LUXE Cerenkovs: Energy Resolution Requirement

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LUXE technical meeting

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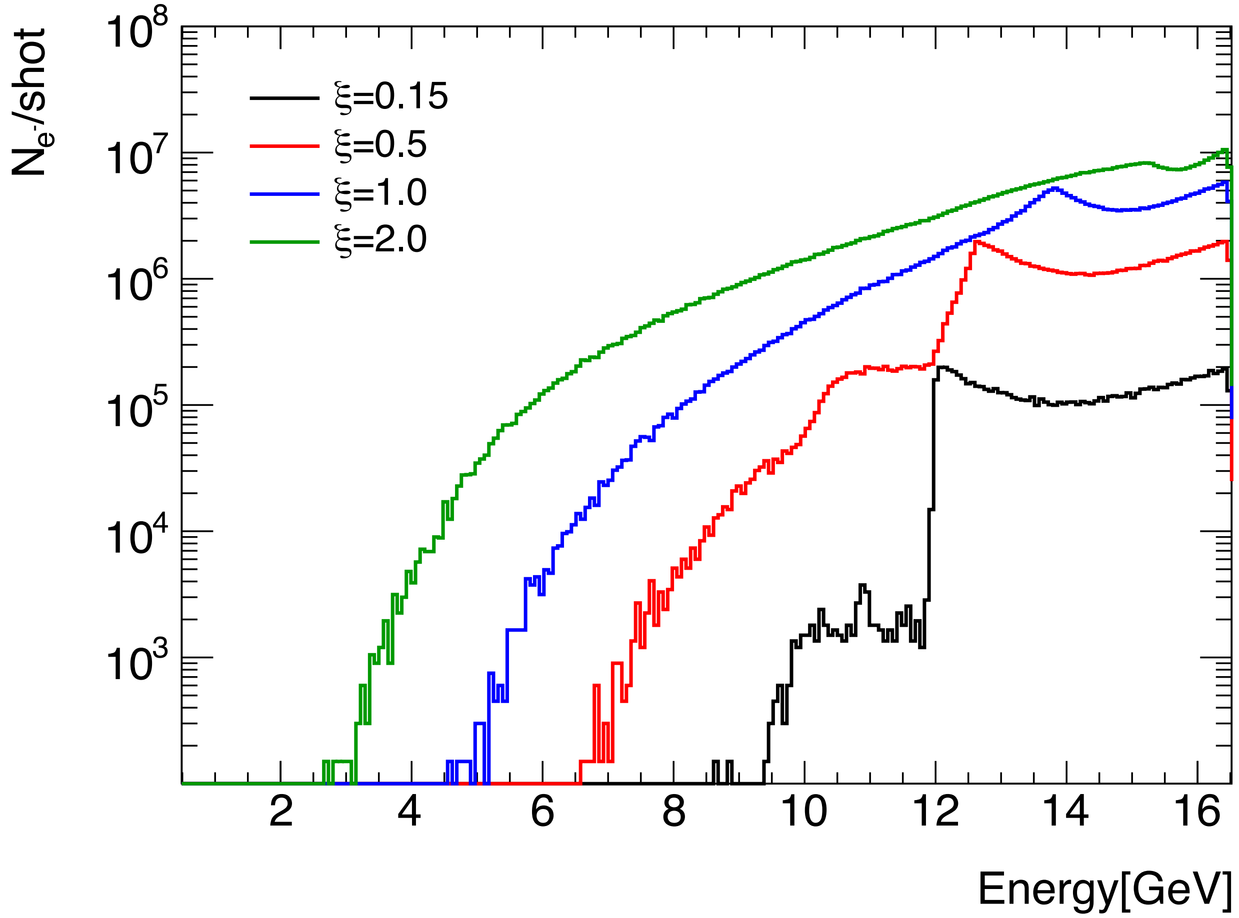
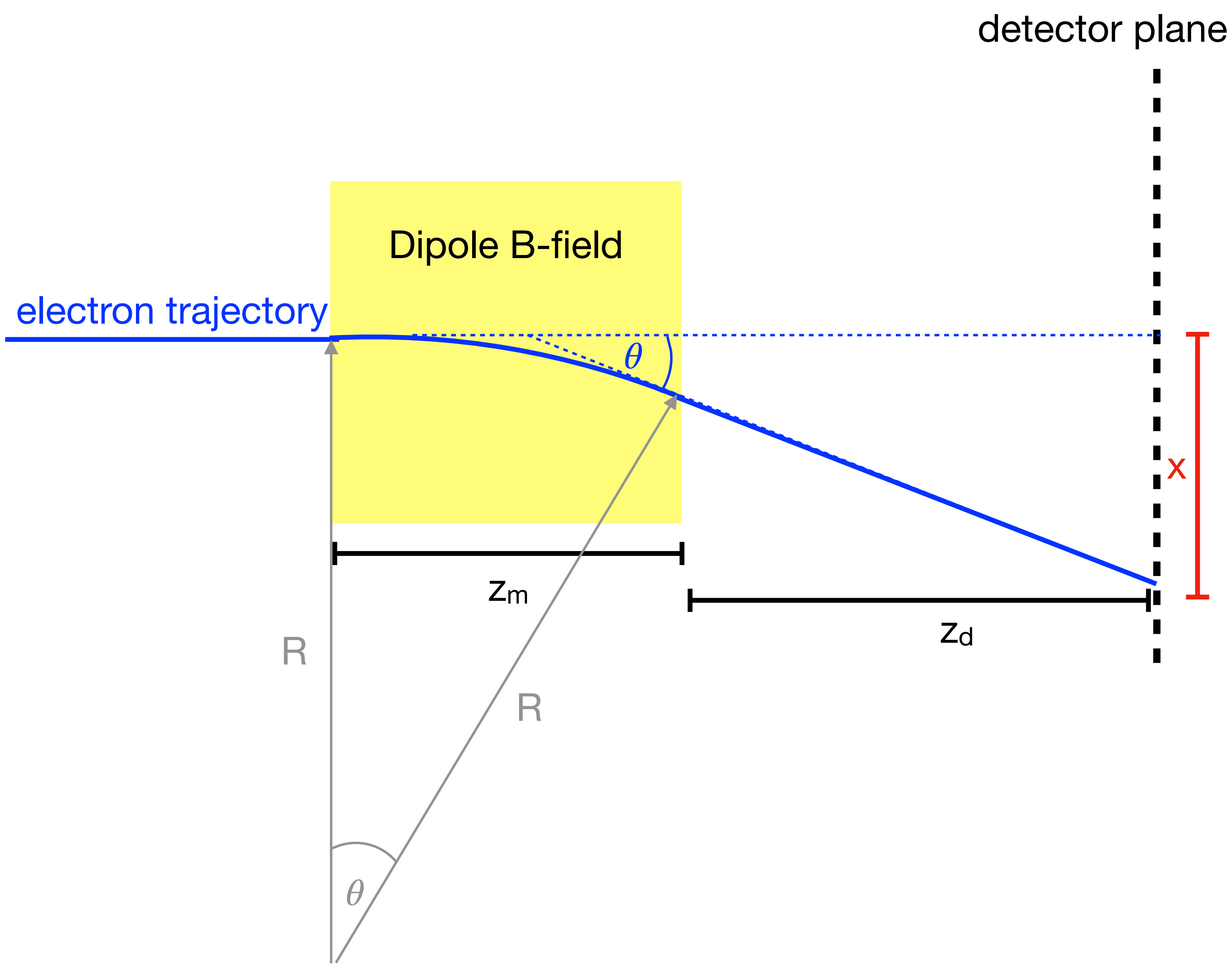
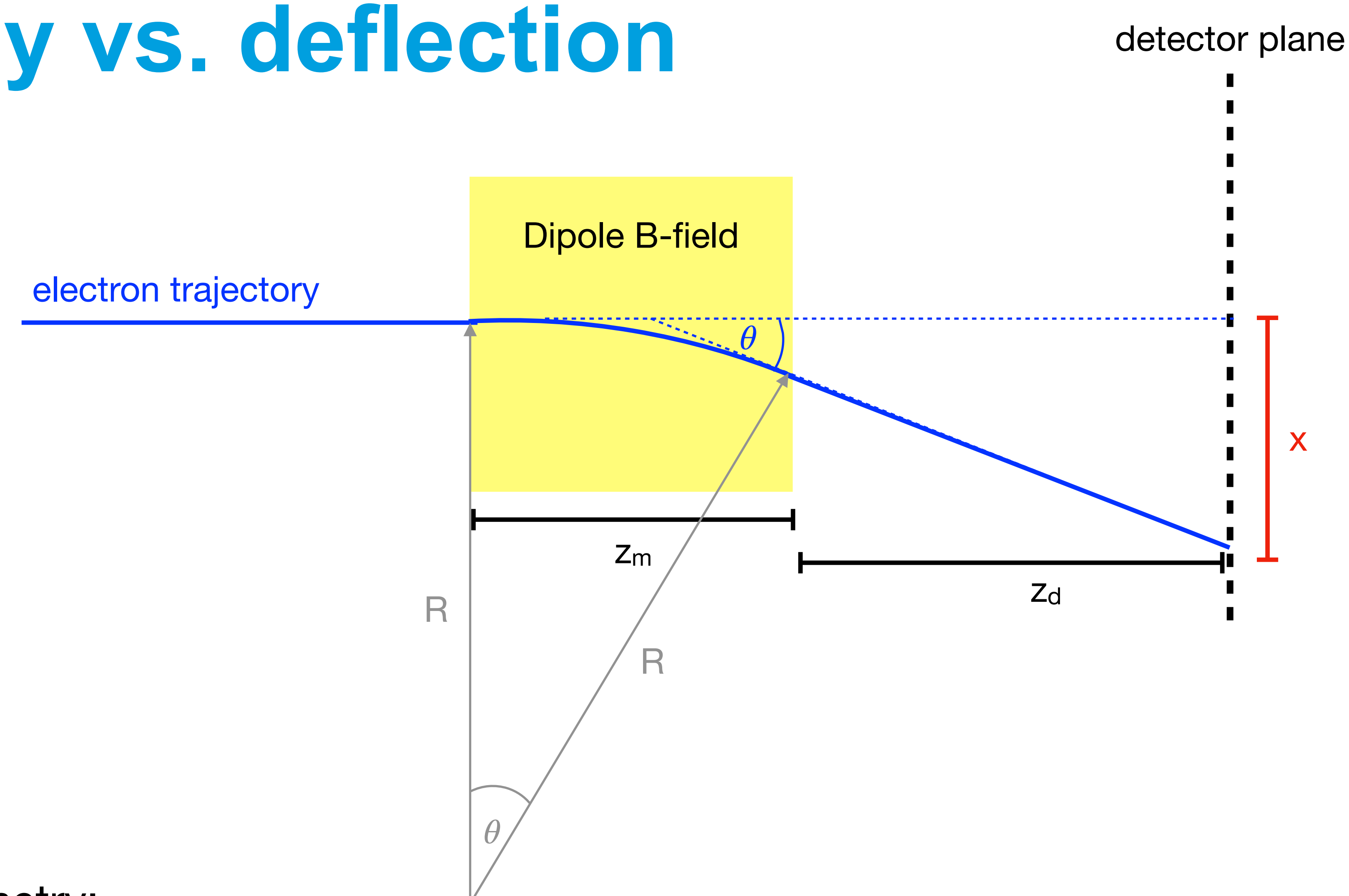
Introduction





- electron energy with Cherenkovs: deflection x after dipole
- difficulty with performance estimate: whenever the geometry changes, segmentation required to get same resolution changes
  → need to re-run fastsim each time
- come up with a performance estimate using energy resolution directly
- Disclaimer: Nothing new here, just a more consistent way of expressing the requirement!

Energy vs. deflection



- from geometry:

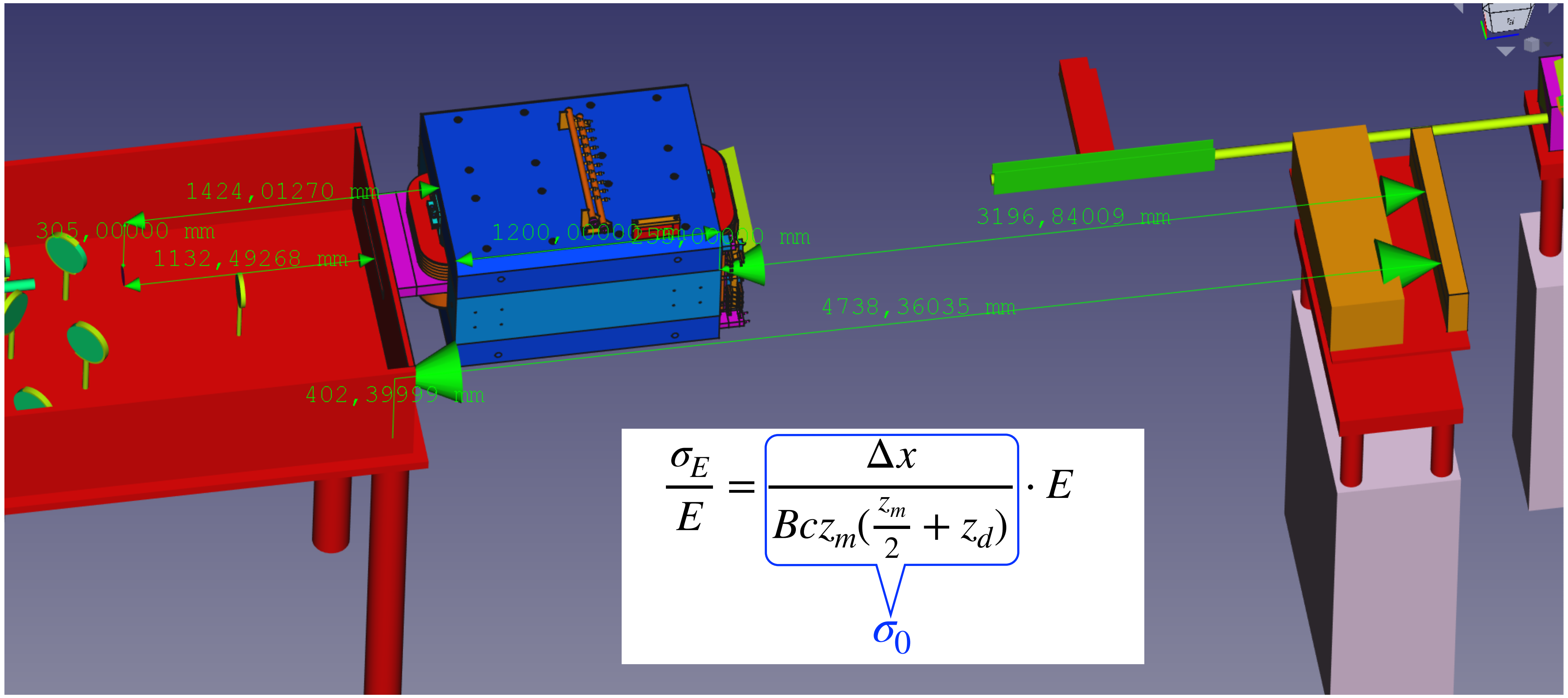
$$x = R - \sqrt{R^2 - z_m^2} + \frac{z_m z_d}{\sqrt{R^2 - z_m^2}} \quad \text{where} \quad R = \frac{E}{Bc} \quad \xrightarrow{\text{Taylor for } z_m/R=0} \quad x = \frac{z_m^2}{2R} + \frac{z_d z_m}{R} + \mathcal{O}\left(\left(\frac{z_m}{R}\right)^3\right)$$

- energy resolution as function of energy E, segmentation Δx and dipole characteristics:

$$\frac{\sigma_E}{E} = \underbrace{\frac{\Delta x}{Bcz_m(\frac{z_m}{2} + z_d)}}_{\sigma_0} \cdot E$$

- linear behaviour in energy typical for dipole spectrometer

Segmentation, Dipole Geometry and σ_0

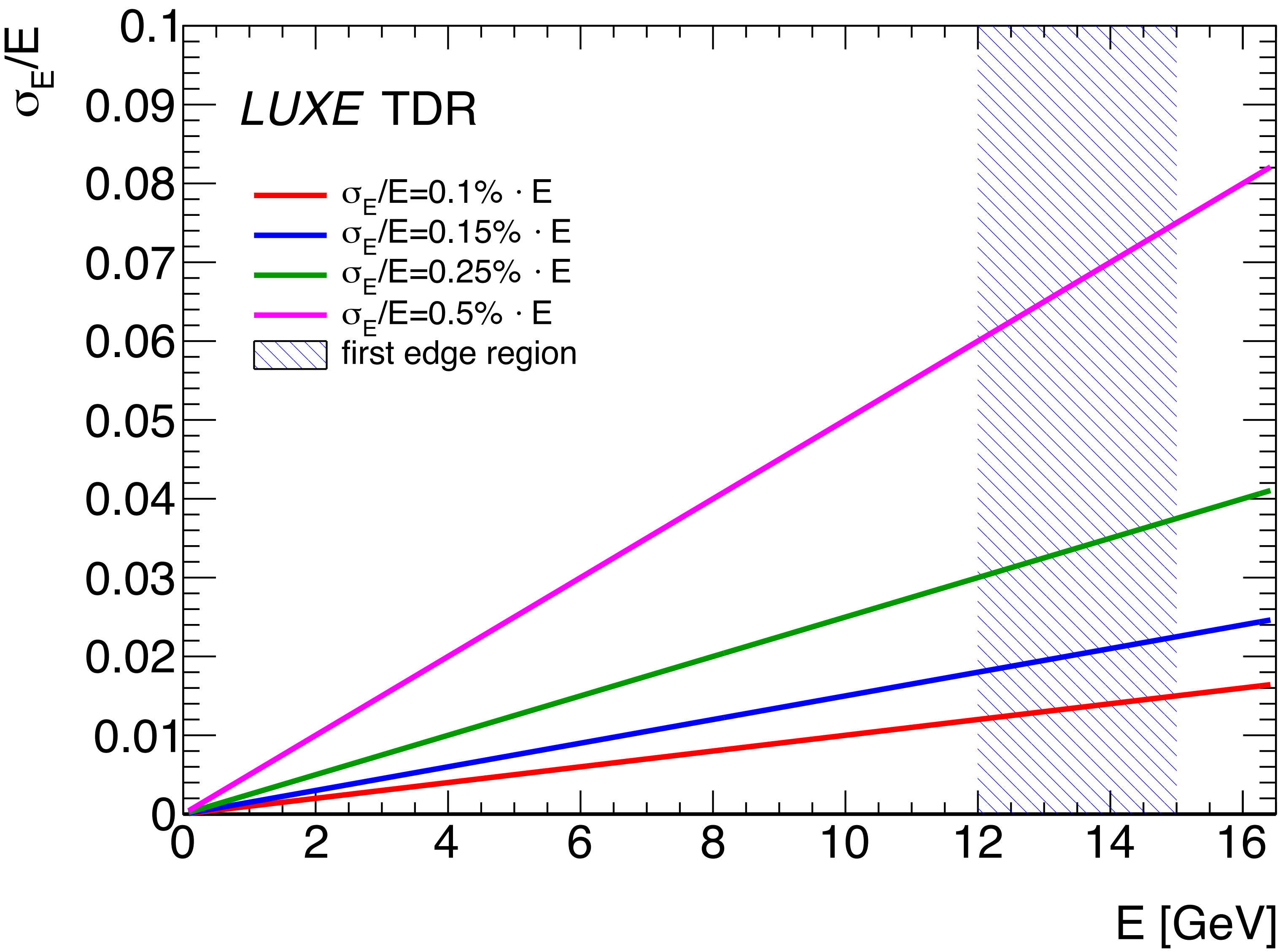


$$\frac{\sigma_E}{E} = \underbrace{\frac{\Delta x}{Bcz_m(\frac{z_m}{2} + z_d)}}_{\sigma_0} \cdot E$$

- current EDS Cherenkov spectrometer: B=1.6T, z_d=3.2m, z_m=1.2m

Segmentation Δx[mm]	σ_0 (for E in GeV)
10	0.0045
6	0.0027
4	0.0018
1	0.00046

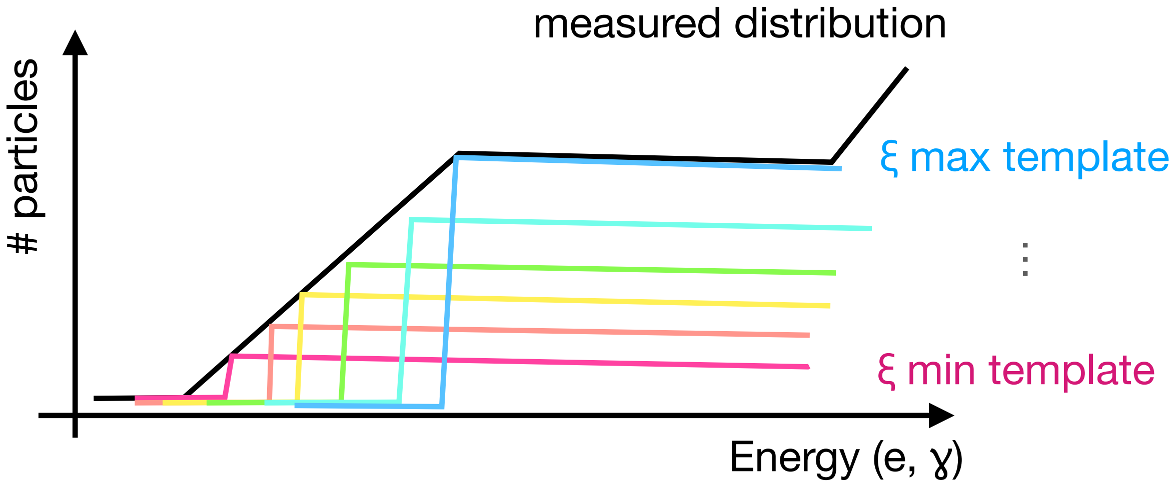
Resolution in First Edge Region

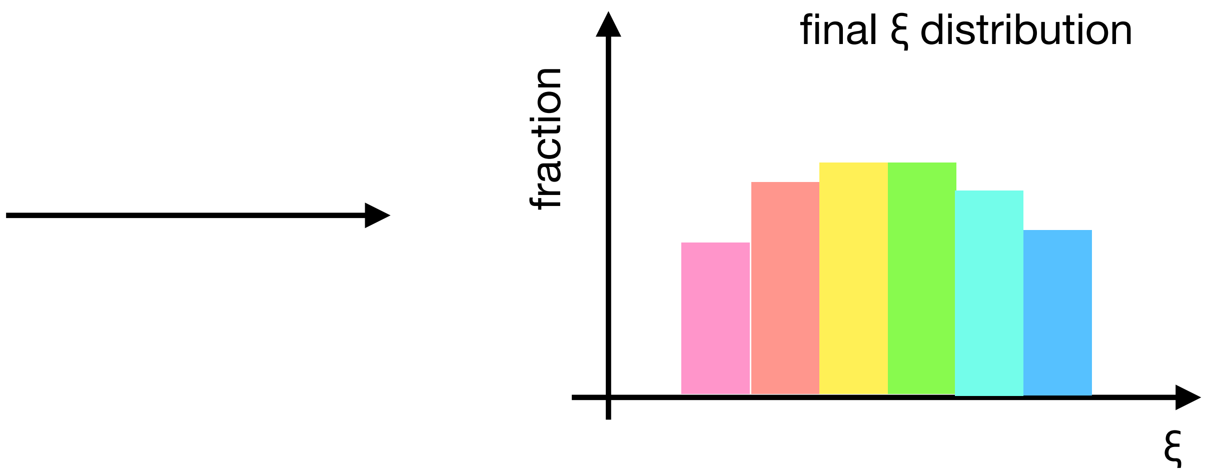


Segmentation Δx[mm]	σ_0 (for E in GeV)	σ_E/E (12 GeV)	σ_E/E (15 GeV)	
10	0.0045	5.4 %	6.9 %	~ pink
6	0.0027	3.3 %	4.1 %	~ green
4	0.0018	2.2 %	2.7 %	
3	0.0014	1.6 %	2.0 %	~ blue
1	0.00046	0.5 %	0.7 %	~ red

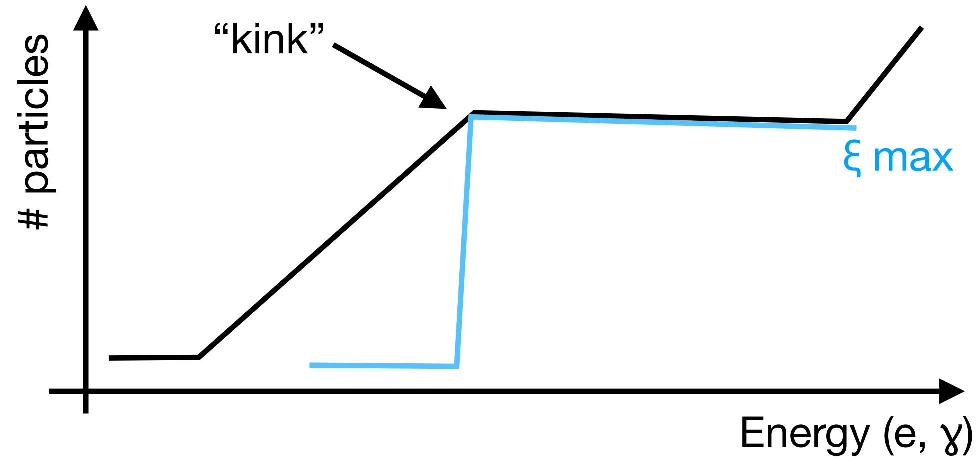
Reminder: Why we are interested in the kink

- Gaussian pulse: overlay of different true ξ leads to dramatic washing-out of edges





- to find edge position for ξ_{max}, find the upper "kink" of the edge



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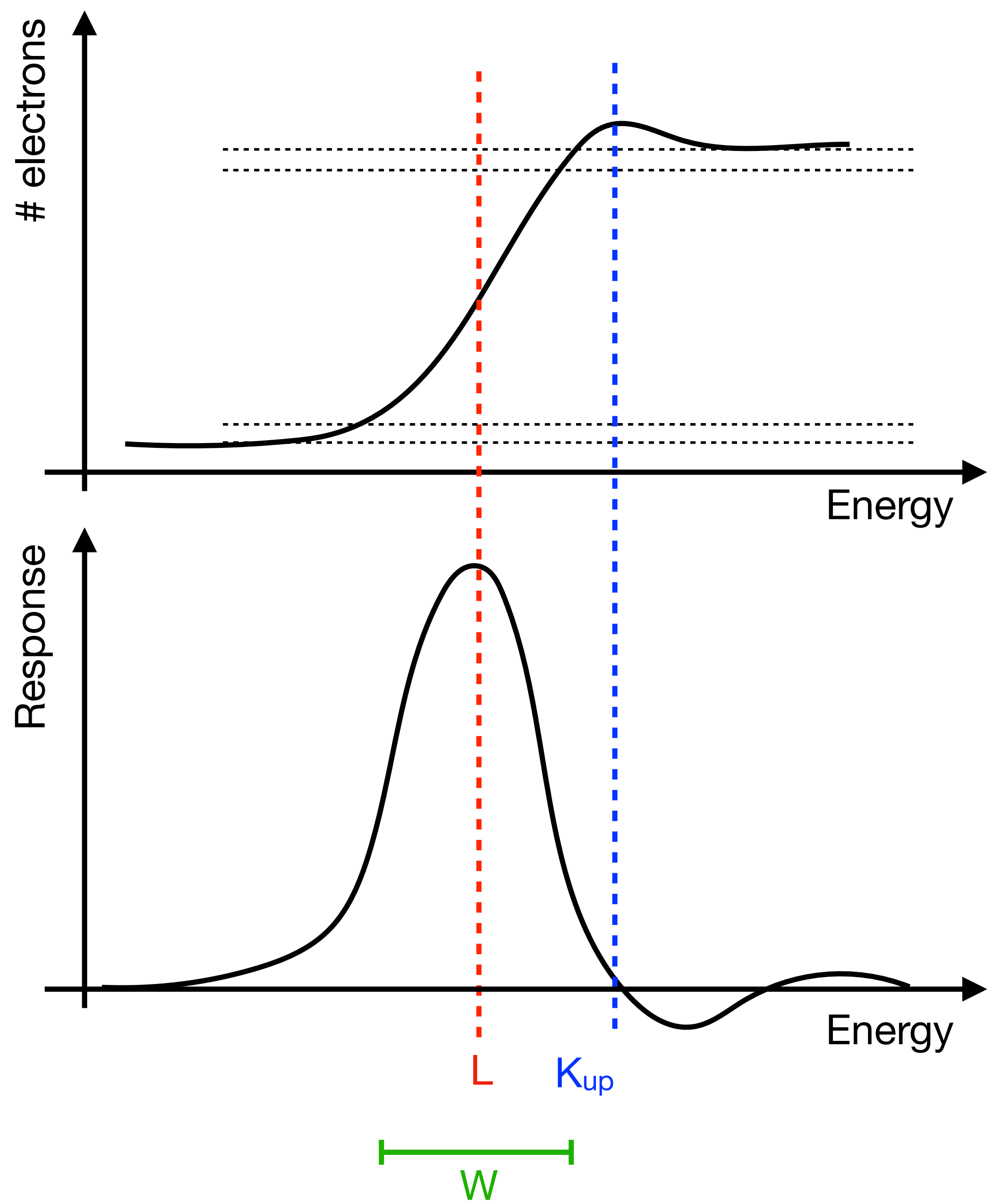
Finite Impulses Response Filter (FIR)

Finite Impulses Response Filter

- edge-like features in function **g(x):**
  → maxima in the convolution $\mathbf{R(x)=h(x)*g(x)}$
  (**h(x)** is a matched filter)
- **R(x)** is called the **Response**
- we have discrete data points $\mathbf{x}=(x_0,\ldots,x_i)$,
  → discretized Response $R_d(i)$:

$$R_d(i) = \sum_{k=-N}^{N} h_d(k) \cdot g_d(i-k)$$

- choice of filter h_d depends on the function g(x)
- Used here: **First derivative of a Gaussian (FDOG)**

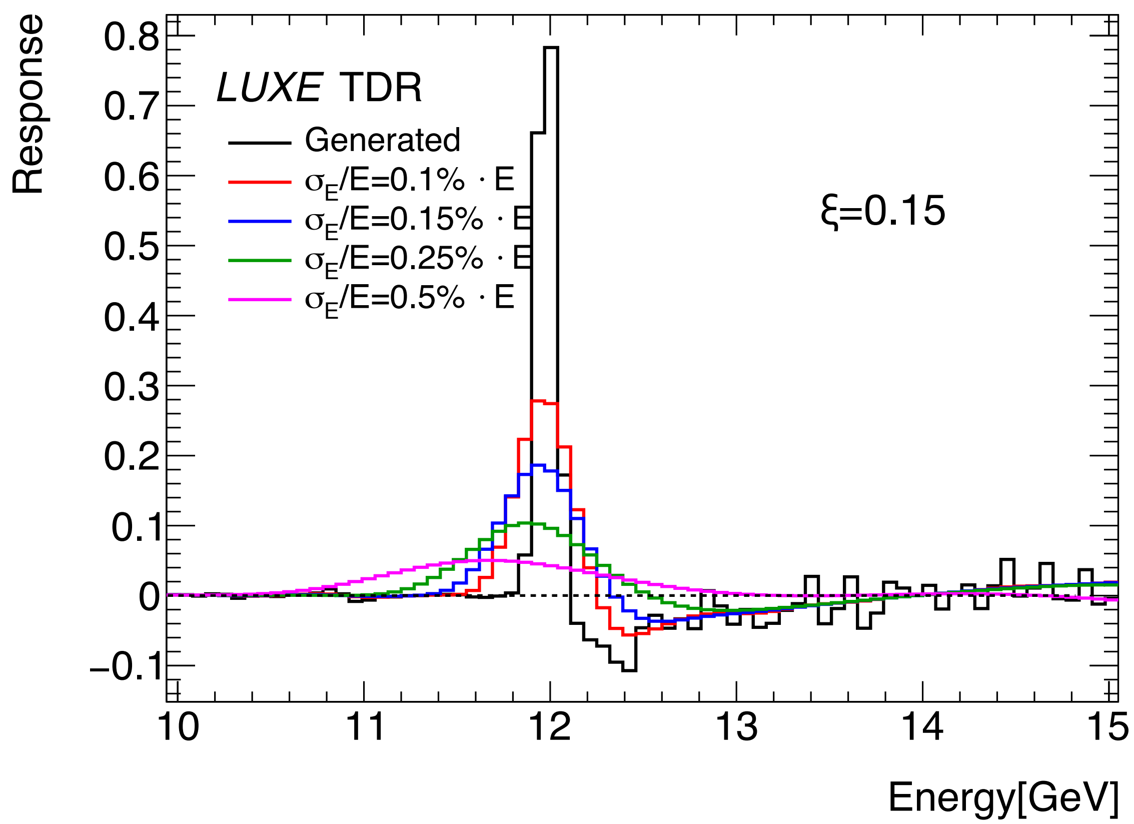


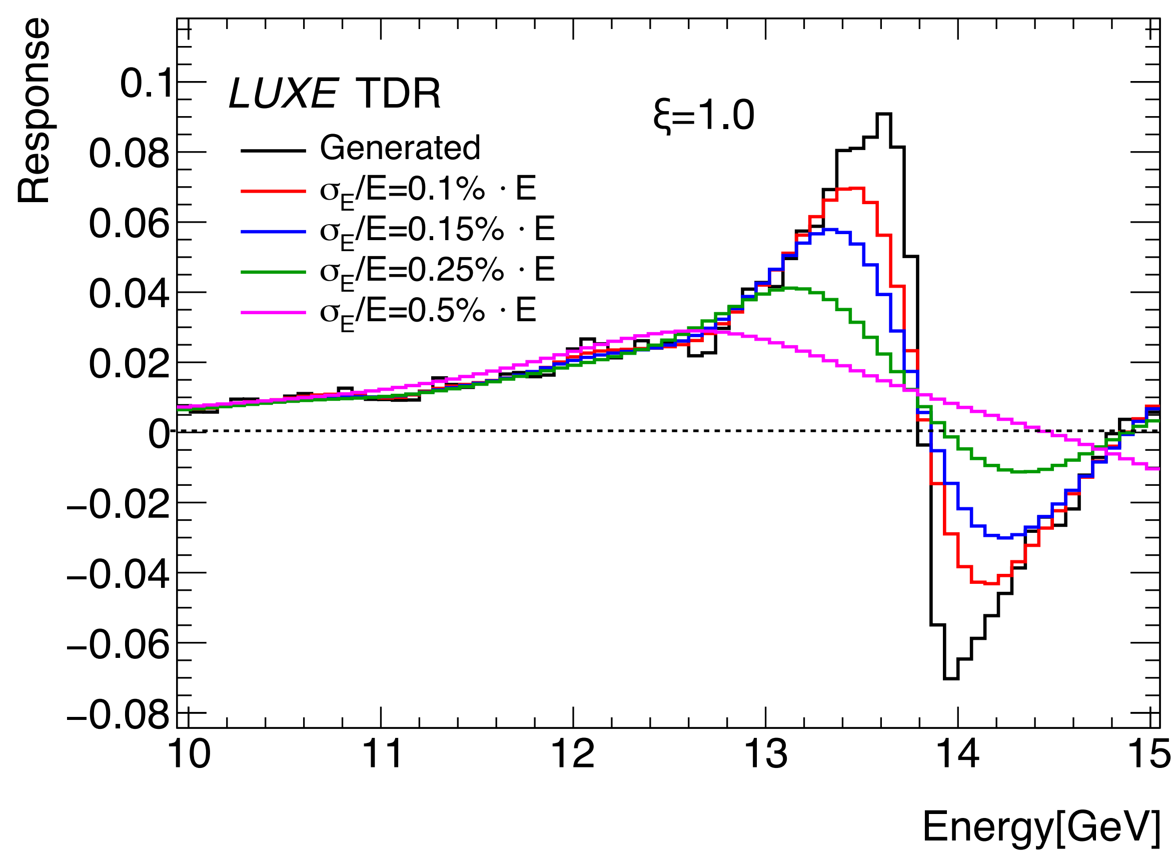
FIR approximates first derivative

— thanks to filters more robust against statistical fluctuations!

Impact on Edge finding

- estimate the impact of limited resolution on the FIR response
- implementation: smear the true electron spectrum with a Gaussian kernel (μ=0, σ_E/E linear in E)





- kink (zero-crossing of response) more robust at higher xi (edge is more smeared out)
- some bias can be corrected
- 4mm straws correspond ~ to blue curve
  → we can probably gain something by having several layers
- 1cm straws (~pink) are definitely too wide
- with this parametrization it's easy to estimate perfomance for new segmentation, dipole geometry etc!

Summary

- propose more general way of expressing requirements for Cherenkovs in terms of energy resolution
- relies purely on dipole parametrization, no need for “fastsim”
- finer details need to be determined with full simulation (e.g. sharing between channels, reco with several layers/overlapping channels)
- will add this in the technical note