# Parton distributions in the proton from the LHeC

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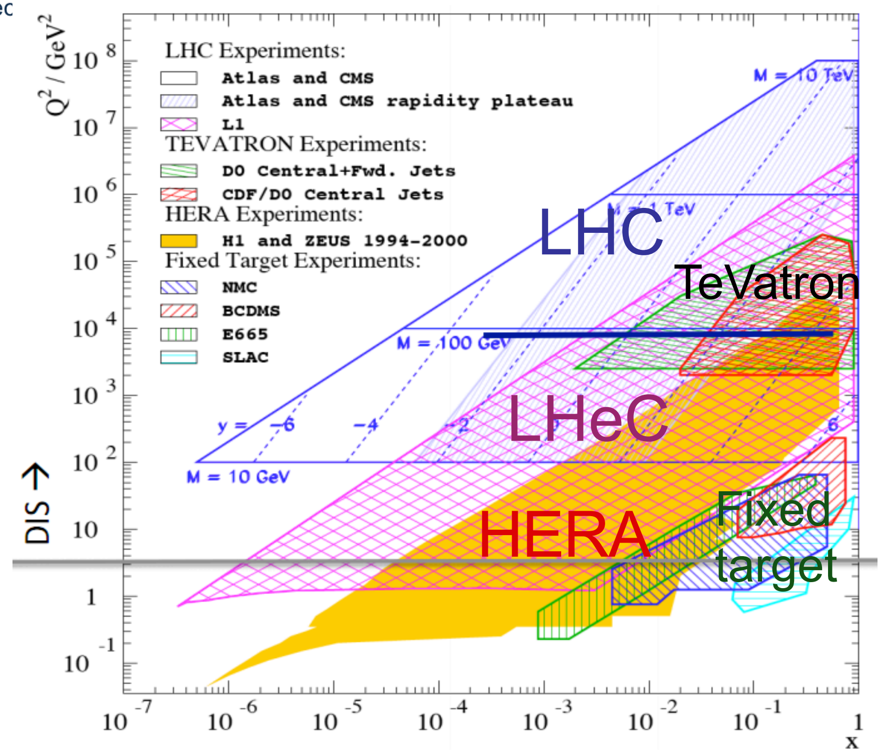
DIS2014

**Warsaw, 28 April - 2 May 2014**

XXII. International Workshop on Deep-Inelastic Scattering and Related Subjec

## Outline:

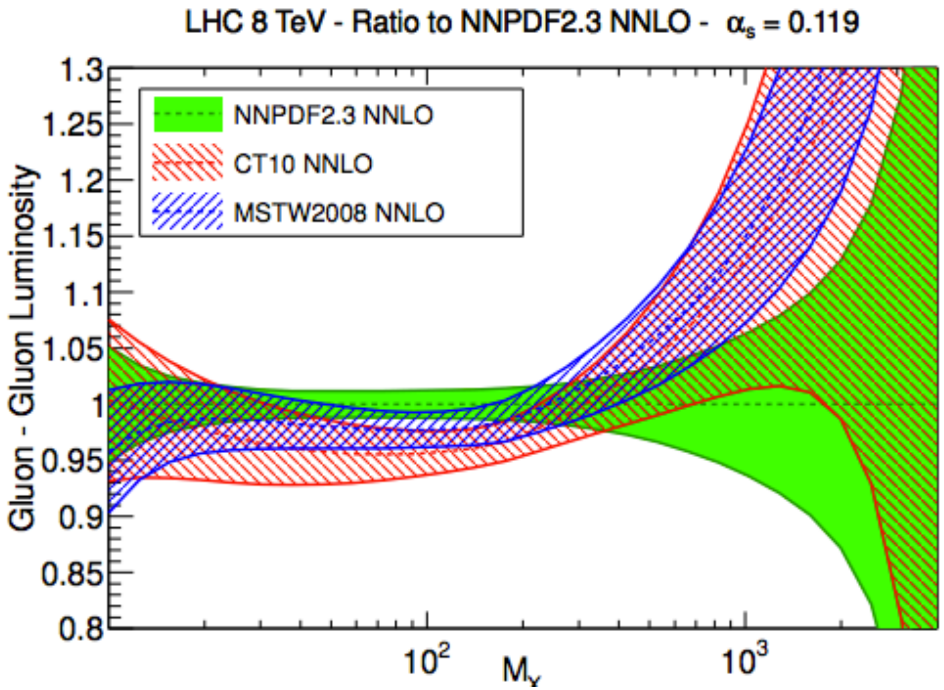
- Current Status on PDFs
- Impact of the LHeC on PDFs
- Summary



# Parton Distribution Functions

14TeV

- Current knowledge and uncertainties display differences that need to be understood and that may have substantial impact.

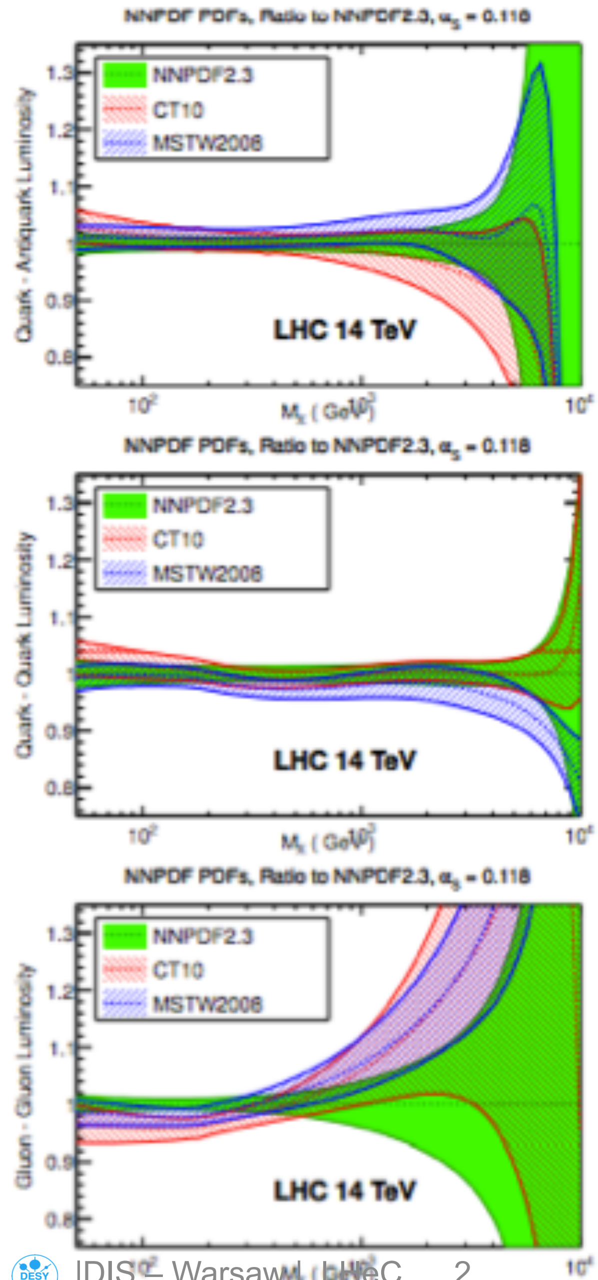



Large uncertainties at large masses degrade the prospects for eventual characterization of new BSM heavy particles

qqbar

qq

gg

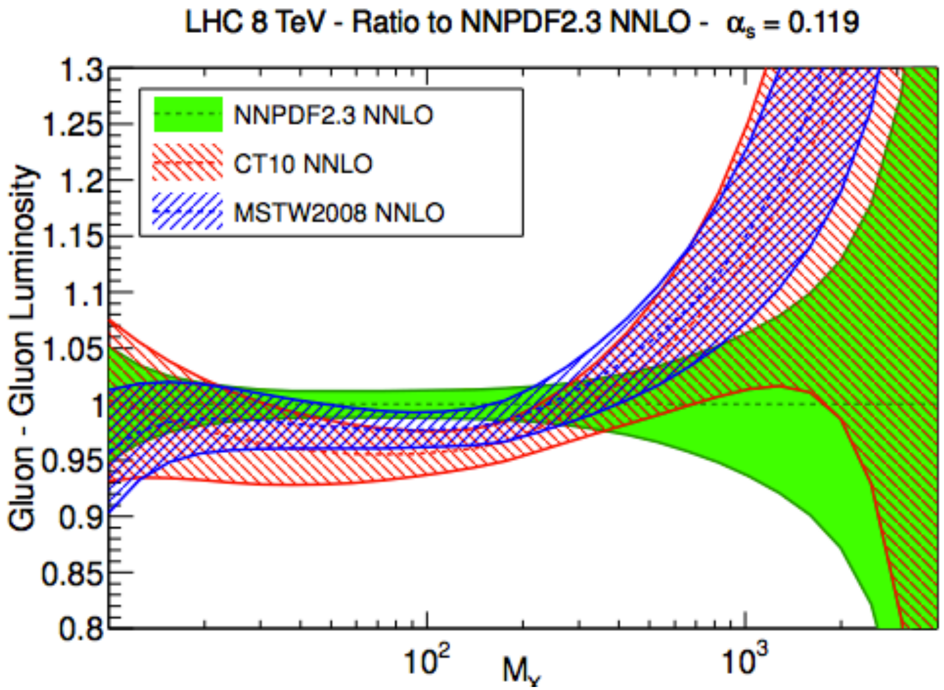


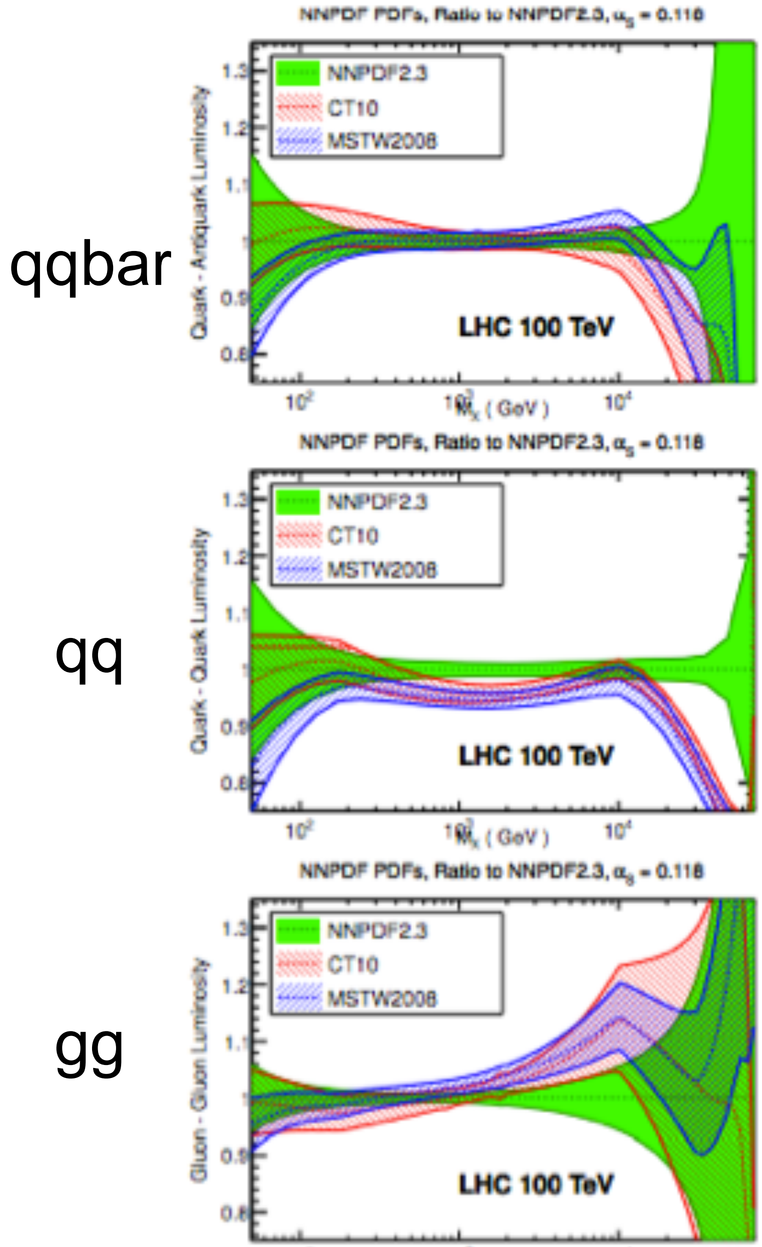

Snowmass13 QCD WG repor J.Rojo

# Parton Distribution Functions

100TeV

- Current knowledge and uncertainties display differences that need to be understood and that may have substantial impact.




Snowmass13 QCD WG repor J.Rojo

Large uncertainties at large masses degrade the prospects for eventual characterization of new BSM heavy particles

# Uncertainty of PDFs

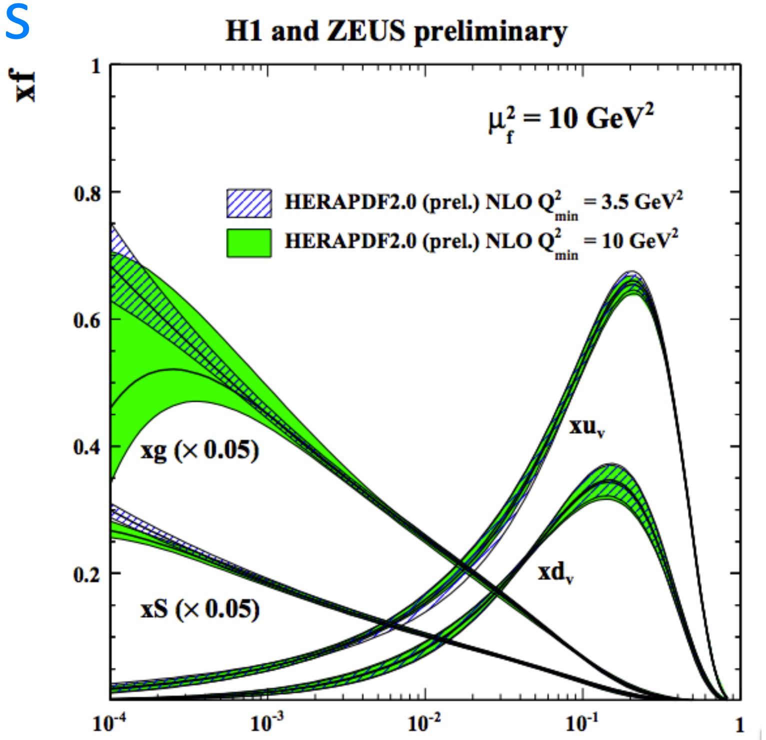
**Light Quarks:**
valence $x < 0.01$, $u_v$ $x > 0.8$, $d_v$ $x>0.6$
light sea (related to strange) -8% ATLAS/$F_2$,
light sea quark asymmetry, d/u=?
Isospin relations (en!) ??

**Strange**: unknown, =dbar? strange valence?

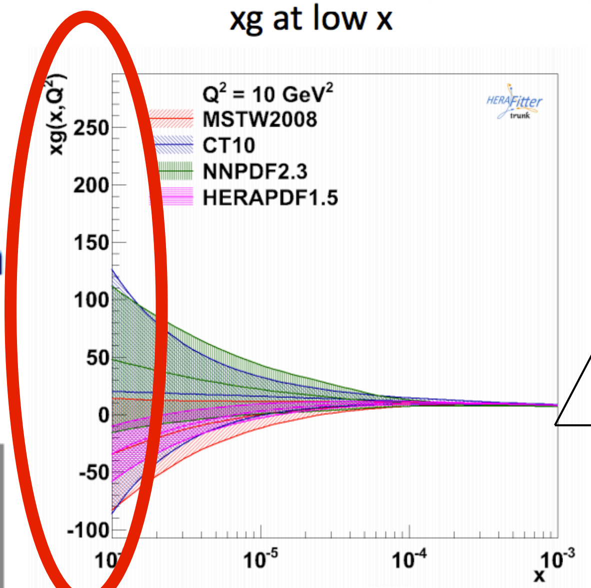
**Charm**: need high precision to % for $\alpha_s$
(recent HERA 5%)
**Beauty**: HERA 10-20%, bb → A?
**Top**: tPDF at high $Q^2$ $>M_t^2$ - unknown

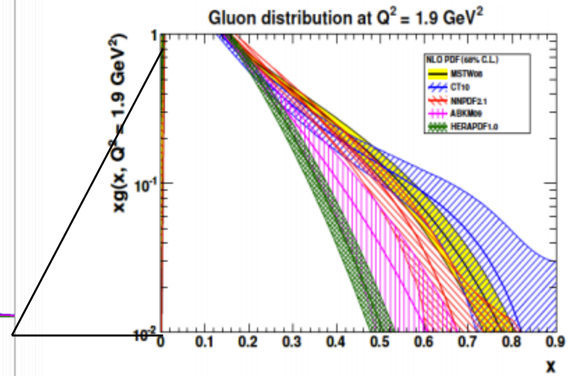
**Gluon**: low x, saturation?, high x - unknown
medium x: preciser for Higgs!
Recent review: cf E.Perez, E.Rizvi 1208.1178, in RPP

..unintegrated, diffractive, generalised, polarised, photonic, nuclear PDFs ???




xg at low x




High x

# The LHeC program

## Design Report 2012


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

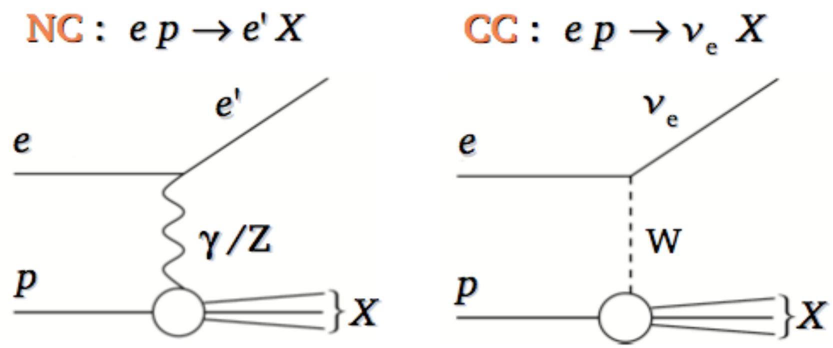
Supported by
CERN, ECFA, NuPECC

arXiv:1206:2913

Since then the proposal re-evaluated by CERN:
CERN has launched the FCC design study in which *he* is an integral part → gives the LHeC 60 GeV ERL design of a new electron accelerator, a long term perspective

# 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

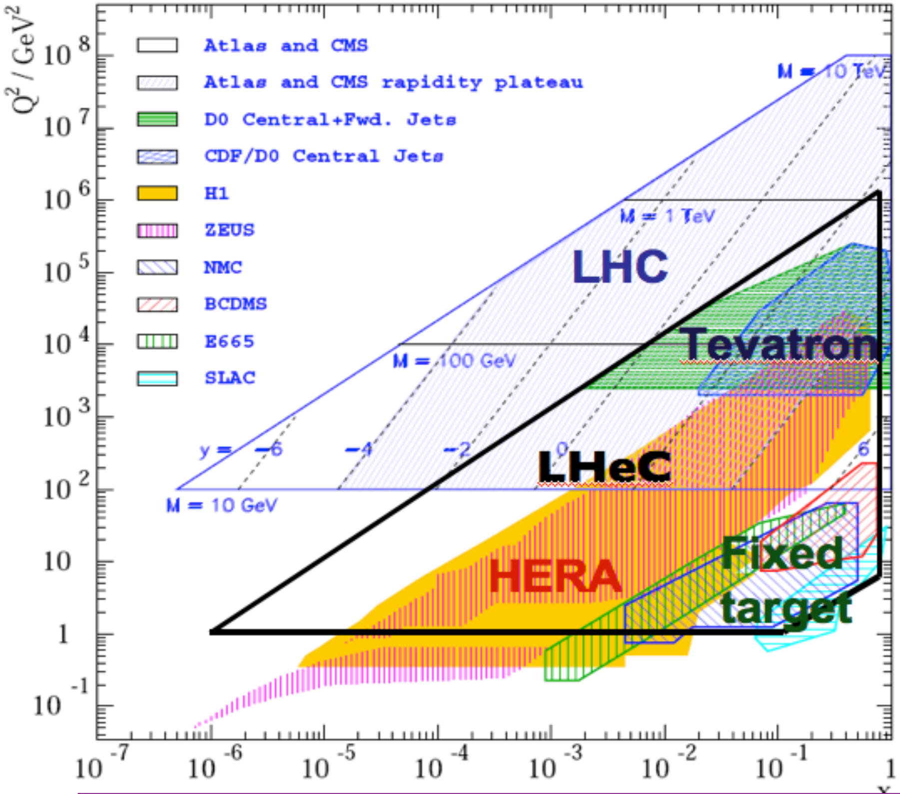
$$x = \frac{Q^2}{2p\cdot q}$$ Bjorken scaling parameter

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

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

  - Double Differential cross sections:

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




At LHeC in an extended range and precision:

- $F_2$ dominates
  - sensitive to all quarks
- $xF_3$
  - sensitive to valence quarks
- $F_L$
  - sensitive to gluons
- also we have F2yZ, sCC+, sCC-

# 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 uncertainty ranges from 0.1% (low $Q^2$) to ~10% for x=0.7 in 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 % |

# QCD Settings for the PDF determination

[HERAFitter framework] HERAFitter

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)
- Full experimental Uncertainties

Theory settings:

- 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

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

  - Impose the fermion and momentum sum rules

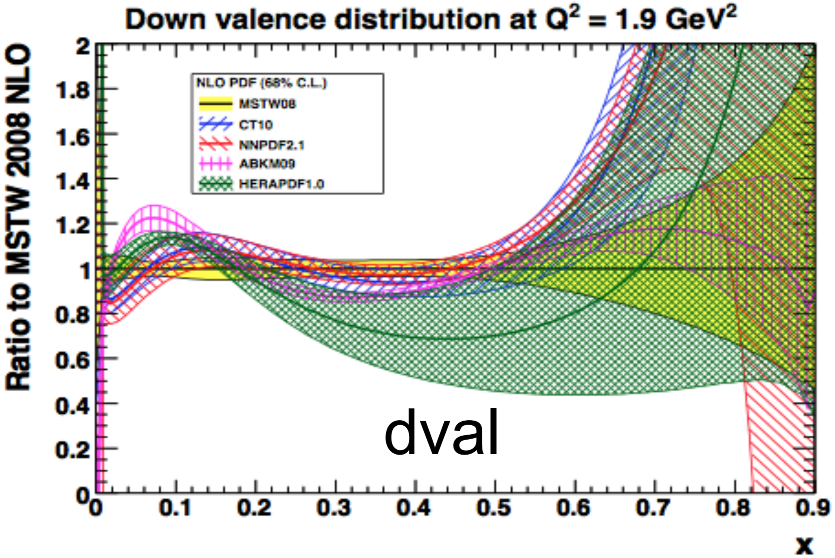
→ LHAPDF grid

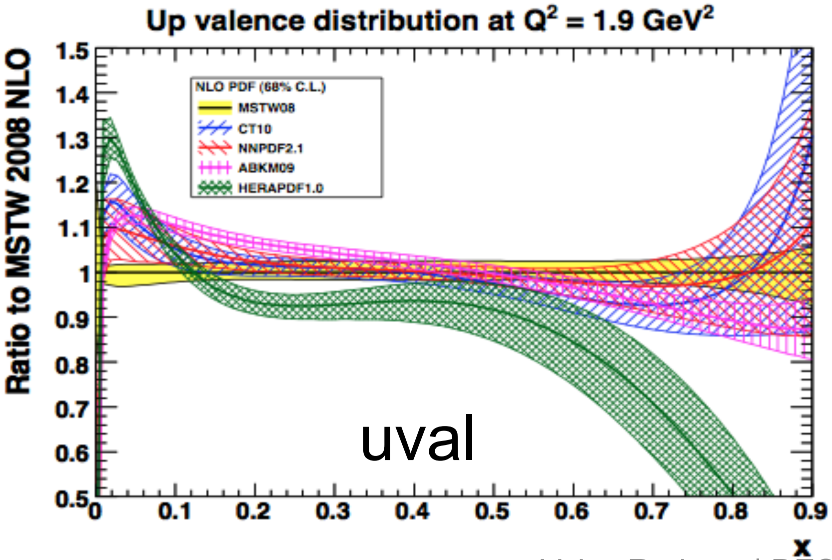
# Valence distribution

- Current knowledge is limited at high x:
  - o Lumi barrier
  - o challenging systematic
  - o nuclear effects
  - o Effects of higher twists
- LHeC could improve the knowledge of the valence at high x to a precision of:
  - o 2% (uval) x=0.8
  - o 4% (dval) x=0.8

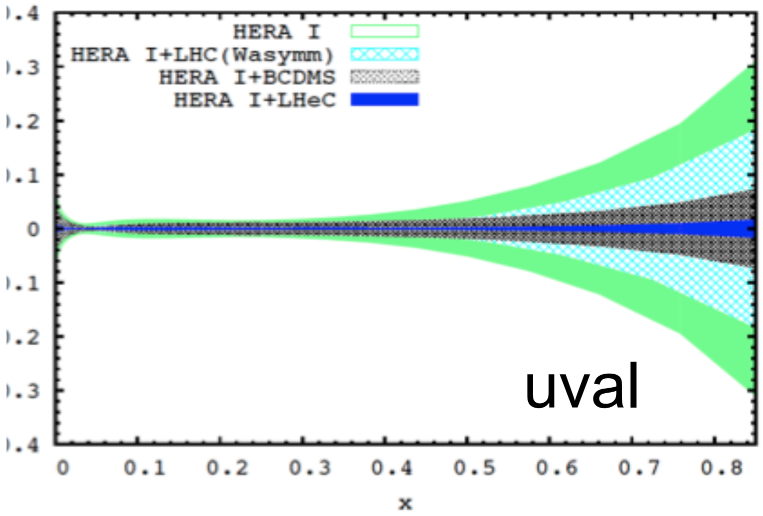
Important for d/u limit clarification

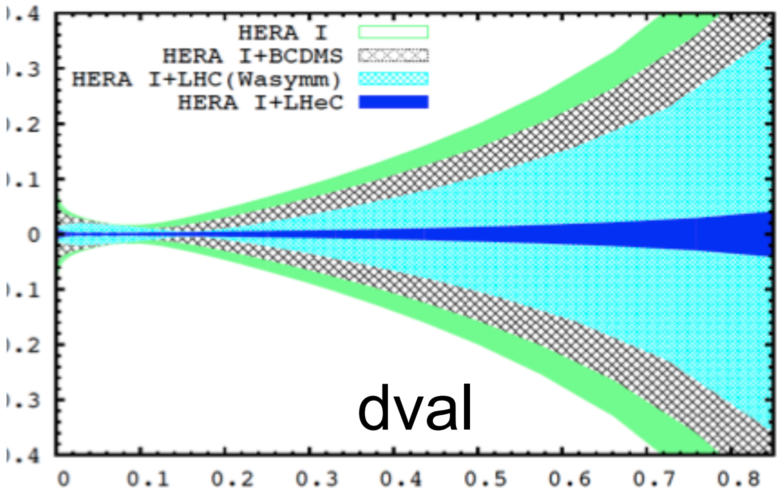
Now…



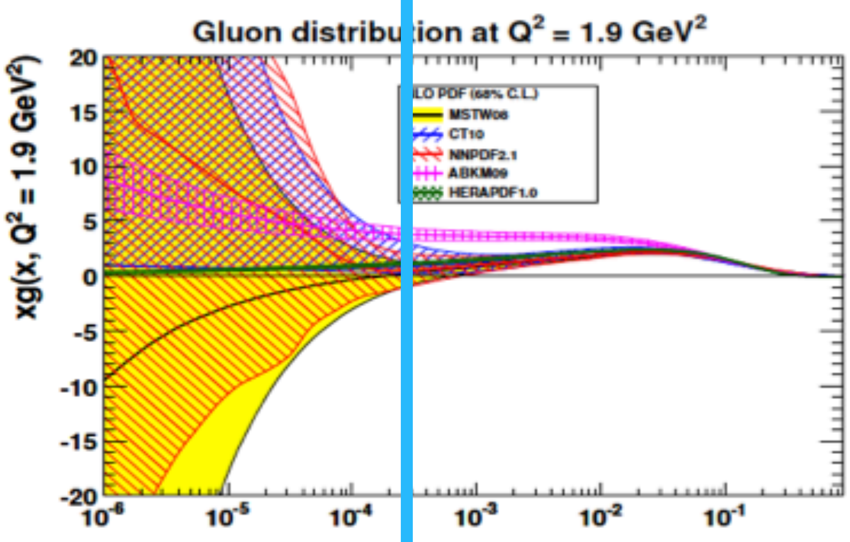

…Then

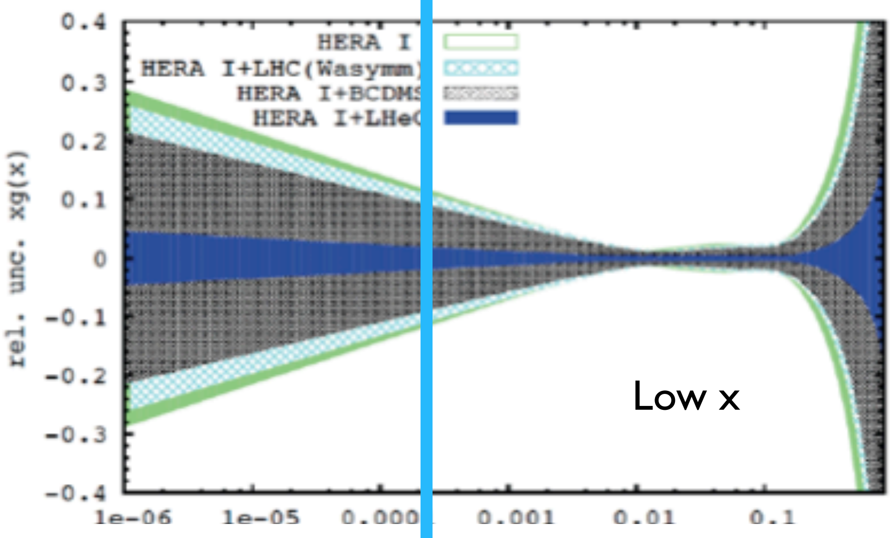


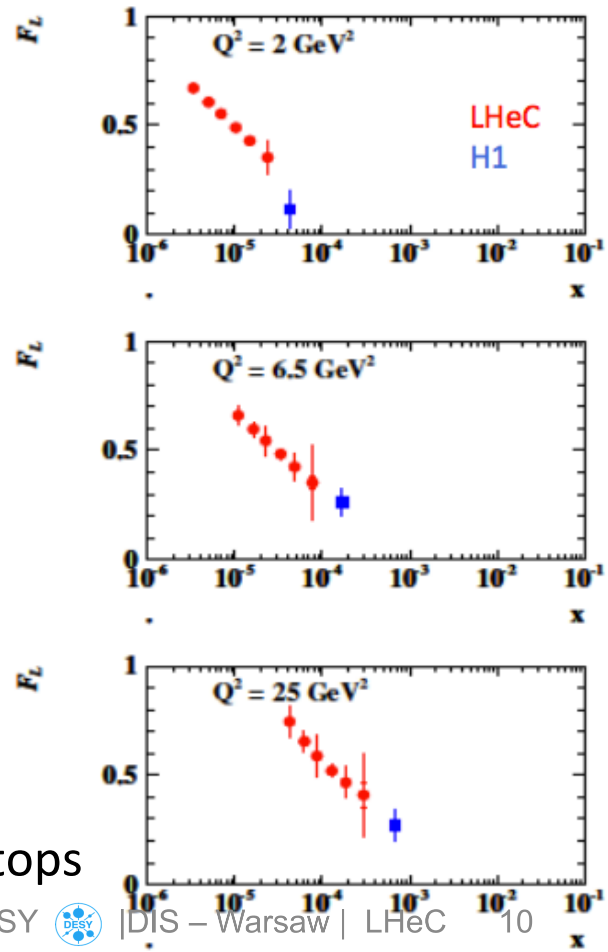



# Gluon PDF at low x

- HERA sensitivity stops at $5x10^{-4}$
  - Uncertainties at lower x driven by param
- LHeC sensitivity extends to $x=10^{-6}$
  - sensitivity to gluon can be improved by FL (not included in this study)




→This is where HERA sensitivity stops

# Gluon PDF at high x

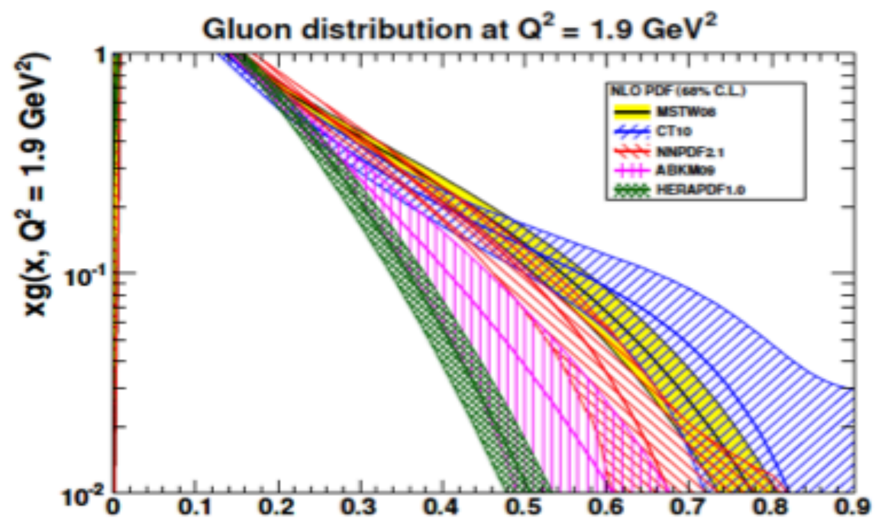
Currently, high x gluon is quite uncertain due to limited statistics and reduced sensitivity:

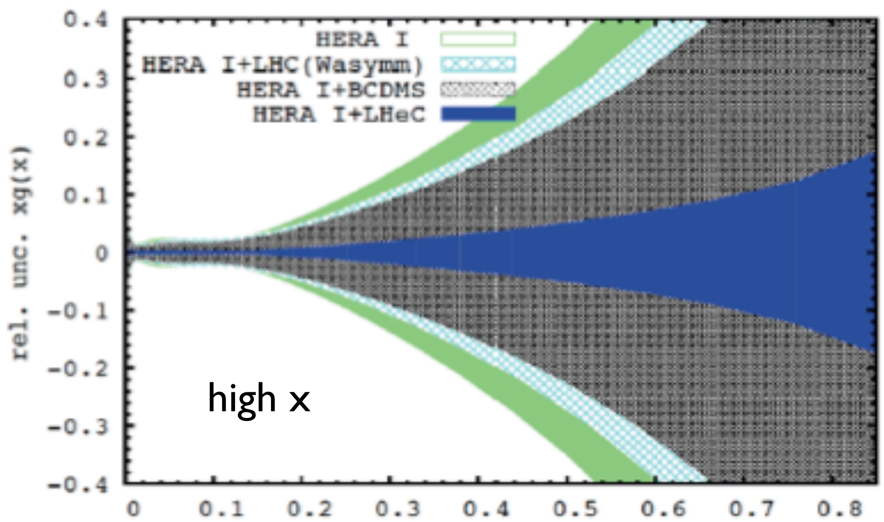
- the gluon effects at high x are in the DGLAP formalism from sea

(valence and gluon are evolved independently)

LHeC can reduce this significantly and it is important to disentangle sea from valence at high x to get precise gluon at high x:

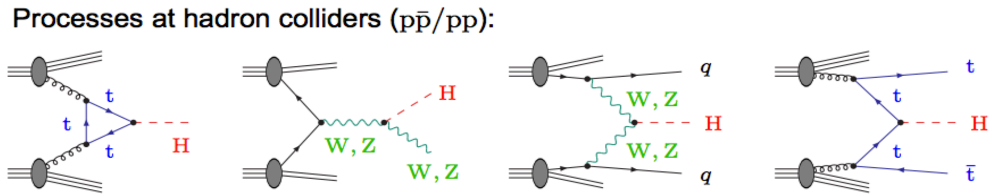
- Measurements such CC+, CC-, F2, F2yZ, xF3 help to provide this decoupling



# Higgs at the 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 is cleanly produced via ZZ or WW fusion and it is complementary to the dominant gg fusion at pp

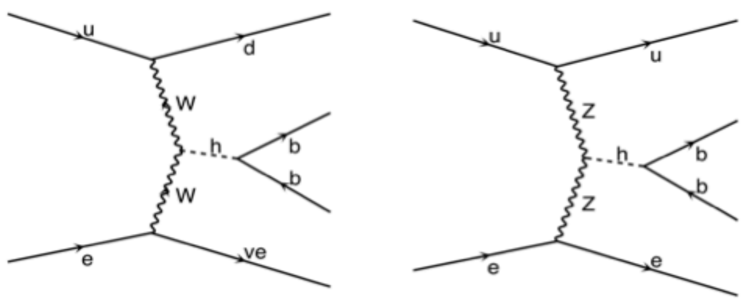
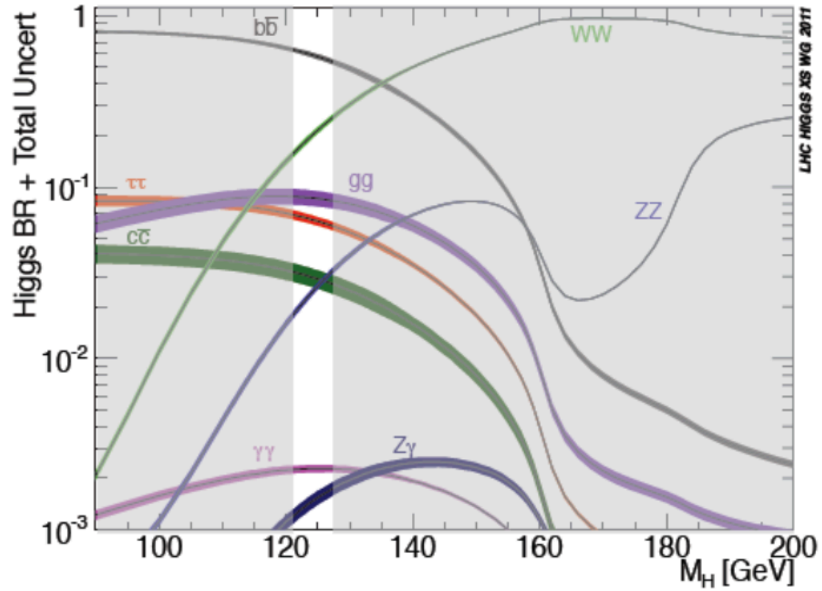
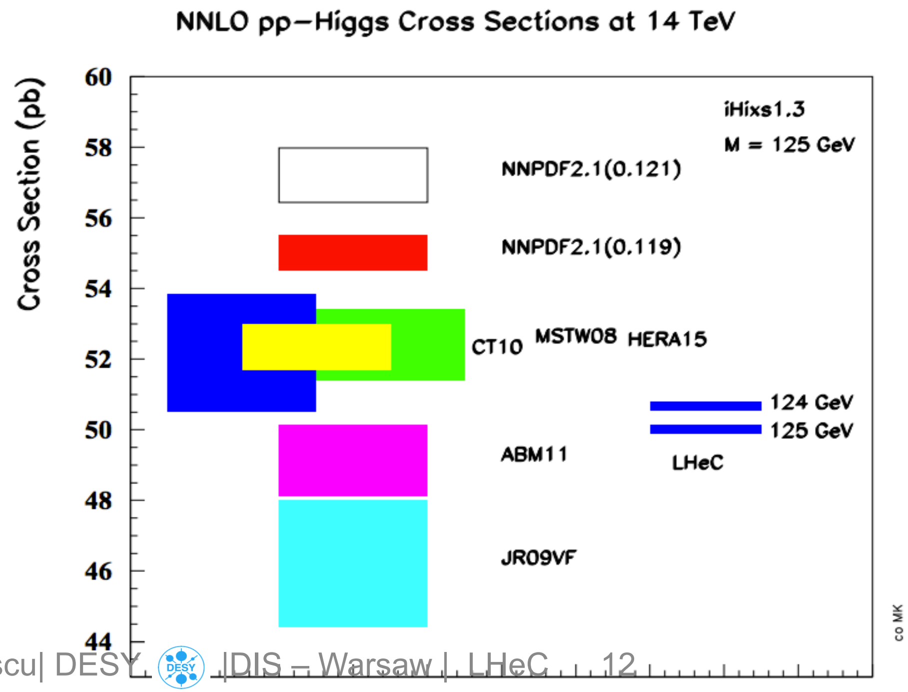



Figure 5.25: Feynman diagrams for CC (left) and NC (right) Higgs production in leadin order QCD at the LHeC. Diagrams produced using MadGraph.




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



# Releasing further PDF constraints

- Releasing further the assumptions:

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

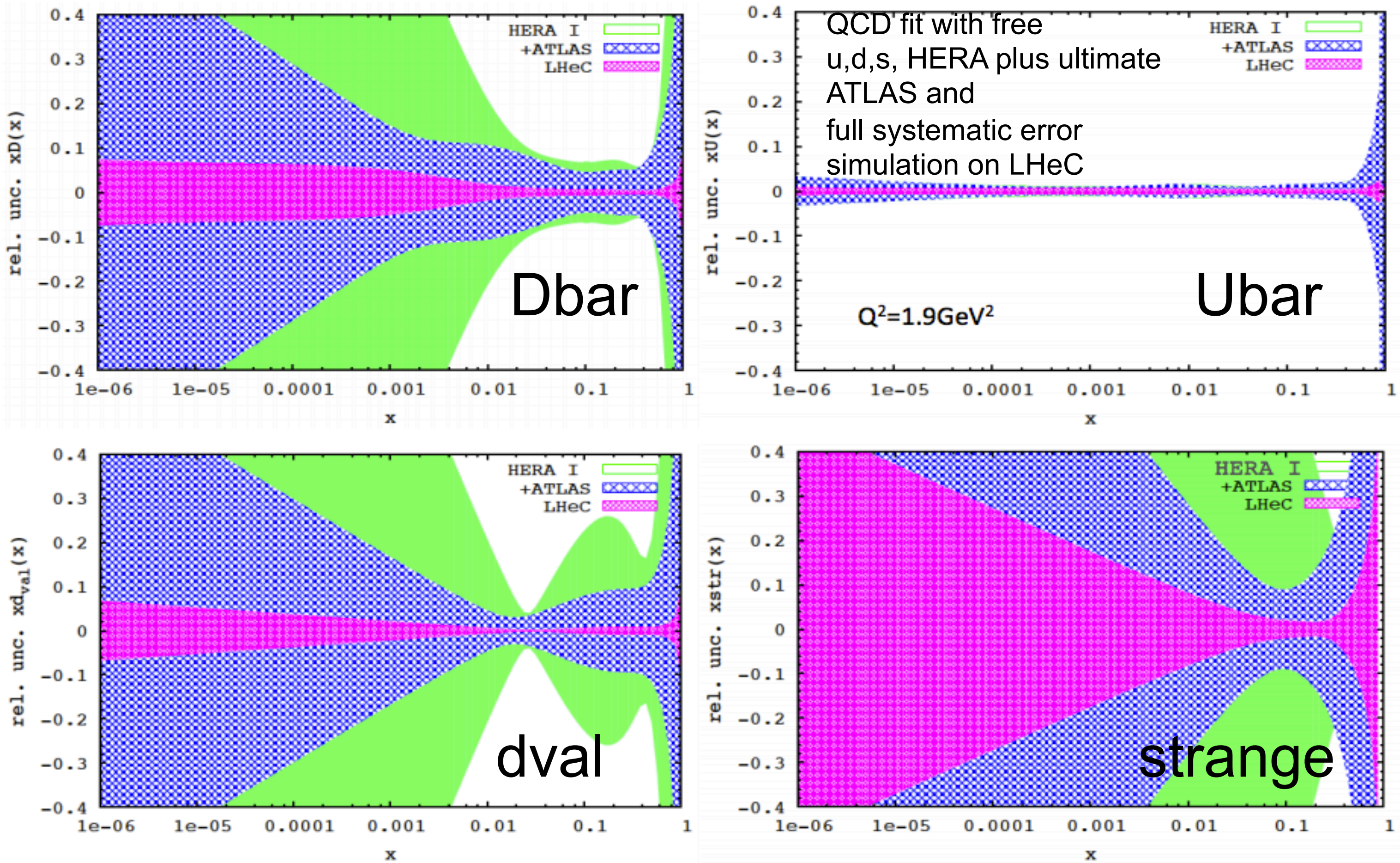
$$
\begin{aligned}
xg(x) &= A_g x^{B_g}(1-x)^{C_g}\,(1+D_g x)\,,\\
xu_v(x) &= A_{u_v} x^{B_{u_v}}(1-x)^{C_{u_v}}\,(1+E_{u_v}x^2)\,,\\
xd_v(x) &= A_{d_v} x^{B_{d_v}}(1-x)^{C_{d_v}}\,,\\
x\bar{u}(x) &= A_{\bar{u}} x^{B_{\bar{u}}}(1-x)^{C_{\bar{u}}}\,,\\
x\bar{d}(x) &= A_{\bar{d}} x^{B_{\bar{d}}}(1-x)^{C_{\bar{d}}}\,,\\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

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

- o 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.

Note that in these studies, only the inclusive measurements were included, however there are high Q2 reach of LHeC together with  the charm taggers that allow for xs determination.

# Unconstrained PDFs




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

# New Configuration

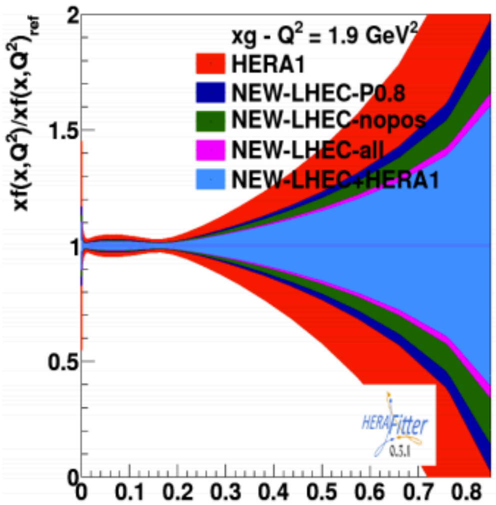
- The ERL configuration does not provide polarised positrons at comparable L
- The interest in the Higgs prefers electrons with negative, high polarisation:

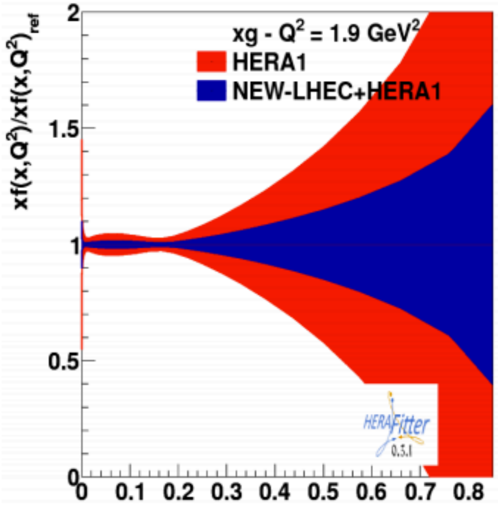
all for ep: Ee=60 GeV, Ep=7000GeV, MSTWLO

| acronym | charge | polarisation | luminosity (fb-1) |
|---|---|---|---|
| mimi | - | -0.8 | 500 |
| mipl | - | +0.8 | 50 |
| plnu | + | 0 | 5 |

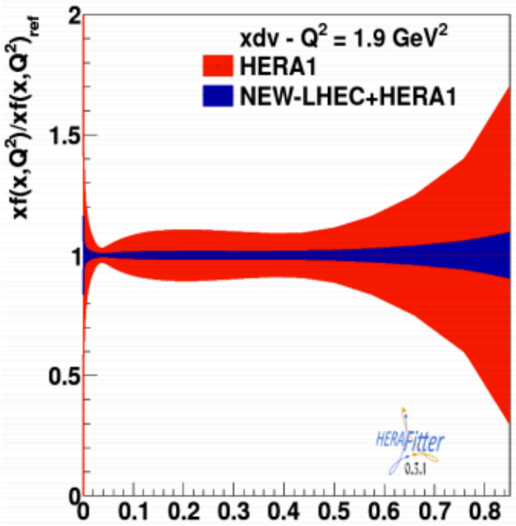
# PDF uncertainties at high x

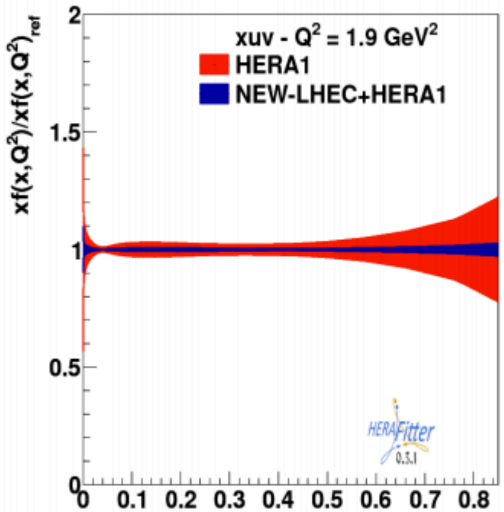
- Gluon distribution for the new scenario:




- Valence distributions for the new scenarios:




Next steps:

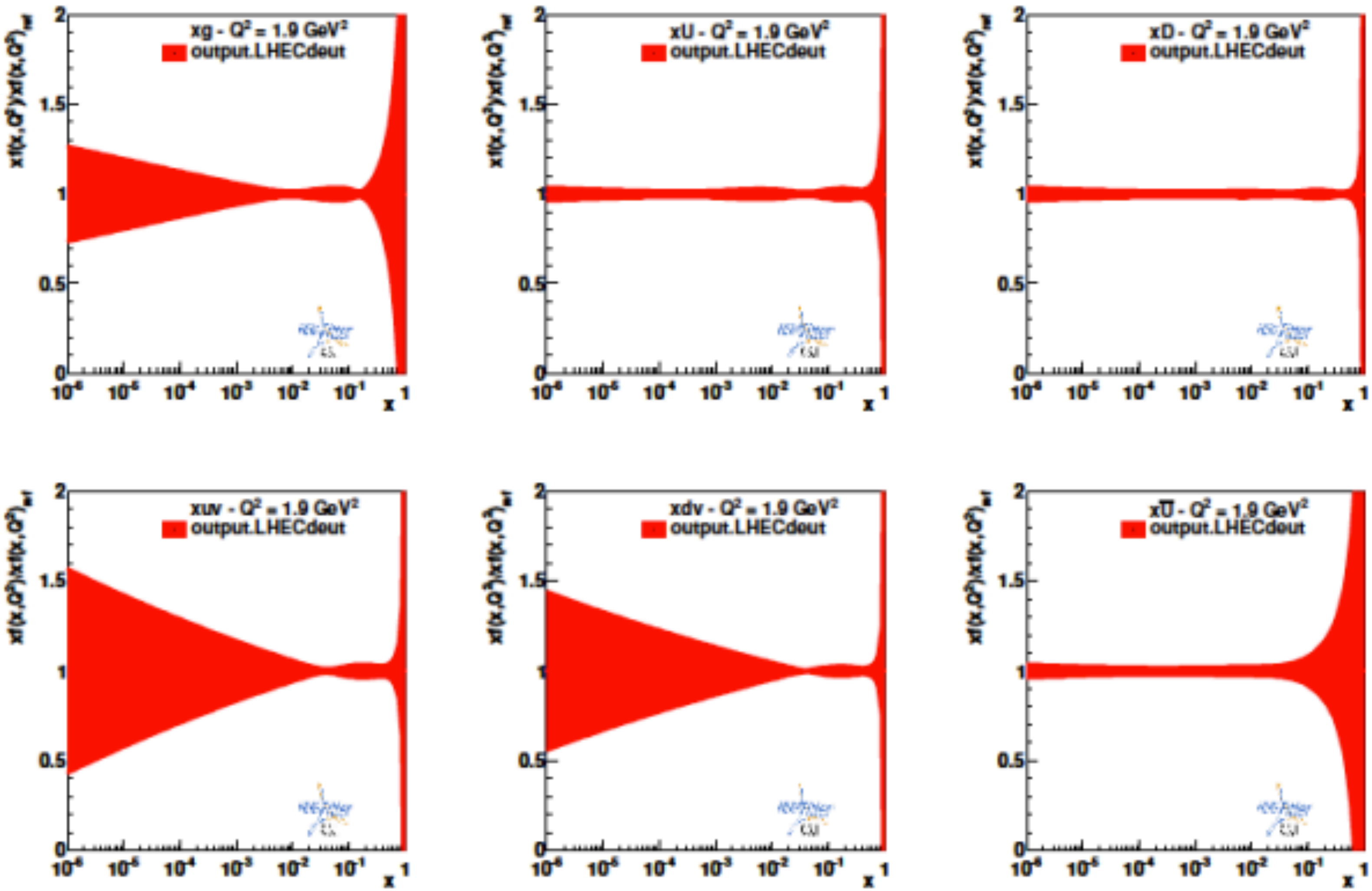
include low Ep

also consider FL

and eD + ep

# Impact of LHeC deuteron data

- 3.5 TeV x 60 GeV,e-, P=-0.8, 1fb-1 Neutral and Charged Current, exp uncertainties




Future fit of jointly ep and eD data will lead to precise unfolding of u-d

# Summary

With the LHeC the determination of the PDFs, quarks and gluons, will be put on a completely new base:

- Determination of all quark PDFs, including d/u, s, c, b
- Mapping of the gluon distribution from nearly $10^{-5}$ to x=1
- Determination of the strong coupling to permille level (CDR)

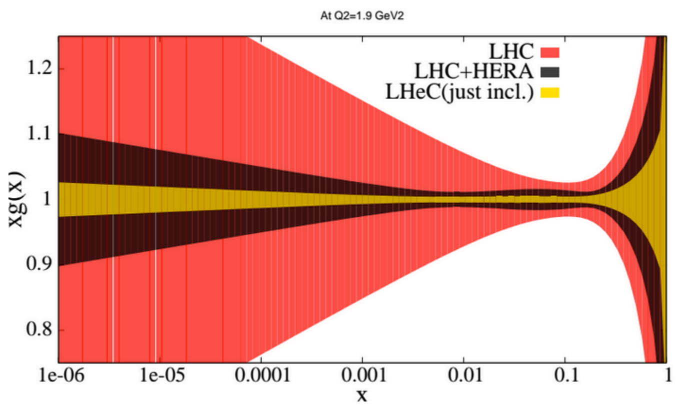
This puts severe requirements to detector design, precision of tracking and calorimetry in large acceptance and to QCD.

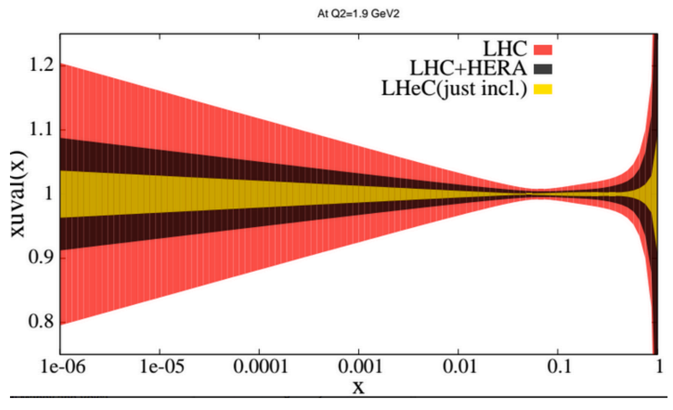
Besides the classic PDFs, the LHeC provides much further insight to photon, neutron, nuclear, Pomeron structure and to the extension of the collinear approximation to generalised PDs.

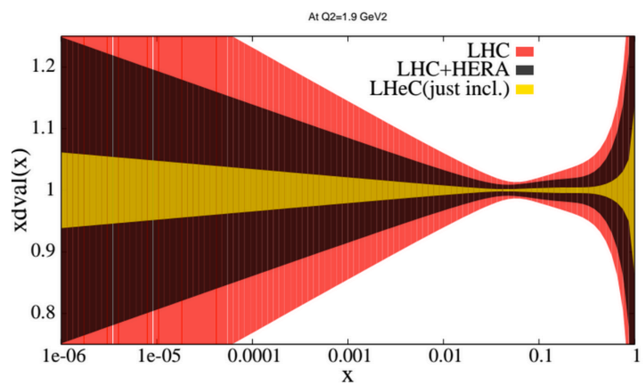
Further studies are envisaged (data optimisation, role of e+, d..)

# Extra Studies

- Can LHC alone give precise PDFs?



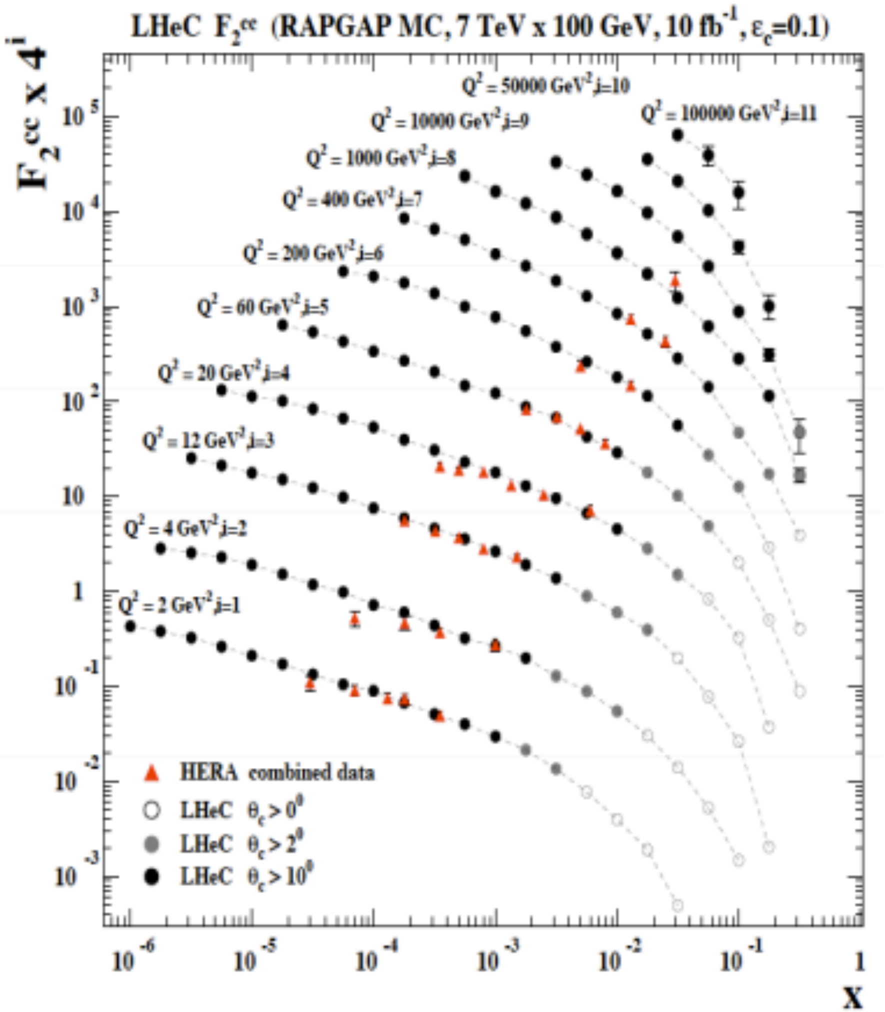



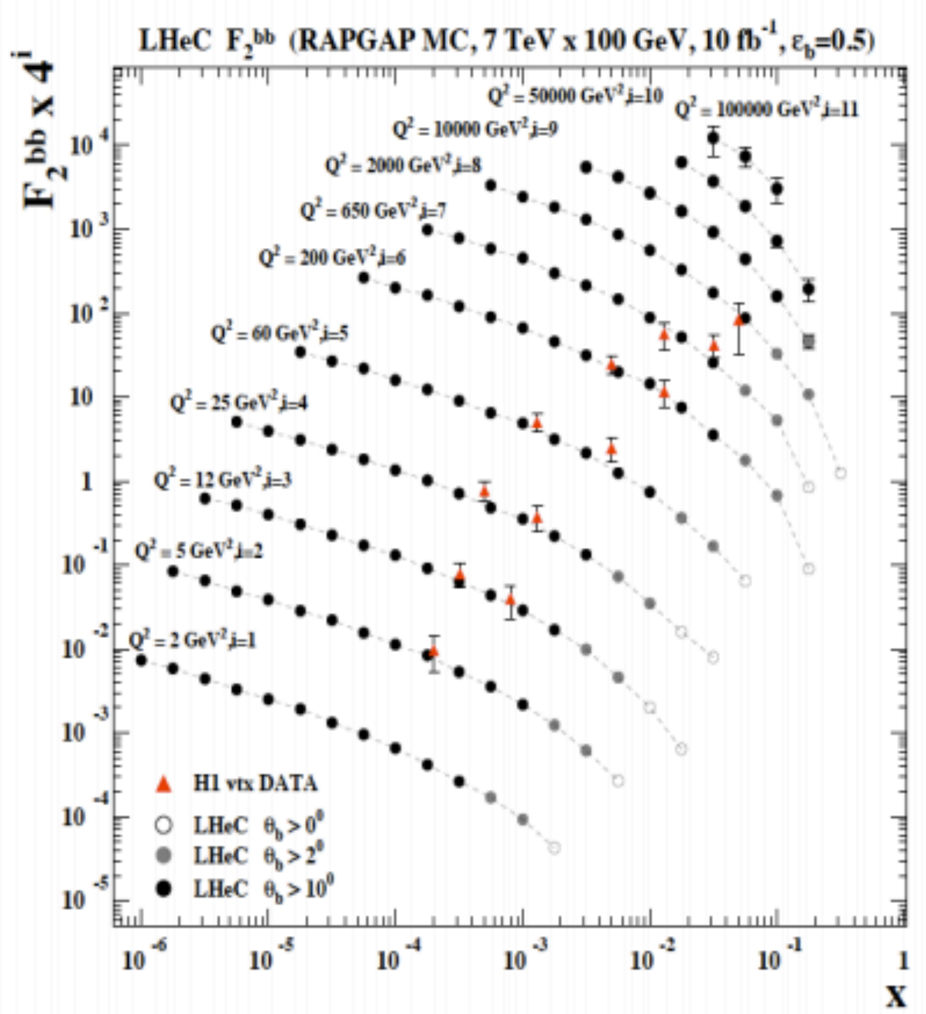

**NOT with any precision NO !**

Present LHC W,Z data and jet data are included and LHC ultimate precision is extrapolated according to our current experience– we are systematics limited already

# PDFs come from DIS

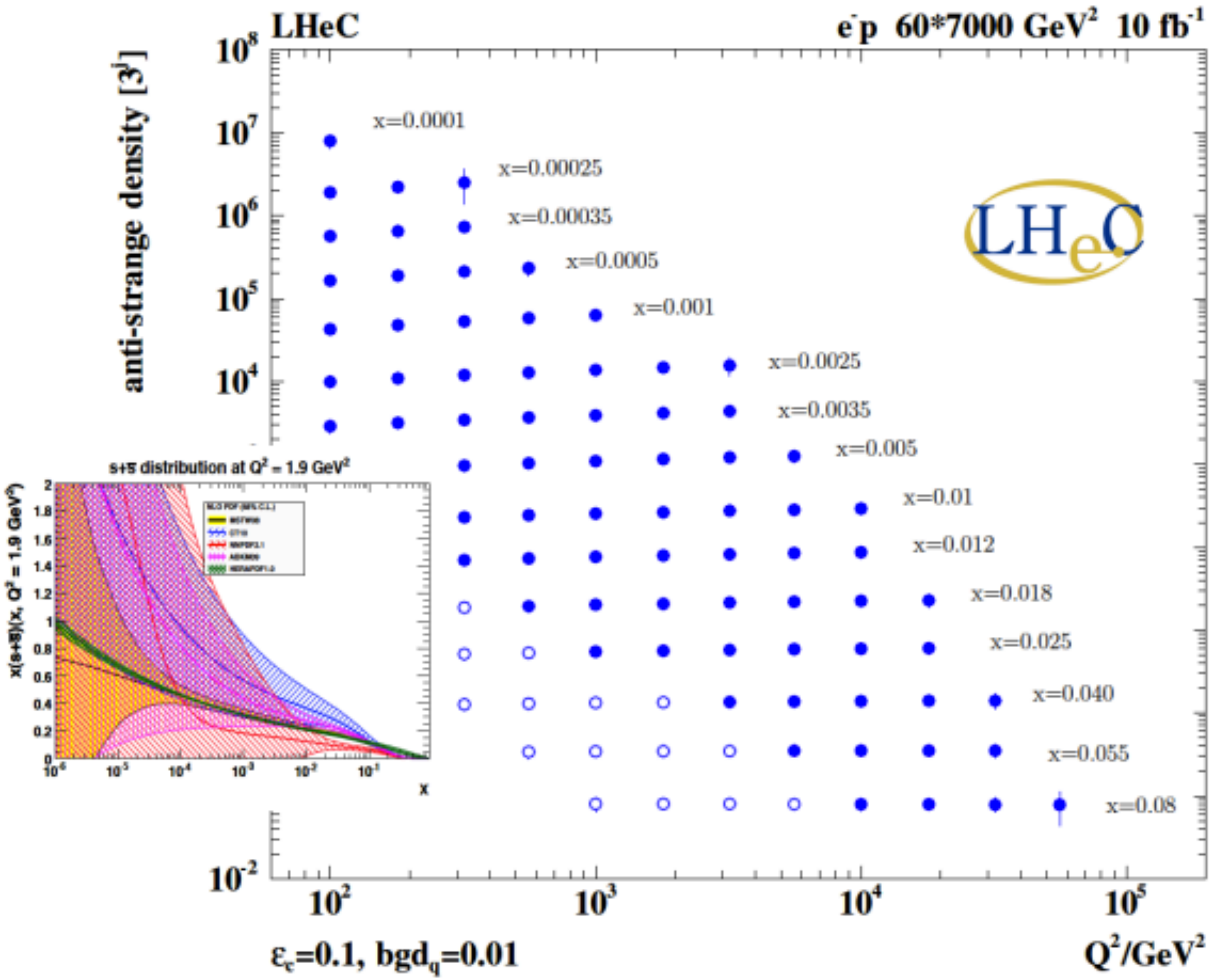
# F2charm and F2beauty from LHeC




**Hugely extended range and much improved precision ($\delta M_c$=60 HERA → 3 MeV)**
will pin down heavy quark behaviour at and far away from thresholds, crucial for prec
In MSSM, Higgs is produced dominantly via bb → H , but where is the MSSM..

# Strangeness from LHeC




High luminosity

High $Q^2$

Small beam spot

Modern Silicon

NO pile-up..

→ First $(x,Q^2)$ measurement of the (anti-)strange density, HQ valence?

$x = 10^{-4}$ .. 0.05
$Q^2 = 100 - 10^5\ GeV^2$

JPhysG 39(2012)7

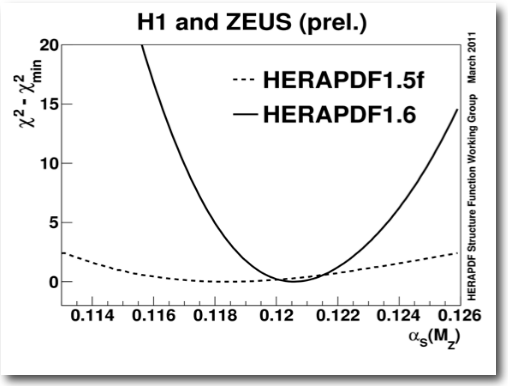
Initial study (CDR): Charm tagging efficiency of 10% and 1% light quark background in impact parameter

# Alphas from DIS

# Precise Alphas from DIS at the LHeC

Strong coupling from DIS processes still seem to prefer smaller values

- Results from HERA show that even with precise HERA data one has to rely on jet measurements in order to constrain gluon PDFs




## The strong coupling "constant"

| Method | Current relative precision | Future relative precision |
|---|---|---|
| $e^+e^-$ evt shapes | expt ~ 1% (LEP)<br>thry ~ 3% (NNLO+NLL, n.p. signif.) [24] | < 1% possible (ILC/TLEP)<br>~ 1.5% (control n.p. via $Q^2$-dep.) |
| $e^+e^-$ jet rates | expt ~ 2% (LEP)<br>thry ~ 1% (NNLO, n.p. moderate) [25] | < 1% possible (ILC/TLEP)<br>~ 0.5% (NLL missing) |
| precision EW | expt ~ 3% ($R_Z$, LEP)<br>thry ~ 0.5% ($N^3$LO, n.p. small) [26, 7] | 0.1% (TLEP [8]), 0.5% (ILC [9])<br>~ 0.3% ($N^4$LO feasible, ~ 10 yrs) |
| $\tau$ decays | expt ~ 0.5% (LEP, B-factories)<br>thry ~ 2% ($N^3$LO, n.p. small) [6] | < 0.2% possible (ILC/TLEP)<br>~ 1% ($N^4$LO feasible, ~ 10 yrs) |
| *ep* colliders | ~ 1–2% (pdf fit dependent)<br>(mostly theory, NNLO) [27, 28, 29, 30] | 0.1% (LHeC + HERA [21])<br>~ 0.5% (at least $N^3$LO required) |
| hadron colliders | ~ 4% (Tev. jets), ~ 3% (LHC $t\bar{t}$)<br>(NLO jets, NNLO $t\bar{t}$, gluon uncert.) [15, 19, 31] | < 1% challenging<br>(NNLO jets imminent [20]) |
| lattice | ~ 0.5% (Wilson loops, correlators, ...)<br>(limited by accuracy of pert. th.) [32, 33, 34] | ~ 0.3%<br>(~ 5 yrs [35]) |

**Table 1-1.** *Summary of current uncertainties in extractions of $\alpha_s(M_Z)$ and targets for future (5–25 years) determinations. For the cases where theory uncertainties are considered separately, the theory uncertainties for future targets reflect a reduction by a factor of about two.*

Snowmass QCD WG report 9/2013

Prospects to measure $\alpha_s(M_Z^2)$ to per mille precision with future ep and ee colliders
Important for gauge unification, precision Higgs at LHC, and to overcome the past..

The determination of the strong

# 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 (accuracy reflects the total experimental uncertainty)

| case | cut [$Q^2$ in $\mathrm{GeV}^2$] | relative precision in % |
|---|---|---|
| HERA only (14p) | $Q^2 > 3.5$ | 1.94 |
| HERA+jets (14p) | $Q^2 > 3.5$ | 0.82 |
| LHeC only (14p) | $Q^2 > 3.5$ | 0.15 |
| LHeC only (10p) | $Q^2 > 3.5$ | 0.17 |
| LHeC only (14p) | $Q^2 > 20.$ | 0.25 |
| LHeC+HERA (10p) | $Q^2 > 3.5$ | 0.11 |
| LHeC+HERA (10p) | $Q^2 > 7.0$ | 0.20 |
| LHeC+HERA (10p) | $Q^2 > 10.$ | 0.26 |

LHeC promises per mille accuracy on alphas!

- Previously (HERA, fixed target) limited by uncertainty of low x, which LHeC can cure;
- full exploitation of this requires pQCD at NNLO;
- LHeC can provide a new level of predicting grand unification

- Gluon

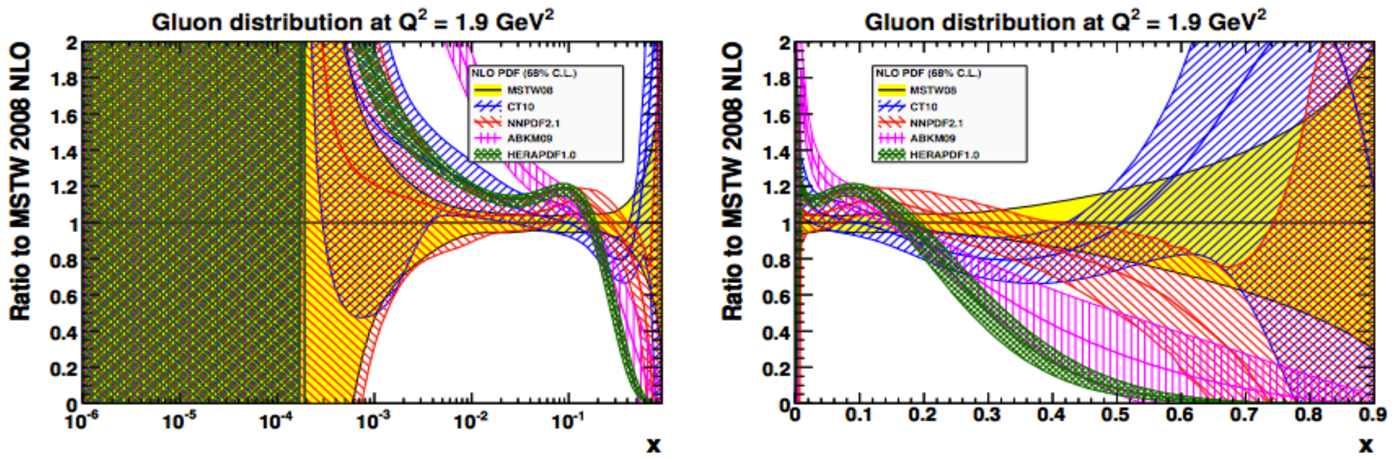



Figure 4.17: Ratios to MSTW08 of gluon distribution and uncertainty bands, at $Q^2 = 1.9\,\text{GeV}^2$, for most of the available recent PDF determinations. Left: logarithmic $x$, right: linear $x$.

- Strange

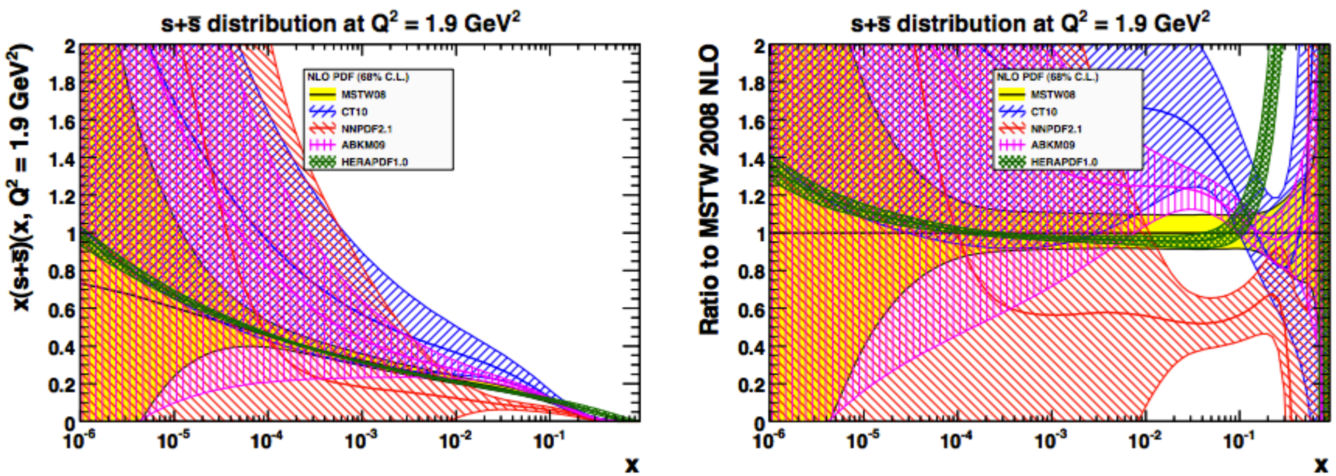
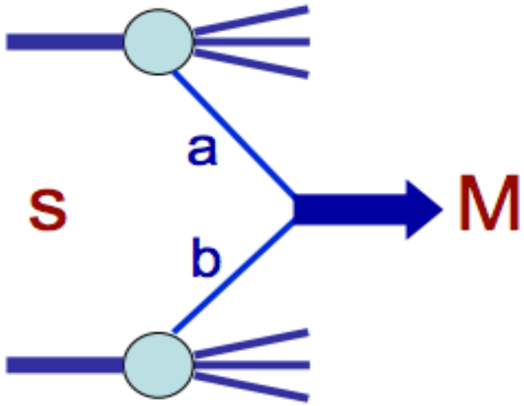



Figure 4.12: Sum of the strange and anti-strange quark distribution as embedded in the NLO QCD fit sets as noted in the legend. Left: $s + \bar{s}$ versus Bjorken $x$ at $Q^2 = 1.9\,\text{GeV}^2$; right: ratio of $s + \bar{s}$ of various PDF determinations to MSTW08. In the HERAPDF1.0 analysis (green) 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 $s + \bar{s}$.

# 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.

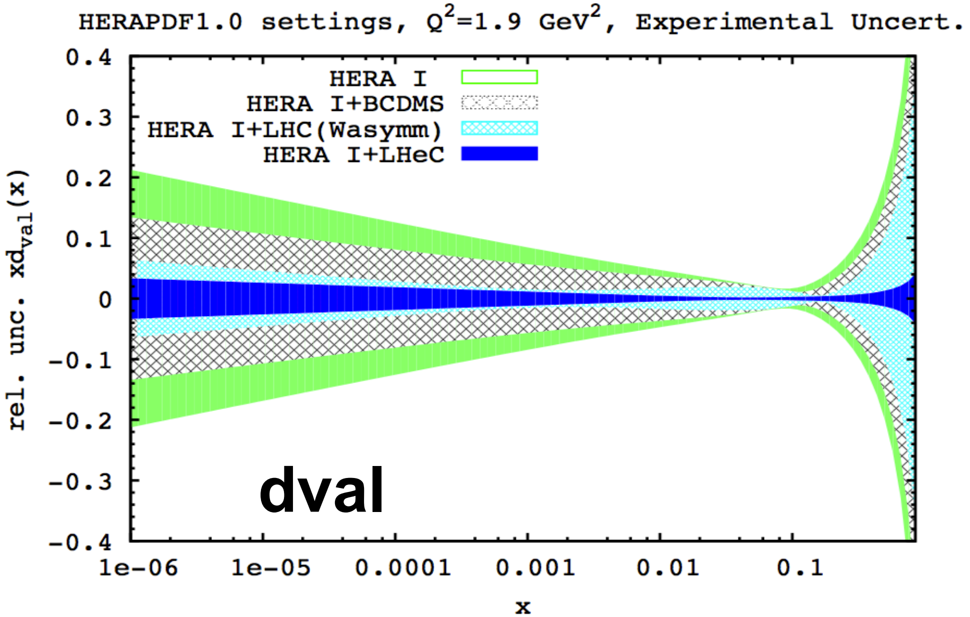
# LHeC studies scenarios

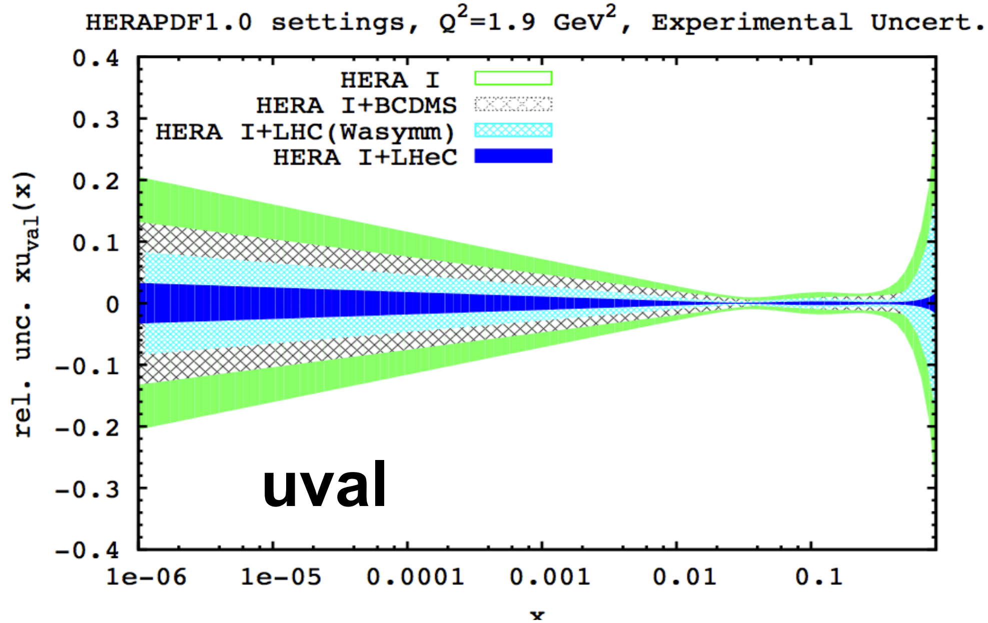
| Set | $E_e$/GeV | $E_N$/TeV | N | $L^+/\text{fb}^{-1}$ | $L^-/\text{fb}^{-1}$ | Pol |
|---|---|---|---|---|---|---|
| A | 20 | 7 | 7 | 1 | 1 | 0 |
| B | 50 | 7 | 7 | 50 | 50 | 0.4 |
| C | 50 | 7 | 7 | 1 | 1 | 0.4 |
| D | 100 | 7 | 7 | 5 | 10 | 0.9 |
| E | 150 | 7 | 7 | 3 | 6 | 0.9 |
| F | 50 | 3.5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

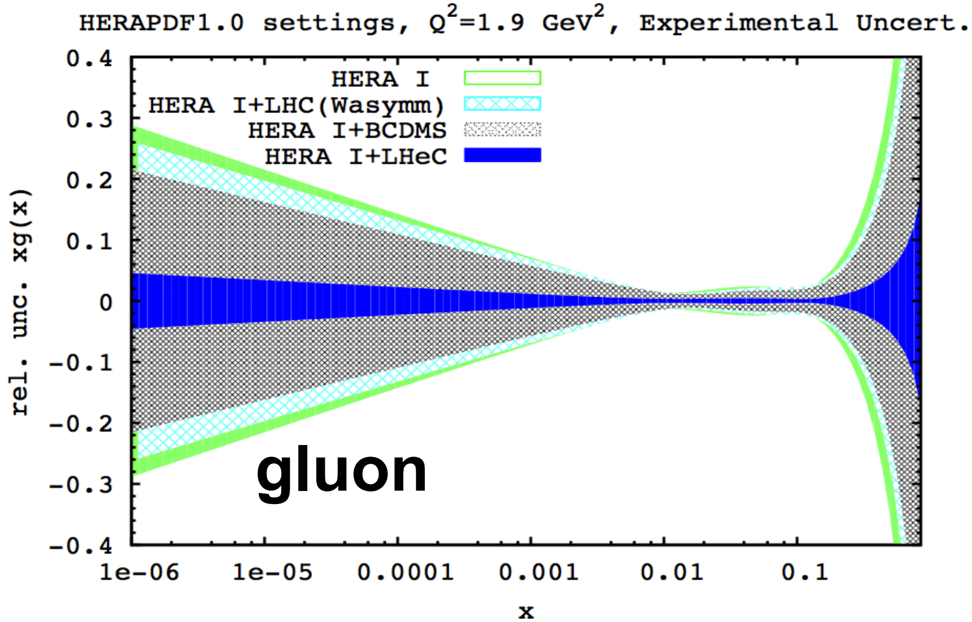
Table 4.2: Conditions for simulated NC and CC data sets for studies on the LHeC physics. Here, A defines a low electron beam energy option which is of interest to reach lowest $Q^2$ because $Q^2_{min}$ decreases $\propto E_e^{-2}$; B is the standard set, with a total luminosity split between different 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 $\beta$ 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 $0.5\,\text{fb}^{-1}$, 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 $x$.

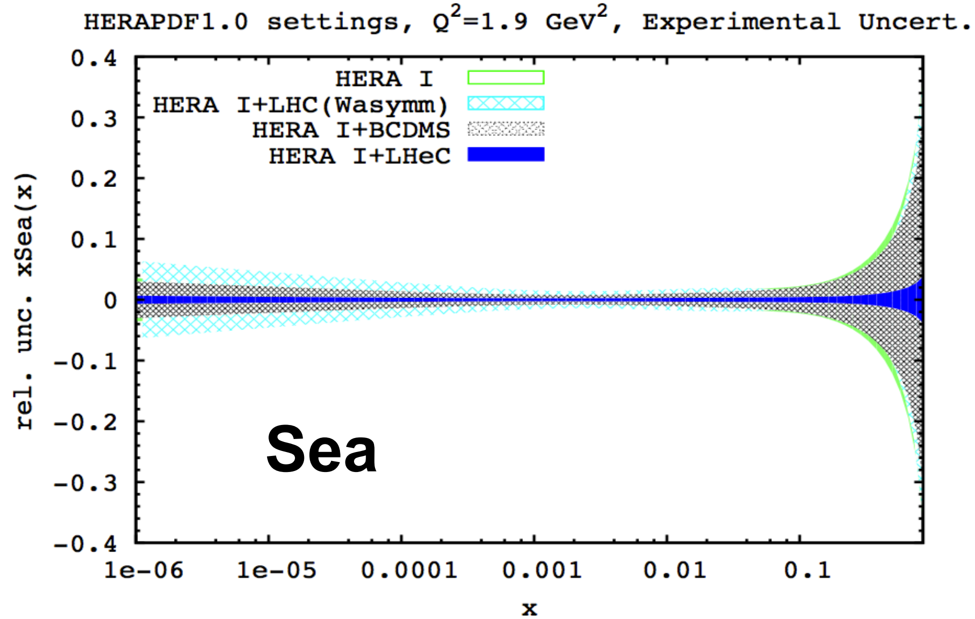
# Impact of LHeC on PDFs: zoom on low x

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



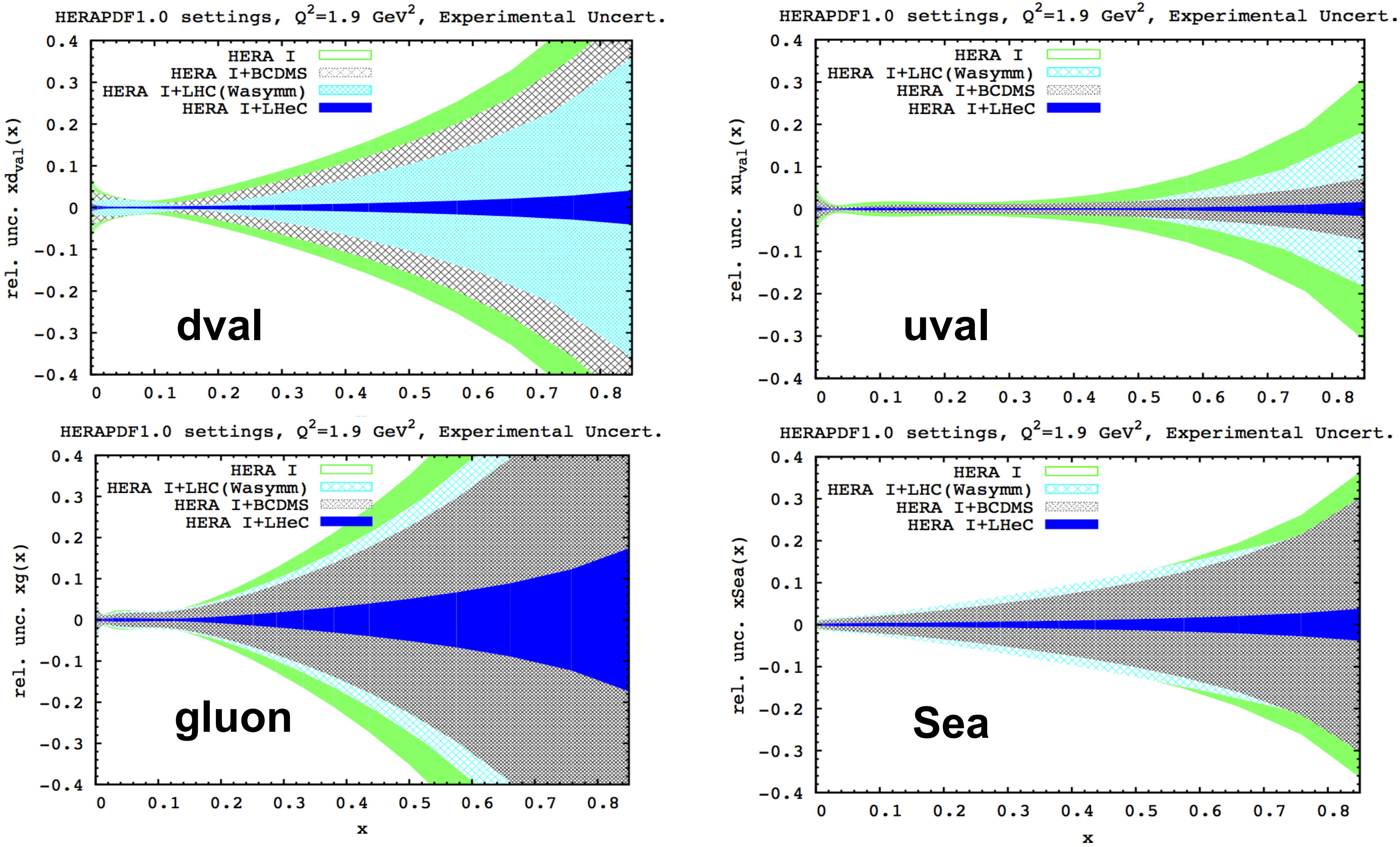



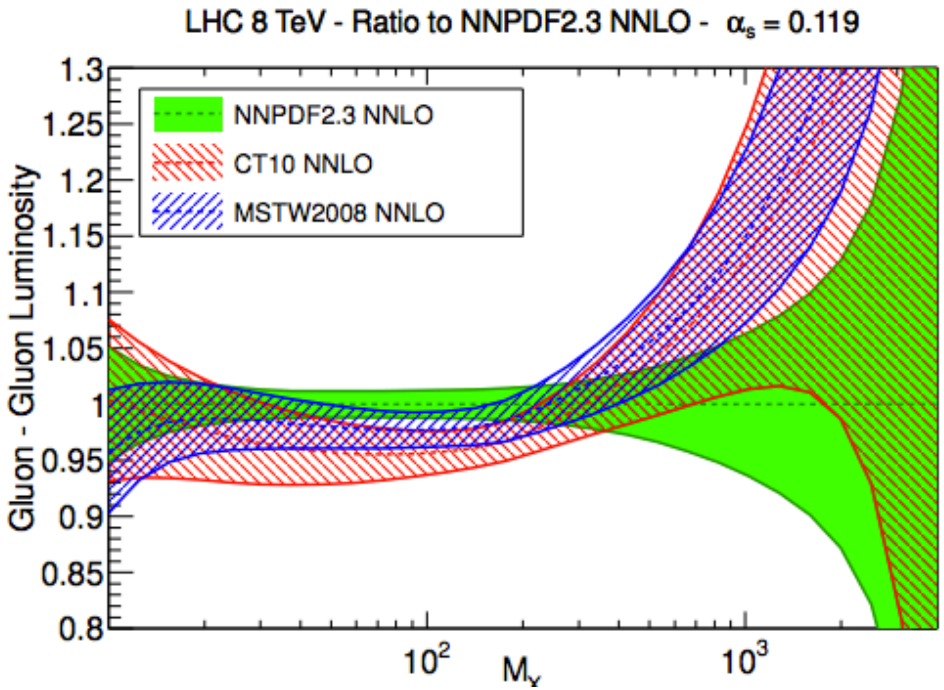
# Impact of LHeC on PDFs: zoom on high x

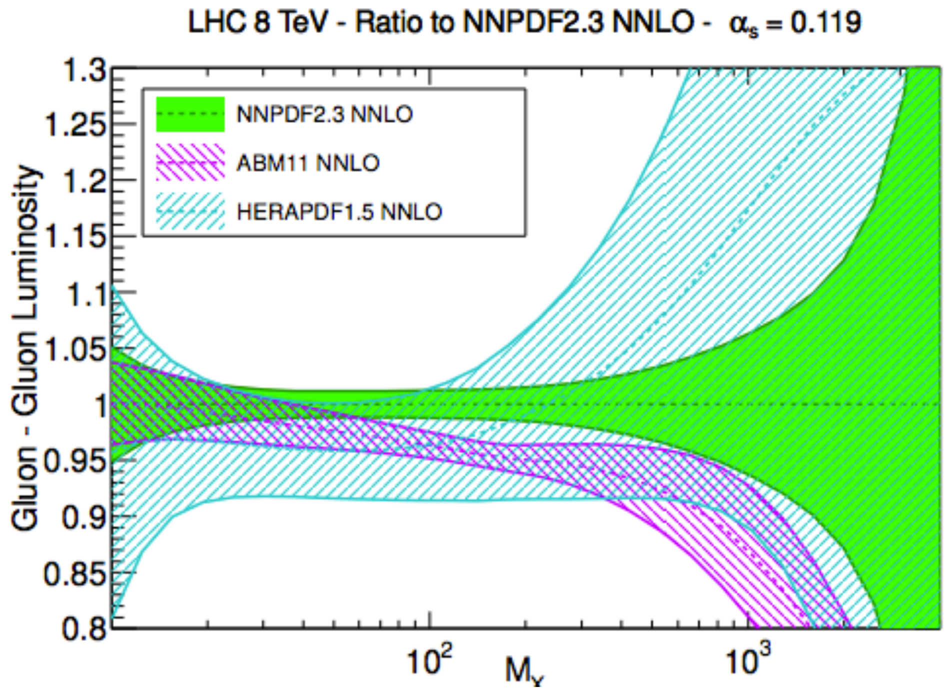
* Experimental uncertainties are shown at the starting scale $Q^2$=1.9 GeV$^2$



# Parton Distribution Functions

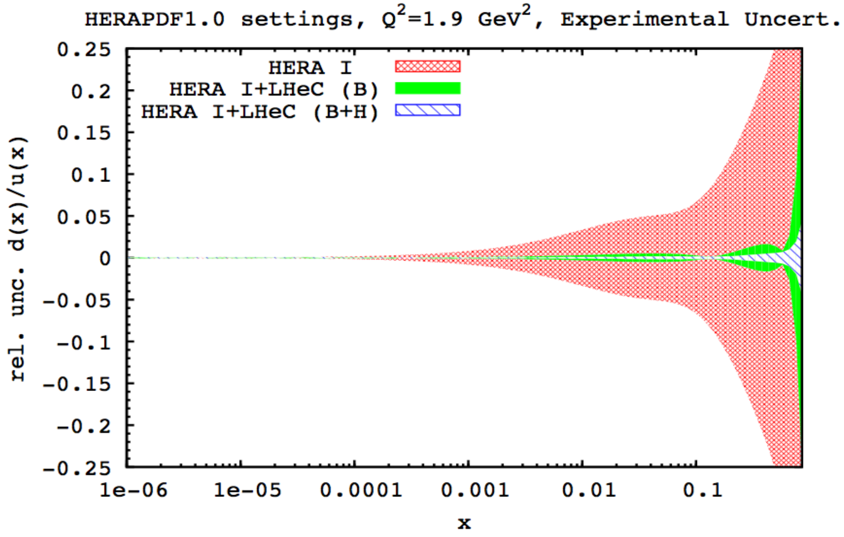
- Current knowledge and uncertainties display differences that need to be understood and that may have substantial impact

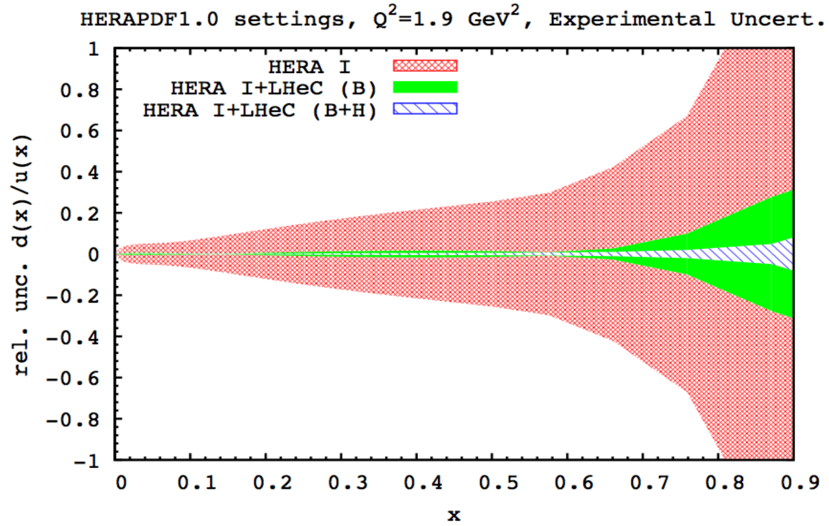


# Impact on d/u ratios

- Constrained decomposition:




- Unconstrained sea decomposition: