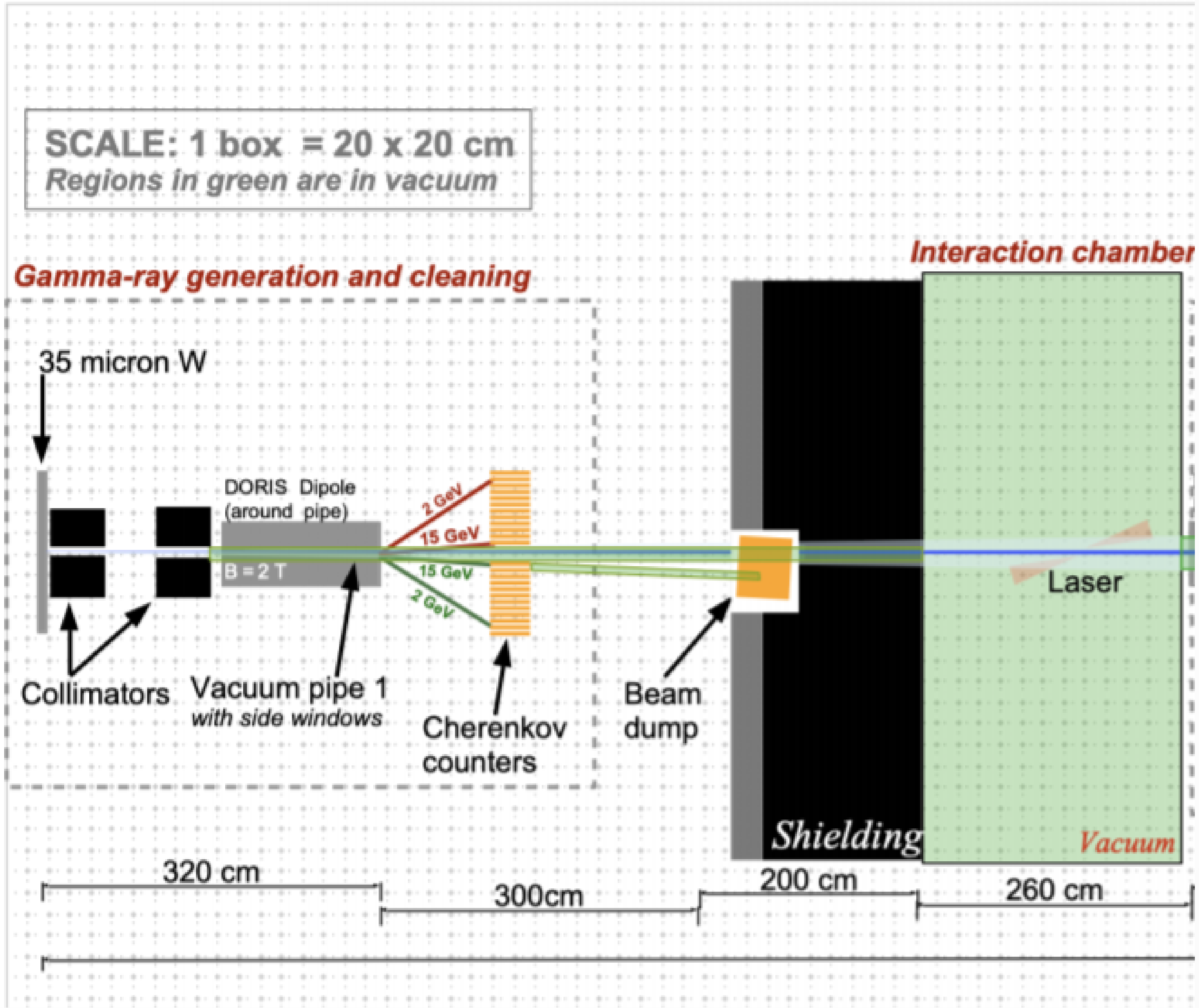
γ – LASER Mode
Beam Monitoring

John Hallford

07/05/2020



SCALE: 1 box = 20 x 20 cm
Regions in green are in vacuum
Gamma-ray generation and cleaning
Interaction chamber
35 micron W
DORIS Dipole (around pipe)
B = 2 T
2 GeV
15 GeV
15 GeV
2 GeV
Laser
Collimators
Vacuum pipe 1
with side windows
Cherenkov counters
Beam dump
Shielding
Vacuum
320 cm
300cm
200 cm
260 cm

Investigating Synchrotron Radiation

Produced with the (Centripetal) Acceleration of Charged Particles in Magnetic Field

Radiates in same direction as movement of charge

Conical distribution which narrows with increasing Lorentz Factor

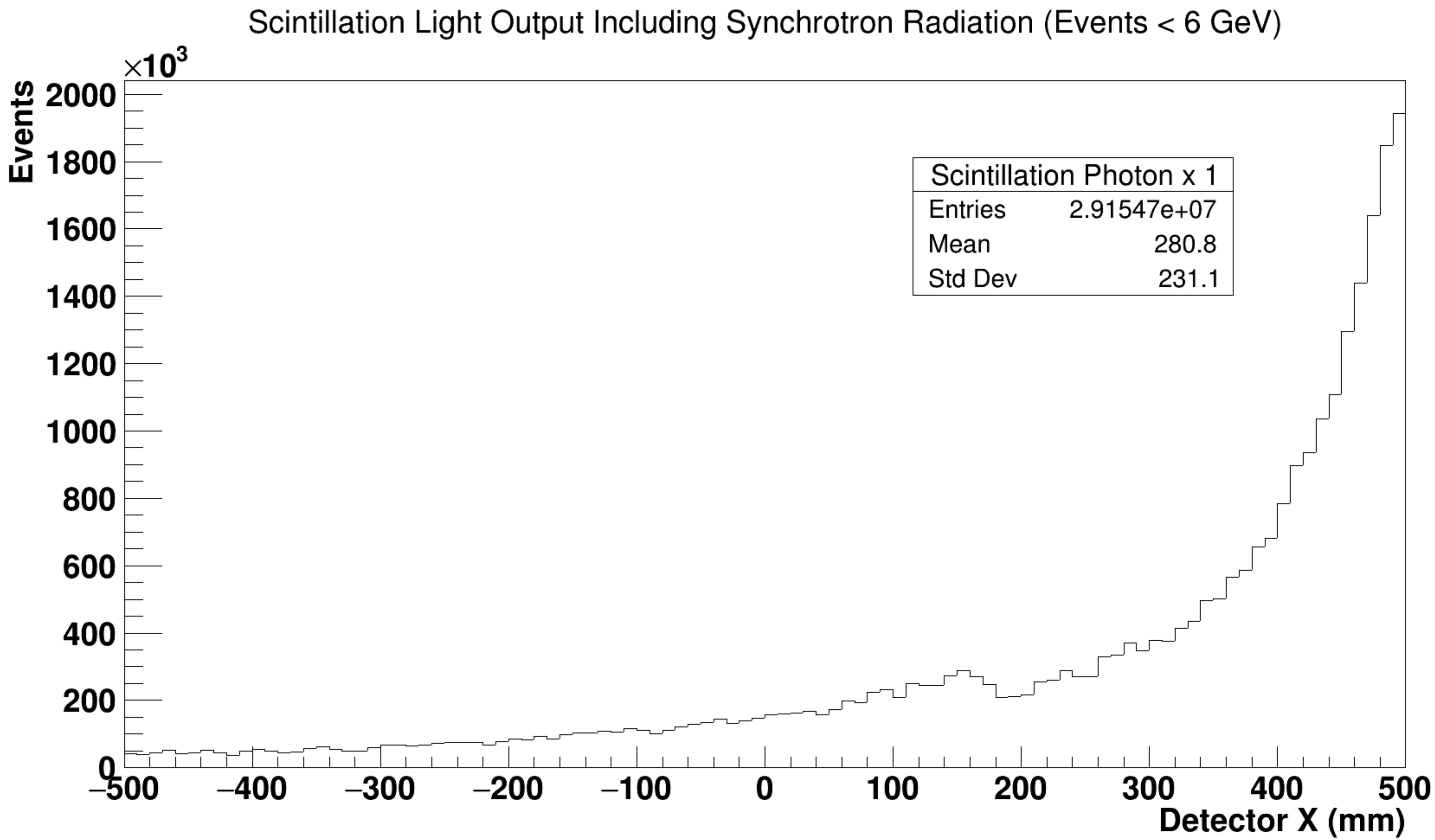
Broad frequency (energy) spectrum with a peak dependent on electron E

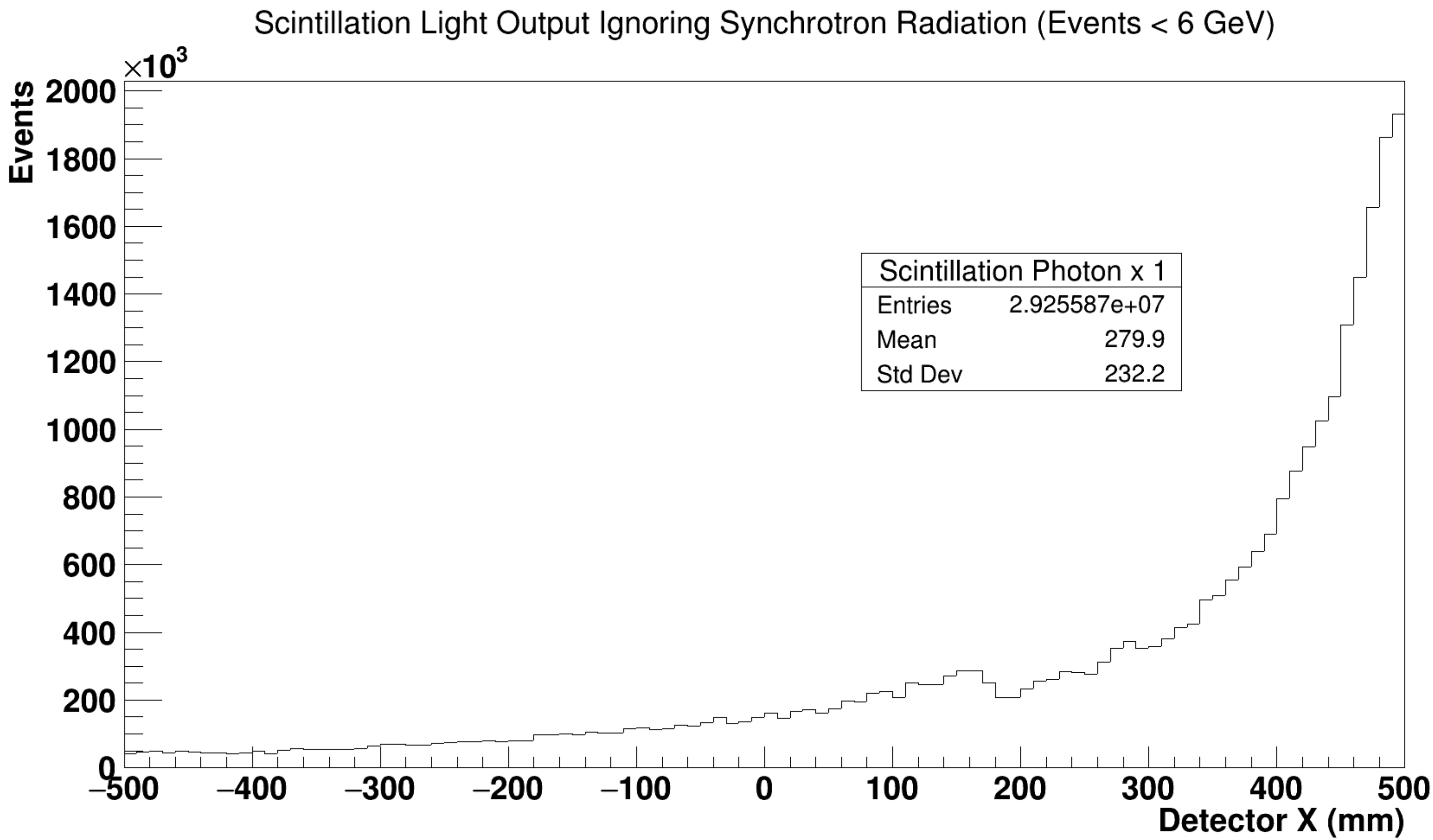
A complex distribution… we can approximate, but for accuracy best to implement in a simulation

$$P = \frac{q^4}{6\pi\epsilon_0 m^4 c^5} E^2 B^2$$

$$\alpha \approx 1/\gamma$$

Electron Energy	Lorentz Factor	Synchrotron Cone Angle (Rad)	Synch. Radiation Spot at 2m	Total Energy Radiated (1m path)
17.5 GeV	34247	2.92 e-5	0.058 mm	~1.54 MeV
10 GeV	19569	5.11 e-5	0.122 mm	~500 keV
1 GeV	1956	5.11 e-4	1.22 mm	~5 keV
100 MeV	196	5.11 e-3	12.2 mm	~50 eV


Scintillation Light Output Including Synchrotron Radiation (Events < 6 GeV)
×10^3
Events
2000
1800
1600
1400
1200
1000
800
600
400
200
0
−500
−400
−300
−200
−100
0
100
200
300
400
500
Detector X (mm)
Scintillation Photon x 1
Entries 2.91547e+07
Mean 280.8
Std Dev 231.1



Scintillation Light Output Ignoring Synchrotron Radiation (Events < 6 GeV)
×10^3
Events
2000
1800
1600
1400
1200
1000
800
600
400
200
0
−500
−400
−300
−200
−100
0
100
200
300
400
500
Detector X (mm)
Scintillation Photon x 1
Entries 2.925587e+07
Mean 279.9
Std Dev 232.2

Scintillator Response for electrons < 6 GeV

Total Scintillation Light output

a = Synch. Rad. enabled : 29154700

b = Synch. Rad. disabled: 29255870

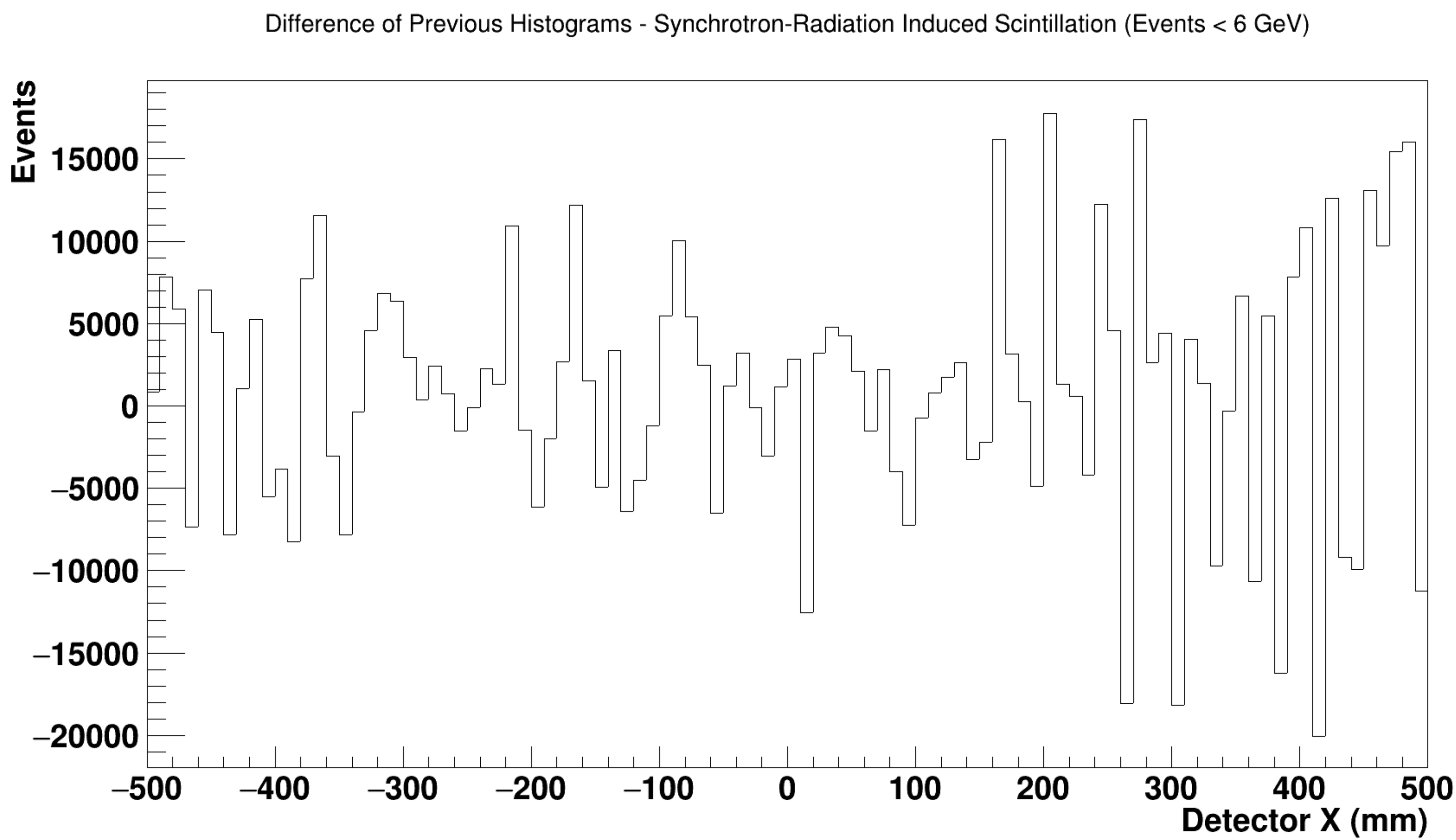
b/a = 1.00347

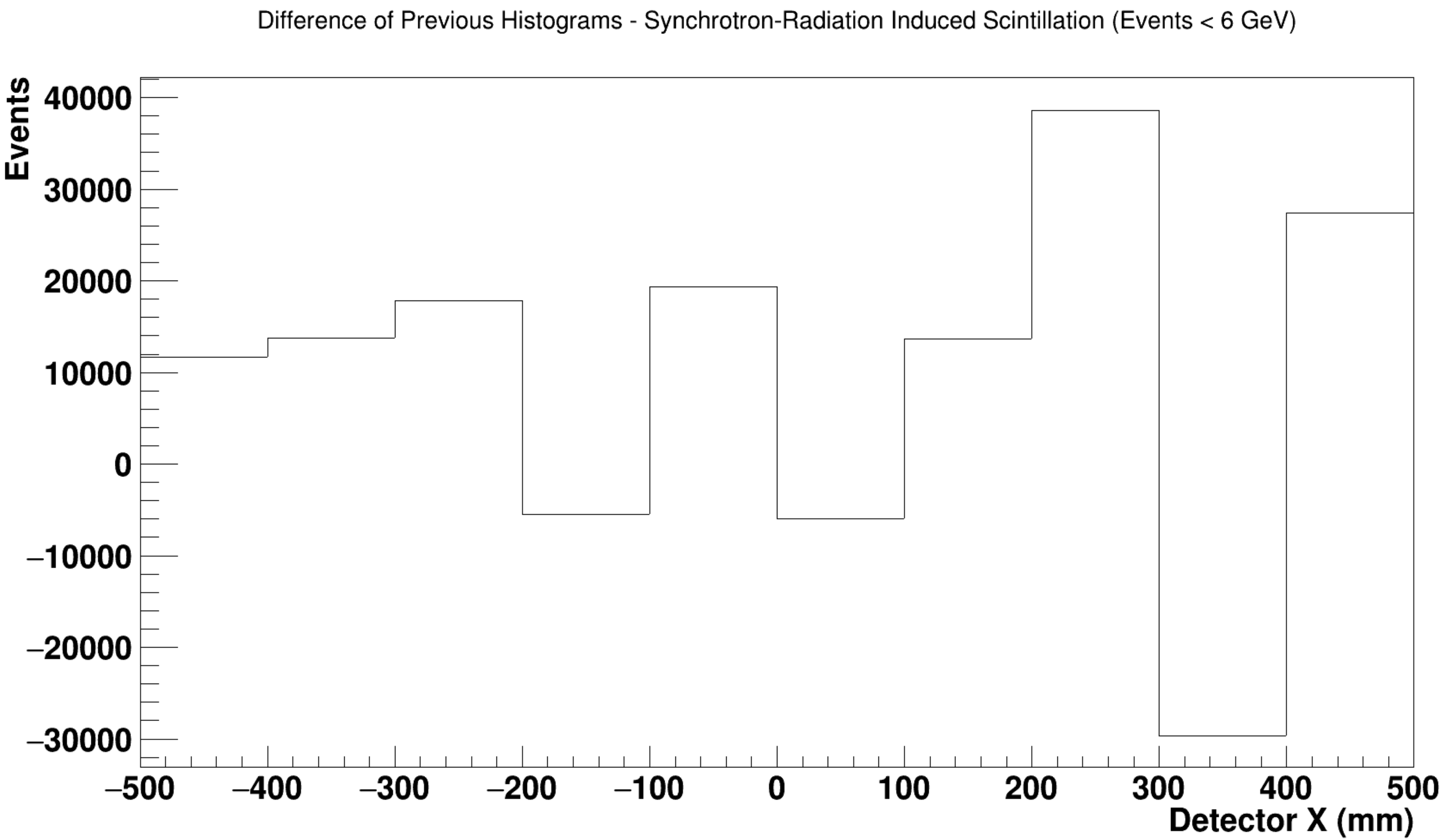
Total Electrons incident on Scintillator

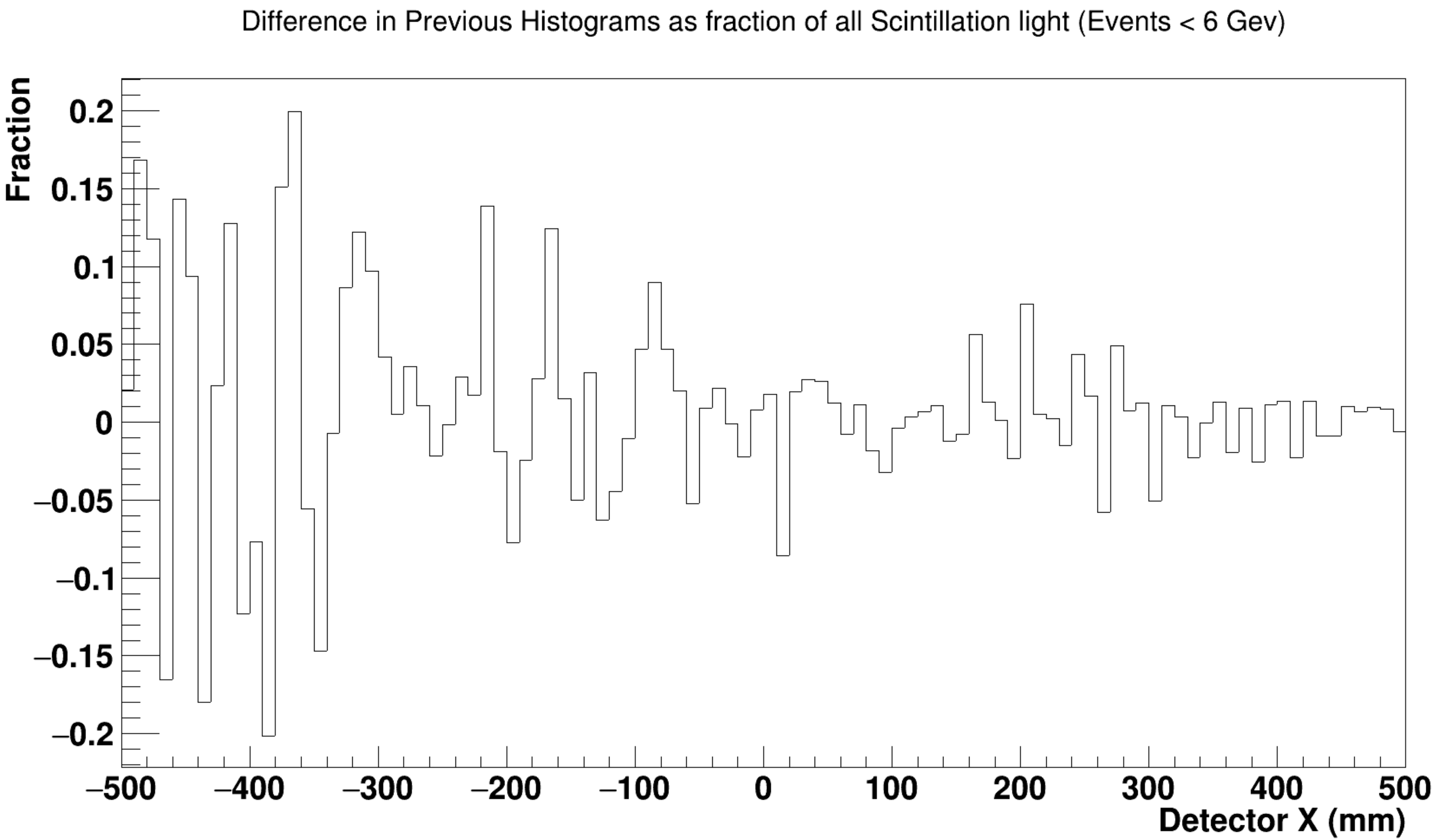
c = Sync. Rad. enabled : 42291

d = Sync. Rad. disabled: 42346

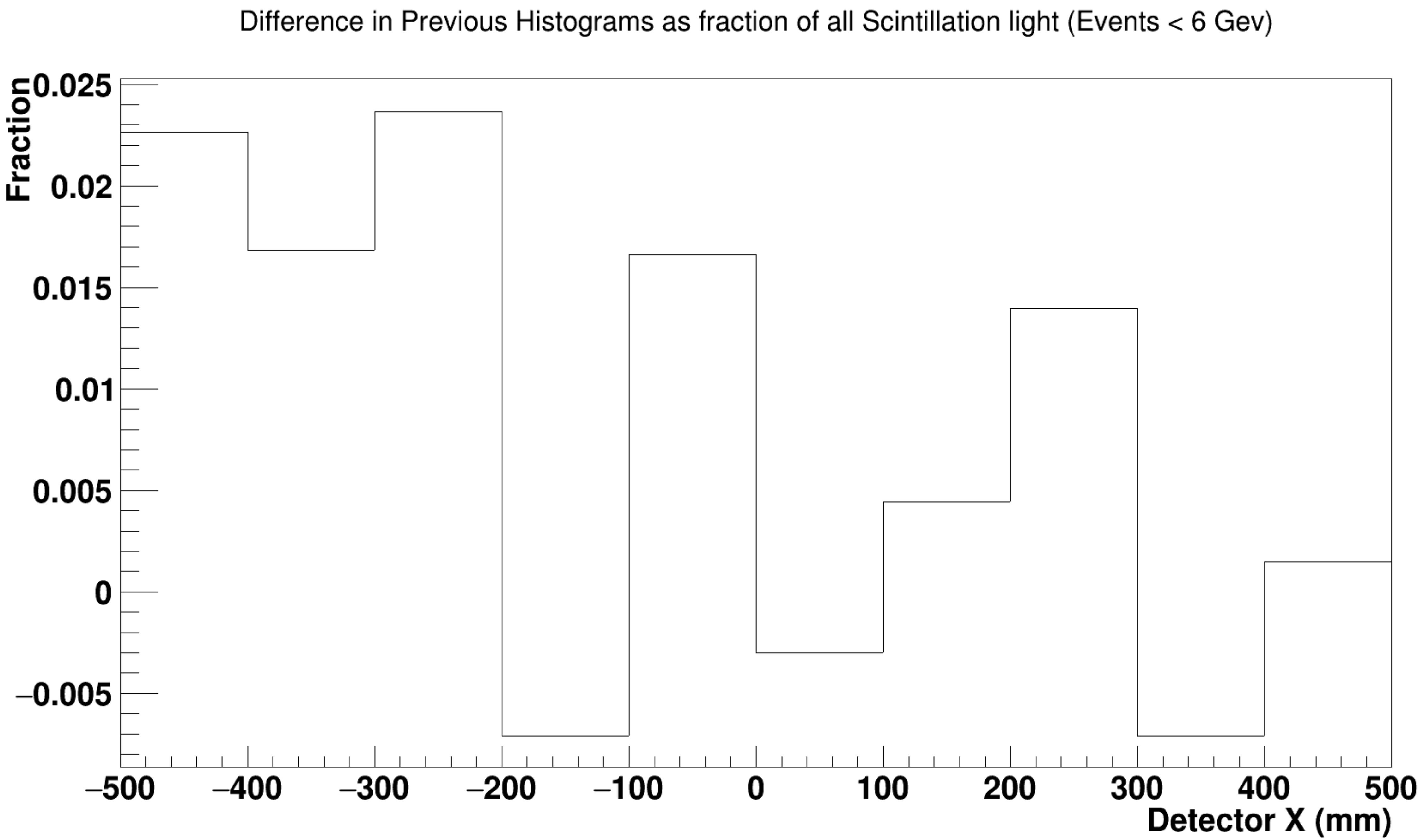
d/c = 1.00343


Difference of Previous Histograms - Synchrotron-Radiation Induced Scintillation (Events < 6 GeV)
Events
15000
10000
5000
0
−5000
−10000
−15000
−20000
−500
−400
−300
−200
−100
0
100
200
300
400
500
Detector X (mm)


Difference of Previous Histograms - Synchrotron-Radiation Induced Scintillation (Events < 6 GeV)
Events
40000
30000
20000
10000
0
−10000
−20000
−30000
−500
−400
−300
−200
−100
0
100
200
300
400
500
Detector X (mm)



Difference in Previous Histograms as fraction of all Scintillation light (Events < 6 Gev)
Fraction
0.2
0.15
0.1
0.05
0
–0.05
–0.1
–0.15
–0.2
–500
–400
–300
–200
–100
0
100
200
300
400
500
Detector X (mm)


Difference in Previous Histograms as fraction of all Scintillation light (Events < 6 Gev)
Fraction
0.025
0.02
0.015
0.01
0.005
0
−0.005
−500
−400
−300
−200
−100
0
100
200
300
400
500
Detector X (mm)

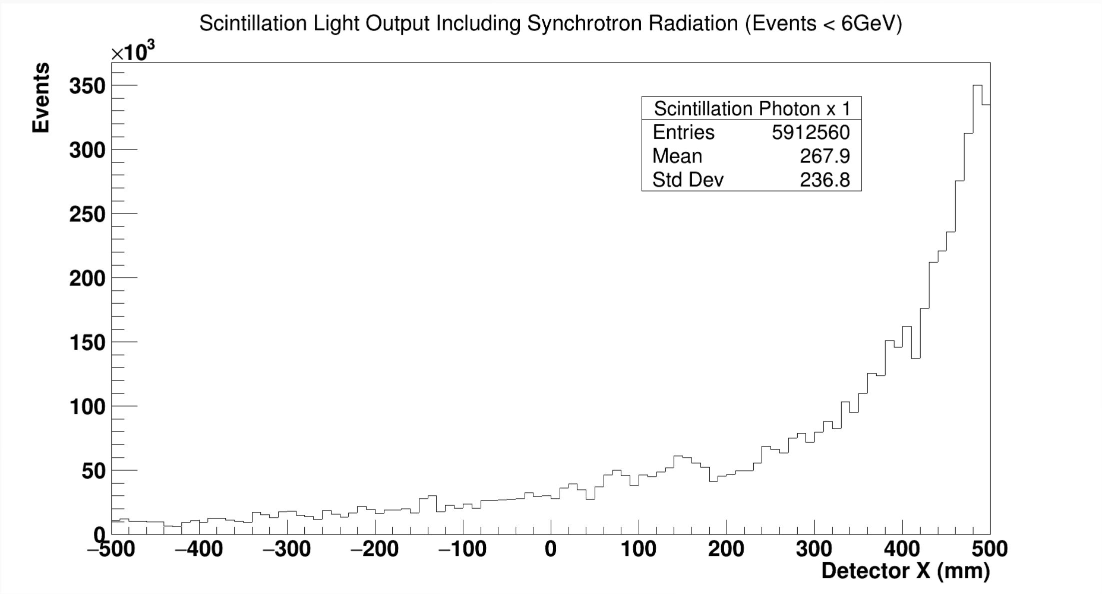
Problems & Further Study

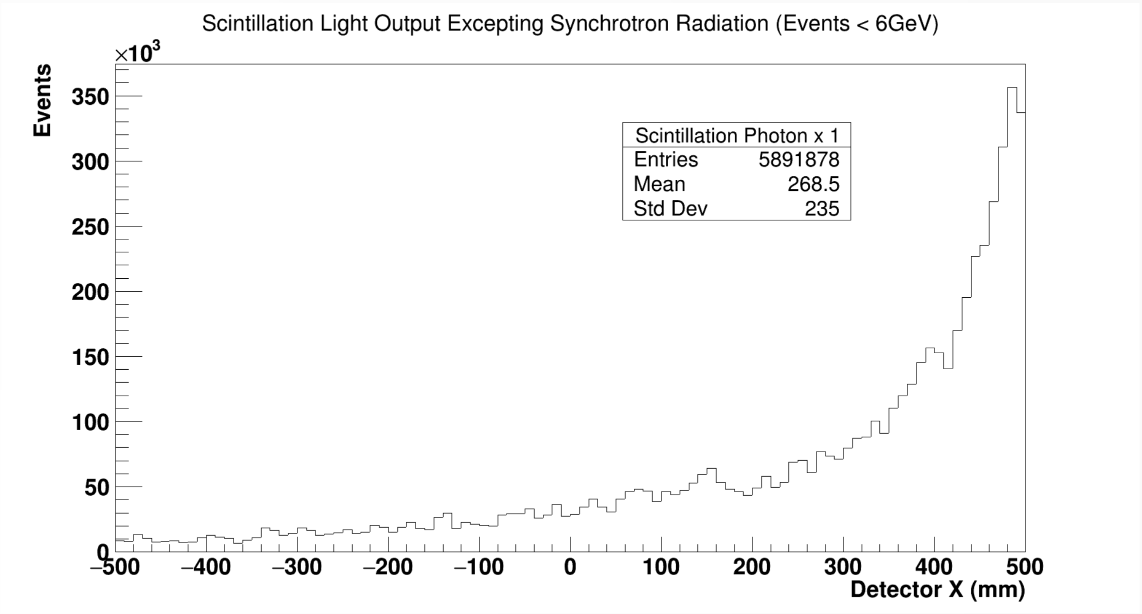
Should perform simulation for all electron energies, for which we have far greater statistics

Should perform small study including the reality of an interfering limited aperture and perhaps the response using a different Scintillating material

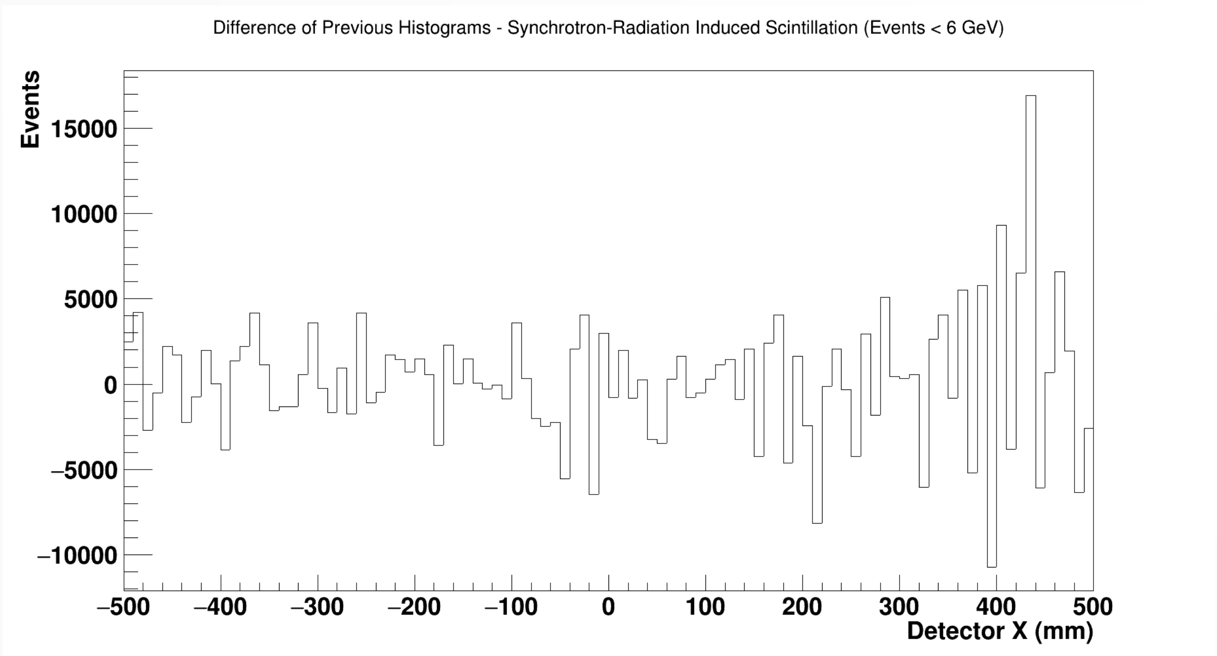
Could a significant portion of this radiation go into the beamline directly? I will investigate, but need some parameters

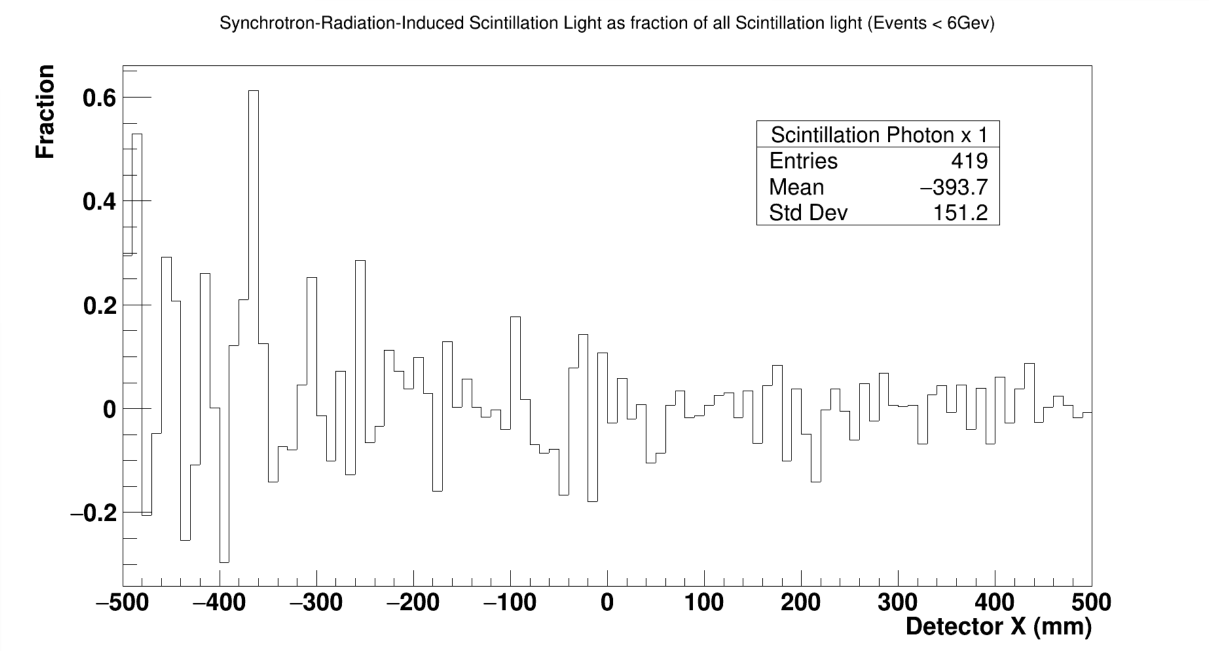
Backup

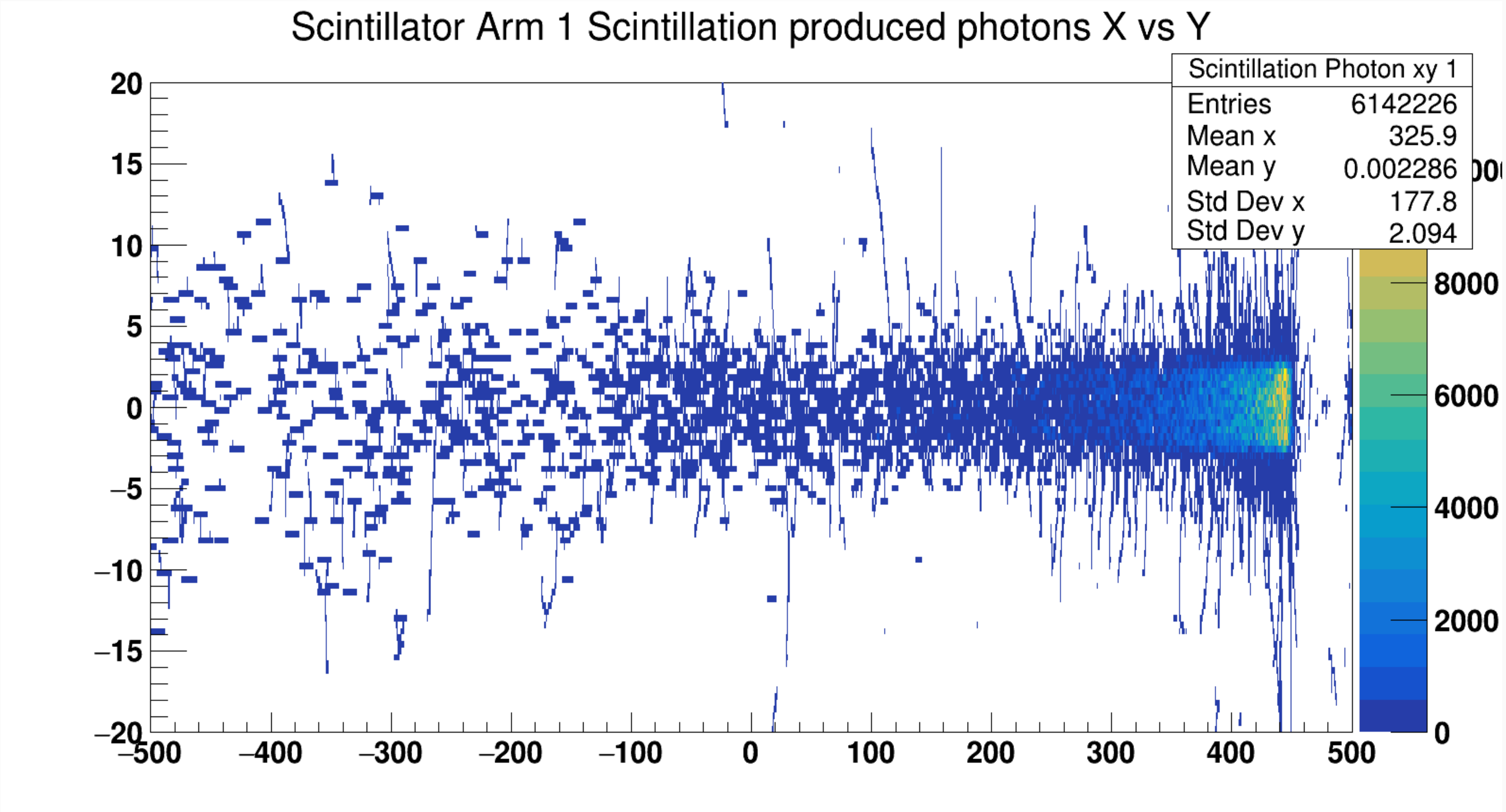




Uniform incident-electron-energy < 6 GeV

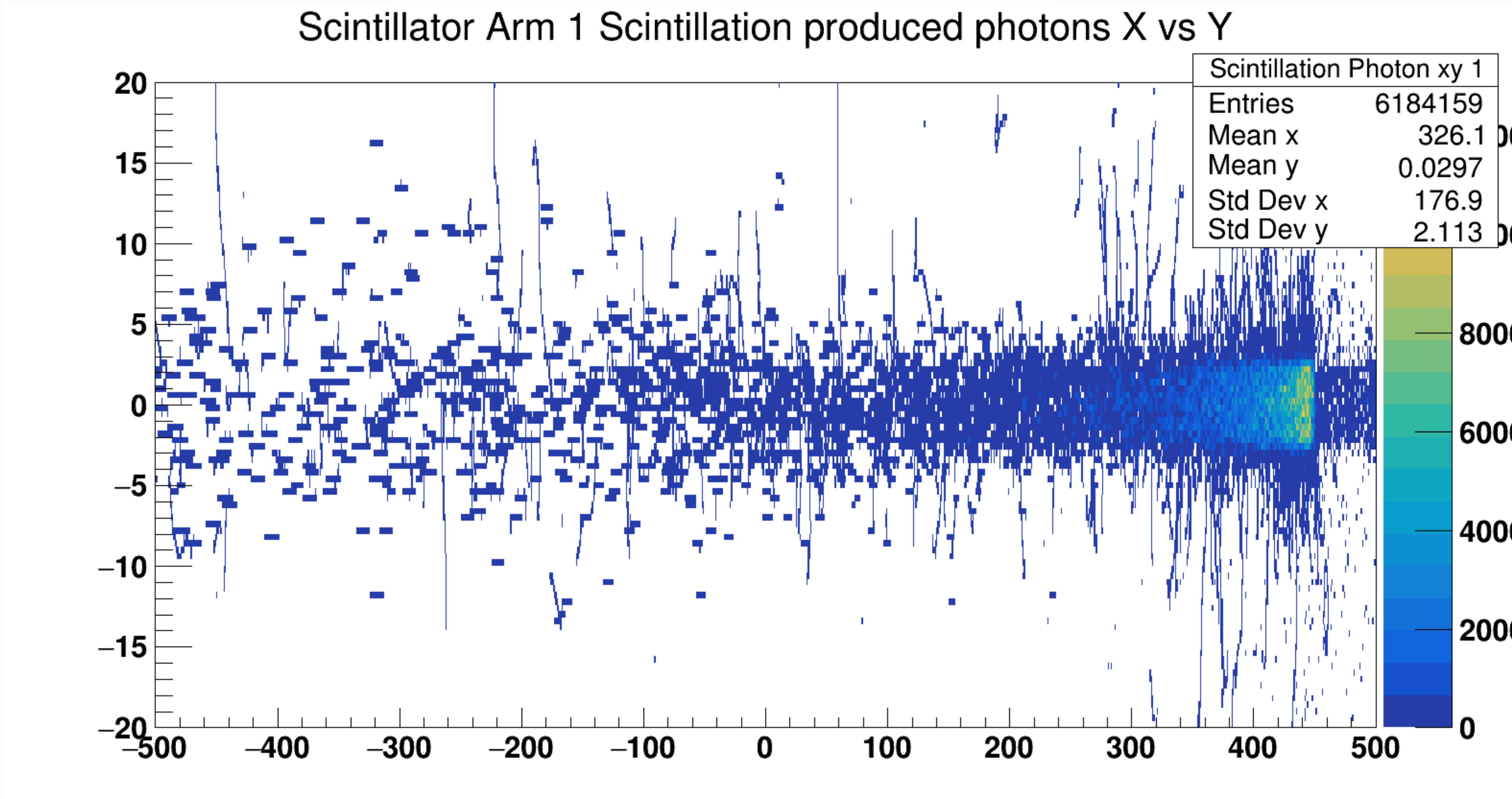






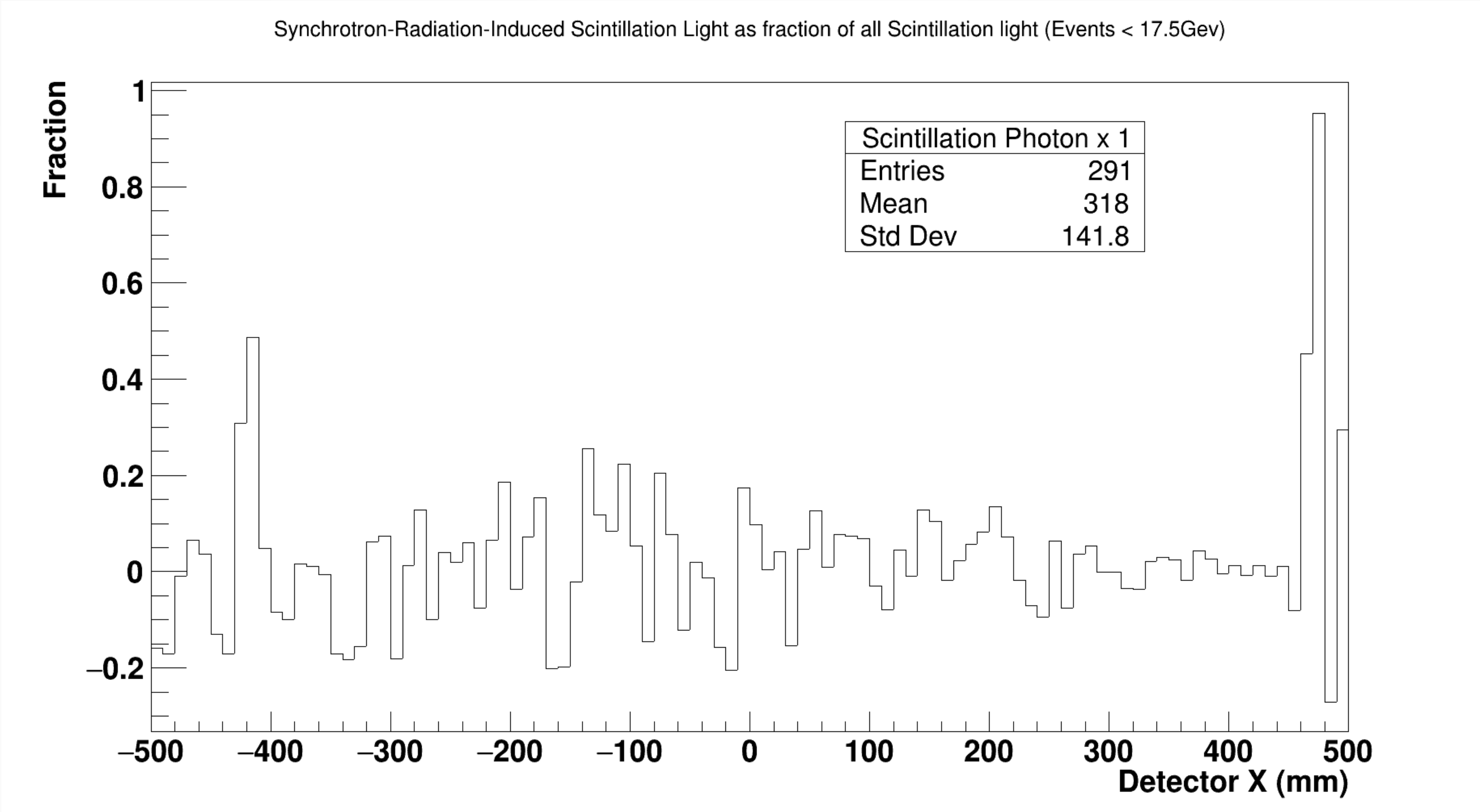
Synchrotron Radiation Excluded

Uniform Incident Electron Energy up to 17.5 GeV

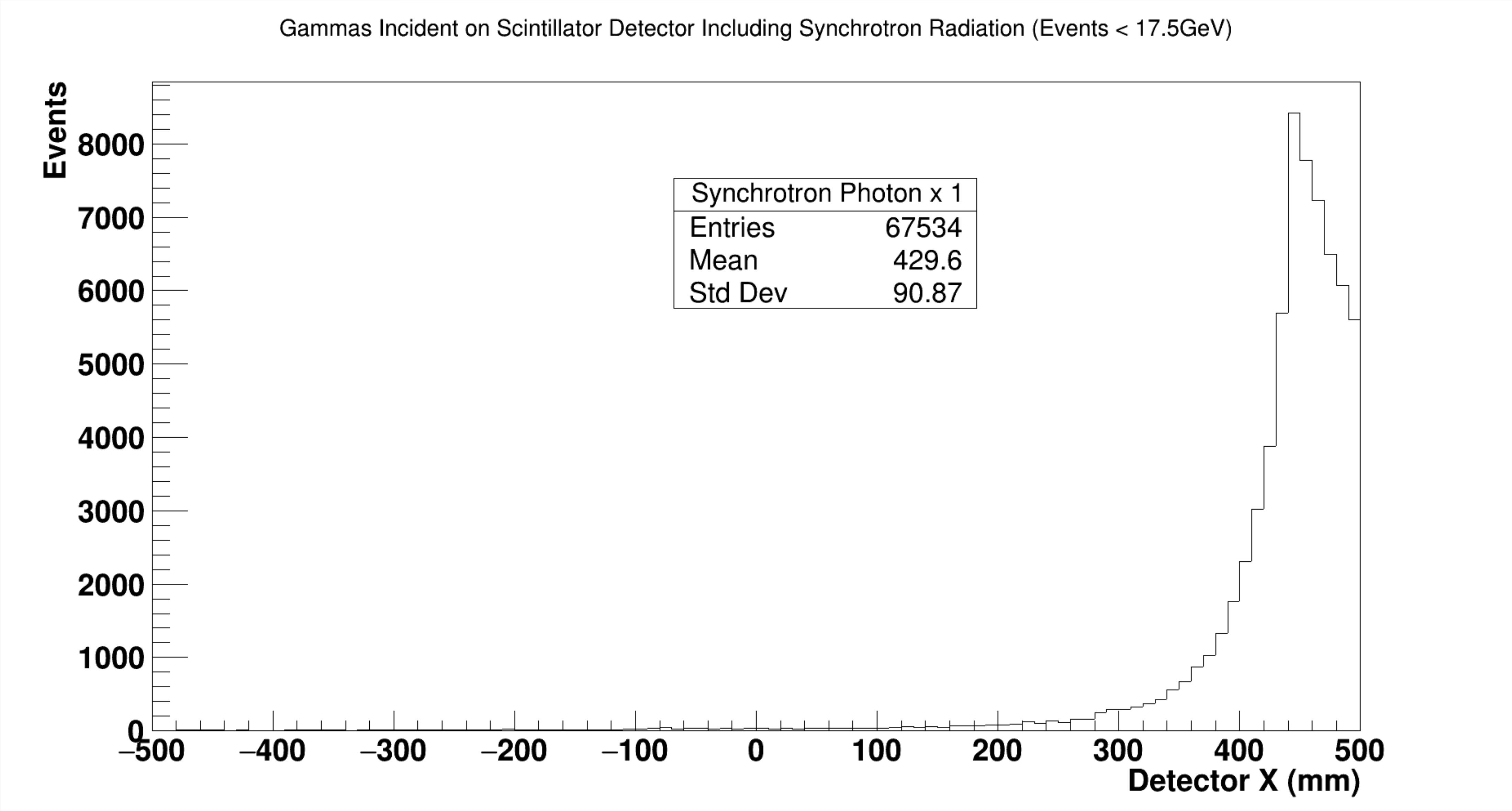


Synchrotron Radiation Included

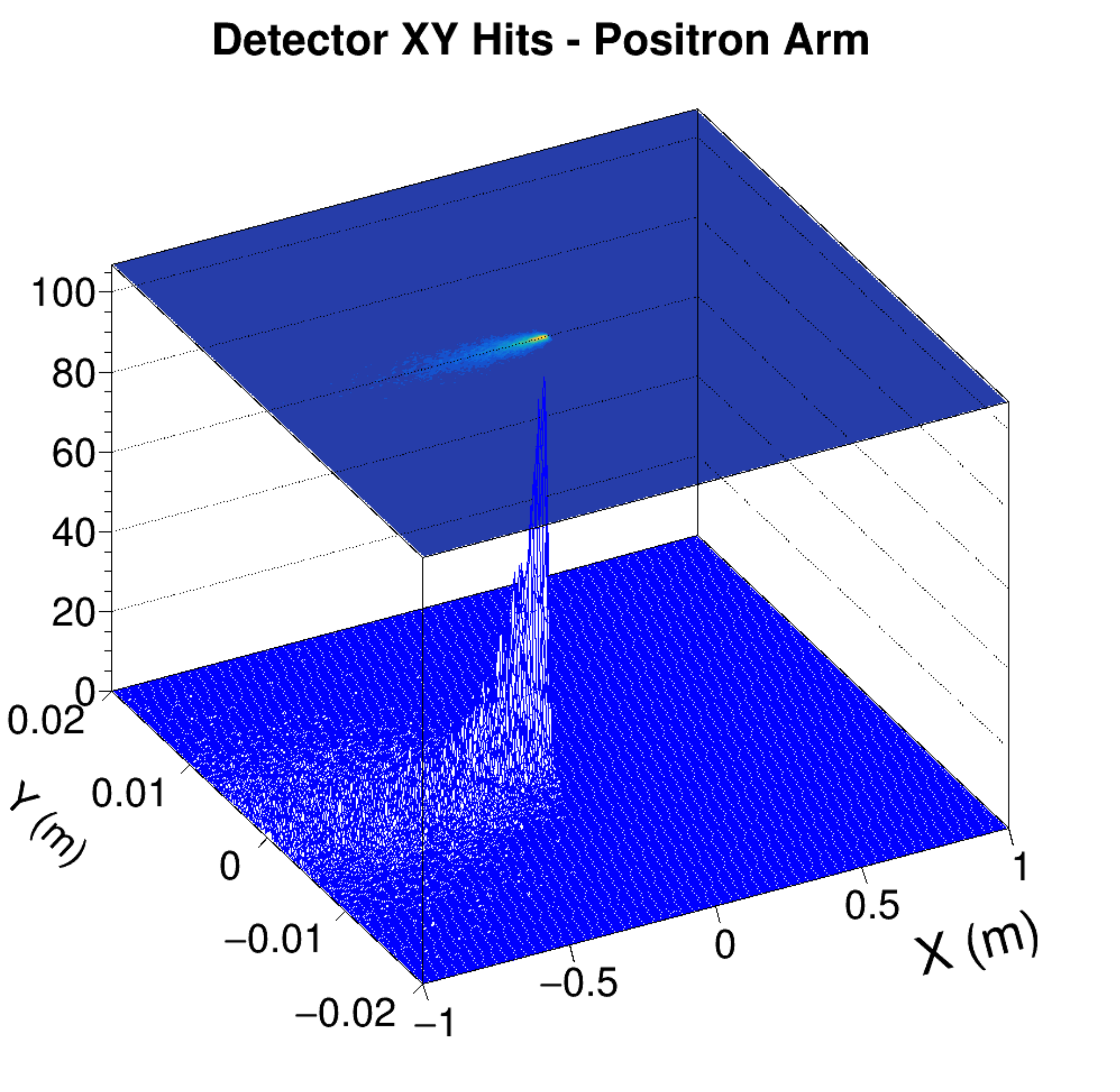
Uniform Incident Electron Energy up to 17.5 GeV



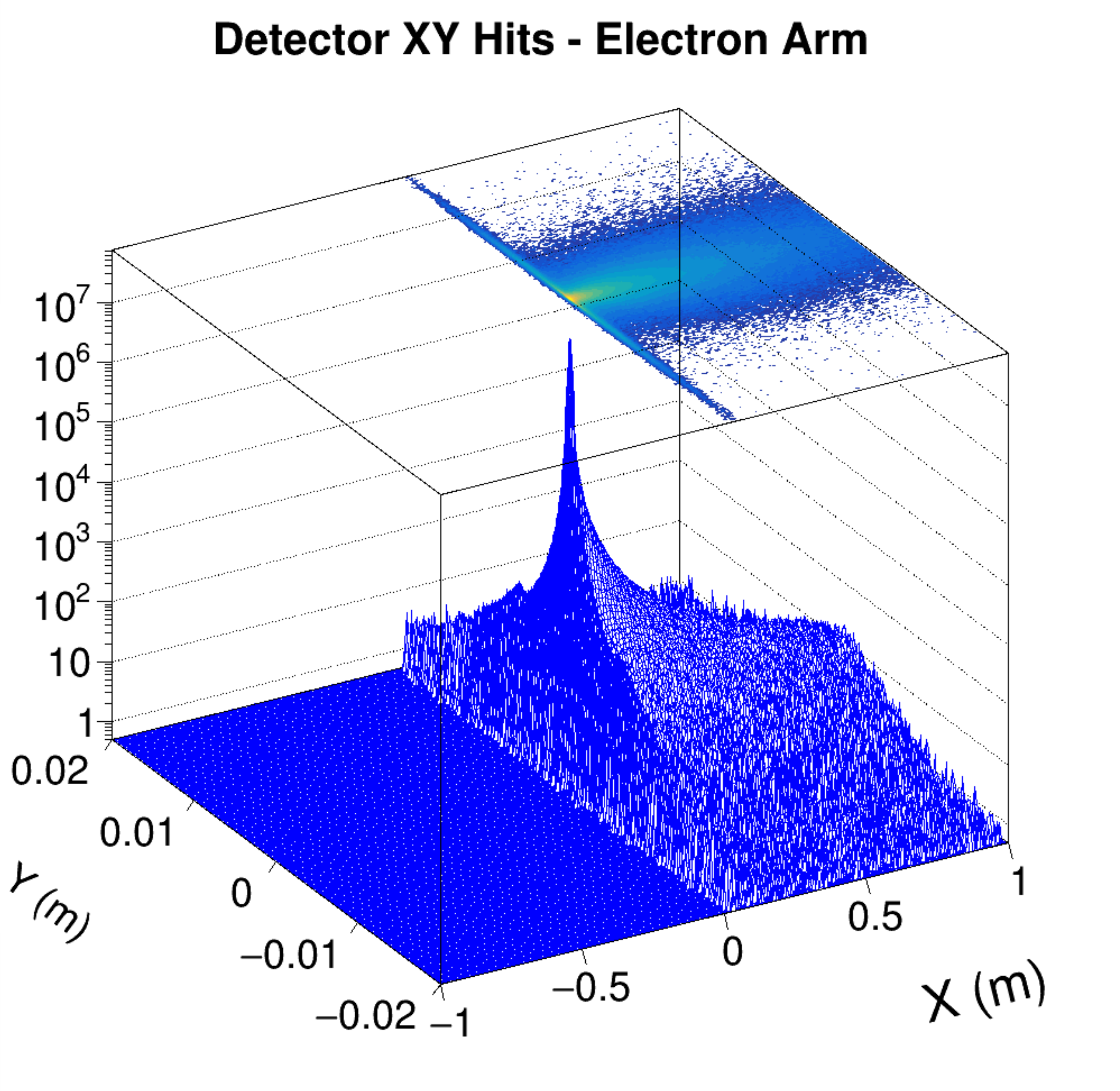
Synchrotron-Radiation-Induced Scintillation Light as fraction of all Scintillation light (Events < 17.5Gev)
Fraction
Scintillation Photon x 1
Entries 291
Mean 318
Std Dev 141.8
1
0.8
0.6
0.4
0.2
0
−0.2
−500
−400
−300
−200
−100
0
100
200
300
400
500
Detector X (mm)



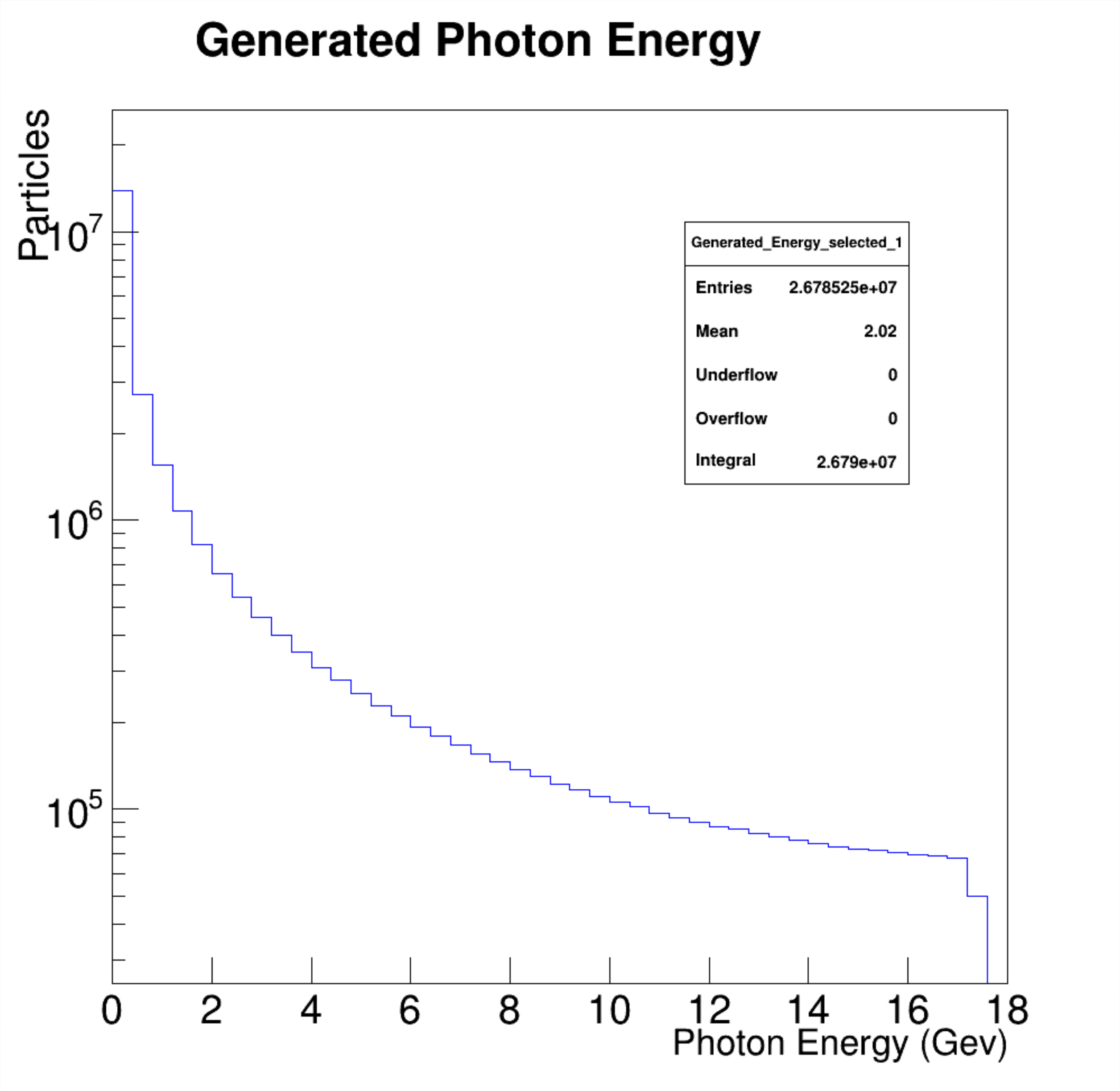
Gammas Incident on Scintillator Detector Including Synchrotron Radiation (Events < 17.5GeV)
Events
8000
7000
6000
5000
4000
3000
2000
1000
0
Synchrotron Photon x 1
Entries 67534
Mean 429.6
Std Dev 90.87
–500
–400
–300
–200
–100
0
100
200
300
400
500
Detector X (mm)



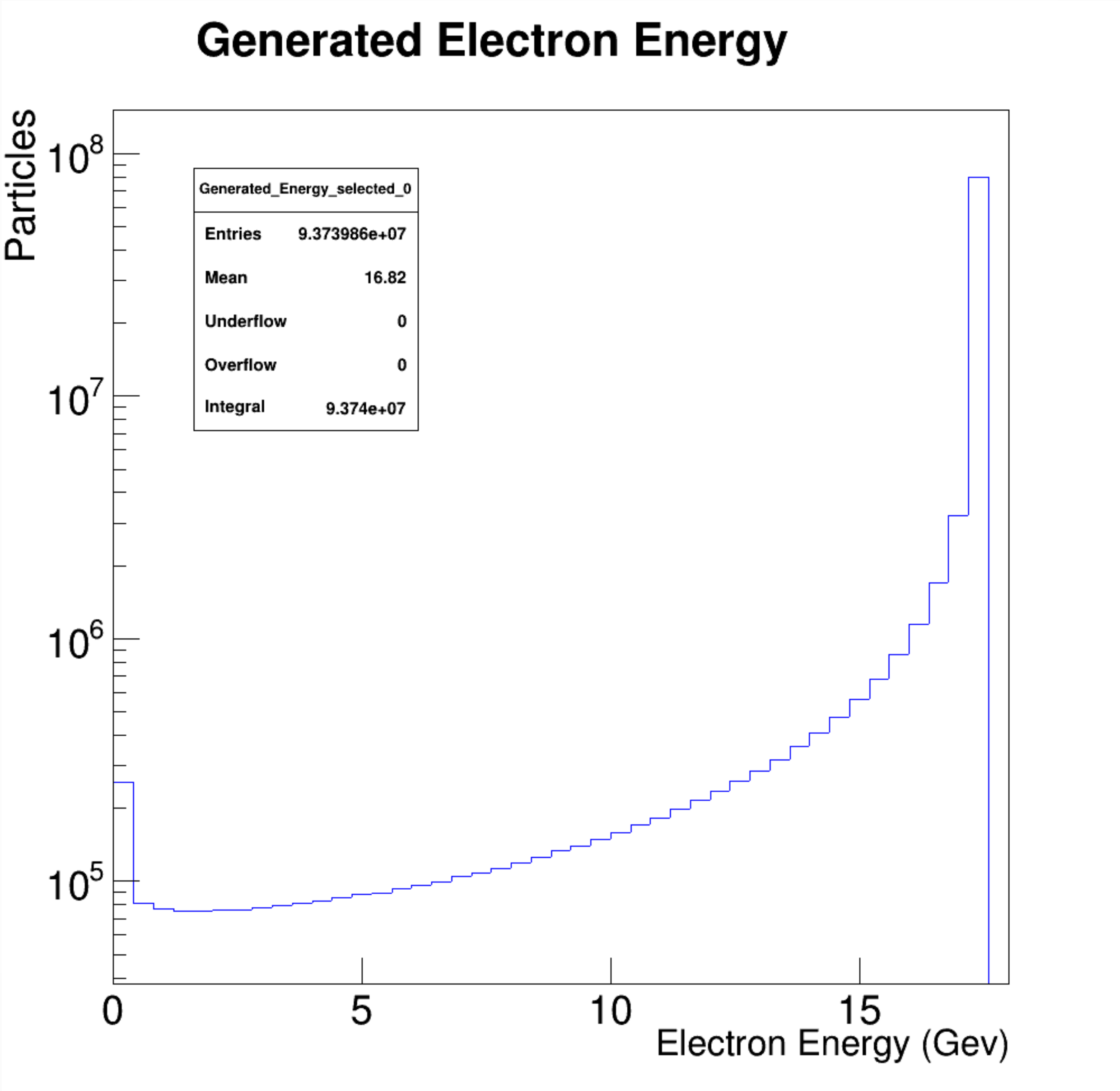
Detector XY Hits - Positron Arm
100
80
60
40
20
0
0.02
0.01
0
−0.01
−0.02
Y (m)
−1
−0.5
0
0.5
1
X (m)



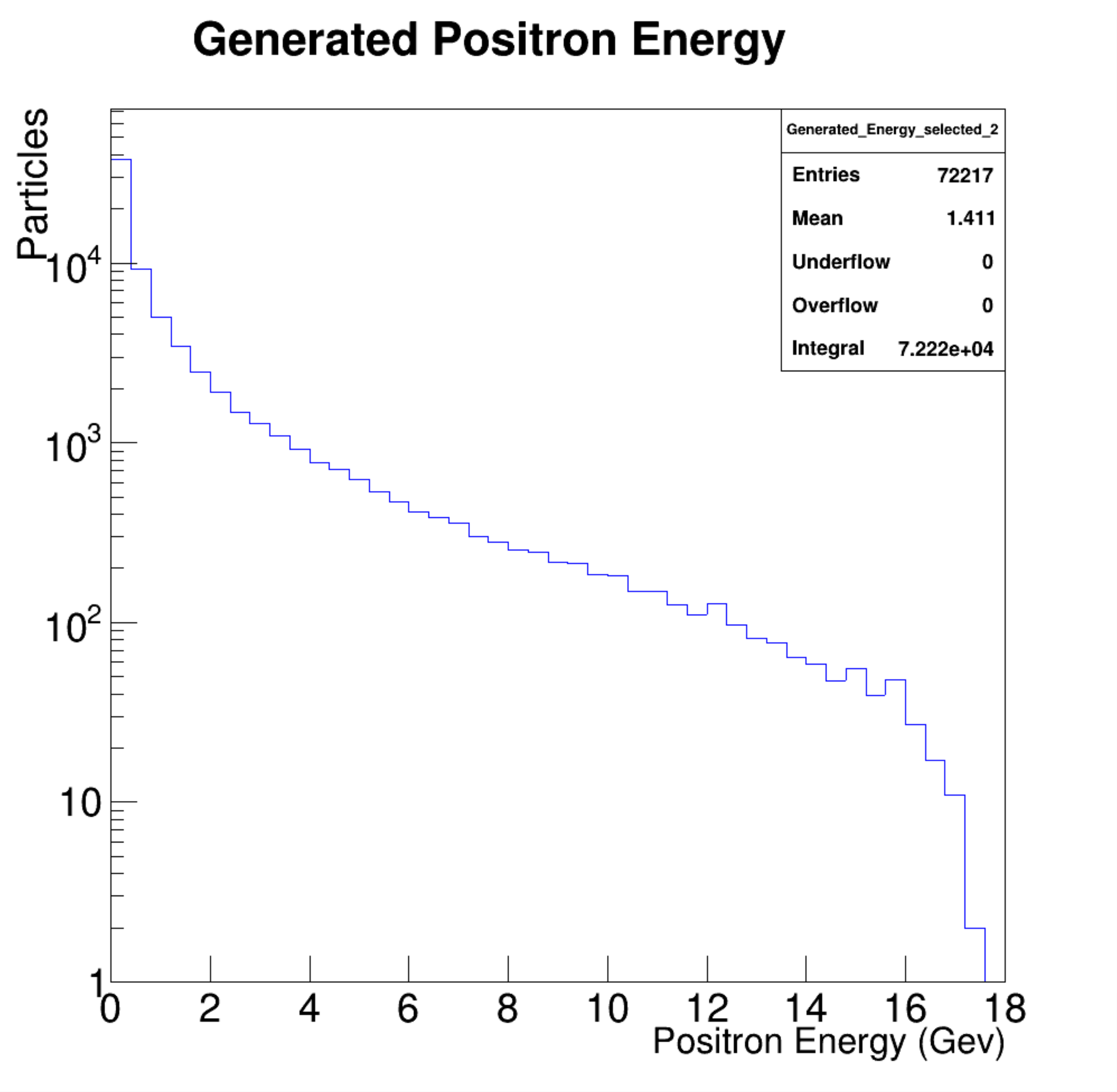
Detector XY Hits - Electron Arm
10^7
10^6
10^5
10^4
10^3
10^2
10
1
0.02
0.01
0
−0.01
−0.02
Y (m)
−1
−0.5
0
0.5
1
X (m)



Generated Photon Energy
Particles
10^7
10^6
10^5
Generated_Energy_selected_1
Entries 2.678525e+07
Mean 2.02
Underflow 0
Overflow 0
Integral 2.679e+07
0 2 4 6 8 10 12 14 16 18
Photon Energy (Gev)



Generated Electron Energy
Particles
10^8
10^7
10^6
10^5
Generated_Energy_selected_0
Entries 9.373986e+07
Mean 16.82
Underflow 0
Overflow 0
Integral 9.374e+07
0
5
10
15
Electron Energy (Gev)


Generated Positron Energy
Generated_Energy_selected_2
Entries 72217
Mean 1.411
Underflow 0
Overflow 0
Integral 7.222e+04
Particles
10^4
10^3
10^2
10
1
0 2 4 6 8 10 12 14 16 18
Positron Energy (Gev)

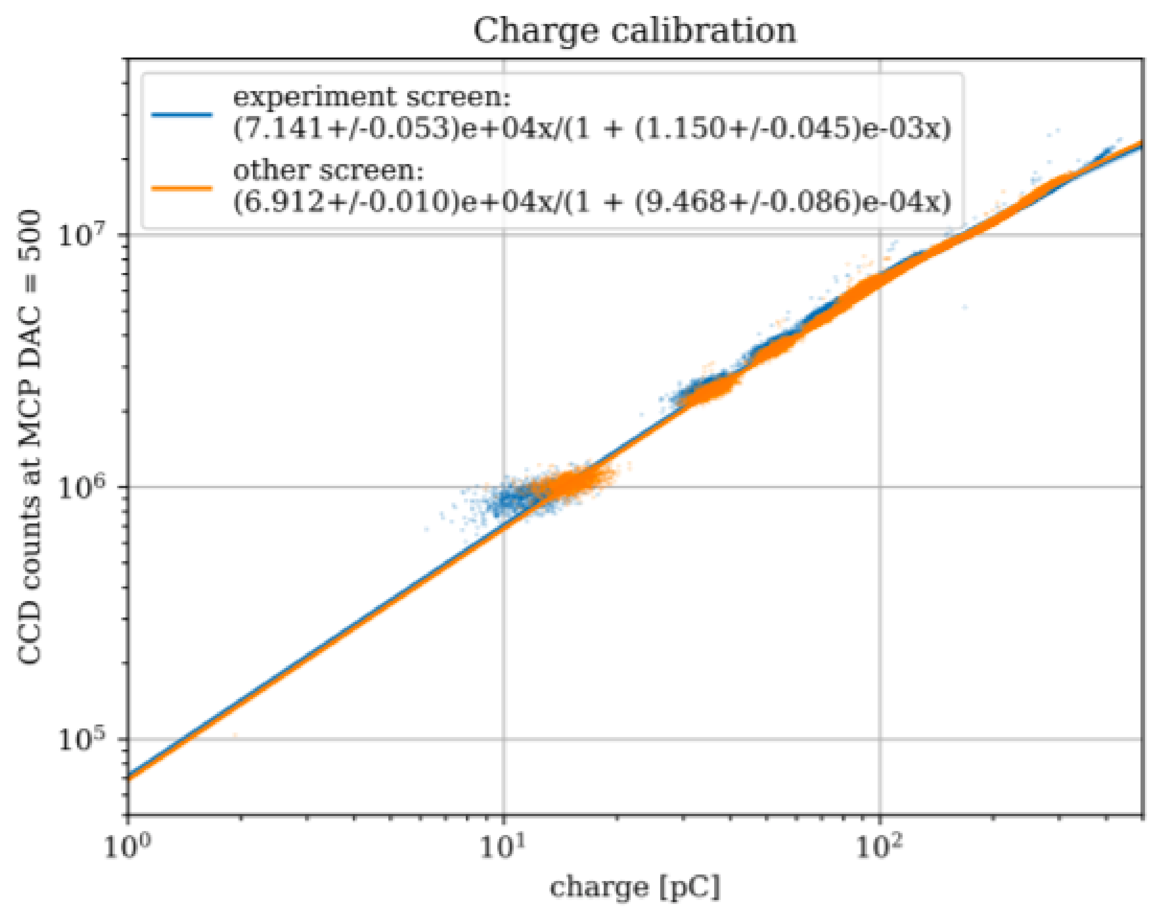


Figure 2: Light vs. charge for both screens

Charge calibration of the AWAKE spectrometer
D. A. Cooke
November 22, 2019

- High intensity spot near beampipe

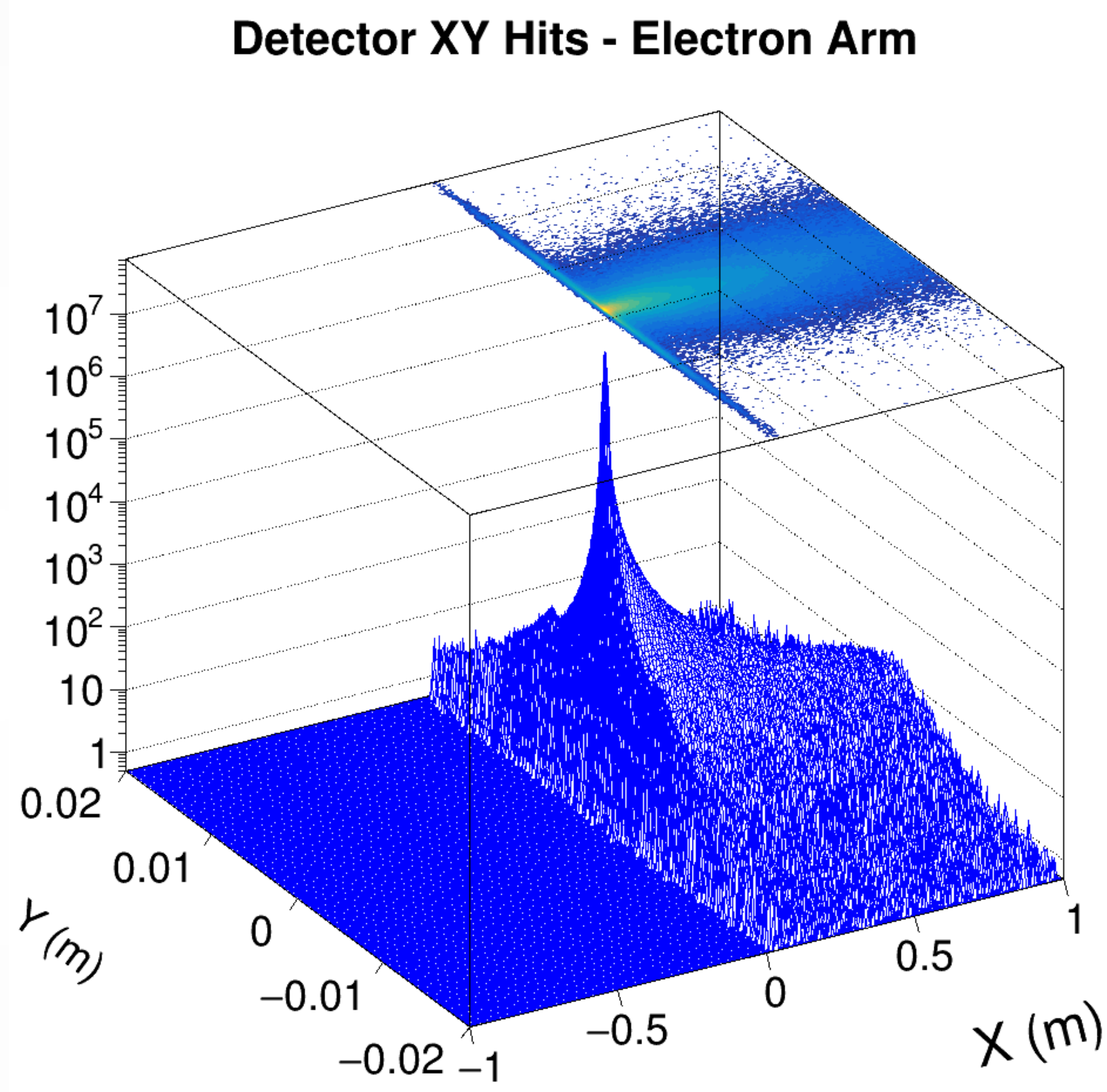
- Mechanism of Cerenkov makes it suited for high energy, high intensity

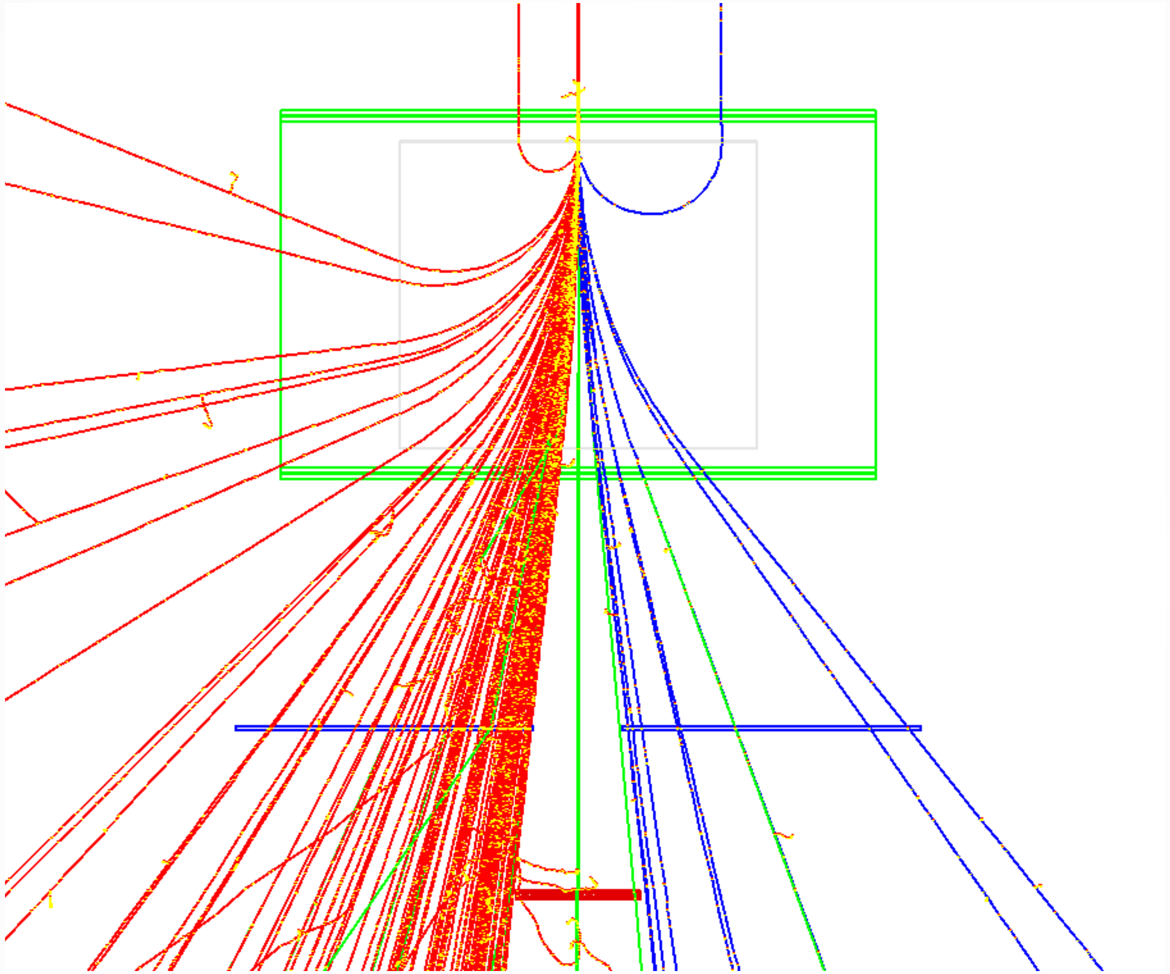
$$\frac{d^2E}{dxd\omega} = \frac{\omega q_e^2 \mu(\omega)}{4\pi}\left(1 - \frac{\beta^2}{n^2(\omega)}\right)$$

- A high dynamic range in this spectrum far exceeds that of one camera

- Multi-Camera set-up possible

- Saturation is a possible concern, but hard to quantify





Scintillation light output with limited steel aperture