

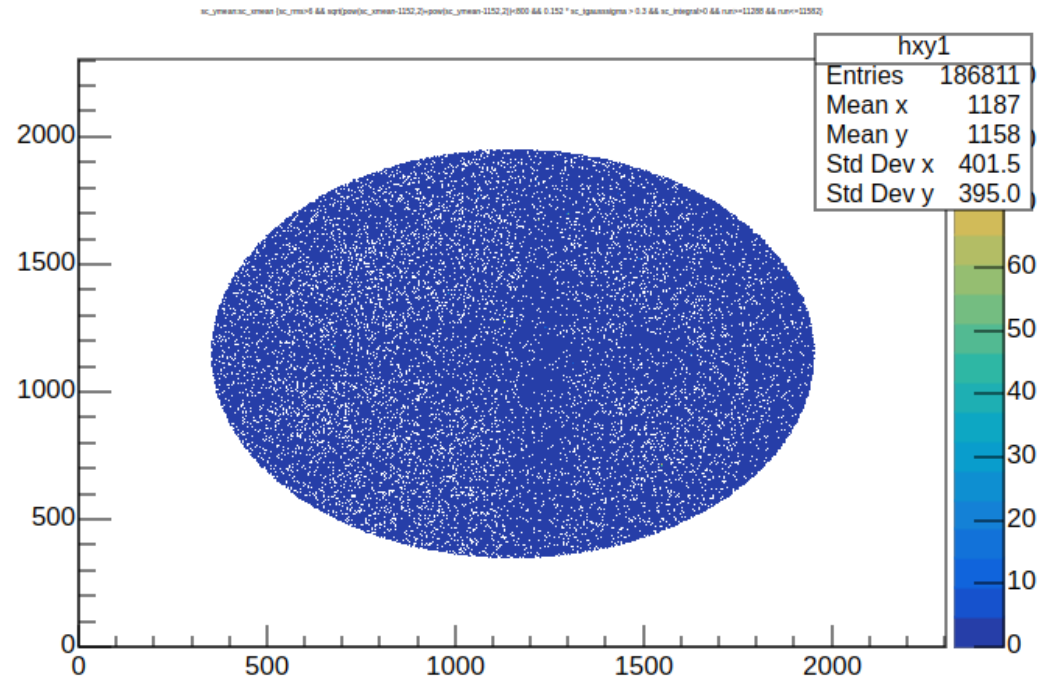
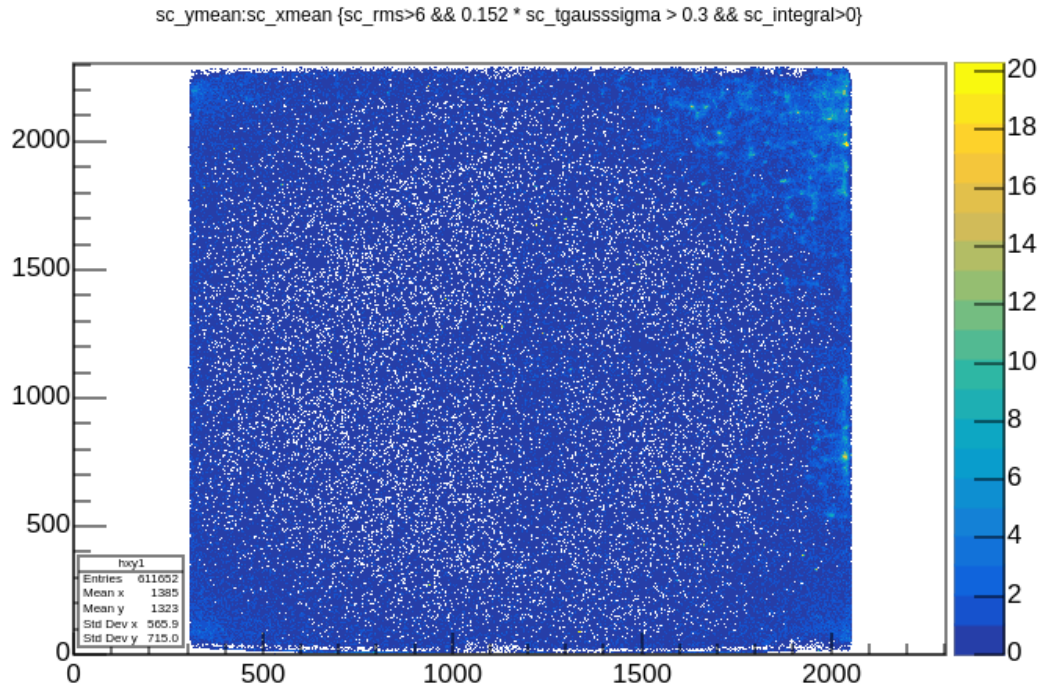
# Energy spectra of LIME background in run2 and MC comparison

F. Di Giambattista, Analysis Meeting, Coimbra, 7-8 June 2023

# Background simulation chain

- Monte Carlo (MC) simulation of expected background in LIME underground with GEANT4
  - Main contributions:
    - External gammas produced in the lab rock
    - Radioactivity of LIME materials (field rings, cathode, acrylic box, GEMs, field cage resistors, camera)
- Digitization is applied
  - Energy deposits in the sensitive volume of gas are diffused, charge amplification and saturation are applied, vignetting effect is included, and images with the same granularity of real data are produced
  - Energy and spatial distribution of simulated events are retained, and the images are comparable with data
- Events are reconstructed with Winter23 version of the code (same as the one used for run2)

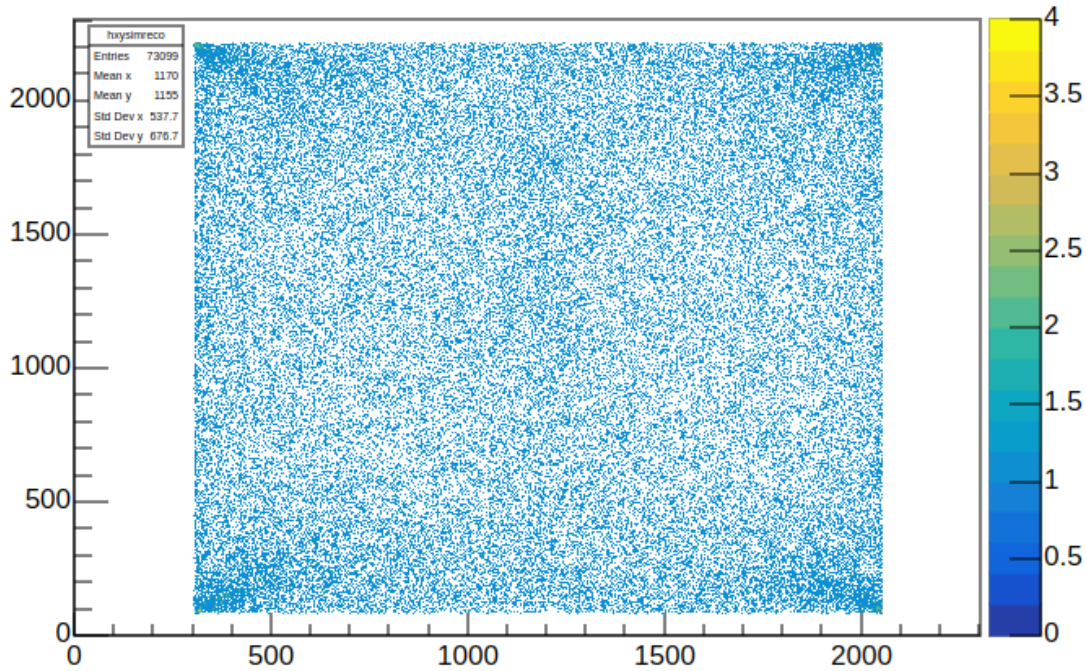
# X-Y distribution – data



Excess of clusters in corners – cut a central circle in the center with 800px radius

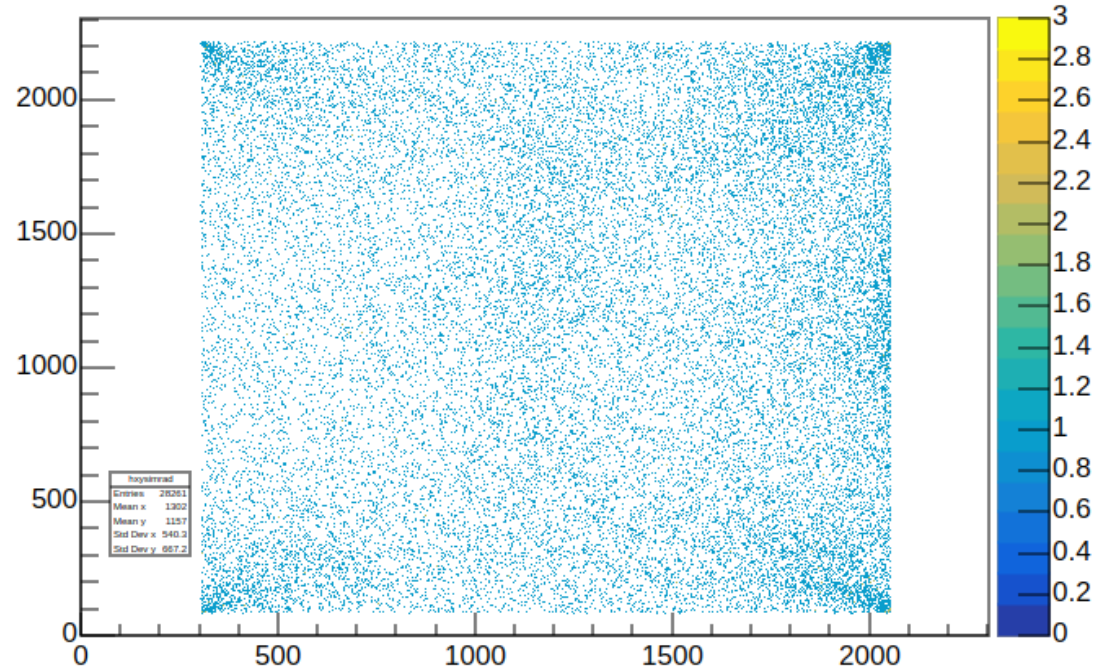
# X-Y distribution – simulation

sc\_ymean:sc\_xmean {sc\_rms>6 && 0.152 \* sc\_tgausssigma > 0.3 && sc\_integral>0}



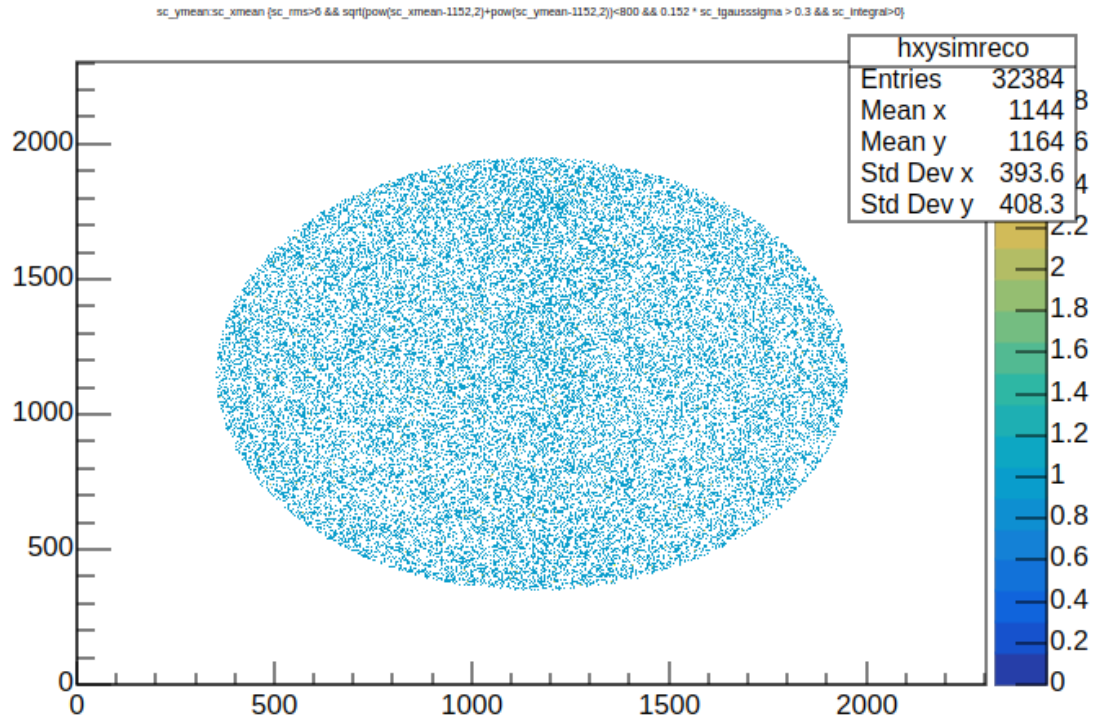
External gammas

sc\_ymean:sc\_xmean {sc\_rms>6 && 0.152 \* sc\_tgausssigma > 0.3 && sc\_integral>0}

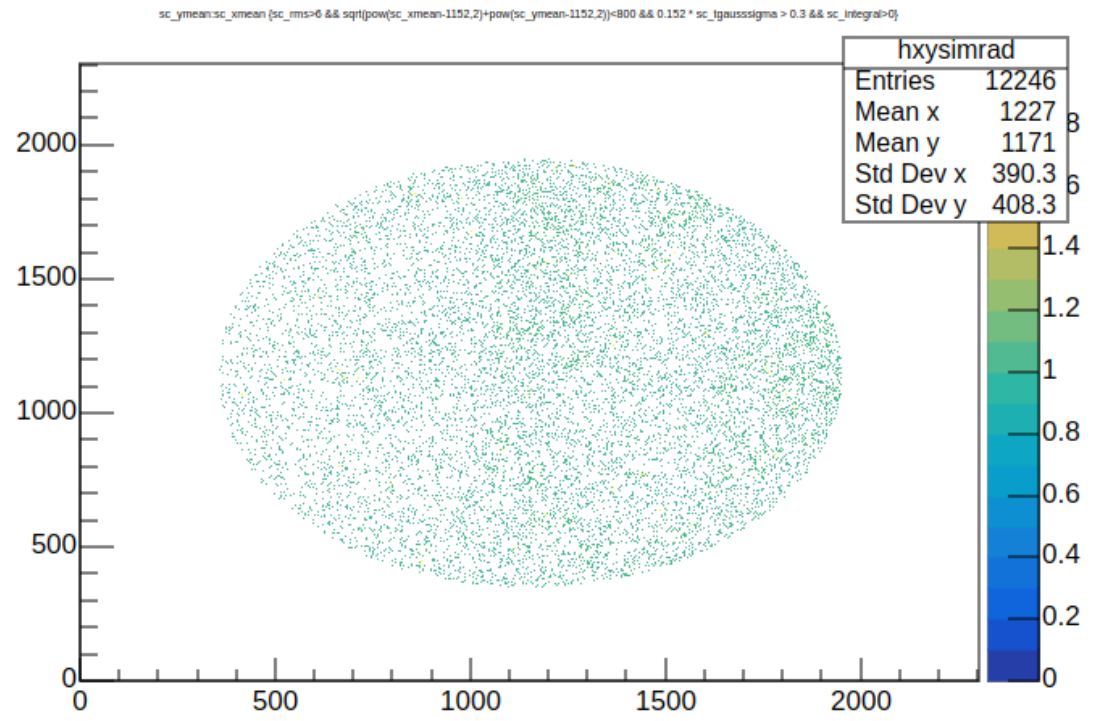


Internal radioactivity

# X-Y distribution – simulation



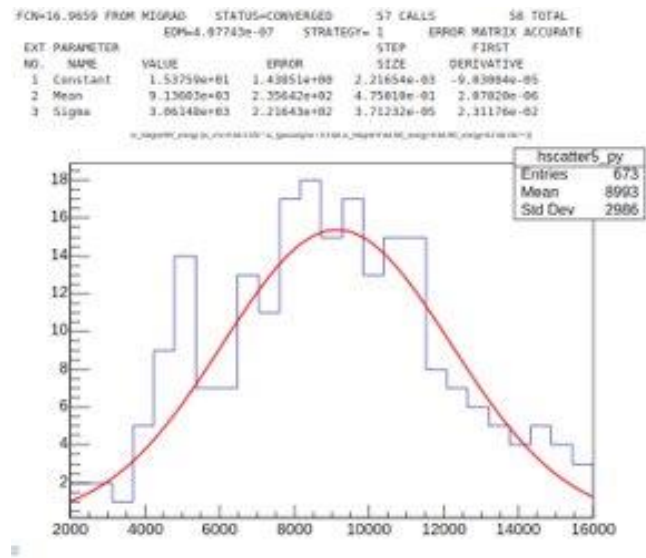
External gammas



Internal radioactivity

# Energy calibration

- For the simulation I used a peak at 8 keV (Cu X-ray)
- For data I used the Fe55 runs to calibrate the reconstructed data from background runs
- In both cases I did a simple Gauss fit



FCN=307.99 FROM MIGRAD STATUS=CONVERGED 96 CALLS 97 TOTAL  
EDM=1.60486e-08 STRATEGY= 1 ERROR MATRIX ACCURATE

EXT. PARAMETER NO.	NAME	VALUE	ERROR	STEP SIZE	FIRST DERIVATIVE
1	Constant	1.76899e+01	9.37833e-01	5.67279e-03	-2.11722e-04
2	Mean	1.21309e+04	6.16021e+01	5.28354e-01	3.66242e-07
3	Sigma	1.62200e+03	6.27894e+01	4.50125e-05	-3.35659e-02

FCN=283.805 FROM MIGRAD STATUS=CONVERGED 103 CALLS 104 TOTAL  
EDM=1.65452e-11 STRATEGY= 1 ERROR MATRIX ACCURATE

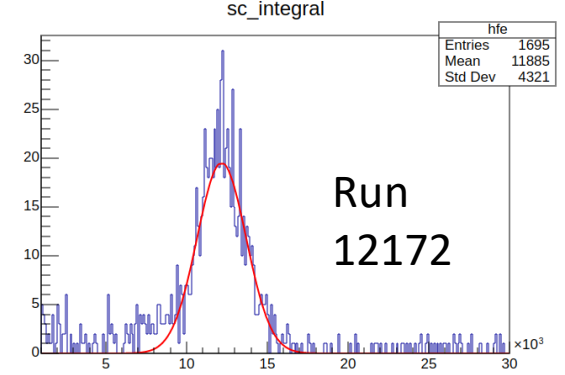
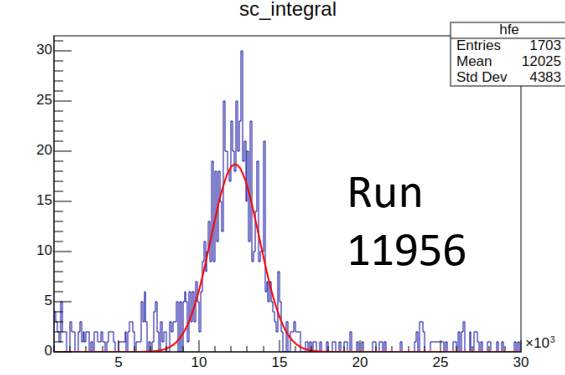
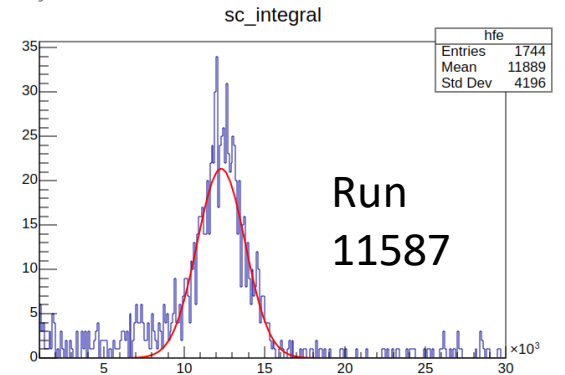
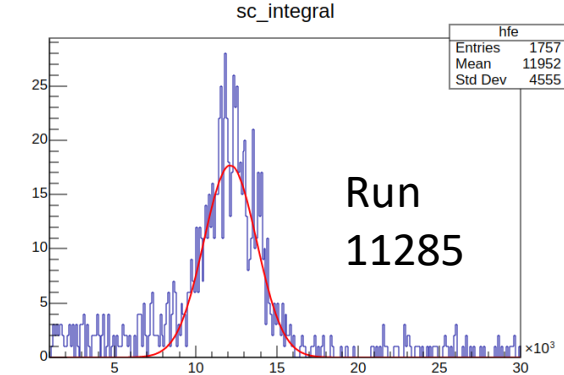
EXT. PARAMETER NO.	NAME	VALUE	ERROR	STEP SIZE	FIRST DERIVATIVE
1	Constant	2.13625e+01	1.16170e+00	6.23861e-03	4.23915e-08
2	Mean	1.23048e+04	5.49269e+01	4.45619e-01	7.62814e-09
3	Sigma	1.49656e+03	5.80813e+01	4.20253e-05	7.73857e-04

FCN=269.163 FROM MIGRAD STATUS=CONVERGED 88 CALLS 89 TOTAL  
EDM=1.07816e-07 STRATEGY= 1 ERROR MATRIX ACCURATE

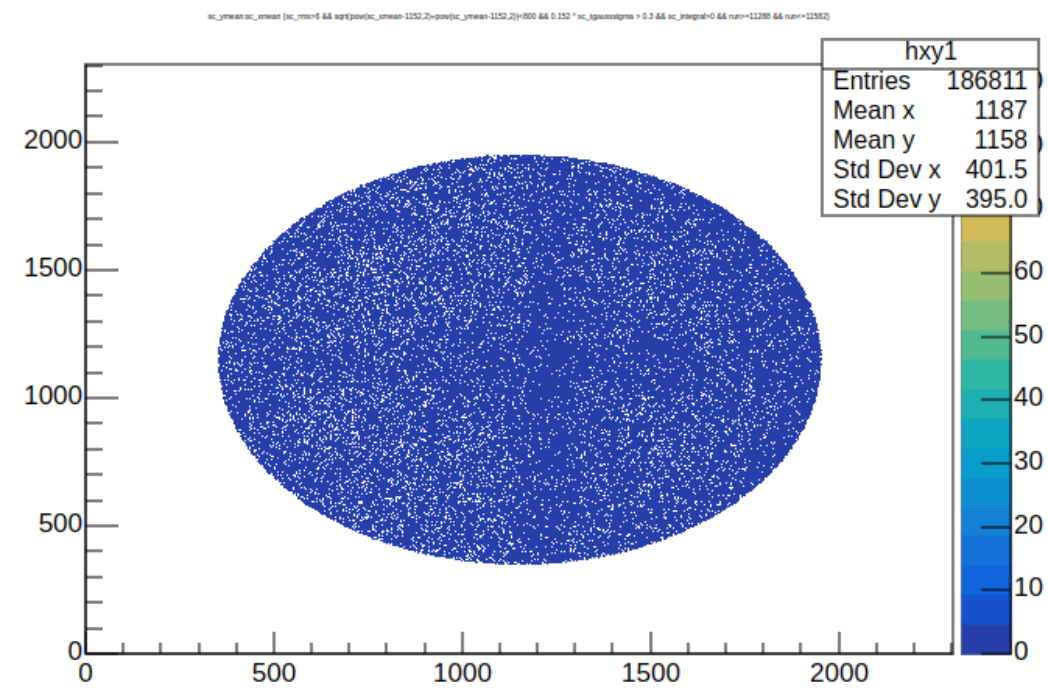
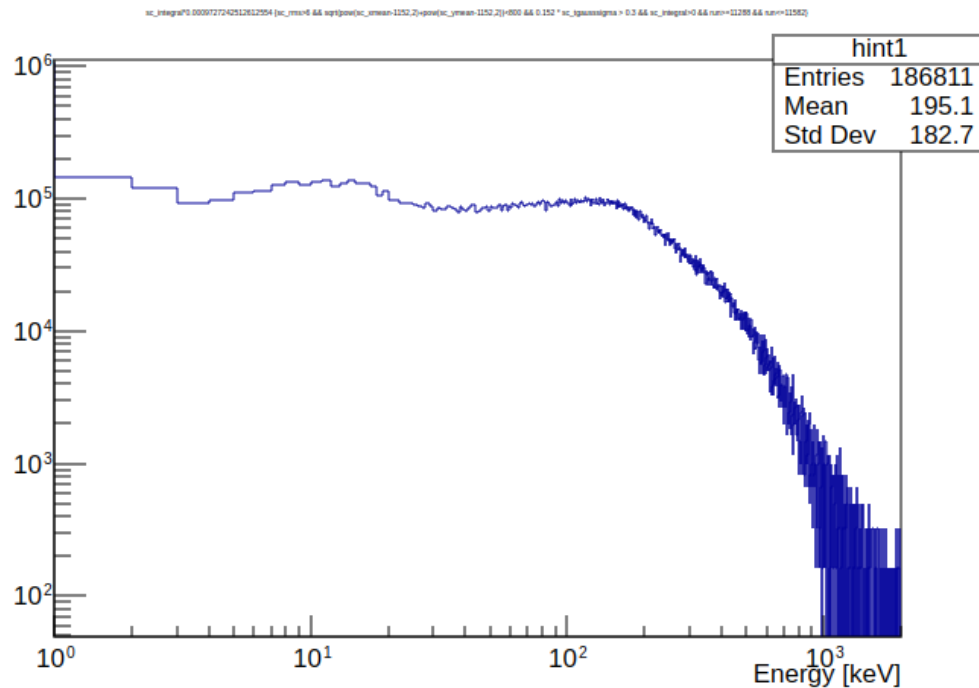
EXT. PARAMETER NO.	NAME	VALUE	ERROR	STEP SIZE	FIRST DERIVATIVE
1	Constant	1.87041e+01	1.07860e+00	5.70873e-03	4.26267e-04
2	Mean	1.22511e+04	5.97982e+01	4.79915e-01	5.55295e-06
3	Sigma	1.50229e+03	7.11769e+01	4.72694e-05	4.96771e-02

FCN=266.029 FROM MIGRAD STATUS=CONVERGED 103 CALLS 104 TOTAL  
EDM=3.3291e-10 STRATEGY= 1 ERROR MATRIX ACCURATE

EXT. PARAMETER NO.	NAME	VALUE	ERROR	STEP SIZE	FIRST DERIVATIVE
1	Constant	1.94884e+01	1.08448e+00	5.72733e-03	-2.47427e-05
2	Mean	1.21760e+04	5.69771e+01	4.54249e-01	-3.18405e-07
3	Sigma	1.51950e+03	6.55460e+01	4.34687e-05	-2.77297e-03

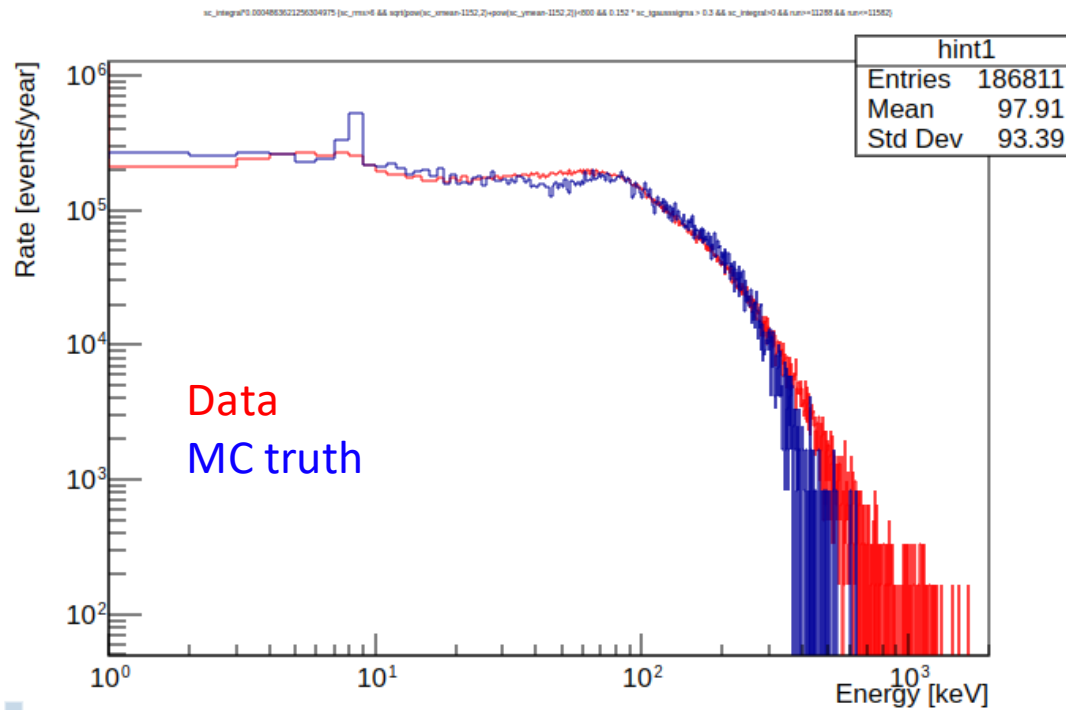


# Energy spectrum – data run2



- Cuts applied:  $sc\_rms > 6 \ \&\& \ \sqrt{pow(sc\_xmean-1152,2)+pow(sc\_ymean-1152,2)} < 800 \ \&\& \ 0.152 * sc\_tgaussigma > 0.3 \ \&\& \ sc\_integral > 0$
- Normalized to the total real time of the runs (stop\_time-start\_time)

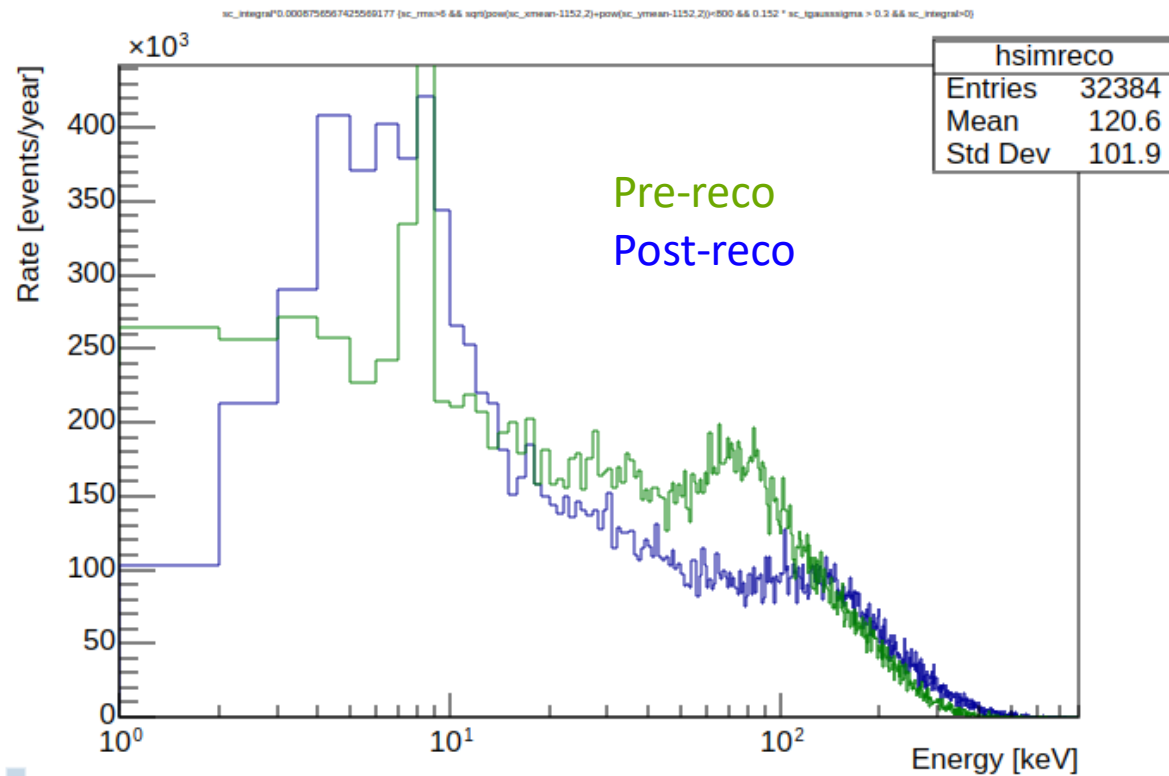
# Energy spectrum comparison pre-reco



- Pre-reconstruction comparison
- External gammas only (it's the main contribution)
- Geometrical cut applied also to MC

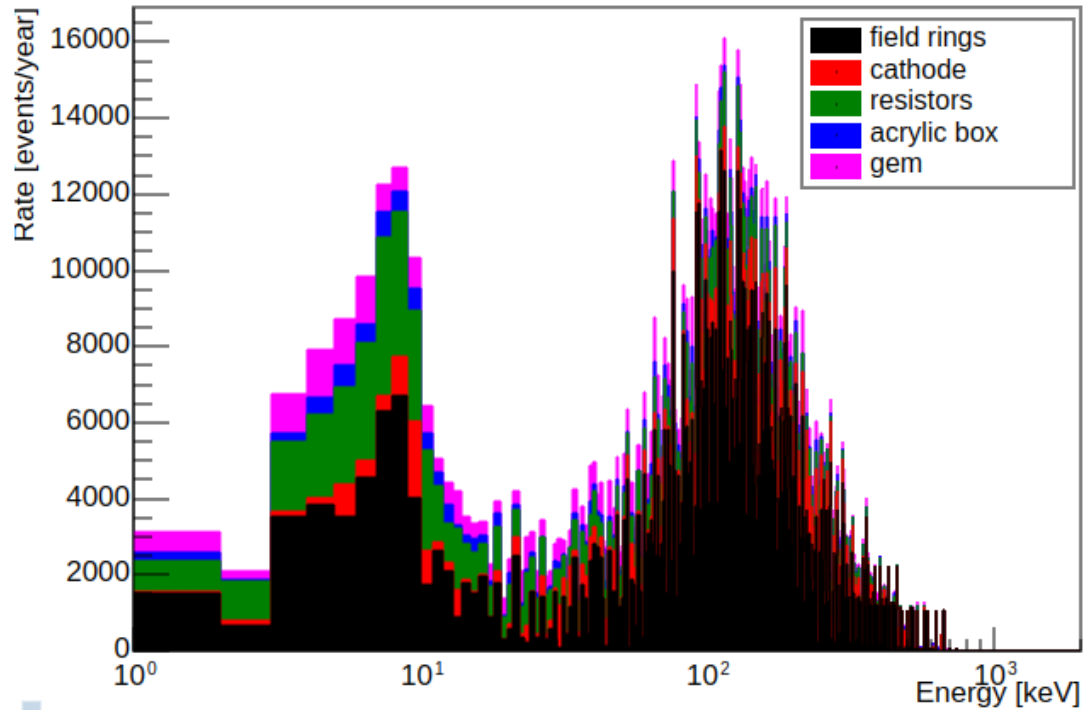


# Energy spectrum – MC simulation

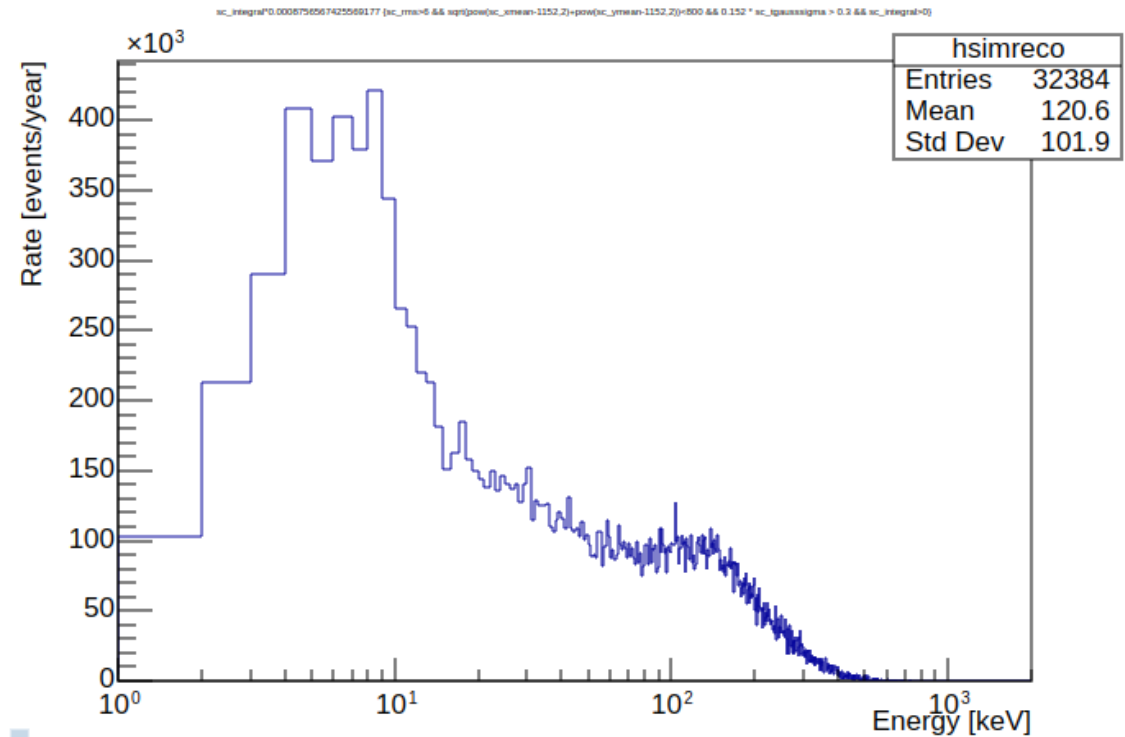


**Pre-reco** (MC truth) and **post-reco** energy spectrum of external gamma simulation comparison

# Energy spectrum – MC simulation

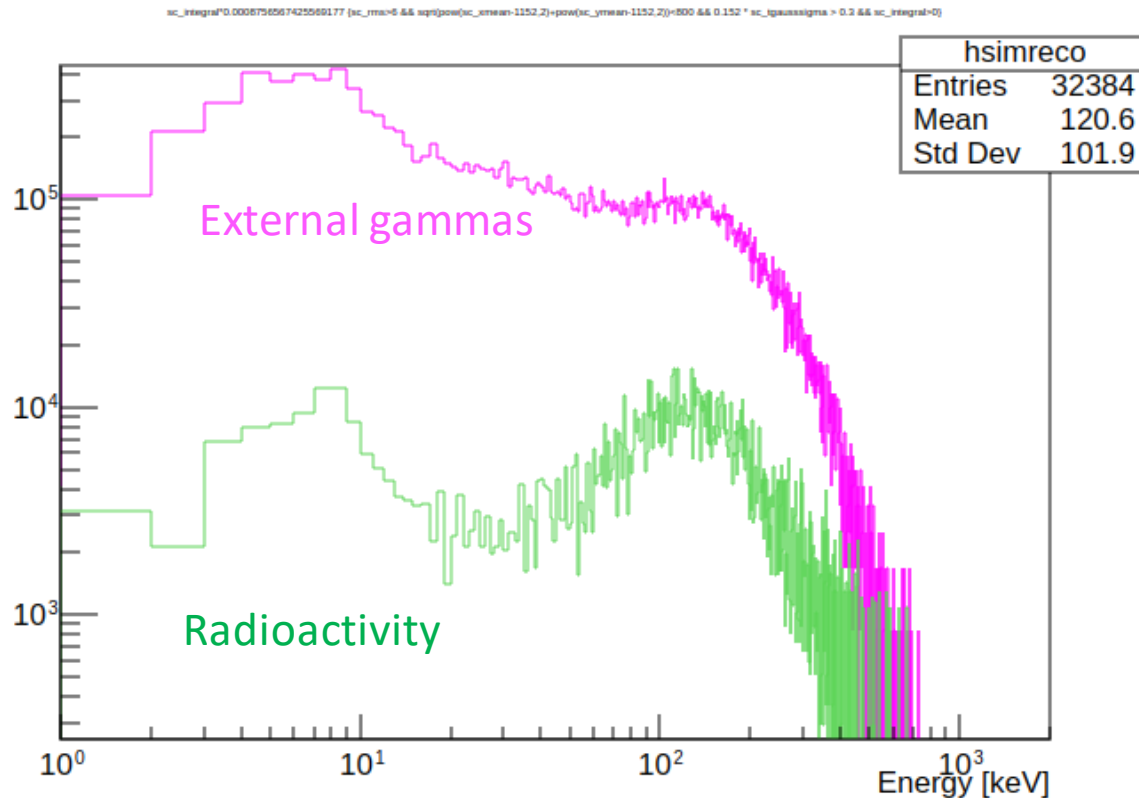


Internal radioactivity



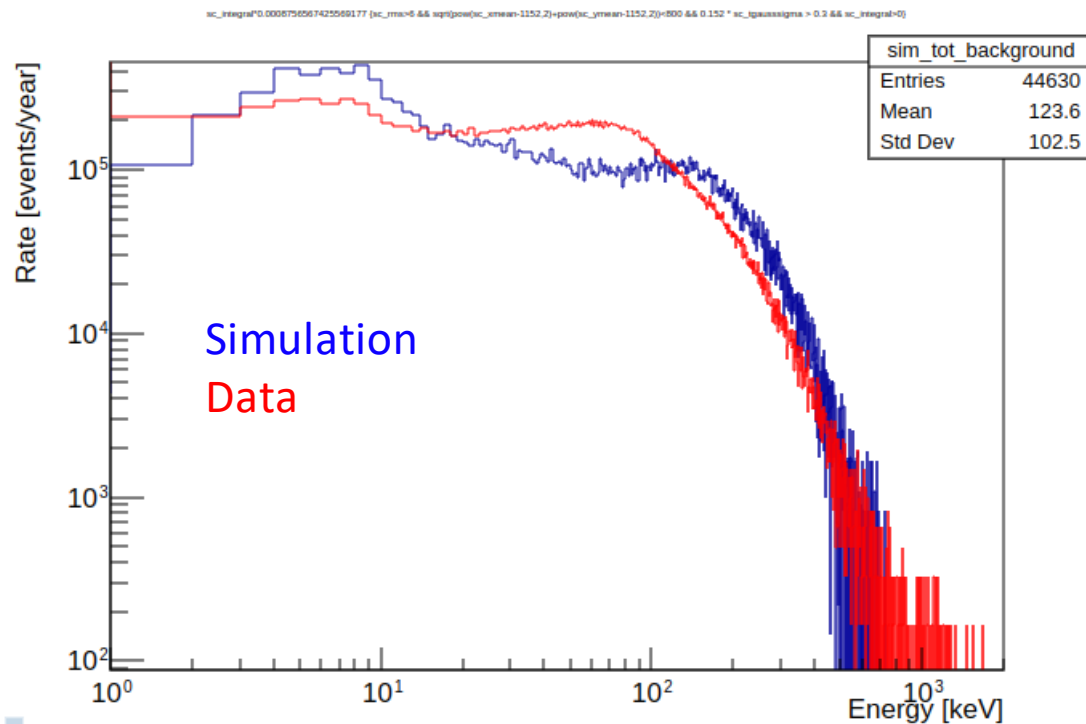
External gammas

# Energy spectrum – MC simulation



- Same cuts as the data
- Normalization:
  - External gammas:  $0.56 \text{ cm}^{-2}\text{s}^{-1}$  flux in Hall C (from Sabre), starting from a surface containing the whole setup
  - Radioactivity: for each detector component, each isotope simulation is normalized with the activity that was *measured* by M.Laubenstein underground

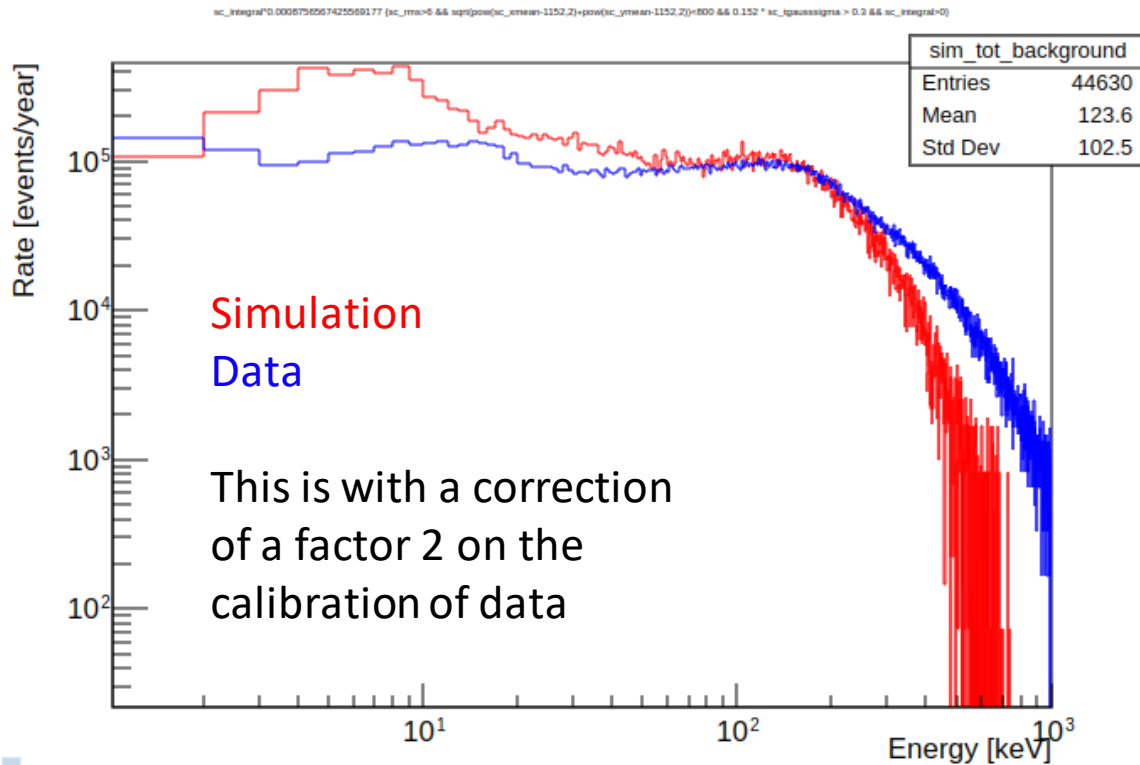
# Energy spectrum comparison



## Integral rates

- **Data:**  $2.95 \times 10^7$  events/yr (0.93 Hz)
- External gammas simulation:  $2.70 \times 10^7$  events/yr (0.86 Hz)
- Radioactivity simulation:  $2.04 \times 10^6$  events/yr (0.065 Hz)
- **Total rate from simulation:**  $2.90 \times 10^7$  events/yr (0.92 Hz)

# Energy spectrum comparison

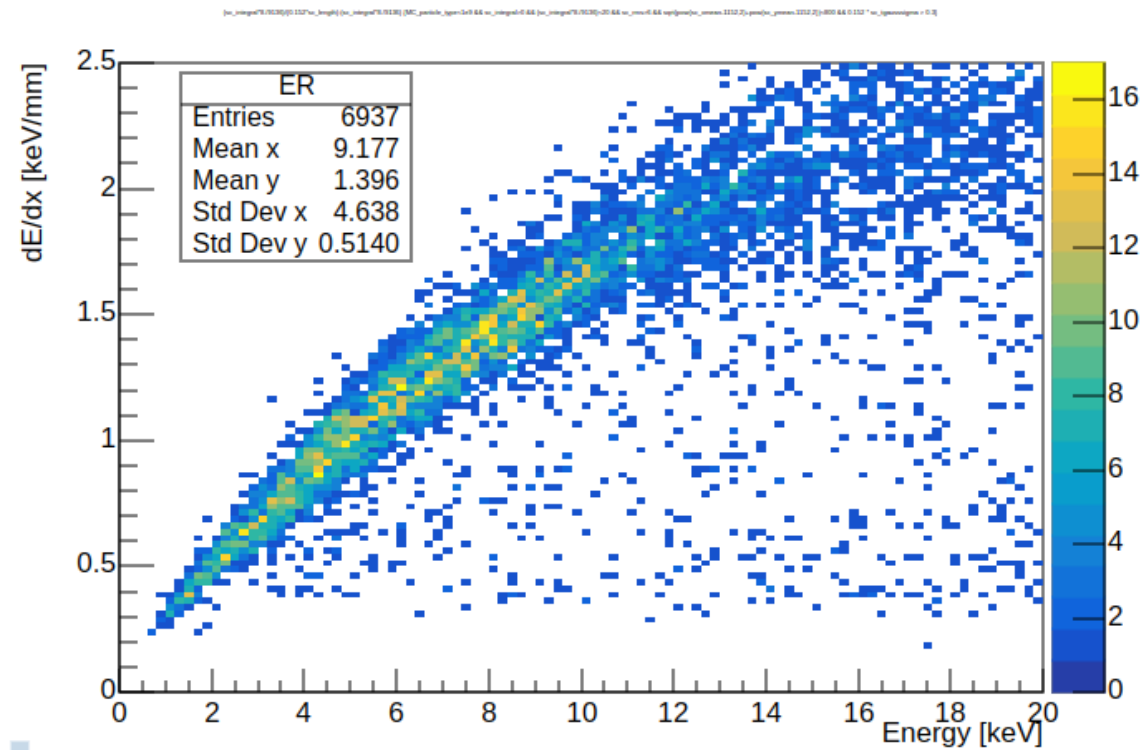


## Integral rates

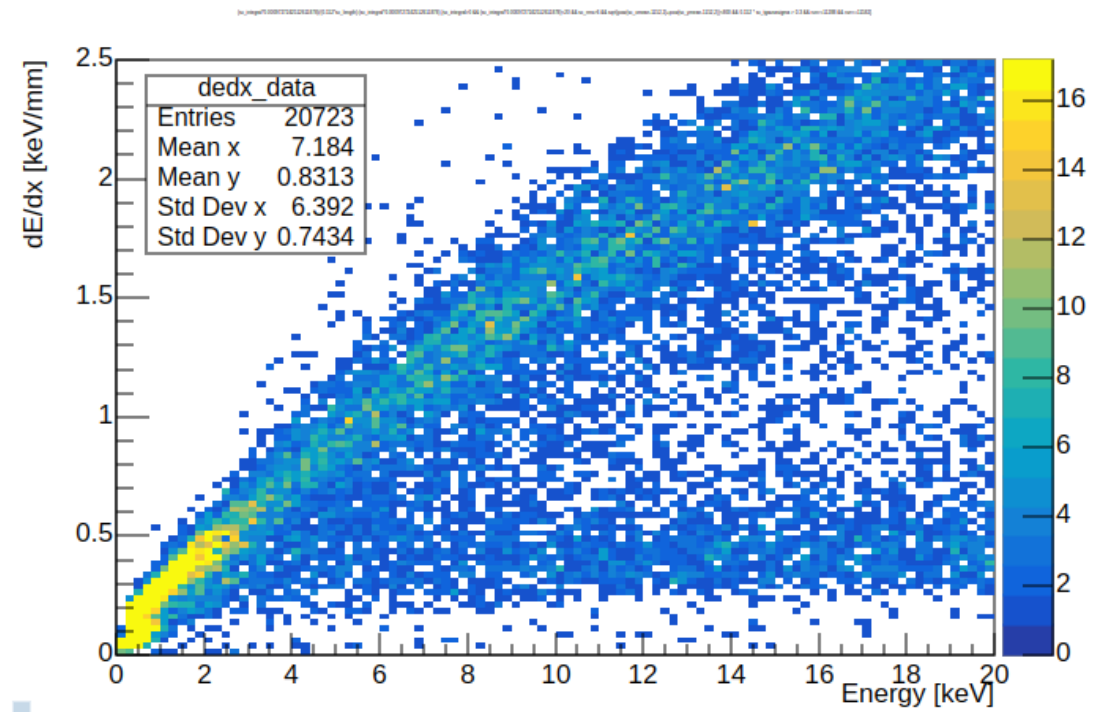
- **Data:**  $2.95 \times 10^7$  events/yr (0.93 Hz)
- External gammas simulation:  $2.70 \times 10^7$  events/yr (0.86 Hz)
- Radioactivity simulation:  $2.04 \times 10^6$  events/yr (0.065 Hz)
- **Total rate from simulation:**  $2.90 \times 10^7$  events/yr (0.92 Hz)

# dE/dx vs energy

## Simulation



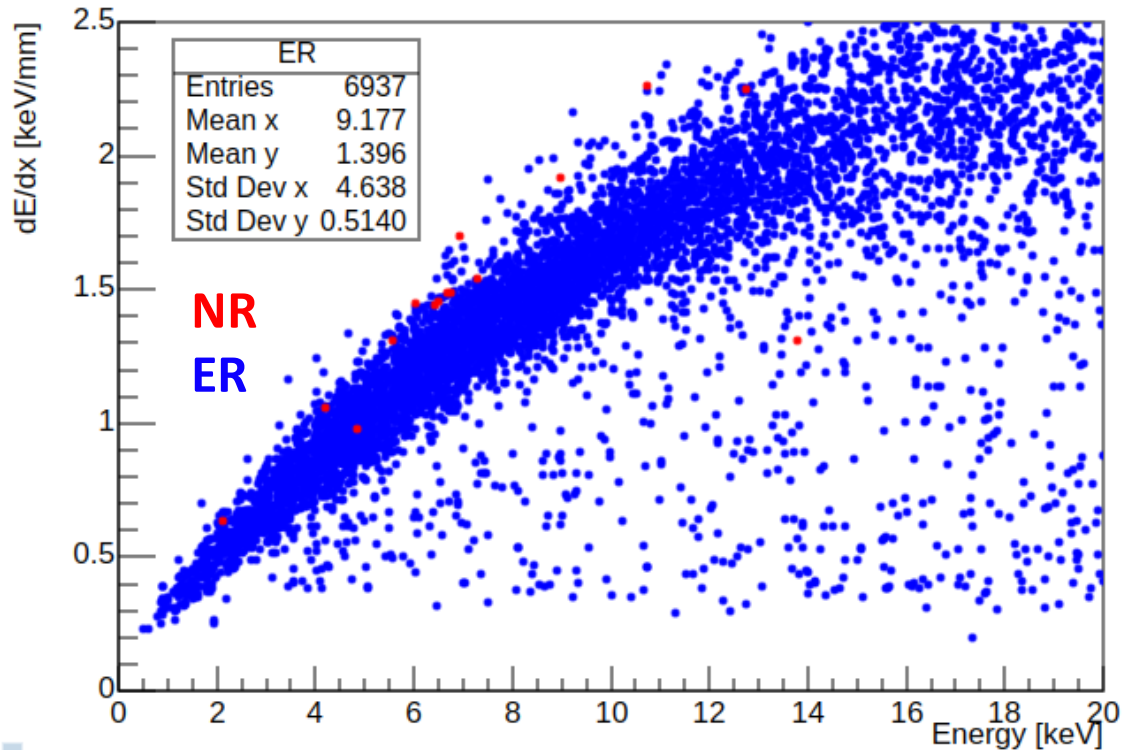
## Data



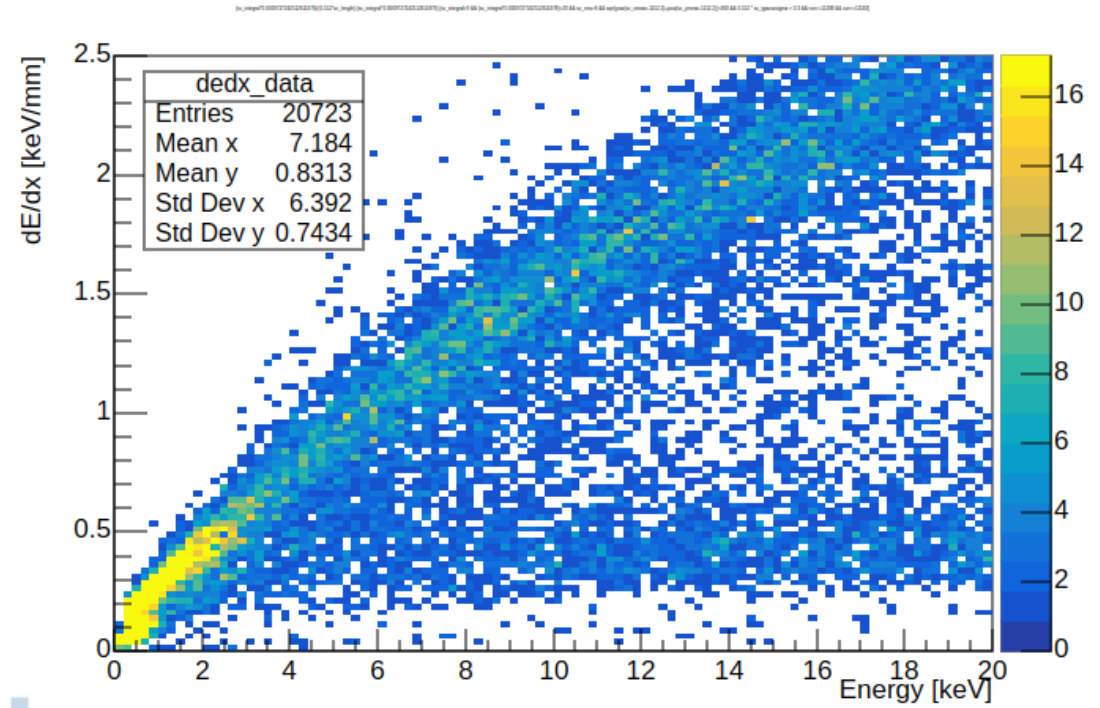
Calibration corrected

# dE/dx vs energy (ER/NR separation)

Simulation

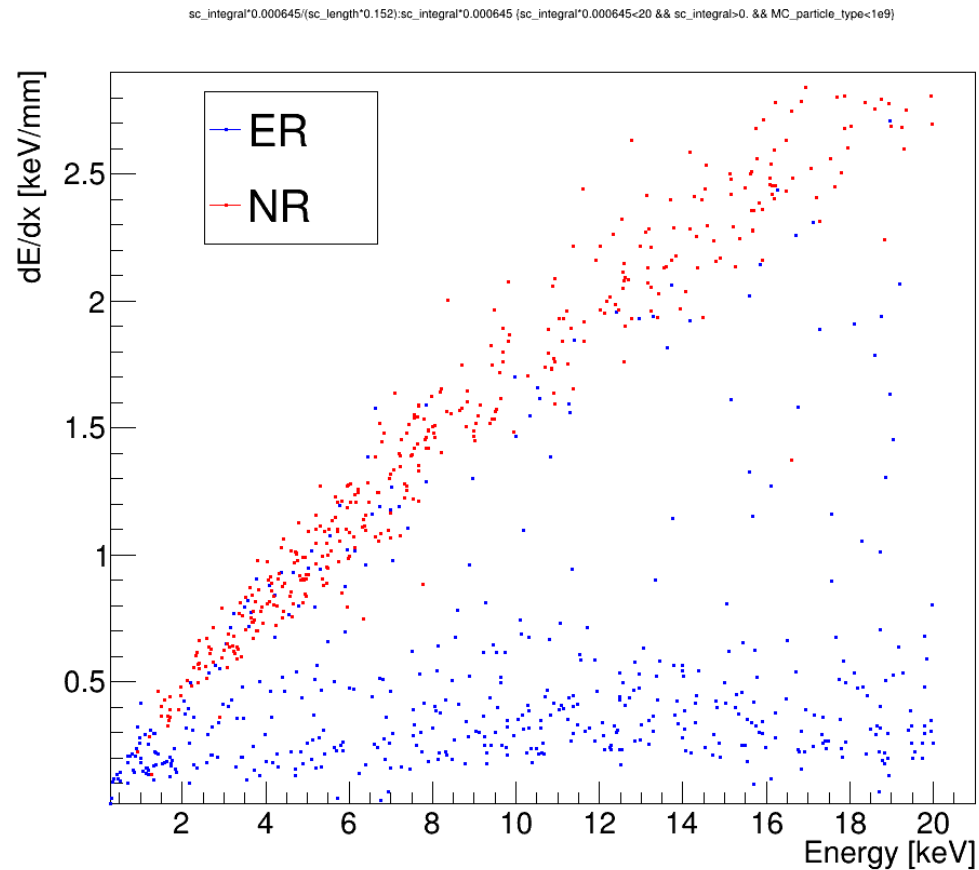


Data



Calibration corrected

# Another example: AmBe simulation



- Geant4 simulation of the AmBe neutron source, in this case both ER and NR are produced in the sensitive gas and can be more easily compared
- NR and ER are divided in two bands



# Next steps

- Correct the calibration of data
- Compare MC to data after energy regression applied
  - Apply regression to simulation

## Images

2D and 3D Event maps;

Evaluate detection efficiency vs E, x, y and z

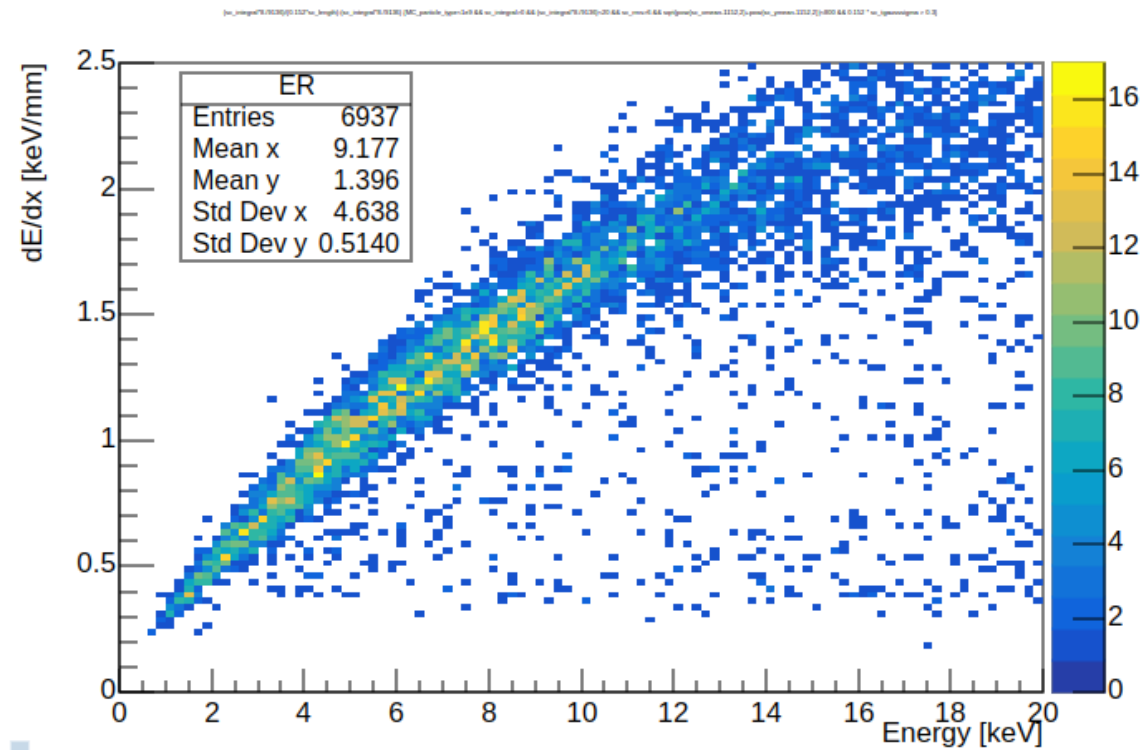
Produce distributions of: E, length, angles

$dE/dx$  vs E (2D, z, 3D)

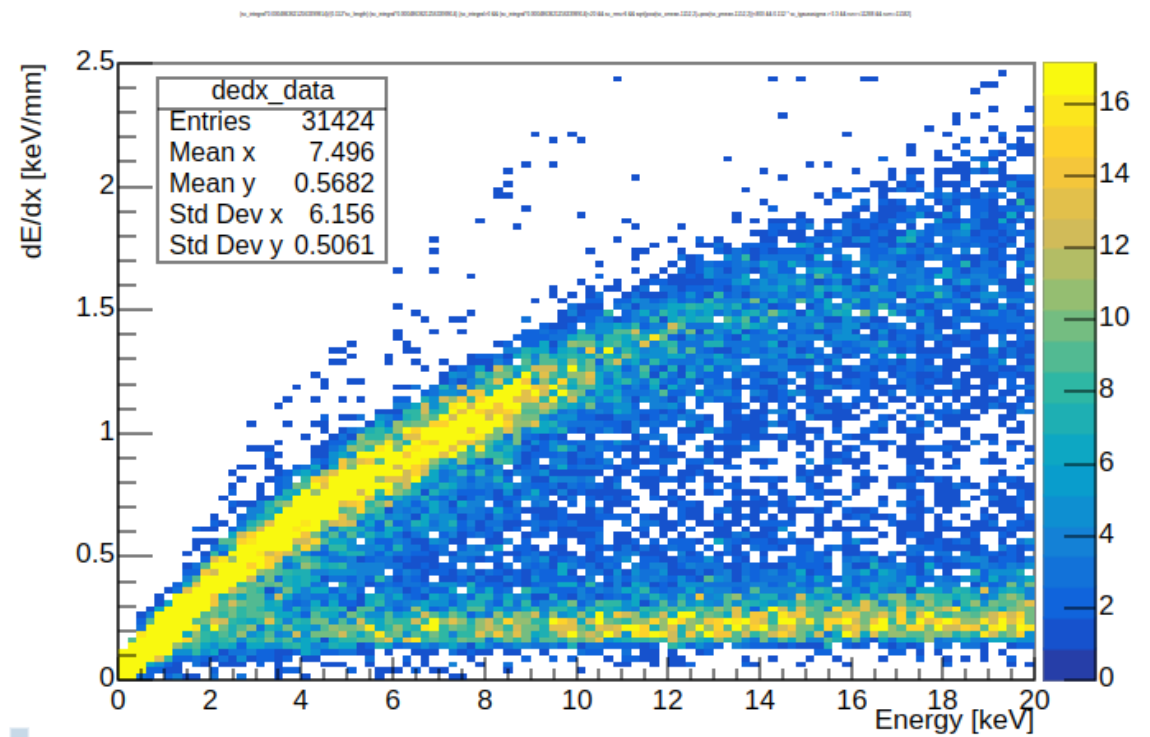
# backup

# dE/dx vs energy

## Simulation



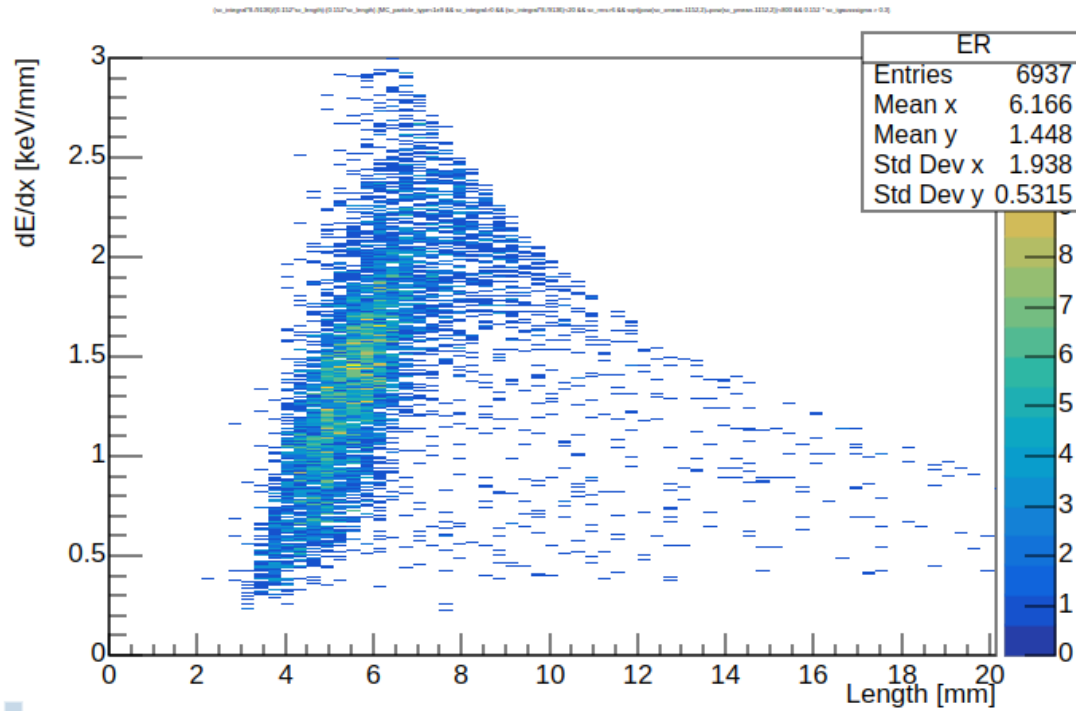
## Data



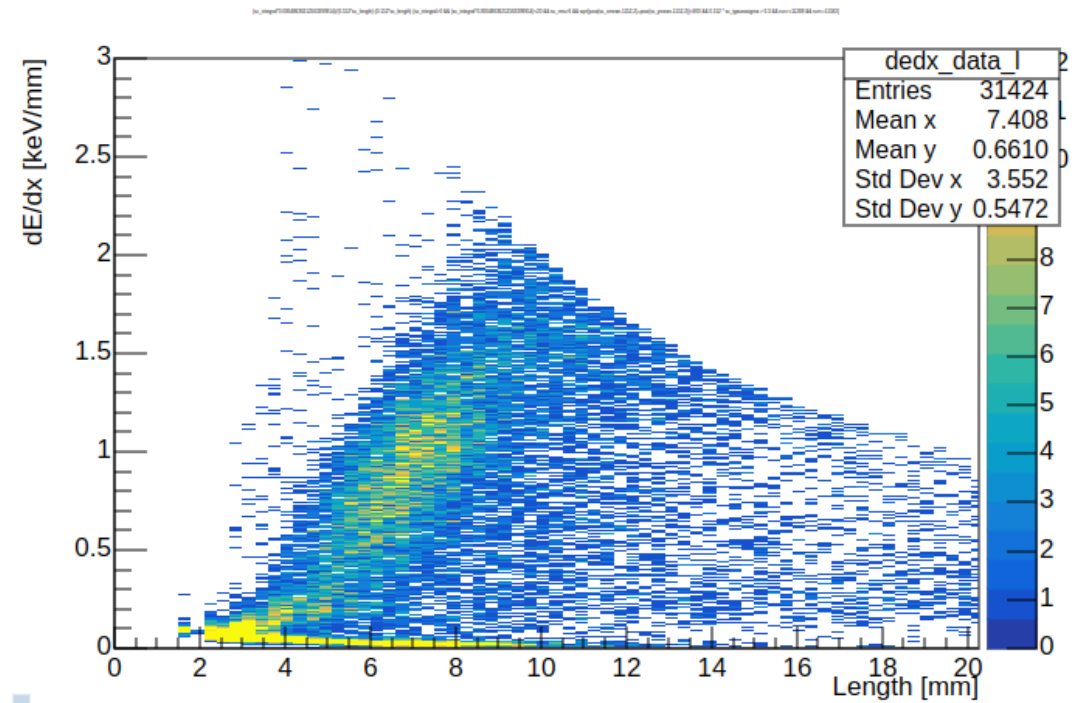
Calibration **not** corrected

# dE/dx vs length

## Simulation



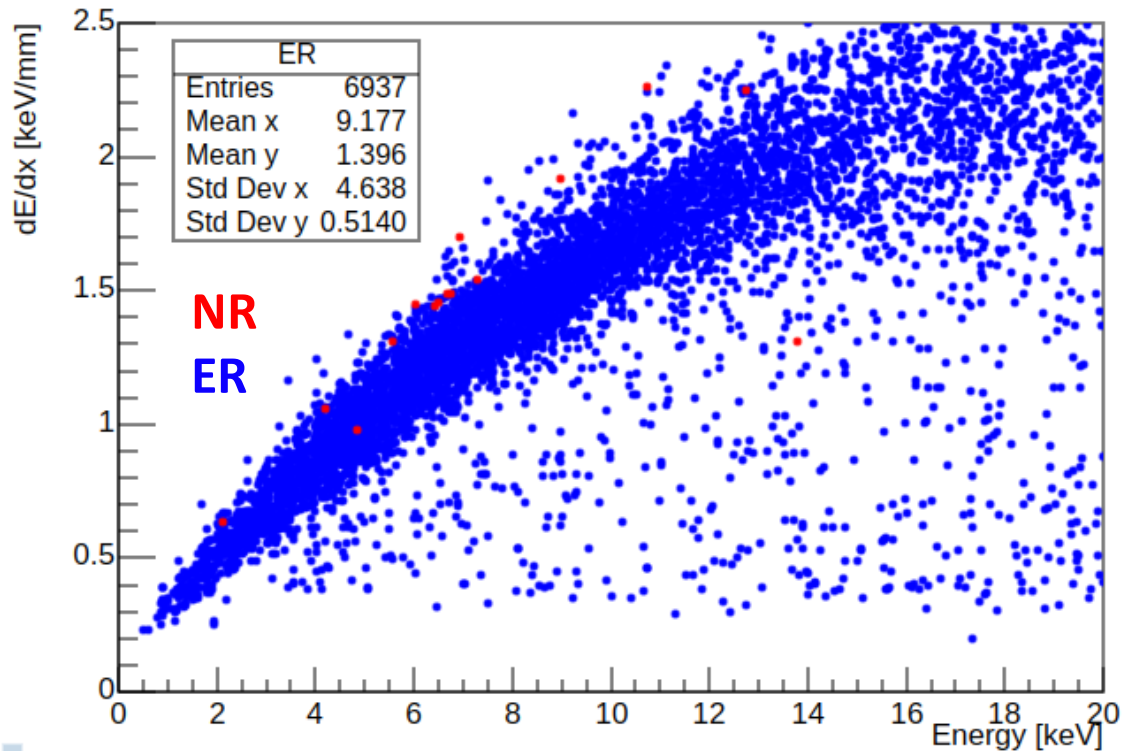
## Data



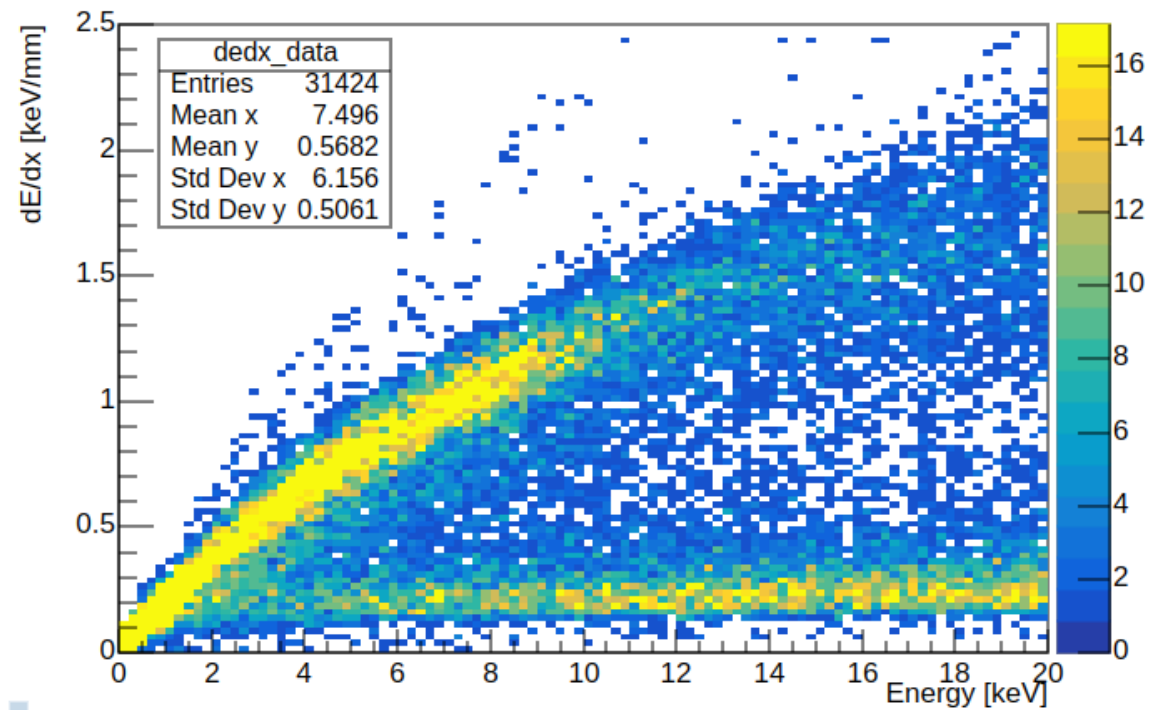
Calibration **not** corrected

# dE/dx vs energy (ER/NR separation)

Simulation



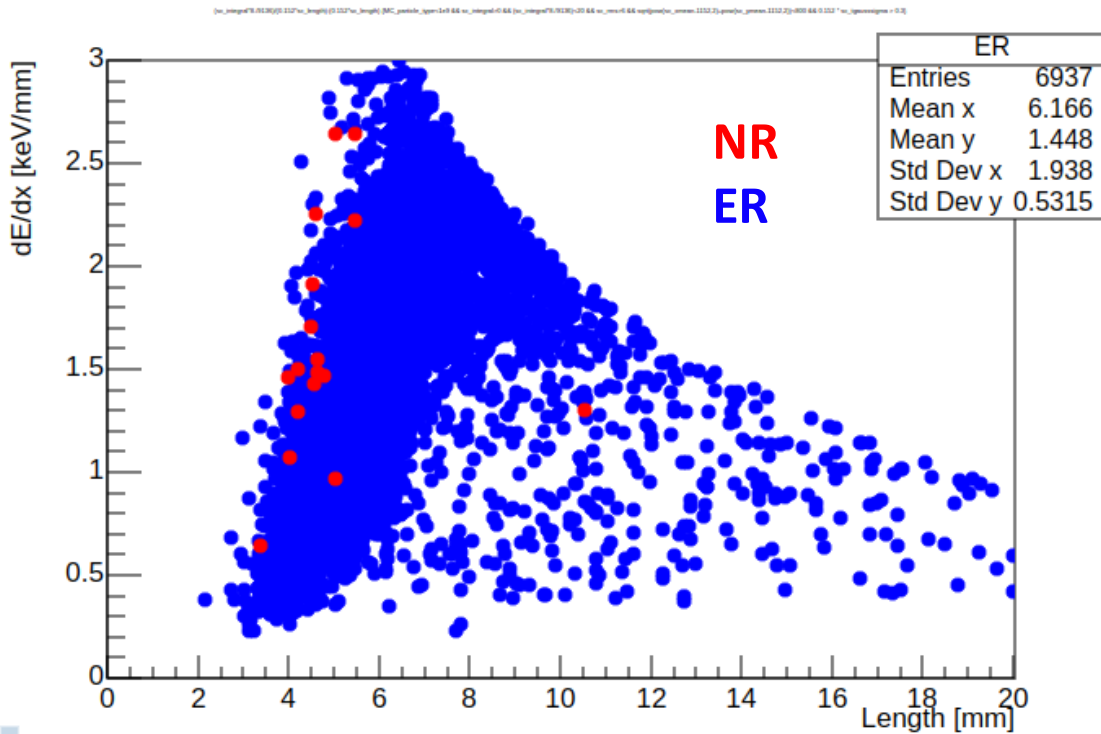
Data



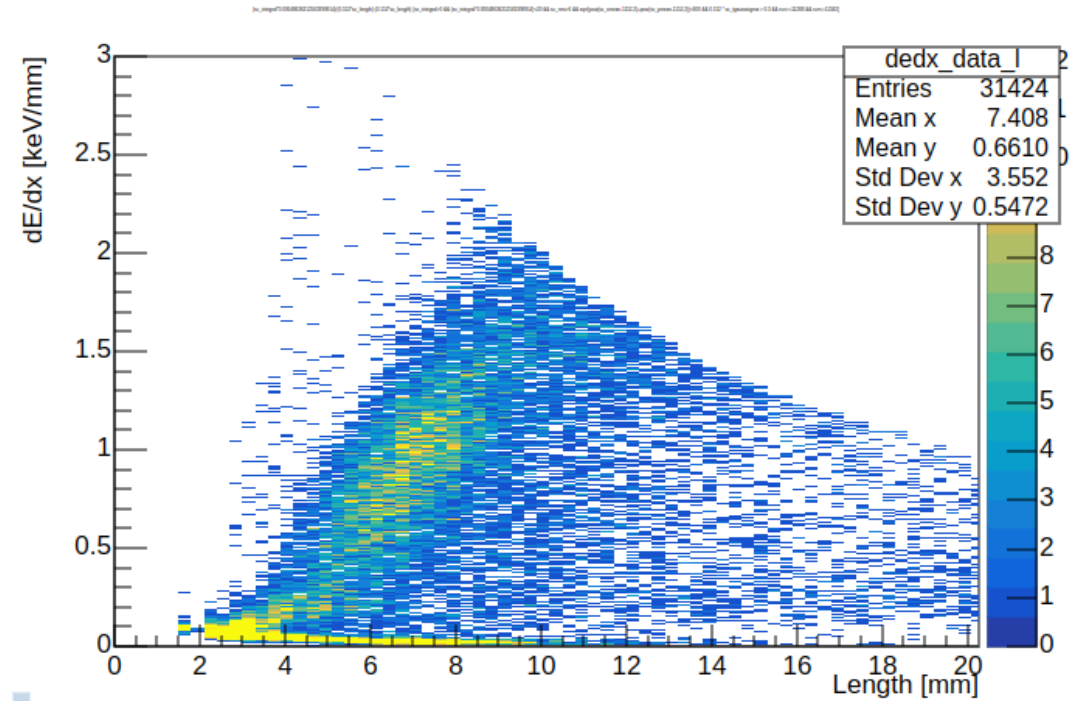
Calibration **not** corrected

# dE/dx vs length (ER/NR separation)

Simulation



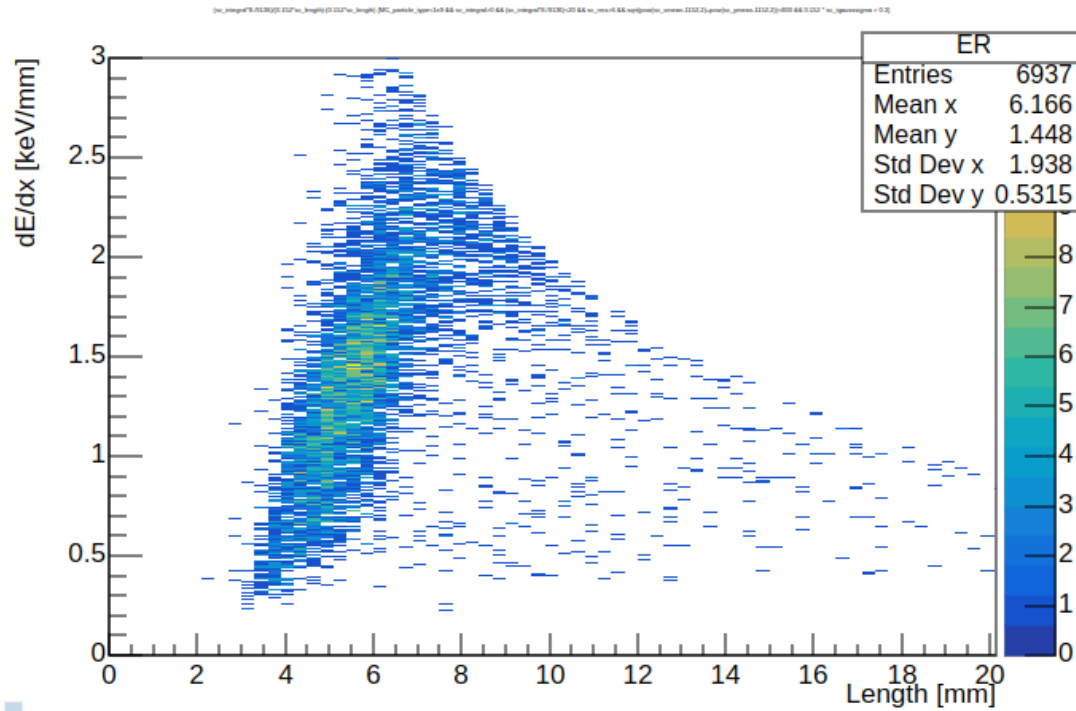
Data



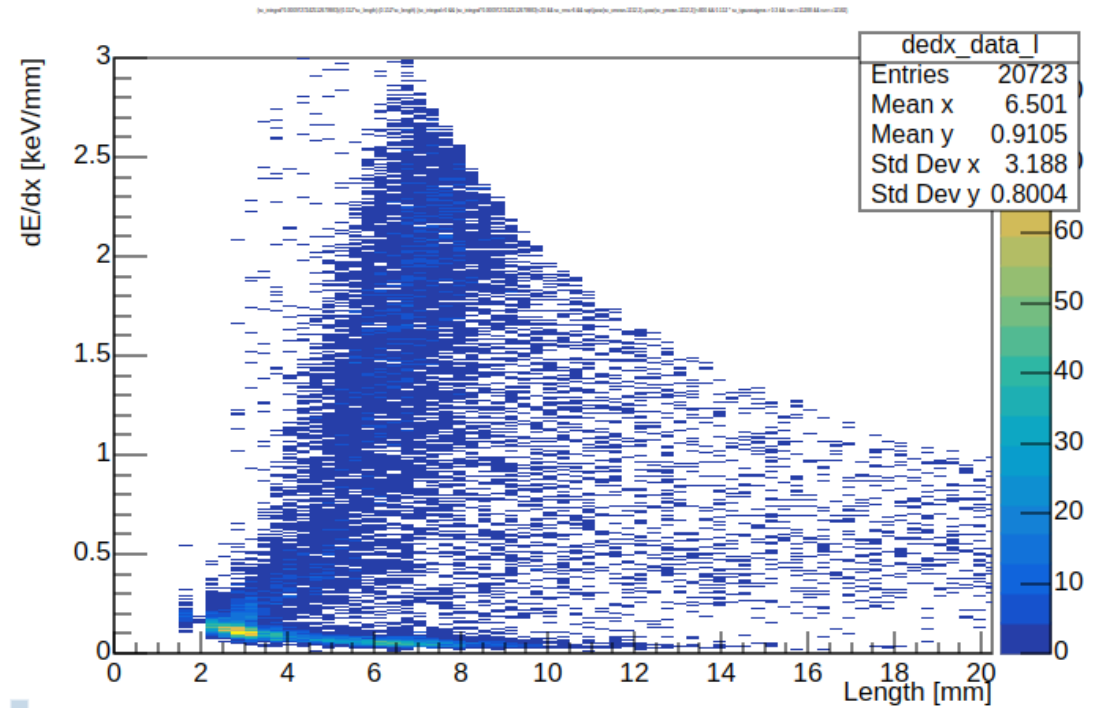
Calibration **not** corrected

# dE/dx vs length

## Simulation



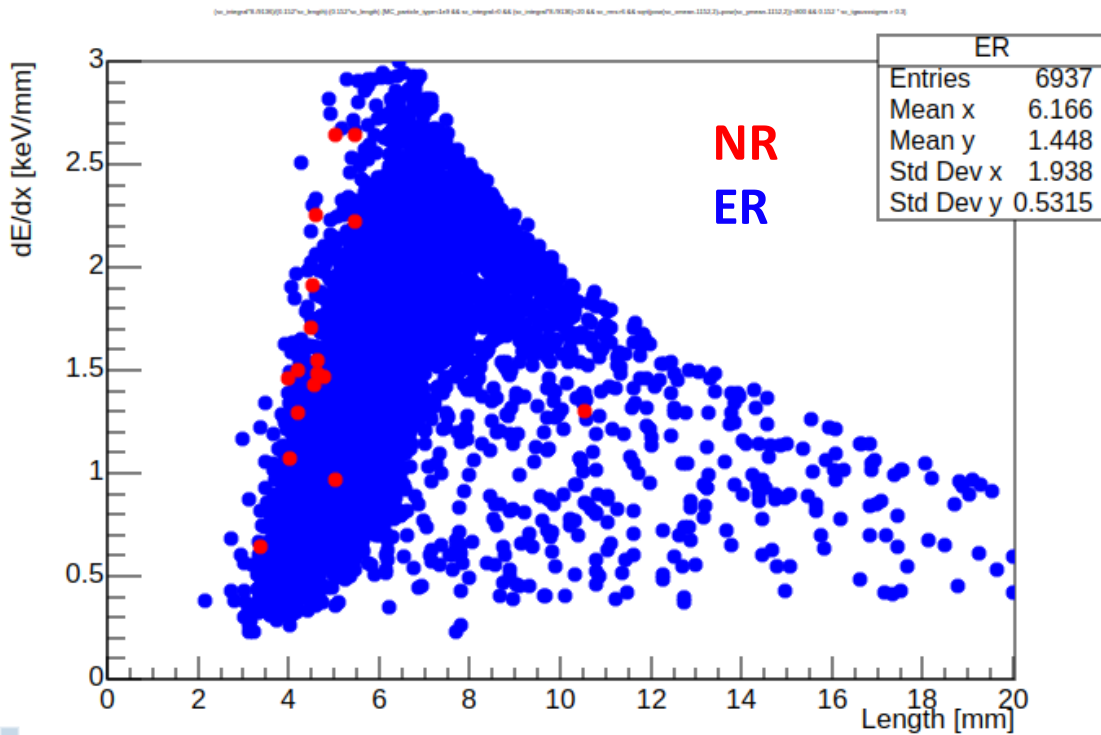
## Data



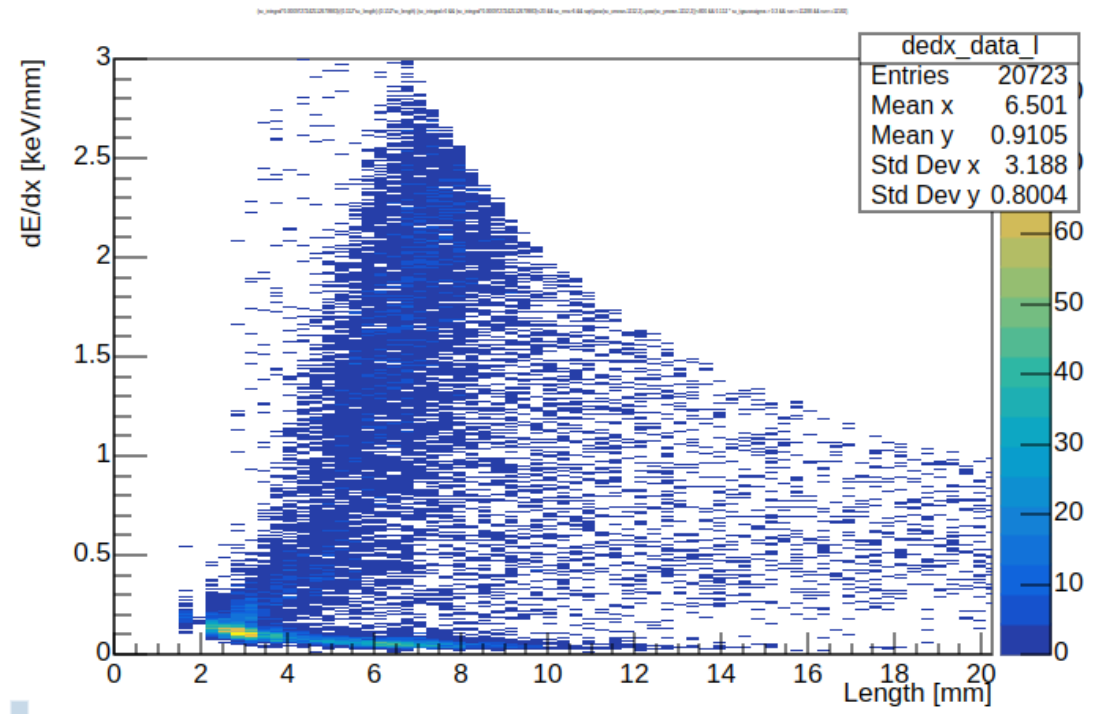
Calibration corrected

# dE/dx vs length (ER/NR separation)

Simulation



Data



Calibration corrected