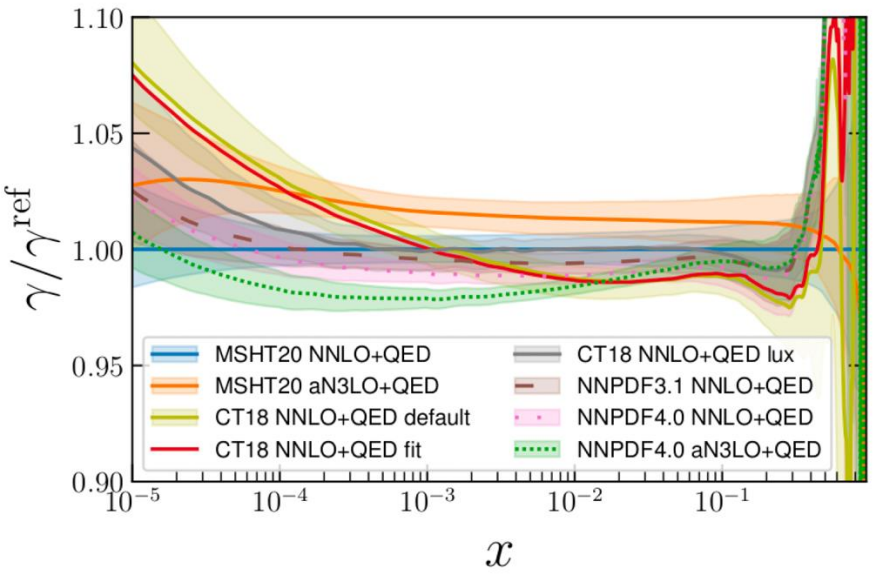
PhysTev 2025

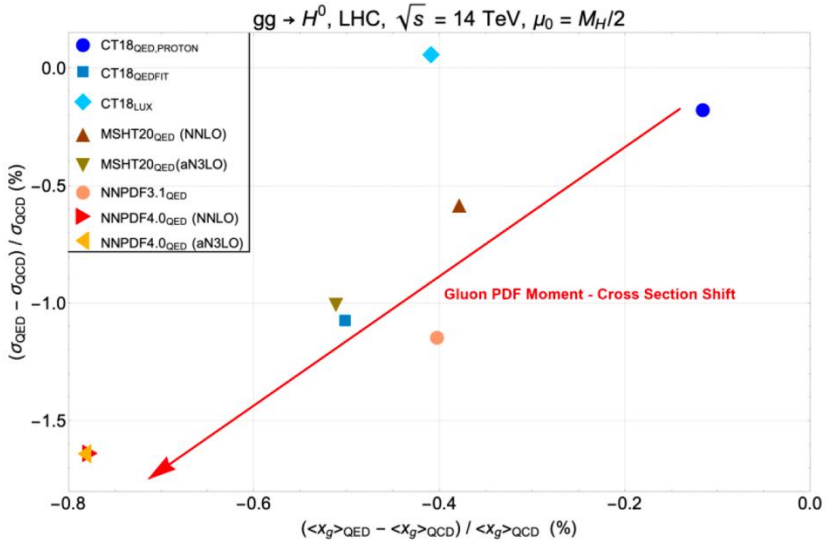
Experimental summary (I)

Ulla Blumenschein, QMUL

- QED corrections to PDF
- PDF profiling in Drell-Yan precision measurements
- Theory and PDF uncertainties for $\sin^2\theta_W$
- α_S from ZpT: ATLAS measurement and TNP study
- Flavor labelling (resolved jets)

QED corrections to PDF





- Photon PDFs consistent between MSHT, CT & NNPDF (fits @ NNLO QCD)
  - $\langle x \rangle_\gamma$ in agreement (e.g. 0.43% @ Q=125GeV)
- Net momenta of other partons reduced to accommodate photon
  - Example: Reduction in gluon leads to ~1% decrease in ggH production
  - Larger (-2%) NNPDF shift partially explained by updated QCD grids and additional datasets used inNNPDF4.0 wrt. 3.1
  - Approximate factorisation of QED & QCD (slight increase aN3LO vs NNLO)

→ ongoing calculation to fully understand difference in ggH cross section

PDF profiling in Drell-Yan precision measurements

Precise Drell-Yan data can be used to profile PDF uncertainties together with the extraction of precision measurements of SM parameters (α_S, $\sin^2\theta_W$, m_W …)

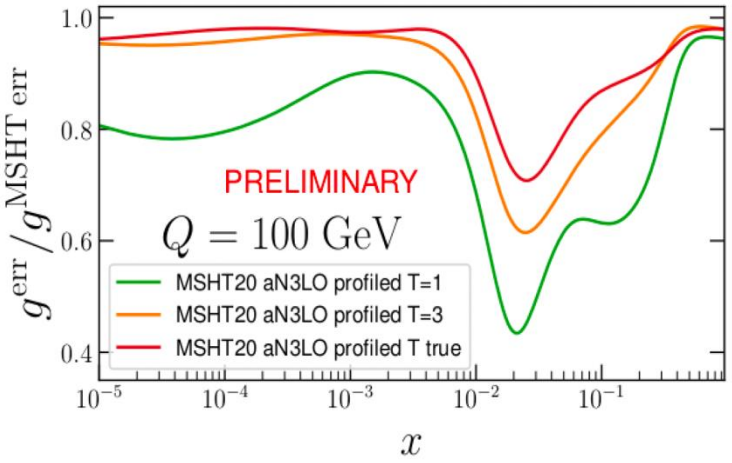
Conditions:
- PDFs not altered significantly (central value, uncertainties)
- PDF uncertainties from previous data consistently included

MSHT and CT use tolerance T_k for EV k: $\Delta\chi_k{}^2 = Tk^2$ → 2-step approach:

(1) Profile PDFs including factors of T_k → obtain consistently profiled PDFs.
- $\chi^2{}_{total} = \chi^2{}_{newdata} + \chi^2{}_{PDF}$, with $\chi^2{}_{PDF} = \sum_k T_k{}^2 (\Theta_k{}^{PDF})^2$

(2) Perform fit with $\Delta\chi^2 = 1$ and obtain PDF uncertainty by scanning profiled PDFs

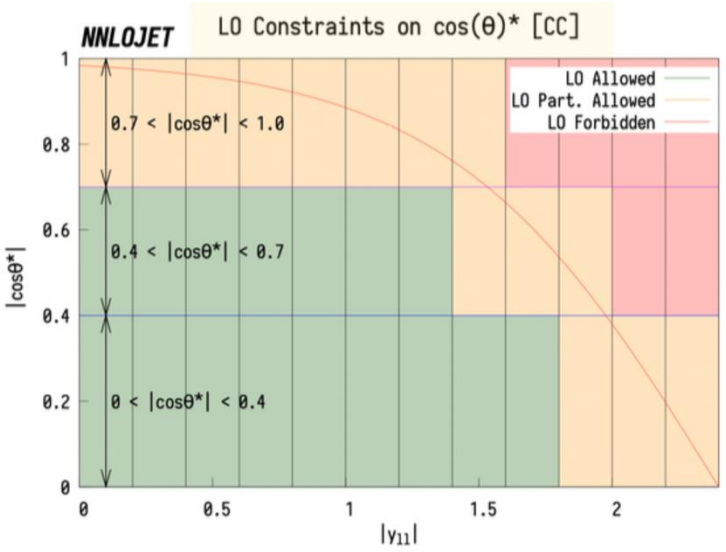
Example: MSHT g PDF
Profiled with Asimov ZpT data:
Still substantial reduction



→ *Consider approach in upcoming precision measurements*

Theory and PDF uncertainties for $\sin^2\theta_W$

Extraction of $\sin^2\Theta_W$ builds on 3D DY measurement: M_{ll}, y_{ll}, $\cos\theta^*$
Green region: normalize xsec, yellow region: AFB → $\sin^2\Theta_W$

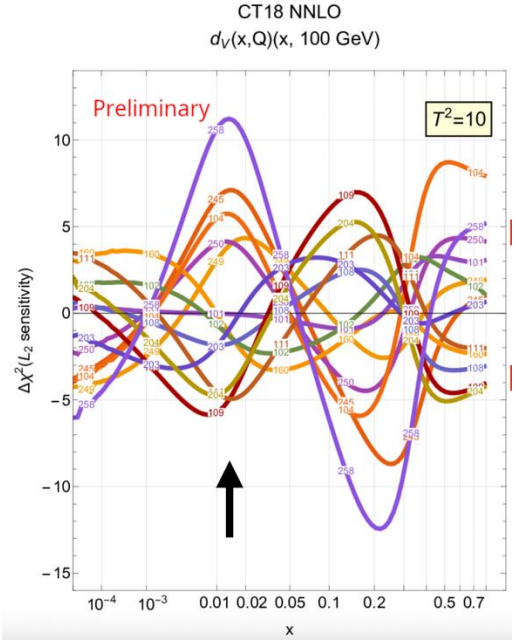


$$A_{\mathrm{FB}} = \frac{\mathrm{d}^3\sigma(\cos\theta^* > 0) - \mathrm{d}^3\sigma(\cos\theta^* < 0)}{\mathrm{d}^3\sigma(\cos\theta^* > 0) + \mathrm{d}^3\sigma(\cos\theta^* < 0)}$$

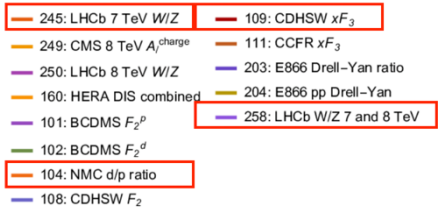
→ Only use numerator for $\sin^2\Theta_W$ extraction? Easier to calculate theory calculations (TNP).

Largest systematic from PDF

- *Profiling? → 2-step approach?*
- Combined fit of $\sin^2\Theta_W$ and PDF
  → sensitivity to $x(d_v)$ at 0.01



L2 sensitivity for d_v example: CT18

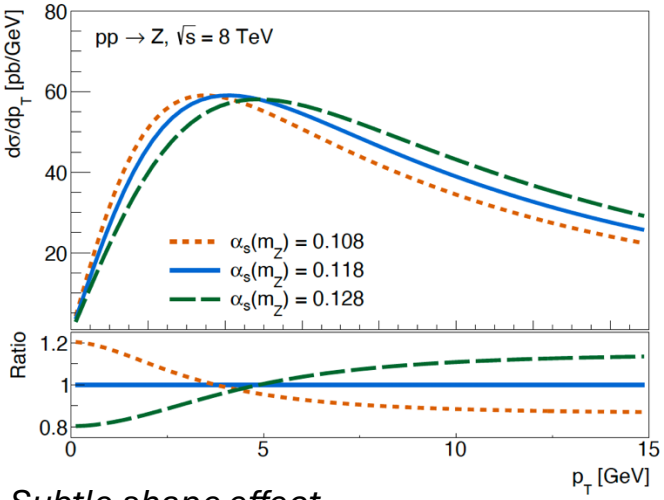


→ can we constrain d_v further? Additional data?

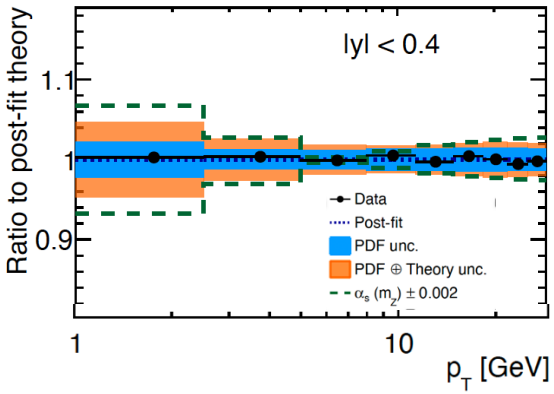
α_S from ZpT: ATLAS measurement

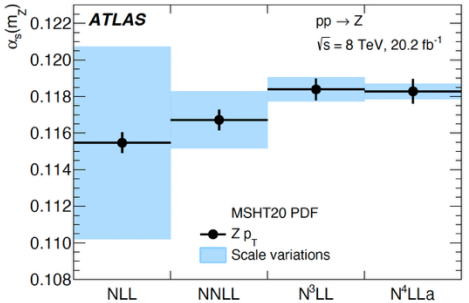
From the low-momentum Sudakov region of ZpT measured in 8 rapidity bins (Ai)
N⁴LLa + N3LO theory with aN³L0 MSHT20 PDF, profiled. Missing higher orders:
variation of μ_f, μ_r and Q (offset method).

$\alpha_s\,(mZ) = 0.1183 \pm 0.0009$

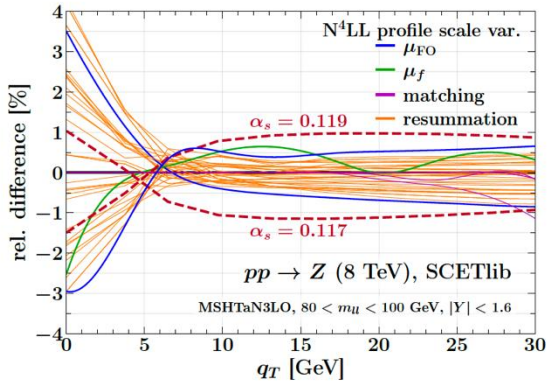


Subtle shape effect





- Validation of PDF uncertainties, e.g. profiling vs fit, tolerance
- Missing higher orders in parameter fits:
  - Fit unc. depends on pT shape (↔ correlations) from higher-order uncertainties vs pT shape from α_s variation.
  - Scale variation yield no meaningful pT shape variations
- Variations of very low scales transferred to variation of high scales

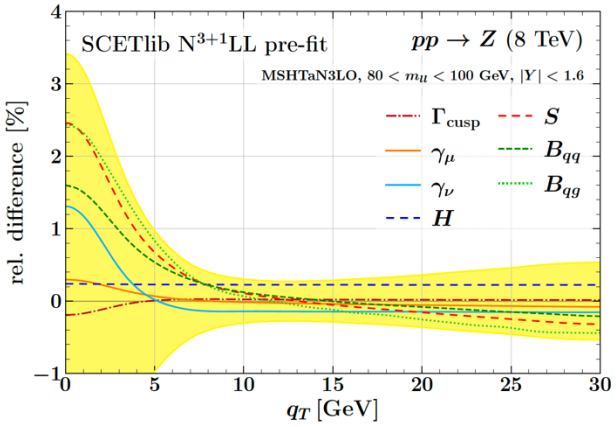


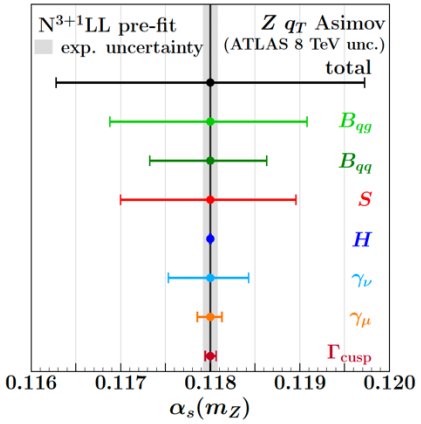
→ comparisons between ATLAS/DYTurbo and Frank/SCETlib for benchmark setups

α_S from ZpT: TNP study

TNP Asimov test of TNP approach for α_S extraction from ZpT (https://arxiv.org/html/2506.13874v1)
TNP for qt resummation at *$N^{3+1}LL$ level , $N^{3+1}LL$ or N4LL pseudo data (SCETlib)*

Offset method:

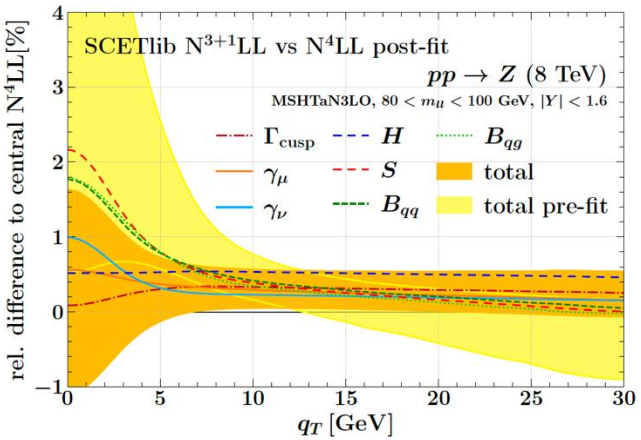


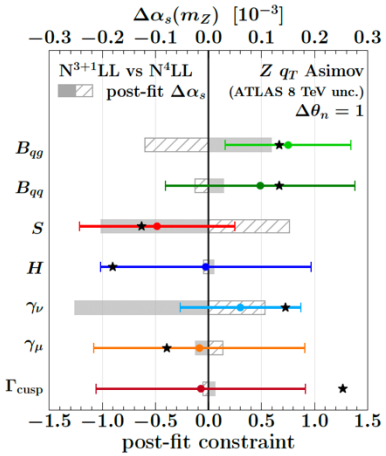


Boundary conditions of Hard, Soft and Beam functions

Cusp and noncusp anomalous dimensions

Profiling, here: $N^{3+1}LL$ against N^4LL pseudo data





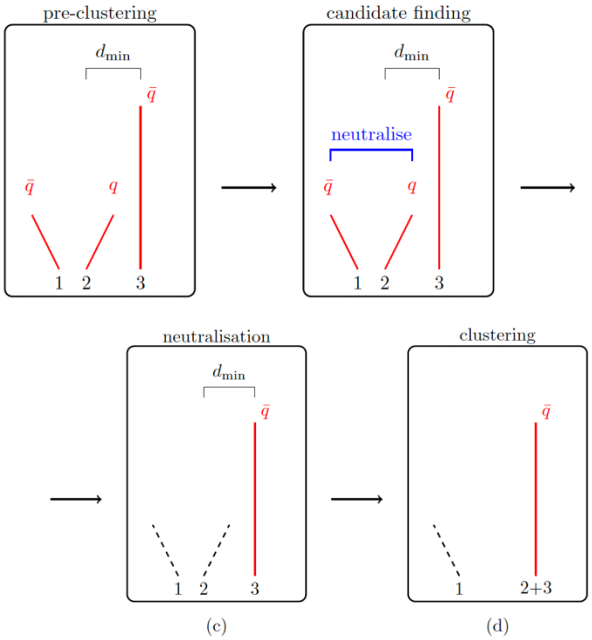
No overfitting,
Similar post-fit uncertainties when fitting various orders wrt N4LL or when relaxing the pre-fit constraints

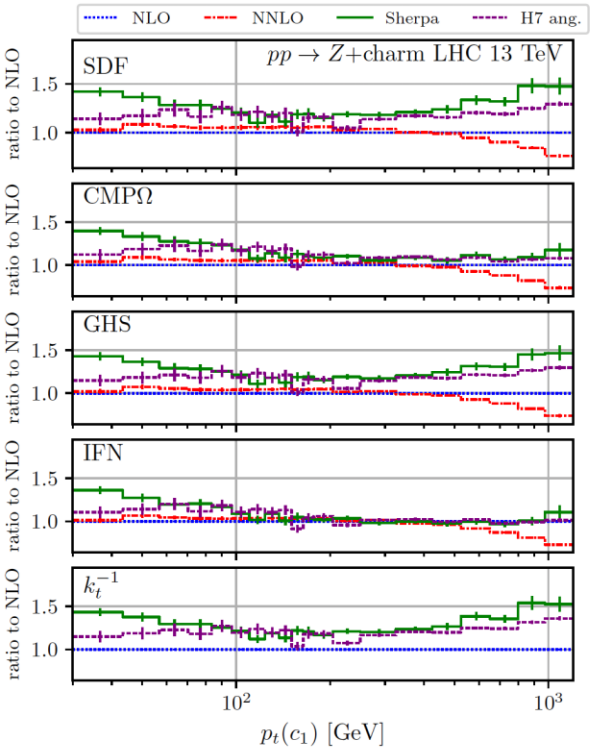
→ *Consider approach in upcoming precision measurements: develop TNP wish list*

Flavor labelling for resolved jets

For NNLO calculations, need IRC safe jet flavor labels (particularly wrt g → bb/cc)
At Les Houches 2023: compared 4 IRC safe flavor labelling approaches:
Soft Drop Flavour (SDF), Flavoured AntikT (CMP), Flavour Dressing (GHS), Interleaved Flavour Neutralisation (IFN)

Performance study in various processes and phase space regions (https://arxiv.org/abs/2506.13449):
IFN: "stands out for its robustness against soft and collinear effects, delivering distributions that change little through the simulation chain"





→ *Experiments will probably start with one of the approaches (disc space/CPU/ person power for flavor tagging)*
→ *Ask for NNLO theory productions with same labelling: W/Z+b(b), W/Z+c(c), ...*

Flavor labelling for resolved jets

Performance study (https://arxiv.org/abs/2506.13449):

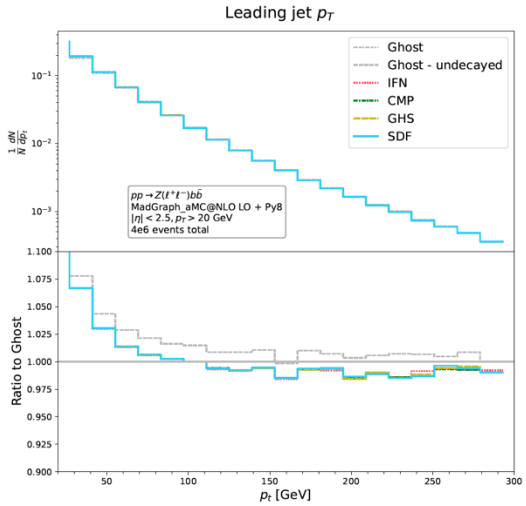
- Traditional cone/ghost reco jet labelling not compatible with IRC safe algorithms

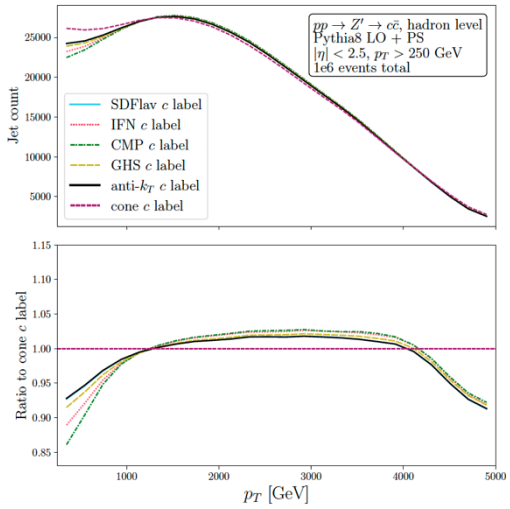
→ *Steps forward:*

(1) Keep reco jet truth labelling and unfold between incompatible definitions (short-term)

(2) Harmonize reco jet labelling, e.g. via ΔR matching with correctly labelled hadron jet

(3) Update (ML) reco jet tagging with new reference (long-term)





(truth) hadron jets flavor labelled

↓ *match truth hadrons or truth jet with reconstructed jet*

(det) reconstructed Jets, truth labelled

↑ *Reference for training*

(det) reconstructed jets, flavor tagged (ML)