Impact of ATLAS measurements on PDFs

XLIV International Symposium on
Multiparticle Dynamics

September 8-12 2014 - Bologna

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European Union
European Social Fund

OPERATIONAL PROGRAMME
EDUCATION AND LIFELONG LEARNING
investing in knowledge society
MINISTRY OF EDUCATION & RELIGIOUS AFFAIRS, CULTURE & SPORTS
MANAGING AUTHORITY

NSRF 2007-2013
programme for development
EUROPEAN SOCIAL FUND

Co-financed by Greece and the European Union

Outline

Content of this talk

- Introduction
- PDFs studies with jets and photons
- PDFs studies with gauge bosons
- Top-quark data
- Summary

See also the talks by
Matthias Weber and **Sofia Chouridou**

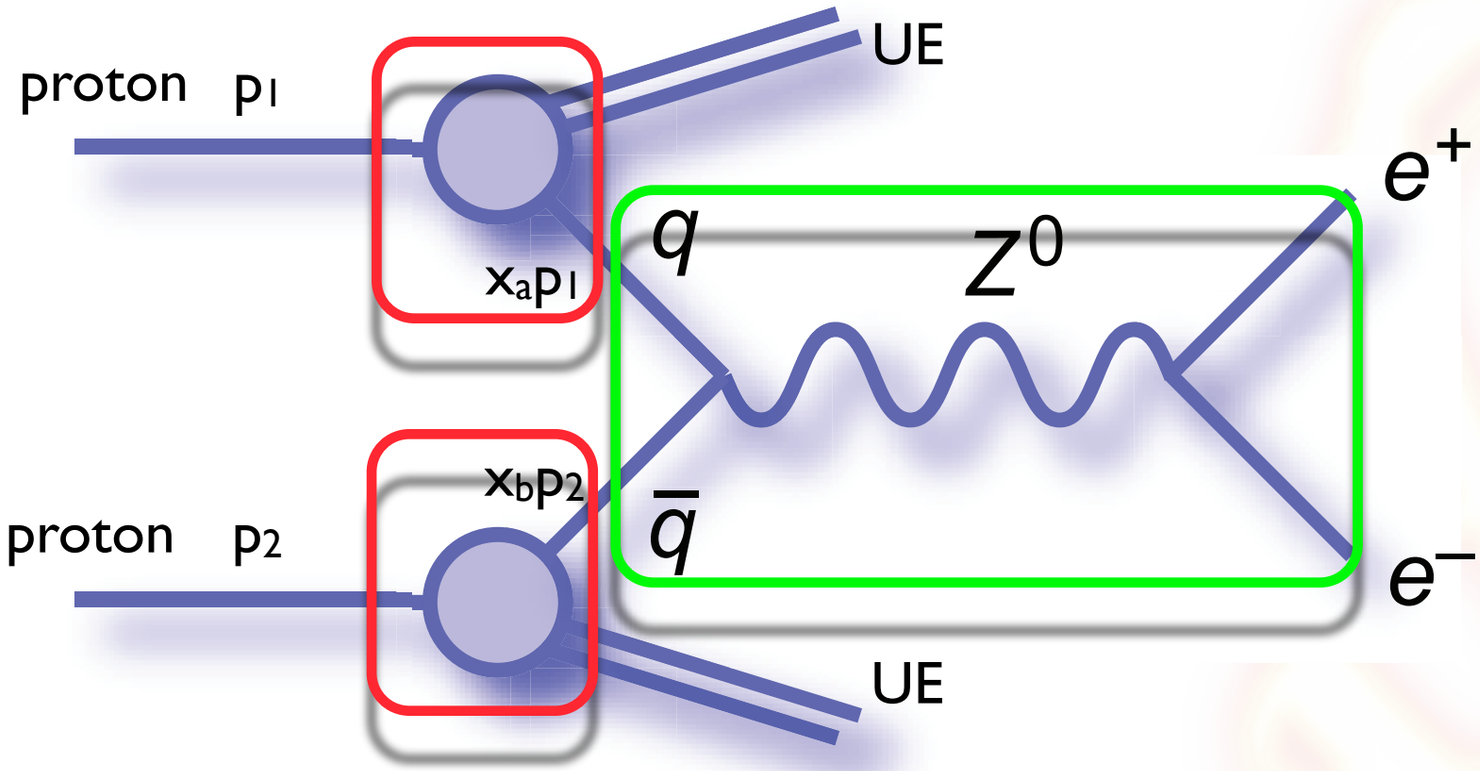
References

PDFs studies with jets and photons
EPJC 73 2509 (2013)
JHEP05(2014)05
ATLAS-CONF-2014-045
Phys. Rev. D 89, 052004 (2014)
ATL-PHYS-PUB-2013-018

PDFs studies with gauge bosons
Phys Rev D 85 072004 (2012)
Phys Rev Lett 109 012001 (2012)
Phys Lett B 725 223 (2013)
JHEP 06 112 (2014)
arXiv:1407.3643
JHEP 05 068 (2014)

Top-quark data
arXiv:1407.0371

Theoretical framework



Perturbative QCD predictions rely on the Collinear Factorisation Theorem

PDFs

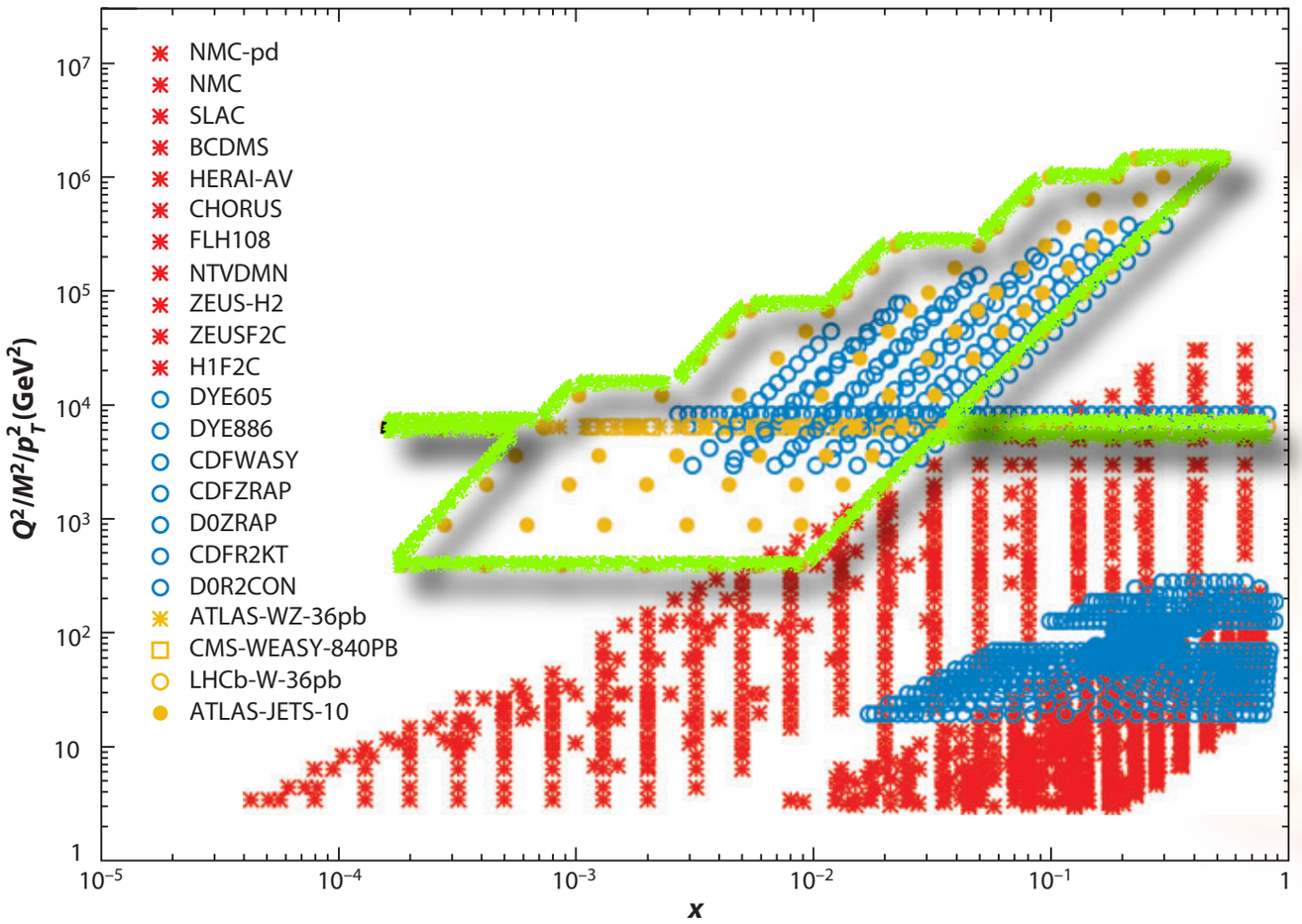
Unconvoluted parton level cross section

$$\sigma = \sum_{ab} \int_0^1 dx_a \int_0^1 dx_b \, f_a(x_a, \mu_F) f_b(x_b, \mu_F) \, \hat{\sigma}_{\mathrm{ab}\to\mathrm{X}}(x_a, x_b, \mu_F, \mu_R)$$

Non perturbative "initial condition" (data)
Perturbative QCD evolution (DGLAP)

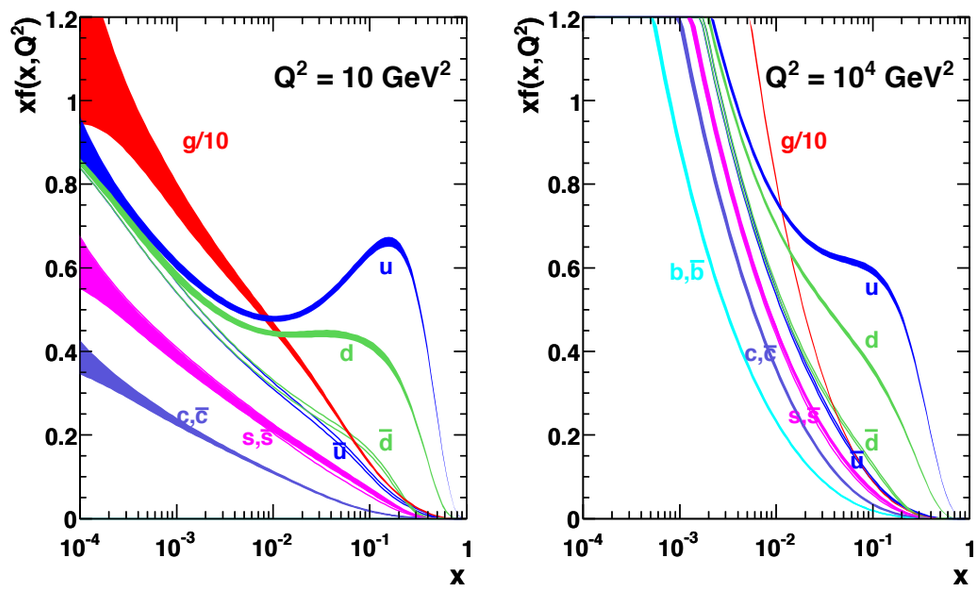
Perturbative QCD

The data



Ann Rev Nucl Part Sci 63 (2013) 291-328

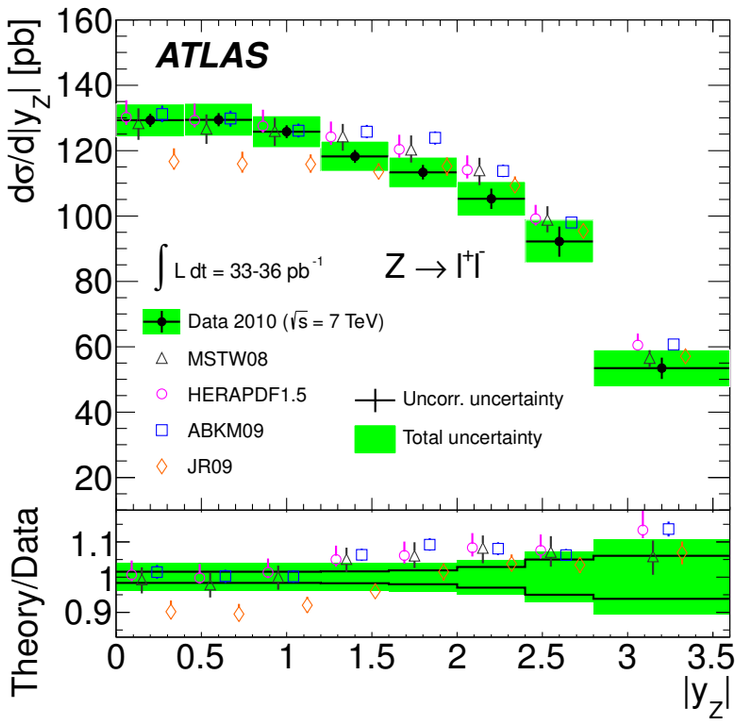
$Q^2=10^2$ GeV^2 **$Q^2=10^4$ GeV^2**

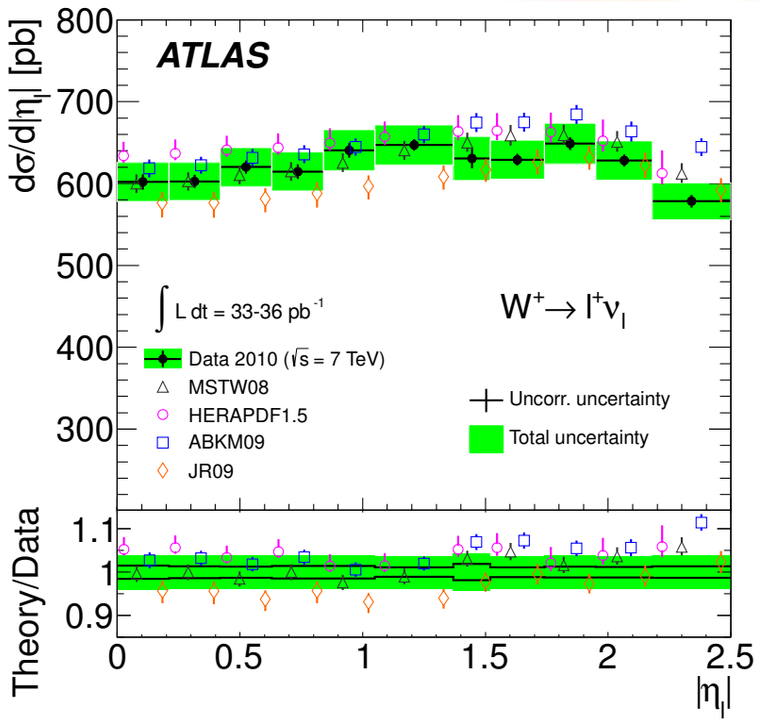


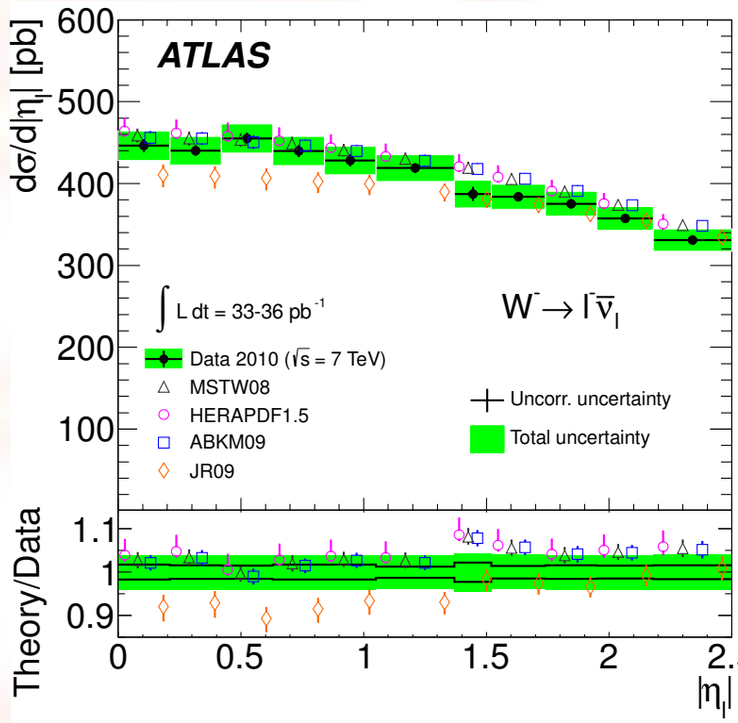
	ABM11(*) Phys. Rev. D86 054009 (2012)	CT10 Phys. Rev. D82 074024 (2012)	MSTW2008 Eur. Phys. J. C64 653 (2009)	NNPDF2.3 Nucl. Phys. B867 244 (2013)
FT DIS	✔	✔	✔	✔
HERA	✔	✔	✔	✔
Tevatron	✗	✔	✔	✔
LHC	✗	✗	✗	✔

(*) The LHC data is included in the updated fit ABM (Phys. Rev. D89 054028 (2014))

Early analysis on W/Z 2010 data

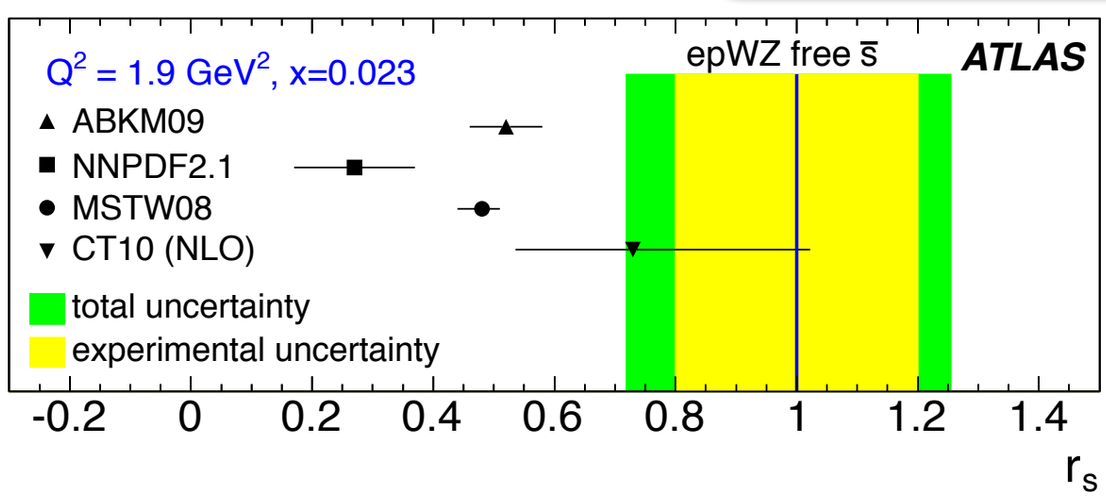




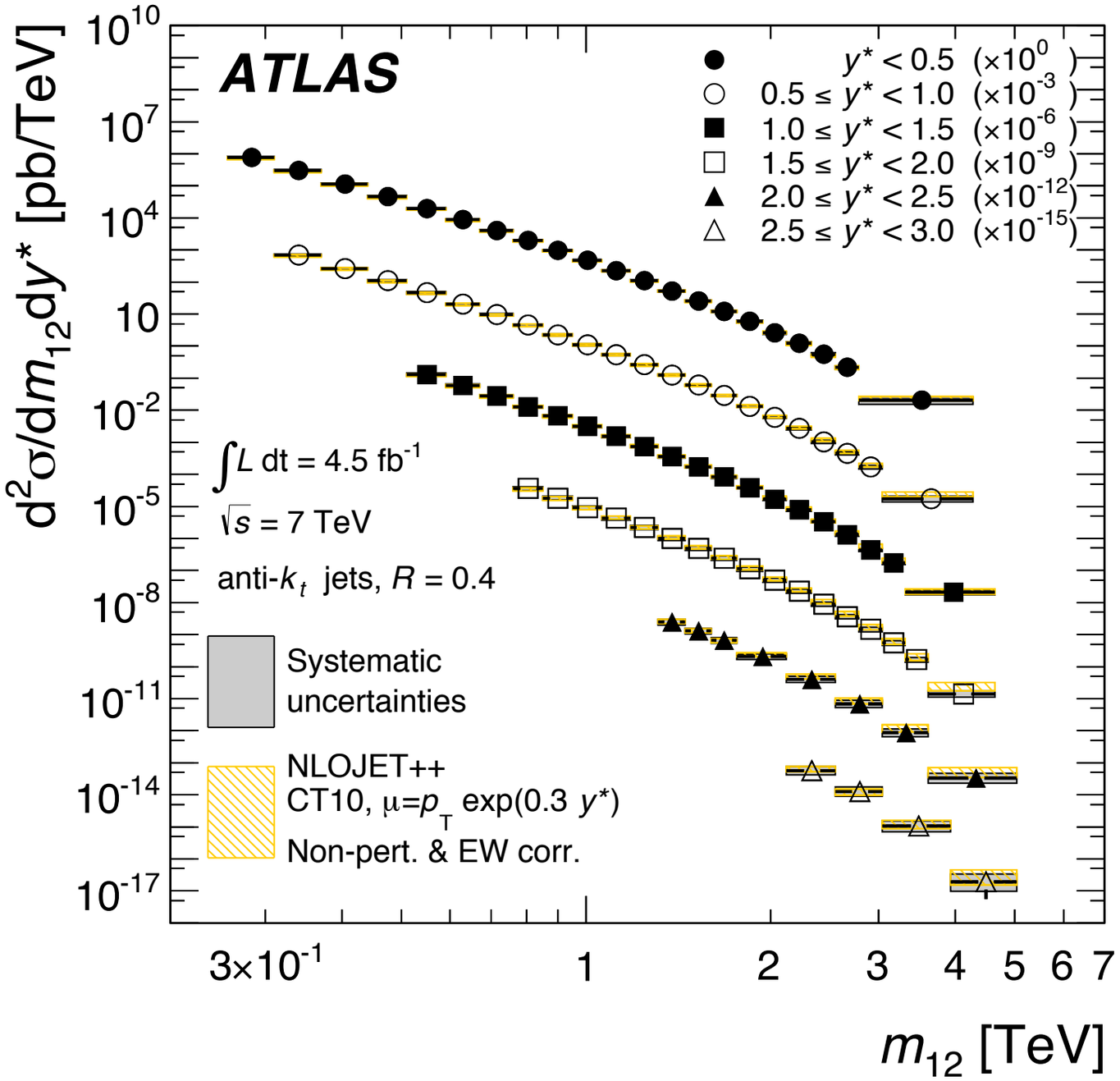


- First ATLAS PDF release: HERA1.5+W/Z 2010 ATLAS data (**ATLAS-epWZ** available from LHAPDF)
  - ☑ Sensitivity to the strange quark PDF
  - ☑ Spread in the available PDF sets
  - ☑ Favors unsupressed strangeness

$$r_s = 0.5\,\frac{s+\bar{s}}{\bar{d}}$$



Jets and photons



- The data span a large kinematic range
- Advanced perturbative calculations are available

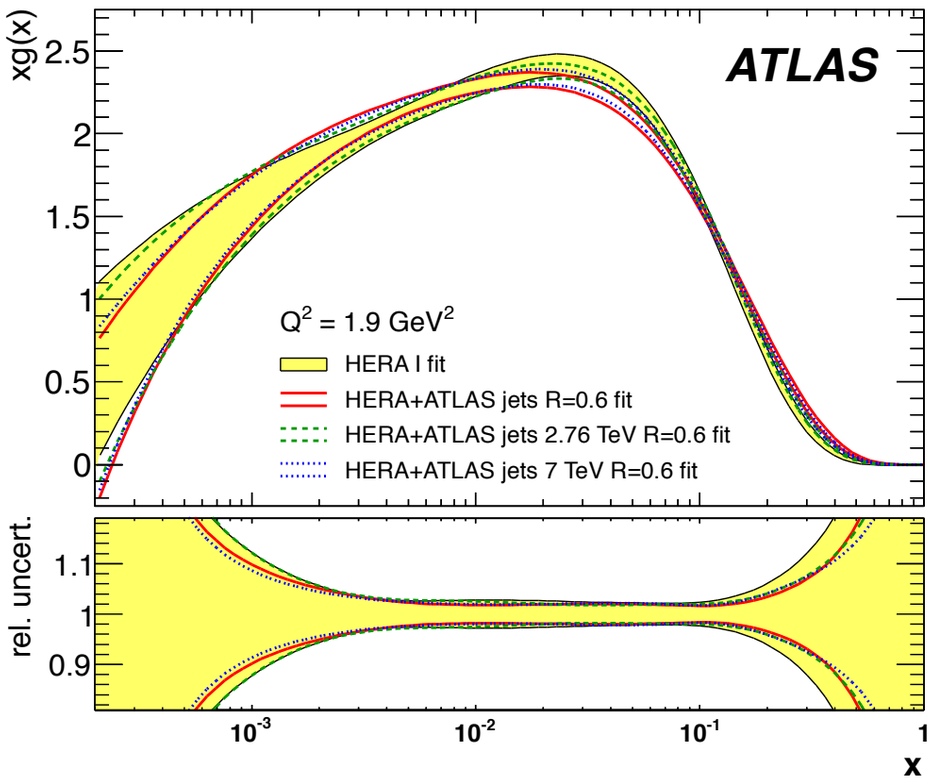
Generator	Prediction
NLOJET++	Up to 3 jets @ NLO
POWHEG	Up to 2 jets @ NLO
JETPHOX	Inclusive γ @NLO
MCFM	Inclusive γ @NLO

- **Sensitivity to the gluon parton distribution function**

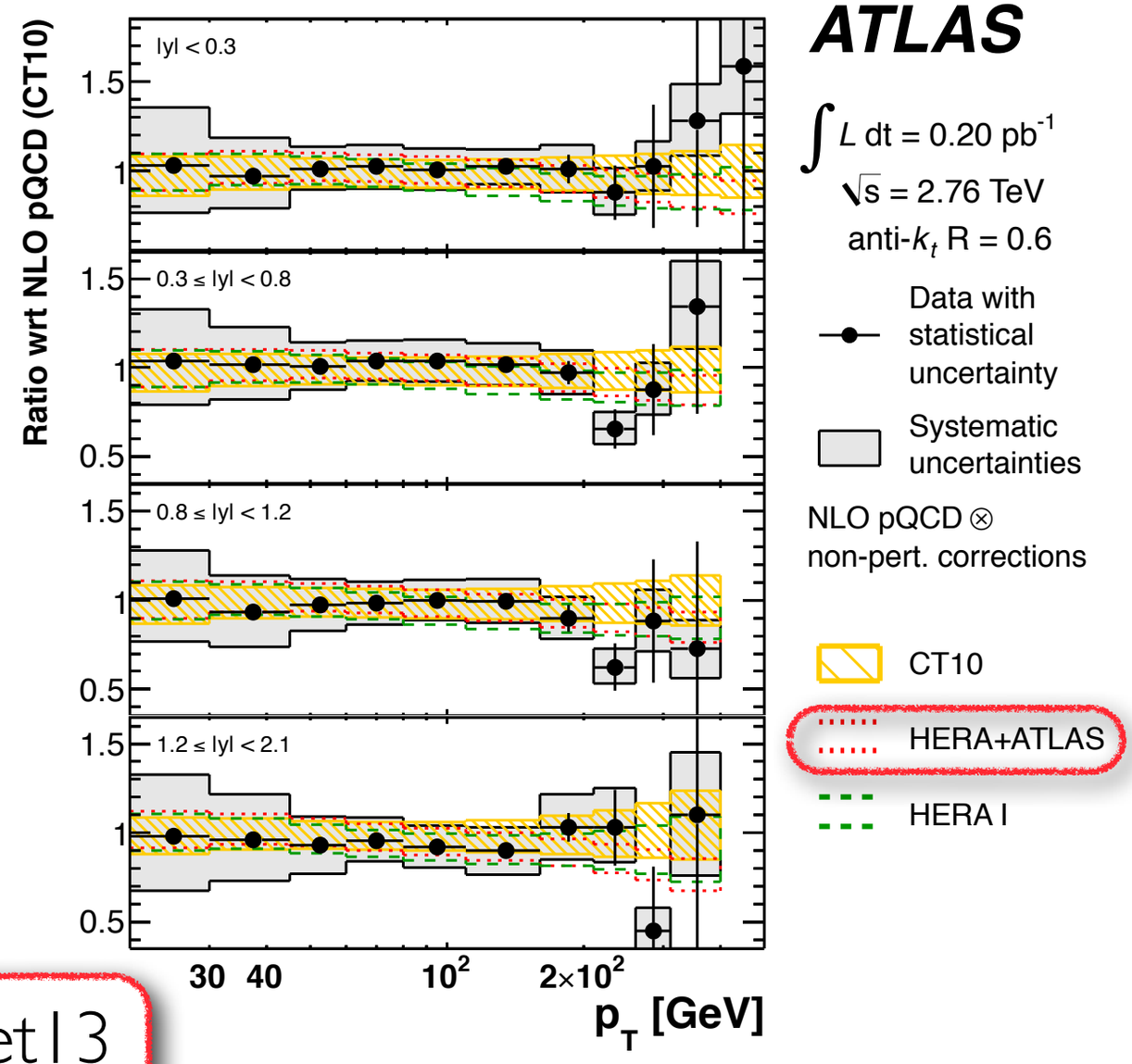
Ratio of inclusive jet cross sections

Constrain the gluon parton density measuring the jet cross sections ratio

$$\rho(y, p_T) = \left[\frac{2.76\ TeV}{7\ TeV}\right]^2 \frac{\sigma^{(2.76)}(y, p_T)}{\sigma^{(7)}(y, p_T)}$$



NLO calculation obtained with NLOJET++
Derived a new PDF set obtained by including the ATLAS jet data in the HERA1.5 dataset



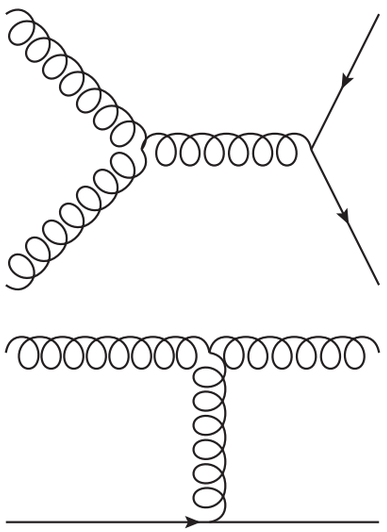
New PDF set has been derived epATLJet13

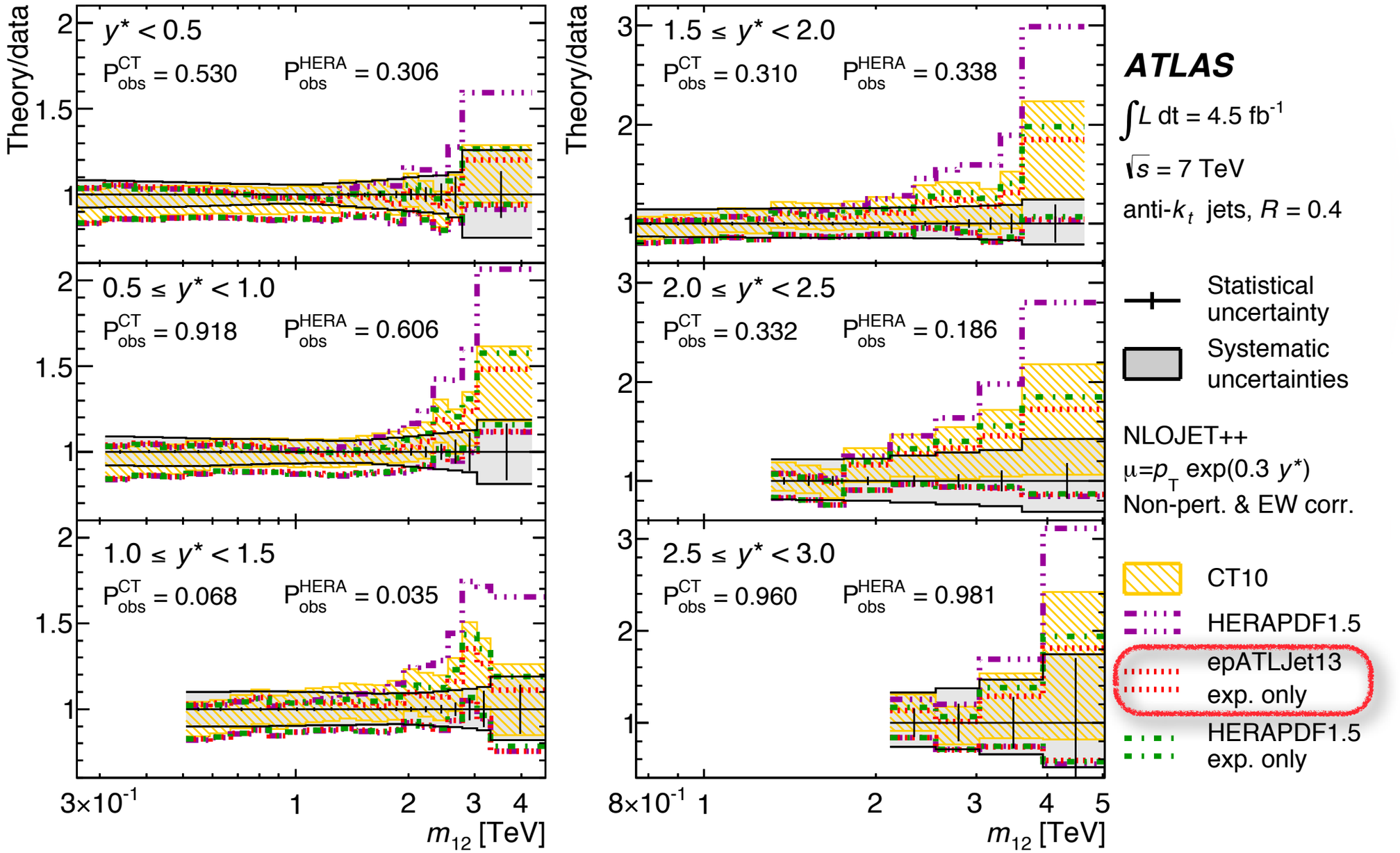
Di-jet cross sections

NLO calculation derived with NLOJET++ (corrected for NLO electroweak effects, Dittmaier et al)

Data are well described by all the PDFs, small tensions with HERA 1.5

Sensitivity to the gluon density function



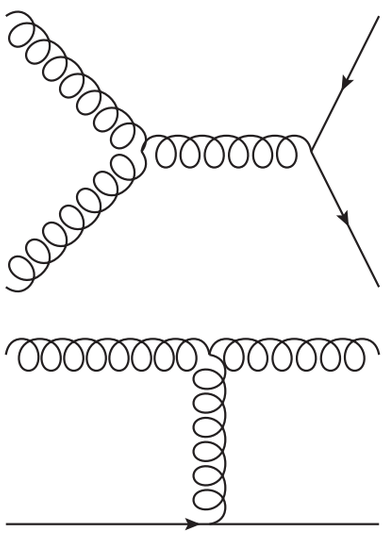


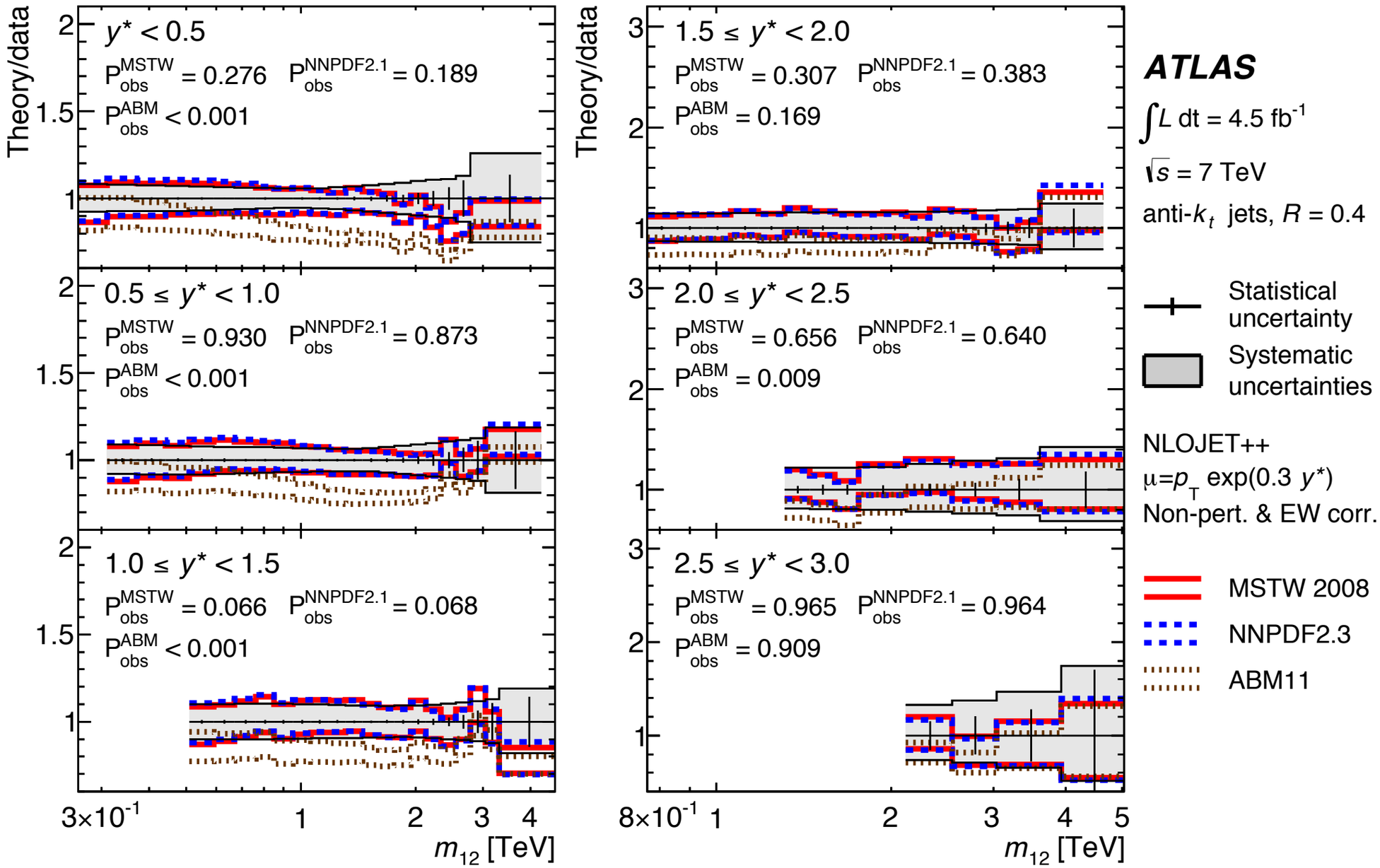
Di-jet cross sections

NLO calculation derived with NLOJET++ (corrected for NLO electroweak effects Dittmaier et al)

ABM11 underestimate measured cross section

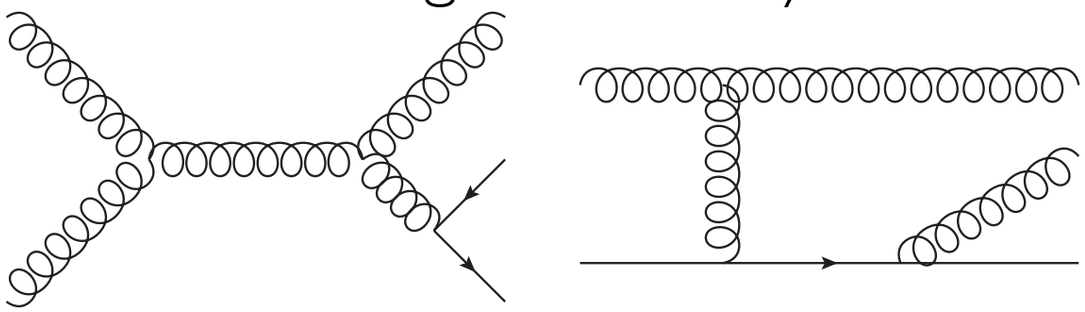
Sensitivity to the gluon density function





Three-jets cross section

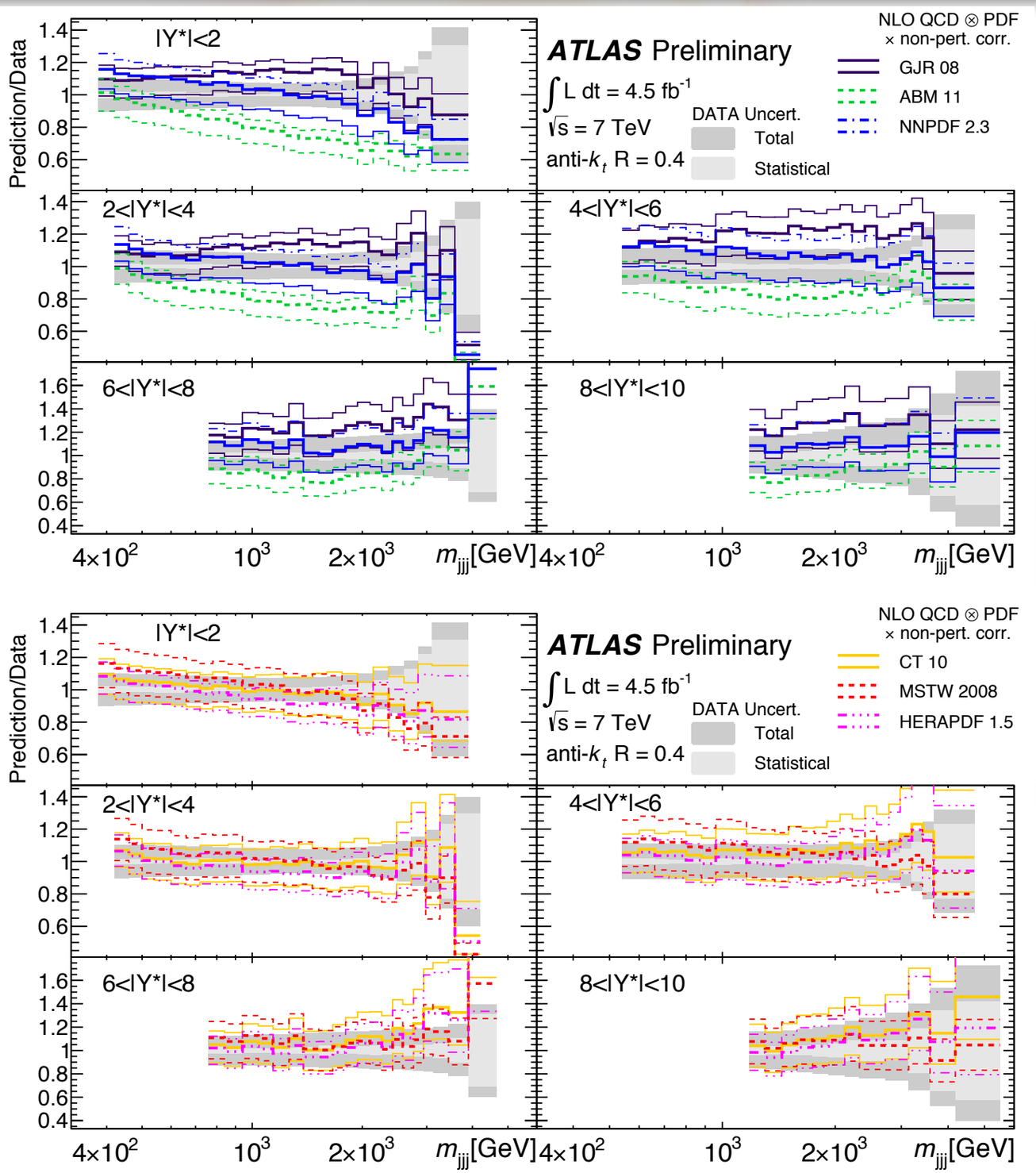
Probes the gluon density function



$$m_{jjj} = \sqrt{(p_1 + p_2 + p_3)^2}$$

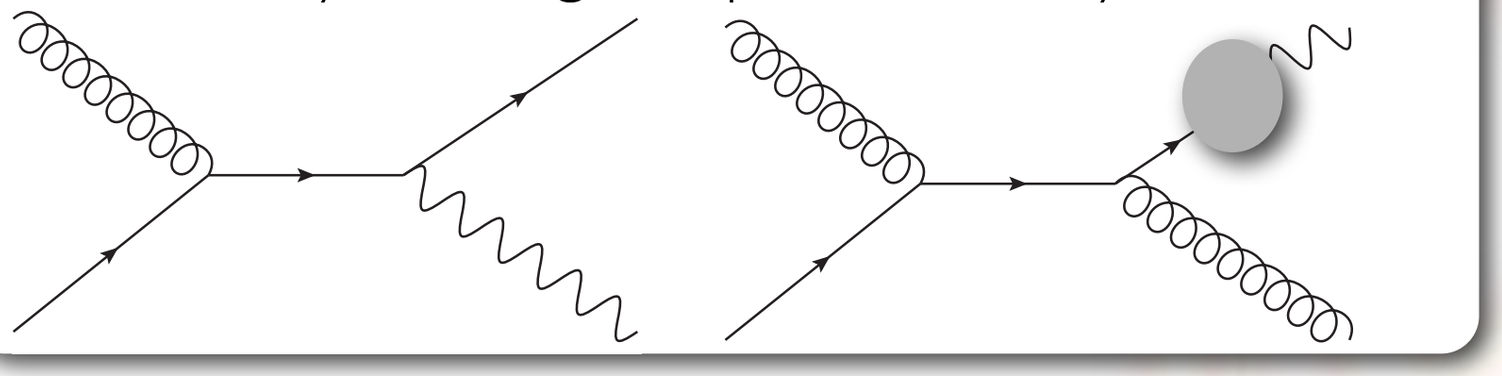
$$|Y^*| = |y_1 - y_2| + |y_2 - y_3| + |y_3 - y_1|$$

- NLO calculation for pp→3jets derived with NLOJET++ (electroweak corrections are not applied)
- **Tensions between the data and ABM11**



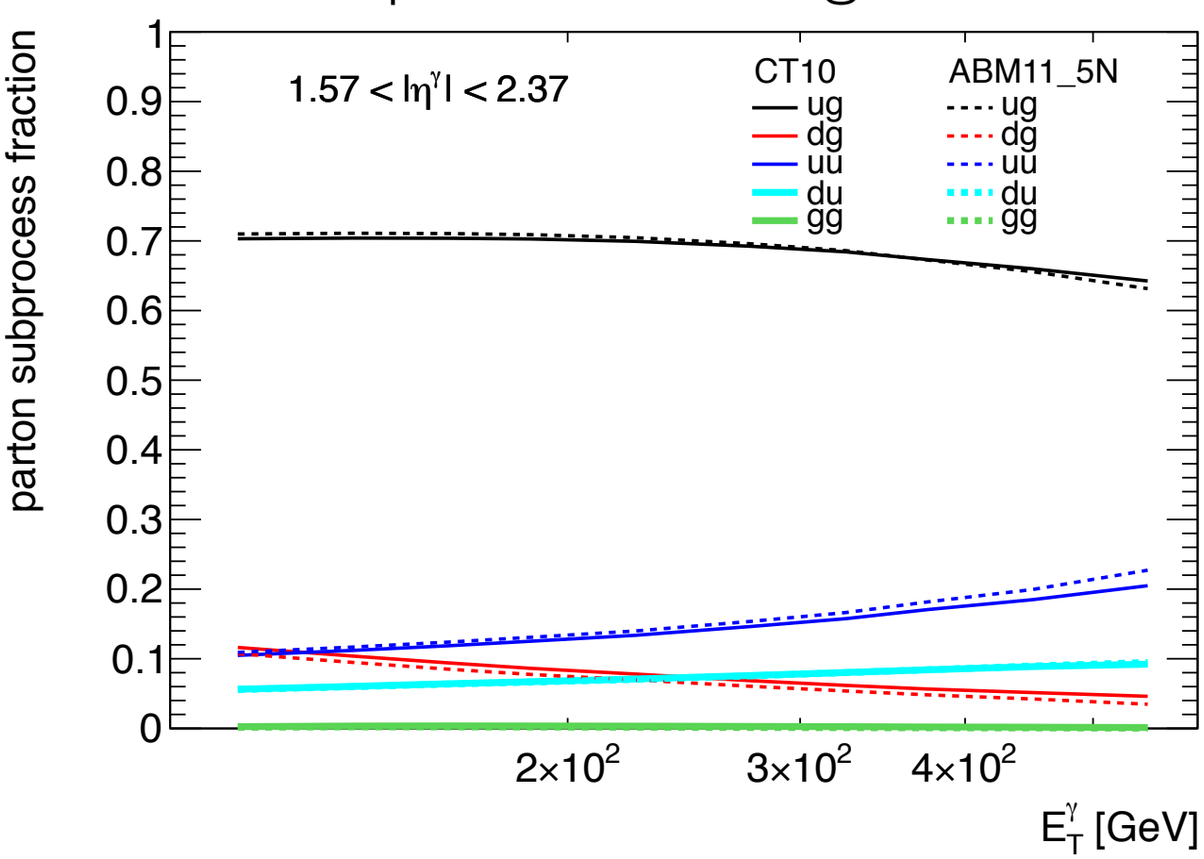
Inclusive photons

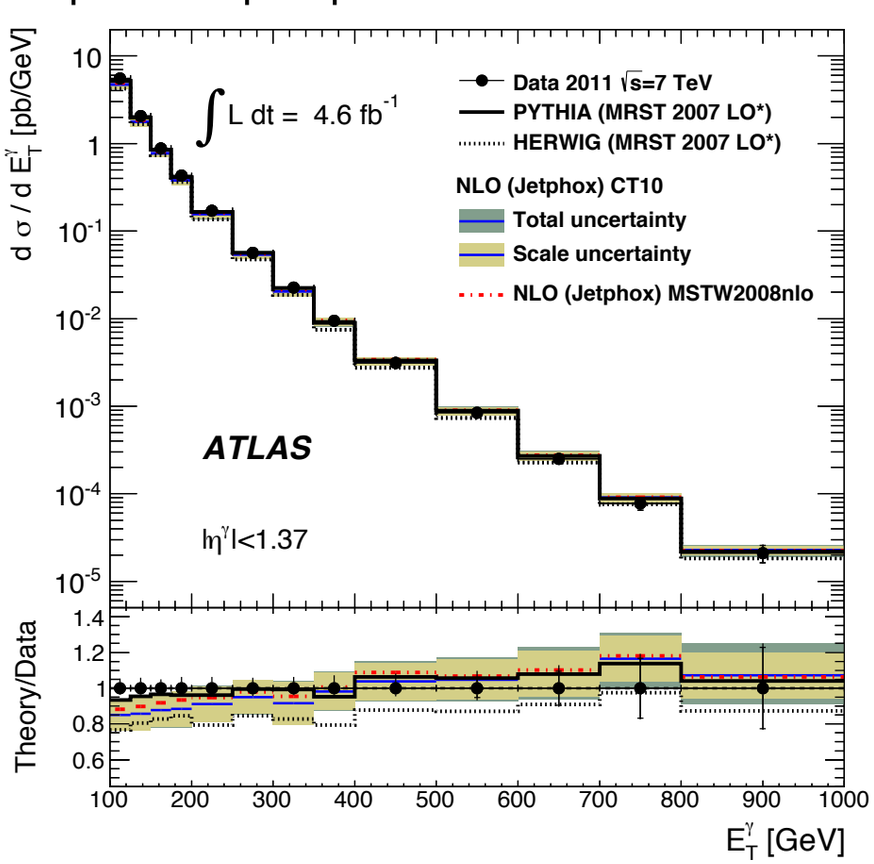
Sensitivity to the gluon parton density function



Benefits from a cleaner experimental environment compared to jet cross section measurements

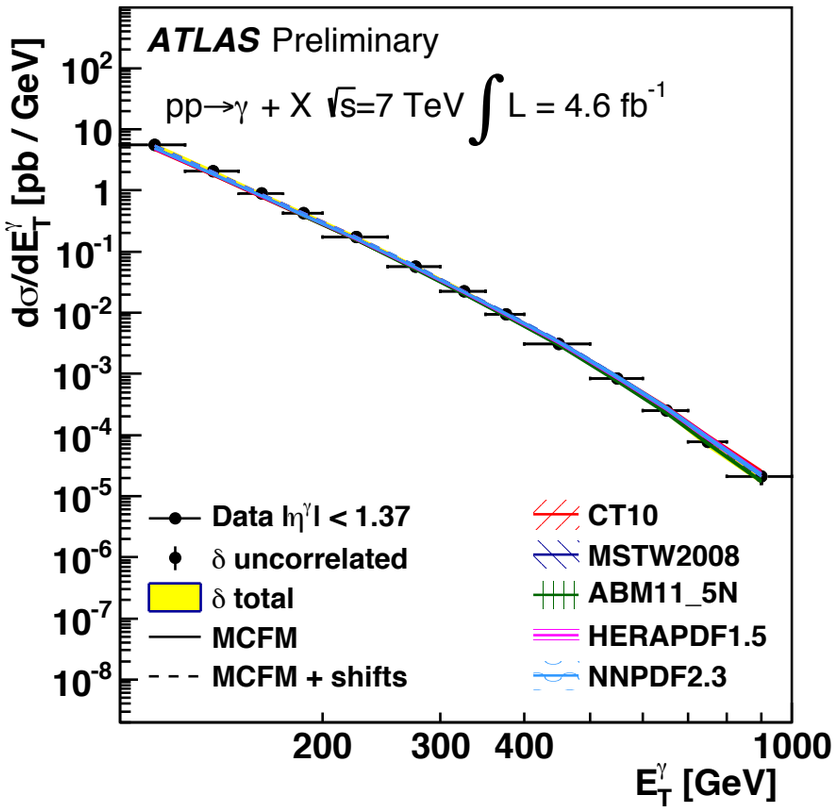
Gluon Compton scattering dominates the prompt photon cross section

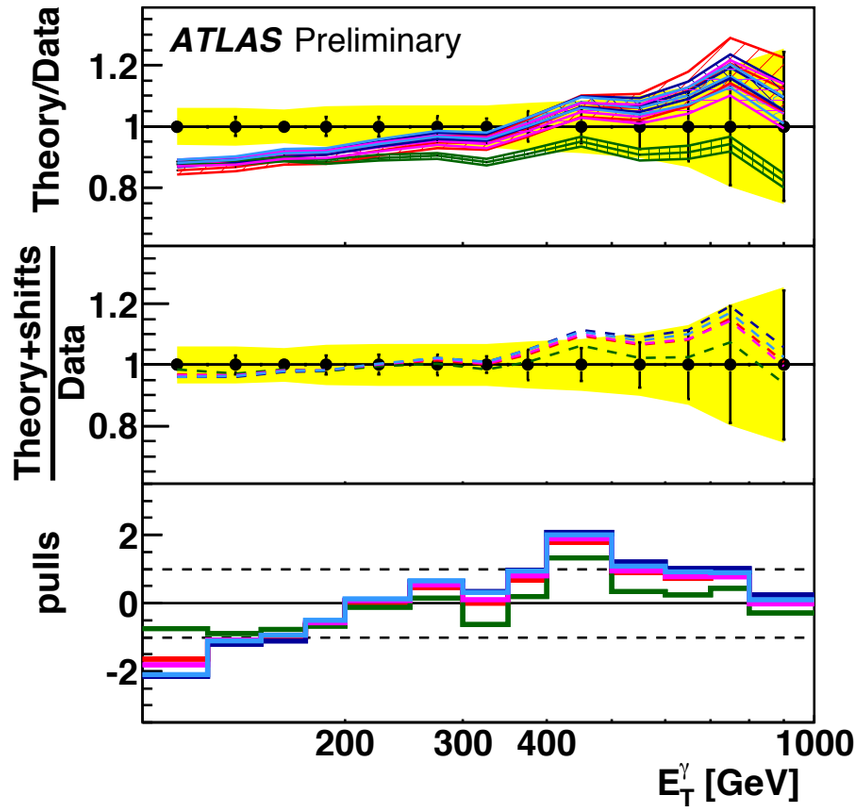




Inclusive photons

- NLO predictions derived with MCFM and JETPHOX
  - ☑ Validated the use of MCFM for fast NLO calculation against JETPHOX
- The use on the ATLAS inclusive photon data could improve the determination of the gluon density at high-x





	Excluding PDF uncertainties $\mu_r = \mu_f = E_T^\gamma$	Envelope	Including PDF uncertainties $\mu_r = \mu_f = E_T^\gamma$	Envelope
CT10	49.1	34.7 - 63.1	29.8	20.0 - 38.4
MSTW2008	39.9	27.2 - 52.7	32.0	21.3 - 42.3
ABM11_5N	16.2	9.2 - 25.5	15.7	8.9 - 24.9
HERAPDF1.5	28.7	19.0 - 38.9	23.6	15.7 - 32.0
NNPDF2.3	33.5	22.6 - 44.7	27.6	18.7 - 36.9

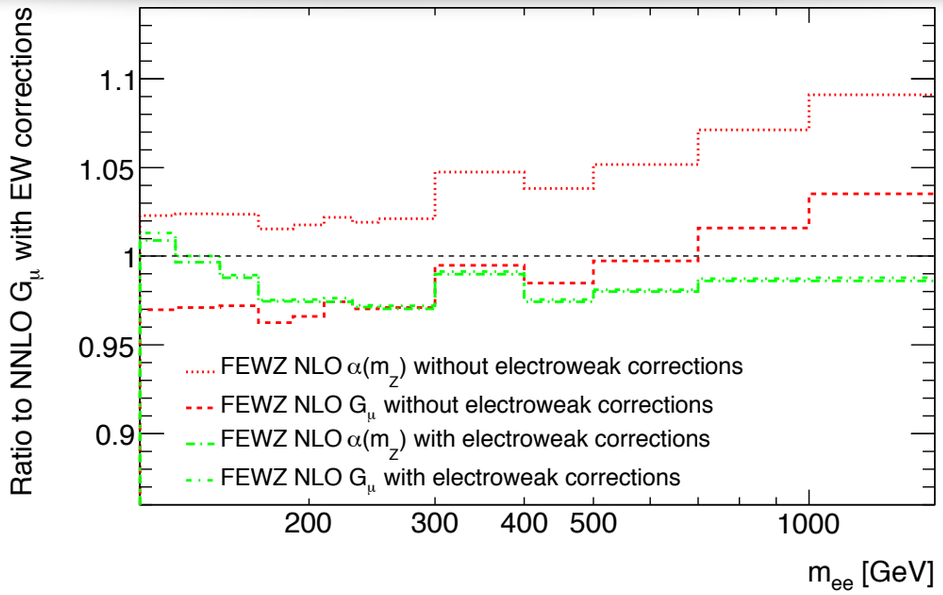
Gauge bosons

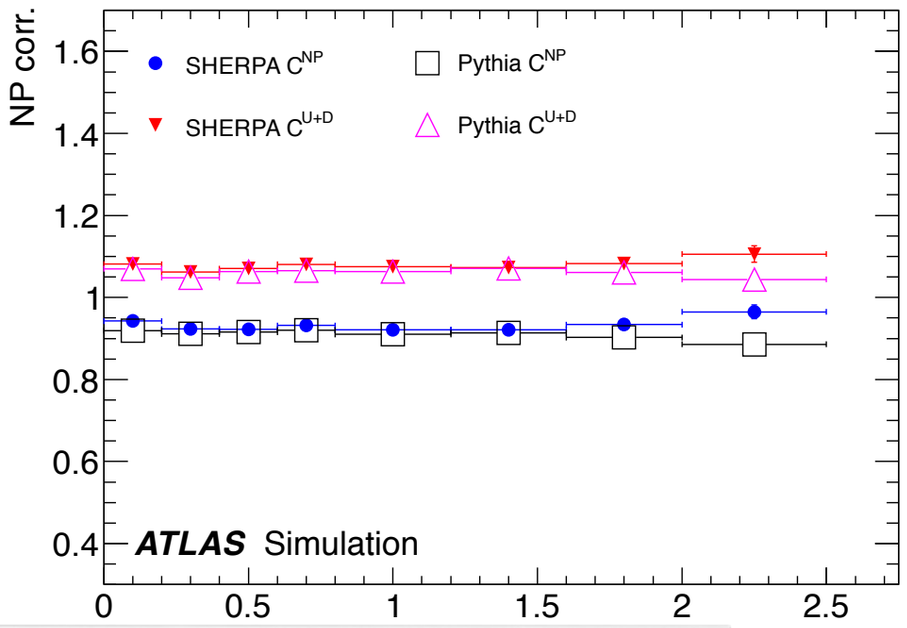
- Clean experimental signatures
- Advanced theoretical predictions

Generator	Prediction
FEWZ	W/Z Up to NNLO + NLO EW
POWHEG	W/Z NLO+PS
MCFM	Z+b(b) @ NLO
aMC@NLO	Z+b(b) @ NLO+PS
aMC@NLO	W+charm @ NLO+PS

- **Probing quarks and photon density functions**

NNLO QCD and NLO EW are relevant



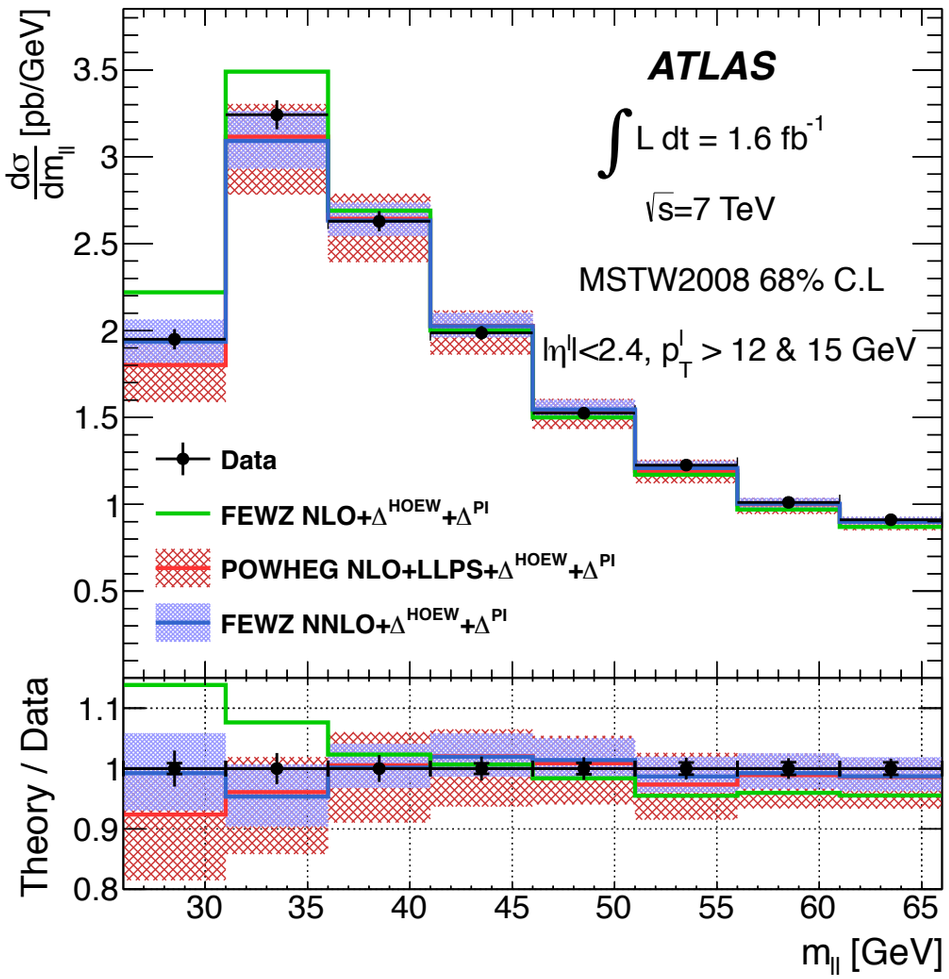


Non perturbative effects are under control

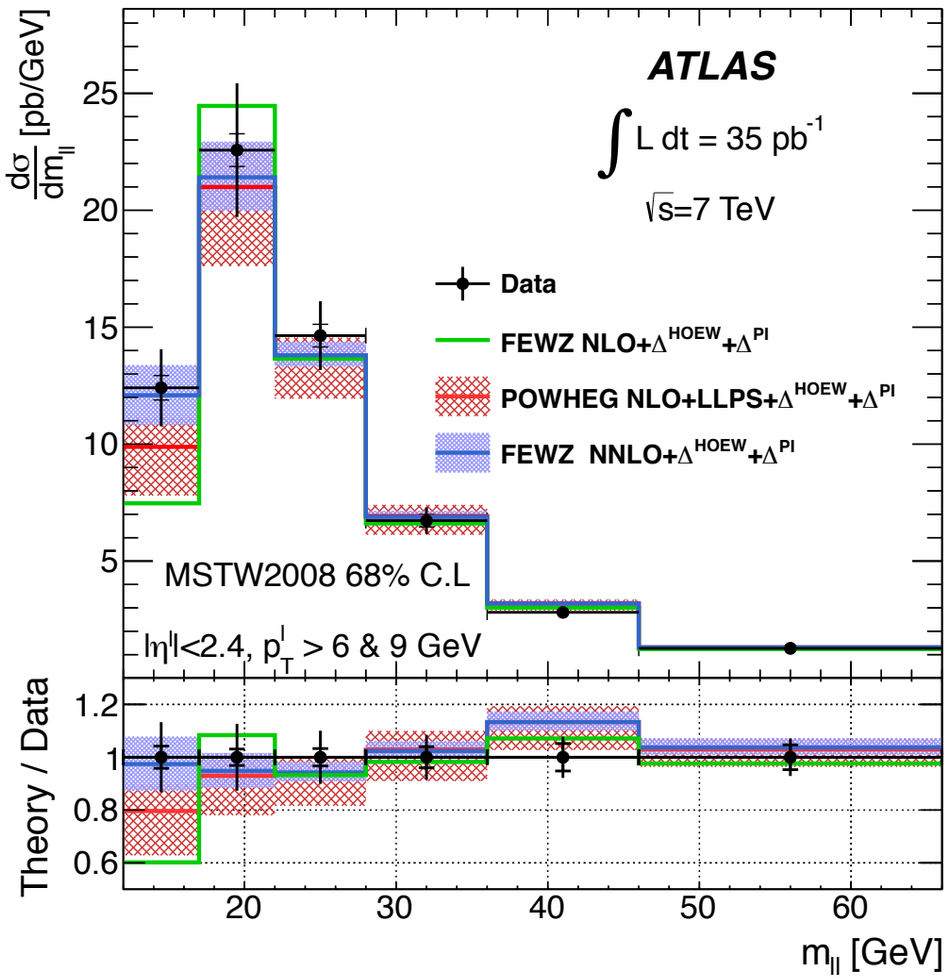
Low mass Drell-Yan

- Prediction combining NNLO QCD + NLO EW + P.I. provides the best description of the data
- NLO QCD calculation provides a poor description of the data at low di-lepton invariant mass

Nominal analysis [26-66 GeV]



Extended analysis [12-66 GeV]



Low mass Drell-Yan

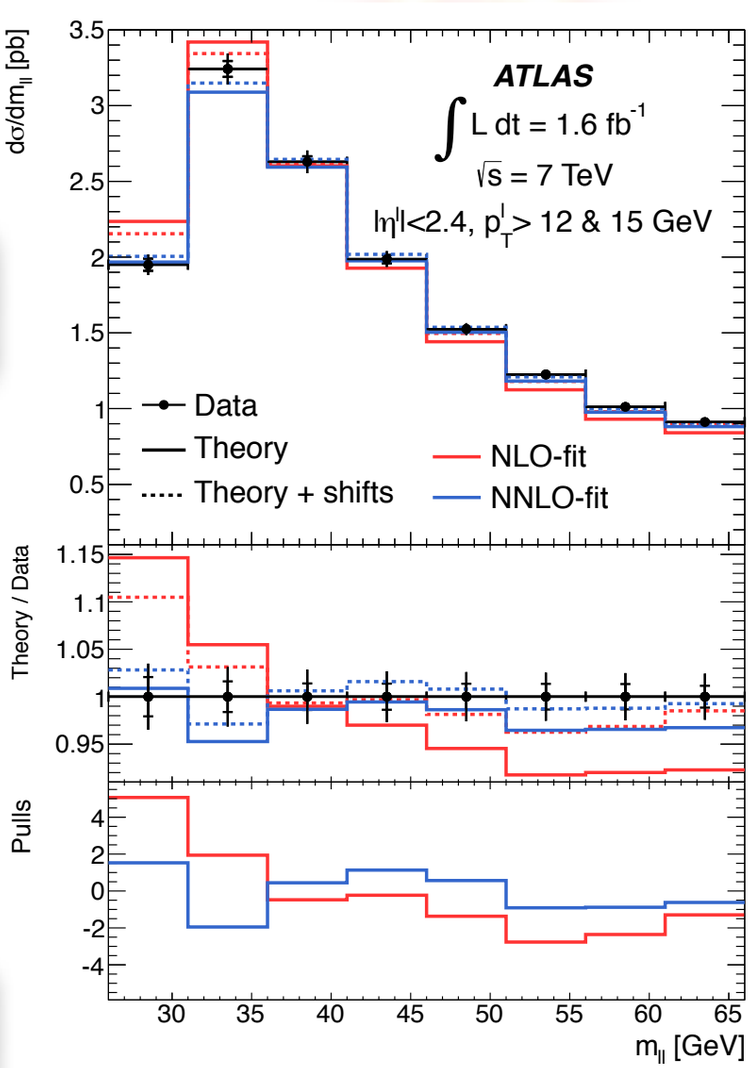
Nominal

Prediction	χ^2 8 points	
	w/o th. err.	with th. err.
POWHEG	22.4	19.8
FEWZ NLO	48.7	28.6
FEWZ NNLO	13.9	12.9

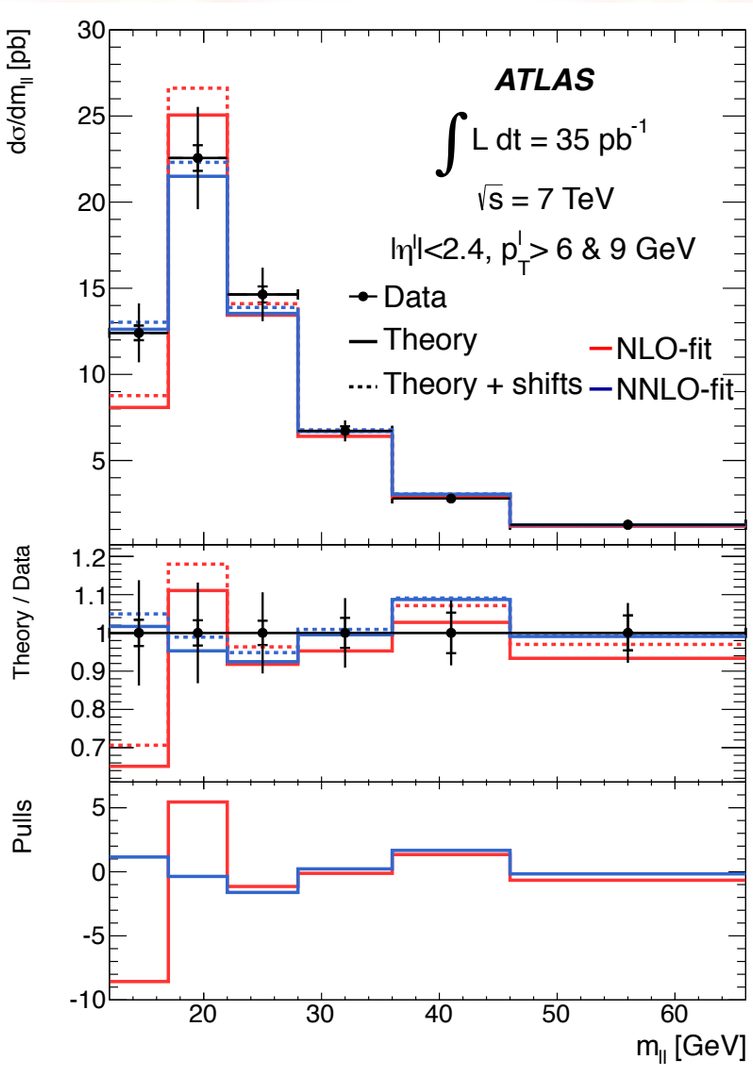
Extended

Prediction	χ^2 6 points	
	w/o th. err.	with th. err.
POWHEG	22.3	18.6
FEWZ NLO	138	133.7
FEWZ NNLO	7.1	7.1

NNLO fit to the data performs significantly better than the NLO



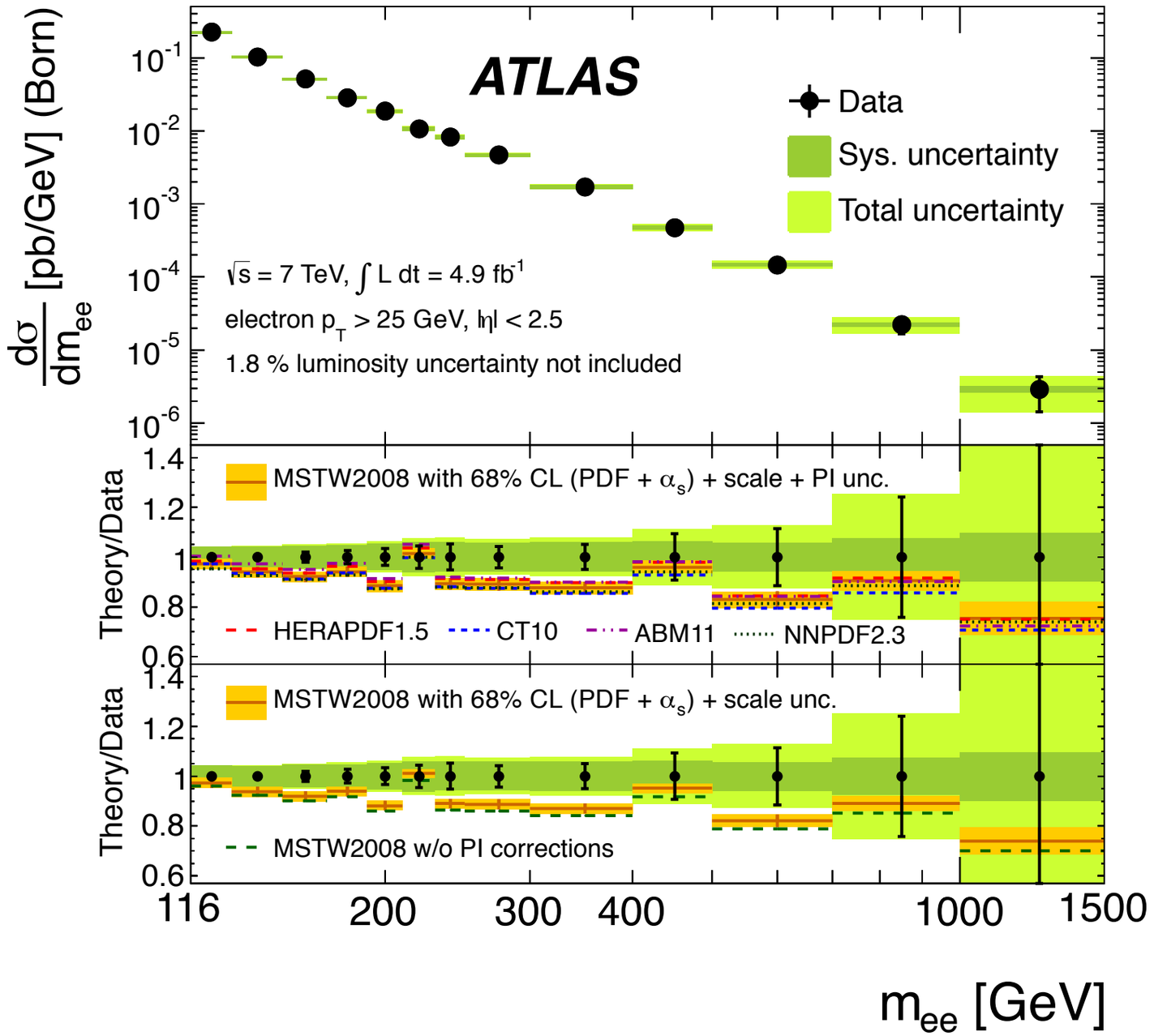
Nominal



Extended

High mass Drell-Yan

- Drell-Yan at high mass as a possible probe of the quark density functions at high-x
- Measurement statistically limited for m_{ee}>400 GeV
- Photon induced corrections have to be included in order to use these data in future PDFs analyses
- **These data have been used for the first fit to the photon PDF (NNPDF Collaboration, arXiv: 1308.0598 [hep-ph].)**

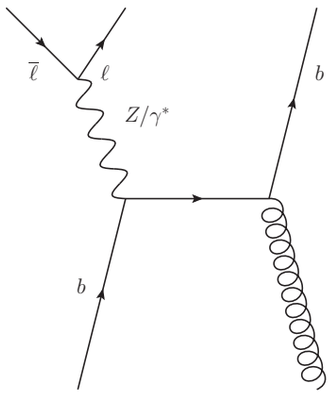


Associated production of b-jets and a Z boson

b-quark PDF?

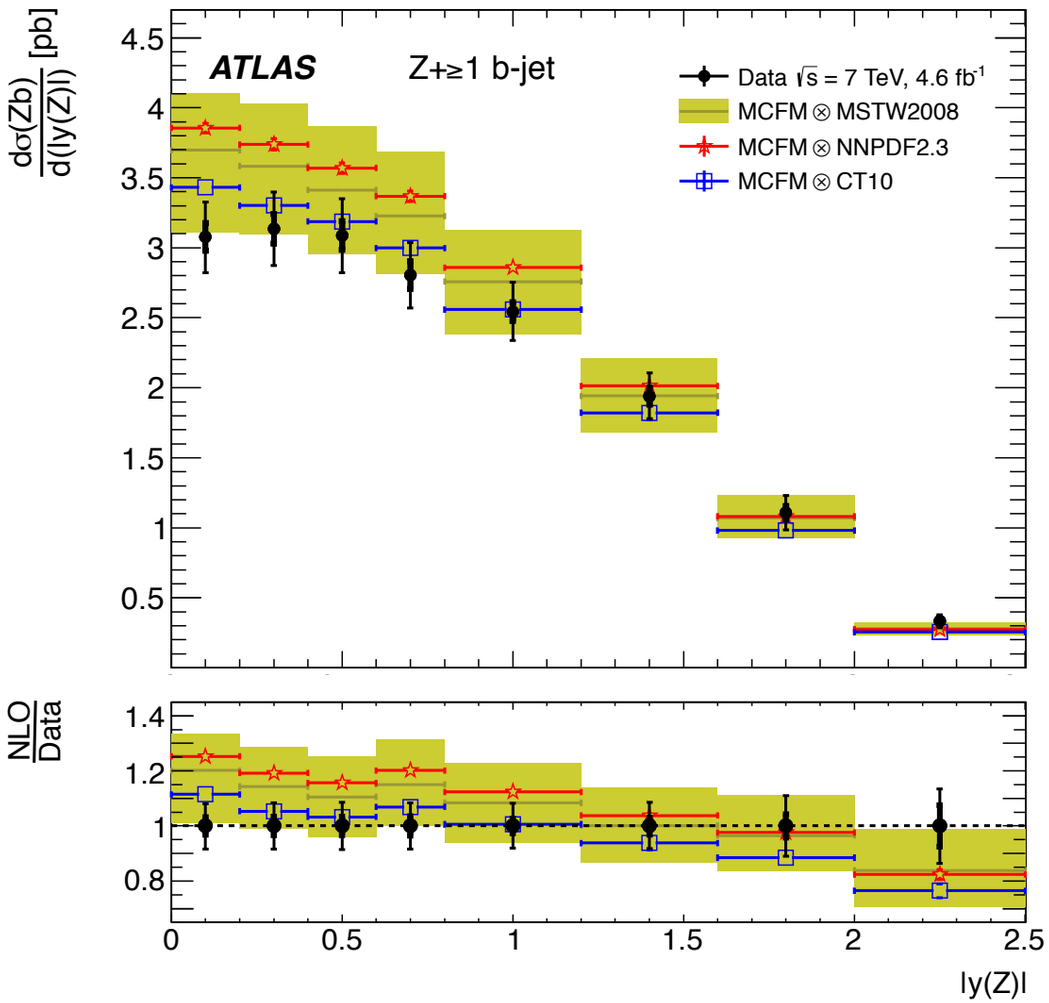
Currently not directly constrained with data(*)

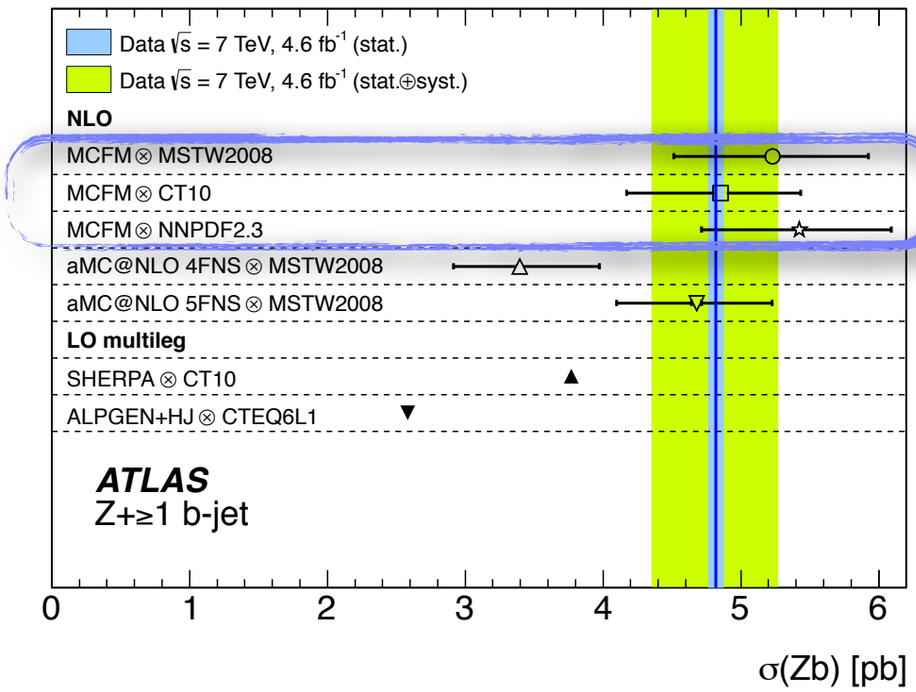
5FNS 5 Flavour Number Scheme



PDF variations affecting mostly the total normalisation

The differences between PDFs is not covered by the PDF uncertainties

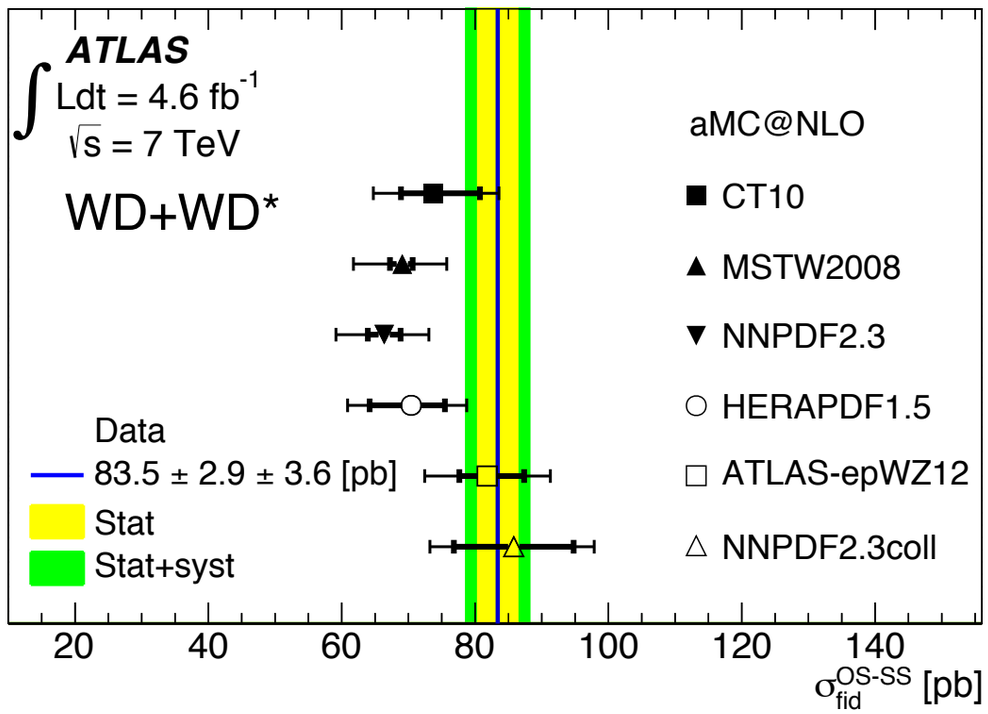


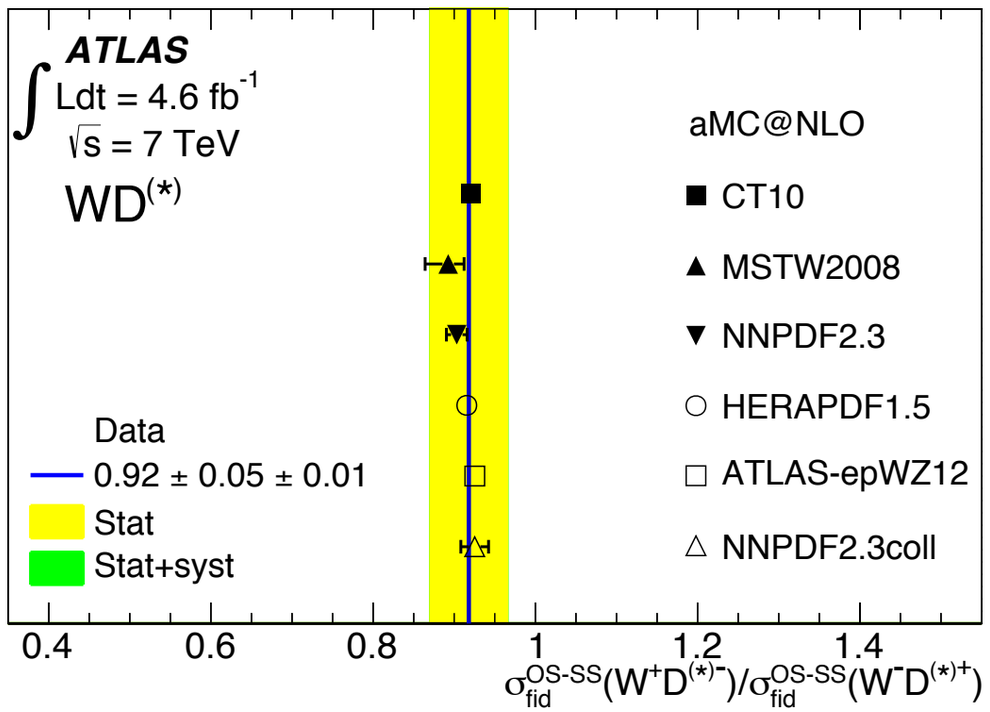


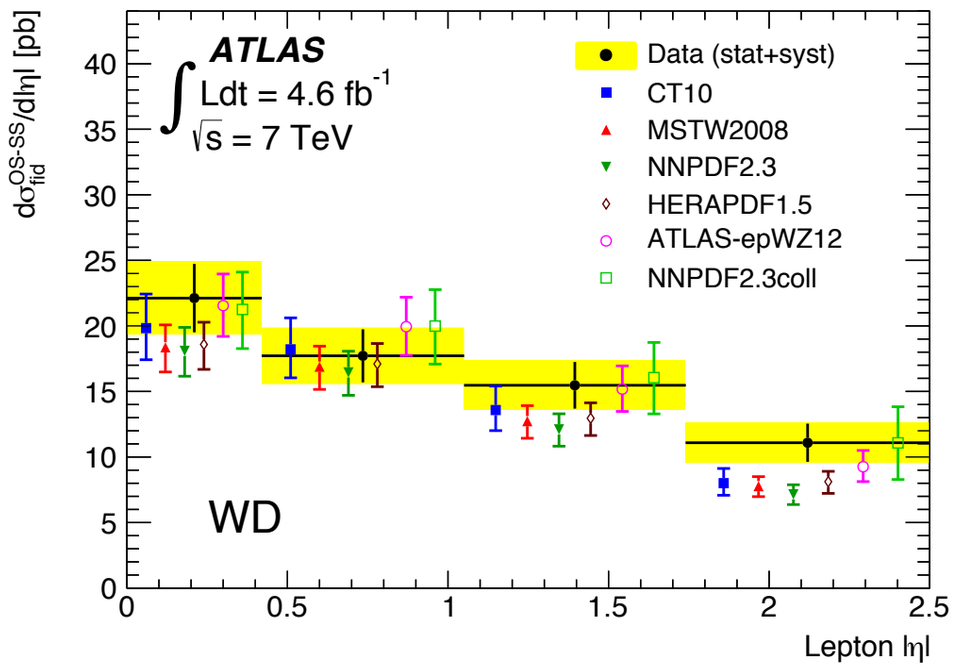
NLO QCD predictions with PDF variations derived with MCFM

(*) Heavy flavour production at HERA could offer similar sensitivity to b-quark PDF

W+charm







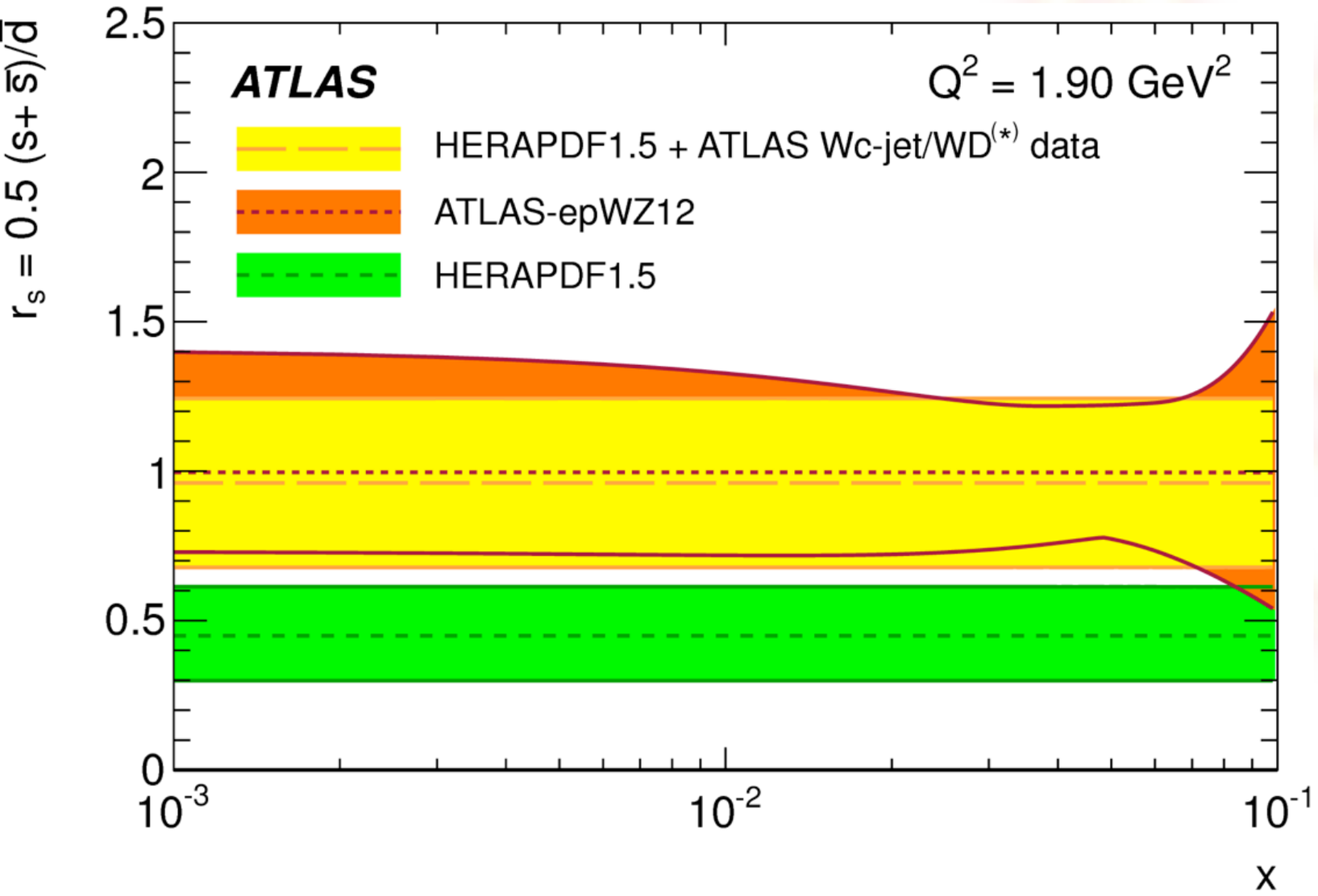
PDF variation affecting mostly the total cross section

W^++charm / W^-+charm sensitive to the s-$\bar{s}$ asymmetry

W+charm

Using (differential) fiducial W+charm cross sections to constrain the strange quark PDFs

$$r_s(x) = 0.5\,\frac{s(x)+\overline{s}(x)}{\overline{d}(x)}$$



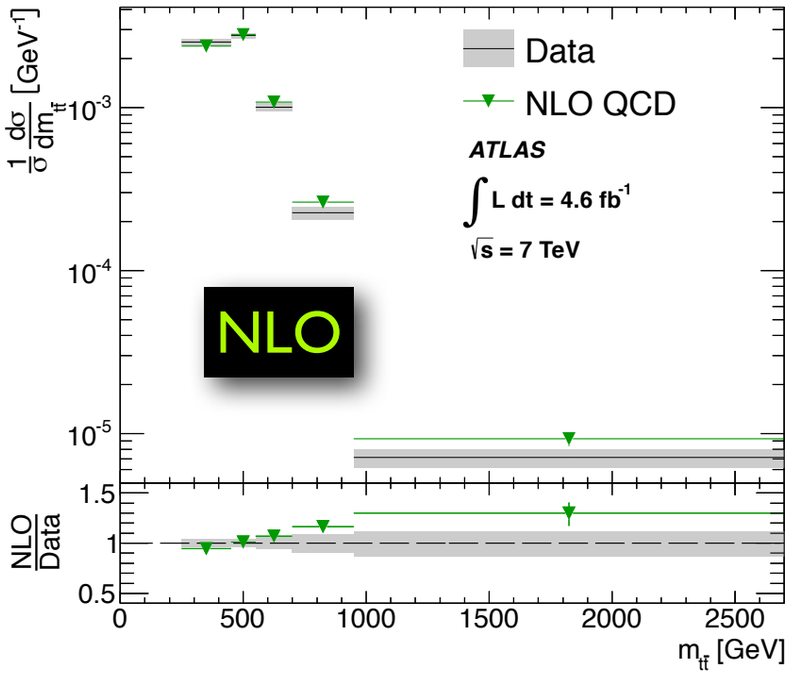
Adding the ATLAS W +charm data on top of the HERA1.5 data

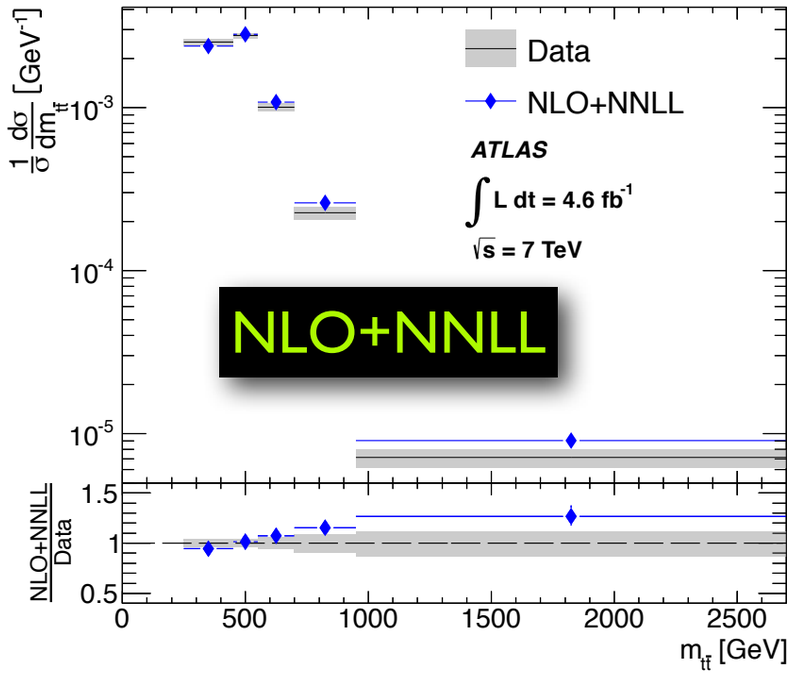
Results consistent with the ATLAS-epWZ12 PDFs

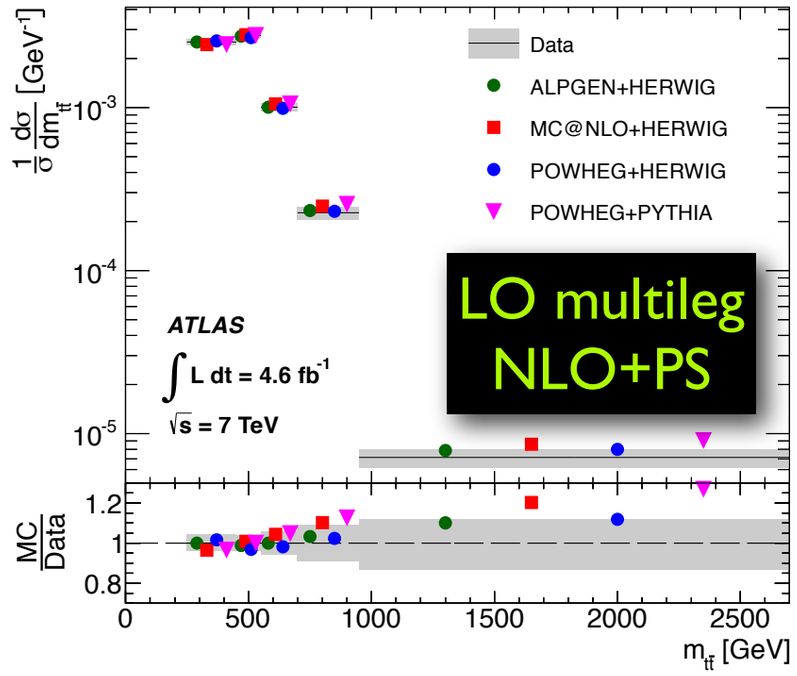
Confirming "unsuppressed strangeness" scenario

Top quark production

- Using the $t\bar{t}$ as a probe of the gluon density function?
- How well the QCD predictions describe the data?
- tt cross section measured as a function of the $t\bar{t}$ invariant mass
  - ☑ The calculations are not able to describe the data at high invariant mass



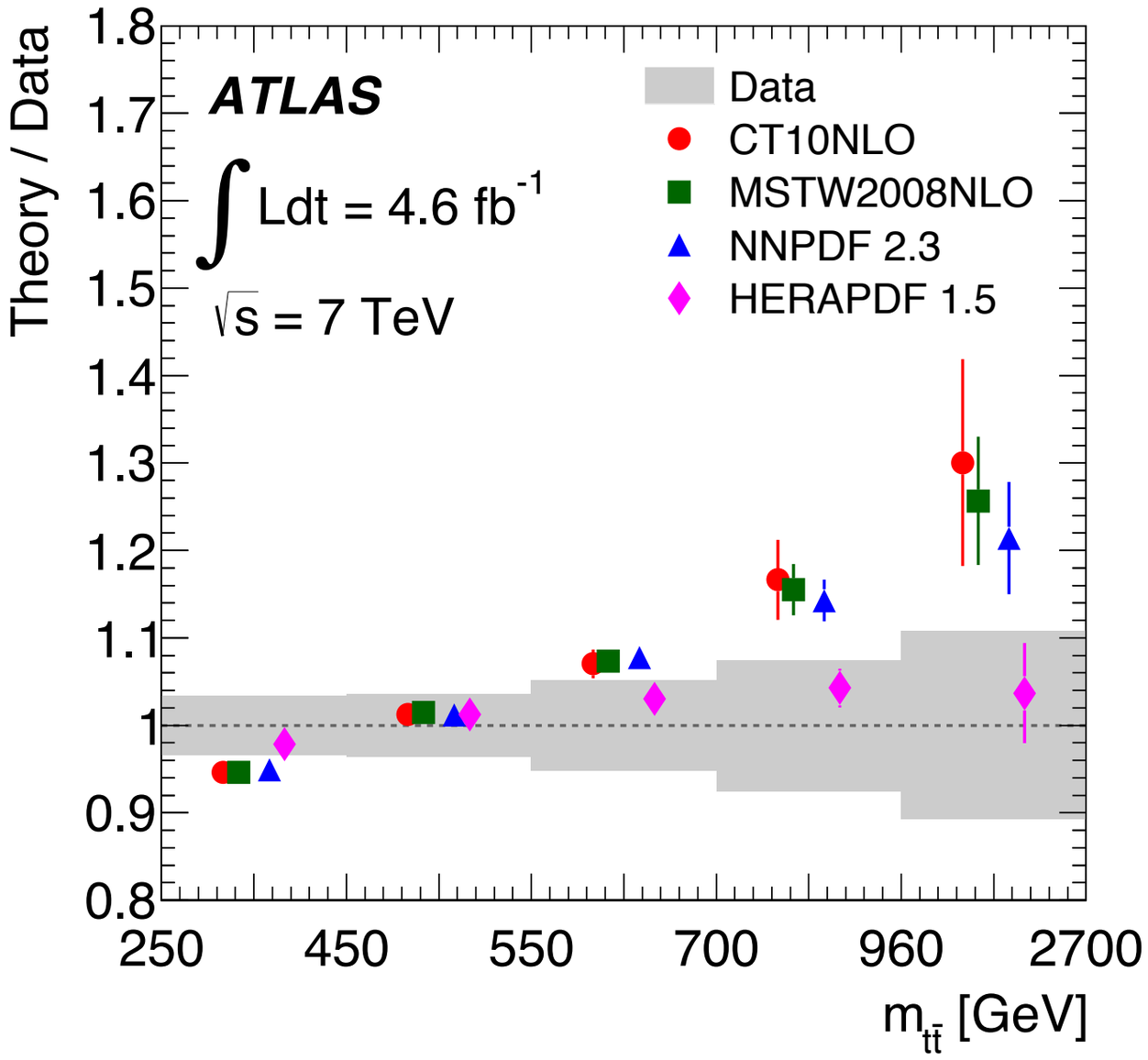


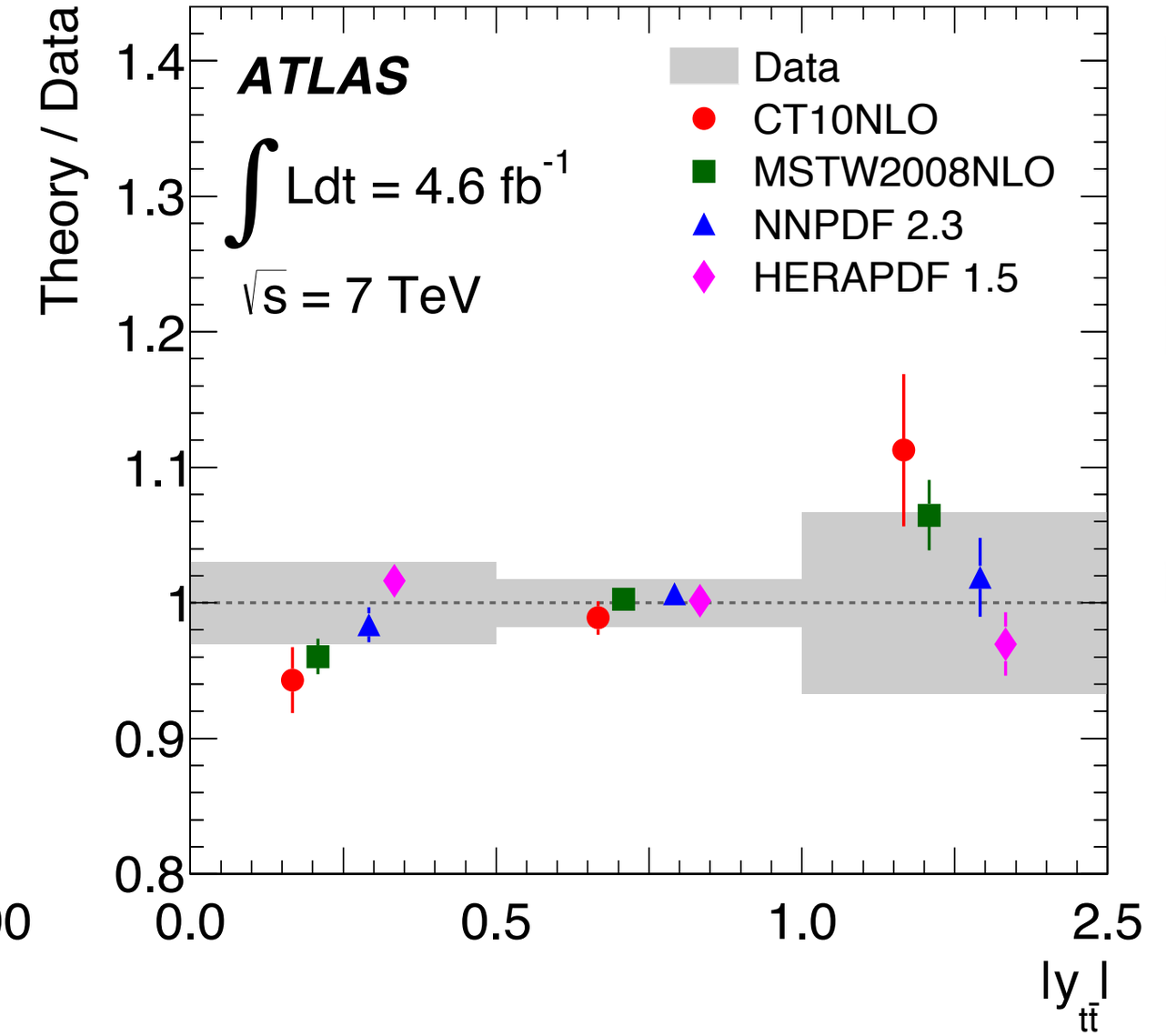


Top pair

HERAPDF 1.5 describes well the data
Tensions between the data and other PDF sets

NLO Predictions derived with MCFM
NLO EW corrections are not included in the NLO predictions





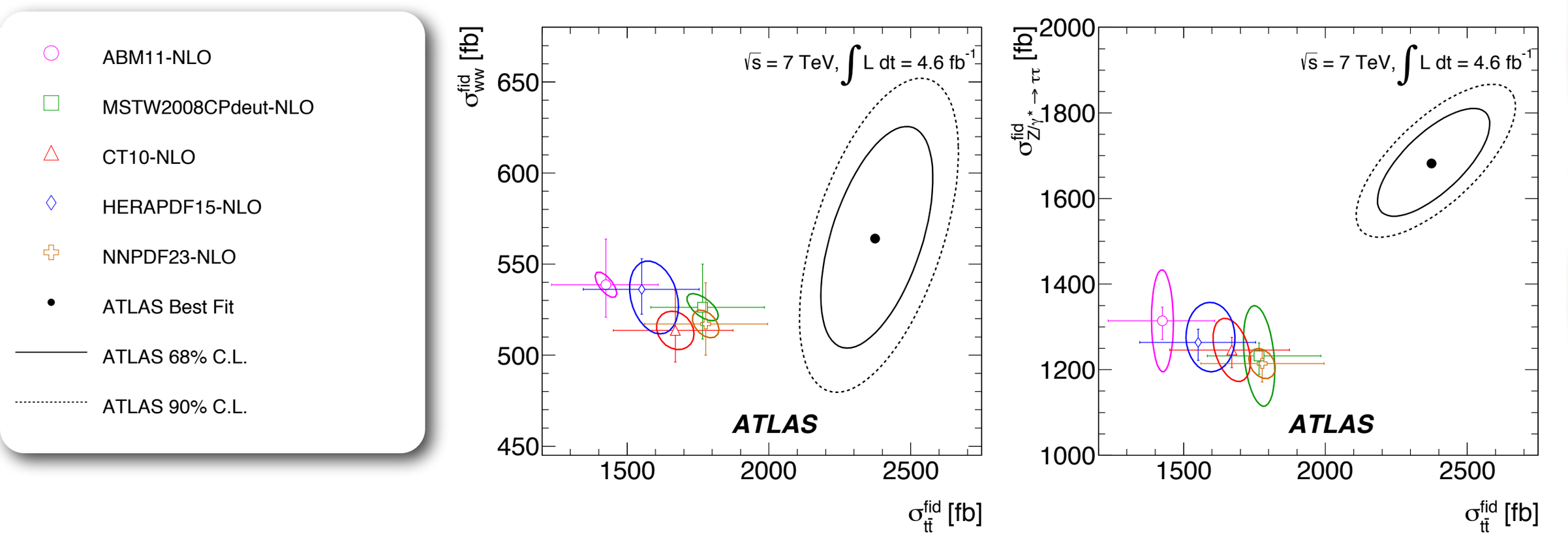
Summary

- First PDFs fits have been performed in ATLAS by using jet, W/Z and W+charm data
  - ☑ Improving knowledge on the gluon density function at high-x and strange quark PDF
- Several other studies of PDFs sensitivity with Run 1 data have been performed
  - ☑ Inclusive photon data and tt cross section exhibit good potential to further constrain the gluon density
- **Evaluating the feasibility of a "global" fit including the ATLAS data**

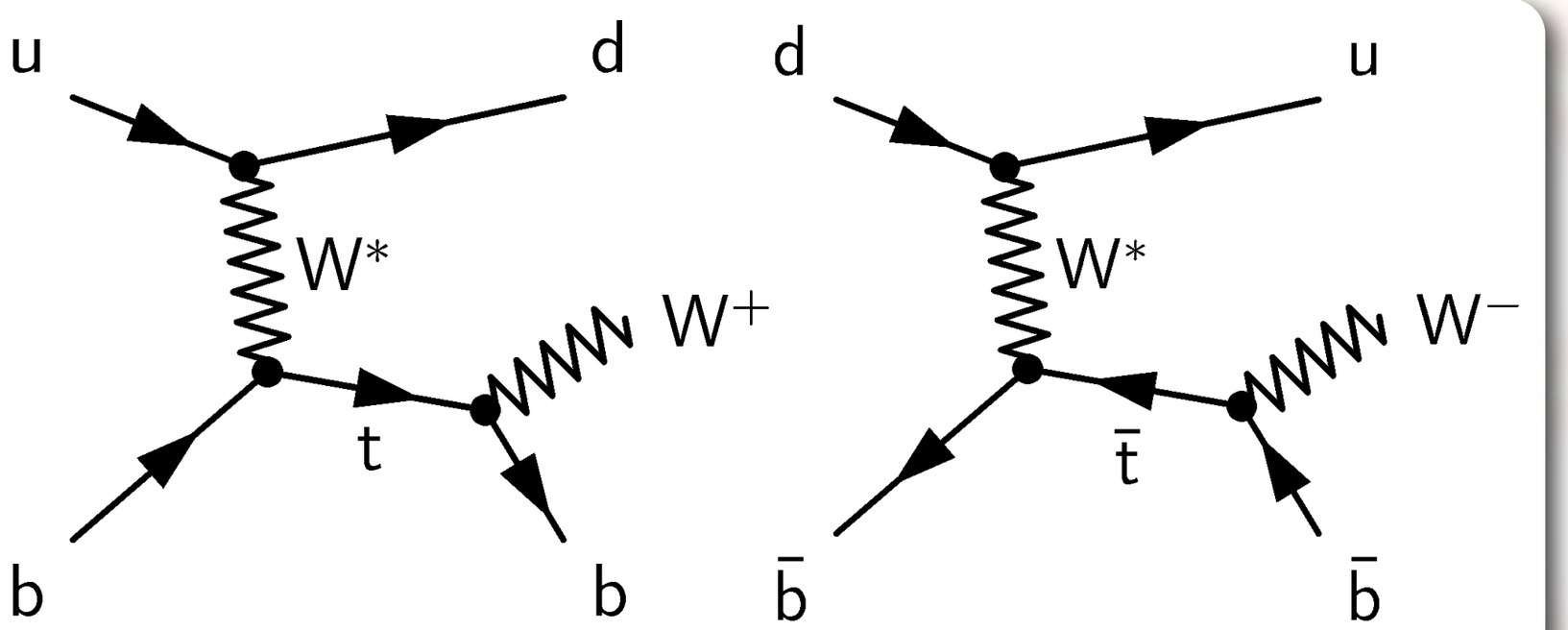
Backup

Simultaneous measurement of tt, Z(→ττ) and WW

- Spread in the tt cross section predictions obtained from different parton distribution functions
  - ☑ Consistent with dedicated tt cross section measurements



t-channel single top



Potential constraints on the b-quark parton density function
Experimental precision to be improved