Parton Distributions in the SMEFT from high-energy Drell-Yan tails

JHEP 07 (2021) 122, arXiv:2104.02723

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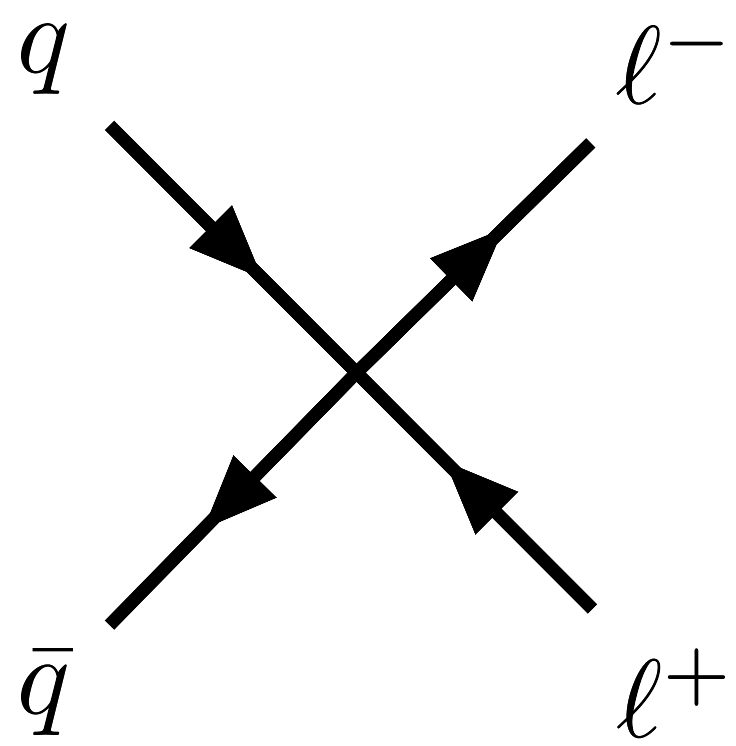
EPS-HEP 2021

The SMEFT from high-energy Drell-Yan tails

A powerful tool for capturing deviations from the SM: $\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_i \frac{C_i}{\Lambda^2}\mathcal{O}_i$

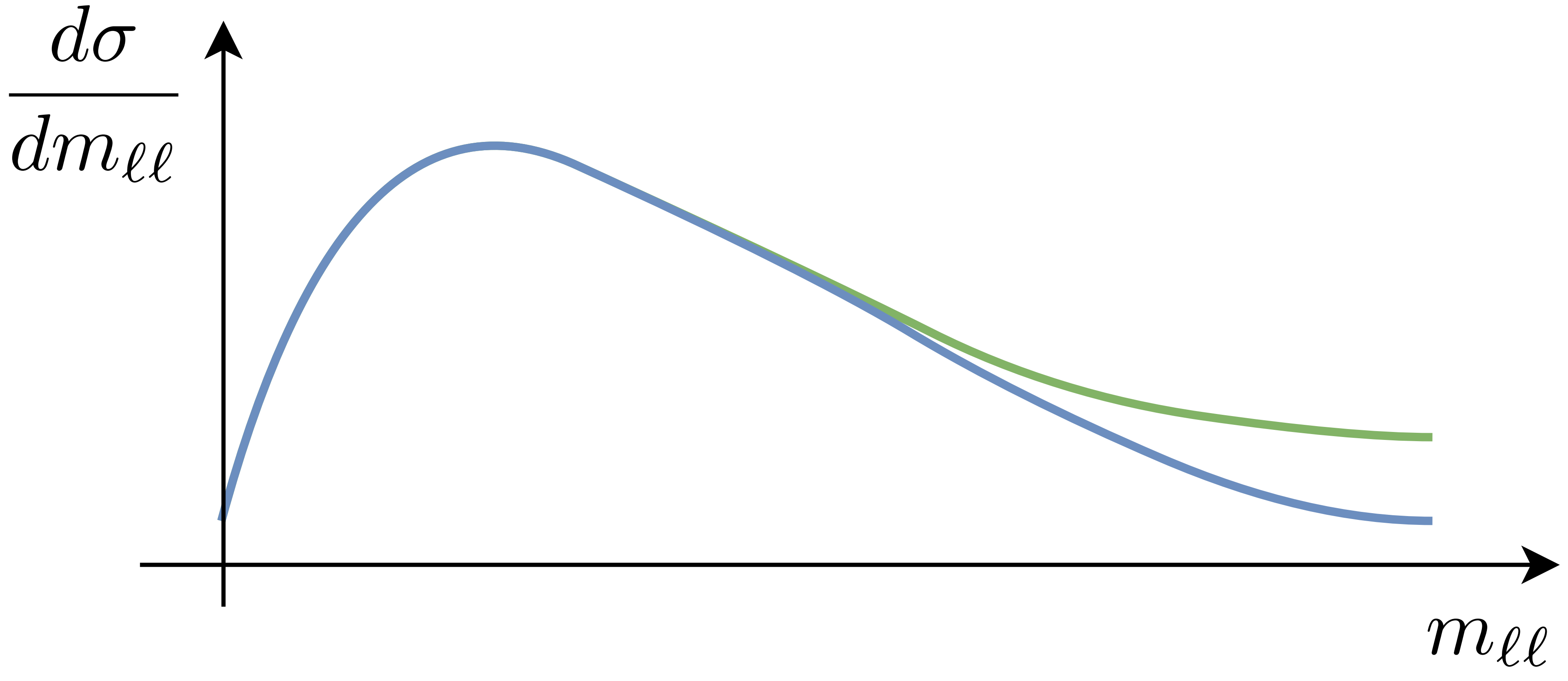
High-mass Drell-Yan measurements are used to probe 4-fermion operators:



$$\mathcal{A} \sim \mathcal{A}_{\text{SM}} + C\frac{E^2}{\Lambda^2}$$

1609.08157
2008.12978

New physics in 4-fermion operators will manifest as a smooth distortion of the high-mass tail:



Parton distribution functions from high-energy Drell-Yan tails

High-mass DY measurements constrain the light quark PDFs in the large-x region

PDFs are an input to EFT fits: $\sigma_{\mathrm{SMEFT}}(C) = f_1 \otimes f_2 \otimes \hat{\sigma}_{\mathrm{SMEFT}}(C)$

But PDFs are found assuming the SM: $\sigma = f_1 \otimes f_2 \otimes \hat{\sigma}_{SM}$

→ *'Standard Model PDFs'*

This is an inconsistency in our theoretical predictions.

How do our constraints on the SMEFT change if we perform a consistent joint determination of the PDFs and SMEFT?

First studied with deep inelastic scattering data by Carrazza et al.: PRL 123 (2019) 13, 132001

Methodology

We perform a scan over C, computing

$$\chi^2(C) = \sum_i (T_i(C) - D_i)(\mathrm{cov}^{-1})_{ij}(T_j(C) - D_j)$$

Using SM PDFs: $\sigma_{\mathrm{SMEFT}}(C) = f_1 \otimes f_2 \otimes \hat{\sigma}_{\mathrm{SMEFT}}(C)$

Using SMEFT PDFs: $\sigma_{\mathrm{SMEFT}}(C) = f_1(C) \otimes f_2(C) \otimes \hat{\sigma}_{\mathrm{SMEFT}}(C)$

For each point in the scan over C, we produce a set of PDFs using the NNPDF3.1 framework

Our work: technical details

Data

DIS

Low-mass and on-shell DY

High-mass DY:

- ATLAS: 7,8 TeV
- CMS: 7,8,13 TeV

Two new physics scenarios

1. **Electroweak oblique parameters** $\hat{W}, \hat{Y}$
2. 4-fermion operator $(\bar{b}_L \gamma^\nu b_L)(\bar{\mu}_L \gamma_\nu \mu_L)$ describing new physics in $R_{K^{(*)}}$

Theory calculations

SM: NNLO QCD and NLO EW

SMEFT: Apply k-factors calculated at LO

$$K_{\text{SMEFT}} = 1 + \hat{W} K_{\hat{W}} + \hat{Y} K_{\hat{Y}}$$

Results: $\hat{W}$

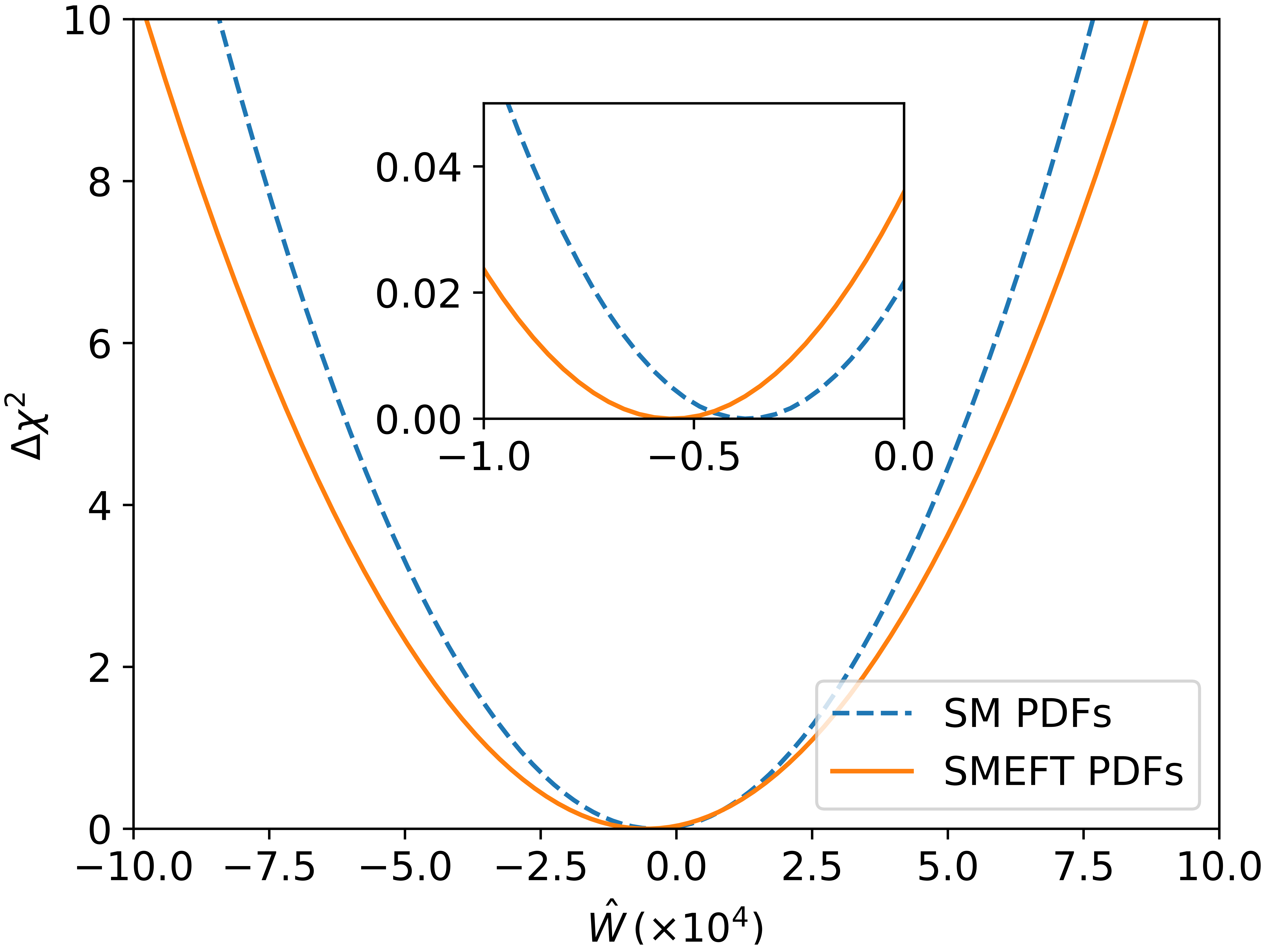
Best-fit shifts by $\delta\hat{W} = -0.2$

Parabola broadens by 15%

When we include PDF uncertainties in the SM PDF fit this becomes:

$$\delta\hat{W} = -0.3$$

Broadening: -11%



High luminosity projections

Using existing high-mass DY data we see a subtle interplay between the PDFs and SMEFT.

How can we expect this to change at the HL-LHC?

Can we avoid the need for a simultaneous fit by removing the high-mass DY data from the PDF fit?

‘Conservative PDFs’

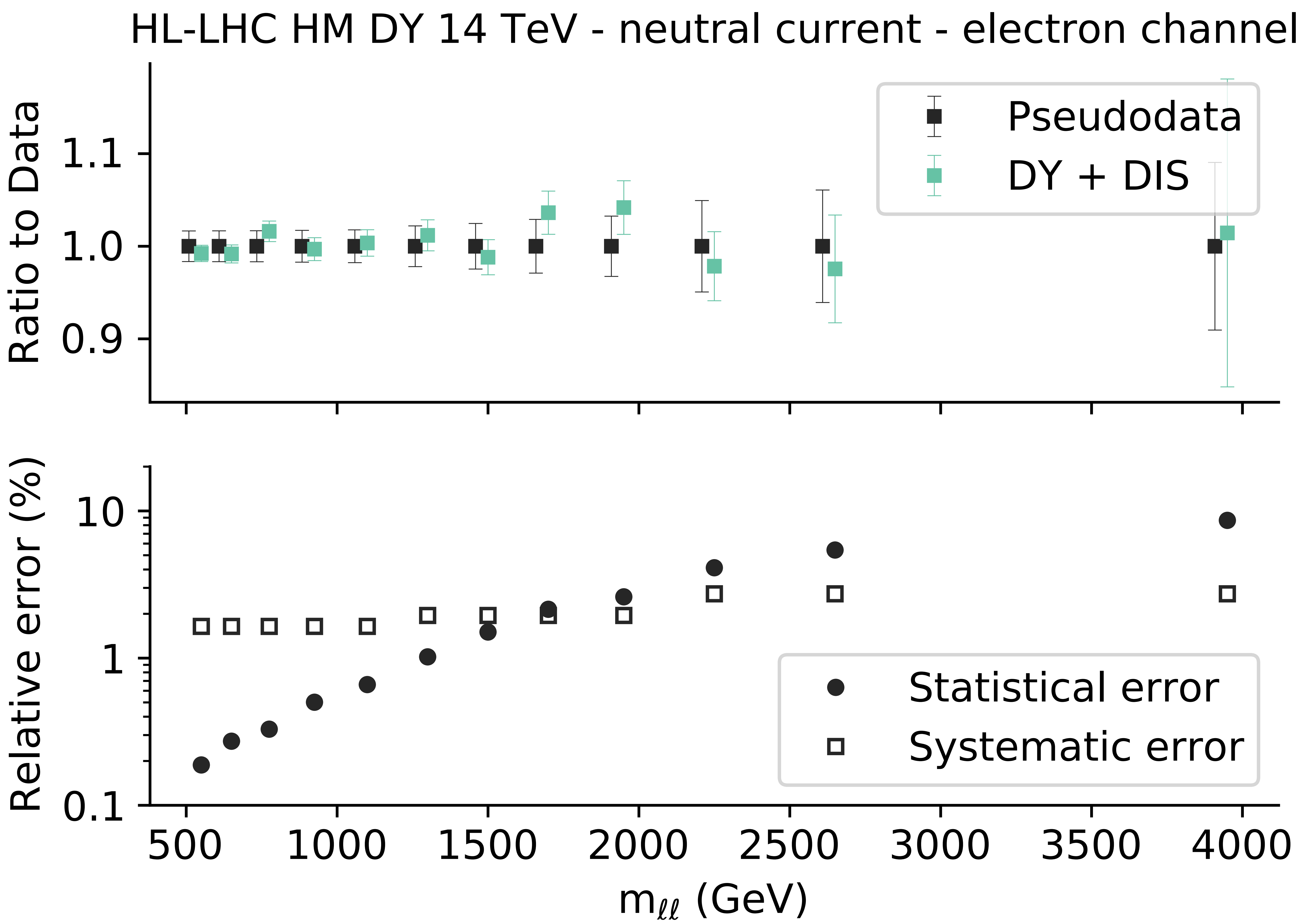
High luminosity projections

We produce pseudodata for neutral and charged current DY:

$$\sqrt{s} = 14 \text{ TeV} \qquad \mathcal{L} = 6 \text{ ab}^{-1}$$

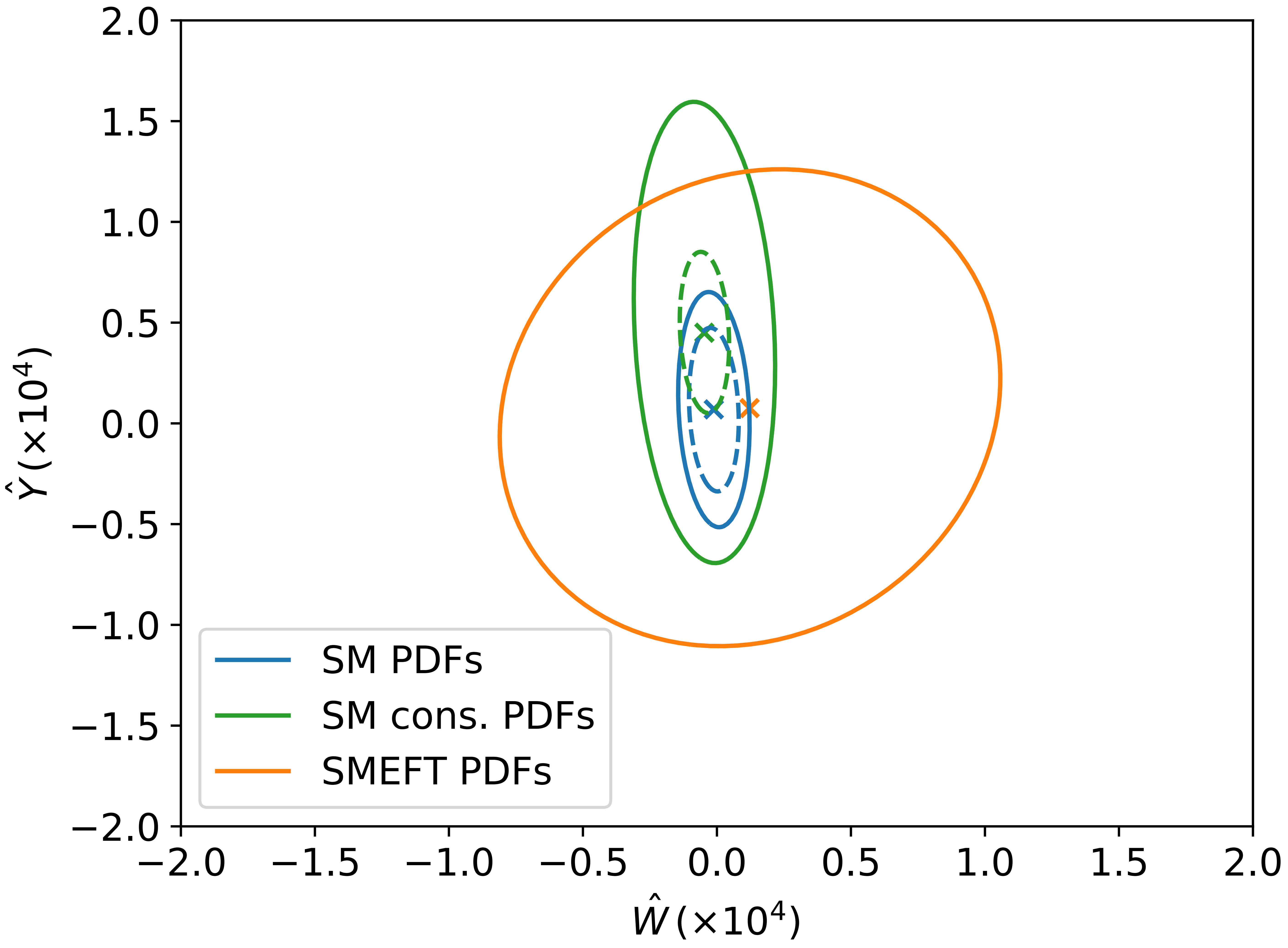
Systematic uncertainties are based on current measurements, reduced by a factor of

$$f_{\text{red}} = 0.2$$



High luminosity projections

Neglecting the interplay leads to a significant overestimate of the EFT constraints.



Conservative SM PDFs remove high-mass DY data but still assume the SM:

→ the situation is improved but the difference is still significant

Conclusions

We have compared the results of a simultaneous fit and a fit using SM PDFs, with DY and DIS data, to study the interplay of PDF and EFT effects.

Using data from LHC Run I and II, the effect of the interplay is visible but still within PDF uncertainties.

At the HL-LHC:

- Not accounting for the interplay may lead to artificially precise constraints on the EFT.
- Conservative PDFs still lead to stronger bounds than SMEFT PDFs.

Next steps:

- Development of a framework capable of handling more operators.
- Further investigation into the definition of conservative PDF sets.