Top Threshold Scan &
Luminosity Spectrum at CLIC

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Motivation

- The top quark mass enters in precision SM calculations (Higgs mass, ...): Good to determine it with high precision
- Theoretically clean definitions of the mass (1S, MSbar) are not what we typically measure in experiments (Invariant mass of decay products): Substantial theory uncertainty, on the level of several 100 MeV
  - With other systematics: LHC limit probably on the GeV level

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- Assume we want to do better than this (precision physics!):
  - Better theory - Promising first results, but this is highly non-trivial
  - Theoretically well understood measurement: Threshold scan with e^+e^-

    ILC / Tesla studies show that substantially better than 100 MeV total uncertainty can be achieved - Does this also work for CLIC?

Threshold Scan - How it works

- The simplest version: Measure the cross section for top pair production at several energies, compare to NNLO QCD theory calculations
  - Need precise understanding of luminosity, and of the effects of the luminosity spectrum on the measured cross section
  - Need to be able to measure at several (*O* 5 - 10) energy points near threshold (within a 5 to 10 GeV energy window) with reasonable integrated luminosity per point (a few to a few 10 fb^{-1})

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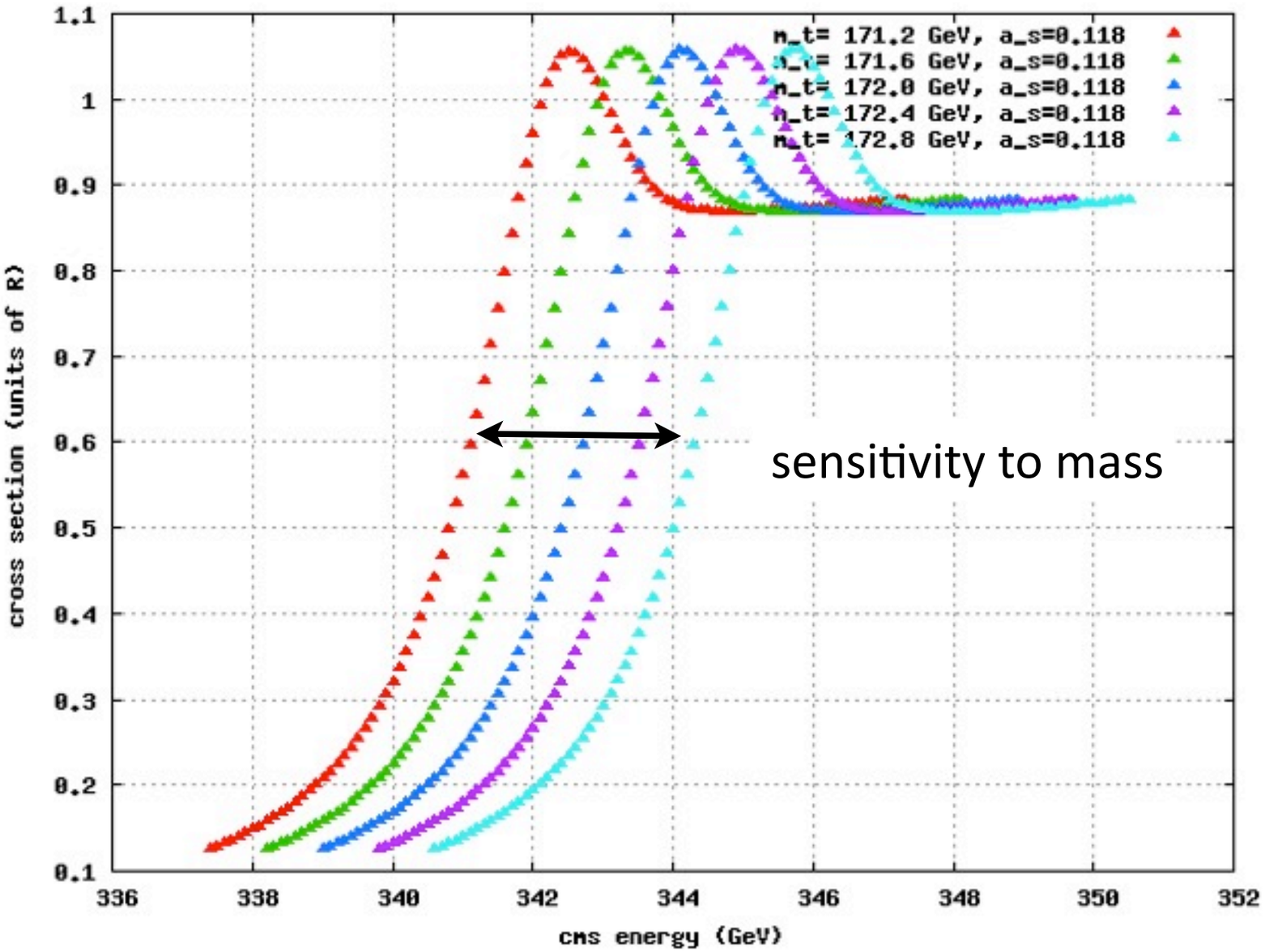
Side remark:

- We do not need energy steps on the sub-100 MeV level
- Cross-sections are small: No point in measuring at more than ~ 10 energy points

Threshold Scan: How it works

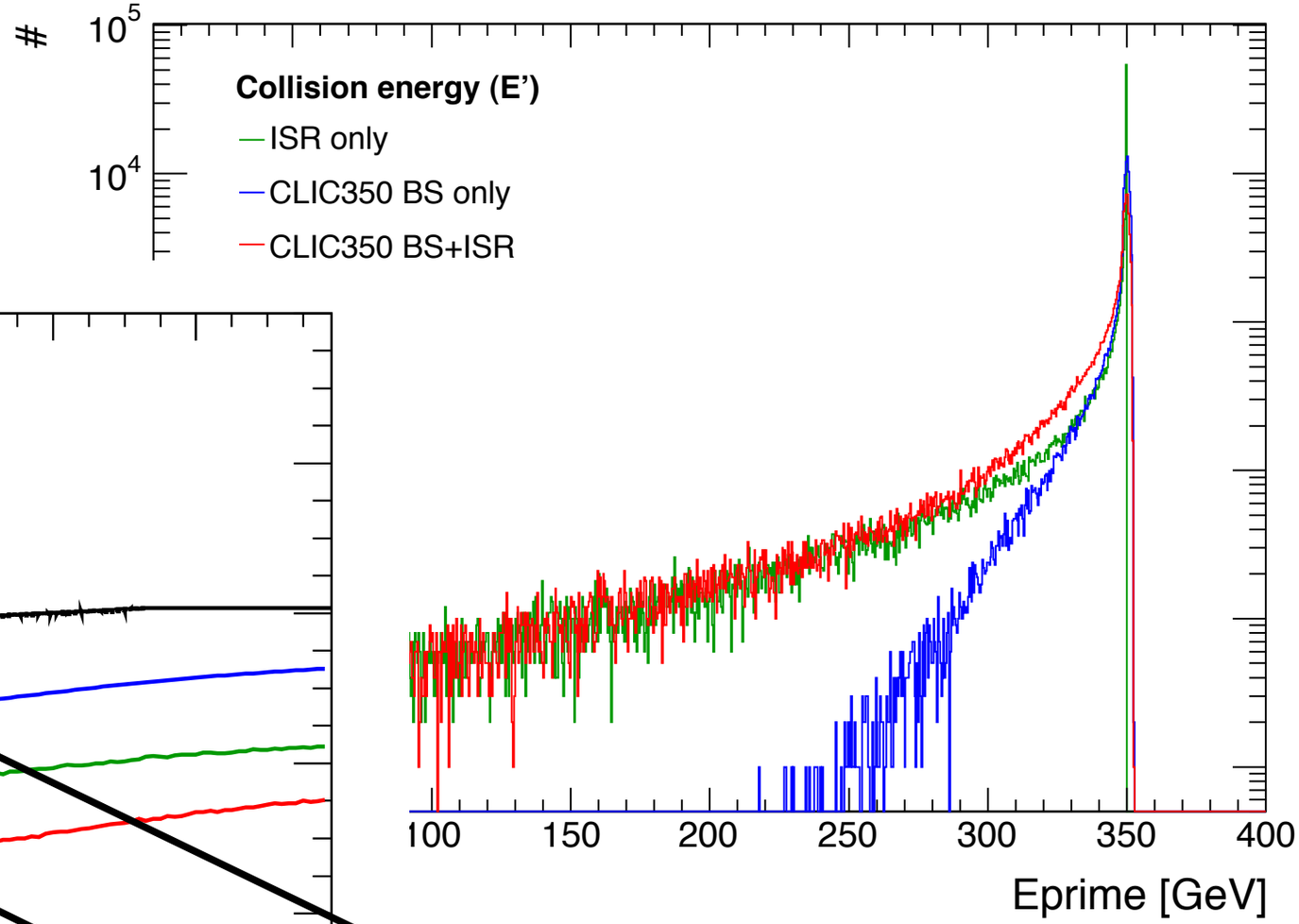


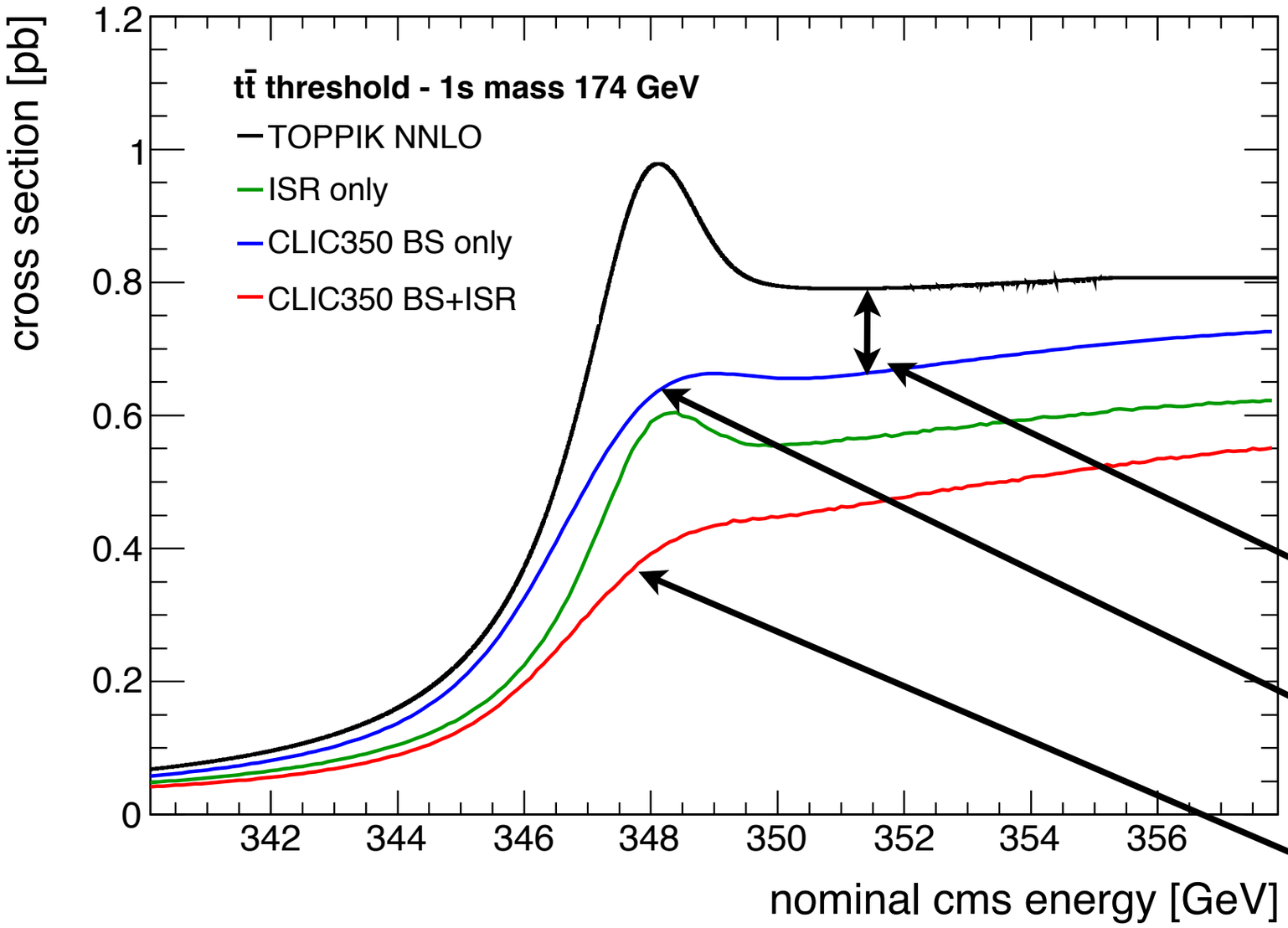
theory ttbar cross section calculated with TOPPIK (Hoang, Teubner)

- Access mass by determining position of edge - shifts linearly with top mass

Threshold and Luminosity Spectrum

- The threshold gets distorted by two effects:
  - ISR
  - Luminosity spectrum





lowering of cross section

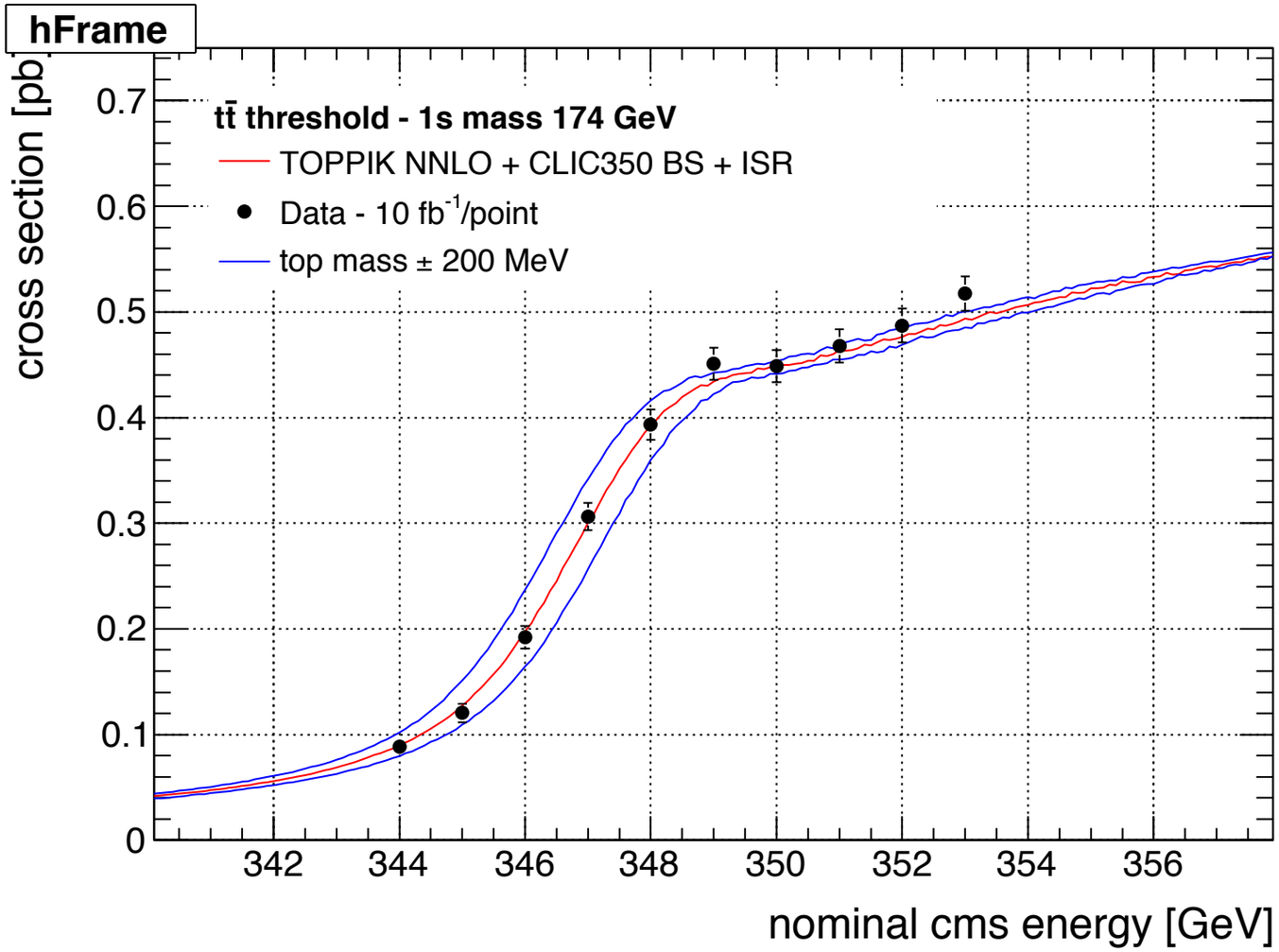
smearing of peak, broadening of edge

further smearing and reduction due to ISR

The Study of a Top Threshold Scan at CLIC

- The idea: Measure the top mass from the cross section at the threshold
  - other variables exist as well, and provide additional sensitivity (A_{FB}, top momentum distribution, ...) - not studied at present
- The problem: No full event generator for the top threshold publicly available
  - Generators like PYTHIA are leading order, plus hadronization: Incorrect threshold behavior (ignores binding effects, ...)
- The approach: Generator-level study, with fully simulated efficiencies
  - Obtain cross section (and with that signal yield) from TOPPIK calculations
  - Take selection efficiencies and background fractions from full simulations, including overlaid background, determines error bars for background-subtracted data points
    - At the moment: Simulations for top pairs in PYTHIA slightly above threshold still in progress - Using efficiencies and scaled background levels from 500 GeV study

How Important is the Luminosity Spectrum?



- Preliminary results:

  ~ 33 MeV statistical error on mass

  ~ 20 MeV systematic uncertainty due to α_s (using PDG error)

Fits assume perfect knowledge of cross section and lumi spectrum

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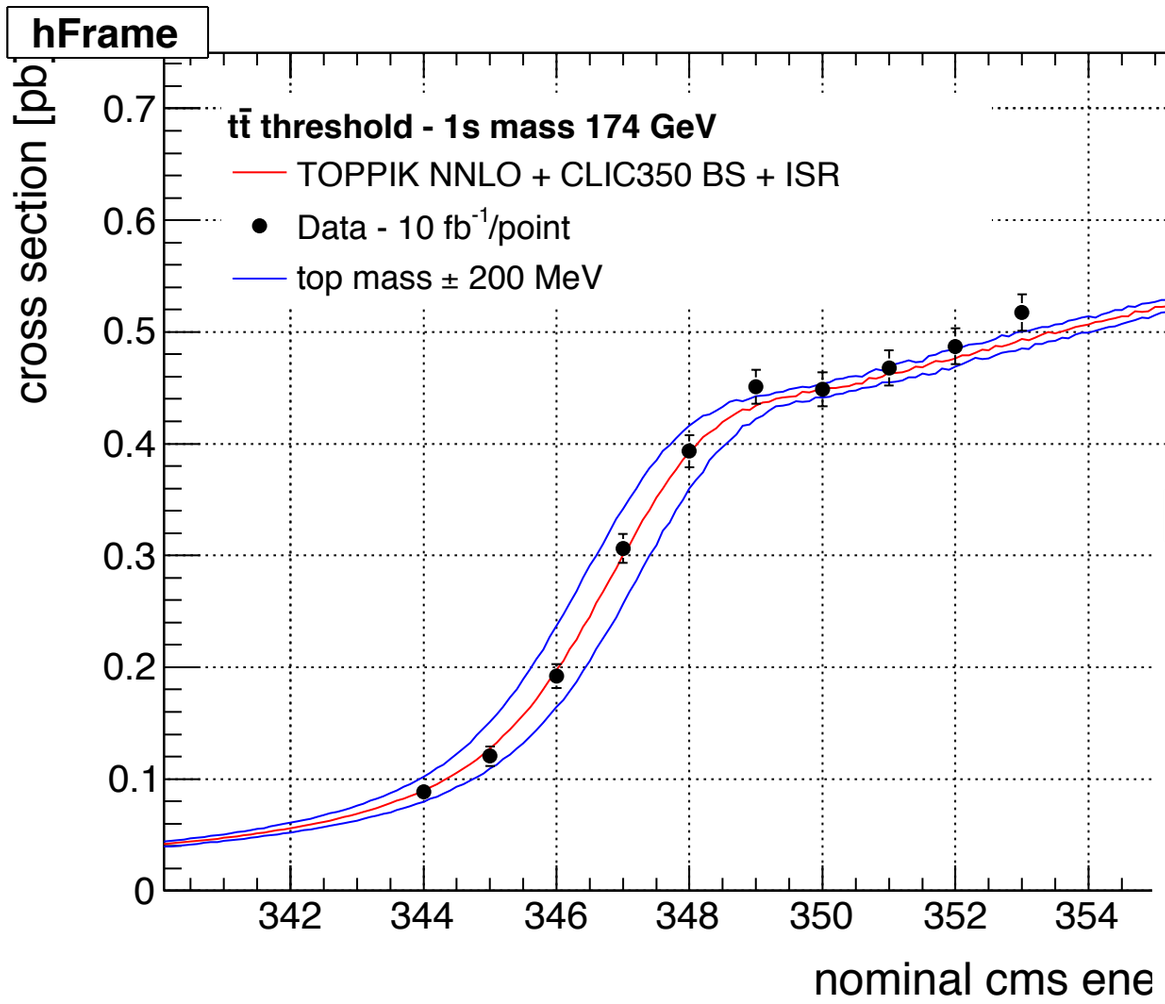


- Preliminary results:

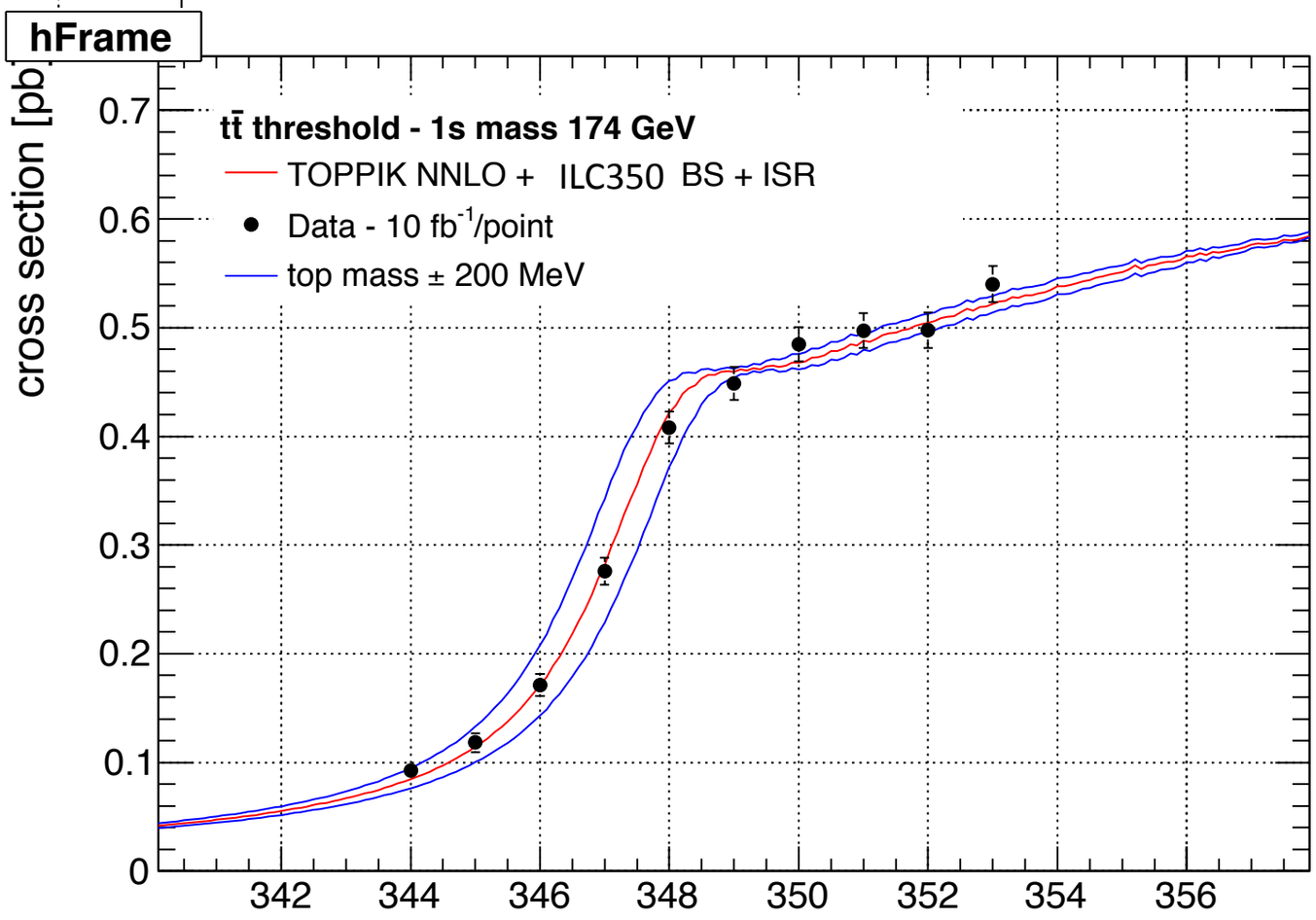
  ~ 33 MeV statistical error on mass

  ~ 20 MeV systematic uncertainty due to α_s (using PDG error)

- ILC luminosity spectrum:

  ~ 30 MeV statistical error on mass

  ~ comparable uncertainty due to α_s



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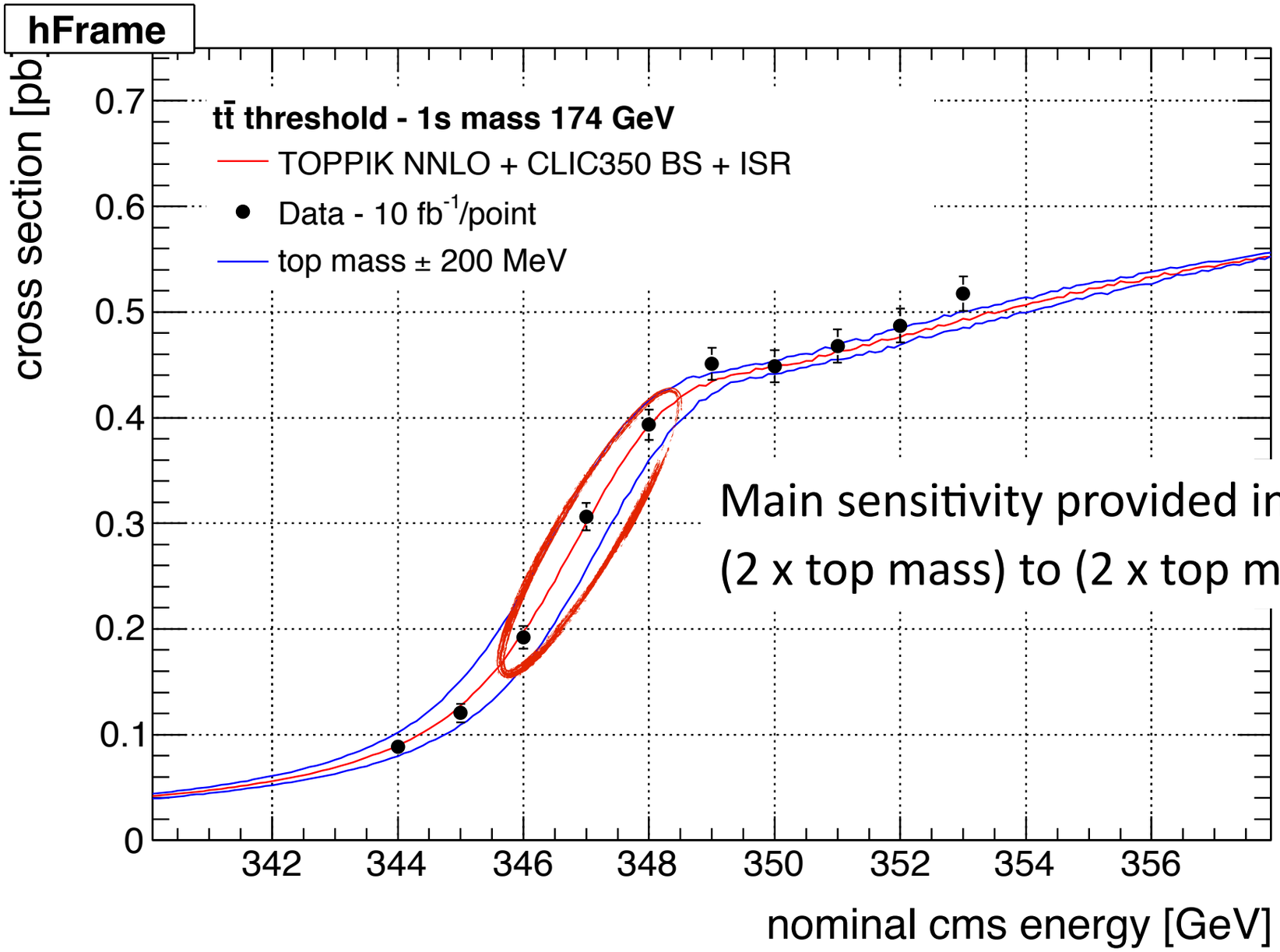
Mass Sensitivity and Scan Points



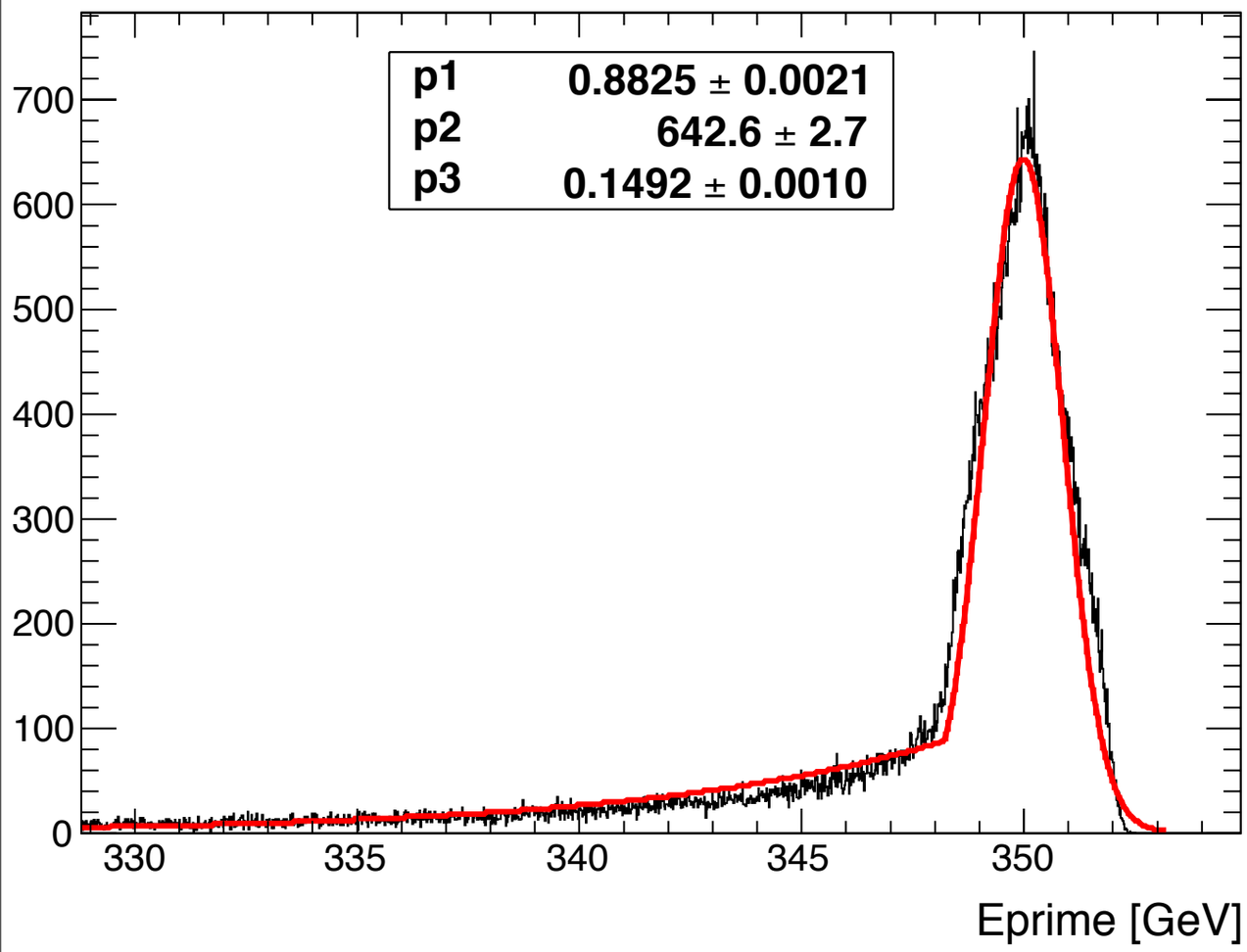
Main sensitivity provided in the range
(2 x top mass) to (2 x top mass - 2 GeV)

In this range:
0.2 pb change at CLIC
0.24 pb change at ILC
Not a dramatic difference!

- Optimization of scan points clearly possible
  - here: clearly too many points above threshold: potentially increases sensitivity to systematic effects from normalization uncertainties

Crucial: Knowledge of the Luminosity Spectrum!

- A first simple test - Parametrize CLIC350 Lumi Spectrum
  - Gaussian peak, exponential tail (starting at - 2 σ for default spectrum)



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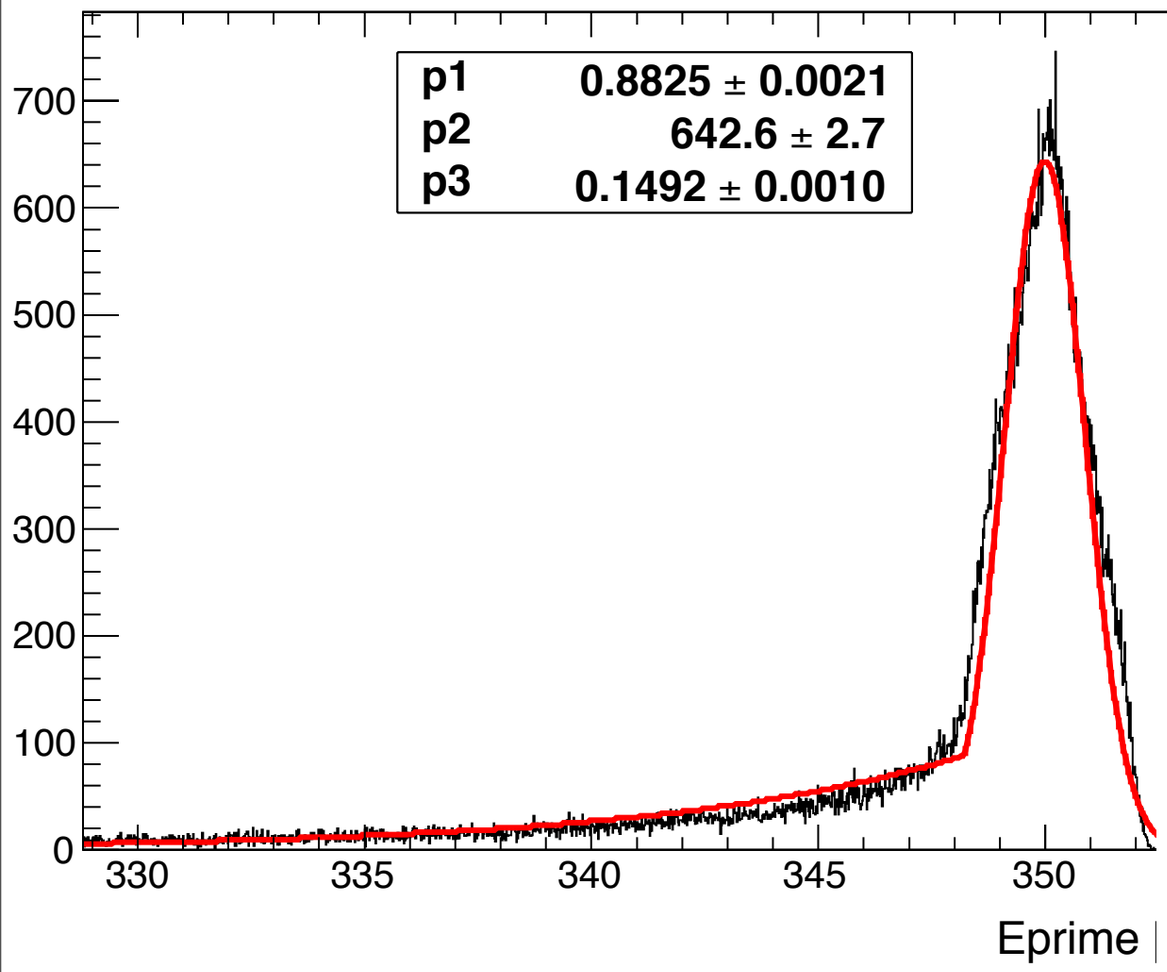
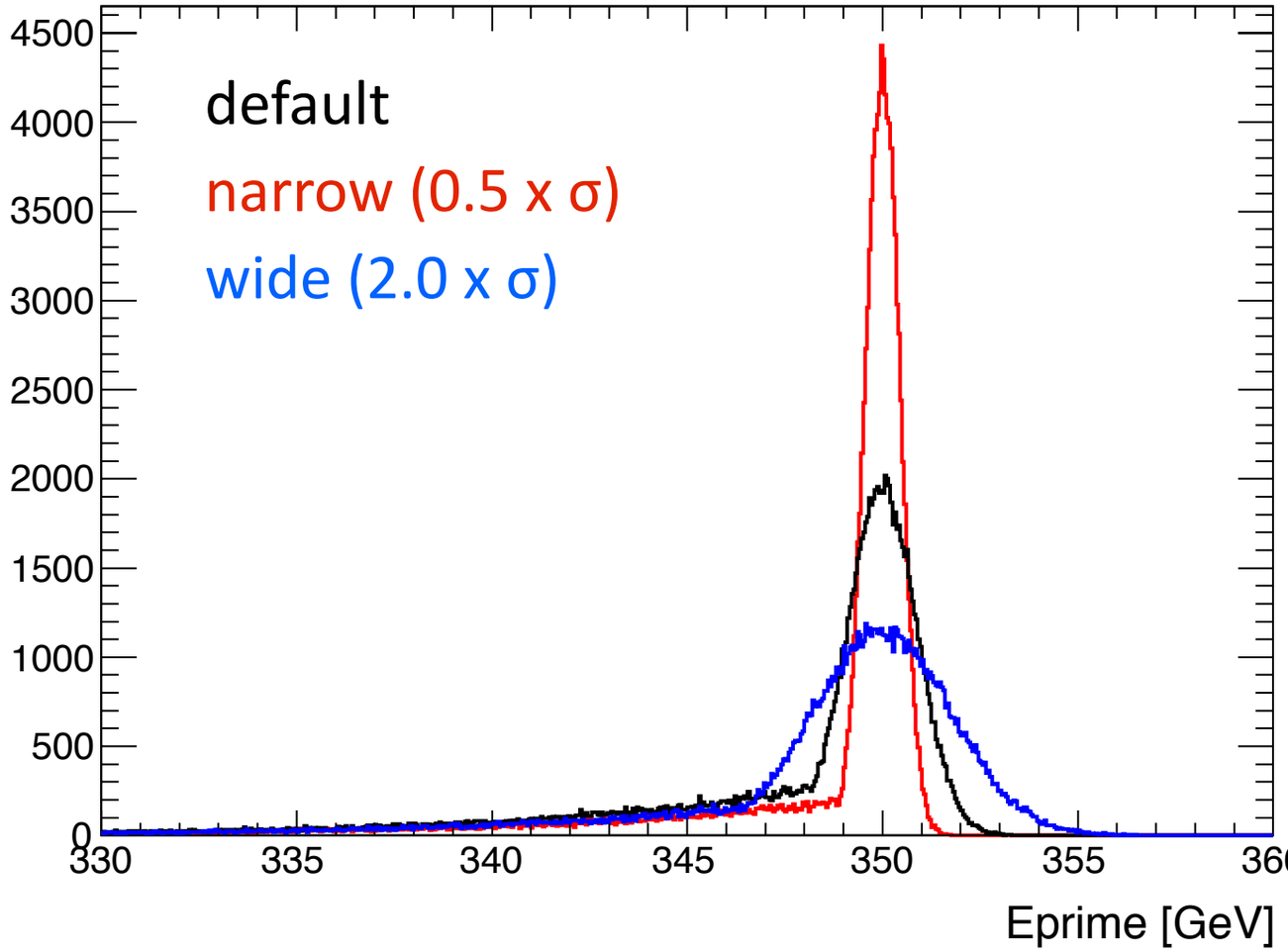
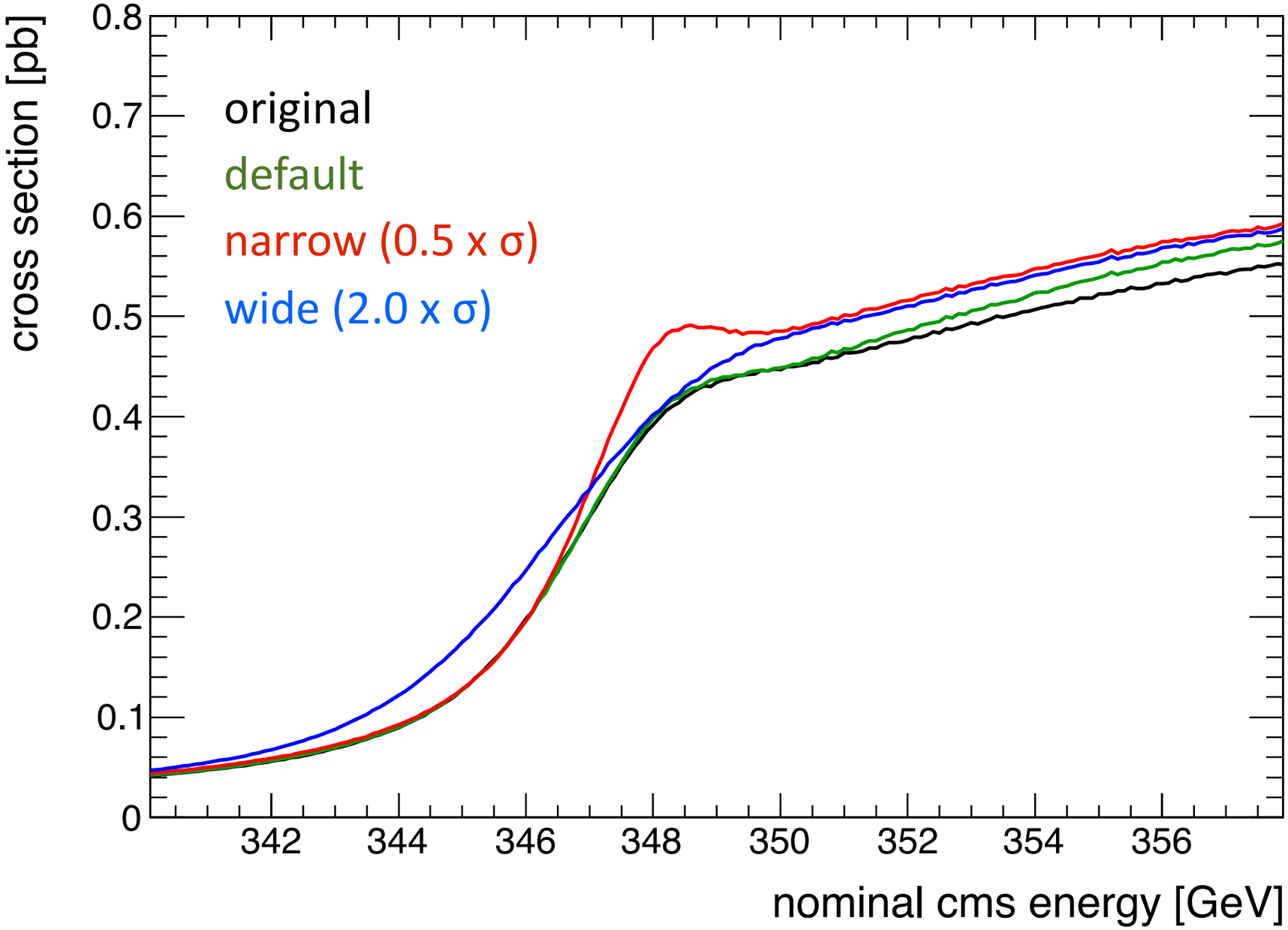


Three parametrizations:



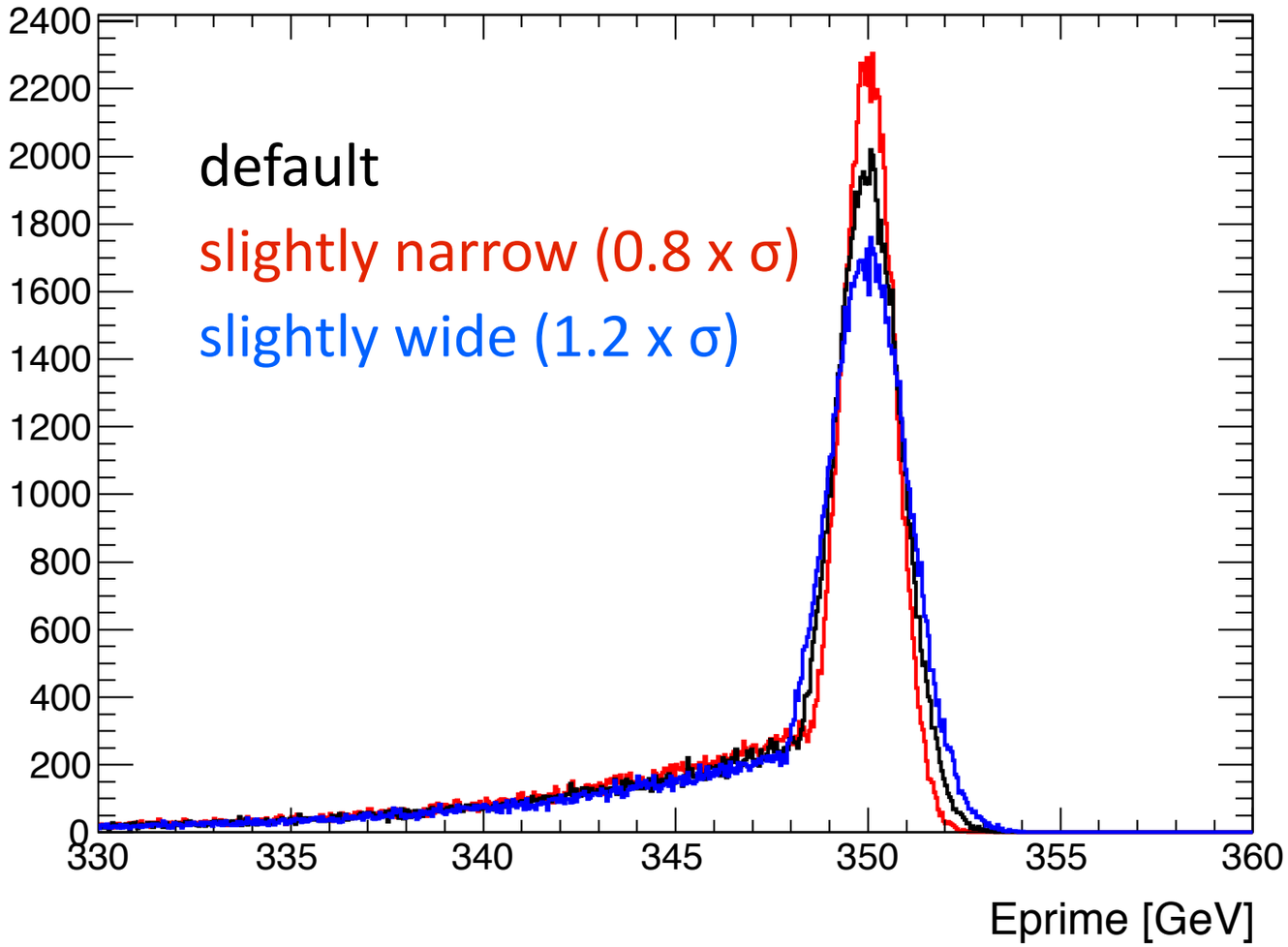
Effect on the Top Threshold



Quick study:
Fit with the default spectrum, study data distributions following default, narrow, wide

- Impact of changes: Softer slope for wide spectrum, harder slope for narrow spectrum increased cross section above threshold in both cases

In addition: Less extreme Variations



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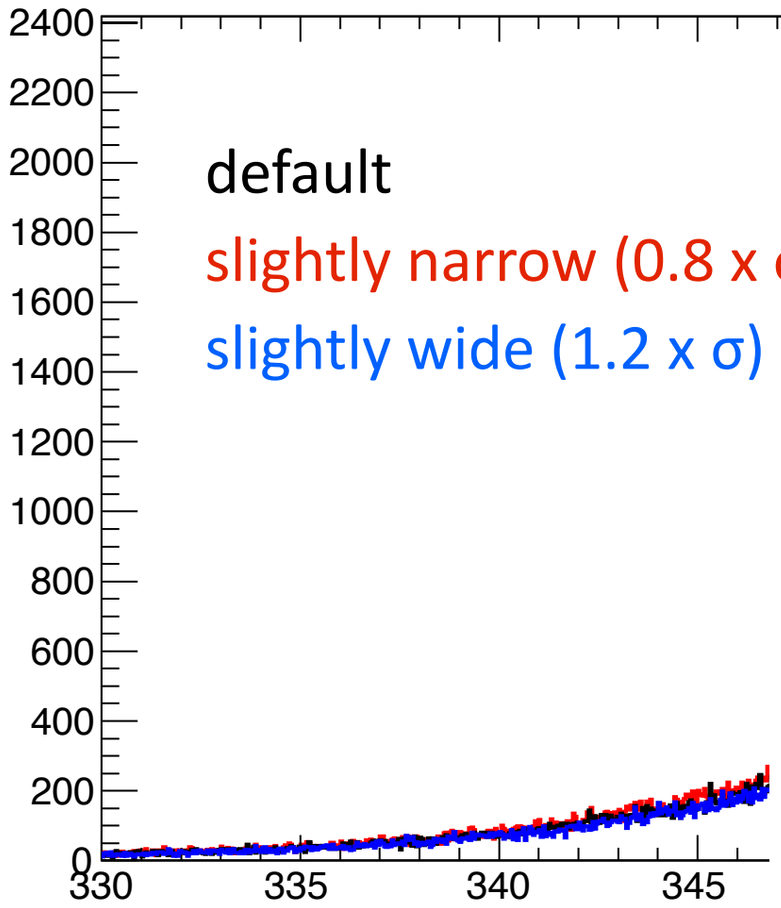
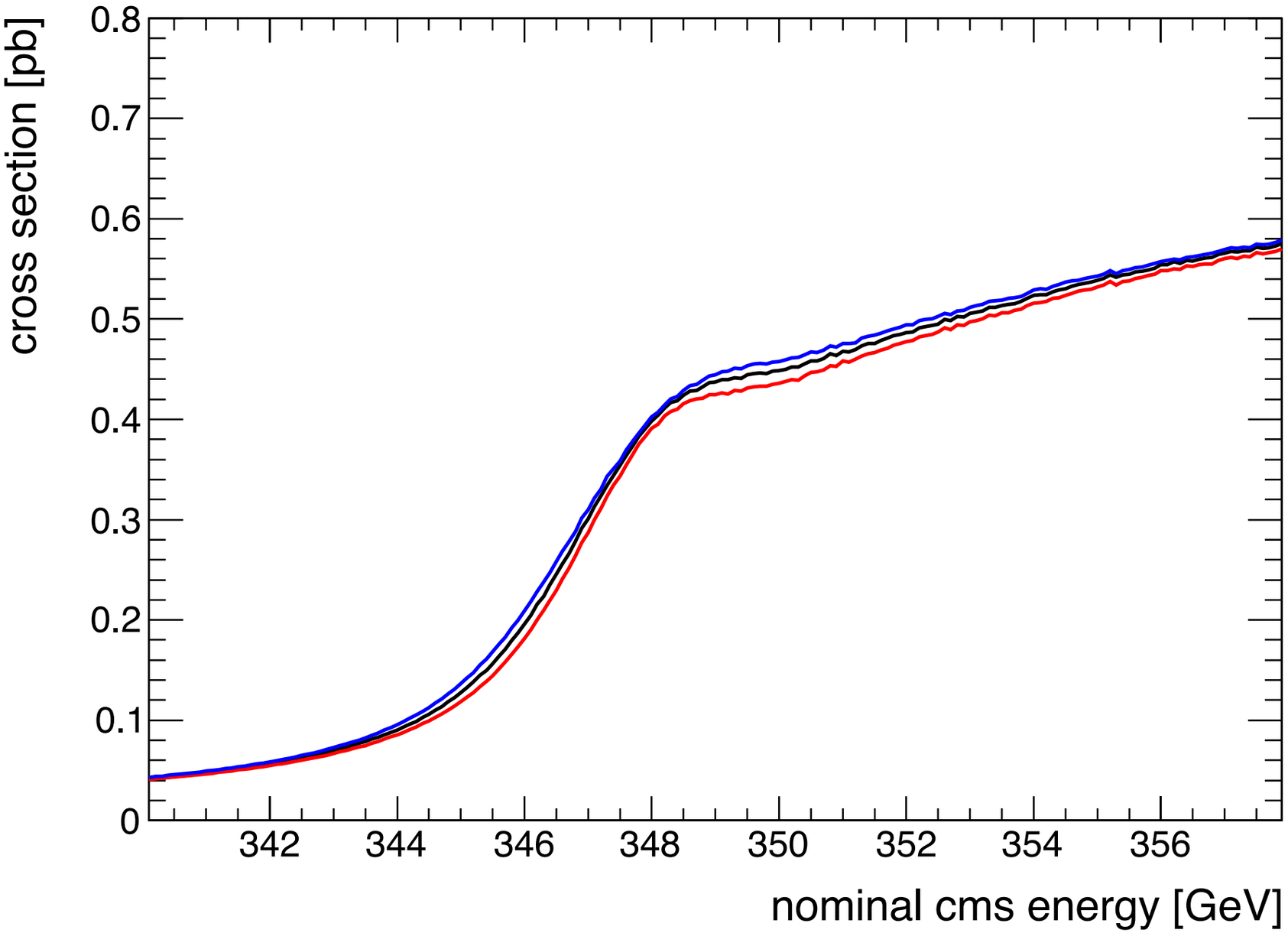
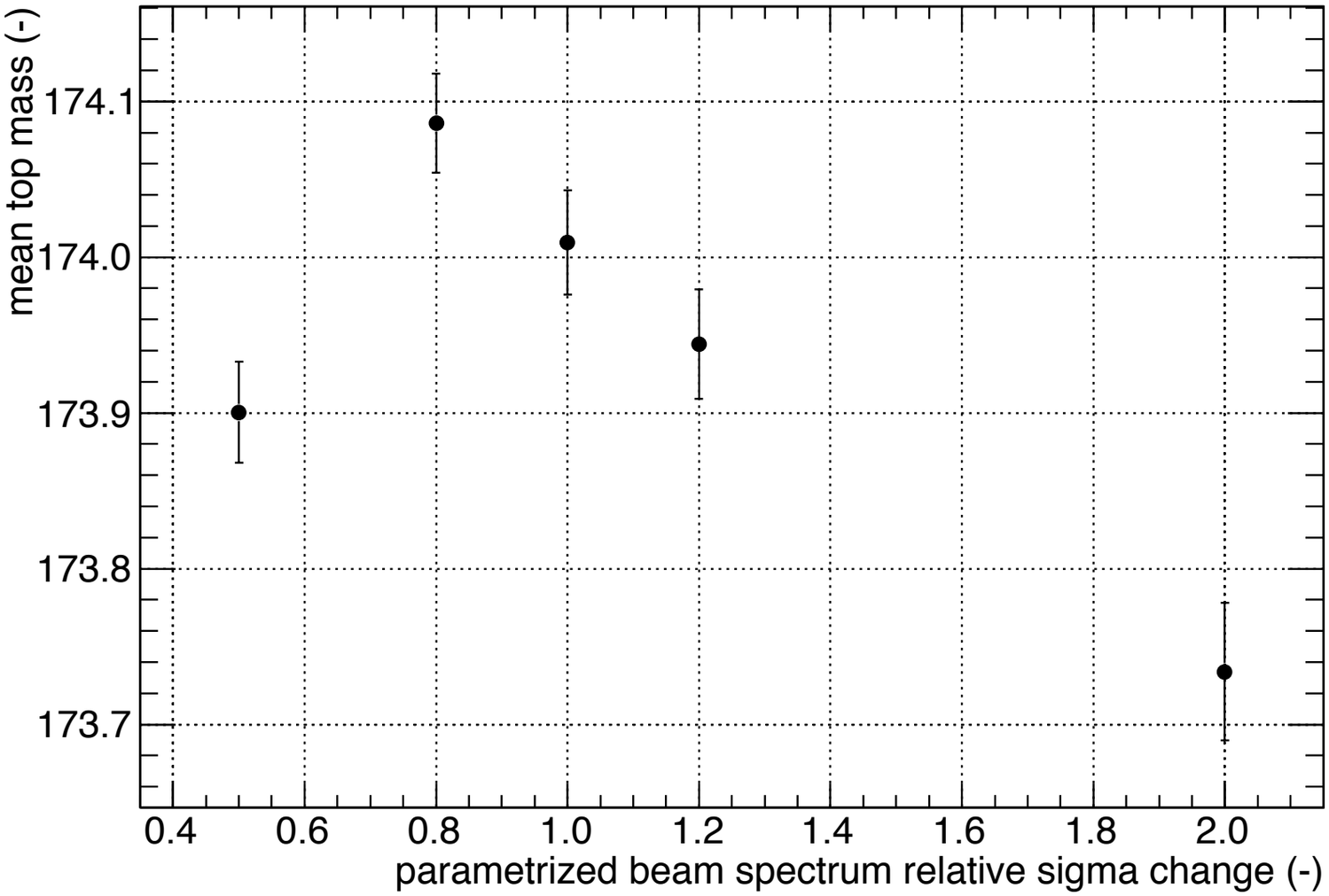


- Moderate impact on cross section: more intuitive ordering of curves



Impact of Changing Spectrum

- The study: Always perform fit with default distribution
  - Data points distributed according to various lumi spectra, always 10 points, 10 fb^{-1} each, in 1 GeV steps



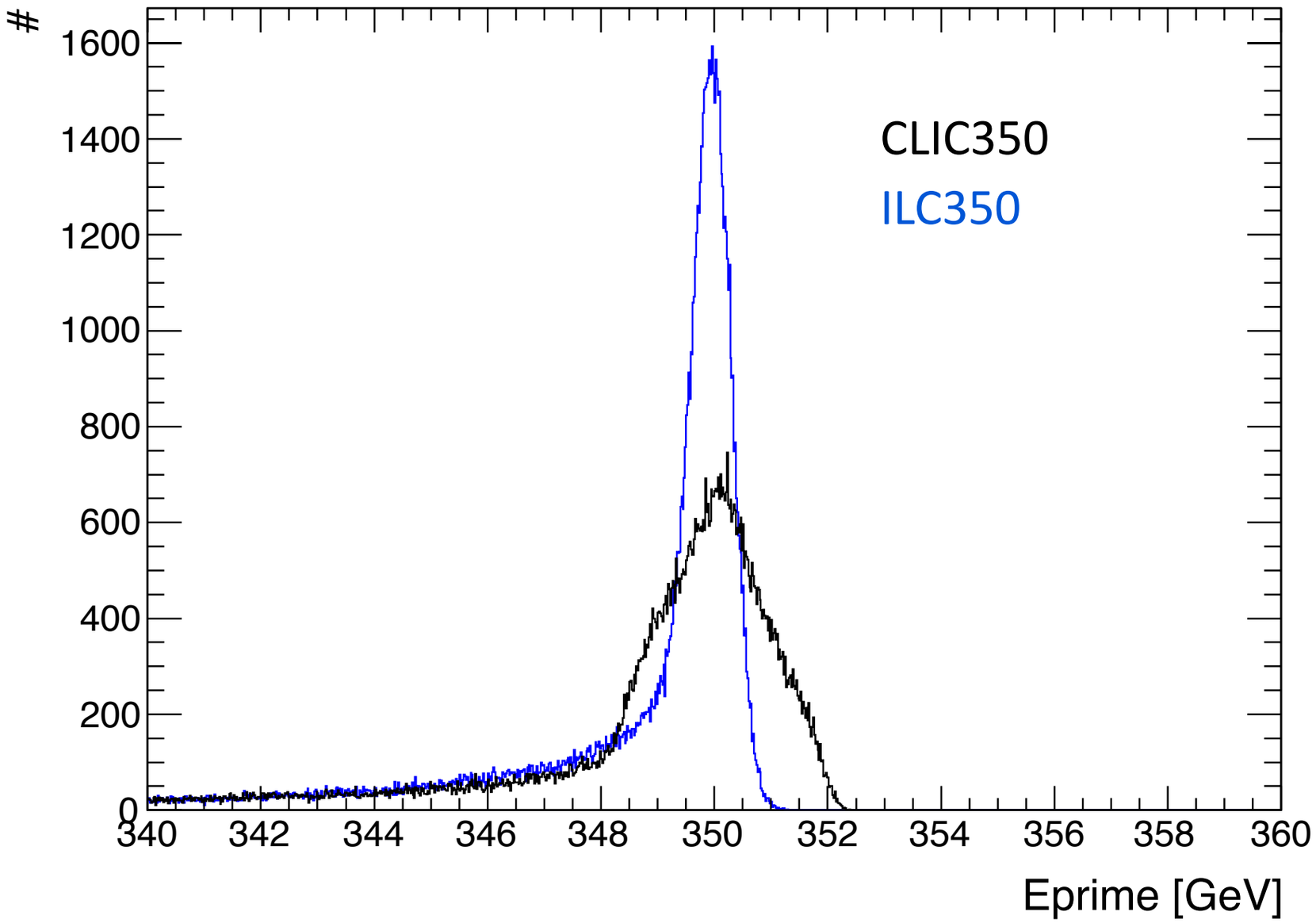
- Substantial bias of the top mass: Already for the smaller variations of the spectrum in excess of expected statistical uncertainty and theory systematics

Conclusions

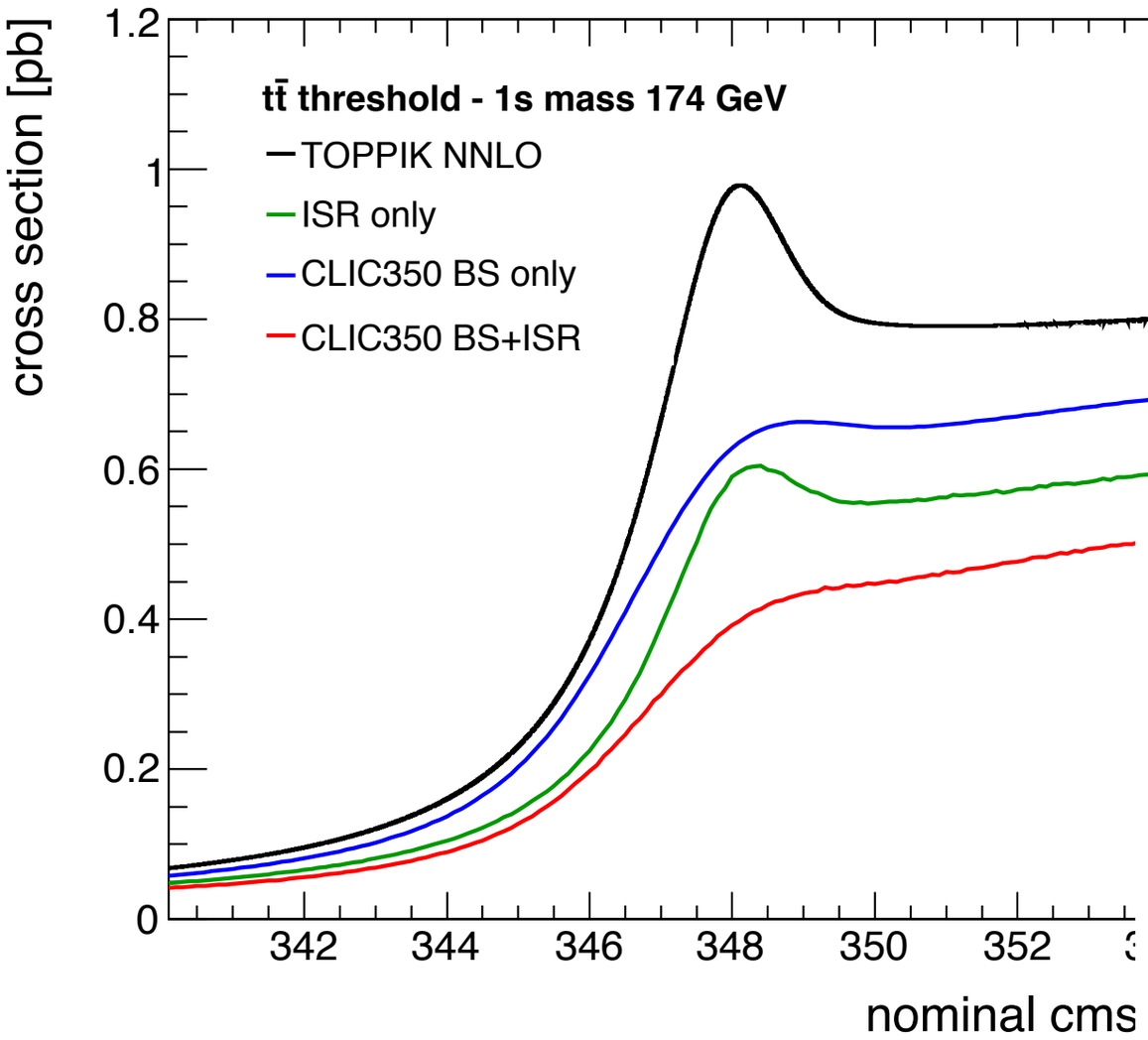
- The beam spectrum itself has a moderate effect on the mass resolution
- The knowledge of the beam spectrum is crucial: Strongly affect precision
  - Particularly important: The knowledge of the main peak of the luminosity distribution
- For a full study: Need to know the expected precision of the luminosity spectrum measurement - Ideally with two additional sets of lumi files (+- 1 sigma)

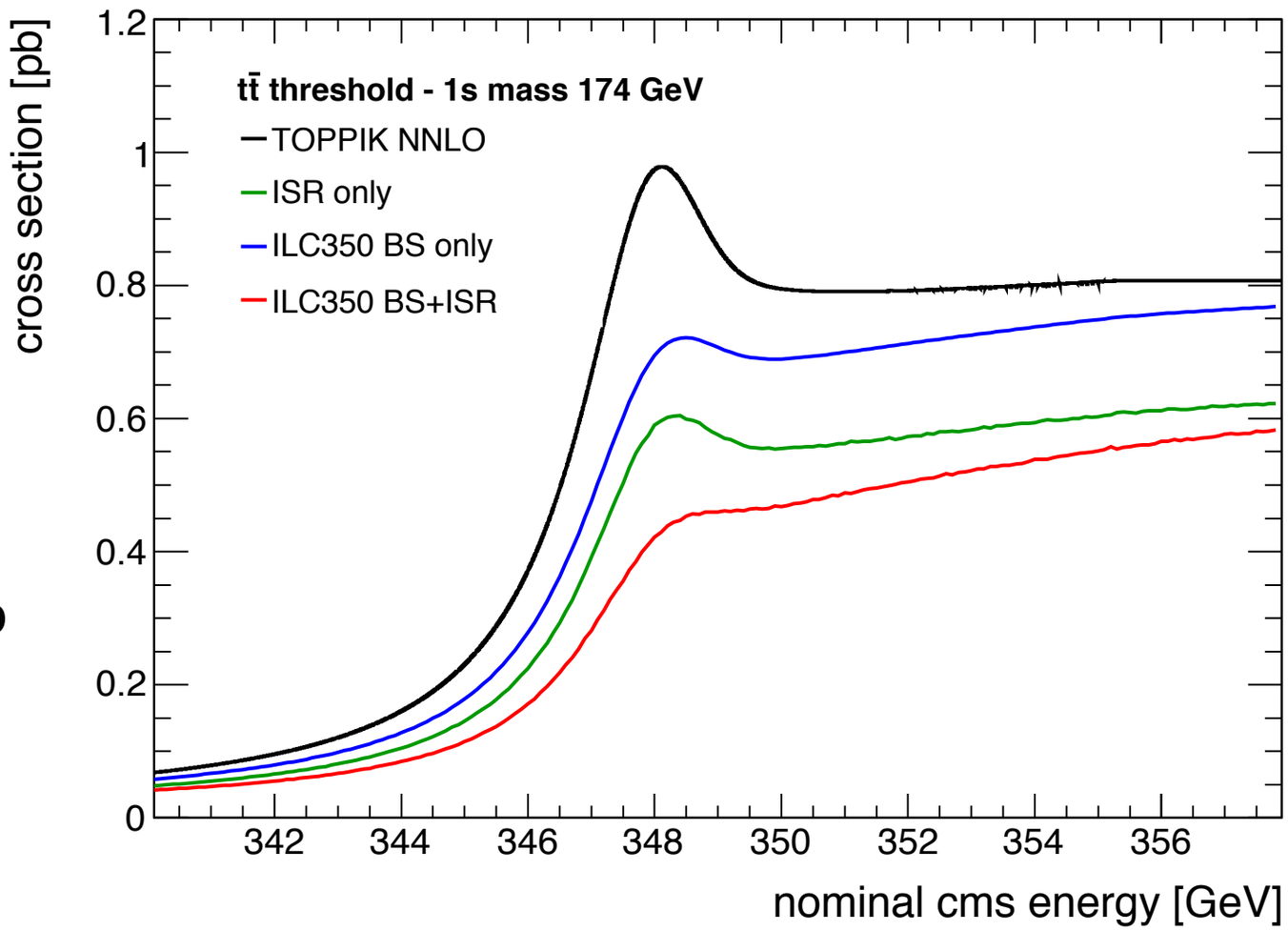
Backup

Beam Spectrum: CLIC vs ILC



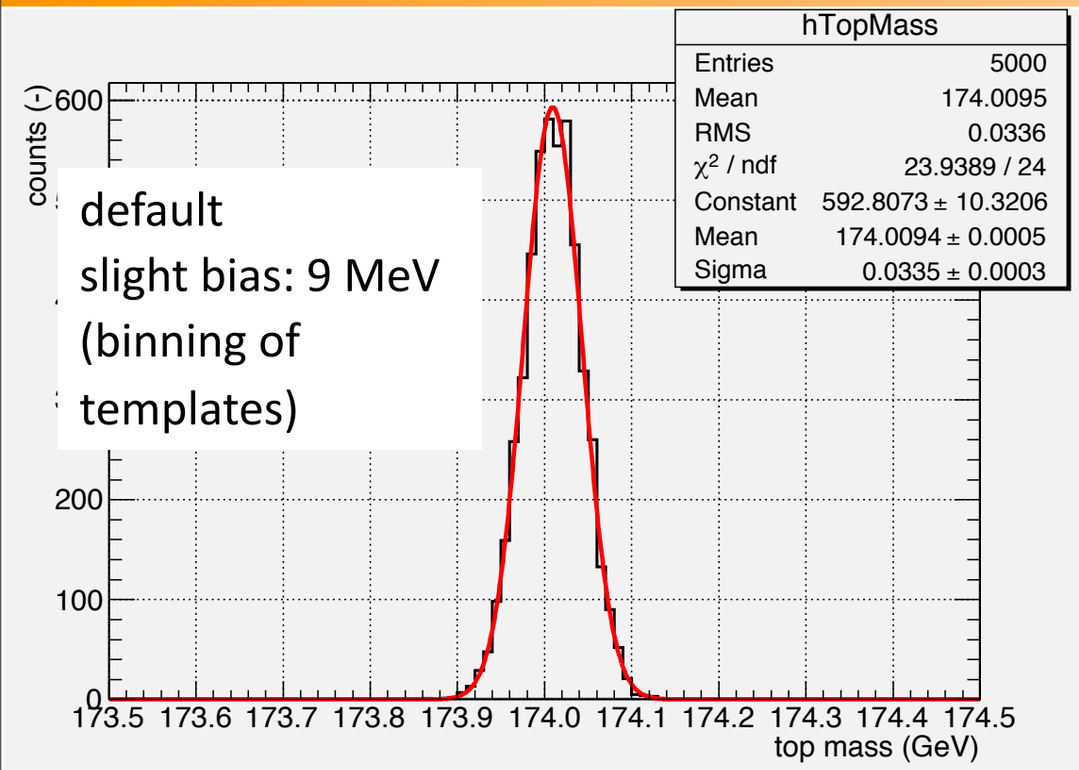
Top Threshold: CLIC vs ILC

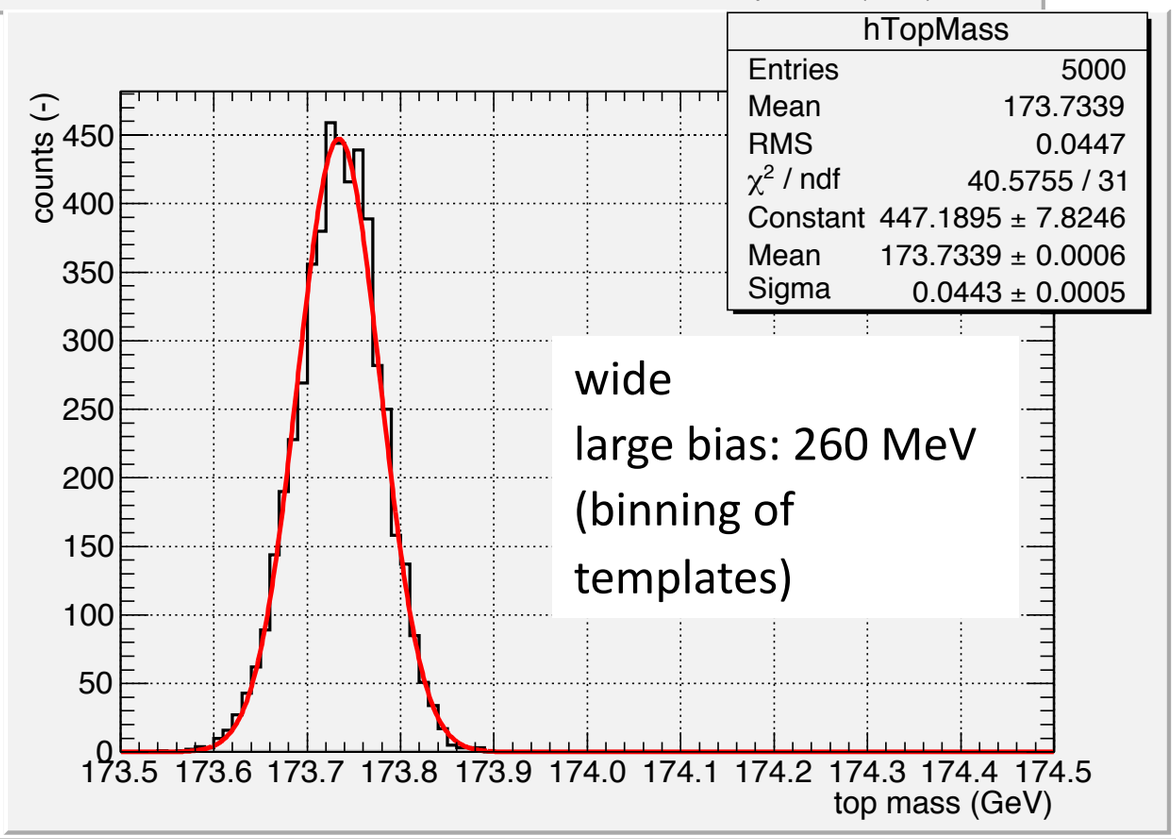


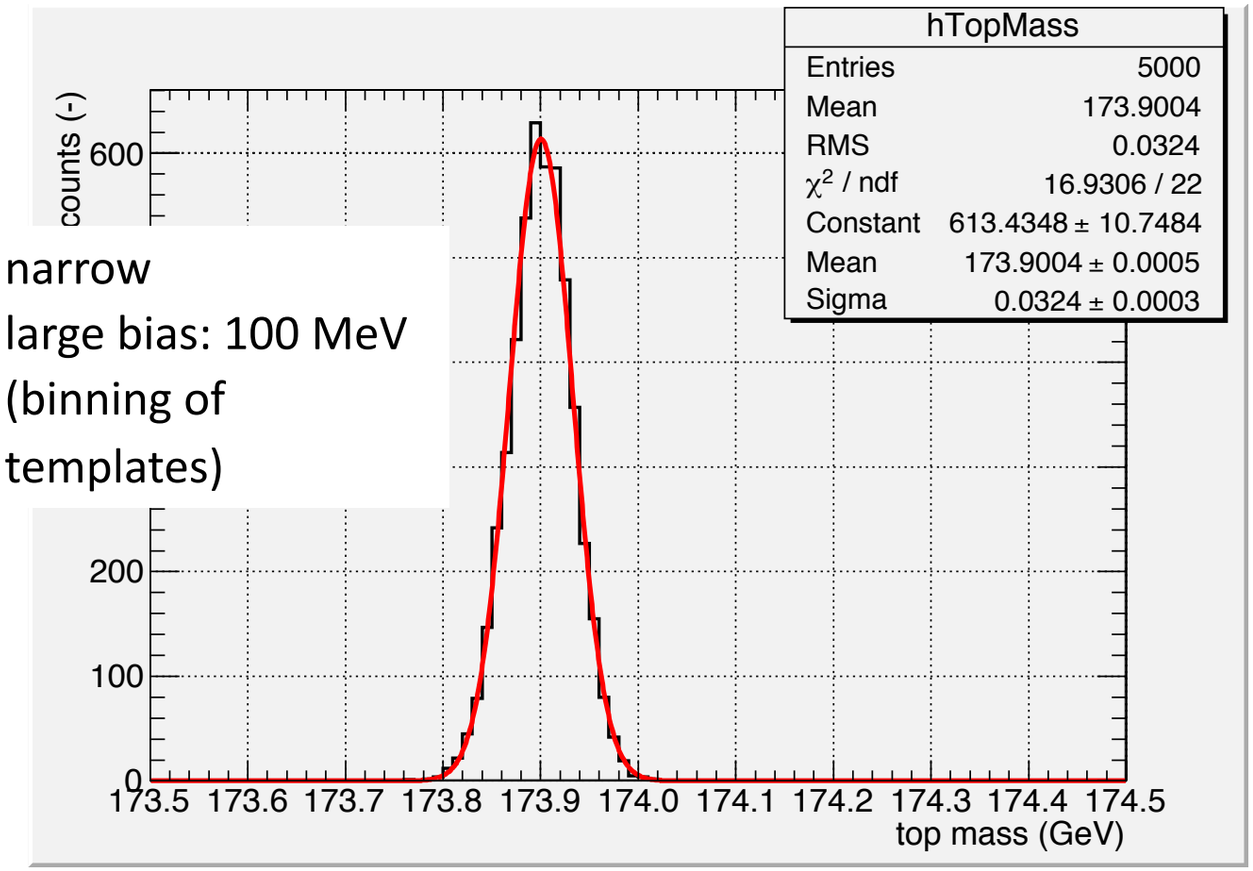


Broader beam energy spectrum leads to softening of edge:

Template Fits - Results







- Substantial bias, far in excess of statistical uncertainty (can potentially be mitigated by different choice of scan points...)