γ – LASER Mode
Beam Monitoring & Scintillation Detectors

John Hallford

University College London

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LUXE

DESY.

The incidence of these particles on a detector plane orthogonal to a beampipe is described by this equation:

$$x = R(1 - cos(sin^{-1}(\frac{z_m}{R}))) + tan(sin^{-1}(\frac{z_m}{R}))z_d$$

We also must create a provision to account for the possible rotation of the detector in the Y axis by an angle of θ. Separating the components of the final x value into x_1, x_2 and x_3, we sum them to obtain the 'global' x-value of the hit.

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

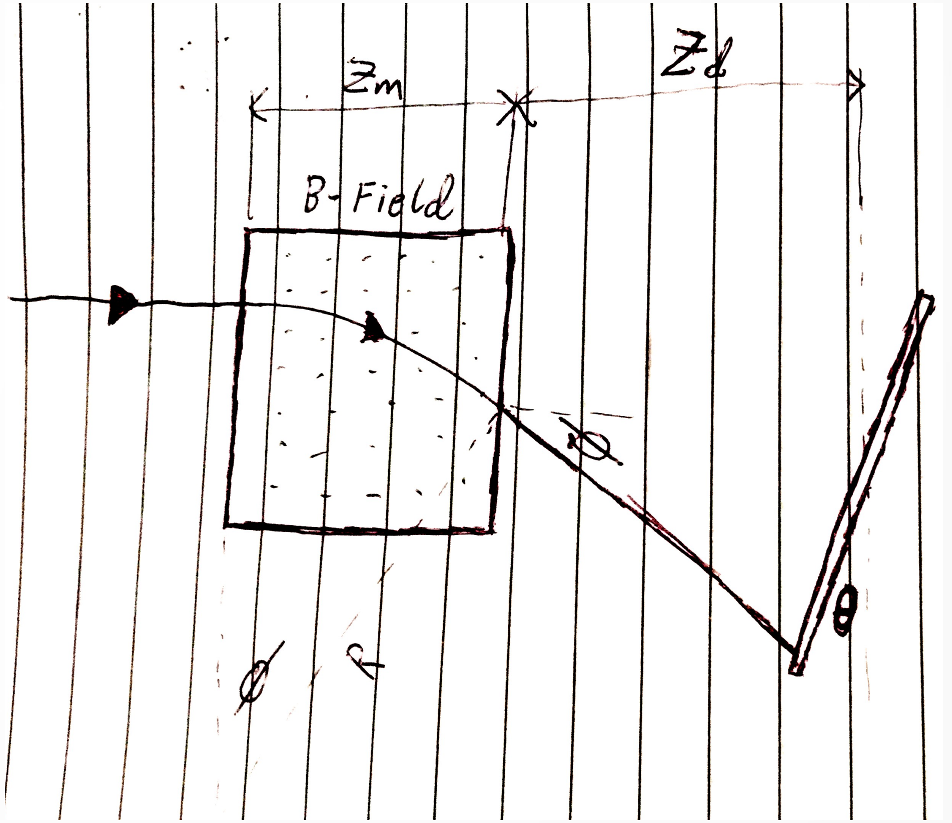
$$x_2 = tan(\phi)z_d$$

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

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

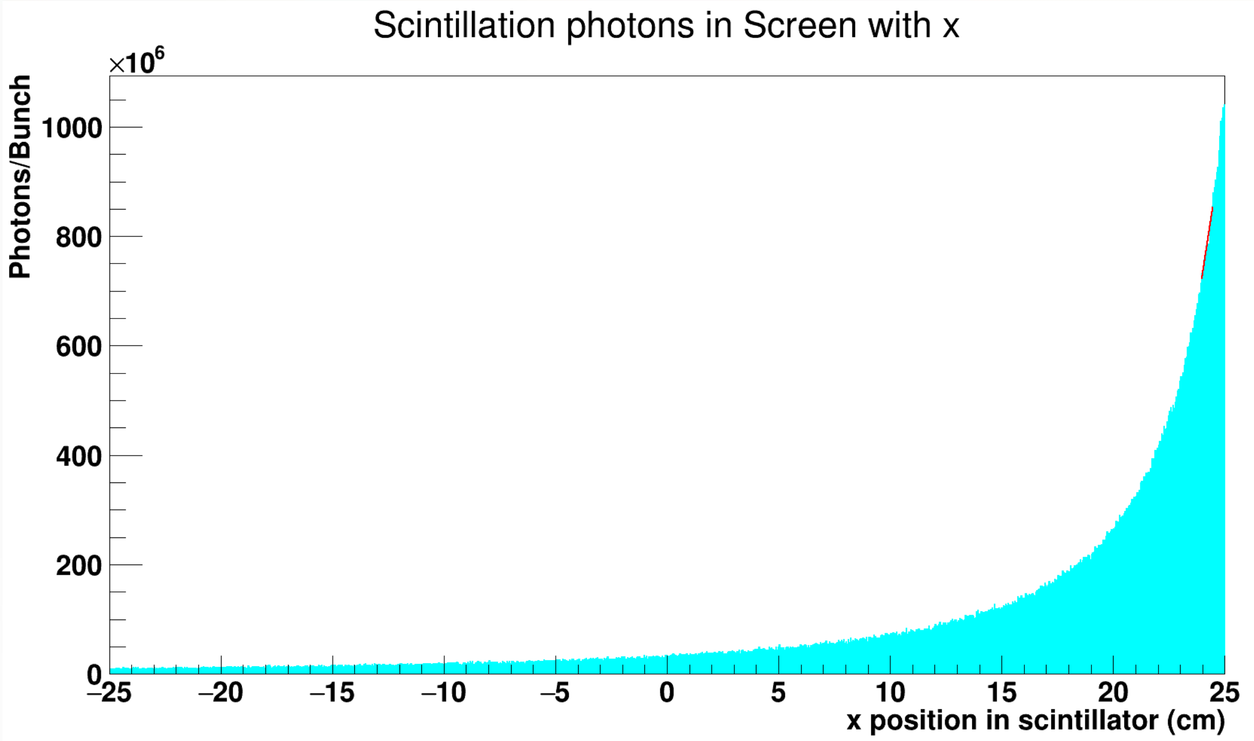
R = E / Bc

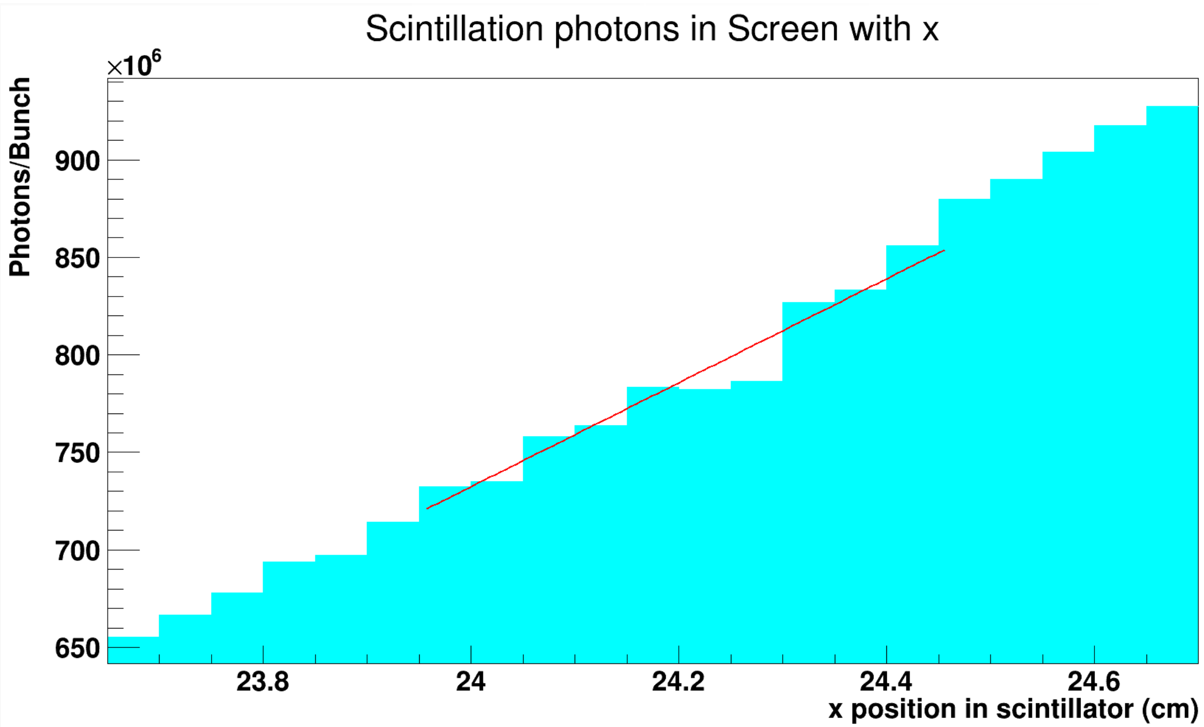
(Energy in eV)



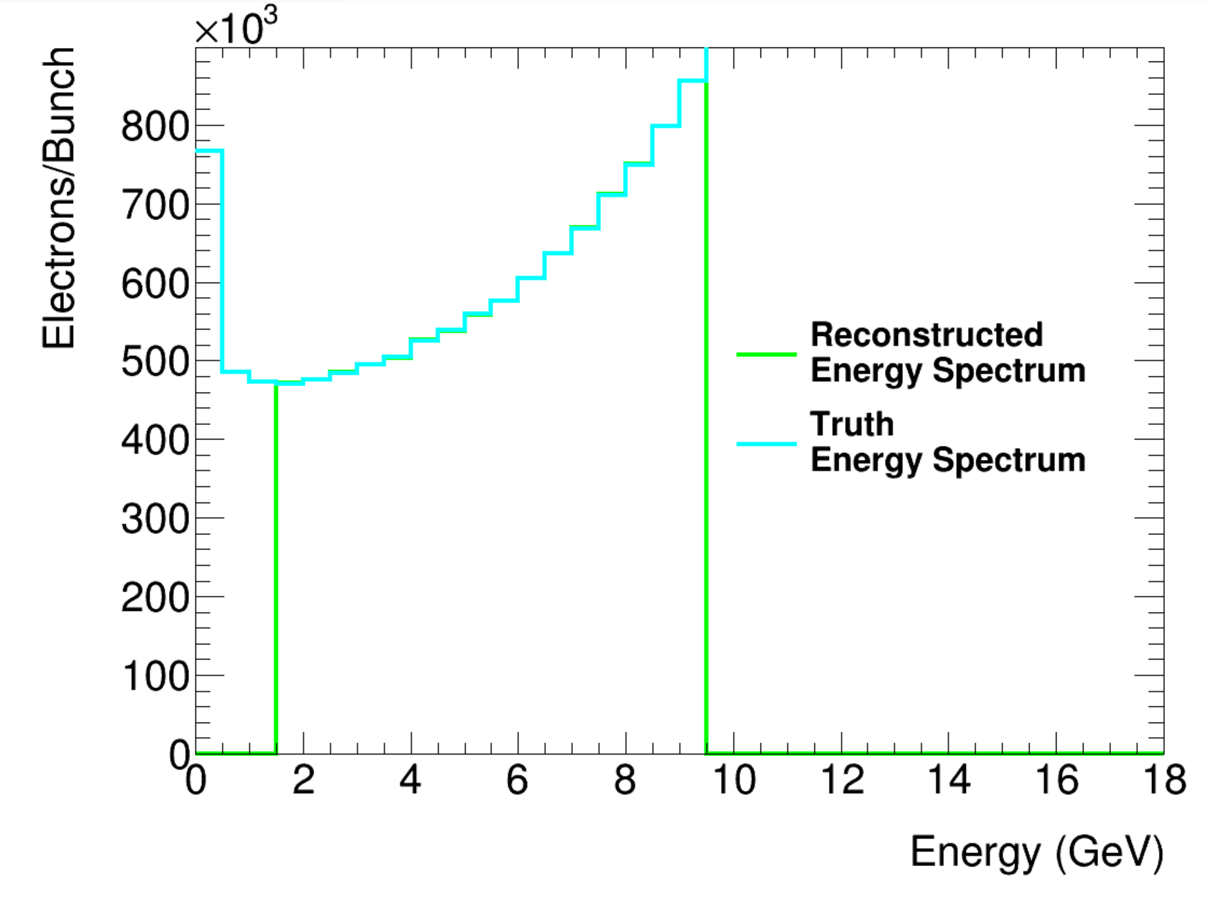
From here, I have looked at the simulated light output profile across detector 'x', and used the previous function to determine x-position for some E. For chosen intervals of E, find the corresponding interval in x, and find the integral of Cerenkov light within. Then need to divide N_photons by photons/Electron for each electron energy, to find an electron E spectrum.

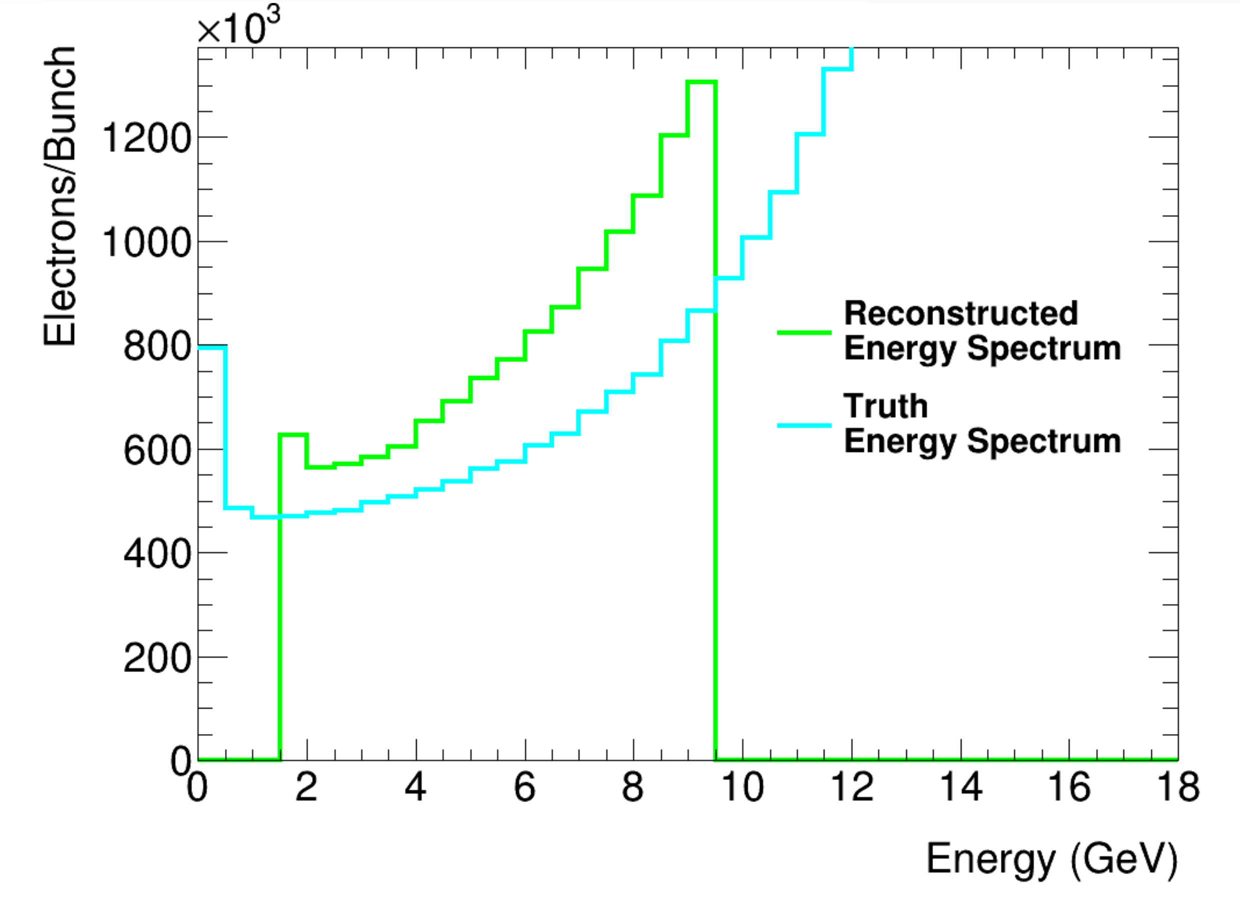
From there we can take $E_{beam} - E_e$ to gather a Photon spectrum





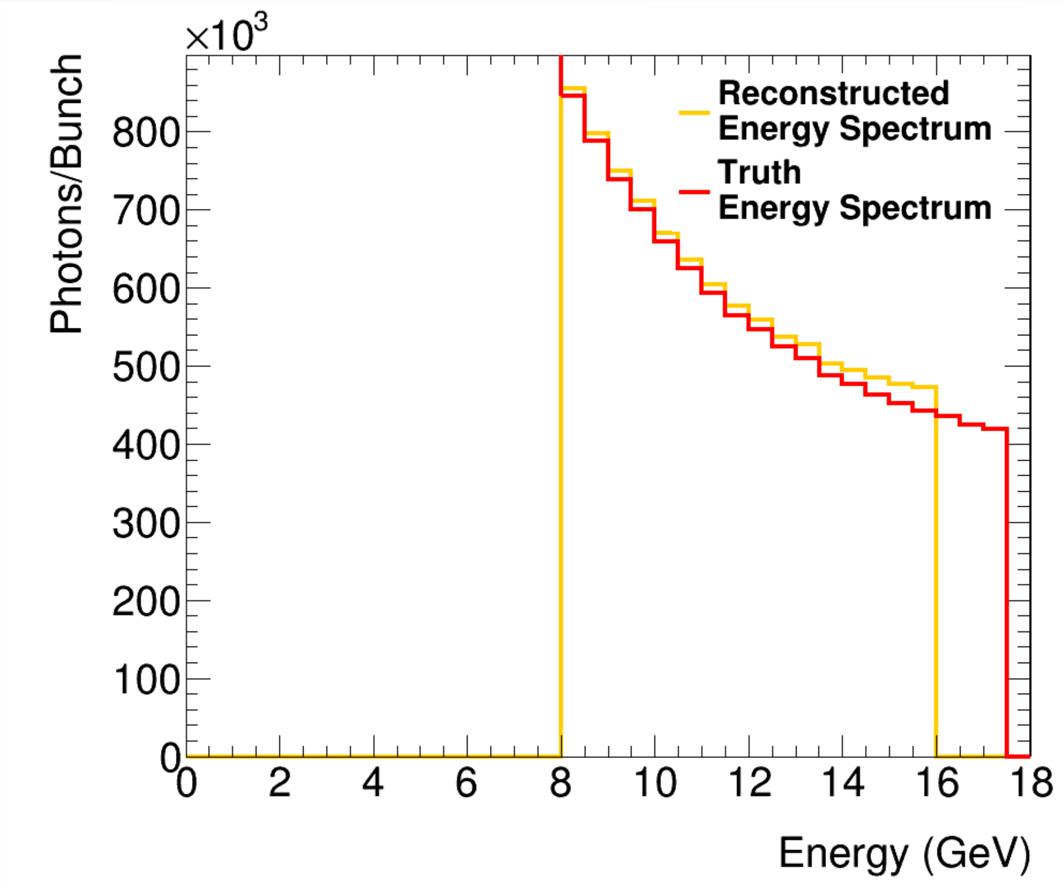
The method of approximating here looks reasonable for the small intervals, by eye at least, even at the steeper section of the spectrum.



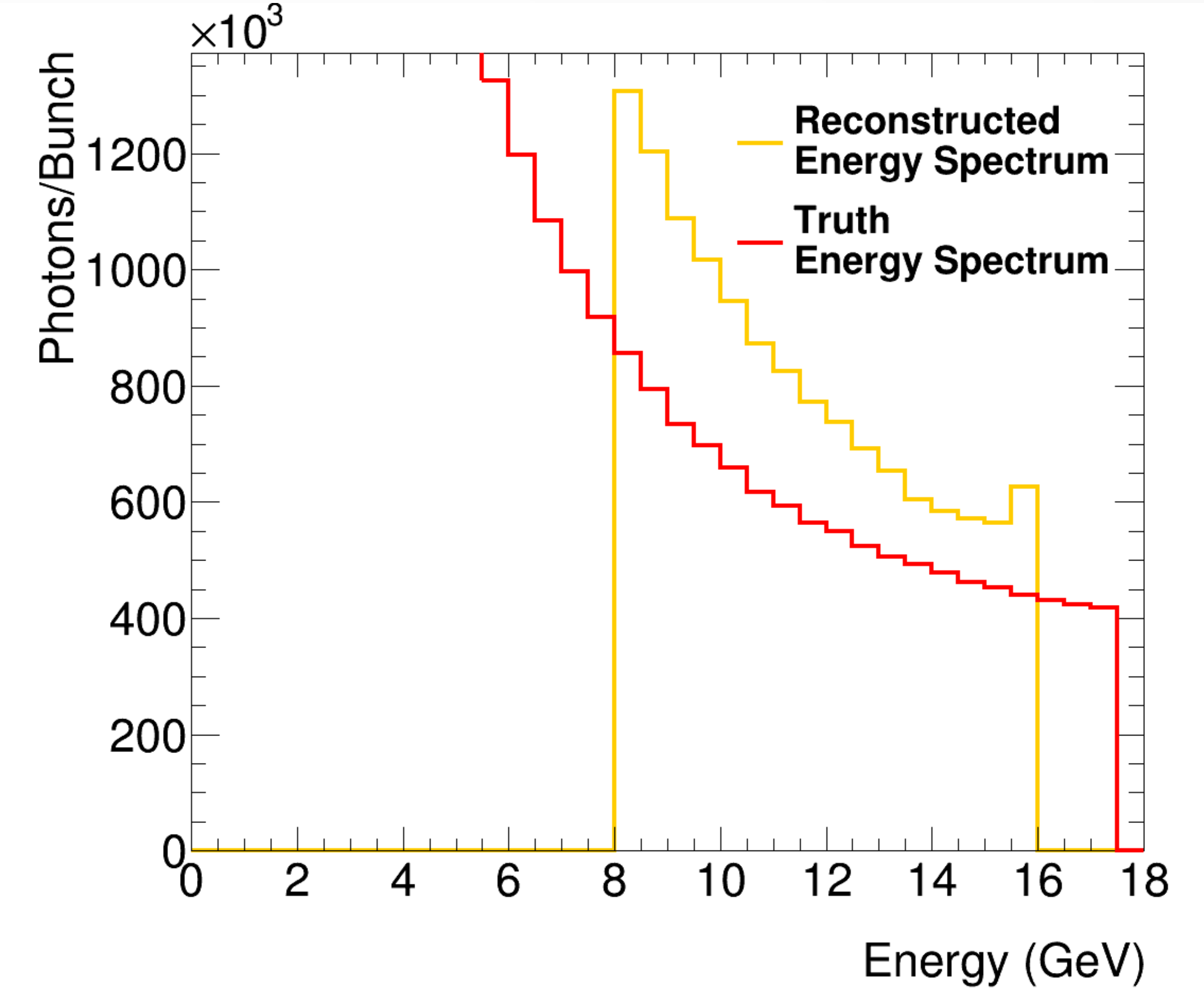


No Beampipe/Air

Full Geometry



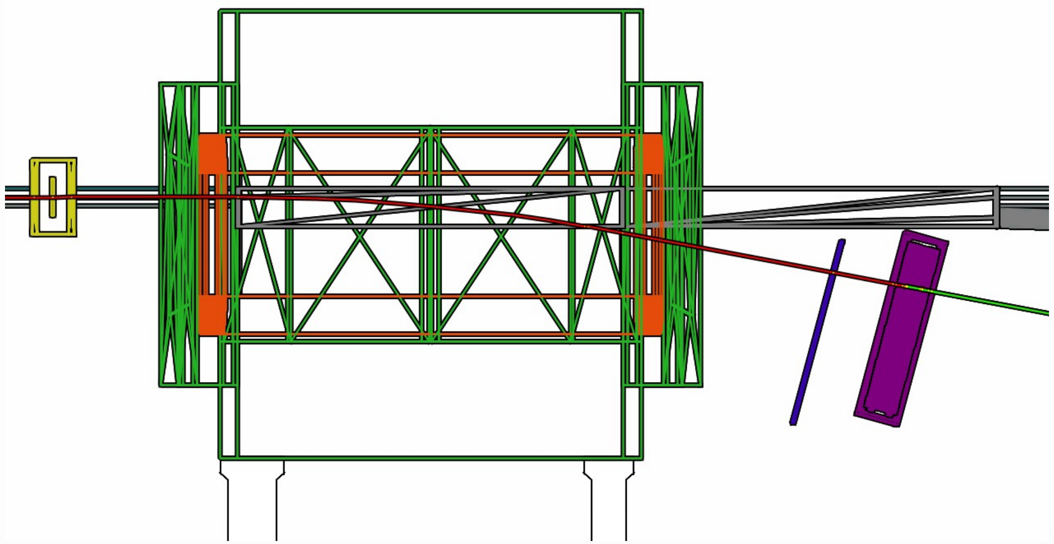
No Beampipe/Air



Full Geometry

Showering through 1.65 mm of Al, or 50 cm of air provides increase of ~2.5 % each

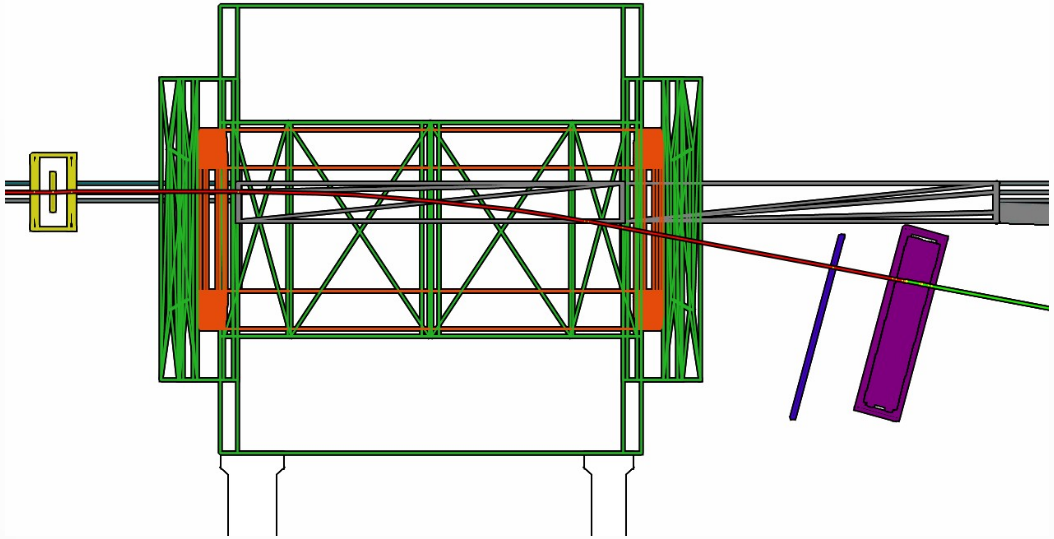
Looking at beampipe geometry, we see that particles will travel through considerably more than the nominal thickness of 1.65 mm



Electrons between our range 1.5 GeV → 10 GeV
Travel at angle towards detector of 3.5° to 25°

Electron approach at 5° :

$1.65/(\sin(5°)) = 18.9$ mm



Scintillator screen 1mm GadOx

Cerenkov 10mm Argon

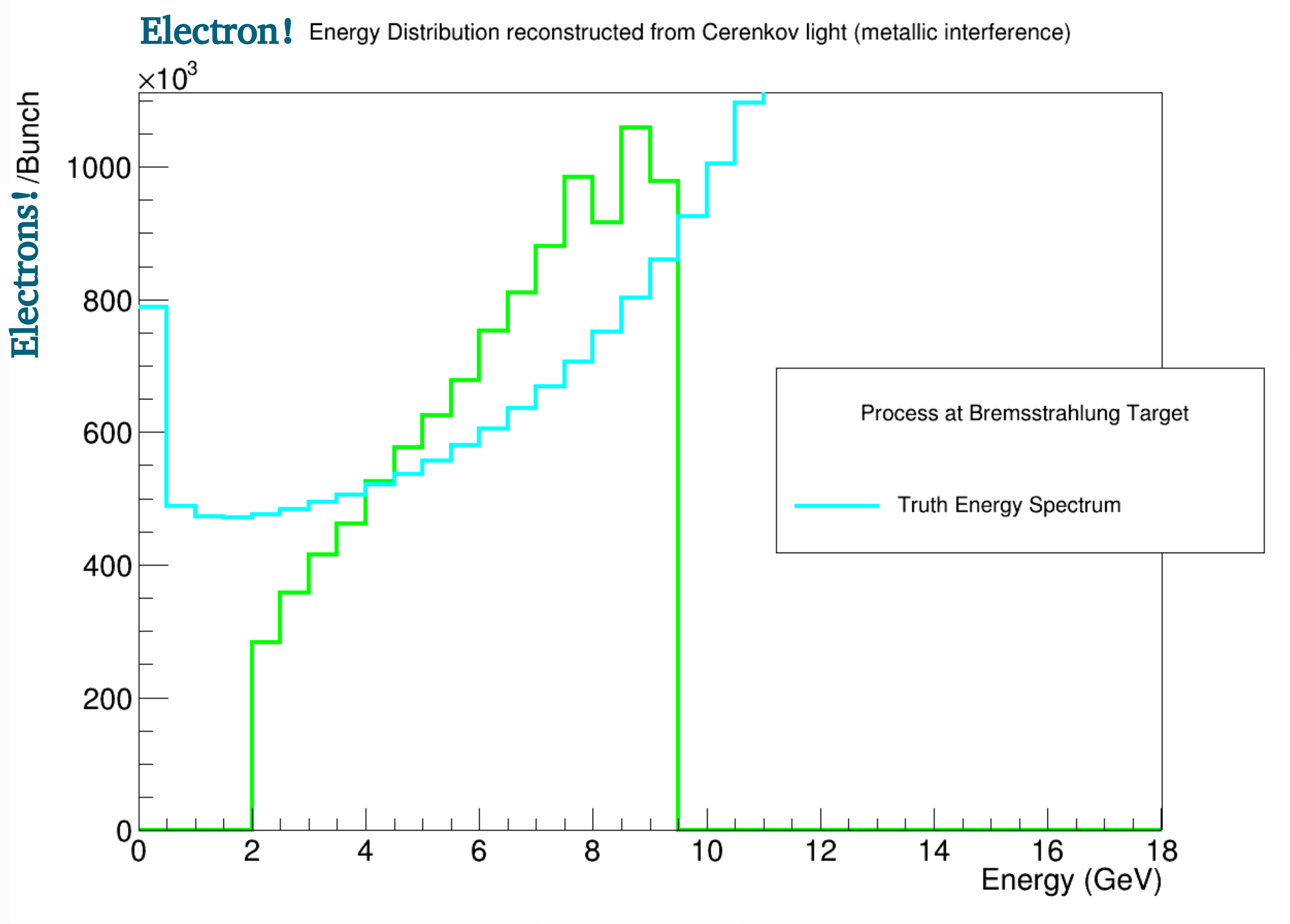
Effect of ~50 cm of Air is few percent (Scintillation)
Negligible (Cerenkov)

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%

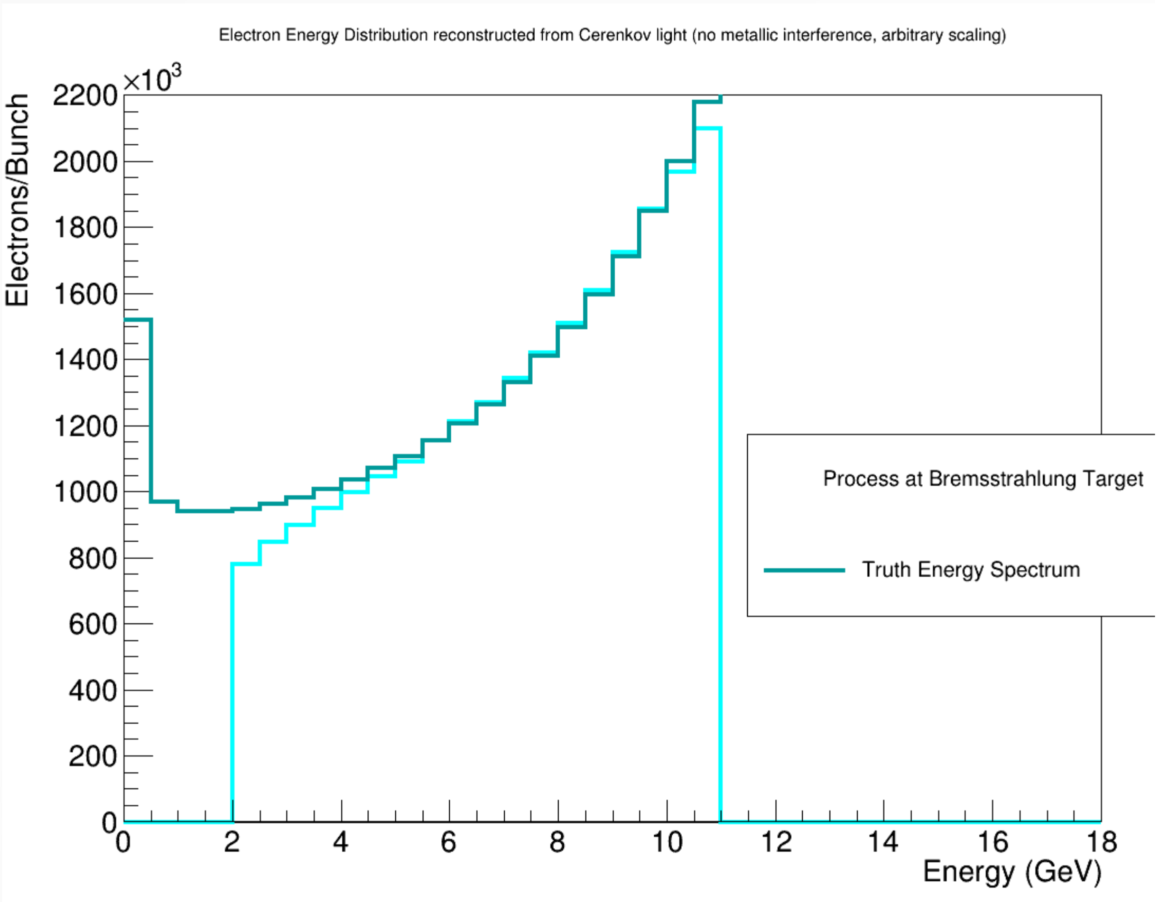
Examining Cerenkovs -

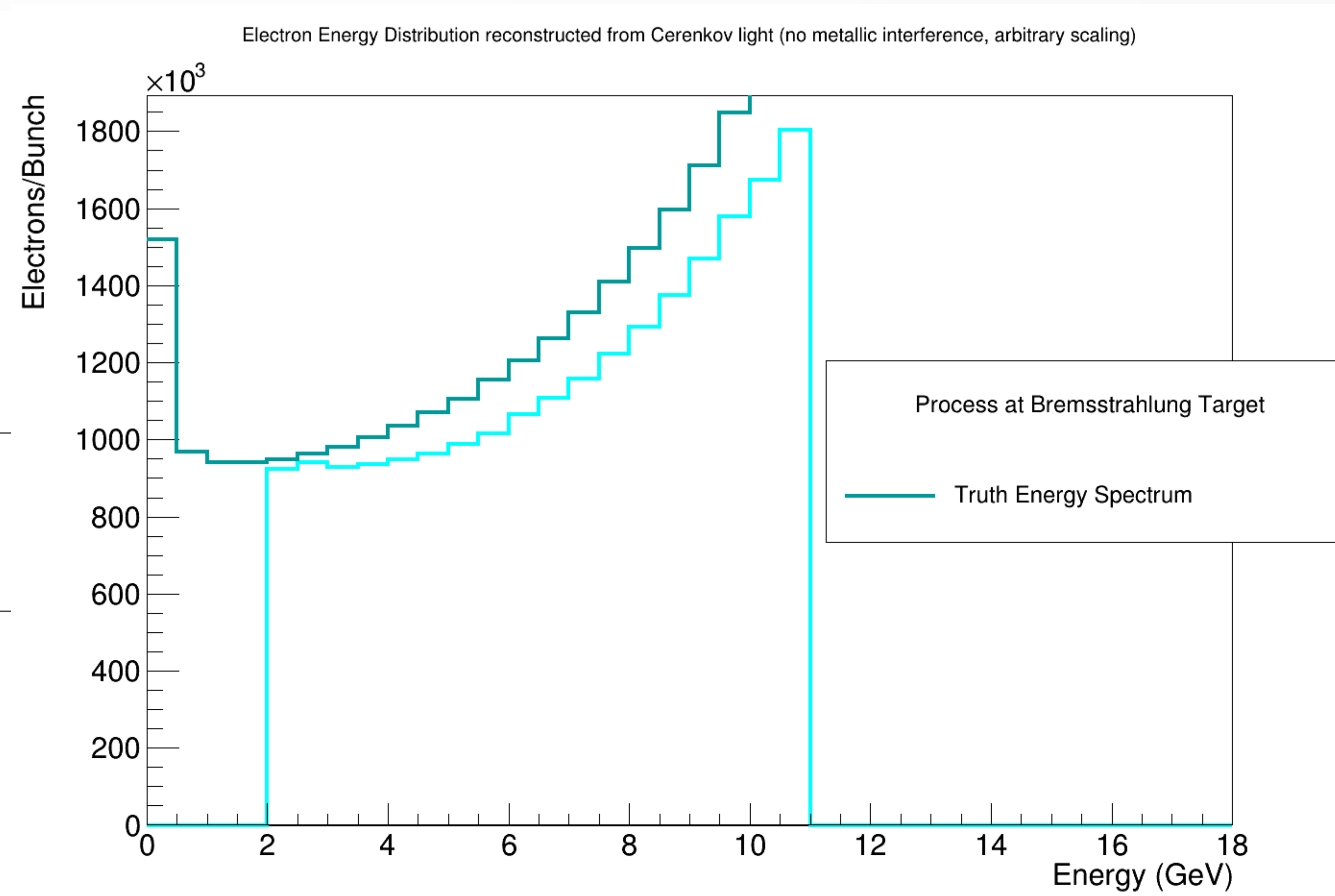
Assume plane through center of channels of length z = 10 mm Ar

1mm channel width as per Compton set-up, 15°



9mm channel width – inappropriate for linear fits noted before. Arbitrary scale.

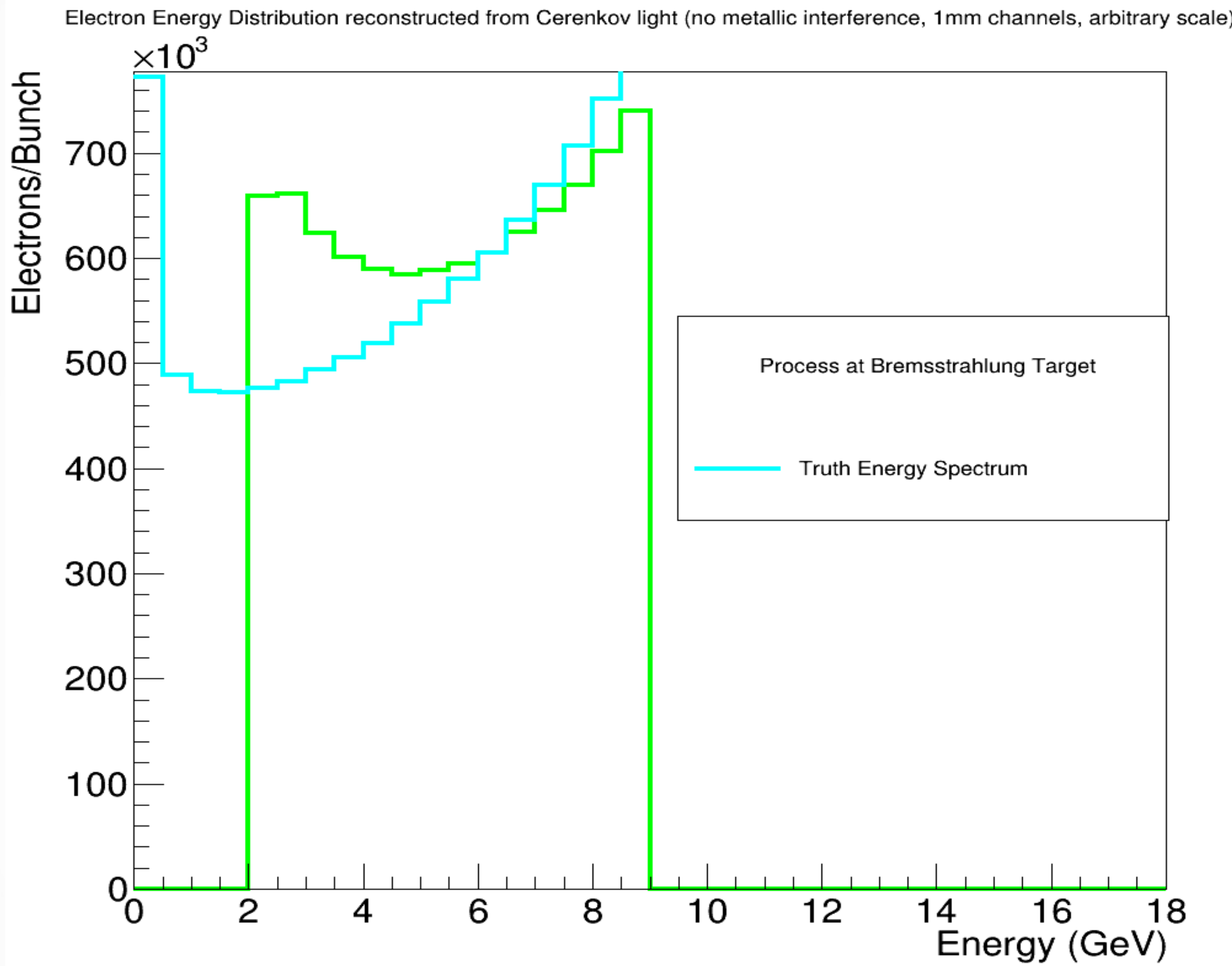




5° alignment

15° det. alignment

2.3mm channel width – broadly accurate, but some divergence of results with wider angle



Now let's look at down to 1mm channels. 15° alignment. At this level the dividers between channels comprise 0.3/1.3 = 23%

Some tentative conclusions:

Beampipe area contributes massively to interference in detectors, but if we can largely solve this even with an effective window thickness ~ 1mm Al. Problem is partially a geometric one.

Narrower channels in Cerenkov may allow better resolution but may mean more sensitivity to angular deviation. Channels which are too wide may fail to produce satisfactory energy spectrum at the granularity required.

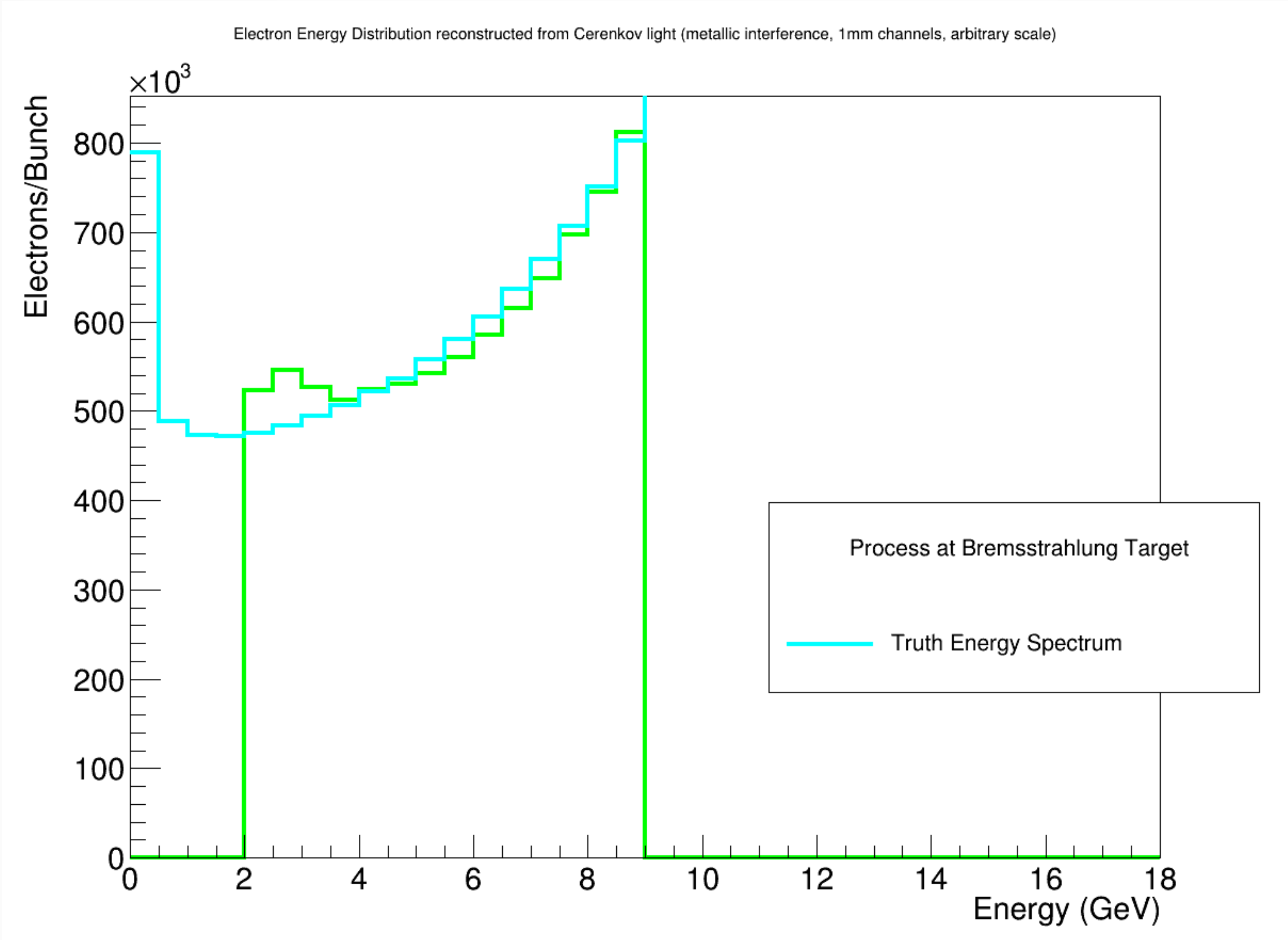
Still to do:

Invert B-field polarity and measure positrons

Either to obtain photon energy distribution directly ($E_{\gamma} \sim 2 \times E_{e+}$) or to subtract numbers of pair-production electrons from electron spectrum

Can try a segmented Cerenkov with more peculiar angles for each channel – technically challenging, both in construction and to analyse right now in simulation.

Backup

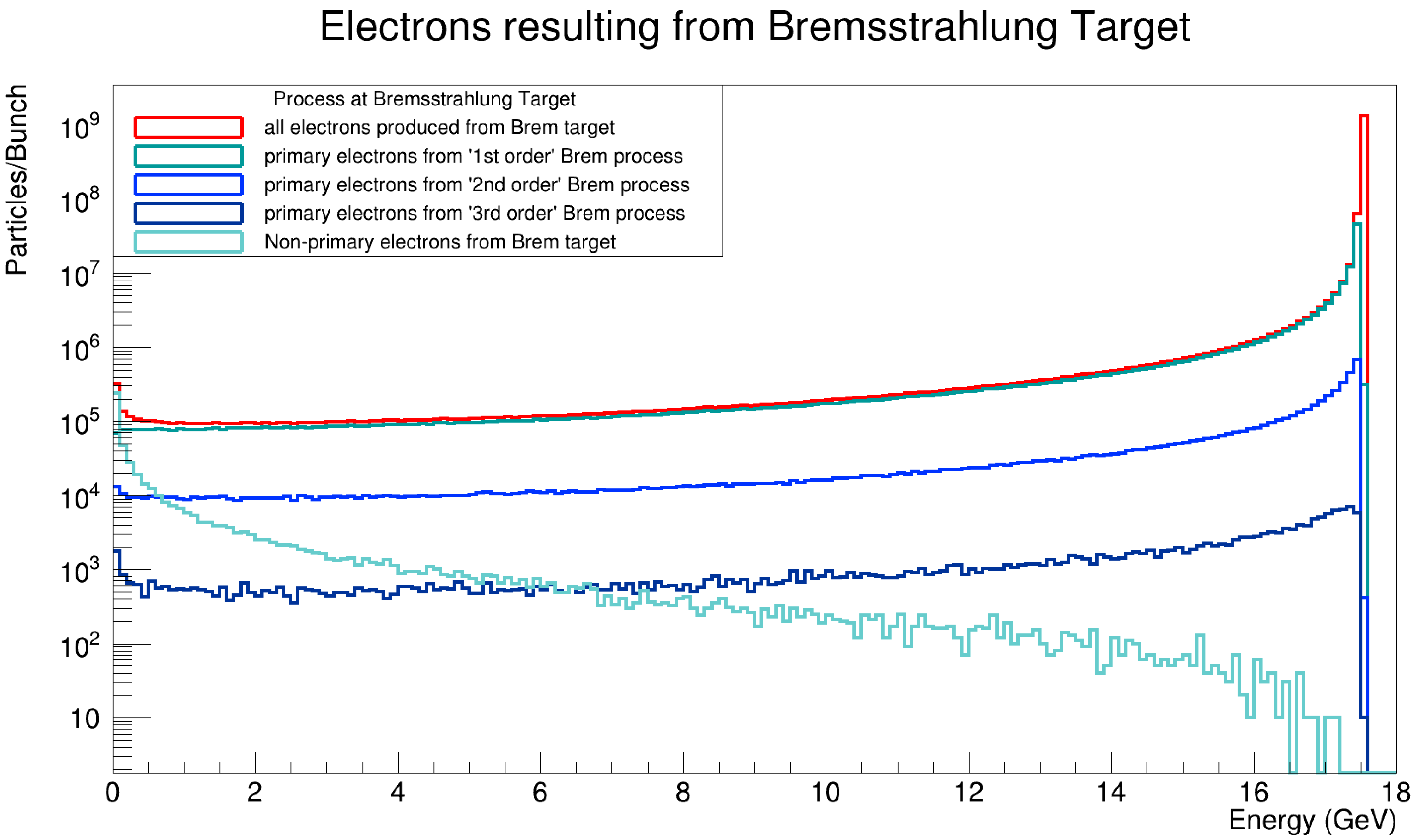

Electron Energy Distribution reconstructed from Cerenkov light (metallic interference, 1mm channels, arbitrary scale)
$\times 10^3$
Electrons/Bunch
0
100
200
300
400
500
600
700
800
0
2
4
6
8
10
12
14
16
18
Energy (GeV)
Process at Bremsstrahlung Target
Truth Energy Spectrum

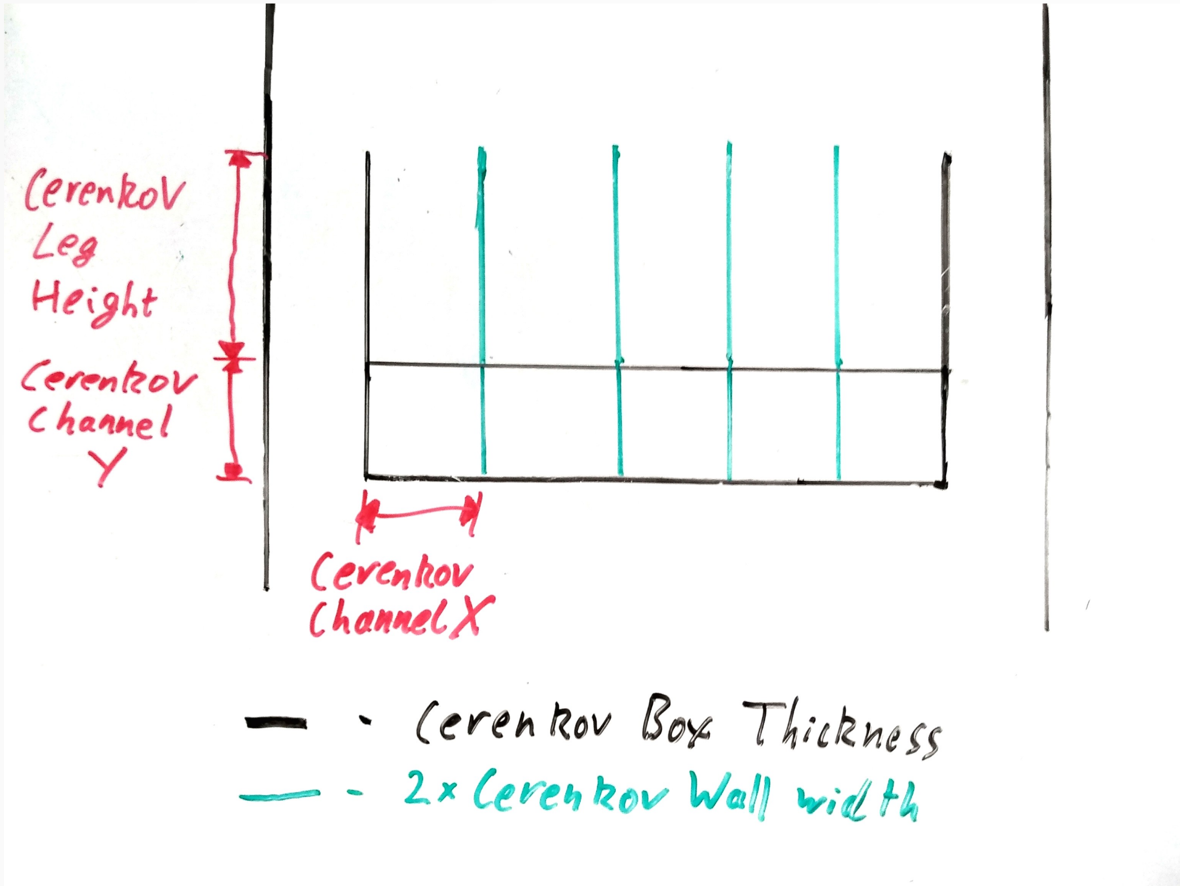
15° alignment

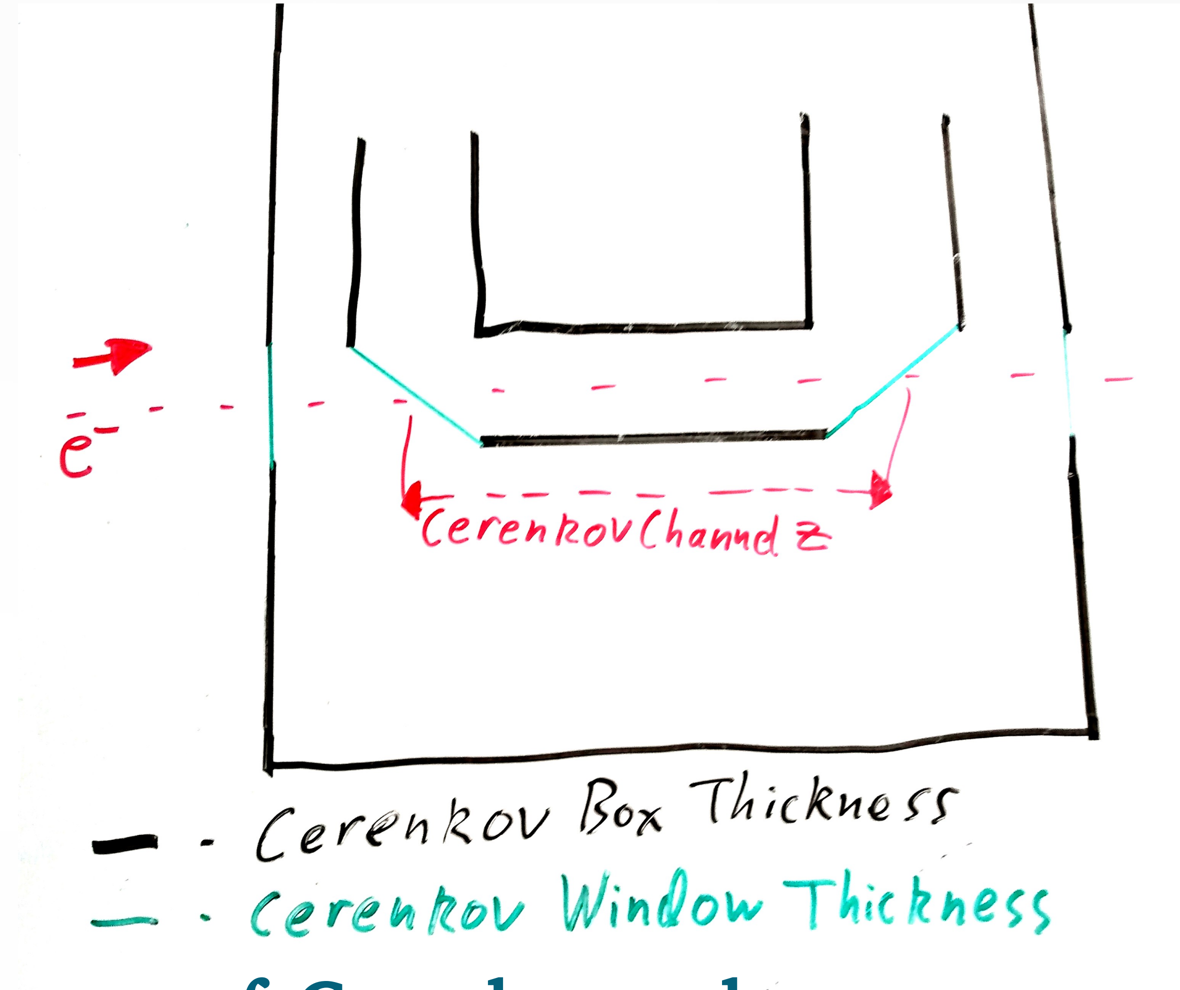
$E = 2.4$ GeV

5° alignment

$E = 7.1$ GeV

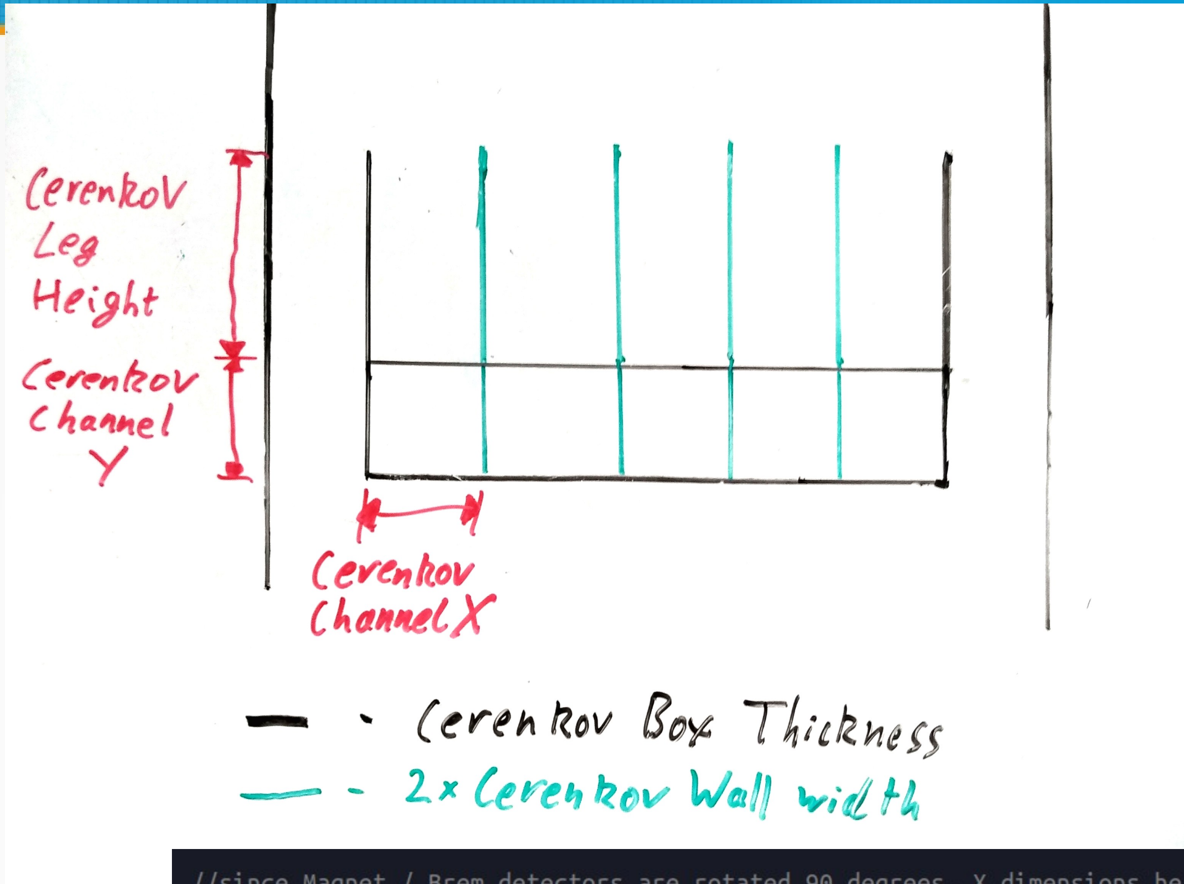

Electrons resulting from Bremsstrahlung Target
Process at Bremsstrahlung Target
all electrons produced from Brem target
primary electrons from '1st order' Brem process
primary electrons from '2nd order' Brem process
primary electrons from '3rd order' Brem process
Non-primary electrons from Brem target
Particles/Bunch
10⁹
10⁸
10⁷
10⁶
10⁵
10⁴
10³
10²
10
0
2
4
6
8
10
12
14
16
18
Energy (GeV)

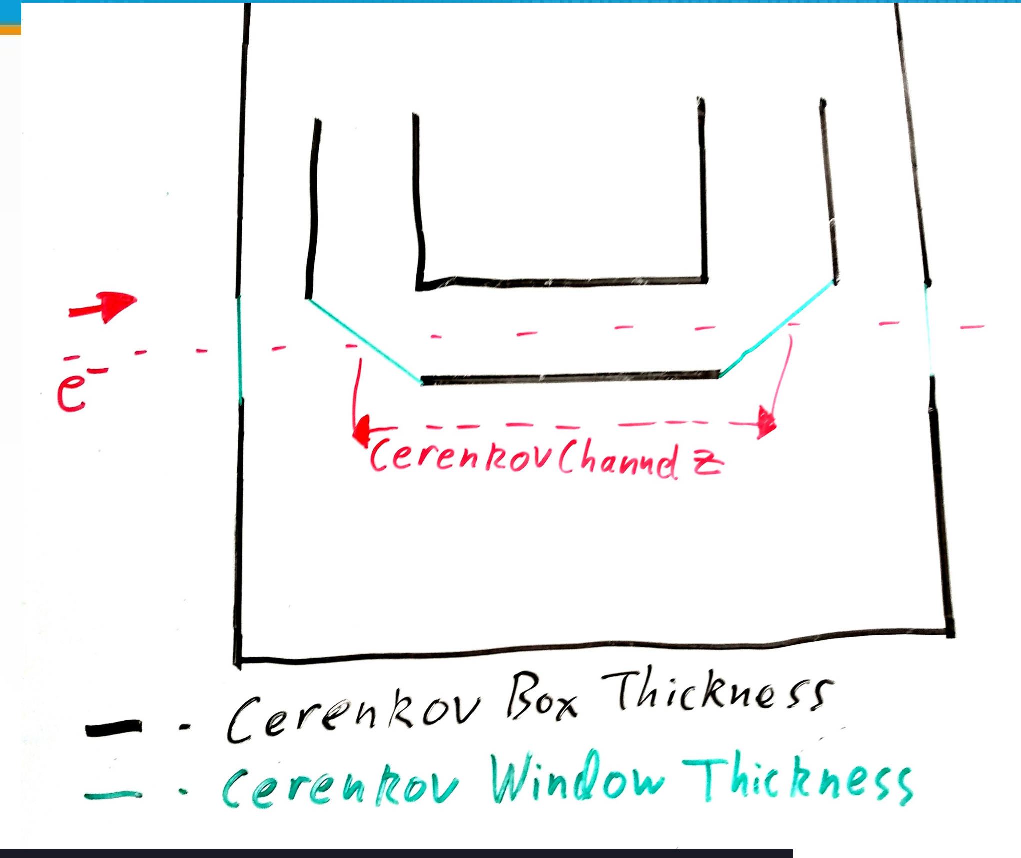




x-y (left) and z-y (right) diagrams of Cerenkov volume.

Upon rotation and placement beside beampipe, 'x' and 'y' directions interchange






```
//since Magnet / Brem detectors are rotated 90 degrees, X dimensions here (Scint/Cerenkov) map to global Y dimensions & vice versa
ScintCerenkovPhysics = false;
ScintAngle = 15. *deg;
ScintXpos = -360. *mm;
ScintZpos = DumpMagnetZpos + (1520./2. + 275.) *mm; //  defining in relation to position of the beam-dump magnet and its length
CerenkovAngle = 5. *deg;
CerenkovXpos = -350. *mm;
CerenkovZpos = DumpMagnetZpos + (1520./2. + 500.) *mm;
ScintX = 500. *mm;
ScintY = 100. *mm;
ScintZ = 1. *mm;
CerenkovWallWidth = 0.15 *mm;
CerenkovBoxThickness = 1. *mm;
CerenkovWindowThickness = 0.3 *mm;
CerenkovchannelX = 9. *mm;
CerenkovchannelY = 9. *mm;
CerenkovchannelZ = 50. *mm;
CerenkovChannels = 50;         // will crash if not even!! unfortunately..
CerenkovLegHeight = 50. *mm;
ScintMaterial = "G4_GADOLINIUM_OXYSULFIDE";
CerenkovMetal = "Aluminium";
CerenkovMedium = "HeliumGas";
```