Determination of Strange Quark Distribution Using Recent CMS Measurements on $W^\pm$ Production

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on behalf of the CMS collaboration

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→ Introduction

→ CMS $W^\pm$ production data

→ W muon asymmetry and W+charm data

→ Impact of $W^\pm$ production data on the PDFs

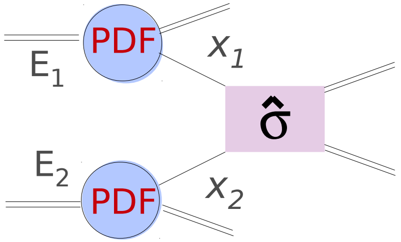
→ Summary

Precise knowledge of the PDFs are essential for predictions at the LHC

PDFs: one of main theory uncertainties in Higgs production, M_W measurement, etc.

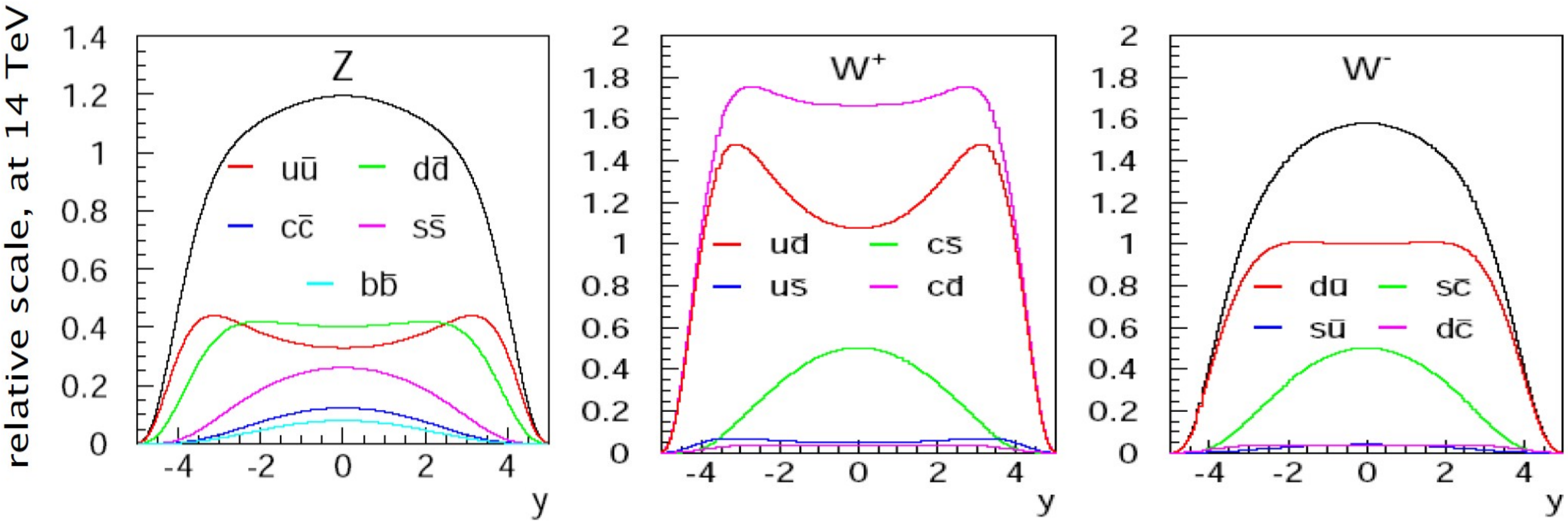
Z and W production at LHC

→ probe different flavour combinations
→ potential to improve quark PDFs



QCD factorisation:

$$\sigma \approx \hat{\sigma} \otimes \text{PDF}$$

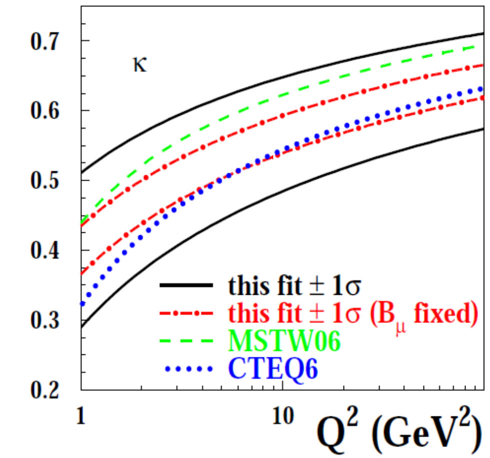


→ u and d quarks dominate for W, all flavours contribute to Z

Strange quark density determination

Strange quark density in the proton is still poorly known

Phys. Lett. B 675, 433 (2009)



→ mainly constrains come from fixed target data (NuTeV, HERMES, NOMAD)

Nucl.Phys. B876(2013) 339

NOMAD measurement

K_s (20 GeV^2)= 0.59 ± 0.019

$$\kappa_s(Q^2) = \frac{\int_0^1 x\left[\bar{s}(x,Q^2)+s(x,Q^2)\right]dx}{\int_0^1 x\left[\bar{u}(x,Q^2)+\bar{d}(x,Q^2)\right]dx}$$

→ LHC Z,W and W+charm data sensitive to strange quark density

The differential ATLAS W$^\pm$, Z data used to measure strange quark density

→ data suggest that light quark sea at low x is flavor symmetric

Phys.Rev.Lett.109(2012)012001

$$r_s = 0.5(s+\bar{s})/\bar{d} = 1.00 \pm 0.20_{\rm exp} \pm 0.07_{\rm mod}{}^{+0.10}_{-0.15}{}_{\rm par}{}^{+0.06}_{-0.07}{}_{\alpha_S} \pm 0.08_{\rm th}$$

at Q_0^2 and $x = 0.023$

(starting scale)

→ same results confirmed by the ATLAS W+charm data (obtained from the χ^2 minimisation procedure)

arXiv:1402:6263

$$r_s = 0.96{}^{+0.16}_{-0.18}{}^{+0.21}_{-0.24} \quad \text{at } Q^2 = 1.9\ \text{GeV}^2$$

see G. Aad's talk

CMS W lepton charge asymmetry

W lepton asymmetry

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

→ overall excess of W^+ over W^- due to presents of two valence *u* quarks in the proton

→ probe valence quarks and PDFs rations (u_v, d_v, d/u, d_v/u_v, dbar/ubar):

CMS W muon asymmetry measurement

→ better resolution for MET using Hadronic Recoil: $u = -MET - \Sigma p_\eta^T$

→ DY sample for normalisation correction

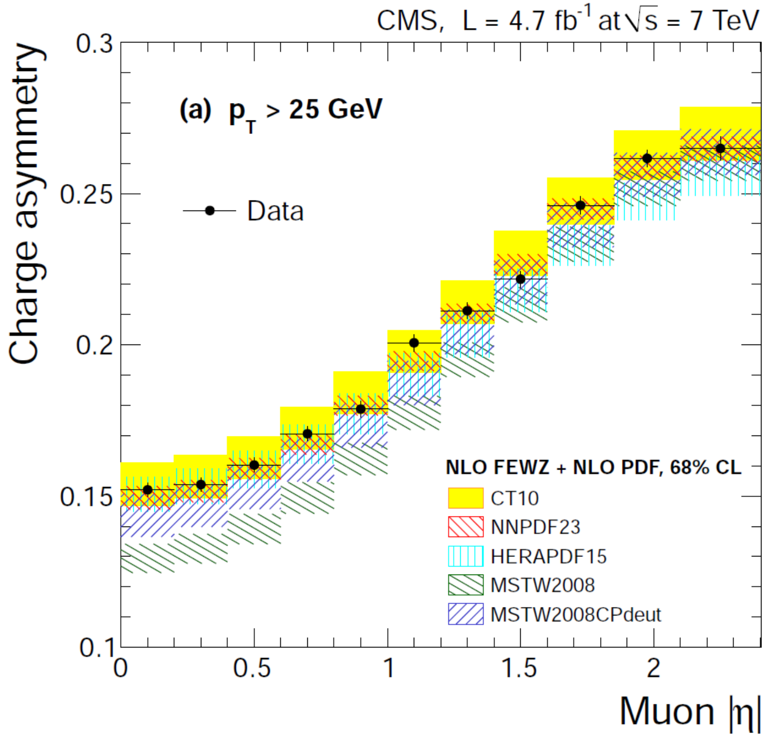
→ binned maximum likelihood fits of MET are used to extract signal (template method)

Muon charge asymmetry:

→ P_l^T>25 and 35 GeV

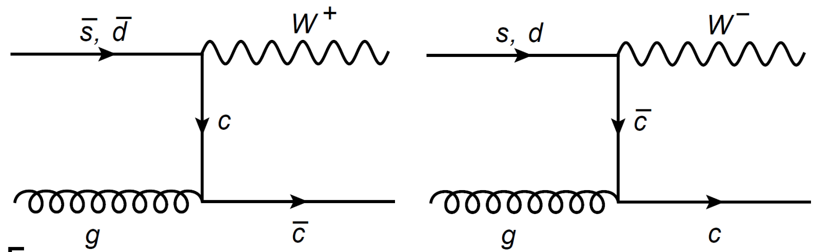
see A. Khukhunaishvili's talk

arXiv:1312:6283



W+charm measurement at CMS

W+charm data → direct sensitivity to the strange quark



Identification:

→ W decays to charged leptons (e or μ) and neutrino

→ c: charm-quark jets with p^T_{jet}>25GeV, $|\eta_{jet}|$<2.5

jets identified: secondary vertex $D^+ \to K^-\pi^+\pi^+$ $(D^- \to K^+\pi^-\pi^-)$

$D^{*+}(2010) \to D^0\pi^+$ $(D^{*-}(2010) \to \bar{D}^0\pi^-)$

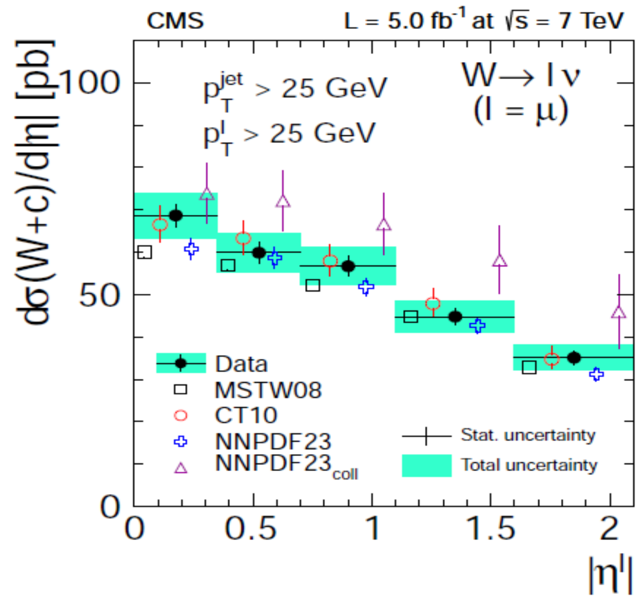
$D^0 \to K^-\pi^+$ $(\bar{D}^0 \to K^+\pi^-)$

semileptonic decay with well identified muon

arXiv:1310:1138

Background subtraction:

perform by subtracting the Same Sign (SS) from the Opposite Sign (OS) distributions



Total and differential cross sections

p_l^T > 25 GeV (W→μν)

p_l^T > 35 GeV (W→μν, W→eν)

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

QCD analysis of CMS W production data

Motivation:

→ study the impact of the W production data on valence-quark distributions

→ test of joined sensitivity of lepton charge asymmetry and W+c data to the strange content of the proton

→ use minimal data input in the PDF fit (HERA I), use most precise CMS data

→ theory calculation for W+c production available to NLO QCD : PDF fit performed at NLO

→ HERAFItter framework is used for the PDF fit www.herafitter.org

→ NNPDF Bayesian reweighting used for qualitative studies of the data impact on the PDFs

QCD analysis settings

QCD analysis at NLO performed using HERAFitter www.herafitter.org

→ parton evolution in Q^2 via DGLAP equations as implemented in QCDNUM

Comp.Phys.Com.182:490,2011

Data: HERA I combined inclusive DIS data JHEP 1001:109 (2010)

→ uncertainty treatment follows HERAPDF1.0 prescription

CMS μ asymmetry data (P^T_l>25 GeV)

→ systematic correlations as covariance matrix

CMS W+charm data (P^T_l>35 GeV)

→ systematic and statistical correlations as full covariance matrix

Theory: predictions from APPLGRID files obtained with MCFM (NLO)

Starting scale $Q^2_0 = 1.9$ GeV^2

$m_c = 1.4$ GeV, $m_b = 4.75$ GeV

heavy flavour scheme: general mass variable flavour scheme RT

scale $\mu_R^2=\mu_F^2=Q^2$

strong coupling $\alpha_S = 0.1176$

→ *variation of parameters later considered in the PDF uncertainties*

Parametrisation

PDF parametrisation at the starting scale (Q^2_0=1.9 GeV^2):

"13p":

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

A: normalisation
B: small x behavior
C: x→ 1 shape

$x\bar{U}=x\bar{u}(+x\bar{c})$
$x\bar{D}=x\bar{d}+x\bar{s}(+x\bar{b})$
$x\bar{s}=f_s x\bar{D}$ with
$f_s=x\bar{s}/(x\bar{d}+x\bar{s})=0.31$

→ *variation of parametrisation (addition of parameters) later considered in the PDF uncertainties*

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$f_s=x\bar{s}/(x\bar{d}+x\bar{s})=0.31$

"15p" or "free-s":

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

~~$x\overline{D}(x) = A_{\overline{D}} x^{B_{\overline{D}}} \cdot (1-x)^{C_{\overline{D}}}.$~~ →

$$
\begin{aligned}
x\,\bar{d}(x) &= A_{\bar{d}}\, x^{B_{\bar{d}}}\, (1-x)^{C_{\bar{d}}} \\
x\,\bar{s}(x) &= A_{\bar{s}}\, x^{B_{\bar{s}}}\, (1-x)^{C_{\bar{s}}}
\end{aligned}
$$

$A_{\bar{u}} = A_{\bar{d}}\ ;\ B_{\bar{u}} = B_{\bar{d}}$

$B_{\bar{s}} = B_{\bar{d}}$ for the central fit, A_s and C_s are free parameter of the fit, assumed s = sbar

$B_{\bar{s}} \neq B_{\bar{d}}$ fit included into parametrisation uncertainty

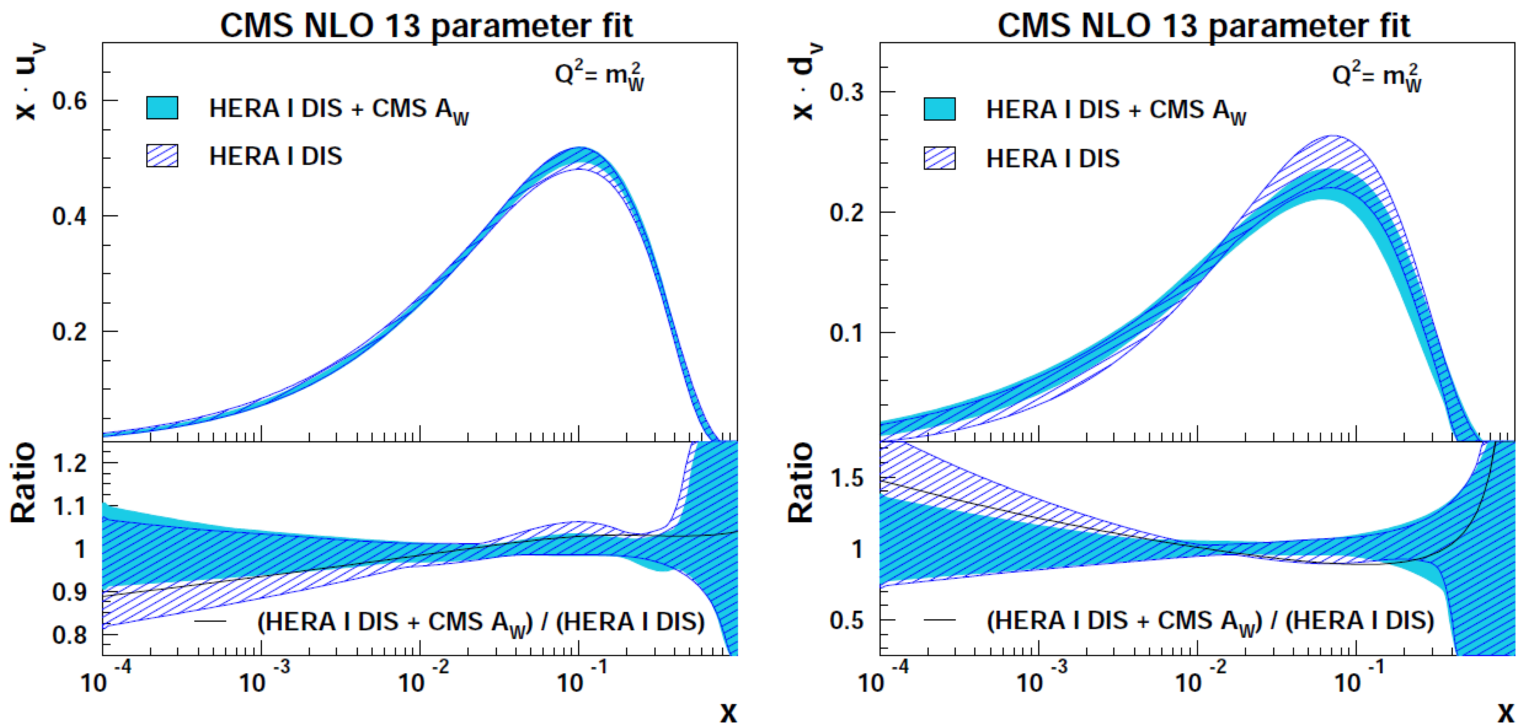
HERA data alone cannot be fitted with this parametrisation because has no sensitivity to s

→ *variation of parametrisation (addition of parameters) later considered in the PDF uncertainties*

Results: CMS W asymmetry data

QCD analysis at NLO, 13 parameter (fixed-s fit)

- HERA I combined DIS data JHEP 1001:109 (2010)
- Muon charge asymmetry in W production at 7 TeV arXiv:1312:6283

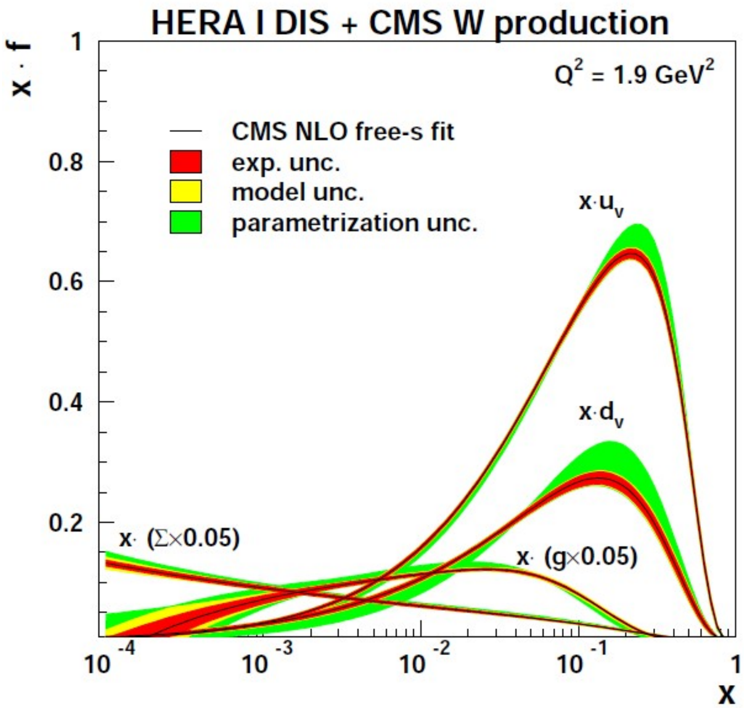


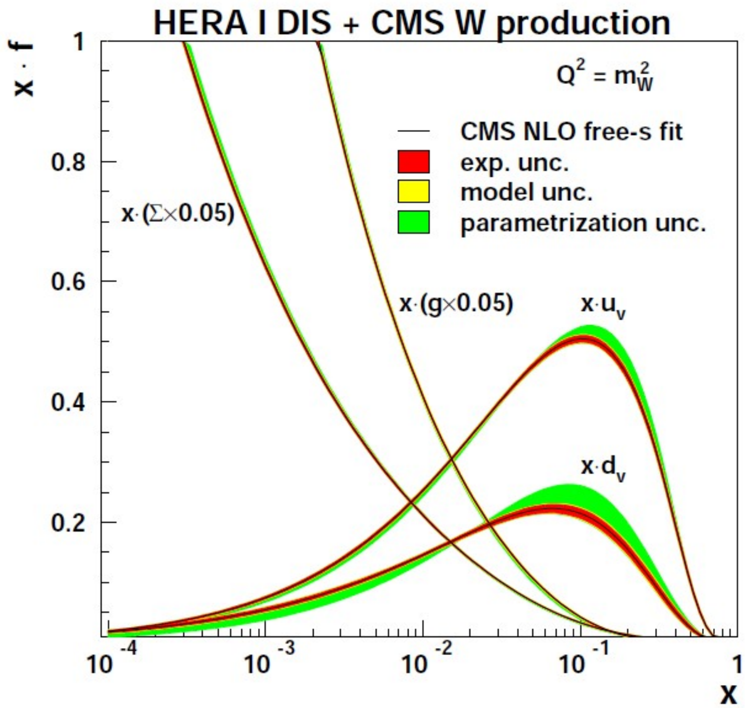
error bands represent total uncertainties, (experimental, model and parametrisation uncertainties)

Change of PDF shape, improved constraints on the valence distributions

QCD analysis at NLO, 15 parameter (free-s fit)

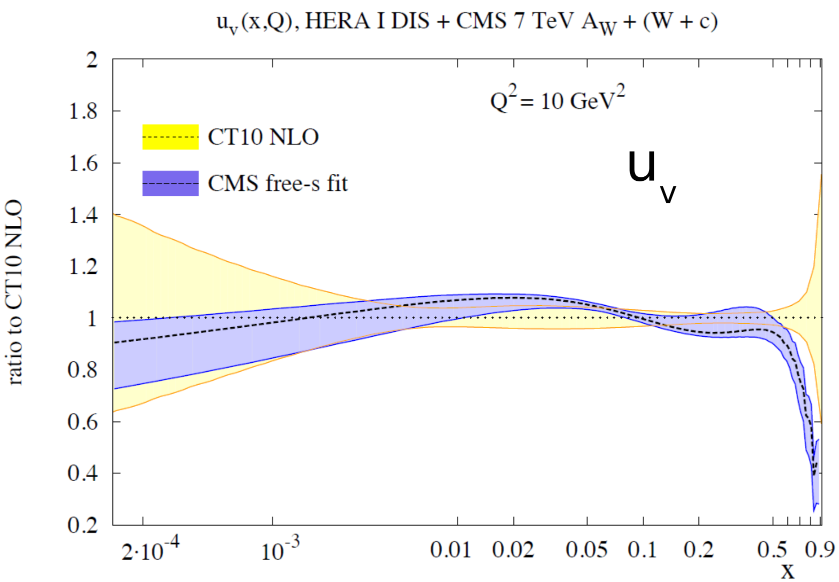
- HERA I combined DIS data JHEP 1001:109 (2010)
- Muon charge asymmetry in W production at 7 TeV arXiv:1312:6283
- Differential cross sections of associated W+c production at 7 TeV arXiv:1310:1138

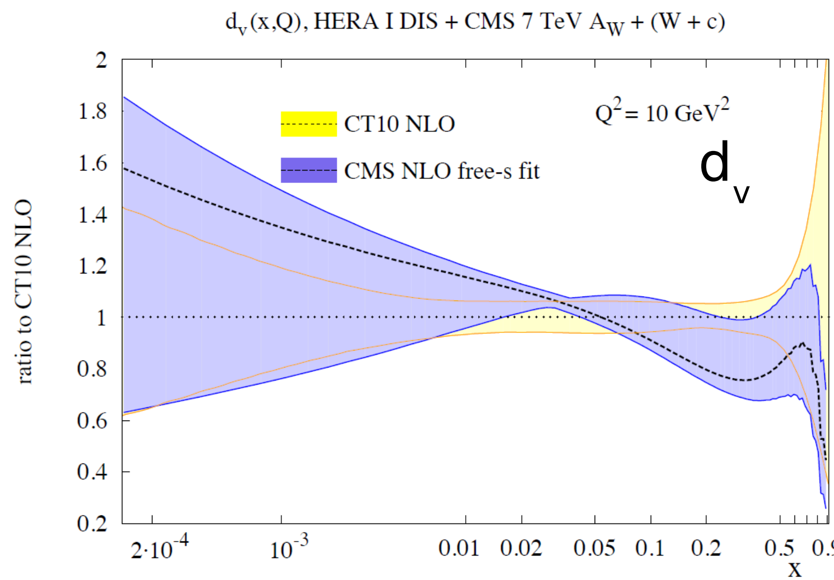


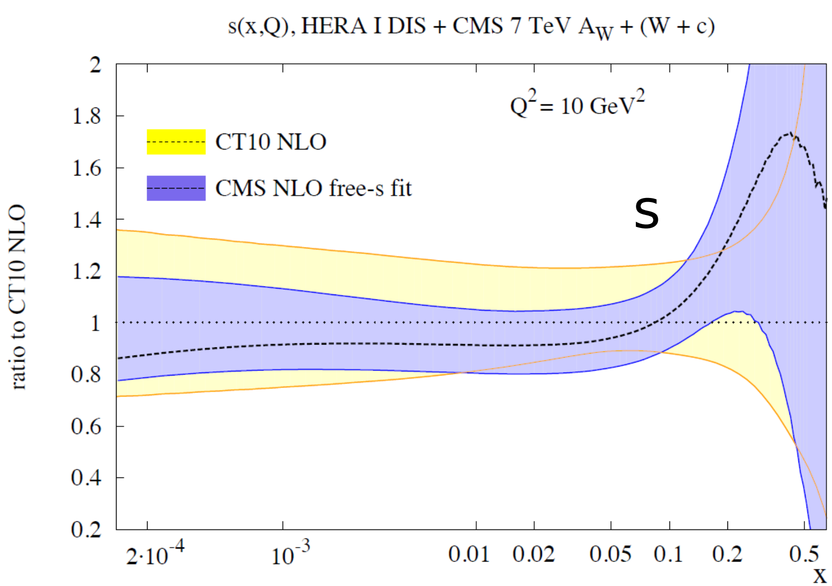


PDFs can be directly compared to NLO results by different PDF groups

Comparison to CT10 PDFs



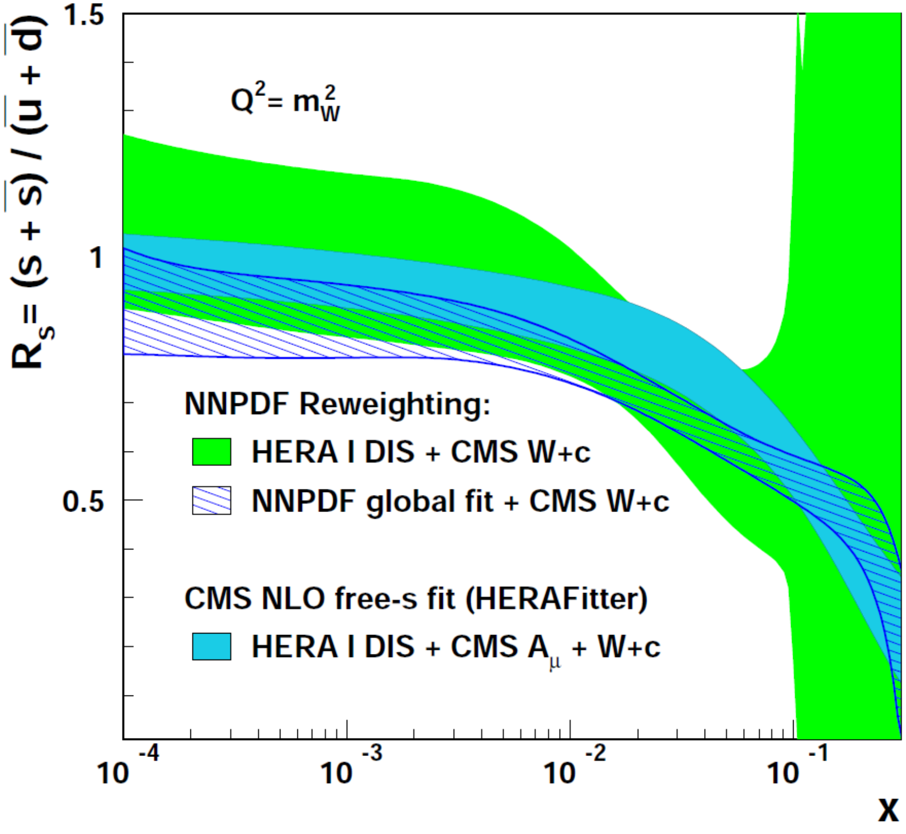




all uncertainties 68% CL

good agreement with CT10NLO
(does not include any LHC data)

Comparison to the NNPDF reweighting



NNPDF reweighting studies

Comparison with:

- HERA I only and W+c data
- global NNPDF2.3 set (includes the neutrino DIS and the ATLAS W,Z data)

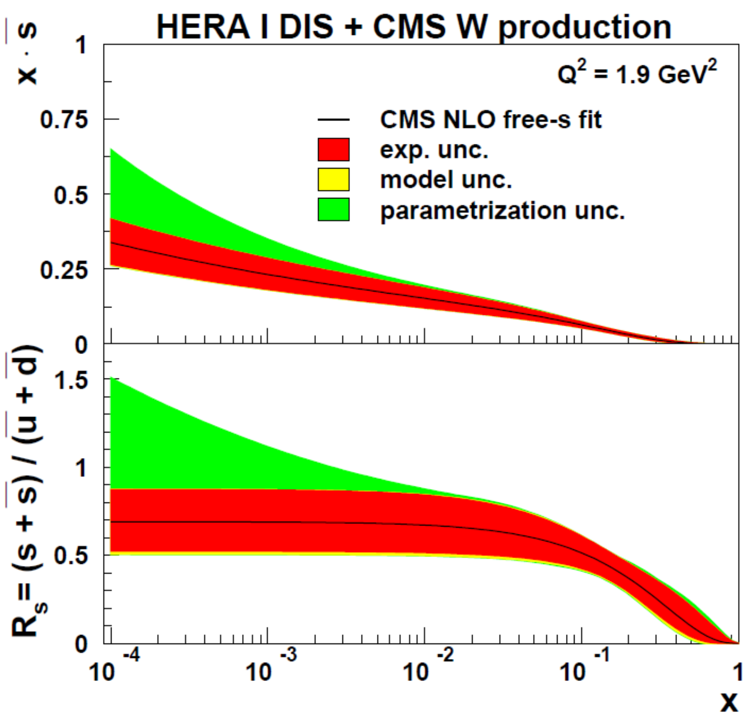
Results of full QCD analysis and NNPDF reweighting are in agreement

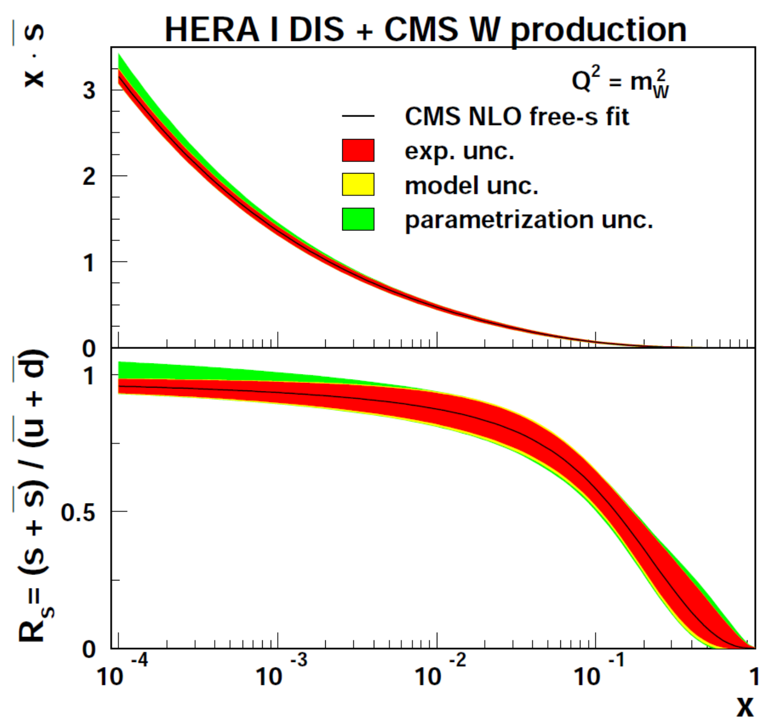
Determination of strangeness using collider only data

Results consistent to the constraints imposed by the neutrino scattering experiments

Results: s quark density

Determination of s quark density in the proton by using W production at CMS





The determined strangeness suppression K_s (20 GeV^2):

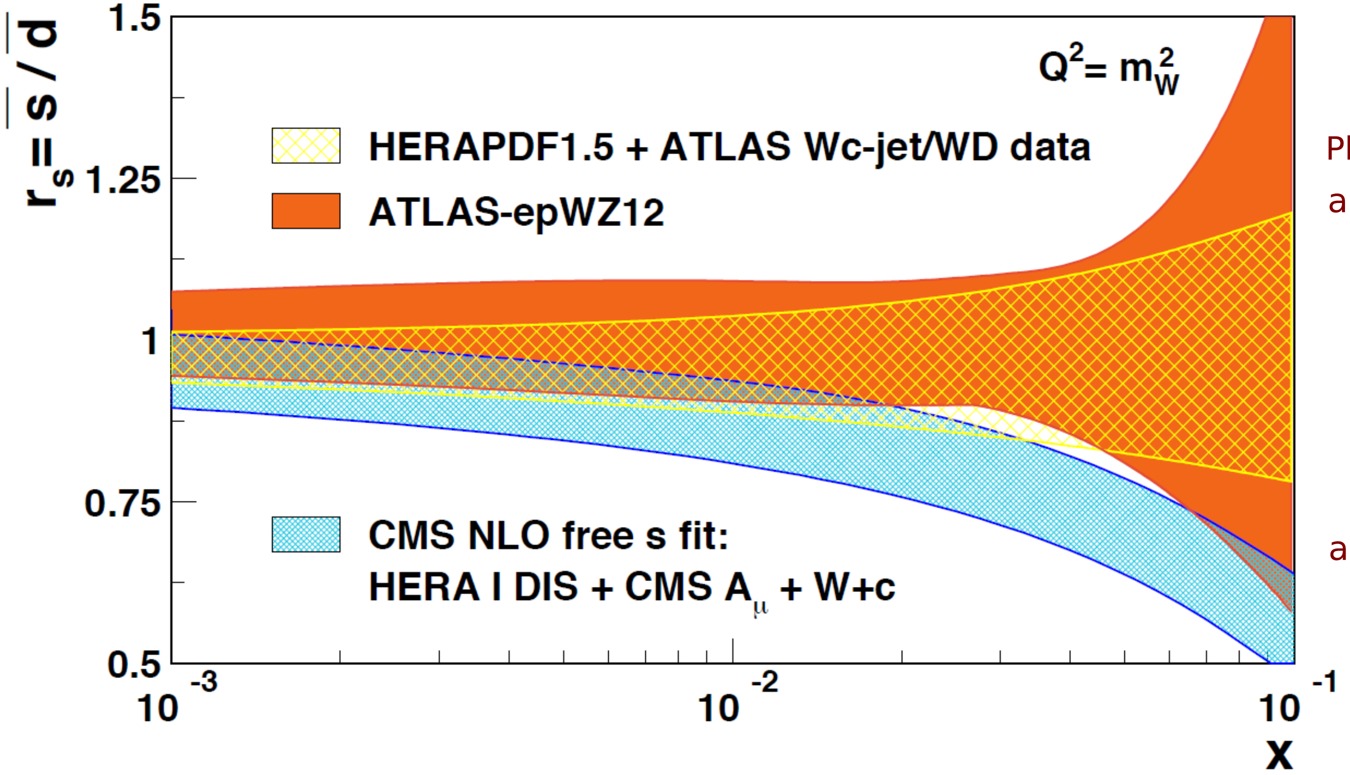
$$\kappa_s = 0.52^{+0.12}_{-0.10}\,(\text{exp.})^{+0.05}_{-0.06}\,(\text{model})^{+0.13}_{-0.10}\,(\text{parametrization})$$

NOMAD K_s (20 GeV^2)= 0.59±0.019 Nucl.Phys. B876(2013) 339

Determined strange fraction is consistent with NOMAD results

Comparison with ATLAS results

Comparison of the ratio of sbar over dbar determined by ATLAS and CMS



Phys.Rev.Lett.109(2012)012001

arXiv:1402:6263

arXiv:1312:6283

Strange fraction determined in CMS is lower than in ATLAS but results are still consistent

Summary

The QCD analysis at NLO with CMS W production data:

Precise CMS measurements of muon charge asymmetry impose stronger constraints on valence quarks

An interplay of W production measurements at CMS is exploited in a PDF fit

→ obtained PDFs consistent with CT10 NLO PDF set

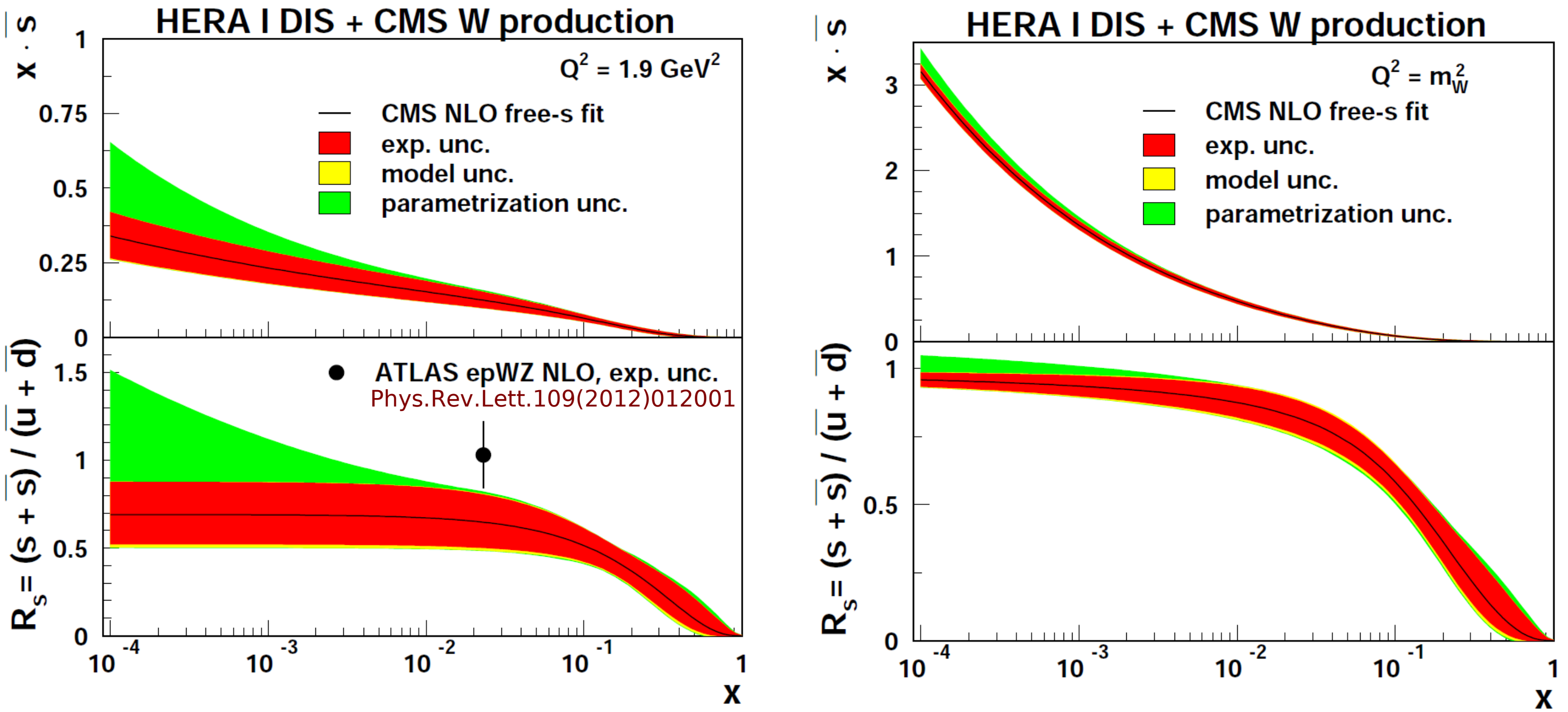
→ results are supported by the NNPDF reweighting studies

→ strangeness suppression $\kappa_s(Q^2=20\ \text{GeV}^2)$ is determined and is consistent with the NOMAD result

→ strange fraction $R_s(x)$ found to be consistent with ATLAS NLO result

Back-up slides

Determination of s quark density in the proton by using W production at CMS



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Determined strange fraction is consistent with NOMAD and ATLAS results