LHC Electroweak Working Group

ptZ and ptW/ptZ determination theoretical predictions and uncertainties open questions

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N3PDF
Machine Learning • PDFs • QCD

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The Electroweak Working Group

- Kick-off meeting: 13-14 December 2017 https://indico.cern.ch/event/678694/

- Three main working groups: Precision measurements in DY processes
  Multiboson production and EFT
  V+jets production

- Precision measurements in DY processes: MW, $\sin^2\theta_W$, MZ, Γ_W, Γ_Z

- Multiple points of interplay between the working groups:
  definition of the procedures necessary to determine SM parameters, EFT parameters
  PDF uncertainties, QCD radiation modelling

- Extensive discussions on ptZ and ptW/ptZ in the Orsay meeting 2-6 October 2017
  https://indico.cern.ch/event/661915/ https://indico.cern.ch/event/661916/

Subgroup on ptZ and ptW/ptZ determination

- MW measurement is one of the very hot topics of the EW WG

  The measurement strongly relies on the knowledge of the ptW spectrum

  Since ptW is poorly measured, one relies on the very accurate knowledge of ptZ to model ptW

  The transfer of information from ptZ to ptW is one of the bottlenecks in the MW measurement

- In the meeting we will start to address some of the questions which naturally emerge:
  - what is the most precise analytical prediction for ptZ ?
  - how well do Shower Monte Carlo codes predict ptZ ?
  - which are the best analytical and Monte Carlo predictions for the ratio ptW/ptZ ?
  - how do we assess the theoretical uncertainty on the ratio ptW/ptZ ?
  - heavy flavour contributions
  - EW contributions
  - what are the best observables to be used for the validation of the TH predictions and estimate of the systematics?

- Very warm invitation to all the interested people (theorists and experimentalists) to join the effort to provide a quantitative answer to these questions!

Analytical results for ptZ

- How precise are our calculations for ptZ?

We need a matching of fixed- and all-orders results

The existence of NNLO-QCD results for ptZ offers the possibility of interesting perturbative studies

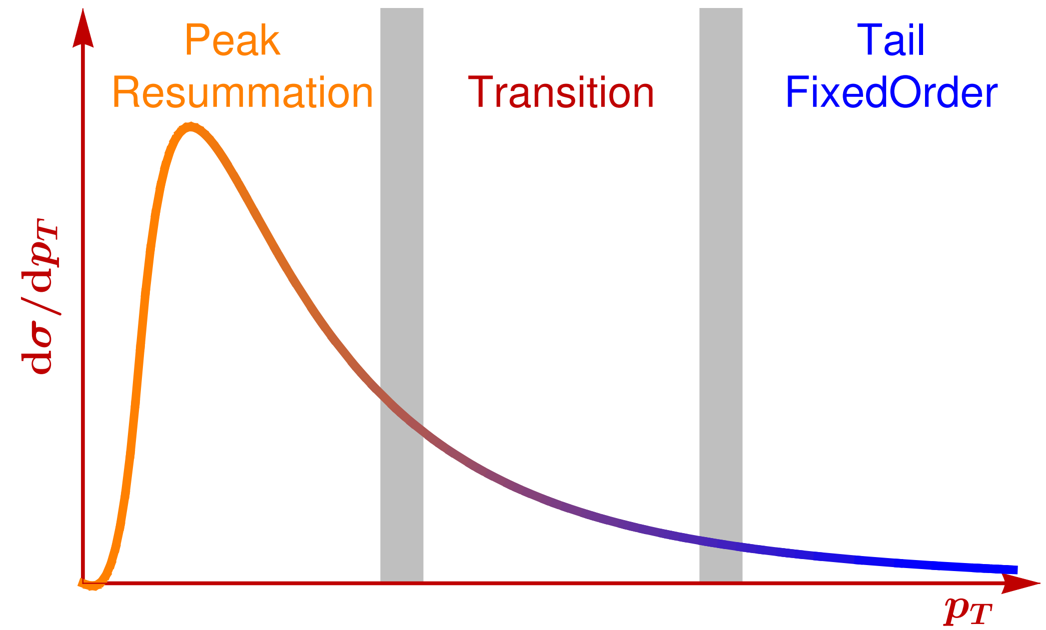
Can we classify the impact of the different classes of available radiative corrections?

Are all the relevant radiative corrections (QCD, EW, heavy flavours)
available in an analytical resummation formalism?

Can we estimate the size of missing, unavailable, radiative corrections?

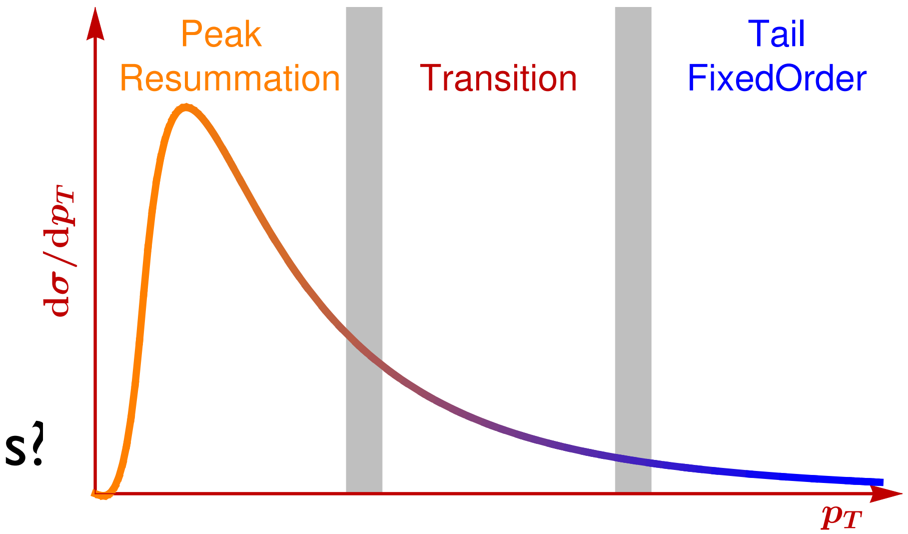
Do we control the impact of the recipes to match fixed- and all-orders results?

The above discussion can be lead on a purely theoretical ground



Can we provide a perturbative best prediction and associated uncertainty band for ptZ in each of the three intervals of ptZ (low, transition, high)?

Analytical results for ptZ



· How accurate are our calculations ?

Do we need non-perturbative contributions to describe the data?

Do the data fall within the purely perturbative uncertainty bands?

What is the impact of matching recipes on the accuracy in the peak/transition/tail regions?

Matching takes care of the transition region but affects in turn the other two

How strong is the interplay between low-ptV and high-ptV regions due to unitarity constraints?

(a non-perturbative term introduced at low-ptV may show up at high-ptV!)

Different matching approaches share the same formal accuracy (fixed-order and logarithmic)

but include higher-orders (in α_s) and subleading (logarithmically) terms in different combinations

Shall we take guidance from the data/predictions comparison to identify a "best" way of modelling ?

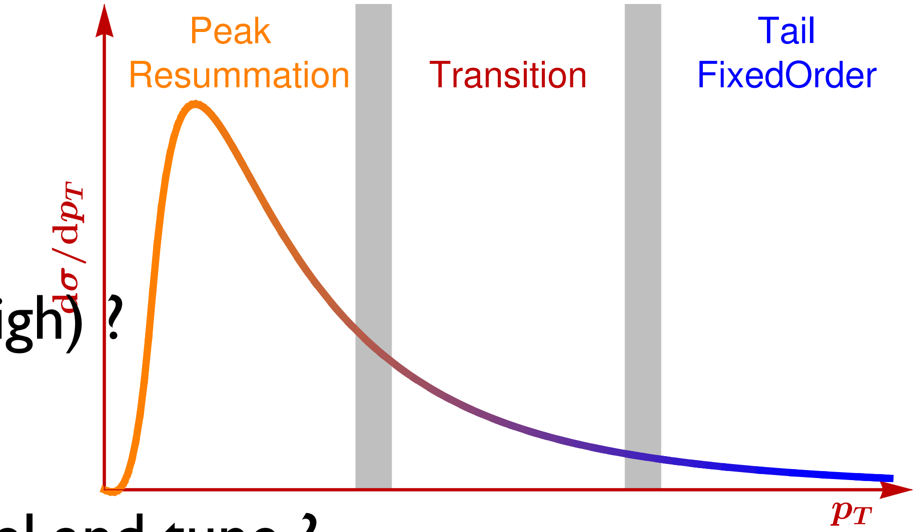
The eventual inclusion of non-perturbative / additional terms e.g. via Parton Shower tuning

must be performed on top of the very best / most comprehensive description available

because it parameterises our ignorance

Which is the role of PDFs and of the PDF uncertainties?

Shower Monte Carlo results for ptZ



Precision

- Which is the perturbative QCD (α_s and logarithmic) content of Shower Monte Carlo codes in the 3 ptZ intervals (low, transition, high) ?
- Can we quantify the perturbative QCD uncertainty of these codes comparing the predictions for a fixed, assigned Parton Shower model and tune ?
- Can we quantify the matching recipe uncertainty of codes sharing the same fixed-order accuracy (NLO-QCD, NNLO-QCD for the total xsec) ?
- Which is the QED impact and the QCD-EW interplay in the 3 ptZ intervals (low, transition, high) ?

  The theoretical uncertainty of the $O(\alpha\alpha_s)$ corrections is modulated by the underlying QCD model

Accuracy

- Which data should be included in the tune of the Parton Shower ?

  Z-resonance region and ptZ < 15 GeV ?

  larger invariant mass window and full ptZ spectrum (at least up to ptZ ~ 100 GeV) ?

  These options may have an impact on the MW determination

- Do we need to make an effort and generate a dedicated Parton Shower tune for each code,

  with all the tunes based on the same set of data,

  in order to achieve a sensible comparison of predictions ?

- PDF role?

Theoretical predictions for ptZ

- What can we learn from the comparison of the available analytical resummation tools
  of the available Shower Monte Carlo tools
  in terms of precision and of achievable accuracy ?
  Do our conclusions change if we focus only on low-ptZ vs the full ptZ spectrum ?

- What is the meaning of reweighing
  a Shower Monte Carlo distribution to an analytical resummation prediction?
  How should we handle the uncertainty estimates after reweighing?

- How can we combine perturbative contributions available in different codes ?

Moving from ptZ to ptW

- The ptZ studies exploit the presence of excellent quality data and
  should allow us to set the limits of our capability to interpret the data in the SM framework
- The main goal of the discussion is to learn how to extrapolate from Z to W
  - for the prediction of the central value
  - for the estimate of the theoretical uncertainty
- NC-DY and CC-DY have strong similarity in their perturbative content, but differ because of
  - different initial state flavour structures
  - different EW charges
  - different reference scales (MW vs MZ)
- The modelling (PS tune) of ptZ should be based on a code that includes all the elements
  of variance between Z and W,
  so that the latter are not encoded in the tune and are not miscounted in the W simulation
- Many of the steps described for ptZ can be repeated in the ptW case
  to estimate the theoretical uncertainty affecting the spectrum (we have both W and Z tools)

  Can we identify the elements of difference between Z and W and
  relate these differences to a breakdown of the perturbative uncertainty in different contributions?

Evaluating ptW/ptZ

Central value

The estimate of the central value looks trivial (we have the tools) but:

How do we choose the perturbative QCD scales (renormalization, factorization, resummation)?

Can we treat the ratio R_{WZ} as an observable that admits a perturbative expansion in α_s and α ?

When we use Shower Monte Carlo,

can we justify the extrapolation (i.e. universality) of the modelling part?

Uncertainty

R_{WZ} is linked to the idea that the theoretical uncertainties common to W and Z cancel in the ratio.

This statement is realized only assuming a well defined pattern (same ξ rescaling the central scale)

for the variation of the pQCD scales in the two processes.

Relaxing this assumption yields a sizeable increase of the uncertainty band.

Arbitrary scale variations in W and Z lead to huge unc. bands, cancelling the advantages of the ratio.

The breakdown of the perturbative uncertainty of ptW and ptZ in different contributions

is the necessary step to progress in the evaluation of the ratio R_{WZ}=ptW/ptZ and its uncertainty.

For those terms common to W and Z → "correlated" uncertainties (same origin)

that differ in W and Z → associated uncertainties propagated as "uncorrelated"

Starting activities on ptZ and ptW/ptZ

ptZ

- Systematic review of available tools (flash presentations this afternoon)
- Benchmarking
- Collection of best predictions
- Definition of theoretical uncertainty

ptW/ptZ

- Identification of the differences between W and Z
  - contributions to the central values
  - contributions to the uncertainty (separately W and Z)
- Combination of the different contributions into R_{WZ}
  - definition of a correlation model
  - validation
  - estimate of the combined uncertainty