Gamma Monitor using backscatters

Borysova Maryna (KINR)

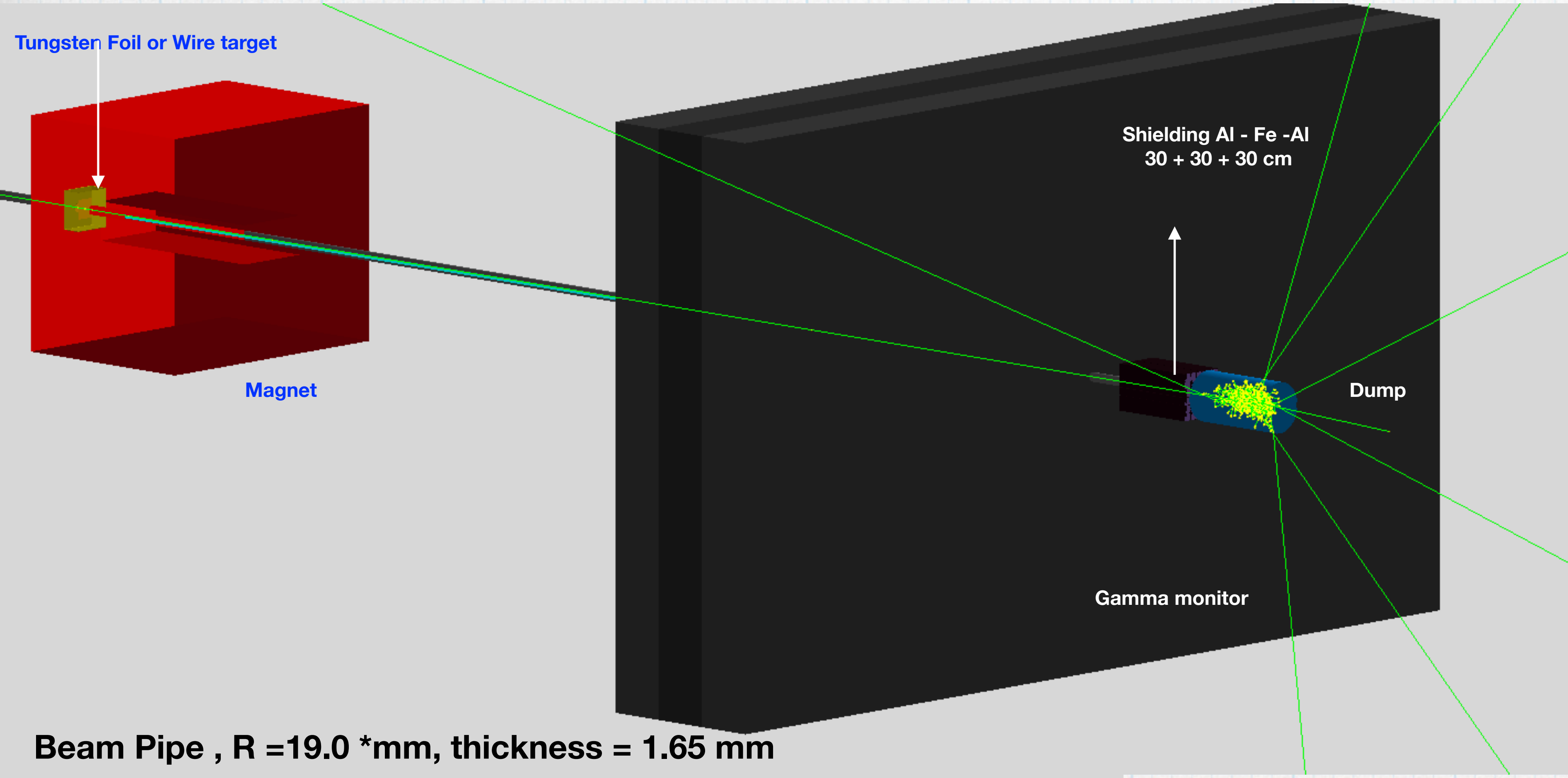
LUXE technical meeting

DESY Hamburg

28/05/20

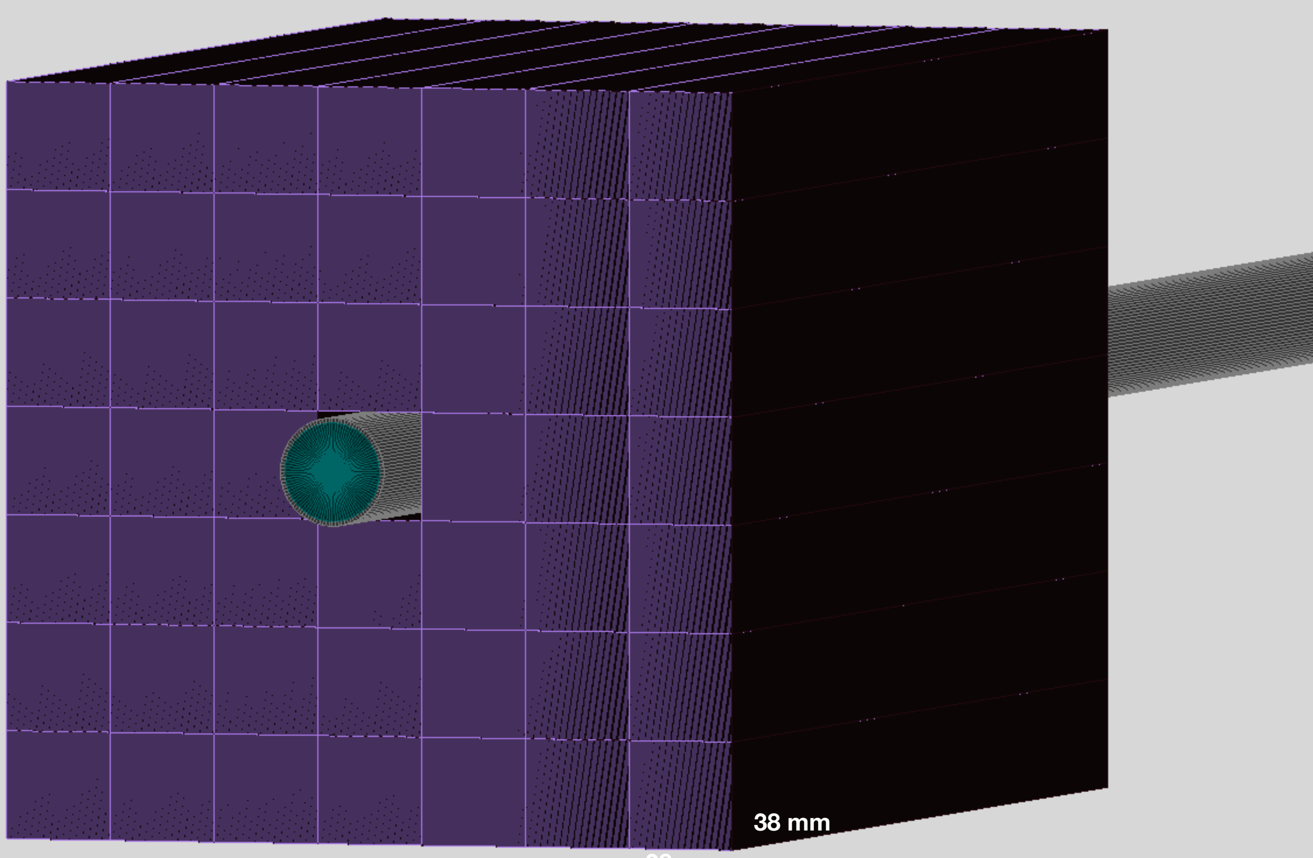
LUXE

Gamma Monitor

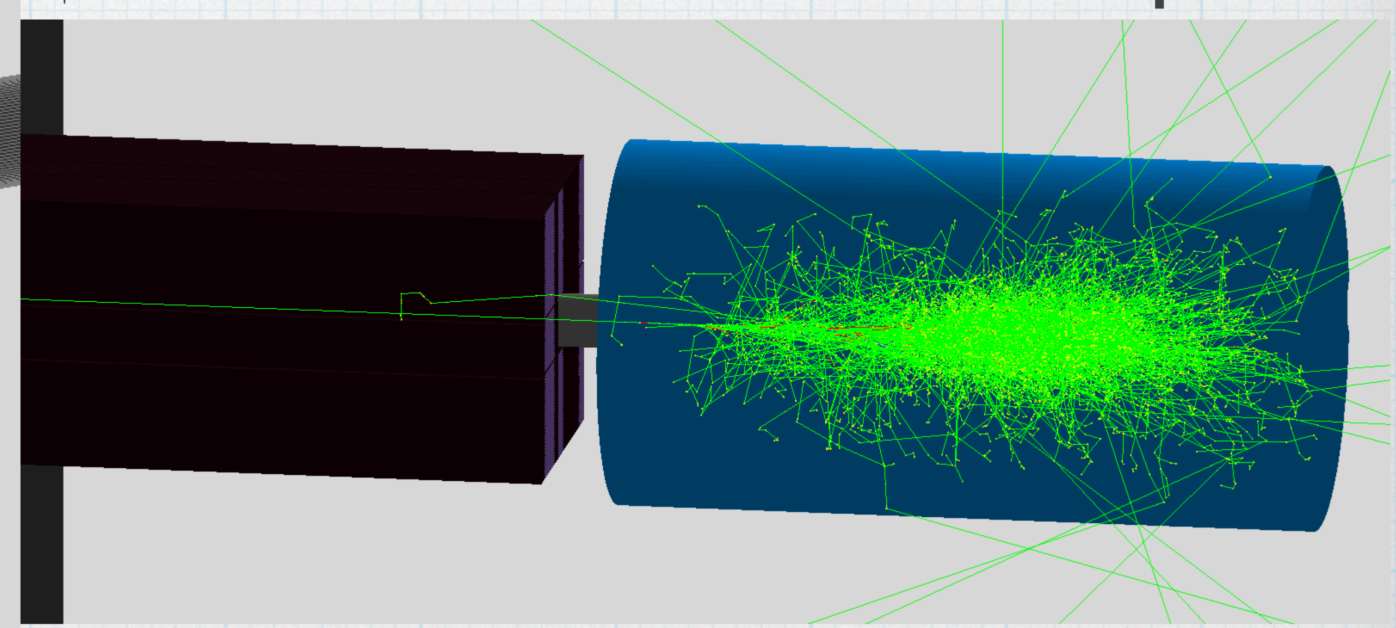


- ✳The implementation of FDS in Luxe geometry with the LG Gamma Monitor made of new LG blocks in front of Al-Cu Dump,
- ✳LG w/ measures 3.8 × 3.8 cm², length is 45 cm
- ✳Wrapped with Aluminium foil of 0.016 mm (typical household foil; no account for air)

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



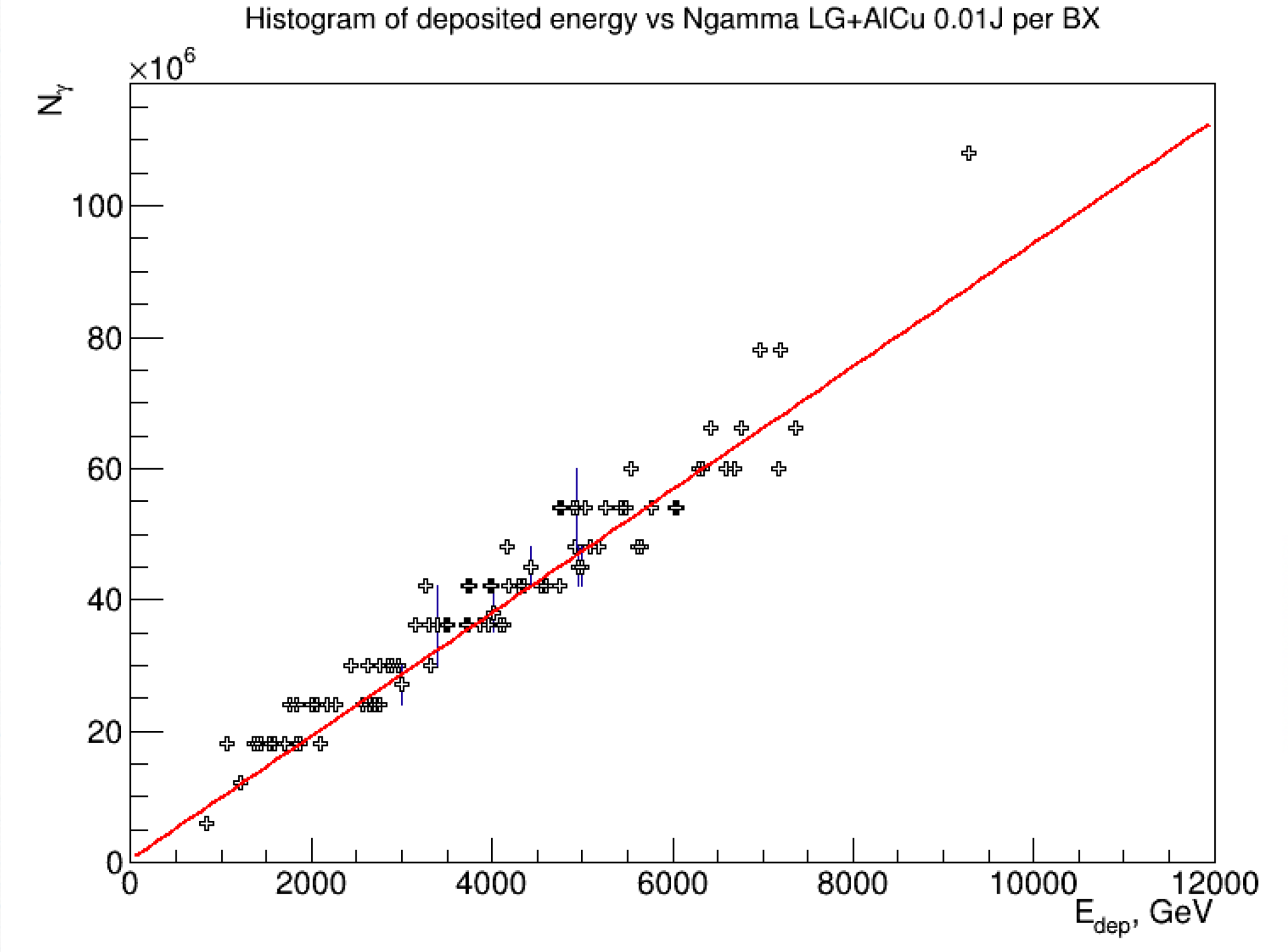
- ✳Distance between Monitor and Dump 2 cm



Uncertainties Estimation

N(E) number of photons

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



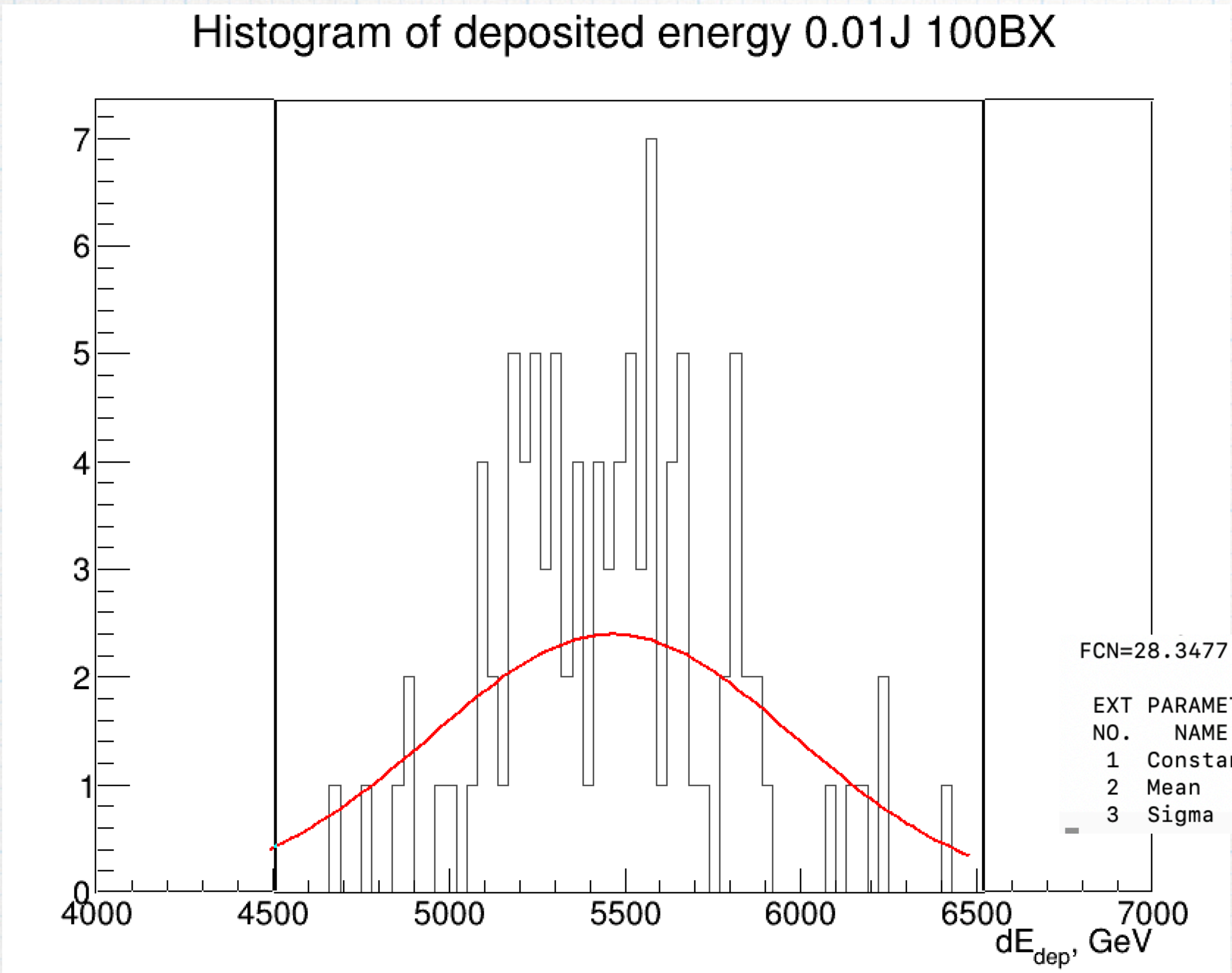
for ξ =0.26

N ~ 1.3 *10^8

$\partial N / \partial E$

```
****************************************
Minimizer is Linear
Chi2                      =      4.09908
NDf                       =            5
p0                        =       519656   +/-   7.48892e+06
p1                        =       9378.9   +/-   1732.65
```

ΔE, for ξ =0.26



One BX was sent 100 times

$N = 1.3 * 10^8$

$\partial N/\partial E = 9379$

```
FCN=28.3477 FROM MIGRAD    STATUS=CONVERGED      38 CALLS          39 TOTAL
                     EDM=6.77299e-09    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                                   STEP         FIRST
 NO.   NAME      VALUE            ERROR          SIZE      DERIVATIVE
  1  Constant     2.39709e+00   3.89960e-01   7.49077e-04  -8.05321e-05
  2  Mean         5.46449e+03   9.45197e+01   2.46721e-01   1.17299e-08
  3  Sigma        5.16123e+02   1.35372e+02   2.17842e-04   8.07357e-04
```

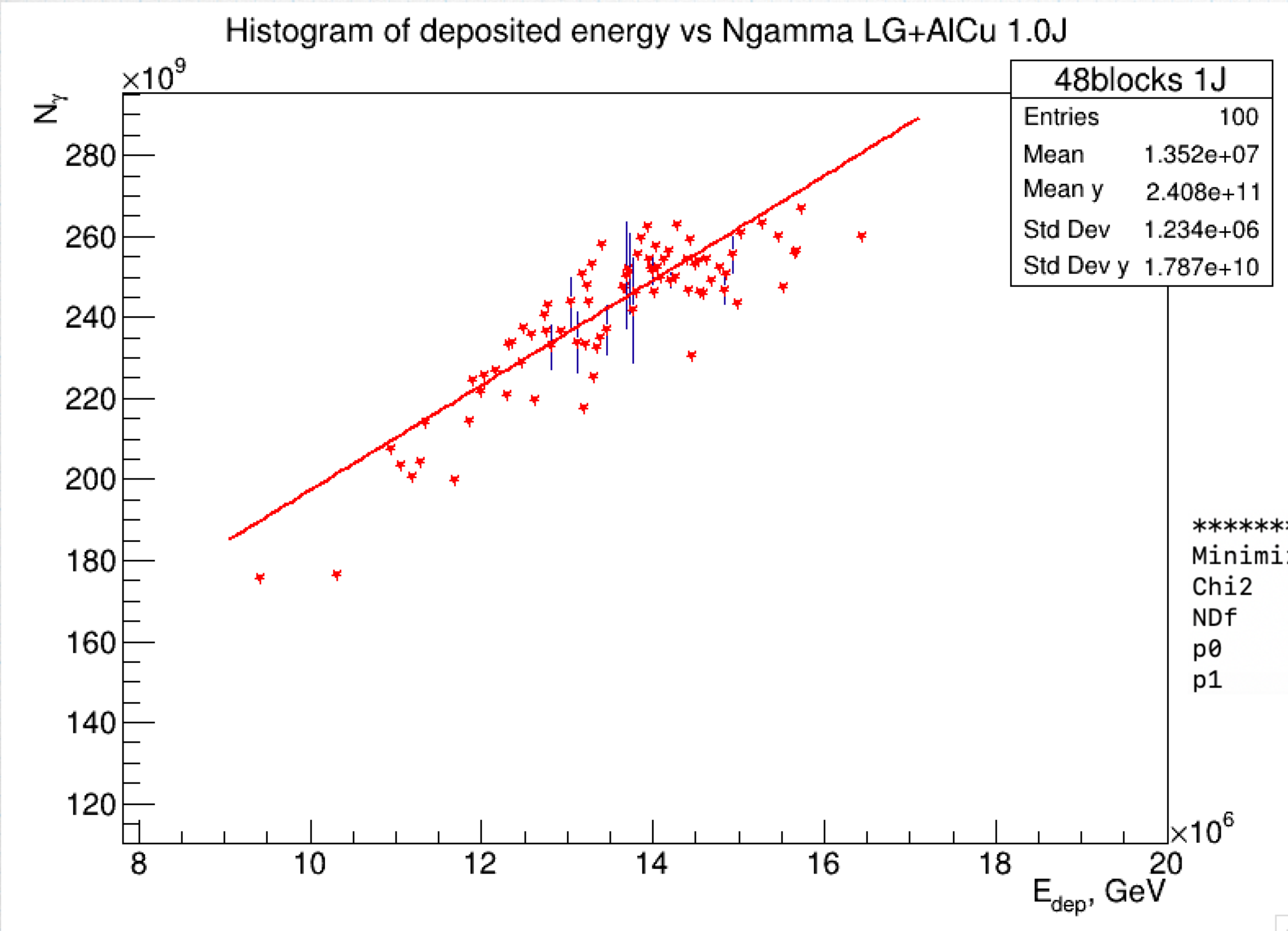
$\Rightarrow \Delta E = 5.2 * 10^2$

$$\frac{\Delta N}{N} = \frac{1}{N}\frac{\partial N}{\partial E}\Delta E = 5.2 * 10^2 * 9379 / 1.3 * 10^8 = 3.6 * 10^{-2}$$

Uncertainties Estimation

N(E) number of photons

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



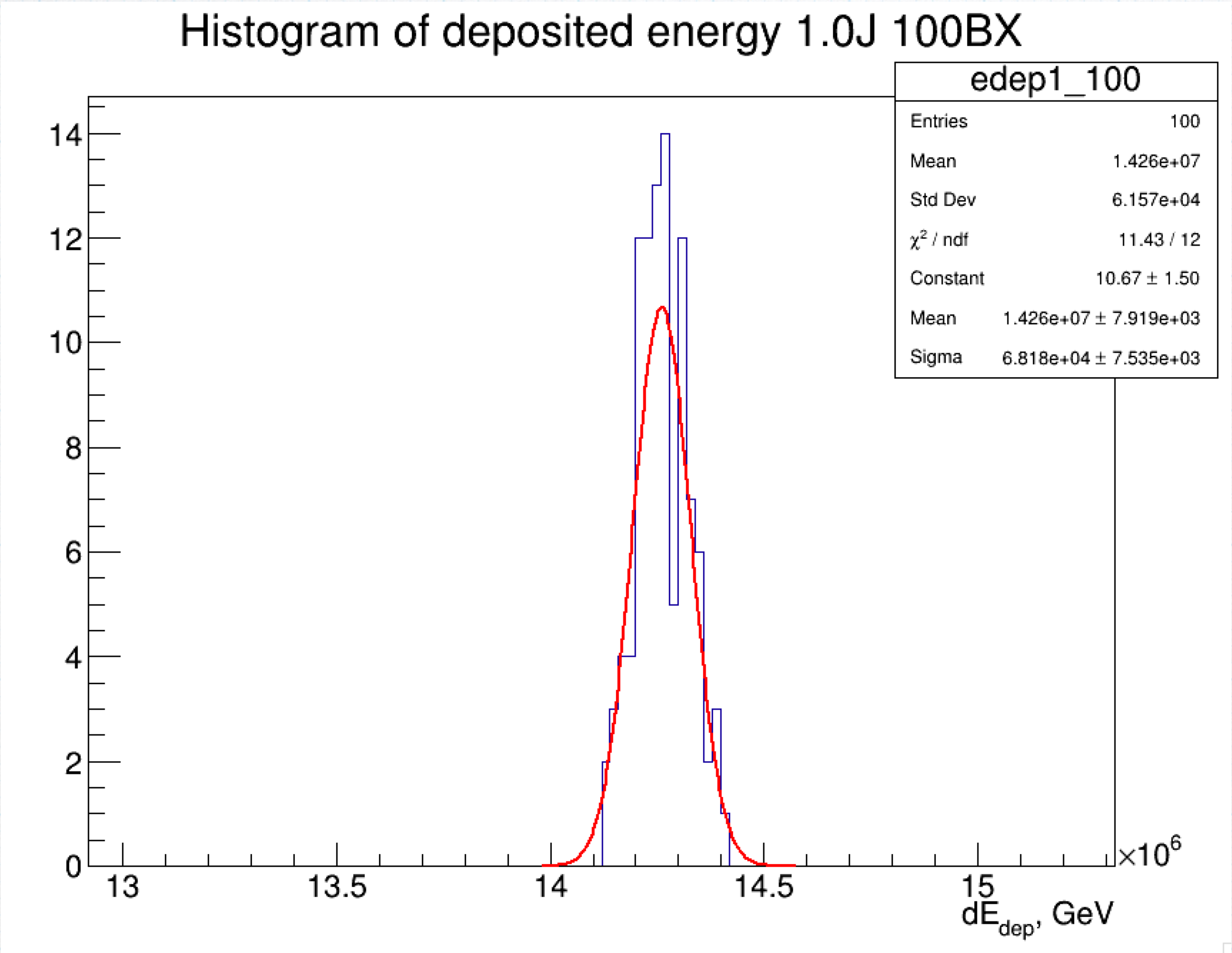
for ξ =2.6

N ~ $2.5 * 10^{11}$

```
****************************************
Minimizer is Linear
Chi2                      =      49.2879
NDf                       =           13
p0                        =  6.79976e+10   +/-   3.97264e+09
p1                        =      12940.5   +/-   282.483
```

$\partial N/\partial E$

ΔE, for ξ =2.6



One BX was sent 100 times
=> $\Delta E = 6.8*10^4$

$N = 2.5*10^{11}$

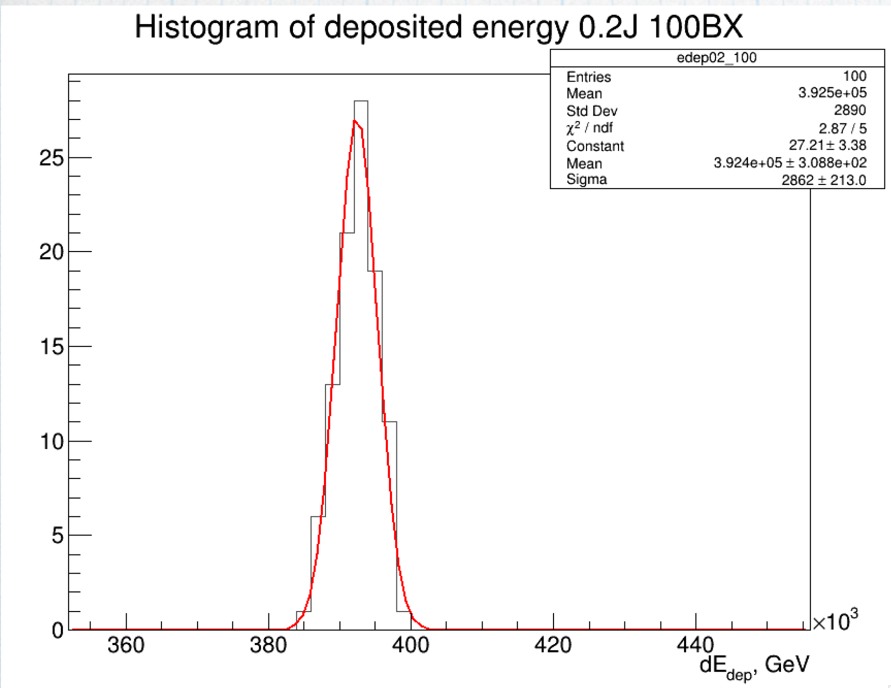
$\partial N/\partial E = 12940$

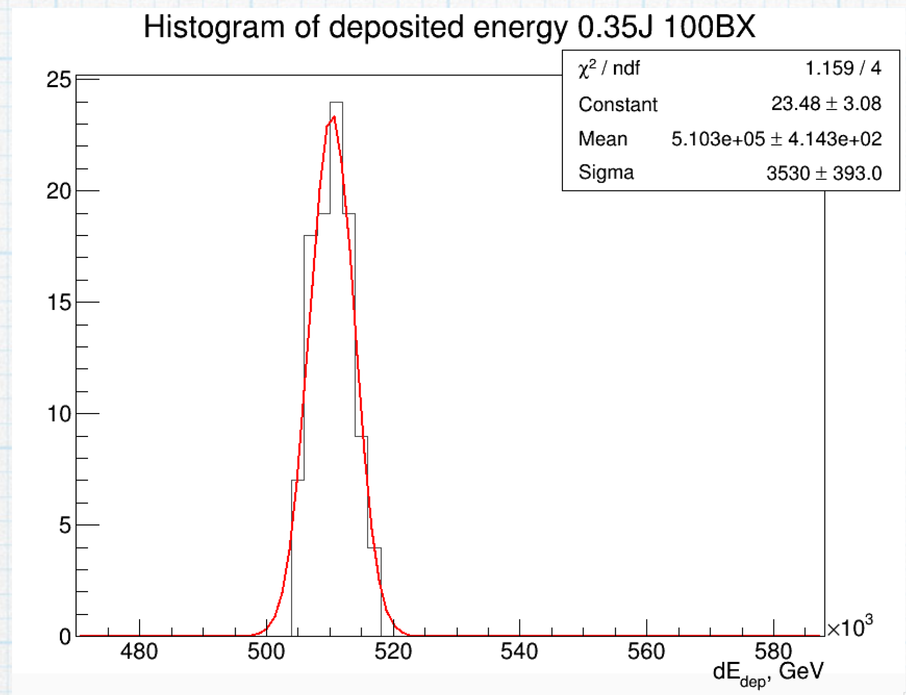
$$\frac{\Delta N}{N} = \frac{1}{N}\frac{\partial N}{\partial E}\Delta E = 6.8*10^4 * 1.3*10^4/2.5*10^{11} = 3.5*10^{-3}$$

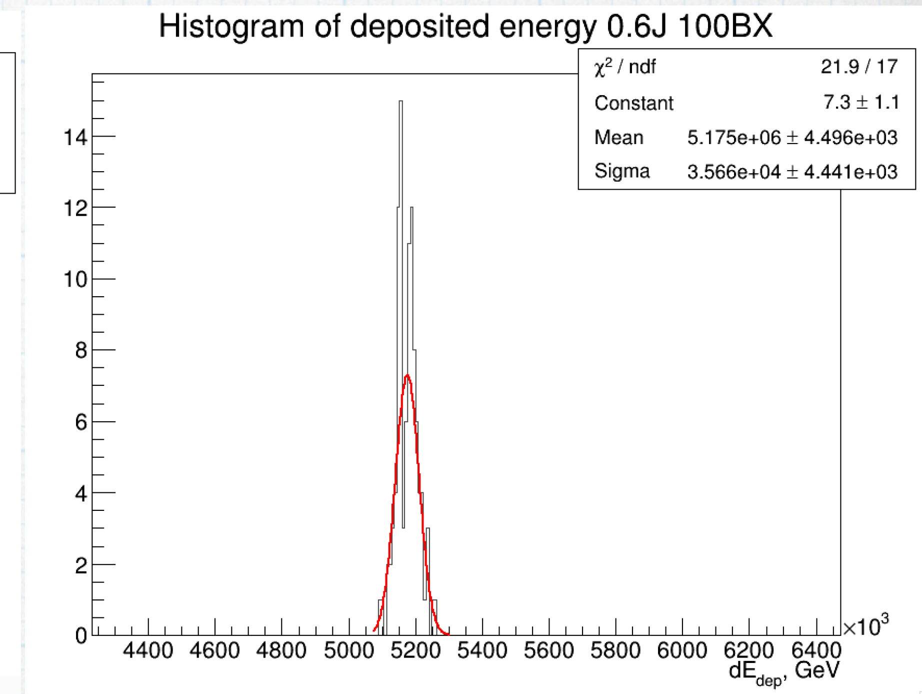
J	ξ
0.01	0.26
0.1	0.82
0.2	1.16
0.35	1.54
0.6	2.02
1.0	2.6

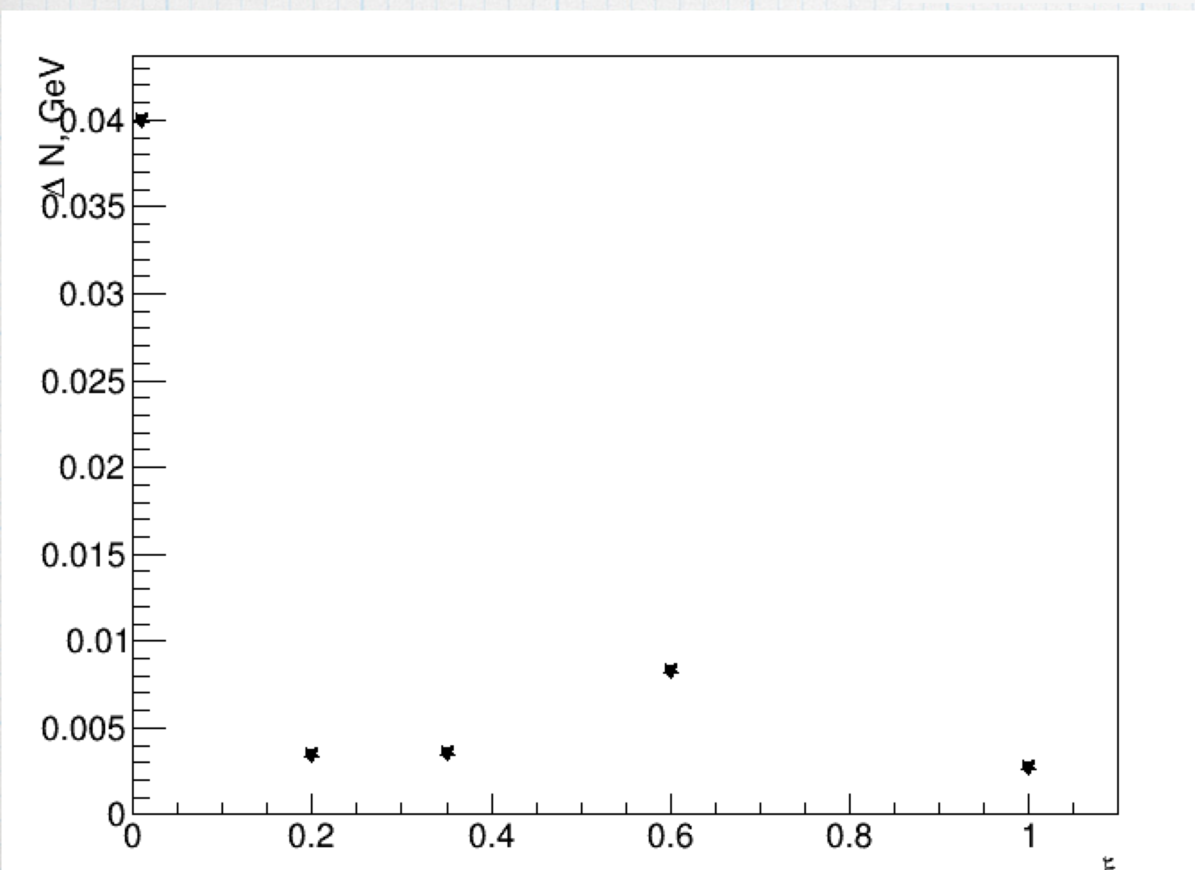
ΔE, for ξ =1.2, 1.5, 1.8

One BX was sent 100 times









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

$\partial N/\partial E \sim 10^4$

- the uncertainty on number of measured photons will be $\sim 3.5 \cdot 10^{-3}$ $3.5 \cdot 10^{-2}$.

Outlook

- **Gamma monitor studies:**

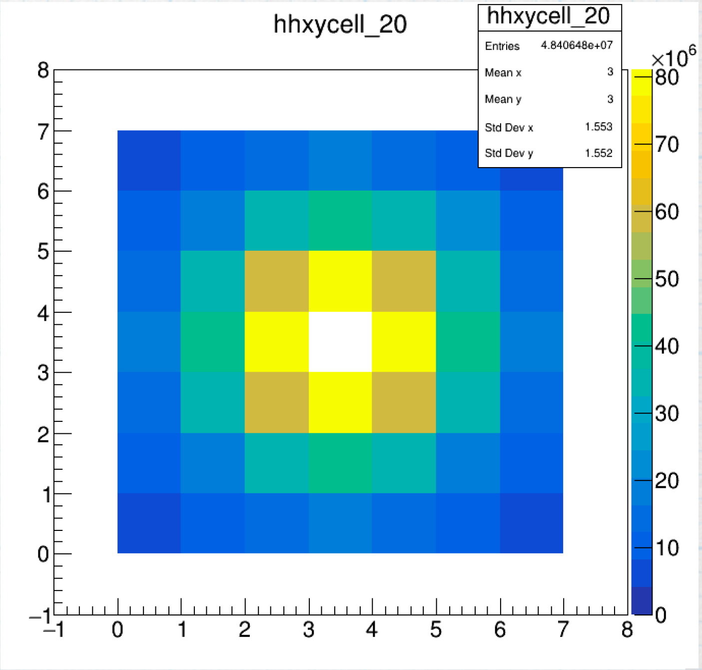
The uncertainties estimation on number of photons for 48 LG blocks

✳ **48 TF1(GAMS) blocks**

✳ **At high laser intensities (1J) for the blocks that closely surround the beam pipe the uncertainty on number of measured photons will be ~ 3.5 $*10^{-3}$**

✳ **To do:**

- ✓ **To estimate uncertainties for other (0.6, 0.35, 0.2, 0.1, 0.01J) laser intensities (running)**
- ✓ **To estimate uncertainties for one LG block**
- ✓ **To estimate uncertainties for each of the three layers**



Back up

MC from A. Hartin

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

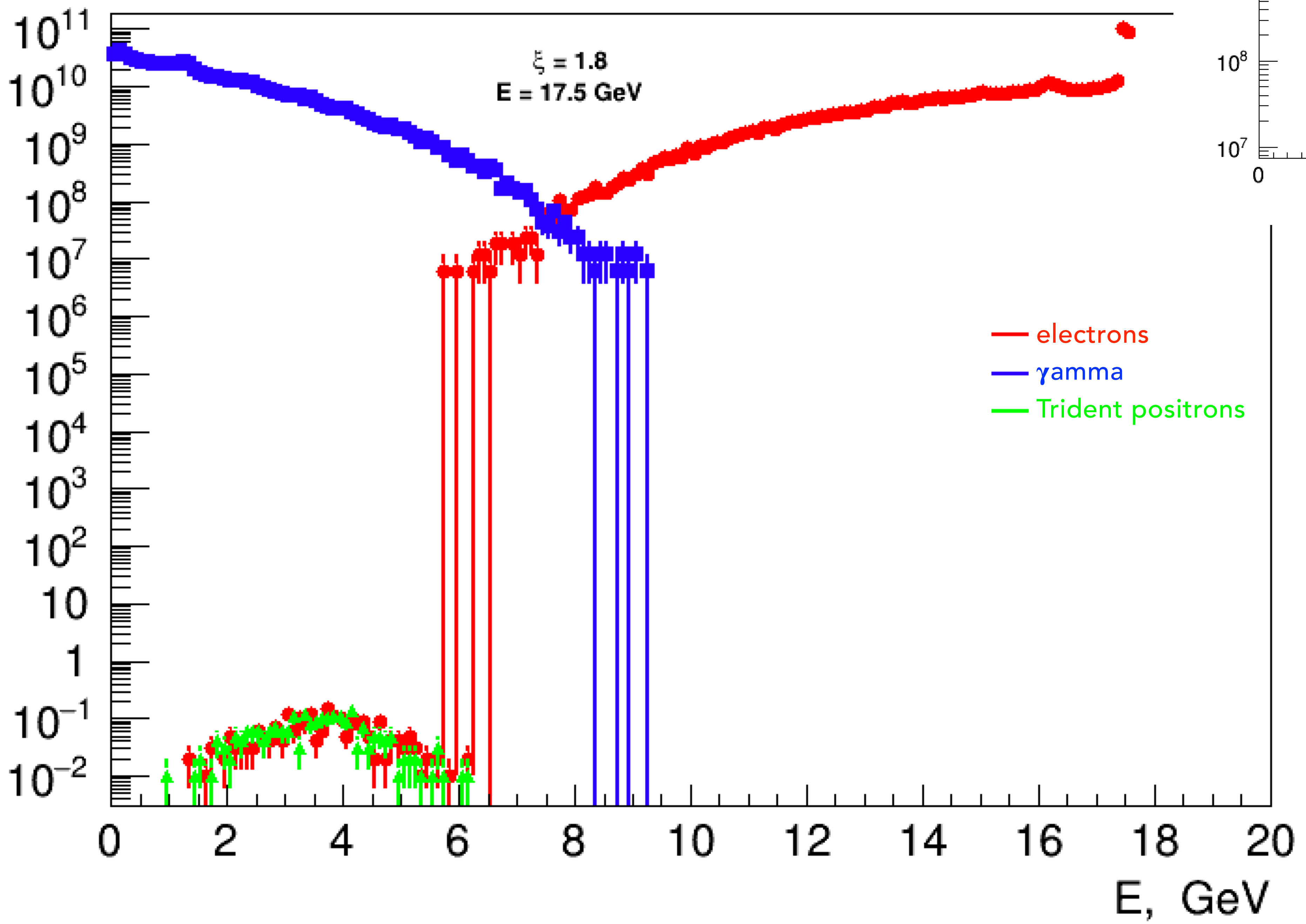
J	ξ
0.01	0.26
0.1	0.82
0.2	1.16
0.35	1.54
0.5	1.83
0.6	2.02
1.0	2.6

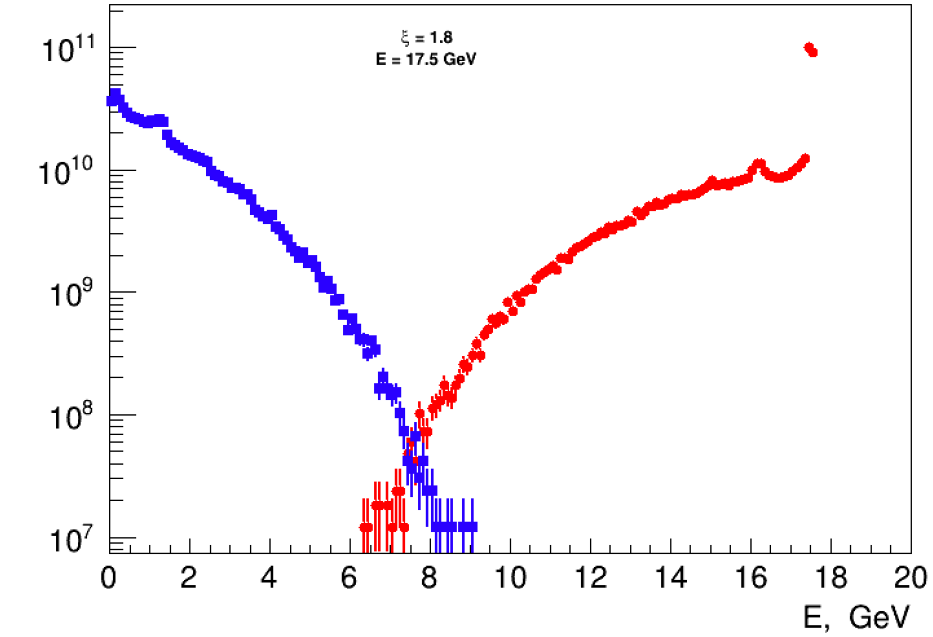
- New MC

- 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 $\xi = 2.6$	rate for $\xi = 0.26$
e^- detector	e^-, $E_e < 16$ GeV	1.5×10^9	6×10^6
e^+ detector	e^+	15.3	< 0.01
Photon detector	γ	6×10^{10}	1×10^7
Photon detector (W foil)	e^+ and e^-	6×10^6	1×10^4
Photon detector (W wire)	e^+ and e^-	1.5×10^5	1×10^2

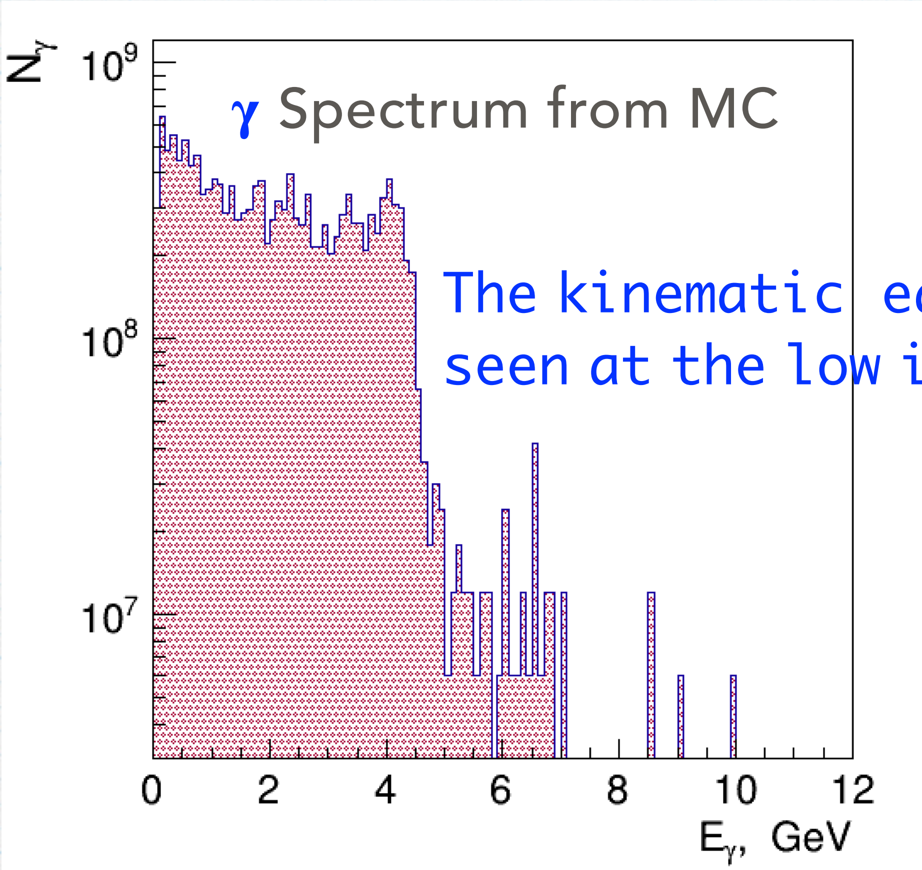
γ and e Spectra from new MC



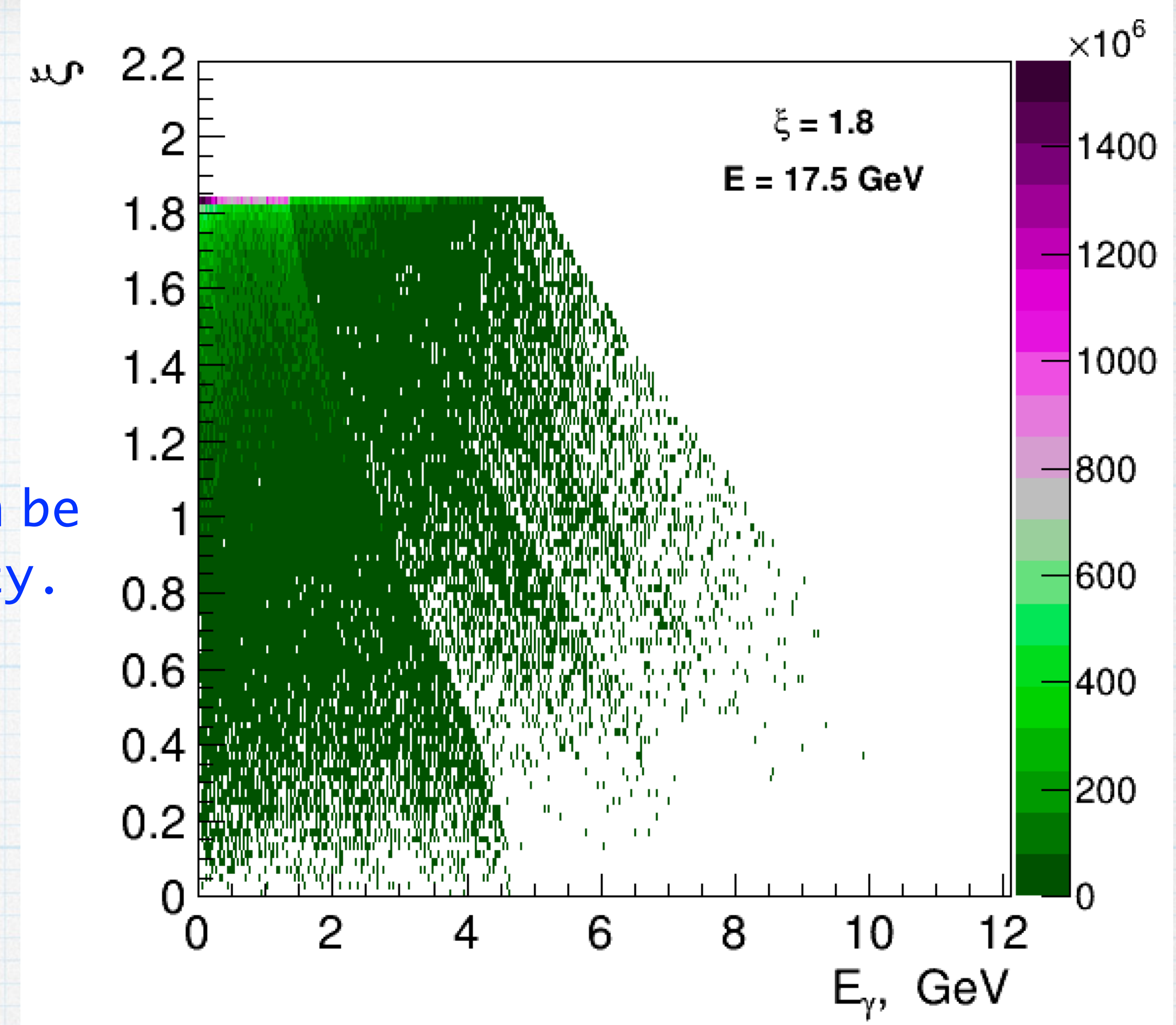


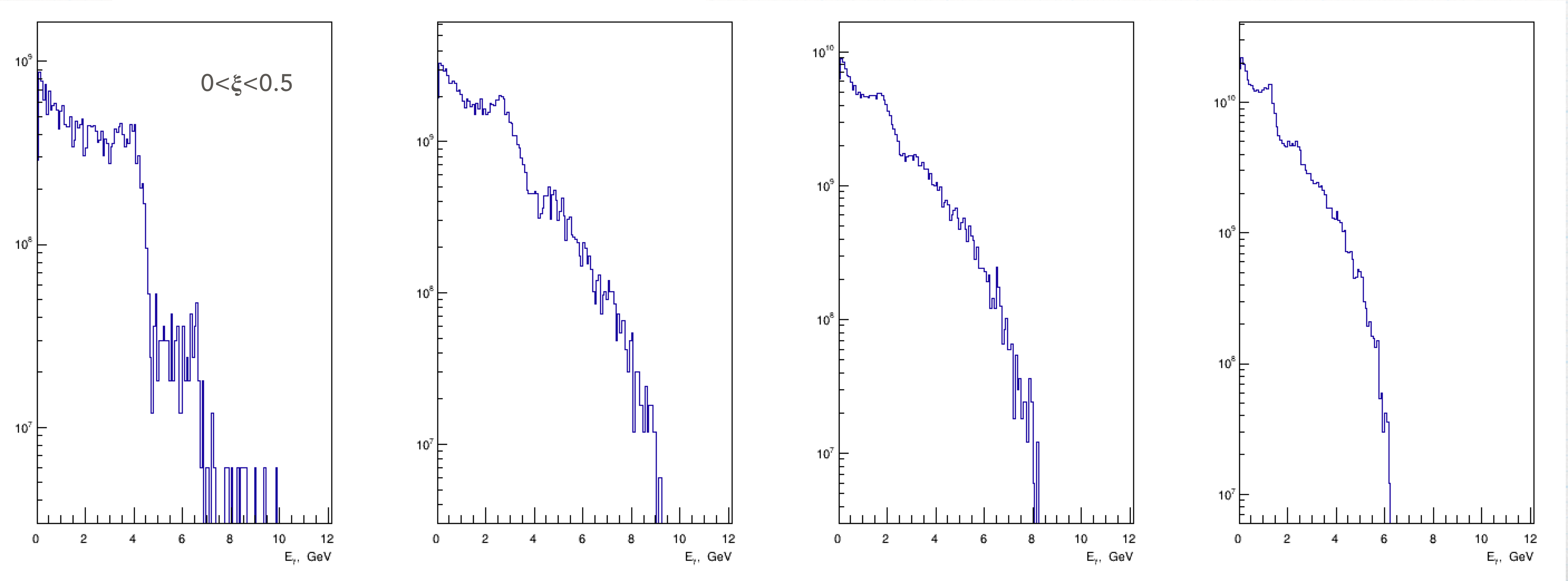
Eγ

ξ vs Eγ FROM MC



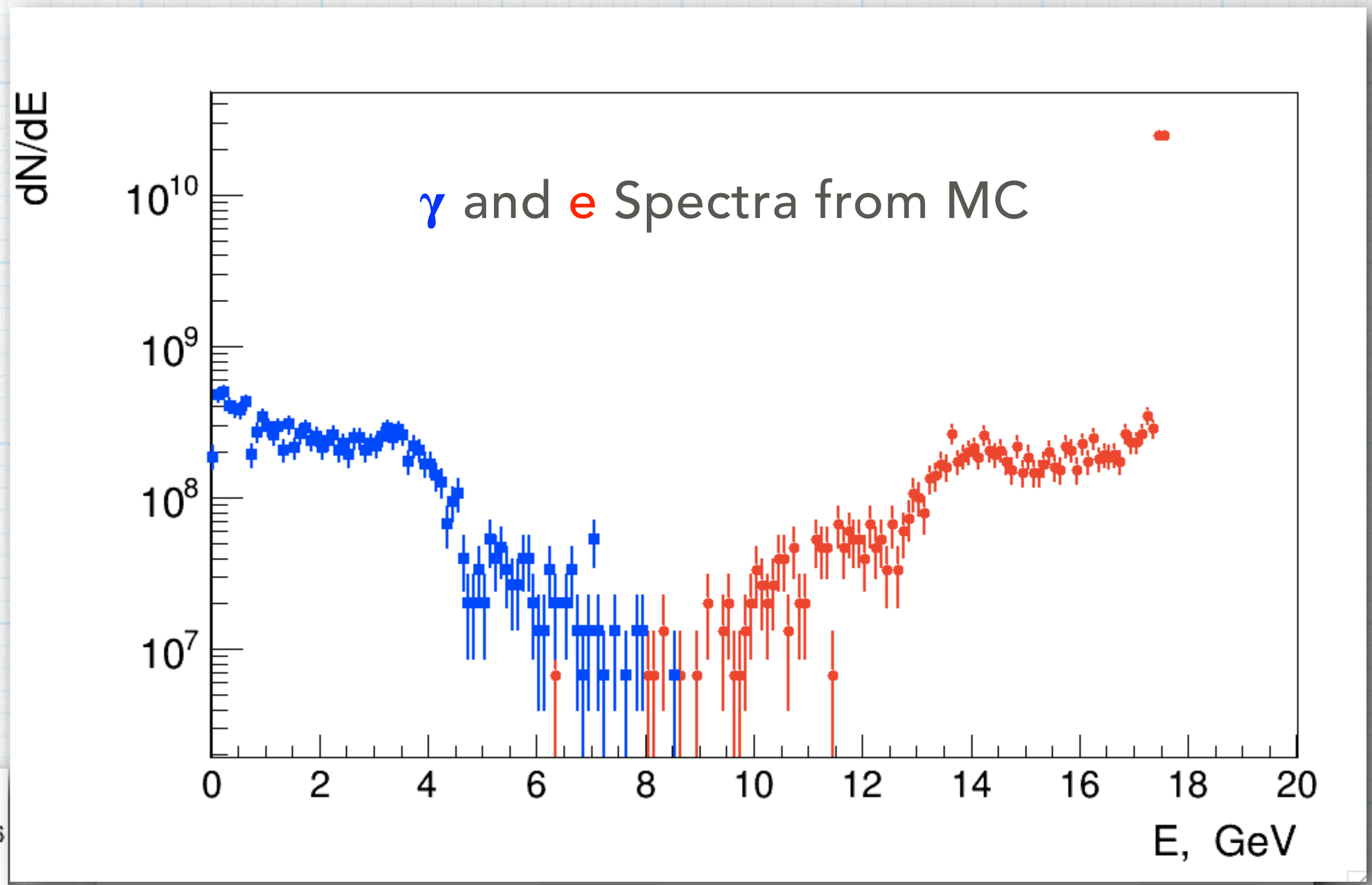
The kinematic edges can be seen at the low intensity.

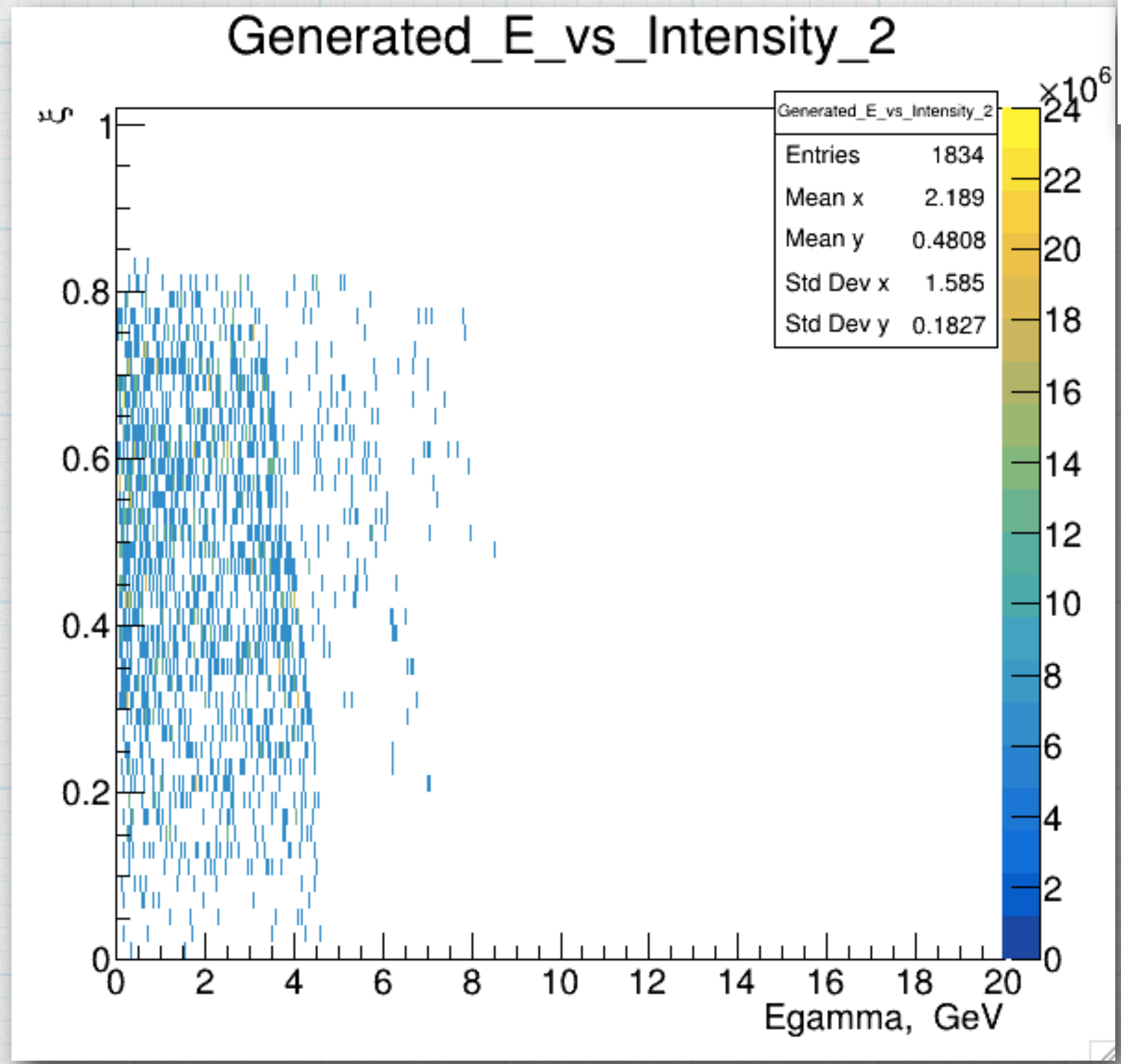


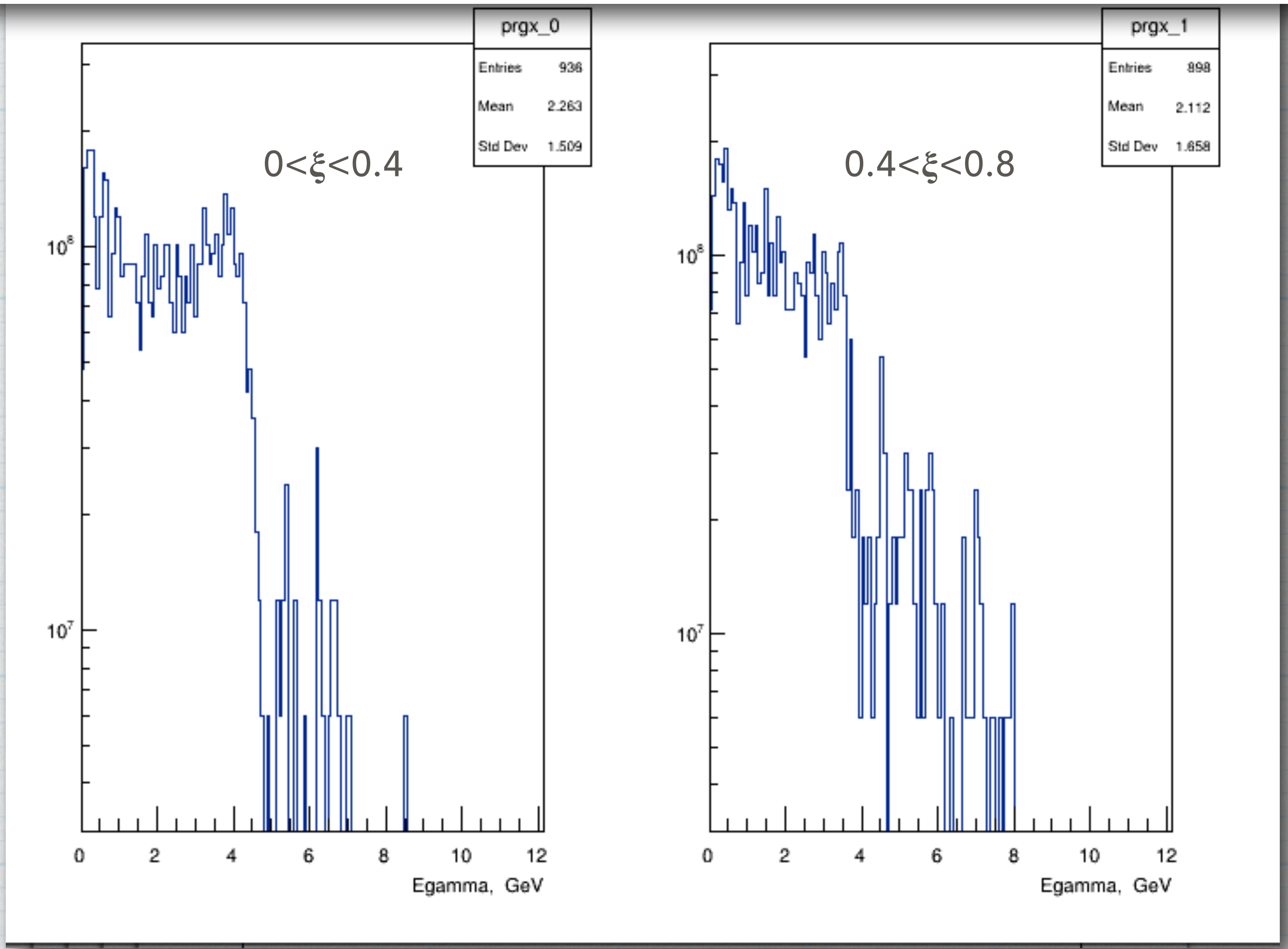


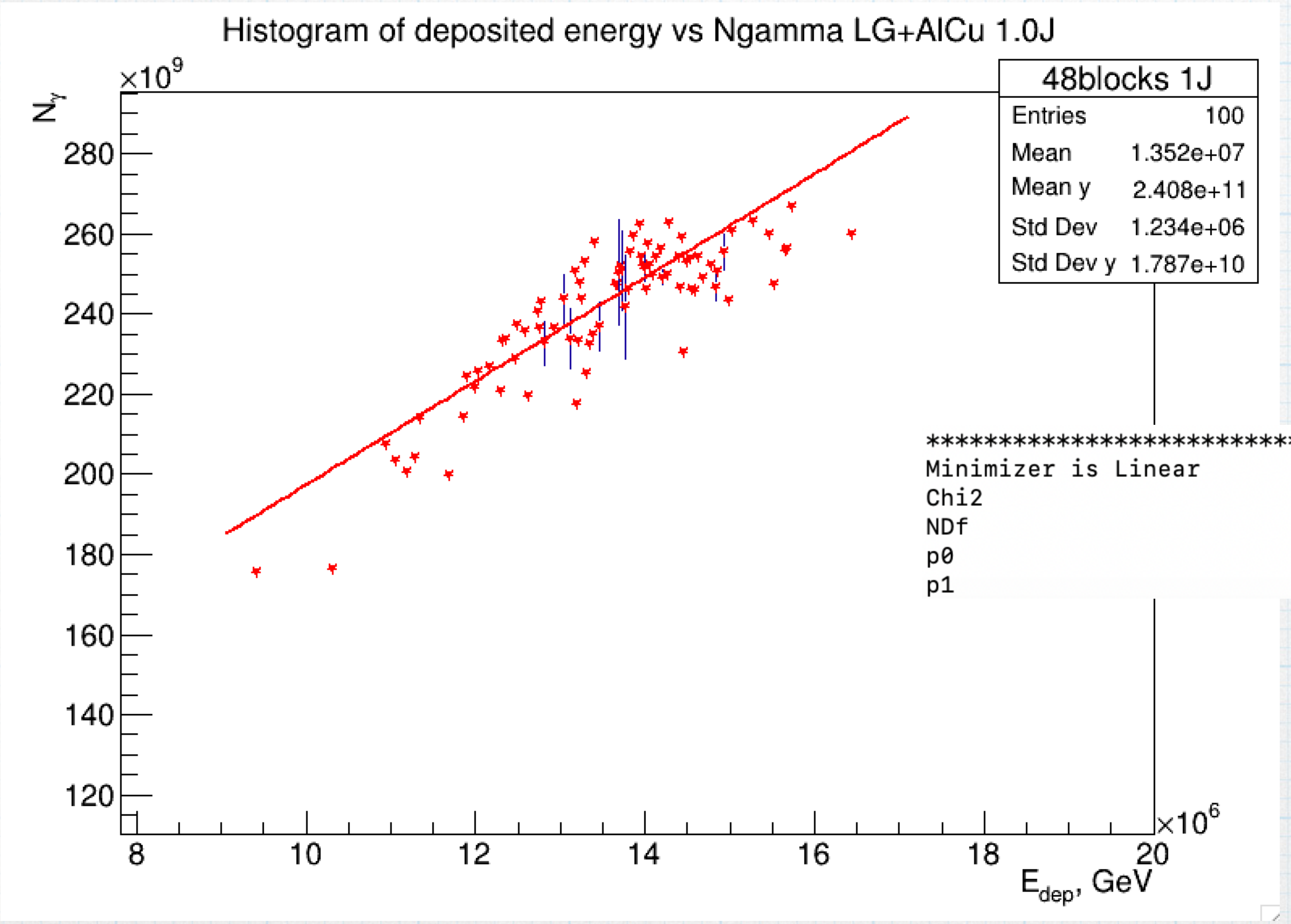
Peak ξ = 0.8

The kinematic edges can be seen at the low intensity.



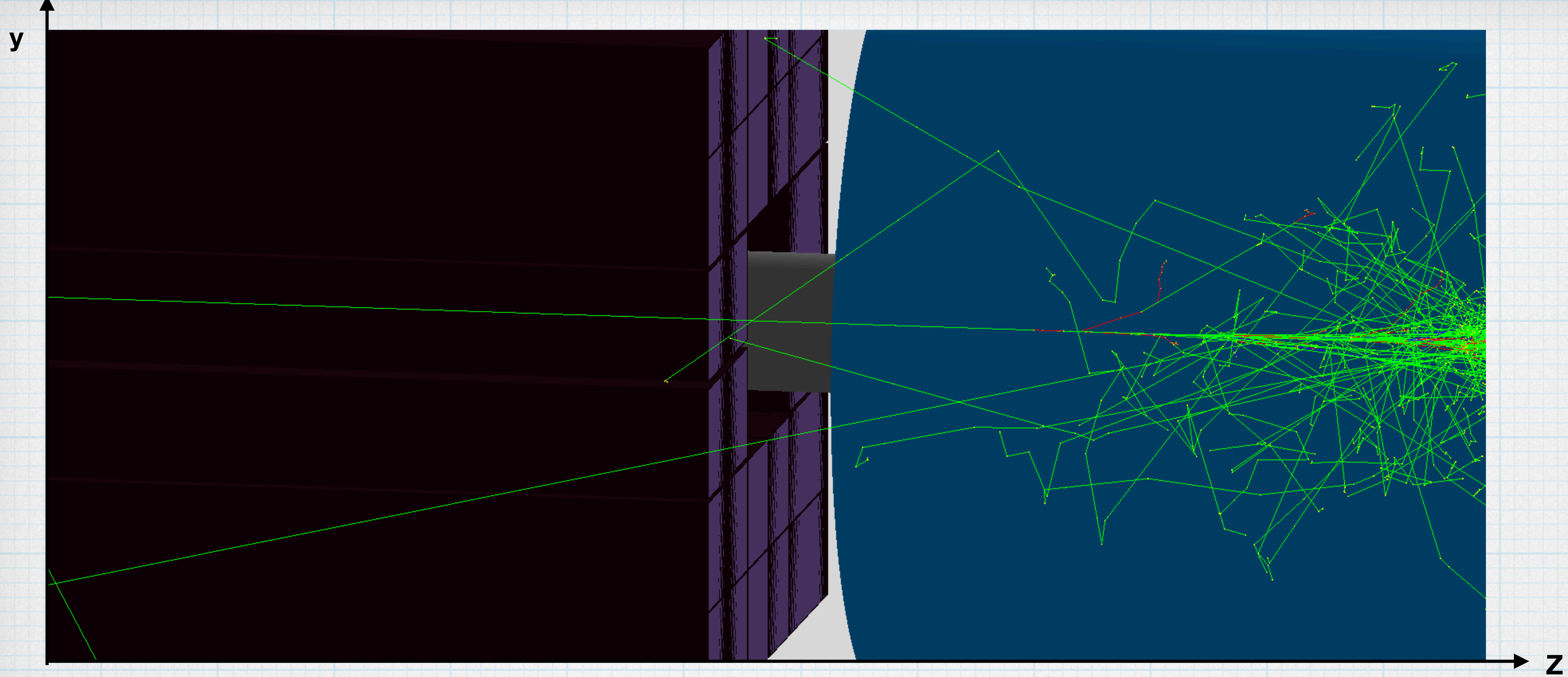






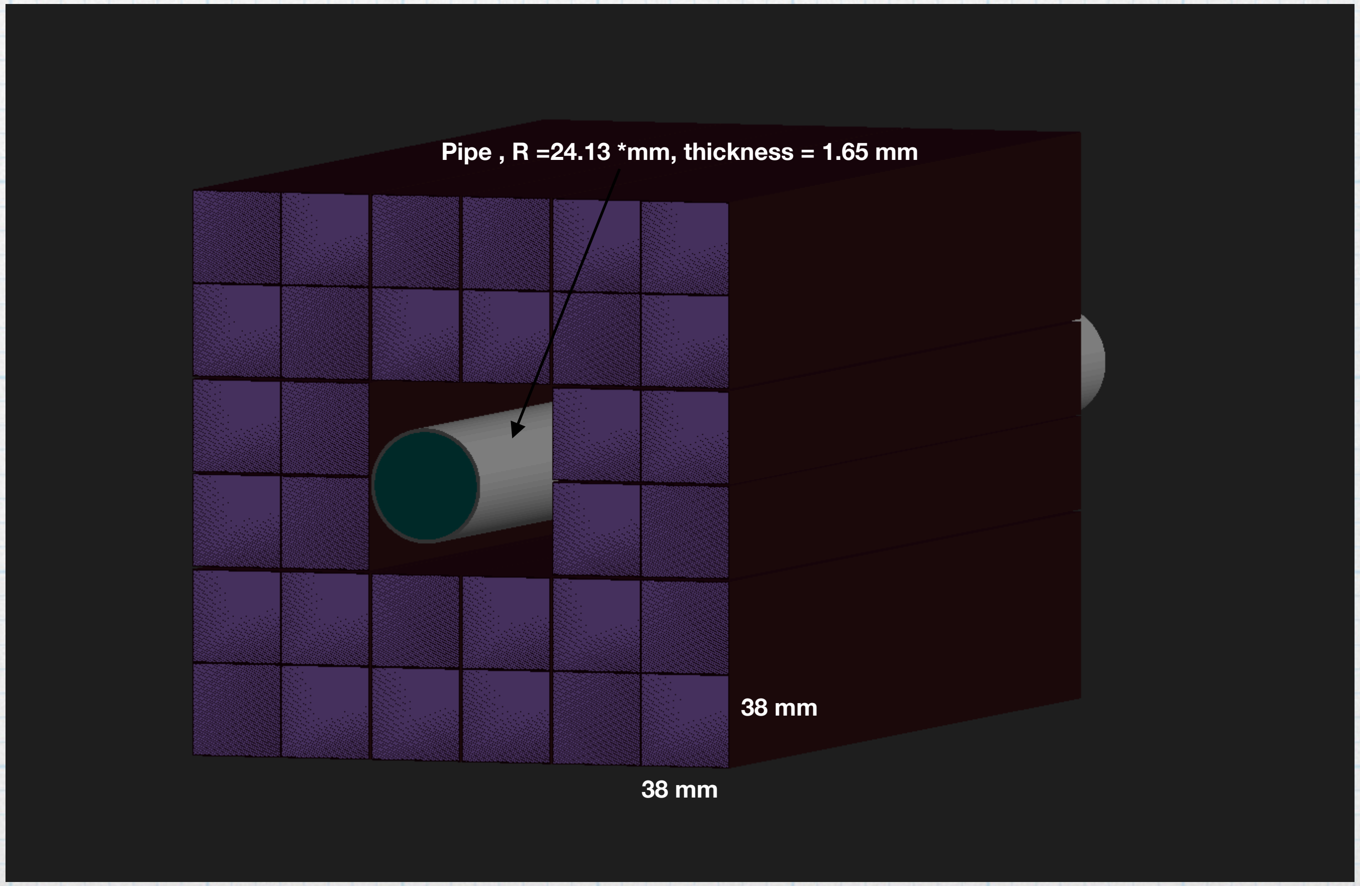

```
****************************************
Minimizer is Linear
Chi2                      =      49.2879
NDf                       =           13
p0                        =  6.79976e+10   +/-   3.97264e+09
p1                        =      12940.5   +/-   282.483
```

```
50 N of photons:  2.54352e+11 per BX edep=  1.39508e+07
```



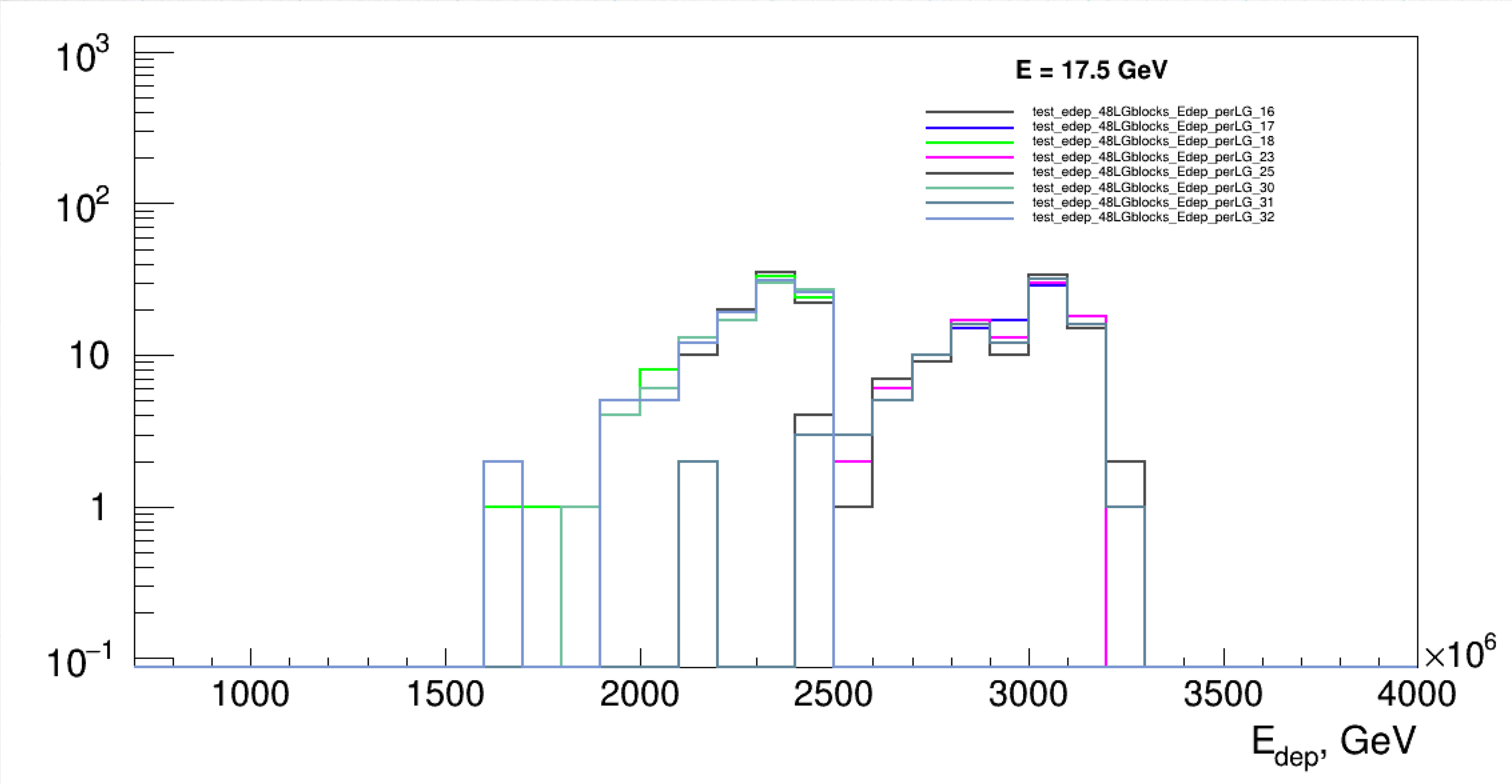
- The implementation in Luxe geometry of the LG Gamma Monitor made of 32 new LG blocks in front of Al-Cu Dump(R(Cu) = 13.0 *cm; R(Al) = 6.5 *cm & L(Al)= 20 *cm)

- 32 LG w/ measures 3.8 × 3.8 cm², length is 45 cm
- Each block is wrapped with Aluminium foil

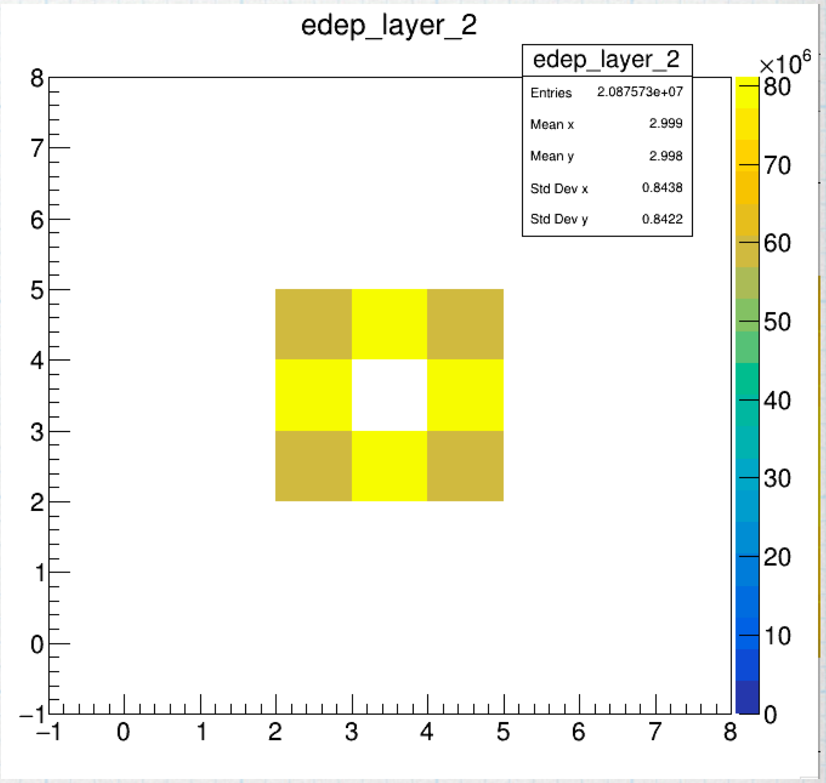


Deposited Energy in the inner layer

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

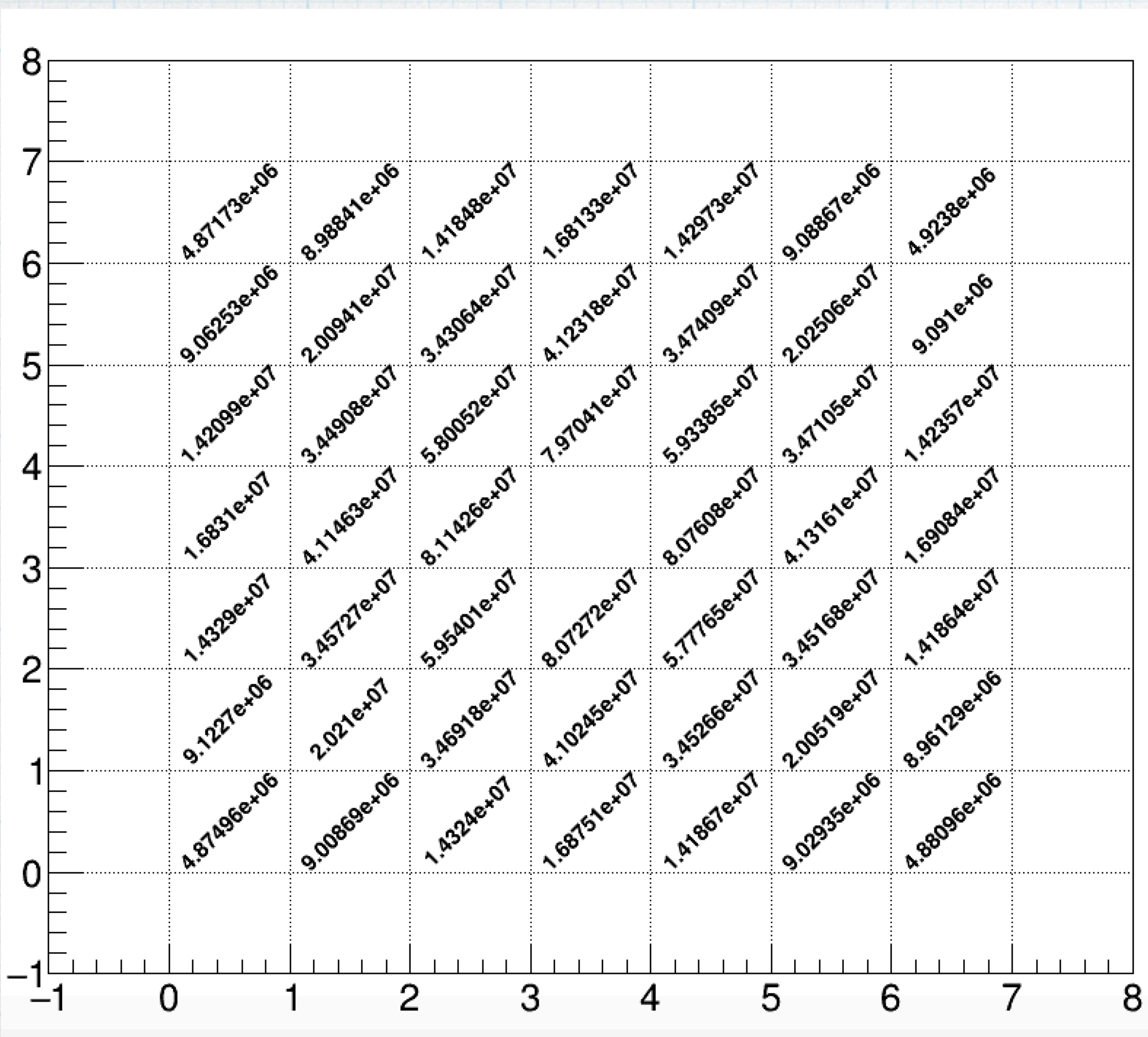


- for ξ =2.6, 100 BX

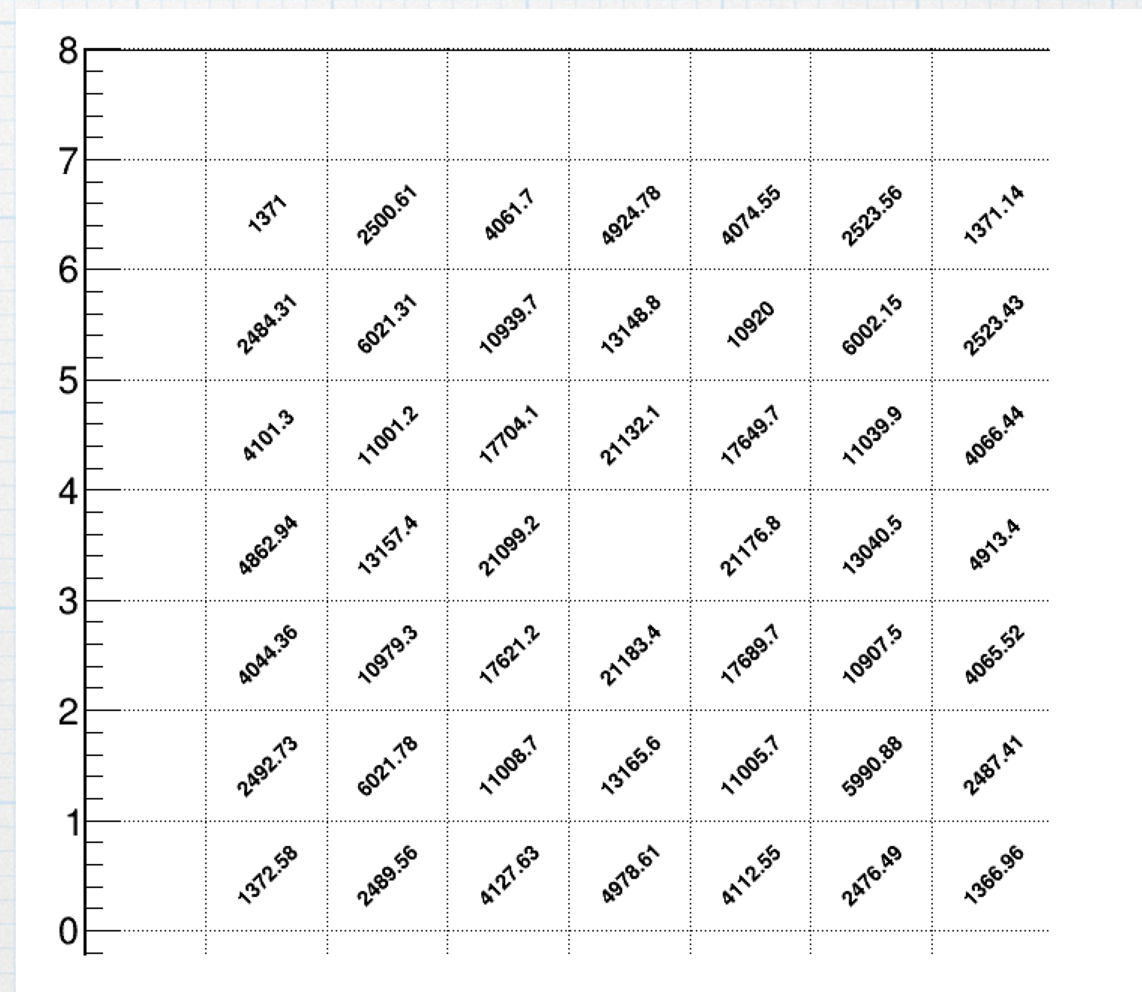


Previously raised issues:

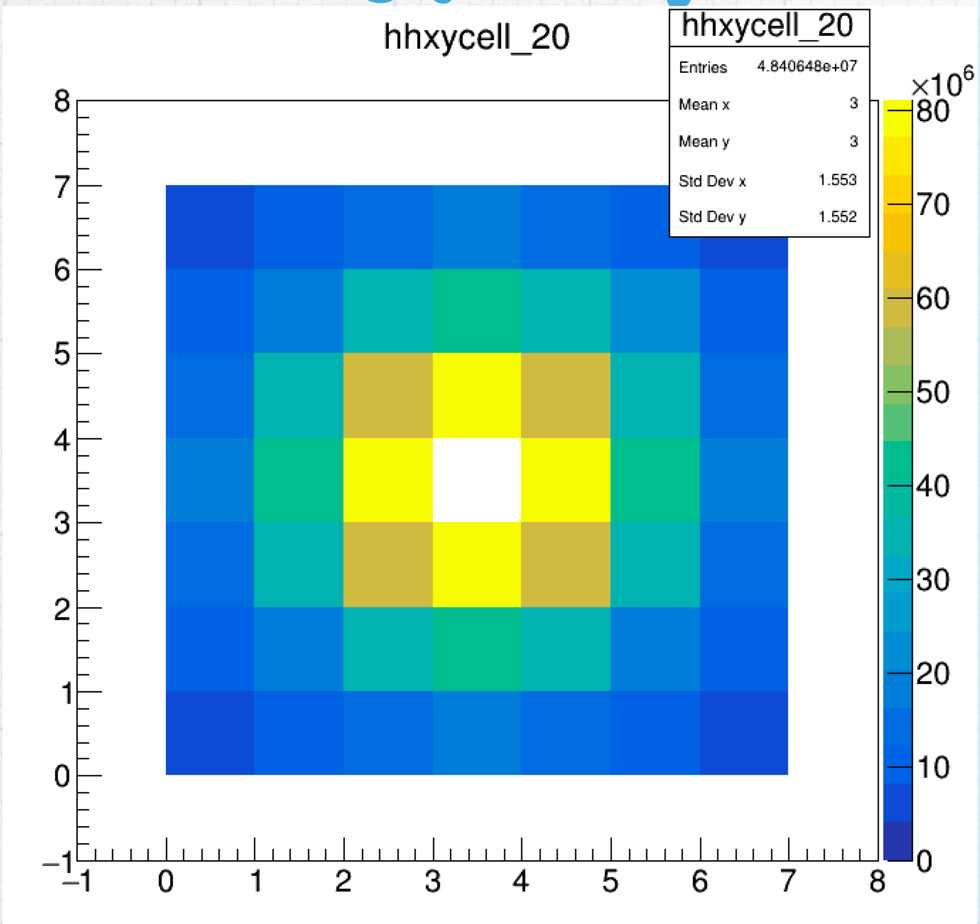
- The units are correct - GEV
- The number of particles entering each block per 100 BX
  - for ξ =2.6

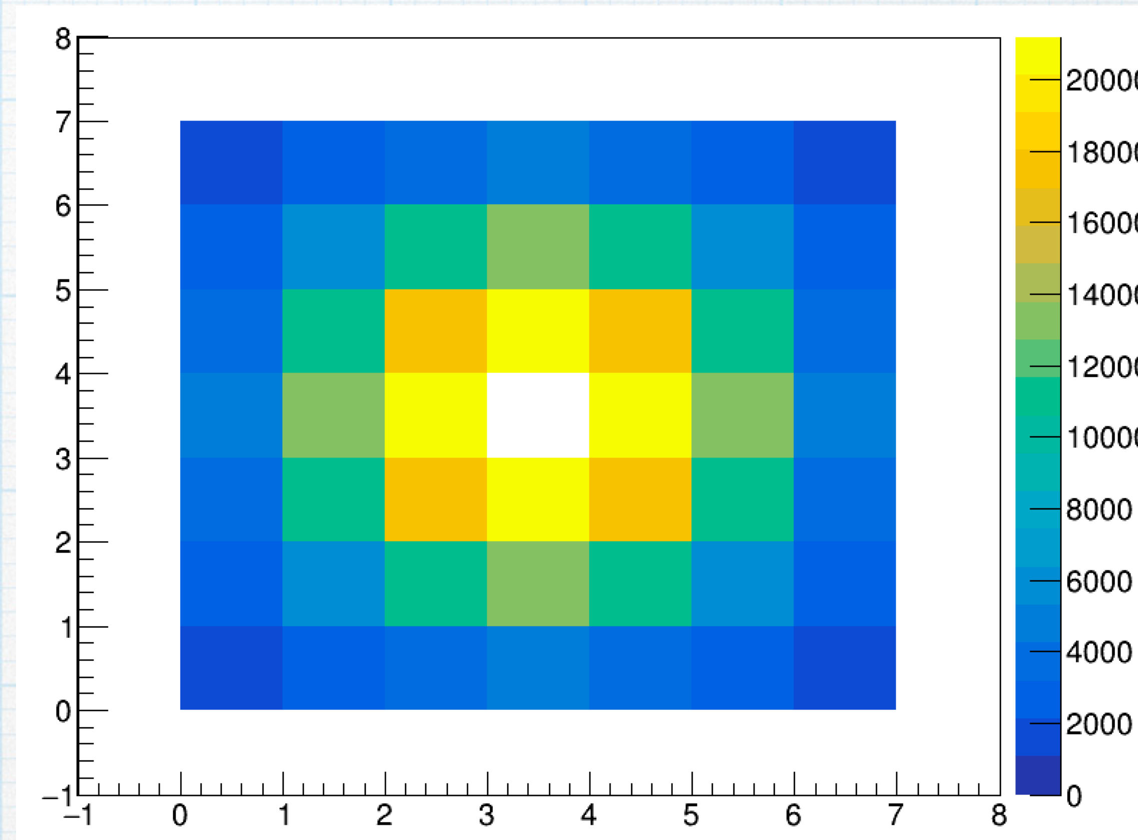


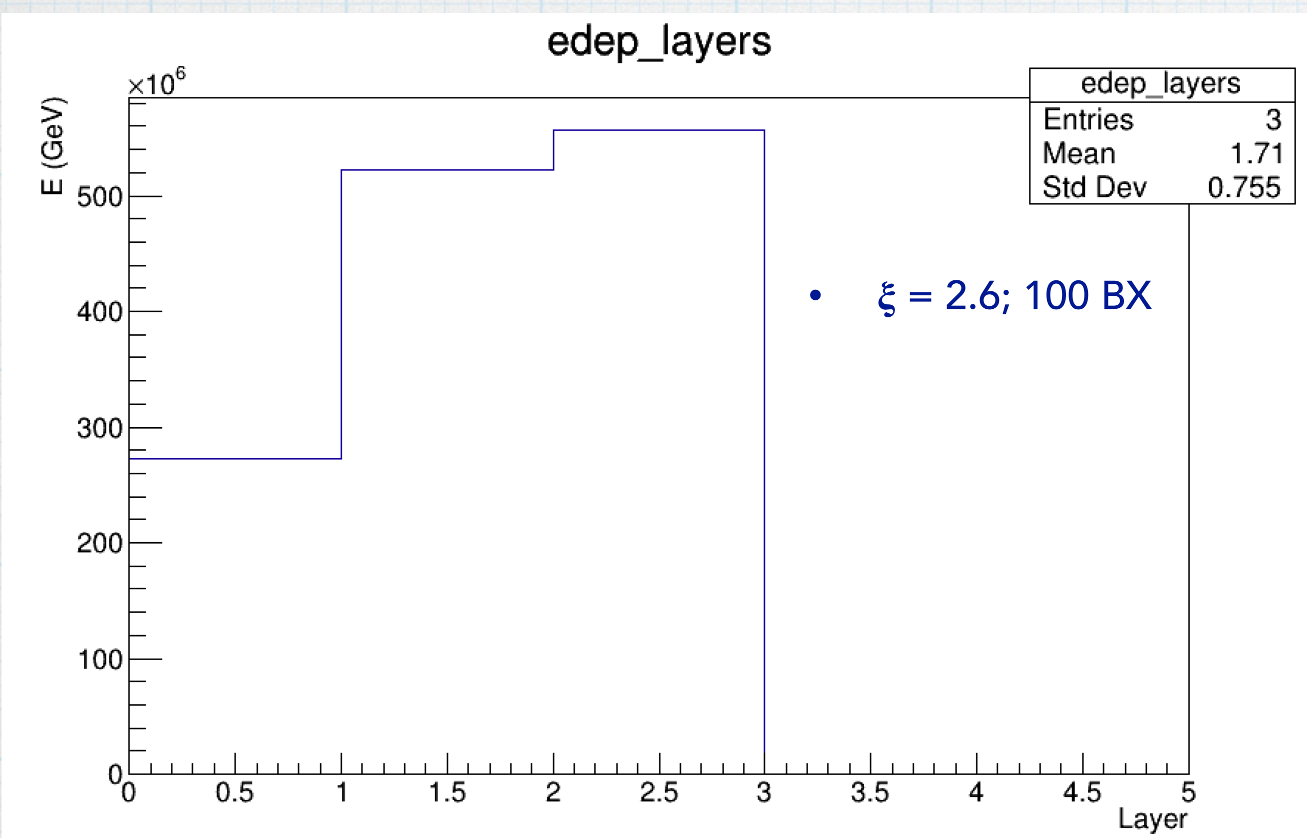
  - for ξ =0.26

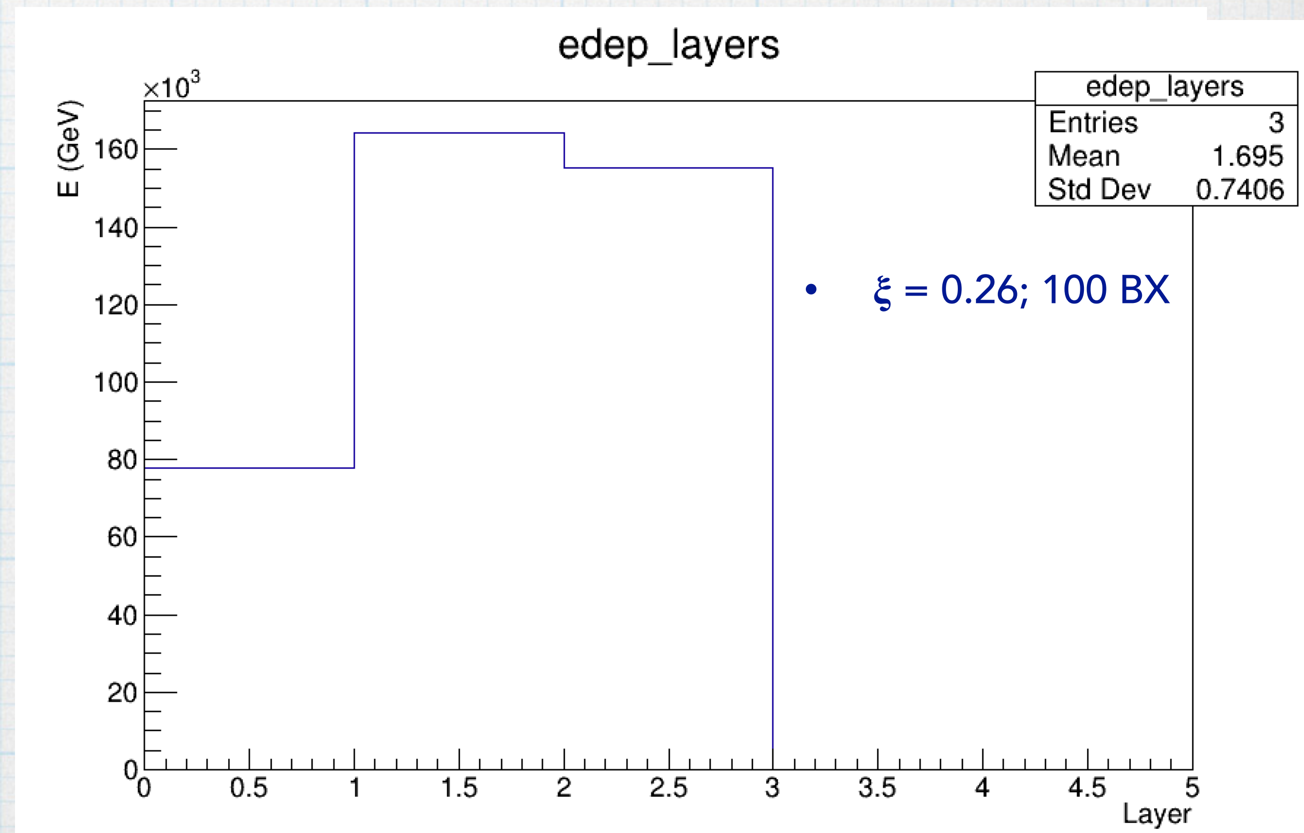


Energy deposit, 48, ξ =2.6 vs ξ=0.26









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.

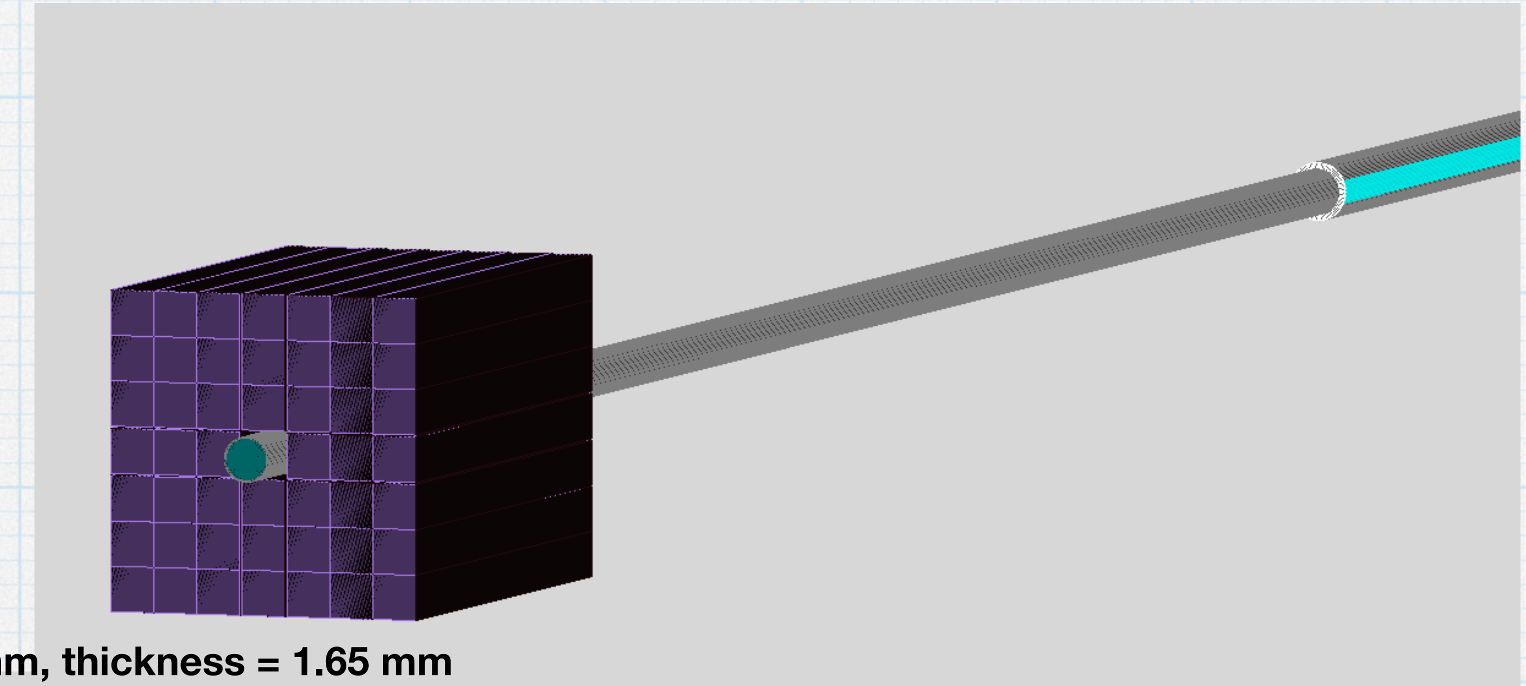
The following requirements must be imposed on a such detector system. • Low-sensitivity to background.
• Linearity within the intensity range $N_{\gamma} = (10^4 - 10^7)$/s.
• Fast ($\tau \approx 10$ ns).

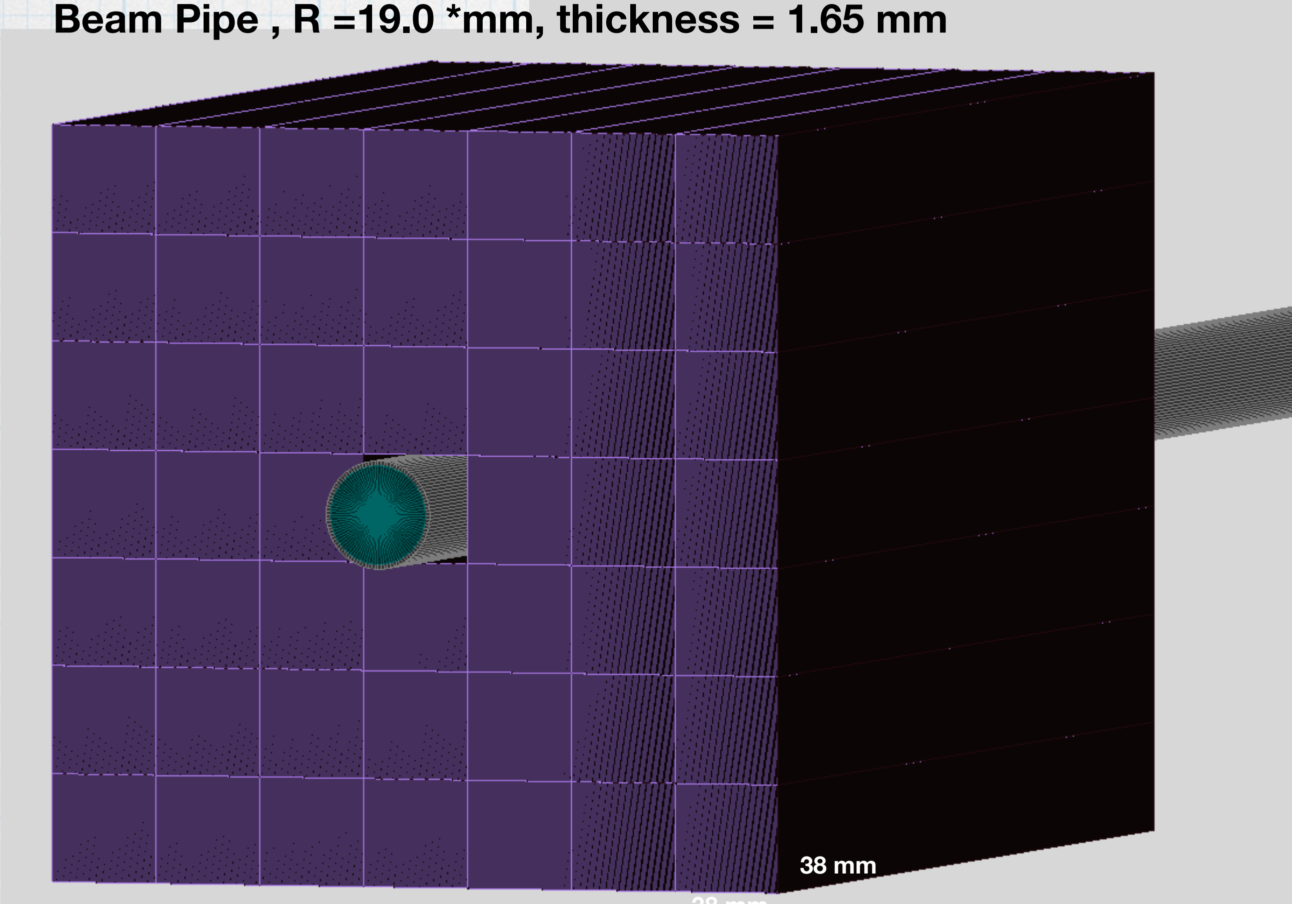
• Spatial resolution: ~100 µm.

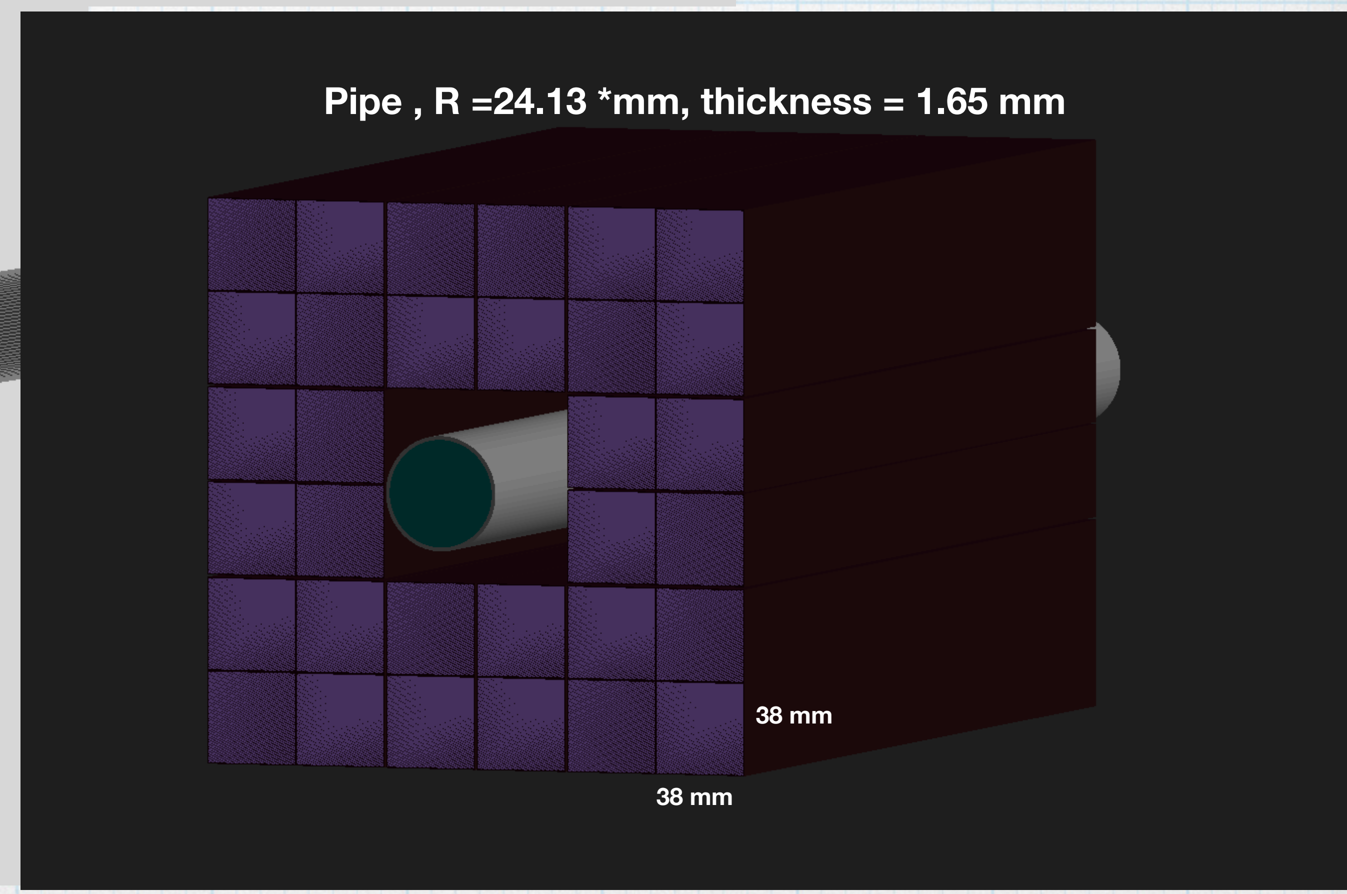
The collaboration plans to construct a fission fragment detector based low pressure wire proportional chambers[73]. This monitor will be located downstream

*

2 configurations: 48 vs 32 LG blocks

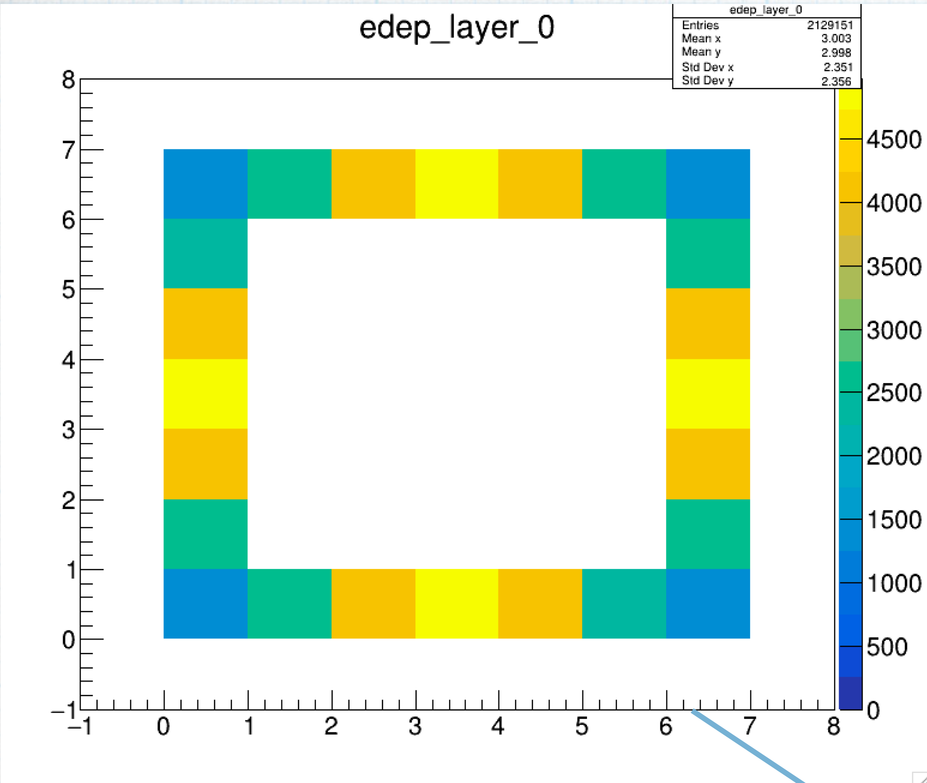


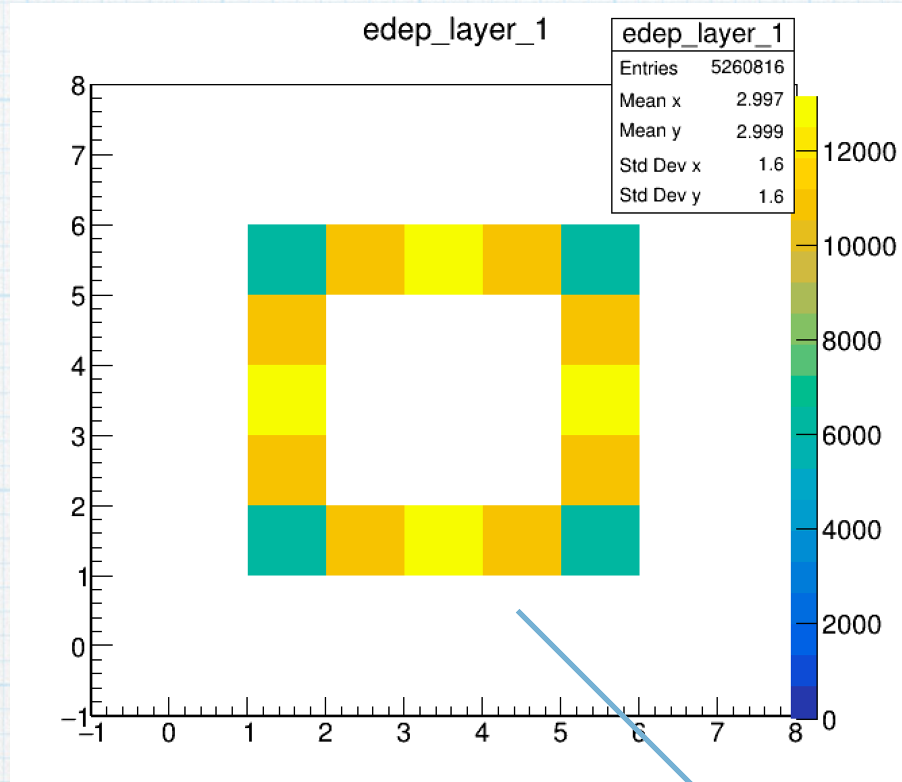


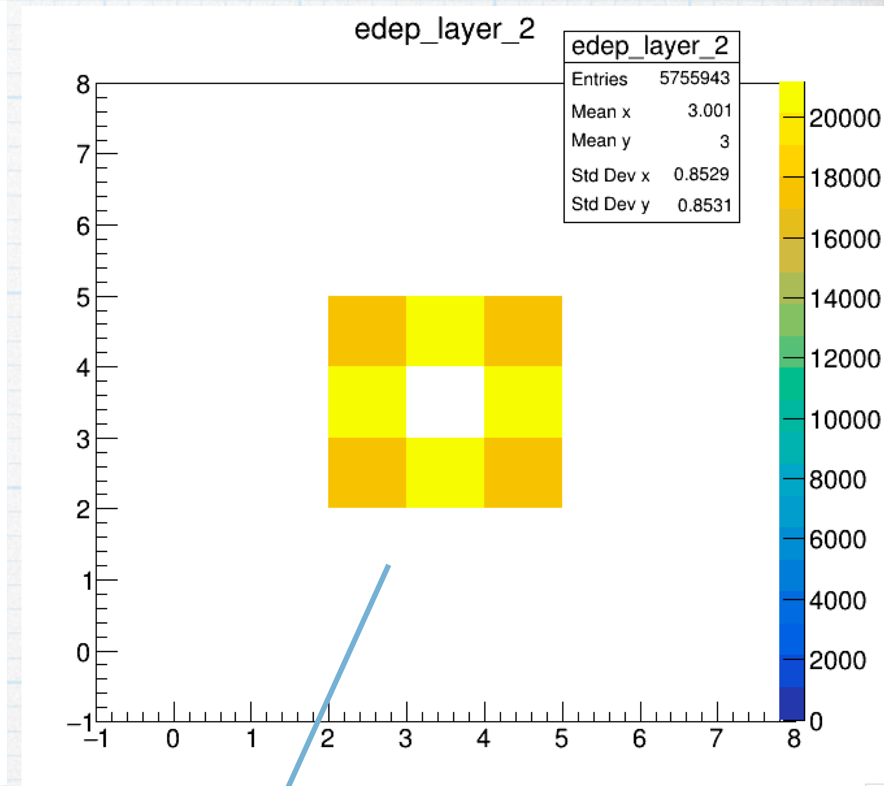


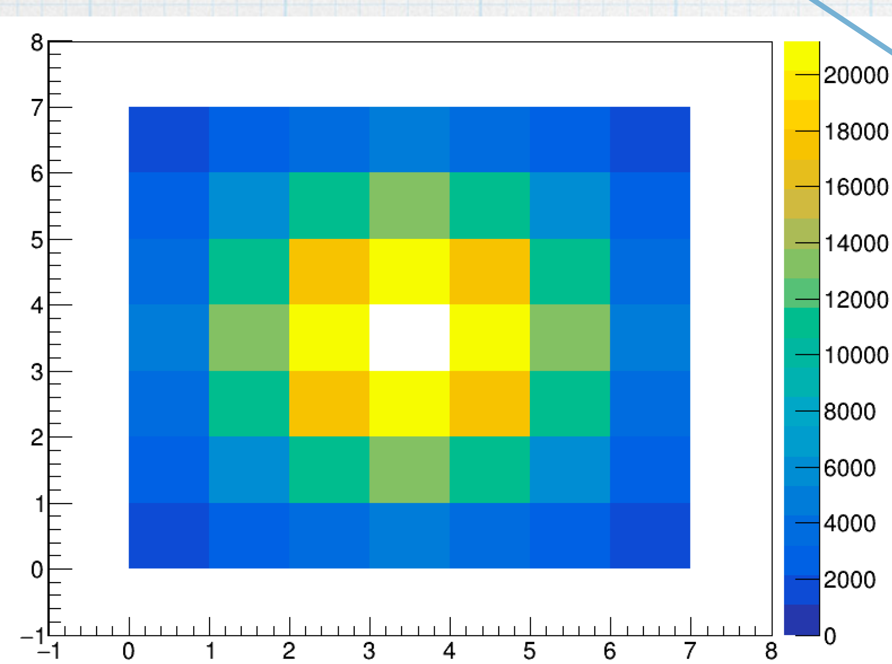
Reduced the size of the beam pipe to be consistent with the blocks size and to be able to monitor the area close to the beam pipe.

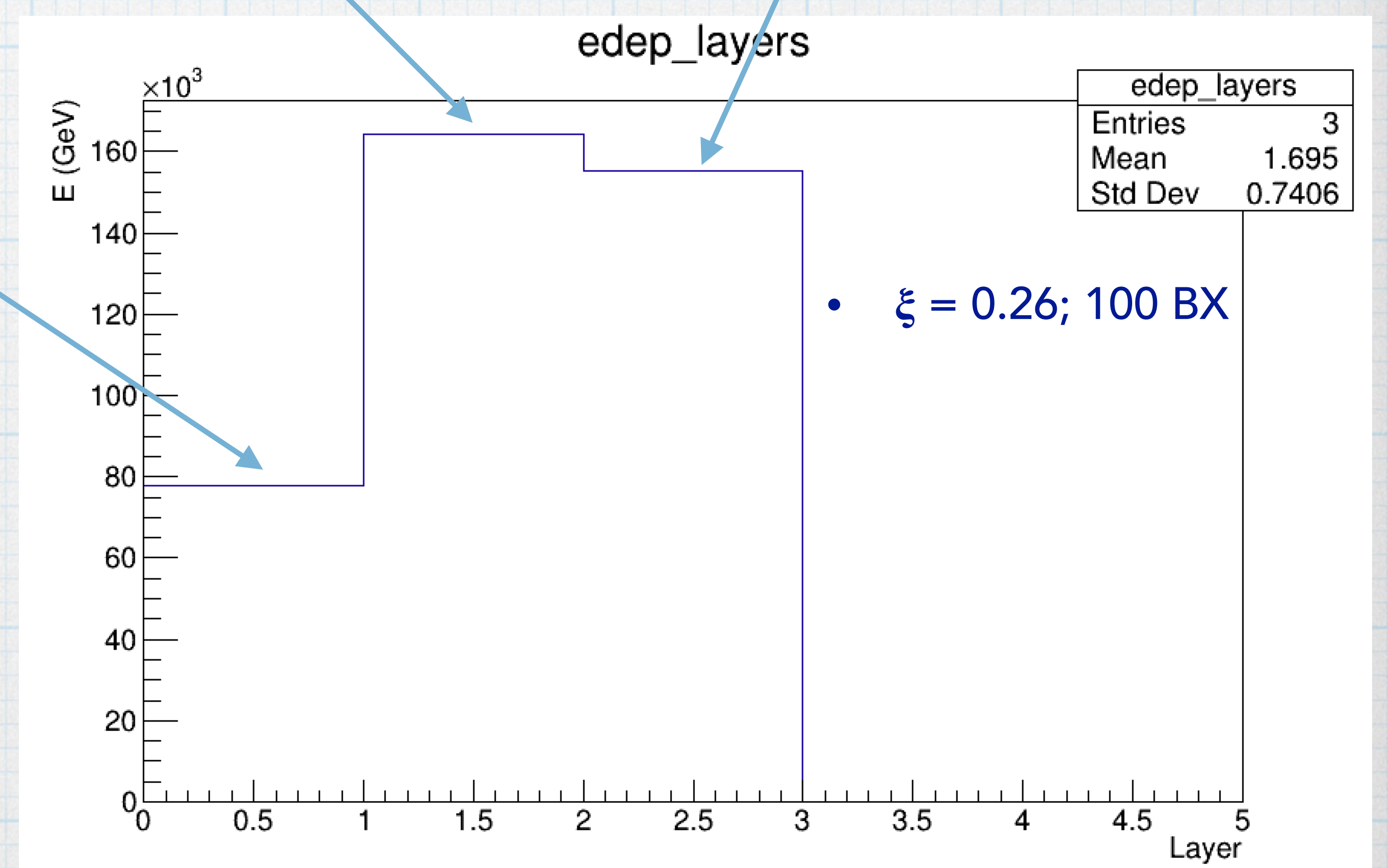
Energy deposition in layers, 48 LG blocks







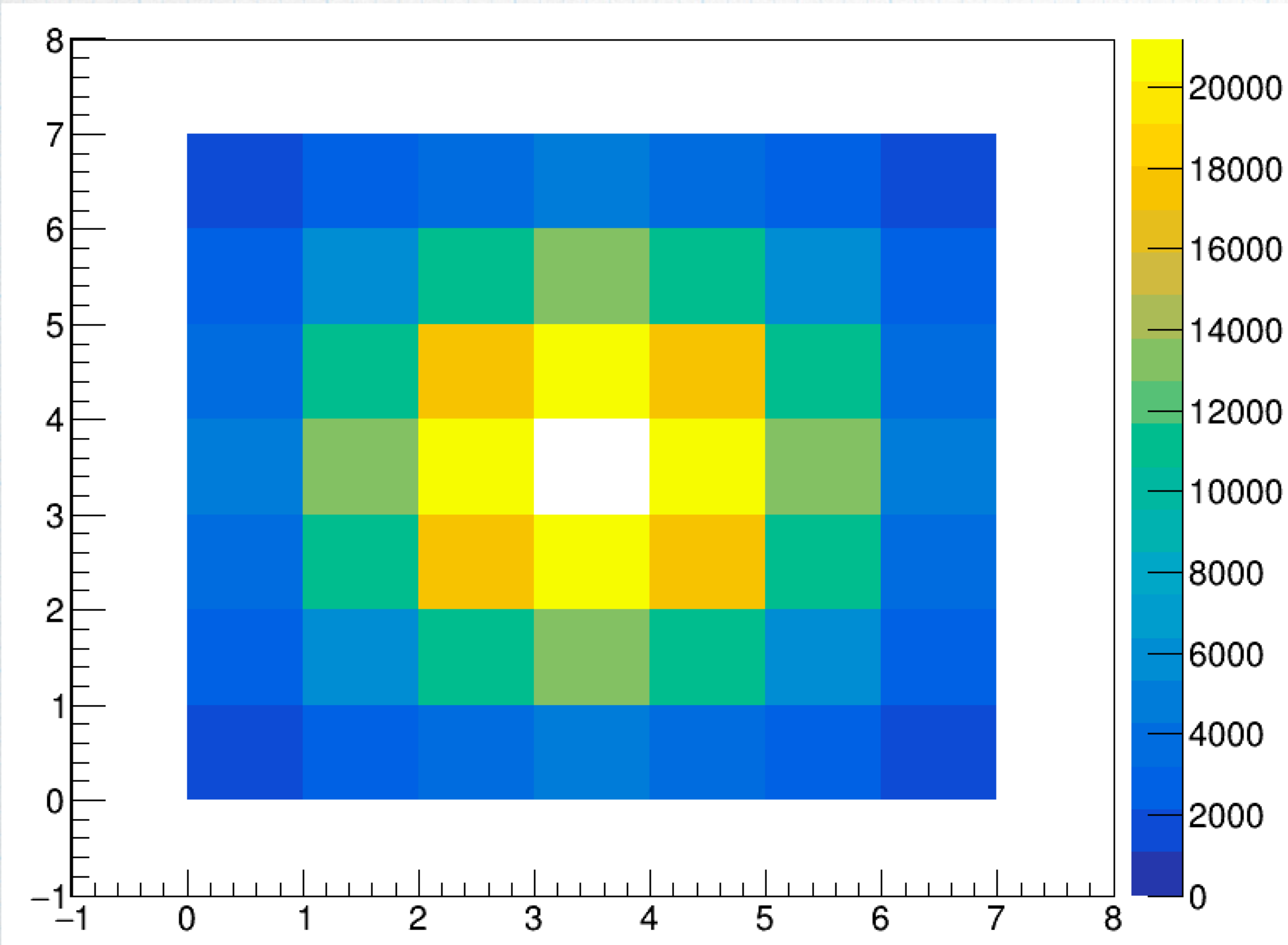


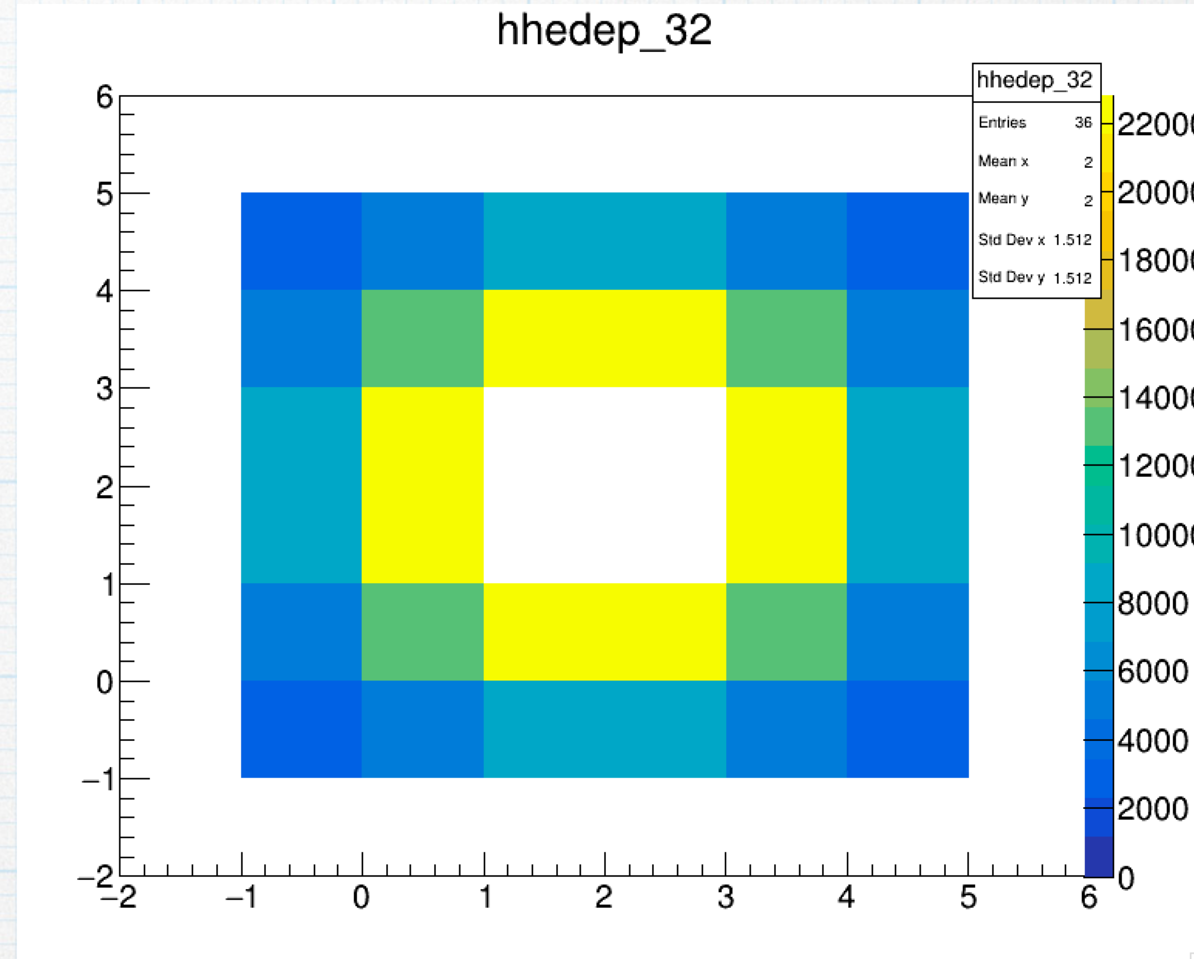


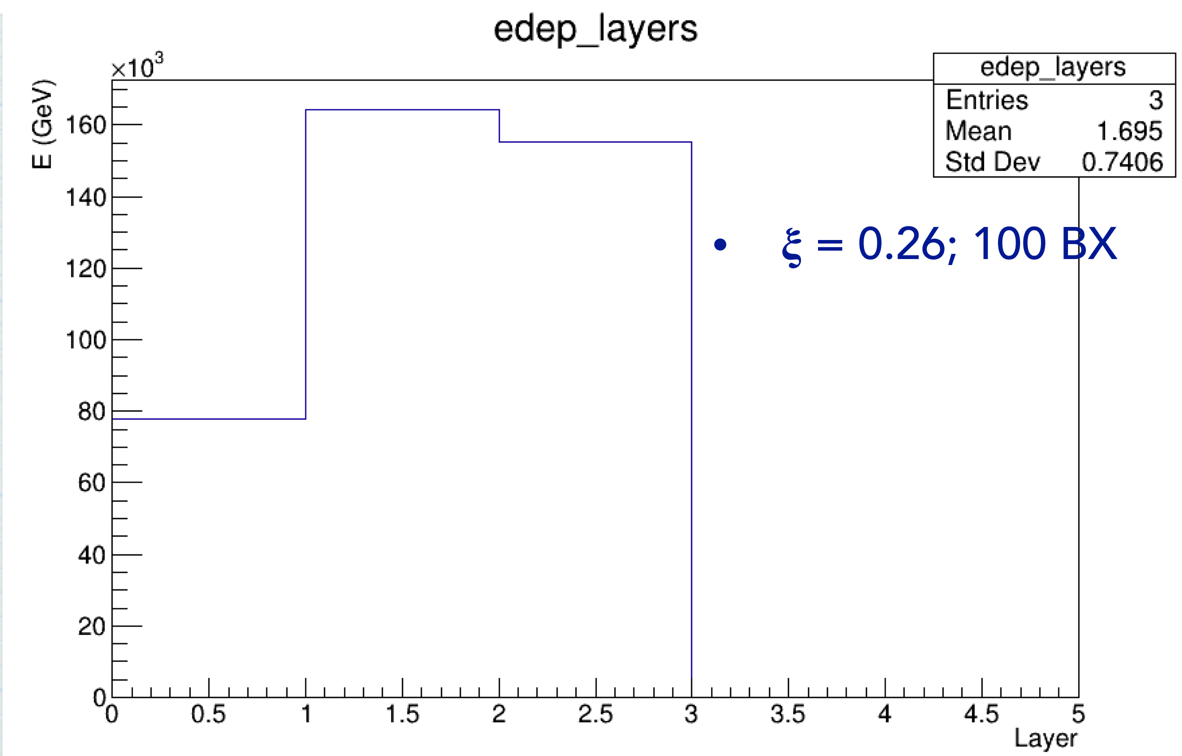
- ξ = 0.26; 100 BX

for ξ=0.26 Edep in the dump ~10^7 ⇒ Edep in the GM ~ 10^3

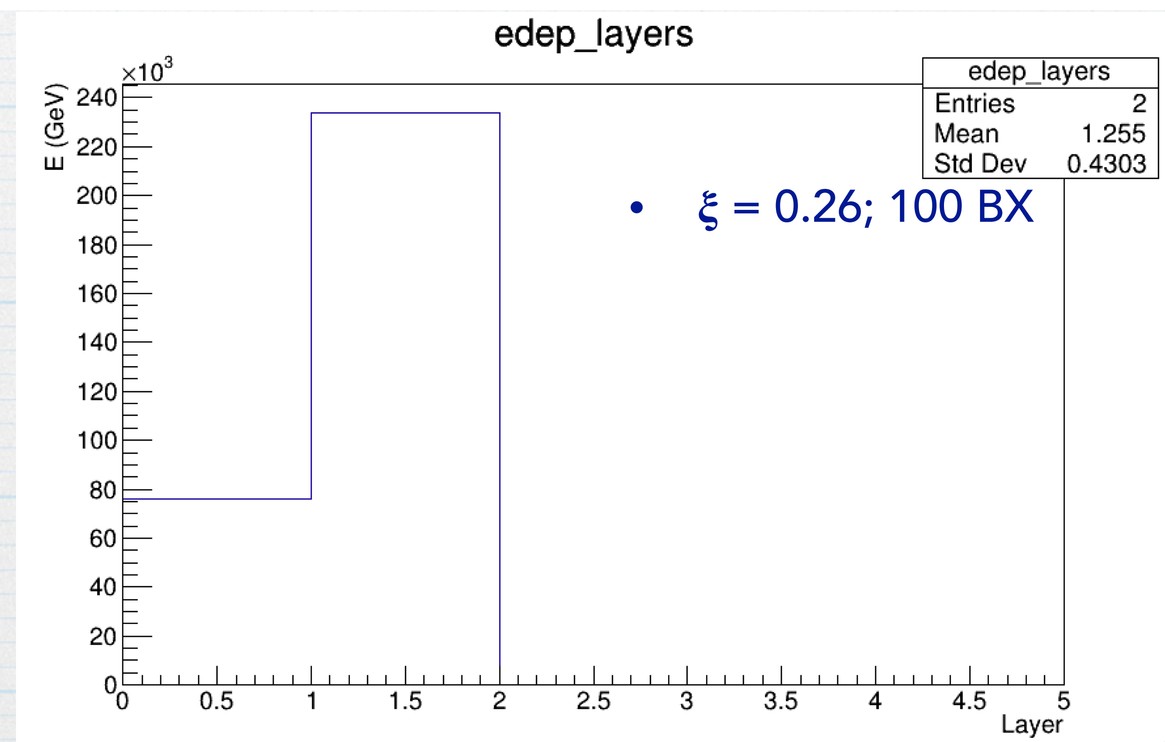
Energy deposition, 48 vs 32 LG blocks







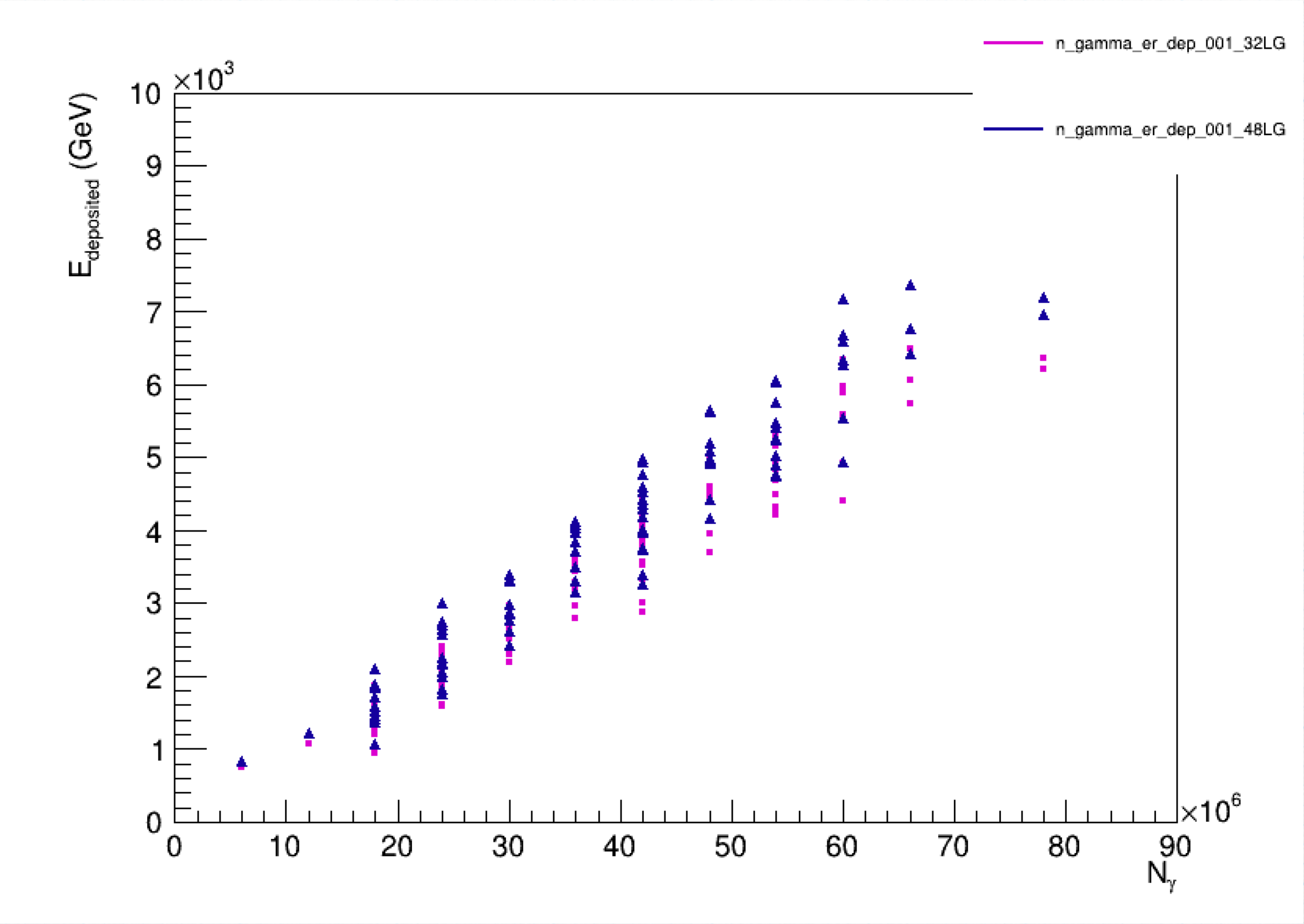
- $\xi = 0.26$; 100 BX



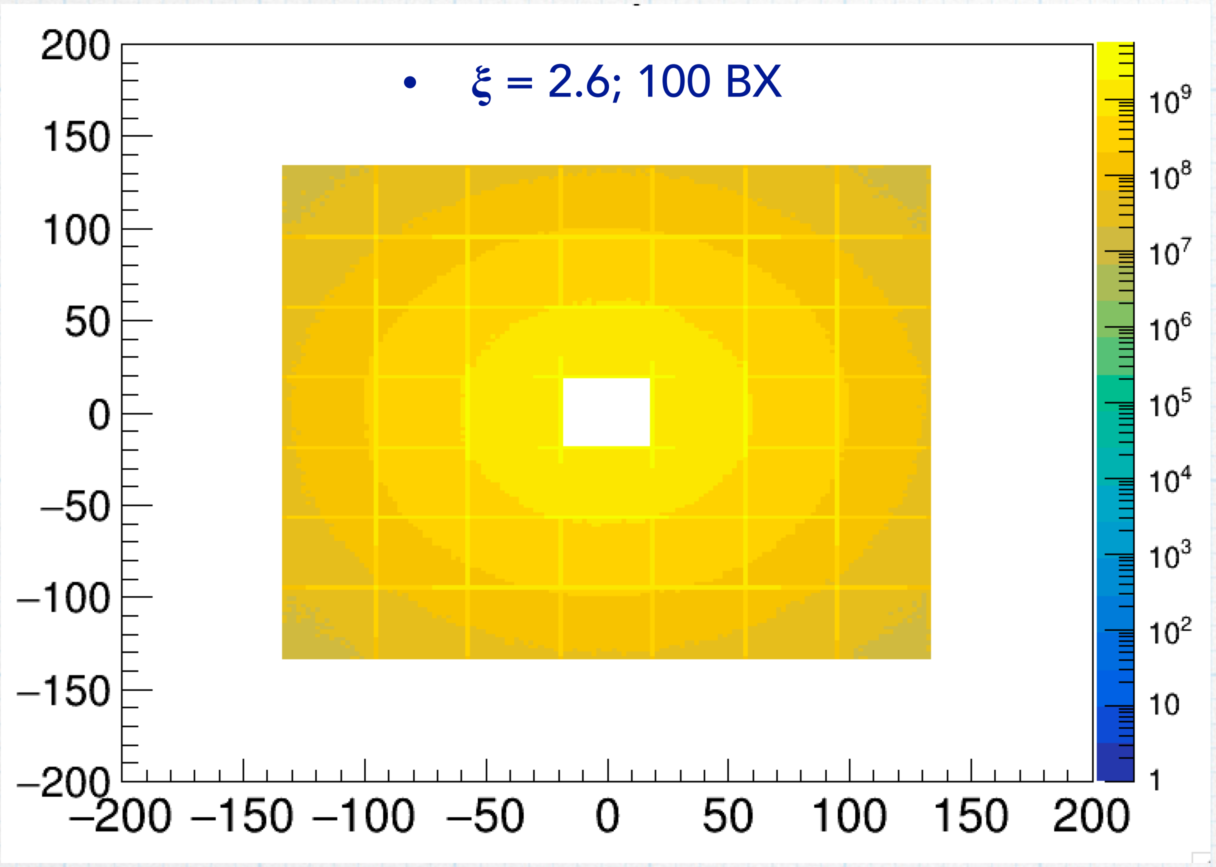
- $\xi = 0.26$; 100 BX

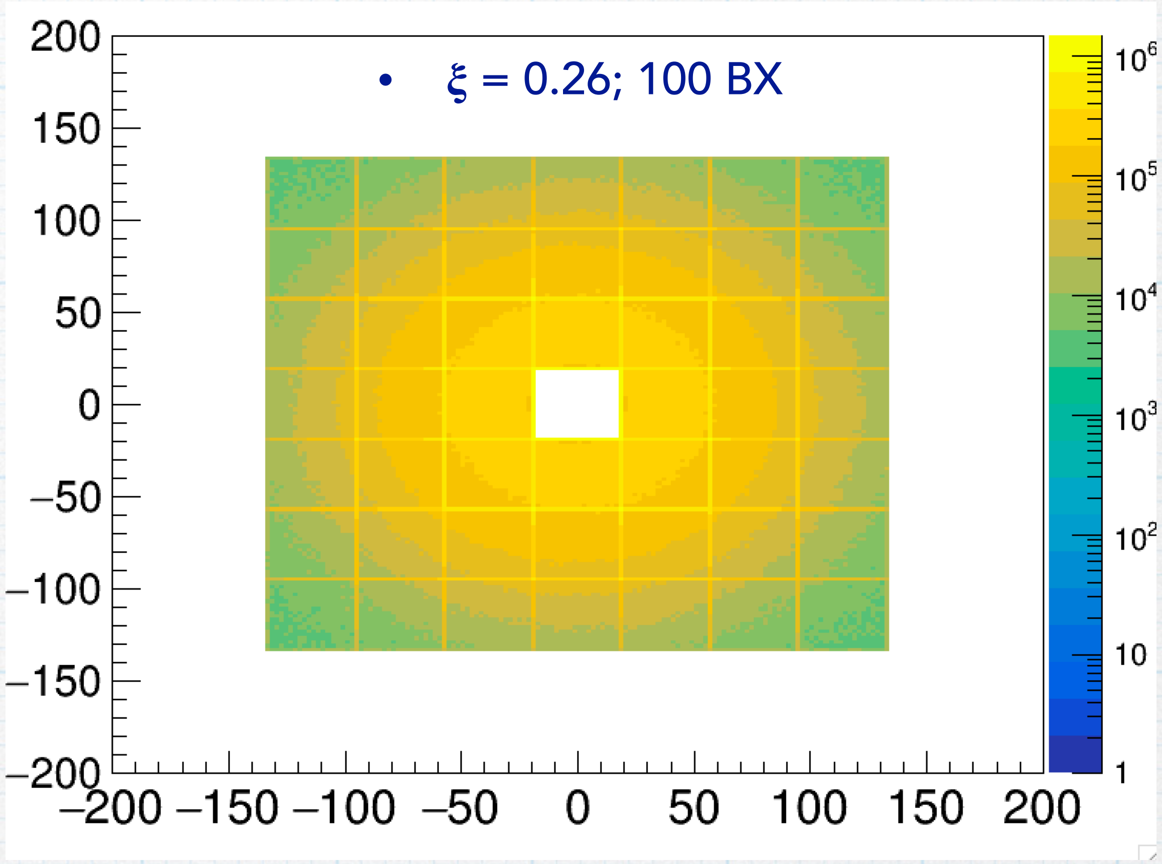
Deposited energy versus true number of photons.

Each point is one BX



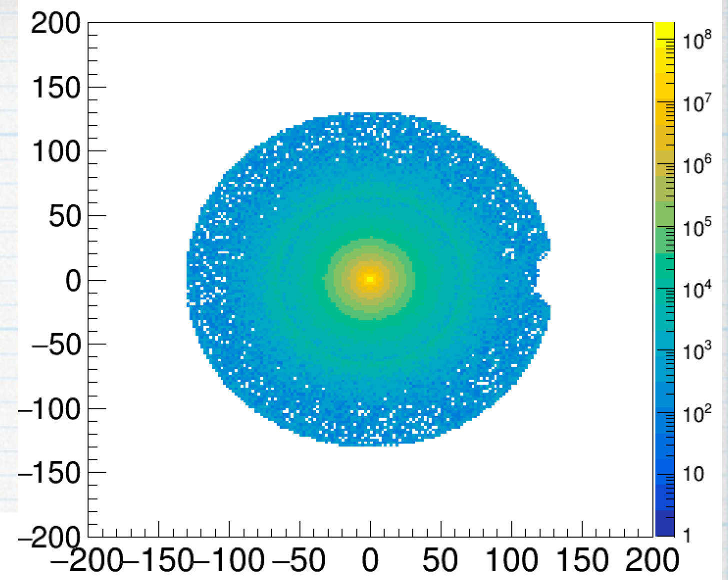
Track density, 48, ξ =2.6 vs ξ=0.26





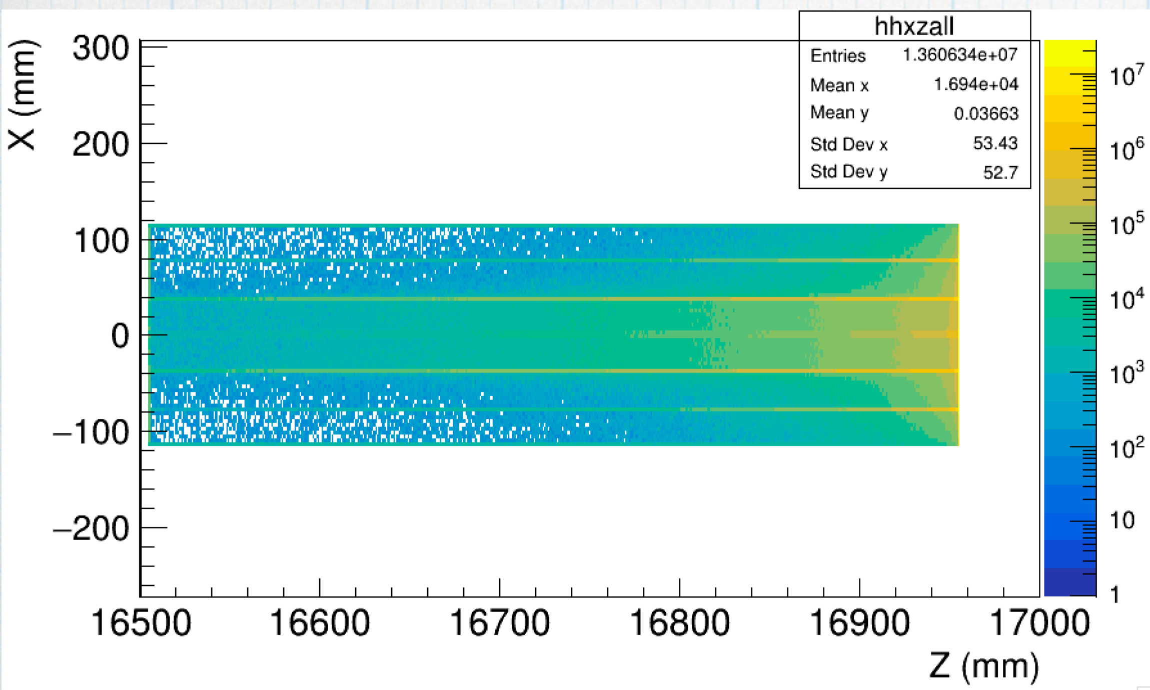
Track density on the surface of LG blocks in XY plane

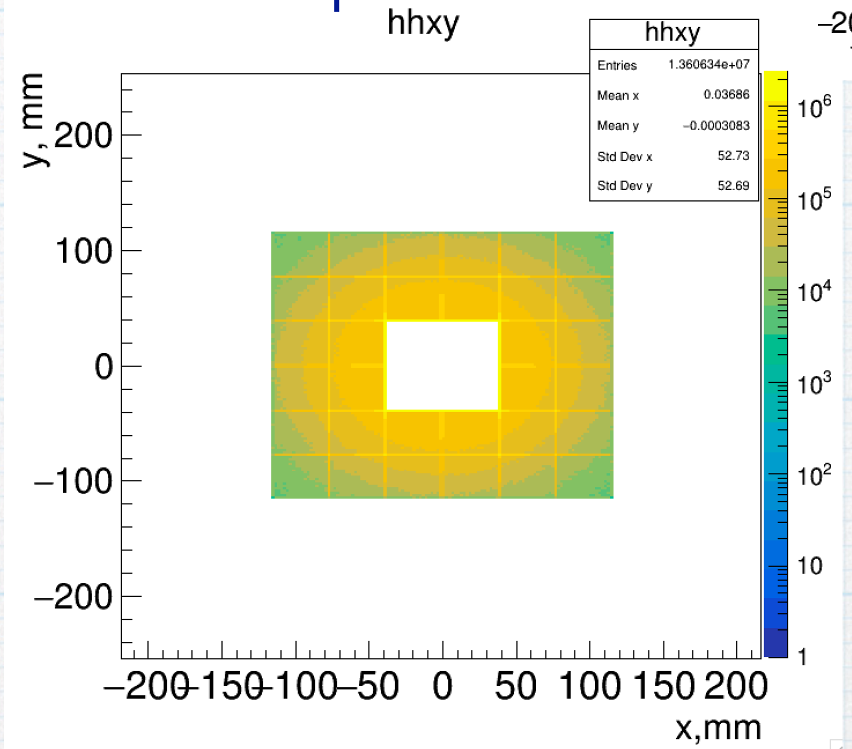
Simulation and Performance 32 LG vs 48 LG



- ξ = 0.26; 100 BX

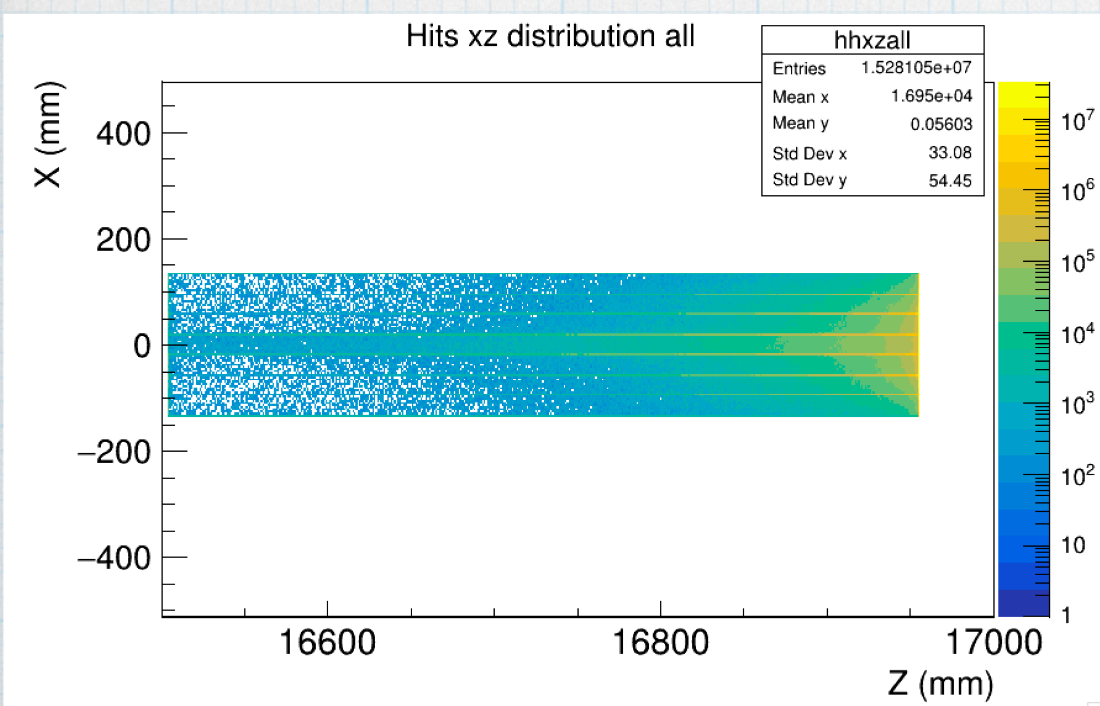
Track density on the surface of LG blocks in XZ and XY planes

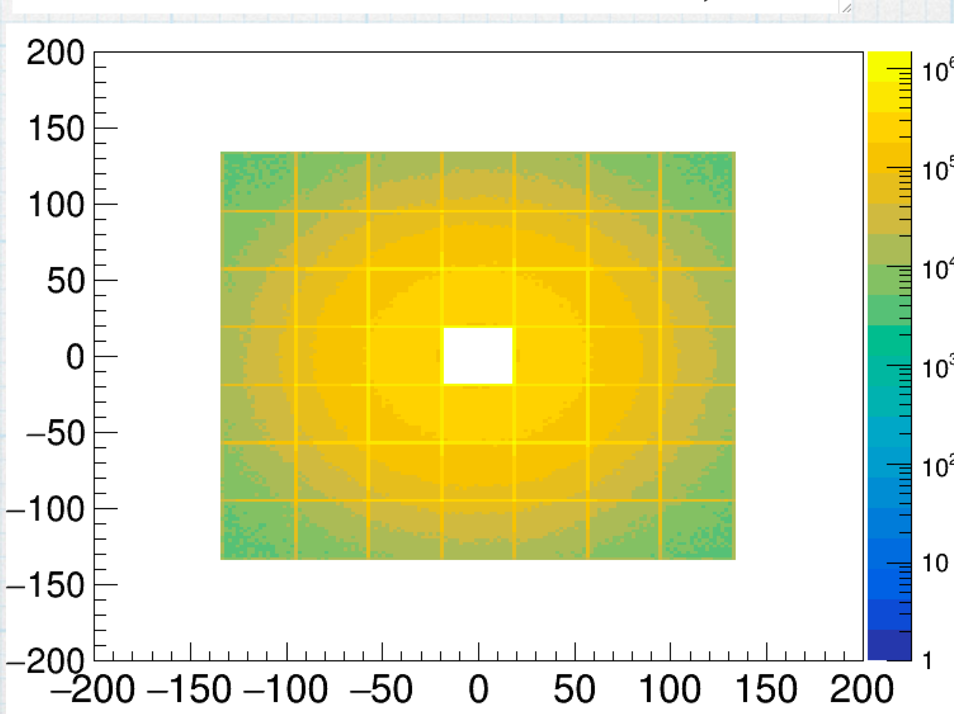


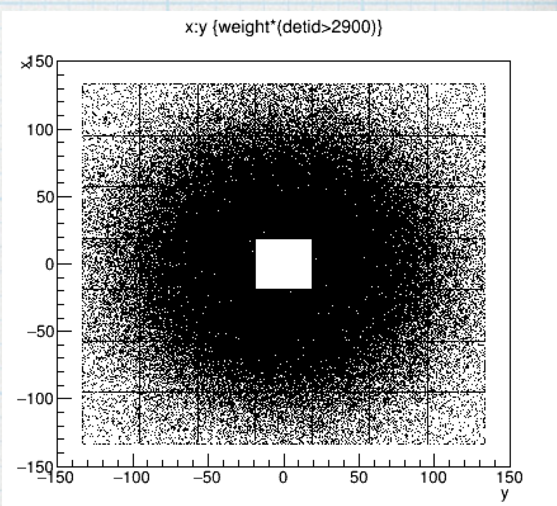


Required all the vertices to be from Beam Dump

- ξ = 0.26; 1 BX

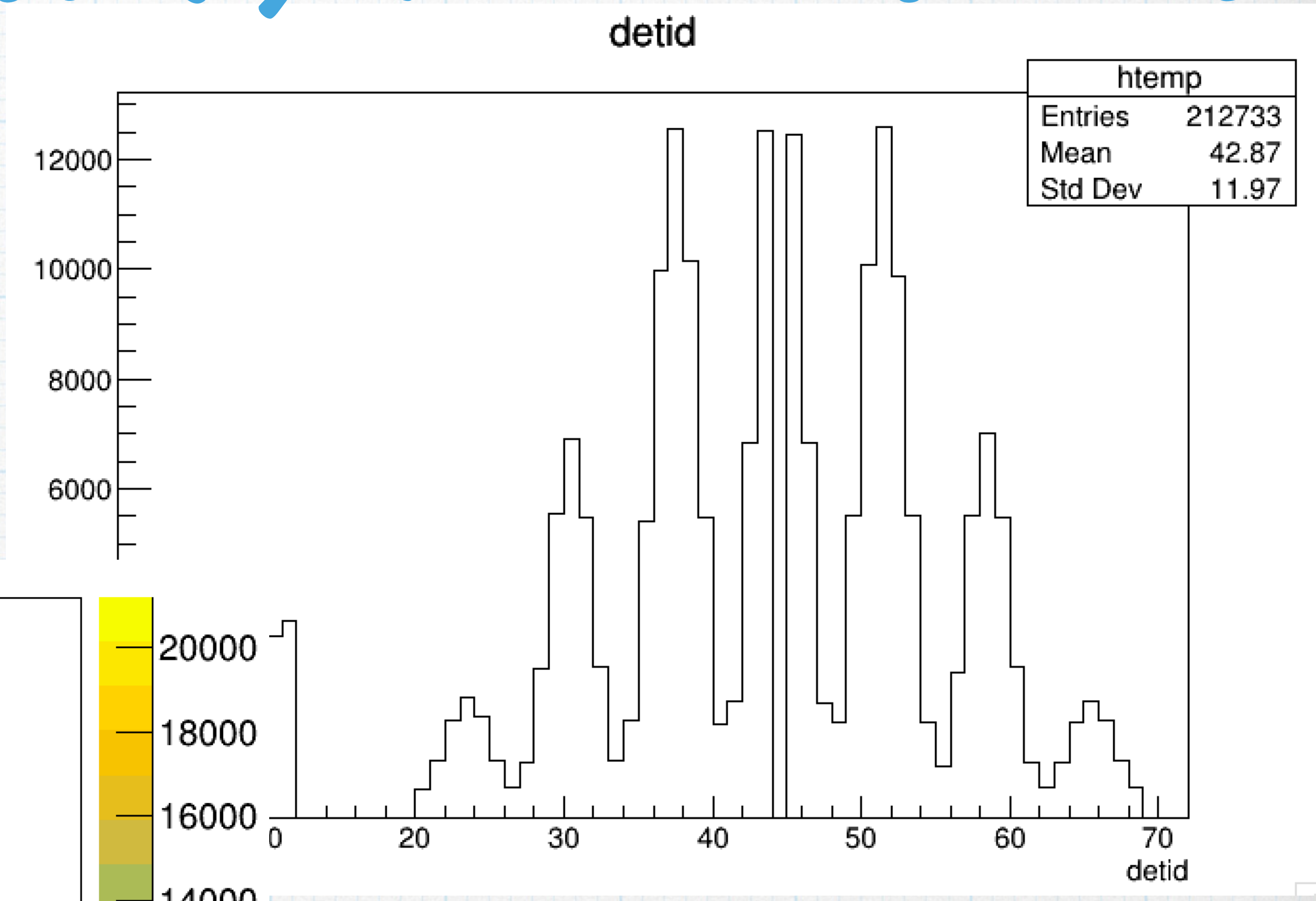


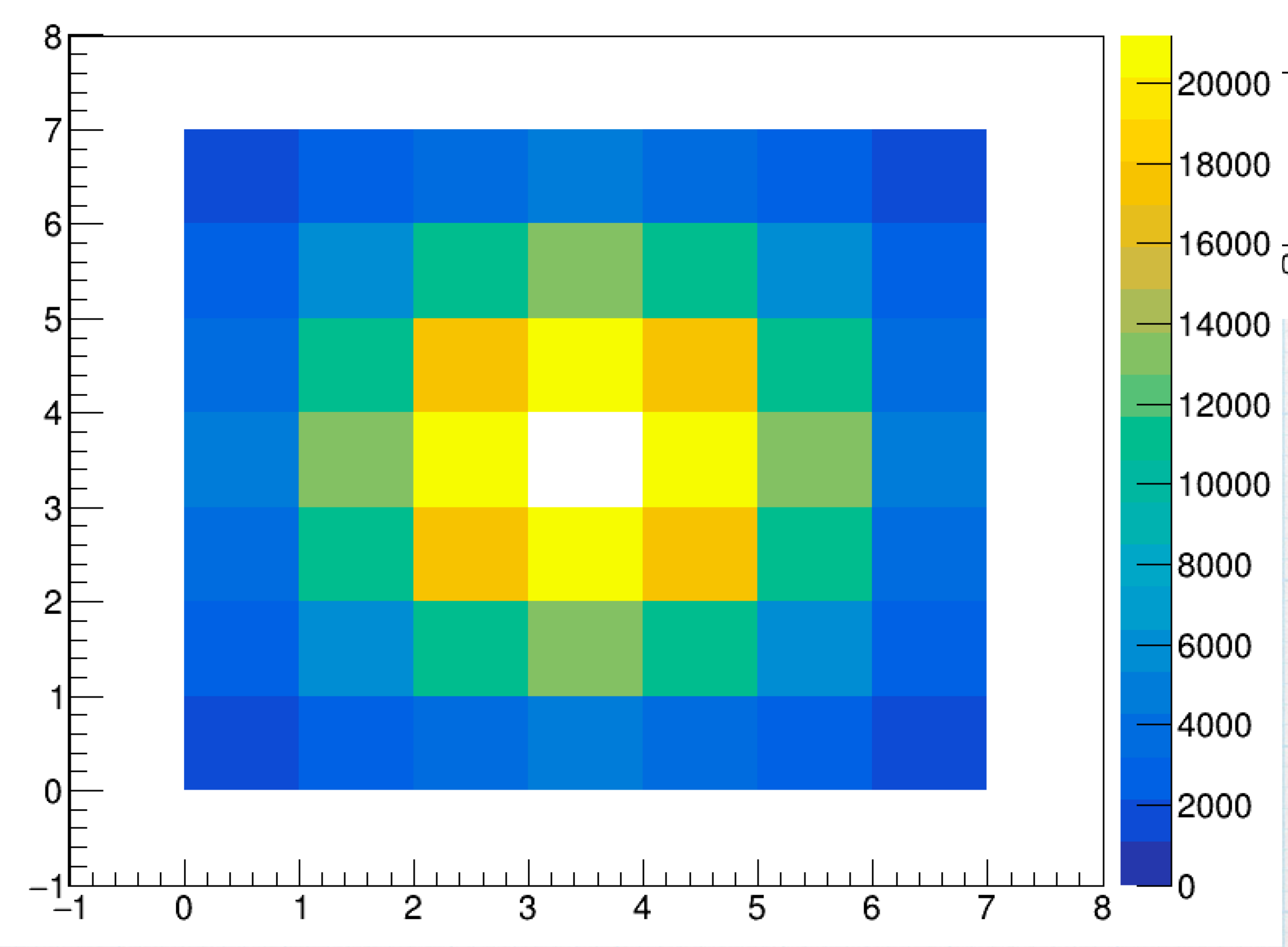




Energy deposition, 48 LG blocks

- 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

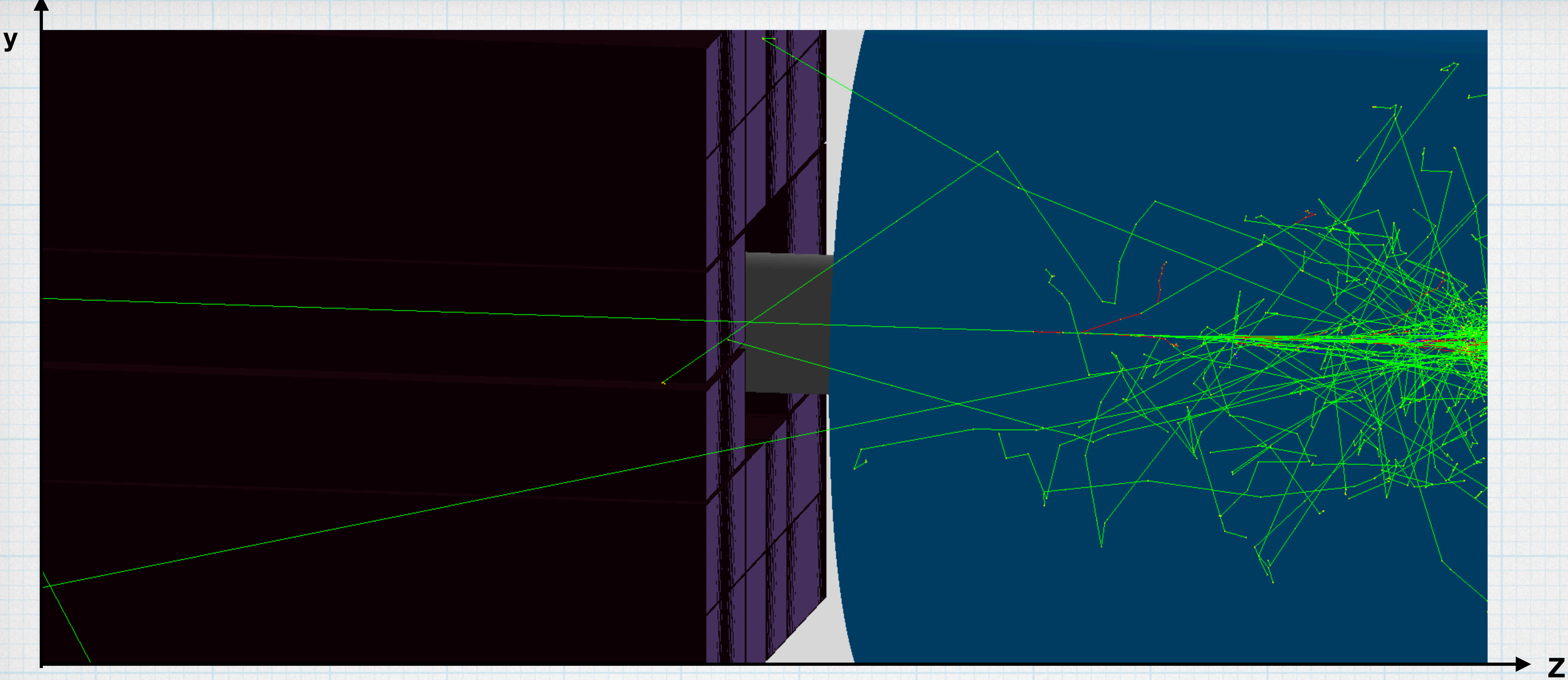
Chemical Composition of TF-1 LG

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
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	

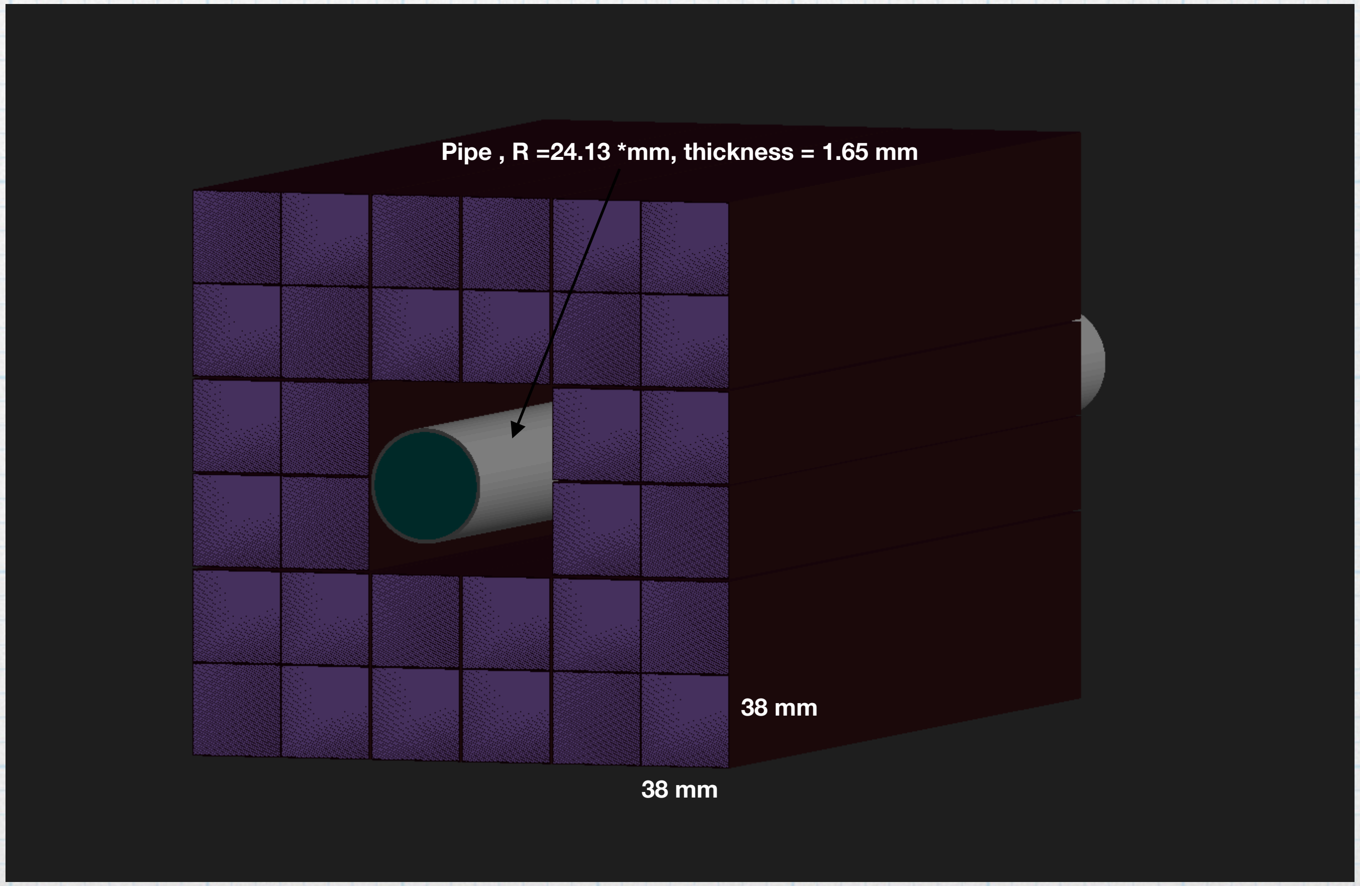
Used previously in
GAMS-2000 spectrometer (Serpuchov)
GAMS-4000 spectrometer (NA-12 experiment, CERN)

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



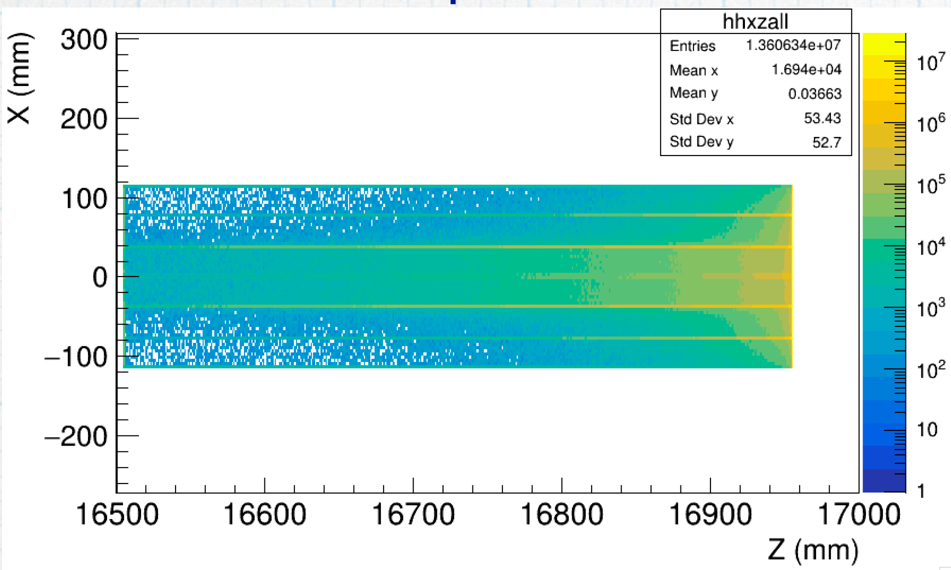
- The implementation in Luxe geometry of the LG Gamma Monitor made of 32 new LG blocks in front of Al-Cu Dump(R(Cu) = 13.0 *cm; R(Al) = 6.5 *cm & L(Al)= 20 *cm)

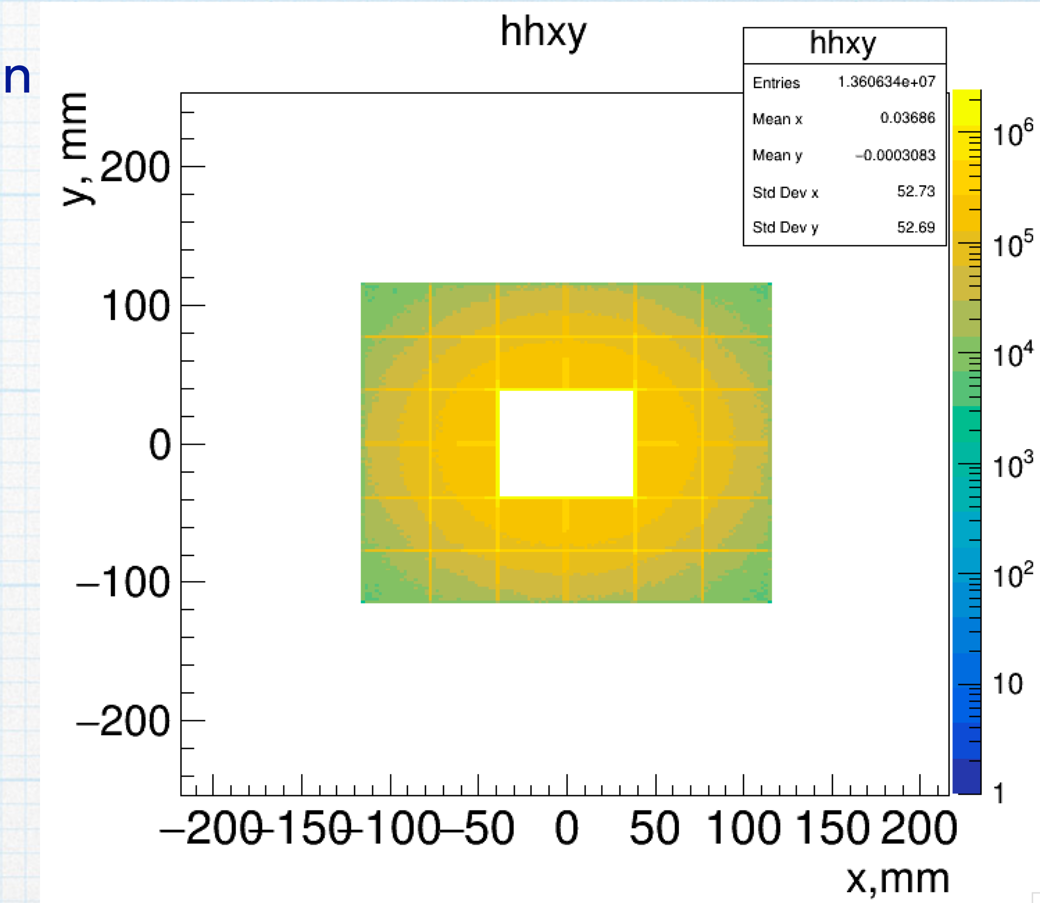
- 32 LG w/ measures 3.8 × 3.8 cm^2, length is 45 cm
- Each block is wrapped with Aluminium foil of 1 mm



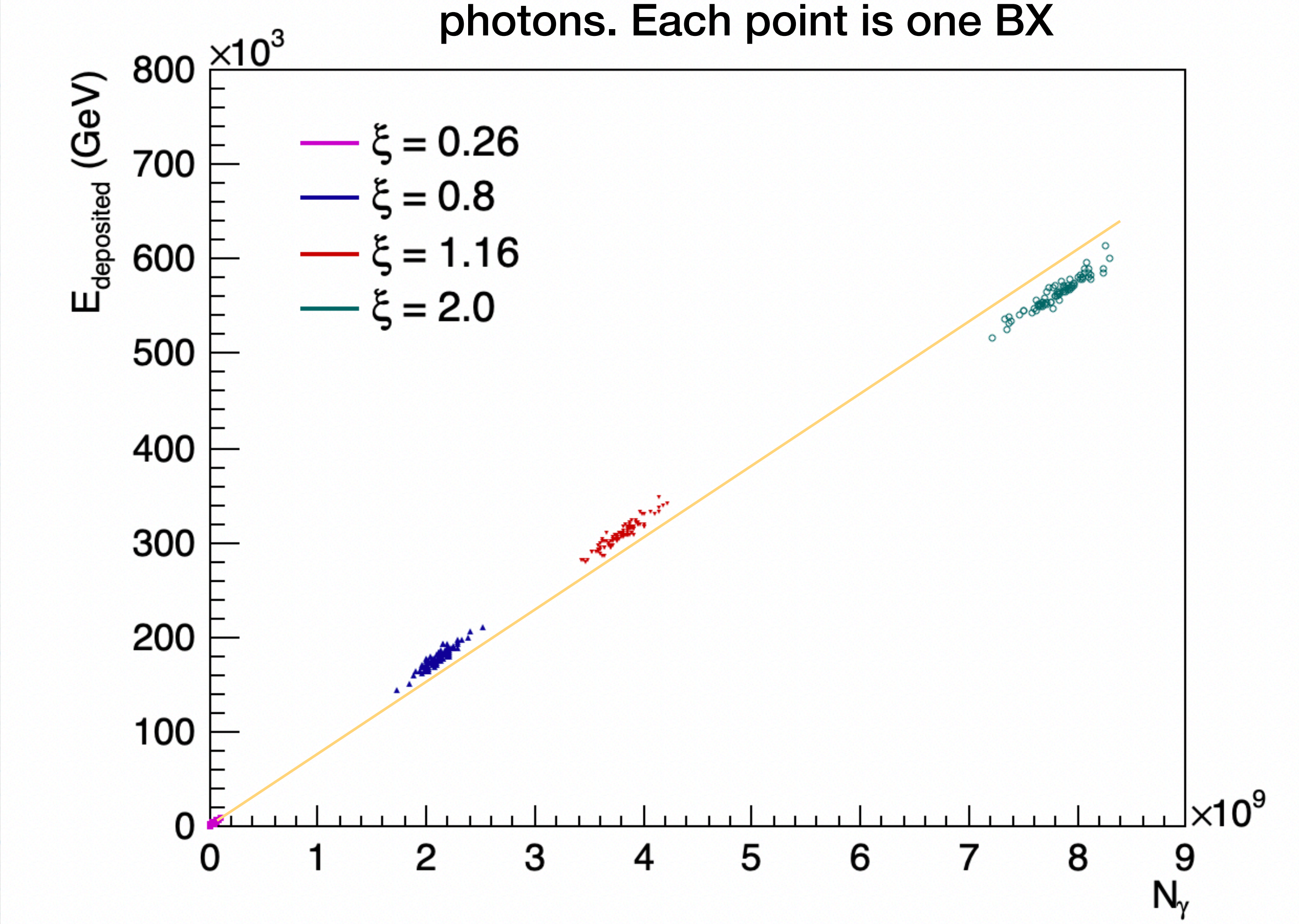
Simulation and Performance

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



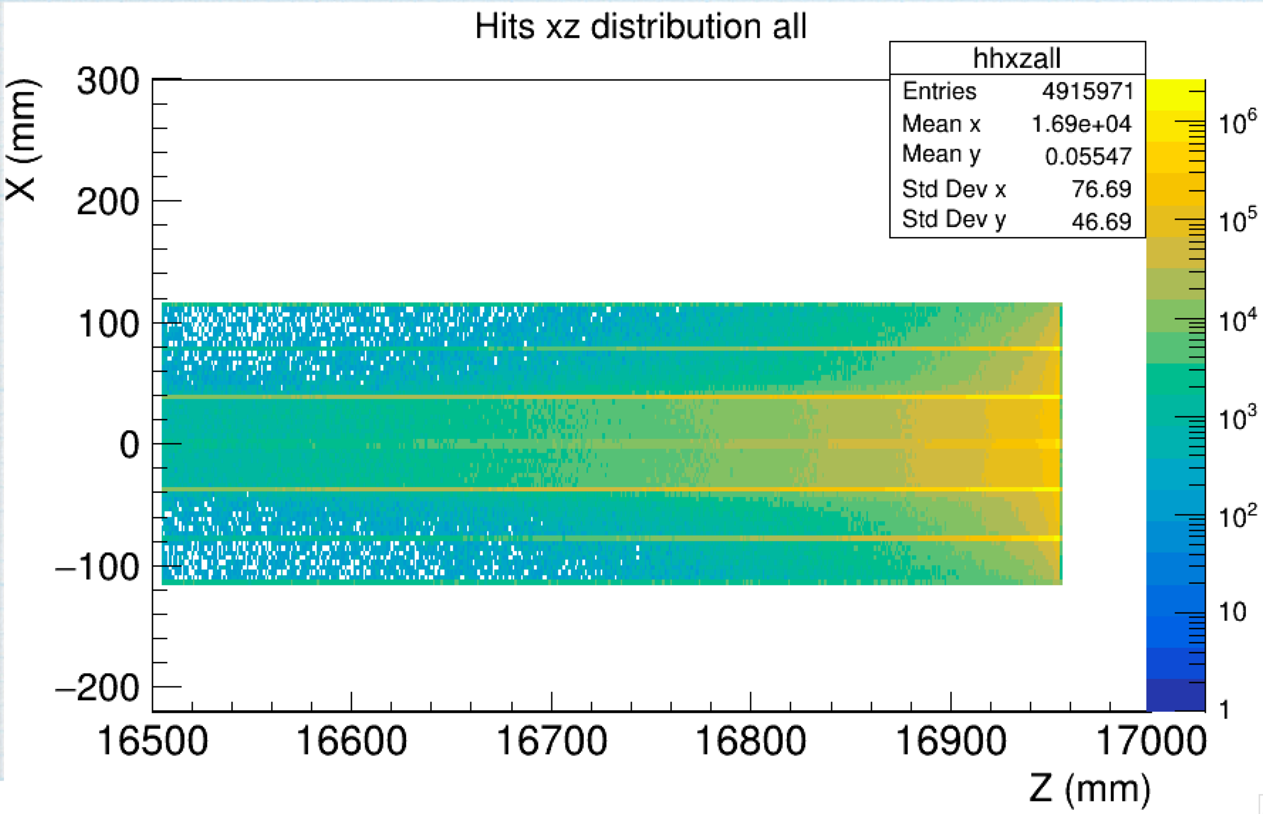


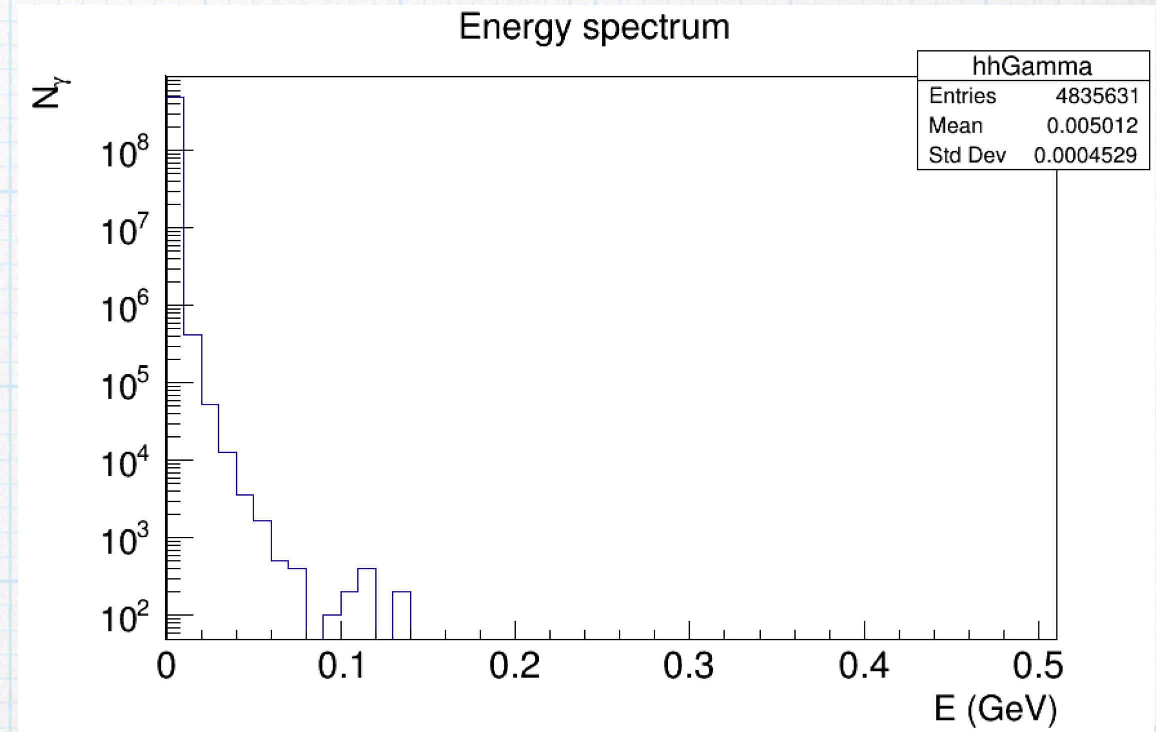
Deposited energy versus true number of photons. Each point is one BX

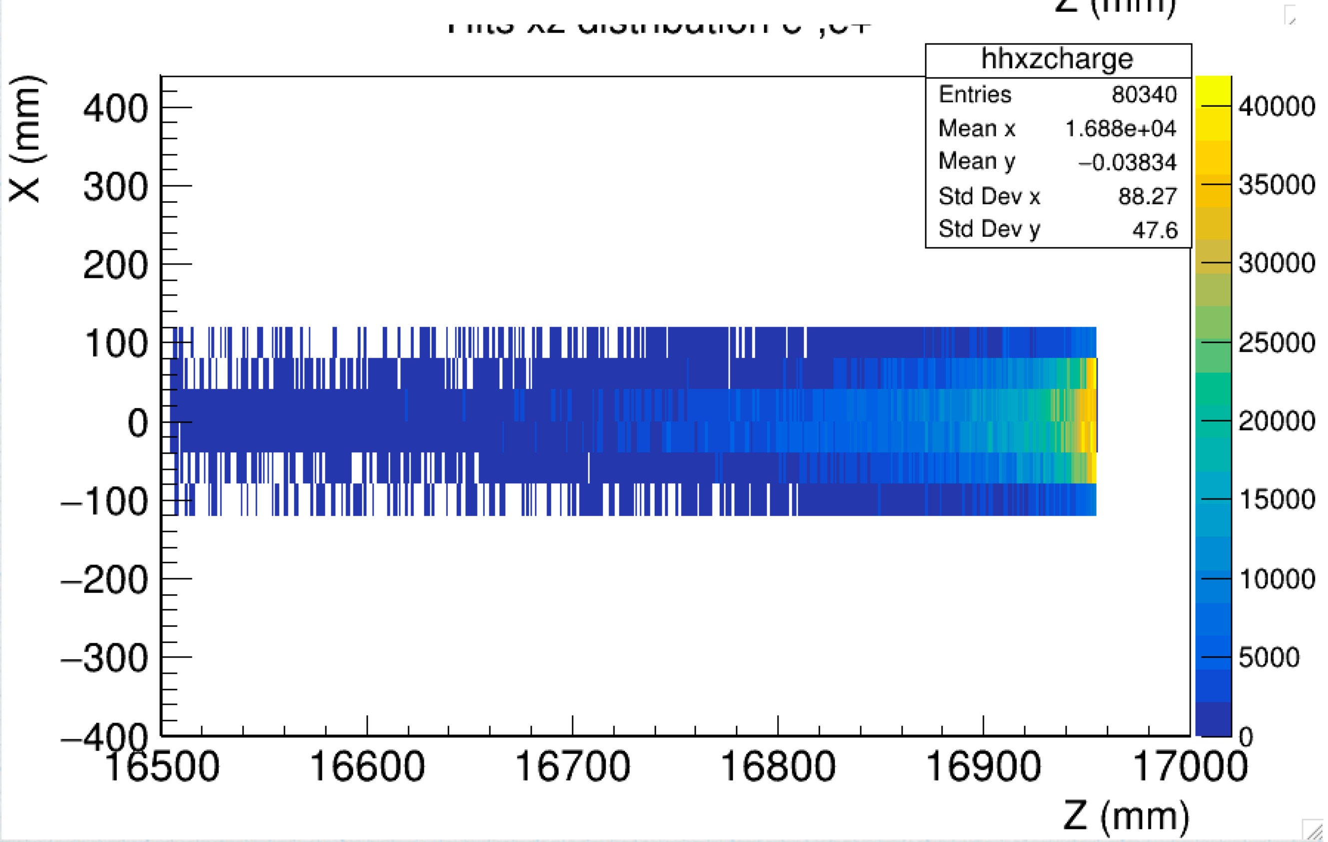


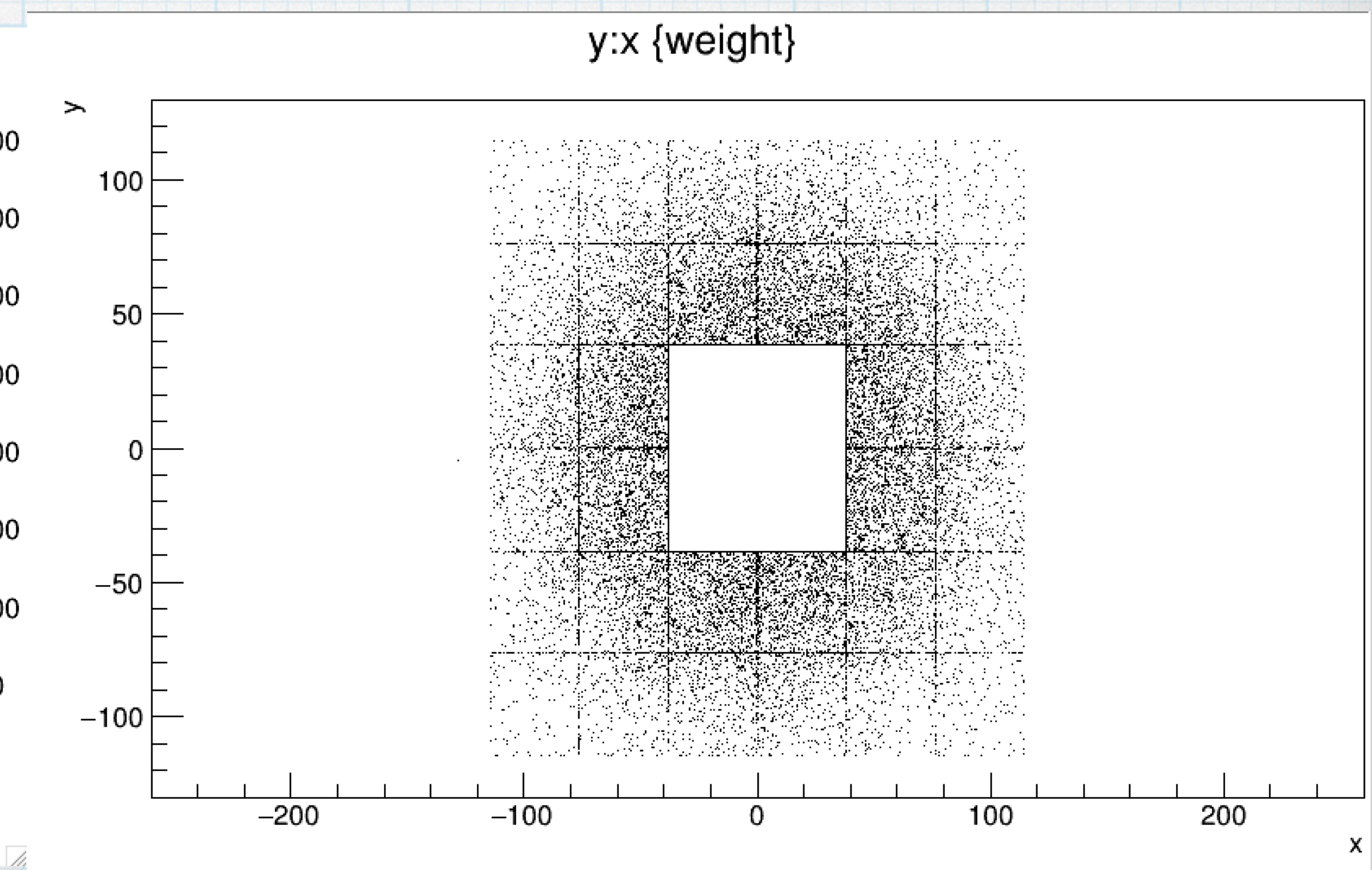
- The (almost) linear dependence of deposited energy on number of incoming photons in GM allows the usage of backscatters for monitoring the photon flux
- For small ξ the HICS spectrum is softer and soft photons produce less back-scatters. This is the reason of small deviation from linearity in Edep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

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

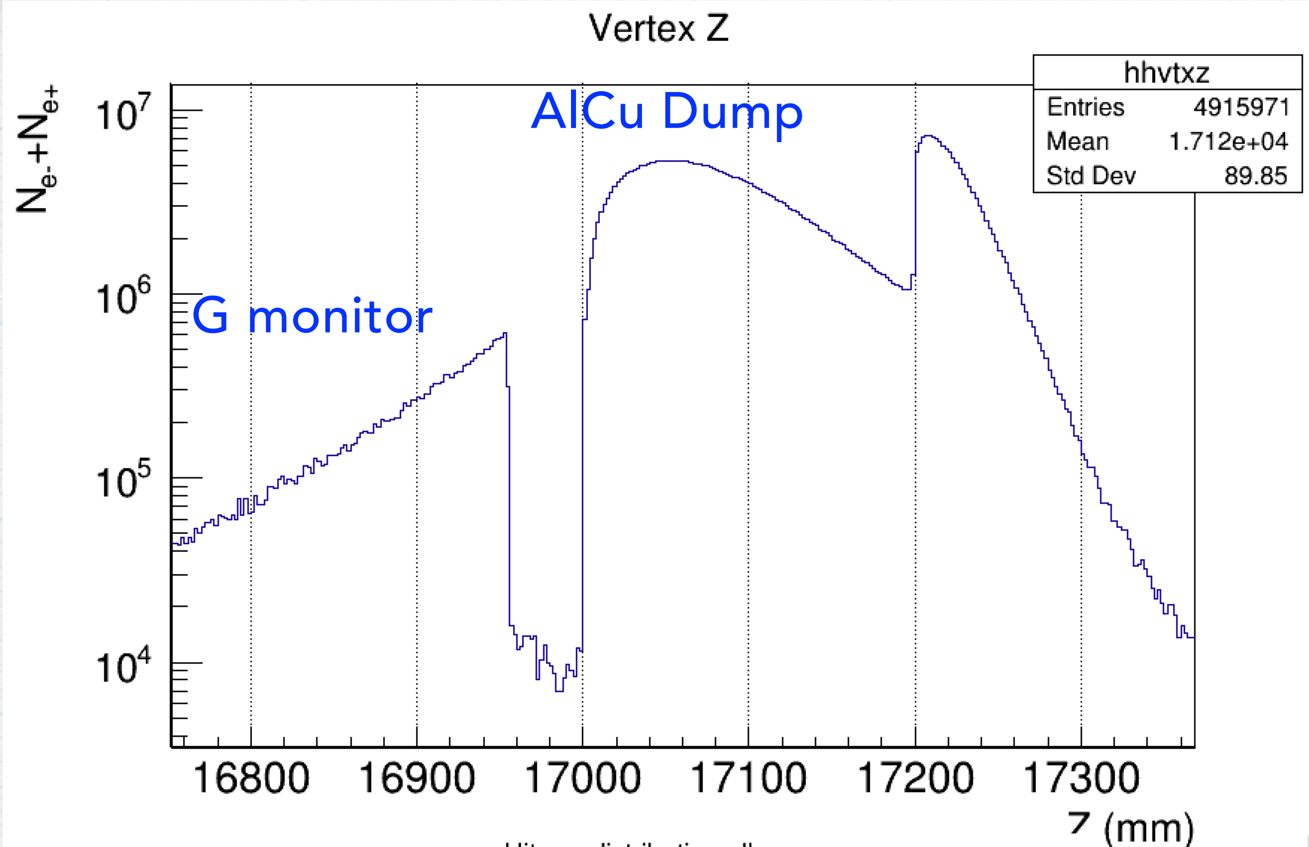


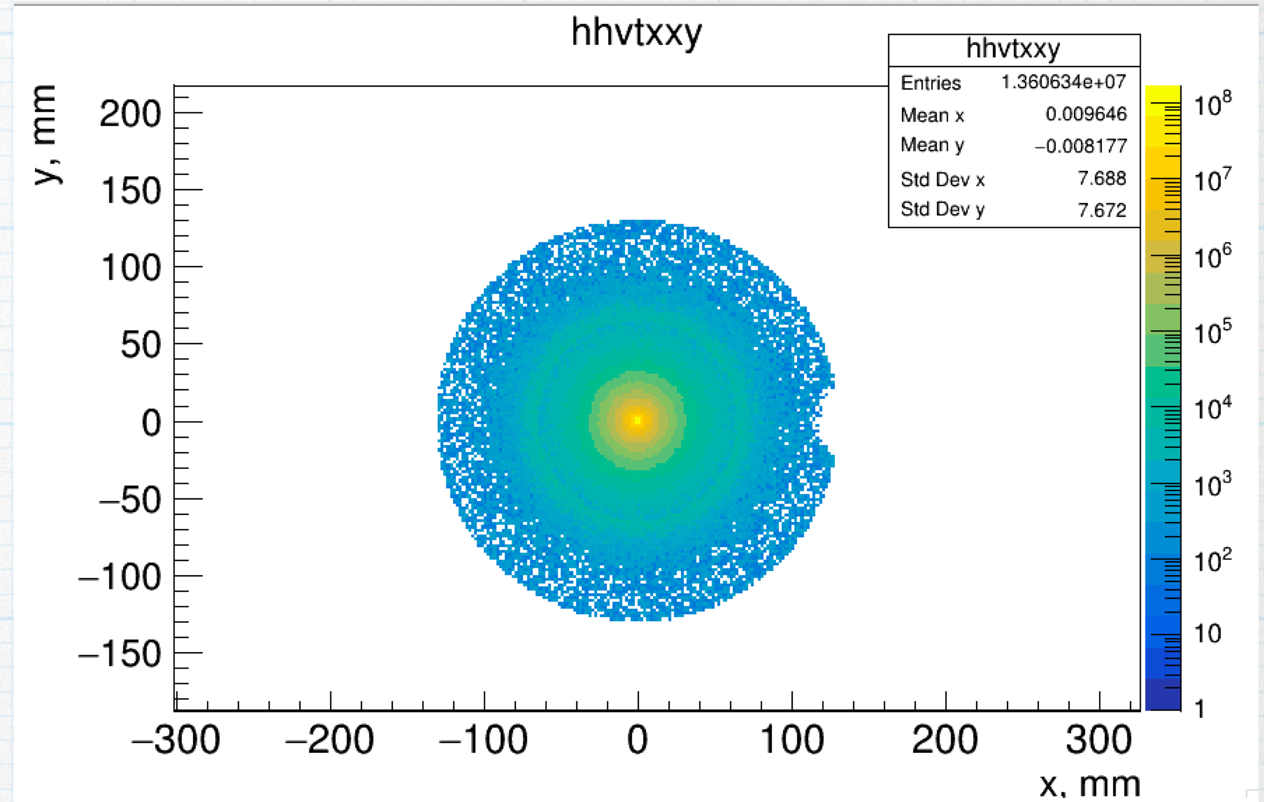


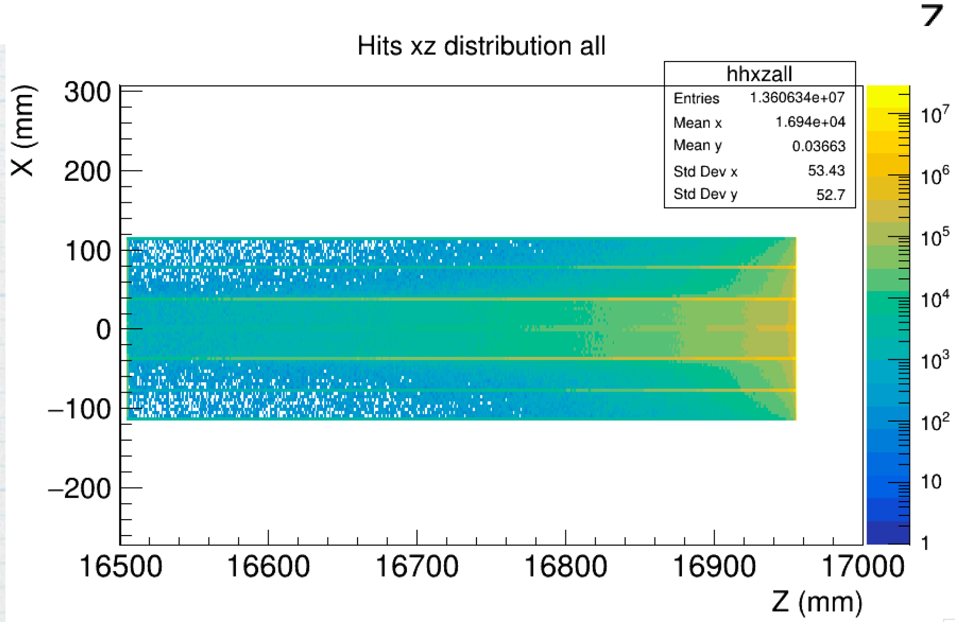


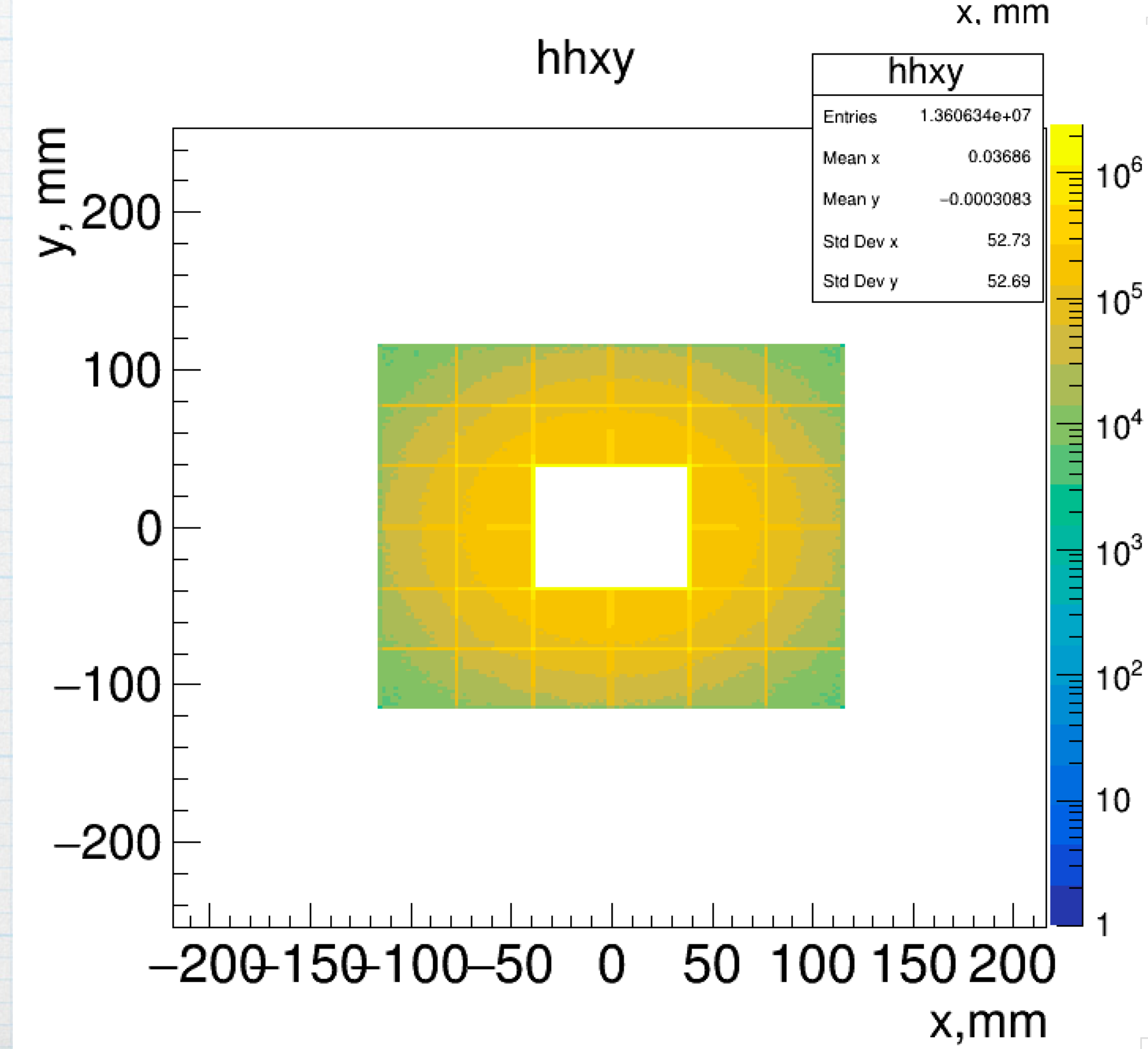


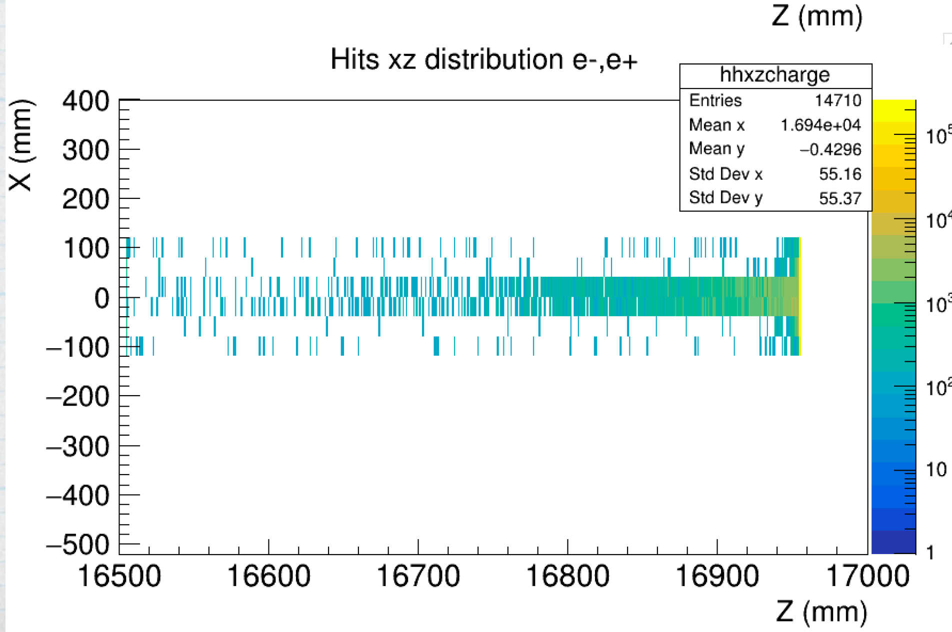
Required all the vertices to be from Beam Dump



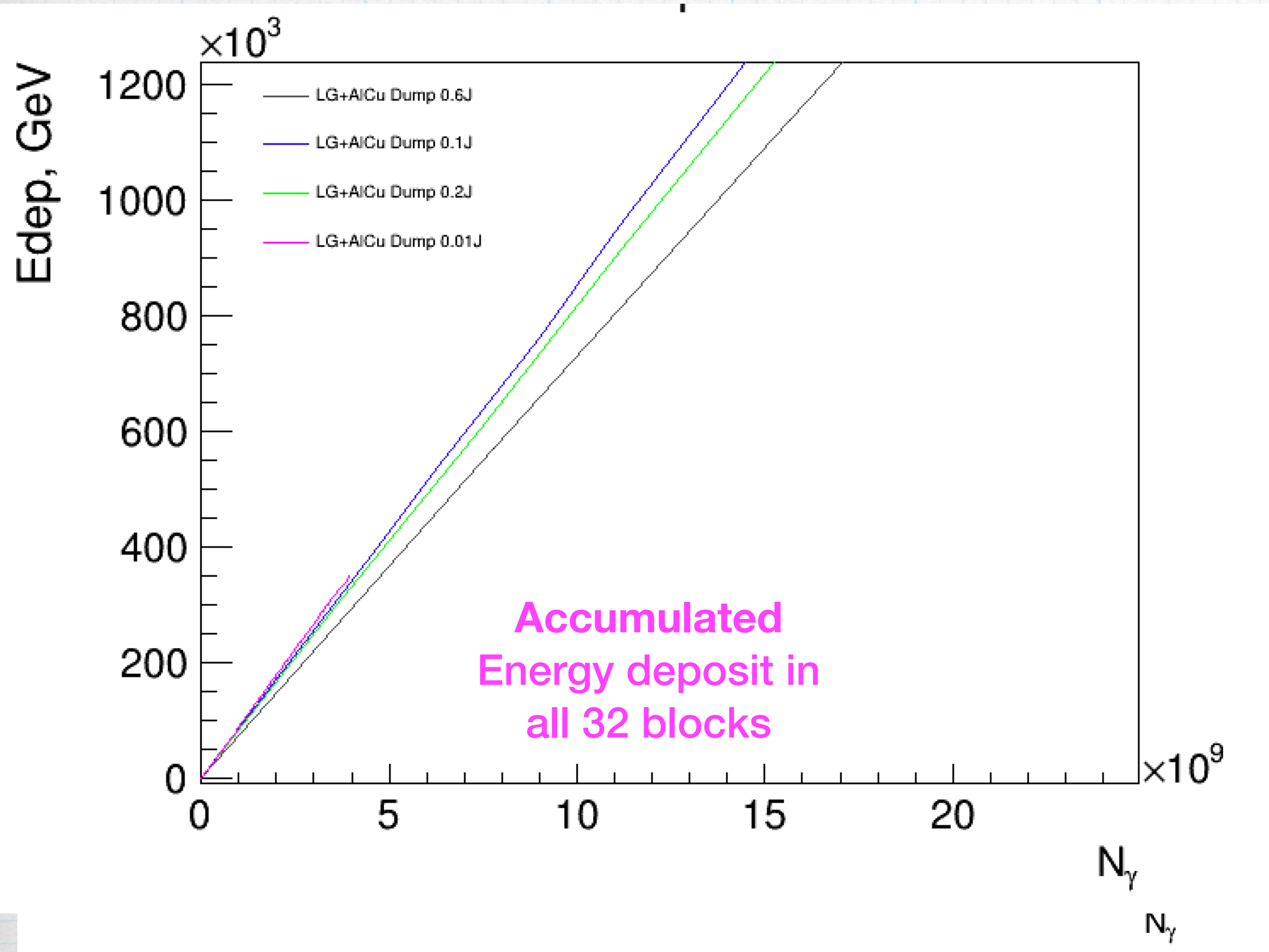


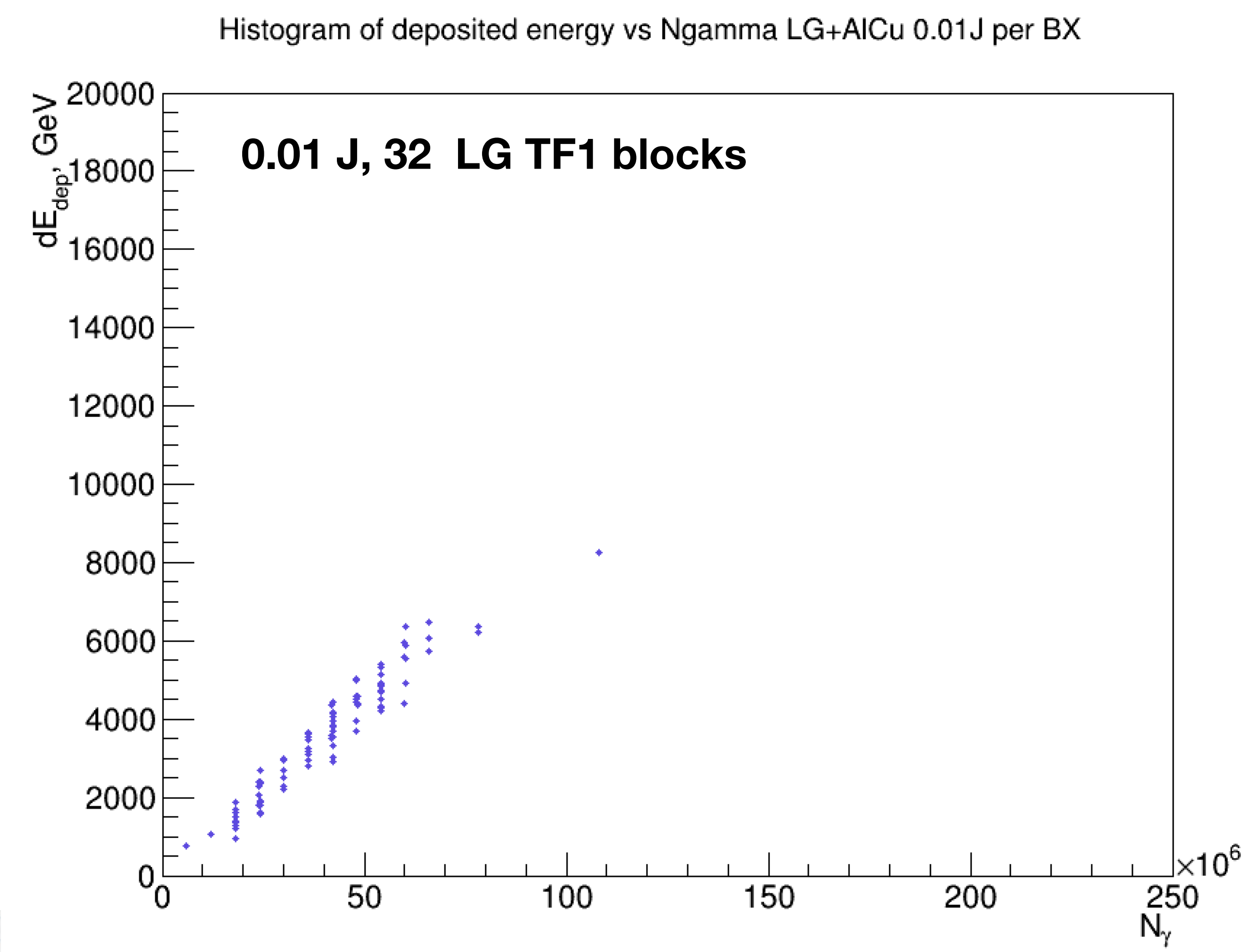






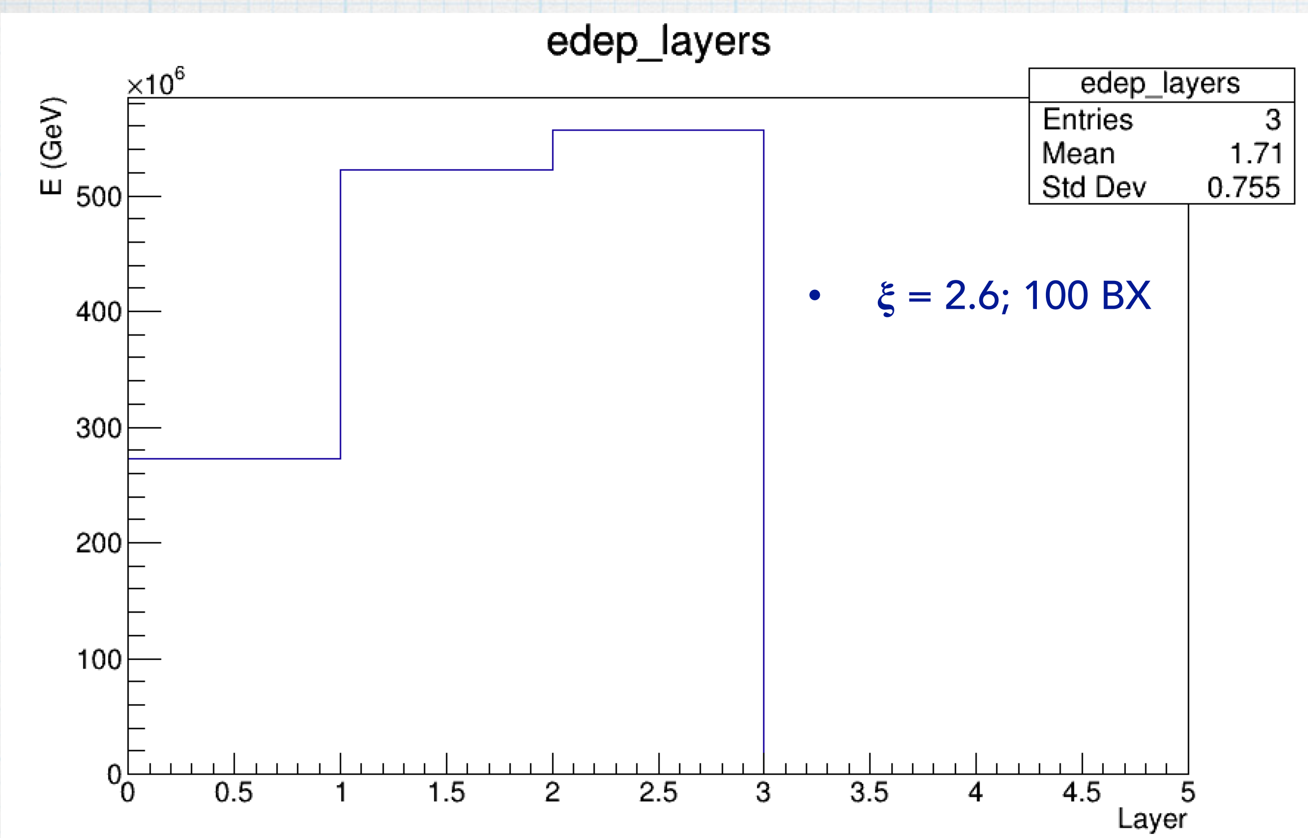
The dependence of deposited energy on number of incoming photons per BX for LG Gamma monitor and AlCu dump



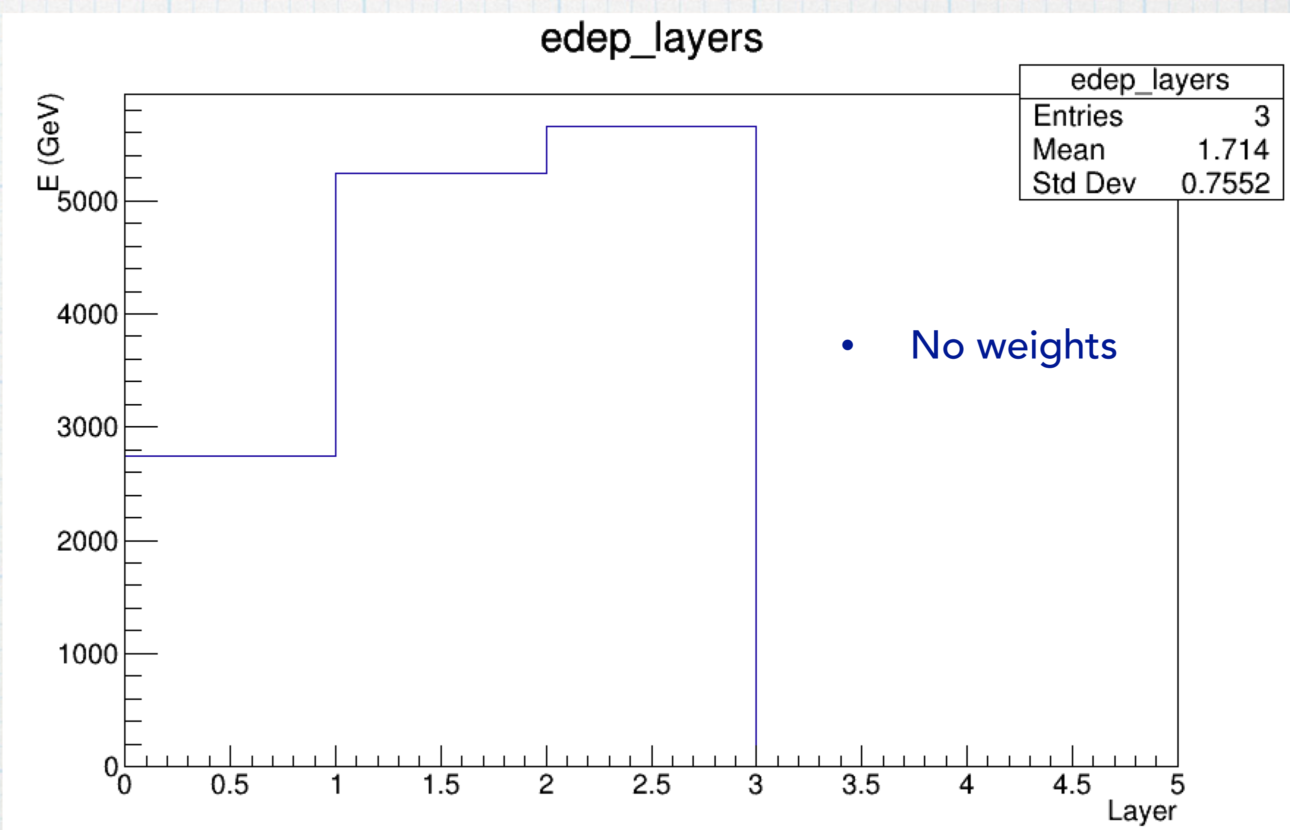


Energy deposit on Ngamma
Each point is one BX, xi=0.26

- for each detID distribution for for 100 BX



- ξ = 2.6; 100 BX



- No weights