Brief report on the theoretical activities of the EWWG subgroup on Drell-Yan physics and precision measurements

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Topics under discussion

Main physics goals:

- high-precision determination of EW parameters: M_W, $\sin^2\theta_W$, M_Z, Γ_W, Γ_Z

- high-precision measurement of DY observables
  (SM candles important to set constraints on the proton PDFs
  and as background to BSM searches)

Specific topics under discussion:

- ptZ distribution:
  role of higher-order QCD radiative corrections, EW effects, heavy-quarks effects
  comparison of the ptW and ptZ distributions

- determination of $\sin^2\theta_W$
  measurement of the lepton-pair invariant mass distribution and forward-backward asymmetry
  role of higher-order EW corrections, interplay of EW and QCD corrections
  impact of PDF uncertainties
  measurement of the angular coefficient a_4

- PDF uncertainties affecting the whole set of DY observables
  associated impact in a global EW fit perspective

Studies on the ptW and ptZ distribution

- relevant in the framework of the Mw measurement

- results at NNLO-QCD presented by A. Huss in January

https://indico.cern.ch/event/698495/contributions/2867618/attachments/1589657/2515045/ahuss.pdf

- progress in the resummation of log(ptV/Mv) terms
  up to (NNLO+N3LL)-QCD accuracy with RadISH
  (Bizon, Monni, Re, Rottoli, Torrielli)
  plot by P. Monni at DIS2018

https://indico.cern.ch/event/656250/contributions/2890115/attachments/1635257/2608671/DIS18_Monni.pdf

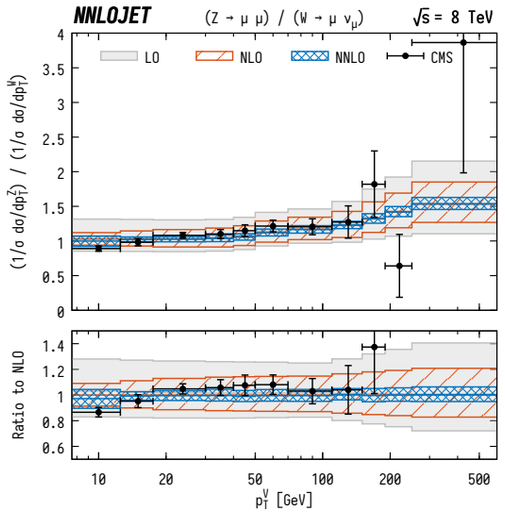
- on-going discussion on the proper treatment
  of heavy-quark effects on the ptZ shape

- need for a systematic treatment of EW effects
  (QED ISR distinguishes W from Z production)

Main goals

- Reliable estimate of the precision (i.e. th. unc.) of the theoretical prediction of ptZ (and ptW)
- Discussion about the accuracy of the th. predictions in the description of the experimental data
- Theoretical guidelines to formulate accurate Shower Monte Carlo simulation tools

Ratio of p_T spectra: Z/W



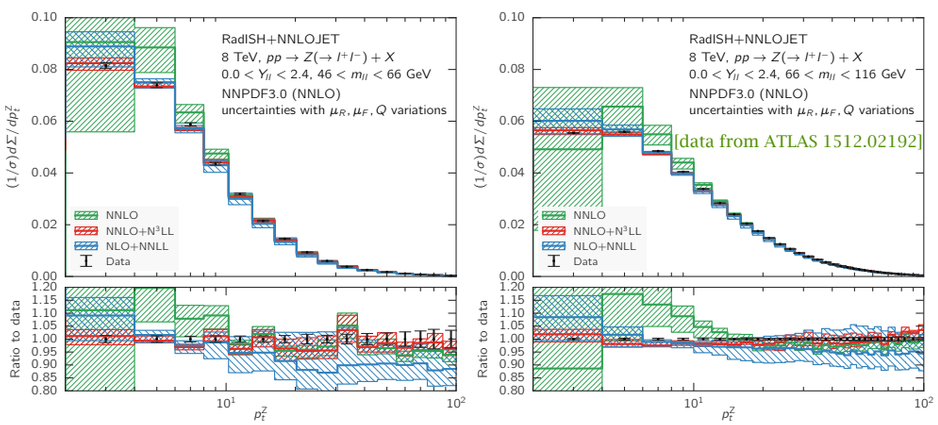
[Gehrmann–De Ridder, Gehrmann, Glover, AH, Walker '17]

- $K_{(N)NLO\ /\ (N)LO} \sim 1$ (very stable)
  ↪ QCD corrections similar: Z vs. W
- data well described by central values

NLO
↪ scale uncertainties ±10–20%

NNLO
↪ scale uncertainties ±5–8%

An example: DY distributions (pT)



➡Matching to differential NNLO from NNLOJET, assume N³LO correction to total XS is zero (i.e. no α_s^3 constant term included)
[Gehrmann-De Ridder, T. Gehrmann, E.W.N. Glover, A. Huss, T.A. Morgan '16]

➡(sub-)percent precision in data, theory can reach ~3-5% accuracy…
Other effects important (QED, PDFs, quark masses, hadronisation)

➡Relevant for W-mass studies

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Studies on the M_{ll} and AFB(M_{ll}) distribution

· relevant in the framework of the $\sin^2\theta_W$ measurement

· the M_{ll} distribution is the basic quantity needed to derive the AFB asymmetry and to extract $\sin^2\theta_W$

· the M_{ll} distribution receives radiative corrections of different origin,
several $O(\alpha^2)$ effects are relevant at the few % level
→ a precise theoretical prediction is a non trivial task

· systematic study of fixed-order predictions at NNLO-QCD and at NLO-EW,
comparing different public codes, in arXiv:1606.02330 → solid benchmarks
→ a classification of further higher-order effects is possible in a common language

· effort to clarify which parameters can be measured at the LHC
  · if we use $\sin^2\theta_W$ as one of the SM Lagrangian inputs → closure test of the SM
  · if we adopt a parametrisation *à-la-LEP* to extract an effective leptonic weak mixing angle,
    → we need to clarify the role and the handling of the systematics

· PDF uncertainties are one example of important theoretical systematic error

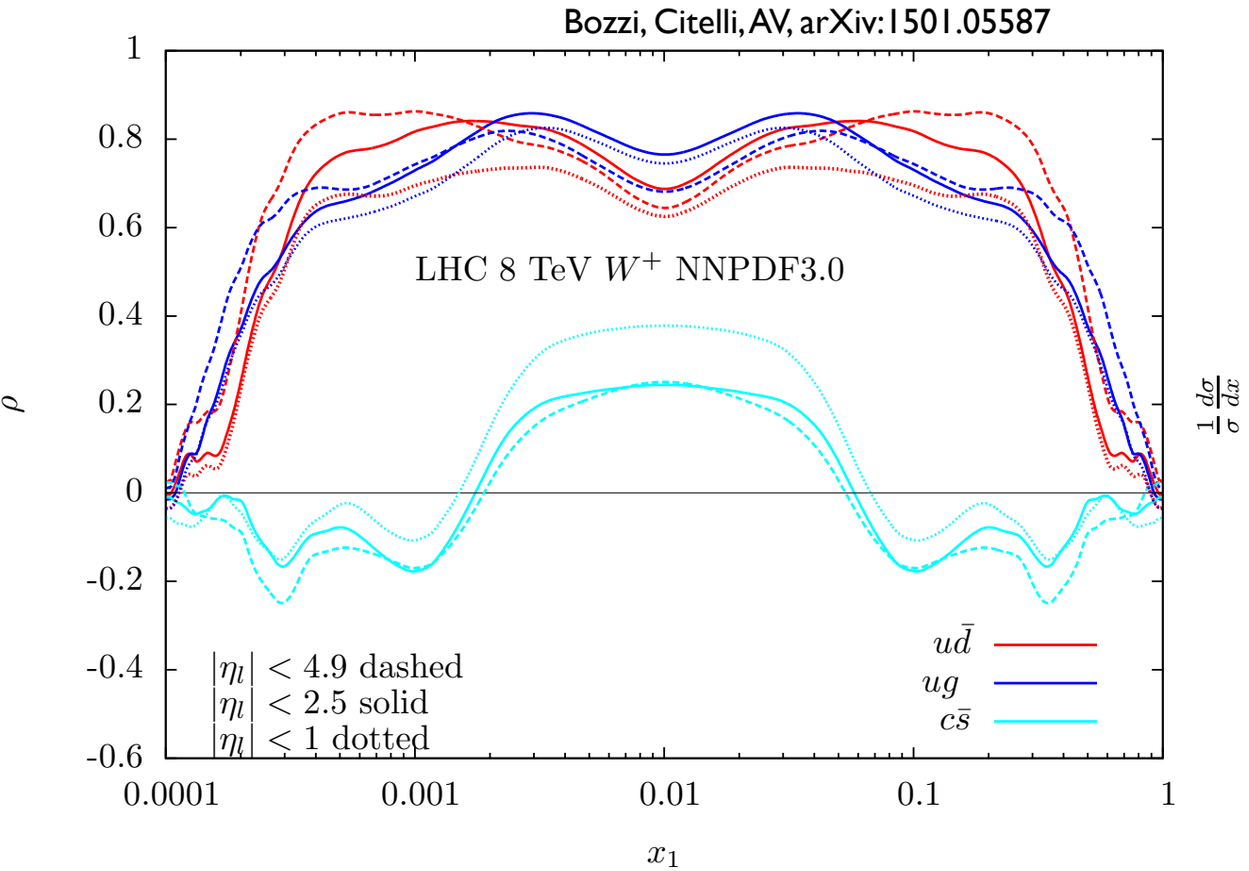
Main goals

· assessment of the theoretical uncertainties on M_{ll} and AFB(M_{ll})
· identification of a framework to interprete the data in terms of fundamental parameters
· validation of tools relevant in the experimental analyses

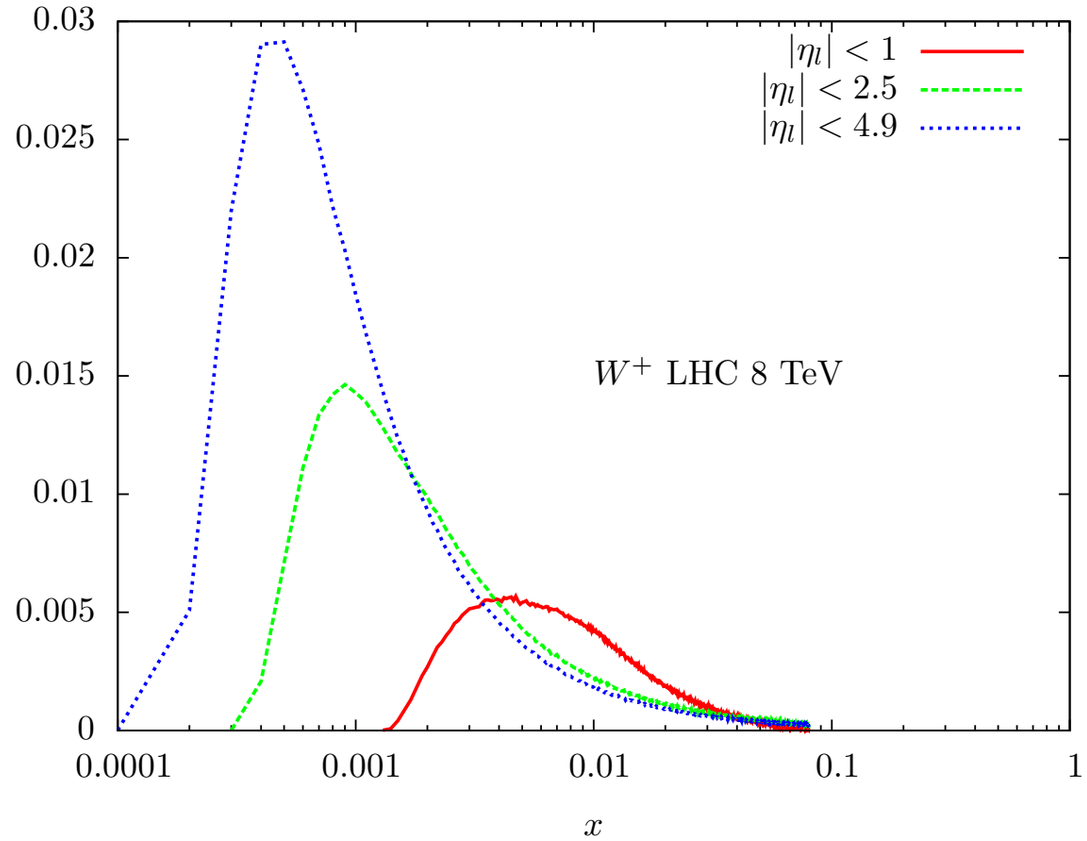
Evaluation of PDF uncertainties in EW precision measurements

- the PDF uncertainties are one of the dominant modelling systematics in MW and $\sin^2\theta_W$ measurement

- an analysis of the correlations between kinematical distributions and parton densities is needed to identify which parton densities contribute the most to the total PDF error require the most significant improvement



correlation between dσ/pt_lep(pt=40) and parton-parton luminosities



DY distribution w.r.t. partonic x with different acceptance cuts

Evaluation of PDF uncertainties in EW precision measurements

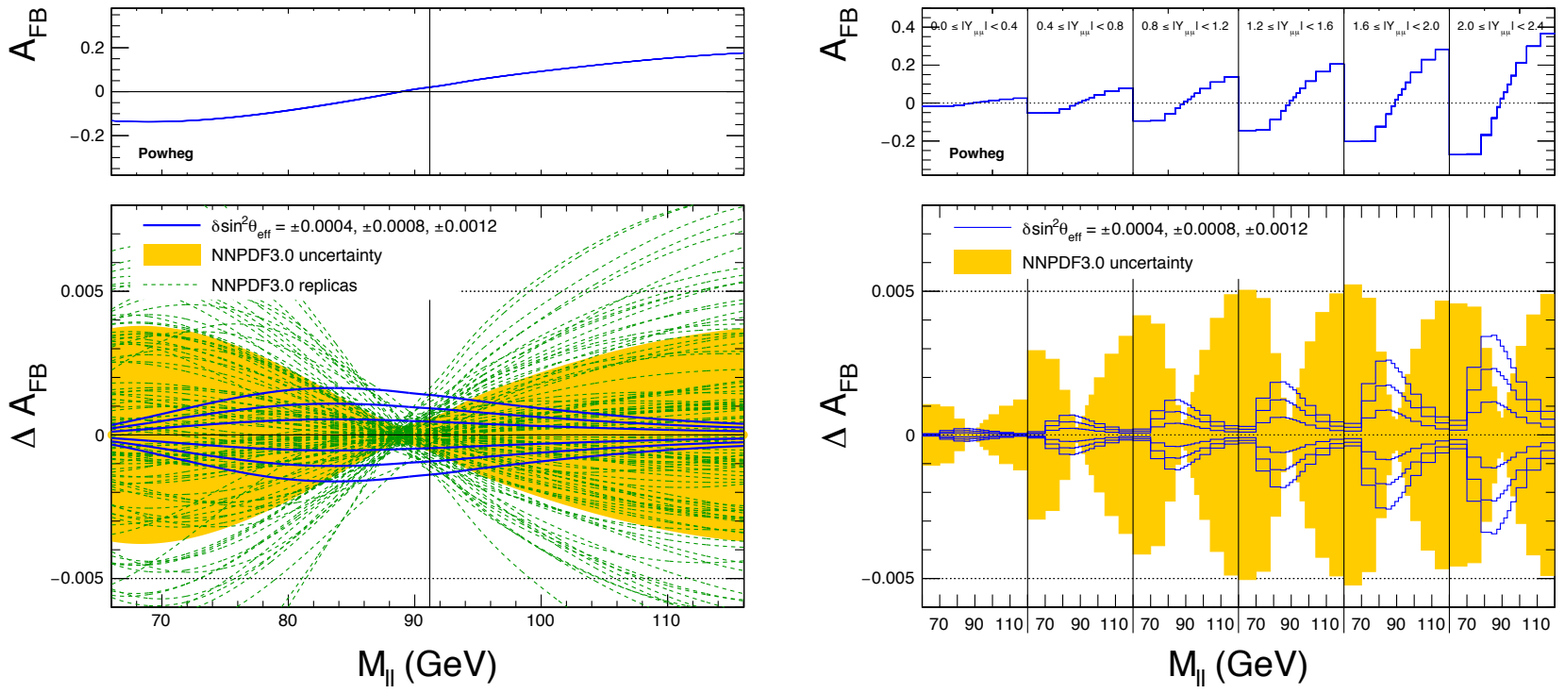
- AFB at the MZ peak is sensitive to $\sin^2\theta_W$,
  at small/large invariant masses is sensitive only to the PDFs
  → a simultaneous fit of all the bins can be used to select the "preferred" PDF replica

https://indico.cern.ch/event/707969/contributions/2936629/attachments/1639521/2617267/LHCewAleko.pdf

PDF reweighting 8

- Observed A_{FB} is very sensitive to PDFs (size of dilution, ratio of u and d to total)
- Large in low and high masses, small near the peak (+ specific dependence on y)

from Aleko Khukhunaishvili talk on 25.04.18



- Perform $\sin^2\theta_{eff}$ fit for each PDF replica (by default we use NNPDF3.0)
- Weight each replica (i) by $w_i(\chi^2_{min})$

A. Bodek et al Euro. Phy. J. C76:115 (2016)

$$w_i = \frac{e^{-\frac{\chi^2_{min}}{2}}}{\frac{1}{N}\sum_{i=1}^{N} e^{-\frac{\chi^2_{min}}{2}}}$$

Main goals of WG1

- identification of the most critical parton densities and of corresponding actions to improve them
- evaluation of the potential of the HL runs to enhance
  the PDF-constraining power of observables/kinematical regions currently limited by statistics