Compton events in simulation

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Input Parameters

Cross section calculation

```
// Laser variables:
Elaser 1.5498E-9    // photon energy in GeV (800nm -> 1.5498eV)
Epulse 2.5e6        // energy per laser pulse in uJ  (should be 5E6)
alpha 0.3           // crossing angle in radian
sigmaxy 10.         // transverse size of pulse in um(round profile assumed!)
sigmaz  0.025       // longitudinal size of pulse in ps

nbxflip 2           // number of BXs between flips of laser helicity

// // Beam variables:
Ee 17.5         // beam energy in GeV
PX 0.0           // horizontal transverse polarisation
PY 0.0           // vertical transverse polarisation
PZ 0.0           // longitudinal polarisation
nelectron 6.25E+9  // number of electrons per bunch XFEL according to Matthew's talk
nbunch 1          // number of bunches per train
ttrain 1.0e3      // duration of bunch train in ms  (3250 bunches * 200ns bunch spacing)
// XFEL according to Mathew's talk
esigmax 0.030      // horizontal beam size in mm
esigmay 0.030      // vertical beam size   in mm
esigmaz 0.334      // longitudinal beam size in ps  (XFEL sigma_z = 20 um ; t = sigma_z / 300 um  * ps)
```

Luminosity → Number of events

Average number of Compton events

```
// integr. Lumi fuer einen bunch = N_e * N_gamma * geometry factor
double lumi = ebeam.getNElectron() * laser.getNgamma() * laser.getGeometryFactor();
```

```
const double Laser::getGeometryFactor() {
  //[sigmaz] = ps => in um: sigmaz*c = sigmaz * 10^-12 * 3*10^8 = sigmaz * 300
  double ginv = 2*3.1415*sigmaxy*sigmaxy
                *sqrt(1+pow(0.5*alpha*sigmaz*300./sigmaxy,2.));
  return 1./ginv;
};

const double Laser::getFullGeometryFactor(double sigmaxe, double sigmaye, double sigmaze) {
   // for small crossing angle, but non-negligible size of electron beam
  //[sigmaz] = [sigmaze] = ps => in um: sigmaz*c = sigmaz * 10^-12 * 3*10^8 = sigmaz * 300
  double ginv = 2*3.1415*sqrt(sigmaxe*sigmaxe+sigmaxy*sigmaxy)
                *sqrt((sigmaye*sigmaye+sigmaxy*sigmaxy)+(sigmaze*sigmaze+sigmaz*sigmaz)*pow(0.5*alpha*300.,2.));
  return 1./ginv;
};
```

$$\mathcal{L} = \frac{N_1 N_2 f N_b}{4\pi\sigma_x\sigma_y} \cdot S\,.$$

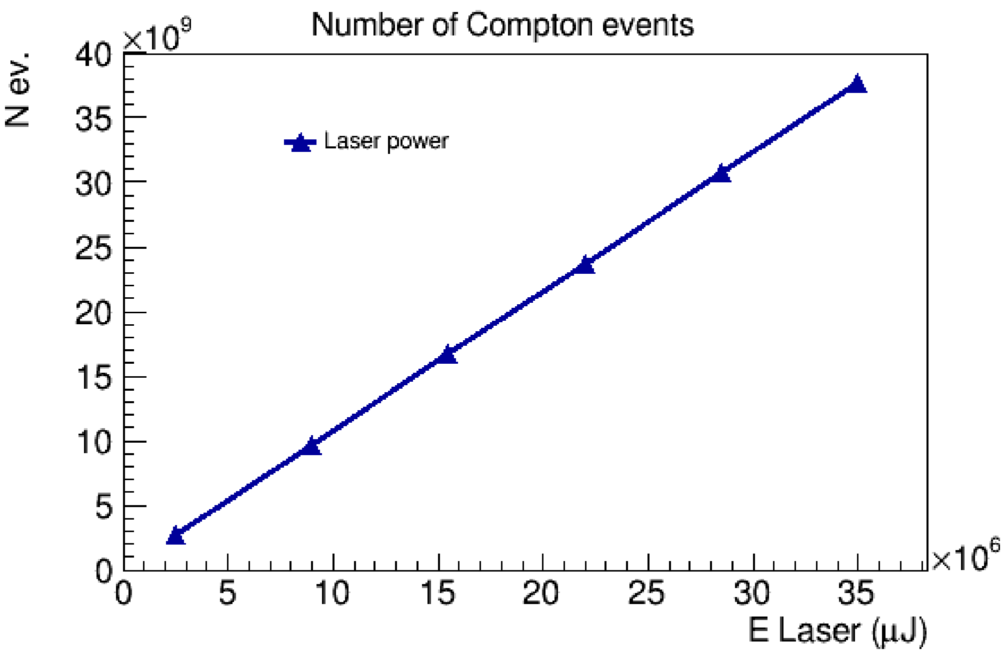
$$\frac{1}{\sqrt{1+(\frac{\sigma_x}{\sigma_s}\tan\frac{\phi}{2})^2}}\frac{1}{\sqrt{1+(\frac{\sigma_s}{\sigma_x}\tan\frac{\phi}{2})^2}}\,.$$

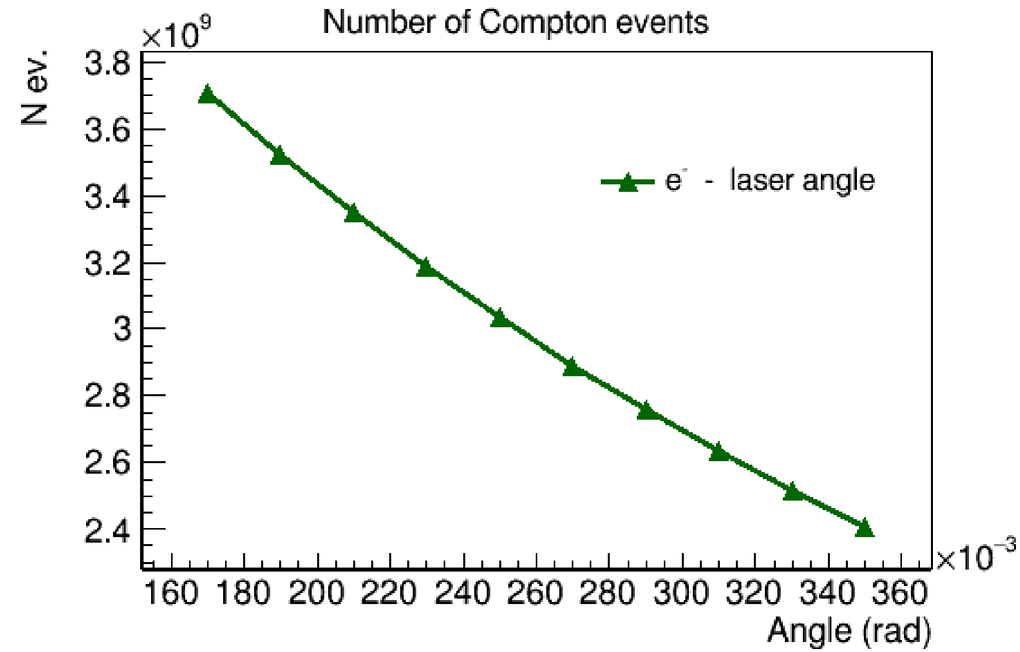
For small crossing angles and $\sigma_s \gg \sigma_{x,y}$ we can simplify the formula to:

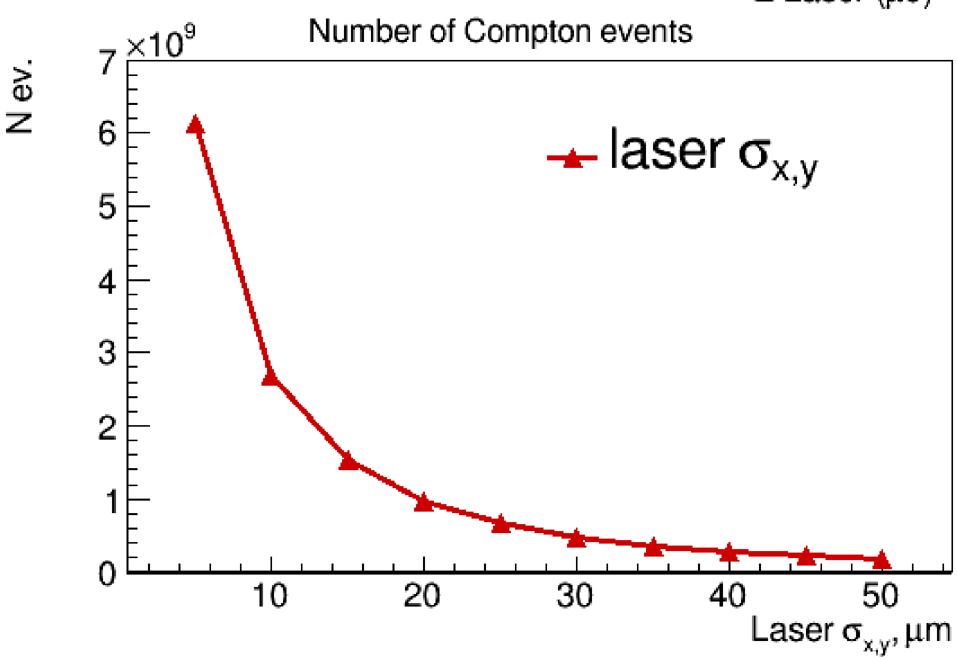
$$S = \frac{1}{\sqrt{1+(\frac{\sigma_s}{\sigma_x}\tan\frac{\phi}{2})^2}} \approx \frac{1}{\sqrt{1+(\frac{\sigma_s}{\sigma_x}\frac{\phi}{2})^2}}\,.$$

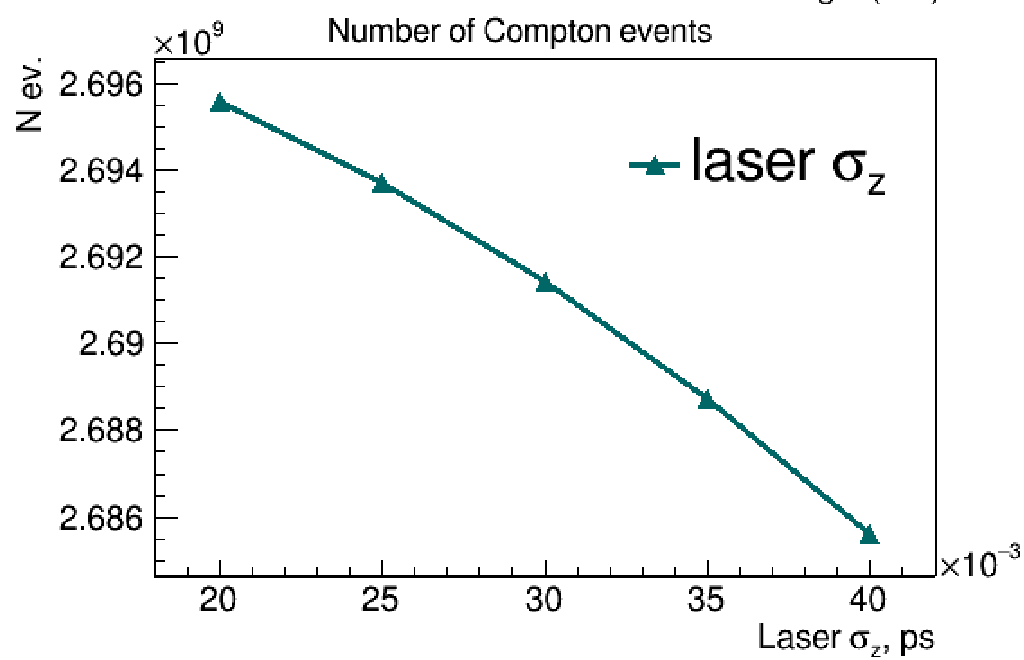
$$\mathcal{L} = \frac{N_1 N_2 f N_b}{2\pi\sqrt{\sigma_{1x}^2+\sigma_{2x}^2}\sqrt{\sigma_{2y}^2+\sigma_{2y}^2}}$$

Number of Compton events

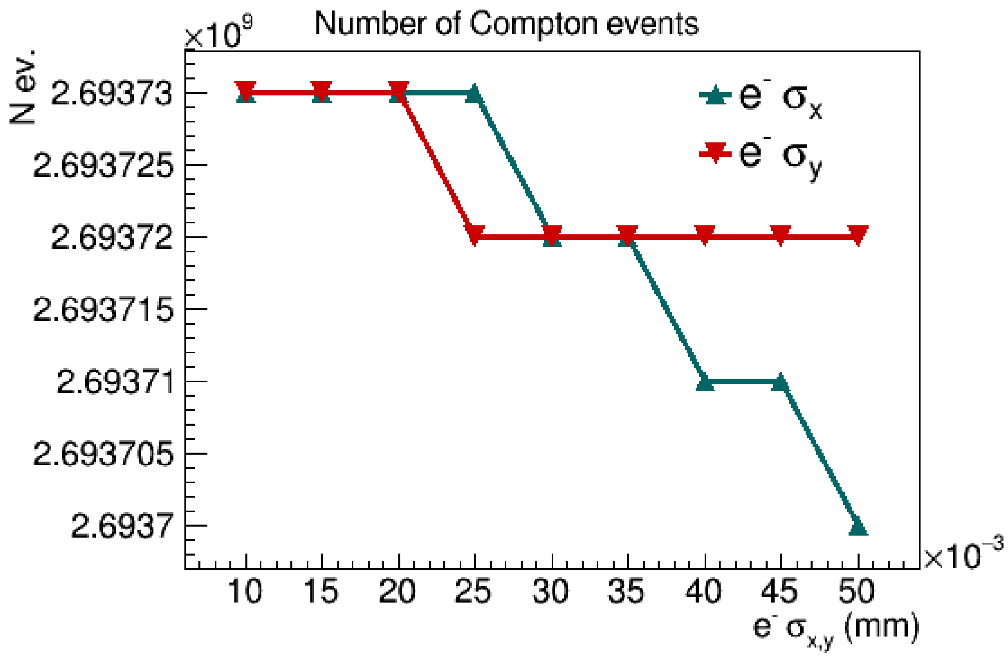


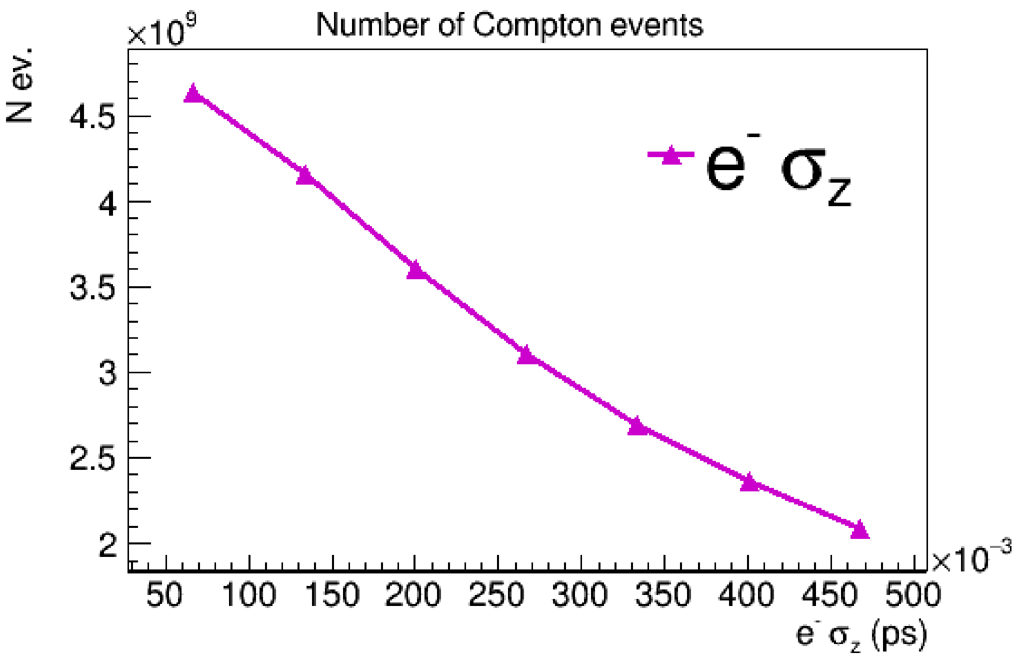






Number of Compton events






```
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```
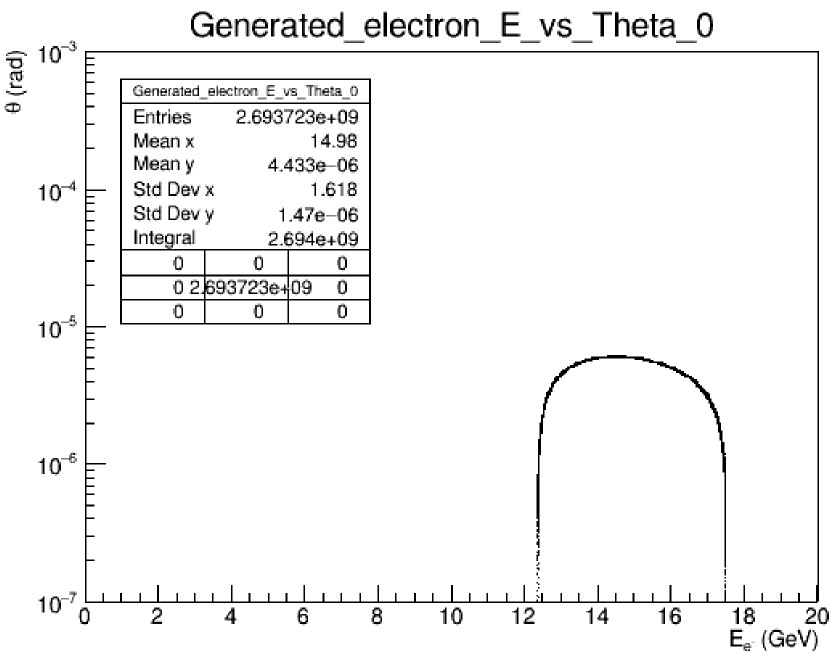
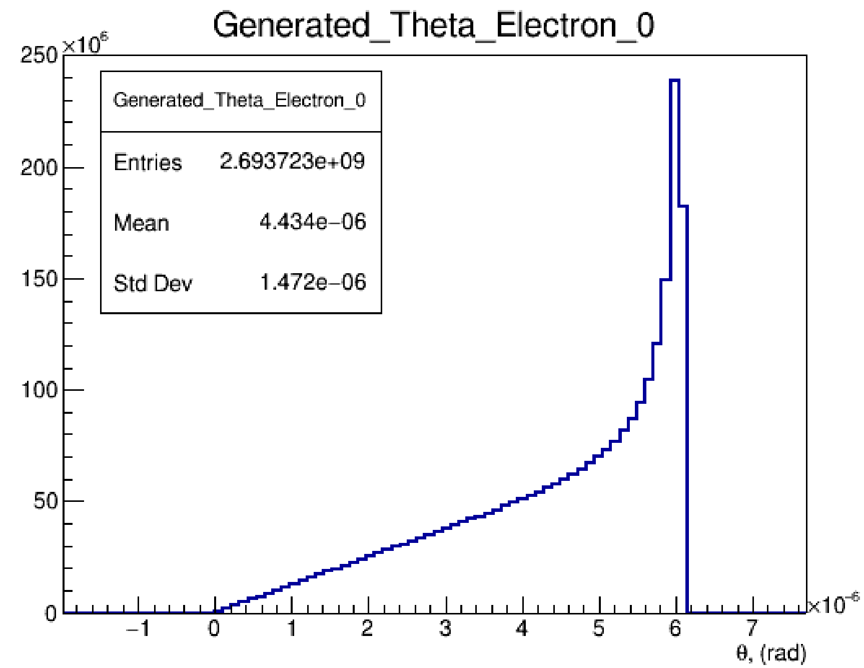
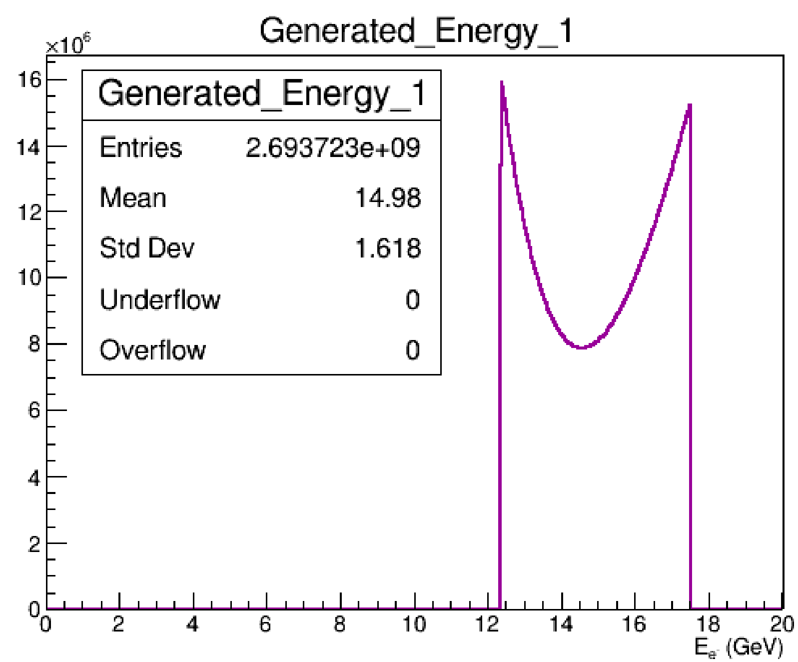

Different units.
While the numbers are used as they are for luminosity calculation (slide 2)

Electrons after interaction

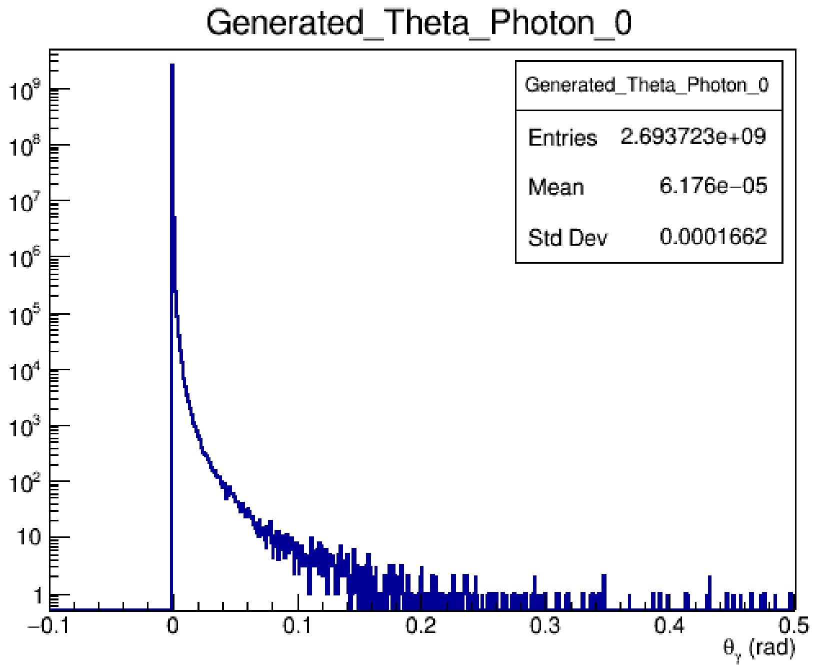


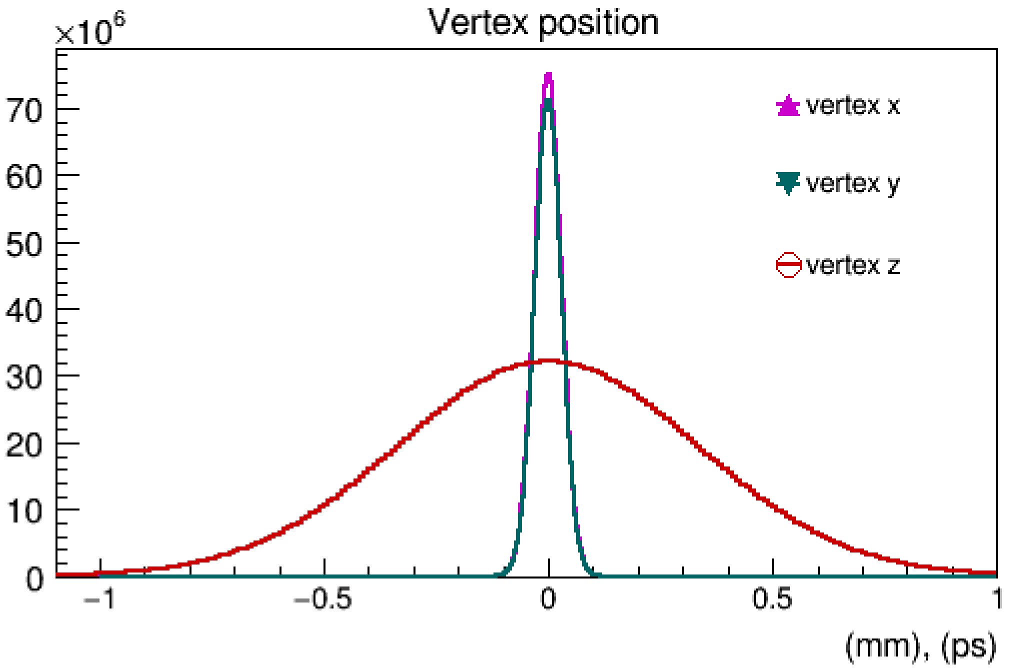




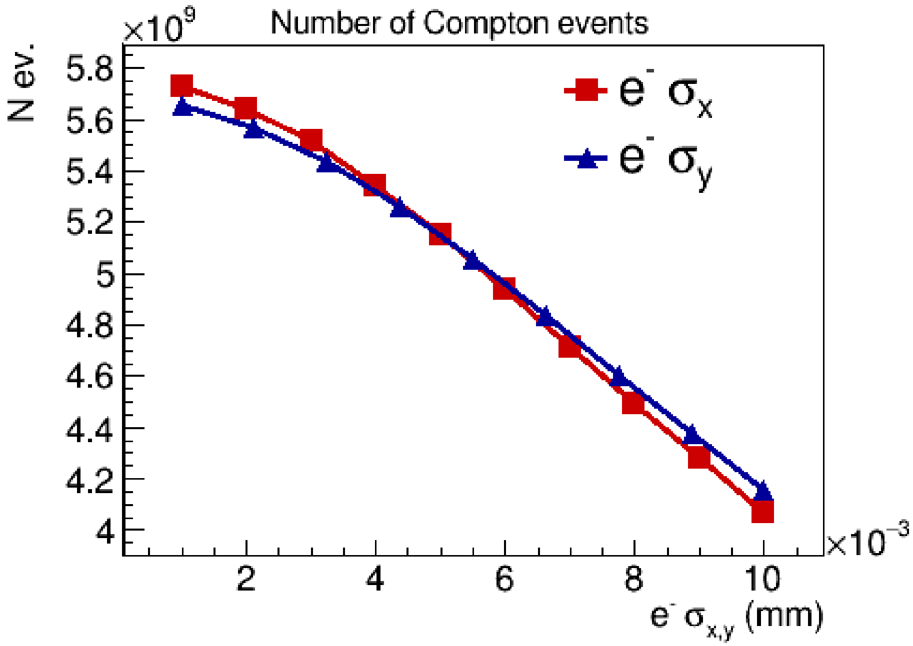
Integrated over azimuthal angle

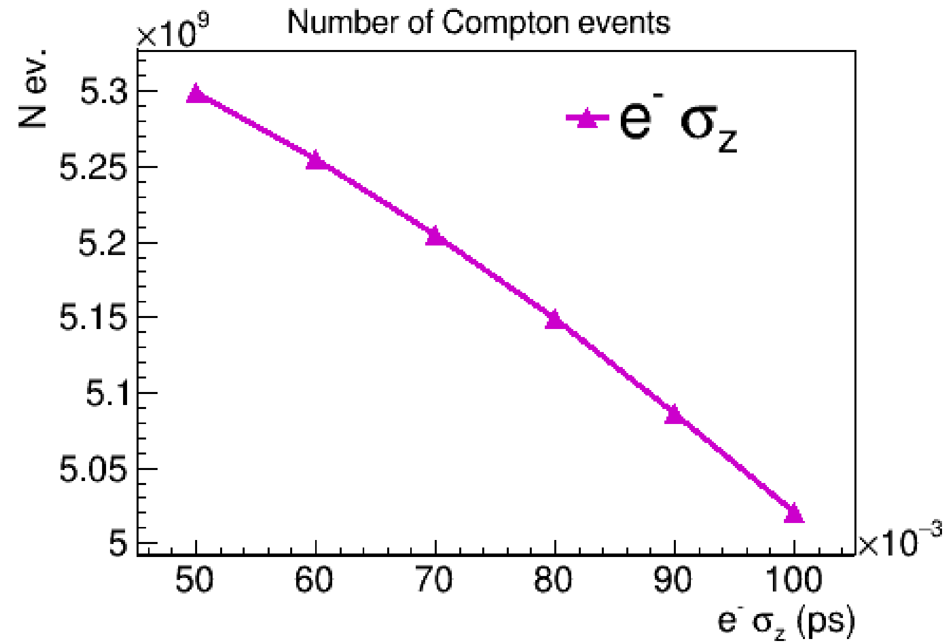
Photons and vertex position

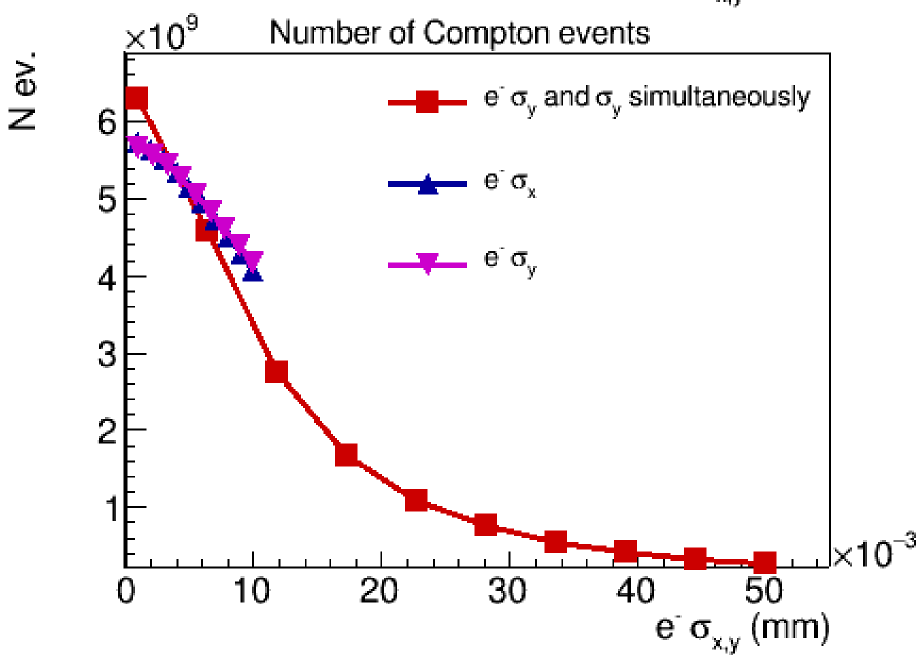


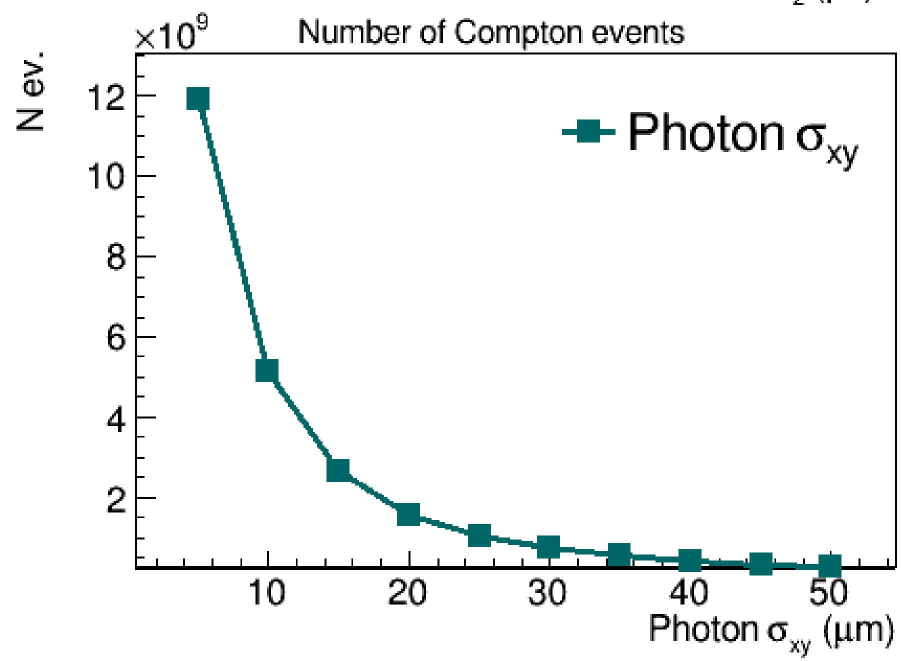


Number of Compton events (correct e^- beam $\sigma_{x,y}$ units)

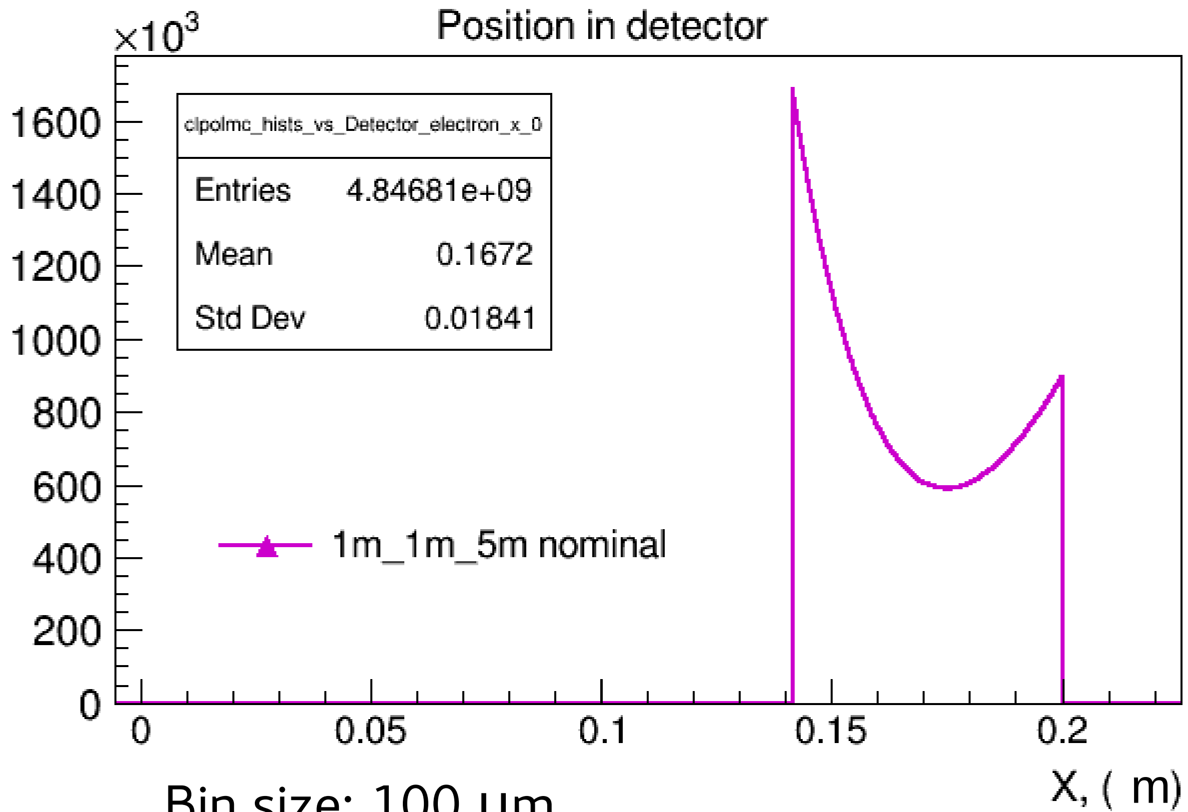






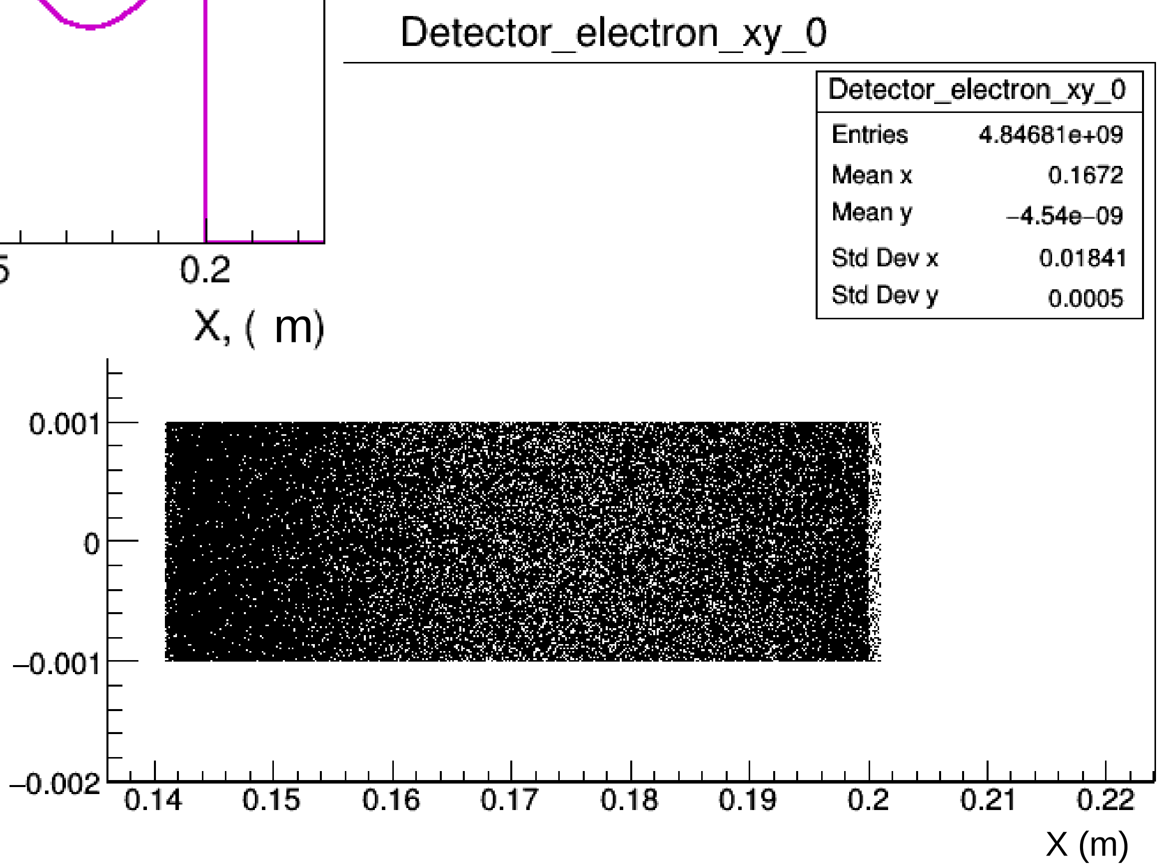


Electron transport though one magnet

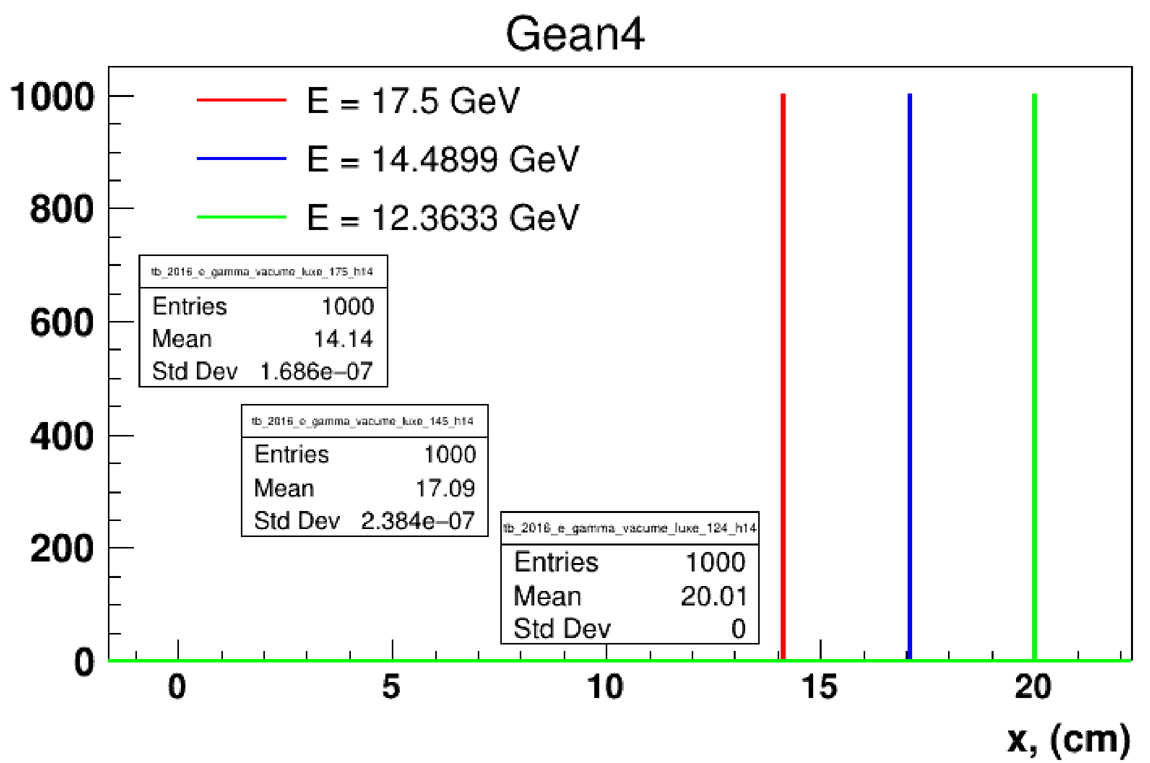


- 1 m drift
- 1 m magnet 1.5 T
- 5 m drift

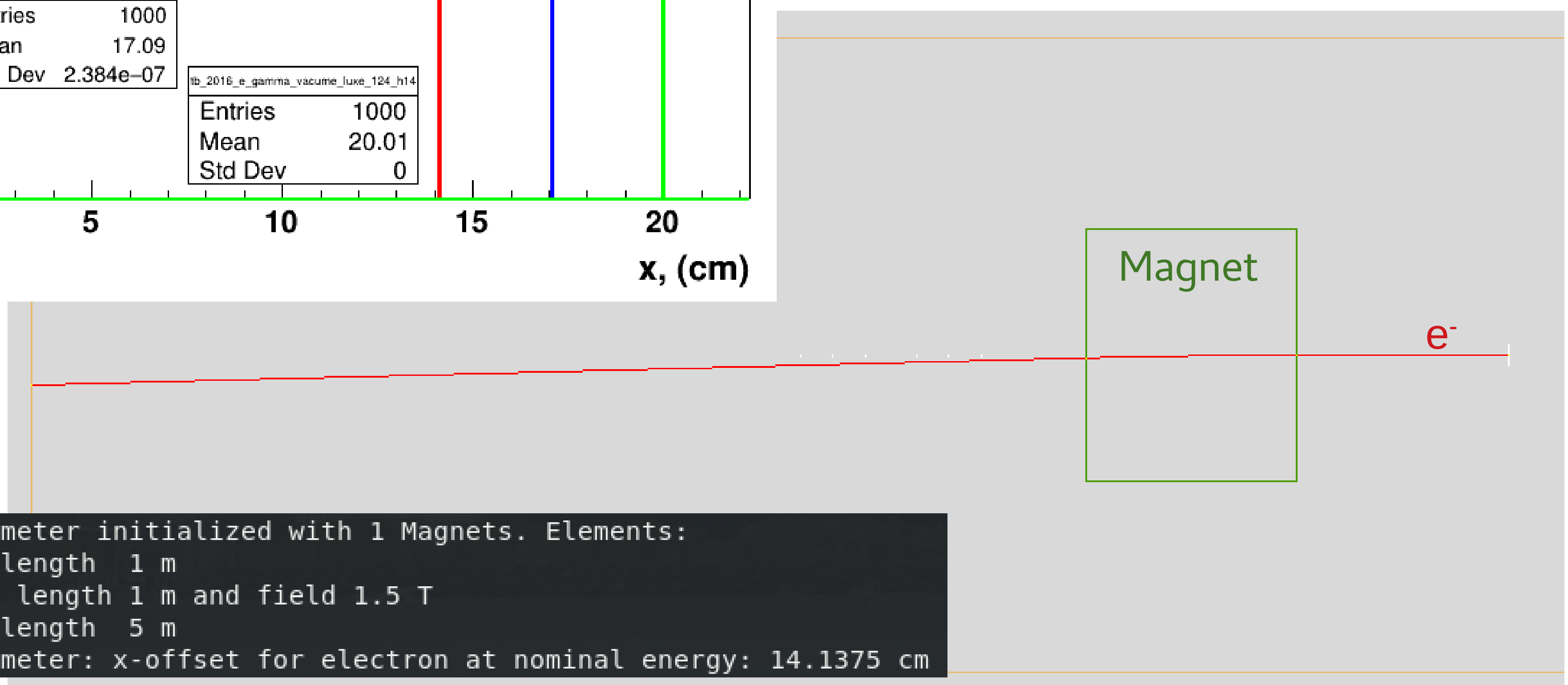
Bin size: 100 µm



Similar Geometry in Geant4



- 1 m drift
- 1 m magnet 1.5 T
- 5 m drift




```
ChicaneSpectrometer initialized with 1 Magnets. Elements:
   Drift with length  1 m
   Magnet with length 1 m and field 1.5 T
   Drift with length  5 m
ChicaneSpectrometer: x-offset for electron at nominal energy: 14.1375 cm
```

```
xOffset: 0.141375
## nominal position of Compton edge:  x_edge = 20.0177 cm
## nominal position of zero crossing: x_zero = 17.0769 cm
```

```
Eedge (electron) = 12.3633 GeV
```

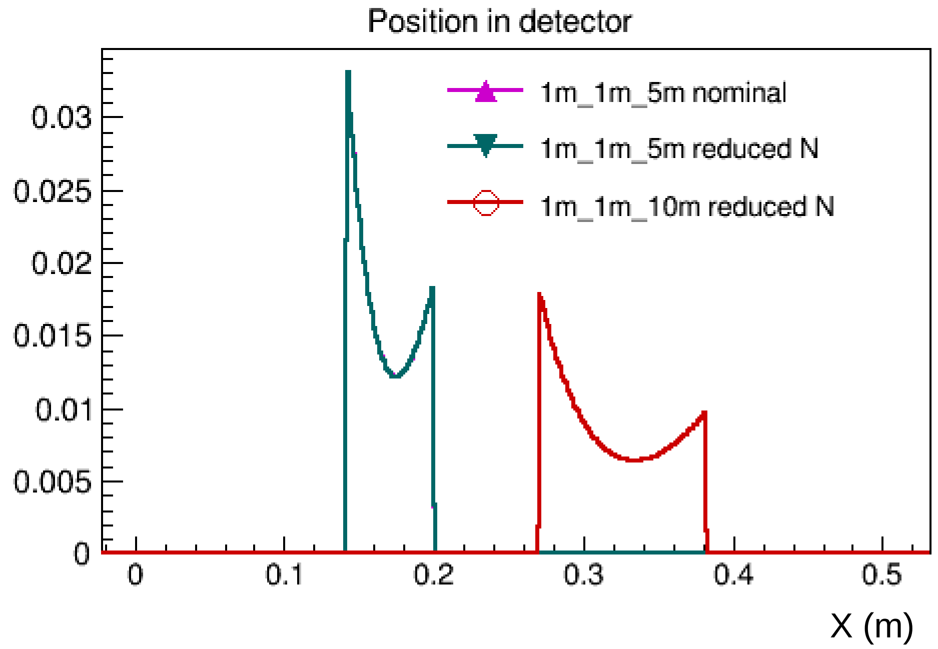
```
Ezero = 14.4899 GeV
```

Electron transport though one magnet

```
ChicaneSpectrometer initialized with 1 Magnets. Elements:
   Drift with length  1 m
   Magnet with length 1 m and field 1.5 T
   Drift with length  10 m
ChicaneSpectrometer: x-offset for electron at nominal energy: 26.99 cm
```

```
## nominal position of Compton edge:  x_edge = 38.2162 cm
## nominal position of zero crossing: x_zero = 32.6017 cm
```

- 1 m drift
- 1 m magnet 1.5 T
- 10 m and 5m drift



3 Magnets and energy scan

Particle transport from IP to Detector

Class ChicaneSpectrometer is used to calculate particle position as it goes from IP to detector

```
    ChicaneSpectrometer spectrometer= ChicaneSpectrometer(nm11, d11, m11, b11, var.getDValue("Ee"));
```

Definition of class ChicaneSpectrometer

```
// constructor
ChicaneSpectrometer::ChicaneSpectrometer(int Nmagnets_, double lengthD_[], double lengthM_[], double Bfield_[], double beamEnergy_){
```

```
    lengthD = new double[Nmagnets+1];
    lengthM = new double[Nmagnets];
//     Bfield  = new double[Nmagnets];
    Bc      = new double[Nmagnets];
```

```
    for(int i=0; i<Nmagnets; i++) {
       track_thru_drift(lengthD[i]);
       track_thru_magnet(lengthM[i],Bc[i],beamEnergy);
    }
    track_thru_drift(lengthD[Nmagnets+1]);
    xOffset = x;
```

Determine X position in detector

```
double ChicaneSpectrometer::getXELDET(double Ee, double THELEC, double PHELEC, double XELEC){
    // neglects ZELEC, assuming x >> z*tan(theta)
```

```
    return x-xOffset;
}
```

Magnets

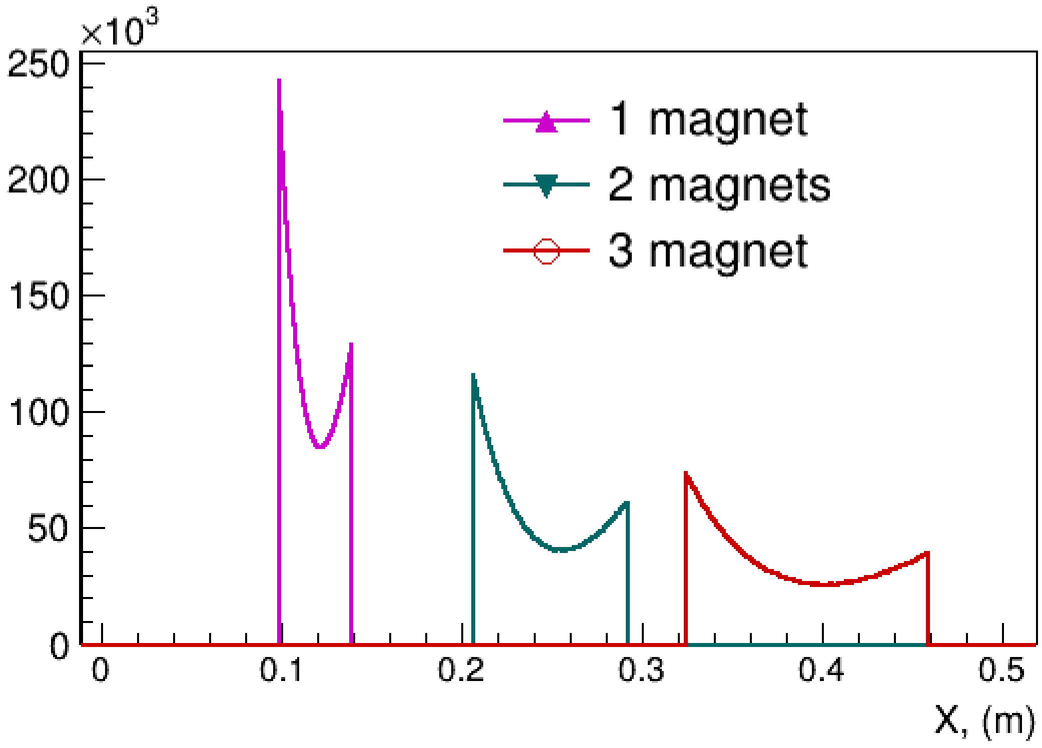
```
ChicaneSpectrometer initialized with 3 Magnets. Elements:
   Drift with length  1 m
   Magnet with length 0.5 m and field 1.12 T
   Drift with length  0.5 m
   Magnet with length 0.5 m and field 1.12 T
   Drift with length  0.5 m
   Magnet with length 0.5 m and field 1.12 T
   Drift with length  10 m
ChicaneSpectrometer: x-offset for electron at nominal energy: 32.3902 cm
##############################################################
```

Eedge (electron) = 12.3633 GeV

x_edge = 45.8655 cm

Code modified to allow simple settings in steer file for arbitrary number of magnets:

```
// // Setting parameters for Spectrometer
driftl    1.0     0.5     0.5    10.0
blength       0.5     0.5     0.5
bfield        1.12    1.12    1.12
```



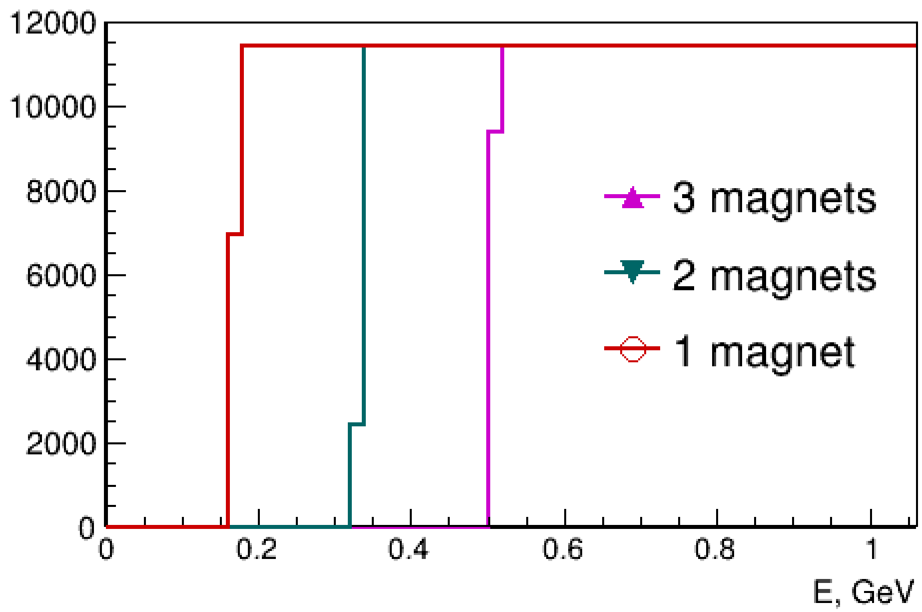
Particle transport through the magnet

class ChicaneSpectrometer,
function which calculate the position of the partical as it travels through the magnet

```
void ChicaneSpectrometer::track_thru_magnet(double l, double Bc_, double E){
```

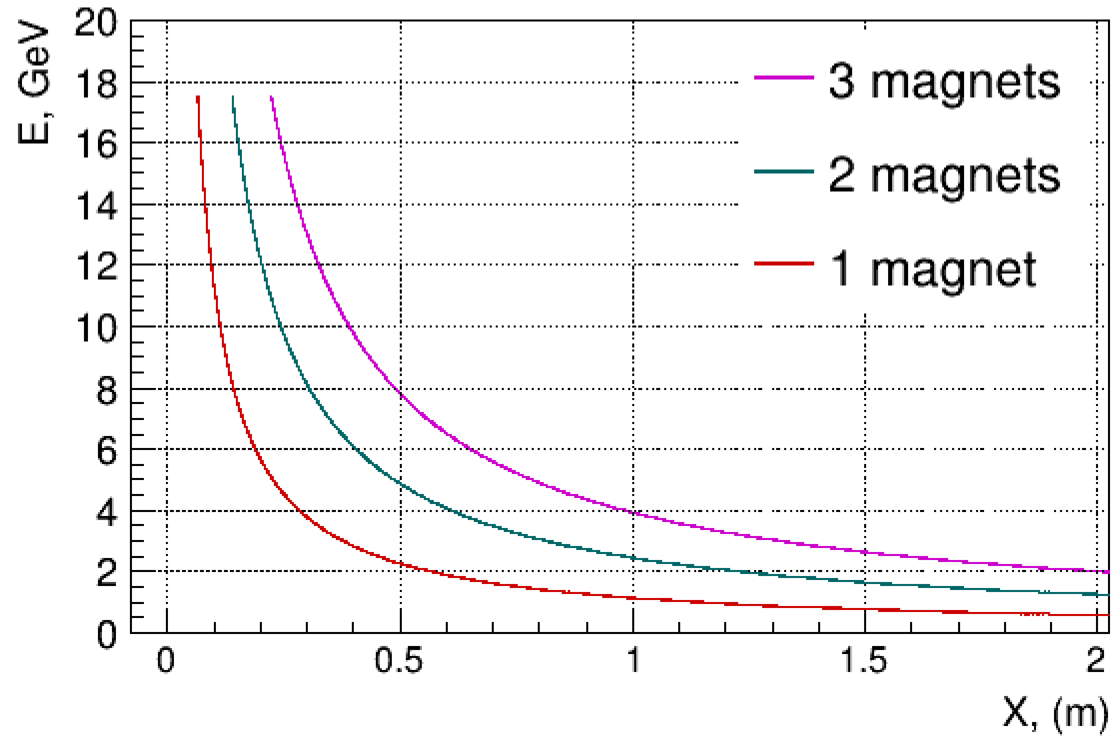
```
        // if this assertion fails, a particle might have made a U-turn in the magnet
        assert(sinAlphaNew<1. || sinAlphaNew>-1.);
        double cosAlphaNew = sqrt(1.-sinAlphaNew*sinAlphaNew);
```

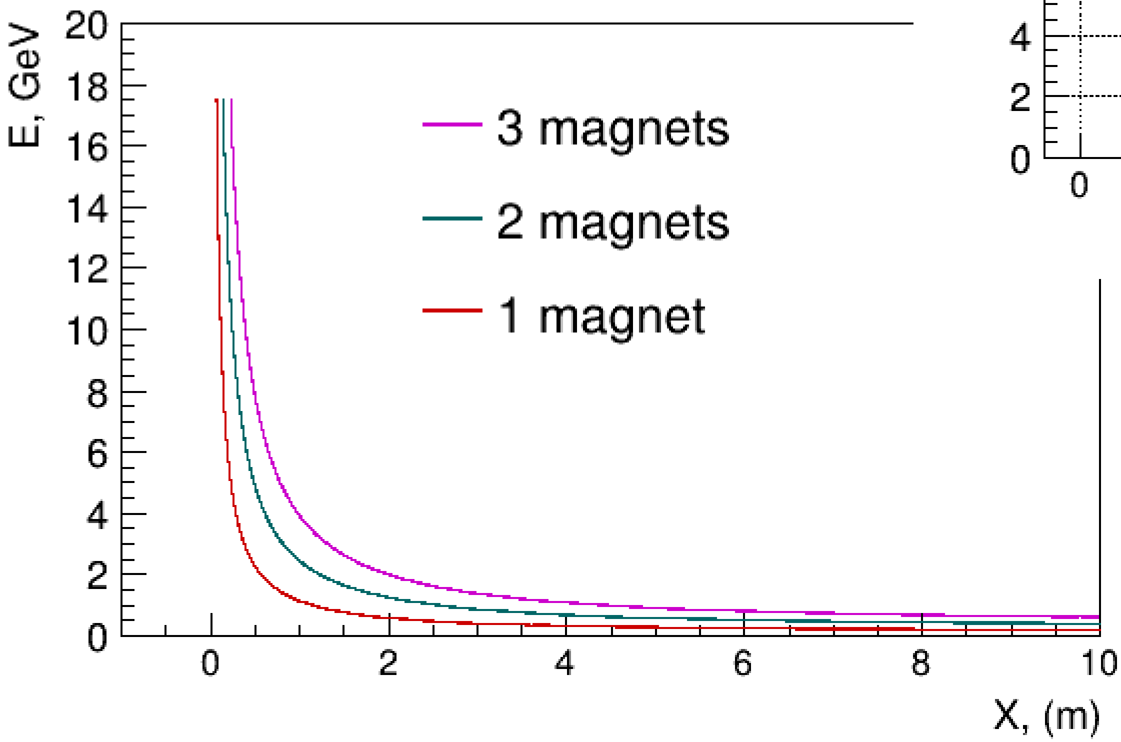
&&



Energy vs Position of electron in detector

// // Setting parameters for Spectrometer
driftl 1.0 0.5 0.5 6.5
blength 0.5 0.5 0.5
bfield 1.12 1.12 1.12



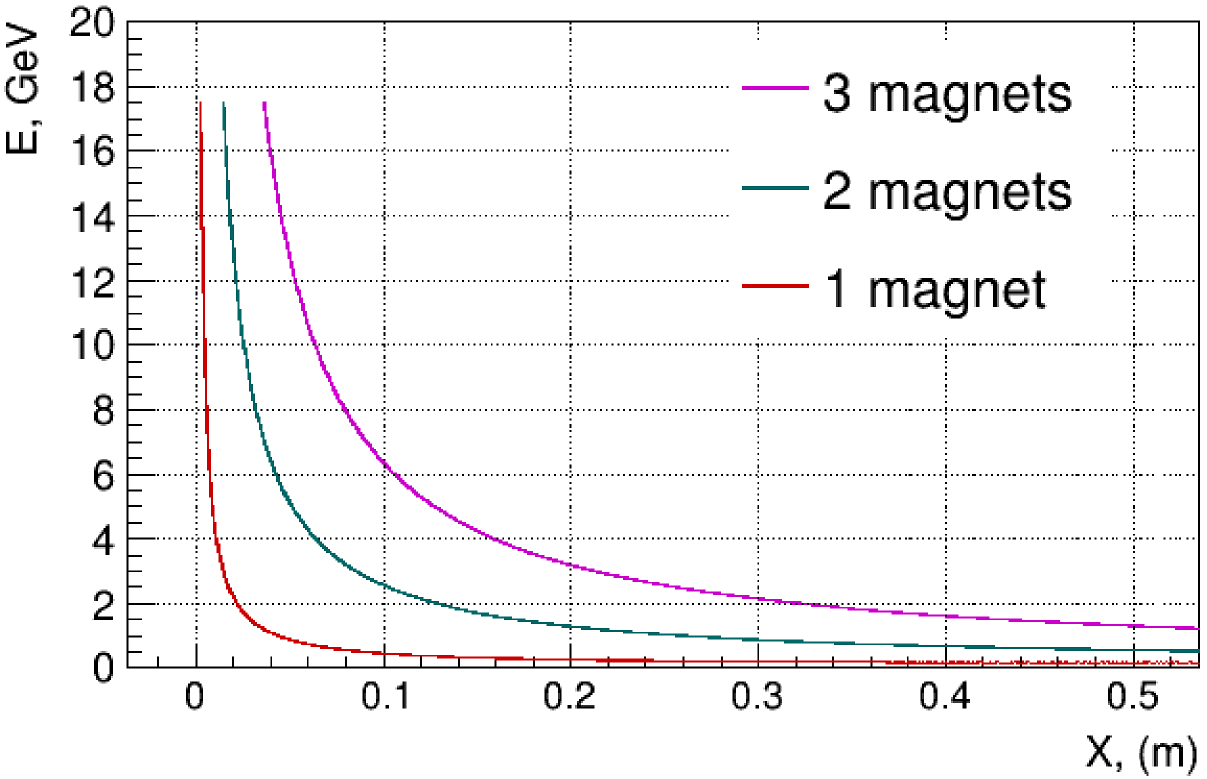


Position right after last magnet

// // Setting parameters for Spectrometer
driftl 1.0 0.5 0.5 0.01
blength 0.5 0.5 0.5
bfield 1.12 1.12 1.12

// // Setting parameters for Spectrometer
driftl 2.0 0.5 0.01
blength 0.5 0.5
bfield 1.12 1.12

// // Setting parameters for Spectrometer
Driftl 3.0 0.01
blength 0.5
bfield 1.12



Ranges for scanning parameters

```
param_id=('Epulse'     'alpha' 'sigmaxy' 'sigmaz' 'esigmax' 'esigmay' 'esigmaz')
p_nom=(     2.5*10^6    0.3     10.0      0.025    0.03      0.03      0.334)
p_min=(     2.5*10^6    0.17    5.0       0.020    0.01      0.01      0.067)
p_max=(     35.0*10^6   0.35    50.0      0.040    0.05      0.05      0.467)
n_points=(  5           9       9         4        8         8         6)
```

```
param_id=('Epulse'     'alpha' 'sigmaxy' 'sigmaz' 'esigmax' 'esigmay' 'esigmaz')
p_nom=(     3.5*10^6    0.3     10.0      0.035    0.005      0.005      0.08)
p_min=(     0.35*10^6   0.17    5.0       0.020    0.001      0.001      0.05)
p_max=(     35.0*10^6   0.35    50.0      0.040    0.01       0.01       0.10)
n_points=(  10          9       9         4        9          8          5)
```

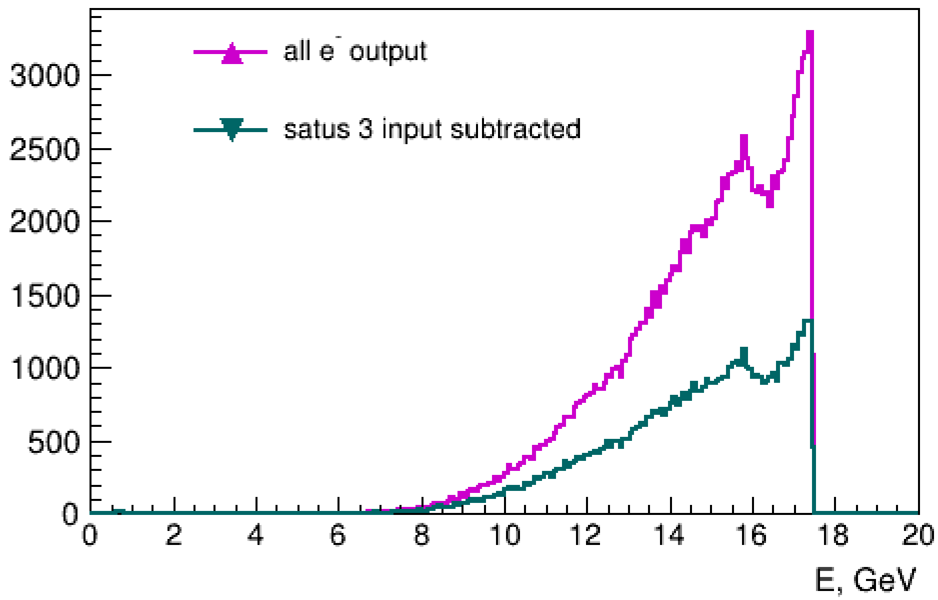
- Introduce beam displacement?
- Study electron registration for different magnets and detectors configurations.

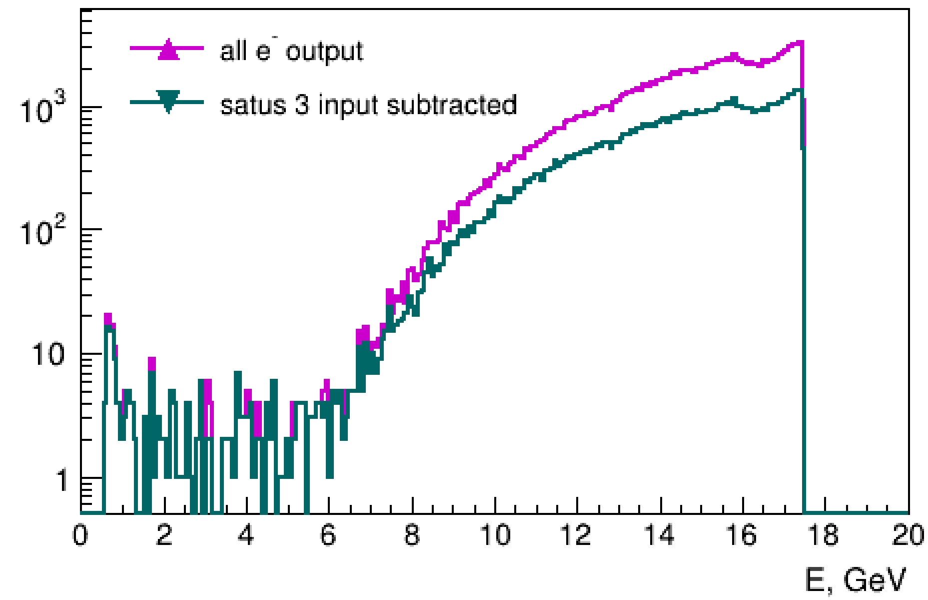
Generated HepEvt

```
C...        NEVHEP        - event number
C...        NHEP          - number of entries in this event
C...    1   ISTHEP(..)    - status code
C...    2   IDHEP(..)     - particle ID, P.D.G. standard
C...    3   JMOHEP(1,..) - position of mother particle in list
C...    4   JMOHEP(2,..) - position of second mother particle in list
C...    5   JDAHEP(1,..) - position of first daughter in list
C...    6   JDAHEP(2,..) - position of last daughter in list
C...    7   PHEP(1,..)    - x momentum in GeV/c
C...    8   PHEP(2,..)    - y momentum in GeV/c
C...    9   PHEP(3,..)    - z momentum in GeV/c
C...    10  PHEP(4,..)    - energy in GeV
C...    11  PHEP(5,..)    - mass in GeV/c**2
C...    12  VHEP(1,..)    - x vertex position in mm
C...    13  VHEP(2,..)    - y vertex position in mm
C...    14  VHEP(3,..)    - z vertex position in mm
C...    15  VHEP(4,..)    - production time in mm/c
```

```
1 3  3 4 5 6  7        8        9          10          11       12        13       14       15
0 11 0 0 2 3 .000114 .000008 17.500476 17.500476 .000511 .004126 -.000054 .030741 .023207 .741414 6.00E+06
3 22 1 0 0 0 .000010 -.000001 2.361195 2.361195 .000000 .004126 -.000054 .030741 .023207 .741414 6.00E+06
3 11 1 0 0 0 .000105 .000009 15.139281 15.139281 .000511 .004126 -.000054 .030741 .023207 .741414 6.00E+06
2 3
3 11 0 0 2 3 .000373 .000063 15.139265 15.139265 .000511 .004127 -.000054 .033624 .026090 1.354559 6.00E+06
3 22 1 0 0 0 .000017 .000009 .574926 .574926 .000000 .004127 -.000054 .033624 .026090 1.354559 6.00E+06
3 11 1 0 0 0 .000356 .000055 14.564339 14.564339 .000511 .004127 -.000054 .033624 .026090 1.354559 6.00E+06
3 3
0 11 0 0 2 3 -.000058 -.000433 17.490063 17.490063 .000511 .001601 .011979 .030442 .026811 1.166966 6.00E+06
3 22 1 0 0 0 -.000003 -.000045 3.723448 3.723448 .000000 .001601 .011979 .030442 .026811 1.166966 6.00E+06
3 11 1 0 0 0 -.000055 -.000387 13.766615 13.766615 .000511 .001601 .011979 .030442 .026811 1.166966 6.00E+06
4 3
3 11 0 0 2 3 -.000055 -.000387 13.766615 13.766615 .000511 .001601 .011979 .030586 .026955 1.496425 6.00E+06
3 22 1 0 0 0 -.000000 -.000001 .029185 .029185 .000000 .001601 .011979 .030586 .026955 1.496425 6.00E+06
3 11 1 0 0 0 -.000055 -.000387 13.737431 13.737431 .000511 .001601 .011979 .030586 .026955 1.496425 6.00E+06
```

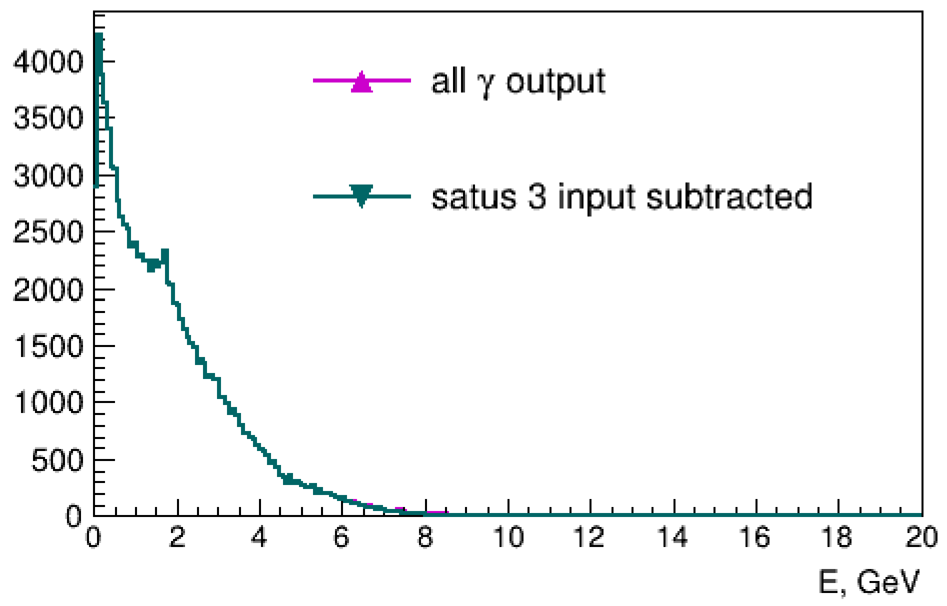
Generated Electron Spectrum

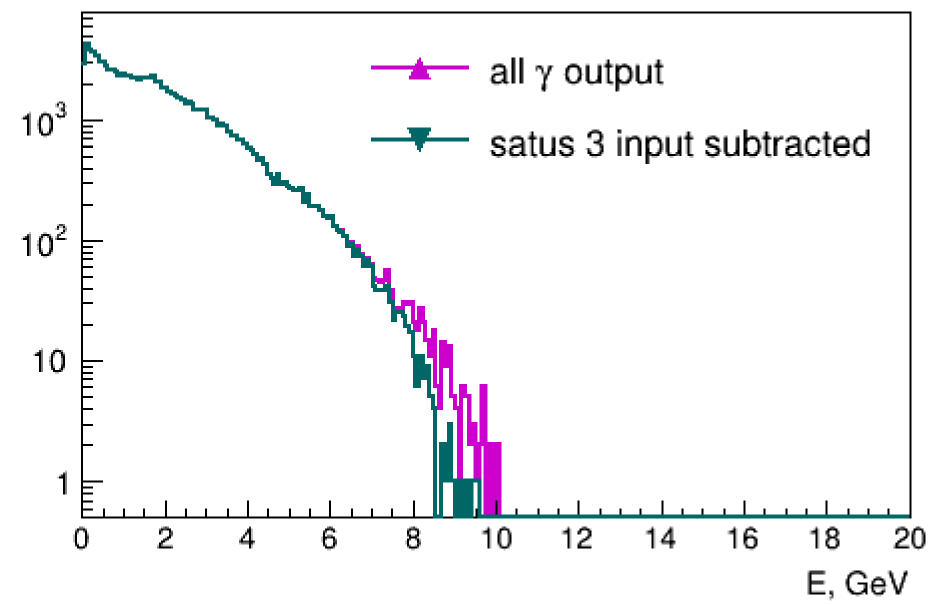


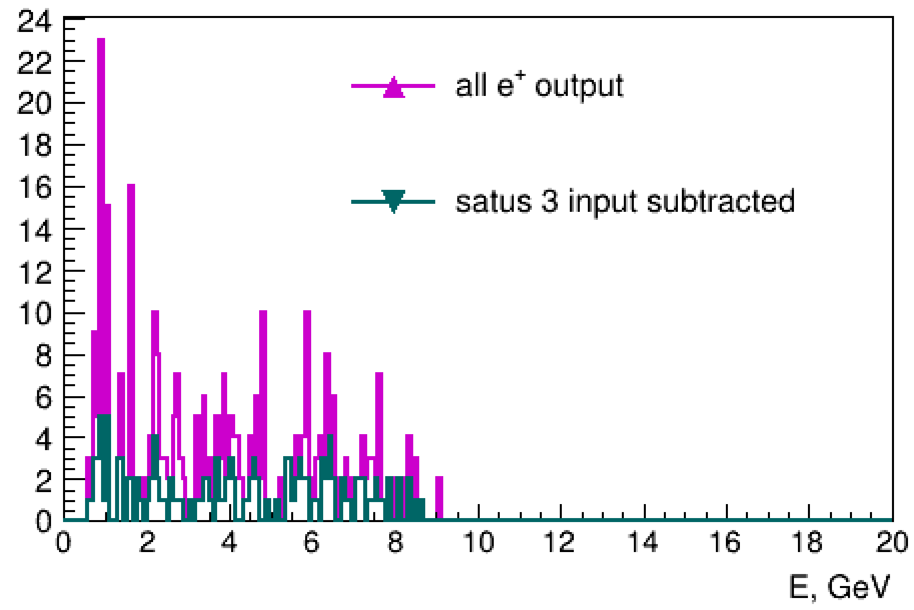



```
[oborysov@flc17 sim_phase0]$ for nn in $(seq 2 4 4352); do cat  IPstrong_luxe_Sep2018_phase0_events_run_091.stdhep | head -n "${nn}" | tail -n 1; done | grep '^3 .*' | wc
    415    7055   45241
[oborysov@flc17 sim_phase0]$ for nn in $(seq 2 4 4352); do cat  IPstrong_luxe_Sep2018_phase0_events_run_091.stdhep | head -n "${nn}" | tail -n 1; done | grep '^0 .*' | wc
    673   11441   73456
[oborysov@flc17 sim_phase0]$ bc
bc 1.06.95
Copyright 1991-1994, 1997, 1998, 2000, 2004, 2006 Free Software Foundation, Inc.
This is free software with ABSOLUTELY NO WARRANTY.
For details type `warranty'.
4352/4
1088
415+673
1088
quit
[oborysov@flc17 sim_phase0]$ wc IPstrong_luxe_Sep2018_phase0_events_run_091.stdhep
  4352  57664 359534 IPstrong_luxe_Sep2018_phase0_events_run_091.stdhep
```

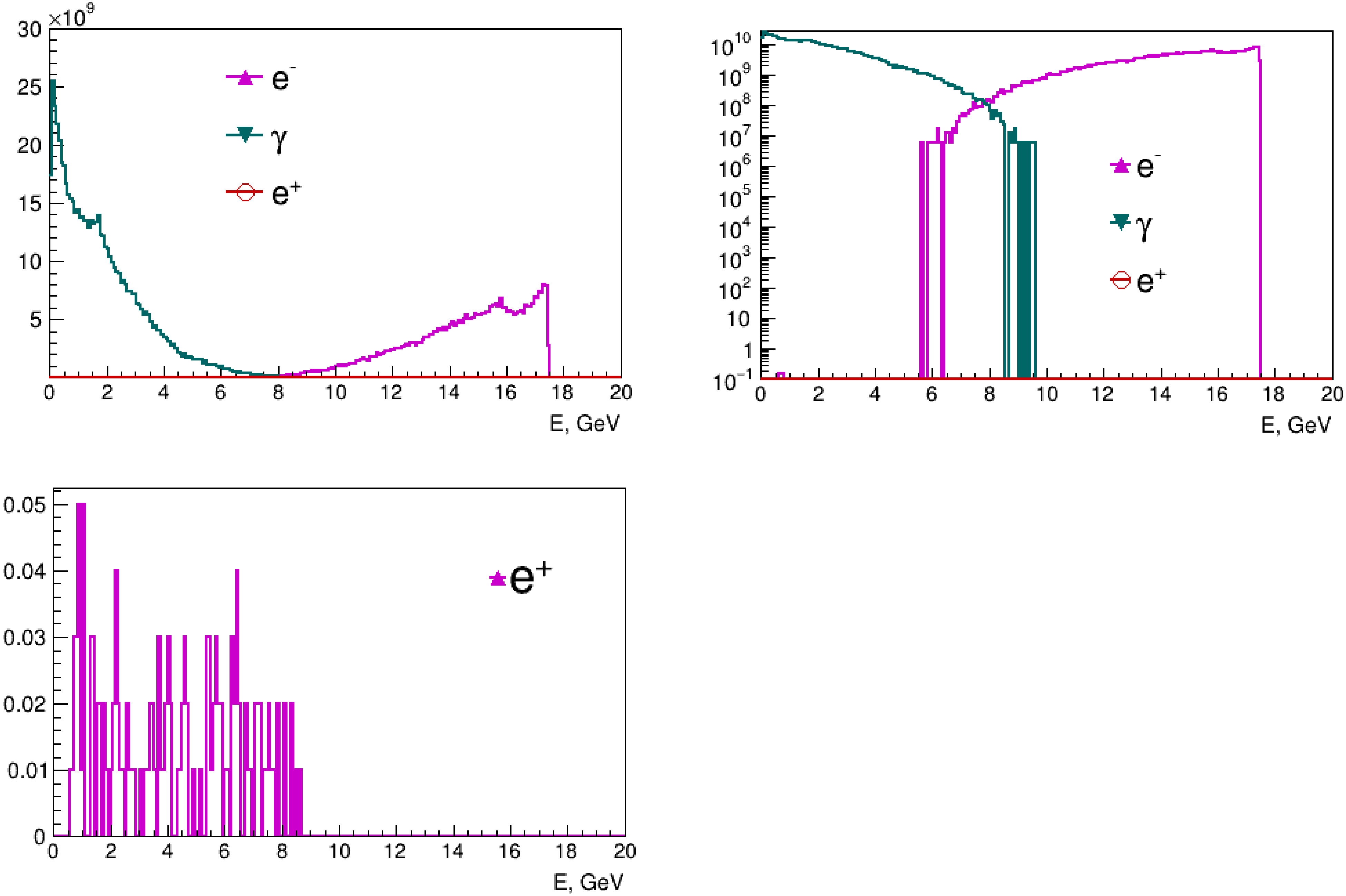
Generated Photon and Positron Spectrum





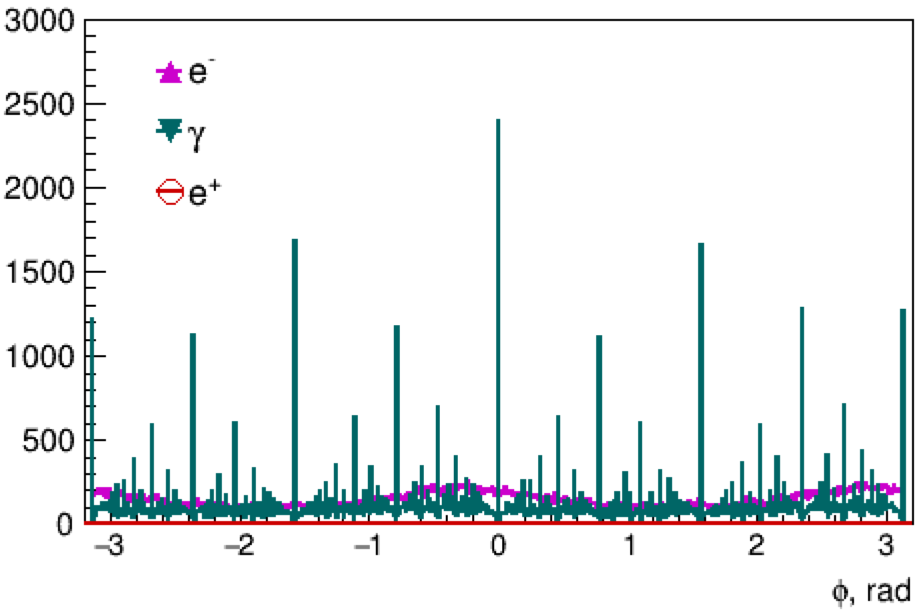


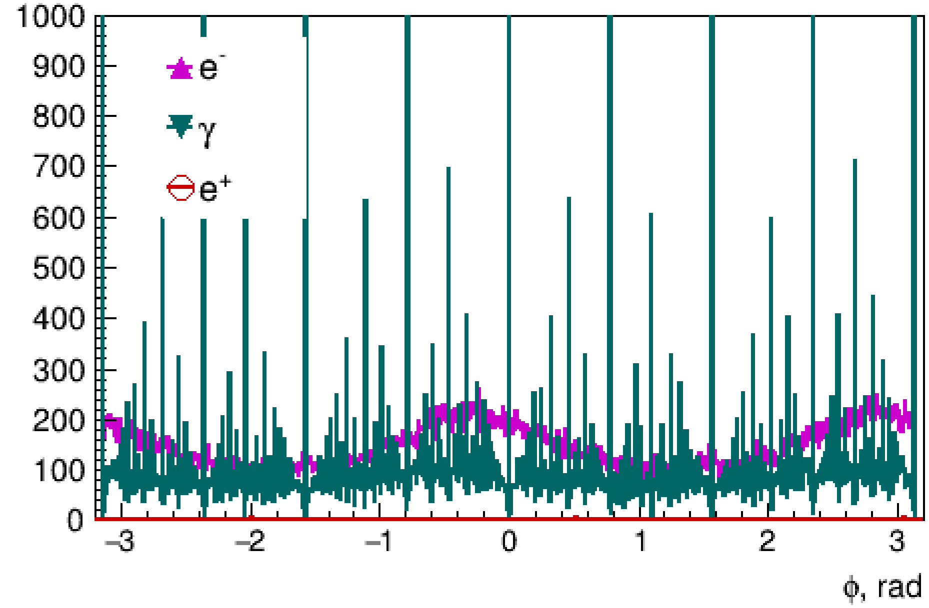
Spectra when build with the weight



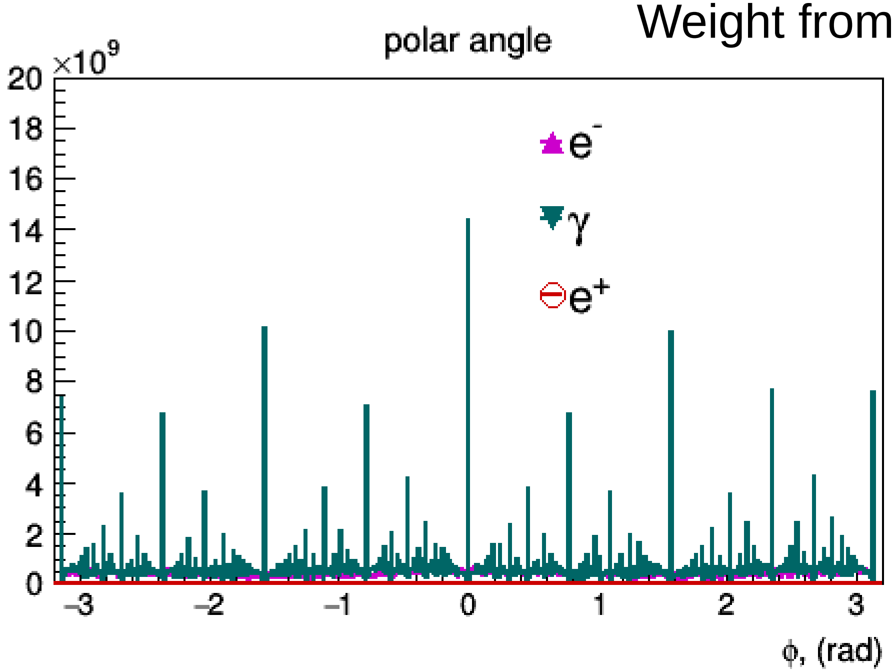
Azimuthal angle distribution

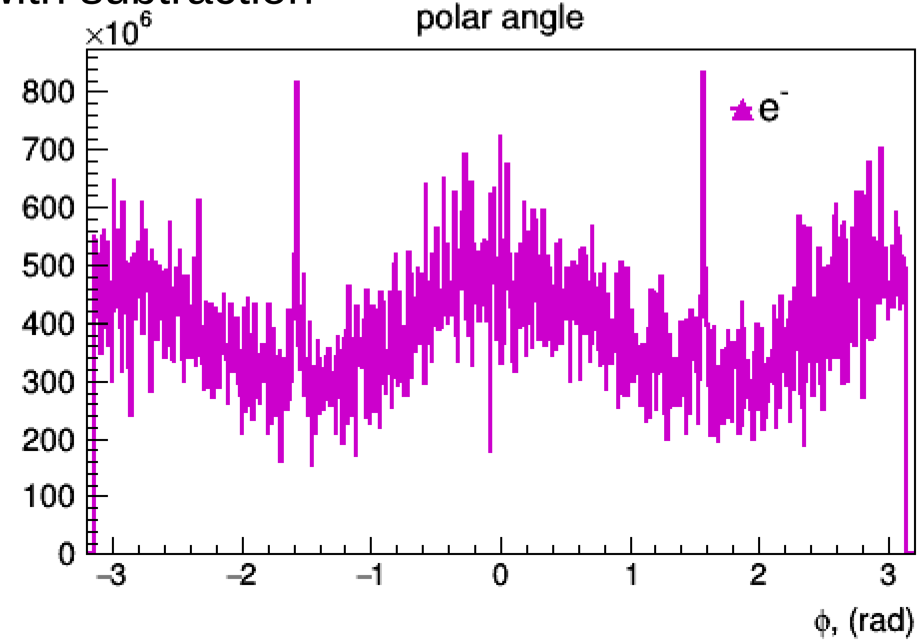
All output with unity weight



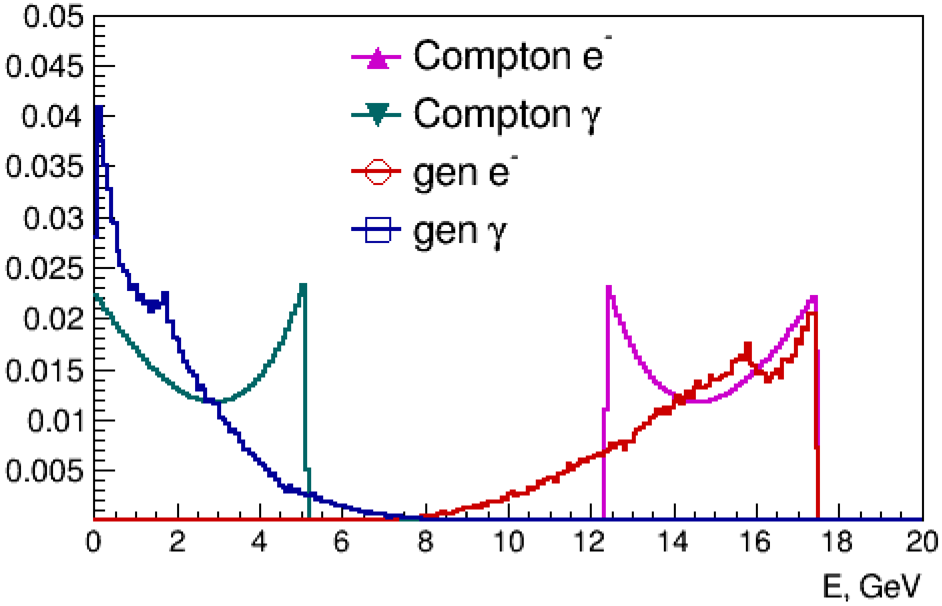


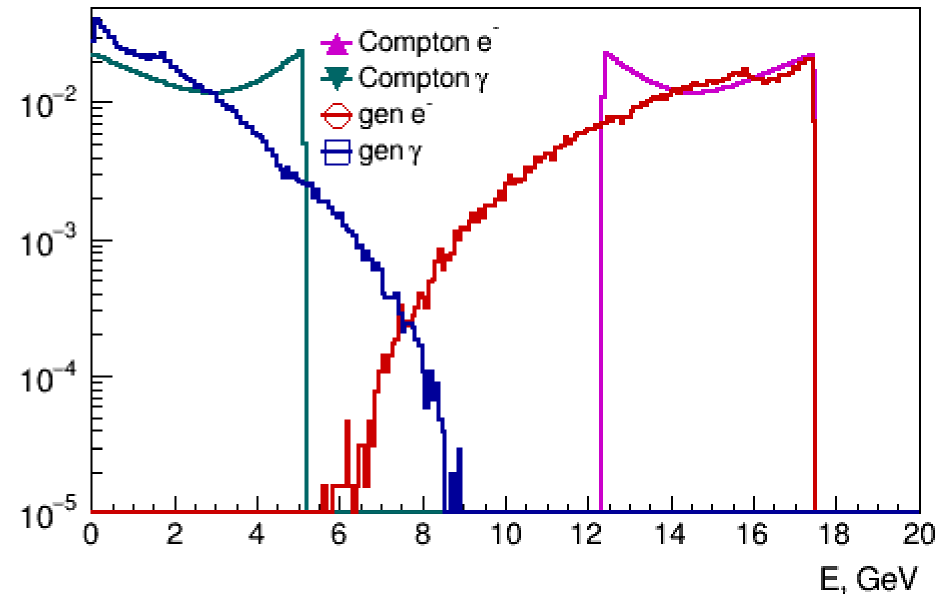
Weight from file with subtraction



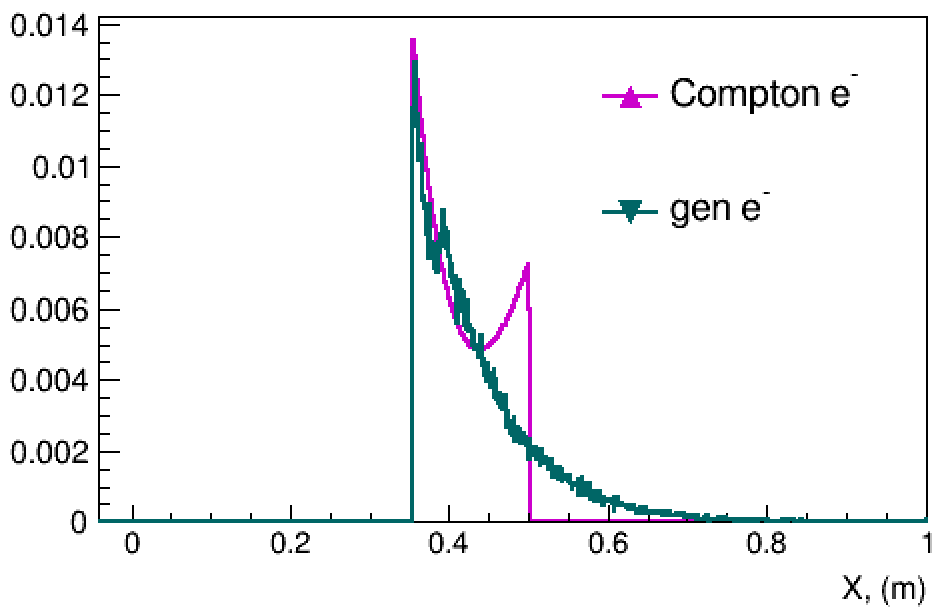


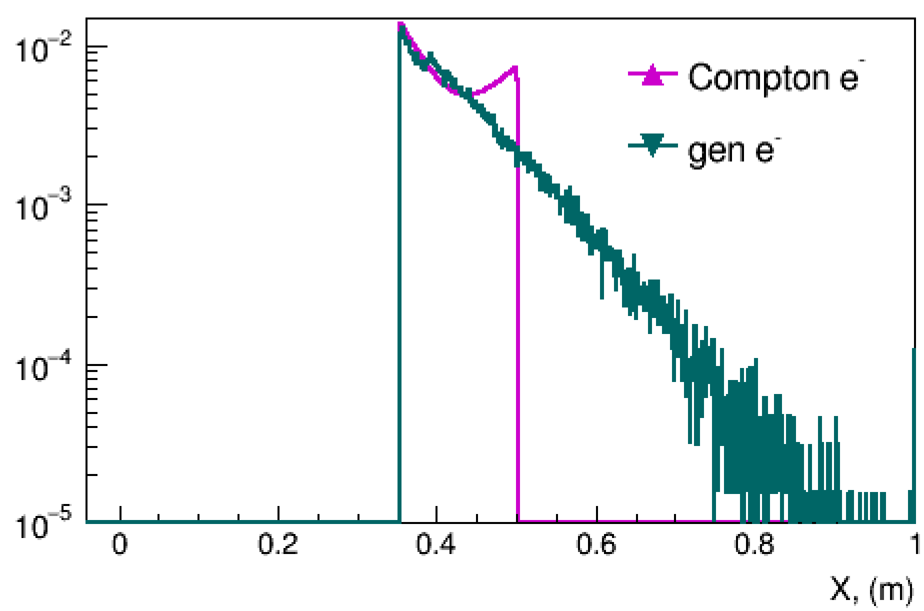
Spectra: Compton vs Generated



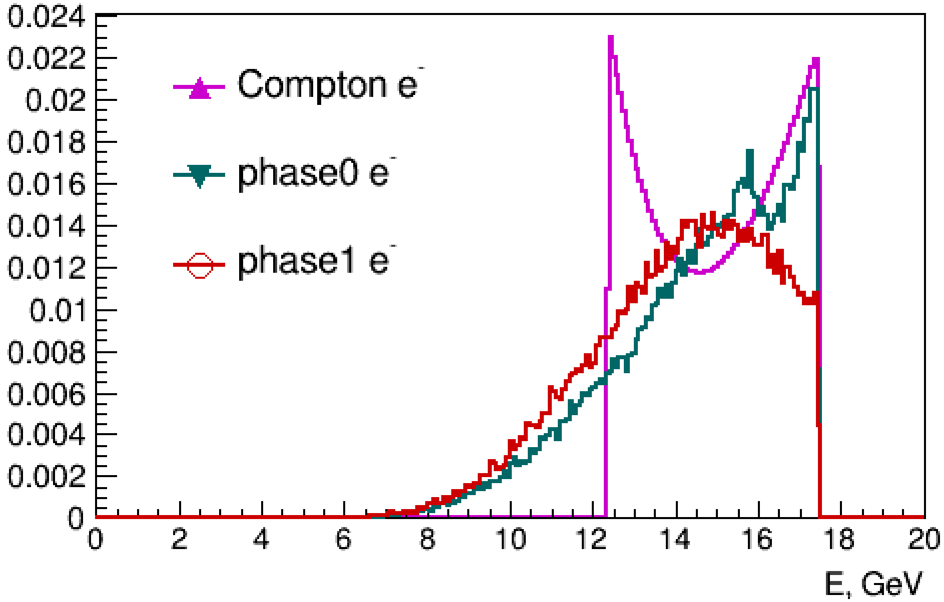


Detector occupancy



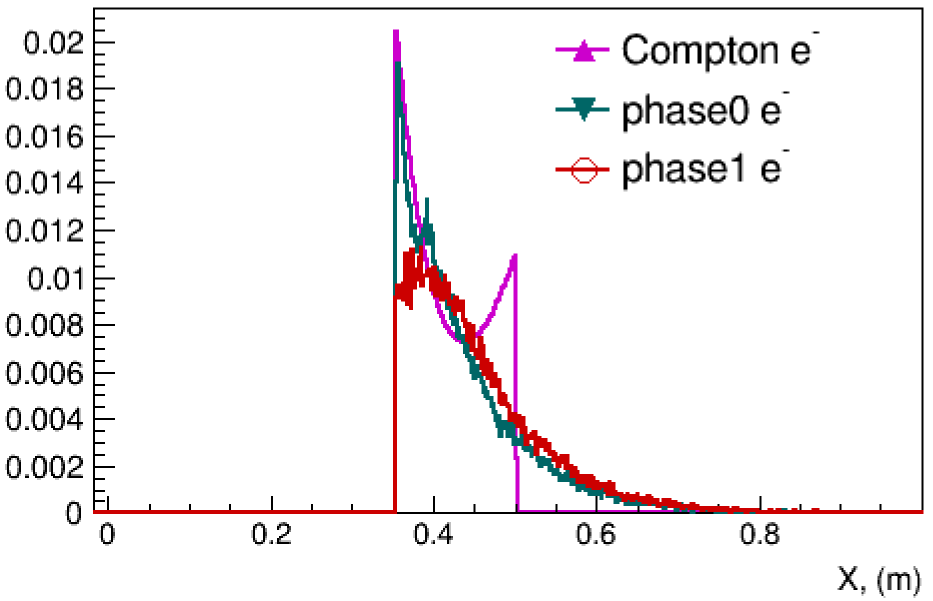


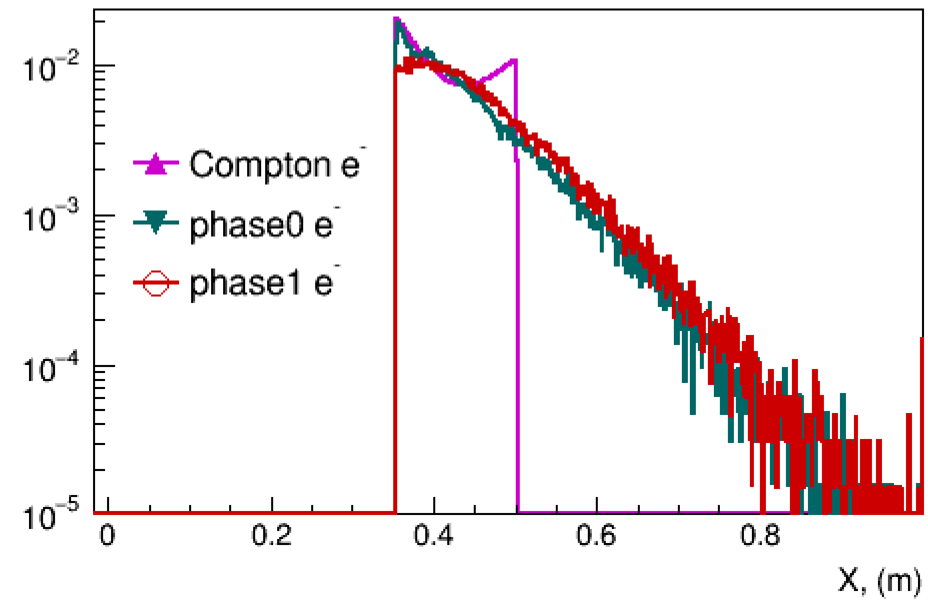
Detector occupancy



Magnet:

```
driftl     1.0      8.0
blength         1.08
bfield          2.24
```





Phase 0 and Phase 1