PDF profiling using the A_0 angular coefficient in NC DY

S. Amoroso, F. Giuli

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Introduction

- ATLAS measurement at $\sqrt{s}$ = 8 TeV here
- A_0 measured as a function of p_T^Z in three different rapidity regions:
  - $|y^Z| < 1.0$
  - $1.0 < |y^Z| < 2.0$
  - $2.0 < |y^Z| < 3.5$
- No cuts on lepton and jet kinematics
- Applying just a cut on $p_T^Z > 11.4$ GeV as in this paper from Gauld et al.
- A_0 constructed starting from Eq. (6) and Eq. (8) of this paper

$$\lambda = \frac{W_T - W_L}{W_T + W_L}$$

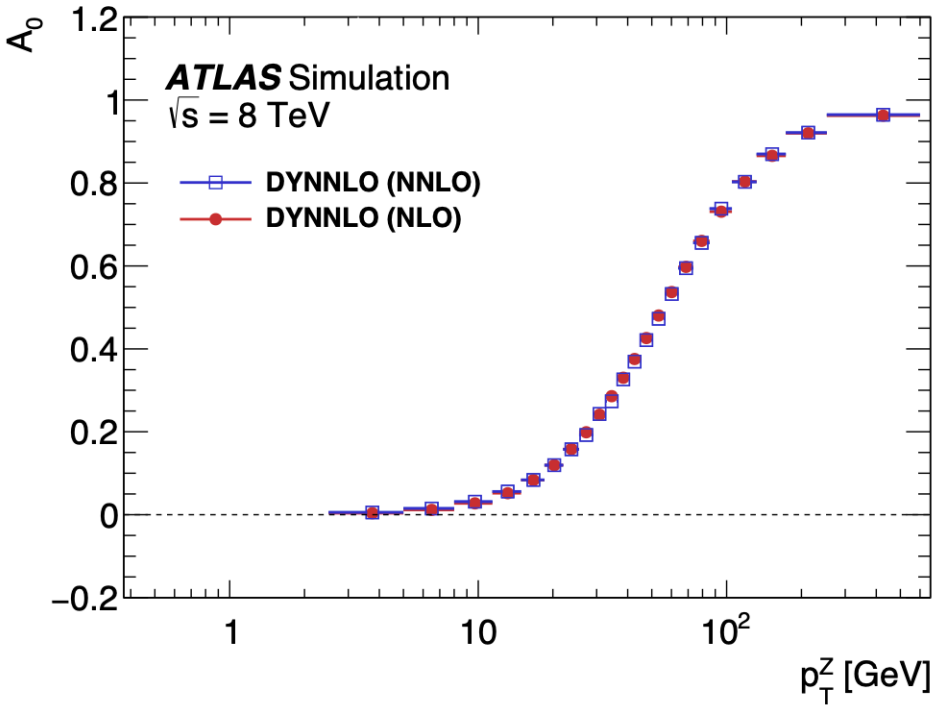
$$2W_T + W_L = \mathcal{N}\frac{d\sigma}{d^4q},$$

$$W_T - W_L = \frac{8}{3}\mathcal{N}\left[\frac{d\sigma}{d^4q}\left(|\cos\theta| > \frac{1}{2}\right) - \frac{d\sigma}{d^4q}\left(|\cos\theta| < \frac{1}{2}\right)\right],$$

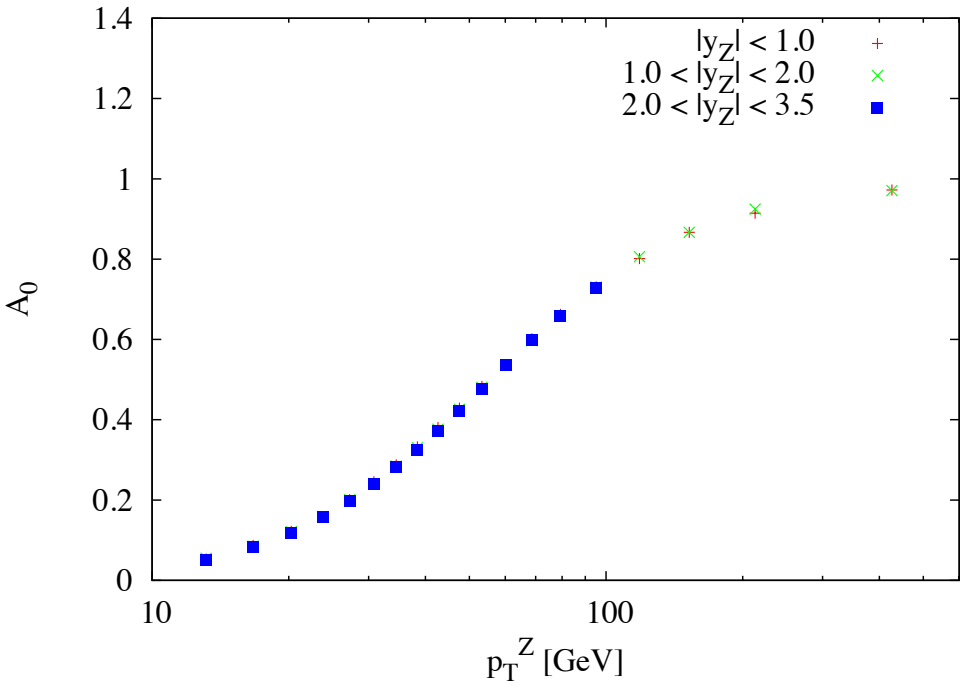
$$\boxed{\lambda = \frac{2 - 3A_0}{2 + A_0}}$$

Comparison with DYNNLO

- LO predictions for $pp \rightarrow Zj$ at FO done using MG5_aMC@NLO v2.6.4 interfaced to APPLgrid v1.5.34 trough aMCfast v1.3.0
- CT14nnlo used as input PDF set at ME-level – **Accuracy of 0.1%**
- Consistency in shape and values



Integrated over y^Z



Three different $|y^Z|$ bins

Status of predictions

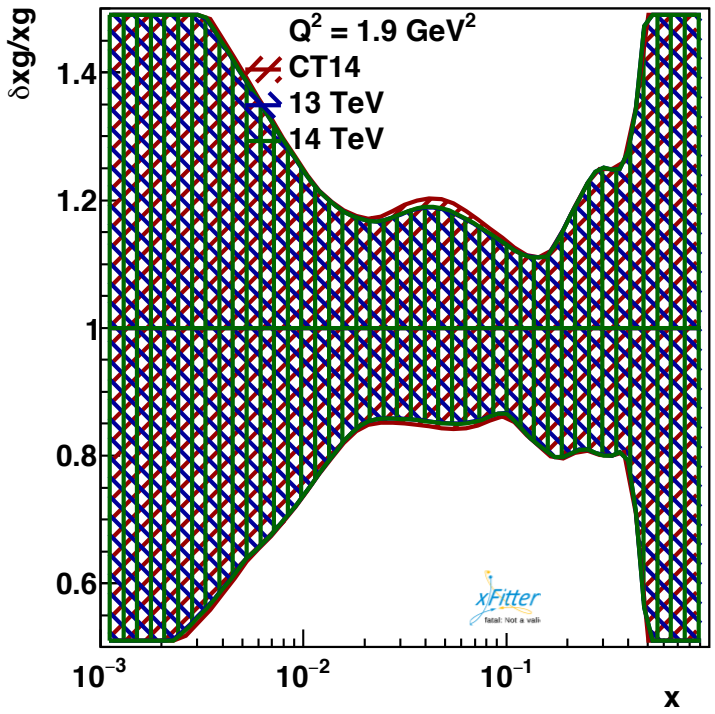
- LO predictions generated for the following regions of the phase space:
  - ATLAS-like phase space: 8, 13, 14 TeV
    - $|y^Z| < 1.0$, $1.0 < |y^Z| < 2.0$, $2.0 < |y^Z| < 3.5$
    - $80 < m_{ll} < 100$ GeV
    - $p_T^Z > 11.4$ GeV
  - ATLAS-like phase space: **8, 13, 14 TeV**
    - same as above BUT integrated in y^Z
  - CMS-like phase space: **8 TeV** only
    - $|y^Z| < 1.0$, $1.0 < |y^Z| < 2.1$
    - $80 < m_{ll} < 100$ GeV
    - $p_T^Z > 10$ GeV
  - ATLAS low-mass region: 13, 14 TeV
    - same p_T^Z, y^Z binning scheme as in the ATLAS 8 TeV measurement
    - $4 < m_{ll} < 8$ GeV
    - $p_T^Z > 2$ GeV (but looking at A_0 just for $p_T^Z > 11.4$ GeV)
  - LHCb-like phase space: 13, 14 TeV
    - $2.0 < |y^Z| < 4.5$
    - $80 < m_{ll} < 100$ GeV
    - $p_T^Z > 10.5$ GeV

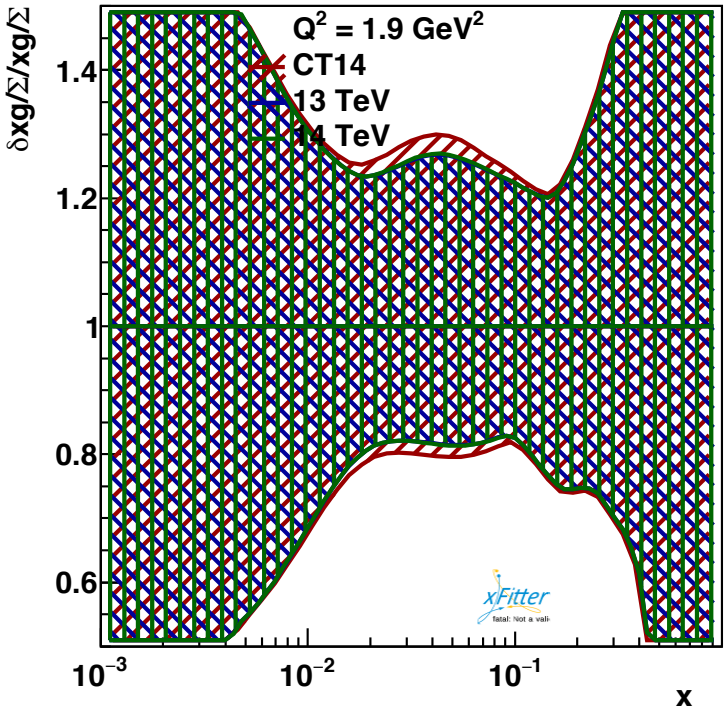
Predictions used by Simone to run some fits

NNLOJET predictions for:
- **ATLAS 8 TeV (y^Z integrated)**
- **CMS 8 TeV**
- **LHCb 8 TeV**

ATLAS-like phase space

- In the ATLAS-like phase space, profiling of 13 and 14 TeV predictions
- Profiling done included all the various y^Z bins

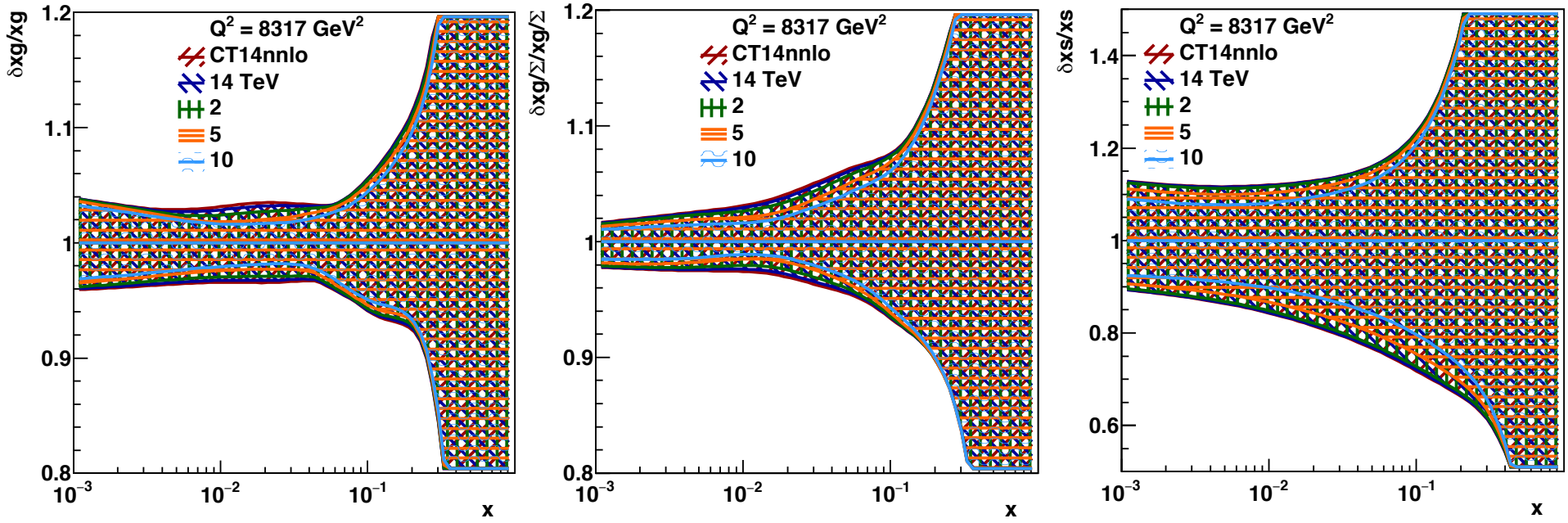




- Sensitivity for xg and gluon/sea ratio for $10^{-2} < x < 0.1$
- No much difference when considering predictions at 13 or 14 TeV

ATLAS-like phase space

- So I modified the ATLAS 8 TeV datafiles scaling the uncertainties by a factor 2, 5 and 10

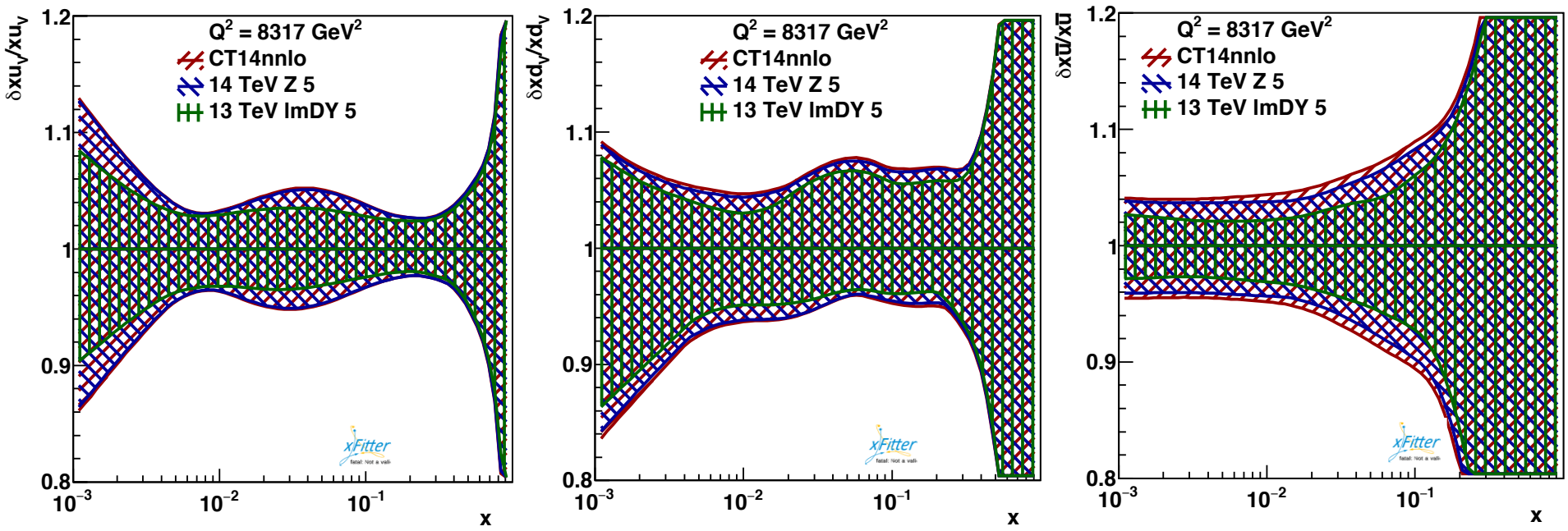


- A reduction of a factor 5 might be a good approximation for HE/HL_LHC studies

- At $Q^2 = m_Z^2$, apart from the gain in xg and gluon/sea ratio, we can also see some improvement in the $x\bar{s}$ PDF

Going to lower invariant masses

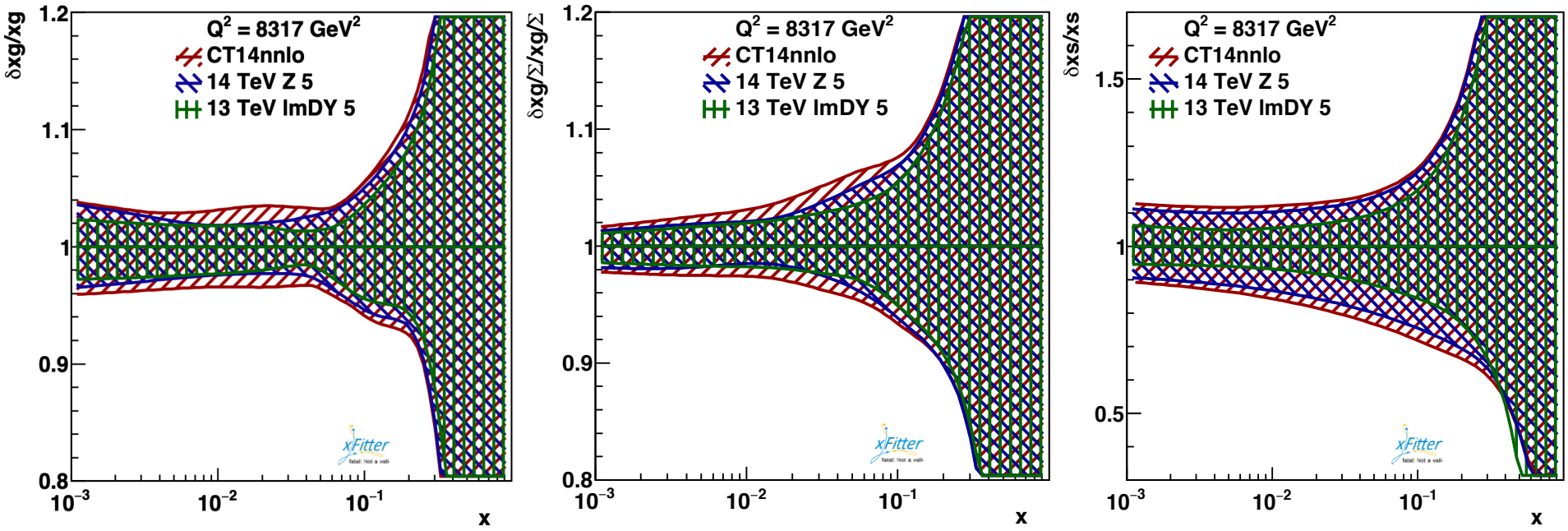
- ATLAS low mass region:
  - same p_T^Z, y^Z binning scheme as in the ATLAS 8 TeV measurement
  - $4 < m_{ll} < 8$ GeV



- When going lower in mass, you start gaining sensitivity in other distributions
- Here the most sensitive ones
- Not a huge difference if considering 13 TeV or 14 TeV predictions

Going to lower invariant masses

- ATLAS low mass region:
  - same p_T^Z, y^Z binning scheme as in the ATLAS 8 TeV measurement
  - $4 < m_{ll} < 8$ GeV

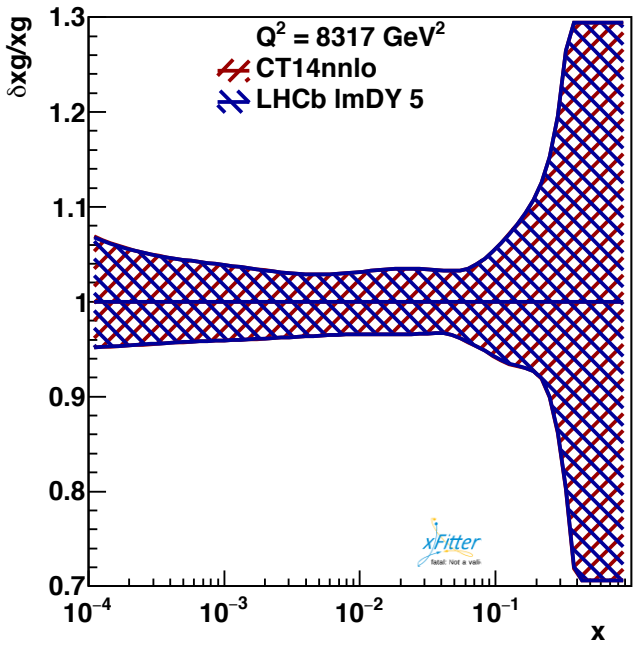


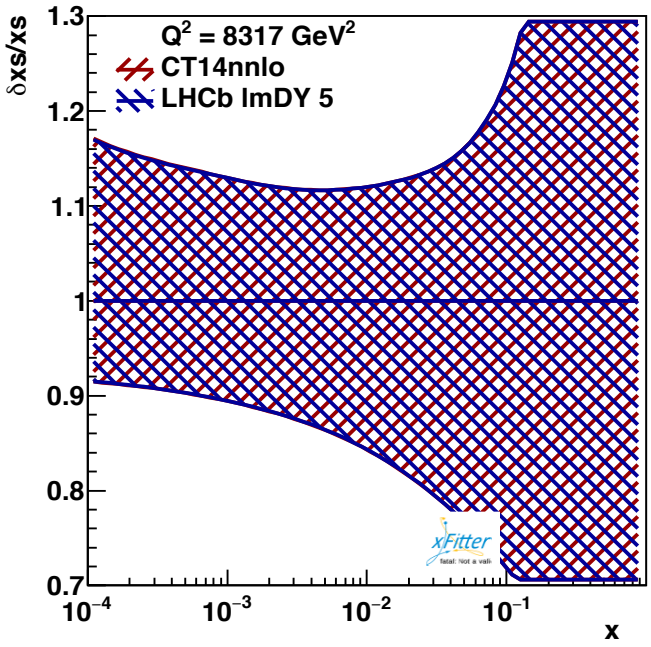
- When going lower in mass, you start gaining sensitivity for higher x e.g. x ~ 0.3
- Huge gain for the $x\bar{s}$ PDF over the whole considered x range
- Not a huge difference if considering 13 TeV or 14 TeV predictions

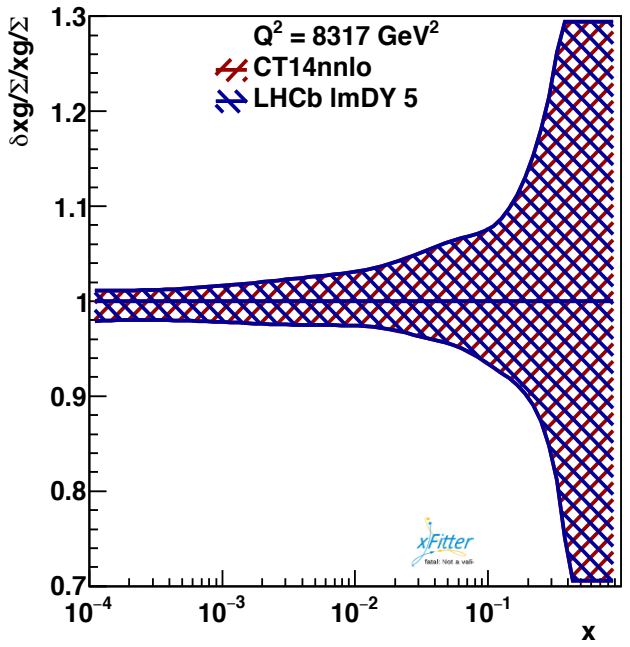
Going to higher rapidities

- LHCb-like phase space: 14 TeV predictions
  - $2.0 < |y^Z| < 4.5$
  - $80 < m_{ll} < 100$ GeV
  - $p_T^Z > 10.5$ GeV

Same level of uncertaities as ATLAS, but statistical uncertainty multiplied by $\sqrt{5}$





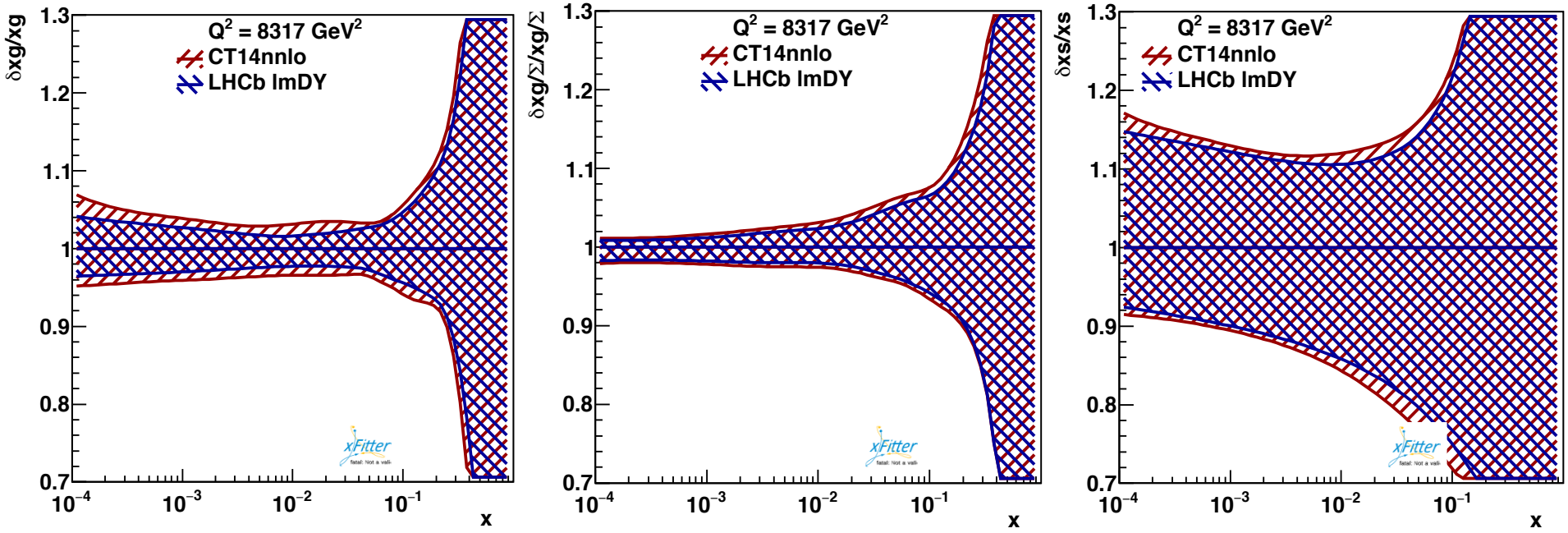


- No gain in PDF at all

- How come? Did I make some mistakes when running profiling? Something else going on here?

Going to higher rapidities

- Quite an extreme test: uncertainties reduced by a factor 50 or 100 in the 12 < m_{ll} < 26 GeV region
- Here the results for the reduction of a factor 100 are shown



- Marginal improvement in a more than unrealistic scenario
- Why? Because PDF are sensible to A_0 data just in the medium-p_T^Z region or intermediate y^Z so 0.01 < x < 0.1, and data in a region for 2.0 < $|y^Z|$ < 4.5 access higher x values (x > 0.5)

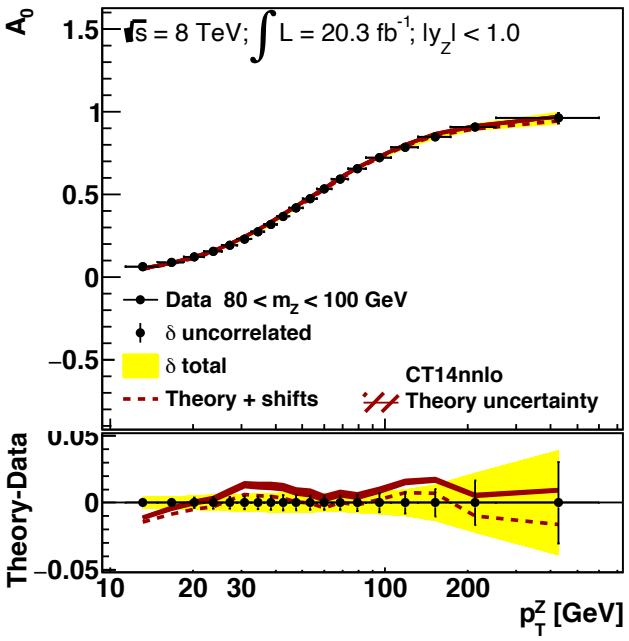
Conclusions & outlook

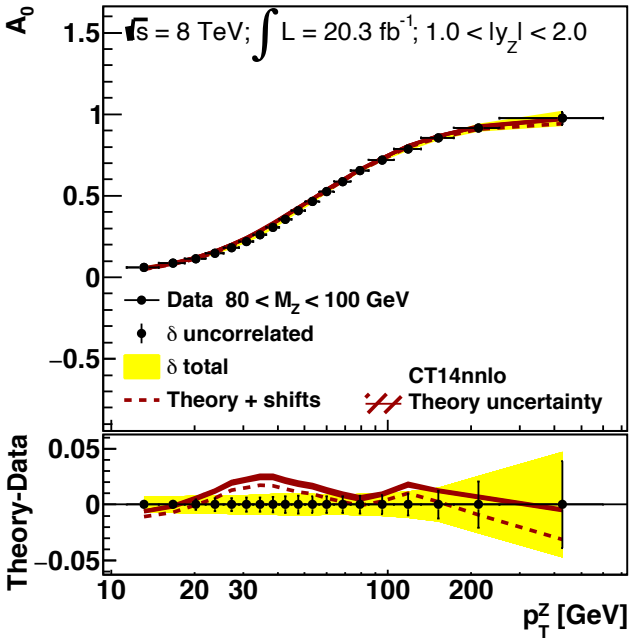
- PDFs con be constrained using A_0 events in DY neutral events
- The most affected PDFs are gluon, gluon/sea ratio and strange (at $Q^2 = m_Z^2$)
- Several predictions at 13 and 14 TeV created probing different regions of the phase space
- Going to low invariant masses helps in constraining PDFs also for x $\gtrsim$ 0.2-0.3
- Going to higher rapidities does not help because PDFs are sensible to A_0 in the medium-p_T^Z region or intermediate y^Z
- kFs computed wrt available NNLOJET predictions and passed them to Simone to run some real fits (not profiling) with ATLAS and CMS data at 8 TeV

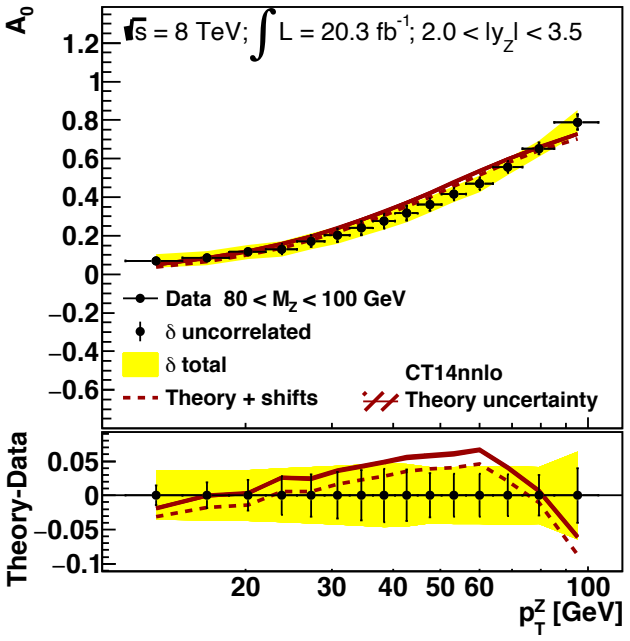
Backup Slides

Comparison with ATLAS data

- LHAPDF Analysis run over the ATLAS data for the three different $|y^Z|$ bins







After minimisation 114.83 53 2.167

46.79(+0.12) 19 ATLAS Z first rapidity bin 2012
42.37(+0.62) 19 ATLAS Z second rapidity bin 2012
18.56(+1.10) 15 ATLAS Z third rapidity bin 2012

ATLAS data description ~OK

Correlated Chi2 5.280349084216914 5
Log penalty Chi2 1.832703780206957 2

PDF sensitivity of this data

- Having a look at the theory errors, I can see some $|y^Z|$ dependence:
  - Errors get smaller when increasing y^Z
  - Errors increase with p_T^Z till p_T^Z ~ 45 GeV and then start decreasing again
- Remember that results are LO (higher accuracy grids production ongoing)
- NLO predictions are running – they should be ready ~next week
- Profiling exercise → not a big effect neither on PDF shape nor uncertainties