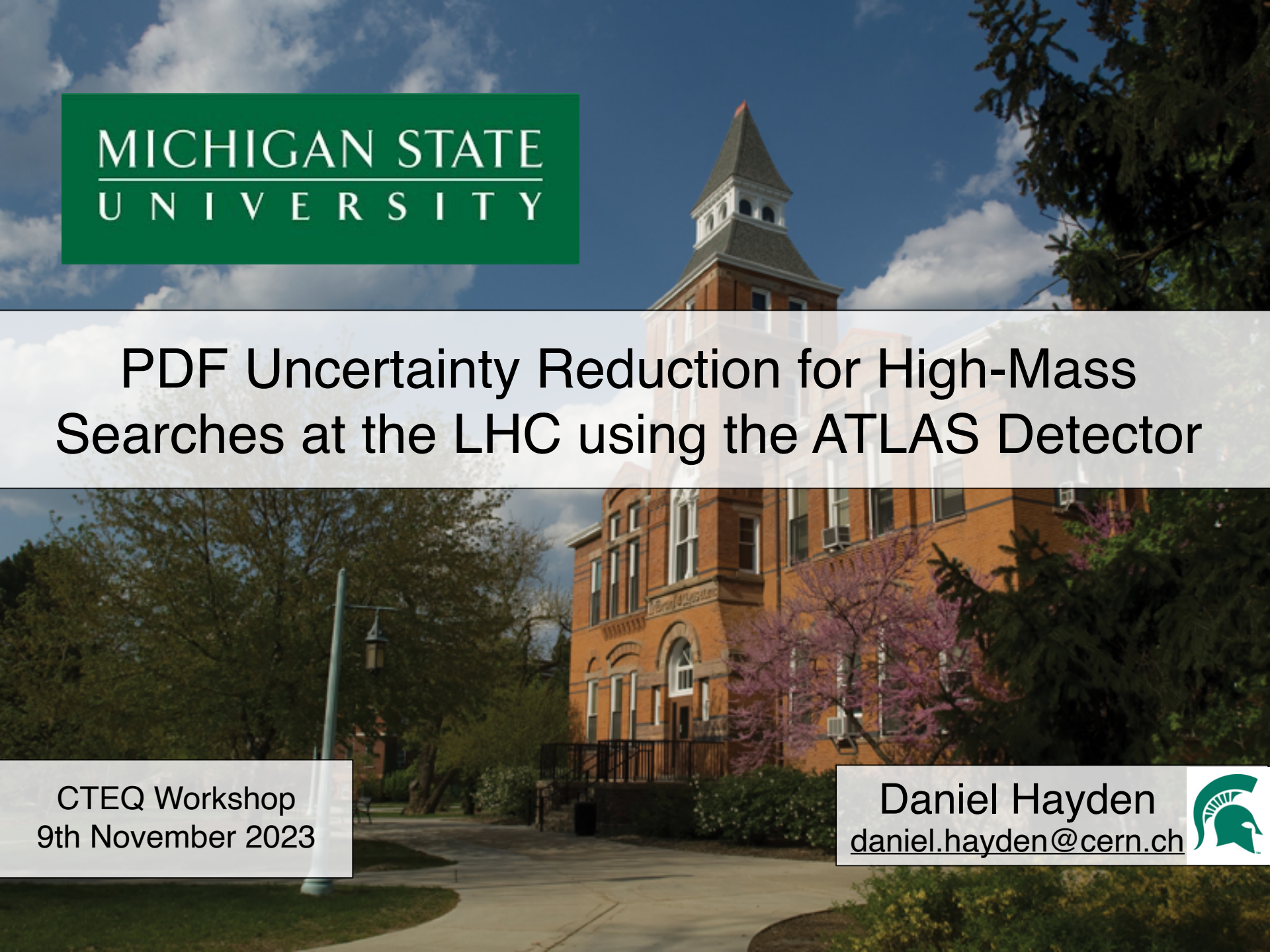

PDF Uncertainty Reduction for High-Mass Searches at the LHC using the ATLAS Detector

CTEQ Workshop
9th November 2023

Daniel Hayden
daniel.hayden@cern.ch

Introduction

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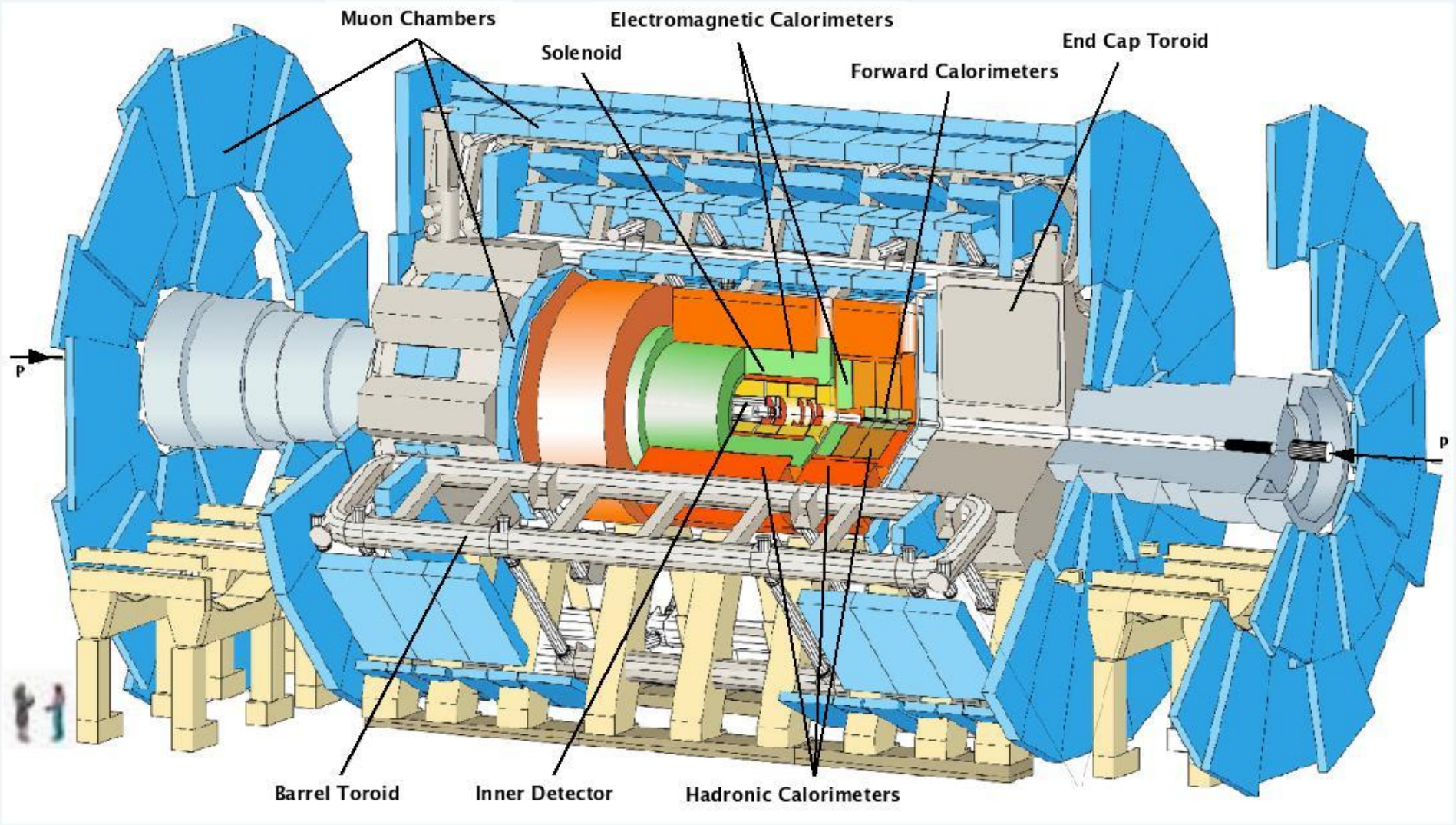

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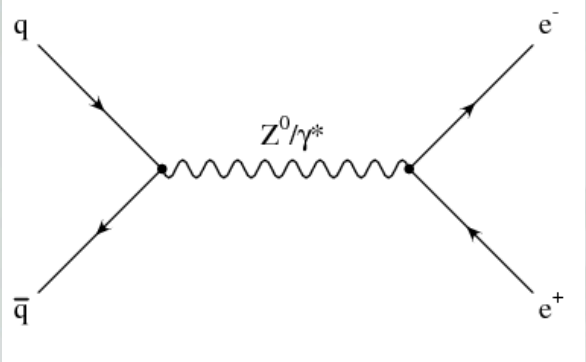

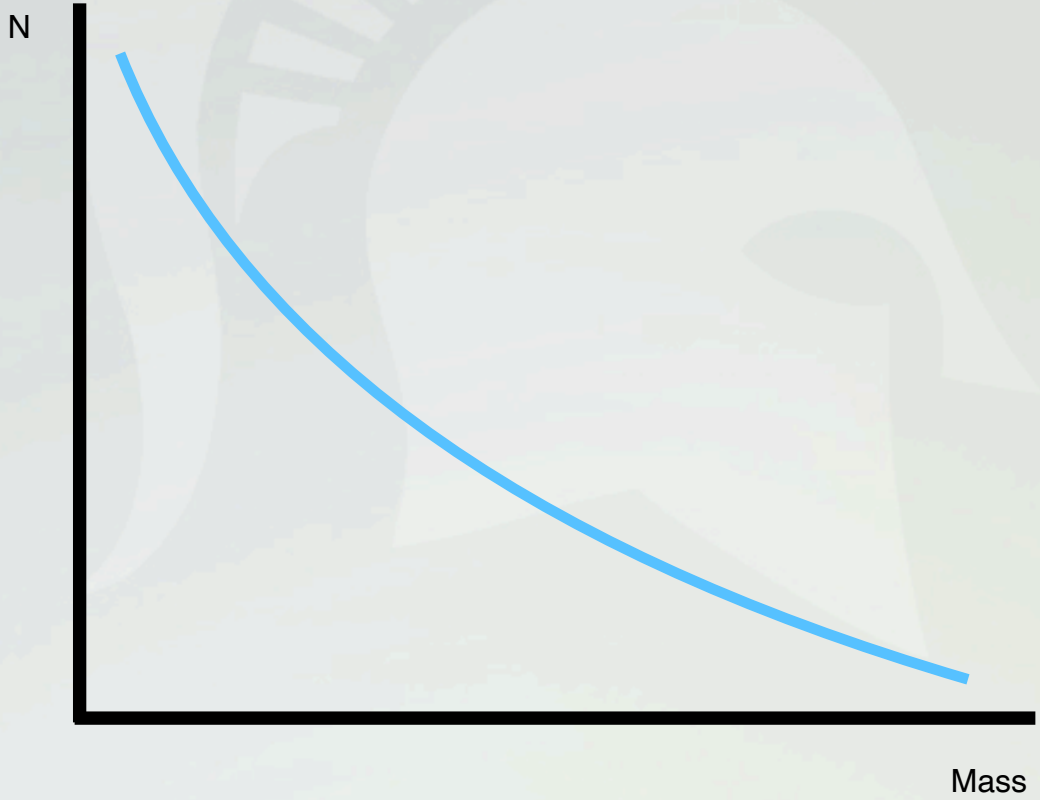

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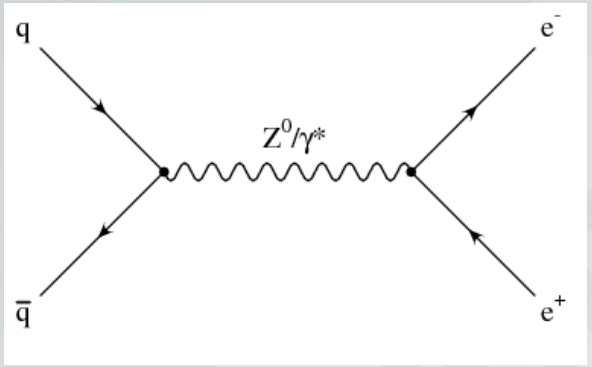

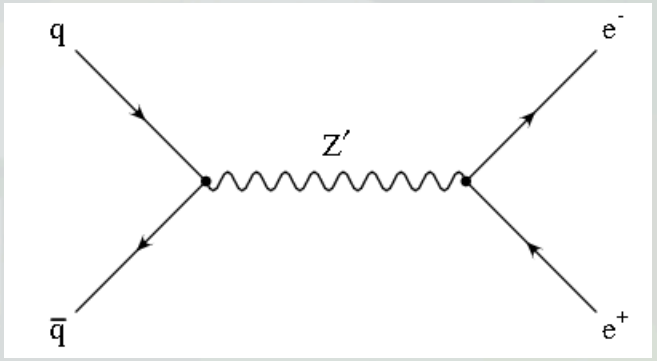

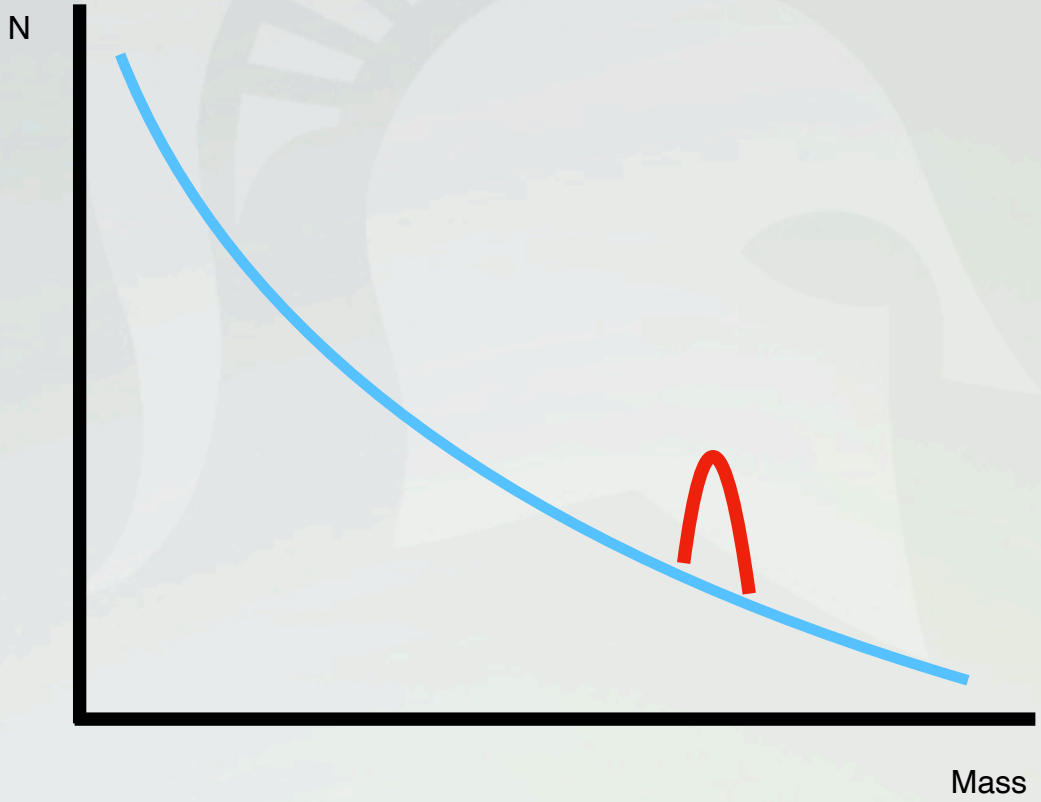

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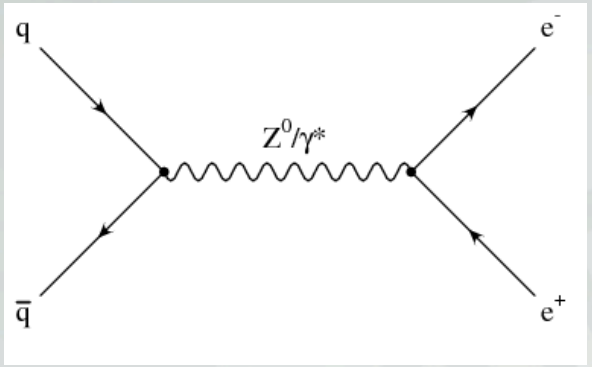

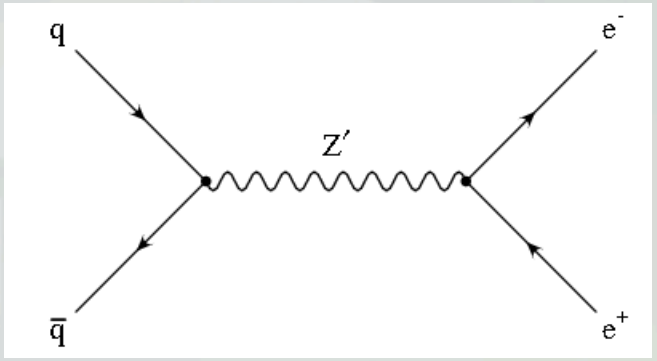

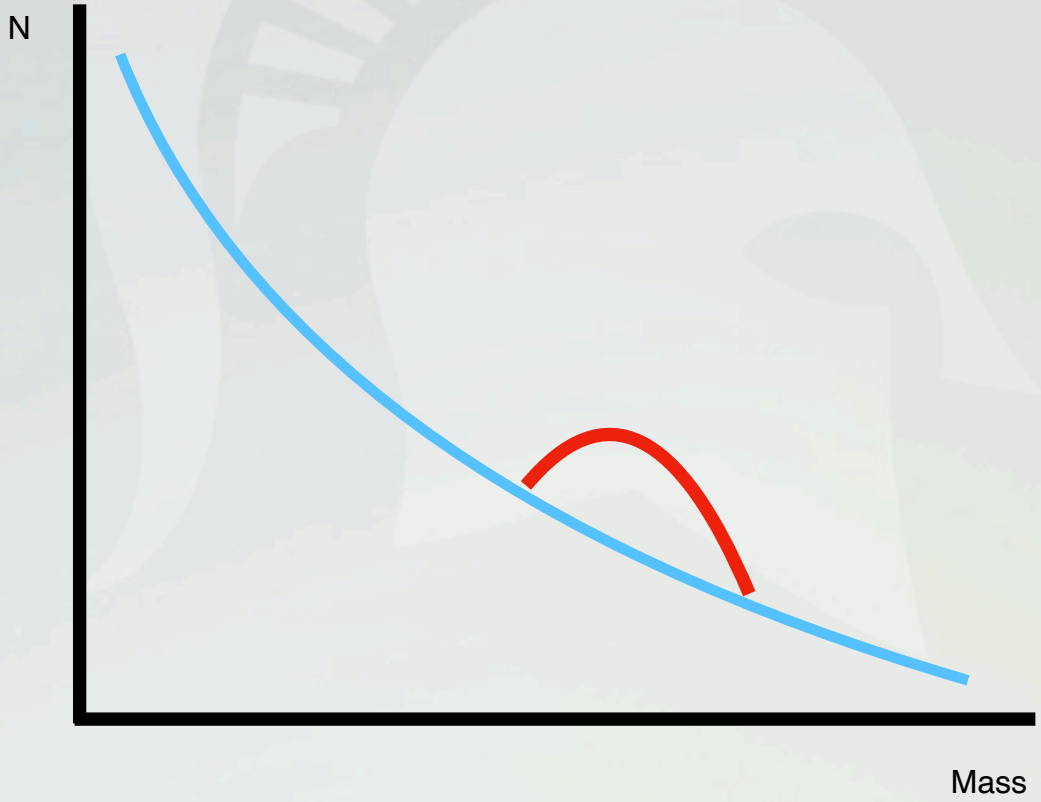

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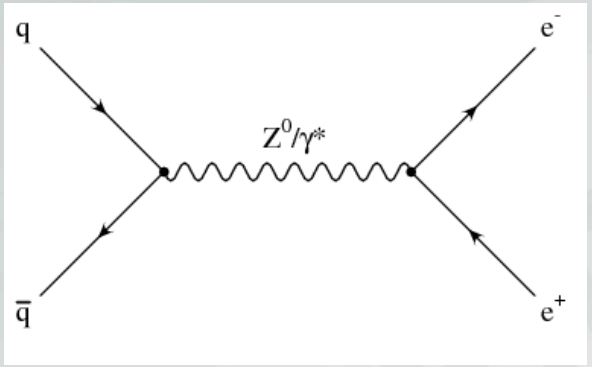

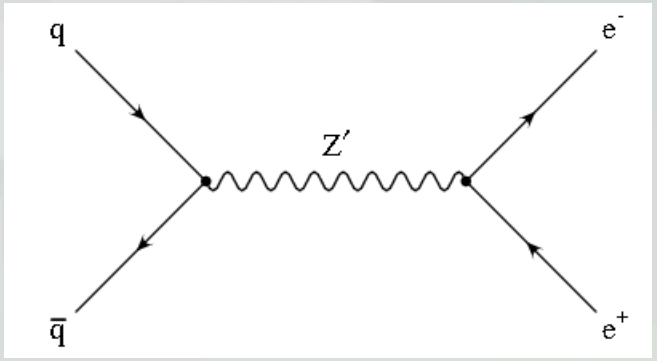

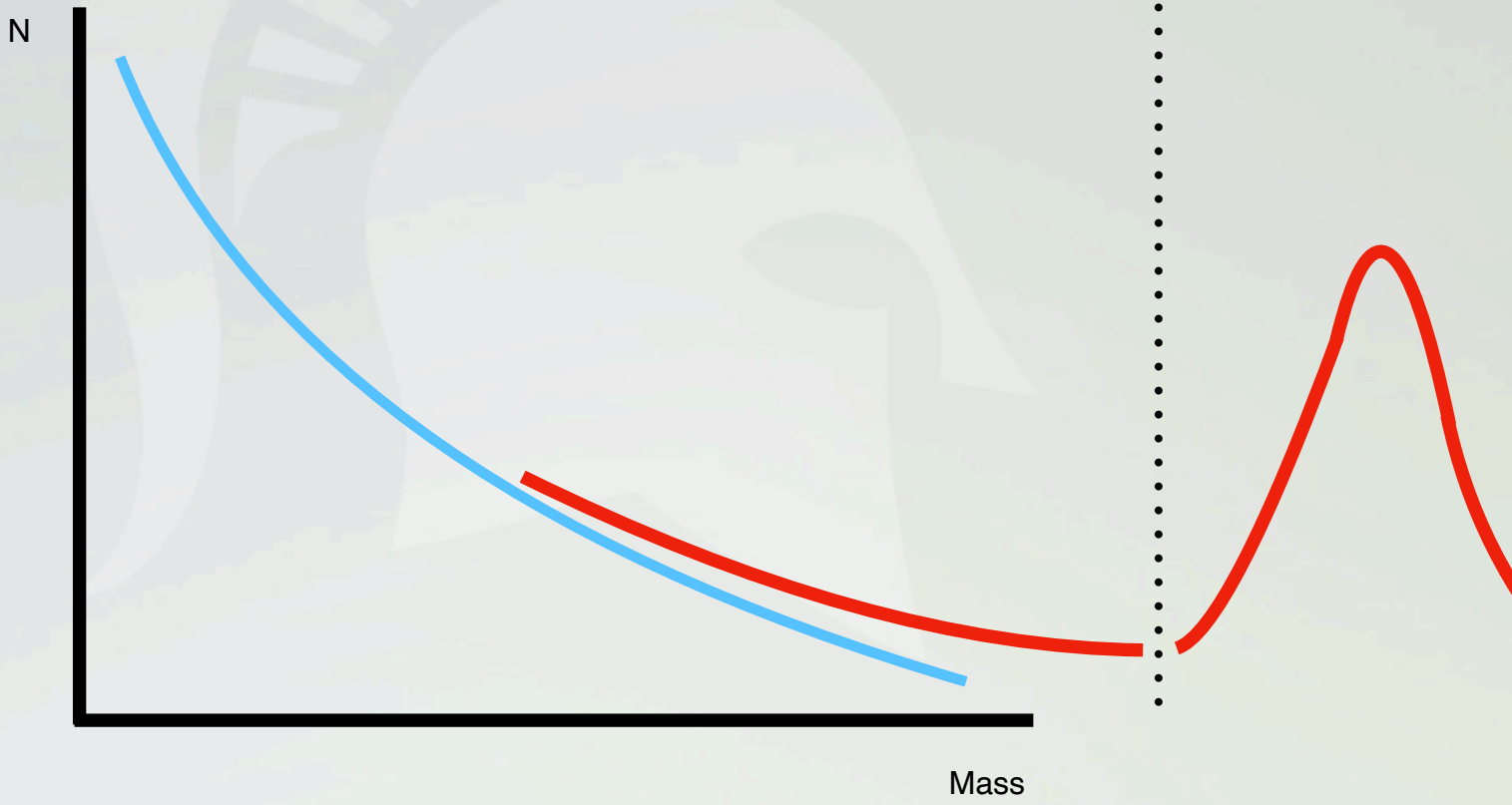

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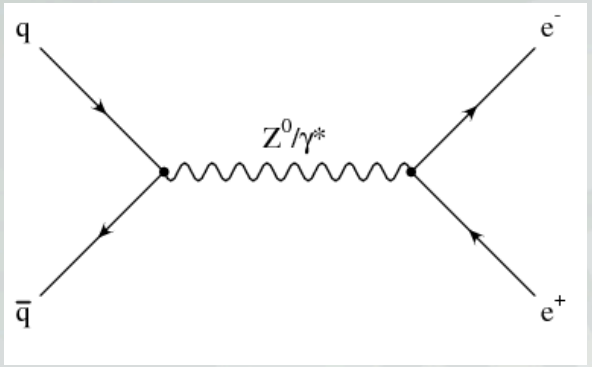
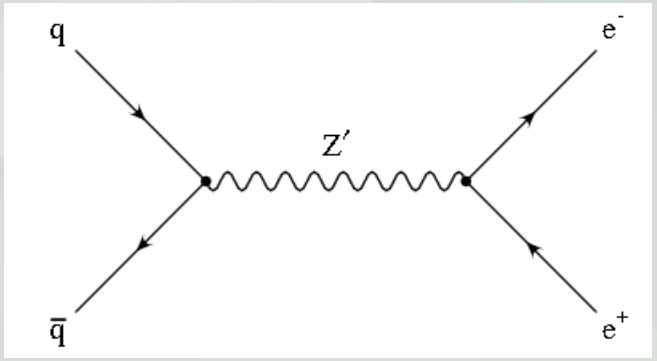




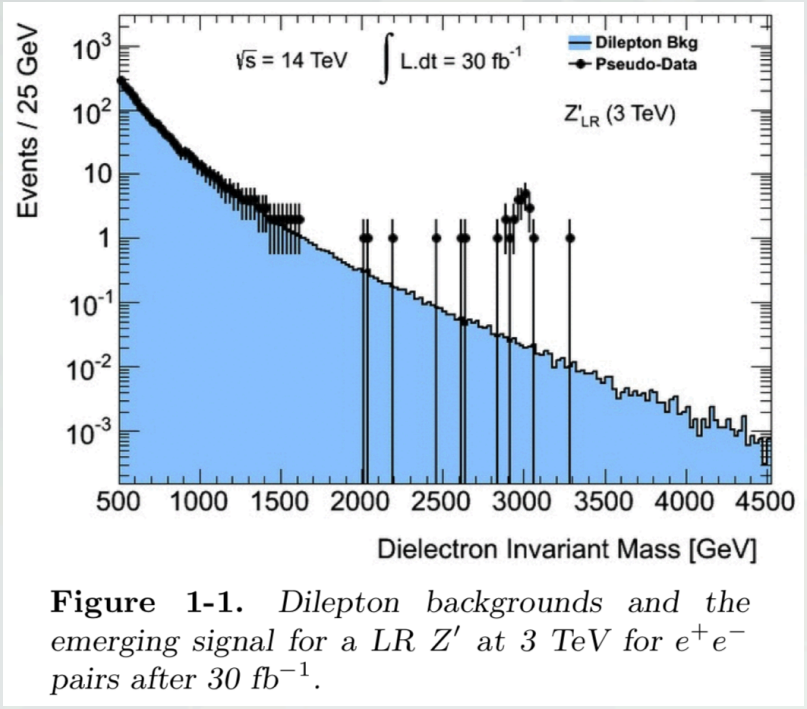
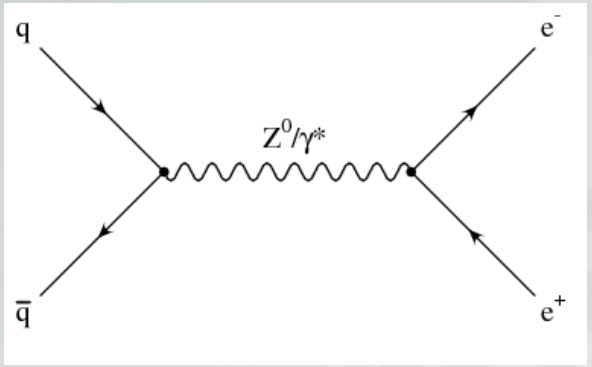


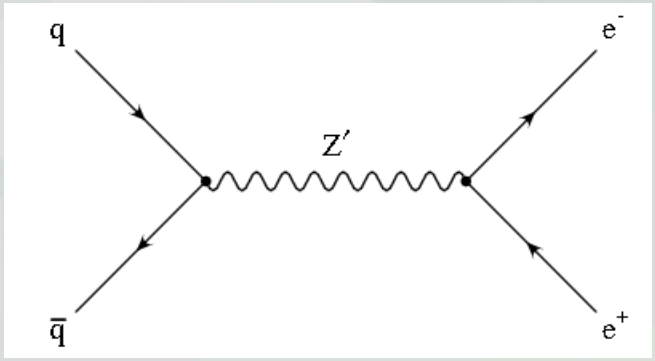
Figure 1-1. *Dilepton backgrounds and the emerging signal for a LR Z' at 3 TeV for e^+e^- pairs after 30 fb^{-1}.*

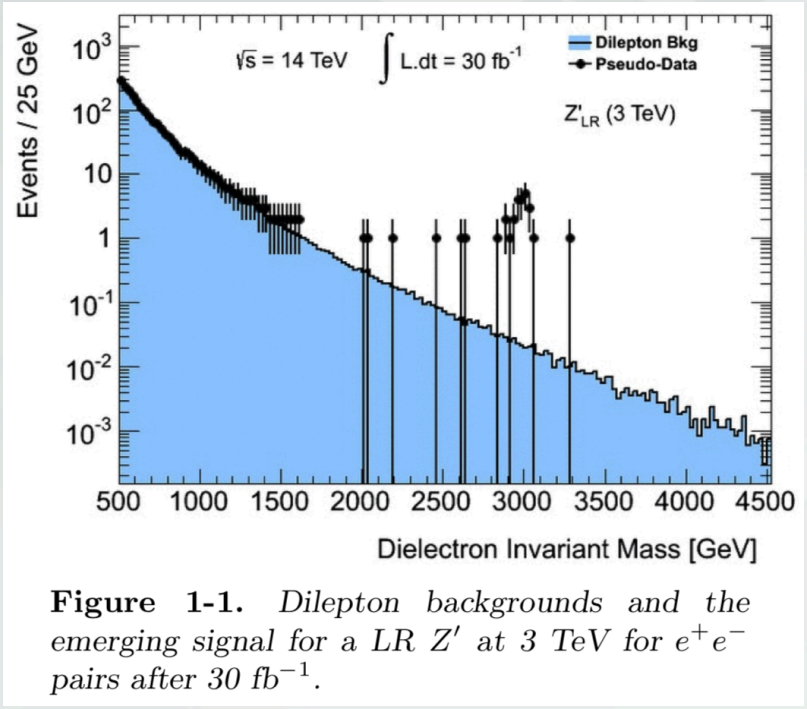
https://arxiv.org/abs/1308.5874

https://arxiv.org/abs/1207.7214

Introduction







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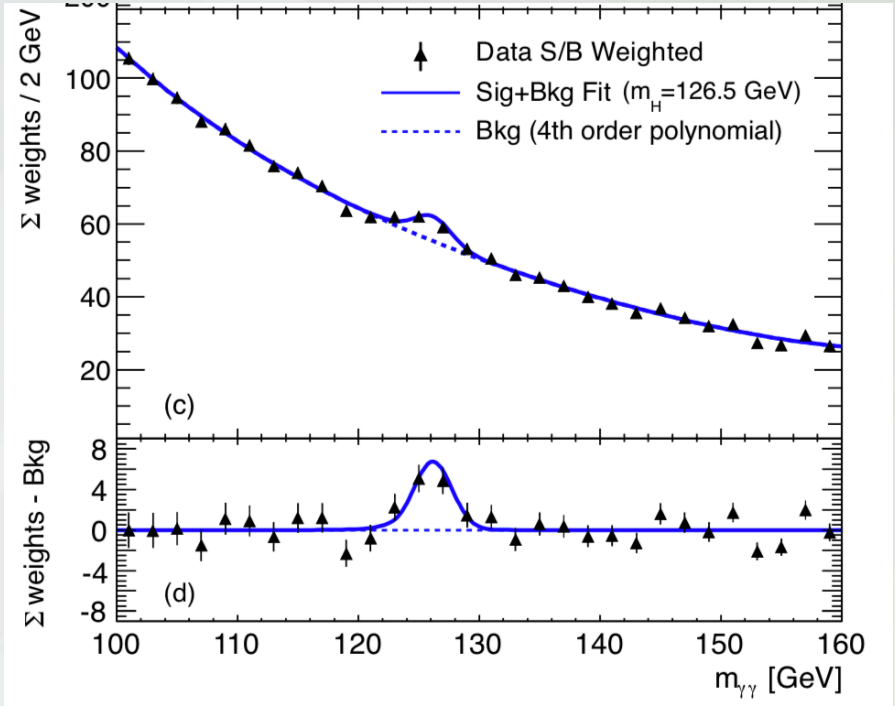

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The Problem

- A high mass discovery would therefore likely proceed differently than many discoveries in the past, facing different challenges.
- Experimental uncertainties reduce with time and effort, but difficult to reduce theory uncertainties without further input.

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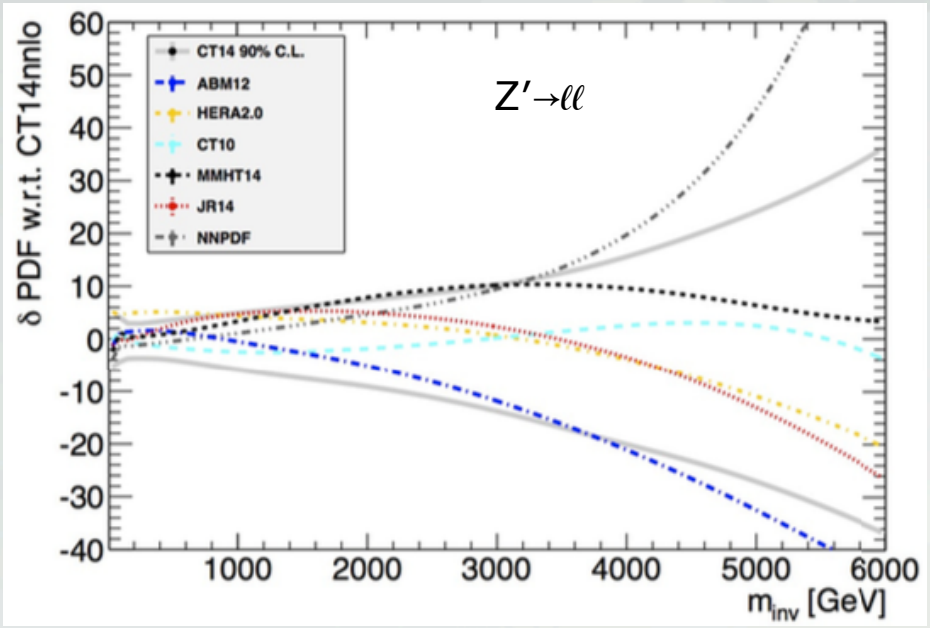
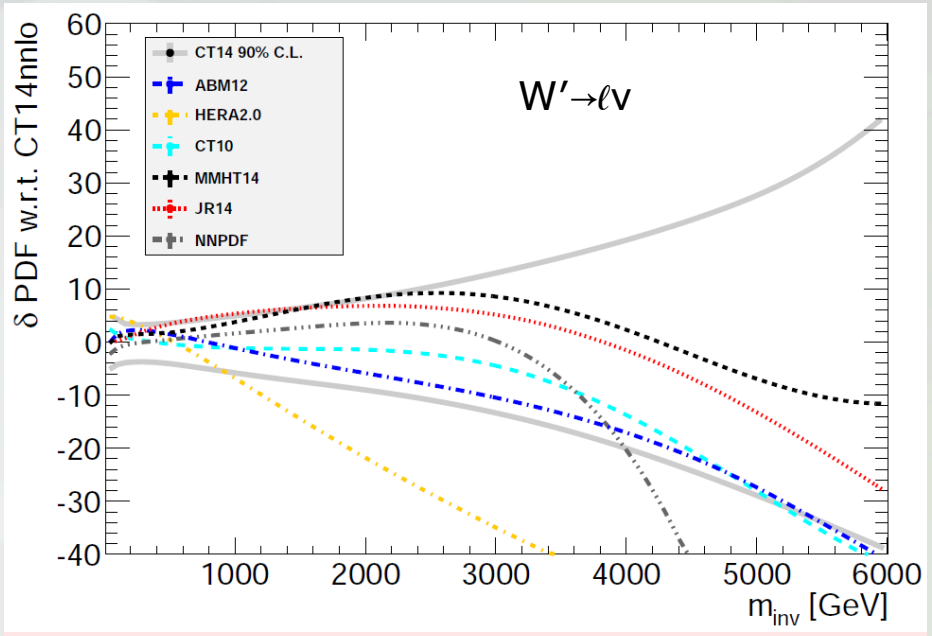




- (Above) PDF eigen-vector variation and PDF choice uncertainty (%)

The Problem

- Resonance Searches: theory uncertainties reduce sensitivity but mainly hamper efforts to distinguish between models.

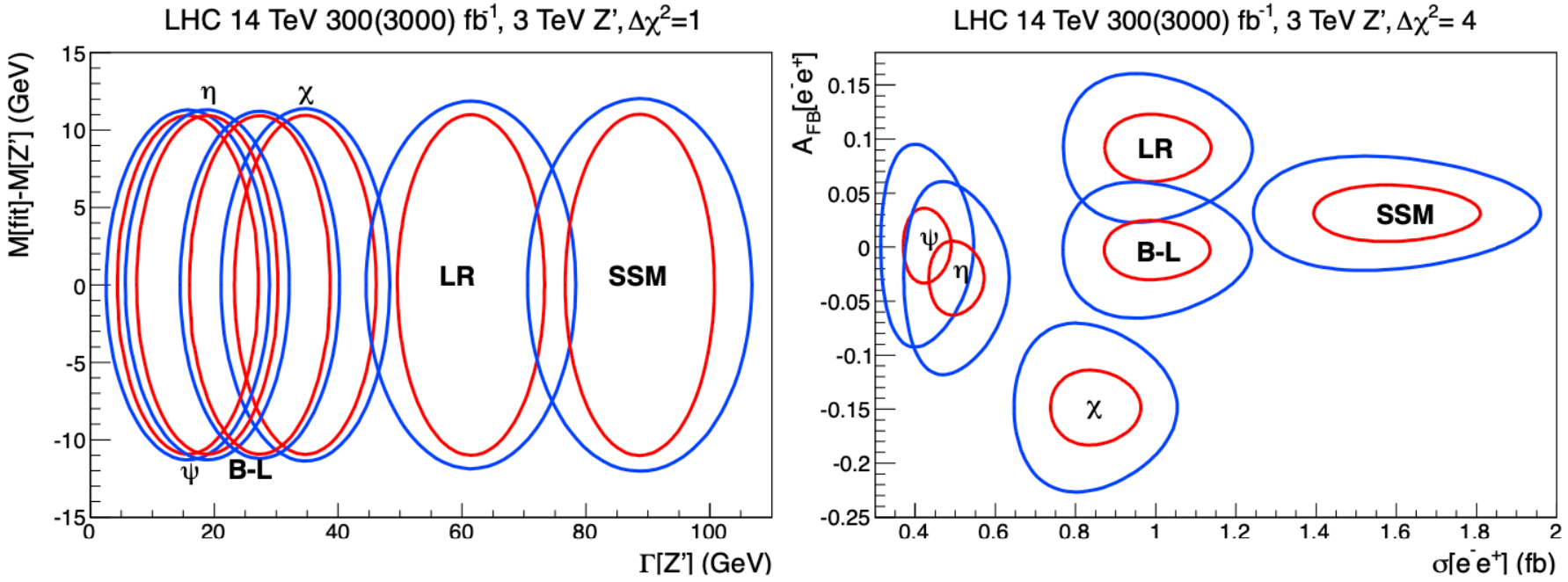
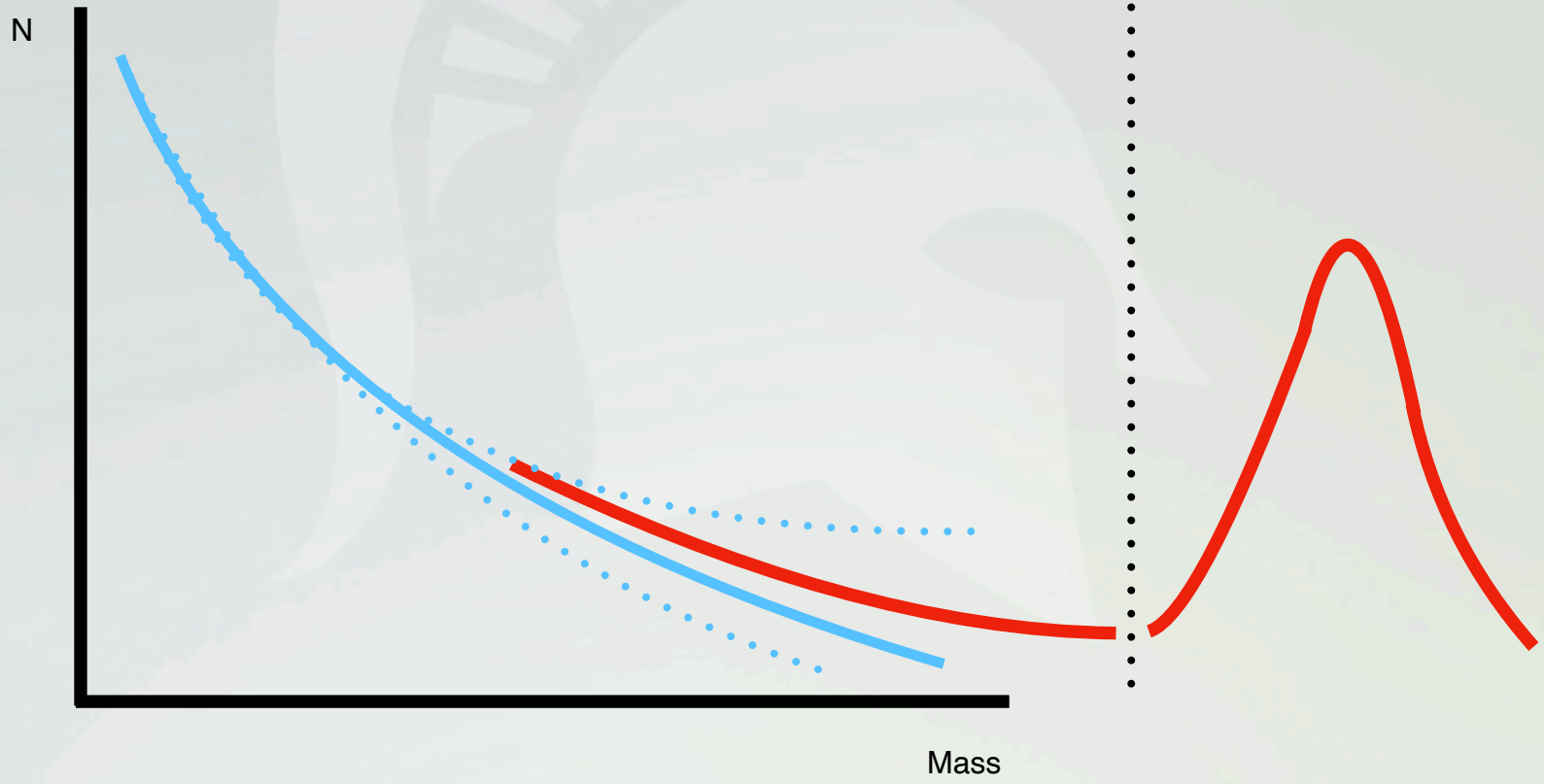


Figure 2. The results for $pp \to Z' \to e^- e^+$ with dielectron invariant mass from $2.8 - 3.2$ TeV. *Left panel*: $\Delta\chi^2 = 1$ contours for the fitted width versus mass for the LHC at 300 fb^{-1} and 3000 fb^{-1}. *Right panel*: $\Delta\chi^2 = 4$ contours of the simulated forward-asymmetry versus the cross section.

https://arxiv.org/abs/1308.2738

The Problem

- Resonance Searches: theory uncertainties reduce sensitivity but mainly hamper efforts to distinguish between models.
- Non-Resonant searches: The situation becomes dire. The uncertainties are so large that you might completely lose sensitivity.



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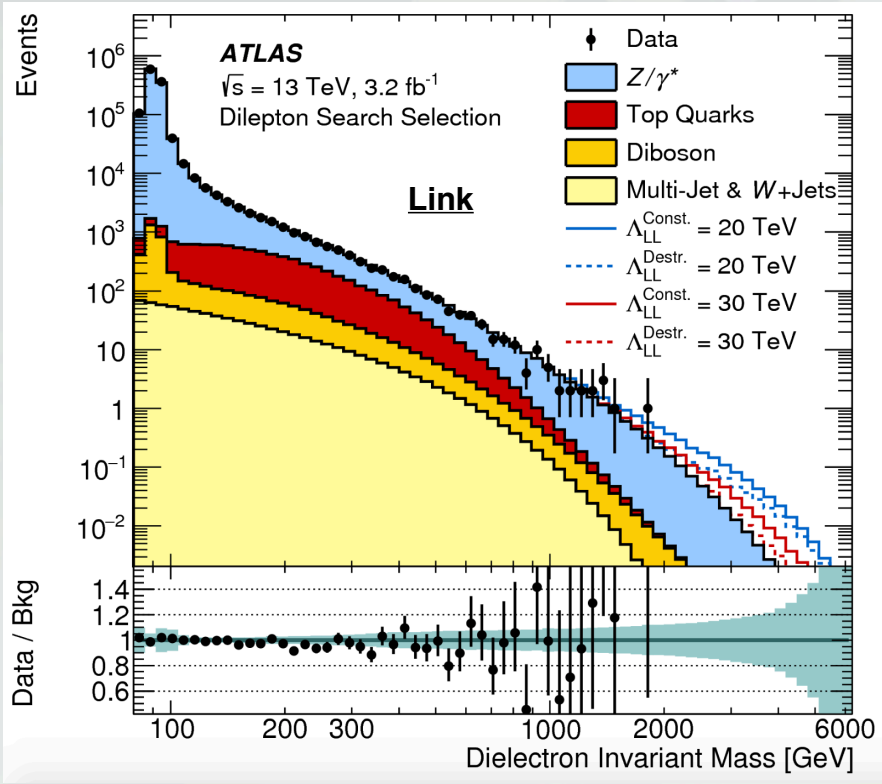
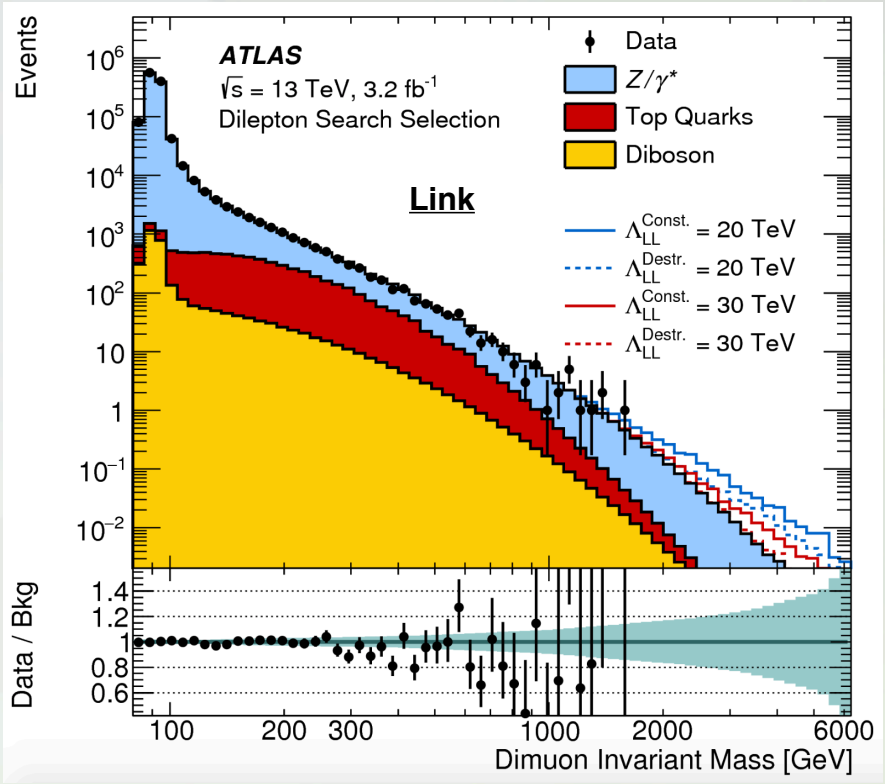
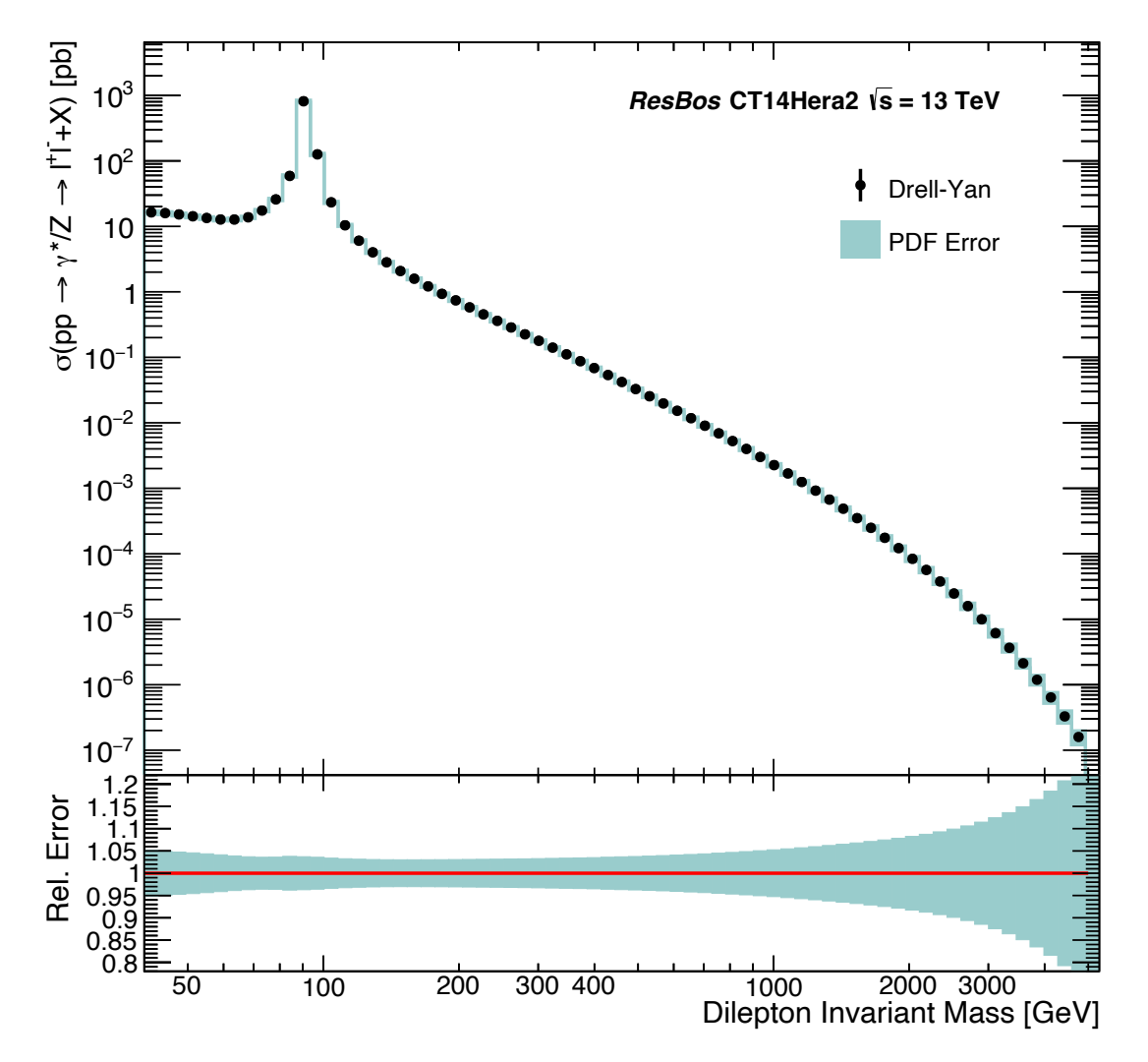




ePump to the Rescue

Link

- In 2019 we (Willis, Brock, Hayden, Hou, Isaacson, Schmidt, Yuan), published a paper identifying a way to tackle this issue.



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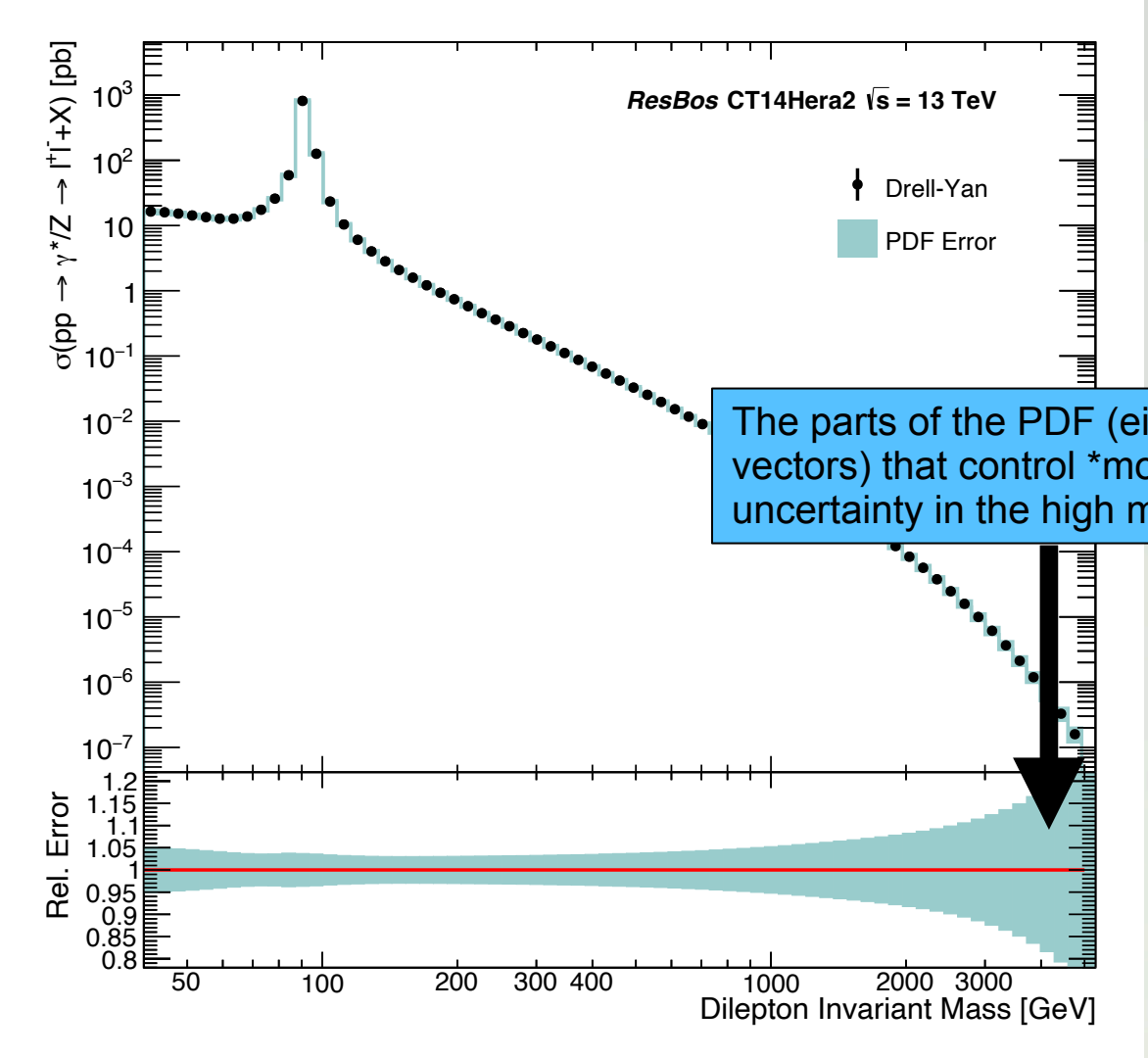

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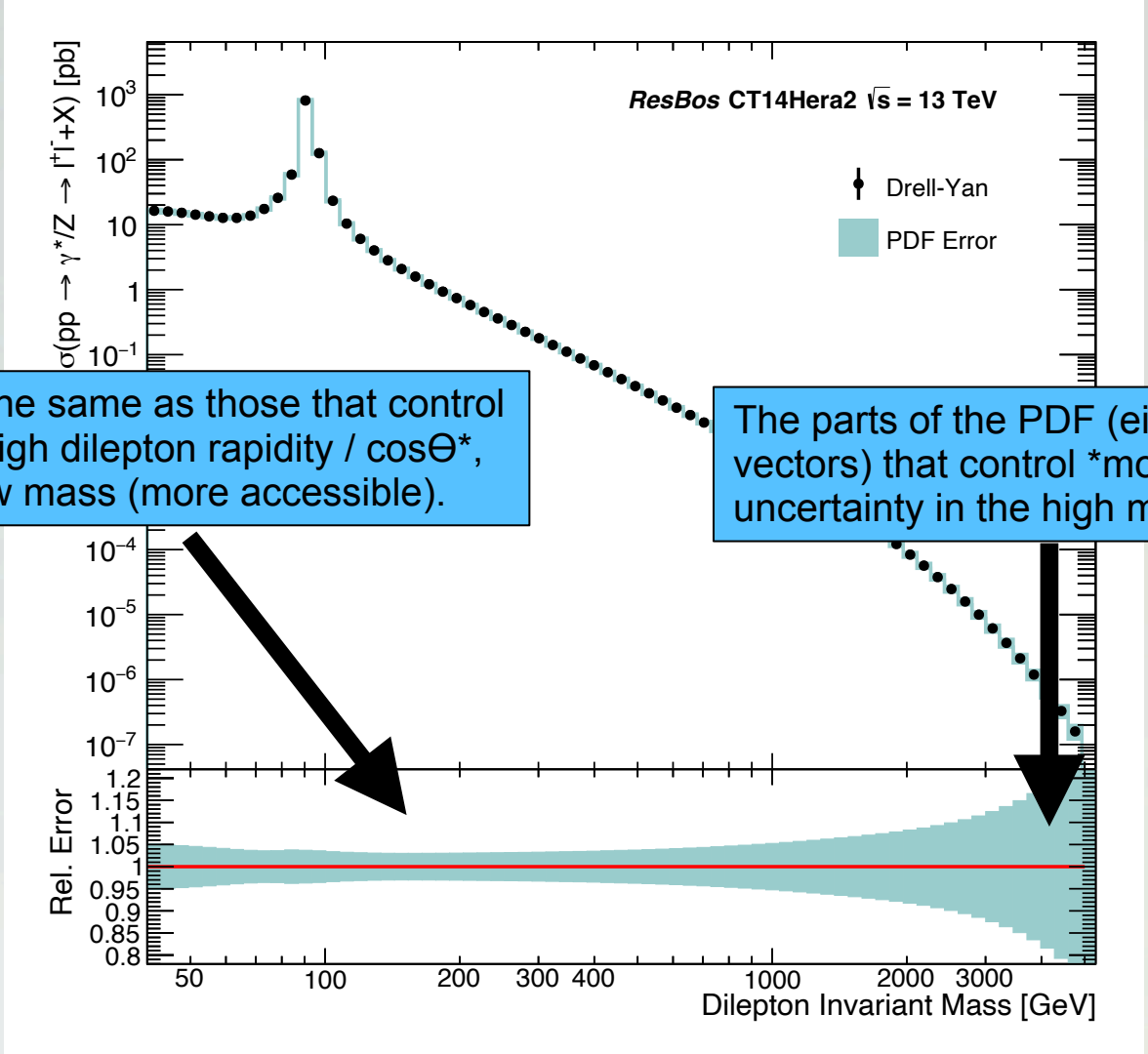

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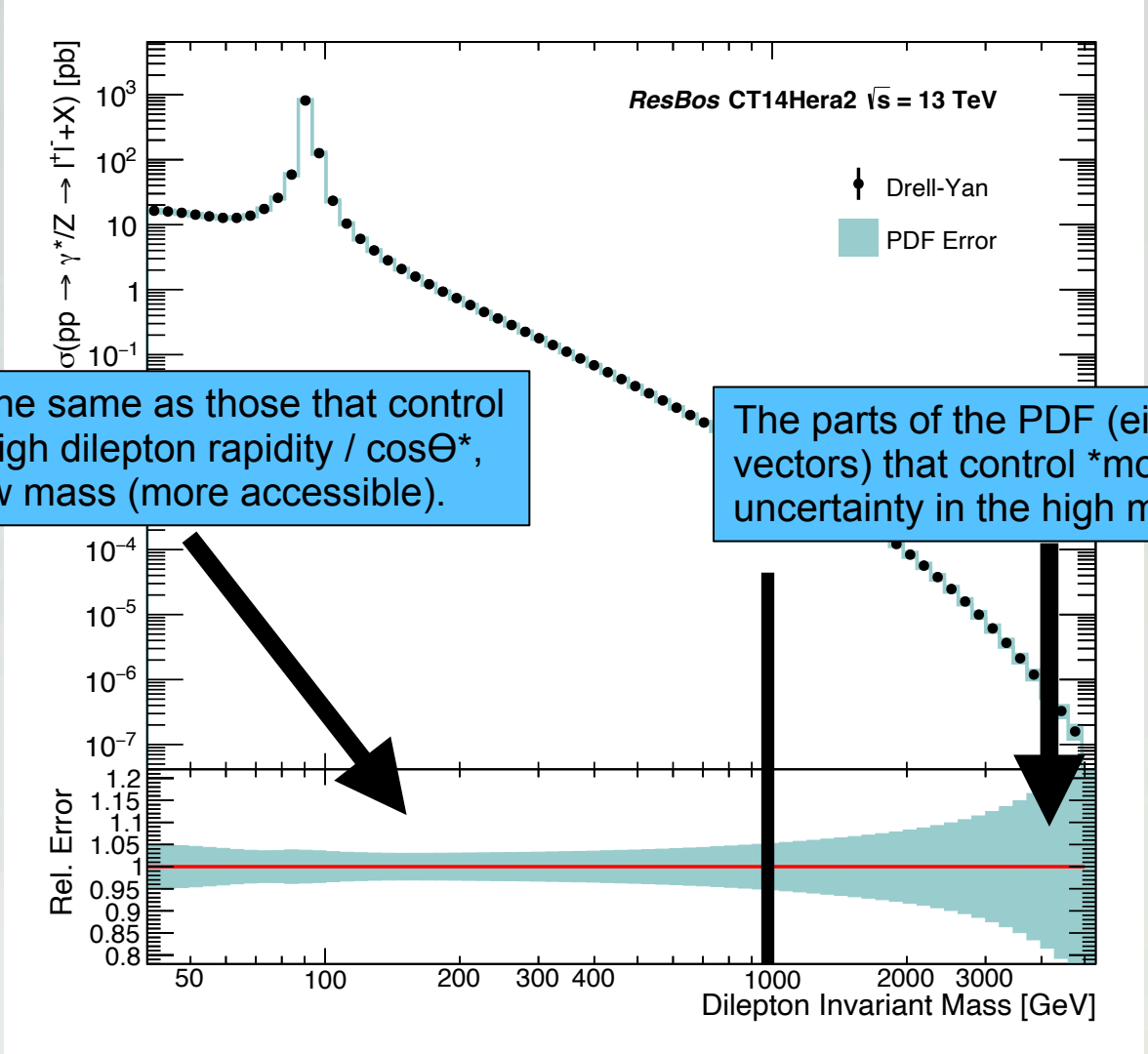

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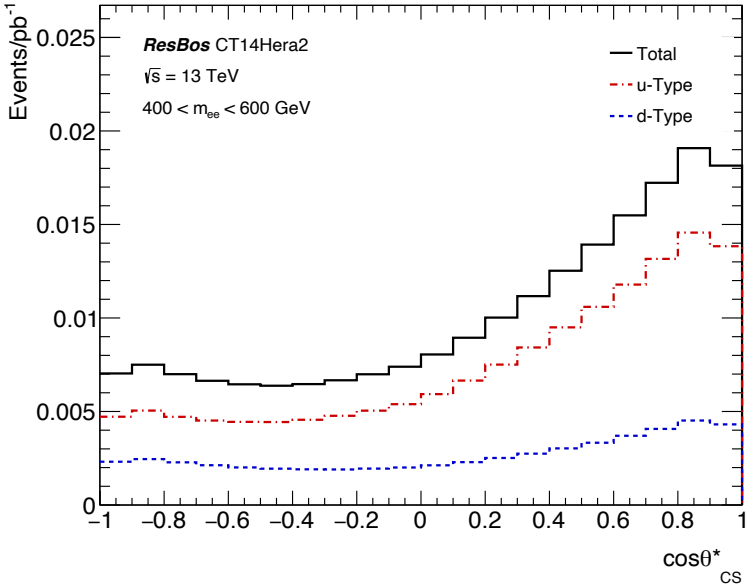

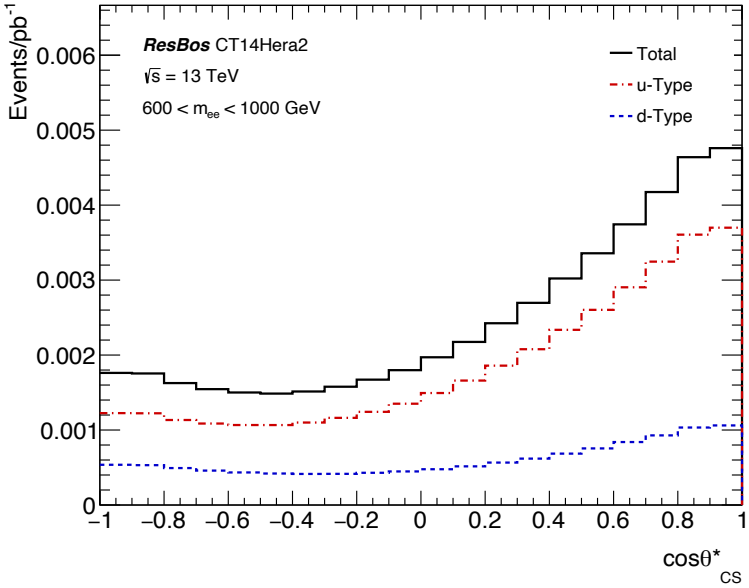

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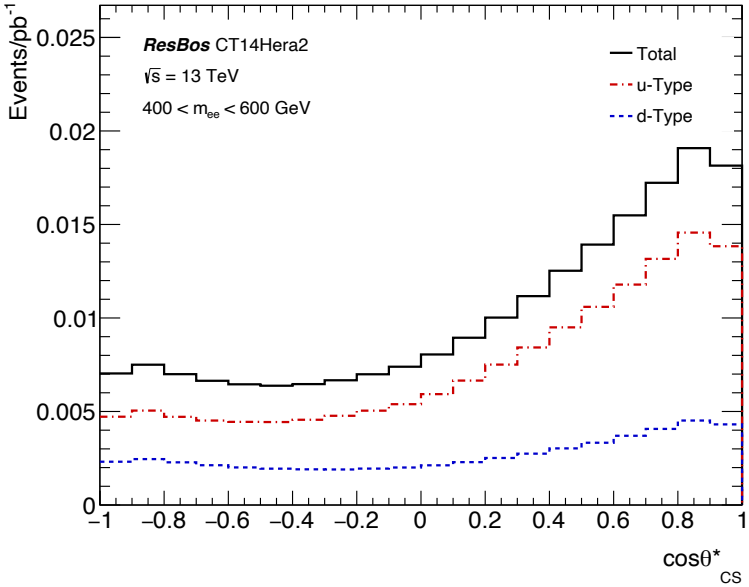

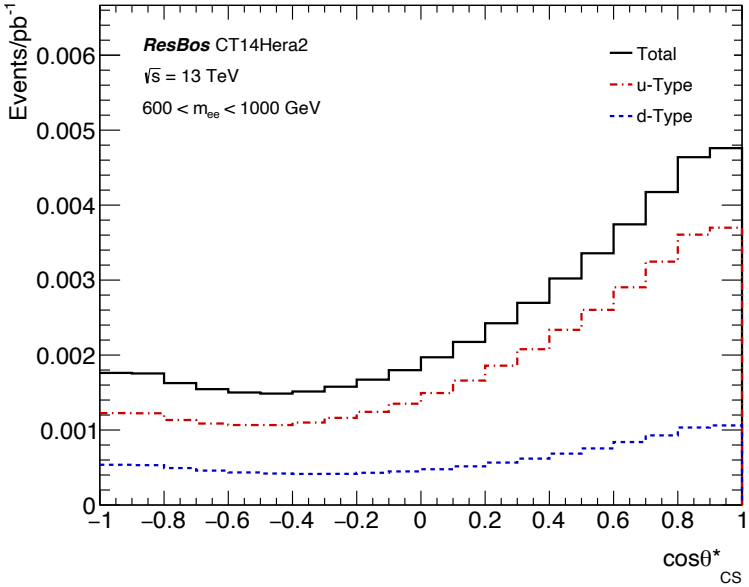

- Re-discovered that the LHC is a very good: up - anti-up quark collider!
- A careful selection of data at low mass (where no signal is expected) could be used to constrain the high-mass PDF uncertainties.

ePump to the Rescue

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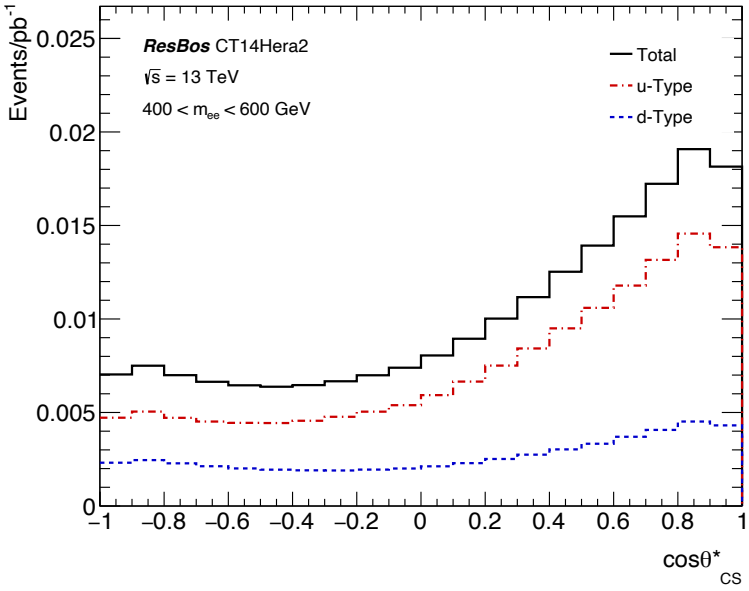

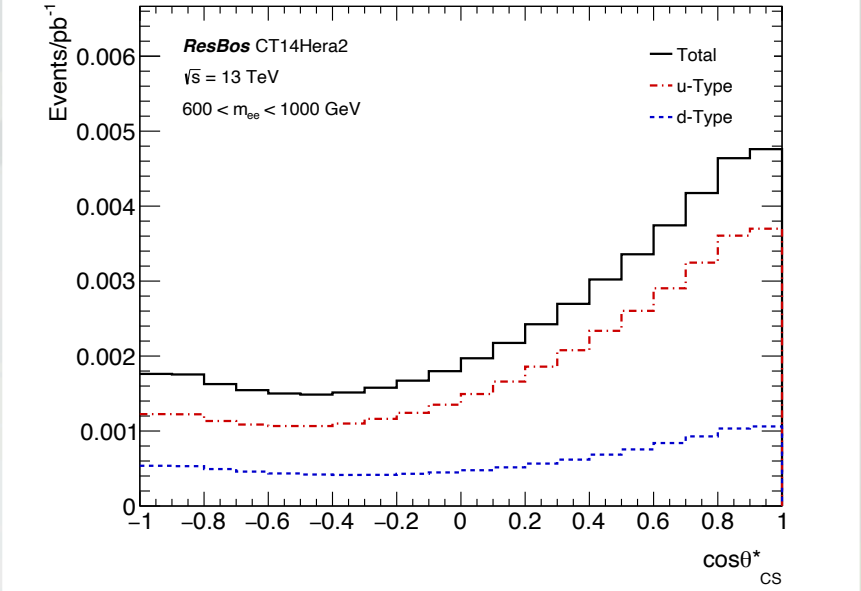

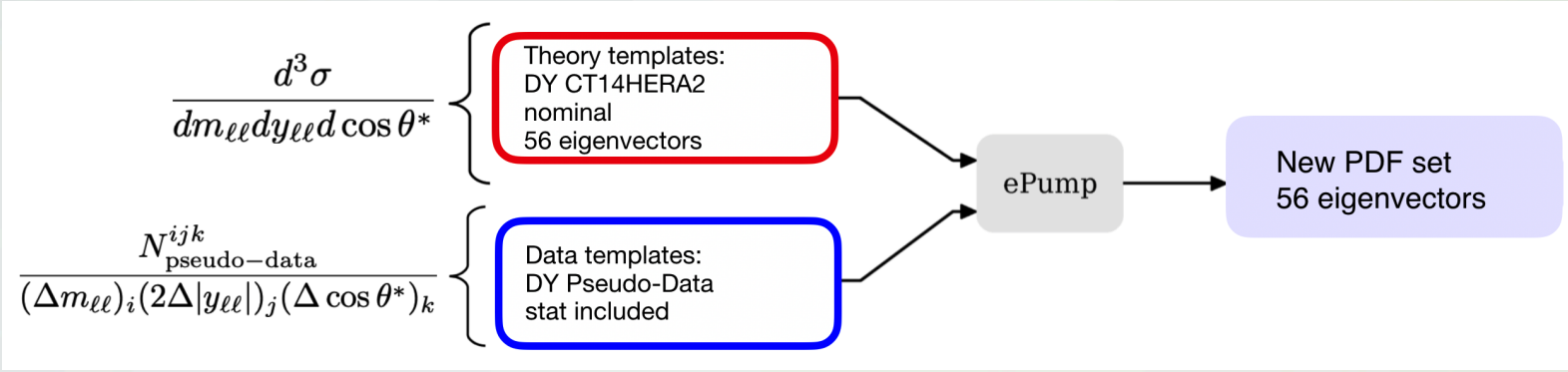

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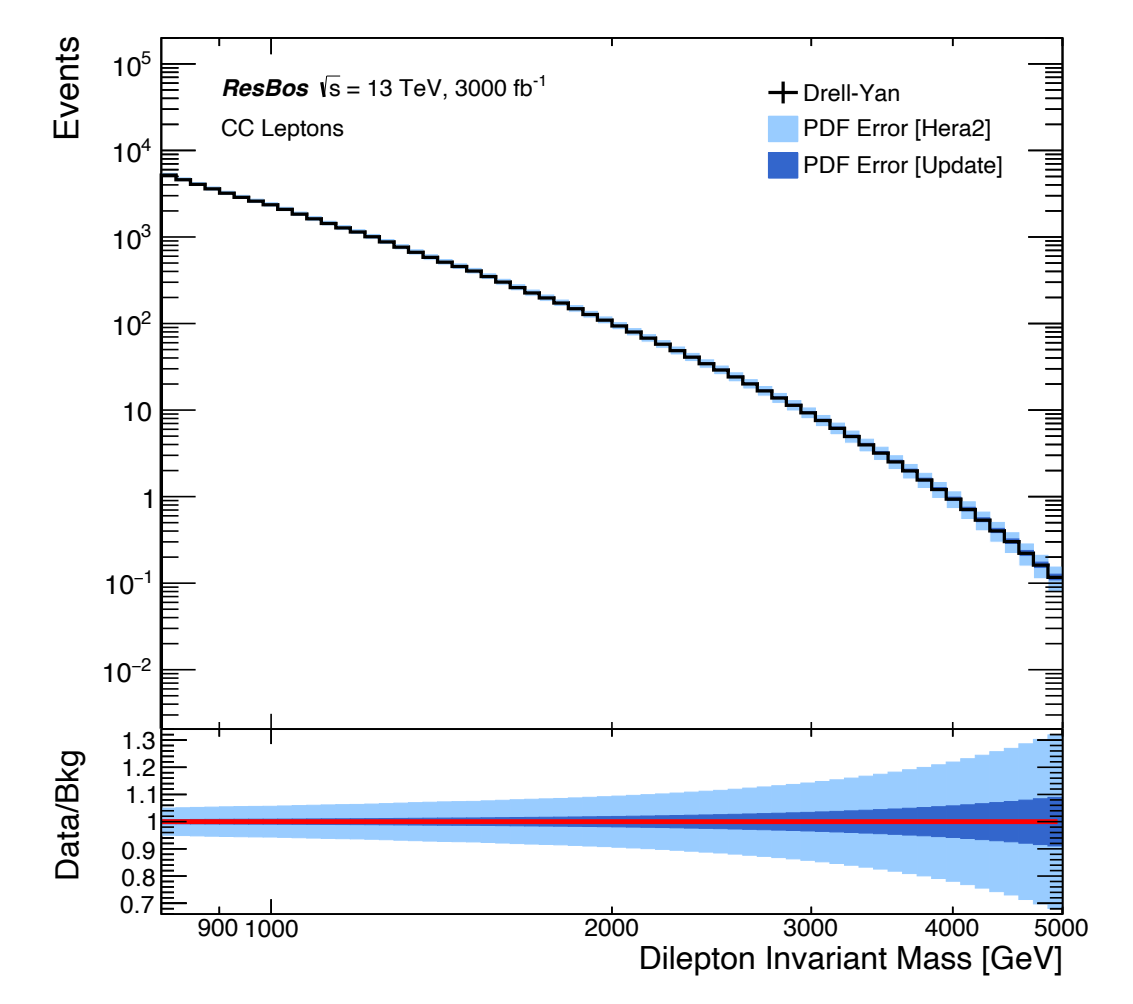

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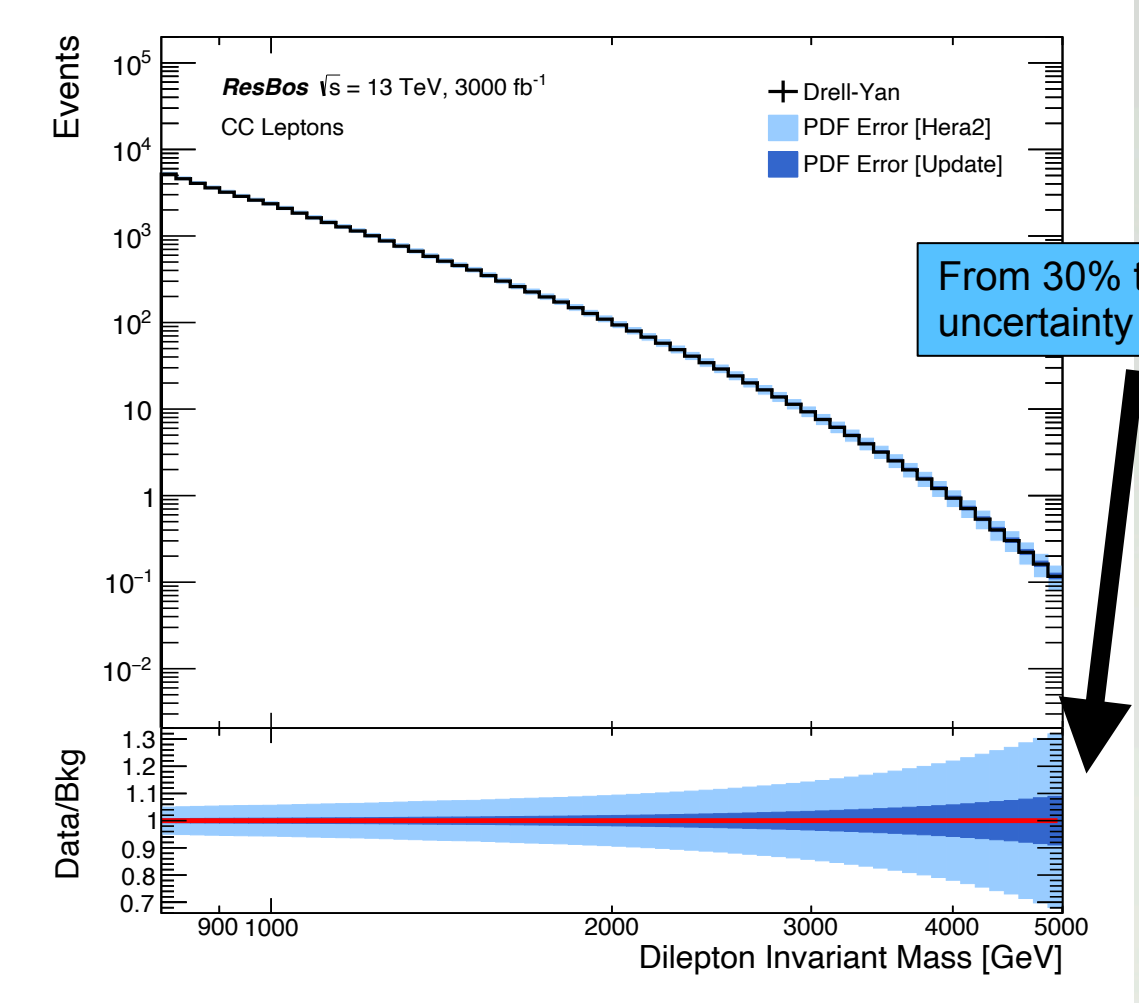

Considering Forward-Backward Asymmetry

Link

- A recent follow up (Fu, Brock, Hayden, Yuan) looked at using forward-backward asymmetry (AFB) as a discriminating variable.

$$A_{FB} = \frac{N_F - N_B}{N_F + N_B},$$

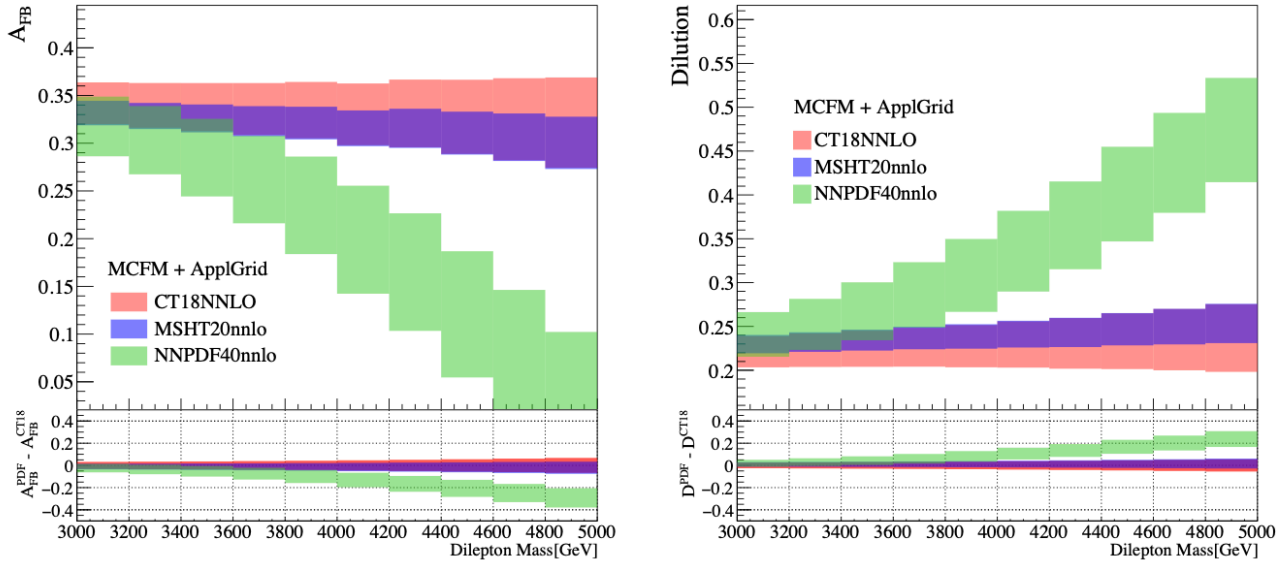

FIG. 9. Comparison of the A_{FB} (left) and Dilution (right) with different PDF input for MCFM at NLO accuracy in the high mass region ($M_{ll} > 3000$ GeV). The band represents the PDF uncertainty.

https://arxiv.org/abs/2307.07839

Considering Forward-Backward Asymmetry

Link

- In this study looked at using AFB at high mass to see if this could potentially improve PDF uncertainty and help differentiate between PDFs.

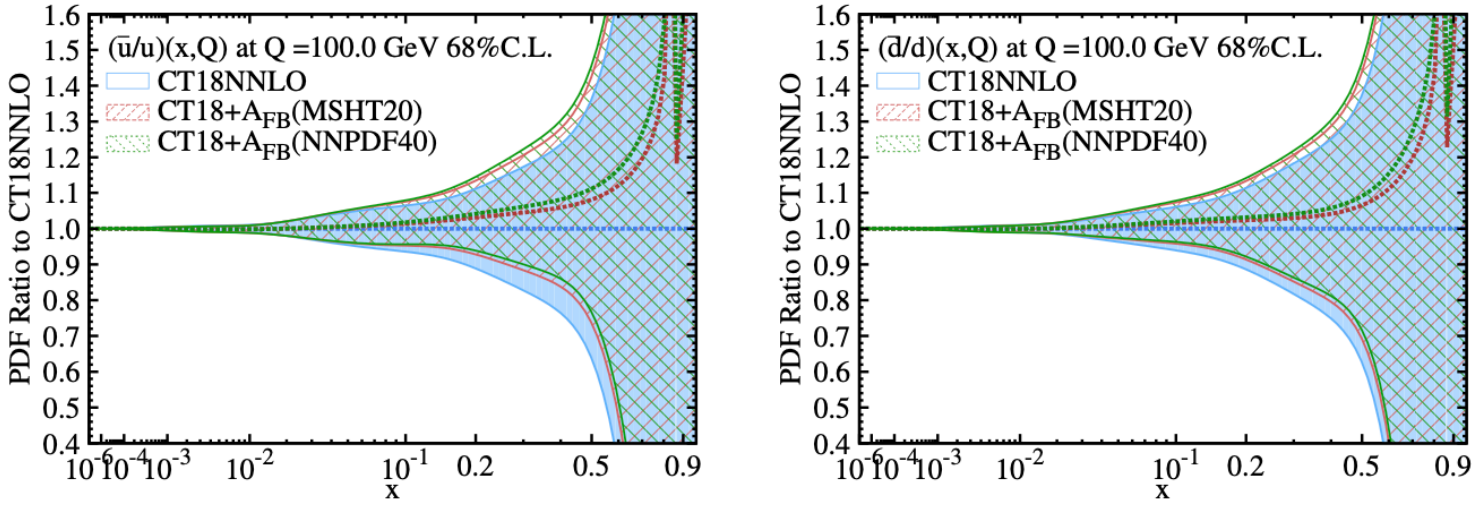

FIG. 6. PDF update of CT18 for $\bar{u}/u$ (left), and $\bar{d}/d$ (right) using A_{FB} pseudo-data generated using MSHT20 and NNPDF4.0. The central value and uncertainty are compared to the CT18 central value.

- With 300 or 3000 \fb, the PDF uncertainty is not improved by much, but is enough to differentiate between the different modern PDFs.

https://arxiv.org/abs/2307.07839

Further Studies

- This was a study using Neutral-Current Drell-Yan, what about Charge-Current?
  - Yao has been working on this too!
  - Triple differential measurements in both NCDY and CCDY look promising.
  - Appears that charge asymmetry also has something to add.

- For the non-resonant searches: at what level of theory uncertainty or integrated luminosity from the LHC do we lose sensitivity completely?
  - Once we establish the above, how much does this theory uncertainty reduction method help? What happens if you push the reduction even further?