QCD@LHC PDF Summary

Pedro Jimenez-Delgado

(for the convenors: S. Glazov, PJD, P. Nadolsky, A. de Roeck)

QCD @ LHC PDF Summary

Most relevant comparisons of data and PDFs

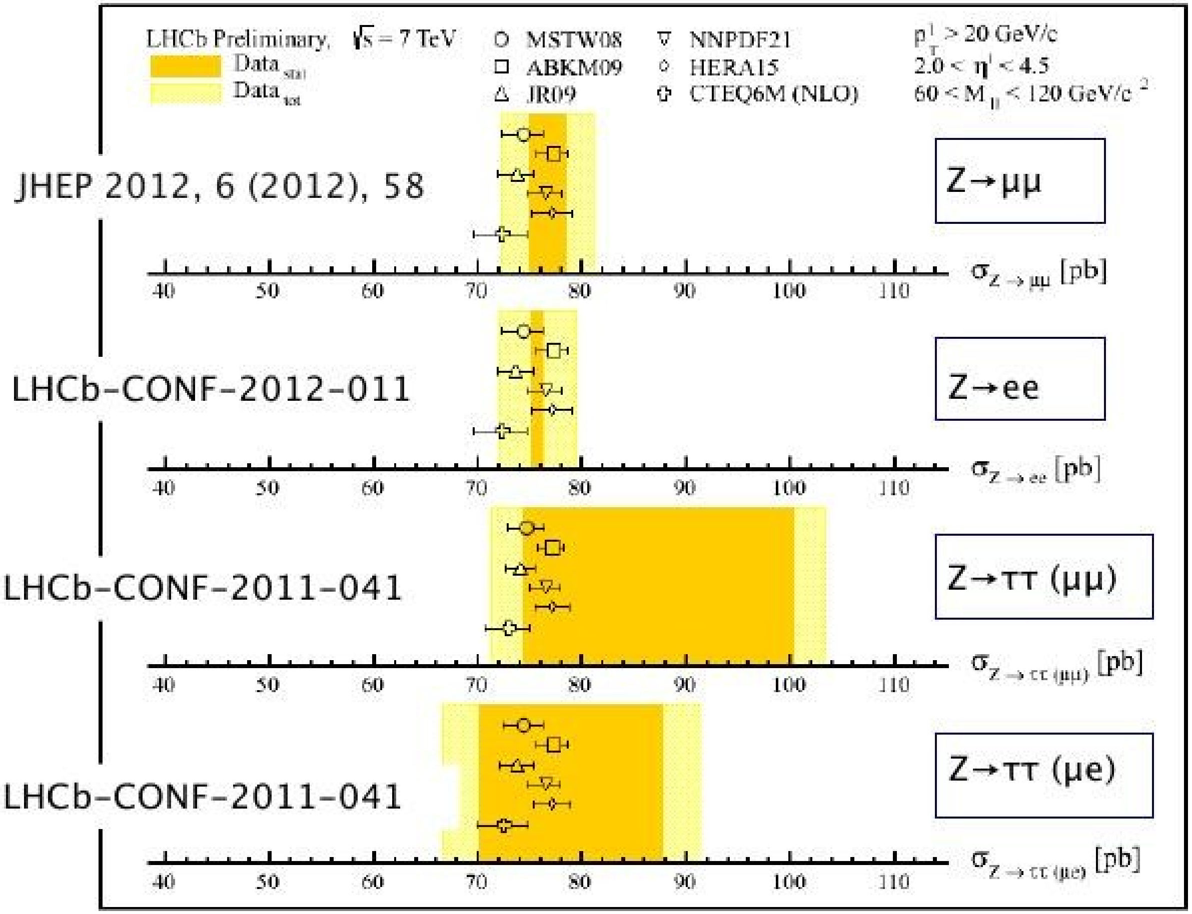
(sorry for the omissions!)

- Vector-boson production
- Top production
- Jet-cross sections
- Strangeness
- Isolated photons

Status reports and/or results from PDF groups

- NNPDF
- CTEQ-JLab
- CTEQ-TEA
- HERAPDF
- ABM
- JR

Z cross-sections at LHCb [K. Müller]



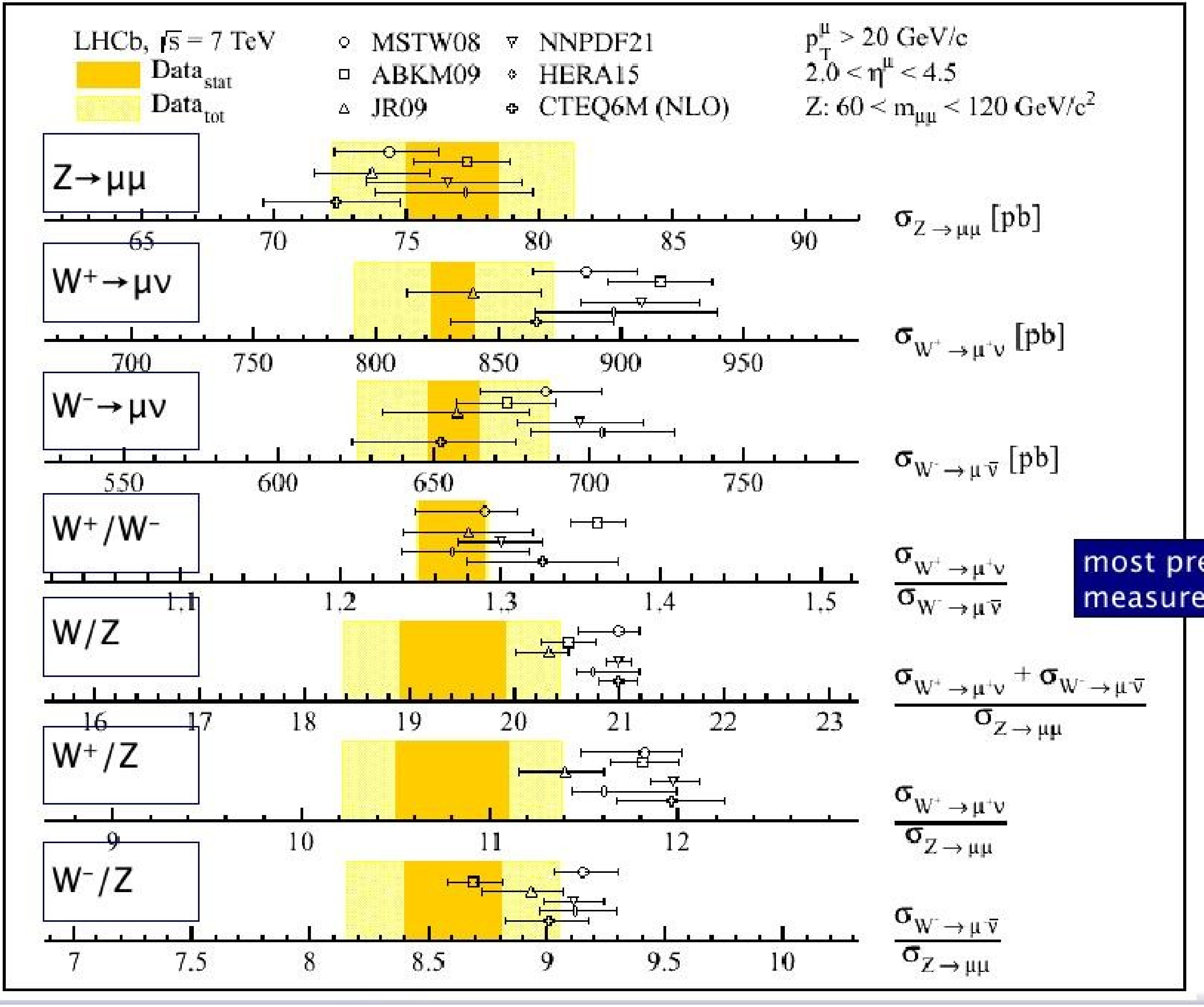
Results compared to NNLO predictions (DYNNLO) with 6 recent PDF sets

- MSTW08. A. Martin, W. Stirling, R. Thorne and G. Watt arXiv:0901.0002
- ABKM09: S. Alekhin, J. Blumlein, S. Klein and S. Moch arXiv:0908.2766
- JR09: P. Jimenez-Delgado and E. Reya arXiv:0810.4274
- NNPDF D. Ball et al. arXiv:1002.4407
- HERA15 H1 and ZEUS collaboration arXiv: 0911.0884
- CTEQ6M P. M. Nadolsky et al. (NLO) arXiv:0802.0007

NNLO (DYNNLO) PDF uncertainties at 68% CL

Fiducial range of the measurement:
$p_T(\mu) > 20$ GeV/c
$2<\eta(\mu)<4.5$
$60 < M(\mu\mu) < 120$ GeV/c^2

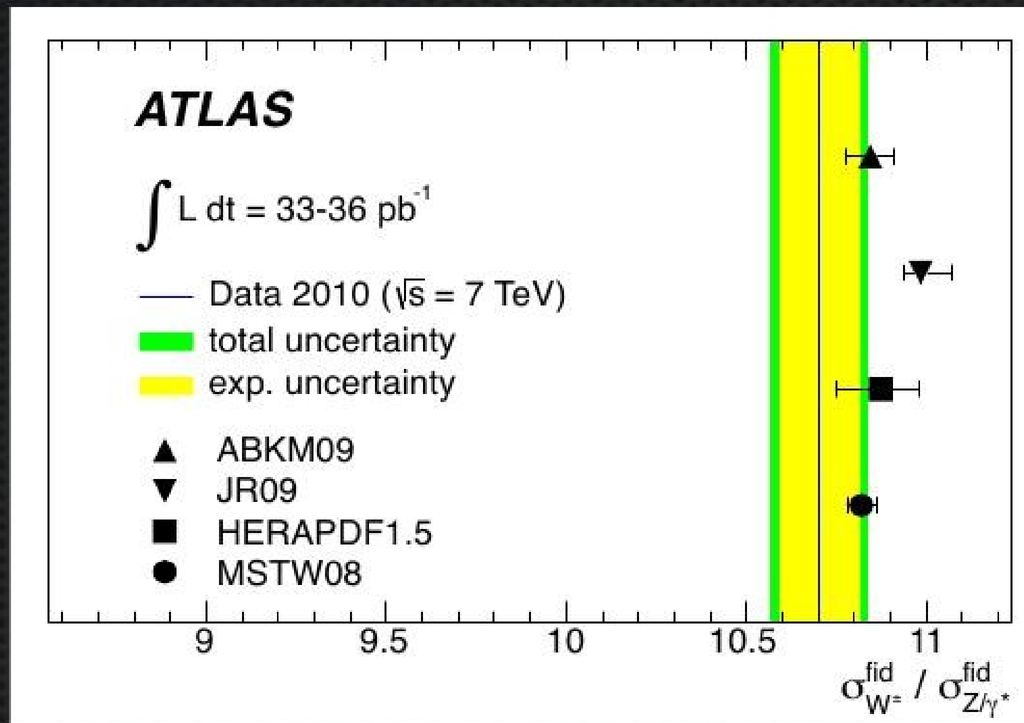
W/Z cross-sections at LHCb [K. Müller]



most precise LHCb measurement: 1.7%

W/Z cross-sections at ATLAS [J. Guimarães da Costa]

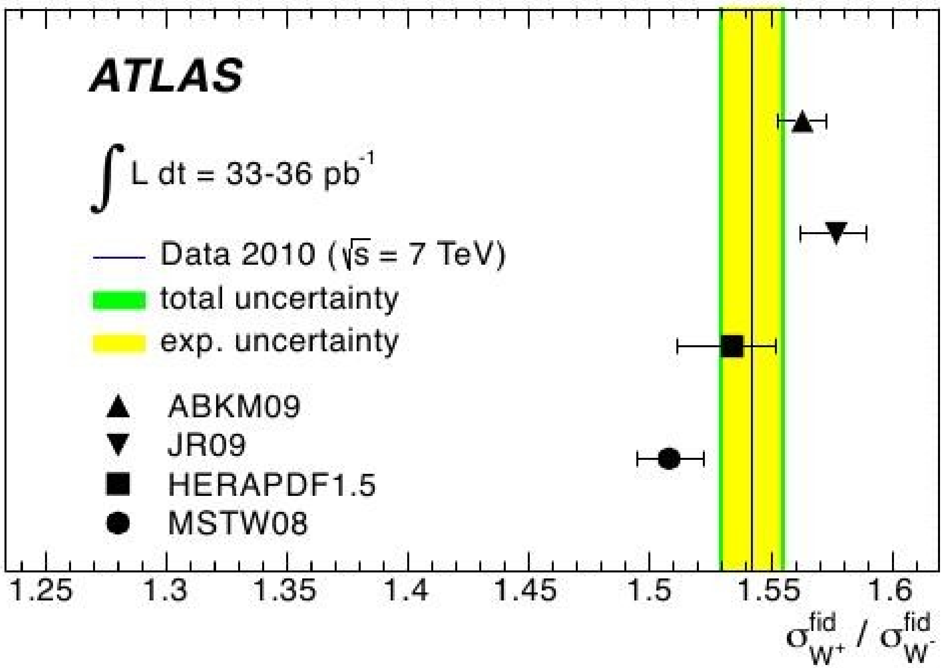
Benefits from experimental and theoretical systematics cancellation

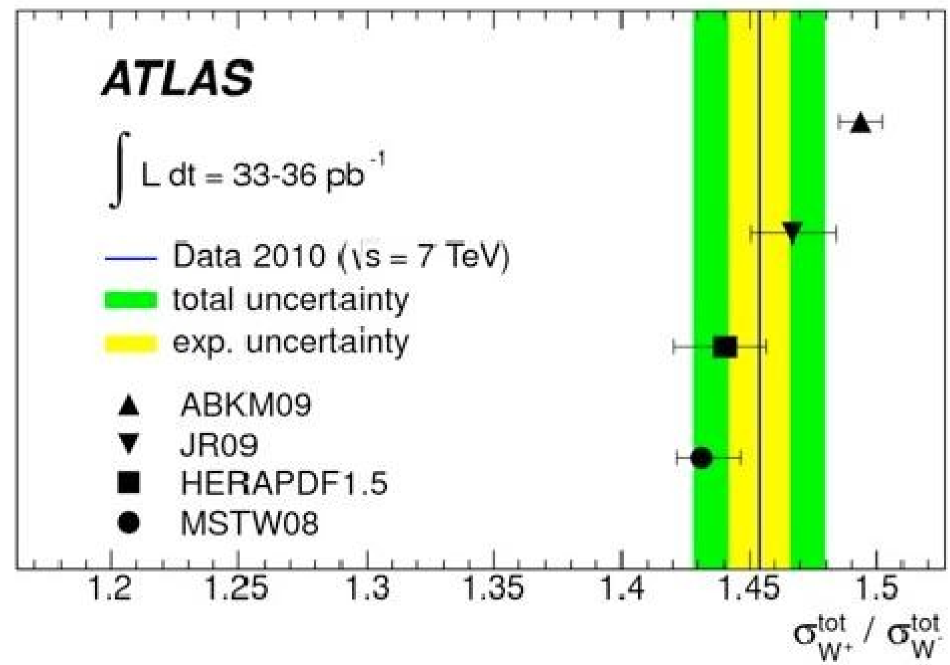


$\sigma\times\mathcal{B}$	$W^\pm/Z$	
$\sigma_{fiducial}$	10.703 ± 0.078 (sta) ± 0.110 (sys) ± 0.008 (acc)	1.3%
σ_{total}	10.893 ± 0.079 (sta) ± 0.110 (sys) ± 0.116 (acc)	1.6%

W/W cross-sections at ATLAS [J. Guimarães da Costa]

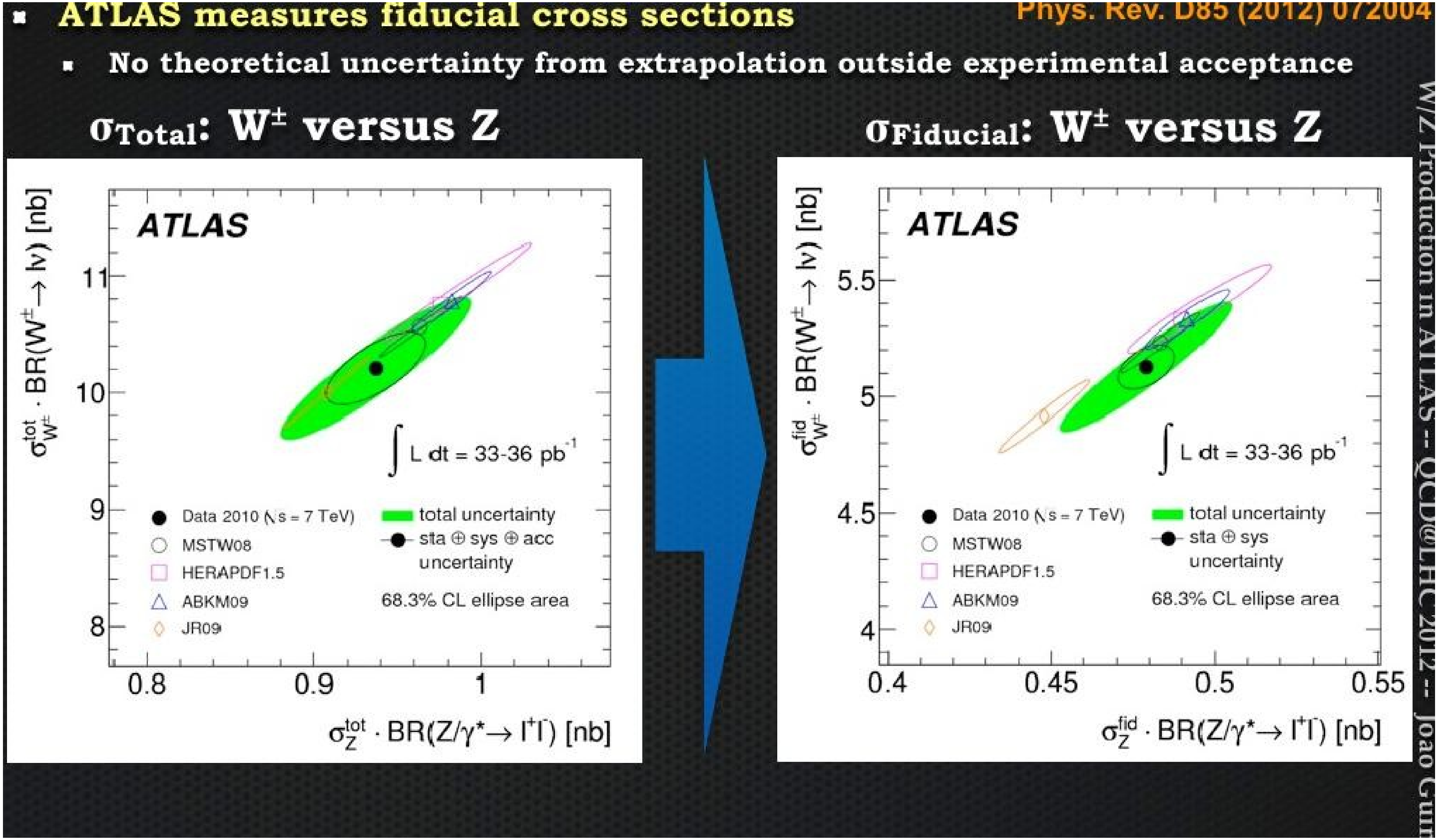
Benefits from experimental and theoretical systematics cancellatio



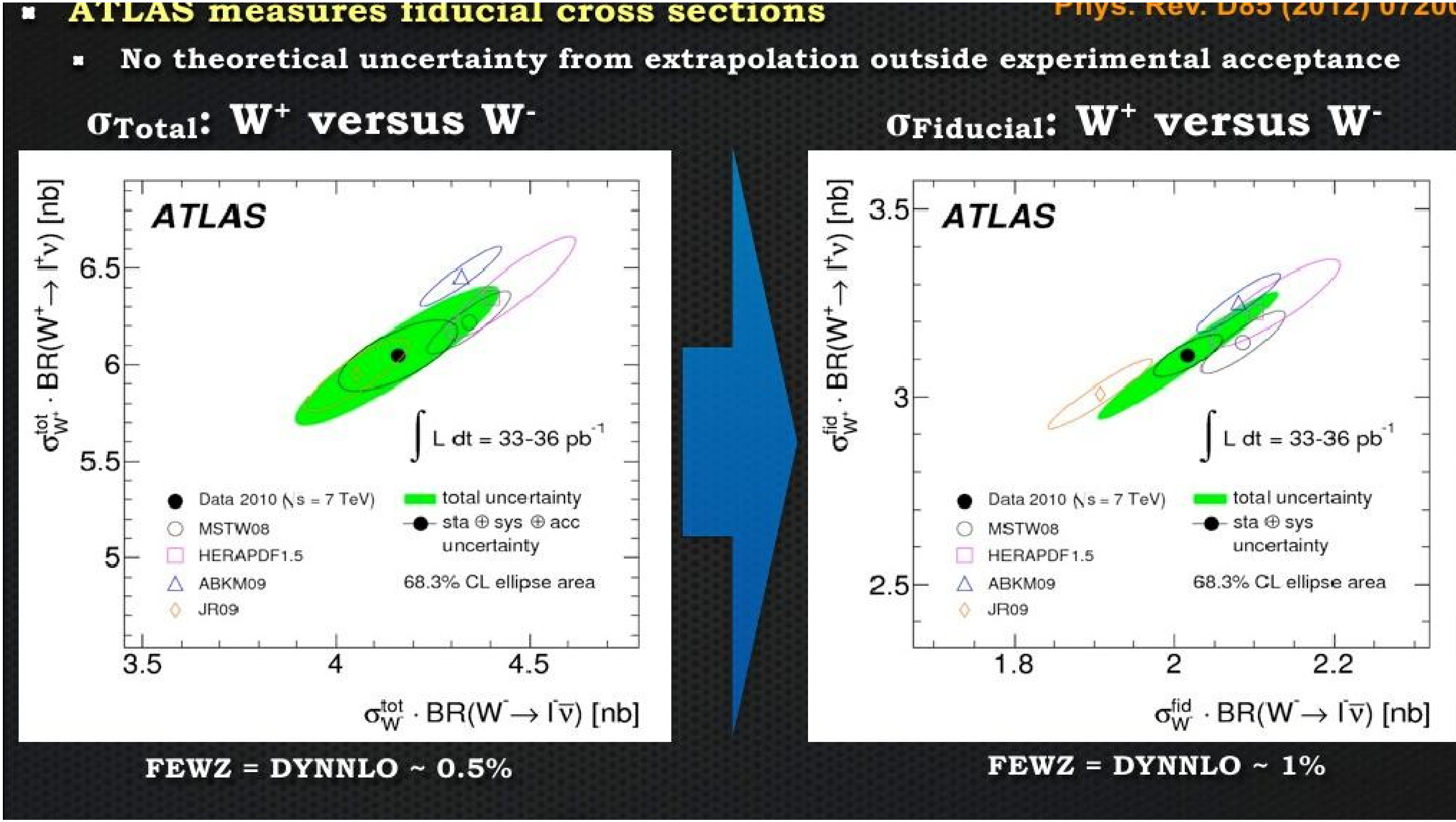


$\sigma \times \mathcal{B}$	W^+/W^-	
$\sigma_{fiducial}$	1.542 ± 0.007 (sta) ± 0.012 (sys) ± 0.001 (acc)	0.9%
σ_{total}	1.454 ± 0.006 (sta) ± 0.012 (sys) ± 0.022 (acc)	1.8%

W/Z cross-sections at ATLAS [J. Guimarães da Costa]



W/W cross-sections at ATLAS [J. Guimarães da Costa]



Z/W cross-sections at CMS [J. Berryhill]

W and Z Cross-Section Ratios@8 TeV

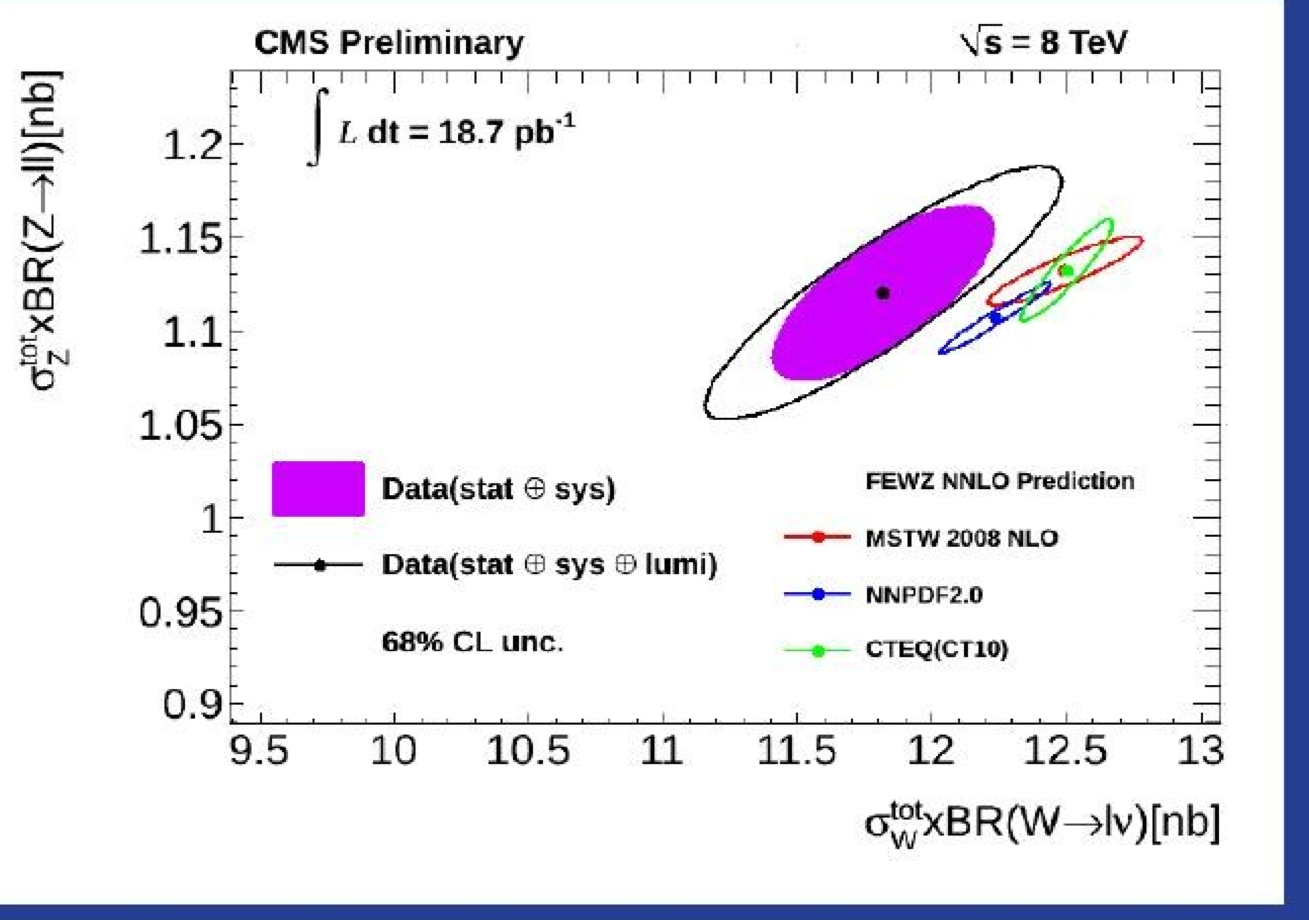
- **W/Z ratio:**
- **acc. ratio theory error**

2% (2.5%) for e (mu)

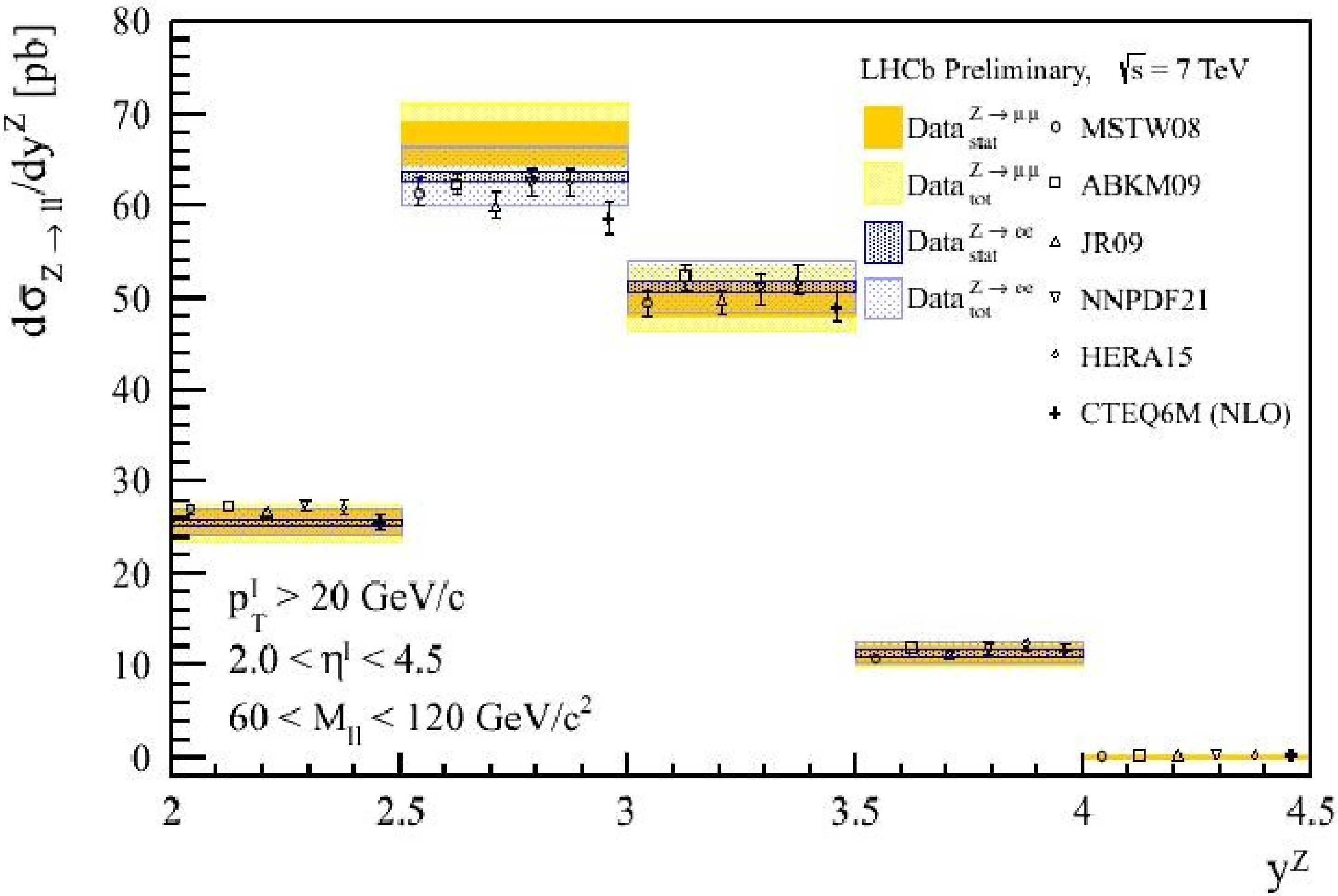
- **Exp. error**

3.9% (1.7%) for e (mu)

- **1.5 sigma agreement with FEWZ + MSTW08 NNLO total cross section**

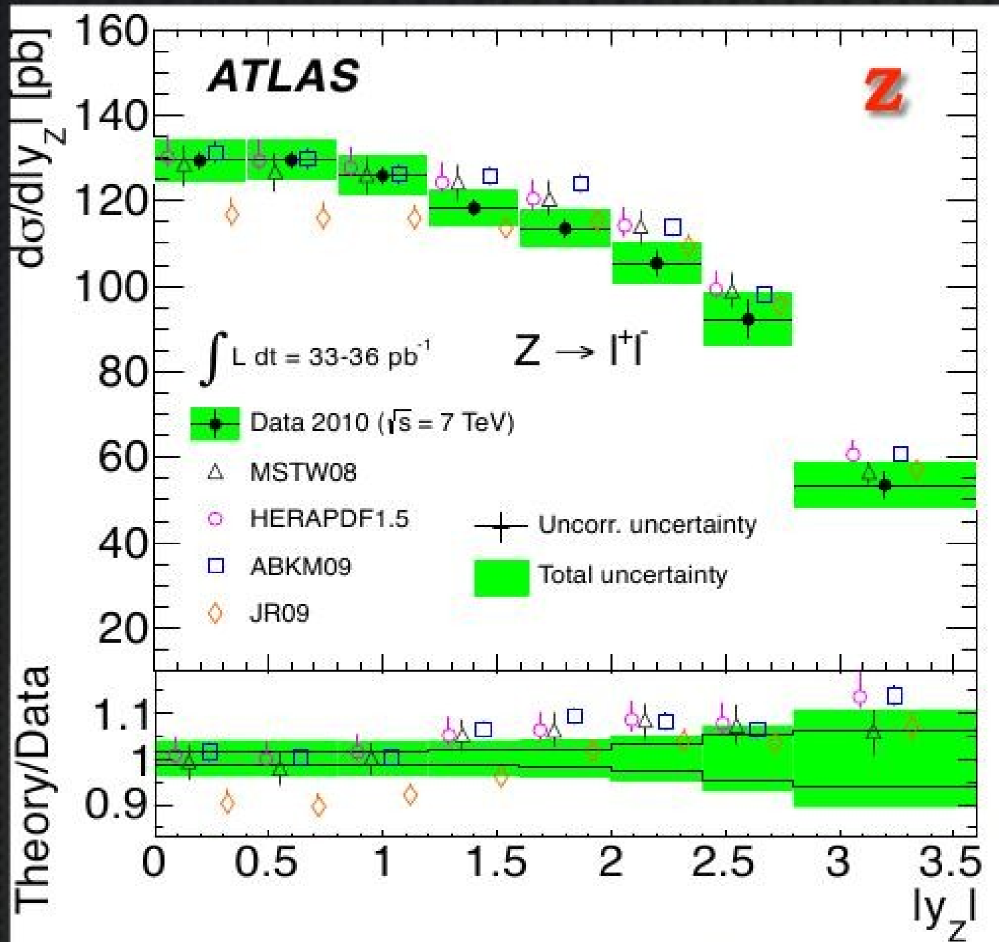


Z rapidity distributions at LHCb [K. Müller]



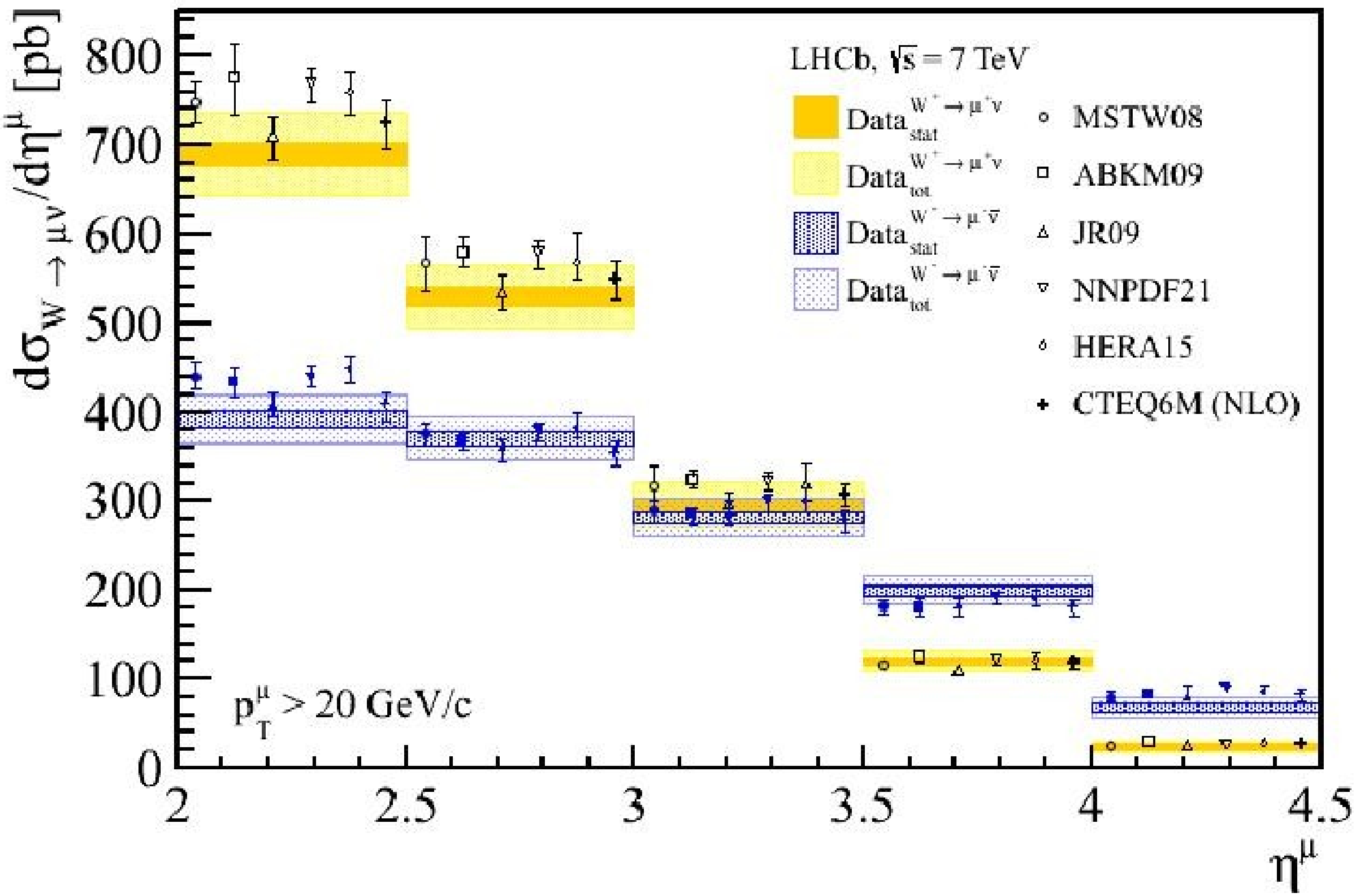
Z → μμ and Z→ ee in agreement with each other and with NNLO predictions

Z rapidity distributions at ATLAS [J. Guimarães da Costa]

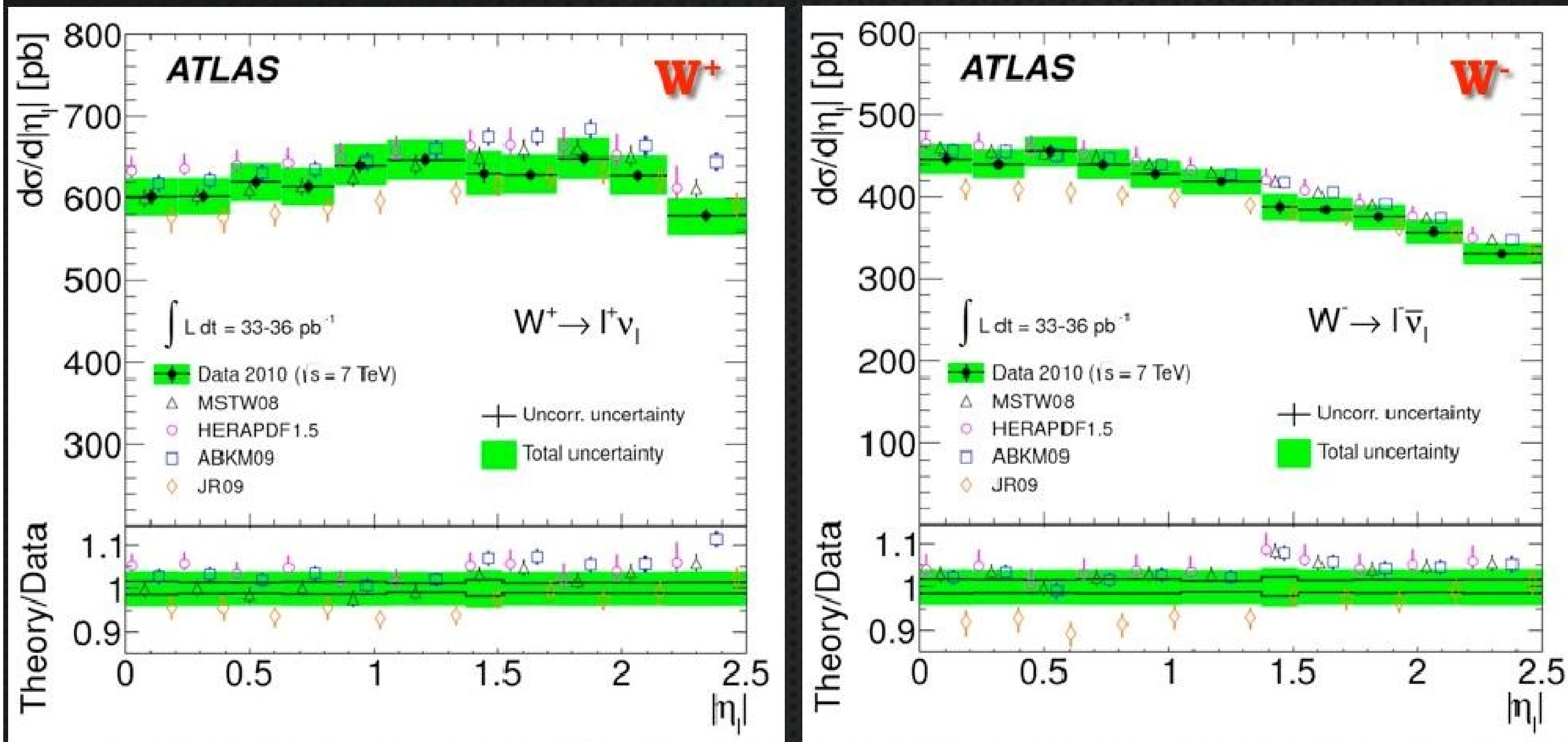


- **Broadly well described by predictions**
- **Can impact PDF central values and uncertainties**
  - **Information on *d*, *u* and *s* decomposition at *x* ~ 0.01**
  - **Full covariance matrix available**

W rapidity distributions at LHCb [K. Müller]

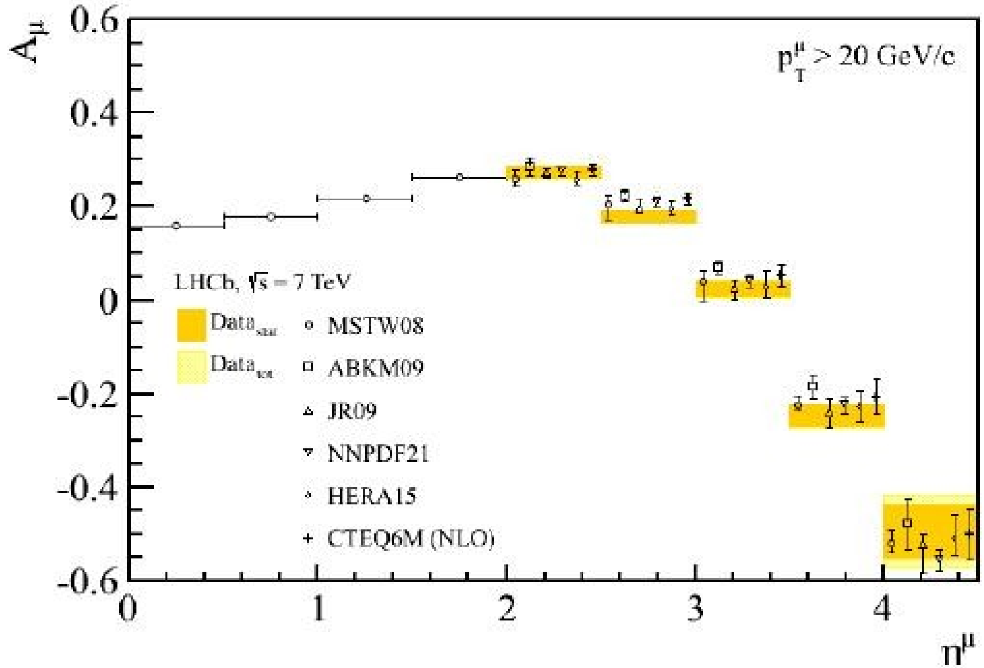


W rapidity distributions at ATLAS [J. Guimarães da Costa]



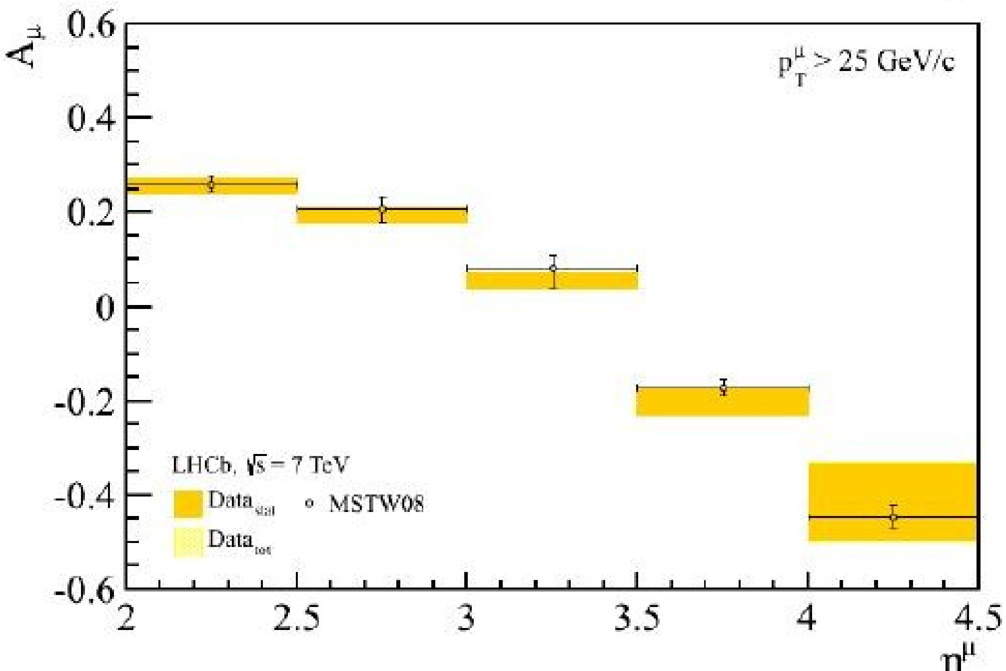
- **Broadly well described by predictions**
- **Can impact PDF central values and uncertainties**
  - **Information on u_v and d_v PDFs**
  - **Full covariance matrix available**

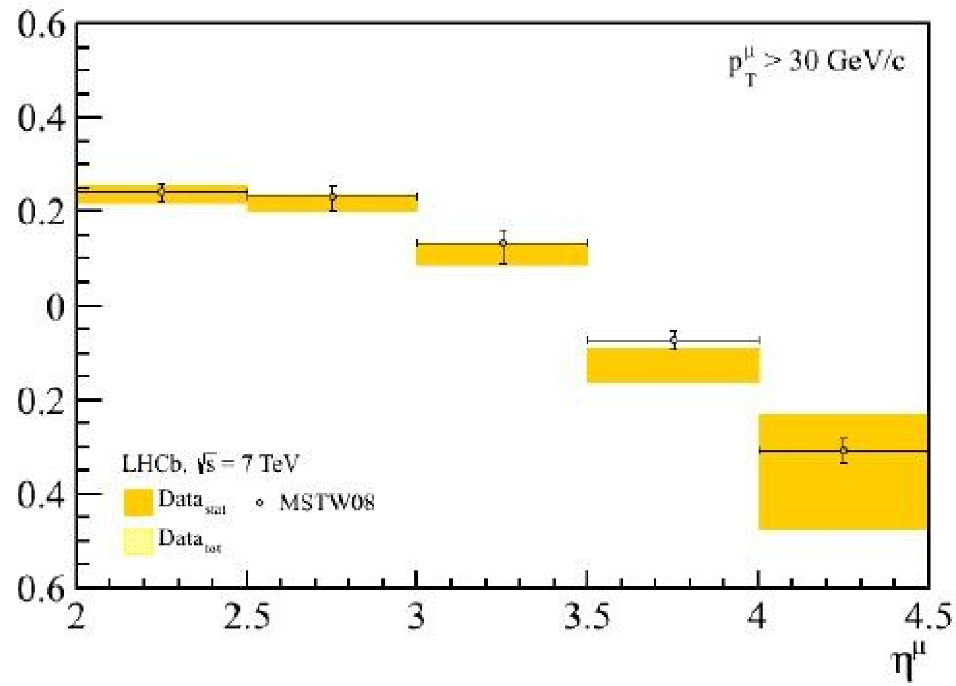
Charge asymmetry at LHCb [K. Müller]



W lepton charge asymmetry for different p_T thresholds

$$A_\mu = \frac{\sigma(W^+ \to \mu^+\nu_\mu) - \sigma(W^- \to \mu^-\bar{\nu}_\mu)}{\sigma(W^+ \to \mu^+\nu_\mu) + \sigma(W^- \to \mu^-\bar{\nu}_\mu)}$$

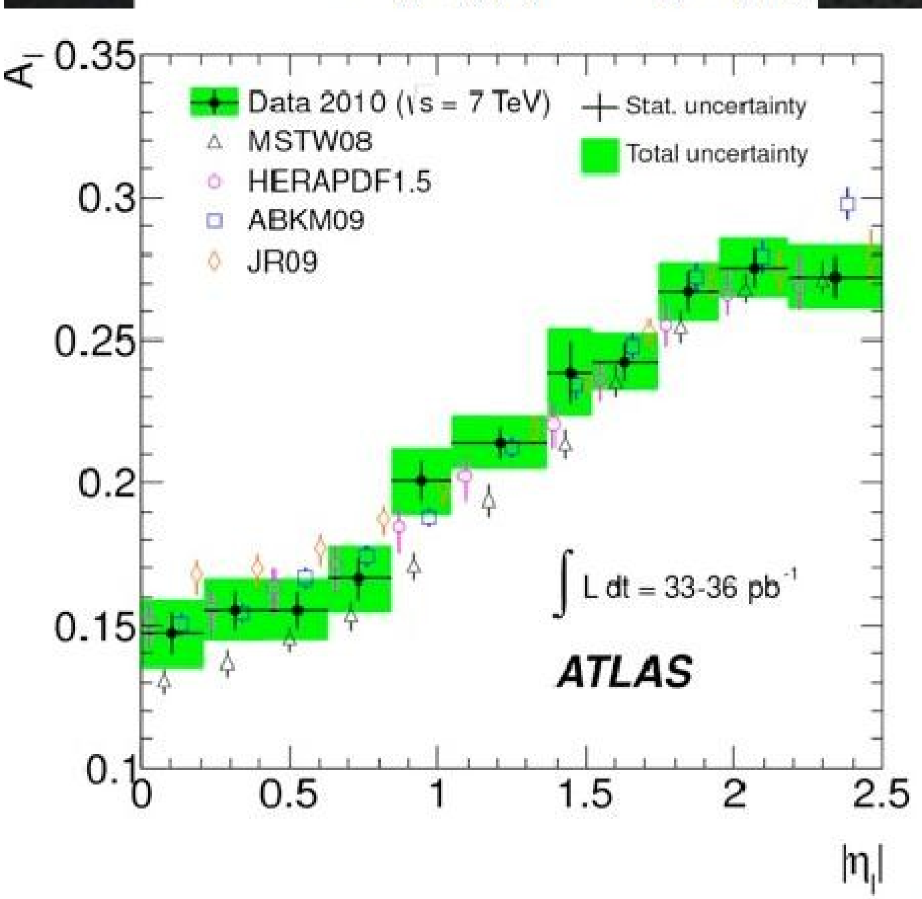


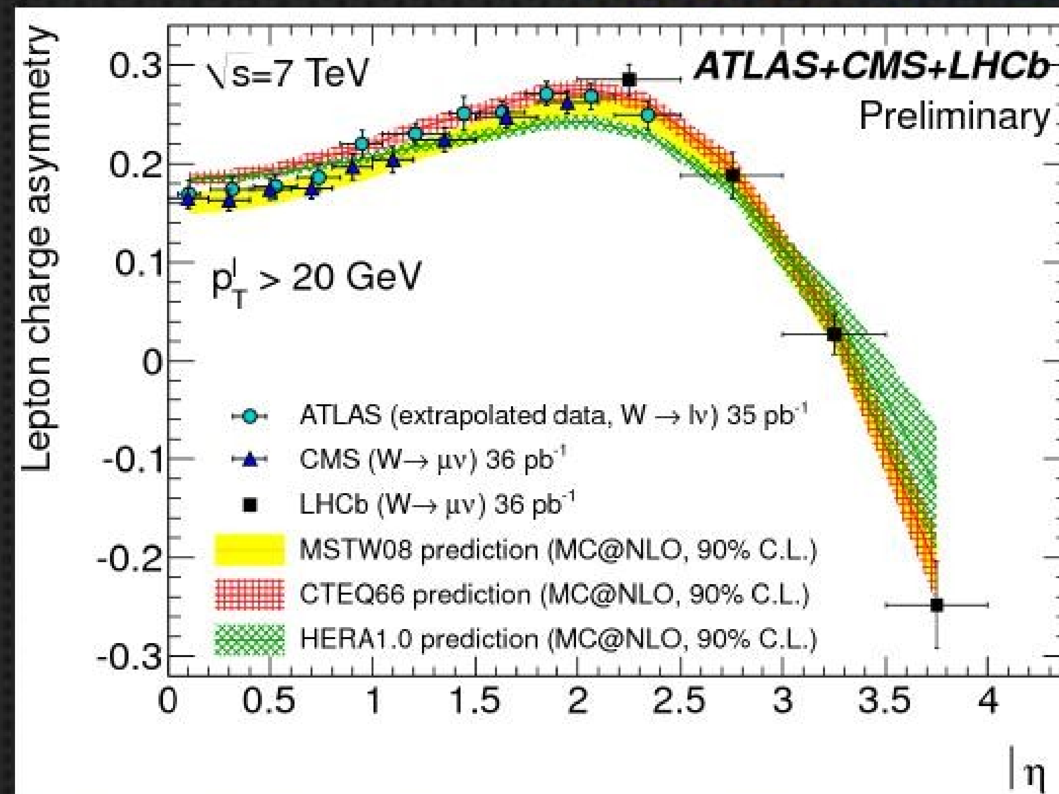


Charge asymmetry at ATLAS [J. Guimarães da Costa]

$$A(\eta_\ell) = \frac{d\sigma_{W^+}(\eta_\ell) - d\sigma_{W^-}(\eta_\ell)}{d\sigma_{W^+}(\eta_\ell) + d\sigma_{W^-}(\eta_\ell)}$$

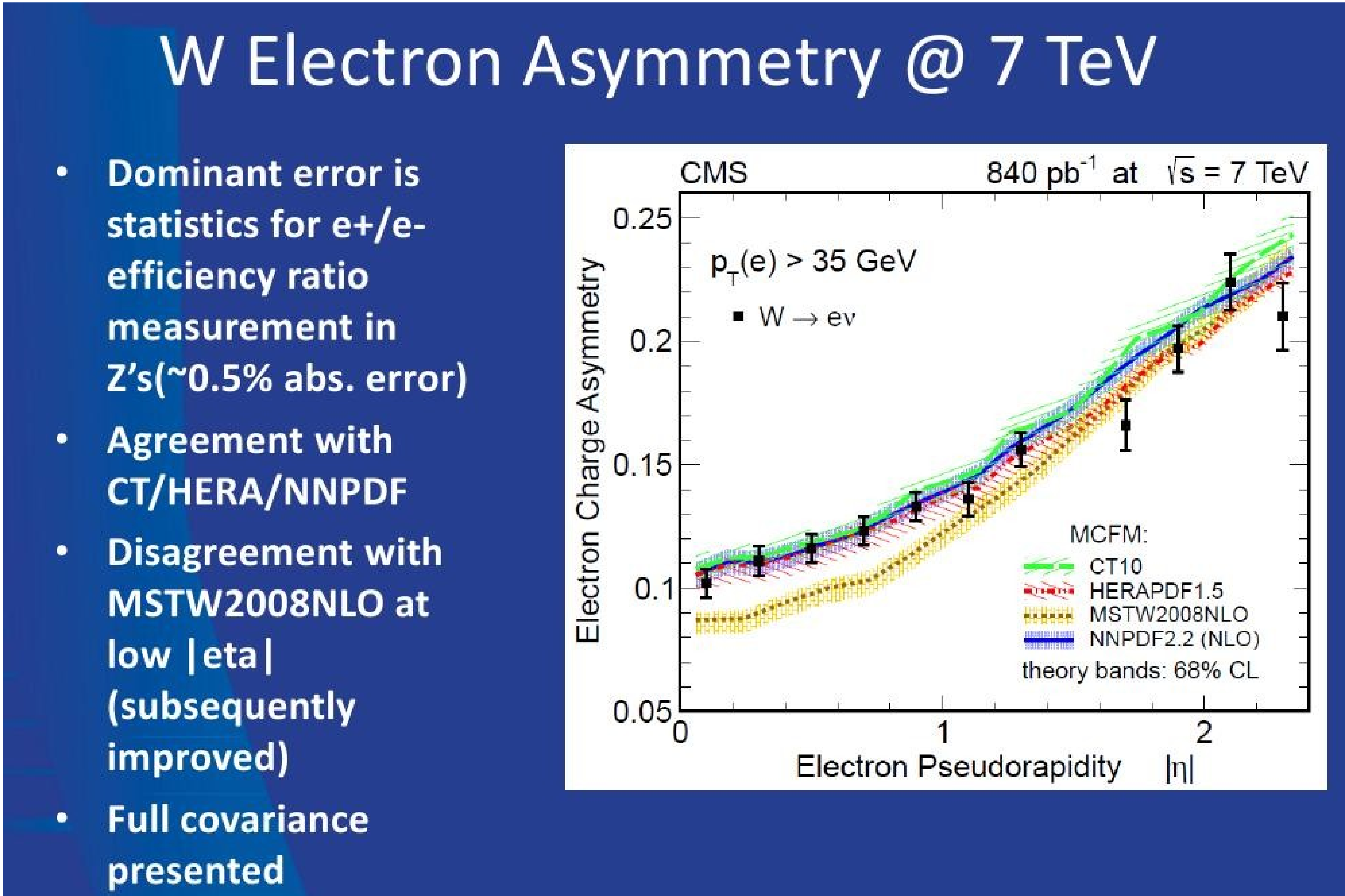
ATLAS-CONF-2011-129



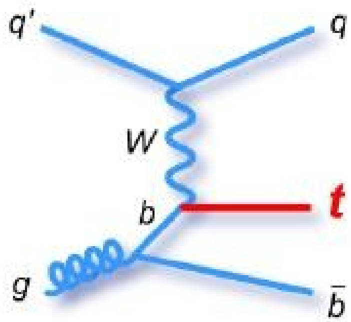


First LHC combined plot (LHC EWK WG)

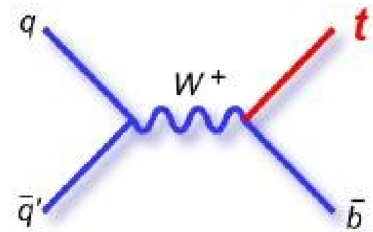
Charge asymmetry at CMS [J. Berryhill]



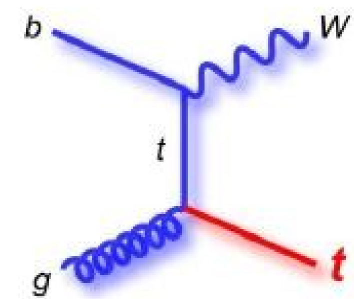
Single top at LHC [F.-P. Schilling]



t-channel

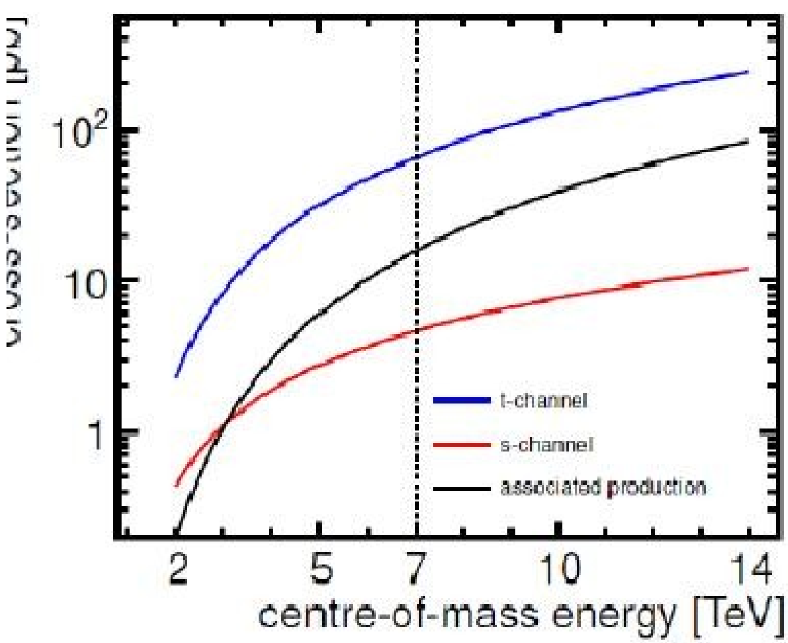


s-channel



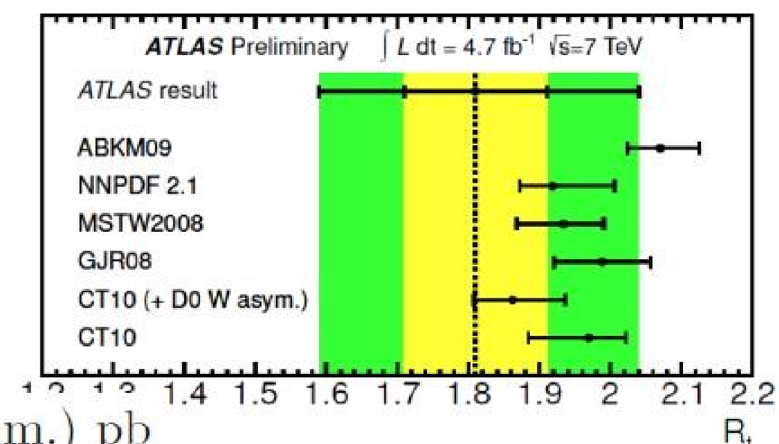
tW-channel
(associated production)

- EWK production of top quarks: test Wtb vertex, measurement of |Vtb|
- PDF sensitivity: b-PDF (t-channel), u/d ratio from R(t/tbar)
- Searches for NP at Wtb vertex



Top/antitop ratio (ATLAS):

$$\sigma_t(t) = 53.2 \pm 10.8\ \text{pb}$$
$$\sigma_t(\bar{t}) = 29.5^{+7.4}_{-7.5}\ \text{pb}$$
$$R_t = 1.81^{+0.23}_{-0.22}.$$

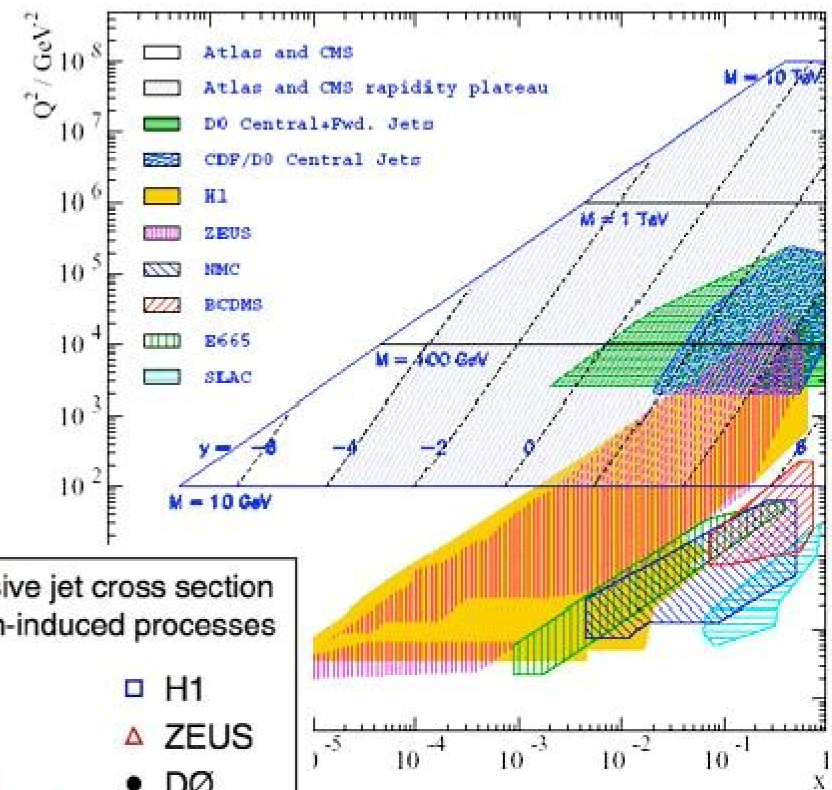


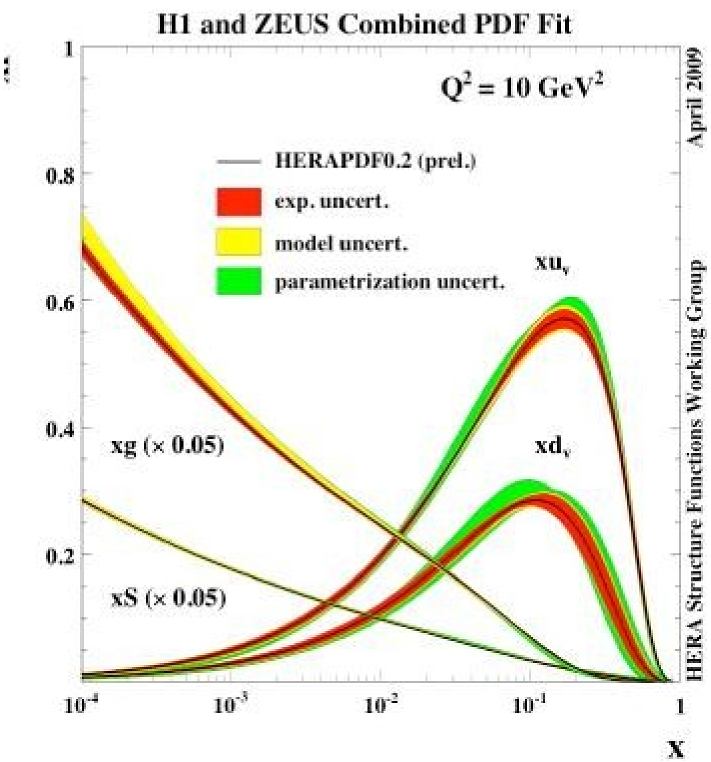
My very short summary:

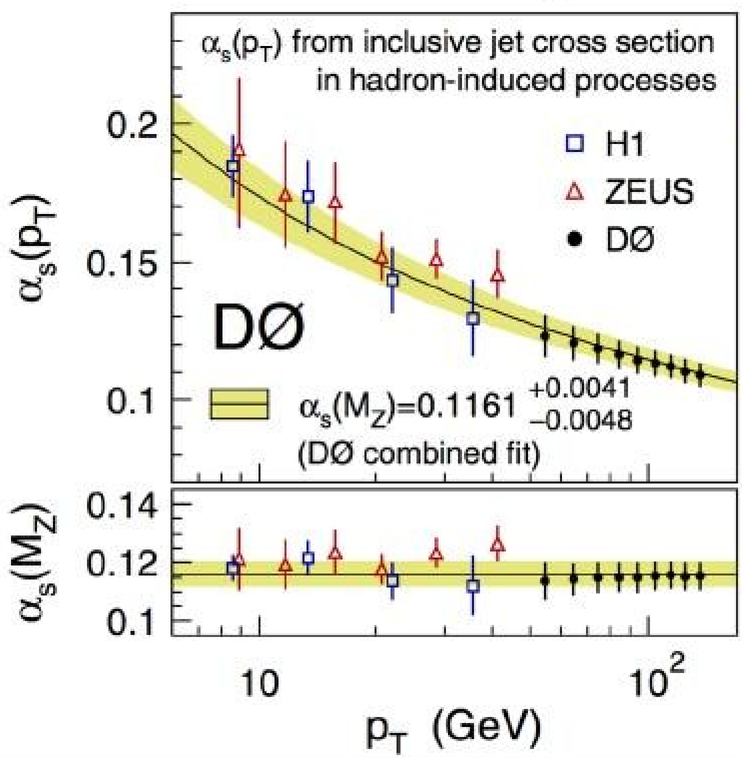
- Generally there is agreement between predictions and measurements
- There are differences here and there
- Data will help to better determine the partonic structure of the nucleon

Jet production at LHC [M. Voutilainen]

- Hadron colliders are complementary to e-p colliders and fixed target experiments
- proton-proton collisions probe high Q^2 and wide range of Bjorken x
- E.g. inclusive jets useful for high-x gluon PDF and determination of α_s running

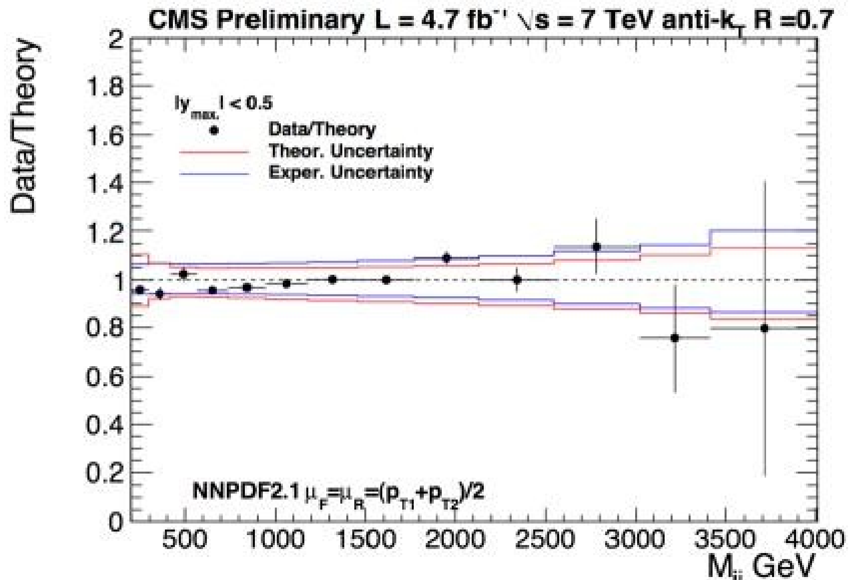


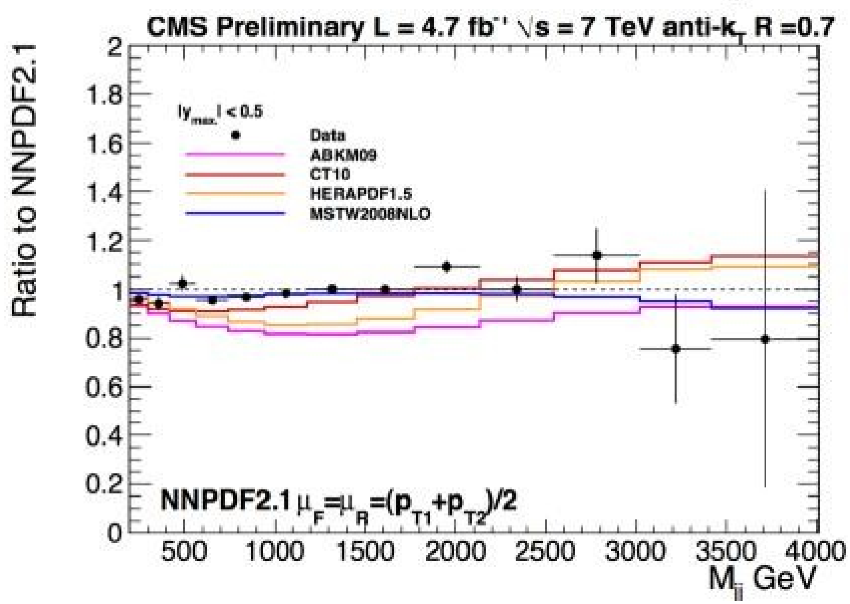


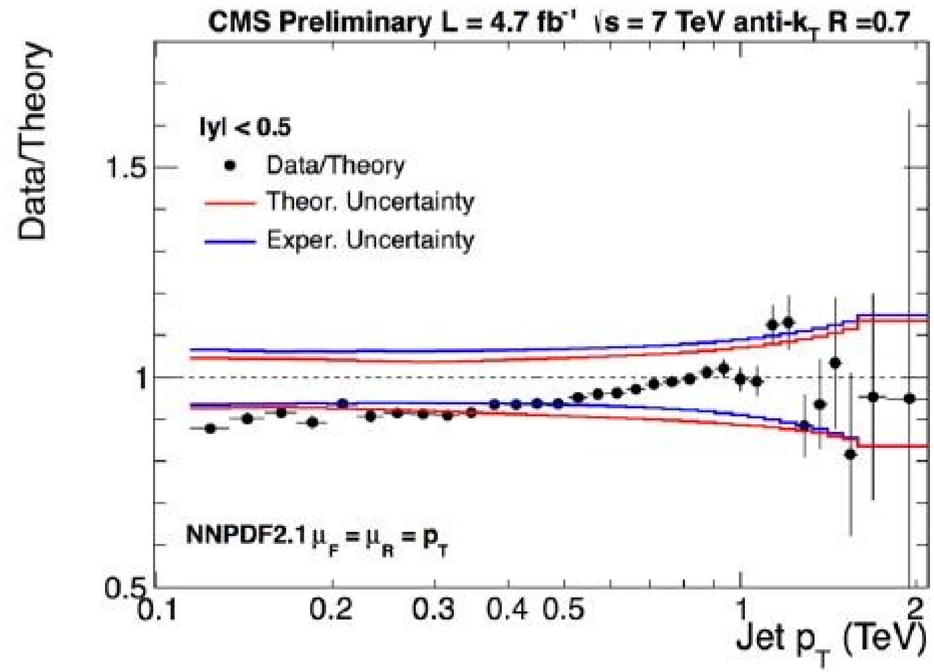


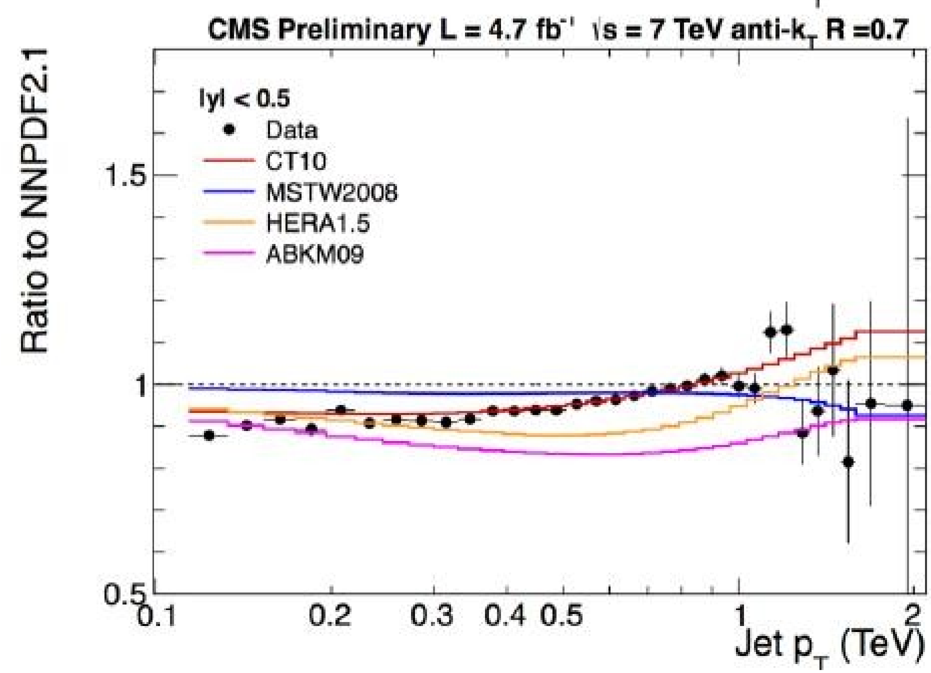
Jet production at LHC [M. Voutilainen]

- With latest LHC data, analyses are reaching precision to constrain PDFs









Jet production at Tevatron [M. Wobisch]

Inclusive jets and dijets included in "global" fits (even at NNLO)

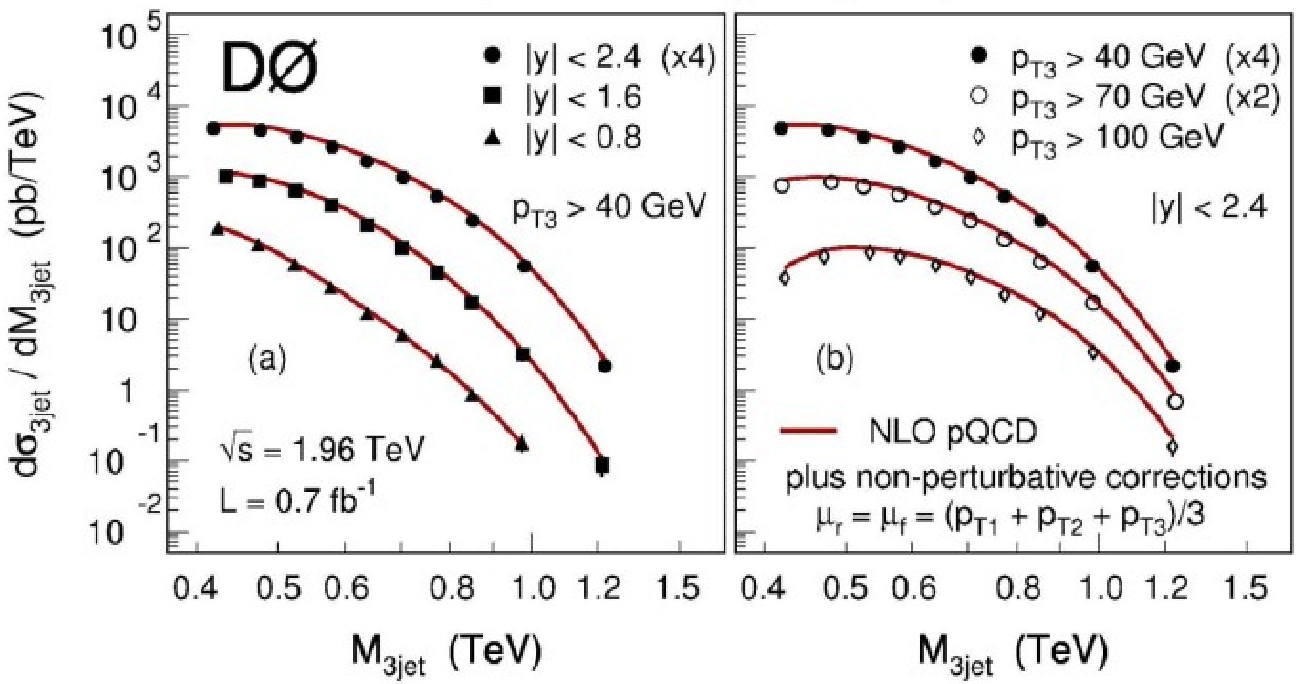
Additional information in the 3-jet cross-section

2-jet cross section:
$O(\alpha_s^2)$ x PDF^2
(correlation of α and gluon density)

3-jet cross section:
$O(\alpha_s^3)$ x PDF^2

analyze 2-jet and 3-jet cross sections:
→ **decorrelate** α_s and gluon density in PDF fits

Phys. Lett. B **704**, 434 (2011)



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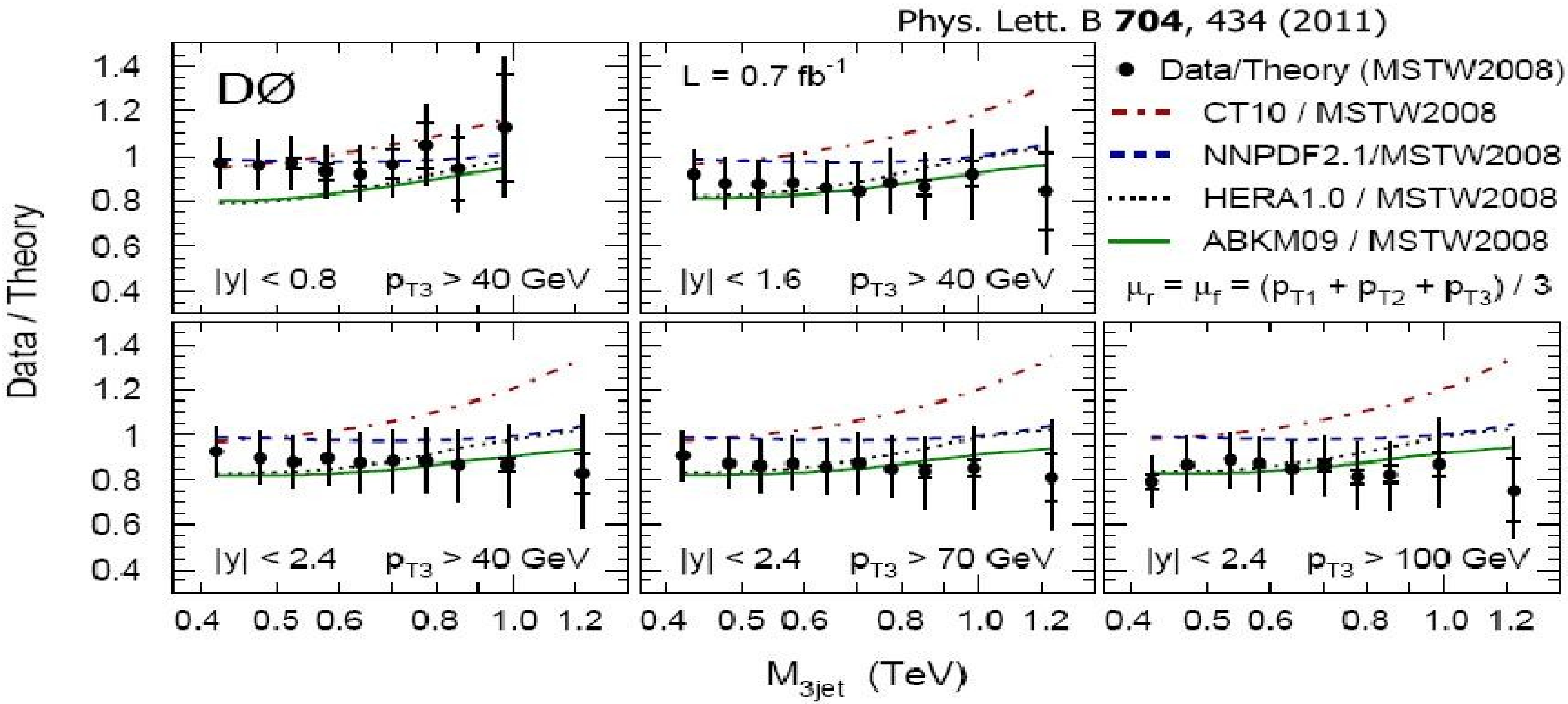
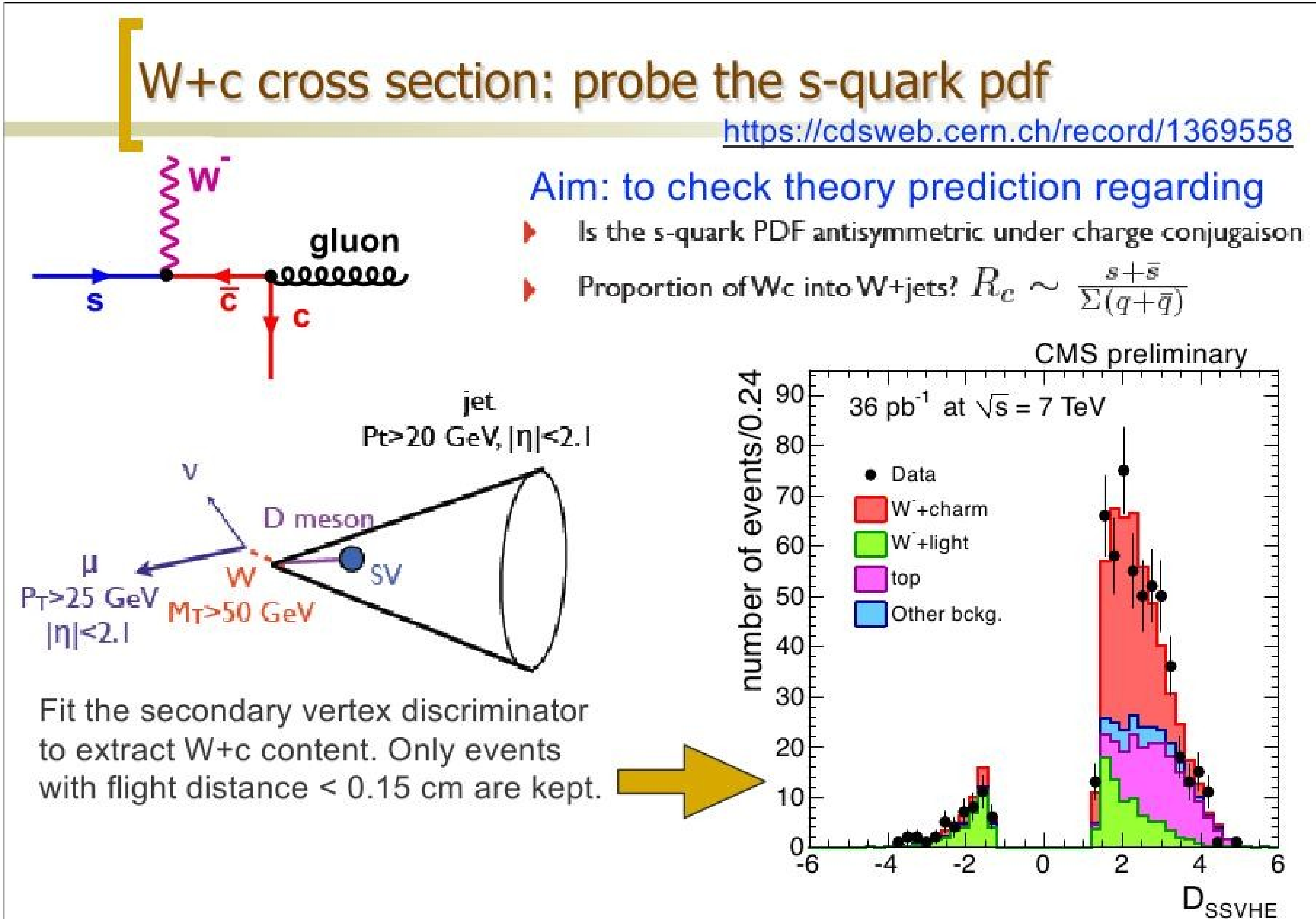


→ ratios data/theory show **different shapes / magnitudes** for recent PDFs

→ potential impact of 3-jet data in PDF fits! (need NNLO!)

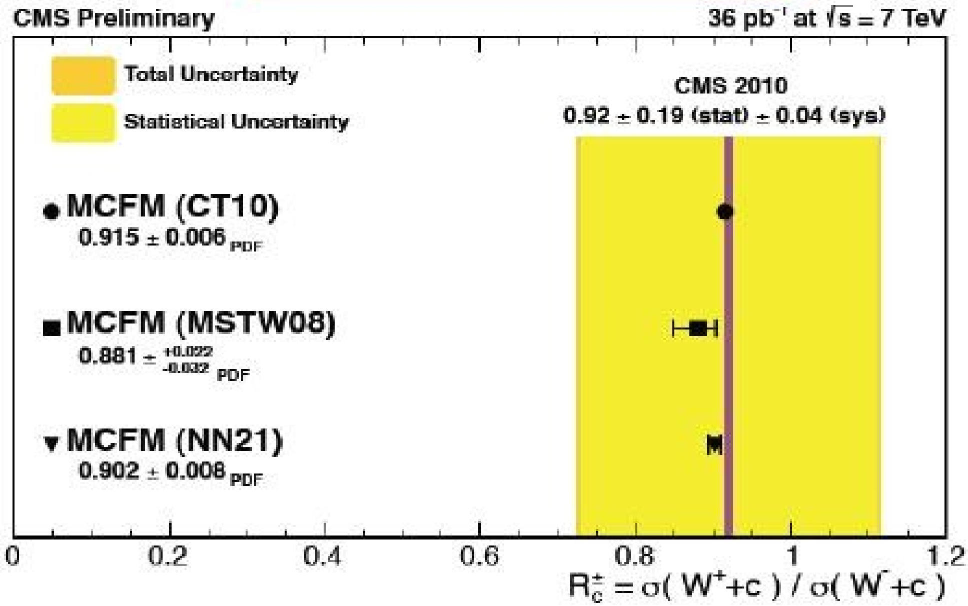
W/Z + Jets production at LHC [K. Mishra]



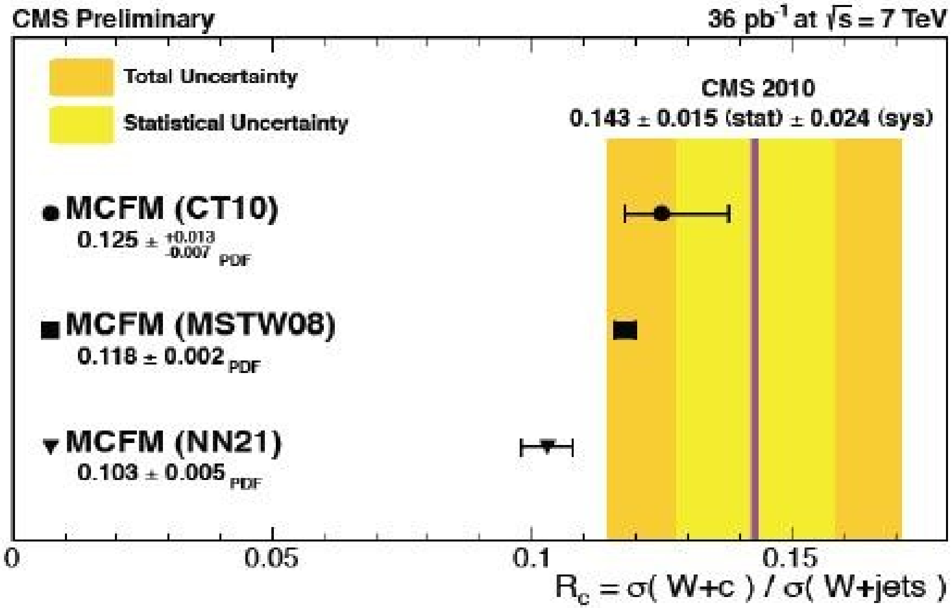
W/Z + Jets production at LHC [K. Mishra]

W+c results

$\sigma(W^+\bar{c})/\sigma(W^-c)$



$\sigma(W+c)/\sigma(W+jets)$

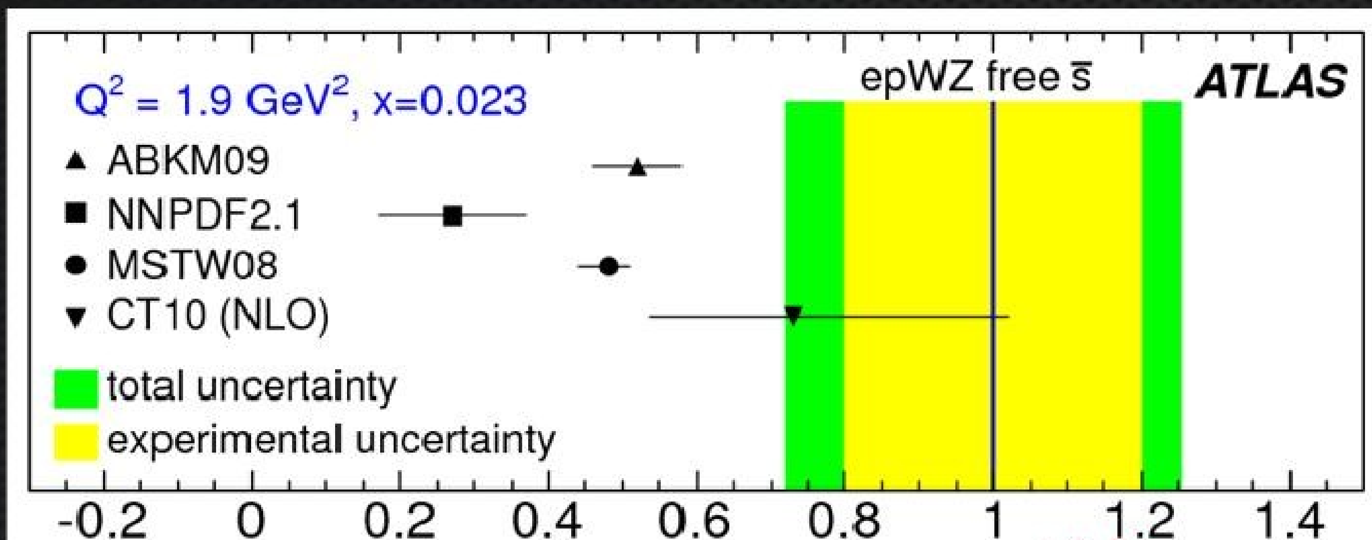


$R^{\pm}_c \neq 1$ because of d/dbar PDF difference,
result compatible with s=sbar PDF
see hep-ph/1203.6781

Overall good agreement b/w data & MC. PDF dependence is visible.

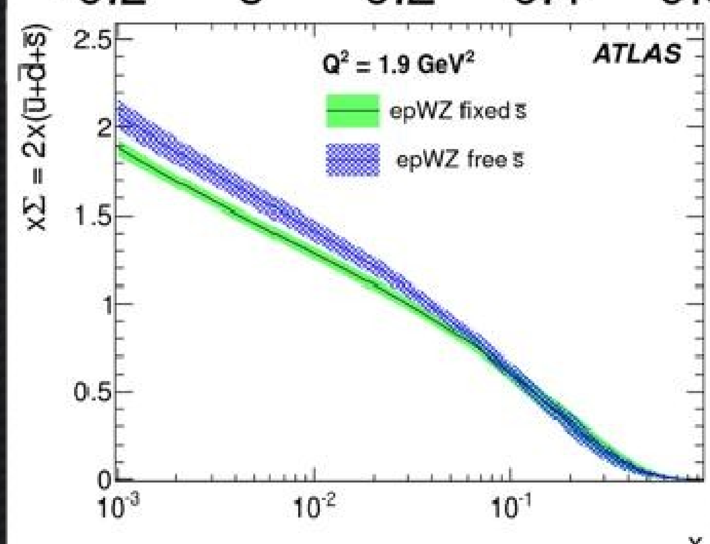
Strangeness from VB at ATLAS [J. Guimarães da Costa]

- **Fit ATLAS differential distributions for W^+, W^- and Z with HERA $e^{\pm}p$ data**
  - **NNLO pQCD analysis**



$$r_s = 1.0^{+0.25}_{-0.28}$$

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



Fit results:

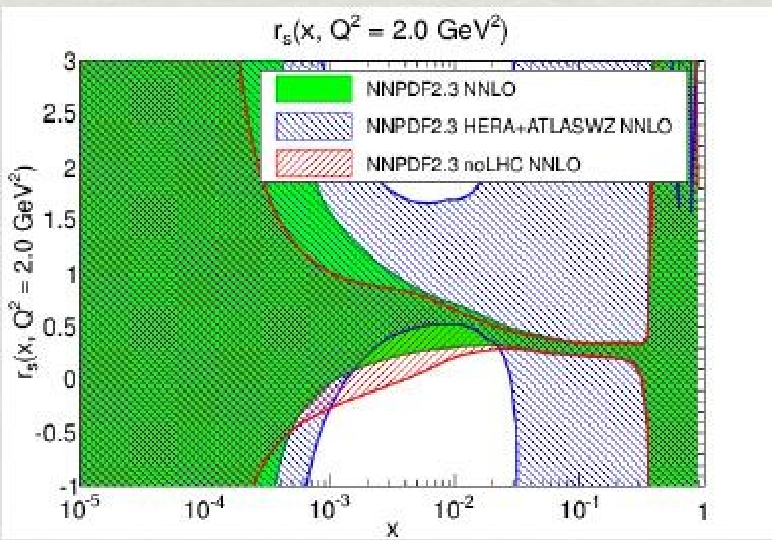
- **Light quark sea at low *x* is flavor symmetric**
- **Total sea enhancement of 8%**

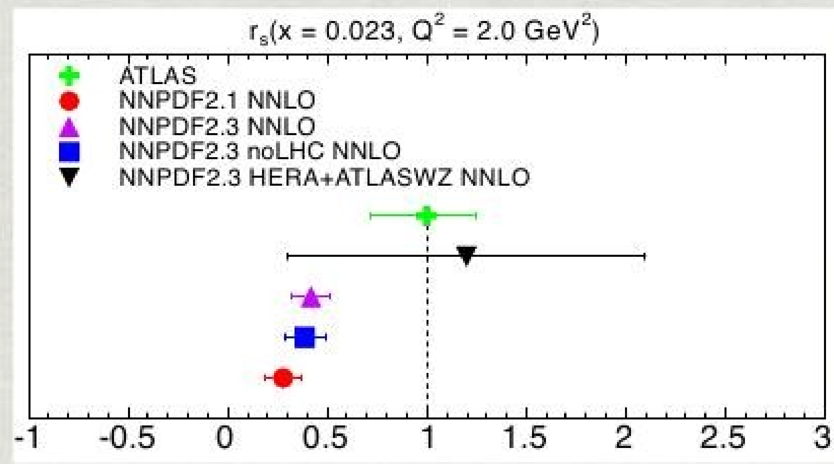
Similar analysis with NNPDF [A. Guffanti]

NNPDF Collaboration

NNPDF2.3

The LHC data - a “strange” story



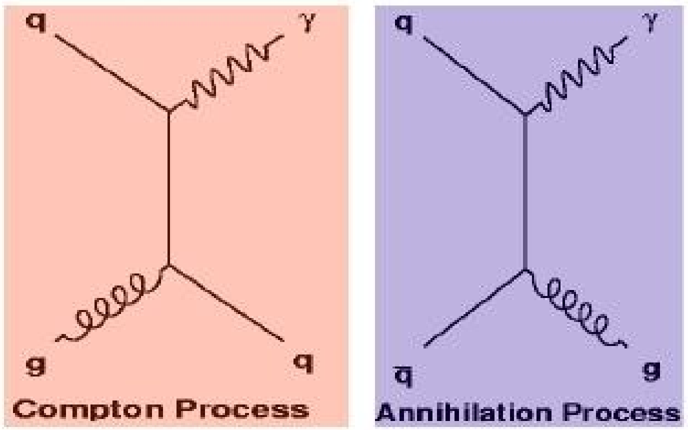


- Strangeness in NNPDF2.3 somewhat larger than NNPDF2.3noLHC in the range $10^{-3}<x<10^{-1}$, though still compatible within errors shows minor small impact of LHC data
- Determination from HERA+ATLAS dataset yields $r_s\sim 1$ but has much larger uncertainties (substantially larger than ATLAS determination)

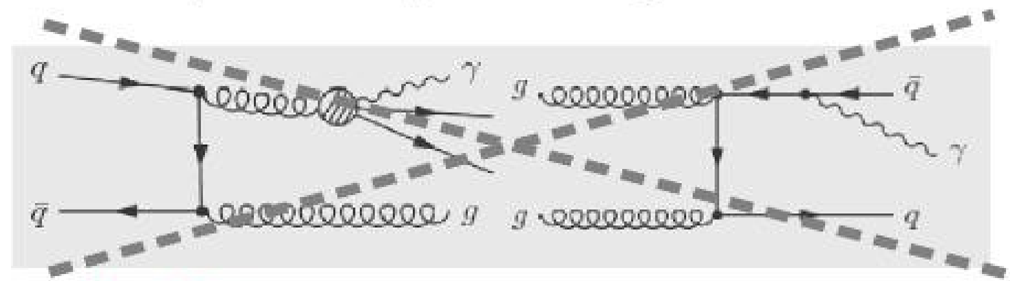
Isolated photons [D. d'Enterria]

Isolated-γ production in hadronic collisions

- Leading partonic production processes in p-p, p-$\bar{p}$ collisions :

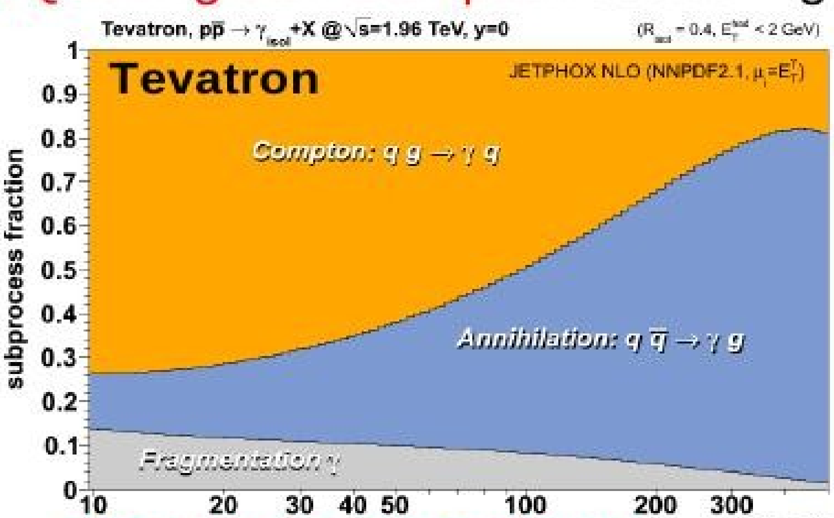


+ parton-to-photon fragmentation:

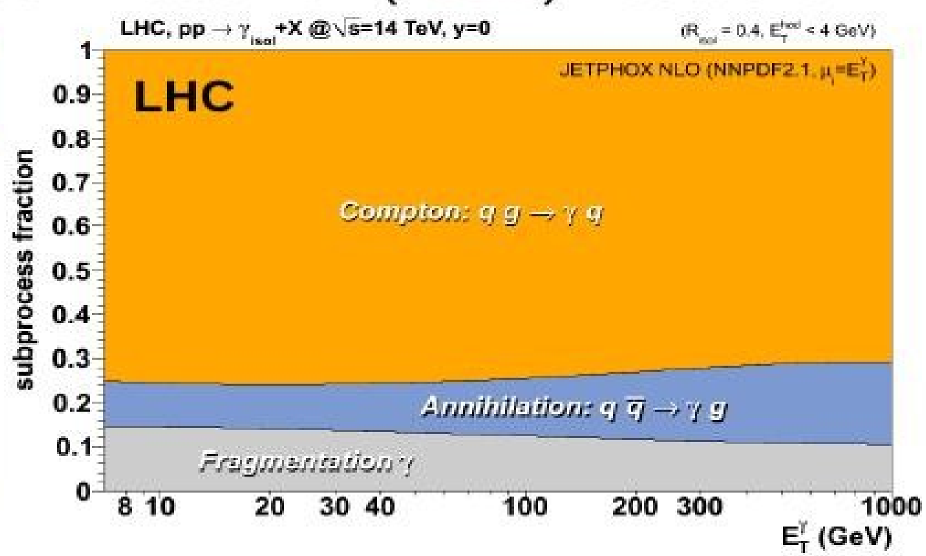


Isolation cuts (e.g. R=0.4, $E_{T,had}$<5 GeV)

- Quark-gluon Compton scattering dominates now (~80%) x-sections:



[D.d'E & J.Rojo, NPB 860 (2012) 311]

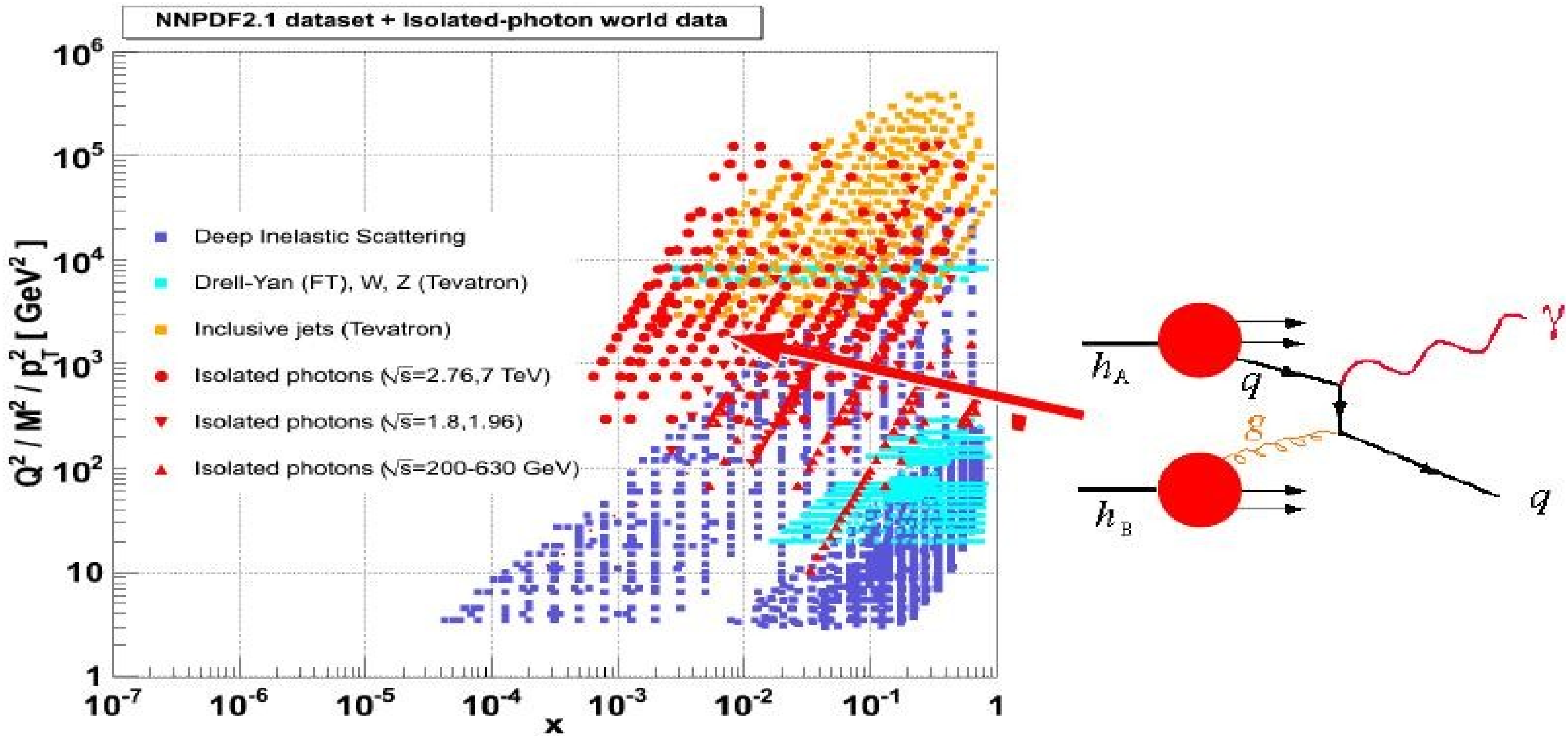


Isolated photons [D. d'Enterria]

(x,Q^2) map of collider isolated-γ datasets

[D.d'E & J.Rojo, NPB 860 (2012) 311]

- Kinematical range of LHC, Tevatron, $Sp\bar{p}S$ & RHIC γ_{isol} data:

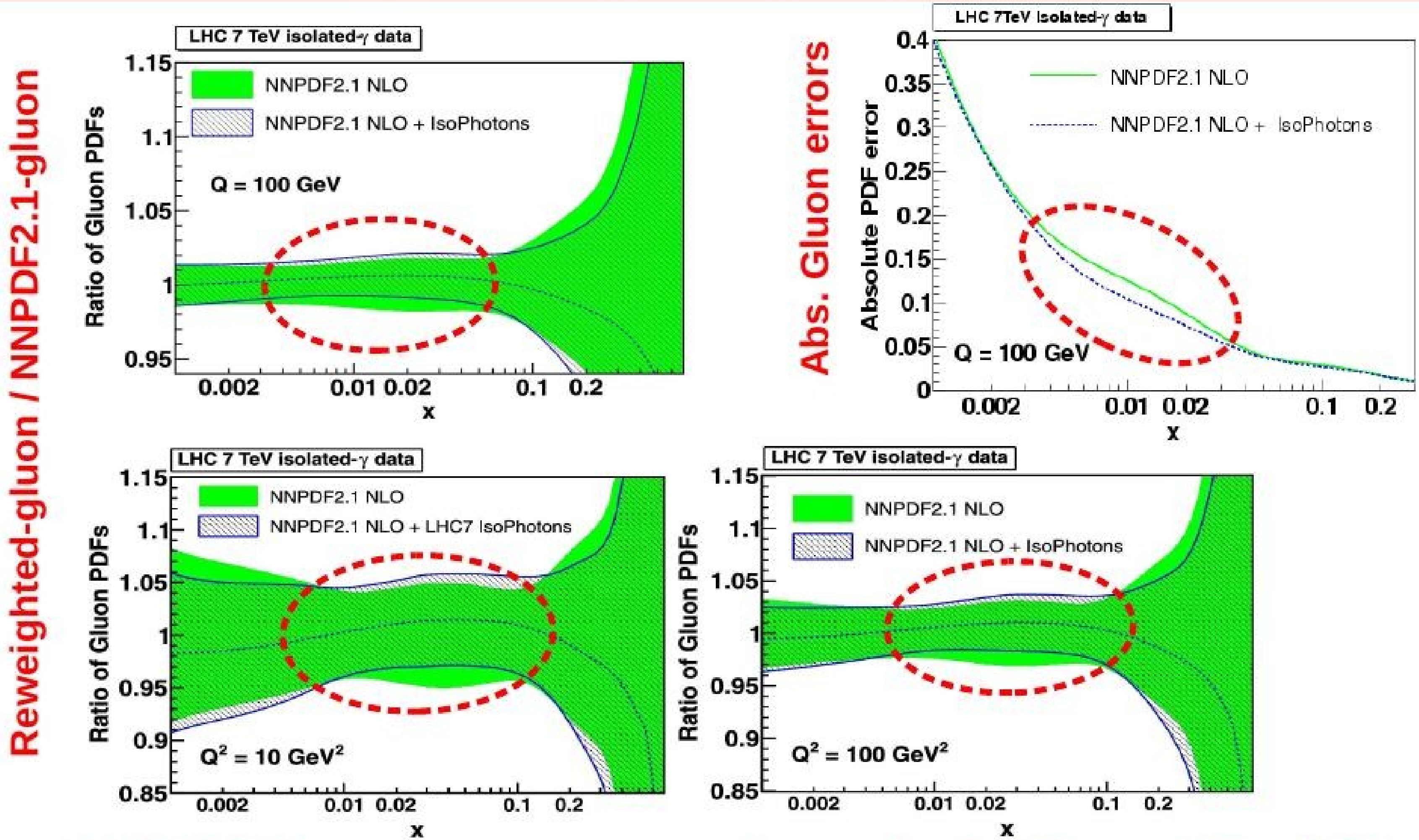


- Direct sensitivity to gluon PDF over wide (x,Q^2) domain

[$xG(x,Q^2)$ only constrained indirectly by DIS & directly by p-p jets at high-x]

Isolated photons [D. d'Enterria]

LHC γ_{isol} data: Impact on gluon PDF



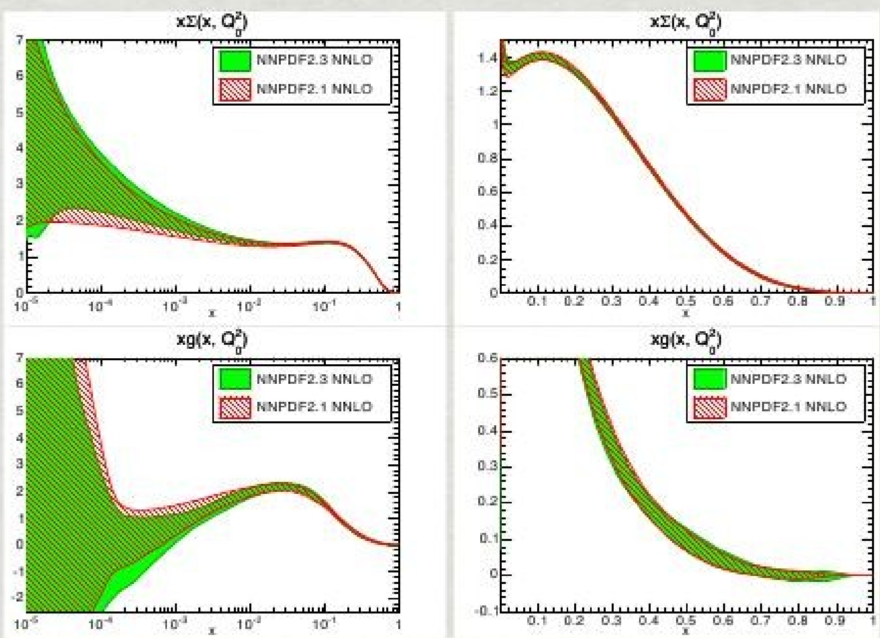
- LHC-7 TeV isolated-photons have impact for $5 \cdot 10^{-3} < x < 0.1$, all Q^2
- Gluon NLO PDF uncertainty reduced by up to ~20%
- Tevatron, Sp$\bar{p}$S, RHIC measurements have negligible impact ...

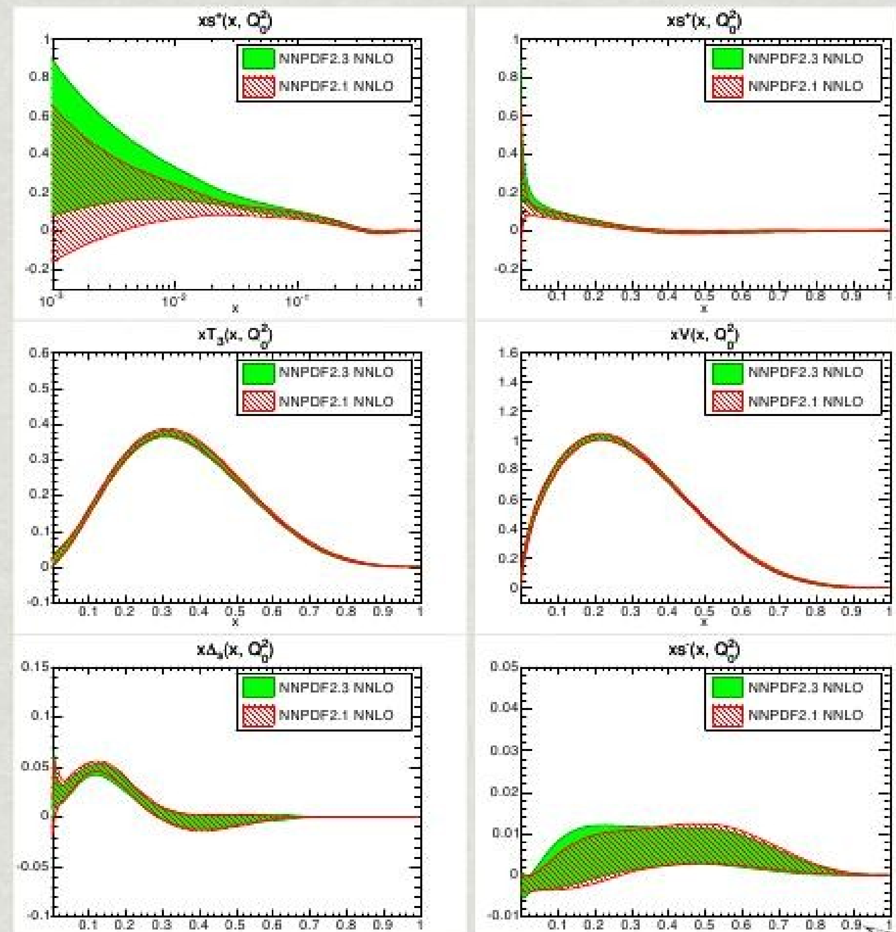
NNPDF [A. Guffanti]

NNPDF2.3

Results - Parton Distributions (NNLO)

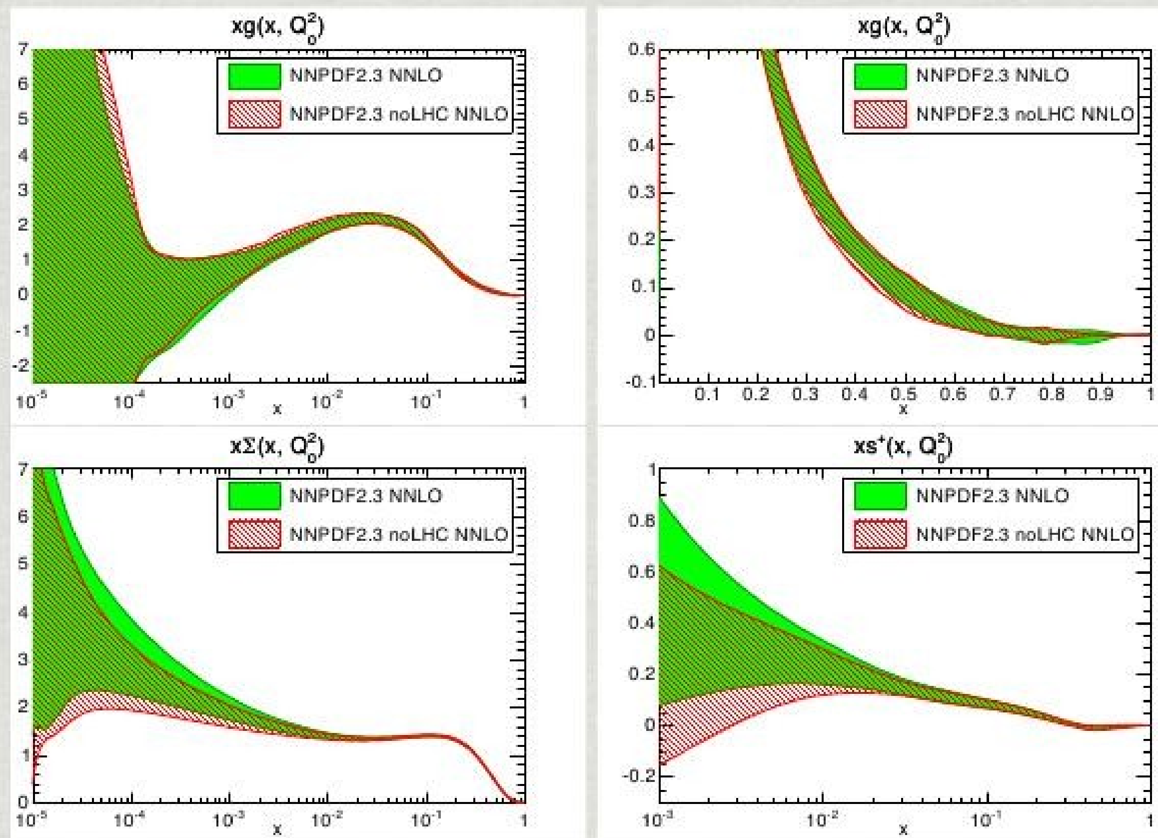
- Detailed comparison with NNPDF2.1
  - addition of LHC data
  - improved minimization
  - corrected error in dimuon cross-section (moderate effect on strangeness)





NNPDF [A. Guffanti]

- Moderate impact of LHC data on extracted PDFs
- Largest impact on singlet quark and strange distribution
- Effect is at most half a sigma shift in central values

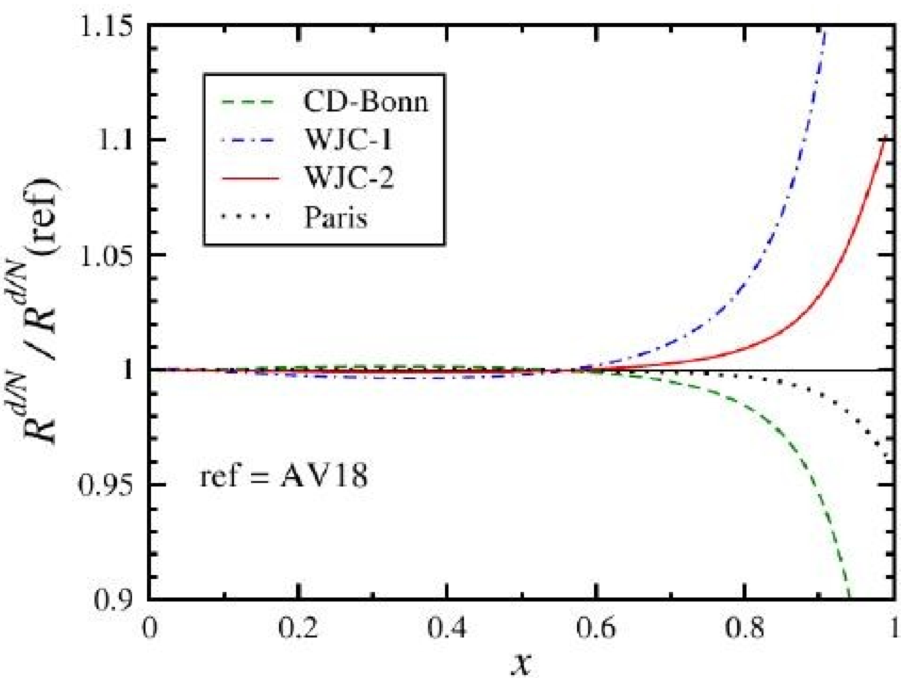


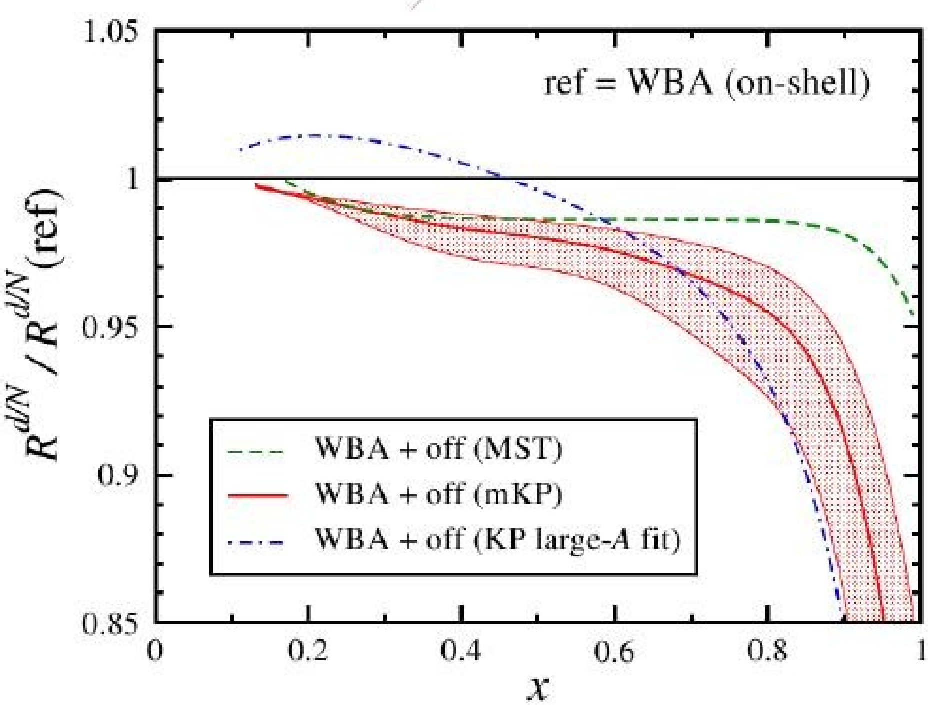
CTEQ-JLAB [A. Accardi]

Focused in understanding the large-x region:

$$F_{2d}(x_B, Q^2) = \int_{x_B}^{A} dy\, \mathcal{S}_A(y, \gamma) F_2^{TMC+HT}(x_B/y, Q^2) \left(1 + \frac{\delta^{off} F_2(x)}{F_2(x)}\right)$$

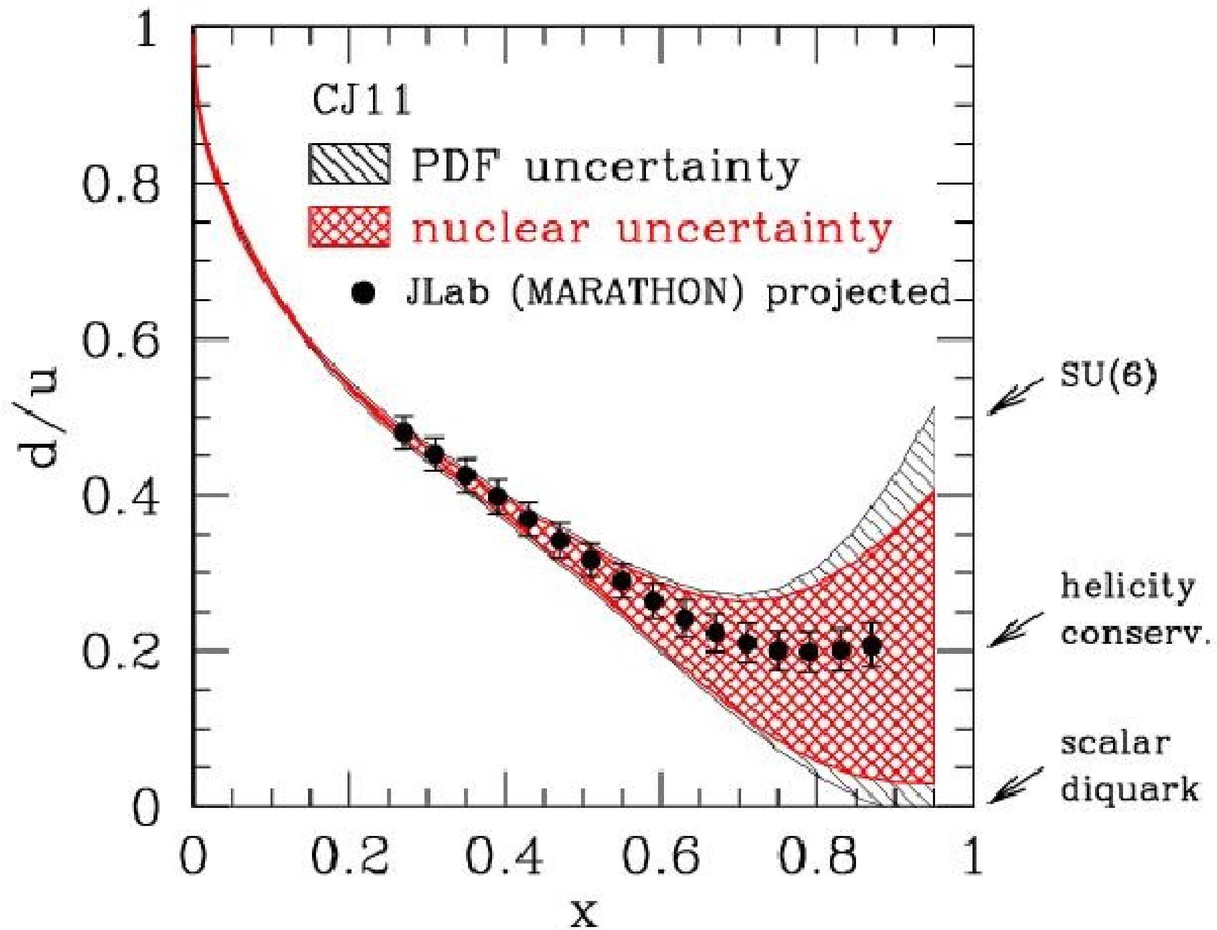
Free nucleon str.fn.

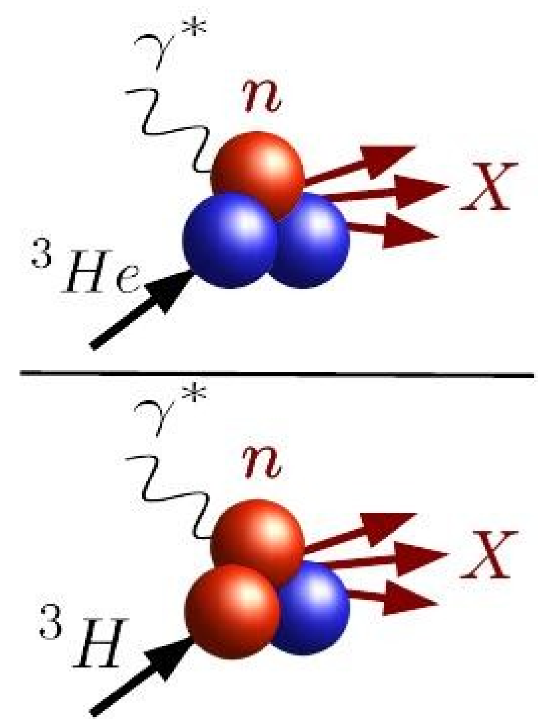




Quasi-free neutrons from MARATHON

Approved JLAB12 experiment



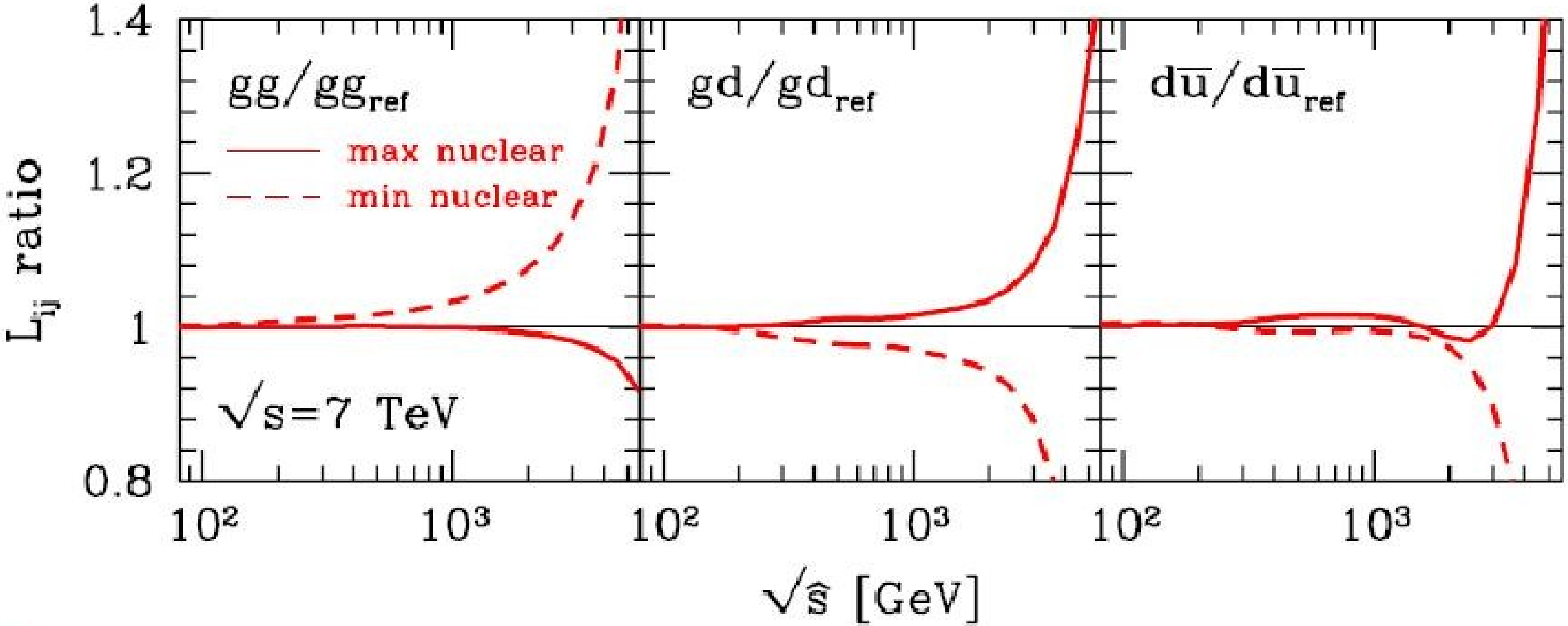


- Nuclear corrections largely cancel in the ratio of $^3He/^3H$ cross sections

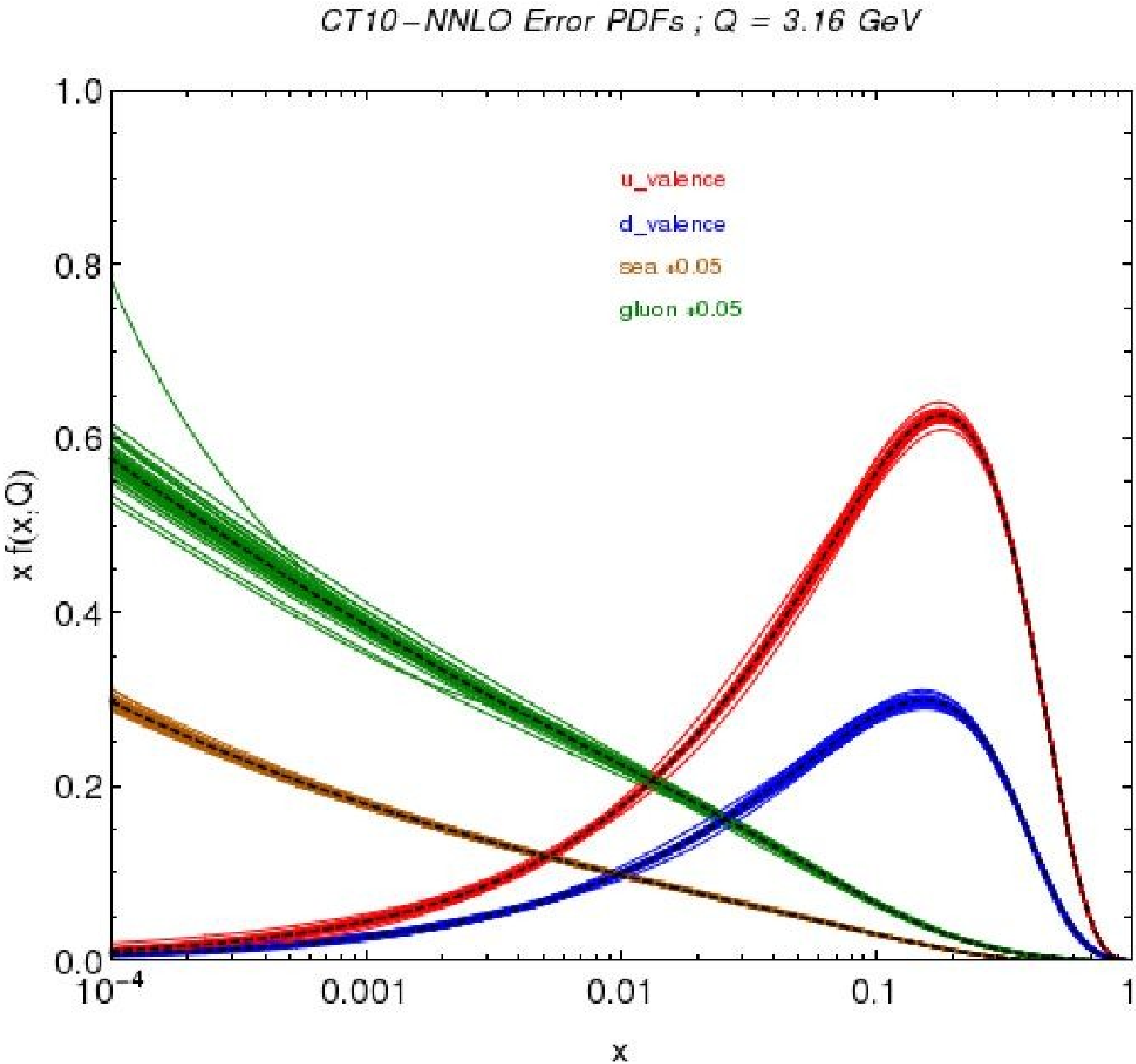
CTEQ-JLAB [A. Accardi]

- Large-x PDF uncertainties affect total cross sections for objects of large mass $\hat{s} = (p_1 + p_2)^2 = x_1 x_2 s$

$$L_{ij} = \frac{1}{s(1+\delta_{ij})}\left[\int_{\hat{s}/s}^{1} \frac{dx}{x} f_i(x,\hat{s})\, f_j\left(\frac{\hat{s}}{xs},\hat{s}\right) + (i \leftrightarrow j)\right]$$

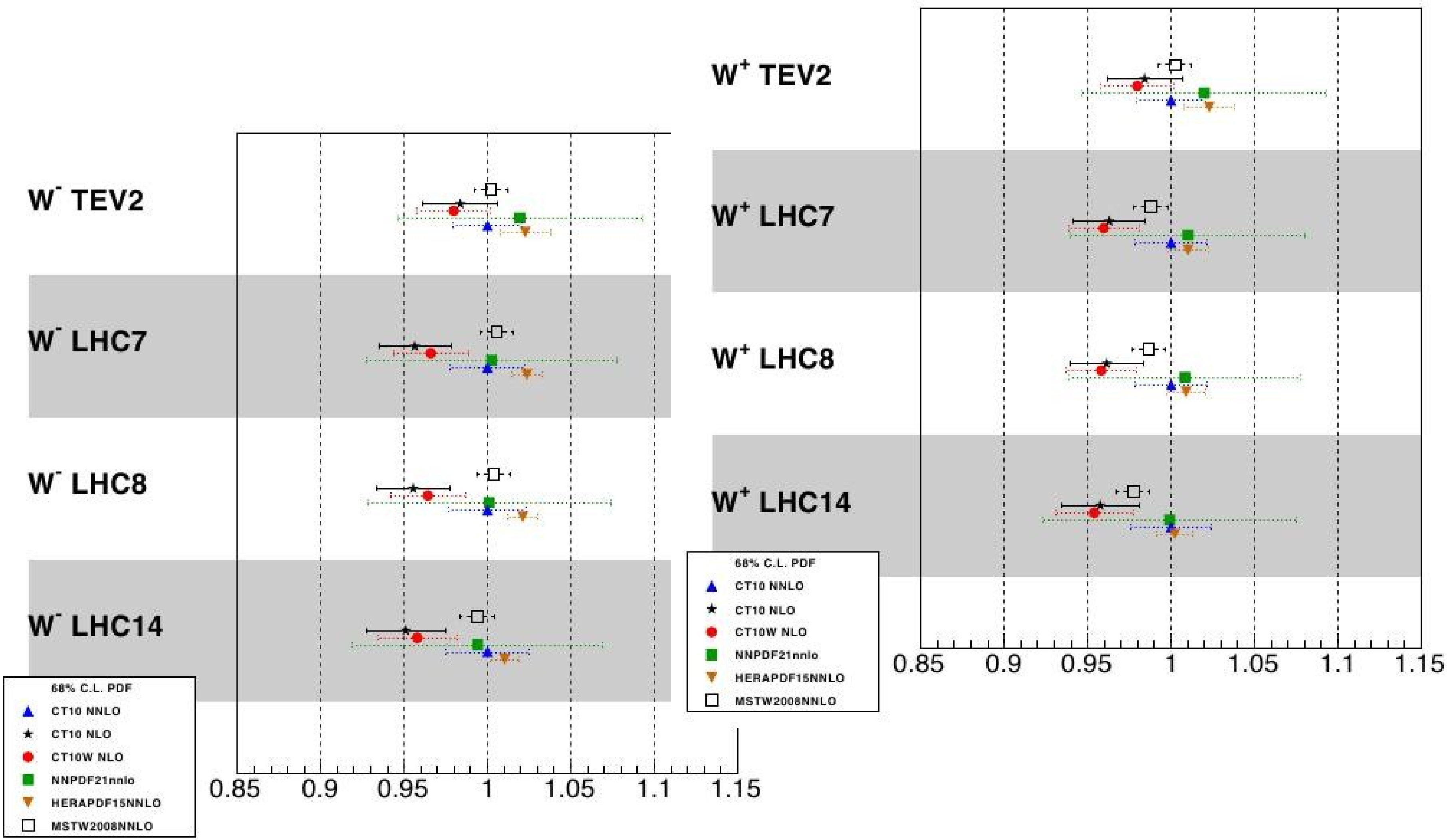


CTEQ-TEA [D. Stump]



CTEQ-TEA [D. Stump]

CT10-NNLO compared with other PDFs for W boson production (NNLO)



HERAPDF [A. M. Cooper-Sarkar]

HERAPDF

QCD@LHC 2012

A M Cooper-Sarkar
on behalf of ZEUS and H1 collaborations

HERAPDF NLO uses the combined H1 and ZEUS data on:

- Inclusive Neutral and Charged Current processes for e^+p and e^-p scattering at 820,920 GeV proton beam energy from HERA-I (HERAPDF1.0) and HERA I+II (HERAPDF1.5)
- There are also studies adding data from the lower energy runs at 460, 575 proton beam energy and from adding combined HERA data on F2charm
- There are also fits adding separate H1 and ZEUS data on inclusive jet production to the inclusive cross section data (HERAPDF1.6)
- Finally HERAPDF1.7 uses ALL of these data sets

HERAPDF NNLO uses just the inclusive cross-section data because of incomplete NNLO calculations for jet data and for charm production

HERAPDF [A. M. Cooper-Sarkar]

•The HERA inclusive data provide precision for the low-x Sea and gluon PDFs, the u-valence is also well measured, and the d-valence is measured without assumptions about nuclear corrections or strong isospin.

•Adding the HERA-II high Q^2 data reduces the uncertainties at high-x. So far this was preliminary, **now the input H1 (DESY-12-107) and ZEUS (DESY-12-145) data sets are finally ready- the HERA-II final combination has begun**

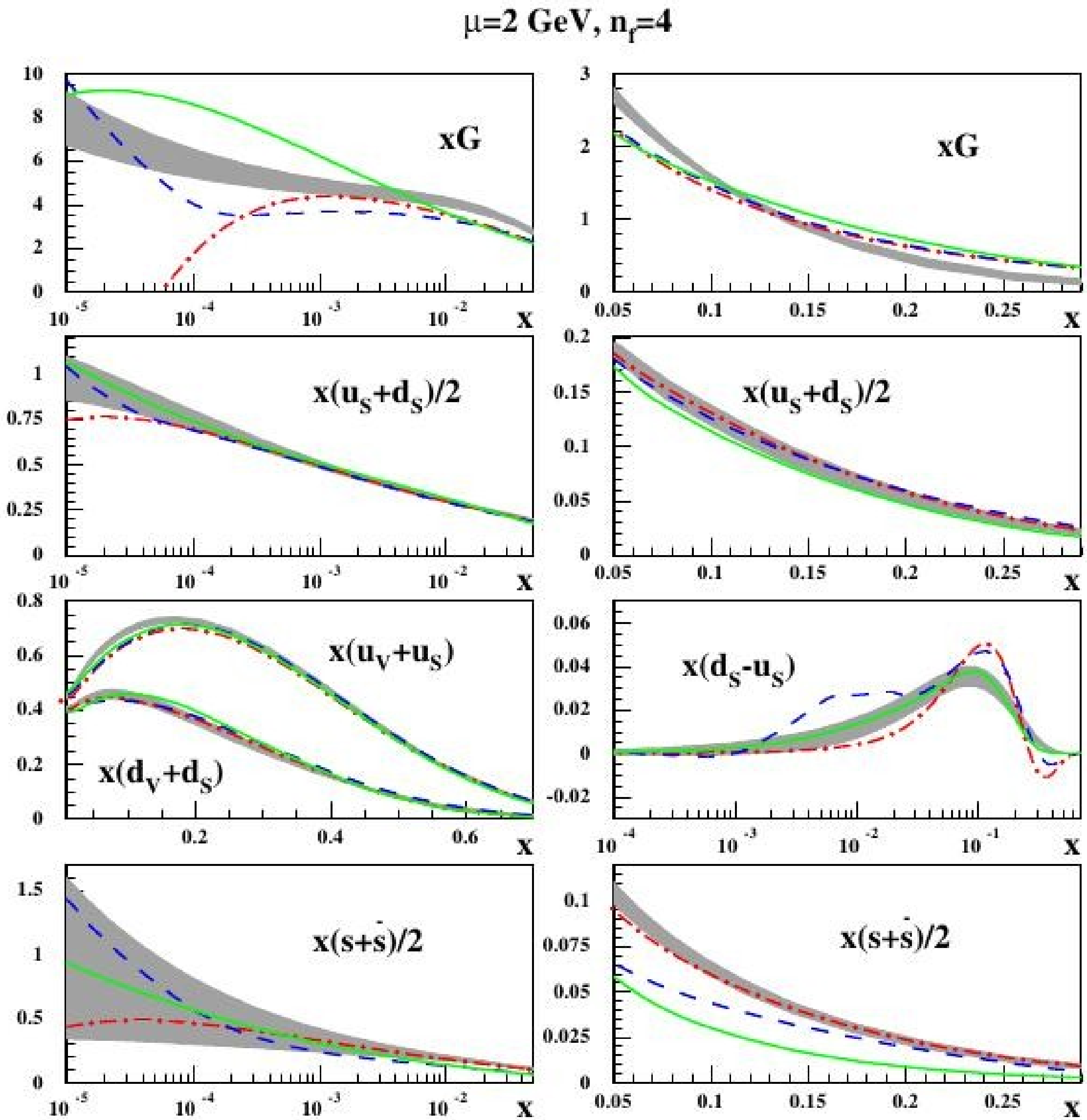
•Adding HERA jet data allows a measurement of $\alpha_S(M_Z)$ and the high-x gluon– further jet data sets will be added

•Adding charm data allows a reduction in model uncertainties concerning the charm mass and scheme. **The charm combination paper is about to have its 3rd editorial board.**

•Adding low energy data will allow us to investigate non-DGLAP behaviour at low x,Q^2

•HERAPDF gives a good description of Tevatron W, Z data and jet data (within its error bands) and a good description of LHC W ,Z and jet data

Parton distributions for the LHC



- 1σ band for ABM11 PDFs (NNLO, 4-flavors) at $\mu = 2$ GeV
  Alekhin, Blümlein, S.M.'12
- comparison with:
  JR09 (solid lines),
  MSTW (dashed dots) and
  NN21 (dashes)
- Some interesting observations to be made . . .

HERAPDF [S.-O. Moch]

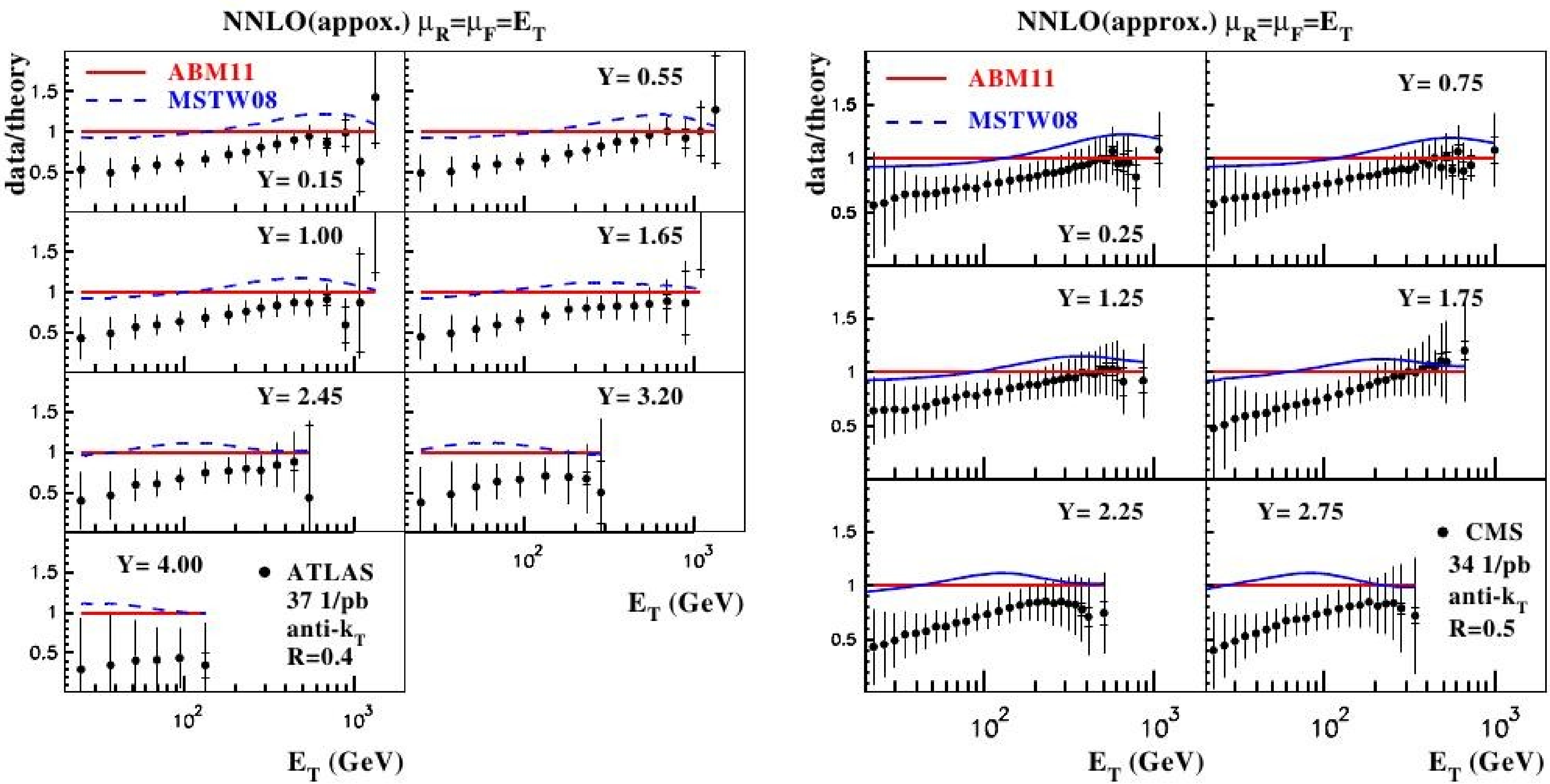
Comparison of α_s determinations

- Differences in α_s values:
  - result from different physics models and analysis procedures
    - target mass corrections (powers of nucleon mass M_N^2/Q^2)
    - higher twist $F_2^{\rm ht} = F_2 + ht^{(4)}(x)/Q^2 + ht^{(6)}(x)/Q^4 + \ldots$
    - error correlations
- Effects for differences between ABM, MSTW and NN21 understood
  - variants of ABM with no higher twist etc. reproduce larger α_s values

	α_s at NNLO	target mass corr.	higher twist	error correl.
ABM11	0.1134 ± 0.0011	yes	yes	yes
NNPDF21	0.1166 ± 0.0008	yes	no	yes
MSTW	0.1171 ± 0.0014	no	no	no

HERAPDF [S.-O. Moch]

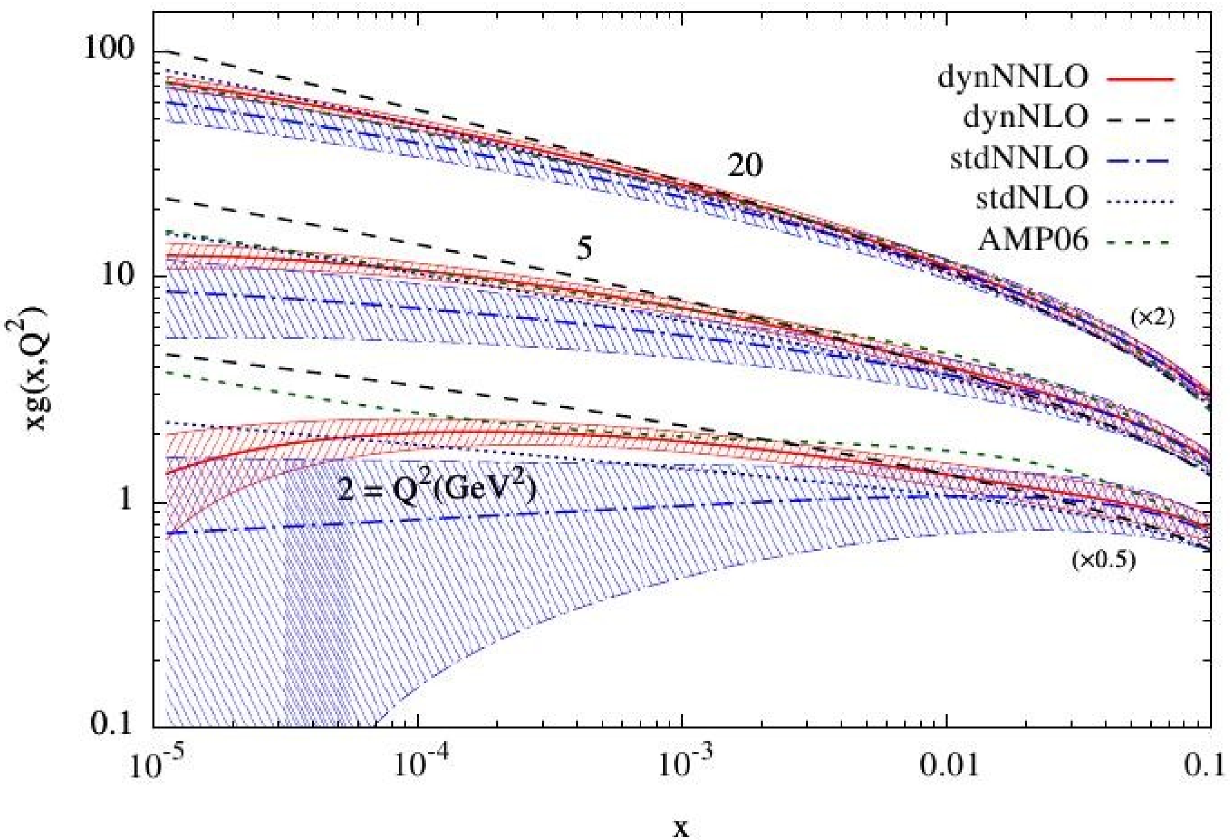
LHC jet data



- Comparision to LHC data: ATLAS coll. (left) and CMS coll. (right) in good agreement
- LHC jet data prefers small gluon PDF at large x

JR [P. Jimenez-Delgado]

Typical dynamical vs "standard" gluons



Evolution from dynamical scales ≡

$\Longrightarrow$ larger "evolution distance"+ valence-like structure (of the input distributions)

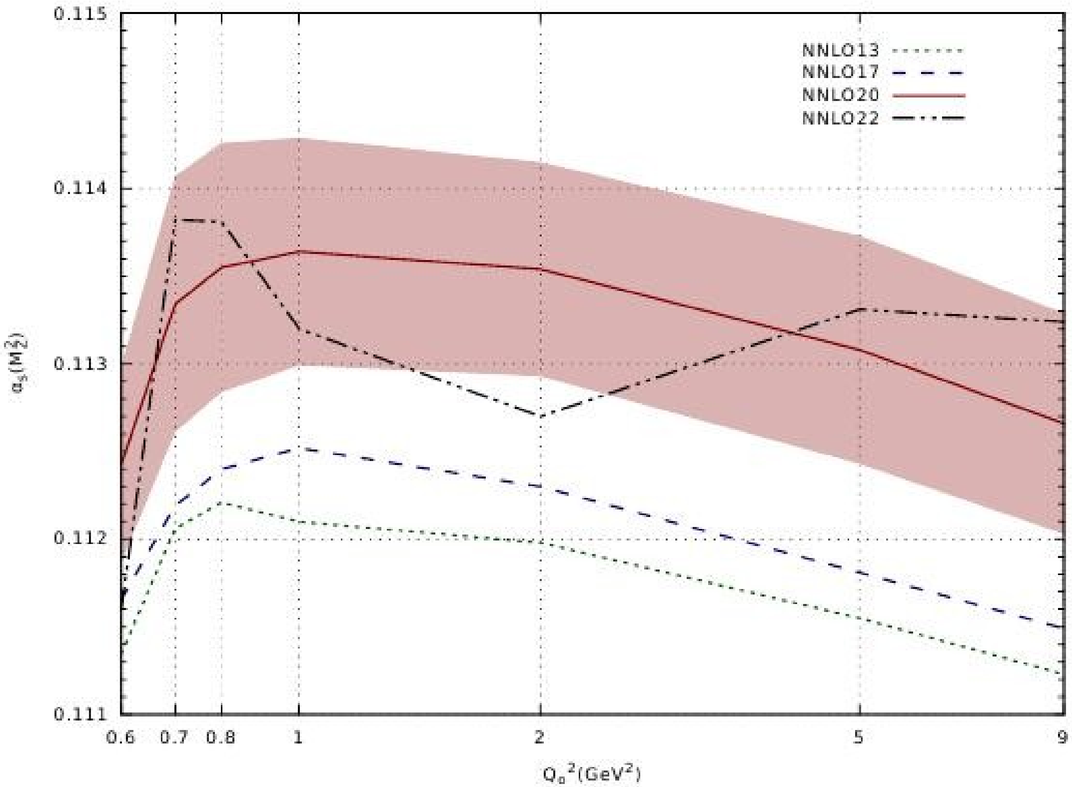
$\Longrightarrow$ less uncertainties and steeper gluons (correspondingly smaller α_s)

Fine tunning marginal (e.g. for DIS in JR09 $\chi^2_{dyn} = 0.90$ comparable to $\chi^2_{std} = 0.87$)

JR [P. Jimenez-Delgado]

Additional uncertainty in $\alpha_s(M_Z^2)$

By considering variations with Q_0^2 one can estimate (a lower limit to) the procedural error ⇒ additional uncertainty for each quantity (quadrature)



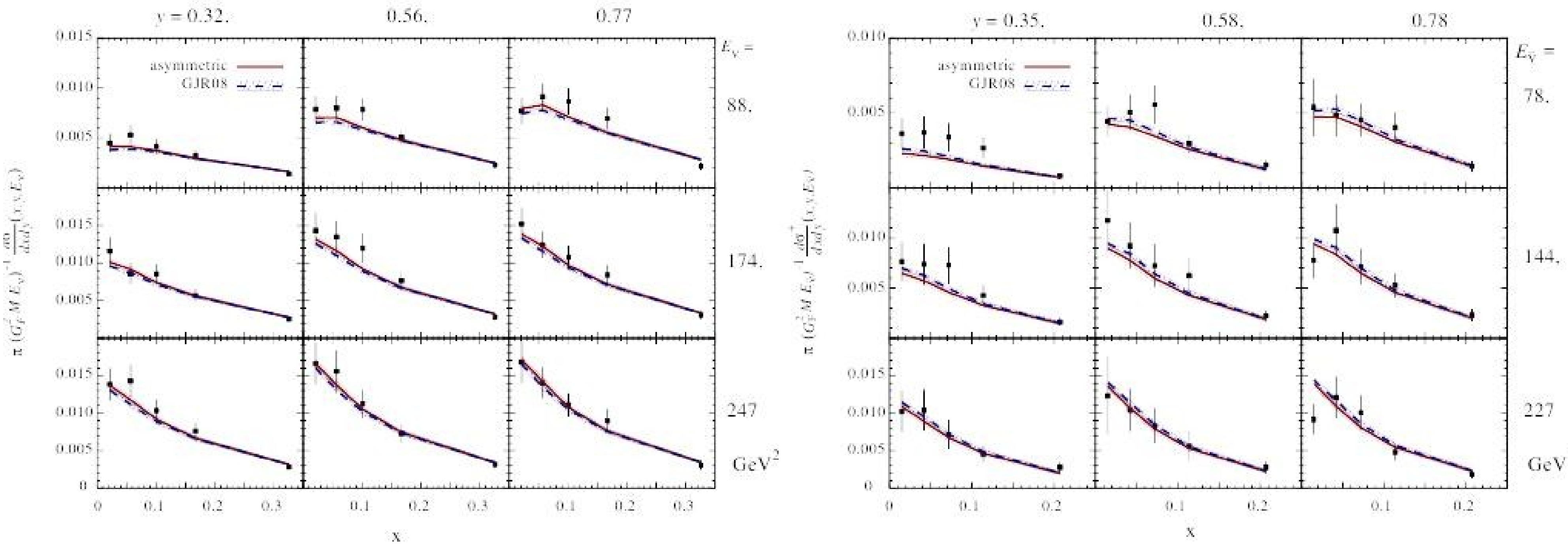
Results stabilize at NNLO20 but variations do not (substantially) decrease

Following our “recipe” we would estimate $\Delta_{\text{bias}}\alpha_s \simeq 0.0006$

⇒ about the same size than the error from experimental uncertainties!!

JR [P. Jimenez-Delgado]

The NuTeV dimuon data



Already well described by GJR08: $\chi^2 = 65$ for 90 data points (1σ)

$\Rightarrow$ radiatively generated strangeness plausible: $s(x,Q_0^2)+\bar{s}(x,Q_0^2)\simeq 0$
(there are no free parameters and data were not included in fit!)

Introducing an asymmetry χ^2 goes down to 60: $s(x,Q_0^2)-\bar{s}(x,Q_0^2)\neq 0$

Thanks to the organizers and thank you all for your attention!