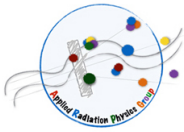


# Status of the fred EM plugin

Giacomo Traini, Gaia Franciosini, Patrizia De Maria



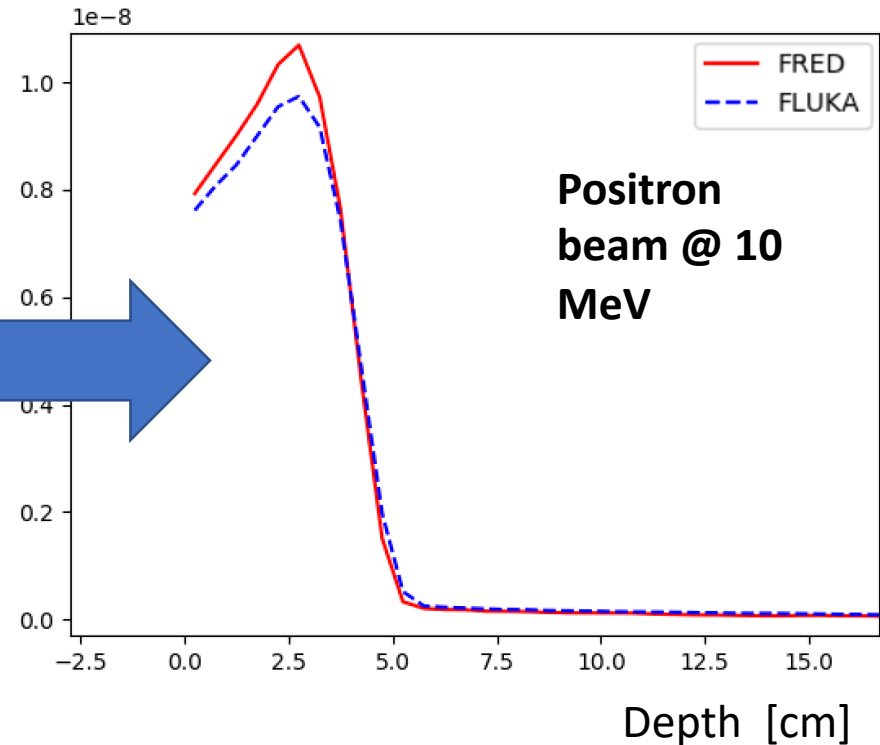
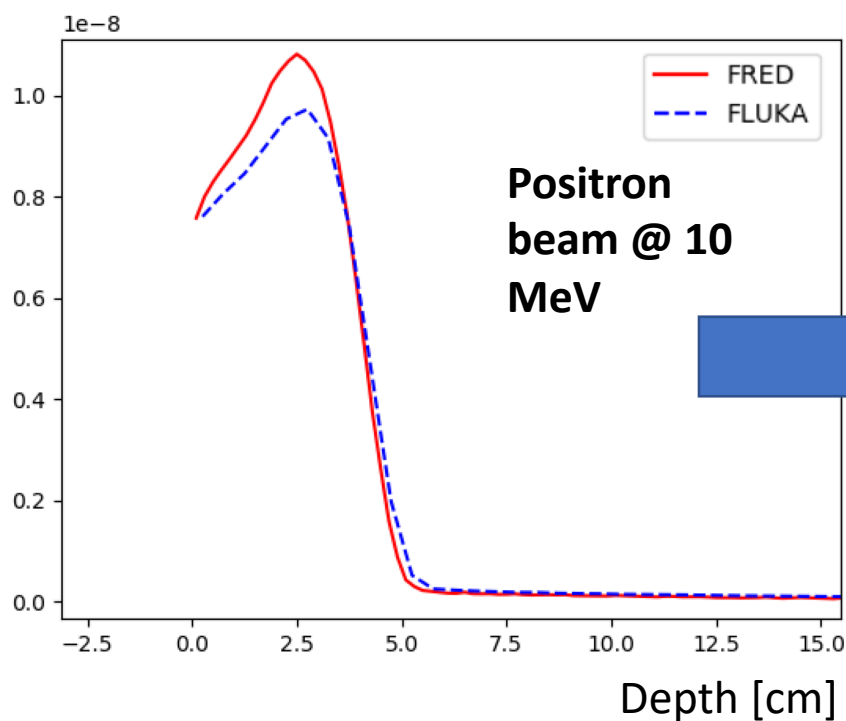
# New features and bug fixes

- A correction on the positrons  $dE/dx$  with respect to the electrons one has been implemented
- The restricted  $dE/dx$  of positrons has been fixed (small error in the computation)
- The positron annihilation in flight has been implemented using the cross section got by the GEANT4 manual

T (MeV)	C (1.7 g/cm <sup>3</sup> )	$S_{\text{co1}}^+(T)/S_{\text{co1}}^-(T)$					
		Al	Cu	Ag	Pb	H <sub>2</sub> O (liq.)	Air
1000	0.976	0.976	0.975	0.975	0.975	0.977	0.981
500	0.976	0.976	0.974	0.974	0.974	0.976	0.981
200	0.975	0.975	0.973	0.973	0.973	0.975	0.980
100	0.974	0.974	0.973	0.972	0.973	0.975	0.979
50	0.974	0.973	0.972	0.972	0.971	0.974	0.978
20	0.972	0.972	0.971	0.971	0.969	0.973	0.977
10	0.972	0.971	0.971	0.969	0.968	0.973	0.976
5	0.972	0.971	0.970	0.969	0.968	0.972	0.974
2	0.974	0.972	0.971	0.969	0.968	0.974	0.975
1	0.978	0.977	0.977	0.975	0.973	0.979	0.979
0.5	0.990	0.989	0.991	0.989	0.989	0.990	0.990
0.2	1.016	1.018	1.023	1.023	1.025	1.016	1.016
0.1	1.039	1.043	1.051	1.054	1.059	1.039	1.039
0.05	1.060	1.067	1.077	1.083	1.094	1.059	1.060
0.02	1.084	1.097	1.112	1.123	1.144	1.084	1.086
0.01	1.102	1.119	1.142	1.158	1.192	1.101	1.104

- The correction is due to the different elementary processes (Bhabha vs Moeller)
- At present all the material are treated as water (the correction weakly depends on the material)

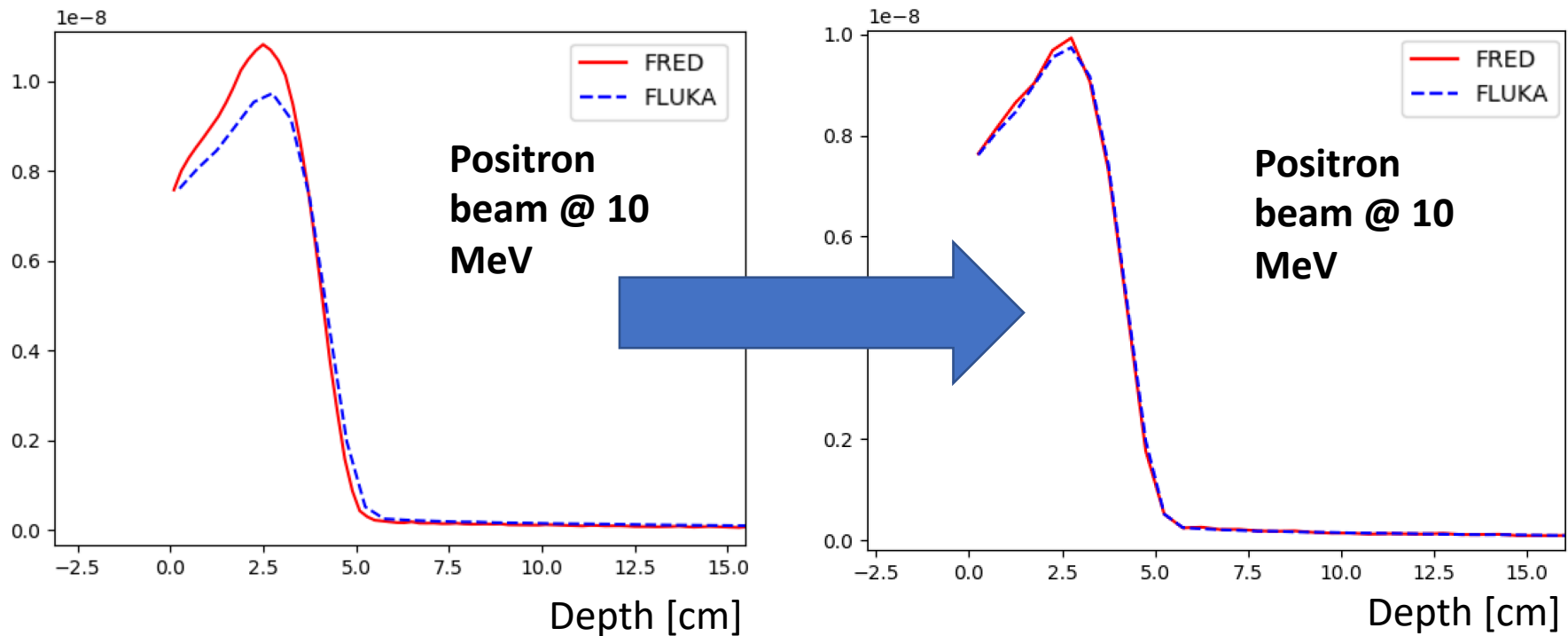
<https://nvlpubs.nist.gov/nistpubs/Legacy/IR/nbsir82-2550.pdf>



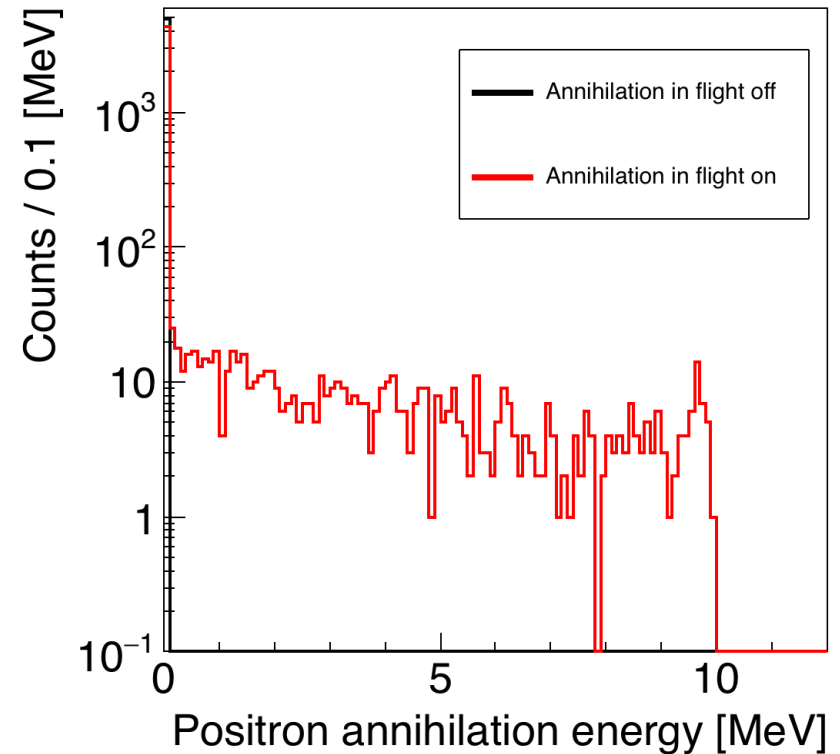
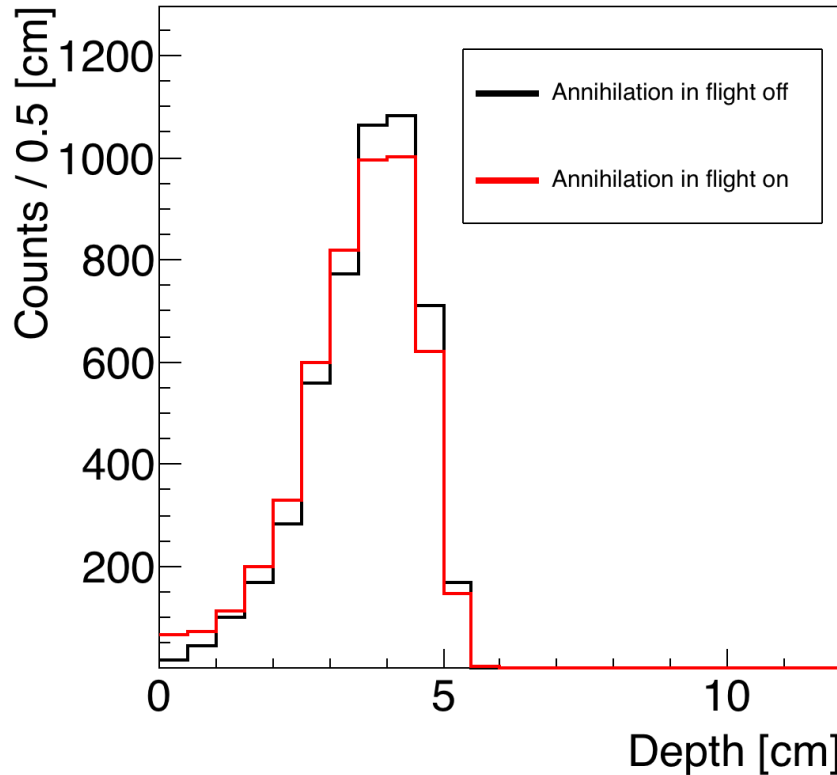
- The ddd show a slightly better agreement with FLUKA but a significant difference before the peak remains

$$\sigma(Z, E) = \frac{Z\pi r_e^2}{\gamma + 1} \left[ \frac{\gamma^2 + 4\gamma + 1}{\gamma^2 - 1} \ln \left( \gamma + \sqrt{\gamma^2 - 1} \right) - \frac{\gamma + 3}{\sqrt{\gamma^2 - 1}} \right]$$

- Total cross section taken from the GEANT4 manual
- The final state sampling has been performed using a isotropic angular distribution in the center of mass frame, retrieving the 4-momentum in the lab frame applying the Lorentz boost
- Warning: GEANT4 provide also  $d\sigma/dE$  and its sampling method...



- In the current plugin version positron can annihilate with the probability given by the cross-section shown below when their energy is  $> 30$  keV. As their energy go below such threshold annihilation is forced

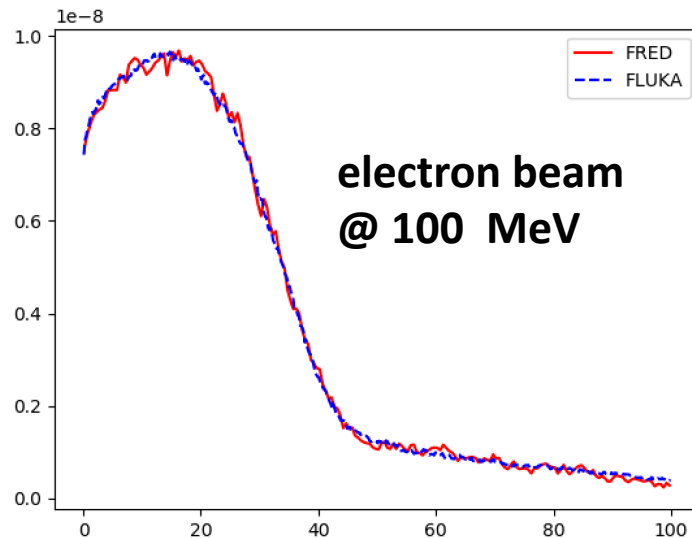
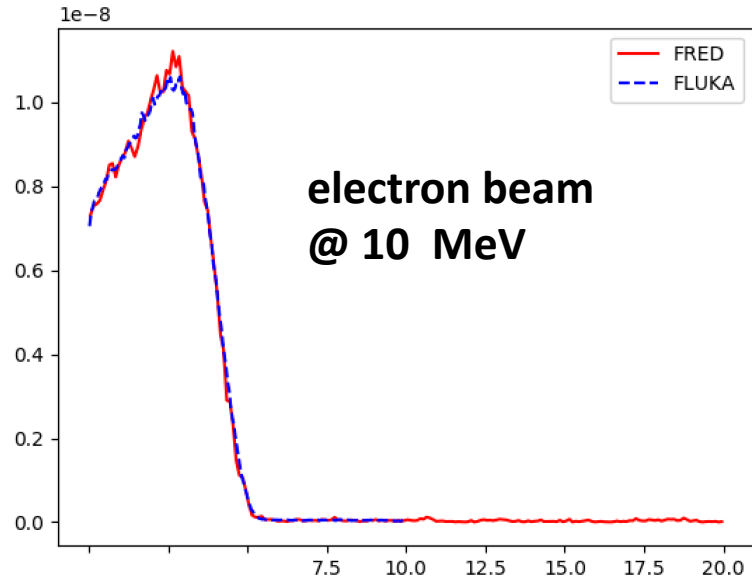
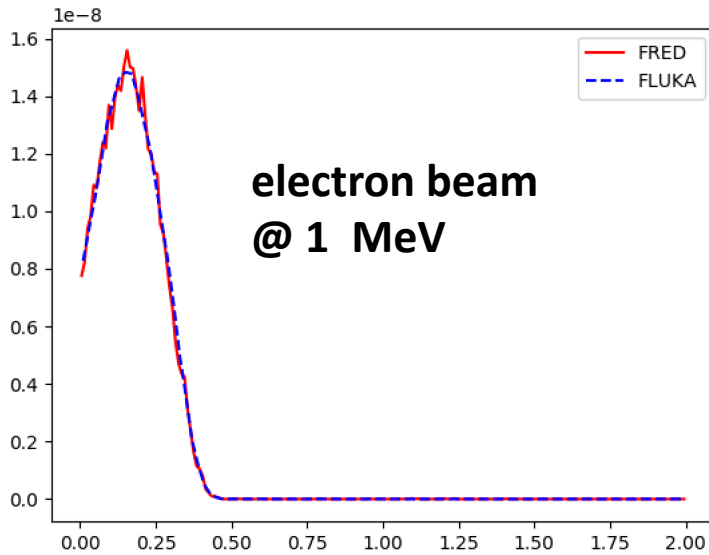


- The  $\sim 10\%$  of the positron annihilates in flight! To be checked with FLUKA...

- We are defining and implementing a standard benchmarking procedure. Gaia is taking care of creating a repository of FLUKA simulations to make a comparison with the FRED output (webpage <http://arpg-serv.ing2.uniroma1.it/twiki/bin/view/Sandbox/FredEMBenchmark>)
  - Dose level benchmark: e-, e+,  $\gamma$ , @ 1,10,100 MeV on “thick” targets (H<sub>2</sub>O, PMMA, Air, Bone, CT(?)). Plots: **ddd**, **lateral profiles (3 depths)**, **dose difference voxel distribution**)
  - Physics process level :: e-, e+,  $\gamma$ , @ 1,10,100 MeV on “thin” targets (H,C,O,Ca,Au, Al (?), Ti (?)). (**secondaries energy-angle distributions @ target exit**, **interactions occurrence (i.e. cross sections)**, **interaction properties plots**) .

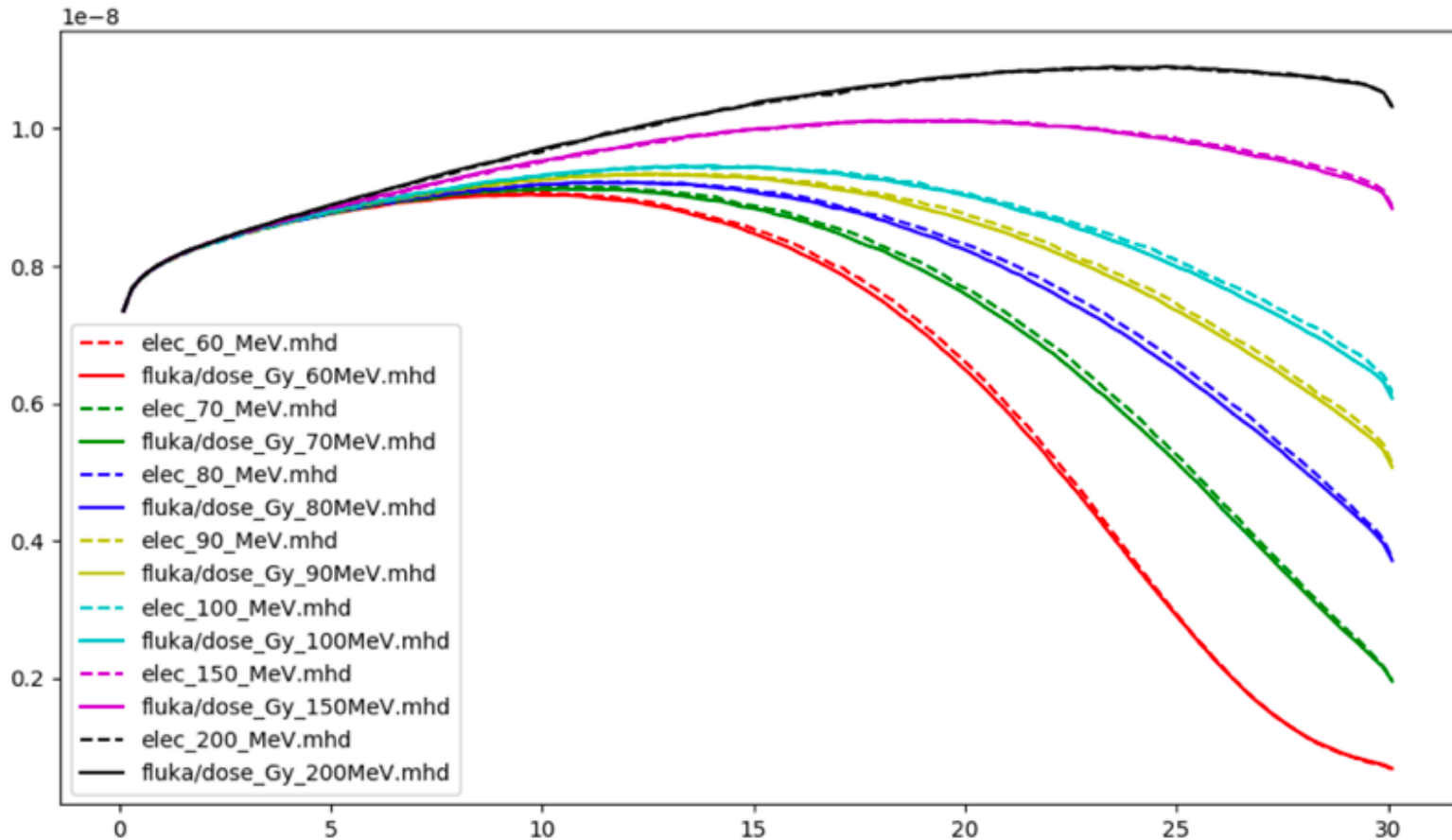
- celo  
- manca  
- in progress



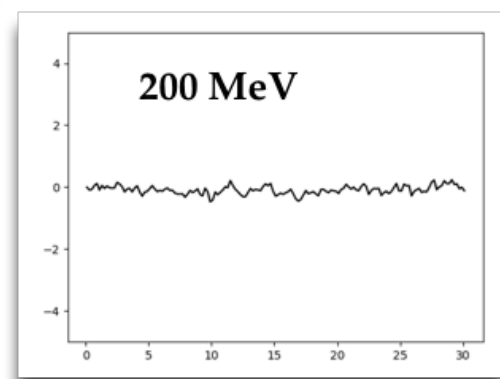
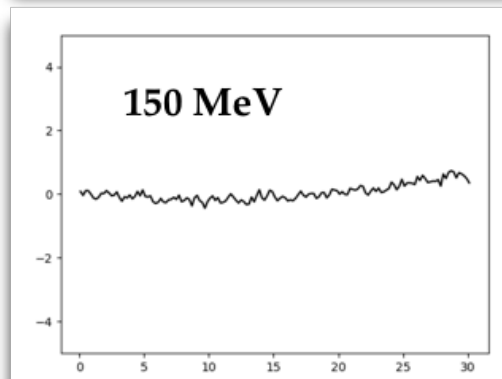
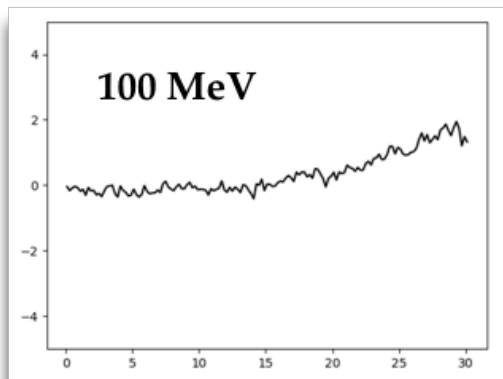
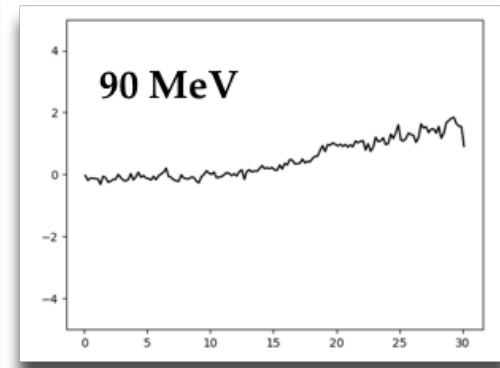
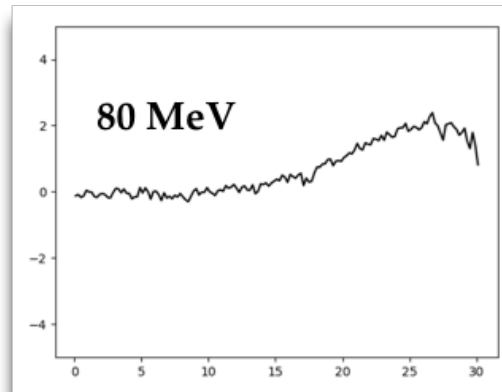
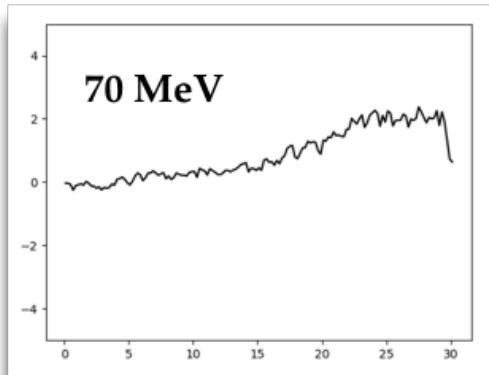
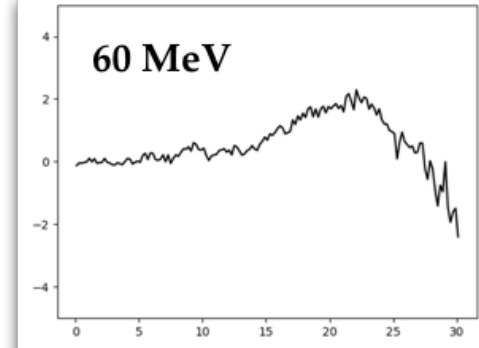


- - - - - FRED  
 ——— FLUKA

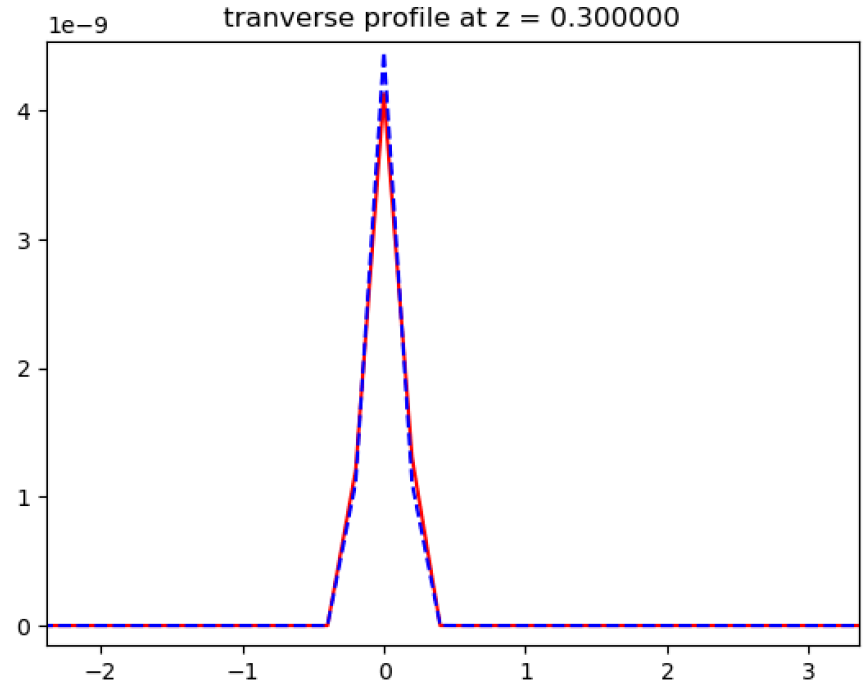
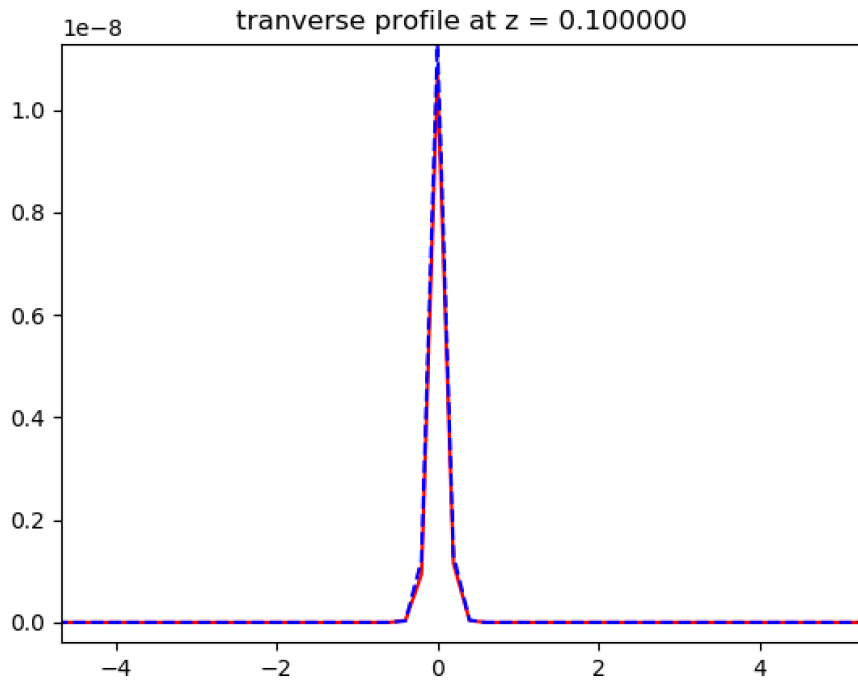
30x30x30 cm<sup>3</sup> H<sub>2</sub>O= cube, E = 60,70,80,90,100,150,200 MeV



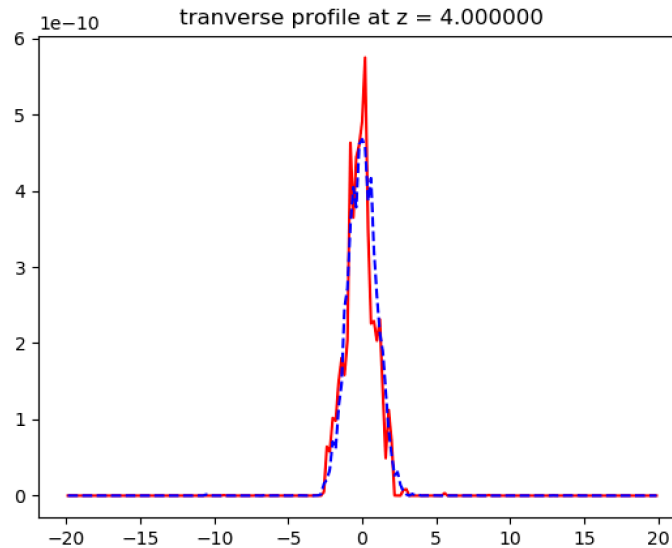
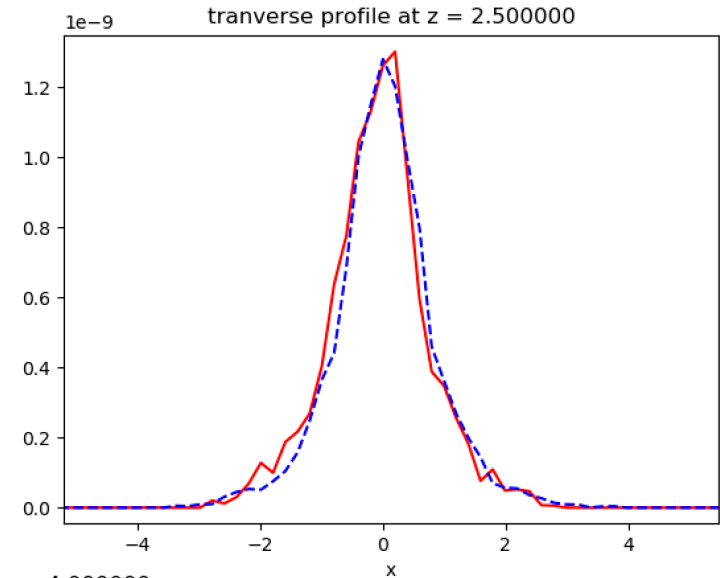
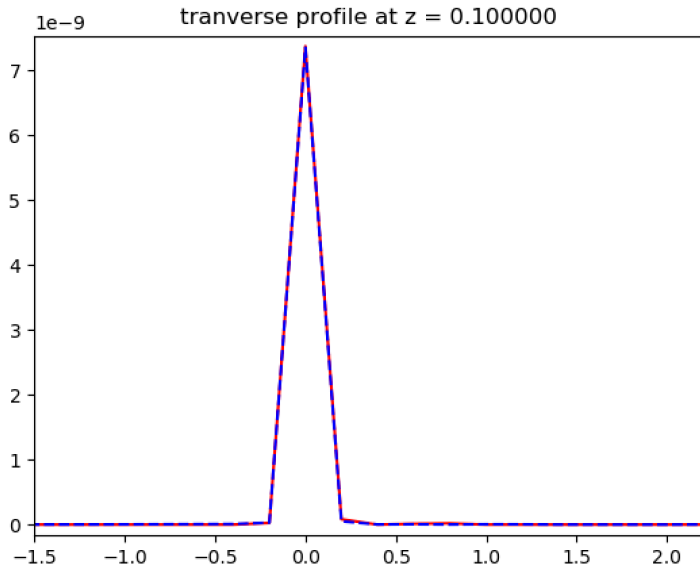
Differenza percentuale delle ddd  
rispetto a fluka



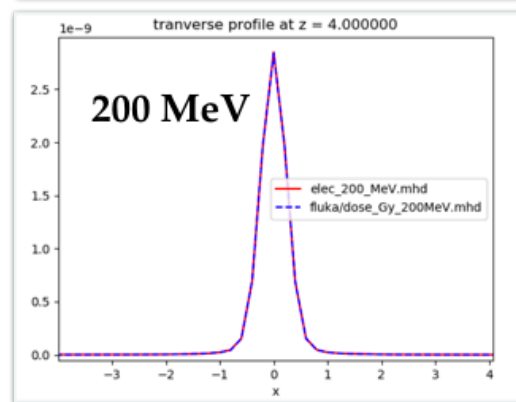
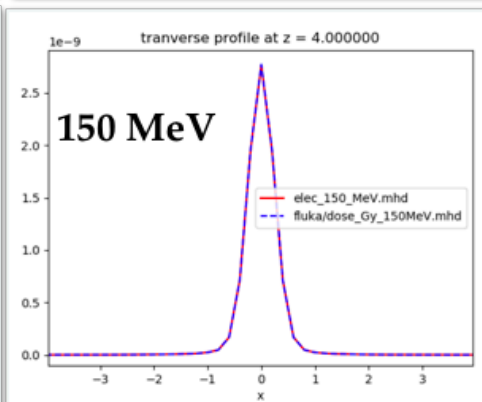
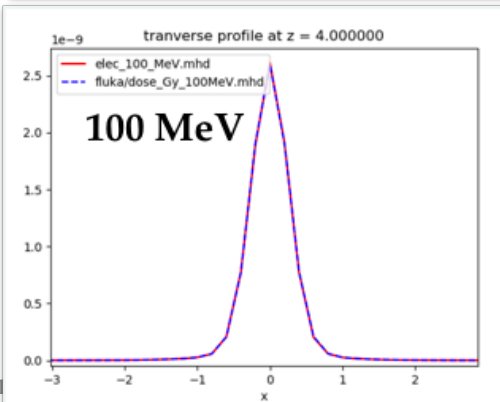
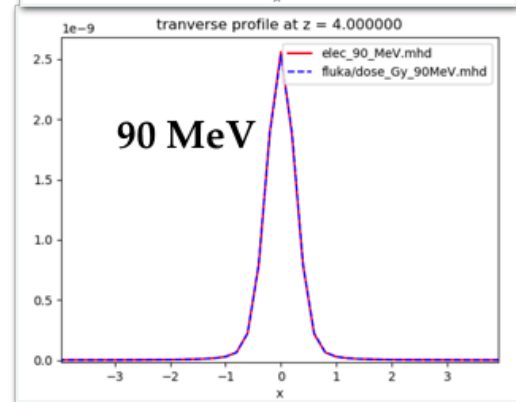
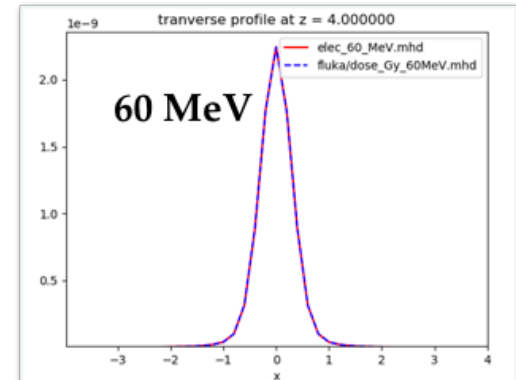
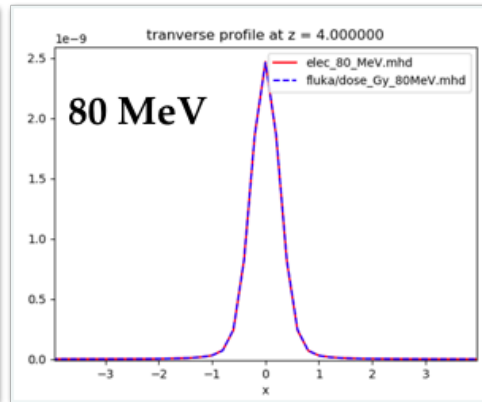
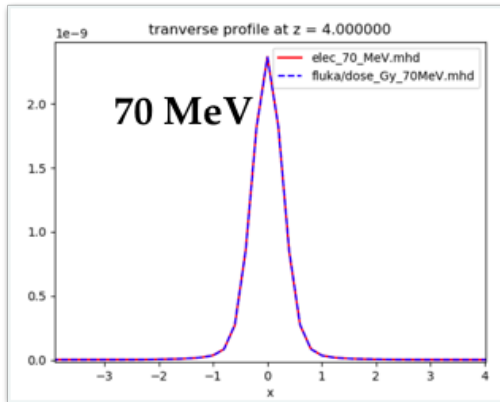
## electron beam @ 1 MeV, depth = 0.1 cm – 0.3 cm



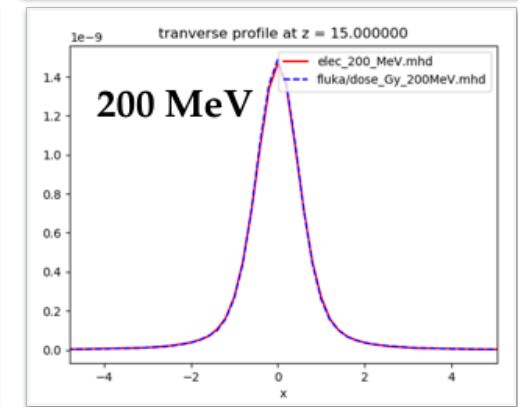
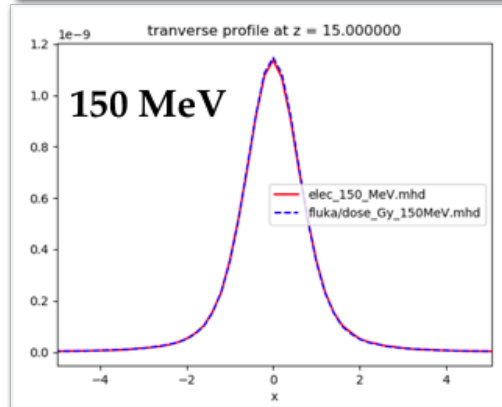
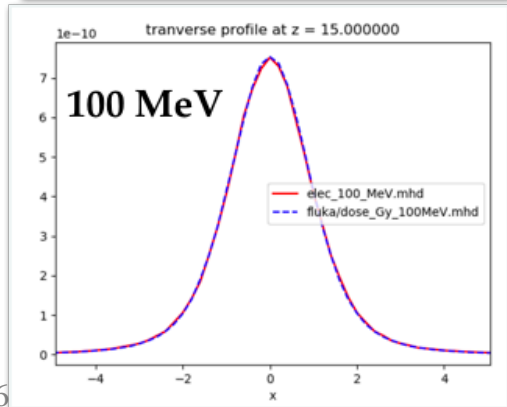
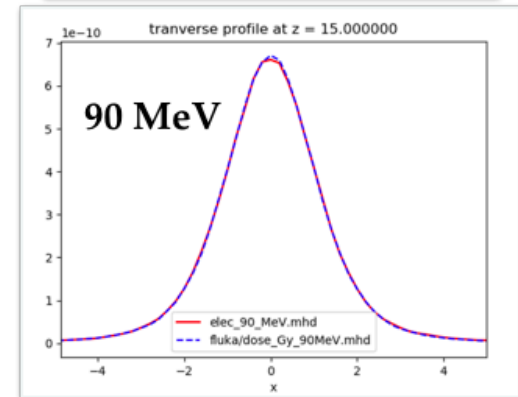
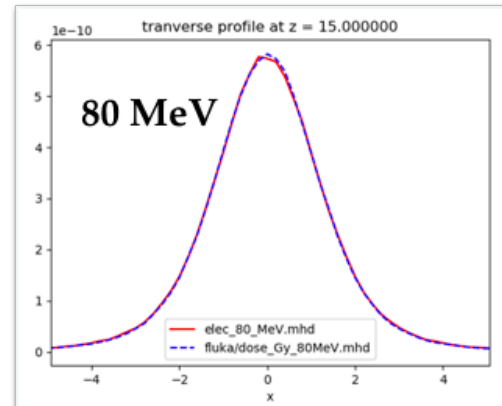
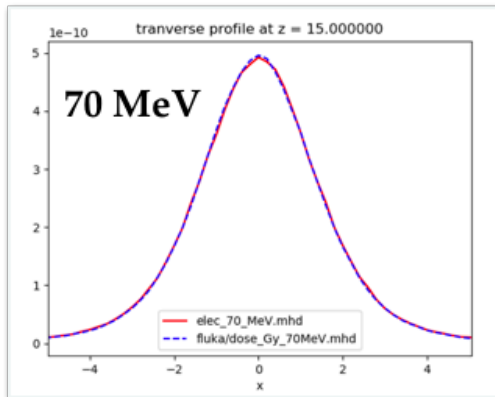
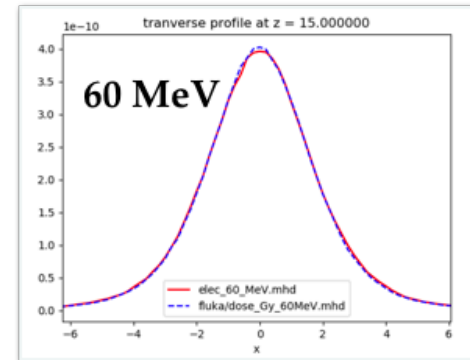
## electron beam @ 10 MeV, depth = 0.1 cm – 2.5 cm - 4.0 cm



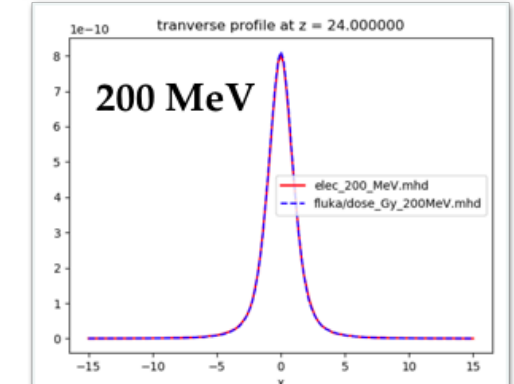
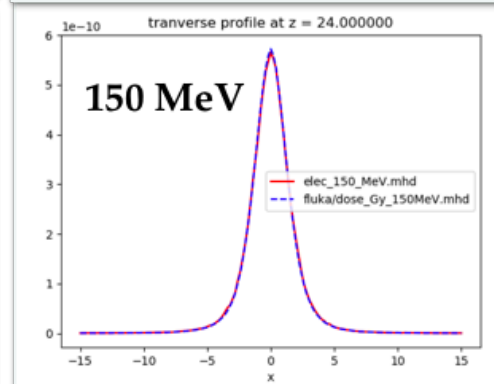
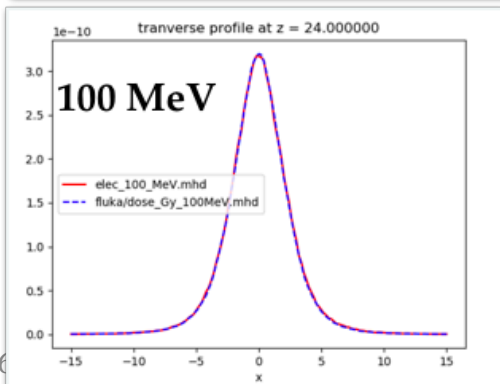
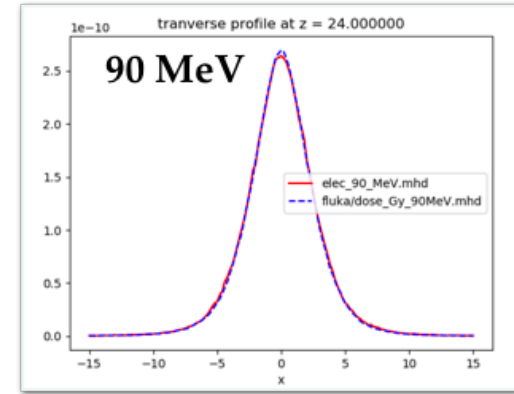
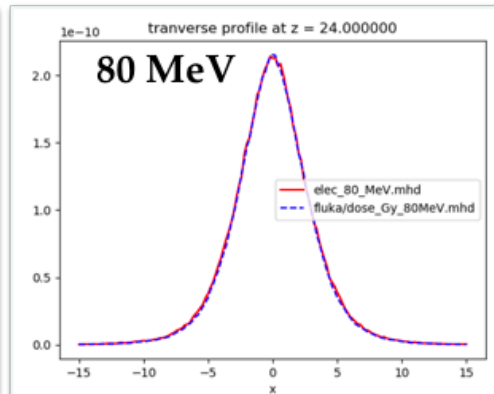
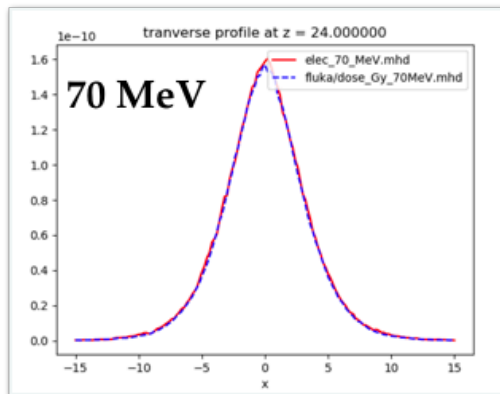
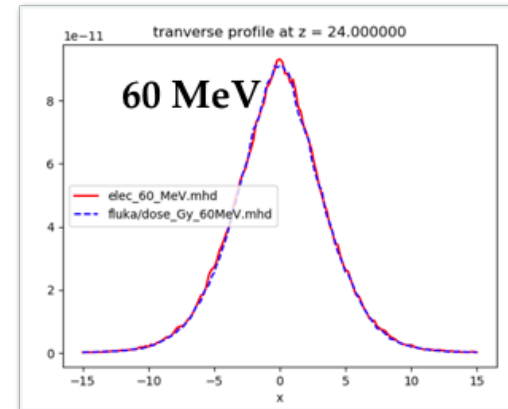
## Transverse Profile at z= 4 cm



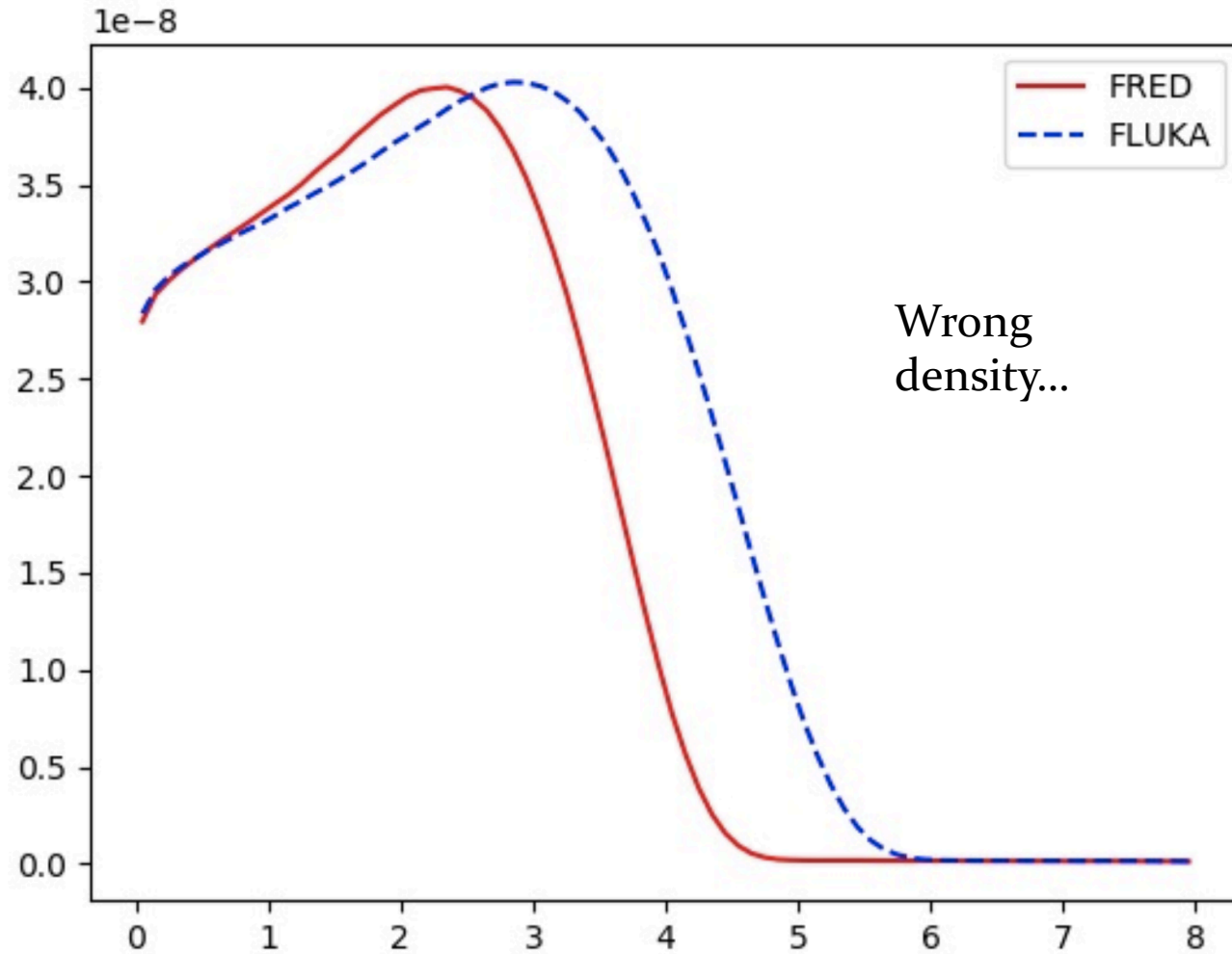
## Transverse Profile at z= 15 cm



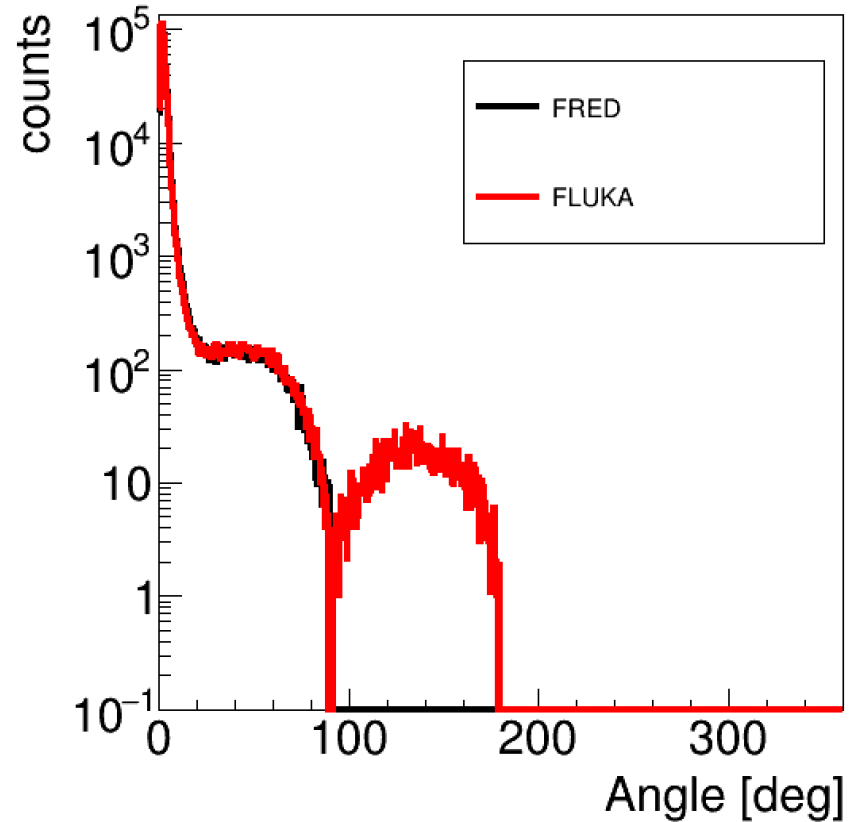
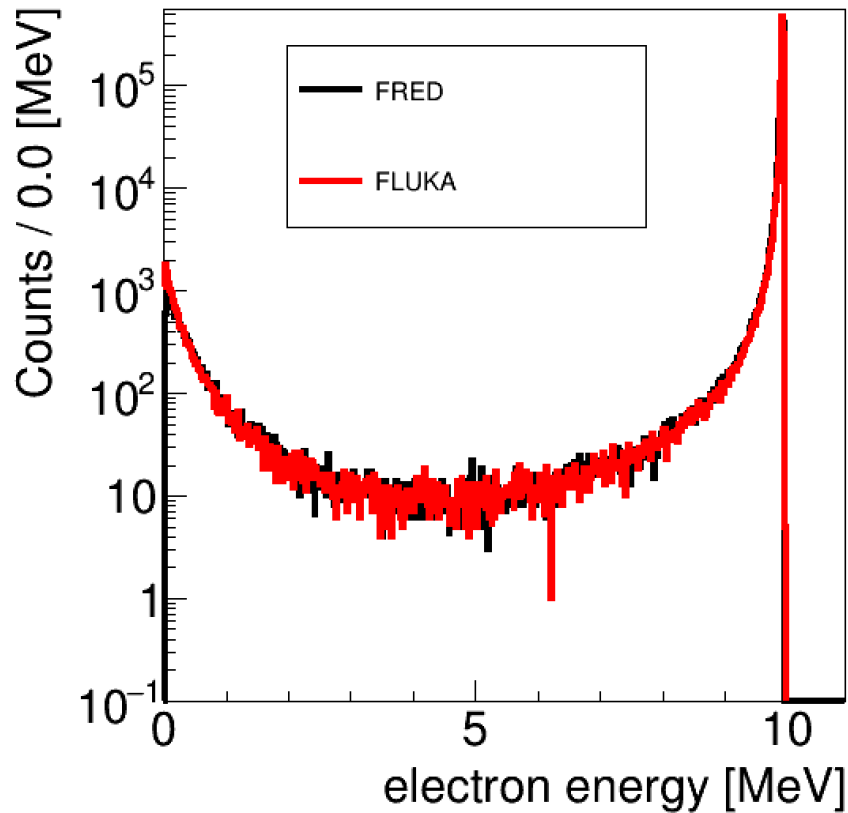
## Transverse Profile at z= 24 cm



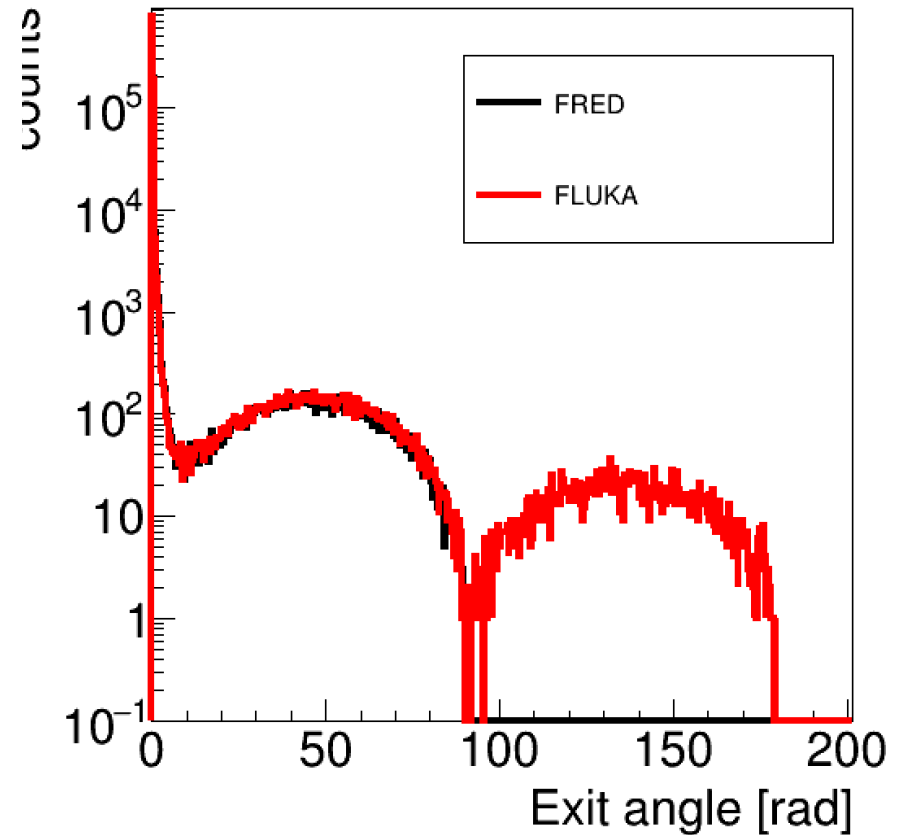
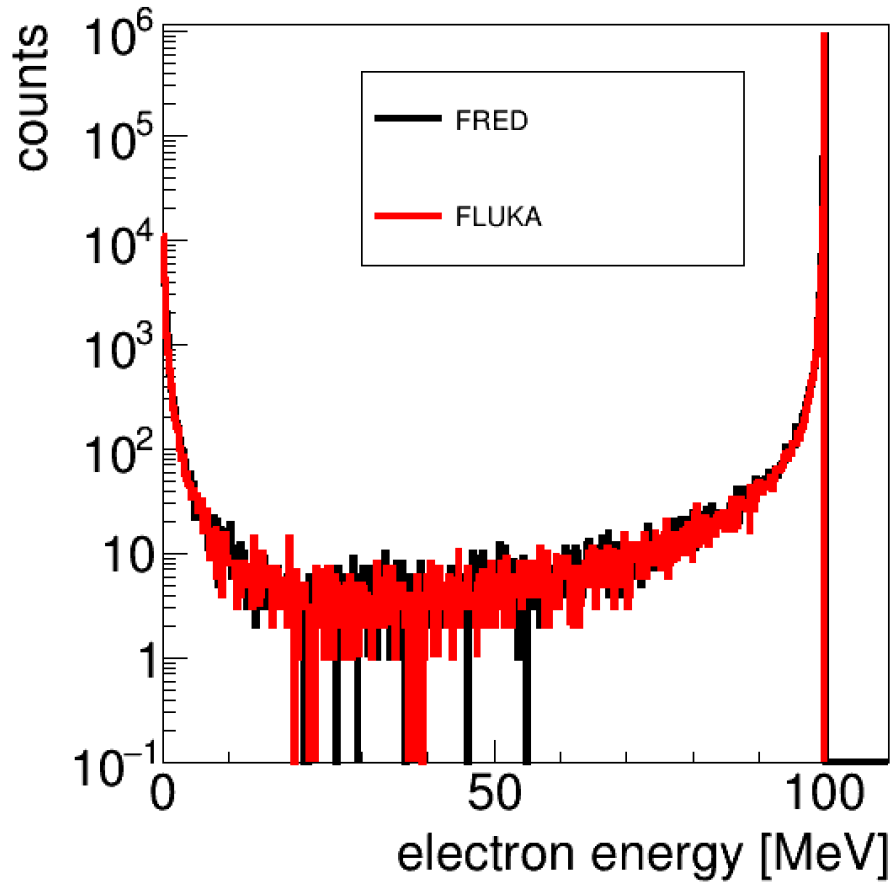




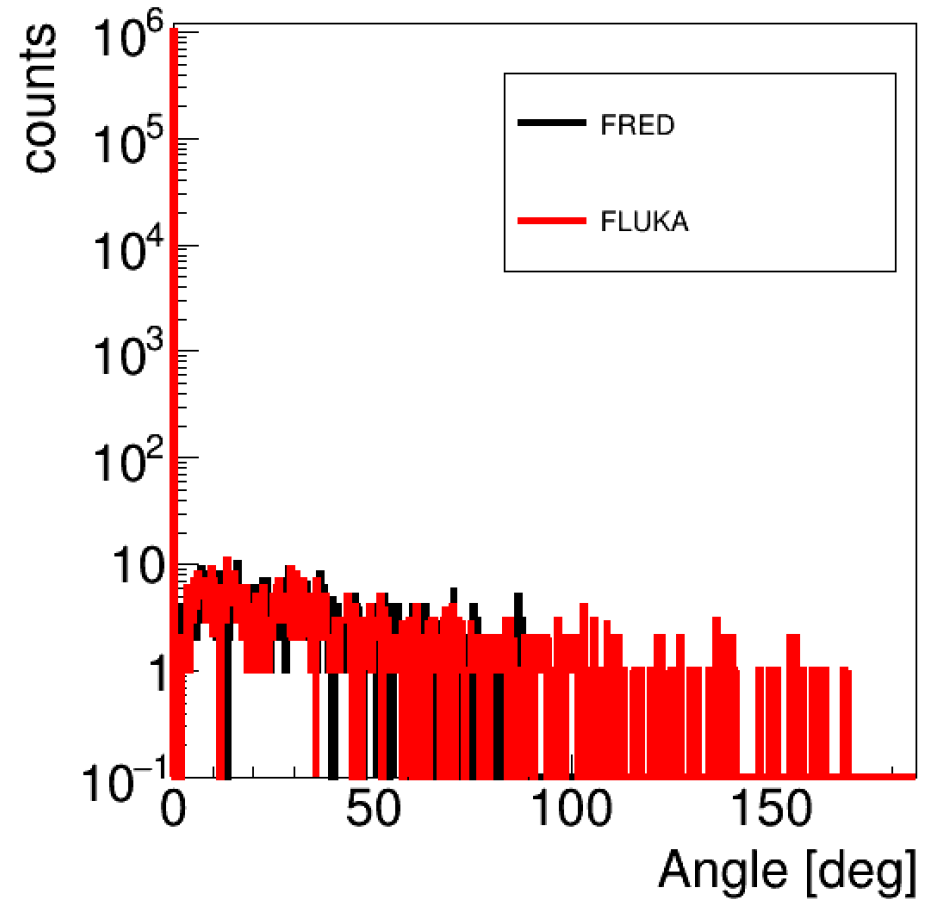
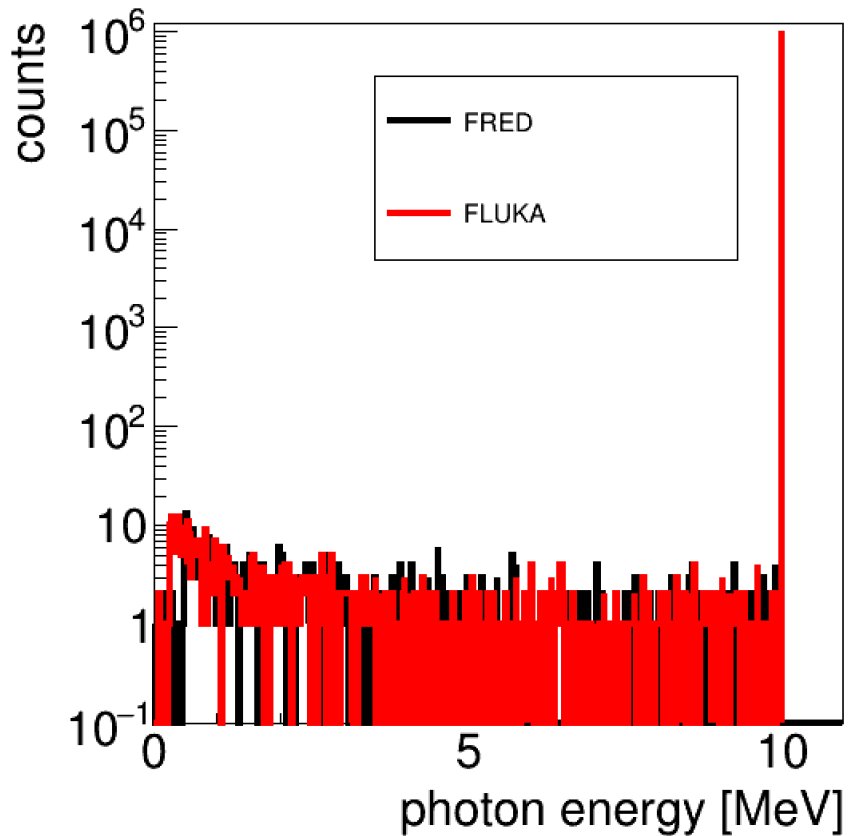
Target 4x4x0.025 cm<sup>3</sup>



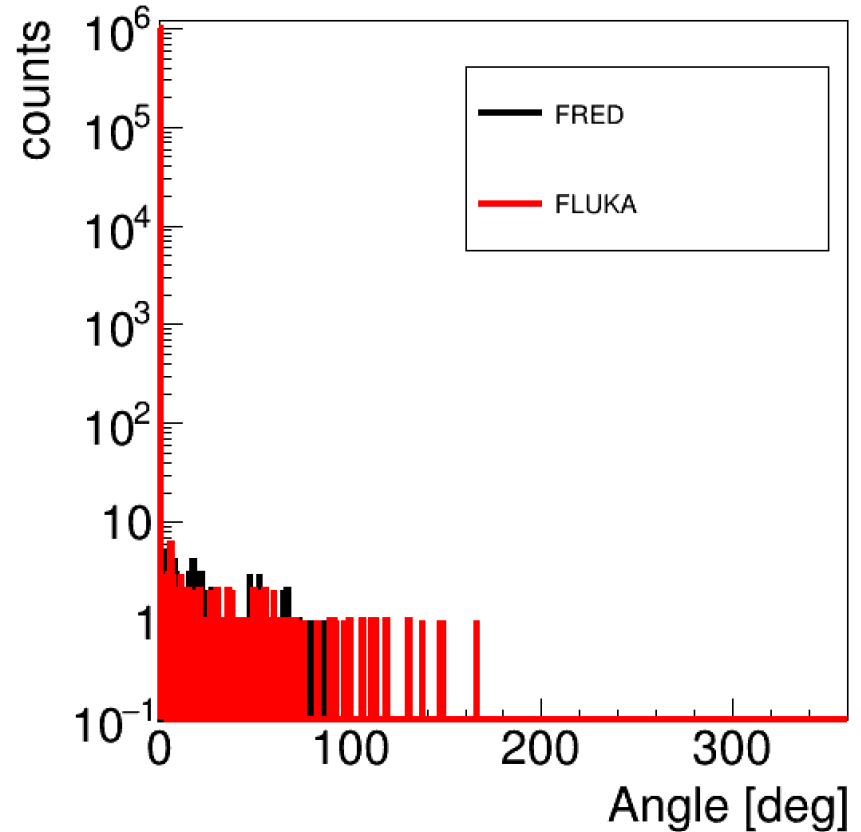
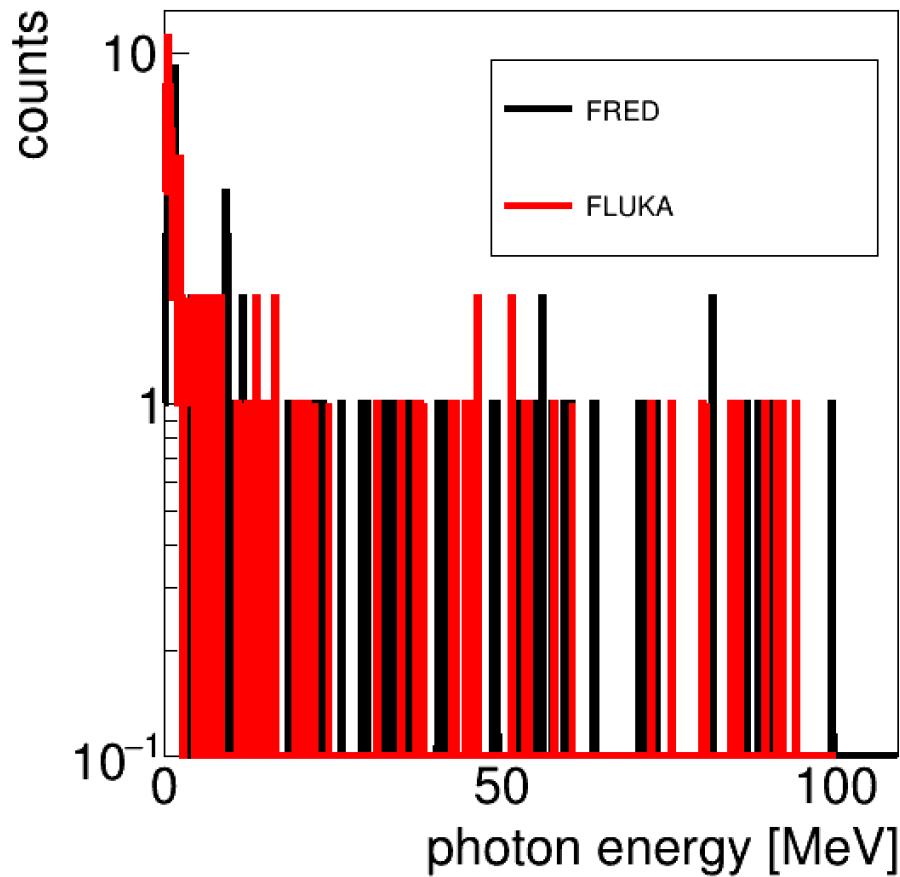
Target 4x4x0.025 cm<sup>3</sup>



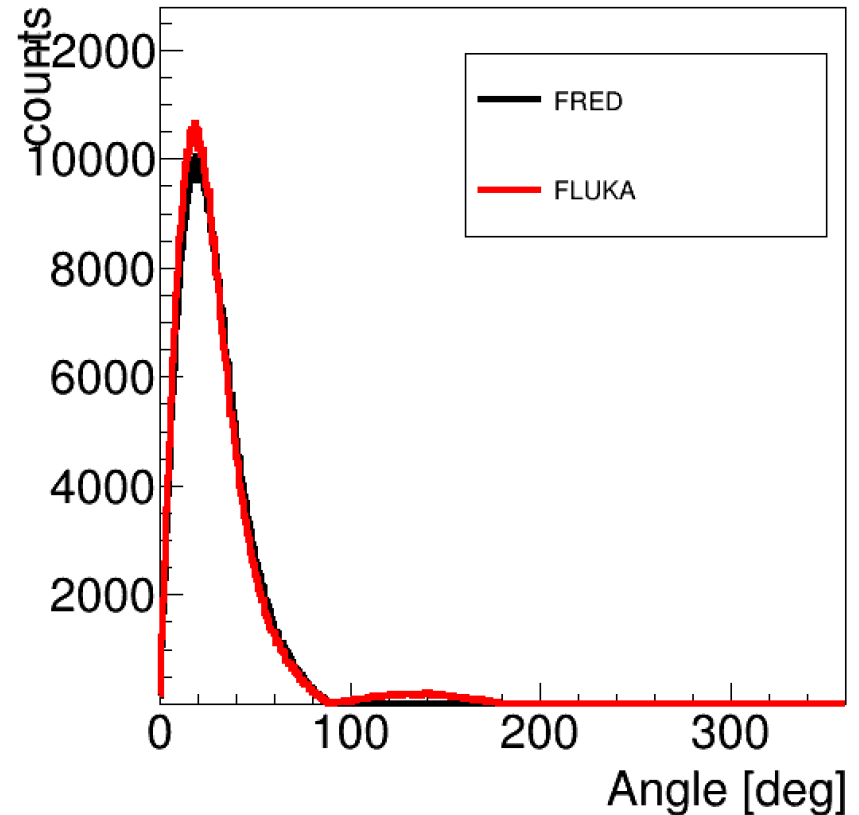
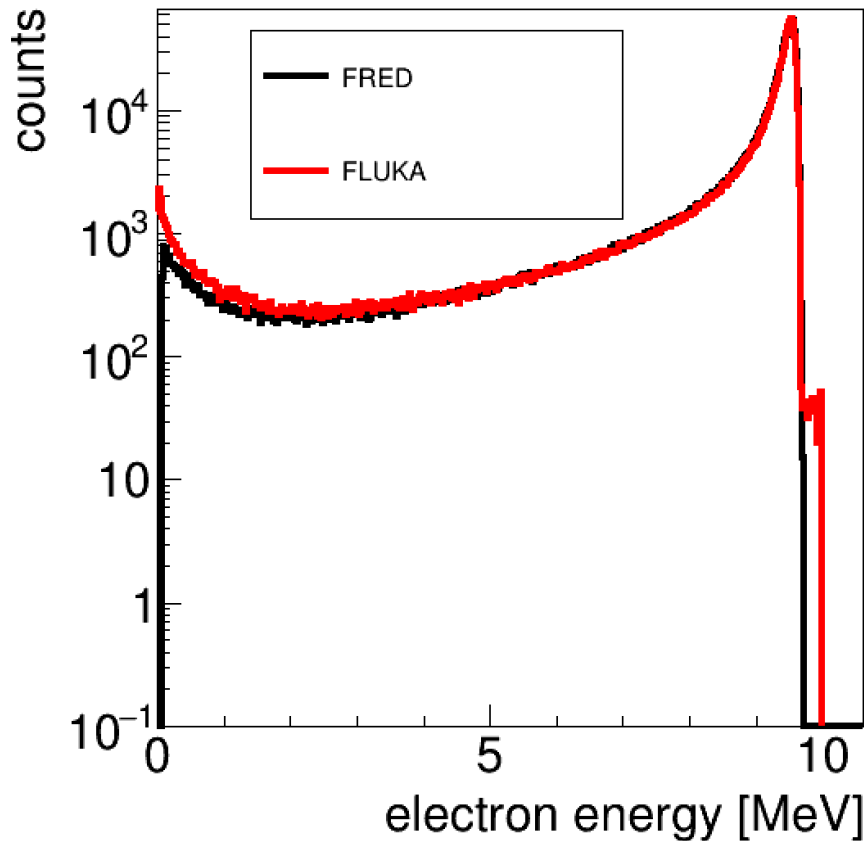
Target 4x4x0.025 cm<sup>3</sup>



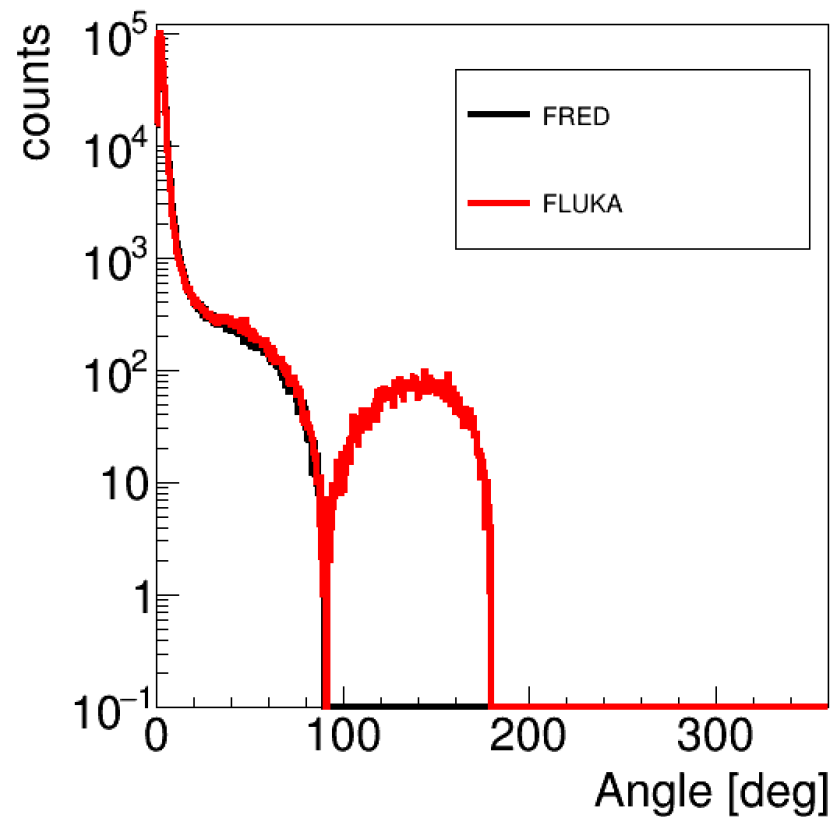
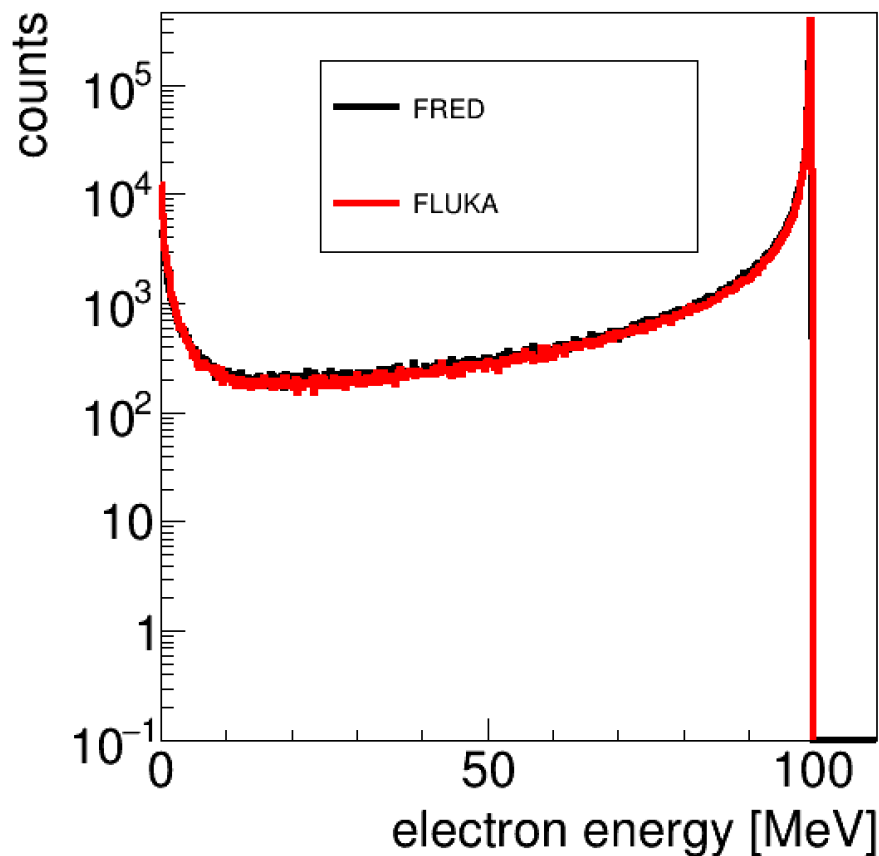
Target 4x4x0.025 cm<sup>3</sup>



Target 4x4x0.025 cm<sup>3</sup>



Target 4x4x0.025 cm<sup>3</sup>



- We have to fill the FLUKA simulation repository and start a systematic comparison with the FRED output.
- The benchmark procedure has to be automated. This will allow to simplify the iter when we will modify the plugin... (it will happen very very soon)
- Next step: tables tables tables tables ... the cross section of many interactions (mostly the more recent) is computed on the fly, wasting time.