FORWARD PHOTONS

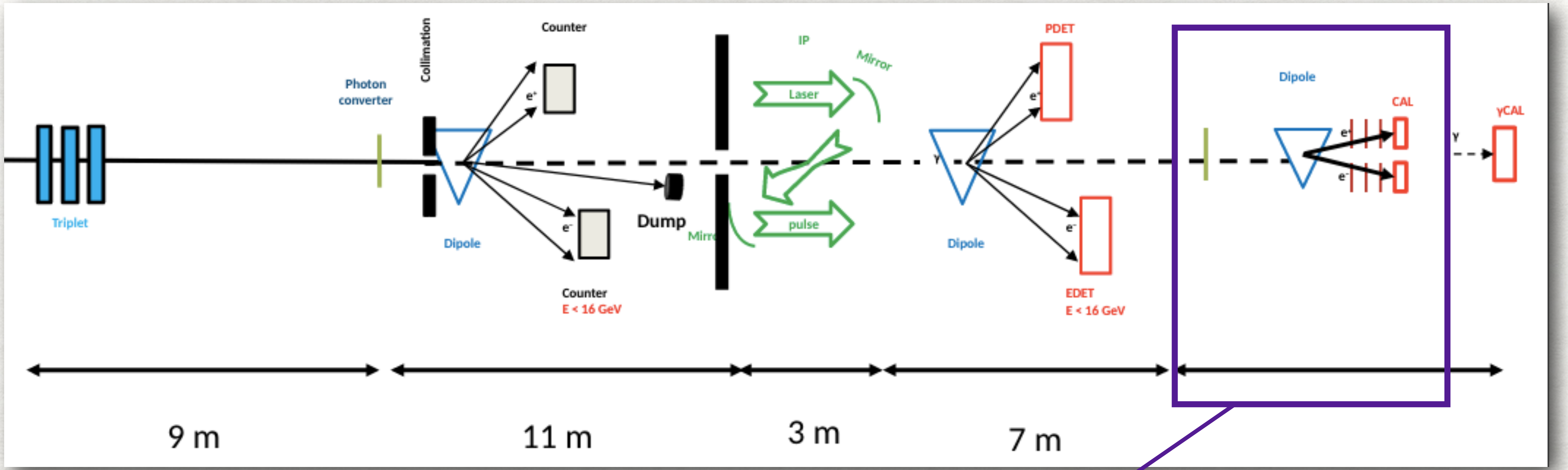
Borysova Maryna (KINR)

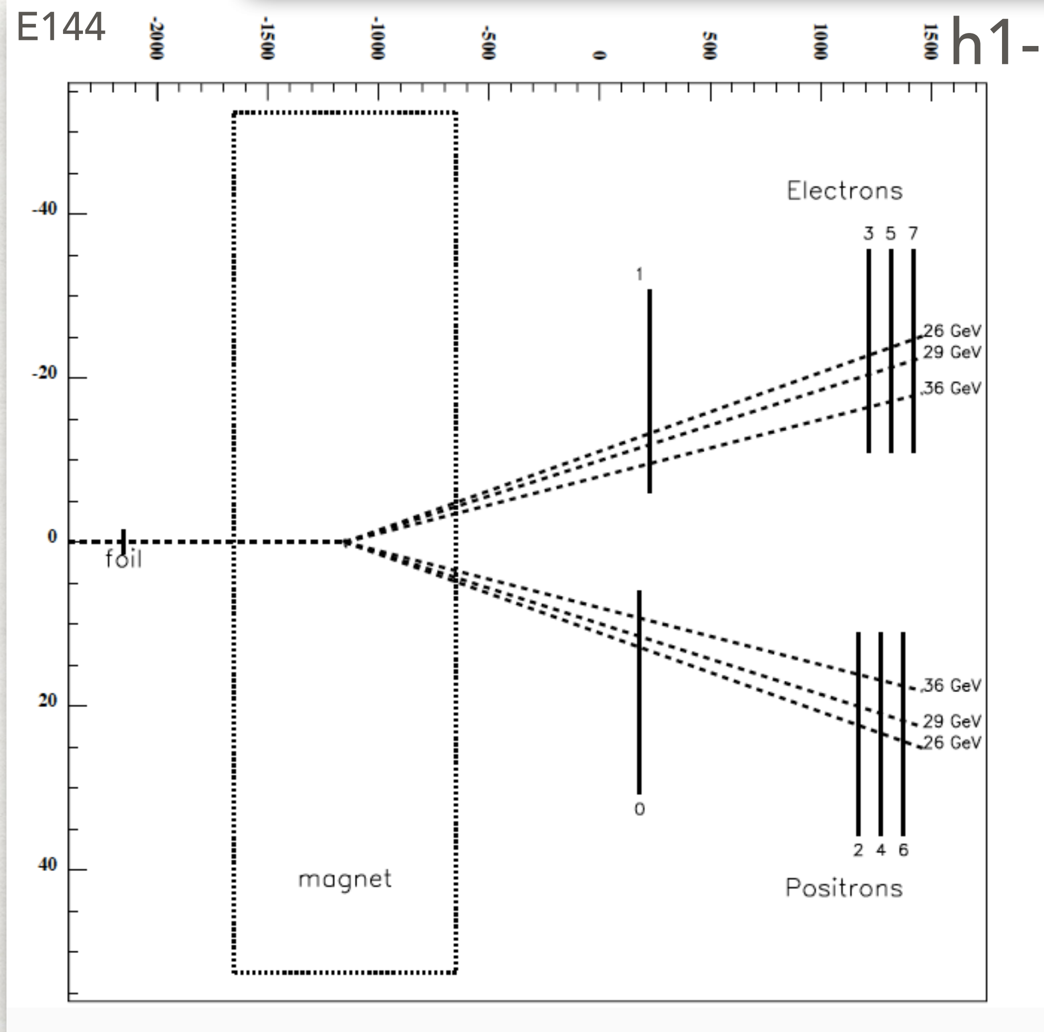
18/03/19

LUXE weekly meeting

LAYOUT FOR FDS OF THE LUXE EXPERIMENT

Photons produced at IP1 proceed down their own beamline through the converter foil and the tracking spectrometer





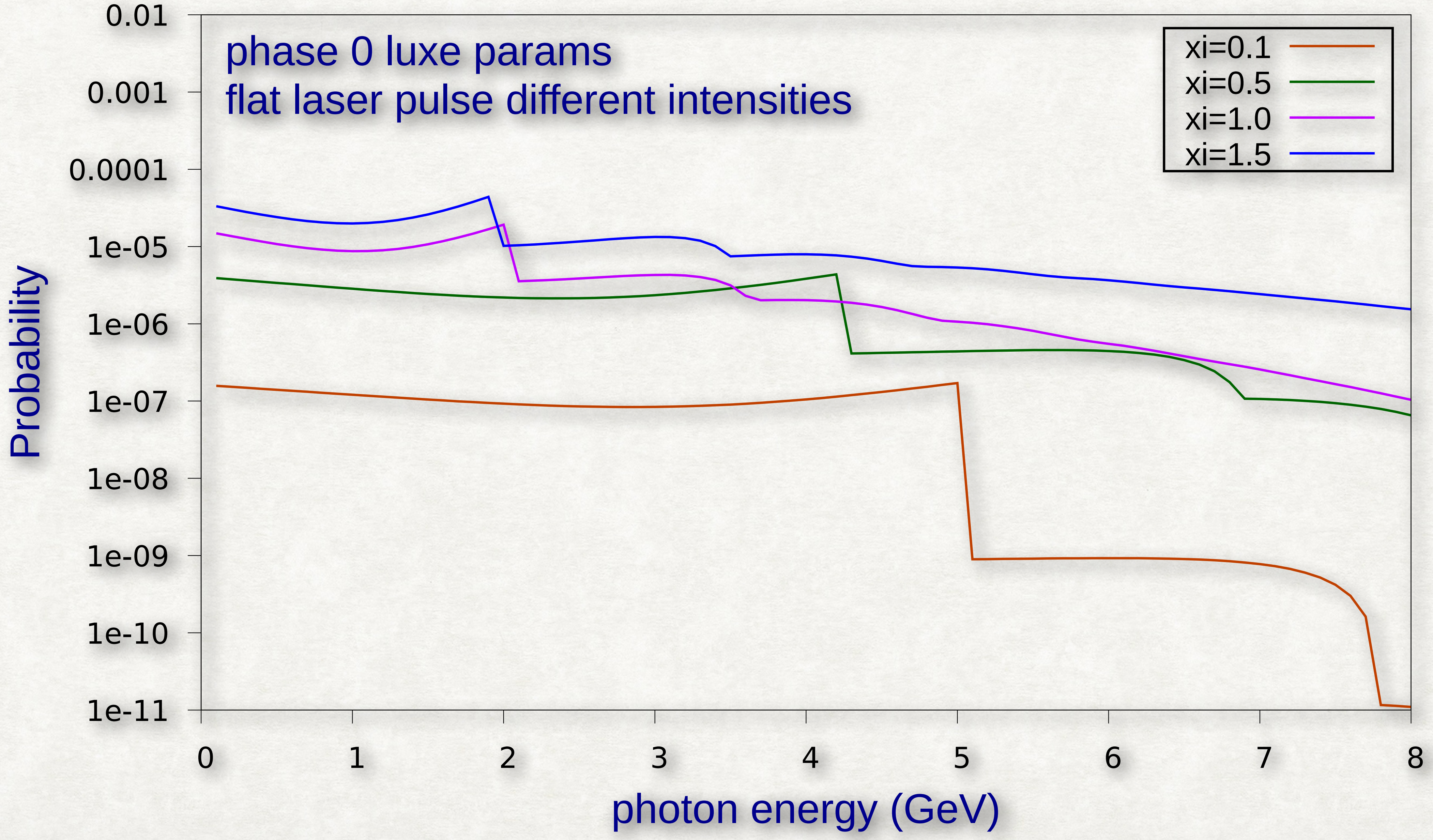
h1->Fit(gsfit, "wR");

$$
\begin{aligned}
e + n\omega &\rightarrow e + \gamma \\
\gamma + n\omega &\rightarrow e^+ + e^-.
\end{aligned}
$$

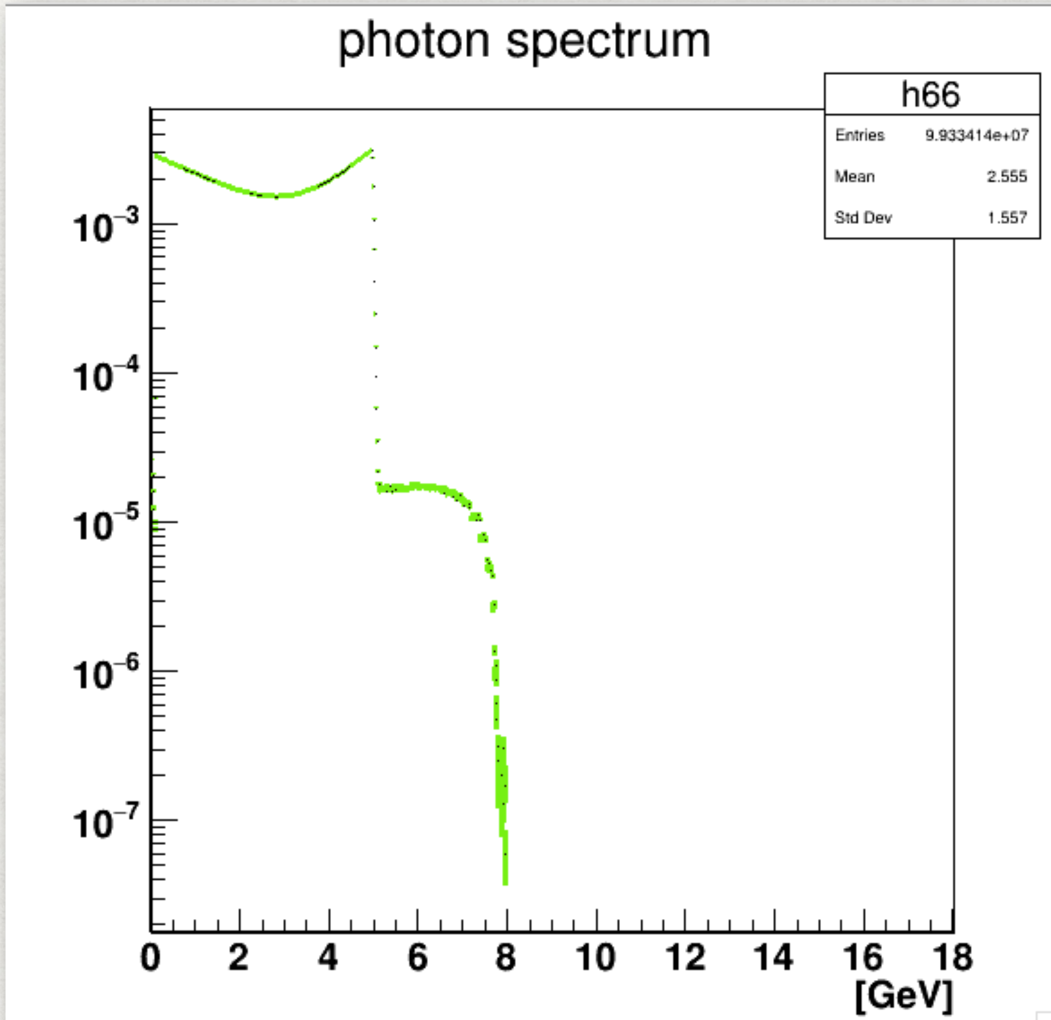
- The data from the two arms of the spectrometer are analyzed independently
- The reconstructed single-particle momentum spectra is compared to a **model spectrum** calculated by convolving the **simulated photon spectrum** with the **Bethe-Heitler pair spectrum**

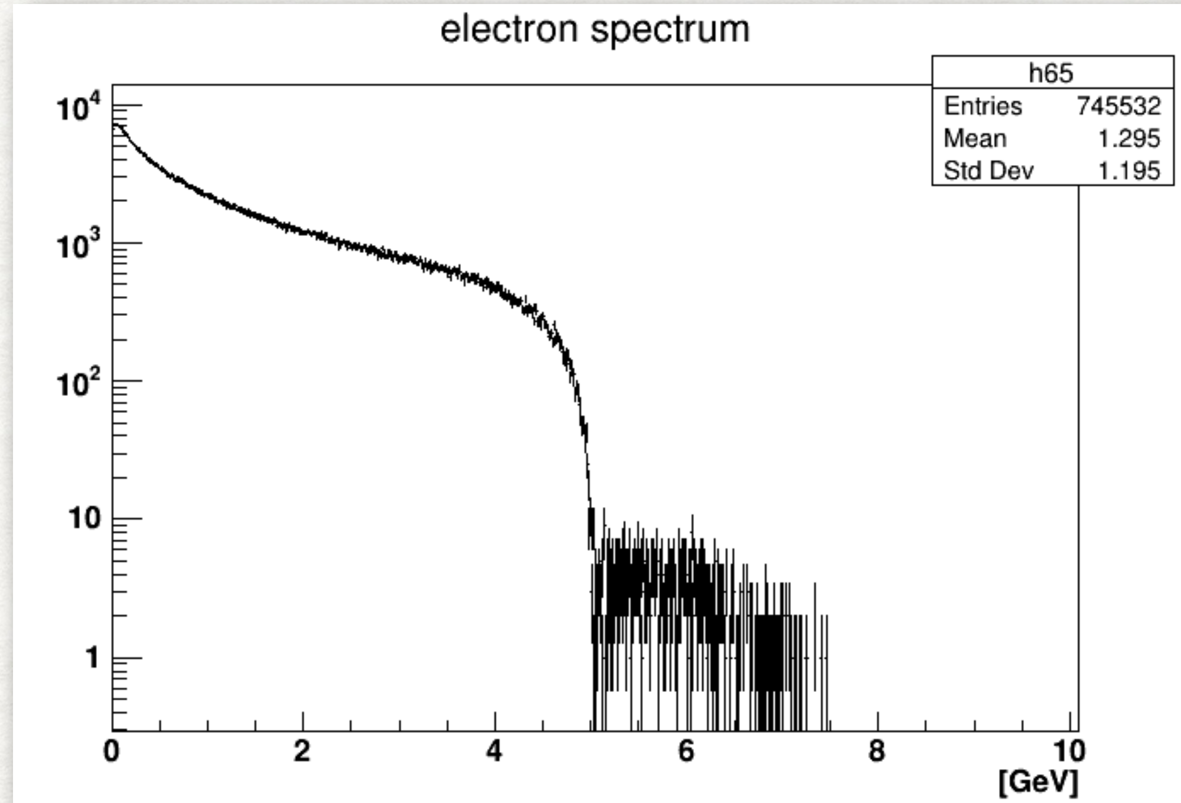
PHOTON SPECTRA VS LASER INTENSITIES

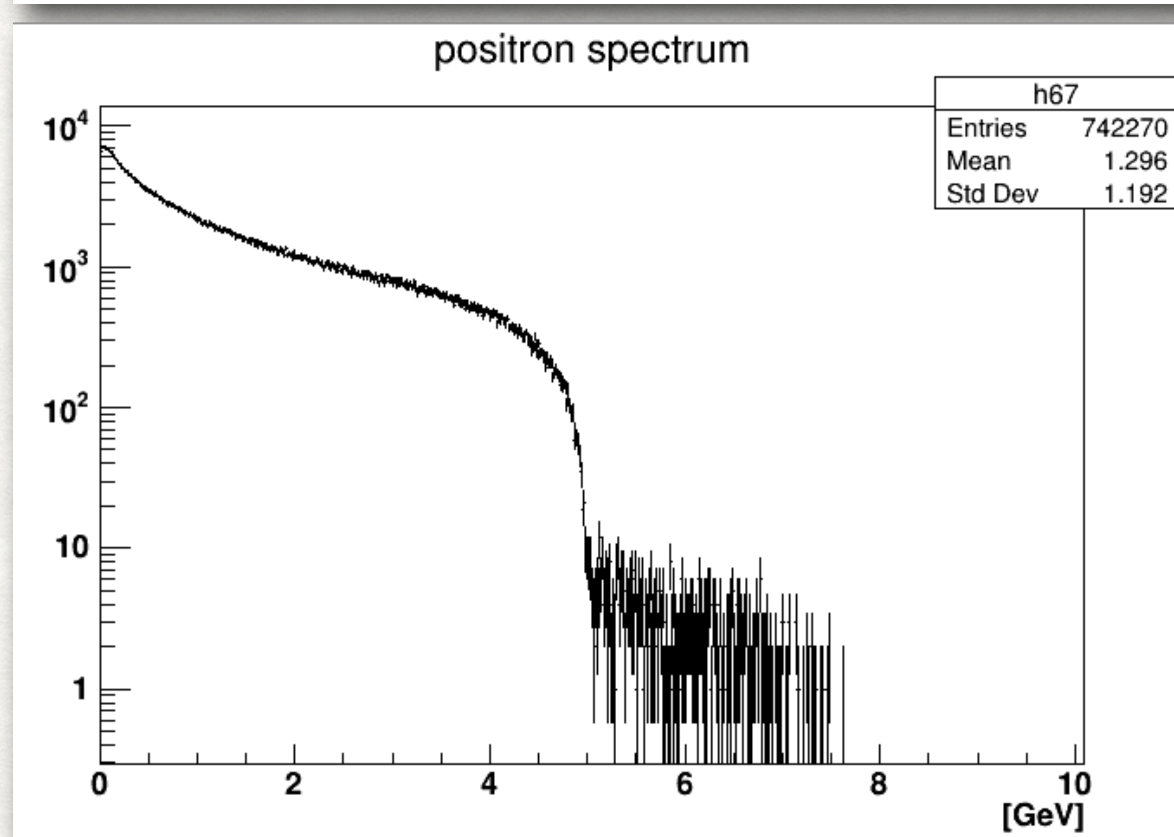
- plot from Anthony



FORWARD PHOTONS IN GEANT4

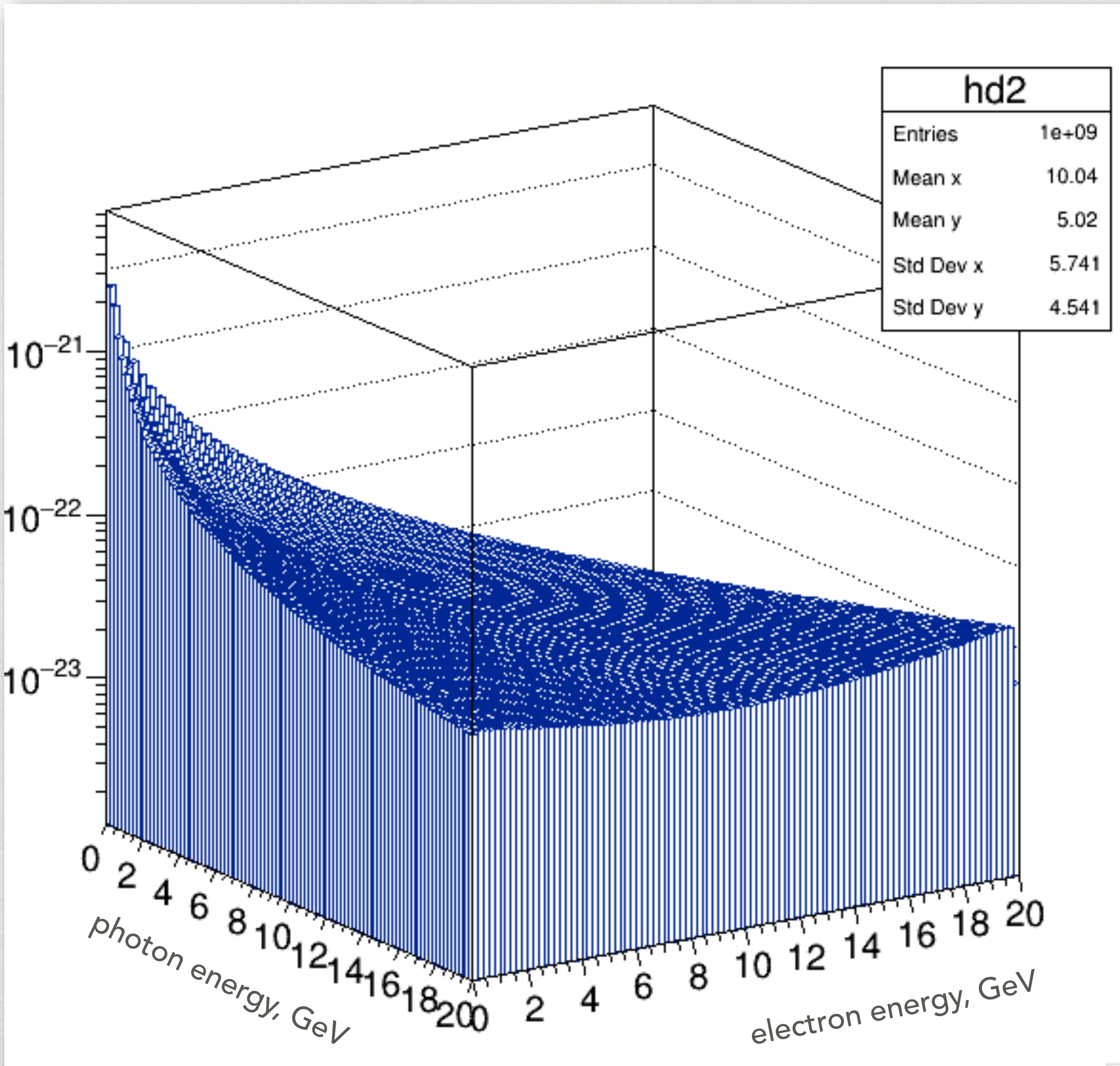






target: Tungsten, 0.35 um
1e8 photons

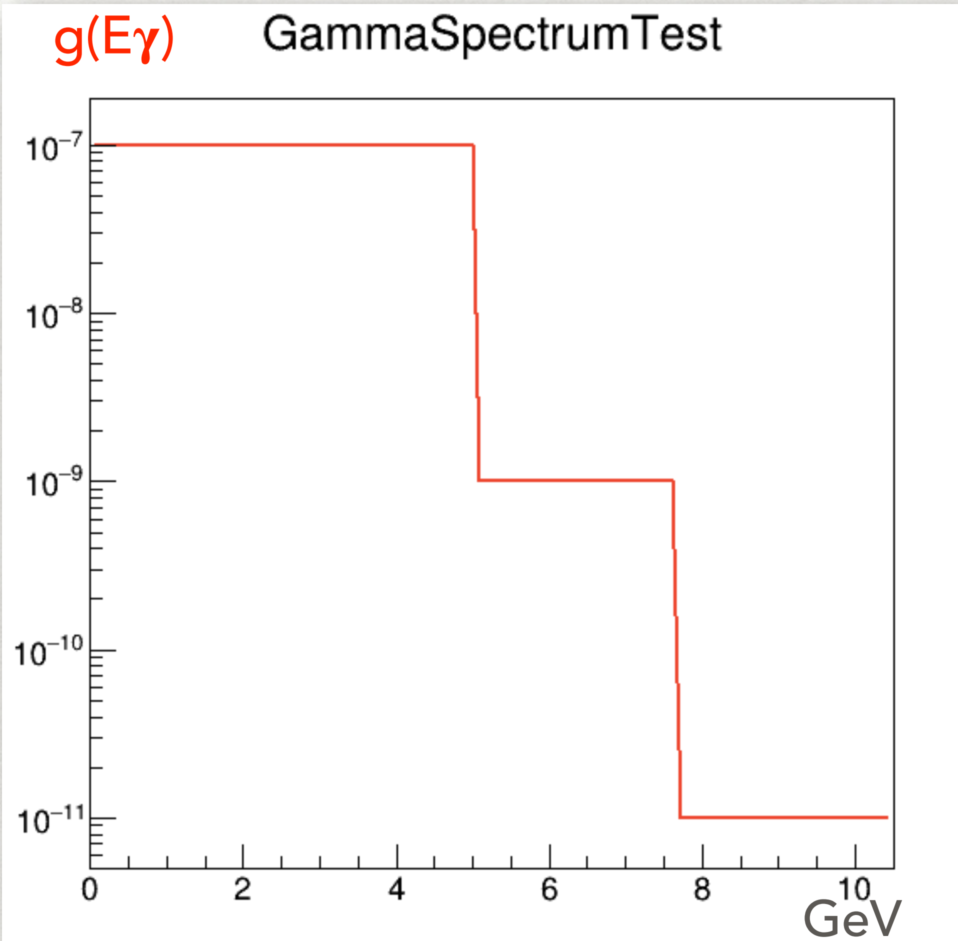
DIFFERENTIAL CROSS-SECTION FROM GEANT4

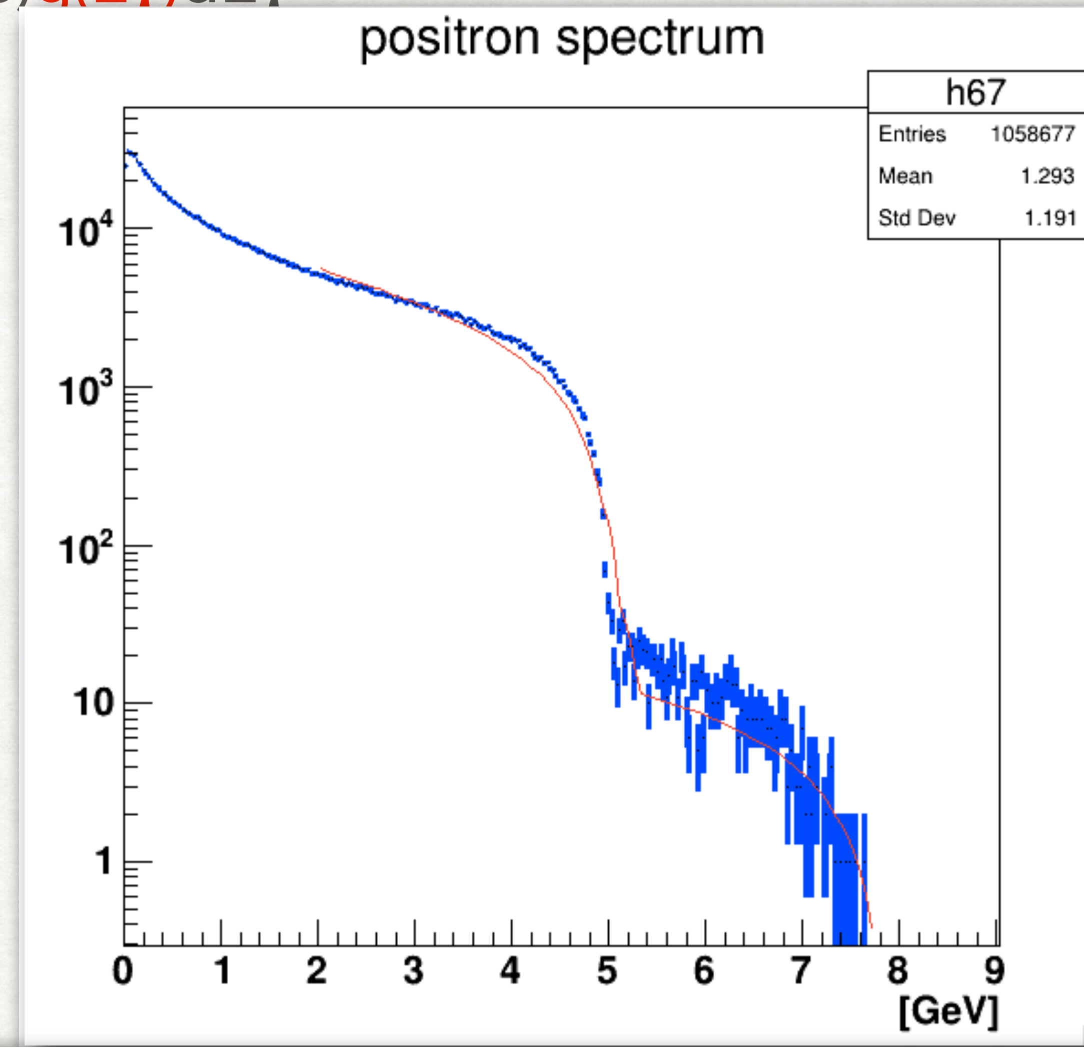


TESTING: COMPTON-LIKE

$$Ee=\int \sigma(E\gamma, Ee)g(E\gamma)dE\gamma$$

target material (W), its thickness 50 um





$$\int \sigma(E\gamma, Ee)g(E\gamma,p1,p2)dE\gamma$$

```
FCN=3847.23 FROM MIGRAD    STATUS=FAILED       586 CALLS         587 TOTAL
                     EDM=0.00146922    STRATEGY= 1  ERROR MATRIX UNCERTAINTY   1.3 per cent
 EXT PARAMETER                APPROXIMATE        STEP         FIRST
 NO.   NAME      VALUE            ERROR          SIZE      DERIVATIVE
  1  p0        0.00000e+00     fixed
  2  p1        2.83448e+06   5.52378e+03  -0.00000e+00   7.82770e-07
  3  p2        5.03009e+00   2.31482e+00   0.00000e+00  -1.91210e+03
  4  p3        0.00000e+00     fixed
  5  p4        1.28127e+04   5.88782e+02   0.00000e+00  -7.97467e-06
  6  p5        7.77573e+00   1.76479e+00  -0.00000e+00   3.62273e+02
  7  p6        1.00000e+00     fixed
FCN=3847.23 FROM MIGRAD    STATUS=CONVERGED     20 CALLS          21 TOTAL
                     EDM=2.48743e-09    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                                   STEP         FIRST
 NO.   NAME      VALUE            ERROR          SIZE      DERIVATIVE
  1  p0        0.00000e+00     fixed
  2  p1        2.83446e+06   5.64367e+03   1.21997e+02   9.80448e-09
  3  p2        5.03009e+00     fixed
  4  p3        0.00000e+00     fixed
  5  p4        1.28143e+04   6.03570e+02   1.80570e+01   8.41417e-08
  6  p5        7.77573e+00     fixed
  7  p6        1.00000e+00     fixed
```

WHAT'S DONE & WHAT'S NEXT

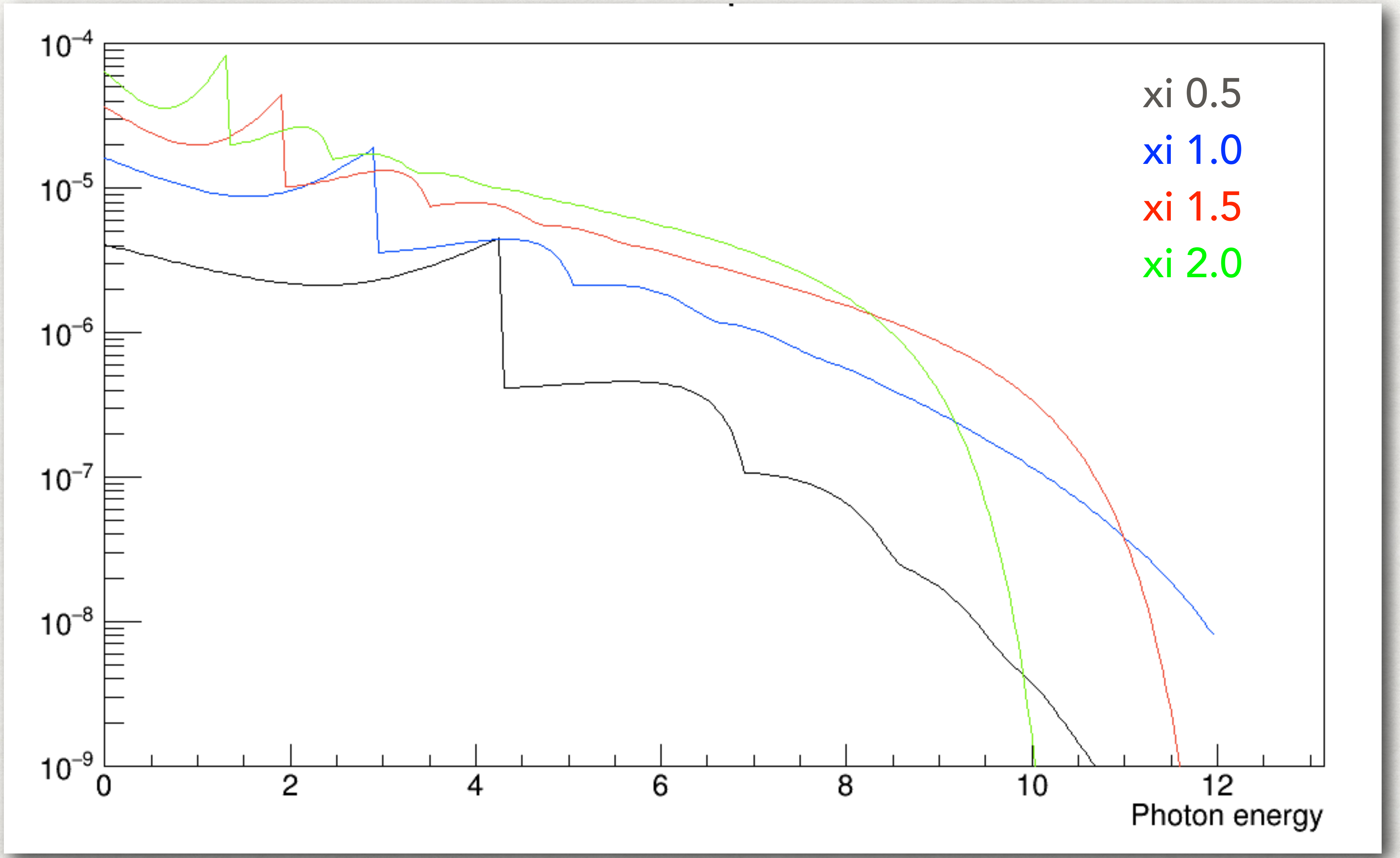
- implemented the use of Bethe-Heitler class from Geant4 for differential cross-section calculations, with corrections and extended for various effects (the screening, the pair creation in the field of atomic electrons, correction to the Born approximation, the LPM suppression mechanism, etc.)
- test if we could fit and find other parameters describing the process: target material (Z).
- to implement the use of string as a target instead of foil

BACK UP

HICS DIFFERENTIAL TRANSITION PROBABILITY VS RADIATED PHOTON ENERGY

per initial particle per 100 fs 800 nm laser. 17.5 GeV initial electrons, 0.9*Pi crossing angle

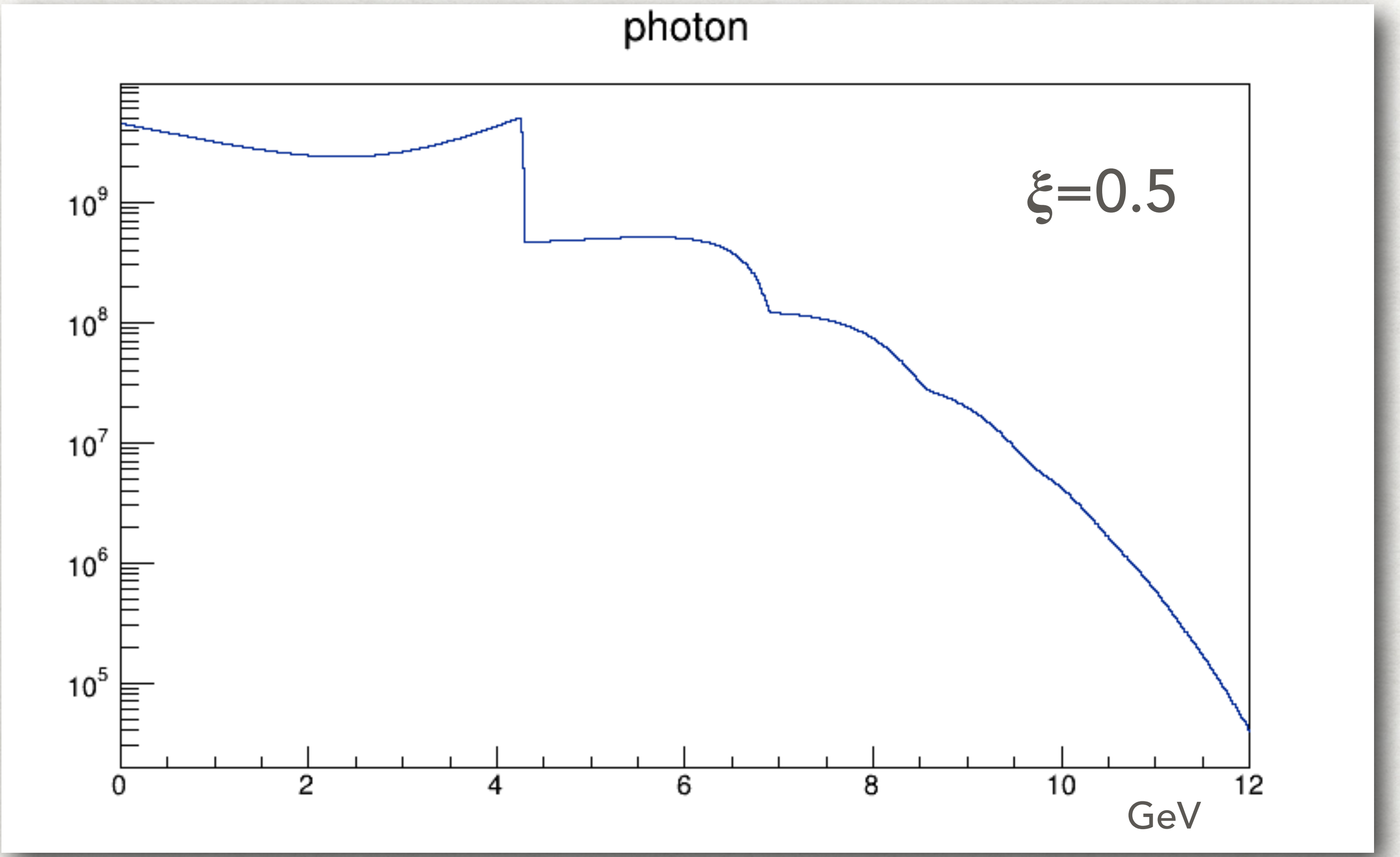
data produced of HICS/IPW/circularly polarized with Mathematica by Anthony Hartin 4/2/2019



ABSOLUTE NUMBER OF PHOTONS

multiply the rate by the mass of the electron in eV, by 510998, then we will get differential transition rate per electron per 100 fs.

multiply it by the number of electrons in the bunch (6.25e+09) and by the laser pulse duration (t=35 fs) (t/ 100fs)



Integral:1.49255e+10

The transverse structure of the laser field is not taken into account in the data (and xi is Gauss max) and it is assumed that the laser field is uniform in transverse direction and it is essentially the same for all electrons

ABSOLUTE NUMBER OF PHOTONS

multiply the rate by the mass of the electron in eV, by 510998, then we will get differential transition rate per electron per 100 fs.

multiply it by the number of electrons in the bunch (6.25e+09) and by the laser pulse duration (t=35 fs) (t/ 100fs)

ξ	1e 100 fs	1e 35 fs (1BX)	N_γ
0.5	6.82	2.39	1.49255E+10
1	24.08	8.43	5.26758E+10
1.5	46.55	16.29	1.01825E+11
2	69.75	24.41	1.52579E+11

The transverse structure of the laser field is not taken into account in the data (and xi is Gauss max) and it is assumed that the laser field is uniform in transverse direction and it is essentially the same for all electrons

ABSOLUTE NUMBER OF PHOTONS W/ ENERGY CUT

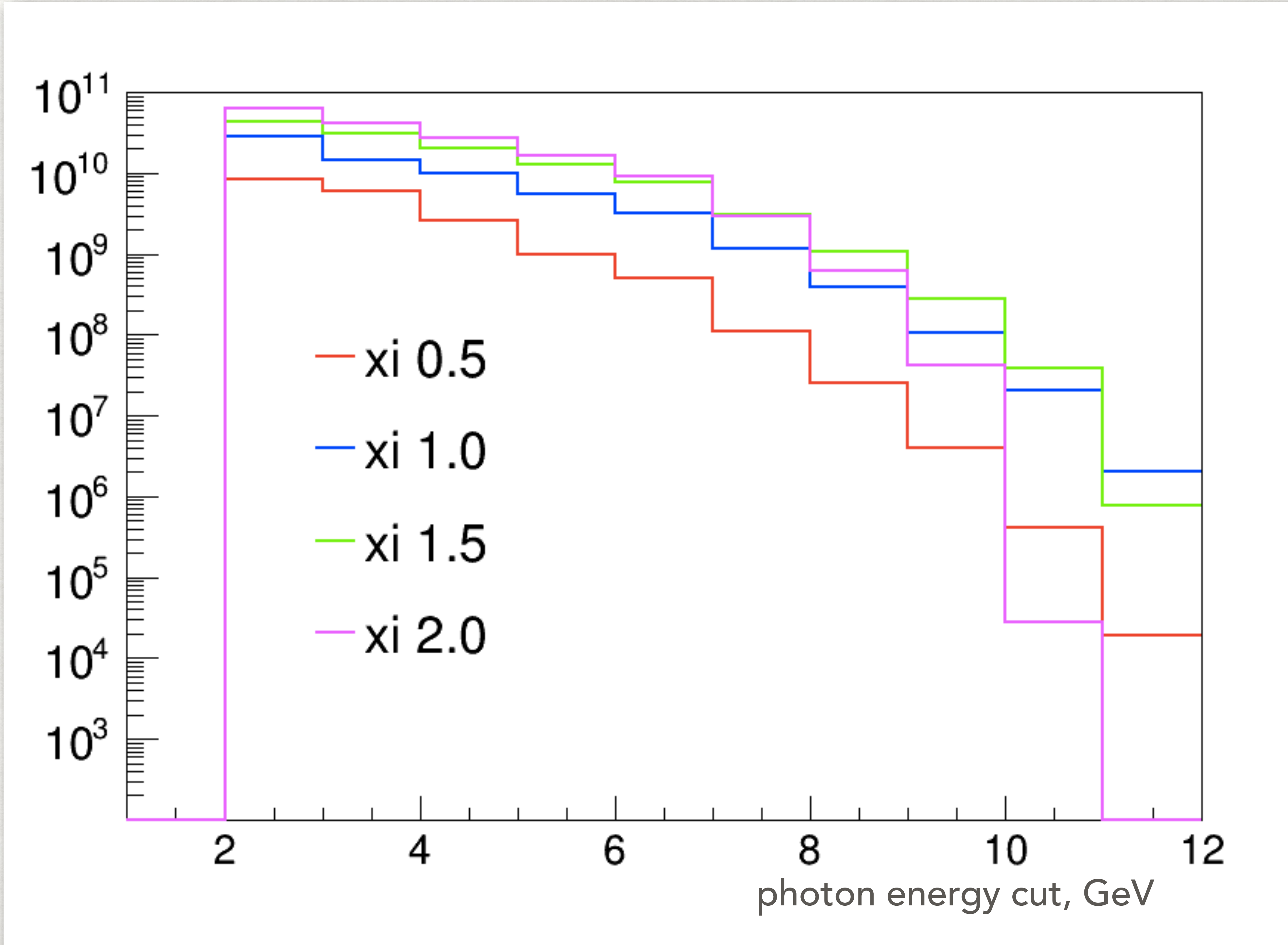
multiply the rate by the mass of the electron in eV, by 510998, then we will get differential transition rate per electron per 100 fs.

multiply it by the number of electrons in the bunch (6.25e+09) and by the laser pulse duration (t=35 fs) (t/ 100fs)

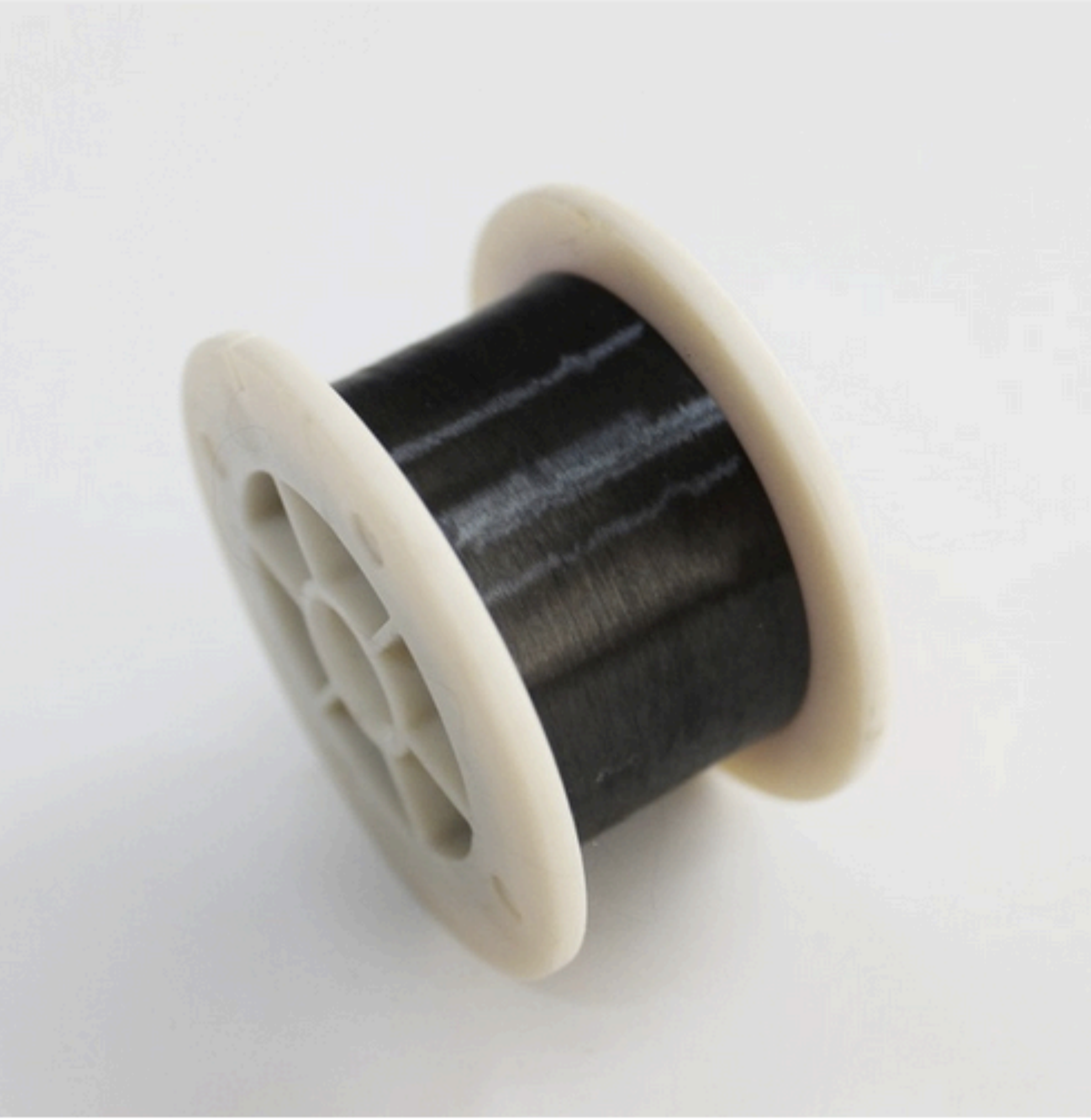
ξ	Nγ	Nγ, Eγ>6.0 Gev	Nγ, Eγ>4.0 Gev	Nγ, Eγ>3.0 Gev	Nγ, Eγ>2.0 Gev
0.5	1.49255E+10	4.94882E+08			
1	5.26758E+10	3.16064E+09	1.00437E+10		
1.5	1.01825E+11	7.71401E+09		3.09275E+10	
2	1.52579E+11	9.25216E+09			6.44808E+10

The transverse structure of the laser field is not taken into account in the data (and xi is Gauss max) and it is assumed that the laser field is uniform in transverse direction and it is essentially the same for all electrons

NUMBER OF PHOTONS W/ ENERGY CUT



TUNGSTEN WIRE AS A TARGET



Mouse over to zoom in

Tungsten wolfram fine wire 0.01mm 0.02mm 0.03mm 0.04mm 0.05mm 0.1mm 0.15mm 0.2mm 0.3mm 0.4mm 0.5mm 1mm for scopes and transits

★★★★★ 5.0 (4 votes) | 9 orders

Price: **US $69.99** / piece

Bulk Price

Diameter: 0.01mm X 10000m | 0.02mm X 2m | 0.03mm X 2m | 0.04mm X 2m | 0.05mm X 2m | 0.1mm X 2m | 0.15mm X 2m | 0.2mm X 2m | 0.3mm X 2m | 0.4mm X 2m | 0.5mm X 2m | 1mm X 2m | 1.5mm X 2m

Shipping: **Free Shipping to Germany via AliExpress Standard Shipping**

Estimated Delivery Time: 23 days

Quantity: 1 piece (4997 pieces available)

Total Price: **US $69.99**

Buy Now | Add to Cart | 20

TOTAL X-SECTION

XCOM: Photon Cross Sections Database (The National Institute of Standards and Technology (NIST))

A web database which can be used to calculate photon cross sections for scattering, photoelectric absorption and pair production, as well as total attenuation coefficients, for any element, compound or mixture ($Z \leq 100$), at energies from 1 keV to 100 GeV.

G4BetheHeitlerModel from Geant4

total cross section per atom in Geant4

E_γ = incident gamma energy, and $X = \ln(E_\gamma / m_e c^2)$

The total cross-section has been parameterised as :

$$\sigma(Z, E_\gamma) = Z(Z+1)\left[F_1(X) + F_2(X)\,Z + \frac{F_3(X)}{Z}\right]$$

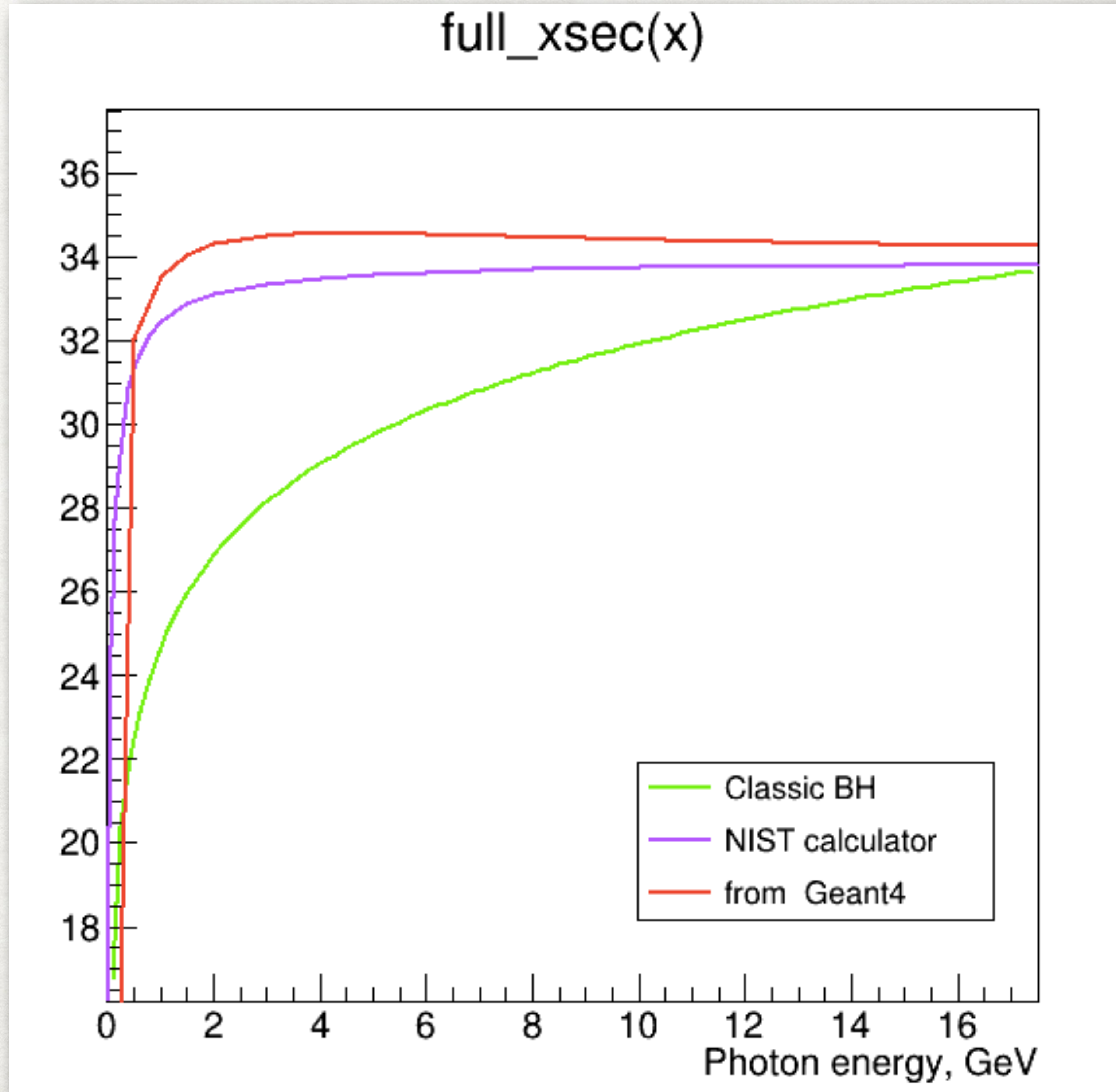
with :

$$\begin{aligned} F_1(X) &= a_0 + a_1 X + a_2 X^2 + a_3 X^3 + a_4 X^4 + a_5 X^5 \\ F_2(X) &= b_0 + b_1 X + b_2 X^2 + b_3 X^3 + b_4 X^4 + b_5 X^5 \\ F_3(X) &= c_0 + c_1 X + c_2 X^2 + c_3 X^3 + c_4 X^4 + c_5 X^5 \end{aligned}$$

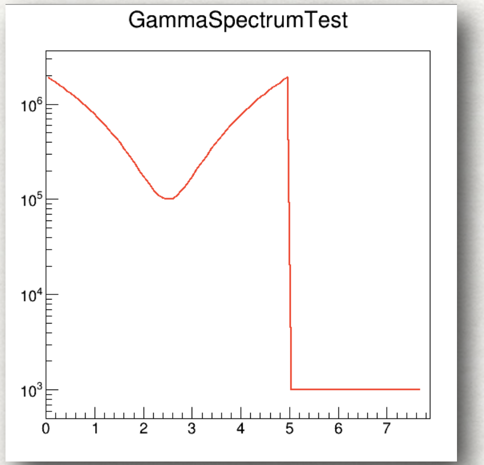
The parameters a_i, b_i, c_i were fitted to the data [hubb80].

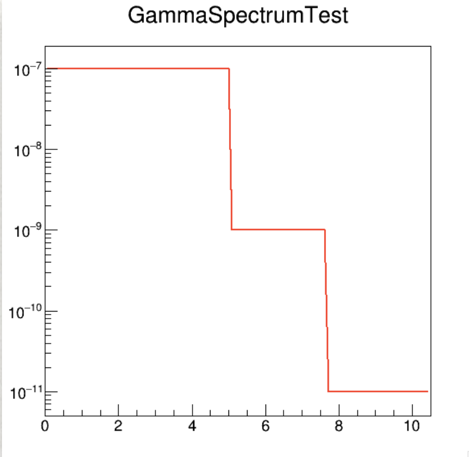
This parameterisation describes the data in the range :

$$\left.\begin{array}{c} 1 \leq Z \leq 100 \\ E_\gamma \in [1.5\ \text{MeV}, 100\ \text{GeV}] \end{array}\right\} \frac{\Delta\sigma}{\sigma} \leq 5\% \quad \text{with a mean value of} \approx 2.2\%$$



FITTED THICKNESS



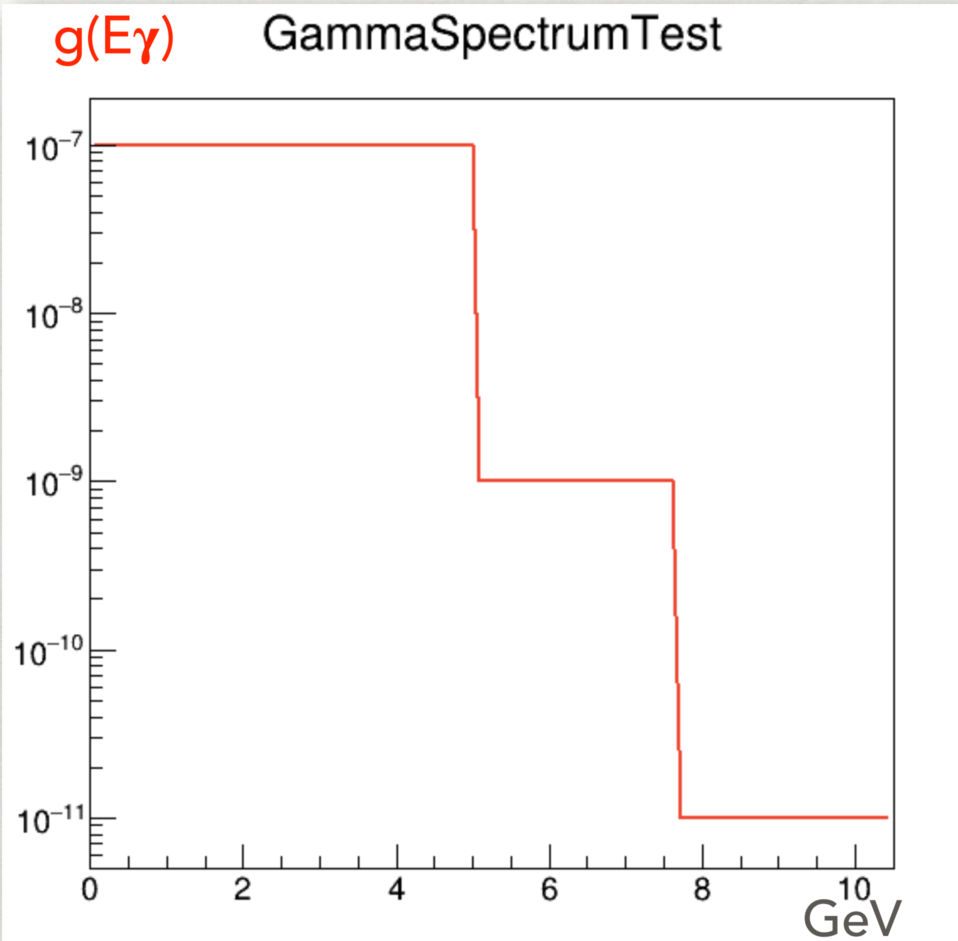


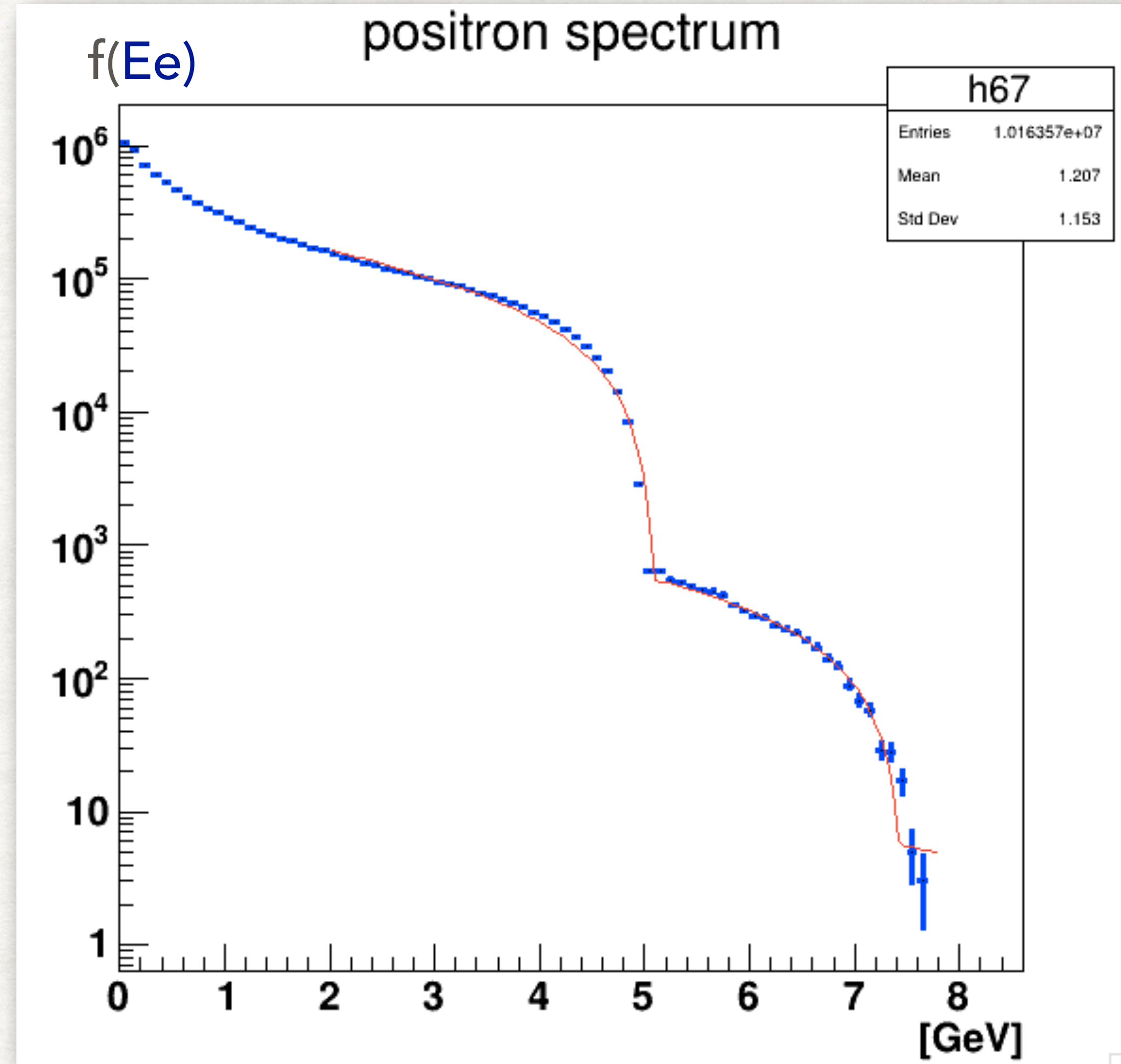
Thickness, cm	p[7] from the fit, cm	p[7] from the fit, cm
$3.5 * 10^{-3}$	$2.55 * 10^{-3}$	$3.2 * 10^{-3}$
$5 * 10^{-3}$	$5.17 * 10^{-3}$	$4.6 * 10^{-3}$
10^{-2}	$0.7 * 10^{-2}$	$0.9 * 10^{-2}$
$2 * 10^{-2}$	$1.8 * 10^{-2}$	$1.8 * 10^{-2}$
$5 * 10^{-2}$	$5.67 * 10^{-2}$	$5.01 * 10^{-2}$

TESTING: COMPTON-LIKE

$$Ee = \int \sigma(E\gamma, Ee) g(E\gamma) dE\gamma$$

target material (W), its thickness 500 um





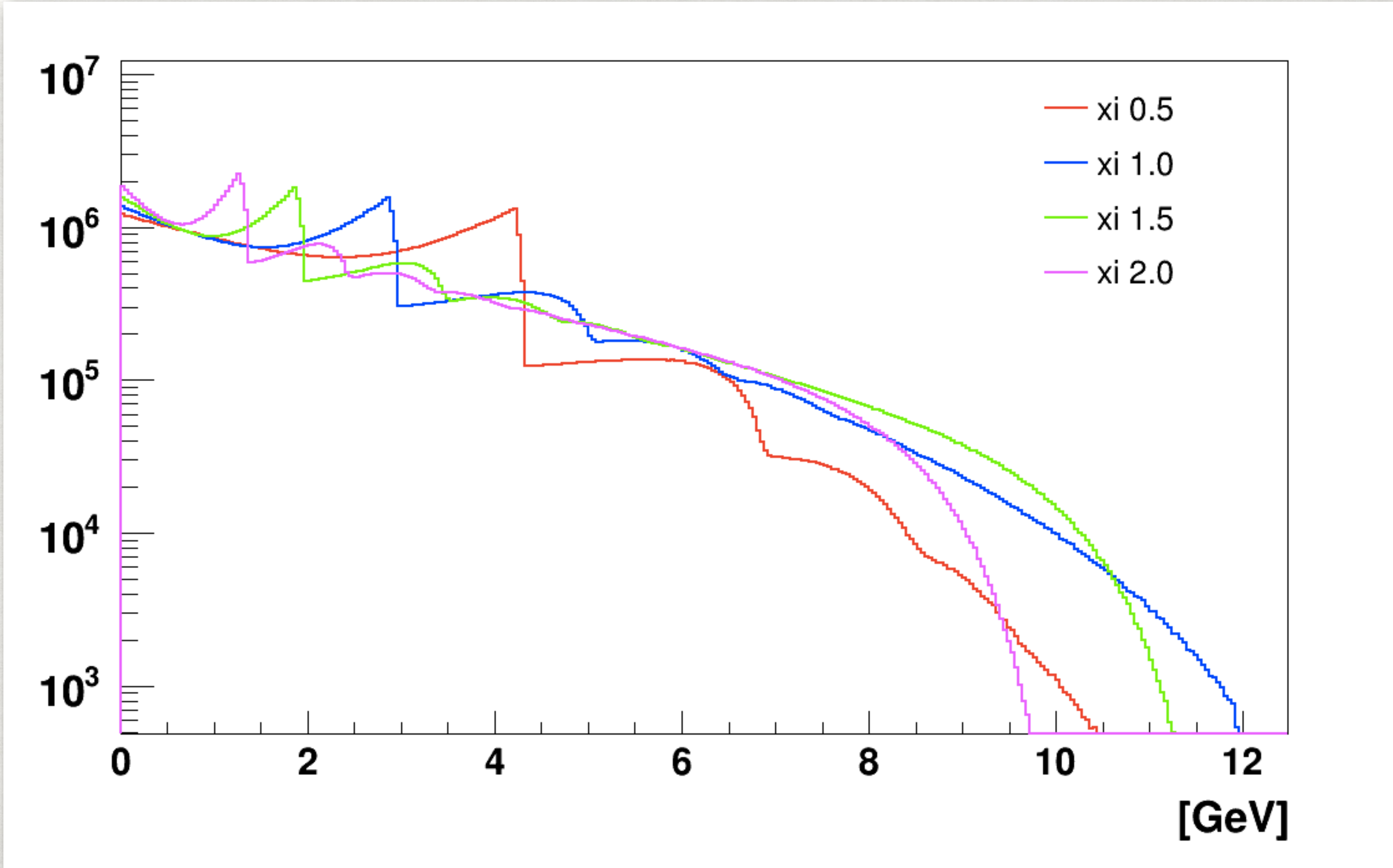
$$\int \sigma(E\gamma, Ee) g(E\gamma, p1, p2) dE\gamma$$

fitting allows finding the parameters quite well :

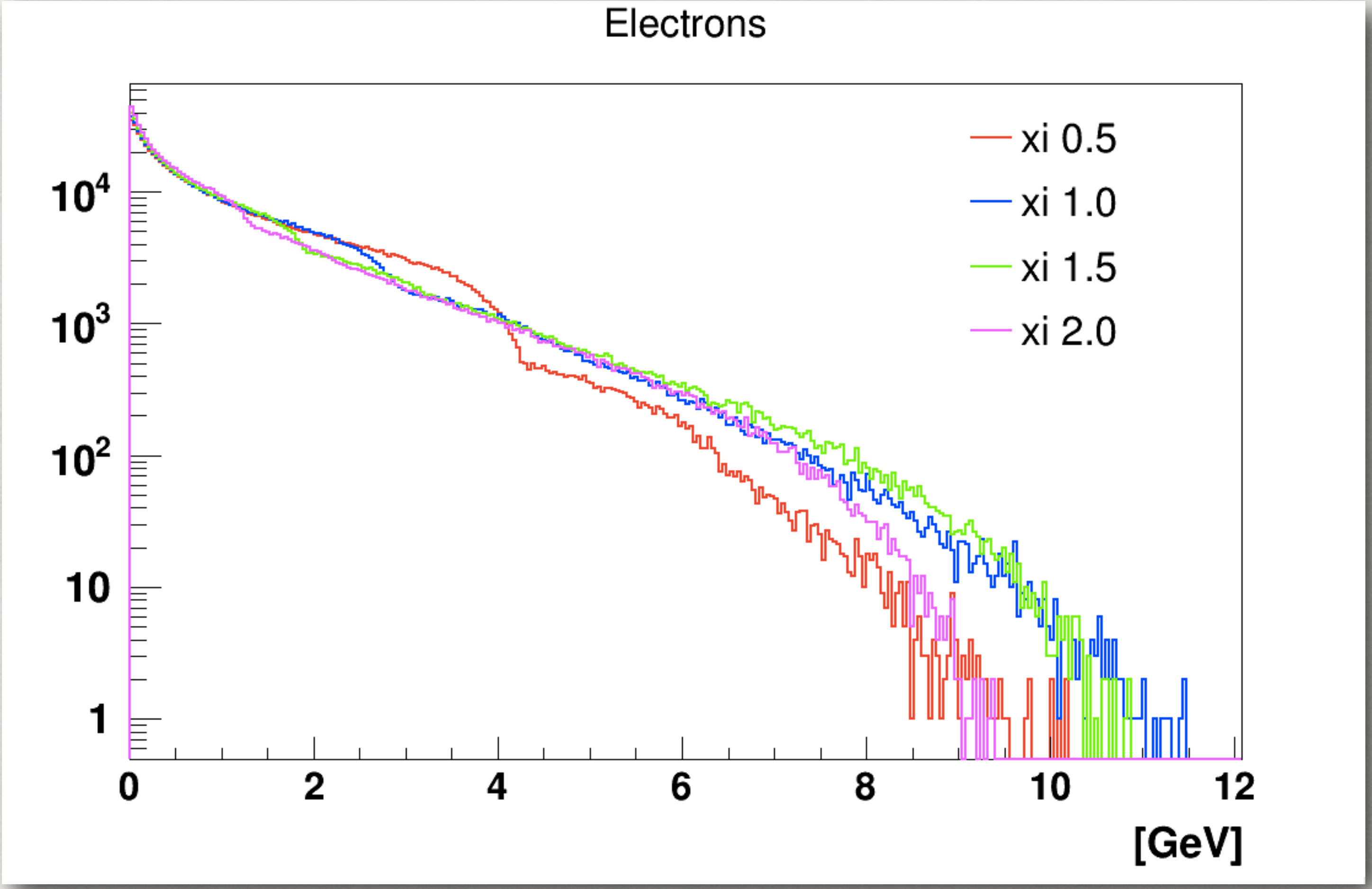
EXT NO.	PARAMETER NAME	VALUE	APPROXIMATE ERROR	STEP SIZE	FIRST DERIVATIVE
1	p0	0.00000e+00	fixed		
2	p1	8.10443e+05	7.55173e+03	4.54179e-07	8.91191e-01
3	p2	5.08073e+00	6.97488e-04	6.53706e-04	1.39541e-01
4	p3	0.00000e+00	fixed		
5	p4	5.78148e+03	1.25645e+02	4.35657e-07	-2.81589e-01
6	p5	7.43076e+00	2.04060e-02	2.03632e-02	-4.17430e-02
7	p6	6.14838e+01	1.53063e+01	2.48844e-05	-8.82892e-03
8	p7	5.01104e-02	4.66919e-04	3.40724e-07	3.39522e+00

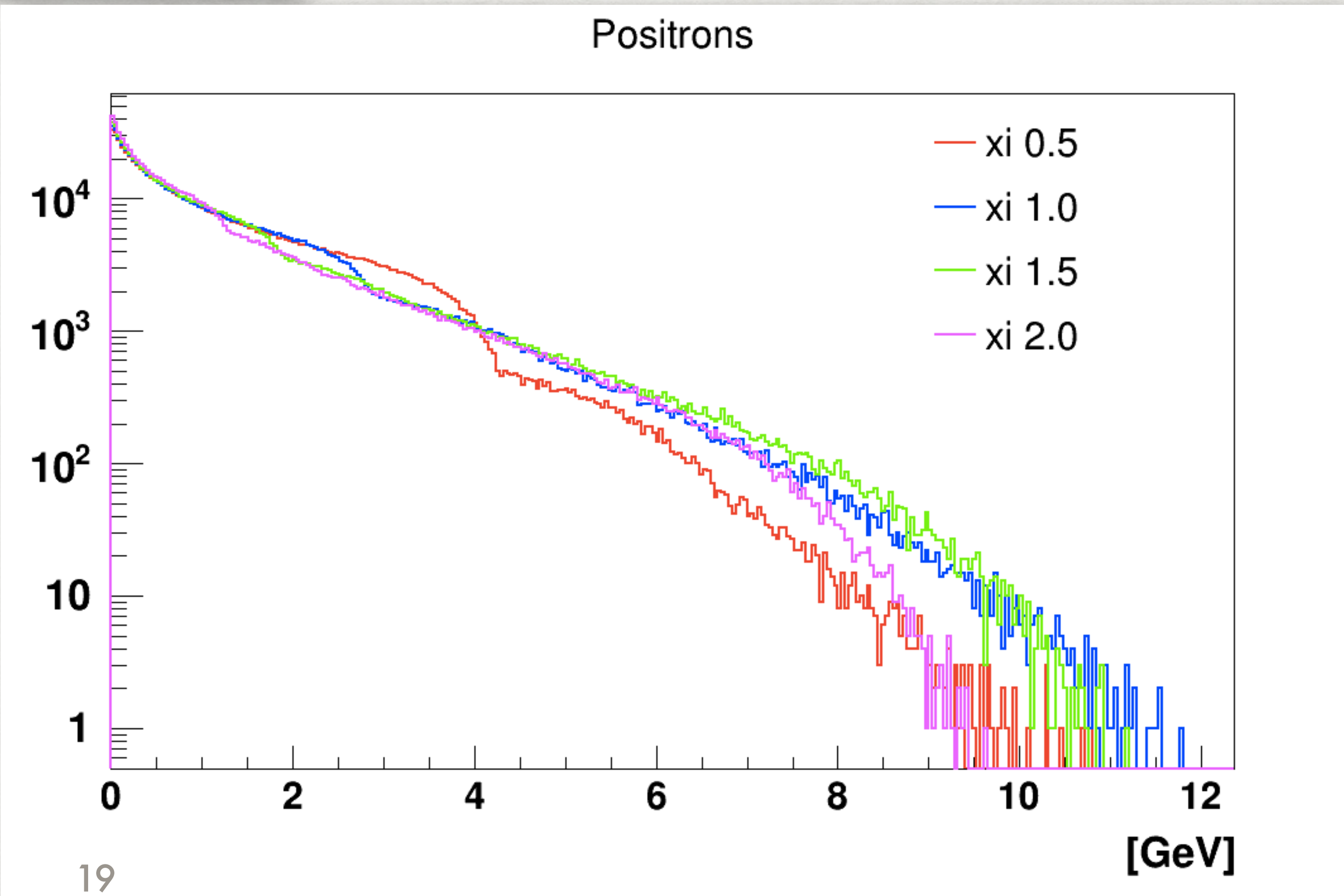
PHOTON SPECTRA FROM GEANT4

10E8 PHOTONS

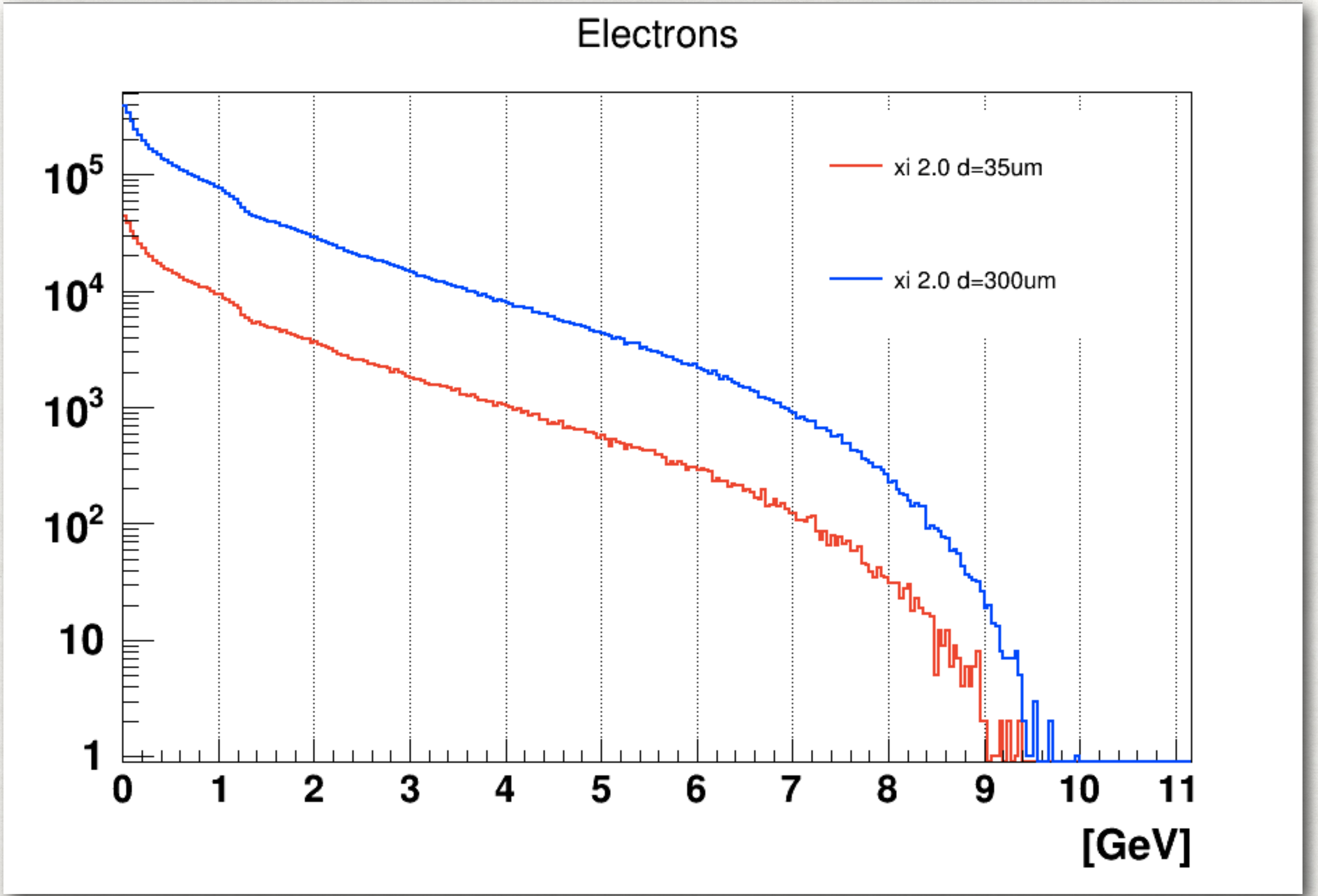


UNC

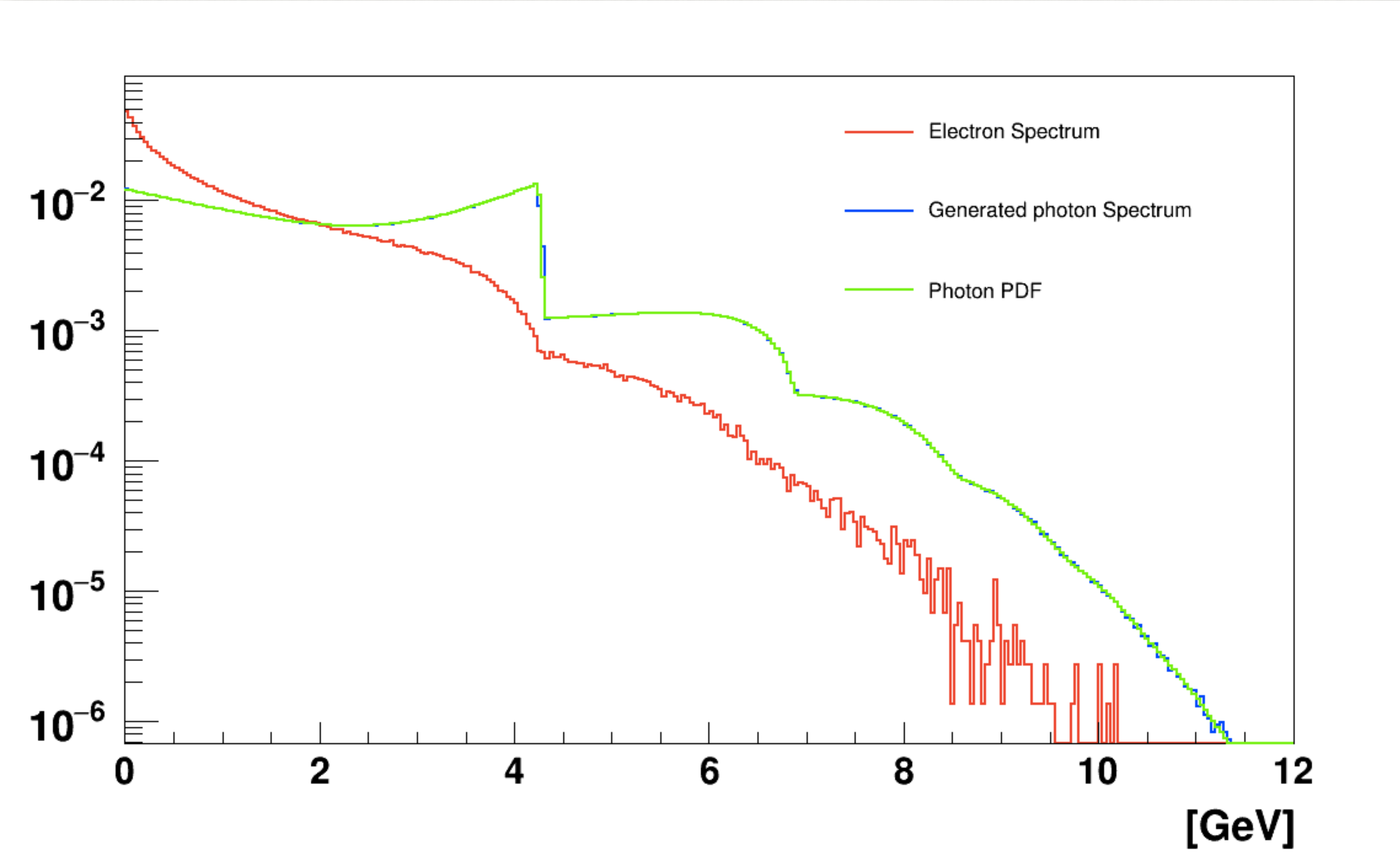

Electrons
xi 0.5
xi 1.0
xi 1.5
xi 2.0
10^4
10^3
10^2
10
1
0
2
4
6
8
10
12
[GeV]


Positrons
xi 0.5
xi 1.0
xi 1.5
xi 2.0
10^4
10^3
10^2
10
1
0
2
4
6
8
10
12
[GeV]

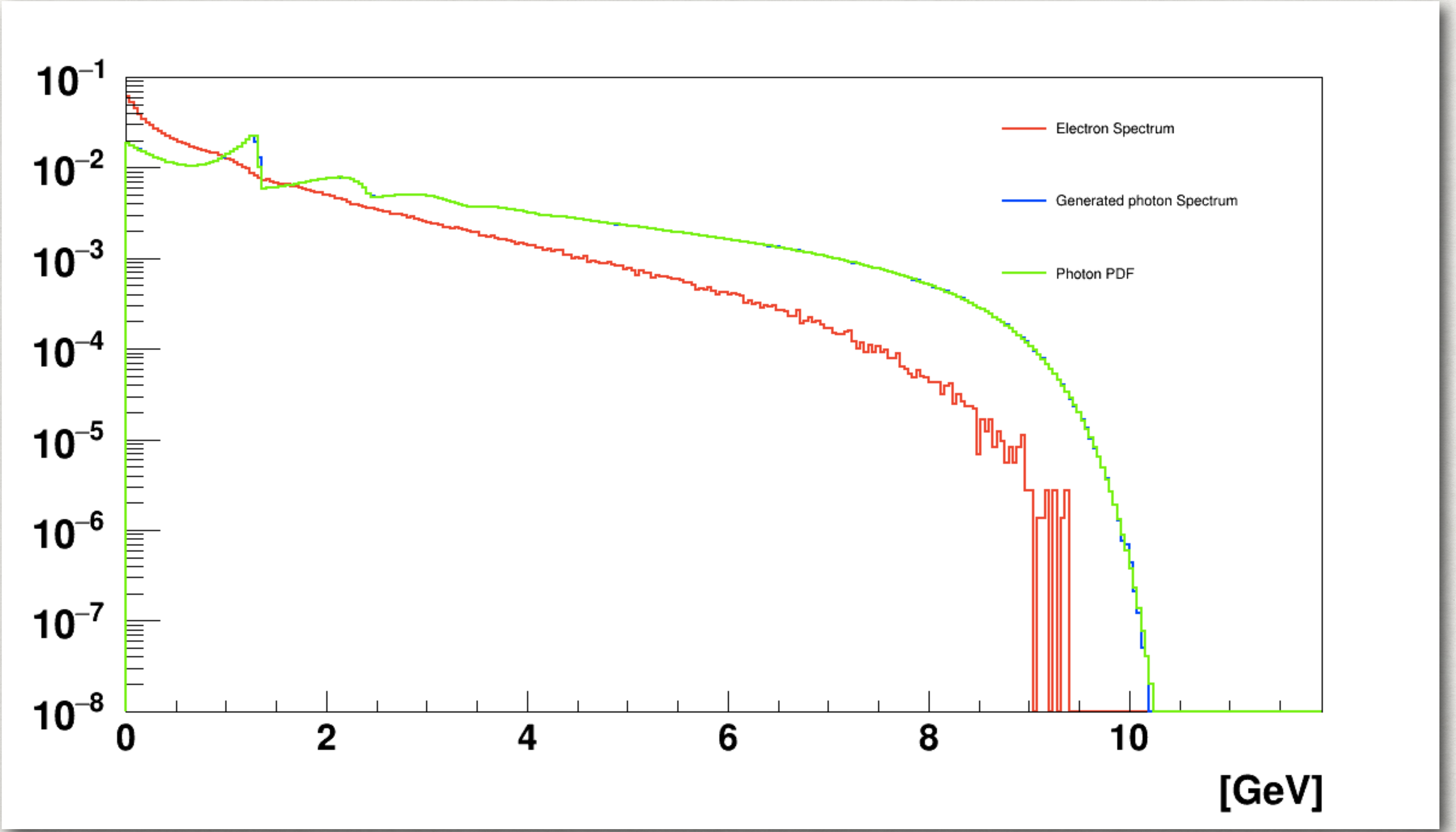
ELECTRON SPECTRA: 35 UM VS 300 UM



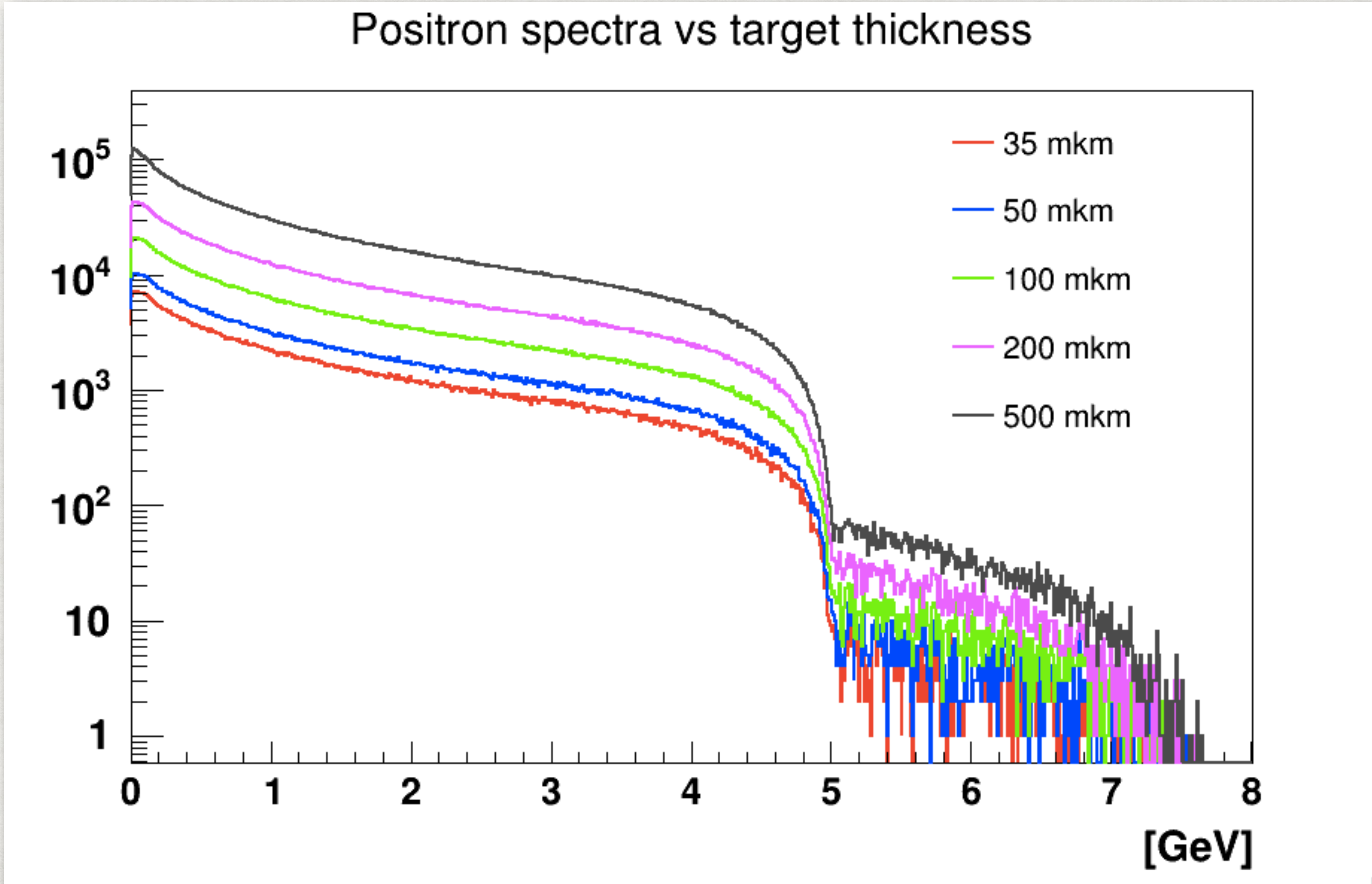
GAMMA AND ELECTRON SPECTRA FOR XI=0.5



GAMMA AND ELECTRON SPECTRA FOR XI=2.0



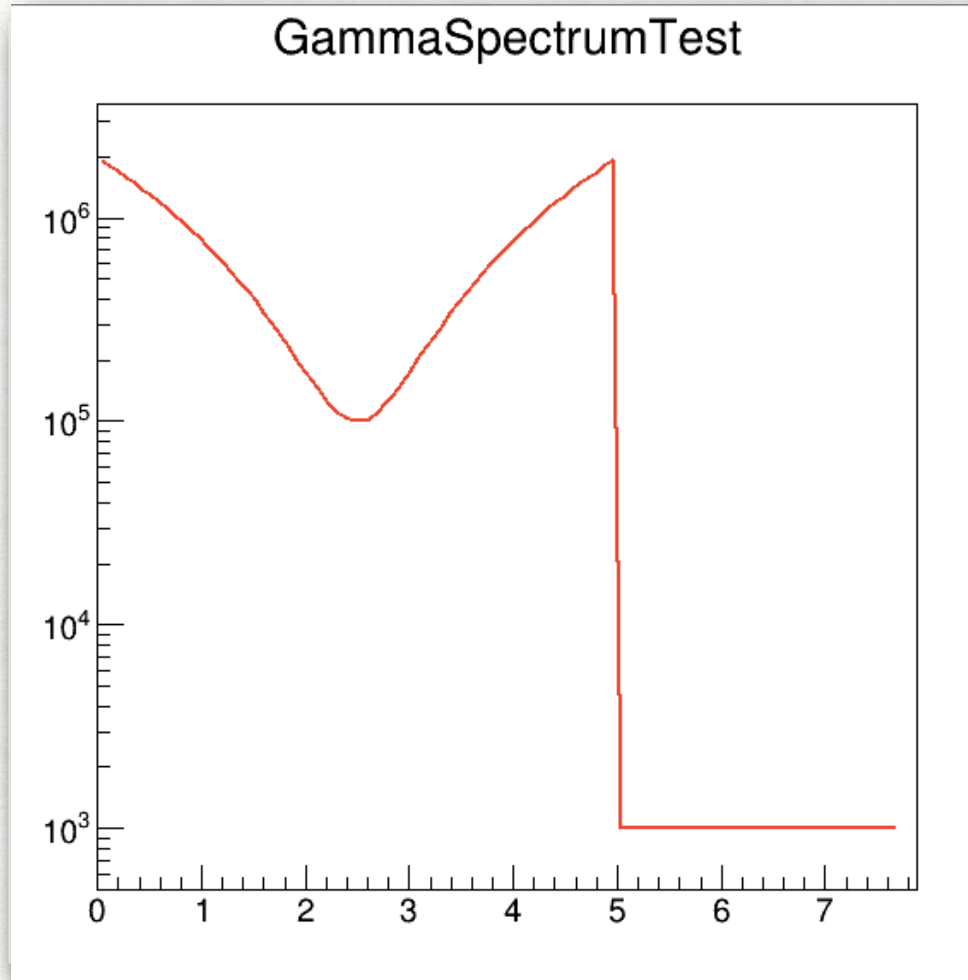
POSITRON SPECTRA VS TARGET THICKNESS IN GEANT4

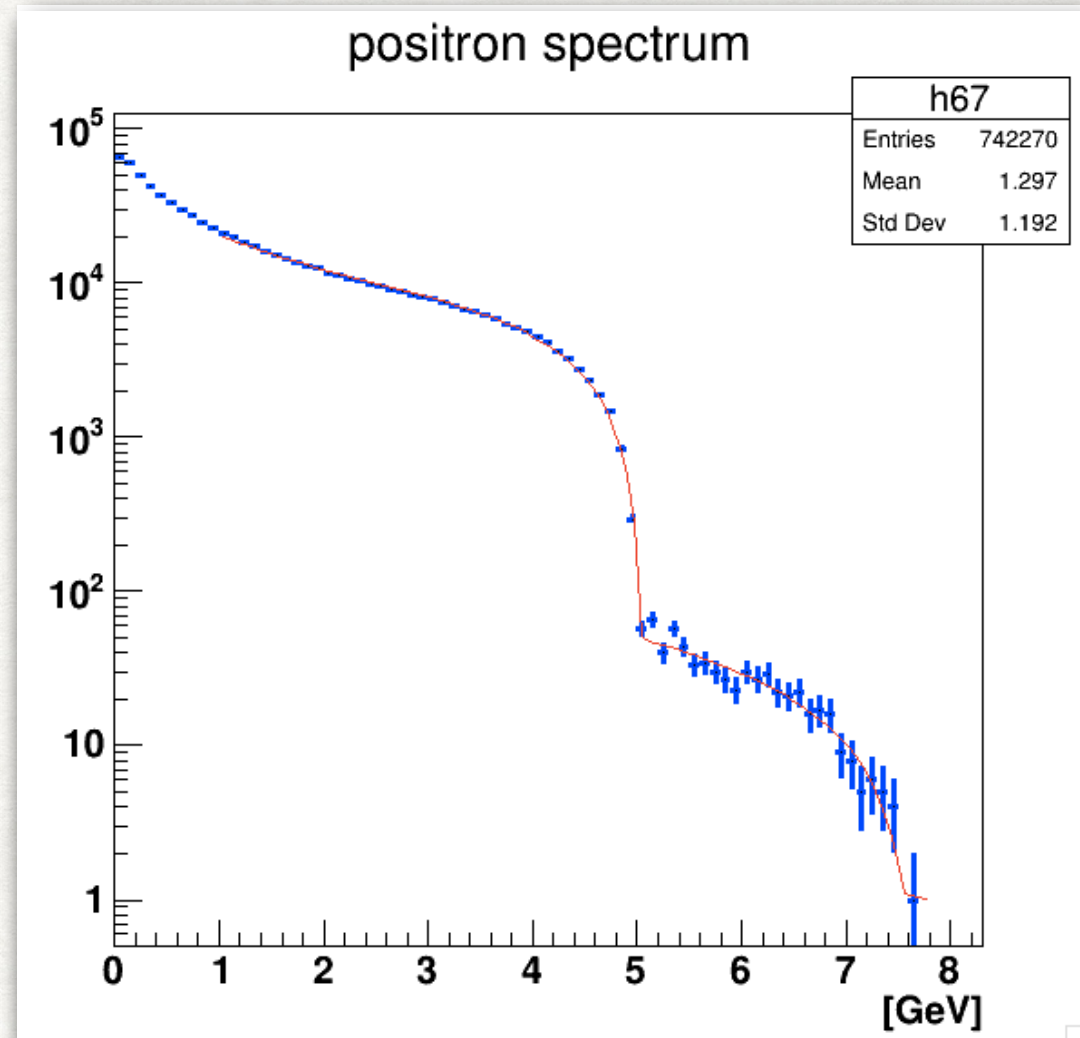


TESTING: COMPTON-LIKE

$Ee = \int \sigma(E\gamma, Ee) g(E\gamma) dE\gamma$

target material (W), its thickness 35 um



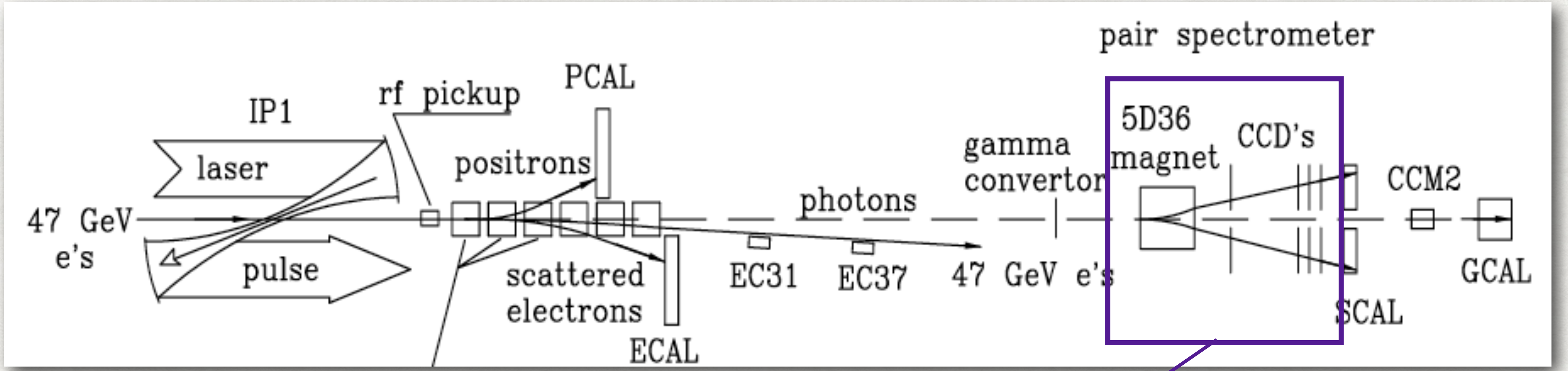


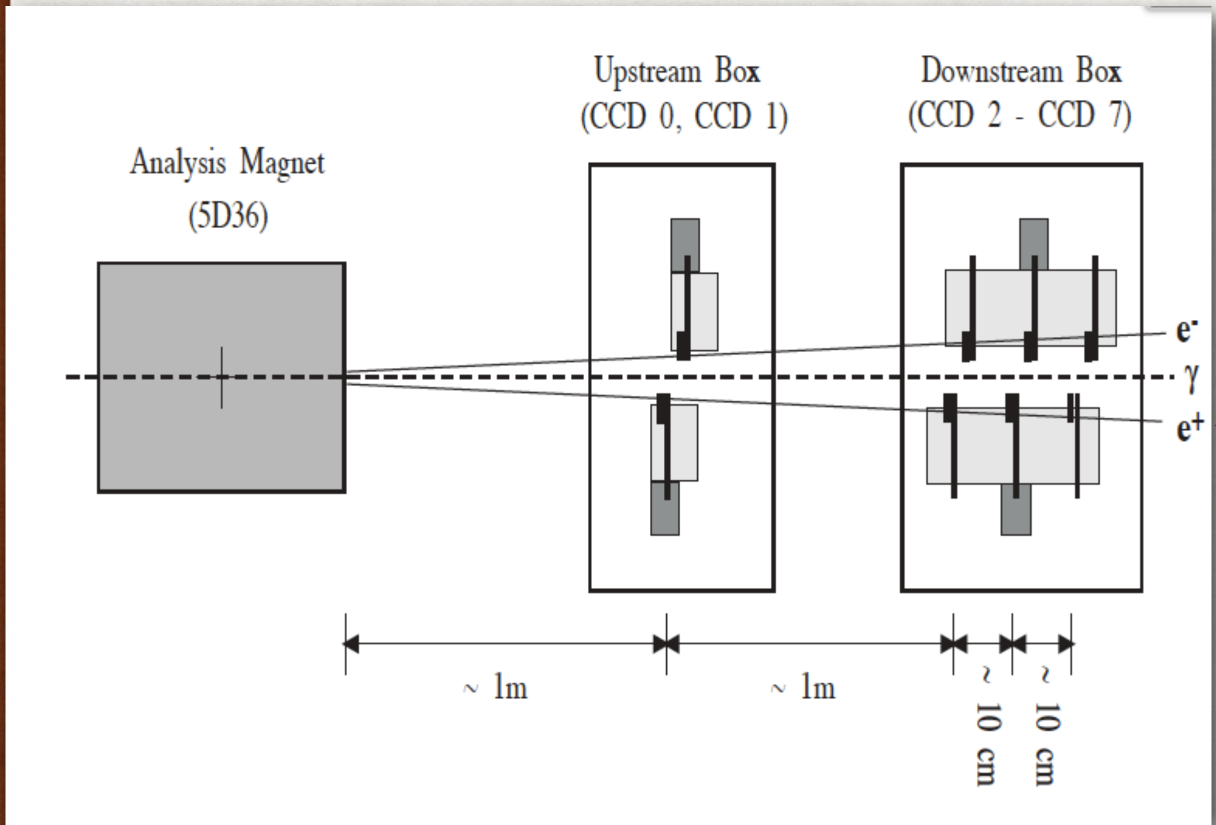
$\int \sigma(E\gamma, Ee) g(E\gamma, p1, p2) dE\gamma$

```
 FCN=145.218 FROM HESSE     STATUS=OK             56 CALLS        1207 TOTAL
                     EDM=4.92239e-08    STRATEGY= 1      ERROR MATRIX ACCURATE
  EXT PARAMETER                                STEP         FIRST
  NO.   NAME      VALUE            ERROR          SIZE      DERIVATIVE
   1  p0           1.85584e+05   3.13357e+04   7.89176e-07  -3.96577e-02
   2  p1           9.96061e+05   9.50413e+05   2.45175e-06   1.51142e-03
   3  p2           5.03997e+00   3.58164e-03   2.97159e-07  -1.51967e-01
   4  p3           0.00000e+00     fixed
   5  p4           1.04141e+04   1.84485e+03   3.30306e-06   1.00640e-02
   6  p5           7.55555e+00   9.87041e-02   7.68131e-03  -5.14074e-04
   7  p6           2.78794e+02   2.50973e+02   1.60564e-05   7.45705e-05
   8  p7           2.31367e-03   3.84606e-04   3.67255e-07  -2.59769e+00
(Int_t) 0
```

LAYOUT FOR THE E-144 EXPERIMENT

Photons produced at IP1 proceed down their own beamline through the converter foil and the tracking spectrometer





e-/e+ tracks were reconstructed using the 3 back planes of CCD's. All triplets of points from the back CCD planes of a given arm were tested to see if they fit a line intercepting a region near the center of the spectrometer magnet. This set of candidate tracks included many “fake" tracks from thermal noise, and combinatoric background of points from different particles.

No attempt was made to use the CCDs in the front plane of the spectrometer in this mode, since the high number of hits led to significant ambiguity in the projection from the back planes to the front.

CCD image sensors: pixel size 22.5*22.5 um

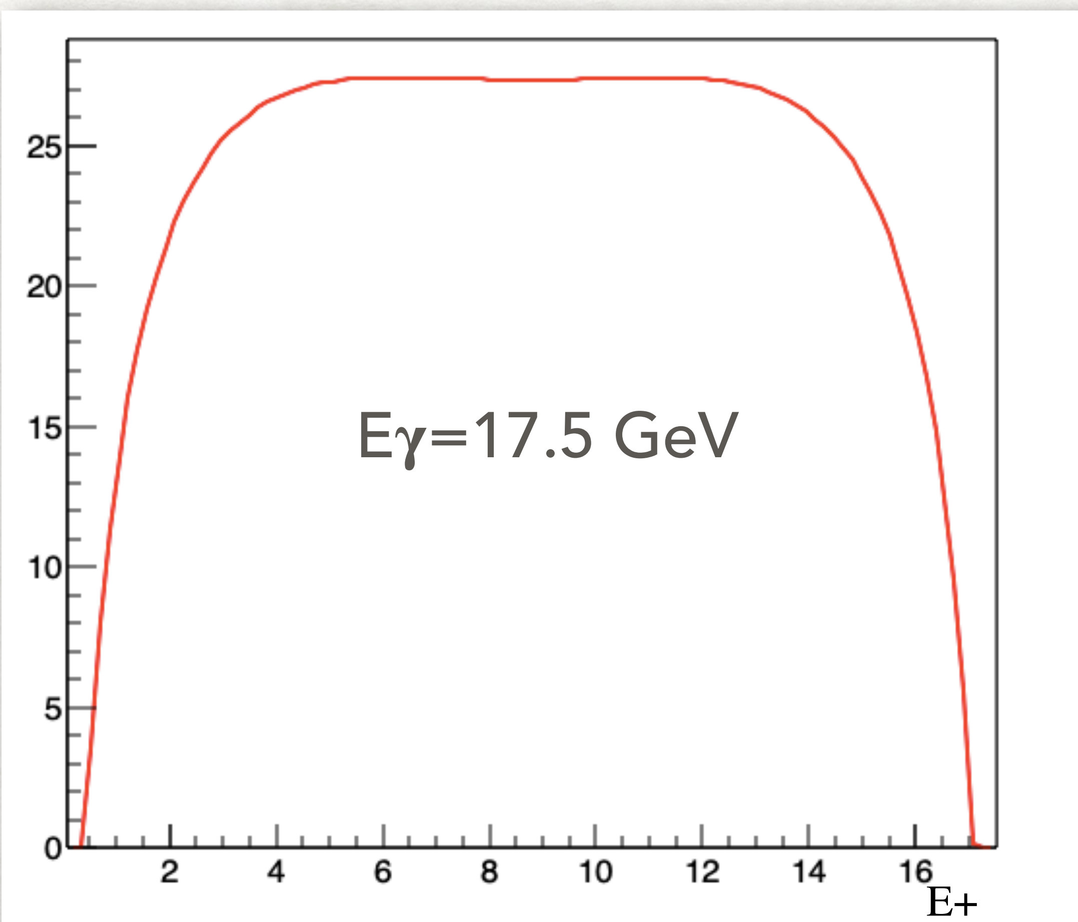
[EEV, 1242*1152].

THE CLASSICAL BETHE-HEITLER PAIR SPECTRUM

The classical Bethe-Heitler formula is currently used:
H.Bethe, W.Heitler, Proc.Roy.Soc.A146 (34)83

$$\Phi\,(E_0)\,dE_0 = \frac{Z^2}{137}\left(\frac{e^2}{mc^2}\right)^2 4\,\frac{E_0{}^2 + E_+{}^2 + \frac{2}{3}E_0E_+}{(h\nu)^3}\,dE_0\left(\log\frac{2E_0E_+}{h\nu mc^2} - \frac{1}{2}\right).$$

energies involved are large compared with mc^2



The idea - to check if any photon spectrum could be restored if we have the classical BH distribution and characteristic shapes of photon spectrum

TOTAL X-SECTION

XCOM: Photon Cross Sections Database (The National Institute of Standards and Technology (NIST))

A web database which can be used to calculate photon cross sections for scattering, photoelectric absorption and pair production, as well as total attenuation coefficients, for any element, compound or mixture ($Z \leq 100$), at energies from 1 keV to 100 GeV.

G4BetheHeitlerModel from Geant4

total cross section per atom in GEANT4

E_γ = incident gamma energy, and $X = \ln(E_\gamma/m_e c^2)$

The total cross-section has been parameterised as :

$$\sigma(Z, E_\gamma) = Z(Z+1)\left[F_1(X) + F_2(X)\,Z + \frac{F_3(X)}{Z}\right]$$

with :

$$\begin{aligned} F_1(X) &= a_0 + a_1 X + a_2 X^2 + a_3 X^3 + a_4 X^4 + a_5 X^5 \\ F_2(X) &= b_0 + b_1 X + b_2 X^2 + b_3 X^3 + b_4 X^4 + b_5 X^5 \\ F_3(X) &= c_0 + c_1 X + c_2 X^2 + c_3 X^3 + c_4 X^4 + c_5 X^5 \end{aligned}$$

The parameters a_i, b_i, c_i were fitted to the data [hubb80].

This parameterisation describes the data in the range :

$$\left.\begin{array}{c} 1 \leq Z \leq 100 \\ E_\gamma \in [1.5\ \text{MeV}, 100\ \text{GeV}] \end{array}\right\} \frac{\Delta\sigma}{\sigma} \leq 5\% \quad \text{with a mean value of} \approx 2.2\%$$