PDFs from the LHeC and the LHC Search Program

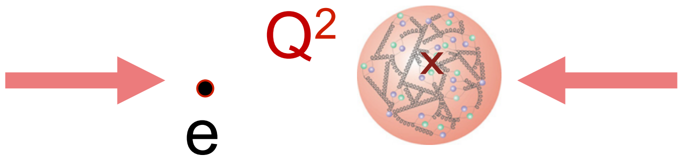
Voica Radescu (DESY)

- Parton Distributions at the LHC
- Potential of the LHeC data on PDFs
- Summary

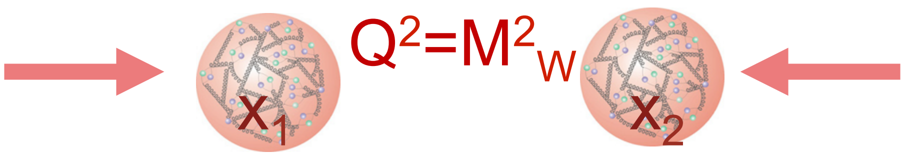
4-8 March 2013 *Universidad Técnica Federico Santa María, Valparaíso, CHILE*
Chile/Continental timezone

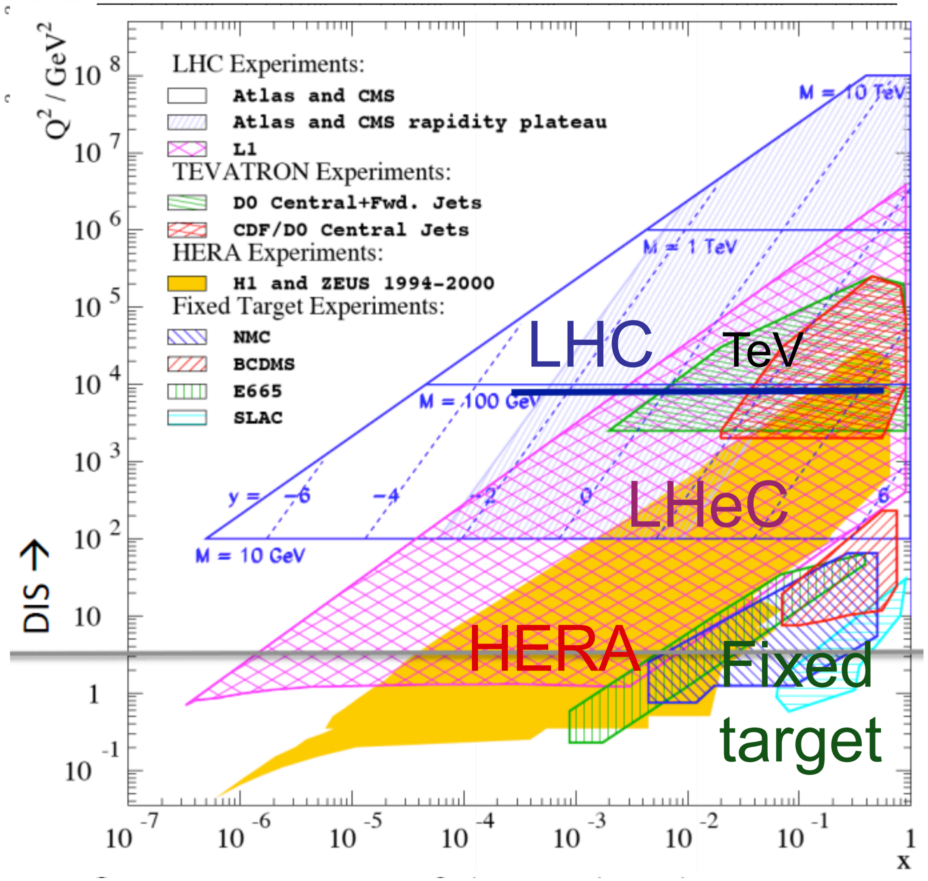
Proton Structure

- Factorization theorem:
  - cross section can be calculated by convoluting short distance calculable partonic reaction with universal parton distributions (PDFs)
- Probing Proton Structure via Deep Inelastic Scattering using elementary particles such as:
  - Neutrinos, muons (fixed target experiments)
  - Electrons (fixed target and collider experiments)



- Knowledge on proton structure can be complemented by the collider experiments at Tevatron and LHC





Persistent experimental effort over the last 40 years both by fixed-target and collider experiments around the world supported by the theoretical developments

Current Status on PDFs

- All available current PDF sets rely mostly on data from HERA (ep collider)

	MSTW08	CTEQ6.6/CT10	NNPDF2.1/2.3	HERAPDF1.0/1.5	ABKM09/ABM11	GJR08/JR09
PDF order	LO, NLO, NNLO	LO, NLO, NNLO	LO, NLO, NNLO	NLO, NNLO	NLO, NNLO	NLO, NNLO
HERA DIS	✔ (old)	✔ (old/new)	✔ (new)	✔ (new/newest)	✔ (new)	✔ (new)
Fixed target DIS	✔	✔	✔	-	✔	✔
Fixed target DY	✔	✔	✔	-	✔	✔
Tevatron W, Z	✔	✔	some	-	some	some
Tevatron jets	✔	✔	✔	-	✔	✔
LHC	-	-	-/W,Z+jets	-	-	-
HF Scheme	RTGMVF	SACOT GMVFN	FONLL GMVFN	RT GMVFN	BMSN FFNS	FFNS
Alphas (NLO)	0.120	0.118(f)	0.119	0.1176(f)	0.1179	0.1145
Alphas (NNLO)	0.1171	0.118(f)	0.1174	0.1176(f)	0.1135	0.1124

The analyses differ in many areas:

- different treatment of heavy quarks
- inclusion of various data sets and account for possible tensions
- different alphas assumption

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	MSTW08	CTEQ6.6/
PDF order	LO, NLO, NNLO	LO, NLO, NNLO
HERA DIS	✔ (old)	✔ (old/ne
Fixed target DIS	✔	✔
Fixed target DY	✔	✔
Tevatron W, Z	✔	✔
Tevatron jets	✔	✔
LHC	-	-
HF Scheme	RTGMVF	SACOT GM
Alphas (NLO)	0.120	0.118(f)
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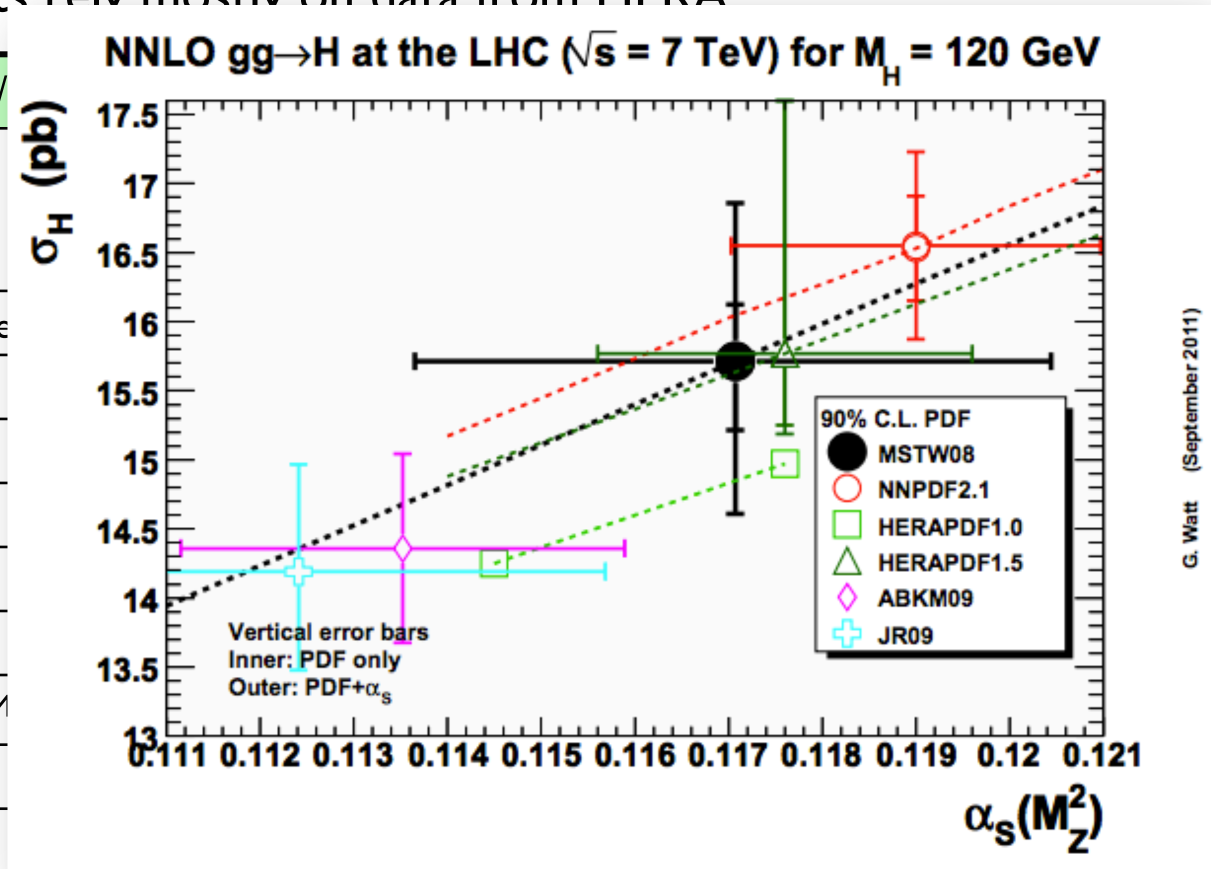

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- different treatment of heavy quarks
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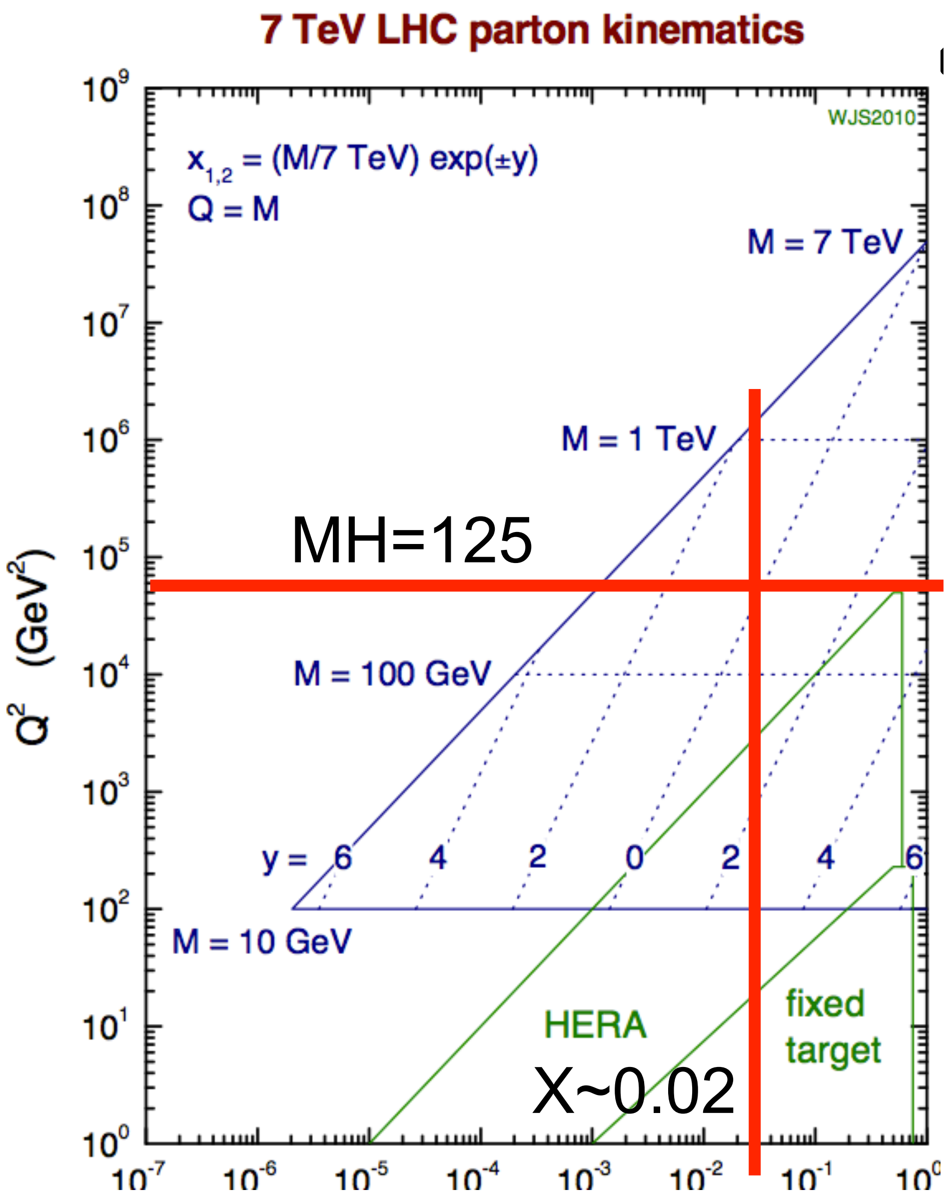
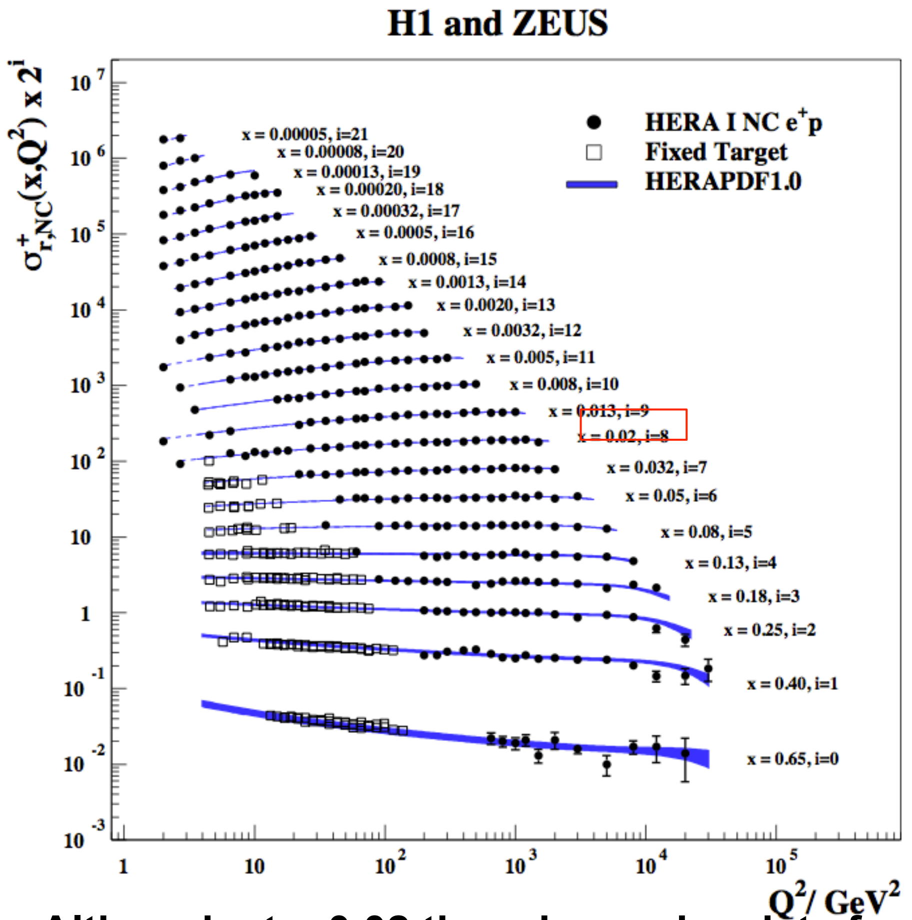
Current Status on PDFs

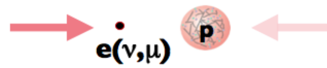




Although at x-0.02 there is precise data from HERA, PDFs are one of main TH uncertainties in Higgs production.

PDF Constraints from HERA and LHC

- Main information on proton structure comes from DIS data at HERA:

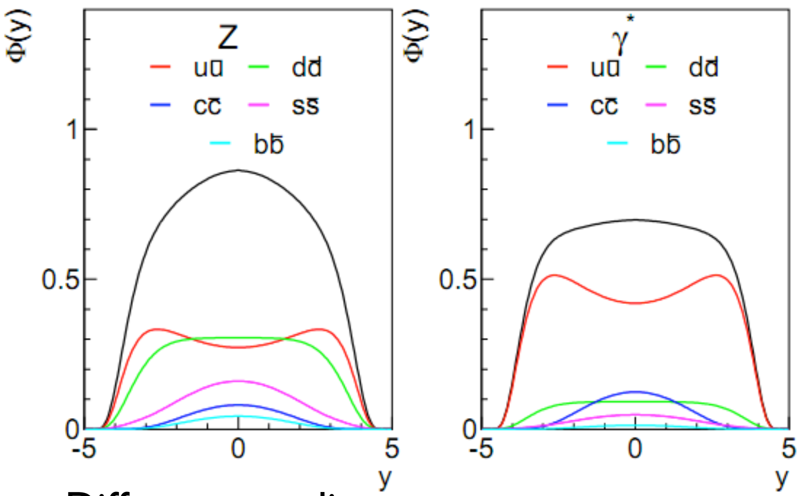


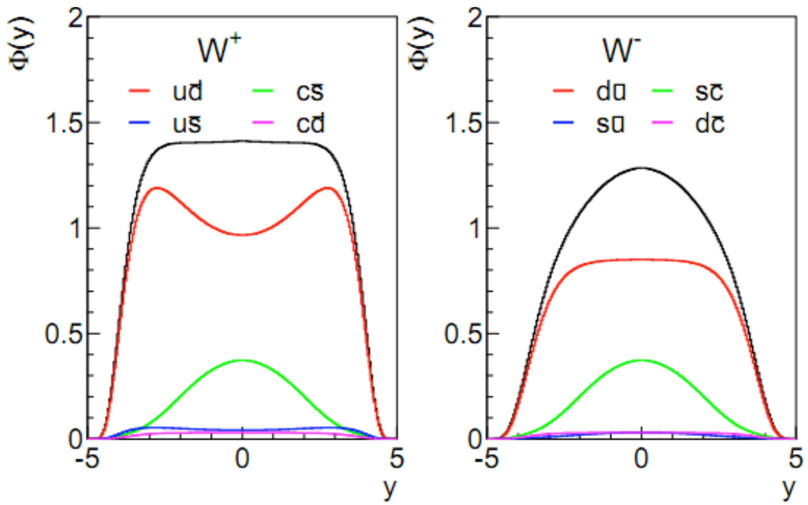
  - probes linear combination of quarks:
    - CC: provides constraints on valence quarks
    - NC: $F_2 \sim 0.44x(u+\bar{u}+c+\bar{c})+0.11x(d+\bar{d}+s+\bar{s}+b+\bar{b})$

- Additional constrain come from DY and jet data at the LHC

  - probe a bi-linear combination of quarks

$$Z \sim 0.29(u\bar{u}+c\bar{c})+0.37(d\bar{d}+s\bar{s}+b\bar{b})$$
$$\gamma^* \sim 0.44(u\bar{u}+c\bar{c})+0.11(d\bar{d}+s\bar{s}+b\bar{b})$$
$$W^+ \sim 0.95(u\bar{d}+c\bar{s})+0.05(u\bar{s}+c\bar{d})$$
$$W^- \sim 0.95(d\bar{u}+s\bar{c})+0.05(d\bar{c}+s\bar{u})$$





  - Different couplings:

    ➔ LHC data can provide complementary information: flavour decomposition of the quark sea

Measurements at LHC to constrain PDFs

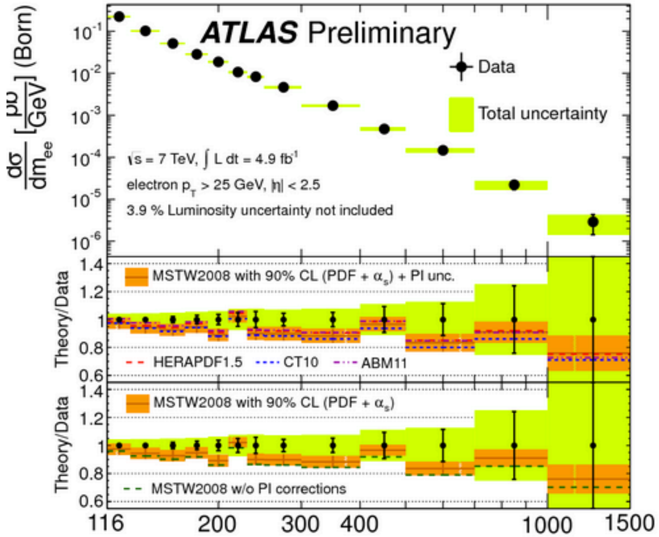
- PDFs are essential for precision physics at the LHC and other hadron colliders:
  - PDFs one of main theory uncertainties in Higgs production
  - PDF uncertainties affect substantially theory predictions for BSM high mass production
- Given the crucial role of the gluon for LHC physics, complementary LHC observables directly sensitive the gluon would be beneficial

- LHC data is introducing completely new observables to be used for PDF constraints:

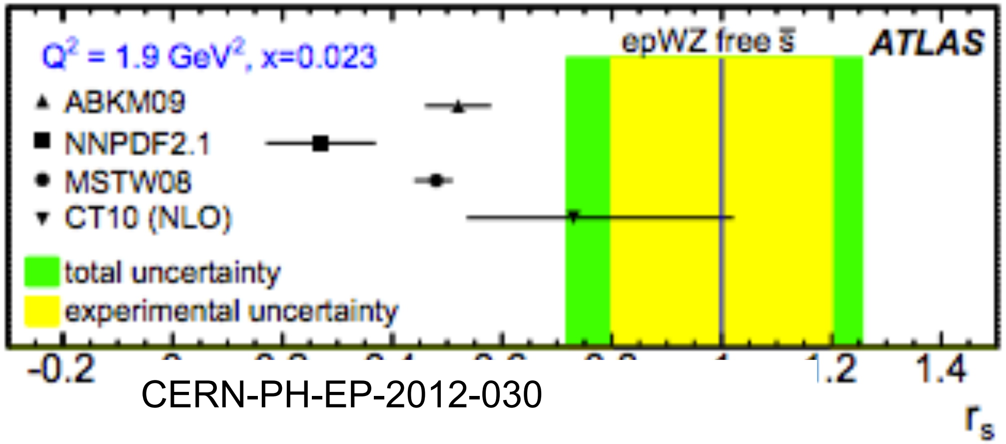
  2010-2011 data:
  - Inclusive jets and dijets, central and forward: high-x quarks and gluons
  - Inclusive W and Z production and asymmetries: quark flavor separation, strangeness
  - Off peak Drell-Yan production at low and high mass: quarks at low and high-x
  - Isolated photons: medium-x gluons
  - W production with charm quarks: direct handle on strangeness (to come)
  - W,Z production with jets: medium and small-x gluon
  - Single top production: gluon and bottom PDFs
  - ttbar production: help to discriminate between different PDF sets - medium x
    - Also a direct handle on the strong coupling
  - Top quark differential distributions: high-x gluon
  - Z+b production sensitive to b-quark

  More stringent constraints are expected with the full 8 TeV and later 13TeV data

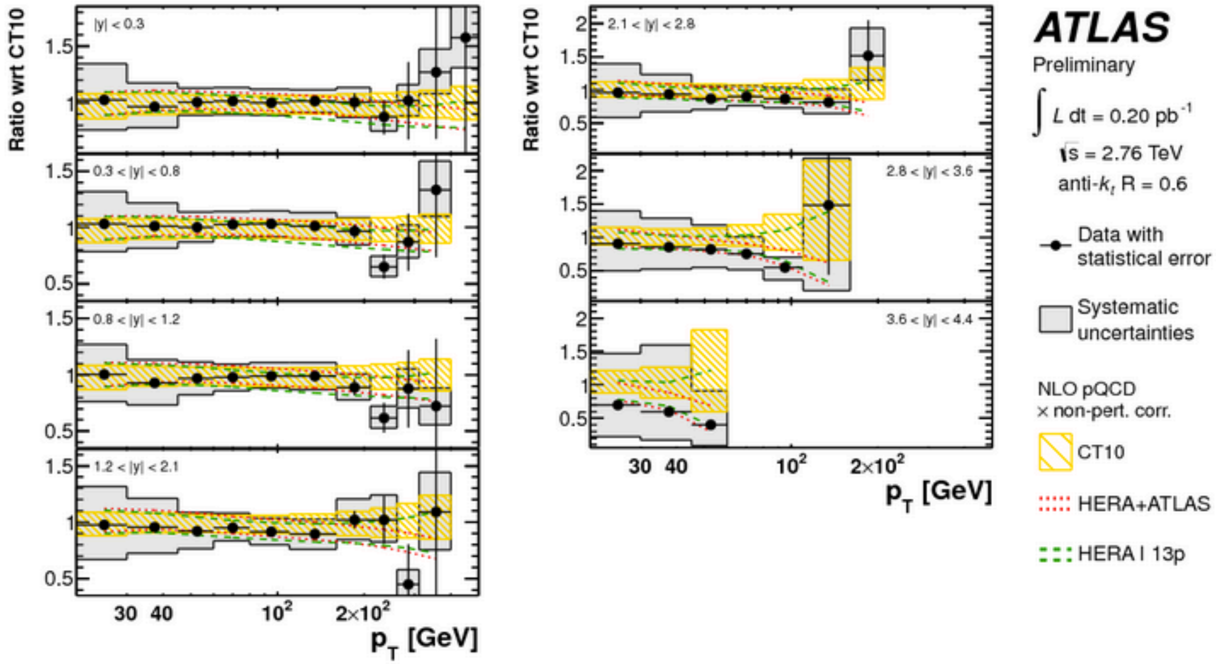
Measurements at LHC to constrain PDFs



ATLAS-CONF-2012-159 High Mass DY



CERN-PH-EP-2012-030



ATLAS-CONF-2012-128

High x searches from LHC

current high-x searches are dominated by PDF uncertainties (20%)

[ATLAS-CONF-2012-129]

- Dominated by ubar,dbar at high x

➔ this uncertainty with LHeC can be reduced

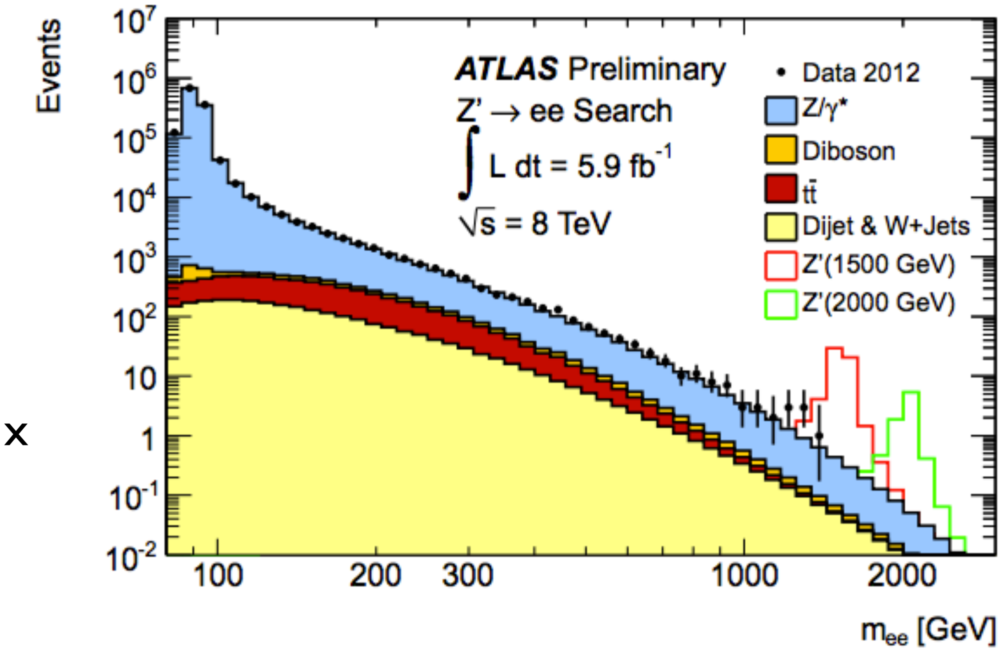
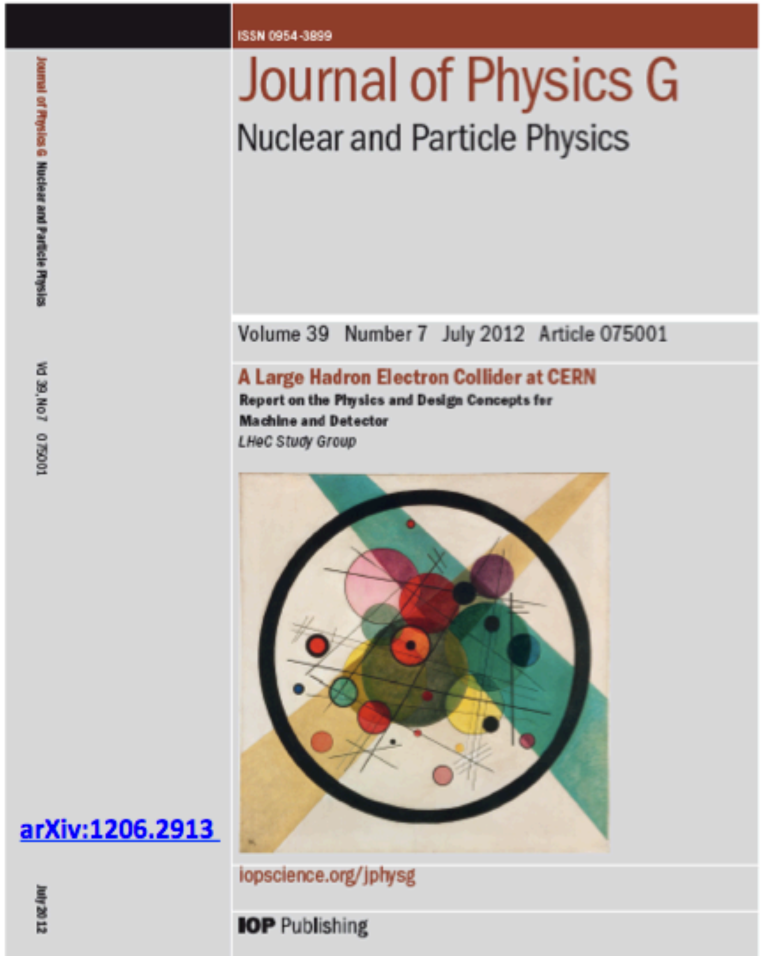


Figure 1: Dielectron invariant mass (m_{ee}) distribution with statistical uncertainties after final selection, compared to the stacked sum of all expected backgrounds, with two selected Z'_{SSM} signals overlaid. The bin width is constant in log m_{ee}.

Table 3: Summary of the main systematic uncertainties on the expected numbers of events at $m_{\ell^+\ell^-}$ = 2 TeV. NA indicates that the uncertainty is not applicable.

Source	Dielectrons		Dimuons	
	Signal	Background	Signal	Background
Normalization	5%	NA	5%	NA
PDF / α_s / α_{em} / scale	NA	20%	NA	20%
Electroweak corrections	NA	4.5%	NA	4.5%
Efficiency	< 3%	< 3%	6%	6%
Dijet and W + jets background	NA	21%	NA	< 3%
Total	5%	30%	8%	21%

The LHeC program



arXiv:1206.2913

http://cern.ch/lhec

J.L.Abelleira Fernandez[16,23], C.Adolphsen[57], P.Adzic[74], A.N.Akay[03], H.Aksakal[39], J.L.Albacete[52], B.Allanach[73], S.Alekhin[17,54], P.Allport[24], V.Andreev[34], R.B.Appleby[14,30], E.Arikan[39], N.Armesto[53,a], G.Azuelos[33,64], M.Bai[37], D.Barber[14,17,24], J.Bartels[18], O.Behnke[17], J.Behr[17], A.S.Belyaev[15,56], I.Ben-Zvi[37], N.Bernard[25], S.Bertolucci[16], S.Bettoni[16], S.Biswal[41], J.Blümlein[17], H.Böttcher[17], A.Bogacz[36], C.Bracco[16], J.Bracinik[06], G.Brandt[44], H.Braun[65], S.Brodsky[57,b], O.Brüning[16], E.Bulyak[12], A.Buniatyan[17], H.Burkhardt[16], I.T.Cakir[02], O.Cakir[01], R.Calaga[16], A.Caldwell[70], V.Cetinkaya[01], V.Chekelian[70], E.Ciapala[16], R.Ciftci[01], A.K.Ciftci[01], B.A.Cole[38], J.C.Collins[48], O.Dadoun[42], J.Dainton[24], A.De.Roeck[16], D.d'Enterria[16], P.DiNezza[72], M.D'Onofrio[24], A.Dudarev[16], A.Eide[60], R.Enberg[63], E.Eroglu[62], K.J.Eskola[21], L.Favart[08], M.Fitterer[16], S.Forte[32], A.Gaddi[16], P.Gambino[59], H.García Morales[16], T.Gehrmann[69], P.Gladkikh[12], C.Glasman[28], A.Glazov[17], R.Godbole[35], B.Goddard[16], T.Greenshaw[24], A.Guffanti[13], V.Guzey[19,36], C.Gwenlan[44], T.Han[50], Y.Hao[37], F.Haug[16], W.Herr[16], A.Hervé[27], B.J.Holzer[16], M.Ishitsuka[58], M.Jacquet[42], B.Jeanneret[16], E.Jensen[16], J.M.Jimenez[16], J.M.Jowett[16], H.Jung[17], H.Karadeniz[02], D.Kayran[37], A.Kilic[62], K.Kimura[58], R.Klees[75], M.Klein[24], U.Klein[24], T.Kluge[24], F.Kocak[62], M.Korostelev[24], A.Kosmicki[16], P.Kostka[17], H.Kowalski[17], M.Kraemer[75], G.Kramer[18], D.Kuchler[16], M.Kuze[58], T.Lappi[21,c], P.Laycock[24], E.Levichev[40], S.Levonian[17], V.N.Litvinenko[37], A.Lombardi[16], J.Maeda[58], C.Marquet[16], B.Mellado[27], K.H.Mess[16], A.Milanese[16], J.G.Milhano[76], S.Moch[17], I.I.Morozov[40], Y.Muttoni[16], S.Myers[16], S.Nandi[55], Z.Nergiz[39], P.R.Newman[06], T.Omori[61], J.Osborne[16], E.Paoloni[49], Y.Papaphilippou[16], C.Pascaud[42], H.Paukkunen[53], E.Perez[16], T.Pieloni[23], E.Pilicer[62], B.Pire[45], R.Placakyte[17], A.Polini[07], V.Ptitsyn[37], Y.Pupkov[40], V.Radescu[17], S.Raychaudhuri[35], L.Rinolfi[16], E.Rizvi[71], R.Rohini[35], J.Rojo[16,31], S.Russenschuck[16], M.Sahin[03], C.A.Salgado[53,a], K.Sampei[58], R.Sassot[09], E.Sauvan[04], M.Schaefer[75], U.Schneekloth[17], T.Schörner-Sadenius[17], D.Schulte[16], A.Senol[22], A.Seryi[44], P.Sievers[16], A.N.Skrinsky[40], W.Smith[27], D.South[17], H.Spiesberger[29], A.M.Stasto[48,d], M.Strikman[48], M.Sullivan[57], S.Sultansoy[03,e], Y.P.Sun[57], B.Surrow[11], L.Szymanowski[66,f], P.Taels[05], I.Tapan[62], T.Tasci[22], E.Tassi[10], H.Ten.Kate[16], J.Terron[28], H.Thiesen[16], L.Thompson[14,30], P.Thompson[06], K.Tokushuku[61], R.Tomás García[16], D.Tommasini[16], D.Trbojevic[37], N.Tsoupas[37], J.Tuckmantel[16], S.Turkoz[01], T.N.Trinh[47], K.Tywoniuk[26], G.Unel[20], T.Ullrich[37], J.Urakawa[61], P.VanMechelen[05], A.Variola[52], R.Veness[16], A.Vivoli[16], P.Vobly[40], J.Wagner[66], R.Wallny[68], S.Wallon[43,46,f], G.Watt[69], C.Weiss[36], U.A.Wiedemann[16], U.Wienands[57], F.Willeke[37], B.-W.Xiao[48], V.Yakimenko[37], A.F.Zarnecki[67], Z.Zhang[42], F.Zimmermann[16], R.Zlebcik[51], F.Zomer[42]

Present LHeC Study group and CDR authors

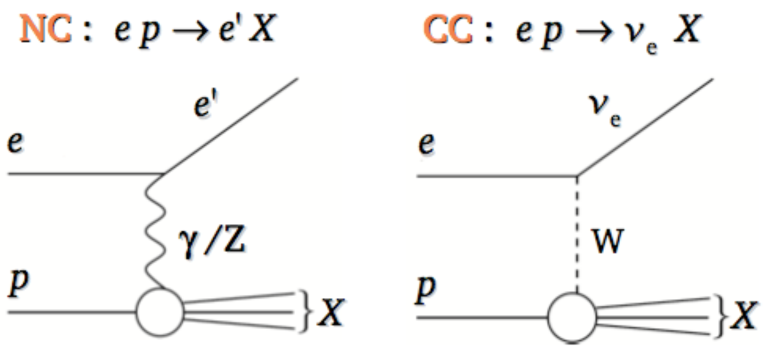
About 200 Experimentalists and Theorists from 76 Institutes

Supported by
CERN, ECFA, NuPECC

arXiv:1206:2913

LHeC ep kinematics

- DIS is best tool to probe structure of the proton:
  - Processes:



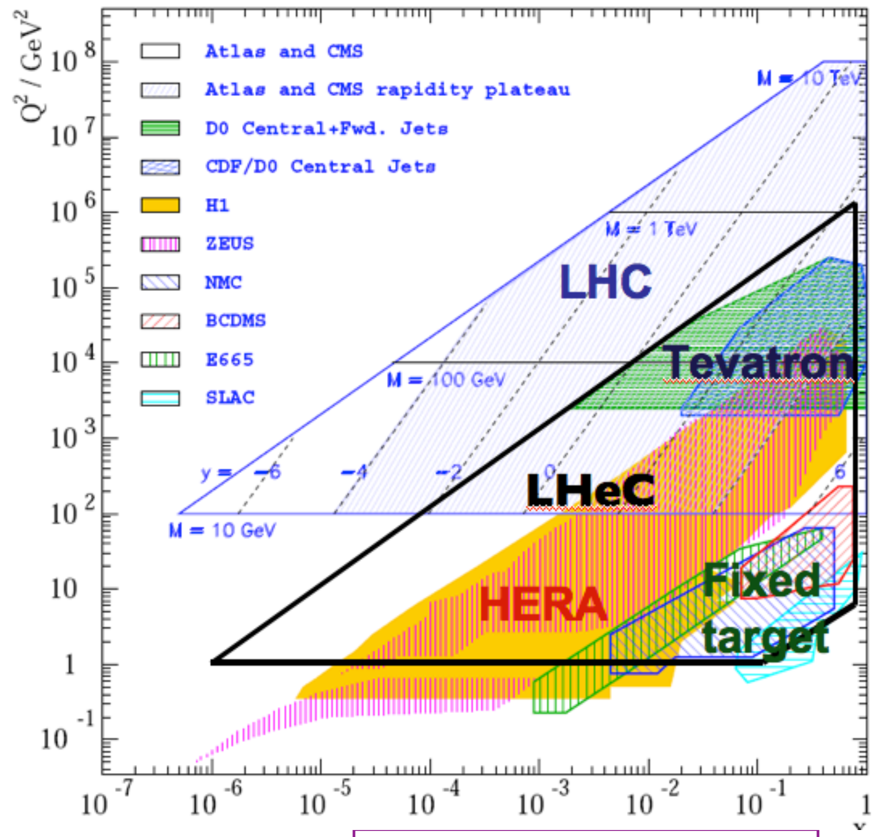
  - Kinematic variables:

$Q^2 = -q^2 = -(k-k')^2$ Virtuality of the exchanged boson

$x = \frac{Q^2}{2p \cdot q}$ Bjorken scaling parameter

$y = \frac{p \cdot q}{p \cdot k}$ Inelasticity parameter

$s = (k+p)^2 = \frac{Q^2}{xy}$ Invariant c.o.m.



- F_2 dominates
  - sensitive to all quarks
- xF_3
  - sensitive to valence quarks
- F_L
  - sensitive to gluons

  - Double Differential cross sections:

$$\sigma_r(x,Q^2) = \frac{d^2\sigma(e^\pm p)}{dx dQ^2}\frac{Q^4 x}{2\pi\alpha^2 Y_+} = F_2(x,Q^2) - \frac{y^2}{Y_+}F_L(x,Q^2) \mp \frac{Y_-}{Y_+}xF_3(x,Q^2)$$

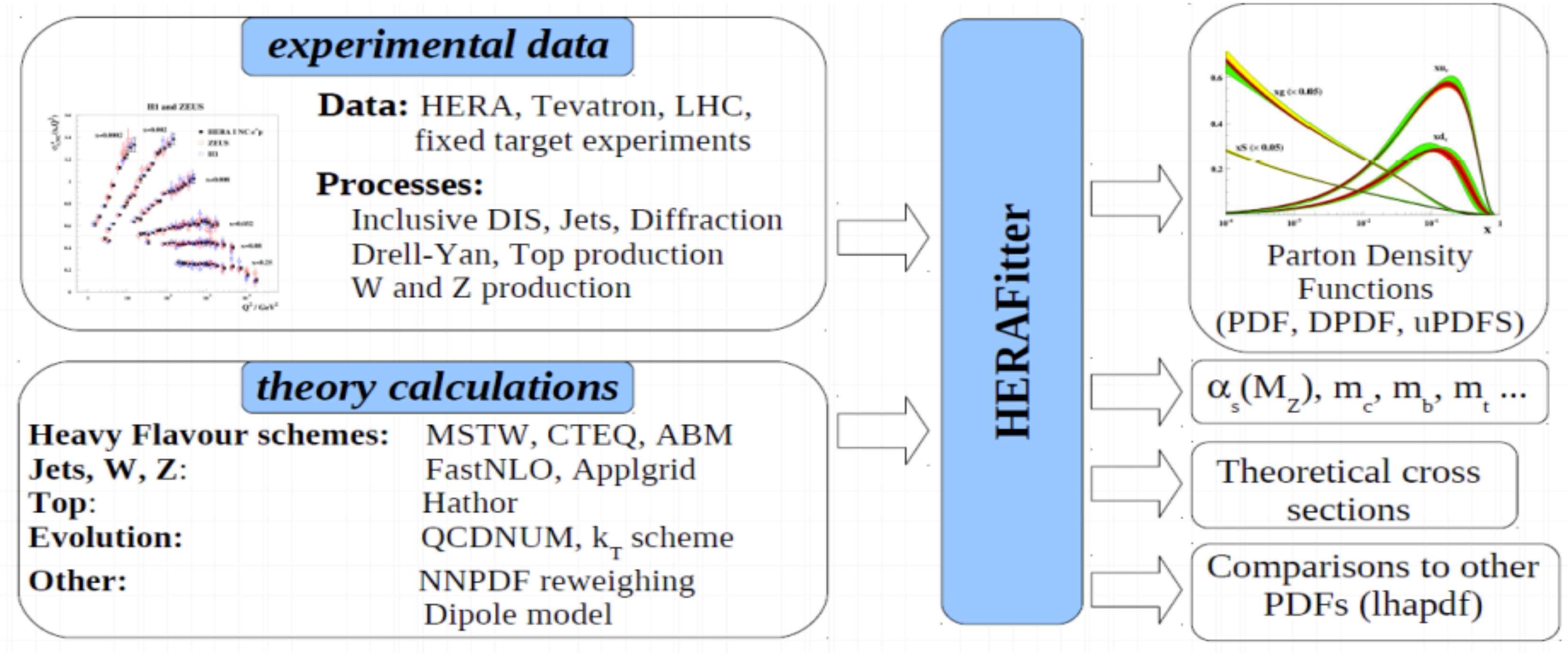
QCD Analysis Framework: HERAFitter Platform

- An open source(GPLv3) QCD fit platform ready to analyse new data and their impact.
- The beta releases can be accessed through the HEPFORGE site or directly

  www.herafitter.org

  - [it requires the QCDNUM package [M. Botje] for evolution]
  - Accessible to anyone for download via registration to provide feedback to the users

    ➔ Next release this month!!!



Simulated LHeC Data

Studied scenarios (described in CDR)

Scenario B: (Lumi $e^{+/-}p$ = 50 fb^{-1}) Ep=7 TeV, Ee=50 GeV, Pol=±0.4

- Kinematic region: 2 < Q^2 < 500 000 GeV^2 and 0.000002 < x < 0.8

Scenario H: (Lumi e^-p = 1 fb^{-1}) Ep=1TeV, Ee=50 GeV, Pol=0

- Kinematic region: 2 < Q^2 < 100 000 GeV^2 and 0.000002 < x < 0.8

Typical uncertainties:

Full simulation of NC and CC inclusive cross section measurements including statistics, uncorrelated and correlated uncertainties – based on typical best values achieved by H1

- Statistical it ranges from 0.1% (low Q^2) to 45% (highest x, Q^2 CC)
- Uncorrelated systematic: 0.7 %
- Correlated systematic: typically 1-3% (for CC high x up to 9%)

source of uncertainty	error on the source or cross section
scattered electron energy scale $\Delta E'_e/E'_e$	0.1 %
scattered electron polar angle	0.1 mrad
hadronic energy scale $\Delta E_h/E_h$	0.5 %
calorimeter noise (only $y < 0.01$)	1-3 %
radiative corrections	0.5%
photoproduction background (only $y > 0.5$)	1 %
global efficiency error	0.7 %

Settings for the PDF determination

- Data:
  - **LHeC simulated data:**
    - **NC e^+p, NC, e^-p, CC e^+p, CC e^-p postive and negative polarisations P=±0.4**
  - Published HERA I (NC, CC $e^{\pm}p$ data, P=0)
    - Kinematics of HERA data: $0.65>x>10^{-4}$, $30\,000 > Q^2 > 3.5$ GeV^2
  - Fixed target data from BCDMS,
  - ATLAS W asymmetry (with adjusted improved uncertainties stat, unc 0.5 and total 1)
    - New ATLAS W, Z 2010 data (with adjusted lumi uncertainty from 3.4 to 1.4)
  - $Q^2_{min}=3.5$ GeV^2 (and $W^2>15$ GeV^2 for BCDMS data)
  - Only experimental Uncertainties

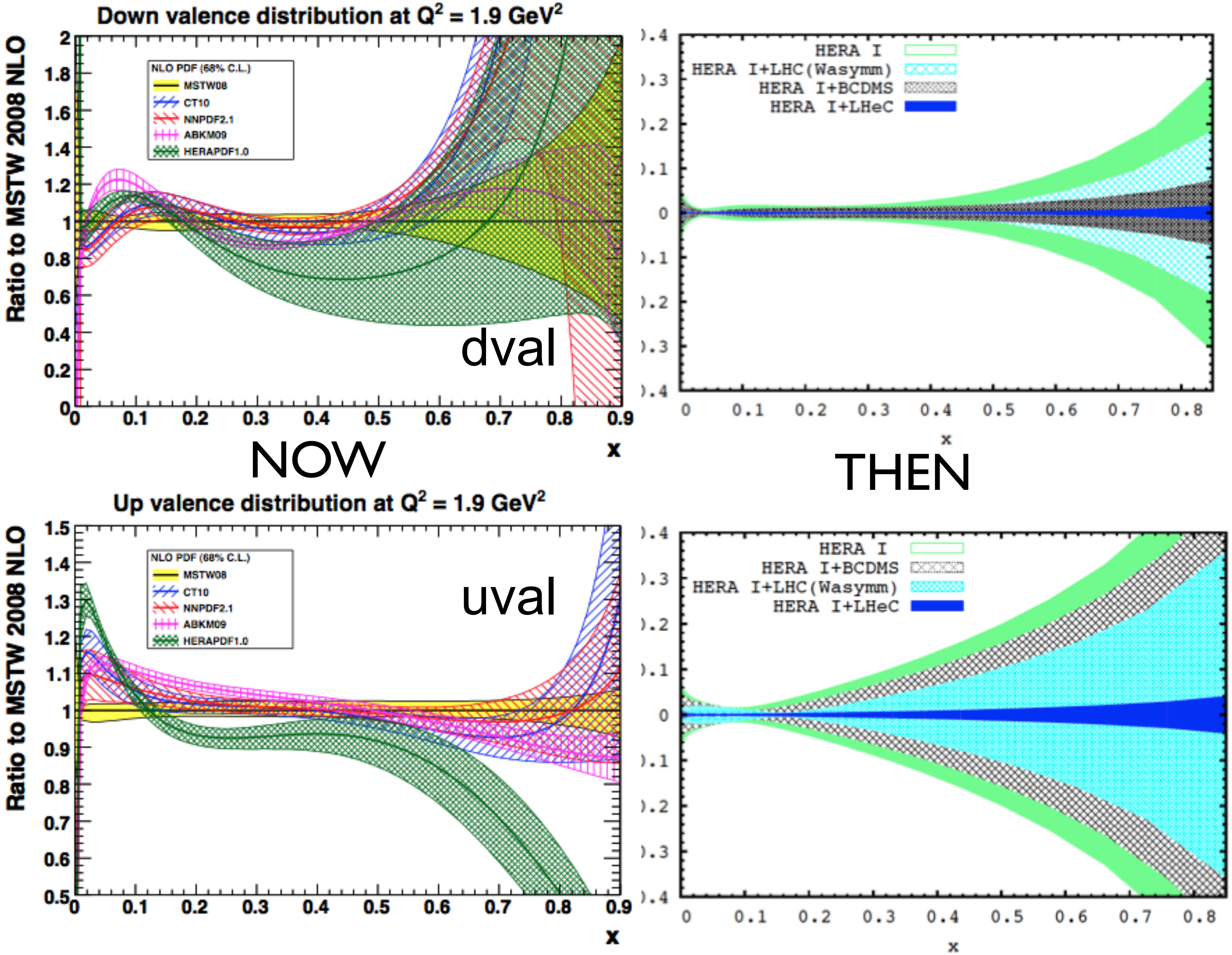
- Initial Theory settings:
  - Same settings as for HERAPDF1.0 has been used [JHEP 1001:109, 2010]:
    - NLO DGLAP [QCDNUM package], RT scheme
  - Fitted PDFs:
    - uval, dval, g, Ubar=ubar+cbar, Dbar=dbar+sbar
      - Sea=Ubar+Dbar
      - sbar=s=fsDbar=dbar fs/(1-fs) with fs=0.31 at starting scale
    - Impose the fermion and momentum sum rules
    - One B parameter for sea and one for valence

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

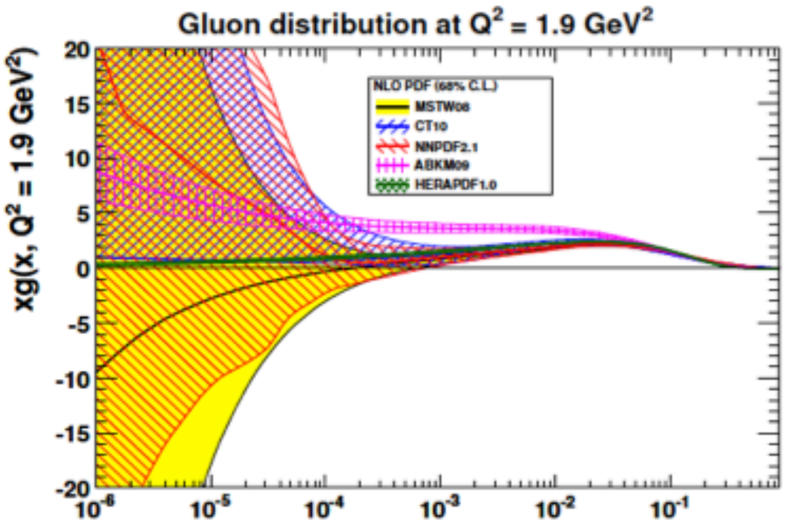
→ LHAPDF grid

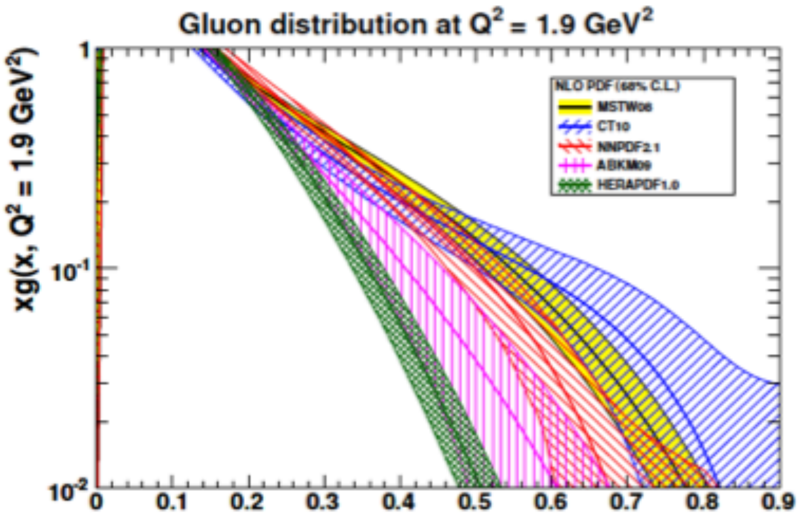
Valence distribution

- Current knowledge is limited at high x:
  - Lumi barrier
  - challenging systematic
  - nuclear effects
- LHeC could improve the knowledge of the valence at high x to 5% precision

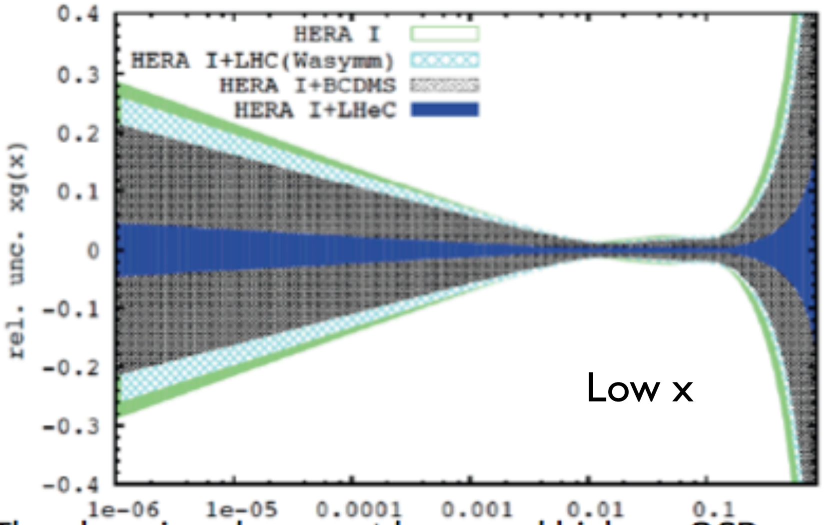


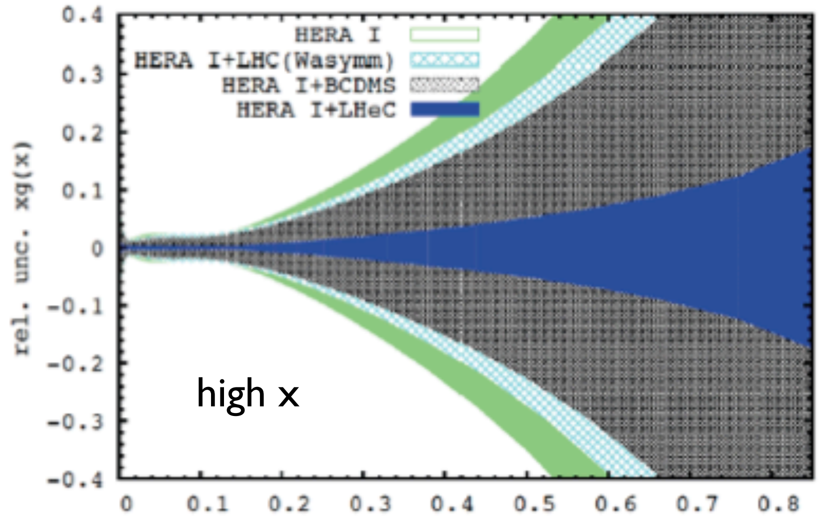
Gluon PDF





QCD fit analysis (default: NC,CC, LHeC only, following HERAPDF) with full experimental errors



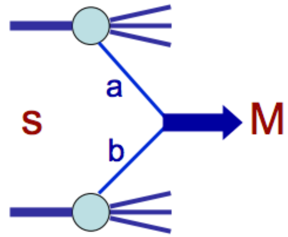


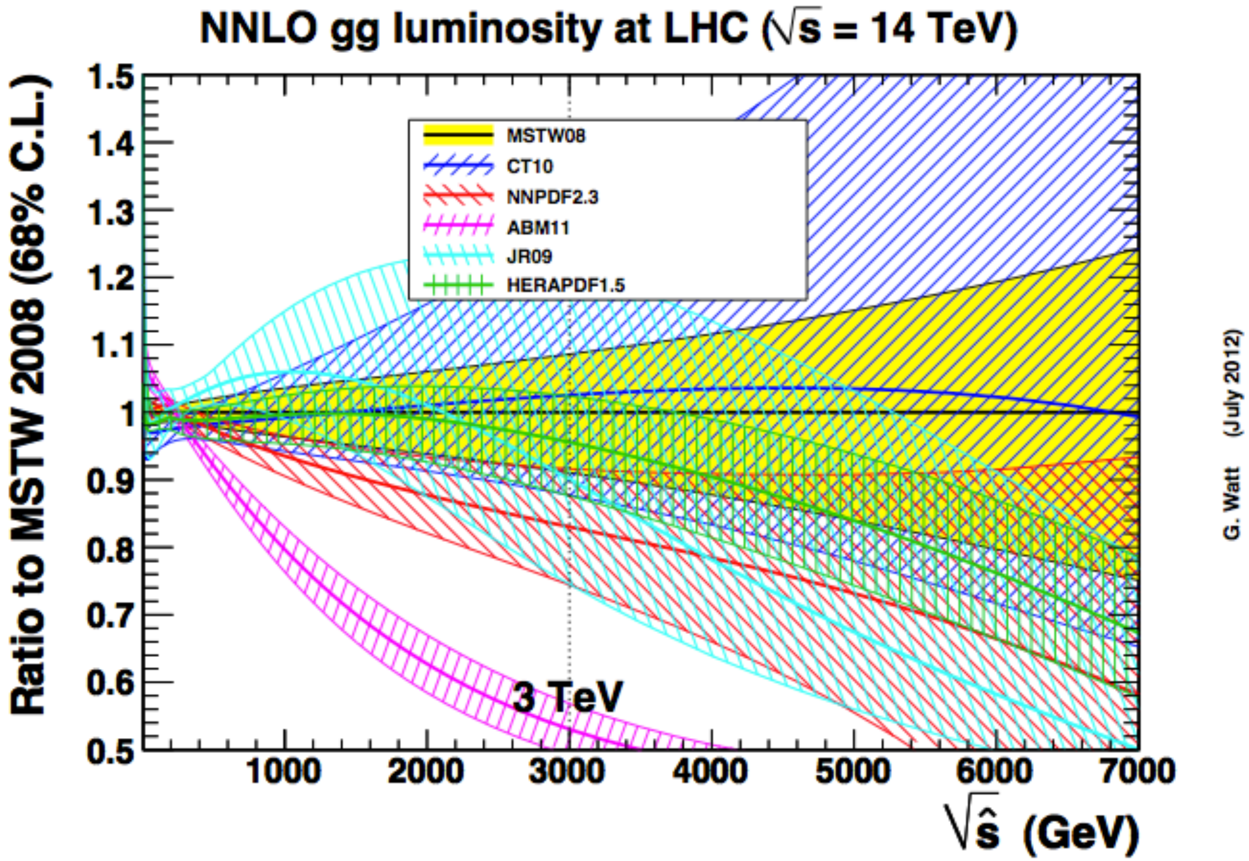
The gluon is unknown at low x and high x – QCD: non-linear evolution, resummation. BSM: hi M – HL-LHC!

Gluon-Gluon Luminosity

- Parton parton luminosity functions provide an easy way to assess the uncertainty on cross sections due to uncertainties in the pdfs

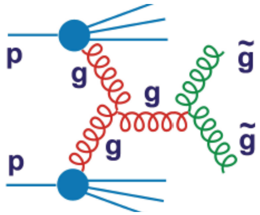
$$\frac{\partial \mathcal{L}_{ab}}{\partial \tau} = \int_{\tau}^{1} \frac{dx}{x} f_a(x, Q^2) f_b(\tau/x, Q^2)$$

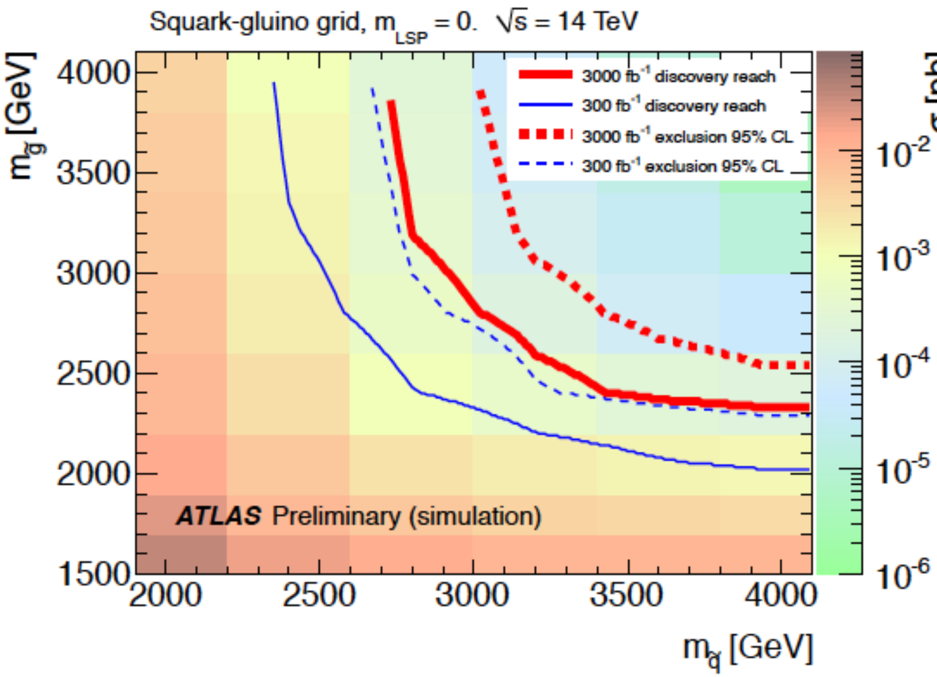


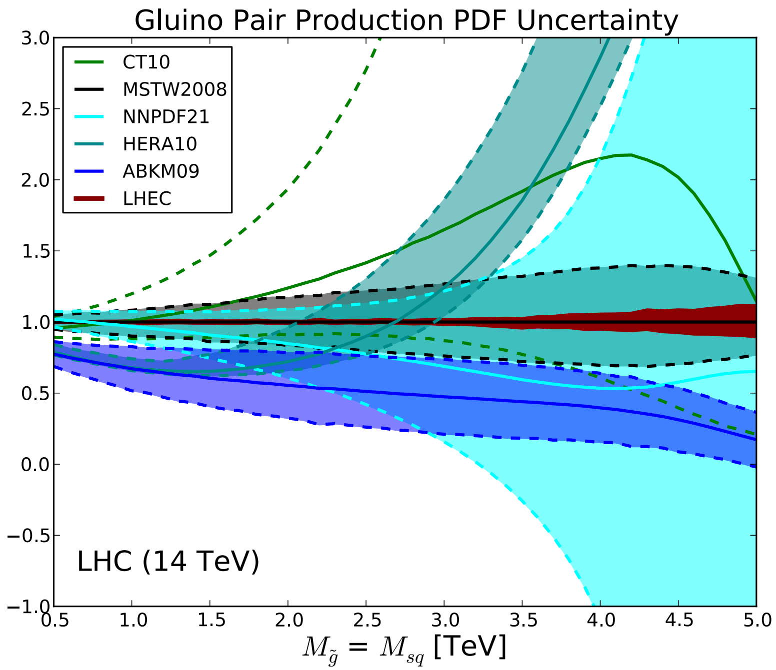


- gg luminosity is a measure of the gluino pair production – one of the interesting SUSY channels with high masses accessible in the HL-LHC phase.

LHeC and the HL-LHC (SUSY searches)





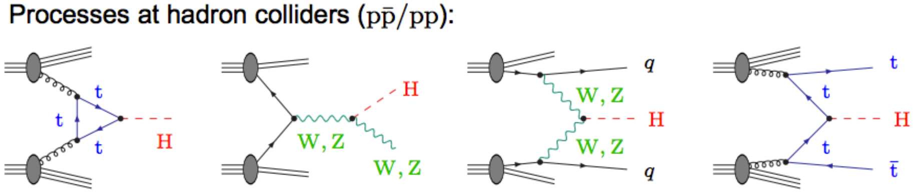


With high energy and luminosity, the LHC search range will be extended to high masses, up to 5 TeV in pair production. At correspondingly high x (> 0.5) the PDFs are unknown to a considerable extent

The HL-LHC (search) programme requires a much more precise understanding of QCD, which the LHeC provides (strong coupling, gluon, valence, factorisation, saturation, diffraction..)

Higgs at LHeC

- The preferred channel for low mass Higgs is in the bbar decay (BR 60%), but at LHC the Hbbar couplings are challenging



- At the LHeC the Higgs boson it is cleanly produced via ZZ or WW fusion and it is complementary to the dominant gg fusion at pp

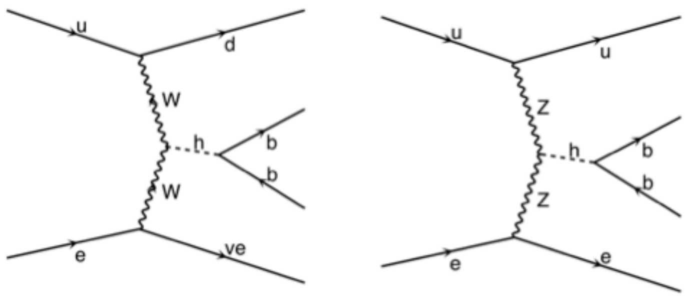
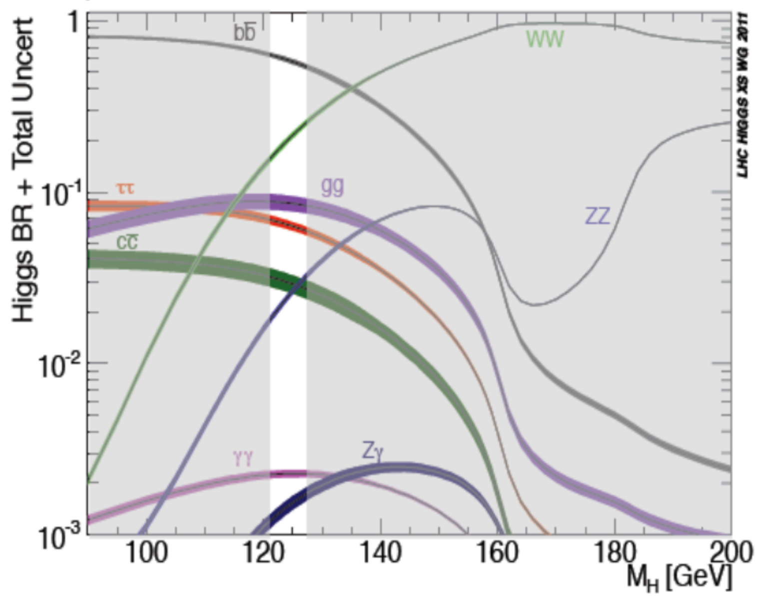
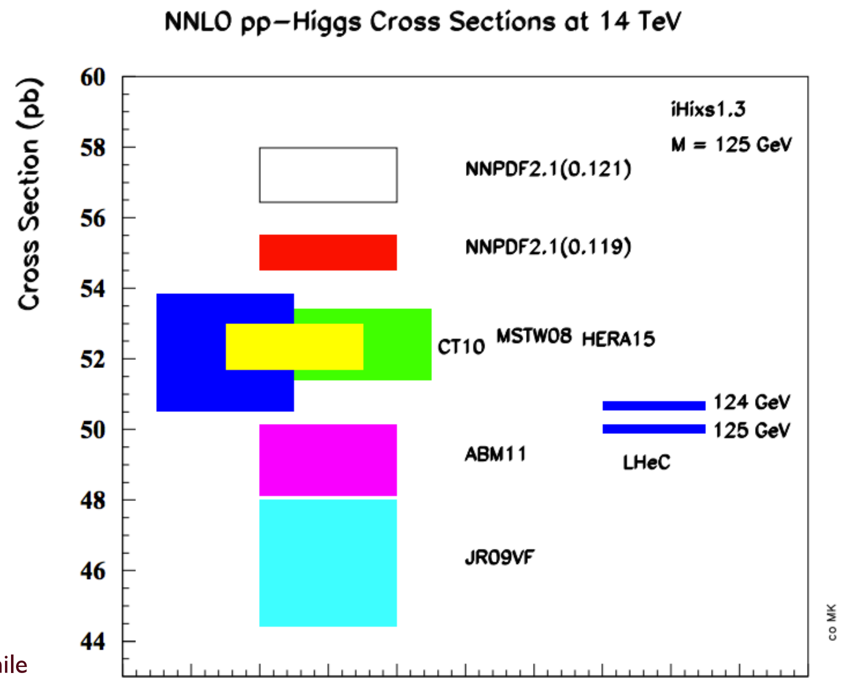


Figure 5.25: Feynman diagrams for CC (left) and NC (right) Higgs production in leadin order QCD at the LHeC. Diagrams produced using MadGraph.

14 TeV gg → H total cross section at the LHC calculated for a variety of PDFs at 68% CL

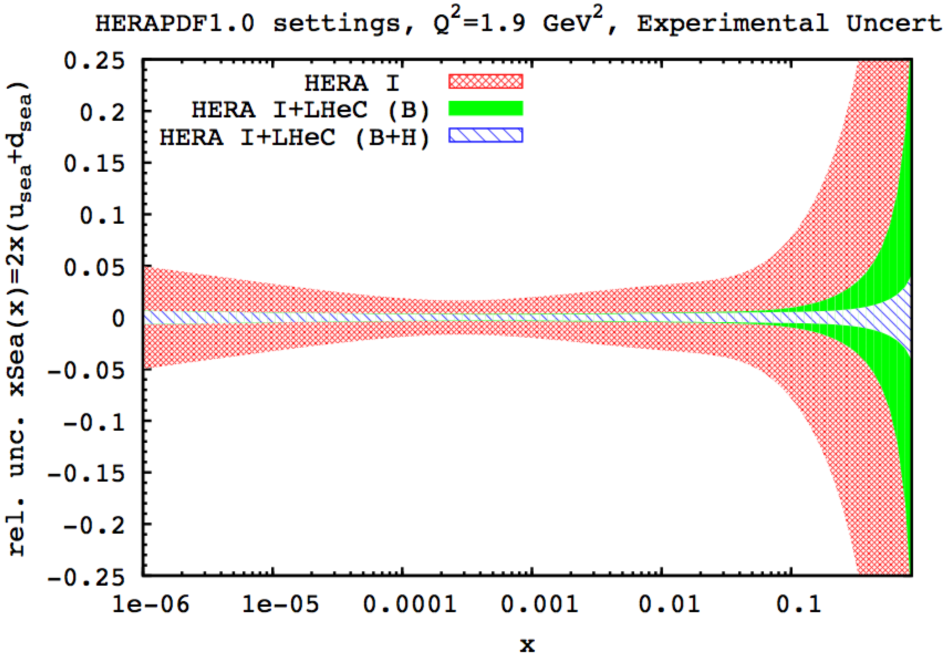
- precision from LHeC can add a very significant constraint on the mass of the Higgs

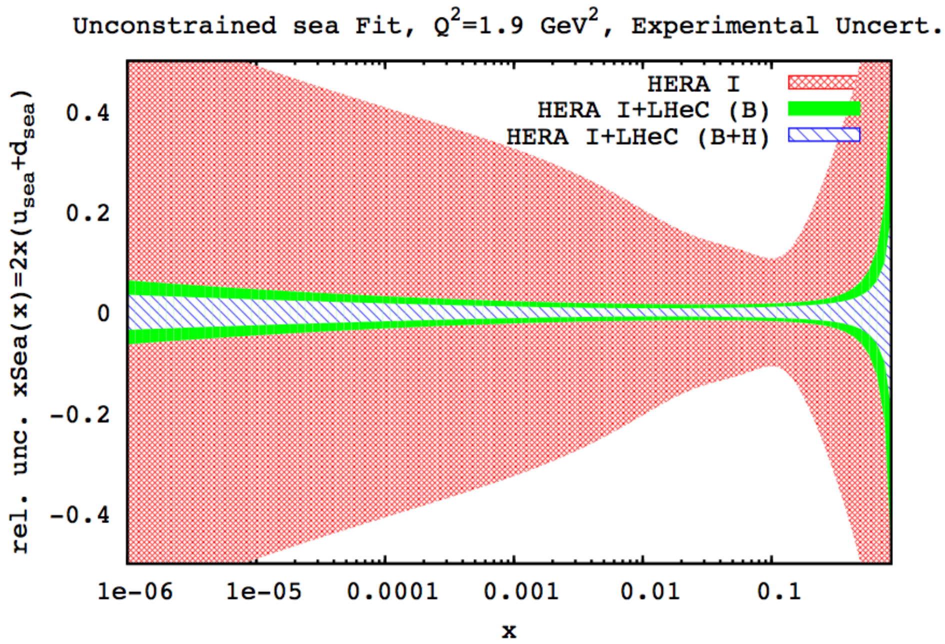




Unconstrained setting at low x

- Usual assumptions for light quark decomposition at low x may not necessary hold.
- Relaxing the assumption at low x that **u=d** , we observe that uncertainties escalate:

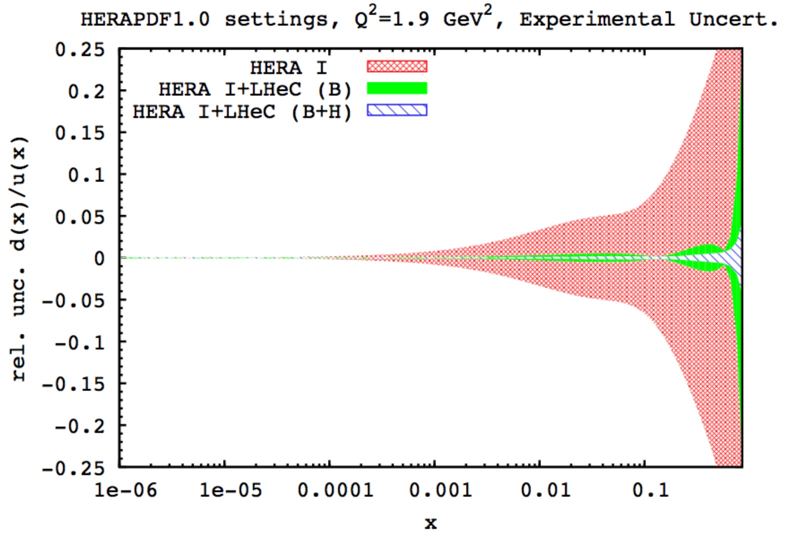


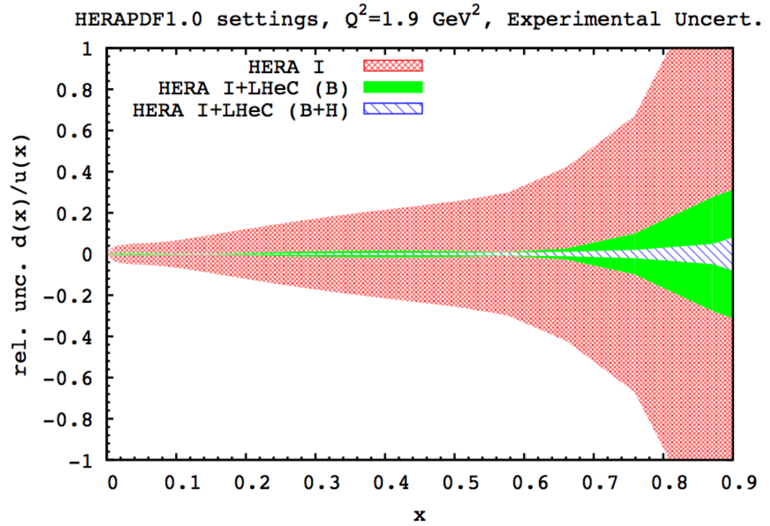


- One can see that for HERA data, if we relax the low x constraint on u and d, the errors are increased tremendously!
- However, when adding the LHeC simulated data, we observe that uncertainties are visibly improved even without this assumption.

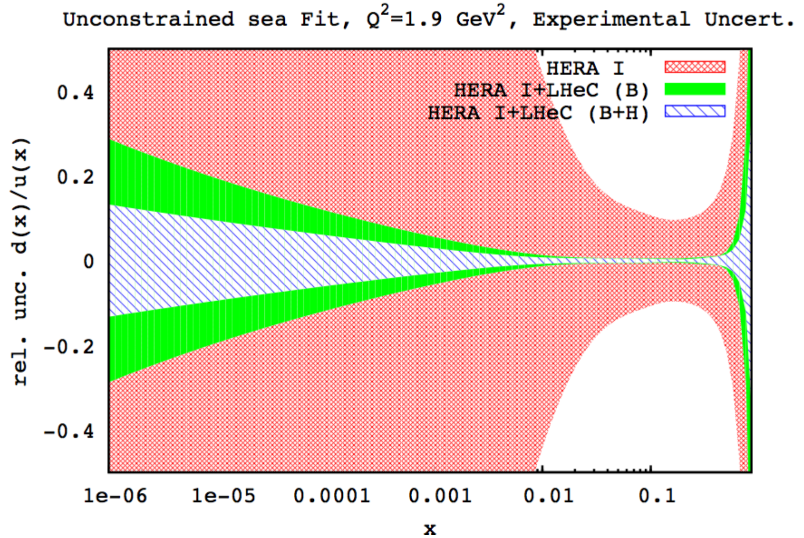
Impact on d/u ratios

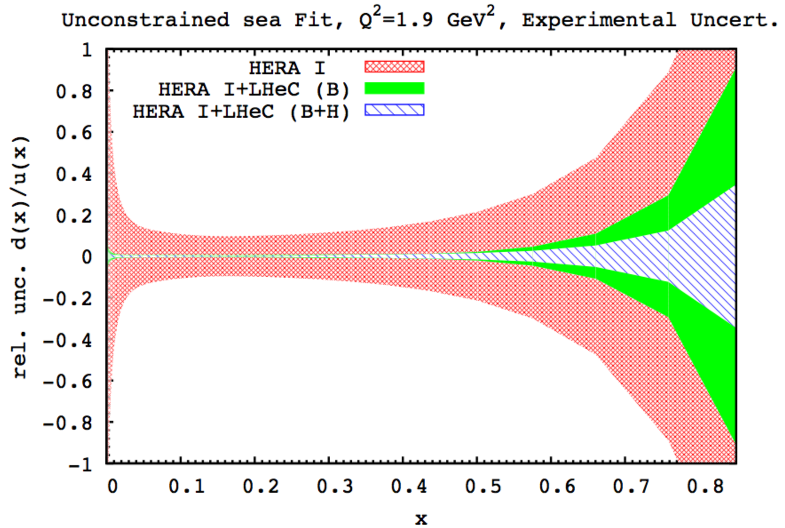
- Constrained decomposition:





- Unconstrained sea decomposition:





Releasing further PDF constraints

- Releasing further the assumptions:

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

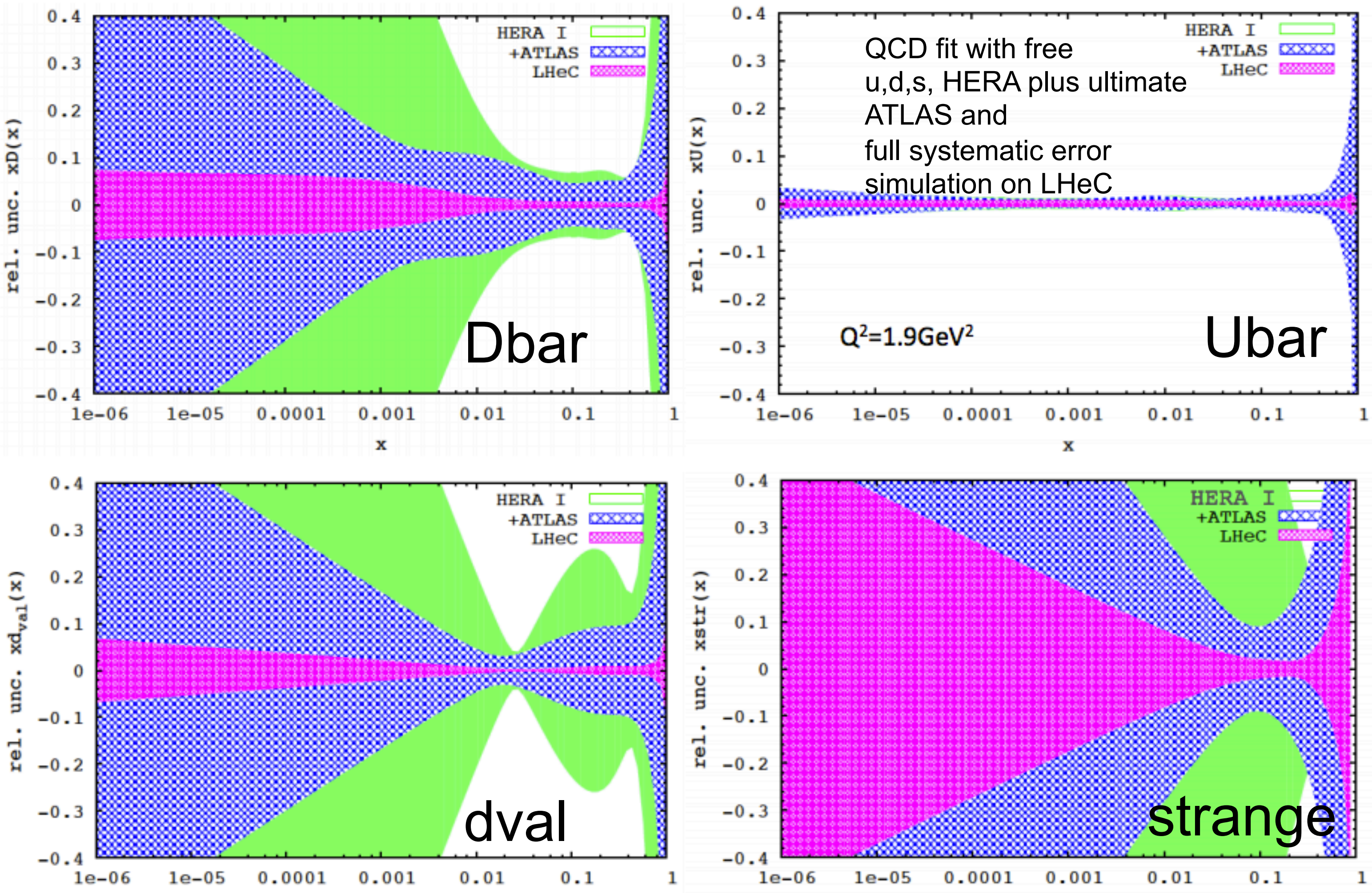
→

$$\begin{aligned} xg(x) &= A_g x^{B_g}(1-x)^{C_g}(1+D_g x), \\ xu_v(x) &= A_{u_v} x^{B_{u_v}}(1-x)^{C_{u_v}}(1+E_{u_v}x^2), \\ xd_v(x) &= A_{d_v} x^{B_{d_v}}(1-x)^{C_{d_v}}, \\ x\overline{u}(x) &= A_{\overline{u}} x^{B_{\overline{u}}}(1-x)^{C_{\overline{u}}}, \\ x\overline{d}(x) &= A_{\overline{d}} x^{B_{\overline{d}}}(1-x)^{C_{\overline{d}}}, \\ xs(x) &= r_s A_s x^{B_s}(1-x)^{C_s} \end{aligned}$$

  - Removing the correlation that ubar=dbar at low x
  - Free parameters for the strange quark are introduced

  - This study was driven by the recent ATLAS results on strange determination, hence we have repeated the impact of LHeC study under the new conditions.

Releasing assumptions: PDFs from HERA+LHC and LHeC

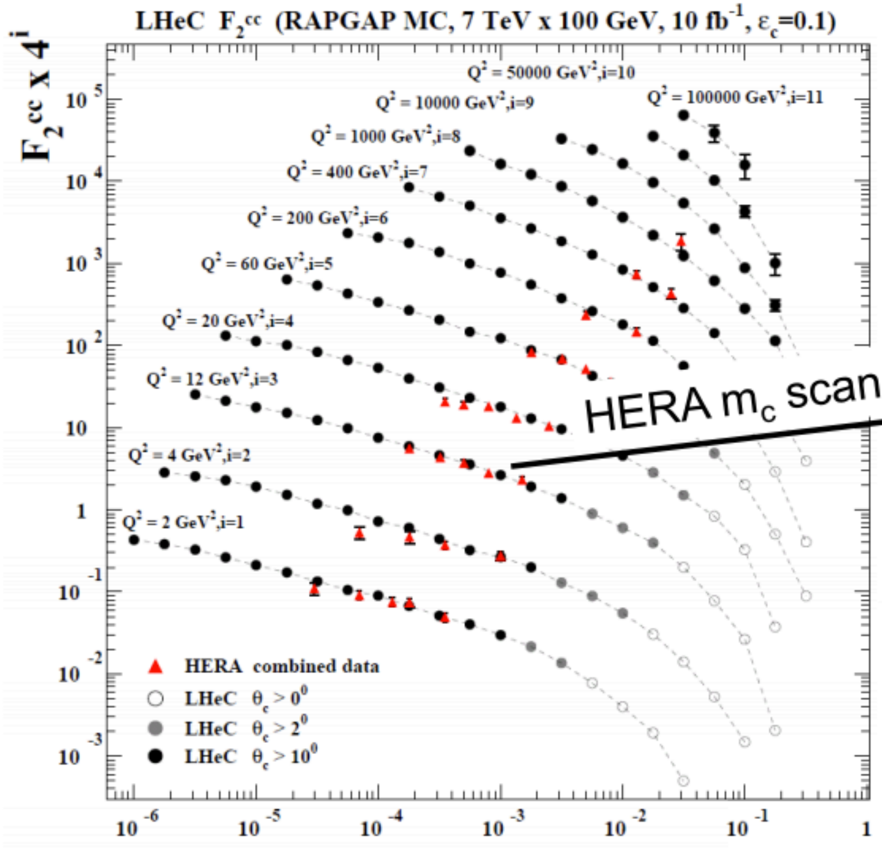


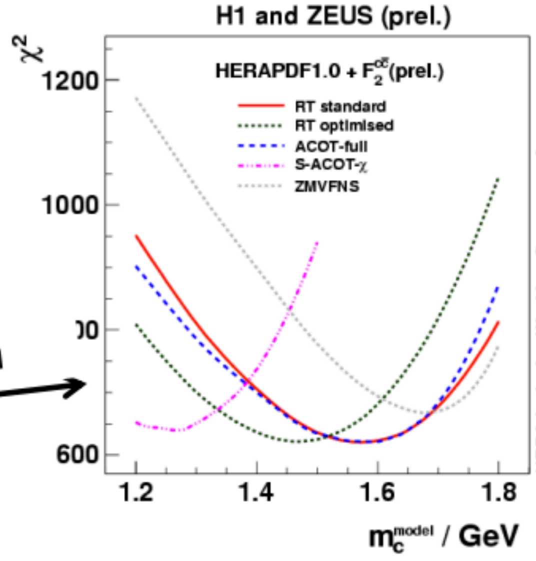
Inclusive LHeC data leads to very precise determination of all PDFs even after removing large bulk of assumptions:

- LHeC ep data constrain better U than D distributions, however deuteron data would symmetrise our understanding.
- Determination of the strange can complement the strange determination from the charm data

Heavy Quarks

- Charm production



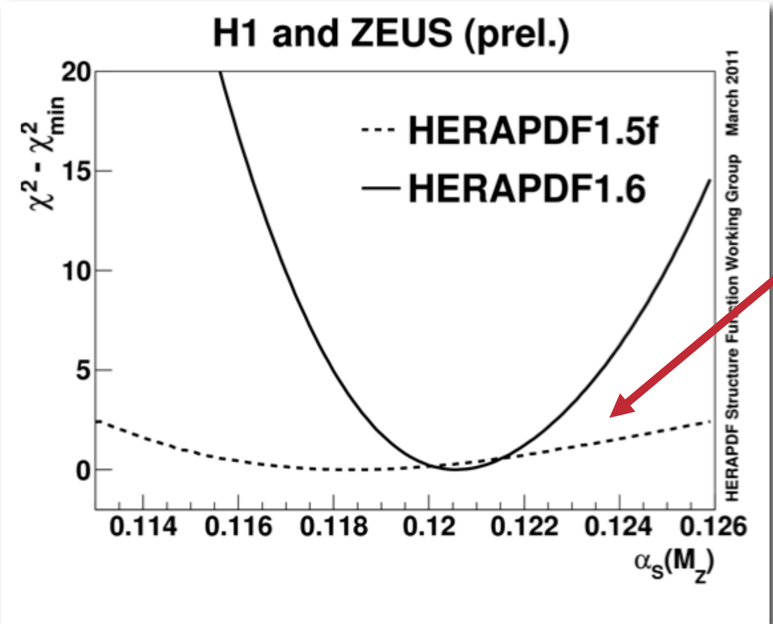


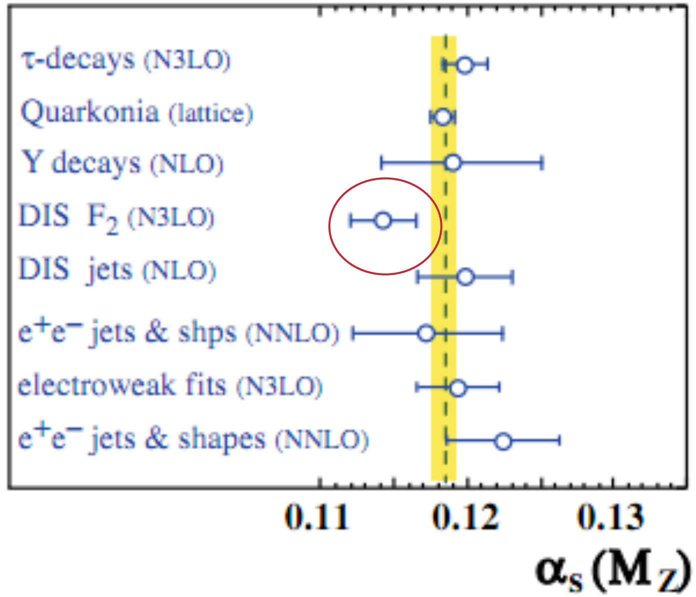
LHeC: Huge phasespace extension and high precision
→ ultraprecise m_c

Data input	Experimental uncertainty on m_c [MeV]
HERA: NC+CC	100
HERA: NC+CC+ F_2^{cc}	60
LHeC: NC+CC	25
LHeC: NC+CC+ F_2^{cc}	3

Precise Alphas from DIS at the LHeC

- Strong coupling from DIS processes still seem to prefer smaller values
  - Recent results from HERA show that even with precise HERA data one has to rely on jet measurements in order to constrain gluon PDFs





The determination of the strong coupling at the LHeC could solve this ambiguity.

(current knowledge is of order 1%, described in CDR)

Expected precision on alphas(Mz) from DIS

- A dedicated study to determine the accuracy of alphas from the LHeC was performed using for the central values the SM prediction smeared within its uncertainties assuming Gauss distribution and taking into account correlations.

case	cut [Q^2 in GeV^2]	α_S	$\pm$uncertainty	relative precision in %
HERA only (14p)	$Q^2 > 3.5$	0.11529	0.002238	1.94
HERA+jets (14p)	$Q^2 > 3.5$	0.12203	0.000995	0.82
LHeC only (14p)	$Q^2 > 3.5$	0.11680	0.000180	0.15
LHeC only (10p)	$Q^2 > 3.5$	0.11796	0.000199	0.17
LHeC only (14p)	$Q^2 > 20.$	0.11602	0.000292	0.25
LHeC+HERA (10p)	$Q^2 > 3.5$	0.11769	0.000132	0.11
LHeC+HERA (10p)	$Q^2 > 7.0$	0.11831	0.000238	0.20
LHeC+HERA (10p)	$Q^2 > 10.$	0.11839	0.000304	0.26

Table 4.4: Results of NLO QCD fits to HERA data (top, without and with jets) to the simulated LHeC data alone and to their combination. Here 10p or 14p denotes two different sets of parametrisations, one, with 10 parameters, the mimimum parameter set used in [38] and the other one with four extra parameters added as has been done for the HERAPDF1.5 fit. The central values of the LHeC based results are obviously of no interest. The result quoted as relative accuracy includes all the statistical and the systematic error sources taking correlations as from the energy scale uncertainties into account.

LHeC promises per mille accuracy on alphas!

Summary

- LHC can provide information on PDF decomposition, additional constrains on anti-quark density.
  - Measurements at high pT, high invariant masses, sensitive to new physics effects, have significant PDF uncertainties.

- The LHeC is a challenging but realistic project with many attractive features in its physics program, its accelerator and detector developments.
  - LHeC could provide stringent constraints on PDF both at high and low x: mix of high/low energy improves precision by better coverage at high x, hence better flavour decomposition
  - LHeC could also address the question of the strong coupling from DIS inclusive data

➔ LHeC represents a natural extension to LHC

- Gluon

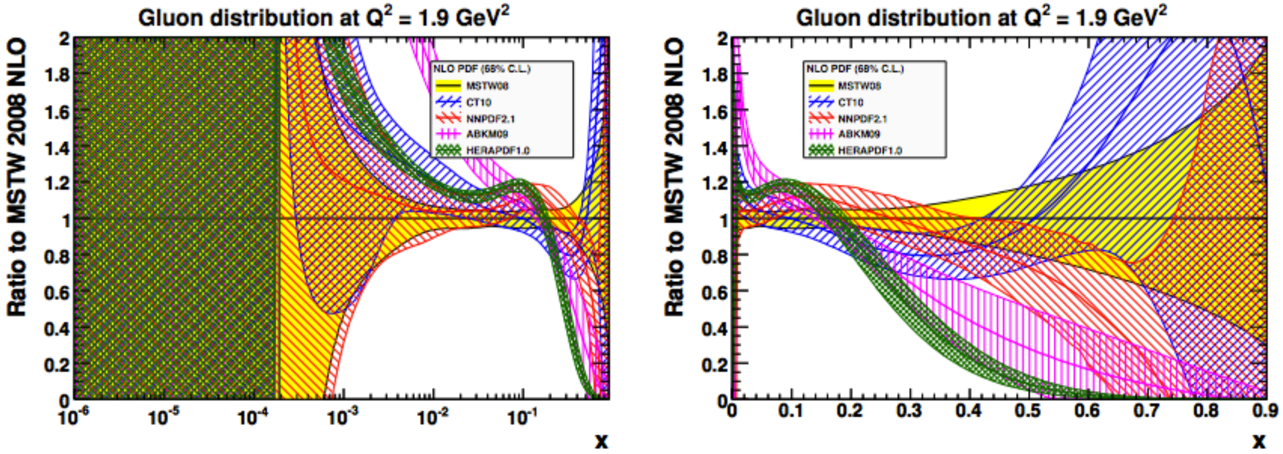


Figure 4.17: Ratios to MSTW08 of gluon distribution and uncertainty bands, at $Q^2 = 1.9\,\mathrm{GeV}^2$, for most of the available recent PDF determinations. Left: logarithmic x, right: linear x.

- Strange

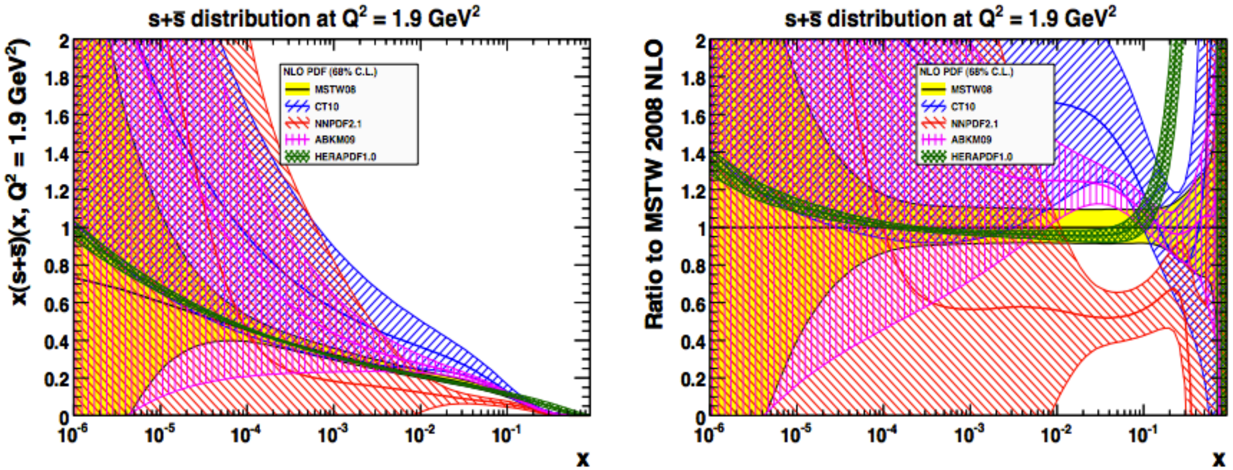


Figure 4.12: Sum of the strange and anti-strange quark distribution as embedded in the NLO QCD fit sets as noted in the legend. Left: $s + \bar{s}$ versus Bjorken x at $Q^2 = 1.9\,\mathrm{GeV}^2$; right: ratio of $s + \bar{s}$ of various PDF determinations to MSTW08. In the HERAPDF1.0 analysis (green) the strange quark distribution is assumed to be a fixed fraction of the down quark distribution which is conventionally assumed to have the same low x behaviour as the up quark distribution, which results in a small uncertainty of $s + \bar{s}$.

Motivation for LHeC

- What HERA could/did not do:

Test of the isospin symmetry (u-d) with eD	no deuterons
Investigation of the q-g dynamics in nuclei	no time for eA
Verification of saturation prediction at low x	too low c.o.m energy
Measurement of the strange quark distribution	too low Luminosity
Discovery of Higgs in WW fusion in CC	too low cross section
Study of top quark distribution in the proton	too low c.o.m energy
Precise measurement of FL	too short running time with low energy runs
Resolving d/u question at large Bjorken x	too low Luminosity
Determination of gluon distribution at hi/lo x	too small range
High precision measurement of α_s	overall not precise enough

HEP needs a TeV energy scale machine with 100 times higher luminosity than HERA to develop DIS physics further and to complement the physics at the LHC. The Large Hadron Collider p and A beams offer a unique opportunity to build a second ep and first eA collider at the energy frontier.

(M. Klein)

ATLAS recent result on strange:

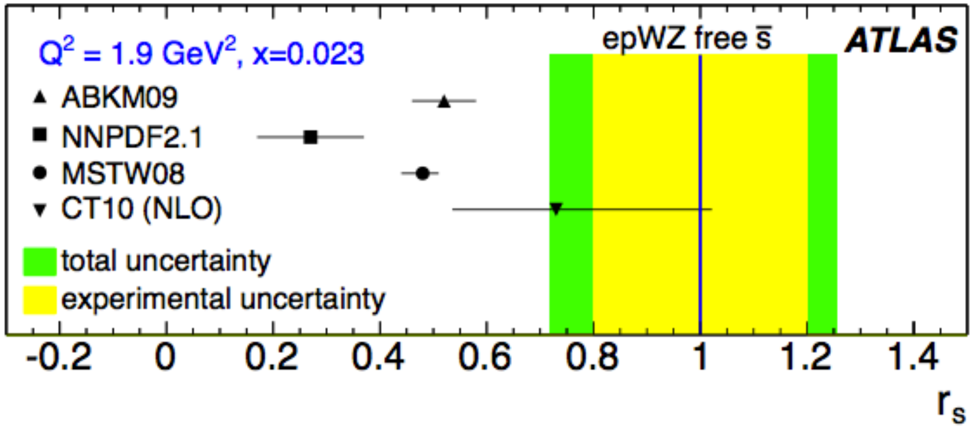


FIG. 2. Predictions for the ratio $r_s = 0.5(s + \bar{s})/\bar{d}$, at $Q^2 = 1.9\,\mathrm{GeV}^2$, $x = 0.023$. Points: global fit results using the PDF uncertainties as quoted; bands: this analysis; inner band, experimental uncertainty; outer band, total uncertainty.

The result on r_s, Eq. 2, evolves to

$$r_s = 1.00 \pm 0.07_{\mathrm{exp}} \pm 0.03_{\mathrm{mod}} {}^{+0.04}_{-0.06}{}_{\mathrm{par}} \pm 0.02_{\alpha_S} \pm 0.03_{\mathrm{th}} \quad (3)$$

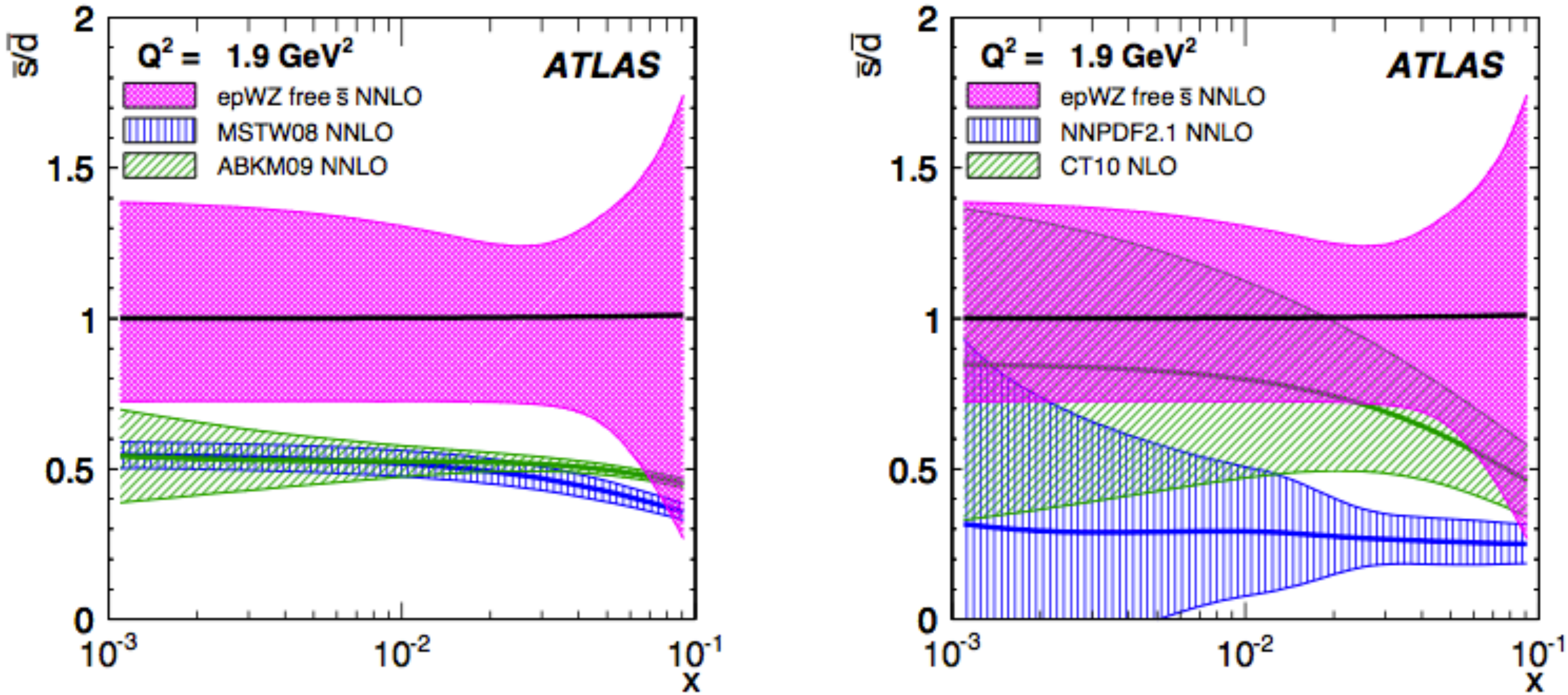
LHeC studies scenarios

Set	E_e/GeV	E_N/TeV	N	L^+/fb^{-1}	L^-/fb^{-1}	Pol
A	20	7	7	1	1	0
B	50	7	7	50	50	0.4
C	50	7	7	1	1	0.4
D	100	7	7	5	10	0.9
E	150	7	7	3	6	0.9
F	50	3.5	7	1	1	0
G	50	2.7	7	0.1	0.1	0.4
H	50	1	7	-	1	0

Table 4.2: Conditions for simulated NC and CC data sets for studies on the LHeC physics. Here, A defines a low electron beam energy option which is of interest to reach lowest Q^2 because Q^2_{min} decreases $\propto E_e^{-2}$; B is the standard set, with a total luminosity split between different polarisation and charge states. C is a lower luminosity version which was considered in case there was a need for a dedicated low/large angle acceptance configuration, which according to more recent findings could be avoided since the luminosity in the restricted acceptance configuration is estimated, from the β functions obtained in the optics design, to be half of the luminosity in the full acceptance configuration; D is an intermediate energy linac-ring version, while E is the highest energy version considered, with the luminosities as given. It is likely that the assumptions for D and E on the positron luminosity are a bit optimistic. However, even with twenty times lower positron than electron luminosity one would have 0.5 fb^{-1}, i.e. the total HERA luminosity equivalent available in option D for example. F is the deuteron and G the lead option; finally H was simulated for a low proton beam energy configuration as is of interest to maximise the acceptance at large x.

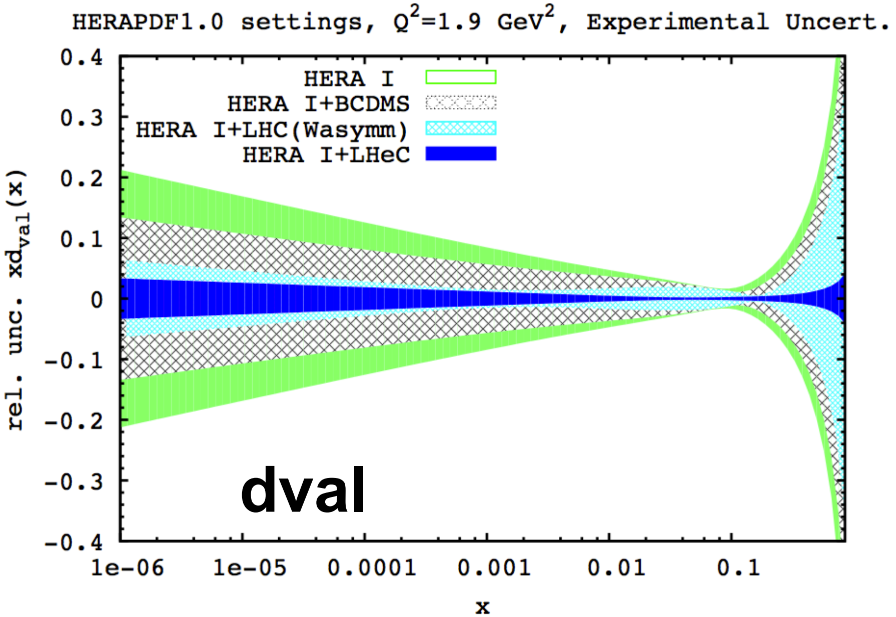
ATLAS Recent Results

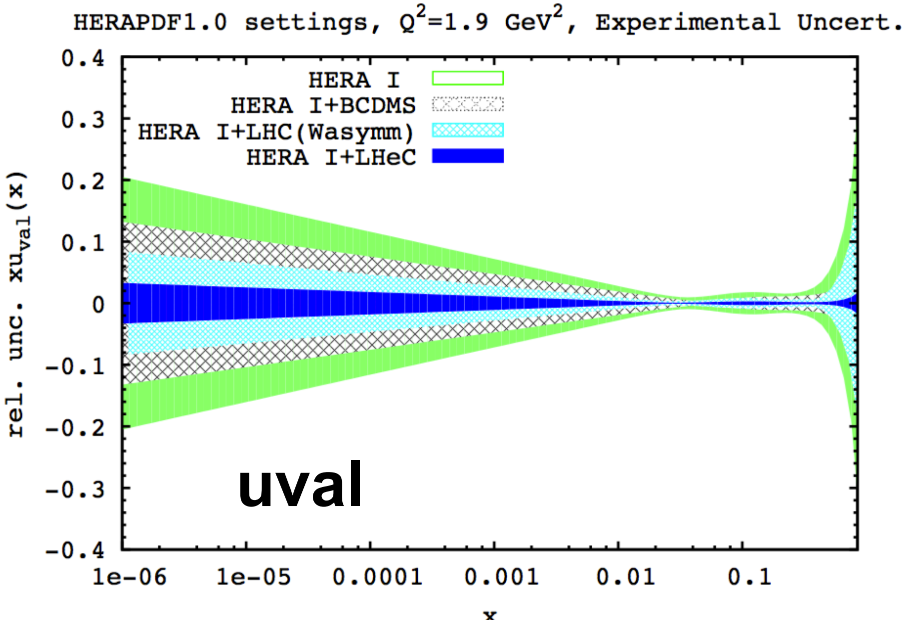
- s/d

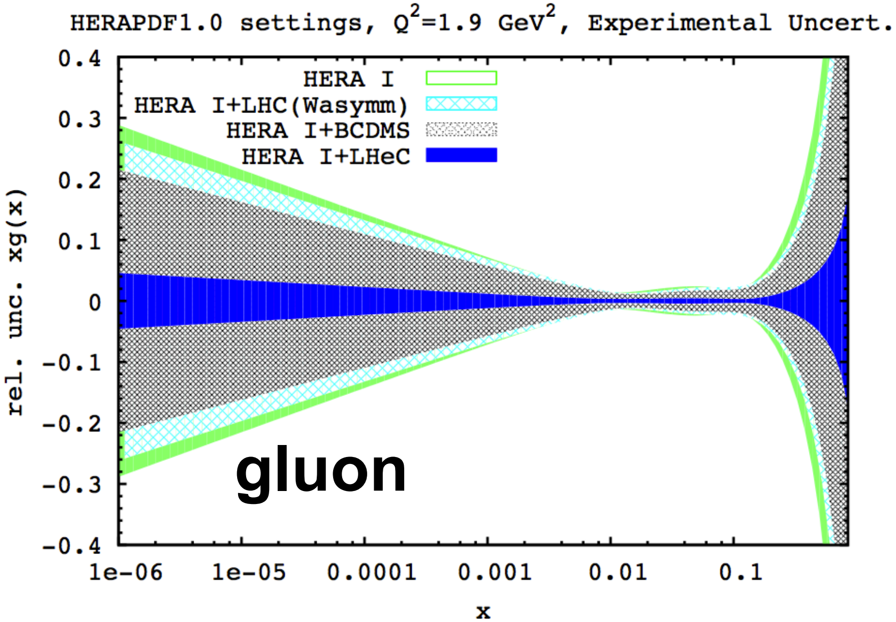


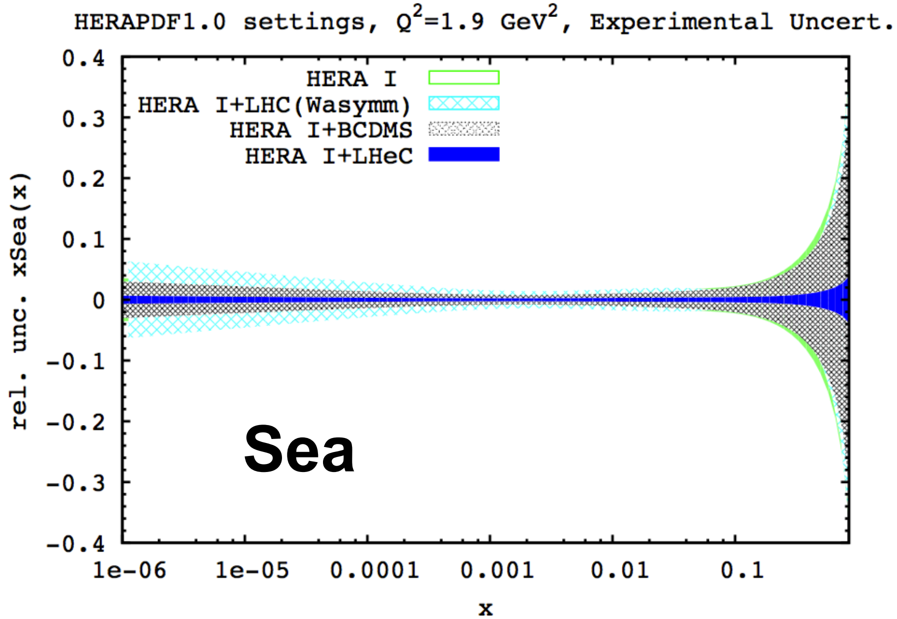
Impact of LHeC on PDFs: zoom on low x

* Experimental uncertainties are shown at the starting scale Q^2=1.9 GeV^2









Impact of LHeC on PDFs: zoom on high x

* Experimental uncertainties are shown at the starting scale $Q^2=1.9$ GeV^2