Scintillation Screen IP Simulation & Reconstruction

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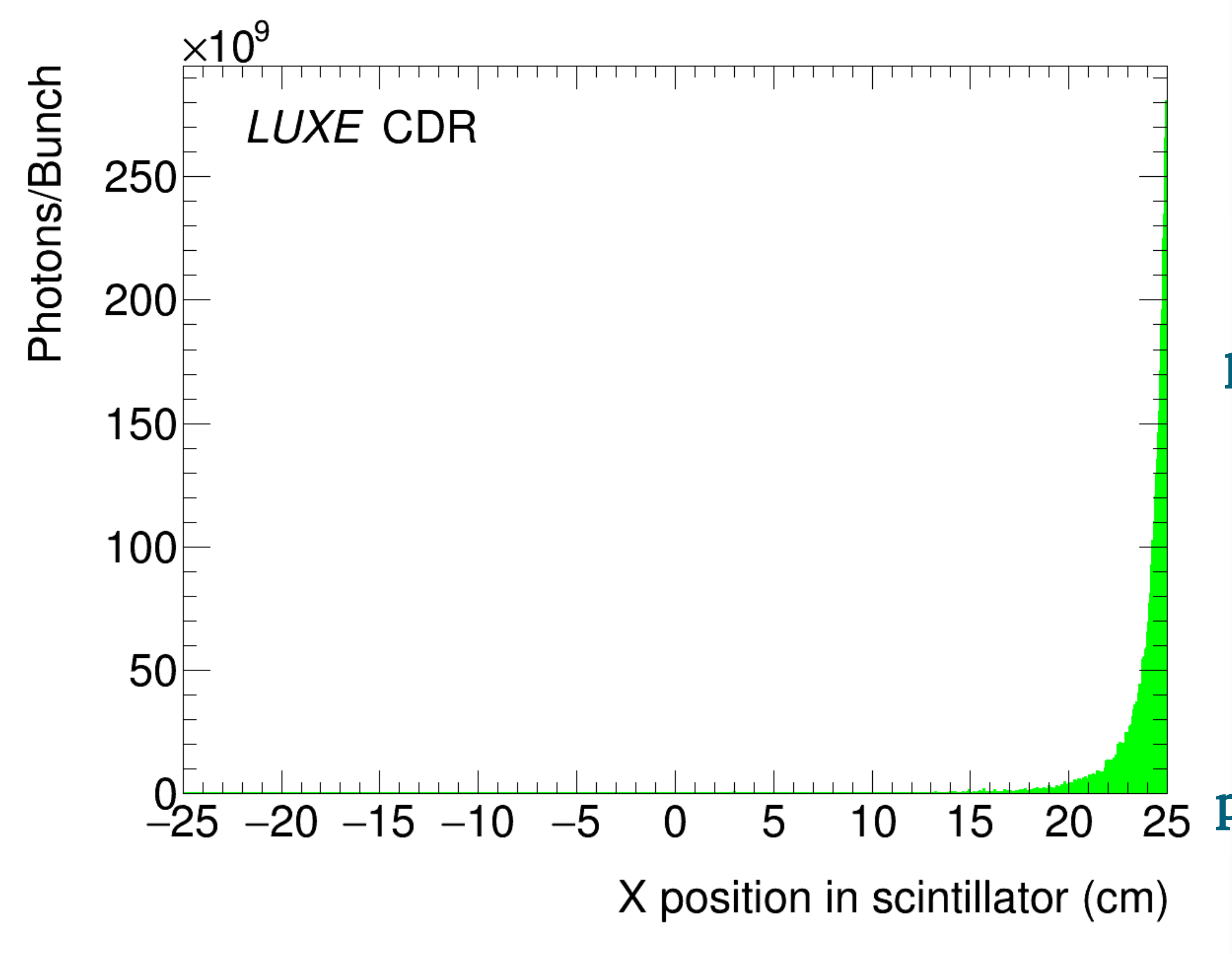


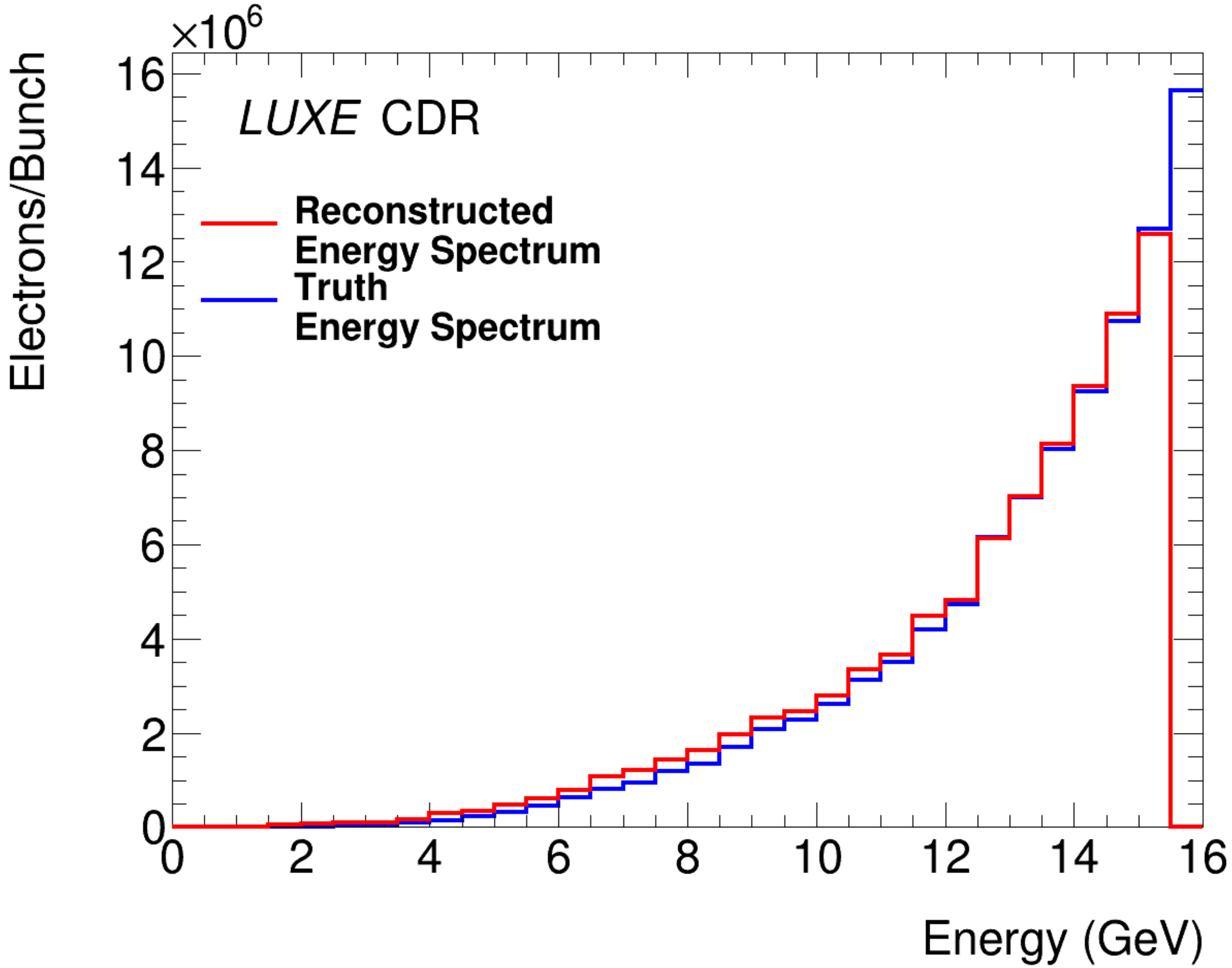
IPstrong Full Scattering
IP Scint. Screen, w_0 = 3µm

Reminder:

- Producing recon vs truth plots for IP e- measurement Lanex screen

- Involves simulating Scintillation processes in Geant4

- Then taking integral of photon light between x position limits corresponding to desired energy interval



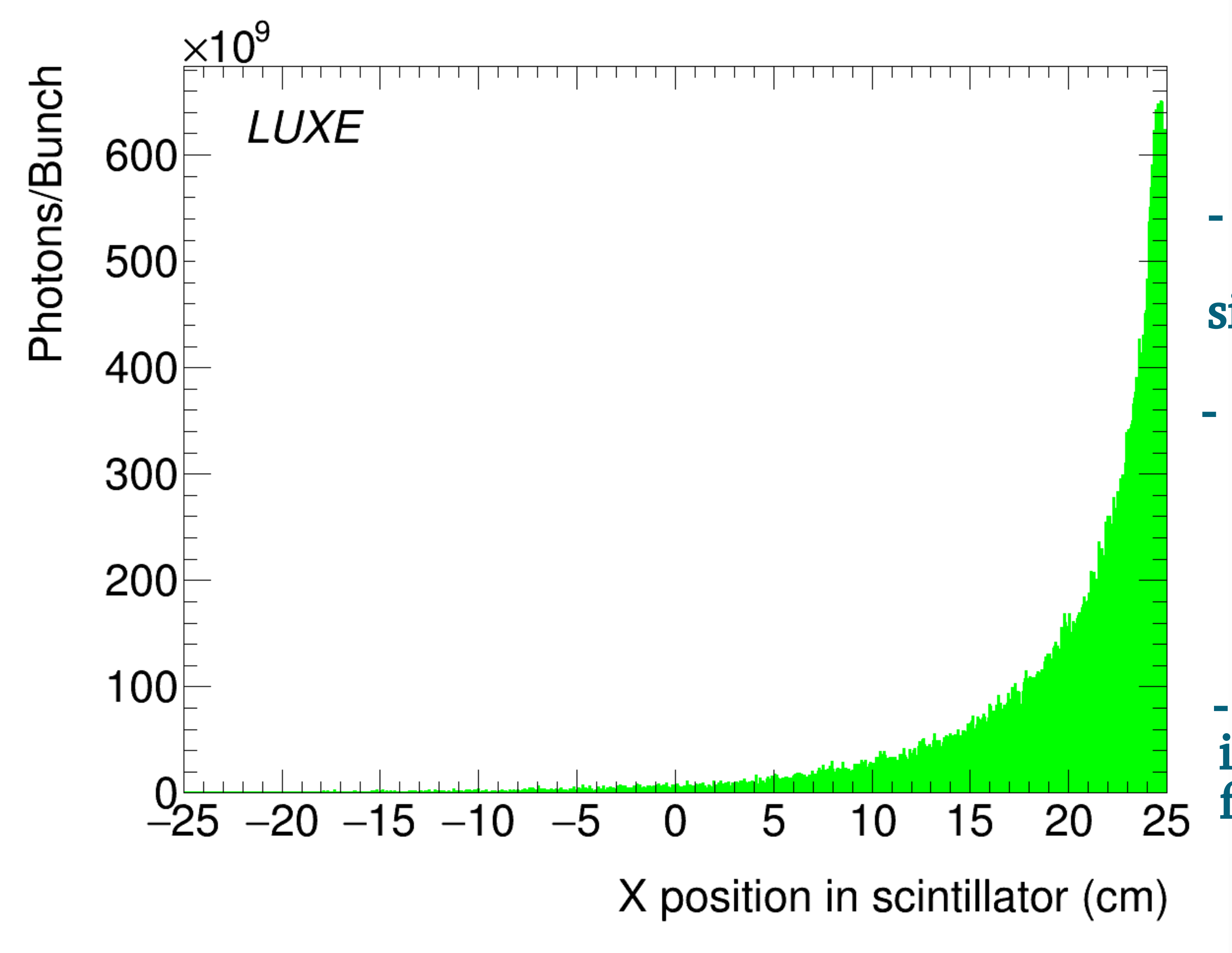
IPstrong Full Scattering
IP Scint. Screen, w_0 = 3µm

- Serious relative overestimate for lower energies, likely some migration from higher energies

- sub-optimal statistics, ~850*2000 macroparticles were used (1.7M). For Brem. managed to use 1/10 of bunch (150M). Excited to use Tom Blackburn's production to improve on this

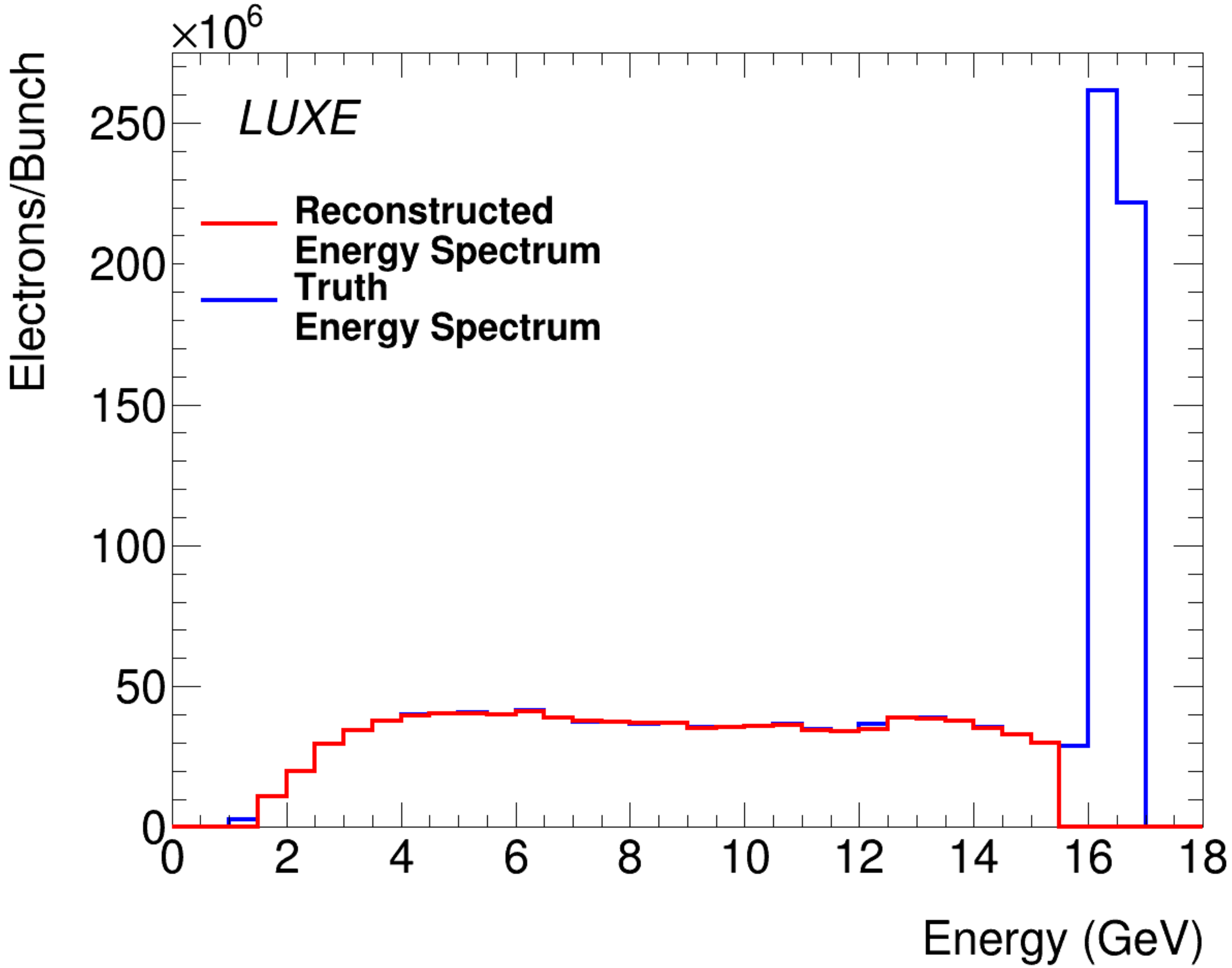
- As seen in light profile, very steep gradients are present. Even a small angular dispersion of scattered secondaries can then affect low-E integral

- Currently 5 cm of air from beam-window to screen – could be useful to evaluate 0 cm



Ptarmigan Full Scattering
IP Scint. Screen, w_0 = 5µm

- Immediately we see in (this particular) ptarmigan simulation a far gentler slope
- Similar but not same LASER spot width
- Disagreement between simulations
- So with a gentler slope the impact of showers migrating from high-E to low-E region is lesser

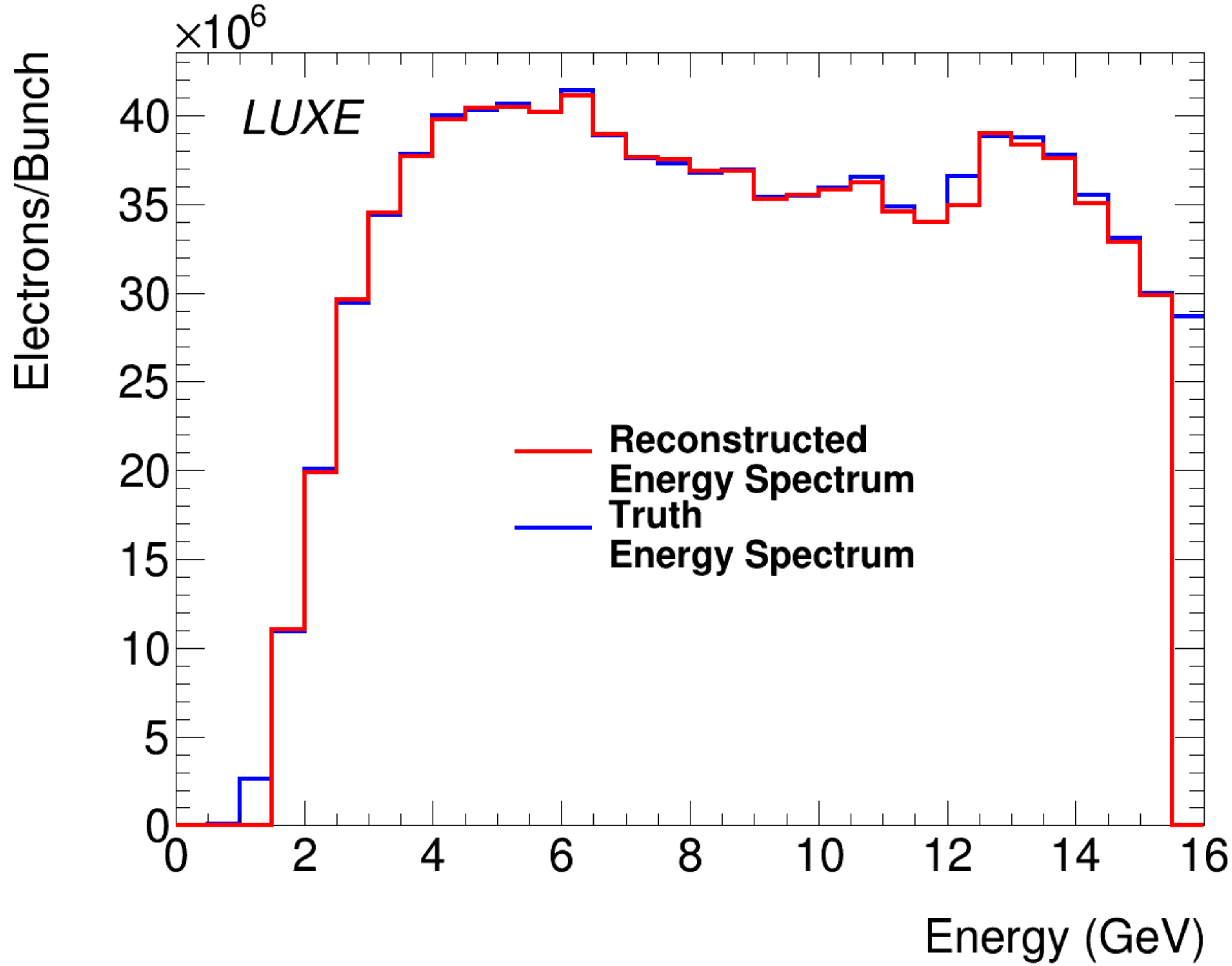


- Good agreement, and no more consistent overestimate at low E!

- Still limited on statistics, using 1 million macroparticles

- This does, to me, give evidence of the idea that steep light gradient in x & showering radius in screen → migration

Ptarmigan Full Scattering
IP Scint. Screen, w_0 = 5µm



Ptarmigan Full Scattering
IP Scint. Screen, w_0 = 5µm

- Good agreement, and no more consistent overestimate at low E!

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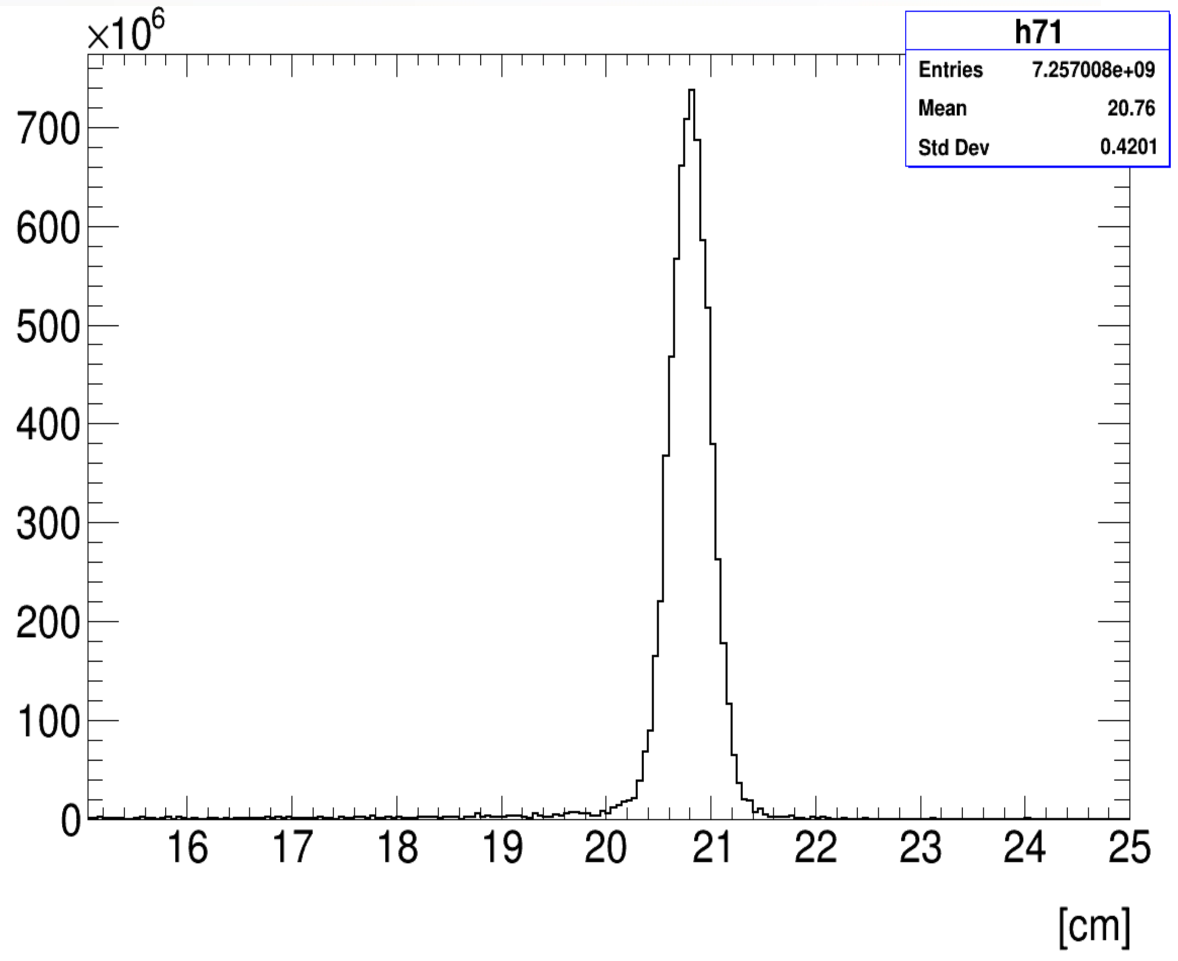
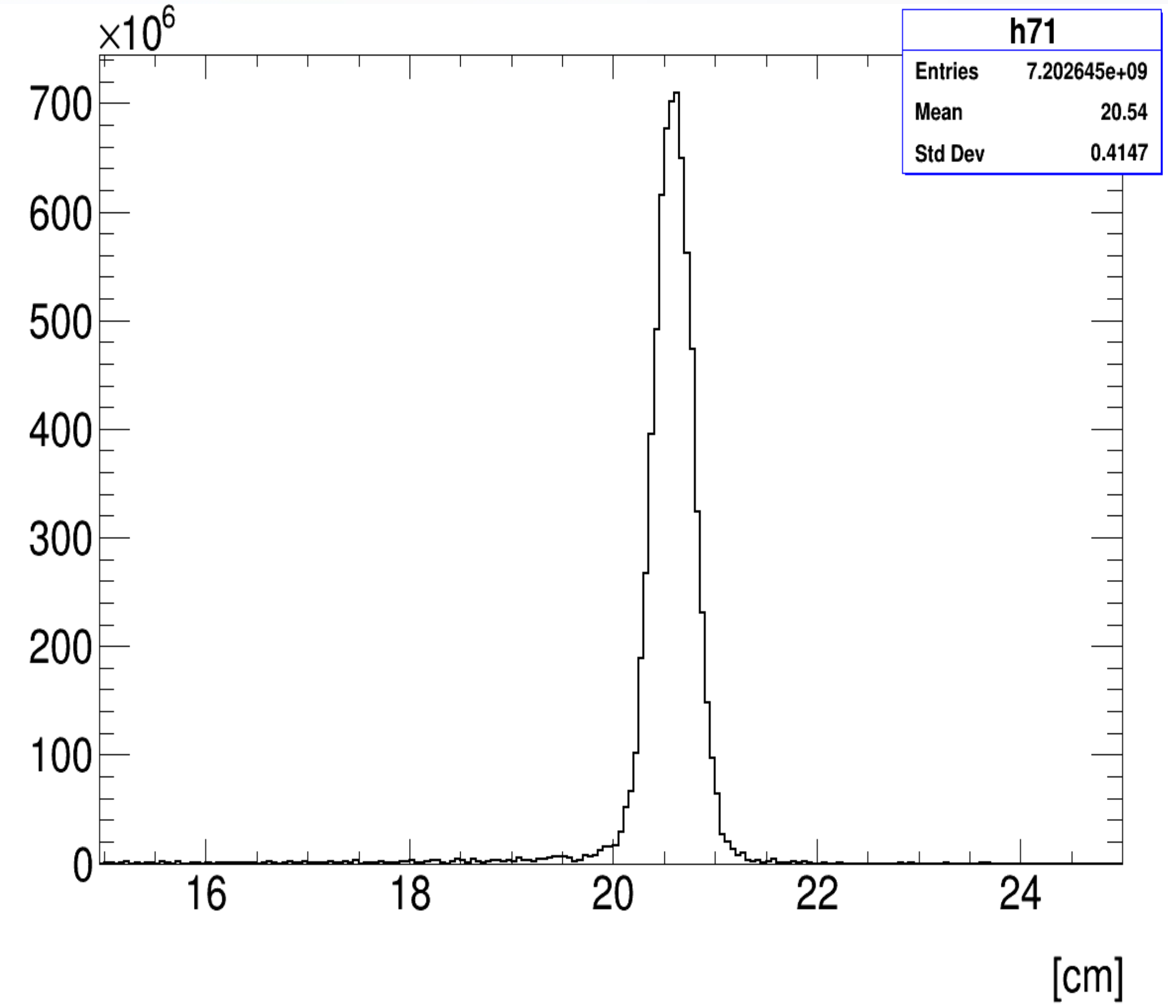
- recon acceptance lower cut at 1.5 GeV, explaingin bump in bottom left



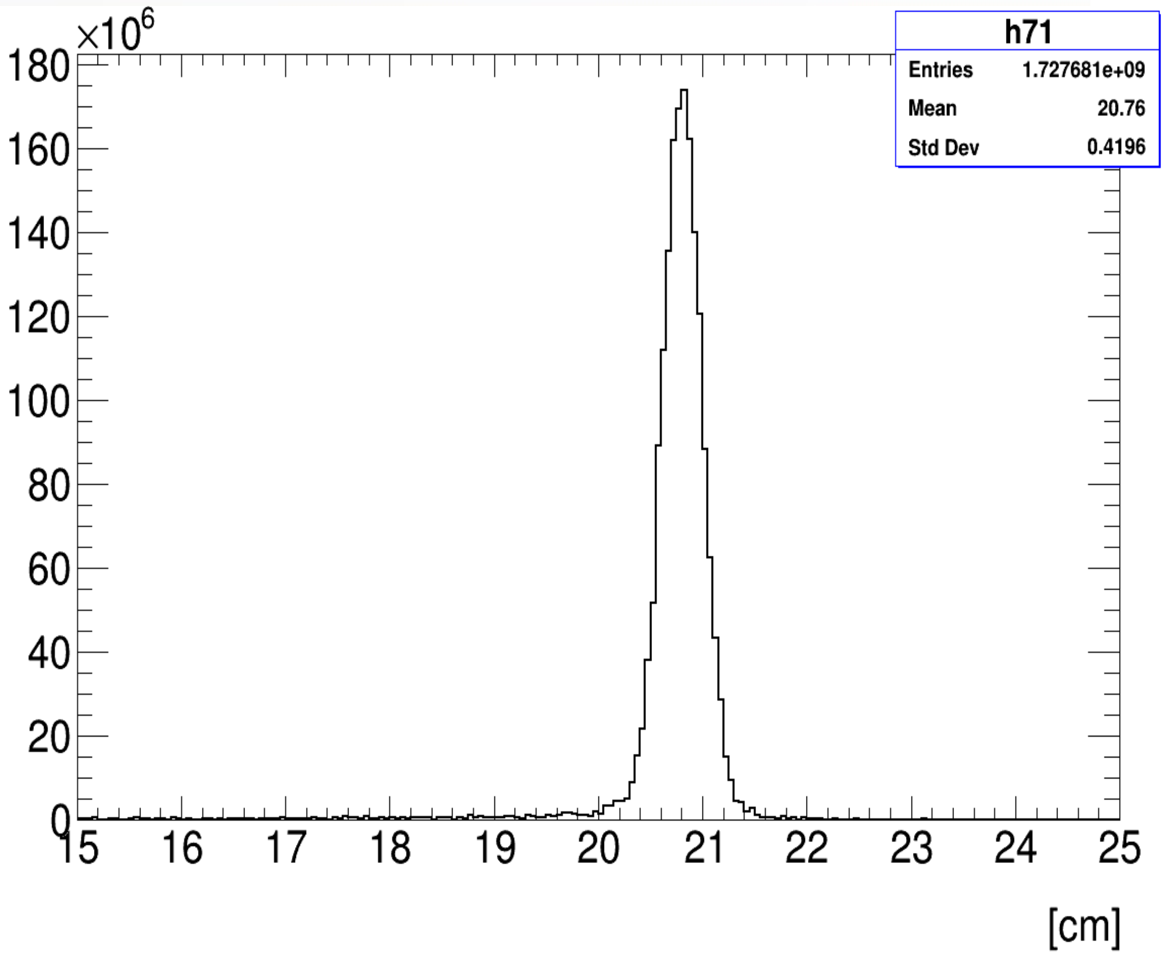


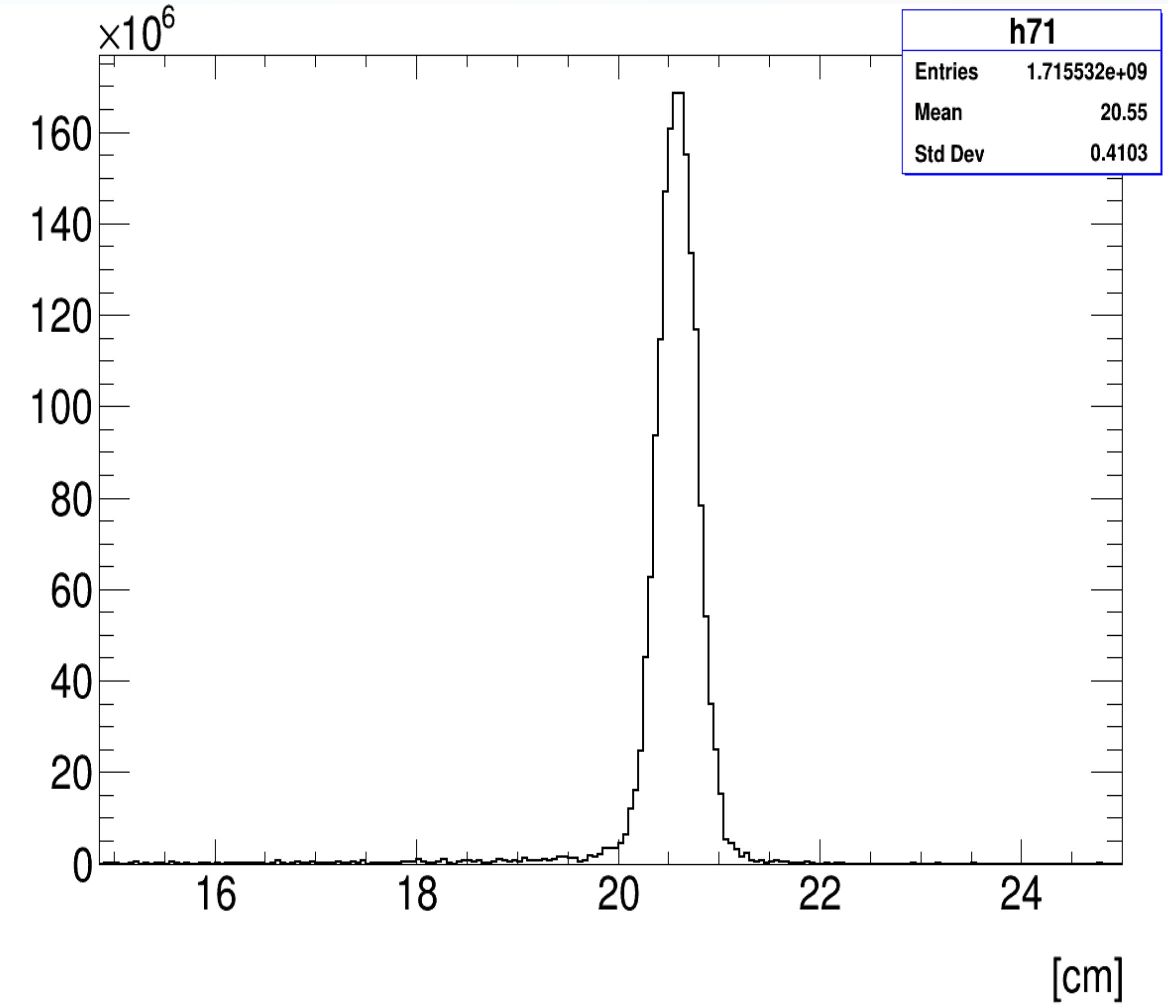
'Taped to Beam-window'
IP Scint. Screen thickness = 500µm

5cm gap from window to screen
IP Scint. Screen thickness = 500µm

- I tried looking at the 'point-source' response of E=7GeV beam in G4

- I feel it clearly has no real effect, looking at std. dev. as a *very* rough indicator



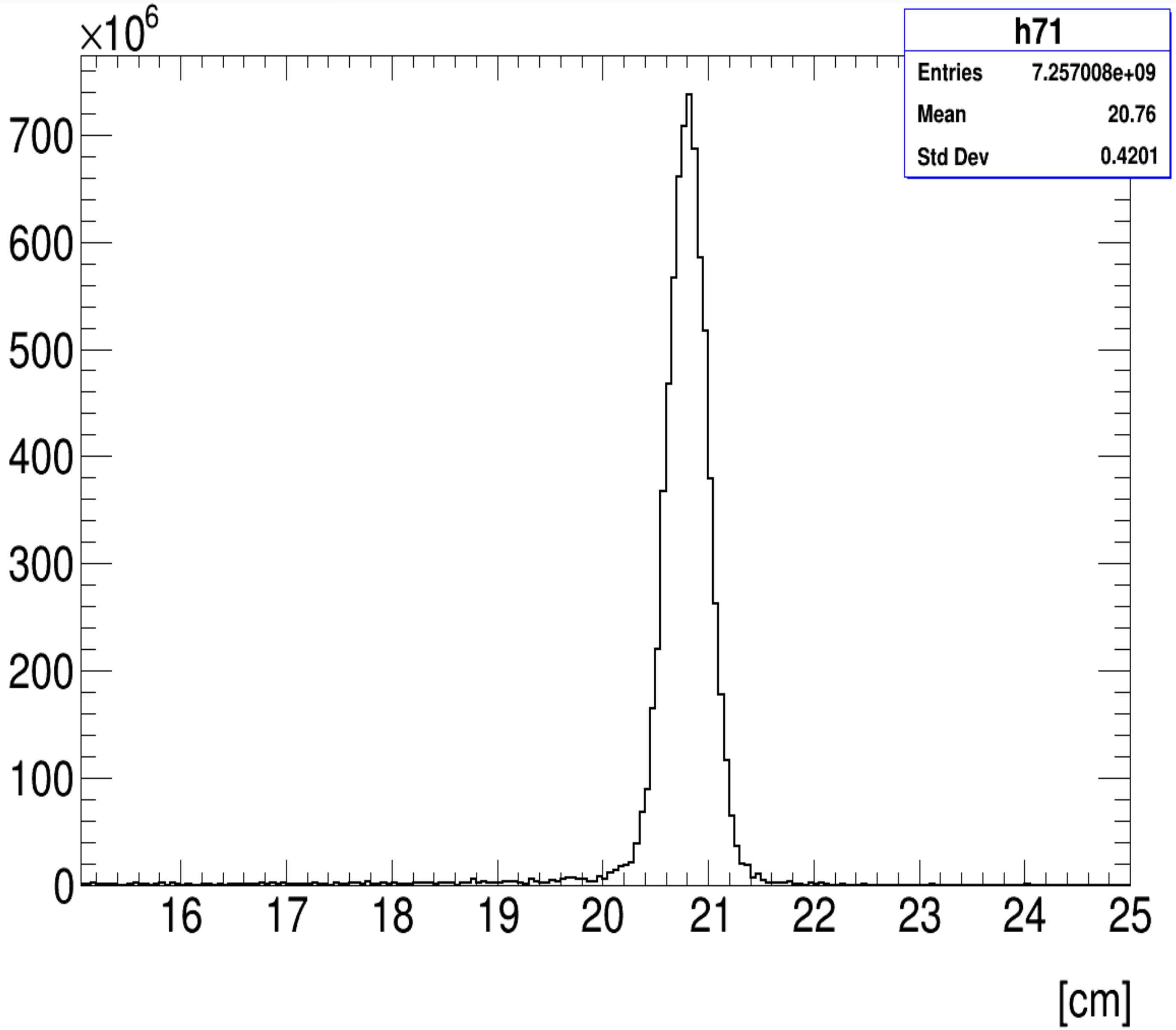


'Taped to Beam-window'
IP Scint. Screen thickness = 125μm

5cm gap from window to screen
IP Scint. Screen thickness = 125μm

- Now also with a thinner screen to look again at response

- Again little effect by eye or std dev

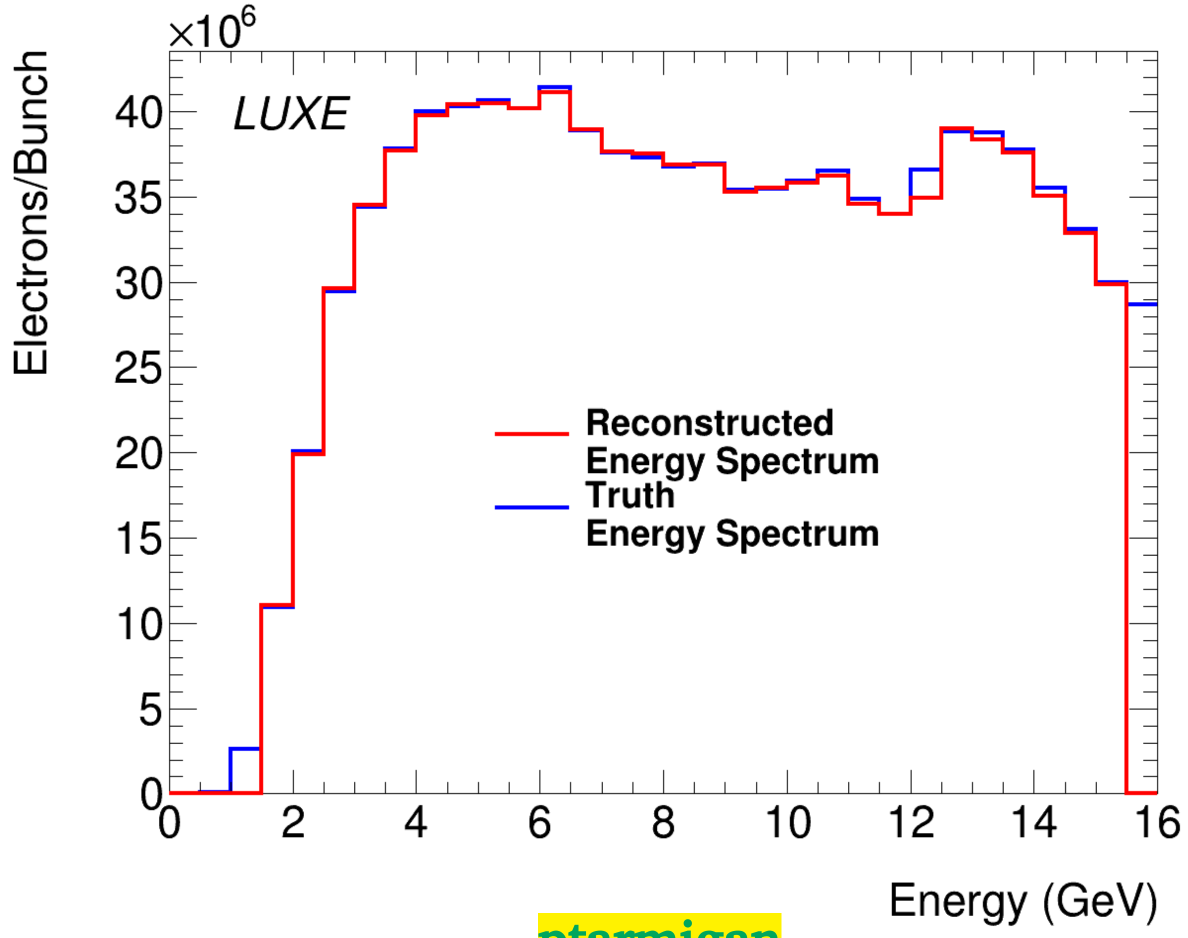


- This dispersion is honestly more than I expected and it is fortunate the reconstructions have been as good as they are!

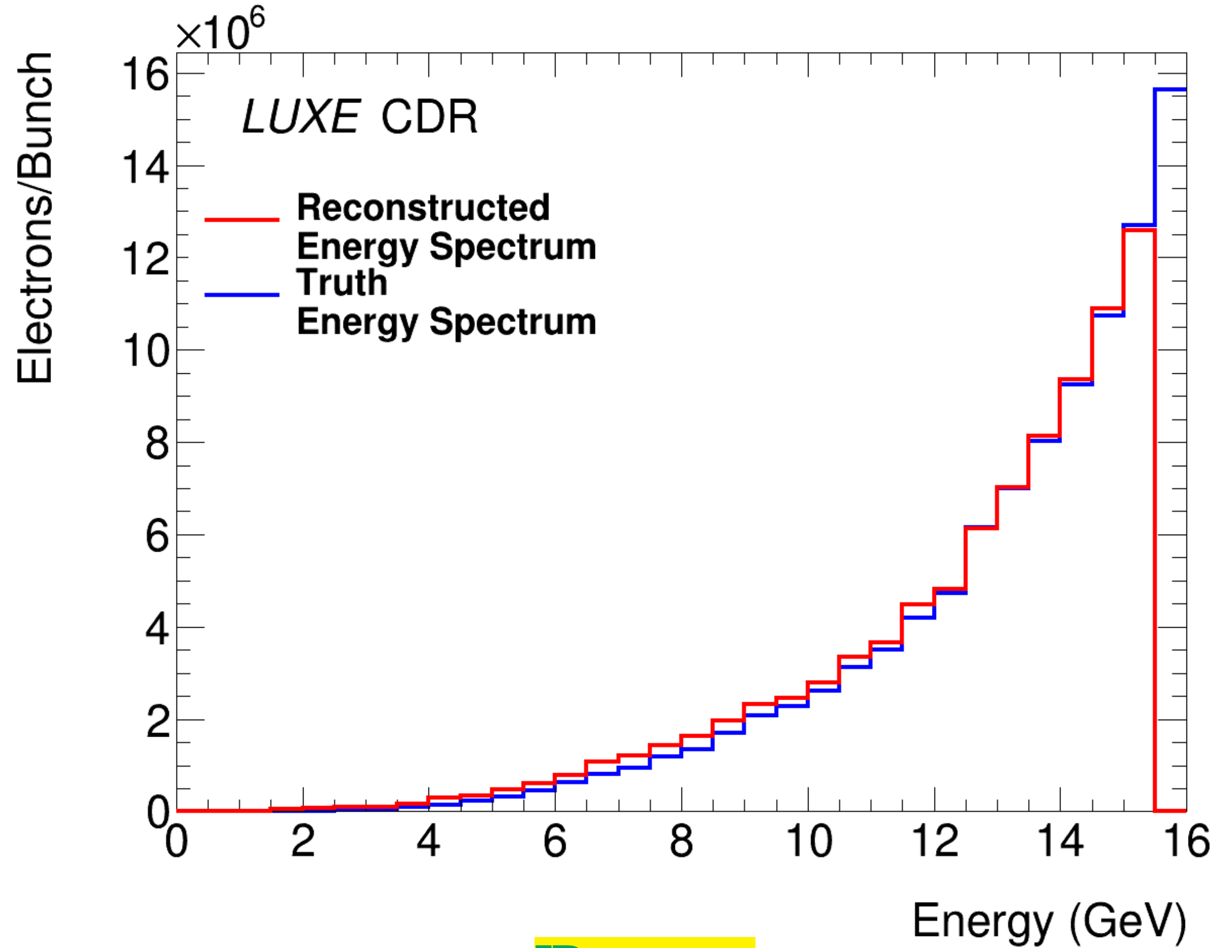
- An intrinsic property of the material? Like the Moliére radius, although the shower is not contained in the material as electrons just pass through

- Manufacturers (Mitsubishi) offer thinner screens and claim higher resolution. This must be in terms of optical obfuscation

'Taped to Beam-window'
IP Scint. Screen thickness = 500µm



ptarmigan
IP Scint. Screen w_0 = 5μm



IPstrong
IP Scint. Screen w_0 = 3μm

- We do not know exactly the ultimate spectra for various xi
- Need to safeguard against these possible high-gradient light distributions
- expect sharp cut-offs in low-xi Compton edge case (but there we use B=2T)

DECONVOLUTION

Of course we can understand the measured spectrum as a convolution of function of incident electrons (f) with single-electron signal response which is broadly Gaussian (g) – as well as additive noise (ϵ).

$$s = (f * g) + \epsilon$$

After measurement of background, which can be done both by measurement of the screen with e-beam only events and light emission outside the central band of signal, this background can effectively be subtracted. Then $s = f$ if the single particle response is of a Dirac-Delta function - or close enough. This has been the assumption so far. To deconvolute, we can use the Fourier transform and Convolution theorem. The Fourier transform of function f in x is:

$$F(\omega) = \mathcal{F}(f(x)) = \int_{-\infty}^{\infty} f(x)\, e^{-i2\pi x\omega} dx$$

and the Convolution Theorem states:

$$\mathcal{F}(f * g) = \mathcal{F}(f) \times \mathcal{F}(g)$$

To make use of this we need an explicit description of the single-response Gaussian (or its Fourier Transform). We can deduce this due to the symmetry of the detection response. I suggest that we can use the y-dimension of the image of the screen to measure an effective single-electron response g. At the high-energy limit of the screen, the response. I suggest that we can use the y-dimension of the image of the screen to measure an effective single-electron response g. At the high-energy limit of the screen, the detector sees the most collimated and most numerous electrons, so we can evaluate this dispersion of energy deposition at that point with:

1. the closest incident electron function to a Dirac-Delta (in y).

2. the best statistics at any point in the image.

The resulting gathered distribution is arbitrarily-scaled. As we define g as the response of one incident electron, we can normalise such that the integral is set to one, and keep the number-of-electron information encoded in f.

With the digital data we have, to use the Fourier transform in this form requires fitting of continuous, integrable functions to the data. It is not wise to rely on this approach as we need to keep the approach generalisable to spectra of a surprising shape. In any case we expect energy distributions with discontinuities in the form of 'Compton Steps' which will prove difficult to fit.

Thankfully we can use instead the Discrete form of the Fourier transform which suits our discrete data. This takes the form:

$$X_k = \sum_{n=0}^{N-1} x_n \, e^{-i\frac{2\pi}{N}kn}$$

$$= \sum_{n=0}^{N-1} x_n \left[cos\left(\frac{2\pi}{N}kn\right) - i\,sin\left(\frac{2\pi}{N}kn\right)\right]$$

Where N is the number of elements in the discrete data, and n and k denote elements within. The inverse Fourier transform is then:

$$x_n = \frac{1}{N} \sum_{k=0}^{N-1} X_k \, e^{i \frac{2\pi}{N} kn}$$

$$= \frac{1}{N} \sum_{k=0}^{N-1} X_k \left[cos\left(\frac{2\pi}{N} kn\right) + i \, sin\left(\frac{2\pi}{N} kn\right)\right]$$

This technique will be used in simulation and its effectiveness considered. Its use in real-life can also account for optical point-spread effects not implemented in simulation.

Outlook:

- Will send more jobs to UCL farm to take ptarmigan and send MC particle through G4 many times to develop statistics

- on a longer timescale, look into running ptarmigan to create these statistics. Tom has explained 10^6 macroparticles takes 3 hrs in one core. Can assume full bunch takes 4500 thread-hours. At UCL with 180 concurrent threads, takes 25 hrs.

- will implement Fourier transform into reconstruction script

- In the process of ordering Cameras & screens to DESY

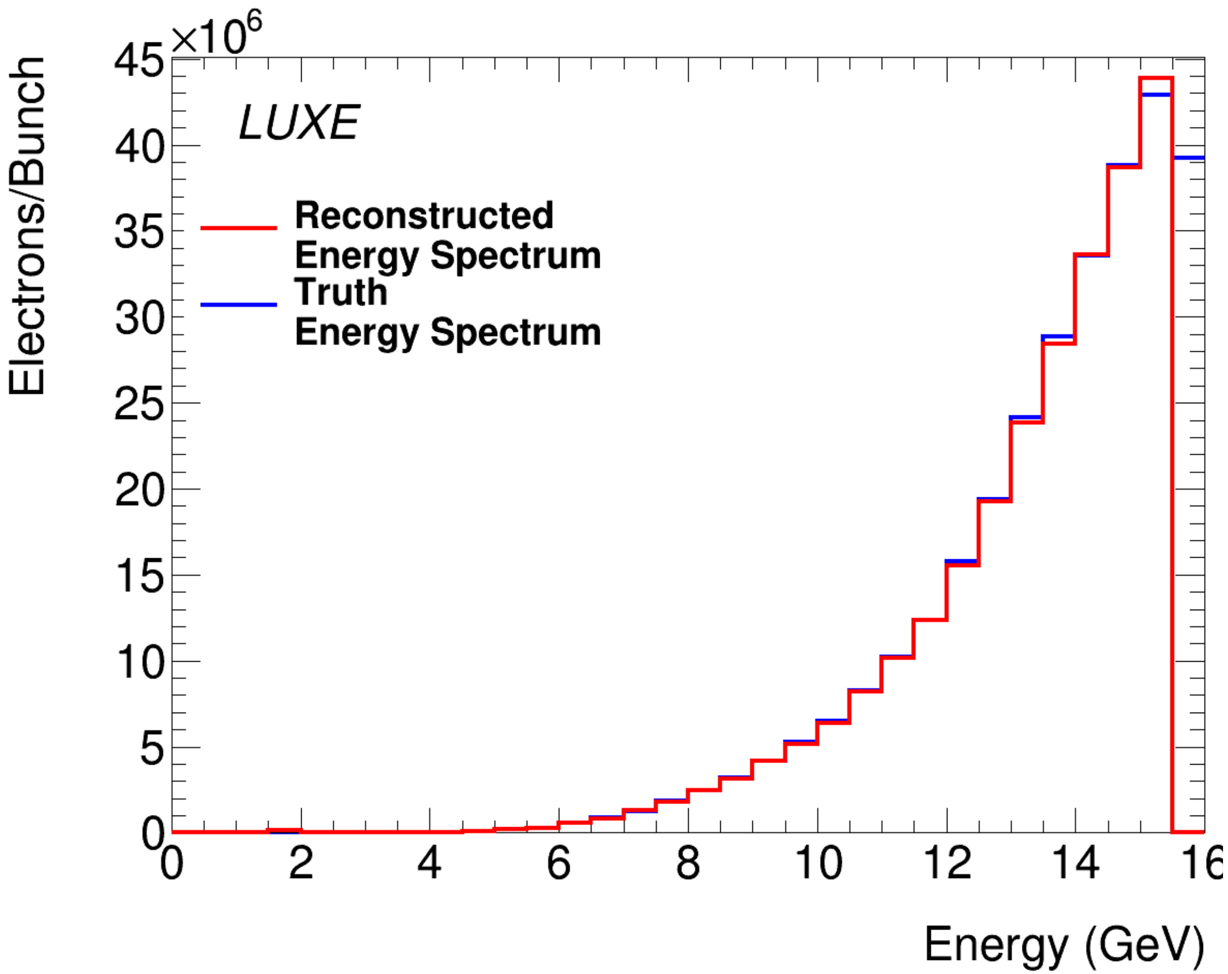
- Not working next week (incl. preparing for Brexit meeting Wed)

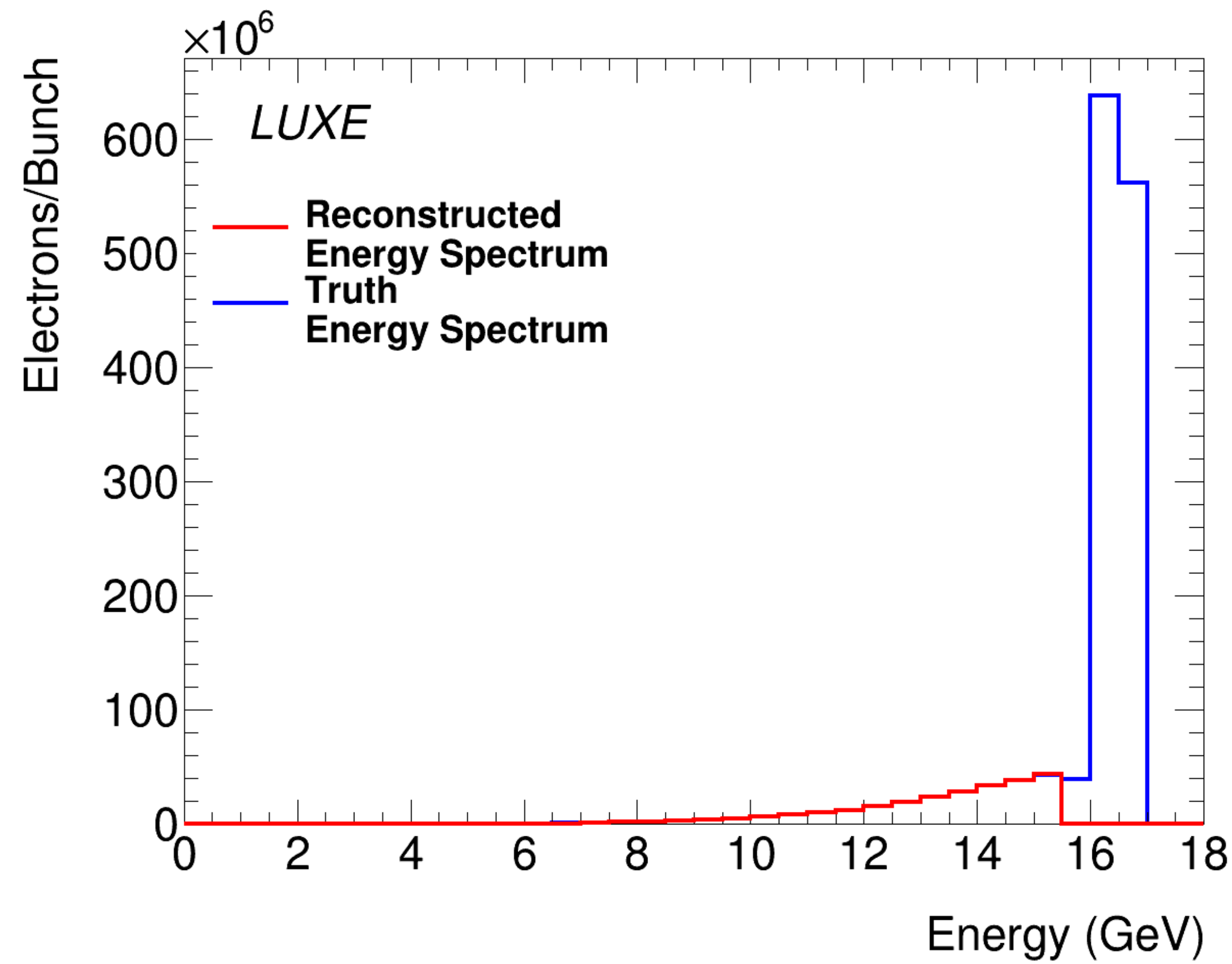
- Also not forgetting Sasha's comments 2 weeks ago about variable binning approach

Addendum:

Choosing JETI40 ptarmigan with xi = 2.0

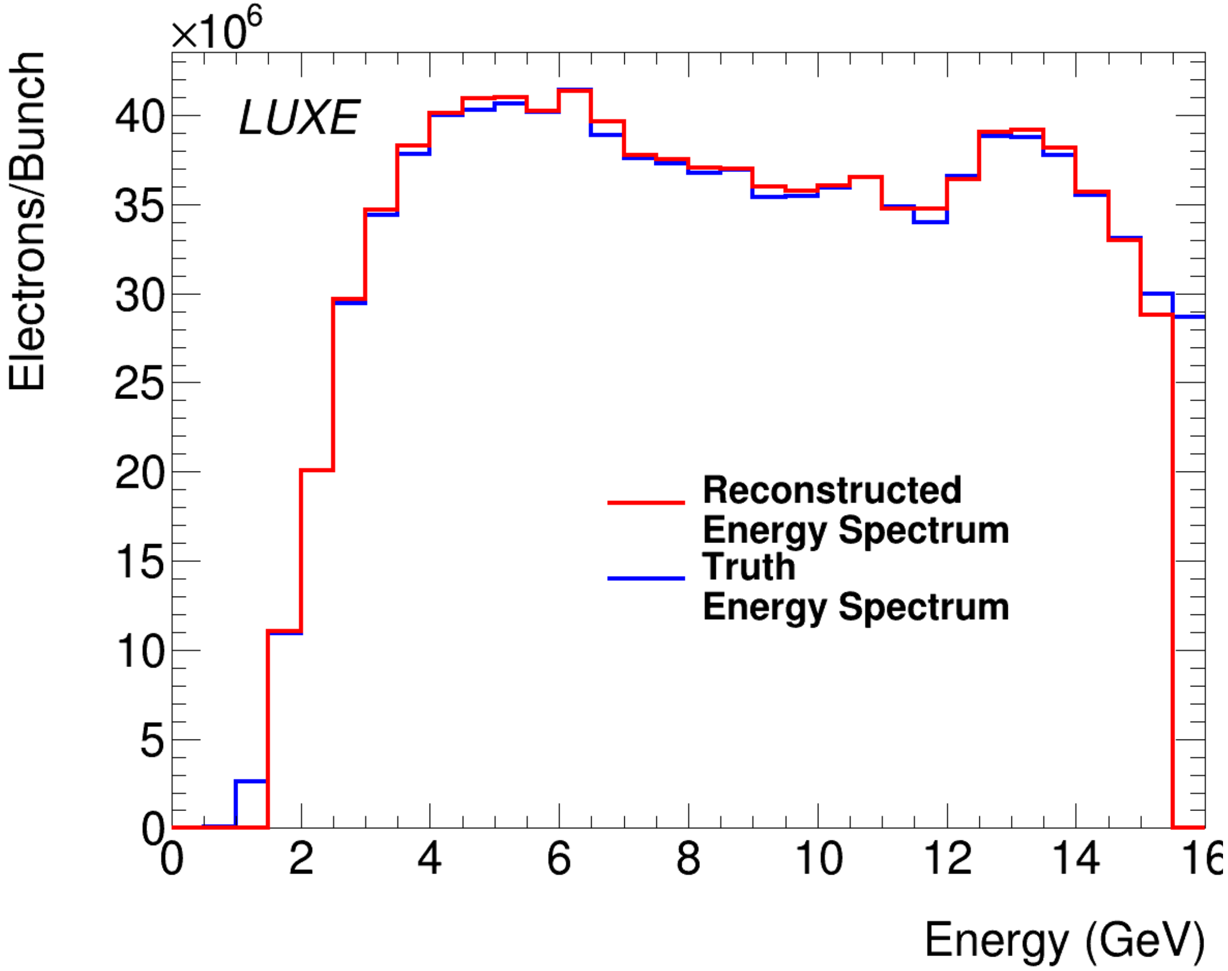
/nfs/dust/luxe/group/MCProduction/Signal/uncompressed/ptarmigan/JETI40/xi_scan/xi2.0_particles.out

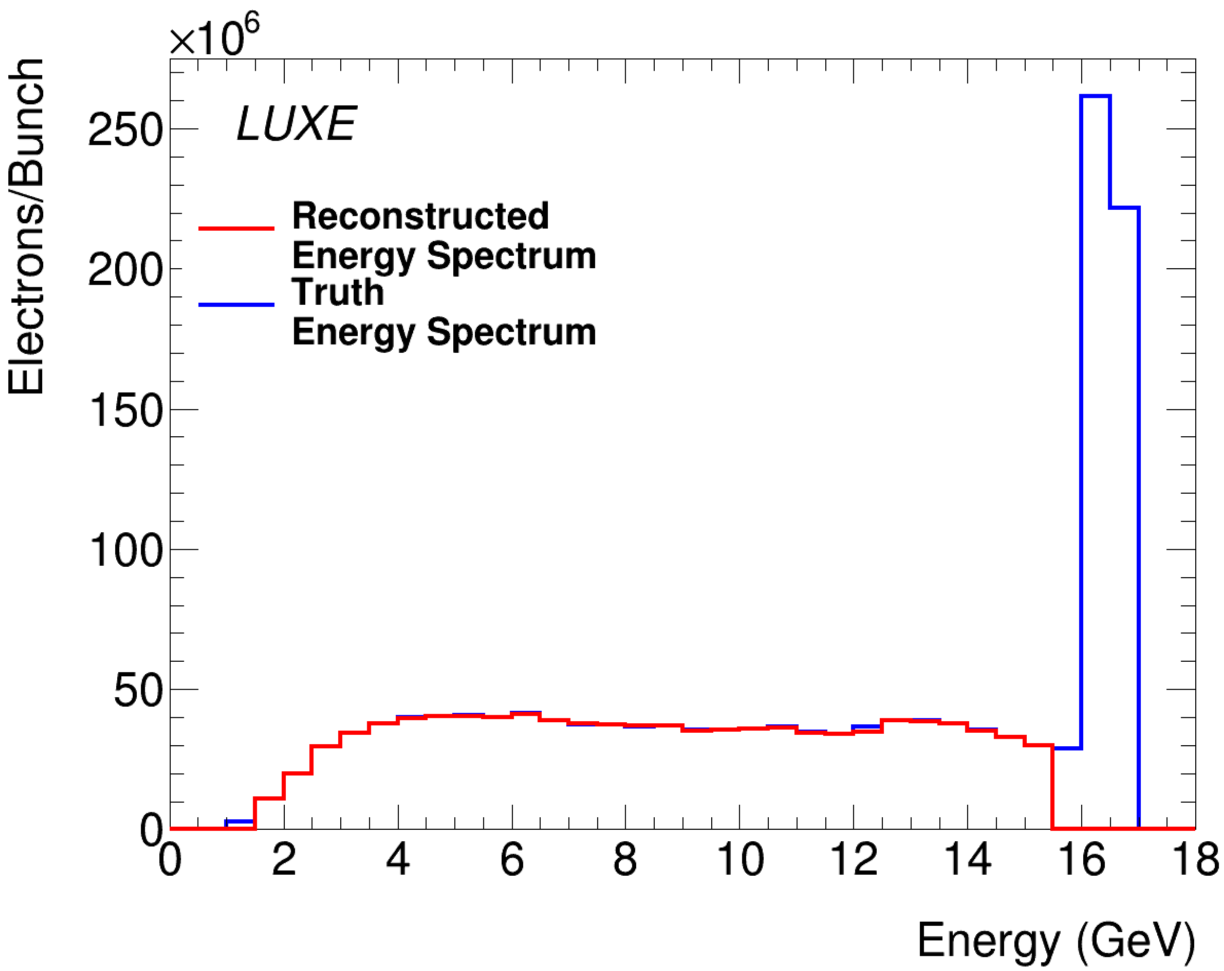




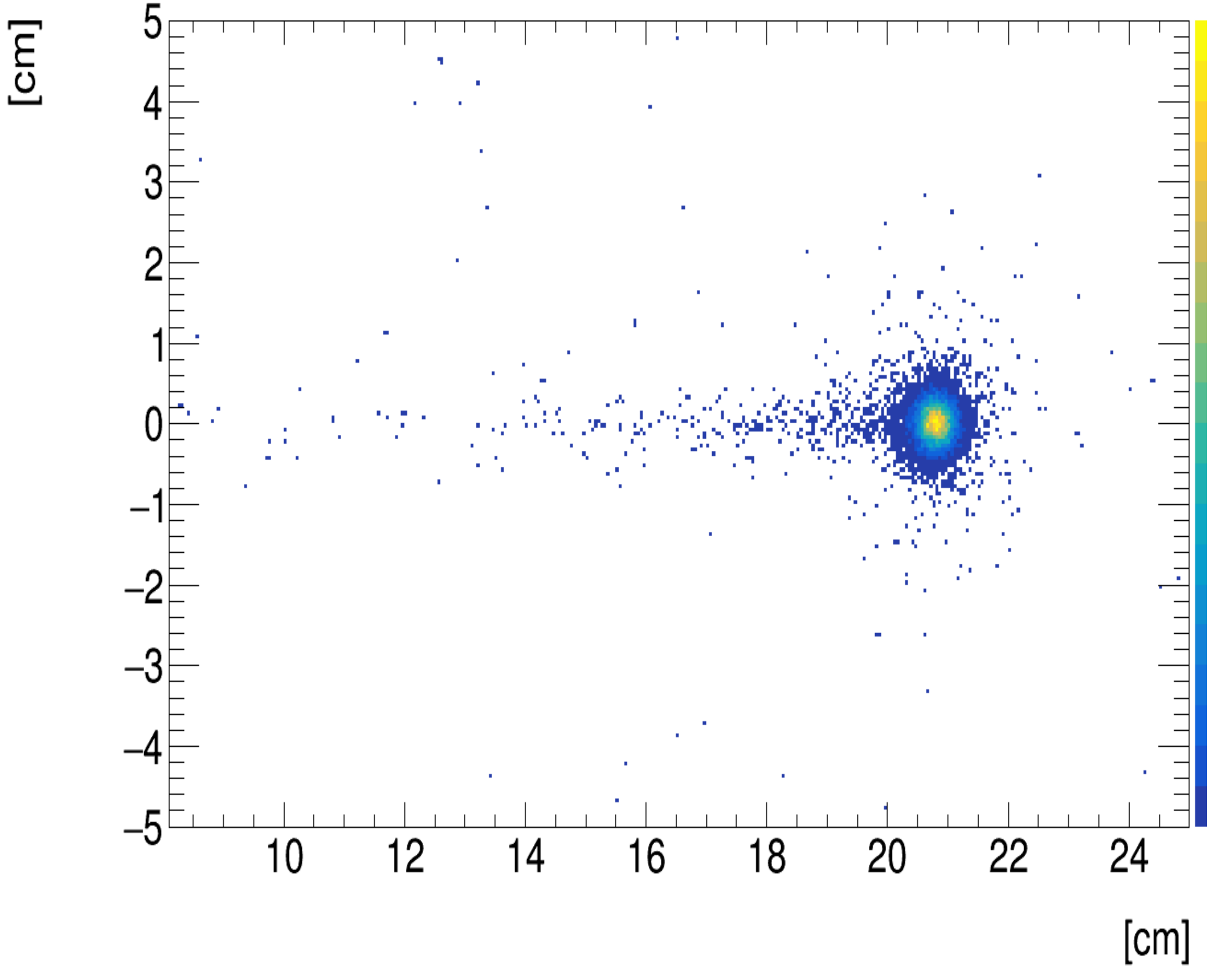
Ptarmigan Full Scattering, JETI40 w0 ~ 12.6, xi = 2.0
IP Scint. Screen, thickness = 500um
'Taped to Beam-window

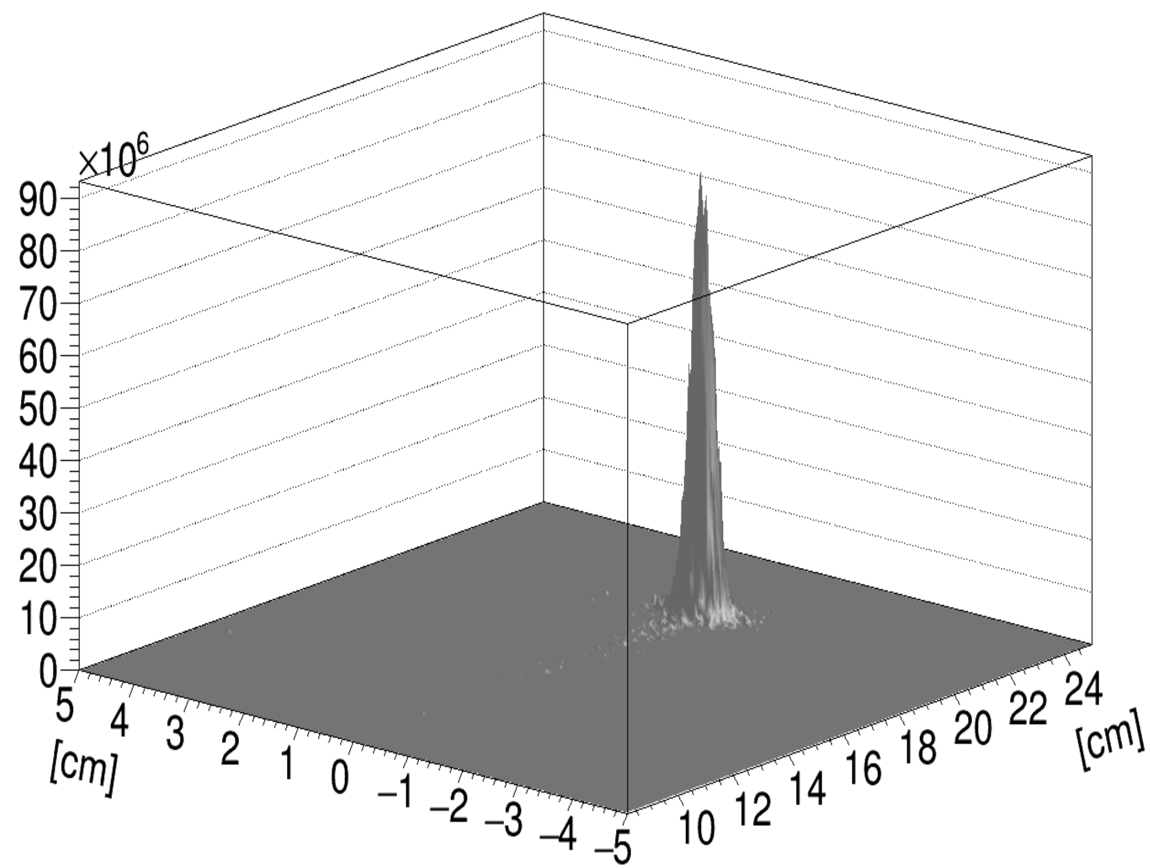
Backup



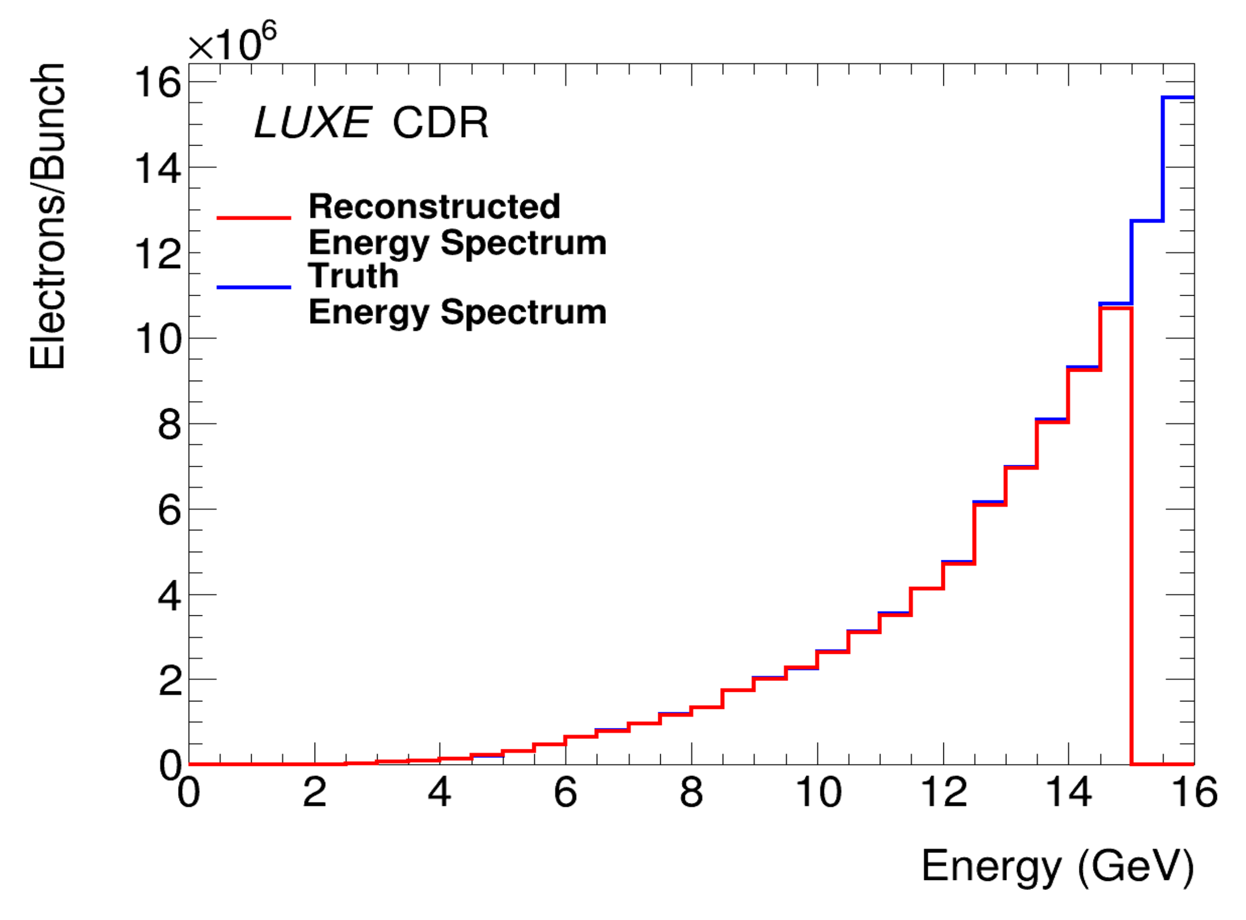


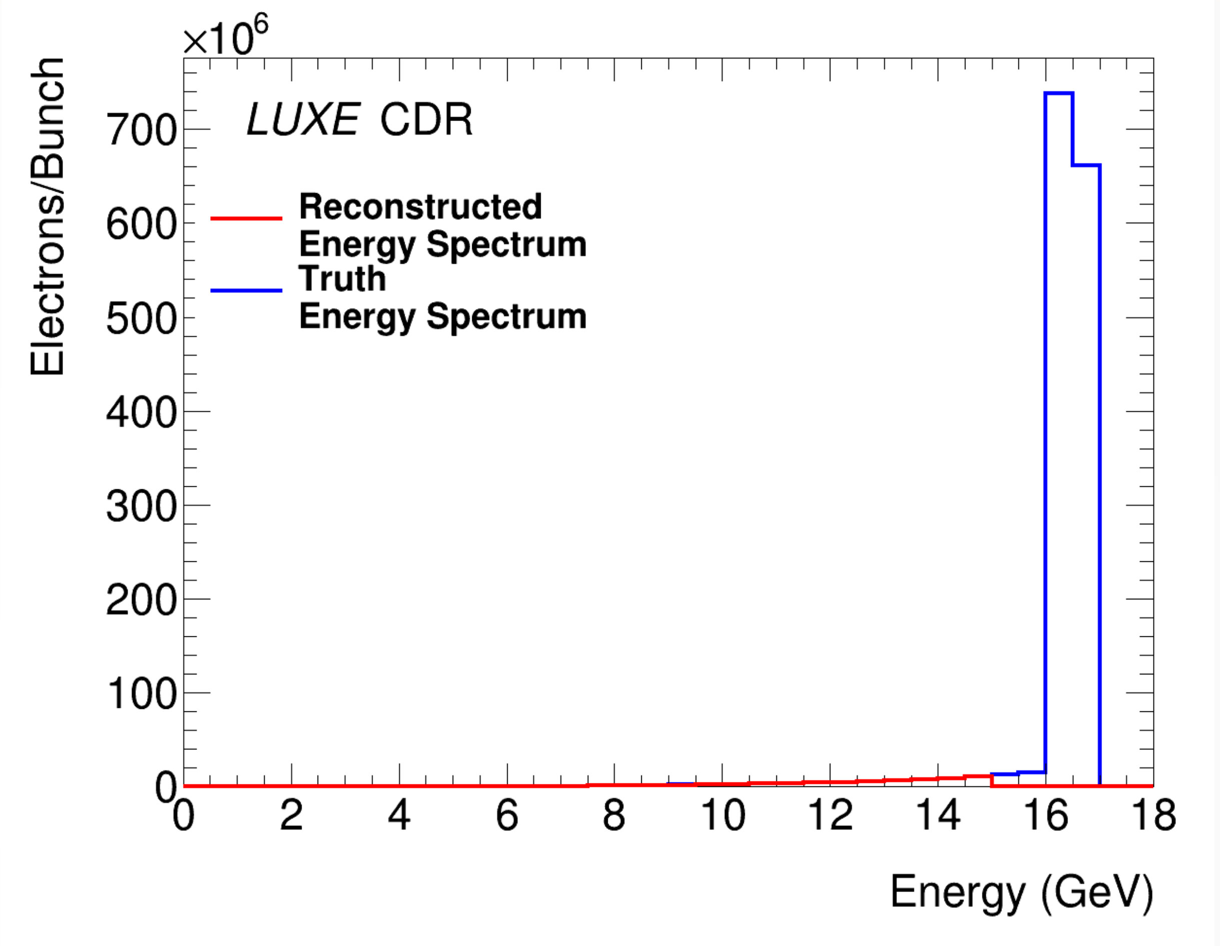
Ptarmigan Full Scattering
IP Scint. Screen, w 0 = 5μm
'Stuck to beam window'





7 GeV 'point source'
'Stuck to beam window'

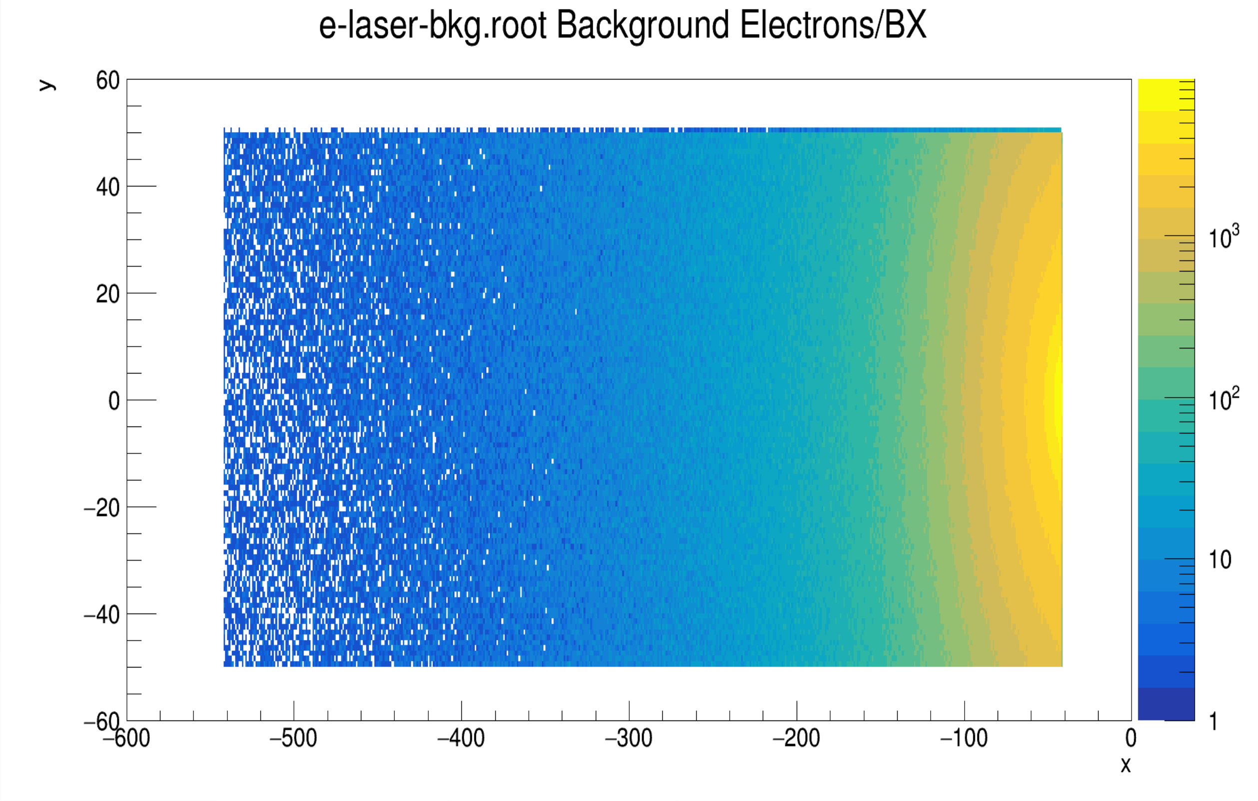




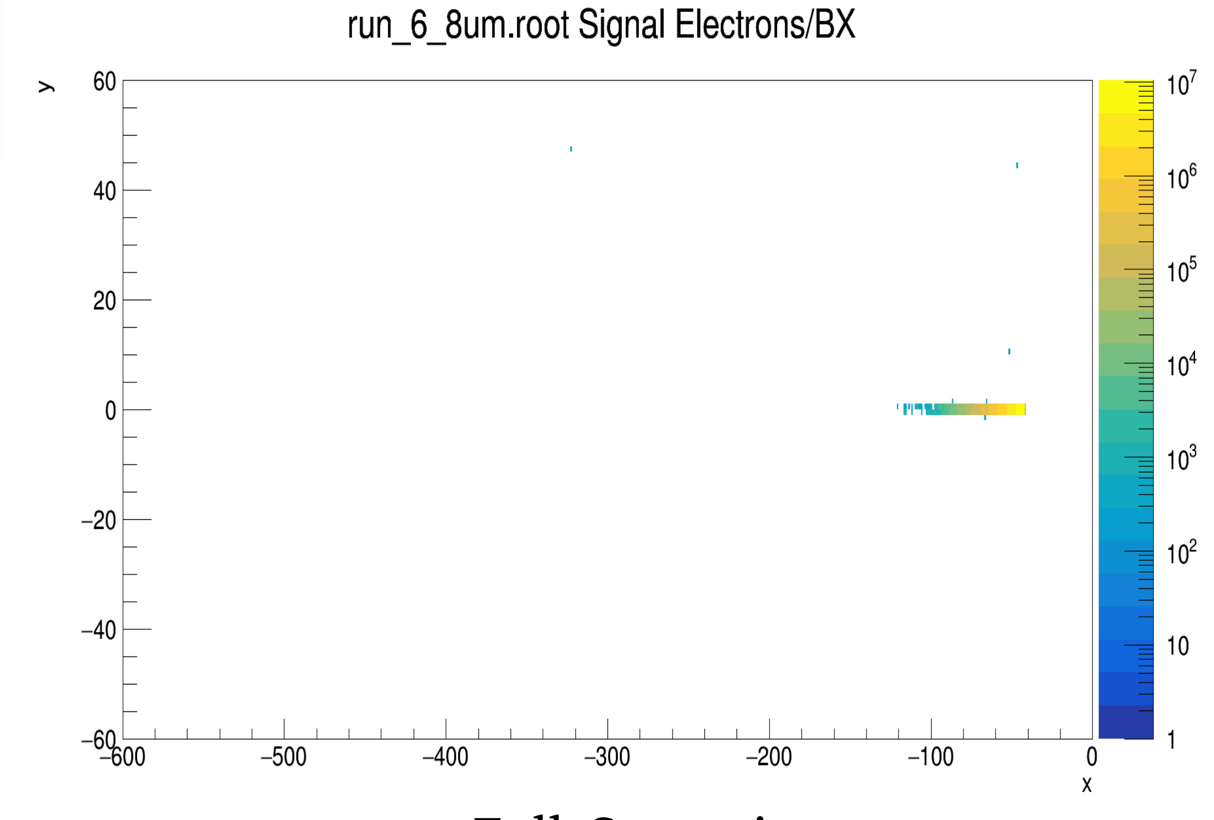
Minimal Scattering from environment
IP Scint. Screen, w_0 = 3µm

Minimal Scattering
IP Scint. Screen, w_0 = 3µm

- energy of 15.5 GeV corresponds to 0.15mm from screen edge, which both in simulation and real life may be fraught. So maybe we round down to 15 GeV



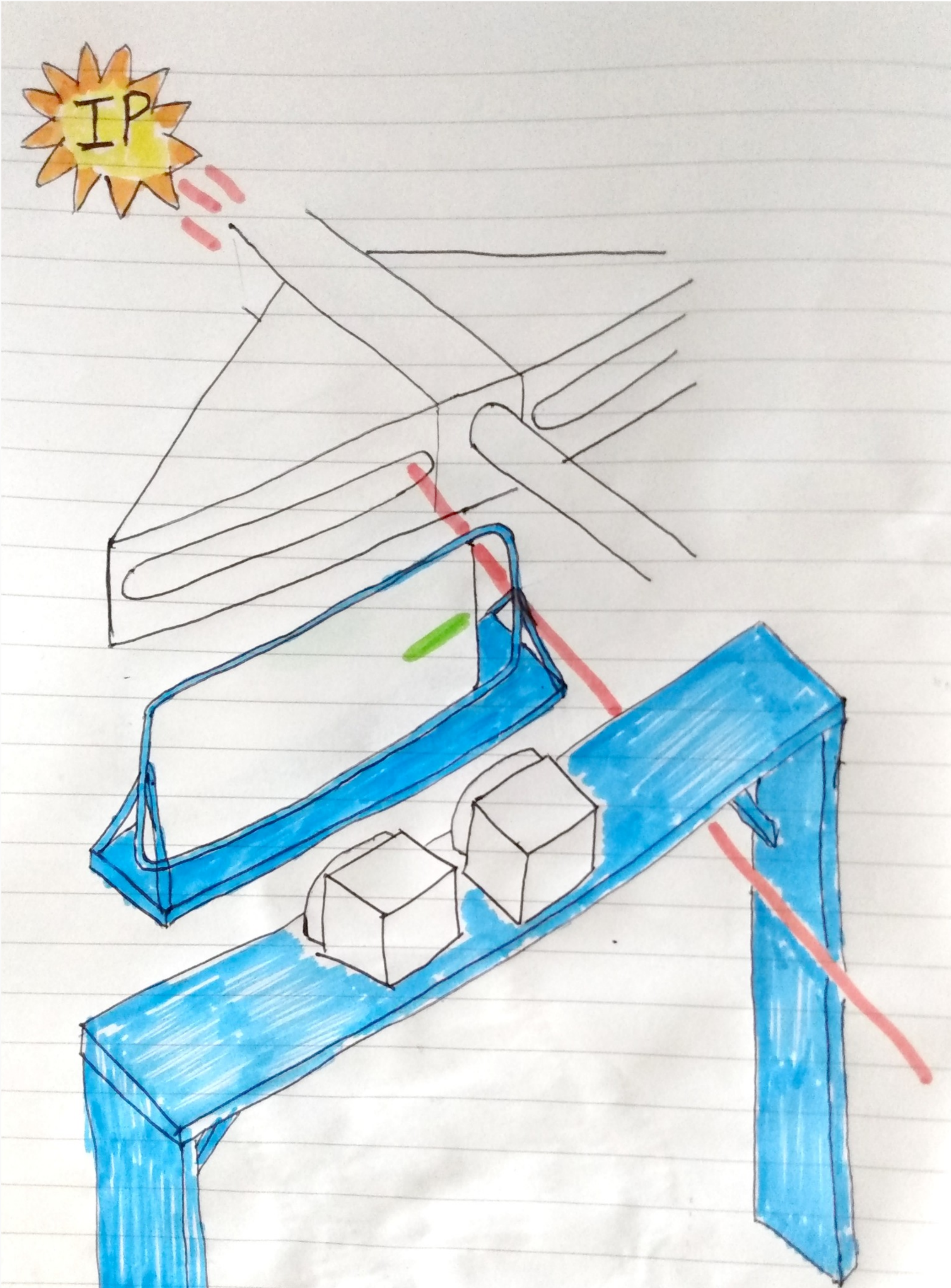
Minimal Scattering from environment
IP Scint. Screen, w_0 = 3µm



Full Scattering
IP Scint. Screen, w_0 = 3µm

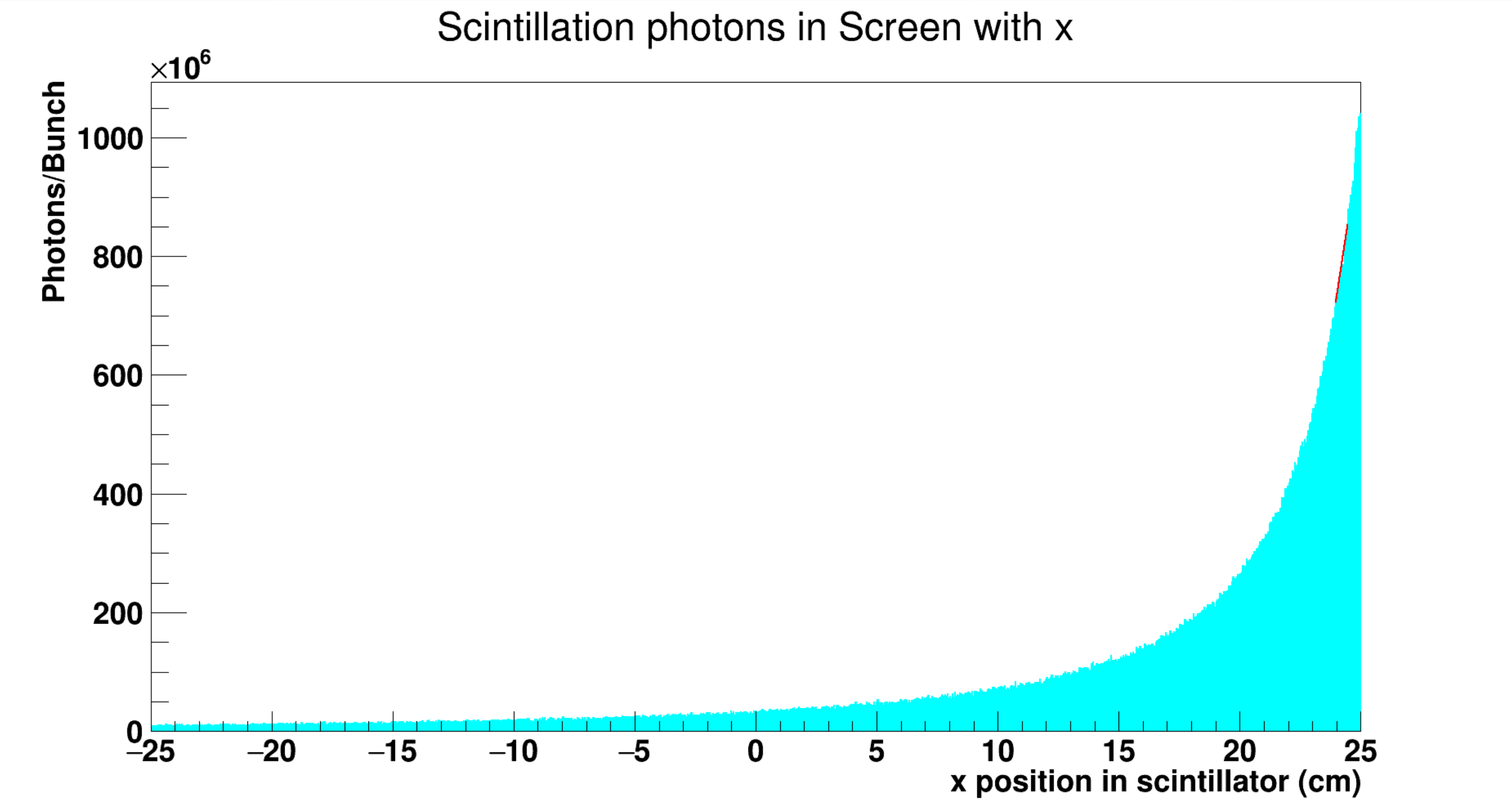
- Tried already a rudimentary background subtraction – taking some integral of some small area above/below central signal band, and subtracting

- Statistics not helping the case with this

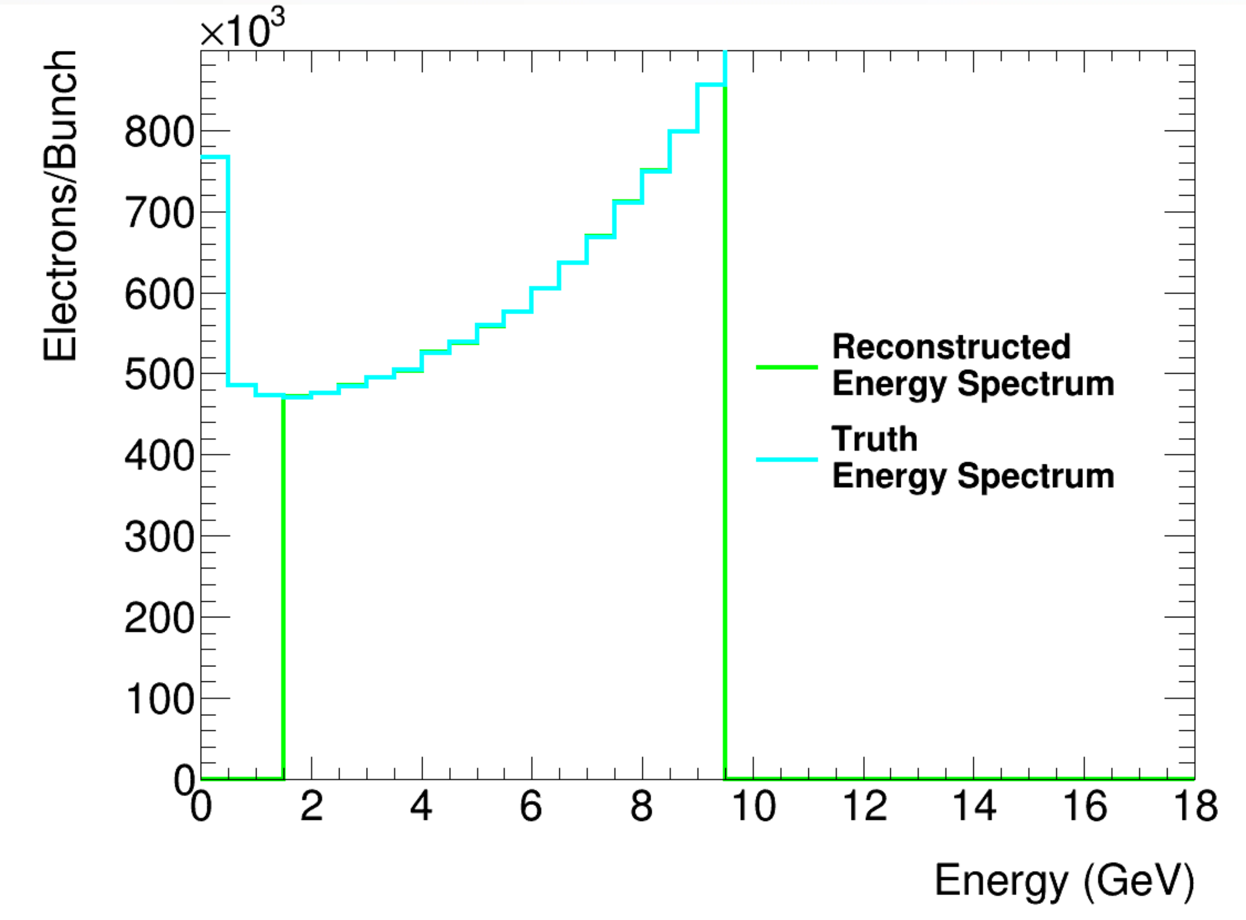


- Will not actually use cameras to collect scint. photon data; to accurately model screen surface optical effects would drastically inflate runtime

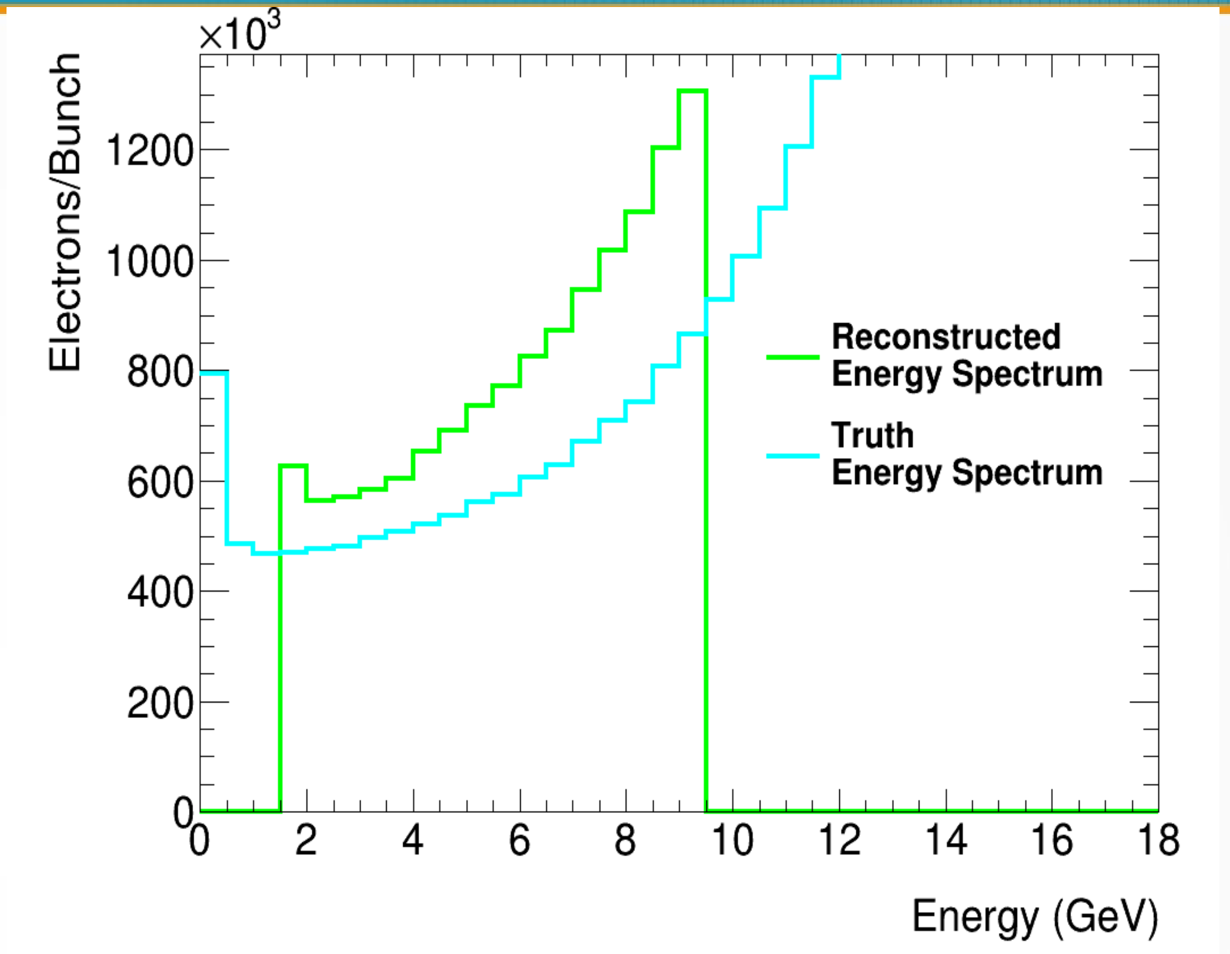
- Instead just use some reasonable figure for (solid angle covered by camera) * (detector efficiency)
And produce e.g. 1/100 number of photons, reducing runtime



Brem. Scint. Screen



Minimal Scattering from environment
Brem Scint. Screen



Full Scattering
Brem. Scint. Screen

File Edit View Search Terminal Help

```
Energy interval 1.5 GeV to 2 GeV
X coord interval -9.44744 cm to 0.29804 cm

Energy interval 2 GeV to 2.5 GeV
X coord interval 0.29804 cm to 6.04324 cm

Energy interval 2.5 GeV to 3 GeV
X coord interval 6.04324 cm to 9.84073 cm

Energy interval 3 GeV to 3.5 GeV
X coord interval 9.84073 cm to 12.5402 cm

Energy interval 3.5 GeV to 4 GeV
X coord interval 12.5402 cm to 14.5587 cm

Energy interval 4 GeV to 4.5 GeV
X coord interval 14.5587 cm to 16.1256 cm

Energy interval 4.5 GeV to 5 GeV
X coord interval 16.1256 cm to 17.3774 cm

Energy interval 5 GeV to 5.5 GeV
X coord interval 17.3774 cm to 18.4005 cm

Energy interval 5.5 GeV to 6 GeV
X coord interval 18.4005 cm to 19.2525 cm

Energy interval 6 GeV to 6.5 GeV
X coord interval 19.2525 cm to 19.973 cm

Energy interval 6.5 GeV to 7 GeV
X coord interval 19.973 cm to 20.5903 cm

Energy interval 7 GeV to 7.5 GeV
X coord interval 20.5903 cm to 21.1251 cm

Energy interval 7.5 GeV to 8 GeV
X coord interval 21.1251 cm to 21.5929 cm

Energy interval 8 GeV to 8.5 GeV
X coord interval 21.5929 cm to 22.0055 cm

Energy interval 8.5 GeV to 9 GeV
X coord interval 22.0055 cm to 22.3723 cm
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File Edit View Search Terminal Help

```
Energy interval 9 GeV to 9.5 GeV
X coord interval 22.3723 cm to 22.7003 cm

Energy interval 9.5 GeV to 10 GeV
X coord interval 22.7003 cm to 22.9956 cm

Energy interval 10 GeV to 10.5 GeV
X coord interval 22.9956 cm to 23.2627 cm

Energy interval 10.5 GeV to 11 GeV
X coord interval 23.2627 cm to 23.5054 cm

Energy interval 11 GeV to 11.5 GeV
X coord interval 23.5054 cm to 23.7271 cm

Energy interval 11.5 GeV to 12 GeV
X coord interval 23.7271 cm to 23.9302 cm

Energy interval 12 GeV to 12.5 GeV
X coord interval 23.9302 cm to 24.1171 cm

Energy interval 12.5 GeV to 13 GeV
X coord interval 24.1171 cm to 24.2896 cm

Energy interval 13 GeV to 13.5 GeV
X coord interval 24.2896 cm to 24.4493 cm

Energy interval 13.5 GeV to 14 GeV
X coord interval 24.4493 cm to 24.5976 cm

Energy interval 14 GeV to 14.5 GeV
X coord interval 24.5976 cm to 24.7357 cm

Energy interval 14.5 GeV to 15 GeV
X coord interval 24.7357 cm to 24.8646 cm

Energy interval 15 GeV to 15.5 GeV
X coord interval 24.8646 cm to 24.9851 cm

Info in <TCanvas::SaveSource>: C++ Macro file: EDS-recon-scintCerenkov_3um-compton.
C has been generated
Info in <TCanvas::Print>: file EDS-recon-scintCerenkov_3um-compton.png has been cre
ated
root [2]
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