PDF WG summary

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Experimental input:

LHC (W/Z, jets, W/Z+jet, W+c, W+b)

Tevatron (jets, W/Z+jet)

HERA: (inclusive NC and CC, F_2^c, F_2^b)

Theoretical input:

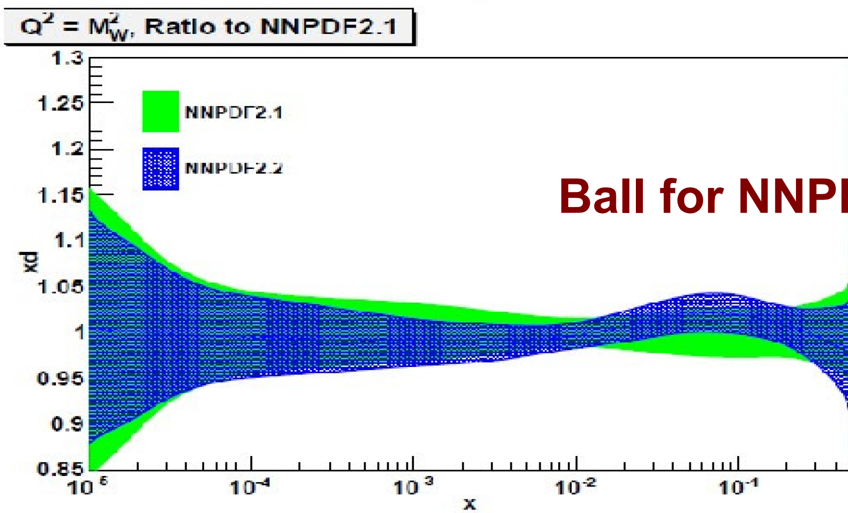
NNLO QCD corrections

Heavy-quark electro-production

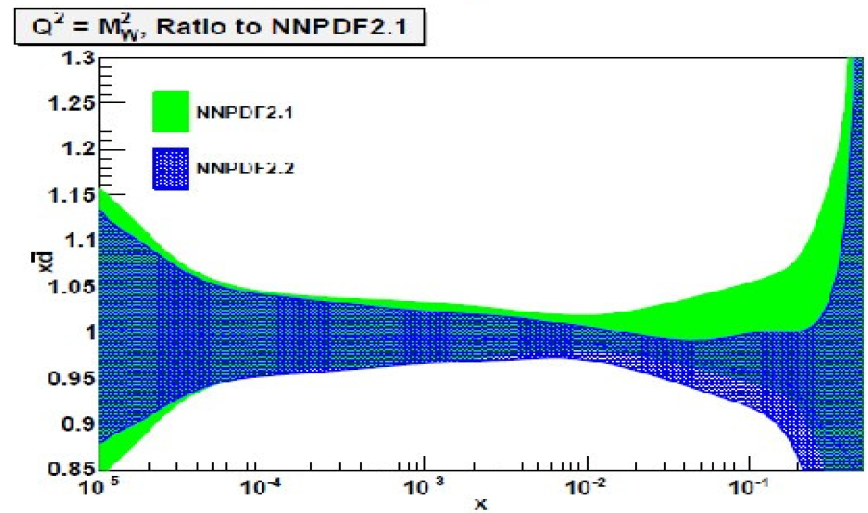
Standard candles and α_s

St.Andrews, 26 Aug 2011

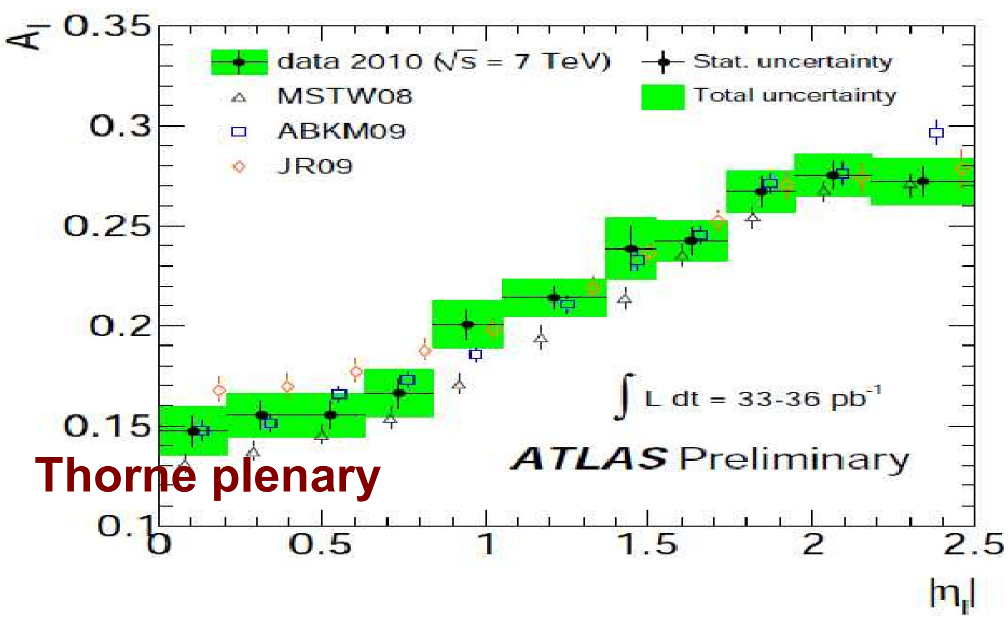
LHC W/Z



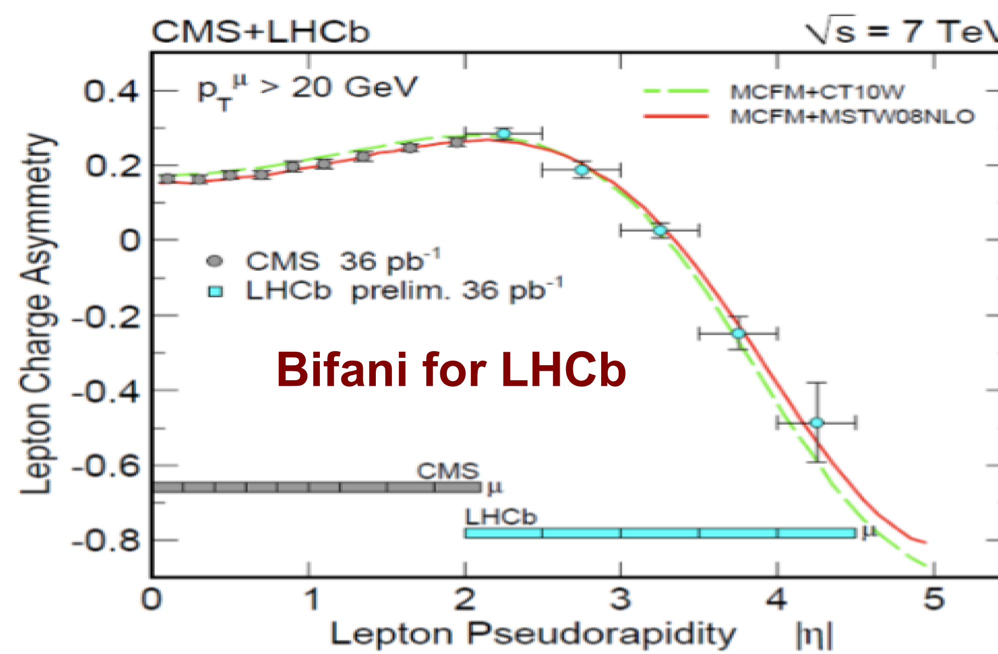
Ball for NNPDF



LHC data for the charge-lepton asymmetry put additional constraint on PDFs



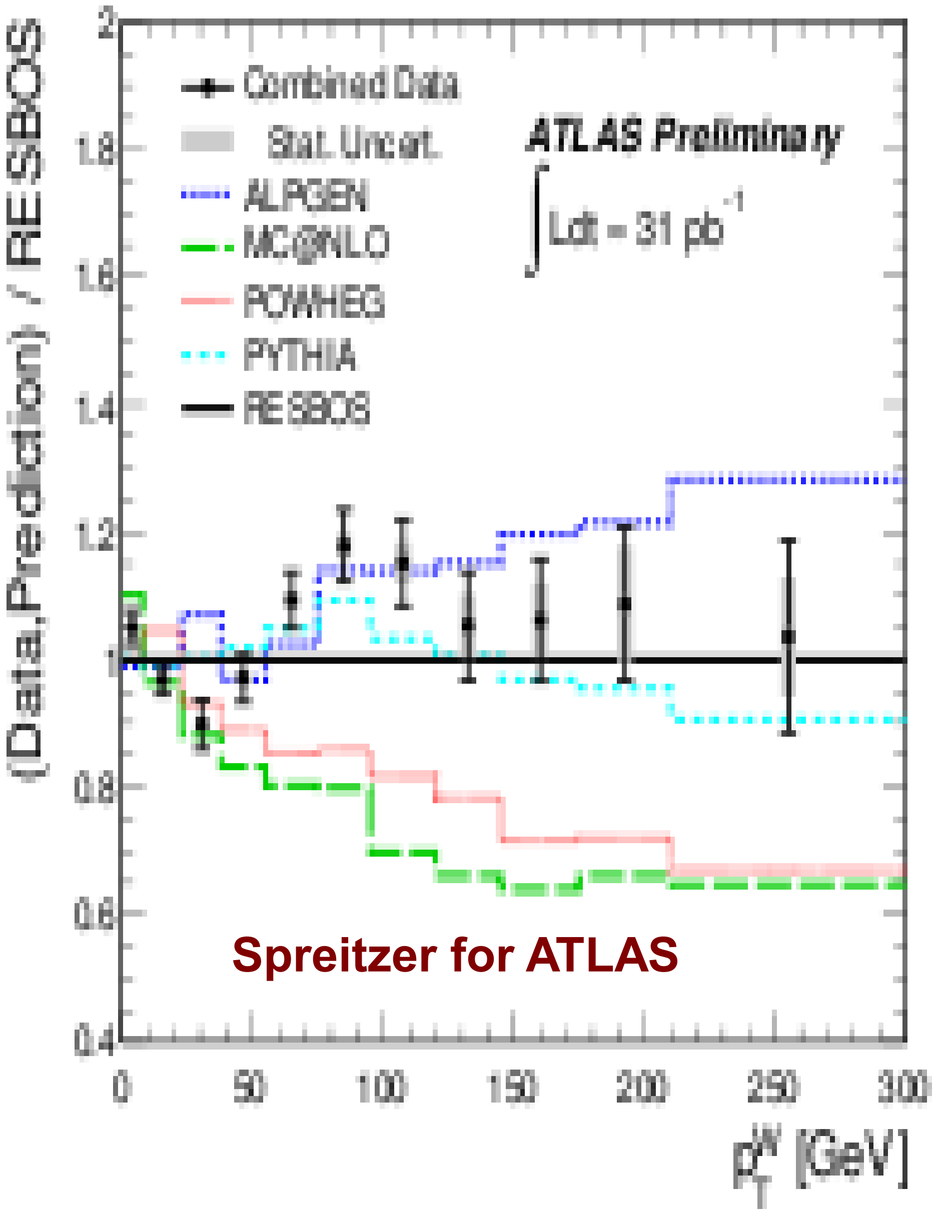
Thorne plenary

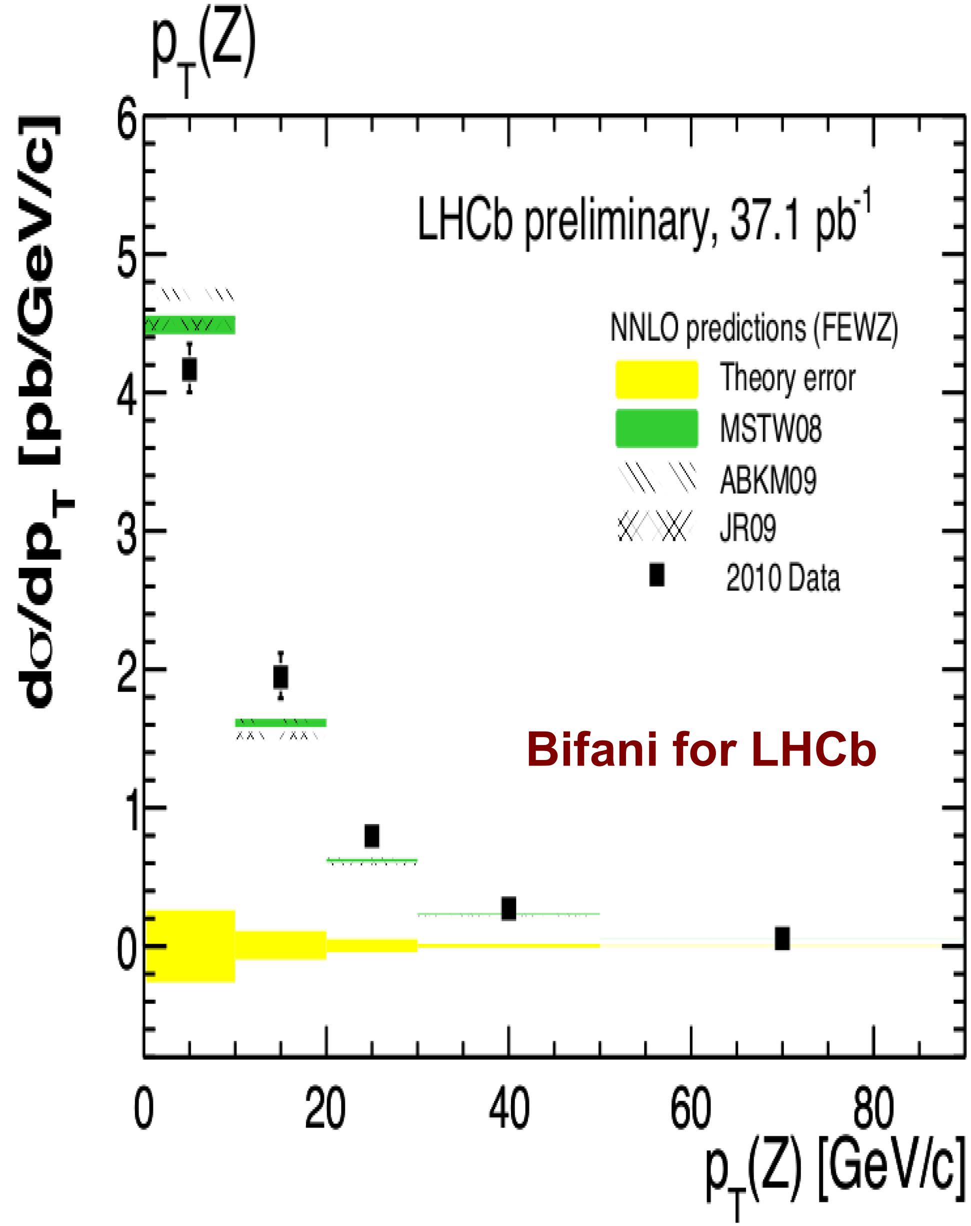


Bifani for LHCb

The asymmetry is sensitive to the cuts on P_T → good understanding of P_T distributions

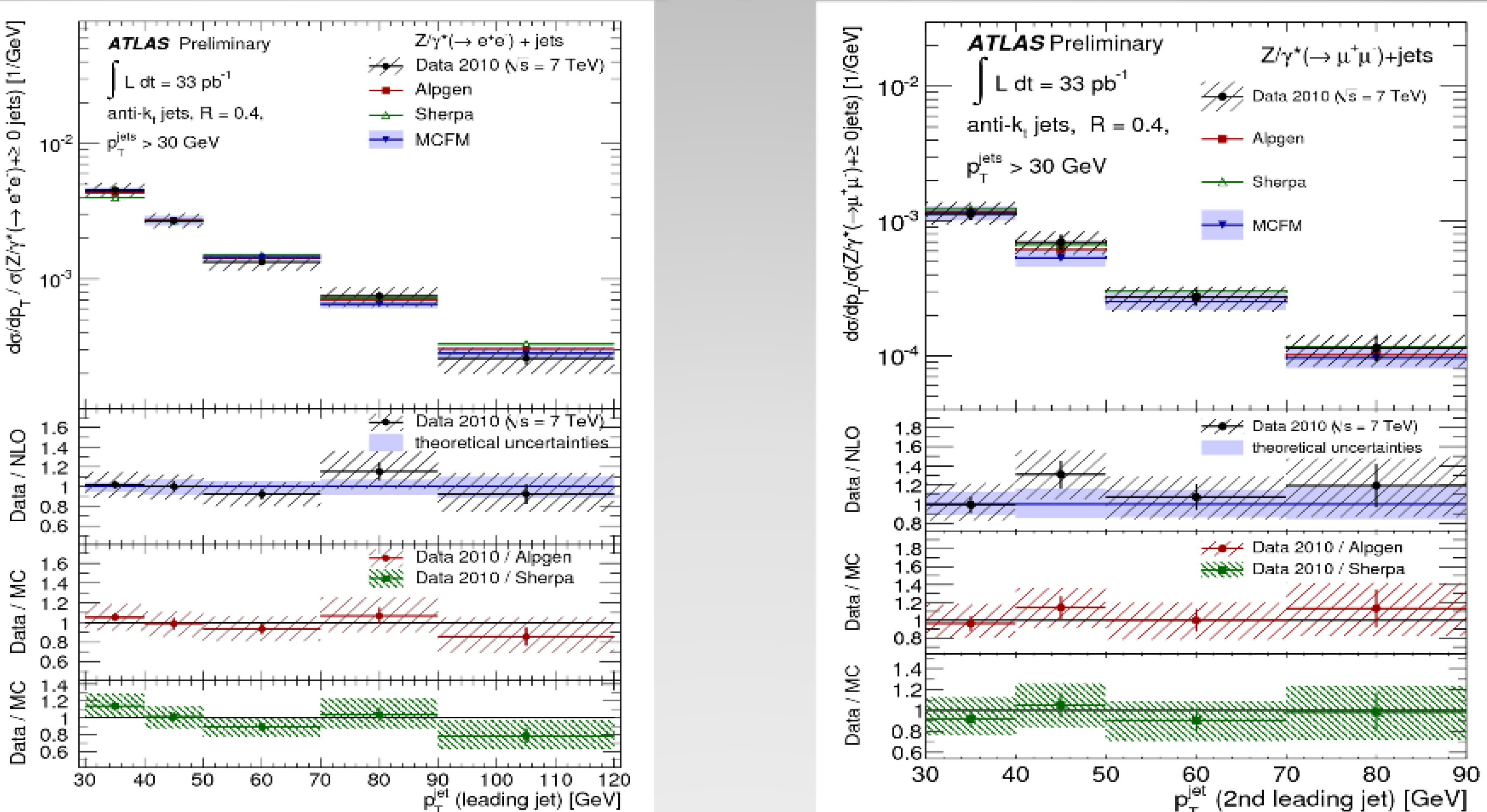
LHC W/Z





The spread in the calculations. RESBOS works better than FEWZ → resummation is required

Jet P_T (Z+jets)



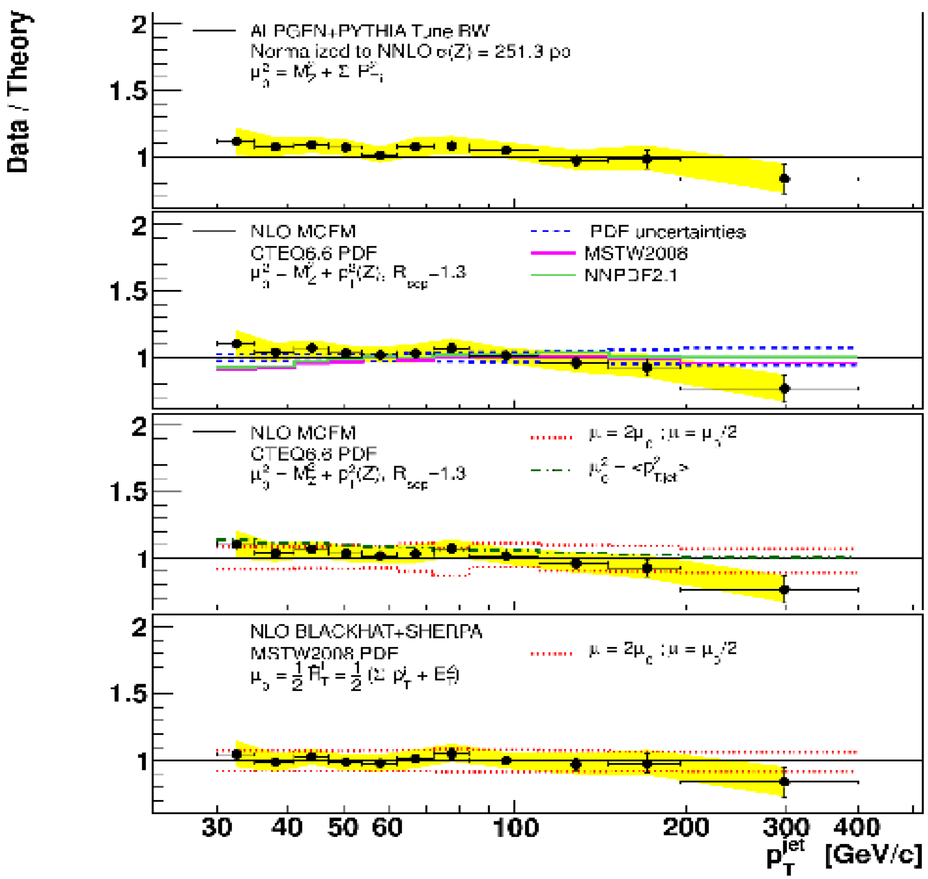
Devetak for ATLAS

Tevatron

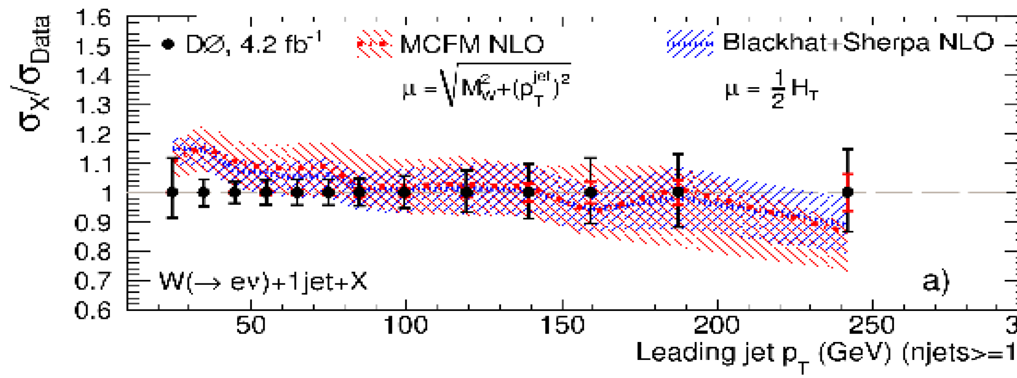
W/Z + jets

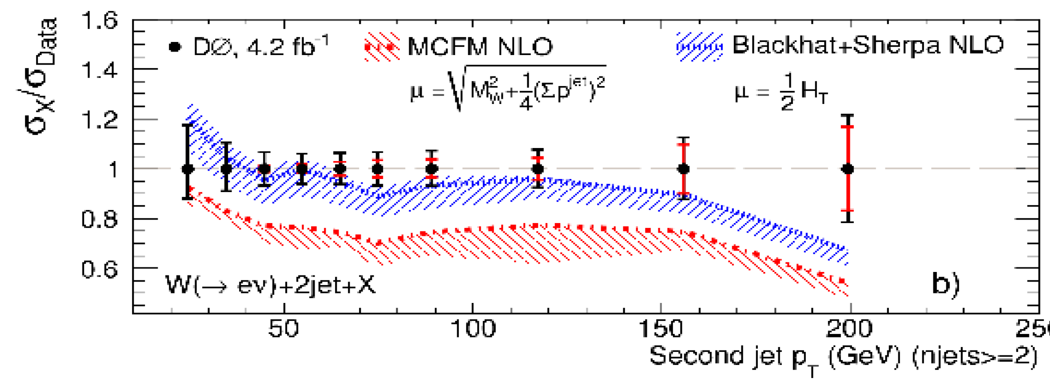
Camarada for CDF and D0

Z + ≥1 jet inclusive P_T^{jet}



W → eν + jets

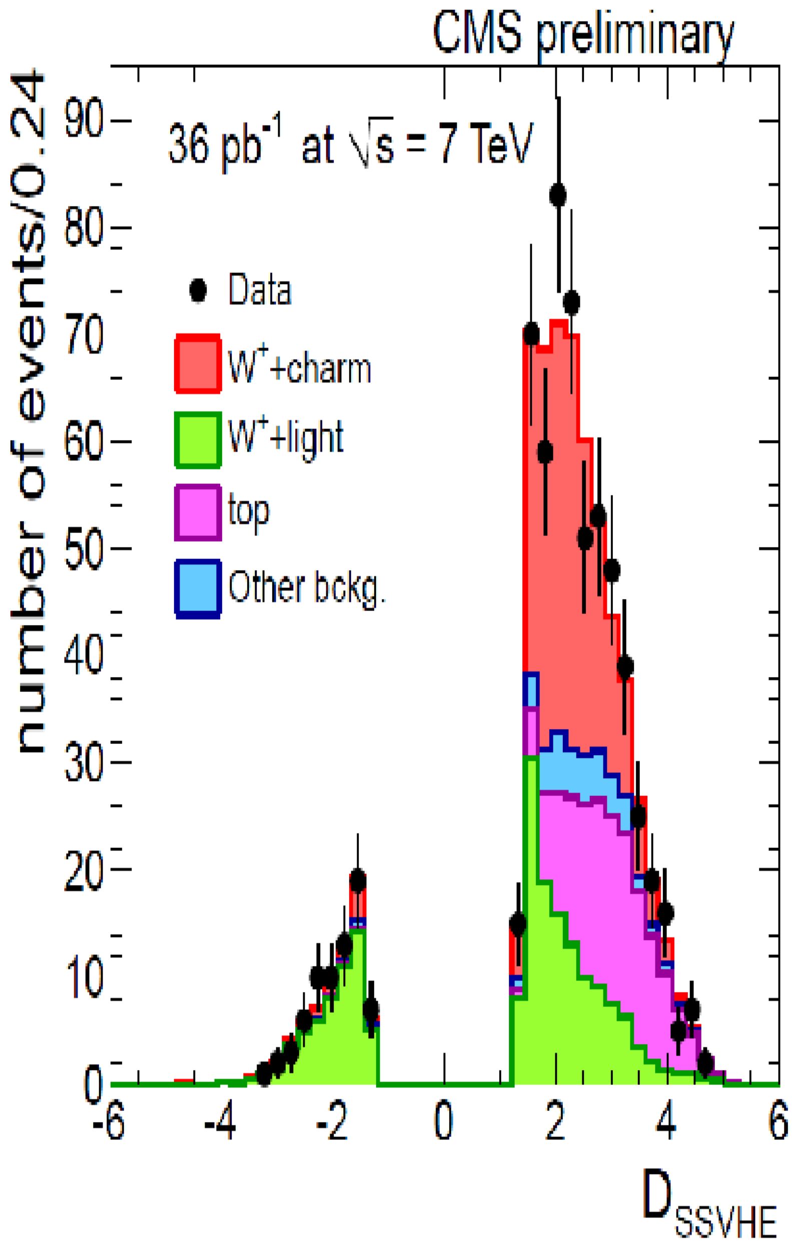


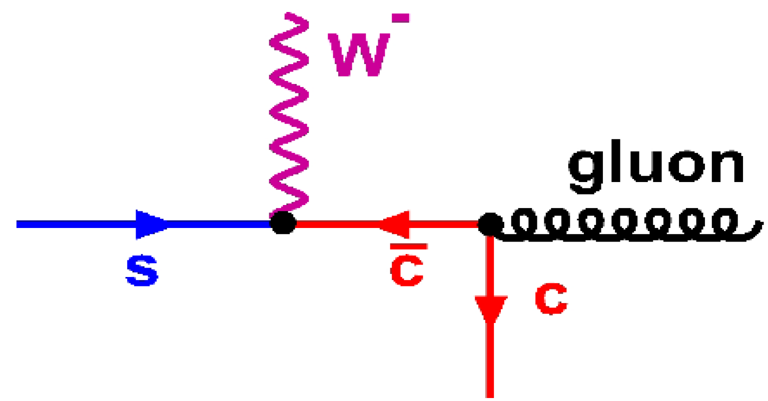


Good Agreement between data and NLO pQCD predictions (BLACKHAT and MCFM)

Theorists are investigating the discrepancy between calculations

W + c





$R_c^{\pm} = \sigma(W^+c) / \sigma(W^-c)$
$R_c = \sigma(W + c) / \sigma(W + j)$

Cutajar for CMS

$$R_c^{\pm} = 0.92 \pm 0.19\,(stat.) \pm 0.04\,(syst.)$$

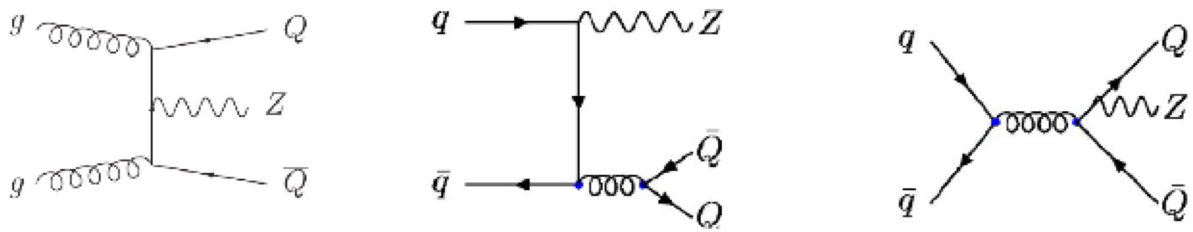
$$R_c = 0.143 \pm 0.015\,(stat.) \pm 0.024\,(syst.)$$

Ratio	MCFM (CT10)	MCFM (MSTW08)	MCFM (NNPDF21)
$R_c^{\pm}$	$0.915^{+0.006}_{-0.006}$	$0.881^{+0.022}_{-0.032}$	0.902 ± 0.008
R_c	$0.125^{+0.013}_{-0.007}$	$0.118^{+0.002}_{-0.002}$	0.103 ± 0.005

The prediction go somewhat lower than the data

LHC Z + b

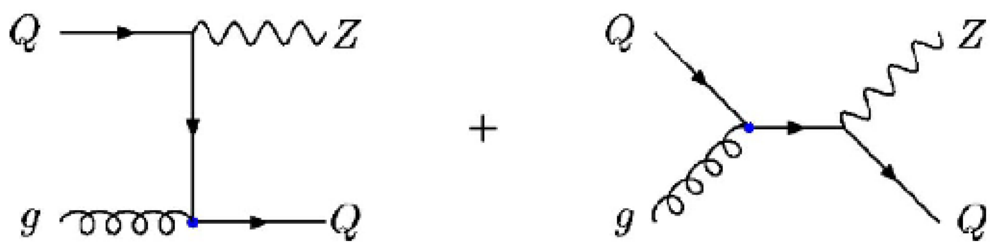
- Fixed flavour scheme: u, d, s, c quarks only in the hard scattering process.



Fixed flavour:
$q\bar{q}/gg \to Z + Q\bar{Q}$,
q = u, d, s, c
Q = b, c

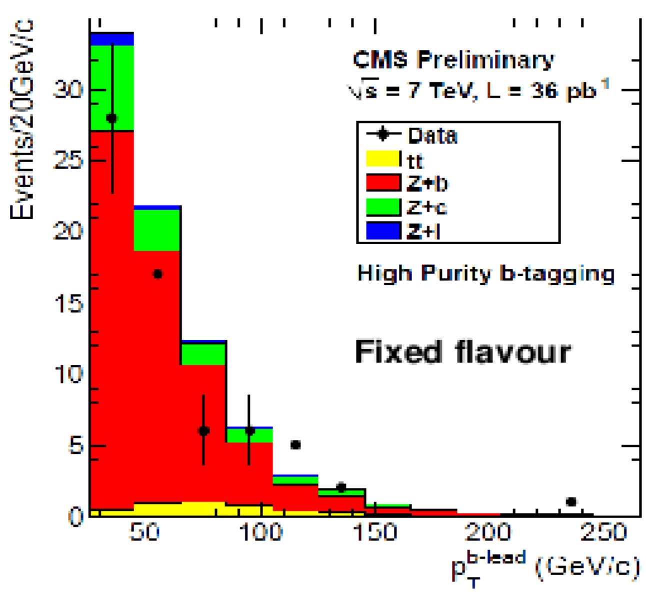
gg channel dominant at LHC!

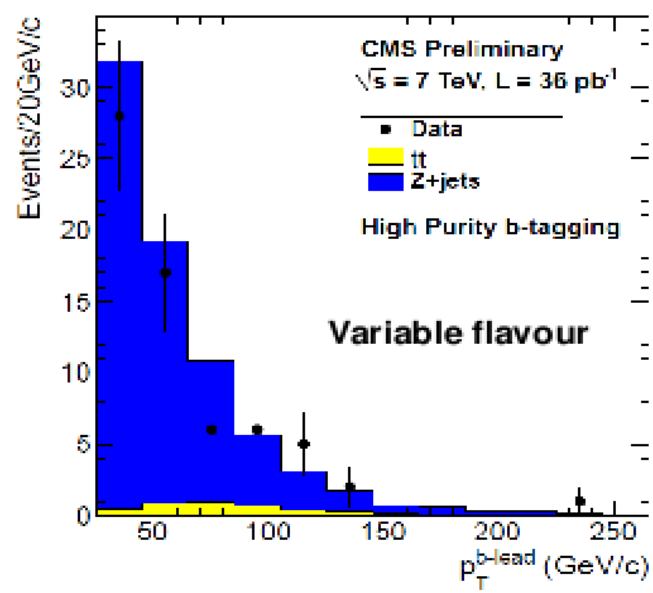
- Variable flavour scheme: b quarks participate directly in hard scattering (gluon splitting integrated into PDF).



Variable flavour:
$g + Q \to Z + Q$,
Q = b, c

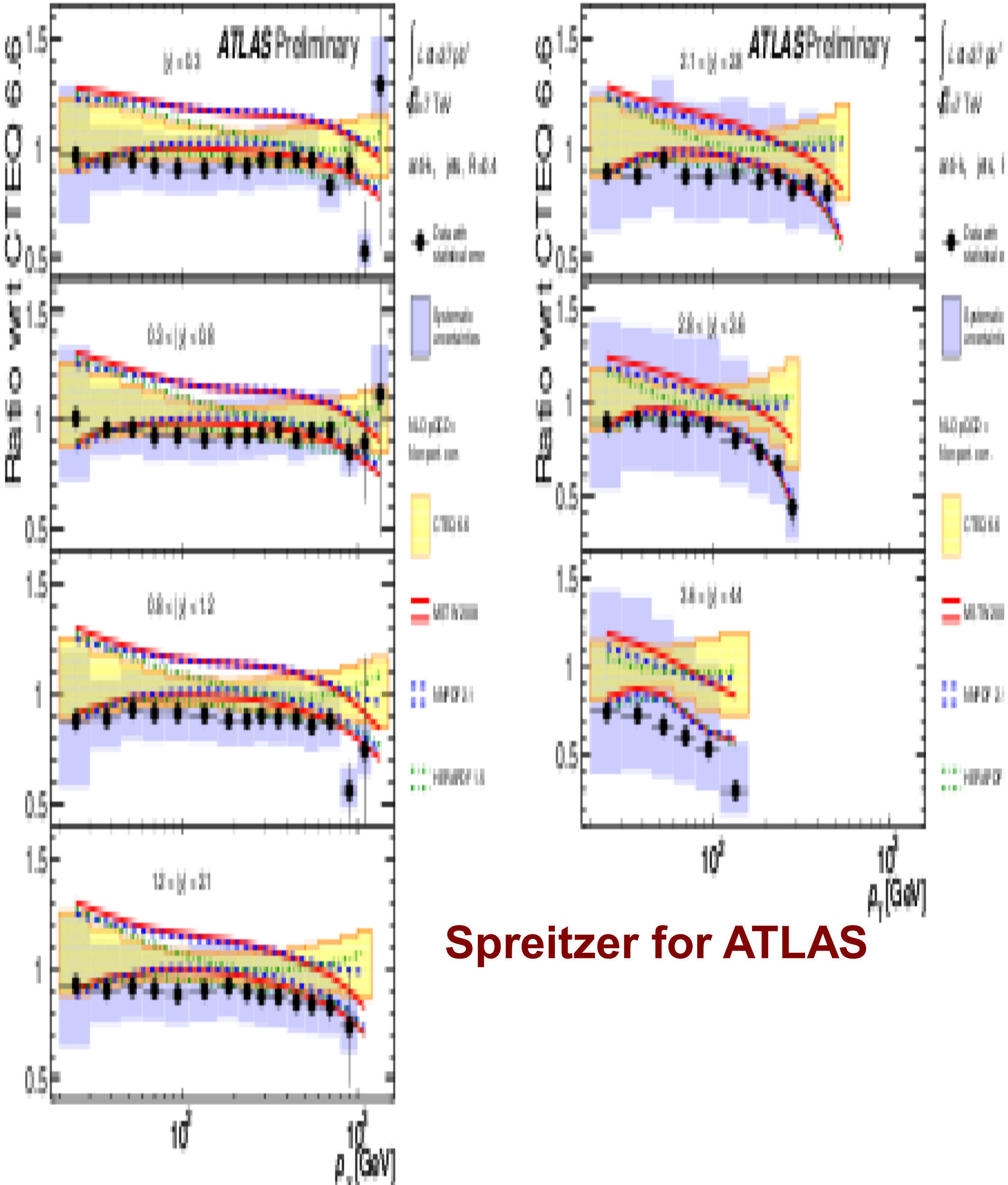
Cutajar for CMS



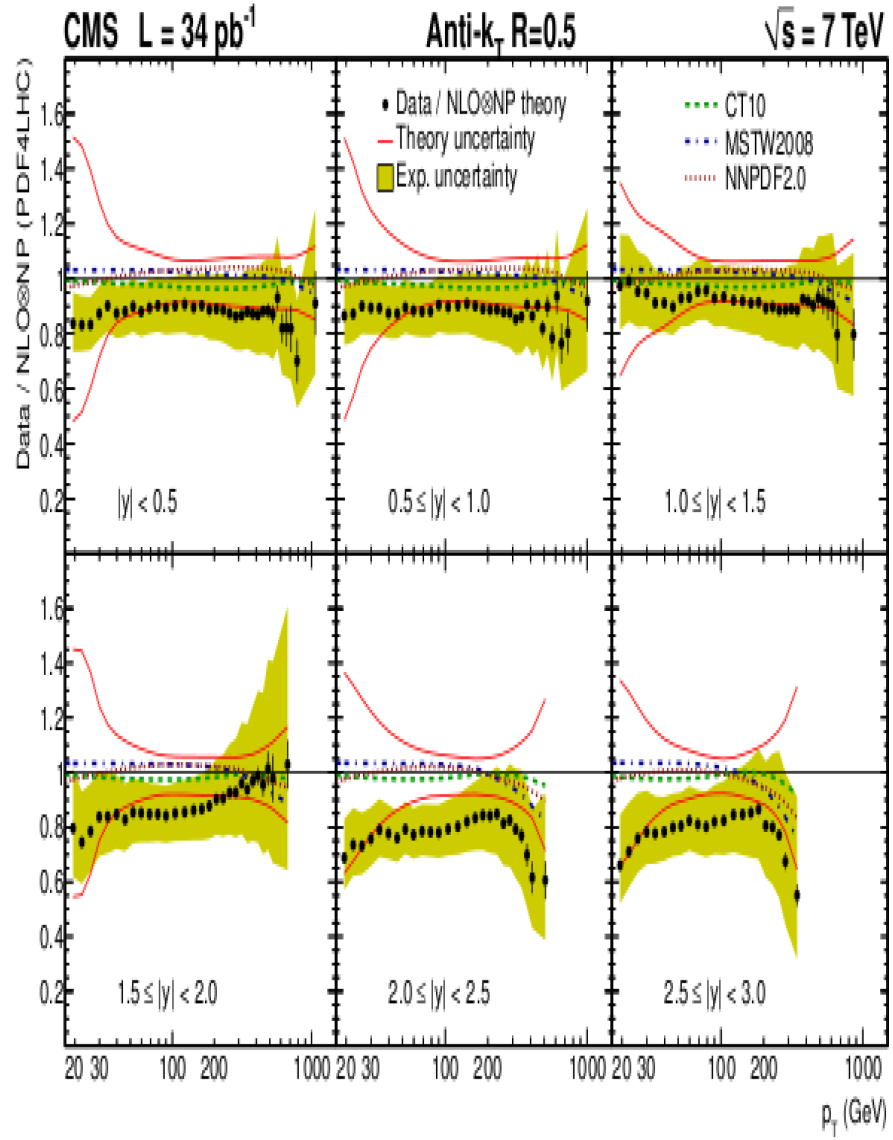


Bigger statistics is necessary to resolve the scheme dependence

LHC jets



Spreitzer for ATLAS

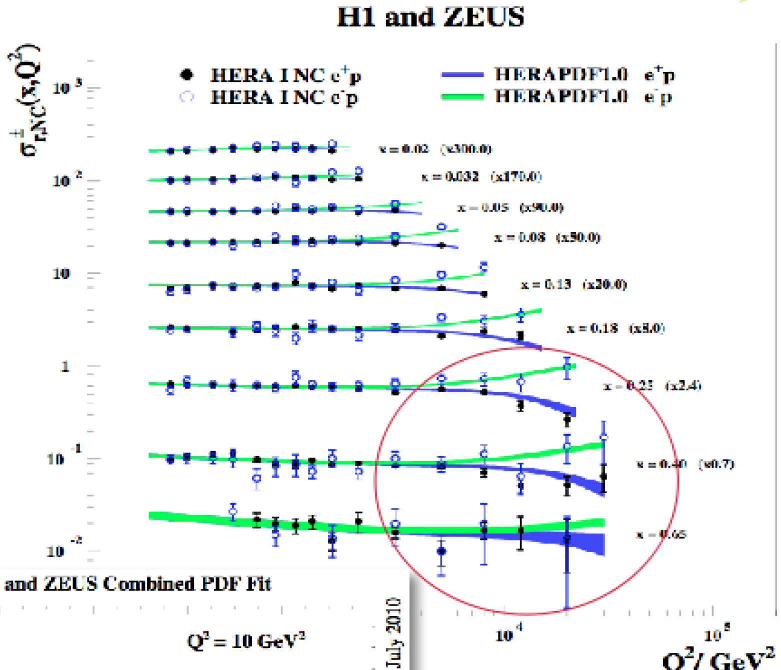


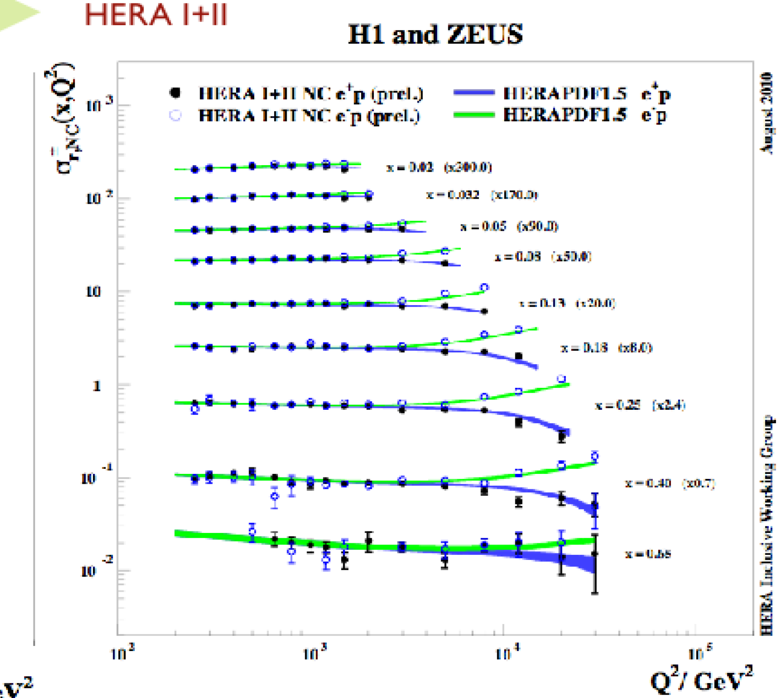
Lenzi for CMS

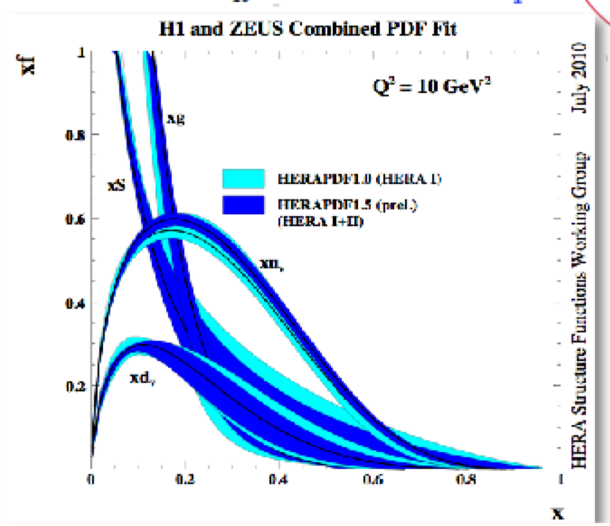
The PDFs tuned to the Tevatron data somewhat undershoot the LHC data → retuning is necessary

NLO PDFs: HERAPDF1.0 ⇒ HERAPDF1.5

- HERAPDF1.0 at NLO based on HERA I data [JHEP 1001-109]
  - HERA I → HERA I+II





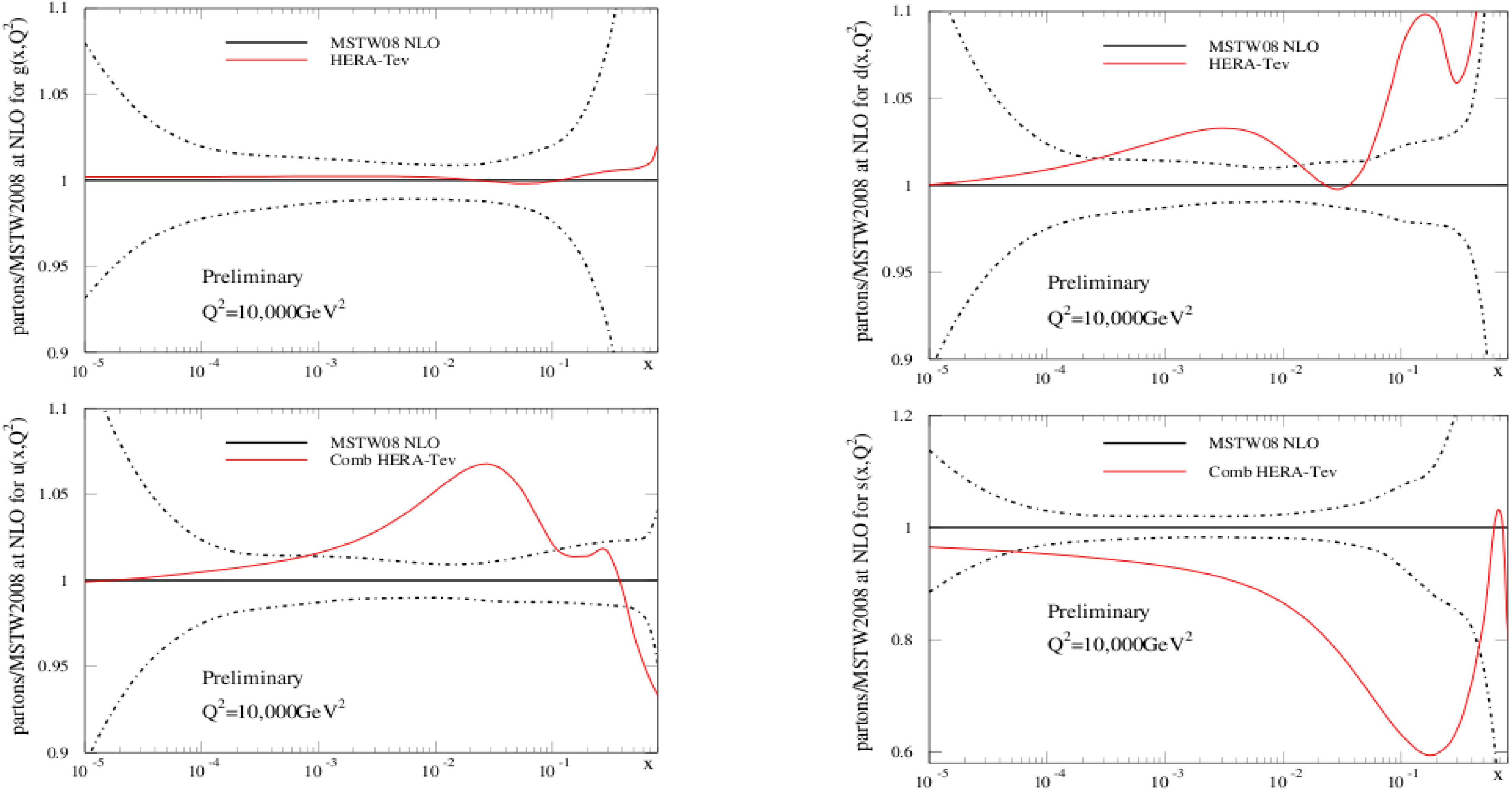


- Larger HERA II luminosity yields in significant improvement in precision at high x, Q^2 reflected in PDFs
  - Valence PDFs more accurate for HERAPDF1.5
  - HERAPDF1.5 has a softer Sea
- Addition of more precise data permits use of more flexible parametrisations and making less assumptions:
  - Allow more flexibility for gluon
  - Free low-x-d-valence from u-valence

Radescu for HERAPDF WG

PDFs from collider data only

Thorne for MSTW

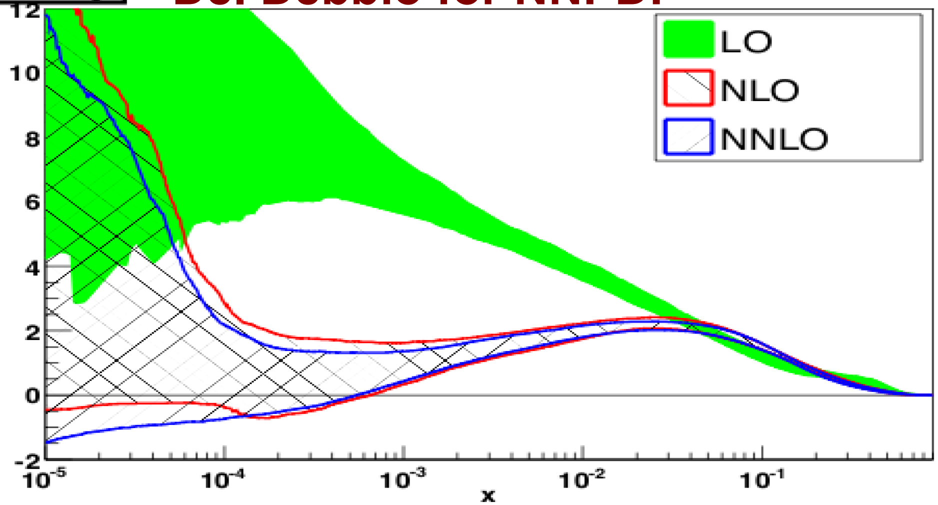


Fits to only collider data require some constraints to stop extreme central behaviour and variation in some PDFs. Uncertainties much bigger, though changes small for gluon. Total cross-sections fairly stable to change in fit, particularly ay the LHC, perhaps because dominated by evolution driven by gluon, but even ratios fairly similar to default. More change at Tevatron.

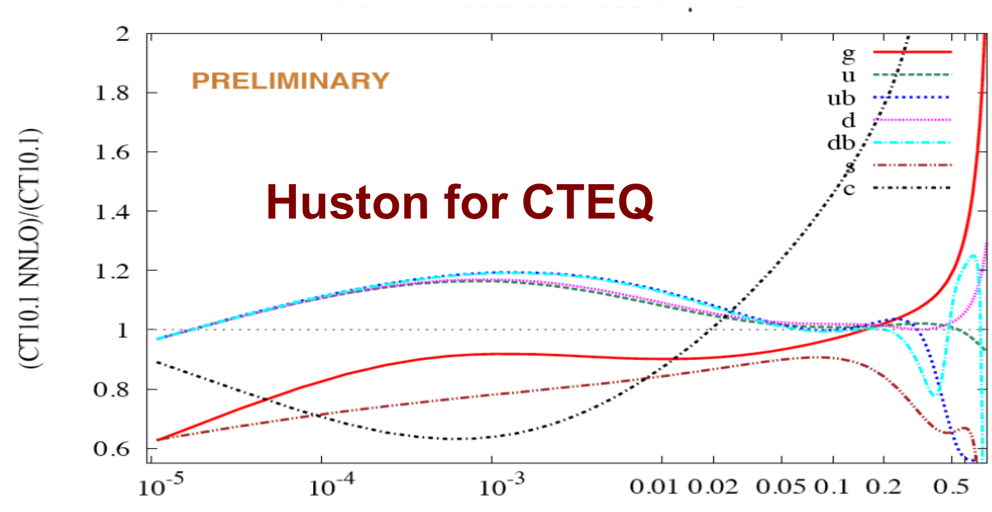
Theory

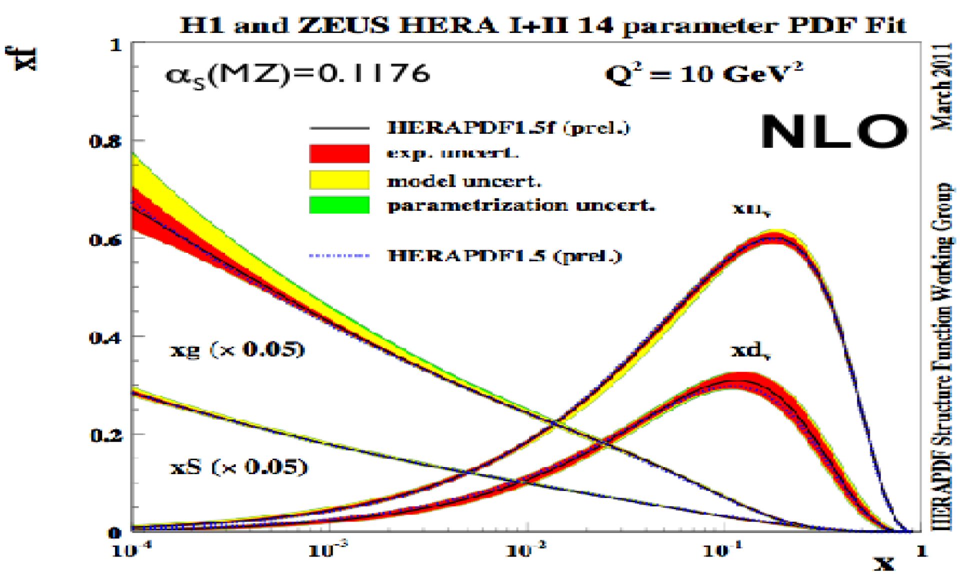
NNLO

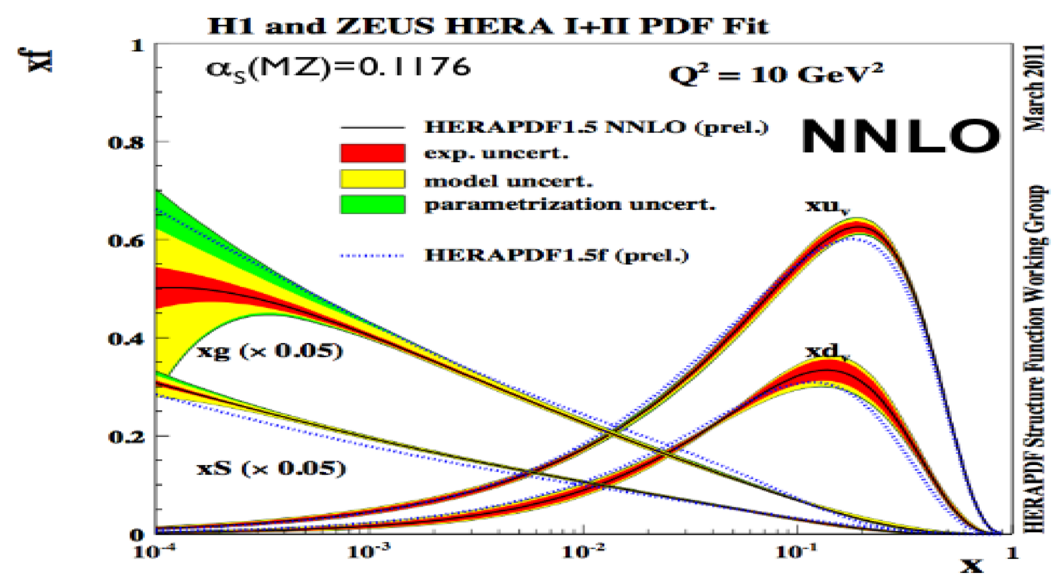
Del Debbio for NNPDF



NNLO to NLO comparison





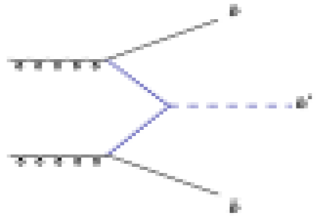
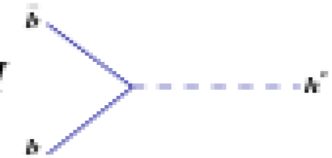


- No much difference for valence PDFs
- Sea is a little steeper
- Gluon more valence like:

Radescu for HERAPDF WG

- *NNLO gluons are positive at small x*
- *NNPDF are more stable wrt NNLO correction than others*

Theory heavy quarks in DIS

FFNS: $gg \to b\bar{b}H$  VFNS: $b\bar{b} \to H$ 

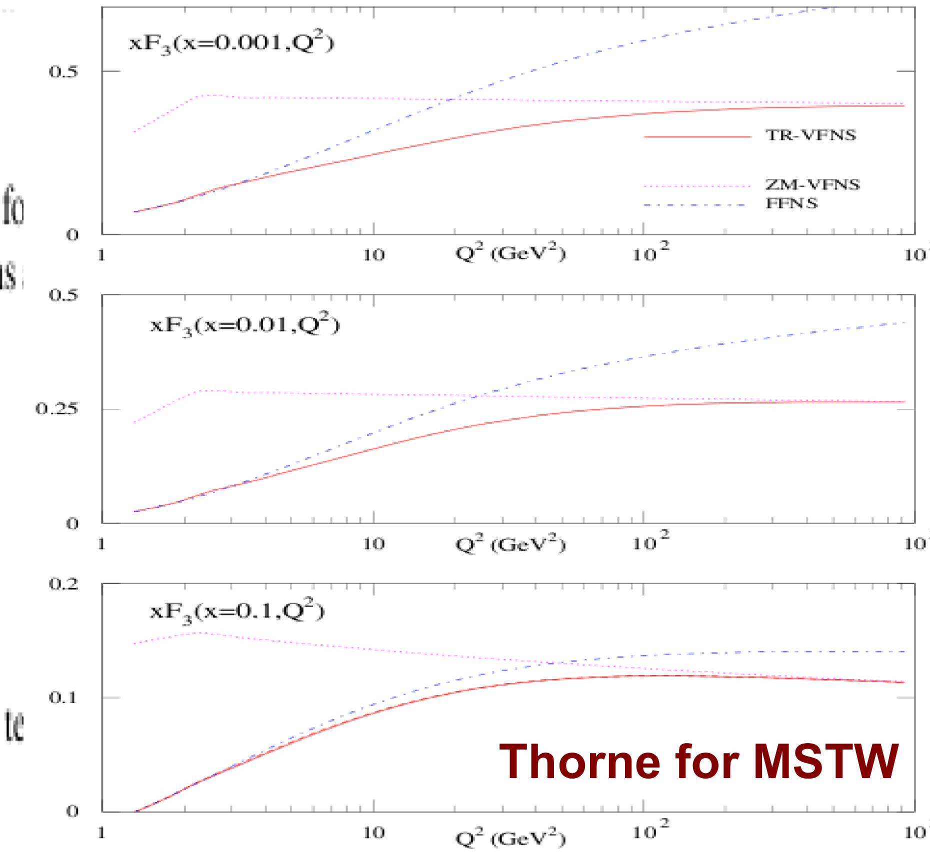
There are many implementations ...

ACOT: Original idea [Aivazis, Collins, Olness, Tung 94] with a simple LO "subtraction term" fo
F_2; later modifications [Kretzer, Tung et al.] extend it to NLO and included simplifications
rescaling variables → S-ACOT(χ) (talk by P. Nadolsky)

BMSN [Buza, Matiounine, Smith, van Neerven 98]: Generalization of original ACOT,
$F^{\mathrm{mod}} = F^{\mathrm{FF,asymp}}$ (see also CSN [Chuvakin, Smith, van Neerven 00])

RT: originally [Roberts, Thorne 98] emphasis on matching F_2 and its first derivative at
transition points; later simplified and extended to NNLO [Thorne 06]; uses a "frozen" te
beyond $Q^2 = m^2$ (talk by R. Thorne)

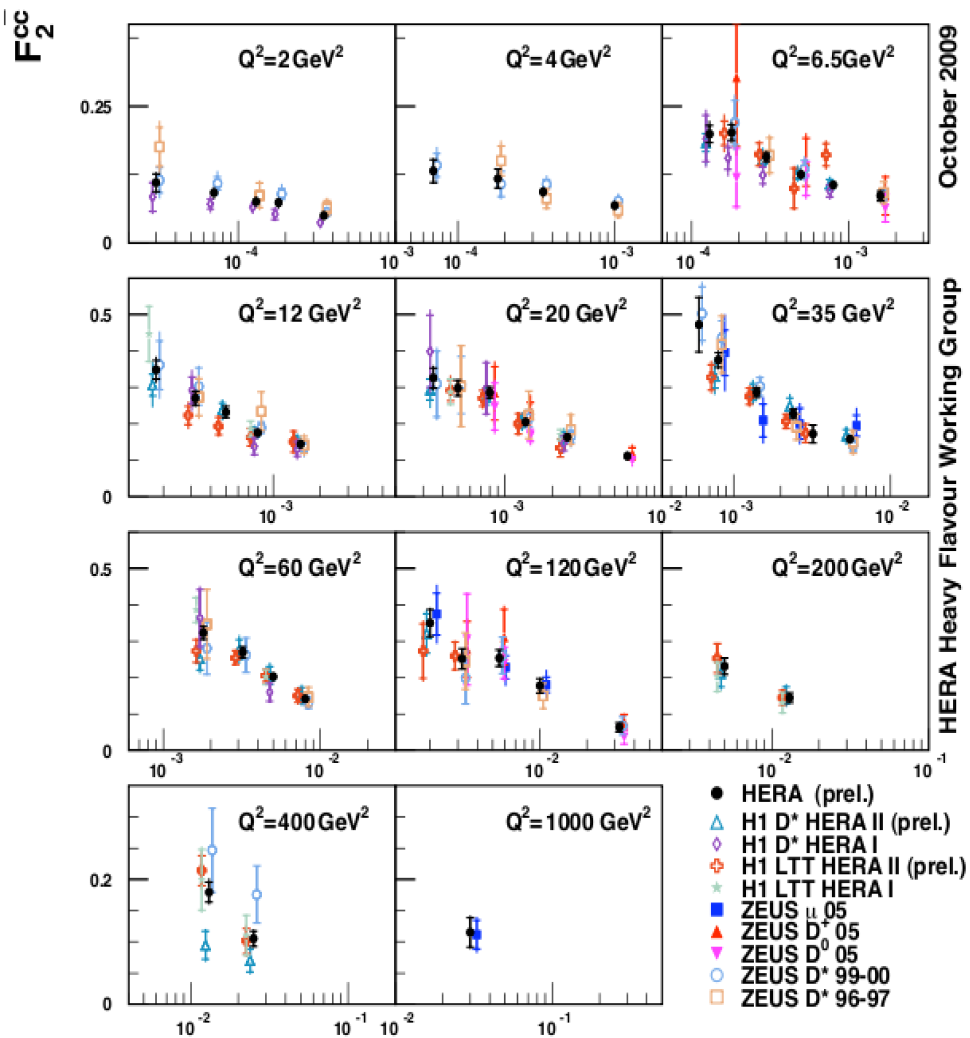
Jimenes-Delgado

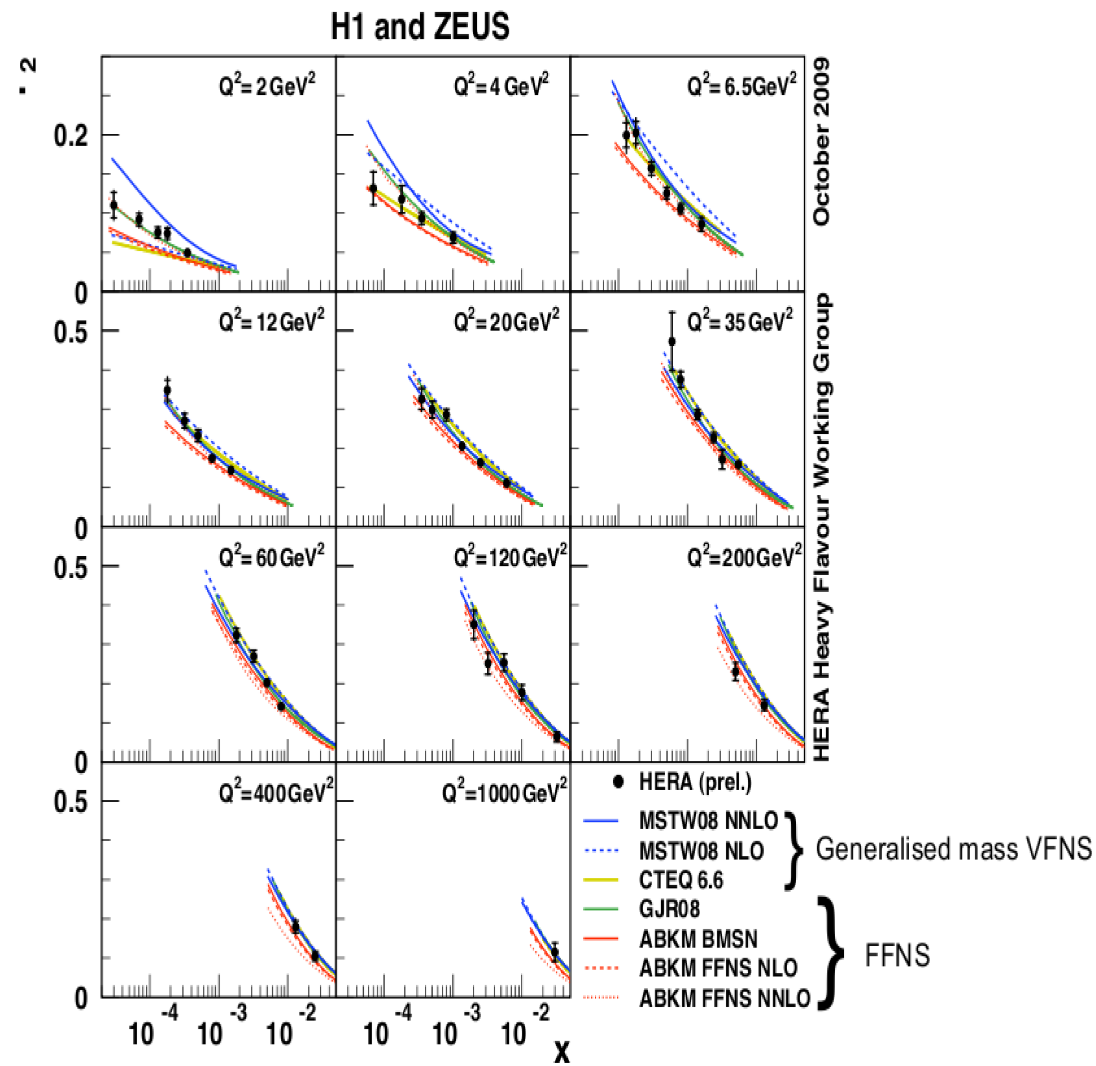


VFNS modeling must preserve Msbar factorization → PDF universality

The VFNS scheme is necessary in places

HERA F_2^{cc}





- In general, FFNS scheme describes data well and better than VFNS does

Wing for H1 and ZEUS

Further improvement with the running-mass definition for Wilson coefficients; the same for the charged current

ABM

Theory NNLO massive OMEs

- Generalized structure of renormalized OMEs:

$$A_{ij}^{(3)}\left(\frac{m^2}{Q^2}\right) = a_{ij}^{(3),3}\ln^3\left(\frac{m^2}{Q^2}\right) + a_{ij}^{(3),2}\ln^2\left(\frac{m^2}{Q^2}\right) + a_{ij}^{(3),1}\ln\left(\frac{m^2}{Q^2}\right) + a_{ij}^{(3),0}$$

  - We computed the $O\left(\alpha_s^3 N_F T_F^2 C_{A,F}\right)$ contributions to all the OMEs A_{ij} which contribute to the nucleonic structure function $F_2(x,Q^2)$ and transversity for general values of the Mellin variable N.
  - All logarithmic contributions $O(\alpha_s^3 \ln^k(Q^2/m^2))$, $k=1,2,3$ have been calculated.

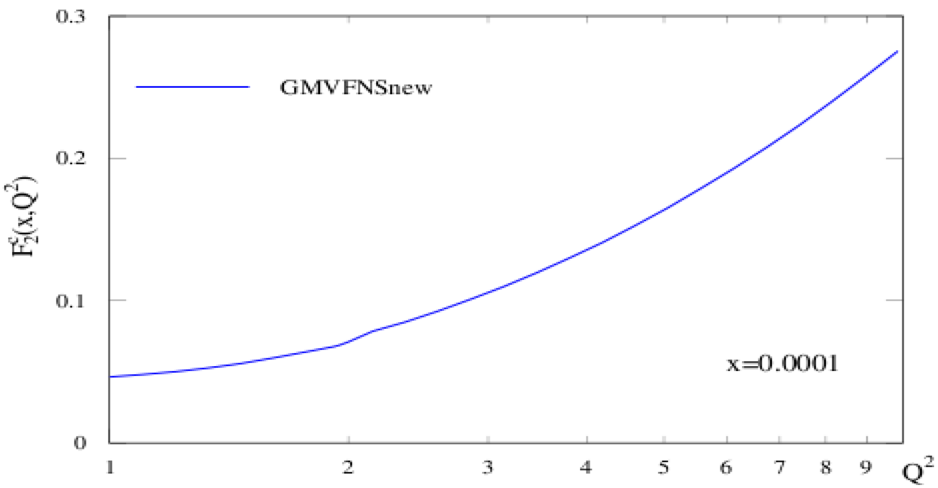
Blümlein

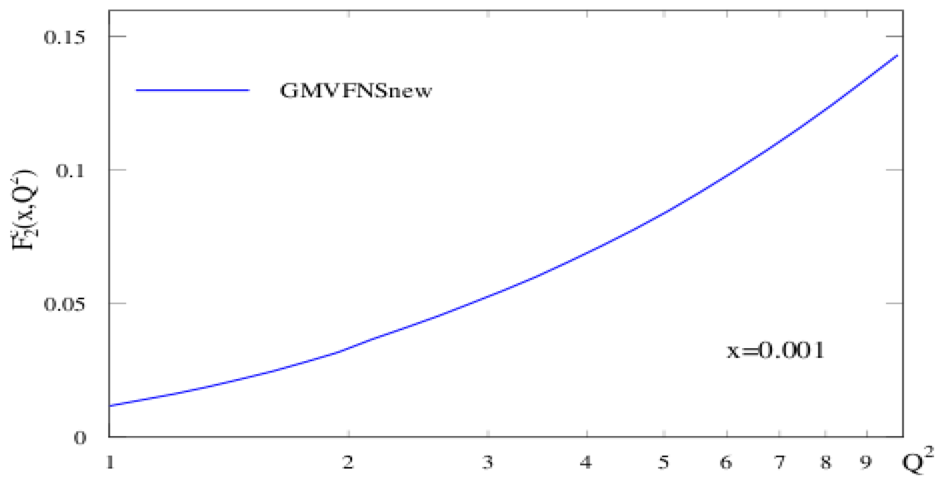
$$\begin{aligned}
a_{Qg}^{(3),0} = \; & N_F T_F^2 C_A \Bigg\{ \frac{16(N^2+N+2)}{27N(N+1)(N+2)}\Big[108 S_{-2,1,1} - 78 S_{2,1,1} - 90 S_{-3,1} + 72 S_{2,-2} - 6 S_{3,1} \\
& -108 S_{-2,1}S_1 + 42 S_{2,1}S_1 - 6S_{-4} + 90 S_{-3}S_1 + 118 S_3 S_1 + 120 S_4 + 18 S_{-2}S_2 + 54 S_{-2}S_1^2 \\
& +33 S_2 S_1^2 + 15 S_2^2 + 2 S_1^4 + 18 S_{-2}\zeta_2 + 9 S_2\zeta_2 + 9 S_1^2\zeta_2 - 42 S_1\zeta_3\Big] \\
& +32\frac{5N^4+14N^3+53N^2+82N+20}{27N(N+1)^2(N+2)^2}\left[6S_{-2,1} - 5S_{-3} - 6S_{-2}S_1\right] \\
& -\frac{64(5N^4+11N^3+50N^2+85N+20)}{27N(N+1)^2(N+2)^2}S_{2,1} - \frac{16(40N^4+151N^3+544N^2+779N+214)}{27N(N+1)^2(N+2)^2}S_2 S_1 \\
& -\frac{32(65N^6+429N^5+1155N^4+725N^3+370N^2+496N+648)}{81(N-1)N^2(N+1)^2(N+2)^2}S_3 \\
& -\frac{16(20N^4+107N^3+344N^2+439N+134)}{81N(N+1)^2(N+2)^2}S_1^3 + \frac{Q_1(N)}{81(N-1)N^3(N+1)^3(N+2)^3}S_2
\end{aligned}$$

Improvement in F_2^{c} at large scales

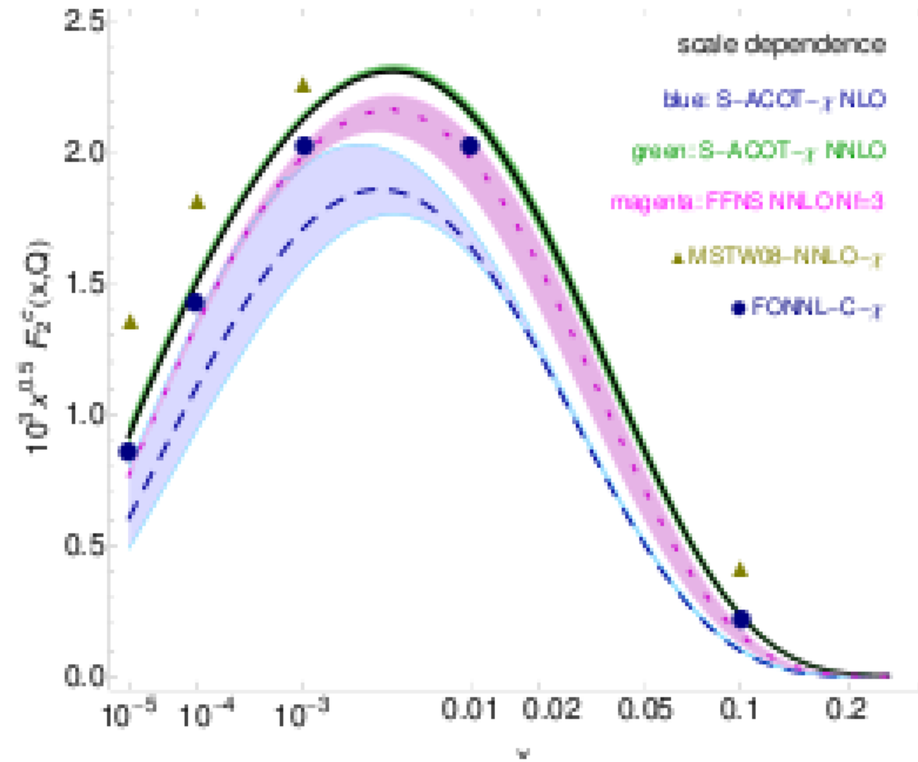
More accurate heavy-quark PDFs

Theory VFNS





Improved threshold calculations (Lo Presti *et al*), not available at time of MSTW2008. Will use in future. Rather similar effect to above. Extremely little change in fit, but slightly smoother $F_2^h(x,Q^2)$. **Thorne for MSTW**



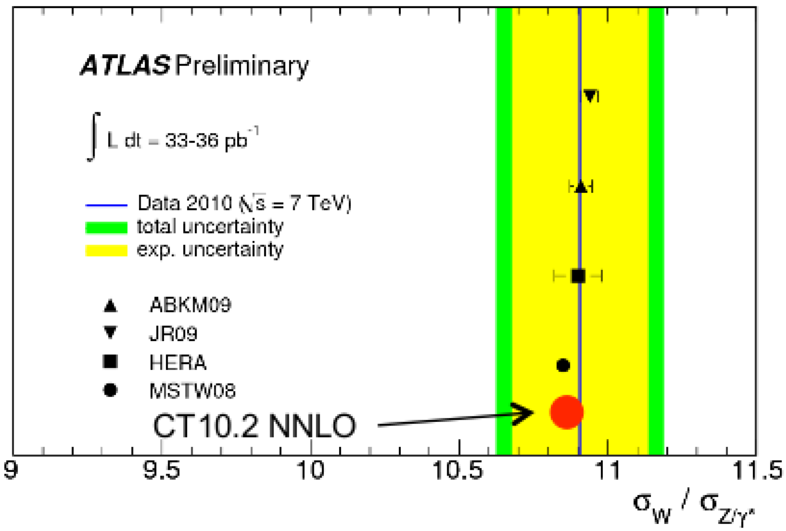
At NNLO and $Q \approx m_c$:

S-ACOT-χ ($N_f = 4$) ≈ FFN ($N_f = 3$) **without tuning**

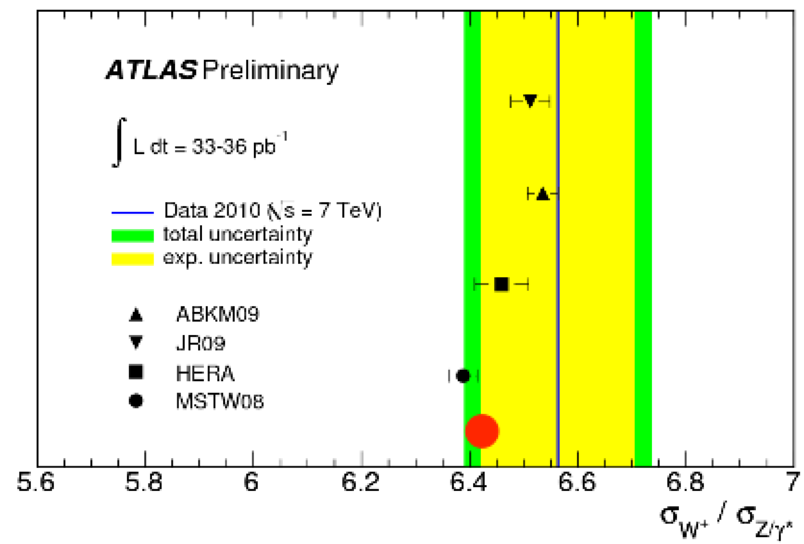
- S-ACOT is numerically close to other NNLO schemes

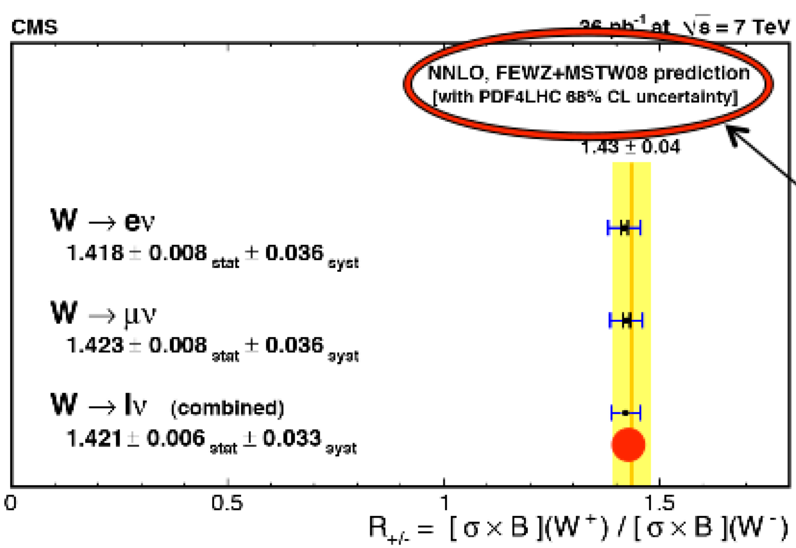
Nadolsky for CTEQ

Standard candles W/Z

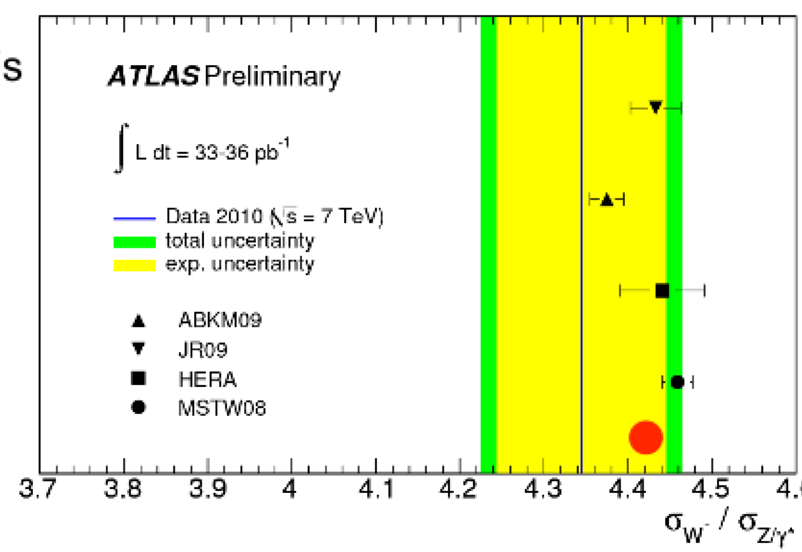


Total W/Z ratio from ATLAS in good agreement with theory, but separate W^+/Z and W^-/Z ratios show some differences (at 1 sigma level) for some of PDFs





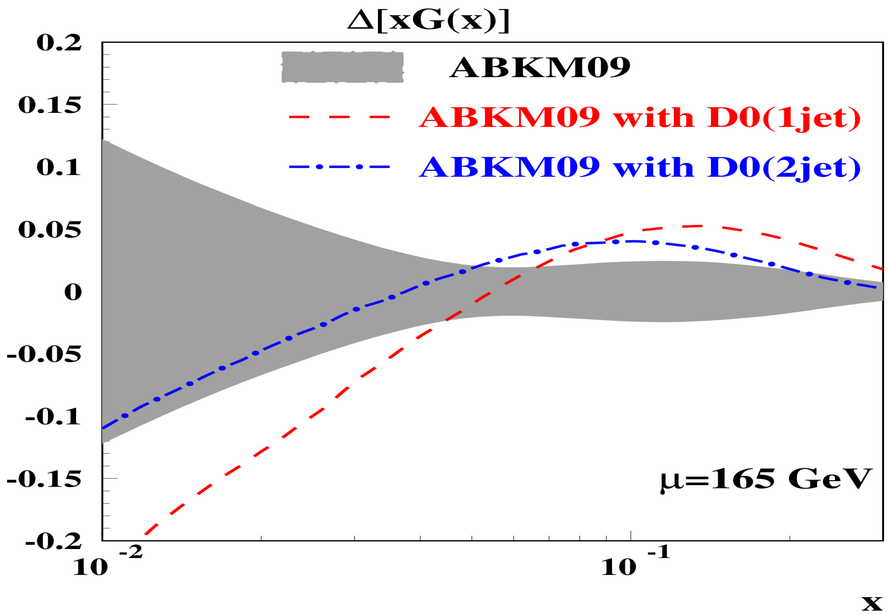
CMS results for W,Z use PDF4LHC recipe for NNLO; good agreement with theory

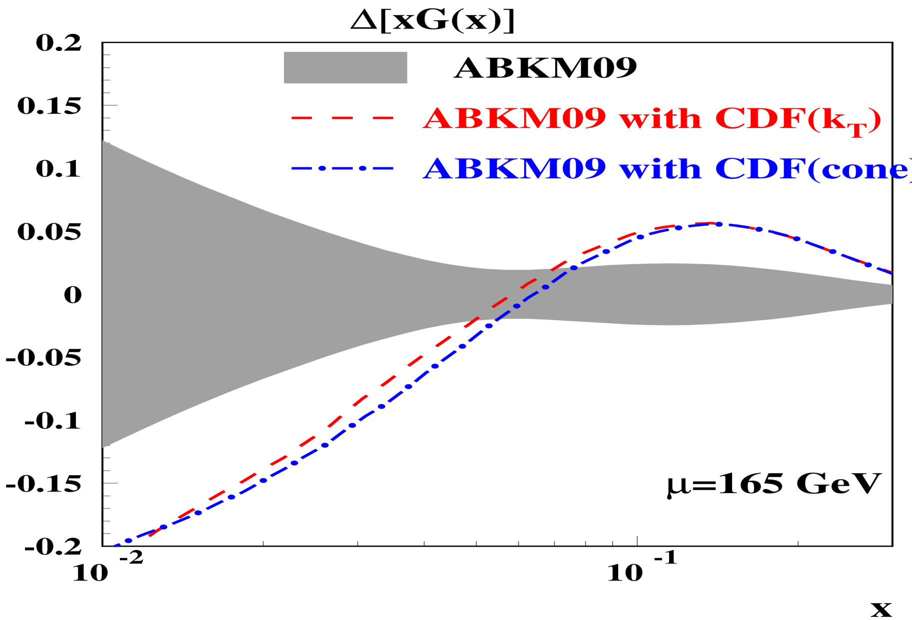


Huston for CTEQ

The NNLO rates updated

Standard candles Higgs



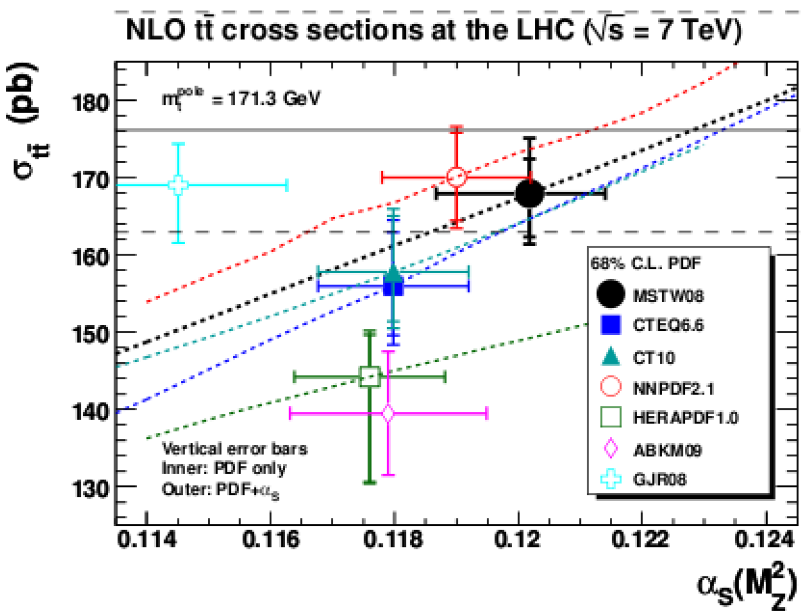


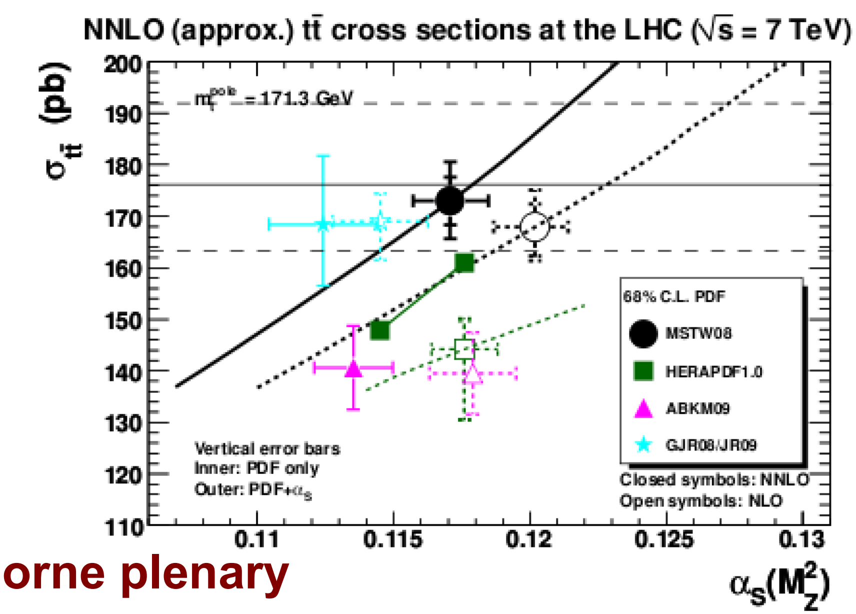
	$\alpha_s(M_Z)$(NNLO)	$\sigma(M_H$=165 GeV) (pb) Tevatron	LHC7
ABKM:	0.1135(14)	0.253(22)	7.05(23)
+ D0(1jet):	0.1149(12)	0.297(12)	7.30(15)
+ D0(2jet):	0.1145(9)	0.281(12)	7.28(14)
+ CDF/k_T	0.1143(9)	0.292(10)	7.18(14)
+ CDF/cone	0.1134(9)	0.283(10)	7.02(14)

ABM

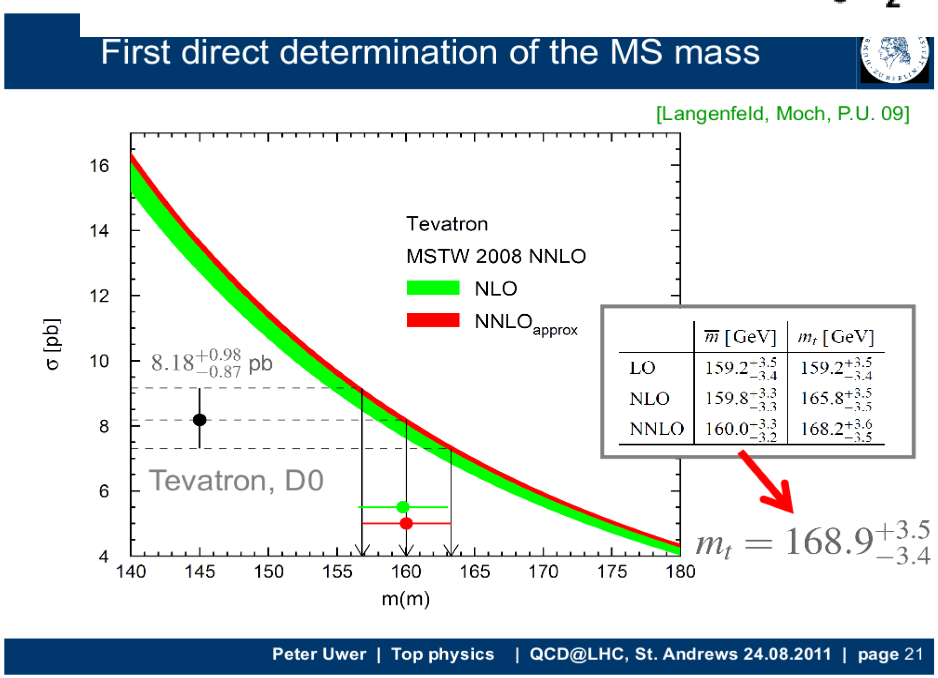
- The Tevatron jet data pull the Higgs up by 1-2σ, depending on the data set; the effect must reduce with the NNLO correction to the jet production taken into account
- For the ATLAS and CMS data effect must be even smaller (cf. Page LHC/jets)

Standard candles ttbar





Thorne plenary



Uwer

Cross sections [pb]:

[Alekhin,Blümlein, Klein, Moch 10]

$m_t = 173 GeV$

$\sqrt{s}$ (TeV)	ABKM09	MSTW2008
1.96 ($p\bar{p}$)	6.91 ± 0.17	7.04
7 (pp)	131.3 ± 7.5	160.5
10 (pp)	343 ± 15	403
14 (pp)	780 ± 28	887

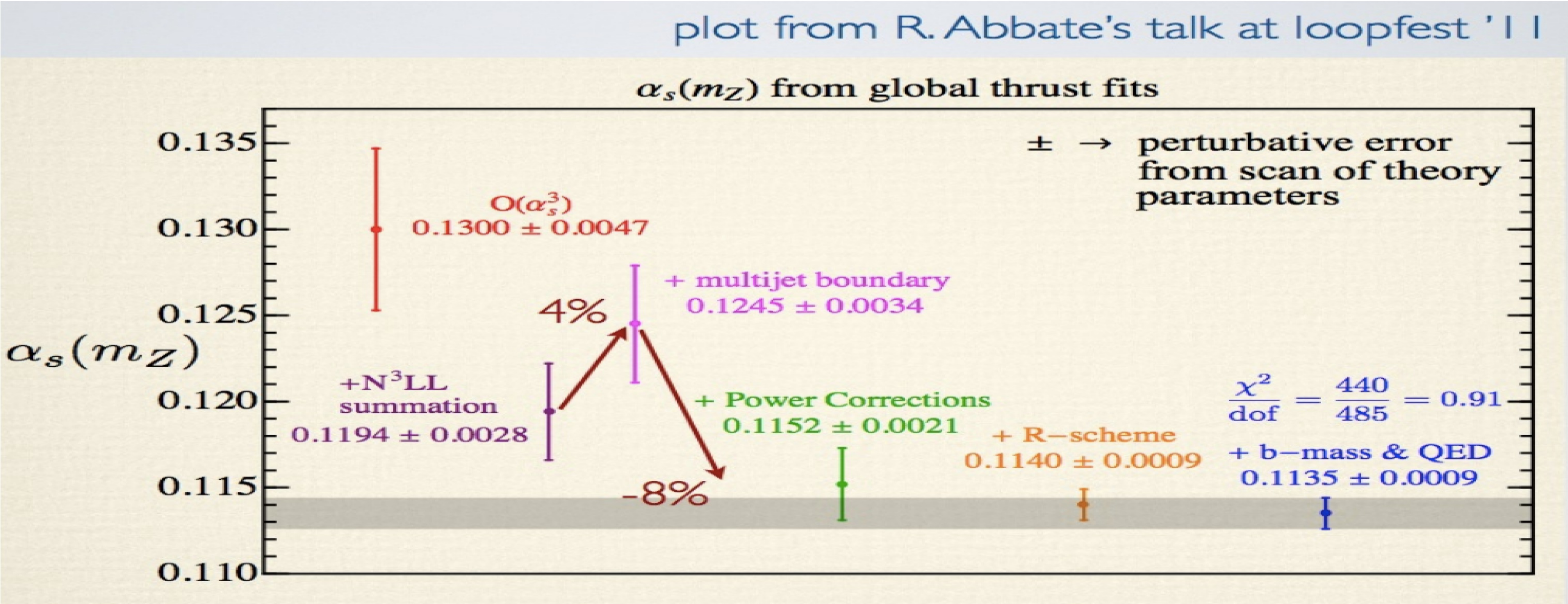
~2-3 % pdf

m_t defined from the Tevatron c.s. Is quite low → bigger c.s. at the LHC

α_s

	$\alpha_s(M_Z^2)$	
BBG (2006)	$0.1134 \, {}^{+0.0019}_{-0.0021}$	valence analysis, NNLO
ABKM	0.1135 ± 0.0014	HQ: FFS $N_f = 3$
ABKM	0.1129 ± 0.0014	HQ: BSMN-approach
JR (2008)	0.1124 ± 0.0020	dynamical approach
MSTW (2008)	0.1171 ± 0.0014	
HERAPDF (2010)	0.1145	(combined H1/ZEUS data, prelimiary)
ABM (2010)	0.1147 ± 0.0012	(FFN, combined H1/ZEUS data in)
ABM (2011)	0.1132 ± 0.0011	(FFN, + running mass, + CC)
A.Hoang et al.	$0.1135 \pm 0.0011 \pm 0.0006$	e^+e^- thrust
BBG (2006)	$0.1141 \, {}^{+0.0020}_{-0.0022}$	valence analysis, N^{3}LO
WA (2009)	0.1184 ± 0.0007	

Blümlein



Becher

α_s goes down with accurate account of the hadronization effects

α_s Results (NLO)

	$\alpha_s(M_Z)$	χ^2_{par}/N_{dof}
NNPDF2.1	$0.1191 \pm 0.0006^{exp} \pm 0.0001^{proc}$	1.6
NNPDF2.1 DIS-only	$0.1178 \pm 0.0009^{exp} \pm 0.0002^{proc}$	0.8
NNPDF2.1 HERA-only	$0.1101 \pm 0.0033^{exp} \pm 0.0003^{proc}$	1.1
NNPDF2.0	$0.1168 \pm 0.0007^{exp} \pm 0.0001^{proc}$	0.4
NNPDF2.0 DIS-only	$0.1145 \pm 0.0010^{exp} \pm 0.0003^{proc}$	1.4.

Ball for NNPDF

	$\alpha_s(M_Z)$	χ^2_{par}/N_{dof}
NNPDF2.1 NNLO	$0.1174 + 0.0006^{exp} + 0.0001^{proc}$	0.6
NNPDF2.1 NNLO DIS-only	$0.1164 \pm 0.0009^{exp} \pm 0.0002^{proc}$	1.1

Small difference between NLO and NNLO (the same for gluons, cf. Page Theory/NNLO)

$$\alpha_s = 0.1202 \pm 0.0013(\exp) \pm 0.0007(mod) \pm 0.0012(had)^{+0.0045}_{-0.0036}(th)$$

Radescu for HERAPDF WG

Defined by the jet data

- NLO: $\alpha_s(M_Z) = 0.11964 \pm 0.0064$ at 90% c.l.
- NNLO: $\alpha_s(M_Z) = 0.118 \pm 0.005$

Huston for CTEQ

Summary

The LHC data already give some constraints on the PDFs: quark distributions at x~0.1

More in nearest future:large-x gluons must get lower

Inclusive and semi-inclusive SFs from HERA Run II: better separation of the gluon and sea distributions

FFN scheme works pretty well in the DIS → improved accuracy of the low-x PDFs

More NNLO PDFs appeared → better benchmarking of standard candles