Background sensitivity studies for GEM based detectors using a Geant4 simulation

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Motivations

Triple-GEM detectors [1] were proposed for the installation in the Muon Endcap 0 (ME0) station of CMS → very harsh radiation environment:

- rates up to 30 kHz/cm^2
- integrated charge up to 200 mC/cm^2 over ten years of operation [2]

The detectors need to be characterized in terms of discharge probability → test at the Cern High energy AcceleRator Mixed (CHARM) facility in 2017.

The CHARM facility

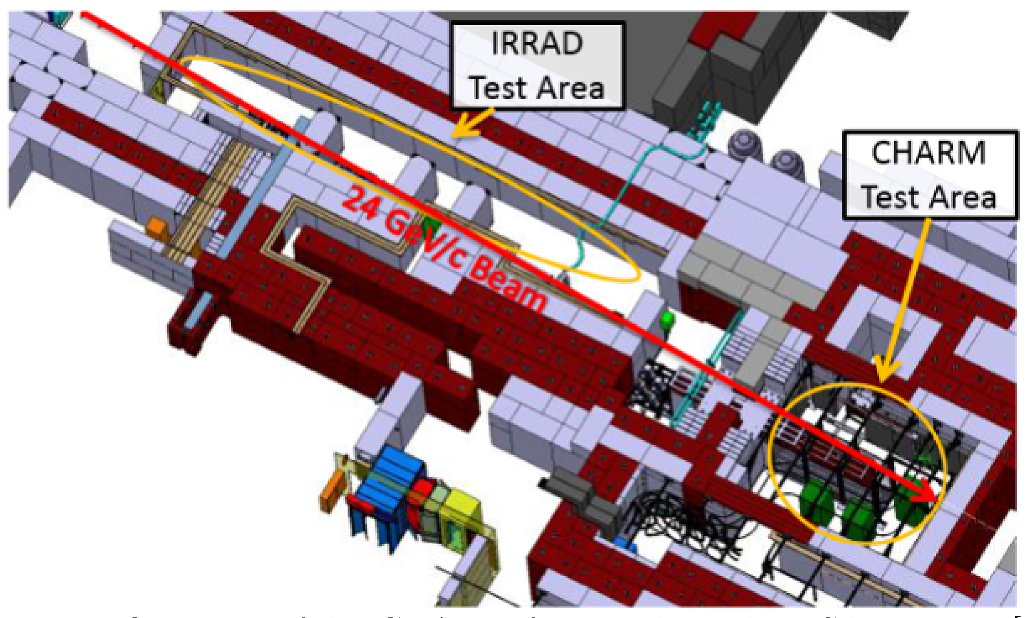

Figure 1: Overview of the CHARM facility along the PS beam line [3].

The CHARM field is produced by the interaction of the 24 GeV/c PS beam with a cylindrical copper or aluminum target. The high energy hadrons (HEH) field produced is mainly composed by neutrons, protons, pions, kaons and muons. An high intensity gamma flux is also present [3].

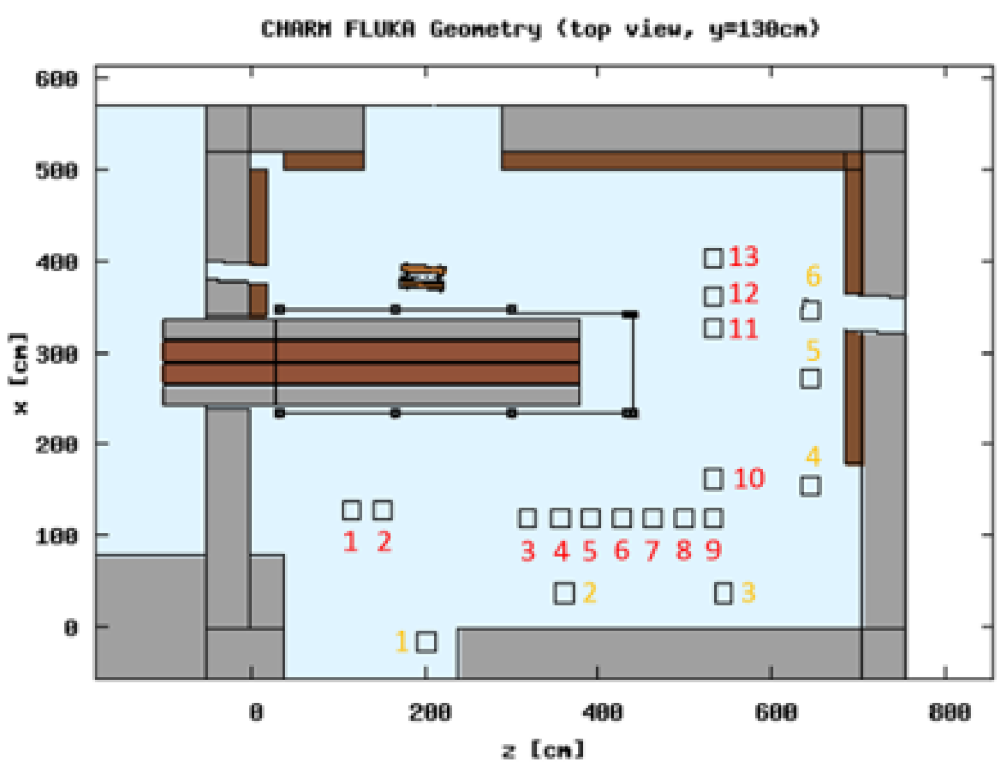

Figure 2: Screen-shot of the test positions as reproduced in the CHARM FLUKA geometry, cut at beam-height. The different irradiation position are shown in red [3].

The intensity of the field is different in the various irradiation positions: for our test the position R3 in Fig.2 was used. The CHARM facility is also equipped with an array of shielding blocks of concrete (grey rectangle in the figure) and iron (in brown) [3]. During our test, the full shielding was used, the irradiation configuration is called *R3 with CuCIIC*, where Cu represents the copper target for the beam.

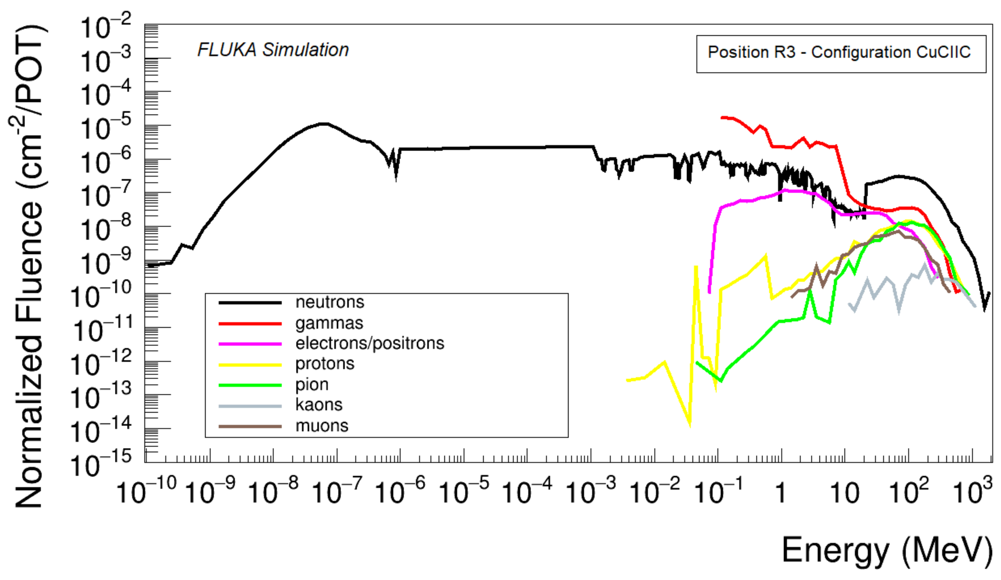

Figure 3: Spectrum of the different particle species present in the irradiation position. The data are coming from a FLUKA simulation performed by the CHARM personnel [4].

Fig.3 shows the normalized fluence in the irradiation position: the wider spectrum is from neutrons, going from 10^{-9} MeV to 10^3 MeV. The contribution of the other particles spectra is relevant only for energies higher than 100 keV.

References

[1] F. Sauli: *GEM: A new concept for electron amplification in gas detectors*, Nucl. Instrum. Meth. A **386**, 531 (1997)

[2] CMS Collaboration: *The Phase-2 Upgrade of the CMS Muons Detectors*,CERN-LHCC-2017-016 ; CMS-TDR-016

[3] A. Thornton: *CHARM Facility Test Area Radiation Field Description*,CERN-ACC-NOTE-2016-12345

[4] A. Infantino: *FLUKA Monte Carlo Modelling of the CHARM Facility's Test Area: Update of the Radiation Field Assessment*, CERN-ACC-NOTE-2017-0059

Simulation of the Triple-GEM detector and of the CHARM field

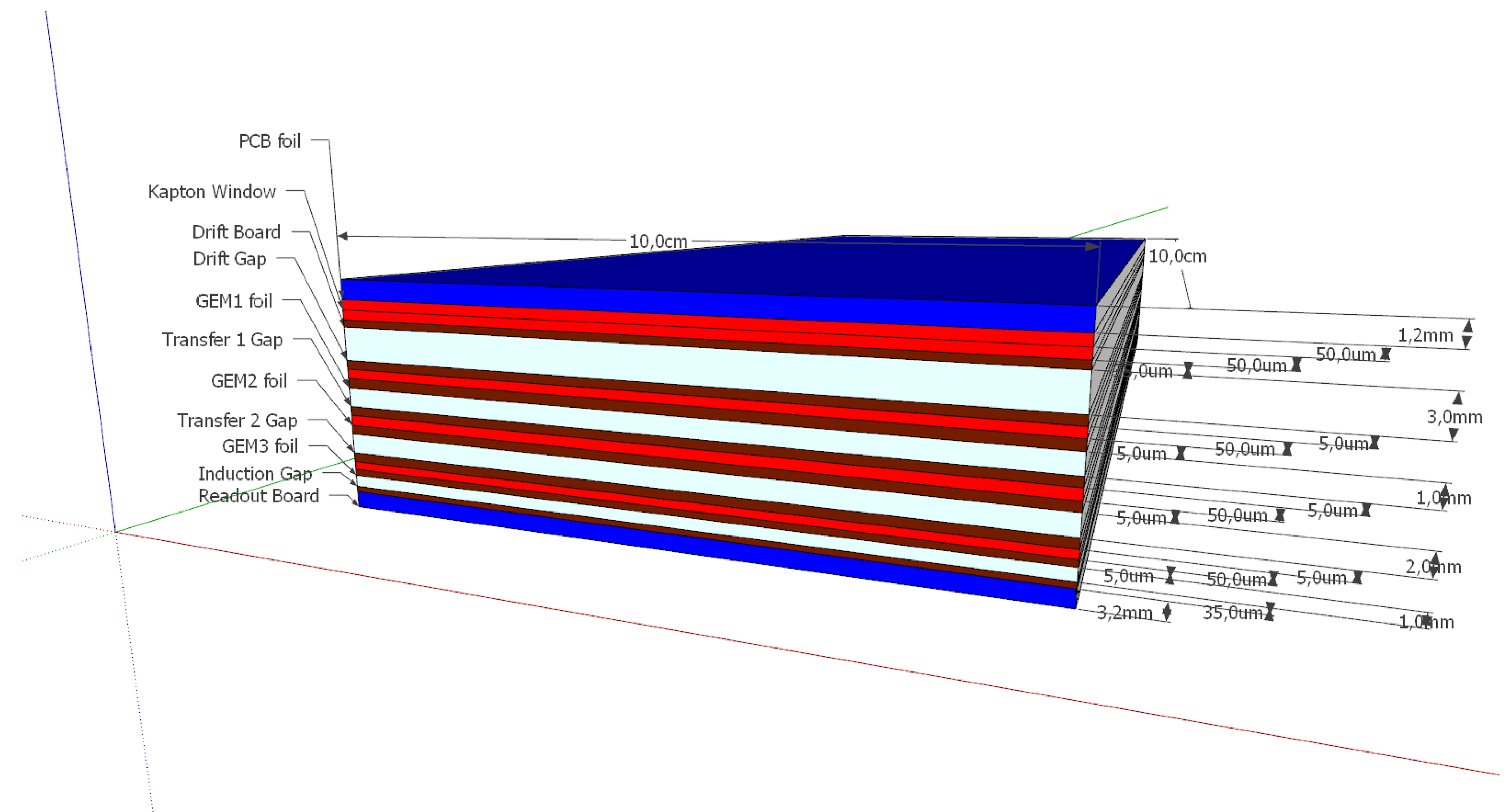

Figure 4: Sketch of the simulated Triple-GEM detector

The geometry simulated is shown in Fig.4:

- Standard Triple-GEM detector with gap configuration 3:1:2:1 mm
- Kapton window, 50 μm-thick, plus PCB (FR4) foil, 1.2 mm-thick, on top, as done during the irradiation
- Gas gaps filled with Ar/CO_2 70/30.
- Size 10×10 cm^2

The simulated particle spectrum is obtained sampling the spectrum in the irradiation position: in Fig.5 the sampling performed for neutrons is shown. Similar processes have been applied for all the particle species.

In the facility, the particles are not coming from a single direction, but they create a gas which surrounds the detector. As the real angular distributions in the irradiation position were not available, we have used those of the CMS muon system to have a realistic situation.

The simulations are performed with Geant4.9.6.p02, using the Physics List FTFP_BERT_HP.

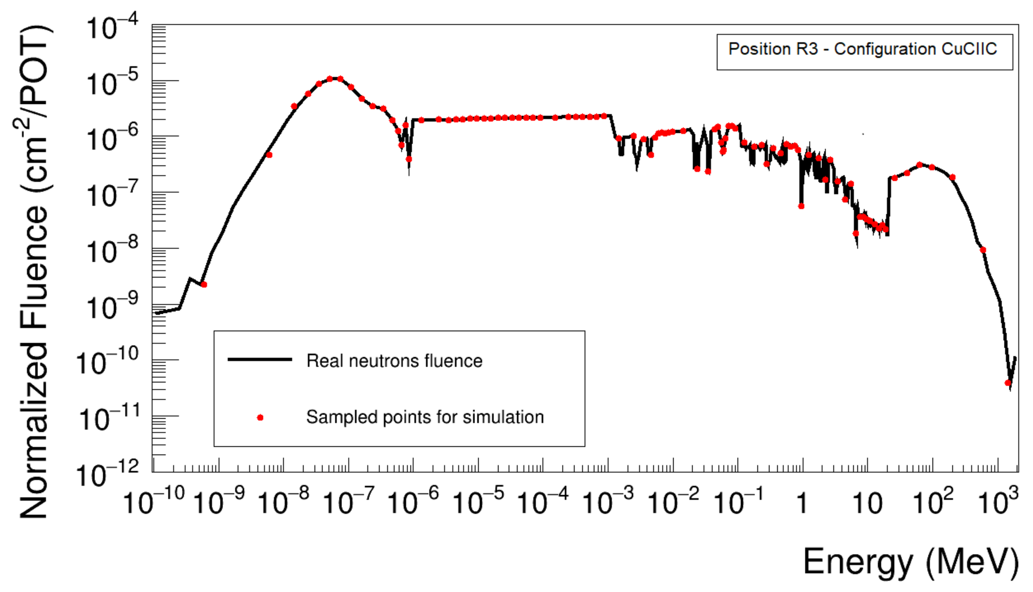

Figure 5: Comparison between the neutron fluence provided by the CHARM personnel (black) and the one used for the Geant4 simulation (red). The simulated one is obtained from a sampling of the complete spectrum.

Sensitivity results

The sensitivity is calculated as:

$$S = \frac{N_{signals}}{N_{incident\ particles}} \tag{1}$$

where $N_{signals}$ is the number of events in which at least one charged particle tracked by Geant reaches either the drift or the transfer 1 gap → *upper limit for the sensitivity.*

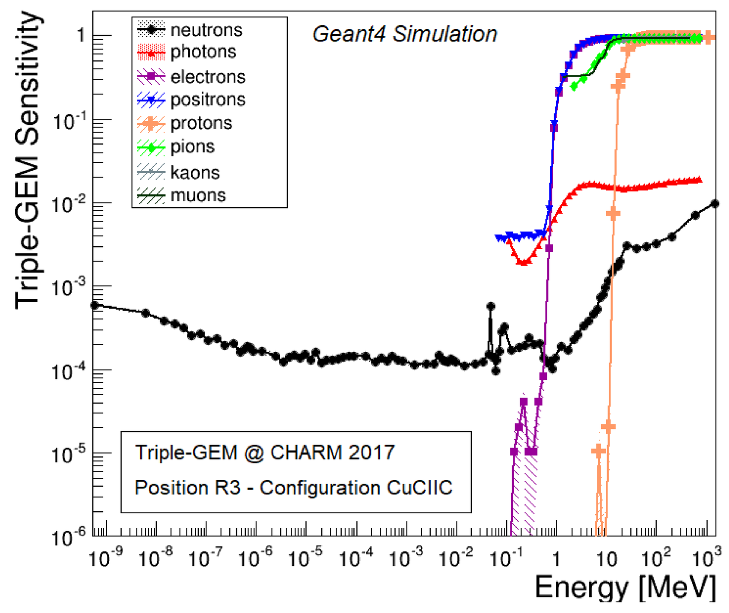

Figure 6: Sensitivity of the Triple-GEM detector exposed to the CHARM flux as a function of the energy of the incident particle, for the different particle species present.

The convolution of the sensitivity with the particles spectra is useful to understand which particle gives the highest contribution in each energy range:

- Below 1 MeV: neutrons are dominant
- Above 1 MeV: neutrons contribution drops in favour of the different species of charged particles.

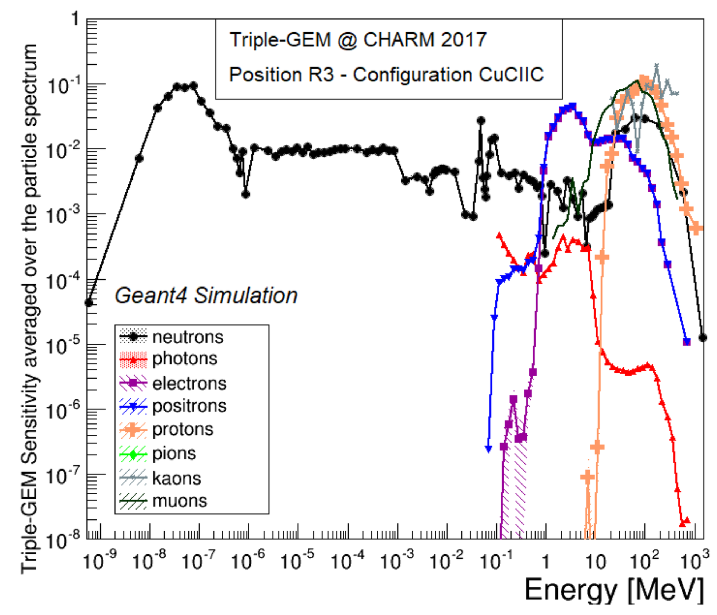

Figure 7: Sensitivity of the Triple-GEM detector averaged over the particles spectra as a function of the energy of the incident particle.

Energy results

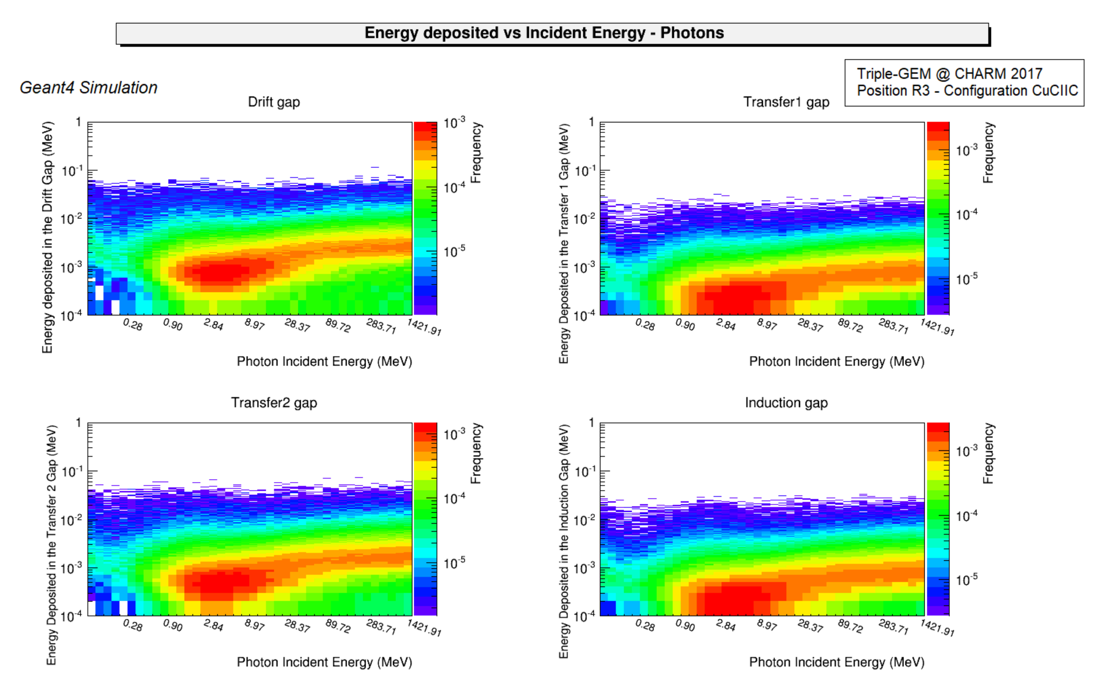

Figure 8: Total energy deposited into the different gaps by a photon hitting the detector, as a function of the energy of the gamma itself.

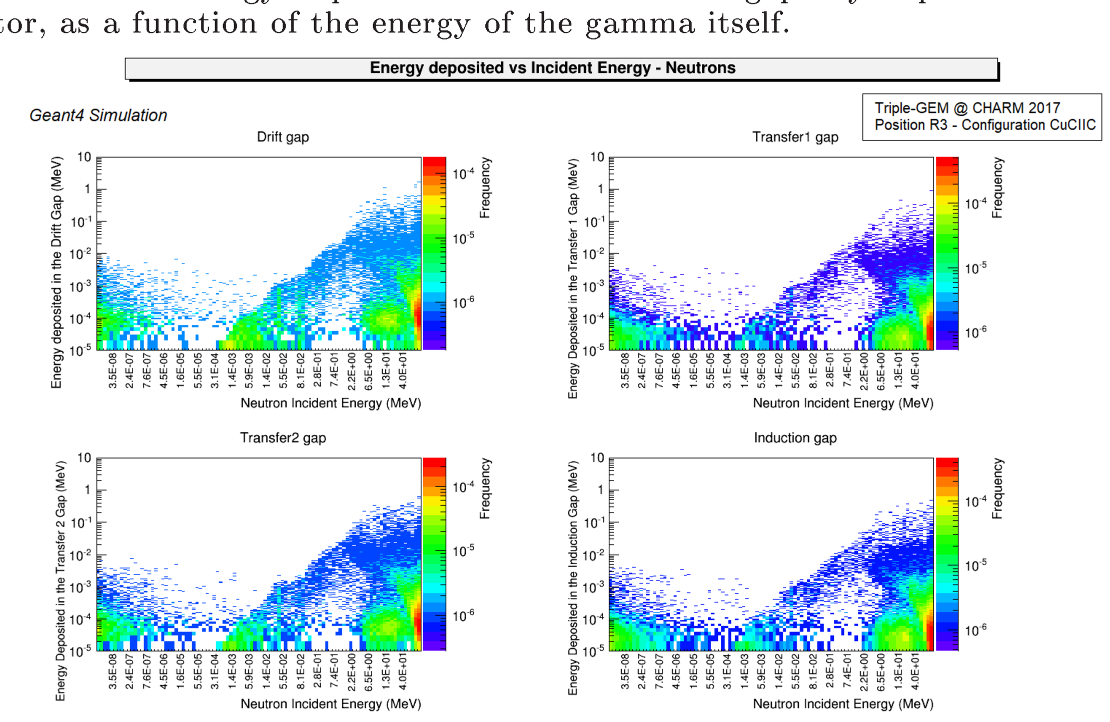

Figure 9: Total energy deposited into the different gaps by a neutron hitting the detector, as a function of the energy of the neutron itself.

Analysis of the energy deposited by the particles into the Triple-GEM detector:

1. Calculation of the total energy deposited in each process that the particle undergo:
   - Fig.8 and Fig.9 → total energy deposited can reach up to ~100 keV for gamma and ~1 MeV for neutrons, the two predominant components of the CMS background
   - Fig.10 → average value deposited in the drift gap as a function of the energy of the incident particle, for each particle species

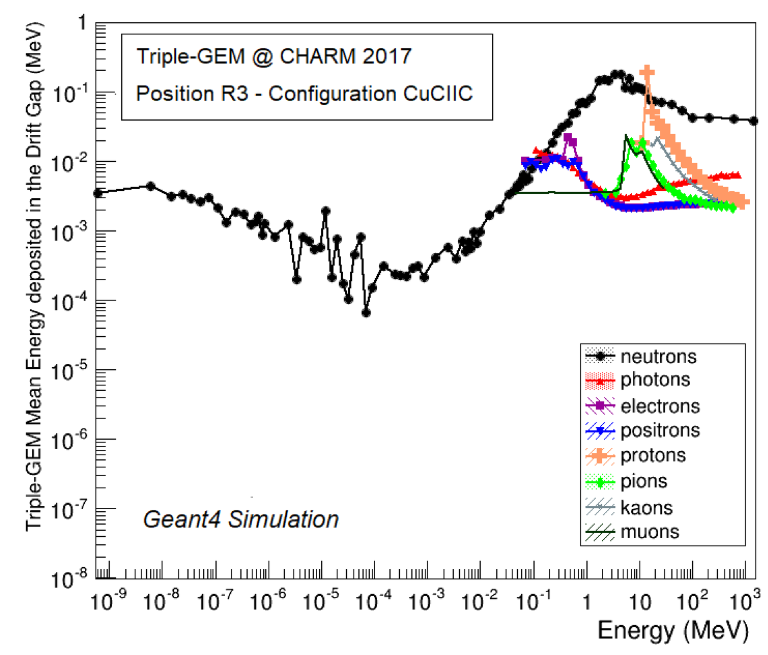

Figure 10: Average total energy deposited into the drift gap by particle hitting the detector as a function of the energy of the incident particle.