Parton distributions with scale uncertainties. A MonteCarlo sampling approach

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Interpretation

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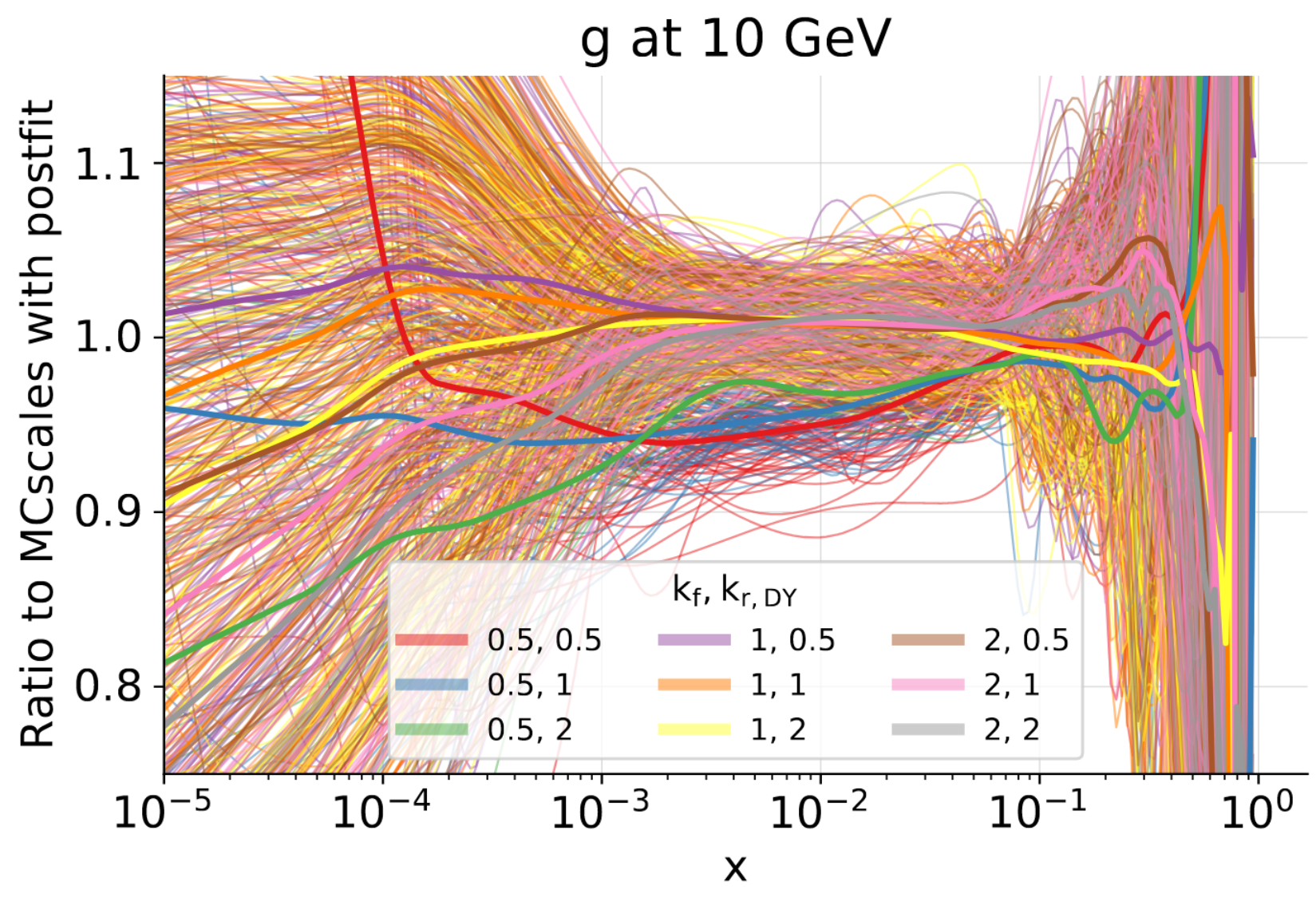
This talk

Parton distributions with scale uncertainties: a MonteCarlo sampling approach
(ZK, Ubiali, Voisey, arxiv:2207.07616)

- Assign different scale multipliers, for each process being fitted, to each NNPDF replica.
- Record the information so scales can be matched between the PDF and the partonic cross section.

What we'll get



`MCscales` replicas for the Drell Yan Process

Scale variations vs MHOUS

We are solving for scale uncertainties

- Scale uncertainty: Scale parameters must be chosen for calculations at finite order.

$$\sigma(Q_r, Q_f) = \hat{\sigma}(Q_r, \alpha_s(Q_R)) \otimes f(Q_f)$$

  - Scales close to the "scale of the process" improve perturbative convergence $\rightarrow$ prior information
- Missing Higher Order Uncertainty (MHOU): Uncertainty due to difference between fixed order and all order.

Scale uncertainties are included on MHOUS, but needed for as long as scale choices are made.

Scales in PDF fits

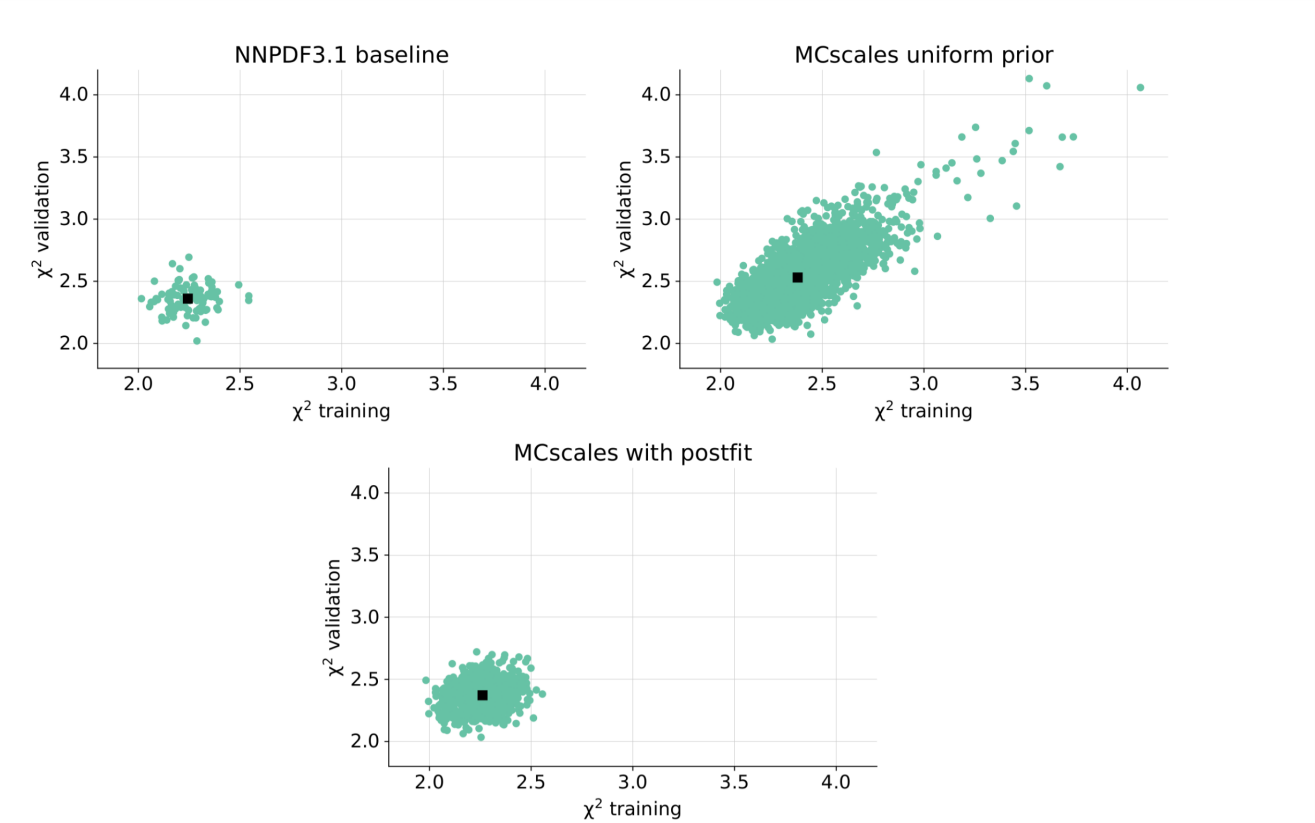
- PDFs produce theory predictions given other theory predictions and experimental data in the PDF fit.
- Each theory prediction in the fit requires a factorization and a renormalization scale.
- When making predictions using PDFs we also need to set scales.

Problems being solved

Scale uncertainties typically estimated by varying target cross section by a factor of two around some central scale:

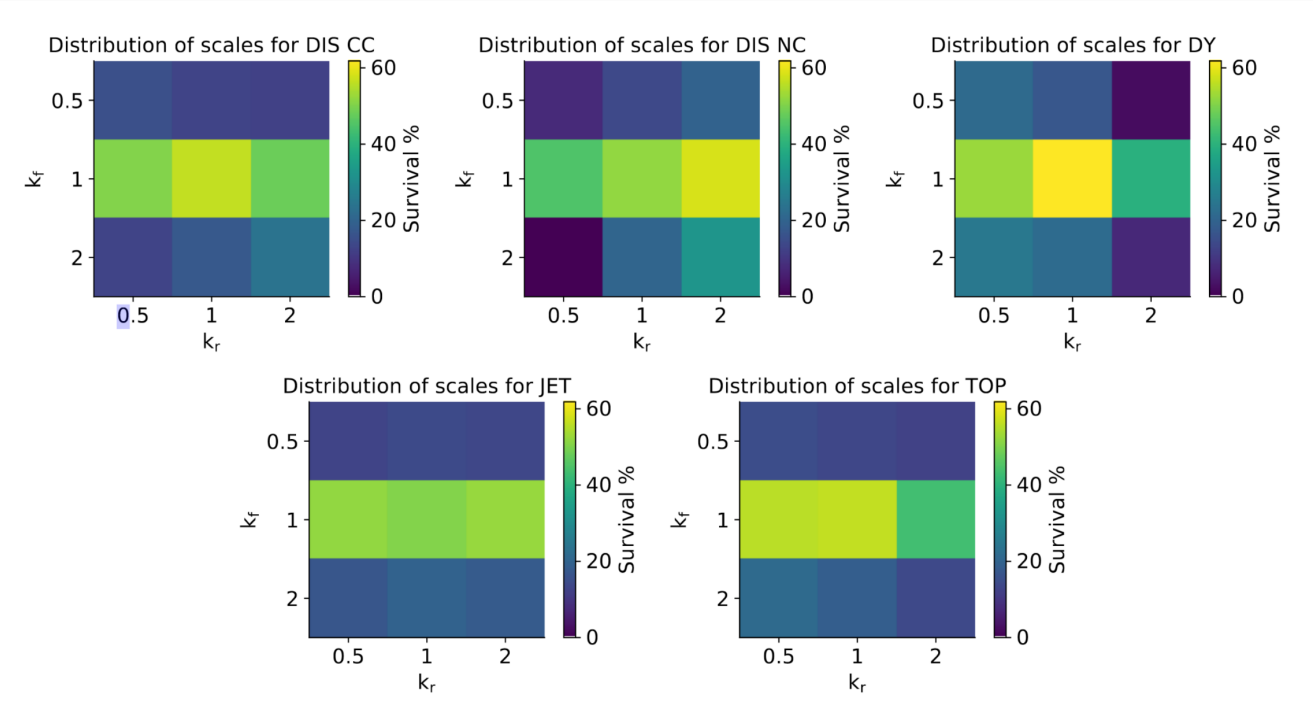
- Effect on PDFs not being considered:
  - Best fit PDFs changed in a non trivial way.
  - Scale variations mismatched w.r.t. theory in the fit.
- Range of scale variation a guess. Is it adequate?

Fit quality allows assessing scale choices



- Fit quality very different for different scale choices
- Use the same selection criterion as the normal NNPDF fit, assuming central scales only
- Allows to assess scale choices!

Survival fraction



- Statistical interpretation of scale variations
- Assessment of ranges of variation

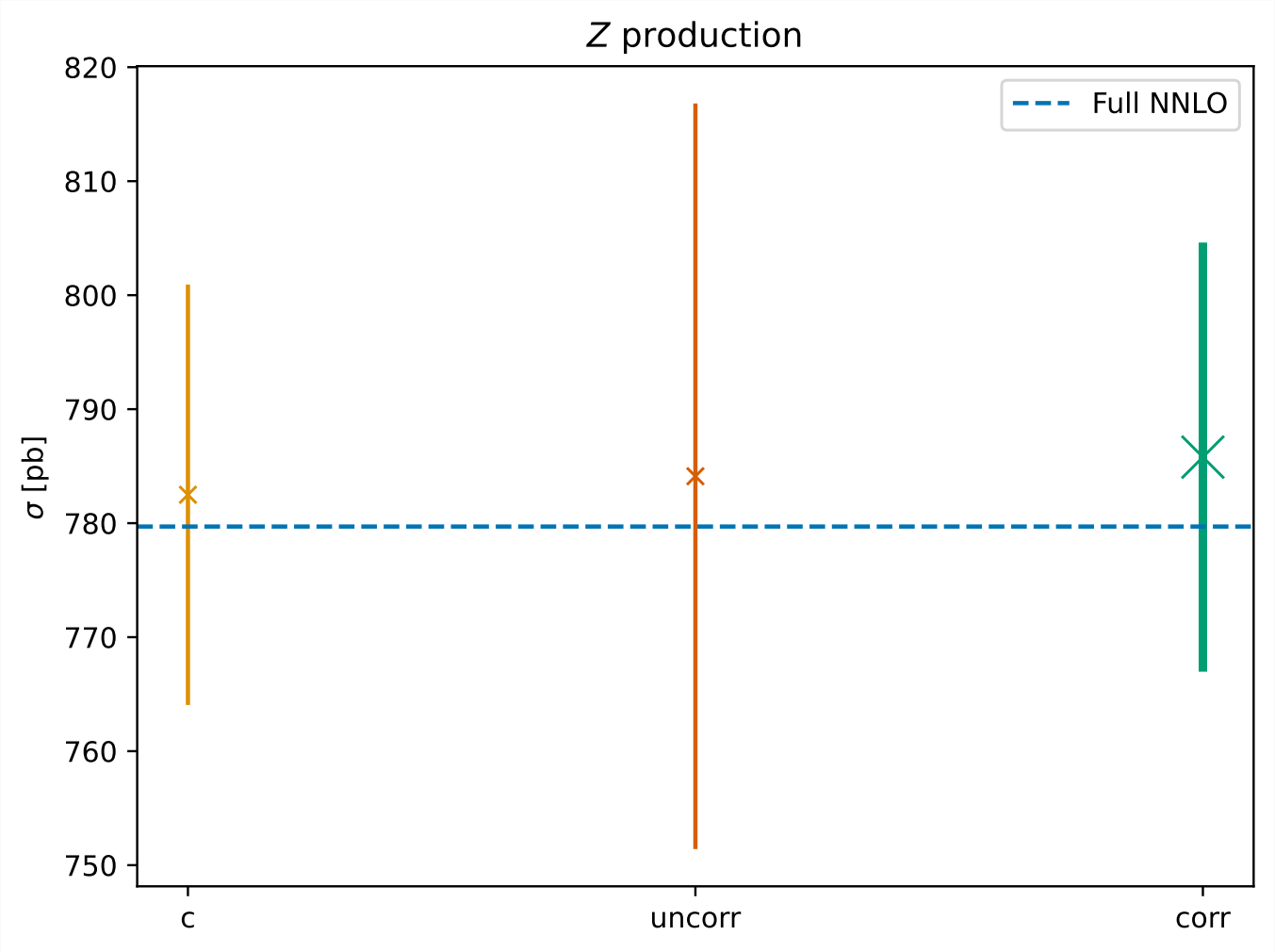
Matched scales convolution

We record the scale multiplier choices for each fitted replica. This allows matching the partonic cross section with the scale choices within each replica

- Monte Carlo sample of N_{rep} `MCscales` prediction including correlated PDF and scale uncertainty

$$\left\{\sigma_k = \hat{\sigma}_p(k_f^{(k)}, k_{r_p}^{(k)}) \otimes f_k(k_f^{(k)}, k_{r_p}^{(k)}) \;\; \forall\, k \in 1 \dots N_{\text{rep}}\right\}$$

Scales must be matched: Example Z cross section



Treating scales as uncorrelated between PDF and partonic cross section largely overestimates the uncertainties

Why MCscales

- Correlation between scale variations in PDFs and partonic cross sections is large.
    - MCscales allows for exact matching
- Transparent specification of scale uncertainties, with tools allowing users to manipulate it.
    - https://github.com/Zaharid/mcscales_tools
- Largest benchmark of effect of scale variations of fit quality.
- NNLO implementation on NNPDF4.0 expected.