Parton Distributions from the LHeC

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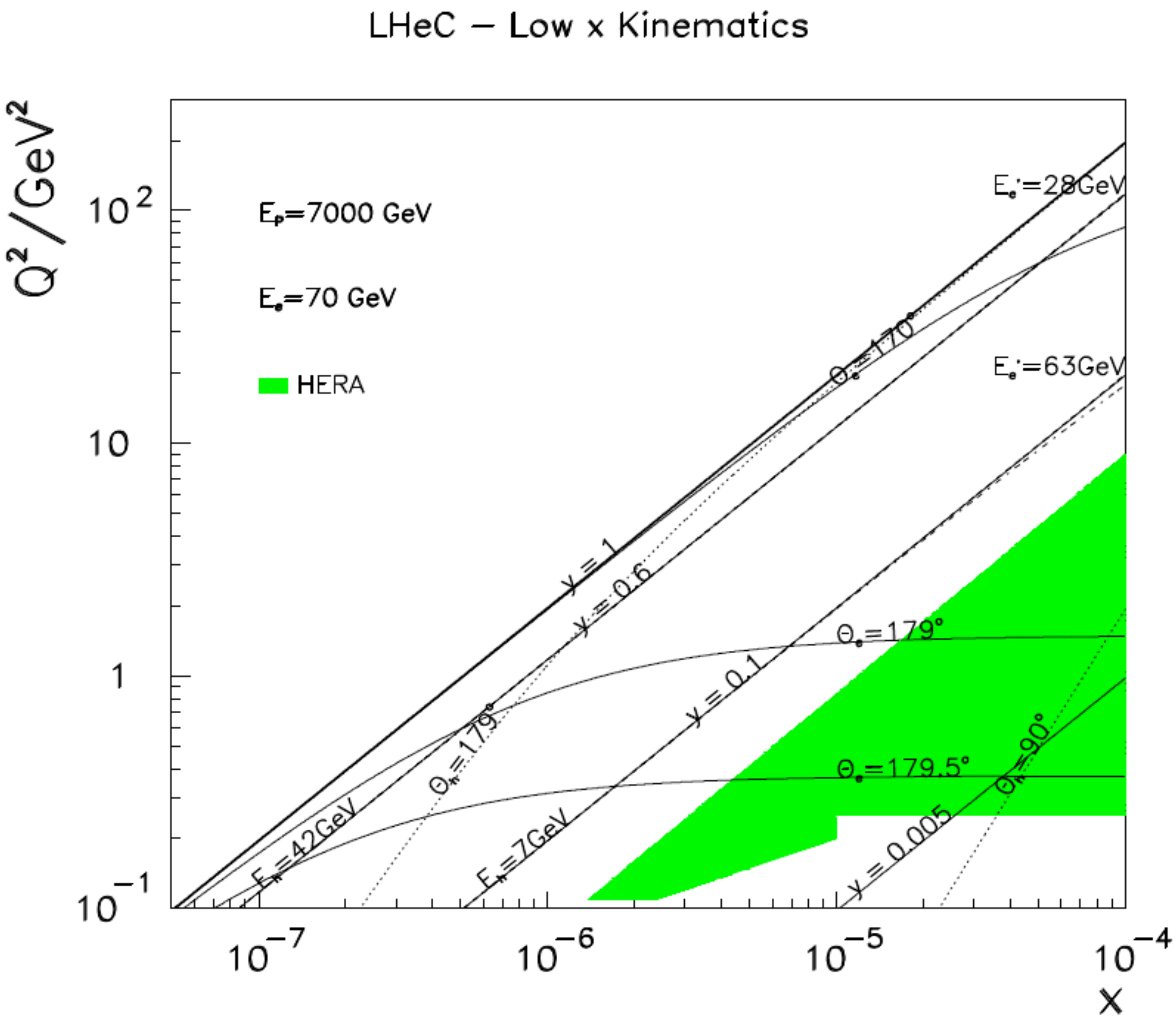
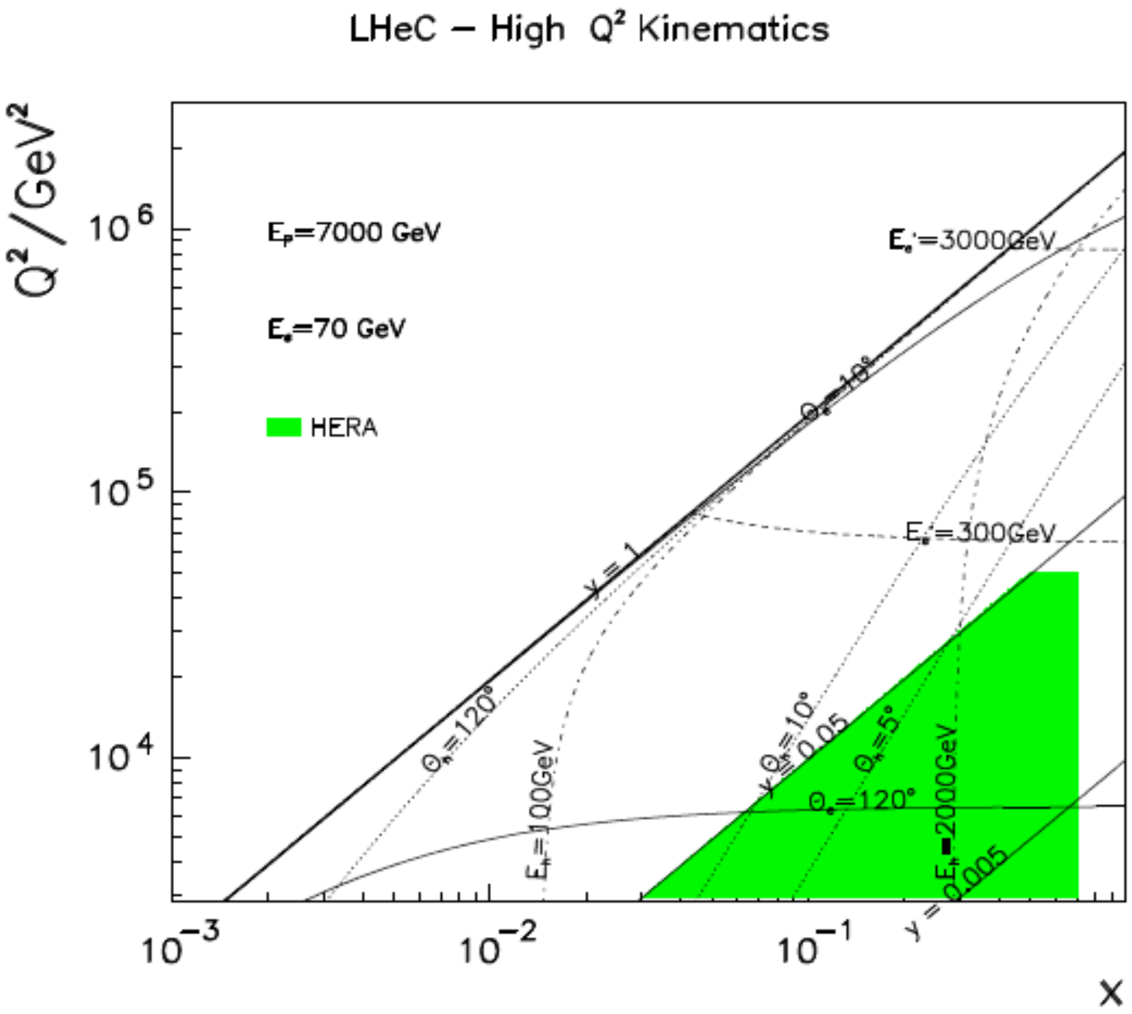
A simulation and study of how well we should be able to measure u,d,s,c,b,t and xg of the proton

in a new ep world of high luminosity and precision measurements in the enormous kinematic range the LHeC would open.



10^5 events
per pb^{-1}
for $Q^2 > 100$
Lumi 'easy'

Dramatic extension of low x kinematic range



Maximum luminosity in JINST06 design achieved with focusing magnets close to IP (9^o cut) two detectors or detector versions required
Low x with 10^{32} , high Q^2 with 10^{33} , about

Detector requirements

High luminosity to reach high Q^2 and large x
$10^{33} - 10^{34}$ $1\text{-}5\ 10^{31}$

Largest possible acceptance
$1\text{-}179^o$ $7\text{-}177^o$

High resolution tracking
0.1 mrad 0.2-1 mrad

Precision electromagnetic calorimetry
0.1% 0.2-0.5%

Precision hadronic calorimetry
0.5% 1%

High precision luminosity measurement
0.5% 1%

LHeC HERA

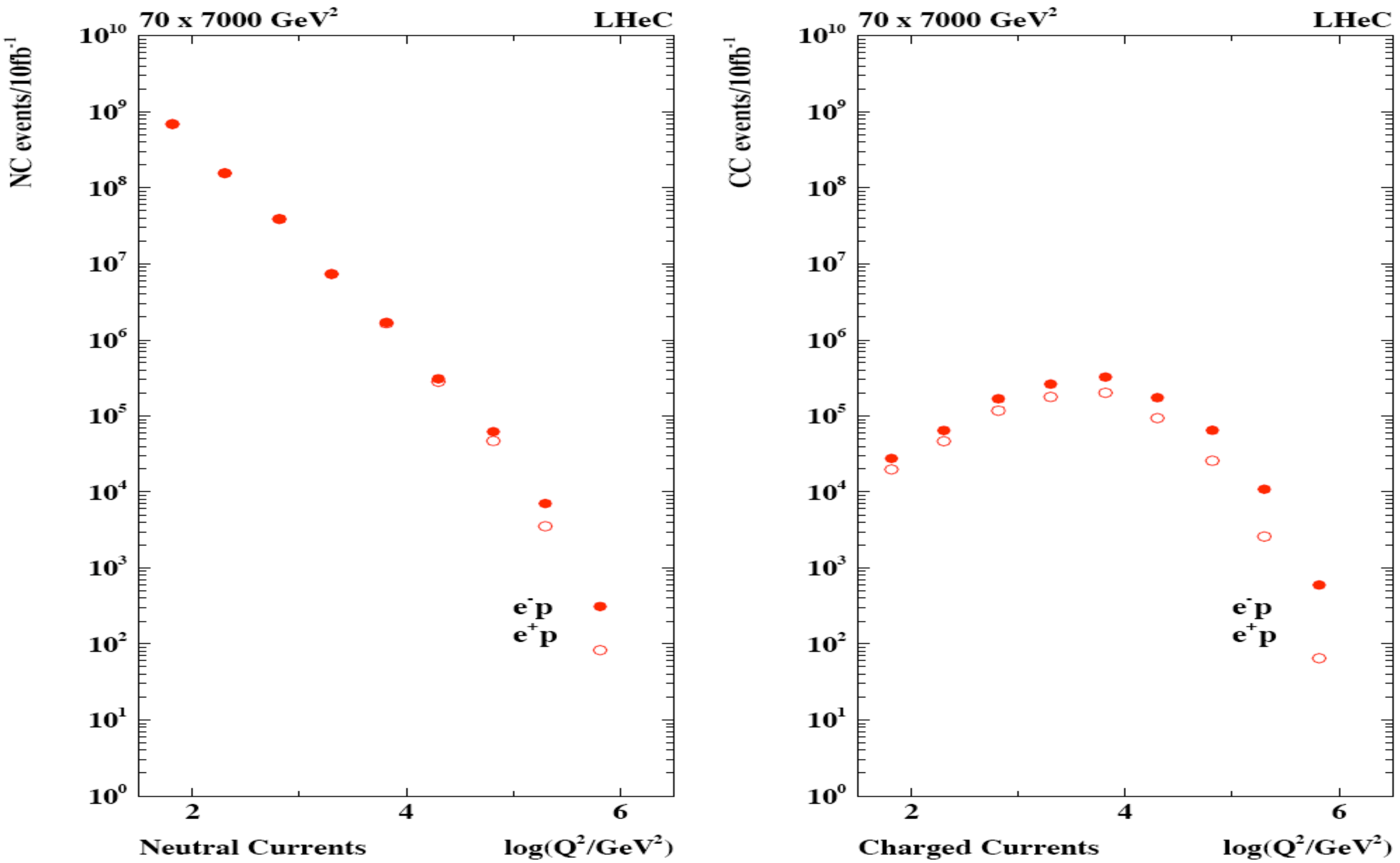
The new detector (L1)

has to be at least
2 times better than the
good old H1

Detector parameters were put in simulation of NC and CC (LO) cross sections with analytic calculation of systematic uncertainties.

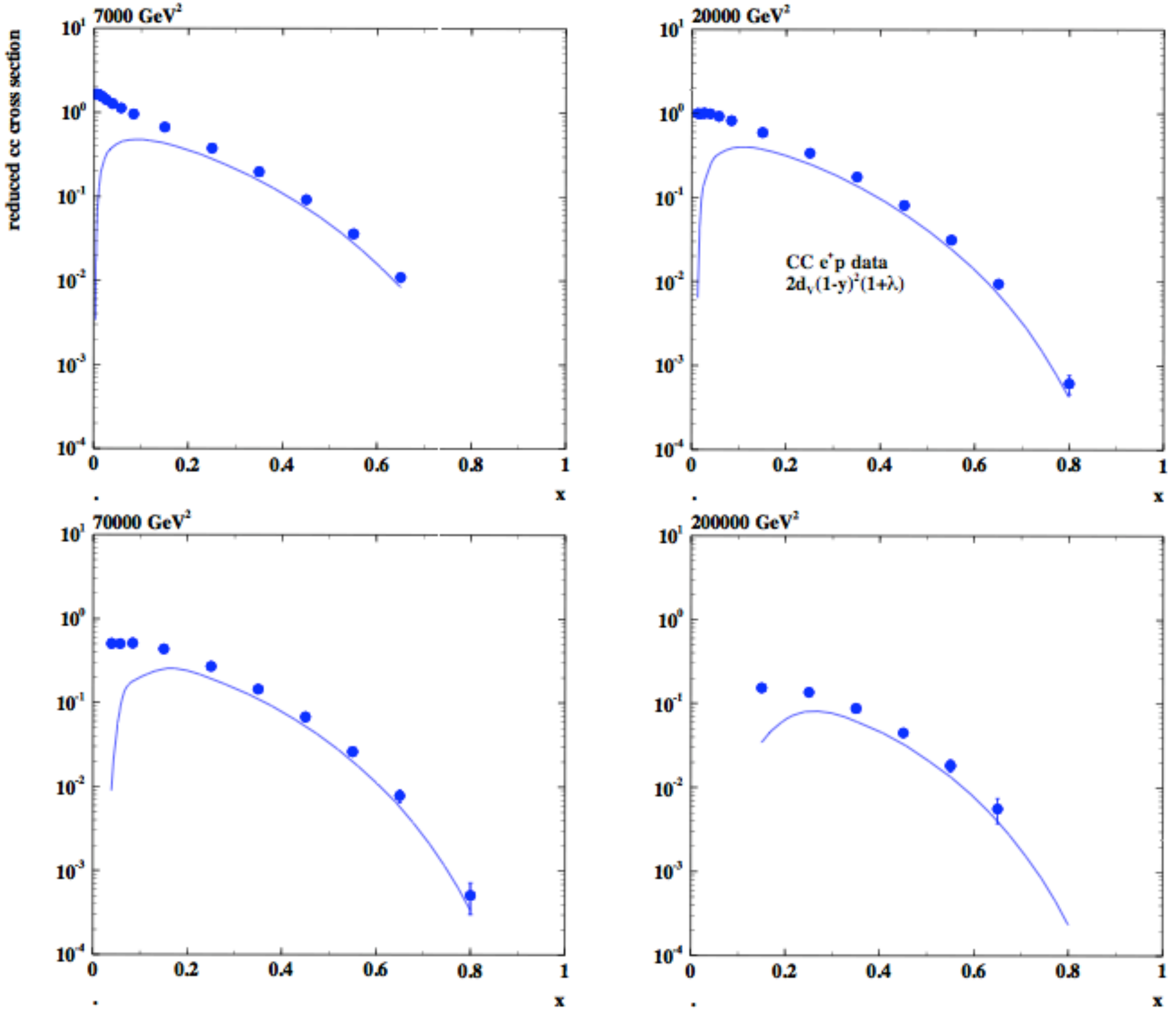
NLO QCD fits to these 'data' were performed, on pdfs by Emmanuelle Perez and on alphas by Thomas Kluge.

Rates

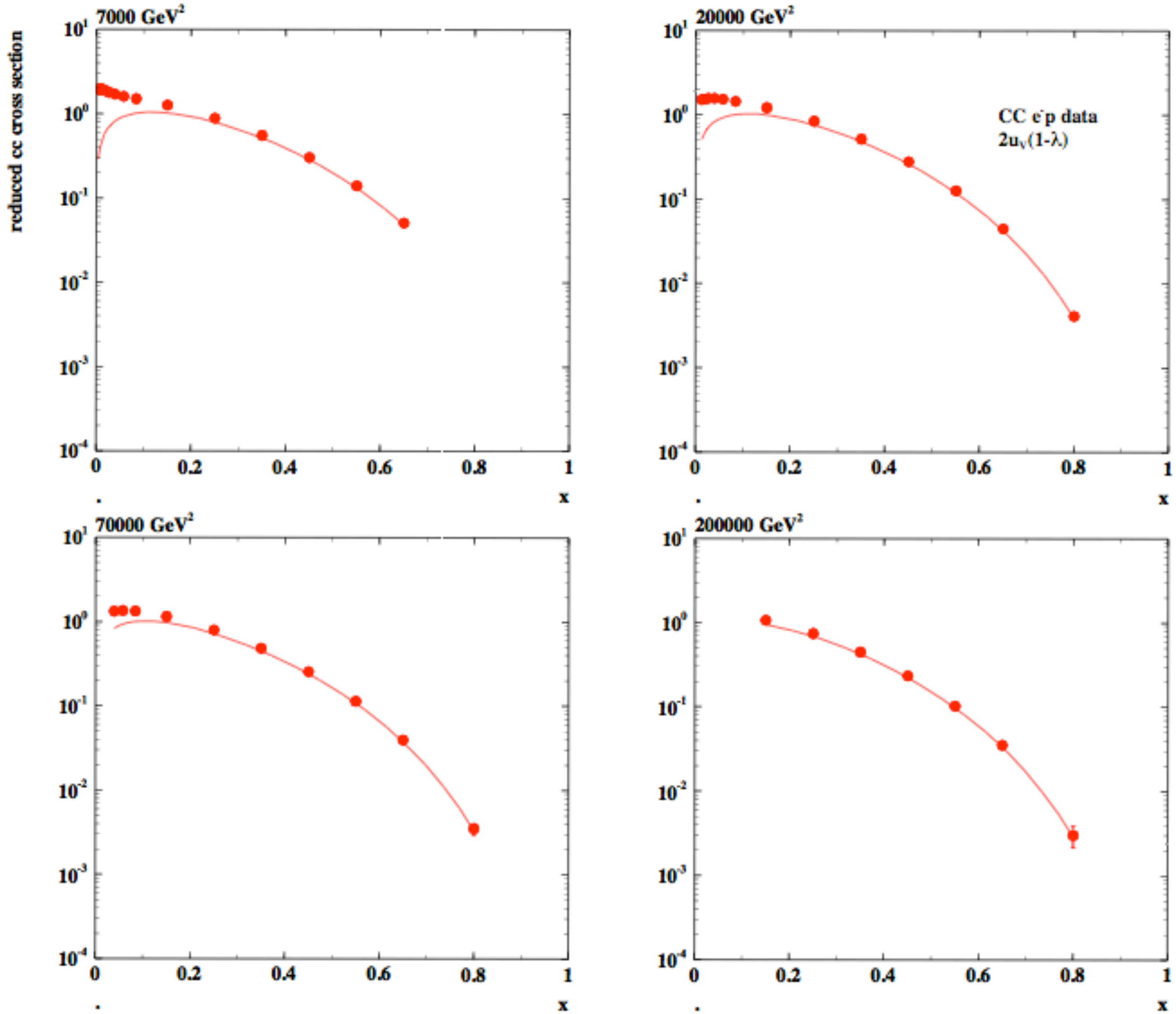


Simulations done for 10fb-1 and statistical error limited to 0.1% at low Q2

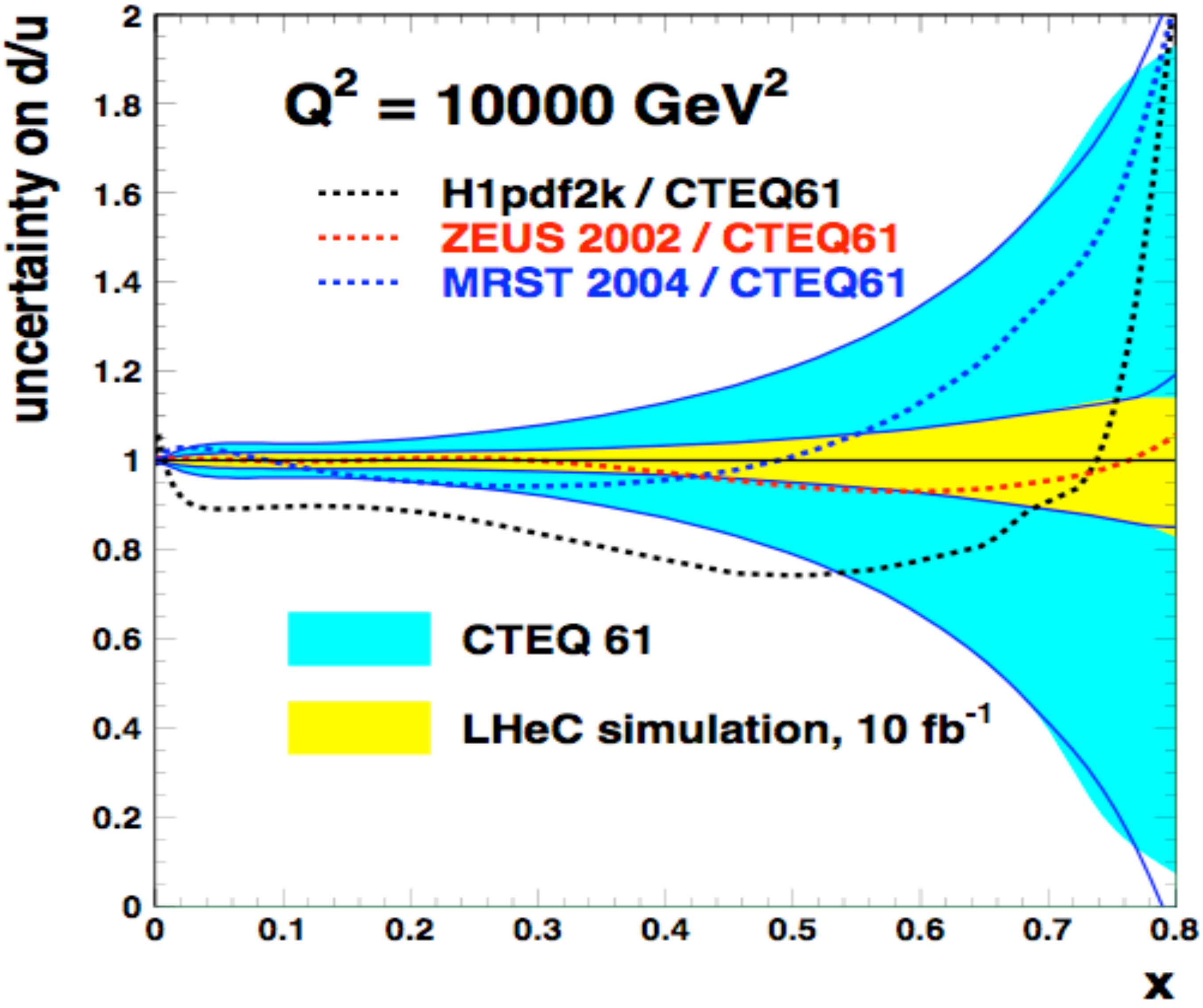
Charged currents (e+)



Charged currents (e-)

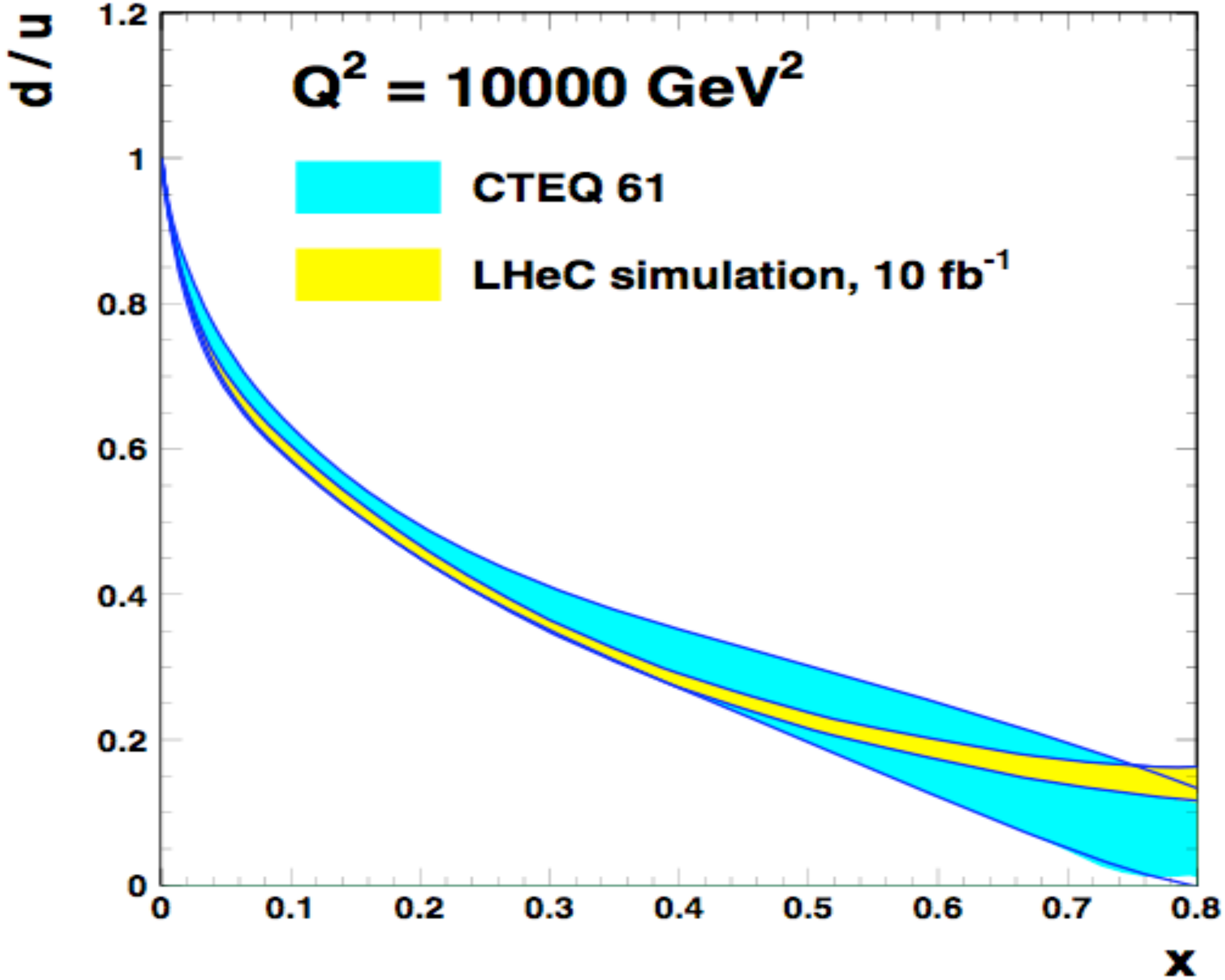


d/u at large x



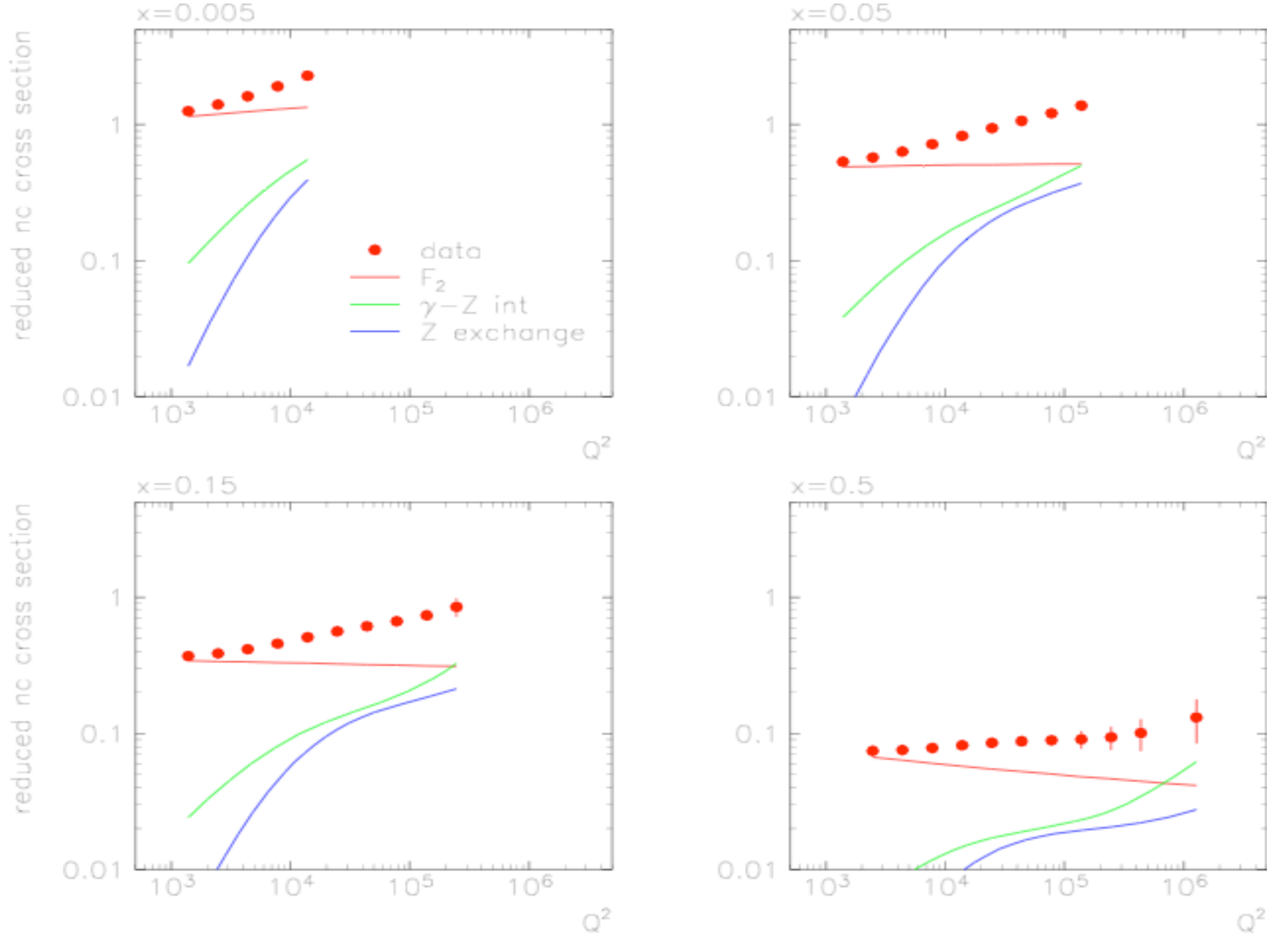
E.Perez

d/u at large x

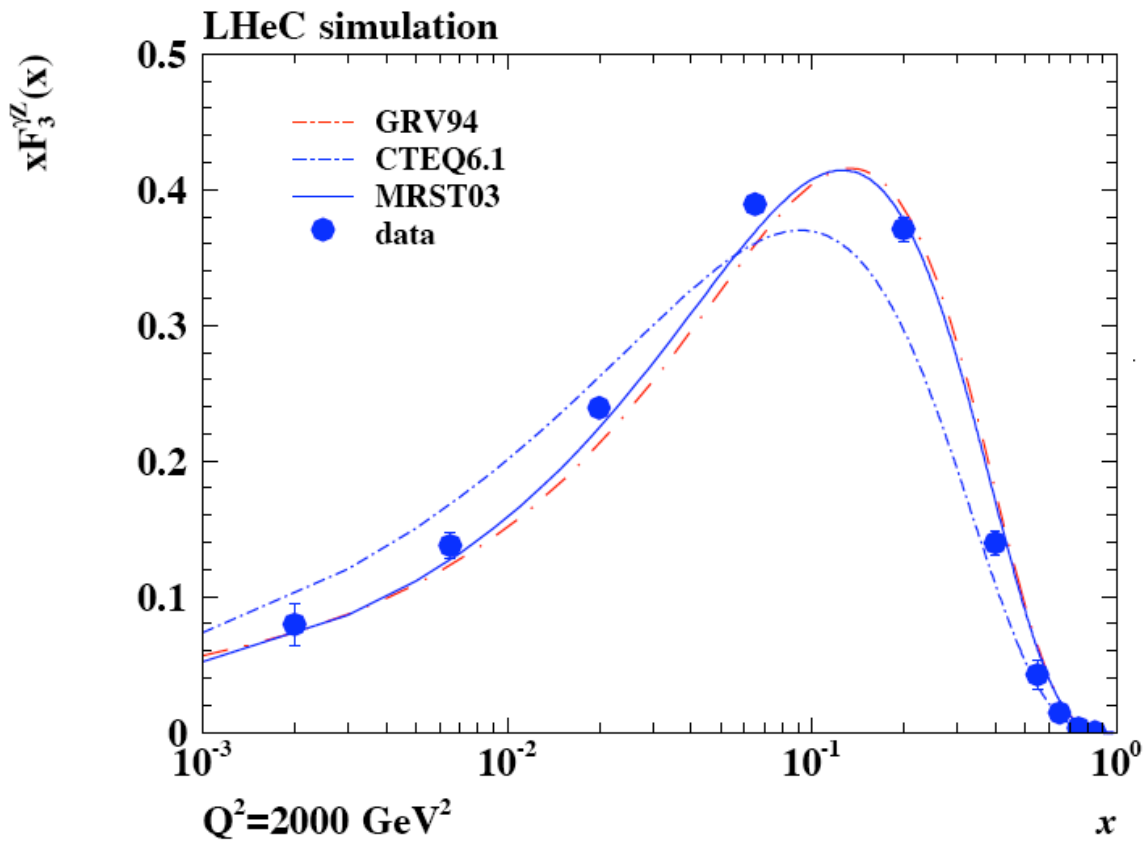


E.Perez

The LHeC is an electroweak machine

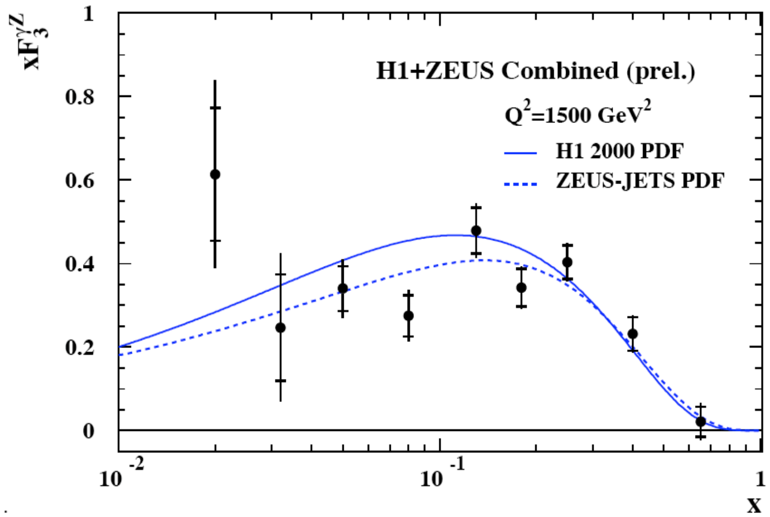


$xF_3^{\gamma Z}$



$$xF_3^{\gamma Z} = 2x[e_u a_u(u_v + \Delta_u) + e_d a_d(d_v + \Delta_d)]$$

HERA I



Valence quarks at low x

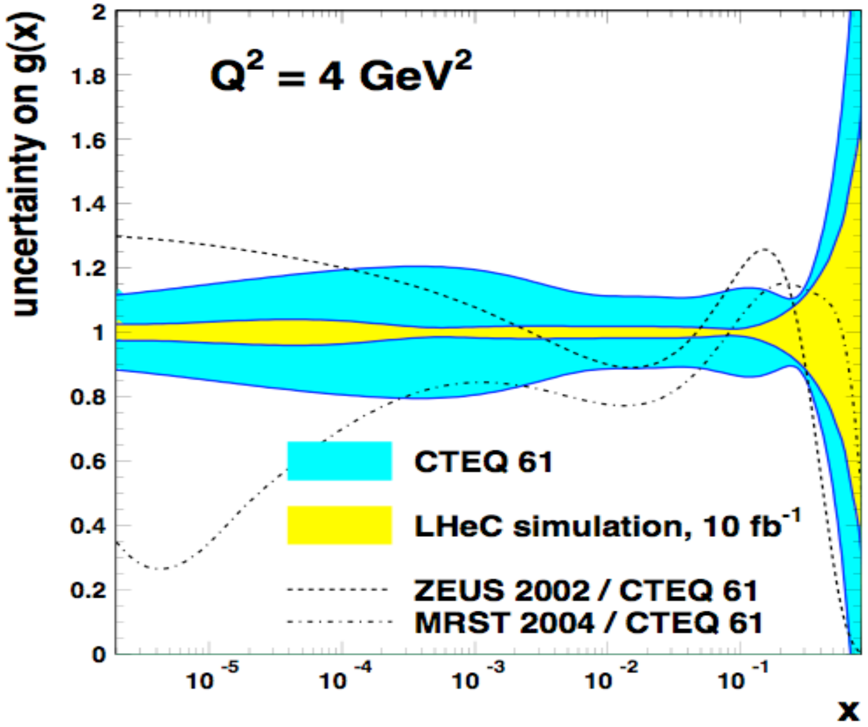
or/and unexpected sea

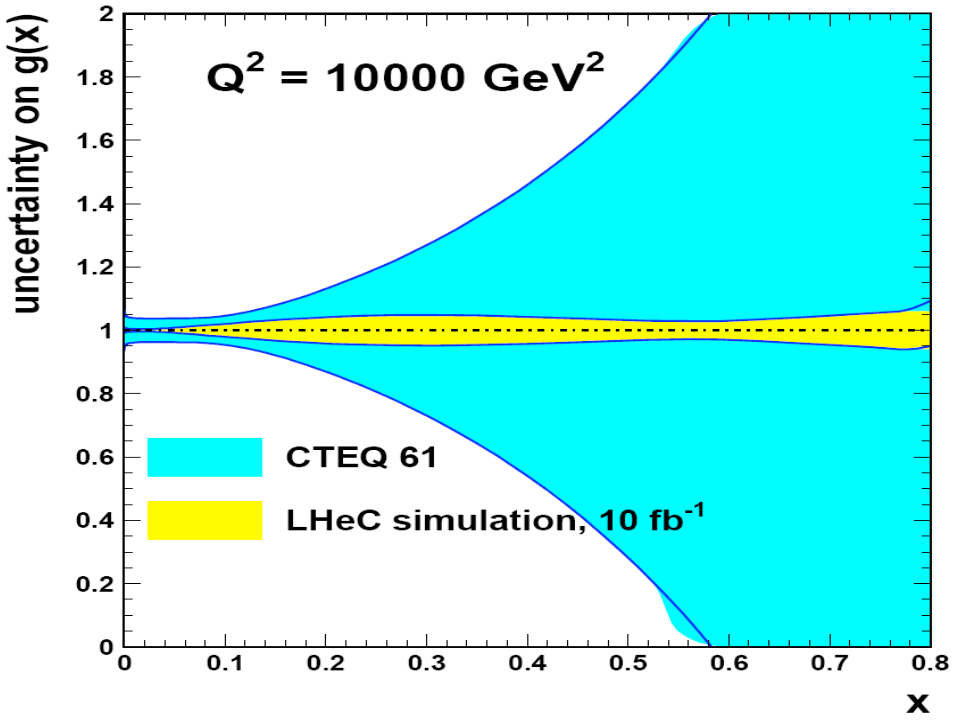
asymmetries

$$\Delta_u = (u_{sea} - \overline{u} + c - \overline{c})$$
$$\Delta_d = (d_{sea} - \overline{d} + s - \overline{s})$$

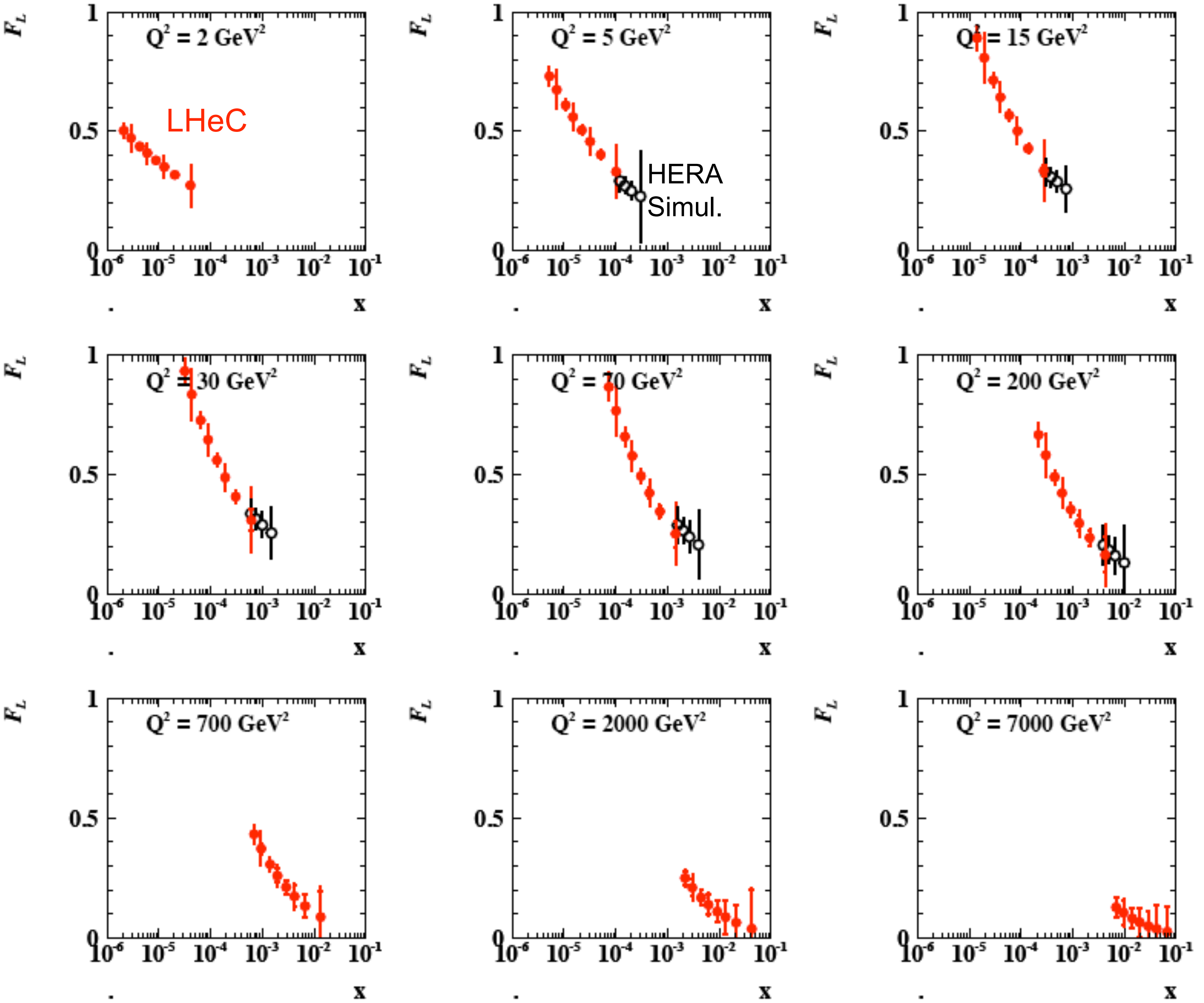
from yZ interference

Gluon Distribution





E.Perez



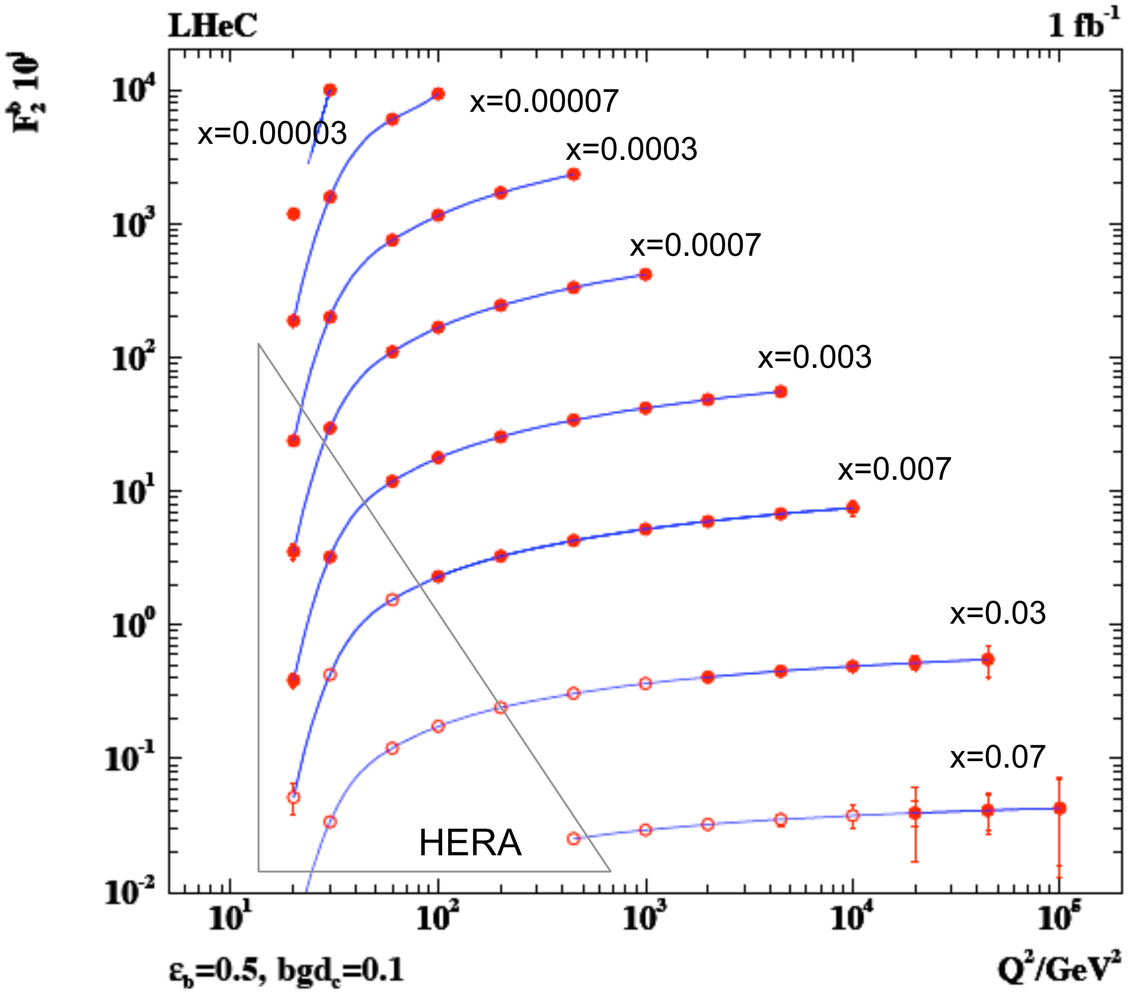
DIS08
J.Forshaw
et al.

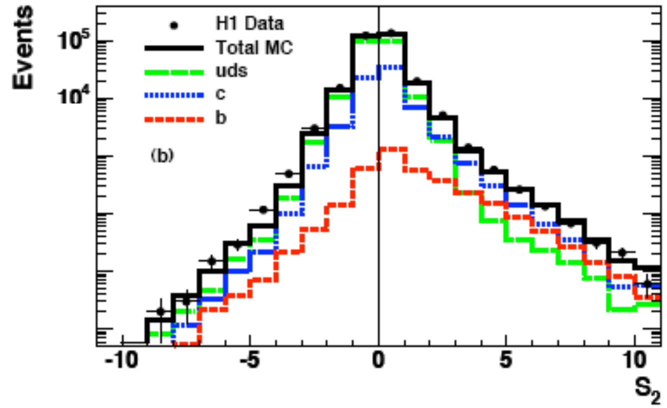
May not be able to simultaneously fit the two proton structure functions F2 and FL when these represent a saturation CDM

With enlarged energy, saturation scale moves into DIS region and DGLAP may truly be shown to fail when confronted with very low x data.

F_L takes long (1986-2008)…

Beauty quark distribution





$1\,fb^{-1}$

$\varepsilon_b = 0.5$

$bgd_c = 0.1$

$\delta_{syst} = 0.1$

$\circ - \vartheta_h \geq 1^o$

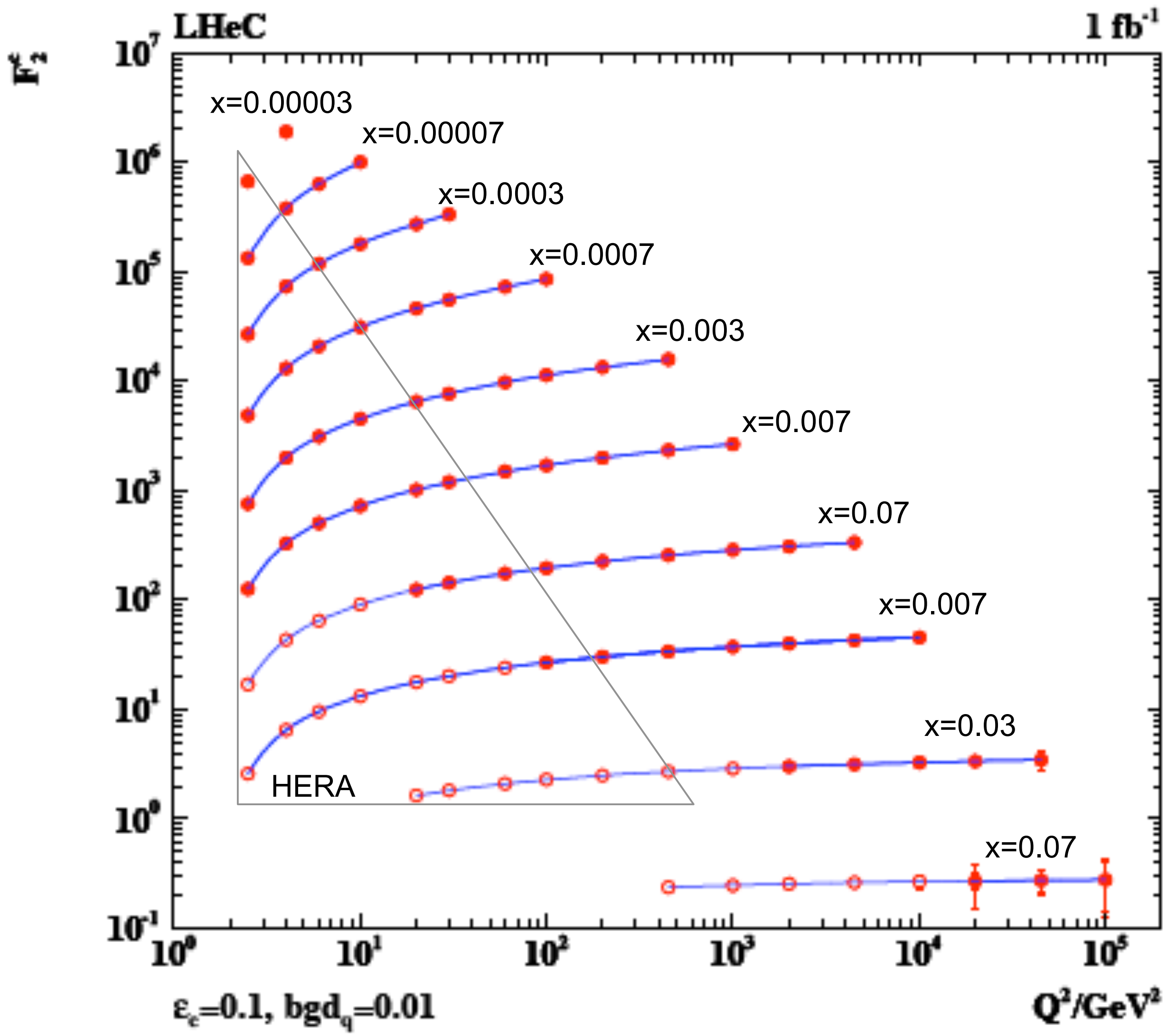
$\bullet - \vartheta_h \geq 10^o$

Impact parameter tagging

At LHeC may also tag decays with dedicated vertex detector

beam spot 35*15 μm^2

Charm quark distribution



$1\,fb^{-1}$

$\varepsilon_c = 0.1$

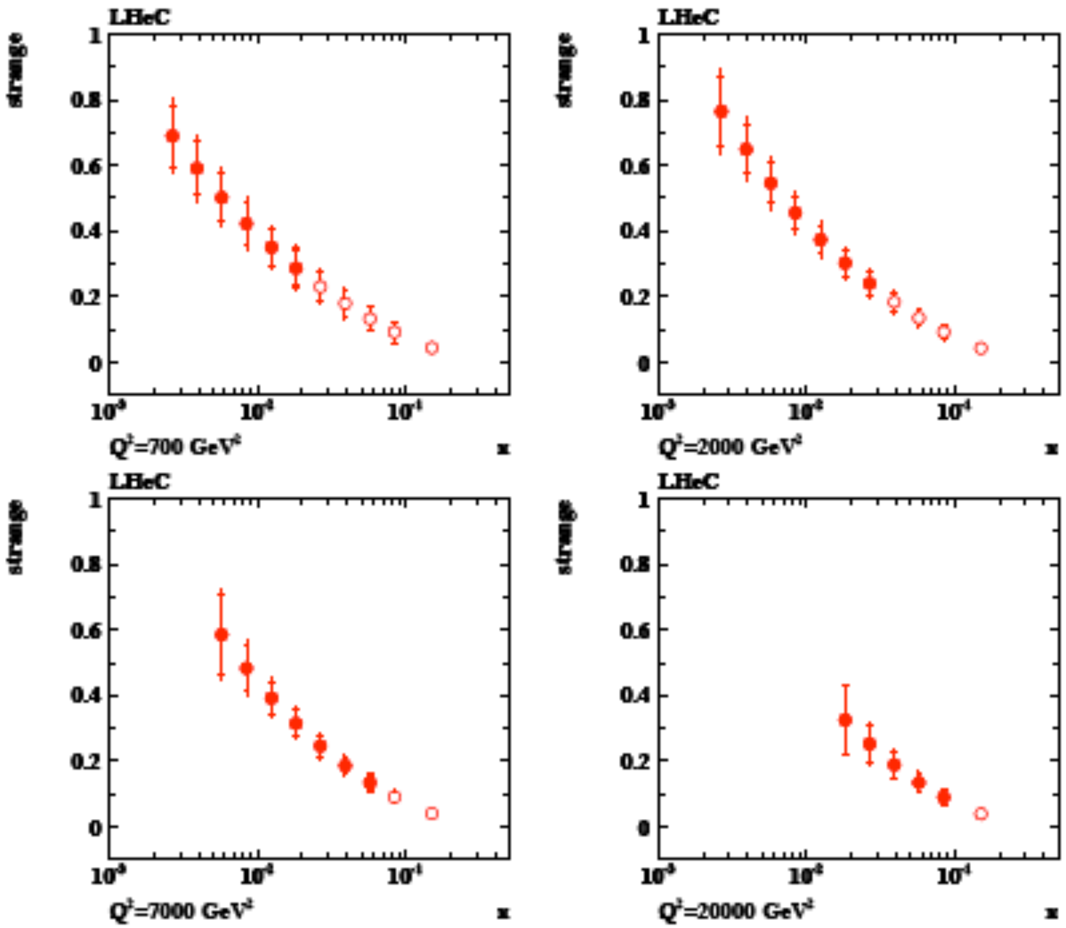
$bgd_q = 0.01$

$\delta_{syst} = 0.1$

$\circ - \vartheta_h \geq 1^o$

$\bullet - \vartheta_h \geq 10^o$

Strange quark distribution



$W^+ s \rightarrow c$

$1 fb^{-1}$

$\varepsilon_c = 0.1$

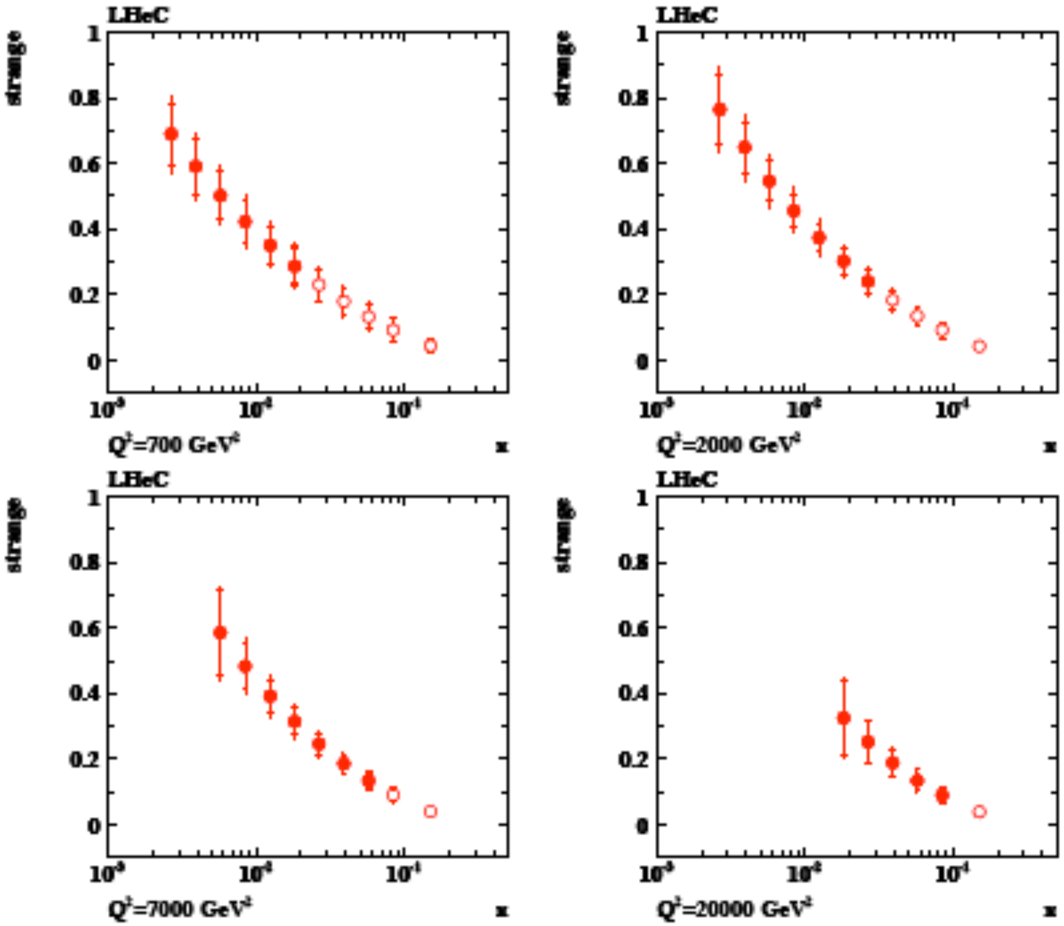
$\varepsilon_q = 0.01$

$\delta_{syst} = 0.1$

$\circ - \vartheta_h \geq 1^o$

$\bullet - \vartheta_h \geq 10^o$

Anti-Strange quark distribution



$W^{-} sbar \rightarrow cbar$

$1\, fb^{-1}$

$\varepsilon_{c} = 0.1$

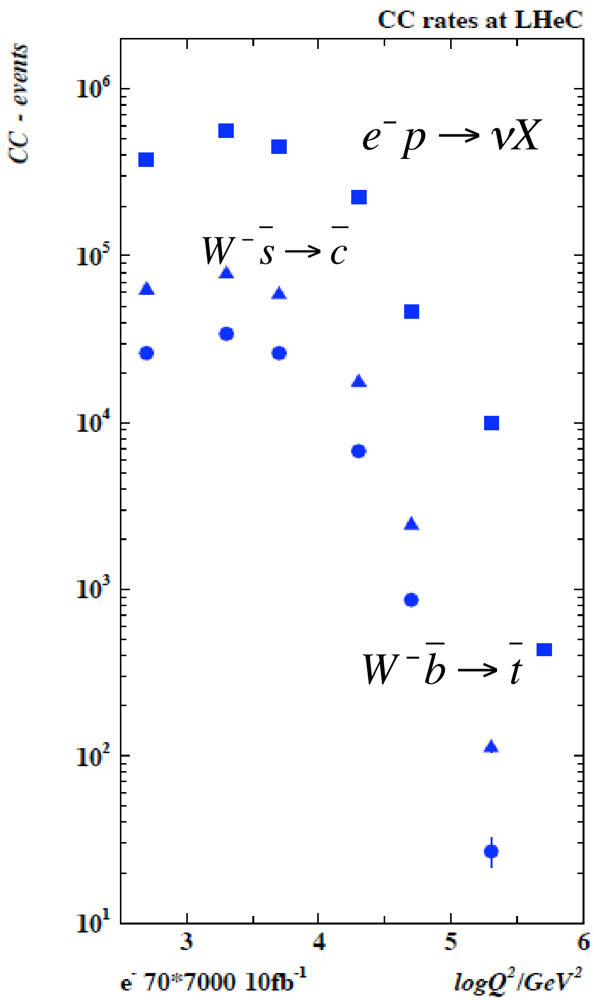
$\varepsilon_{q} = 0.01$

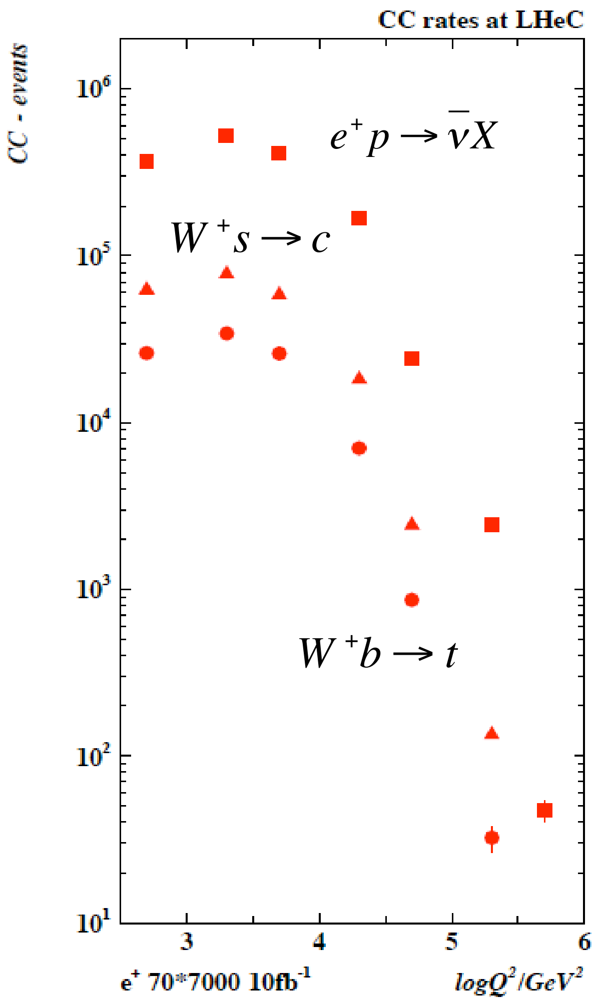
$\delta_{syst} = 0.1$

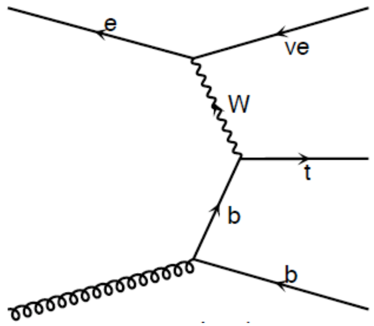
$\circ - \vartheta_{h} \geq 1^{o}$

$\bullet - \vartheta_{h} \geq 10^{o}$

$\overline{\text{Top}}$ and Top Production at the LHeC (cc)





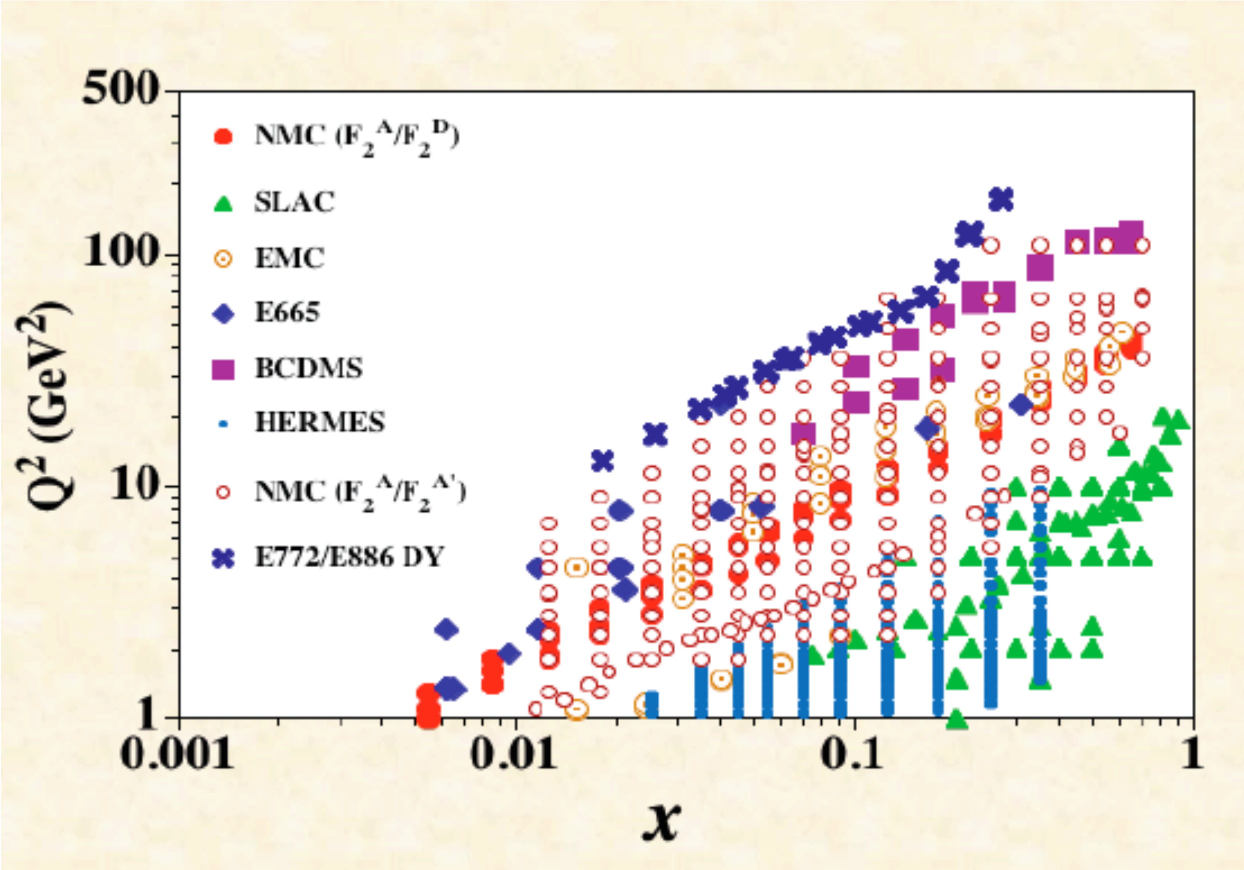


LHeC is a single top and tbar quark factory

with a CC cross section of O(10)pb - worth studying further

Cross section to be Checked (pdf's)

Available data on F_2 in nuclei

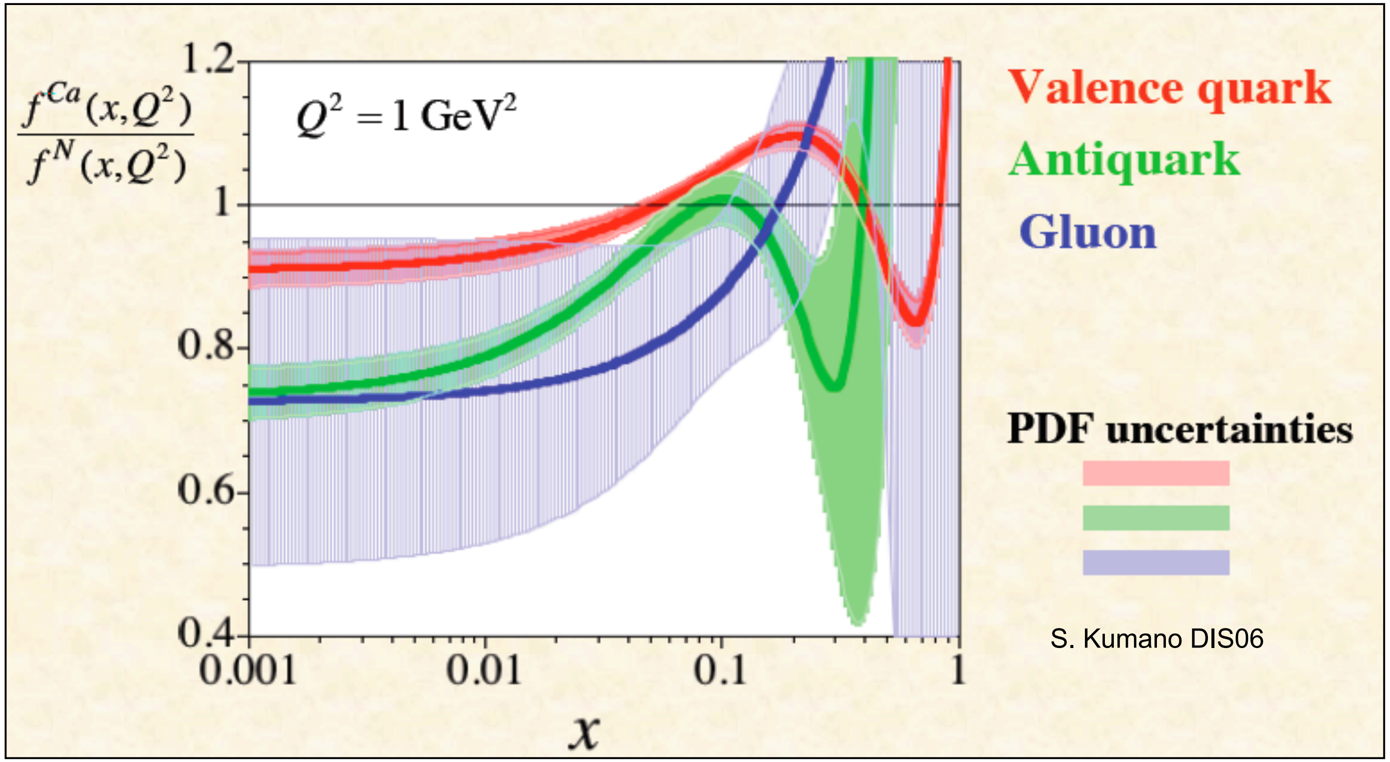


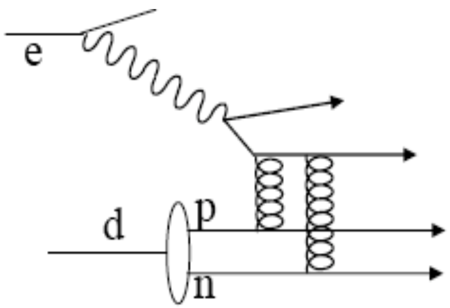
Limited information on quarks and nearly none on gluons

The LHeC extends the eA kinematic range by 4 orders of magnitude

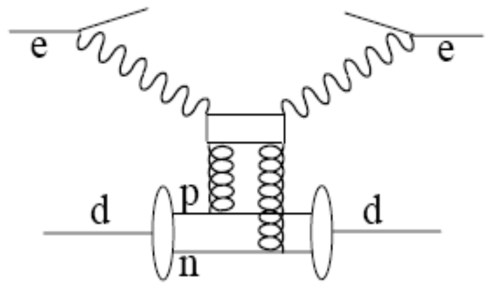
K.Eskola (ed), hep-ph/0308248; S. Kumano DIS06; D.Florian and R. Sassot, hep-ph/0311227; FGS, Phys Rev.D71(05)054001; LMcLerran,Glasma..

Determination of nPDF's



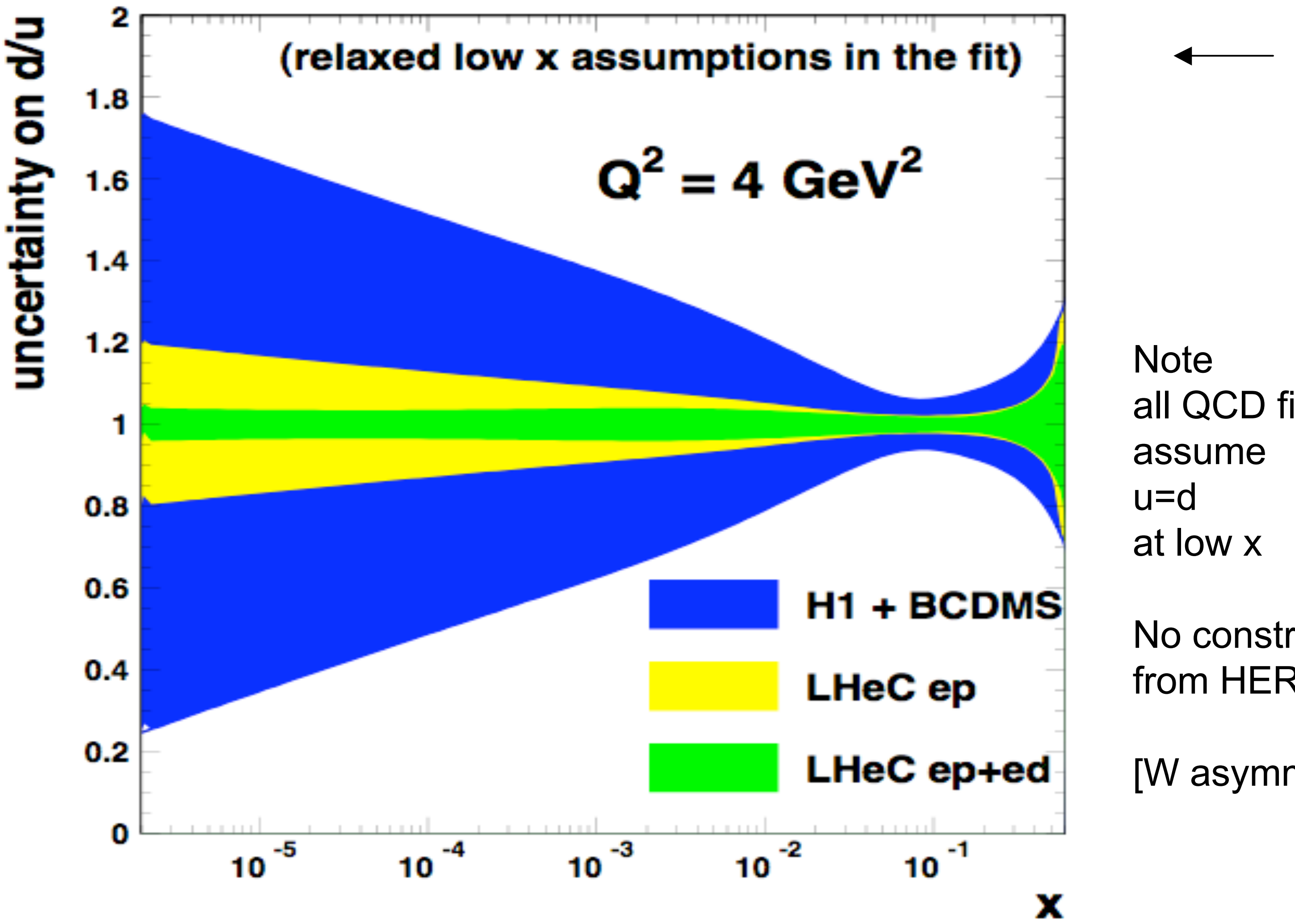


In eA at the collider, test Gribovs relation between shadowing and diffraction, control nuclear effects at low Bjorken x to high accuracy



Max Klein LHeC pdf Divonne 2.9.08

d/u at low x from deuterons

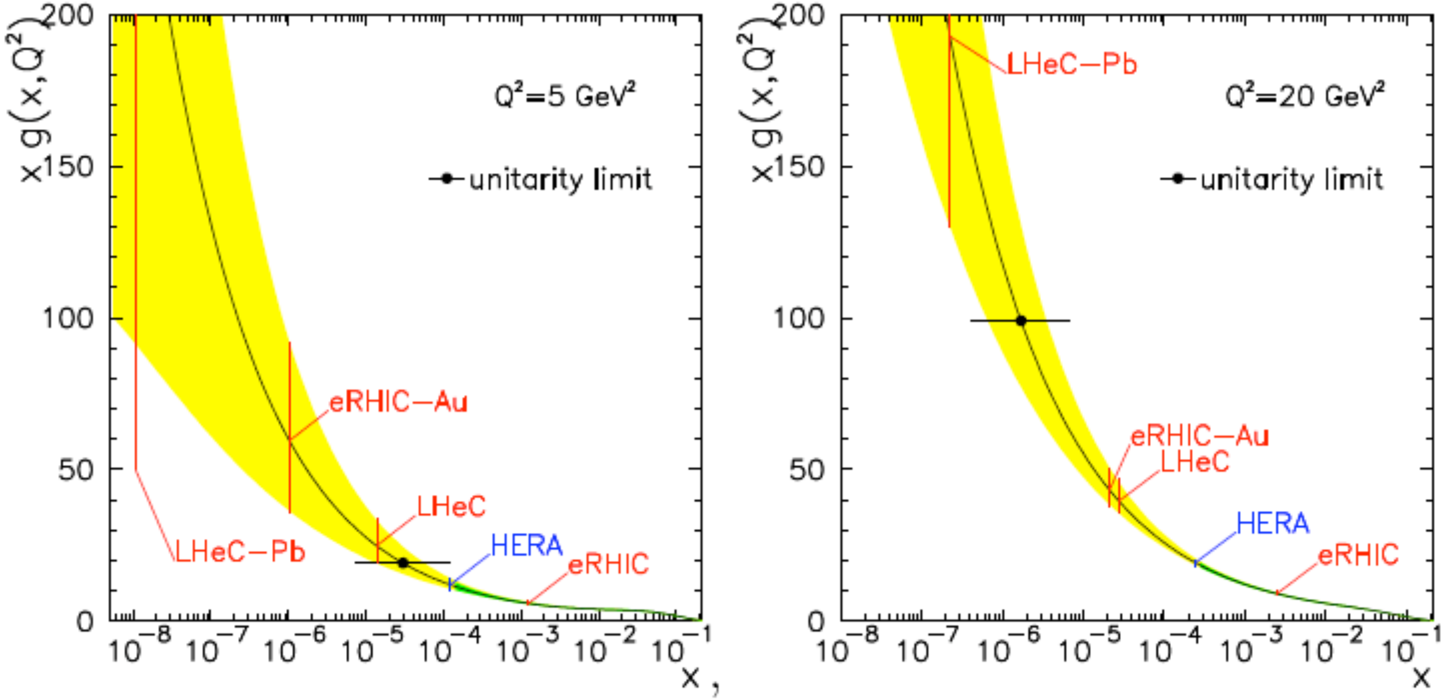


Note
all QCD fits
assume
u=d
at low x

No constraint
from HERA

[W asymmetry]

Gluon density - amplification?



High density $\frac{g_A/\pi r_A^2}{g_p/\pi r_p^2} = A^{1/3}\frac{g_A}{Ag_p}$

Unitarity $xg(x,Q^2) \le \frac{1}{\pi N_c \alpha_s(Q^2)} Q^2 R^2 \simeq \frac{Q^2}{\alpha_s}$

Summary

The LHeC has the potential to completely unfold the partonic content of the proton: u,d, c,s, t,b for the first time and in an unprecedent kinematic range. This is based on inclusive NC, CC cross sections complemented by heavy quark identification.

Puzzles as u/d at large x or a strange-antistrange asymmetry will be solved.

Precision measurements are possible of xg (up to large x) and the beauty density which are of particular relevance for the LHC. The whole p structure which the LHC assumes to know will become accurately known.

There is a huge potential for electroweak physics in these accurate data (couplings, G2, ..) not yet studied.

Low x physics will be lead to a new area with the extension of the kinematic range and high precision measurements, as of F2 and also FL.

Neutron distributions will become measurable in deuteron runs with p,n,d tagging. Diffraction is predicted to constrain shadowing.

Not much done on nuclear pdfs, apart from a visualisation of the $A^{1/3}$ amplification of the gluon density, though here the impact of the LHeC is most striking (extension by 4 orders of magnitude!)

Backup slides

JINST

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Deep inelastic electron-nucleon scattering at the LHC

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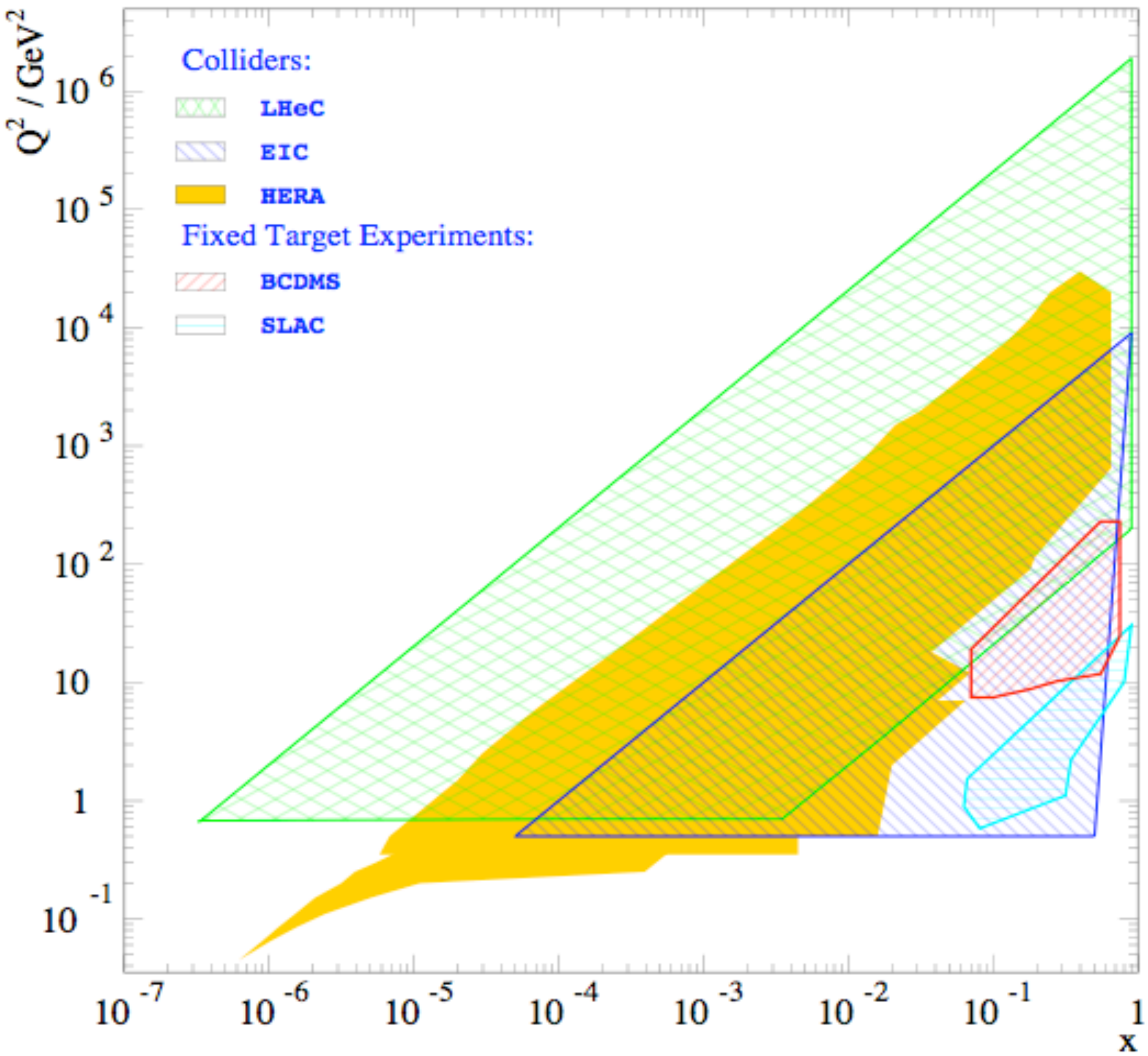
ABSTRACT: The physics, and a design, of a Large Hadron Electron Collider (LHeC) are sketched. With high luminosity, $10^{33}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$, and high energy, $\sqrt{s} = 1.4$ TeV, such a collider can be built in which a 70 GeV electron (positron) beam in the LHC tunnel is in collision with one of the LHC hadron beams and which operates simultaneously with the LHC. The LHeC makes possible deep-inelastic lepton-hadron (ep, eD and eA) scattering for momentum transfers Q^2 beyond $10^6\,\mathrm{GeV}^2$ and for Bjorken x down to the 10^{-6}. New sensitivity to the existence of new states of matter, primarily in the lepton-quark sector and in dense partonic systems, is achieved. The precision possible with an electron-hadron experiment brings in addition crucial accuracy in the determination of hadron structure, as described in Quantum Chromodynamics, and of parton dynamics at the TeV energy scale. The LHeC thus complements the proton-proton and ion programmes, adds substantial new discovery potential to them, and is important for a full understanding of physics in the LHC energy range.

KEYWORDS: Accelerator modelling and simulations (multi-particle dynamics; single-particle dynamics); Large detector systems for particle and astroparticle physics.

2006 JINST 1 P10001

LHeC, HERA and EIC



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