Updates on QCD modelling for the low-μ W-mass analysis

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Non-Perturbative QCD effects

TMD fits to Z - p_{T} and auxiliary Drell-Yan data

- **Precisely constrain NP QCD effects** already before m(*W*) fit
- NP effects related to intrinsic transverse momentum of partons can be described by TMD PDFs
- **DYTurbo NP model** characterised by
  - a **NP cutoff** (prescription for regularizing Landau pole of α_s running) $\rightarrow$ $b_*^2 = b/(1 + b^2/b_{\mathrm{lim}}^2)$
  - a **NP Sudakov form factor** parametrising NP transverse modes in TMDs $\rightarrow$ $S_{\mathrm{NP}}(b) = \exp\left[-g_j(b) - g_K(b)\log\frac{m_{\ell\ell}^2}{Q_0^2}\right]$
- Several S_{NP} parameterisations implemented in DYTurbo
  - Current **baseline** model relies on **Collins-Rogers parametrisation** $\rightarrow$ $S_{\mathrm{NP}}(b \,|\, g_1, q, \lambda, g_0, b_{\mathrm{lim}}, Q_0)$
- Extract and constrain g_0, g_1, q, λ by fitting Drell-Yan data to state-of-the-art DYTurbo predictions
  - **Key advantage**: can properly **account for correlation between PDF and NP QCD** uncertainties
  - Interfacing DYTurbo to xFitter allows simultaneous profiling

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TMD fits to Z - p_{T} and auxiliary Drell-Yan data

- **NP QCD dynamics expected to be universal → Same NP model** describing Drell-Yan, $W^{\pm}$, Z data

- TMD fits should **include**:

  - **Data from ATLAS DY measurements**

    - **8 TeV Z - p_{T} data** in y bins, fitted up to $p_{\mathrm{T}}^{Z} \leq 29$ GeV: **provide most stringent constraints** on NP parameters
    - **13 TeV low-mass DY** $p_{\mathrm{T}}(\mu\mu)$ data in M bins, fitted up to $p_{\mathrm{T}}^{\mu\mu} \leq 10$ GeV: **expand NP sensitivity**.

      (5 and 13 TeV W and Z - p_{T} data measured at low μ will also be included as a cross-check)

  - **But also data from fixed-target DY measurements:** help to better constrain g_0

    - $p_{\mathrm{T}}(\mu\mu)$ data from Fermilab-E288: $p\,N(\mathrm{Pt}) \rightarrow \mu^{+}\mu^{-}\,\mathrm{X}$ at √s = 19.4 / 23.8 / 27.4 GeV
    - $p_{\mathrm{T}}(\mu\mu)$ data from Fermilab-E605: $p\,N(\mathrm{Cu}) \rightarrow \mu^{+}\mu^{-}\,\mathrm{X}$ at √s = 38.8 GeV
    - $p_{\mathrm{T}}(\mu\mu)$ data from Fermilab-E772: $pd \rightarrow \mu^{+}\mu^{-}\,X$ at √s = 38.8 GeV

  - **And data from Tevatron**: help to constrain valence PDFs at high-x, no HF-initiated processes

    - Z - p_{T} data from CDF at 1.96 TeV, p_{T} bins of 0.5 GeV fitted up to $p_{\mathrm{T}}^{Z} \leq 30$ GeV: sensitive to g_1 through the position of the Sudakov peak.

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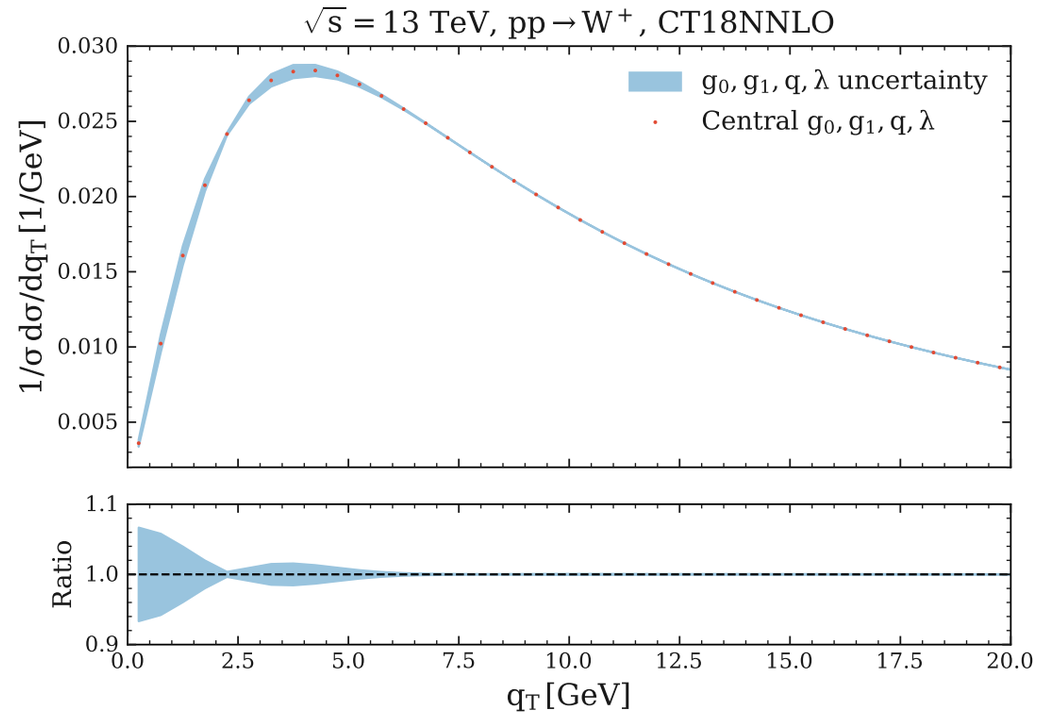
TMD fits to Z - p_{T} and auxiliary Drell-Yan data

- **(Preliminary) fit results:**
  - $g_0 = 0.508 \pm 0.053\ \mathrm{GeV}^2$
  - $g_1 = 0.612 \pm 0.039\ \mathrm{GeV}^2$
  - $\lambda = 2.501 \pm 0.416\ \mathrm{GeV}^2$
  - $q = 0.003 \pm 0.001\ \mathrm{GeV}^4$

$$
\begin{array}{c} \\ g_0 \\ g_1 \\ \lambda \\ q \end{array}
\begin{array}{c}
\begin{array}{cccc} g_0 & g_1 & \lambda & q \end{array} \\
\begin{pmatrix} 1 & 0.1148 & 0.3419 & -0.8067 \\ 0.1148 & 1 & 0.8876 & -0.001803 \\ 0.3419 & 0.8876 & 1 & -0.007184 \\ -0.8067 & -0.001803 & -0.007184 & 1 \end{pmatrix}
\end{array}
$$



- In the pipeline: **TODOs**
  - Extract **full correlation of NP QCD effects** → simultaneous profiling of PDF and TMD uncertainties
  - **Assess NP QCD systematic uncertainties:**
    - Repeat fit with predictions based on other available aN3LO PDF sets, i.e. NNPDFan3lo
    - Test alternative NP models, e.g. SCETLIB model, and effects induced by variations of b_{lim}, Q_0

Modelling of heavy-flavour contributions

TODOs: theoretical uncertainties induced by quark flavour models

- Evaluate effects due to charm and bottom quark masses and thresholds with alternative fits

  - Baseline fit is performed with **backward fixed-flavour PDF evolution**
    → repeat fit using **variable-flavour number (VFN) scheme forward evolution**

  - Fit with **variable-flavour number for the running of** α_s in the Sudakov form factor

  - Fit with independent **variations of charm and bottom PDF matching scales**, μ_c and μ_c
    → control modelling uncertainties in the region of the heavy-quark thresholds

- Assess impact of modelling variations related to HFs on the sensitive W/Z - p_{T} ratio