Full-Function-Fit of Reconstructed Electron Spectra

John Hallford

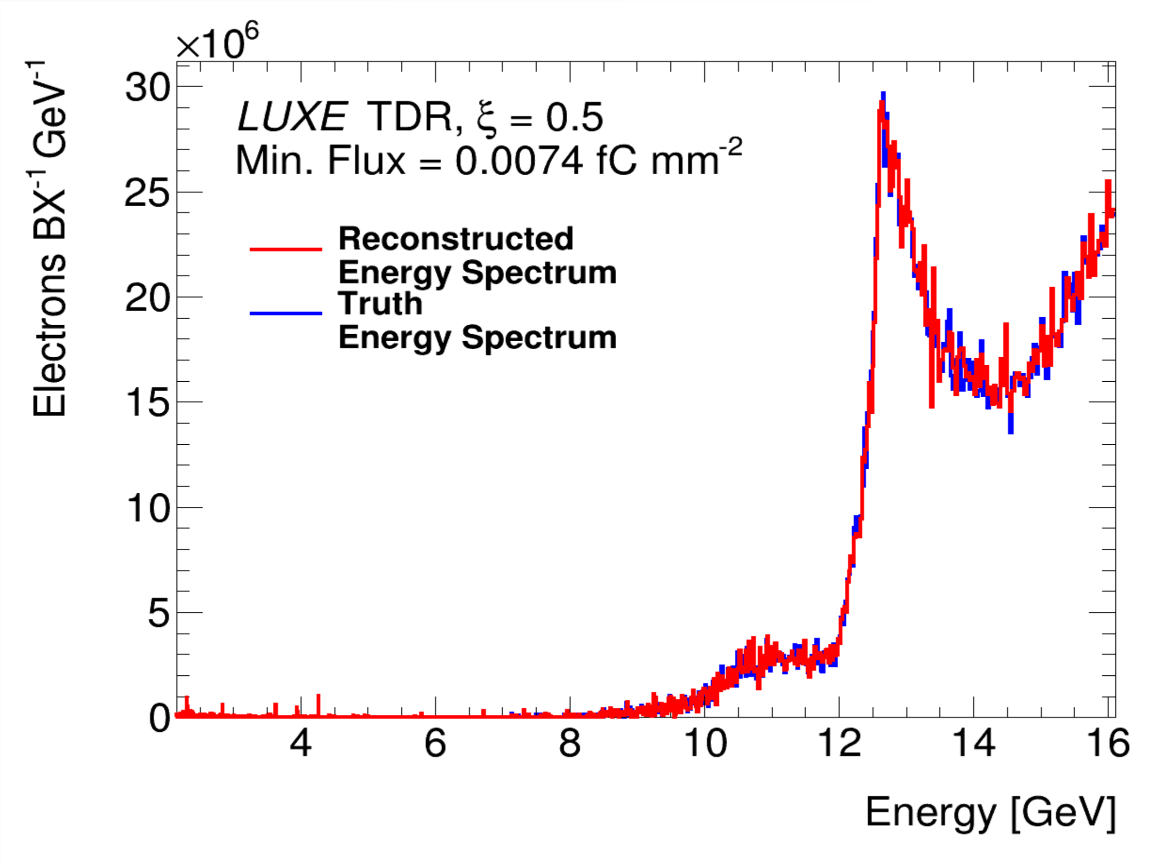
University College London

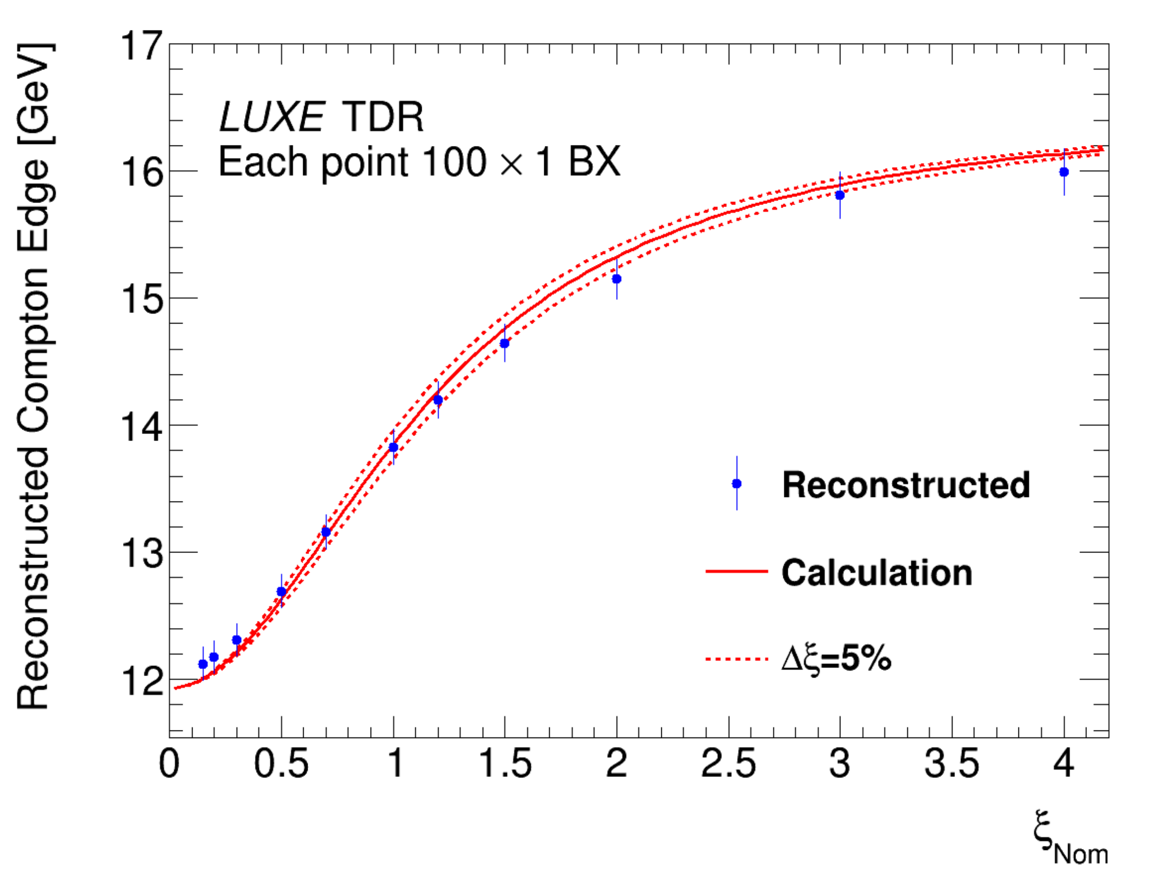
16/03/2023

Previously we have made reconstructions of EDS electron spectra with the scintillator screen & camera setector simulation pipeline:

SFQED Monte Carlo → Scint. System Detector Geant4 Simulation → Reconstruction of e^- energy

These have been compared to 'truth', and also the Compton edge feature analysed & compared to theoretical expectation





It would also be nice to make a fit of the full spectrum, and see if we can extract a ξ value. Means working with some very involved functions:

$$\Gamma_{\mathrm{HICS}} = -\frac{\alpha m^2}{\epsilon_{\mathrm{i}}} \sum_{n=1}^{\infty} \int_0^{u_n} \frac{du}{(1+u)^2} \left[\mathrm{J}_n^2(z_u) - \frac{\xi^2}{4} \frac{1+(1+u)^2}{1+u} \left(\mathrm{J}_{n+1}^2 + \mathrm{J}_{n\text{-}1}^2 - 2\,\mathrm{J}_n^2 \right) \right]$$

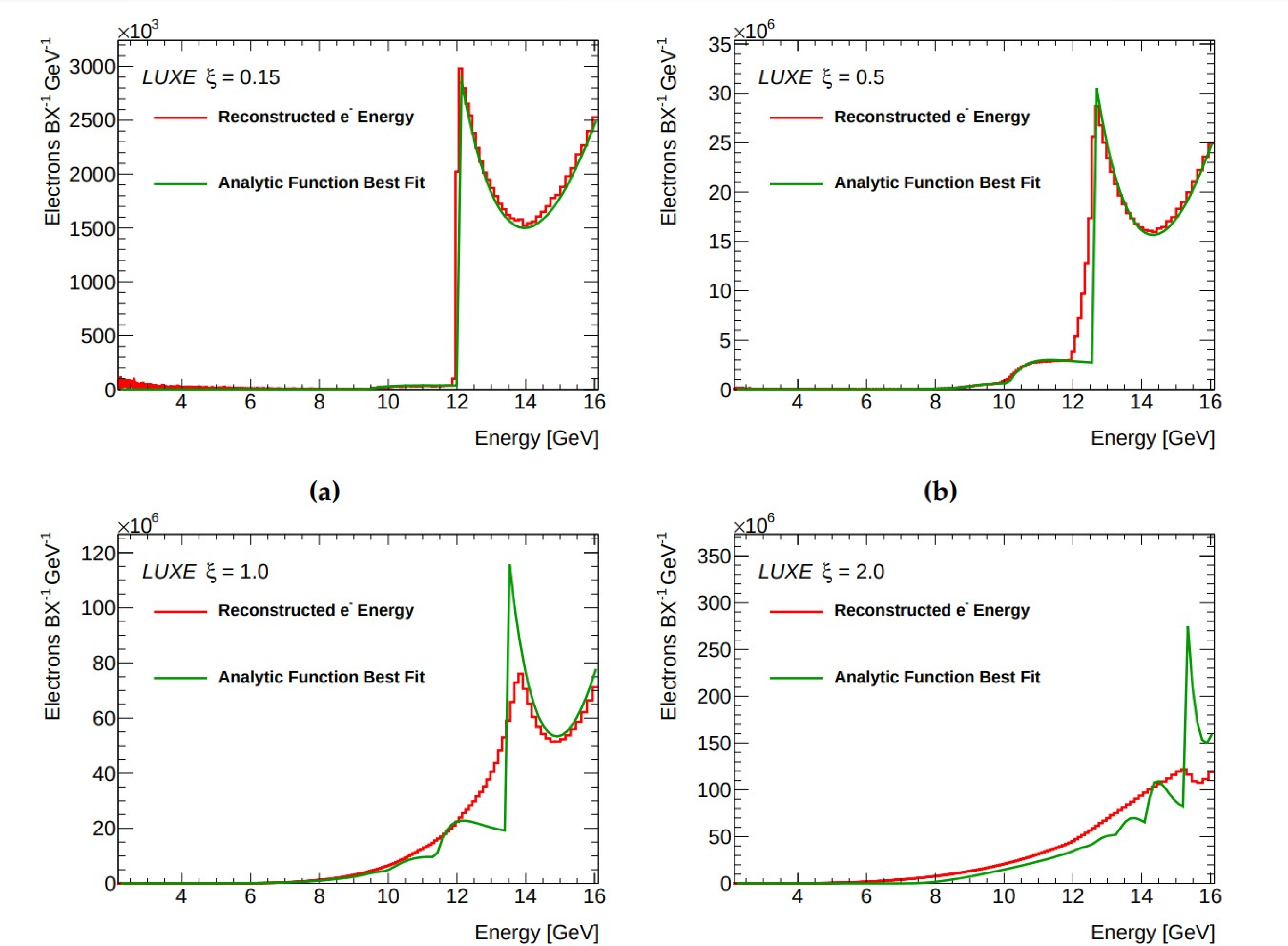
$$z_{\mathrm{u}} \equiv \frac{m^2 \xi \sqrt{1+\xi^2}}{k \cdot p_i} [u(u_n - u)]^{1/2}, \quad u_n \equiv \frac{2(k.p_i)\,n}{m^2(1+\xi^2)}, \quad \xi \equiv \frac{e|A|}{m}$$

With good knowledge of physical constants, incident electron & laser photon momenta, only two parameters are really needed: an overall scaling parameter, and the ξ parameter. Here I try to make the fit and extract the ξ parameter for a range of ξ_sim, the peak ξ in the initial MC simulation

The function is only usable for constant ξ and electron energy

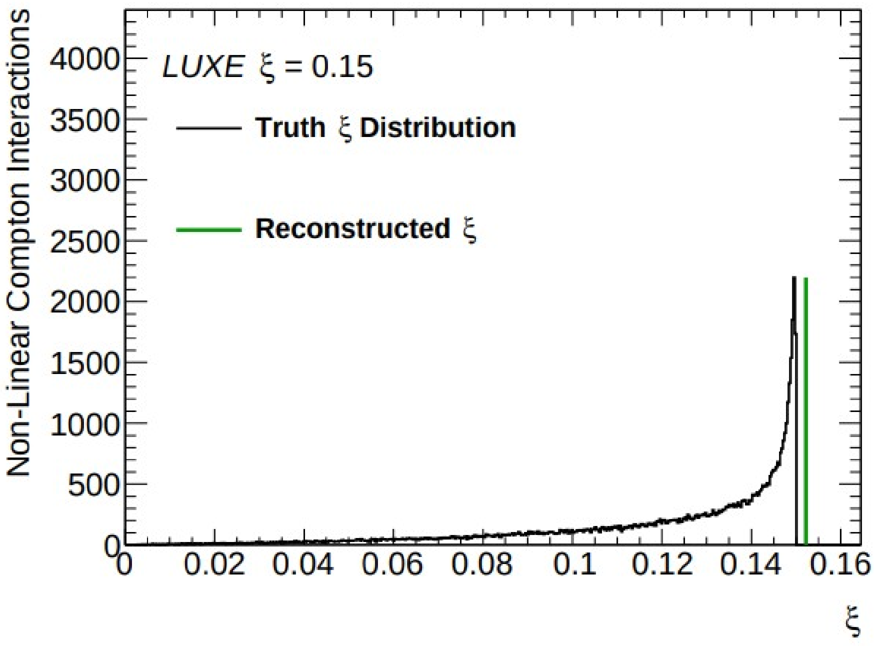
The final electron distribution can then be highly distorted for non-uniform ξ, or multiple-emission-electrons, both seen in the high-ξ_sim case

More details: C. Harvey, T. Heinzl, and A. Ilderton, Phys. Rev. A79, 063407 (2009), 0903.4151.

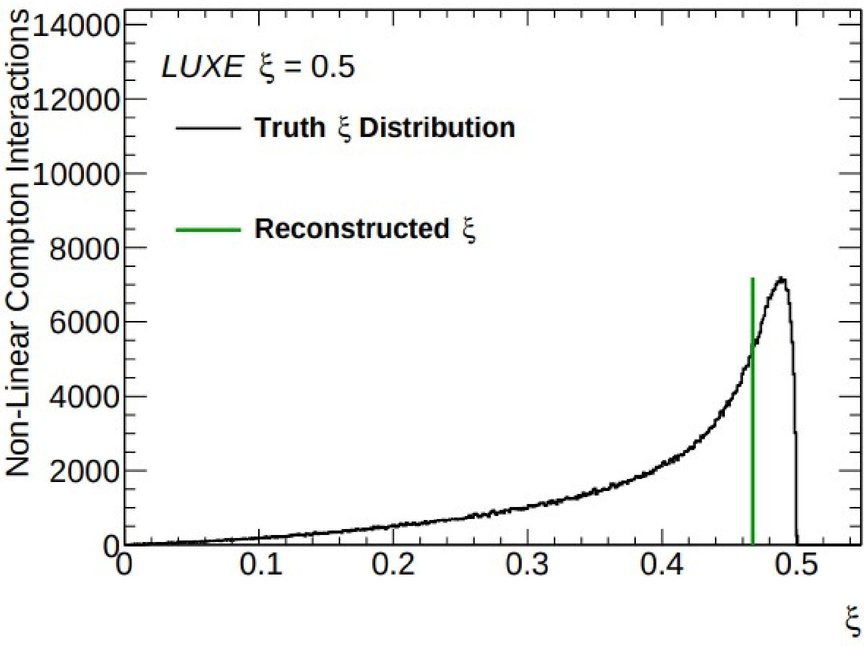


So far fits are only convergent for ξ = 0.15, 0.2; the very lowest ξ values for phase-0 (convergence is seen up to 0.7 for phase-I simulations).

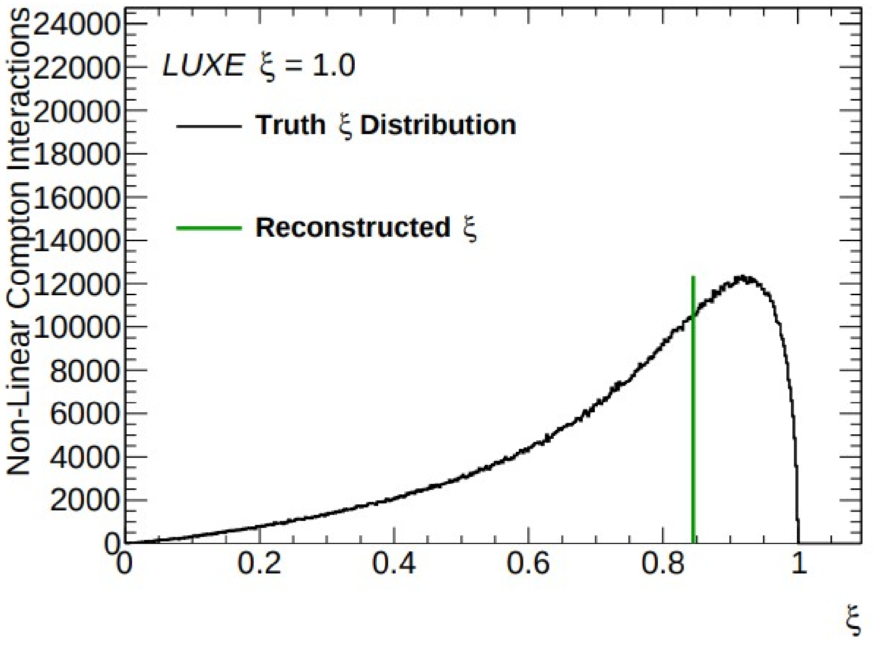
For greater peak ξ, the two previously described spectrum-smearing mechanisms dominate

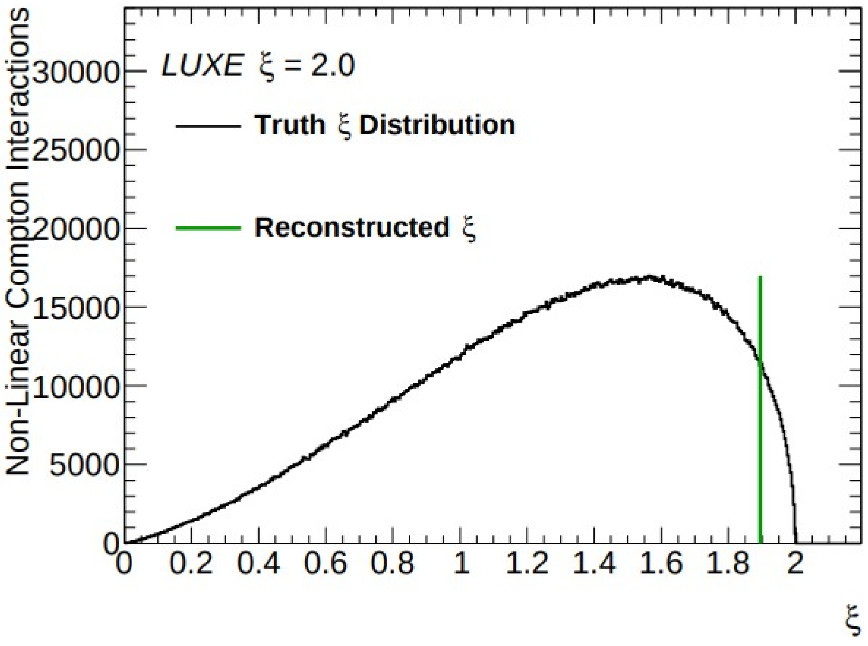


(a)

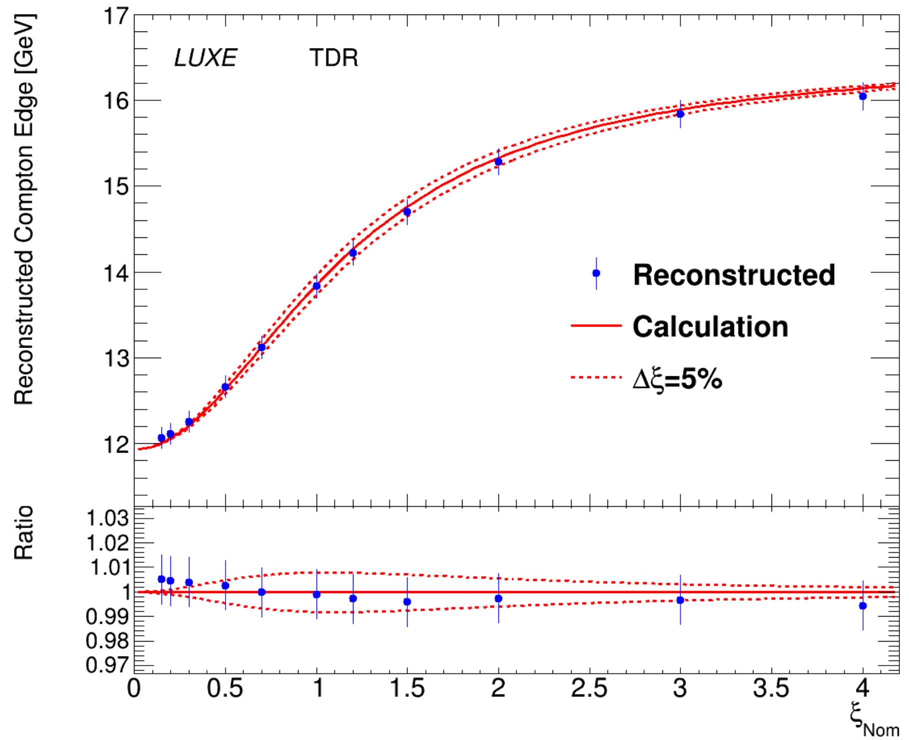


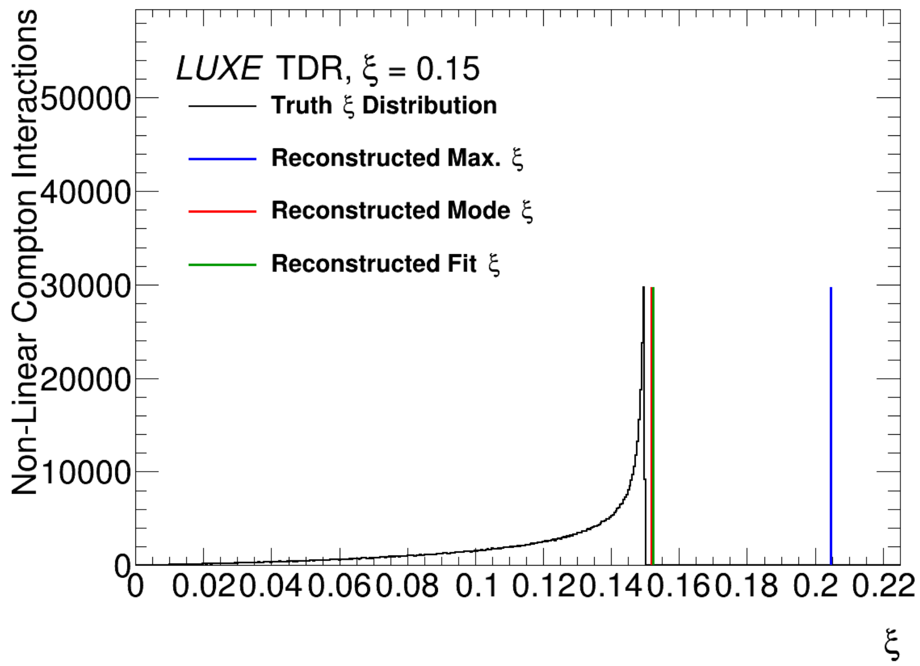
(b)

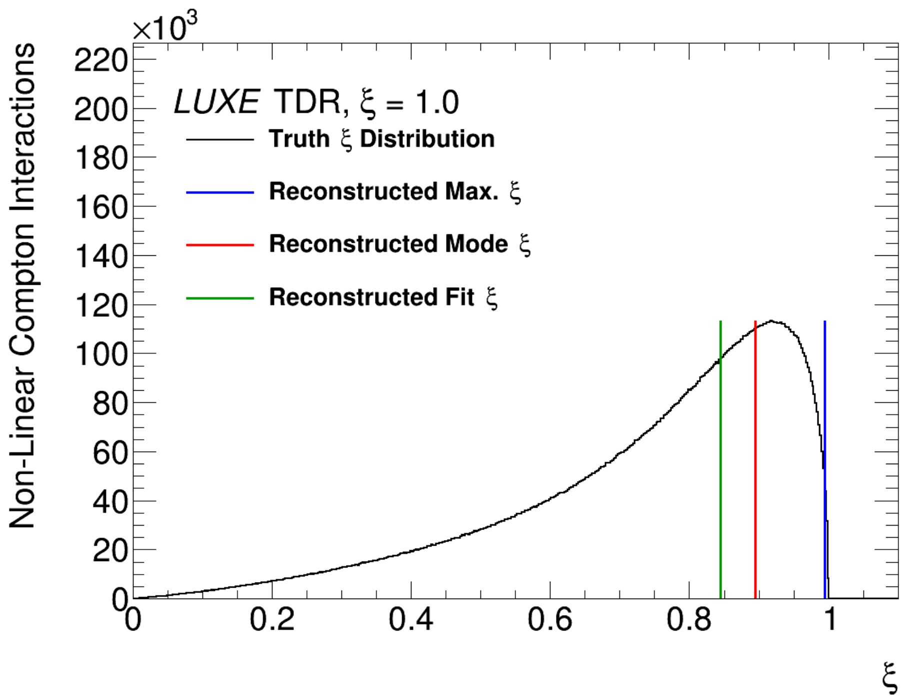


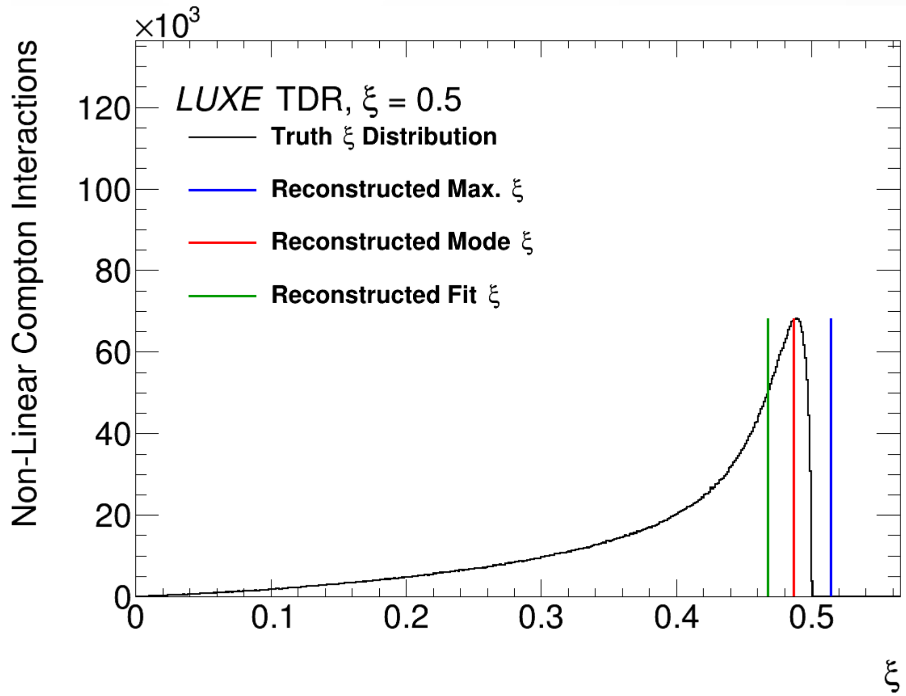


Regardless of a convergent fit, the final ξ parameter is generally smaller than the ξ_max









Regardless of a convergent fit, the final ξ parameter is generally smaller than the ξ_max

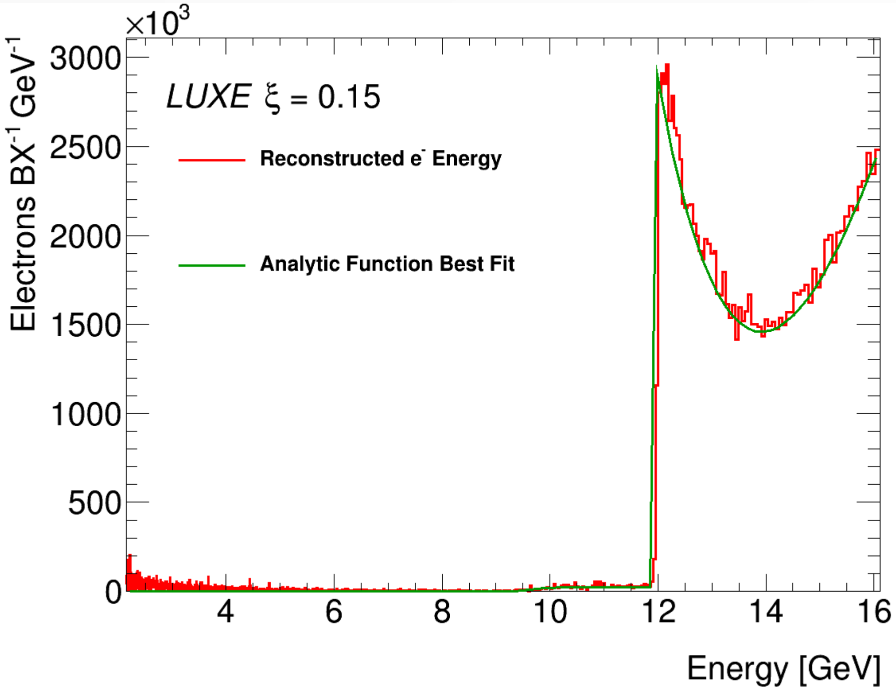
Analysis of the Compton edge is poor at high ξ (smearing) or low ξ;

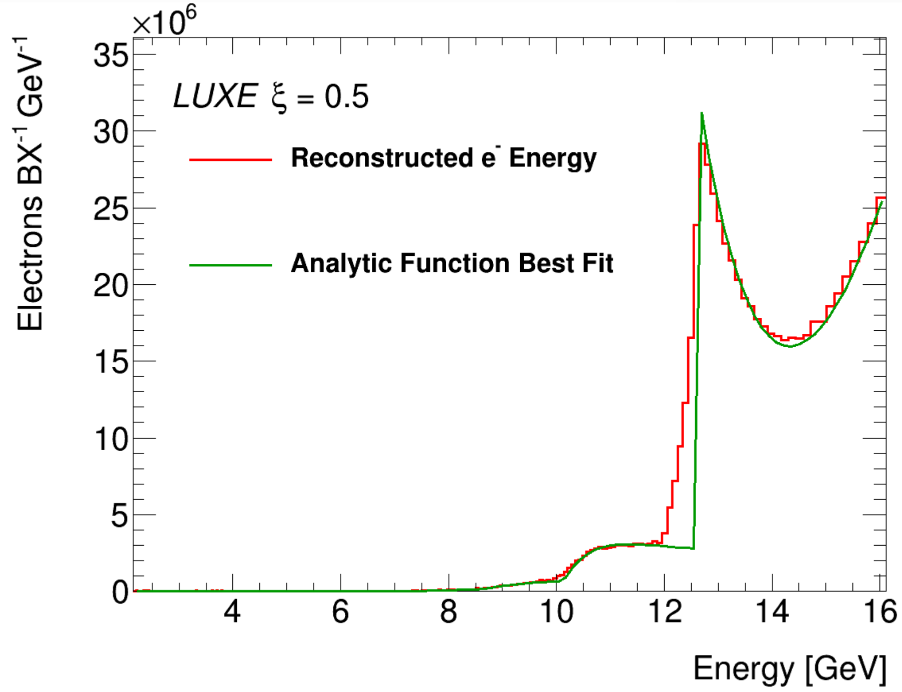
Blue line is peak of Compton edge → ξ

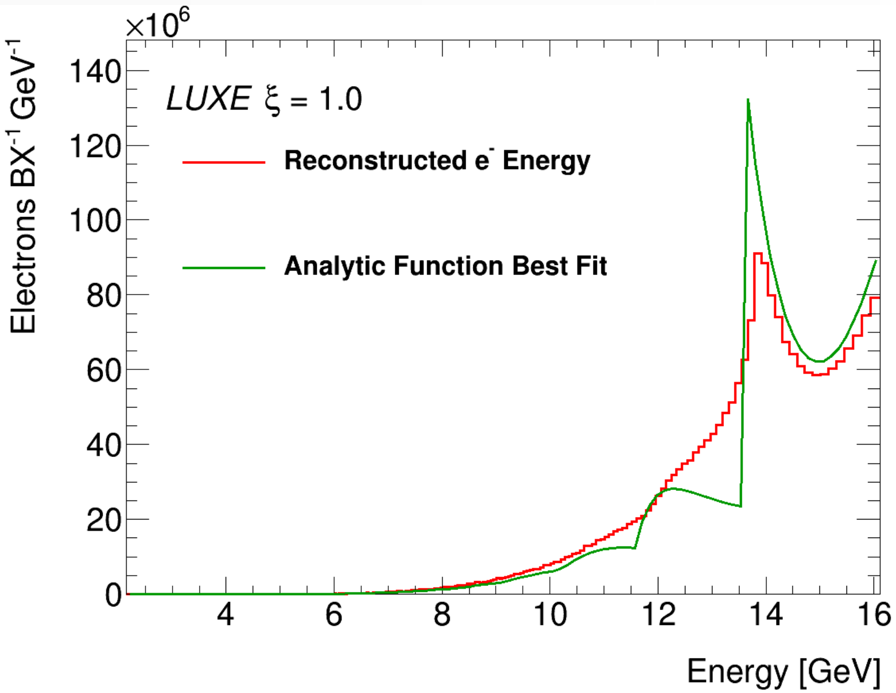
Red line is steepest point of edge → ξ

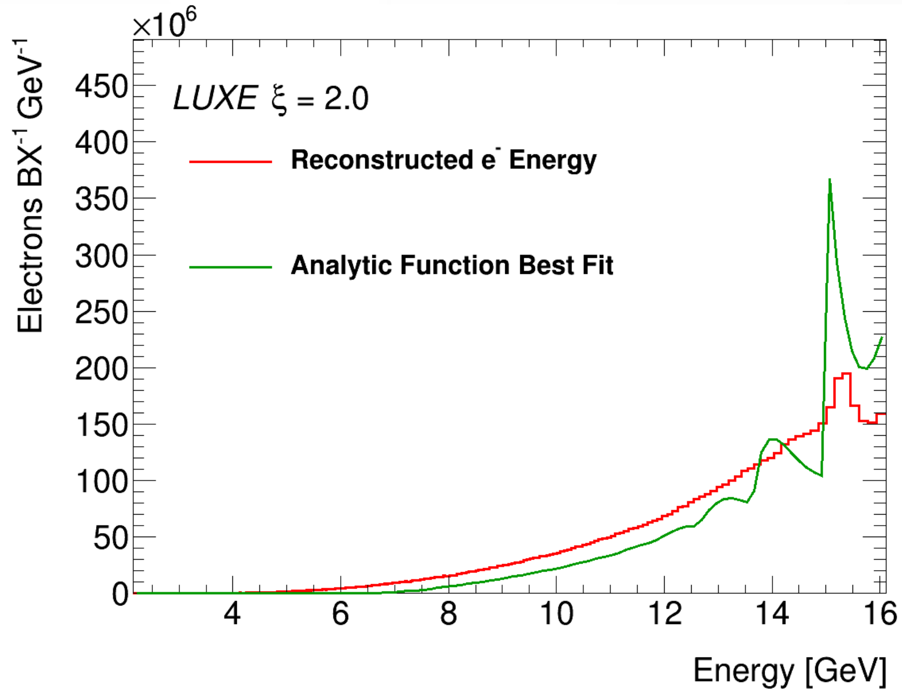
Green line is full-function-fit ξ param.

backup



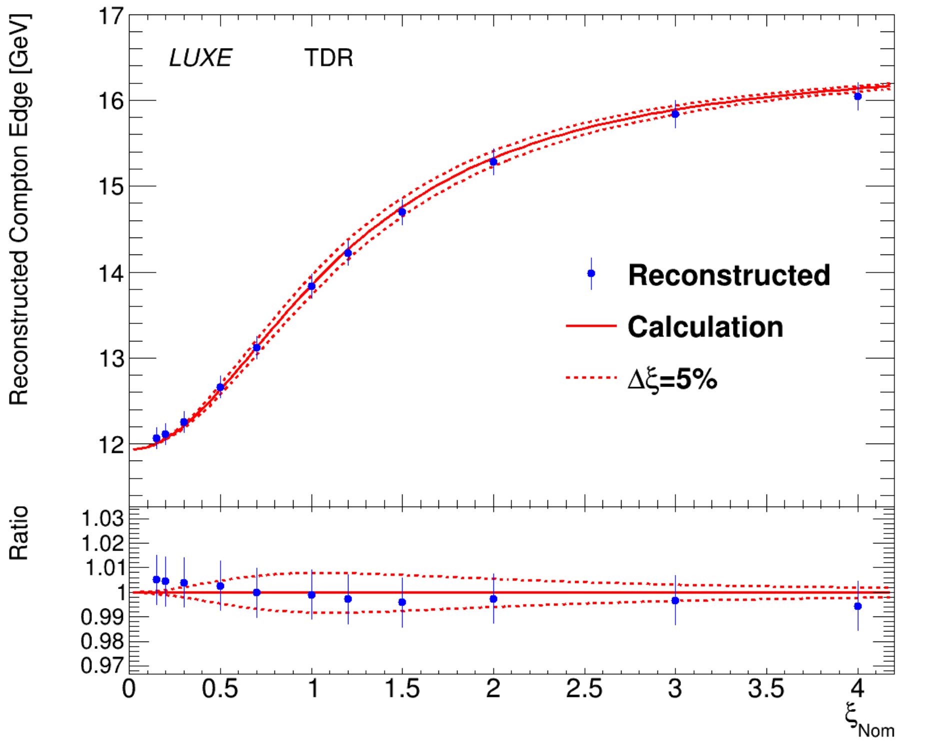


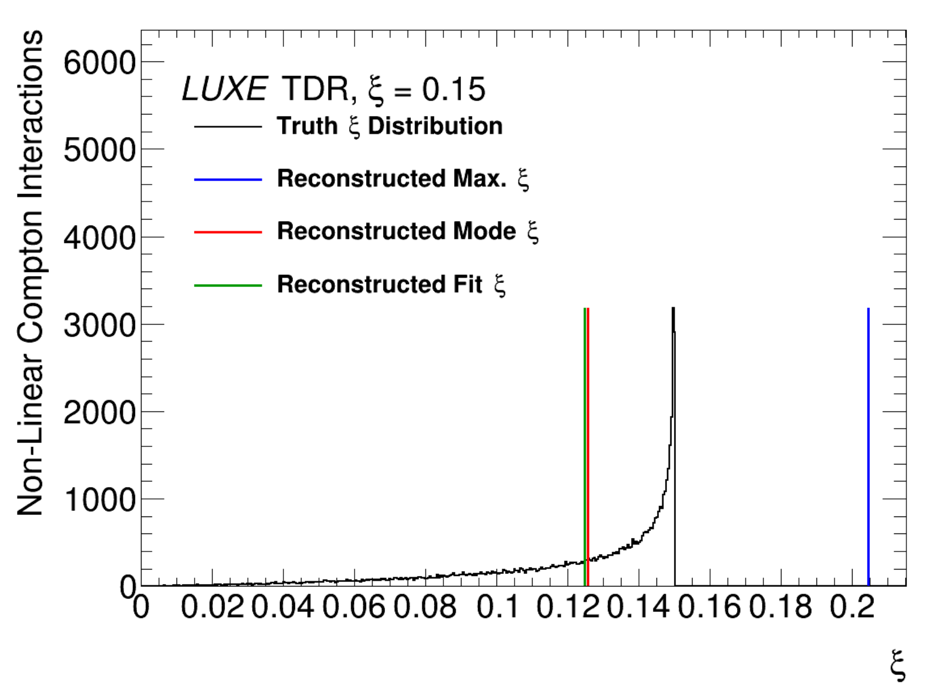


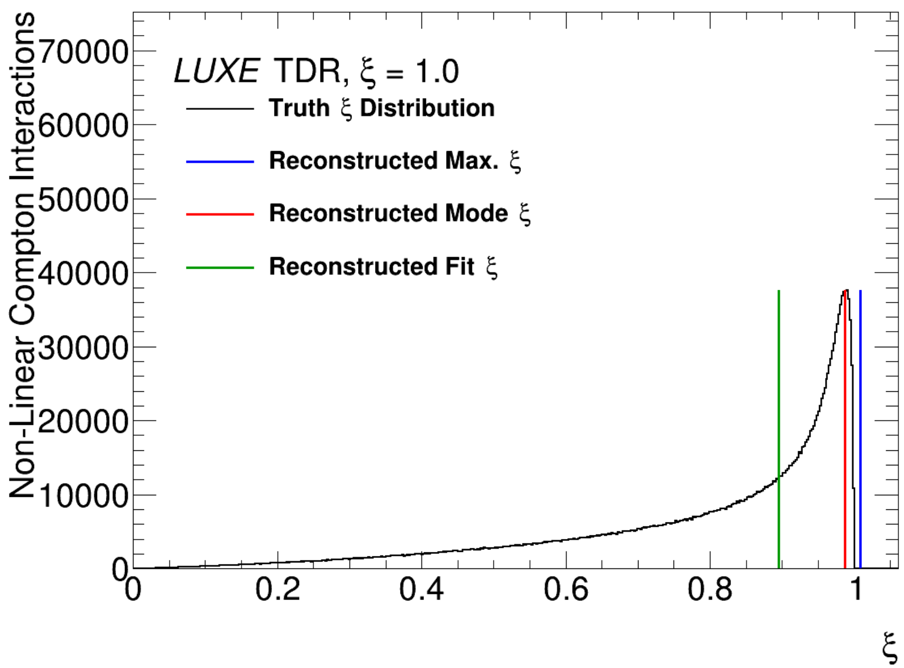


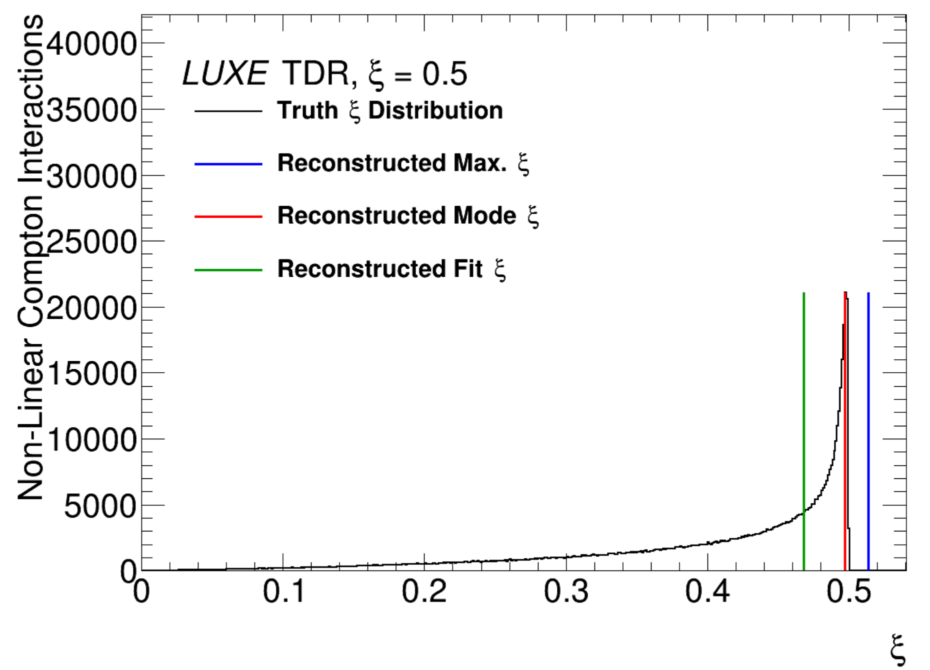
Phase-I laser simulations

‘Convergence’ from ROOTfit up to ξ_max = 0.7









Phase-I simulations

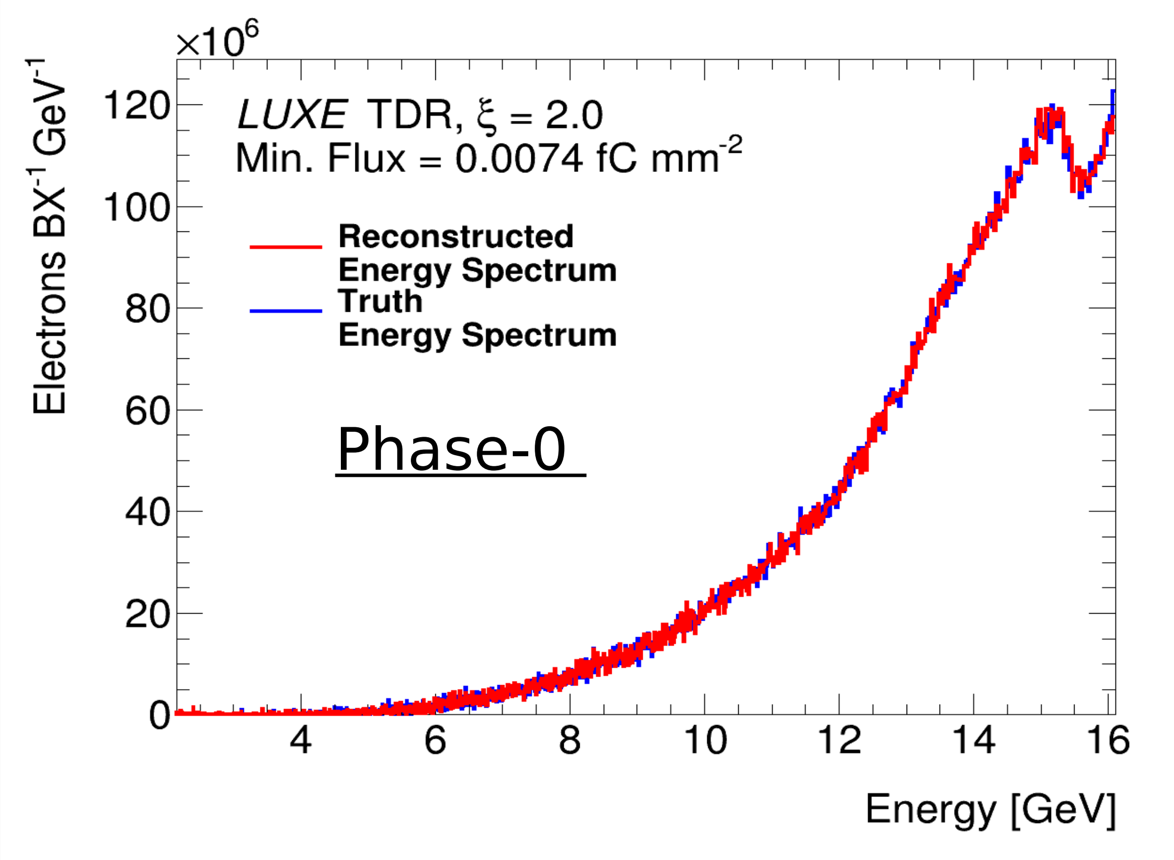
Blue line is peak of Compton edge → ξ

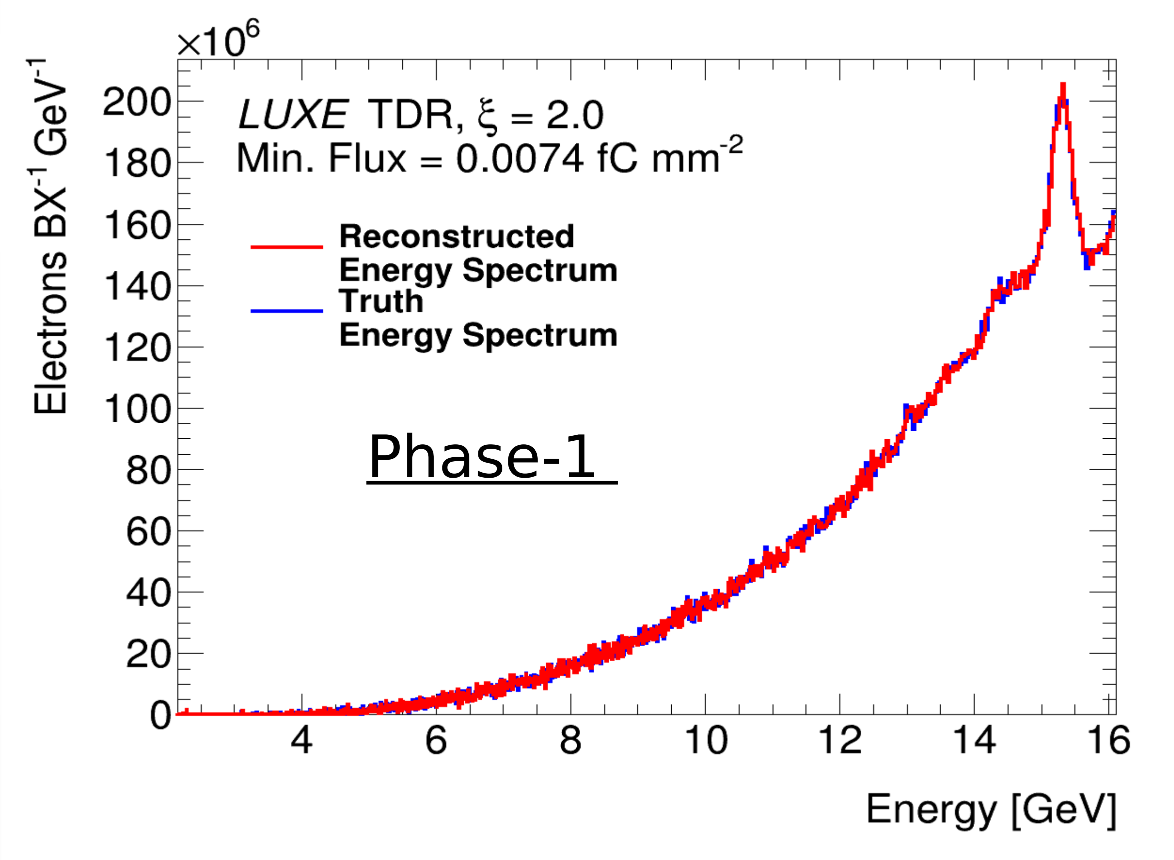
Red line is steepest point of edge → ξ

Green line is full-function-fit ξ param.

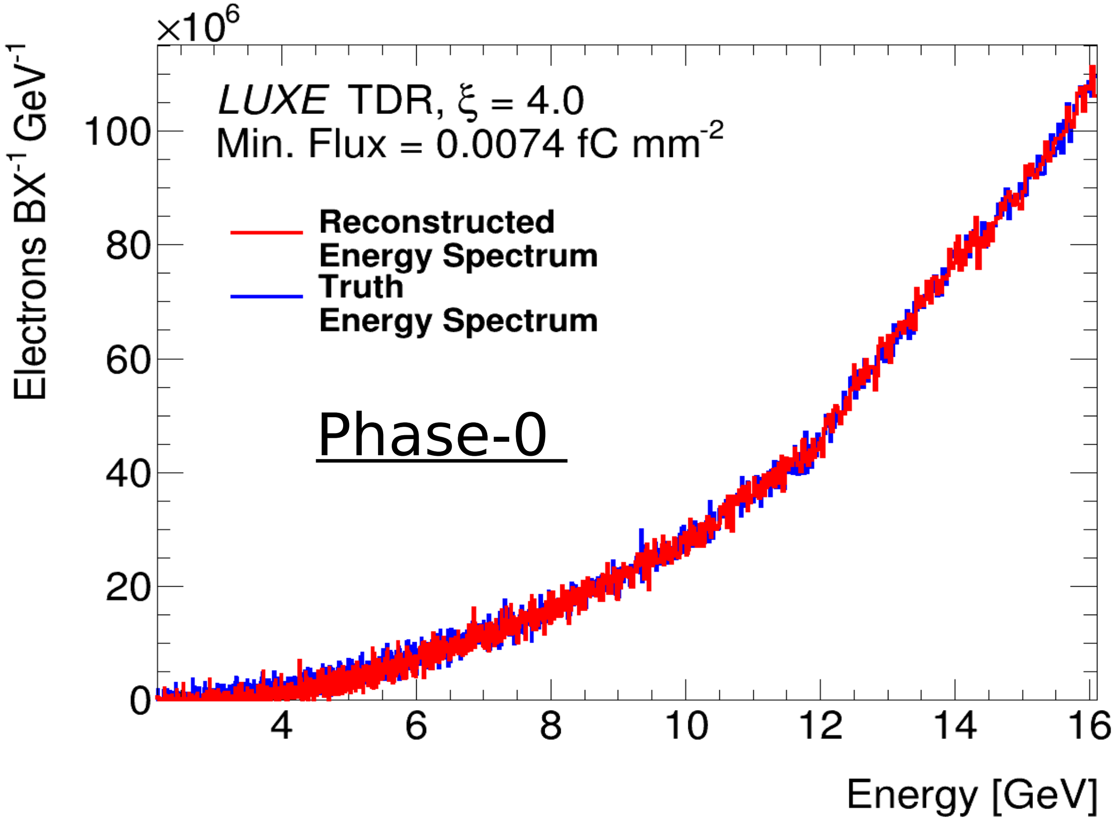
First is the comparison of electron spectra to the phase-0 data:

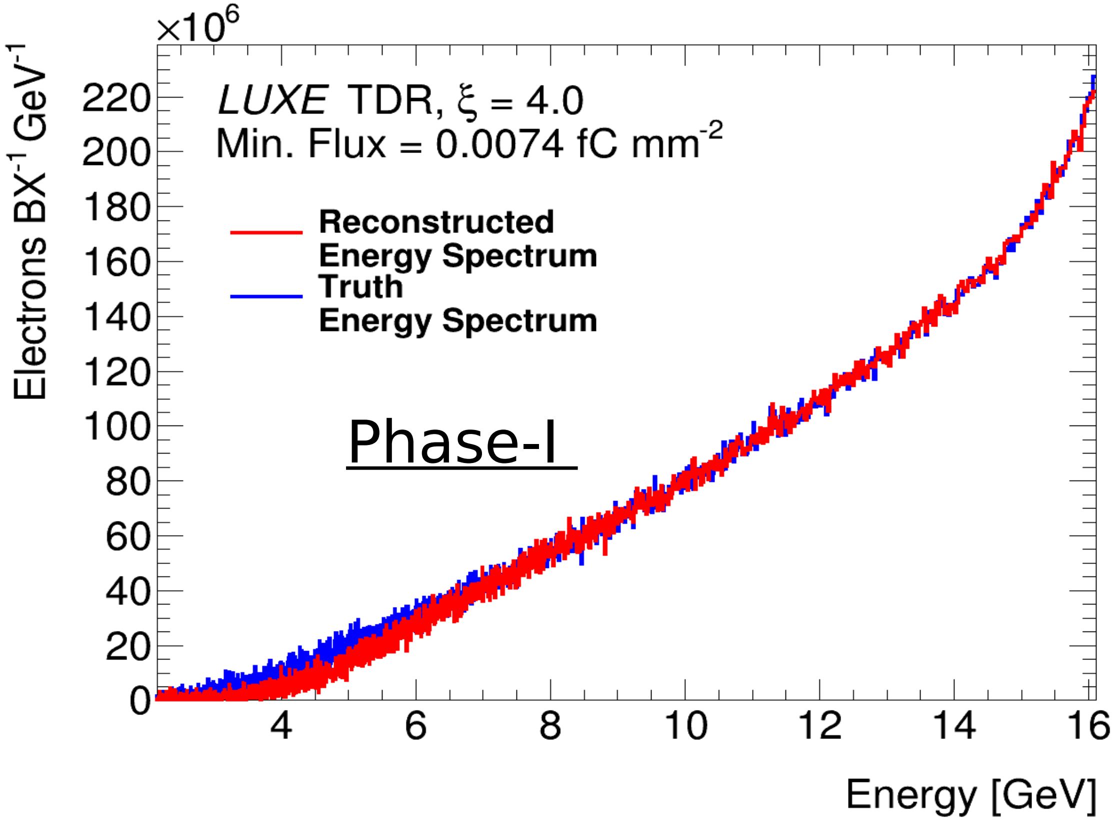
At higher ξ there is now more scattering occuring, and the spectra are less washed-out, so the Compton edge is more obvious.





The increase in total scattering rate is larger for higher ξ. Both the energy-differential-probability function changing with ξ, and the increased likelihood of one electron radiating multiple times, means the spectra pushes further into the low-energy region.





At lower ξ, results look very similar. But we are now using a pulse with 8x the energy, I would expect the electrons to travel through at least factor 2x longer in the IP laser spot, so give at least 2x more electrons. But the (BX normalised)

Maybe this is not how the focussing works in the longitudinal direction?