Cherenkov & Scintillation Detectors At the LUXE Experiment

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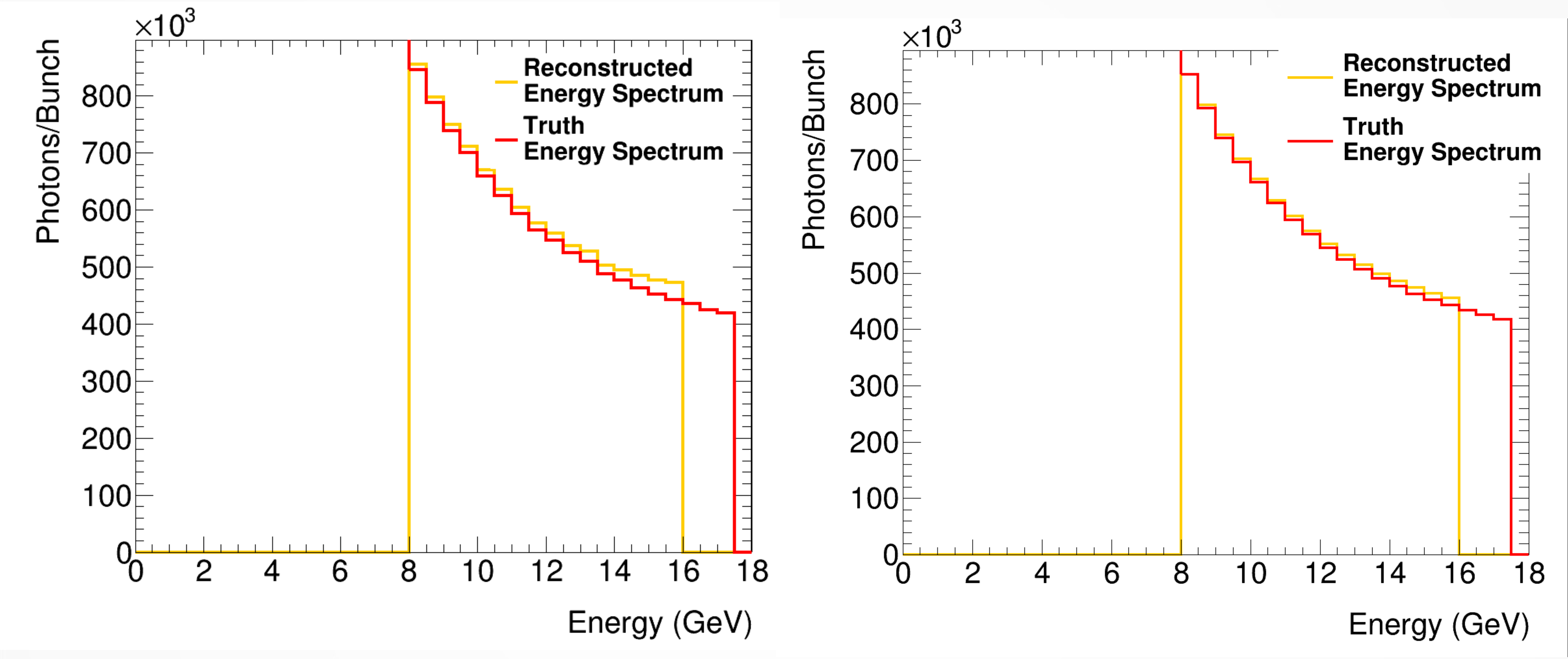
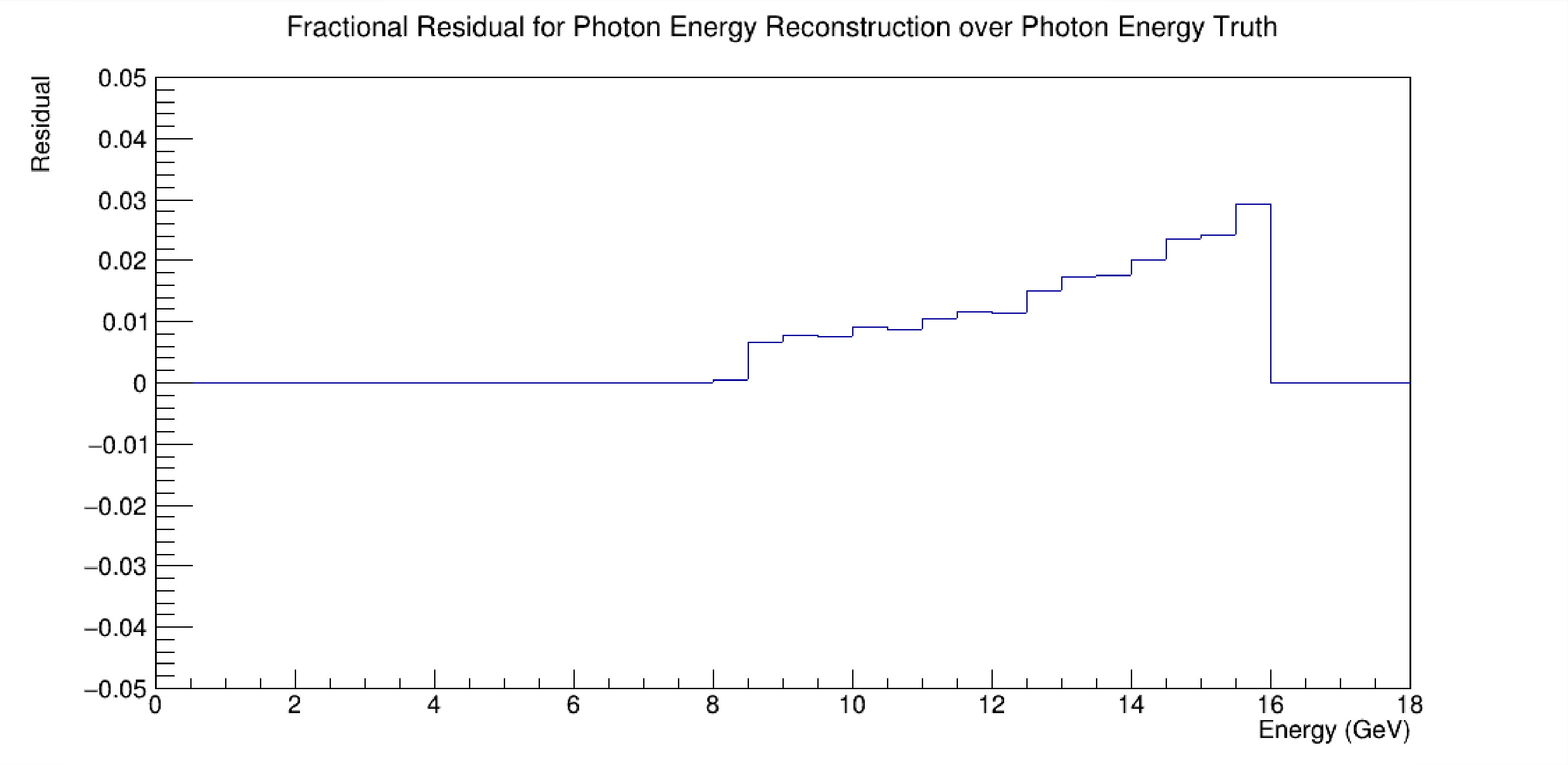
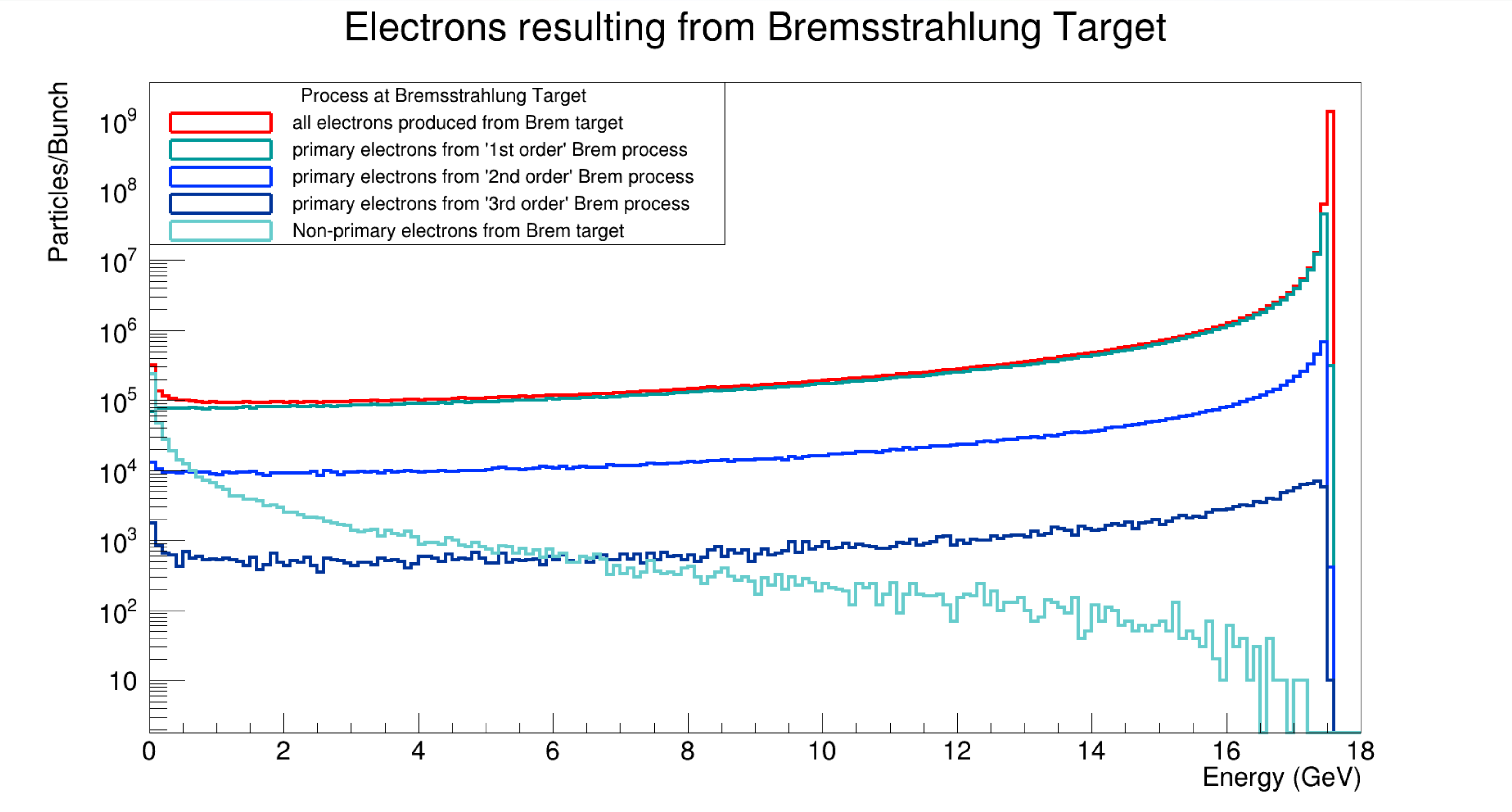


Reconstructed Photon spectrum without converted-pair correction (left) and with (right).



For our idealised version, we are looking at a discrepancy of up to 2.9%. Hard to say if this may be a dominant uncertainty as of now. Statistical uncertainty should prove insignificant over a decent timescale, but the error of the camera affects and B-field are likely to contribute reasonably too.



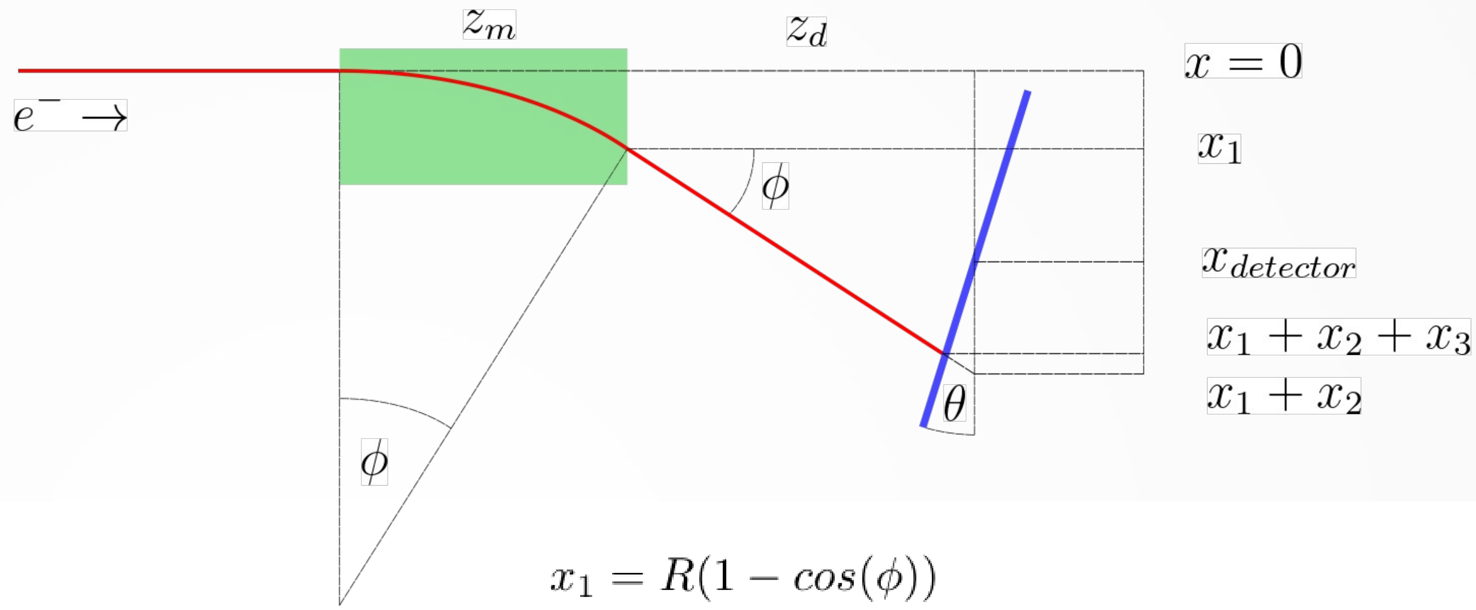
Simulated in Geant4, with bunches of 1.5 x 10^9 17.5-GeV e^-
Adding to the general LUXE Geant simulation.

Backup

Magnetic Action

Using the expressions opposite I relate energy to position, and can reconstruct energy strictly from position of hit in a detector plane.

This is useful as the flux in this region is high enough to thwart sensitive detectors which directly measure energy



$$x_1 = R(1 - cos(\phi))$$

$$x_2 = tan(\phi)z_d$$

$$x_3 = \frac{tan(\theta)tan(\phi)(x_{detector} - x_1 - x_2)}{1 + tan(\theta)tan(\phi)}$$

Where $\phi = sin^{-1}(\frac{z_m}{R})$. From there mapping to the detector's 'local' x coordinates is elementary: $x_{local} = x_{global} - x_{detector}/cos(\theta)$

$$R = \frac{E_{\text{eV}}}{Bc}$$

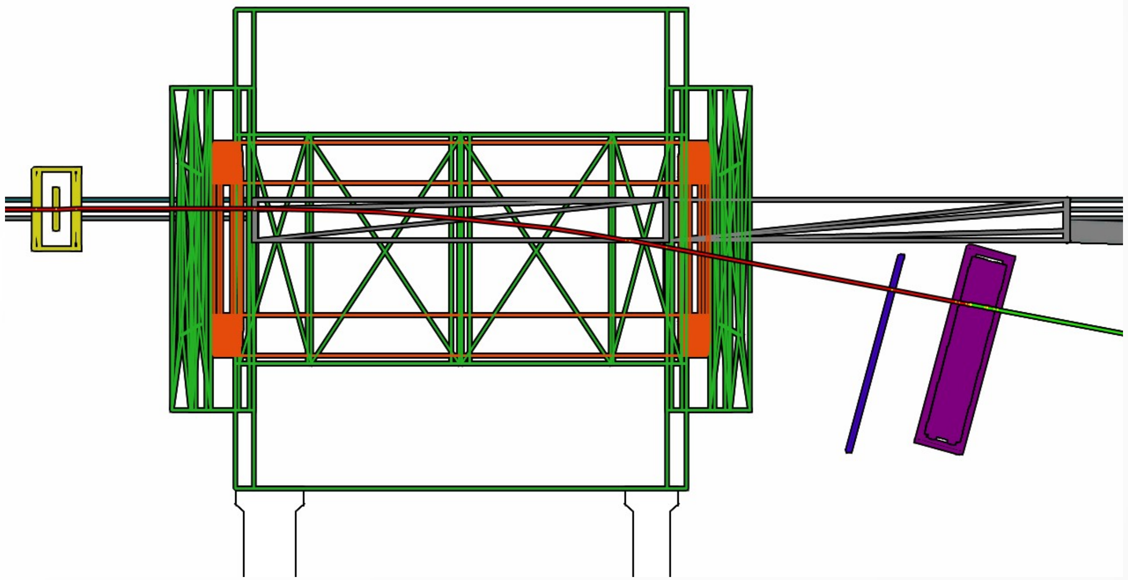
Where we use $v \approx c$ and $E = \gamma m_e c^2$ considering our highly relativistic particles, and substitute E/q for E in eV units.

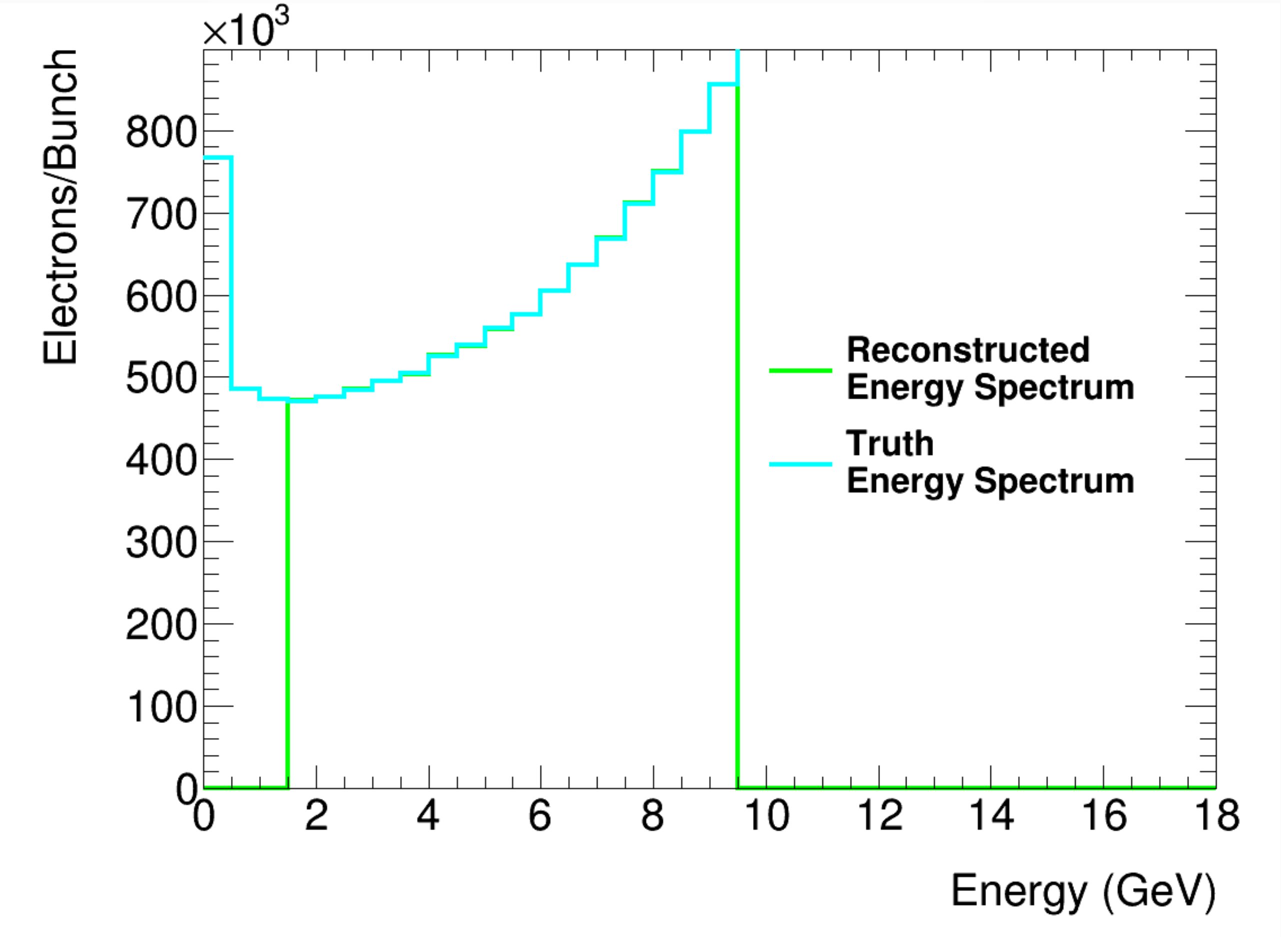
Implementation

- We shall implement a union of Cherenkov and Scintillator detectors to measure the e- energy spectrum.

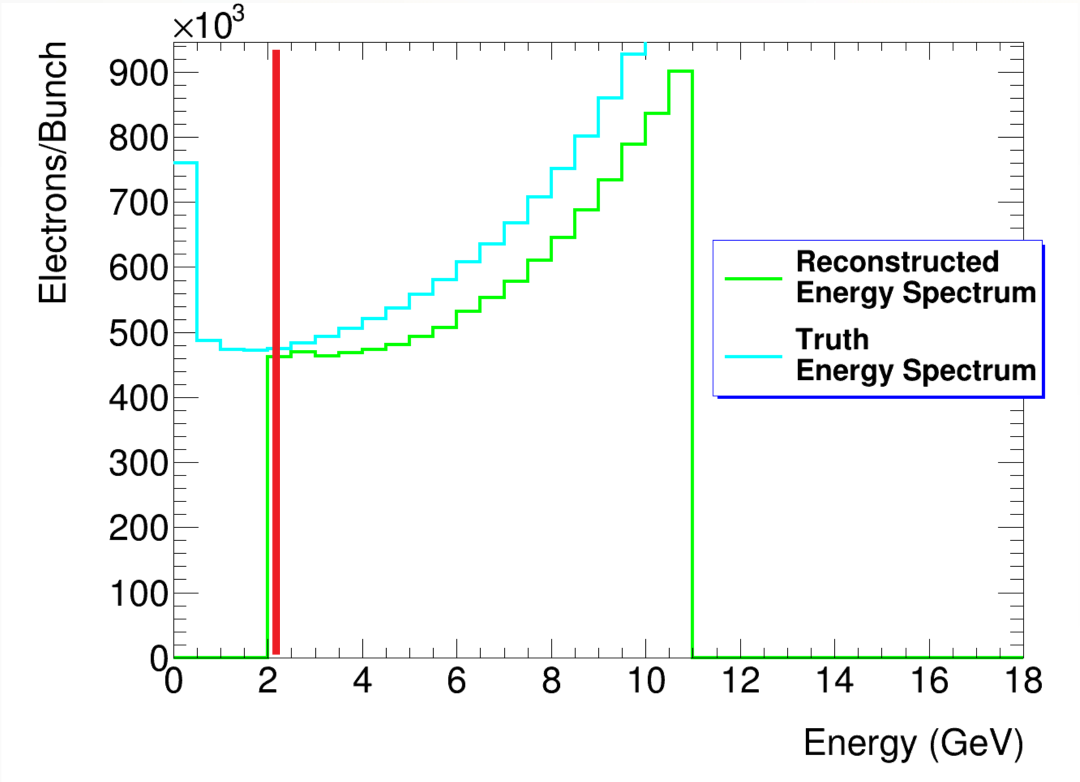
- As opposed to previous graphic, I place the beamline off-axis with respect to center of B-field, and measure only one spectrum (e^-,e^+) at one time.

- By reversing polarity of the dipole, the spectrum of positrons from the foil target can be measured. This can be used as correction for the Brem-electron measurement or directly - as a statistical average, this energy distribution is one-half of the photon distribution.

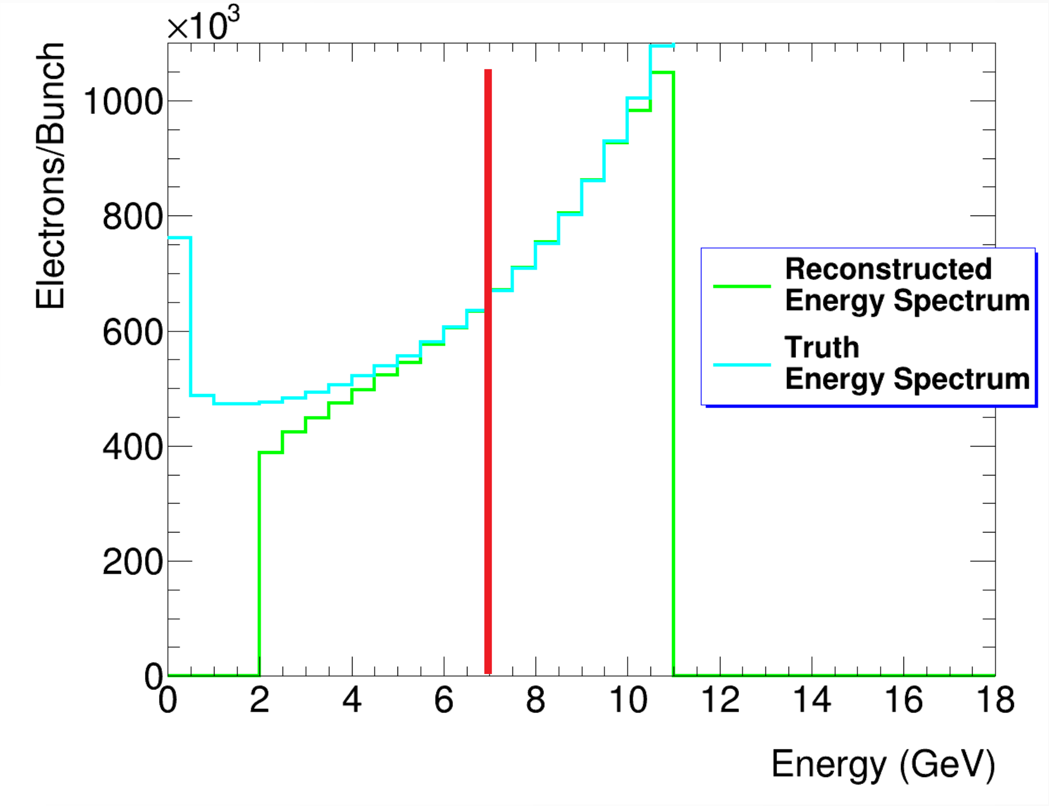




Reconstruction of Electron energy spectrum for simulated data from a Scintillation screen in Geant4. This shows the response without any interfering matter (air, beampipe). Again, bunches if 1.5×10^9 e^- at 17.5 GeV.

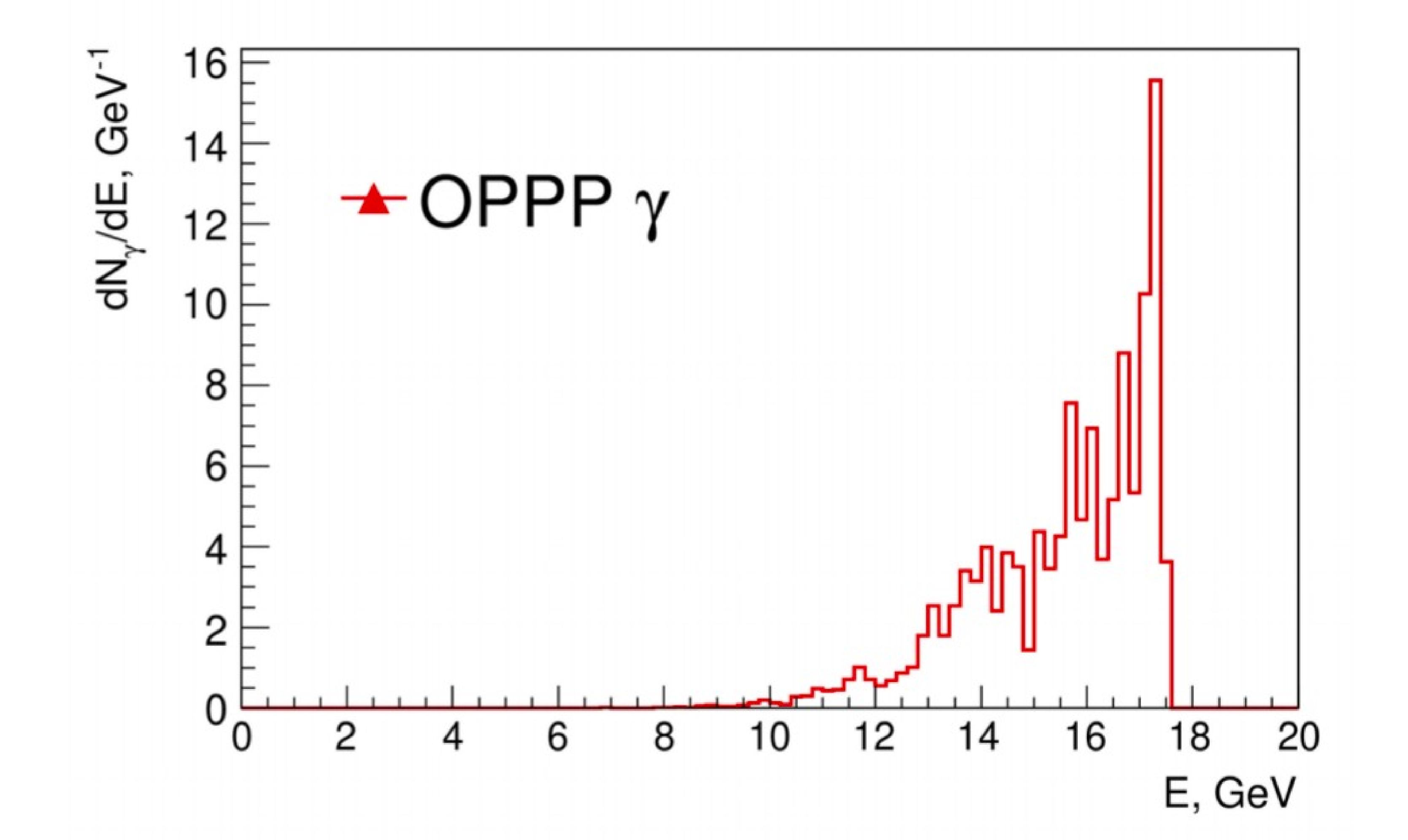


15° alignment



5° alignment

Reconstructions of electron energy spectra from the foil target for two different simulations with arbitrary scale. Both show the response without any interfering matter (air, Beampipe) for a Cherenkov detector in Geant4 with 2.3 mm channels. The mechanics of the function of this device means that it's sensitive to discrepancy in angular approach of the incoming particles. A better design could include more planes of these channels.



dN$_\gamma$/dE, GeV^{-1}
16
14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14
16
18
20
OPPP γ
E, GeV

For the simplest Bremsstrahlung interaction, this is necessarily:

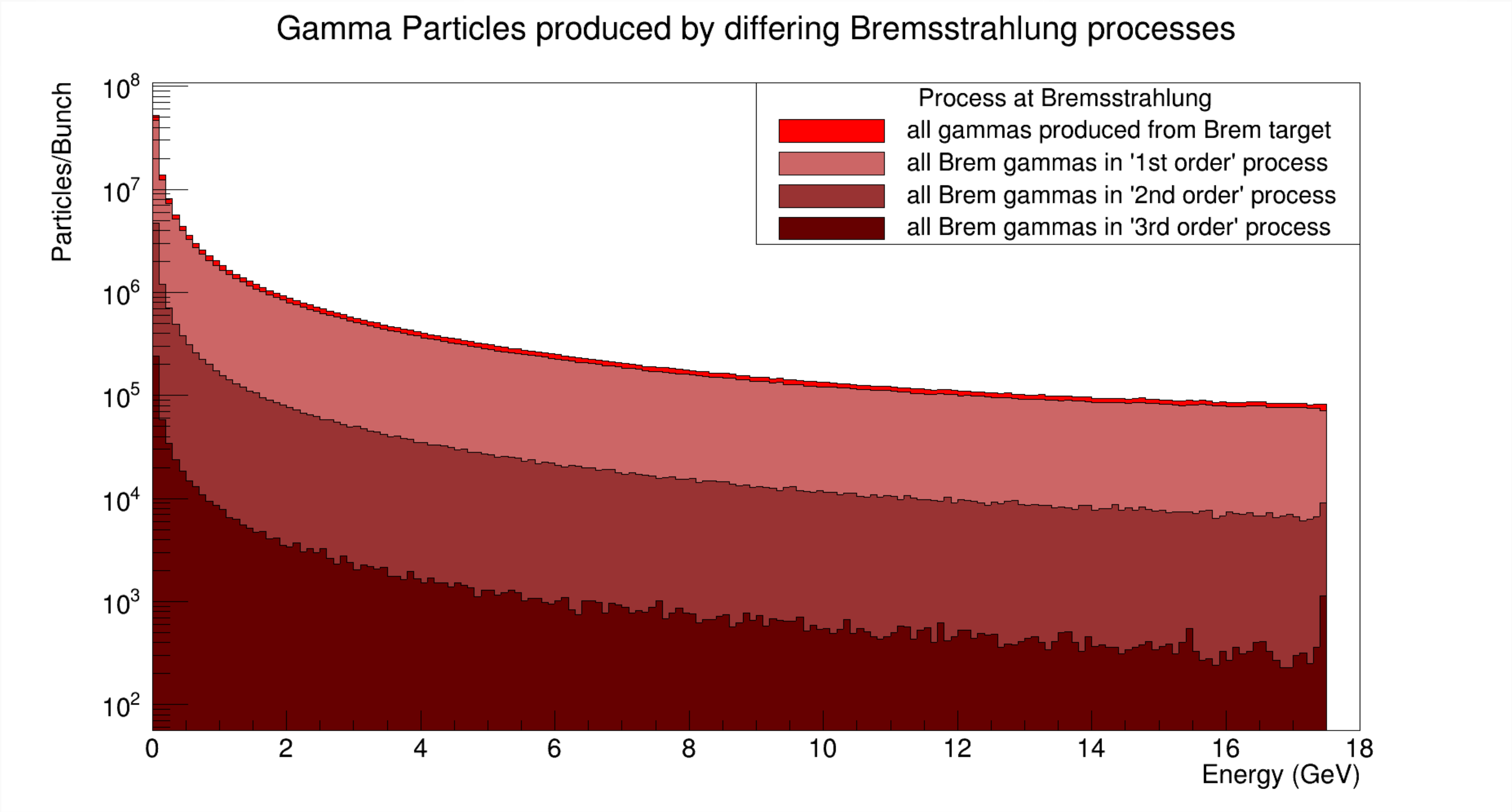
$$E_\gamma = E_{beam} - E_e$$

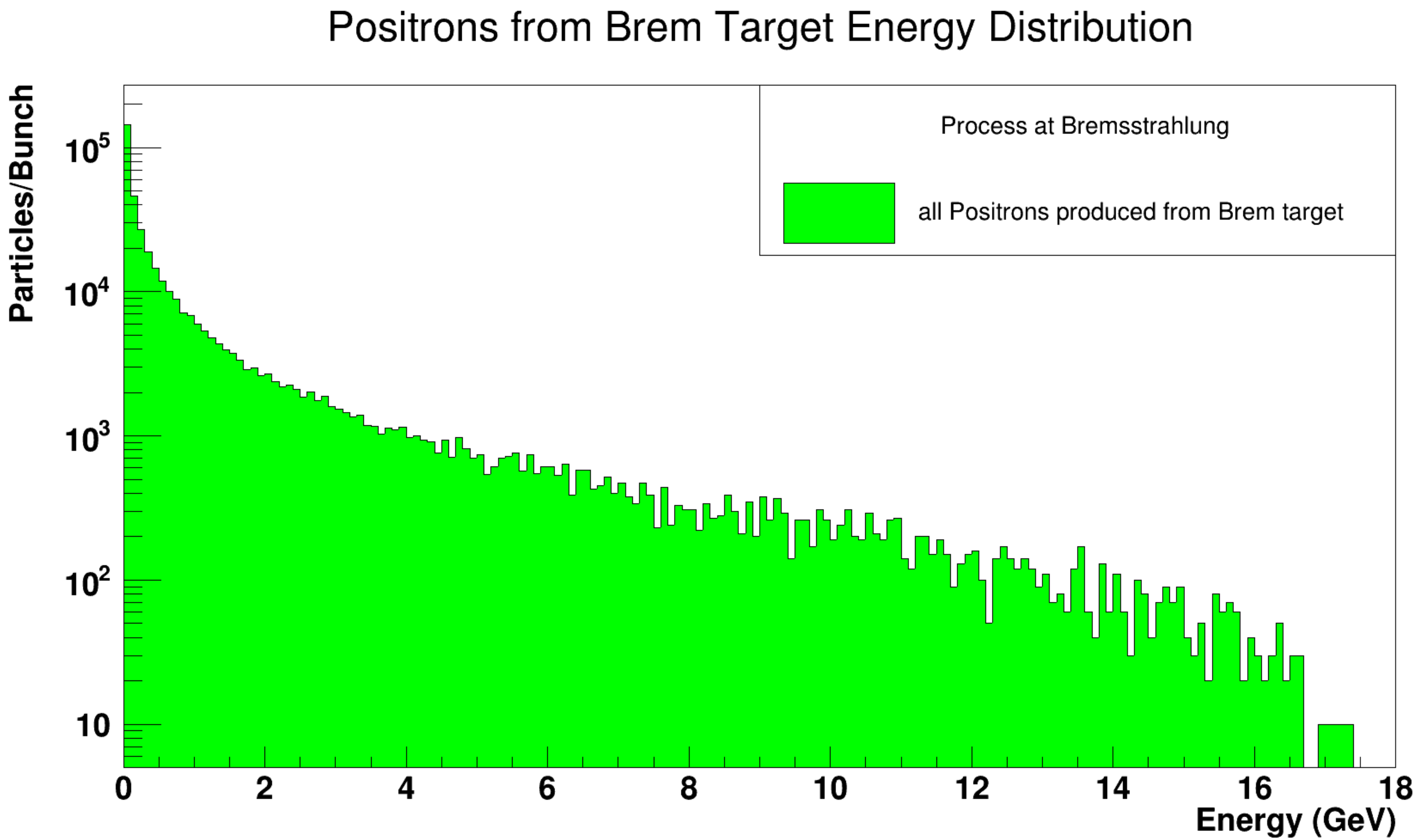
For two successive Bremsstrahlung interactions:

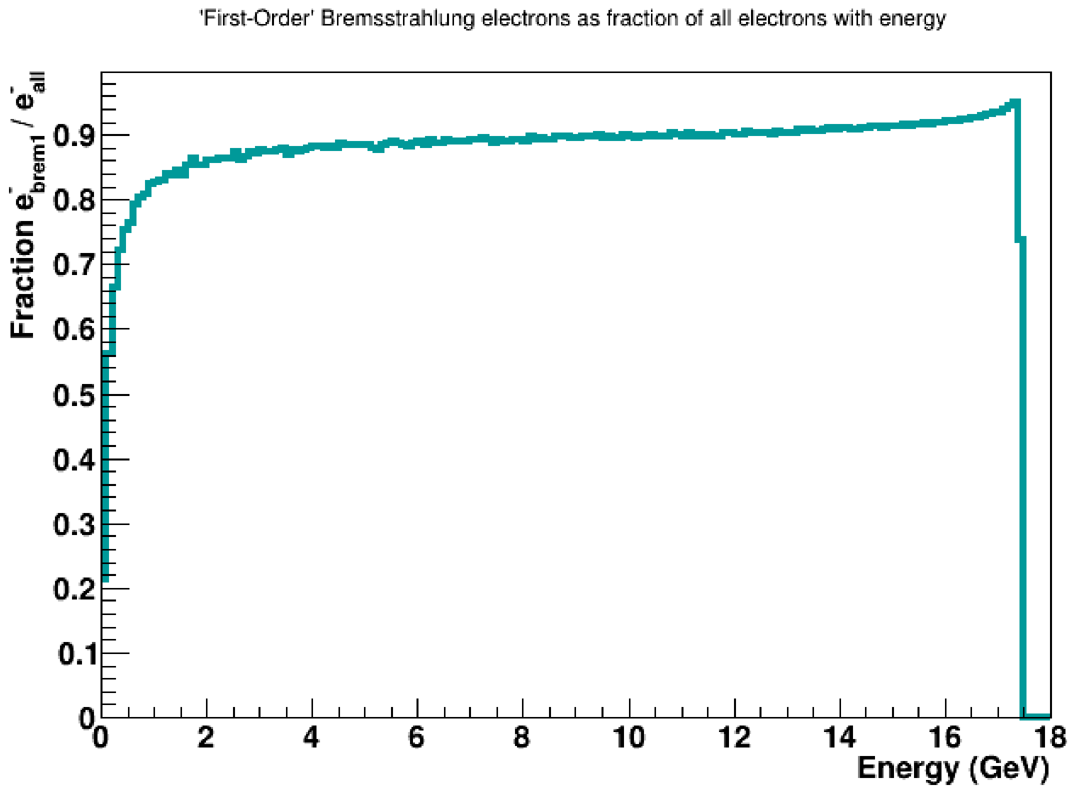
$$E_e = E_{beam} - E_{\gamma 1} - E_{\gamma 2}$$

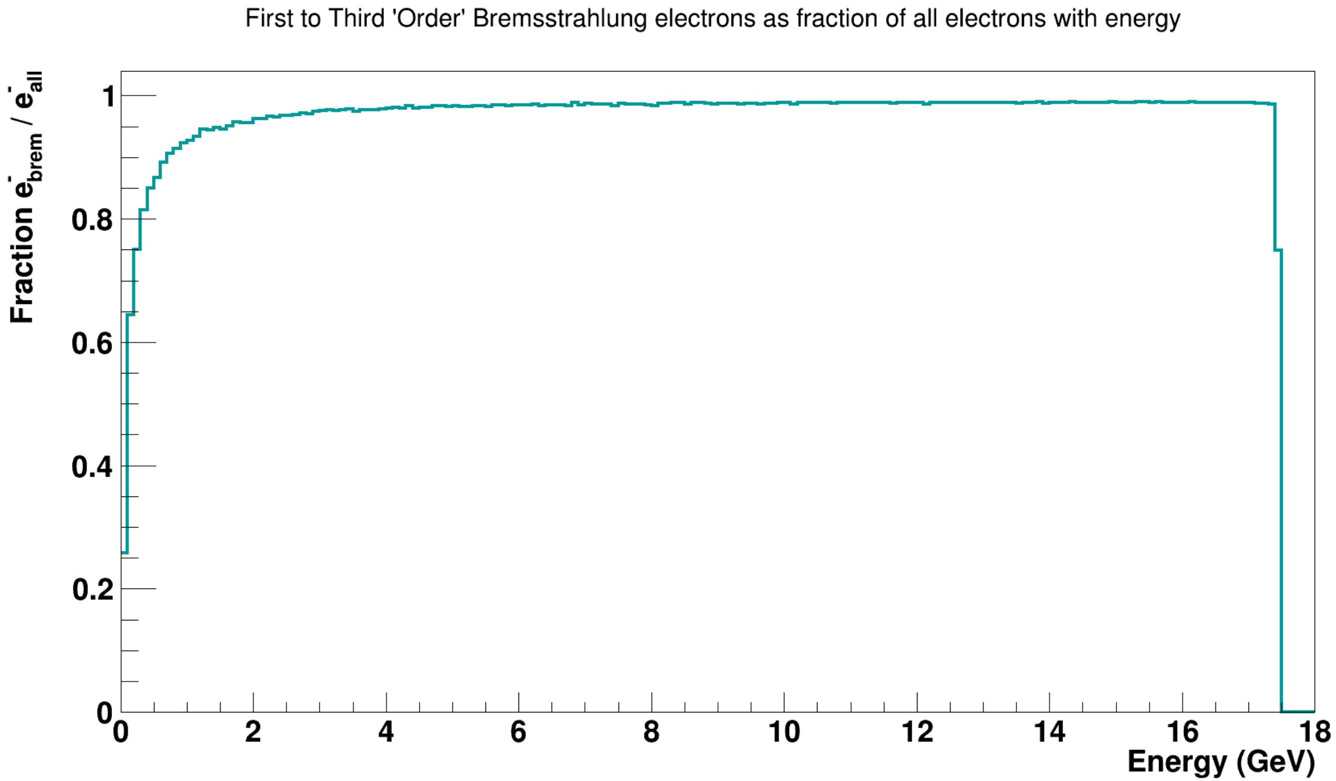
The emitted gamma can also undergo pair production, where as a statistical average the energy of each positron is one half of the gamma energy

This trend is of course weaker as a statistical average and the creation of positrons far less frequent than Bremsstrahlung


Gamma Particles produced by differing Bremsstrahlung processes
Particles/Bunch
10^8
10^7
10^6
10^5
10^4
10^3
10^2
0
2
4
6
8
10
12
14
16
18
Energy (GeV)
Process at Bremsstrahlung
all gammas produced from Brem target
all Brem gammas in '1st order' process
all Brem gammas in '2nd order' process
all Brem gammas in '3rd order' process


Positrons from Brem Target Energy Distribution
Process at Bremsstrahlung
all Positrons produced from Brem target
Particles/Bunch
10
10^2
10^3
10^4
10^5
0
2
4
6
8
10
12
14
16
18
Energy (GeV)


'First-Order' Bremsstrahlung electrons as fraction of all electrons with energy
Fraction e-brem1 / e-all
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0
2
4
6
8
10
12
14
16
18
Energy (GeV)


First to Third 'Order' Bremsstrahlung electrons as fraction of all electrons with energy
Fraction e-brem / e-all
0
0.2
0.4
0.6
0.8
1
0
2
4
6
8
10
12
14
16
18
Energy (GeV)

Scintillator screen 1mm GadOx

Cerenkov 10mm Argon

Effect of ~50 cm of Air is few percent (Scintillation) Negligible (Cerenkov)

Nominal Al Thickness	Photon output Per 10 GeV e^- (Scintillator)	Fraction of No Beampipe (Scintillator)	Photon output Per 10 GeV e^- (Cerenkov)	Fraction of No Beampipe (Cerenkov)
0 mm	92160	100%	1.3695	100%
1.65 mm	95180	103.3%	1.37661	100.5%
18.9 mm	131400	142.6%	1.60871	117.5%