LHeC
Large Hadron electron Collider project

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http://www.cern.ch/lhec

CERN, 8 February 2013

Project Development

2007: Invitation by SPC to ECFA and by (r)ECFA to work out a design concept

2008: First CERN-ECFA Workshop in Divonne (1.-3.9.08)

2009: 2nd CERN-ECFA-NuPECC Workshop at Divonne (1.-3.9.09)

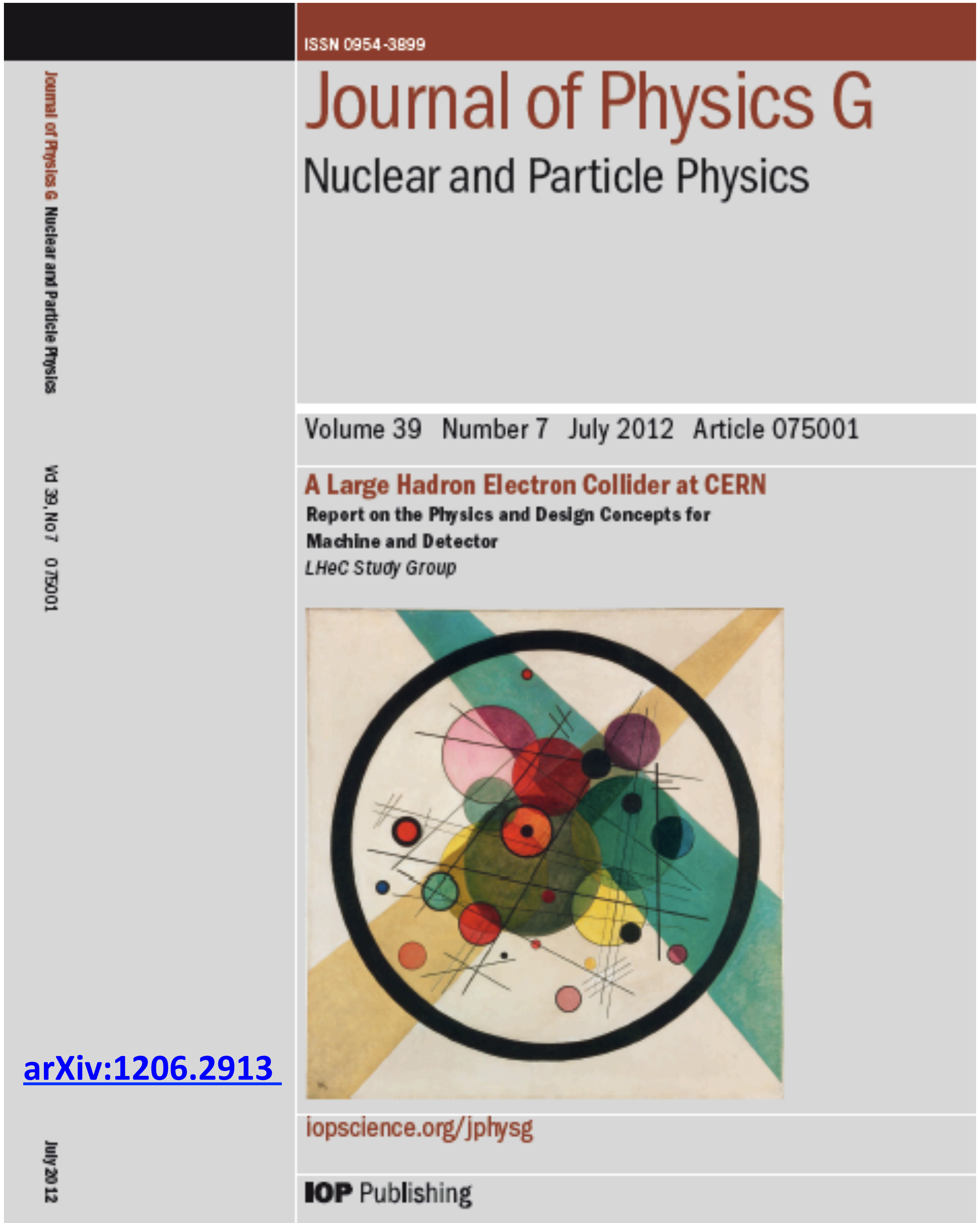
2010: Report to CERN SPC (June)
3rd CERN-ECFA-NuPECC Workshop at Chavannes-de-Bogis (12.-13.11.10)
NuPECC puts LHeC to its Longe Range Plan for Nuclear Physics (12/10)

2011: Draft CDR (530 pages on Physics, Detector and Accelerator) (5.8.11)
refereed and being updated

2012: Discussion of LHeC at LHC Machine Workshop (Chamonix)
Publication of CDR – European Strategy
New workshop (June14-15, 2012)

LHeC has some history already ..

Conceptual Design Report



arXiv:1206.2913

LHeC Study Group

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193 authors
631 pages
947 references
5 chapters
14 sections

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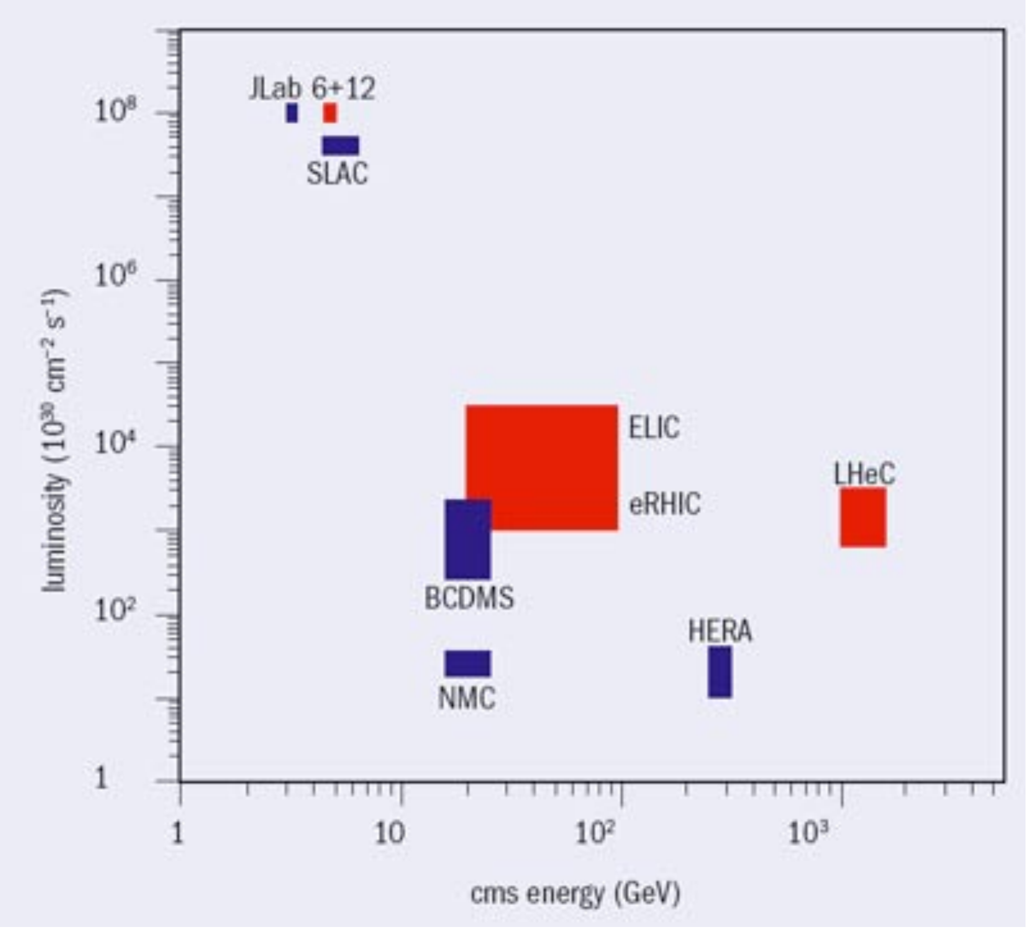


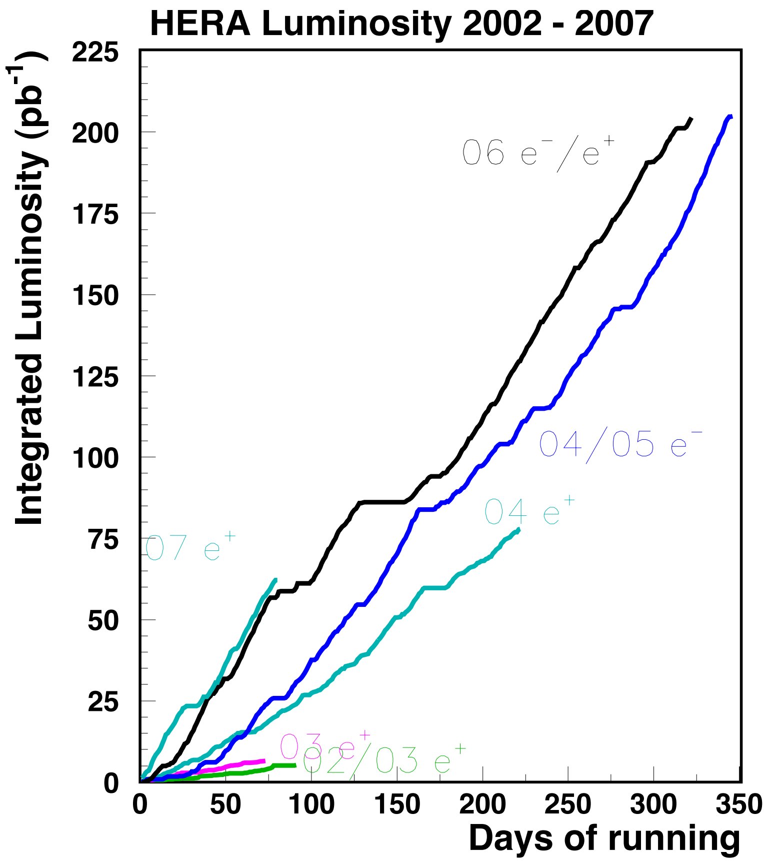
LHeC is the latest & most promising idea to take ep physics to the TeV centre-of-mass scale …
… at high luminosity

Outline of the talk:

- Physics motivation
- Accelerator and detector design
- Physics possibilities
- Timeline and outlook

Deep inelastic electron-proton collider

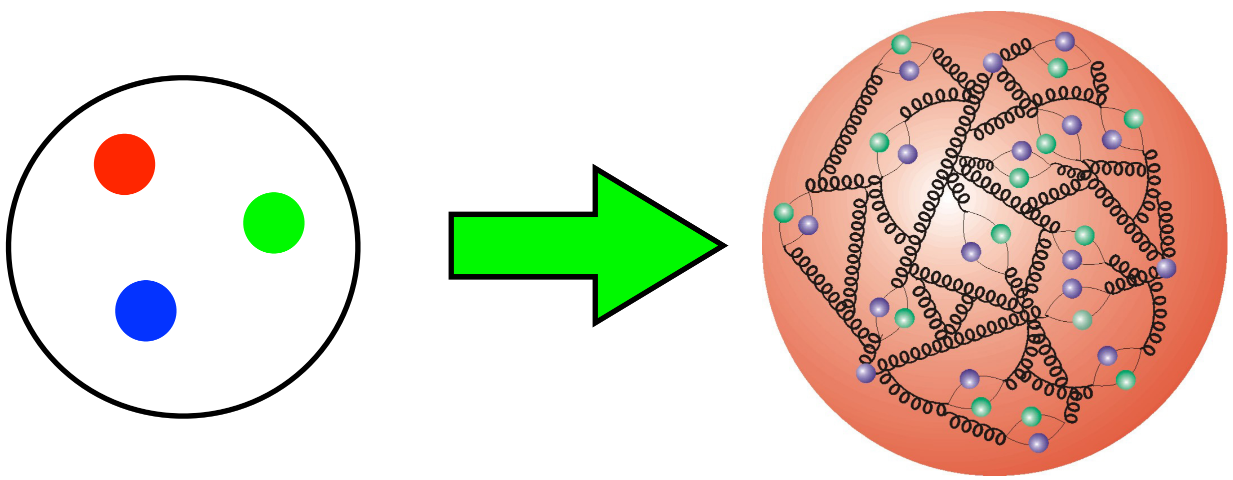
HERA Hamburg 1992-2007

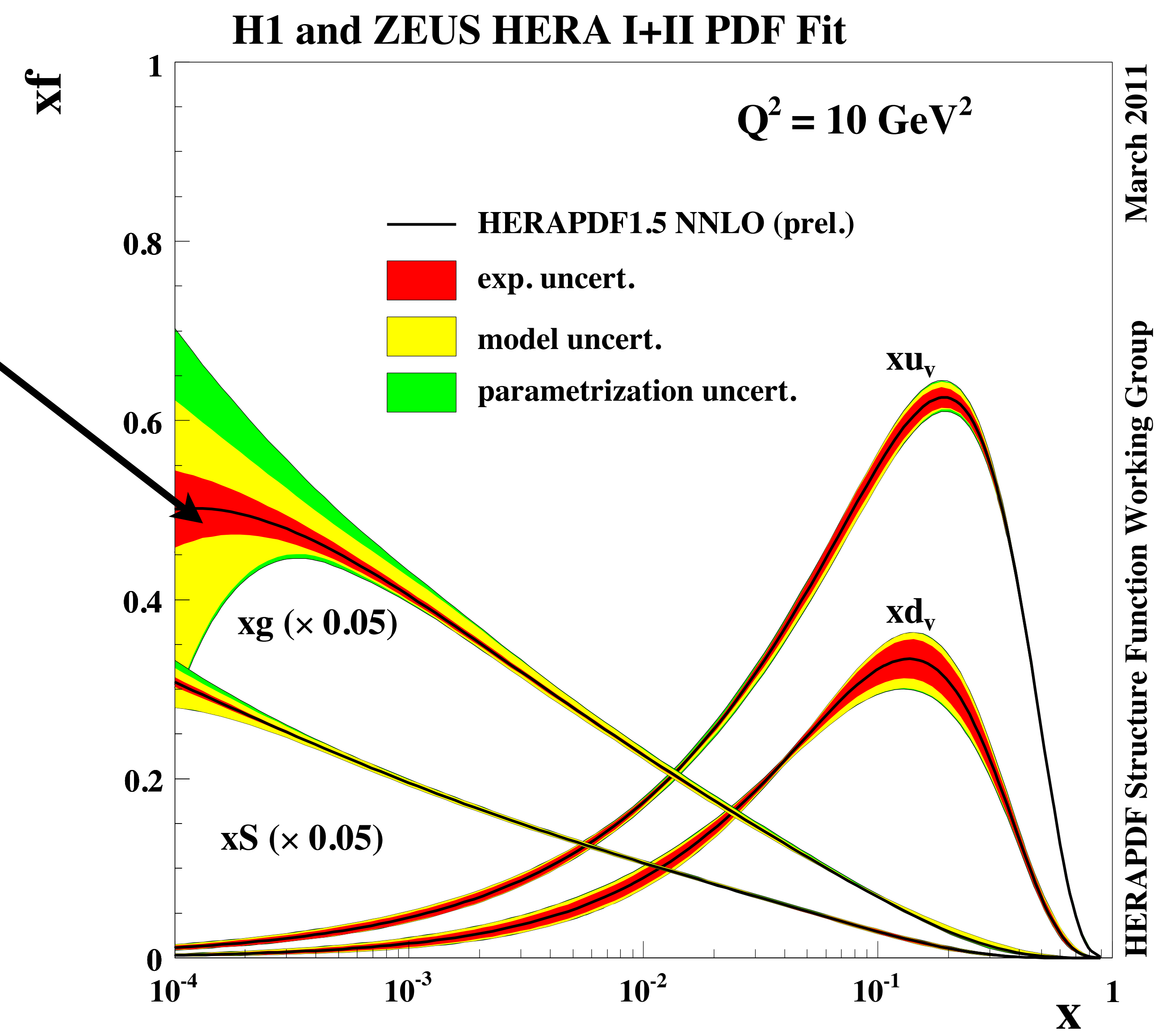


Results from HERA

HERA established detailed proton structure: parton density functions.

Increasing role of gluons at small x. Proton structure is highly complex due to the QCD radiation (evolution).





Other results: measurement of coupling constant, jets, photon structure, diffractive processes, charm and bottom structure functions, limits for new physics (leptoquarks).

Limitations of HERA

HERA in one box
the first ep collider

$E_p * E_e =$
$920 * 27.6 GeV^2$
$\sqrt{s} = 2\sqrt{E_e E_p} = 320$ GeV

$L = 1..4\ 10^{31} cm^{-2} s^{-1}$
→ $\Sigma L = 0.5 fb^{-1}$
1992-2000 & 2003-2007

$Q^2 = [0.1 -- 3 * 10^4]\ GeV^2$
-4-momentum transfer^2

$x = Q^2/(sy) \cong 10^{-4}$ .. 0.7
Bjorken x

$y \cong 0.005$ .. 0.9
inelasticity

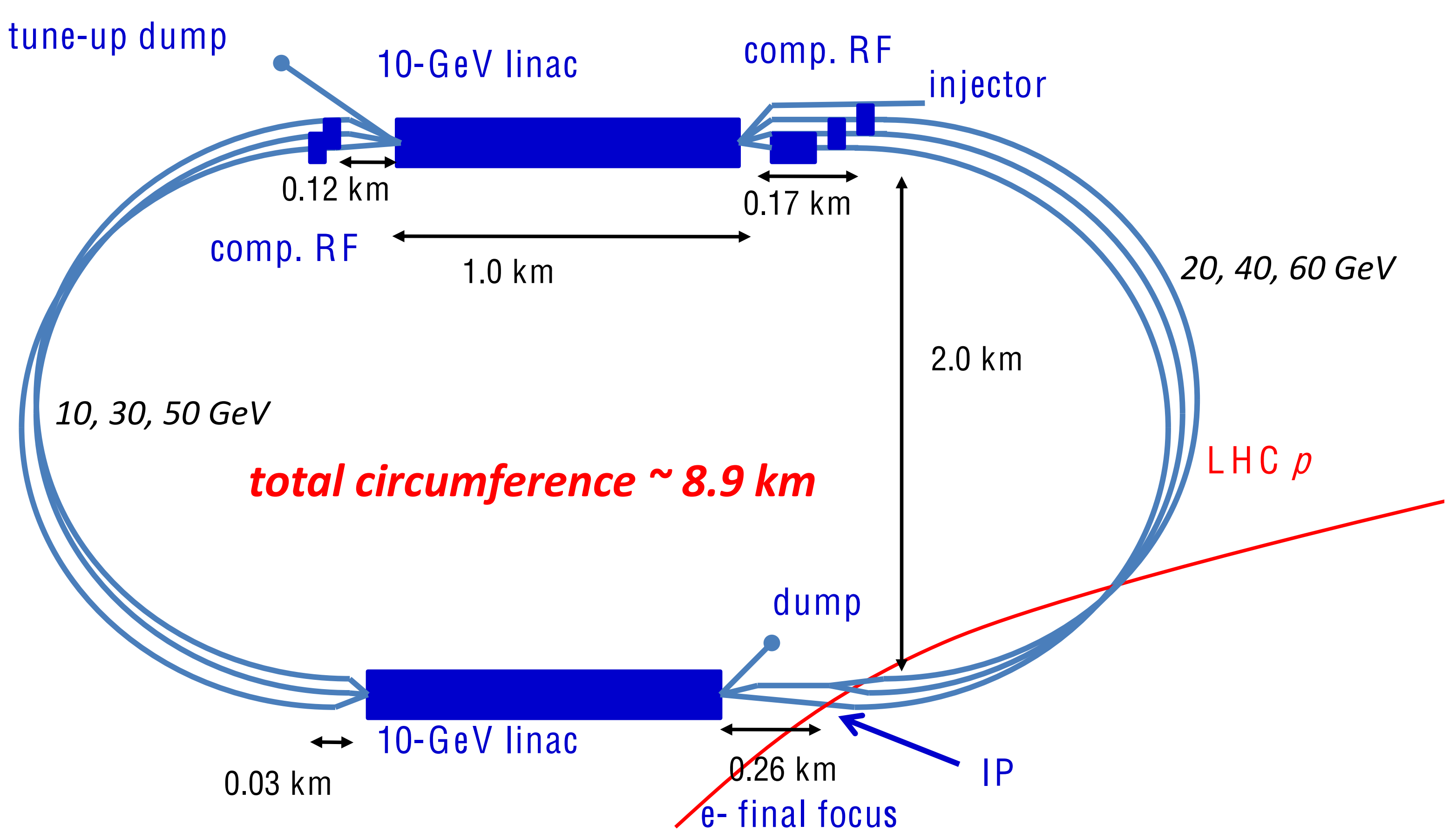
- Low luminosity for high precision(large x)
- No deutrons
- No heavy nuclei
- Low x saturation ?(too small s)
- Precision measurement of α_s (overall not precise enough)
- …

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.

Physics motivation for ep/eA in TeV range

- Details of parton structure of the nucleon (from ep,ed/eA), full unfolding of PDFs. Measurement of GPDs and unintegrated PDFs.
- Mapping the gluon field down to very low x. Saturation physics.
- Heavy quarks, factorization, diffraction, electroweak processes.
- Properties of Higgs. Very good sensitivity to: H to bbar, H to WW coupling in the 120-130 GeV mass range.
- Searches and understanding of new physics. Very precise measurement of the coupling constant. Leptoquarks, excited leptons...
- Deep inelastic scattering off nuclei. Nuclear parton distributions. Pinning down the initial state for heavy ion collisions.

Accelerator design in linac-ring option



500 MeV injection
3 turns
2 linacs, 10 GeV
energy recovery
90% polarisation

$$L = 10^{33}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$$

Higher energy:
140 GeV linac
ILC type
31.5 MV/m
without energy recovery
lower luminosity

Design Parameters

parameter [unit]	LHeC	
species	e	p, $^{208}Pb^{82+}$
beam energy (/nucleon) [GeV]	60	7000, 2760
bunch spacing [ns]	25, 100	25, 100
bunch intensity (nucleon) [10^{10}]	0.1 (0.2), 0.4	17 (22), 2.5
beam current [mA]	6.4 (12.8)	860 (1110), 6
rms bunch length [mm]	0.6	75.5
polarization [%]	90 (e^+ none)	none, none
normalized rms emittance [μm]	50	3.75 (2.0), 1.5
geometric rms emittance [nm]	0.43	0.50 (0.31)
IP beta function $\beta^*_{x,y}$ [m]	0.12 (0.032)	0.1 (0.05)
IP spot size [μm]	7.2 (3.7)	7.2 (3.7)
synchrotron tune Q_s	—	1.9×10^{-3}
hadron beam-beam parameter	0.0001 (0.0002)	
lepton disruption parameter D	6 (30)	
crossing angle	0 (detector-integrated dipole)	
hourglass reduction factor H_{hg}	0.91 (0.67)	
pinch enhancement factor H_D	1.35 (0.3 for e^+)	
CM energy [TeV]	1.3, 0.81	
luminosity / nucleon [10^{33} cm^{-2}s^{-1}]	1 (10), 0.2	

arXiv:1211:5102

Designed for synchronous ep and pp operation during the HL-LHC phase.

Energy Recovery Linac (3 pass)

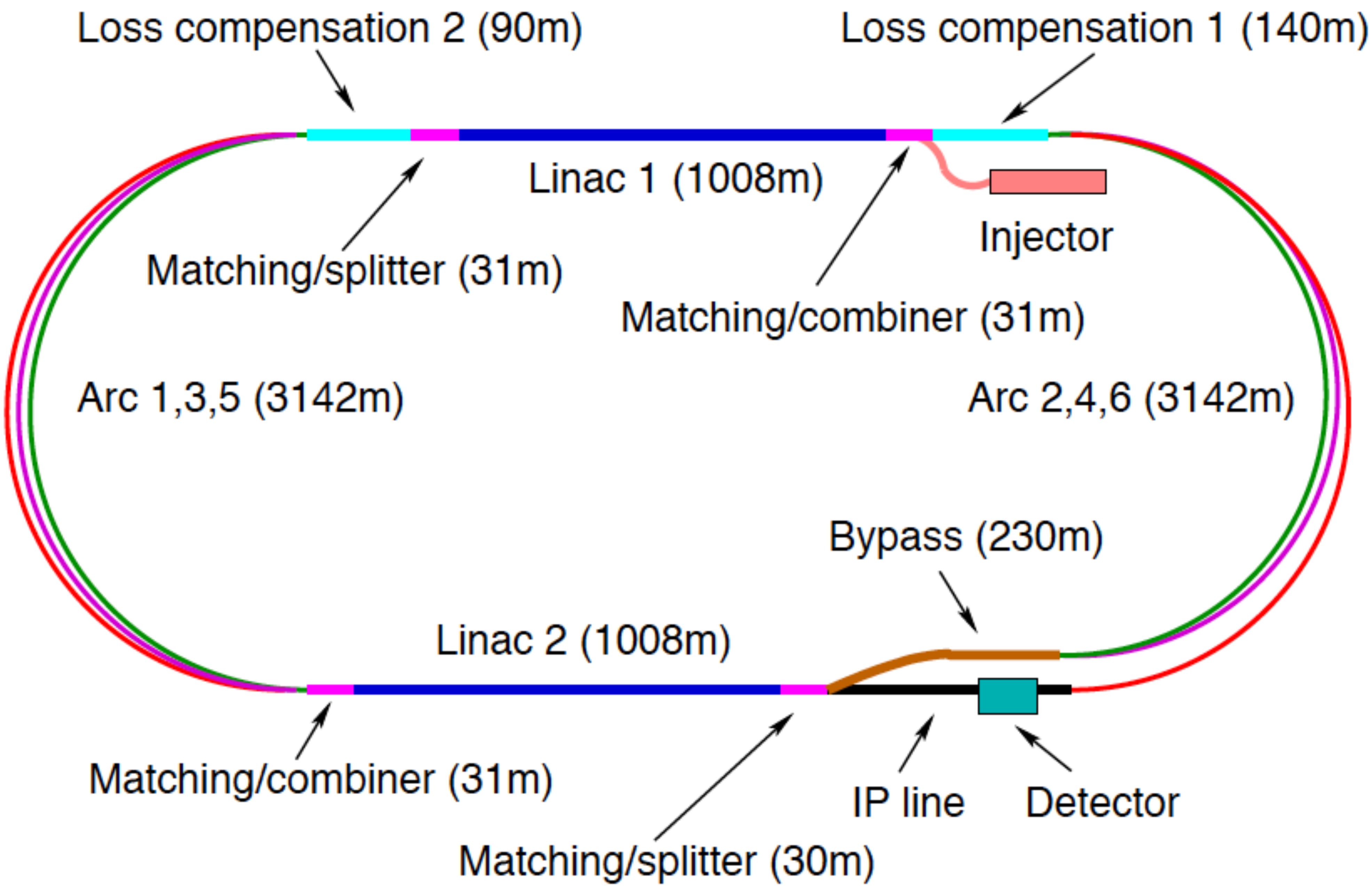
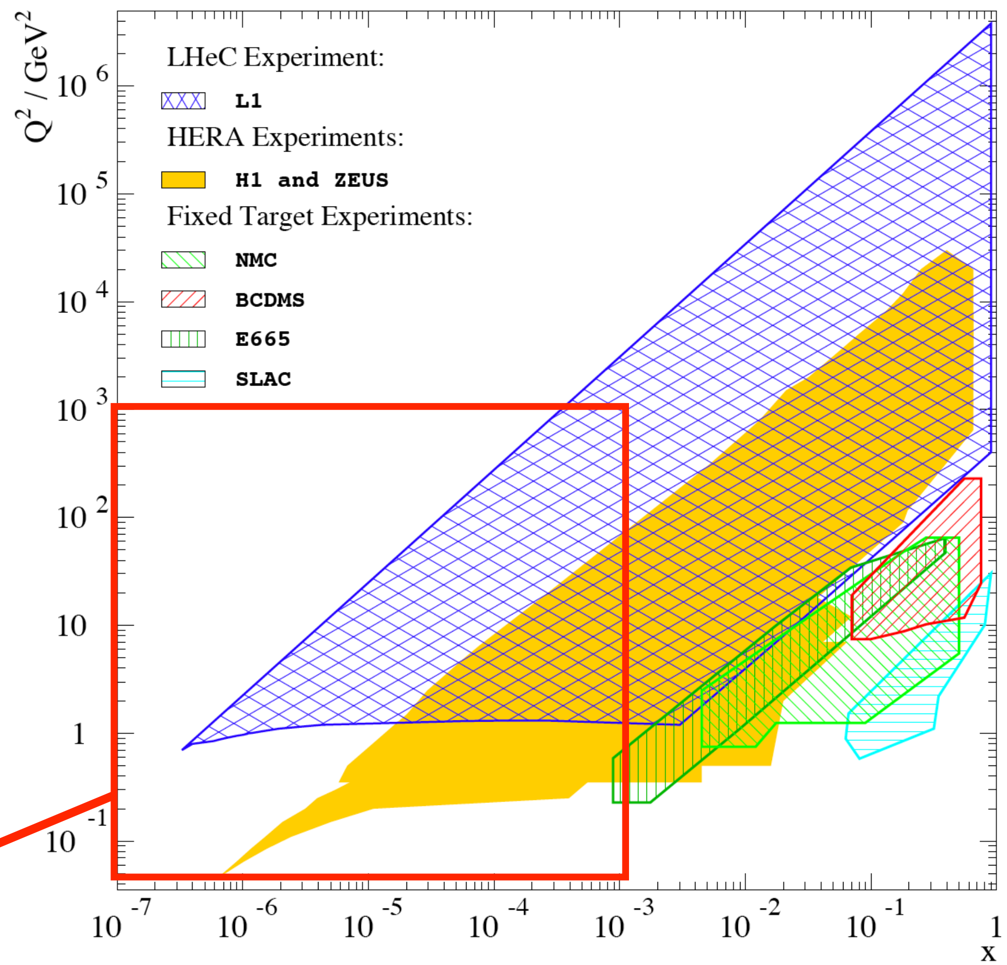


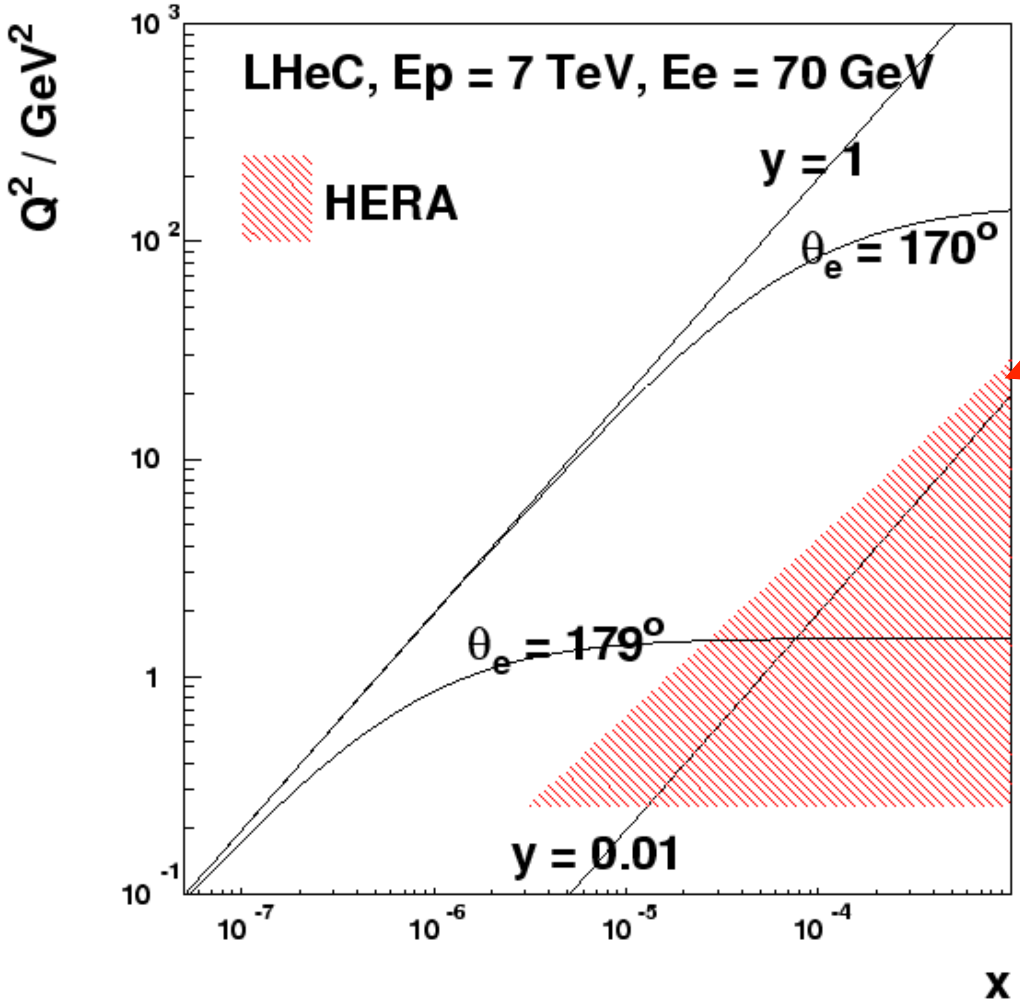
Figure 1: Schematic view on the LHeC racetrack configuration. Each linac accelerates the beam to 10 GeV, which leads to a 60 GeV electron energy at the collision point with three passes through the opposite linear structures of 60 cavity-cryo modules each. The arc radius is about 1 km, mainly determined by the synchrotron radiation loss of the 60 GeV beam which is returned from the IP and decelerated for recovering the beam power. Comprehensive design studies of the lattice, optics, beam (beam) dynamics, dump, IR and return arc magnets, as well as auxiliary systems such as RF, cryogenics or spin rotators are contained in the CDR [1], which as for physics and detector had been reviewed by 24 referees appointed by CERN.

Ring-Ring option as fall back;

Detector Acceptance Requirements

Access to Q^2=1 GeV^2 in ep mode for all x > 5 x 10^{-7} requires scattered electron acceptance to 179°





Similarly, need 1° acceptance in outgoing proton direction to contain hadrons at high x (essential for good kinematic reconstruction)

LHeC kinematics

ep/ea collisions

$$E_p = 7 \text{ TeV}$$
$$E_A = 2.75 \text{ TeV/nucleon}$$
$$E_e = 50 - 150 \text{ GeV}$$
$$\sqrt{s} \simeq 1 - 2 \text{ TeV}$$

- **Requirements**:

* Luminosity~10^{33} $cm^{-2}s^{-1}$. eA: L_{en}~10^{32} $cm^{-2}s^{-1}$

* Acceptance: 1-179 degrees (low-x ep/eA).

* Tracking to 1 mrad.

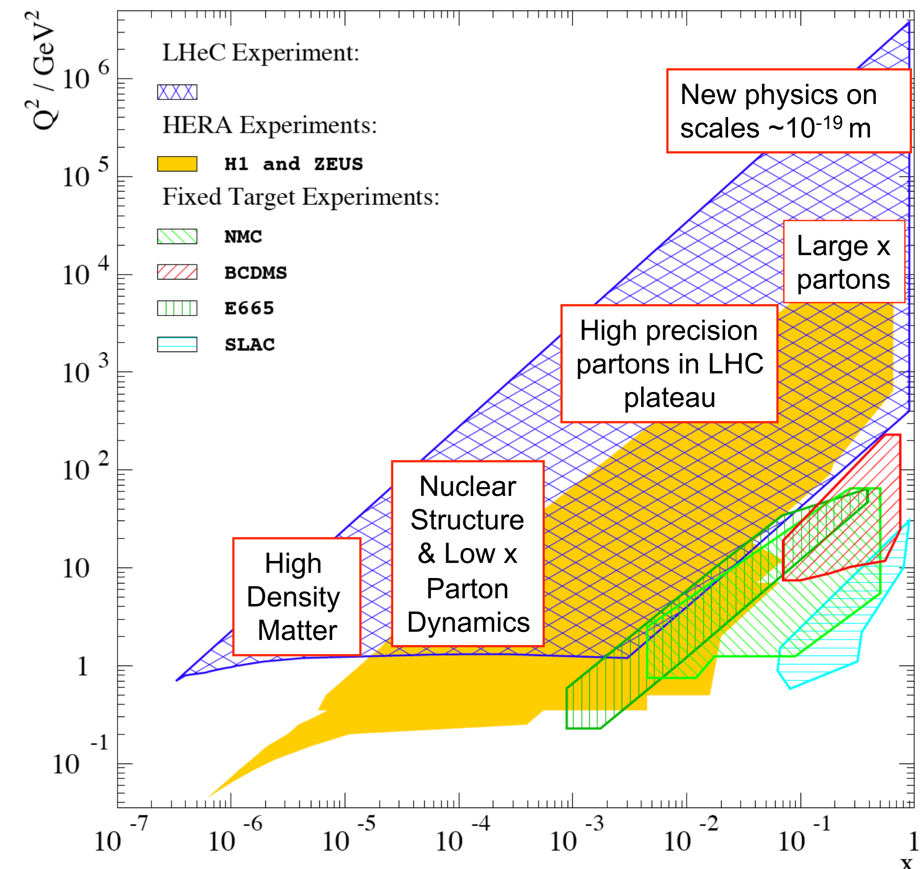
* EMCAL calibration to 0.1 %.

* HCAL calibration to 0.5 %.

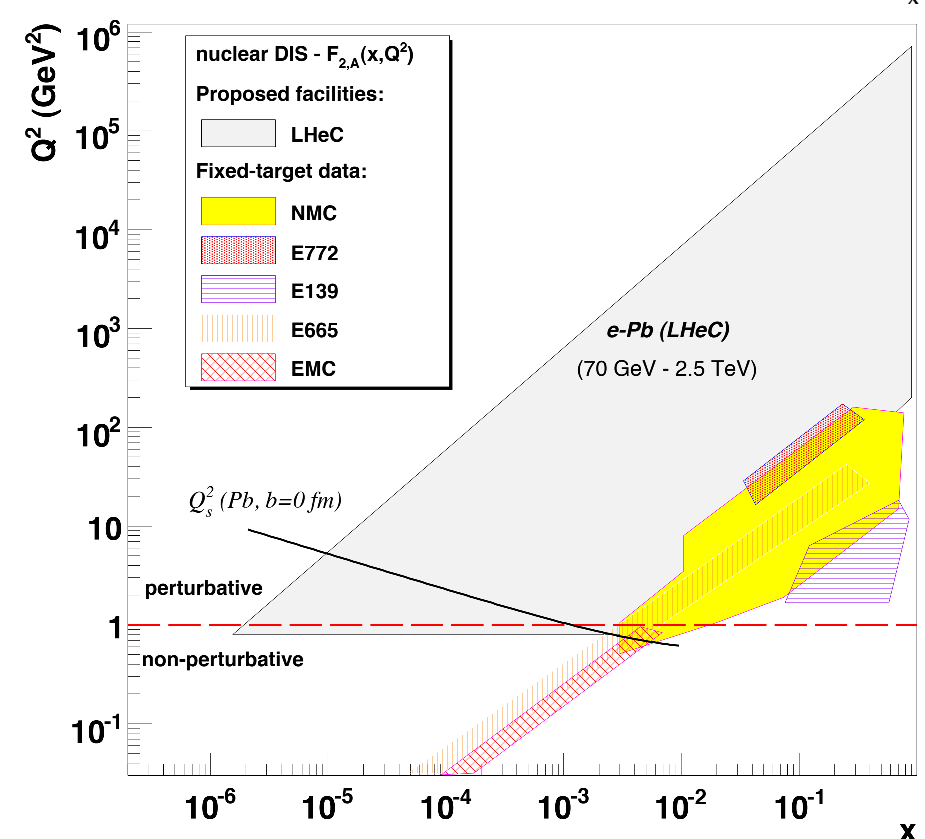
* Luminosity determination to 1 %.

* Compatible with LHC operation.

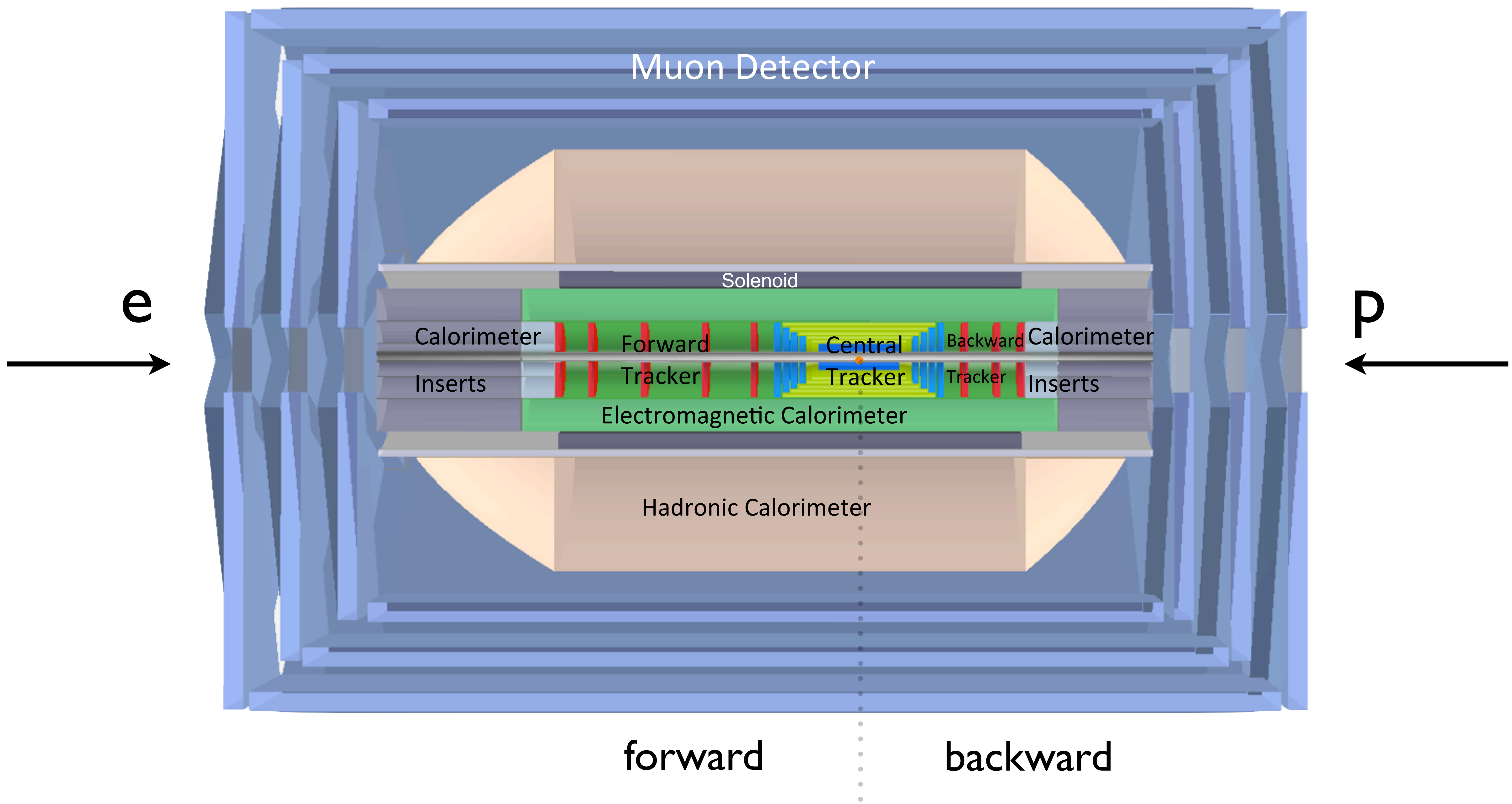
ep



eA



Detector design



Forward/backward asymmetry in energy deposited and thus in geometry and technology
Present dimensions: LxD =14x9m^2 [CMS 21 x 15m^2, ATLAS 45 x 25 m^2]
Taggers at -62m (e),100m (γ,LR), -22.4m (γ,RR), +100m (n), +420m (p)

Physics possibilities

Beyond Standard Model

Leptoquarks
Contact Interactions
Excited Fermions
Higgs in MSSM
Heavy Leptons
4th generation quarks
Z'
SUSY
???

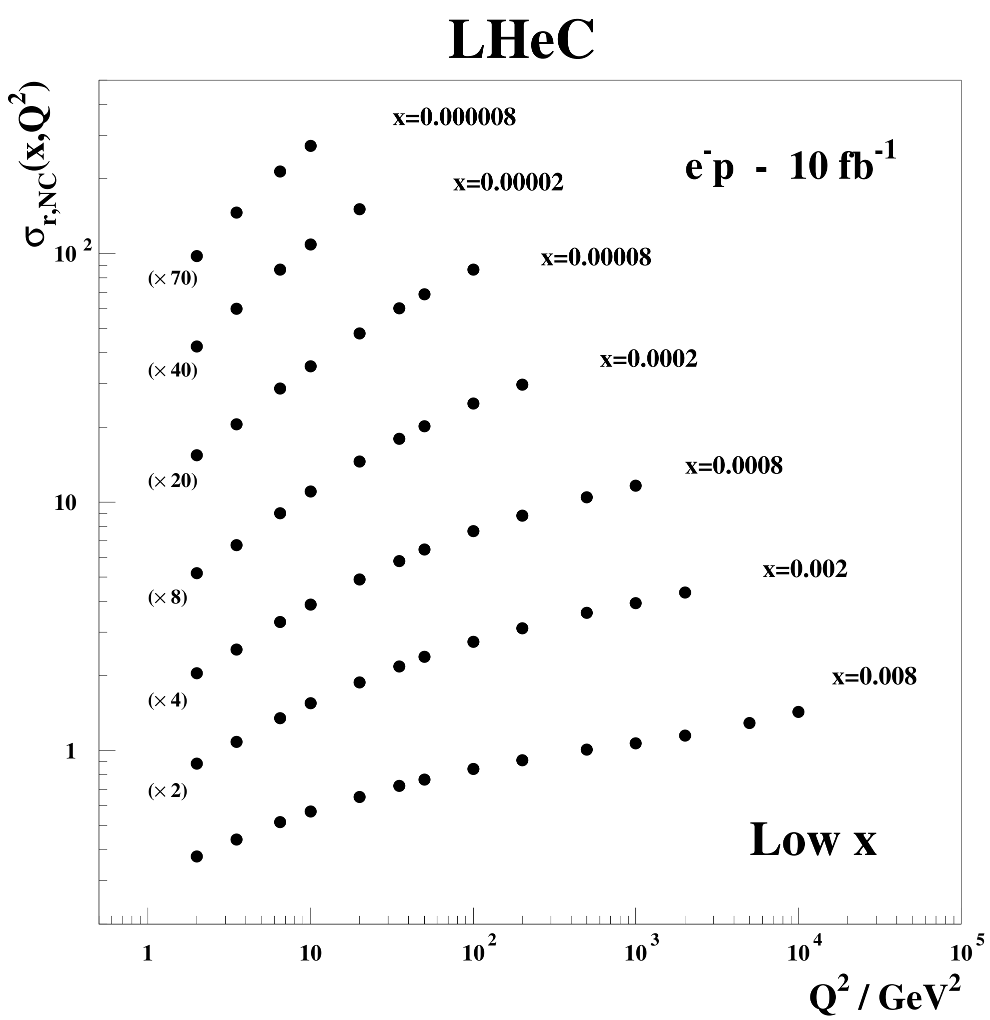
QCD and EW precision physics

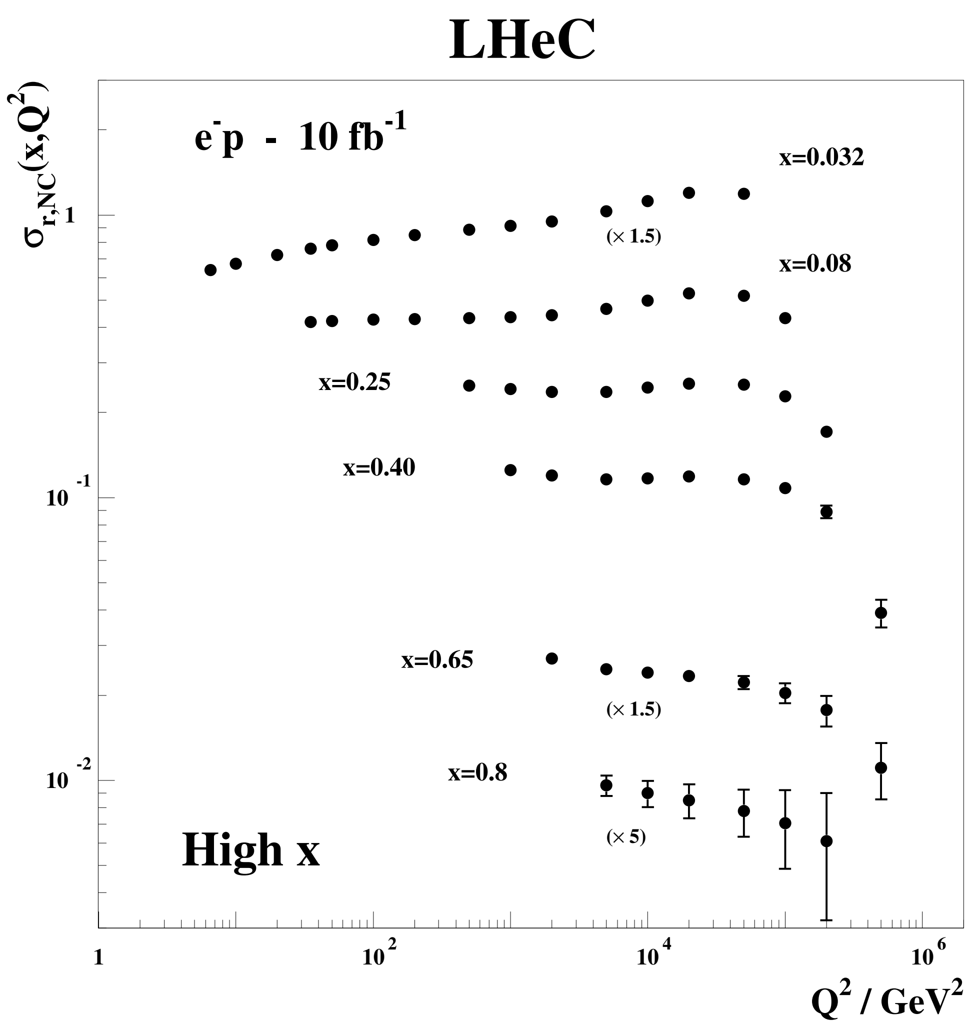
Structure functions
Quark distributions from direct measurements
Strong coupling constant to high accuracy
Higgs in SM
Gluon distribution in extended x range to unprecedented accuracy
Single top and anti-top production
Electroweak couplings
Heavy quark fragmentation functions
Heavy flavor production with high accuracy
Jets and QCD in photoproduction
Partonic structure of the photon
...

Small x and high parton densities

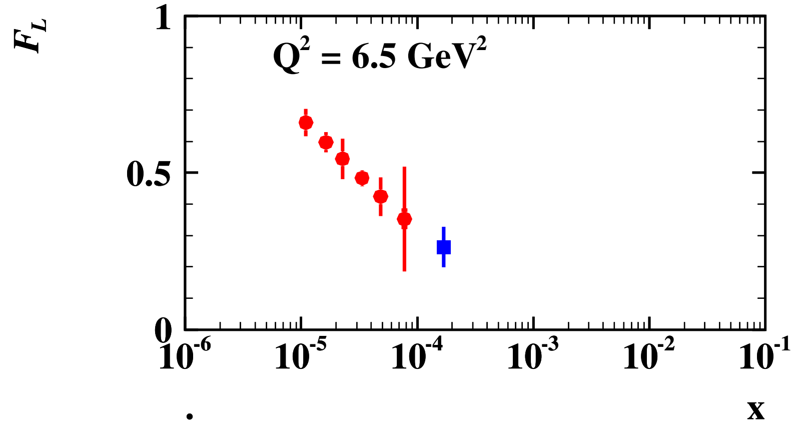
New regime at low x
Saturation
Diffraction
Vector Mesons
Deeply Virtual Compoton Scattering
Forward jets and parton dynamics
DIS on nuclei
Generalized/unintegrated parton distribution functions

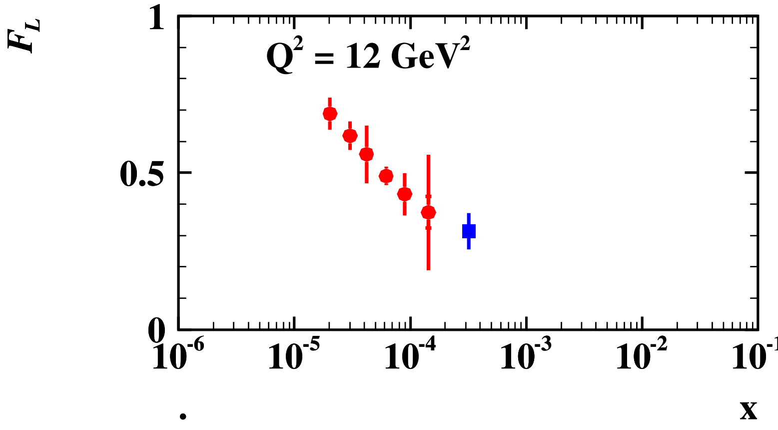
F_2, F_L structure functions





Reduced cross section: huge kinematic range and excellent accuracy





Longitudinal structure function: lowering electron energy

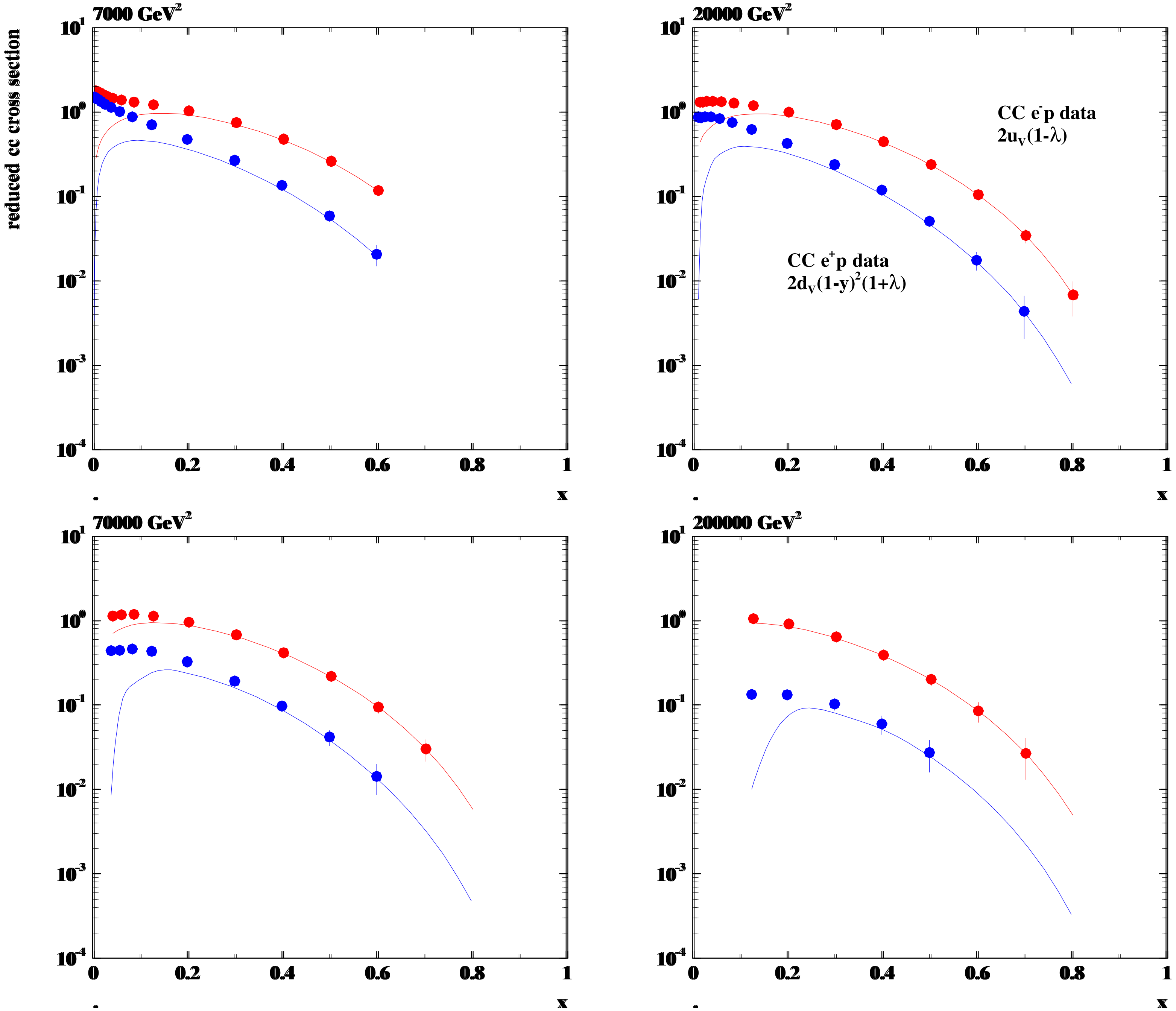
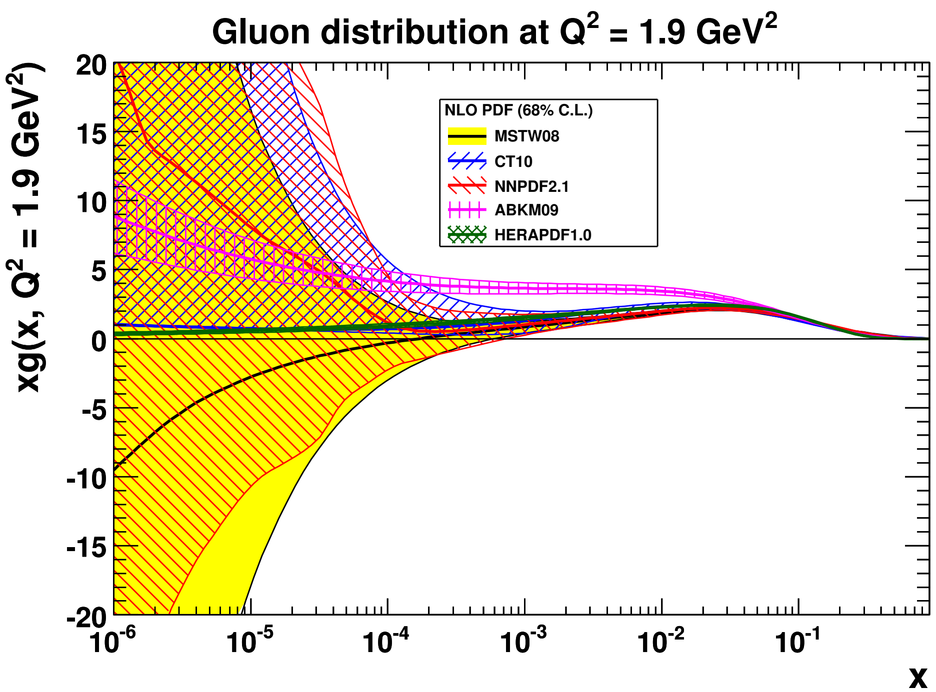


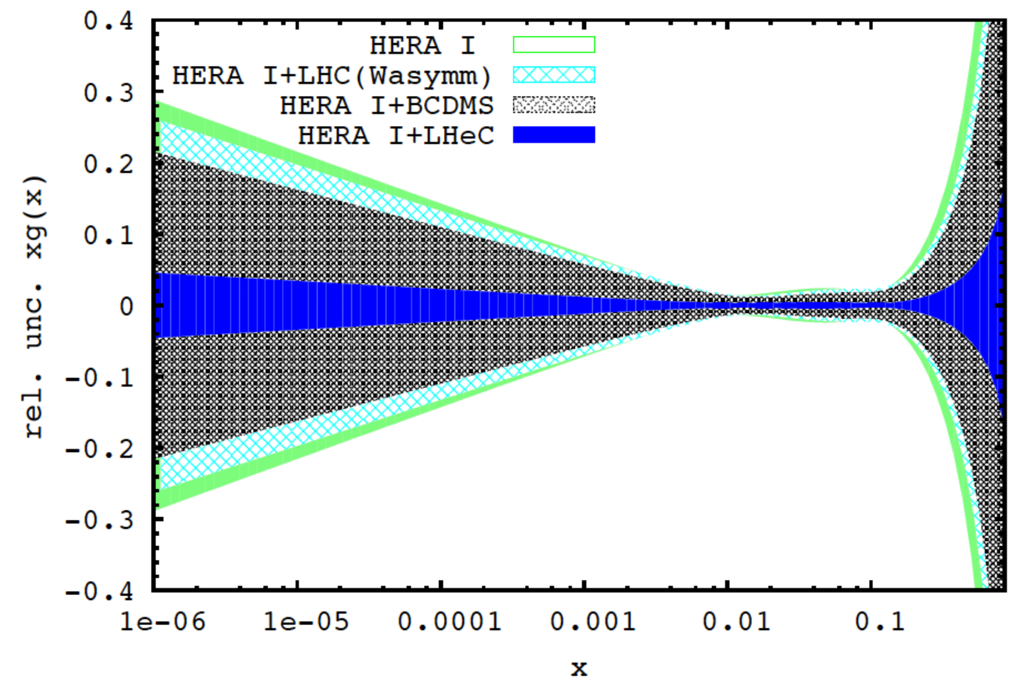
Figure 3.6: Reduced charged current cross sections with statistical uncertainties corresponding to $1\,\mathrm{fb}^{-1}$ electron (top data points, red) and positron (lower data points, blue) proton scattering at the LHeC, The curves are determined by the dominant valence quark distributions, u_v for e^-p and d_v for e^+p. In the simulation the lepton polarisation is taken to be zero. The valence-quark approximation of the reduced cross section is seen to hold at $x \geq 0.3$. A precise determination of the u/d ratio up to large x appears to be feasible at very high Q^2.

Constraining the pdfs

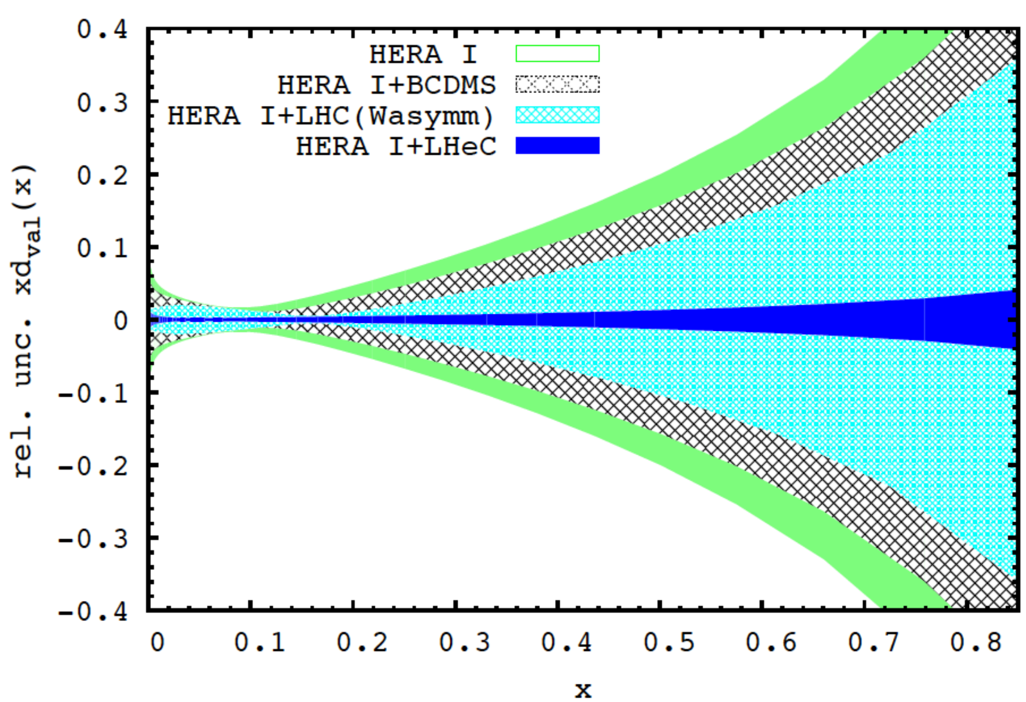
Gluon at small x: large uncertainties



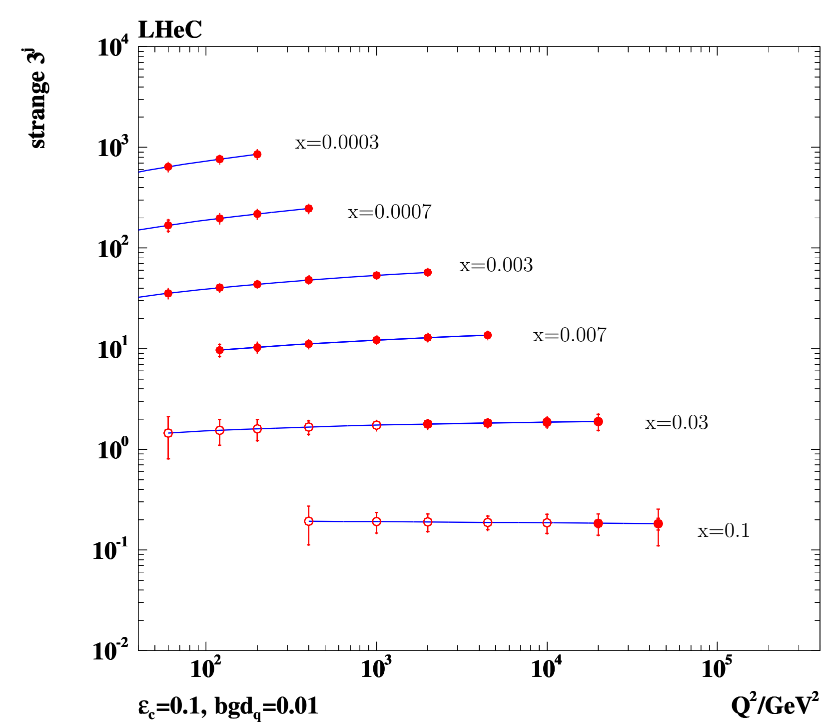
Constraints by including LHeC simulated data



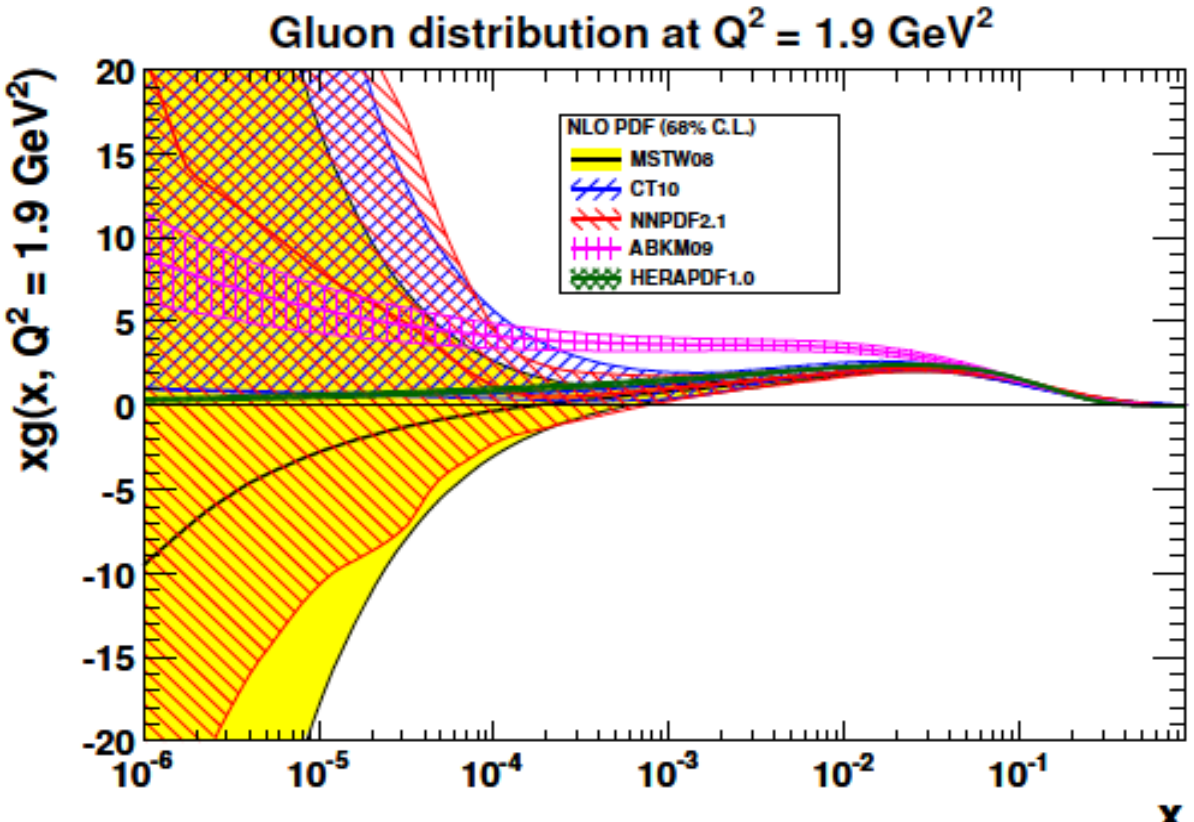
Constraints on valence at large x

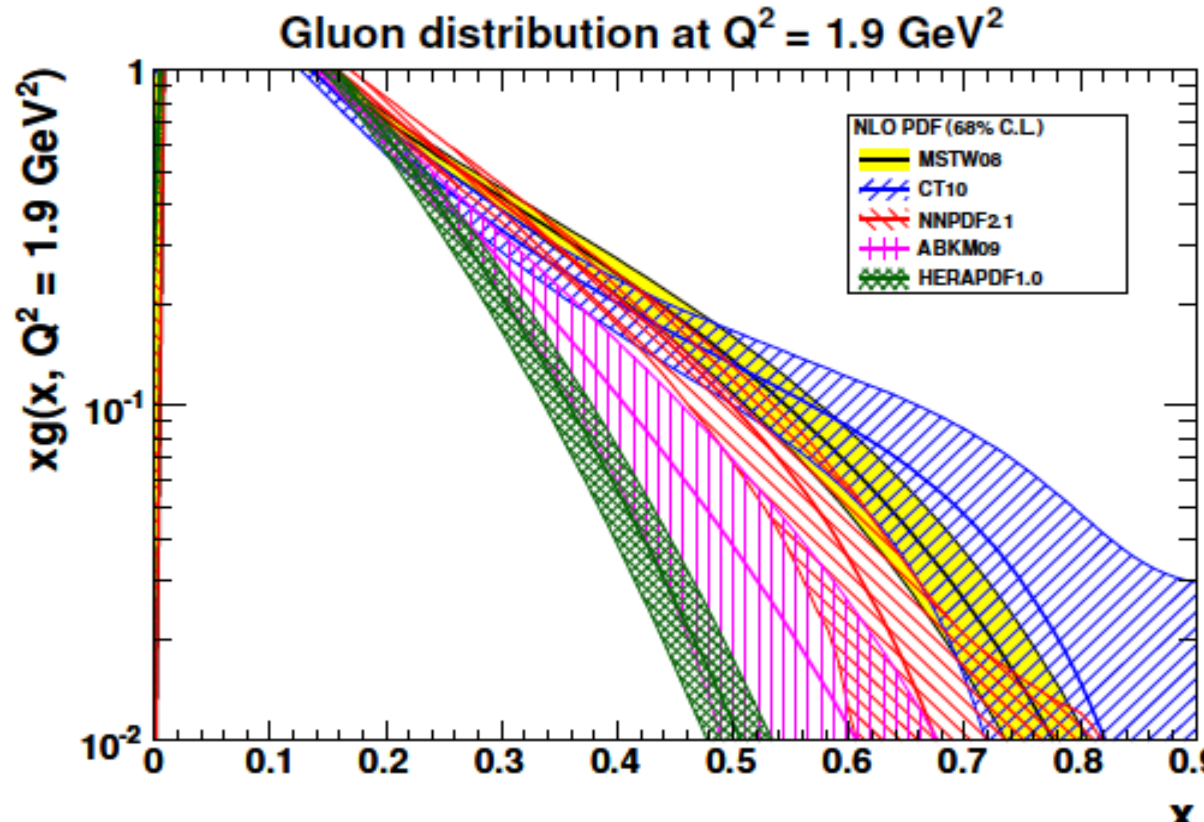


Constraints of strange quark density through charm tagging

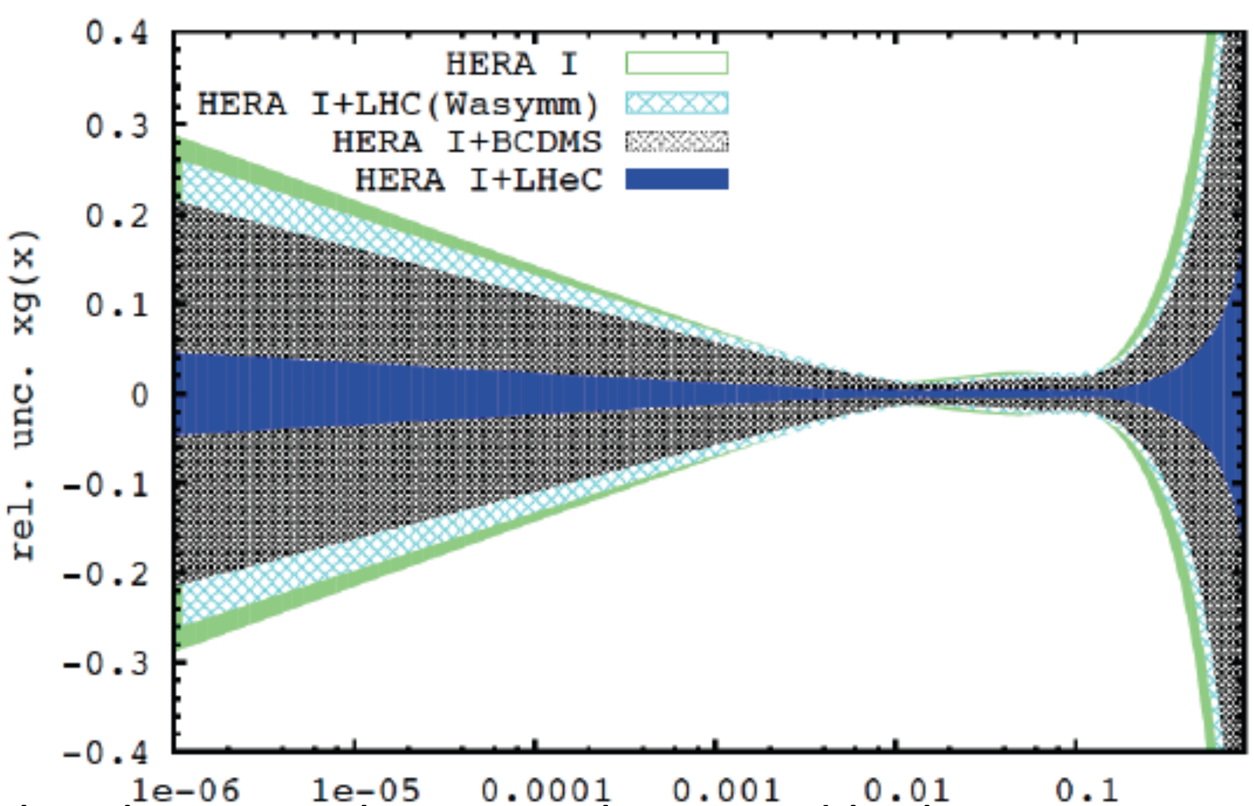


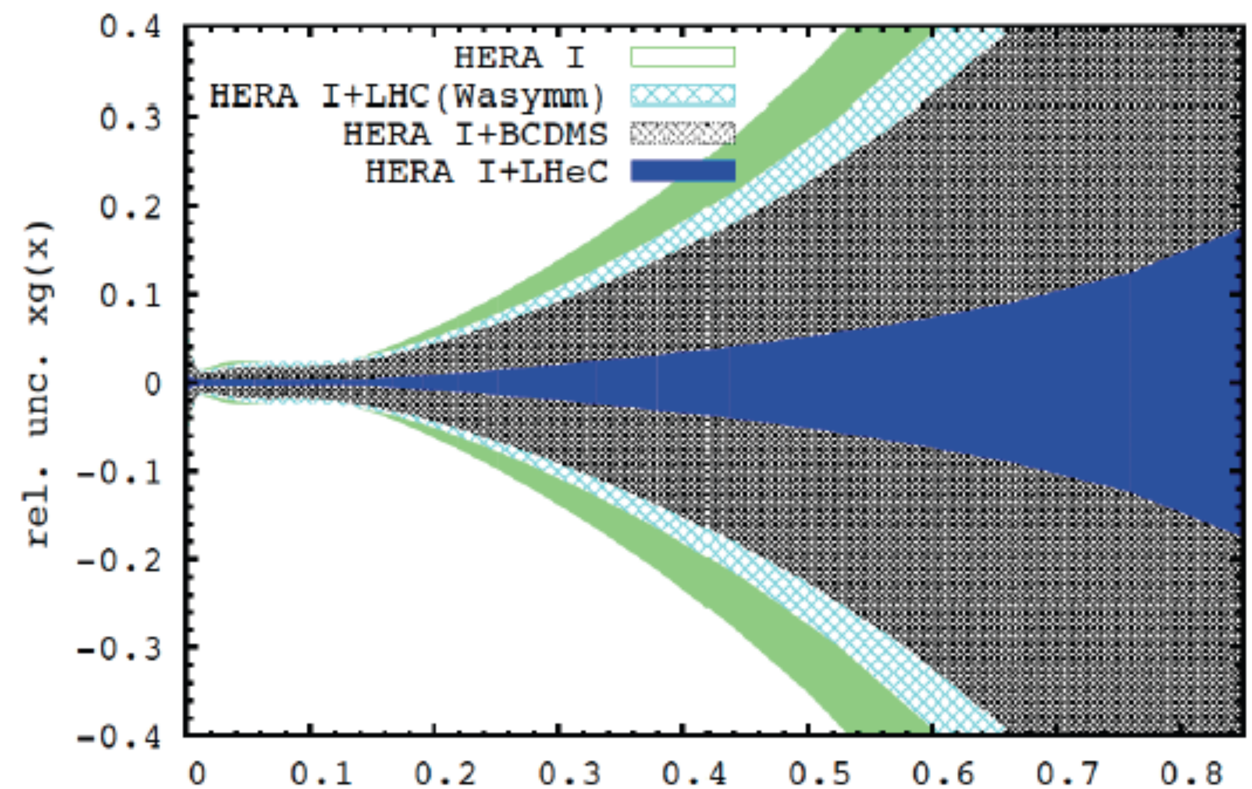
Mapping the Gluon Distribution





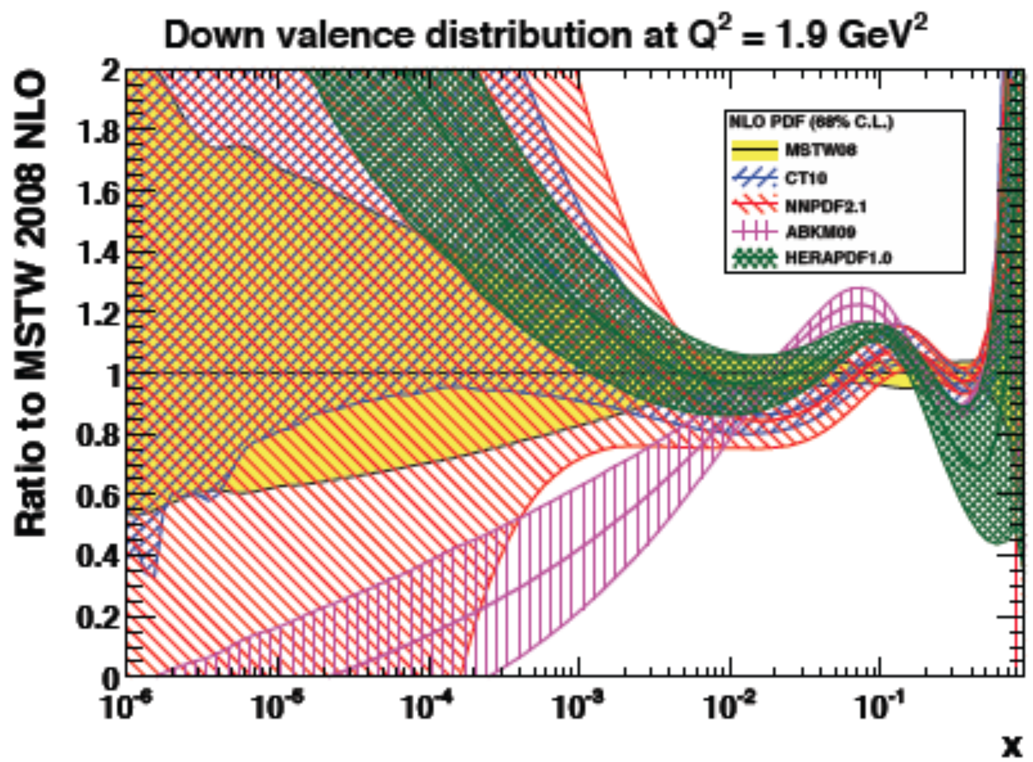
QCD fit analysis (default: NC,CC, LHeC only, following HERAPDF) with full experimental errors

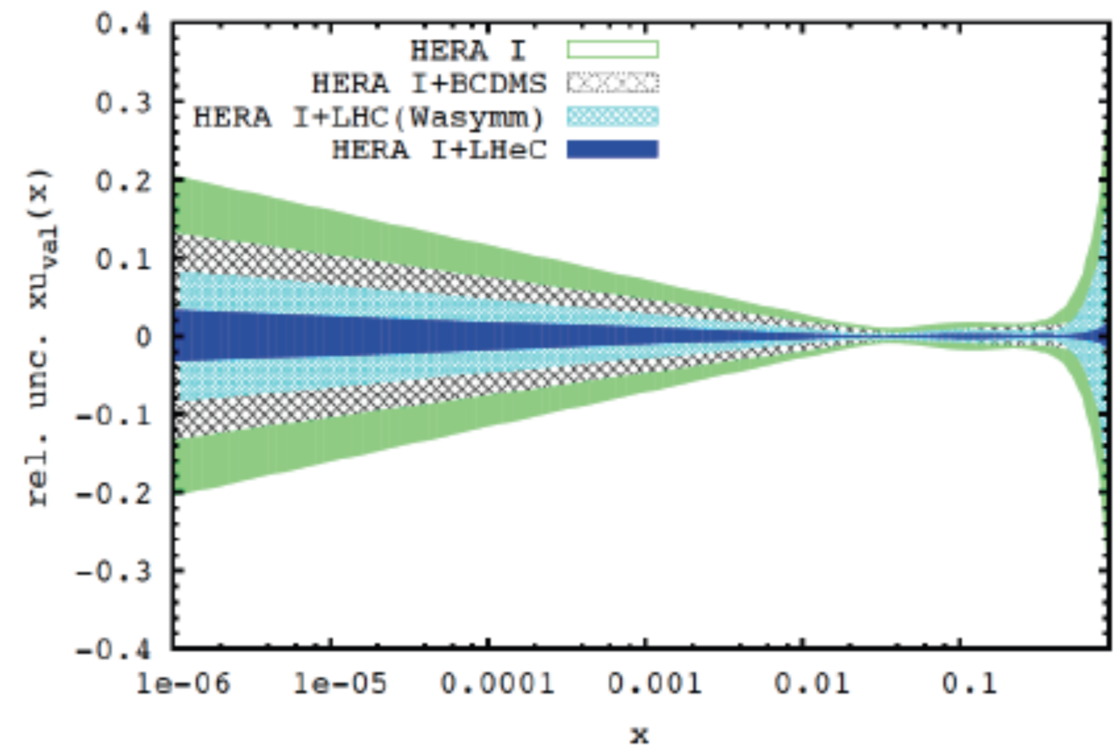


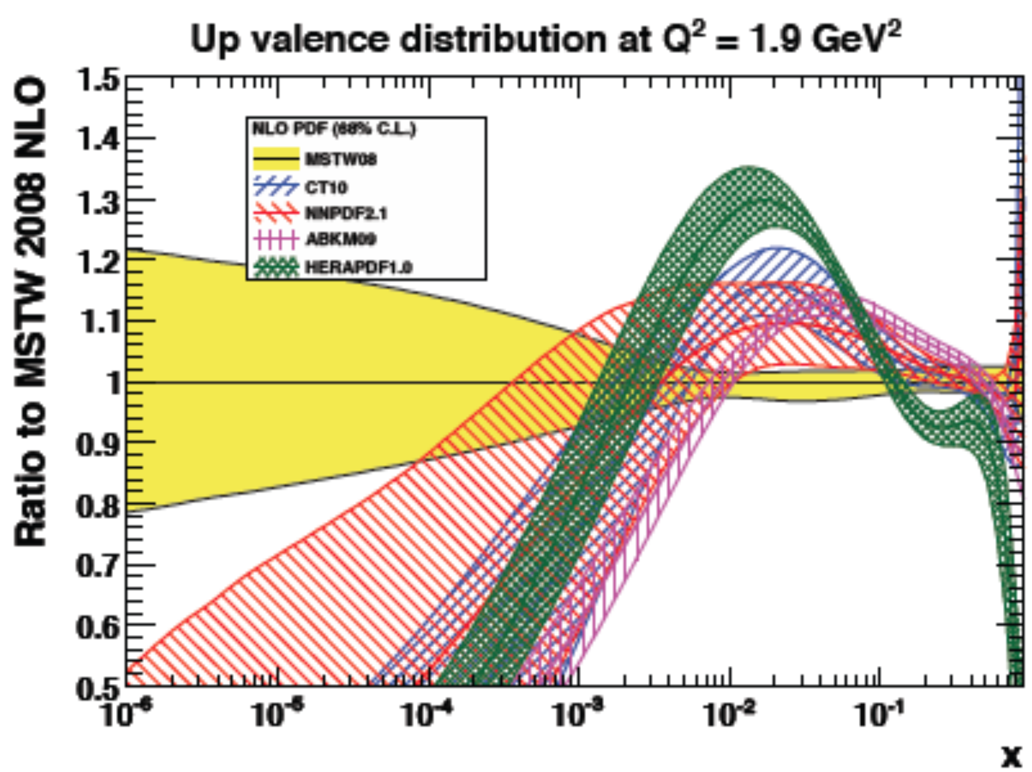


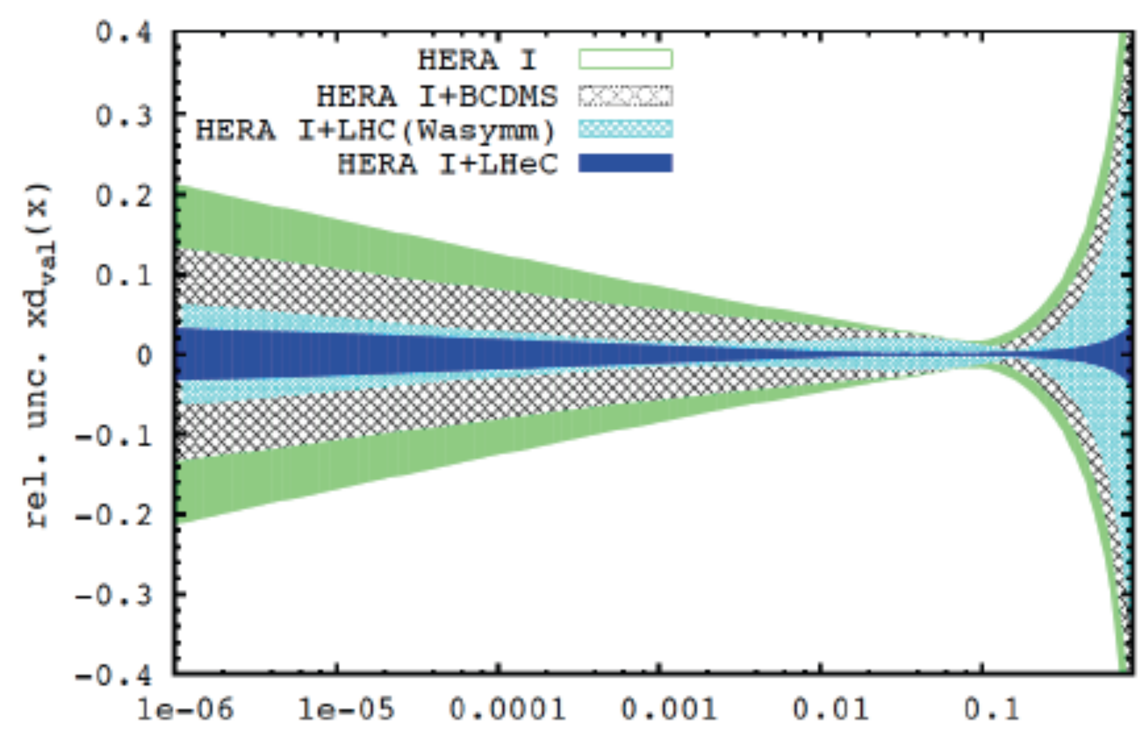
The gluon is unknown at low x and high x – QCD: non-linear evolution, resummation. BSM: hi M – HL-LHC!

Valence Quarks









Long time to understand d/u. LHeC: free of higher twist

More on valence quarks: xF3

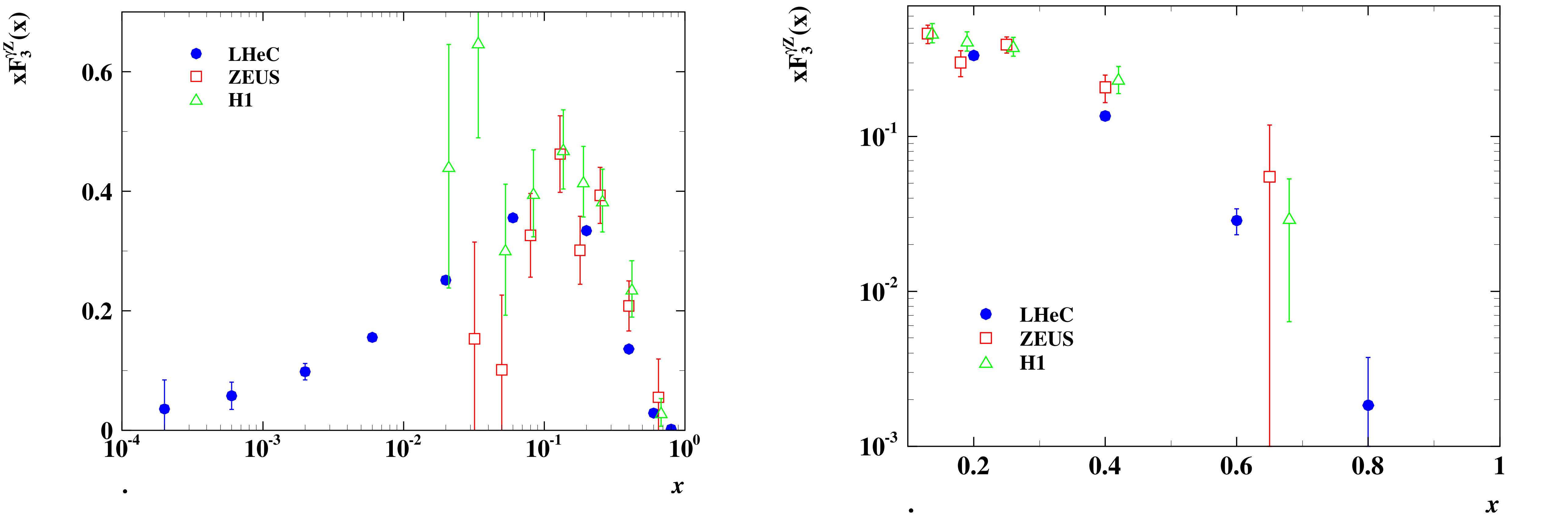
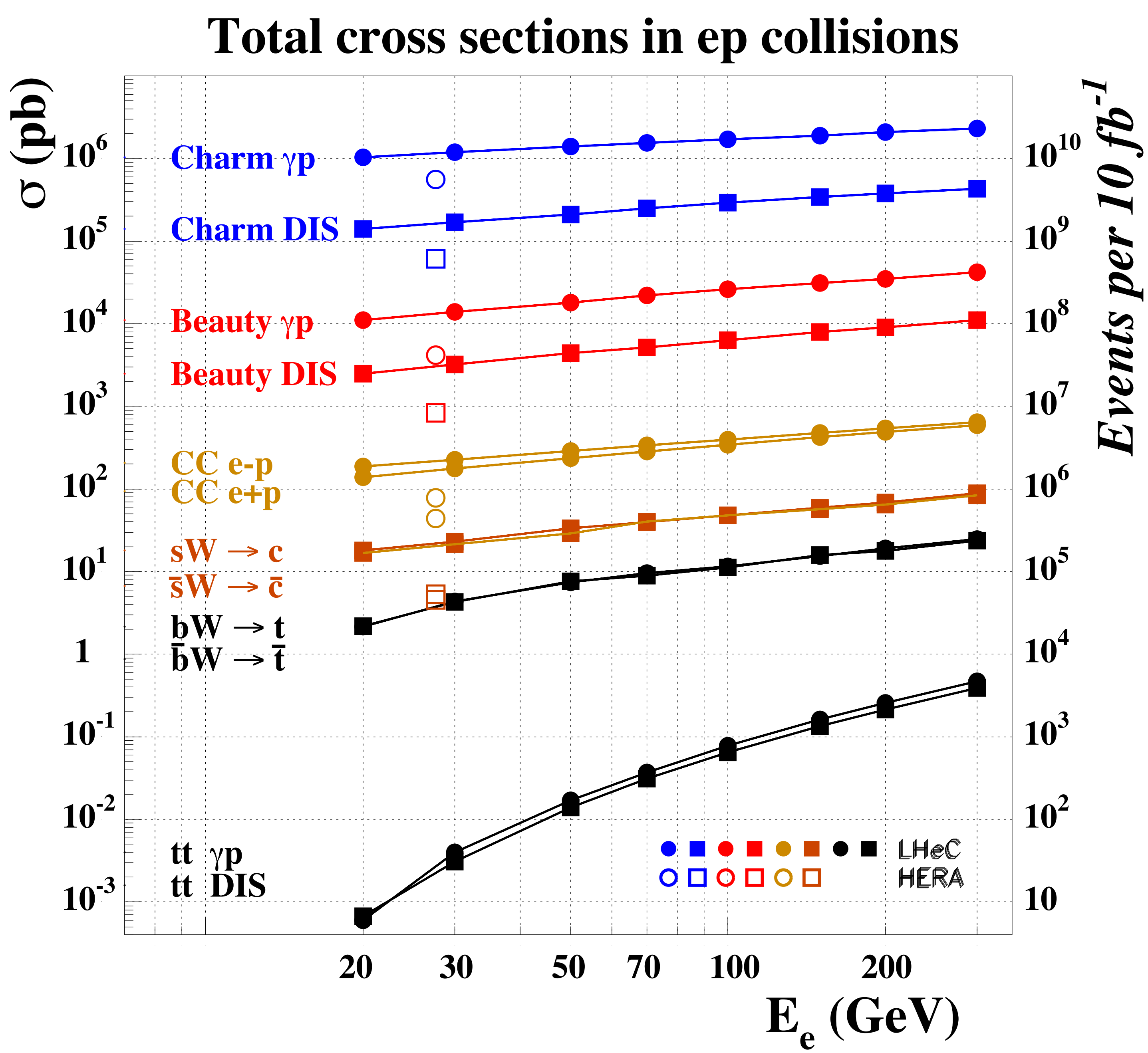
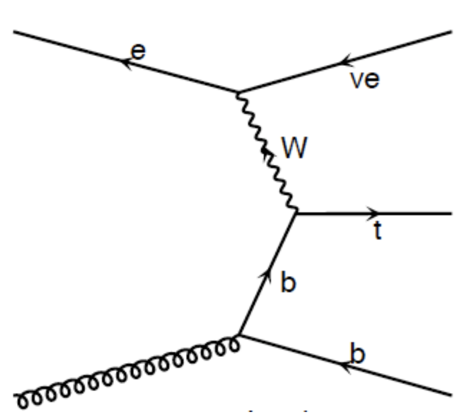


Figure 3.11: Simulation of the LHeC measurement of the interference structure function $xF_3^{\gamma Z}$ from unpolarised $e^{\pm}p$ scattering with $10\,\text{fb}^{-1}$ luminosity per beam (blue, closed points) compared with the HERA II data as obtained by H1 (preliminary, green triangles) and by ZEUS (red squares) with about $0.15\,\text{fb}^{-1}$ luminosity per beam charge. The H1 x values are enlarged by 10 % of their given values for clarity. It should be noted that any significant deviation of sea from anti-quarks, see Eq. 3.27, would cause $xF_3^{\gamma Z}$ at low x to not tend to zero. The top plot shows an average of $xF_3^{\gamma Z}$ over Q^2 projected to a chosen Q^2 value of $1500\,\text{GeV}^2$ exploiting the fact that the valence quarks are approximately independent of Q^2. The lower plot is a zoom into the high x region.

Physics with heavy flavors

Luminosity
$10\ fb^{-1}$

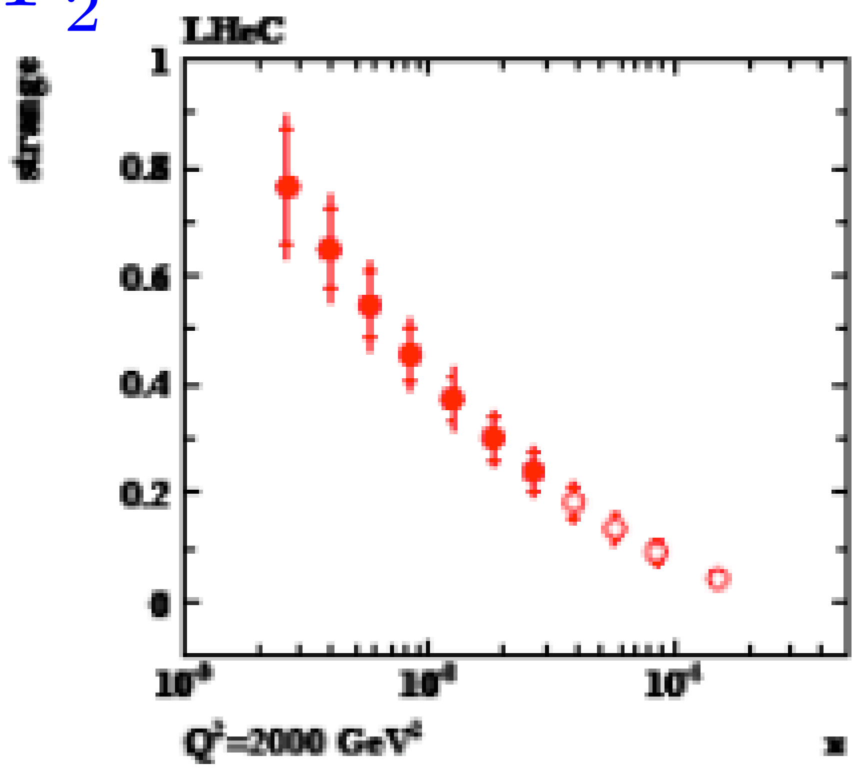


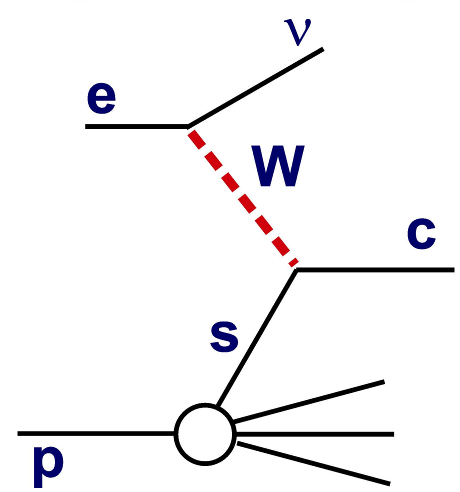


LHeC is a flavor factory!

Flavor decomposition

F_2^{strange}

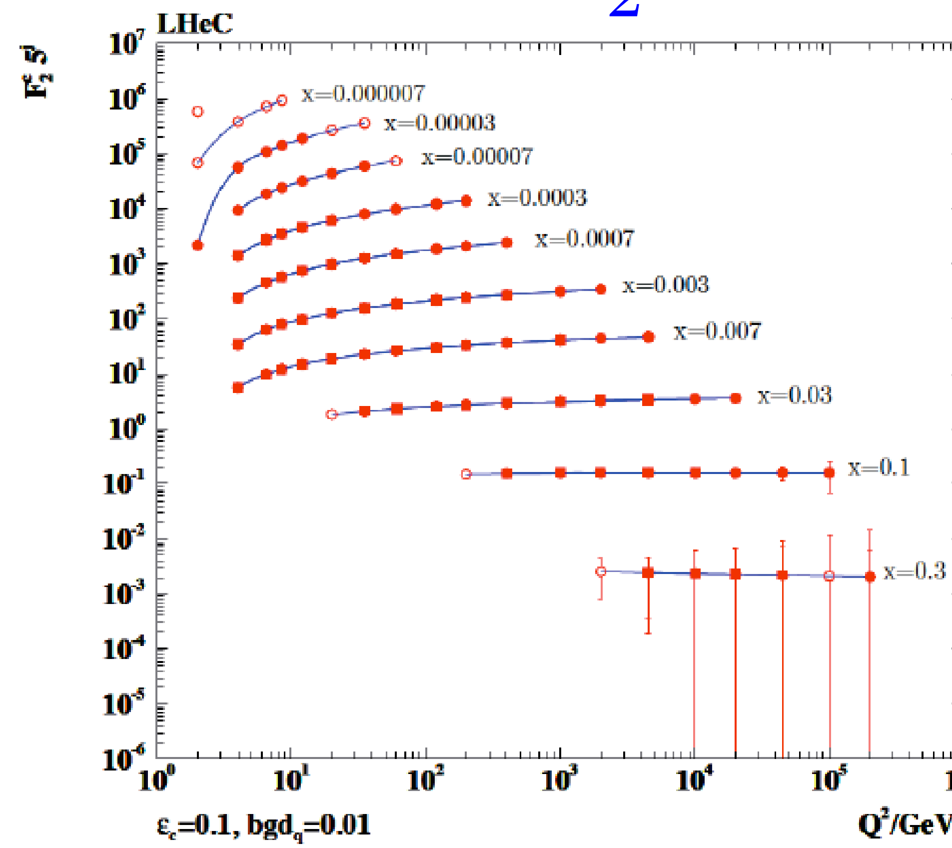




● LHeC 10° acceptance

○ LHEC 1° acceptance

F_2^{charm}



Systematic error dominates (so far 3%)

Precise measurement near threshold and up to 10^5 GeV²

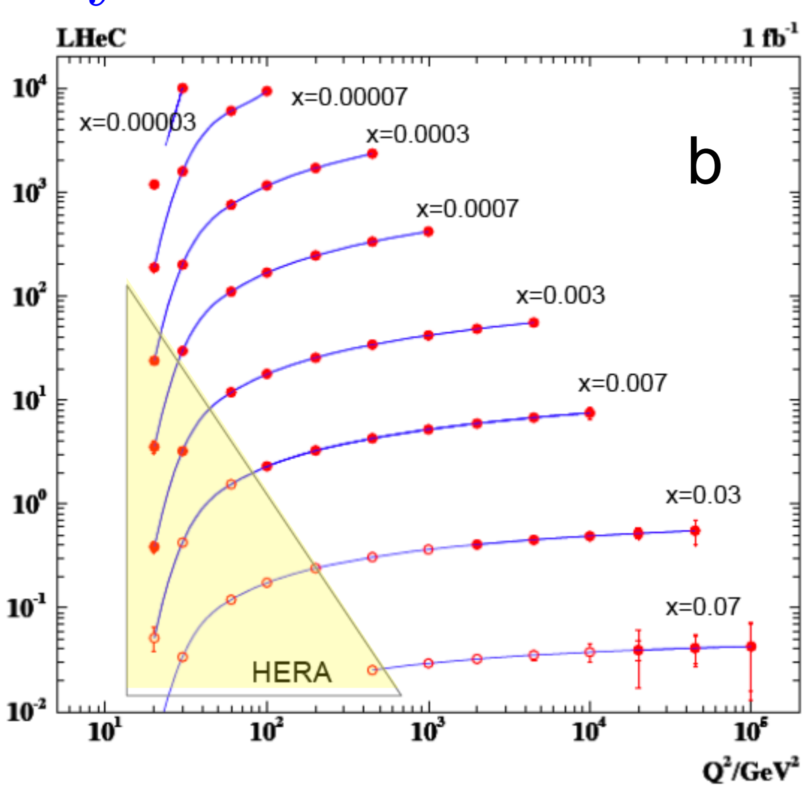
F_2^{cc} will become precision testing ground for QCD and proton structure

open: 1°

closed: 10°

box: 1 TeV

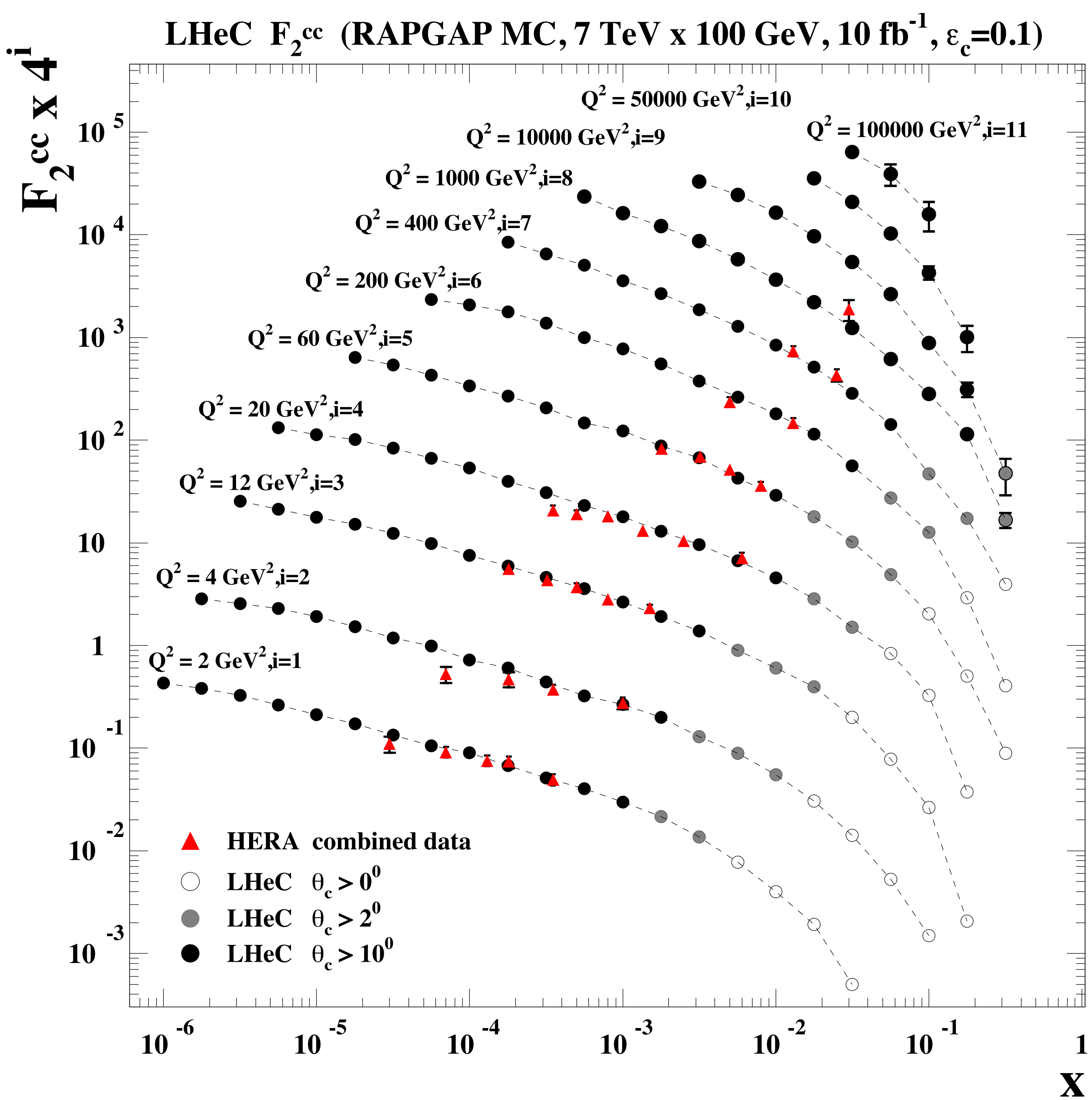
F_2^{beauty}



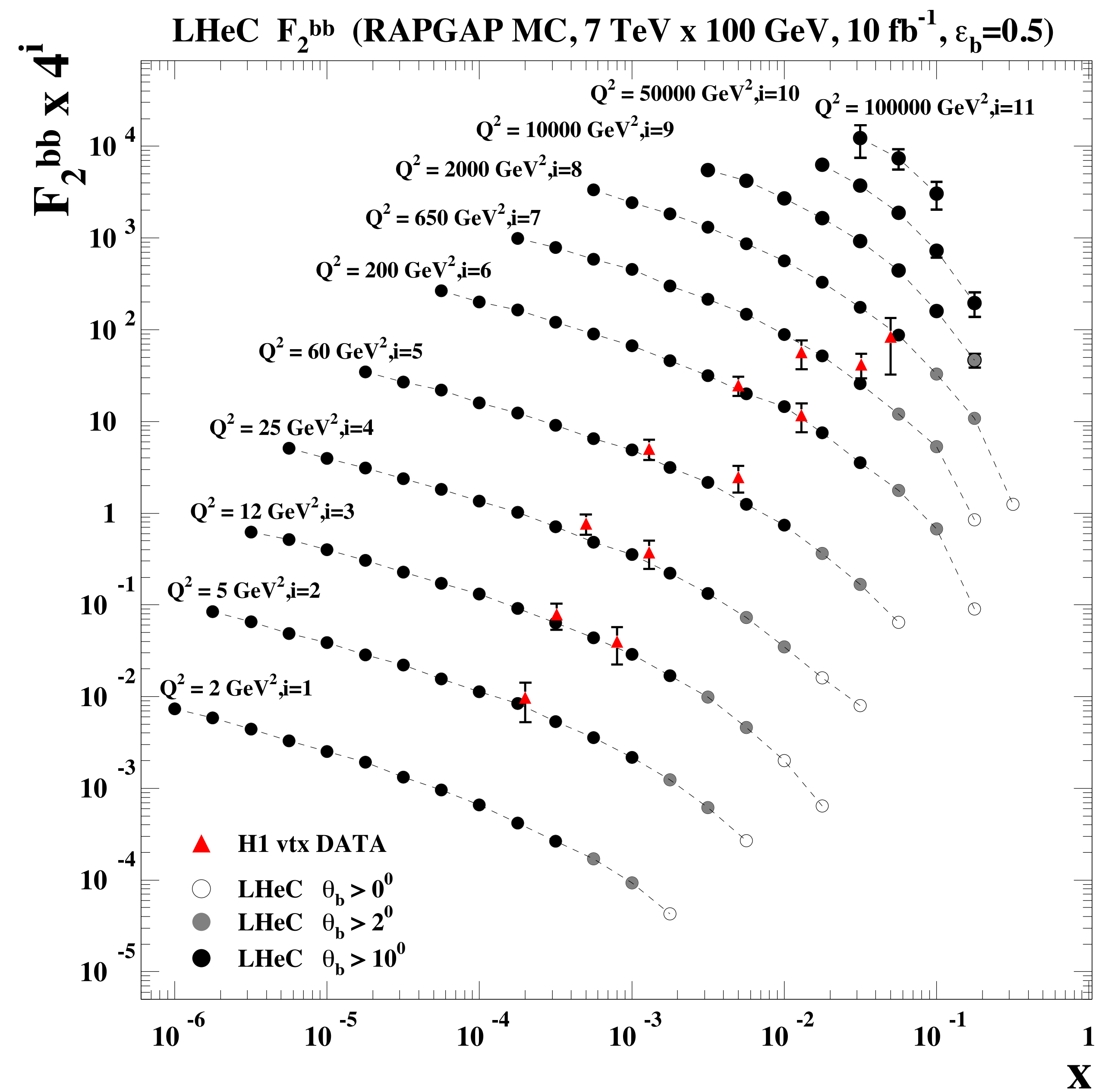
- High precision c,b measurements
- Possible s (and sbar) from charged current
- b is a small x observable
- Also possible $Wb \rightarrow t$

Flavor decomposition

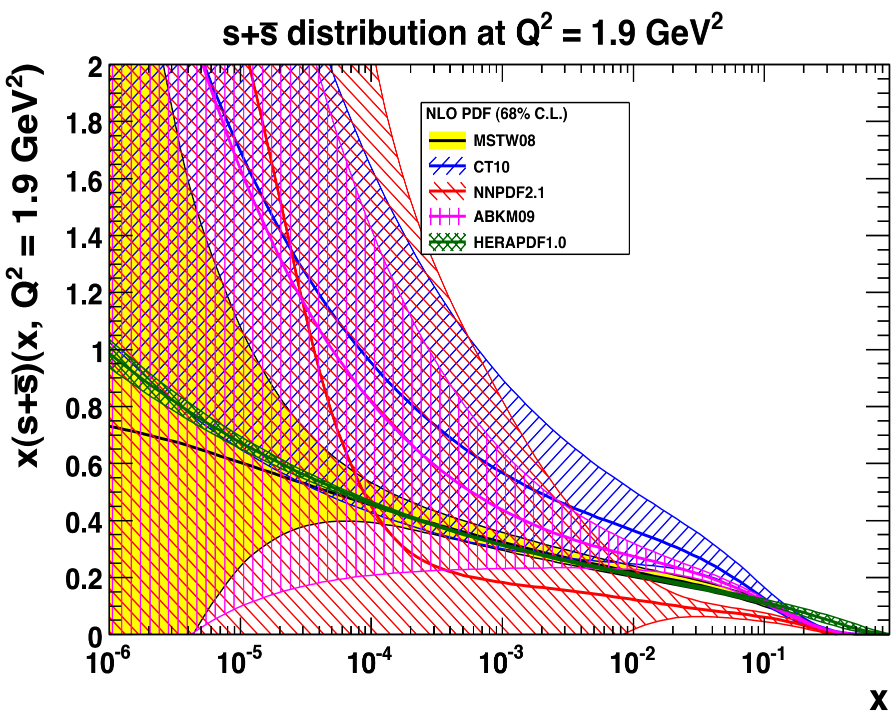
Charm

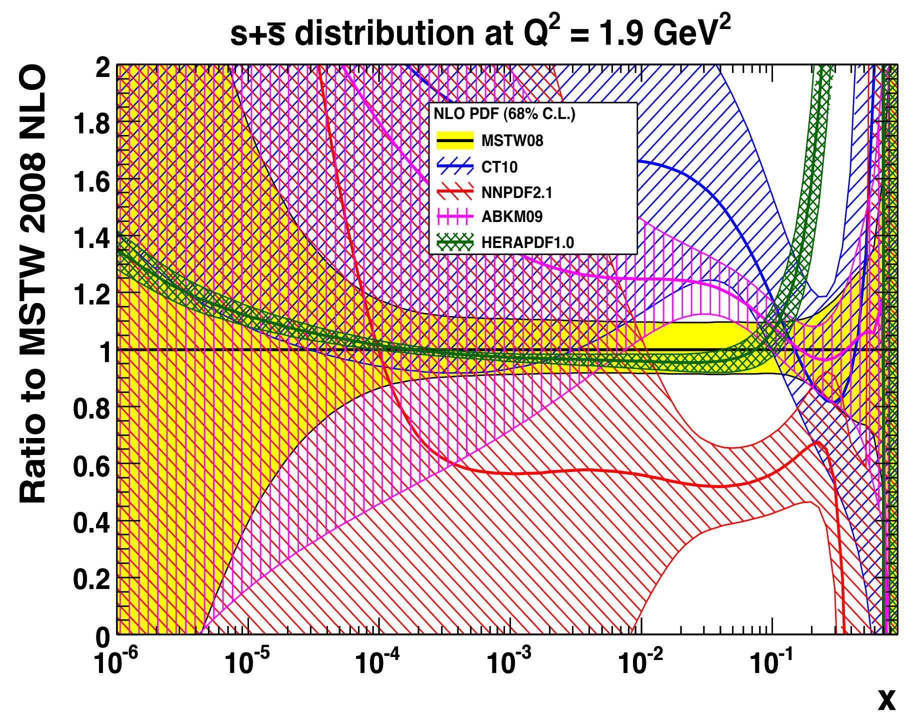


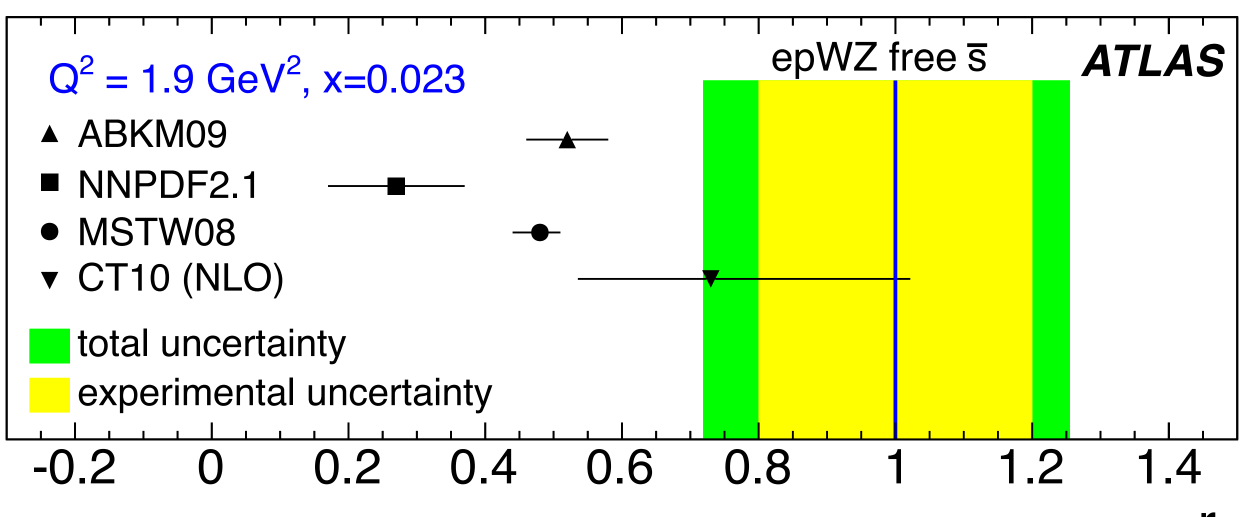
Beauty



Strange quark distributions: results from LHC



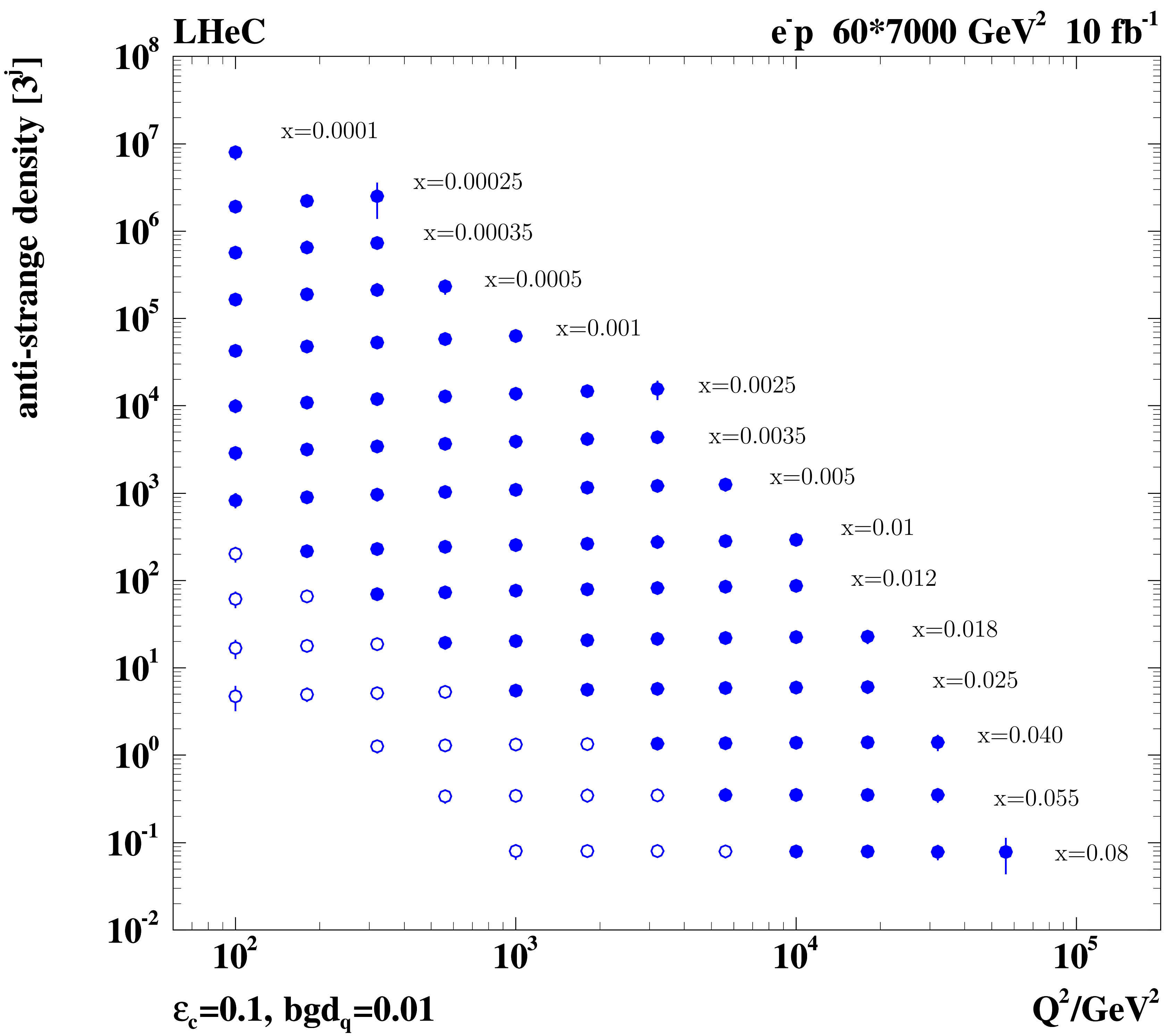




Trend confirmed in NNPDF collider only fit

Previous MSTW, NNPDF analysis indicated strangeness suppression. ATLAS points to SU(3) symmetry with 0.5(sbar+s)/dbar ratio

Strange pdf from LHeC



High lumi
High Q
Charm tagging efficiency 10%
Closed points acceptance
to 10 degrees
Open points acceptance
to 1 degree

Why deuteron?

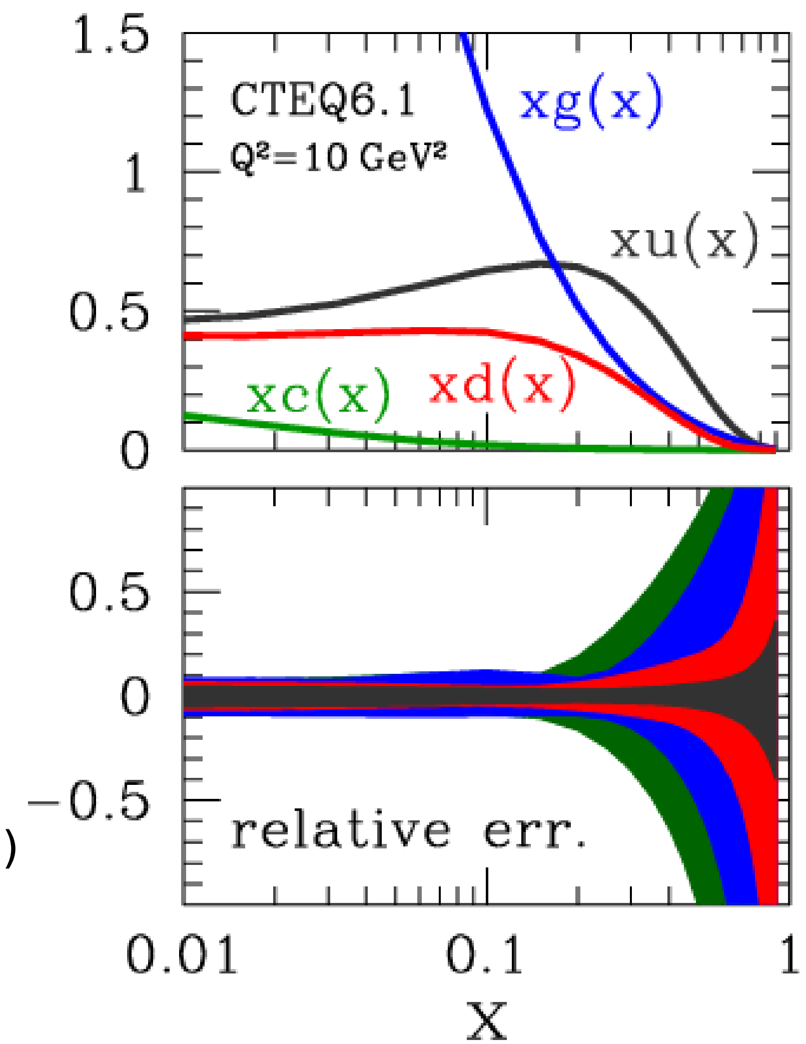
- **Deuteron as effective neutron beam**
- Quark flavor decomposition

$$F_2(p) \propto 4u + d$$

$$F_2(n) \propto u + 4d$$

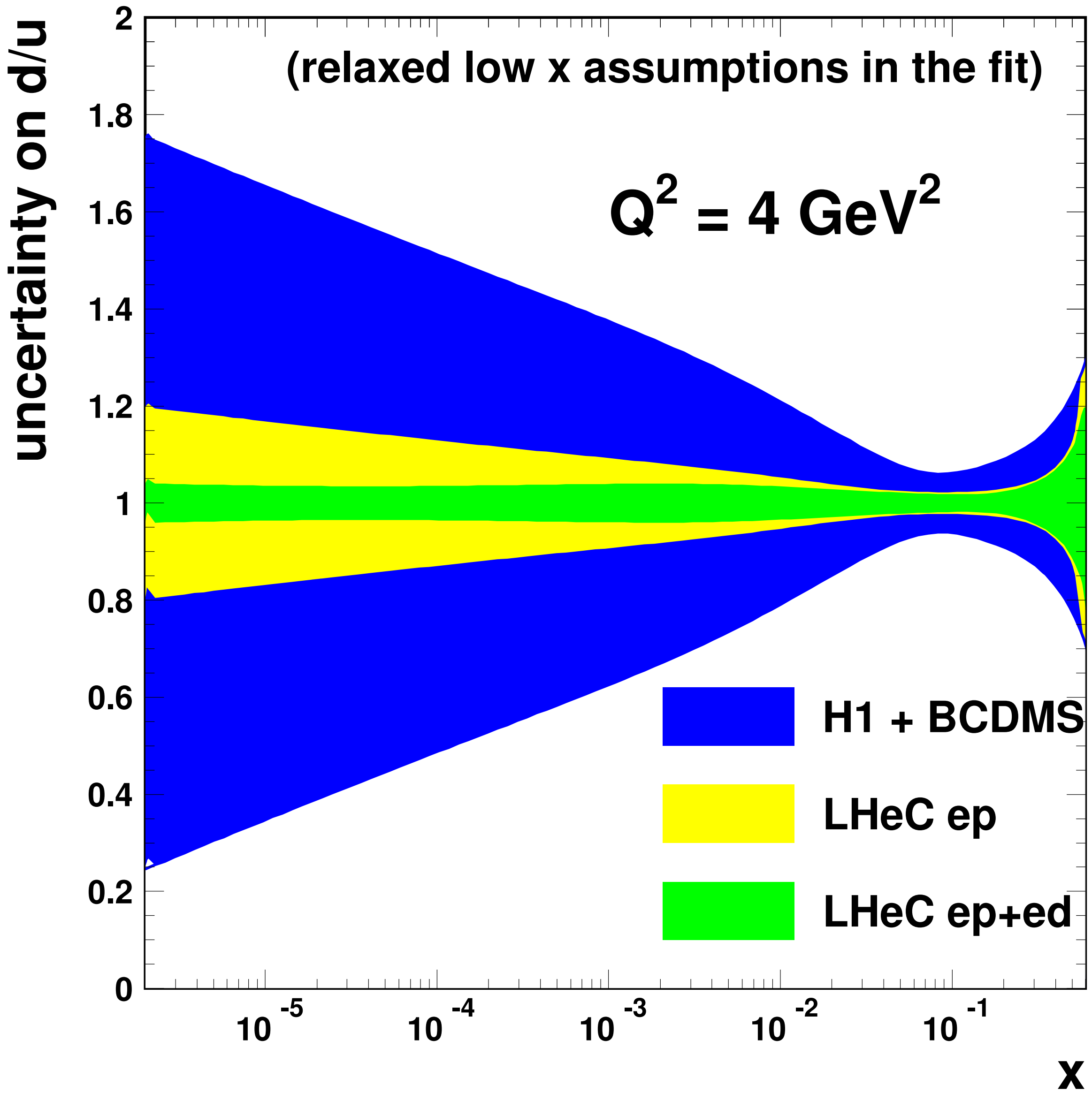
- Particularly important at large *x*
  - Large d-quark uncertainty
  - *d/u* ratio at x → 1 probes non perturbative proton structure

Accardi et al. [CTEQ-JLab collab.] PRD84(2011)

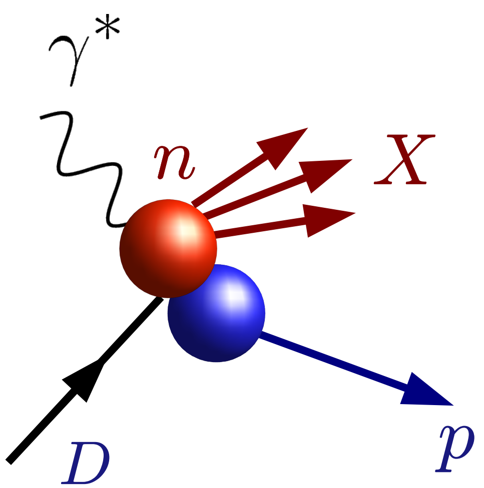


- At $x \lesssim 10^{-2}$ sea quarks dominate, expect $F_2(p) \approx F_2(n)$

Deutrons: constraints on light quark sea asymmetry



spectator tagging



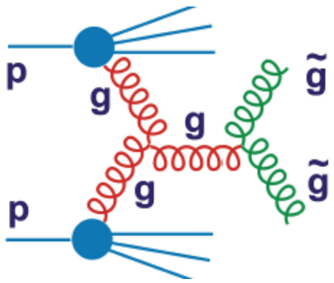
Deuterons crucial for :
neutron structure
flavor separation

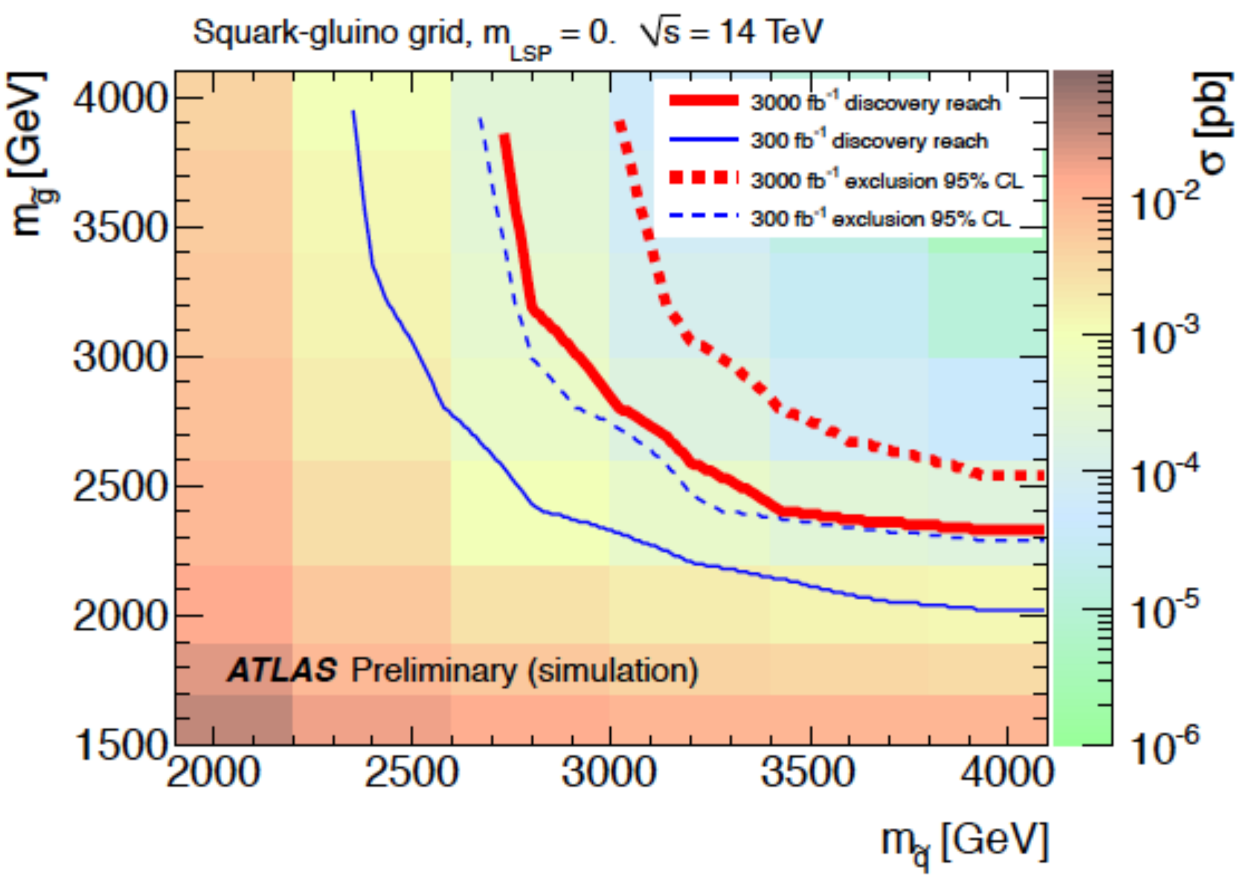
Tests of charge symmetry using electrons and positrons

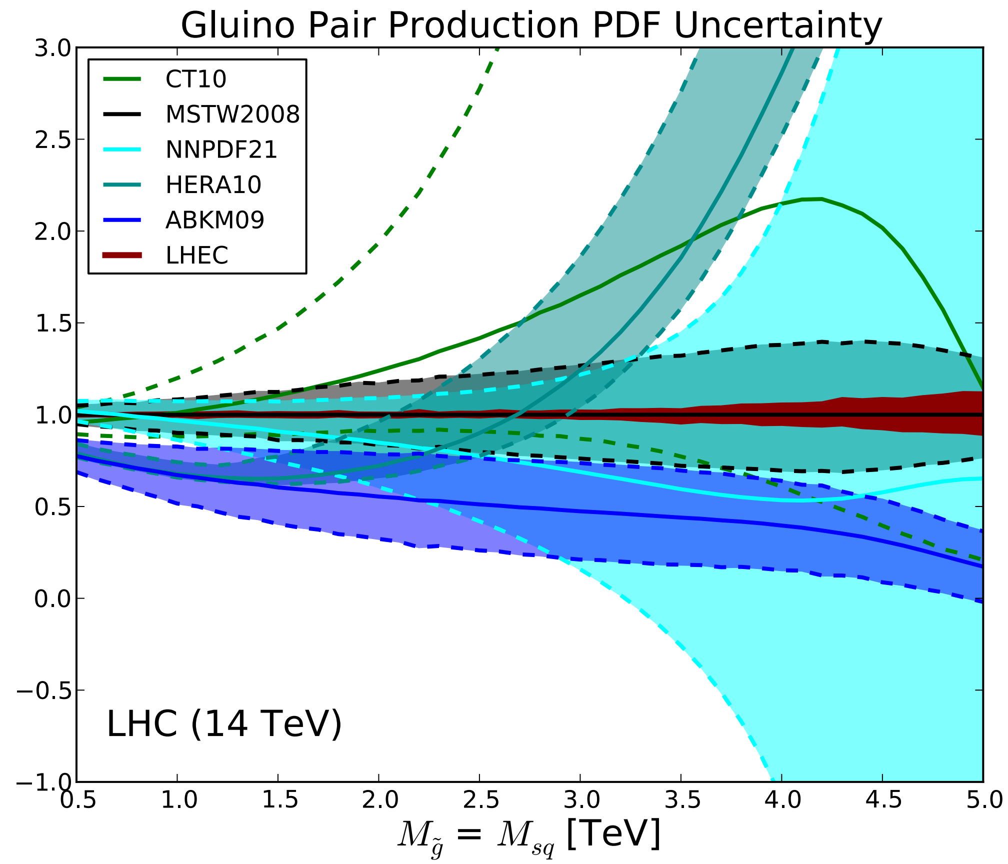
$$R^- = 2\frac{W_2^{-D} - W_2^{+D}}{W_2^{-p} + W_2^{+p}}$$

Complementarity of LHeC to LHC

Searching for High Mass SUSY

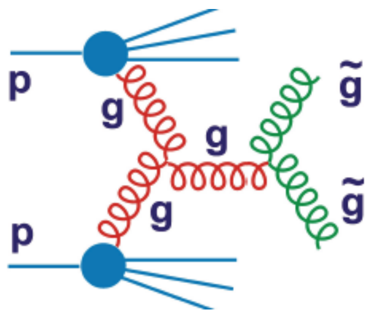


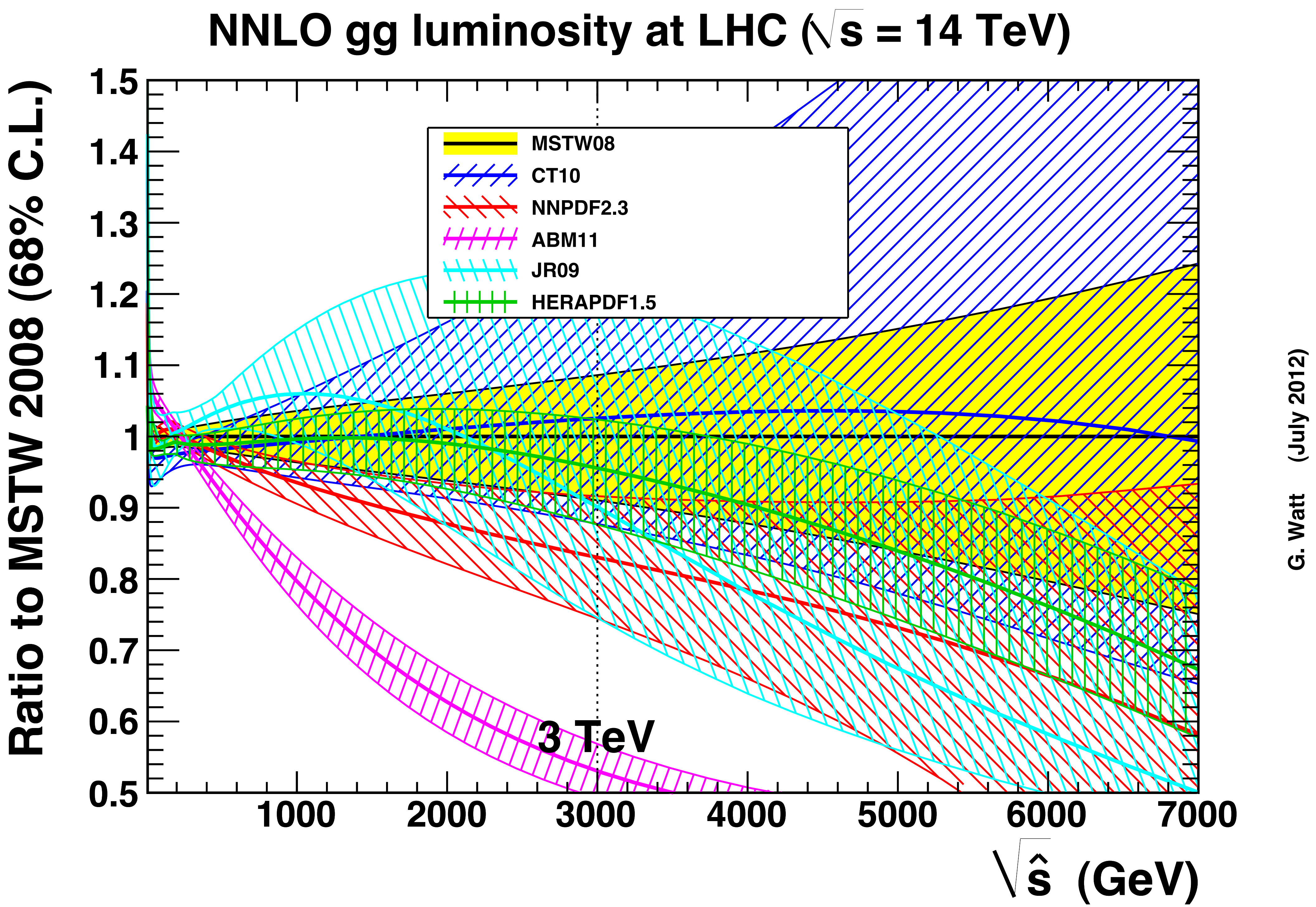




With high energy and luminosity, the LHC search range will be extended to high masses, up to ~5 TeV in pair production, and PDF uncertainties come in ~ 1/(1-x).

Gluon-Gluon Luminosity



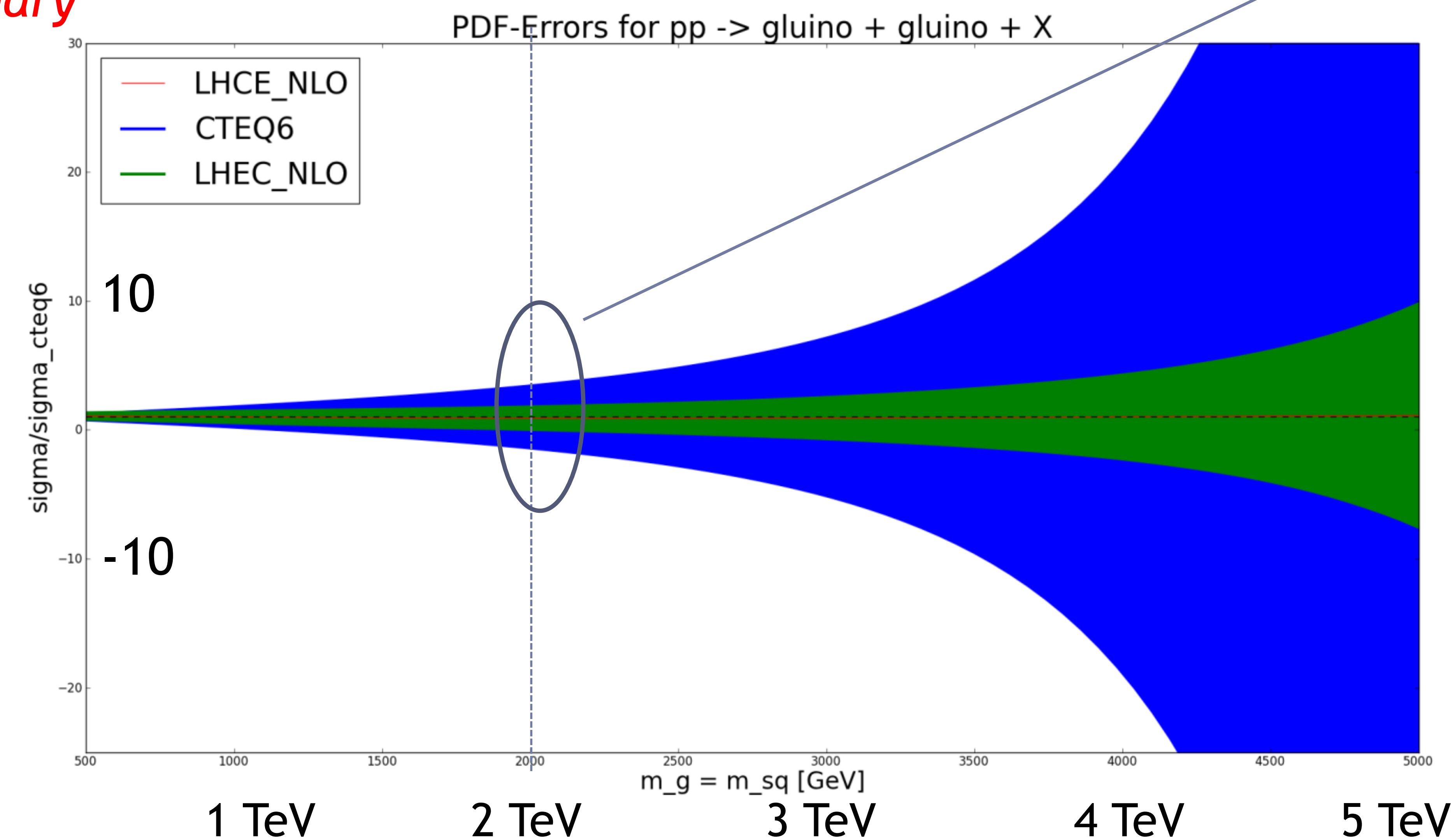


What the LHeC can do

- M.Kramer and R.Klees working on impact of improved PDF fits on theoretical predictions for SUSY process:
  - Example: gl-gl production (assuming m_gl = m_sq)
  - without(blue, CTEQ6) and with (green) LHeC PDF

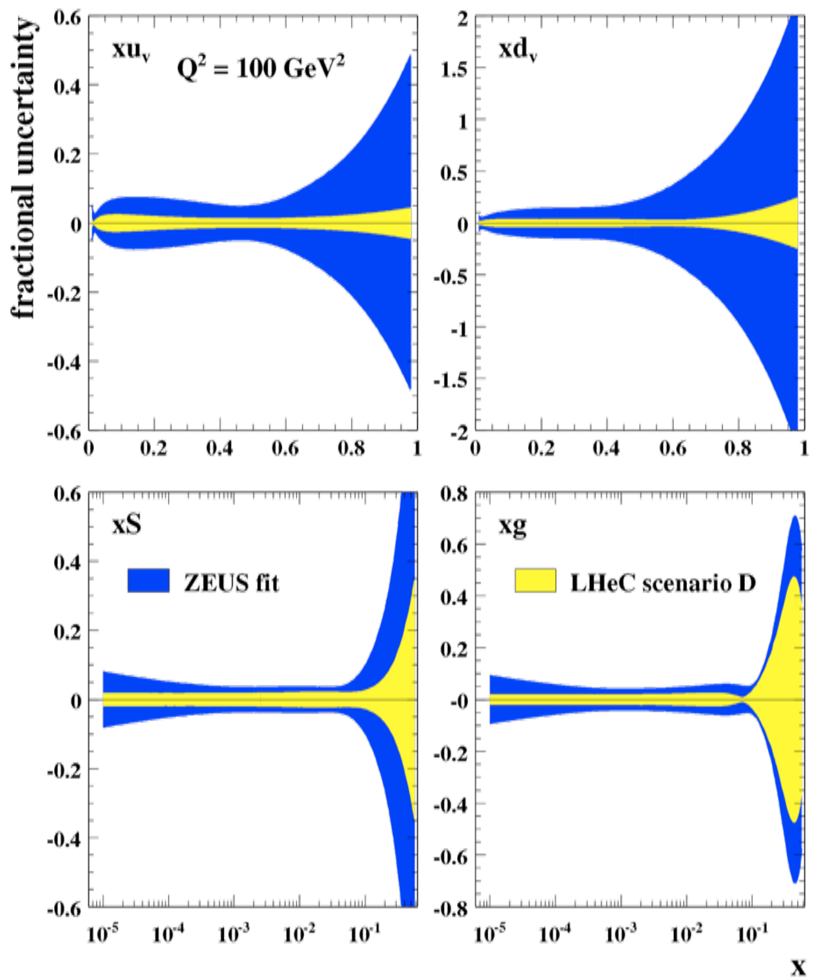
Improve of
factor of 2-3 @ 2 TeV
factor of 10 at 3.5 TeV

preliminary

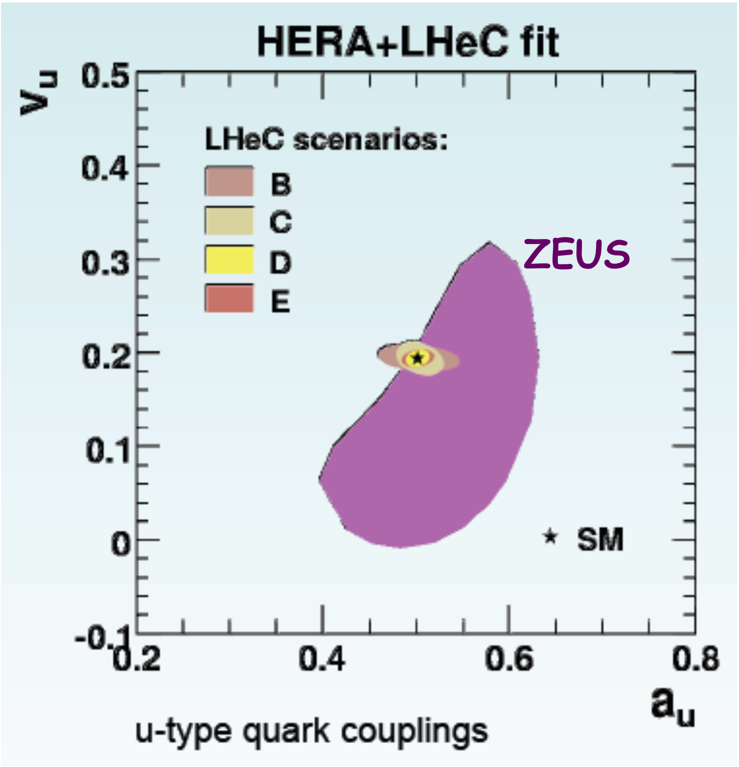


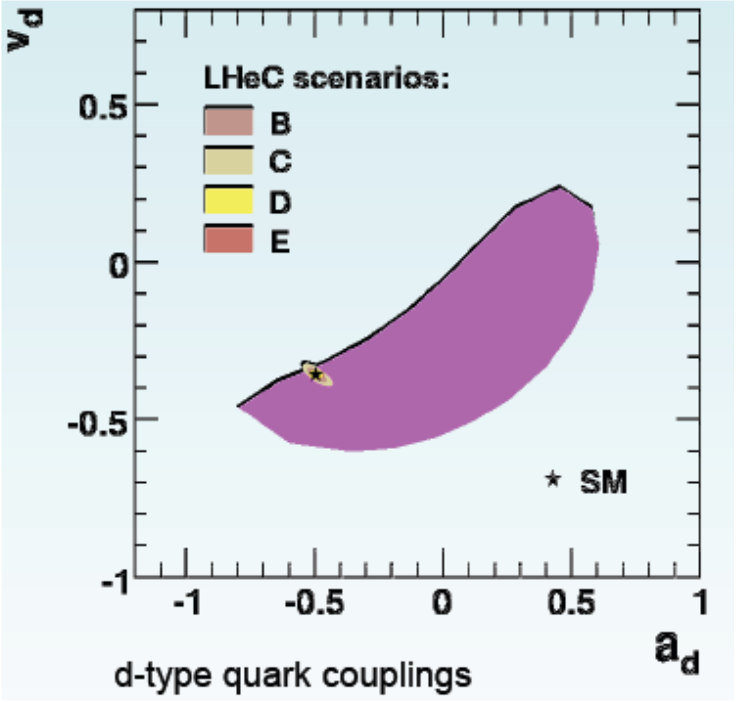
Electroweak precision

PDFs & EW Couplings



[Gwenlan]





Using ZEUS fitting code, HERA + LHeC data … EW couplings free

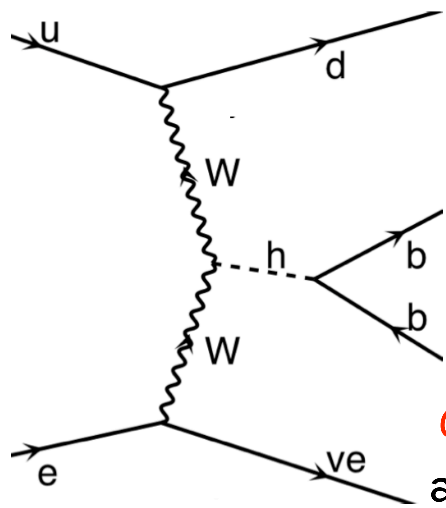
E_e = 100 GeV, L = 10+5 fb^{-1}, P = +/- 0.9

Also measurement of weak mixing angle below and above Mz (scale variation)

Higgs at the LHeC

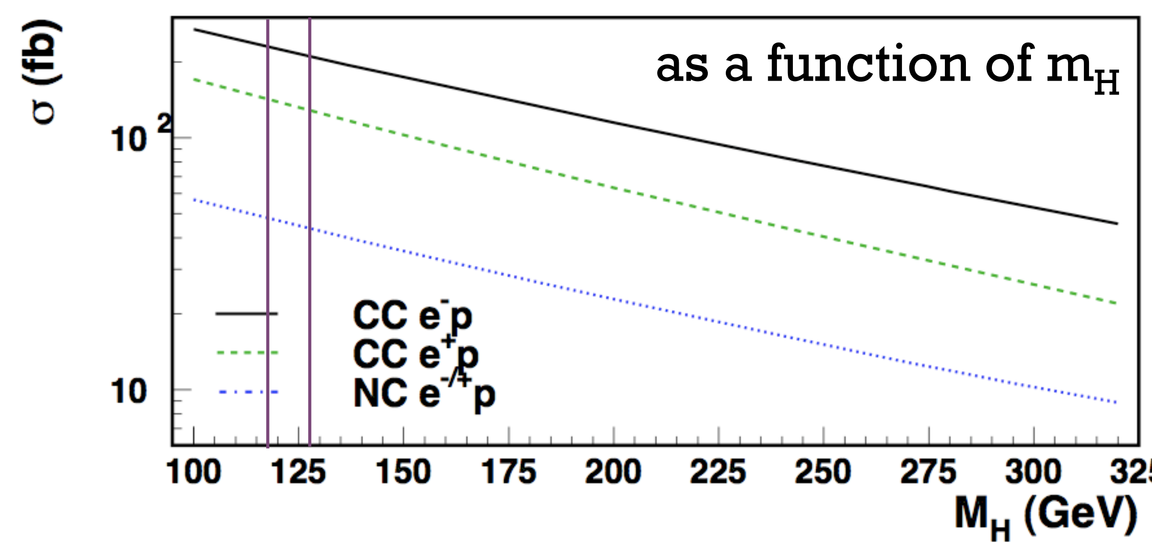
Signal

CC: $H \rightarrow b\bar{b}$ (BR ~ 0.7 at M_H=120GeV)



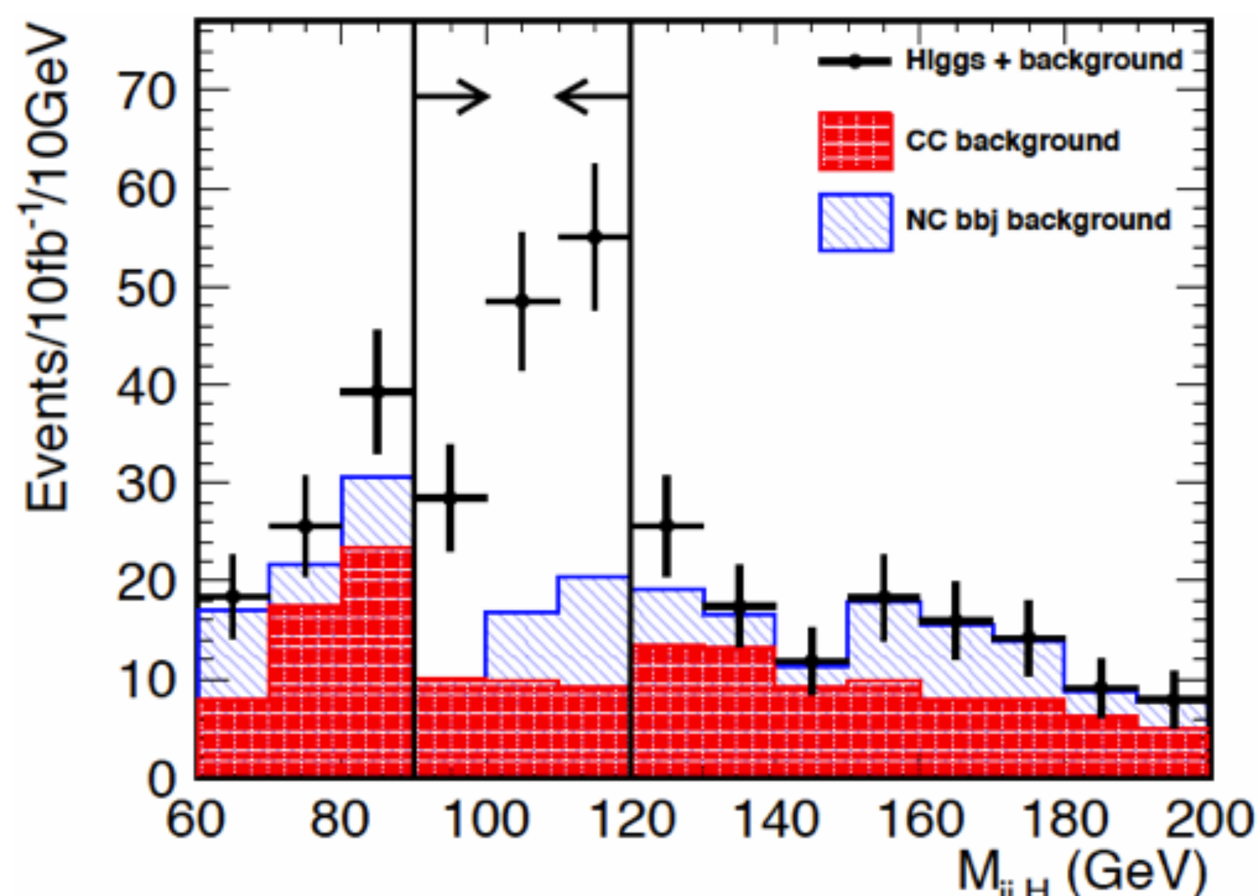
σ ~ 0.16 pb
at $\sqrt{s}$=2.05TeV

Higgs production cross-section
at $\sqrt{s}$ = 1.98TeV (E_e=140GeV, E_p=7TeV)



CC Higgs production cross-section
(M_H = 120 GeV)

Electron beam energy	50 GeV	100 GeV	150 GeV
cross-section (fb)	81	165	239



Higss can be studied at the LHeC.
High rates in CC interactions.
bbar channel cleaner at the LHeC.
Precision measurements of WW and ZZ couplings. CP properties.

Higgs at the LHeC

Talk by Masaki Ishitsuka at Chavannes-de-Bogis

Signal and background cut flow

- Beam energy:
  - Electron beam 150 GeV
  - Proton beam 7 TeV
- SM Higgs mass 120 GeV
- Luminosity 10 fb^{-1}

	$H \to bb$	CC DIS	NC bbj	S/N	$S/\sqrt{N}$
NC rejection	816	123000	4630	6.38×10^{-3}	2.28
+ b-tag requirement + Higgs invariant mass	178	1620	179	9.92×10^{-2}	4.21
All cuts	84.6	29.1	18.3	1.79	12.3

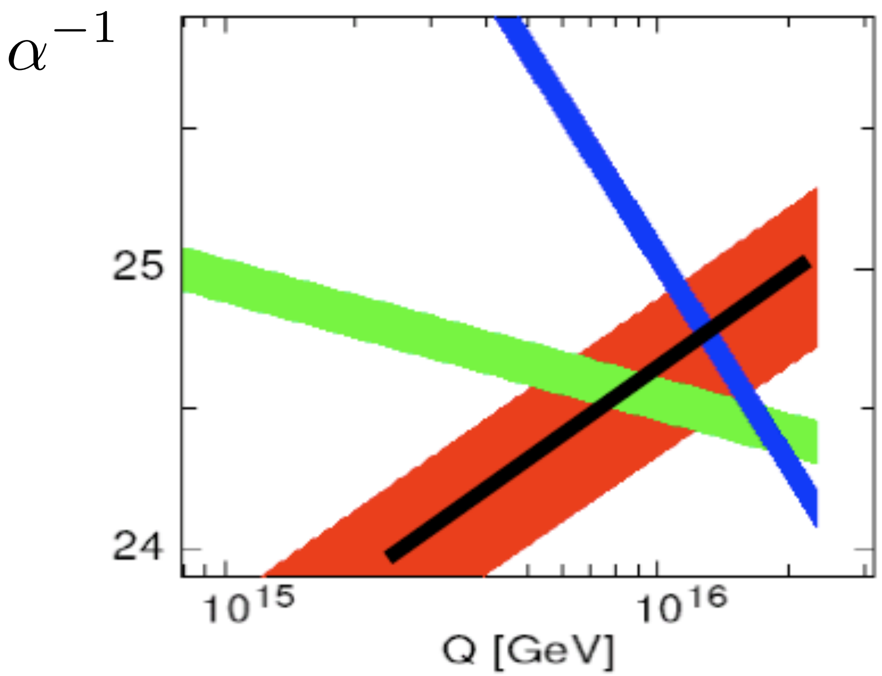
- Beam energy:
  - Electron beam 150 GeV ⇒ 60 GeV
  - Proton beam 7 TeV
- SM Higgs mass 120 GeV
- Luminosity 10 fb^{-1} ⇒ 100 fb^{-1}

	E_e = 150 GeV (10 fb^{-1})	E_e = 60 GeV (100 fb^{-1})
$H \to bb$ signal	84.6	248
S/N	1.79	1.05
$S/\sqrt{N}$	12.3	16.1

- We can explore other channels
  - NC Higgs production in ZZ fusion
  - Other light Higgs decay channels

Measurement of strong coupling

Unification of coupling constants?

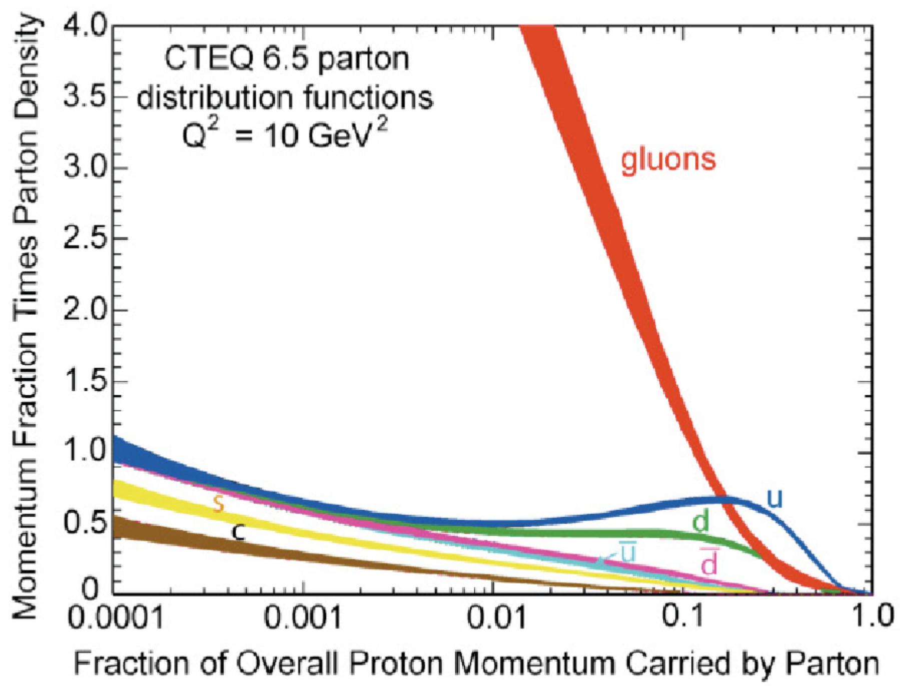


Strong coupling is least known of all couplings
Grand unification predictions suffer from uncertainty
DIS tends to be lower than the world average
LHeC: per mille accuracy (now percent accuracy)

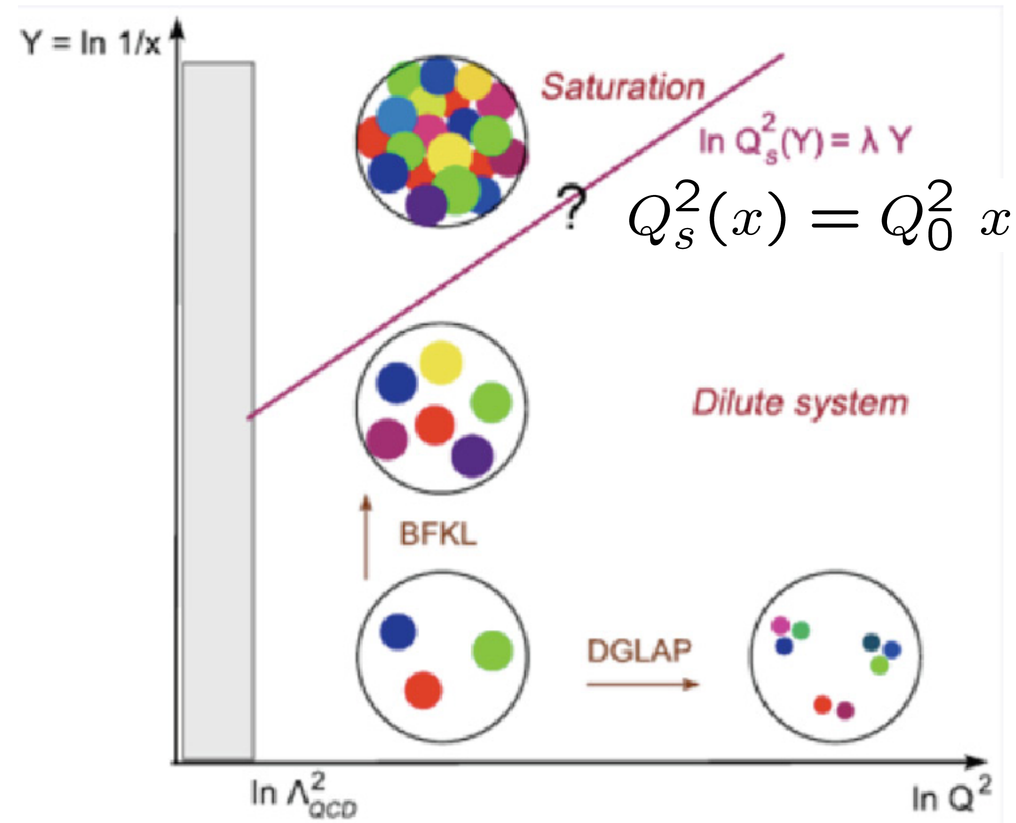
A dedicated study was performed to determine the accuracy of alphas from the LHeC was performed using for the central values the SM prediction smeared within its uncertainties assuming Gauss distribution and taking into account correlations

case	cut $[Q^2\ (\mathrm{GeV}^2)]$	α_S	uncertainty	relative precision (%)
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

Low x and saturation



HERA established strong growth of the gluon density towards small x
Parton saturation: recombination of gluons at sufficiently high densities leading to nonlinear modification of the evolution equations.
Emergence of a dynamical scale: saturation scale dependent on energy.



$$Q_s^2(x) = Q_0^2 \; x^{-\lambda}$$

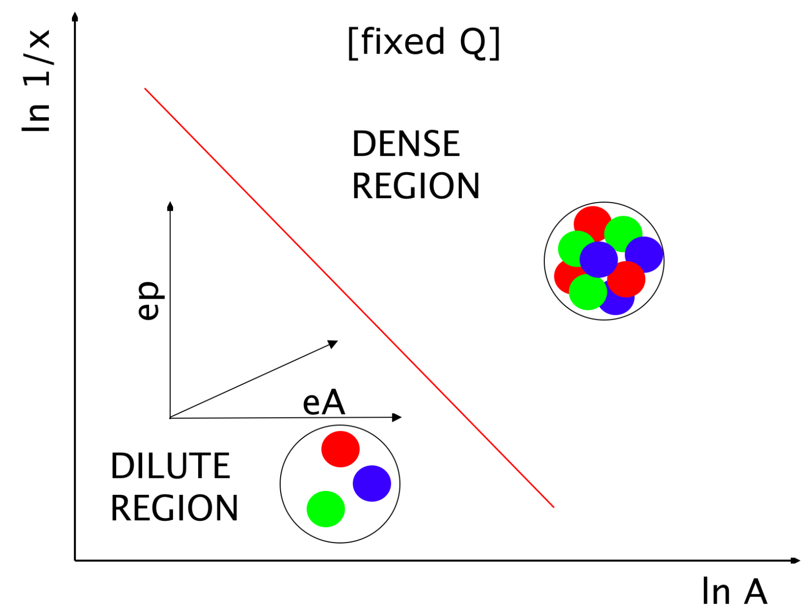
What we learned from HERA about saturation?

Linear DGLAP evolution works well at HERA.
Hints of saturation at low Q and low x: deterioration of the global fit in that region.
Large diffractive component.
Success of the dipole models in the description of the data.
The models point at the low value of the saturation scale
LHeC would provide an access to a kinematic regime where the saturation scale is perturbative

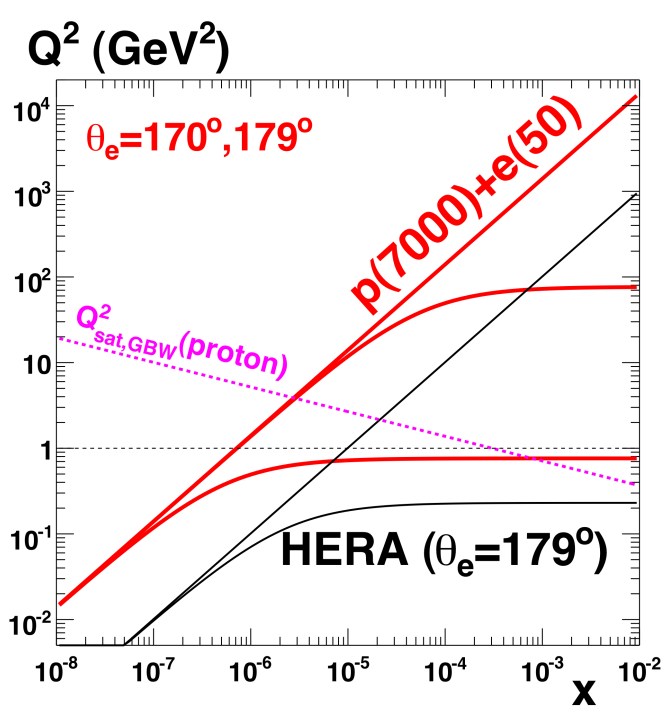
Strategy for making target more 'black'

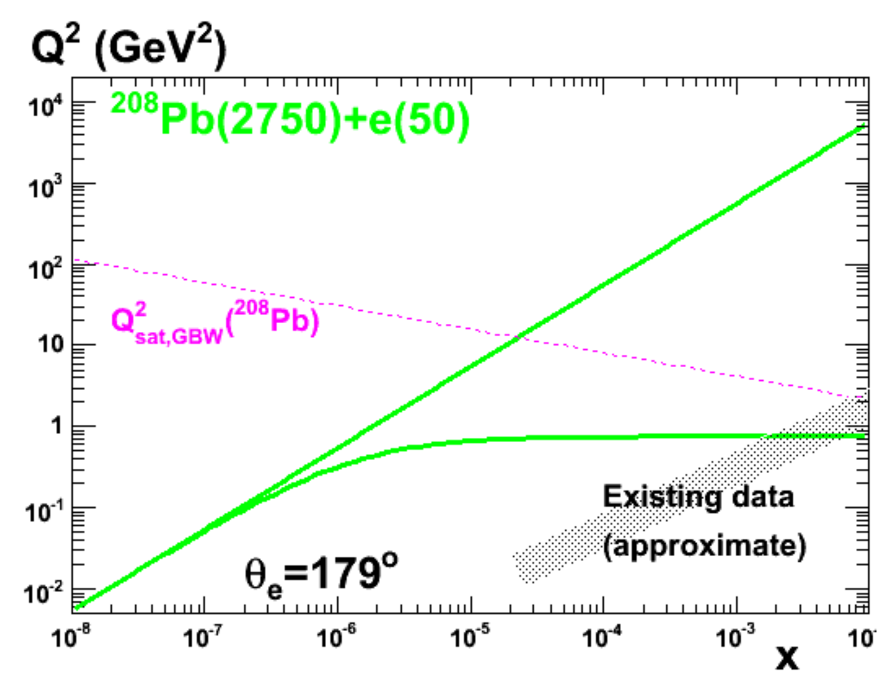
LHeC would deliver a two-pronged approach:

Probing lower x in ep. Evolution of a single source



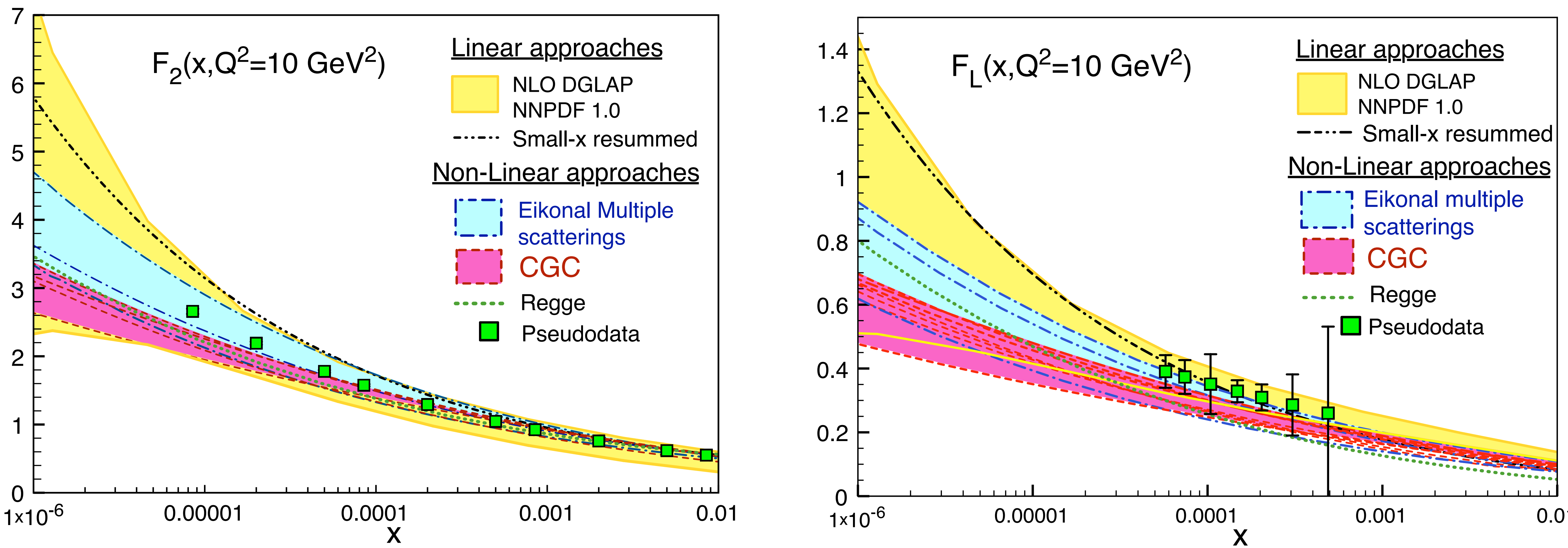
More nucleons: eA scattering. Many sources overlapping in impact parameter .





F_2, F_L structure functions at low x

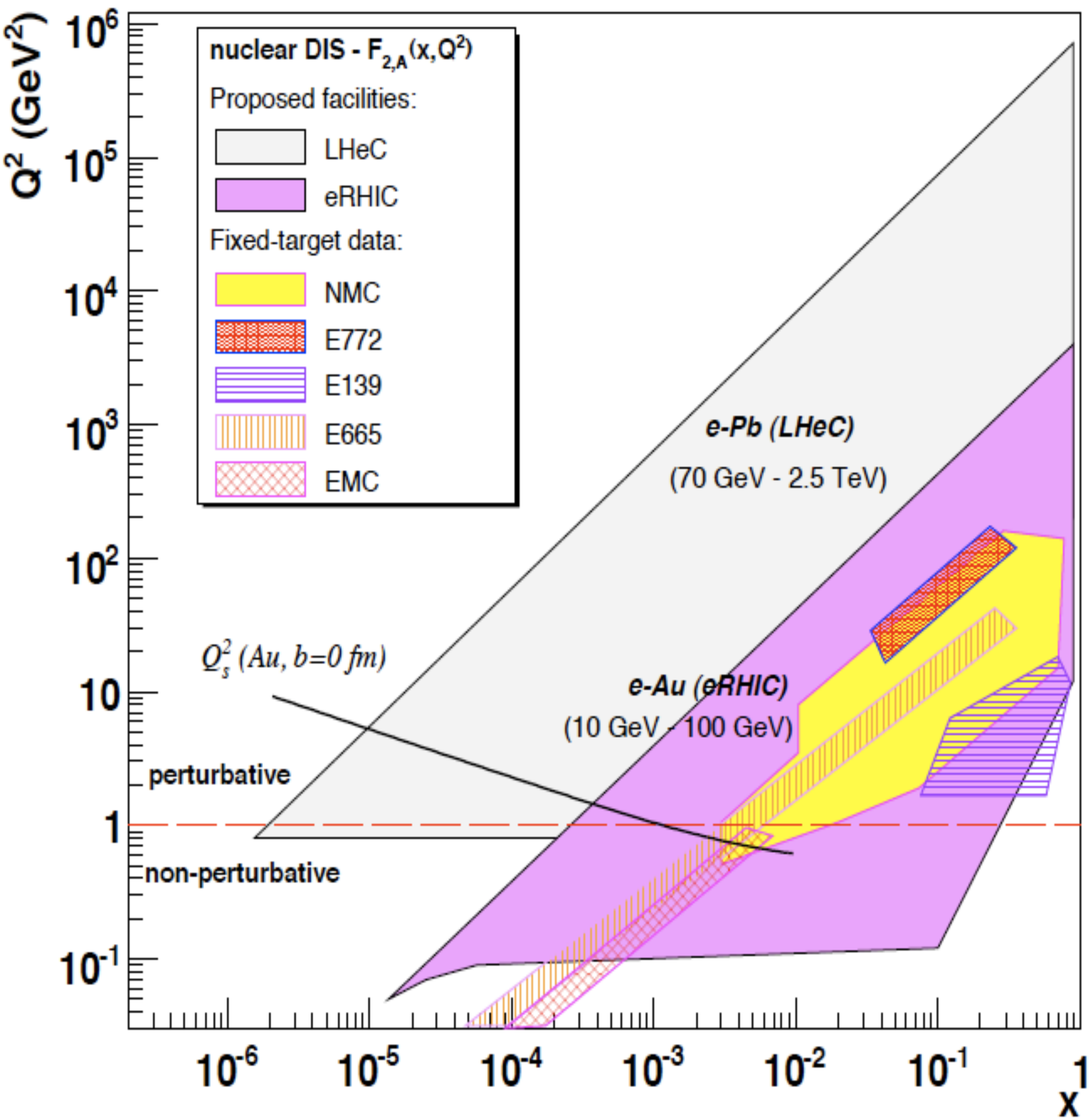
Precision measurements of structure functions at very low x: test DGLAP, small x, saturation inspired approaches.



Interestingly, rather small band of uncertainties for models based on saturation as compared with the calculations based on the linear evolution. Possible cause: the nonlinear evolution washes out any uncertainties due to the initial conditions, or too constrained parametrization used within the similar framework.

approx. 2% error on the F2 pseudodata, and 8% on the FL pseudodata ,should be able to distinguish between some of the scenarios.

Heavy Ion Physics



EIC programme:
see recent workshop arXiv:1108.1713 [nucl-th]

Initial conditions of QGP

Hadronization in Media

Nuclear Parton Distributions

Black body limit

Saturation in *ep* AND in *eA*?

Diffraction in *eA* scattering

Deuterons: tag *p* in *en* to beat Fermi motion and exploit diffraction-shadowing relation

…

LHeC eA is natural continuation of (part of) the heavy ion physics of the LHC (*AA* and *pA*, forward)

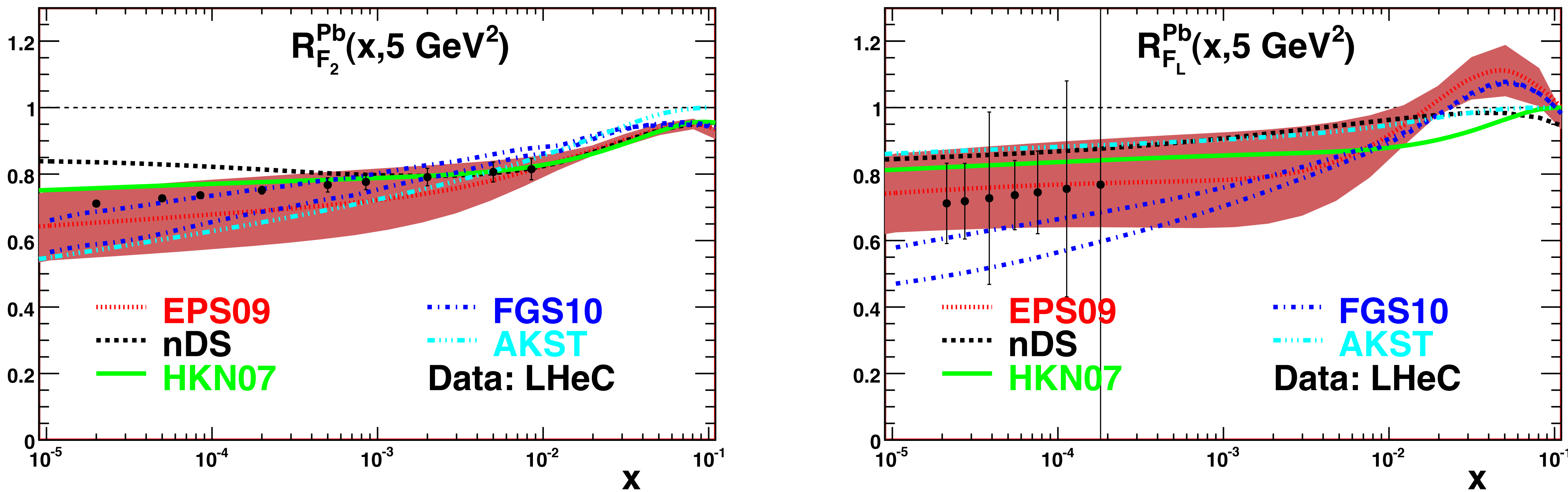
Nuclear structure functions at LHeC

Nuclear ratio for structure function or a parton density:

$$R_f^A(x,Q^2) = \frac{f^A(x,Q^2)}{A \times f^N(x,Q^2)}$$

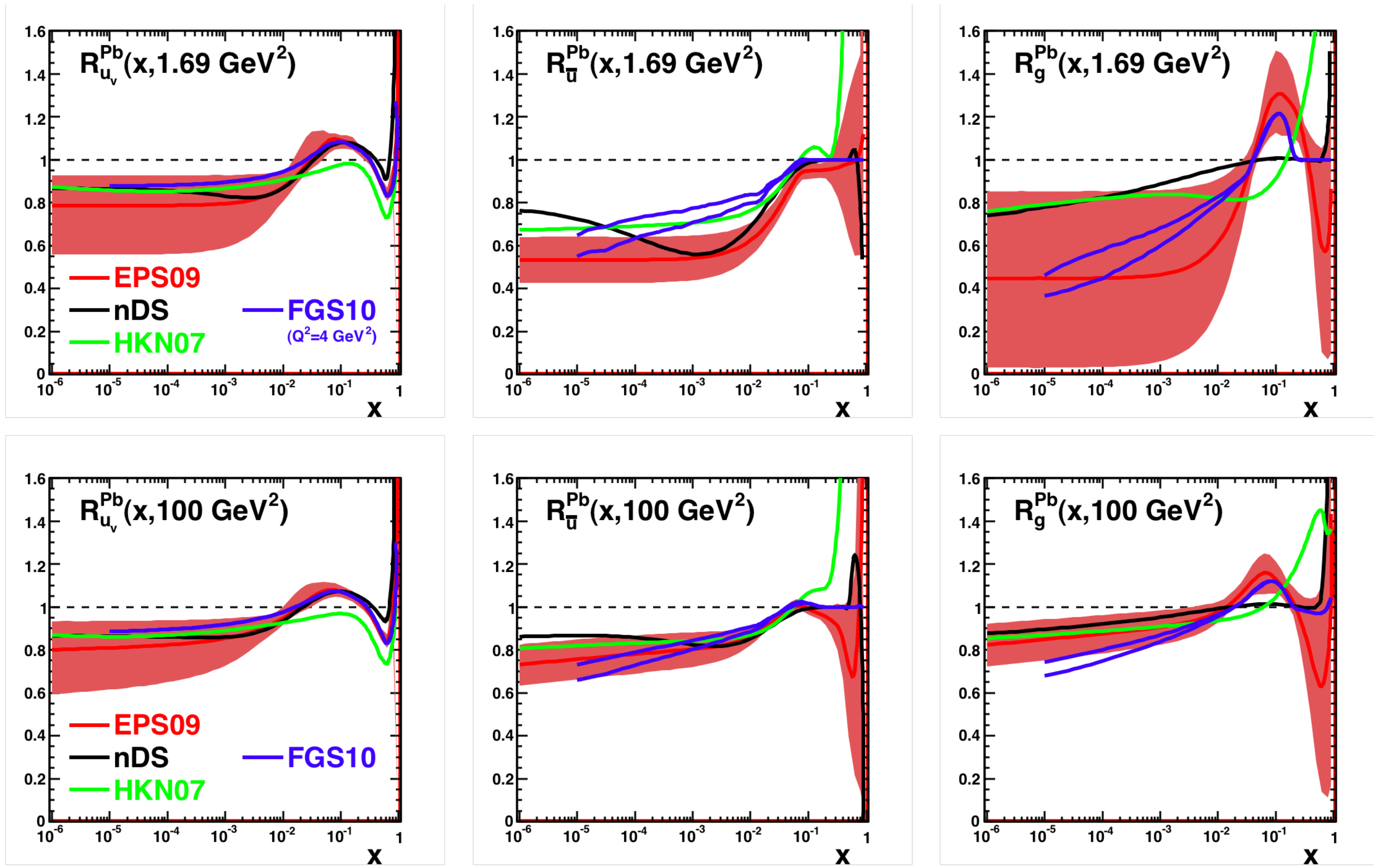
Nuclear effects $R^A \neq 1$

LHeC potential: precisely measure partonic structure of the nuclei at small x.



Nuclear structure functions measured with very high accuracy.

Nuclear parton distributions

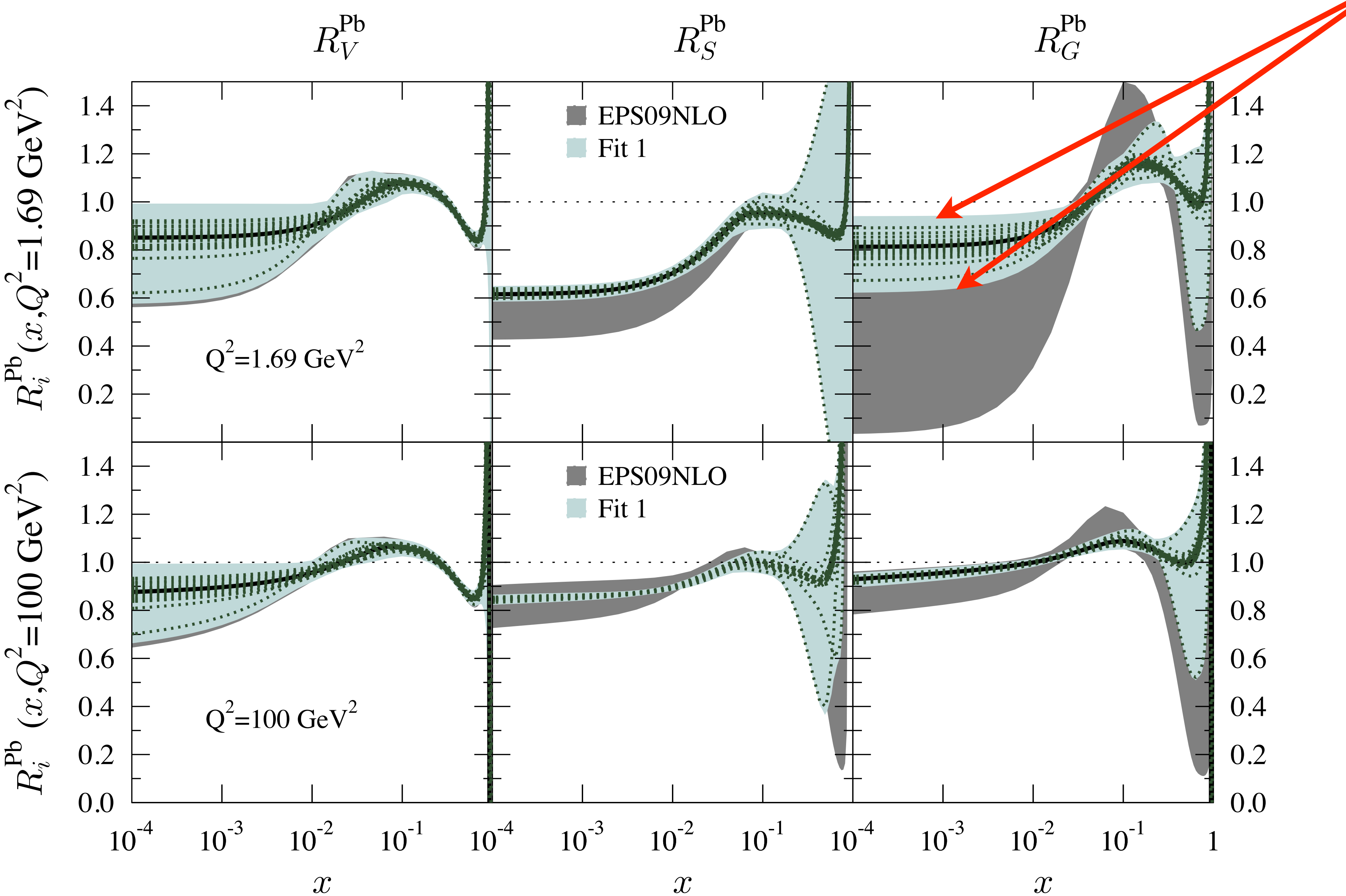


R_i = Nuclear PDF i / (A * proton PDF i)

Current status: nuclear parton distribution functions are poorly known at small x. Especially gluon density, below x=0.01 can be anything between 0 and 1....

Nuclear parton distributions at LHeC

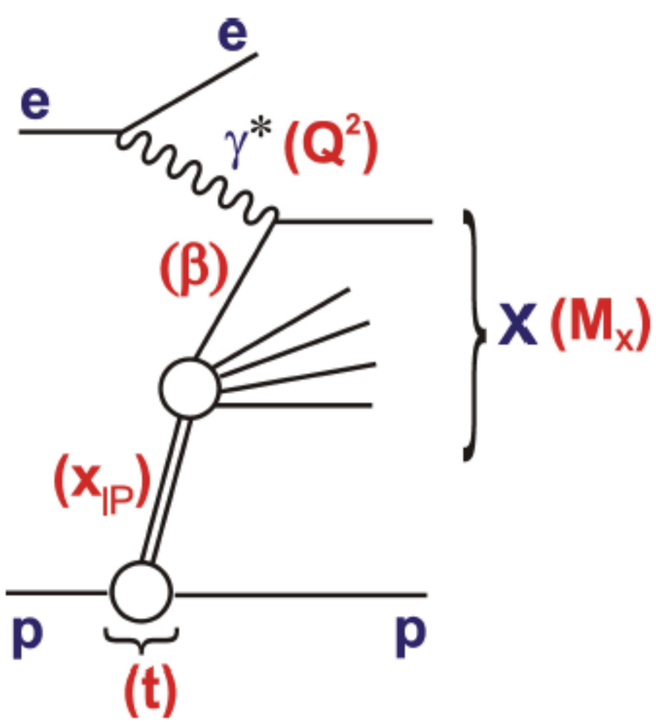
Global NLO fit with the LHeC pseudodata included



Much smaller uncertainties.

Very large constraint on the low x gluons and sea quarks with the LHeC pseudodata .

Diffraction



$$x_{IP} = \frac{Q^2 + M_X^2 - t}{Q^2 + W^2}$$

momentum fraction of the Pomeron w.r.t hadron

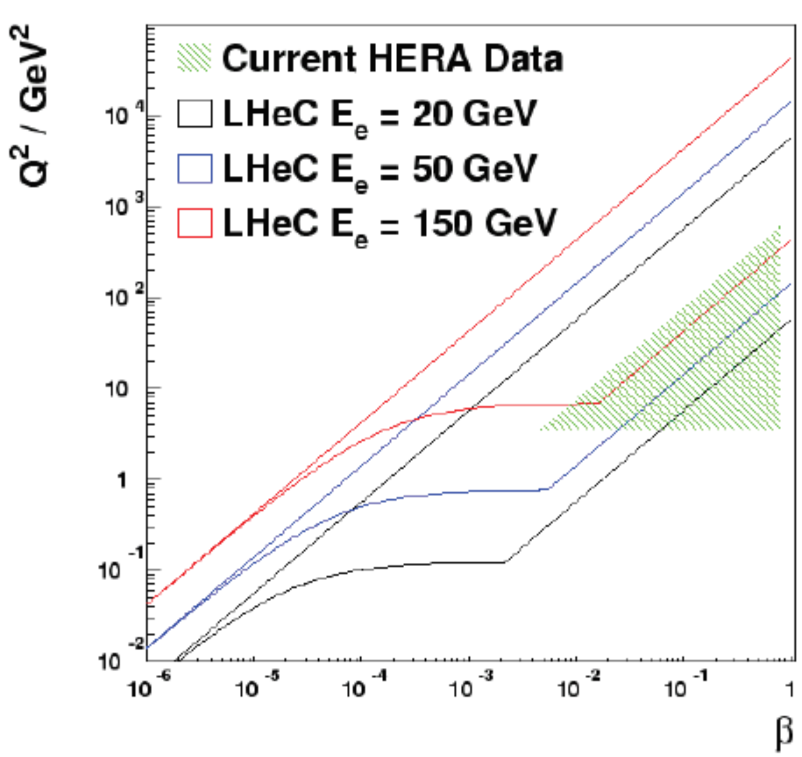
$$\beta = \frac{Q^2}{Q^2 + M_X^2 - t}$$

momentum fraction of parton w.r.t Pomeron

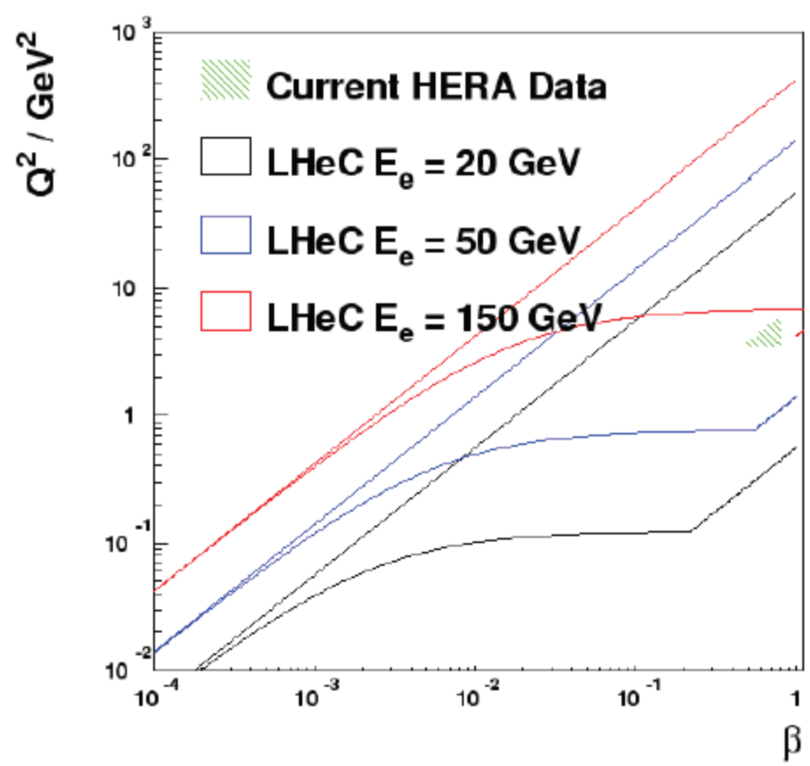
$$x_{Bj} = x_{IP}\beta$$

Methods: Leading proton tagging, large rapidity gap selection

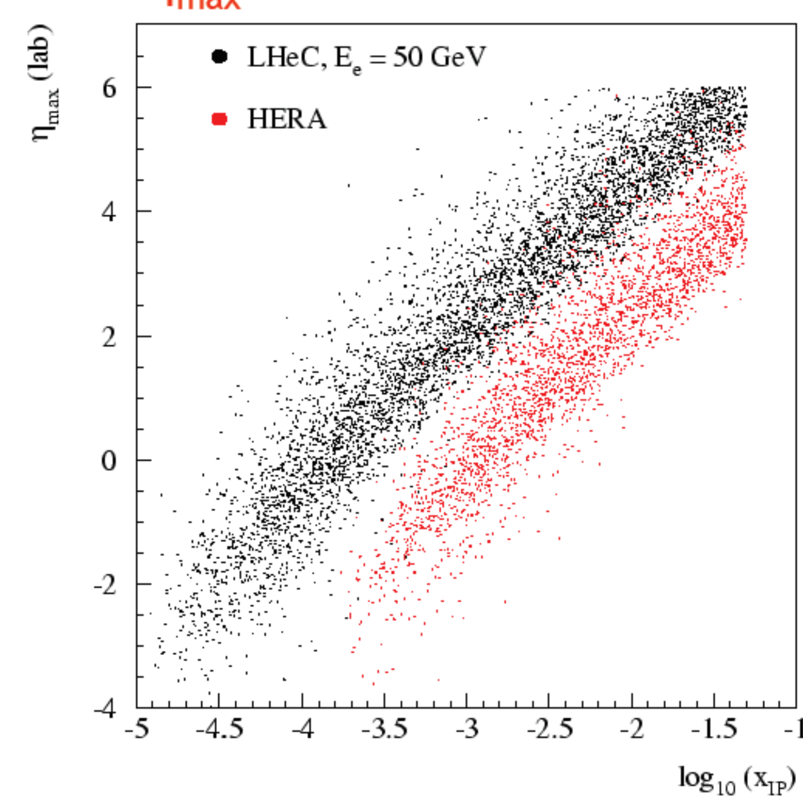
Diffractive Kinematics at x_{IP}=0.01



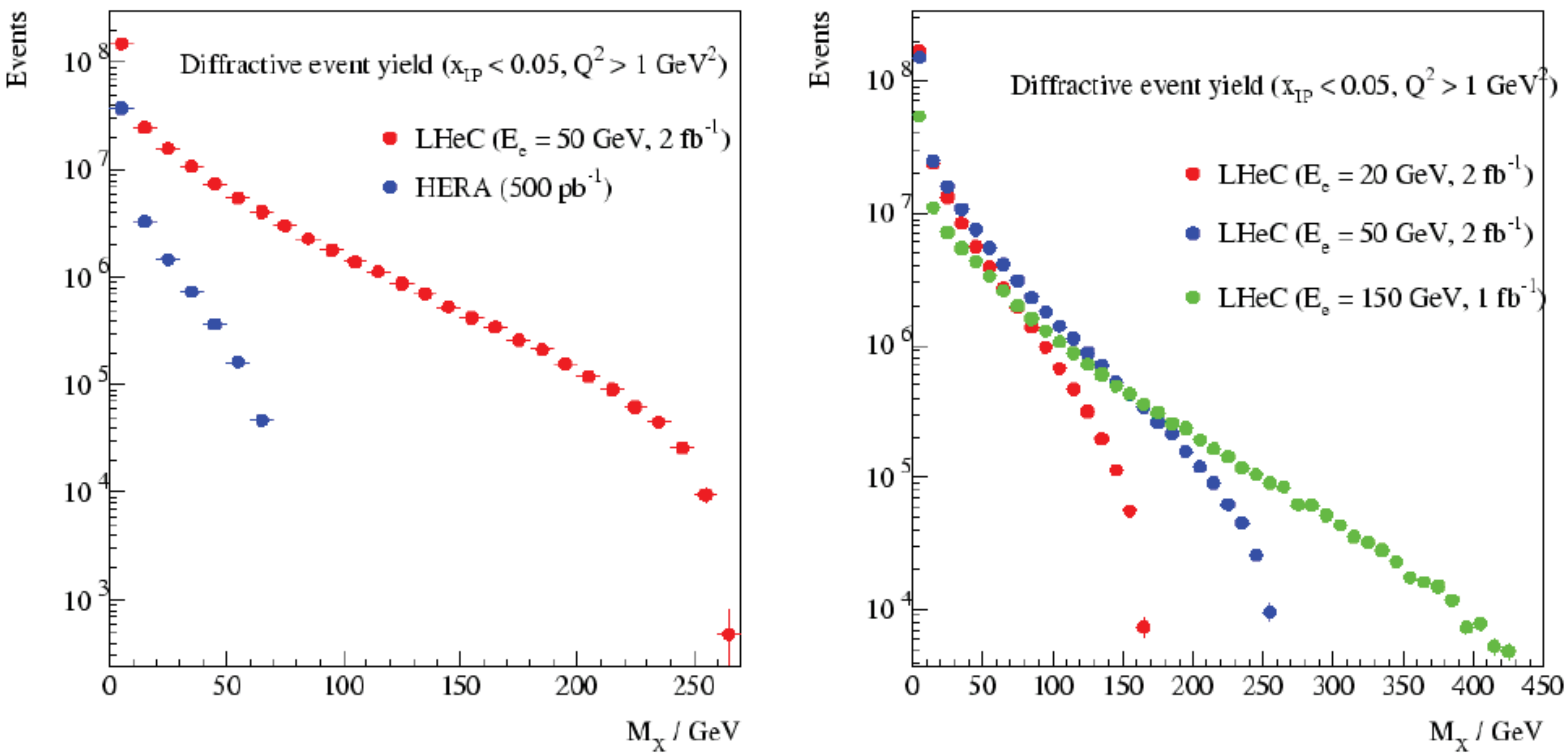
Diffractive Kinematics at x_{IP}=0.0001



η_{max} from LRG selection ...

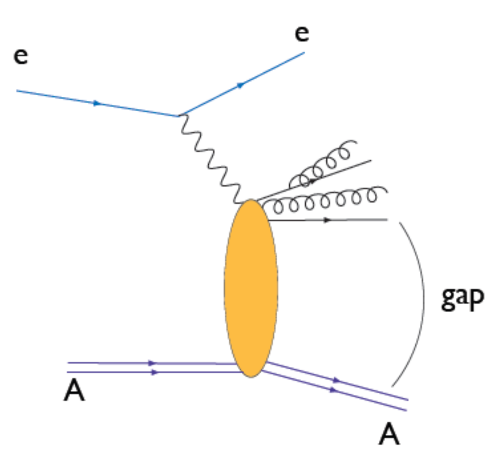


Diffractive mass distribution

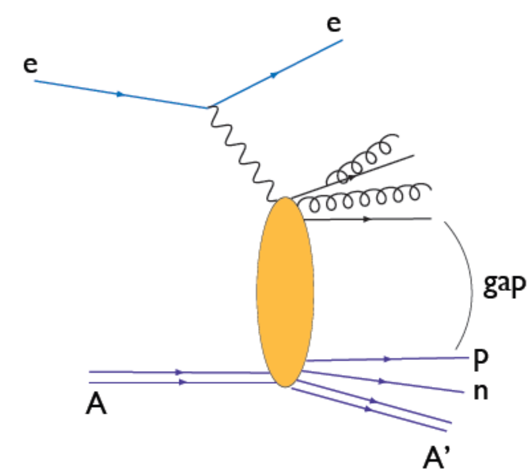


New domain of diffractive masses.
M_X can include W/Z/beauty

Inclusive diffraction in eA

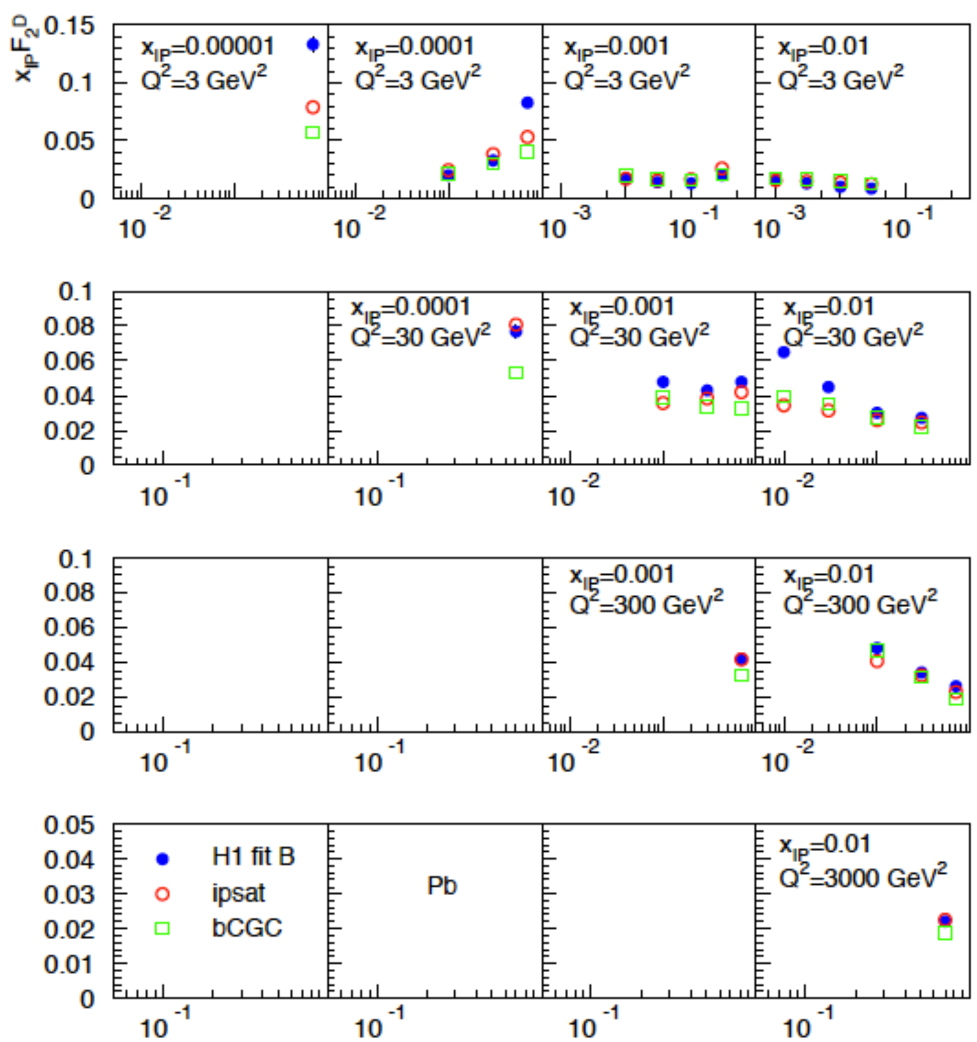


coherent

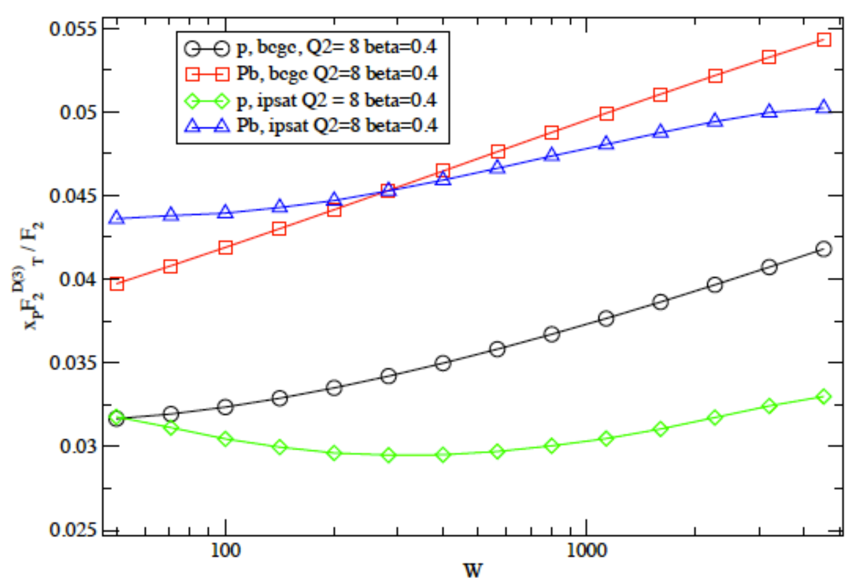


incoherent

Diffractive structure function for Pb



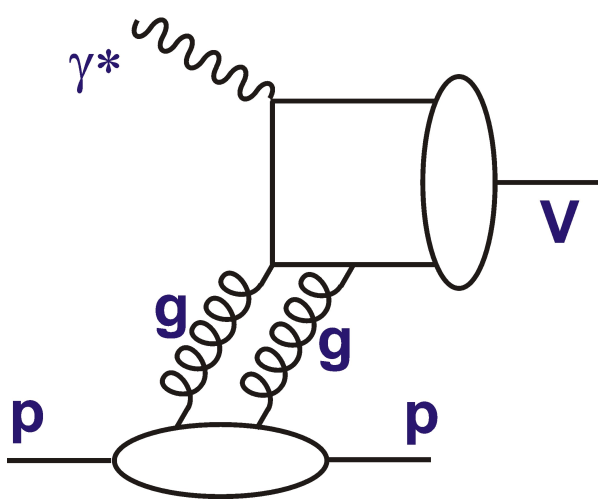
Diffractive to inclusive ratio for protons and Pb



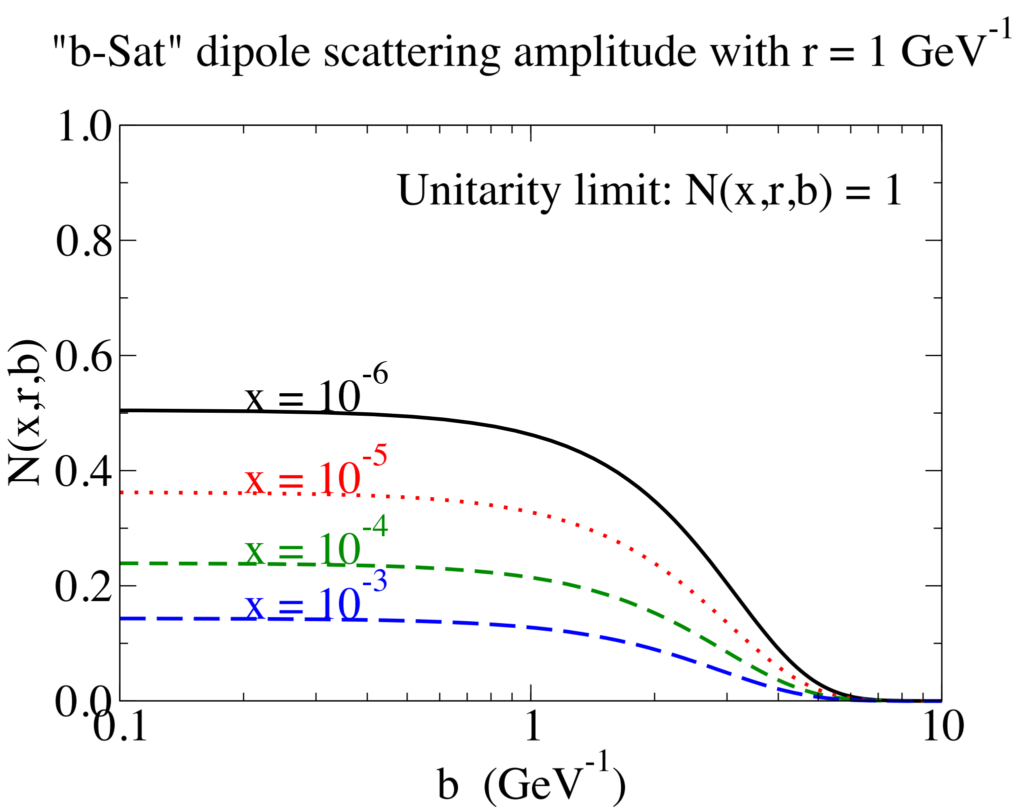
Enhanced diffraction in the nuclear case

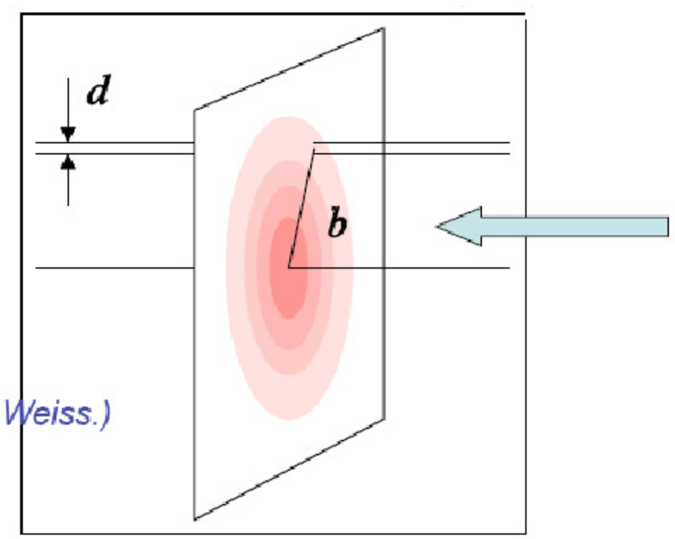
Study of diffractive dijets, heavy quarks for the factorization tests

Exclusive diffraction



- Exclusive diffractive production of VM is an excellent process for extracting the dipole amplitude and GPDs
- Suitable process for estimating the 'blackness' of the interaction.
- t-dependence provides an information about the impact parameter profile of the amplitude.





(figure from C. Weiss.)

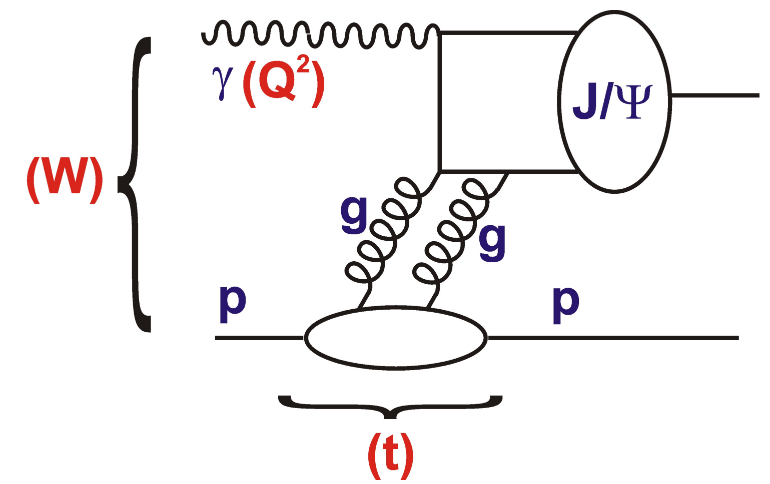
Central black region growing with decrease of x.

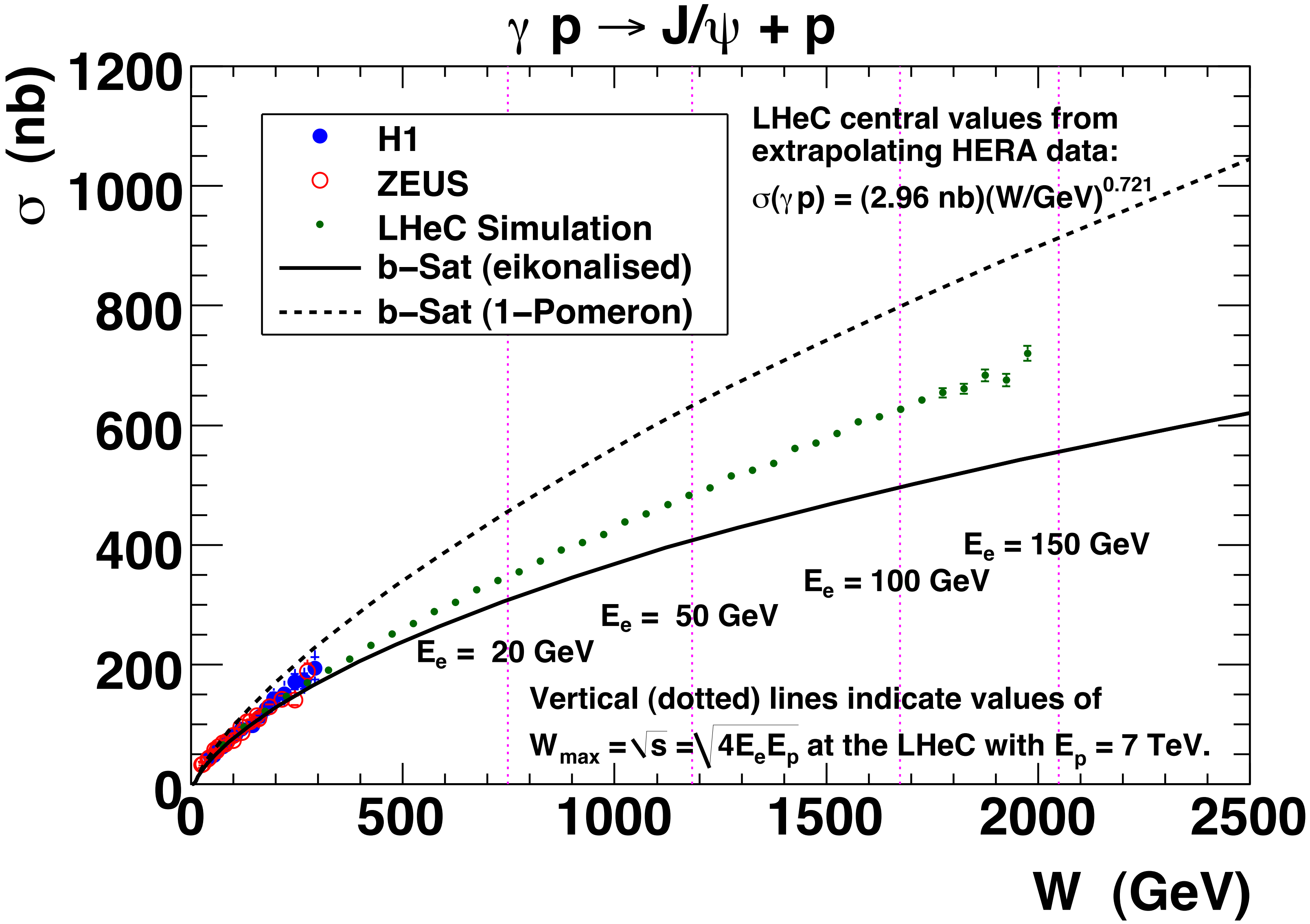
Large momentum transfer t probes small impact parameter where the density of interaction region is most dense.

Exclusive diffraction: predictions

$$\sigma^{\gamma p \to J/\Psi + p}(W)$$

- b-Sat dipole model (Golec-Biernat, Wuesthoff, Bartels, Motyka, Kowalski, Watt)
- eikonalised: with saturation
- 1-Pomeron: no saturation





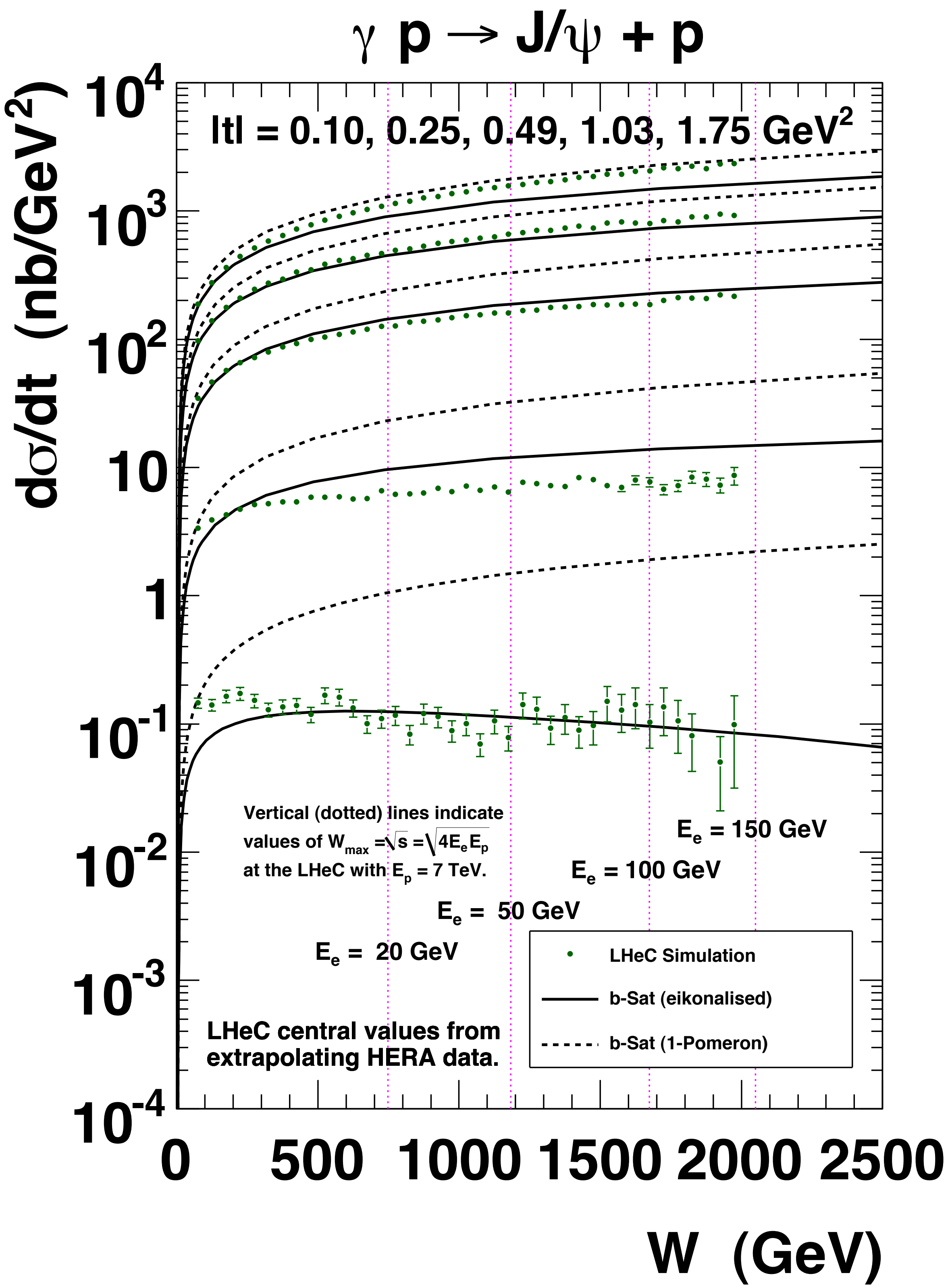
Large effects even for the t-integrated observable.

Different W behavior depending whether saturation is included or not.

Simulated data are from extrapolated fit to HERA data

LHeC can distinguish between the different scenarios.

Exclusive diffraction: t-dependence

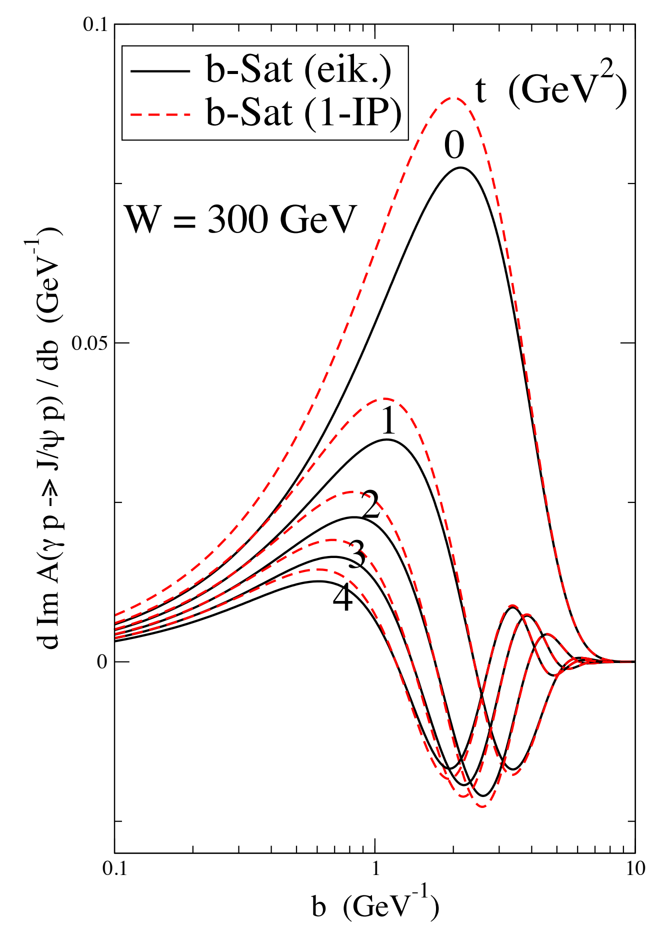


Photoproduction in bins of W and t.

Already for small values of t and smallest energies large discrepancies between the models. LHeC can discriminate.

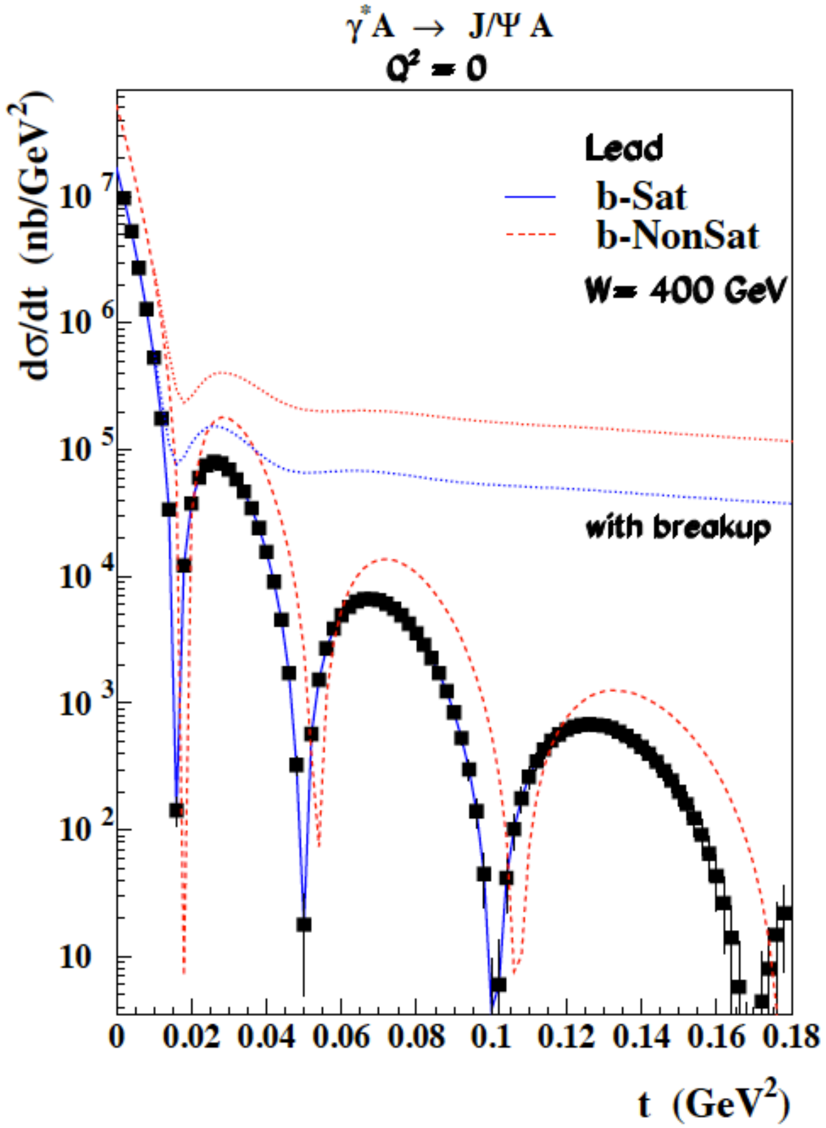
Large values of t : increased sensitivity to small impact parameters.

Amplitude as a function of the impact parameter.

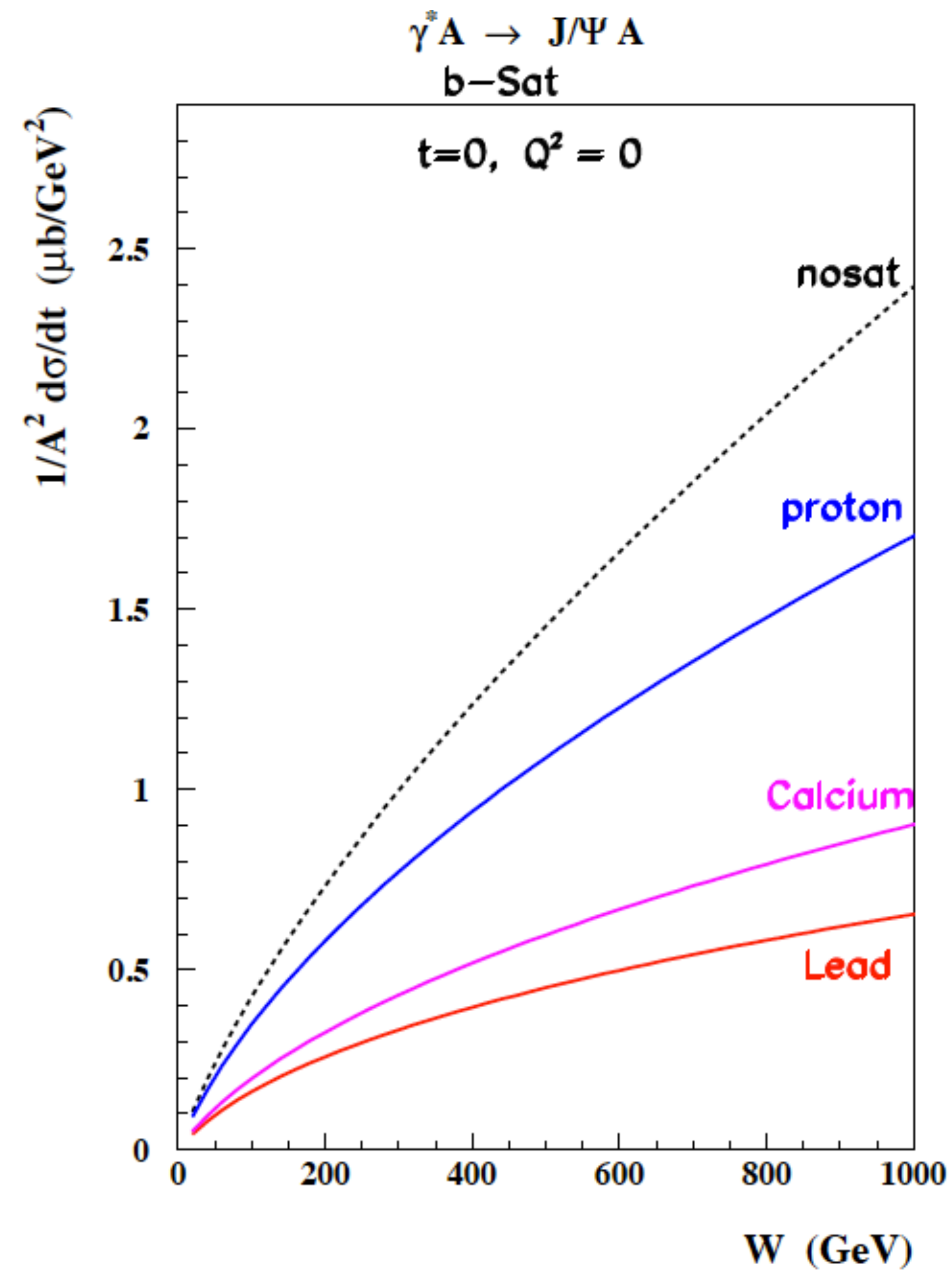


Exclusive diffraction on nuclei

Possibility of using the same principle to learn about the gluon distribution in the nucleus.
Possible nuclear resonances at small t?



Energy dependence for different targets.



t-dependence: characteristic dips.
Challenges: need to distinguish between coherent and incoherent diffraction. Need dedicated instrumentation, zero degree calorimeter.

Summary

- LHeC has an unprecedented potential as a high luminosity, high energy DIS machine. Offering a unique window for small x physics and high parton density regime.
- Precision DIS measurements: constraining and unfolding PDFs, heavy flavor physics, precision strong coupling , precision electroweak measurements. Higgs properties.
- eA at high energy essential to untangle the complex nuclear structure at low x and constrain the initial conditions for AA at the LHC. Complementary to pp/pA/AA.
- CDR for the project is complete: arXiv:1206.2913
- Next steps in the near future:
  - Reorganization of the working groups. Forming a collaboration.
  - Detailed evaluation of the relation of ep/eA program to LHC (esp. pp and pA) is needed.
  - First steps towards Technical Design Report.

http://cern.ch/lhec

backup

Photoproduction cross section

Explore dual nature of the photon: pointlike interactions or hadronic behavior.

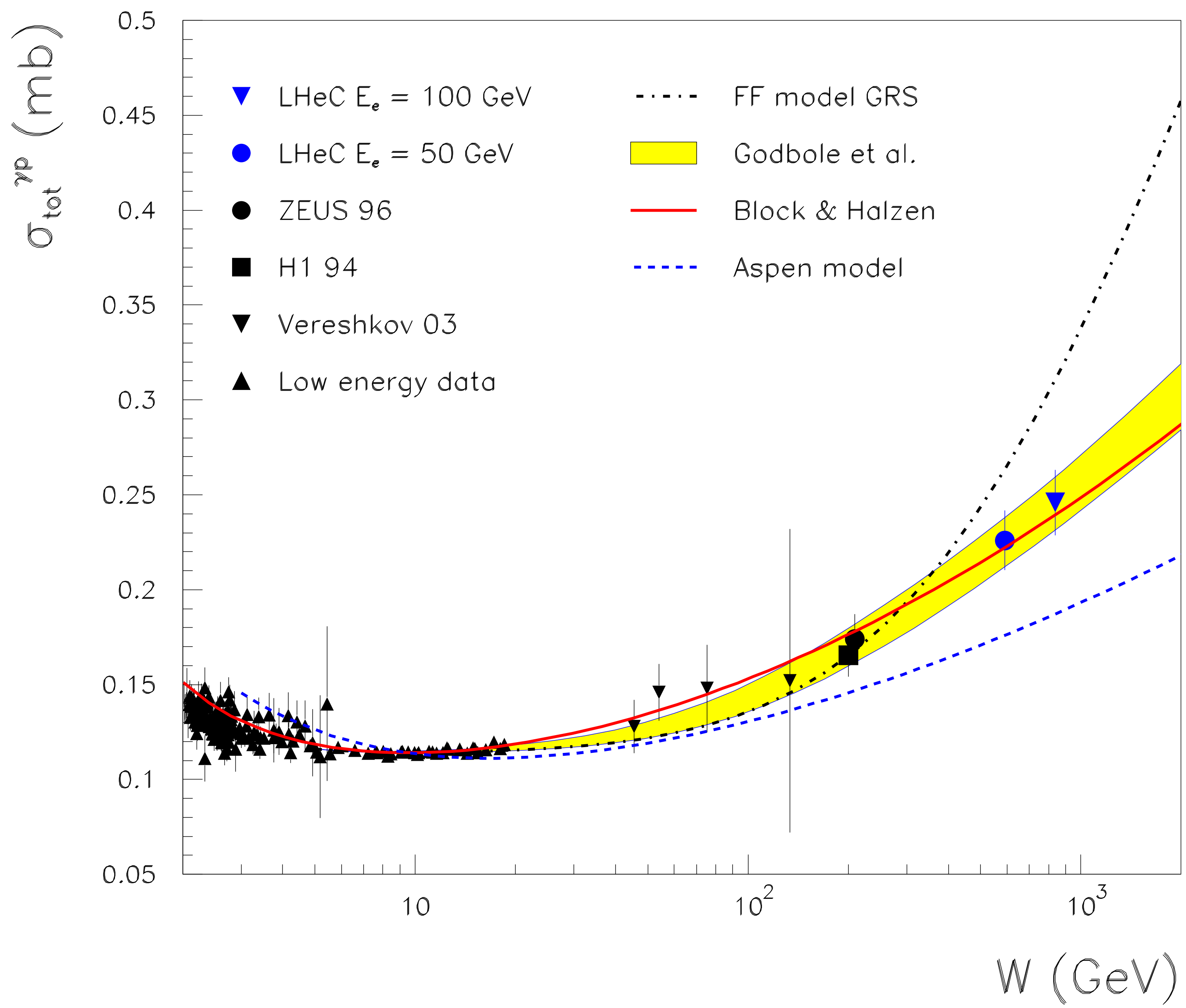
Tests of universality of hadronic cross sections, unitarity, transition between perturbative and nonperturbative regimes.

Dedicated detectors for small angle scattered electrons at 62m from the interaction point.

Kinematics of events:

$$Q^2 \sim 0.01$$

$$y \sim 0.3$$

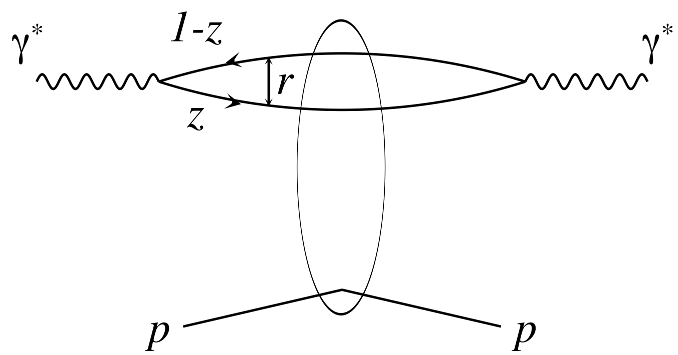


Systematics is the limiting factor here. Assumed 7% for the simulated data as in H1 and ZEUS.

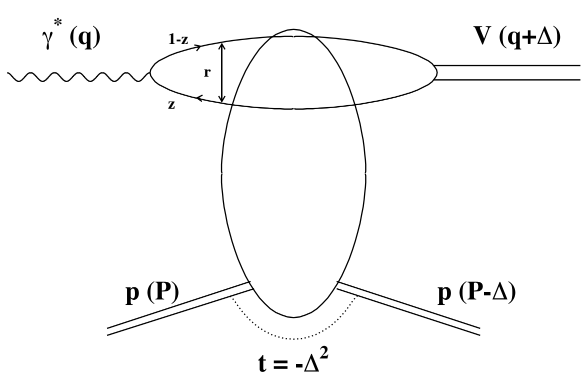
Diffraction and saturation

Dipole model at high energy: photon fluctuates into qqbar pair and undergoes an interaction with the target

$$\sigma_{T,L}(x,Q^2) = \int d^2\mathbf{r} \int_0^1 dz \sum_f |\Psi^f_{T,L}(\mathbf{r},z,Q^2)|^2 \, \hat{\sigma}(x,\mathbf{r}) \, .$$

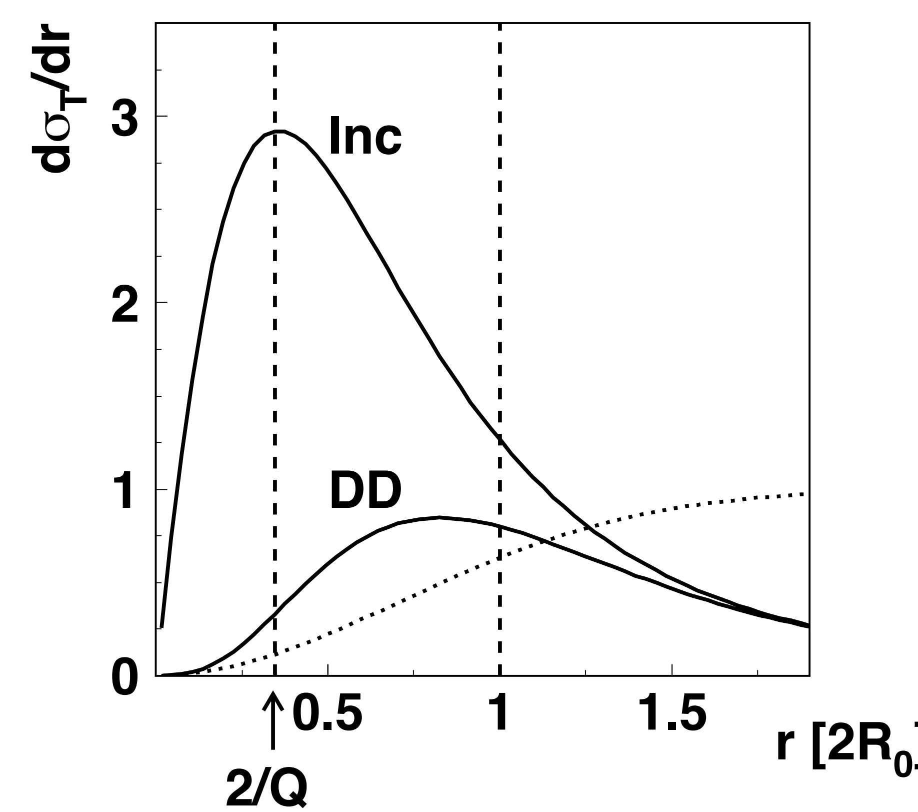


Inclusive: dominated by relatively hard component



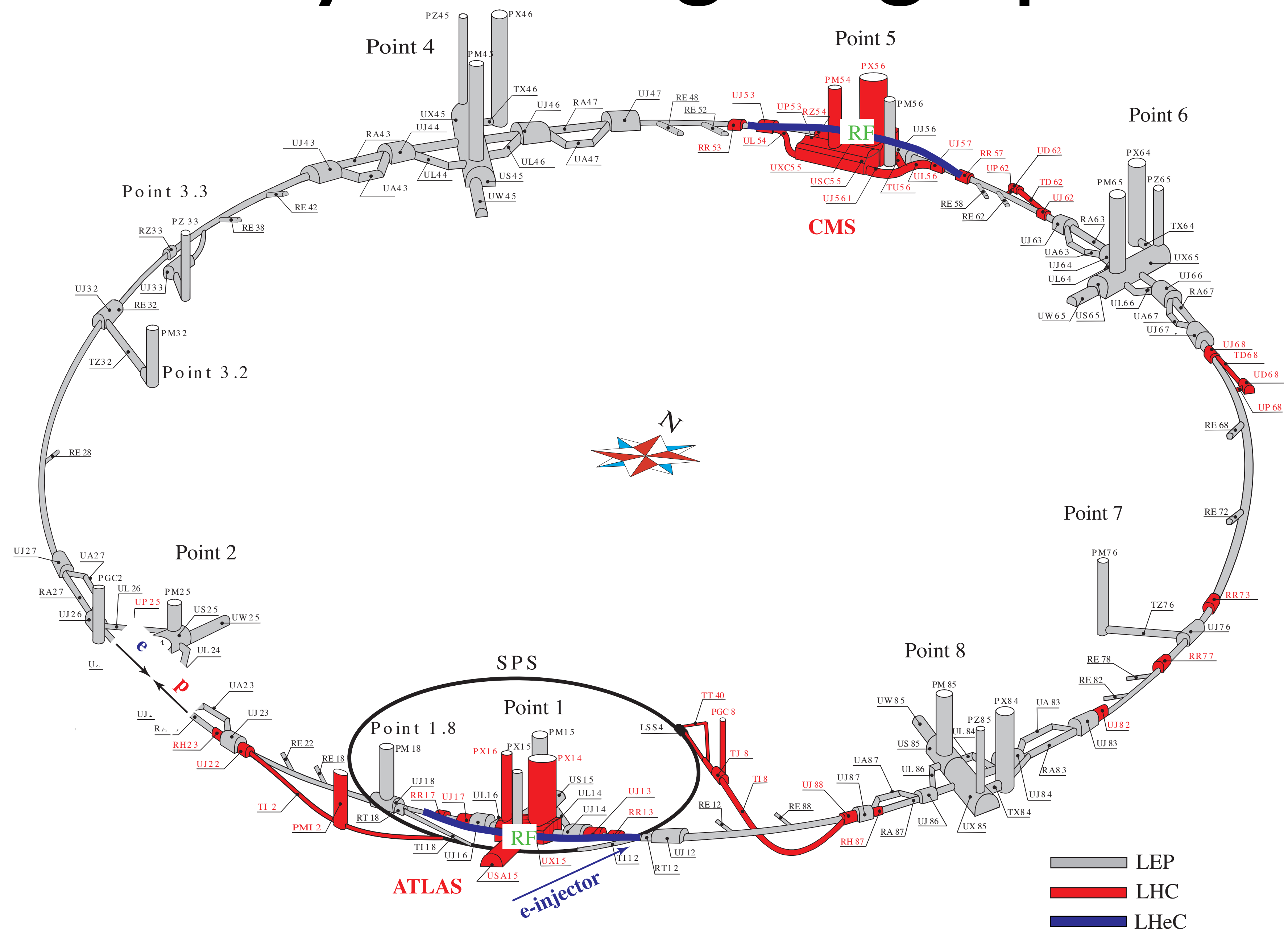
Diffractive: dominated by the semi-hard momenta

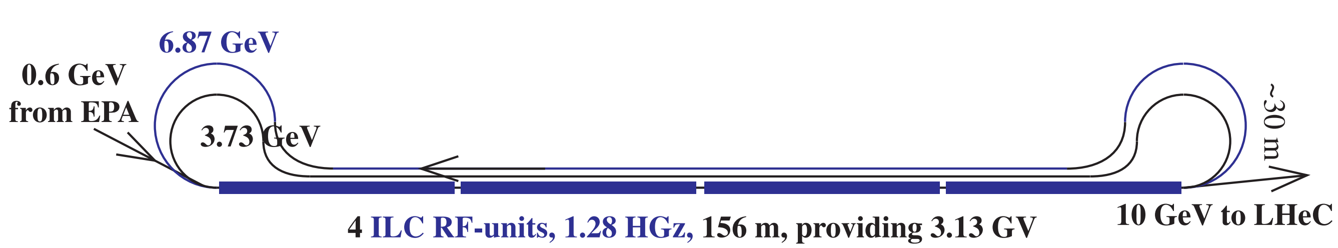
overlap function in the dipole model
typical dipole sizes involved in the process



Diffraction is a collective phenomenon.
Explore relation with saturation.

LHeC layout: ring-ring option



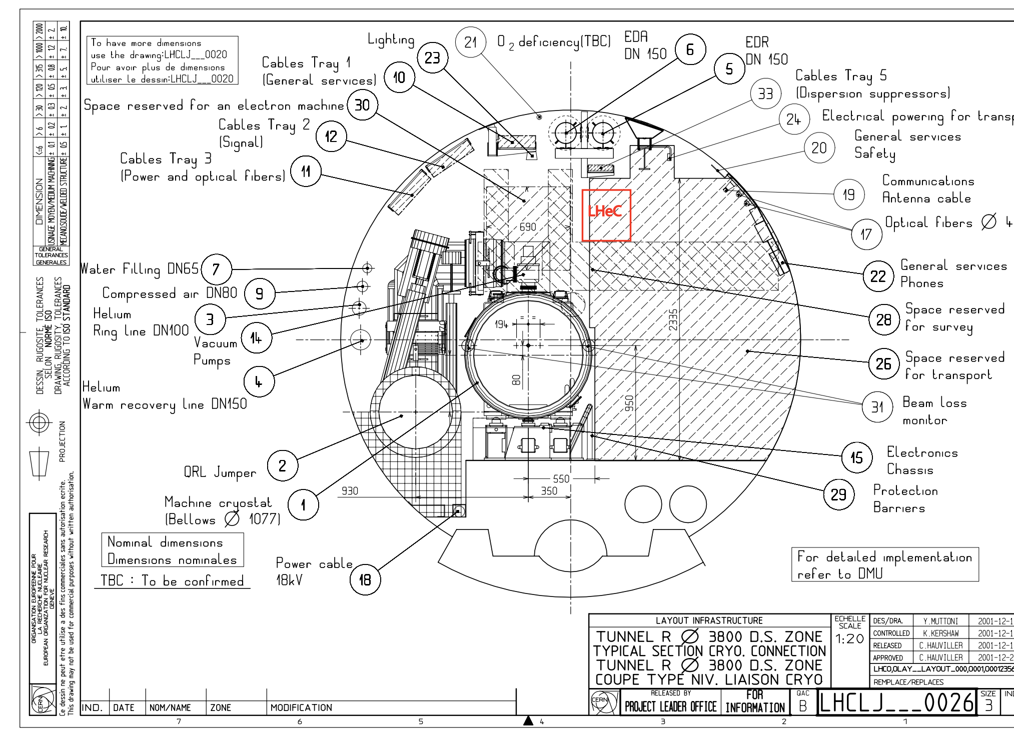


10 GeV injector

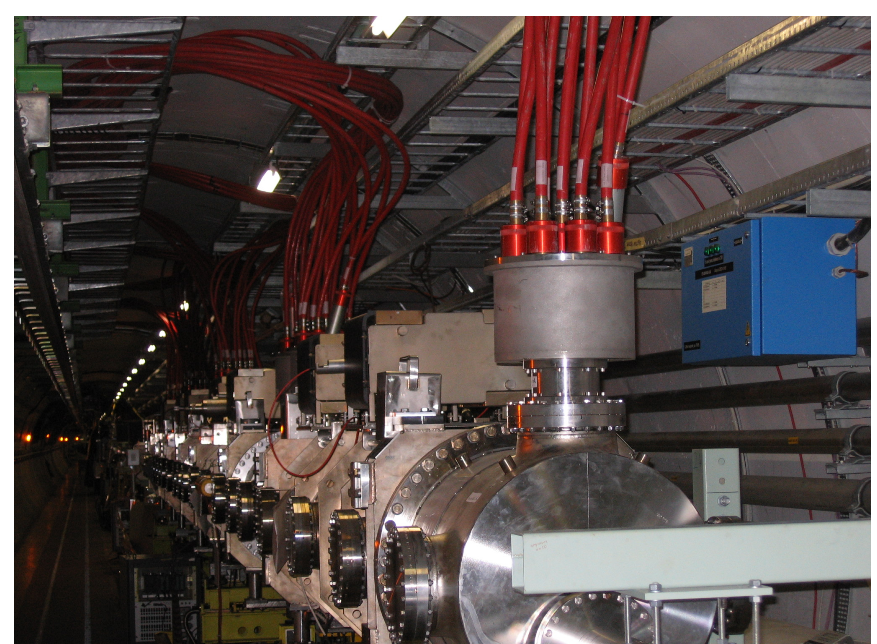
Accelerator design

Multi-lab involvement: CERN, BNL, Novosibirsk, Cockroft, Cornell, DESY, EPFL Lausanne, JLab, KEK , Liverpool, SLAC, TAC Turkey, NTFU Norway, INFN, ...

Design constraint: power consumption < 100 MW. Electron energy 60 GeV in ring-ring mode



Installation 1m above LHC and 60cm to the inside.
By-passes of existing experiments.
Challenging, but possible.



Leptoquarks

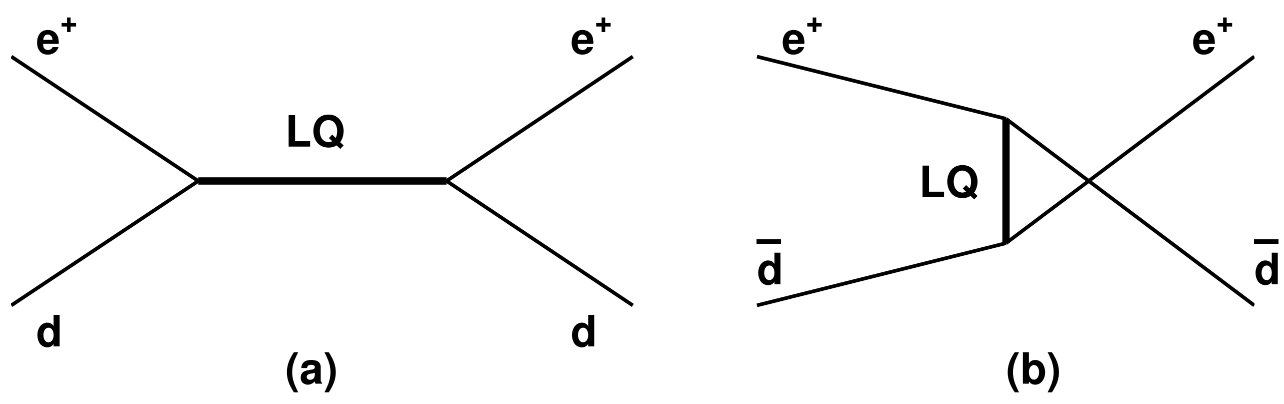
Leptoquarks appear in many extensions of the SM.

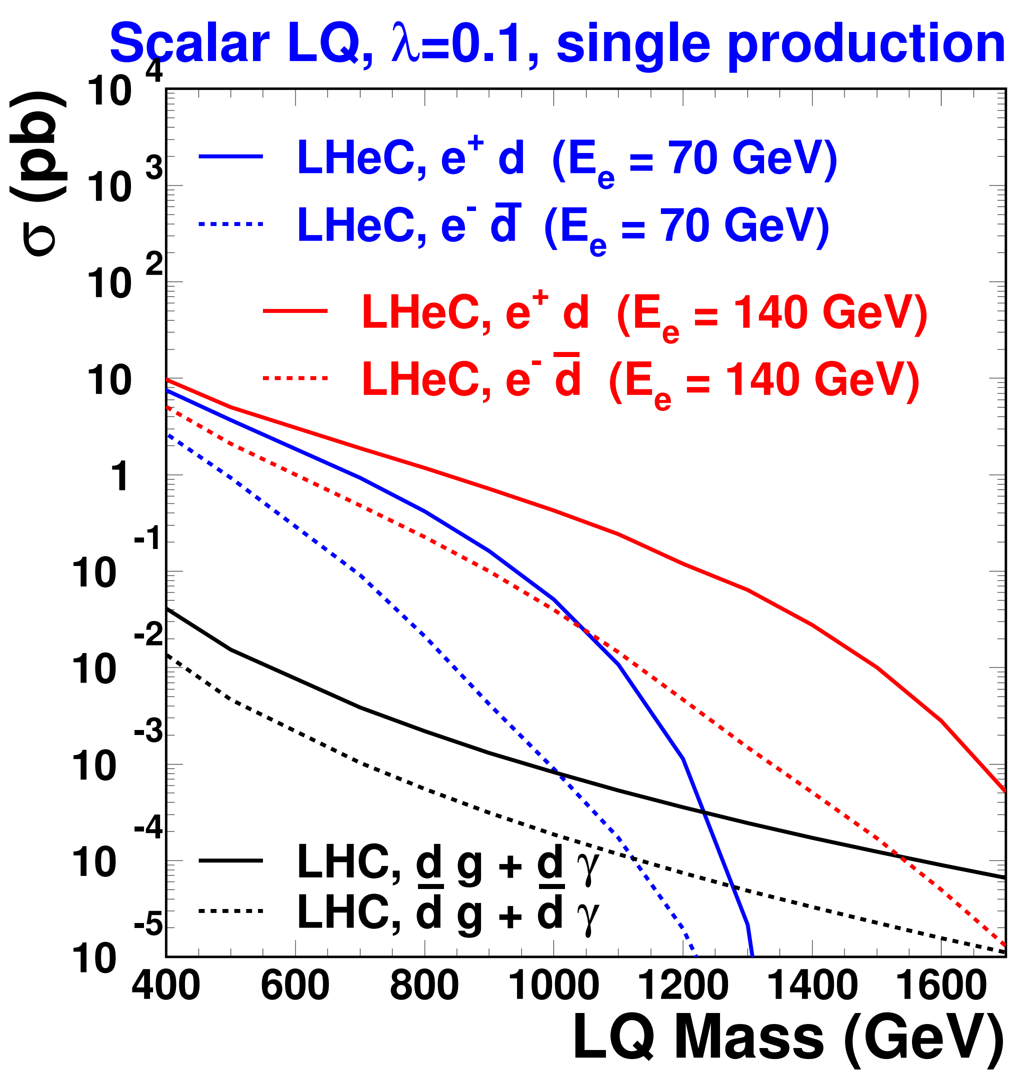
May help explain remarkable symmetry between lepton and quark sectors.

Produced via fusion of electron with the quark (antiquark) from the proton.

In pp leptoquarks mainly produced in pairs. Single production in ep. Better suited for studies of properties (quantum numbers etc.)

Mass sensitivity to 1.0-1.5 TeV. Comparable with LHC, much cleaner!

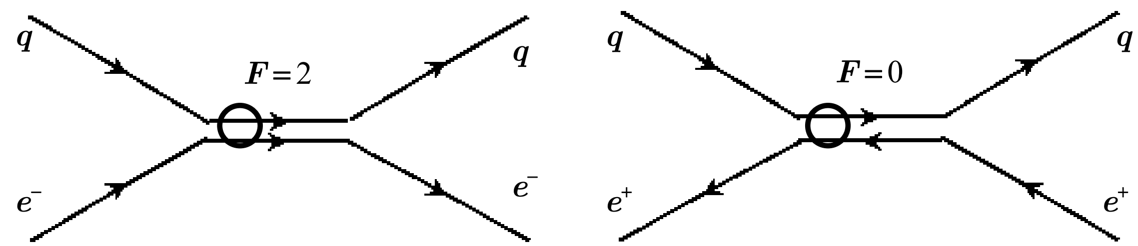


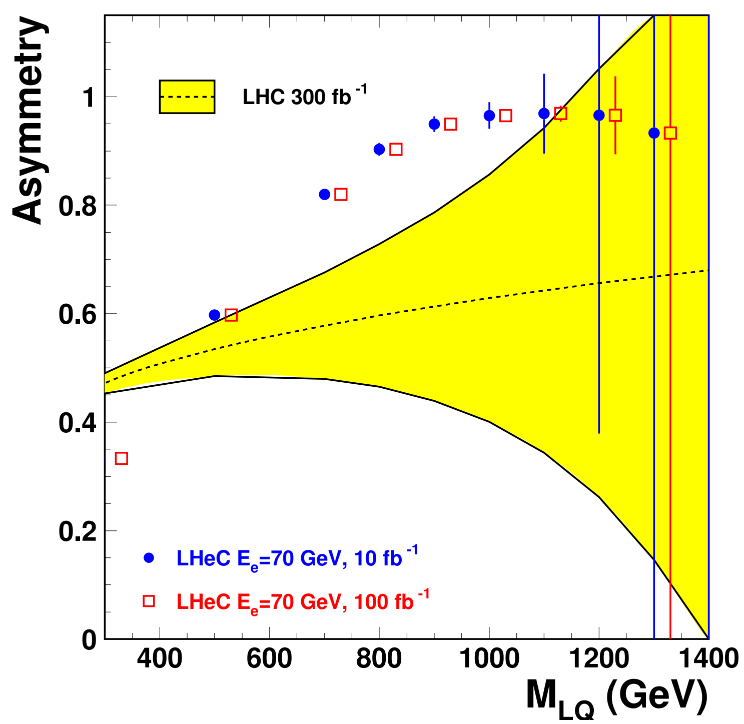


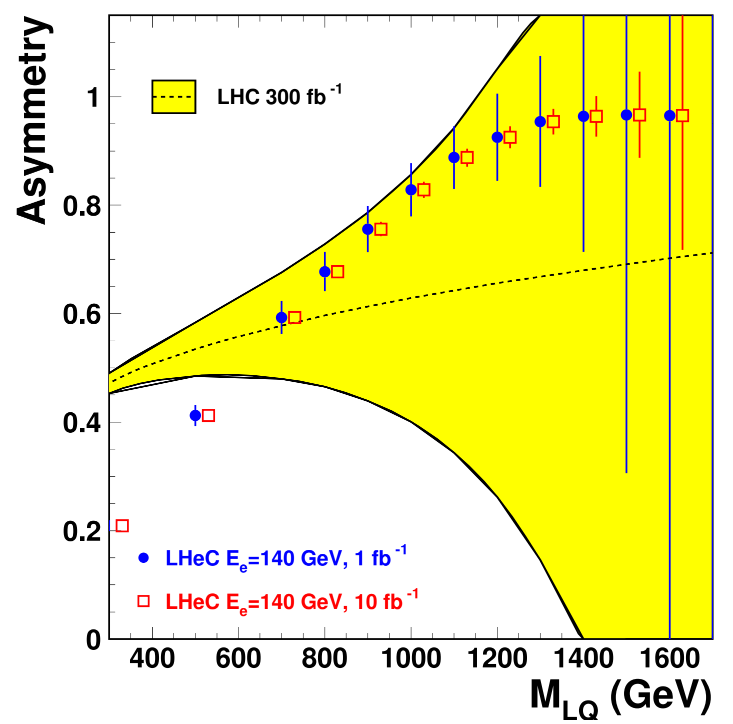
Leptoquark properties

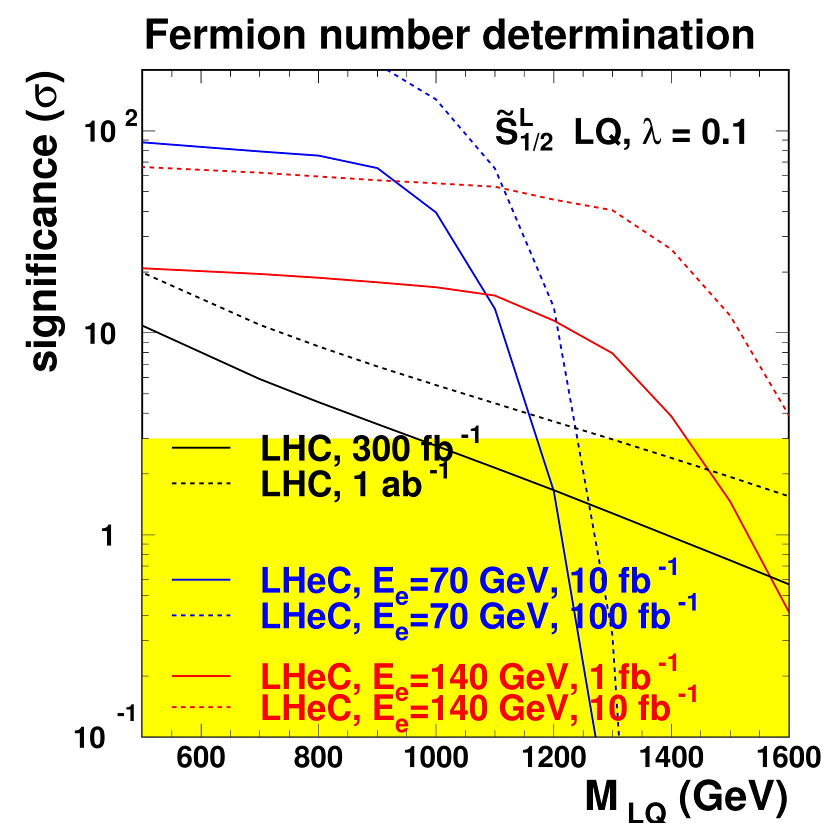
- Quantum numbers and couplings:
  - **F: fermion number can be obtained from asymmetry in single LQ production, since q have higher x than $\bar{q}$**

$$A = \frac{\sigma_{e^-} - \sigma_{e^+}}{\sigma_{e^-} + \sigma_{e^+}} \begin{cases} > 0 \text{ for F=2} \\ < 0 \text{ for F=0} \end{cases}$$



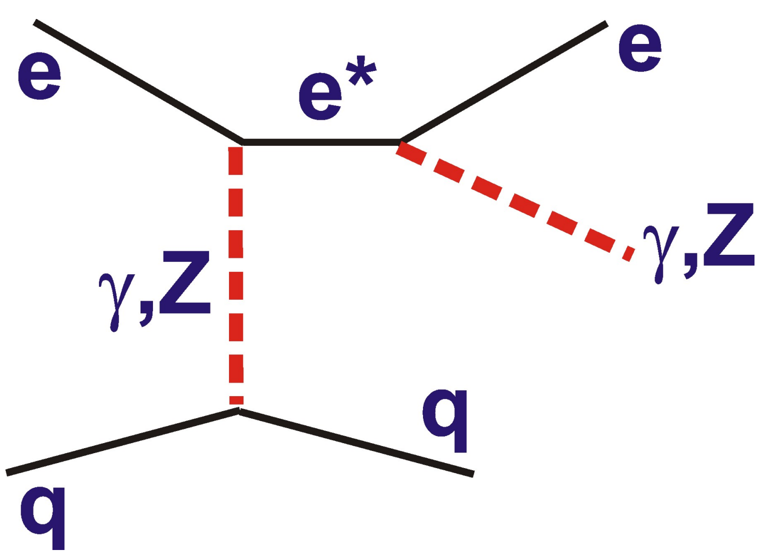


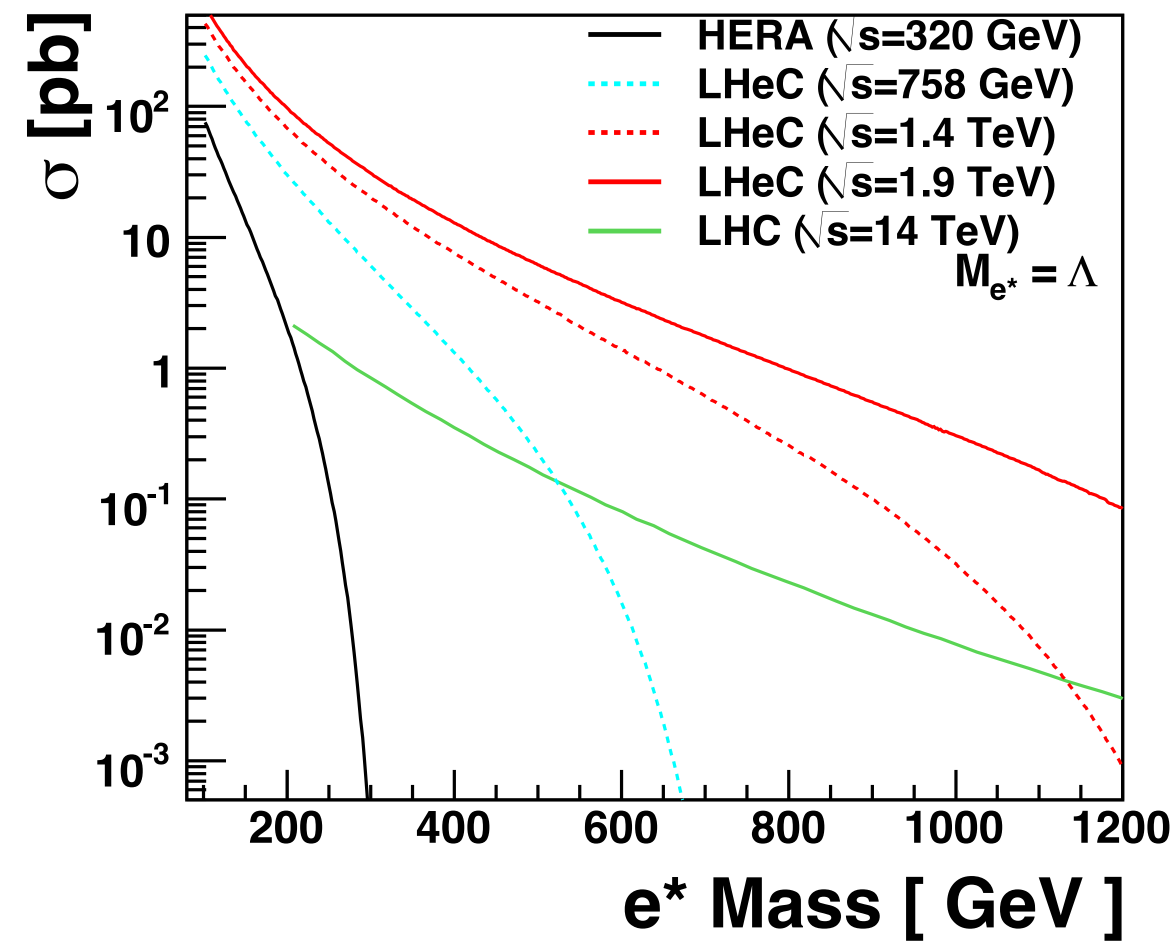


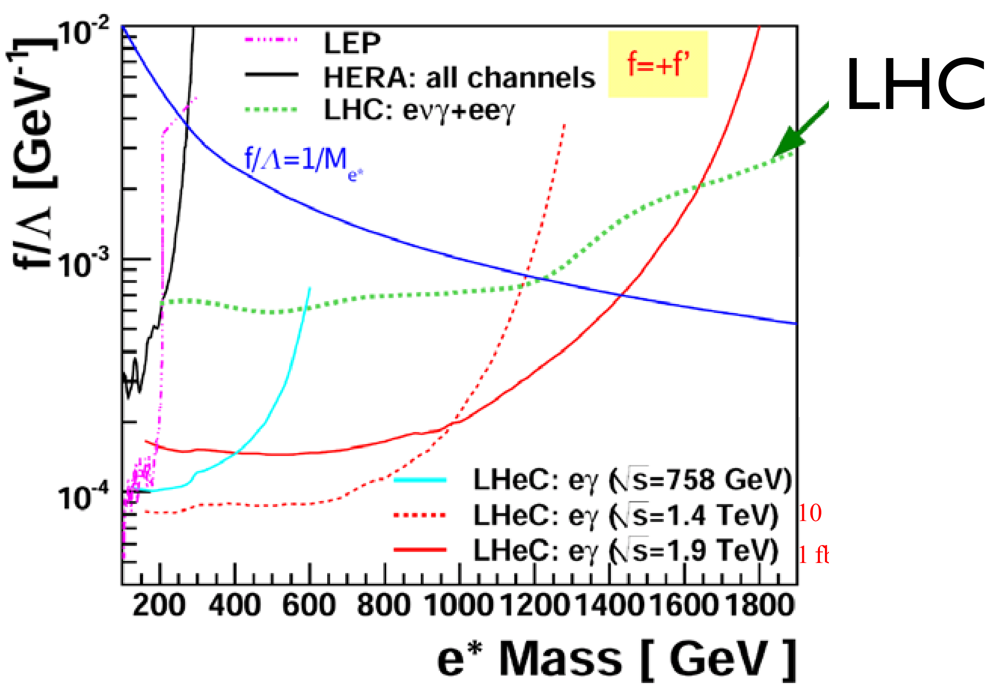


Excited leptons

Why 3 families ? Could be a sign of composite structure. Excited leptons could appear as sign of compositeness. Heavier leptons (4th family). Appear in GUTs and technicolor models.





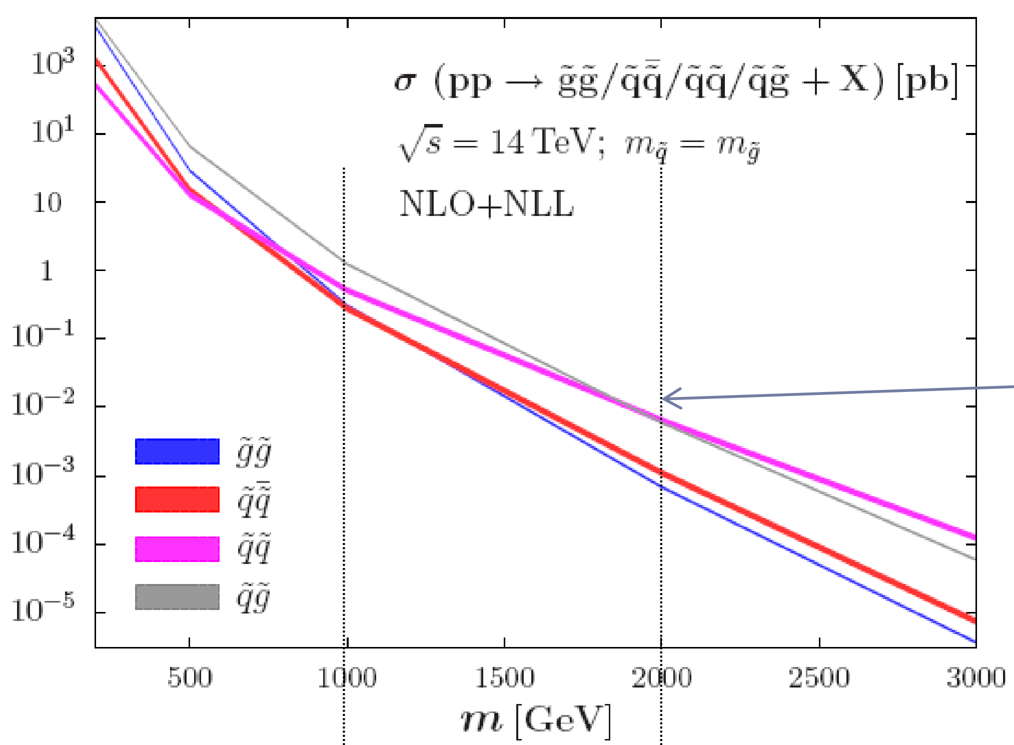


Monica d'Onofrio talk at Chavannes-de-Bogis

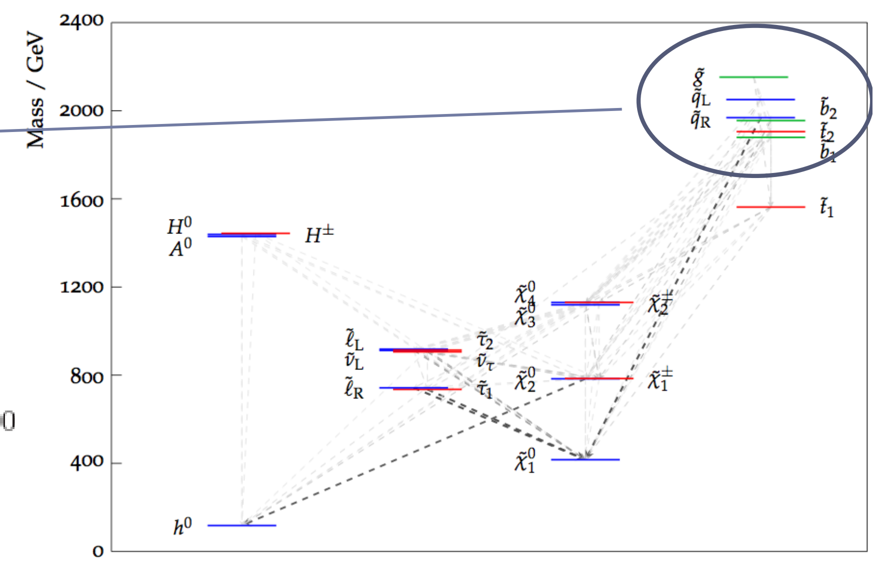
- **SUSY @ LHeC**
  - Possible searches in R-parity violation SUSY scenarios
  - complementarities with LHC:
    - Implication of LHC findings for LHeC reach
    - Implication of LHeC PDF constraints on SUSY for the LHC
    - New uncharted scenarios

Strong production

- xsection ~ 2.5 pb for m = 1000 GeV, ~ 0.01 pb for m(squark, gluino) = 2 TeV → clearly, high stats samples are needed.



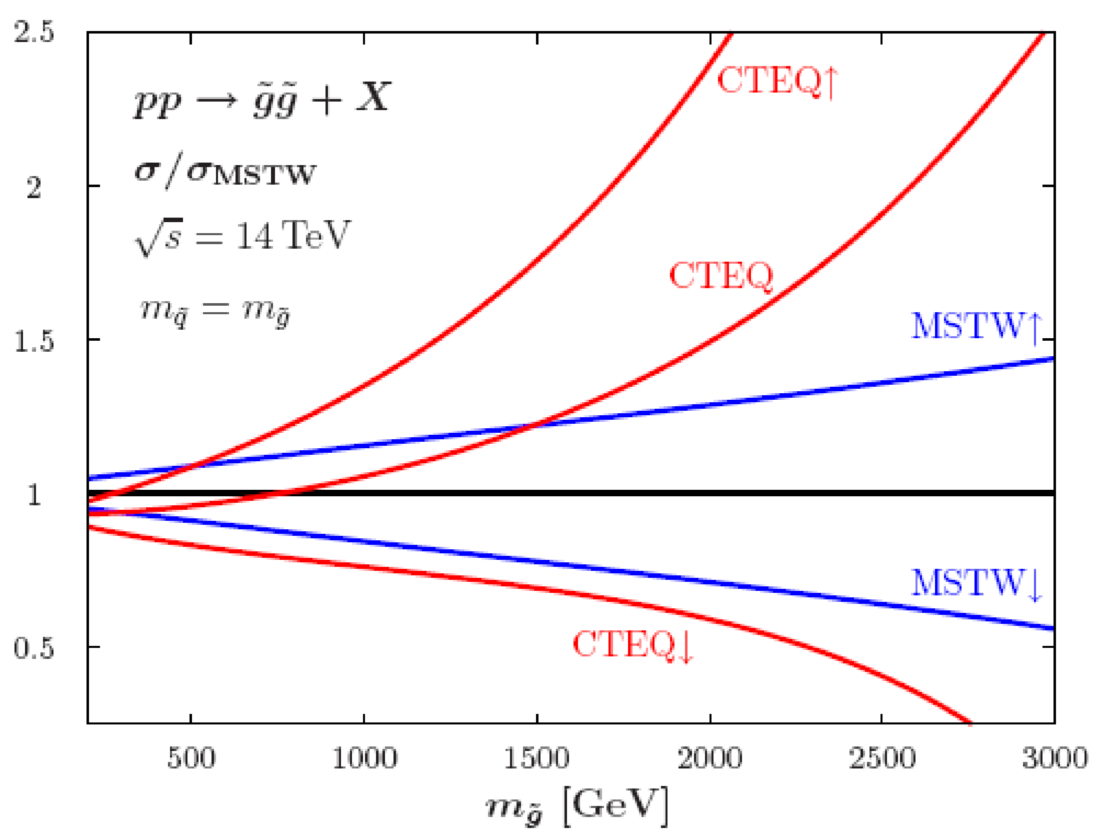
mSUGRA reference point:
m0=650, m1/2=975, xs 1.1E-05 nb

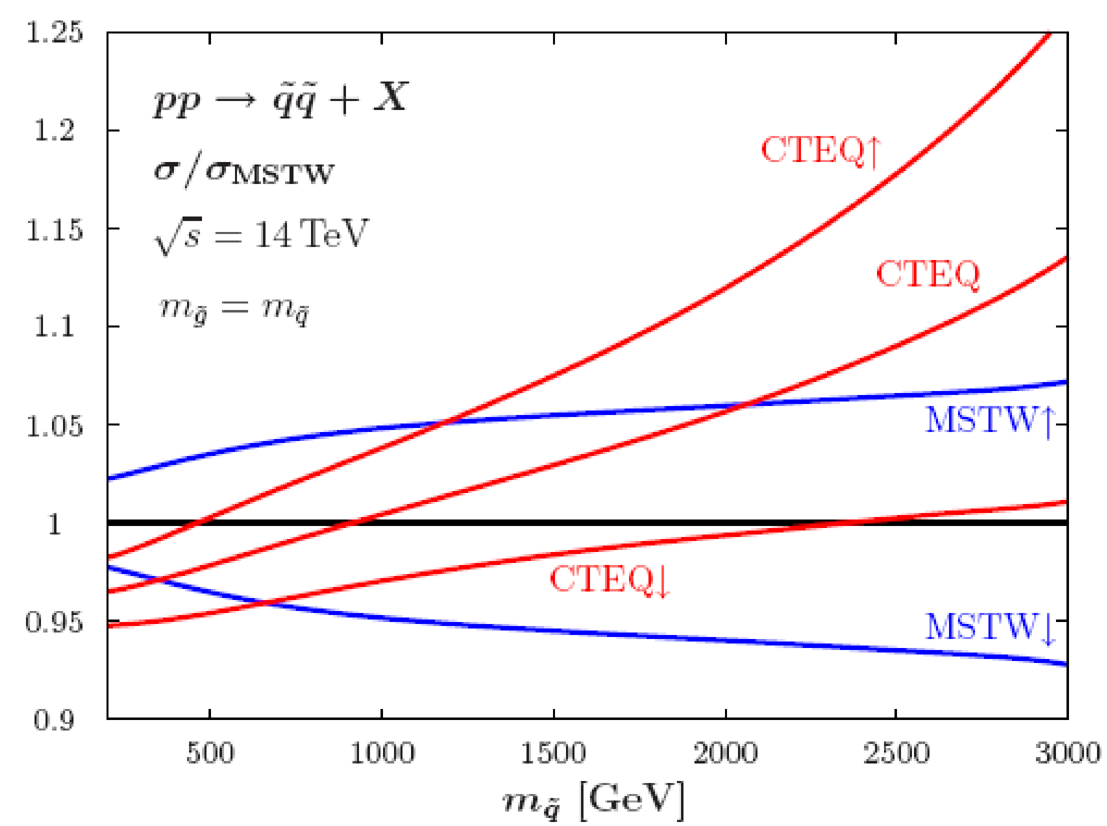


Decay chain might be complex, including Z or Higgs

Importance of PDF

- If we see deviations from SM, will be important to characterize the physics underneath
- The case of strong production:





→ driven by gluon pdf at large x

→ sizeable uncertainty $\approx \pm 25\%$ for $m \approx 1$ TeV

→ driven by valence quark pdfs at large x

→ small uncertainty $\approx \pm 5\%$ for $m \approx 1$ TeV