# Proposals for unified treatment of model and theory uncertainties

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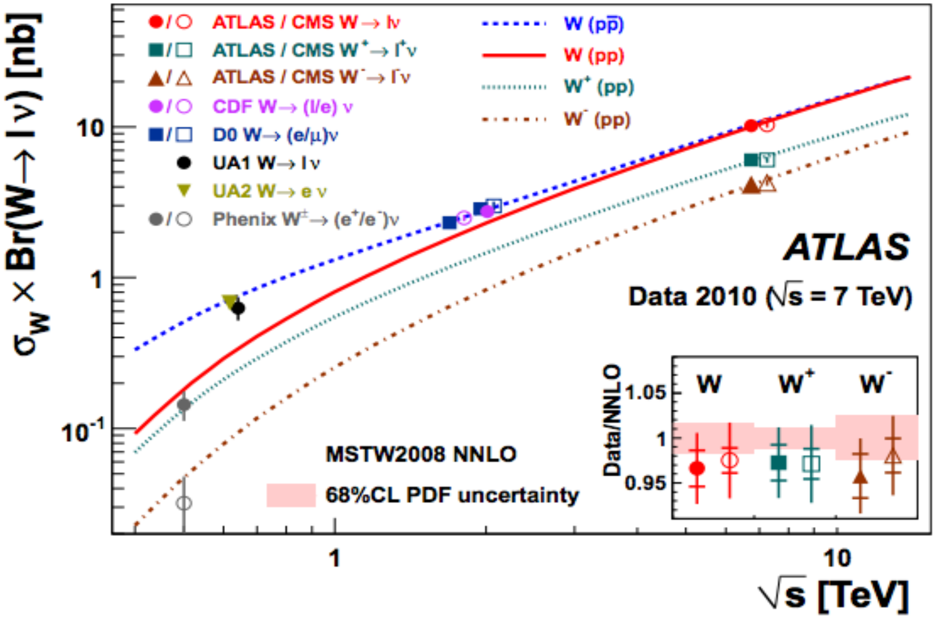
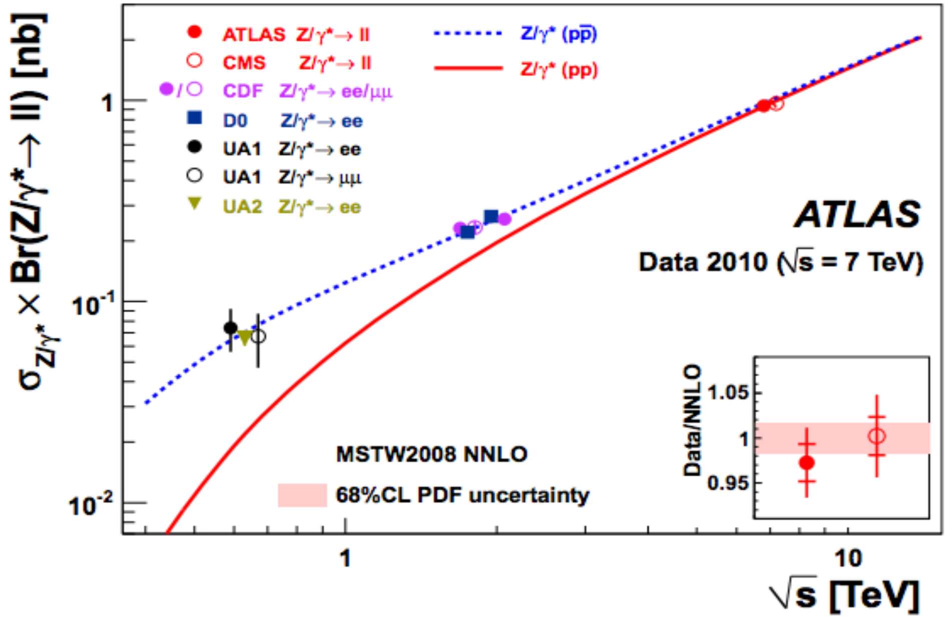
# Theory and model uncertainties and total cross sections




- Extrapolation to total phase space introduces an extra uncertainty of 1 to 2% - of similar or even larger size than the experimental uncertainties – but allows comparisons with other experimental results.
- Measurements are in good agreement with theory predictions at NNLO QCD for both pp and pp- collider results.

# LHC W, Z Cross Section Measurements

$$\sigma^{tot}_{W(Z)} \cdot BR(W(Z) \to \ell\nu\ (\ell\ell)) = \frac{N^{sig}_{W(Z)}}{A_{W(Z)} \cdot C_{W(Z)} \cdot L_{W(Z)}}$$

$$A_{W/Z} = \frac{N_{\mathrm{MC,gen,cut}}}{N_{\mathrm{MC,gen,all}}} \qquad C_{W/Z} = \frac{N_{\mathrm{MC,rec}}}{N_{\mathrm{MC,gen,cut}}}$$

- Fiducial cross section for described kinematic and geometrical cuts are corrected for detector and QED FSR effects.
- Corrections for reconstruction, trigger, lepton identification and QED FSR effects are performed with a single factor $C_{W(Z)}$ taken from Monte Carlo interfaced with Photos (e.g. $N_{MC,gen}$ *before QED FSR*).

- Extrapolated and total cross sections, respectively, are obtained calculating the geometrical acceptance $A_{W(Z)}$ (or extrapolation factors) using dedicated Monte Carlo samples.

# Evaluation of theory and model uncertainties

Proposal :

Use same methodology for estimating systematic uncertainties due to our knowledge of theory and modelling of the process.

It should be applied for

- the fiducial cross section measurements
- the determination of interpolation and extrapolation factors required for comparisons between the lepton channels and then between experiments
- the determination of the acceptances required for any total cross section measurements

Benefits :

- We can then better compare directly the systematic uncertainties due to theory and model assumptions between the experiments.
- We may have a better handle of understanding of correlations due to use of similar theory or MC models between experiments.

→ may be important for joint PDF fits of LHC W, Z precision data.

# Potential strategy

Baseline Monte Carlo:

- use NLO ME event generators as a default for unfolding (e.g. MC@NLO and Powheg) with an up-to-date NLO PDF (e.g. CT10), however those MC's may have deficits describing specific phase spaces like high $p^T_{Z,W}$
- remark : for variables like $p^T_{Z,W}$ we may also use generators like Alpgen or Sherpa (but note : those may have deficits describing e.g. rapidity)

1) Systematic uncertainties arising from our knowledge of PDFs

- use ONE set of PDF eigenvectors to account for 'experimental input' uncertainties : CT10 (90% C.L.)
- use method of PDF reweighting on the baseline Monte Carlo sample to get the uncertainties
  - ➔ calculate asymmetric and symmetric errors and compare
  - ➔ use symmetric results in case

# Potential strategy … cont'd

2) Estimate effects due to different PDF sets

- use DIFFERENT PDF predictions to account for possible differences in the theory/way, the fits have been performed (deviations between predictions are partially NOT covered by the PDF uncertainties) : CT10 versus HERAPDF1.5 and versus MSTW2008NLO using the same generator (MC@NLO)
- calculations done using PDF reweighting : uncertainty due to PDF reweighting added in quadrature (Atlas found non-closure of about 1% for Z, 0.5% for W)
- NOT addressed : uncertainty due to $\alpha_S$ : this would require separate generation of samples or use of external programs (like FEWZ or DYNNLO)

3) Estimate effects due to modelling of parton showers (and underlying event)

- use SAME PDF but different parton shower generator : e.g. CT10 in Powheg+Pythia versus Powheg+Herwig
- requires new generation of high statistics MC samples

# A comment on the EW parameter choice

1) MC generation :

- Here usually the 'world-best' values are taken from PDG, i.e. usually not a clear EW schema
- PDG Z and W widths contain already corrections due to remaining HO EW and QCD ($\alpha_S$) uncertainties
- Different MC programs have quite different use of EW and other input parameters, partially hard to understand and to control

2) External parton-level programs

- programs like FEWZ and DYNNLO allow for a clear definition of the EW parameter schema which e.g. allows one to test the SM more rigorously
- a "wise" choice of the EW parameter schema may minimise the missing pure weak effects, e.g. like the $G_\mu$ schema

$$\frac{1}{\alpha_G} = \frac{\sqrt{2} G_\mu M_W^2}{\pi} \left(1 - \frac{M_W^2}{M_Z^2}\right); \quad \sin^2\theta_W = 1 - \frac{M_W^2}{M_Z^2}$$

- However, such definitions are not well suited for ALL kind of measurements, e.g. not for $A_{fb}$ and $\sin^2\theta$

# Uncertainties due to HO EW

Estimating the remaining HO EW corrections are particularly challenging and depend of the chosen EW parameter scheme and parameter inputs.

Note : Since the QED FSR effects are the most significant contribution, it is essential that the QED FSR is properly modelled in the simulation and QED FSR photons are passed to the same reconstruction as the data.

On the generator level, we may then further calculate different levels of QED FSR correction which are defined as follows

- "born" : full correction of QED FSR
- "dressed" : recombine lepton and radiated photons within a cone of 0.1
- "bare" : leptons after QED FSR

The publication of those correction factors may then enhance our understanding what was done in the experiment.

We should not try and correct data for remaining (or "missing") HO EW effects which are QED ISR, QED ISR and FSR interferences, and pure weak effects.

However, all those "missing" effects needs to be estimated, e.g.

- to obtain corrections of the HO QCD calculations, e.g. for PDF fits
- to obtain uncertainties in the shapes of *simulated distributions* for unfolding e.g. Z lineshape

# Uncertainties due to HO EW … cont’d

1) <u>“Standard” so far :</u>

- experimenters are using external HO EW programs (e.g. HORACE or SANC) for an estimate of “missing” HO EW contributions
- however, those are based on LO QCD calculations and results need to “rescaled” to match for HO QCD calculations; and it does not include any folded effects between EW and QCD higher orders
- they are partially not well matched to the EW parameter schema and the amount of QED FSR already taken care off in the MC generation
- so, there are strong limitations and the resulting accuracy is unclear
- can be only used for rough uncertainty estimates for the “born” , “bare” and “dressed” levels ➔ more sophisticated evaluation are needed here

2) <u>Ongoing developments :</u>

- since long, there are efforts ongoing, to combine HO QCD and EW effects
- but it is difficult, e.g. see recent progress for Powheg interfaced with Horace or SANC interfaced to Pythia
- those developments will be crucial for W, Z precision measurements

# Points for discussion

- Should we try and use 68% C.L. errors for experimental uncertainties but e.g. also for the PDF eigenvectors?
- Is there an improved way of reweighting of generated events to achieve better predictions for specific variables?
- Preferred way of publication of correlations/covariance matrices/ nuisance parameters: which level of break down of error sources is needed?
- How to estimate better the EW related uncertainties for 'born', 'dressed' and 'bare' QED FSR corrected data?
- How to achieve consistency between EW parameter schema implemented in MC generation and external calculations?
- How to estimate missing HO EW corrections in a consistent way, also for more complex kinematic variables like $pt_{Z,W}$?