Signal & Background at e-LASER IP

John Hallford

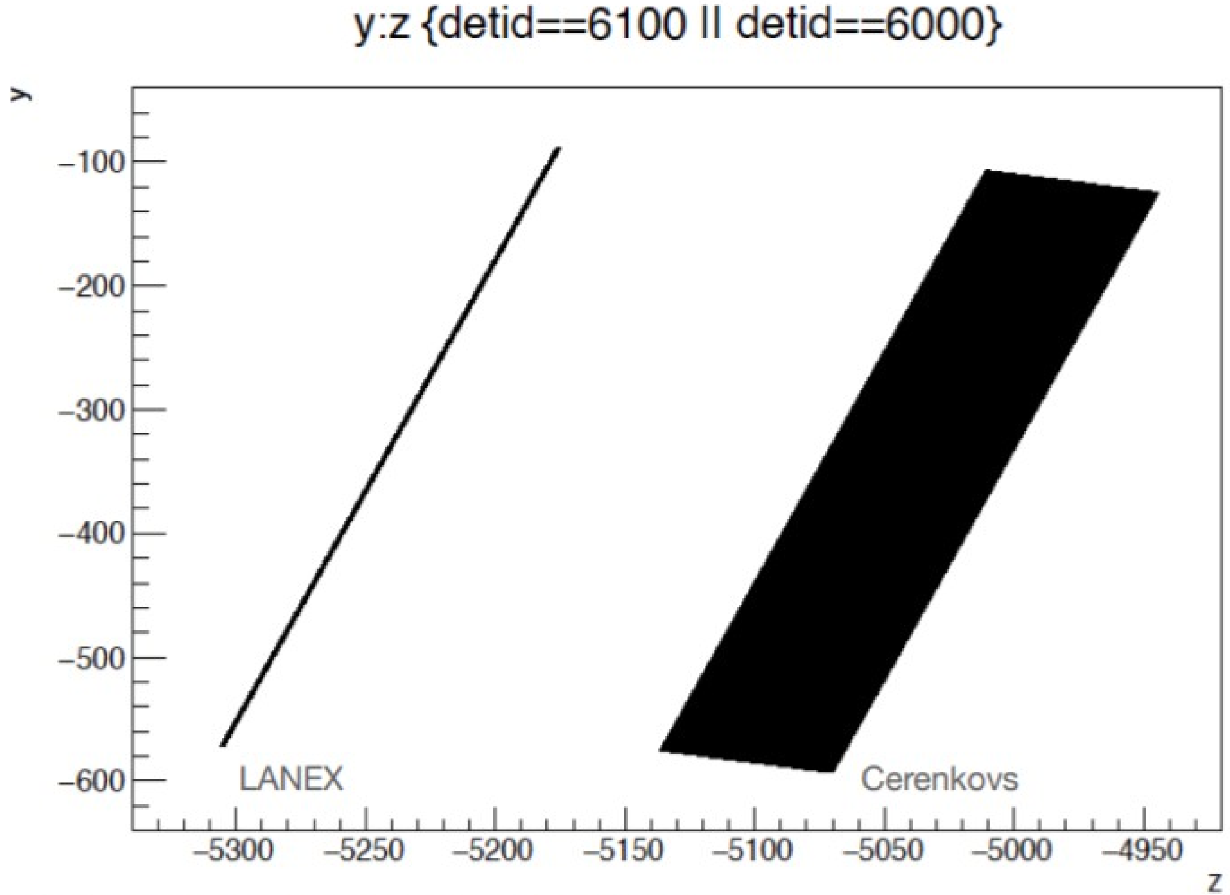
University College London

25/11/2020

Looking once more at producing plots describing signal, background at locations featuring scintillator, Cerenkov detectors at LUXE

- Ruth has produced plots for the Brem. Region, defining background in the G4 sim as coming downstream of the detector, and signal as from the front

Brems system

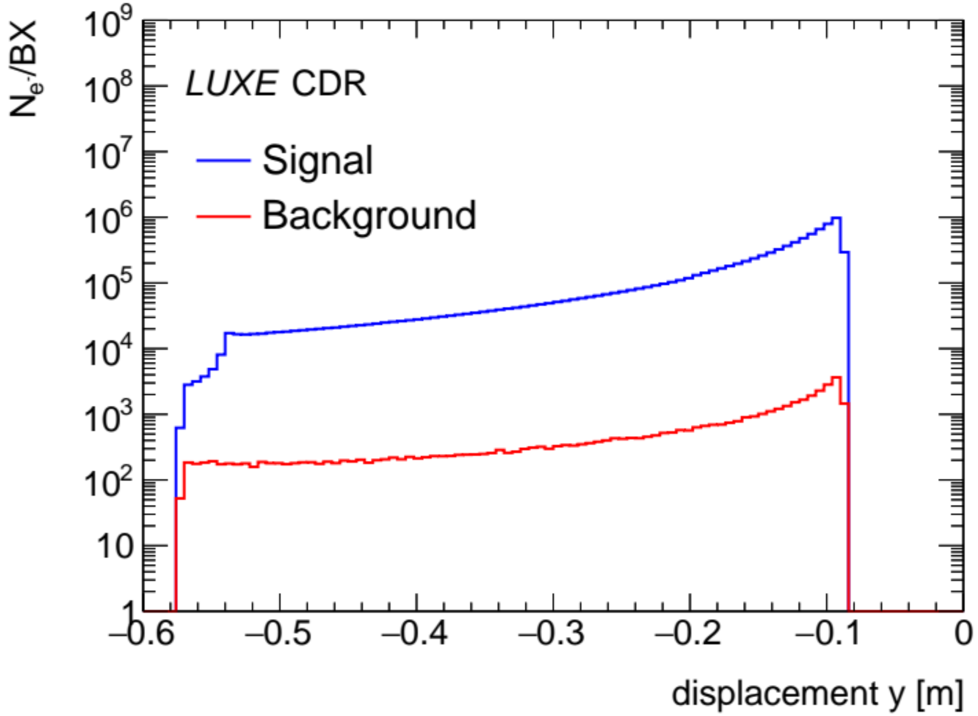


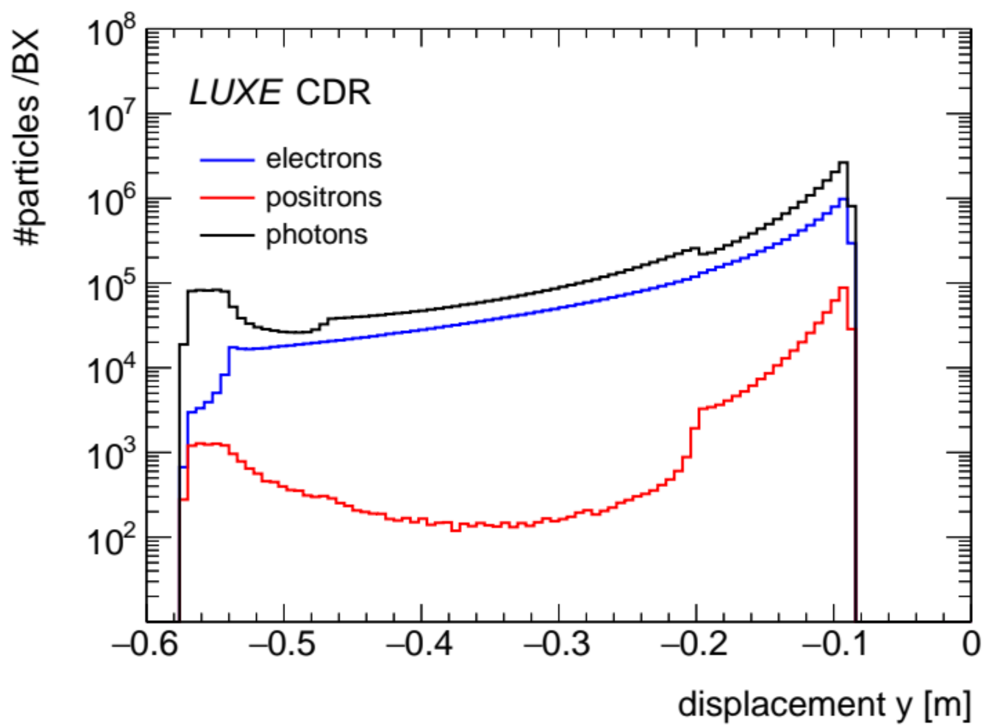
- Lanex screen and Cerenkovs in initial Brems spectrometer

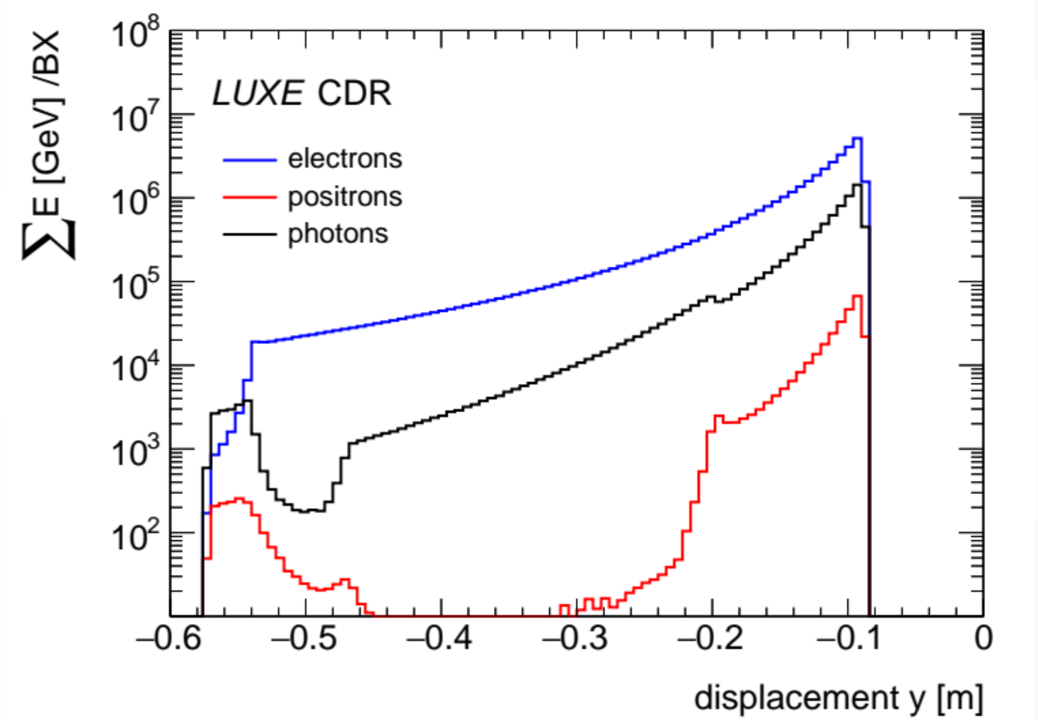
- Aim: Background estimate for Brems
- we have no simulation “without the target”
- expect beam background will mostly come from the back of the detectors (expect little interaction of the beam electrons on their way to the Brems system)

Use vtxz>-5170 for LANEX and vtxz>4940 for Cerenkovs to select Backgrounds!

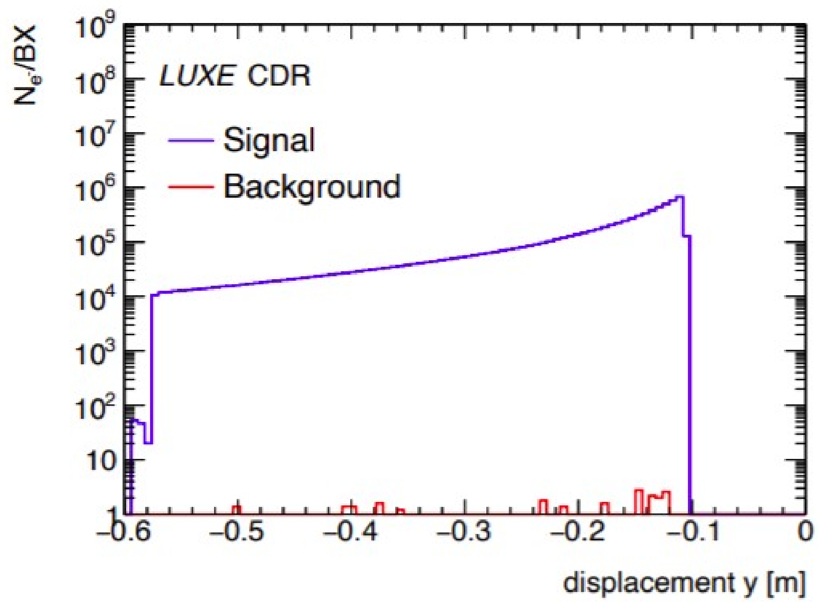
Gamma-LASER Brem. Region Scintillation screen (from Ruth)

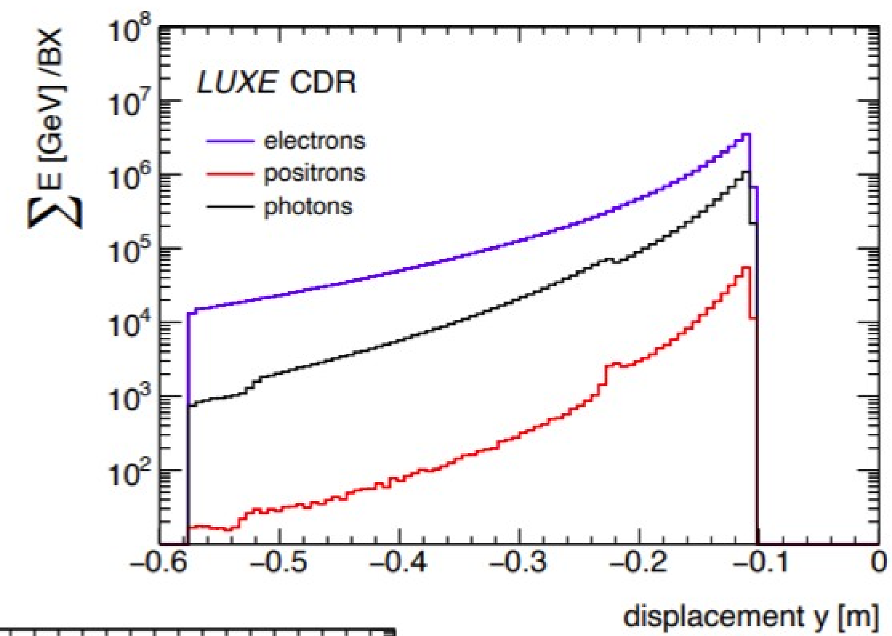


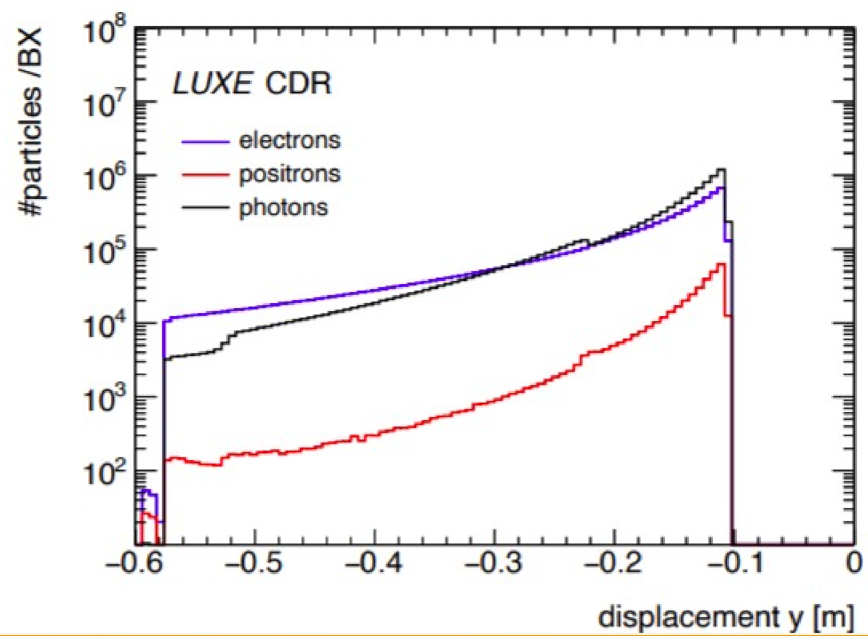




Gamma-LASER Brem. Region – Cerenkov Detector (from Ruth)





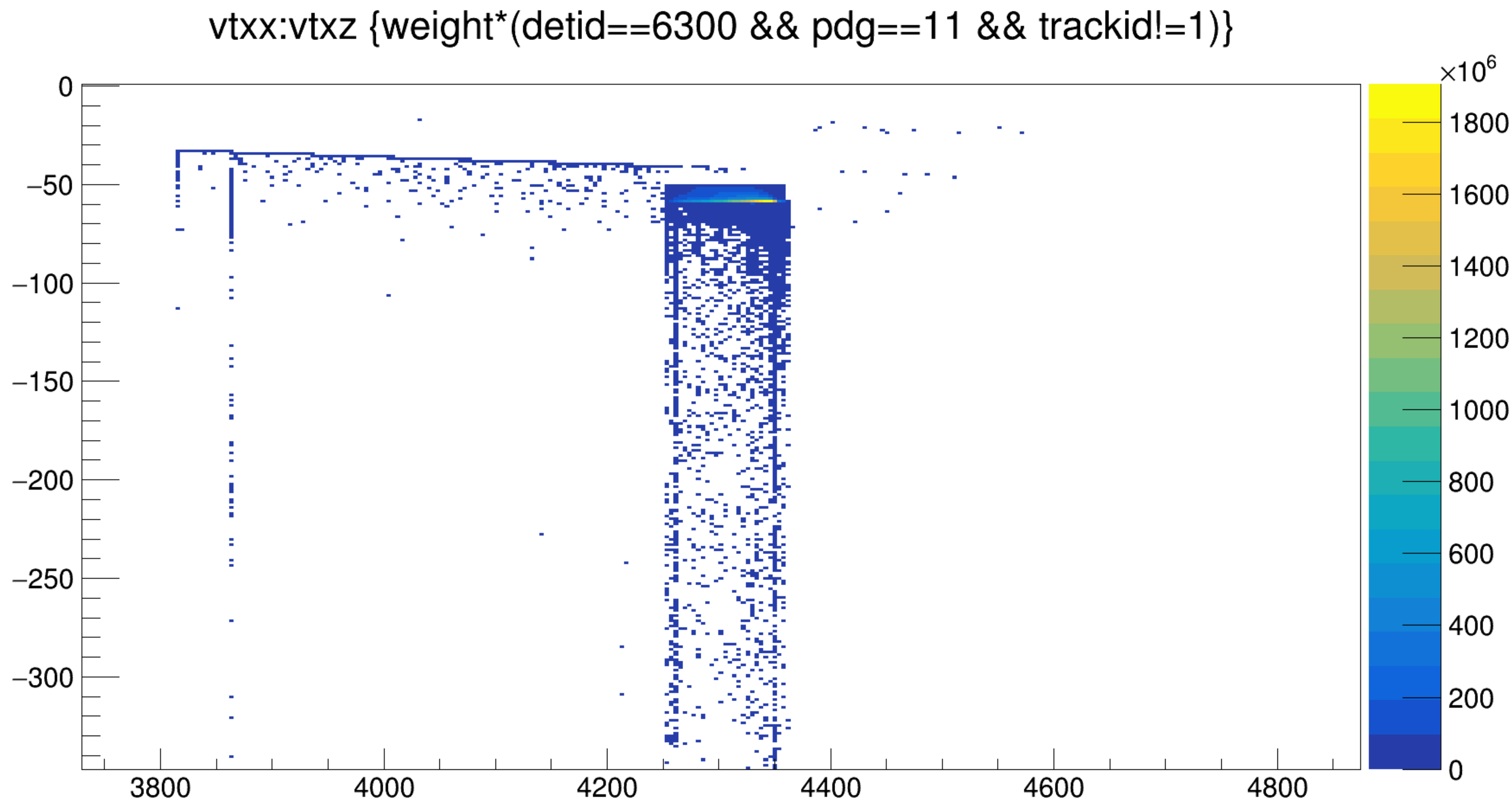


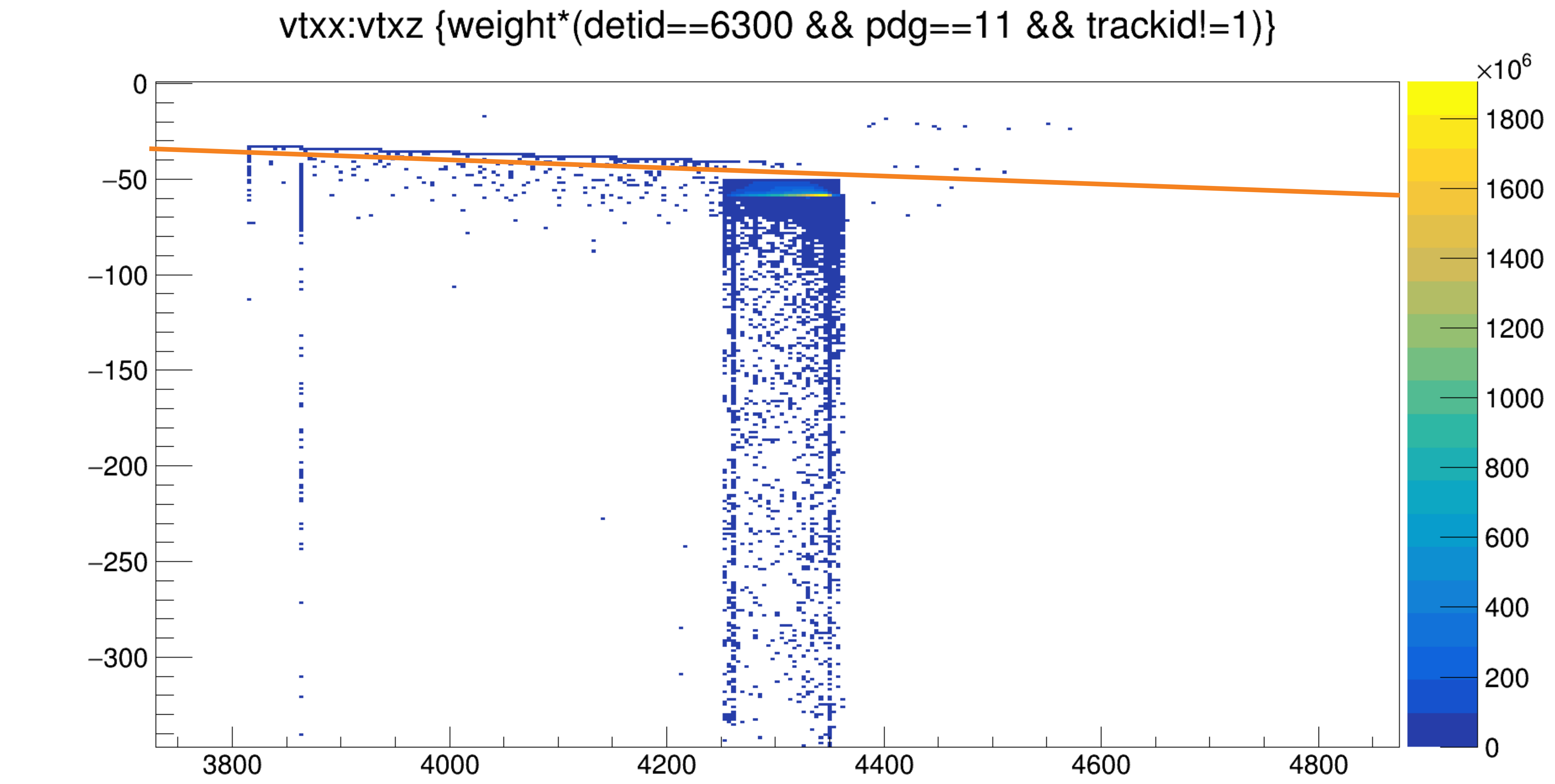
+ numbers for bar charts
(integrals of these plots)

- For e-laser IP region, we have a special simulation of just the (16.5 GeV) e^- beam which can act as background. We can then use the simulation of Ipstrong MC ouput, propagated through G4 as signal

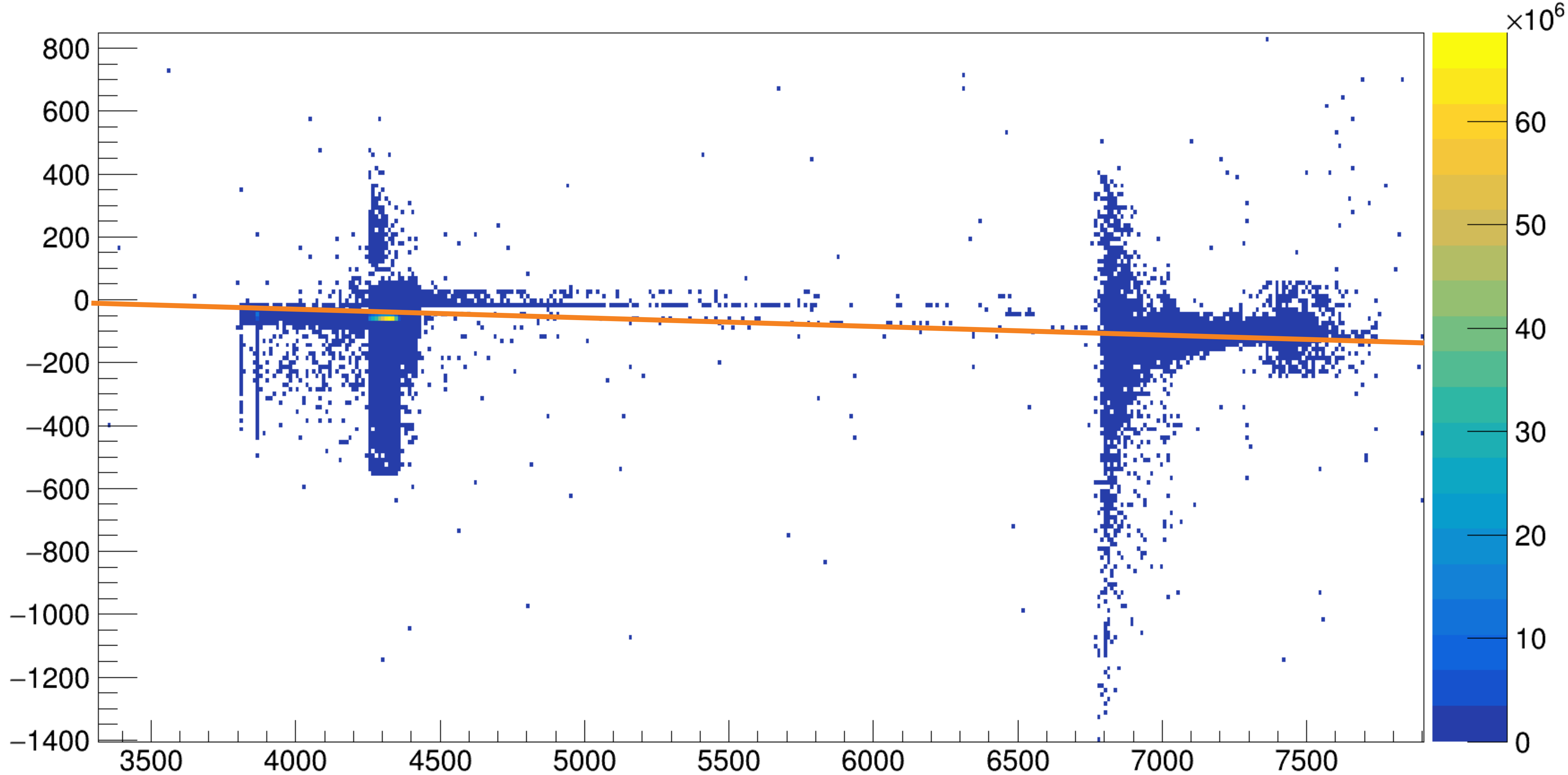
- These files still include the electron beam (minus e^- scattered to lower E) so we need to exclude the effect of this beam still

- I have made a try of this with a simple geometric plane cut with the creation vertex of particles

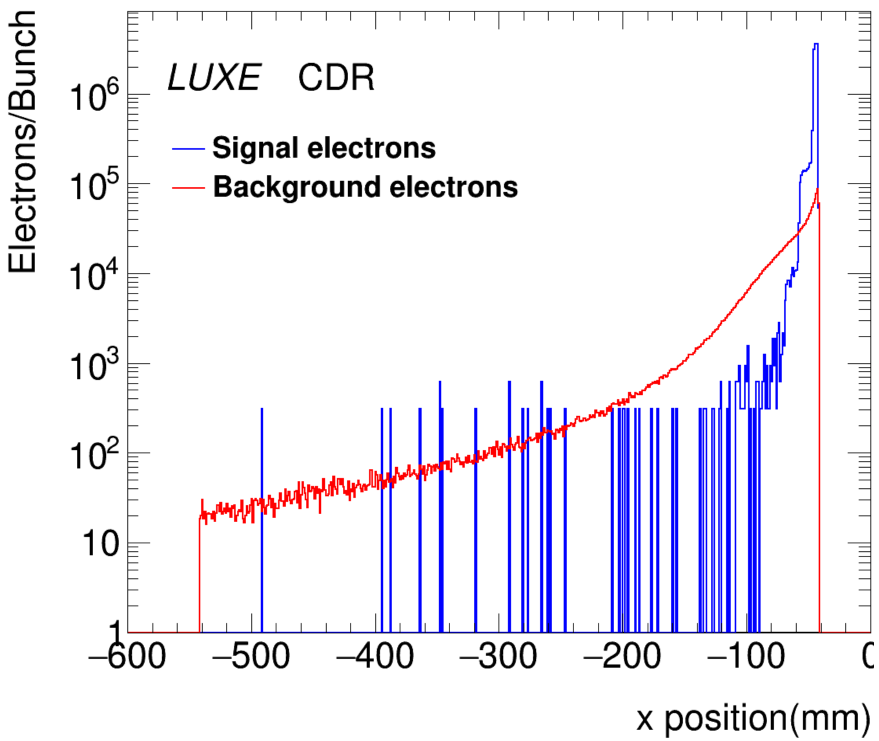

vtxx:vtxz {weight*(detid==6300 && pdg==11 && trackid!=1)}
0
−50
−100
−150
−200
−250
−300
3800
4000
4200
4400
4600
4800
×10^6
1800
1600
1400
1200
1000
800
600
400
200
0

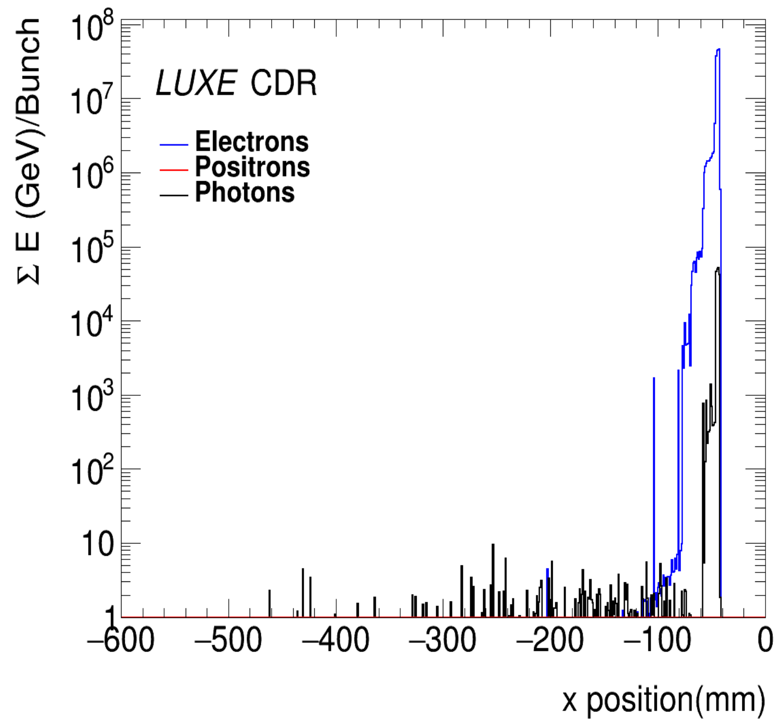

vtxx:vtxz {weight*(detid==6300 && pdg==11 && trackid!=1)}
0
−50
−100
−150
−200
−250
−300
3800
4000
4200
4400
4600
4800
×10^6
1800
1600
1400
1200
1000
800
600
400
200
0

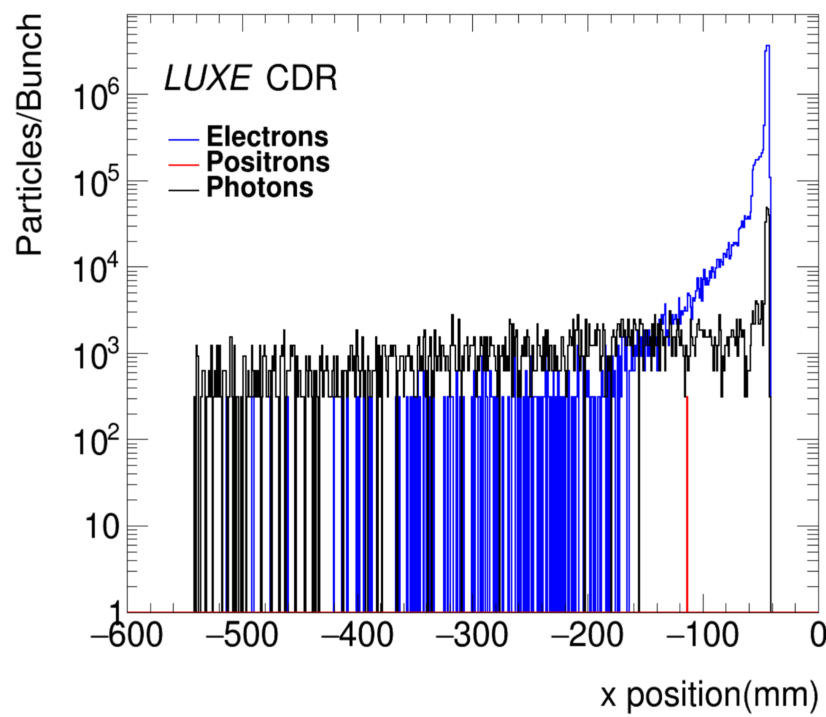
vtxx:vtxz {weight*(detid==6300 && trackid!=1)}



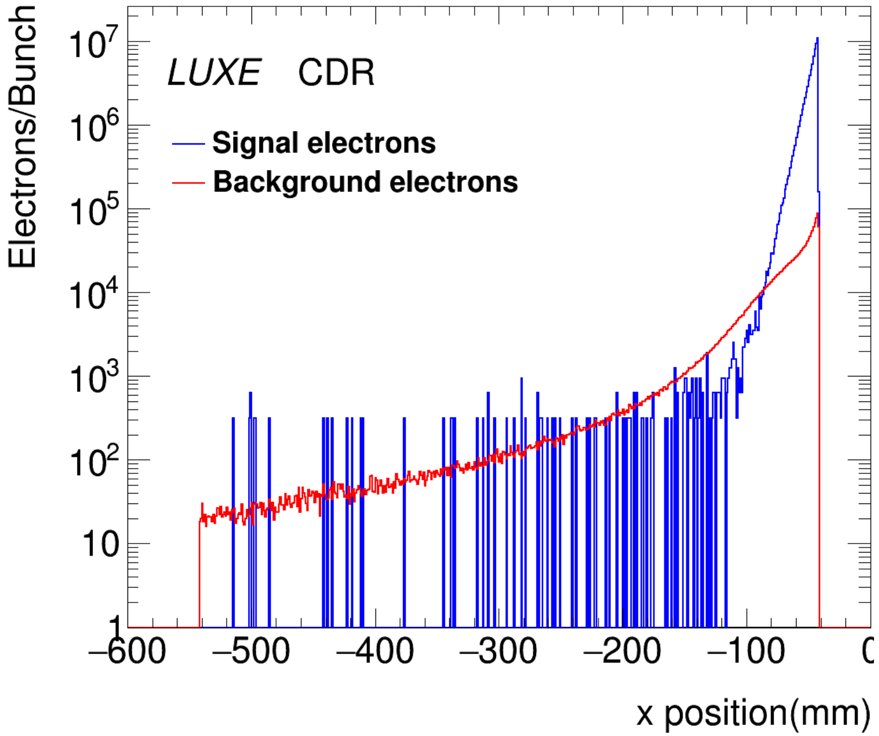
E-LASER postIP e- region – Low Xi - Scintillator

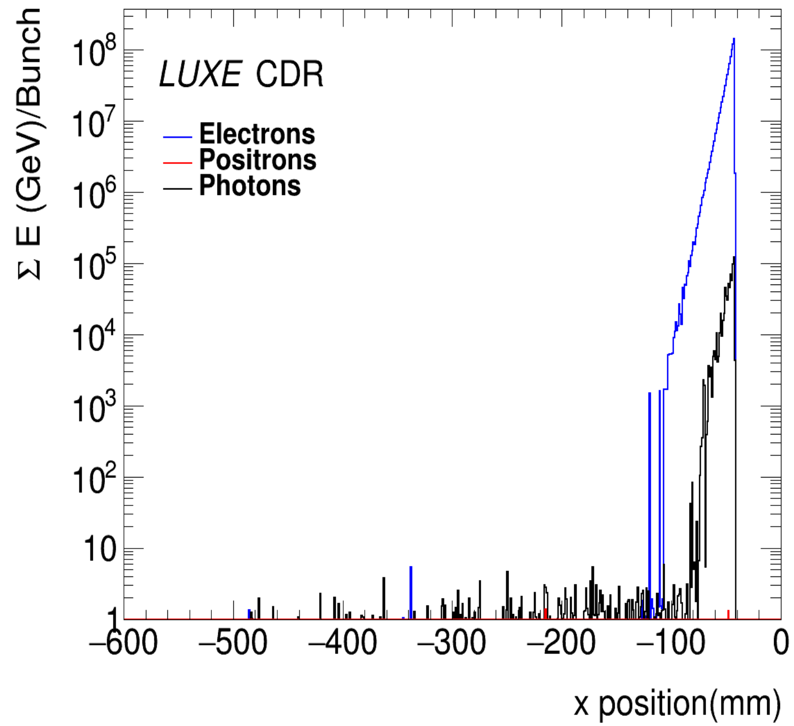


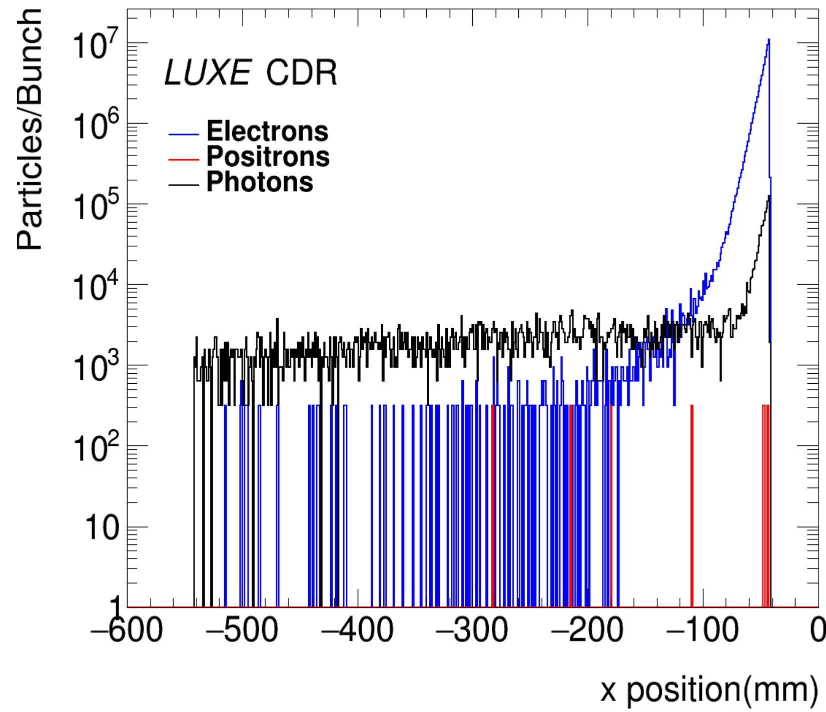




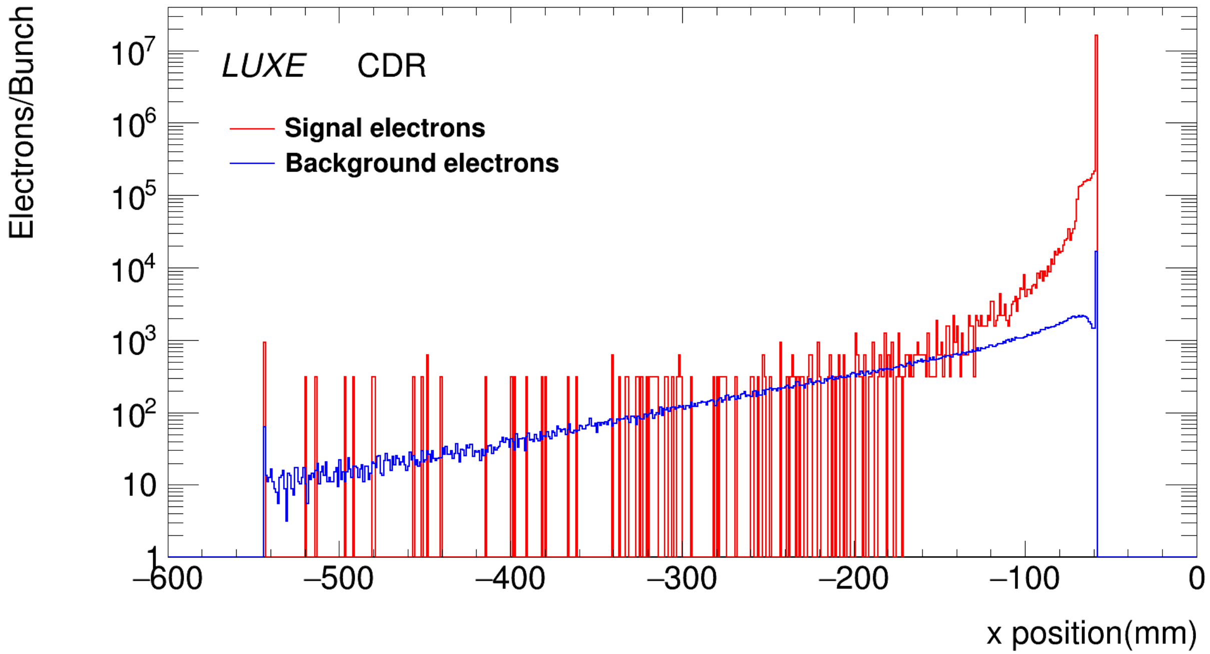
E-LASER postIP e⁻ region – High Xi - Scintillator

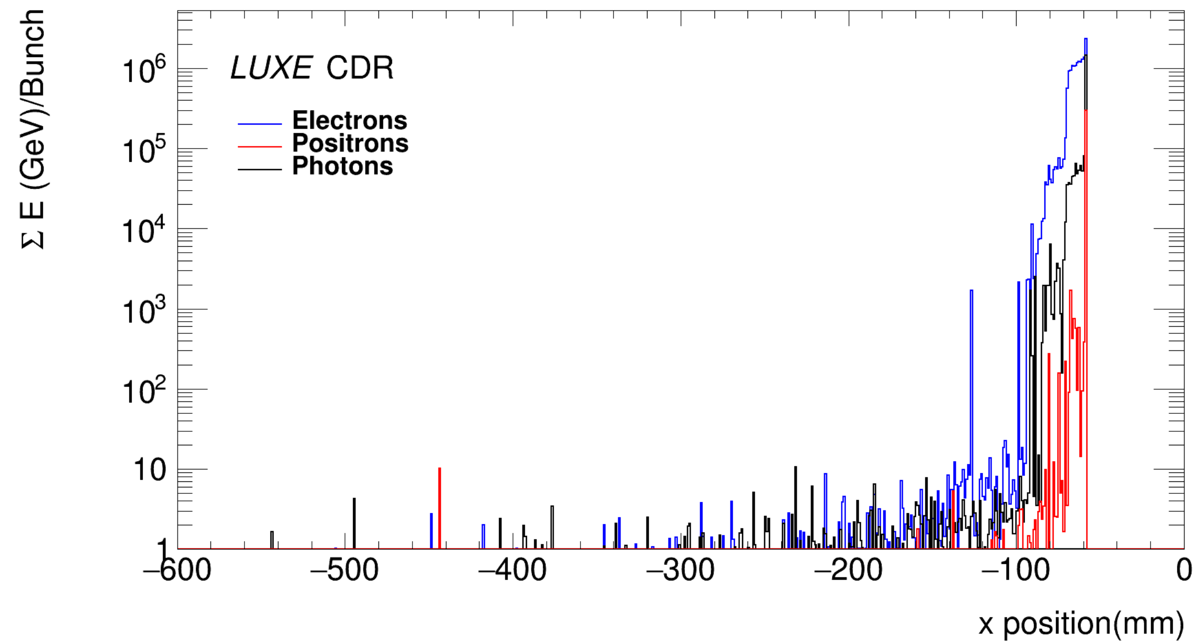


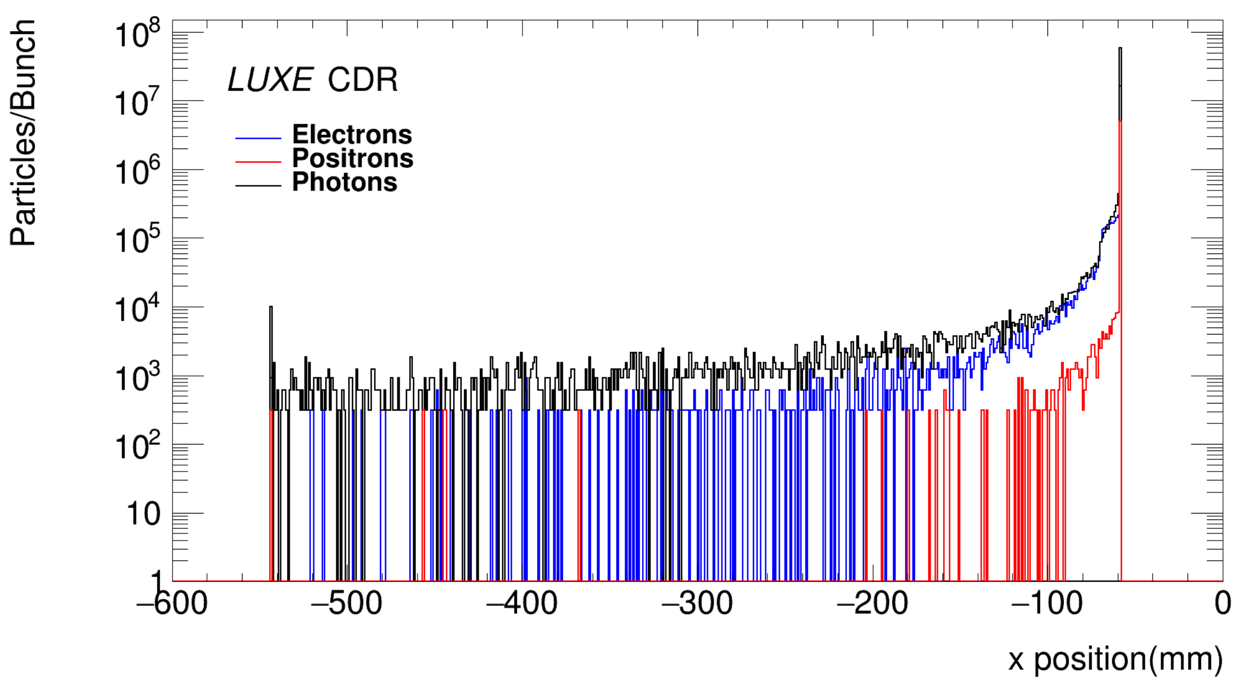




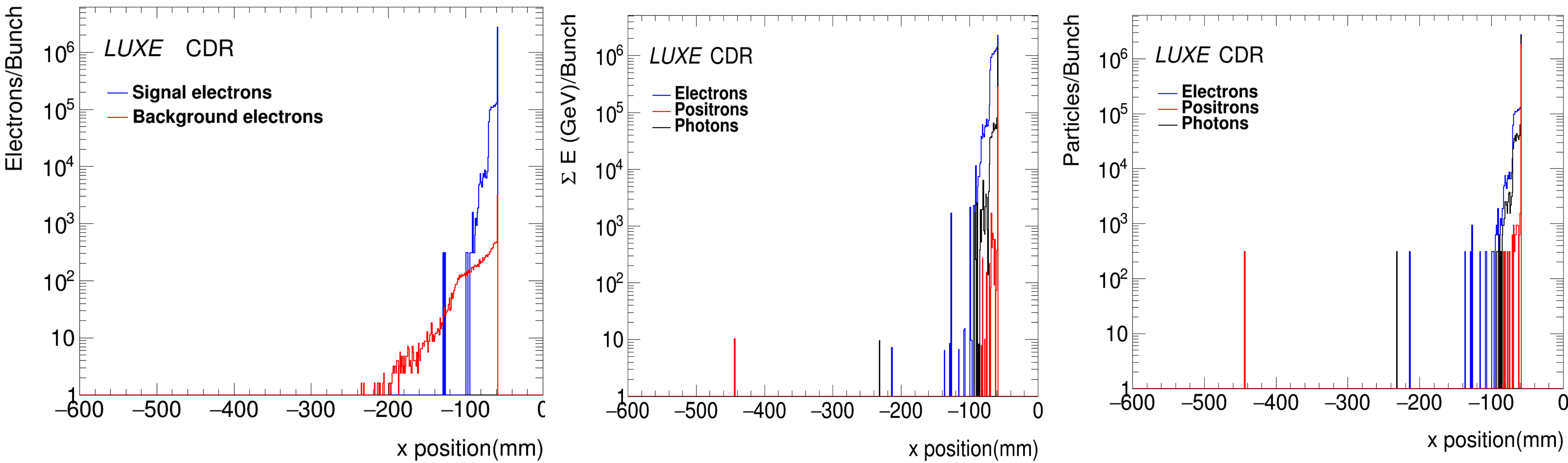
E-LASER postIP e^- region – Low Xi – Cerenkov



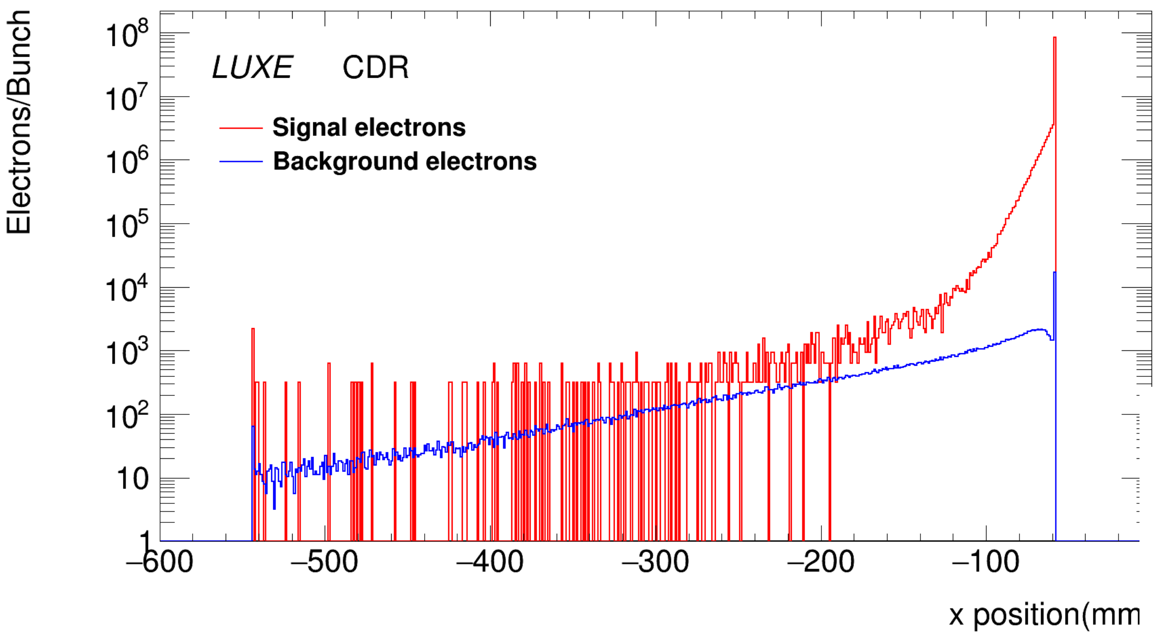


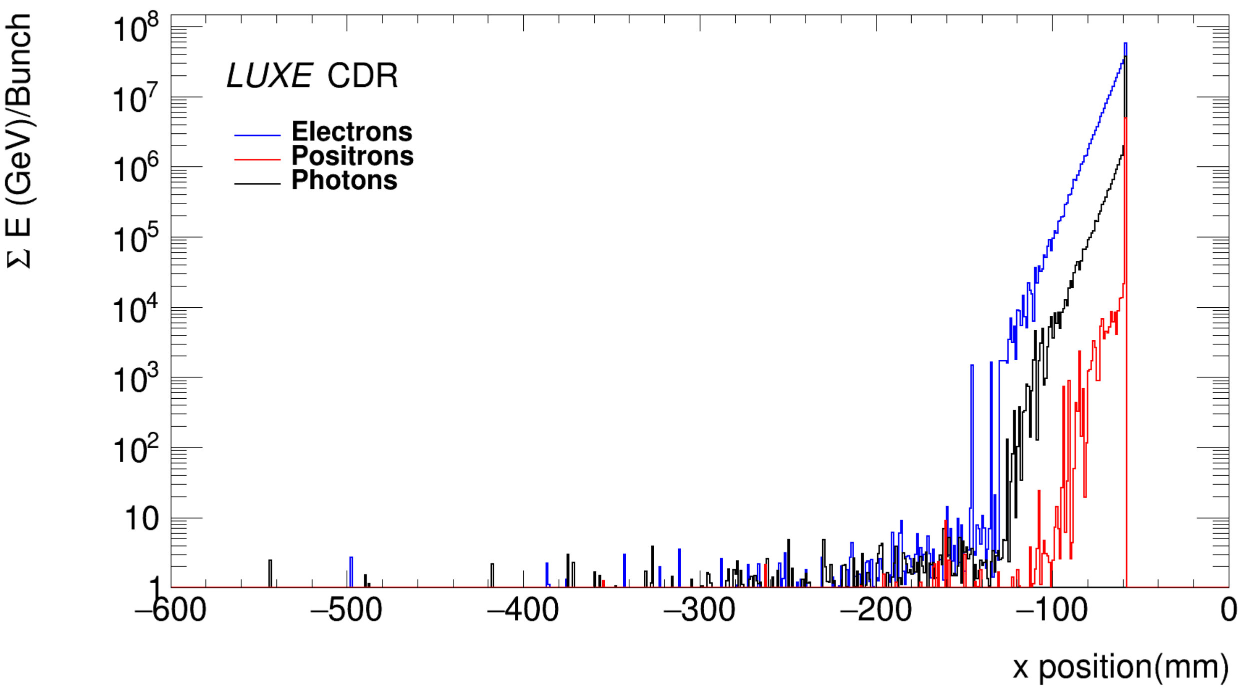


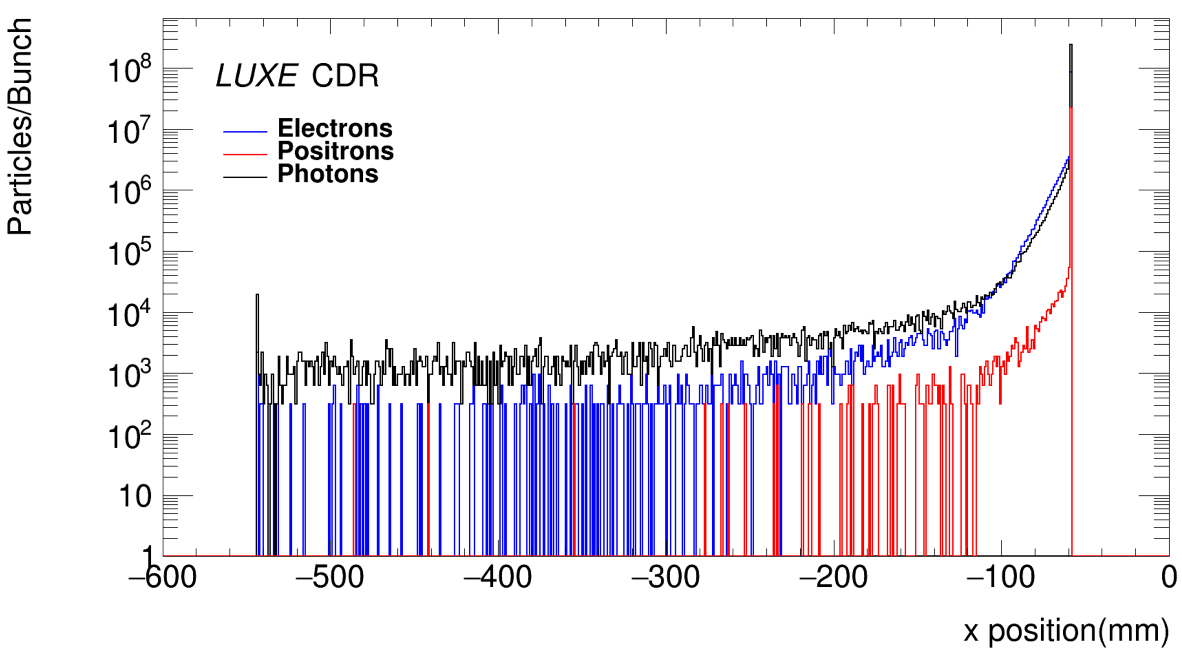
E-LASER postIP e⁻ region – Low Xi – Cerenkov – E>20 MeV selection



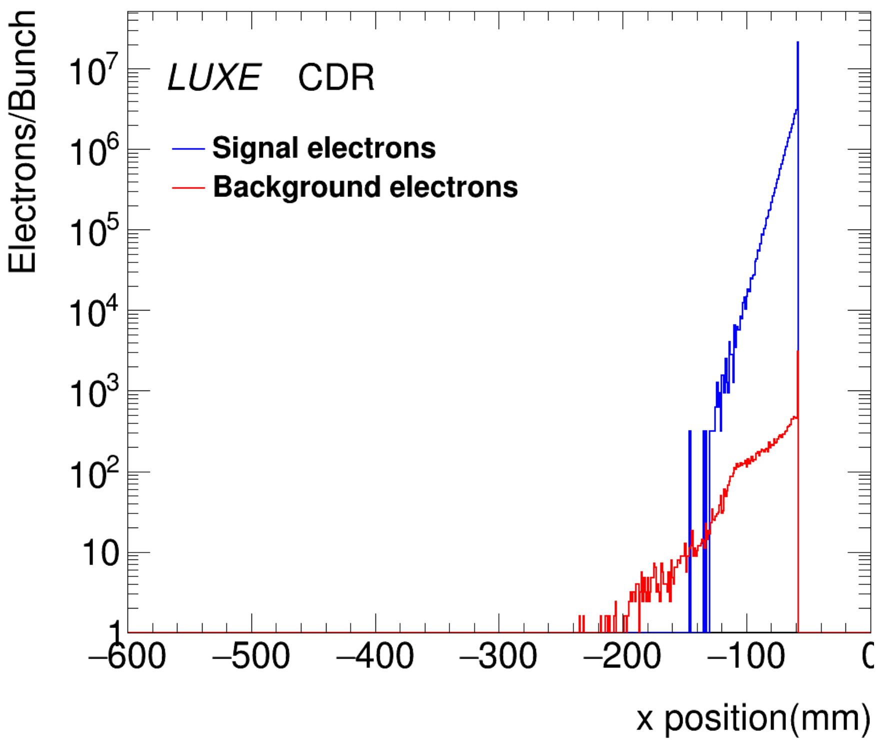
E-LASER postIP e- region – High Xi – Cerenkov

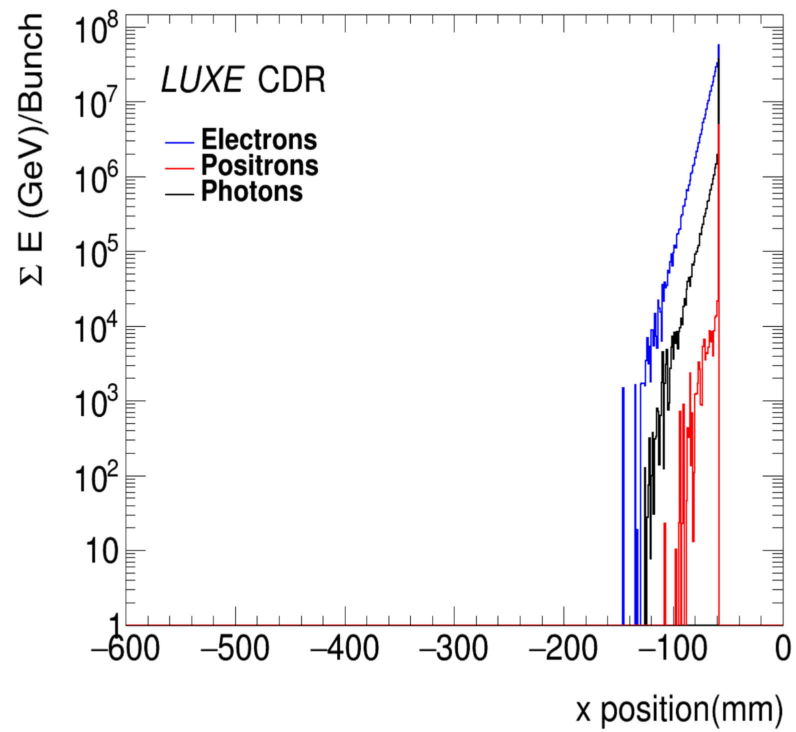


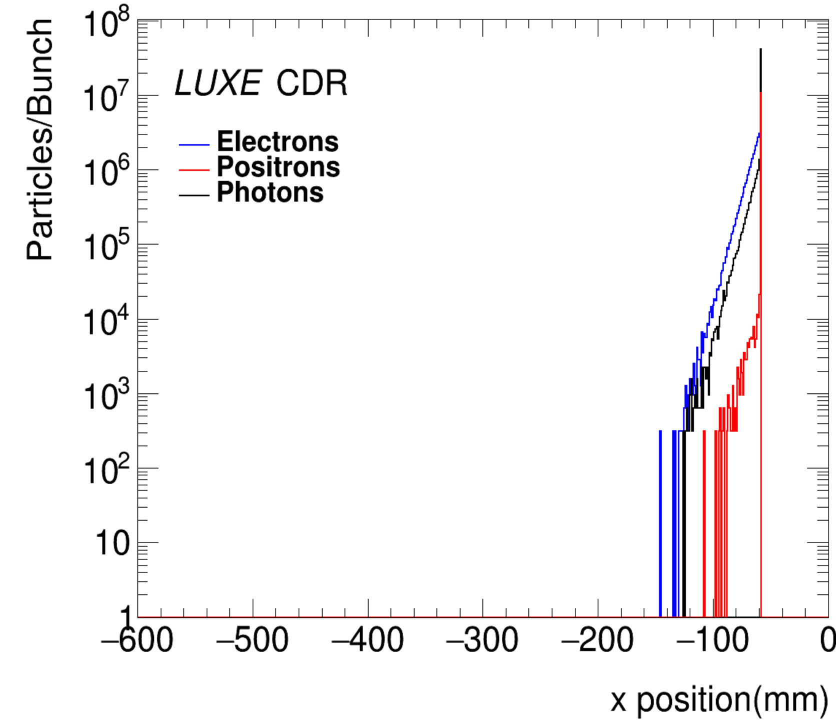




E-LASER postIP e⁻ region – High Xi – Cerenkov – E>20 MeV selection







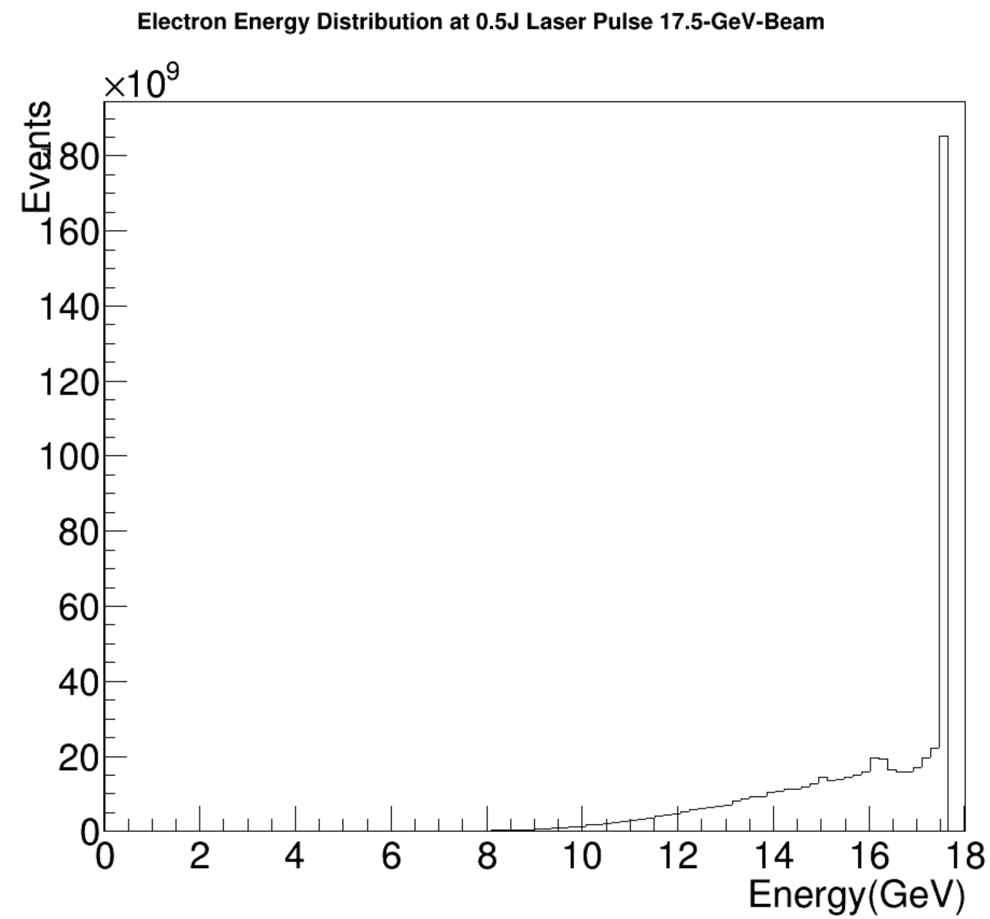
- important to maintain units in these similar plots? (m) vs (mm)?

- vary binning plot-to-plot to ensure readability?

- Large spike at low x in Cerenkov plots not seen in Brem. Plots. Likely due to subtleties in S & B definitions

- Still need to evaluate effect of reduced beam population from scattering pushing e^- into detector acceptance (signal). First look at xi~2 shows almost 2/3 of e- have E<16.4 GeV, so the bkg lines will be reduced but not by more than factor 10. Need to check I am using the correct files, however!

- All this dependent on Ipstrong MC simulations, including HICS rate – which is now corrected to be greater (for higher xi)

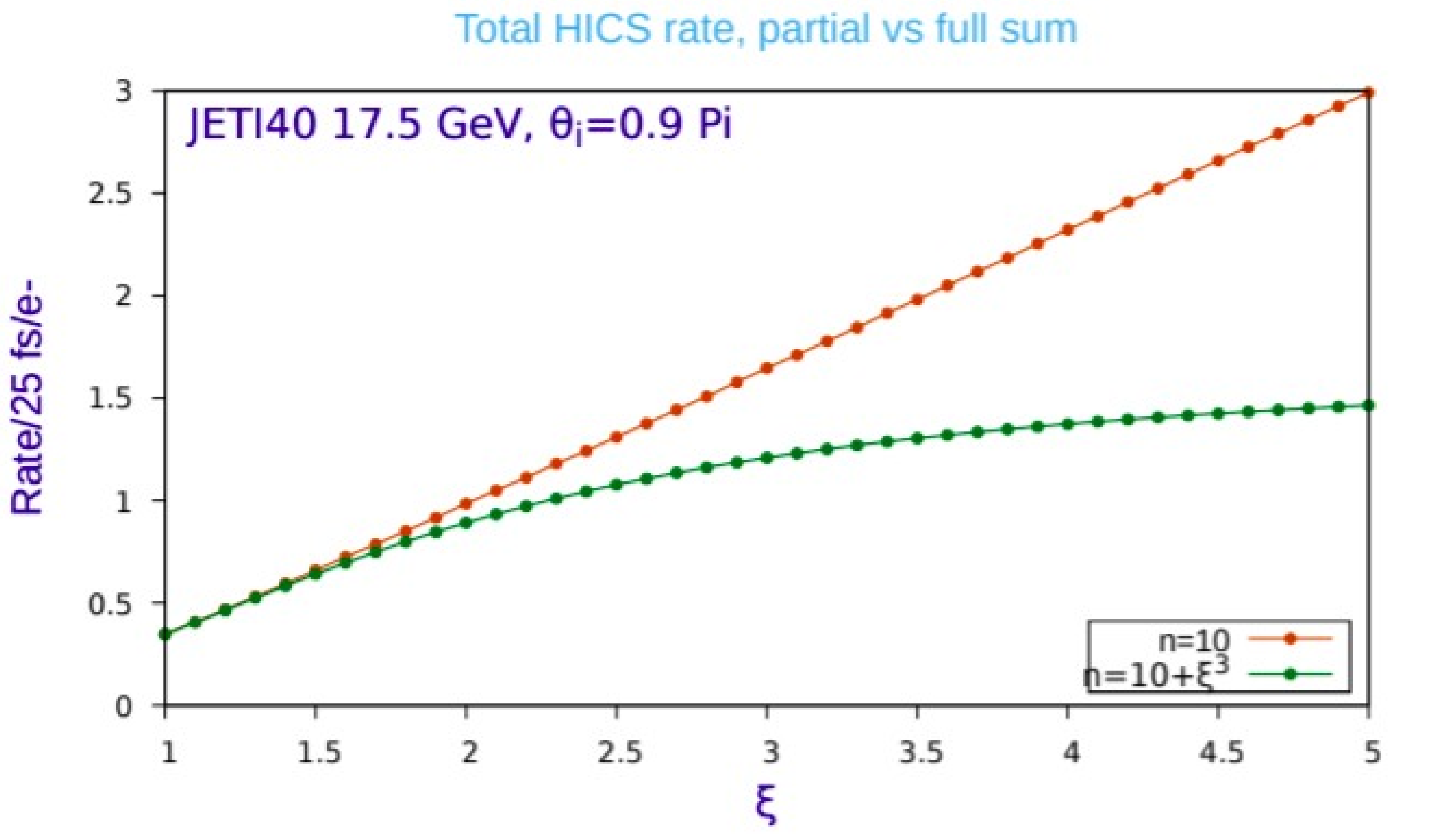


E spectrum for e^- for 100 BX, Xi = 1.8

- no effect on low xi

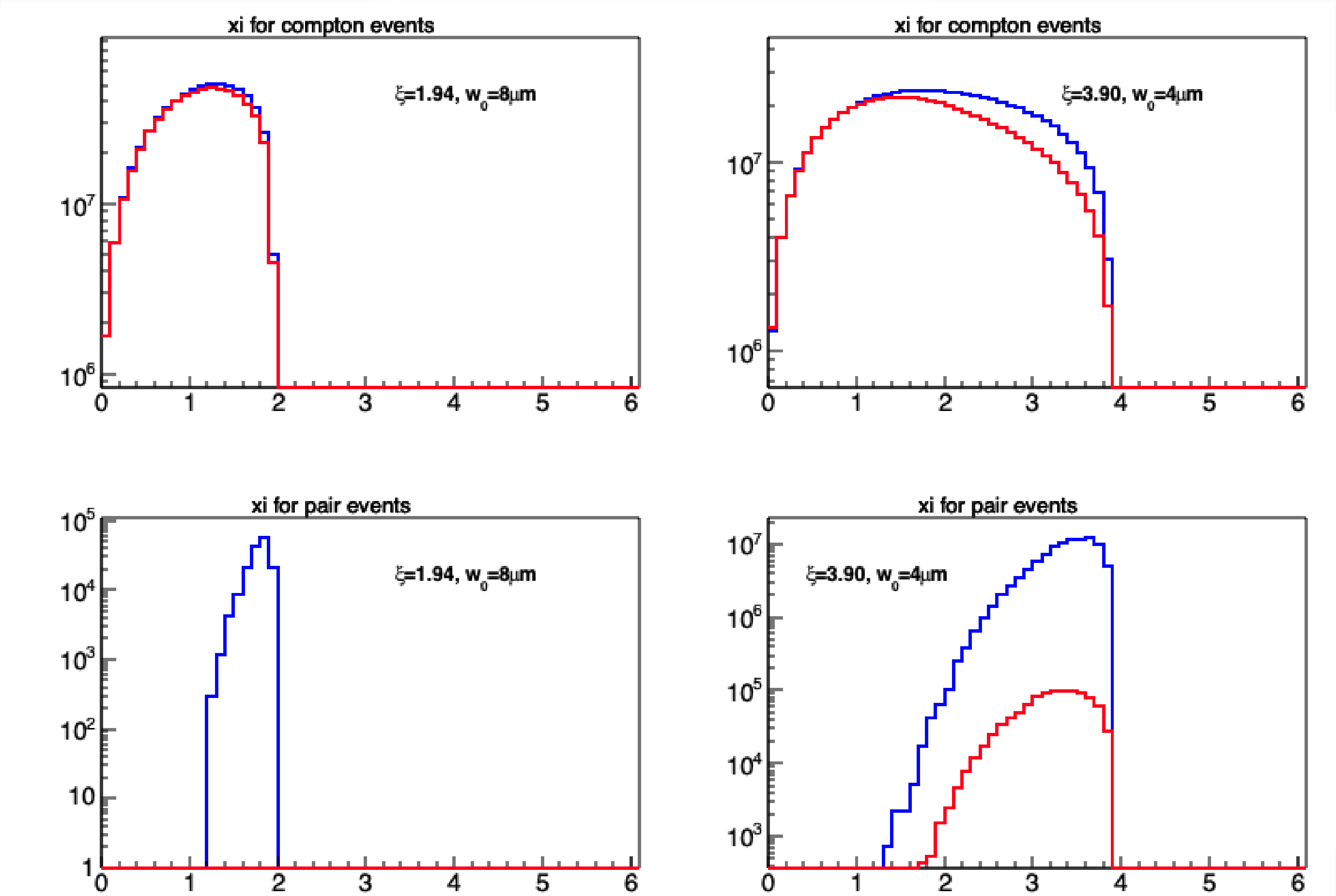
- ~100% increase for high-xi near 5

- no time to redo all simulation, especially passing results through G4???



Tony's slides 24/11/20

Backup



Beate's slides 24/11/20

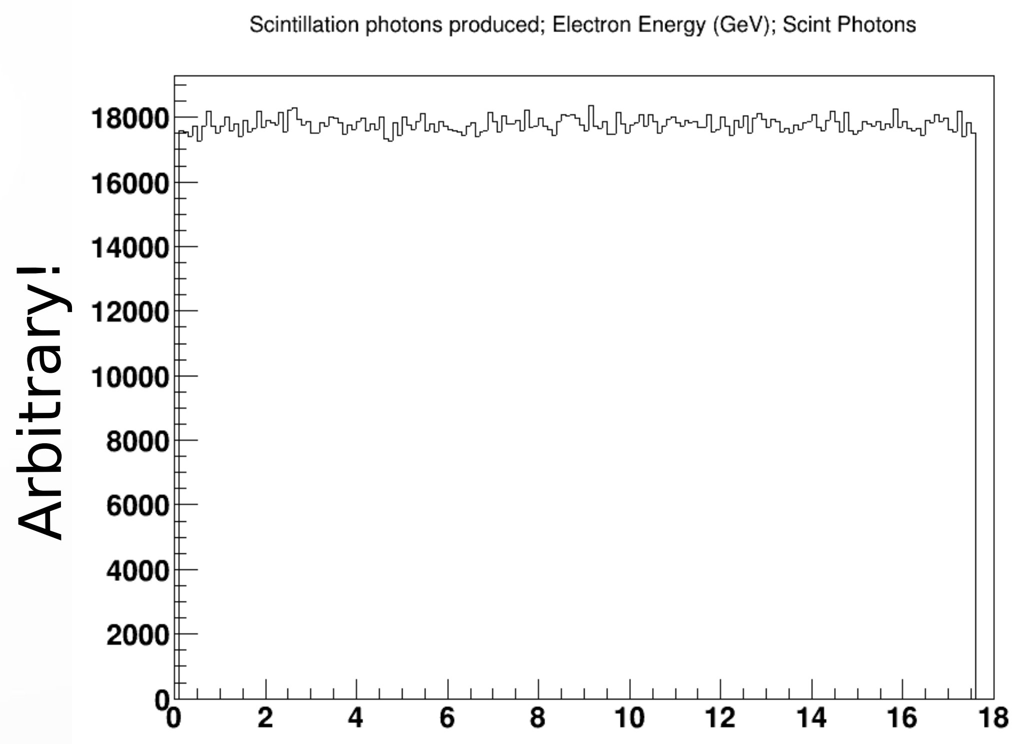
$$\frac{dE}{dx} = \frac{ne^6}{4\pi m_e c^2 \beta^2 \varepsilon_0^2}\left(ln\left(\frac{2m_e c^2 \beta^2}{I(1-\beta^2)}\right) - \beta^2 \right)$$

I have noted in the past that this is flat for high-E and **β** ~ 1. But that's not necessarily the case looking at the denominator in the ln term. In fact it must strictly increase to an asymptote as **β** → 1

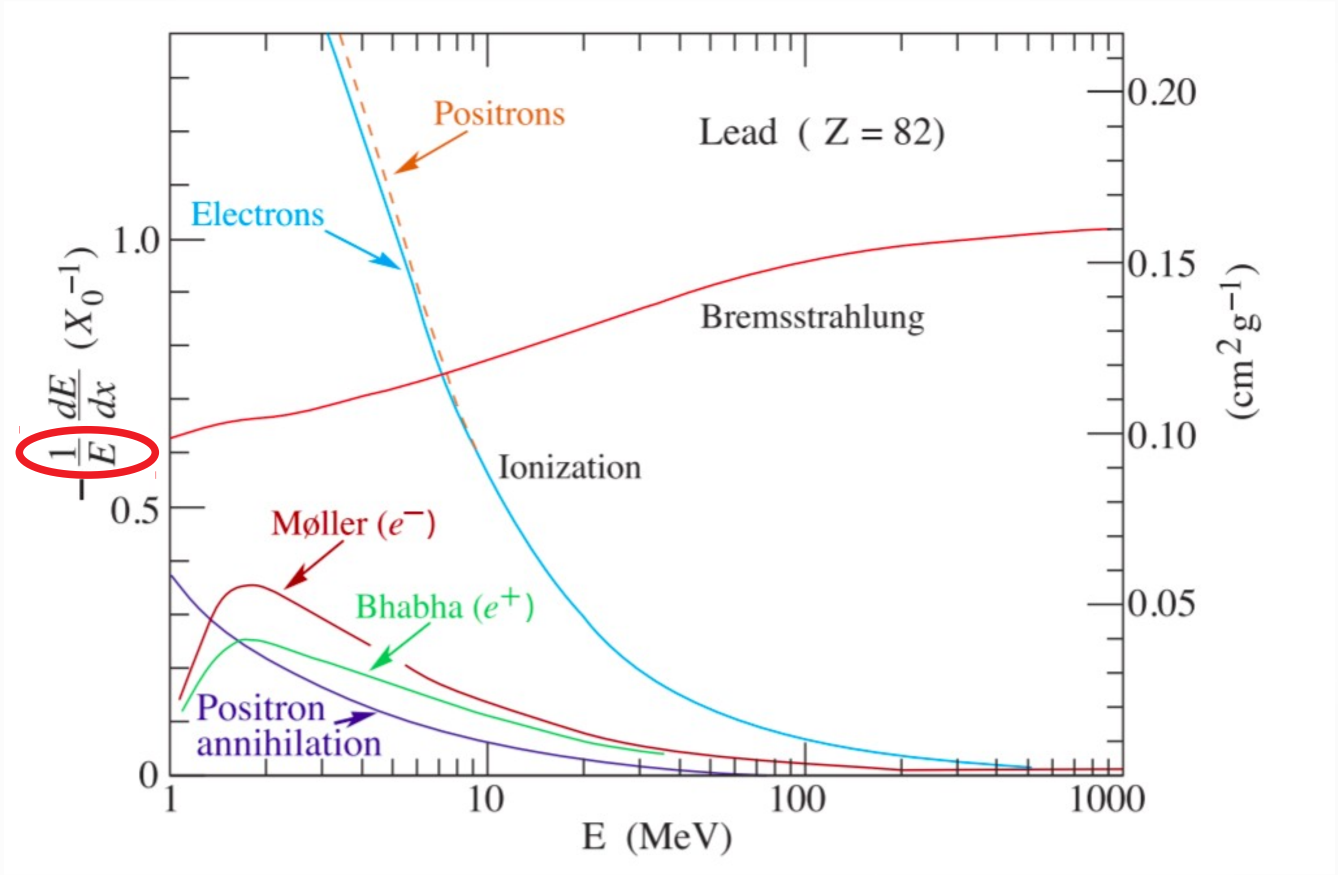
One reason I overlooked this is the Flatness Geant4 has showed so far in the GeV region supporting and invariance of dE/dX.

The Bethe equation is a general expression and I need to search if there are more appropriate eqns. For high-E e^-

So investigation continues including finding what exactly Geant4 does

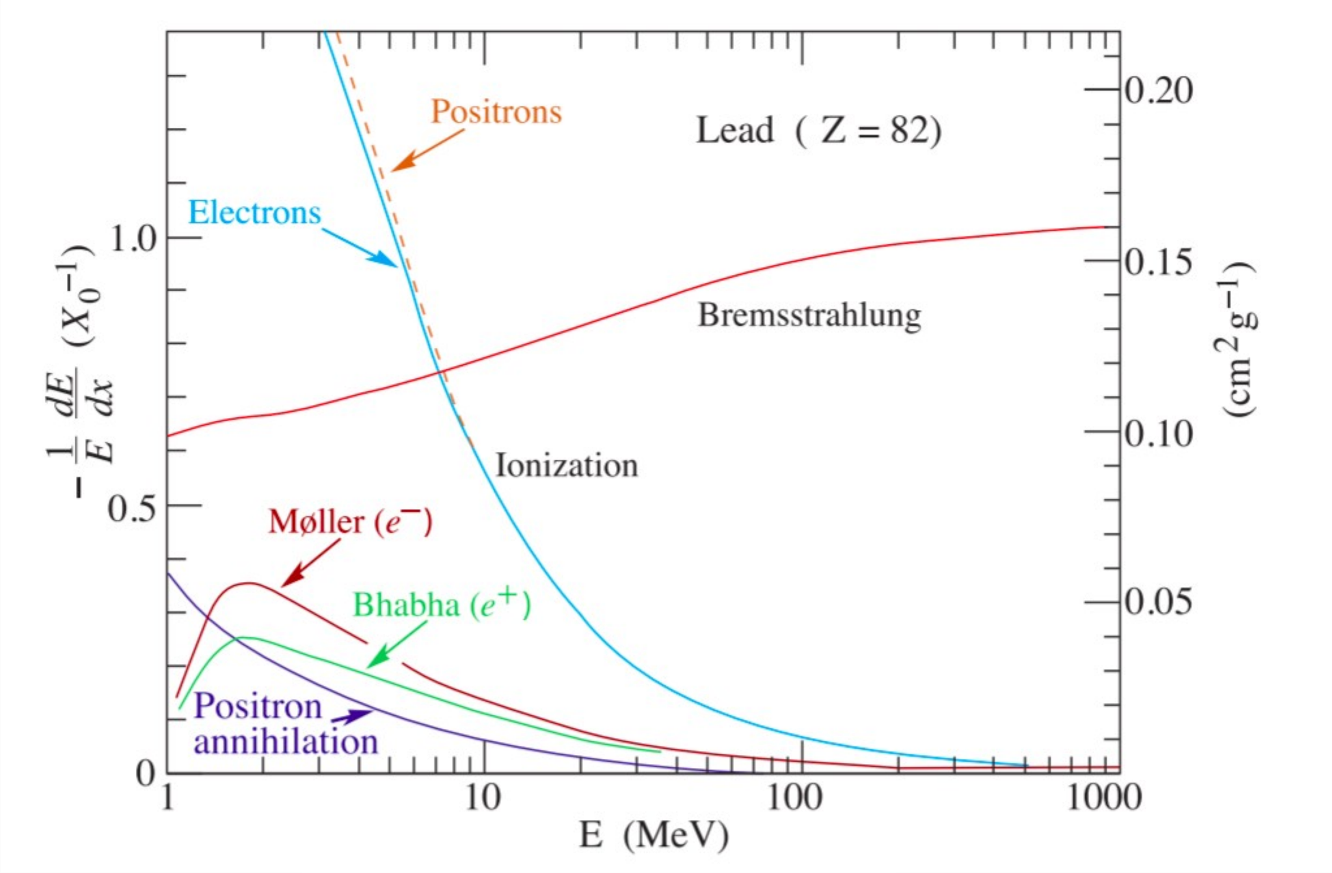


But naturally these electrons lose energy most of all by Bremsstrahlung (and also subsequent pair creation). Yet almost all the energy from these photons is lost i.e. not converted to Scintillation light. Total energy loss of O(GeV) e⁻ are dependent on particle Energy.



The Review of Particle Physics (2020)
P.A. Zyla et al. (Particle Data Group),
Figure 34.11

But naturally these electrons lose energy most of all by Bremsstrahlung (and also subsequent pair creation). Yet almost all the energy from these photons is lost i.e. not converted to Scintillation light. Total energy loss of O(GeV) e^- are dependent on particle Energy.



The Review of Particle Physics (2020)
P.A. Zyla et al. (Particle Data Group),
Figure 34.11

→ energy lost by an incoming particle is not necessarily all ‘deposited’ in material

→ Geant4 Tracks individual particles down to some low-E cut, and also deposition of energy

$$\Sigma\ E_{particles} + \Sigma\ E_{deposition} = E_{tot}$$

→ This is a term Geant4 keeps to represent energy loss in matter that it cannot do by explicit particle tracking (shifting to an averaging of continuous radiation for low-E radiation)

→ Daughter particles, especially higher-E photons created by Brem. Can escape the screen and their energy does not transform to scintillation light

→ So total energy loss is higher – what does this do for Cherenkov signal?

Bethe Equation
for charged particle energy deposition in matter

$$\frac{dE}{dx} = \frac{ne^6}{4\pi m_e c^2 \beta^2 \varepsilon_0^2}\left(ln\left(\frac{2m_e c^2 \beta^2}{I(1-\beta^2)}\right) - \beta^2\right)$$

Frank-Tamm Formula
For energy loss of charged particle through Cherenkov Radiation

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

Bethe Equation
for charged particle energy deposition in matter

$$\frac{dE}{dx} = \frac{ne^6}{4\pi m_e c^2 \beta^2 \varepsilon_0^2} \left(ln \left(\frac{2m_e c^2 \beta^2}{I(1-\beta^2)} \right) - \beta^2 \right)$$

Frank-Tamm Formula
For energy loss of charged particle through Cherenkov Radiation

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

Let's quickly evaluate the trend of this term for relevant **β**

Is it flat? Do we see +ve gradient approaching the asymptote

And let's create an evaluation of percentage relative signal for Cerenkov radiation for example e⁻ and those e- after 0.5 mm of GadOx in G4

E_i	β_i	E_f	β_f	$Č_f$ / $Č_i$	Ψ
10 MeV	0.998817	9.15 MeV	0.998227	0 E<20MeV	13.81
100 MeV	0.999987	95.42 MeV	0.999953	87.27%	18.32
1 GeV	0.9999998 7	955.6 MeV	0.9999998 57	99.995%	22.93
10 GeV	0.9999999 987	9.526 GeV	0.9999999 9856	99.99% 9's to 6 d.p.	27.53
17.5 GeV	0.9999999 9957	16.75 GeV	0.9999999 99535	Rounded to =1 by ROOT!	28.64

$$I = (10\ \mathrm{eV}) \cdot Z$$

$$\Psi = \left(ln\left(\frac{2m_e c^2 \beta^2}{I(1-\beta^2)} \right) - \beta^2 \right)$$

Take O2, lightest nucleus in GadOx, z=16 → I = 160 eV

→ This is evaluation of mean E. In truth the Cerenkov response will be slightly more complex as some proportion of incident e^- lose enough energy to drop below threshold, for example

→ So with a n_primary = 10000, re-making this response with G4:

E_i	β_i	E_f	β_f	$Č_f$ / $Č_i$	Ψ
10 MeV	0.998817	9.15 MeV	0.998227	0 E<20MeV	13.81
100 MeV	0.999987	95.42 MeV	0.999953	98.23%	18.32
1 GeV	0.99999987	955.6 MeV	0.999999857	99.7%	22.93
10 GeV	0.9999999987	9.526 GeV	0.99999999856	99.98%	27.53
17.5 GeV	0.99999999957	16.75 GeV	0.999999999535	99.999%	28.64