Status of FTM GEANT4 simulations:

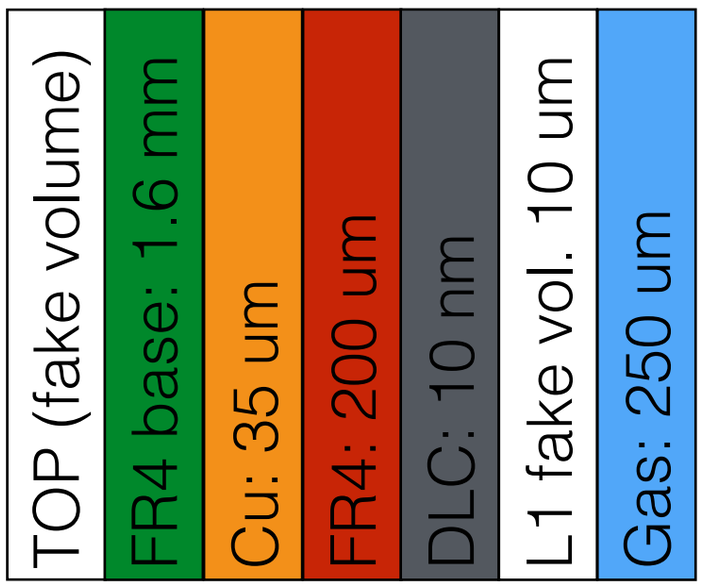
- FTM for charged particles (Oct 2017 prototype)
  - X-ray spectra trough different materials (Cu fluorescence)
  - photon conversion probability in Cu and FR4
- FTM for PET-photons
  - photon conversion probability of different materials to design a new prototype

Raffaella Radogna

AMPTEK X-ray (Ag) spectrum

- X-ray spectrum in gas
- only 1 layer simulated

Simulated Geometry
base + 1 layer



Material's details

Fr4: Epoxy (for FR4)

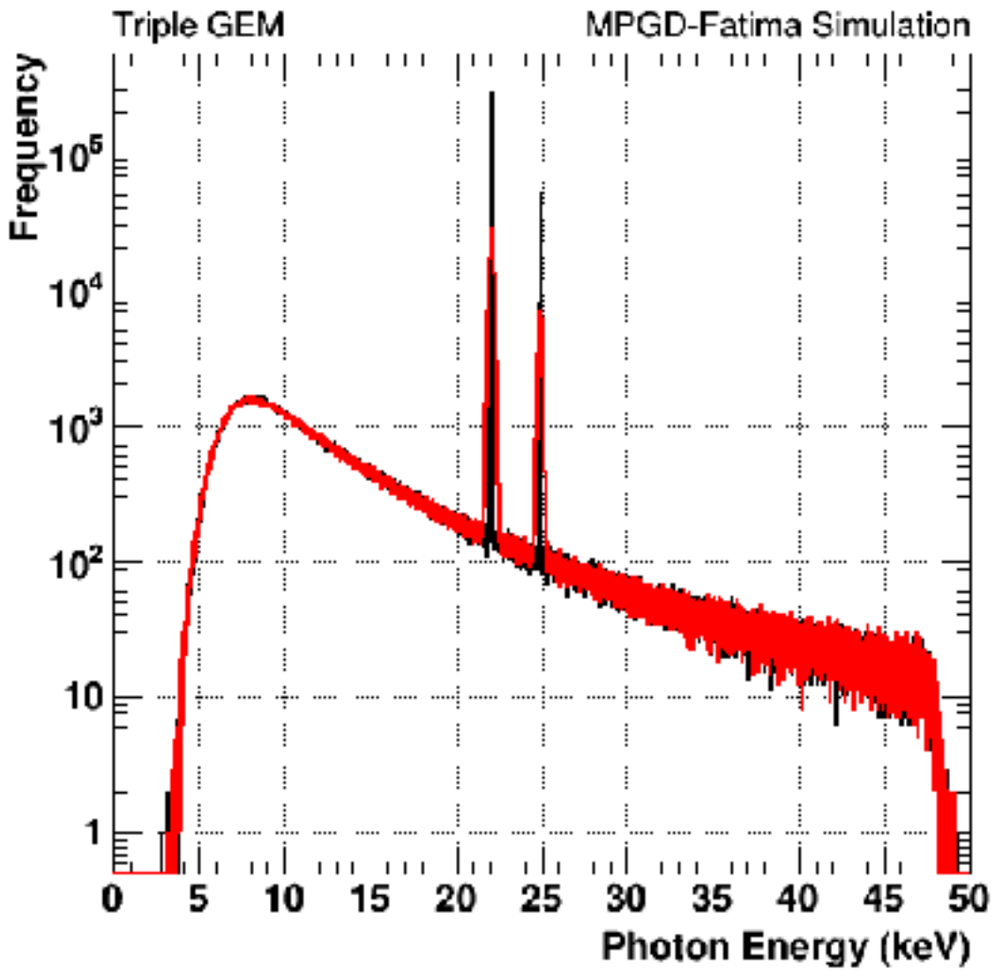
```
  //from http://www.physi.uni-heidelberg.de/~adler/
TRD/TRDunterlagen/RadiatonLength/tgc2.htm //???
  density = 1.2*g/cm3;
  G4Material* Epoxy = new G4Material("Epoxy" ,
density, numel=2);
  Epoxy->AddElement(elH, natoms=2);
  Epoxy->AddElement(elC, natoms=2);
  //SiO2 (Quarz)
  G4Material* SiO2 =  new
G4Material("SiO2",density= 2.200*g/cm3, numel=2);
  SiO2->AddElement(elSi, natoms=1);
  SiO2->AddElement(elO , natoms=2);
  //FR4 (Glass + Epoxy)
  density = 1.86*g/cm3;
  G4Material* FR4 = new G4Material("FR4"  ,
density, numel=2);
  FR4->AddMaterial(Epoxy, fractionMass=0.472);
  FR4->AddMaterial(SiO2, fractionMass=0.528);
  fr4Material = FR4;
```

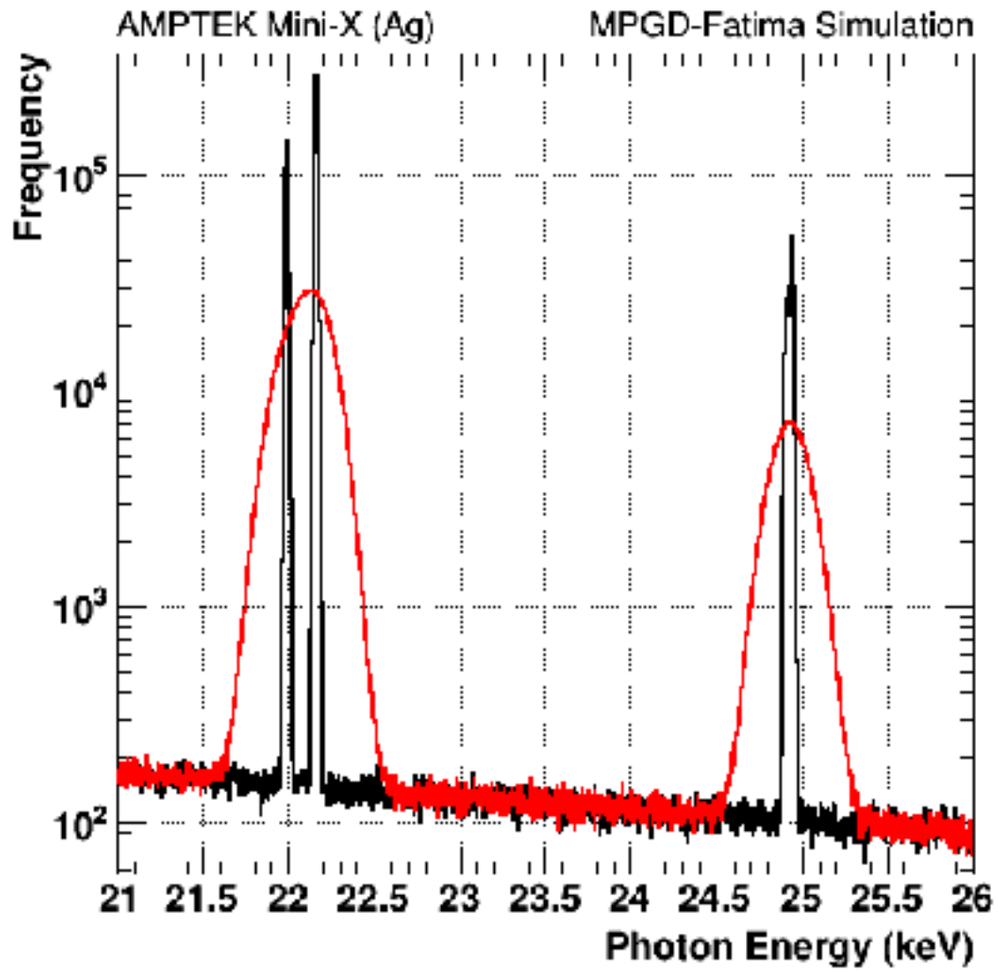
Cu: G4_Cu

DLC: G4_GRAPHITE material used with default density of 1.7 gr/cm^3

Peaks for the X-ray spectrum of Ag

Parametrized initial spectrum





in red the effect of the detector resolution of the silicon drift detector X-123SDD used to measure the spectrum

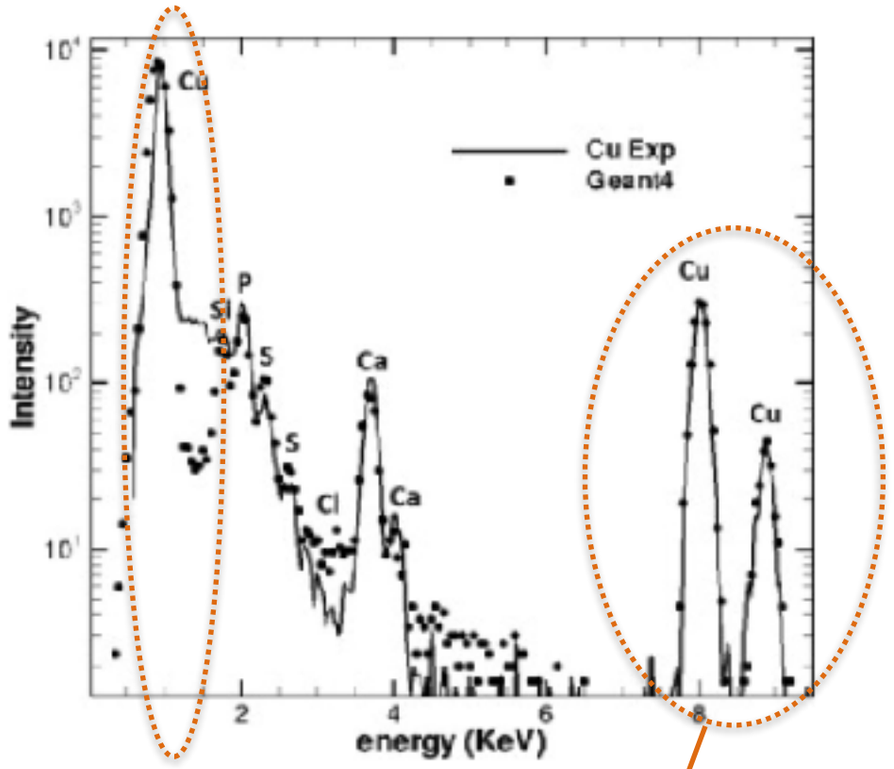
Activate Cu florescence in GEANT4

Physics settings

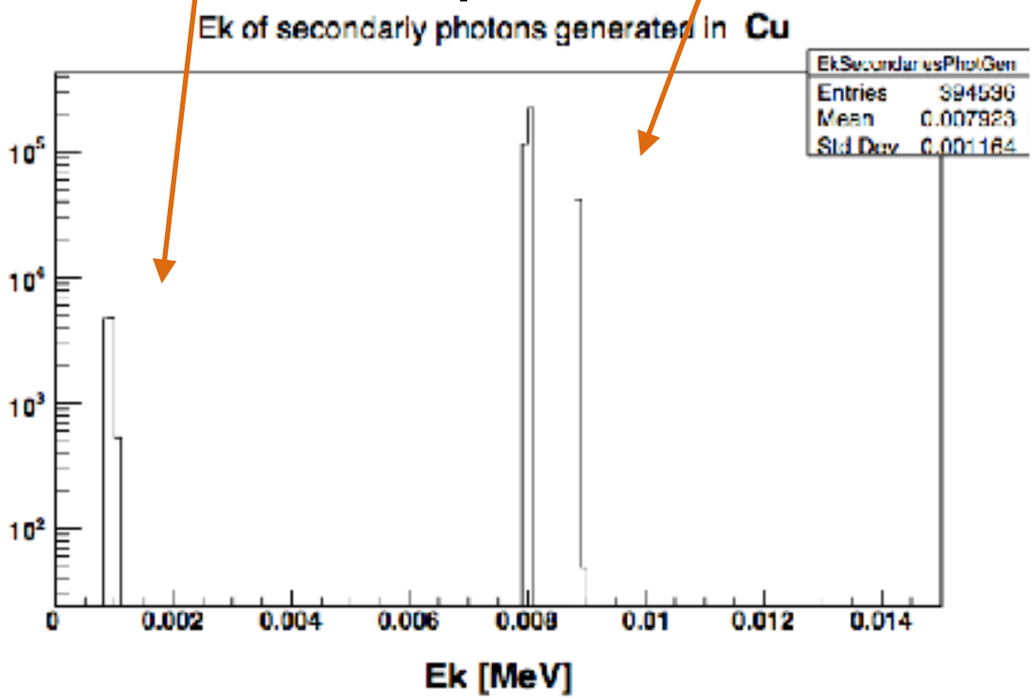
```
/testem/phys/addPhysics emlivermore

/process/em/fluo true
/process/em/auger true
/process/em/augerCascade true
/process/em/pixe true
/process/em/AddPAIRegion all GasDetector
pai
# For
emCal.GetCSDARange(energy,particle,material
);
/process/eLoss/CSDARange true
#
/run/setCut 10 nm
#/cuts/setLowEdge 750 eV
/cuts/setLowEdge 100 eV
```

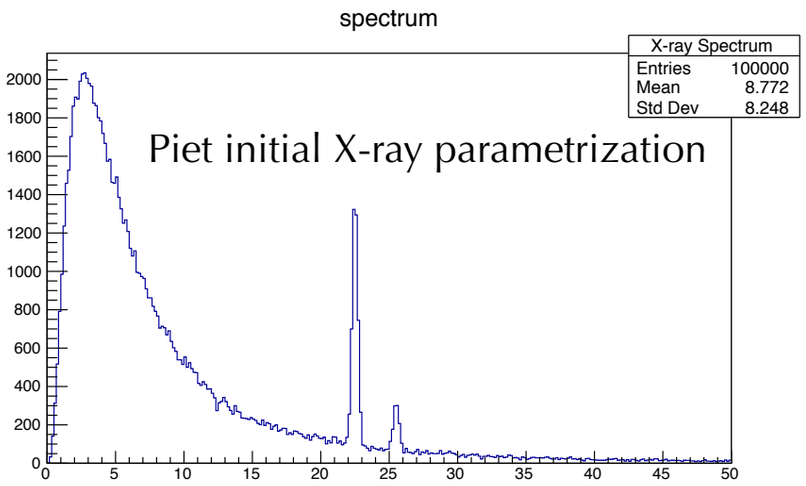
Nucl. Instrum. and Meth. B 316 (2013) 1-5
https://doi.org/10.1016/j.nimb.2013.08.006

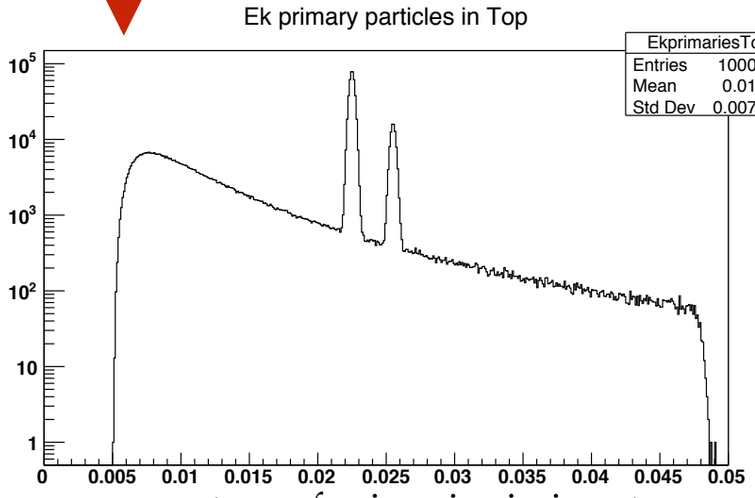


GEANT4 Cu peaks

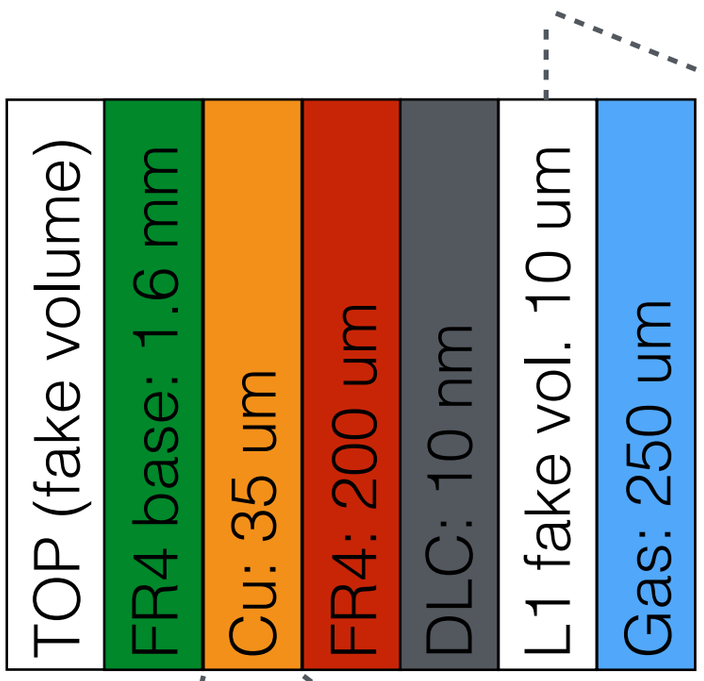


Spectrum in different materials

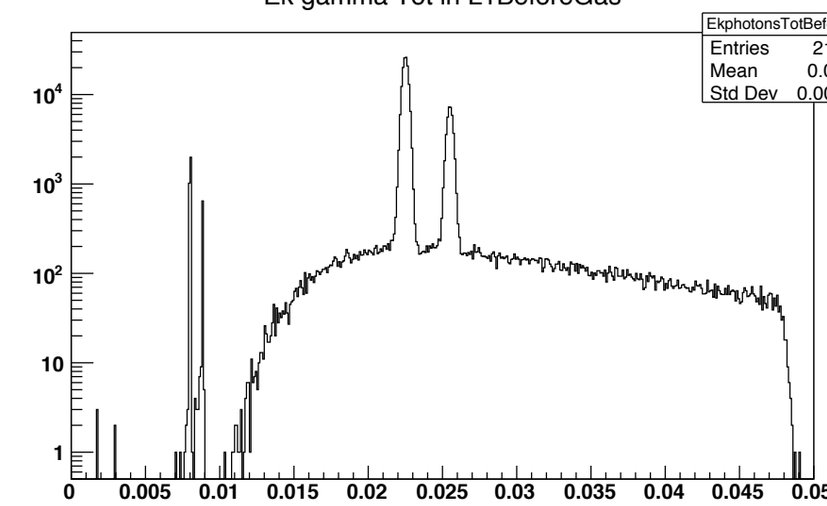




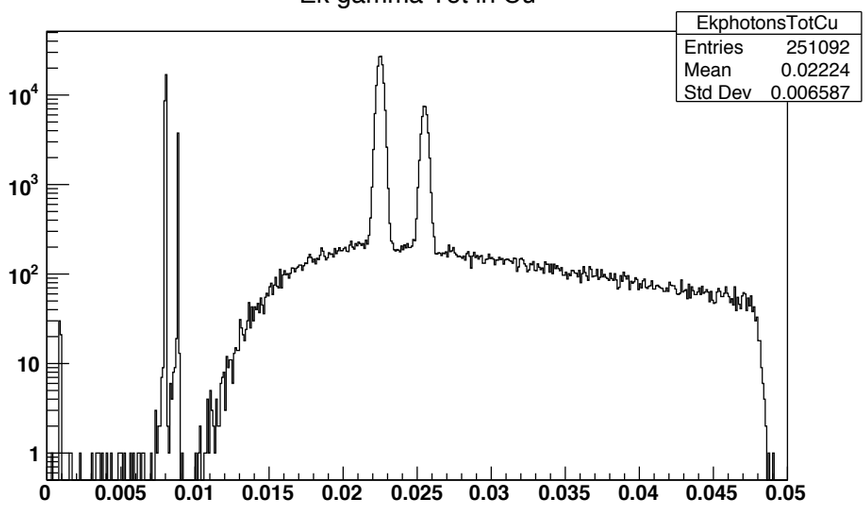
spectum of primaries in input



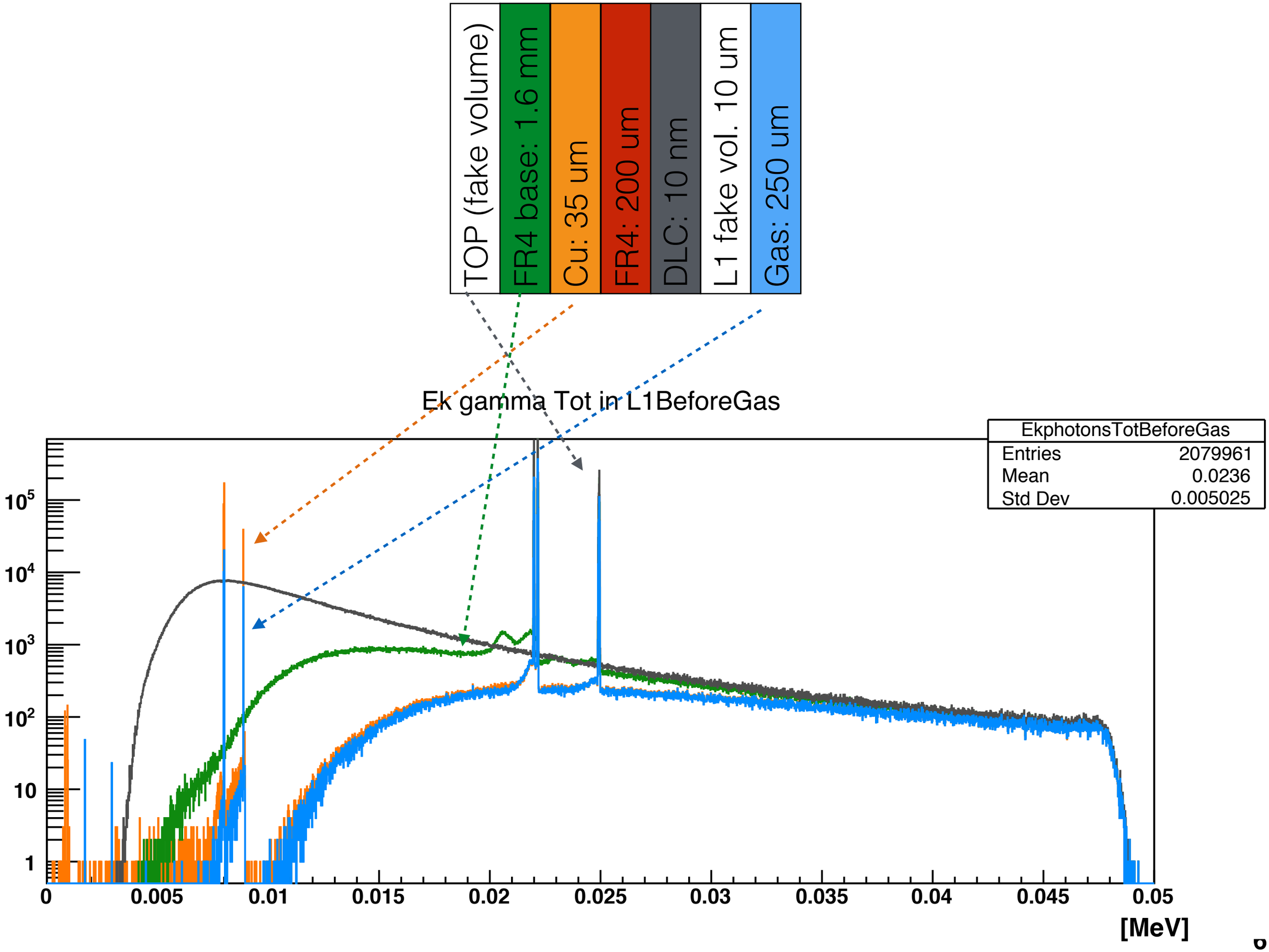
spectrum after 1.6 mm of FR4

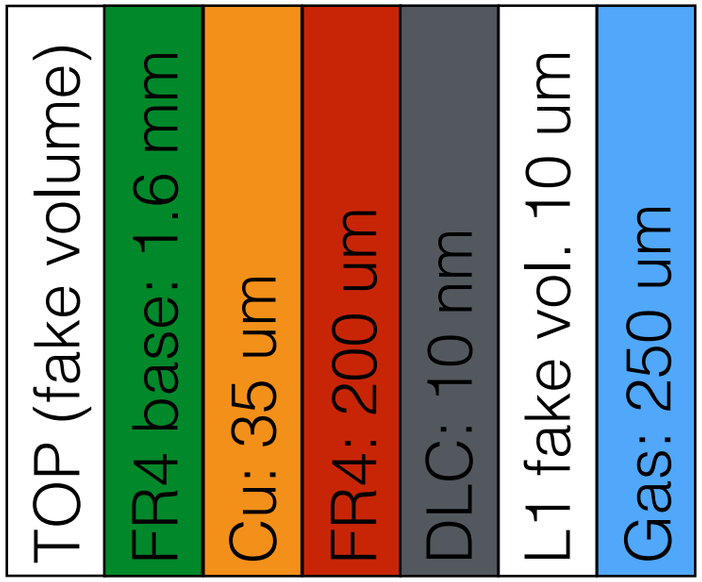


spectrum of gammas (primaries+secondaries) just entering the Gas



spectrum of gammas (primaries+secondaries) exiting Cu


TOP (fake volume)
FR4 base: 1.6 mm
Cu: 35 um
FR4: 200 um
DLC: 10 nm
L1 fake vol. 10 um
Gas: 250 um
Ek gamma Tot in L1BeforeGas
EkphotonsTotBeforeGas
Entries 2079961
Mean 0.0236
Std Dev 0.005025
10^5
10^4
10^3
10^2
10
1
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
[MeV]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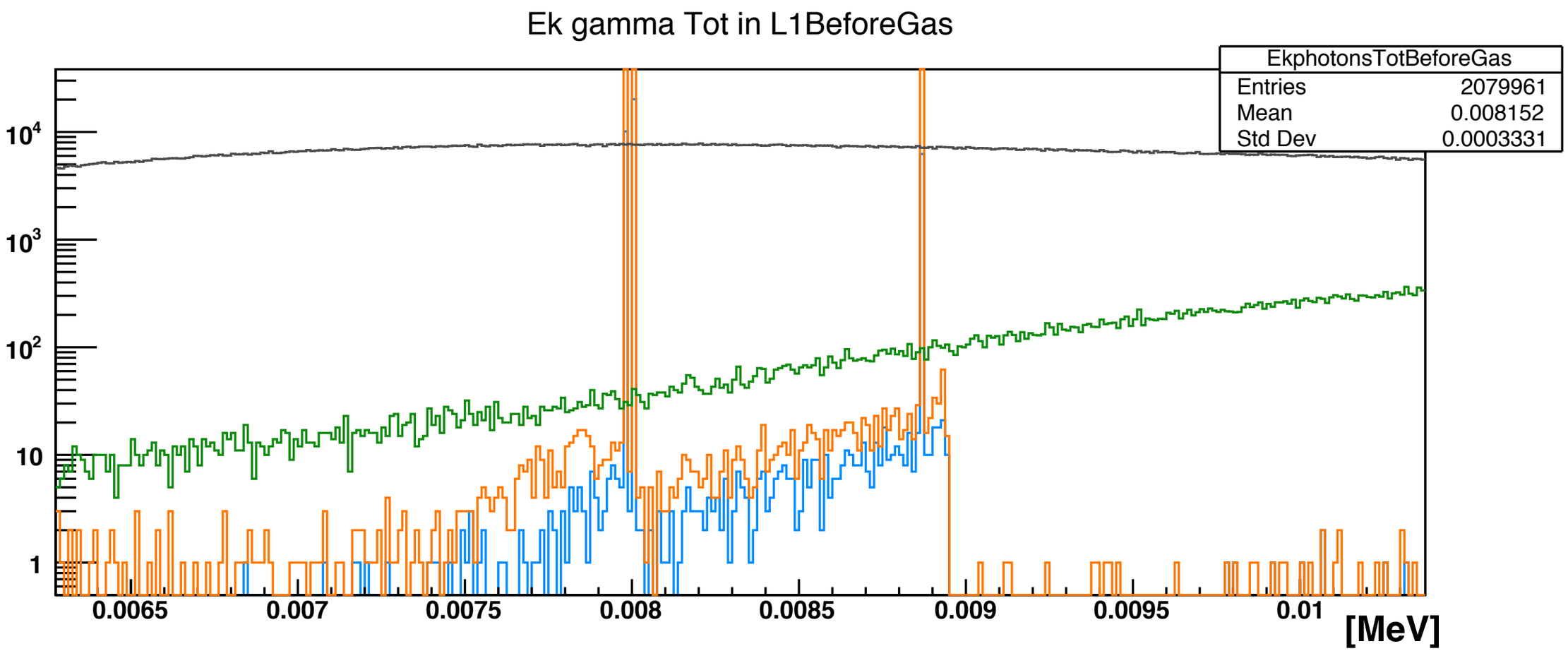
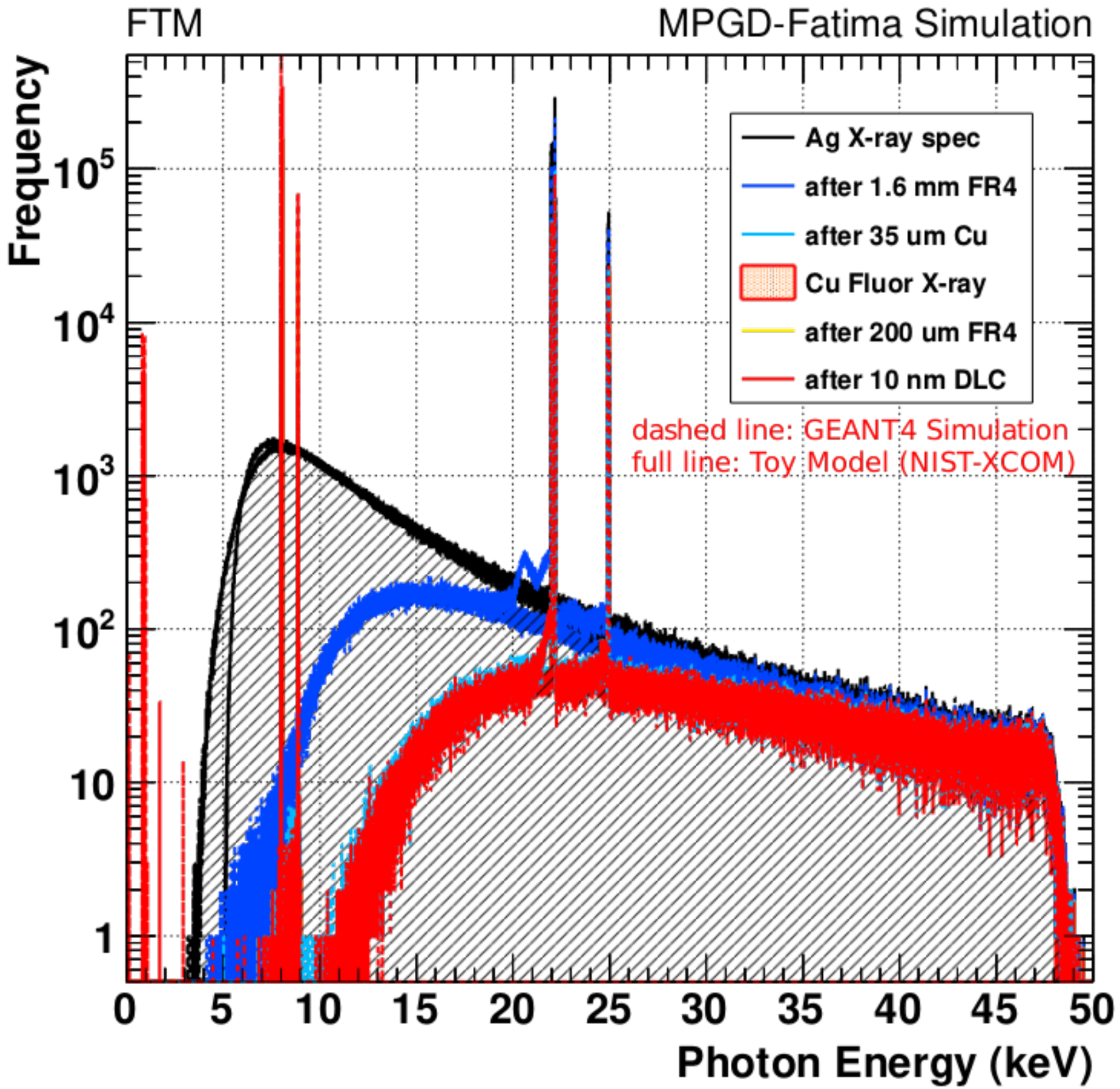
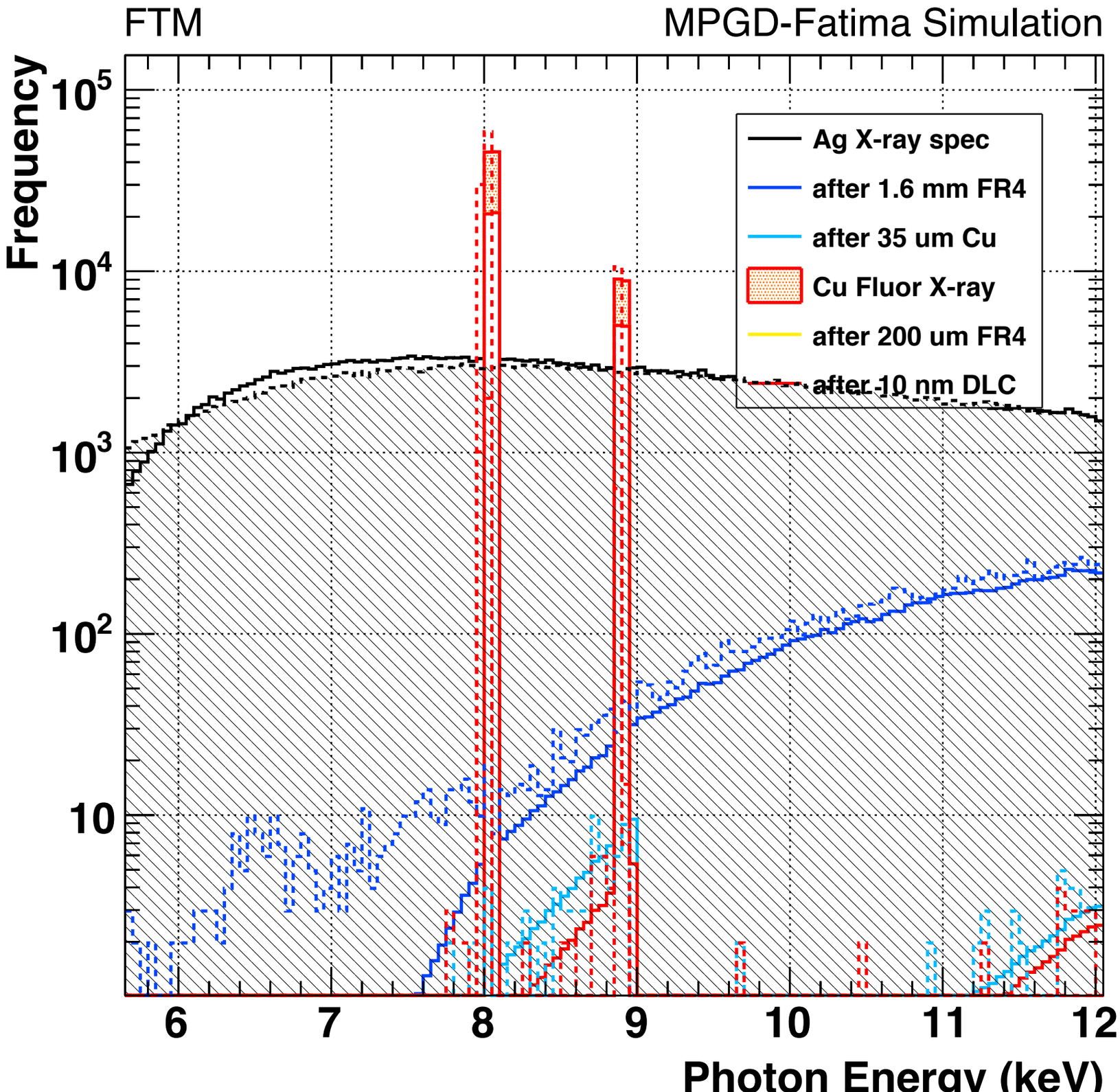

Ek gamma Tot in L1BeforeGas
EkphotonsTotBeforeGas
Entries 2079961
Mean 0.008152
Std Dev 0.0003331
10^4
10^3
10^2
10
1
0.0065
0.007
0.0075
0.008
0.0085
0.009
0.0095
0.01
[MeV]

Comparison with toy model expectations



Comparison with toy model expectations

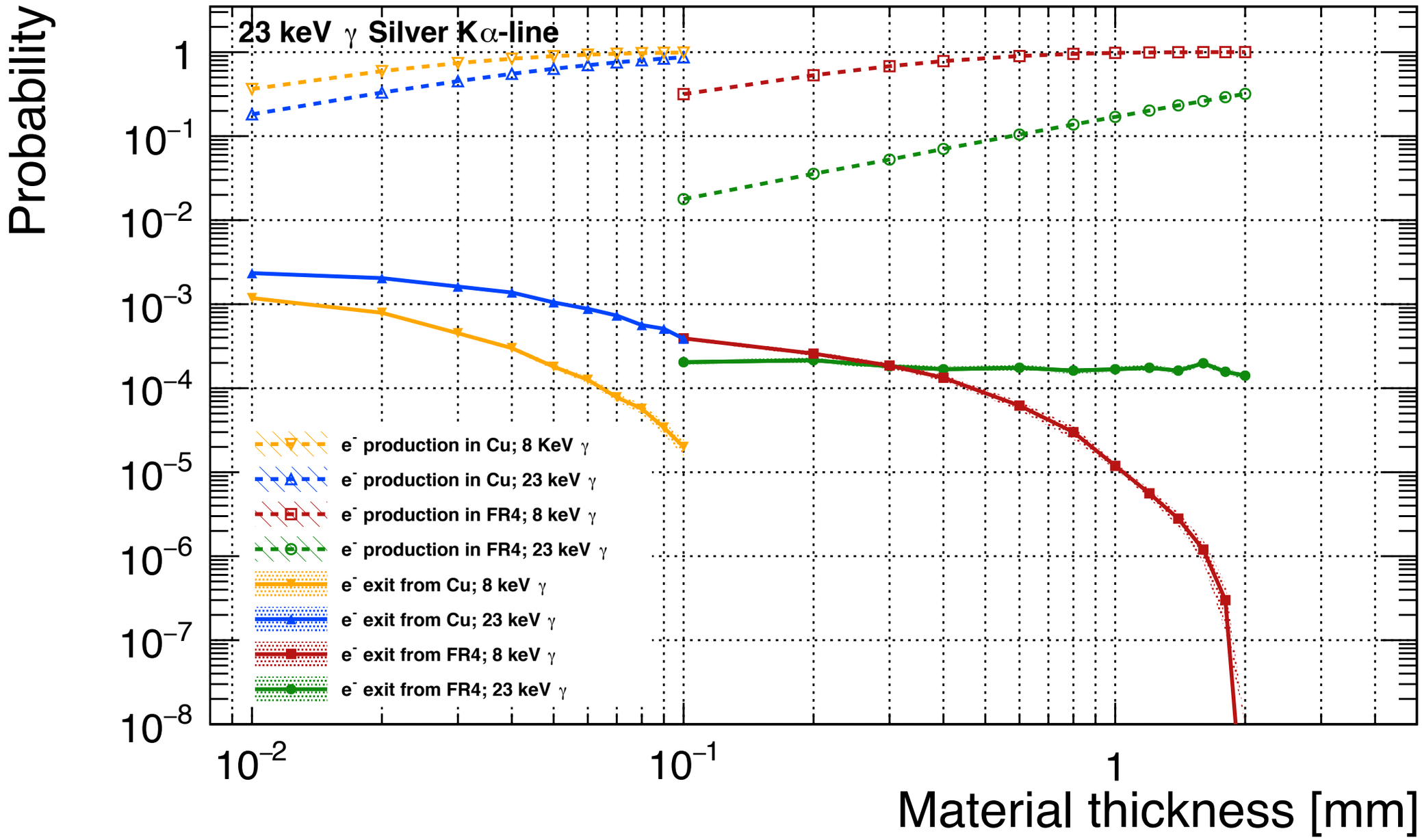


PrimaryGeneratorAction

```
std::random_device rd;
std::default_random_engine gen(rd());

std::normal_distribution<G4double> ka1(22.163,0.009); // width 9.16 eV intensity 100
std::normal_distribution<G4double> ka2(21.991,0.009); // width 9.32 eV intensity  50
std::normal_distribution<G4double> kb2(24.943,0.010); // width ???? eV intensity  20
std::normal_distribution<G4double> kb3(24.912,0.010); // width ???? eV intensity  10
std::fisher_f_distribution<G4double> fi3(10.0,4.0);
std::uniform_real_distribution<G4double>  br(0.0,1.0);
std::normal_distribution<G4double> smear(0,2./2.355);

G4double back3=10.*fi3(gen);
G4double value = 0.;
G4double b= br(gen);
G4double e= br(gen);
G4double sigmoid_on =0., sigmoid_off = 0.;
// Intensity for Ka1 is 100, while the (merged) Ka2 is 50, Kb1 = 20, Kb1 = 10

// Assume 200 intensity for the background ==> total sum is 380, 150 for Ka, 30 Kb
while (!(value != 0. && e<sigmoid_on && e<sigmoid_off)){
b= br(gen);

if (b<100./380) {
    value= ka1(gen);
} else if (b>100./380 && b<150./380){
    value = ka2(gen);
} else if (b>150./380 && b<170./380){
    value= kb2(gen);
} else if (b>170./380 && b<180./380){
    value= kb3(gen);
// -----------------
} else {
    value = back3/2. + 5; // Shift of Peak Position from 2.5keV --> 7.5 keV
    // smear value with gaussian
    value += smear(gen);
}
    G4double sigmoid_on_den =1.+std::exp(-5*(value-4));
    G4double sigmoid_off_den = 1.+std::exp(-5*(value-48));
    sigmoid_on = 1./(sigmoid_on_den);
    sigmoid_off = 1.-1./(sigmoid_off_den);

}
// convolute with sigmoid / logistic to have smooth turn-on from 3-5keV
// throw random number ... if it is smaller than the value of the sigmoid; accept
//double e = br(gen);
//if(e<sigmoid_on->Eval(value) && e<sigmoid_off->Eval(value)) {
  //  spectrum->Fill(value); // do not expect any influence on Char X-ray peaks since we are far from turn-on of sigmoid (100% eff).
//}
//////////////////////////
fParticleGun->SetParticleEnergy(value*keV);
```

photon conversion probability

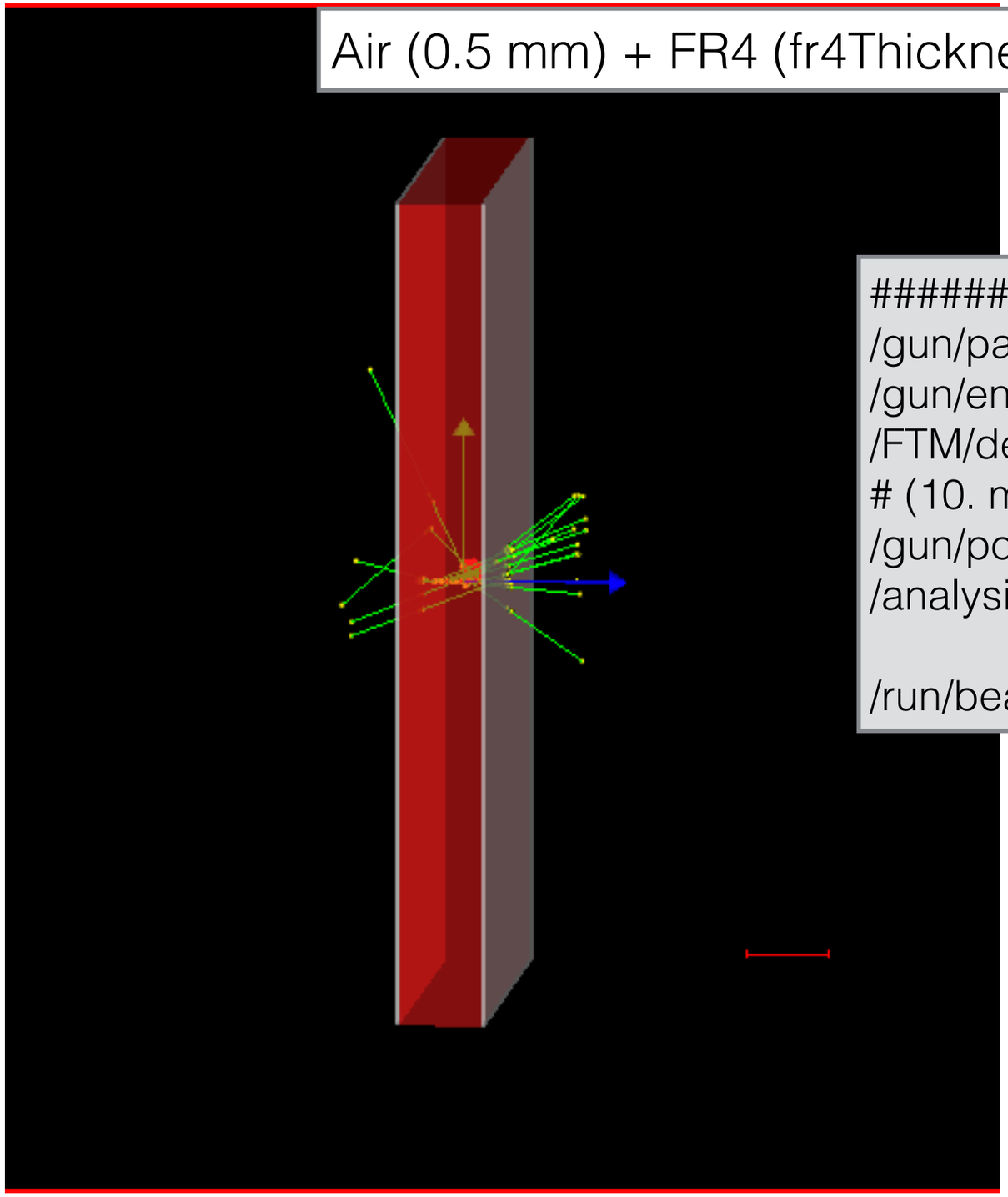
23KeV and 8 KeV gamma interaction in FR4 and Cu



PET-gamma conversion probability

1000 gamma in 10mm of FR4

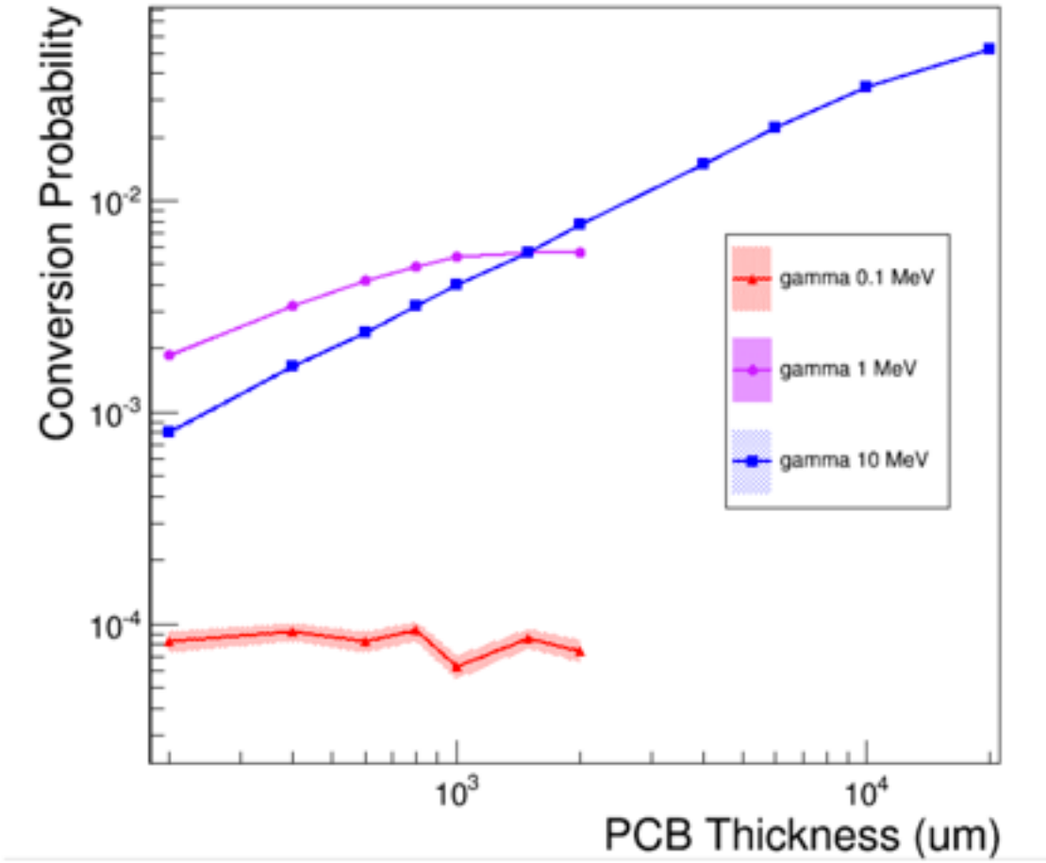
Air (0.5 mm) + FR4 (fr4Thickness) + Air (0.5 mm)

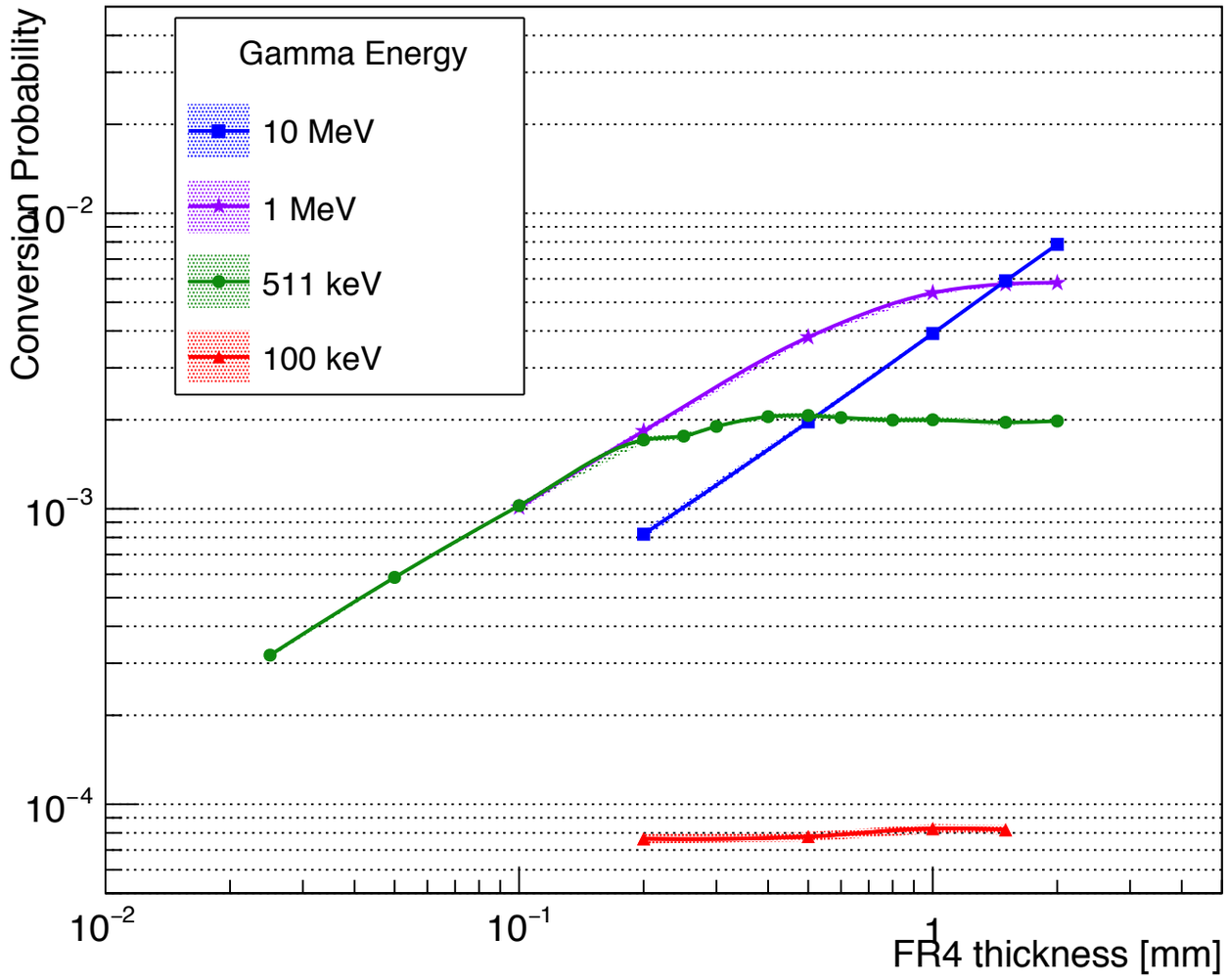


```
########### 10. mm FR4
/gun/particle gamma
/gun/energy 511 keV
/FTM/detector/fr4Thickness 10. mm
# (10. mm + 1mm)/2 = 5.5 mm (initial position of my gun)
/gun/position 0. 0. -5.5 mm
/analysis/setFileName FTM_511keV_fr4_10000um

/run/beamOn 1000
```

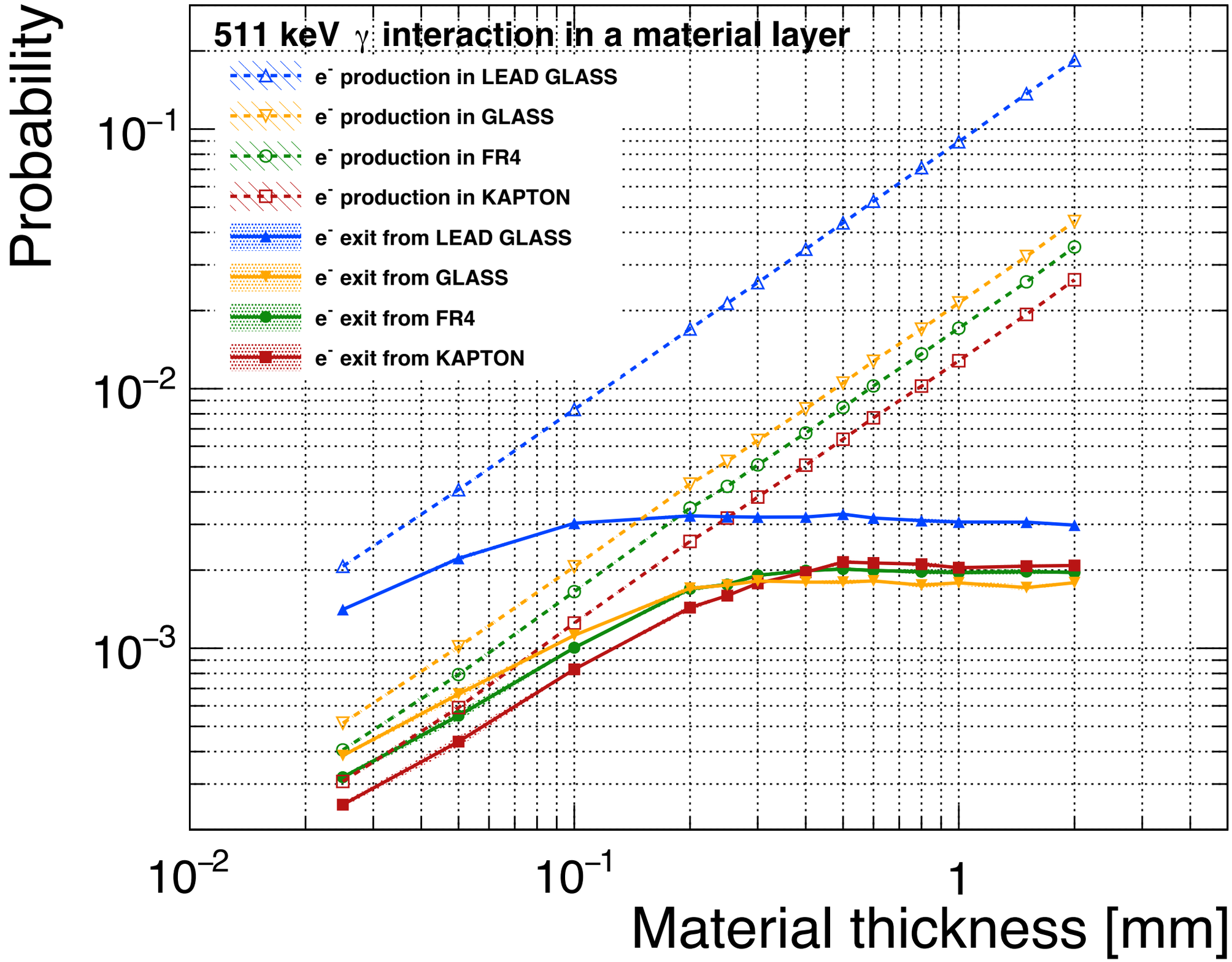
Code Validation

Alice

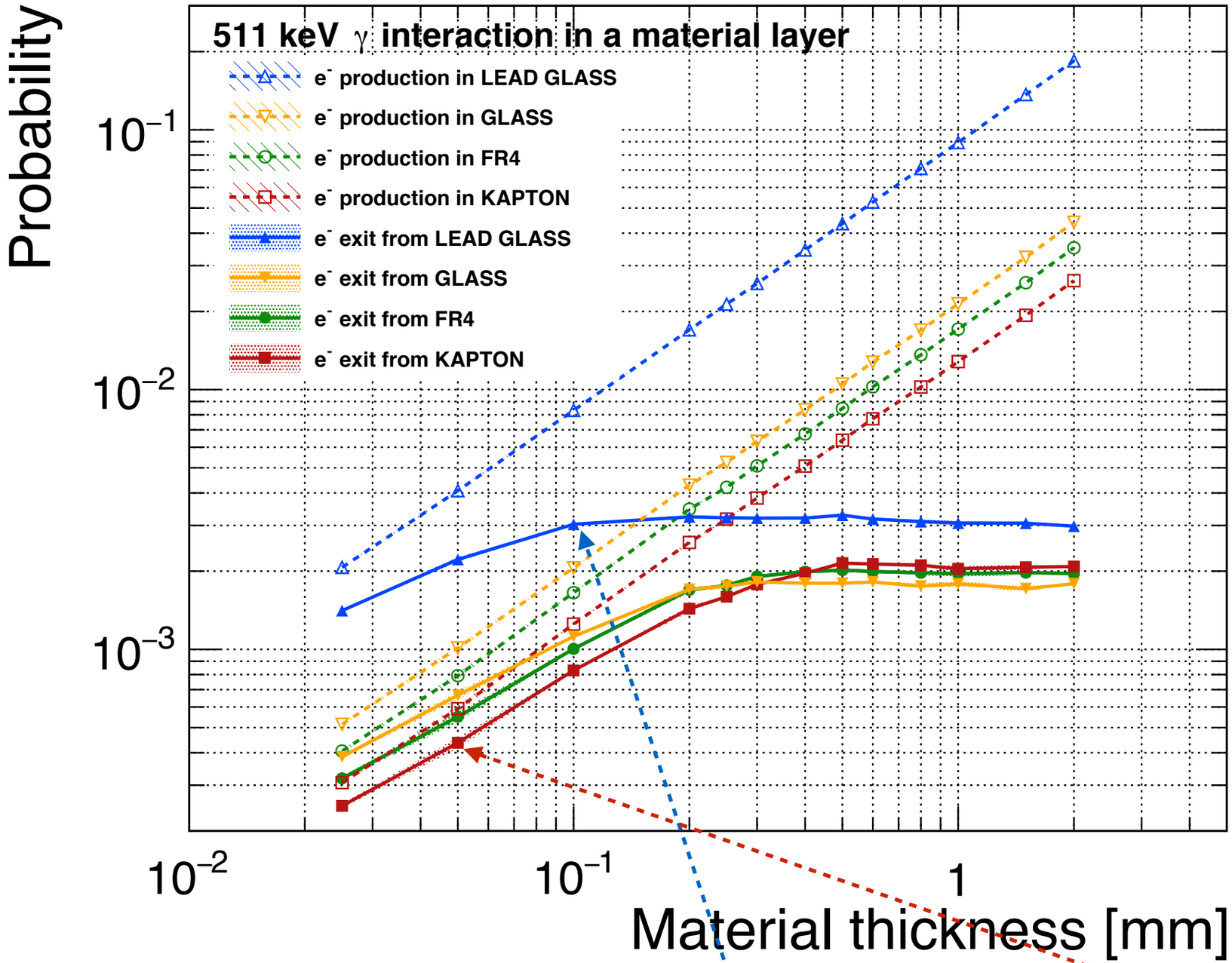


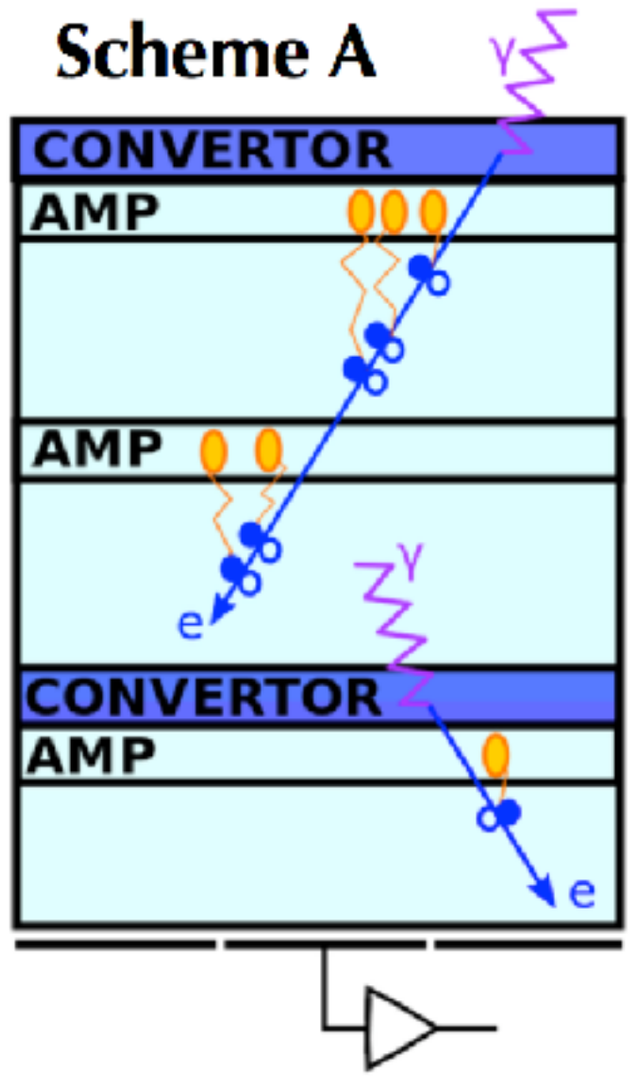


Electron production and exit prob.



Scheme A

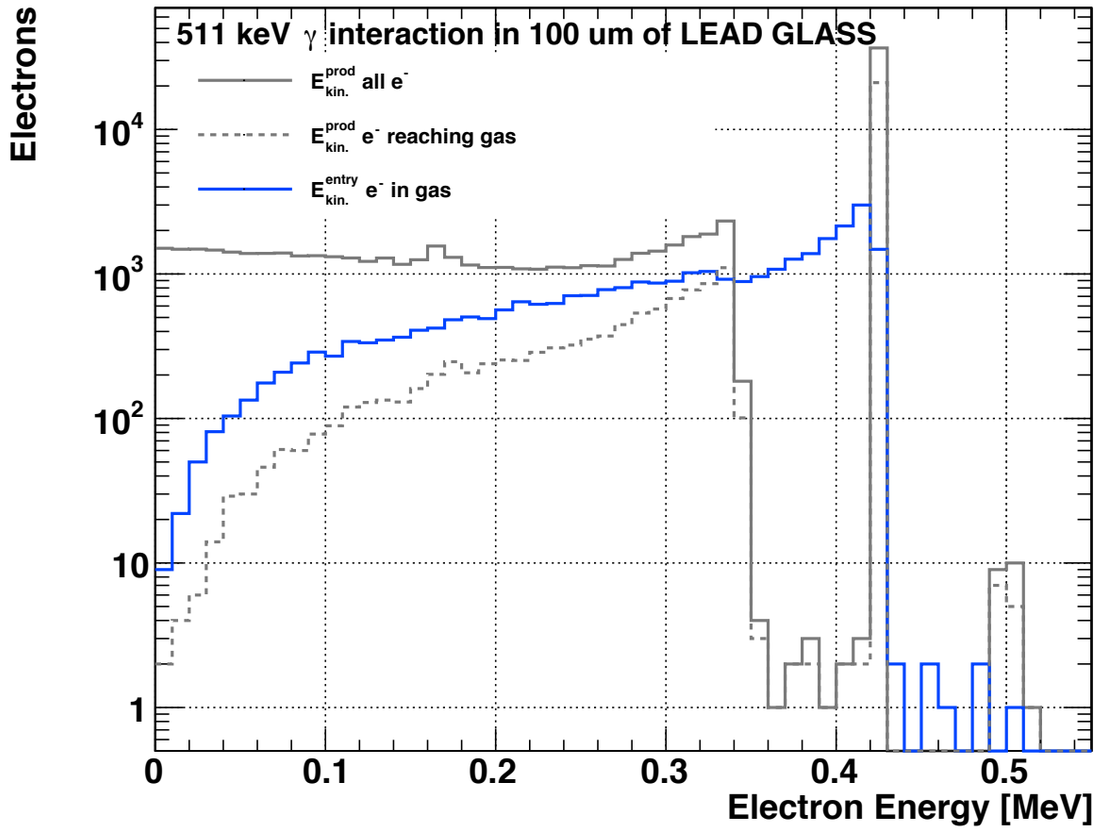


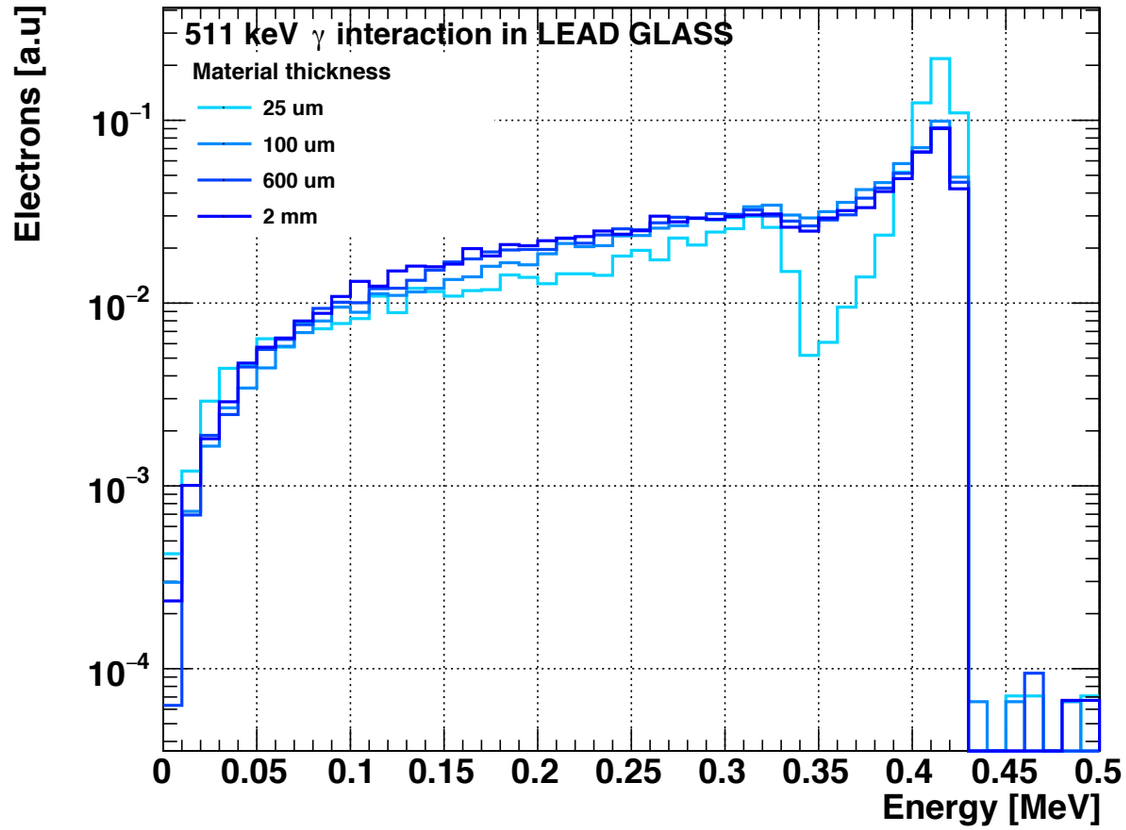


photon converted in **high-Z material** + several **thin amplification layers**

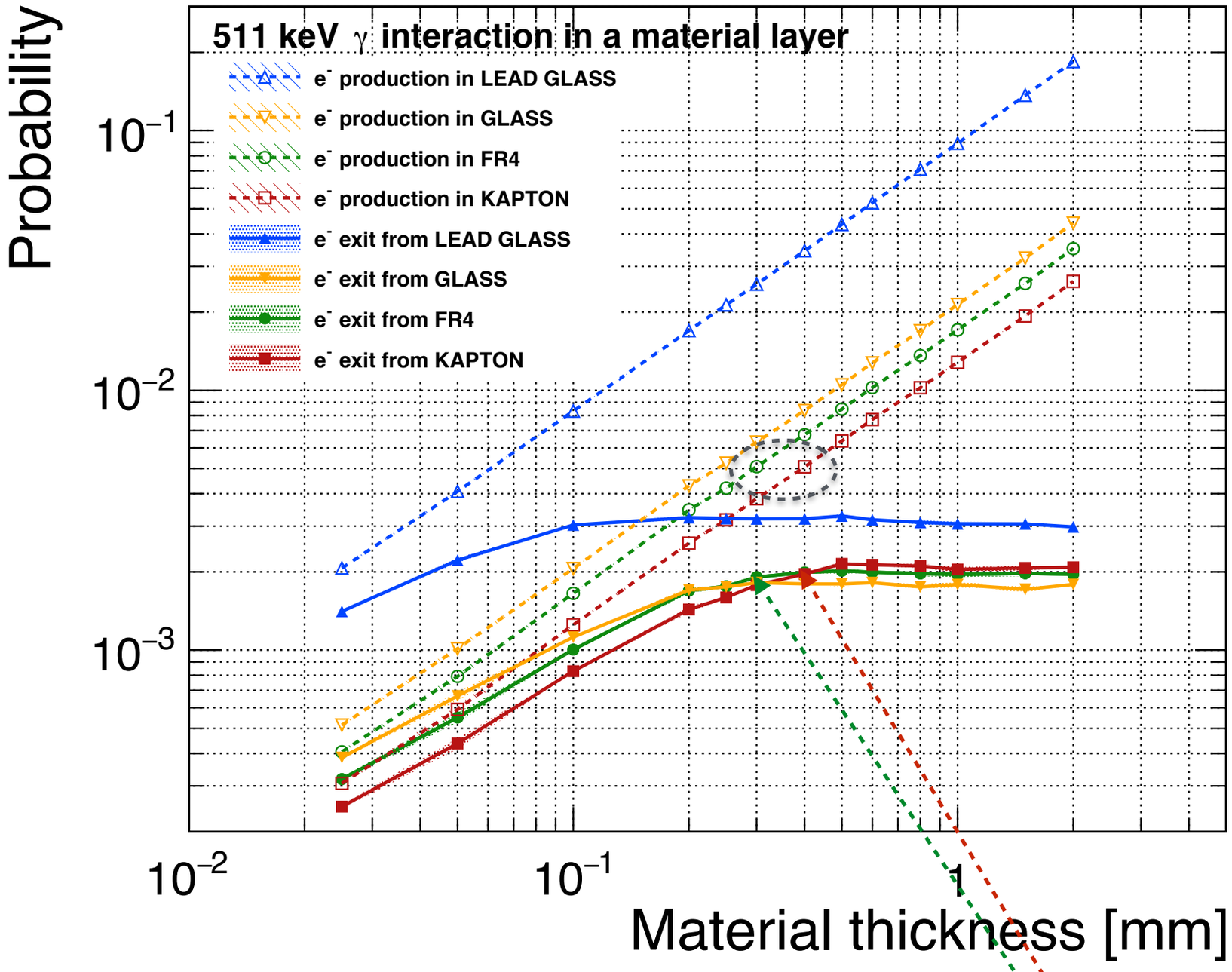
Scheme A: **100 um Lead glass** + **50 um Kapton**

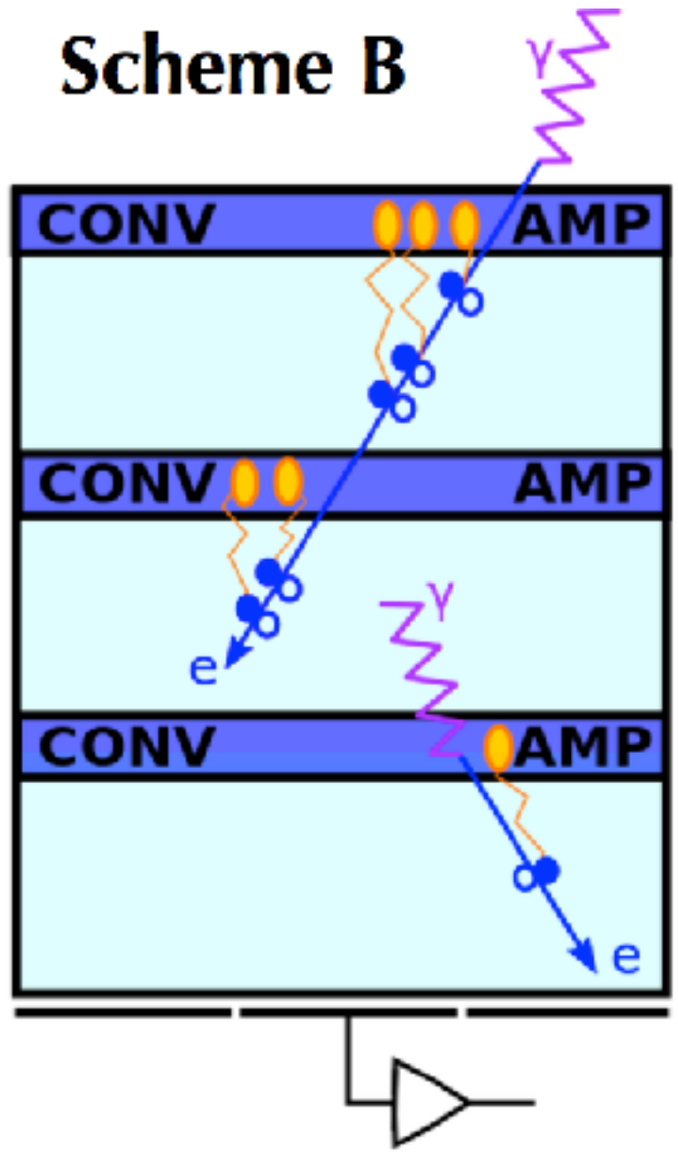
Scheme A: 100 um Lead glass + 50 um Kapton





Scheme B

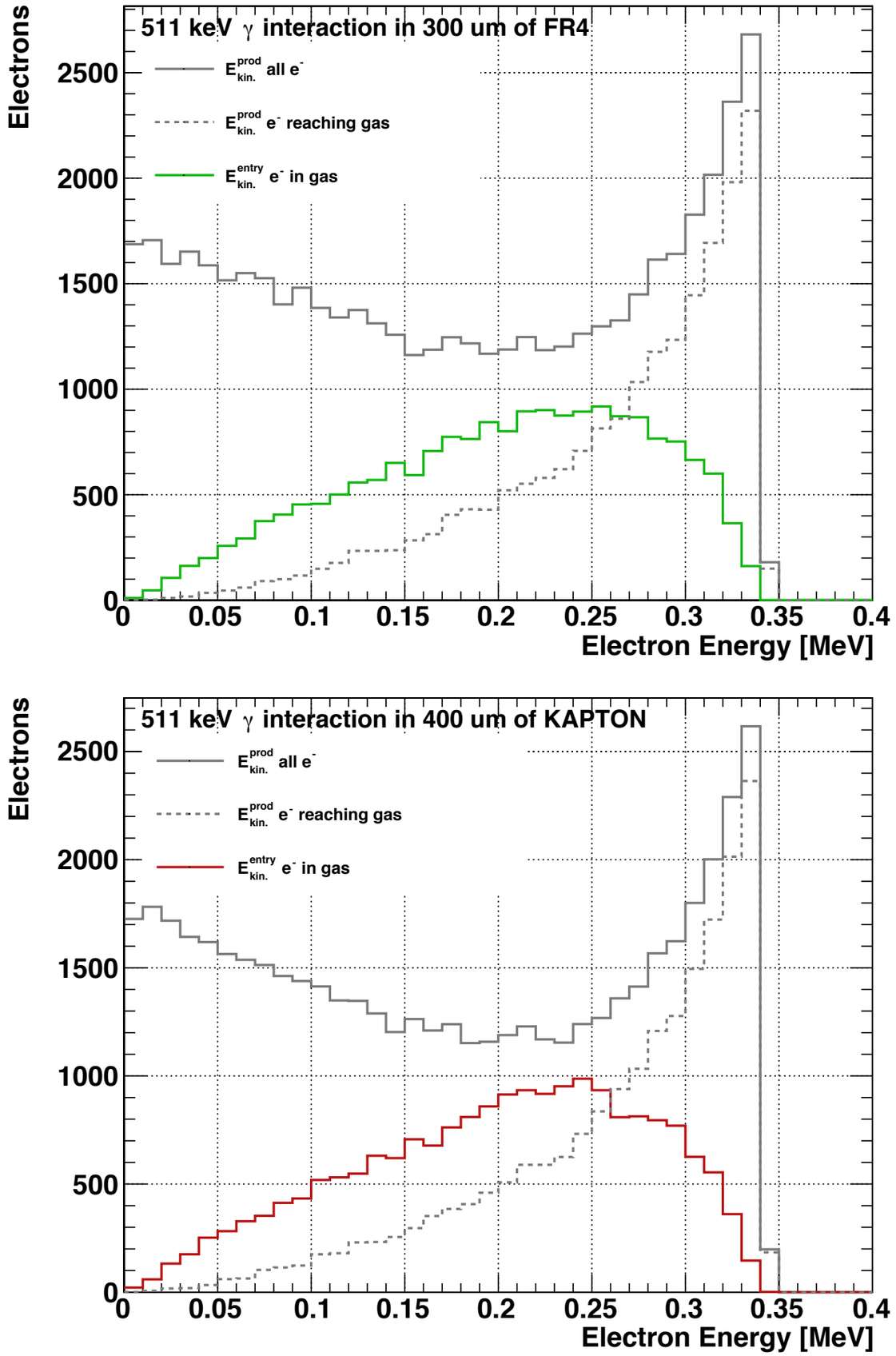


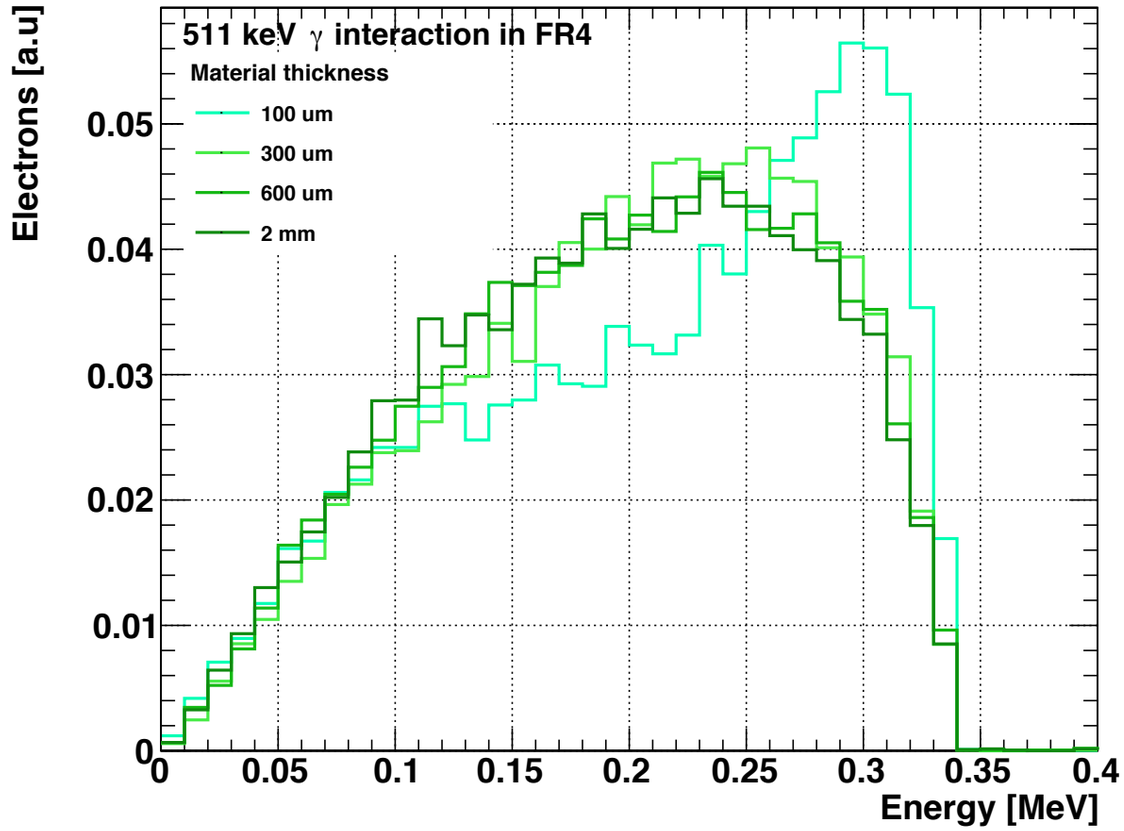


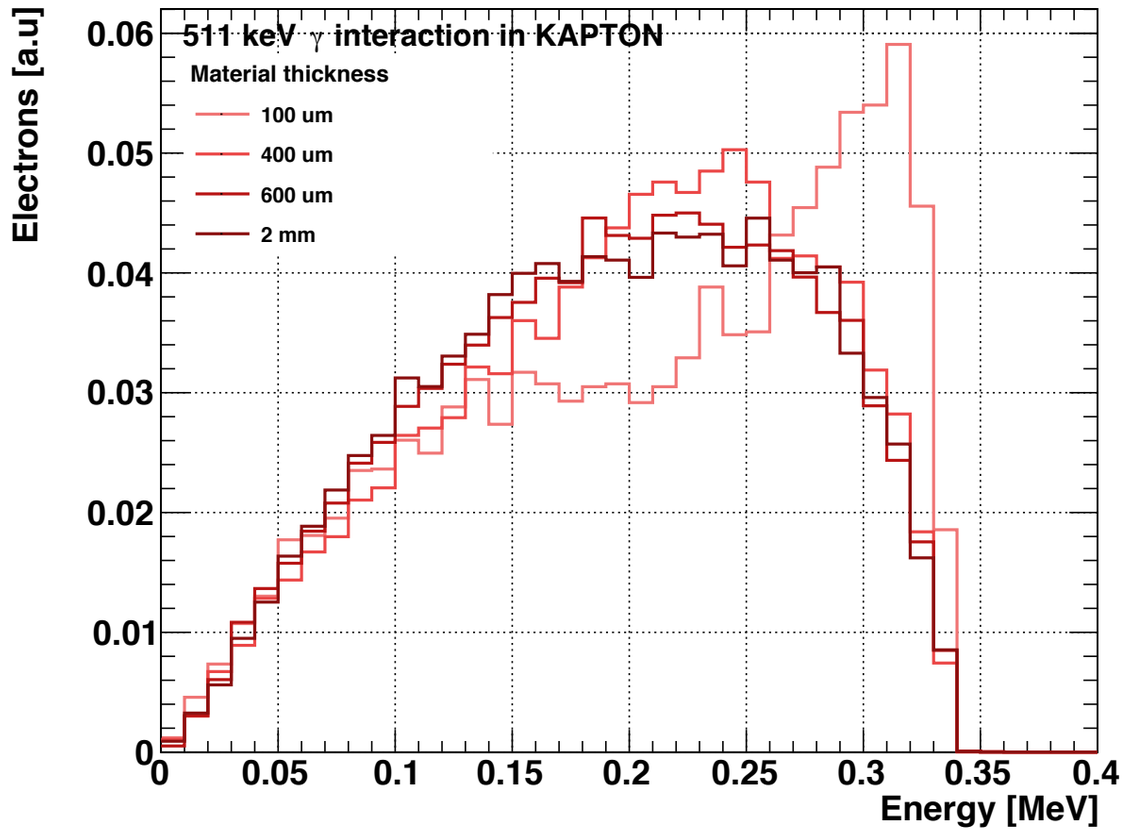
photon convert in each **amplification layer**

Scheme B: amplification layer made of **300 um of FR4** **or** **400 um of Kapton**

Scheme B: 300um of FR4 or 400um of Kapton







To Do

- study the ionization in gas in the drift region
- cluster distribution using GEANT (to compare with Garfield)
- distance from amp. layer to estimate the time resolution
- range in drift region to estimate the energy resolution

Working on Geant/Garfield interface in my code (finally!)
Following this instuctions:
- https://garfieldpp.web.cern.ch/garfieldpp/examples/geant4-interface/
- https://indico.cern.ch/event/702782/contributions/2901395/attachments/1604015/2544118/Pfeiffer_Geant4_Garfield_RD51_2018.pdf