AmBe MC truth study

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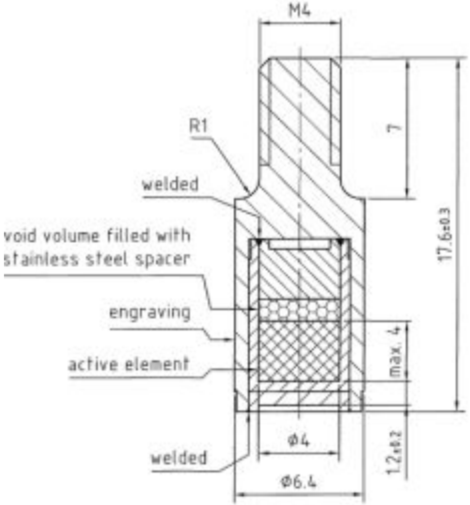
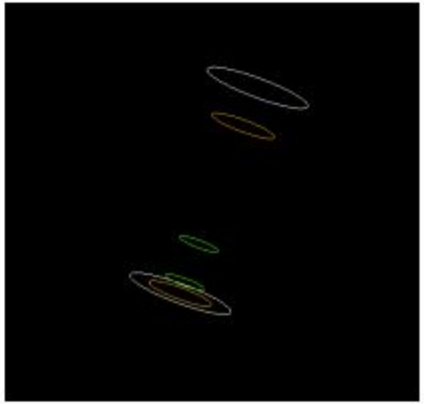
Overview

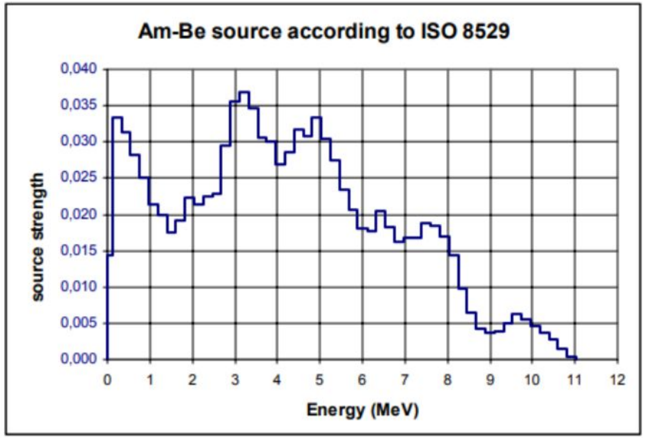
We did some simple studies on the MC simulation of AmBe neutrons, made by Flaminia. The objective was to better understand the simulation (probability of interaction of neutrons, kinematics, quenching factor…).

Also, we implemented the QF (from Flaminia’s SRIM simulation).

AmBe source (in Flaminia's simulation)







https://rifj.ifj.edu.pl/handle/item/217

- Simplified geometry in GEANT4:
    - Capsule: stainless steel cylinder with 6.4mm diameter, 17.6mm height
    - AmBe source: cylinder made of homogeneous mix of AmO_2 and Be, 4mm diameter, 4mm height
- Neutrons generated from AmBe disk with standard ISO spectrum

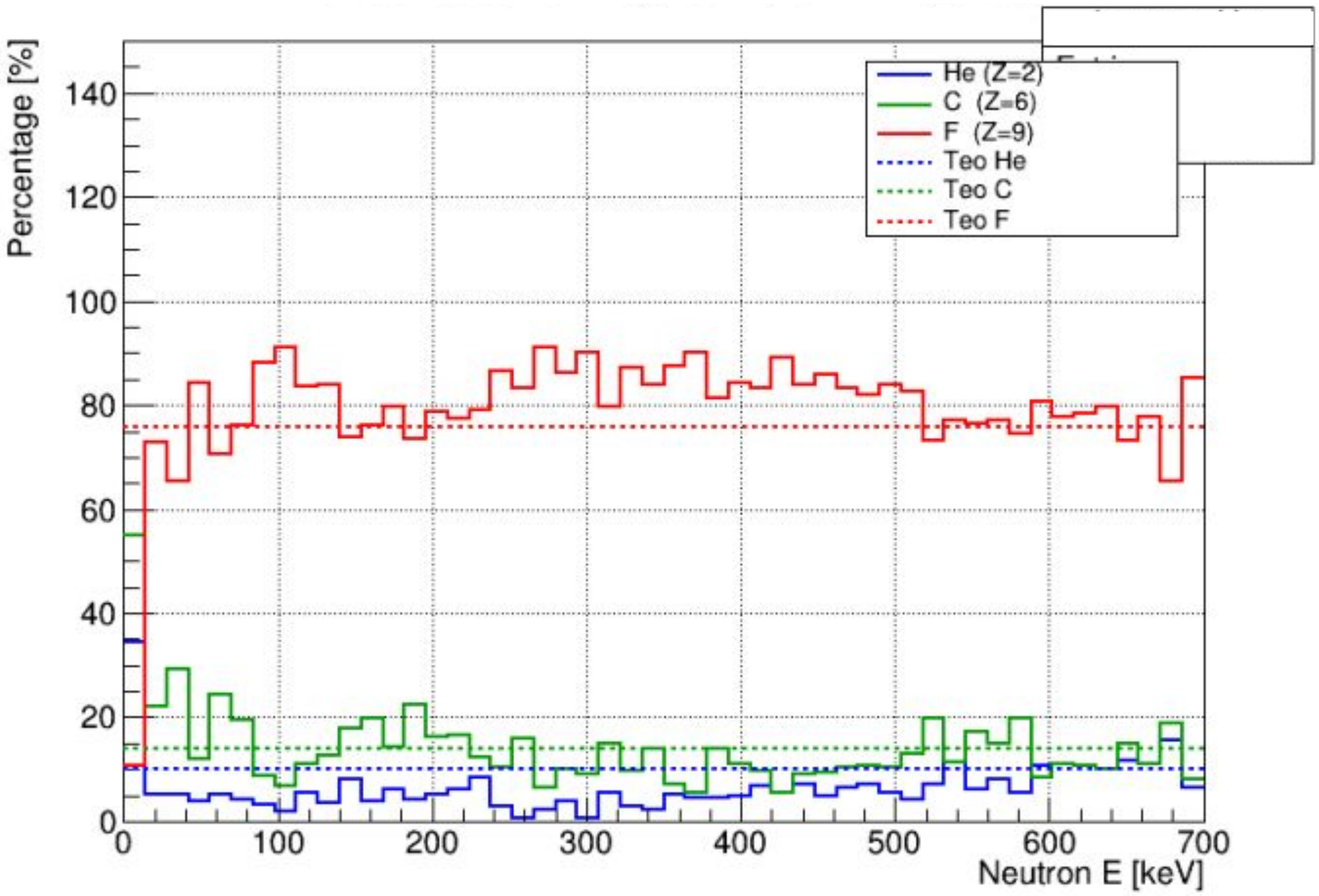
We can estimate the probability of interaction of neutrons with different nuclei in first approximation under the following assumptions:

$$R \approx r_0 A^{1/3}$$

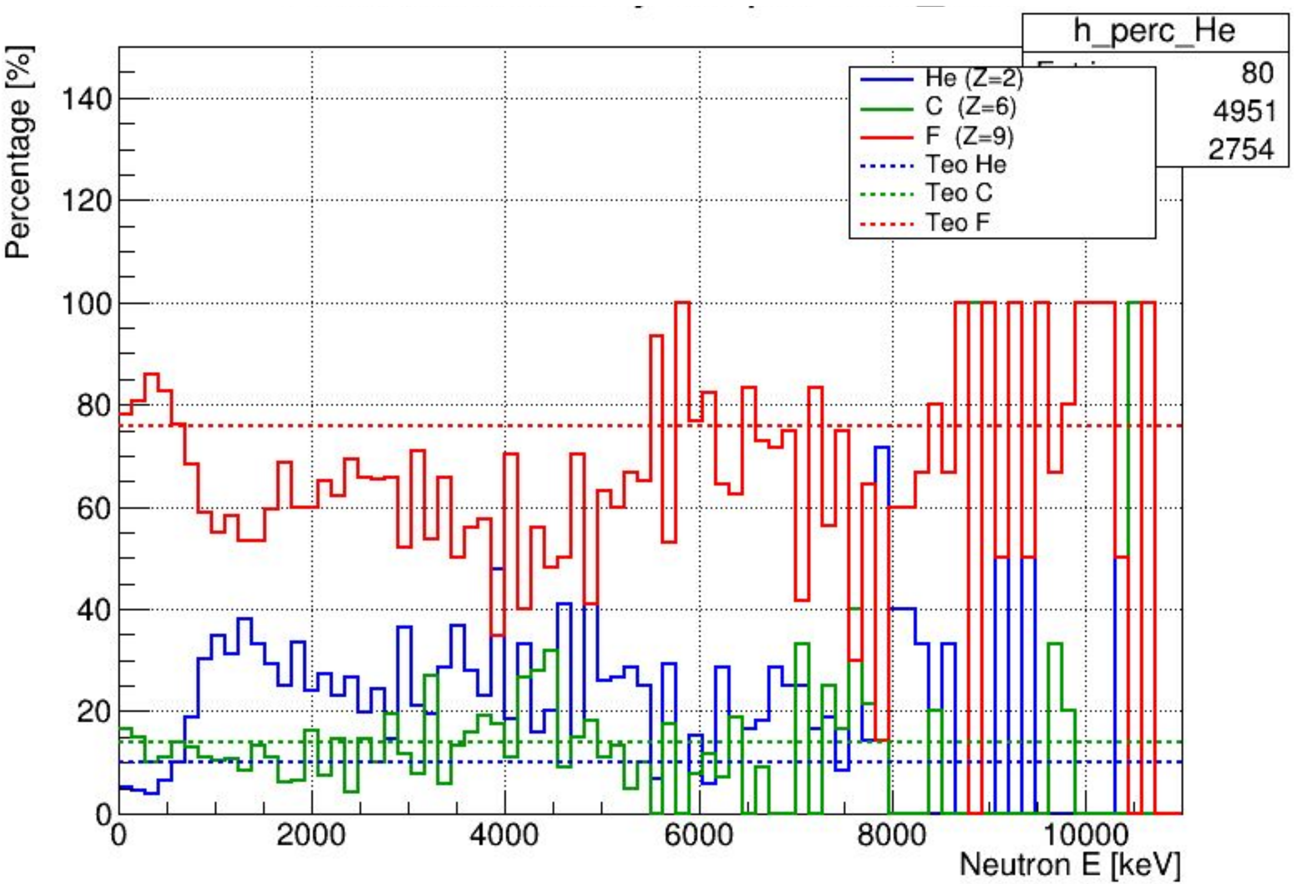
$$\sigma \sim \pi R^2 \sim \pi r_0^2 A^{2/3}$$

Elemento	Probabilità (%)	
He	10.08	← $0.6 \times 1 \times A_{\mathrm{He}}^{\frac{2}{3}}$
C	13.98	← $0.4 \times 1 \times A_{\mathrm{C}}^{\frac{2}{3}}$
F	75.95	← $0.4 \times 4 \times A_{\mathrm{F}}^{\frac{2}{3}}$

And compare the theoretical values with G4 simulation

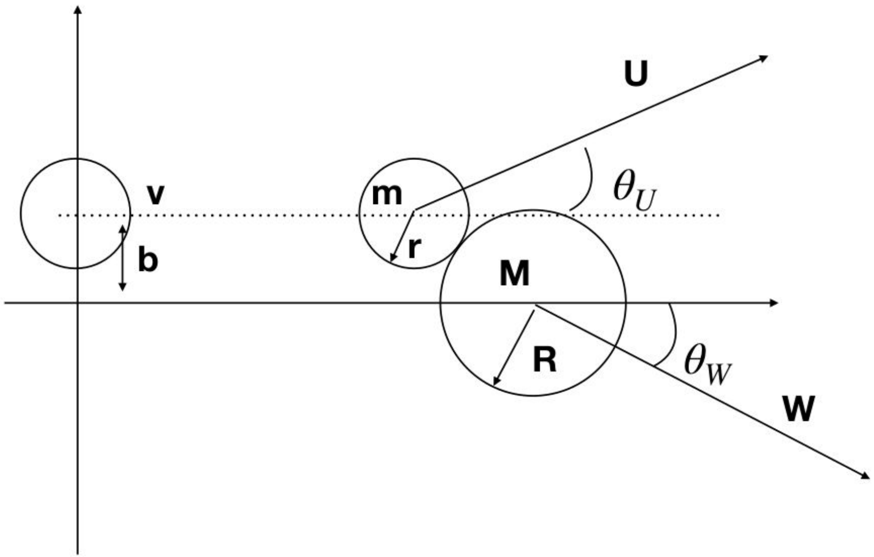


While above 1 MeV the probability of interaction is not that simple and depends on nuclear cross sections



From simple non relativistic kinematics

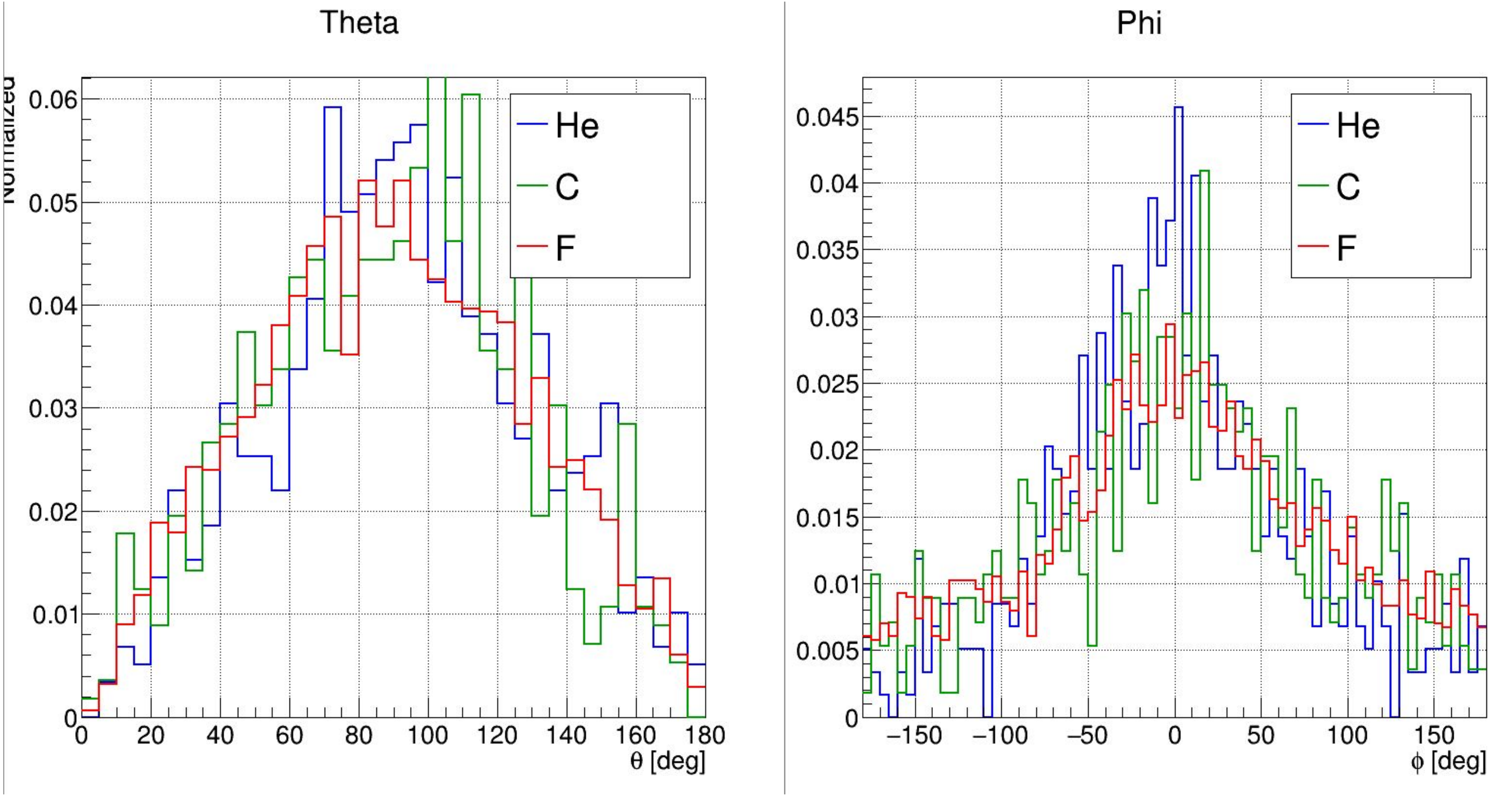
$$\begin{cases} U_x = \frac{v}{m+M}(m - M\cos\gamma) \\ U_y = \frac{M}{m+M} v \sin\gamma \end{cases}, \begin{cases} W_x = \frac{mv}{m+M}(1+\cos\gamma) \\ W_y = -\frac{mv}{m+M}\sin\gamma \end{cases}$$



$$\theta_W = \arctan\left(-\frac{\sin\gamma}{1+\cos\gamma}\right)$$

$$\sin\gamma = \frac{b}{r+R}$$

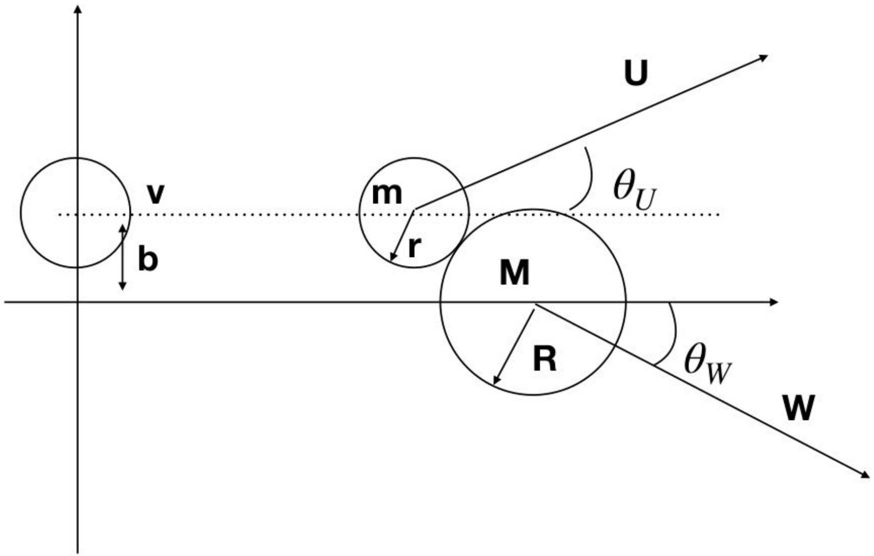
So, the angle doesn't depend on the masses



Theta and phi are the recoil directions in the laboratory reference frame

A bit more of basic kinematics:

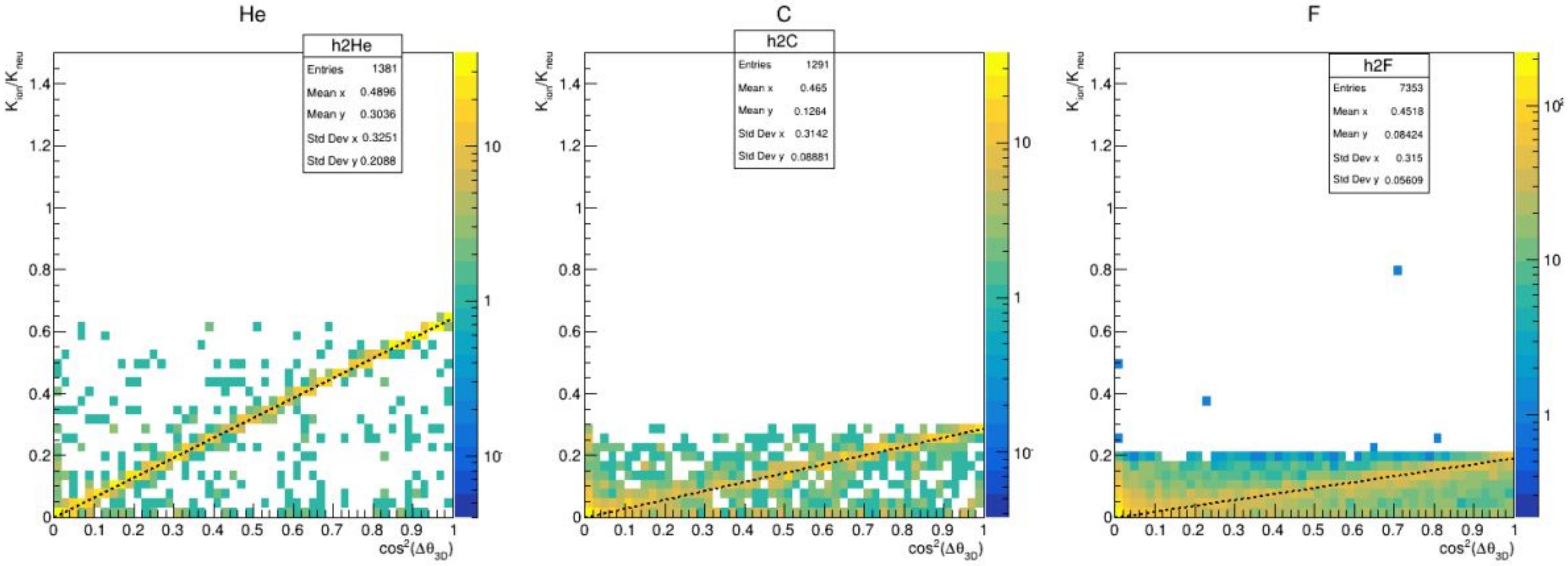
$$\begin{cases} U_x = \frac{v}{m+M}(m - M\cos\gamma) \\ U_y = \frac{M}{m+M} v \sin\gamma \end{cases}, \begin{cases} W_x = \frac{mv}{m+M}(1+\cos\gamma) \\ W_y = -\frac{mv}{m+M}\sin\gamma \end{cases}$$



$$\epsilon = \frac{M(W_x^2 + W_y^2)}{mv^2} = \frac{2mM(1+\cos\gamma)}{(m+M)^2}$$

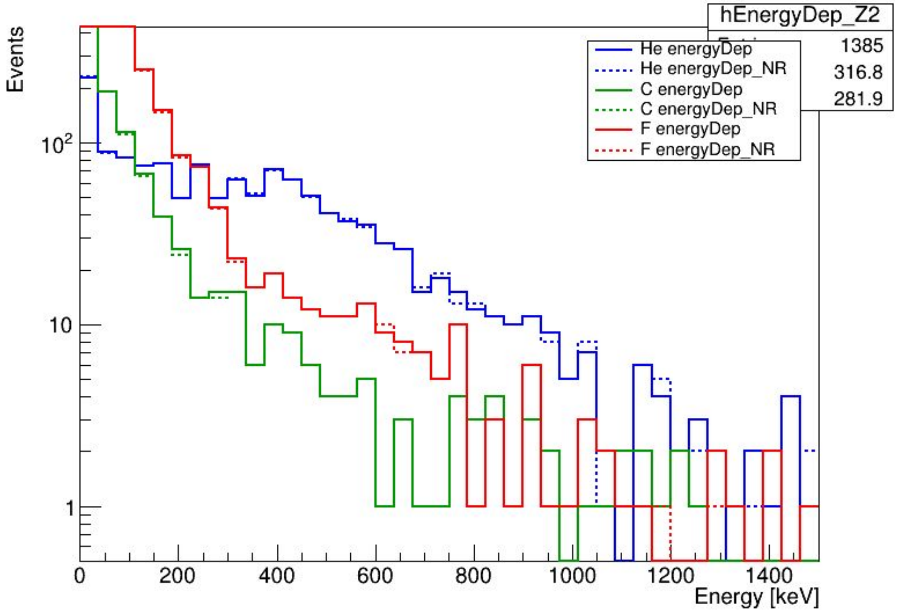
$$\epsilon = \frac{4mM}{(m+M)^2}\cos^2\theta_w$$

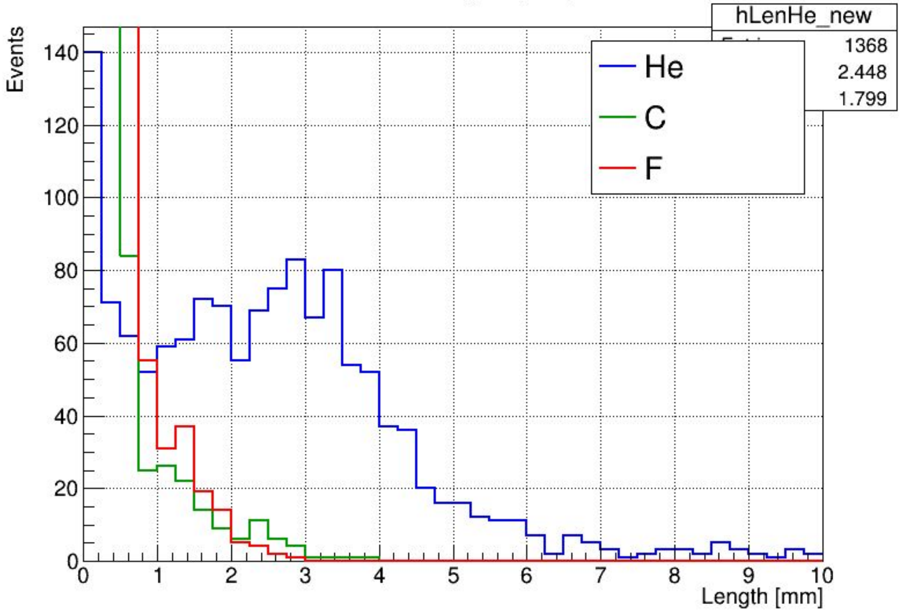
Elemento	ϵ_{max}
He	0.643064
C	0.286103
F	0.191495



deltaTheta is the direction of the recoil with respect to the neutron direction

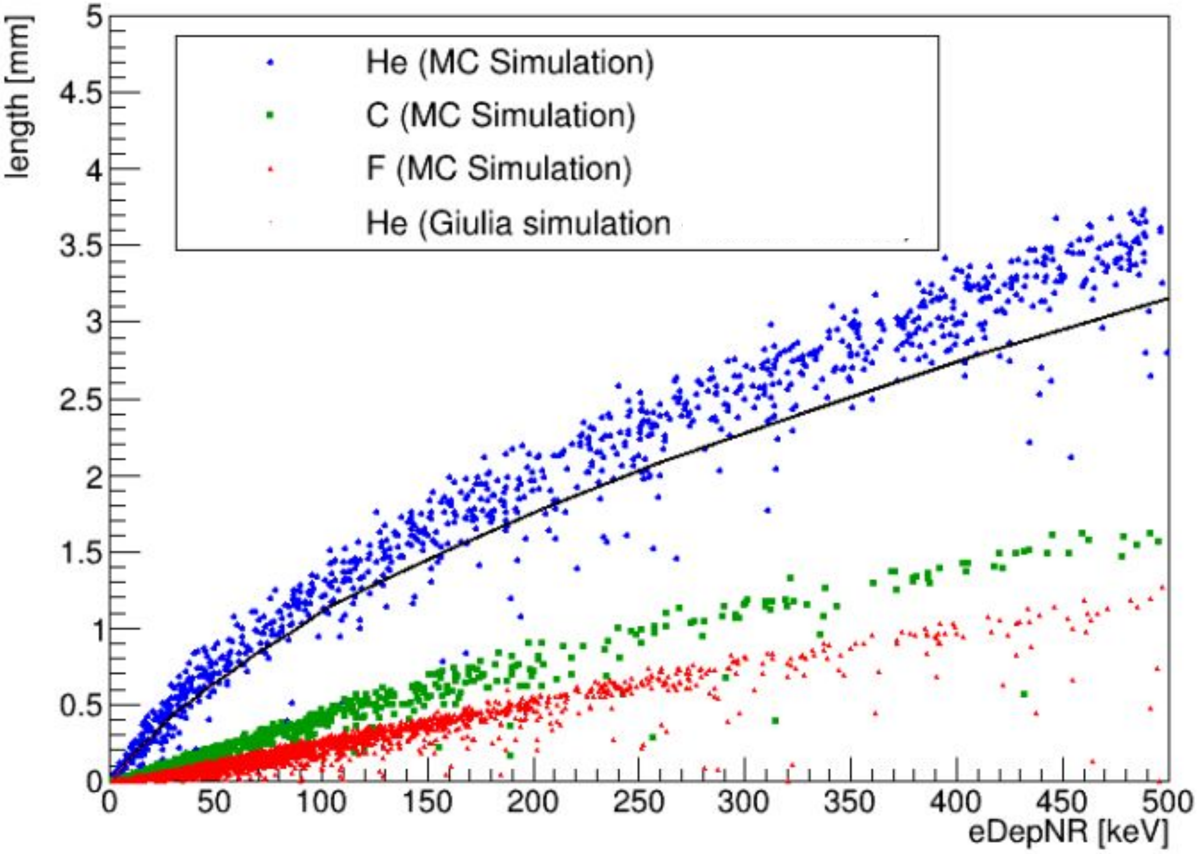
The events outside the diagonal is because I am not using the actual recoil direction (currently it's not saved by Geant), but I am computing it by my self (average of the direction hit by hit, for the first 5 hits)



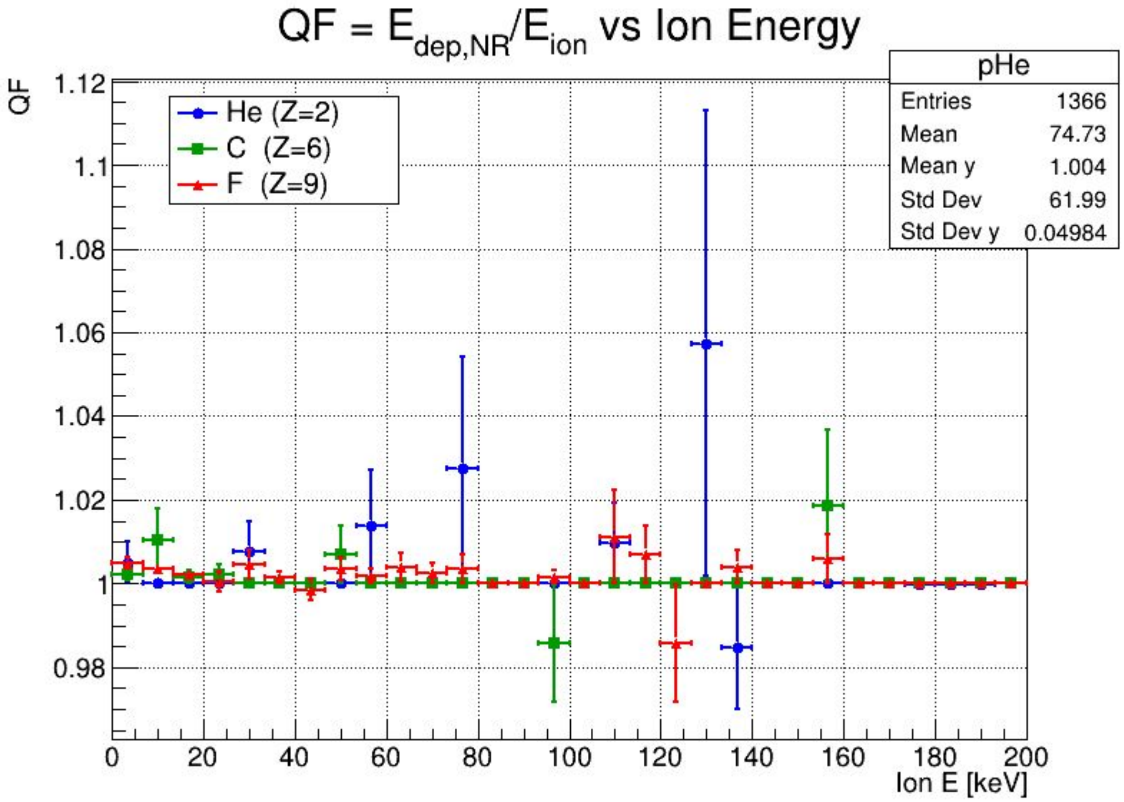


Helium NR start to be the majority of NR above 300 keV (no QF), with a length* of 2-4 mm

Putting the information together we get the range vs E. Similar to what Giulia simualted (black line), if we neglect minor differences due to the way the length si computed (straggling or not)

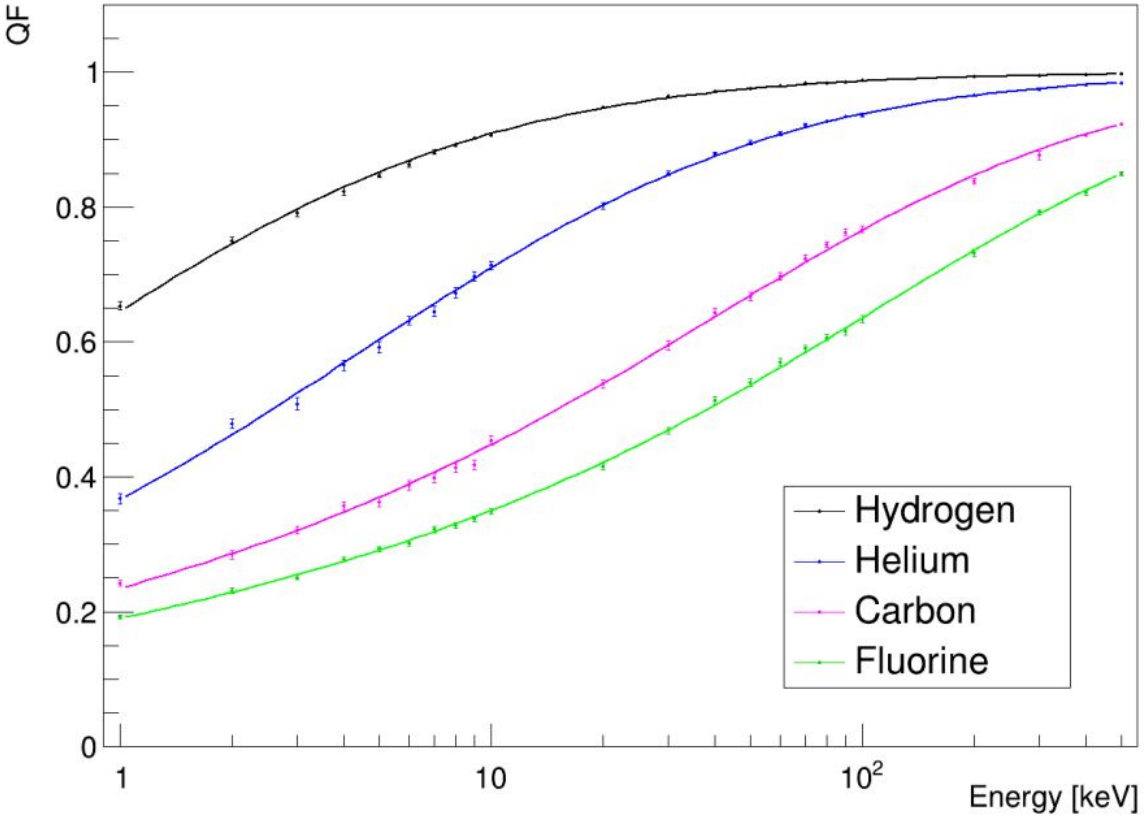


However there is no QF in the simulation.

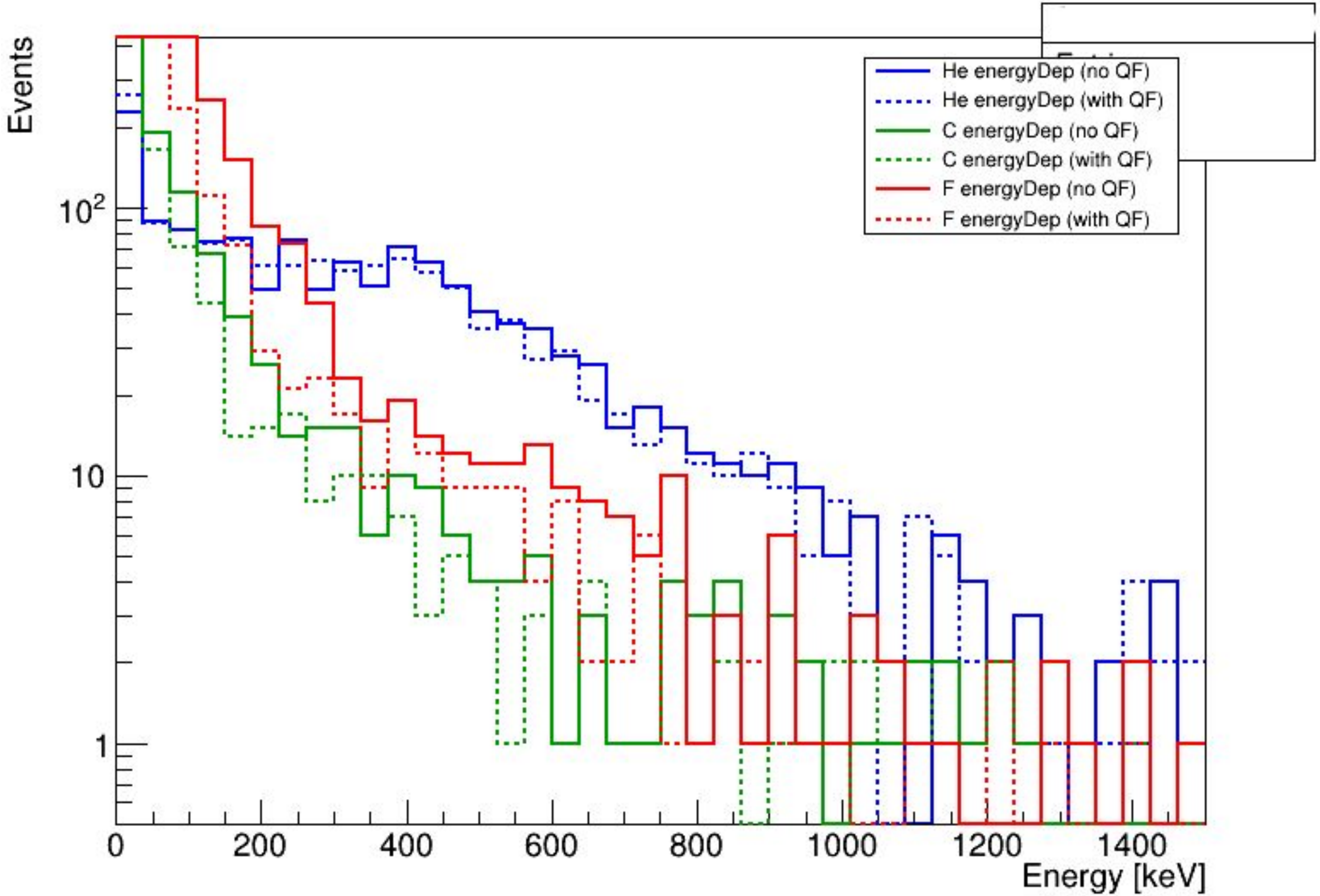


For eahc NR event, according to the type (He, C, F) we loop over the geant4 hit and accordion the the kinetic energy of the ion in each hit, we multiply the energy deposit of that hit for the SRIM QF.

From Flaminia's thesis (computed with SRIM)



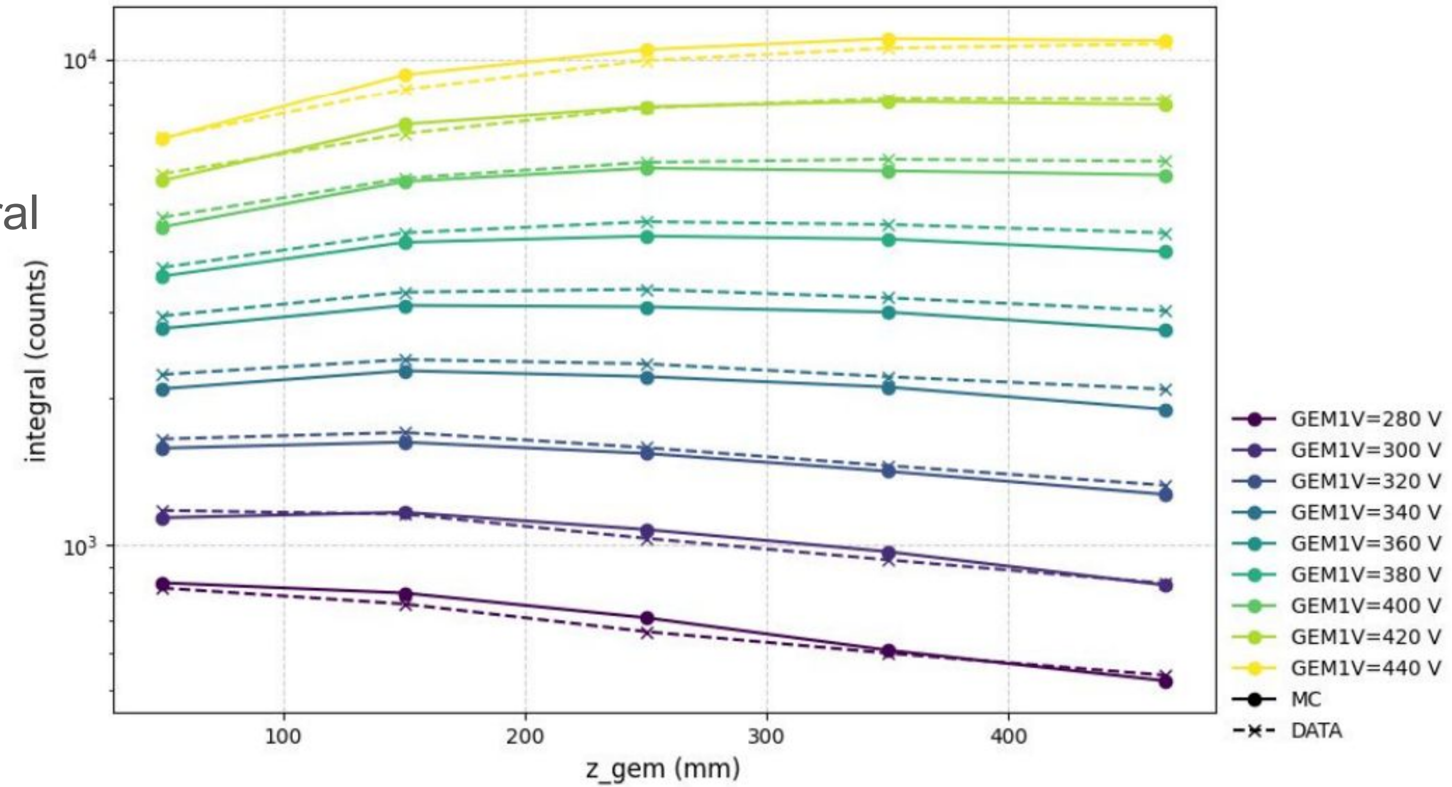
Now with QF


He energyDep (no QF)
He energyDep (with QF)
C energyDep (no QF)
C energyDep (with QF)
F energyDep (no QF)
F energyDep (with QF)
Events
10^2
10
1
0
200
400
600
800
1000
1200
1400
Energy [keV]

Next step: digitization

We know we can to reproduce the integral of iron spots in several conditions (given that the gas quality is not changing)

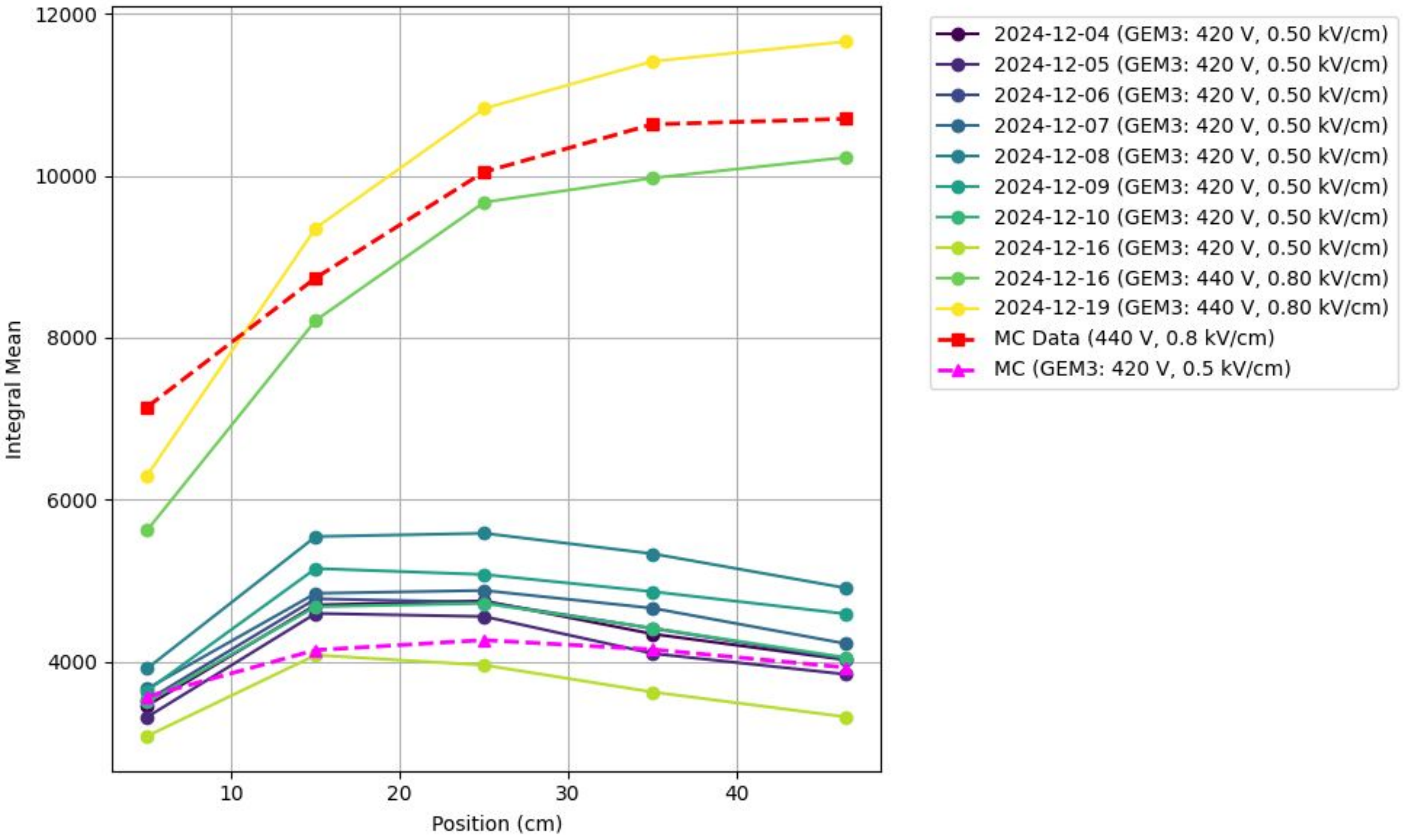
Collaboration Meeting 2024



However when looking at the AmBe campaign calibrations…

High variability in LY, we can reproduce iron calibration with big errors…

We’ll need to find a set of digitization parameters (g0, that is the the non linearity of the gain, and absorption length).



Next steps

- **First Quick Comparison (by this week):**
  Rapidly validate the simulated energy spectrum using Luca's 2023 AmBe data with fixed parameters in **digitization** and the already implemented QF.

- **Final Comparison:**
  Perform a full analysis of the 2024 AmBe campaign to extract both energy and length distributions. Utilize Flaminia's code for a **high-statistics simulation**: incorporating the SRIM-derived QF and **saving NR real directions** for directionality study. For digitization we'll use different sets of parameters to reproduce variability of gas quality

Thanks