

PDF and BSM interplay in the top and Drell-Yan sector

Based on: [PBSP Collaboration, 2602.20235]

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PBSP 

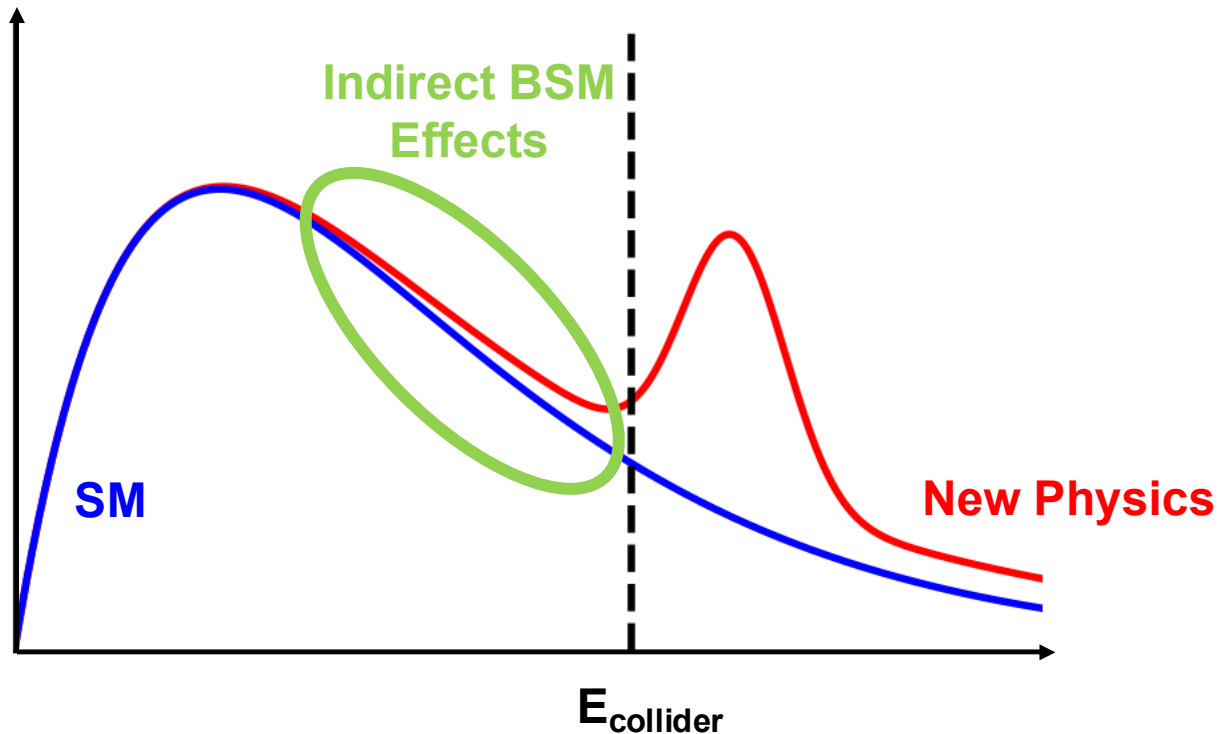


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Indirect BSM searches



- Looking toward indirect searches with **SMEFT**

$$\mathcal{L}_{SMEFT} = \mathcal{L}_{SM} + \sum_{d=5}^{\infty} \sum_i \frac{C_i}{\Lambda^{d-4}} \mathcal{O}_i^{(d)}$$

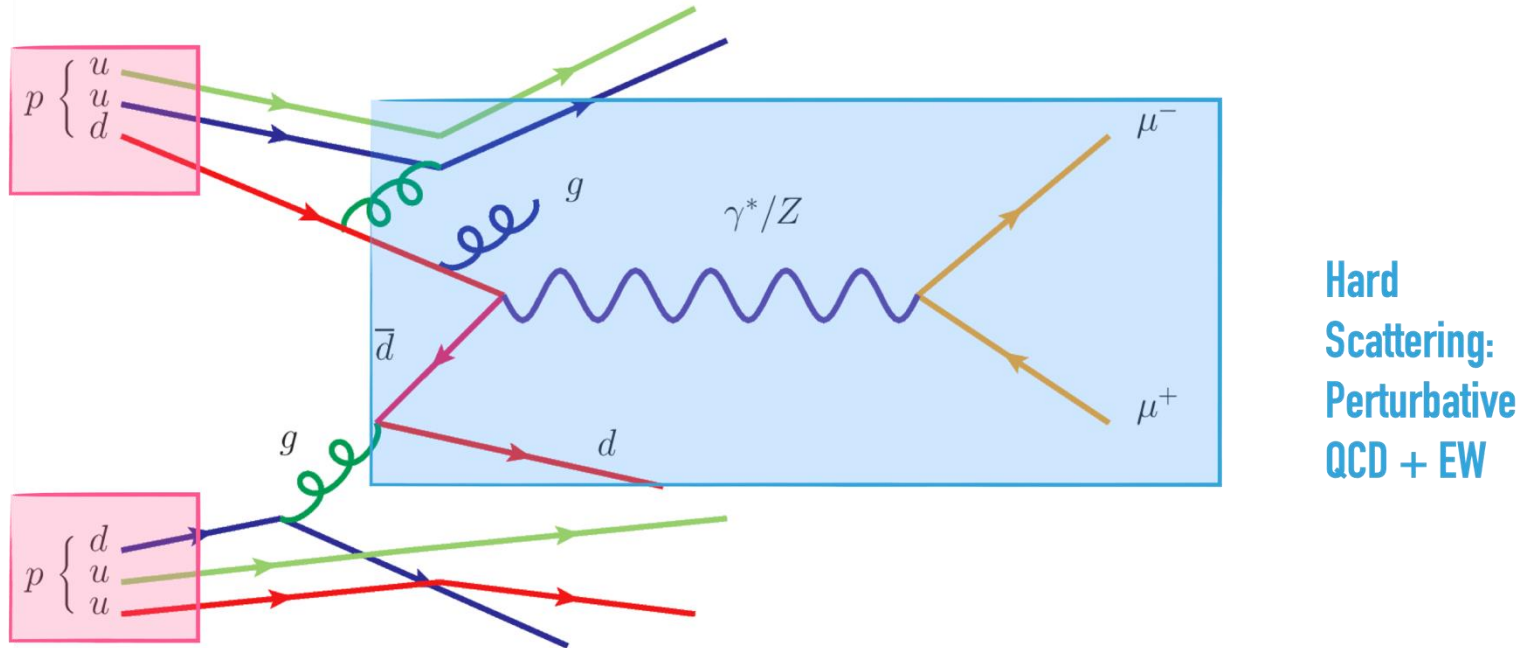
- Requires precision in experimental data and theory in high energy tails

PDF uncertainties are a dominant limitation

BSM Bias in PDFs

Collinear factorization theorem

Parton
Distribution
Functions



To improve PDFs for precision searches:

- Include more data (Run III, HL-LHC, EIC etc) to constrain large- x regions [2410.00963]

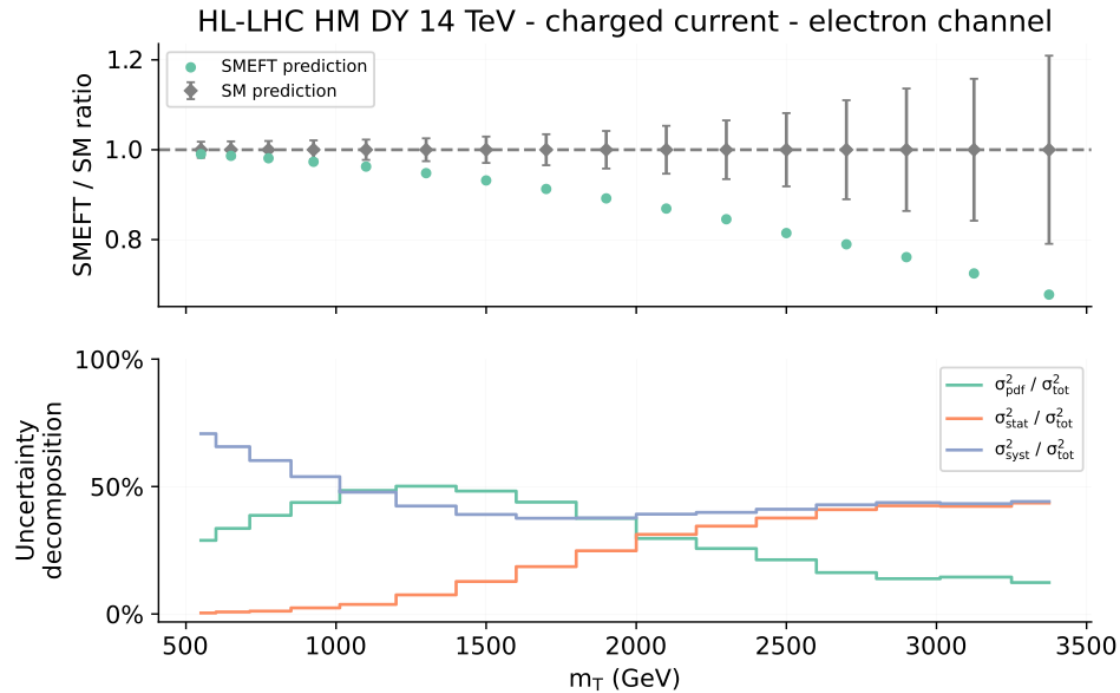
- **Avoid BSM bias**

$$d\sigma^{pp \rightarrow ab} = \sum_{i,j} \boxed{f_i \otimes f_j} \otimes \boxed{d\hat{\sigma}^{ij \rightarrow ab}} + \dots$$

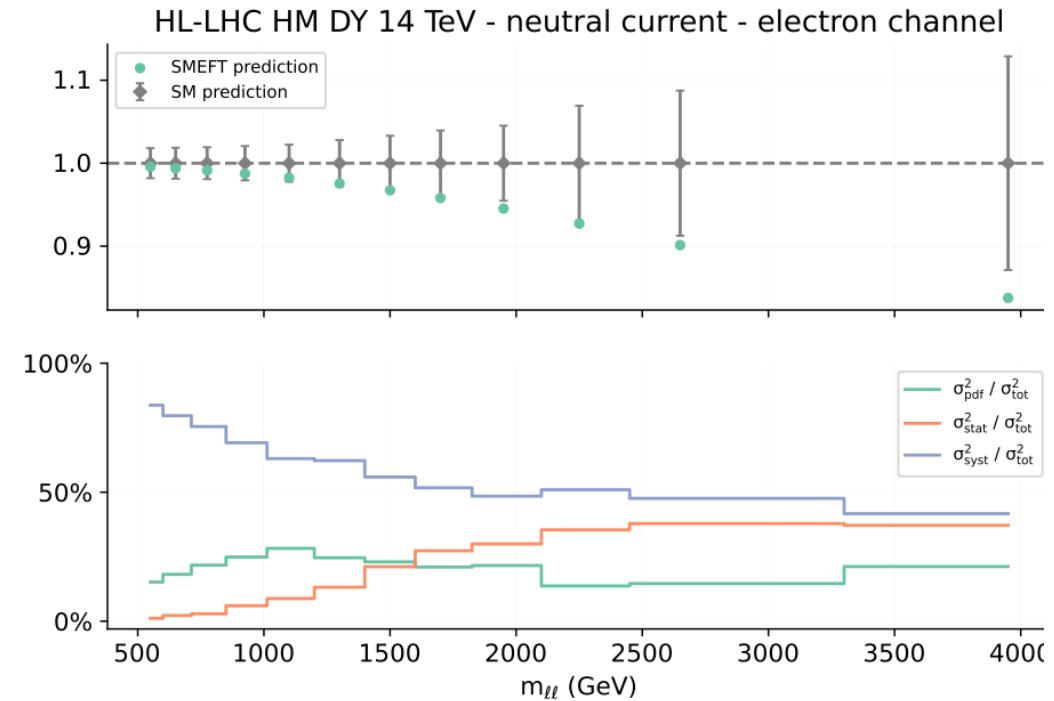
Injecting New Physics into HL-LHC Projections

A flavour universal W' with $M_{W'}=13.8\text{TeV}$ injected into the data

Charged Current



Neutral Current

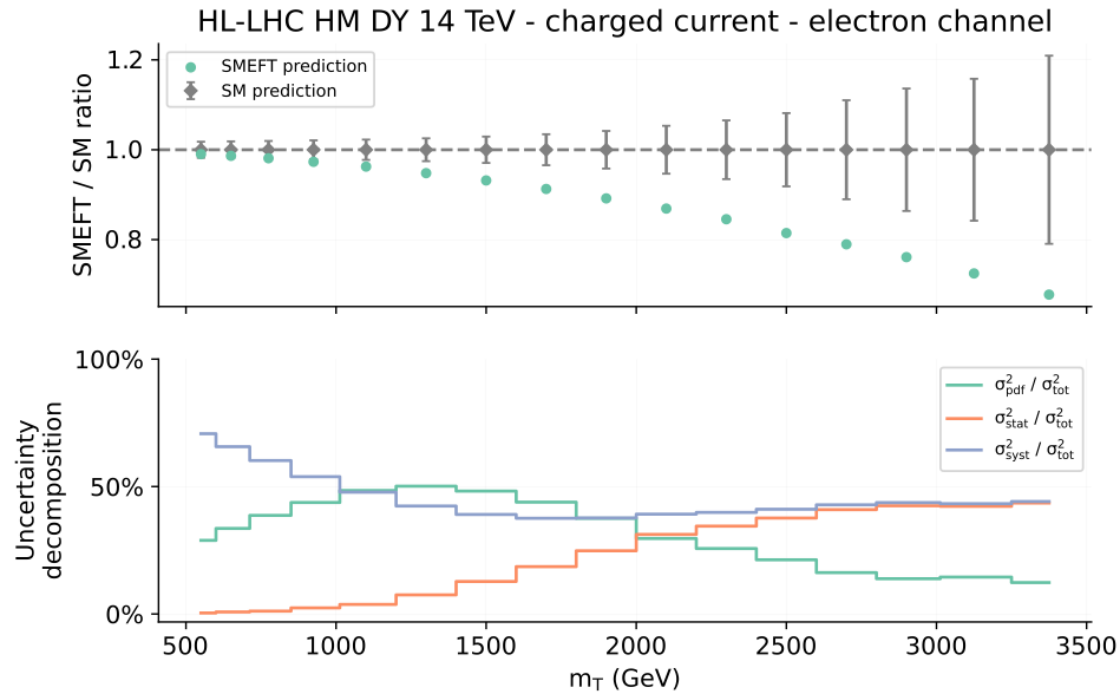


[PBSP, 2602.20235]

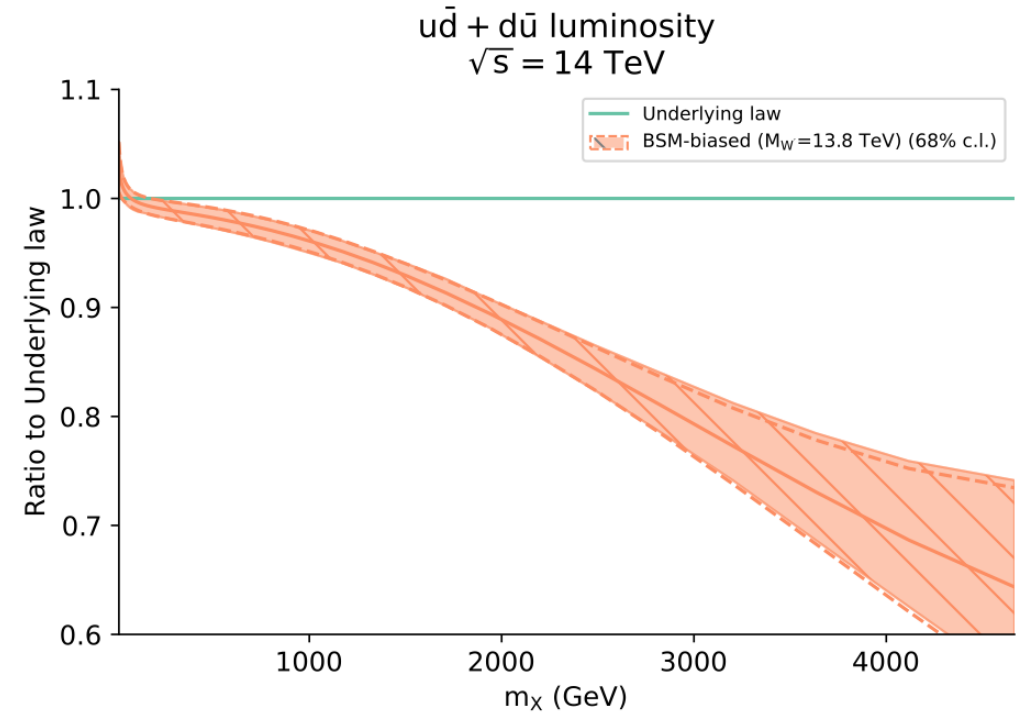
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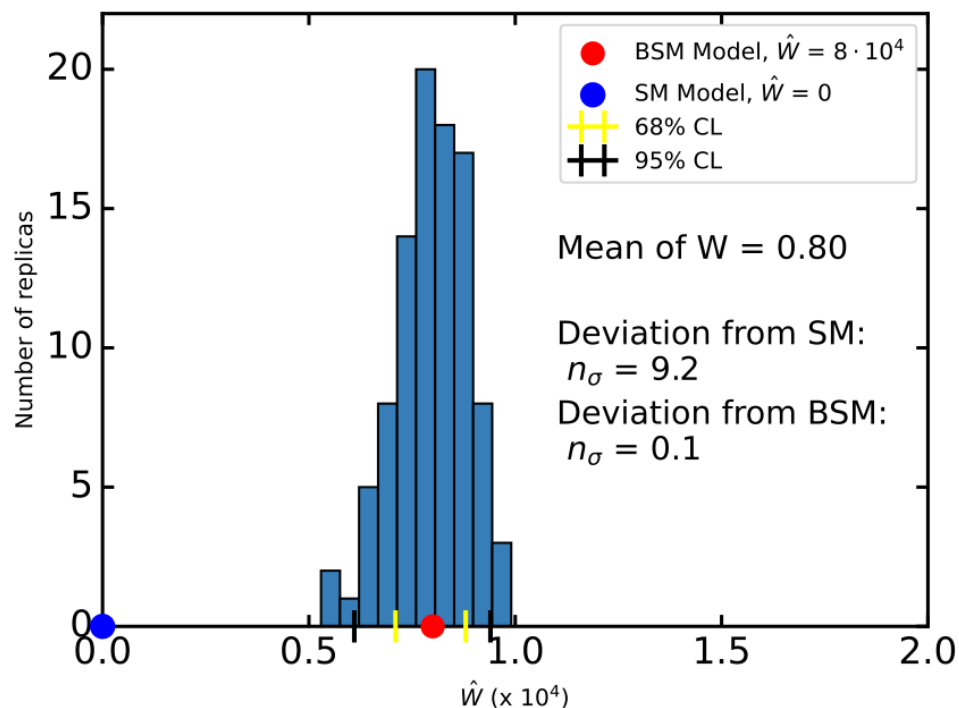
[PBSP, 2602.20235]



$$\mathcal{L}_{\text{true}} \otimes \hat{\sigma}_{BSM} \approx \mathcal{L}_{BSM\text{-biased}} \otimes \hat{\sigma}_{SM}$$

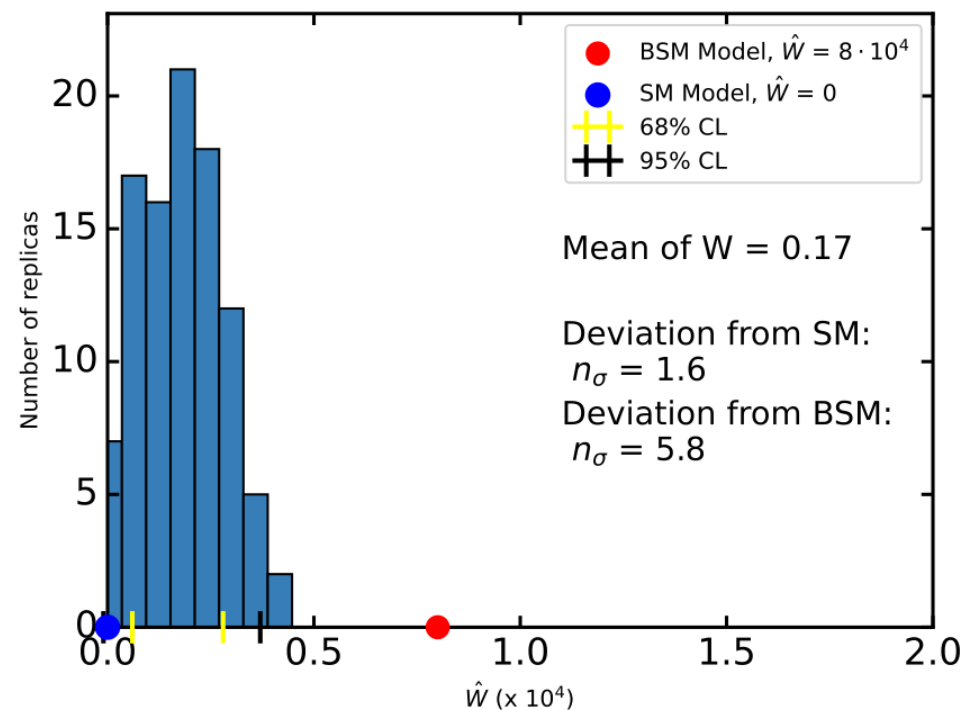
Missing New Physics

SMEFT Fit with True PDF



SMEFT Fit with BSM Biased PDF

- Misses new physics



$$\mathcal{L}_{true} \otimes \hat{\sigma}_{BSM} \approx \mathcal{L}_{BSM-biased} \otimes \hat{\sigma}_{SM}$$

Tools for combating BSM bias in PDFs

Two methods of 'safe' PDF fitting

1 - Separate fit with conservative PDF

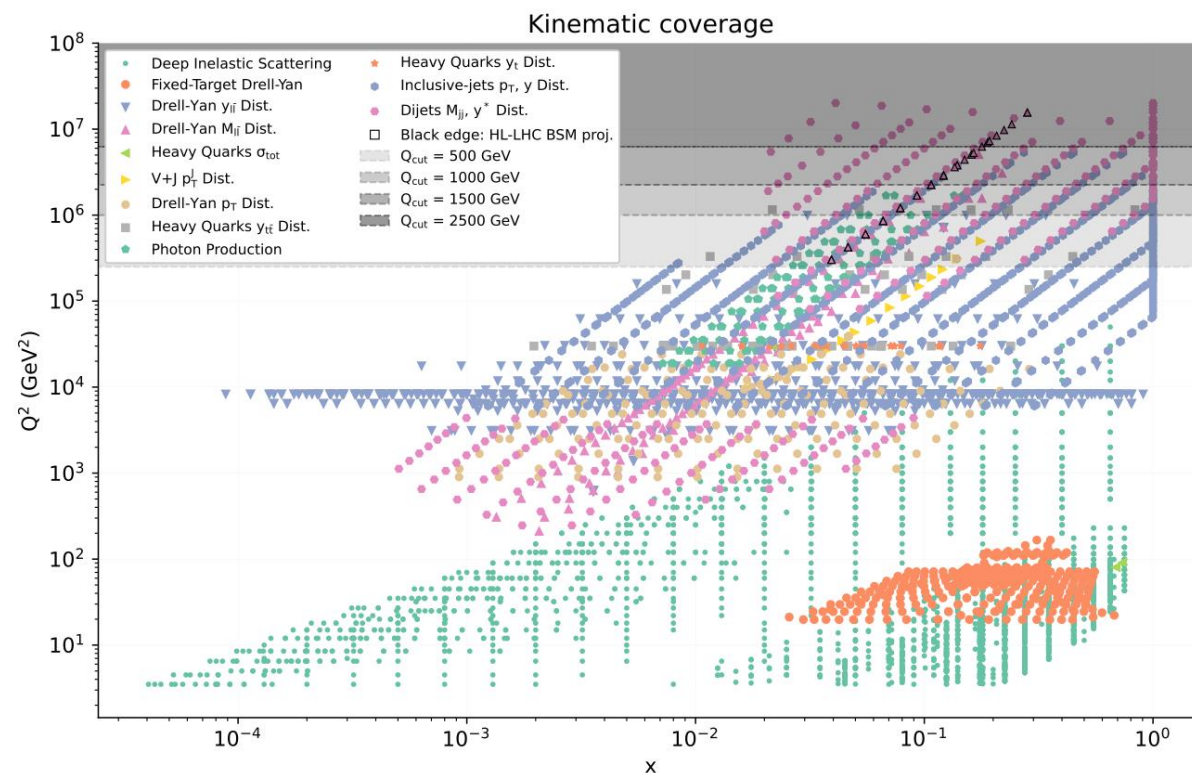
Fit PDF on set of data below the energy scale where BSM effects are present



Then, fit SMEFT using this 'conservative' PDF

Cons

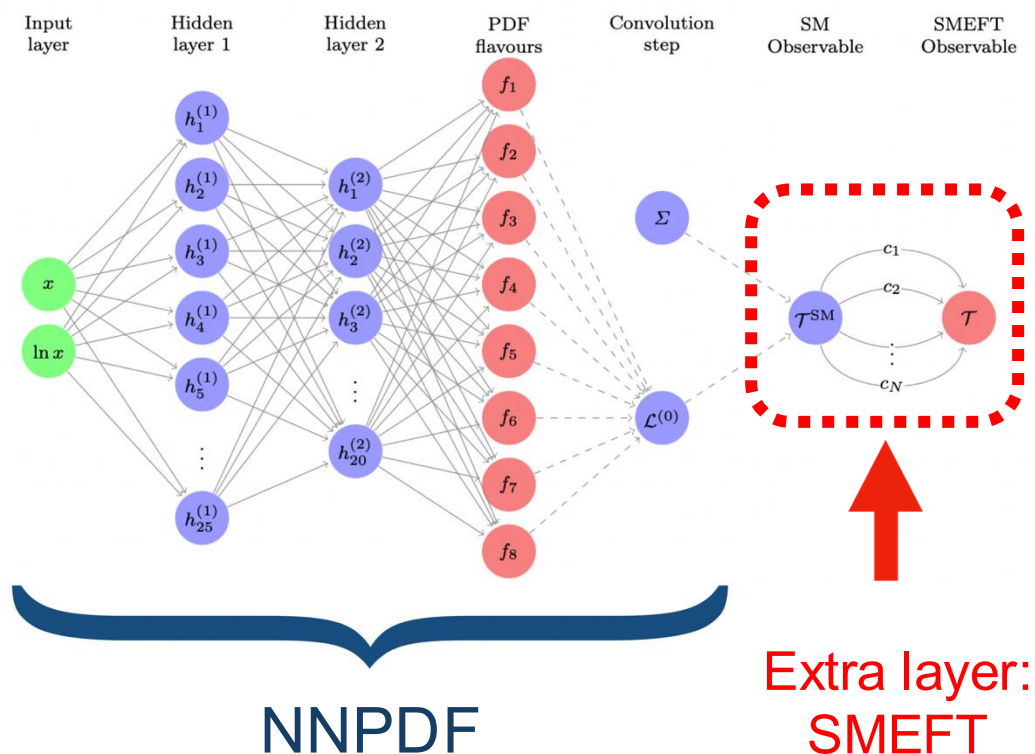
- Assumes SM
- Removes useful constraints in large- x regions



Tools for combating BSM bias in PDFs

Two methods of 'safe' PDF fitting

2 – Simultaneous PDF + SMEFT fit

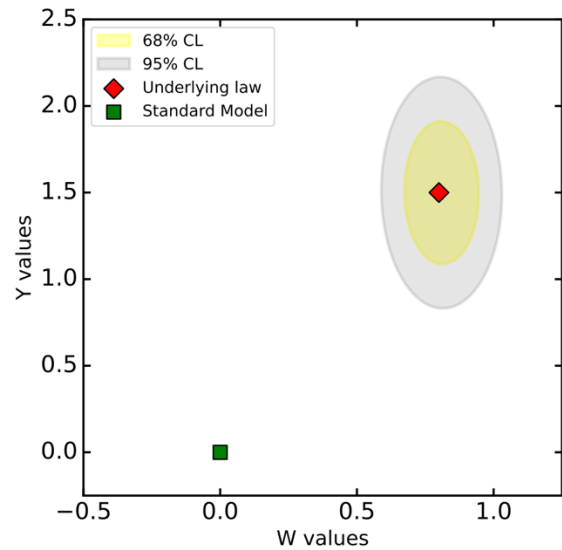


[Iranipour et Ubiali, 2201.07240]

SIMUnet:

- Open-source tool:
github.com/HEP-PBSP/SIMUnet
[PBSP, 2402.03308]
- Fits PDFs and Wilson coefficients simultaneously
- Performs contaminated PDF fits through injection of BSM effect

PDFs for New Physics searched in HMDY

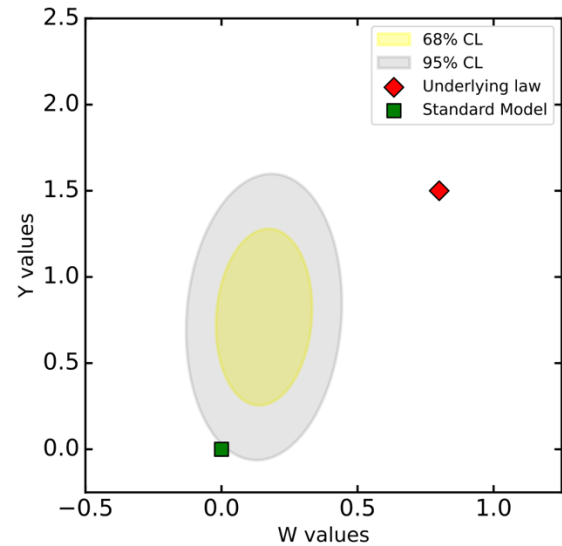
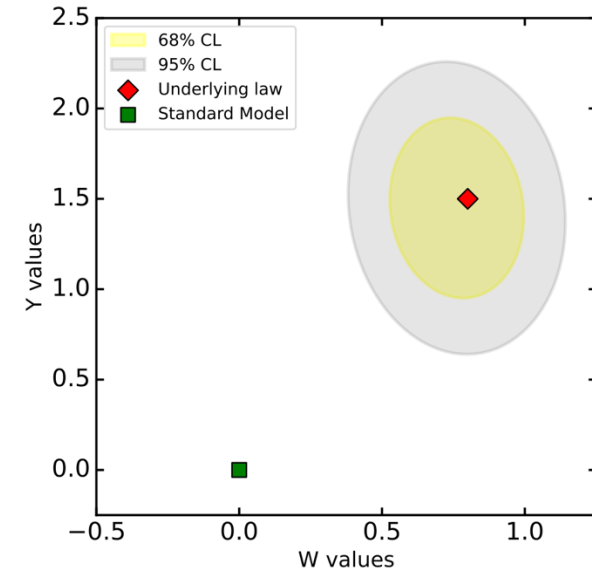


SMEFT only fit
(True PDF)

✗ Impossible

Simultaneous fit
(no PDF assumption)

✓ Doable

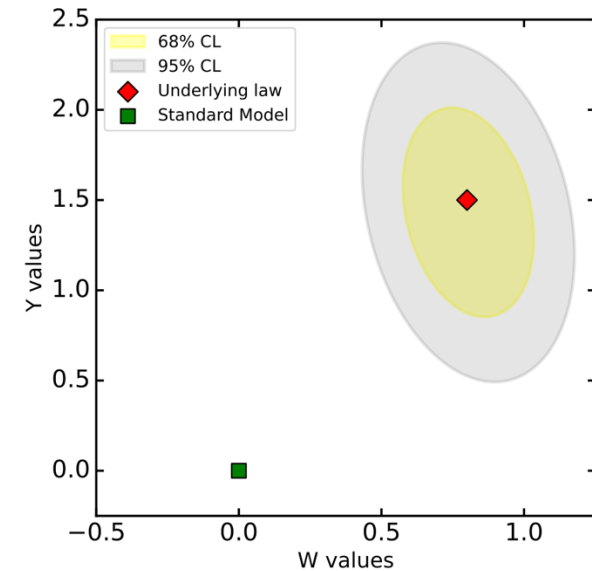


SMEFT only fit
(BSM-biased PDF)

✗ Wrong

SMEFT only fit
(Conservative PDF)

✓ Doable

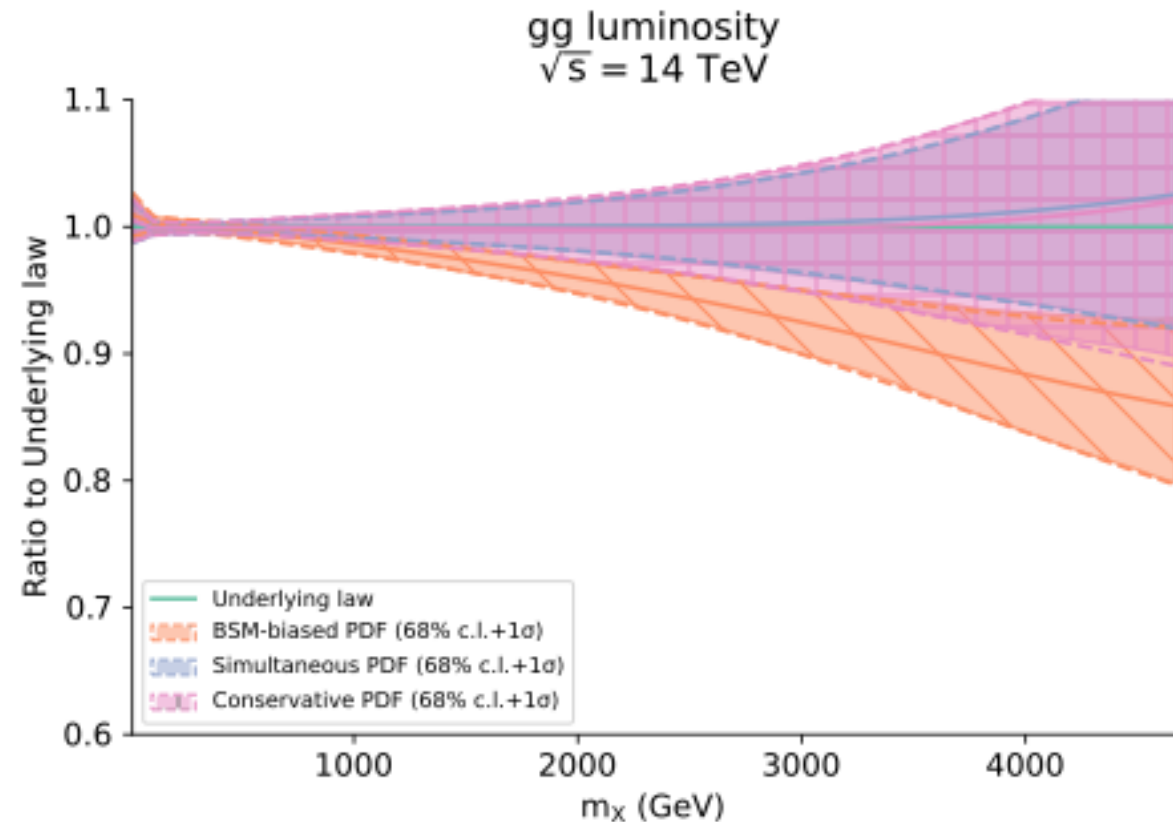


PDFs for New Physics searched in Top Sector

A massive Coloron (“heavy gluon”) injected into the data

Partial **BSM absorption** into gg PDF

SMEFT bounds deviate from the true underlying injected effect



Summary and Future Work

- Signs of new physics can be fitted away in PDF
 - Inaccurate PDFs
 - Missed New Physics
- Can combat this with conservative fit or simultaneous PDF + SMEFT fits [SIMUnet 2402.03308]
- Explored BSM and PDF interplay in HMDY and top sector – Future work in jet sector [Greljo, Hammou, Merlotti, Smolkovic, Ubiali, forthcoming]
- Developing a Bayesian framework for simultaneous PDF + SMEFT fits [2510.03391]

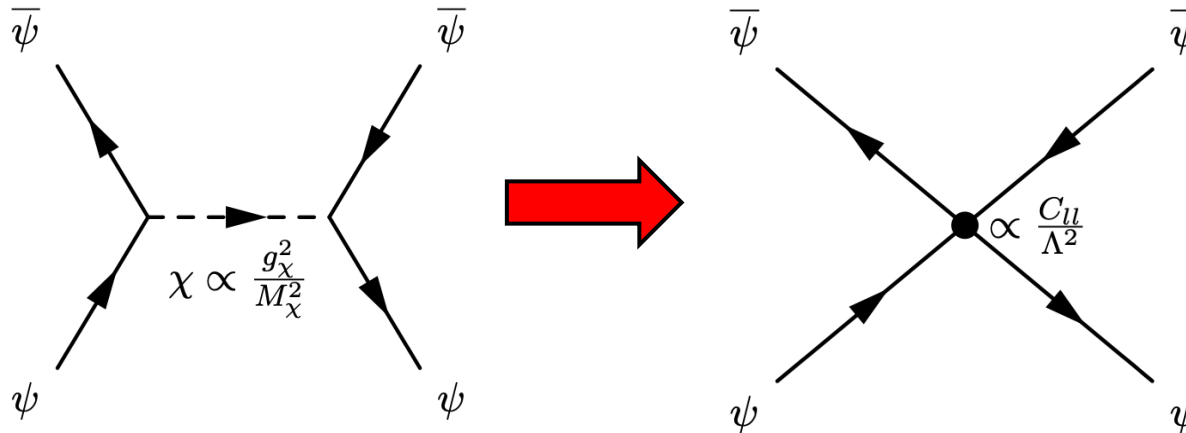


Backup Slides

SMEFT – An Effective Plan

Standard model effective field theory (SMEFT) can be used to parameterise new physics for **indirect searches**

Integrate out heavy fields



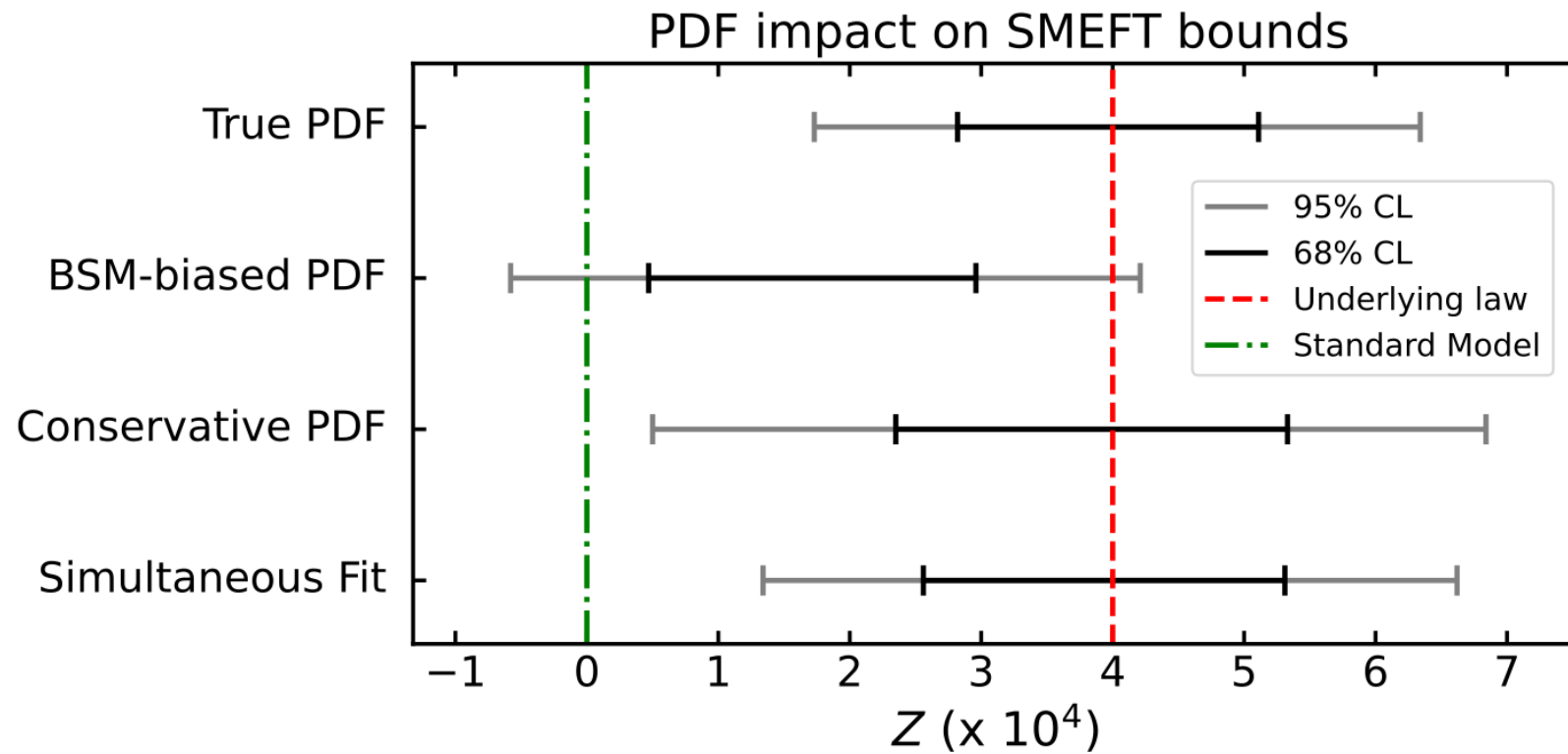
- Dim-6 basis of operators contains **2499** operators

[B. Grzadkowski et al., 1008.4884]

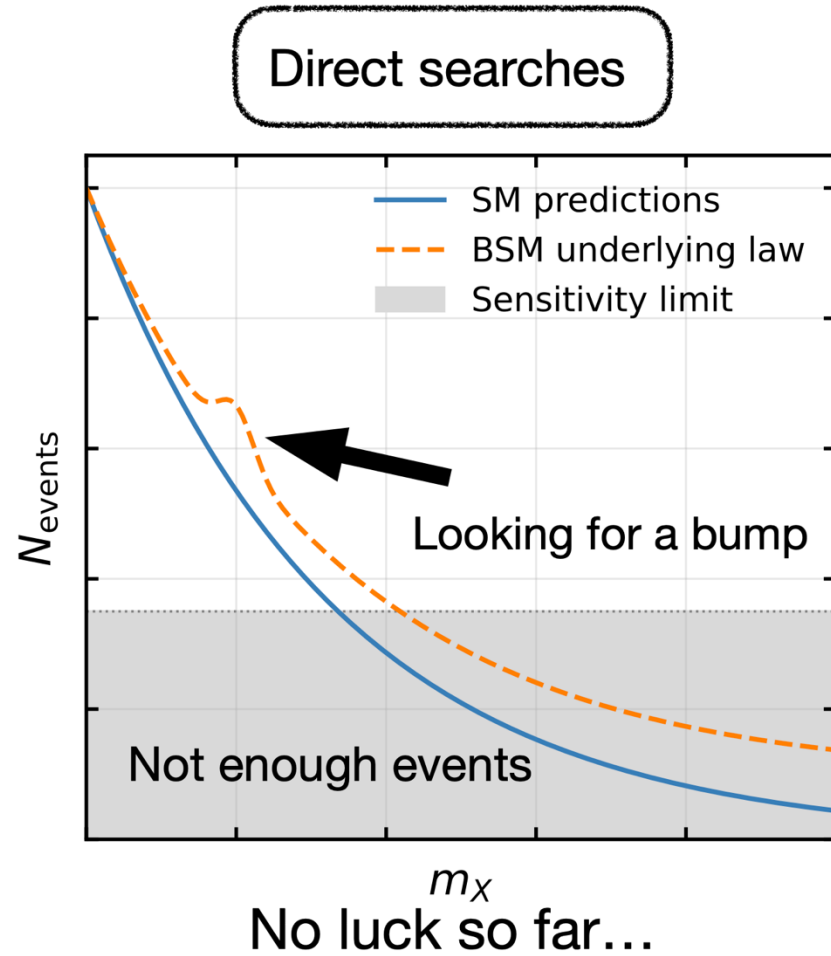
- Experimental data can constrain $\frac{C}{\Lambda^2}$ in a model agnostic approach

$$\mathcal{L}_{SMEFT} = \mathcal{L}_{SM} + \sum_{d=5}^{\infty} \sum_i \frac{C_i}{\Lambda^{d-4}} \mathcal{O}_i^{(d)}$$

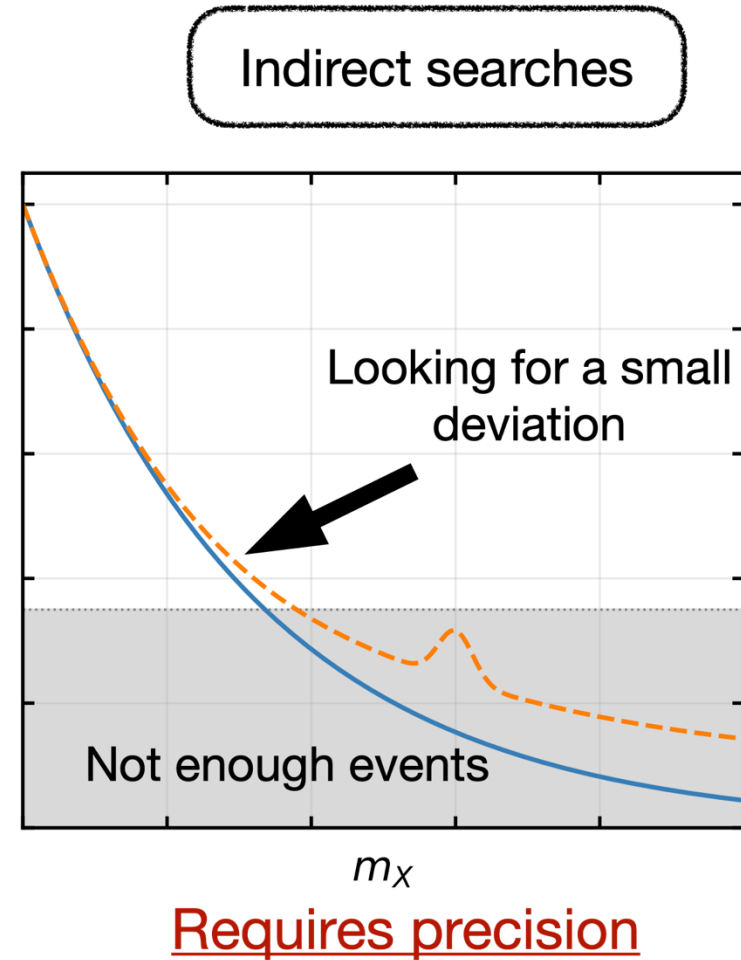
SMEFT Bounds from Top Sector Study



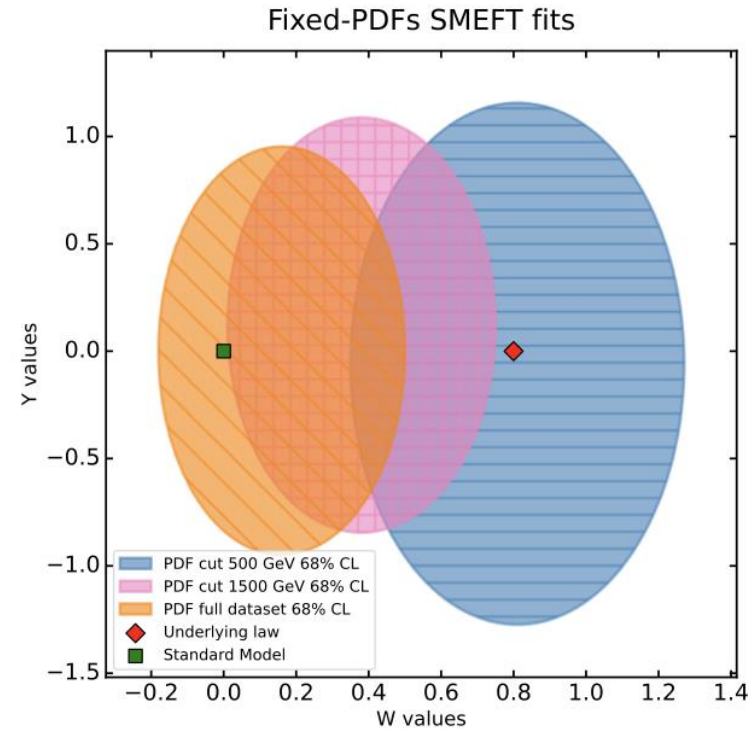
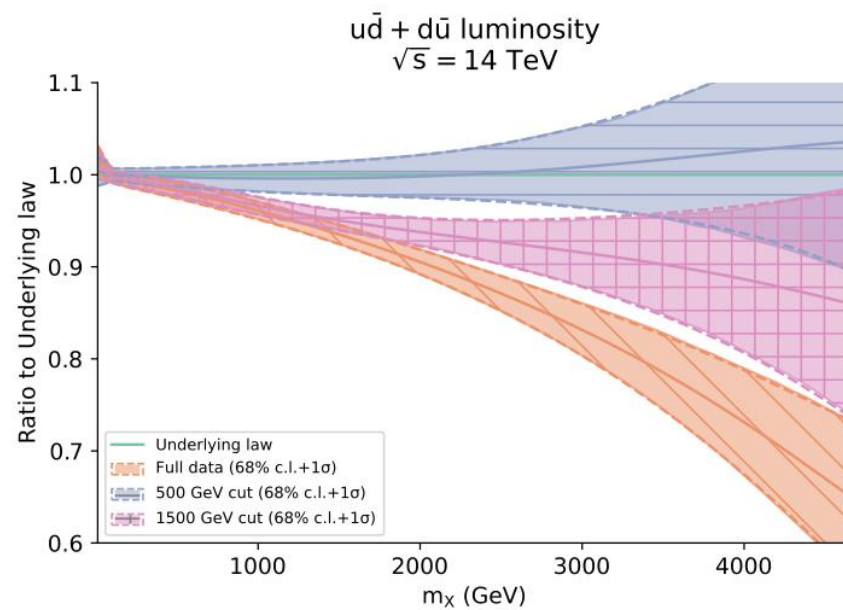
“Correct” diagram for indirect searches



x



Other tools – Energy Cut Offs

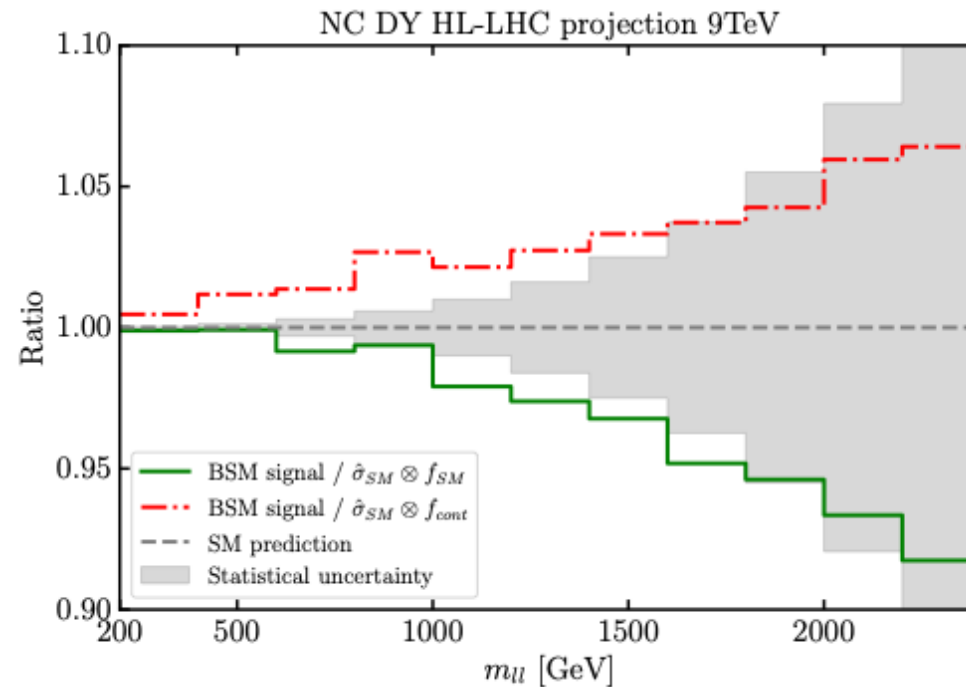
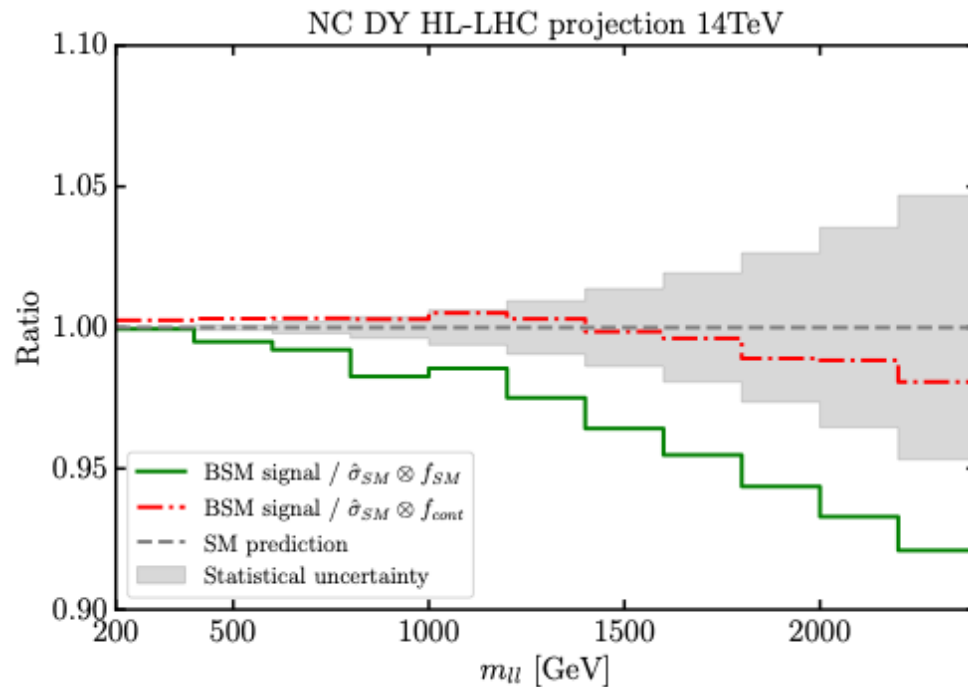


SM only pseudodata only
shows change in
uncertainties as cut off is
increased

Other Tools –

Test observables to break Bjorken-x and M degeneracy

$$M^2 = x_1 x_2 s,$$



Selection Criteria

Two criteria:

$$\chi^2 = (D - T_{SM})^T \cdot V_{cov}^{-1} \cdot (D - T_{SM})$$

- χ^2 -statistics:

$$\frac{\chi^2}{n_{dat}} > 1.5 \rightarrow \text{excluded}$$

- n_σ standard deviation:

$$n_\sigma > 2 \rightarrow \text{excluded}$$

$$n_\sigma = \frac{\chi^2 - 1}{\sigma_{\chi^2}}$$

x