Theoretical Uncertainties in PDF fits

a discussion on an unknown unknown

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What drives PDF uncertainties

Quick Overview

Uncertainties on PDFs are determined by:

- Experimental uncertainties
  - Hessian vs. Monte Carlo
  - See paper from R. Thorne & G. Watt, arXiv:1205.4021
- Uncertainties on model parameters
  - α_s
  - Heavy Flavour masses
  - .....
- Theoretical (perturbative) uncertainties
  - Higher Orders

What drives PDF uncertainties

Paramter uncertainties

- Sets with different values of parameters or fitting together with PDF
- Size of uncertainty is similar at NLO and NNLO
- Can, in principle, be taken as external parameters to the fit (i.e. assume PDG values)

What drives PDF uncertainties

Theoretical uncertainties

- Not included in any of currently available PDF sets
- Due to unknown higher orders
- (Should) Decrease when going up in PT order
- NNLO-NLO difference **is** the theoretical uncertainty on NLO PDFs
- ... but what about the uncertainty on NNLO PDFs?

Theoretical uncertainties

Stefano's Proposal

A PRESCRIPTION? (UP FOR DISCUSSION)

HOW SHOULD ONE COMPUTE THE THEORETICAL UNCERTAINTY ONOBSERVABLES?

- AT NLO REPLACE NLO WITH NNLO PDFS (WITH MATRIX ELEMNT UNCHANGED), & TAKE |NLO-NNLO| SHIFT AS UNCERTAINTY
- AT NNLO DETERMINE CACCIARI-HOUDEAU UNCERTAINTY, SHIFT CENTRAL PDF BY THE RESULT
- IN ALL CASES TAKE THIS AS PDF THEORETICAL UNCERTAINTY, COMBINE WITH STANDARD SCALE VARIATION UNCERTAINTY

  LINEAR SUM MIGHT LEAD TO OVERESTIMATE; ENVELOPE PERHAPS MORE REASONABLE?

[S. Forte, PDF4LHC - Nov. 2012]

Theoretical uncertainties in global fits

A lesson from Higgs searches

Include the uncertainty on the scale variations in the **Likelihood** that you are employing in the fit

$$\mathcal{L}(X|\mu,\nu) = \prod_i \frac{e^{-\lambda_i(\mu,\nu)}\lambda_i^{X_i}(\mu,\nu)}{X_i!} \times \prod_j \pi_j(\tilde{\nu}_j|\nu_j)$$

where for the "unmeasured" nuisance parameters (like the perturbative scale) the distribution has to be modeled from assumptions:

- Log-Normal (as done in Higgs searches)
- "Worst-case scenario" (as proposed in Dulat & Mitsberger, arXiv:1204.3851)
- Extended version of Cacciari-Houdeau
- .....

Theoretical Uncertainties

The Cacciari-Houdeau method

[M. Cacciari & N. Houdeau, arXiv:1105.5152]

- Developed for assessing uncertainties due to renormalization scale variation
- Formulate a Bayesian model to parametrize uncertainties due to the truncation of the PT series in terms of **credibility intervals**
- Once the assumptions are stated the derivation is rigorous
- Generically write an observable as a perturbative expansion as

$$\sigma_k = c_l \alpha_s^l + \cdots + c_k \alpha_s^k$$

- The uncertainty on the truncated series in than given by

$$d_k^{(p)} = \begin{cases} \alpha_s^{k+1} \max\{|c_l|, \ldots, |c_k|\} \frac{n_c+1}{n_c} p\% & \text{if } p\% \leq \frac{n_c}{n_c+1} \\ \alpha_s^{k+1} \max\{|c_l|, \ldots, |c_k|\} \left[(n_c+1)(1-p\%)\right]^{-1/n_c} & \text{if } p\% > \frac{n_c}{n_c+1} \end{cases}$$

Theoretical Uncertainties

Extending the Cacciari-Houdeau method

[E. Bagnaschi, M. Cacciari, L. Jenniches & AG, in progress]

- Work is in progress to:
  - better understand the features of the original method (dependence on the expansion parameter)
  - extend the method to accommodate factorization scale variations
    (increase a function rather than a number)
  - (A slightly modified version of) the present version of the method can be used to include uncertainties on PDFs due to truncating the PT series for AP splitting functions

Conclusions

... well, not really

It's easy to guess that we all agree the inclusion of theoretical uncertainties in PDF fits is becoming a pressing problem

There are techniques we can borrow from other studies

... but we are still at the level of throwing out ideas which need testing and full understanding

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The floor is now open for discussion