PDF activities and relevant measurements in CMS

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PDF4LHC
CERN, 8 Oct 2012

Introduction

Precise LHC data become increasingly important for PDF constrains

In this talk will focus on most relevant and recent CMS measurements for PDFs and corresponding PDF studies:

- QCD jets
- W and Z bosons
- W+c
- DY differential measurements
- Top physics
- Photons
- pPb (nuclear PDFs)

(here not covered: forward physics)

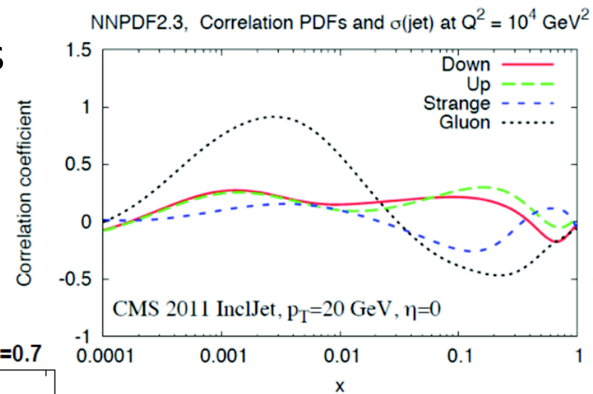
PDF studies in CMS and relevant questions are discussed in PDF@CMS forum

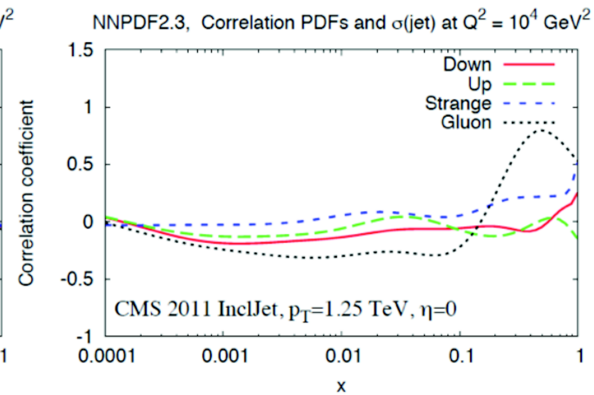
QCD jets

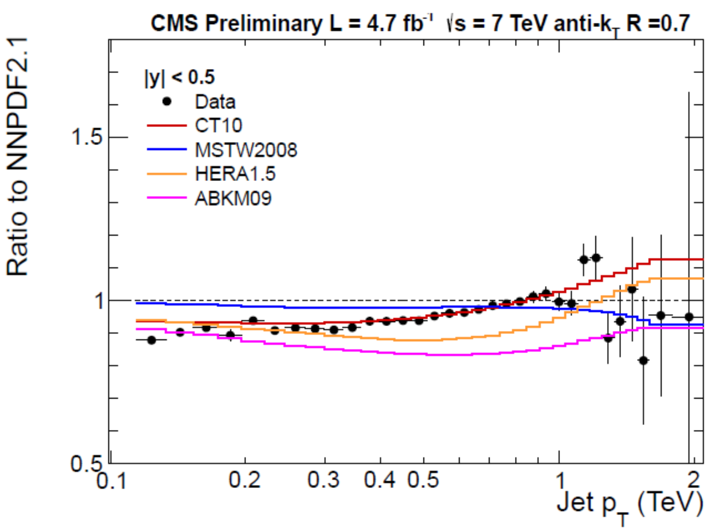
Double-differential inclusive and dijet measurement (7 TeV, 5 fb^{-1})
→ constrains: large-x gluon and large-x quarks
→ α_s determination

→ data at central rapidities are sensitive to gluon

QCD-11-004







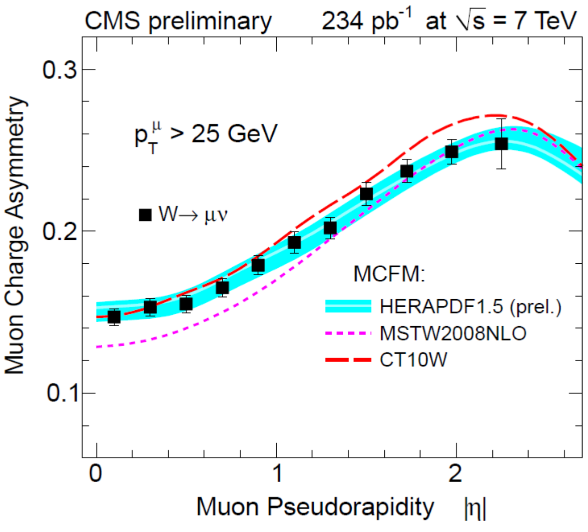
- good agreement with various PDFs with small deviations at large p_T
- full covariance matrices (systematic and statistical) will be provided with the publication (*plan: few weeks*)
- PDF study with jet data and α_s determination is ongoing

Ongoing: 3-jet/2-jet ratio and α_s extraction

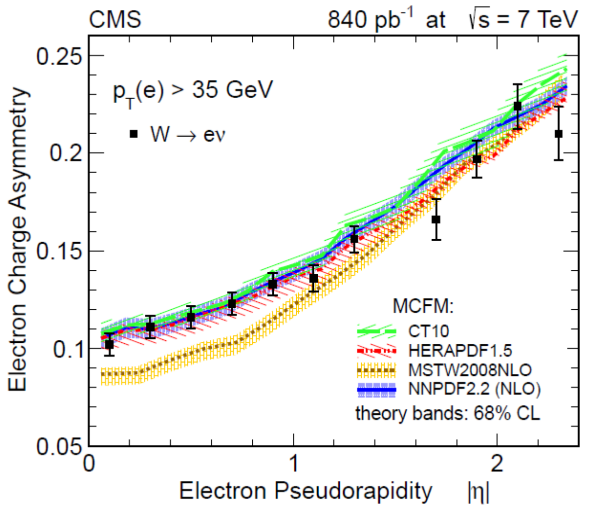
W and Z bosons

CMS W and Z measurements:
→ W lepton asymmetry is manly sensitive to differences between u and d
→ all flavours contribute to Z rapidity

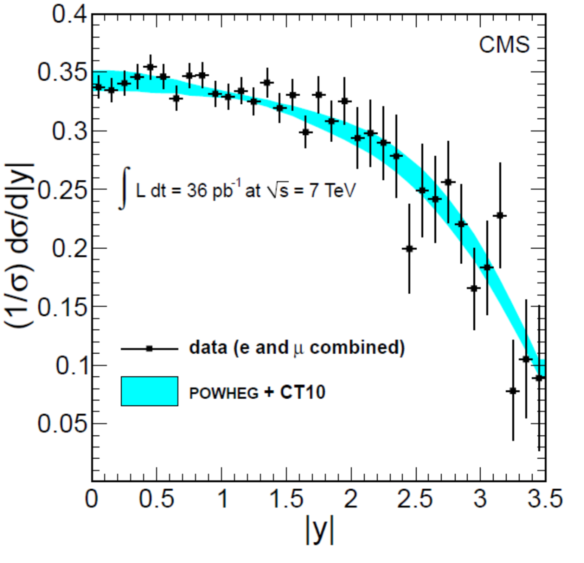
EWK-11-005



SMP-12-001



EWK-10-010



Ongoing: full 2011 W muon asymmetry analysis (*plan: end of the year*)

W and Z bosons: strangeness study

NLO QCD analysis using the HERAFitter to determine s quark density

K. Lipka, R. Plačakytė, A. Vargas

Input: HERA-I data plus CMS W asymmetry (e and μ) and Z-rapidity data
→ systematic sources for each data set but no correlations between them

Settings: (HERAPDF1.0) and free-s parametrization:

General form: $xf(x,Q_0^2) = Ax^B(1-x)^C(1+Dx+Ex^2)$

A: overall normalisation
B: small x behavior
C: $x \rightarrow 1$ shape

s: $x\bar{s} = A_s x^{Bs}(1-x)^{Cs}$ and

$x\bar{s}=f_s\,(x\bar{d} + x\bar{s})$ at starting scale

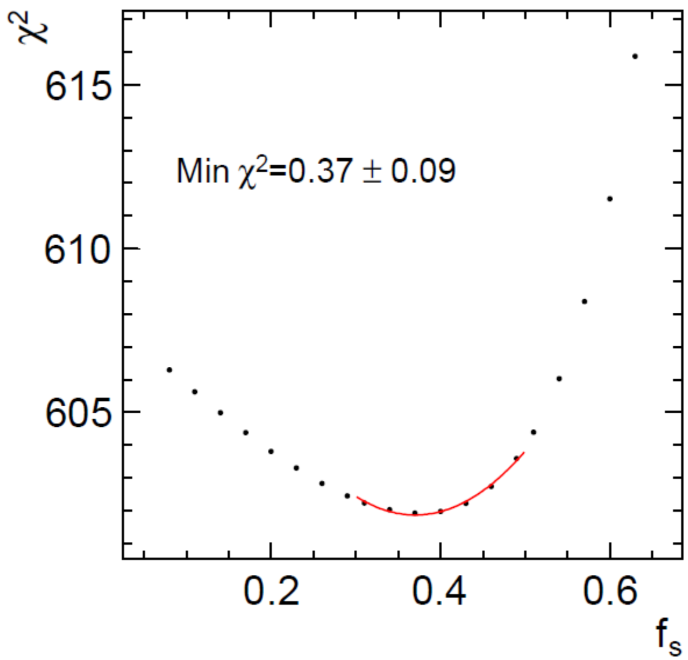
Note: HERA data alone not sufficient to constrain the strange component and is usually coupled to d quark via xD=xd+xs

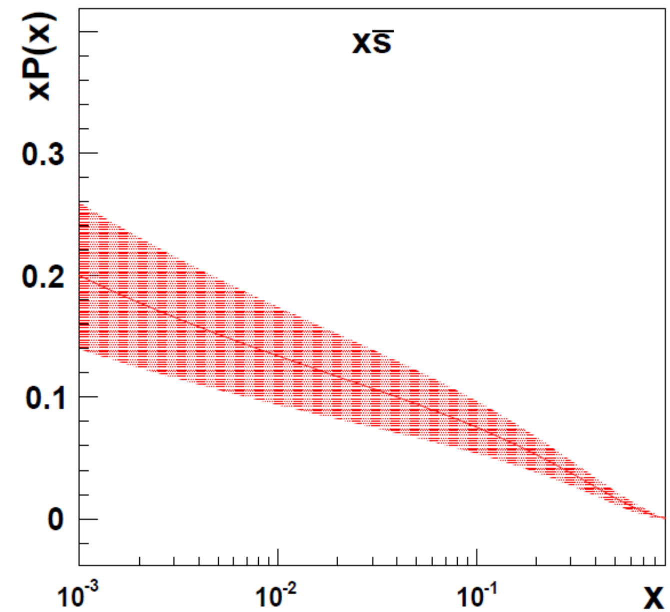
W and Z bosons: strangeness study

NLO QCD analysis using the HERAFitter to determine s quark density

K. Lipka, R. Plačakytė, A. Vargas

Study ongoing, here experimental errors only (model and parametrisation uncertainties to be added)!





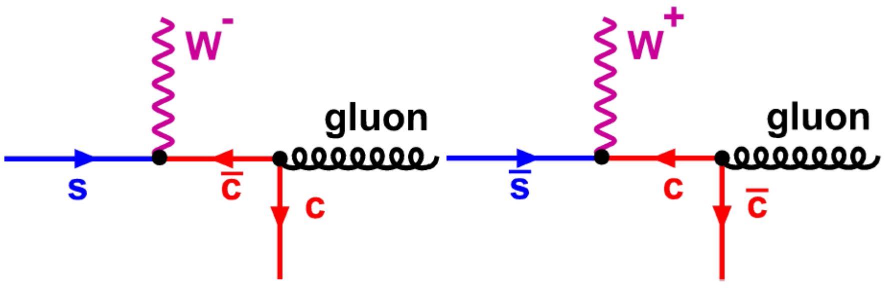
$f_s = 0.37$ corresponds to $r_s = \frac{x\bar{s}}{x\bar{d}} = 0.66$

ATLAS result (arXiv:1203.4051): $r_s = 1.00 \pm 0.20_{\mathrm{exp}} \pm 0.07_{\mathrm{mod}}{}^{+0.10}_{-0.15}{}_{\mathrm{par}}{}^{+0.06}_{-0.07}{}_{\alpha_S} \pm 0.08_{\mathrm{th}}.$

W + charm measurement in CMS

There are discrepancies in s density between different PDF sets which are not understood

W+charm data → direct probe of the strange PDF

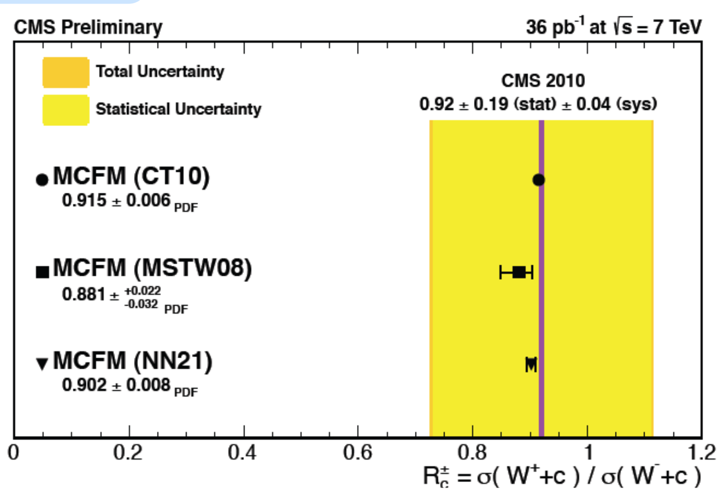


> 10% of the W + jets events at the LHC contain c jets

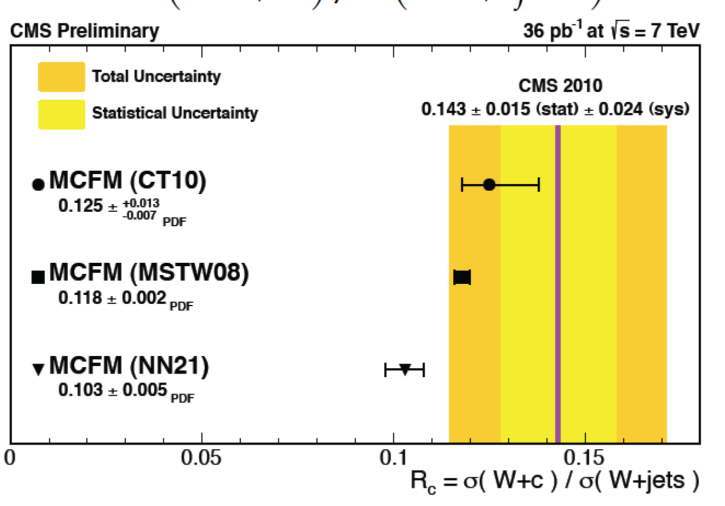
→ s can be disentangled tagging W^+ and W^- events

EWK-11-013

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



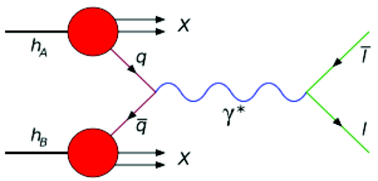
$$\sigma(W+c)/\sigma(W+jets)$$



Ongoing: differential distributions with 2011 data (reduced uncertainties)

DY double differential measurement

→ Drell-Yan measurements at low M_{ll} values constrain small-x region (different PDF sensitivity than at M_Z)



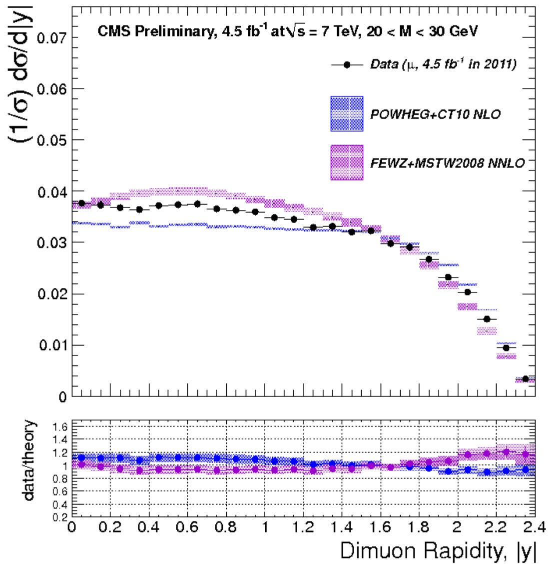
Differential DY measurement in CMS with 2010 data

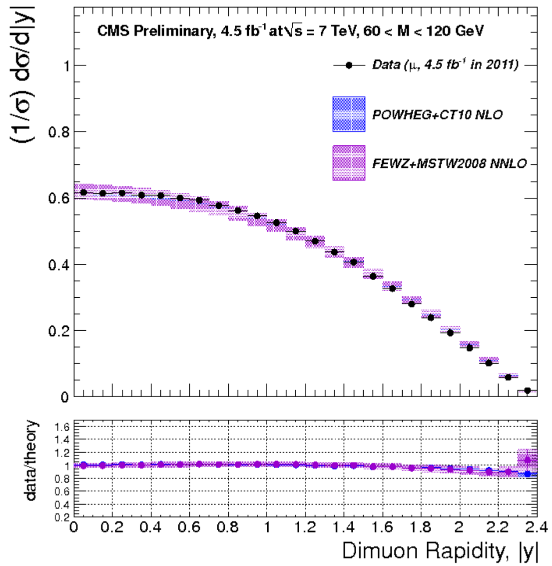
EWK-10-007

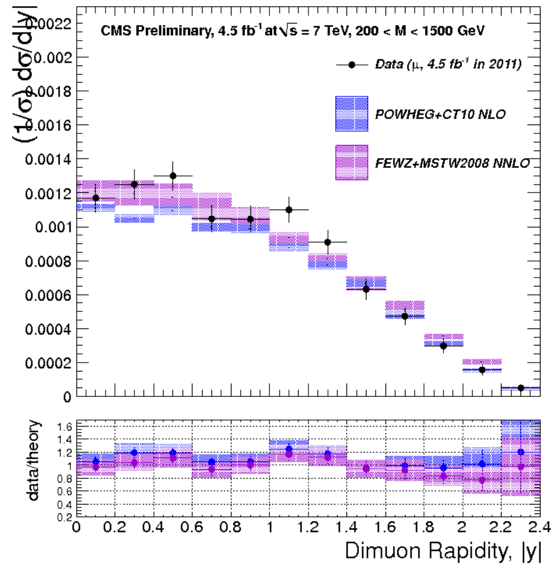
Preliminary update with 2011 data +double differential measurement for muons

- in plans: add electron channel
- full covariance matrices will be provided

EWK-11-007







plan: end of the year

Top physics

ttbar: production at LHC via *gg* fusion (dominant) and *qqbar* anihilation

S. Naumann-Emme, K. Lipka

Available theory predictions (exact NNLO for qqbar, approx NNLO for gg):

1.3 TOP++

1.3 HATHOR (new high energy approximation for soft g-resummation)

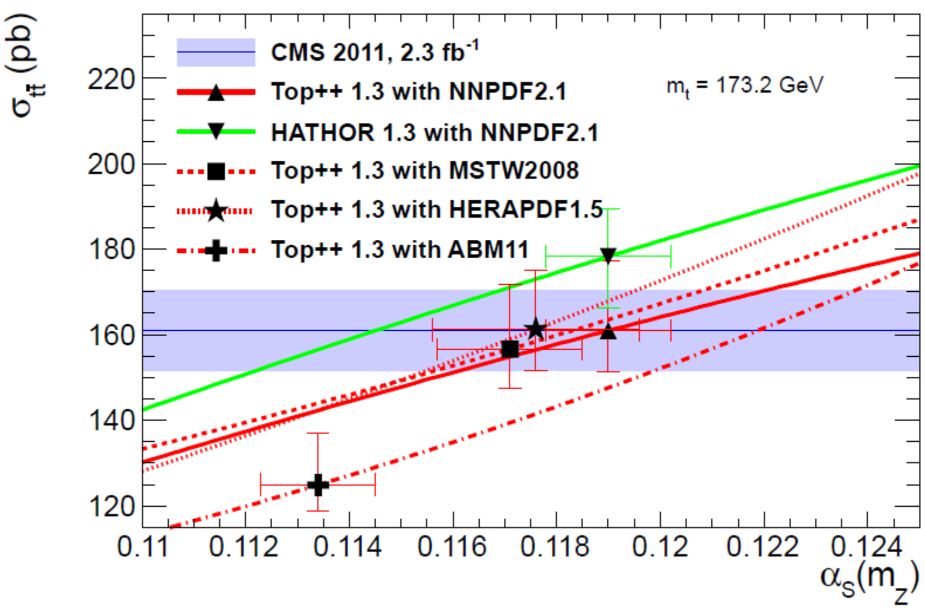
With the measured σ_{ttbar} one can either

- fix α_s to extract m_t (D0, ATLAS, CMS)
- fix m_t to extract α_s (new!)

(simultaneous α_s and m_t :with diff σ_{ttbar})

NEW CMS result:

TOP-12-022



→ α_s dependence of the σ_{ttbar}

→ higher HATHOR predictions due to new high-energy approx.

→ lower ABM prediction due to smaller gluon

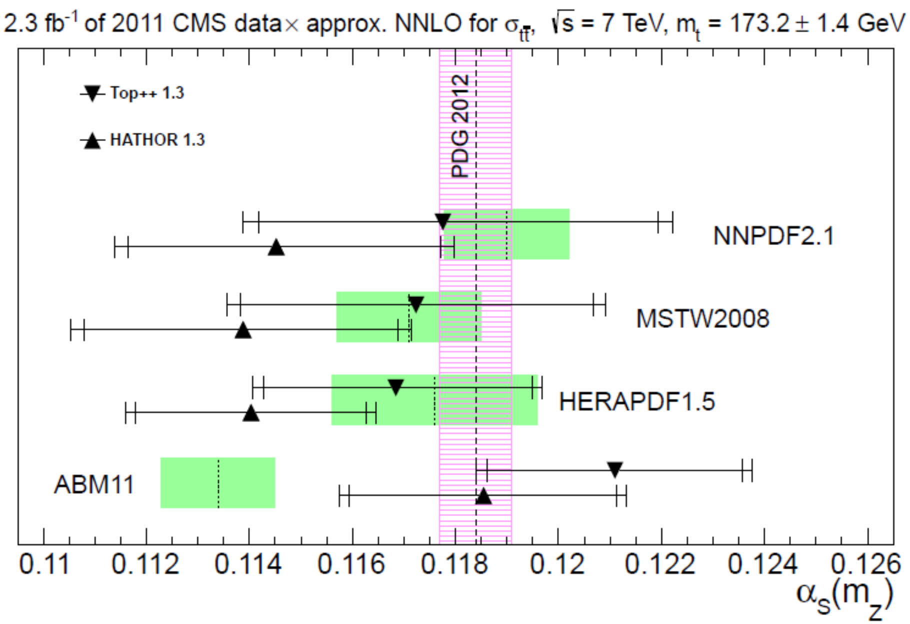
Top physics

At fixed m_t (173.2±0.94 GeV CDF&D0 arXiv:1207.1069), can determine α_s through comparison of measured and predicted cross section

→ details on extraction technique: TOP-012-022

S. Naumann-Emme, K. Lipka

TOP-12-022



		Most likely value	Uncertainty Total	Uncertainty From δm_t
Top++ 1.3	with NNPDF2.1	0.1178	$^{+0.0045}_{-0.0039}$	$^{+0.0015}_{-0.0015}$
HATHOR 1.3	with NNPDF2.1	0.1145	$^{+0.0034}_{-0.0031}$	$^{+0.0013}_{-0.0013}$
Top++ 1.3	with MSTW2008	0.1172	$^{+0.0037}_{-0.0037}$	$^{+0.0013}_{-0.0014}$
HATHOR 1.3	with MSTW2008	0.1139	$^{+0.0033}_{-0.0034}$	$^{+0.0013}_{-0.0013}$
Top++ 1.3	with HERAPDF1.5	0.1168	$^{+0.0028}_{-0.0028}$	$^{+0.0010}_{-0.0011}$
HATHOR 1.3	with HERAPDF1.5	0.1140	$^{+0.0024}_{-0.0024}$	$^{+0.0010}_{-0.0010}$
Top++ 1.3	with ABM11	0.1211	$^{+0.0027}_{-0.0027}$	$^{+0.0010}_{-0.0010}$
HATHOR 1.3	with ABM11	0.1185	$^{+0.0028}_{-0.0028}$	$^{+0.0010}_{-0.0010}$

→ results obtained with NNPDF, MSTW, HERAPDF are similar, ABM yields larger α_s due to smaller gluon PDF

→ new high-energy approx. of HATHOR 1.3 results in 3% lower extracted α_s(Mz)

Outlook: simultaneous g PDF, α_s and m_t fit from differential measurement

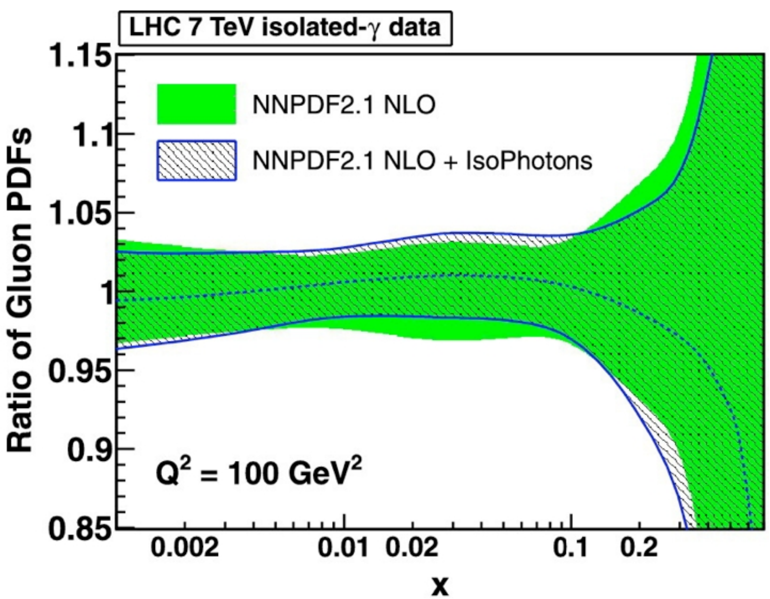
Photon PDFs

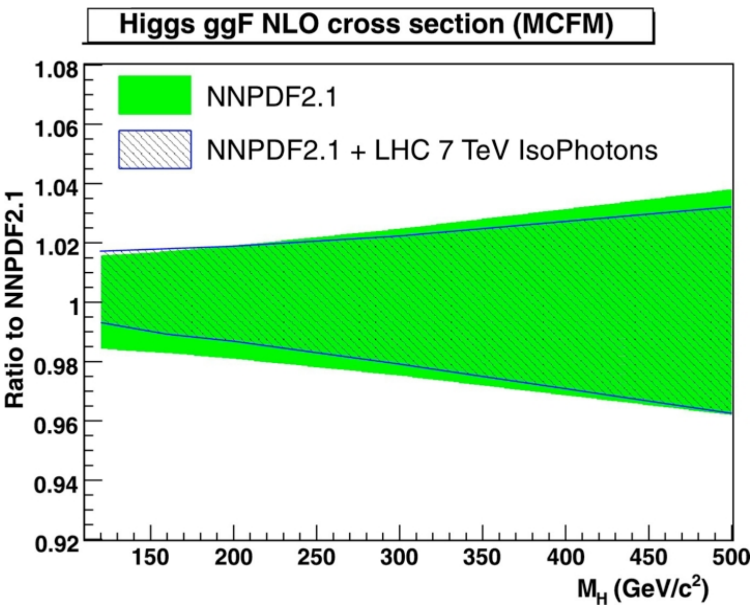
Isolated γ production data directly sensitive to gluon

Isolated photon production measurements carried in CMS and ATLAS

→ data precise enough to constrain gluon, reduction of uncertainties at x~0.02

D. D'Enteria, J. Rojo NPB 860 (2012) 311





→ with increasing data precision and improved theory isolated photon data become an important component in determination of gluon PDF

more details in afternoon talk

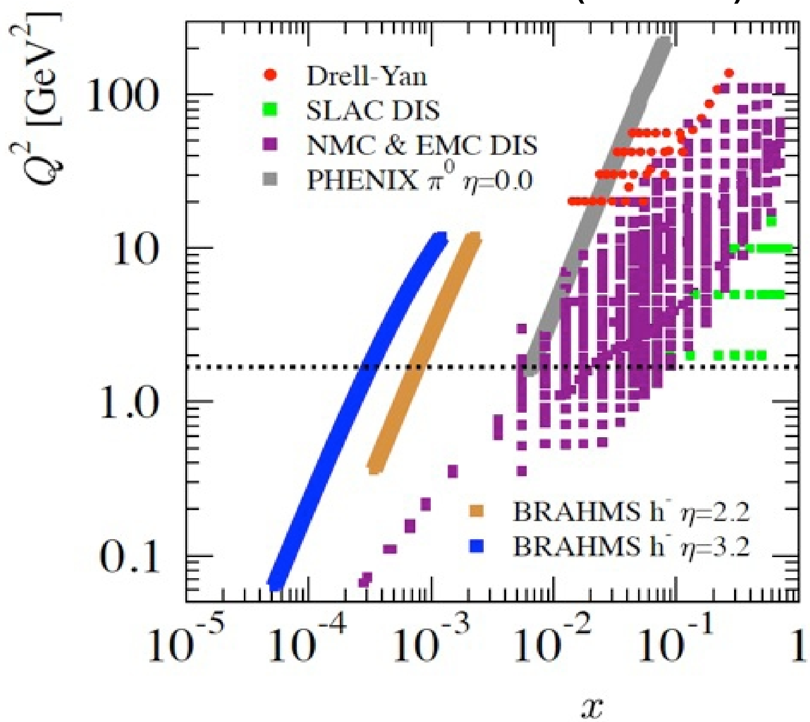
Nuclear PDFs

Differently to proton PDFs, there are much less experimental data available for nuclear PDFs case (especially in x<0.01 region)

→ large nPDF uncertainties in LHC relevant region

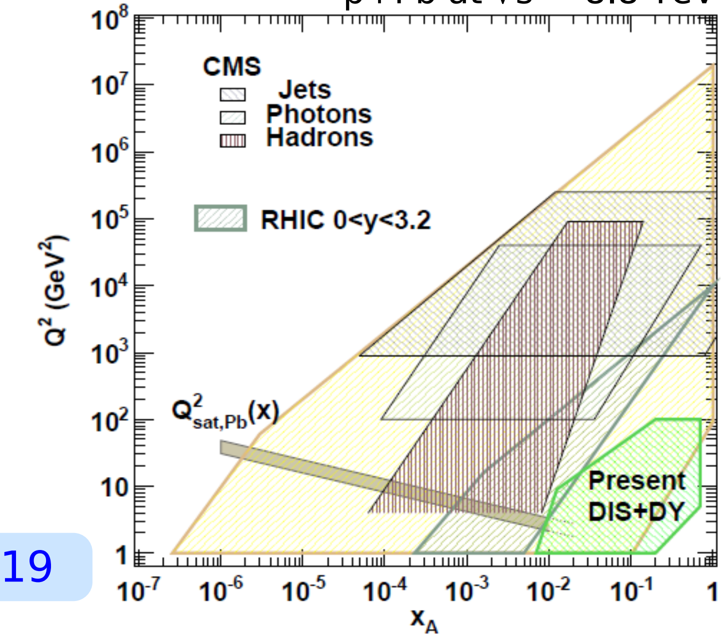
J. Rojo

Nuclear PDFs (EPS09)



arXiv:1105.3919

→ EIC and LHeC could significantly improve situational but there are opportunities in pPb at the LHC



Nuclear PDFs

Universality: same PDFs enter different processes

J. Rojo

- In principle, one could extract PDFs for heavier nuclei as in the proton case. Need to assume that **QCD factorization holds in nuclei** as in protons
- The scarceness of nuclear data requires to simultaneously fit the dependence with **Bjorken-x** and with the **nuclear number** A as **deviations from a proton PDF set:**

$$f_i^A(x,Q^2) \equiv R_i^A(x,Q^2) f_i^{\rm CTEQ6.1M}(x,Q^2)$$

EPS09

- Also **isospin symmetry** has to be taken into account - important difference as compared to proton PDFs

$$\begin{aligned} u_A(x,Q^2) &= \frac{Z}{A} f_u^A(x,Q^2) + \frac{A-Z}{A} f_d^A(x,Q^2) \\ d_A(x,Q^2) &= \frac{Z}{A} f_d^A(x,Q^2) + \frac{A-Z}{A} f_u^A(x,Q^2) \end{aligned}$$

- **Momentum and baryon** sum rules must apply for all **nuclear numbers** A

$$\sum_{i=q,\bar{q},g} \int_0^1 dx\, x f_i^A(x,Q_0^2) = 1, \quad \int_0^1 dx \left[f_{uV}^A(x,Q_0^2) + f_{dV}^A(x,Q_0^2) \right] = 3$$

Juan Rojo PDF@CMS Meeting, CERN, 04/06/2012

Nuclear PDFs

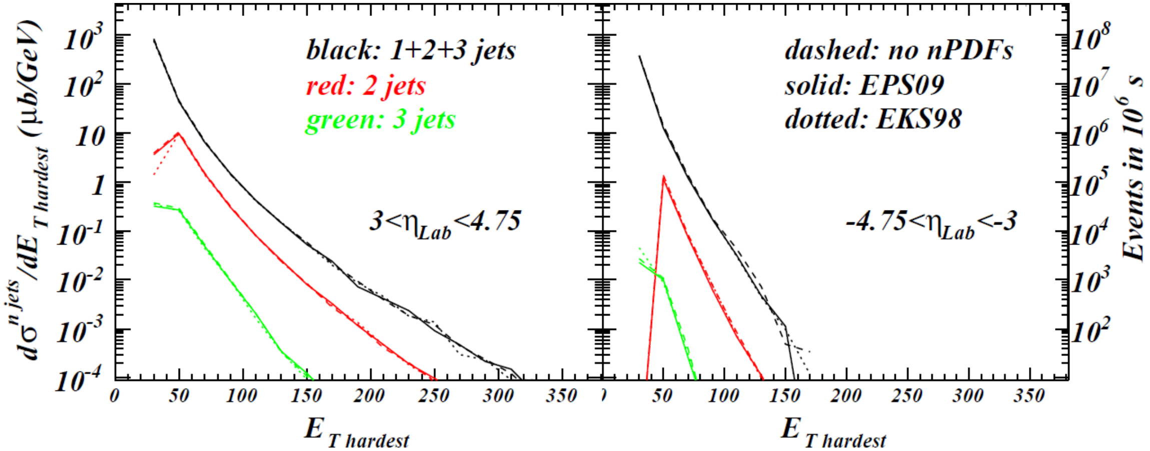
Many processes of interest in pPb run including:

J. Rojo

- inclusive jet production
- W and Z production
- low-mass DY
- open heavy flavour production
- isolated photon production

e.g. jets are essential for understanding of jet quenching and important for studies of nuclear effects in PbPb

figure: nuclear effects are small, i.e. up to 20% but should be possible to access



→ detailed report of scientific opportunities in p-nucleus collisions at LHC:

Proton-Nucleus Collisions at the LHC: Scientific Opportunities and Requirements

CERN-PH-TH/2011-119
LHC-Project-Report-1181

arXiv:1105.3919

Collider-only Nuclear PDFs (RHIC+LHC) would open interesting opportunities!

Summary

Various PDF activities are being performed in CMS including:

→ jets

→ Z,W, strangeness, (off-resonance DY, W+charm)

→ top

→ photons

→ nuclear PDFs (pPb LHC run)

PDF relevant CMS measurements (not all) presented

→ many of them are planed to be published still this year

→ detailed reports in later sessions

Back-up slides

PDF determination in HERAPDF 1.0

DGLAP at NLO → QCD predictions

PDFs parametrised (at starting scale Q^2_0) using standard parametrisation form:

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

A: overall normalisation

B: small x behavior

C: x→1 shape

The optimal number of parameters chosen by saturation of the χ^2

- central fit with:
  10 free parameters for HERA I data
  14 for HERA I and II data

xg, xu_v, xd_v, $x\bar{U}$, $x\bar{D}$

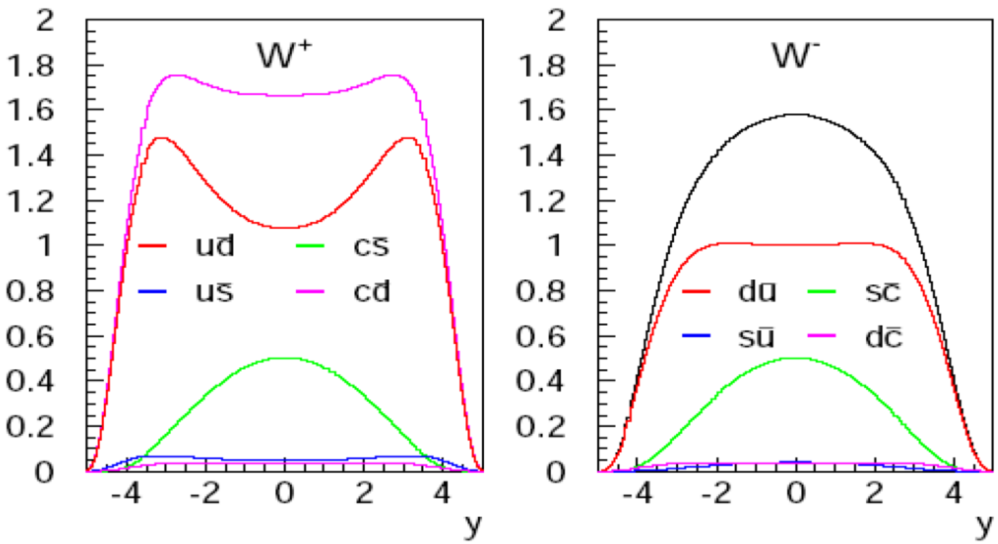
where $x\bar{U}=x\bar{u}$ and $x\bar{D}=x\bar{d}+x\bar{s}$ at the starting scale ($x\bar{s}=f_s x\bar{D}$ with $f_s=0.31$)

A_g, A_{uv}, A_{dv} are fixed by sum rules

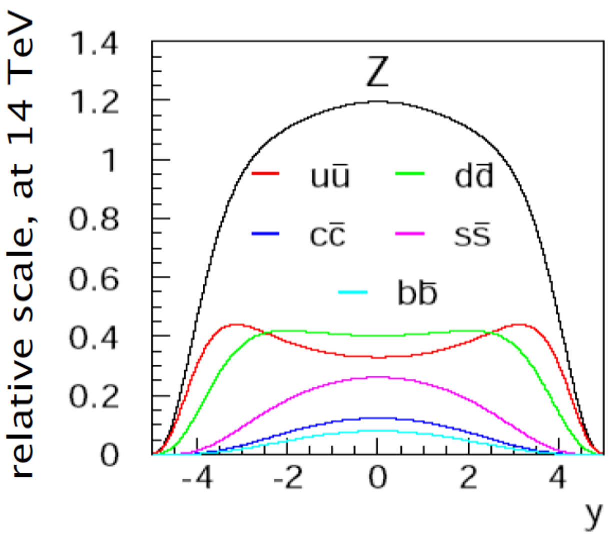
extra constrains for small x behavior of d- and u-type quarks:

$B_{uv}=B_{dv}$, $B_{\bar{U}}=B_{\bar{D}}$, $A_{\bar{U}}=A_{\bar{D}}(1-f_s)$ for $\bar{u}=\bar{d}$ as $x\to 0$

Proton-Proton Collisions: W/Z production



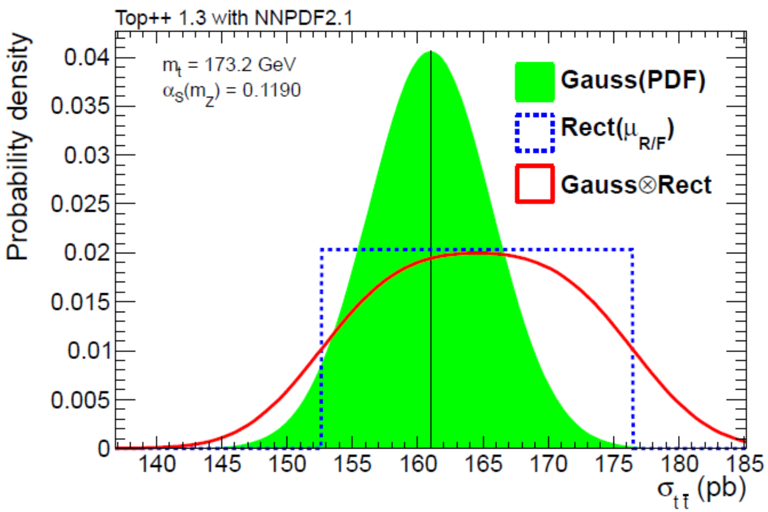
- for W **u** and **d** quarks dominate

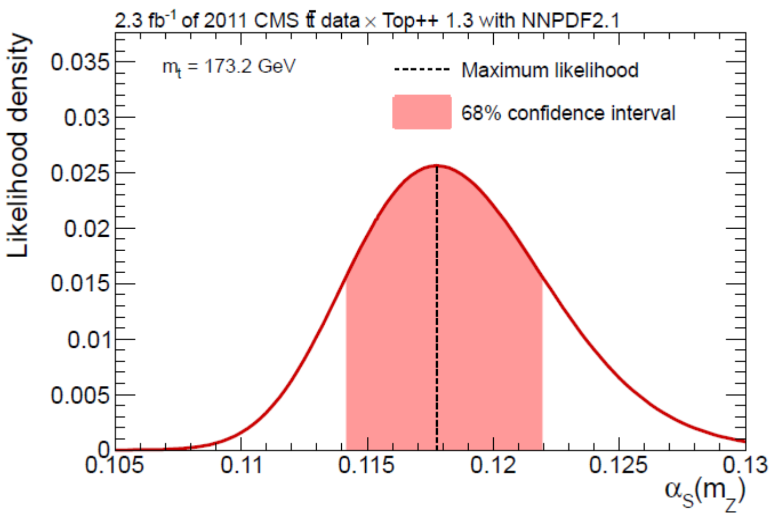


- all flavours contribute to Z

Precise parton distributions are needed for LHC analyses

Top: α_s extraction technique





TOP-12-022

1. For the predicted $\sigma_{t\bar{t}}$, convolve a Gaussian for the PDF uncertainty with a rectangular covering the whole range given by the variation of renormalization and factorization scale

2. Obtain a likelihood by folding the probability function for the predicted $\sigma_{t\bar{t}}$ with a Gaussian probability function for the measured $\sigma_{t\bar{t}}$:

$$L(\alpha_S) = \int f_{\mathrm{exp}}(\sigma|\alpha_S)\ f_{\mathrm{th}}(\sigma|\alpha_S)\ d\sigma$$