Data-MC comparison

CYGNO simulation meeting – 18/09/2023

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LIME underground data

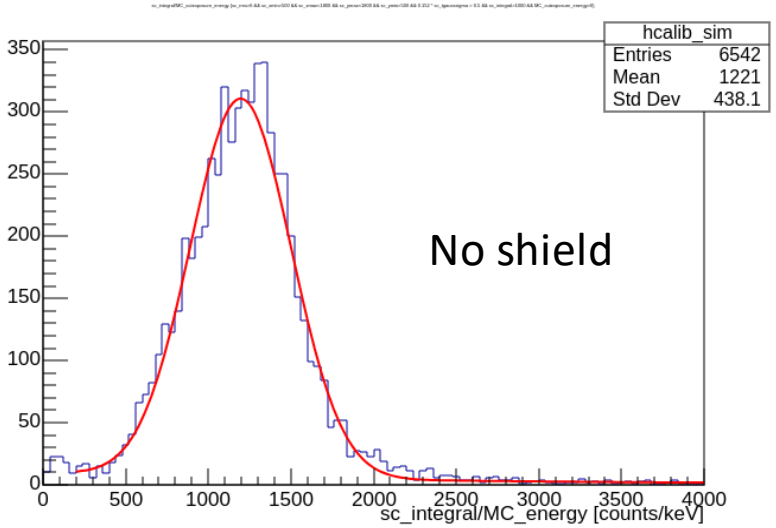
- **Run1: runs 5923-6743**
- **Run2: runs 11289-12191**
- **Run3: runs 22726-23762**
- **Normalization: (# selected sc) * C / T**
  - T = total duration of runs (stop_time-start_time)
  - C = dead time correction
    - C = (K+m)/K , where K = # of selected sc, m = missed events
    - Number of missed events is extracted for each image from a Poisson probability distribution with mean=R*dead_time, where R = (PMT measured rate), and dead_time=(0.03+0.012*k) ms, where k is the number of selected sc for each image, tcam=30ms, twf=12ms (from Stefano Piacentini work on the dead time)
  - Selection cuts: *fake_cut* = sc_rms>6 && 0.152 * sc_tgausssigma > 0.5 && sc_integral>1000
  - I tried different geometrical cuts
    - sc_xmin>400 && sc_xmax<1900 && sc_ymax<1900 && sc_ymin>400 (I used this for all the plots in this presentation)
    - sqrt(pow(sc_xmean-1152,2)+pow(sc_ymean-1152,2))<R (R=800,900,1000...)
- I **calibrated** each run with the closest calibration run in position 3 (at the center of the detector)

LIME background simulation

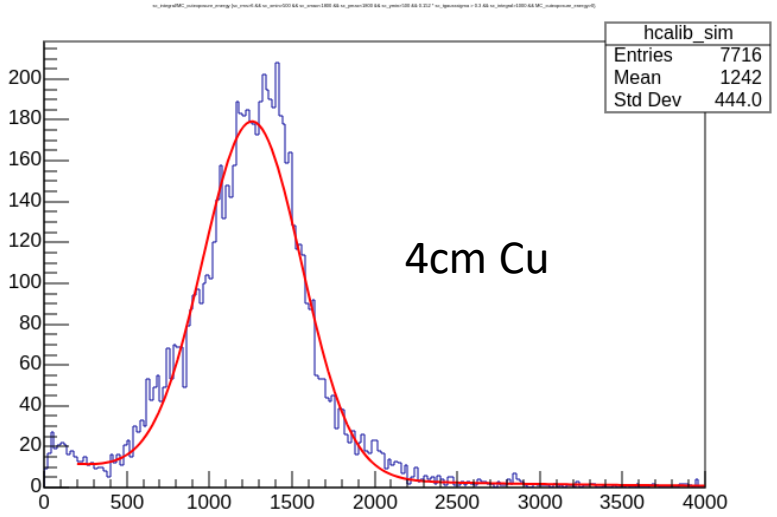
- **GEANT4:**
  - External gammas with no shield (only aluminium Faraday cage), 4cm of copper, 10cm of copper
  - Radioactivity: field rings, resistors, cathode, GEM, acrylic box
    - I simulated an equivalent of 120hr and got 0 events from the camera
  - *What was left out*: shielding radioactivity, external neutrons, radiogenic neutrons, cosmogenic neutrons – they should all be subdominant contributions

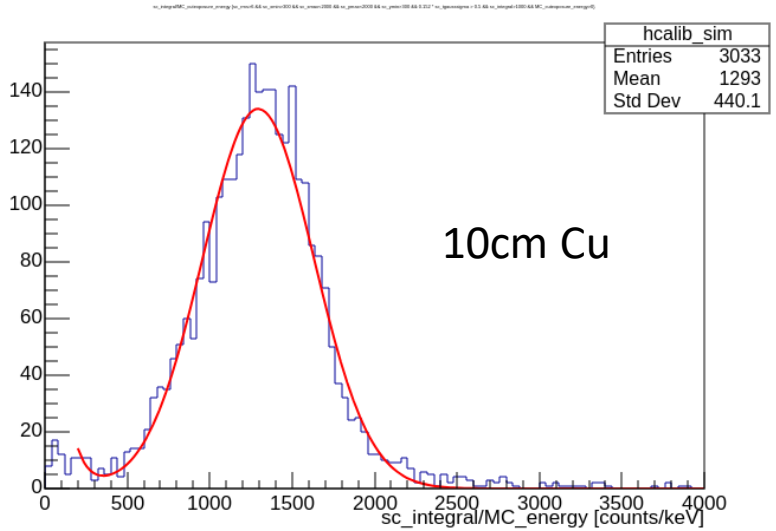
- **Digitization:**
  - I used real pedestal runs from Run1, Run2 and Run3 as a background for external gammas events (for now the radioactivity was simulated only with Run2 pedestal runs)
  - I apply the vignetting map 4117 from an overground **cosmics run** in LNF
  - I implemented the effect of the camera exposure: some tracks are cut (partially or completely) because the camera is not fully exposed (it's opening or closing)
    - Parameters: exposure time 300ms, readout time 184.4ms
- **Reconstruction:**
  - I used the winter23-patch2 tag
    - I should have used another version for run1?
  - For the vignetting correction I used the only-**optical** map

LIME background simulation



- I calibrated the cluster integral by fitting with a gaussian the ratio between sc_integral and the true energy for all events
- I used the external gamma simulation in the three configurations, and used the same calibration also for radioactivity



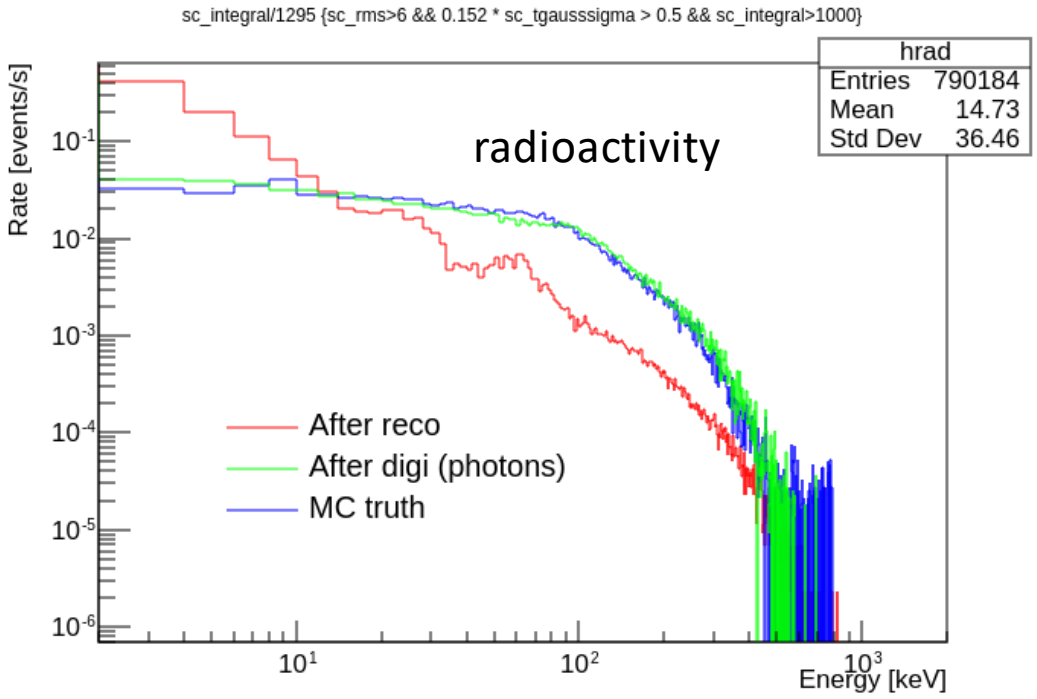


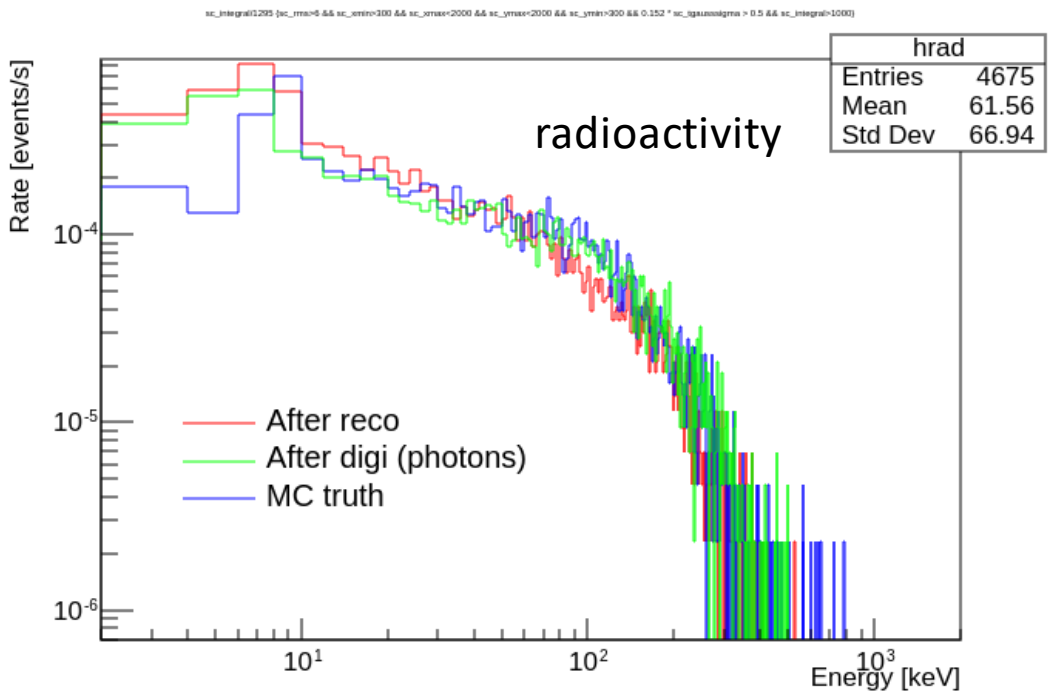
Gauss fit parameters:

No shield: mean 1197, sigma 306
4cm Cu: mean 1260, sigma 298
10cm Cu: mean 1295, sigma 338

MC simulation chain

- I checked how the energy spectrum changes from GEANT4 (MC truth) to digitization (number of photons) to the final reconstruction
- I selected the events applying the *fake_cut*
- I calibrated in energy the after digi and after reco spectra to compare with MC truth

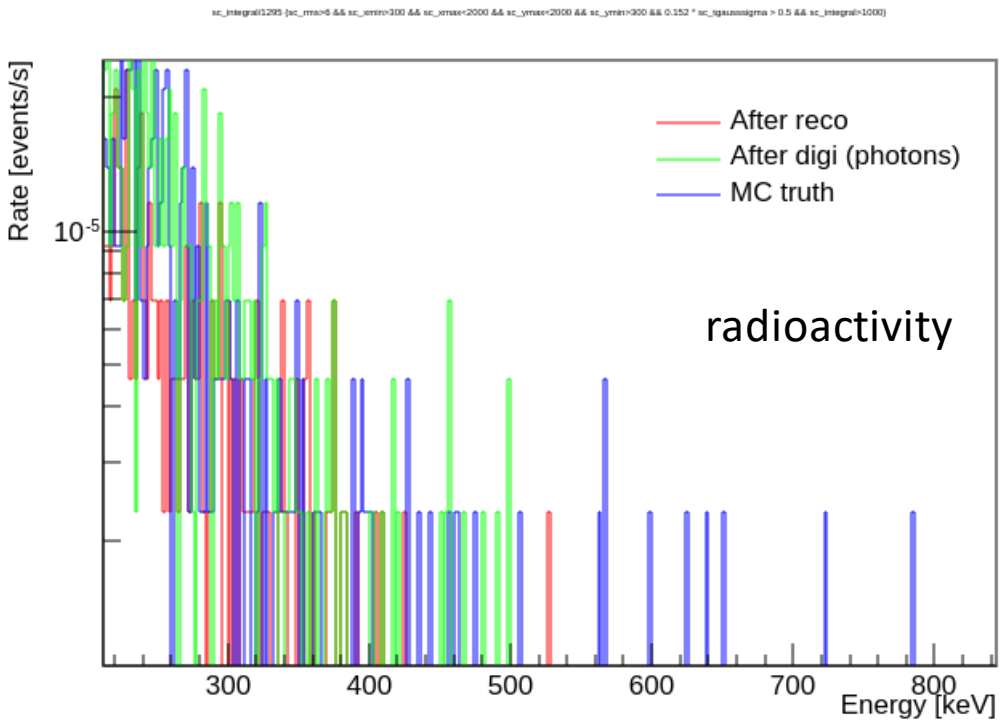




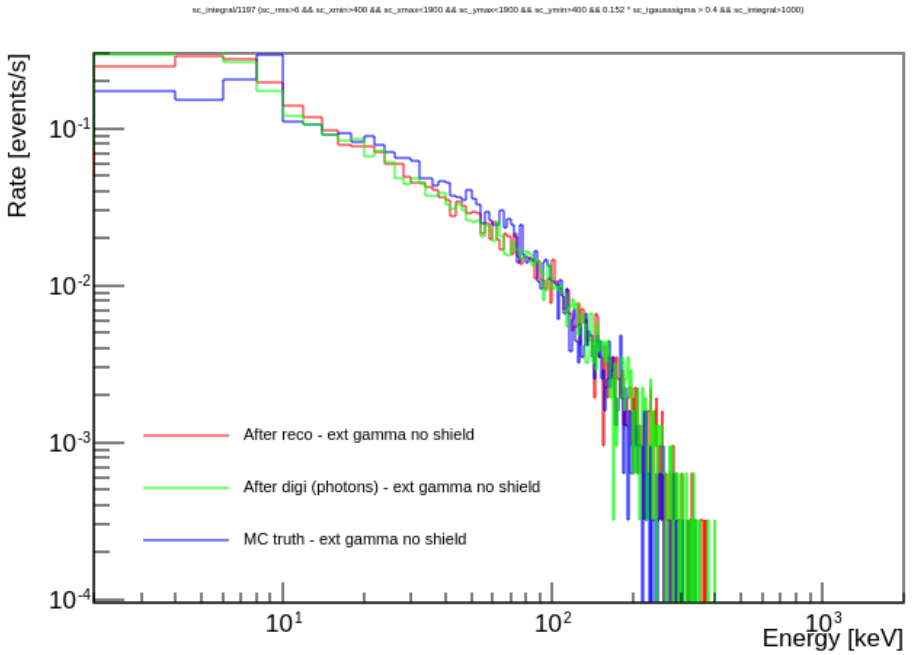
MC simulation chain

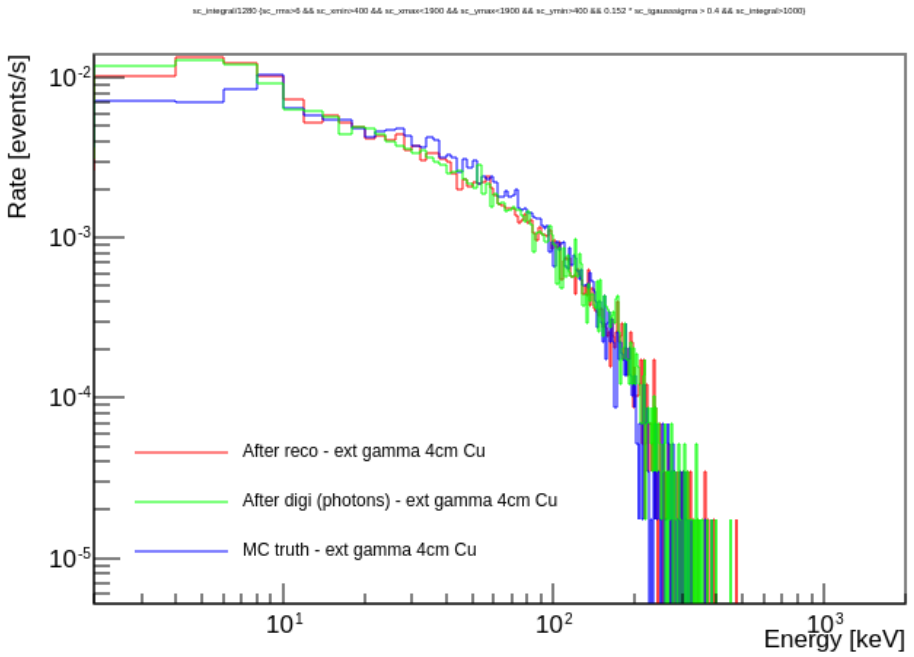
- I checked how the energy spectrum changes from GEANT4 (MC truth) to digitization (number of photons) to the final reconstruction
- I selected the events applying the *fake_cut*
- I calibrated in energy the after digi and after reco spectra to compare with MC truth

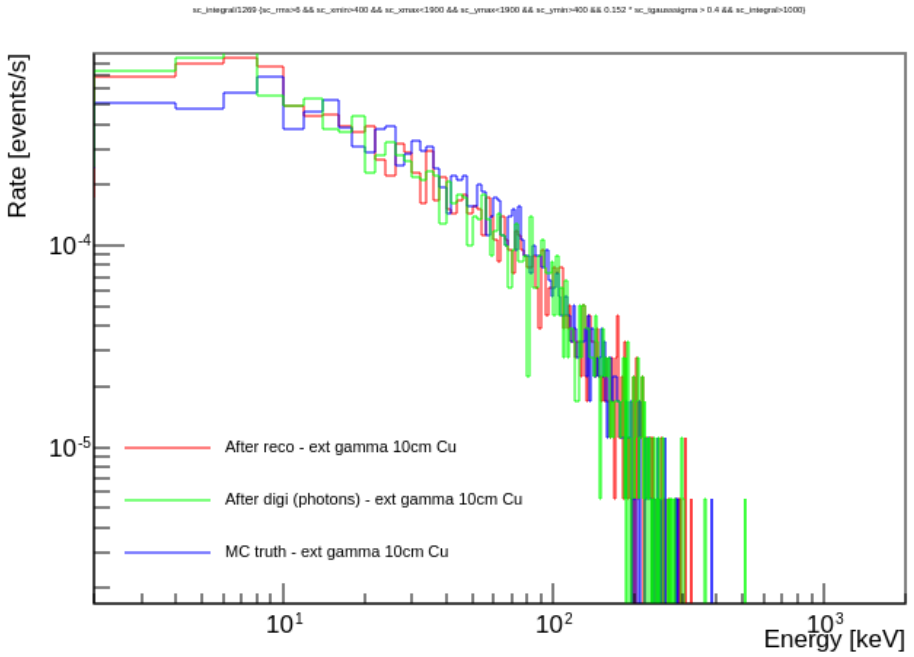
- MC true energy is up to 800 keV because that is the maximum energy I set to digitize the tracks
- After digitization the maximum energy becomes 500keV
- At these energies there are mainly alphas; could this be an over-estimation of the simulated saturation? (there are events in data at those energies, only missing in the MC)



MC simulation chain

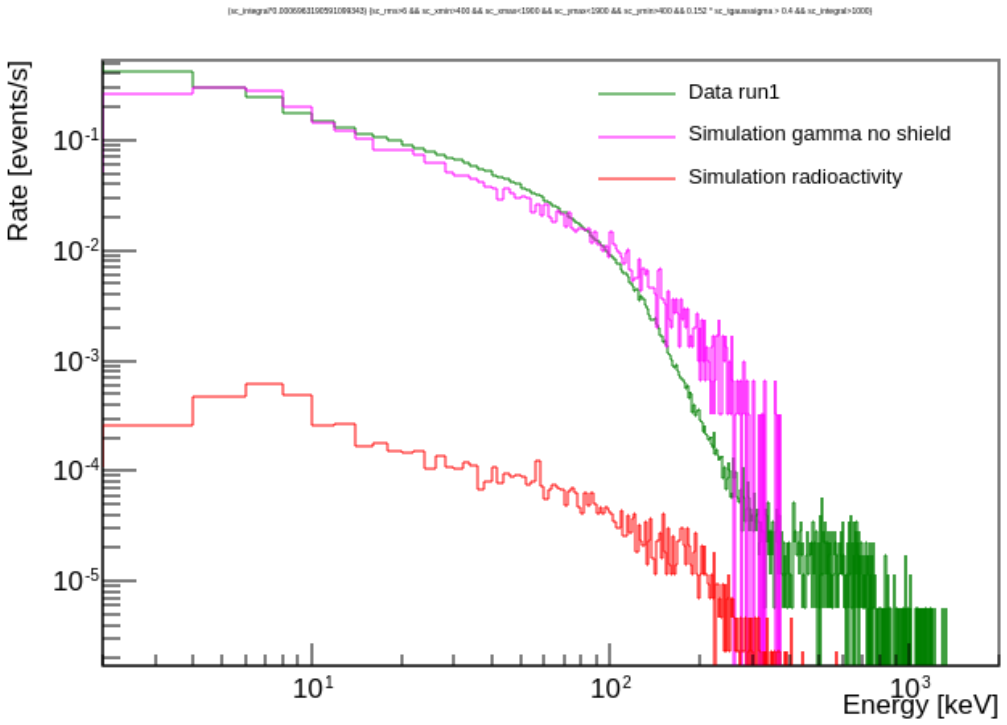


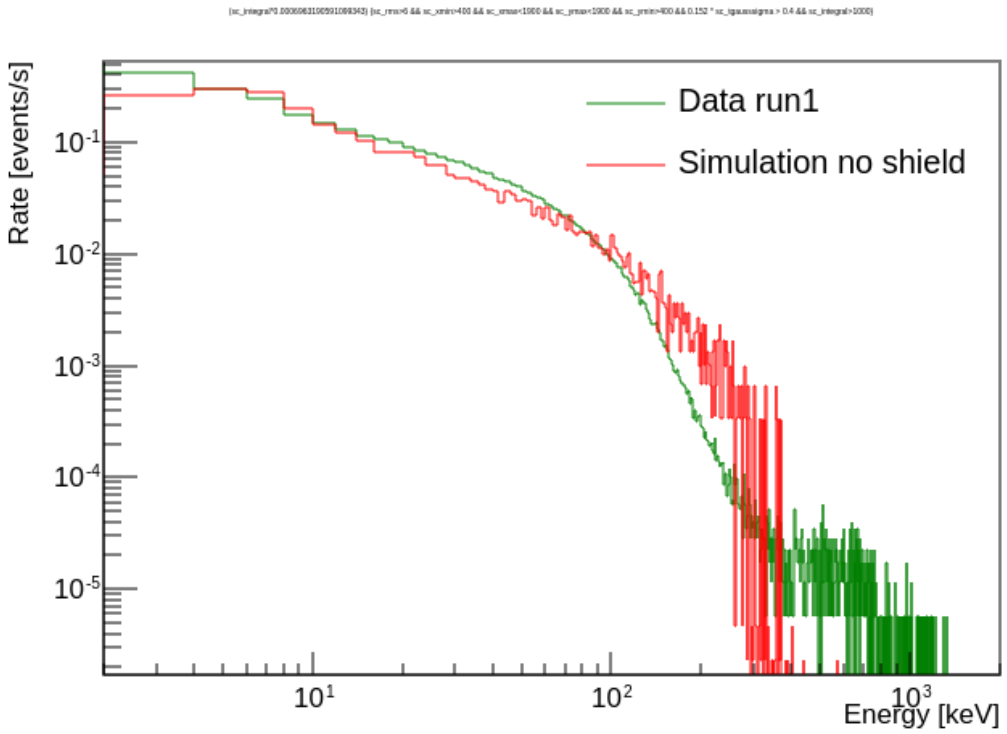




- I did the same comparison with external gamma simulation
- The shape does not seem to change significantly below 500keV

Run1 – MC energy spectrum comparison

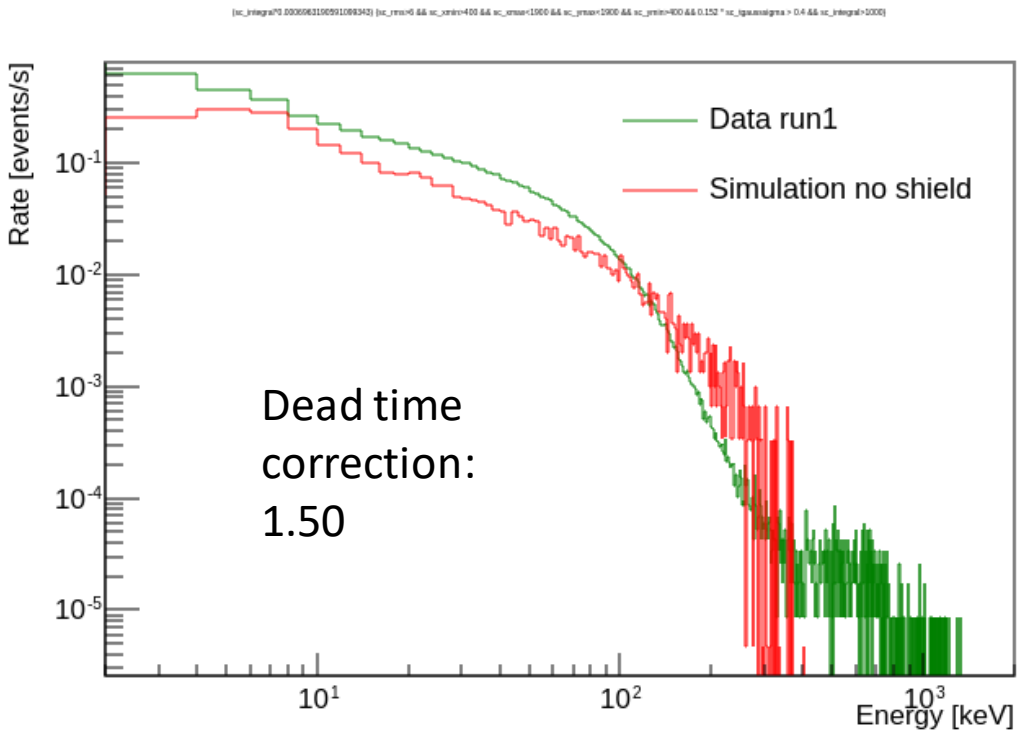


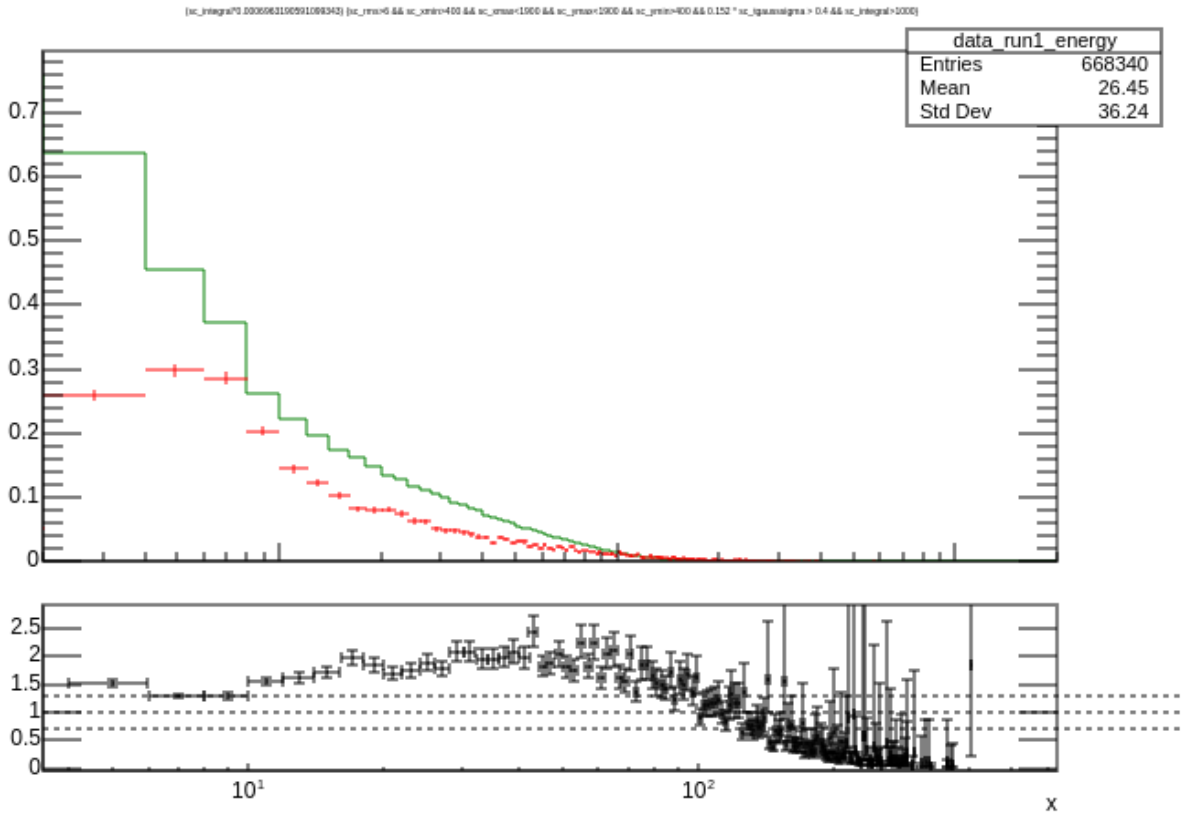


- No dead time correction (1.5)
- If the simulation makes high energy alphas saturate more than reality, those would end up in the high energy tail, producing the discrepancy - Other theories? Ideas? Wrong calibration?

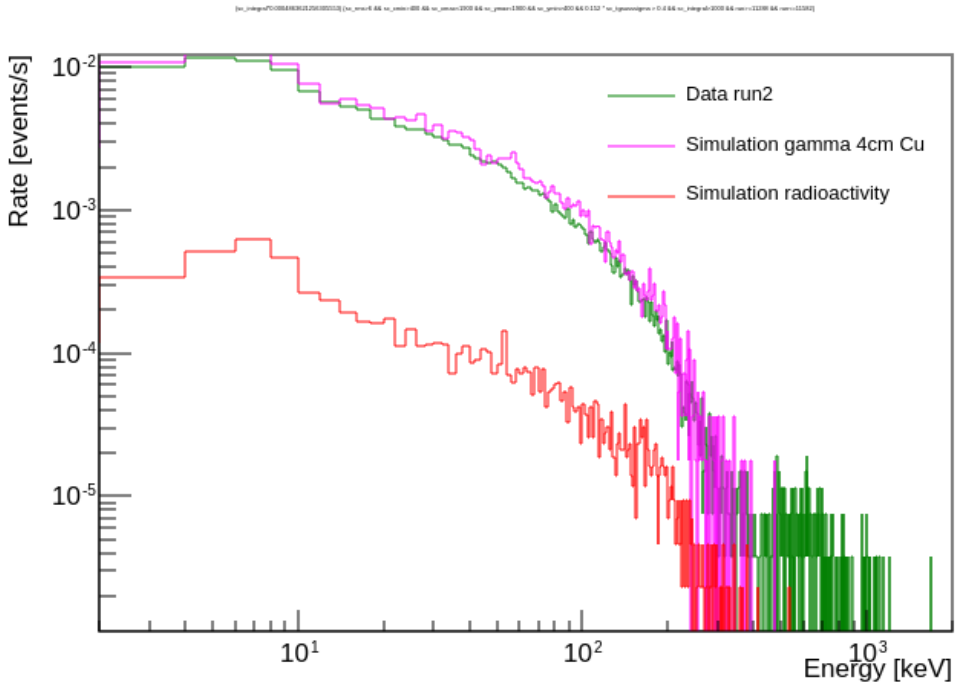
Run1 – MC energy spectrum comparison

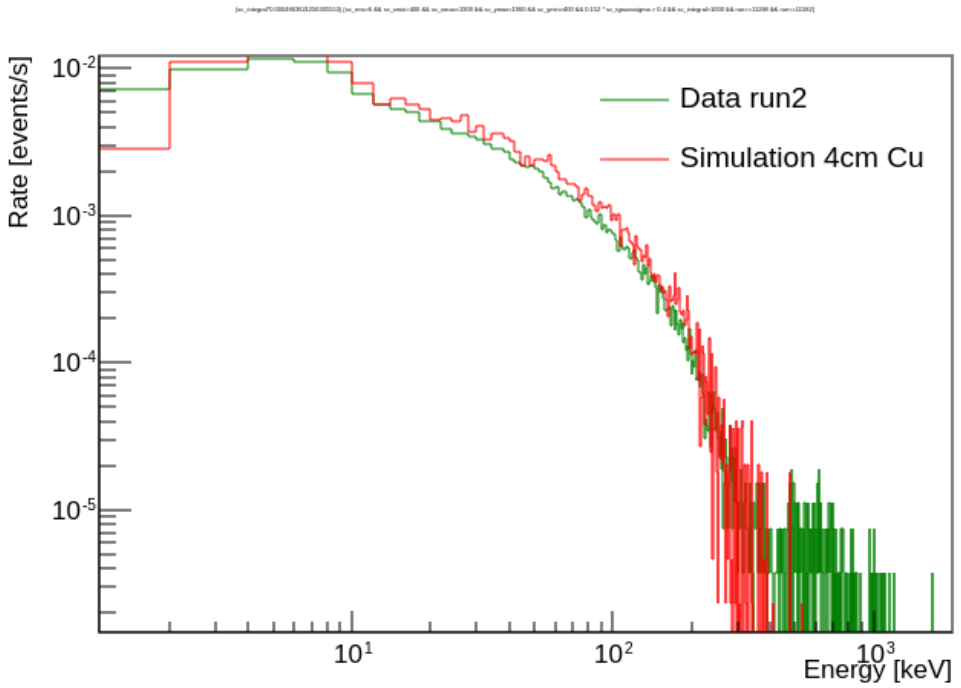
Adding dead time correction:





Run2 – MC energy spectrum comparison

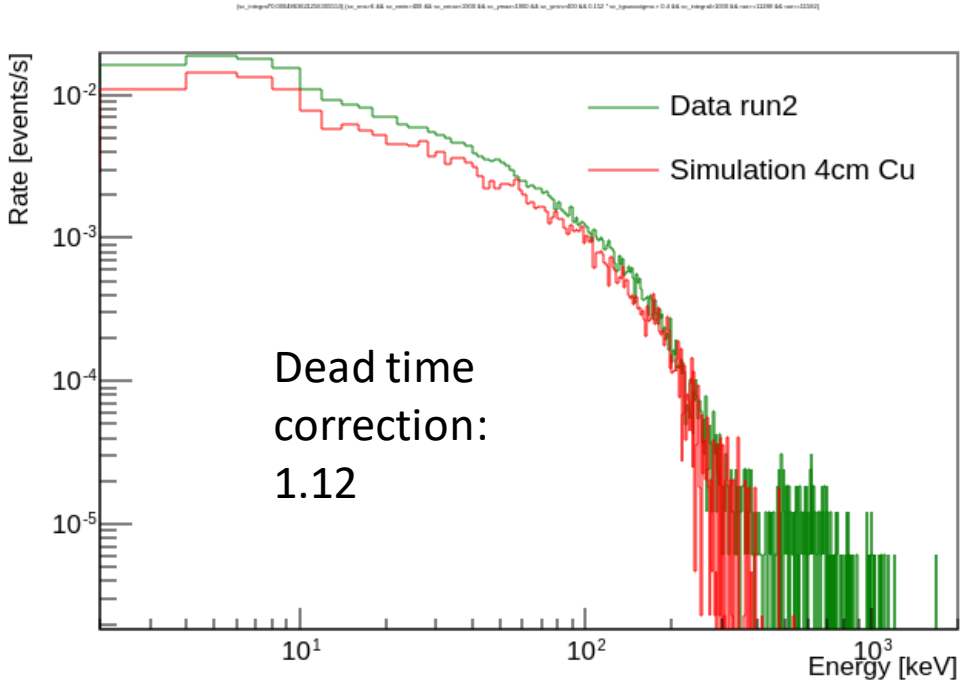


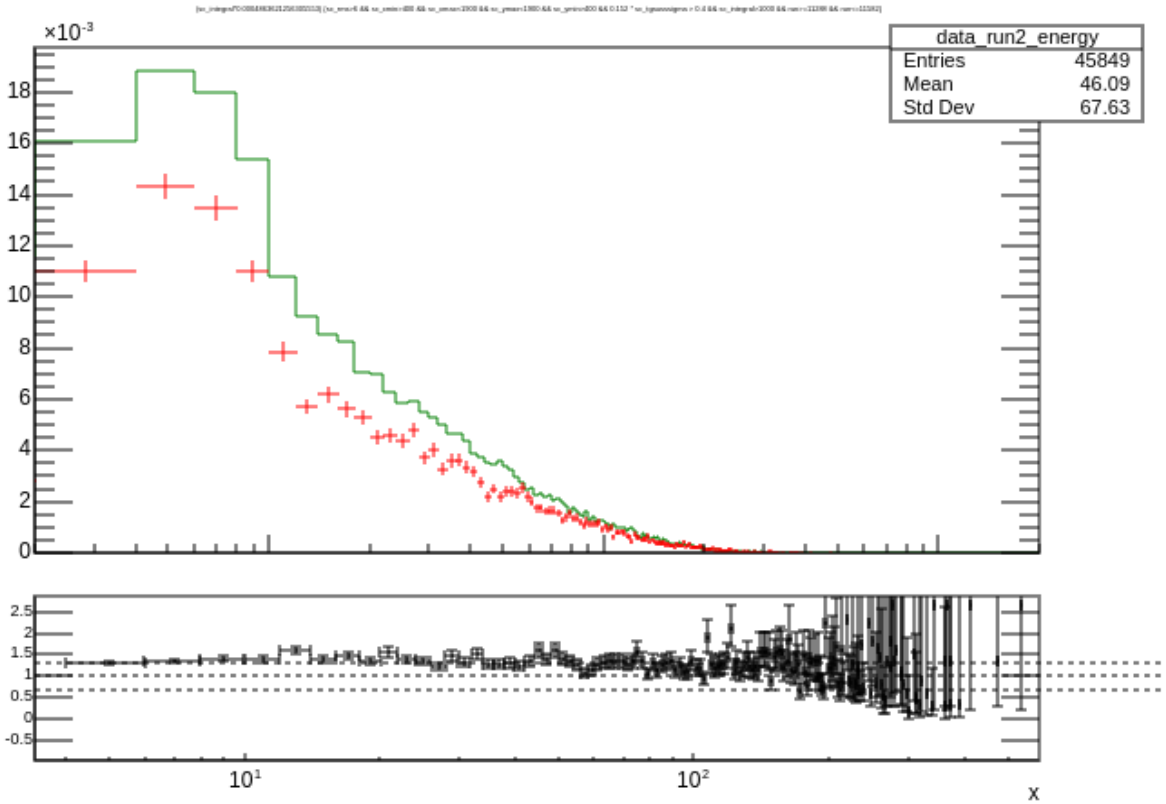


- No dead time correction (1.12)
- Data and simulation seem consistent; only issue (present in every run) is the excess at high energy (alphas)

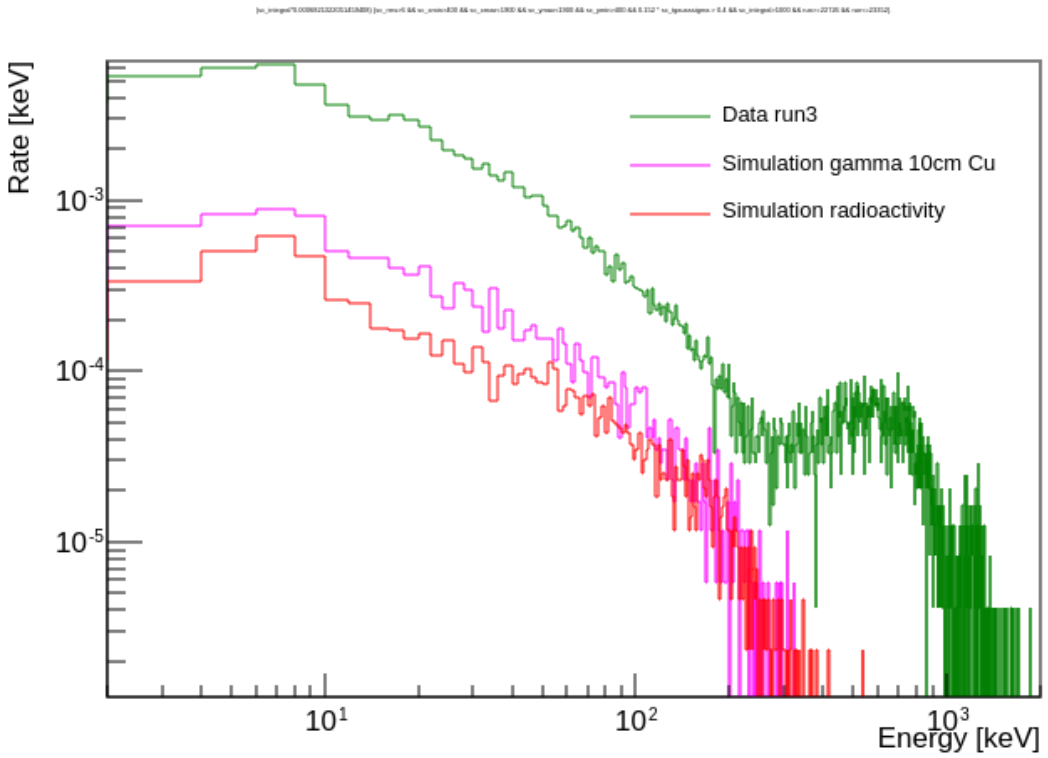
Run2 – MC energy spectrum comparison

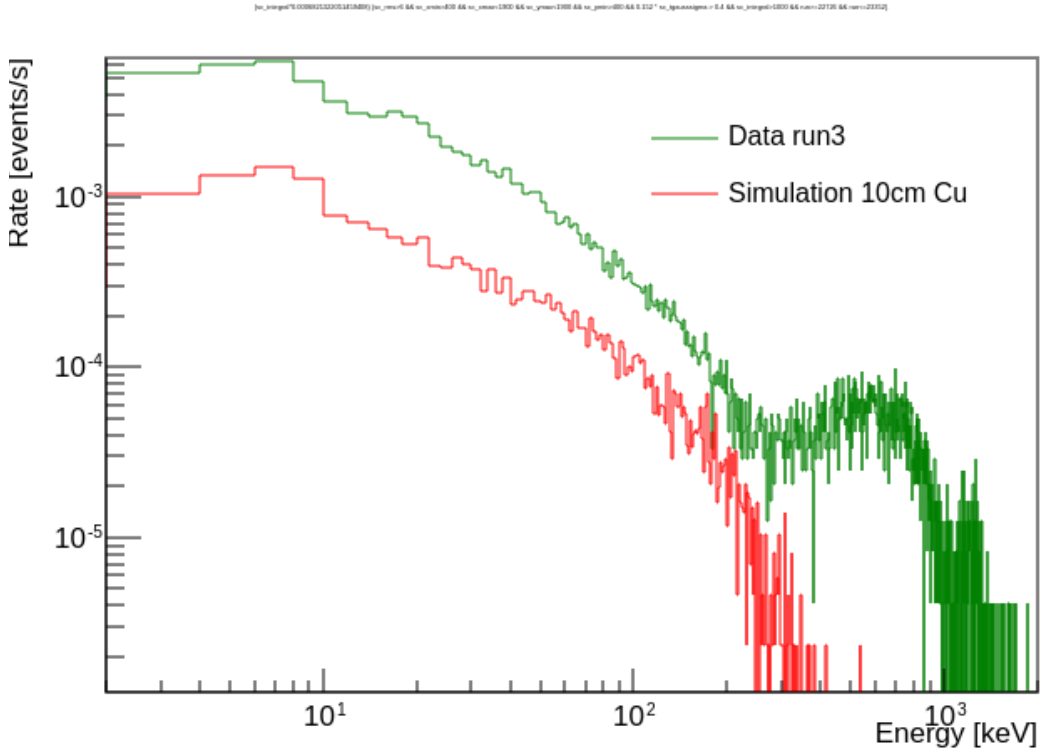
Adding dead time correction:





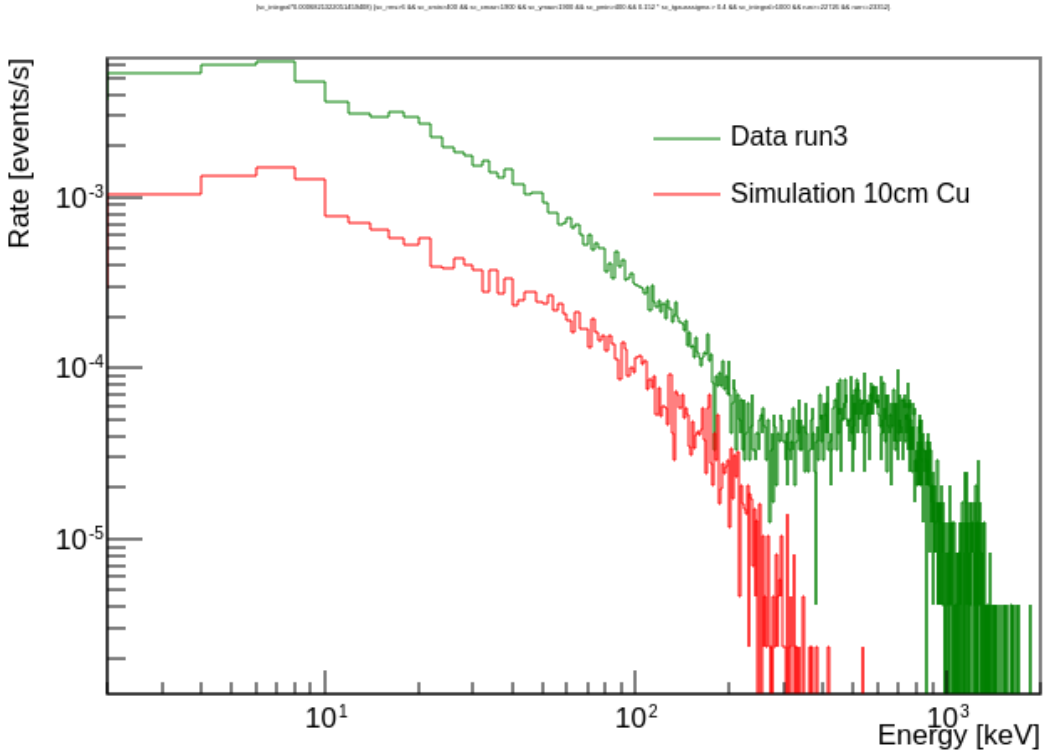
Run3 – MC comparison

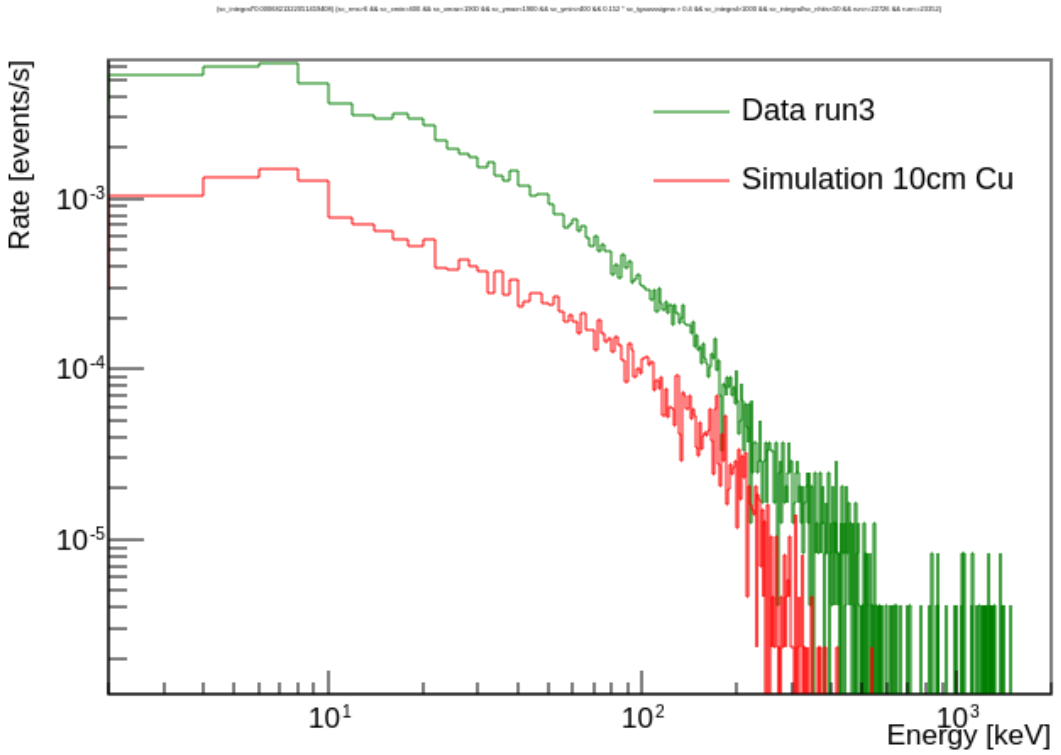




- No dead time correction applied (1.02)
- Largest MC/data discrepancy in Run3 (in addition to the high energy issue)
- About a factor 4 difference in the rate

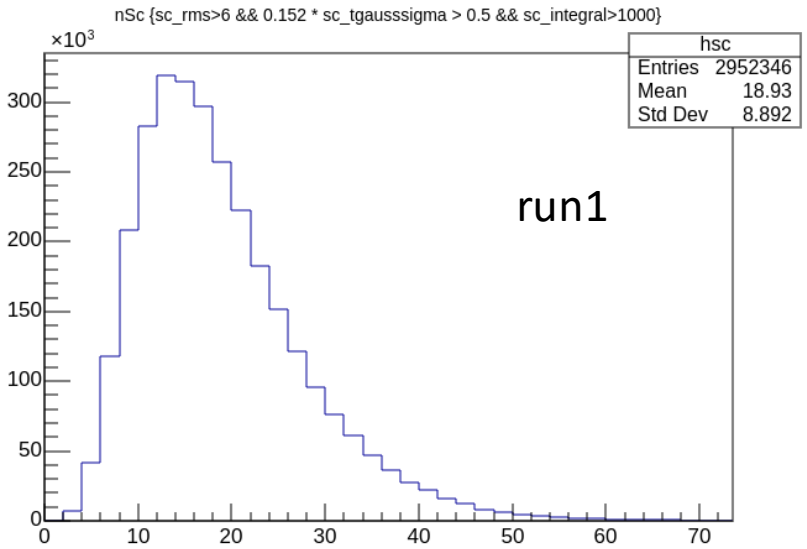
Run3 – MC comparison

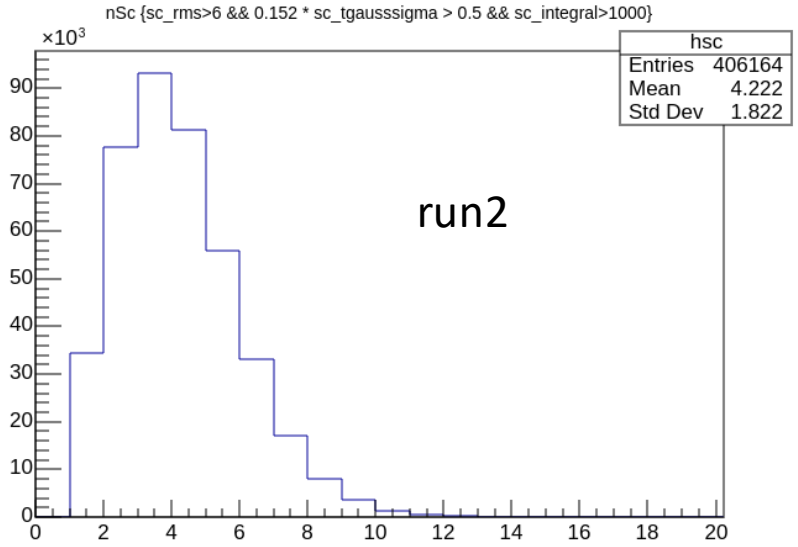


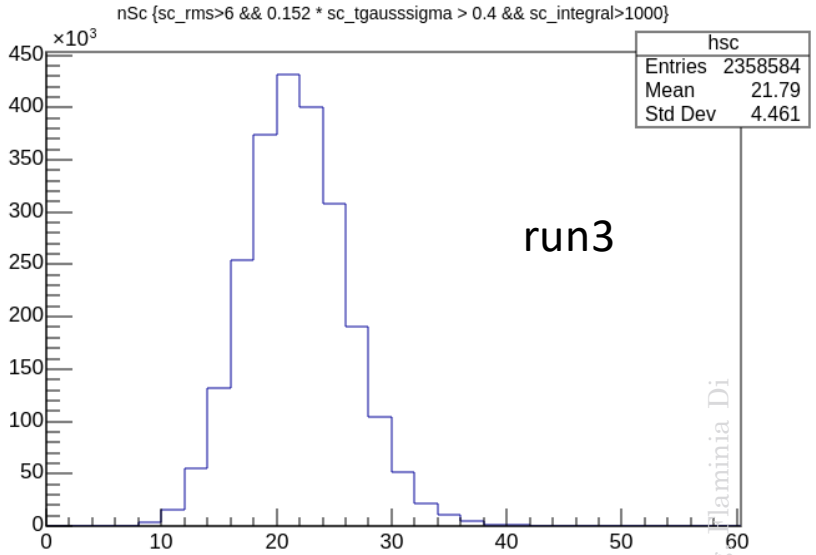


- On the right I applied a cut on the density: sc_integral/sc_nhits<50
  - The discrepancy is not only due to alphas or high density tracks in general

Run1,2,3 – nSc

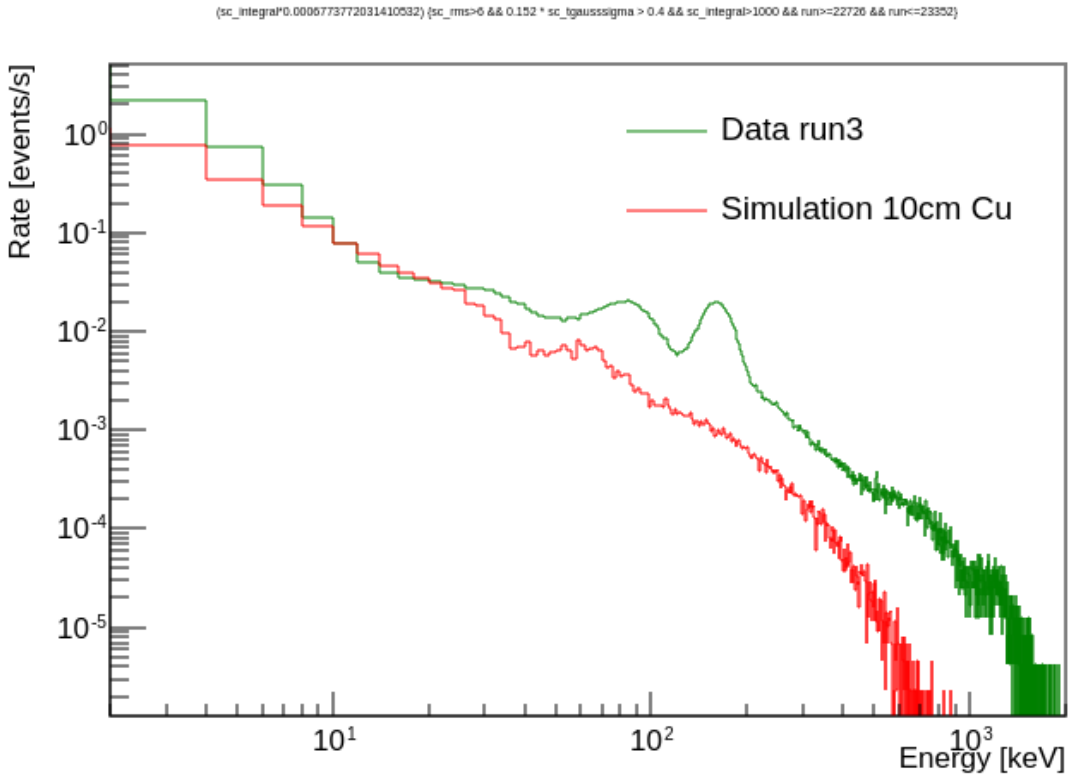




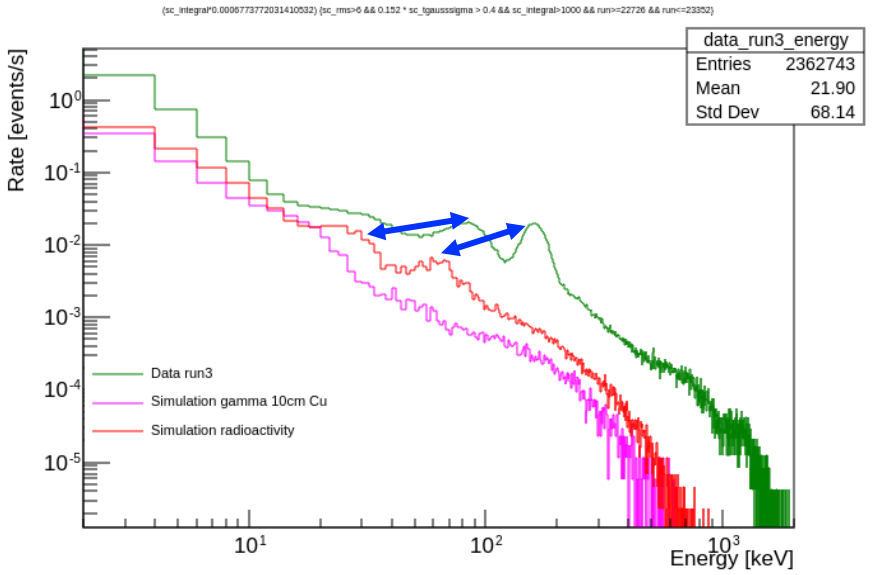


- Same cut: *fake_cut*=sc_rms>6 && 0.152 * sc_tgausssigma > 0.4 && sc_integral>1000
- If the *fake_cut* cuts out fake events with a sufficient efficiency, then I expect nSc to decrease...
- The cut might not work for Run3 because the camera is different? In principle it should be less noisy

Run3 – additional component?

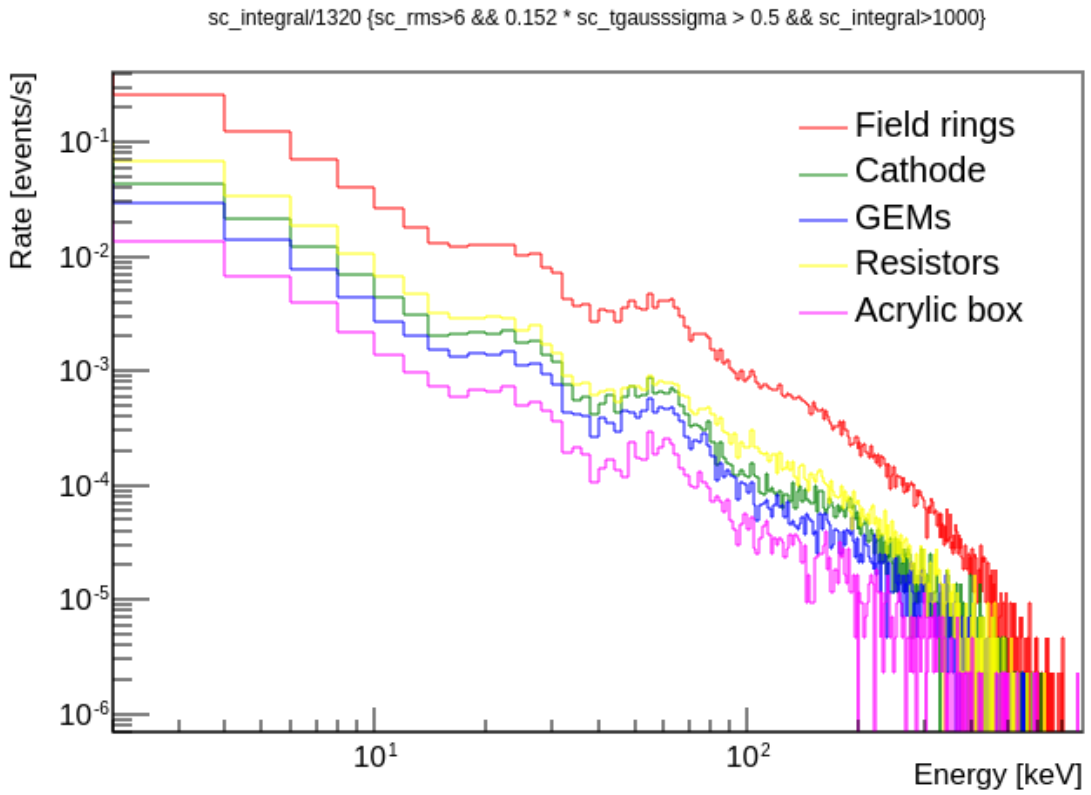


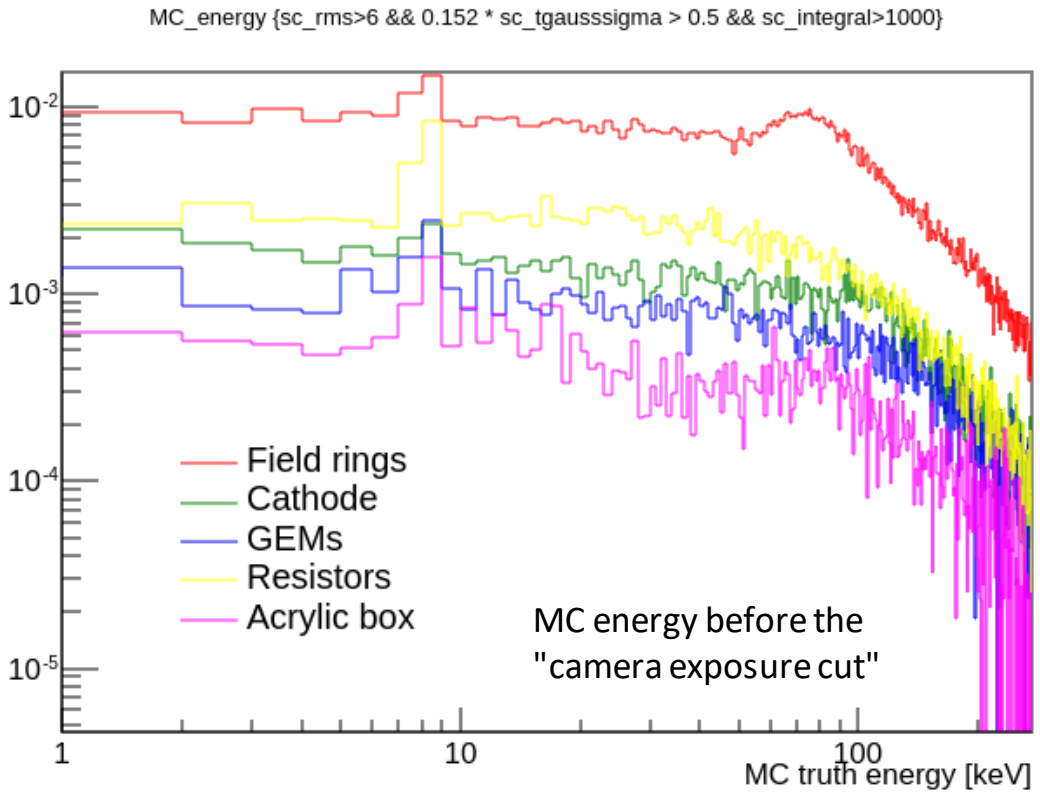
- Without geometrical cut, there are clearly visible peaks at 84keV and 161keV (and also at high energy, around 680keV and at 1138keV)
- I could not identify the source of these peaks*
  - Maybe the calibration of data is wrong?



*I checked gammas and X-rays, but basically I didn't find something consistent with *only* those peaks

Run3 – peaks from radioactivity

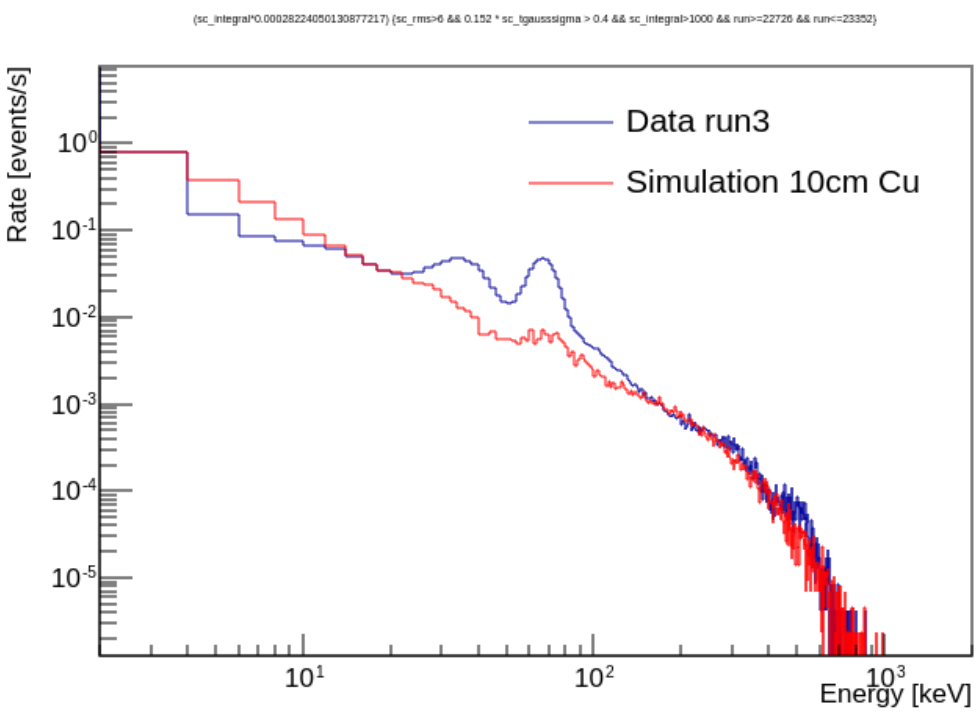


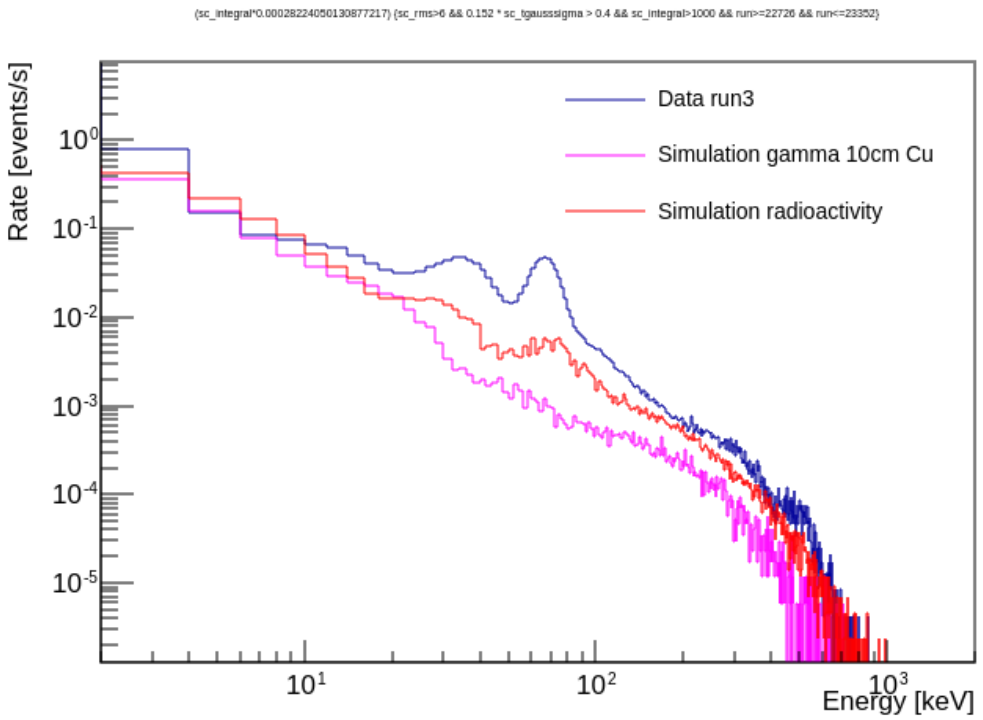


In the MC simulation, these peaks are around 25keV and 59keV, but there are no actual peaks in the MC true energy, only a peak from the field rings around 74keV (which is quite broad... it's not a single peak)

Run3 – calibration is wrong?

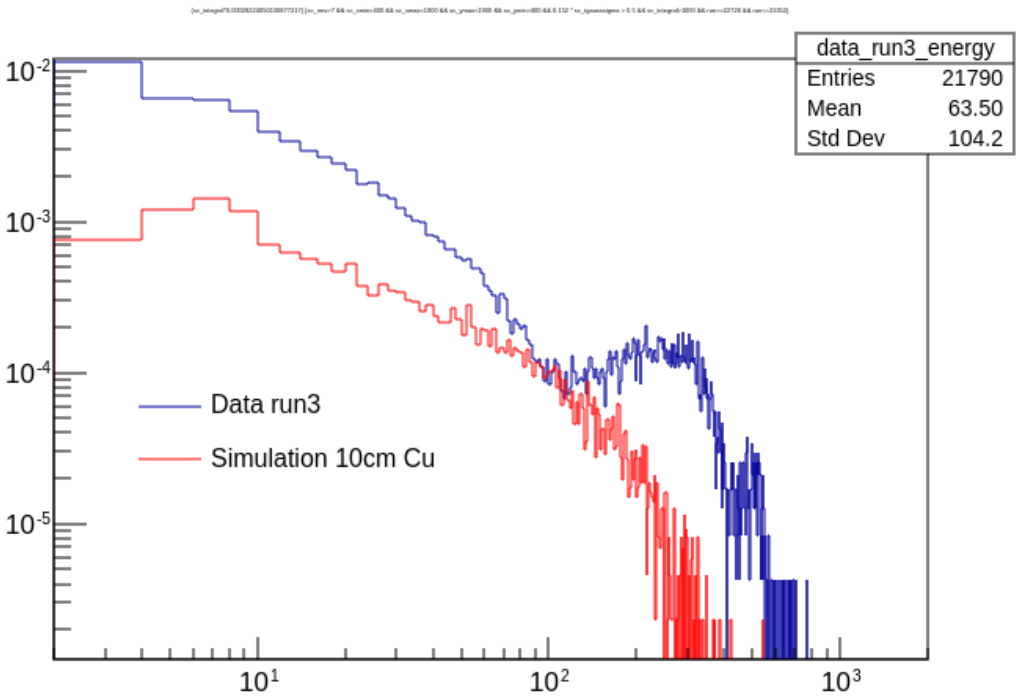
- Whatever the reason for these peaks is, it seems it's both in data and MC
- I manually corrected the calibration in data by a factor 2.4 (but no physical meaning in this number)
- The similar peaks in the radioactivity simulation now match better (and the overall shape is more similar)

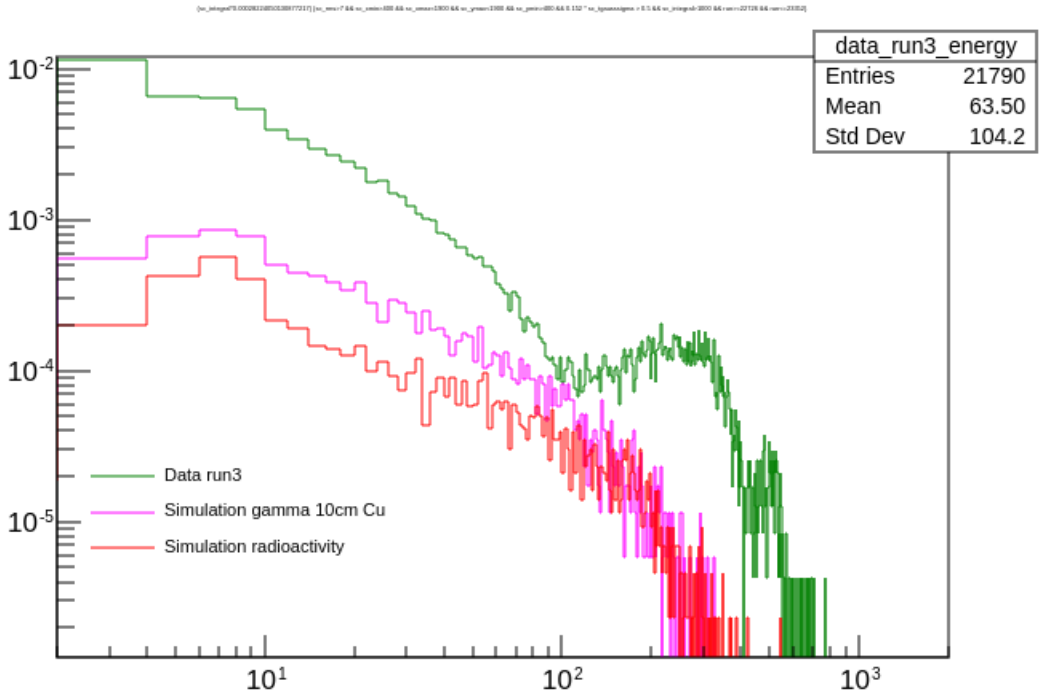




Run3 – adding back geometrical cut

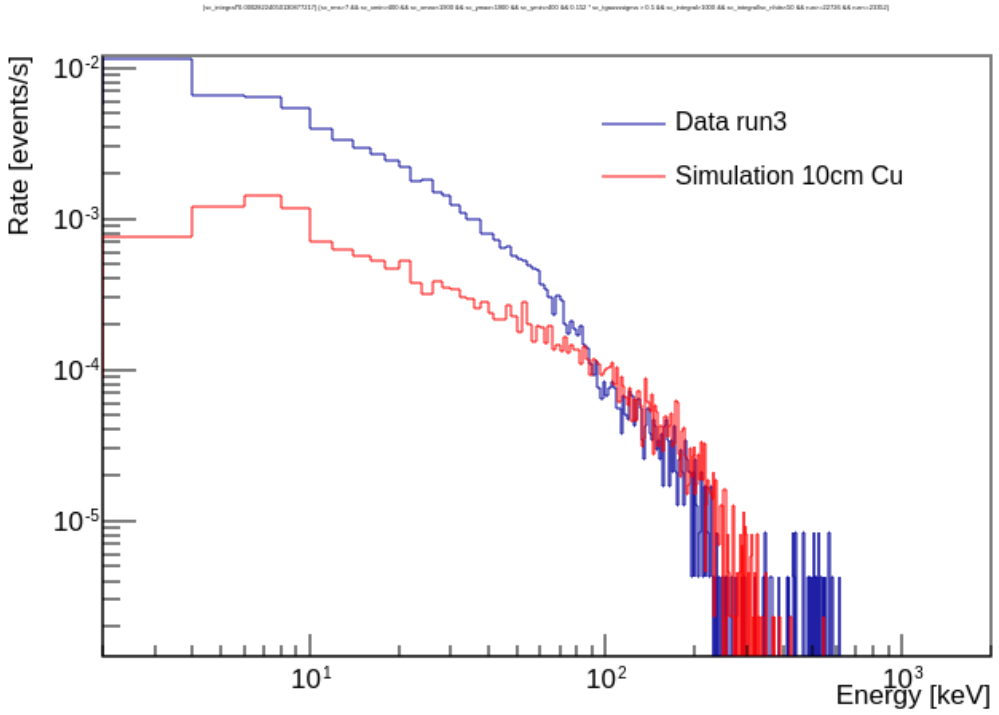
- Adding back the geometrical cut with this corrected-calibration, there is still an excess below 100keV

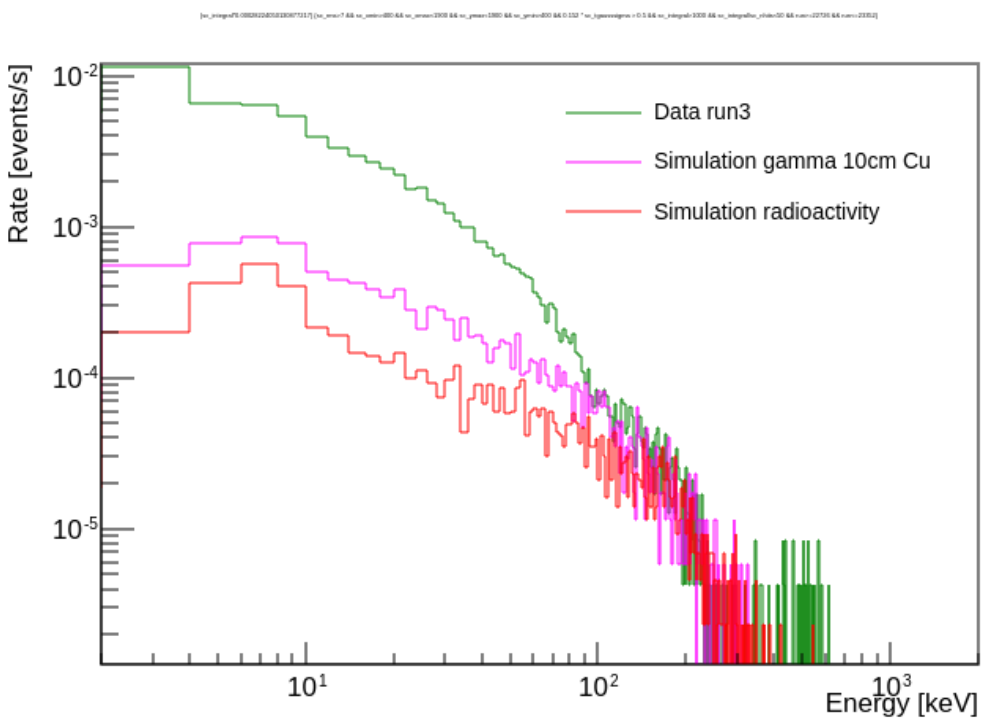




Run3 – what's wrong?

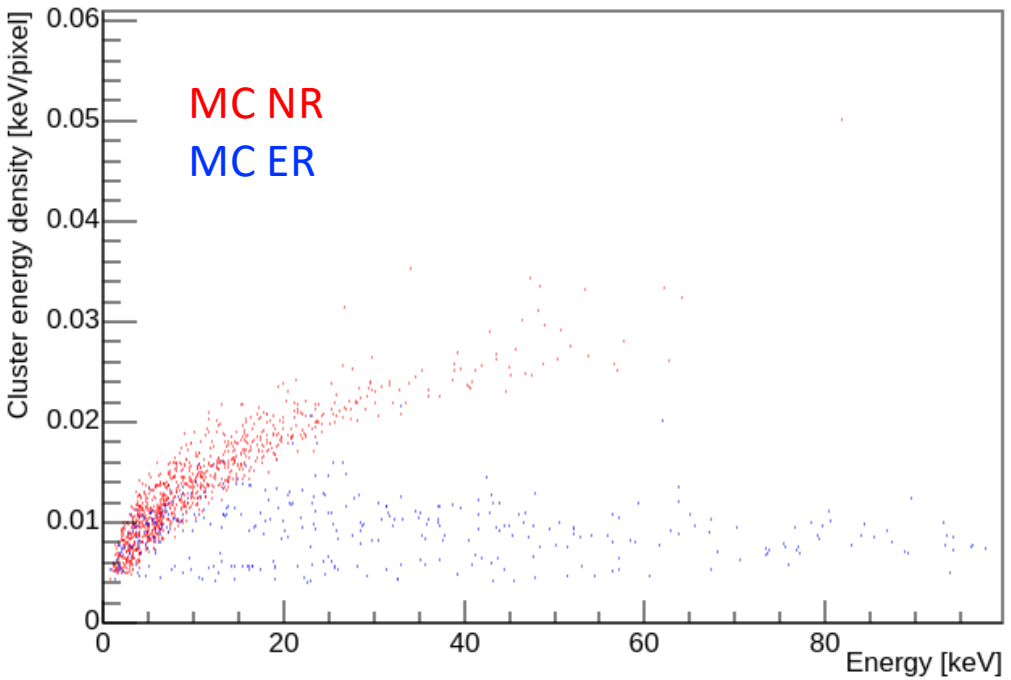
- Adding back the geometrical cut with this corrected-calibration, there is still an excess below 100keV
- Adding also the cut on alphas (density<50)

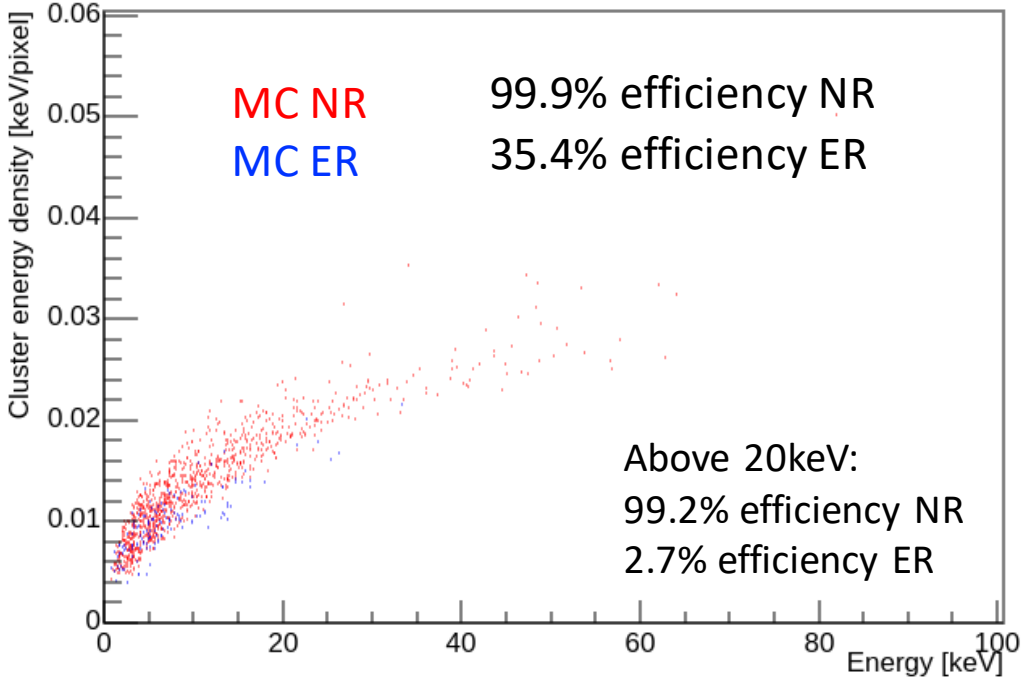




AmBe runs – MC comparison

- I digitized and reconstructed the **neutron** simulation (gammas should be simulated separately), 10hr equivalent time
- Calibrated with AmBe+Fe runs
- Simple cut on density (calibrated_energy/sc_nhits)





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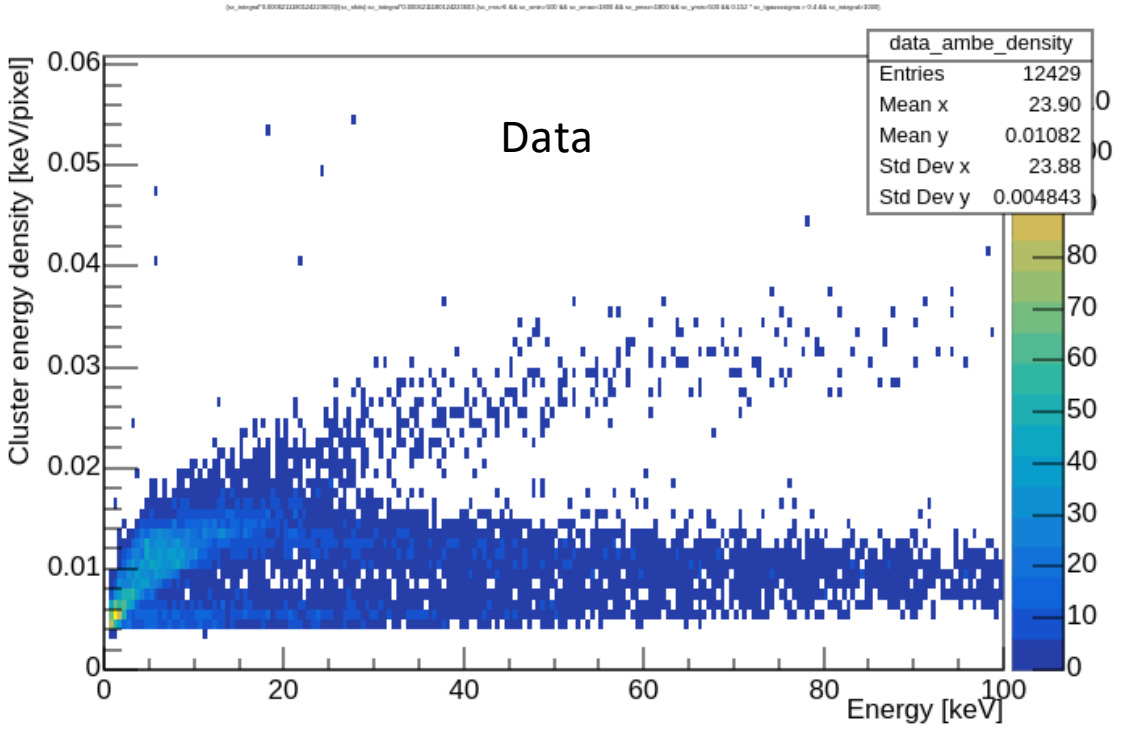
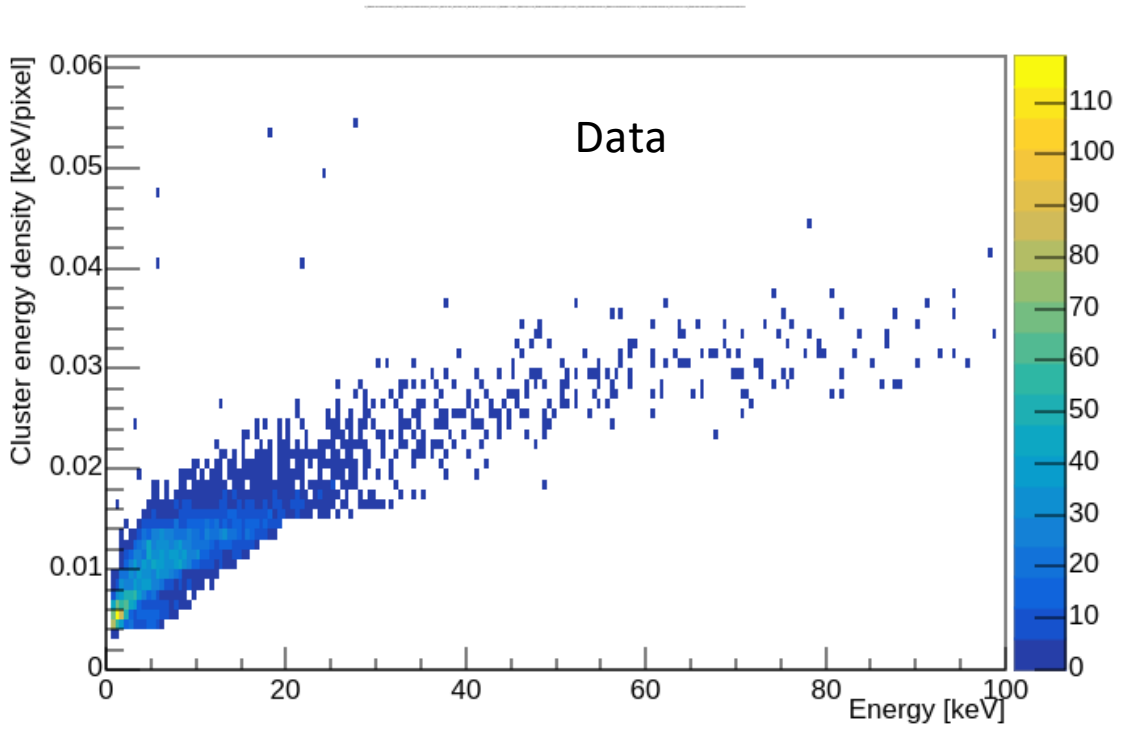
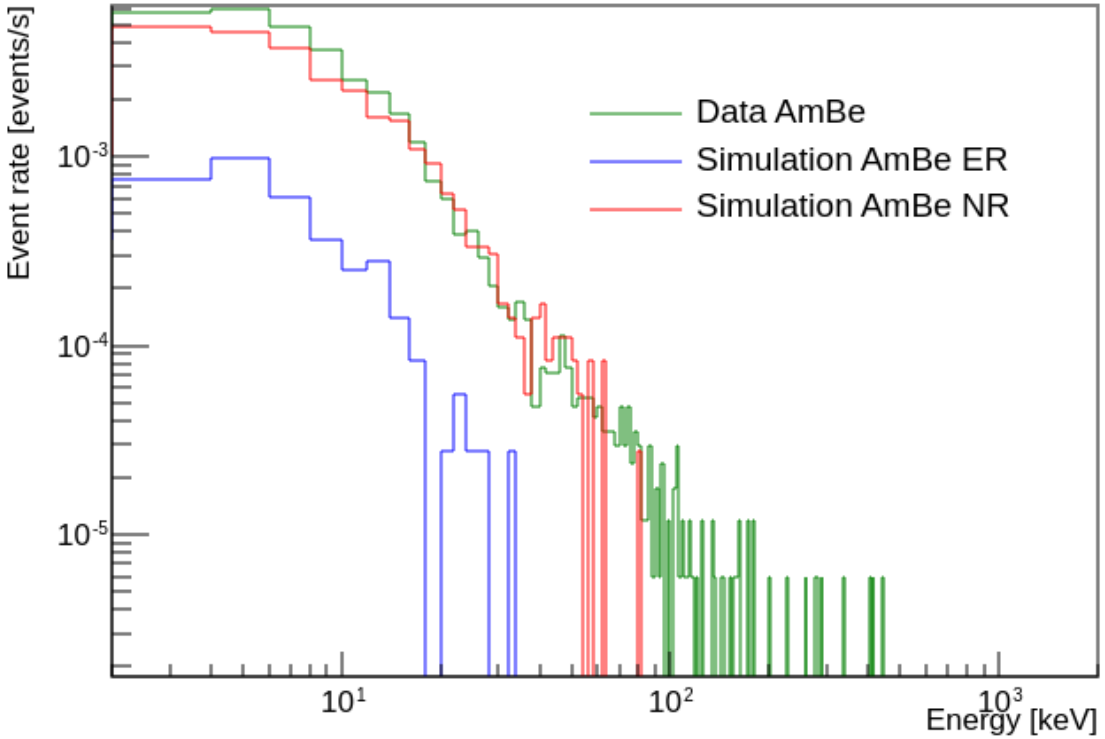
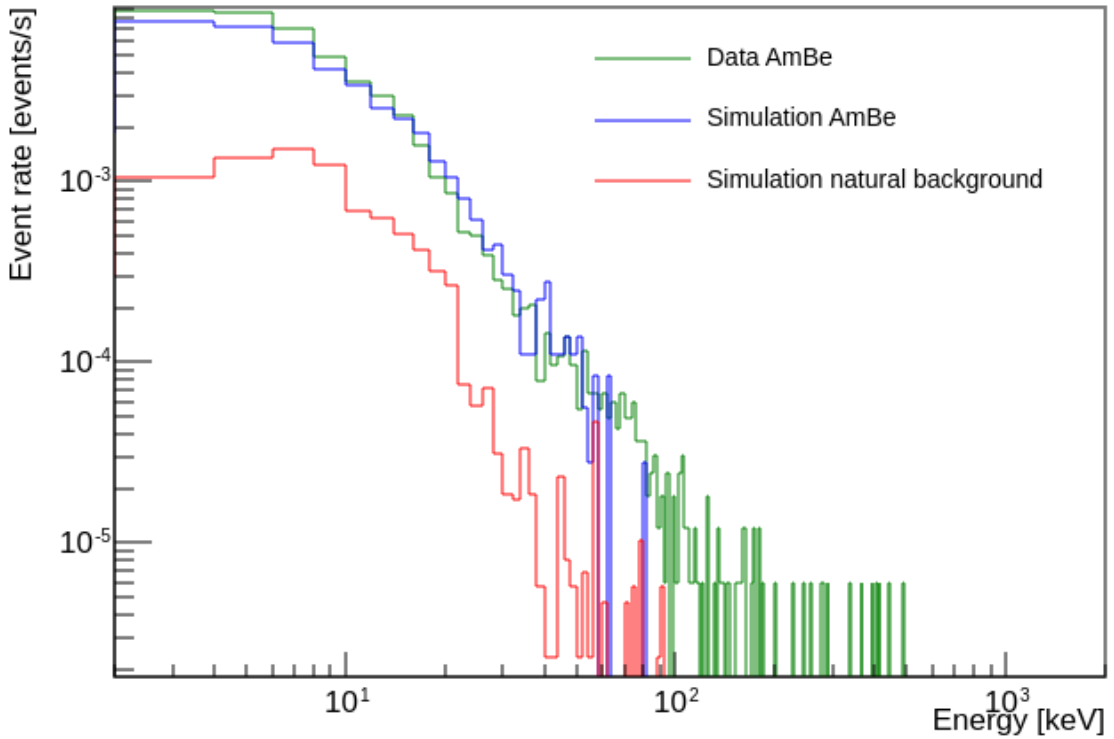




AmBe runs – MC comparison

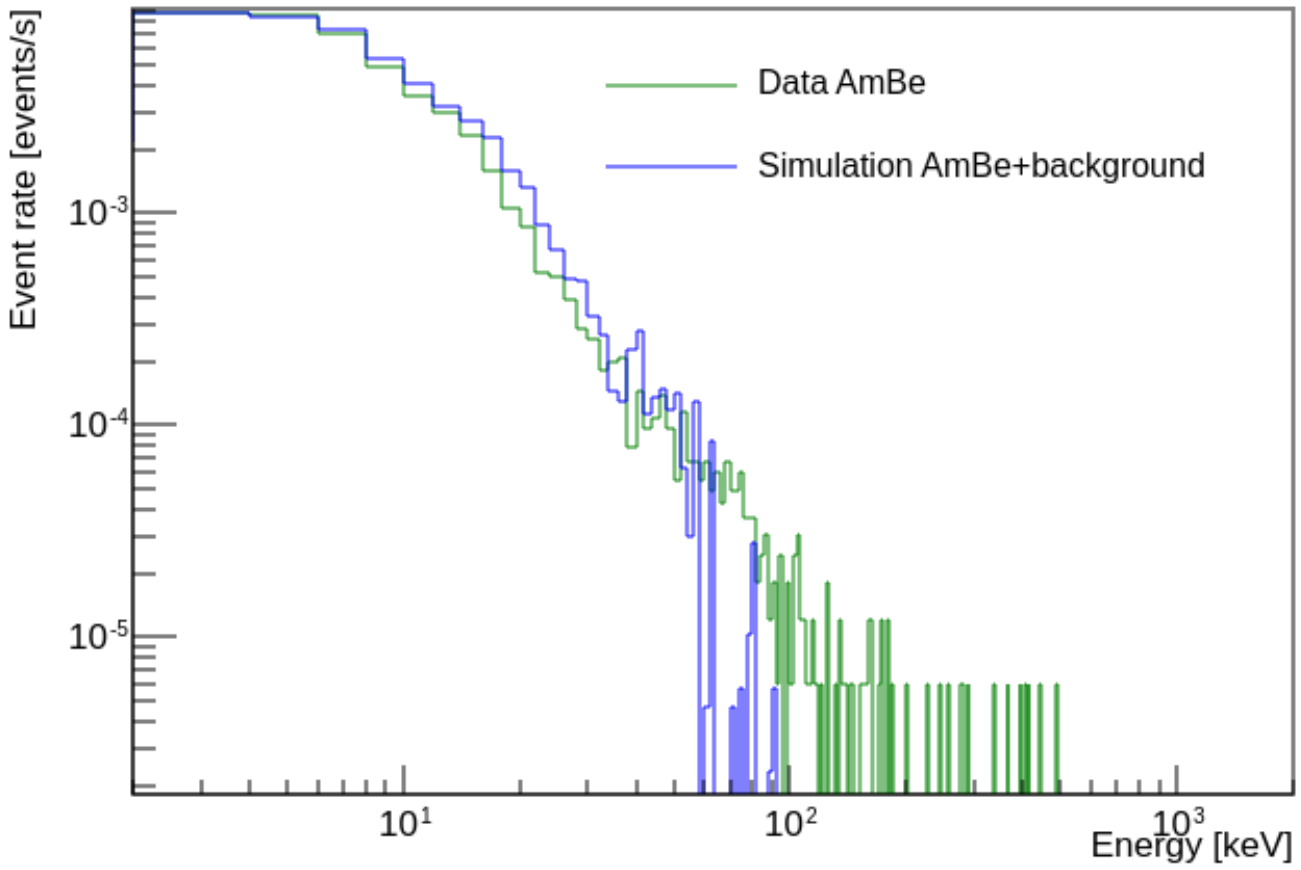
I applied the NR cut to both MC and data





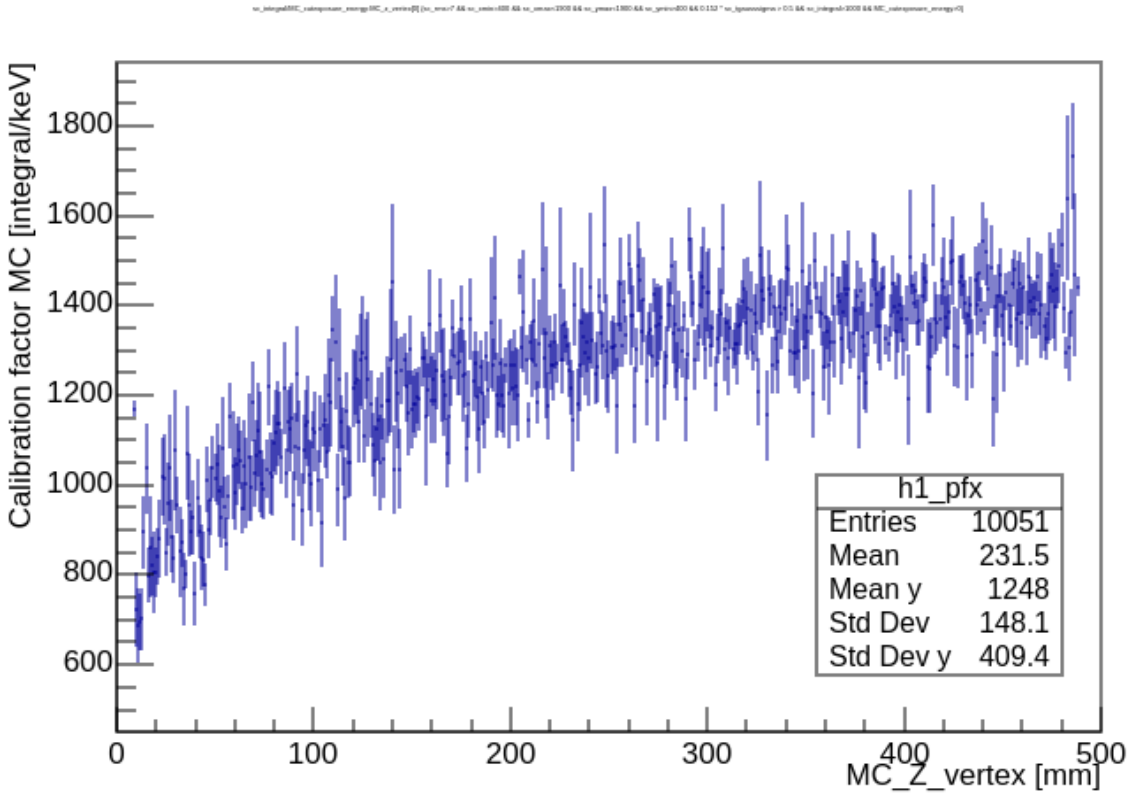
AmBe runs – MC comparison

The two spectra seem pretty consistent

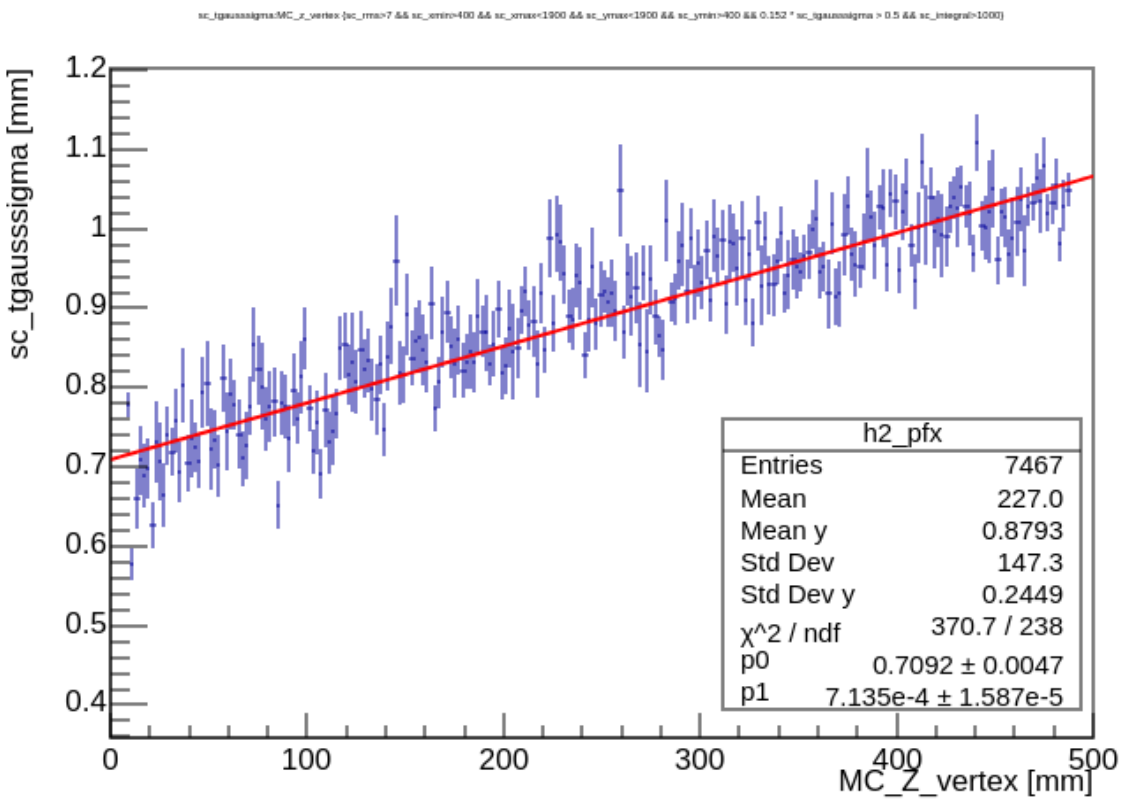


backup

MC calibration vs Z



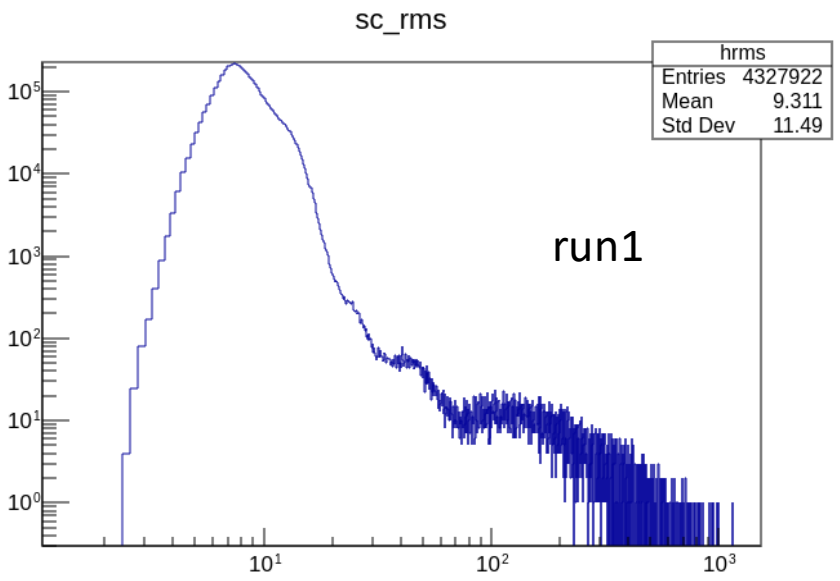
Calibration factor of MC (gammas, 4cm Cu) as a function of Z (distance from GEM)

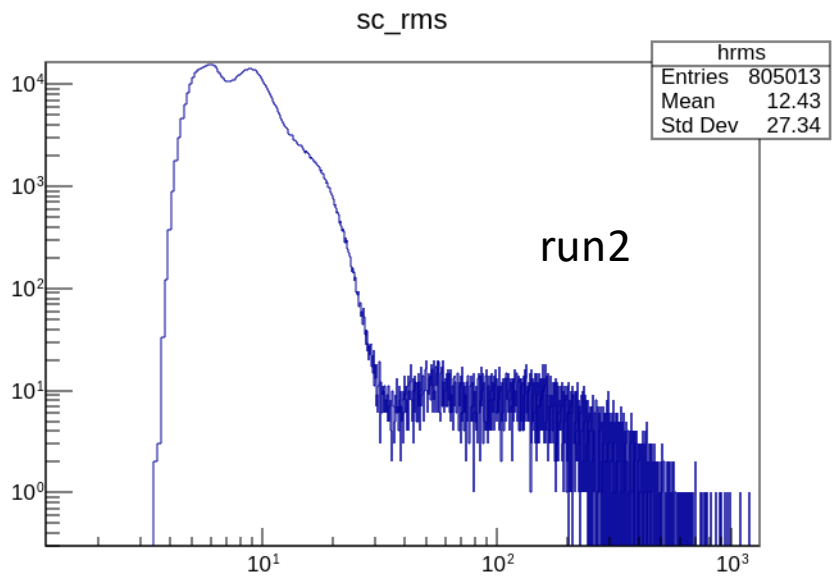


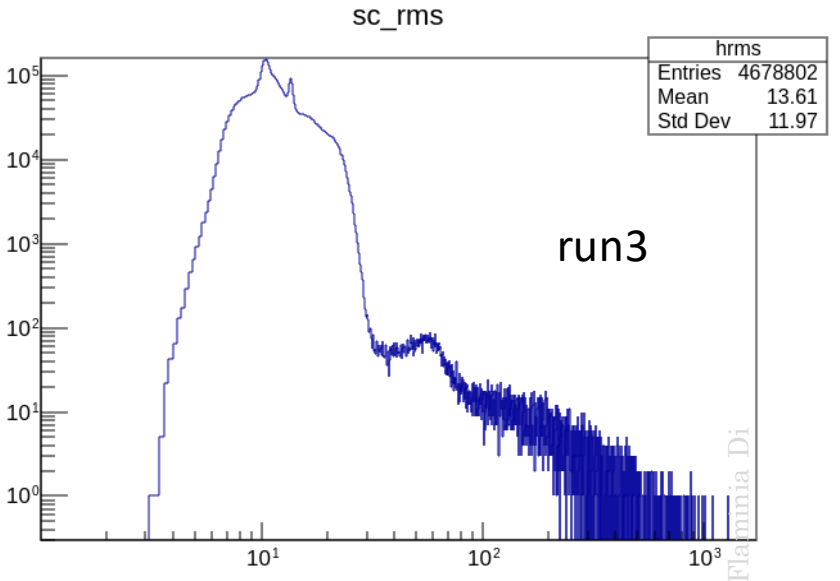
sc_tgausssigma vs distance from GEMs

(I tried to use this as an estimate of z also for data and selecting only z>250mm to compare the spectrum – but no visible change)

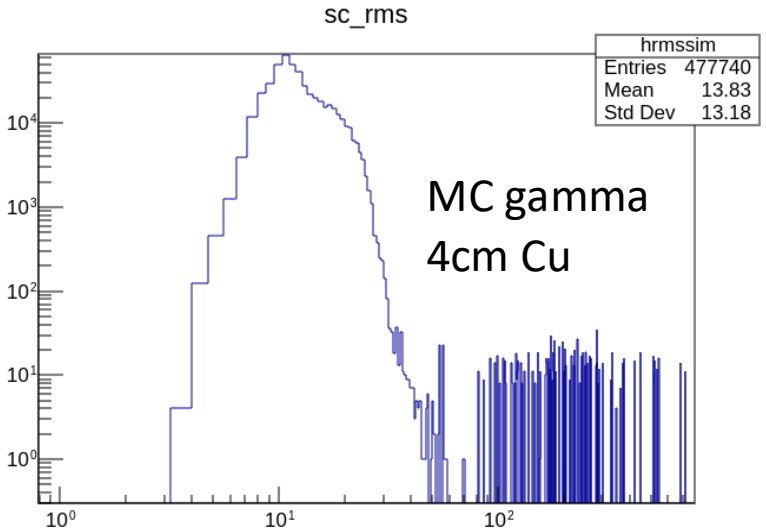
Run1,2,3 – sc_rms







- I checked the cut on sc_rms(>6) by plotting sc_rms with no cuts
  - What are these peaks ar fixed rms?
  - In run3 one can see multiple peaks, very pronounced, at 13,15 and 55
- For comparison, the MC simulation does not show these structures



Run3 – sc_rms:sc_integral