Finite Impulses Response Filters for Compton Edge reconstruction

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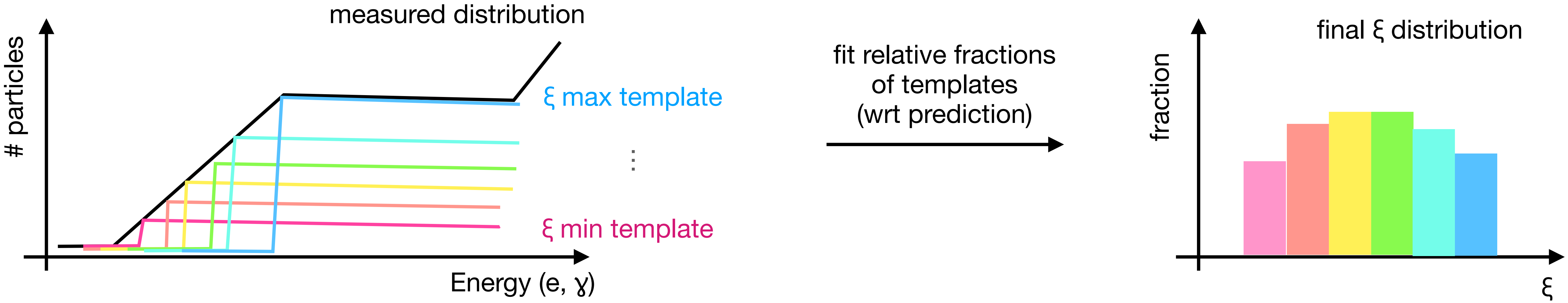
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

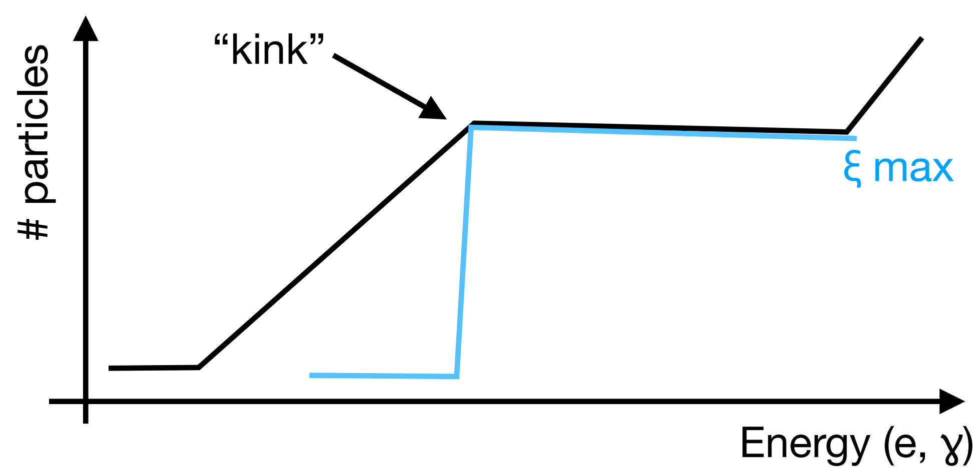
Reminder: Why we are interested in the kink

- Gaussian pulse: overlay of different true ξ leads to dramatic washing-out of edges
- final analysis should be a template fit (template of different ξ bins) fit to the spectrum



For the CDR propose simple approach:

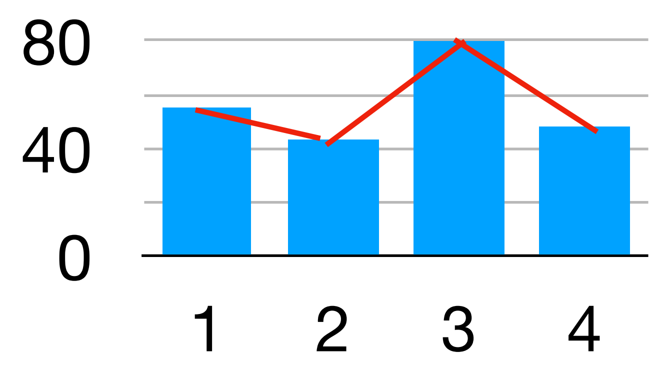
- instead of differentiation, try to find the “kink” of the edge
- for low enough ξ (high w0) , this position corresponds to ξ_{max}



Finite Impulses Response Filter (FIR)

Before: Simple Differentiation for Edge finding

- get electron x distribution
- calculate slope bin-by-bin
  → bin with max. slope = edge
- susceptible to statistical fluctuations!



method used by J. List et. al.

Finite Impulses Response Filter

- edge-like features in function **g(x)** can be identified by maxima in the convolution **R(x)=h(x)** $*$ **g(x)** where **h(x)** is a matched filter
- **R(x)** is called the **Response**
- we have discrete data points **x=**$(x_0,\ldots,x_i)$, need discretized Response $R_d(i)$

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

- different filters h_d available, optimal choice depends on the function g(x)
- Used here: **First derivative of a Gaussian (FDOG)**

$$h_d(k) = -k \exp(-\frac{k^2}{2\sigma^2}) \text{ for } -N \leq k \leq N$$

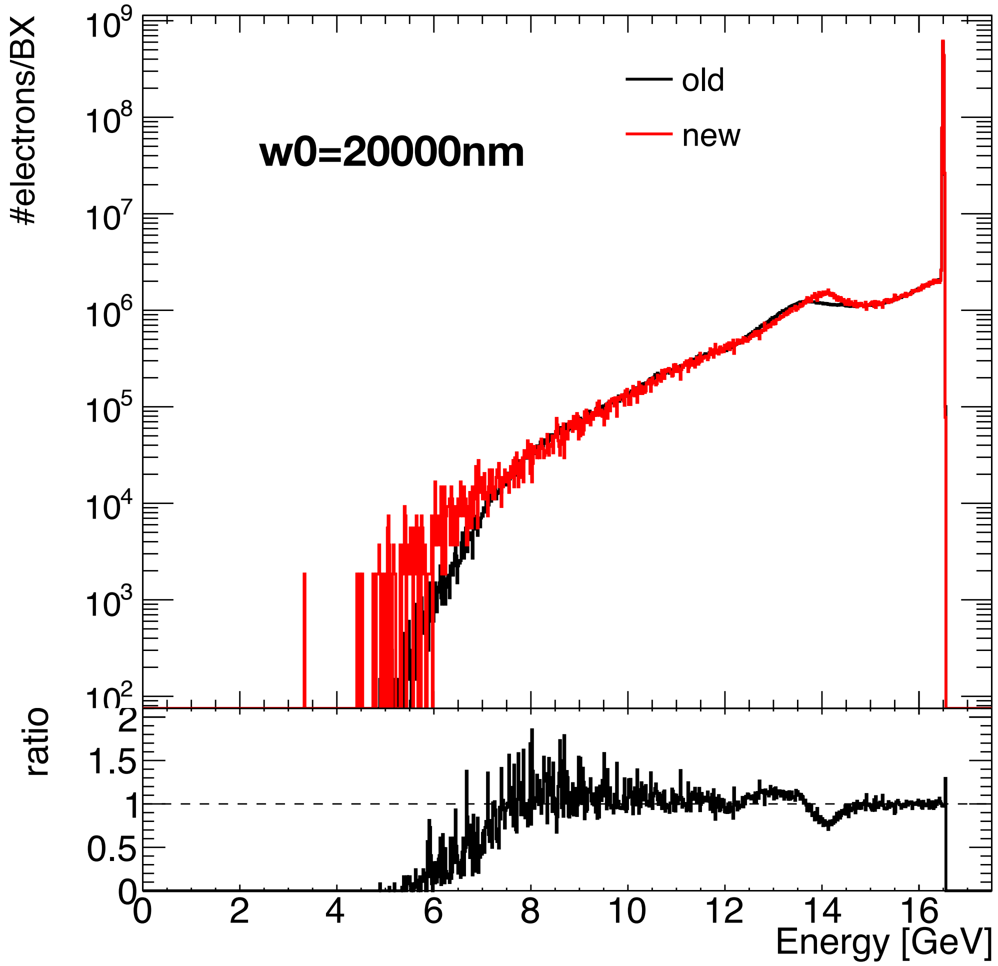
FIR approximates first derivative

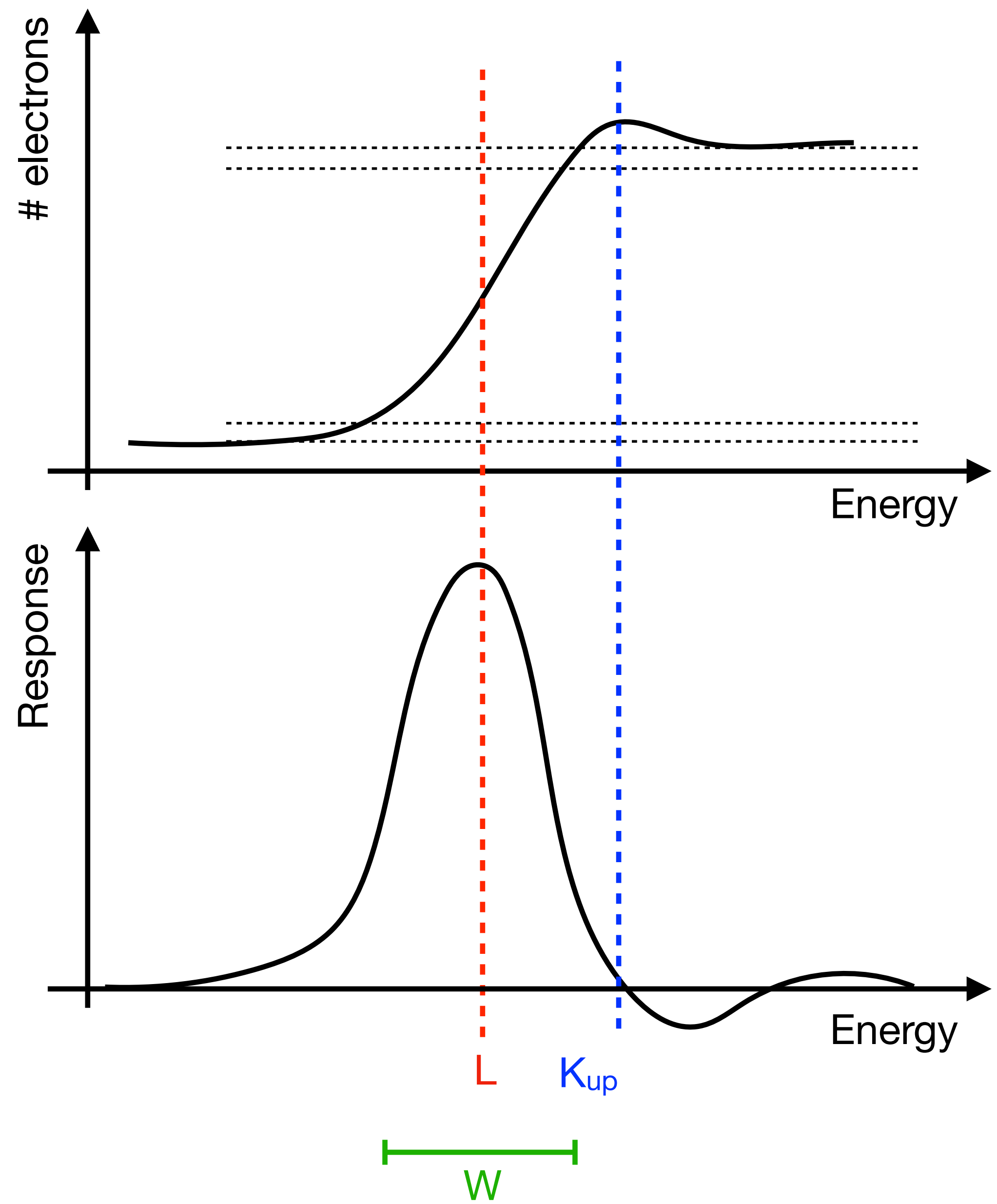
— thanks to filters more robust against statistical fluctuations!

Finite Impulses Response Filter (FIR)

Features of interest in our Compton spectrum:

- location **L**: edge position, maximum of Response
- kinks $\mathbf{K_{up}}$: edge end point, determined by finding zero-crossing of Response function





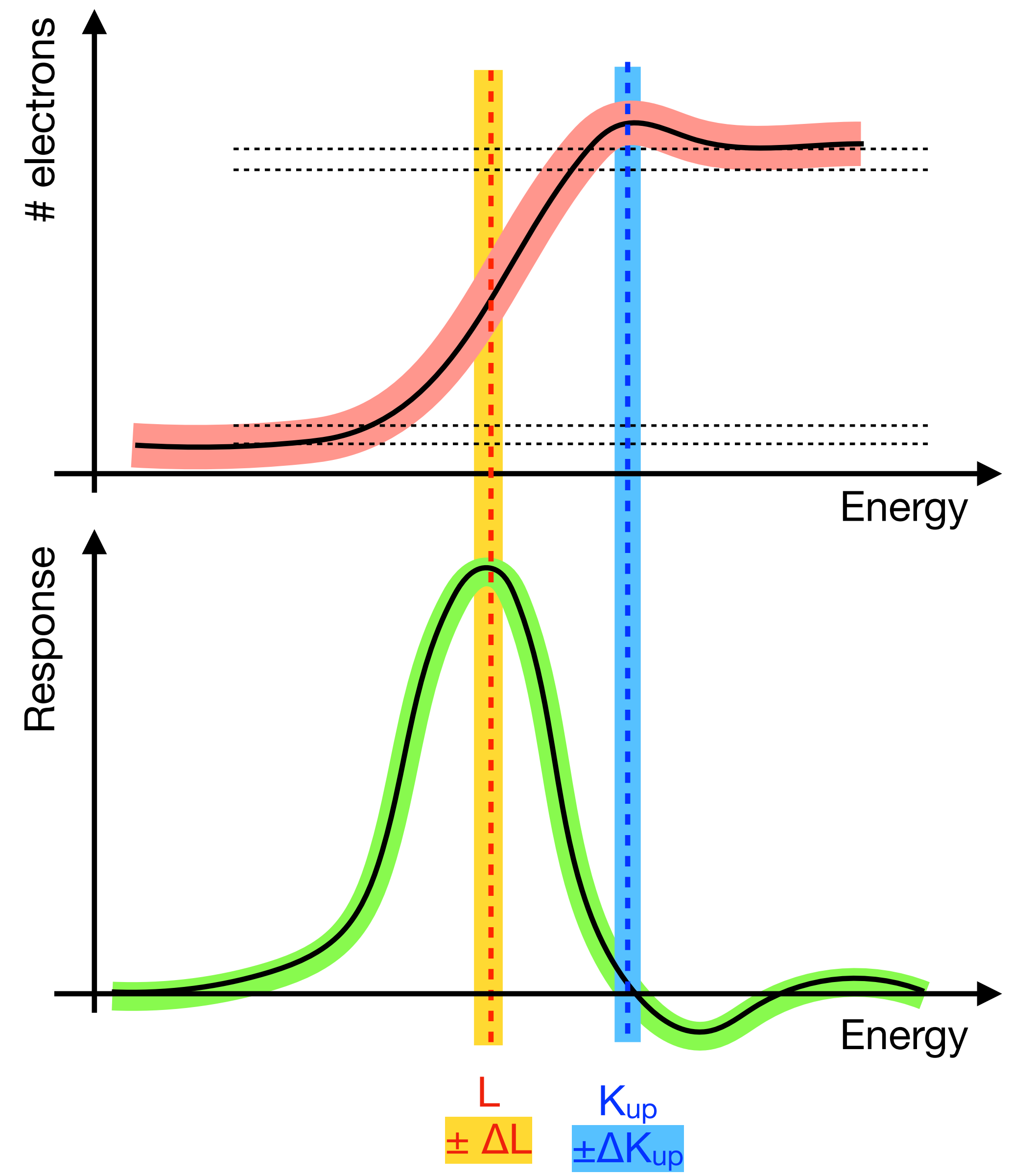
How to estimate uncertainties?

- variations in spectrum lead to variations in the response
  → uncertainties on determined edge and upper kink location

Prescription:
for each independent source of uncertainty…

1) Obtain electron energy spectrum varied by $\pm 1\sigma$
2) Run the FIR on the varied spectrum, get new response, get L’ and K_{up}’
3) Calculate $\Delta L = L' - L_{Nom}$, $\Delta K_{up} = K_{up}' - K_{up,Nom}$

finally add all Δ up in quadrature to get total uncertainty



Which uncertainties enter?

1) Statistical uncertainty on electron rate:

- √N of the number of measured electrons
- Caveat: Need to agree on size of our dataset! so far I did for 3600 BX (1h data-taking at 1Hz)

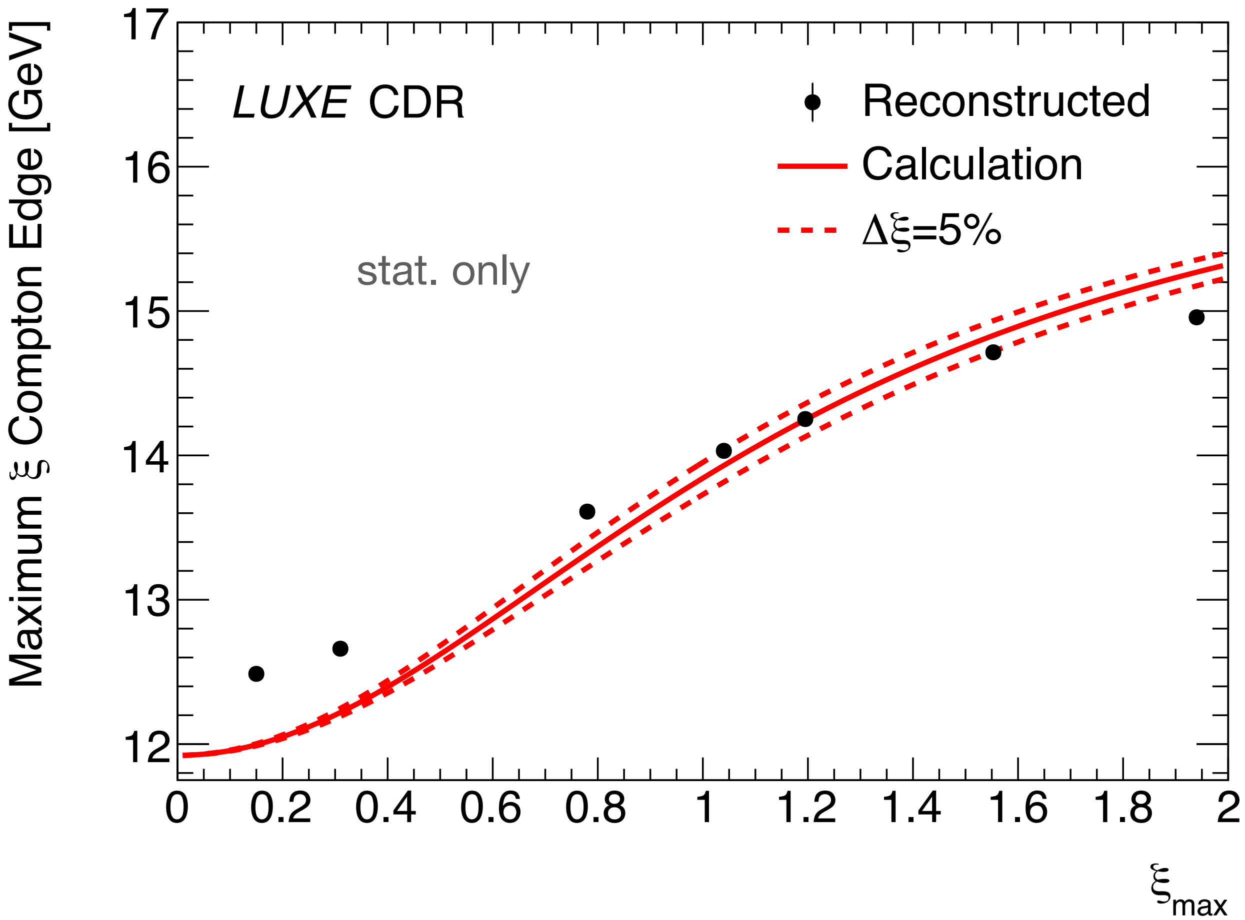
How to estimate?
Throw toy experiments - get a new histogram with
gaussian distributed random numbers ($\mu_i = N_{nom,i}$, $\sigma_i = \sqrt{N_{nom,i}}$ where $N_{nom,i}$=nominal content of bin i)

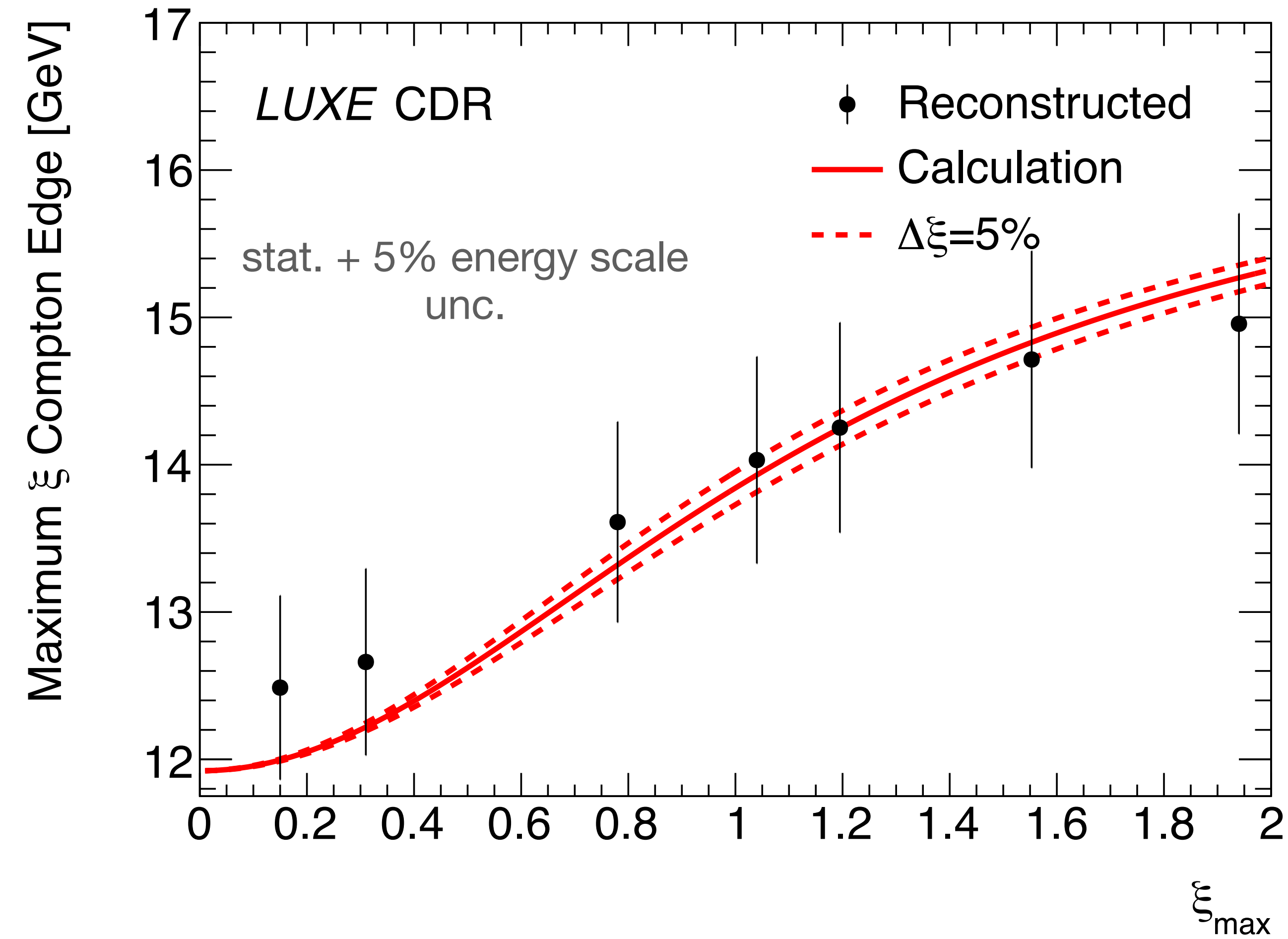
2) Systematic uncertainties:

- B-field uncertainty (Energy scale!)
- Detector-related uncertainties:
  (i.e. for Cerenkov)
  - photon statistics (<1%)
  - detector non-linearity (~1-2%)
  - calibration uncertainty (~1-2%)
  - background uncertainty (?)

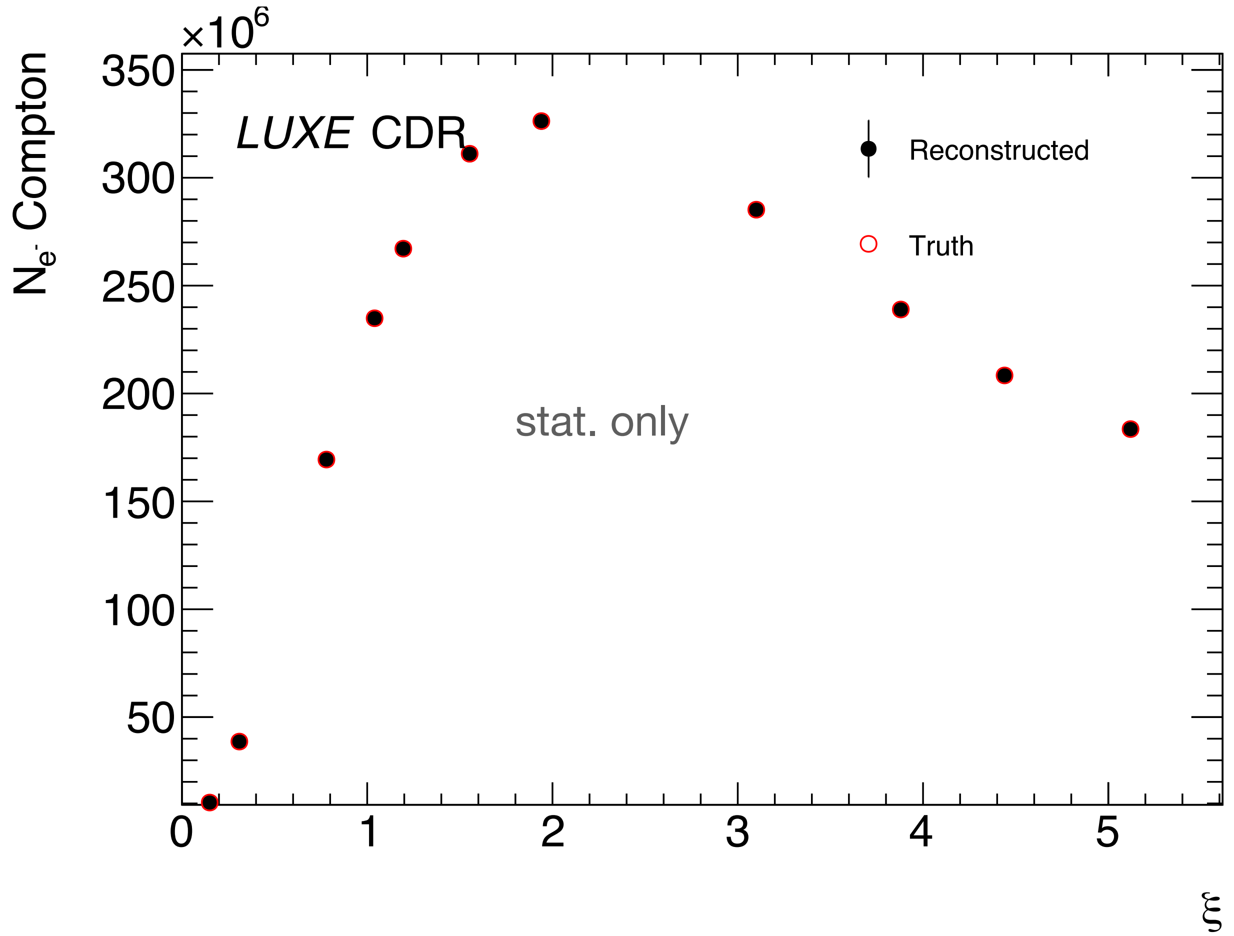
  How to estimate?
  Dipole field: E is proportional to B
  Other uncertainties (except for Bkg unc.) affect mainly the total norm!

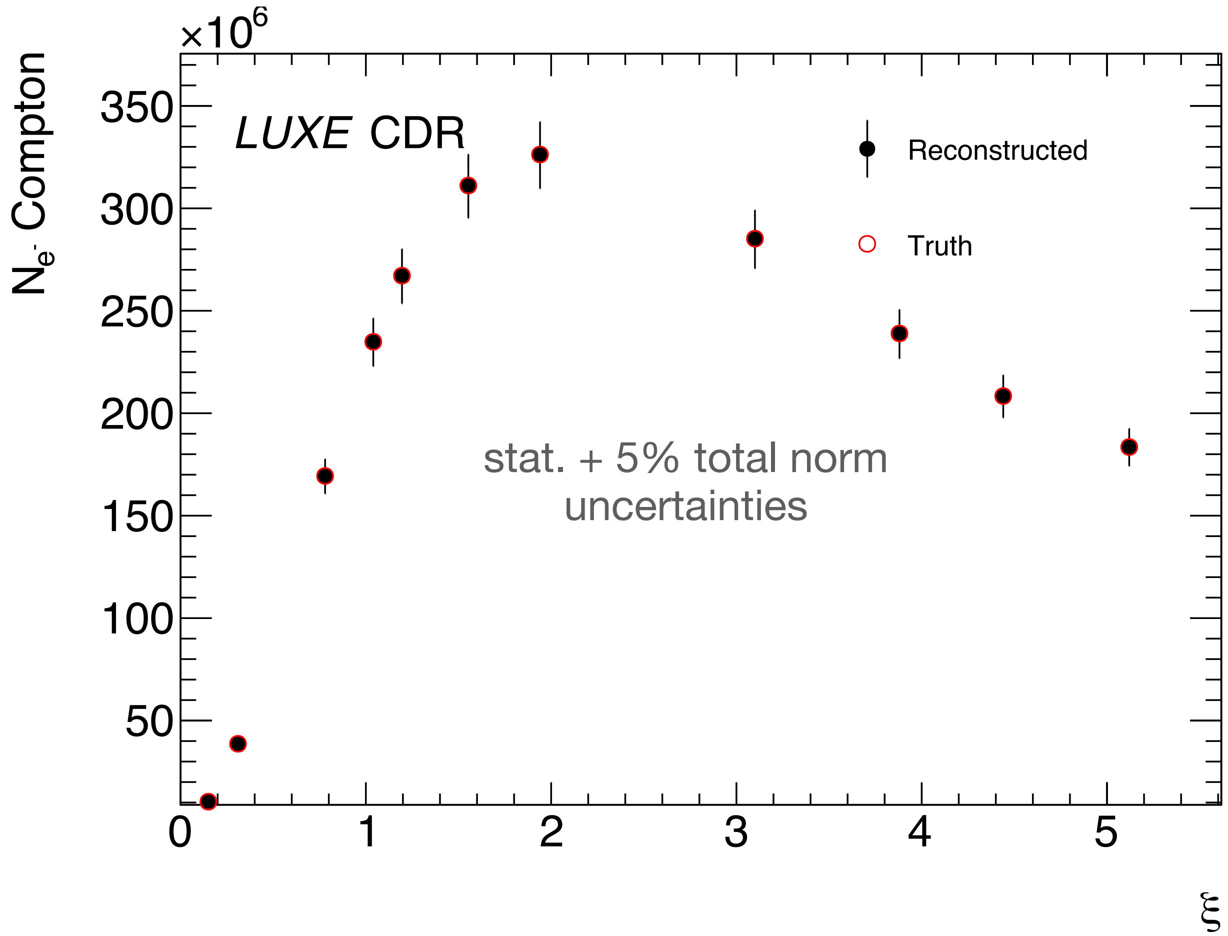
Impact of Uncertainties





Impact of Uncertainties





Summary

- study impact of uncertainties on edge-finding with finite impules response filters
- statistical uncertainties: evaluate using toy MC
  → very small uncertainties for 1h data-taking
- possible systematics: - Dipole field uncertainty
  - photon statistics
  - count rate uncertainty
- assume 5% total norm and energy scale uncertainties
  → reasonable?