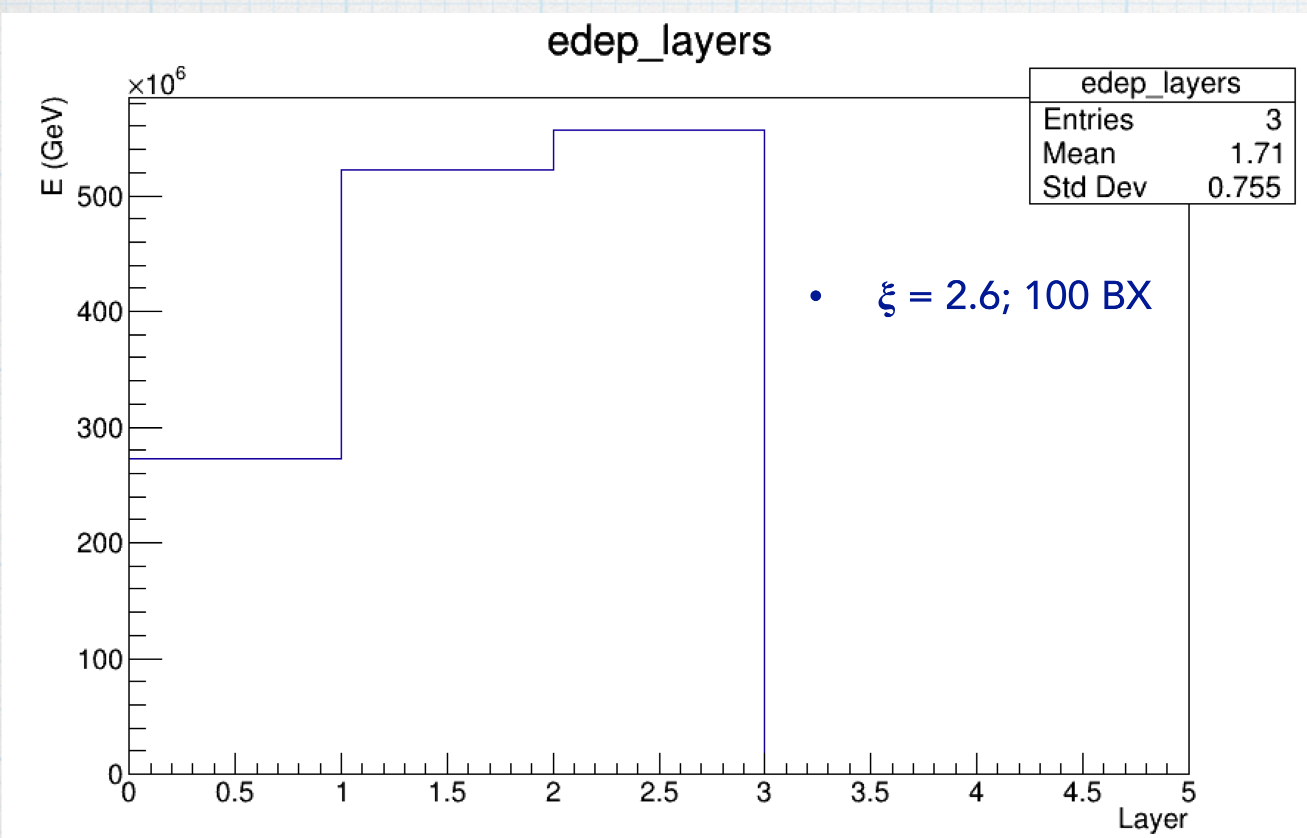
  - for ξ =0.26

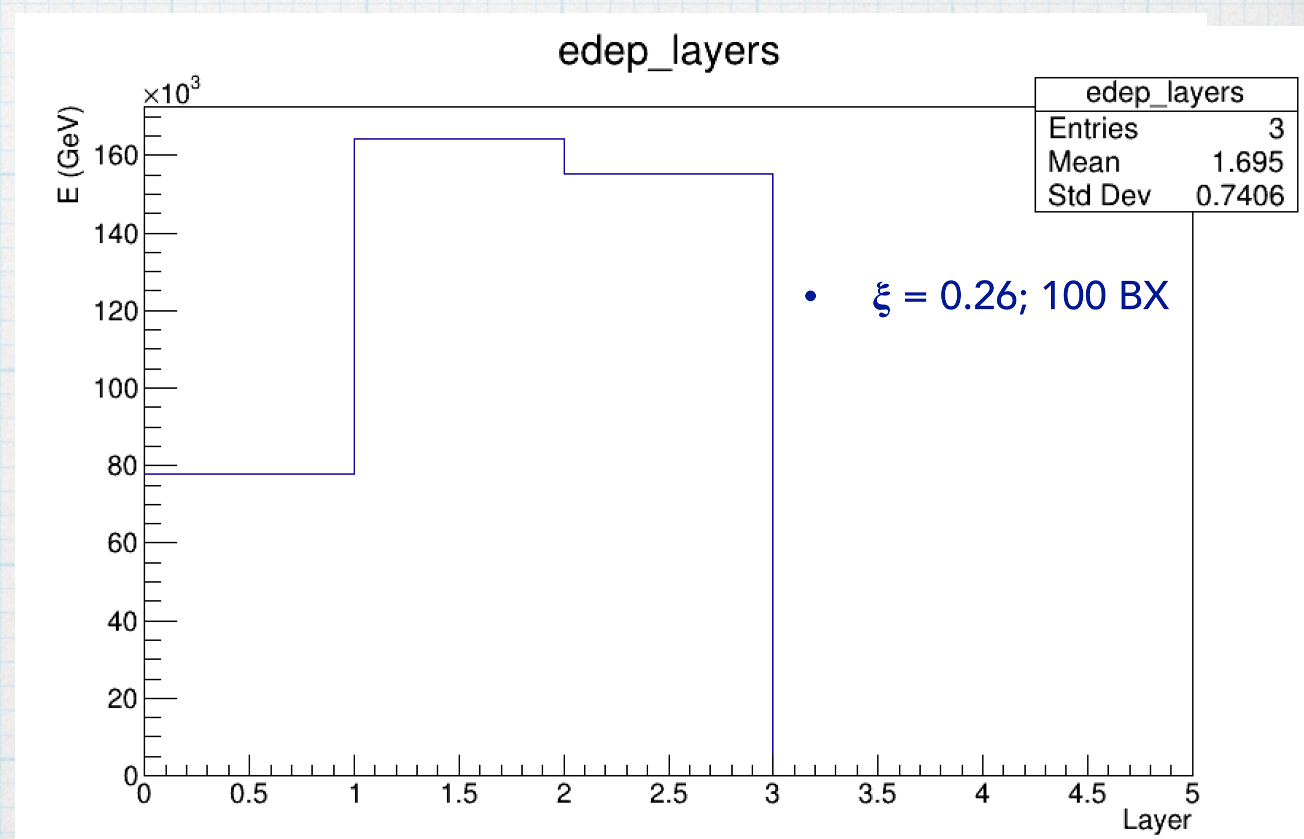


Energy deposit, 48, ξ =2.6 vs ξ=0.26









The exact energy absorption mechanism by the scintillator depends on the type and energy of radiation involved, but for X- or γ-photons the absorption is described by the relation

$$I/I_0=e^{-\mu d},$$

where I0 and I are the intensities of the incident and transmitted radiation,
μ the linear absorption coefficient and d the thickness of the scintillator.
γ-ray (100 keV <hvhv< 10 MeV) spectrum, although detection of charged particles and even neutrons is possible as well.

As the inorganic scintillating materials are crystalline, they suffer from defects in the crystal lattice. Such defects can be induced by radiation, thus the inorganic scintillating materials suffer heavily from *radiation damage*. It results in a reduction of the attenuation length (due to new scattering centres) as well as the reduction of the light yield (due to damage to the activation centres).

*

Intensity/Profile On-line Monitor

For on-line control of the relative intensity and profile of the photon beam, we will need a detector which can provide continuous real time information during the data acquisition period, as well as information in the data stream for off-line analysis.

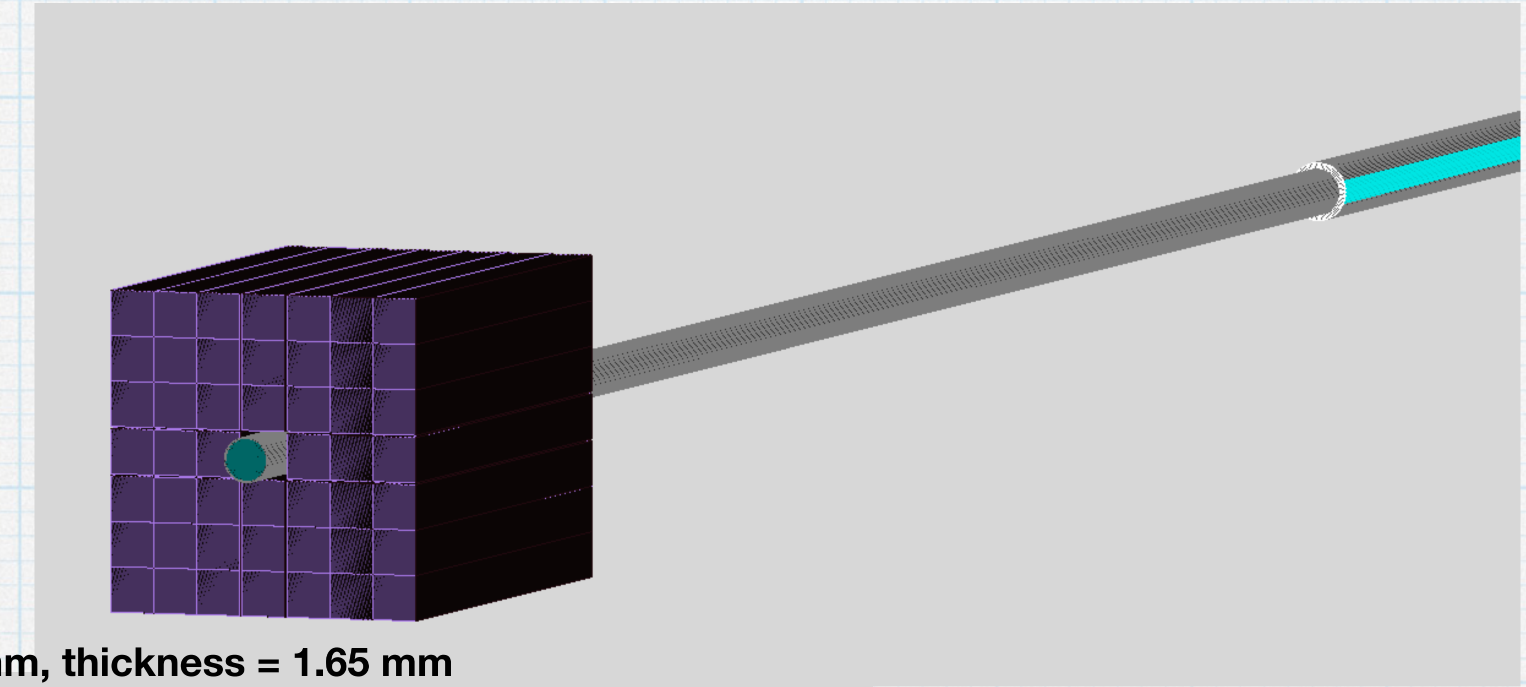
The following requirements must be imposed on a such detector system. • Low-sensitivity to background.
• Linearity within the intensity range $N_\gamma = (10^4 - 10^7)$/s.
• Fast ($\tau \approx 10$ ns).

• Spatial resolution: ~100 μm.

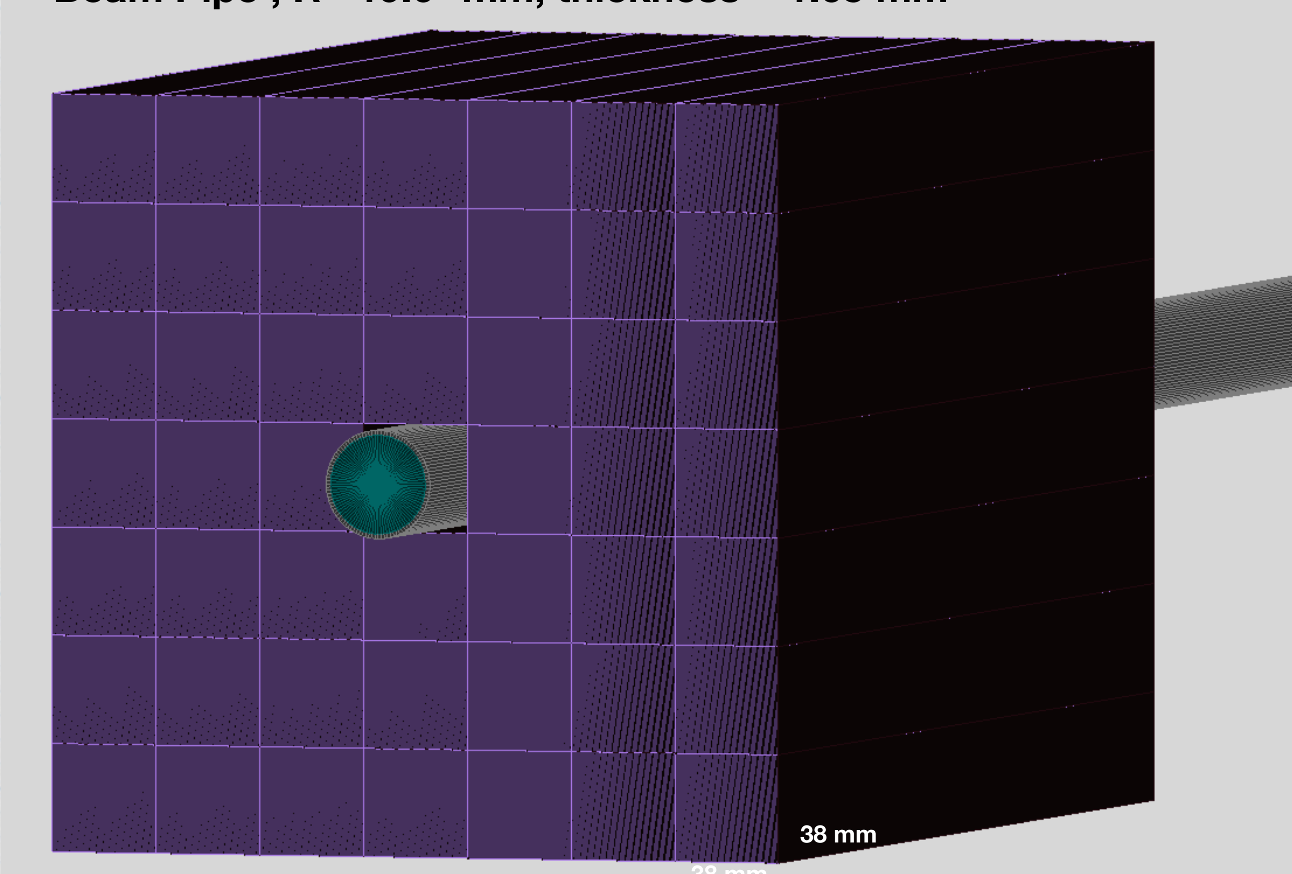
The collaboration plans to construct a fission fragment detector based low pressure wire proportional chambers[73]. This monitor will be located downstream

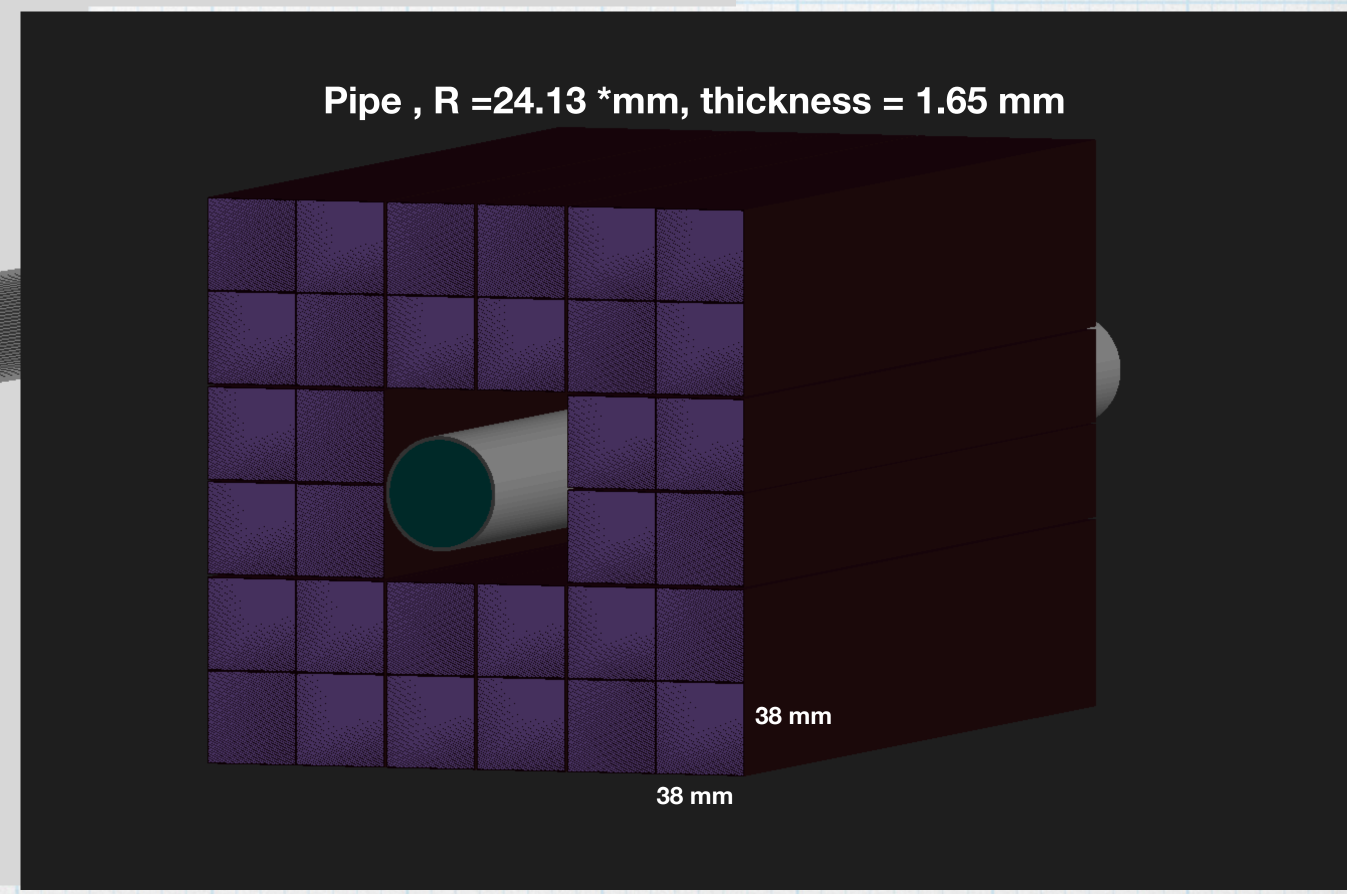
*

2 configurations: 48 vs 32 LG blocks



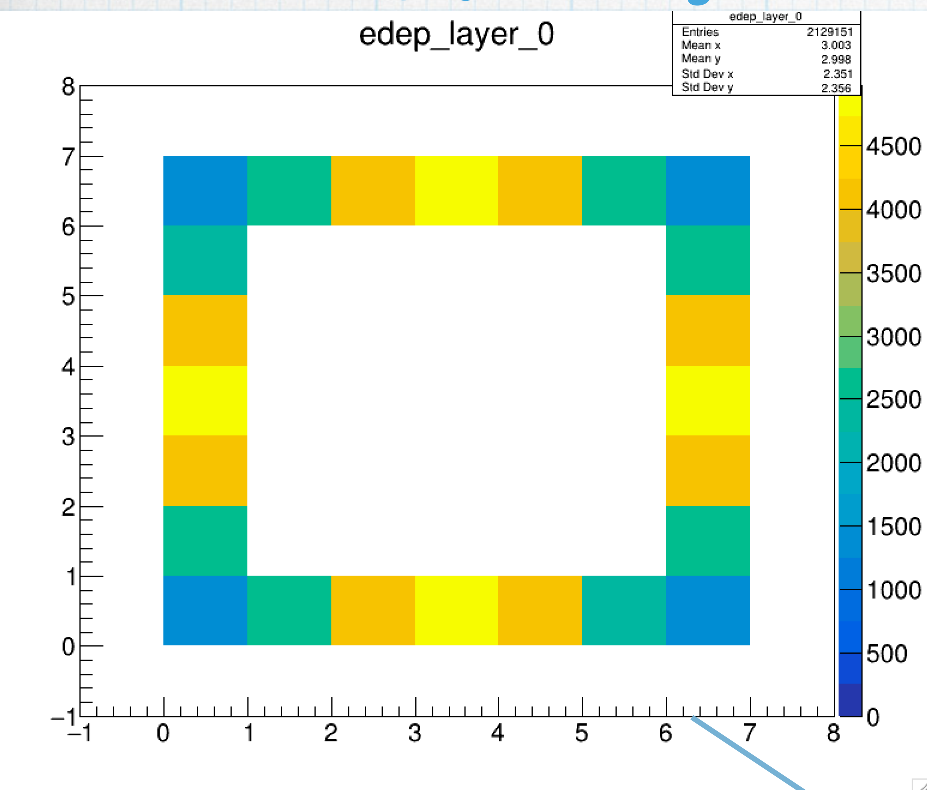
Beam Pipe , R =19.0 *mm, thickness = 1.65 mm

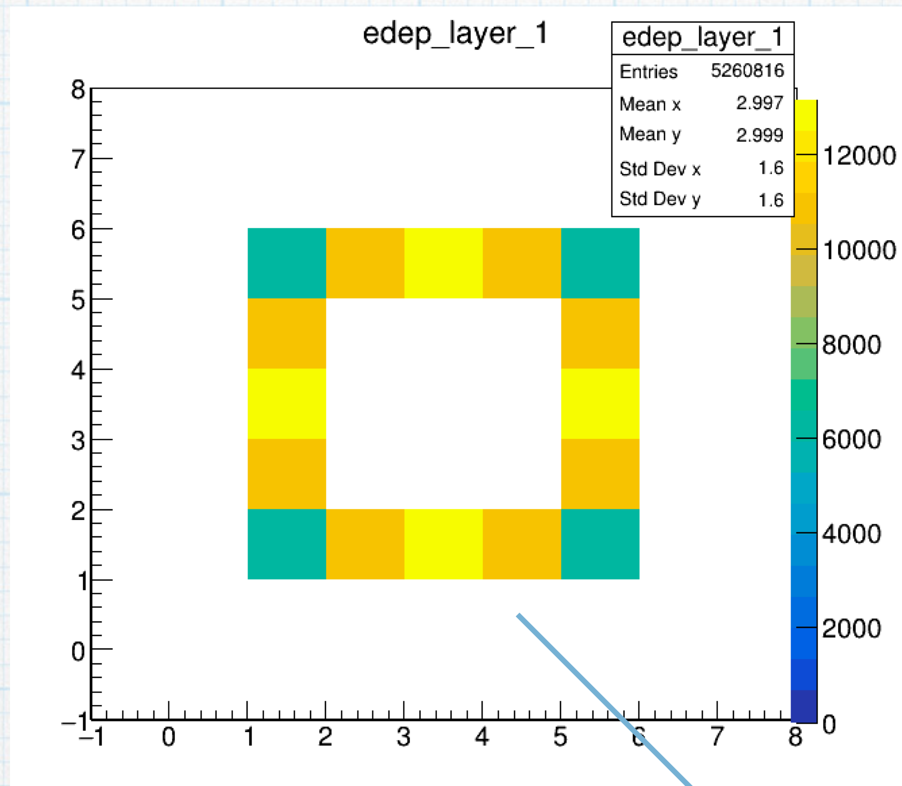


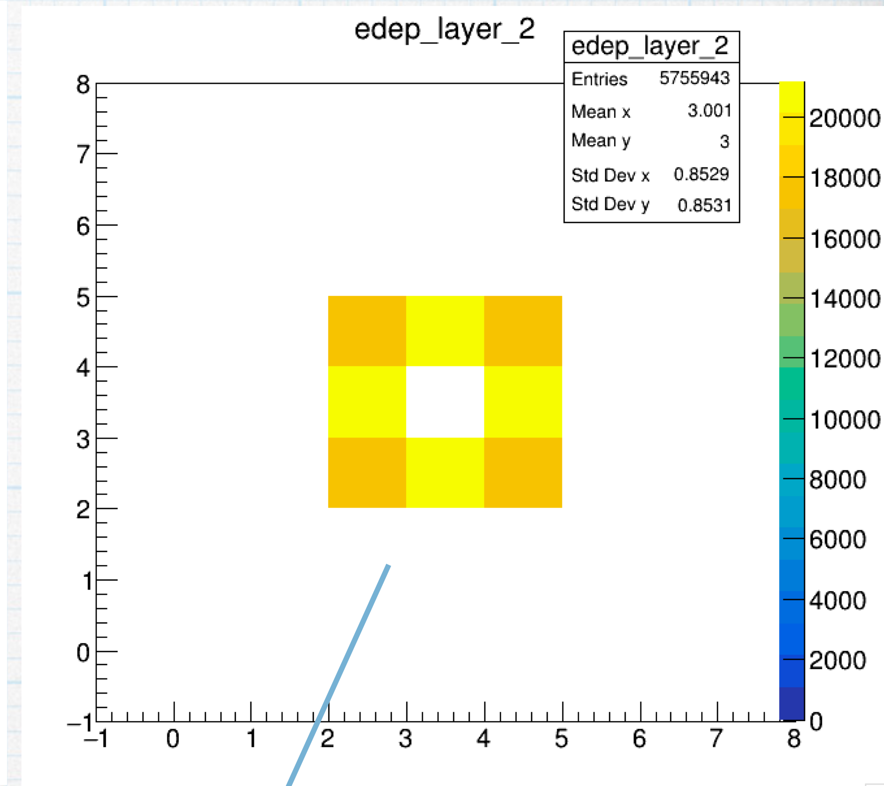


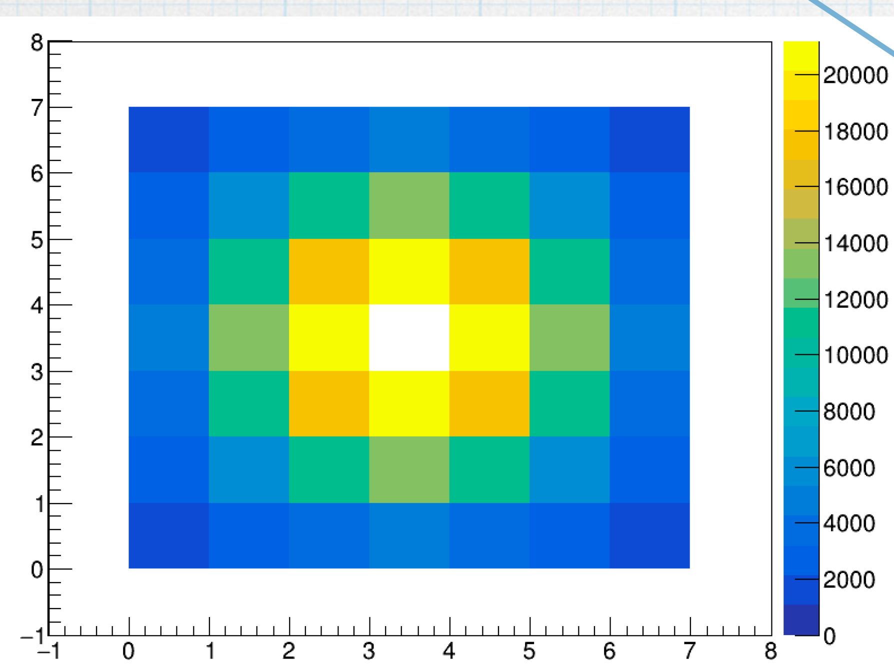
Reduced the size of the beam pipe to be consistent with the blocks size and to be able to monitor the area close to the beam pipe.

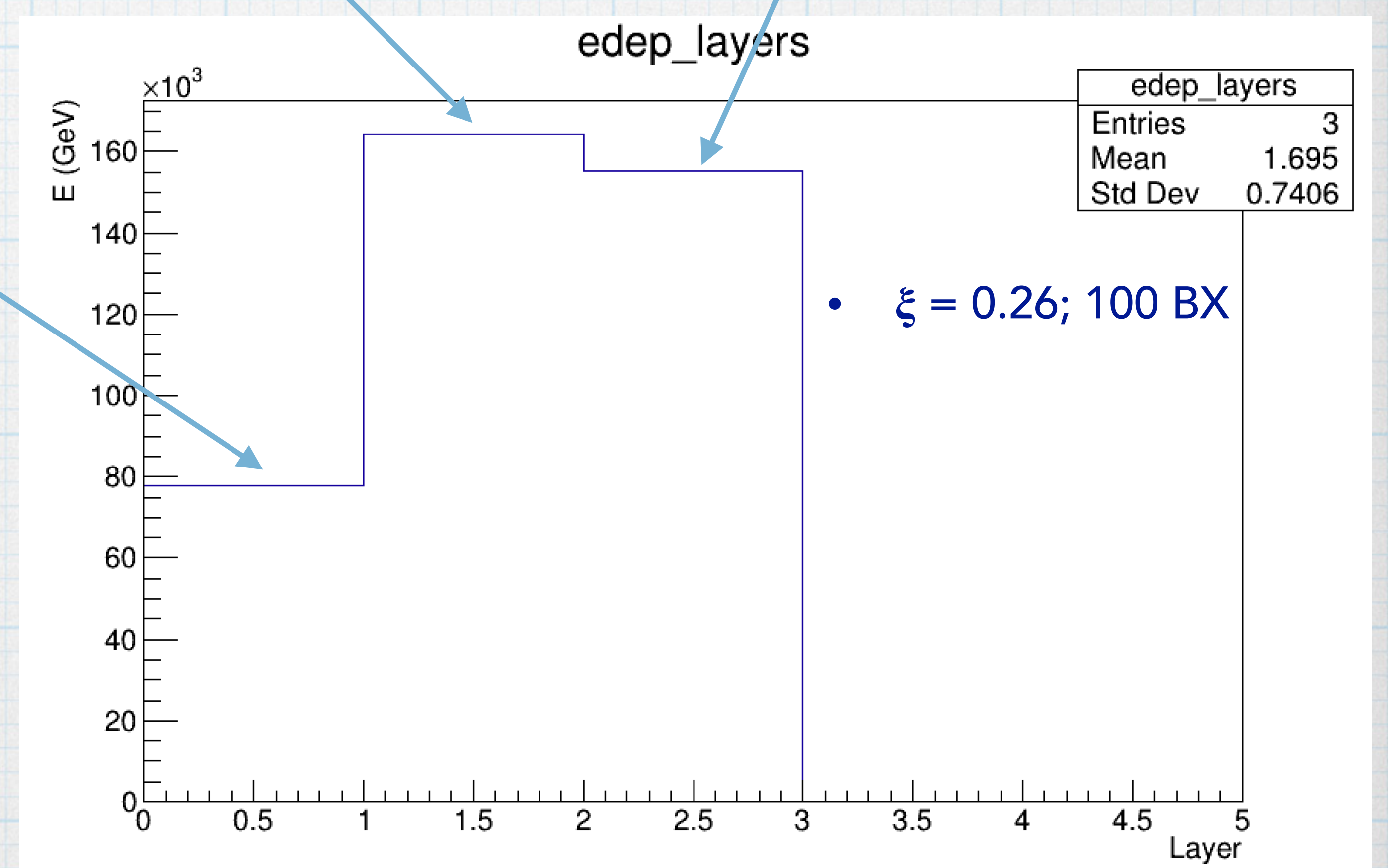
Energy deposition in layers, 48 LG blocks





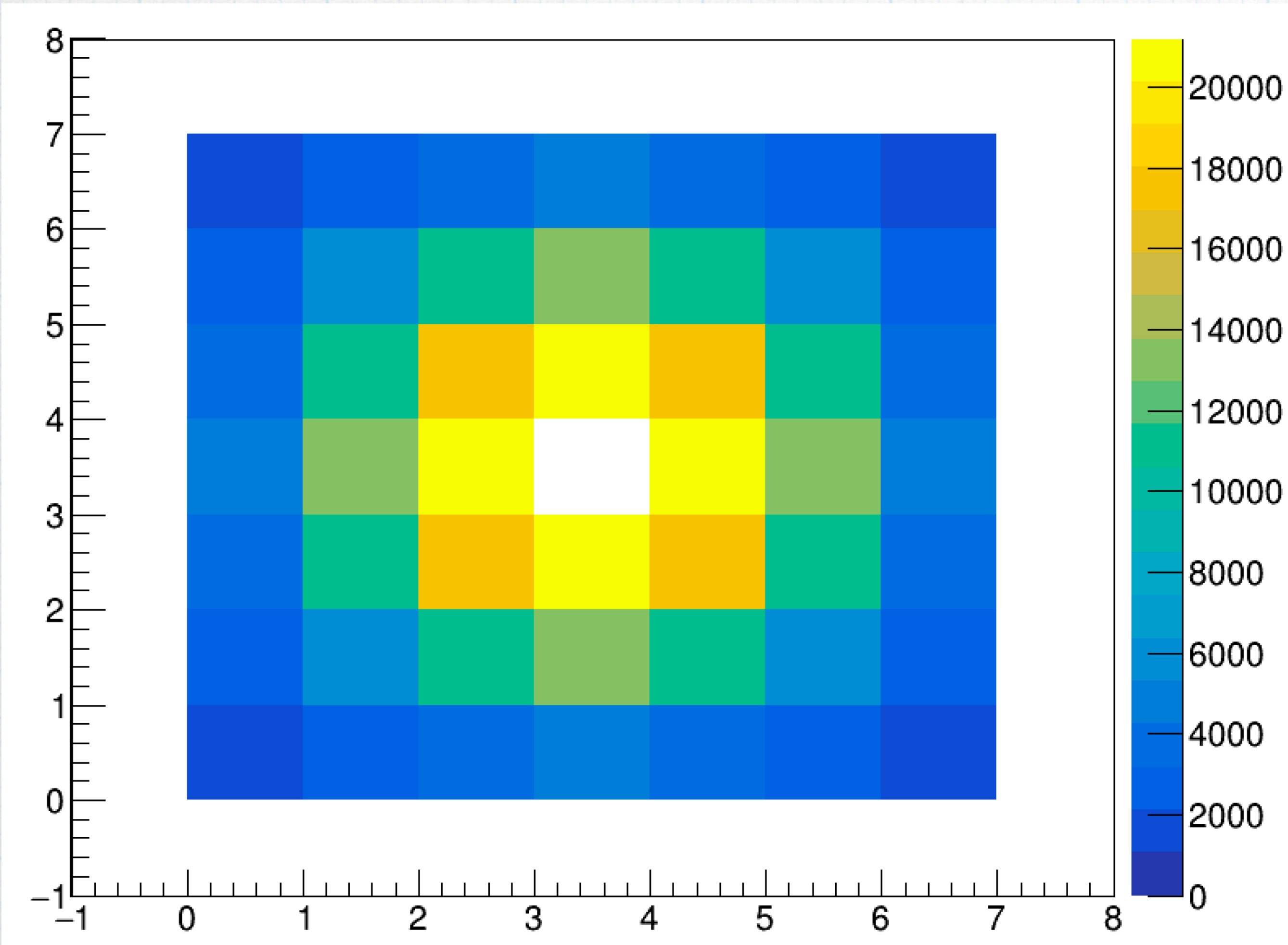


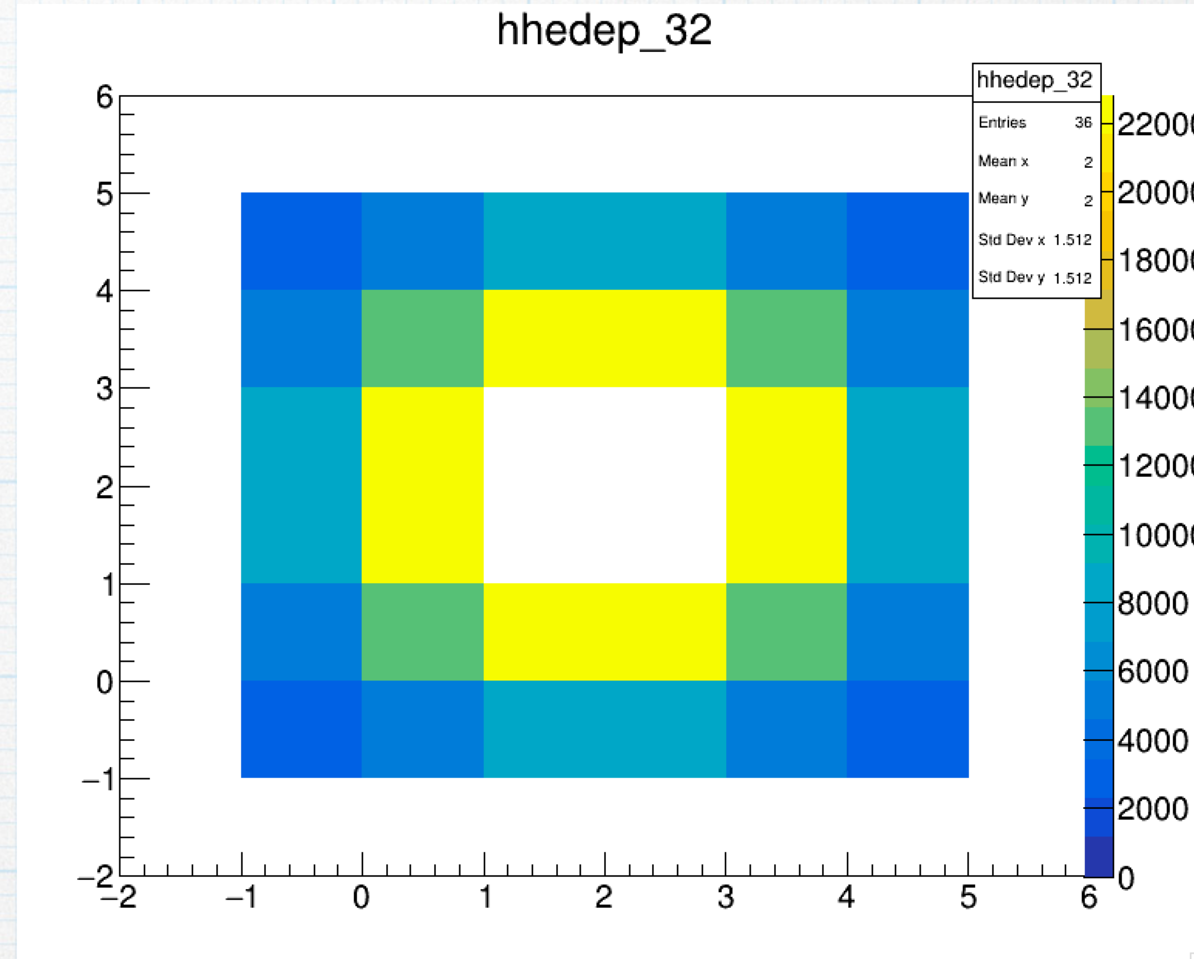


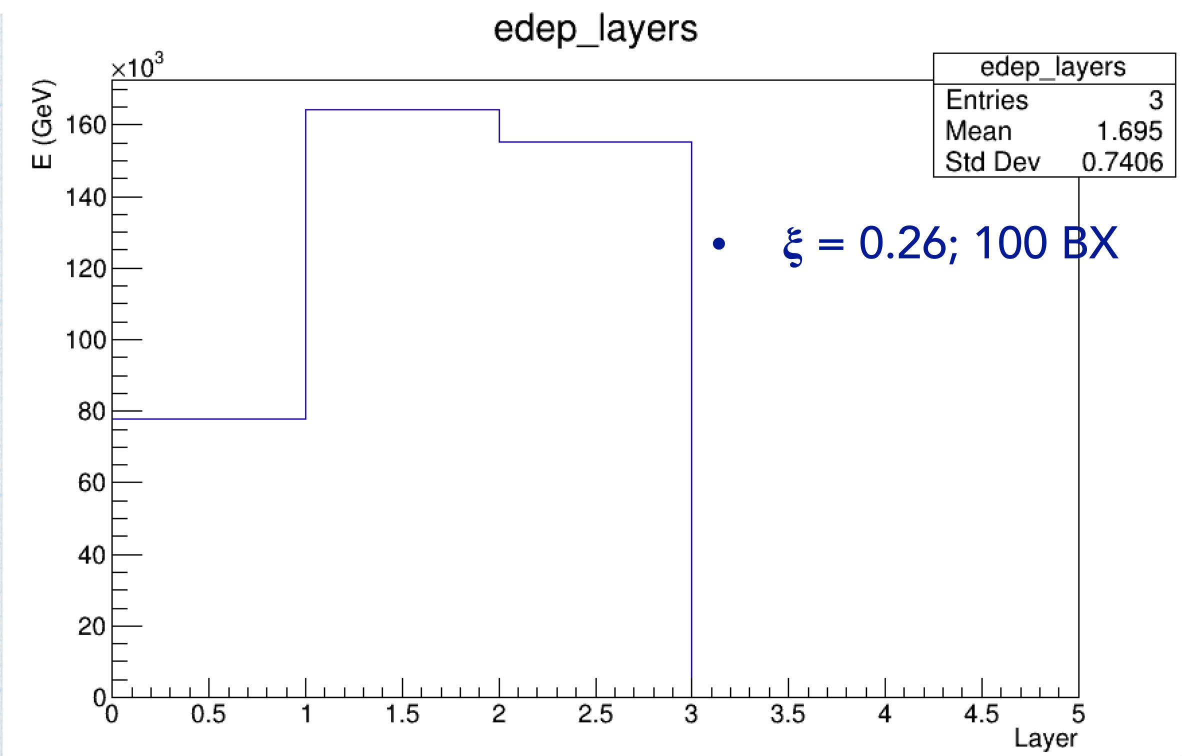


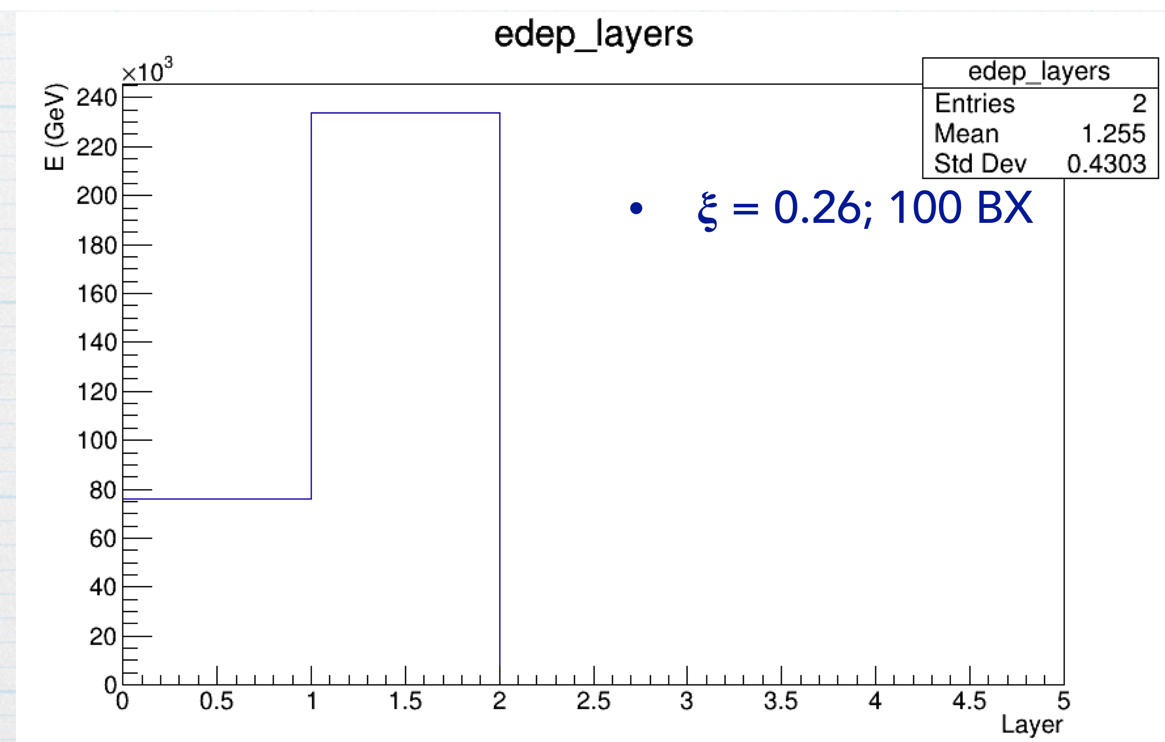
for ξ=0.26 Edep in the dump ~10⁷ ⇒ Edep in the GM ~ 10³

Energy deposition, 48 vs 32 LG blocks



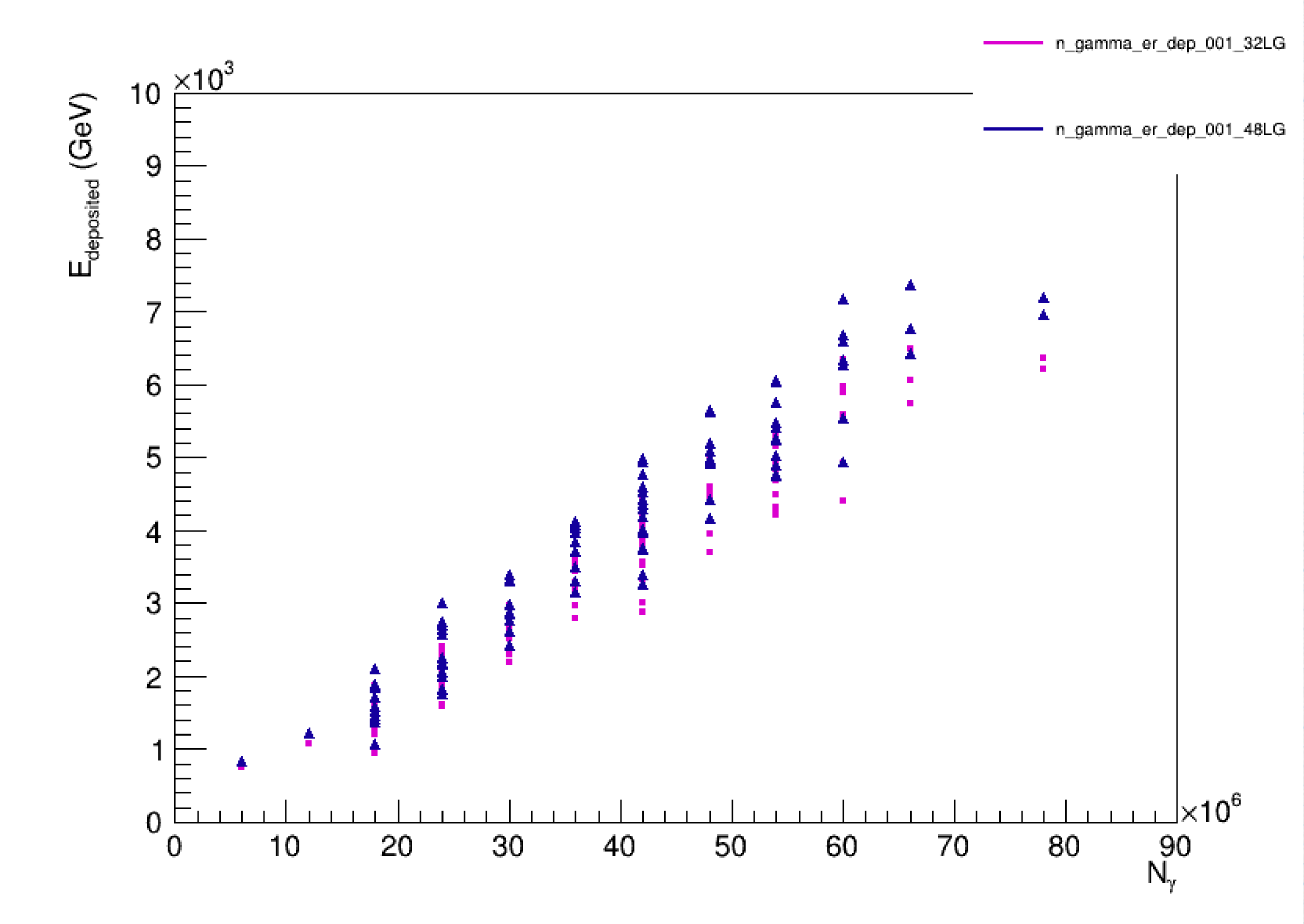




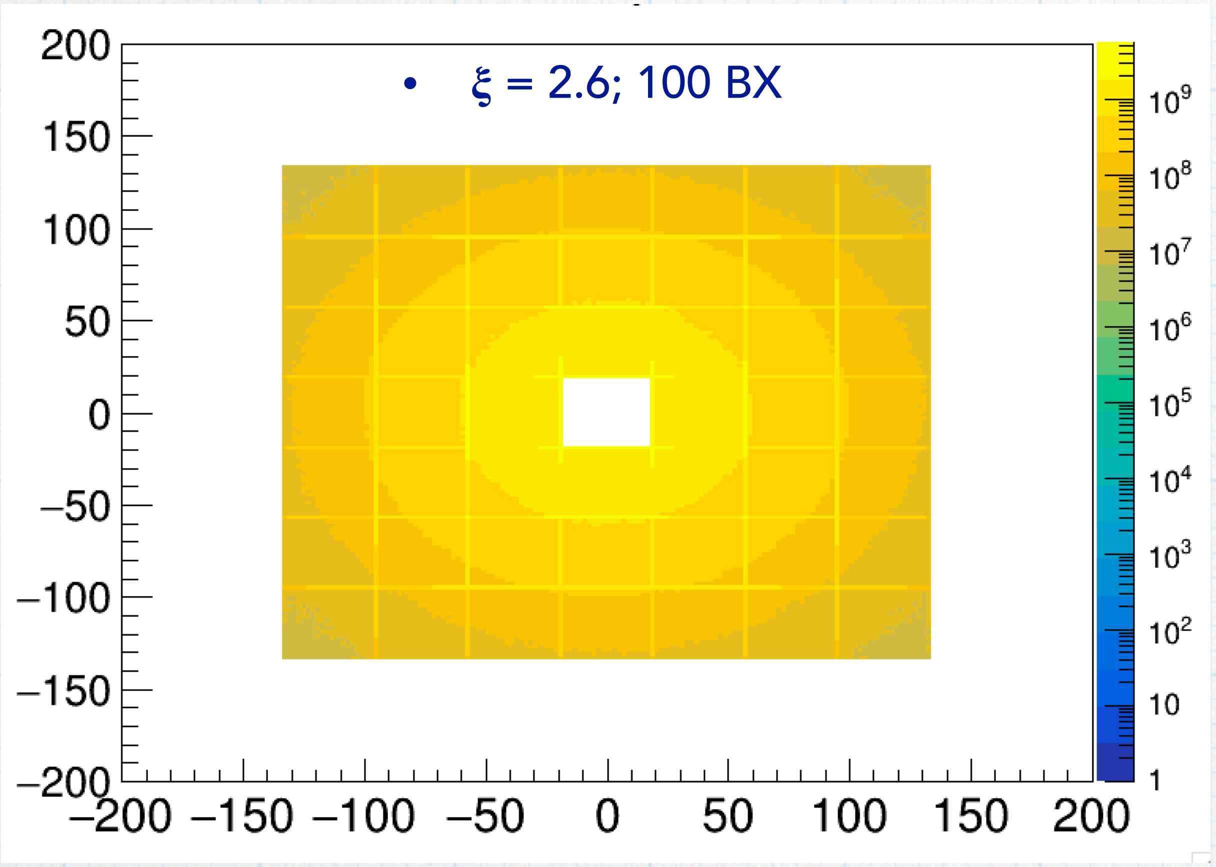


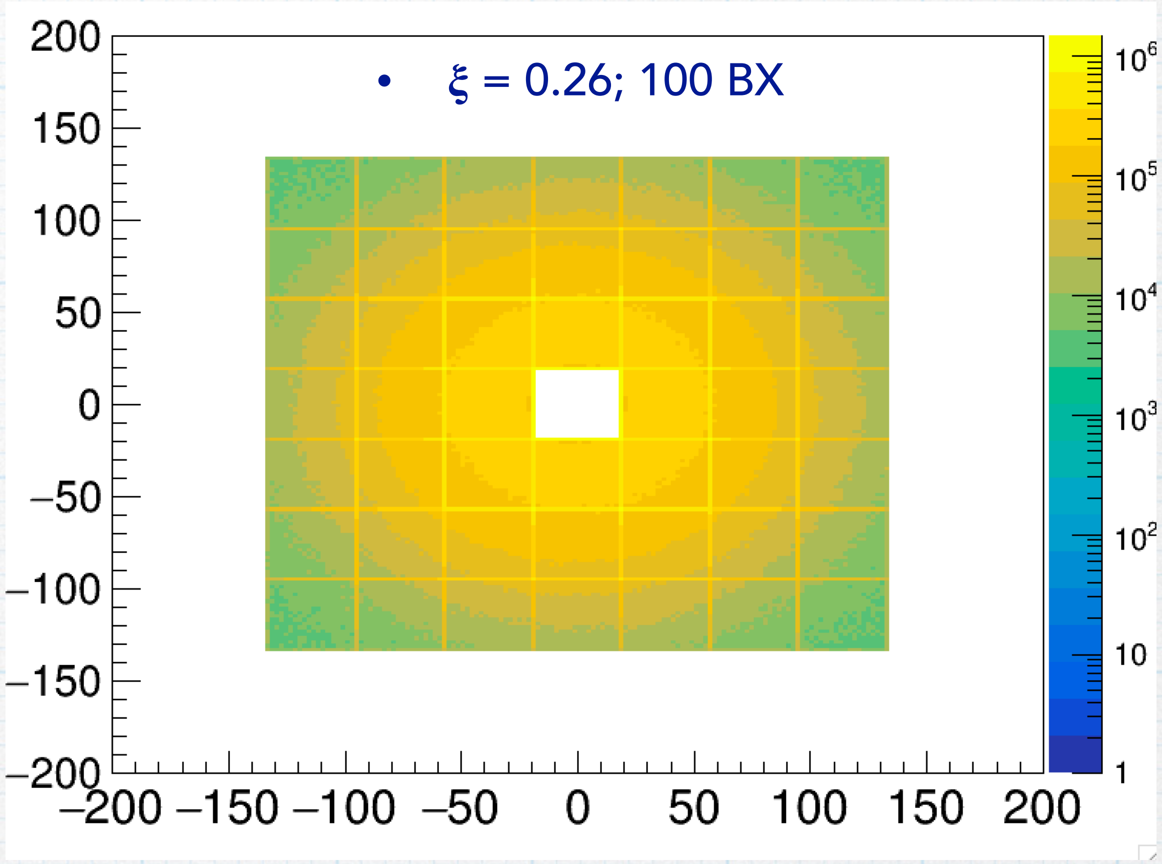
Deposited energy versus true number of photons.

Each point is one BX



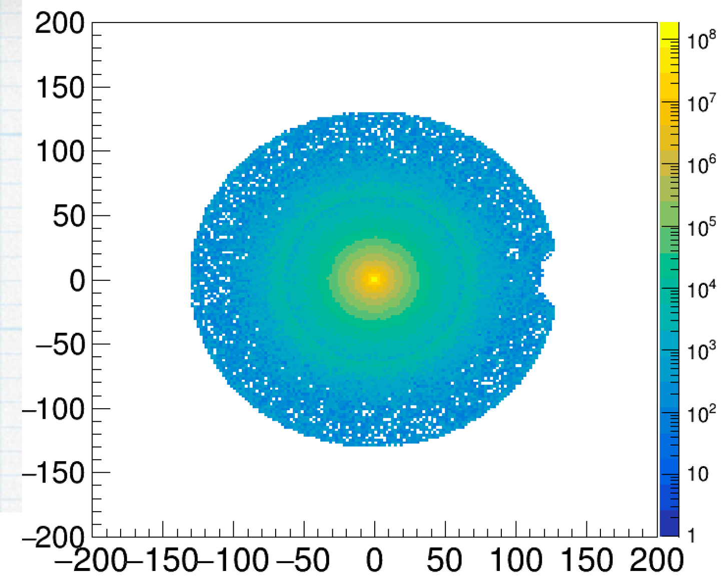
Track density, 48, ξ =2.6 vs ξ=0.26





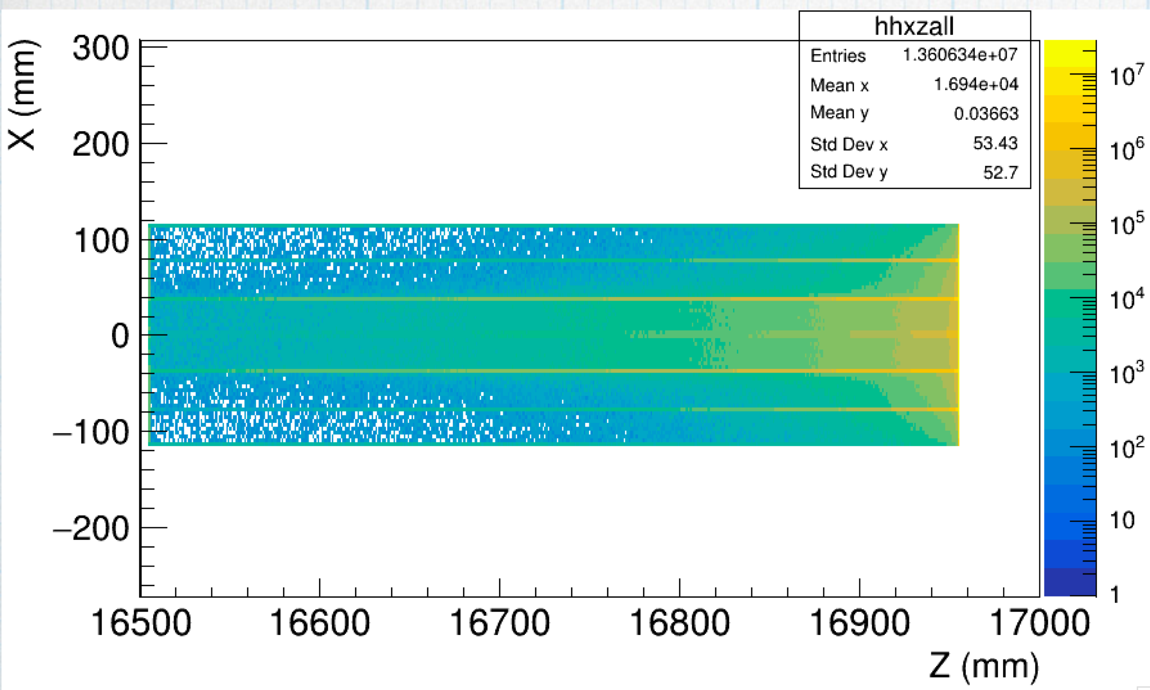
Track density on the surface of LG blocks in XY plane

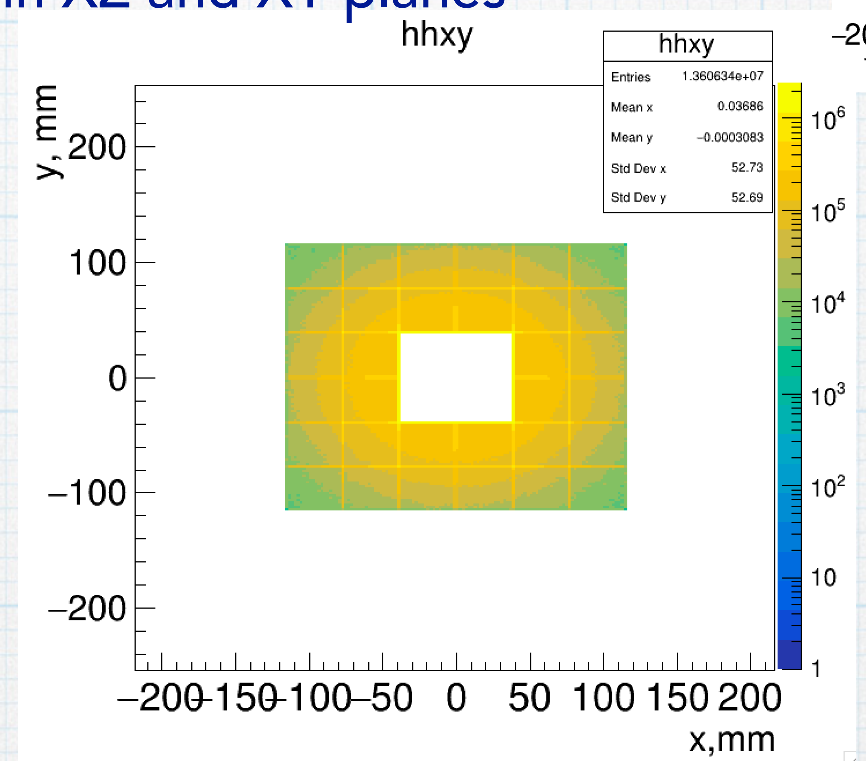
Simulation and Performance 32 LG vs 48 LG



- ξ = 0.26; 100 BX

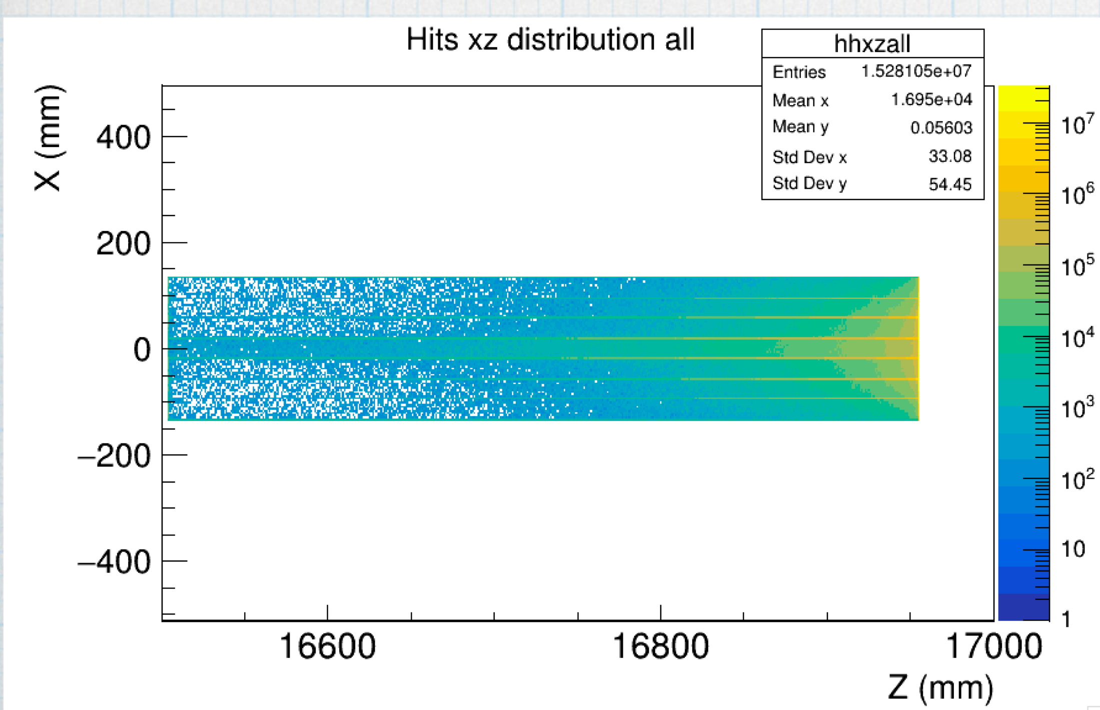
Track density on the surface of LG blocks in XZ and XY planes

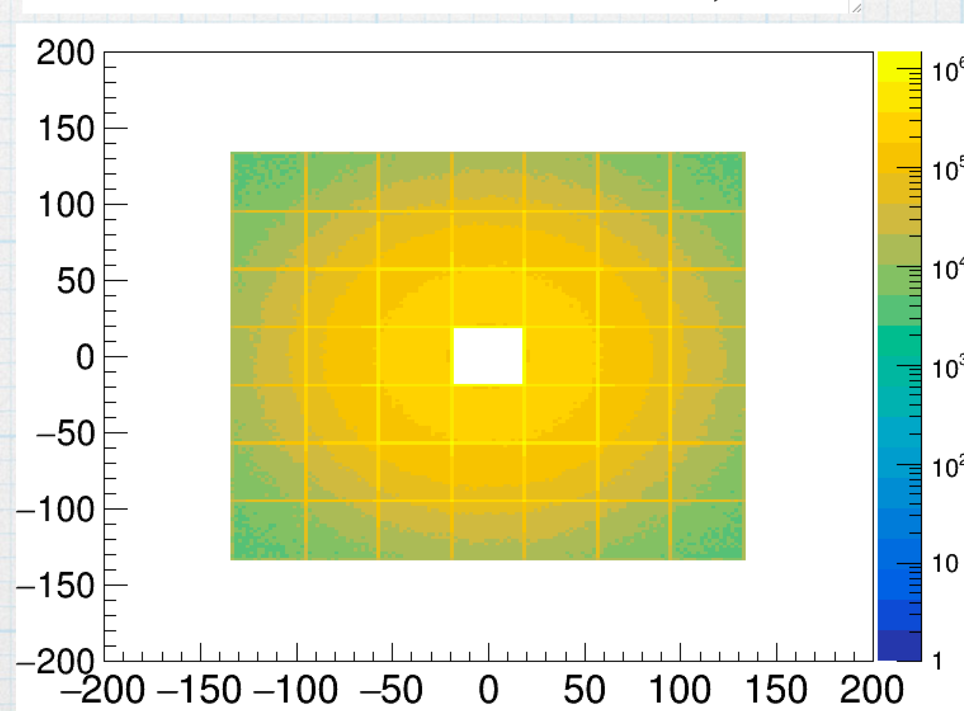


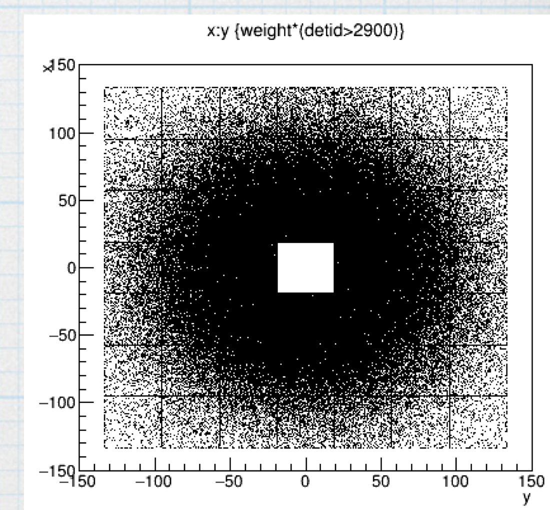


Required all the vertices to be from Beam Dump

- ξ = 0.26; 1 BX

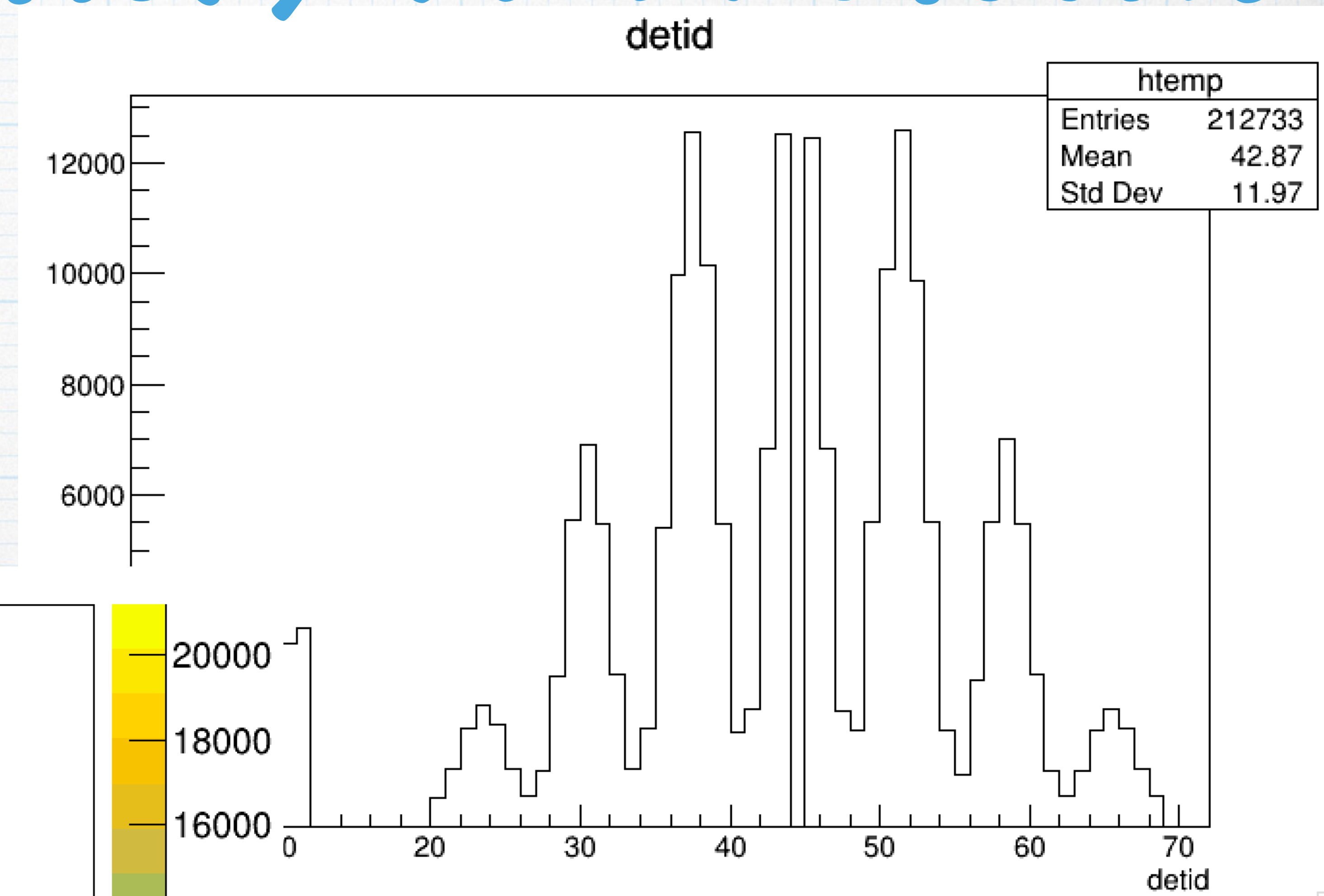


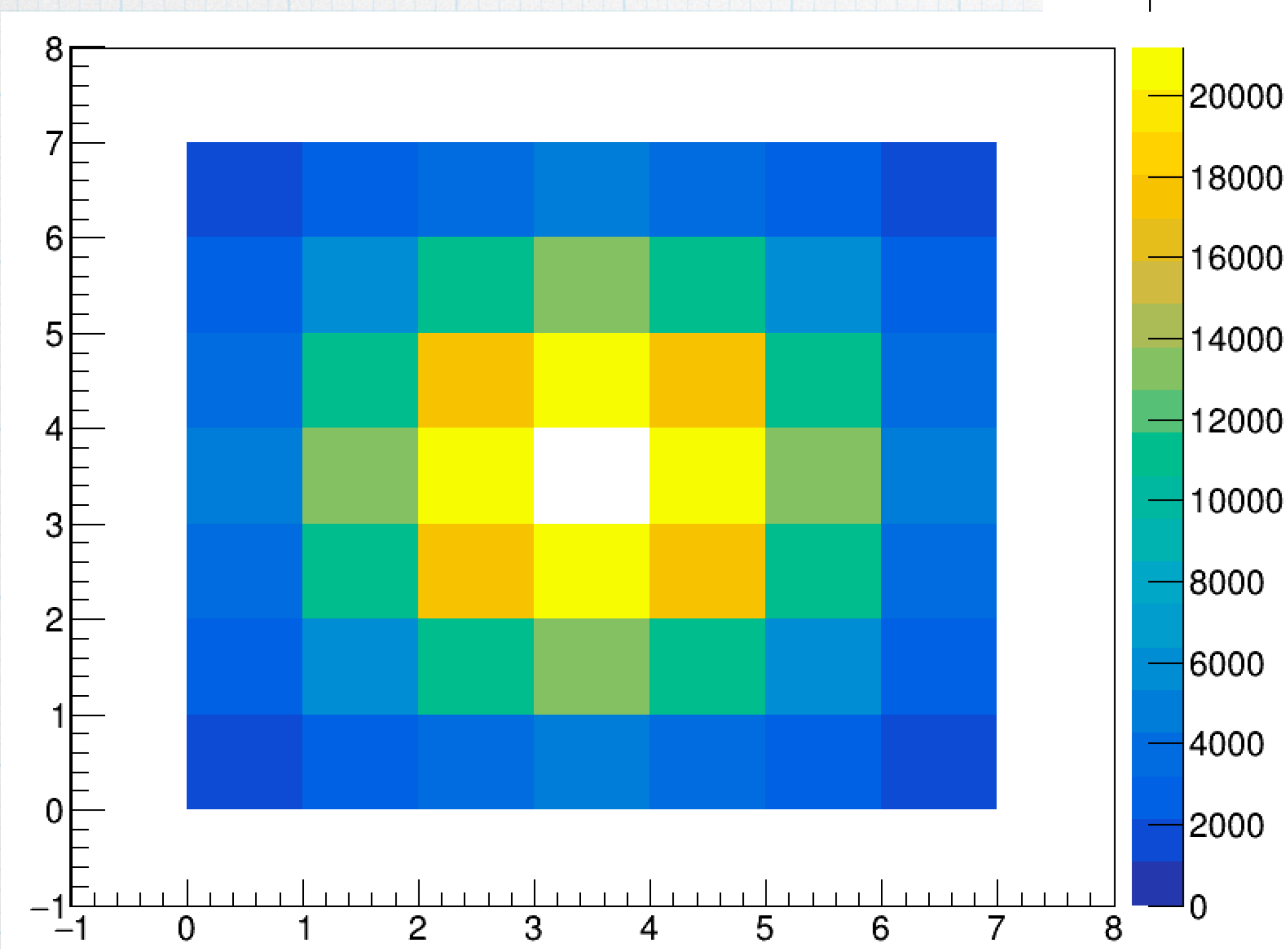




Energy deposition, 48 LG blocks

- ξ = 0.26; 100 BX





Row = detid / 7

Column = detid % 7

Lead glass blocks found in Hera West

- 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

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
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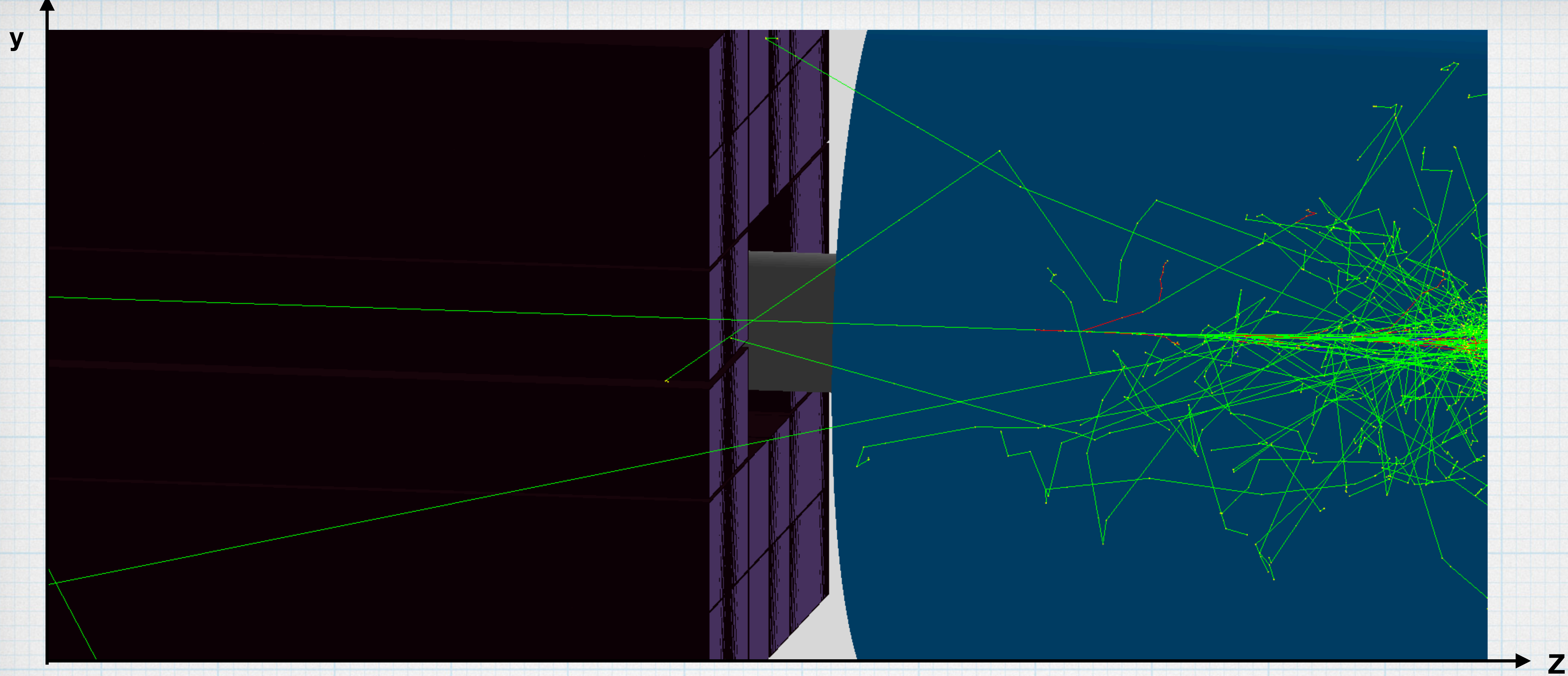
Radiation length (cm)	2.50	AS-0.001812
Density (g/cm^3)	3.86	
Critical energy (MeV)	15.57	
Refraction index	1.6476	

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 $\sigma_E/E = 0.011 + 0.053 / \sqrt{E(GeV)}$.



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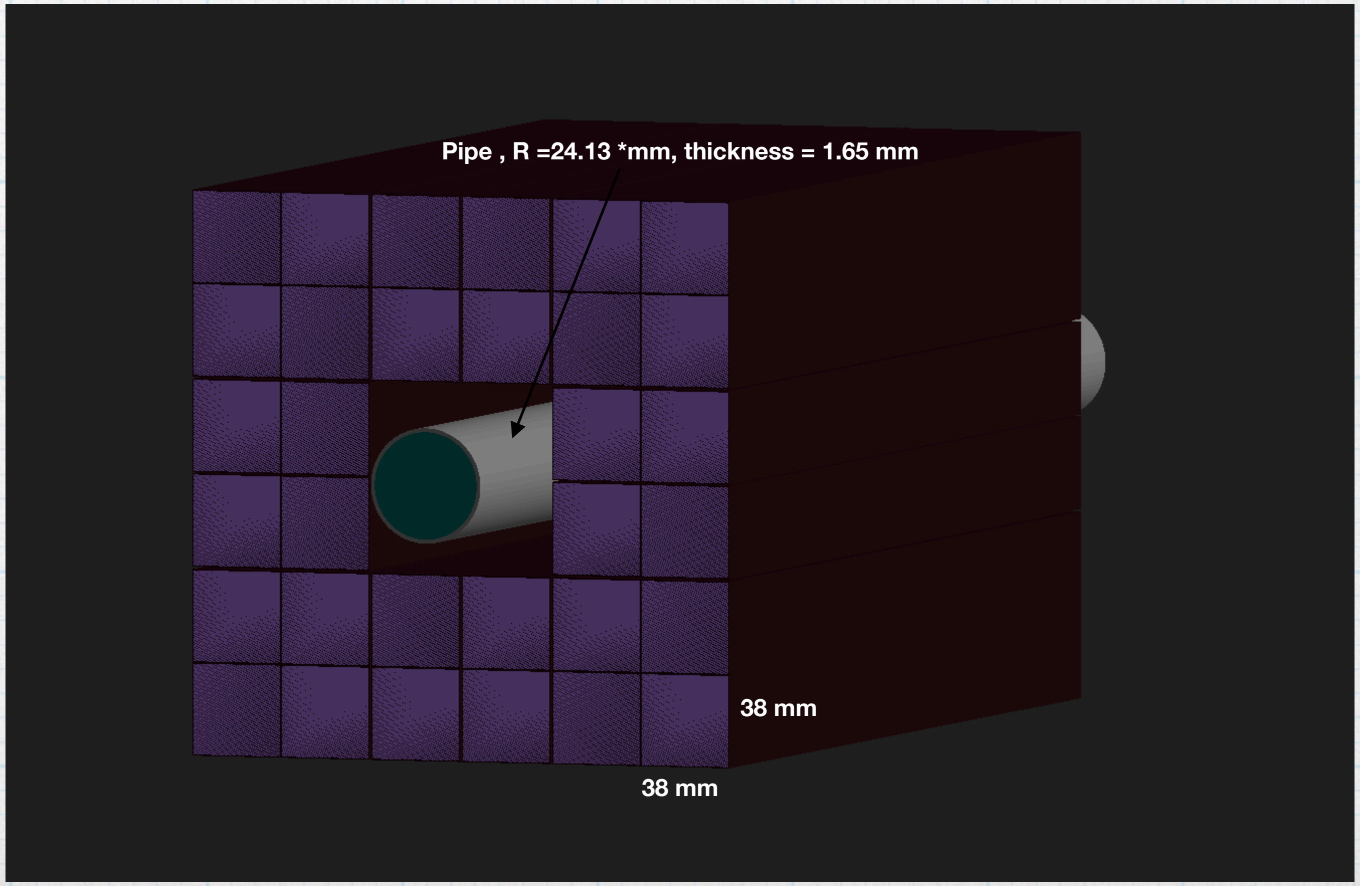
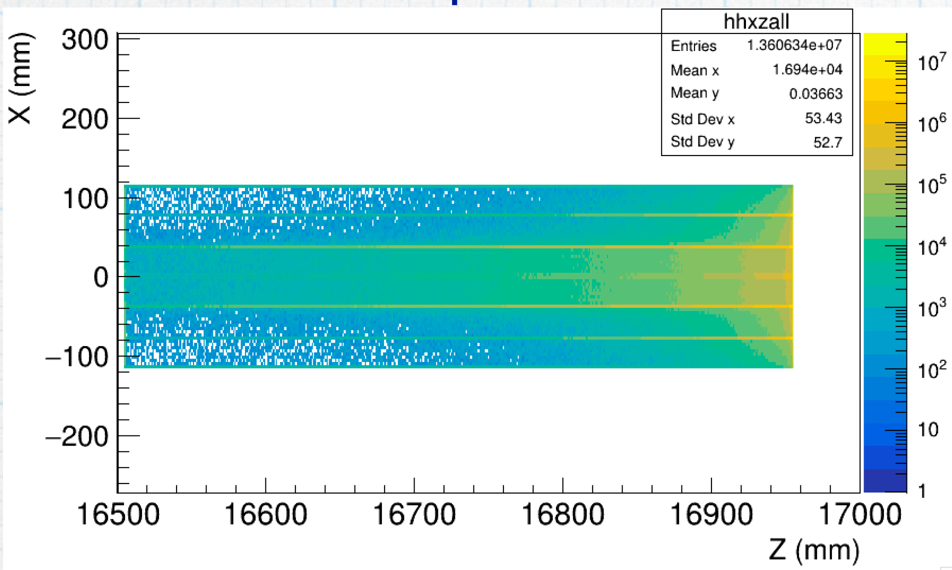
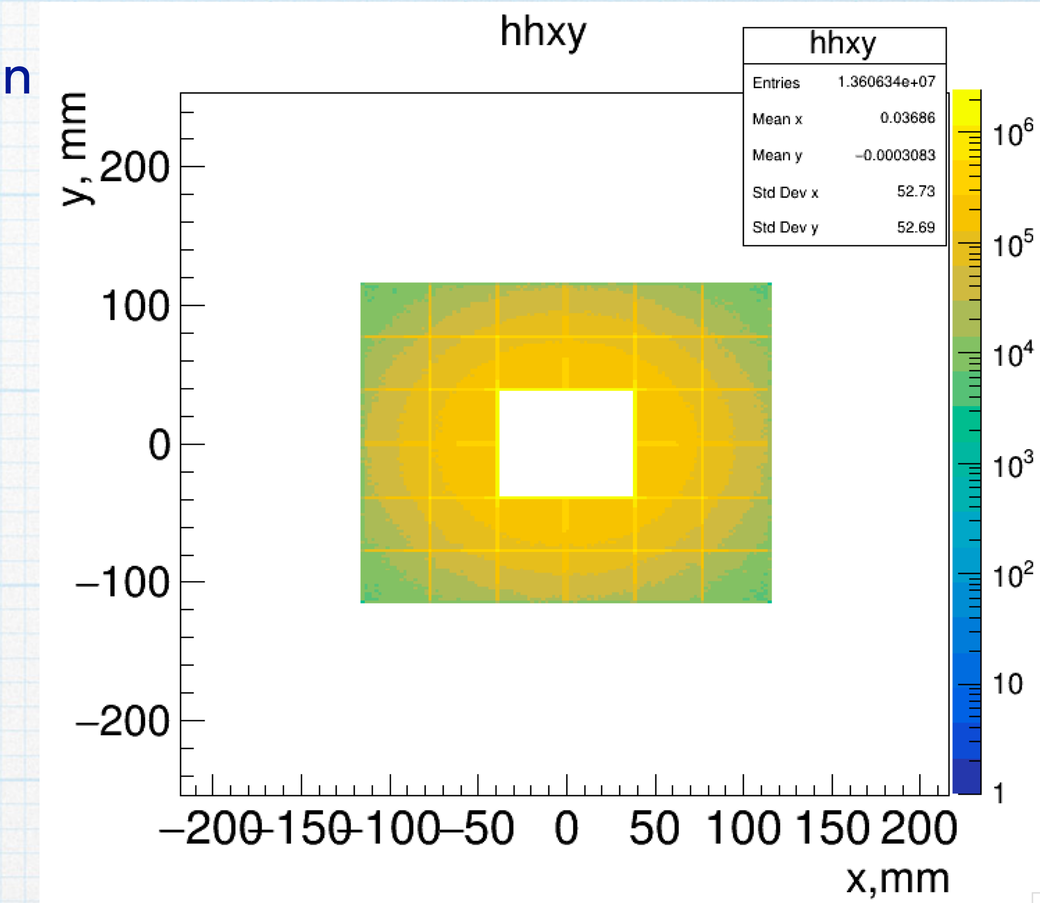


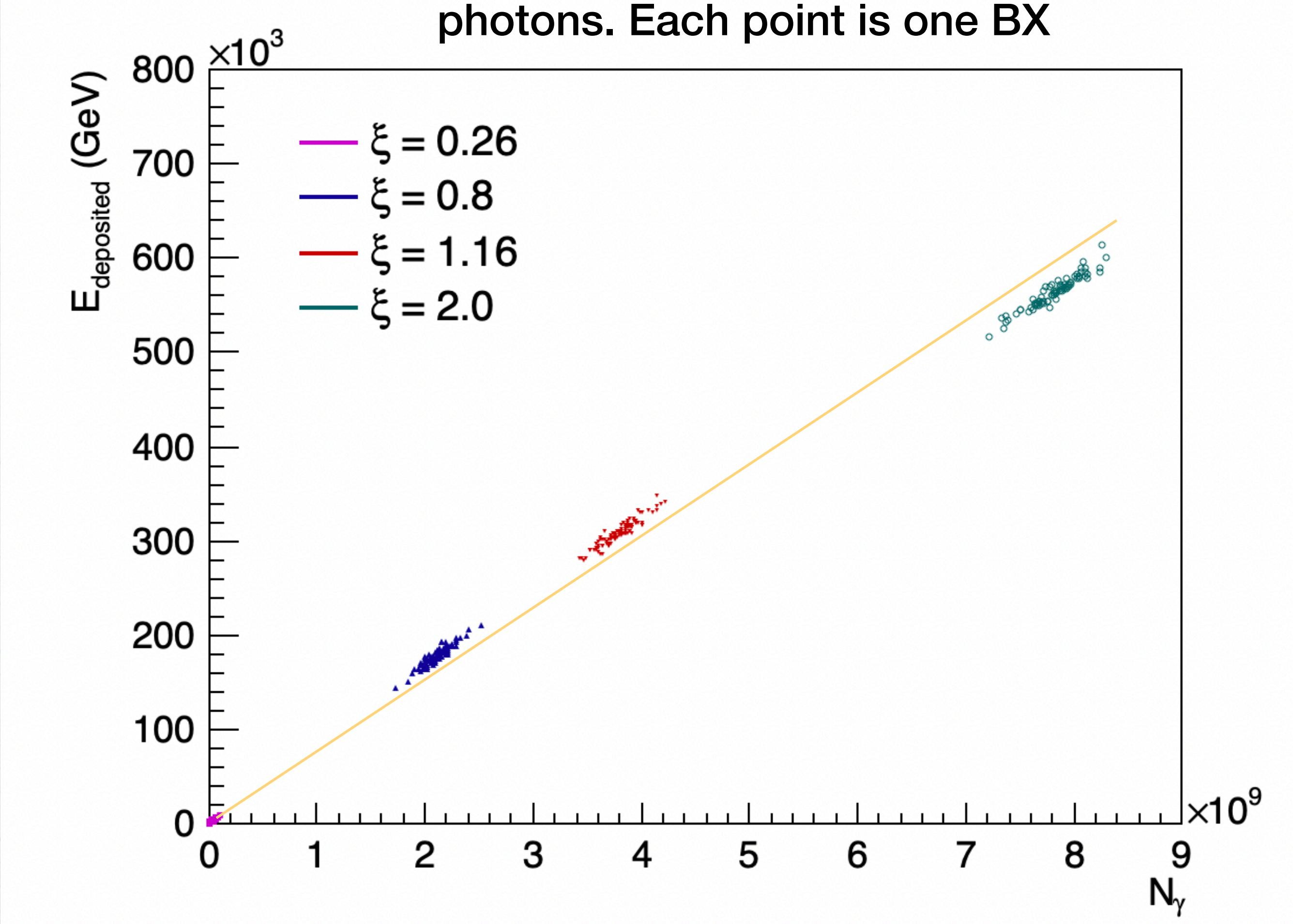
Simulation and Performance

Track density on the surface of LG blocks in XY and XZ planes



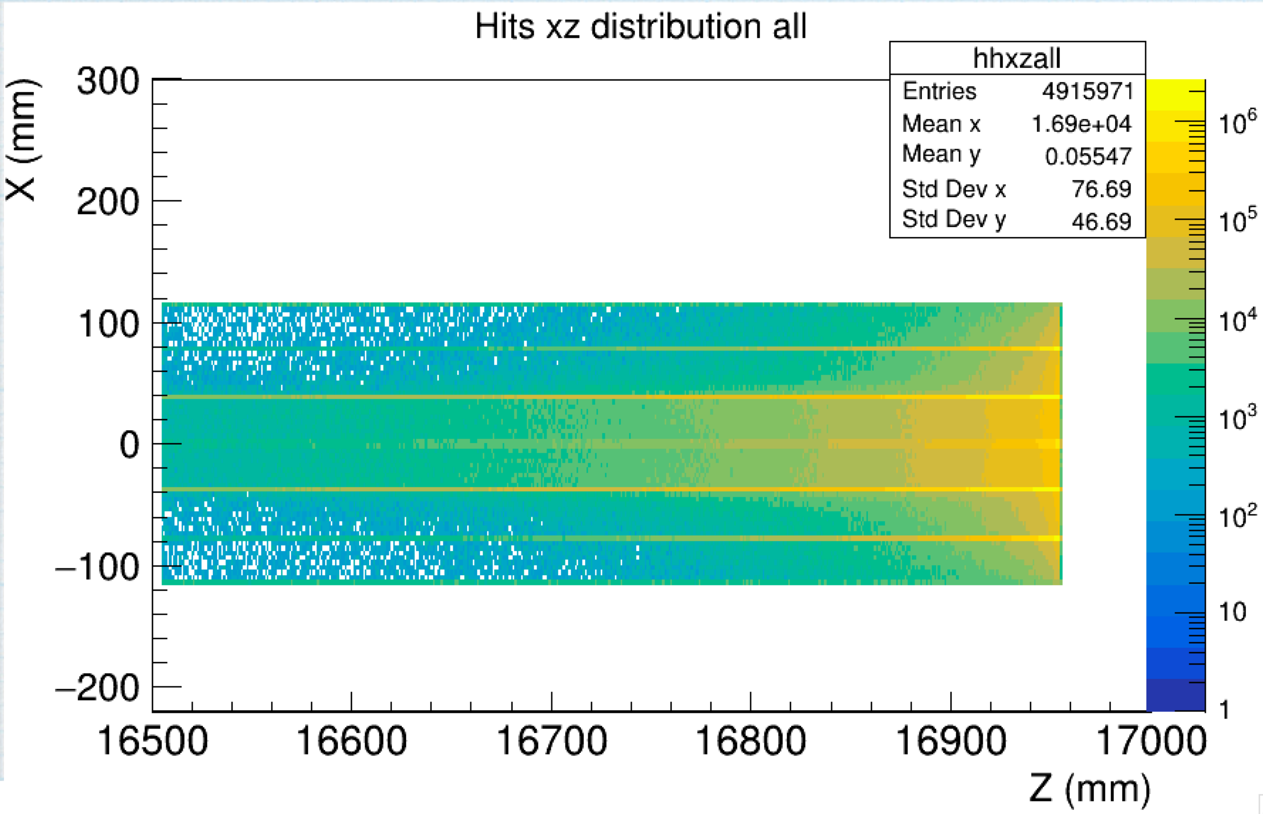


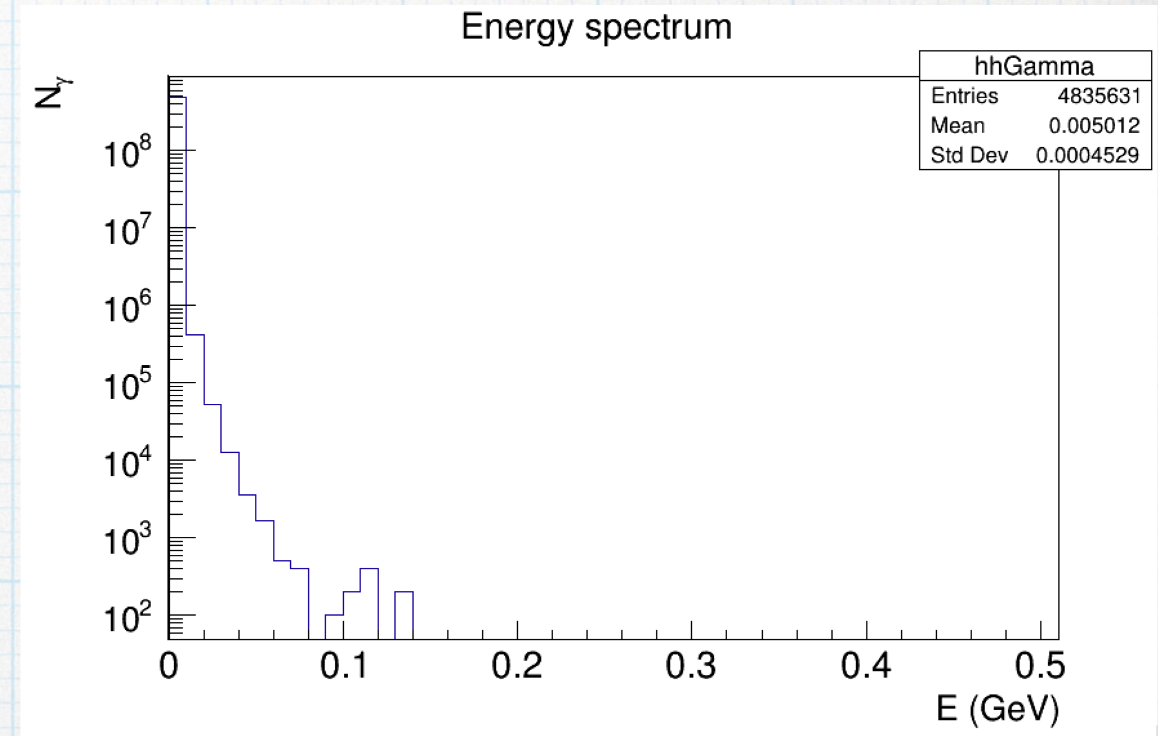
Deposited energy versus true number of photons. Each point is one BX

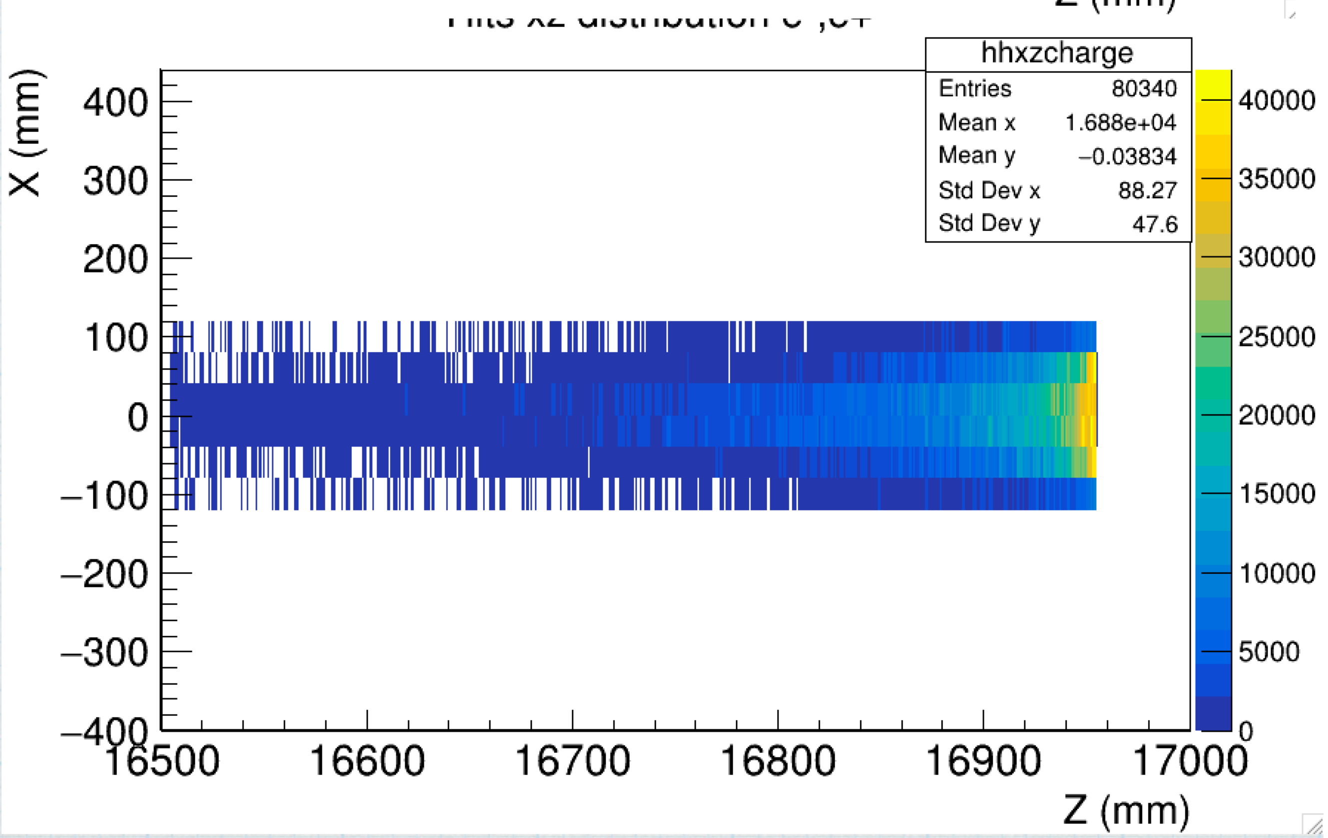


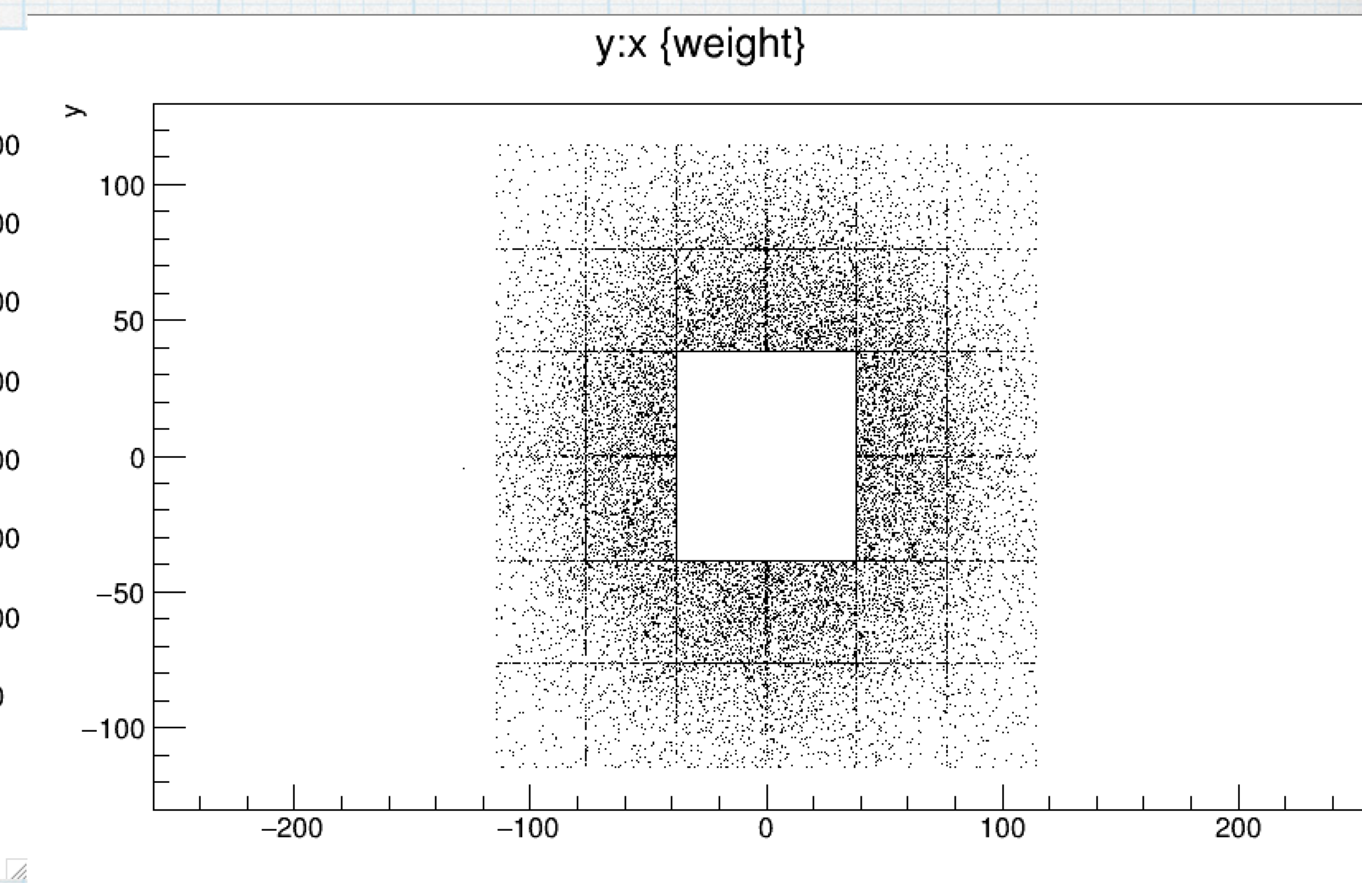
- The (almost) linear dependence of deposited energy on number of incoming photons in GM allows the usage of backscatters for monitoring the photon flux
- For small ξ the HICS spectrum is softer and soft photons produce less back-scatters. This is the reason of small deviation from linearity in Edep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

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









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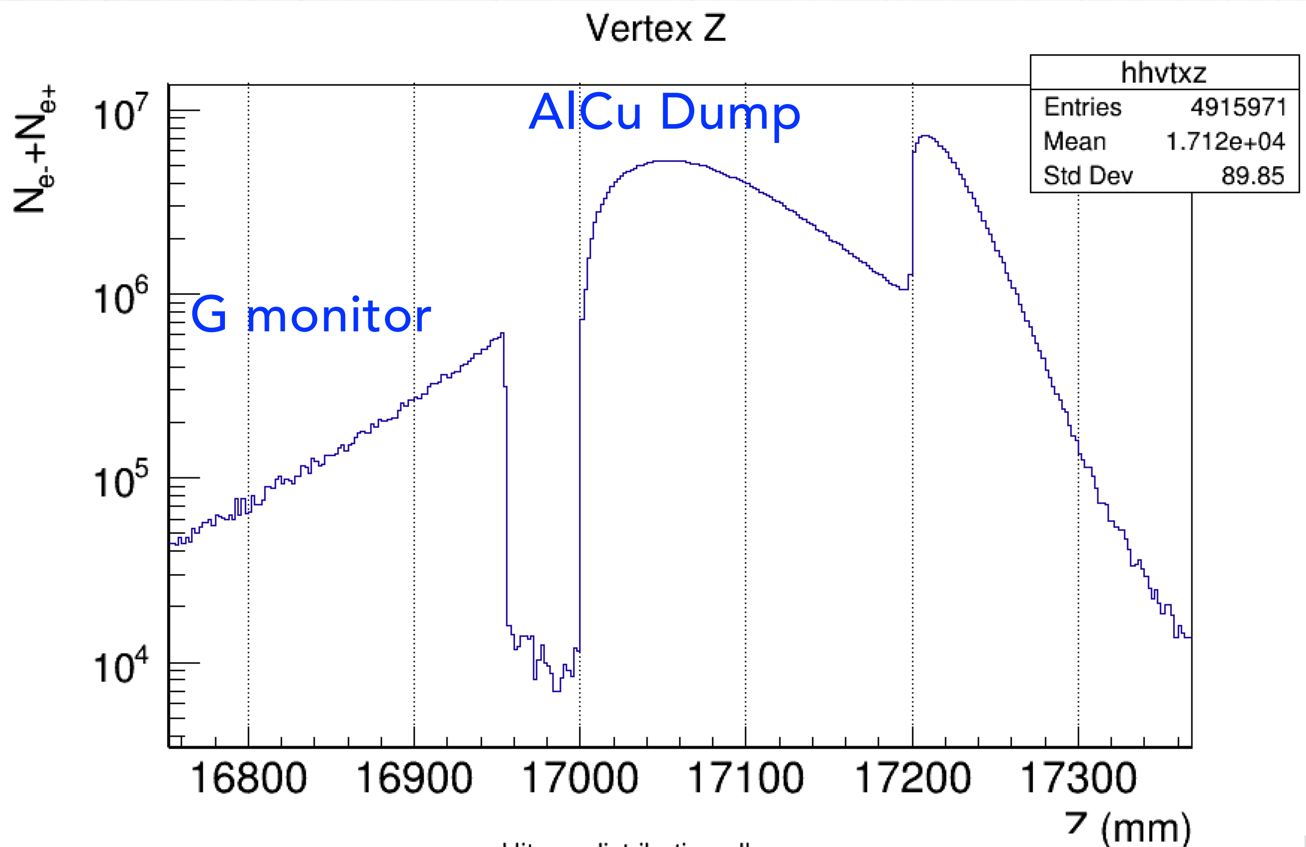
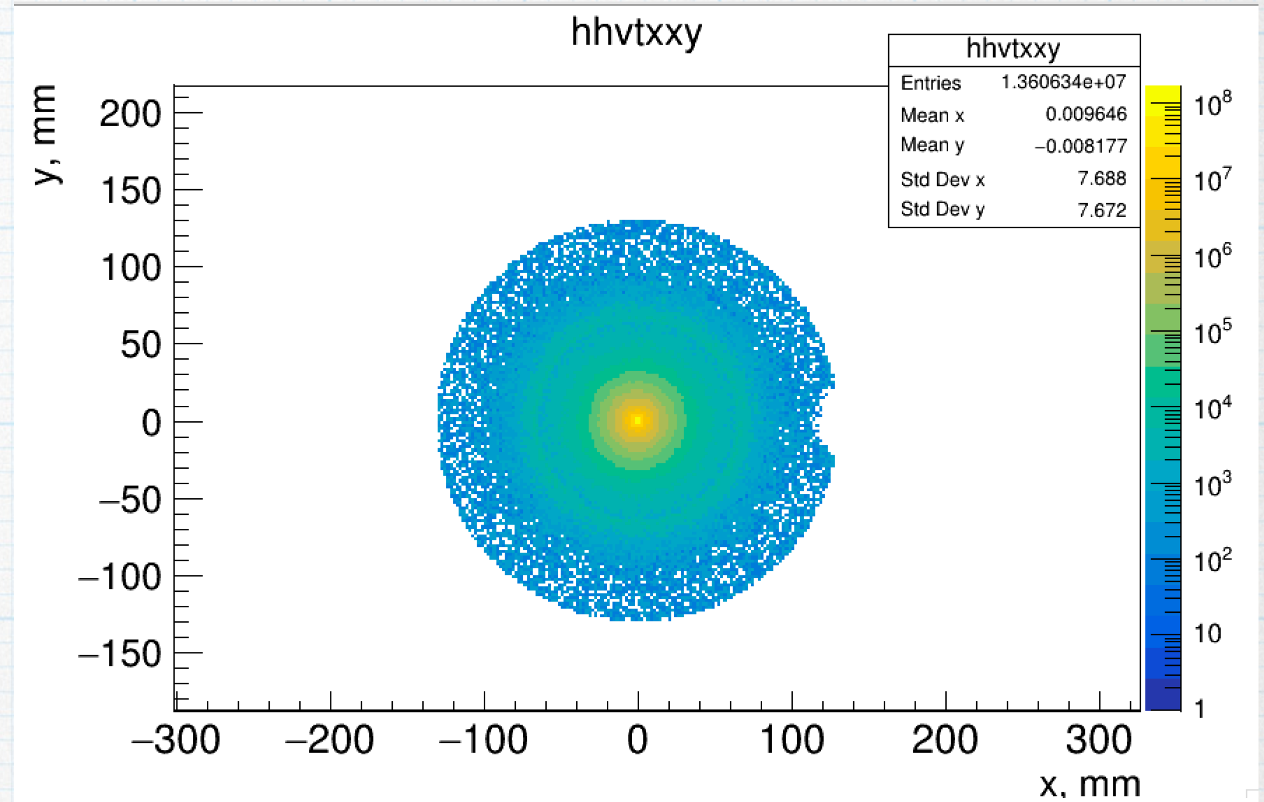
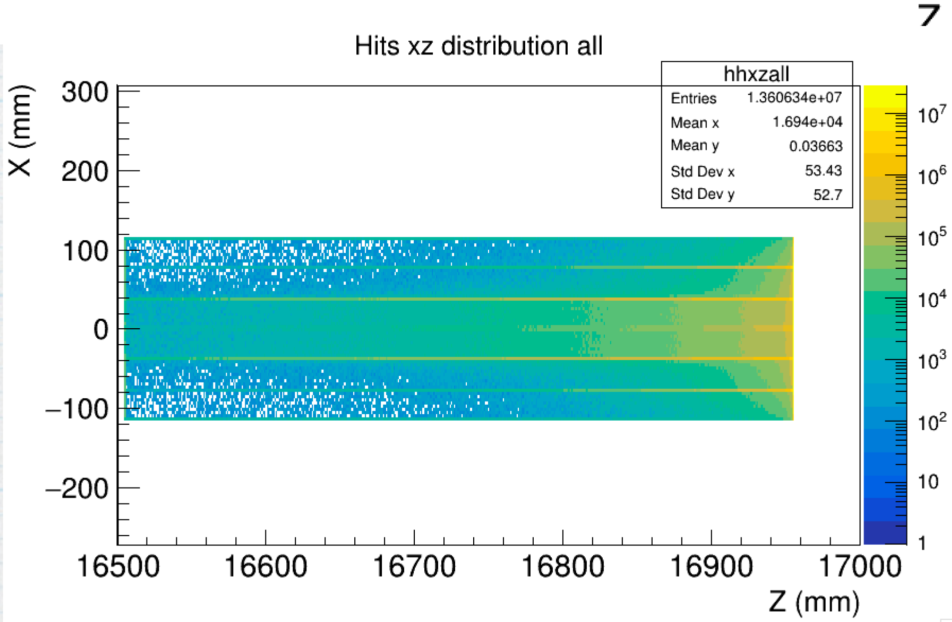
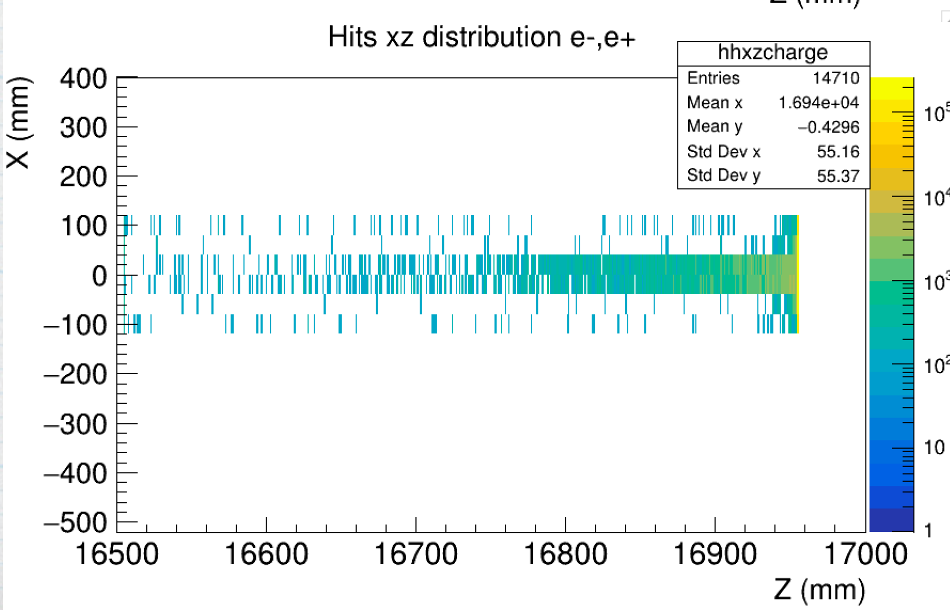
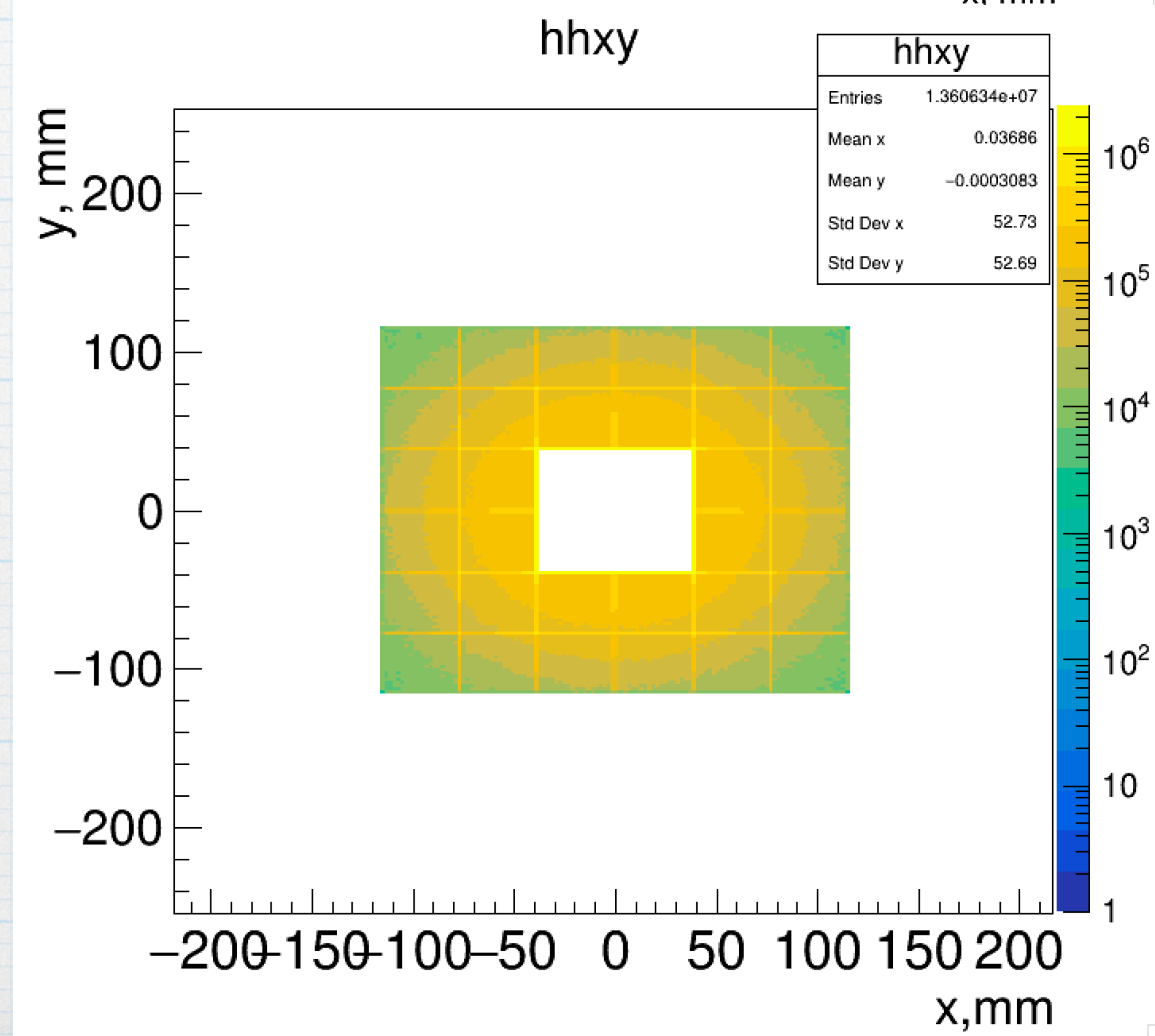


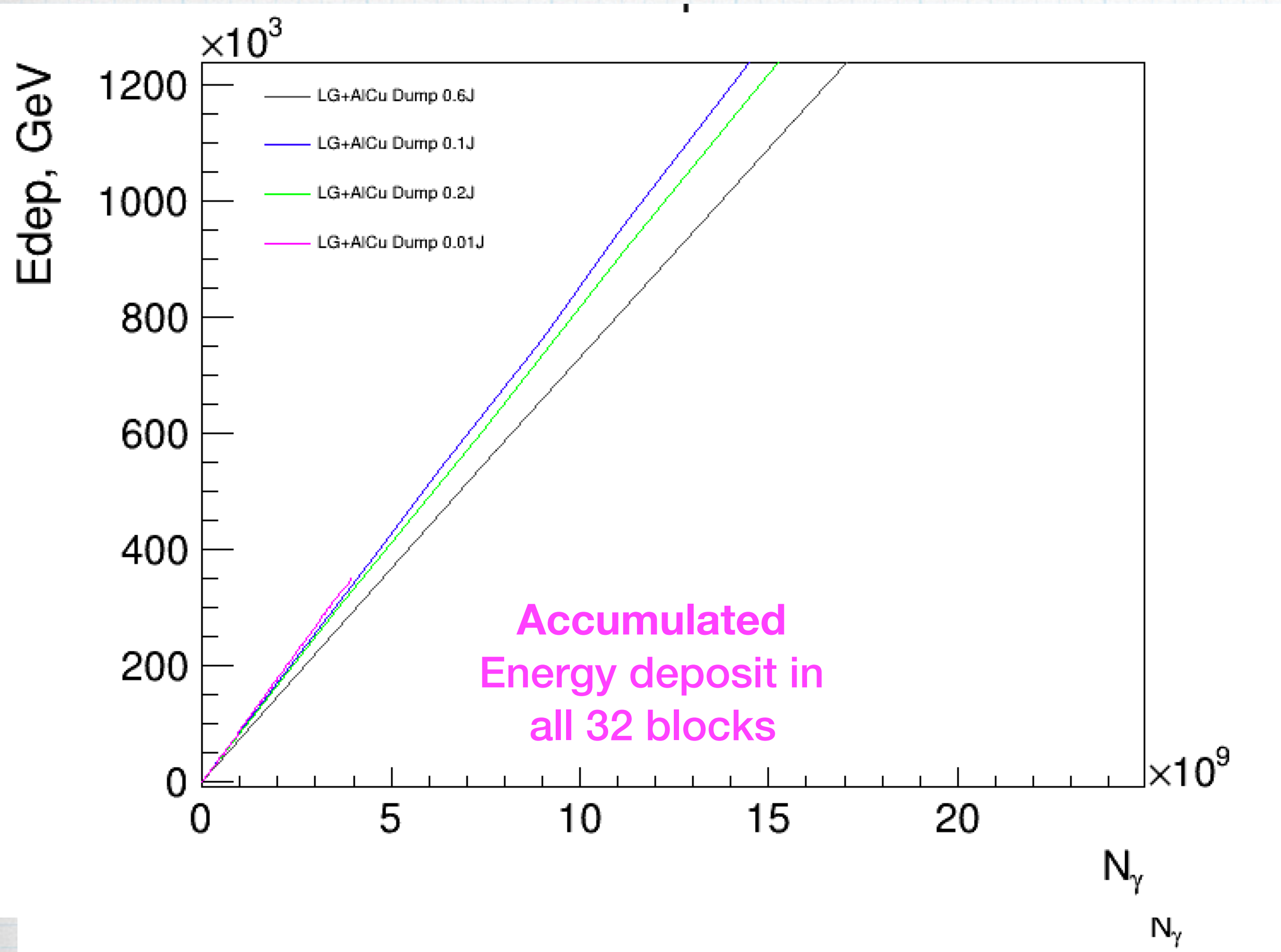


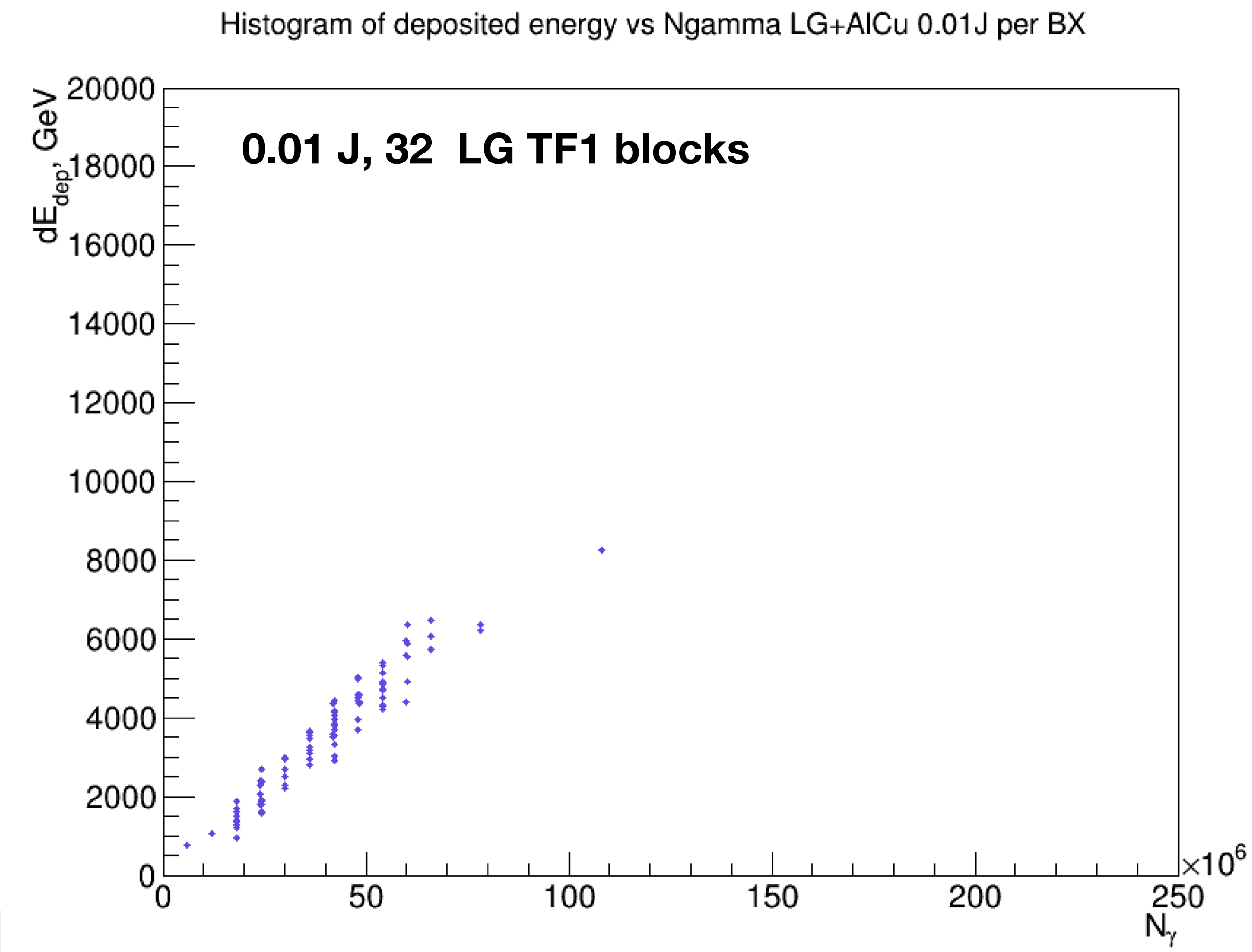






The dependence of deposited energy on number of incoming photons per BX for LG Gamma monitor and AlCu dump





Energy deposit on Ngamma
Each point is one BX, xi=0.26

- for each detID distribution for for 100 BX