LHC measurements for constraining parton distribution functions

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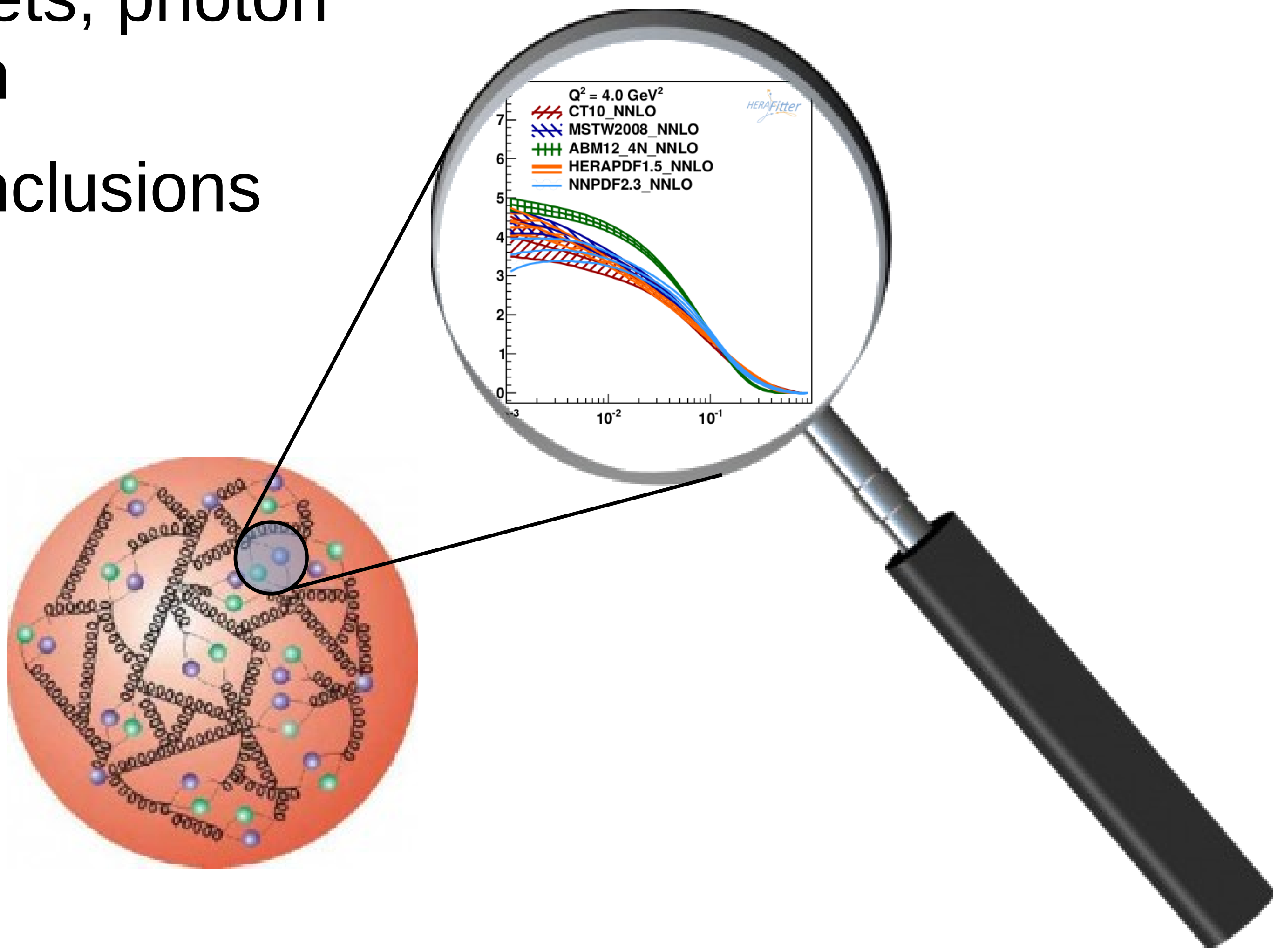
Saclay – 30 Jan 2017

LHC measurements for constraining PDFs

- Introduction and motivation
- LHC measurements sensitive to PDFs: Drell-Yan, jets, photon and top production
- Prospects and conclusions



PDFs in the LHC era

Any prediction of physics observable at hadron colliders requires knowledge of the PDFs

PDFs

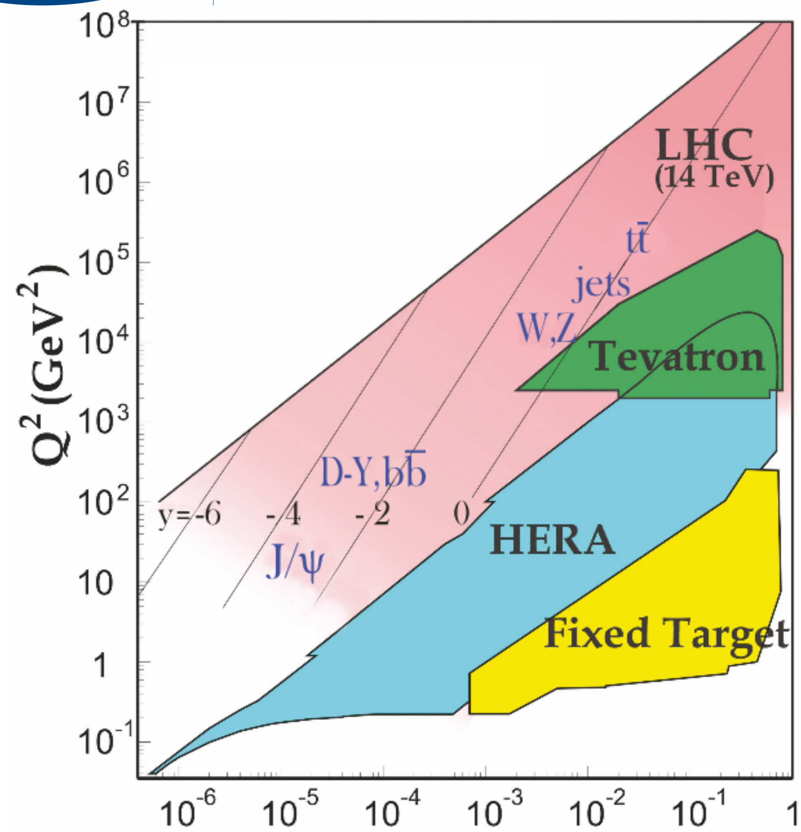
Partonic cross sections

Factorisation theorem*:

$$\sigma_{pp\to X} = \Sigma_{i,j} \int dx_1 dx_2 f_i^p(x_1,\mu) f_j^p(x_2,\mu) \times \sigma_{i,j}$$

- Cross section are calculated by convoluting short distance partonic reactions with Parton Distribution Functions (PDFs)
- Discovery of new exciting physics relies on precise knowledge of proton structure
- PDFs are among the dominant uncertainties for the W mass, weak-mixing angle, and gg → H production

**The factorisation theorem is proven rigorously only for DIS and inclusive DY, predictions and PDF fits of other semi-inclusive processes in hadron-hadron collisions are based on the assumption that the factorization holds also there*

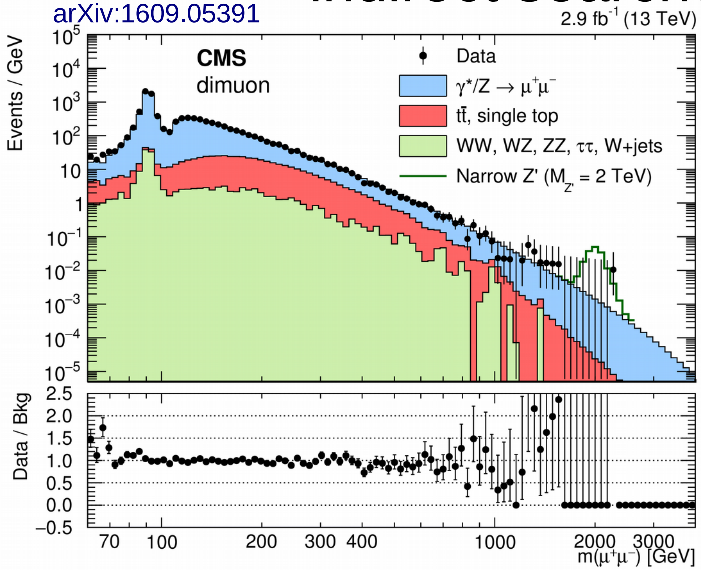


From PDG Chin. Phys. C, 40, 100001 (2016)

PDFs in the LHC era

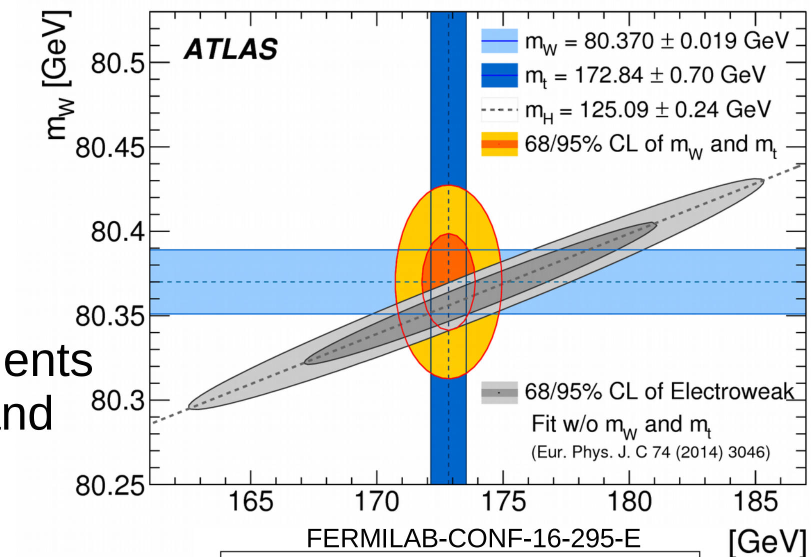
Accurate knowledge of the PDFs is crucial for direct searches of new physics, as well as for indirect searches through precision measurements

arXiv:1609.05391



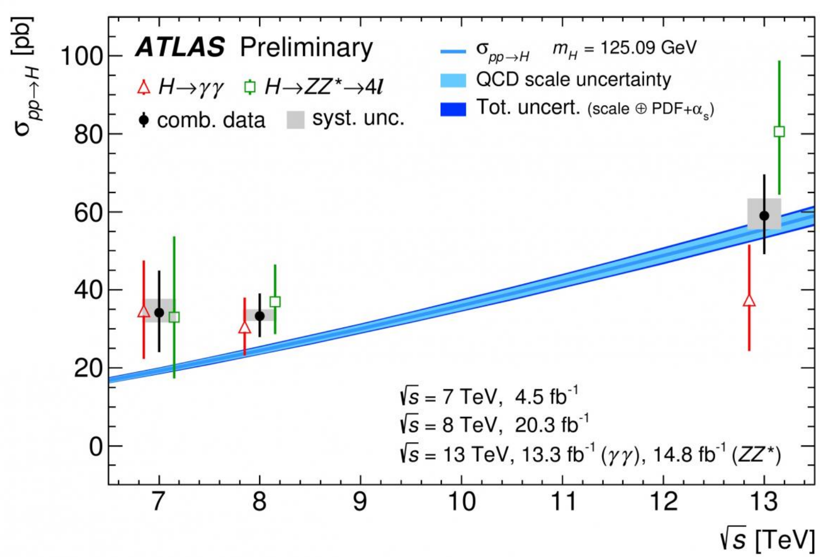
Direct searches

arXiv:1701.07240



Precise measurements of cross sections and EW observables

ATLAS-CONF-2016-081



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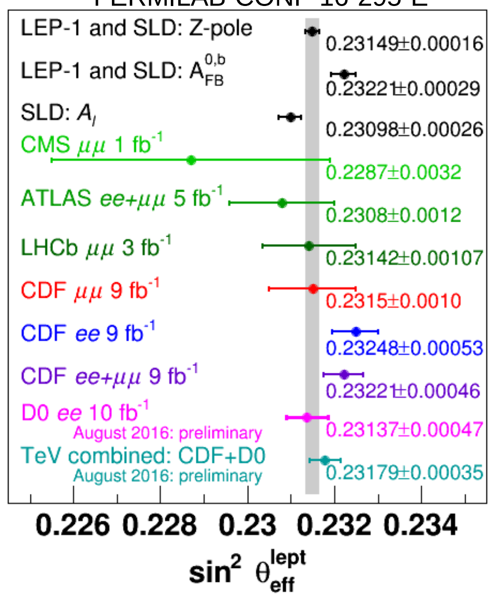
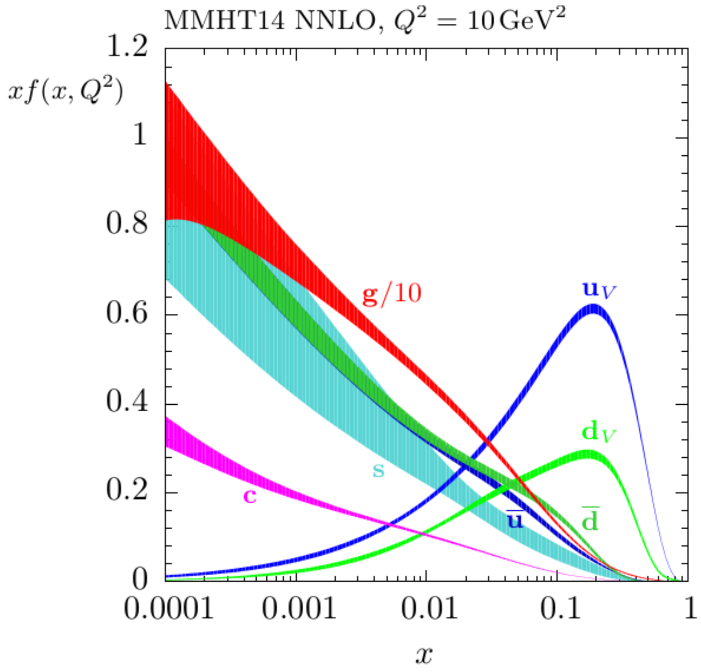


Parton distribution functions

- In a naive leading-order perspective, PDFs can be seen as the probability of finding a parton in a hadron which carries a momentum fraction x



- In the collinear factorization, PDFs are a function of Bjorken-x, the momentum fraction, and Q^2, the “factorization” scale of the process

- PDFs cannot (yet) be predicted by first principles with non-perturbative QCD calculations (lattice)
- However, perturbative QCD accurately predicts the evolution of PDFs in Q^2
- It is necessary and sufficient to use experimental inputs to determine the boundary conditions, i.e. the PDFs $f(x,Q0^2)$ at a given starting scale of the order $Q0^2 \sim 1\ \mathrm{GeV}^2$

Schematic of PDF determination

PDF determination is a complex problem, with a variety of solutions, namely PDF sets

Input data

Theory predictions

Partonic cross sections $\otimes$ **PDF evolved at all scales**

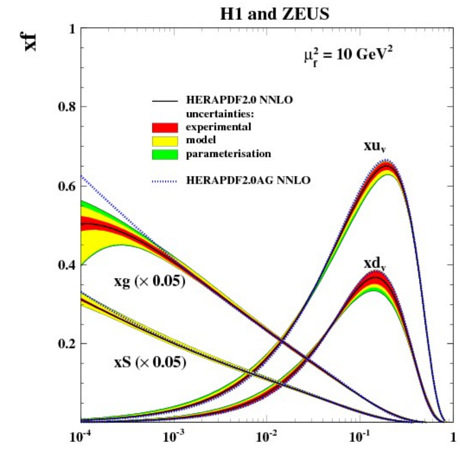
χ^2 test

Minimisation (Fit) of the PDF parameters at the starting scale

DGLAP evolution

PDF parametrisation at the starting scale ~ 1 GeV with ~ 20 free parameters

Result:
$f(x,Q^2)$
at all scales



arXiv:1506.06042

Variety of PDF sets

A complex problem leads to a variety of solutions.

- PDF sets differ by:
  - Input data: all or part of DIS, Tevatron, LHC, fixed target, neutrino data
  - Determination of PDF uncertainties: hessian, MC replica
  - Parametrization of the PDF functional form: polynomials, NN
  - QCD perturbative order: LO, NLO, NNLO
  - Heavy flavour scheme for the DIS cross section: Variable flavour number scheme (VFNS), Fixed flavour number scheme (FFNS)
  - Choice of $\alpha_s(M_Z)$, top, charm, and bottom masses
  - χ^2 definition and χ^2 tolerance criteria

Variety of PDF sets

V. Radescu

	CT14	MMHT15	NNPDF3.0	HERAPDF2.0	ABM12	CJ12	JR14
HQ scheme	VFNS (ACOT-χ)	VFNS (TR opt)	VFNS (FONLL)	VFNS (TR opt)	FFNS Run mc (ABM)	VFNS (ACOT)	FFNS (JR)
orders	LO, NLO, NLLO	LO, NLO, NLLO	LO, NLO, NLLO	LO, NLO, NLLO	NLLO	NLO	NLO, NLLO
α(Mz)	fixed (fitted)	fixed (fitted)	fixed	fixed	fitted	fixed	fitted
α(Mz) LO α(Mz) NLO α(Mz) NNLO	0.1300 0.1180 (0.117) 0.1180 (0.115)	0.1350 0.1180 (0.1201) 0.1180 (0.1172)	0.1180 0.1180 0.1180	0.1300 0.1180 0.1180	- - 0.1132	- 0.118 -	- 0.1158 0.1136
Nr param.	Pol. Bernst. 28	Pol. Cheb. 25	NN (259)	Pol. 14	Pol. 24	Pol. 22	Pol.25
PDF assumptions	ubar/dbar=1(x->0) u/d=1 (x->0)	s-sbar=fit. dbar-ubar=fit.	dbar-ubar=fit	ubar=dbar (x->0) sbar=0.67* dbar	s=sbar dbar-ubar=fit	dv/uv=const s+sbar=k(ubar+dbar)	dbar-ubar=fit
Stat. treatm.	Hessian $\Delta\chi2$=100 (90% CL)	Hessian $\Delta\chi2$ Dynamical (68% CL)	Monte Carlo (68% CL)	Hessian $\Delta\chi2$=1 (68% CL)	Hessian $\Delta\chi2$=1 (68% CL)	Hessian $\Delta\chi2$=1 (68% CL)	Hessian $\Delta\chi2$=1 (68% CL)
Q2min	2	2	3.5	3.5	2.5	1.69	2
HERA data	HERA I+ charm	HERA I charm jets	HERA I+ H1 and ZEUS II charm	HERA I+II	HERA I charm	HERA I	HERA I charm jets
Fix. Target DIS	✓	✓	✓	N/A	✓	JLAB, high x ✓	JLAB, high x ✓
Tevatron W,Z	✓	✓	✓	N/A	✗	✓	✗
Tevatron Jets	✓	✓	✓	N/A	✗	✗	✓
Fix. Target DY	✓	✓	✓	N/A	✓	✓	✓
LHC WZ	✓	✓	✓	N/A	✓	✗	✗
LHC jets	✓	✓	✓	N/A	✗	✗	✗
LHC top	✗	✓	✓	N/A	✓	✗	✗
LHC charm	✗	✗	✓	N/A	✗	✗	✗
References	arXiv:1506.07443	arXiv:1412.3989	arXiv:1410.8849	arXiv:1506.06042	arXiv:1310.3059	arXiv:1212.1702	arXiv:1403.1852

Limitation of DIS measurements

- PDFs are most precisely determined from DIS data, and the currently most precise dataset is the combined HERA-II inclusive DIS measurement
- However, DIS structure functions probe only particular combinations of PDFs: DIS data leads to a very precise determination of valence PDFs and total sea.
- Limitations:
  - d_v is less precisely determined than u_v
  - We miss precise knowledge of the flavour decomposition of the light sea, i.e. “How strange is the proton?”
  - The gluon PDF is determined only through scaling violation in DIS, leading to larger uncertainties, especially in the high-x region, which is crucial for searches

Motivation for LHC measurements for PDFs

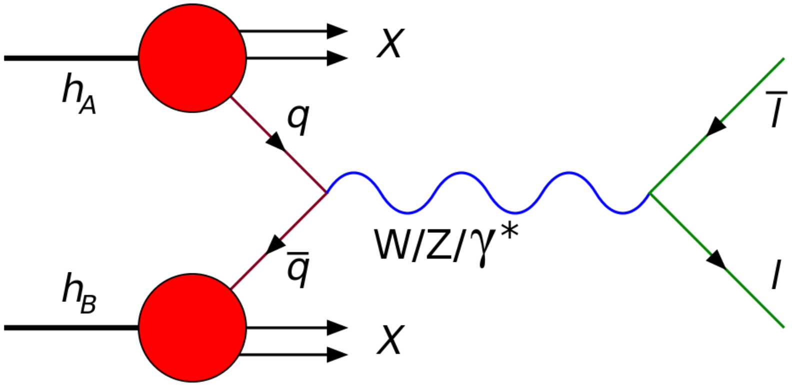
- Cross section measurements at hadron colliders cannot replace the invaluable ep DIS data
- Nevertheless they can provide important complementary information in the corners of the phase space not well covered by other datasets
- The LHC data can also help to resolve some of the disagreement between datasets and PDF groups, e.g. on the strange and gluon PDFs

Process	Sensitivity
Drell-Yan	Flavour decomposition of the sea, u_v, d_v, γ PDF
W+charm	Strange PDF
Jets	High-x gluon PDF
Photon	Medium-x gluon PDF
Top pair	Medium- and high-x gluon PDF

- Other measurements not yet fully exploited: diboson, single top, W/Z+jet
- Precise data requires precise theory:NNLO QCD, NLO EW, non-pQCD, and PS corrections

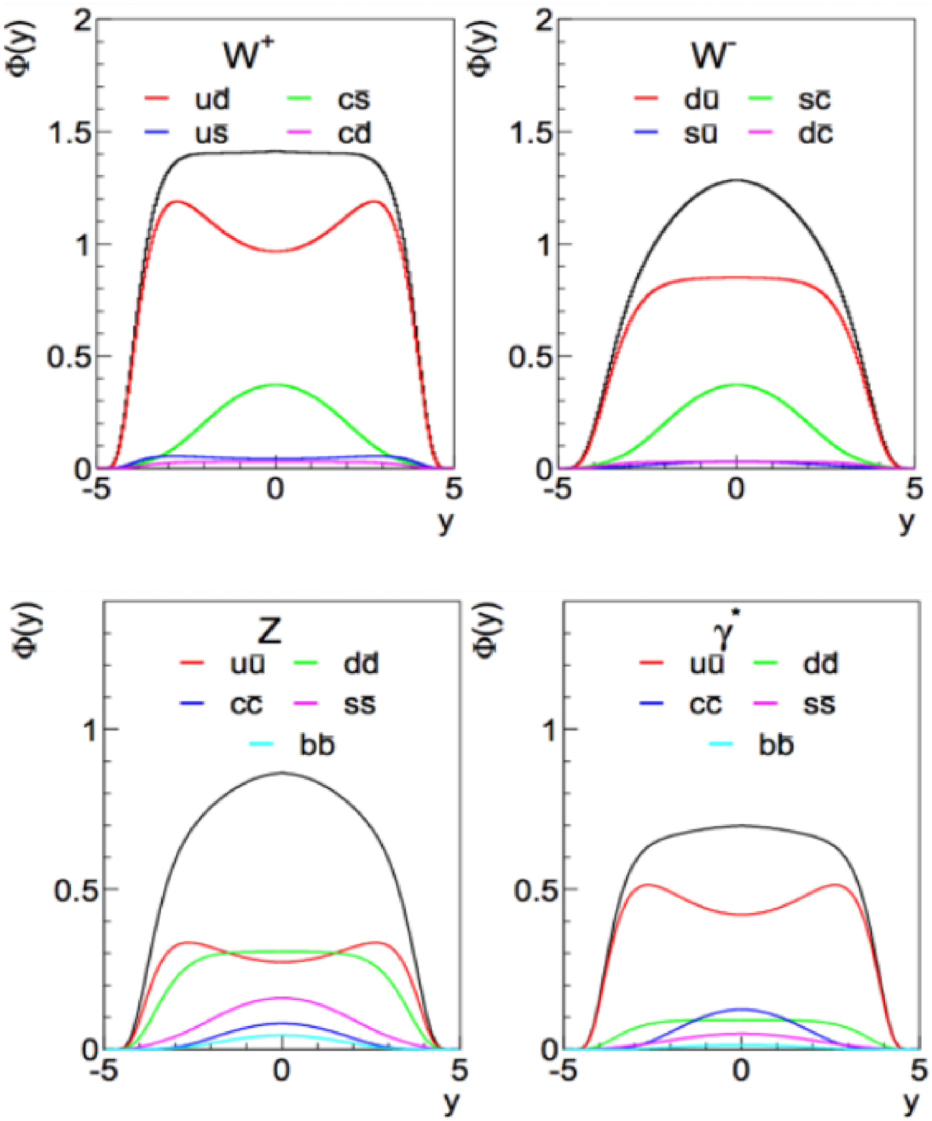
Including LHC measurements into a QCD analysis for PDF determination allows stress testing QCD and the factorisation theorem

Drell-Yan measurements



- W, Z cross sections and asymmetry at 7, 8 and 13 TeV
- W, Z at forward rapidities and the iso-spin asymmetry
- W + charm and the strange PDF
- High mass Drell-Yan and the photon PDF
- Tevatron W, Z data and the d_v PDF

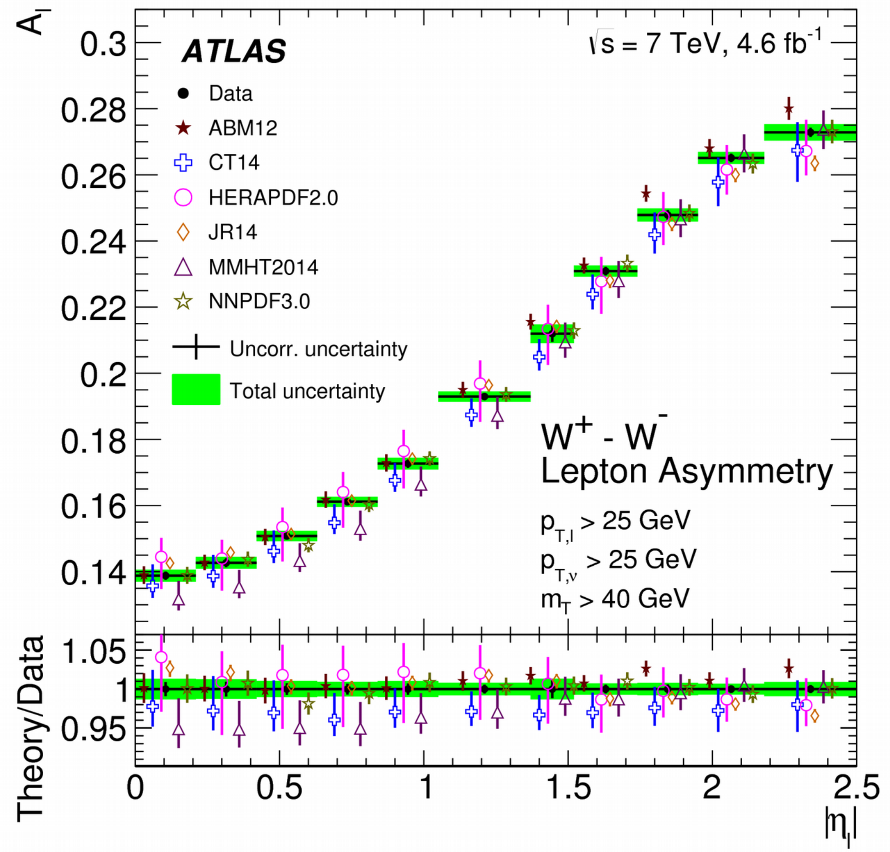
W, Z rapidity cross section measurements

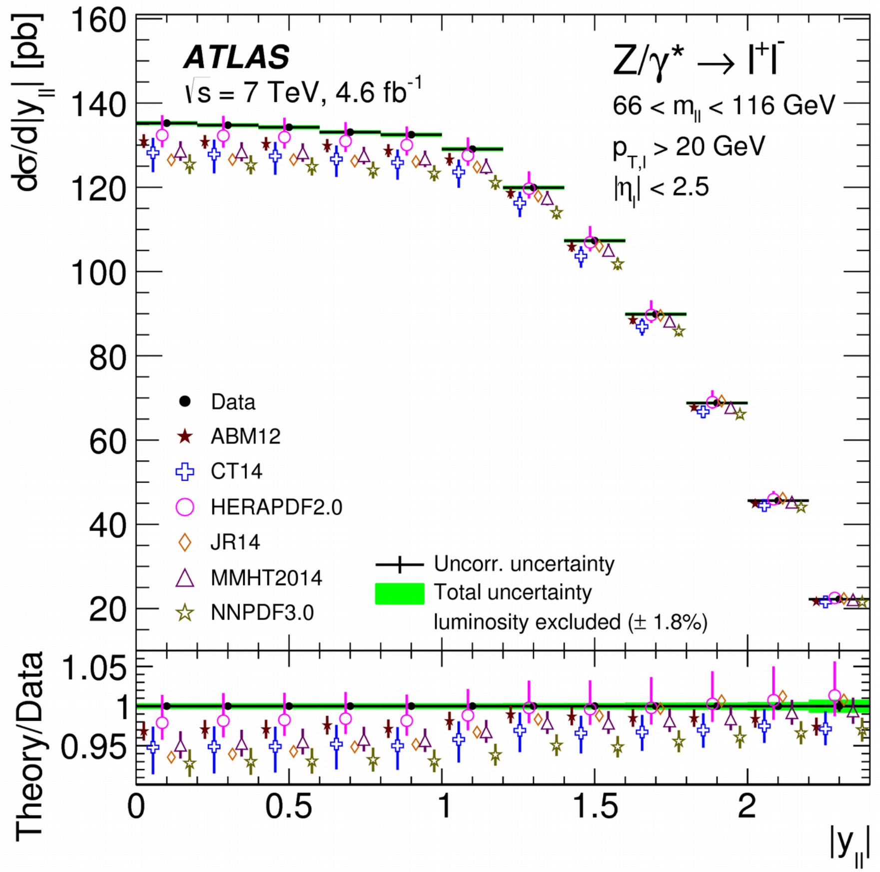


- W, Z, and γ* production in pp collisions probe different combinations of PDFs
- W charge asymmetry measurements provide constraints on the u_v and d_v PDFs
- The shape of the Z rapidity distribution, and the W/Z ratio probes the strange PDF

ATLAS W, Z rapidity measurements

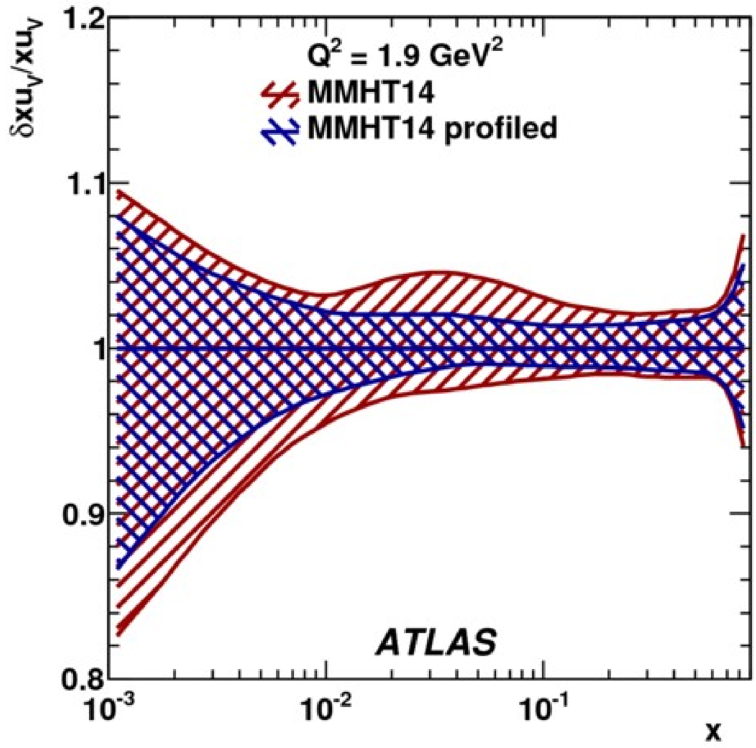
arXiv:1612.03016





- sqrt(s) = 7 TeV, 4.6 fb-1 of integrated luminosity
- Electron and muon channels are combined
- Extremely precise measurement: total uncertainties are at the level of 0.3-1%, excluding the luminosity uncertainty of 1.8%

QCD analysis of ATLAS W,Z rapidity

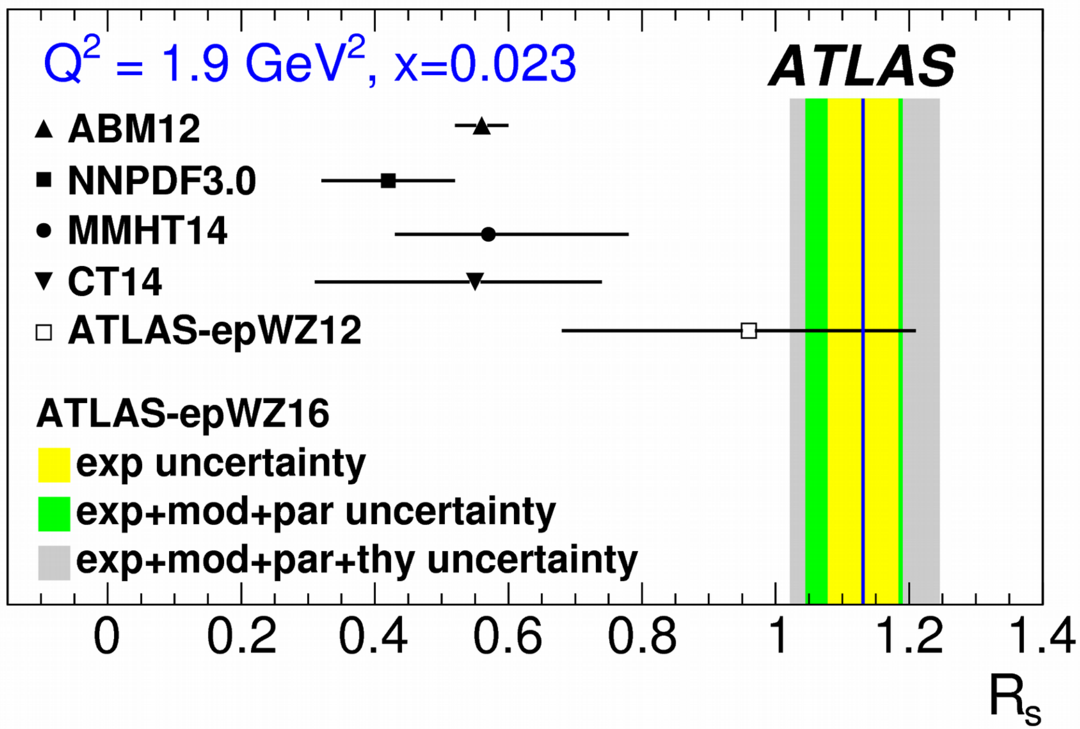


- The measurement is included in a PDF fit, and provides significant constraints on the u valence PDFs

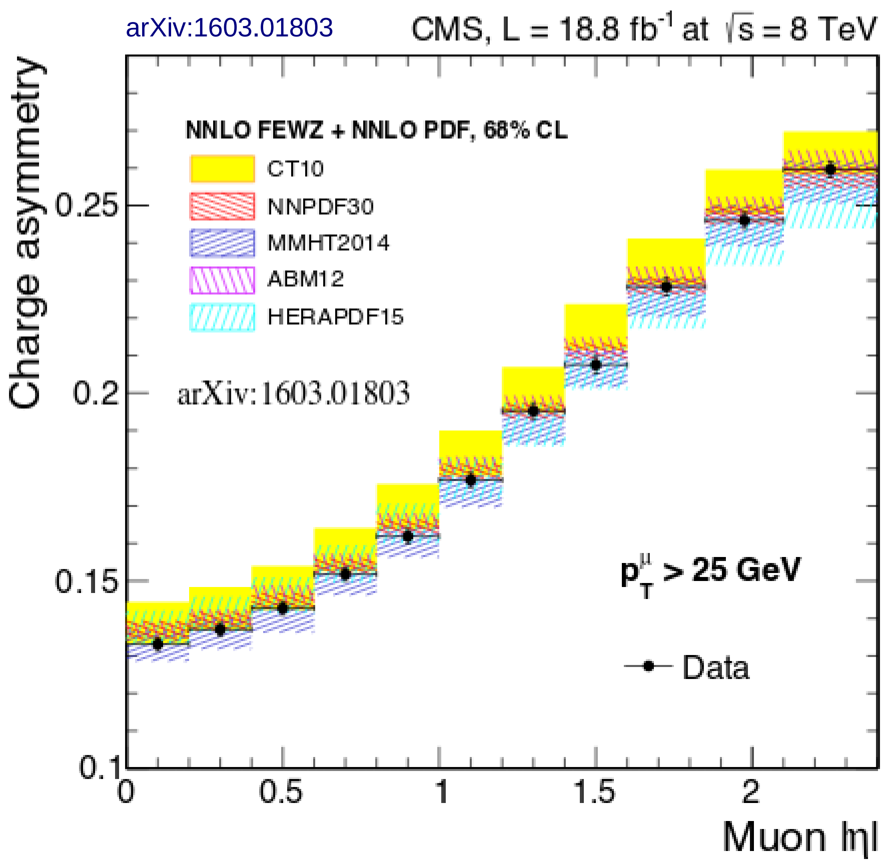
- Strong indication of non-suppressed strangeness

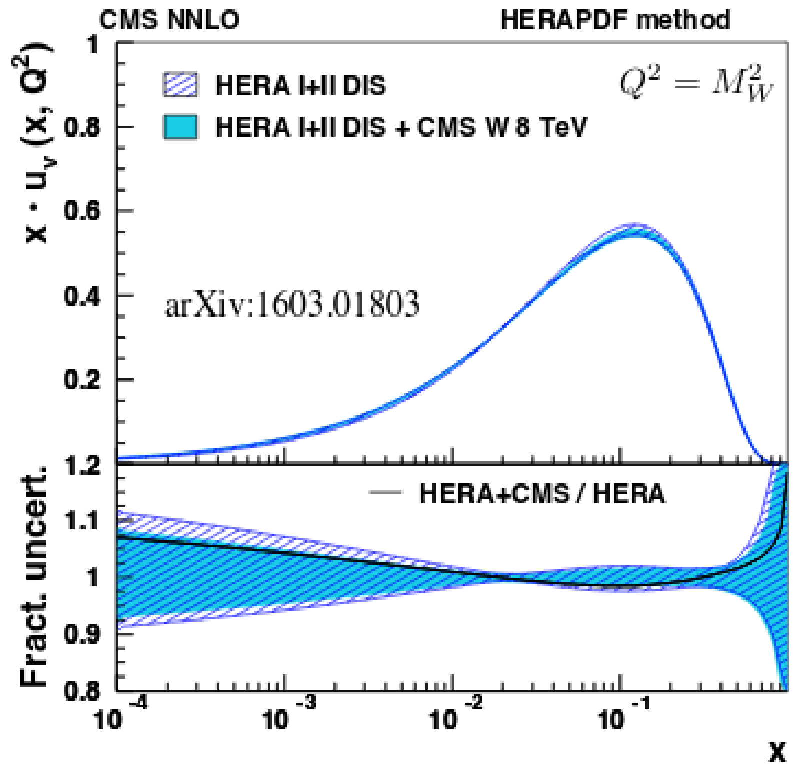
$$R_s = \frac{s+\bar{s}}{\bar{u}+\bar{d}}$$

arXiv:1612.03016



CMS W asymmetry



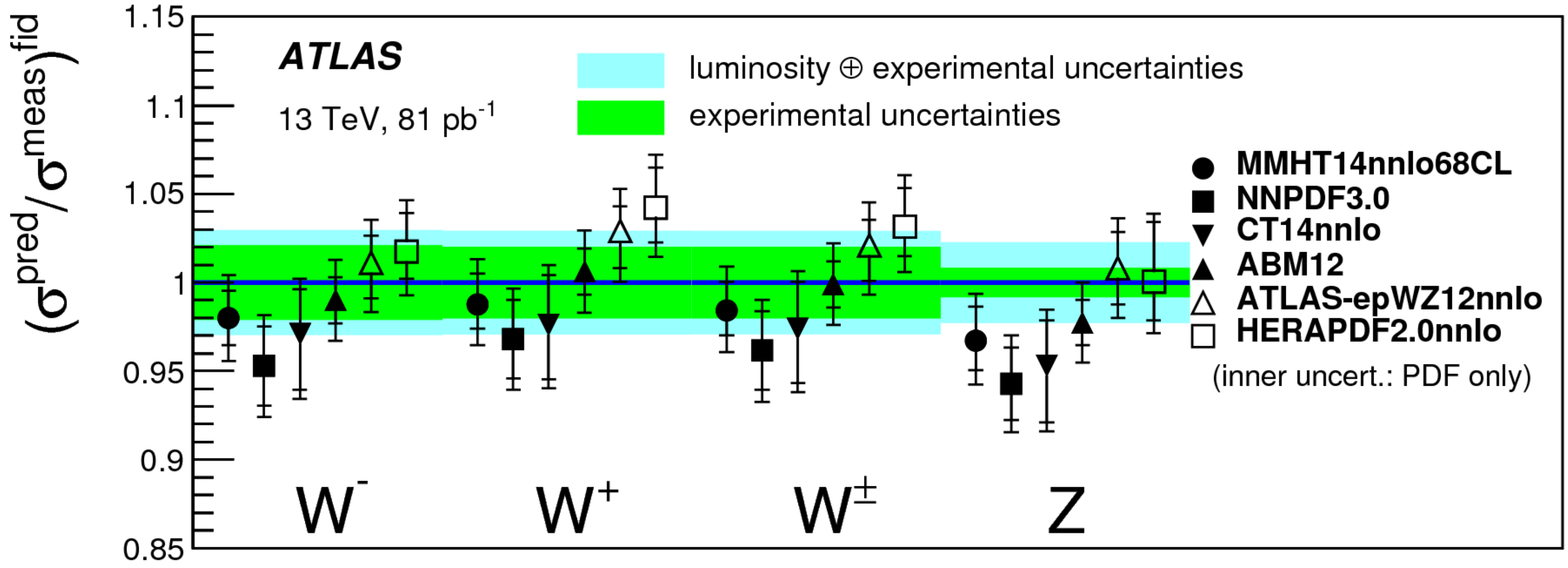


- CMS measurement of muon charge asymmetry in W production at 8 TeV
- The measurement is included in a PDF fit, and provides constraints on the valence PDFs

W and Z production cross section at 13 TeV

- Total W and Z cross sections are compared to various PDF sets

Phys.Lett. B759 (2016) 601



- Provides valuable information for the determination of PDFs

- Uncertainties:

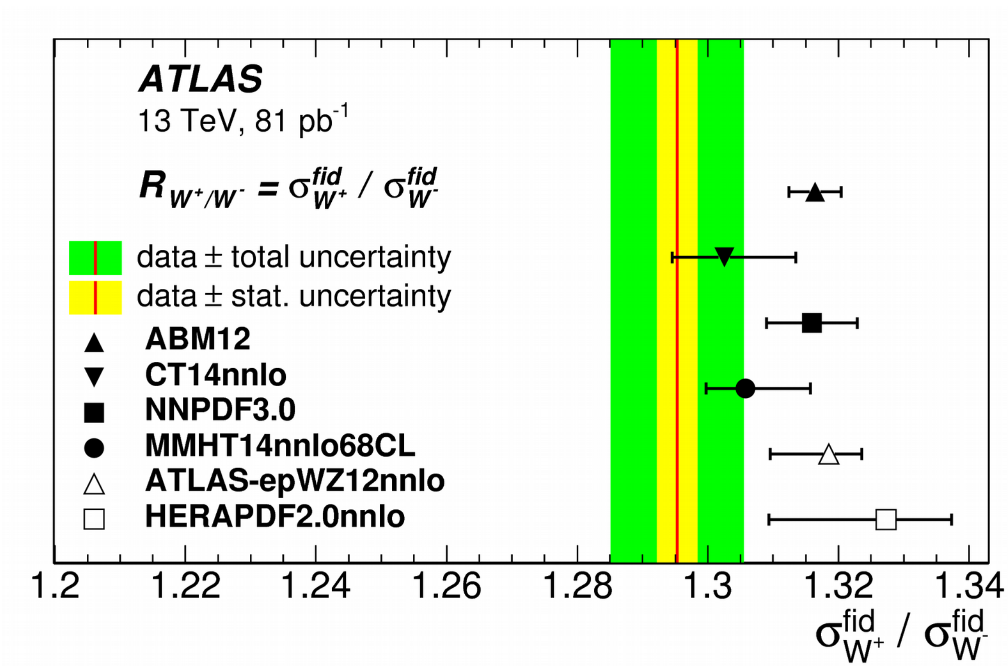
  Luminosity: 2.1%

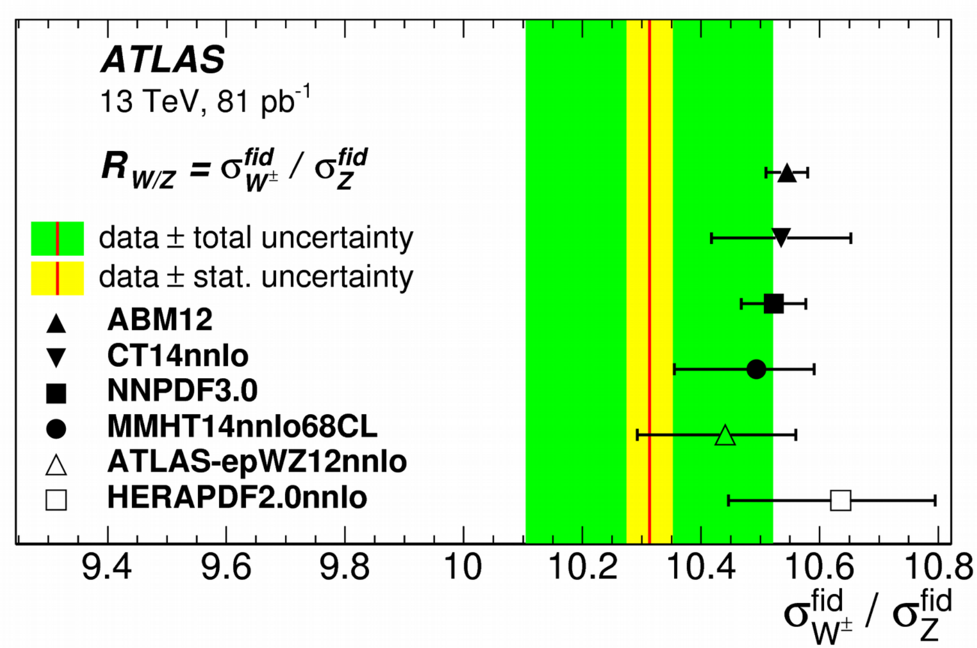
  experimental W: ~2%

  experimental Z: ~1%

W and Z production cross section at 13 TeV

- Ratios of W/Z and W+/W- cross sections are a sensitive probe of PDFs
- Luminosity uncertainty cancels in the ratio



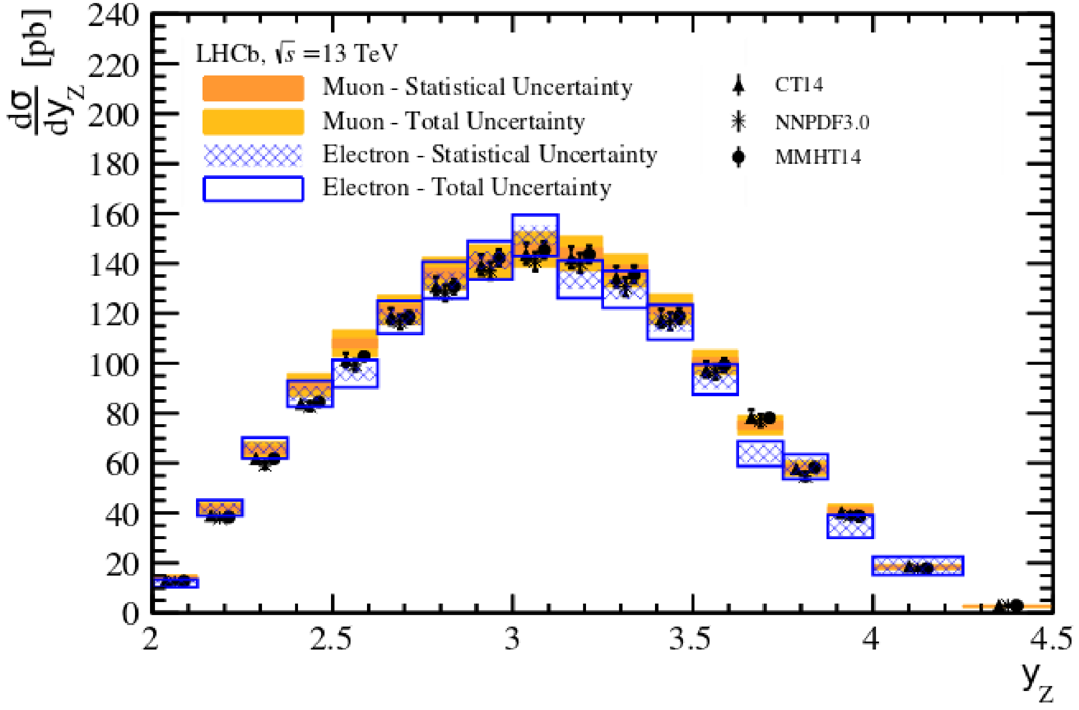


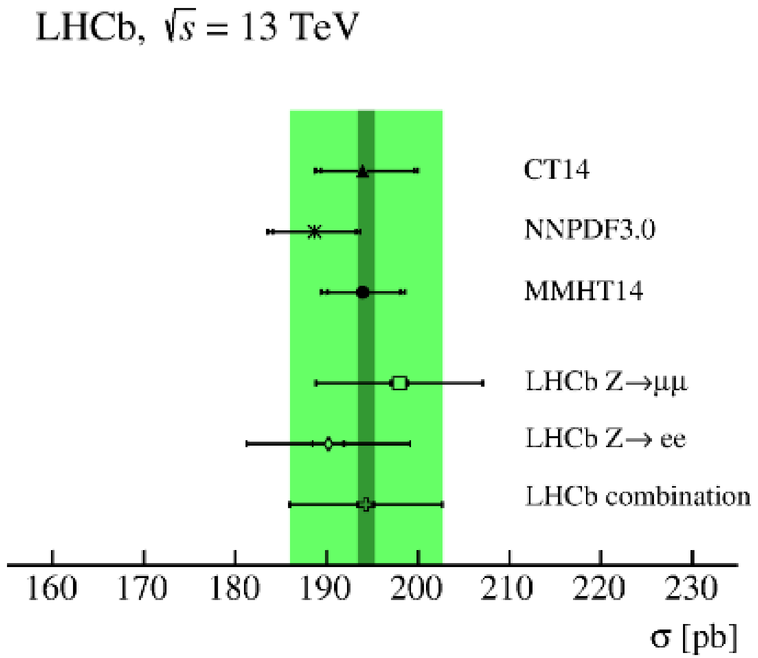
- The W+/W- ratio is sensitive to the uv/dv ratio at low Bjorken-x
- The W/Z ratio is sensitive to the strange PDF

The results show a mild preference for unsuppressed strangeness, that is s/d ~ 1 at low Bjorken-x

Z at forward rapidity

arXiv:1607.06495

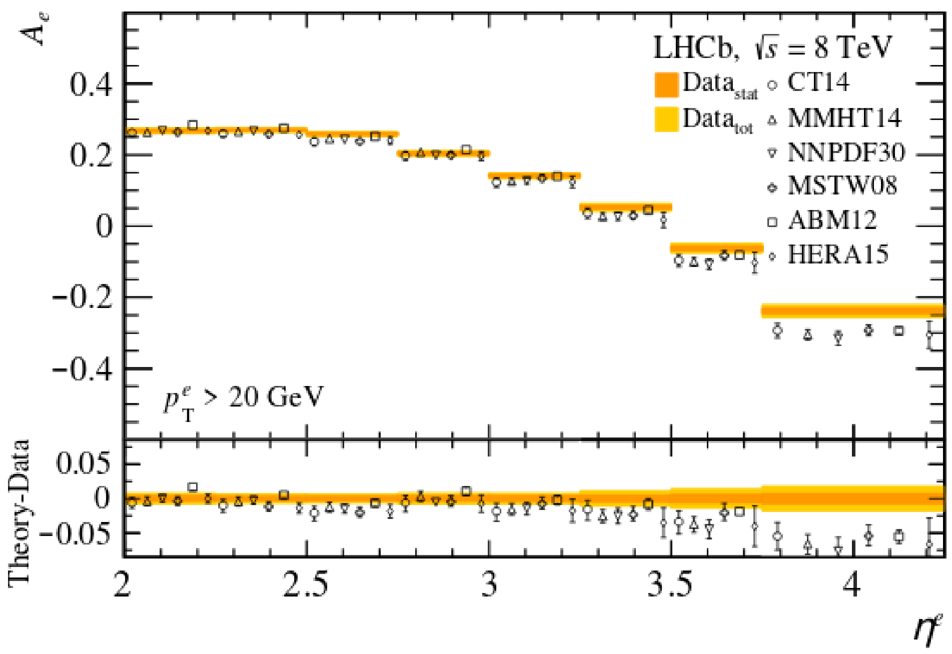




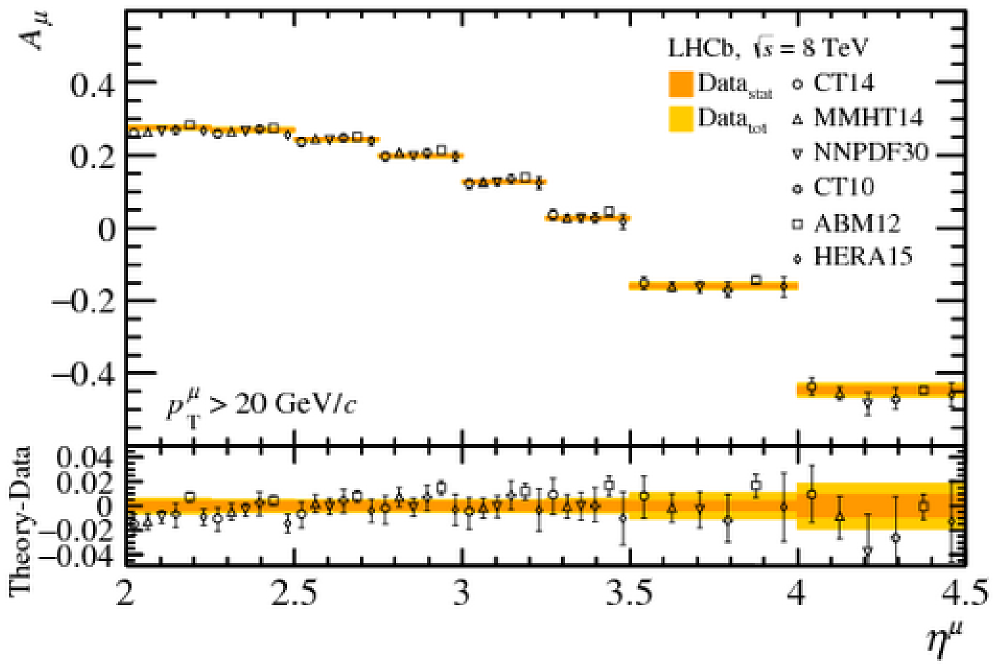
- Measurement in the electron and muon channels
- Large rapidity, close to Z production ymax ~ 5
- Probes PDFs in the high-x and low-x regions

W at forward rapidity

arXiv:1608.01484

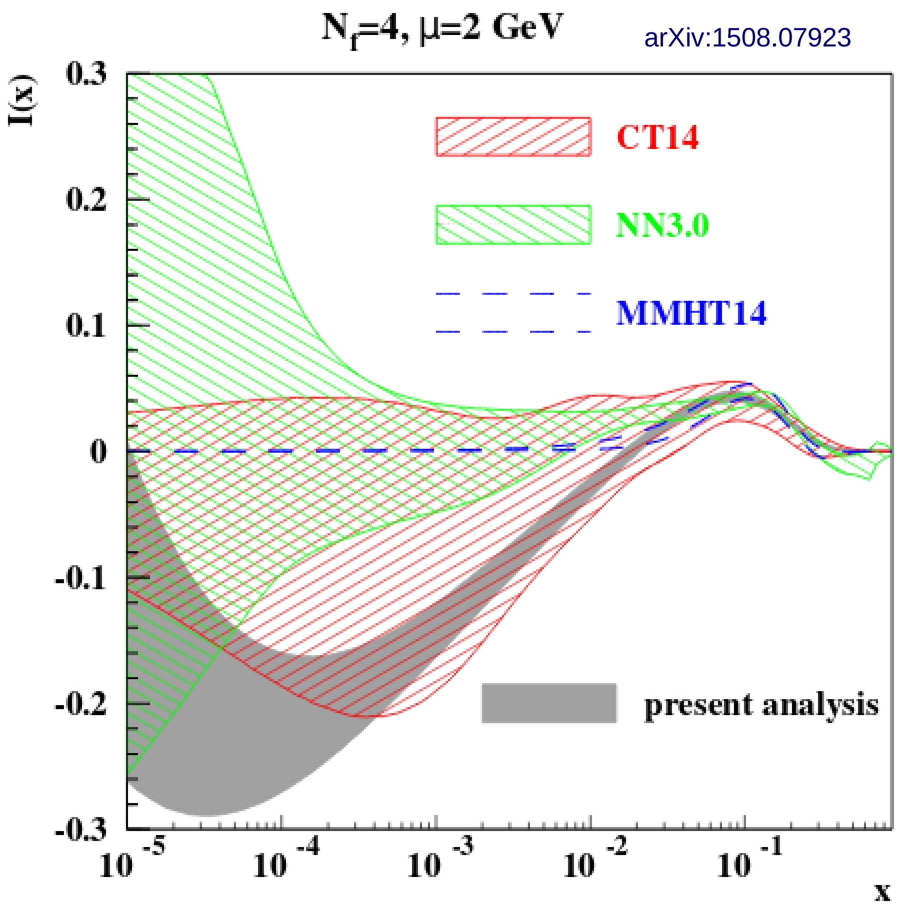


arXiv:1511.08039



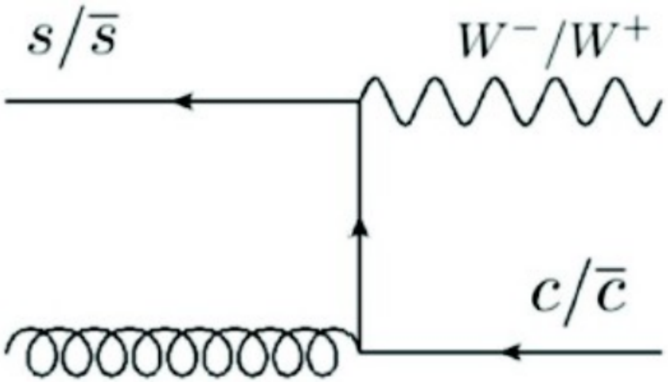
- Measurements of lepton charge asymmetry in the electron and muon channels at 8 TeV
- Allows testing of the iso-spin asymmetry of the sea at low-x $I(x) = x(\bar{d} - \bar{u})$

Iso-spin asymmetry of the sea

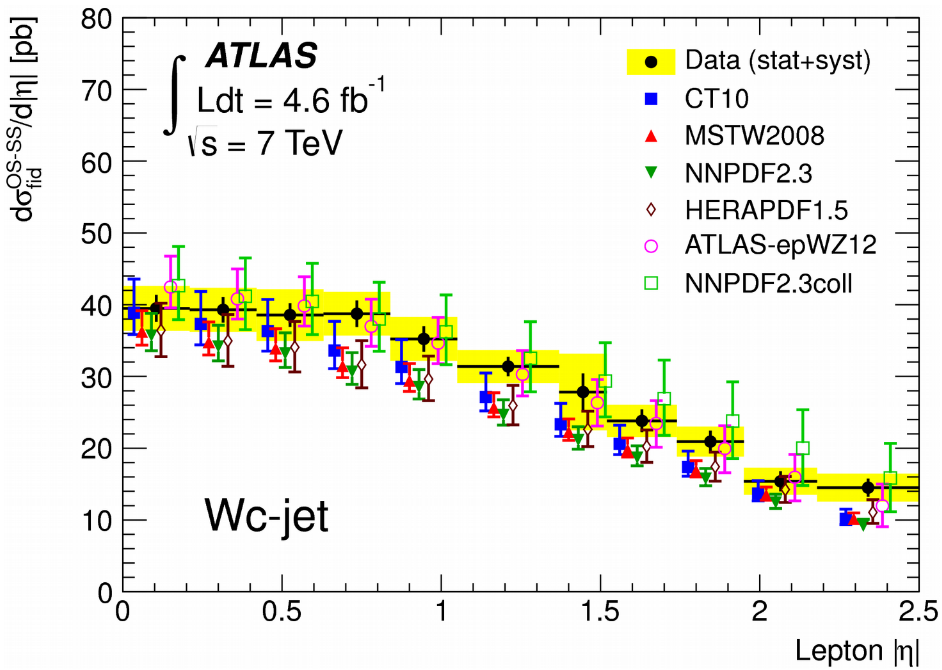


- The inclusion of the LHCb W, Z data in PDF fits shows a preference for negative iso-spin asymmetry $I(x) = x(\bar{d} - \bar{u})$ at low x
- Contraddicts the usual assumption in older PDF sets of $\bar{d} = \bar{u}$ at low x

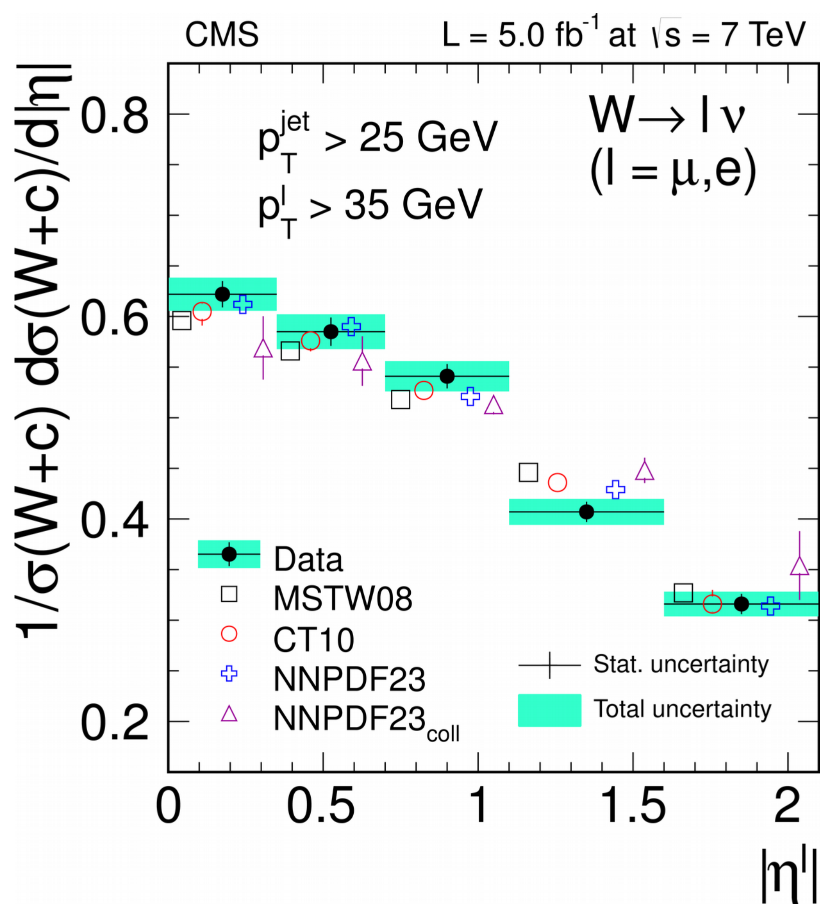
- W + single charm at LO is mainly produced by *gs → W+c*
- Sensitive to the strange PDF
- Exploit charge correlation to distinguish between *W + c* and *W + (g → c$\bar{c}$)*



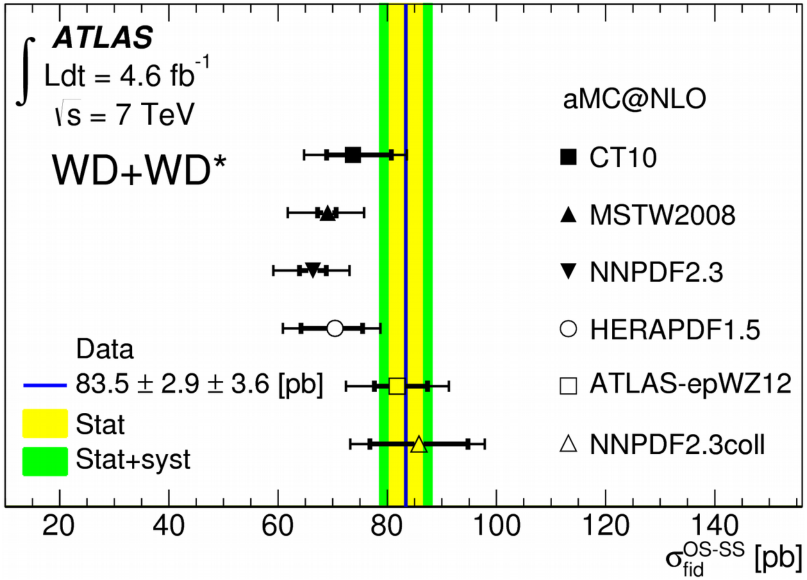
arXiv:1402.6263



arXiv:1310.1138

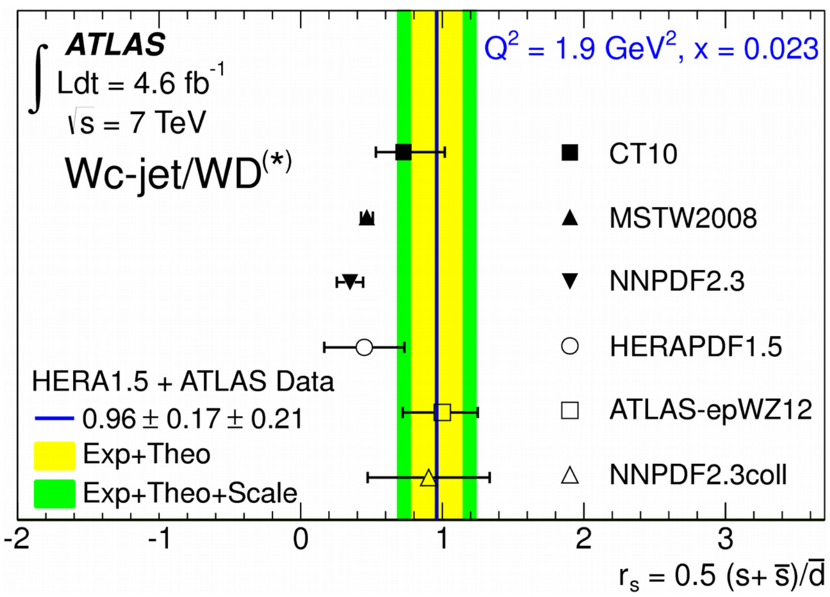


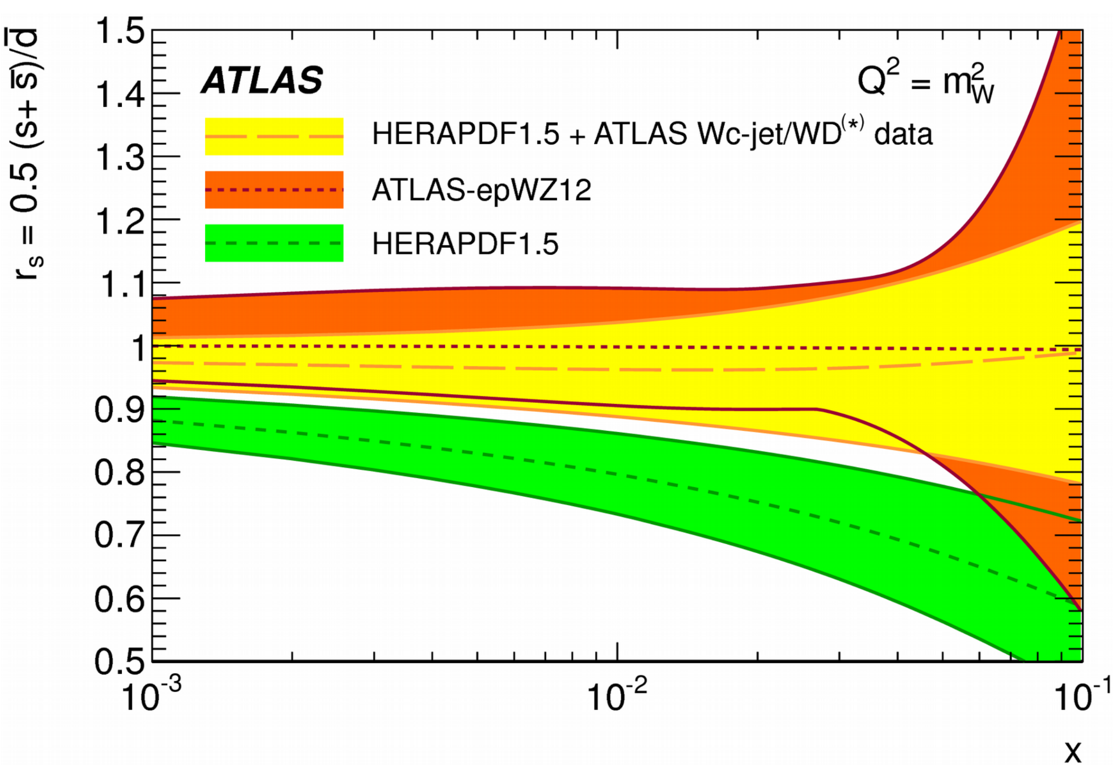
W+charm ATLAS



- ATLAS measurement of W+charm cross section is in agreement with predictions using ATLAS-epWZ12 and NNPDF2.3coll, which have enhanced strangeness
- When the W+charm data is included in a PDF fit, it yields rs = 0.96 ± 0.27

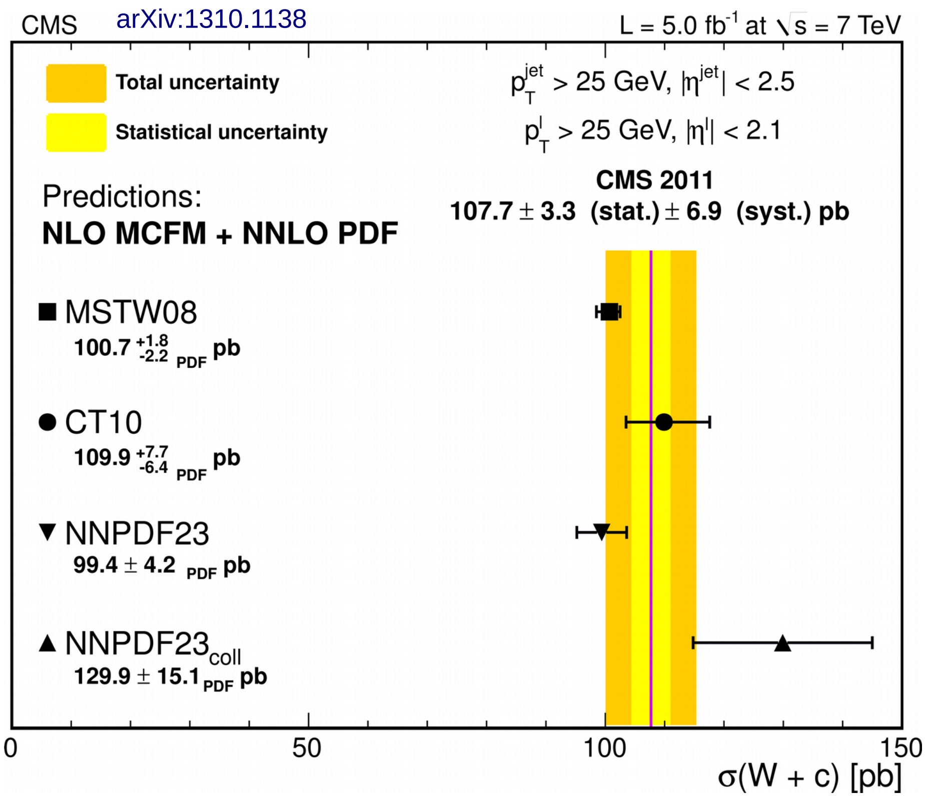
arXiv:1402.6263



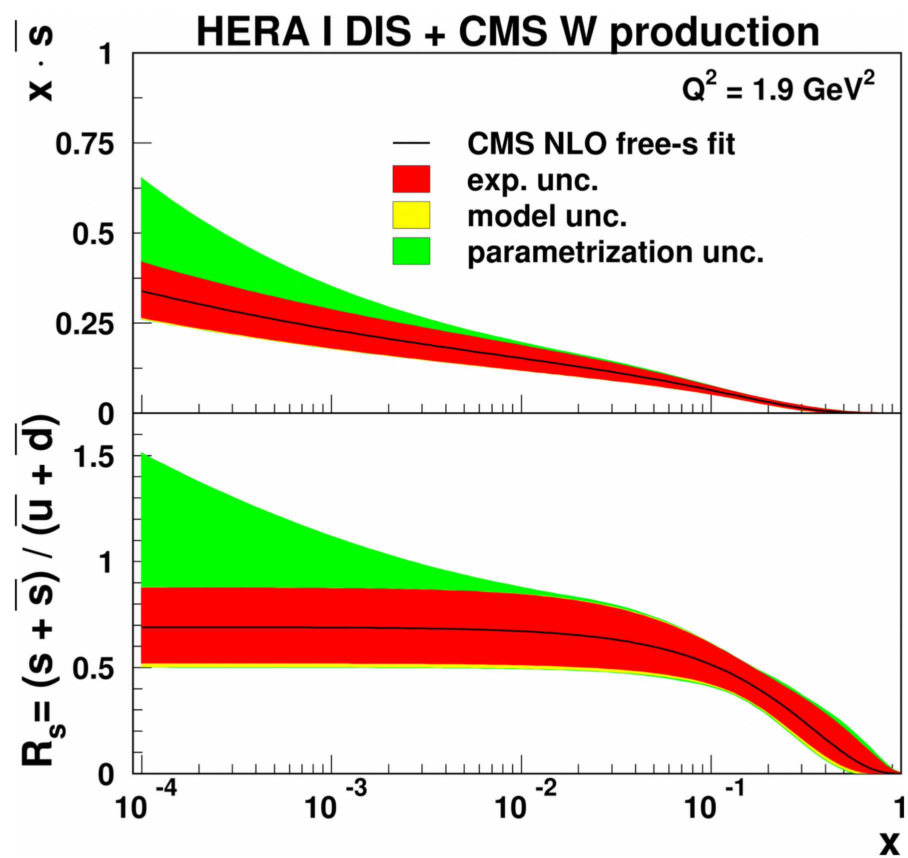


W+charm

- CMS measurement of W+charm cross section is in agreement with CT10, which is in between suppressed and enhanced strangeness
- A PDF fit including this data yields Rs ~ 0.7

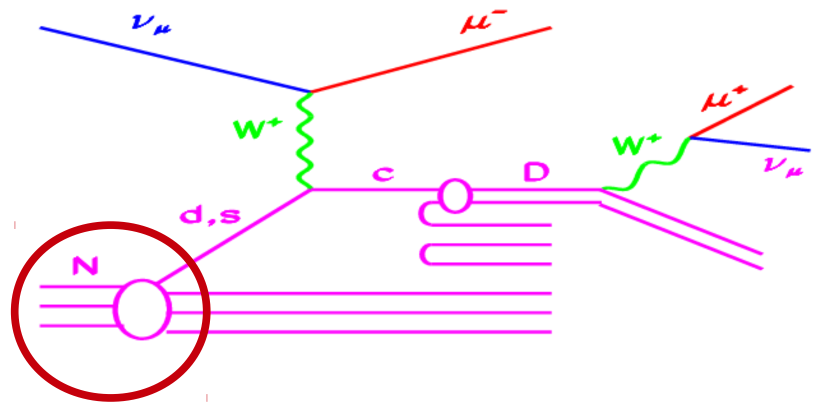


arXiv:1312.6283

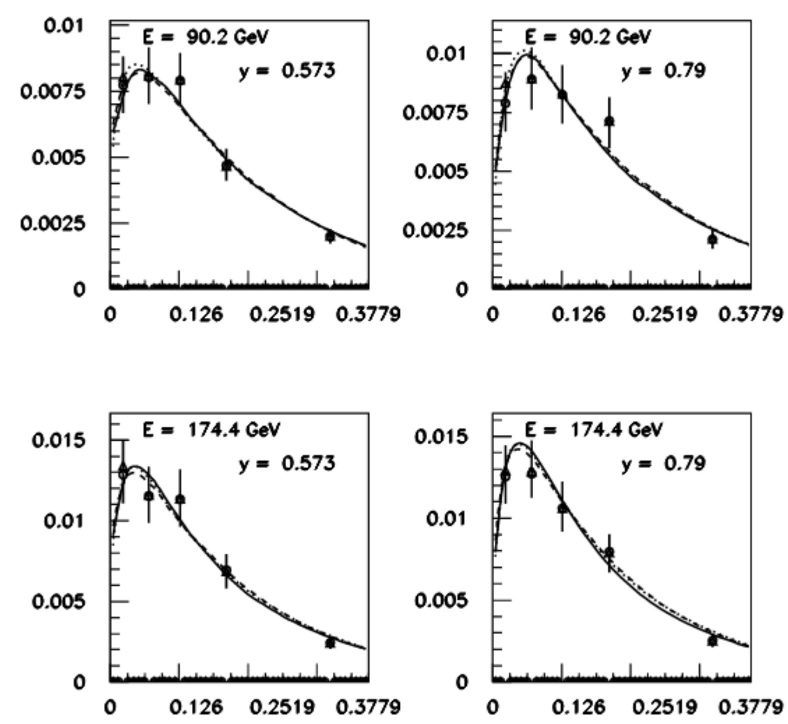


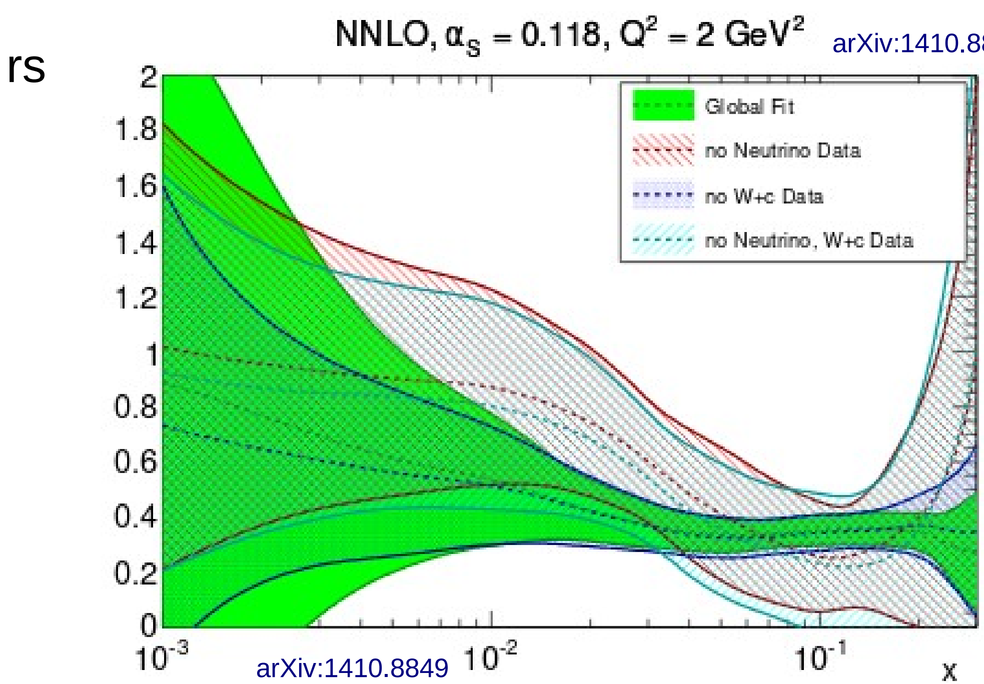
Suppressed strangeness

- Why most PDFs predict suppressed strangeness?
- The neutrino data prefers rs ~ 0.5
- However the determination of the strange PDF from neutrino data relies on nuclear corrections, which does not affect W+c and Drell-Yan measurements in hadron collisions



arXiv:hep-ex/0102049





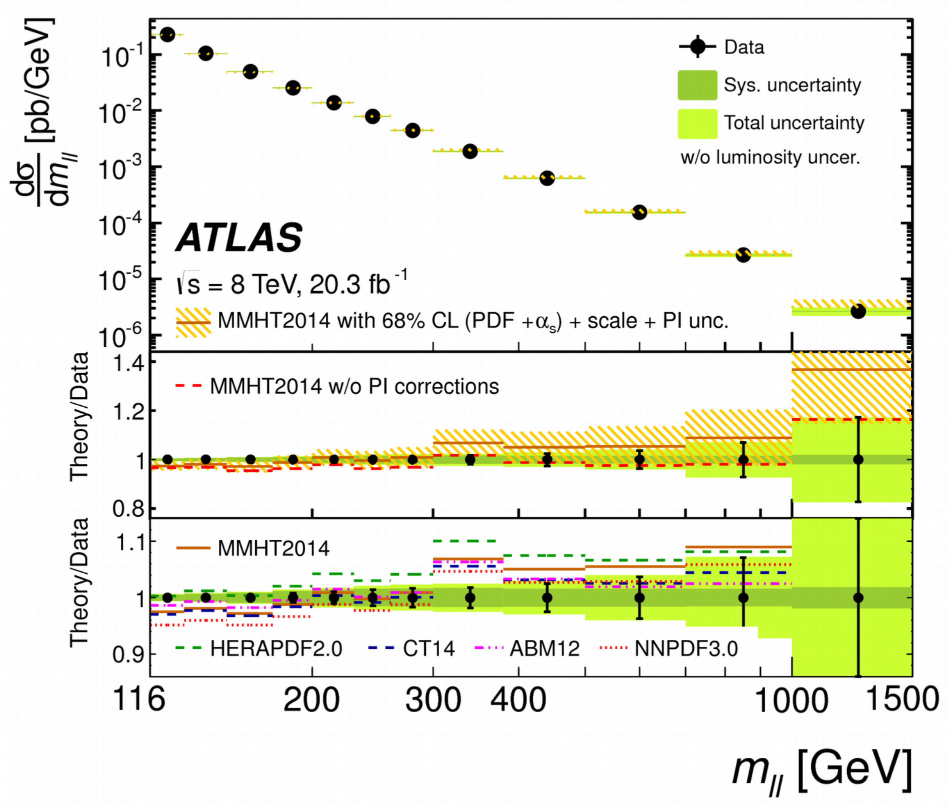
arXiv:1410.8849

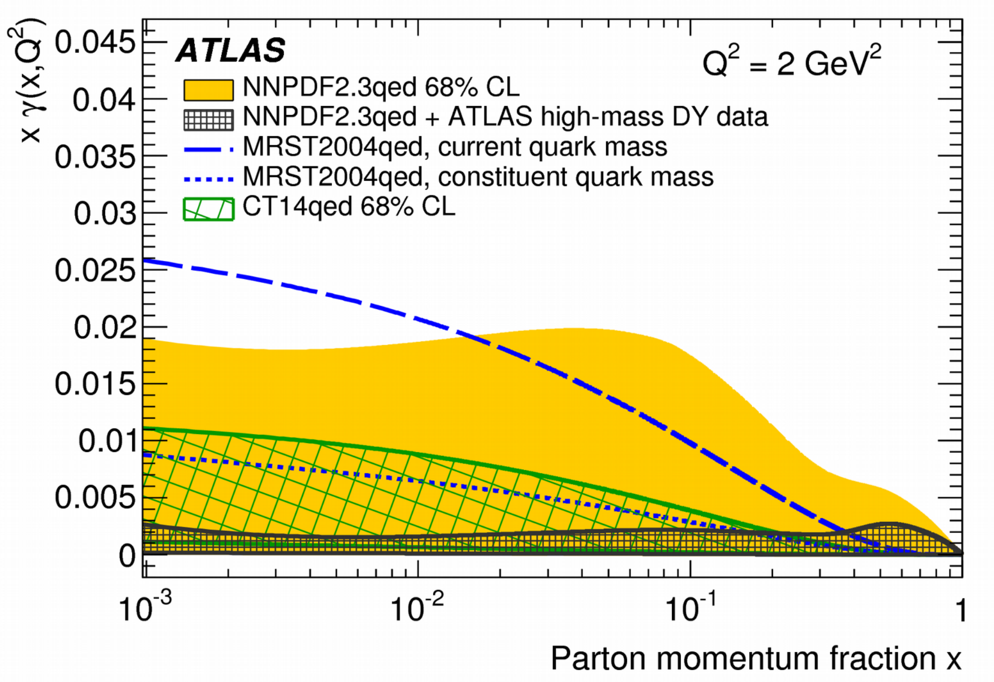
arXiv:1410.8849

High mass DY at 8 TeV

- Measurement in the electron and muon channels, experimental uncertainty at the level of 1% at low m_{ll} (plus 1.9% luminosity)
- Sensitive to photon induced $\gamma\gamma \rightarrow ll$ process, allows probing the photon PDF

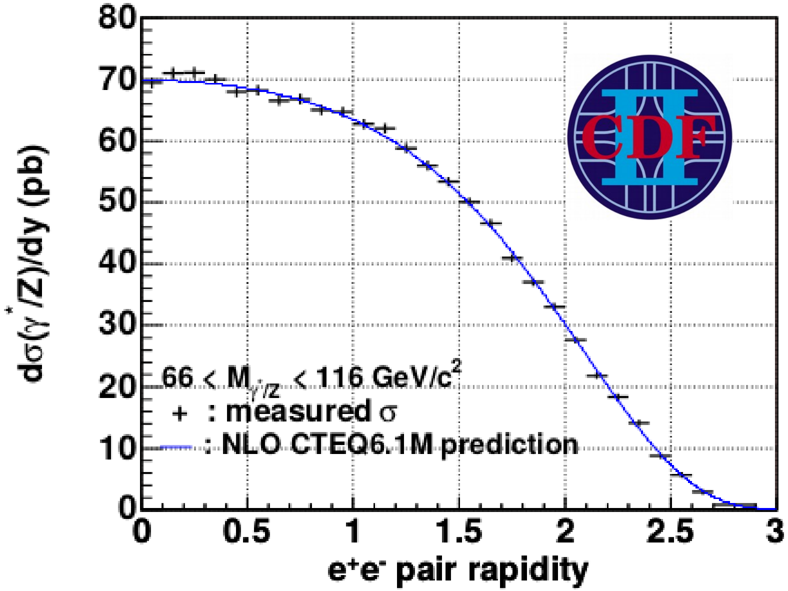
arXiv:1606.01736



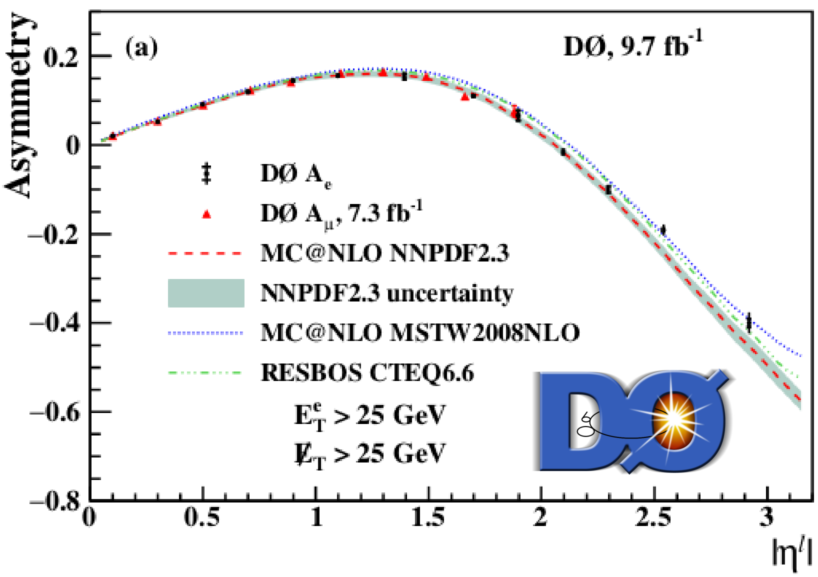


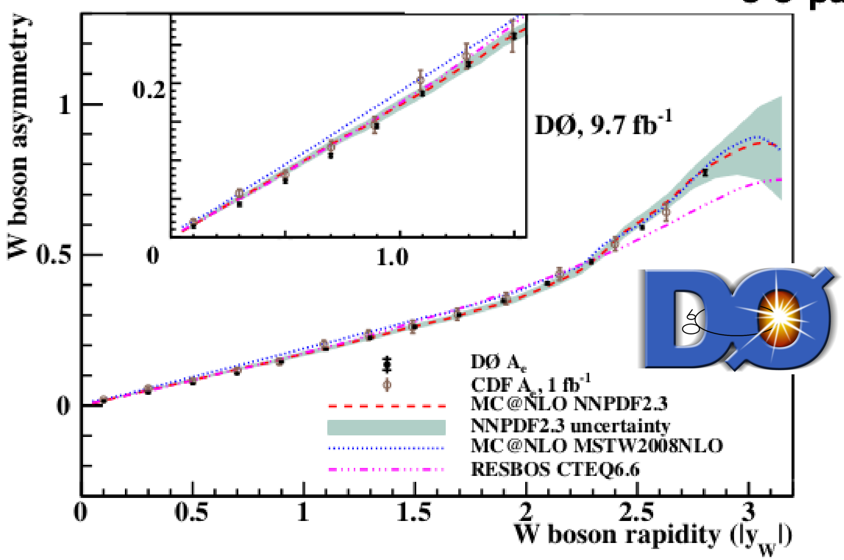
Tevatron W and Z data sets

- 3 types of observables
  - Z dσ/dy (CDF and D0)
  - Lepton charge asymmetry in W → l,ν (D0)
  - W charge asymmetry (CDF and D0)



Fast theory predictions calculated
with MCFM+APPLGRID



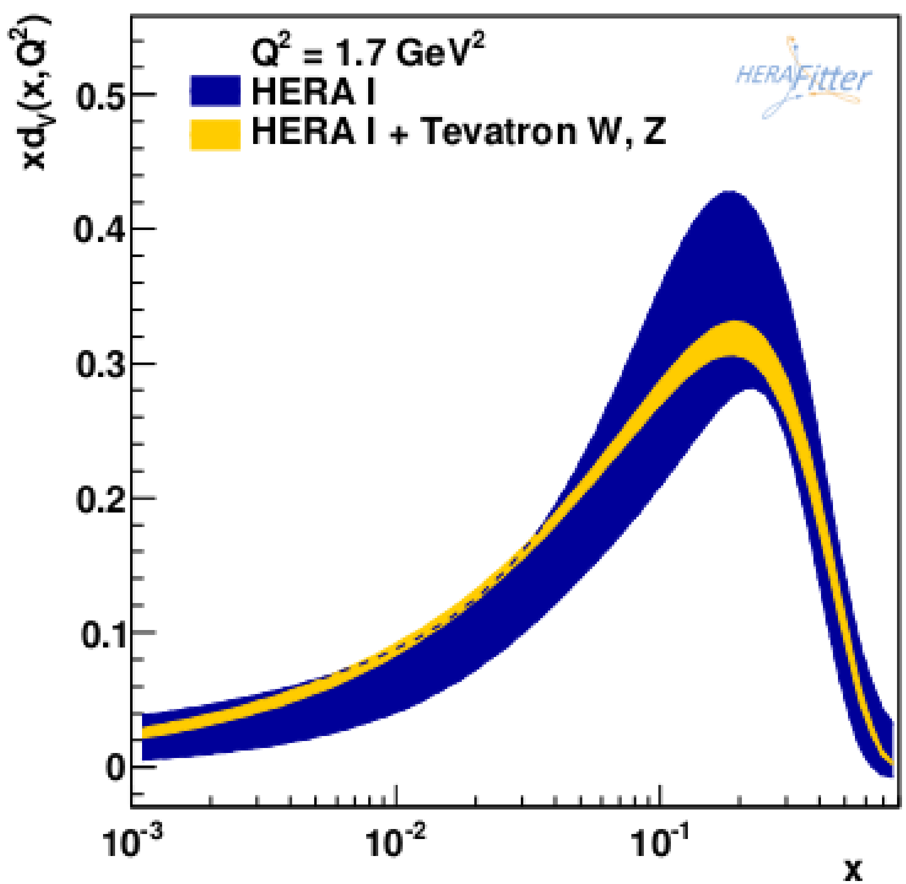


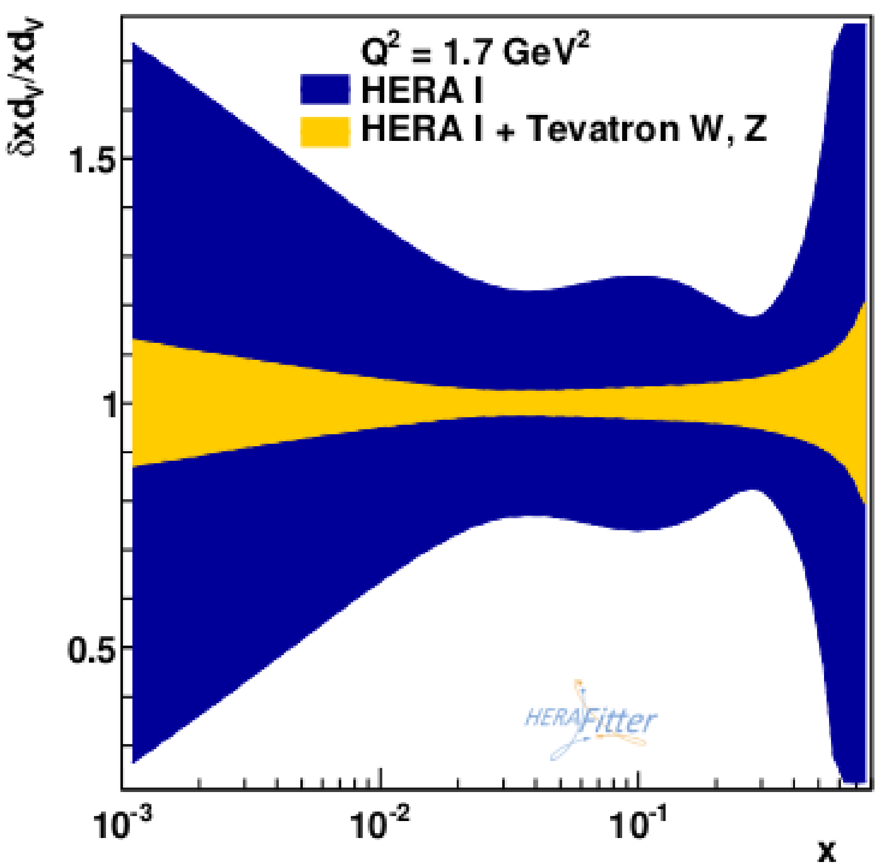
- Revised correlation model: uncertainties of data-driven corrections are treated as bin-to-bin uncorrelated (lepton ID, trigger, and charge efficiencies)
- Reasonable assumption: these corrections are influenced by stat noise

Impact on d-quark valence PDF

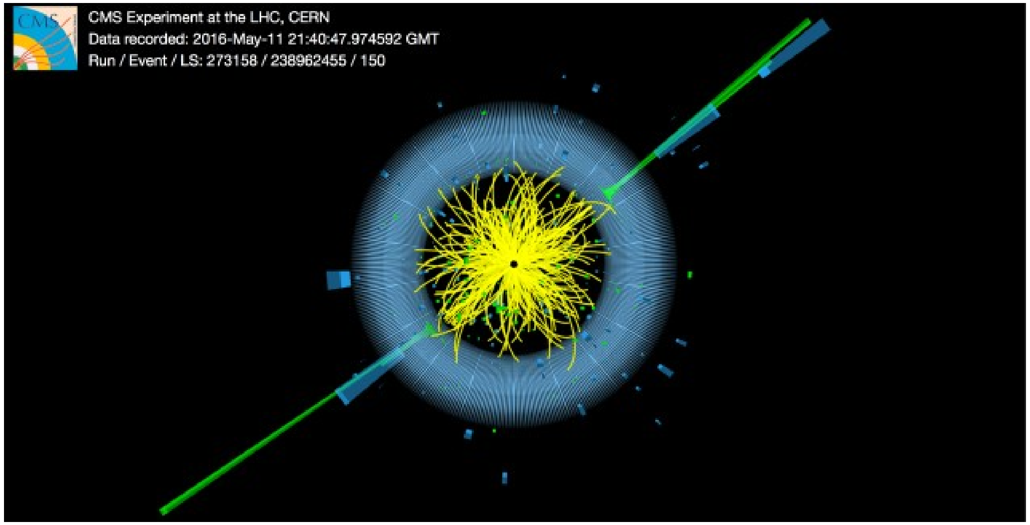
- The impact of the Tevatron W, Z data is assessed by comparing PDFs extracted from a fit to only HERA I data
- Observed large impact on d-quark valence PDF, mainly driven by the measurements of W charge asymmetry

arXiv:1503.05221



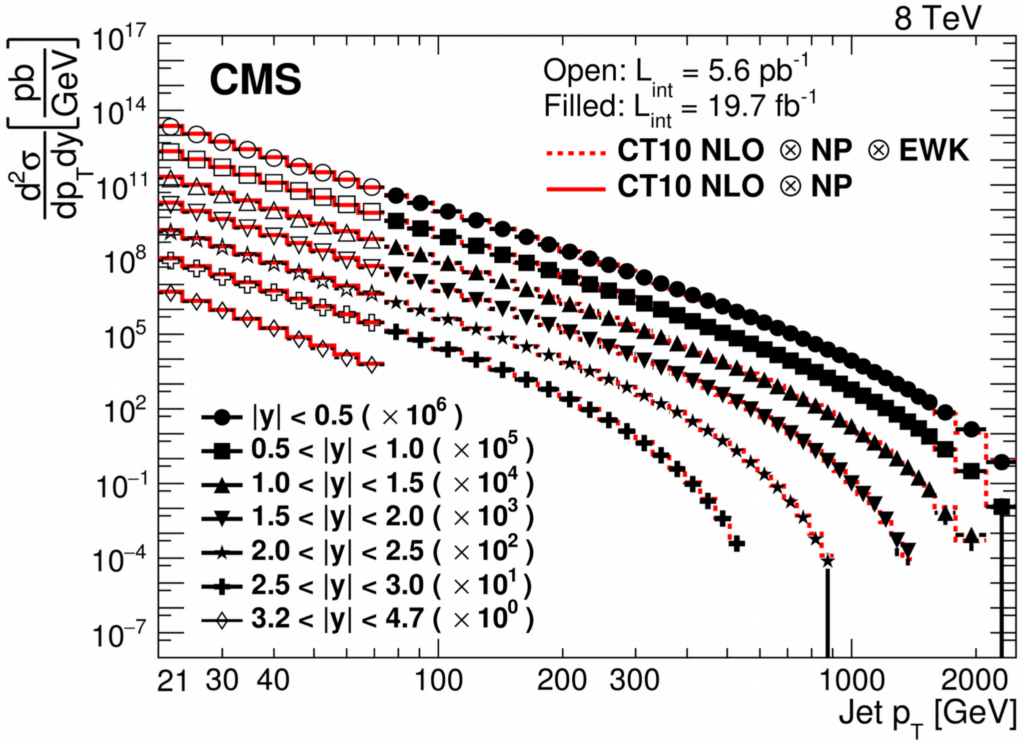


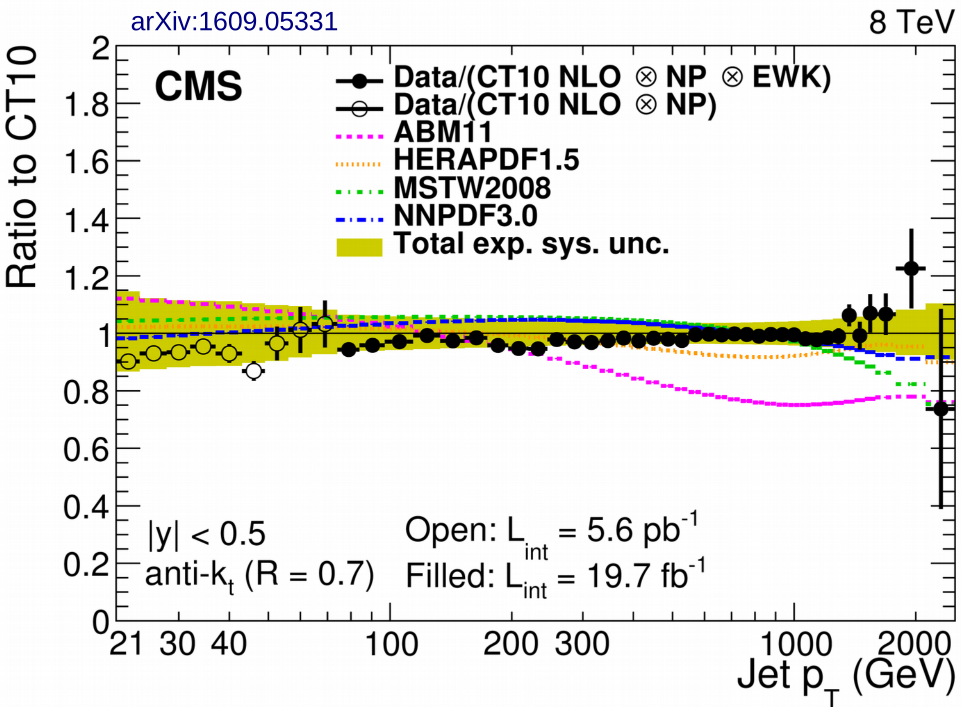
Inclusive jet production

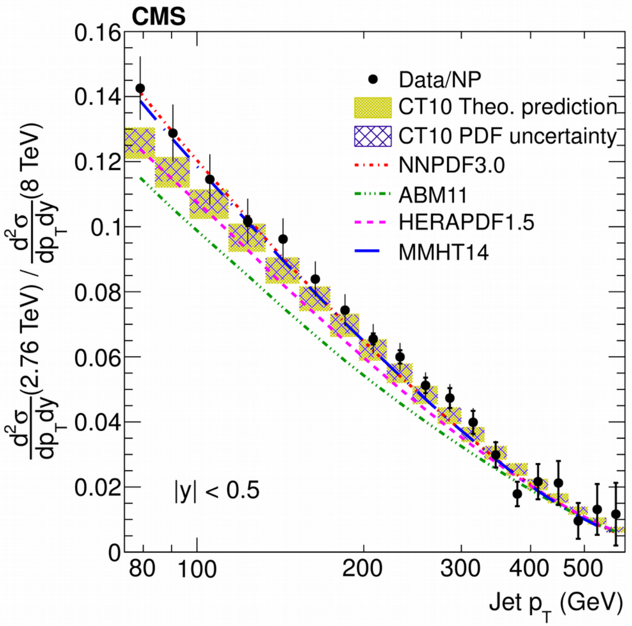


- CMS 2.76, 7 and 8 TeV jets
- ATLAS 2.76 and 7 TeV jets
- ATLAS 7 and 8 TeV prompt photon

CMS inclusive jet production at 2.76, 7 and 8 TeV

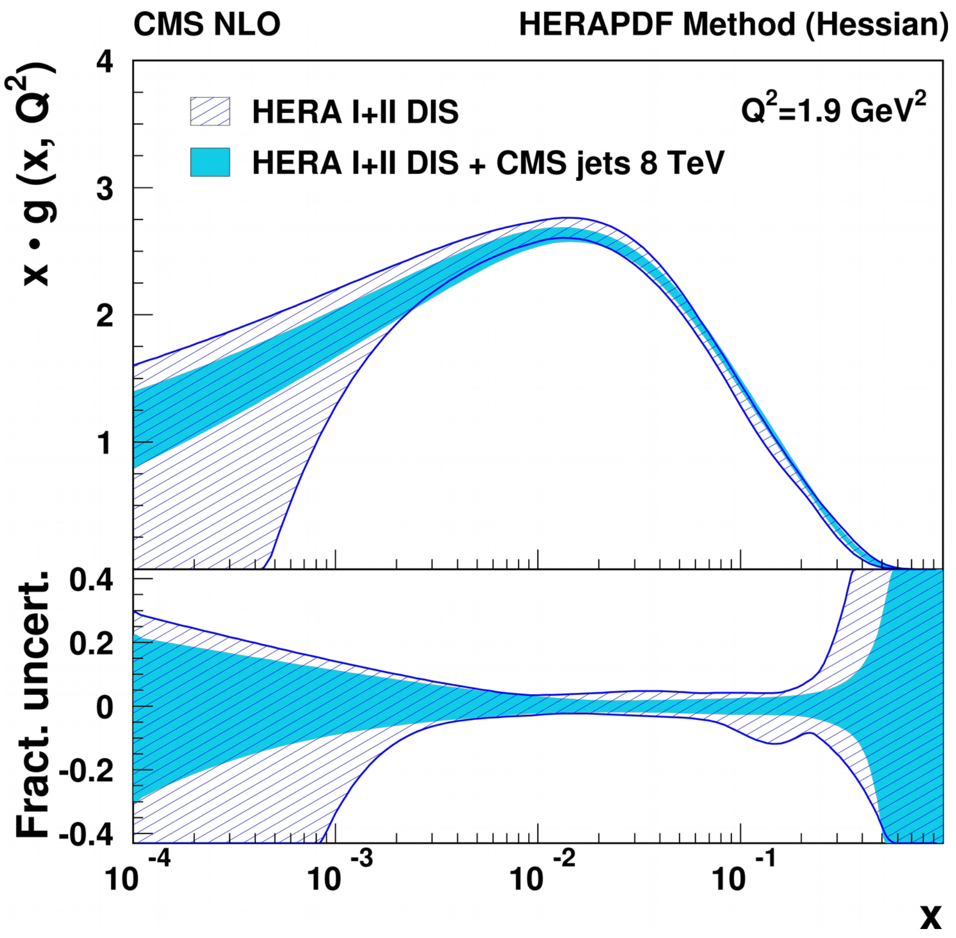




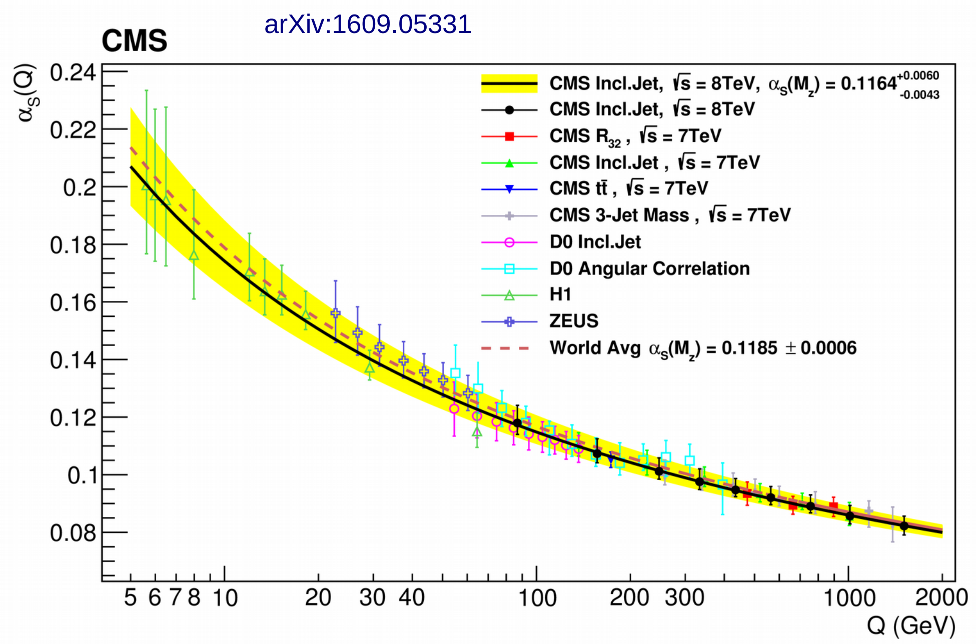


- The measurement is sensitive to the gluon PDF
- ABM11 prediction strongly excluded
- Ratio of cross sections at 8 TeV and 2.76 TeV are also sensitive to PDFs

CMS inclusive jets



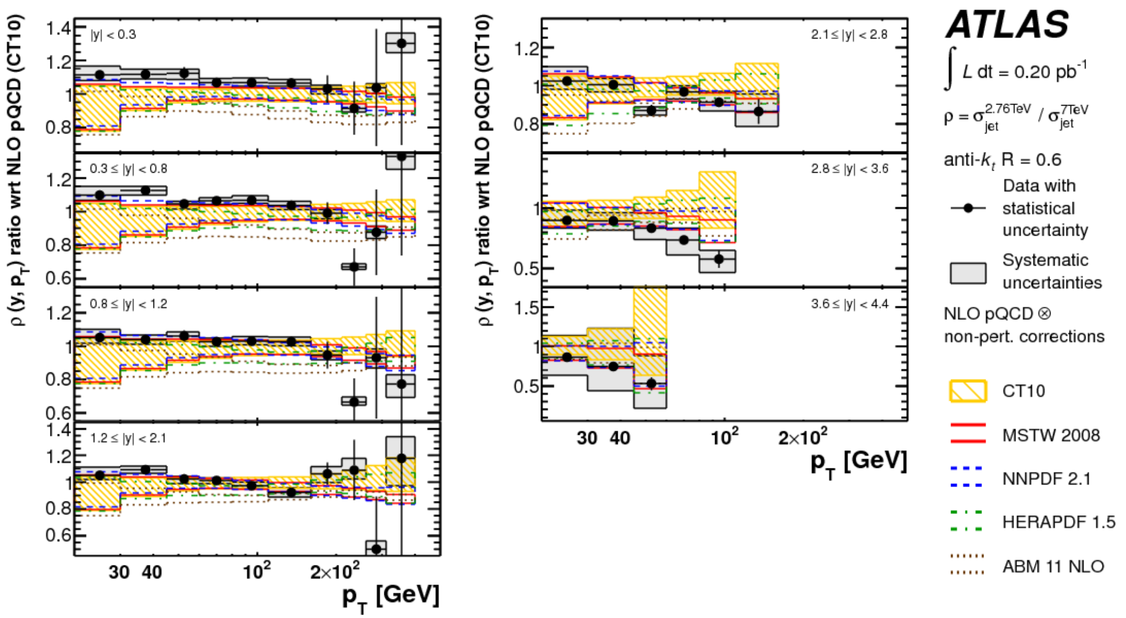
- Strong reduction of the gluon PDF uncertainty, especially at high-x

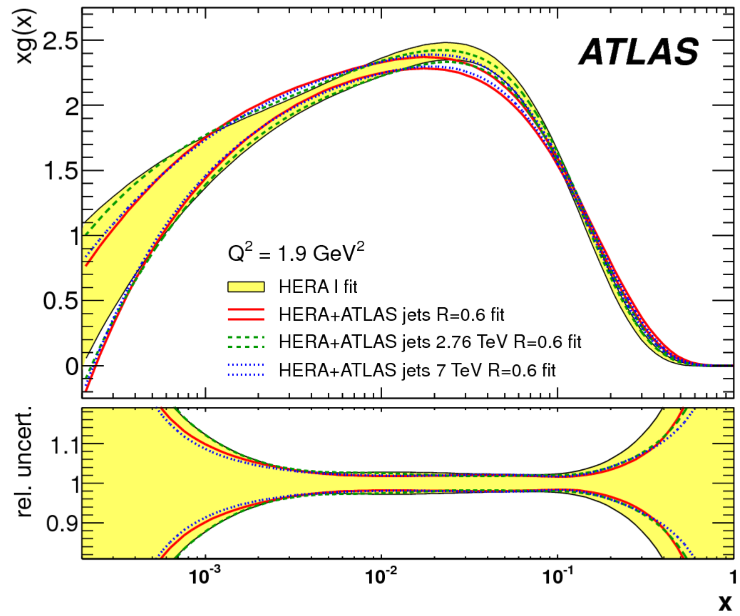


- The measurement is used to determine $\alpha_s(m_Z)$, and to probe its running up to 1.5 TeV

ATLAS inclusive jet production at 2.76 and 7 TeV

arXiv:1304.4739

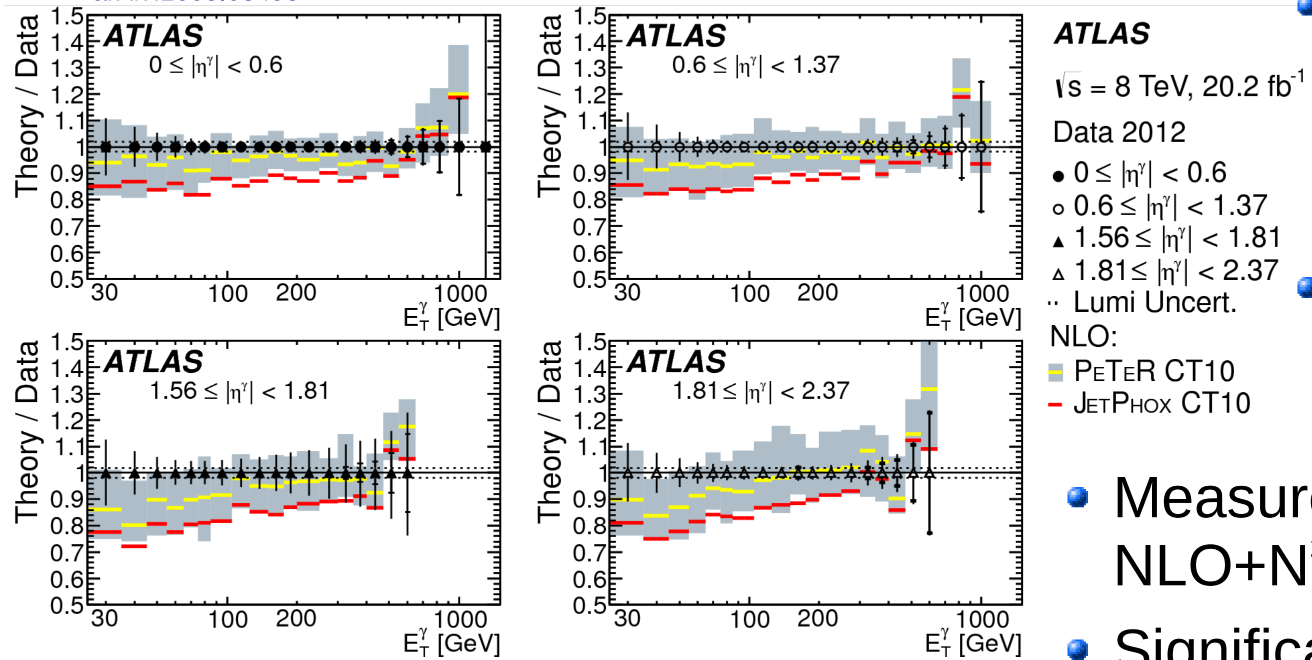




- Previous ATLAS analysis also shows an improvement in the gluon PDF
- This analysis shows a slightly different trend at high-x, with a harder gluon PDF in mild tension with the determination from DIS data

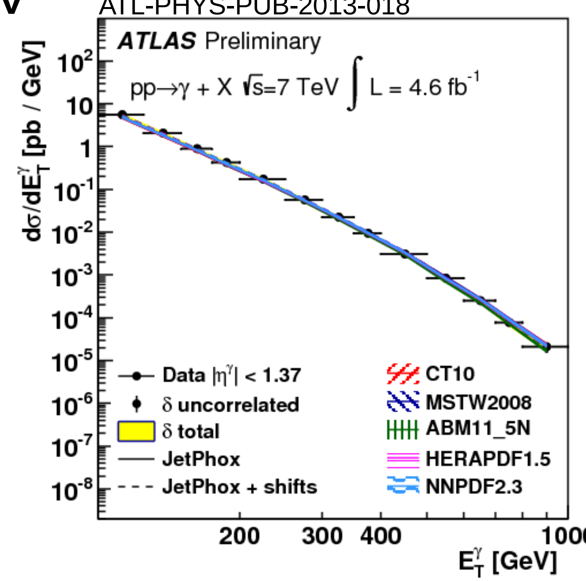
Prompt photon production

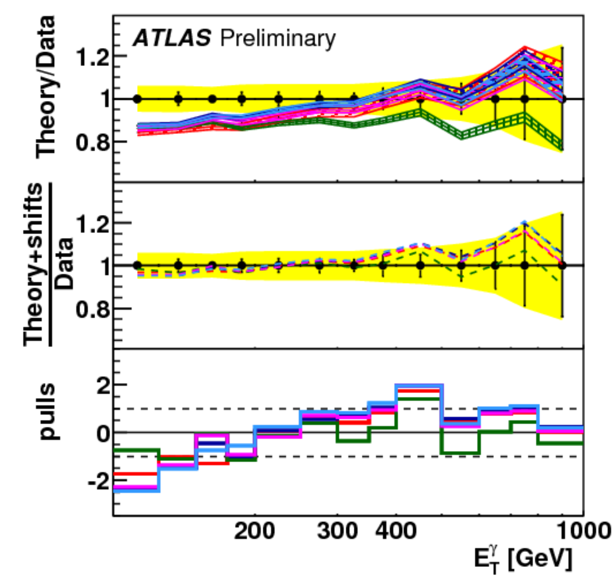
arXiv:1605.03495



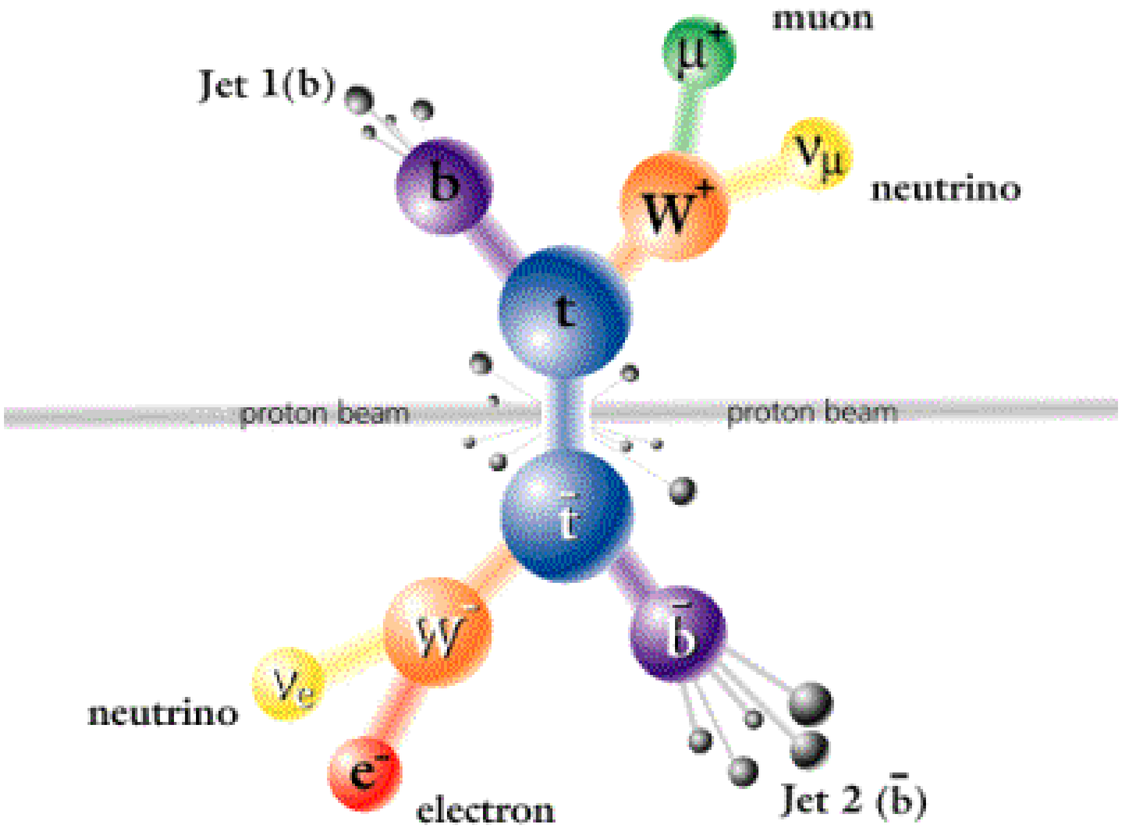
- Measurement of isolated photons at 8 TeV, sensitive to the gluon PDF in the medium-x region
- Could reduce PDFs uncertainty of Higgs cross section predictions
- Measurement well described by NLO+N^{3}LL (PeTeR)
- Significant fragmentation corrections at low- and medium-ET
- Sensistivity study with 7 TeV measurement shows potential of the data to discriminate between different PDF sets

ATL-PHYS-PUB-2013-018



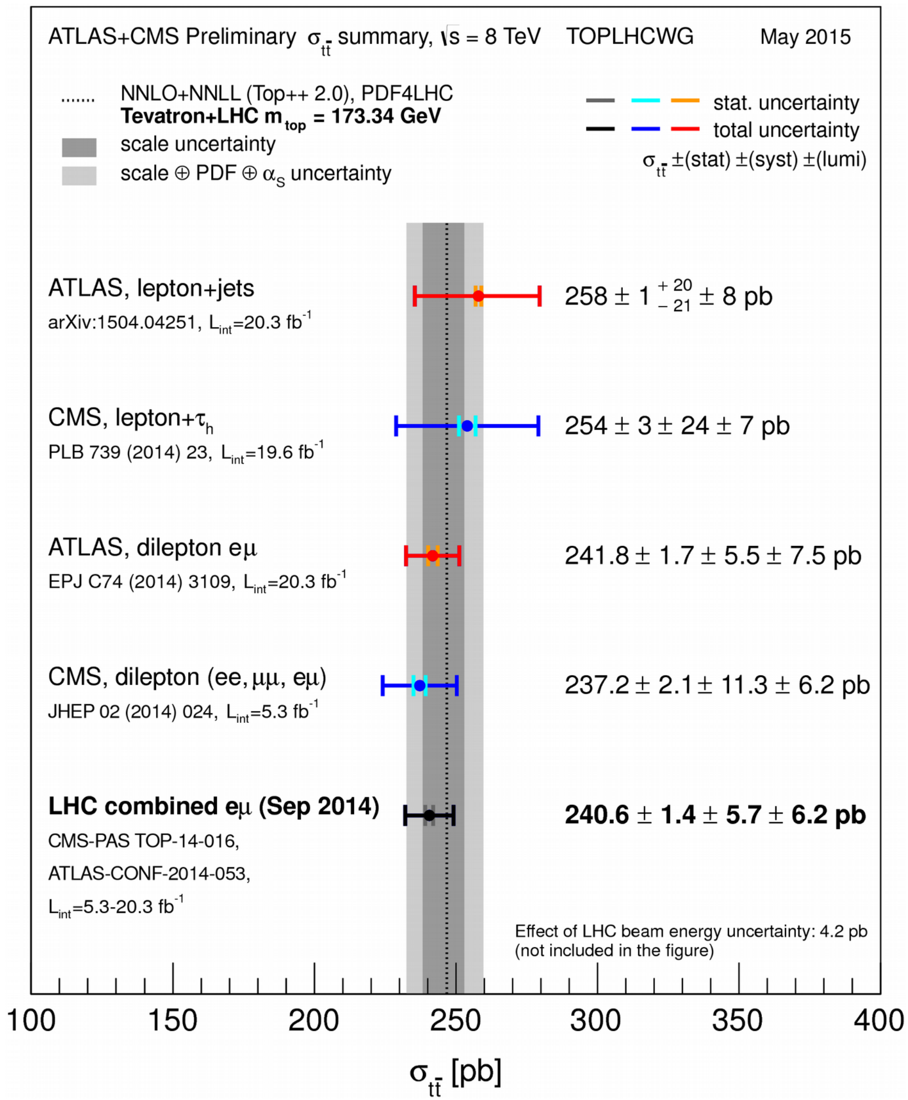


Heavy quark production

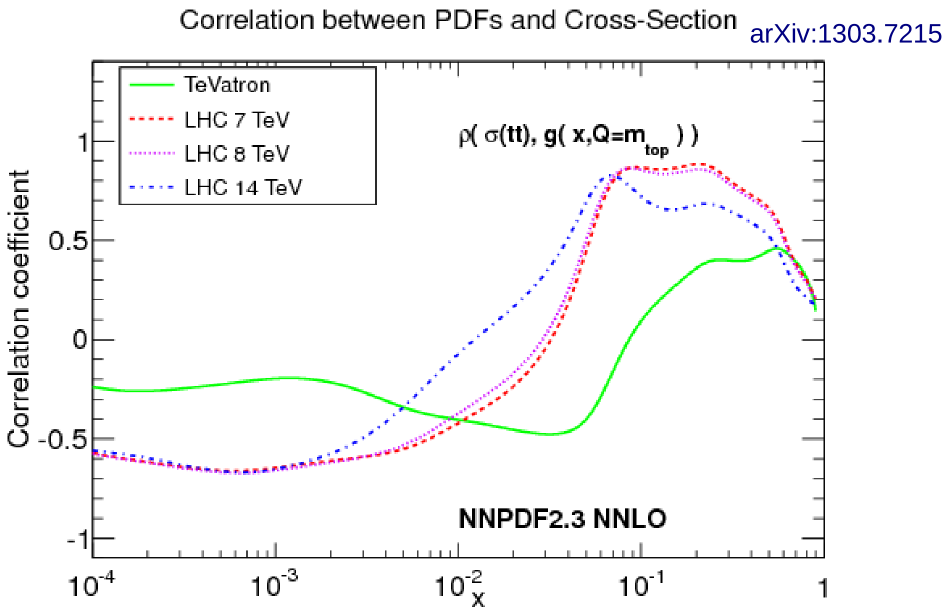


- $t\bar{t}$ inclusive cross sections
- $t\bar{t}$ differential cross sections
- $t\bar{t}$/Z ratios
- Charm and bottom production at LHCb

Top pair inclusive cross section measurements

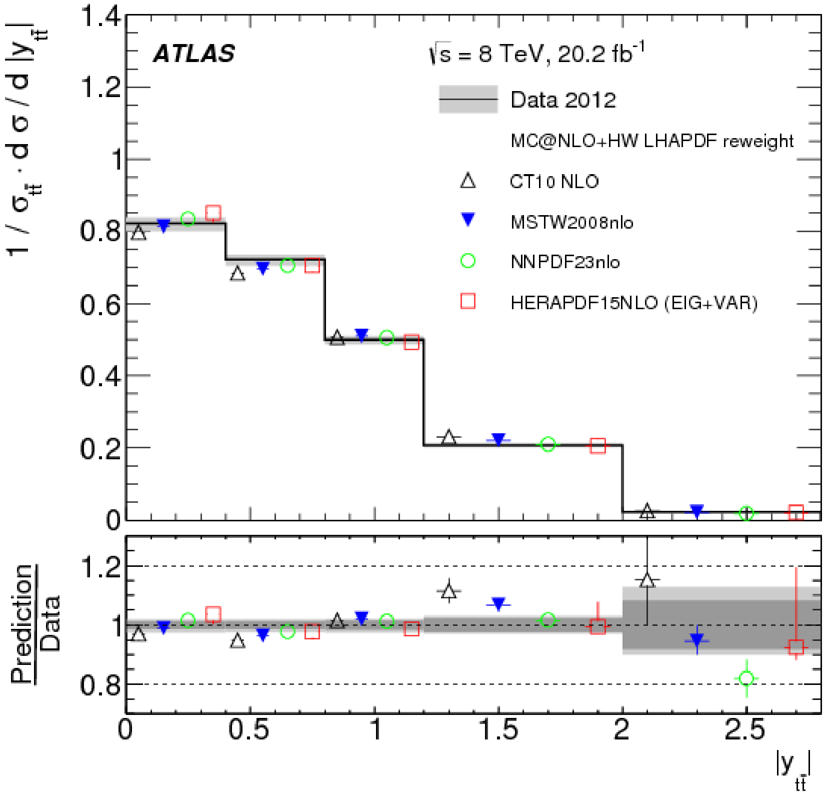


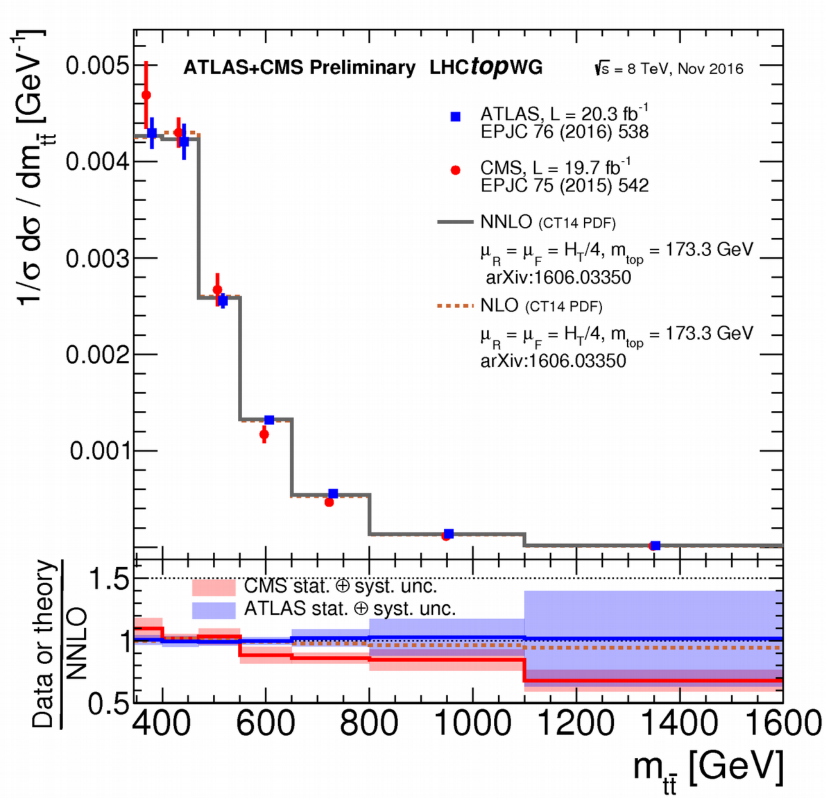
- $t\bar{t}$ inclusive cross sections are included in the latest global PDF fits, as MMHT and NNPDF
- Provide constraints on the medium- and high-x gluon



Top differential cross sections

arXiv:1607.07281

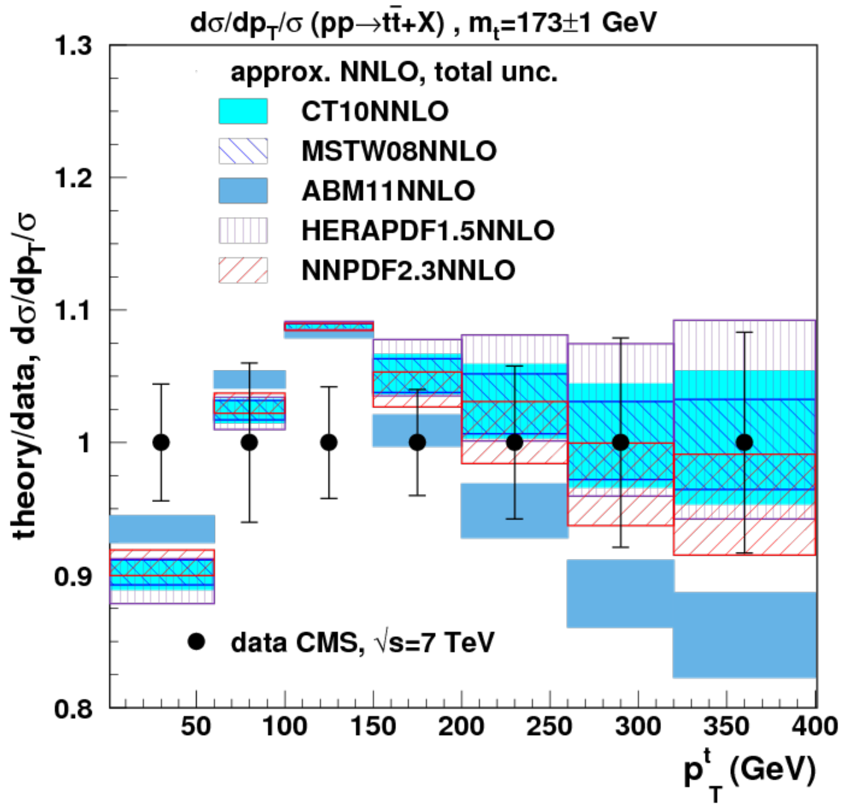


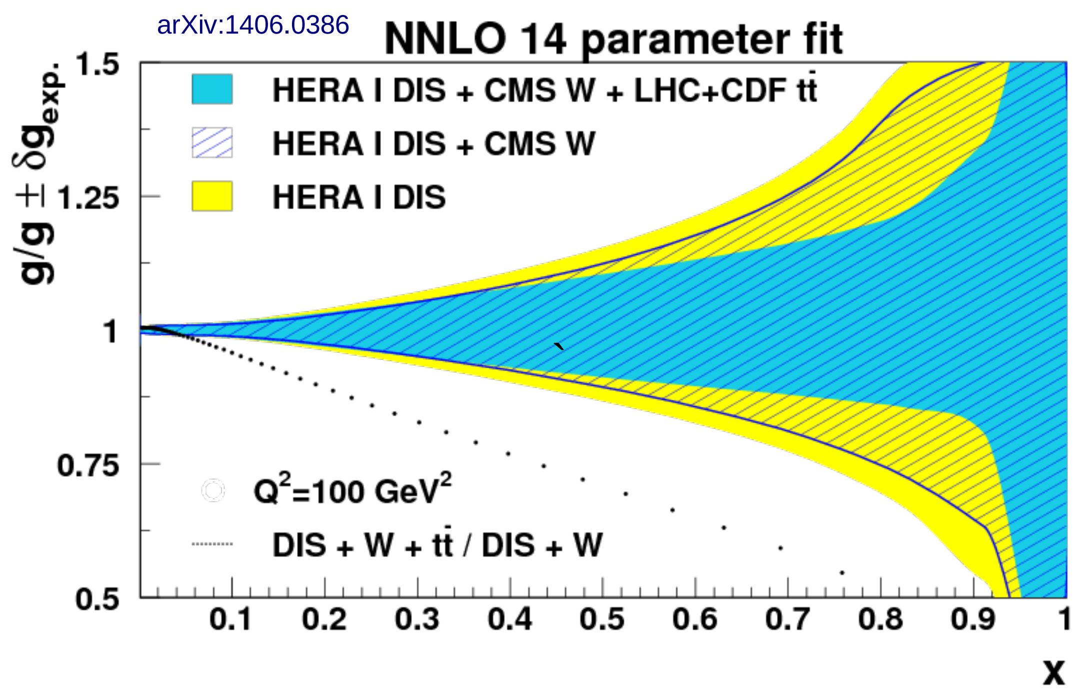


- Differential cross section measurements allows probing the gluon PDFs at even higher Bjorken-x
- NNLO predictions of $t\bar{t}$ differential cross sections are now available, which makes it possible to include this data in PDF fits at NNLO

PDF fits to $t\bar{t}$ differential cross sections

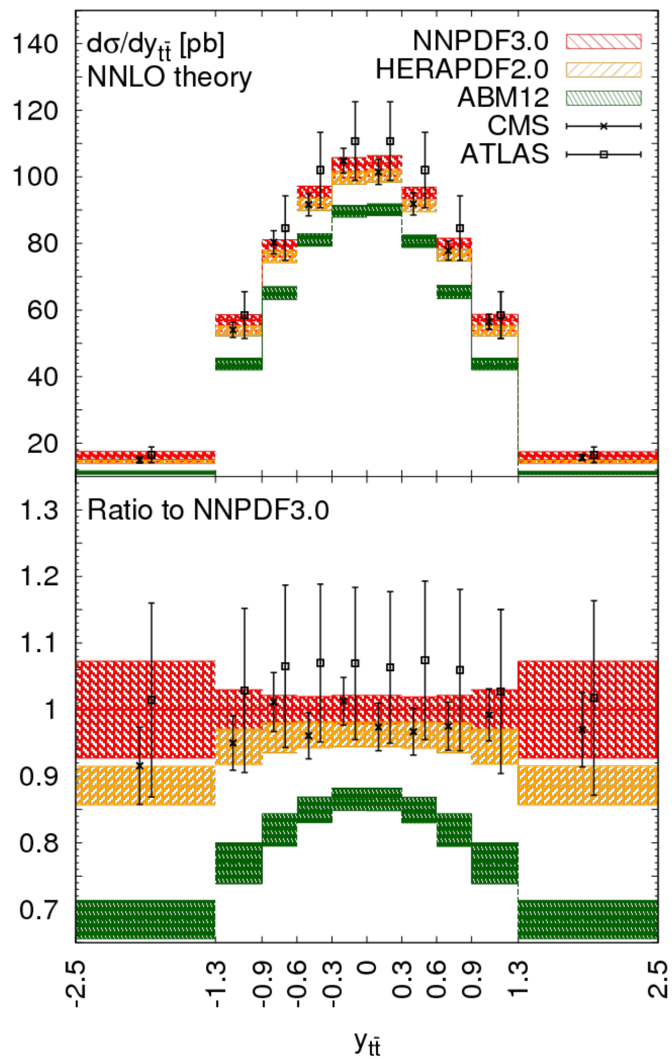
- First studies of PDF fits to top pair differential cross sections were performed with approx NNLO predictions
- Significant improvement of the gluon PDF at high-x



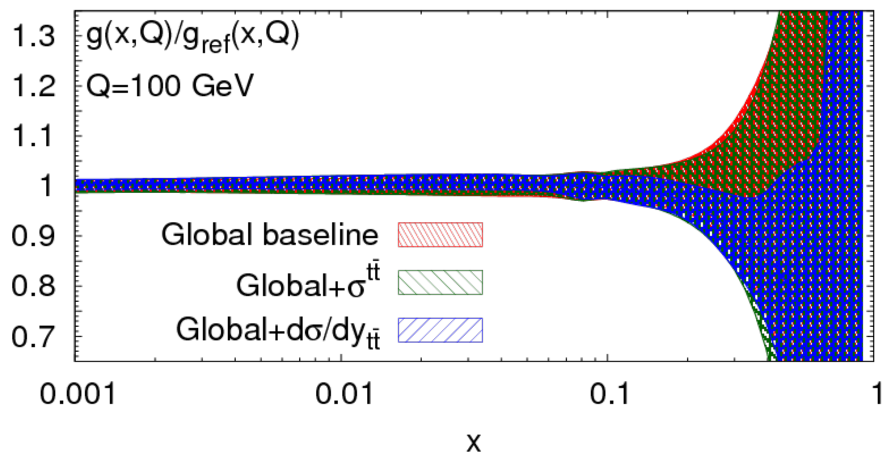


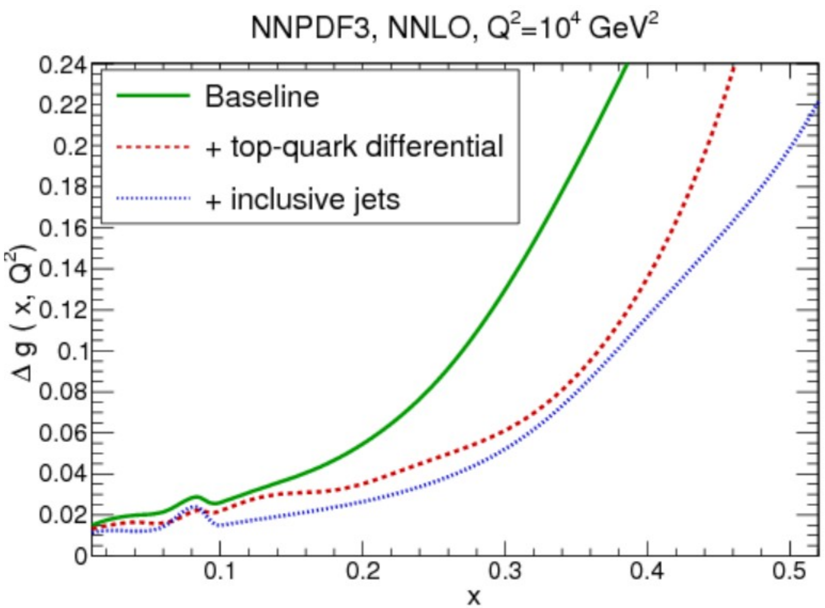
PDF fits to $t\bar{t}$ differential cross sections

arXiv:1611.08609



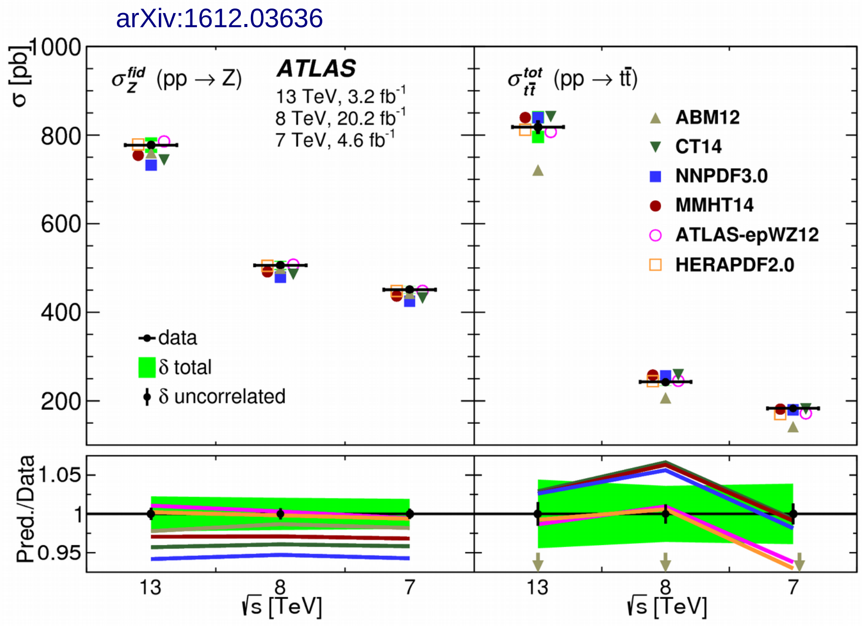
- A recent analysis performed the first PDF fit to top pair differential cross sections at NNLO
- Significant improvement of the gluon PDF at high-x



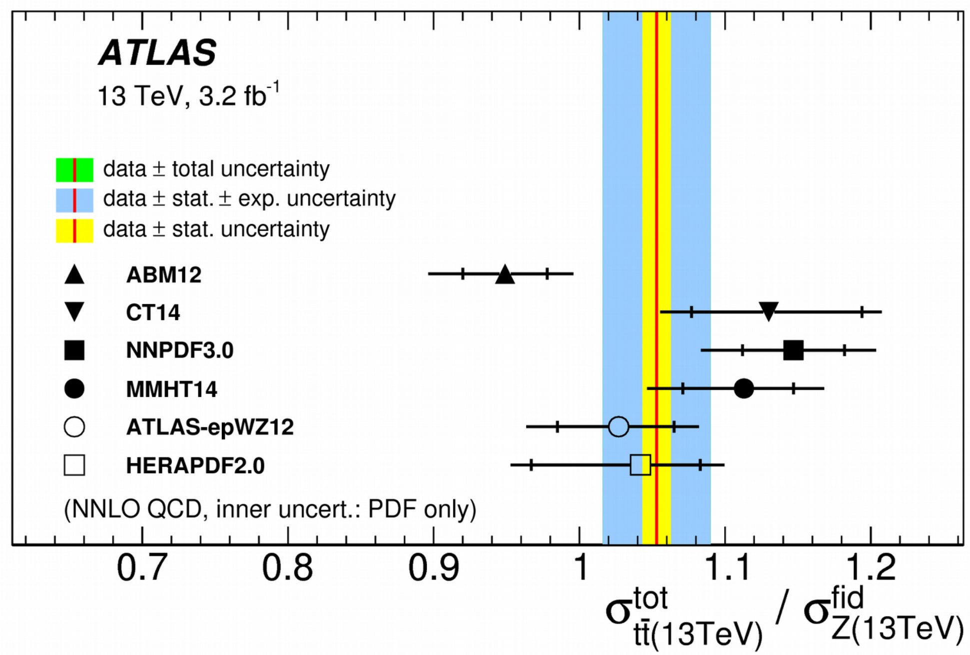


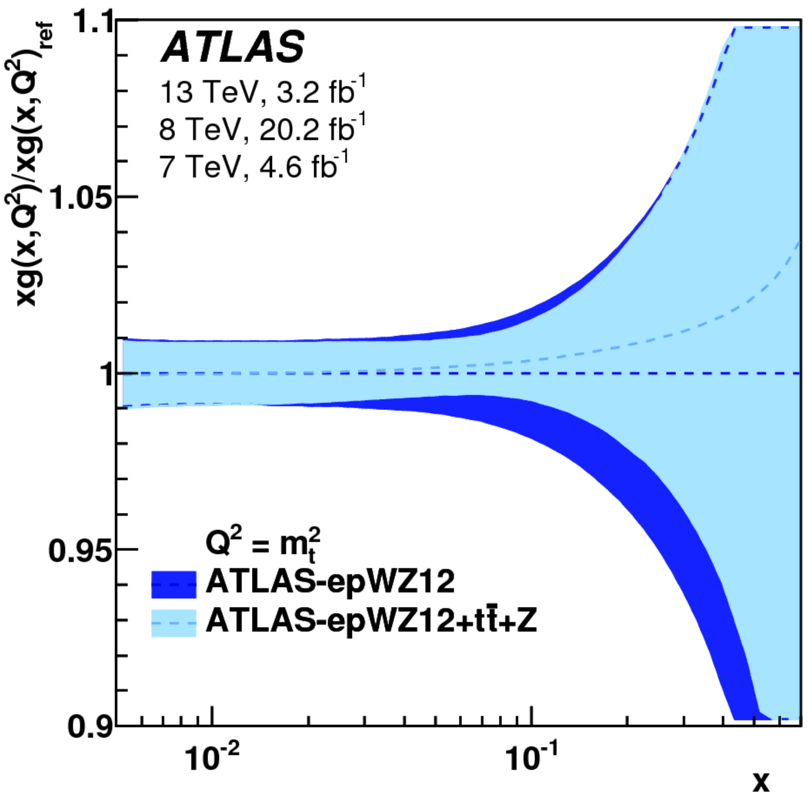
- Reduction in the gluon PDF uncertainty comparable to jet data

$t\bar{t}$ / Z ratio measurement



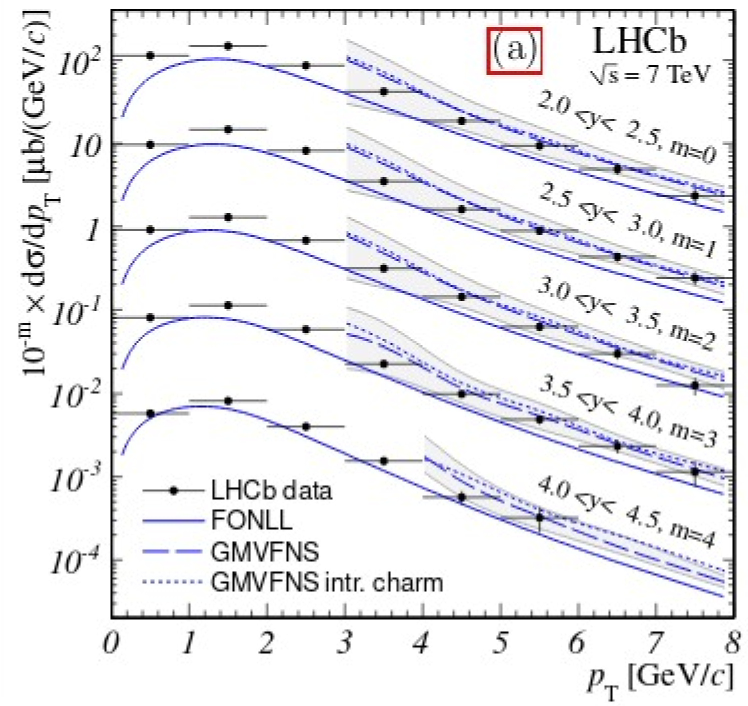
- Measurement of $t\bar{t}$ / Z ratio at 7, 8, and 13 TeV
- Single and double ratio measurements are not affected by luminosity uncertainties
- Provide even better constraints on the gluon PDF at high x



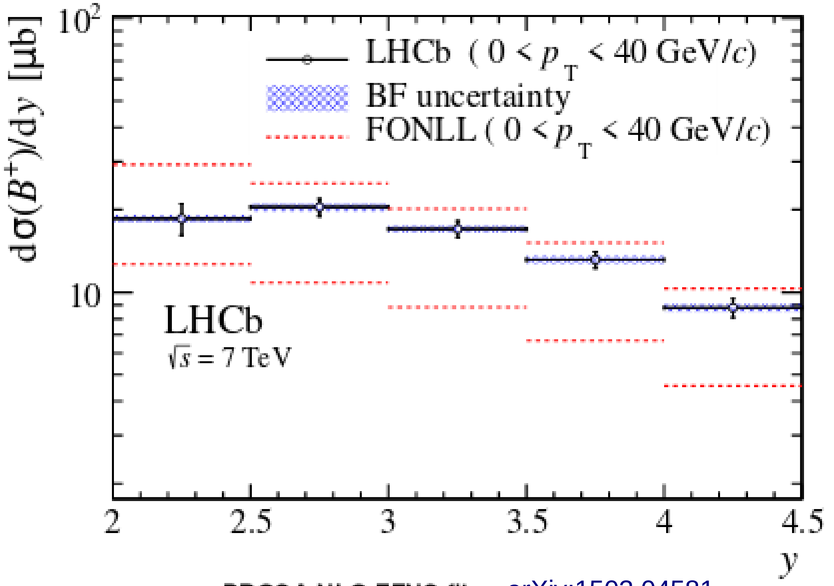


Charm and bottom production at LHCb

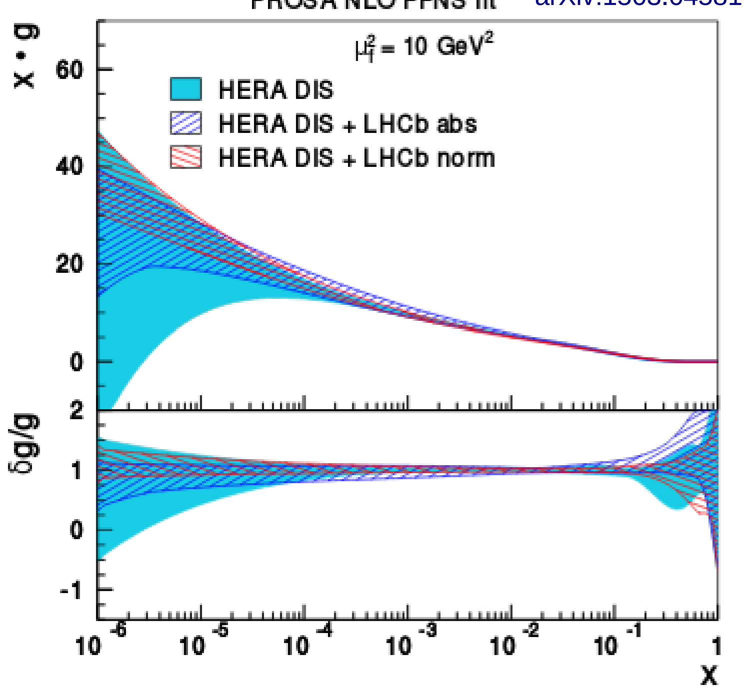
arXiv:1302.2864



arXiv:1306.3663



arXiv:1503.04581



- LHCb measurements of charm and bottom mesons production in the forward region
- Provide constraints on the low-x gluon PDF

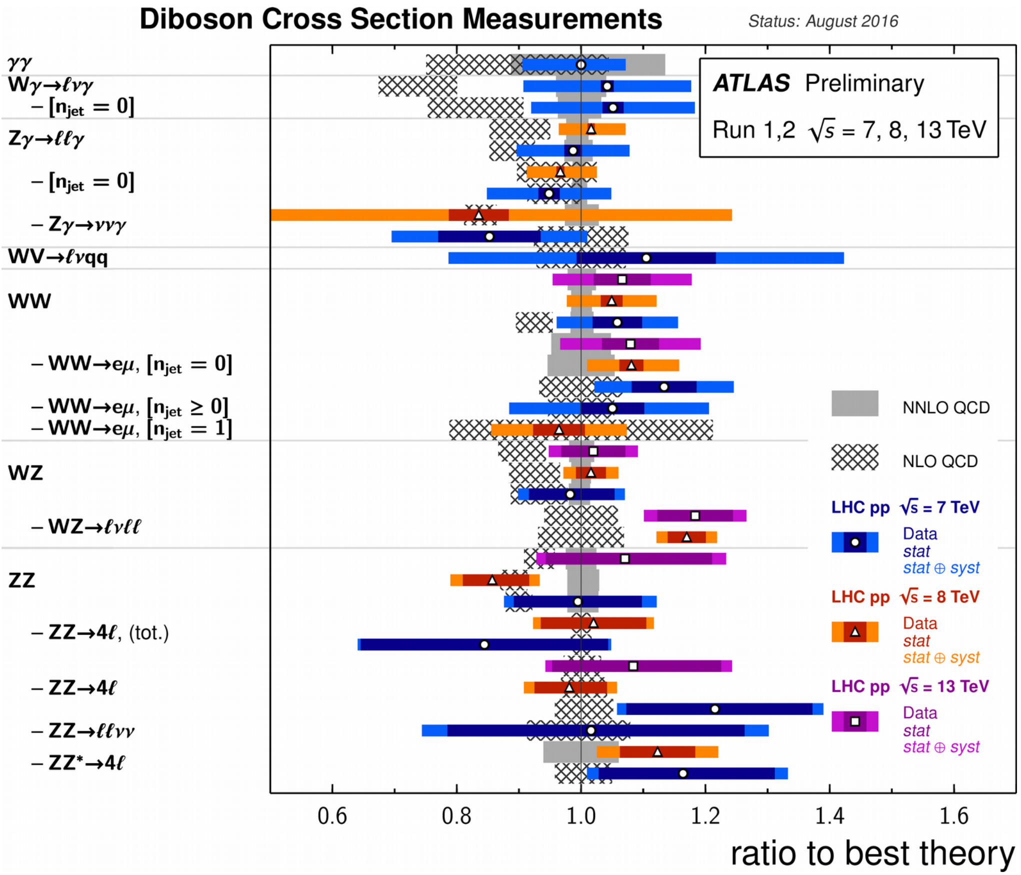
Prospects for PDF constraints with LHC data

- With the full Run II data sample, other measurements will be precise enough to be used for PDF determination, as WW, WZ, ZZ production, single top, and even Higgs

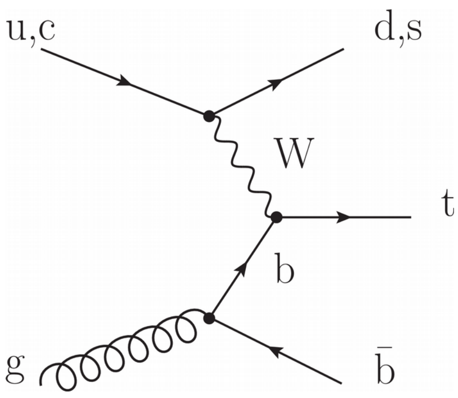
- Current precise measurements can be used to constraints PDFs thank to new available calculations at NNLO, as W+jets and Z+jets

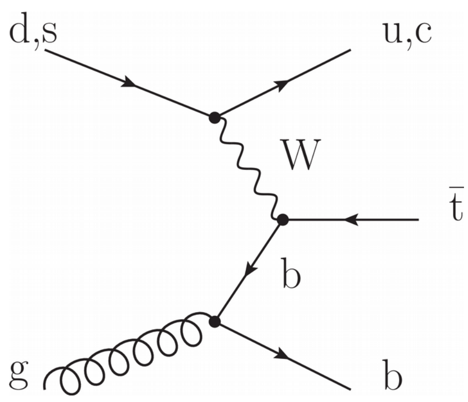
- To which extent it is acceptable to use LHC data to determine PDFs for LHC searches? Special care should be taken when including additional LHC data in PDF fits, not to swallow new physics into the PDFs → The ideal situation is to combine a QCD analysis for PDF determination with the search for new physics

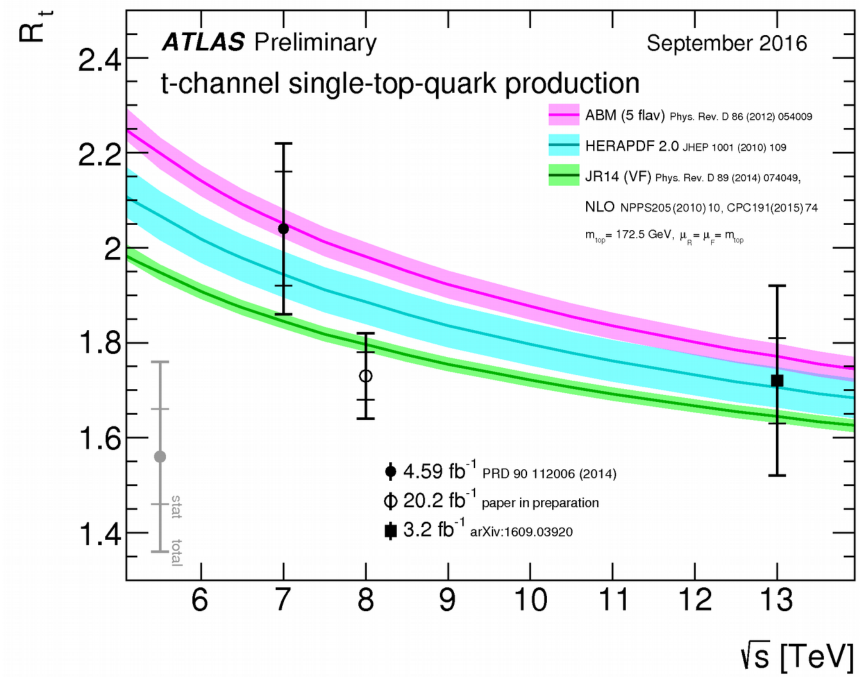
Diboson production

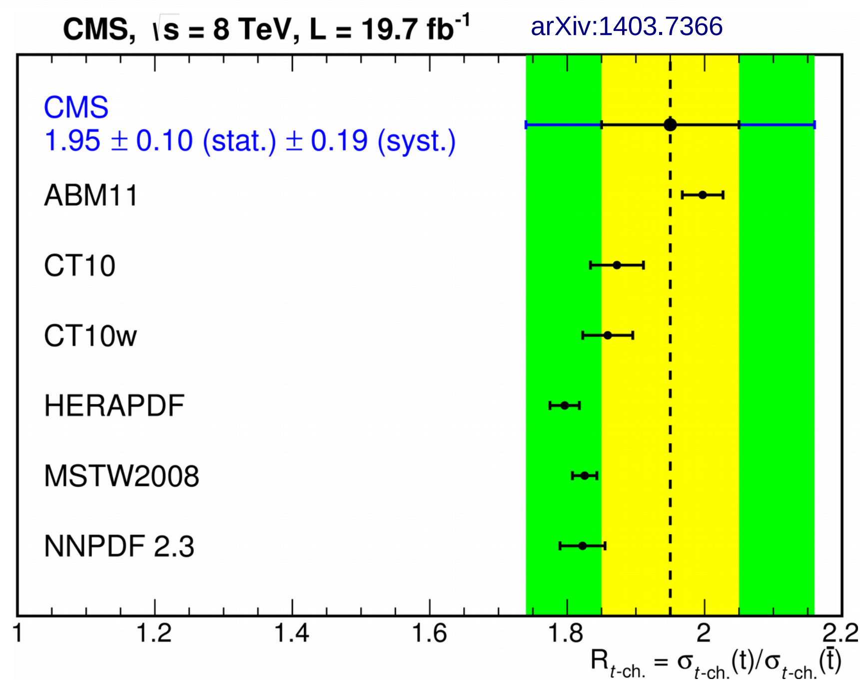


- Diboson cross sections measurements benefit from the larger statistics available in Run 2
- NNLO QCD predictions have been recently completed
- Could provide complementary constraints to the sea and valence PDFs in the medium- and high-x region



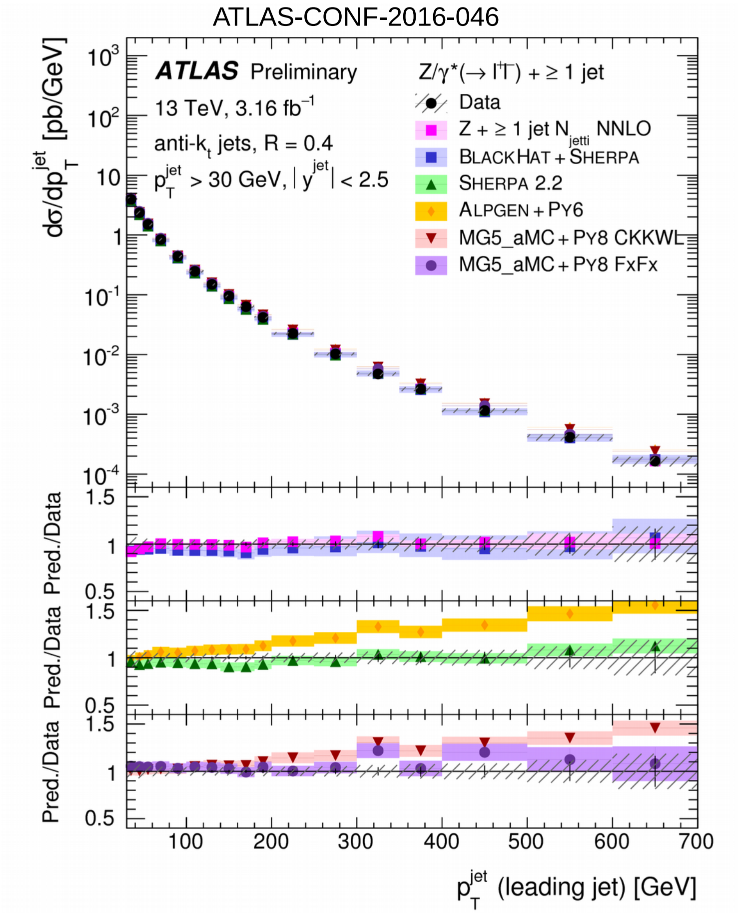


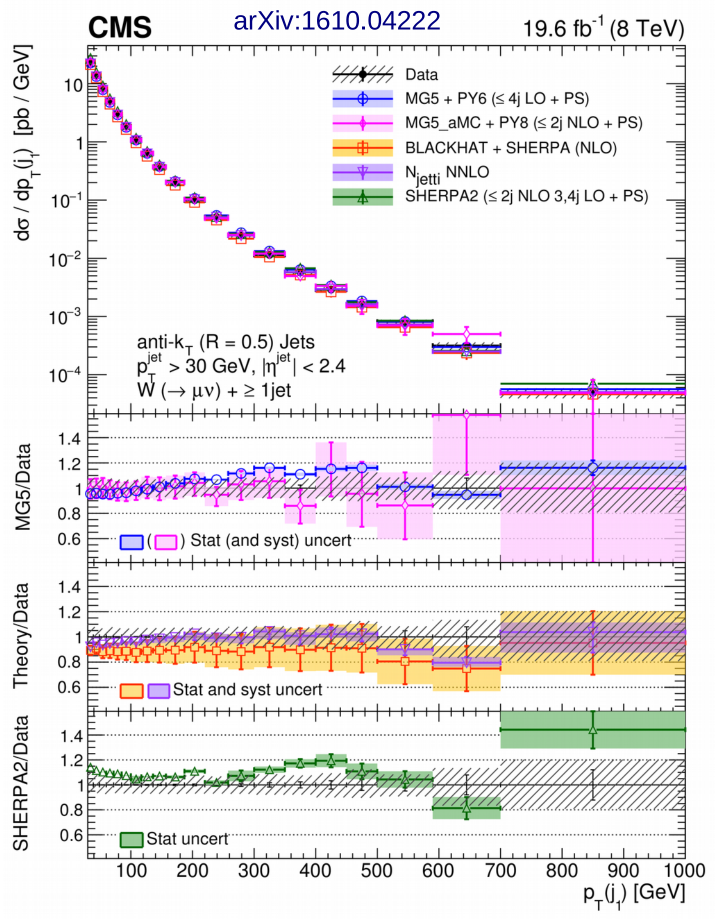




- The ratio of top/antitop production in the t-channel is sensitive to the u/d ratio at high-x

V+jet

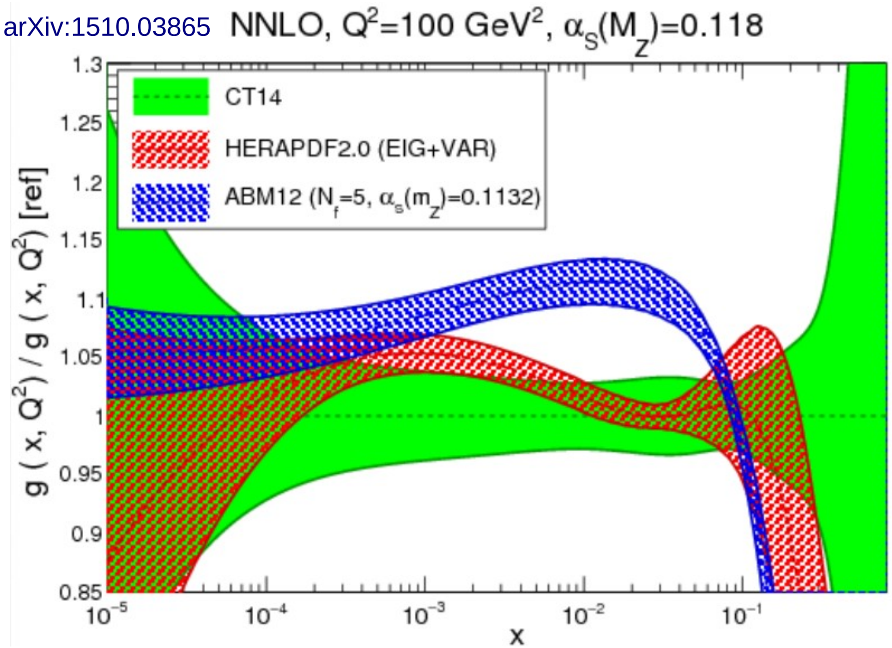


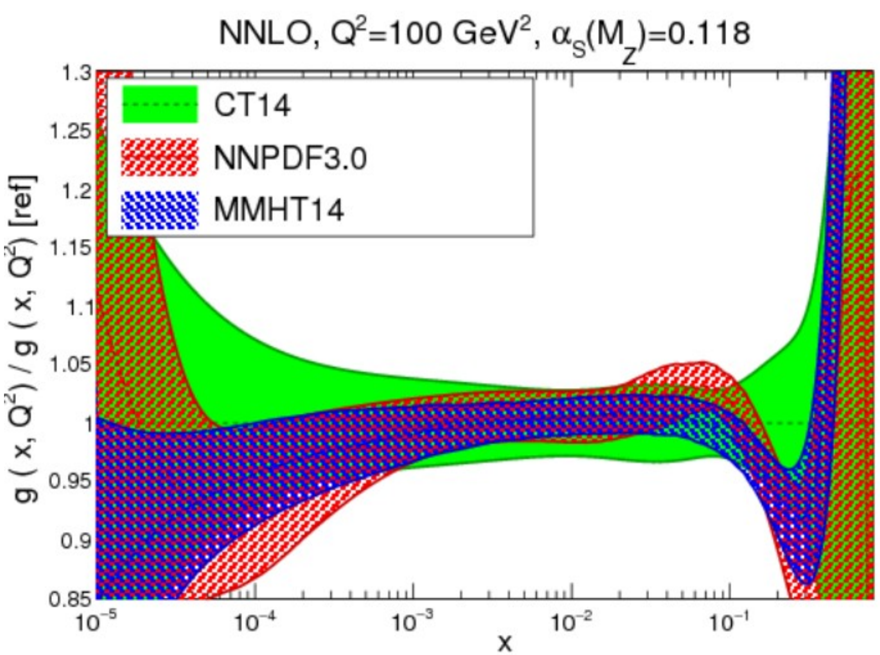


- NNLO predictions for W and Z + jet are now available
- Good agreement between data and NNLO, and reduced scale variation uncertainties allows to use these measurements in PDF fits
- Expected sensitivity to the gluon PDF, and to α_s

Prospects for the gluon PDF

arXiv:1510.03865





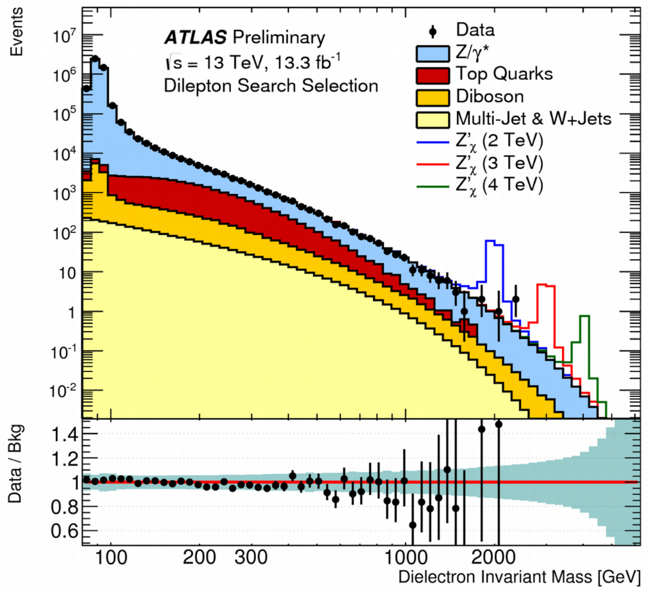
- The precise knowledge of the gluon PDF at high-x is crucial for BSM searches in high mass final states
- The gluon PDF of HERAPDF at high-x is softer than the VFNS global PDF sets. Is this an indication of tension between DIS and jet data?
- The ABM gluon PDF (FFNS) is much softer than the others. Does it mean that FFNS is not a good model for hadron collider predictions, or that the gluon PDF at high-x has a large irreducible theoretical uncertainty?
- QCD analyses of recent measurements of jets, top, and V+jets differential cross sections, using the new available NNLO predictions for these processes could answer these questions in the near future

Summary and conclusions

- PDFs are an essential ingredient for the physics programme at the LHC. PDF extraction is a complex problem with a variety of solutions
- LHC measurements can provide important constraints to the PDFs, complementary to DIS data, and allow to stress test the factorization theorem
- Recent precise LHC measurements are shedding light on long-standing PDF issues, as the strange content of the proton, the low-x isospin asymmetry, and the high-x gluon PDF. However special care should be taken when including LHC data in PDF fits, not to swallow new physics into the PDFs
- For fully exploiting the potential of these measurements, fast and fully differential NNLO QCD predictions are required, including NLO EW, non-pQCD, and PS corrections when relevant

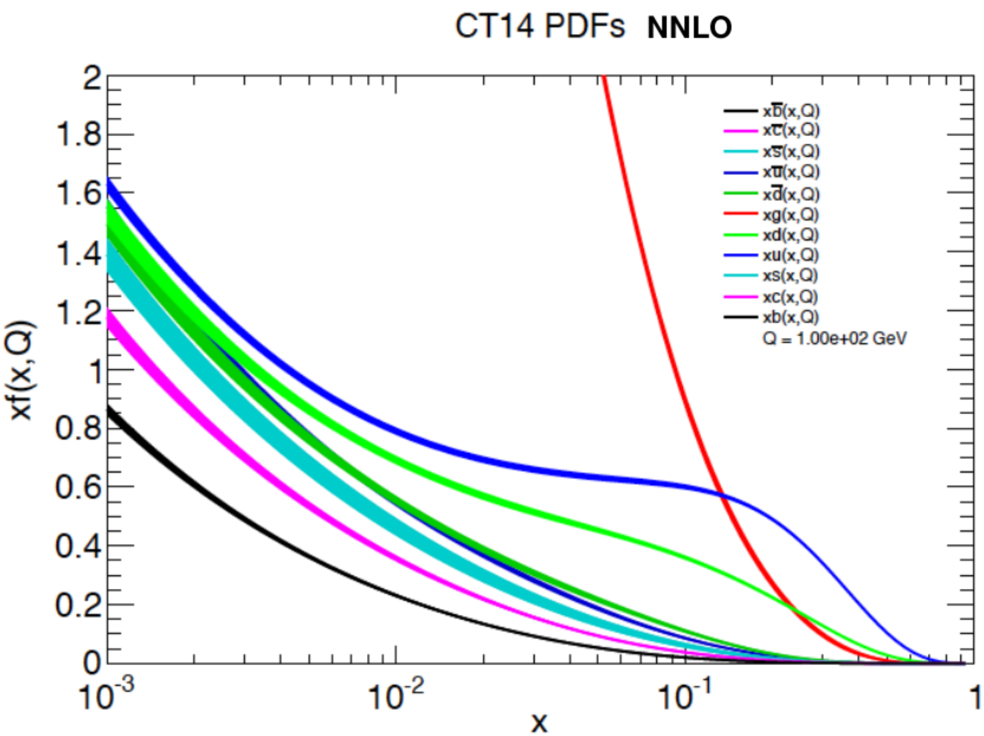
BACKUP

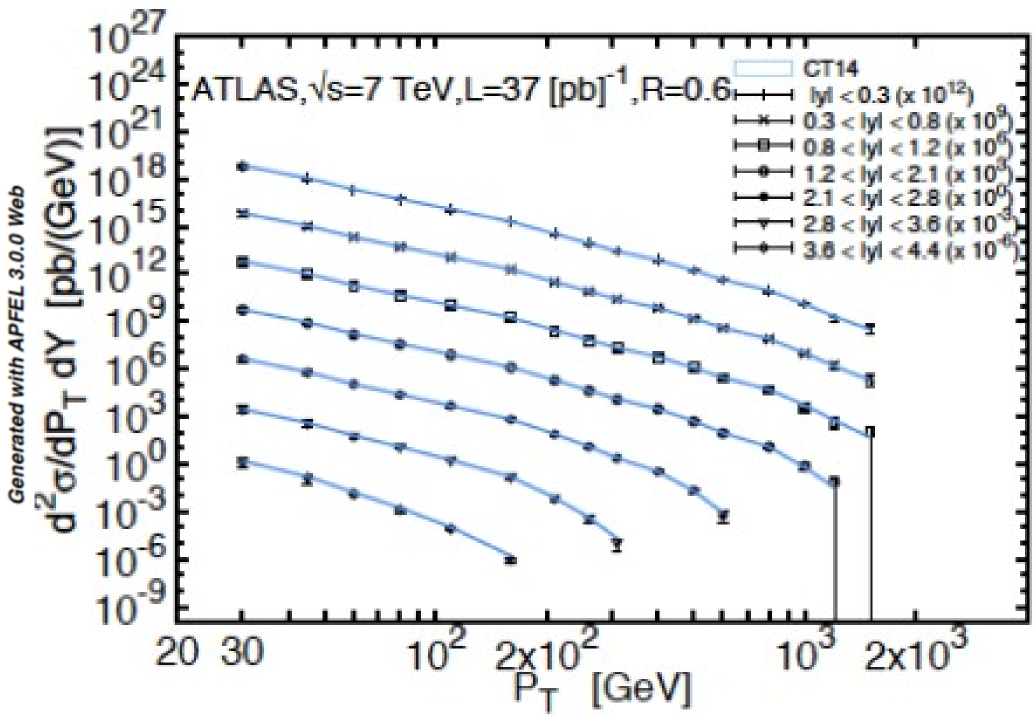
Uncertainty for dilepton search ATLAS 13 TeV



Source	Dielectron Signal	Dielectron Background	Dimuon Signal	Dimuon Background
Luminosity	2.9% (2.9%)	2.9% (2.9%)	2.9% (2.9%)	2.9% (2.9%)
MC Statistical	<1.0% (<1.0%)	<1.0% (<1.0%)	<1.0% (<1.0%)	<1.0% (<1.0%)
Beam Energy	2.0% (4.1%)	2.0% (4.1%)	1.9% (3.3%)	1.9% (3.3%)
DY PDF Choice	N/A	<1.0% (8.4%)	N/A	<1.0% (2.0%)
DY PDF Variation	N/A	8.7% (18.5%)	N/A	7.6% (13.2%)
DY PDF Scale	N/A	1.0% (2.0%)	N/A	0.9% (1.5%)
DY α_S	N/A	1.6% (2.7%)	N/A	1.4% (2.3%)
DY EW Corrections	N/A	2.4% (5.5%)	N/A	2.0% (4.0%)
DY Photon-induced Corrections	N/A	3.4% (7.6%)	N/A	3.0% (5.5%)
Top Quarks Theoretical	N/A	<1.0% (<1.0%)	N/A	<1.0% (<1.0%)
Dibosons Theoretical	N/A	<1.0% (<1.0%)	N/A	<1.0% (<1.0%)
Reconstruction Efficiency	<1.0% (<1.0%)	<1.0% (<1.0%)	10.4% (16.7%)	10.4% (16.7%)
Isolation Efficiency	4.0% (4.0%)	4.0% (4.0%)	1.8% (2.0%)	1.8% (2.0%)
Trigger Efficiency	<1.0% (<1.0%)	<1.0% (<1.0%)	<1.0% (<1.0%)	<1.0% (<1.0%)
Identification Efficiency	3.0% (2.9%)	3.0% (2.9%)	N/A	N/A
Lepton Energy Scale	<1.0% (<1.0%)	4.2% (7.3%)	<1.0% (<1.0%)	<1.0% (<1.0%)
Lepton Energy Resolution	<1.0% (<1.0%)	<1.0% (<1.0%)	2.3% (2.1%)	3.6% (9.9%)
Multi-jet & W+jets	N/A	<1.0% (<1.0%)	N/A	N/A
Total	6.2% (7.1%)	12.4% (24.8%)	11.4% (17.5%)	14.6% (25.2%)

Latestt CTEQ PDF – CT14



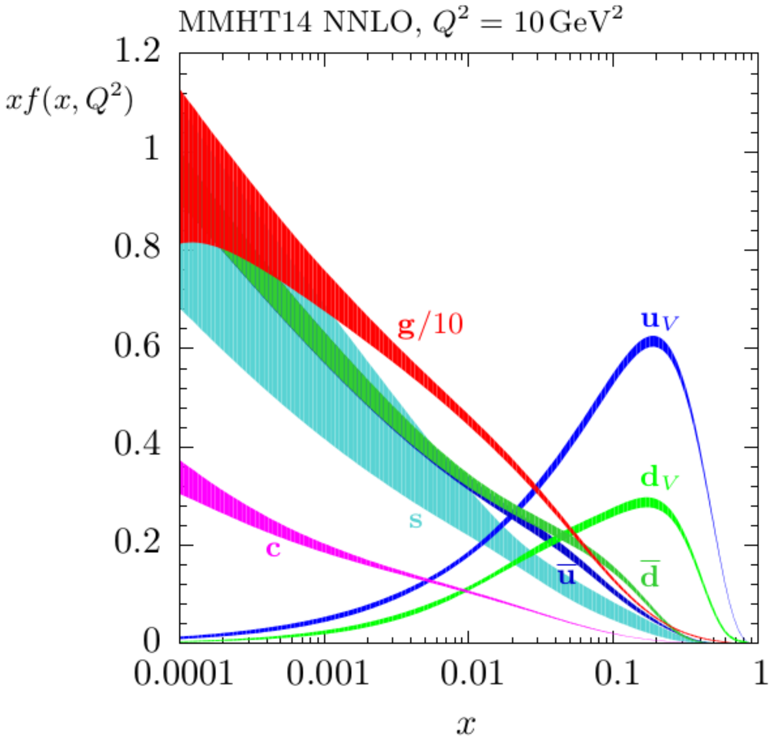


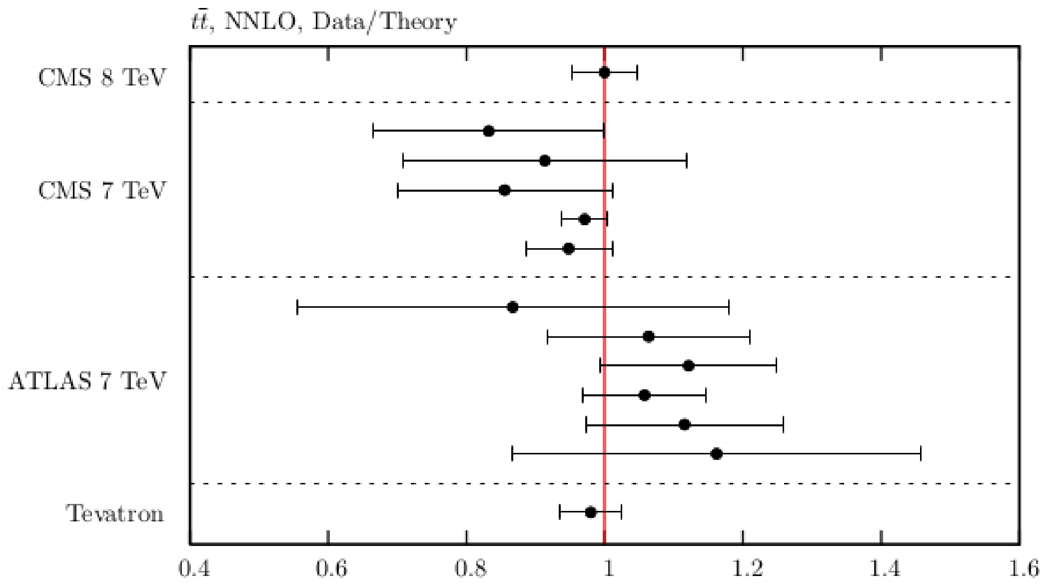
- More flexible parametrization than MMHT/MSTW
  → more conservative uncertainties

MMHT2014 (formerly MSTW) PDFs

- The MMHT2014 PDFs supersede the MSTW2008 PDFs
- Good agreement with LHC Run 1 data, including W asymmetry
- With respect to CTEQ, have fewer free parameters, smaller χ^2 tolerance criteria, smaller uncertainties

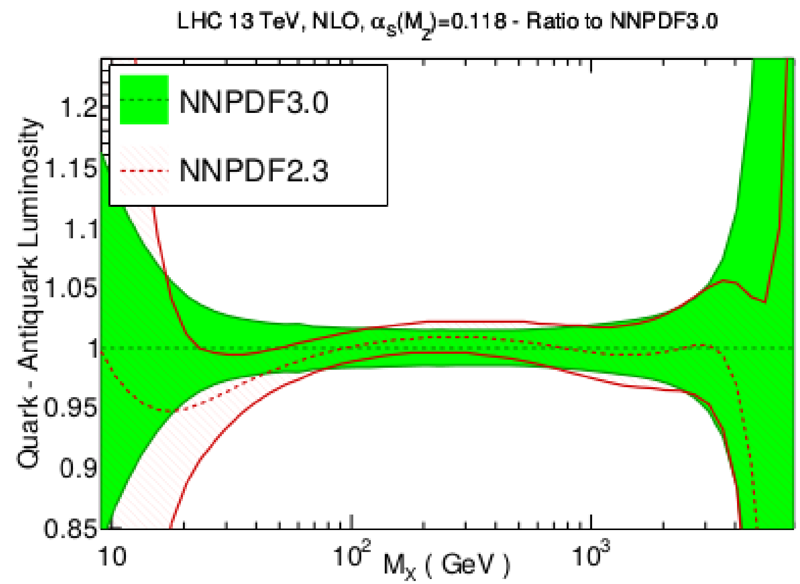
  → aim for precision, but also less conservative uncertainties
- Only sets which currently includes the latest Tevatron W-charge asymmetry data → best precision on valence PDF

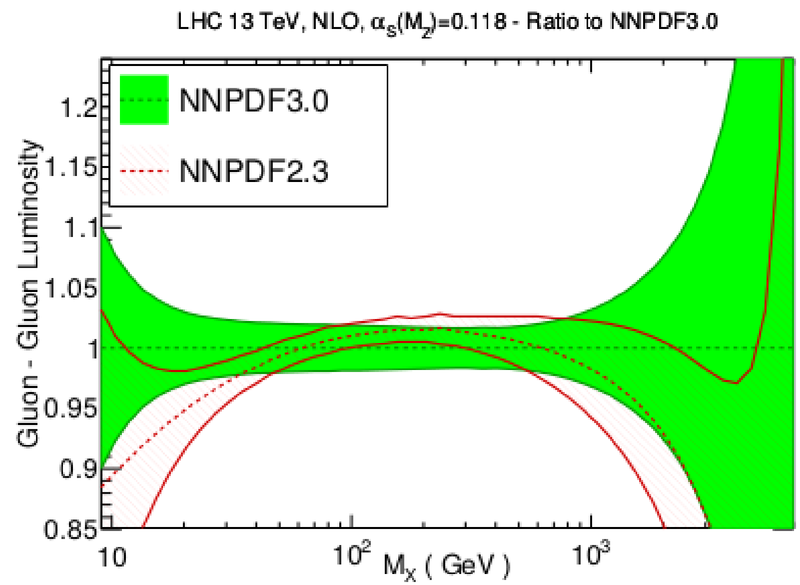




NNPDF – NNPDF3.0

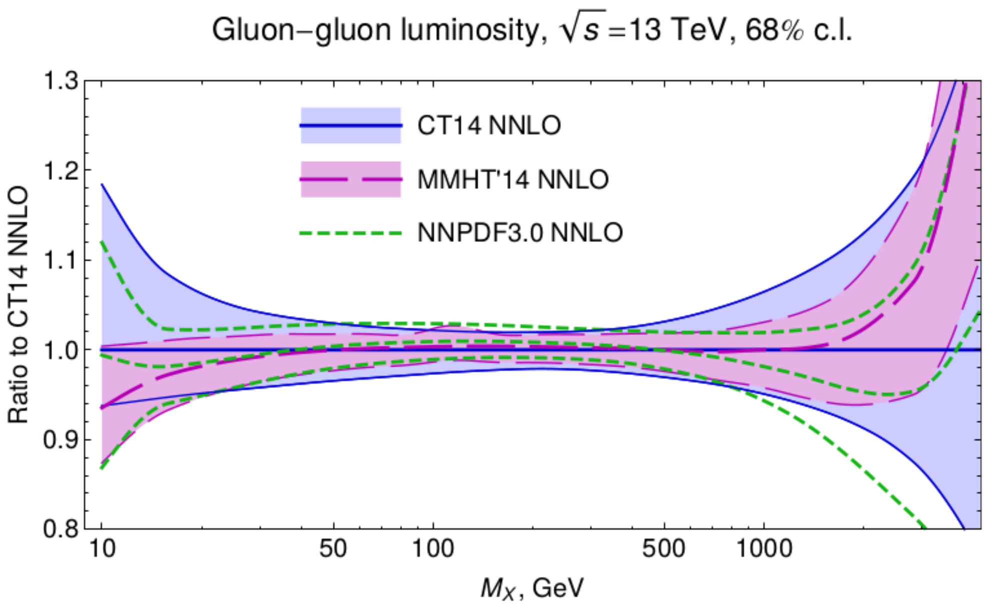
- Most flexible, unbiased, Neural Network parametrization, conservative approach very appropriate for searches
- Allow for negative PDFs at high-x, need special prescription to deal with negative cross sections for BSM processes
- Monte Carlo PDF uncertainties: MC replica provide a solid statistical representation of the PDF probability
- Include widest range of LHC Run I data
- Frequent updates, new PDF sets every year or less
- Closure tests

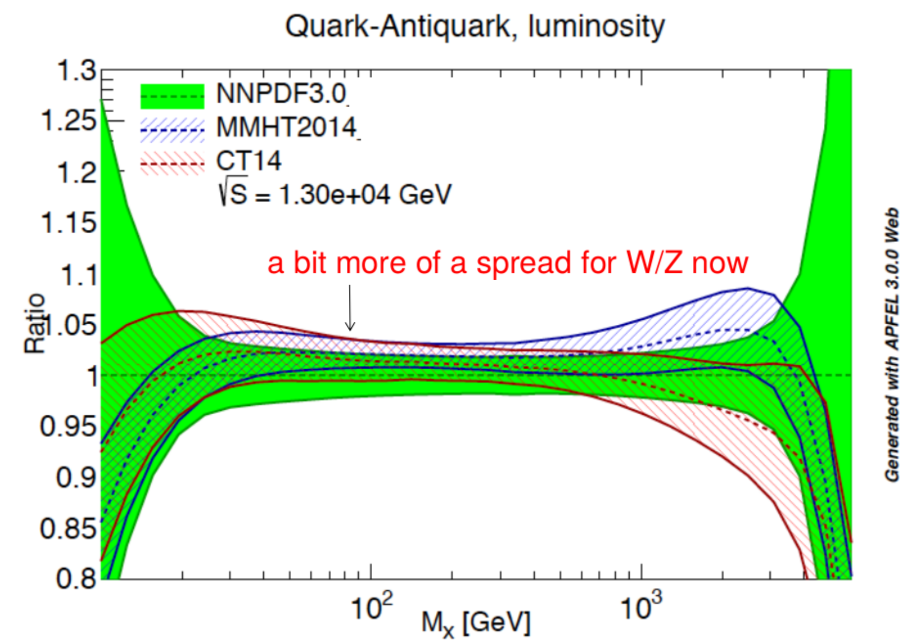




Important things to know about PDFs – gg and $q\bar{q}$

- The latest global PDF sets, MMHT2014, CT14 and NNPDF3.0, agree quite well on the gluon-gluon luminosity, while they disagree on the valence PDF and, as a consequence, on the quark-quark luminosity





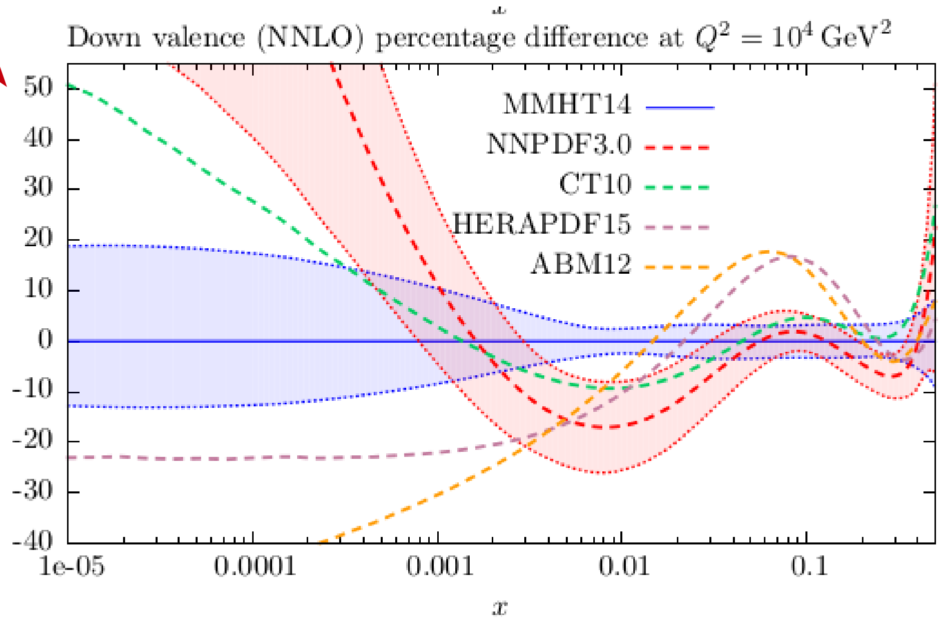
- For gluon-initiated processes and medium Bjorken-x it is sufficient to consider the uncertainties of one PDF set, or the PDF4LHC15 set
- For quark-initiated processes, and when a conservative estimate is needed, it should be better to build an envelope of the various sets to estimate the PDF uncertainty

Important things to know about PDFs – gg and $q\bar{q}$

- Since gg luminosity is now very consistent among CT, MMHT and NNPDF PDF sets: expect very similar top, Higgs cross sections
- In turn, d valence PDFs (and quark-antiquark luminosities) are not consistent, affects W, Z, VH, diboson processes

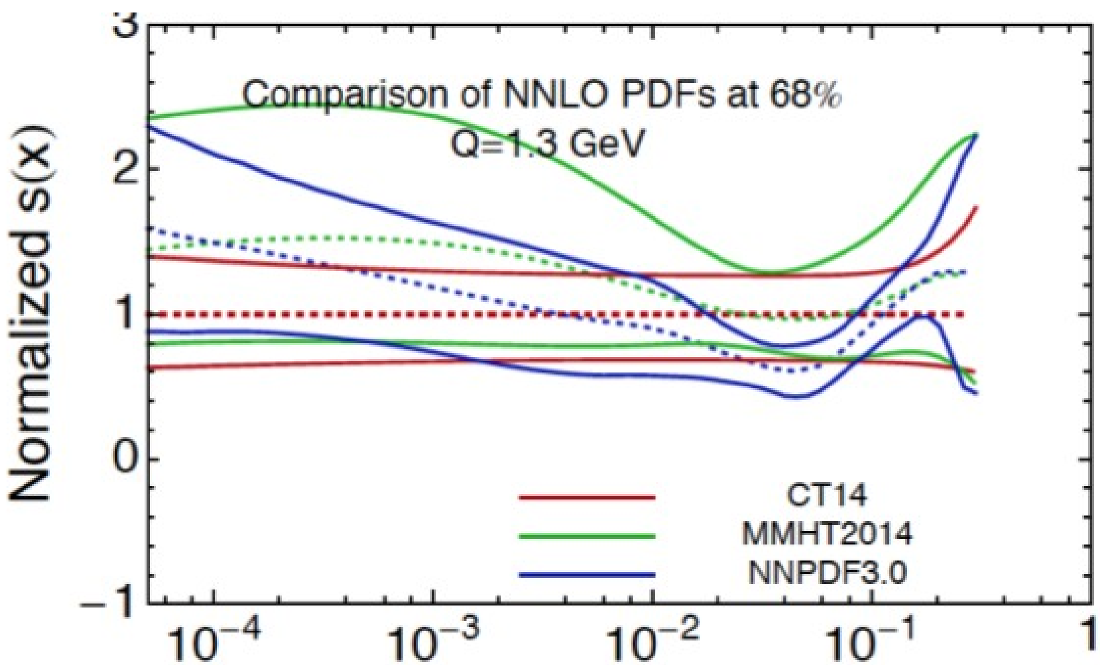
$$\sigma(gg \to H), \sqrt(s) = 13\mathrm{TeV}$$

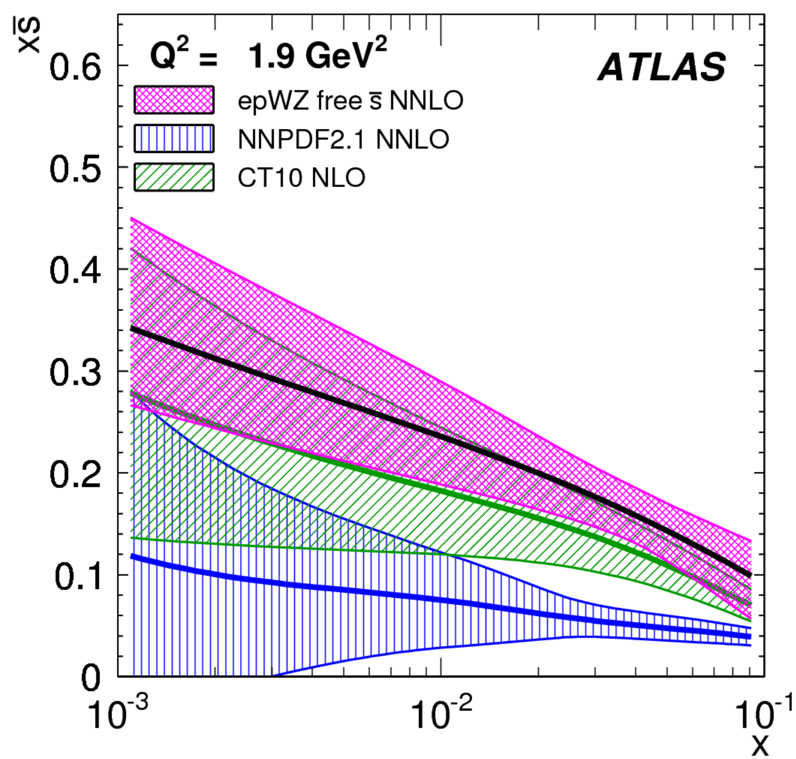
CT14	MMHT2014	NNPDF3.0
42.68 pb	42.70 pb	42.97 pb
+2.0% -2.4%	+1.3% -1.8%	+1.9% -1.9%



Important things to know about PDFs – strange

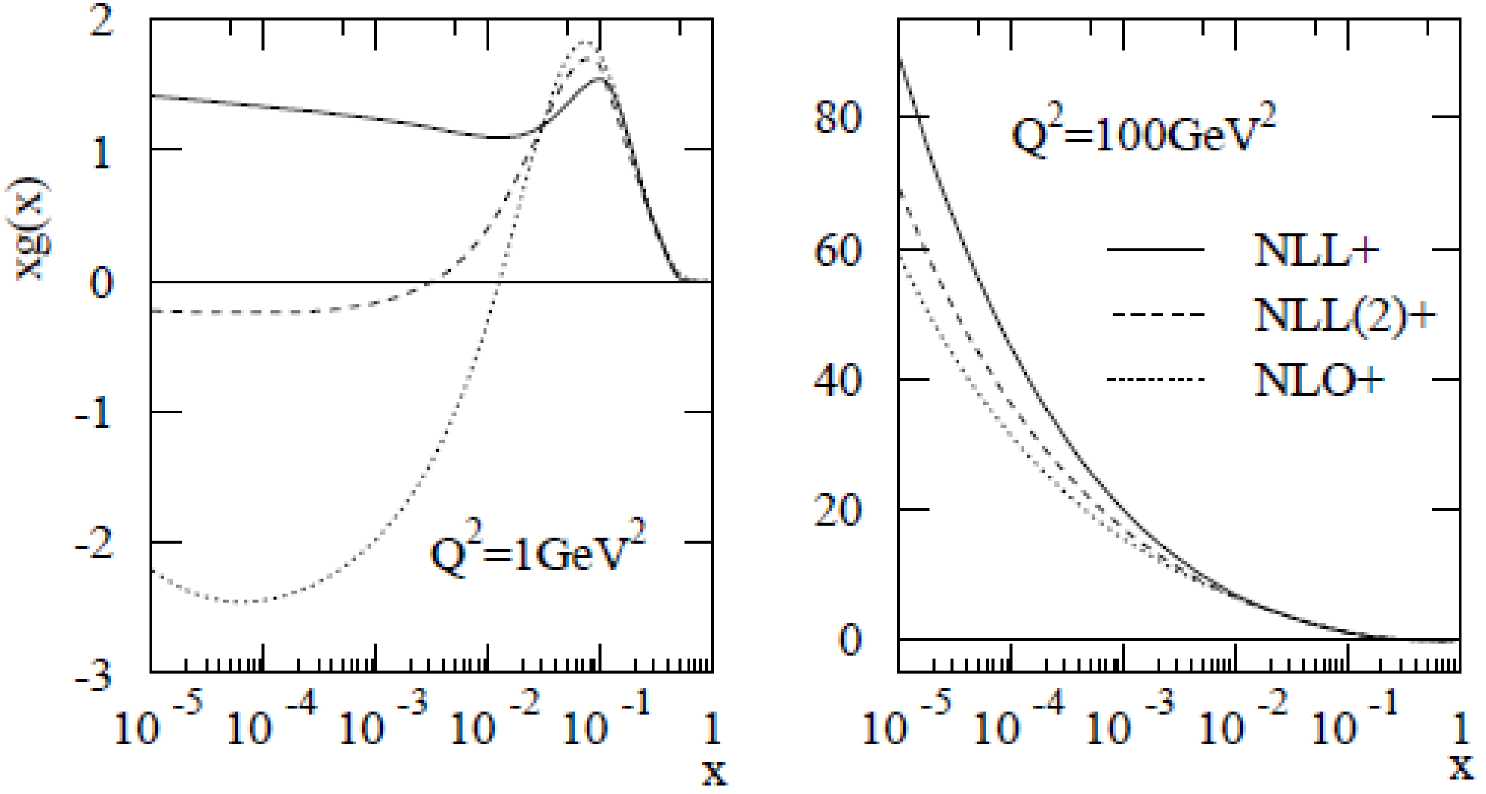
- ATLASepWZ PDF set is currently the only set which has enhanced strangeness





LO PDF for PS and MPI

arXiv:1103.0555



- Attempts of including ln(1/x) terms (small x resummation) leads to enhanced gluon PDFs at low-x, and positive gluon PDFs also at small Q2