FORWARD PHOTONS

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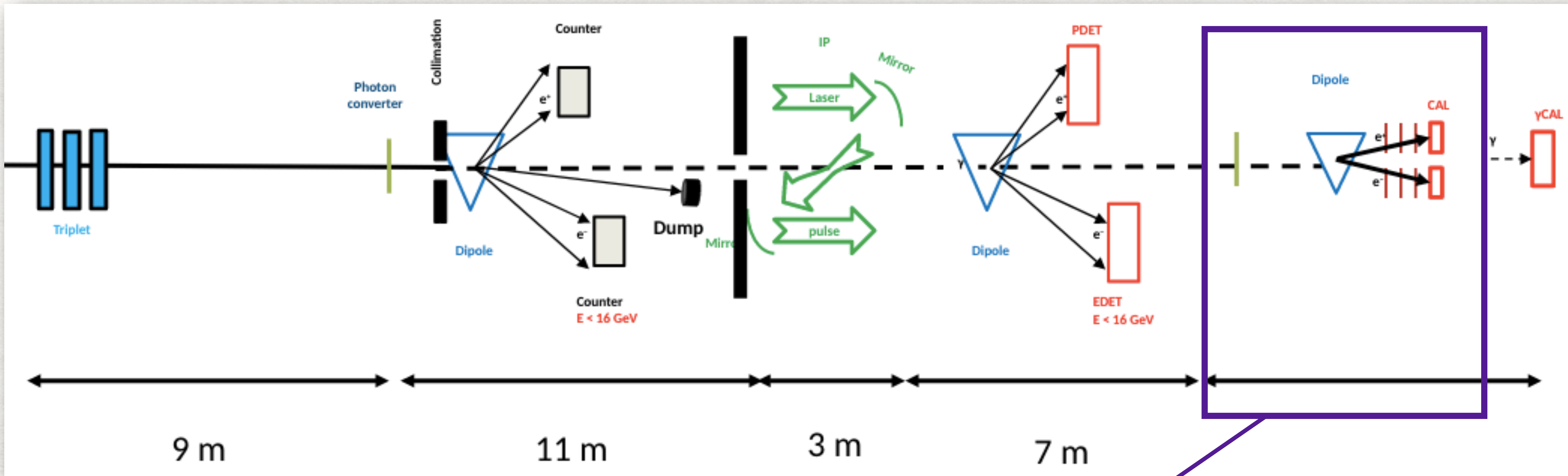
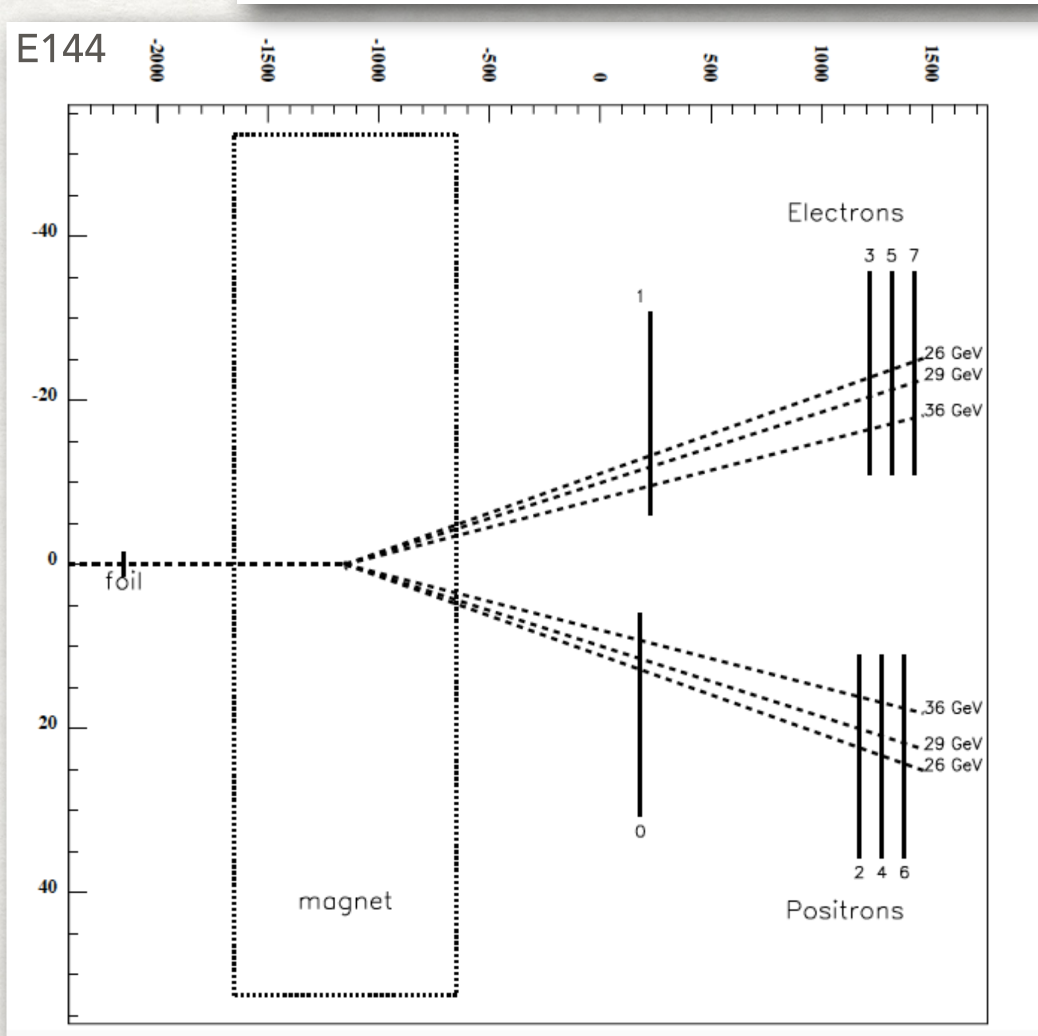
18/02/19

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

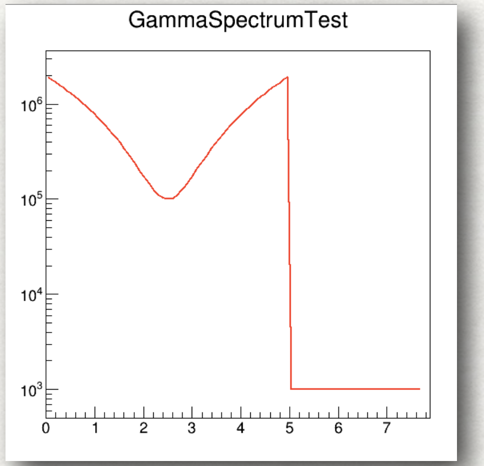


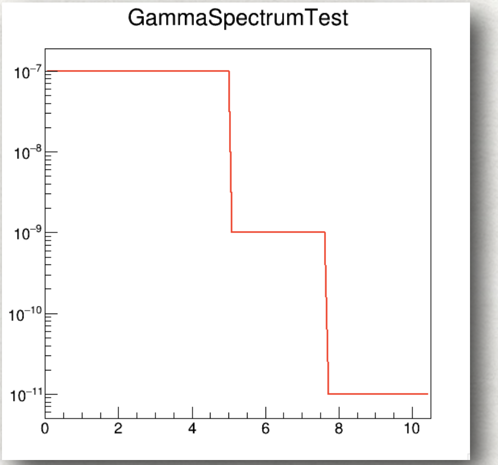


$$
\begin{aligned}
e + n\omega &\rightarrow e + \gamma \\
\gamma + n\omega &\rightarrow e^{+} + e^{-}.
\end{aligned}
$$

- 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**

FITTED THICKNESS



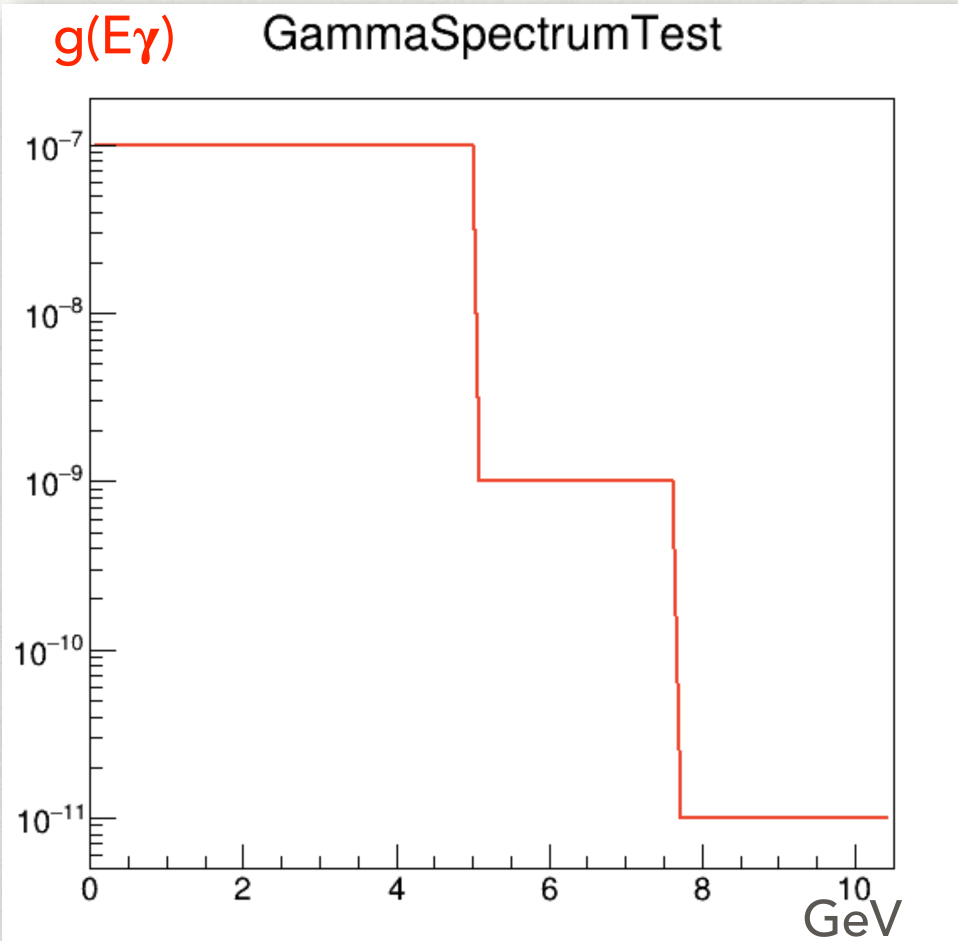


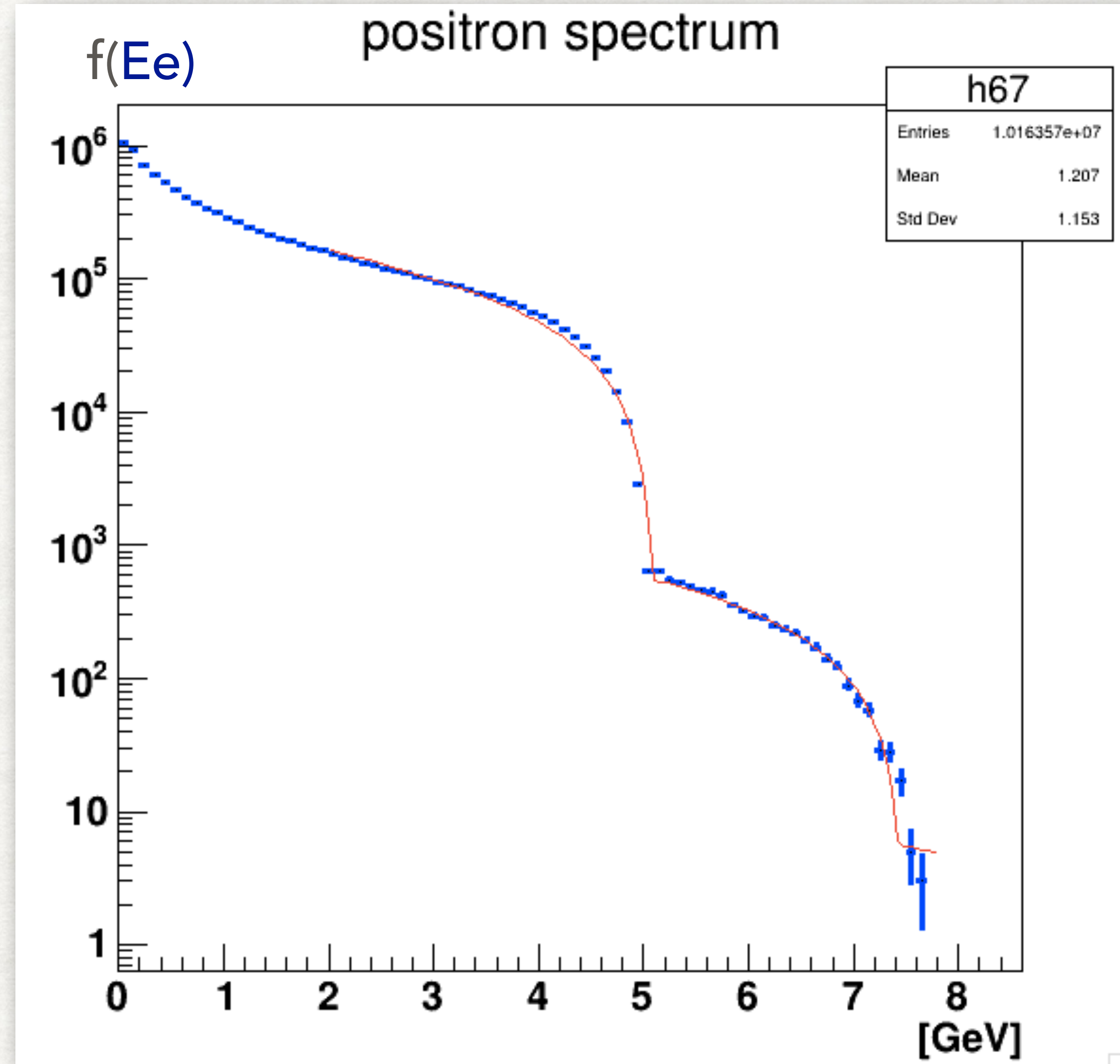
Thickness, cm	p[7] from the fit, cm	p[7] from the fit, cm
$3.5 * 10^{-3}$	$2.55 * 10^{-3}$	$3.2 * 10^{-3}$
$5 * 10^{-3}$	$5.17 * 10^{-3}$	$4.6 * 10^{-3}$
10^{-2}	$0.7 * 10^{-2}$	$0.9 * 10^{-2}$
$2 * 10^{-2}$	$1.8 * 10^{-2}$	$1.8 * 10^{-2}$
$5 * 10^{-2}$	$5.67 * 10^{-2}$	$5.01 * 10^{-2}$

TESTING: COMPTON-LIKE

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

target material (W), its thickness 500 um





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

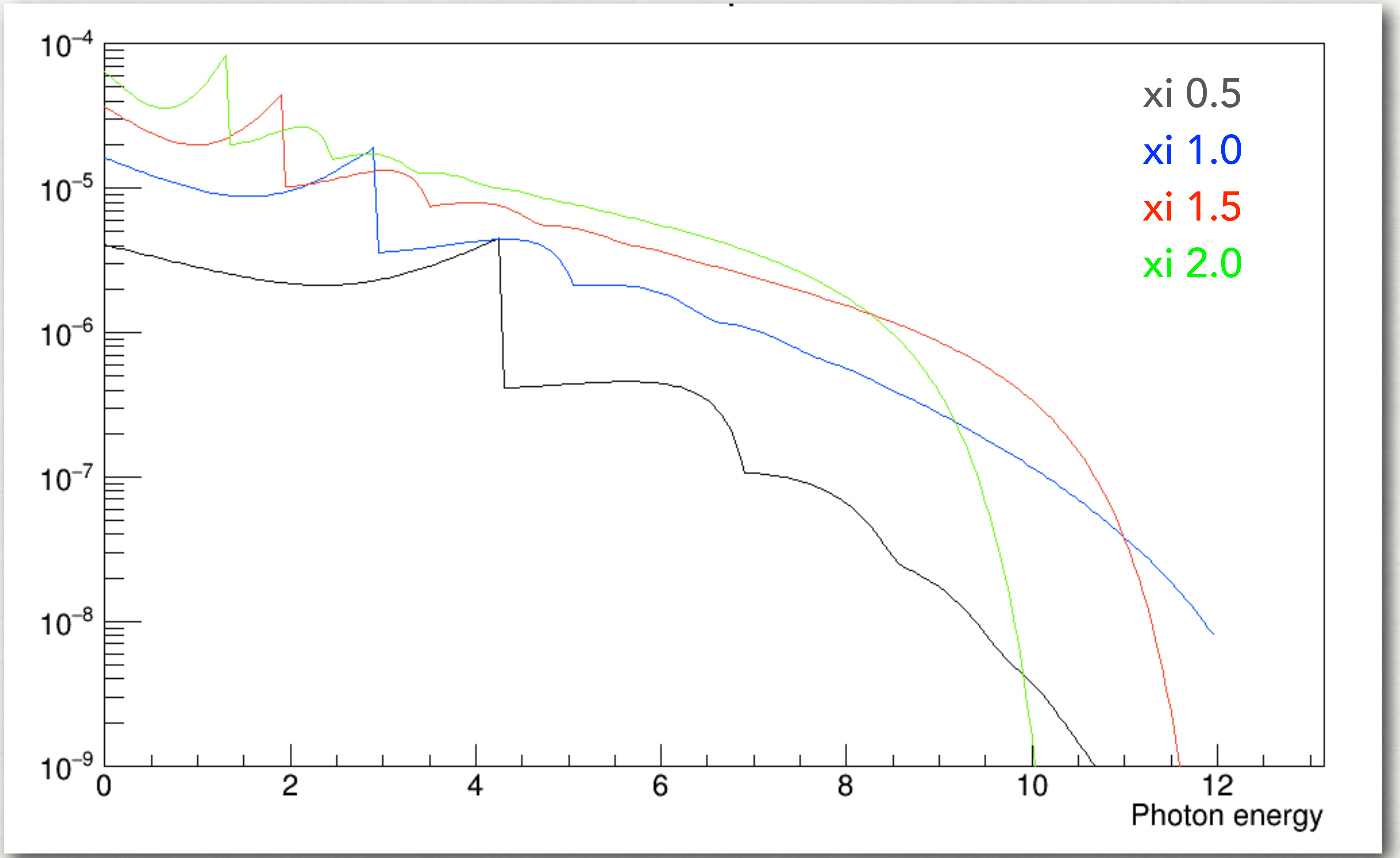
fitting allows finding the parameters quite well :

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

HICS DIFFERENTIAL TRANSITION PROBABILITY VS RADIATED PHOTON ENERGY

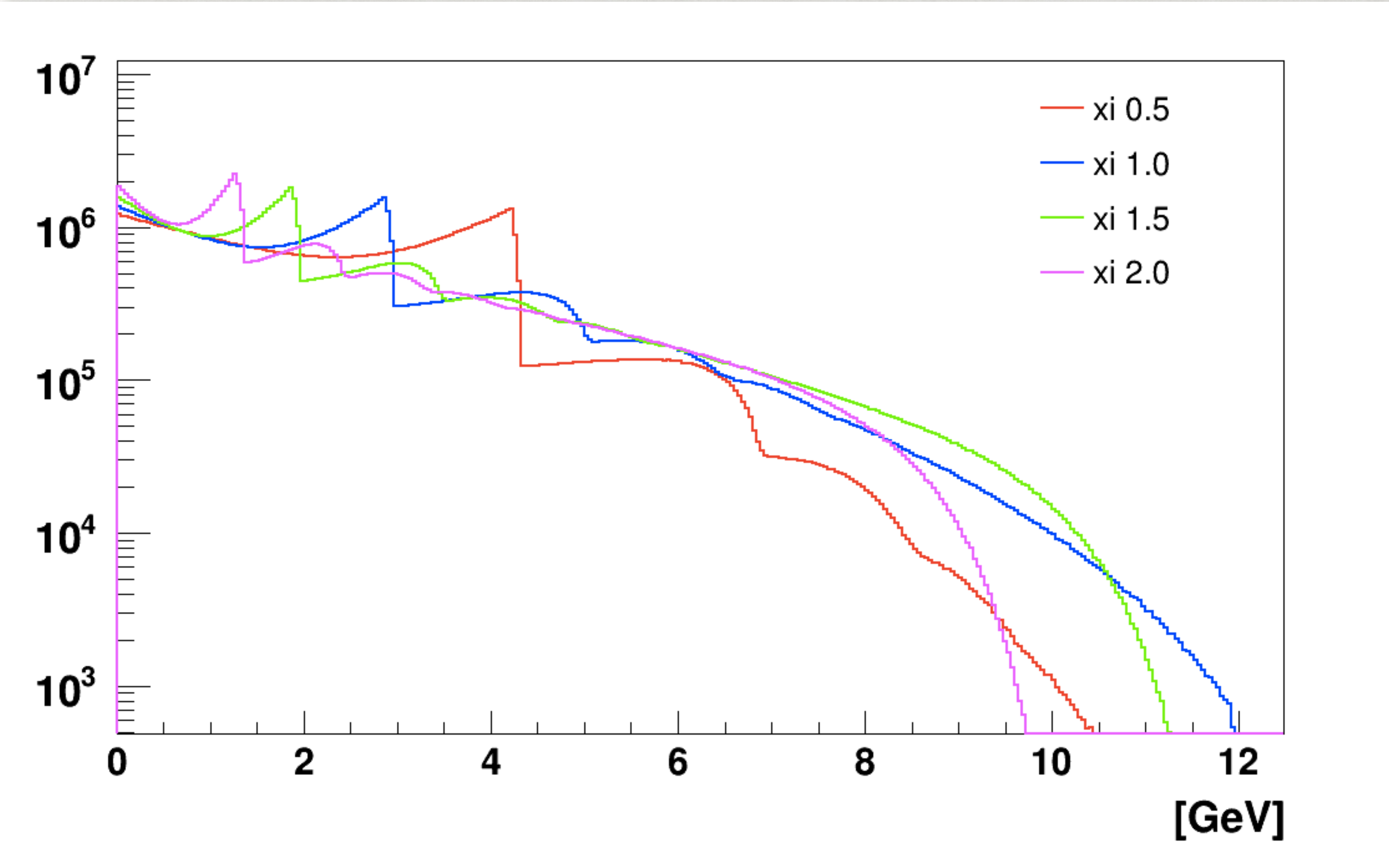
per initial particle per 100 fs 800 nm laser. 17.5 GeV initial electrons, 0.9*Pi crossing angle

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

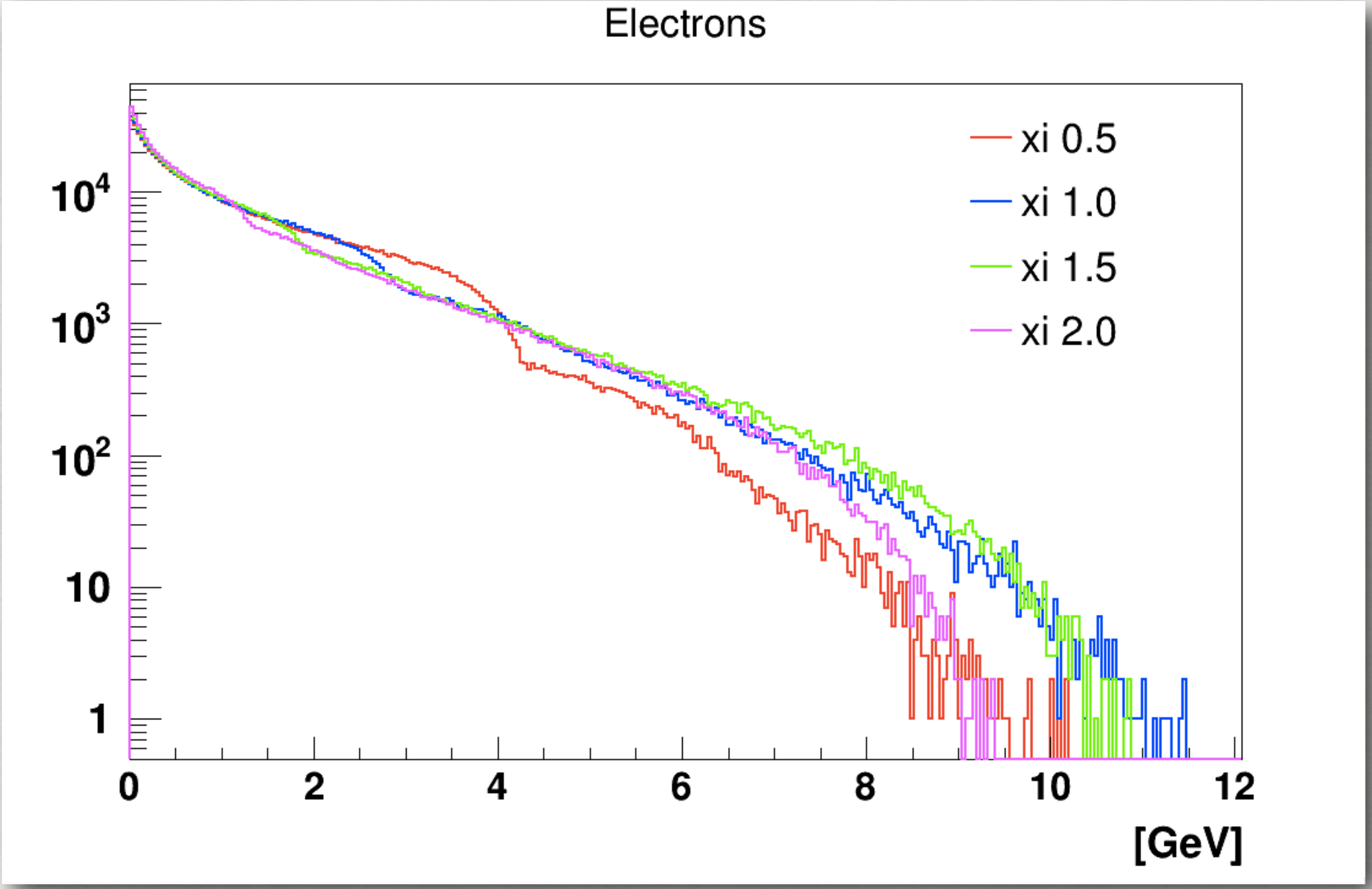


PHOTON SPECTRA FROM GEANT4

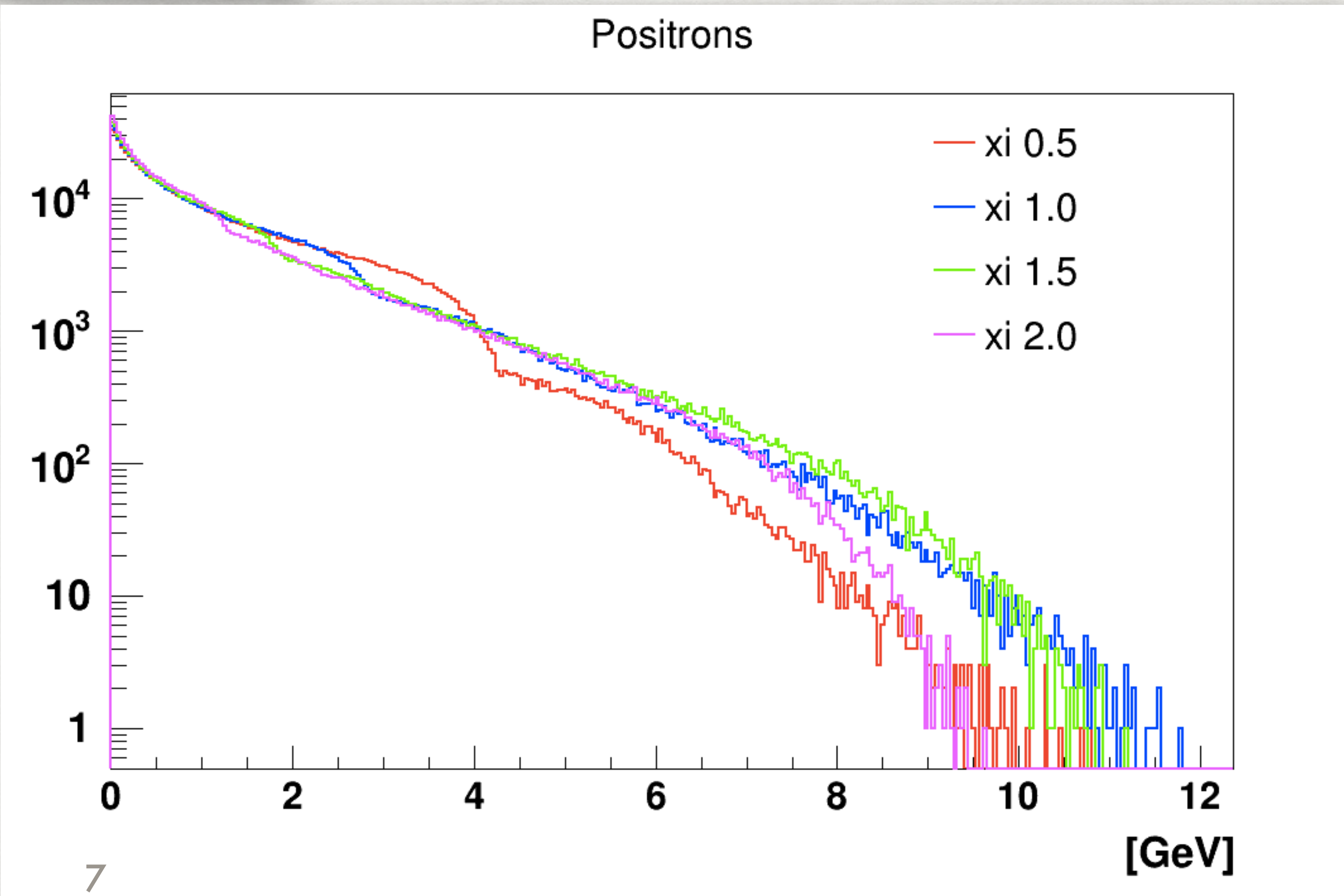
10E8 PHOTONS



UNC

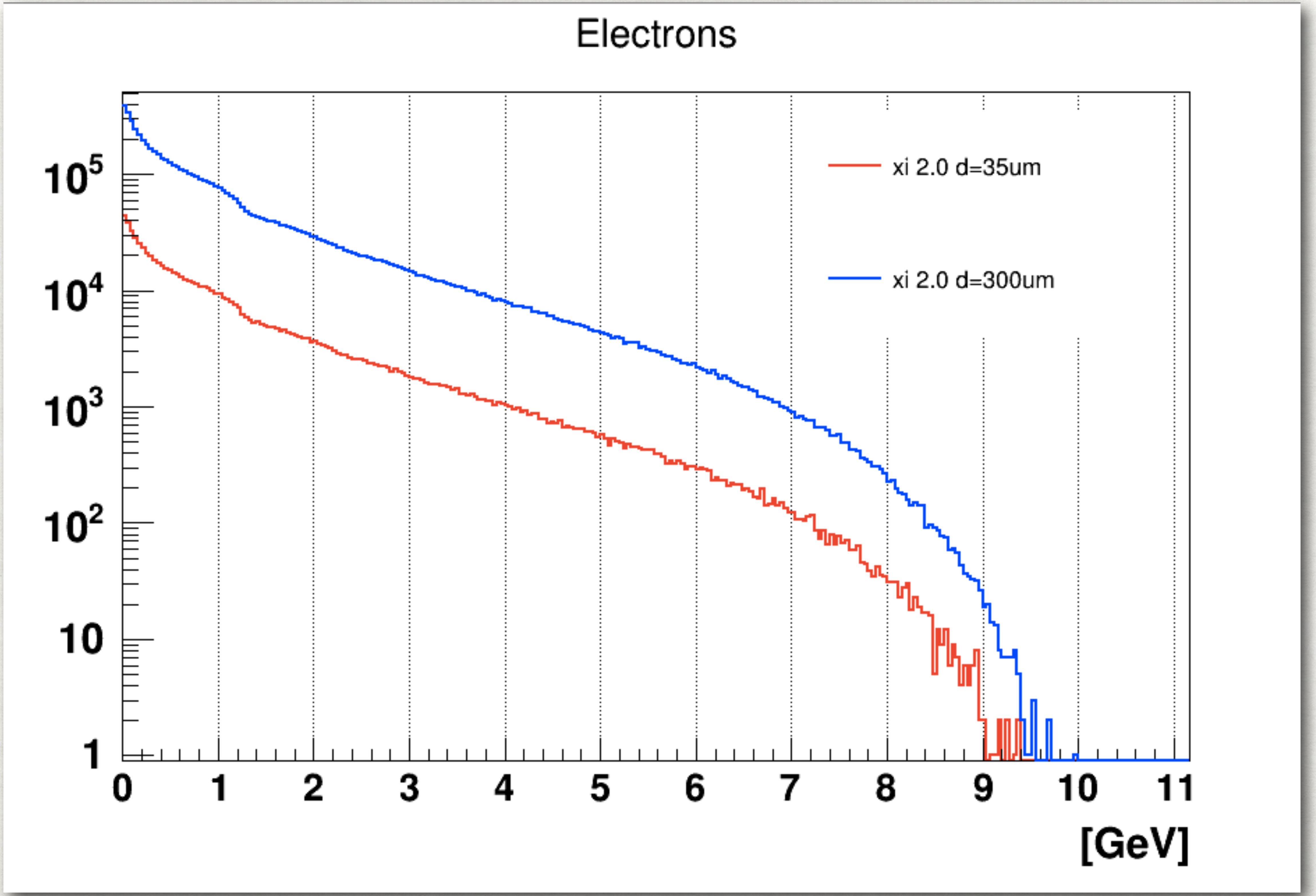


Electrons
xi 0.5
xi 1.0
xi 1.5
xi 2.0
10^4
10^3
10^2
10
1
0
2
4
6
8
10
12
[GeV]

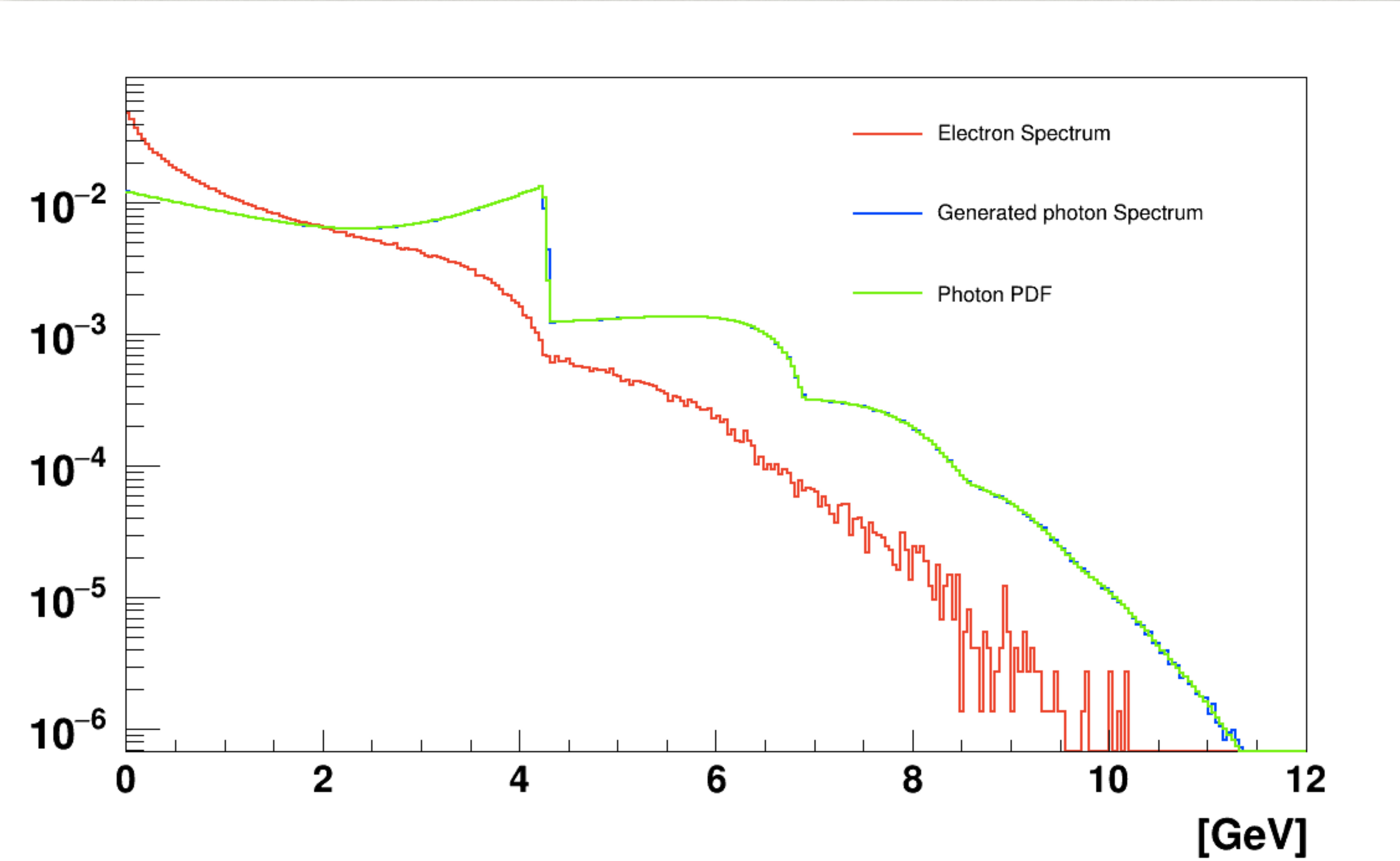


Positrons
xi 0.5
xi 1.0
xi 1.5
xi 2.0
10^4
10^3
10^2
10
1
0
2
4
6
8
10
12
[GeV]

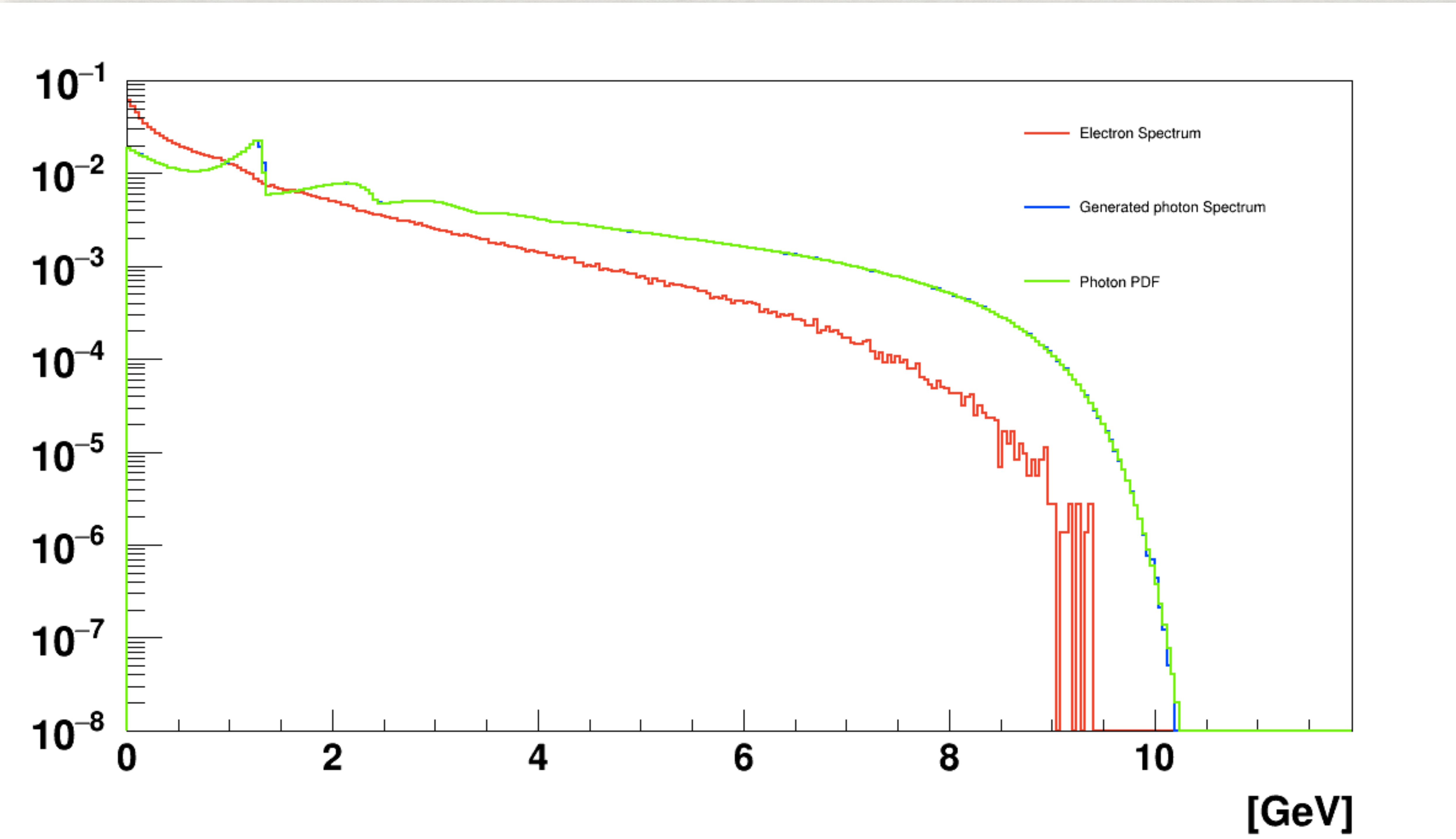
ELECTRON SPECTRA: 35 UM VS 300 UM



GAMMA AND ELECTRON SPECTRA FOR XI=0.5



GAMMA AND ELECTRON SPECTRA FOR XI=2.0

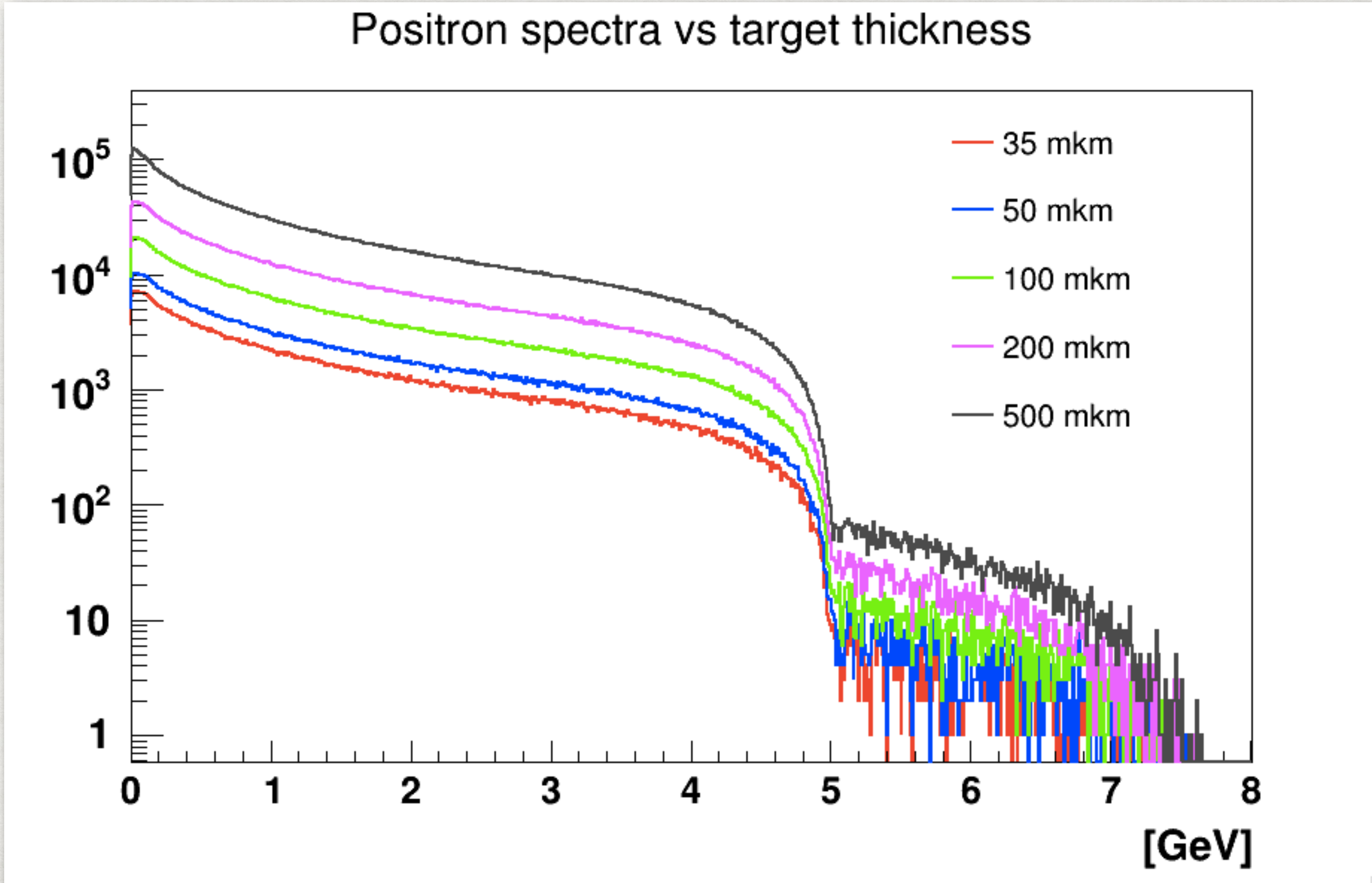


WHAT'S NEXT

- tested if we could fit and find parameters describing the thickness of tungsten target and number of kinematic edges of photon spectra.
- test if we could fit and find other parameters describing the process: target material (Z).
- To use Bethe-Heitler formula, corrected and extended for various effects (the screening, the pair creation in e the field of atomic electrons, correction to the Born approximation, the LPM suppression mechanism, etc.)

BACK UP

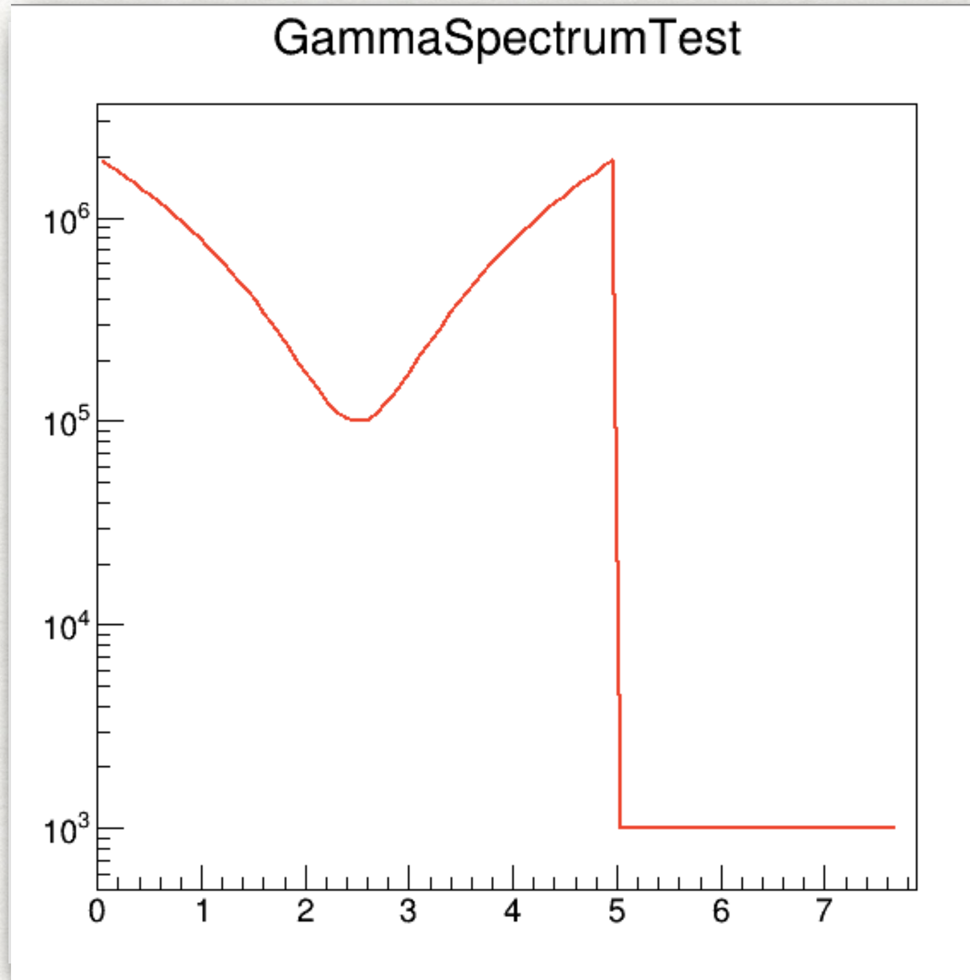
POSITRON SPECTRA VS TARGET THICKNESS IN GEANT4

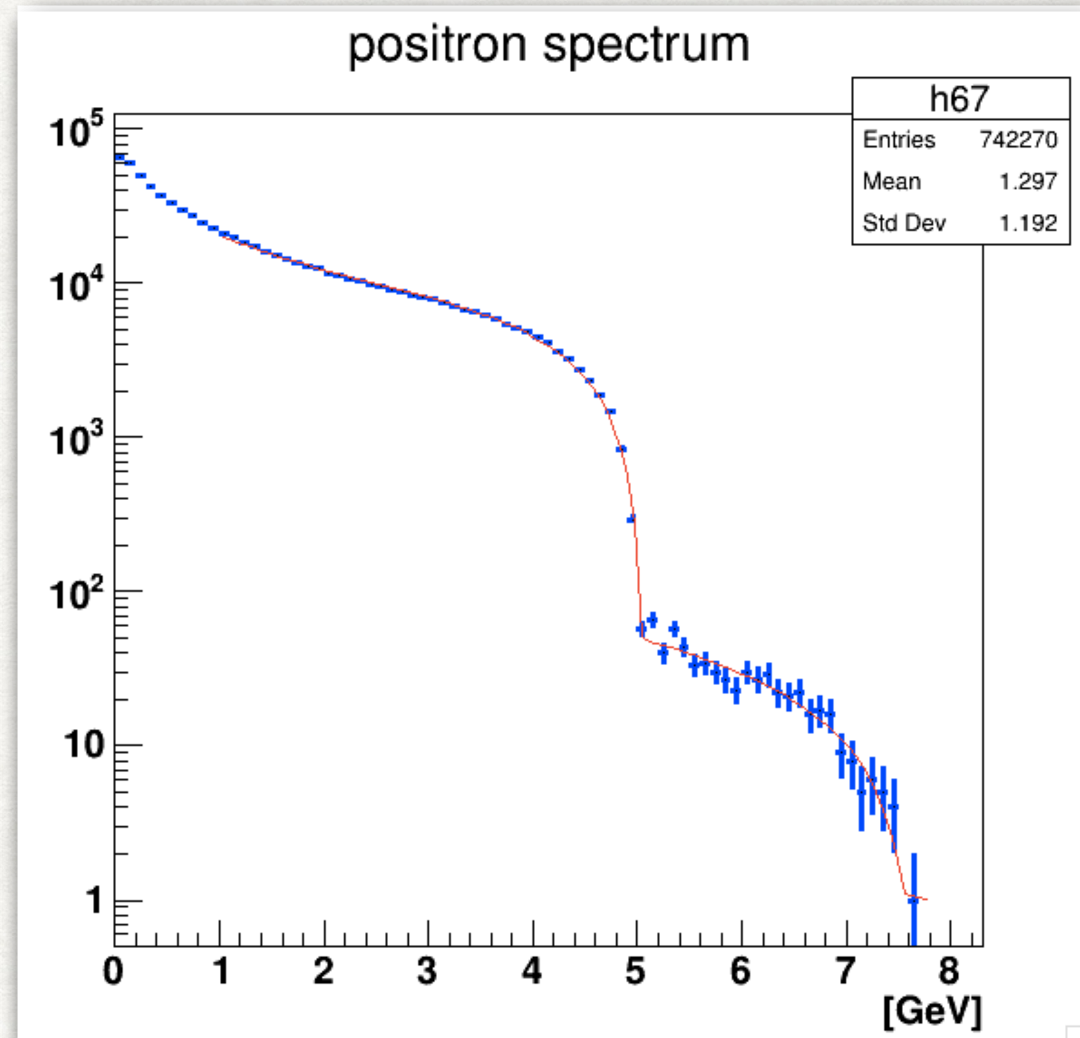


TESTING: COMPTON-LIKE

Ee=∫σ(Eγ, Ee)g(Eγ)dEγ

target material (W), its thickness 35 um





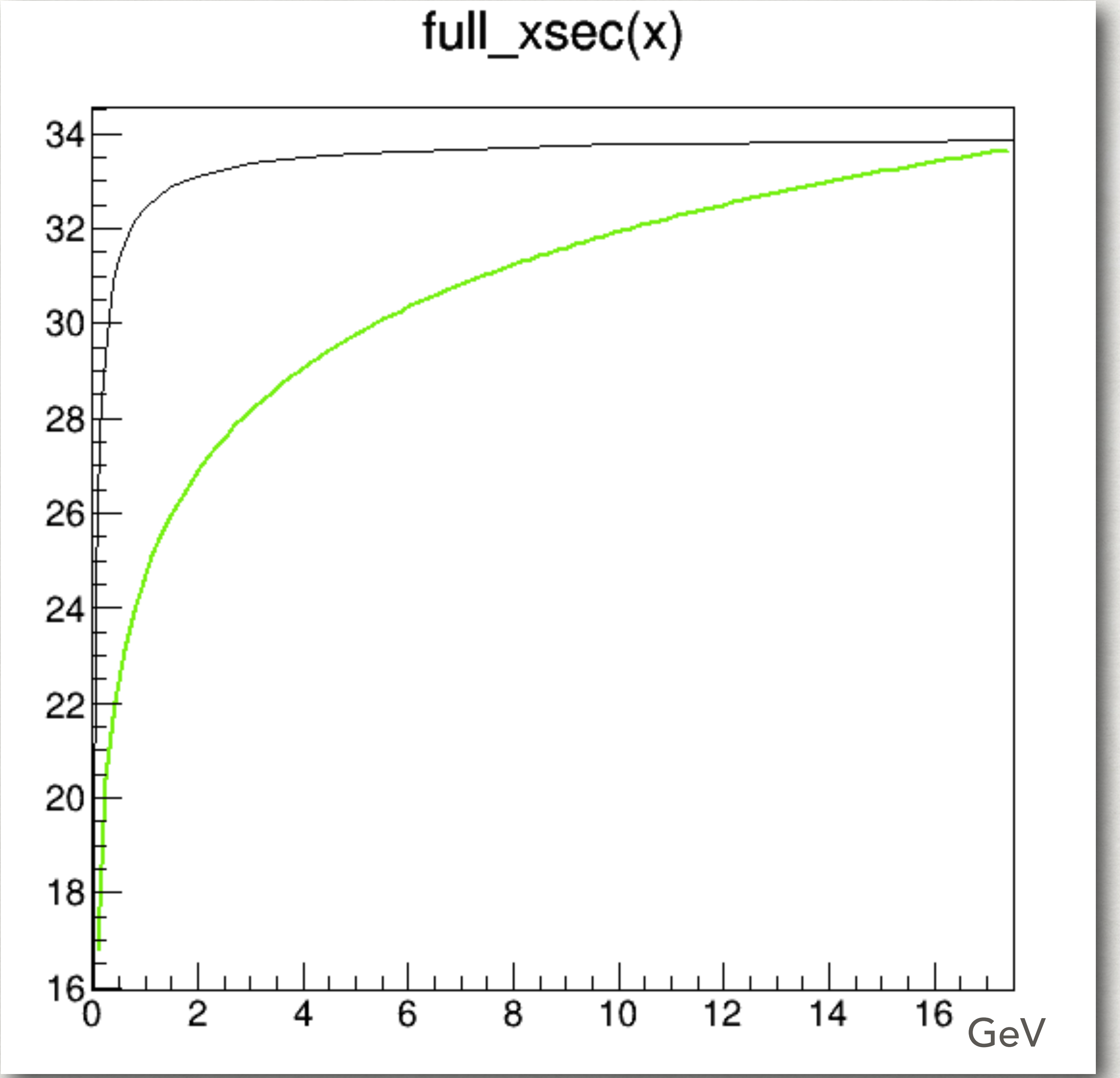
∫σ(Eγ, Ee)g(Eγ,p1,p2)dEγ

```
 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
```

TOTAL X-SECTION

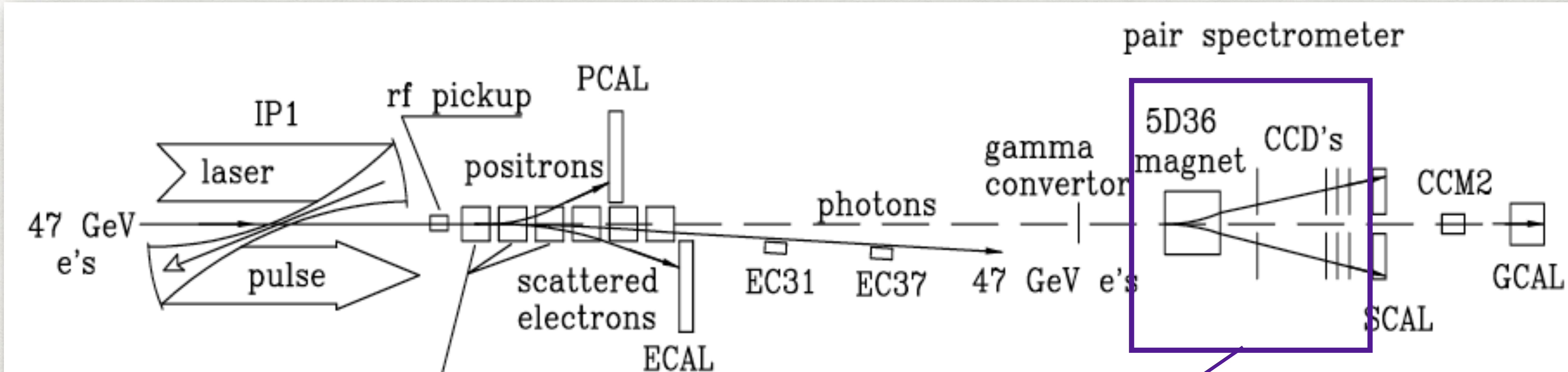
XCOM: Photon Cross Sections Database (The National Institute of Standards and Technology (NIST))

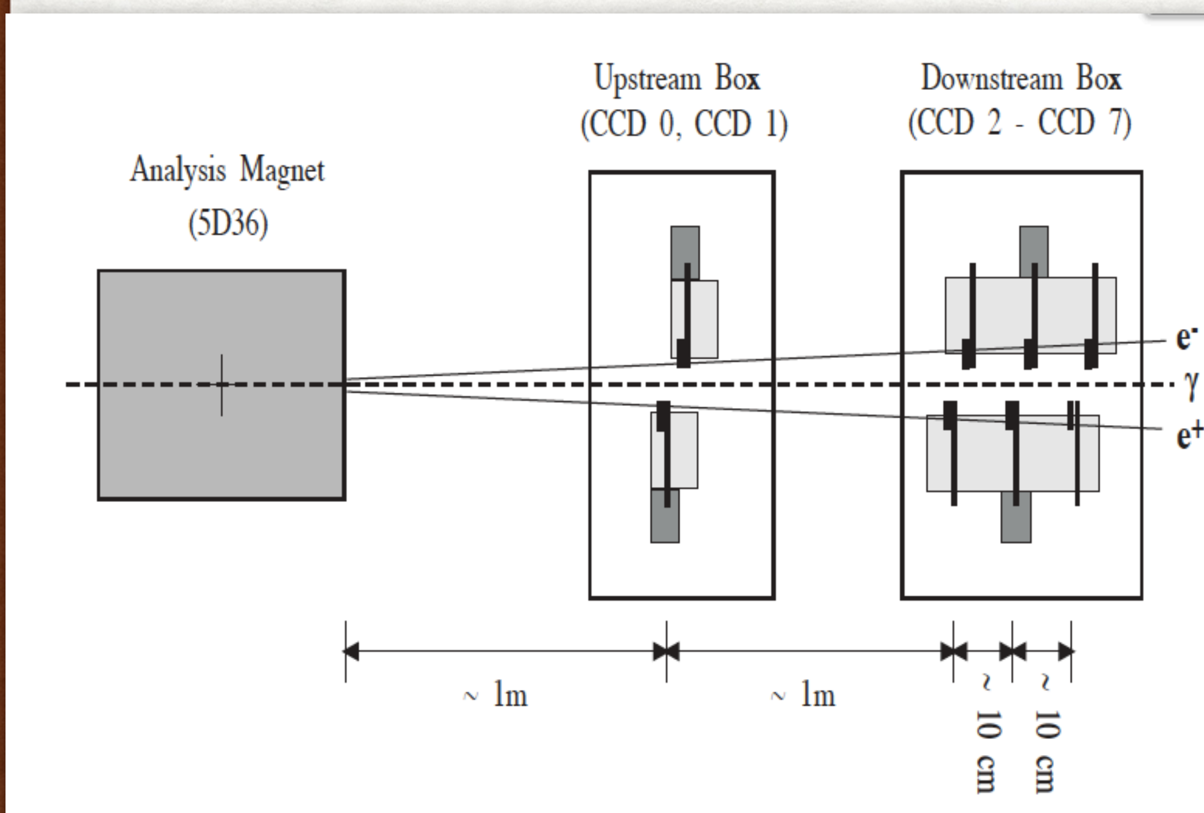
A web database which can be used to calculate photon cross sections for scattering, photoelectric absorption and pair production, as well as total attenuation coefficients, for any element, compound or mixture ($Z \leq 100$), at energies from 1 keV to 100 GeV.



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

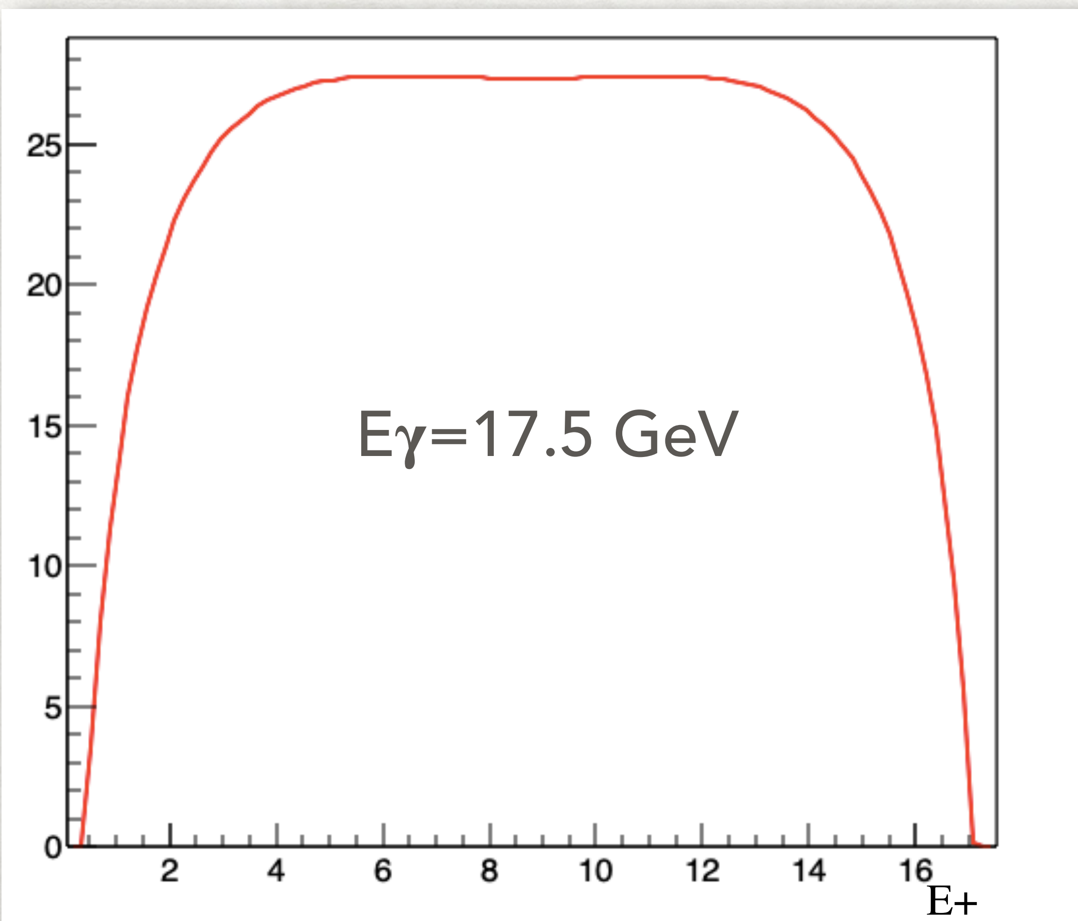
[EEV, 1242*1152].

THE CLASSICAL BETHE-HEITLER PAIR SPECTRUM

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

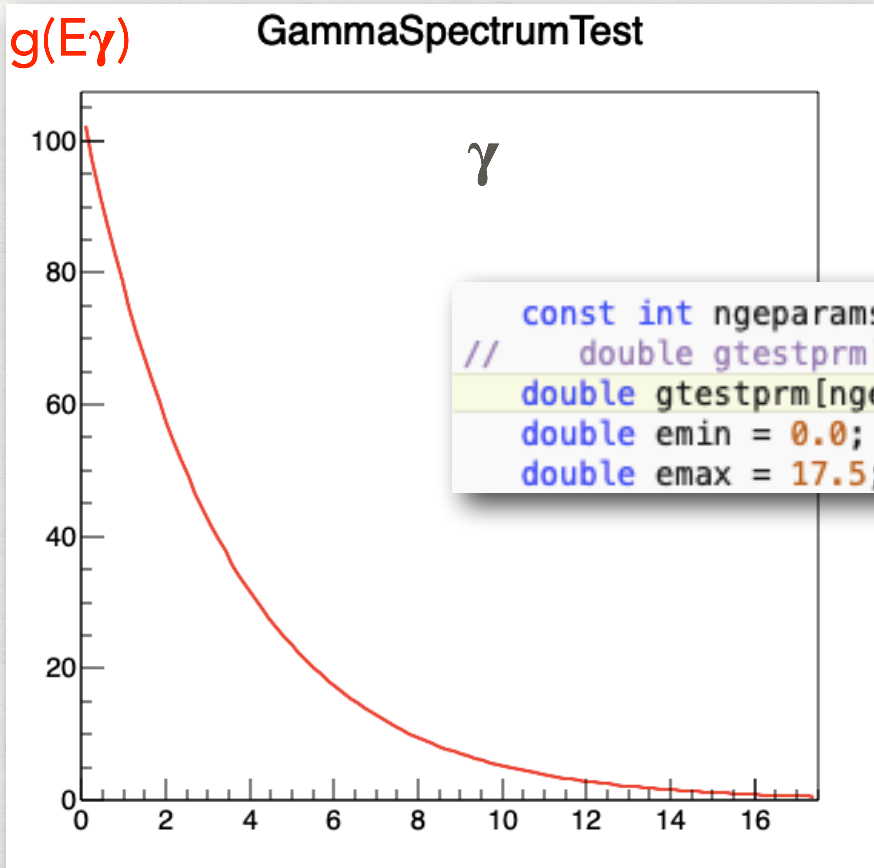
$$\Phi\,(E_0)\,dE_0 = \frac{Z^2}{137}\left(\frac{e^2}{mc^2}\right)^2 4\,\frac{E_0{}^2 + E_+{}^2 + \frac{2}{3}E_0E_+}{(h\nu)^3}\,dE_0\left(\log\frac{2E_0E_+}{h\nu mc^2} - \frac{1}{2}\right).$$

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

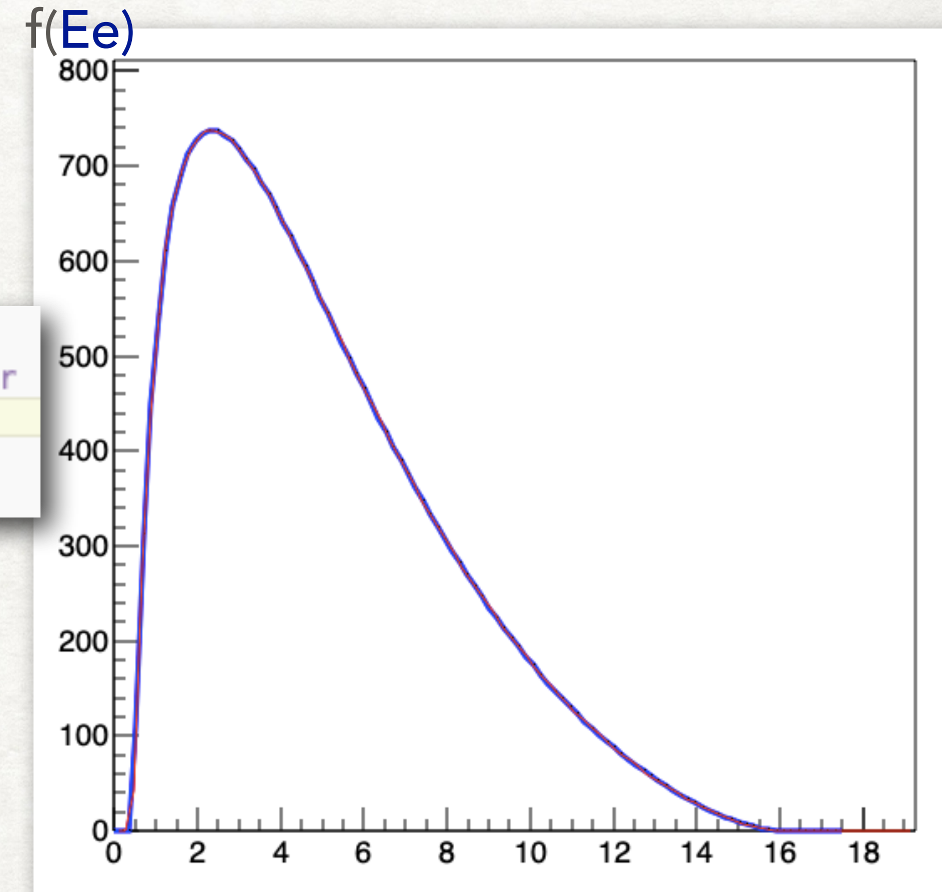
TESTING: EXPONENTIAL



BH

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

```
   const int ngeparams = 2;
//     double gtestprm[ngeparams] = {100.0, 17.5};   // linear
   double gtestprm[ngeparams] = {105.0, 0.3};    // exp
   double emin = 0.0;
   double emax = 17.5;
```

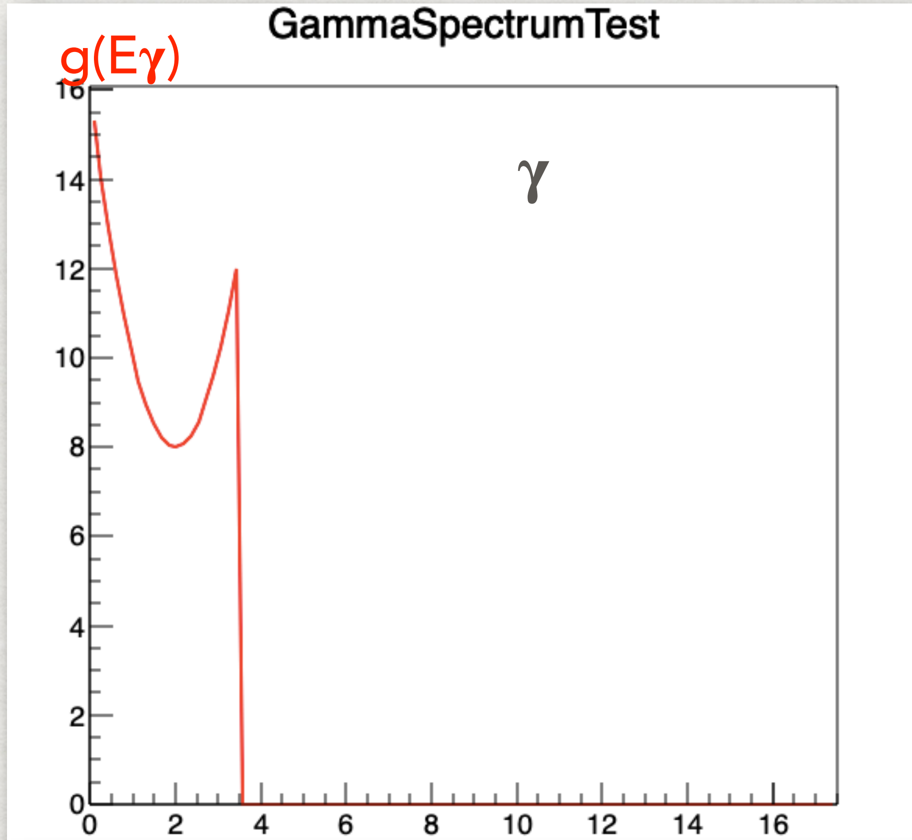


$\int \sigma(E\gamma, Ee) g(E\gamma, p1, p2) dE\gamma$

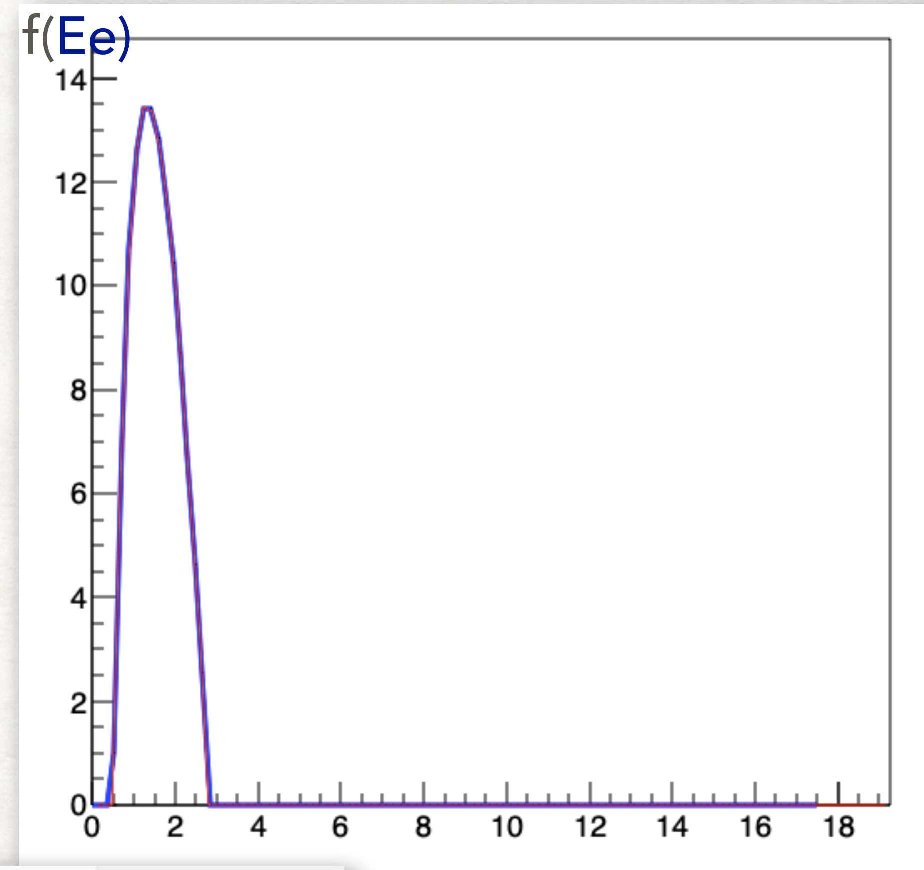
fitting allows finding the parameters with high precision

```
****************************************
Minimizer is Minuit / Migrad
Chi2                      =  8.52694e-11
NDf                       =           98
Edm                       =  1.70646e-10
NCalls                    =          167
p0                        =          105   +/-   1.72634e-07
p1                        =          0.3   +/-   1.73966e-10
```

TESTING: COMPTON-LIKE



$E_e = \int \sigma(E_\gamma, E_e) g(E_\gamma) dE_\gamma$




```
//    double gtestprm[ngeparams] = {100.0, 17.5};  // linear
//    double gtestprm[ngeparams] = {105.0, 0.3};   // exp
  const int ngeparams = 3;    double gtestprm[ngeparams] = {2.0, 2.0, 8.0};  // parabola like Compton
```

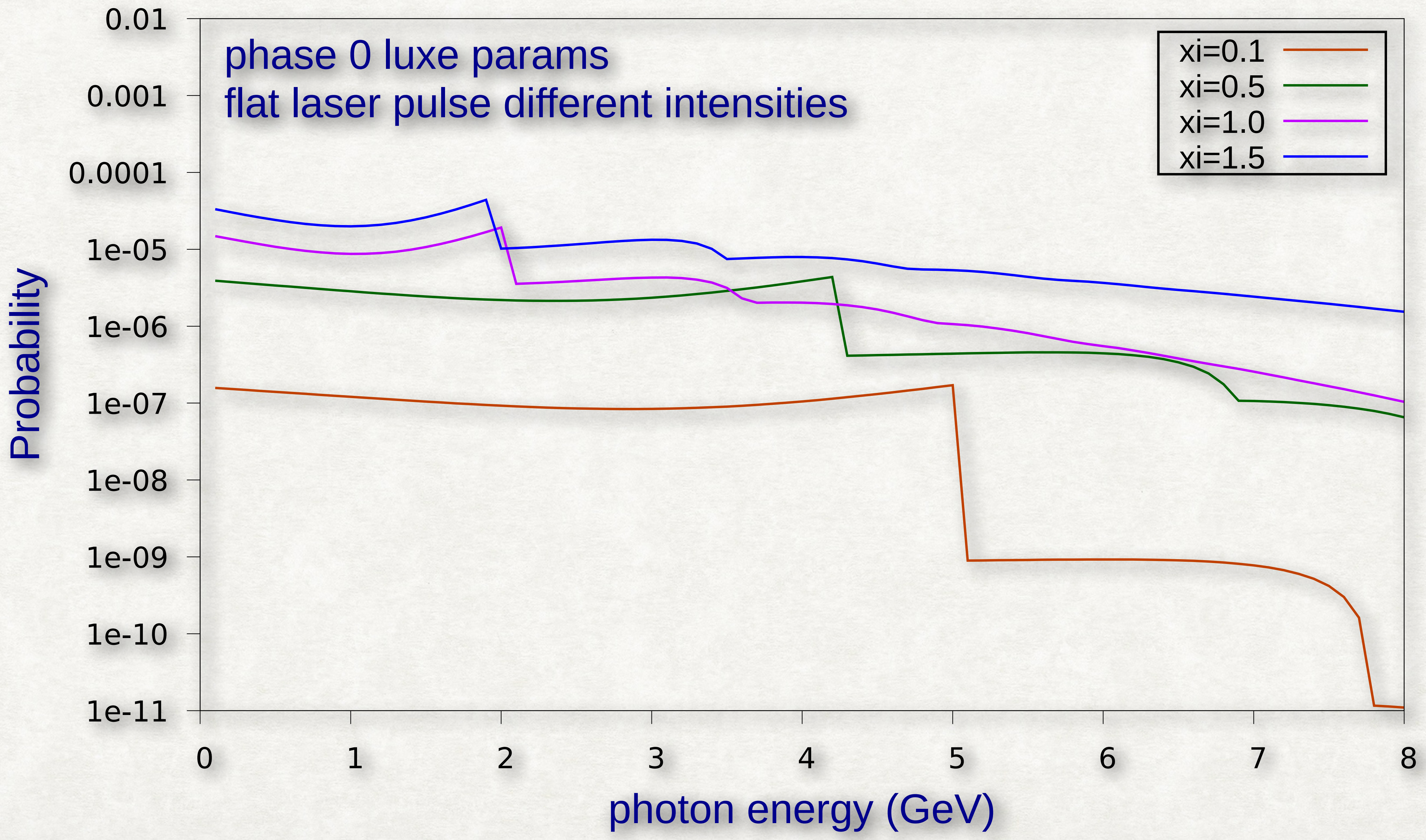
$\int \sigma(E_\gamma, E_e) g(E_\gamma, p1, p2) dE_\gamma$

fitting allows finding the parameters quite well :

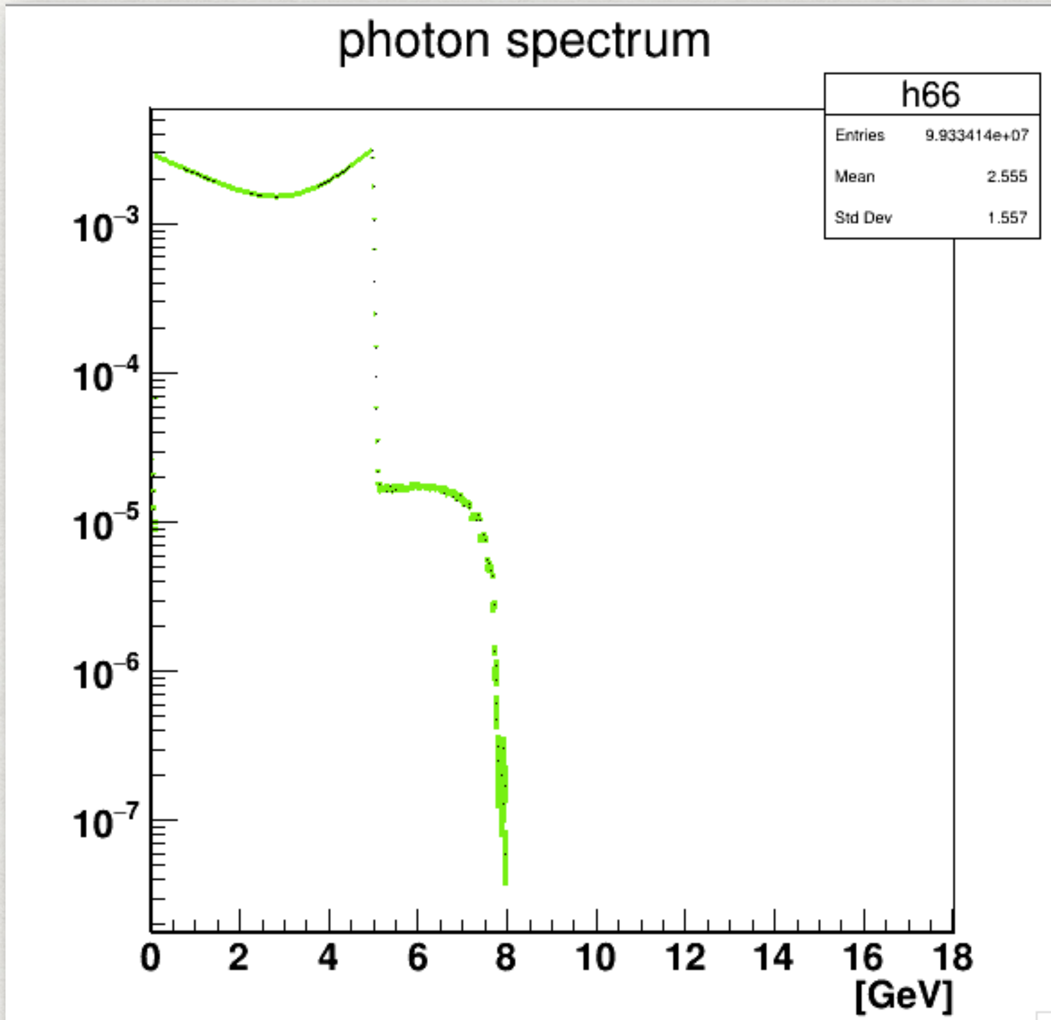
```
****************************************
Minimizer is Minuit / MigradImproved
Chi2                      =  5.92197e-07
NDf                       =           97
Edm                       =  1.27179e-06
NCalls                    =          342
p0                        =       1.9899   +/-   0.00109921
p1                        =      1.99569   +/-   0.000468708
p2                        =      7.99435   +/-   0.000639219
```

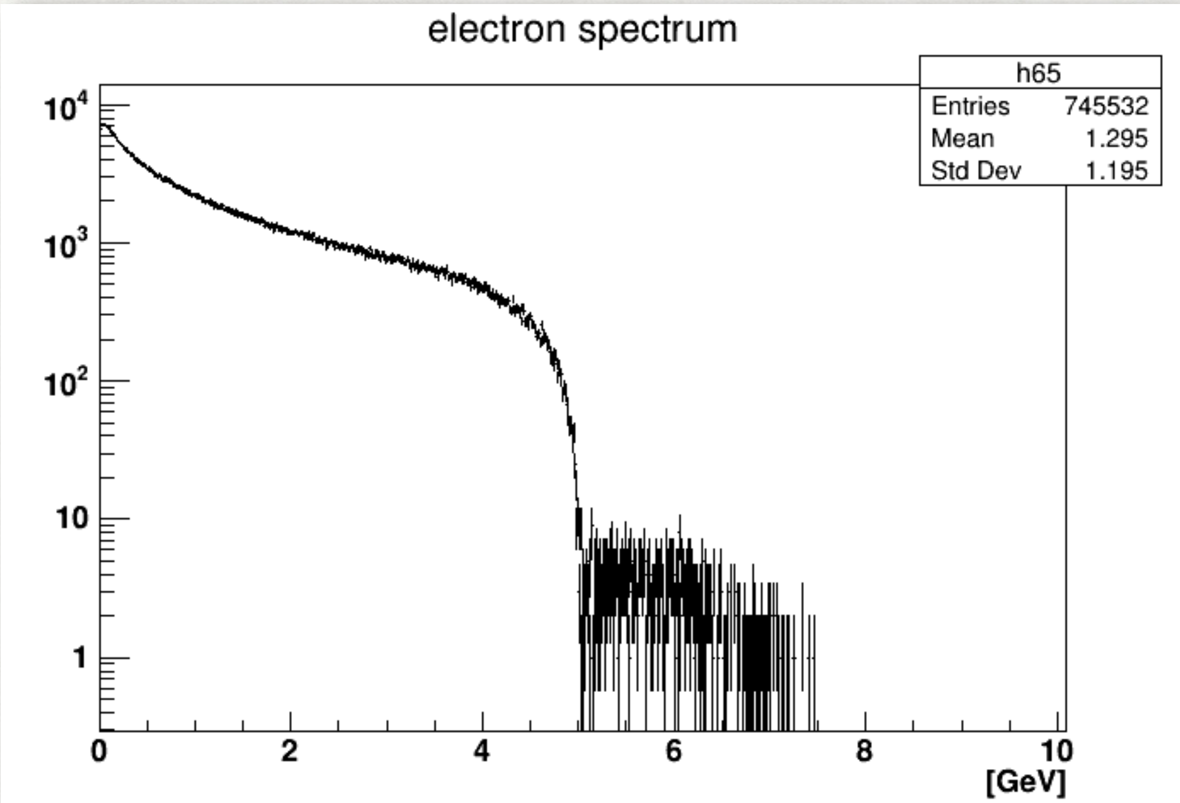
PHOTON SPECTRA VS LASER INTENSITIES

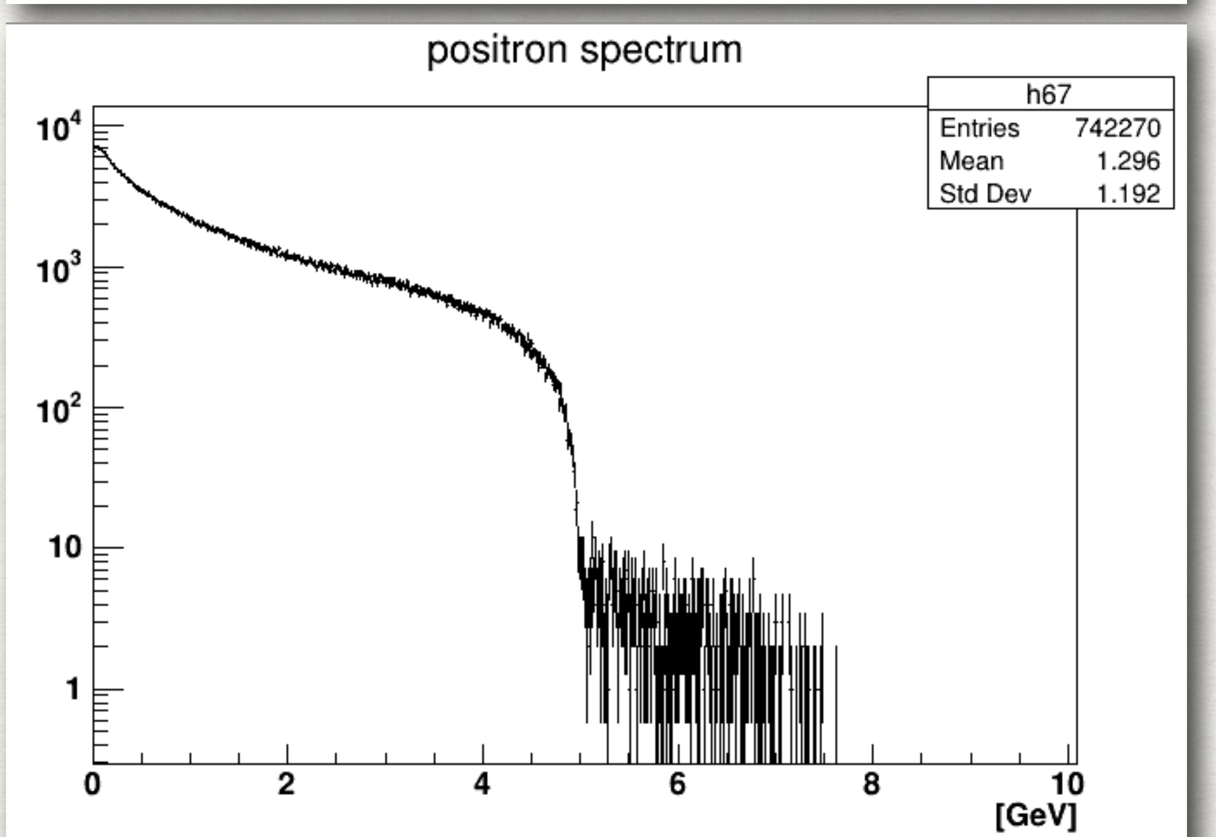
- plot from Anthony



FORWARD PHOTONS IN GEANT4



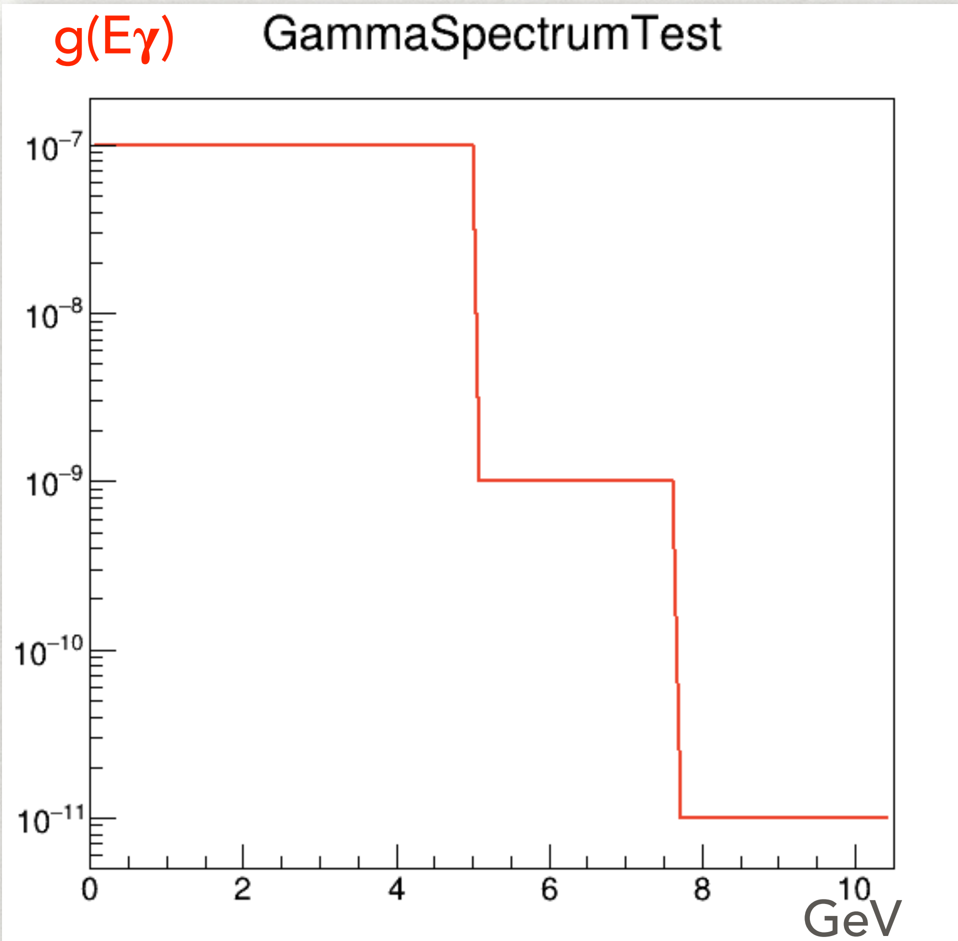


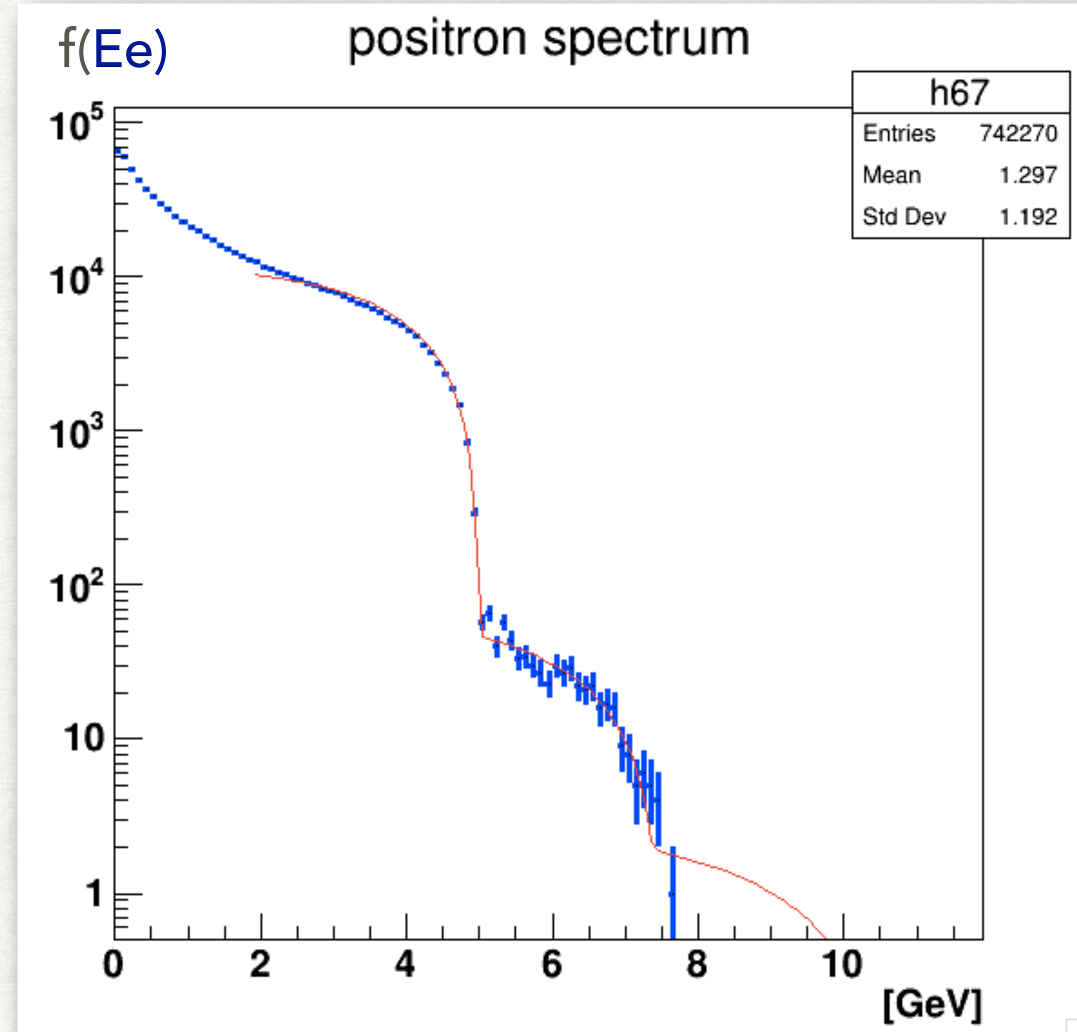


target: Tungsten, 0.35 um
1e8 photons

TESTING: COMPTON-LIKE

$E_e = \int \sigma(E_\gamma, E_e)\, g(E_\gamma)\, dE_\gamma$





$\int \sigma(E_\gamma, E_e)\, g(E_\gamma, p1, p2)\, dE_\gamma$

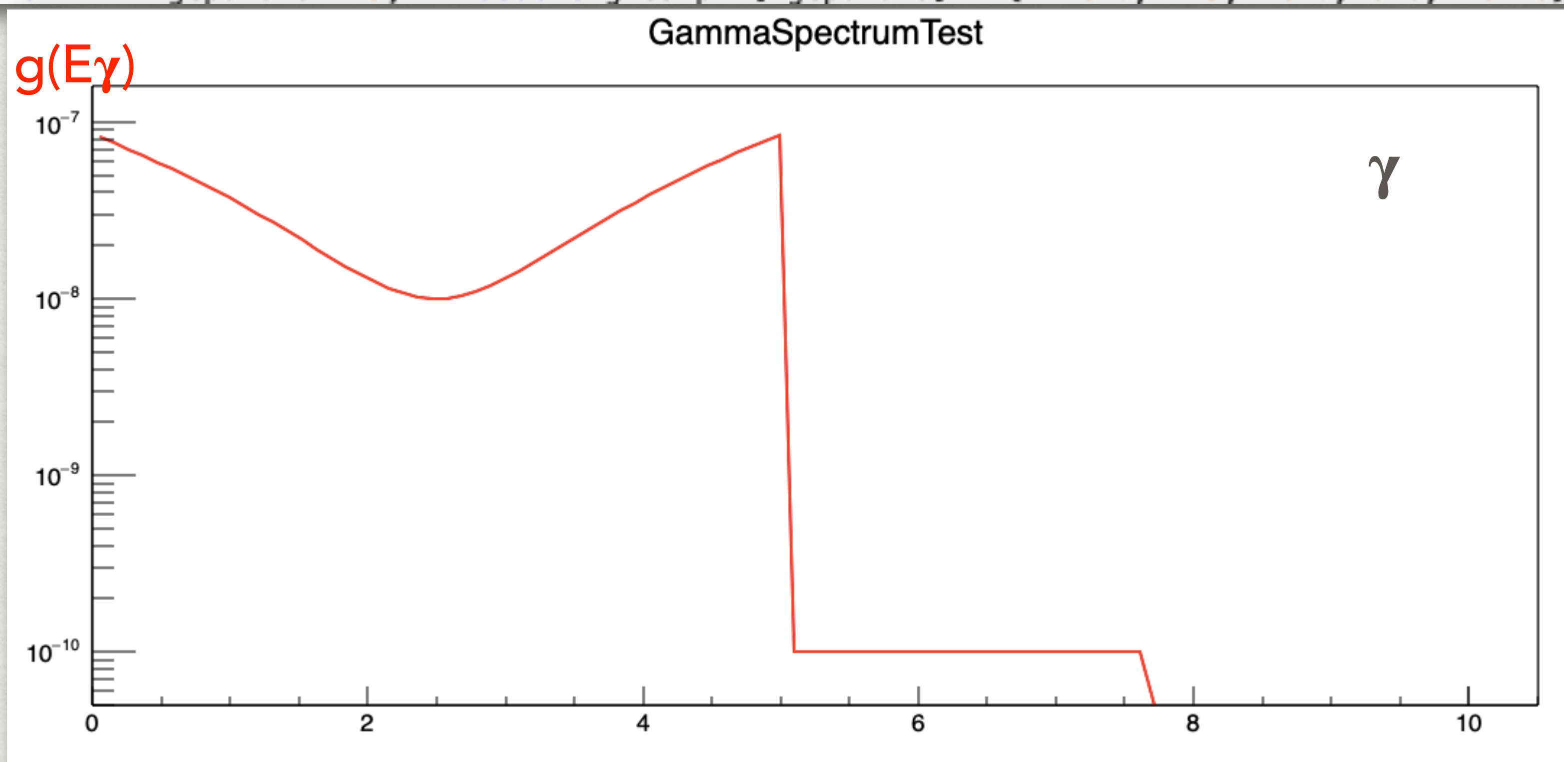
fitting allows finding the parameters quite well :

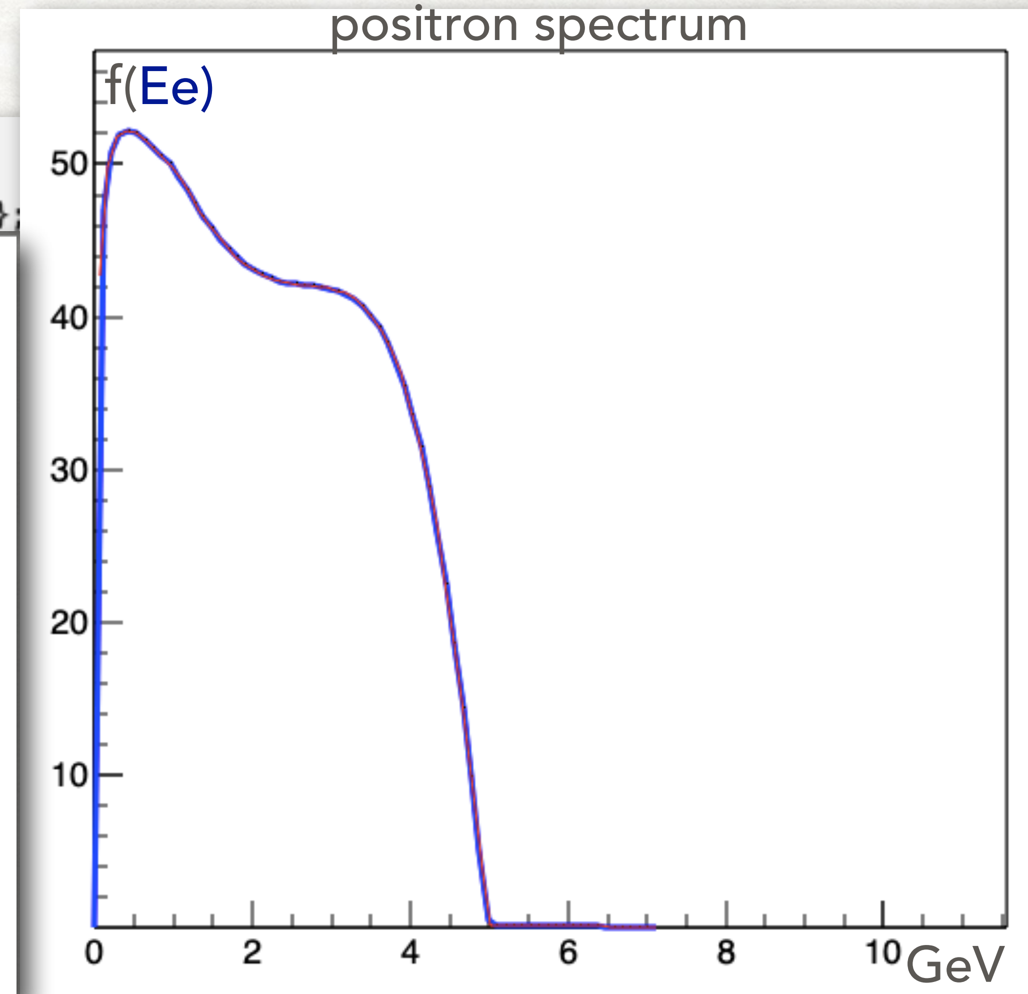
```
FCN=1309.19 FROM HESSE     STATUS=OK            39 CALLS         442 TOTAL
                    EDM=9.77144e-09    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                                 STEP         FIRST
 NO.   NAME      VALUE            ERROR         SIZE      DERIVATIVE
  1  p0         0.00000e+00     fixed
  2  p1         3.71863e-05   1.18274e-07   7.47299e-08  -9.55179e+00
  3  p2         5.00872e+00   2.75457e-03   2.31805e-06   2.53148e-02
  4  p3         0.00000e+00     fixed
  5  p4         1.02419e-07   7.39607e-09   7.48765e-08** at limit **
  6  p5         7.38500e+00   8.55688e-02   1.42343e-05  -1.88485e-03
  7  p6         2.16581e-09   1.14383e-09   3.41734e-06   8.55195e-03
```

TESTING: COMPTON-LIKE

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

```
    double gtestprm[ngeparams] = {100.0, 17.5};   // linear
    double gtestprm[ngeparams] = {105.0, 0.3};    // exp
const int ngeparams = 5;     double gtestprm[ngeparams] = {1.2e-8, 2.5, 1e-8, 0.0, 1e-10};
```





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

fitting allows finding the parameters quite well :

```
******************************************
Minimizer is Minuit / MigradImproved
Chi2                      =  6.09809e-07
NDf                       =           96
Edm                       =  1.21973e-06
NCalls                    =          404
p0                        =  1.20003e-08   +/-   6.73267e-14
p1                        =      2.50003   +/-   5.02686e-06
p2                        =  1.00002e-08   +/-   5.23111e-14
p3                        =            0                        (fixed)
p4                        =  9.99282e-11   +/-   1.04159e-14
```