Discussion on theory uncertainties in M_W and α_s LHC measurements

(A. Huss, M. Mangano, A. Vicini, P. Monni)

CERN - 26 February 2024

Why this meeting?

- The precision reached by recent & ongoing LHC measurements of α_s and M_W requires a control over TH uncertainties that is unprecedented at hadron colliders. The assessment of such uncertainties is notoriously challenging and demands the input from the community of TH/EP experts.

- One can structure today's discussion into the following 3 points:

  - **TH unc. in observables**: The estimate of TH uncertainty in observables used in the measurement (e.g. ptZ, leptonic distributions, etc.) requires a technical discussion among experts to establish what the state-of-the-art precision is (e.g. scale uncertainties, PDFs, non-pert effects, QCD⊕QED, …)
  - **Propagation of TH unc. in the measurement**: The implementation and propagation of the above uncertainties in the analyses involves many subtle points (e.g. statistical interpretation, correlations, …). It is necessary to establish how different sources of error (e.g. scales, PDFs) impact the extracted parameter. Interaction with EP experts crucial for this step
  - **Reduction of TH unc. with data-driven techniques**: Data is often used to improve the quality of the modelling and reduce TH unc. (e.g. via profiling of PDFs or scales, tuning). Can we validate the robustness of these methods with some simplified examples (e.g. is any bias being introduced)? Can we formulate criteria for the applicability of this class of approaches?

Structure of the discussion & follow-up activities

- This meeting is meant as a platform to discuss these points, in order to provide the community with the necessary understanding and trigger activities aimed at addressing the aforementioned problems

  ➡ Concrete input from the experts is very welcome on all fronts, in order to improve or complement what will be proposed today

- In the following we list a few possible exercises that can be performed within this effort to gain insight into these problems. The exercises are meant to be an initial step to dive into these complicated questions, and will hopefully trigger more in-depth investigations

- Feel free to suggest improvements and/or new items to the list, your opinion and contribution is essential. [Some obvious missing elements are, e.g., the discussion of EW and QED corrections, also discussed within the EWWG]

Case study: PDFs

- **Profiling (M_W related)**: the goal is to verify whether the PDF profiling (e.g. using ptZ) biases the parametrisation of the proton content when describing other observables. We can consider performing PDF profiling using a set of exp. data (e.g. ptZ) [explore also the use of pseudo-data], then:

  - Study the impact of profiling on, e.g. i) a global χ^2; ii) the description of observables sensitive to gluon PDFs / quark PDFs (e.g. yZ).

  - Keep tolerance factor in profiling and minimise χ^2 as a function of the extracted parameter

- **Correlations (α_s related)**: Quantify the correlation between the PDFs (e.g. gluon) and α_s with different PDF sets. From this, discuss how extracting α_s with a specific set is affected by the underlying correlation, and how to account for this uncertainty in the parameter

Case study: non-perturbative corrections

- **Parametrisation and correlation with α_s**: the goal is to assess the quality of the modelling of non-perturbative (NP) effects, and establish whether the large correlation with α_s at small ptZ can introduce a bias in the extracted value of the strong coupling

  - To test the adopted NP model, we can start from a reference global TMD fit as pseudo-data. Within the same framework/code, we can now replace the TMD model with a NP parametrisation and extract simultaneously the NP parameters as well as α_s. Is the value of α_s compatible with the one used to generate the pseudo-data distributions? How much does the picture change when one adjusts both lower and upper bounds of the fitting range? Explore the use of a TMD global fit as NP model in α_s extraction

  - Discuss a future set of ptZ measurements across different Q^2 and y_Z bins to disentangle the correlation between α_s and the NP model.

Case study: perturbative uncertainties

- **Simplified model for tuning**: the goal is to create a simplified tuning model. Ongoing brainstorming on a simplified model
  - Start with a study of ptW/ptZ ratio with state of the art predictions, and assess TH uncertainty
  - Study of the propagation of scale uncertainties in tuning

Organization of follow-up work

- We propose a coordinated exercise to investigate the above questions. Everyone interested in actively contributing is welcome to join the effort

  ➡ Other examples exist within the Higgs WG (e.g. predictions for boosted Higgs production) & in the DM WG (e.g. assessment of TH uncertainties in mono-jet dark matter searches), both published in journals

- The activities will involve and benefit from the whole community of TH & EP experts. The progress can be reported regularly in public meetings of the EWWG

- The findings will be eventually documented in public notes, to be posted on CDS and arXiv after proper scrutiny by the whole community. Publication in the new SciPost category on Physics Community Reports will be also considered to reward the contribution of young researchers