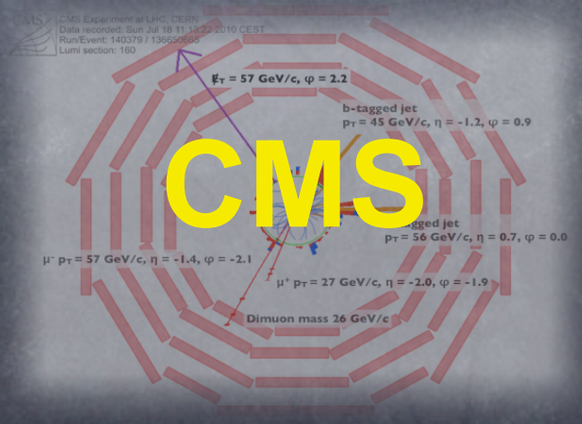
Parton Distribution Functions: Experimental Results

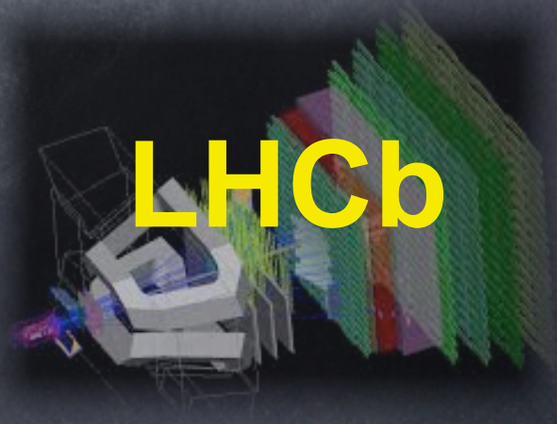
Katerina Lipka

HERA

ATLAS



CMS



LHCb

Standard Model at the LHC, Florence 2015

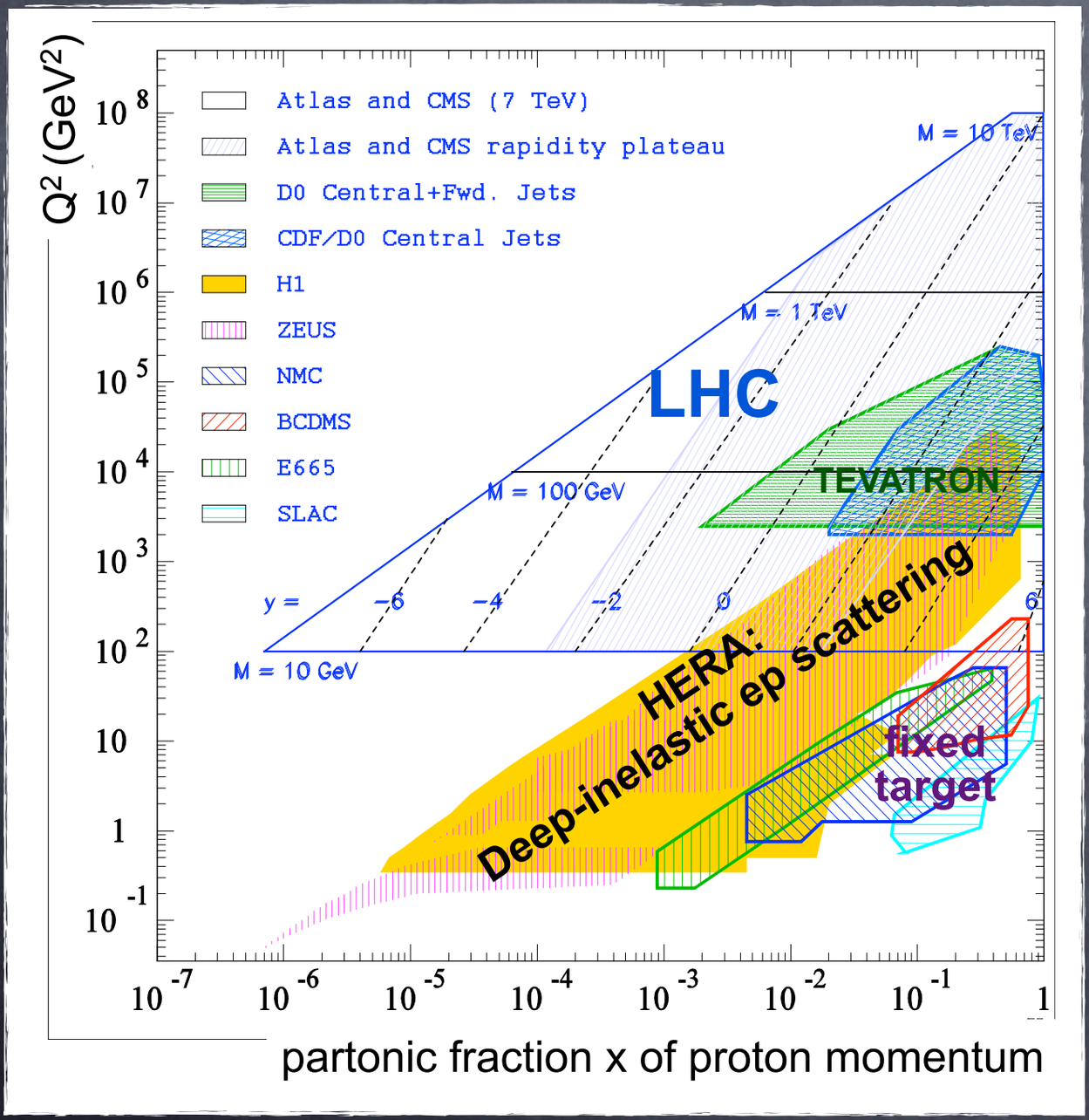
PDF-SENSITIVE MEASUREMENTS

Parton Distribution Functions

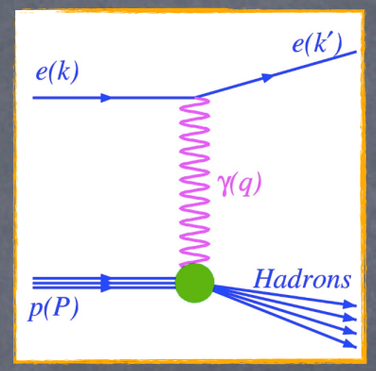
$f_i(Q^2, x)$

provided by theory

determined experimentally



- HERA DIS: quarks, gluon @ low, medium x



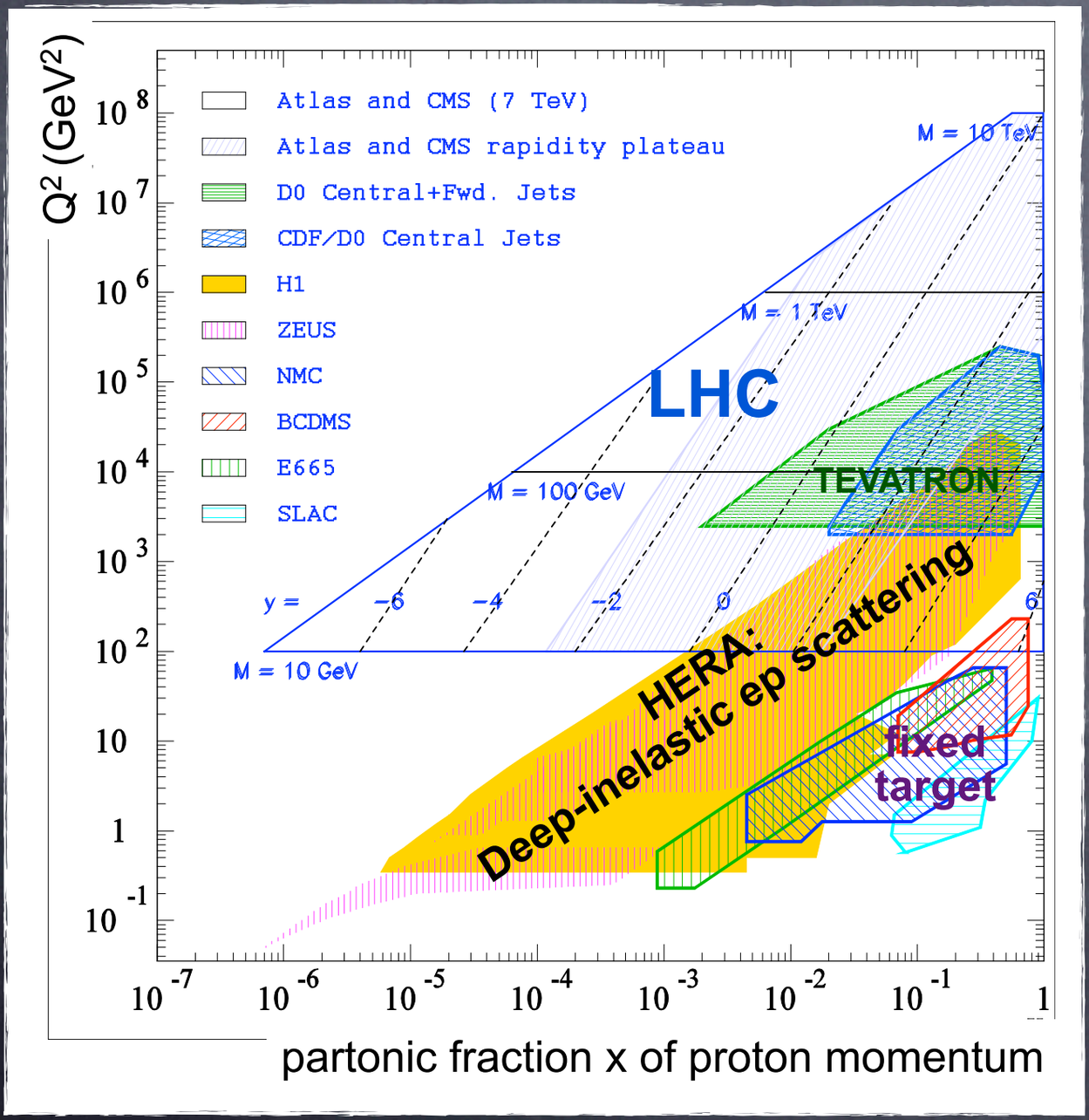
PDF-SENSITIVE MEASUREMENTS

Parton Distribution Functions

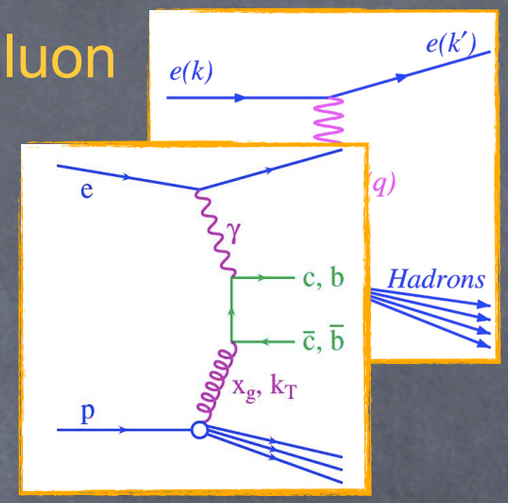
$f_i(Q^2, x)$

provided by theory

determined experimentally



- HERA DIS: quarks, gluon @ low, medium x
- HERA heavy-quarks: gluon, m_c, m_b



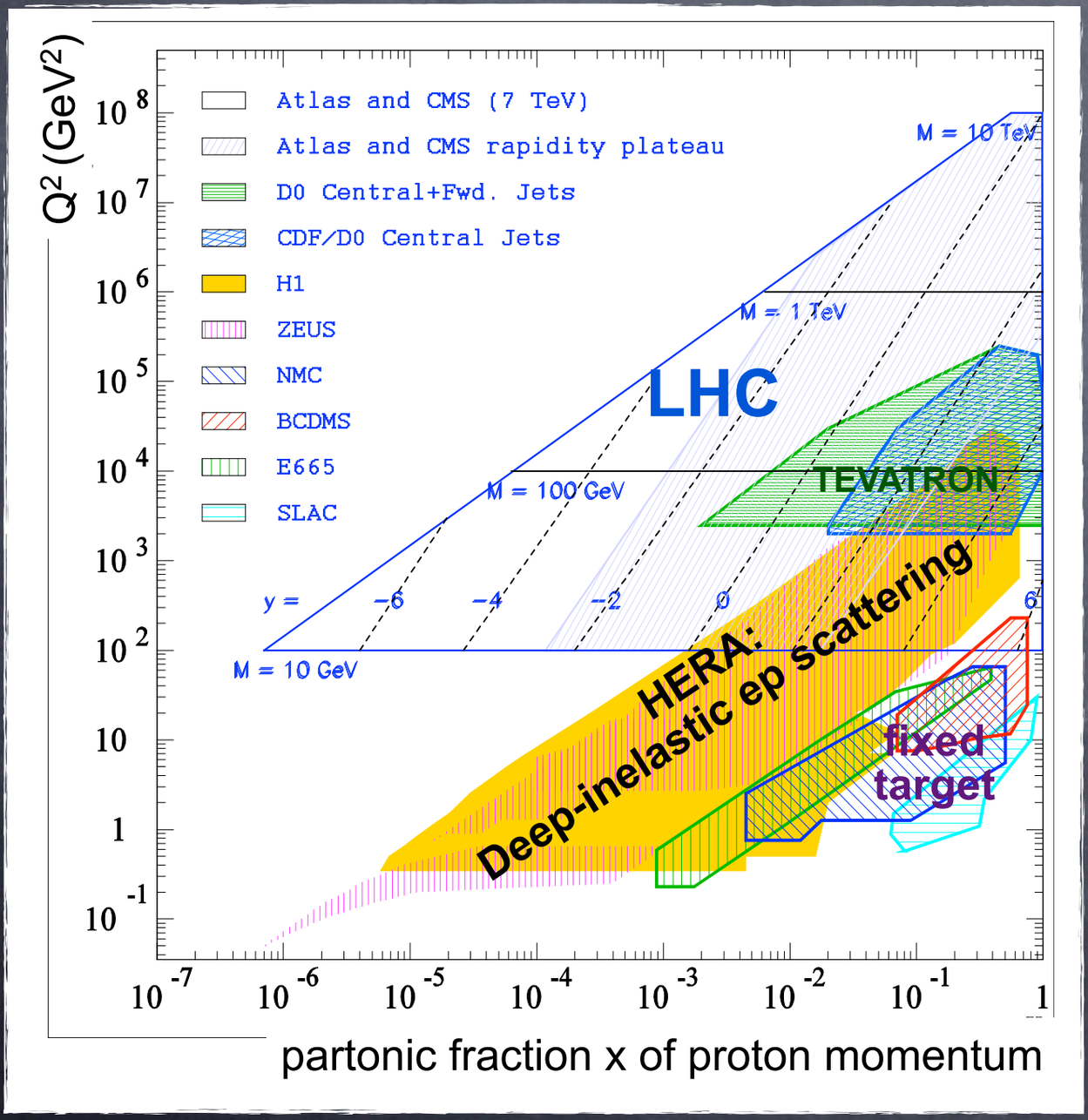
PDF-SENSITIVE MEASUREMENTS

Parton Distribution Functions

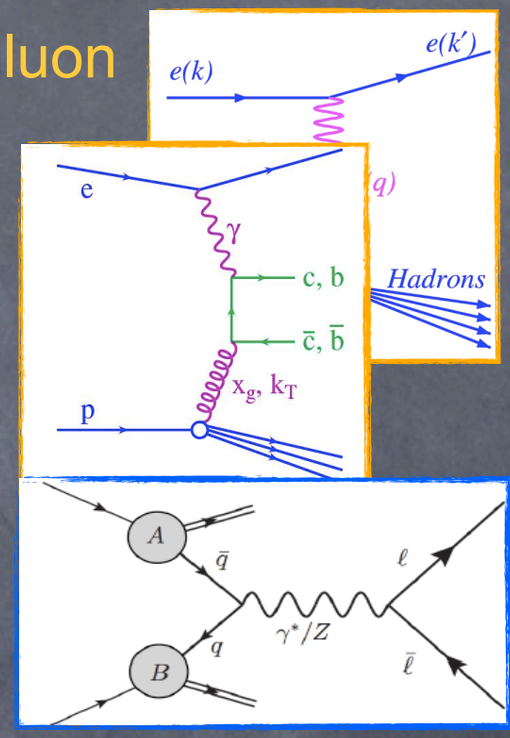
$f_i(Q^2, x)$

provided by theory

determined experimentally



- HERA DIS: quarks, gluon @ low, medium x
- HERA heavy-quarks: gluon, m_c, m_b



- LHC W,Z: light quarks at low and high x

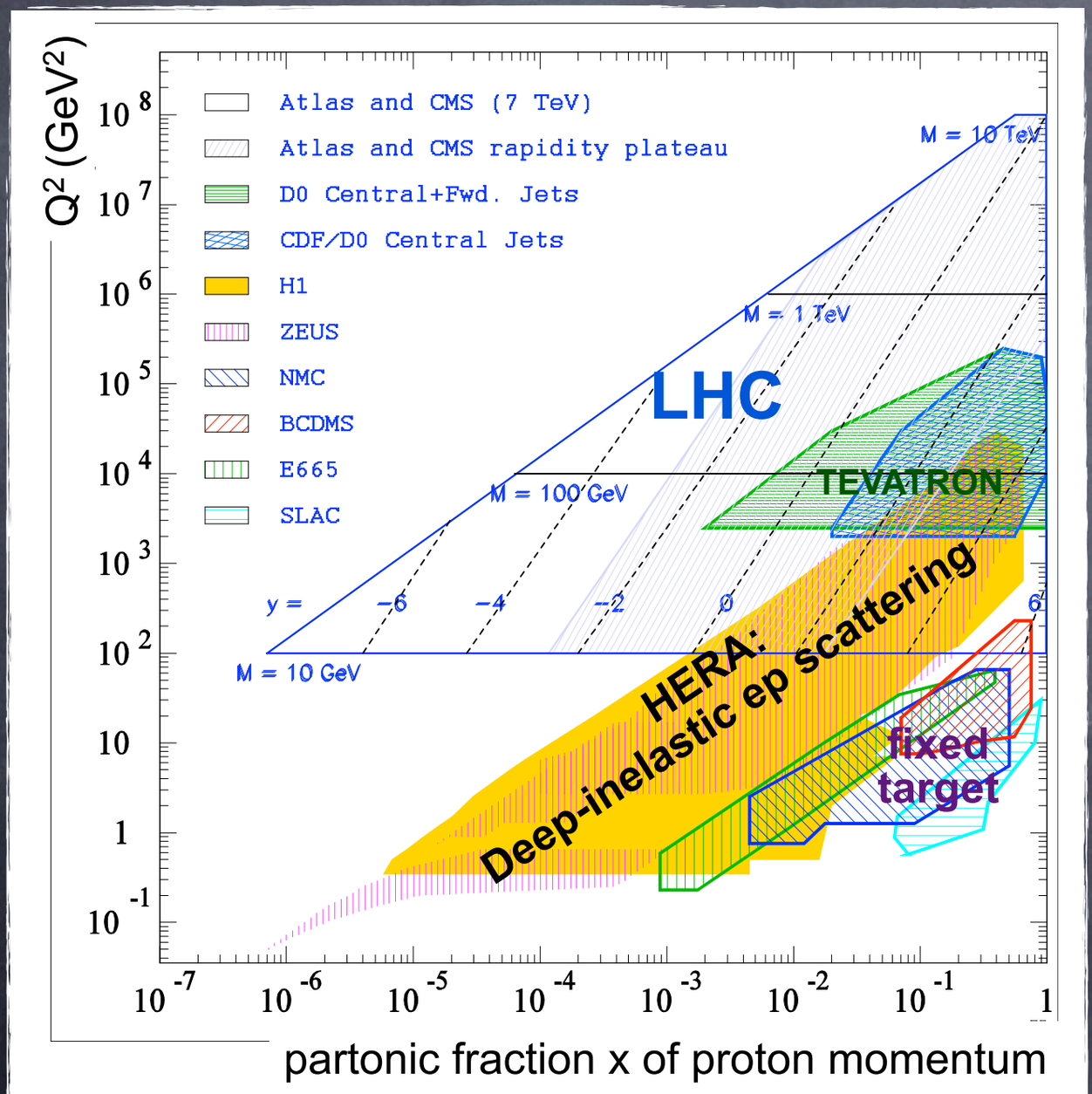
PDF-SENSITIVE MEASUREMENTS

Parton Distribution Functions

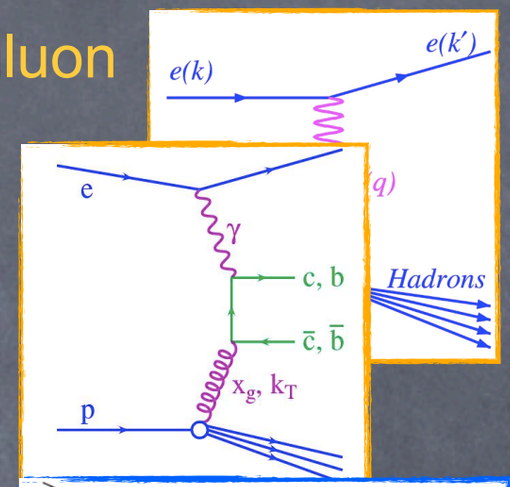
$f_i(Q^2, x)$

provided by theory

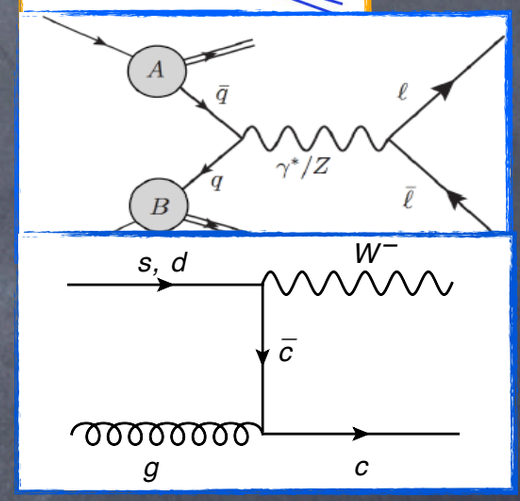
determined experimentally



- HERA DIS: quarks, gluon @ low, medium x
- HERA heavy-quarks: gluon, m_c, m_b



- LHC W,Z: light quarks at low and high x
- LHC W+c: s-quark medium x



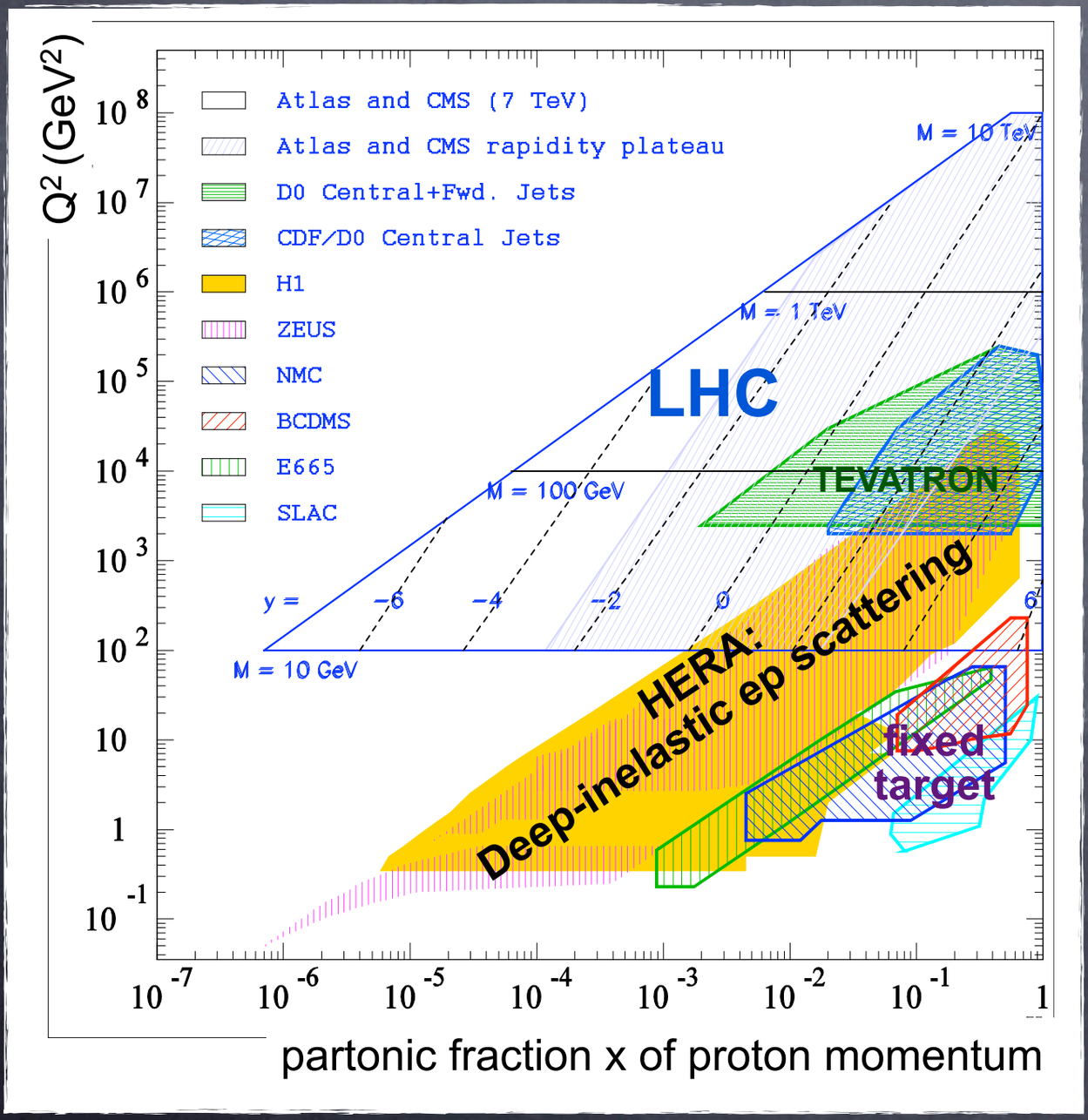
PDF-SENSITIVE MEASUREMENTS

Parton Distribution Functions

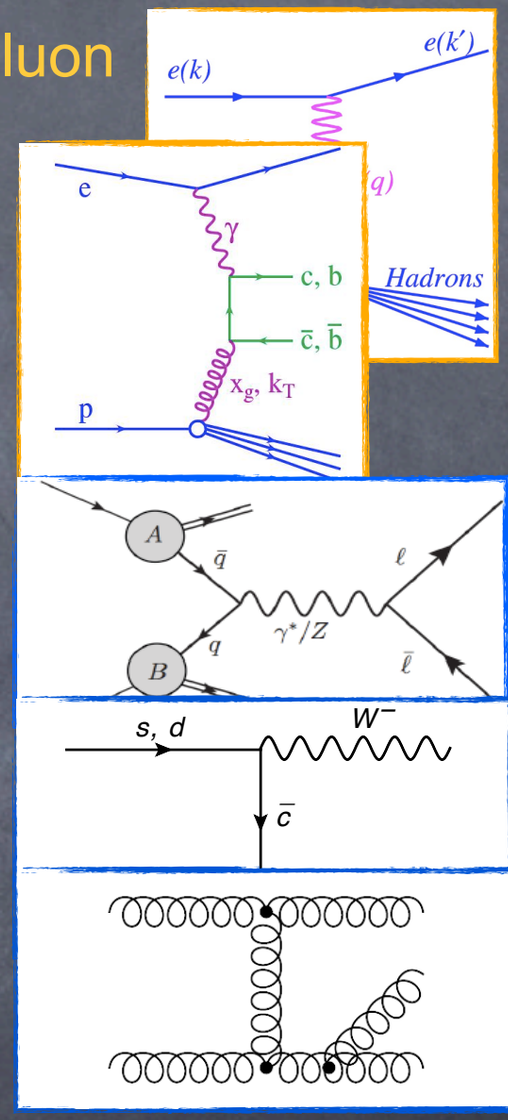
$f_i(Q^2, x)$

provided by theory

determined experimentally



- HERA DIS: quarks, gluon @ low, medium x
- HERA heavy-quarks: gluon, m_c, m_b



- LHC W,Z: light quarks at low and high x
- LHC W+c: s-quark medium x
- LHC jets: gluon at medium x

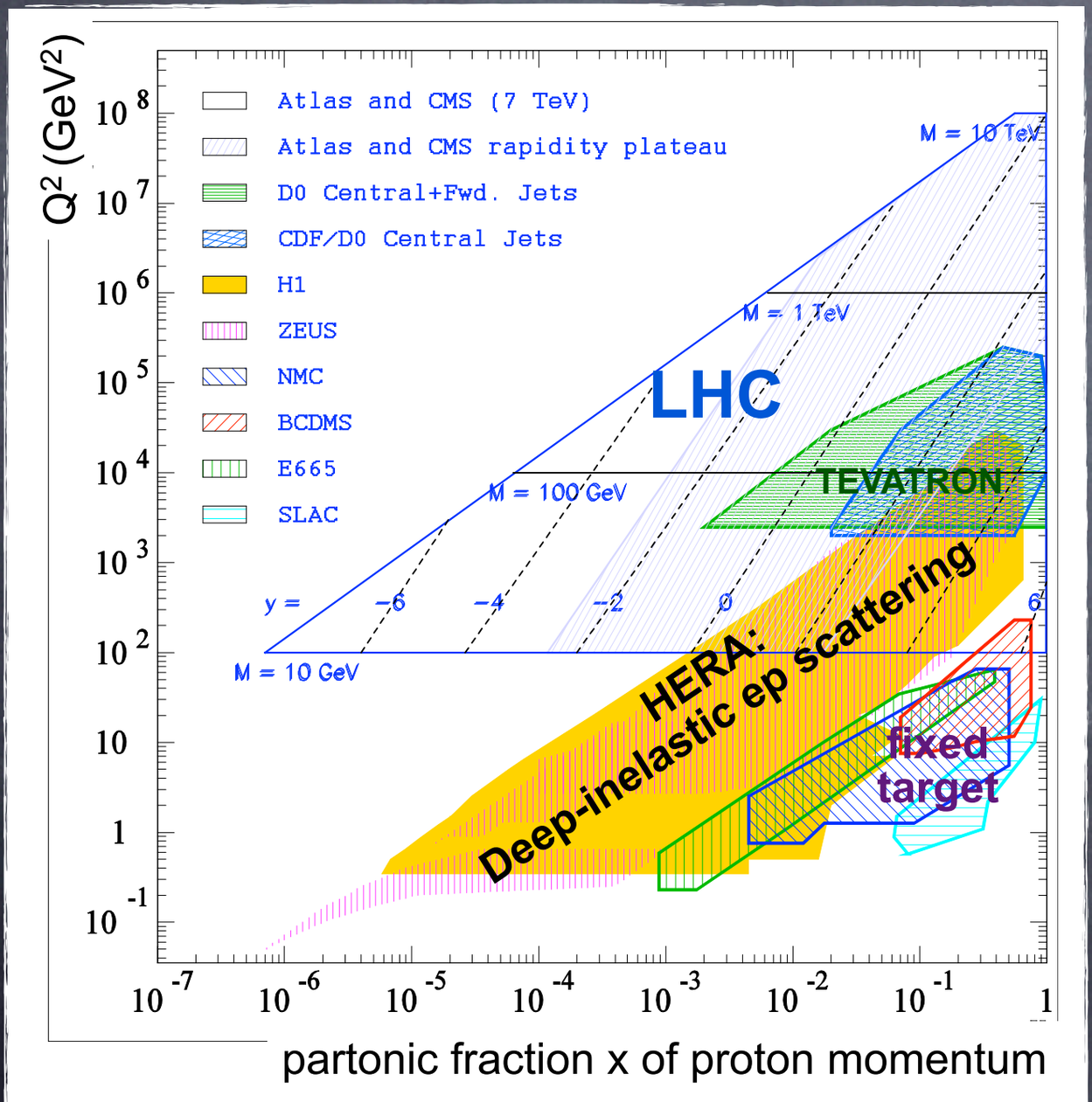
PDF-SENSITIVE MEASUREMENTS

Parton Distribution Functions

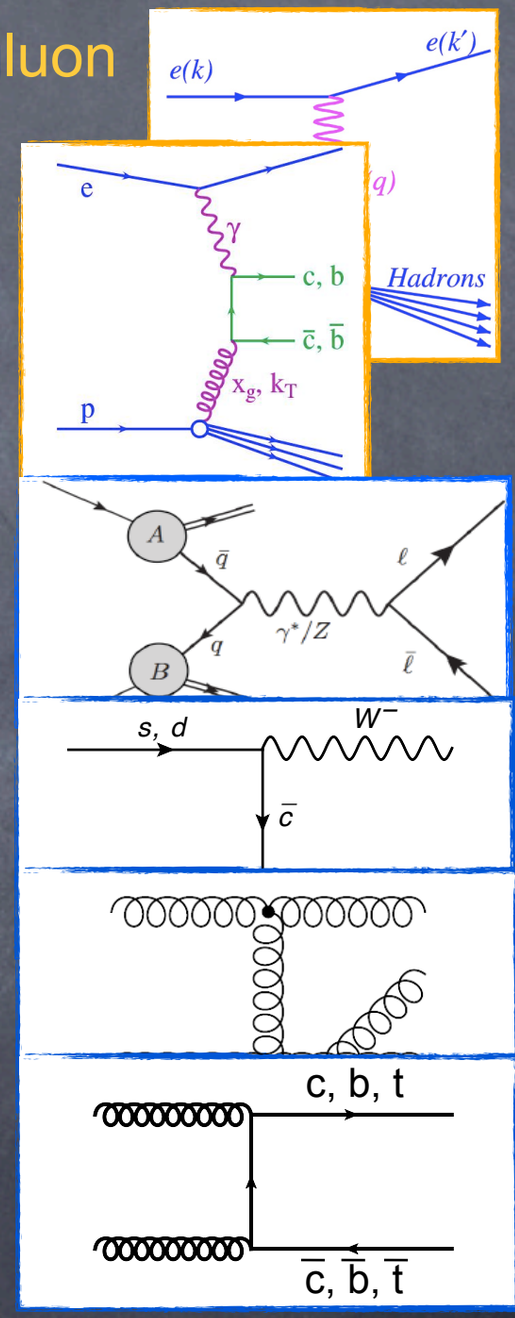
$f_i(Q^2, x)$

provided by theory

determined experimentally



- HERA DIS: quarks, gluon @ low, medium x
- HERA heavy-quarks: gluon, m_c, m_b
- LHC W,Z: light quarks at low and high x
- LHC W+c: s-quark medium x
- LHC jets: gluon at medium x
- LHC HQ-pairs: gluon at low&high x

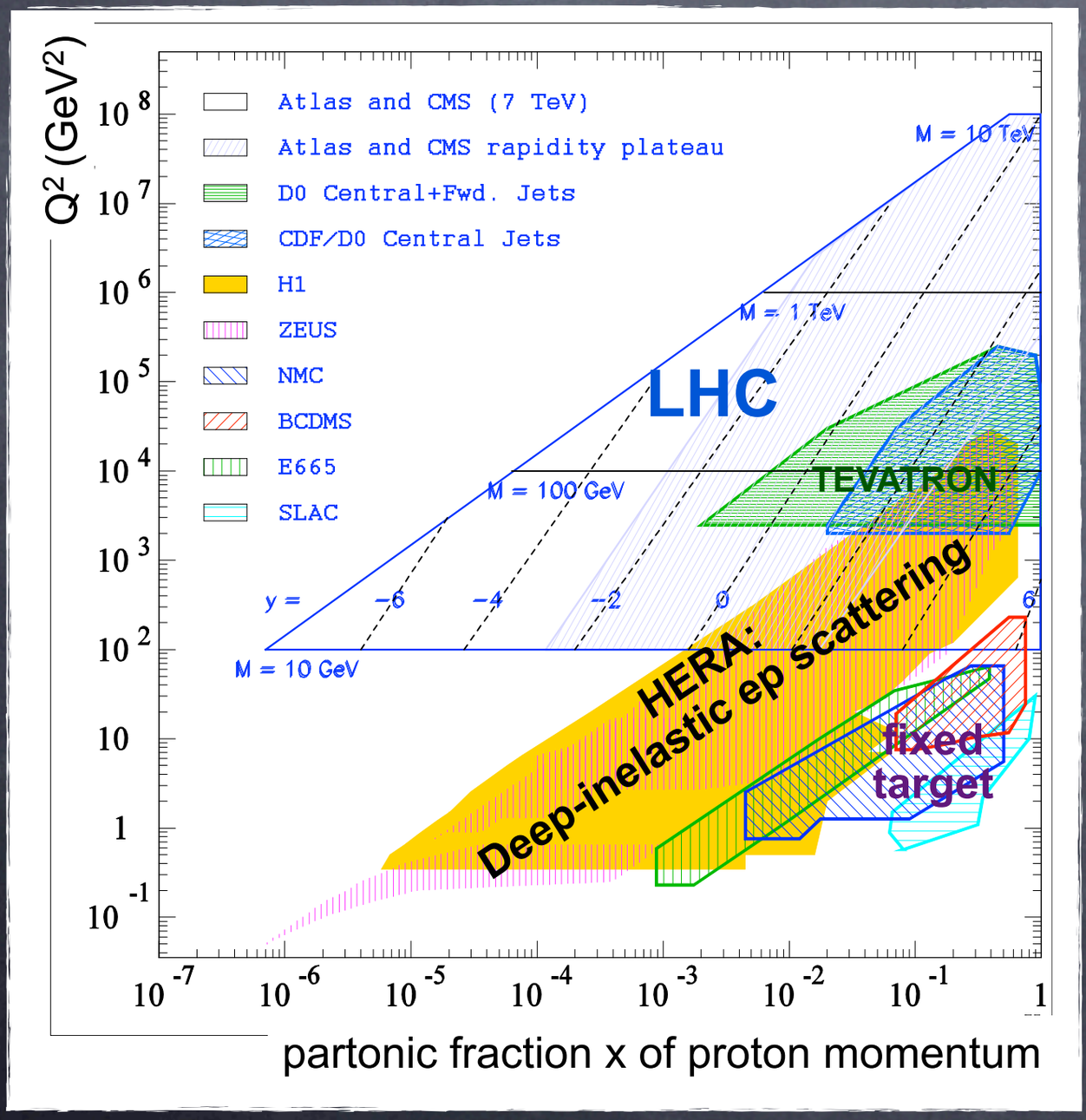


PDF-SENSITIVE MEASUREMENTS

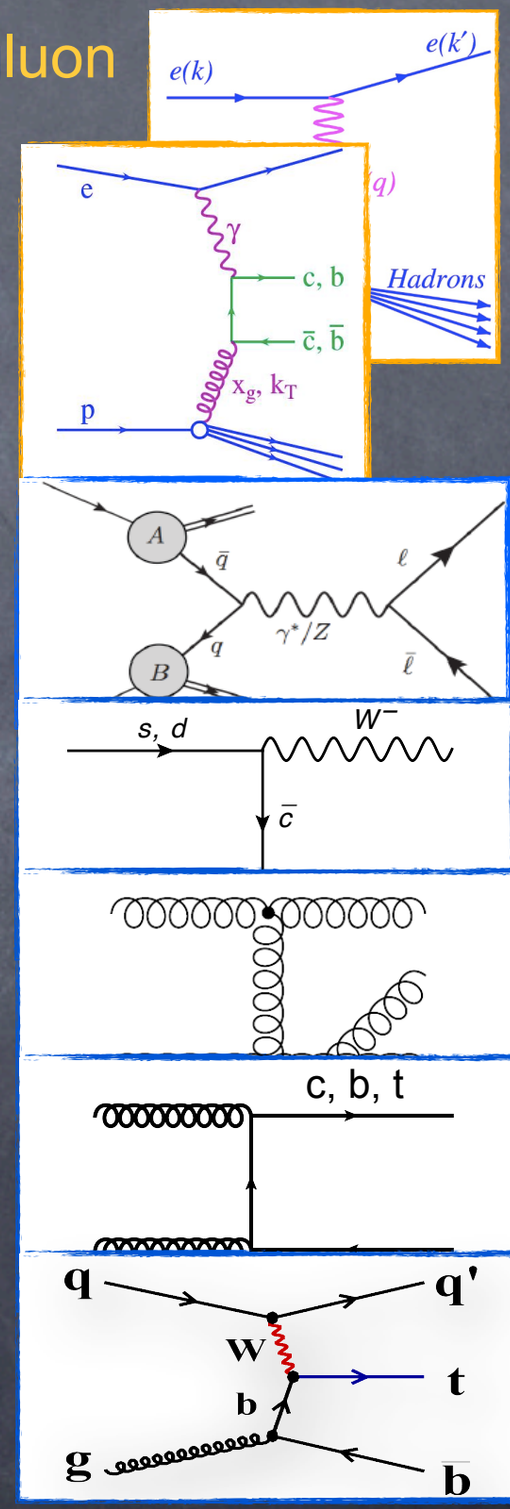
Parton Distribution Functions

$f_i(Q^2, x)$

provided by theory ← → determined experimentally

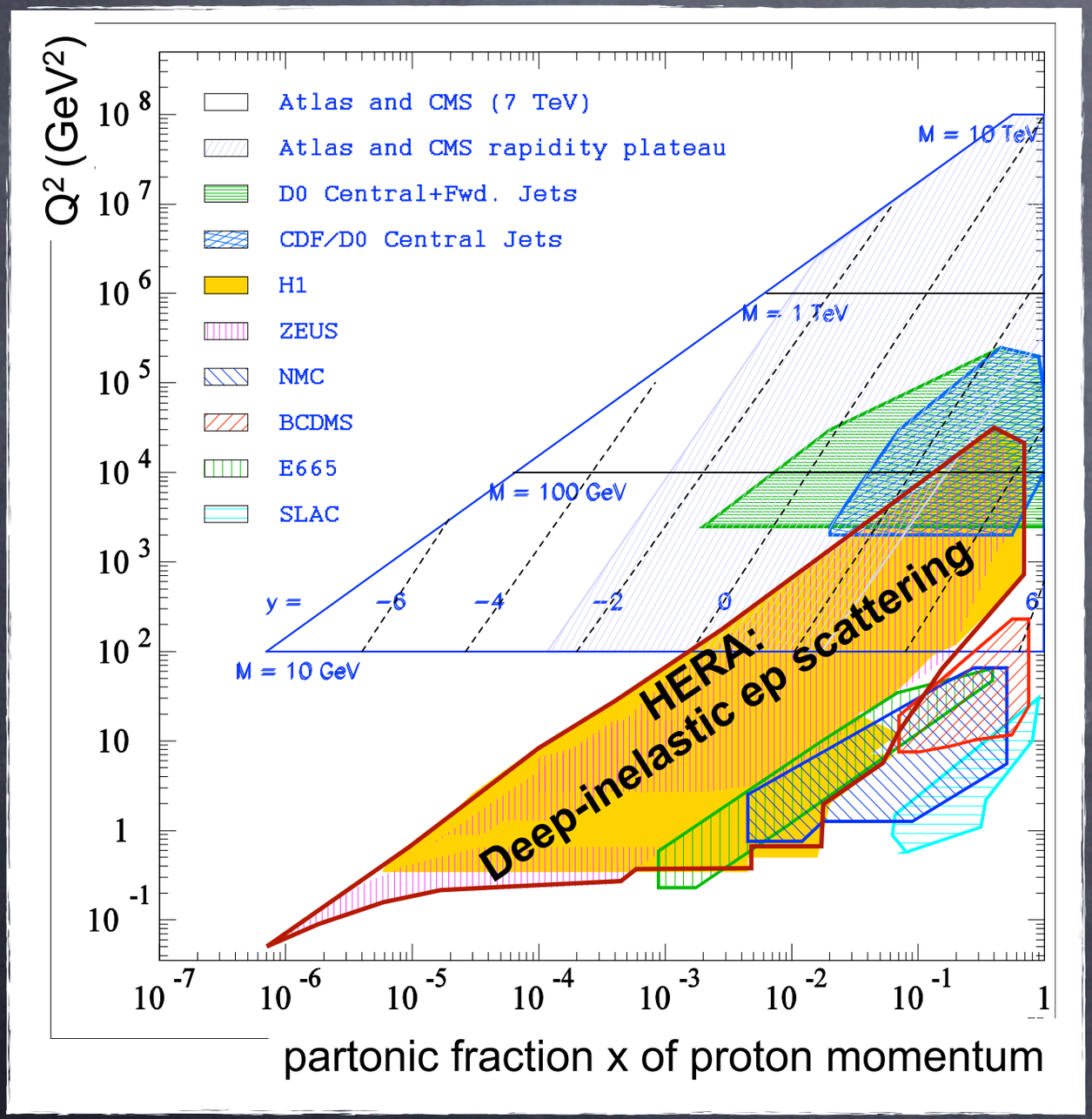


- HERA DIS: quarks, gluon @ low, medium x
- HERA heavy-quarks: gluon, m_c, m_b
- LHC W,Z: light quarks at low and high x
- LHC W+c: s-quark medium x
- LHC jets: gluon at medium x
- LHC HQ-pairs: gluon at low&high x
- LHC single top u, d and b quarks

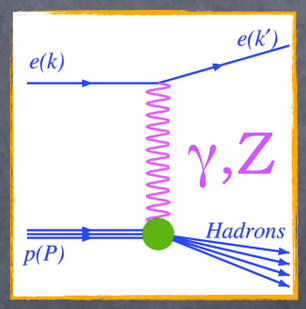


FINAL WORD ON HERA DATA

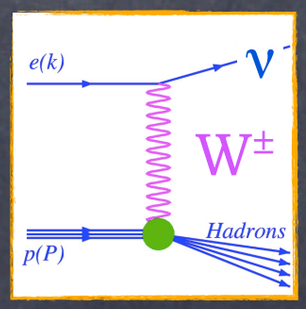
Backbone of any PDF determination
Deep-Inelastic Scattering at HERA:
world-only $e^{\pm}p$ ring accelerator, $\sqrt{s_{max}}$= 318 GeV



HERA I 1992-2000,
HERA II 2003-2007
collider experiments H1 & ZEUS,
integrated Luminosity ~0.5 fb^{-1} /experiment



neutral current:
valence-quark distributions
gluon via scaling violations

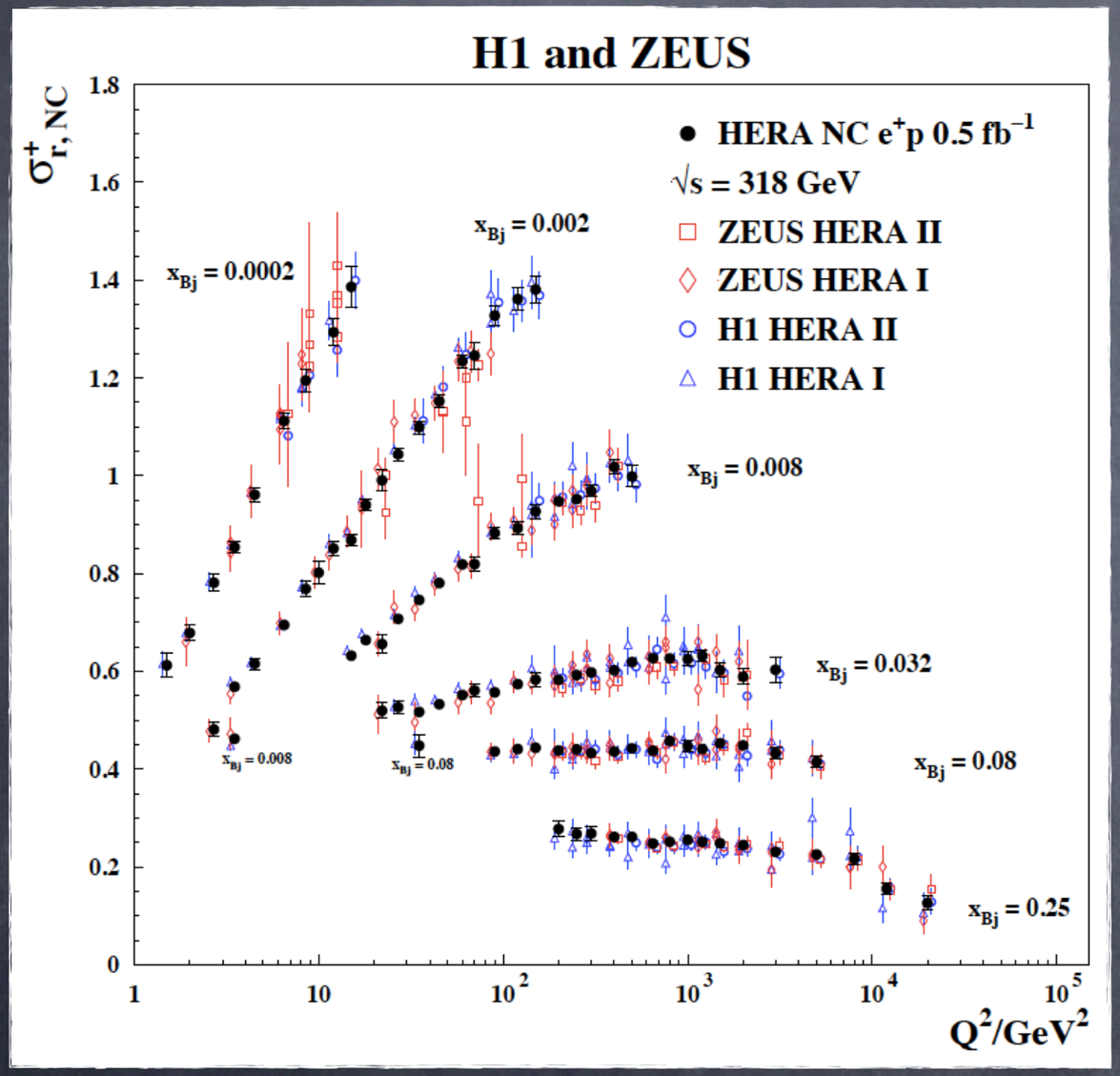


charged current:
quark flavour separation

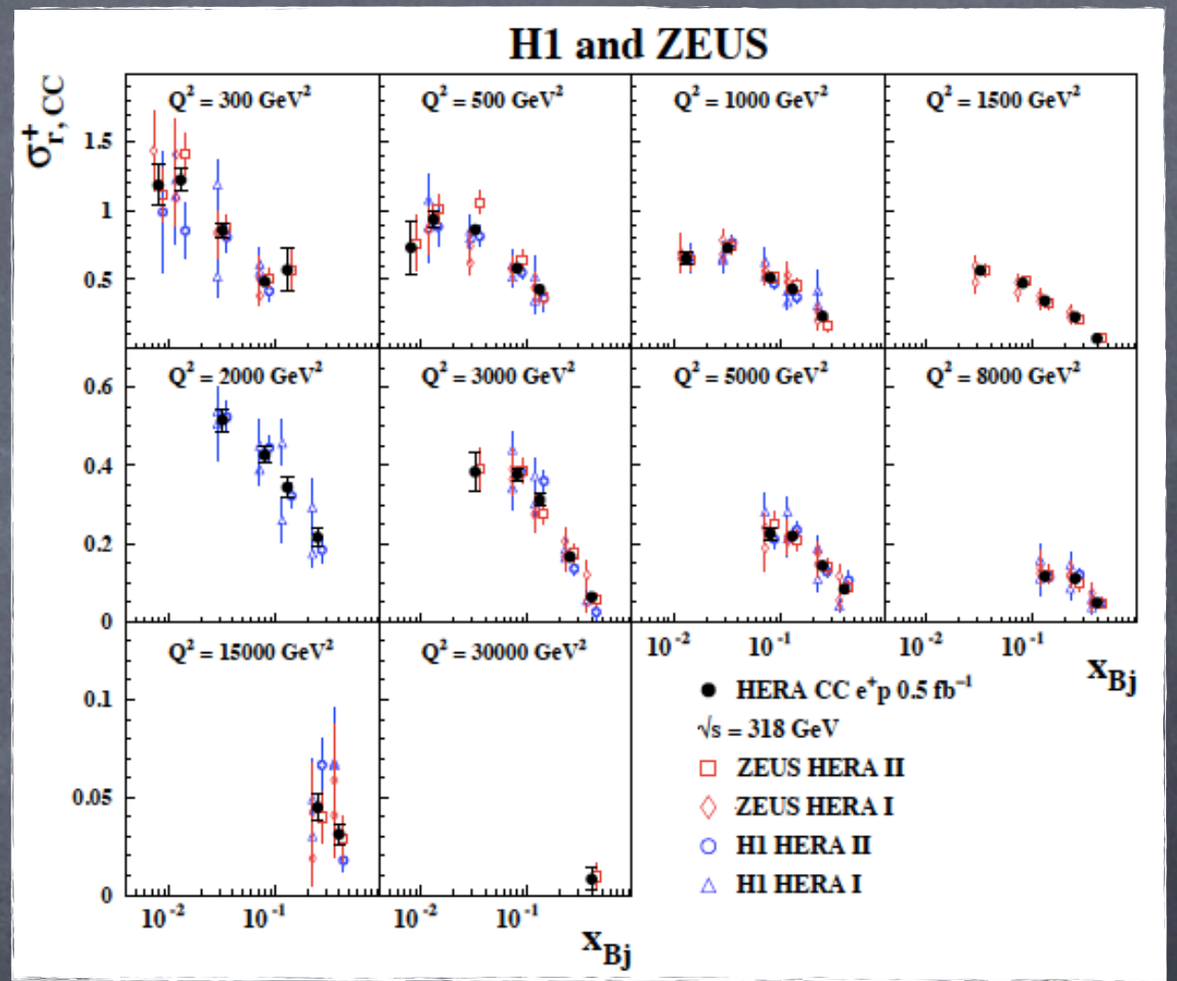
FINAL WORD ON HERA DATA

Sneak-preview: combined HERA data (to be presented at DIS2015 next week)

neutral current e^+p:



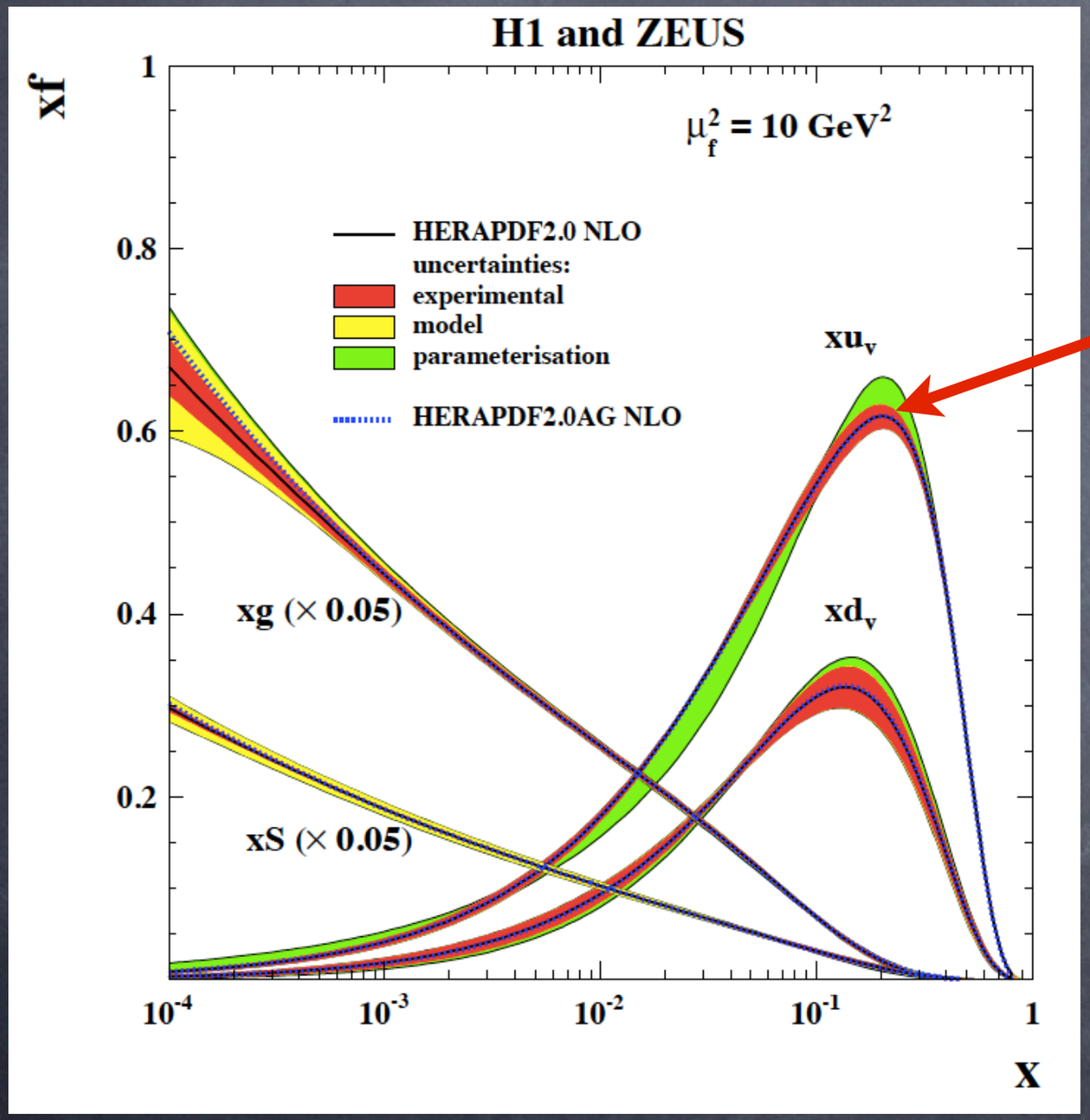
charged current e^+p:



In the combination, all correlations of systematic uncertainties accounted for. A single consistent set of most precise DIS measurements.

HERAPDF2.0

HERAPDF2.0: based exclusively on HERA DIS data, obtained at LO, NLO and NNLO



14 parameter fit, NLO DGLAP
Heavy quarks: massive
Variable Flavour Number Scheme
Scales: $\mu_r = \mu_f = Q^2$
Experimentally very precise

Parameterization at starting scale:

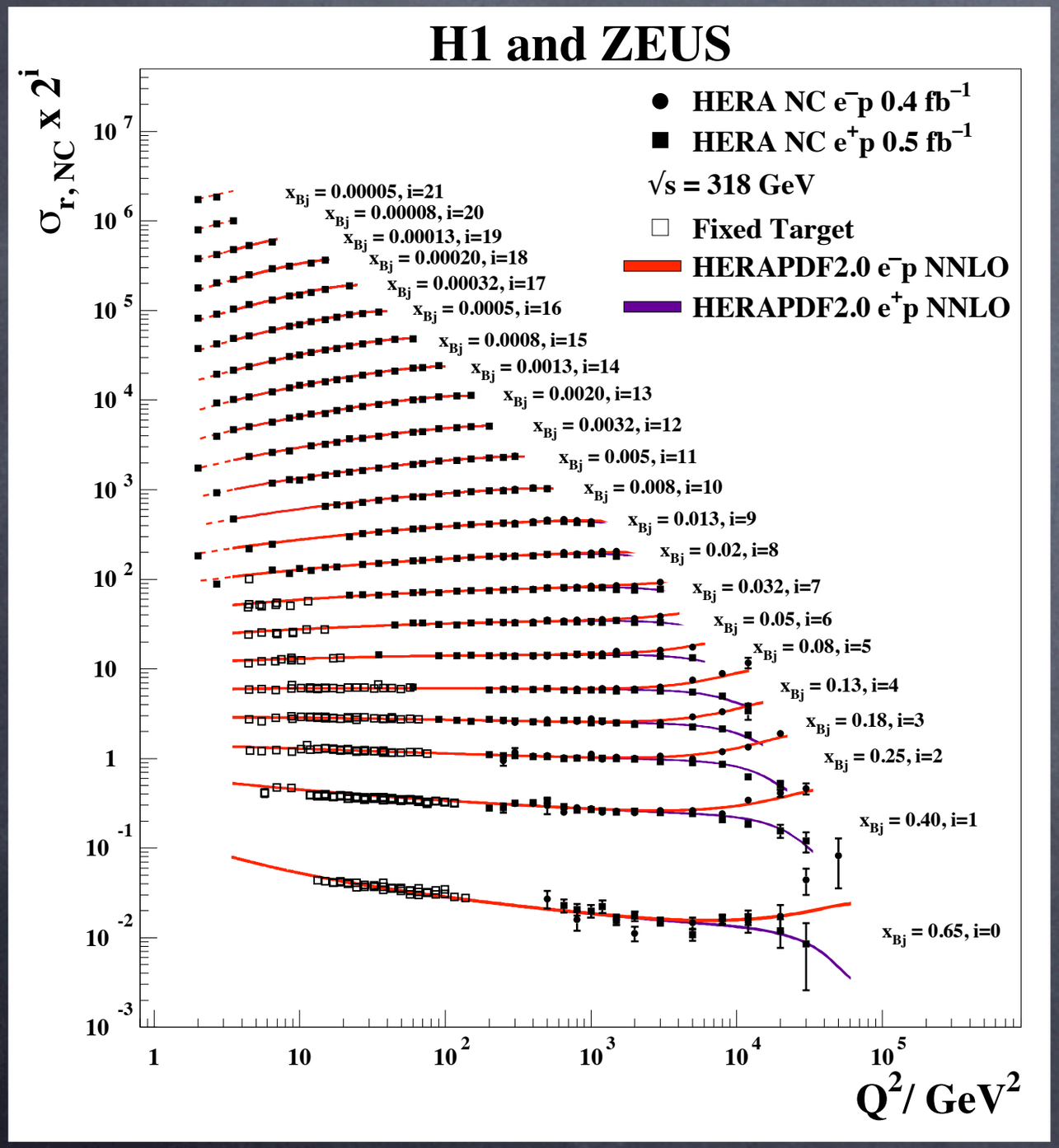
$$
\begin{aligned}
xg(x) &= A_g x^{B_g}(1-x)^{C_g} - A'_g x^{B'_g}(1-x)^{C'_g}, \\
xu_v(x) &= A_{u_v} x^{B_{u_v}}(1-x)^{C_{u_v}}\left(1 + E_{u_v}x^2\right), \\
xd_v(x) &= A_{d_v} x^{B_{d_v}}(1-x)^{C_{d_v}}, \\
x\bar{U}(x) &= A_{\bar{U}} x^{B_{\bar{U}}}(1-x)^{C_{\bar{U}}}\left(1 + D_{\bar{U}}x\right), \\
x\bar{D}(x) &= A_{\bar{D}} x^{B_{\bar{D}}}(1-x)^{C_{\bar{D}}}.
\end{aligned}
$$

Model assumptions and variations
(m_{HQ}, strangeness in the sea, Q^2_0, α_S)

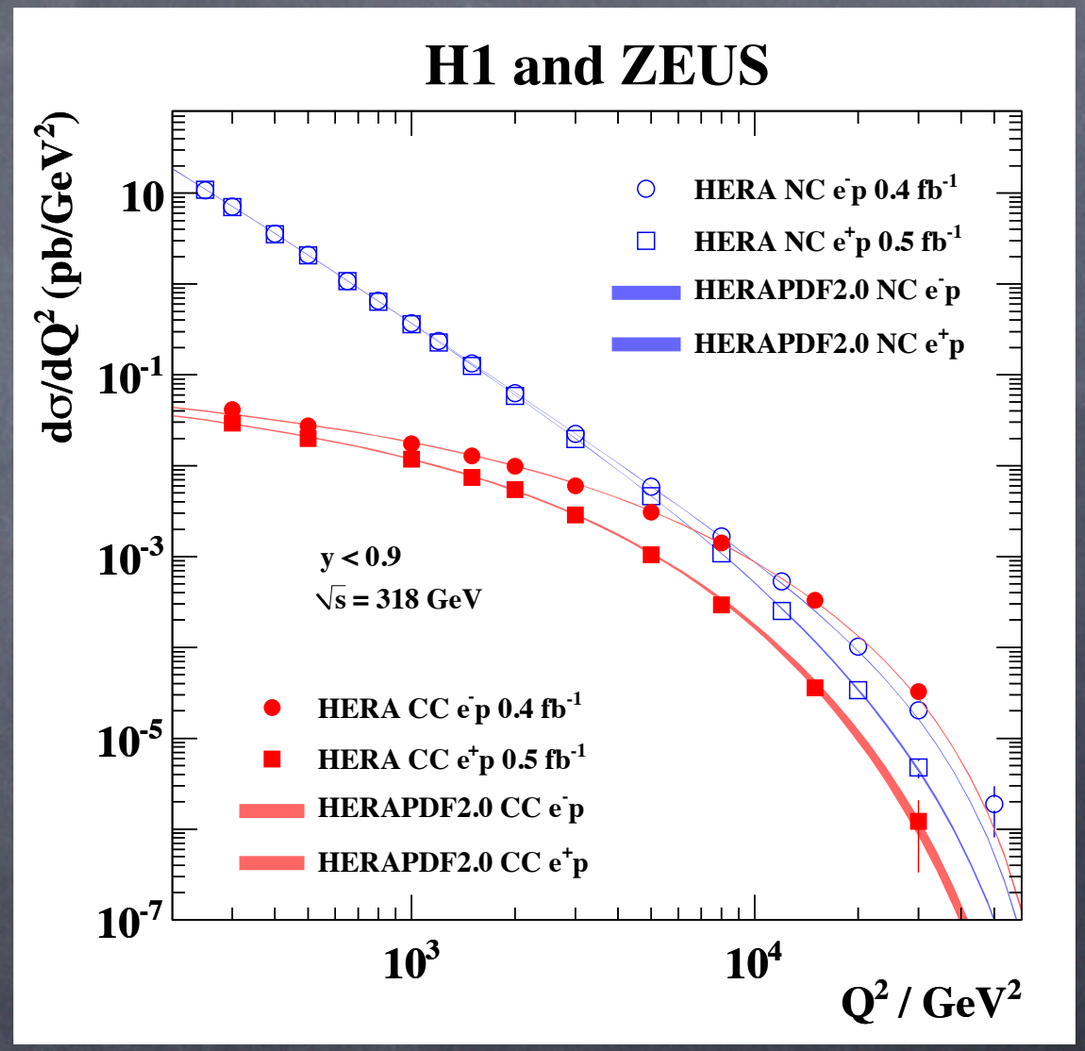
PDFs also determined by including HERA data on heavy-flavor and jet production

HERAPDF2.0 VS DATA

Scaling violations, Z/γ interference ...



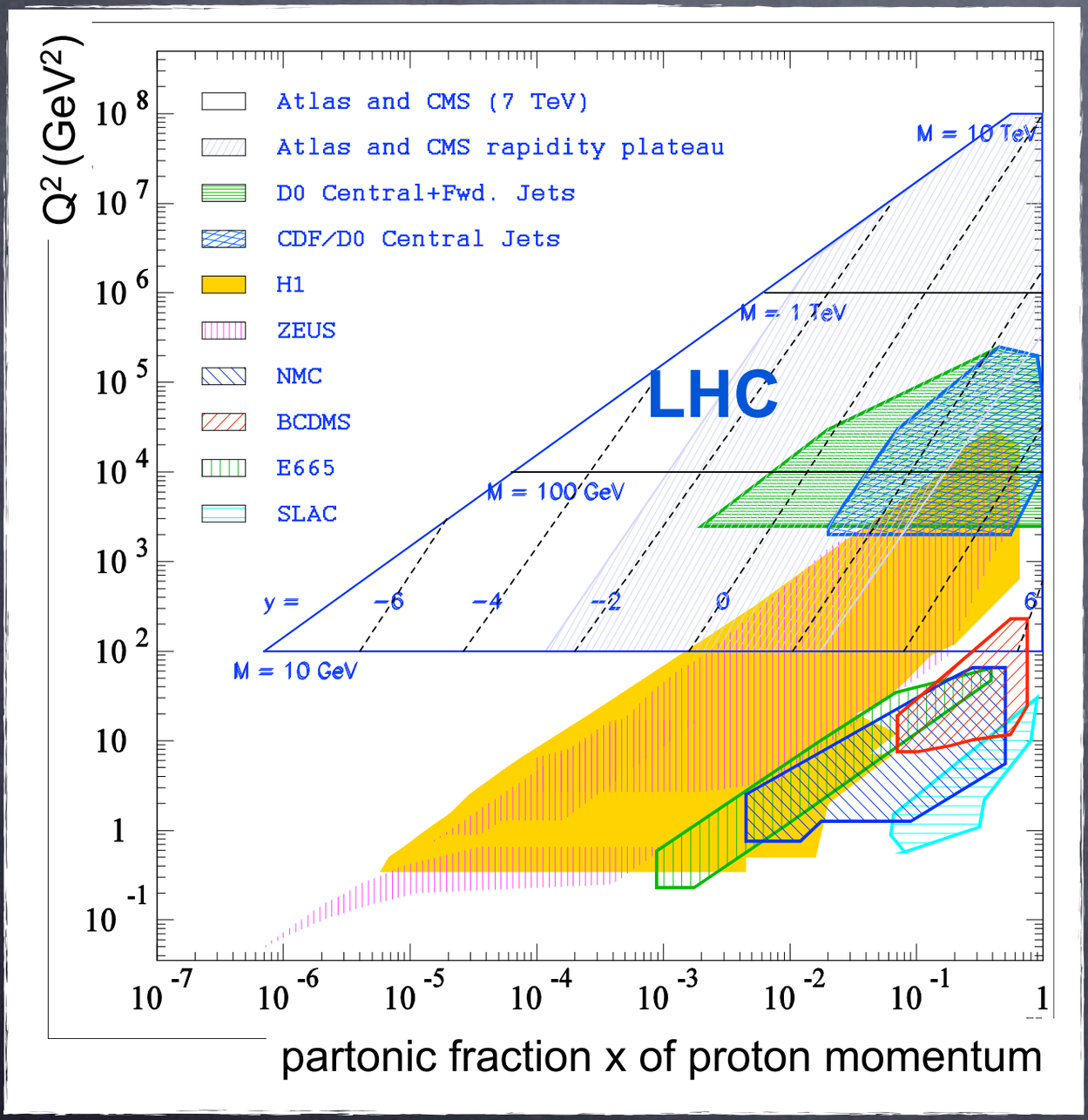
and electroweak unification



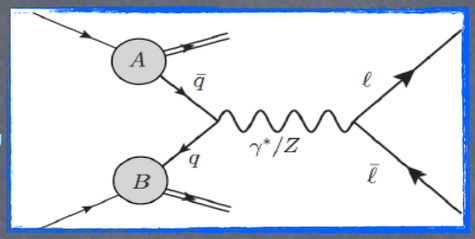
at ultimate precision !

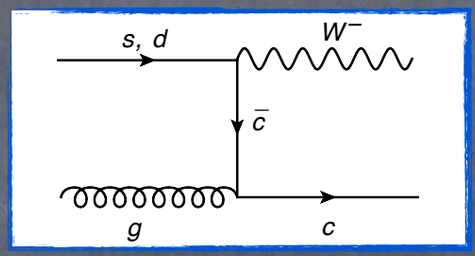
PDF CONSTRAINTS FROM LHC

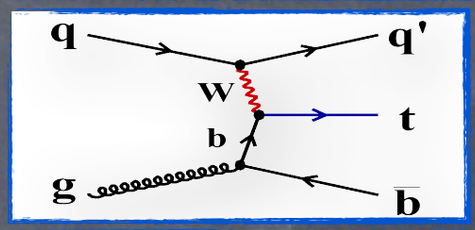
need improvements in
quark flavor separation at medium x,
gluon at low and at high x
➡ impact of the LHC measurements

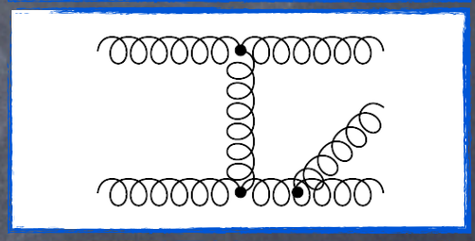


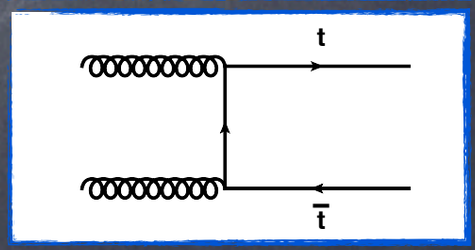
- DY: light quarks, flavor separation, gluon
- W+c: s-quark
- single top: u, d, b
- jets: gluon, α_S medium x
- top-pairs: gluon high x
- forward c, b: gluon low & high x

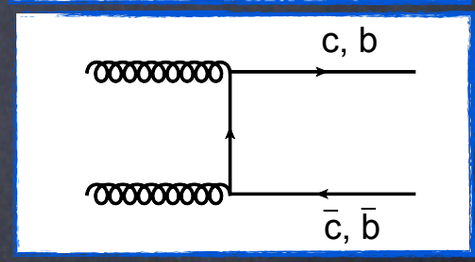






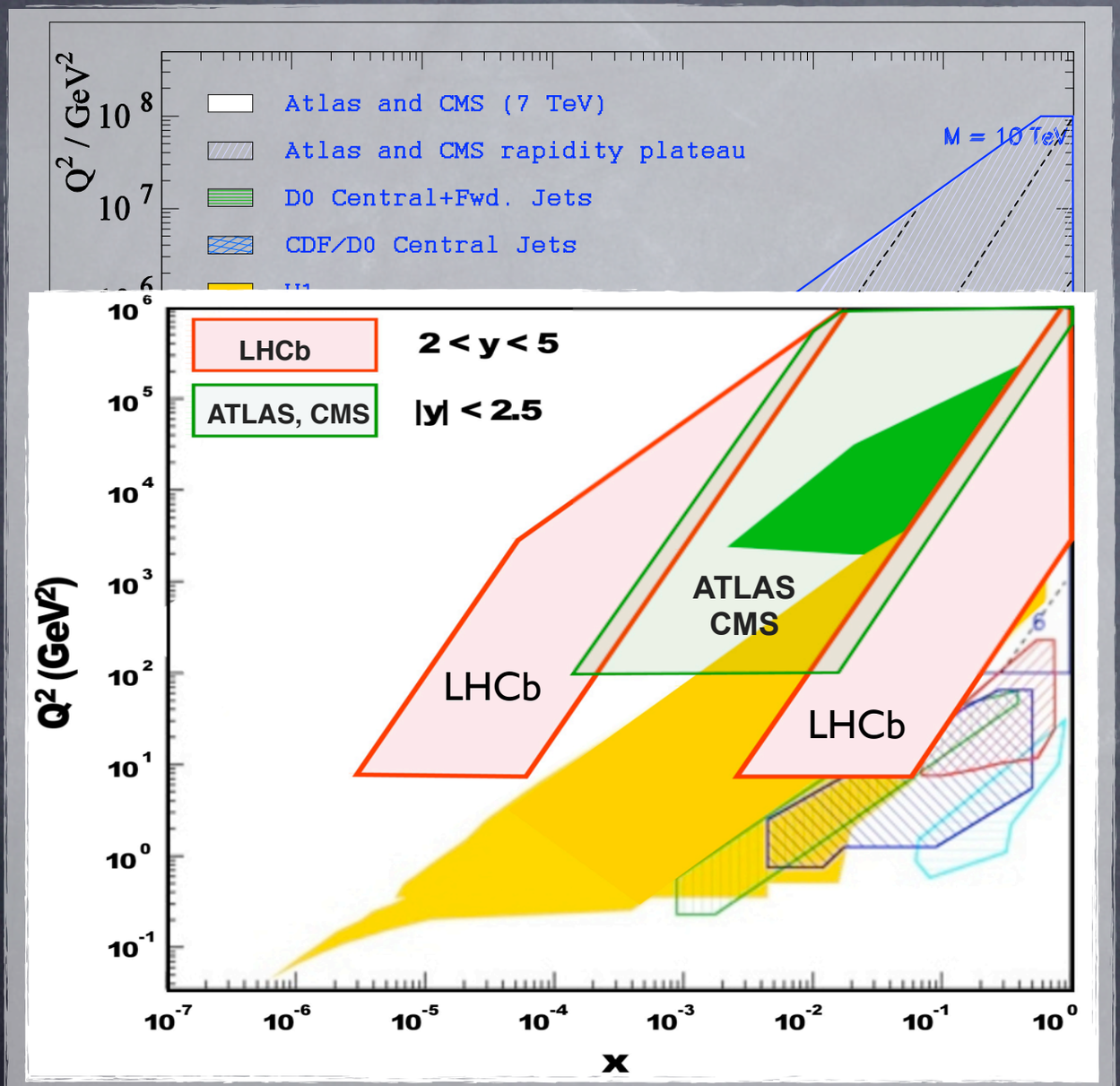




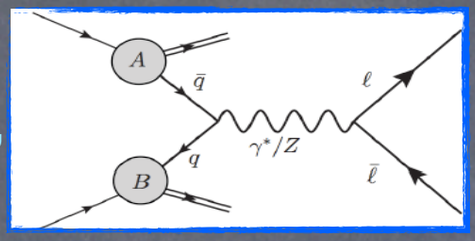


PDF CONSTRAINTS FROM LHC

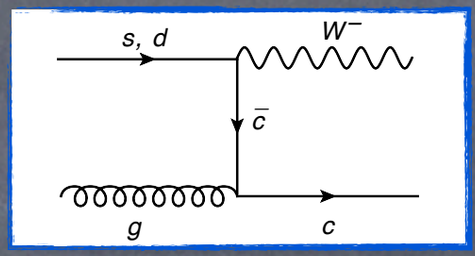
need improvements in
quark flavor separation at medium x,
gluon at low and at high x
➡ impact of the LHC measurements



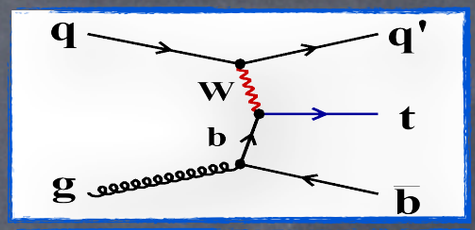
- DY: light quarks, flavor separation, gluon



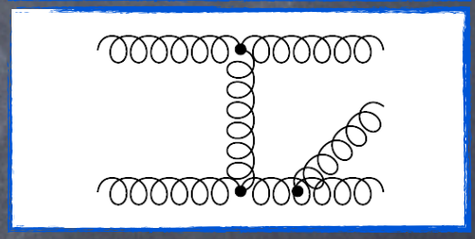
- W+c: s-quark



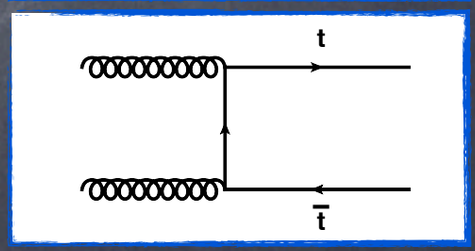
- single top: u, d, b



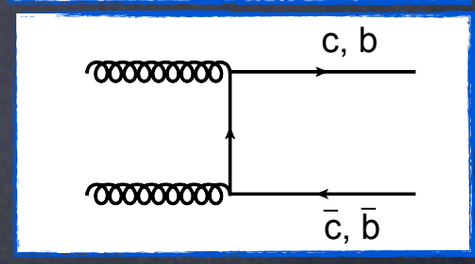
- jets: gluon, α_S medium x



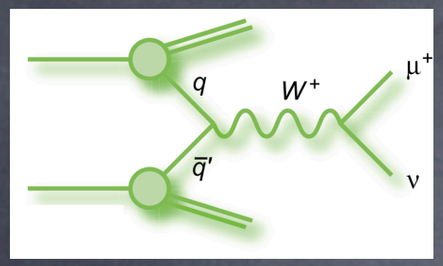
- top-pairs: gluon high x



- forward c, b: gluon low & high x

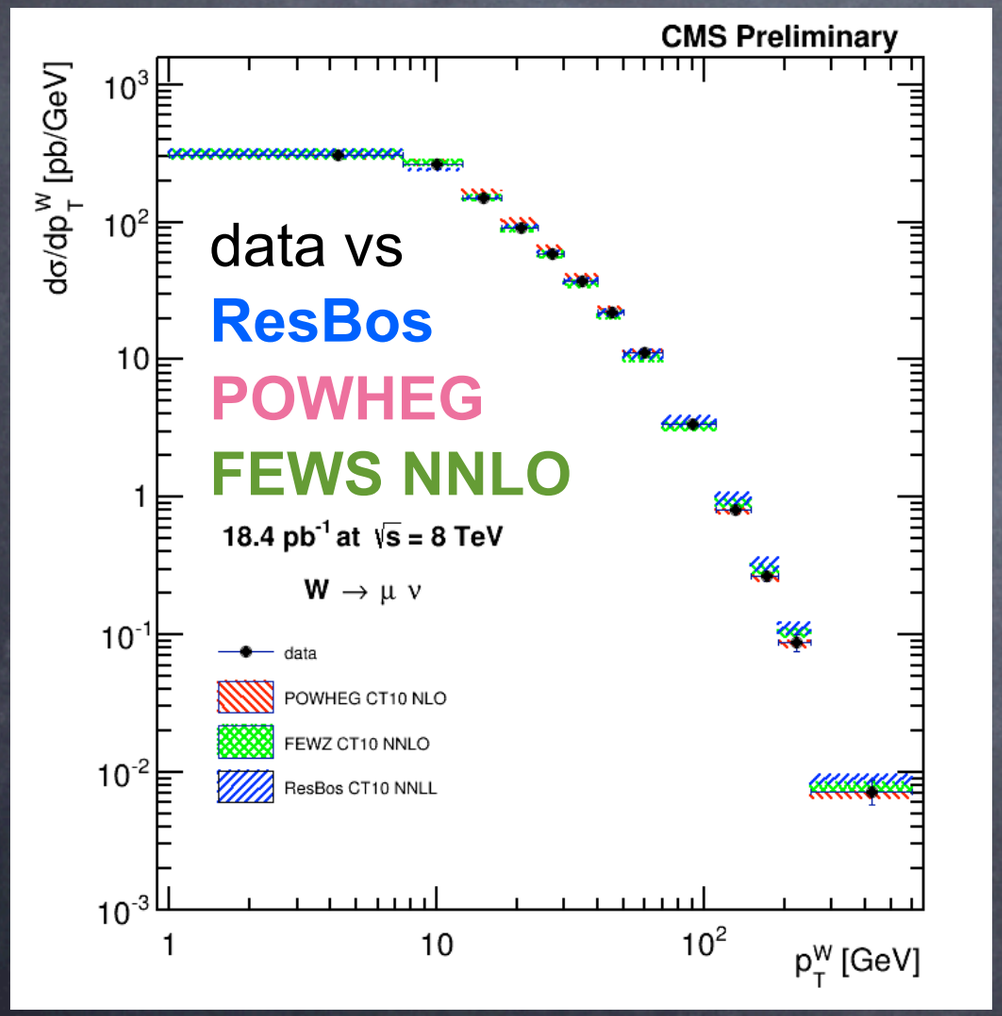


PROBING PDFs WITH W-BOSON PRODUCTION

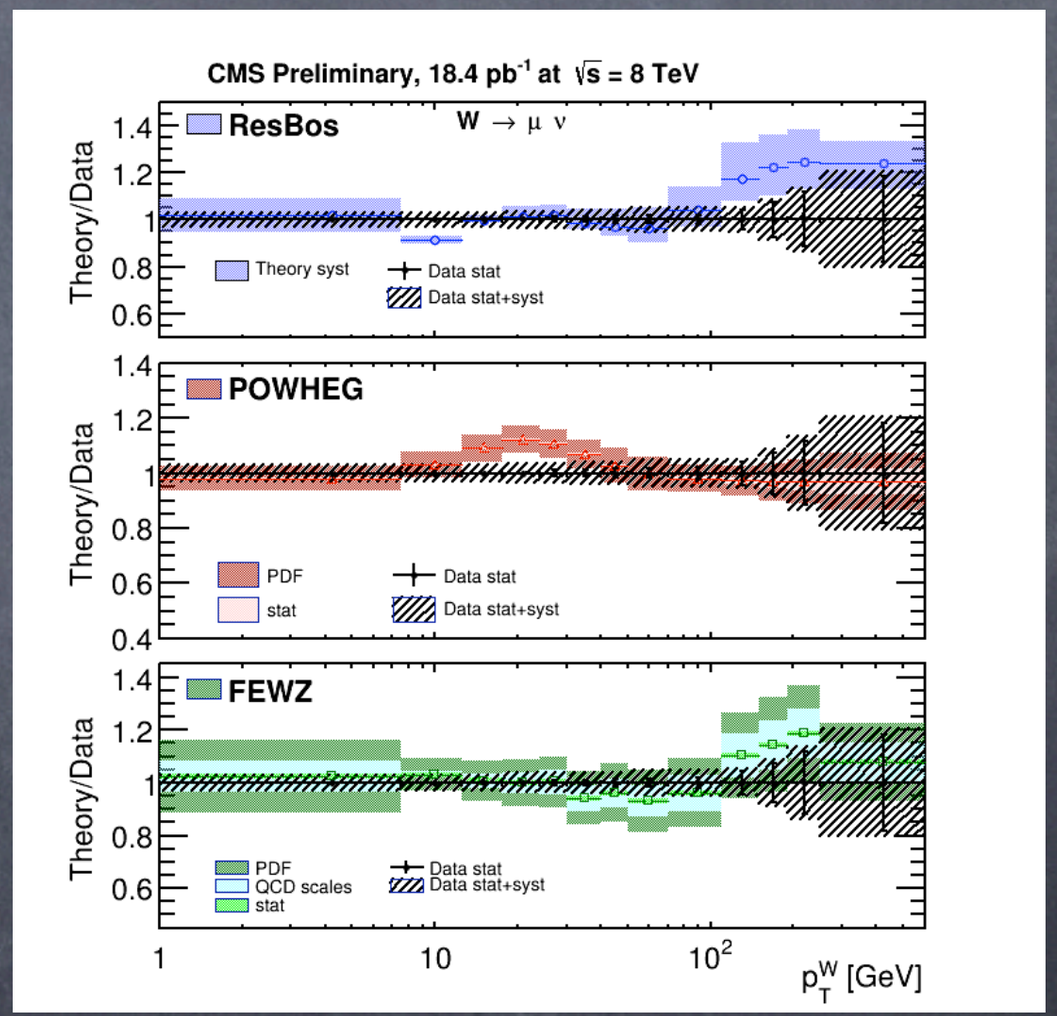


In pp collisions, production of NC and CC Drell-Yan events probes light quark distributions in the proton

W-boson production at 8 TeV, electron and muon channels, $\mathcal{L}$ = 18.4 pb^{-1}



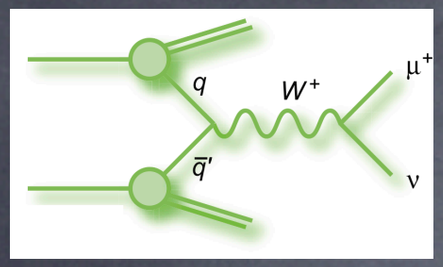
CMS PAS SMP-13-006



CMS PAS SMP-13-006

Expect PDF constraints in particular at lower p_T(W)

PROBING PDFs WITH W-BOSON PRODUCTION

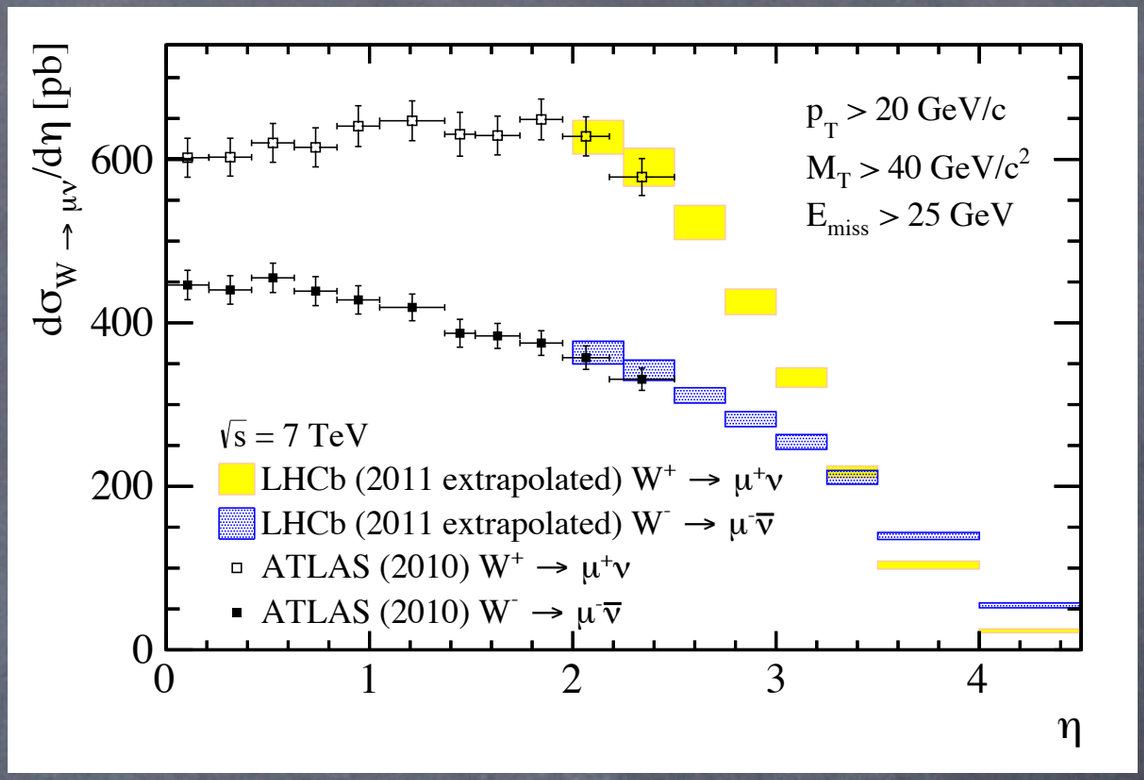


production of W^+ or W^- probes different flavors

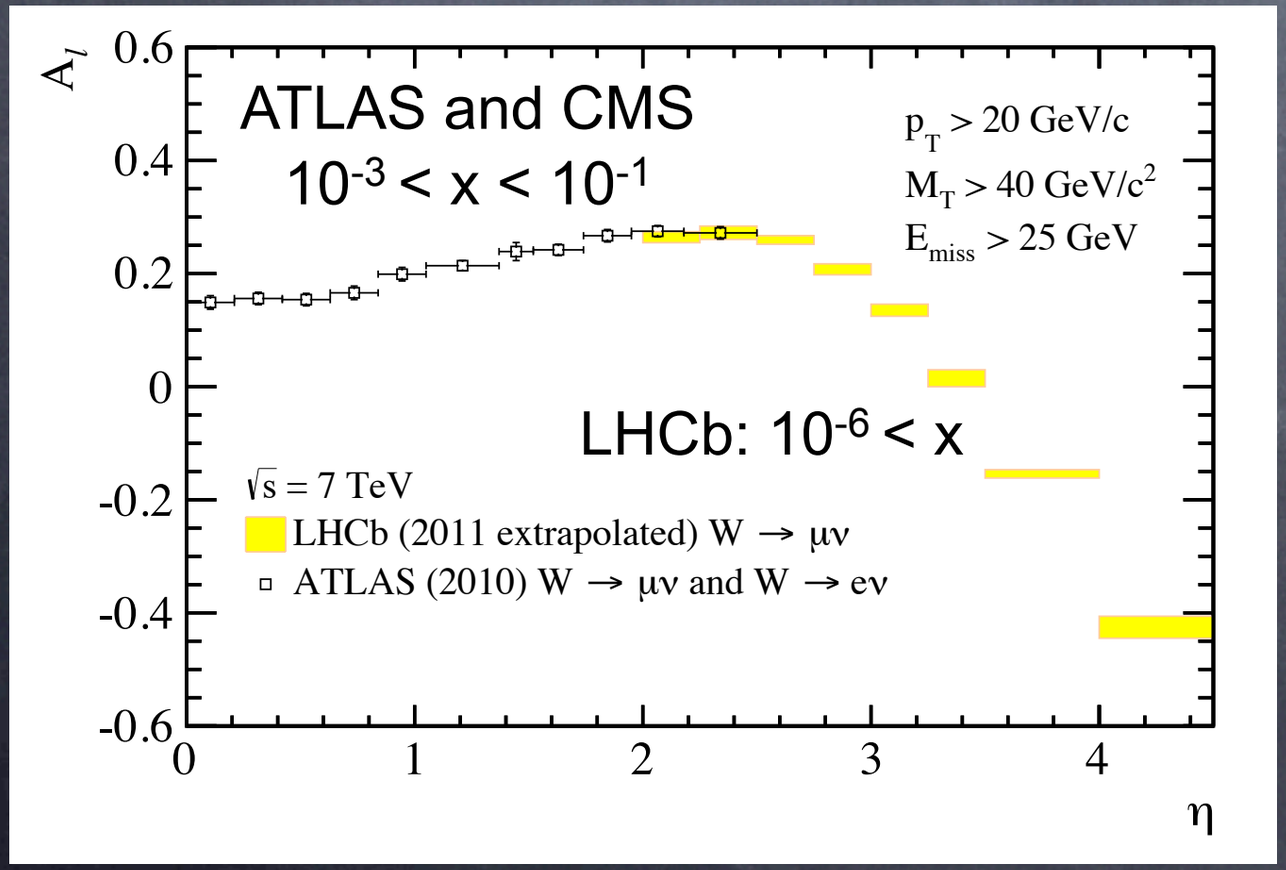
Lepton-charge asymmetry constrains valence

$$A_W = \frac{W^+ - W^-}{W^+ + W^-} \approx \frac{u_v - d_v}{u_v + d_v + 2u_{sea}}$$

[LHCb] JHEP 12 (2014) 079

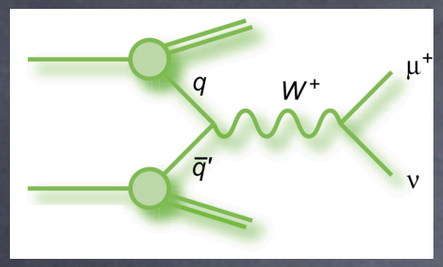


[LHCb] JHEP 12 (2014) 079



NB: For comparison, LHCb results are extrapolated to the fiducial volume of ATLAS, correcting for $M_T > 40$ and $E_T > 20$

PROBING PDFs WITH W-BOSON PRODUCTION

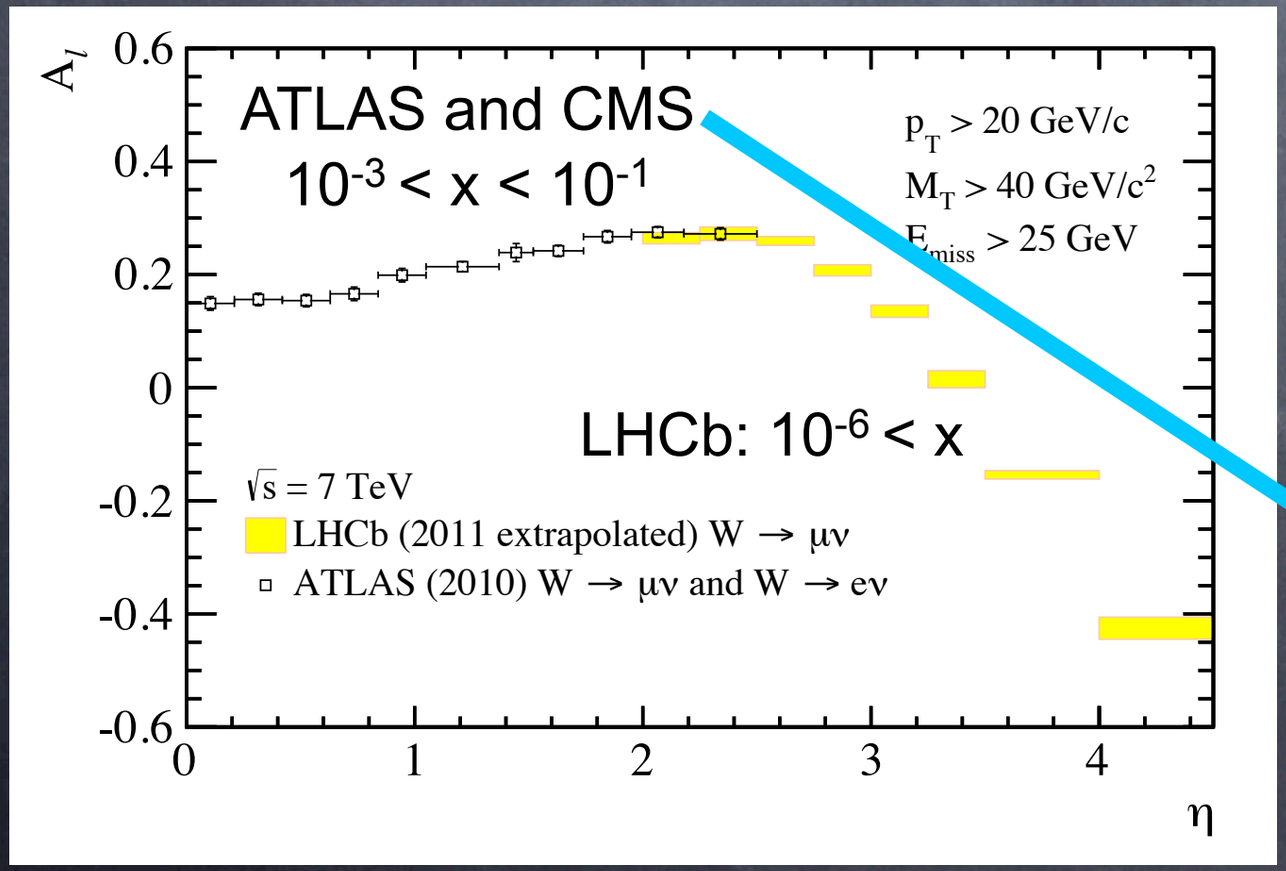


production of W^+ or W^- probes different flavors

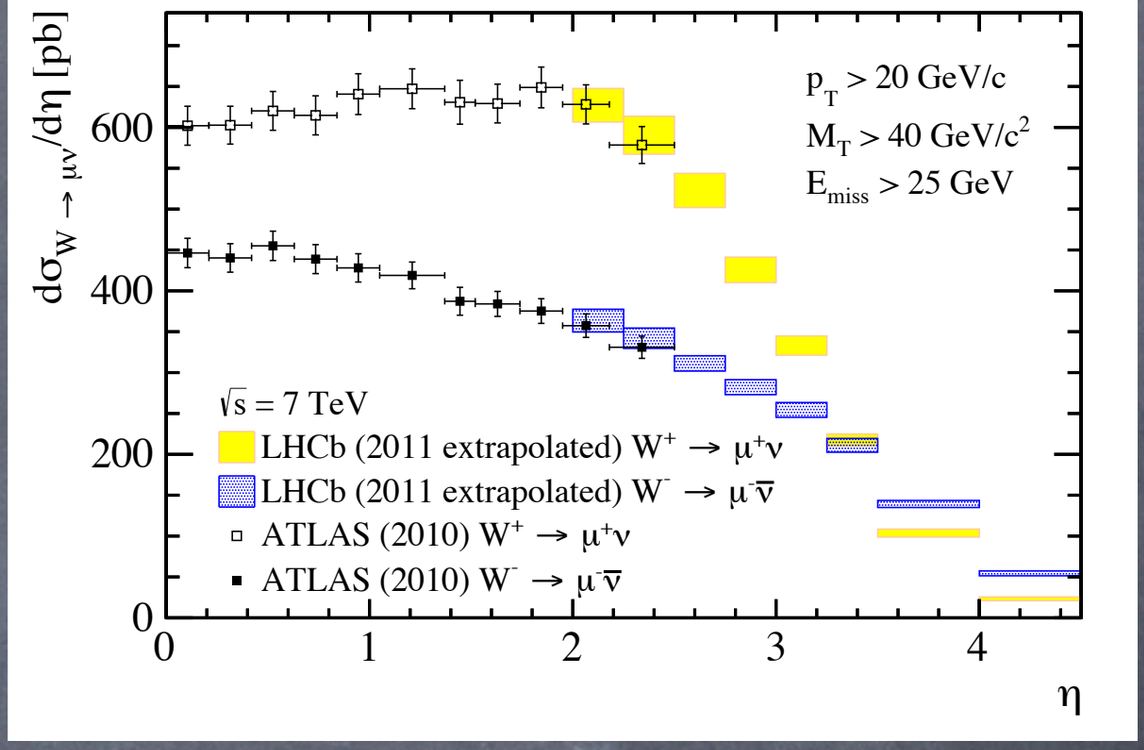
Lepton-charge asymmetry constrains valence

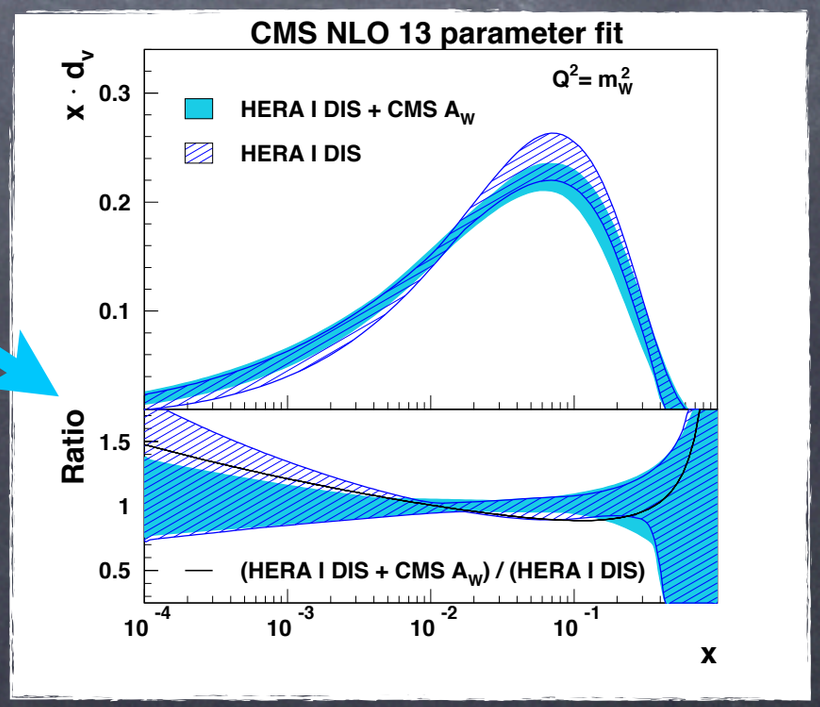
$$A_W = \frac{W^+ - W^-}{W^+ + W^-} \approx \frac{u_v - d_v}{u_v + d_v + 2u_{sea}}$$

[LHCb] JHEP 12 (2014) 079



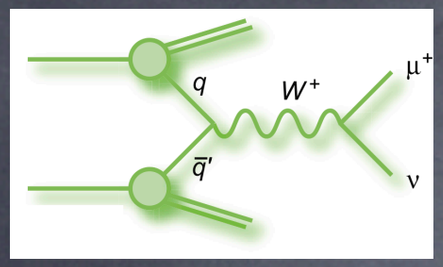
[LHCb] JHEP 12 (2014) 079





[CMS] PRD 90 (2014) 032004

PROBING PDFs WITH W-BOSON PRODUCTION

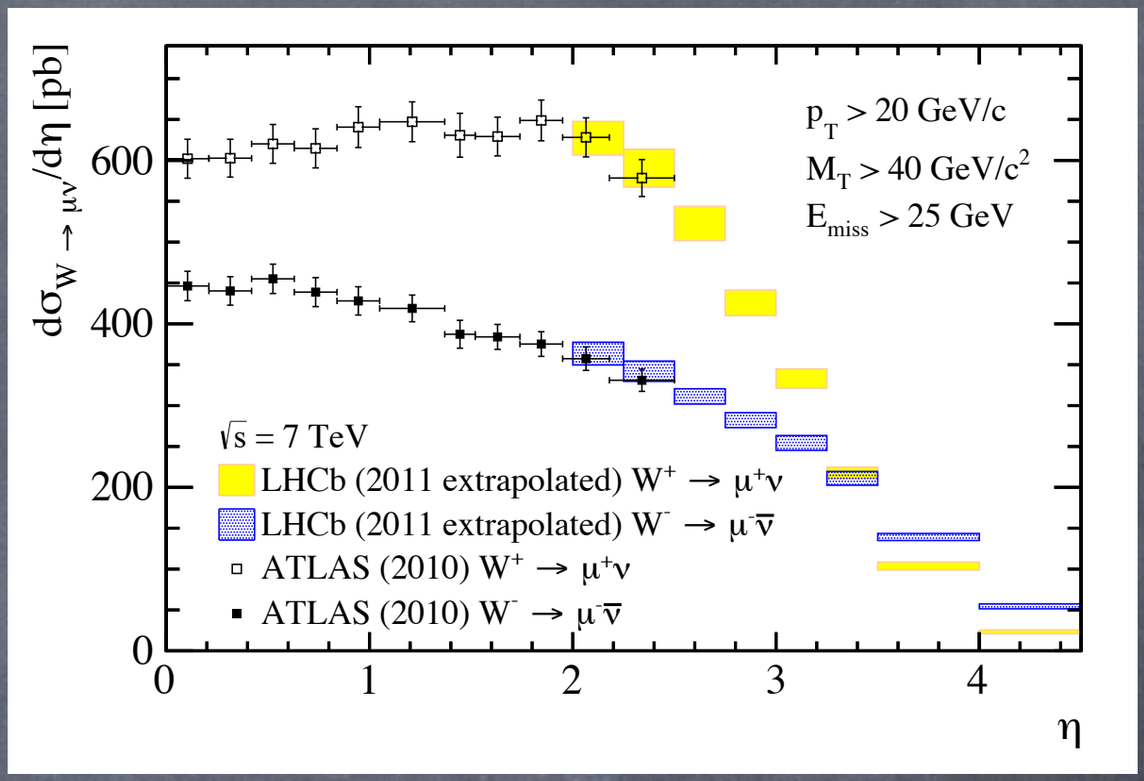


production of W^+ or W^- probes different flavors

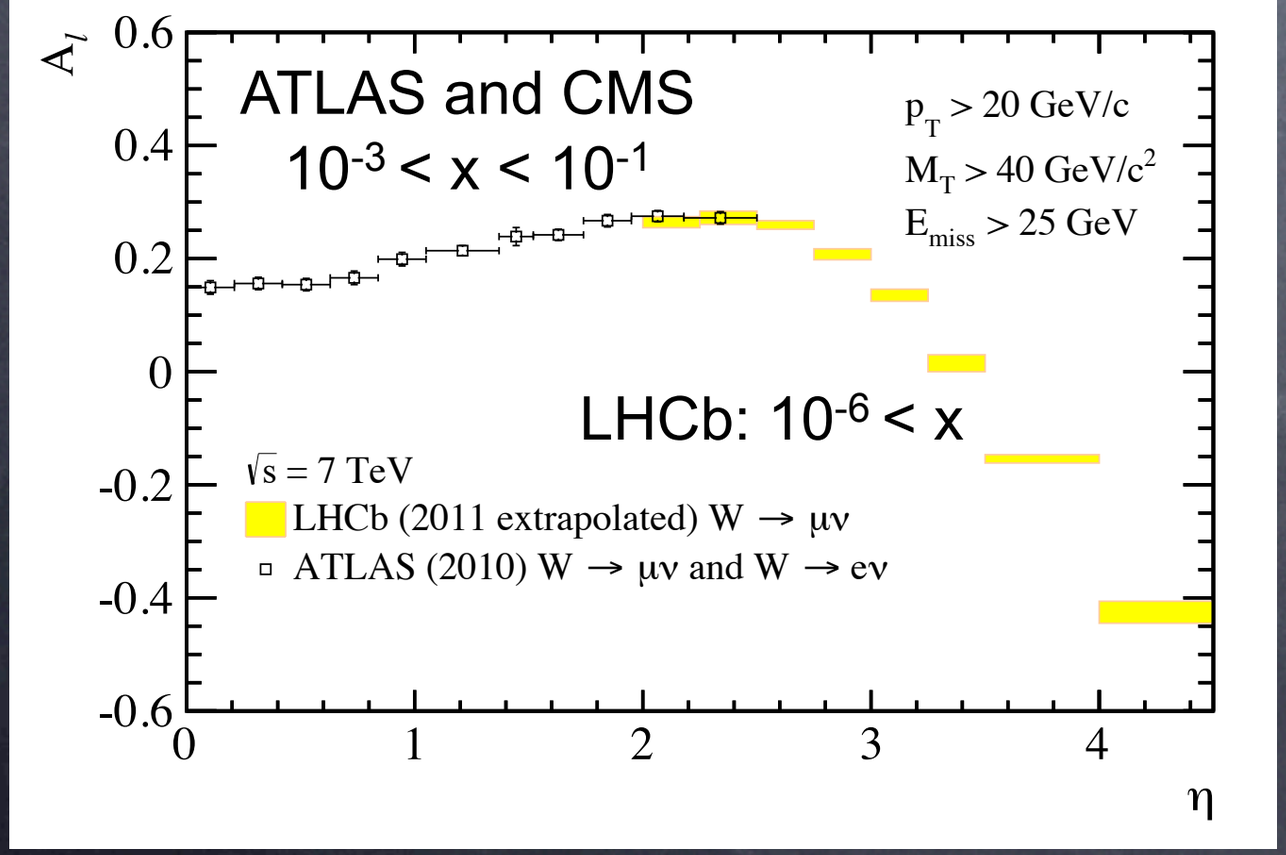
Lepton-charge asymmetry constrains valence

$$A_W = \frac{W^+ - W^-}{W^+ + W^-} \approx \frac{u_v - d_v}{u_v + d_v + 2u_{sea}}$$

[LHCb] JHEP 12 (2014) 079



[LHCb] JHEP 12 (2014) 079

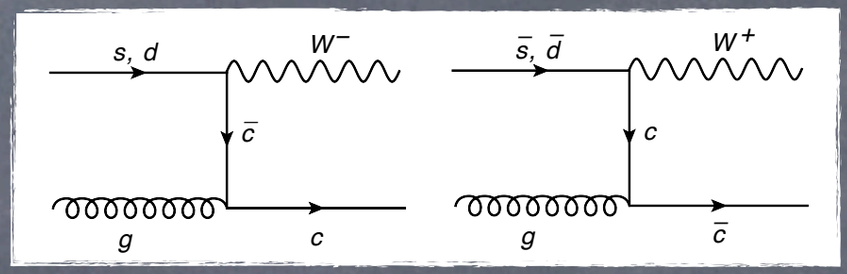


LHC measurements probe light-quark distributions in wide x range

8 TeV data forthcoming

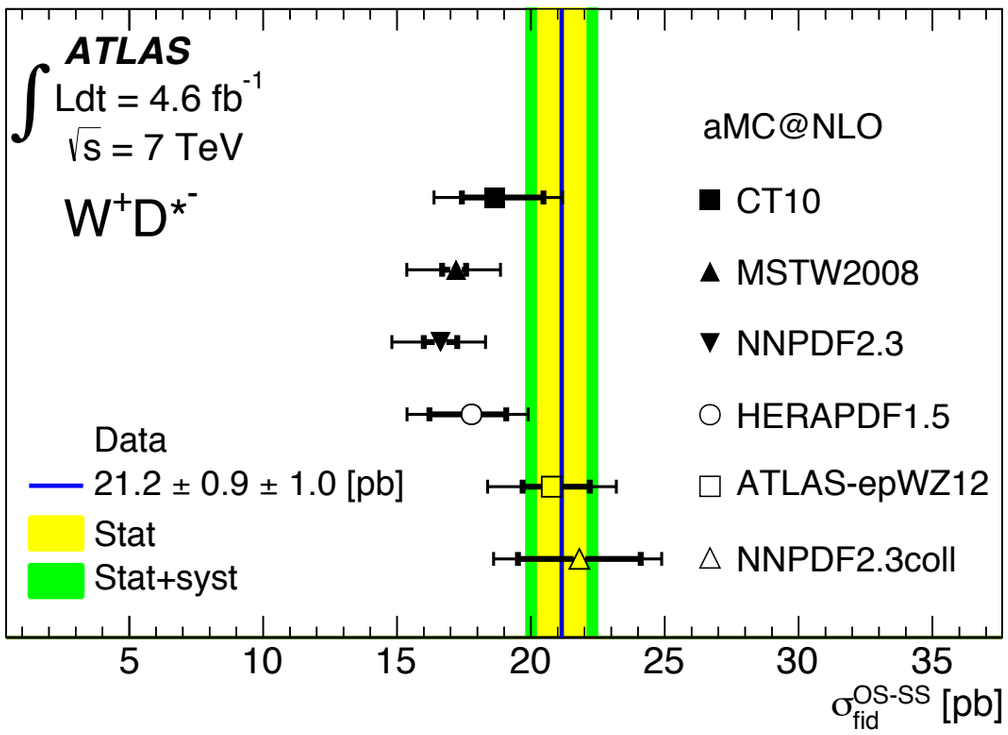
FLAVOUR DECOMPOSITION: W+CHARM

In pp collisions, production process of W+c probes strange quark directly at LO

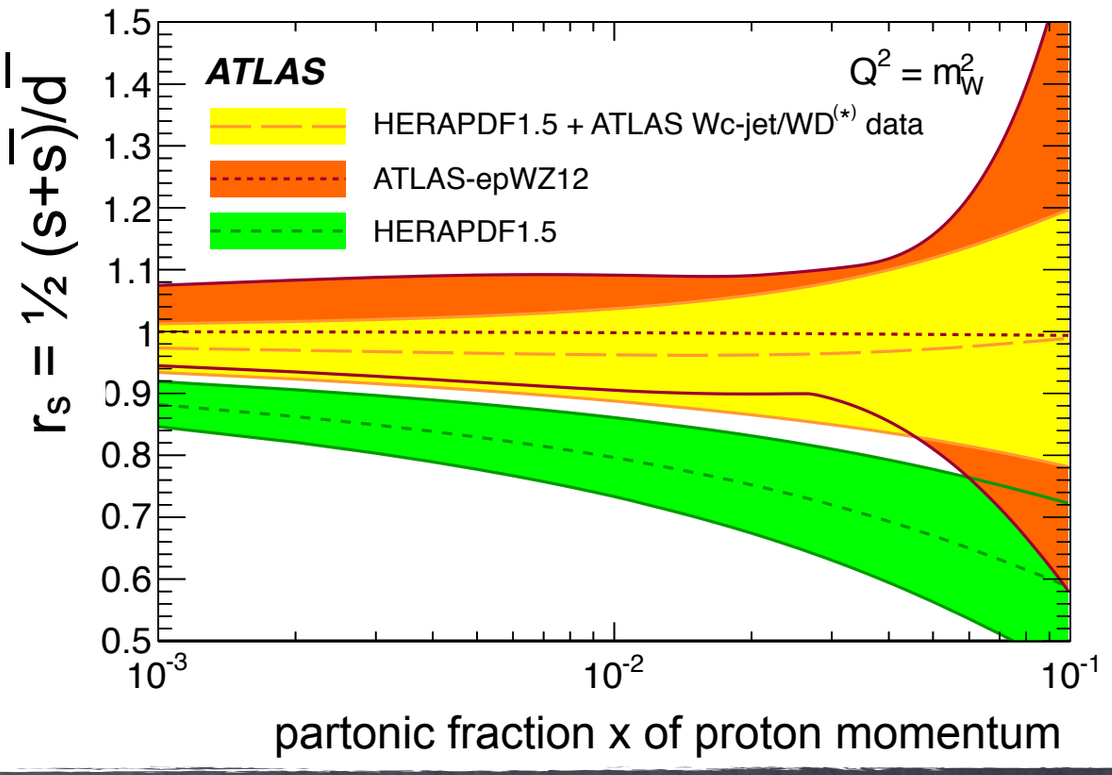


Measure W+c-hadron production

[ATLAS] JHEP 1405 (2014) 068



Determine s-quark distribution

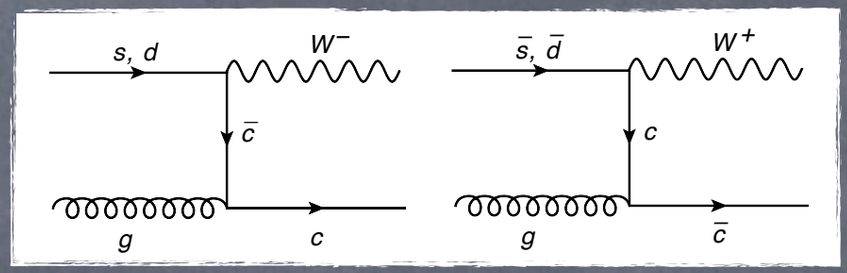


LHC W+c measurements constrain strange-quark distribution

Ongoing: analysis of the measurement of W+c-jet production √s = 8 TeV
expect reduction of statistical uncertainties by a factor of 2

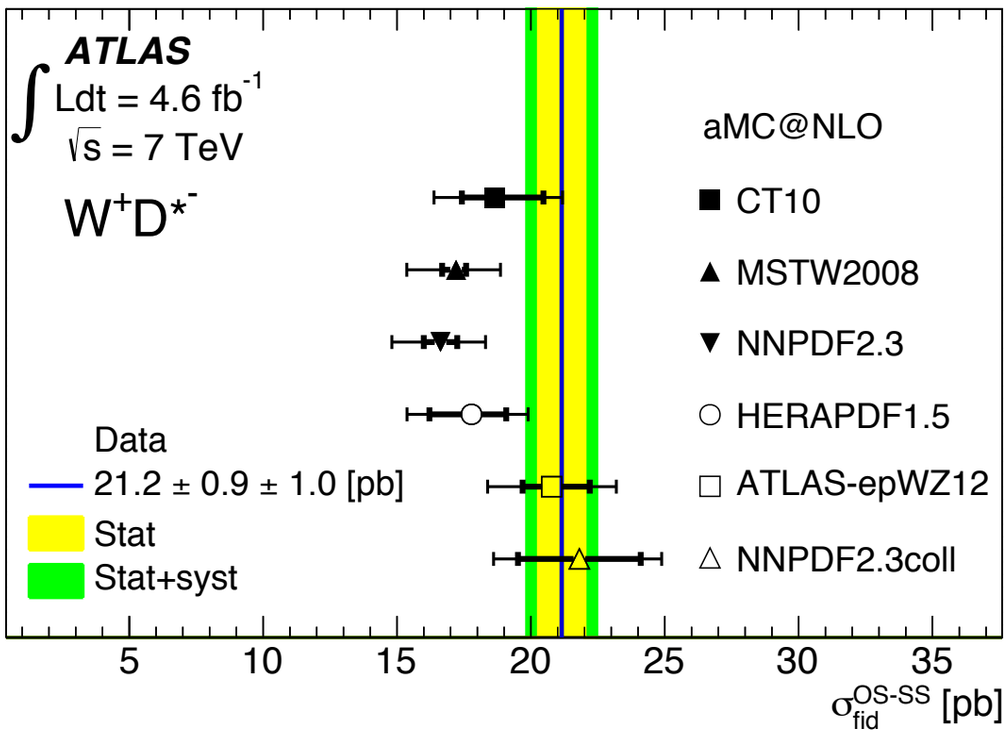
FLAVOUR DECOMPOSITION: W+CHARM

In pp collisions, production process of W+c probes strange quark directly at LO



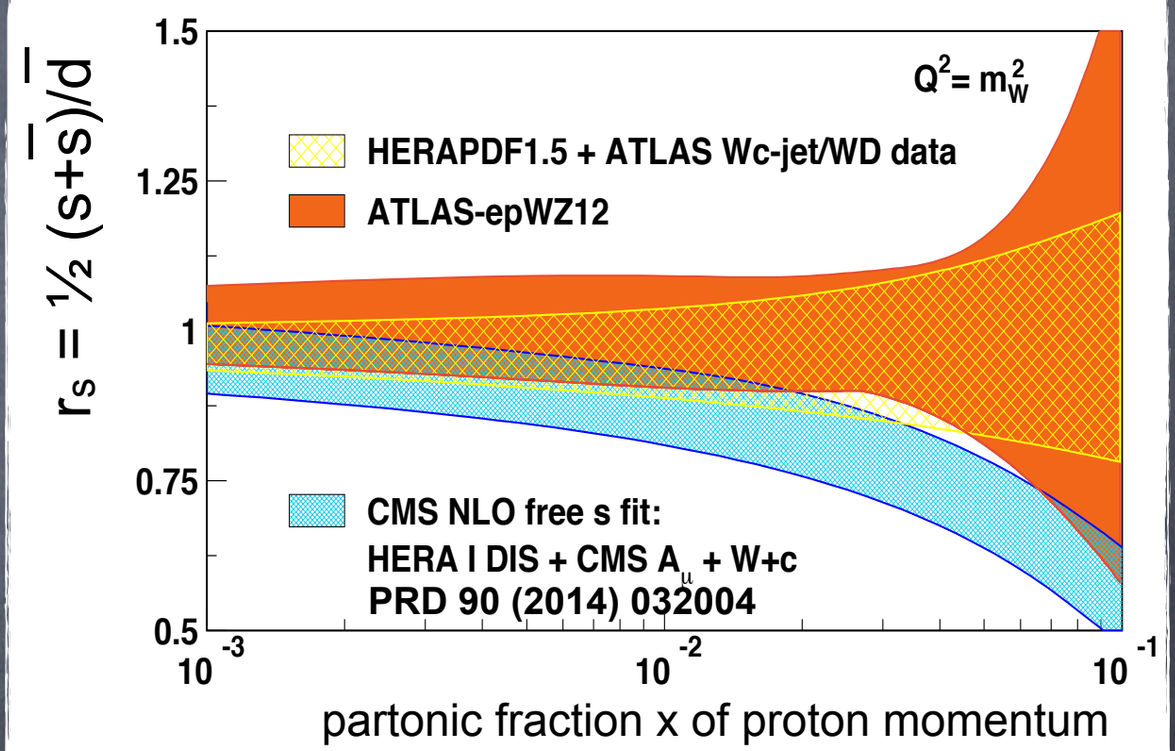
Measure W+c-hadron production

[ATLAS] JHEP 1405 (2014) 068



Determine s-quark distribution

+ [CMS] PRD 90 (2014) 032004



ATLAS: s-quark distribution enhanced wrt results of neutrino scattering

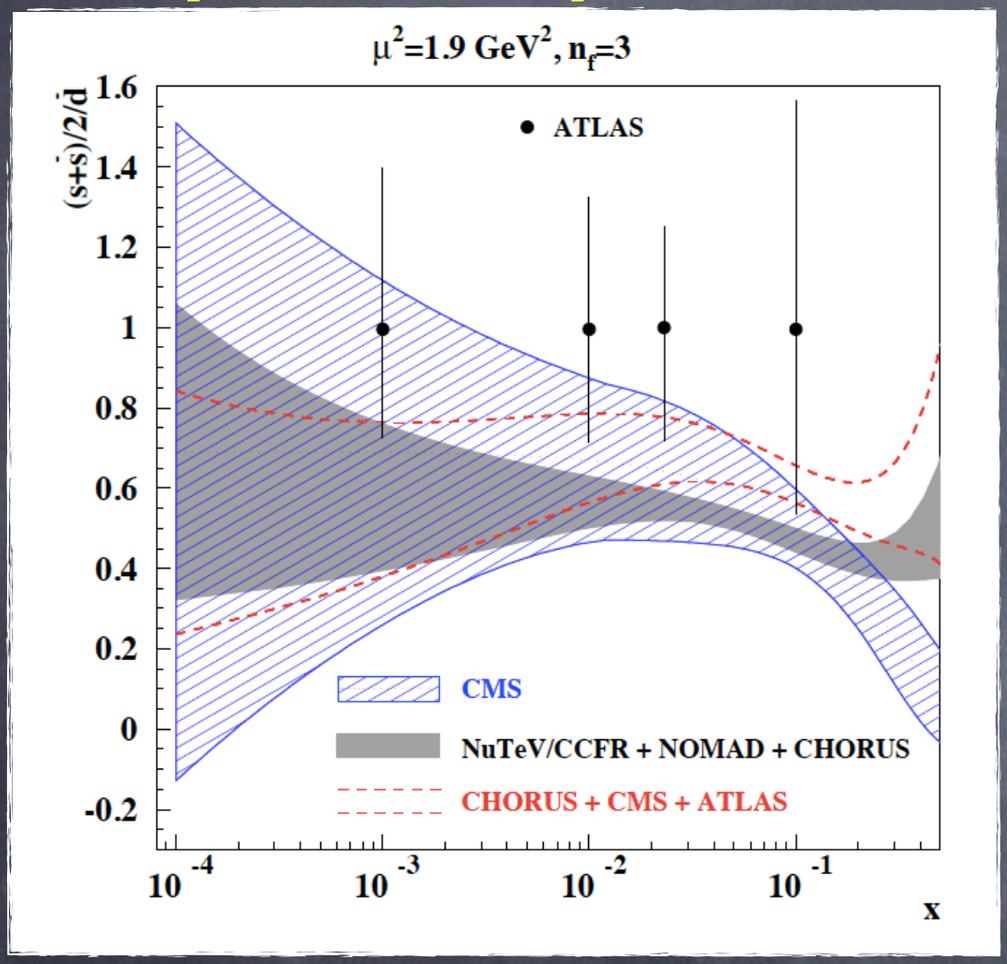
CMS: s-quark distribution agrees well with results neutrino scattering

Check consistency of LHC measurements in a joined QCD analysis

FLAVOUR DECOMPOSITION: W+CHARM

Joined analysis of W+c from ATLAS and CMS data and neutrino scattering

[S. Alekhin et al.] arXiv:1404.6469



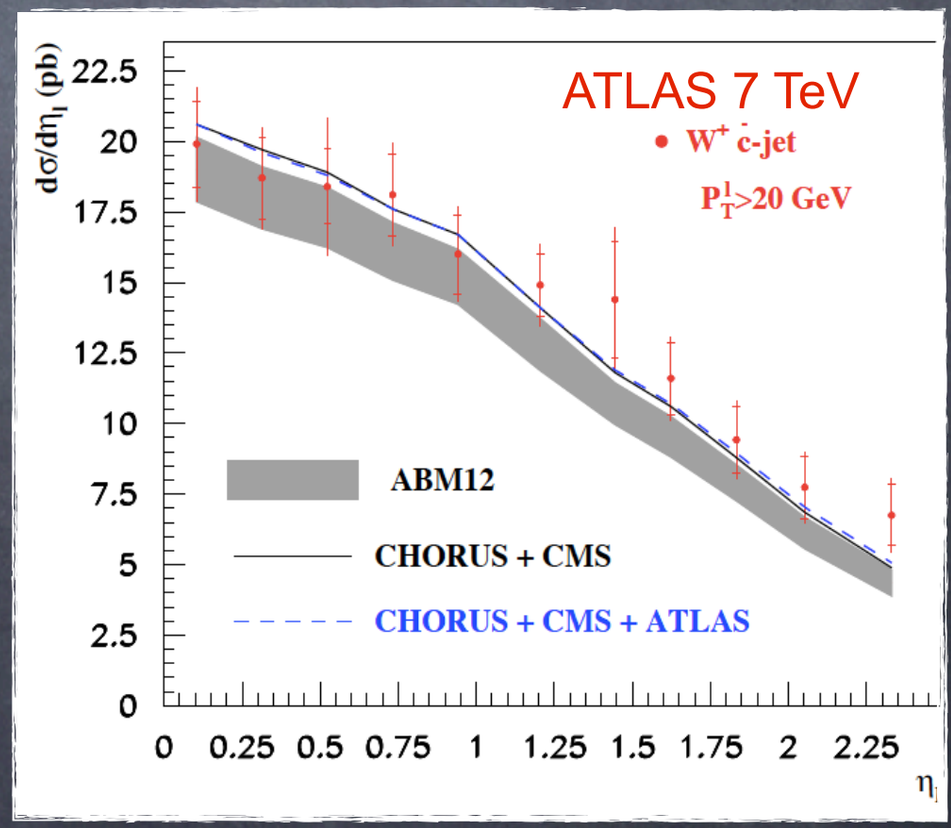
- Strangeness suppression factor determined

  $\kappa_S(Q^2 = 20\ \text{GeV}^2) = 0.654 \pm 0.030$

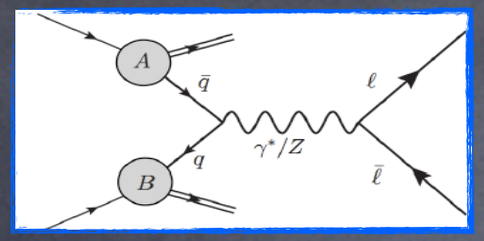
- ABM PDF with updated results of ν−scattering experiments agrees well with CMS NLO fit

- ATLAS s-distribution is slightly enhanced,
  but correlated with d-quark sea suppression!

In the combined analysis of CHORUS, CMS and ATLAS data no inconsistency between LHC measurements is observed.



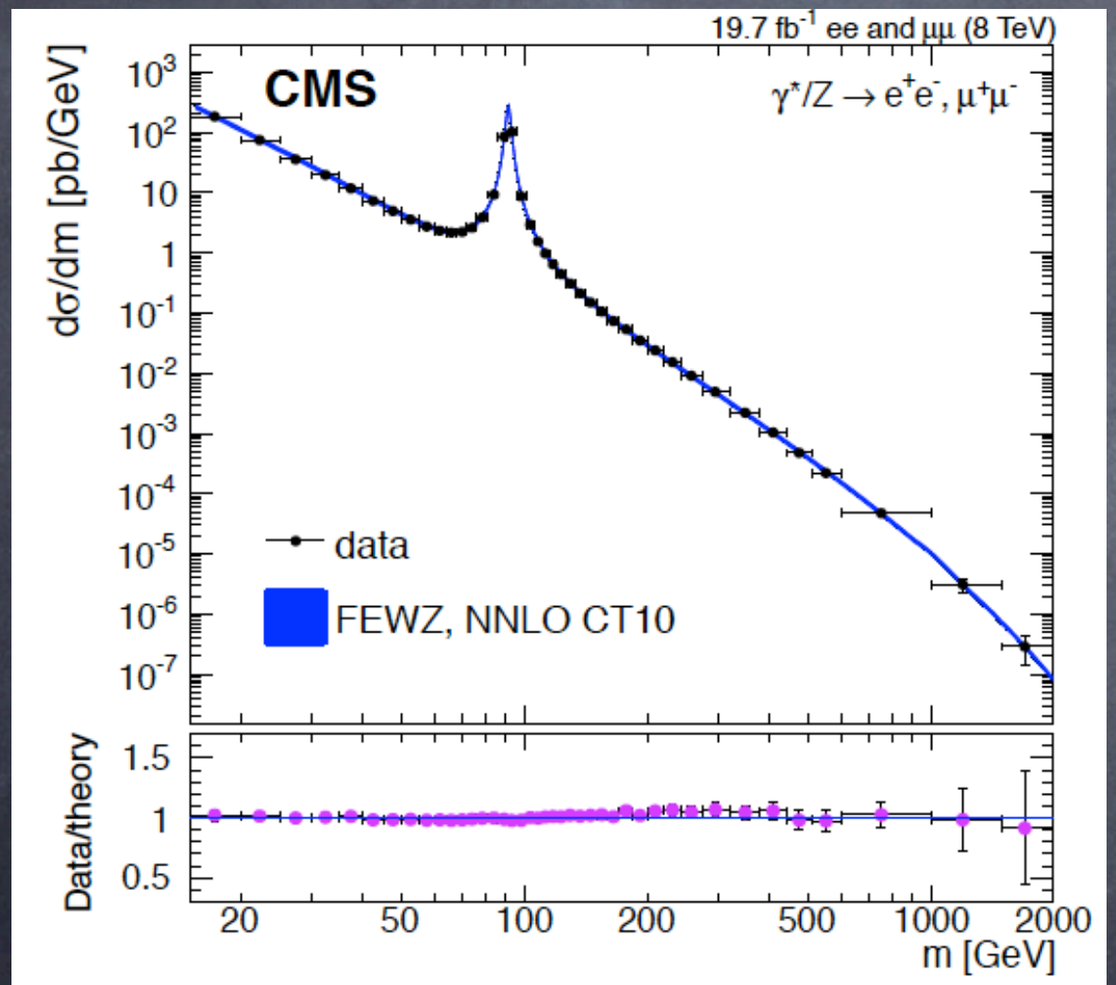
PROBING PDFs WITH DRELL-YAN PRODUCTION



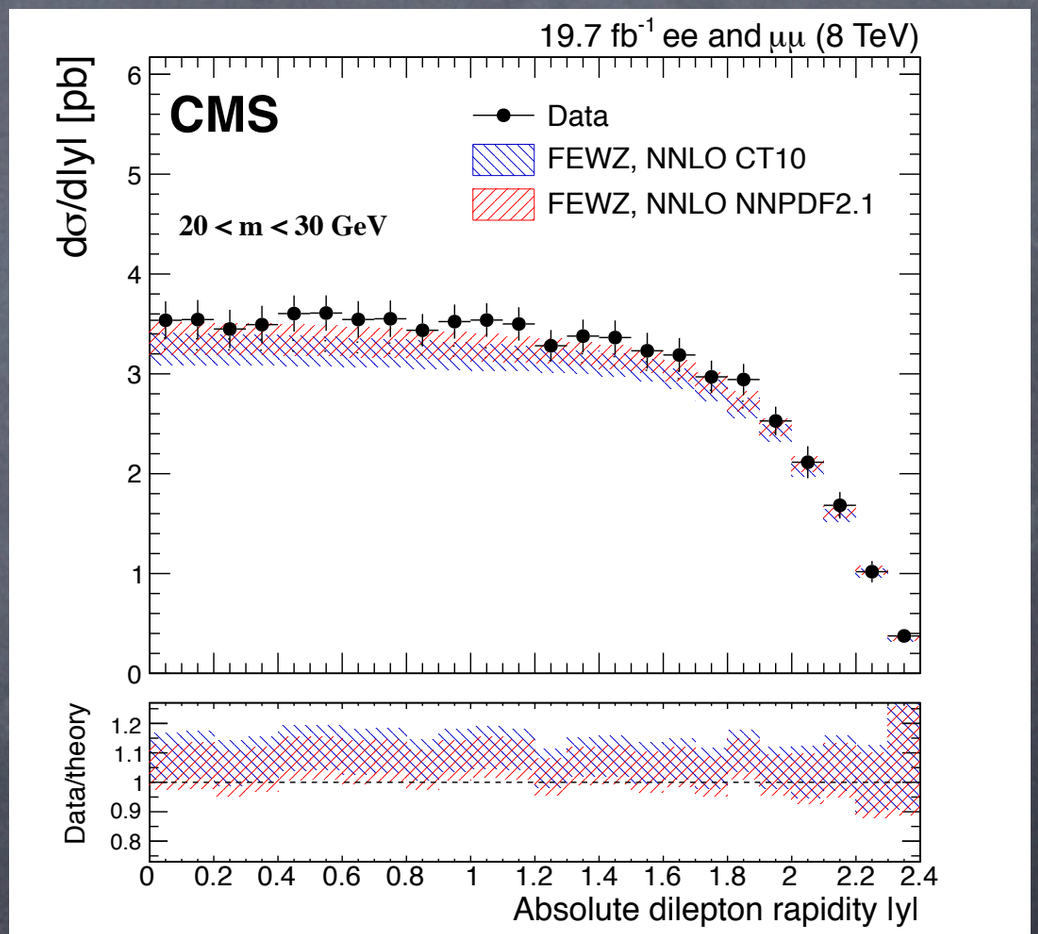
[CMS] EPJC 75 (2015) 4, 147

differential DY production at 8 TeV, $\mathcal{L}$ = 19.7 fb^{-1} combined $e^+e^-/\mu^+\mu^-$

results at both, post-FSR ("bare") and pre-FSR ("born") levels

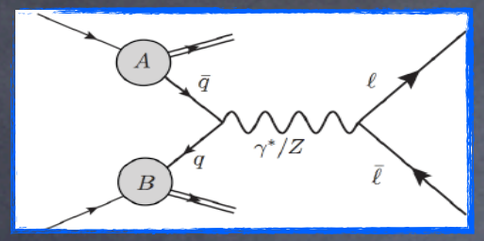


Fiducial differential cross sections measured in 6 di-lepton mass bins:



perfect description over 10 orders !

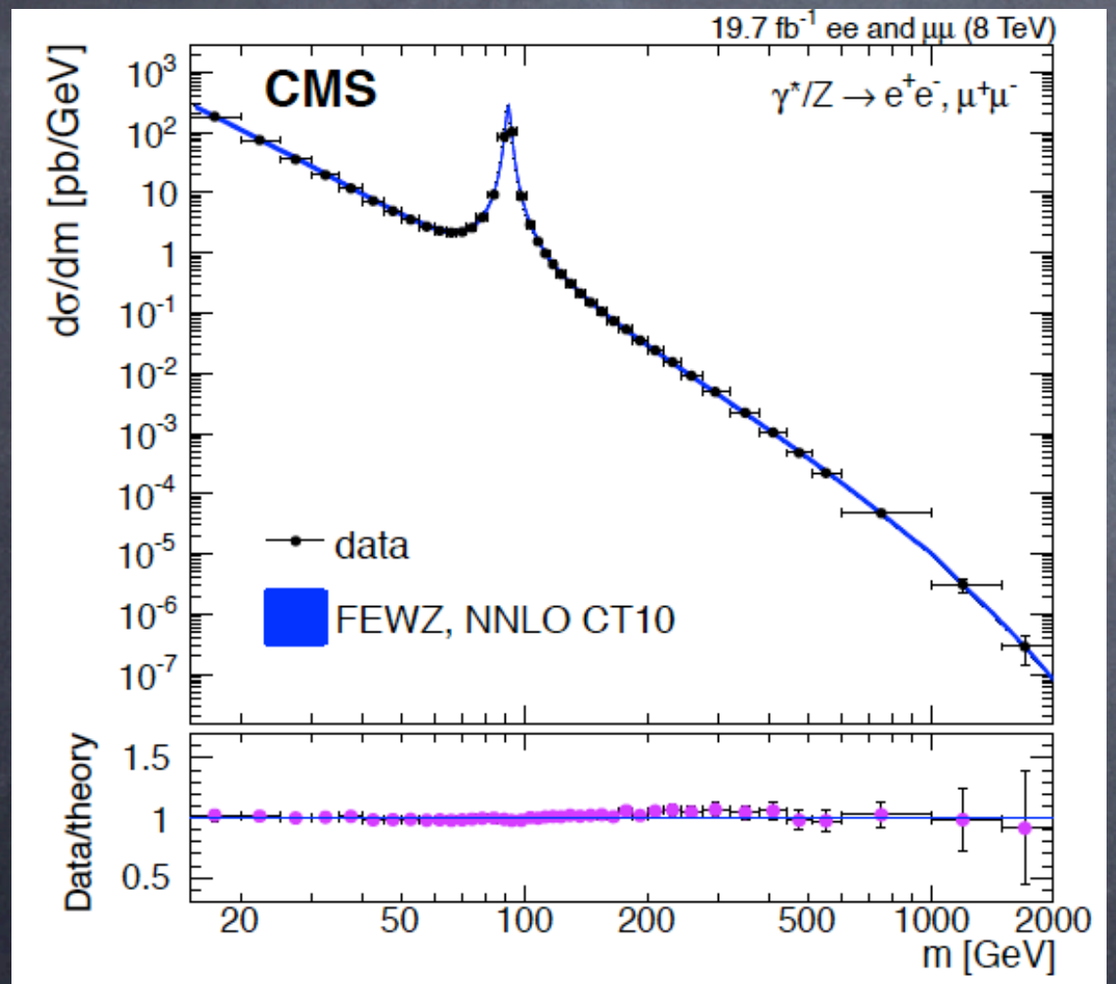
PROBING PDFs WITH DRELL-YAN PRODUCTION



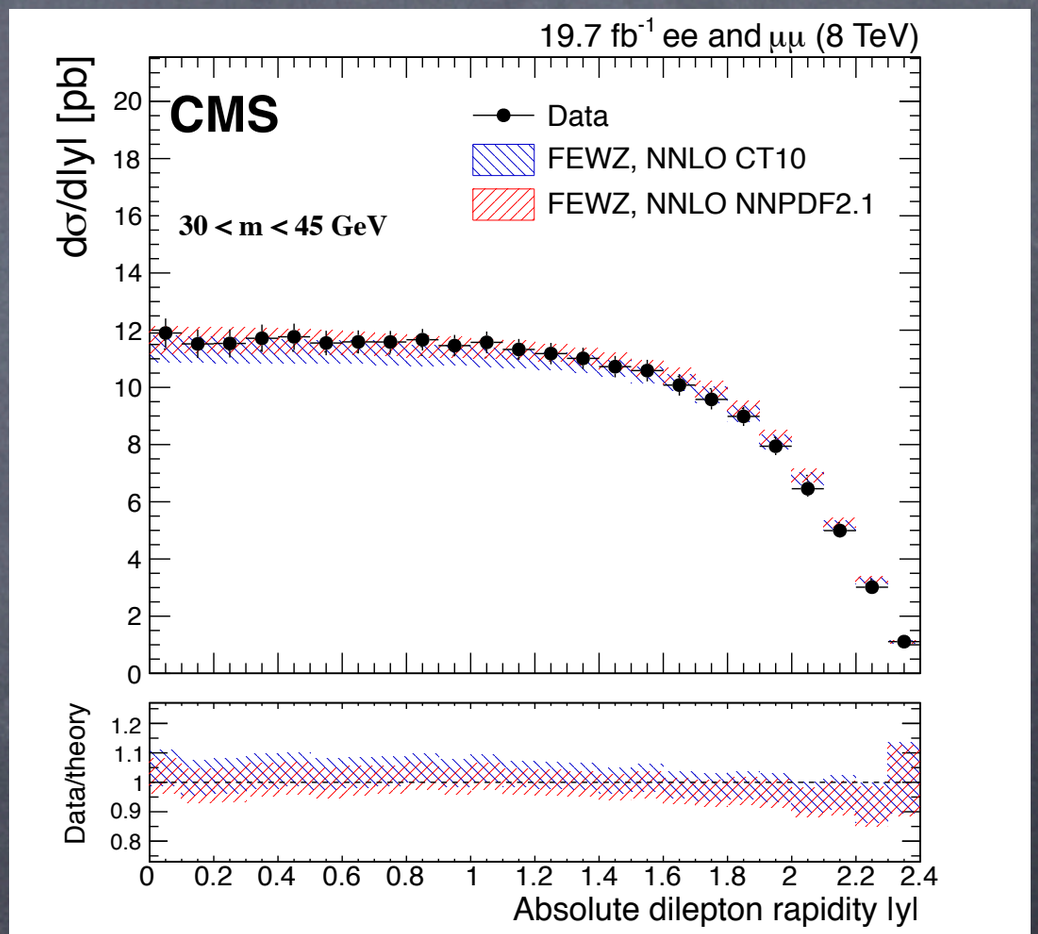
[CMS] EPJC 75 (2015) 4, 147

differential DY production at 8 TeV, $\mathcal{L}$ = 19.7 fb^{-1} combined $e^+e^-/\mu^+\mu^-$

results at both, post-FSR ("bare") and pre-FSR ("born") levels

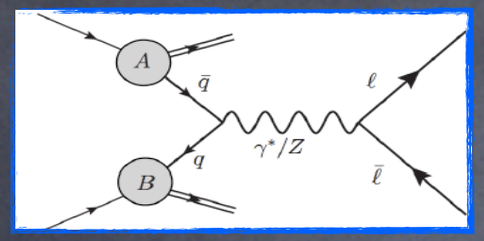


Fiducial differential cross sections measured in 6 di-lepton mass bins:



perfect description over 10 orders !

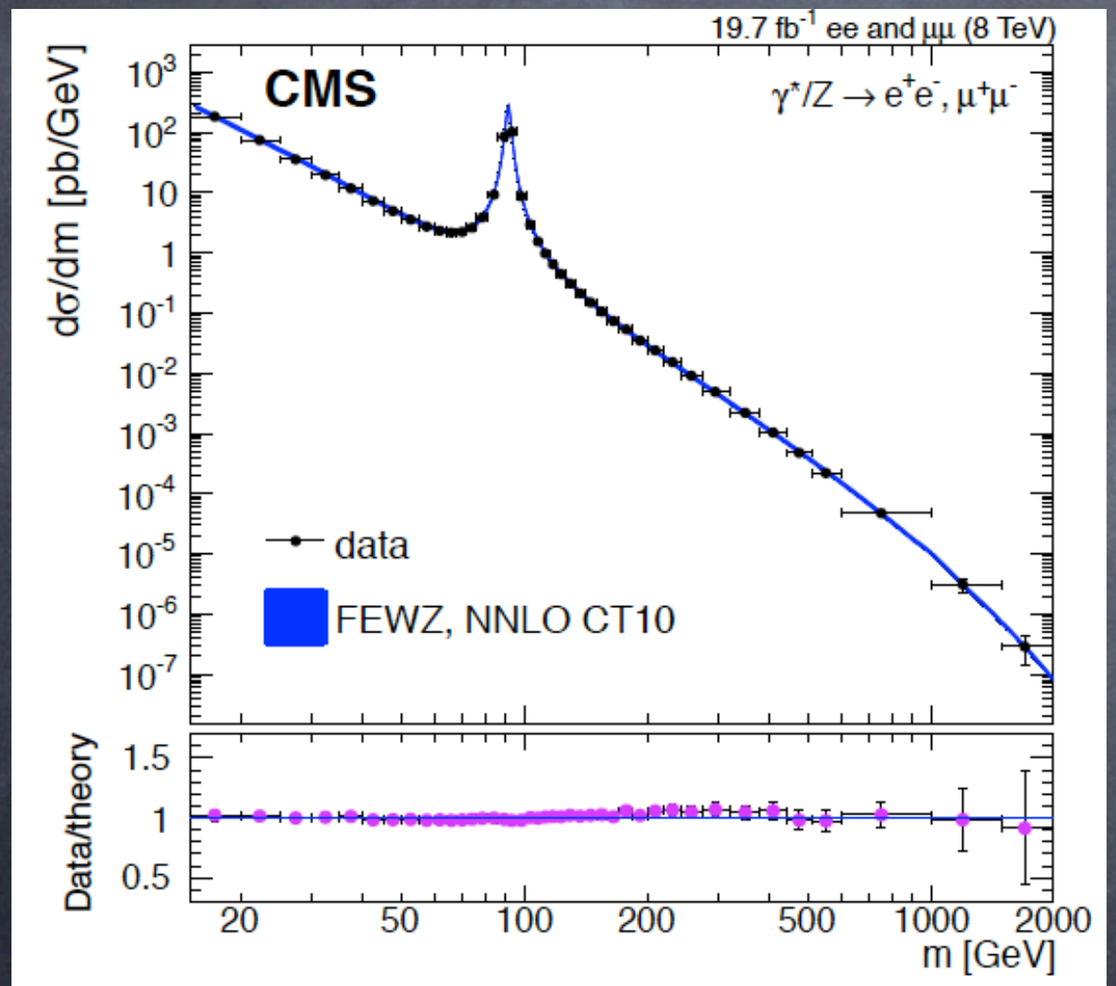
PROBING PDFs WITH DRELL-YAN PRODUCTION



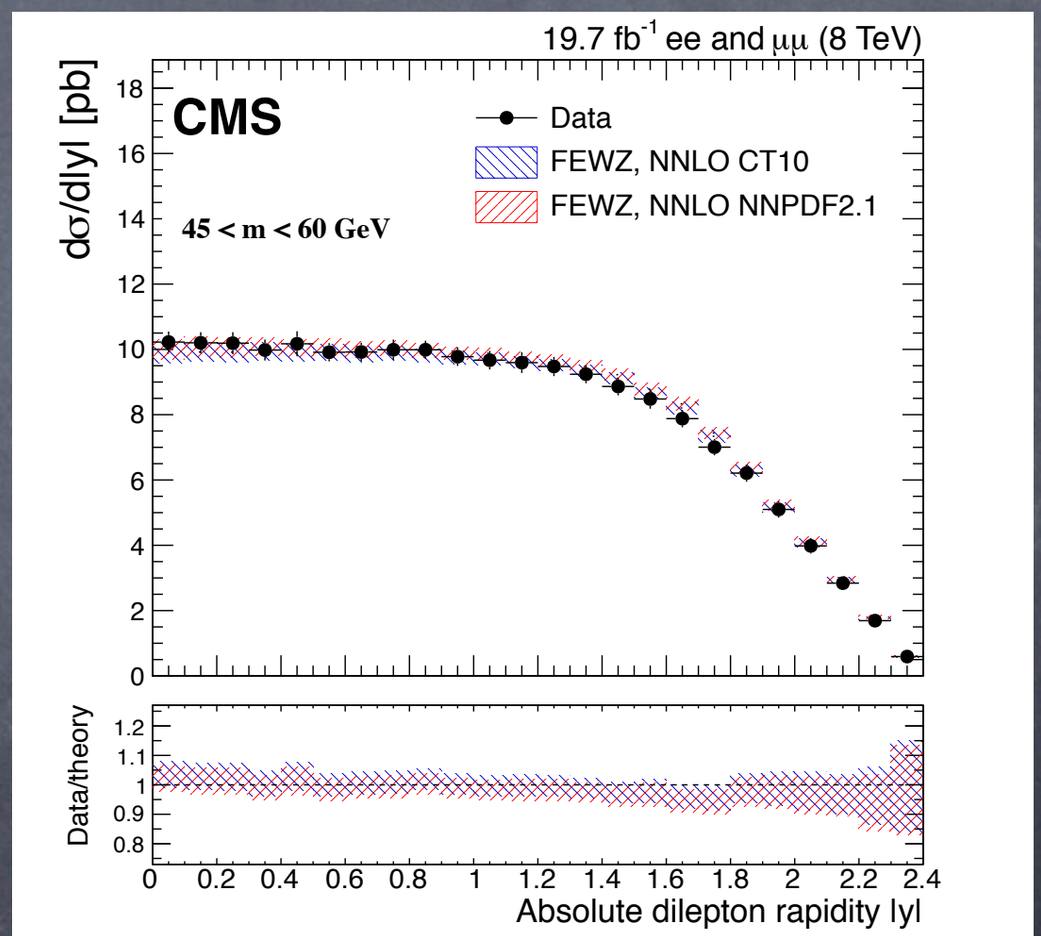
[CMS] EPJC 75 (2015) 4, 147

differential DY production at 8 TeV, $\mathcal{L}$ = 19.7 fb^{-1} combined $e^+e^-/\mu^+\mu^-$

results at both, post-FSR ("bare") and pre-FSR ("born") levels

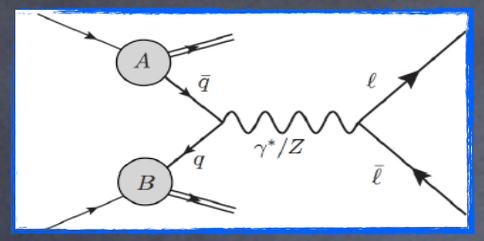


Fiducial differential cross sections measured in 6 di-lepton mass bins:



perfect description over 10 orders !

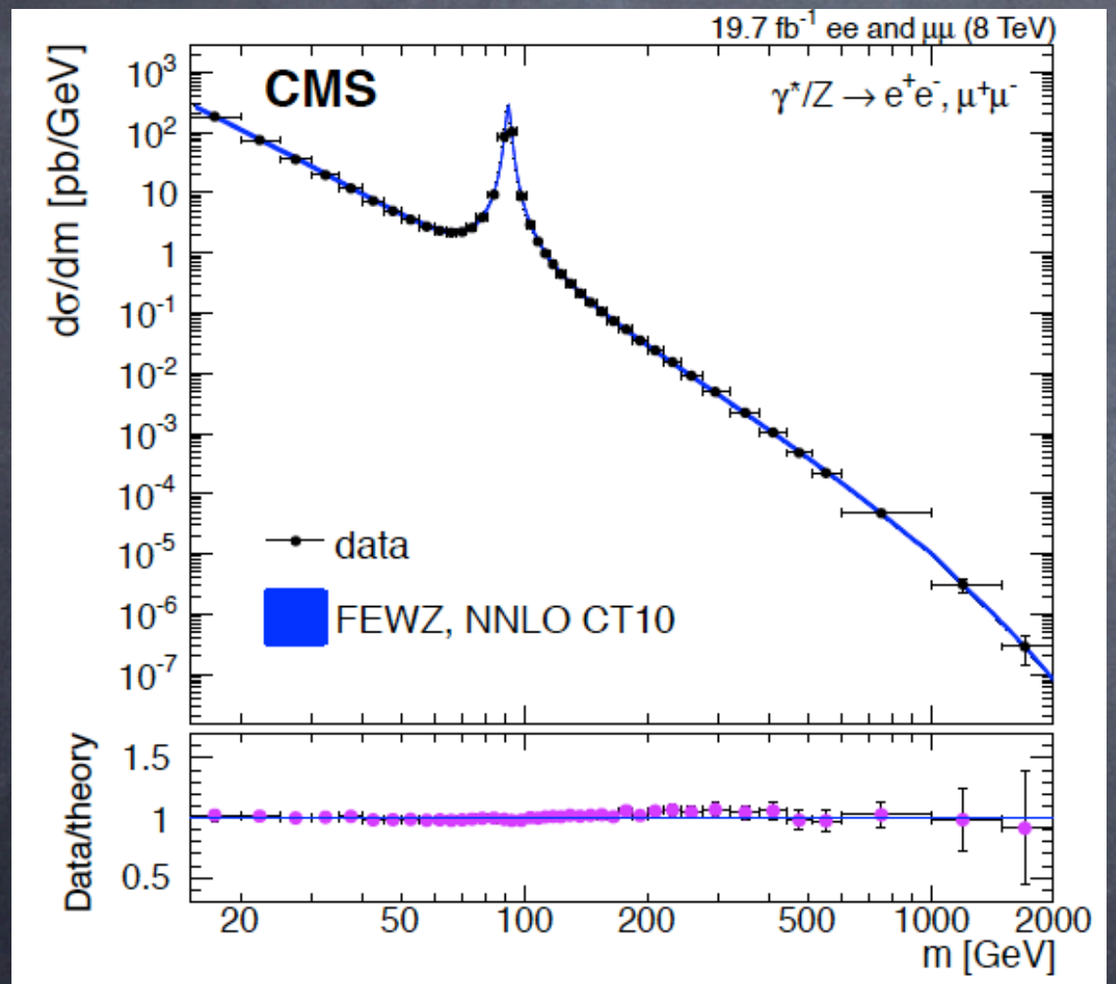
PROBING PDFs WITH DRELL-YAN PRODUCTION



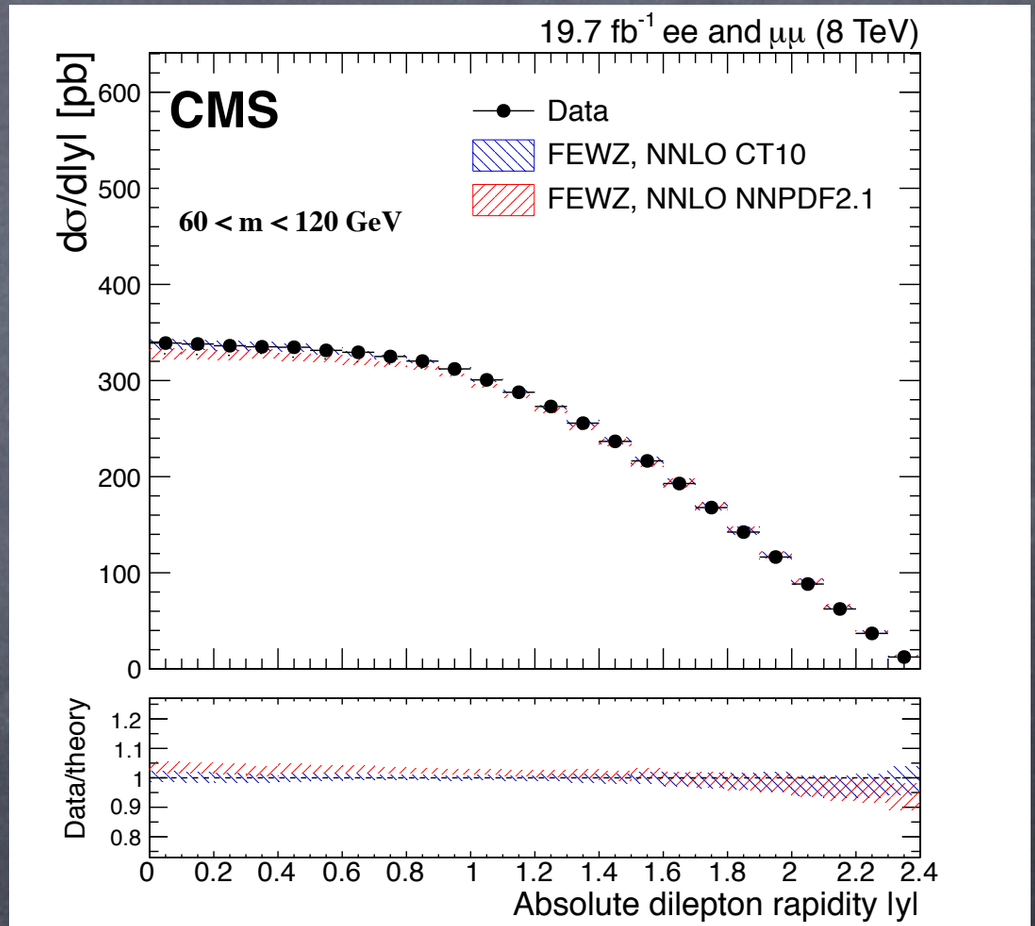
[CMS] EPJC 75 (2015) 4, 147

differential DY production at 8 TeV, $\mathcal{L}$ = 19.7 fb^{-1} combined $e^+e^-/\mu^+\mu^-$

results at both, post-FSR ("bare") and pre-FSR ("born") levels

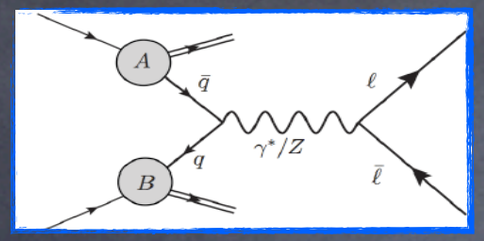


Fiducial differential cross sections measured in 6 di-lepton mass bins:



perfect description over 10 orders !

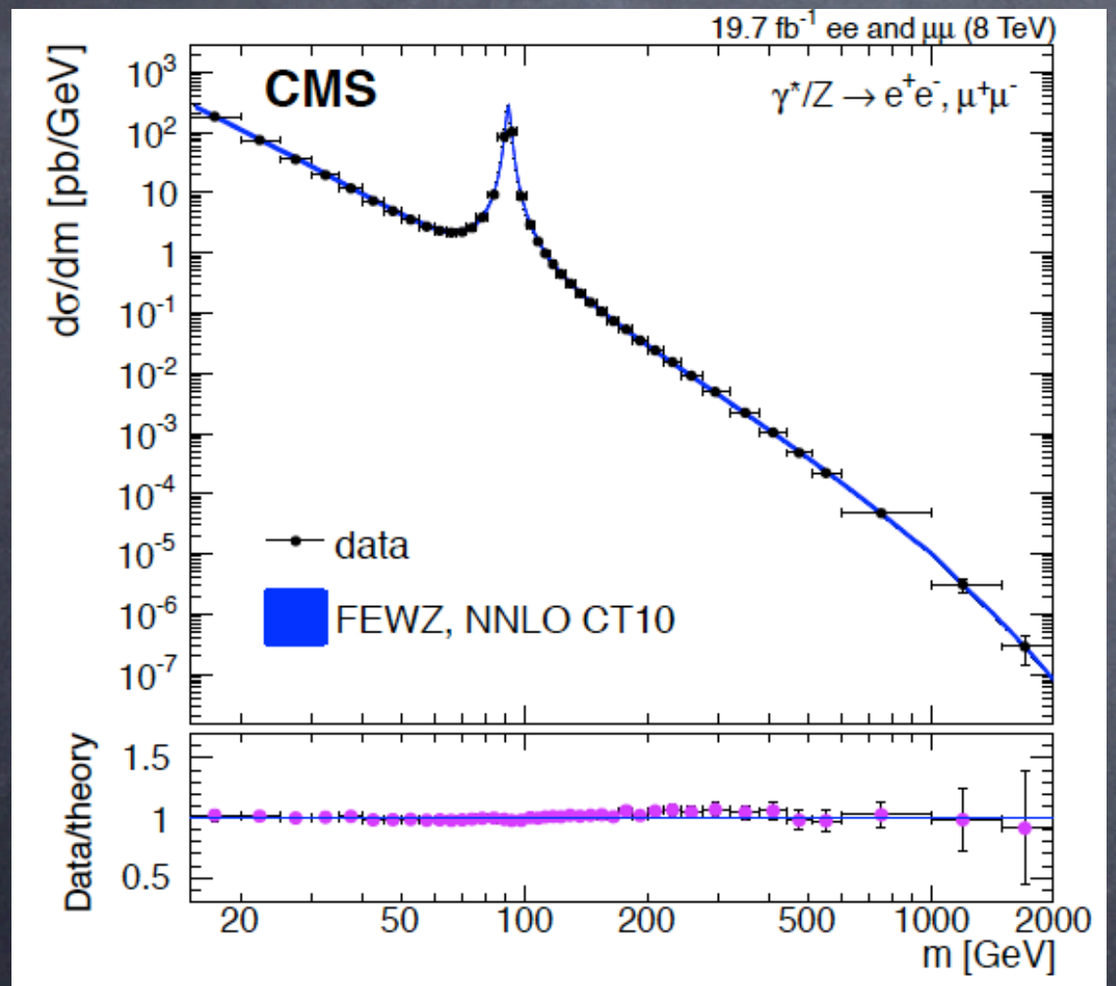
PROBING PDFs WITH DRELL-YAN PRODUCTION



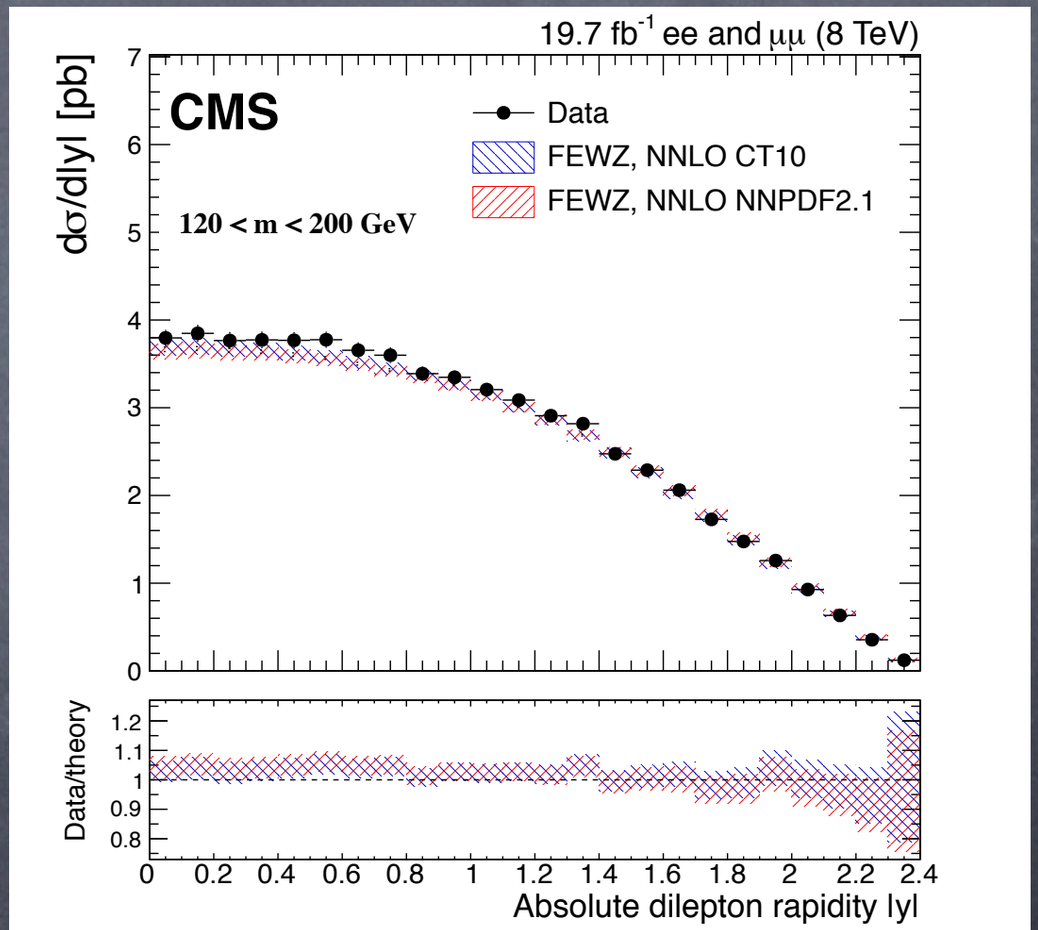
[CMS] EPJC 75 (2015) 4, 147

differential DY production at 8 TeV, $\mathcal{L}$ = 19.7 fb^{-1} combined $e^+e^-/\mu^+\mu^-$

results at both, post-FSR ("bare") and pre-FSR ("born") levels

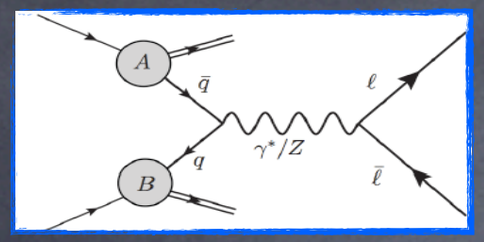


Fiducial differential cross sections measured in 6 di-lepton mass bins:



perfect description over 10 orders !

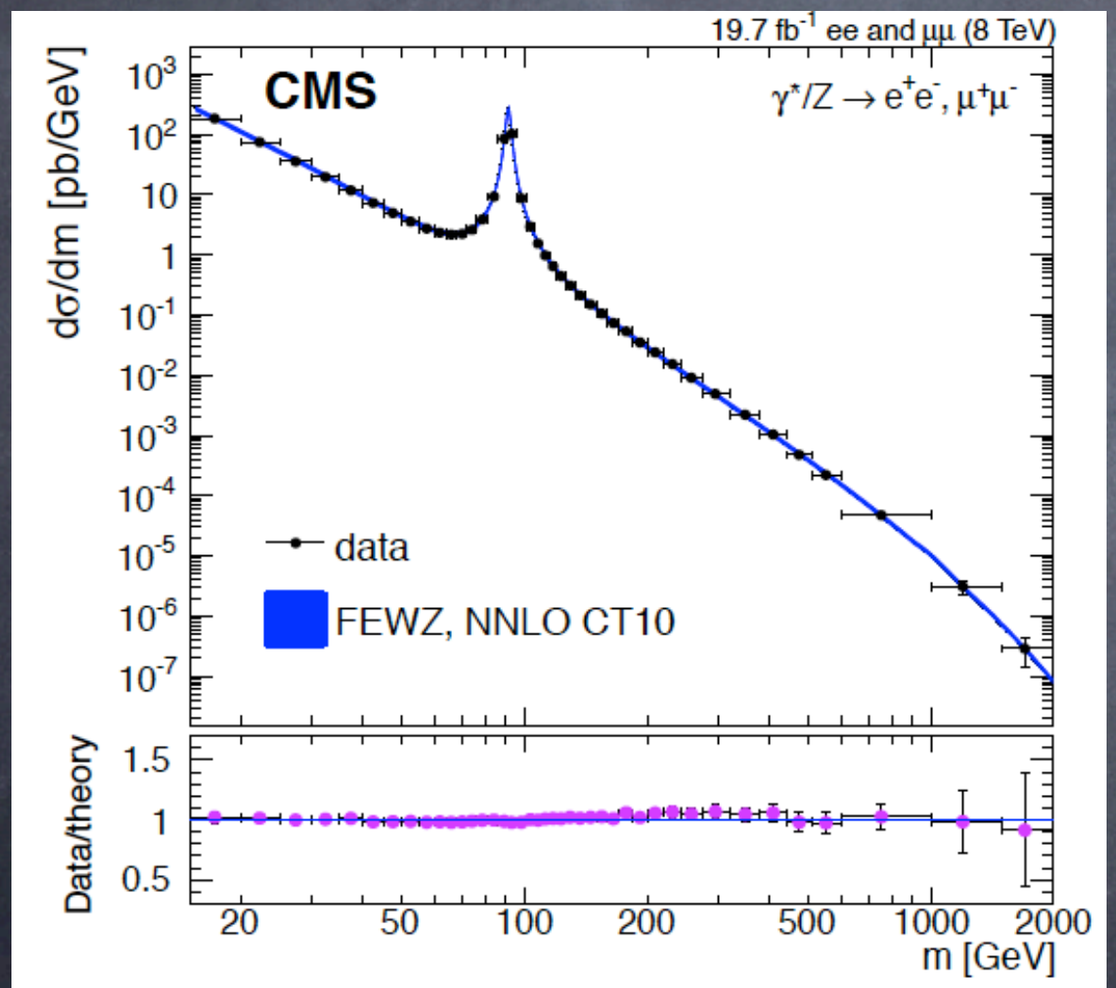
PROBING PDFs WITH DRELL-YAN PRODUCTION



[CMS] EPJC 75 (2015) 4, 147

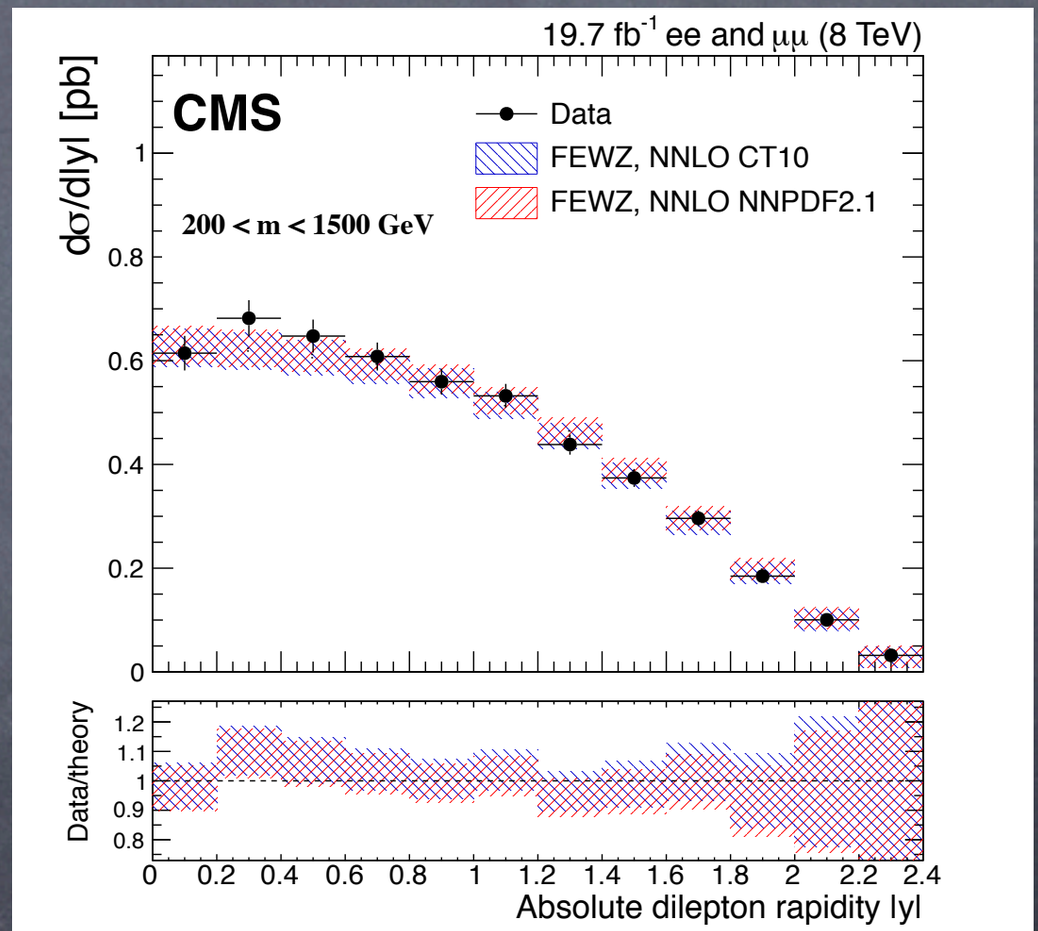
differential DY production at 8 TeV, $\mathcal{L}$ = 19.7 fb^{-1} combined $e^+e^-/\mu^+\mu^-$

results at both, post-FSR ("bare") and pre-FSR ("born") levels



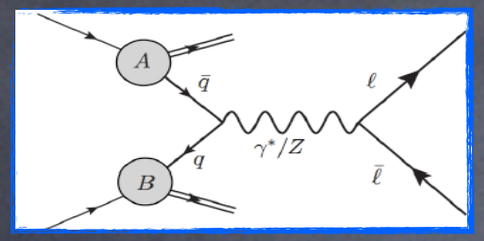
perfect description over 10 orders !

Fiducial differential cross sections measured in 6 di-lepton mass bins:



expect largest impact on PDFs at low and high mass

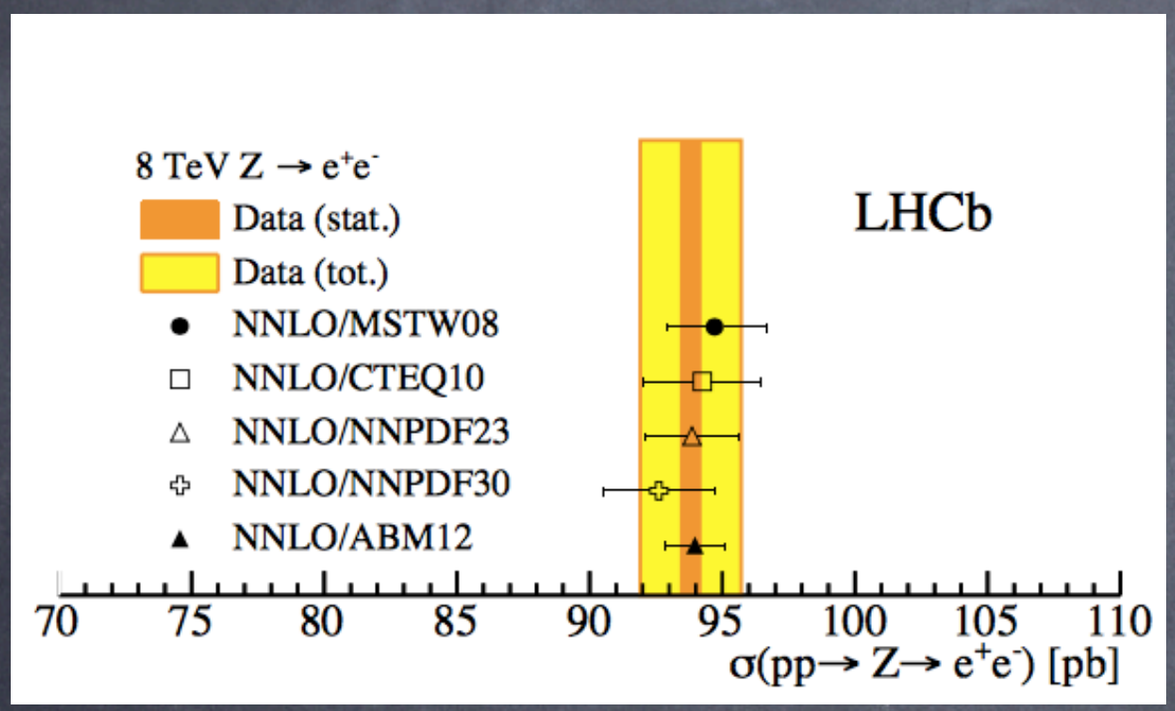
PROBING PDFs WITH Z-BOSON PRODUCTION



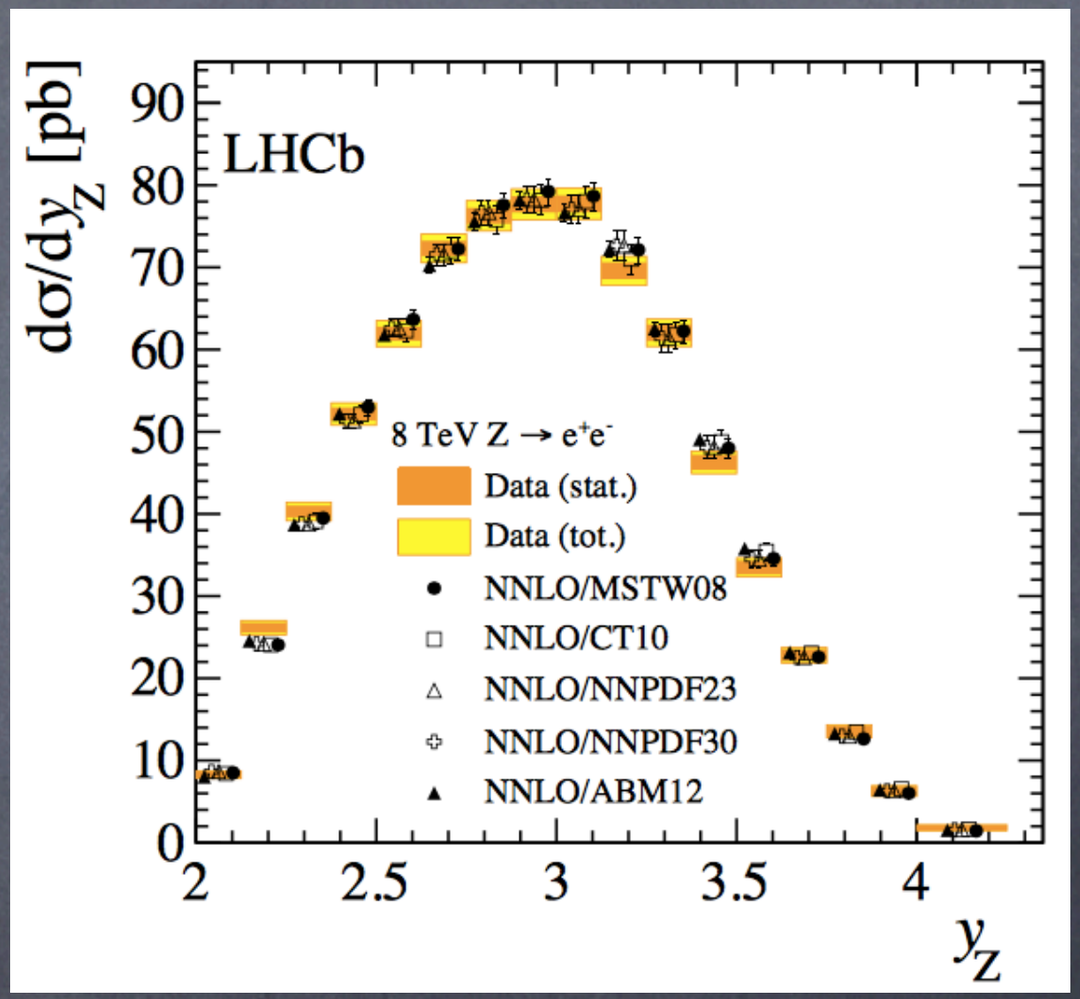
$Z \rightarrow e^+e^-$ $2.0 < \eta < 4.5$ and $p_T > 20$ GeV $60 < m_{ll} < 120$ GeV

$\sqrt{s}$ = 8 TeV, 2.0 fb^{-1}

[LHCb] arXiv:1503.00963



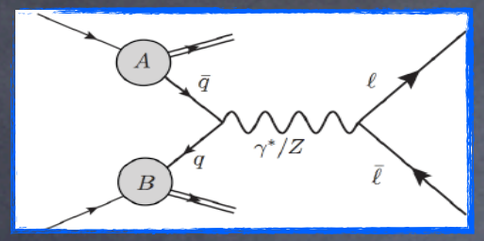
$\sigma(pp \rightarrow Z \rightarrow e^+e^-) = 93.81 \pm 0.41(stat) \pm 1.48(syst) \pm 1.14(lumi)$ pb



good agreement with NNLO prediction based on different PDFs

rapidity distribution sensitive to light-flavour content of the sea

PROBING PDFs WITH Z-BOSON PRODUCTION

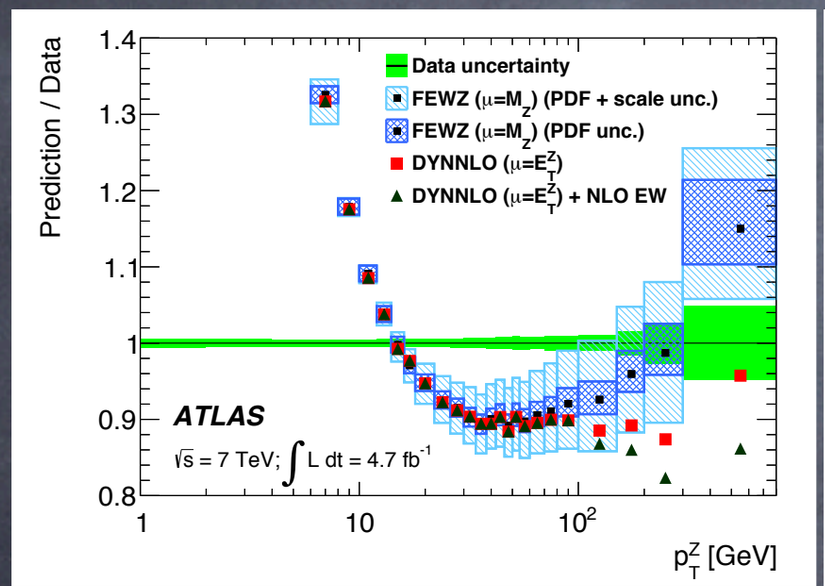


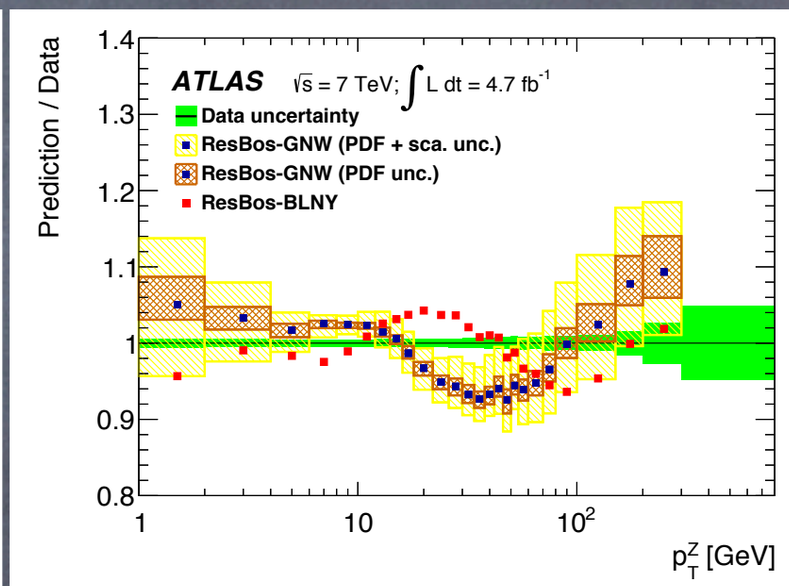
Transverse momentum of Z/γ* production sensitive to the gluon

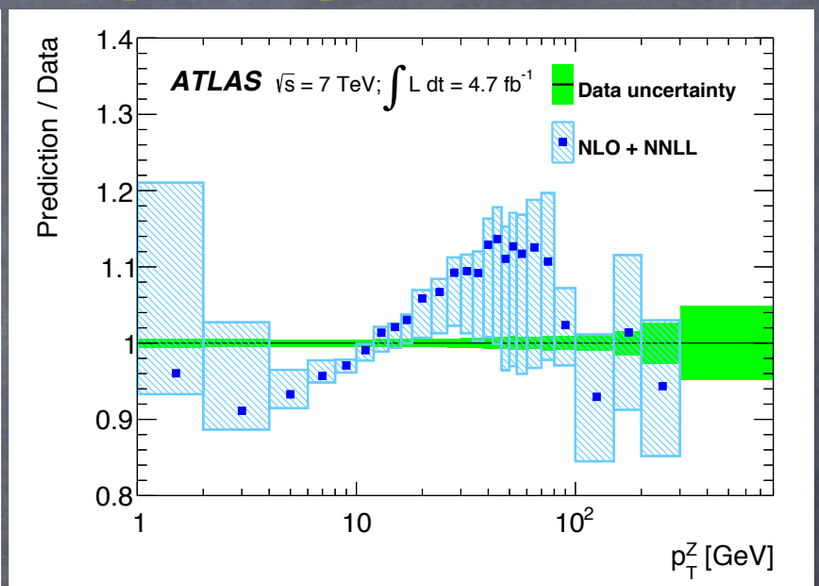
Z/γ* production at 7 TeV, combined $e^+e^-/\mu^+\mu^-$ $\mathcal{L}$ = 4.7 fb^{-1}

Ratios between various predictions and the combined measurement of $p_T(Z)$

[ATLAS] arXiv:1406.3660







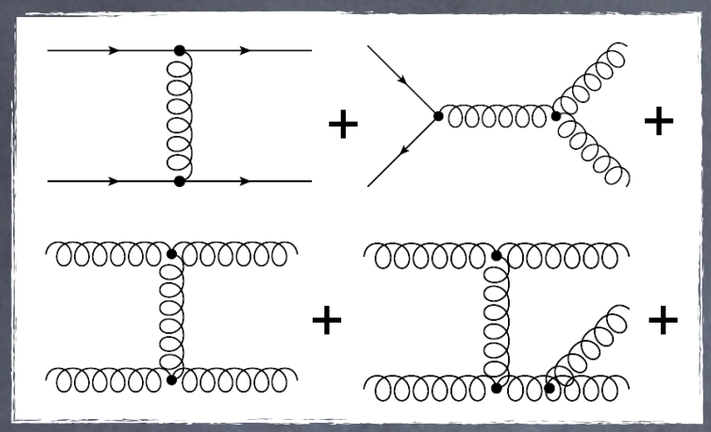
High p_T (qg scattering dominates): higher-order QCD and EW corrections are needed
Low p_T (governed by ISR): need to account for interplay between PDF and soft QCD

Large effect from variations of the QCD scales and of the resummation scale.
Large dependence on non-pQCD parametrization

Measurements used to tune the Pythia8 and Powheg+Pythia8 generators

GLUON DISTRIBUTION: JET PRODUCTION

Inclusive jet production in pp collisions at LHC directly sensitive to PDFs and α_S



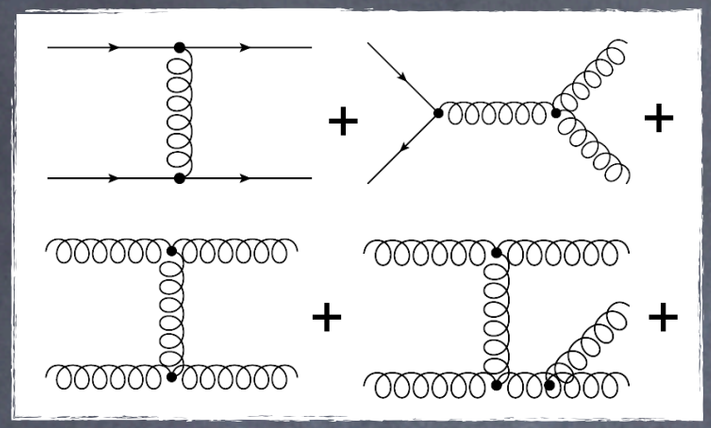
ATLAS 7 TeV, $\mathcal{L}$ = 4.5 fb^{-1} ***JHEP02(2015)153***

CMS 7 TeV, $\mathcal{L}$ = 5 fb^{-1} ***PRD 87 (2012) 12002***

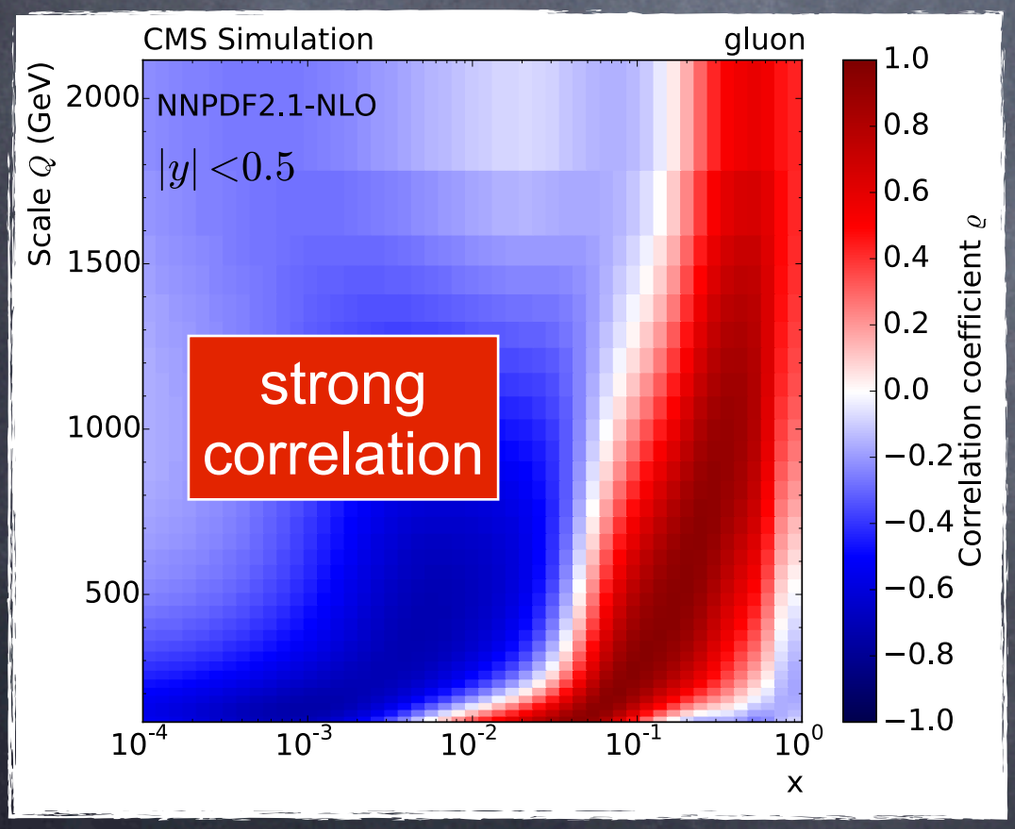
CMS 8 TeV, $\mathcal{L}$ = 10.7 fb^{-1} ***CMS-PAS-SMP-12-012***

GLUON DISTRIBUTION: JET PRODUCTION

Inclusive jet production in pp collisions at LHC directly sensitive to PDFs and α_S



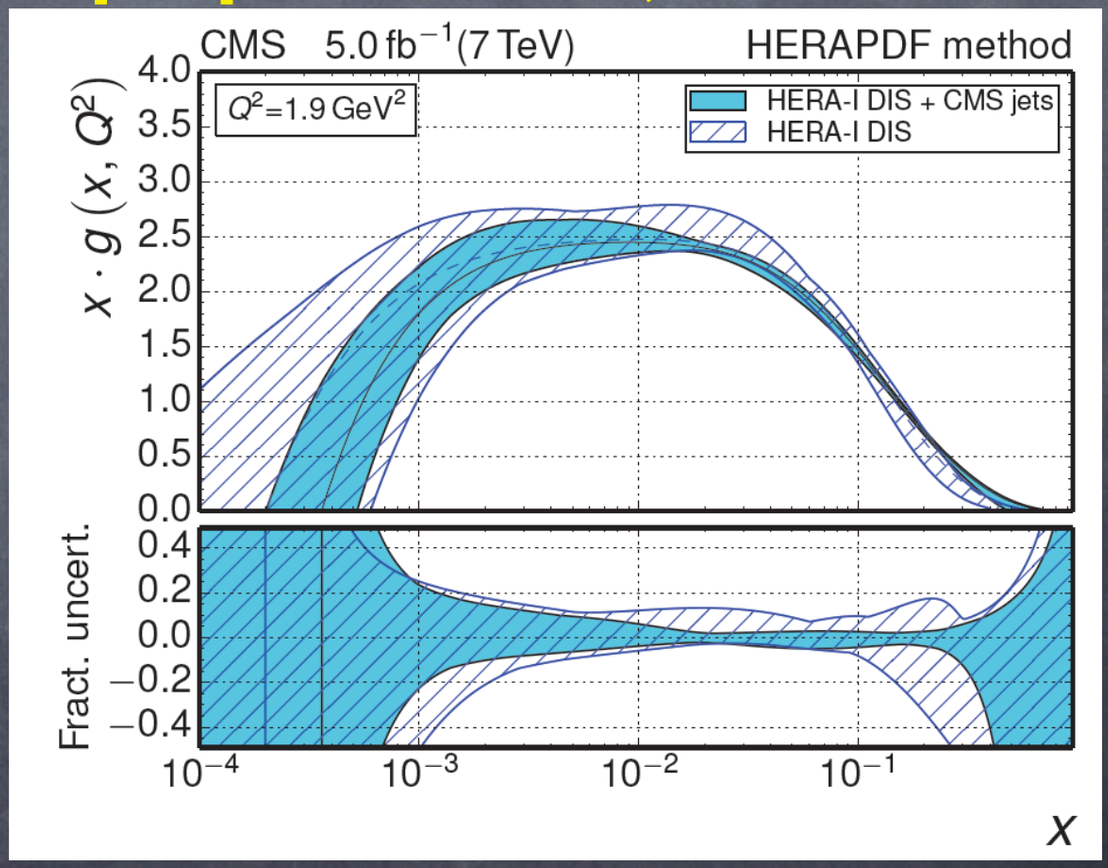
... quantified by correlation coefficients:



QCD analysis at NLO using HERAFitter

- HERA DIS data *[JHEP 1001:109 (2010)]*
- CMS jet production √s=7 TeV *[PRD 87 (2012) 12002]*

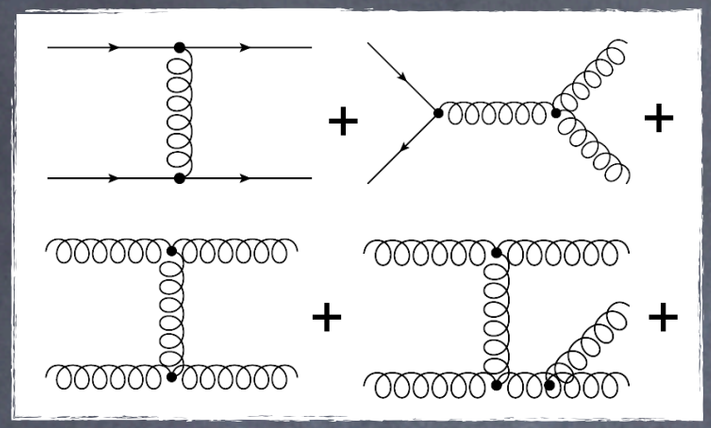
[CMS] arXiv:1410.6765 ; CMS-SMP-12-028



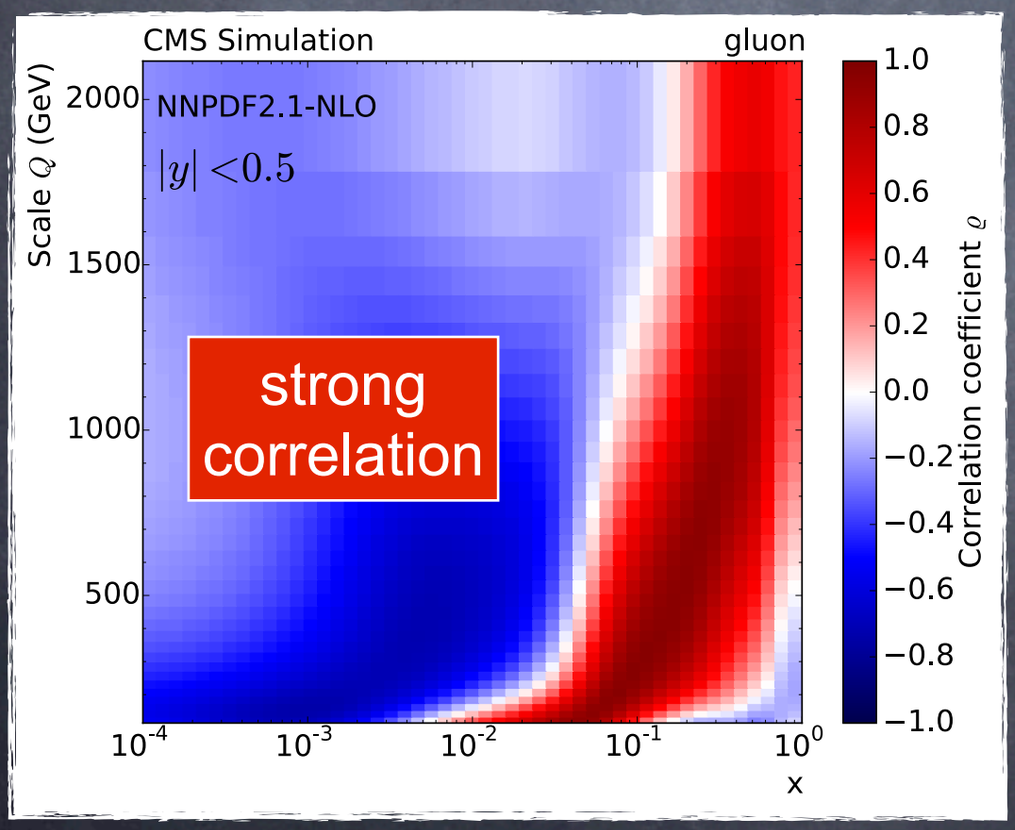
LHC jet measurements reduce error on g(x) at medium x

GLUON DISTRIBUTION: JET PRODUCTION

Inclusive jet production in pp collisions at LHC directly sensitive to PDFs and α_S



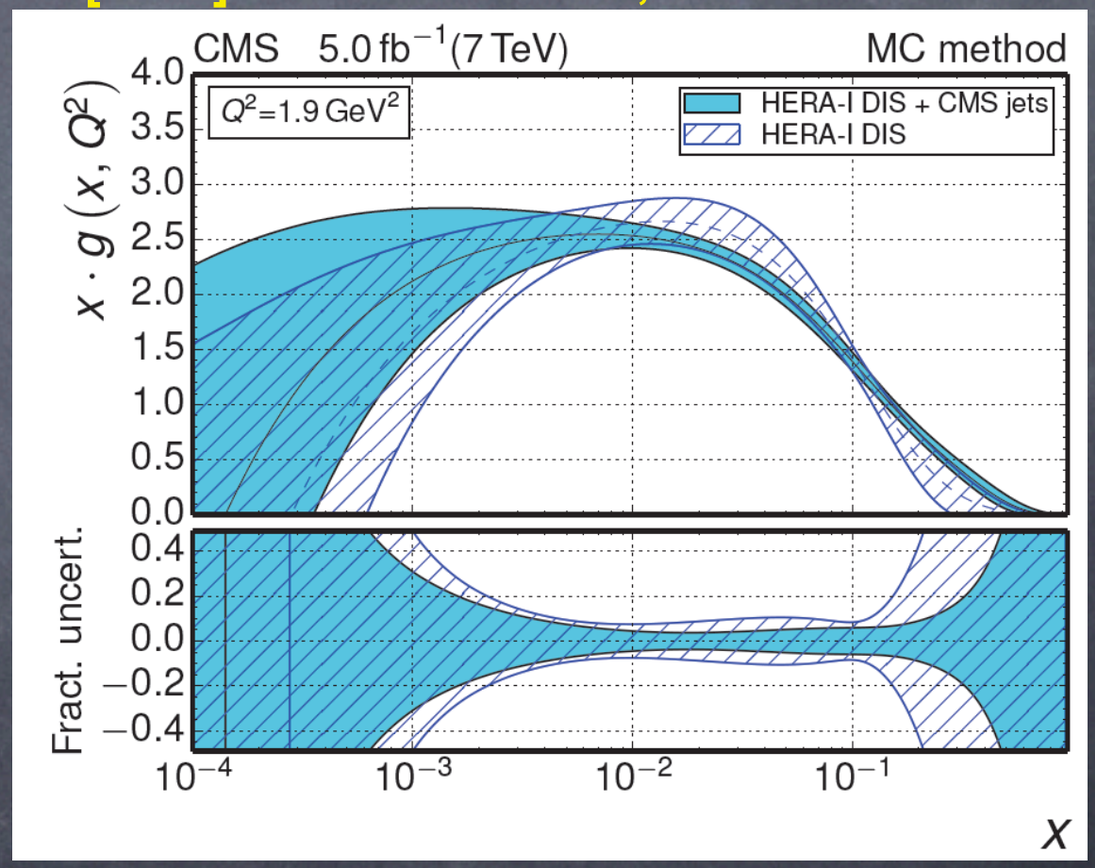
... quantified by correlation coefficients:



QCD analysis at NLO using HERAFitter

- HERA DIS data *[JHEP 1001:109 (2010)]*
- CMS jet production √s=7 TeV *[PRD 87 (2012) 12002]*

[CMS] arXiv:1410.6765 ; CMS-SMP-12-028

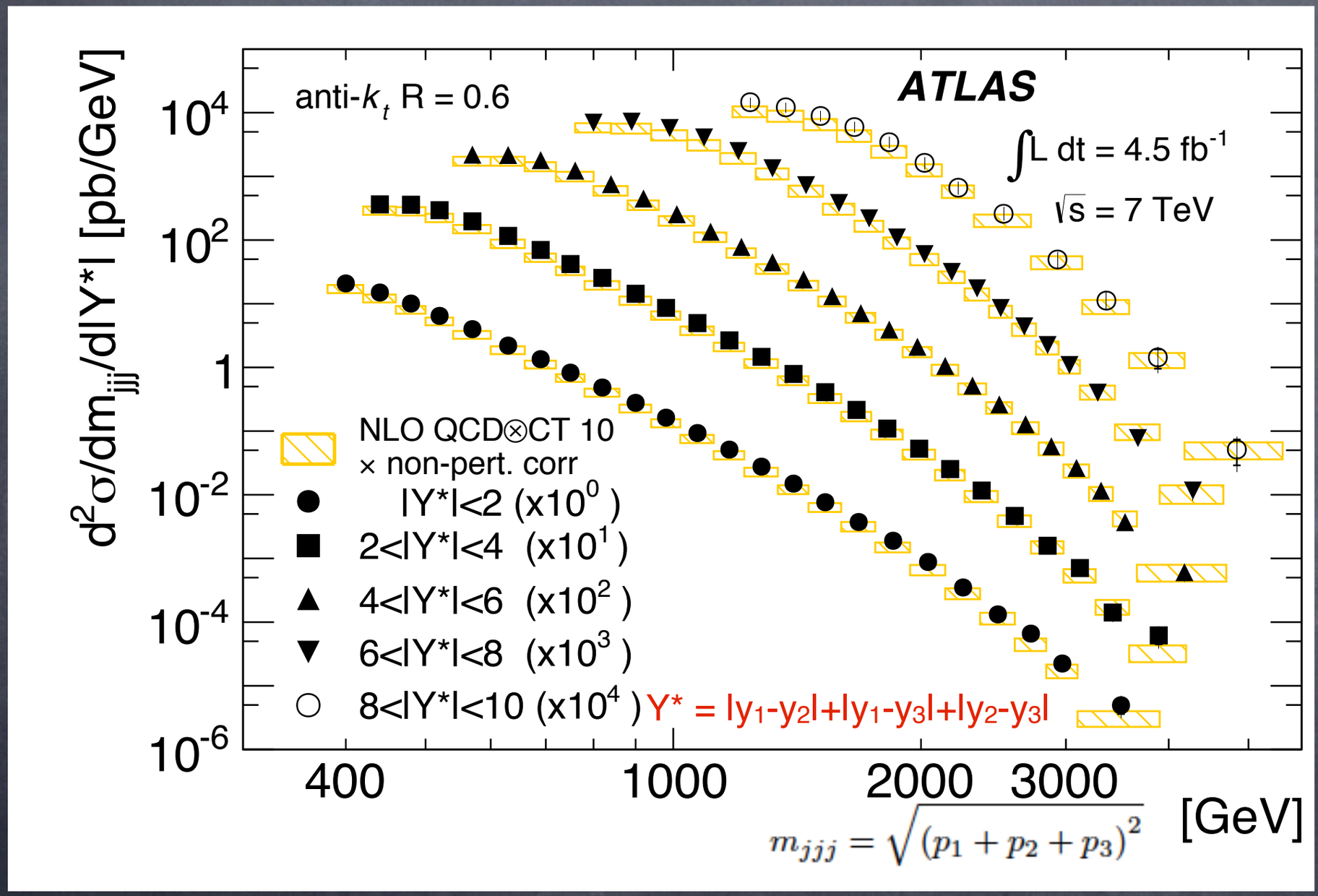


LHC jet measurements reduce error on g(x) at medium x

GLUON DISTRIBUTION: JET PRODUCTION

3 jet production: study further particularities of QCD and test PDF sensitivity

[ATLAS] arXiv:1411.1855

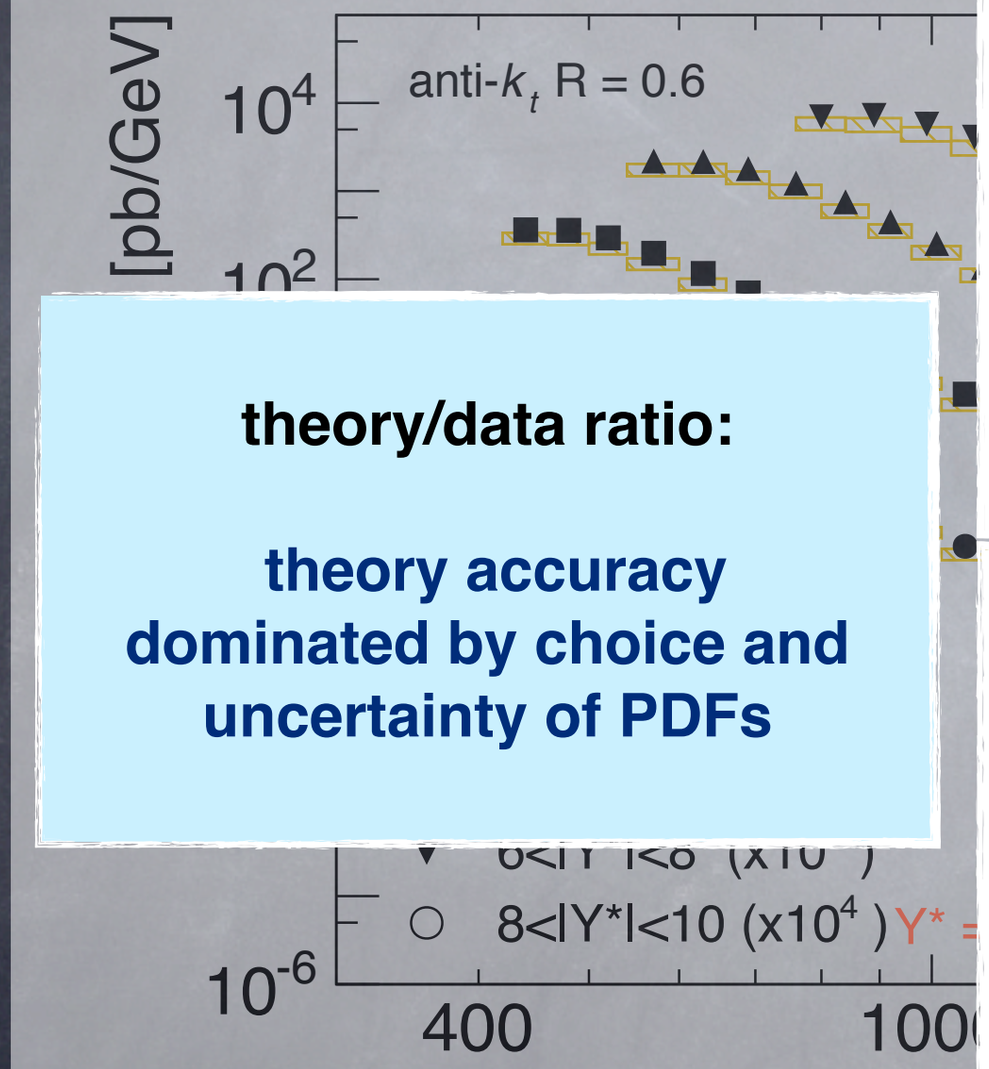


Theory prediction: NLOJEt++ x NP corrections (EW correction not calculated yet)

GLUON DISTRIBUTION: JET PRODUCTION

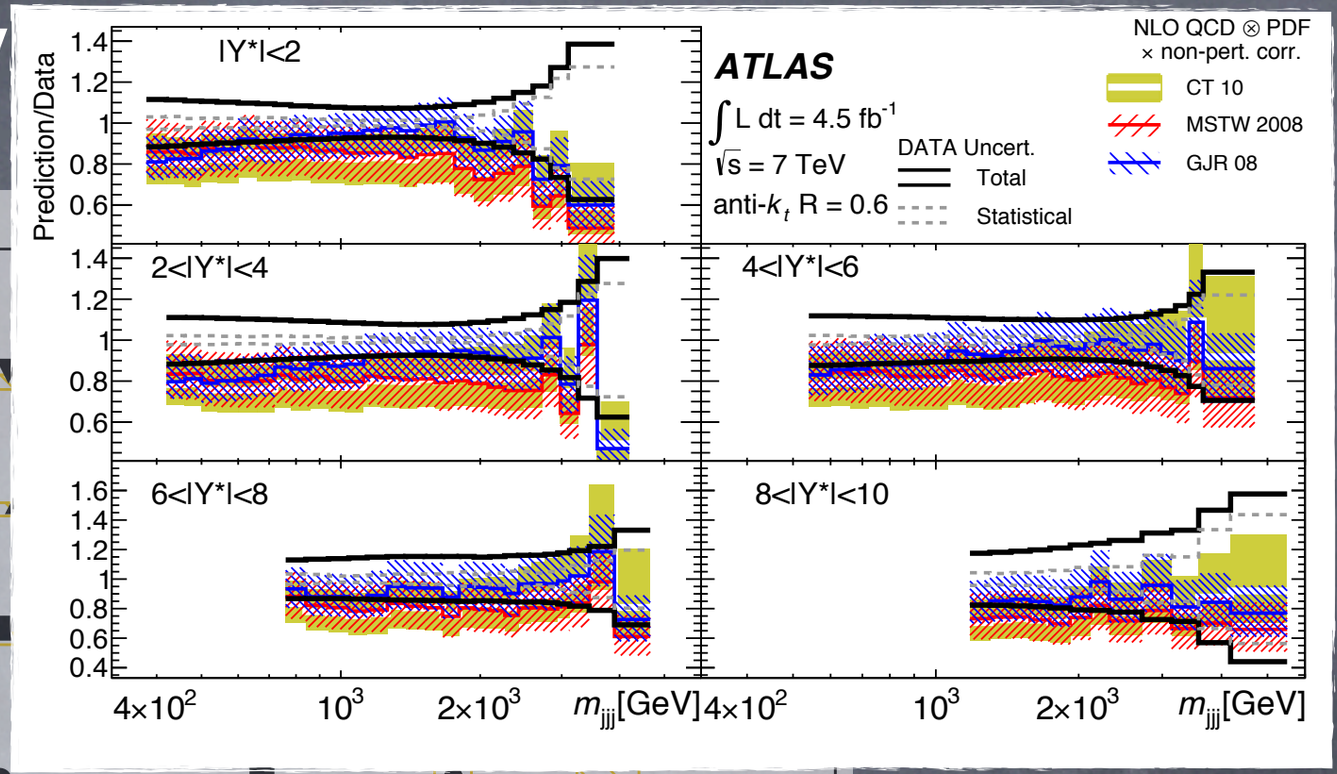
3 jet production: test PDF sensitivity

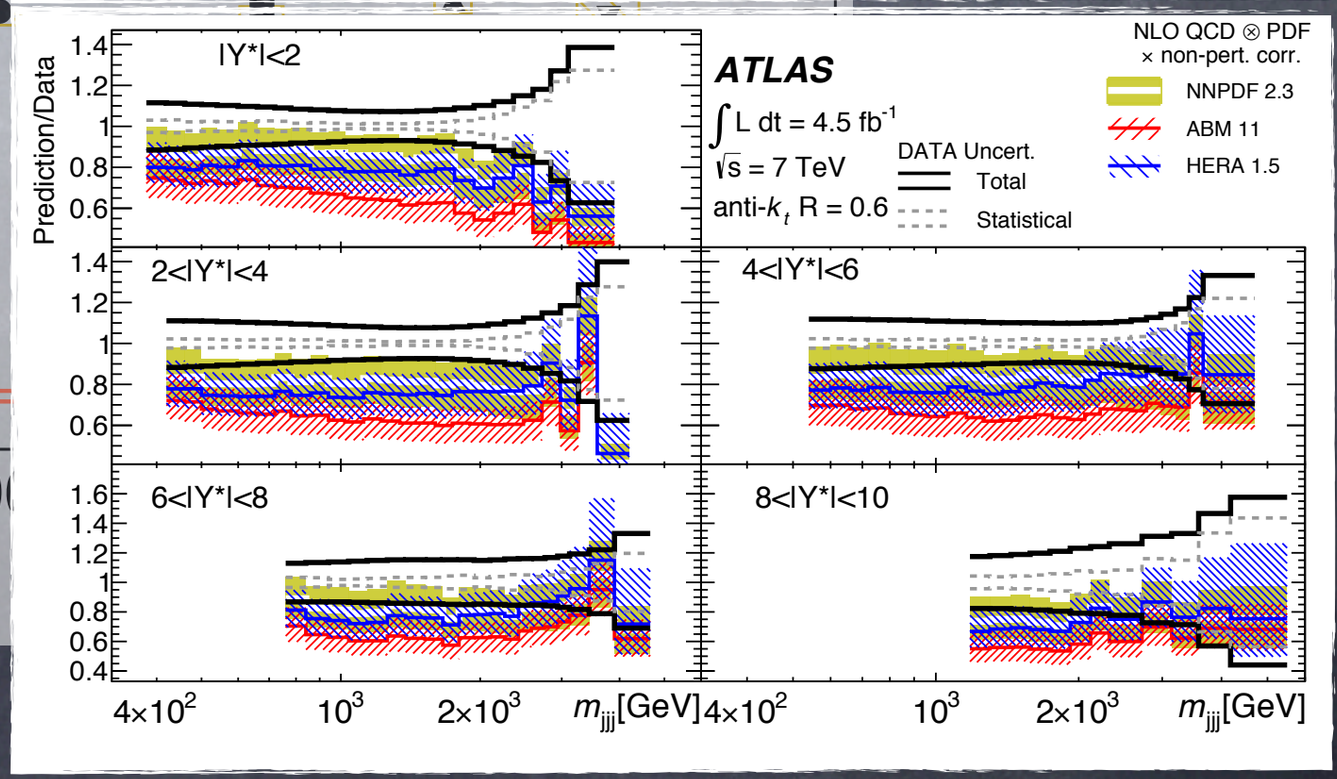
[ATLAS] arXiv:1411.1855



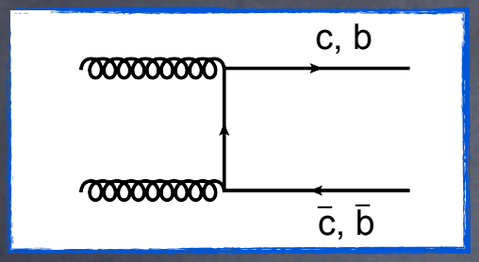
theory/data ratio:

theory accuracy dominated by choice and uncertainty of PDFs



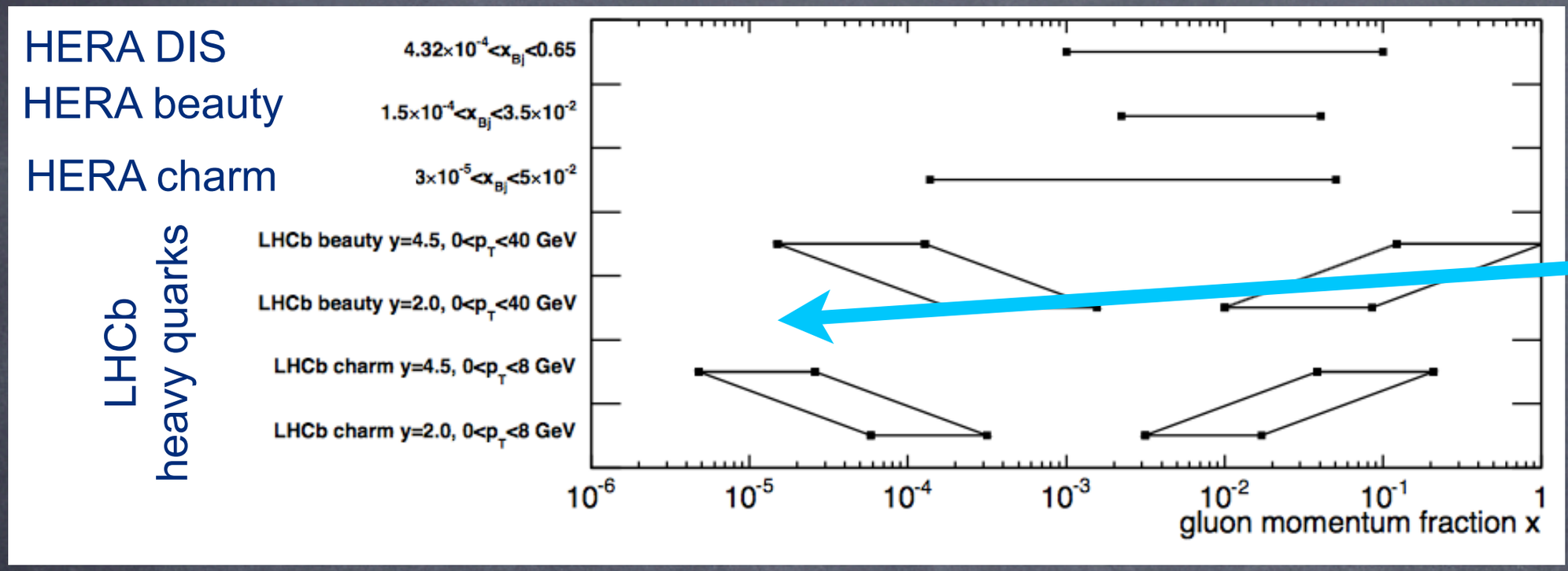


GLUON DISTRIBUTION AT LOW X

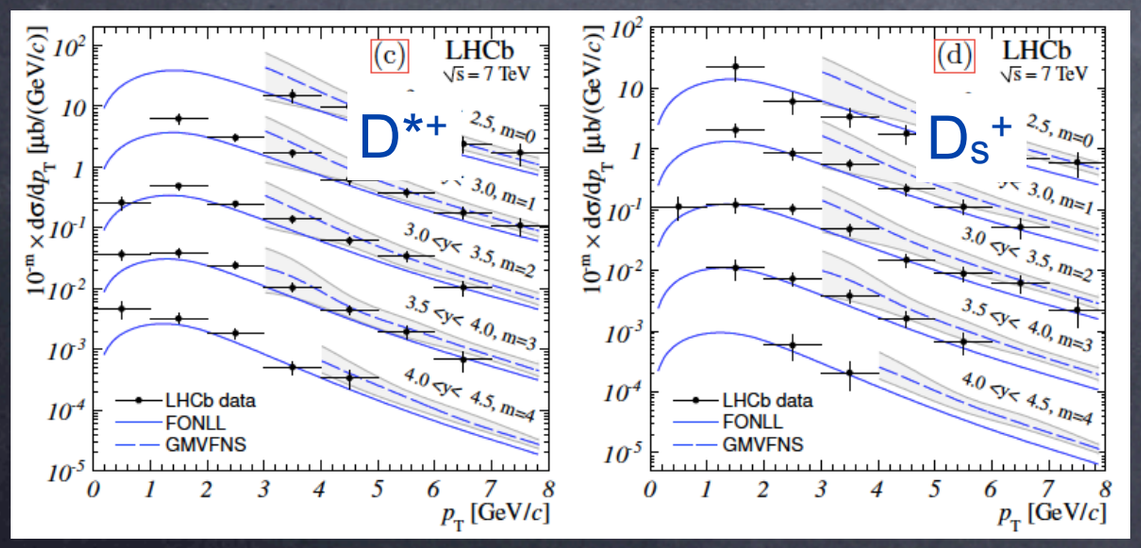


Heavy-quarks are produced in pp via gluon fusion

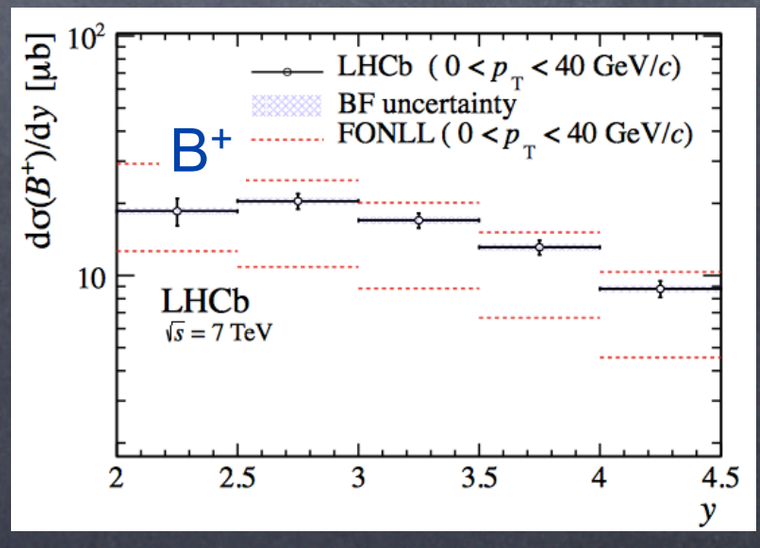
Kinematics of LHCb probes low x



not covered by other experiments



[LHCb] NPB871 (2013) 1



[LHCb] JHEP 08 (2013) 117

GLUON DISTRIBUTION AT LOW X

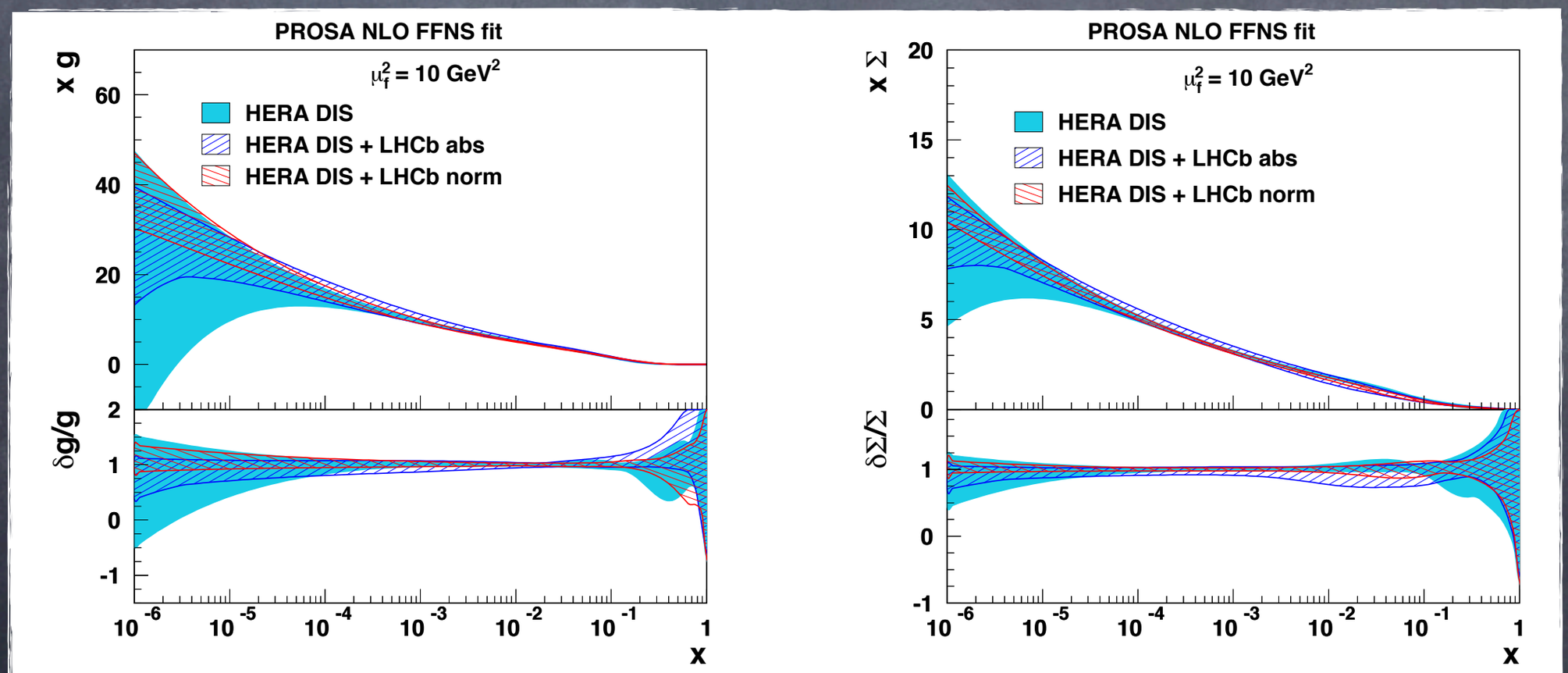
QCD analysis at NLO using HERAFitter

[PROSA] arXiv:1503.04581

- HERA inclusive DIS *[JHEP 1001:109 (2010)]*
- HERA heavy quarks *[EPJC 73(2013) 2311, JHEP1409(2014)127]*
- **LHCb HQ measurements included in a PDF fit for the first time:**

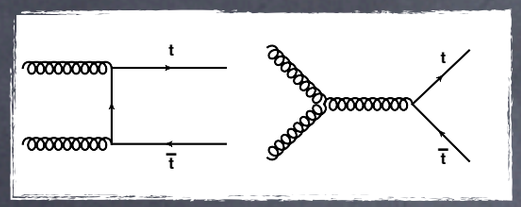
  charm (D^0,D^+,D^{*+},D^+_s,Λ_c), $0 < p_T < 8$ GeV **[Nucl. Phys. B871 (2013) 1]** 7 TeV $\mathcal{L} = 15 nb^{-1}$

  beauty(B^+,B^0,B_s^0), $0 < p_T < 40$ GeV **[JHEP 08 (2013) 117]** 7 TeV $\mathcal{L} = 0.36\ fb^{-1}$



LHCb c, b- measurements reduce error on g(x) at very low x

GLUON DISTRIBUTION AT HIGH X

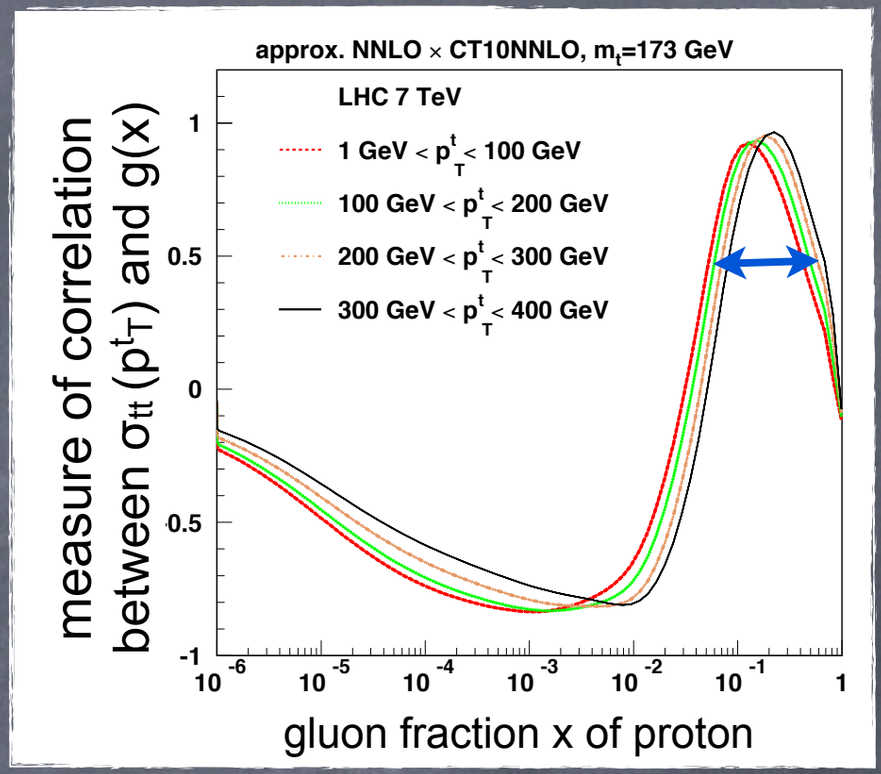


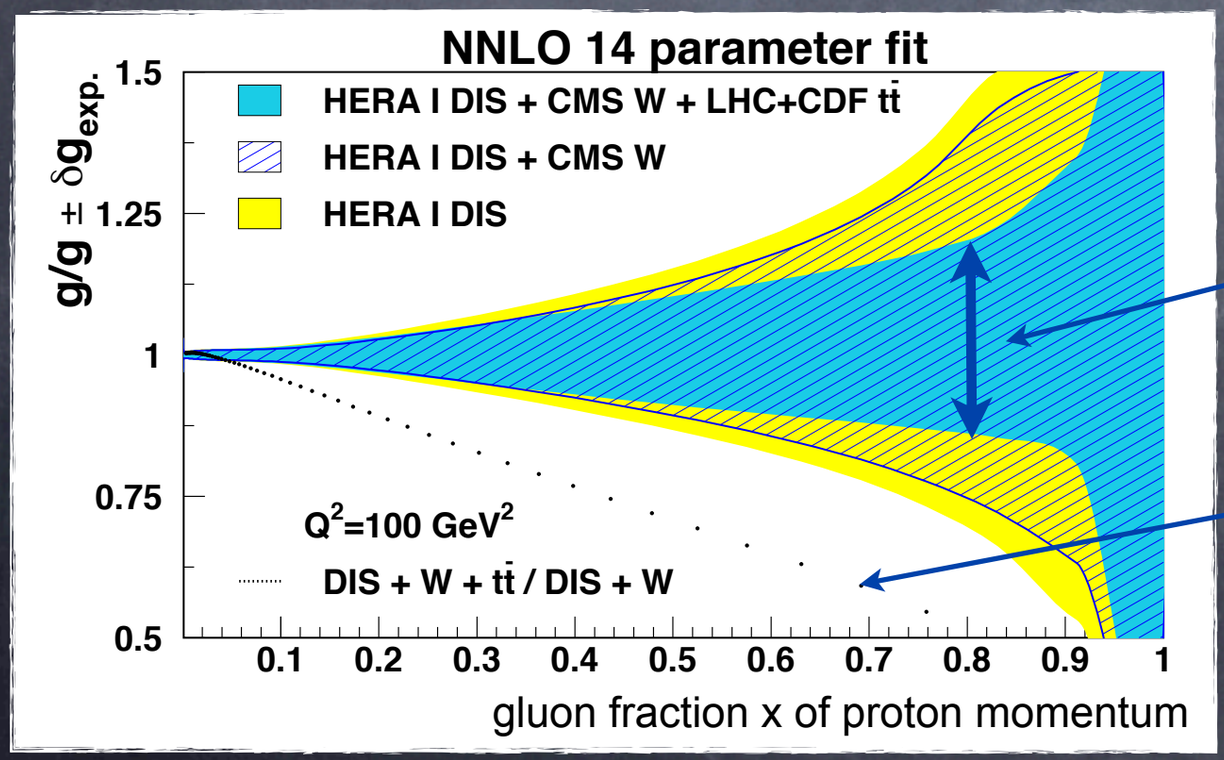
In pp collisions top-quark pairs are produced via gg fusion probing gluon at high x

[M. Guzzi et al] JHEP 1501 (2015) 082

tt data in QCD analysis at NNLO using HERAFitter:

- HERA DIS data *[JHEP 1001:109 (2010)]*
- W asymmetry *[CMS* Phys. Rew. D 90 (2014) 032004*]*
- **top-quark pair production in pp:**
  ATLAS and CMS data on inclusive and differential cross sections at 7 and 8 TeV





LHC tt measurements reduce uncertainty on gluon distribution at high x

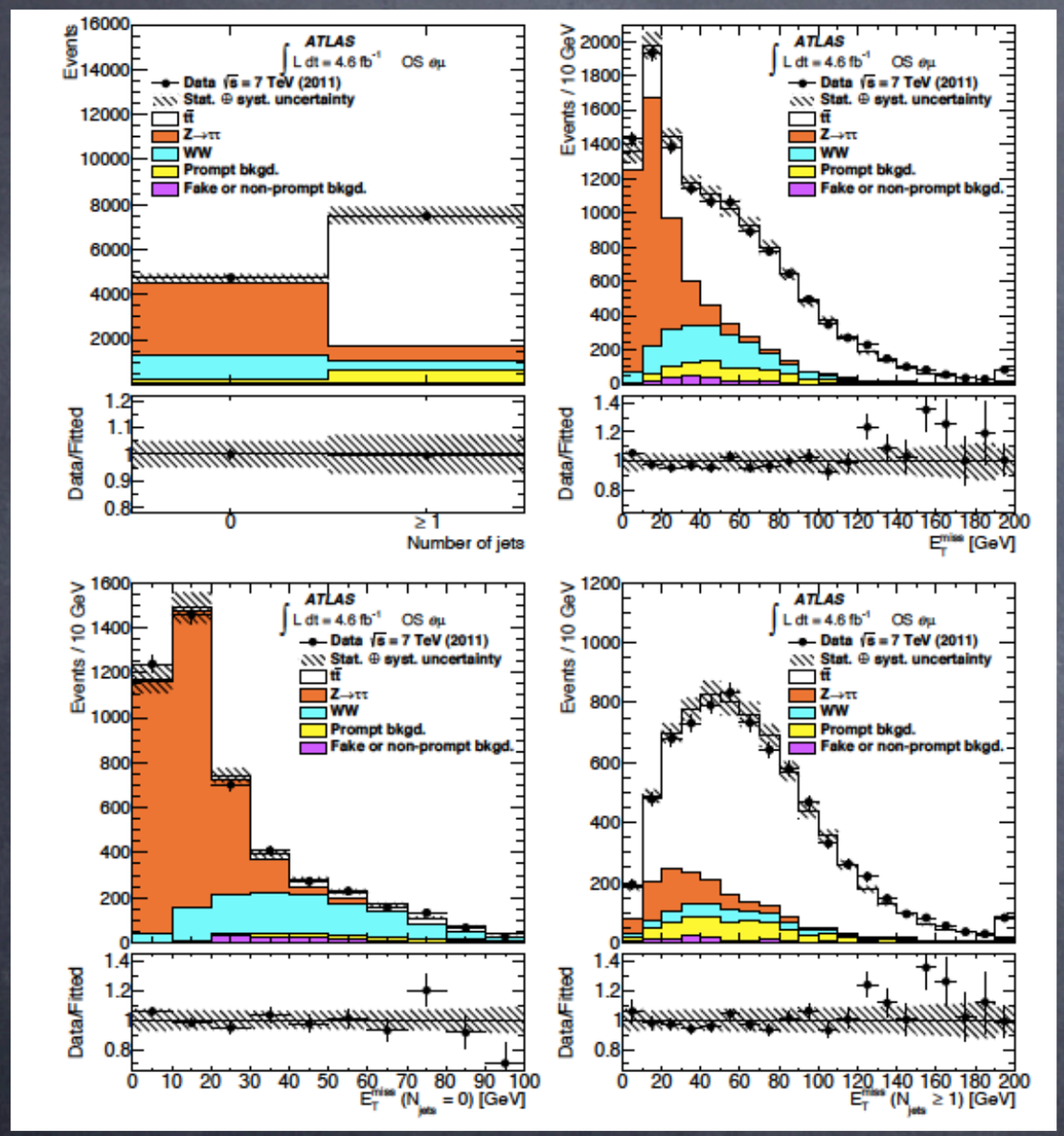
g(x) changes shape

Expect stronger constraint from 13 and 14 TeV data

STRINGENT TEST OF STANDARD MODEL

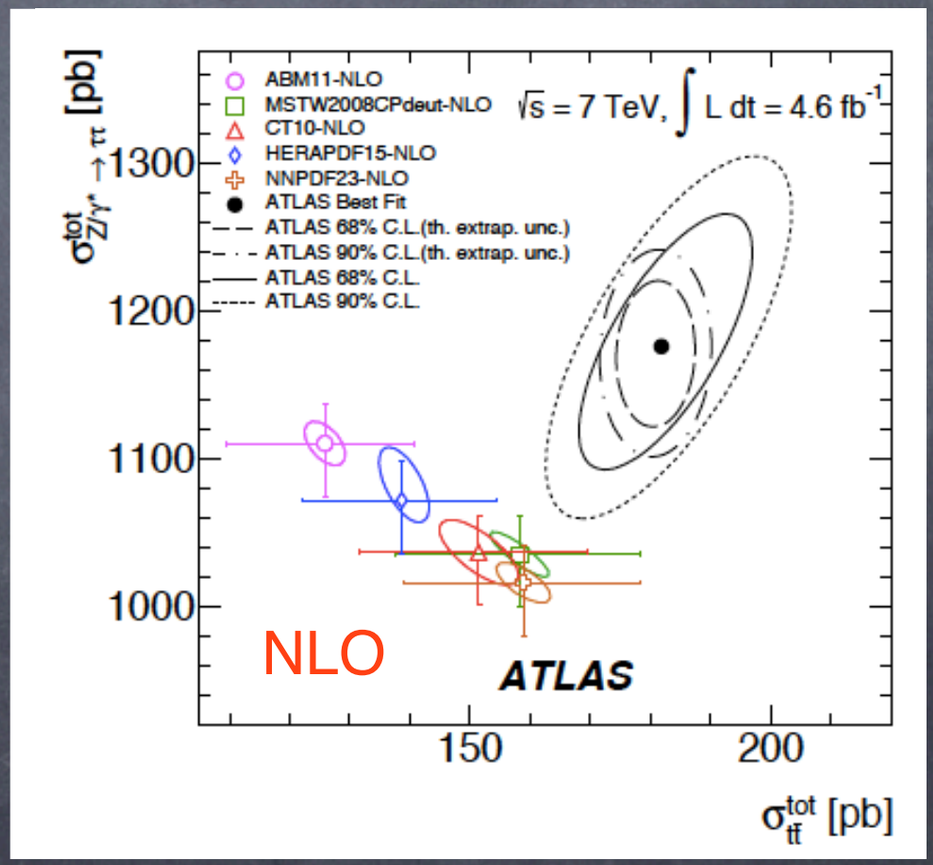
Simultaneous measurements of the top-pair, WW,and Z→ττ production cross-sections

[ATLAS] PRD D91 (2015) 5, 052005



Study common final state (eμ)- events in two-dimensional parameter space (E^{T}_{miss} , N_{jets})

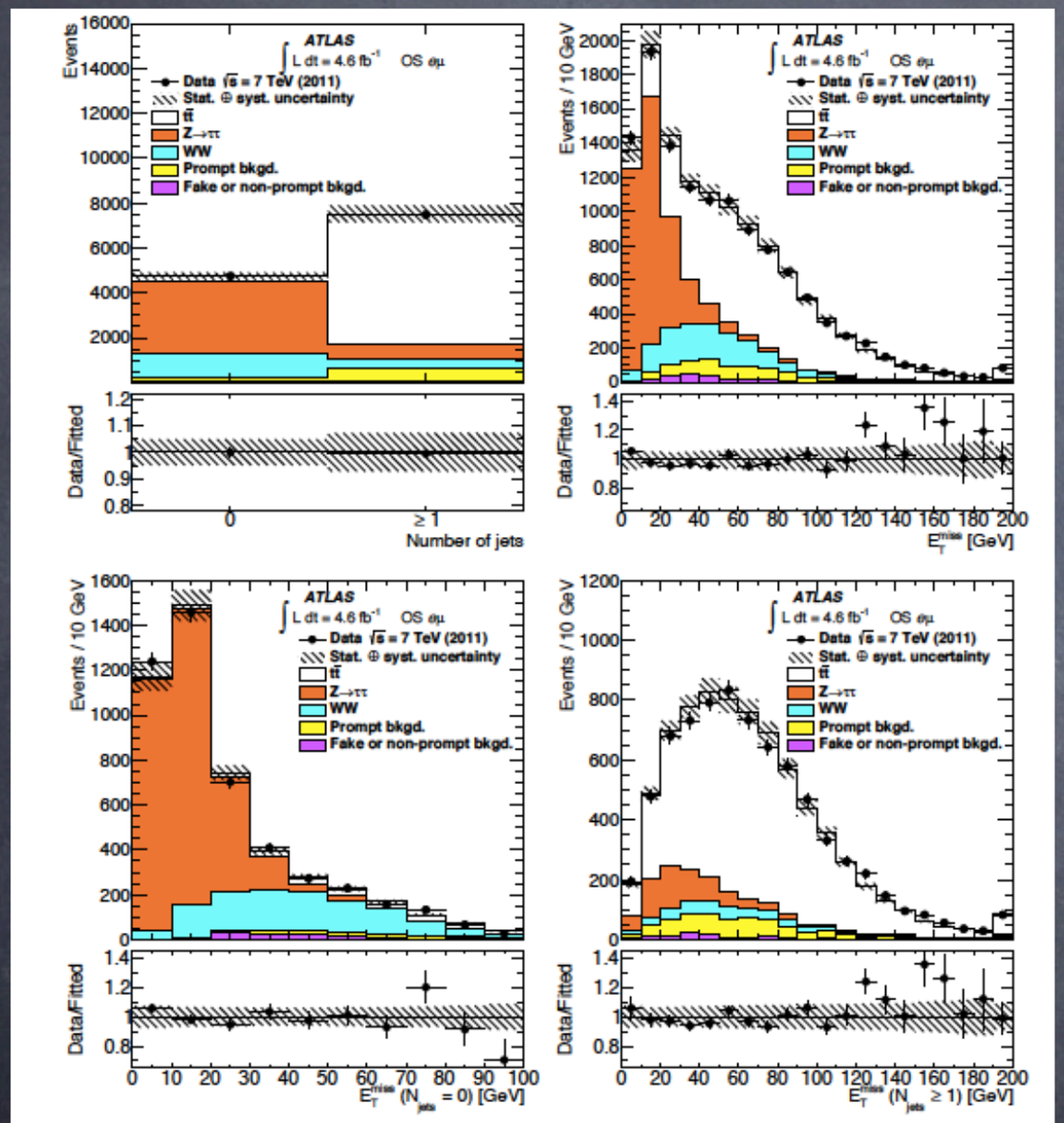
investigate correlation between cross-section when using common PDFs in MC



STRINGENT TEST OF STANDARD MODEL

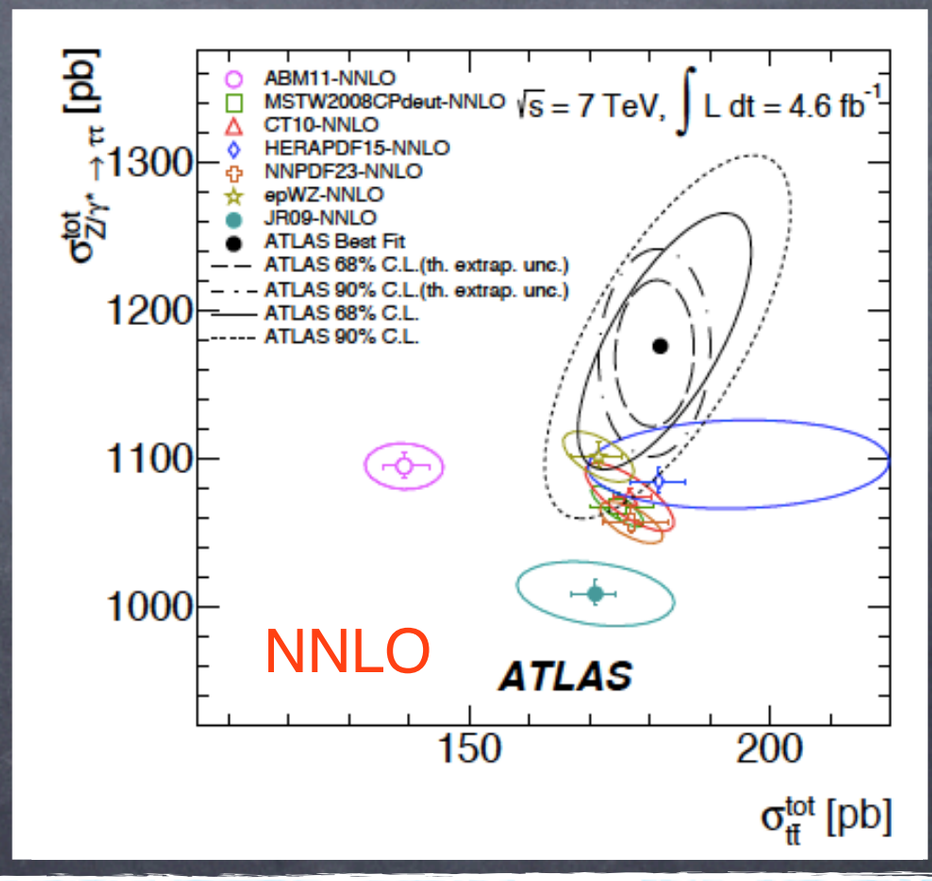
Simultaneous measurements of the top-pair, WW,and Z→ττ production cross-sections

[ATLAS] PRD D91 (2015) 5, 052005



Study common final state (eμ)- events in two-dimensional parameter space (E^{T}_{miss} , N_{jets})

investigate correlation between cross-section when using common PDFs in MC



NNLO does better than NLO, PDF uncertainty dominant uncertainty at NNLO

SUMMARY

Final word on inclusive DIS: combined HERA measurements coming out

- Ultimate-precision data used in the HERAPDF2.0 PDF series

LHC Run I measurements used for improvement on light-quark distributions

- ATLAS and CMS data: precision in medium x range
- LHCb probes x down to 10^{-6}
- Associated W+charm production constrains s-quark

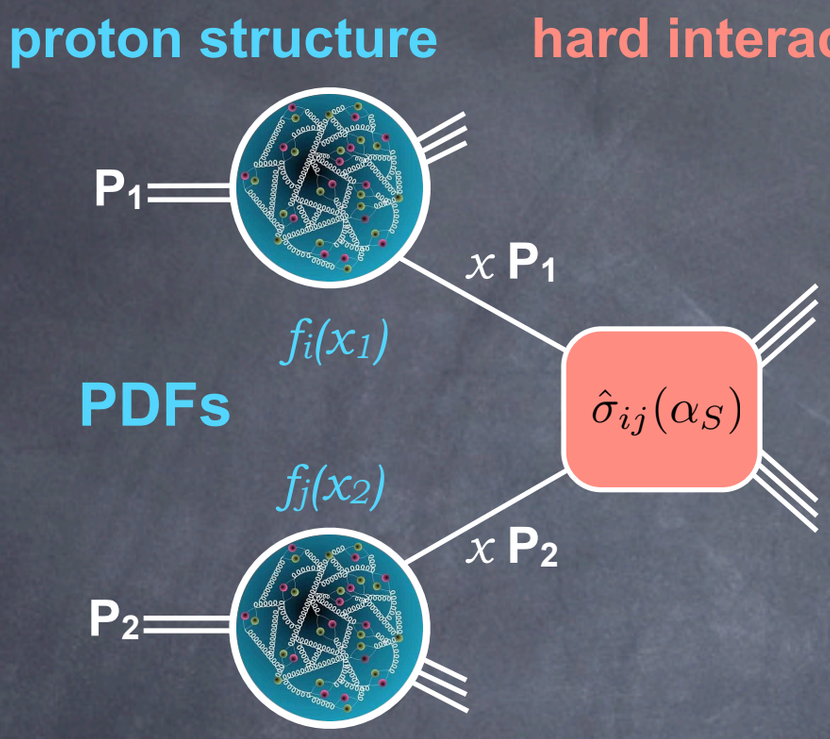
LHC Run I measurements used for improvement on gluon distributions

- ATLAS and CMS jet data: improved precision at medium x
- Top-pair production has high potential to improve accuracy at high x
- Heavy-flavor production at LHCb improves gluon precision down to $x = 10^{-6}$

Run I has shown high potential of the LHC
to improve the understanding of the proton structure,
more data are still to come to be used in precision QCD analyses

BACK UP

NEED FOR EXPERIMENTAL INPUT



Partons: quarks & gluons

Q^2 : typical energy scale in the process

x : partonic fraction of the proton momentum

Rate = (structure of 2 protons) ⊗ σ_{ij}

Parton Distribution Functions

$f_i(Q^2, x)$

provided by theory

determined experimentally

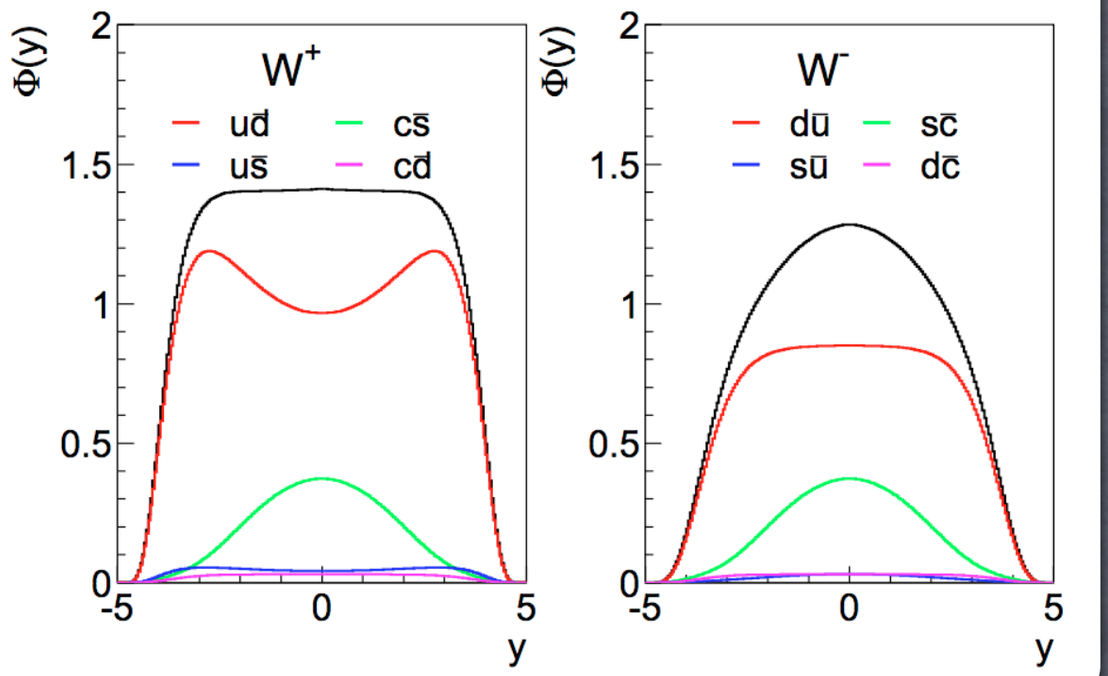
at the very edge of theory and experiment, correlated with fundamental QCD parameters

Improvement of PDFs precision demands theory & experiment collaboration and implies a variety of measurements and theory calculations

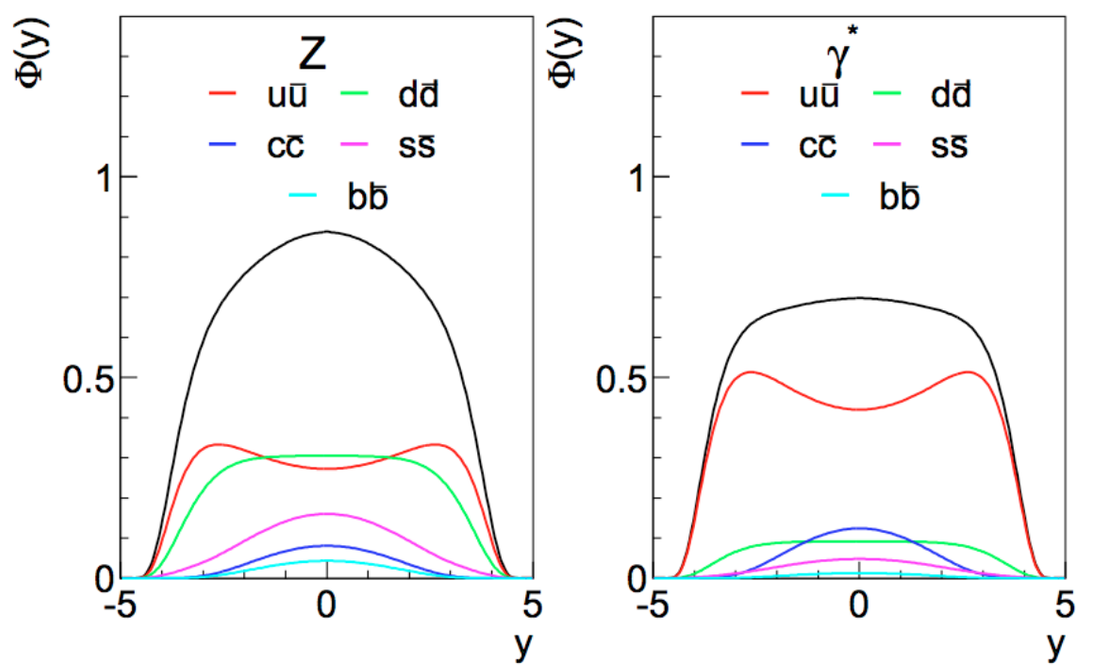
PDF SENSITIVITY OF EWK BOSON PRODUCTION

Measurements of Drell-Yan production probe bi-linear combination of PDFs

$$W^+ \approx 0.95(u\bar{d} + c\bar{s}) + 0.05(u\bar{s} + c\bar{d})$$
$$W^- \approx 0.95(d\bar{u} + s\bar{c}) + 0.05(d\bar{c} + s\bar{u})$$



$$Z \approx 0.29(u\bar{u} + c\bar{c}) + 0.37(d\bar{d} + s\bar{s} + b\bar{b})$$
$$\gamma^* \approx 0.44(u\bar{u} + c\bar{c}) + 0.11(d\bar{d} + s\bar{s} + b\bar{b})$$



NB: LO with suppressed strangeness

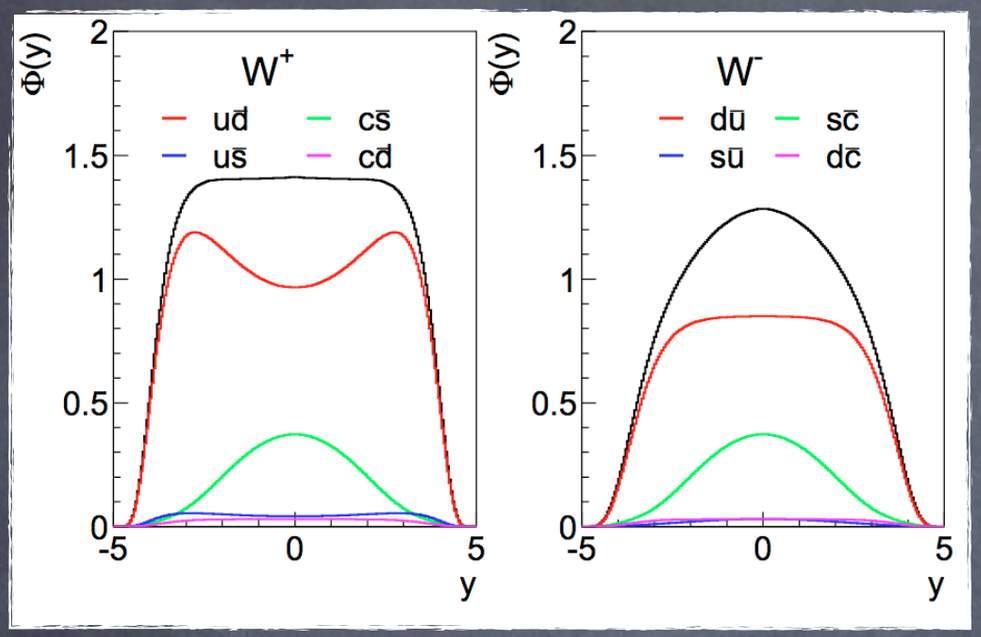
...courtesy A.Glazov/V.Radescu

differential cross sections for W and Z production provide important information on light quarks and the sea decomposition

(particularly interesting is strange-quark distribution, which is poorly known)

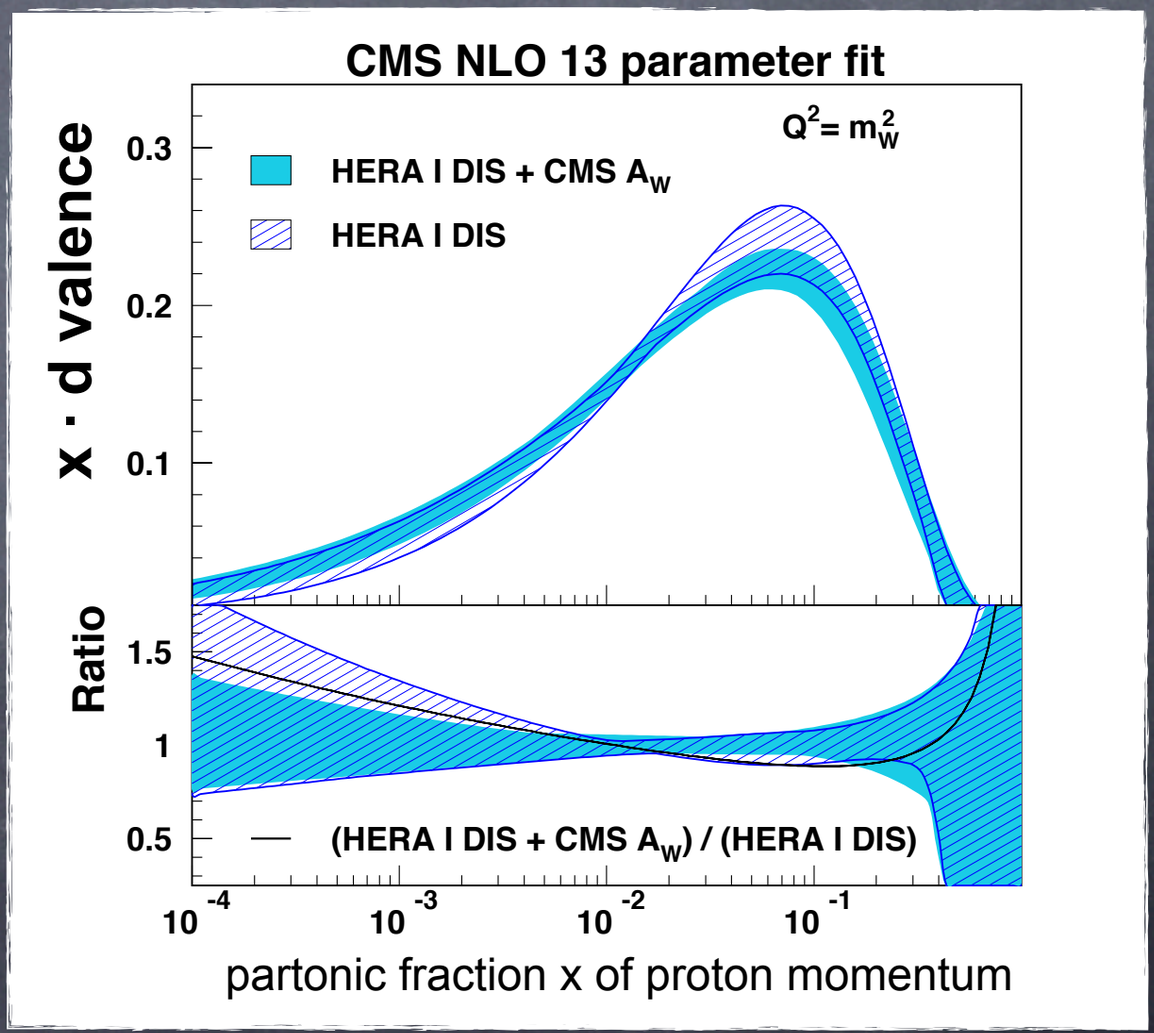
Valence: W PRODUCTION

Lepton asymmetry in W production at LHC probes valence quark distributions



$$A_W = \frac{W^+ - W^-}{W^+ + W^-} \approx \frac{u_v - d_v}{u_v + d_v + 2u_{sea}}$$

[CMS Collaboration], PRD 90 (2014) 032004



QCD analysis at NLO using HERAFitter

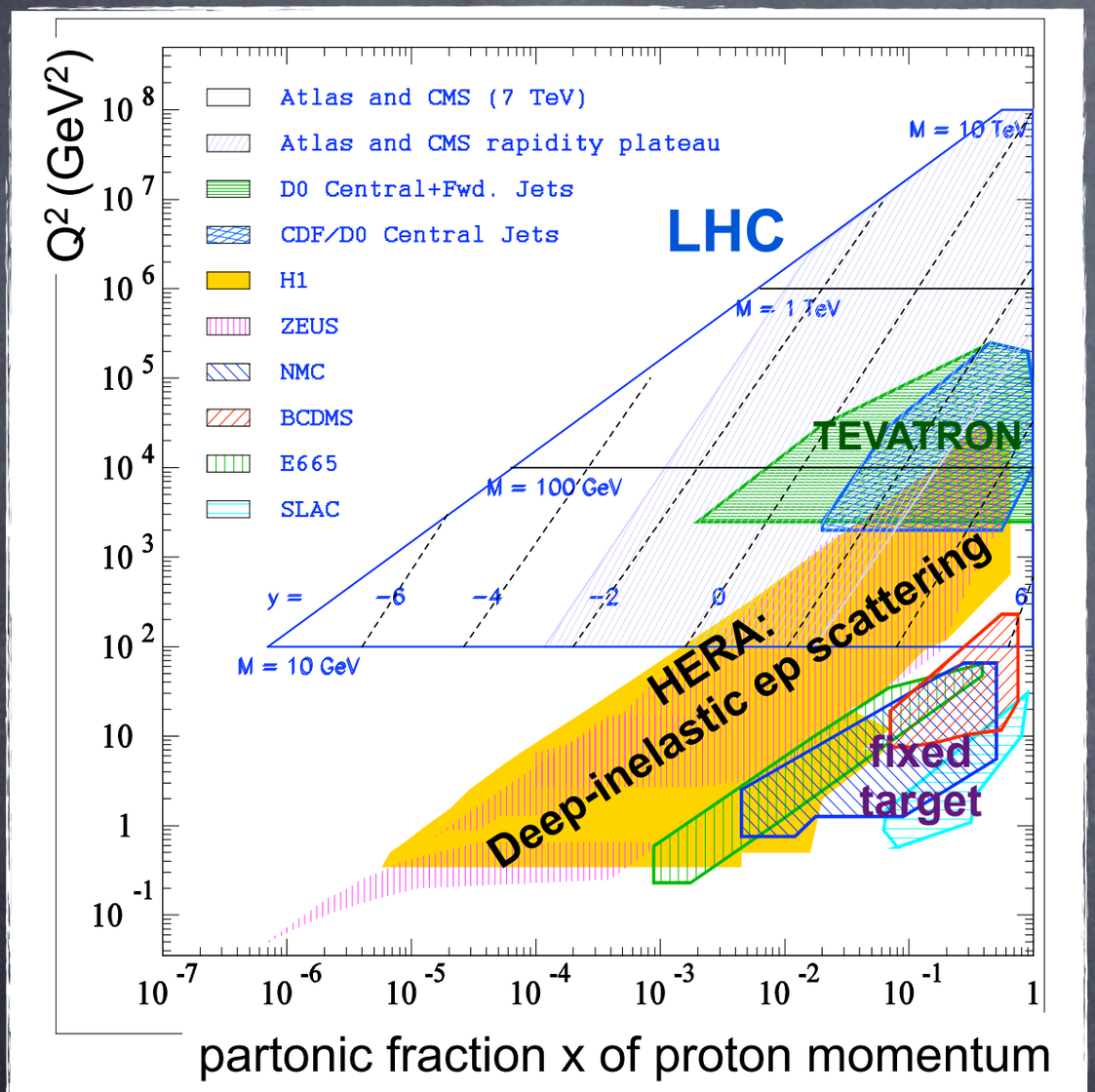
- HERA inclusive DIS *[JHEP 1001:109 (2010)]*
- CMS muon charge asymmetry in W production

LHC measurements of lepton charge asymmetry in W production

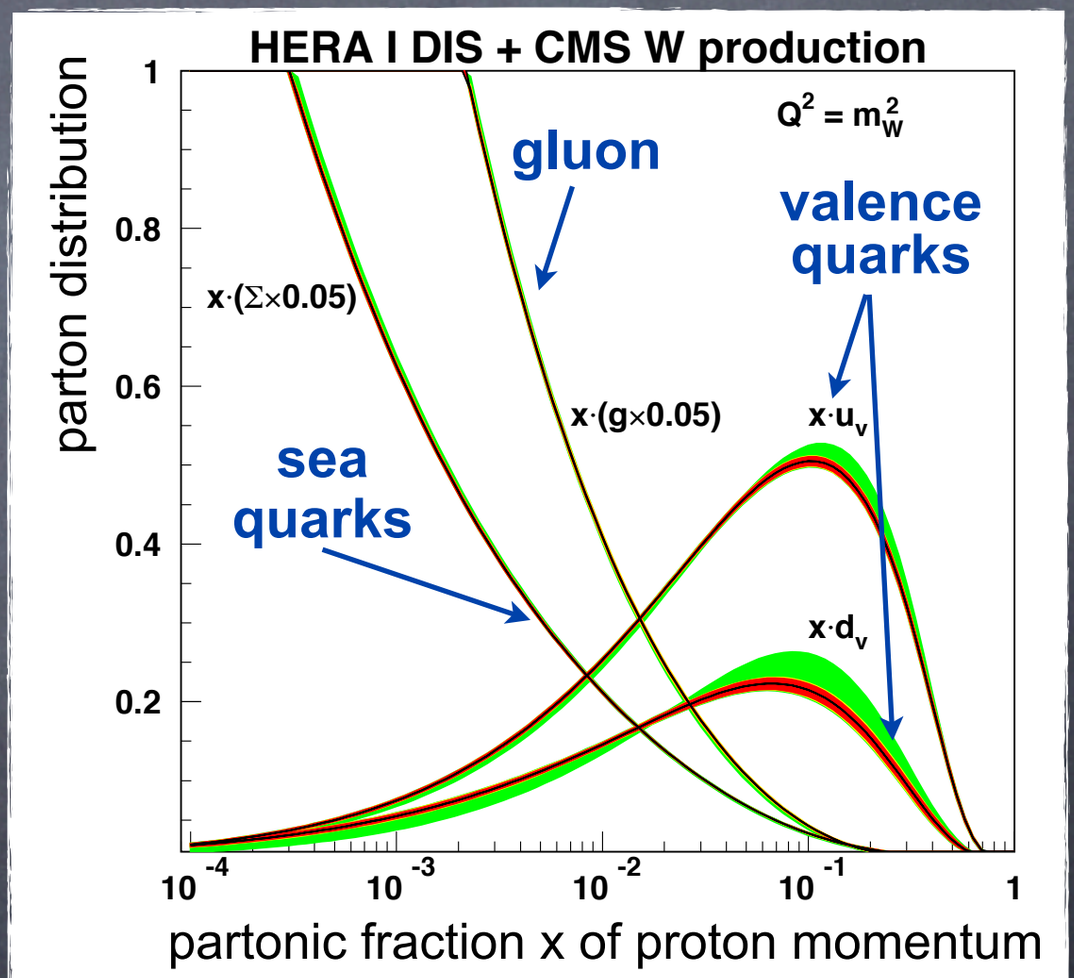
reduce uncertainty on u- and d- valence distributions

GENERAL IDEA OF A QCD ANALYSIS

PDF for flavor i: $f_i=f_i(x,Q^2)$
Q^2 dependence predicted by QCD
x-dependence determined from data



- parameterize PDFs at a scale Q^2_0:
  $f(x)=Ax^B(1-x)^C(1+Dx+Ex^2)$
- evolve these PDFs to $Q^2>Q^2_0$
- construct expected cross sections
- χ^2 - fit to the experimental data

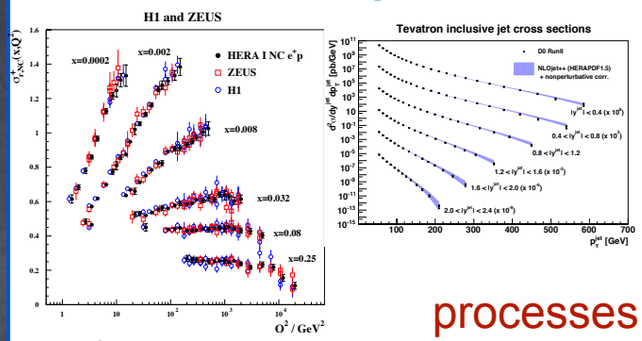


PDFs determined mostly from HERA data, LHC provides further constraints

QCD ANALYSIS TOOL: HERAFitter

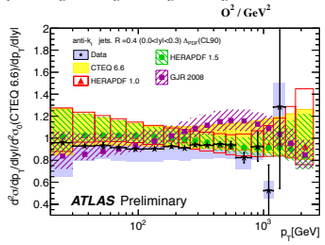
developed to test impact of the measurements on e.g. PDFs **during data analysis**

experimental input



experiments:
HERA, Tevatron, LHC, fixed target

processes:
NC, CC DIS, jets, diffraction, heavy quarks (c,b,t)
Drell-Yan, W production



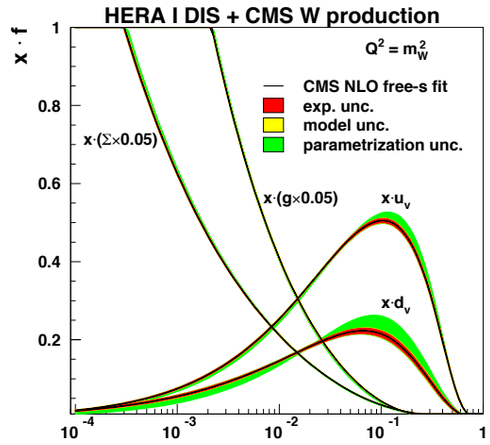
theoretical calculations/tools

Heavy quark schemes:	MSTW, CTEQ, ABM
Jets, W, Z production:	fastNLO, Applgrid
Top production	NNLO (Hathor)
QCD Evolution	DGLAP (QCDNUM)
	k_T factorisation
Alternative tools	NNPDF reweighting
Other models	Dipole model

+ Different error treatment models
+ Tools for data combination (HERAaverager)

… details see talk A. Glazov

HERAFitter



PDF or uPDF or DPDF

$\alpha_S(M_Z), m_c, m_b, m_t, f_s, ..$

Theory predictions

Benchmarking

Comparison of schemes

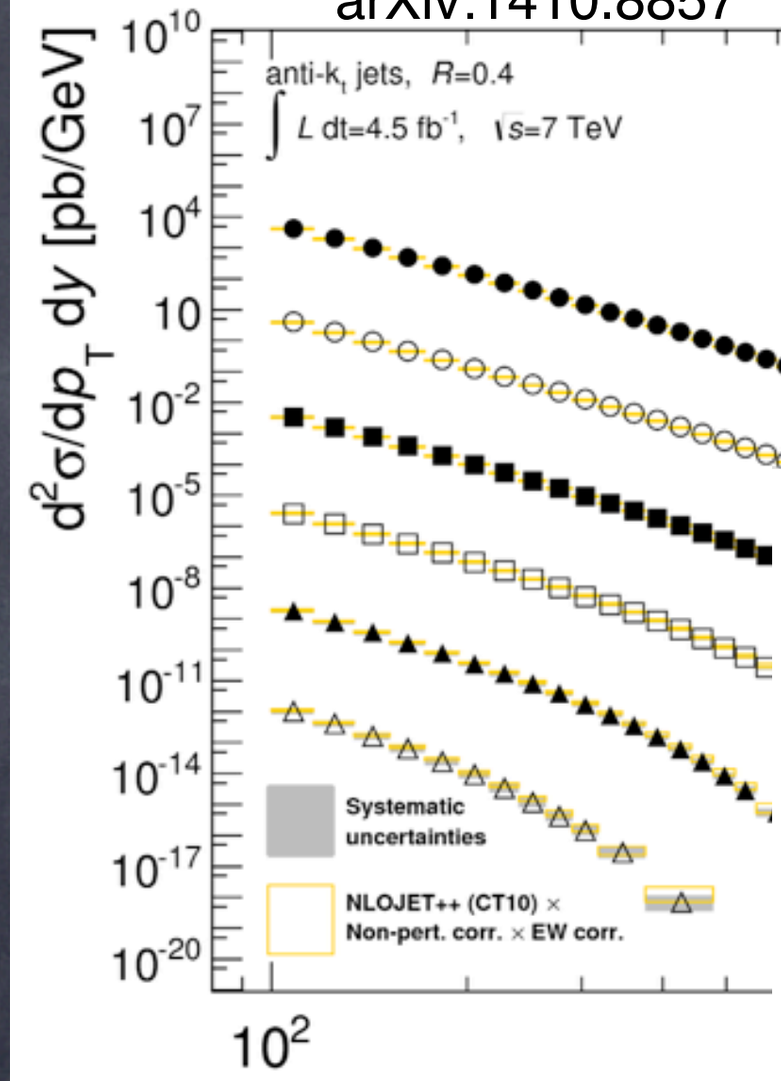
arXiv:1410.4412

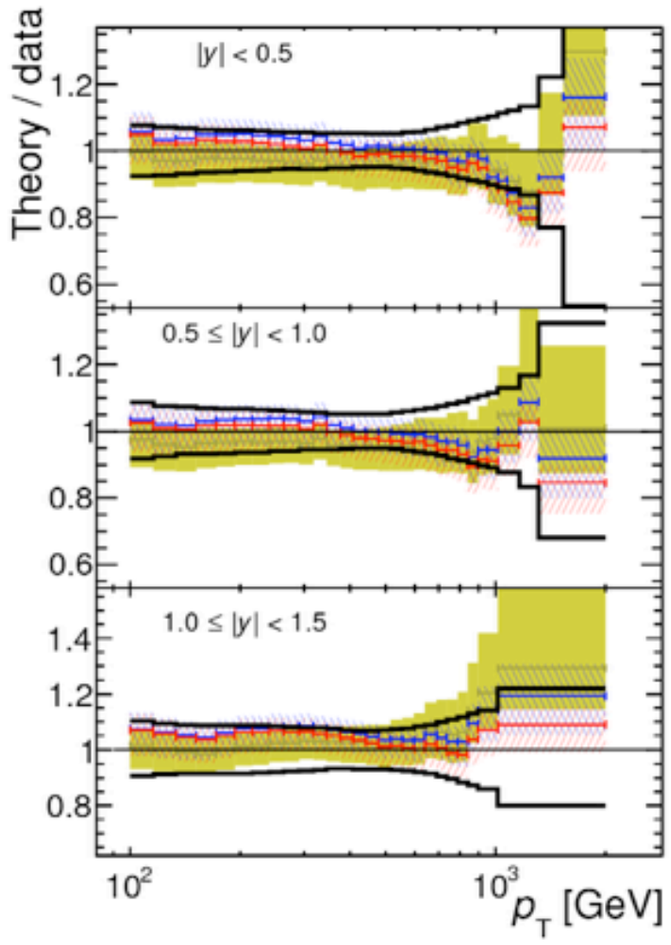
HERAFitter

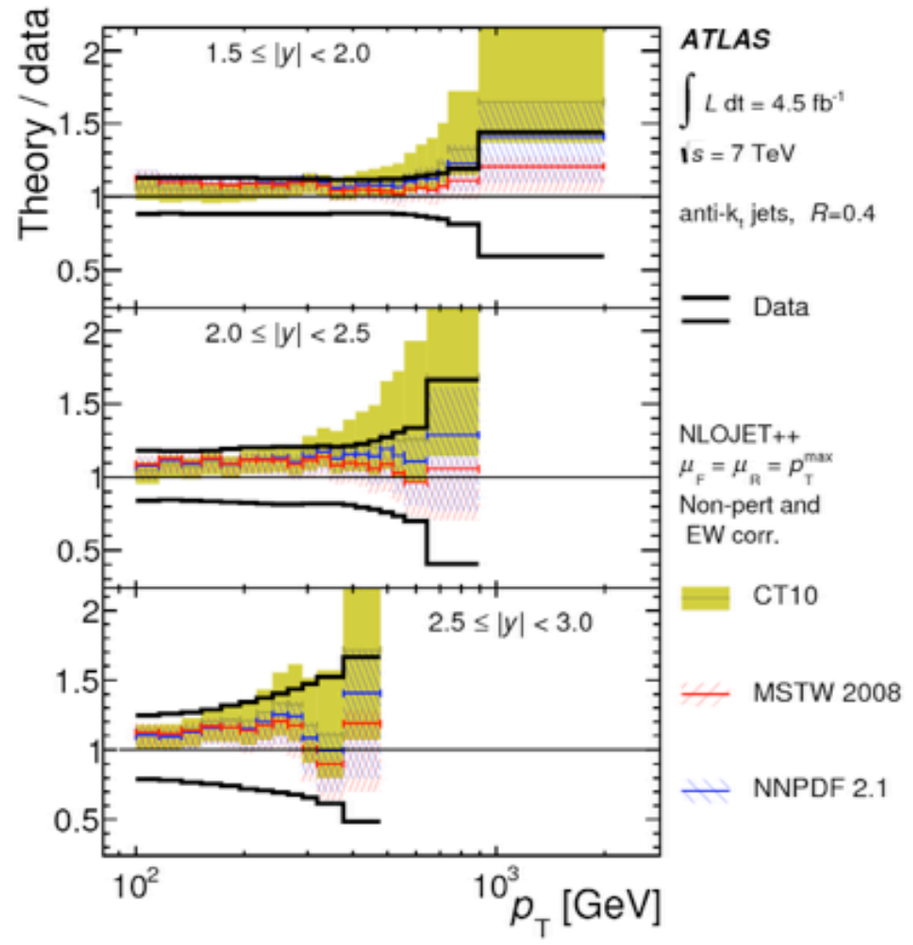
https://www.herafitter.org/HERAFitter

GLUON AT MEDIUM X: JET PRODUCTION

arXiv:1410.8857 **JHEP 1502 (2015) 153**

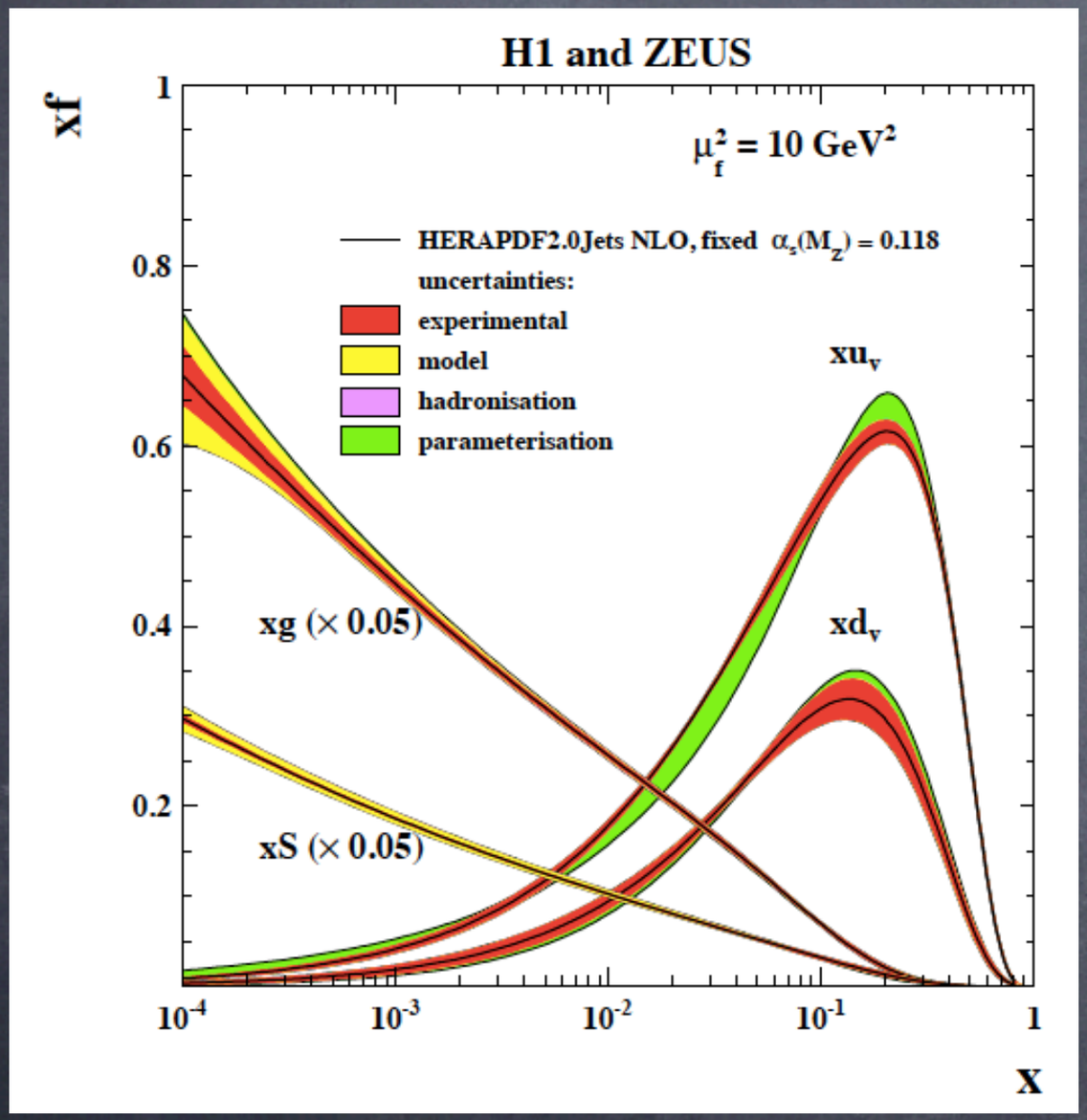




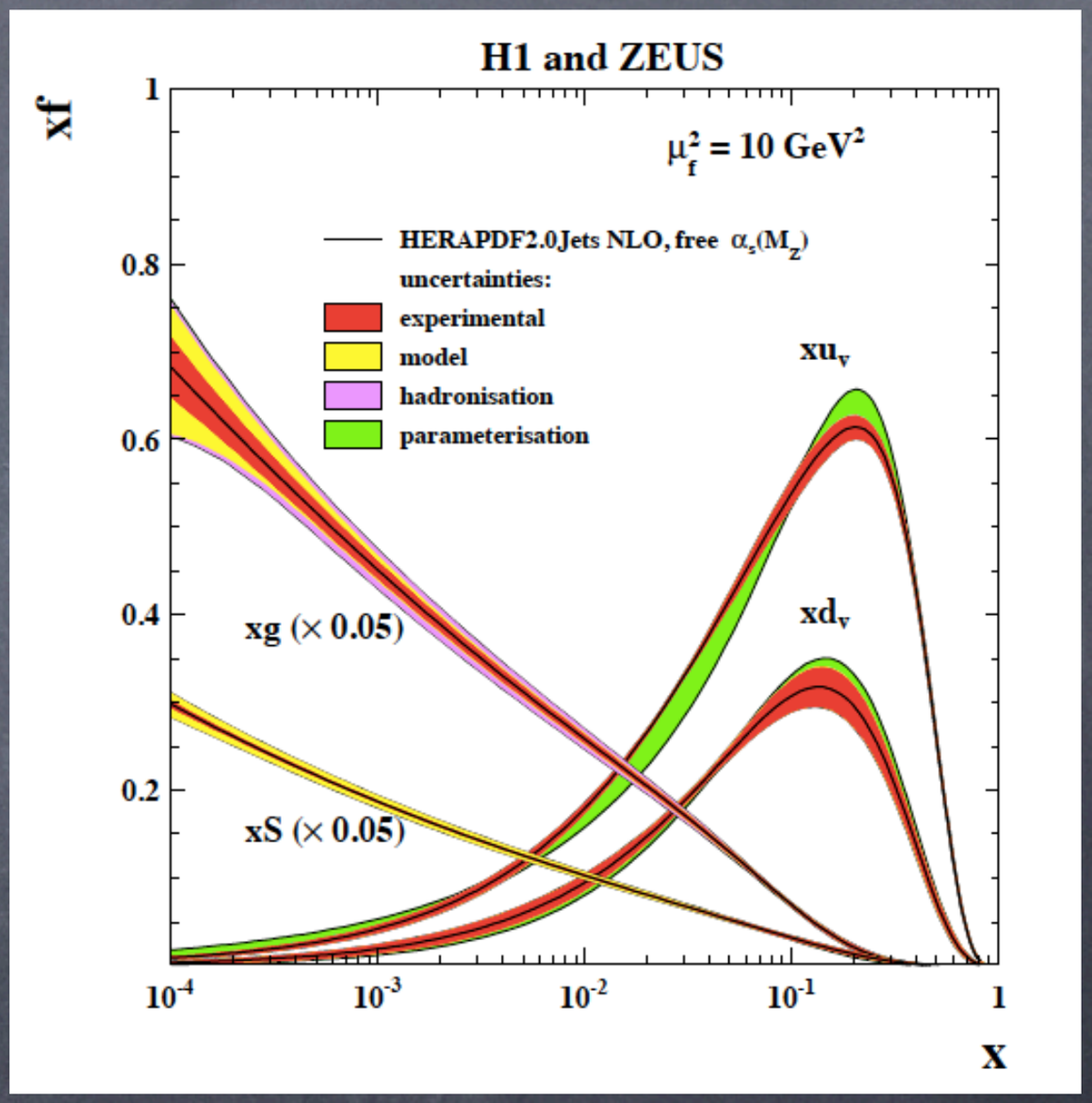


Correlation of g(x) α_s : HERAPDF2.0 Jets

... using **FIXED** α_s

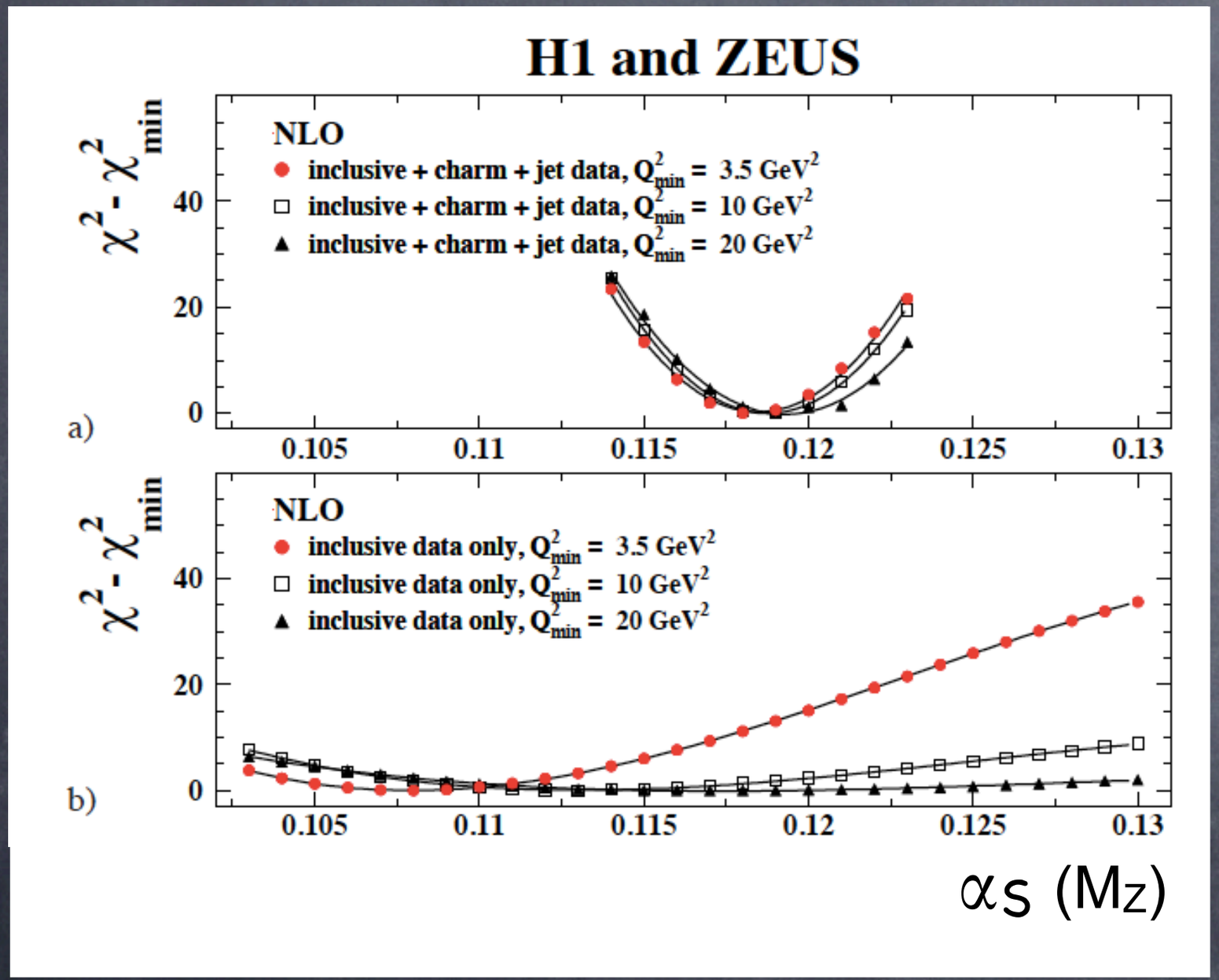


... using **FREE** α_s



The uncertainty on the gluon distribution is increased by releasing α_s, but the intrinsic correlation of the gluon and strong coupling is reduced

DIS JET DATA CONSTRAIN α_s

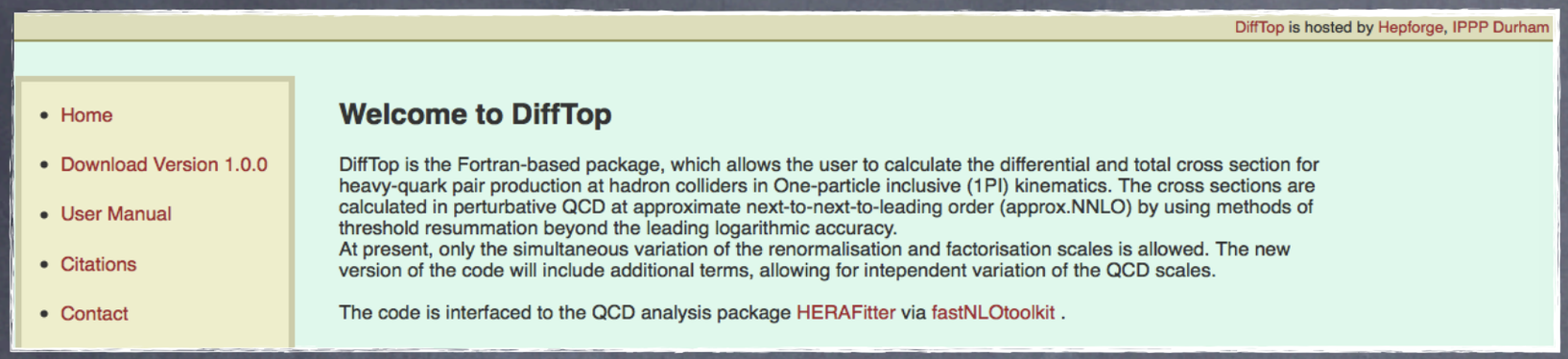


inclusive + Jets + charm

inclusive data only

GLUON at high x: TOP-PAIR PRODUCTION

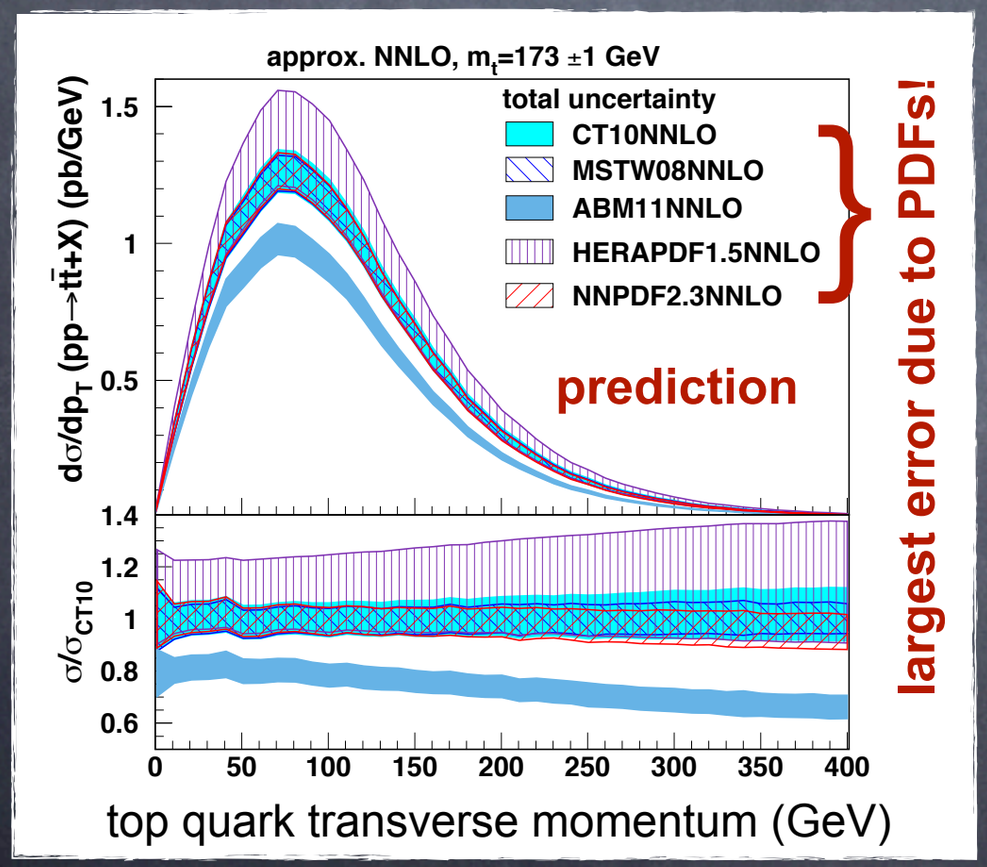
Difftop : calculator for differential top-pair production kinematics at approx. NNLO



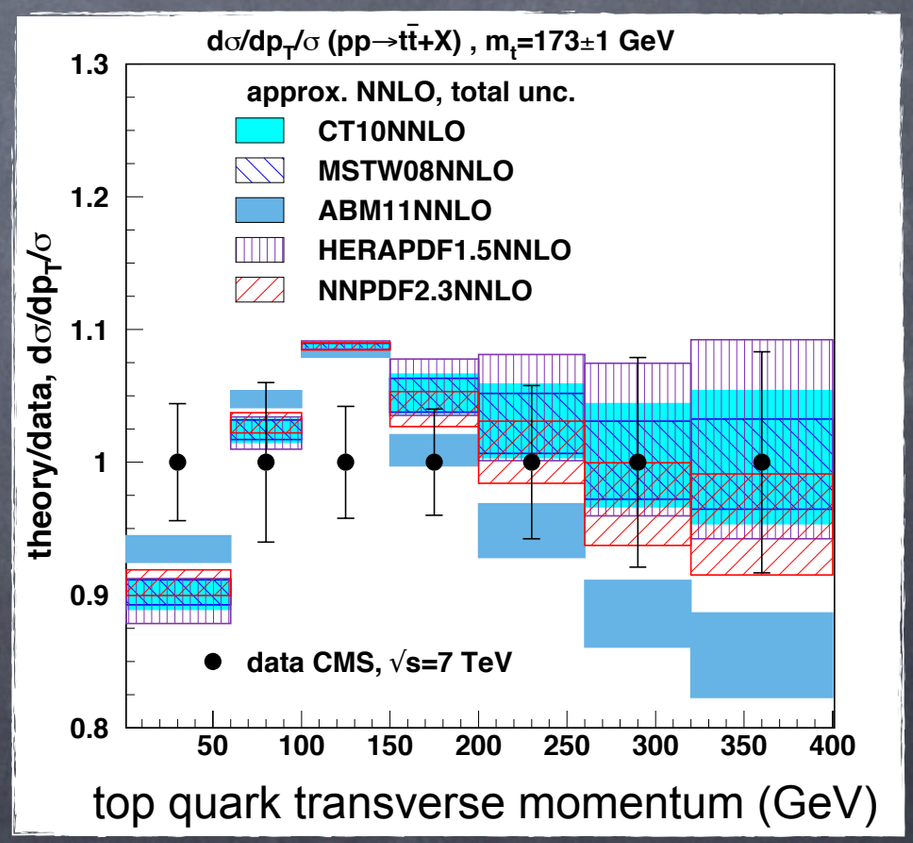
http://difftop.hepforge.org/

JHEP 1501 (2015) 082

Development within PROSA collaboration



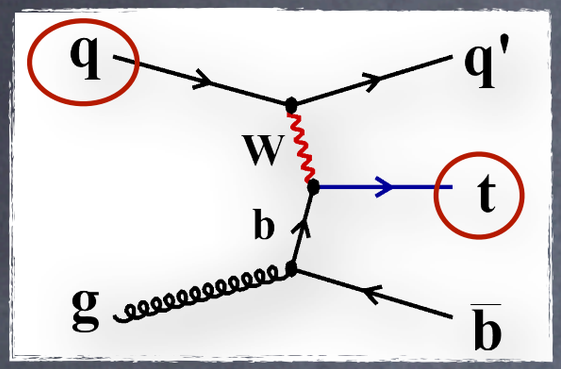
compare to LHC measurements



For the first time, possible to use top kinematics in PDF fits at NNLO QCD

QUARK: SINGLE TOP PRODUCTION

t-channel single top-quark production in pp collisions @ LHC

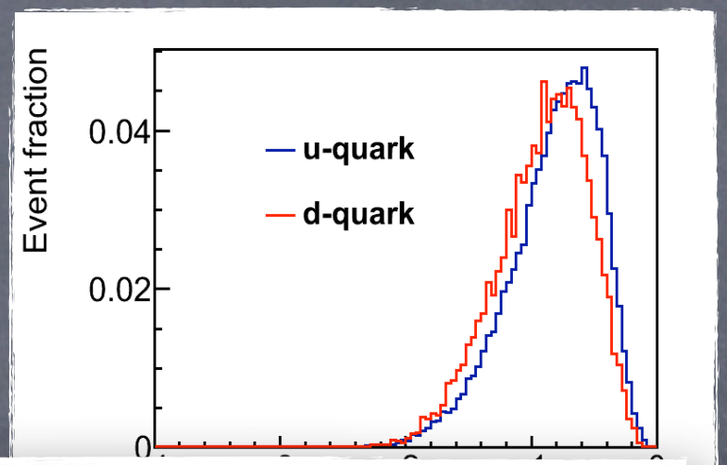


Probe the struck light quark through **kinematics** and **charge** of top-quark

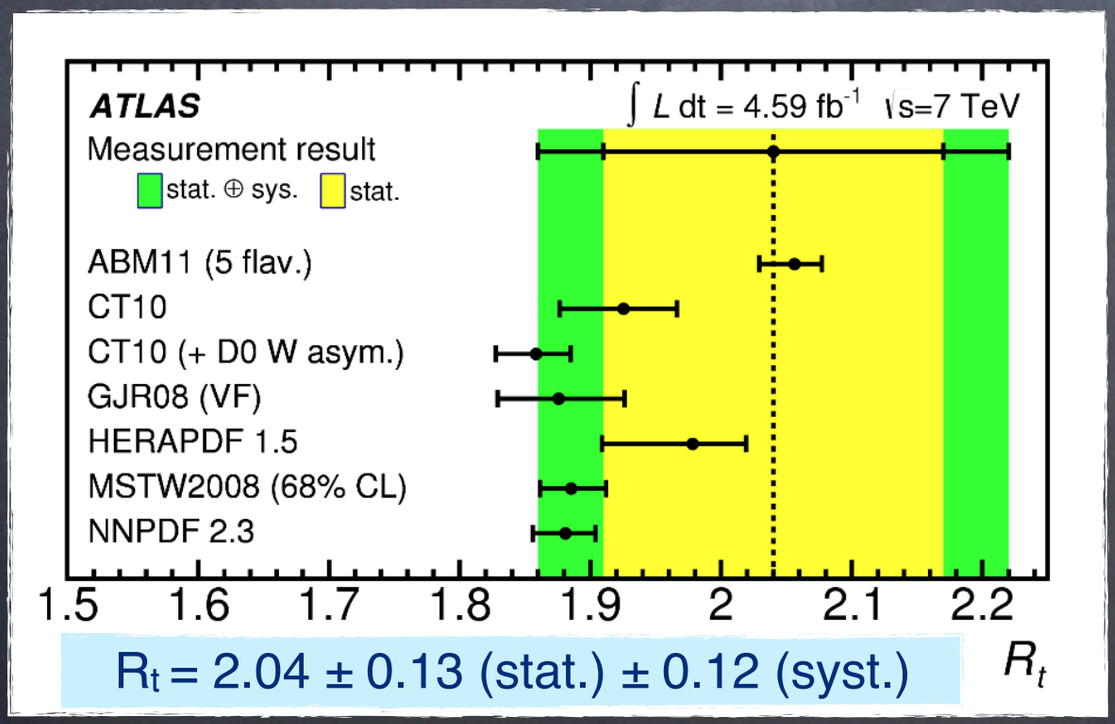
→ measure inclusive cross sections

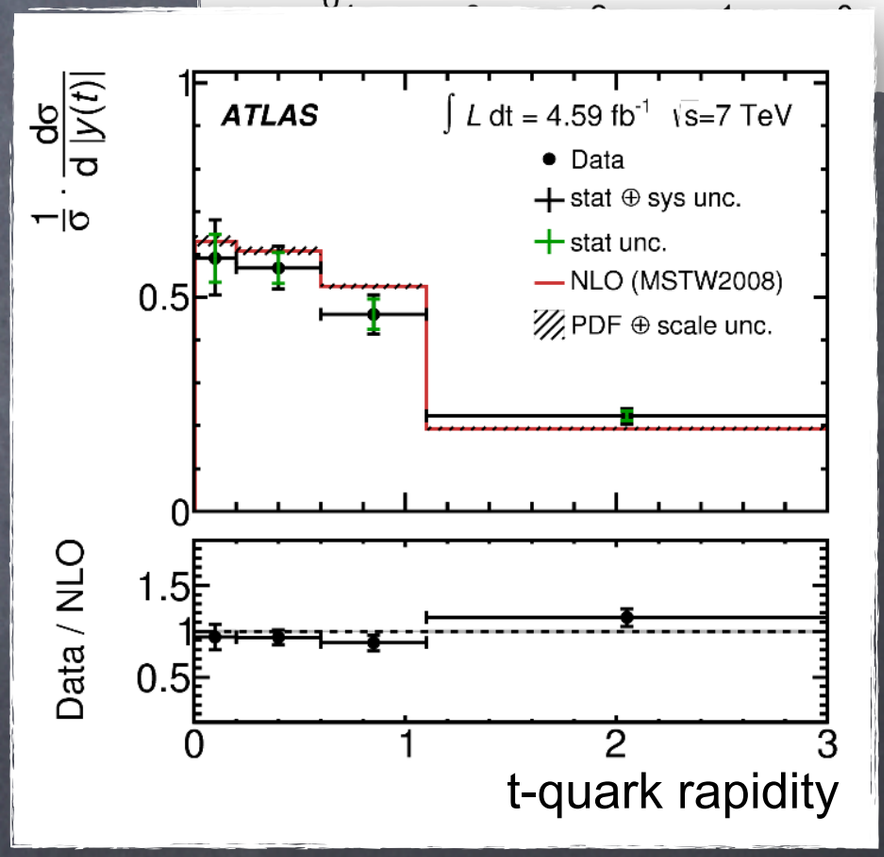
→ measure top/antitop ratio R_t

→ **measure top kinematics**



PRD. 90, 112006 (2014)



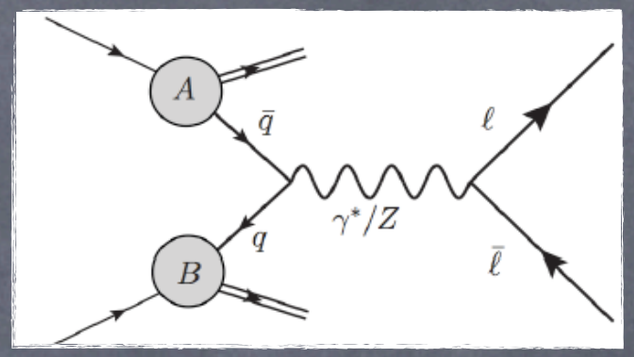


… details see talk K. Becker

LHC single-t measurements are sensitive to light quark distributions

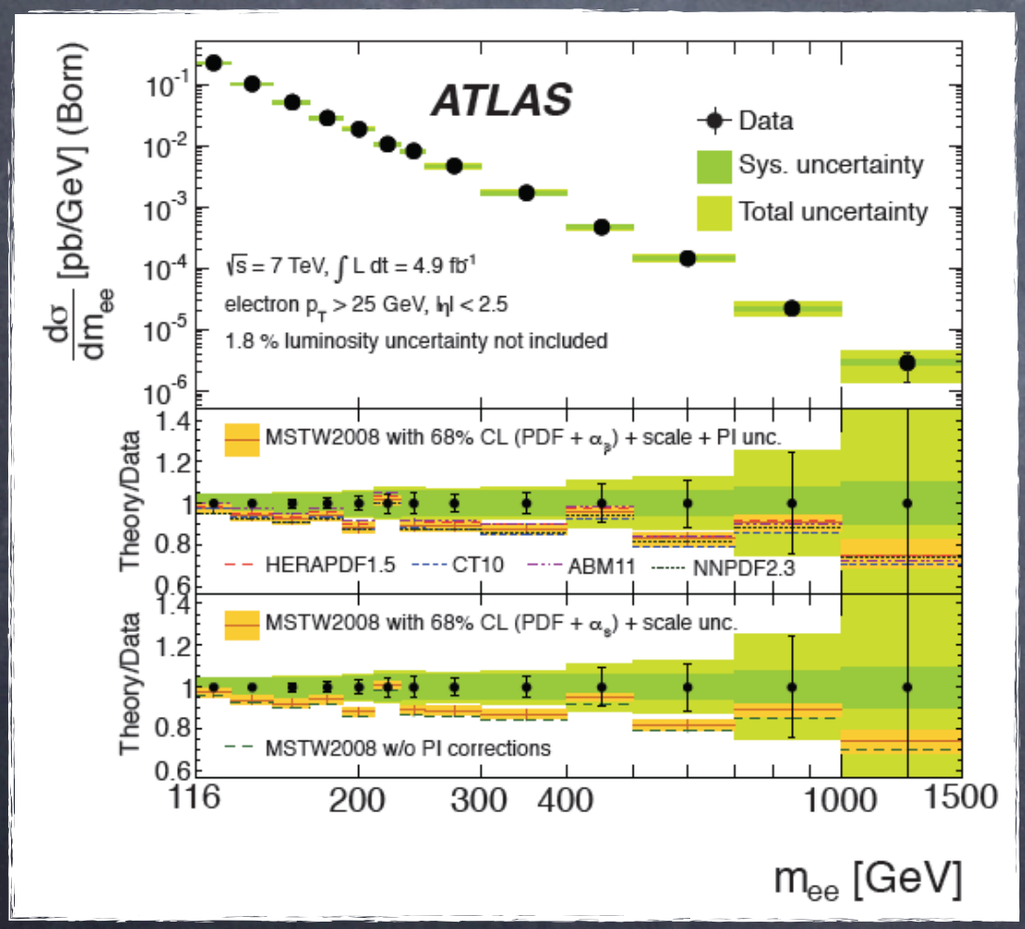
Quarks: DRELL - YAN

Drell-Yan process probes light quark distributions



ATLAS $\sqrt{s}$ = 7 TeV measurements compared to NNLO pQCD calculation (FEWS3.1) + EW corr.

PLB 725 (2013) 223



Measurement of double-differential Drell-Yan cross sections at $\sqrt{s}$= 8 TeV in progress

as a function of invariant mass and rapidity:

sensitive to light quark and photon PDFs

Combined Measurements