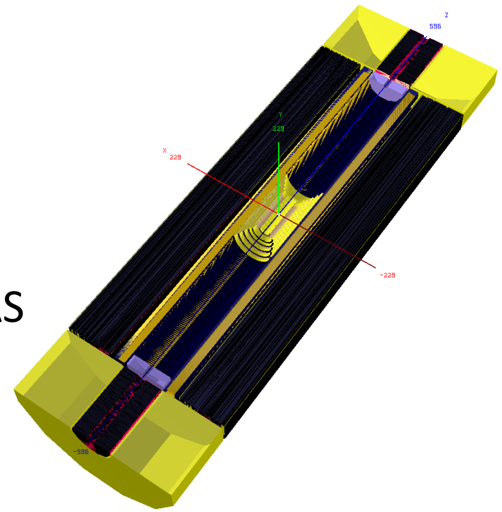
Physics [partons, xg, α_s, H] **with the LHeC**

accompanying slides to
blackboard presentation

Max Klein
University of Liverpool, ATLAS



http://cern.ch.lhec
LPCC March 2013

CDR LHeC (600p) arXiv:1206.2913 JPhysG
O.Brüning, MK arXiv:1305.2090 MPLA

Les Houches Workshop, June 9th , 2013

M.Froissart ICHEP (“Rochester”) 1966

THEORY

H.Murayama – ICFA11

FUNDAMENTAL THEORETICAL QUESTIONS

M. Froissart, Rapporteur

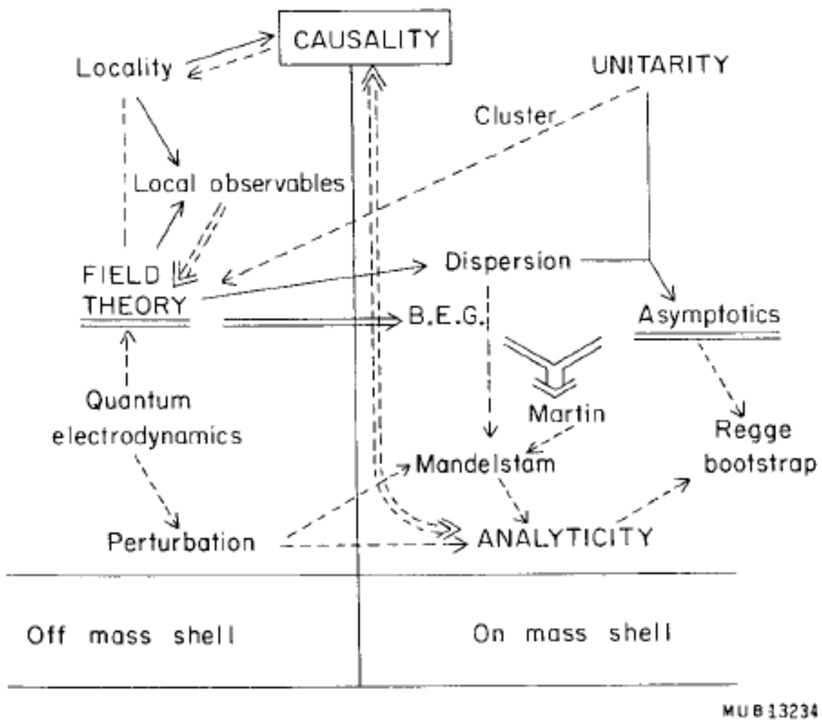
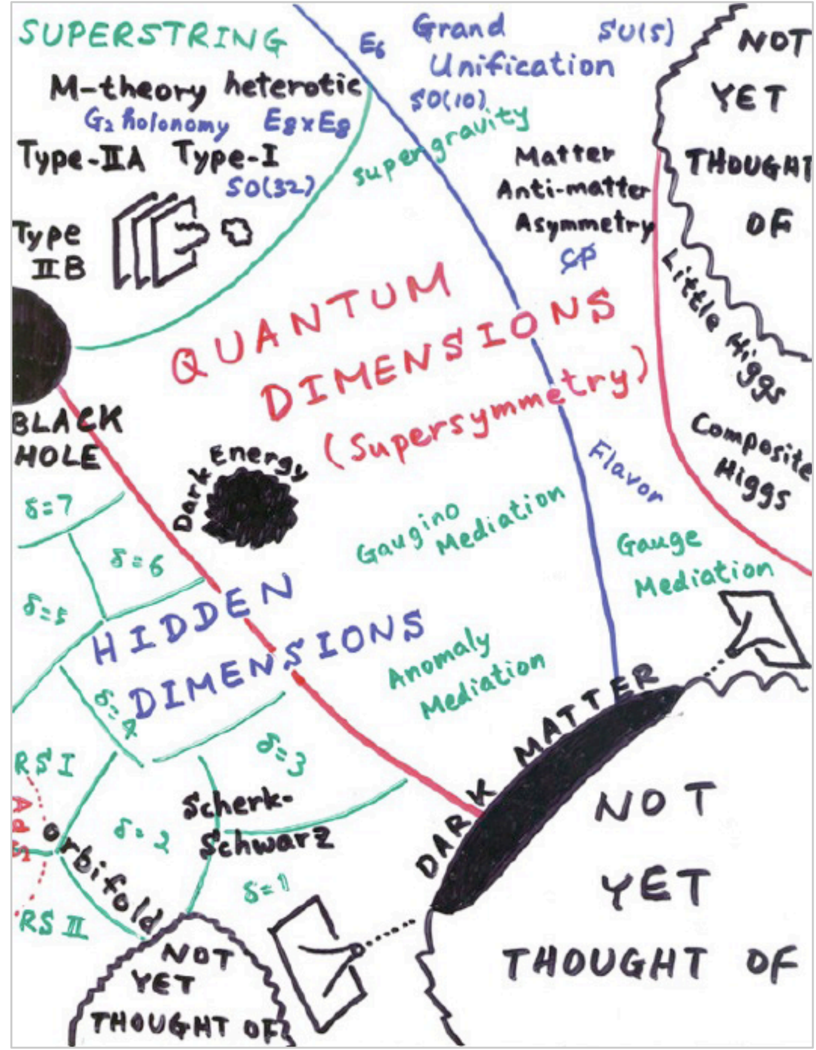


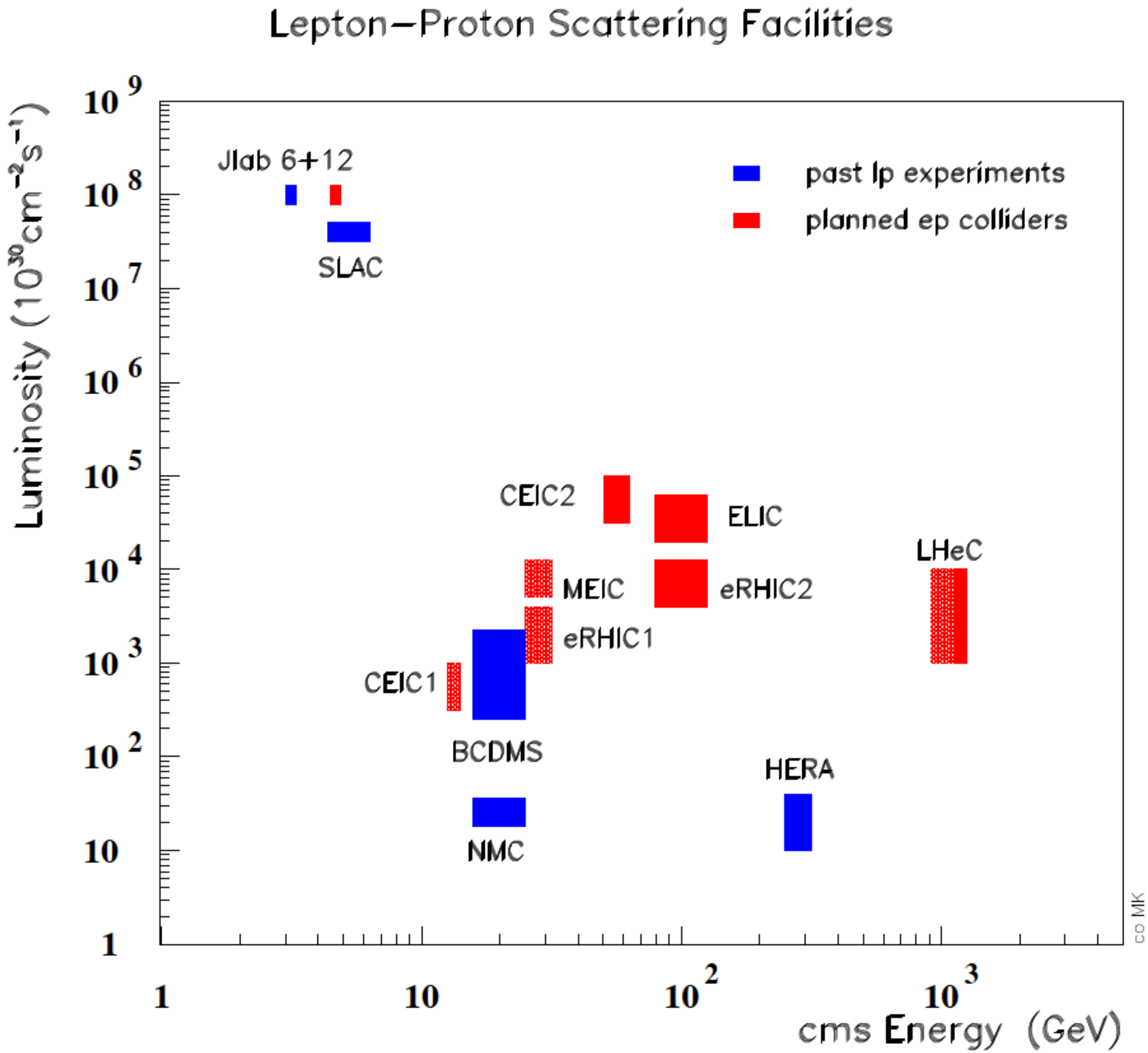
Fig. 1-1. Logical map of "Fundamental" concepts.



→ Quarks in 1969

→ ?in 2015+?

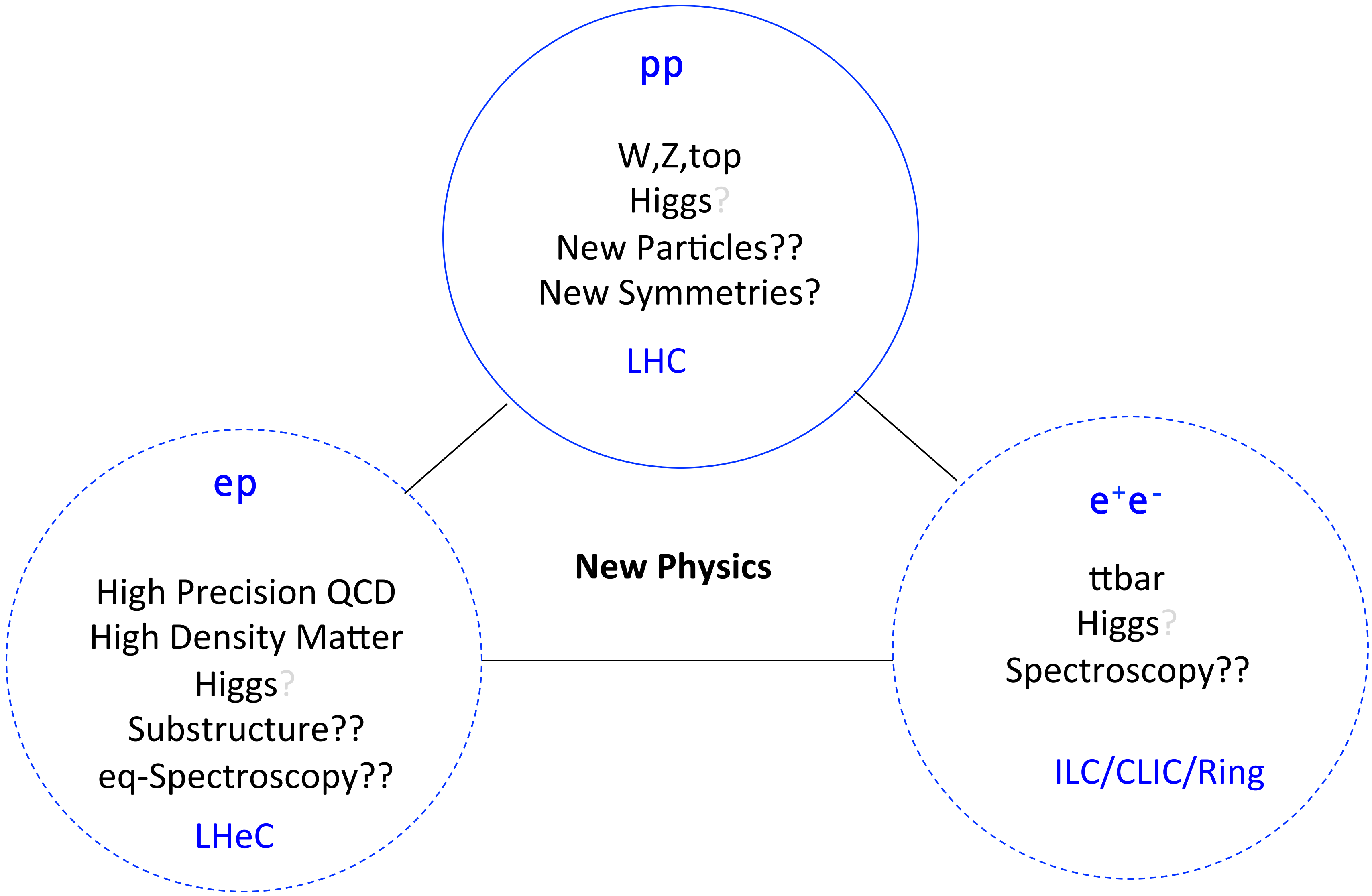
We like to see particle physics as driven by experiment … Burt Richter



Energy frontier deep inelastic scattering - following HERA with the LHC

LHeC: A new laboratory for particle physics, a 5th large LHC experiment

The TeV Scale [2012-2035..]



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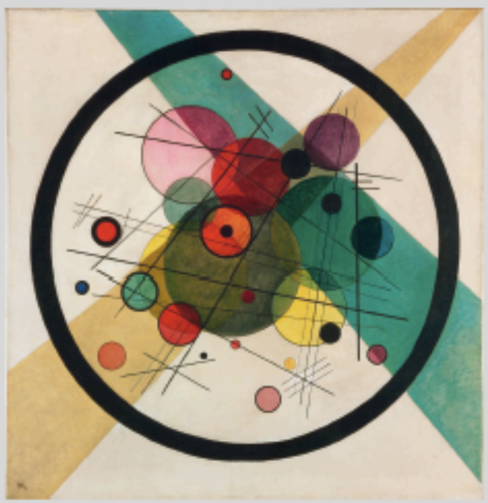
Nuclear and Particle Physics

Volume 39 Number 7 July 2012 Article 075001

A Large Hadron Electron Collider at CERN

Report on the Physics and Design Concepts for Machine and Detector

LHeC Study Group



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arXiv:1206.2913

arXiv:1211.4831 and 5102

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Published 600 pages conceptual design report (CDR) written by 150 authors from 60 Institutes. Reviewed by ECFA, NuPECC (long range plan), Referees invited by CERN. Published June 2012.

http://cern.ch/lhec

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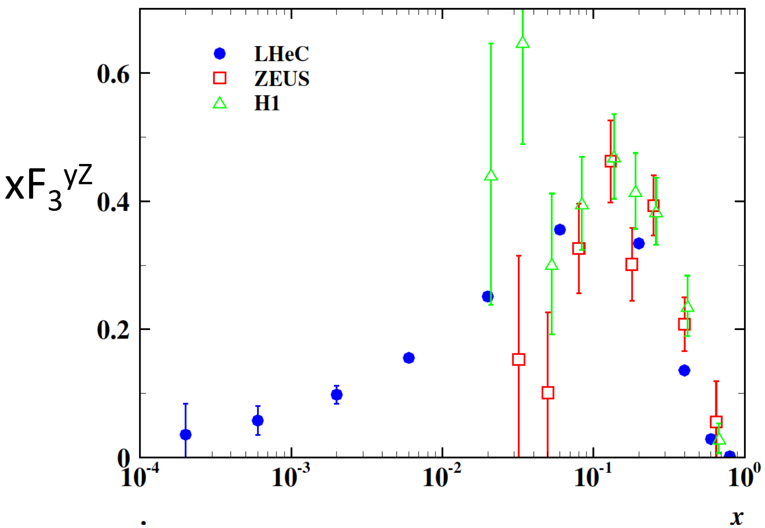
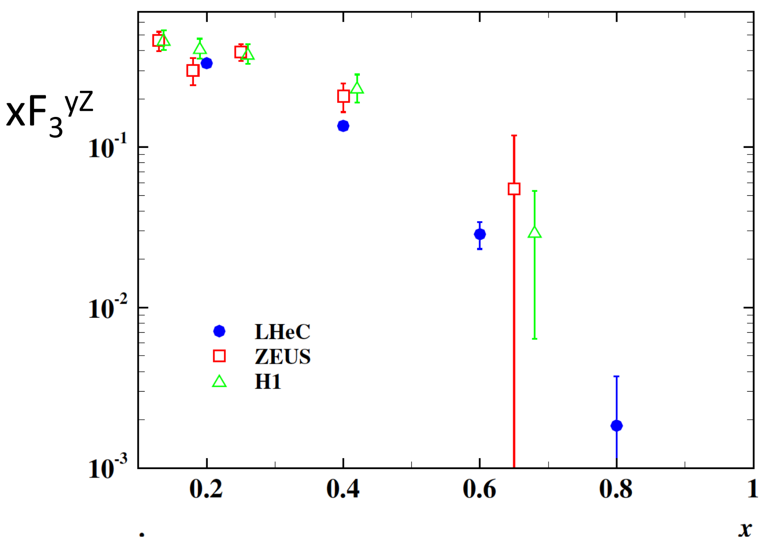
Present LHeC Study group and CDR authors

About 200 Experimentalists and Theorists from 76 Institutes

Supported by
CERN, ECFA, NuPECC

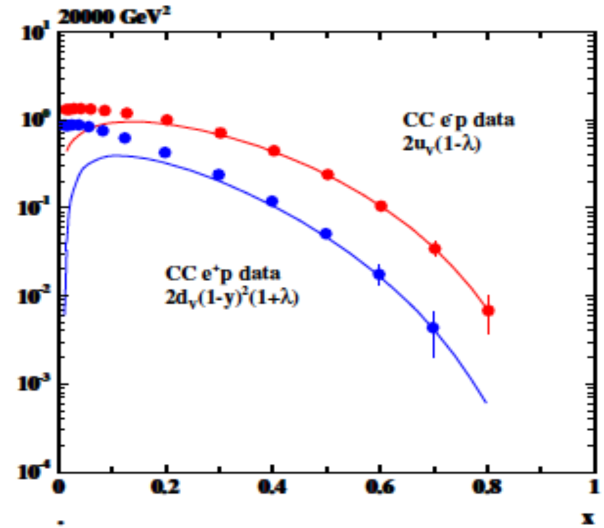
Primary measurements – simulated – high Q^2

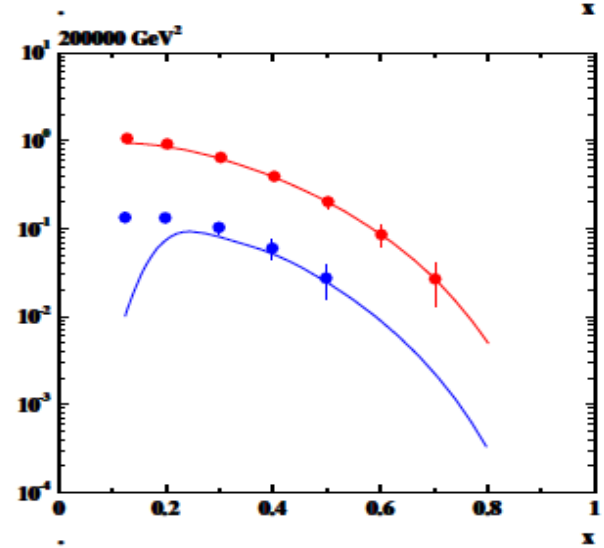




Precision electroweak measurements
PV with polarisation, $F_2^{b,Z}$, NC couplings..

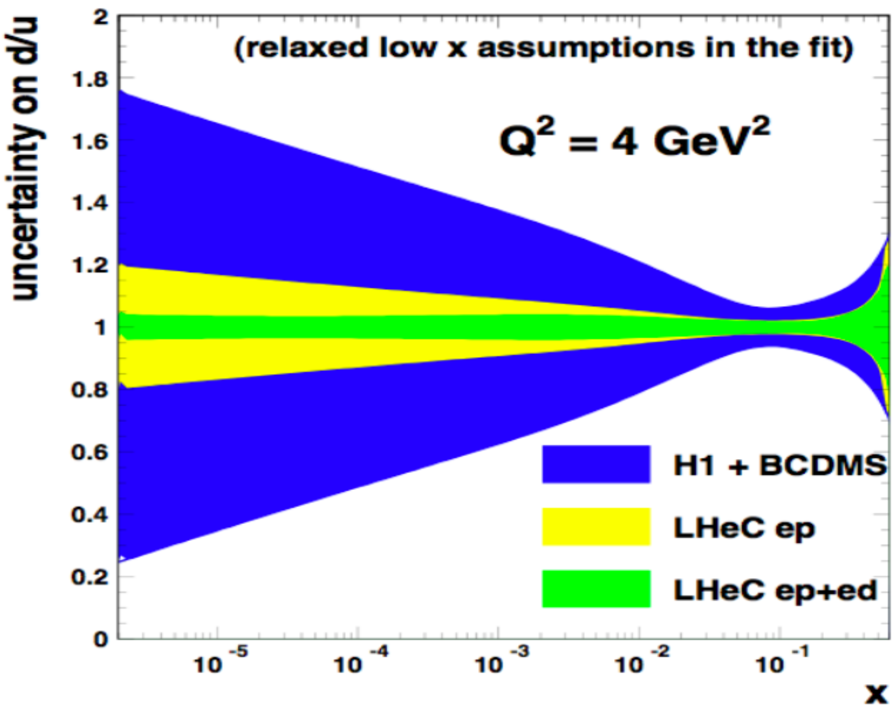
Precision CC measurements: top [10pb]
valence quarks, high x, V_{tb}, strange, ..





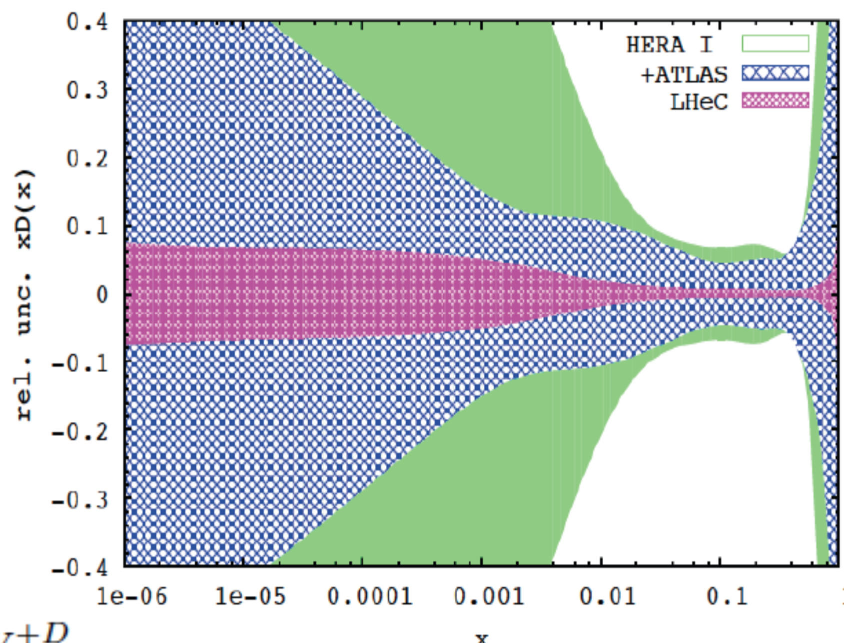
Deuterons and Light Sea Quark Asymmetry

d/u at low x from deuterons



D="total down" from LHeC (ep) fit with FREE d-u difference, including simulated high precision LHC W,Z

CDR



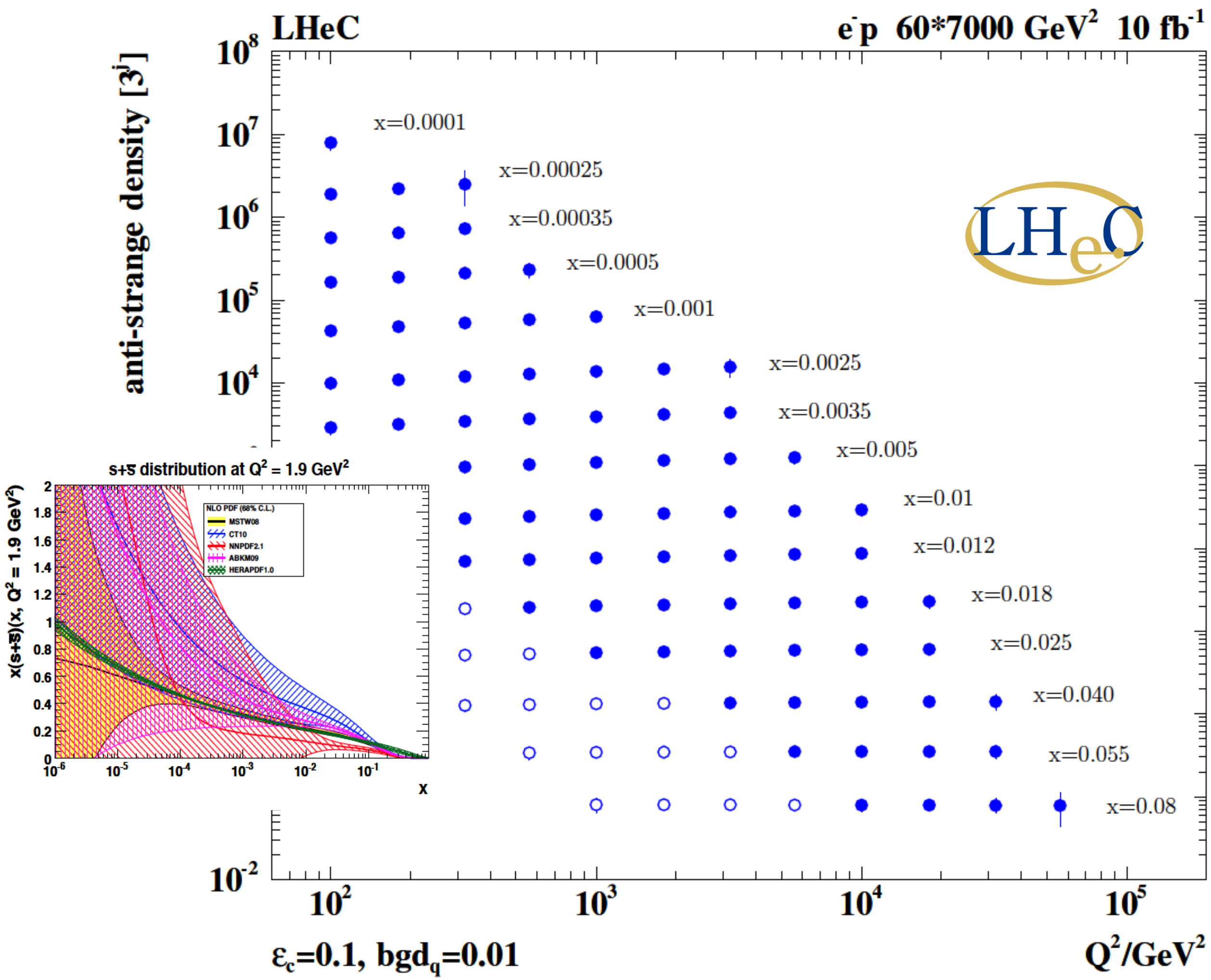
Deuterons: Crucial for

- NS-S decomposition
- Neutron structure
- Flavour separation

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

Nice: Gribov relation and spectator tagging to get rid off shadowing and Fermi motion!!

Strange Quark Distribution



High luminosity

High Q^2

Small beam spot

Modern Silicon

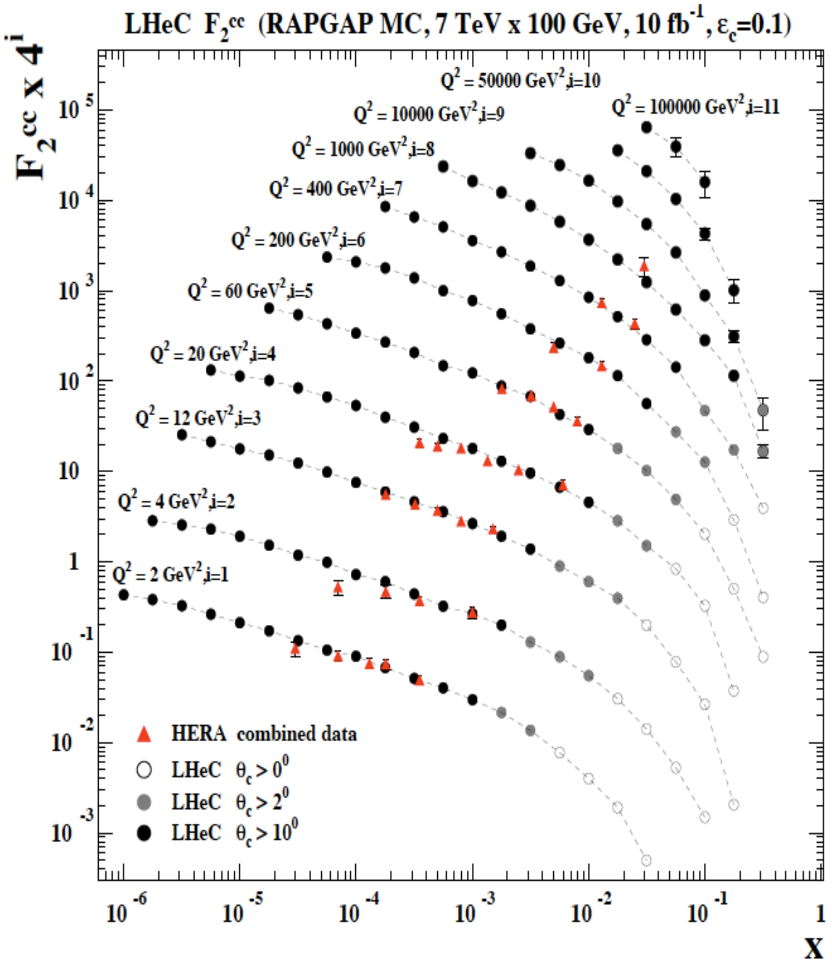
NO pile-up..

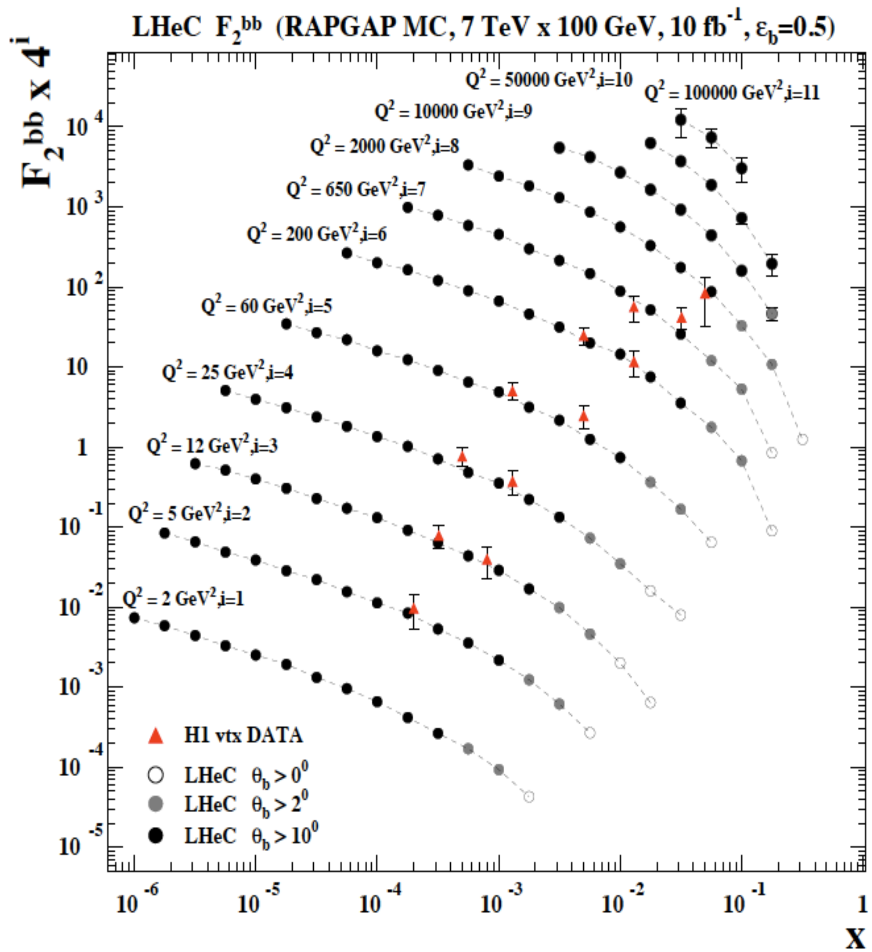
→ First (x,Q^2) measurement of the (anti-)strange density, HQ valence?

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

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

F_2^{charm} and F_2^{beauty} from LHeC



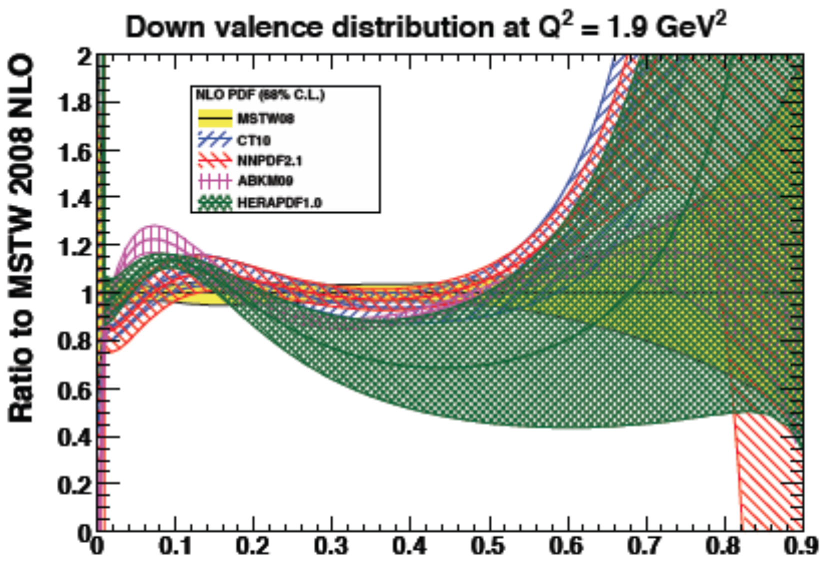


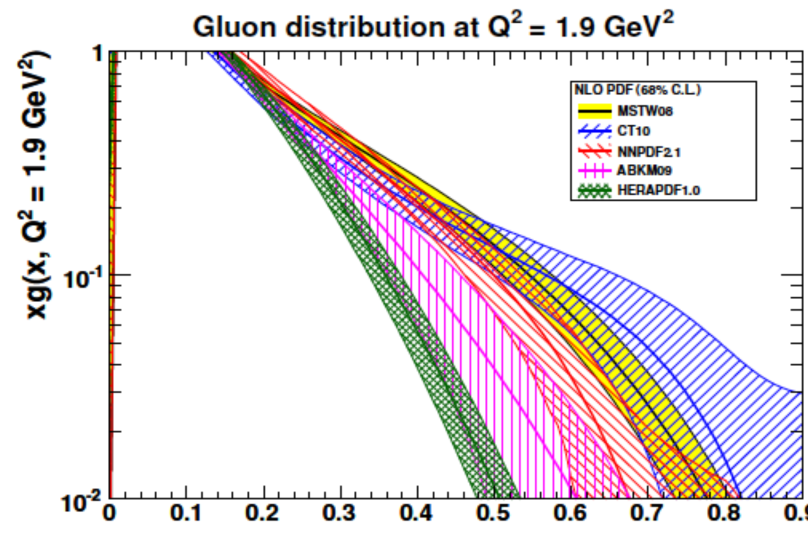
Hugely extended range and much improved precision (δM_c=60 HERA → 3 MeV)

will pin down heavy quark behaviour at and far away from thresholds, crucial for precision t,H..

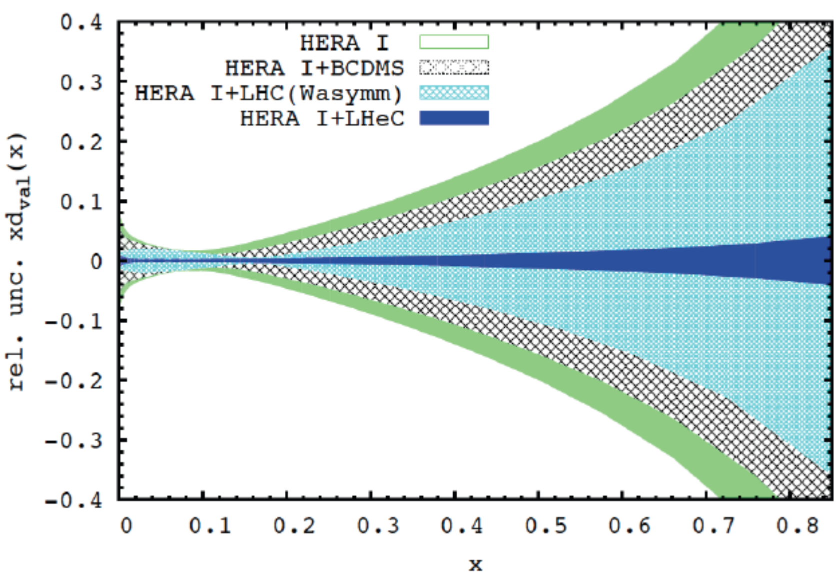
In MSSM, Higgs is produced dominantly via bb → H , but where is the MSSM..

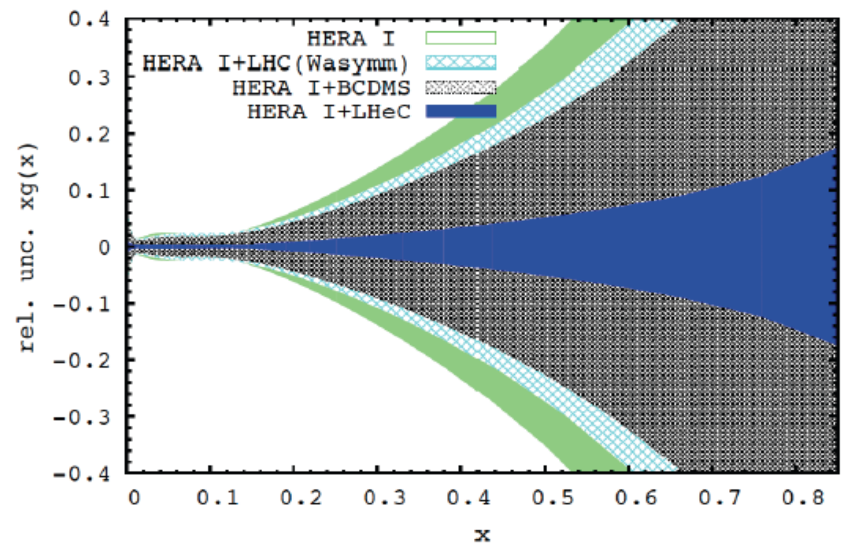
PDFs at Large x

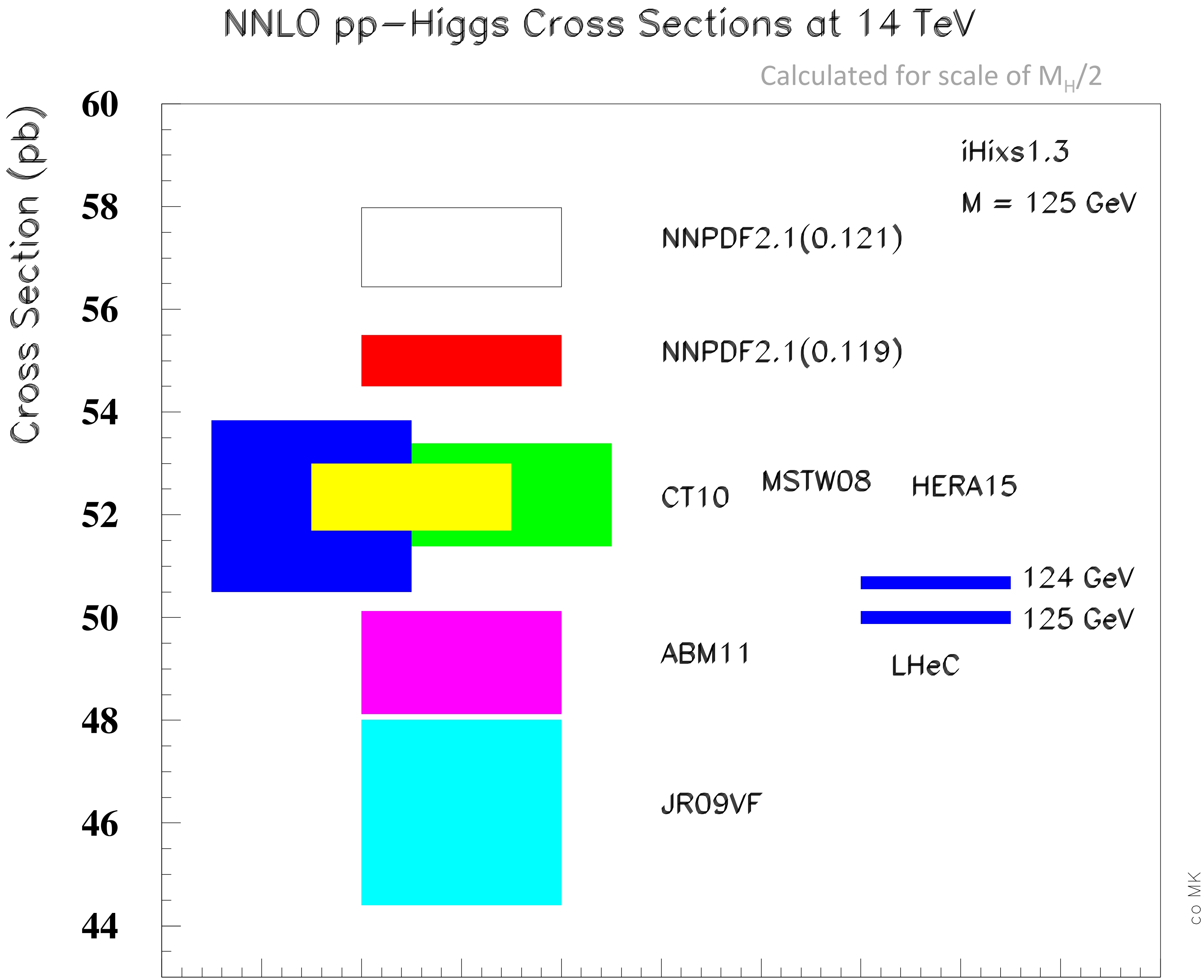




No higher twist corrections, free of nuclear uncertainties, high precision test of factorisation







Exp uncertainty of predicted H cross section is 0.25% (sys+sta), using LHeC only.

Leads to H mass sensitivity.

Strong coupling underlying parameter (0.005 – 10%). LHeC: 0.0002

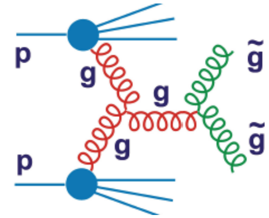
Needs N^{3}LO

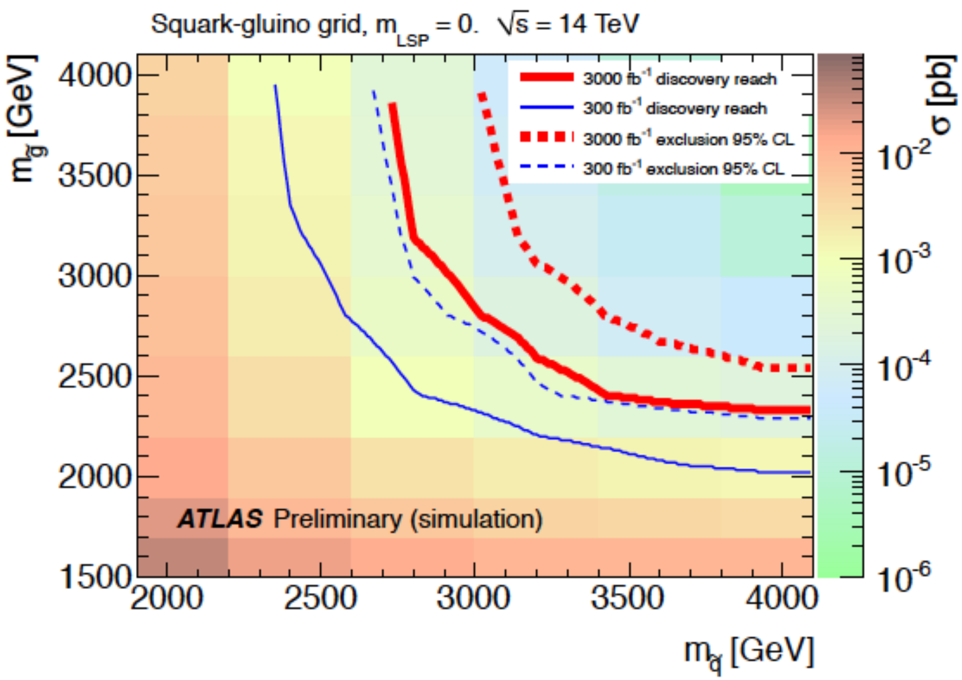
HQ treatment important

PRECISION σ(H)

Bandurin (ICHEP12) Higgs physics at the LHC is limited by the PDF knowledge

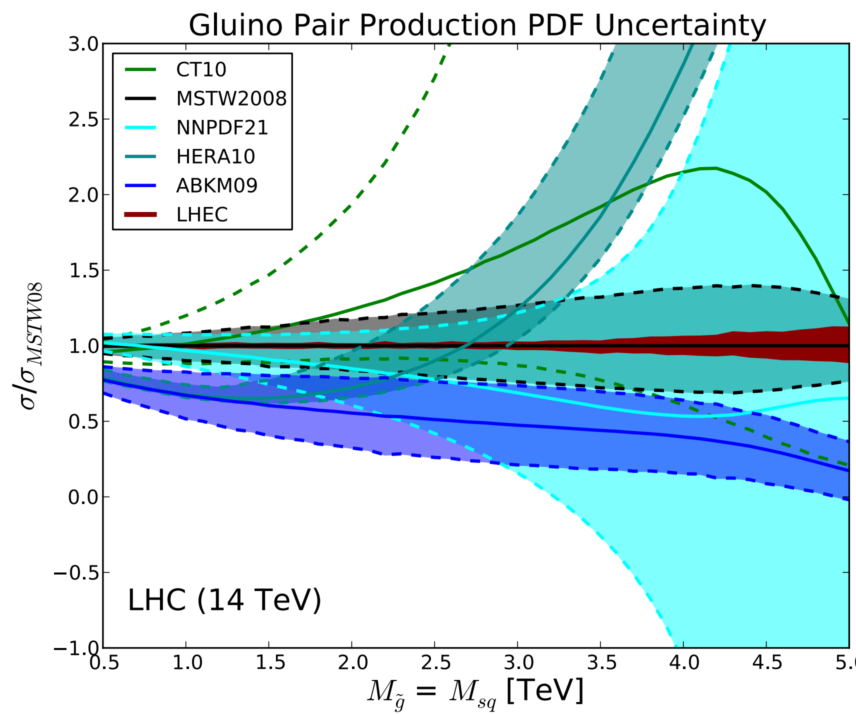
Link to HL LHC, e.g. High Mass SUSY





ATLAS October 2012 "Physics at High Luminosity"

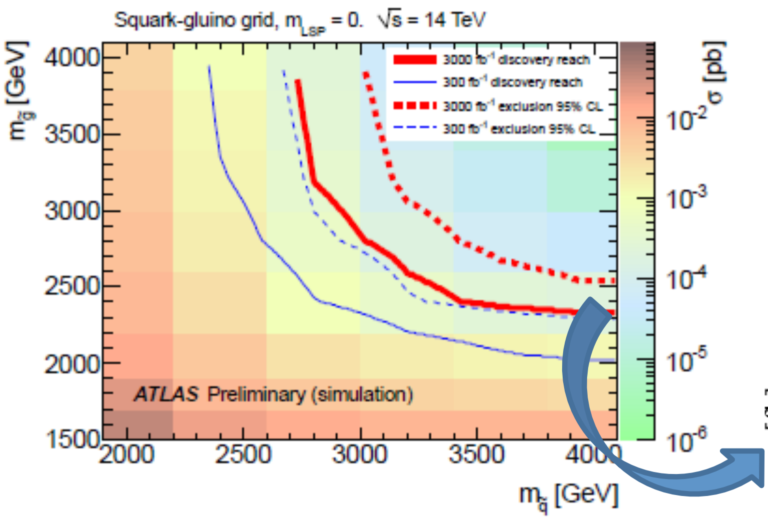
LHeC: arXiv:1211.5102



With high energy and luminosity, the LHC search range will be extended to high masses, up to 4-5 TeV in pair production, and PDF uncertainties come in ~ 1/(1-x), CI effects?

Impact on discovery/exclusion reach

- PDF uncertainties impact discovery / exclusion reach:
  - Total yields
  - Shape variations on discriminating quantities (in progress)

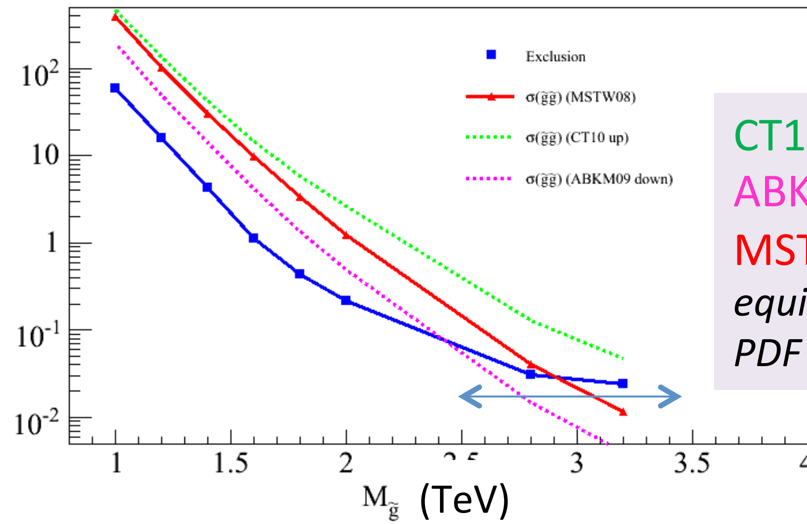


Caution: **very very** preliminary, mostly as illustration

(UL for gl-gl courtesy of G.Redlinger)

Impact on discovery/exclusion contours under various PDF hypothesis in progress

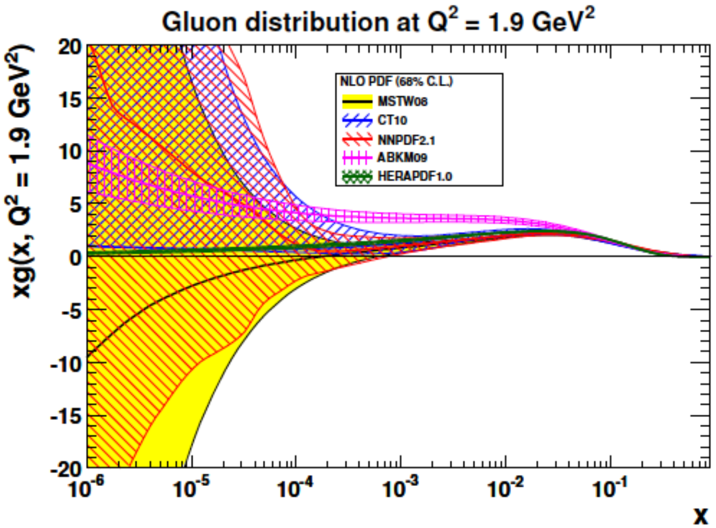
LHC @ 14 TeV 3 ab-1, M(squark) > 4 TeV

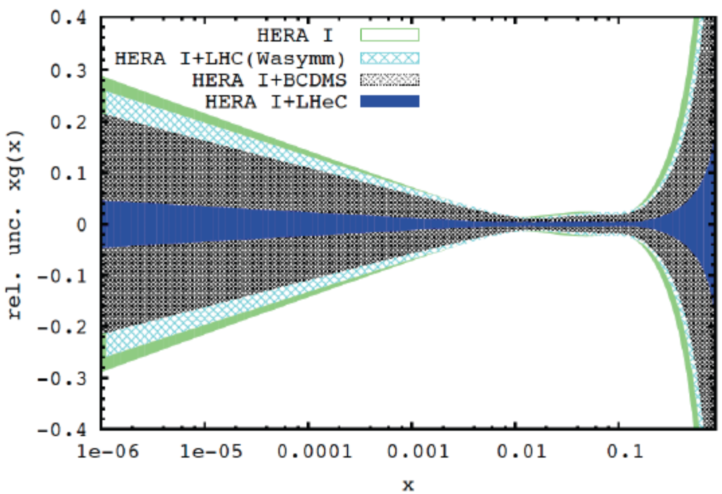


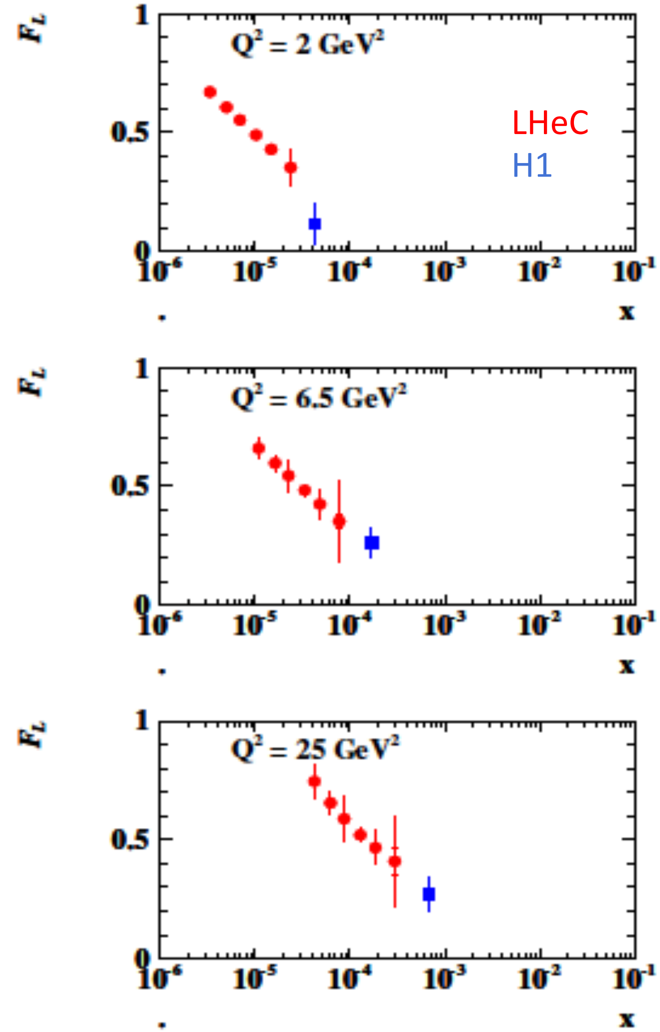
CT10 up
ABKM09 down
MSTW08
equivalent to LHeC PDF

Note: impact of PDF uncertainties on SM background also not negligible
However → mitigated by usage of Control Regions and semi data-driven estimate

Gluon Saturation at Low x?





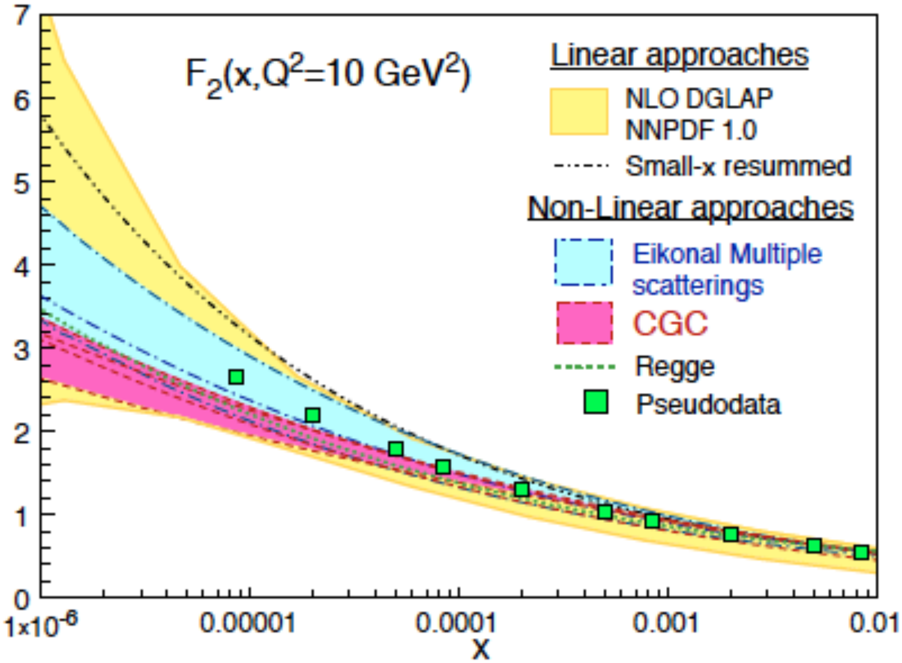


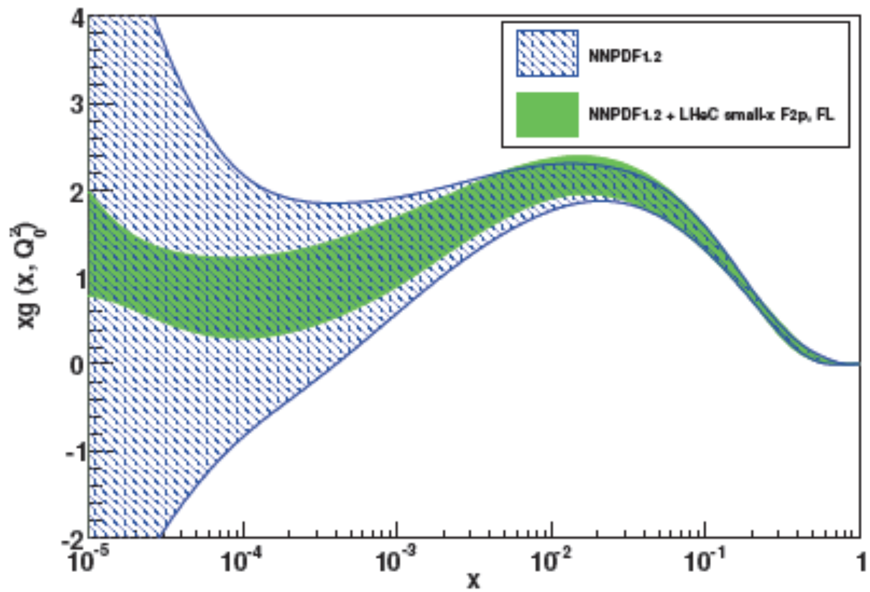
Gluon measurement down to x=10^{-5}, **Saturation or no saturation** (F_2 and precise F_L)
Non-linear evolution equations? Relations to string theory, and **SUSY at ~10 TeV**?

cf H.Kowalski, L.Lipatov, D.Ross, arXiv:1205.6713

Partons at low x

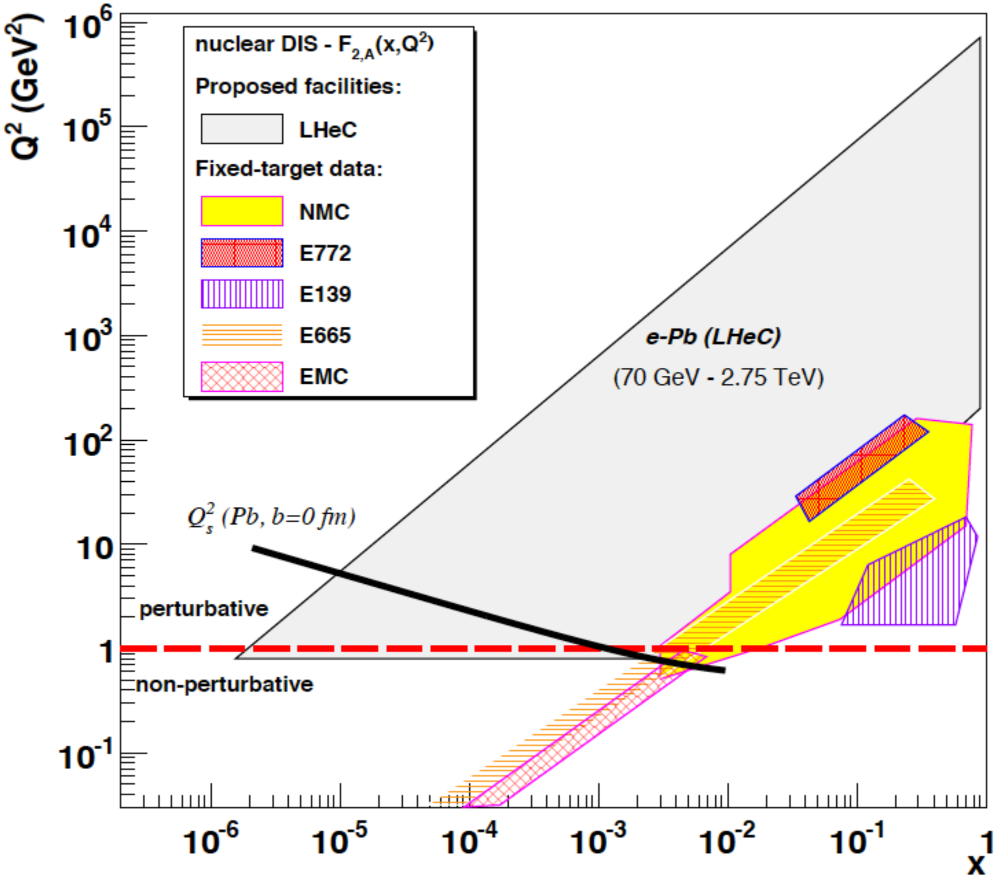
Studies within NNPDF (CDR 8/12)

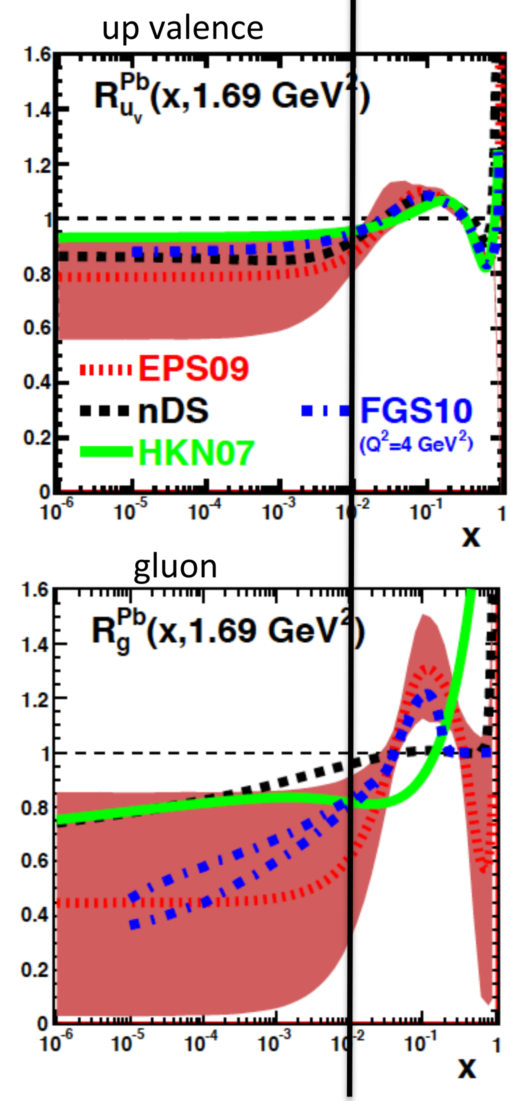




High precision F_2 and F_L pin down low x phenomenology and determine the gluon distribution down to x~10^{-5}

Nuclear Parton Distributions





eA physics is essentially not done yet (no eA at HERA!)
→ LHeC has huge discovery potential for new HI physics
(bb limit, saturation, deconfinement, hadronisation,QGP..)
and will put nPDFs on completely new ground

unmeasured | known?

eRHIC/EIC would be an important step beyond fixed targets..

The strong coupling constant

	$\alpha_s(M_Z)$	
BBG	$0.1134 \begin{smallmatrix} +0.0019 \\ -0.0021 \end{smallmatrix}$	valence analysis, NNLO [235, 236]
BB	0.1132 ± 0.0022	valence analysis, NNLO [237]
GRS	0.112	valence analysis, NNLO [238]
ABKM	0.1135 ± 0.0014	HQ: FFNS $n_f = 3$ [228]
ABKM	0.1129 ± 0.0014	HQ: BSMN-approach [228]
JR	0.1124 ± 0.0020	dynamical approach [231]
JR	0.1158 ± 0.0035	standard fit [231]
ABM11	0.1134 ± 0.0011	[229]
MSTW	0.1171 ± 0.0014	[239]
NN21	0.1173 ± 0.0007	[233]
CT10	0.118 ± 0.005	[240]
Gehrmann et al.	$0.1153 \pm 0.0017 \pm 0.0023$	e^+e^- thrust [241]
Abbate et al.	$0.1135 \pm 0.0011 \pm 0.0006$	e^+e^- thrust [242]
3 jet rate	0.1175 ± 0.0025	Dissertori et al. 2009 [243]
Z-decay	0.1189 ± 0.0026	BCK 2008/12 (N^3LO) [121, 244]
τ decay	0.1212 ± 0.0019	BCK 2008 [244]
τ decay	0.1204 ± 0.0016	Pich 2011 [20]
τ decay	0.1180 ± 0.0008	Beneke, Jamin 2008 [245]
lattice	0.1205 ± 0.0010	PACS-CS 2009 (2+1 fl.) [246]
lattice	0.1184 ± 0.0006	HPQCD 2010 [247]
lattice	0.1200 ± 0.0014	ETM 2012 (2+1+1 fl.) [248]
BBG	$0.1141 \begin{smallmatrix} +0.0020 \\ -0.0022 \end{smallmatrix}$	valence analysis, $N^3LO(*)$ [235]
BB	0.1137 ± 0.0022	valence analysis, $N^3LO(*)$ [237]
world average	0.1184 ± 0.0007	[249] (2009)
	0.1183 ± 0.0010	[20] (2011)

α_s is the worst measured fundamental coupling constant. Is there grand unification?

In DIS, values (NNLO) range from 0.113 to 0.118.

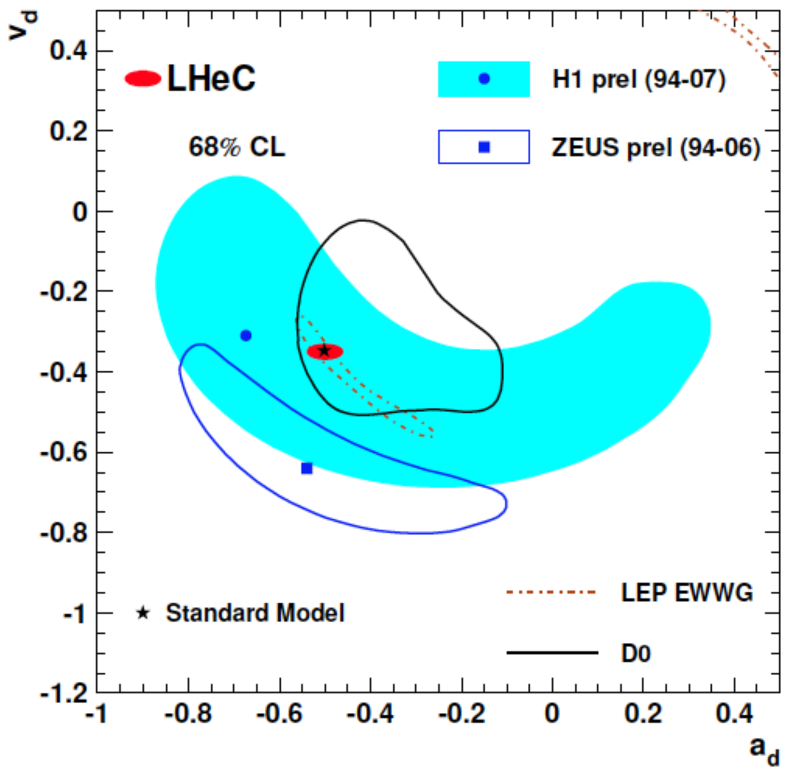
τ leads to about 0.120

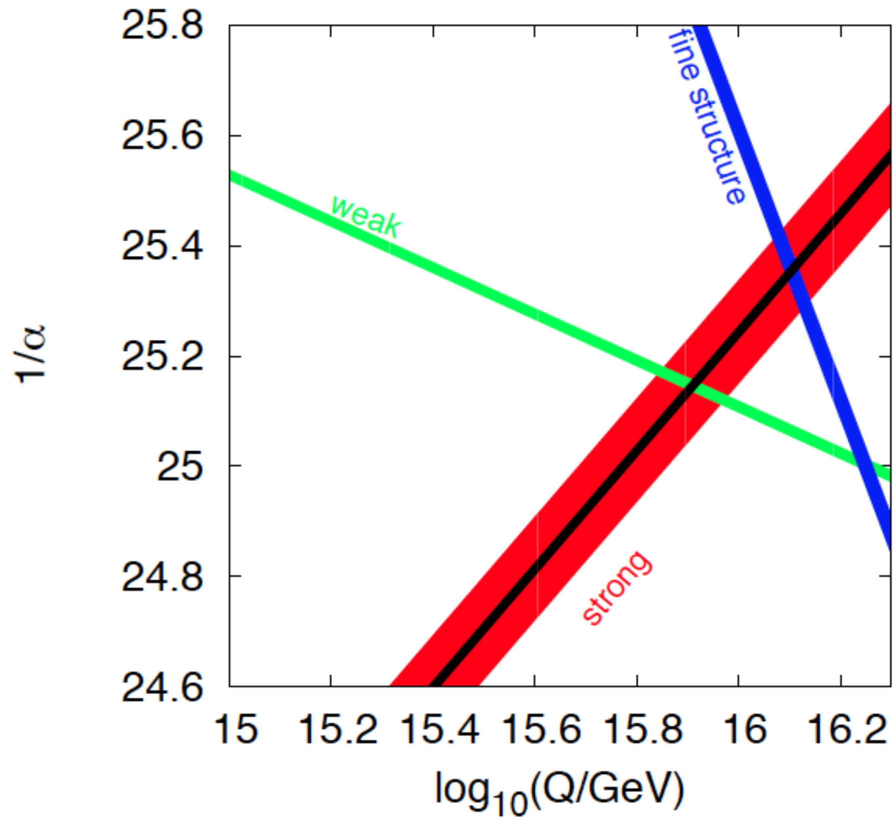
Lattice predictions seem to determine the world average.

The LHeC has the potential to measure αs to permille accuracy (0.0002) from a consistent data set. This leads to high precision understanding of all related effects (low x, δM_c=3MeV) and pQCD at N^3LO

J.Bluemlein, Why Precision, arXiv:1205.4991

High Precision DIS





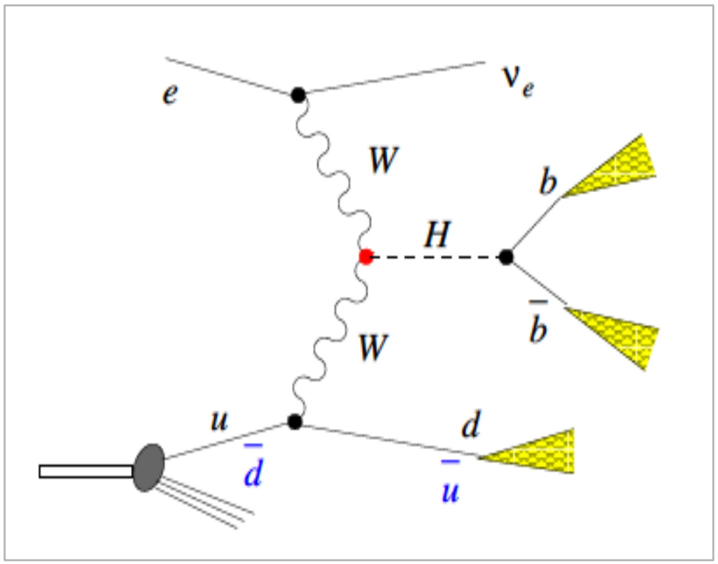
$Q^2 \gg M_{Z,W}^2$, high luminosity, large acceptance
Unprecedented precision in NC and CC
Contact interactions probed to 50 TeV
Scale dependence of $\sin^2\theta$ left and right to LEP

→ A renaissance of deep inelastic scattering ←

Solving a 30 year old puzzle:
α_s small in DIS or high with jets?
Per mille measurement accuracy
Testing QCD lattice calculations
Constraining GUT (CMSSM40.2.5)
Charm mass to 3MeV, N^3LO

Higgs at the LHeC

Clean final state, no pile-up, low QCD bgd, uniquely WW and ZZ, small theory unc.ties



Default

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

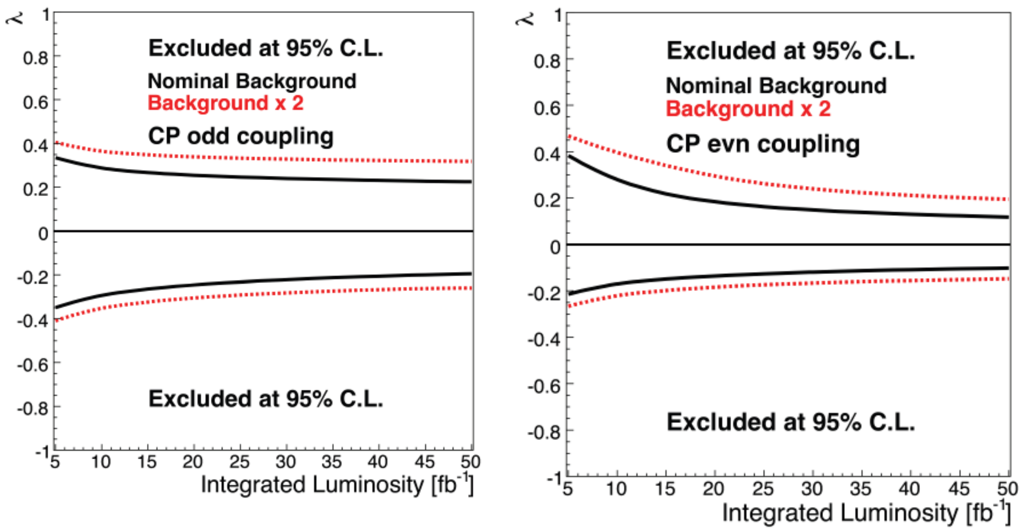
U. Klein, ICHEP12, Melbourne for the LHeC

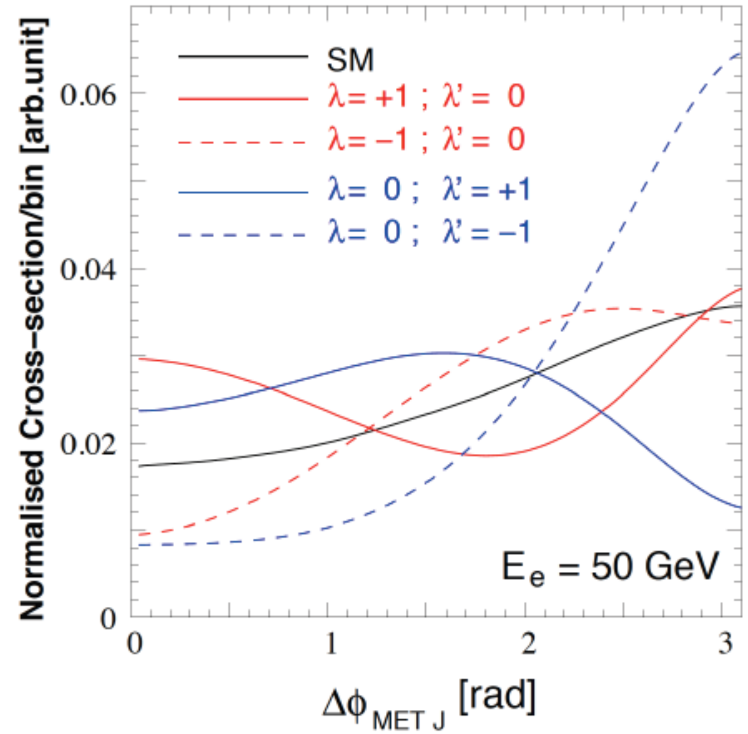
Full simulation of ep → nu H X → nu bbar X: reconstruction efficiency of 2.5%

With **polarised** electrons, 100fb^{-1} - bb coupling measurement precision of 2-3%.

CP Higgs at the LHeC

In the SM the Higgs is a $J^{PC}=0^{++}$ state. One needs to measure the EV if CP is conserved, and the mixture of even and odd states if it is not.





λ (λ') anomalous CP (non) conserving terms

$$\mathcal{L}_{\text{int}} = -gM_W \left(W_\mu W^\mu + \frac{1}{2\cos\theta_W} Z_\mu Z^\mu \right) H$$

$$\Gamma^{\mu\nu}_{(\text{SM})}(p,q) = \; -gM_W \, g^{\mu\nu}$$

$$\Gamma^{\text{BSM}}_{\mu\nu}(p,q) = \frac{g}{M_W} \left[\lambda \left(p \cdot q \, g_{\mu\nu} - p_\nu q_\mu \right) + i \, \lambda' \, \epsilon_{\mu\nu\rho\sigma} p^\rho q^\sigma \right]$$

S.Biswal et al, PhysRevLett.109.261801

CP Properties

The behaviour very similar to that seen for pp. So the disribution can look at CP property of the Higgs cleanly.

This behaviour essentially follows from the behaviour of matrix element square.

In LHC studies, the modification in the ϕ distribution (dips and peaks) were used with VBF specific cuts. We see that the structure is there even w/out those cuts.

Further no ambiguity about sign of ϕ.

At LHeC the entire range of ϕ is available.

B.Mellado at LPCC 3/13

LHeC at 10^{34} Luminosity

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	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	
CM energy [TeV]	1300, 810	
luminosity / nucleon [10^{33} cm^{-2}s^{-1}]	1 (10), 0.2	

Table 1: LHeC ep and eA collider parameters. The numbers give the default CDR values, with optimum values for maximum ep luminosity in parentheses and values for the ePb configuration separated by a comma.

LHeC Collaboration arXiv:1211:5102, see also O.Bruening and M.Klein arXiv:1305.2090

LHeC Higgs Rates

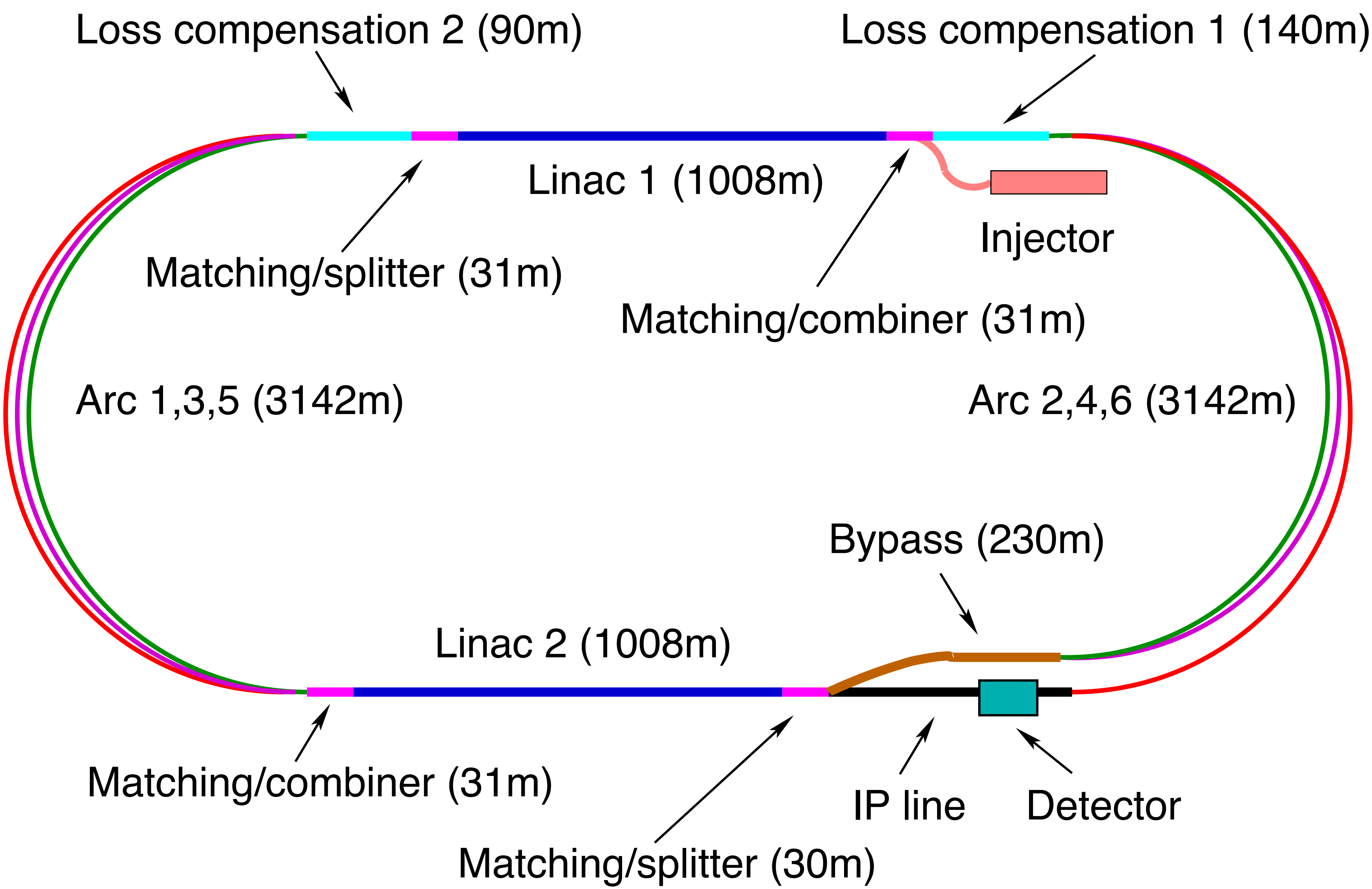
LHeC Higgs		CC (e^-p)	NC (e^-p)	CC (e^+p)
Polarisation		-0.8	-0.8	0
Luminosity [ab^{-1}]		1	1	0.1
Cross Section [fb]		196	25	58
Decay	BrFraction	N^H_{CC} e^-p	N^H_{NC} e^-p	N^H_{CC} e^+p
$H \to b\bar{b}$	0.577	113 100	13 900	3 350
$H \to c\bar{c}$	0.029	5 700	700	170
$H \to \tau^+\tau^-$	0.063	12 350	1 600	370
$H \to \mu\mu$	0.00022	50	5	–
$H \to 4l$	0.00013	30	3	–
$H \to 2l2\nu$	0.0106	2 080	250	60
$H \to gg$	0.086	16 850	2 050	500
$H \to WW$	0.215	42 100	5 150	1 250
$H \to ZZ$	0.0264	5 200	600	150
$H \to \gamma\gamma$	0.00228	450	60	15
$H \to Z\gamma$	0.00154	300	40	10

Summary of LHeC Physics [arXiv:1211:4831+5102]

The LHeC represents a new laboratory for exploring a hugely extended region of phase space with an unprecedented high luminosity in high energy DIS. It builds the link to the LHC and a future pure lepton collider, similar to the complementarity between HERA and the Tevatron and LEP, yet with much higher precision in an extended energy range. Its physics is fundamentally new, and it also is complementary especially to the LHC, for which the electron beam is an upgrade. Given the broad range of physics questions, there are various ways to classify these, partially overlapping. An attempt for a schematic overview on the LHeC physics programme as seen from today is presented in Tab. 3. The conquest of new regions of phase space and intensity has often lead to surprises, which tend to be difficult to tabulate.

QCD Discoveries	$\alpha_s < 0.12$, $q_{sea} \neq \overline{q}$, instanton, odderon, low x: (n0) saturation, $\overline{u} \neq \overline{d}$
Higgs	WW and ZZ production, $H \rightarrow b\overline{b}$, $H \rightarrow 4l$, CP eigenstate
Substructure	electromagnetic quark radius, e^*, ν^*, W?, Z?, top?, H?
New and BSM Physics	leptoquarks, RPV SUSY, Higgs CP, contact interactions, GUT through α_s
Top Quark	top PDF, $xt = x\overline{t}$?, single top in DIS, anomalous top
Relations to LHC	SUSY, high x partons and high mass SUSY, Higgs, LQs, QCD, precision PDFs
Gluon Distribution	saturation, $x \simeq 1$, J/ψ, Υ, Pomeron, local spots?, F_L, F_2^c
Precision DIS	$\delta\alpha_s \simeq 0.1\,\%$, $\delta M_c \simeq 3\,\mathrm{MeV}$, $v_{u,d}$, $a_{u,d}$ to $2-3\,\%$, $\sin^2\Theta(\mu)$, F_L, F_2^b
Parton Structure	Proton, Deuteron, Neutron, Ions, Photon
Quark Distributions	valence $10^{-4} \lesssim x \lesssim 1$, light sea, d/u, $s = \overline{s}$?, charm, beauty, top
QCD	N^{3}LO, factorisation, resummation, emission, AdS/CFT, BFKL evolution
Deuteron	singlet evolution, light sea, hidden colour, neutron, diffraction-shadowing
Heavy Ions	initial QGP, nPDFs, hadronization inside media, black limit, saturation
Modified Partons	PDFs "independent" of fits, unintegrated, generalised, photonic, diffractive
HERA continuation	F_L, xF_3, $F_2^{\gamma Z}$, high x partons, α_s, nuclear structure, ..

Table 3: Schematic overview on key physics topics for investigation with the LHeC.



60 GeV electron beam energy, L= 10^{33} $cm^{-2}s^{-1}$, √s=1.3 TeV: Q^2_{max}= 10^6 GeV^2, 10^{-6} < x< 1
Recirculating linac (2 * 1km, 2*60 cavity cryo modules, 3 passes, energy recovery)

The default LR LHeC design configuration

Towards an LHeC ERL Test Facility at CERN

Contribution to IPAC13

STRAWMAN OPTICS DESIGN FOR THE LHeC ERL TEST FACILITY

A. Valloni*, O. Bruning, R. Calaga, E. Jensen, M. Klein, R.Tomas, F. Zimmermann,
CERN, Geneva, Switzerland
A. Bogacz, D. Douglas, Jefferson Lab, Newport News Virginia

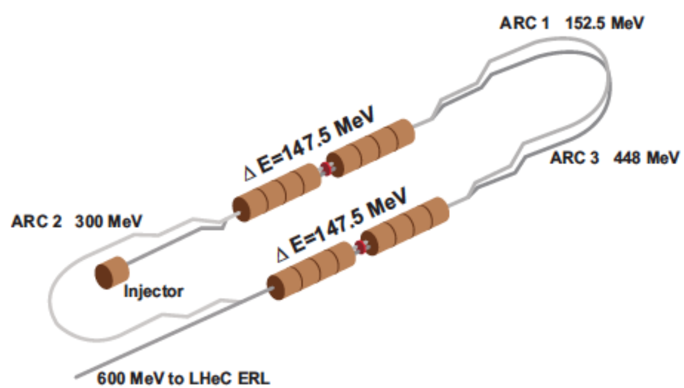


Figure 2: Consequent upgrade to LHeC pre-accelerator. By modifying the machine backleg to include a second full cryomodule, the recirculator can deliver higher beam energy of 600 MeV.

Daresbury Workshop:

- Collaboration: CERN, AsTEC, CI, JeffersonLab, U Mainz, +
- LHeC Parameters (C,Q,source,I) rather conservative
- Test Facility to develop full technology, key: cavity
- RF frequency chosen

Proposal for an LHeC ERL Test Facility at CERN

R. Calaga, E. Ciapala, E. Jensen
CERN, Geneva, Switzerland

CERN-LHeC-Note-2012-001 ACC

October 17, 2012

Rama.Calaga@cern.ch

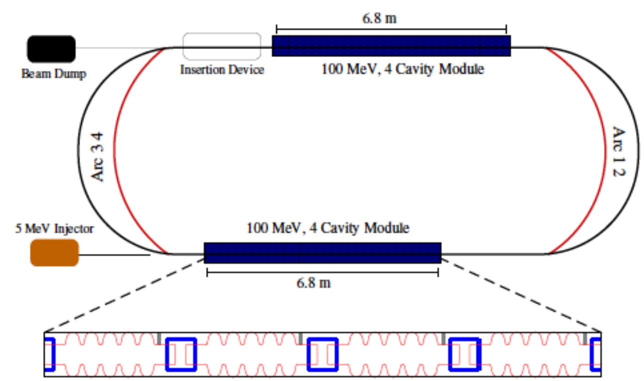
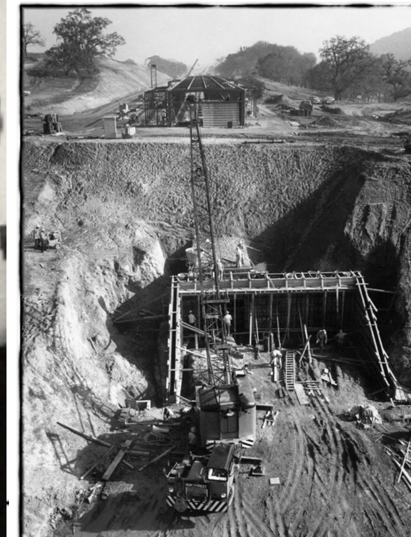


Table 3: Future ERLs for electron-hadron colliders

Parameter	JLab MEIC	BNL eRHIC	CERN LHeC
Energy [GeV]	5-10	20	60
Frequency [MHz]	750	704	n×40
# of passes	-	6	3
Current/pass [mA]	3	50	6.6
Charge [nC]	4	3.5	0.3
Bunch Length [mm]	7.5	2.0	0.3

can one build a 2-3-km long linac?

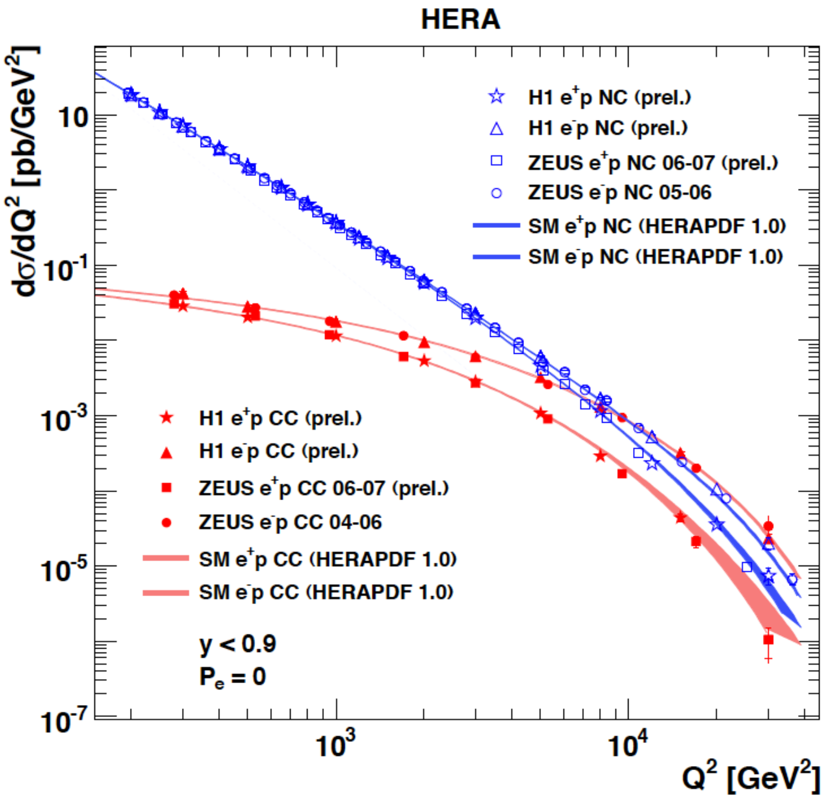


it has been done before

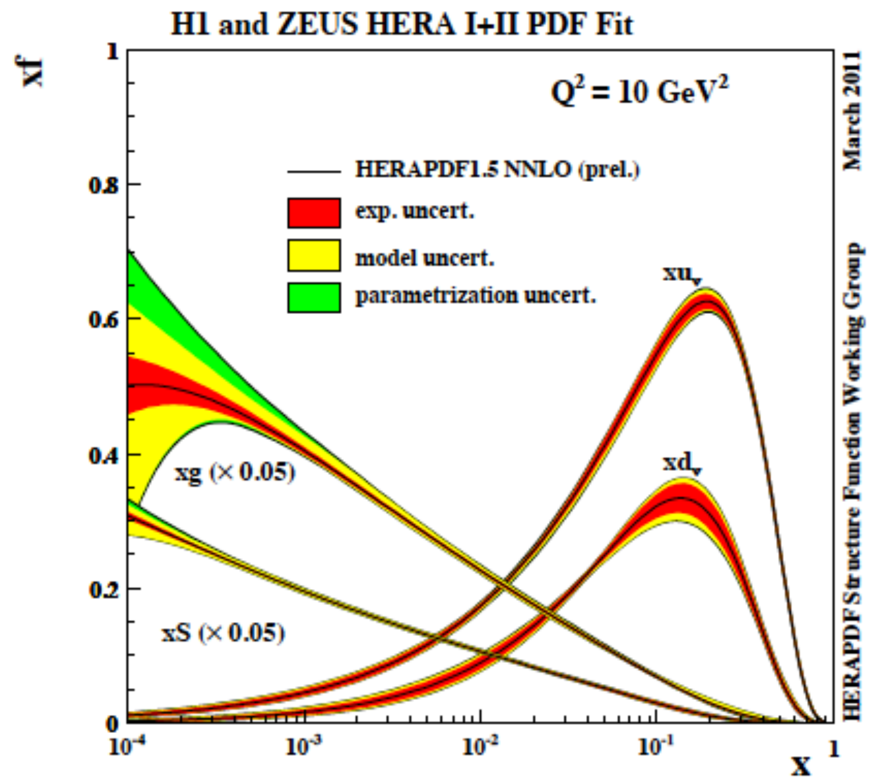
Courtesy F.Zimmermann

Backup

Unique DIS Physics - Results from HERA



The weak and electromagnetic interactions reach similar strength when $Q^2 \geq M^2_{W,Z}$



F_2 rises towards low x, and xg too.
Parton evolution - QCD to NNLO

Measurements on α_s, Basic tests of QCD: longitudinal structure function, jet production, γ structure
Some 10% of the cross section is diffractive (ep → eXp) : **diffractive partons; c,b quark distributions**
New concepts: unintegrated parton distributions (k_T) , generalised parton distributions (DVCS)
New limits for leptoquarks, excited electrons and neutrinos, quark substructure, RPV SUSY
Interpretation of the Tevatron measurements (high Et jet excess, M_W, searches..), + **base for PDF fits**..

M.Klein, R.Yoshida: **Collider Physics at HERA** Prog.Part.Nucl.Phys. 61 (2008) 343-393 and recent H1,ZEUS results
A Recent review of **The Theory of Deep Inelastic Scattering**: J.Bluemlein arXiv:1208.6087 ProgPartNuclPhys 69(2013)28

ECFA Review 2007-2012

CERN SPC, [r]ECFA Mandate given in 2007 to work out the LHeC physics, detector and accelerator design(s) – looking back to 1994 CDR and referee process carefully evaluated by ECFA committee

… We believe that such a comparison is desirable to promote the LHeC physics case by highlighting the uniqueness of its physics programme, and by viewing it in a larger context of physics at the frontiers of highest energy, highest precision and highest densities.

Stressed: Link to LHC physics and operation, link to HEP, cost estimates, R&D, DIS community

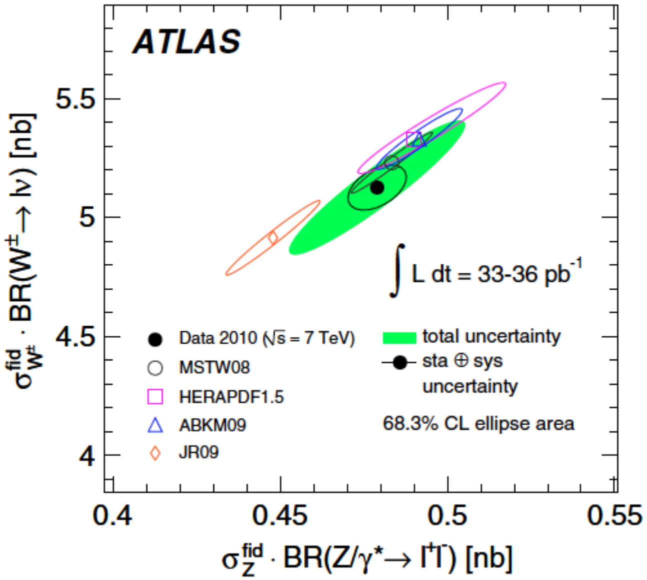
It is our opinion that only the linac-ring option is viable. We point out that there are still important issues to be addressed concerning the physics potential, the accelerator and the detector.

We regard the design effort carried out on the machine as very valuable also for other projects.

Most important is to assemble a strong community in particle and nuclear physics to push further this challenging project, and to secure resources for the ensuing R&D projects towards the formulation of a TDR.

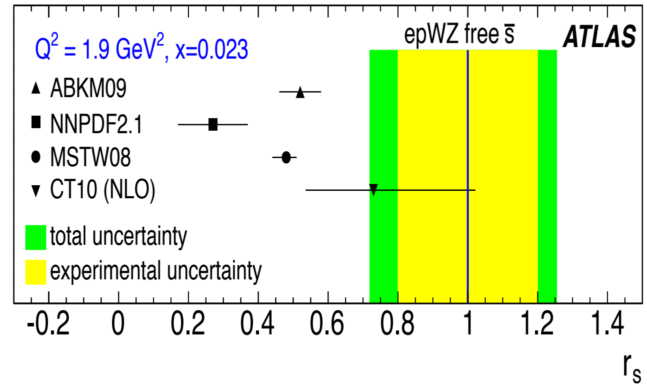
ECFA Statement ECFA/12/279 December 2012

PDF constraints from LHC - Di-Lepton Production

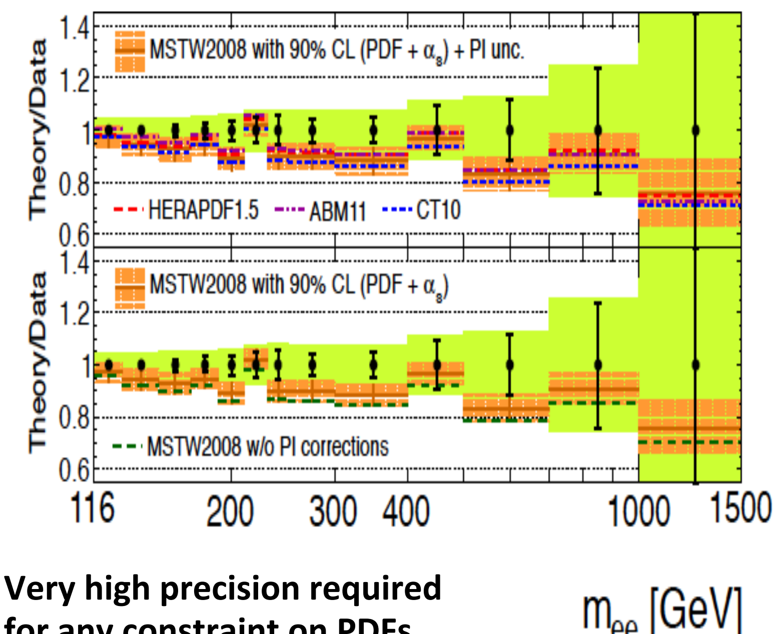


PRD D85 (2012) 072004

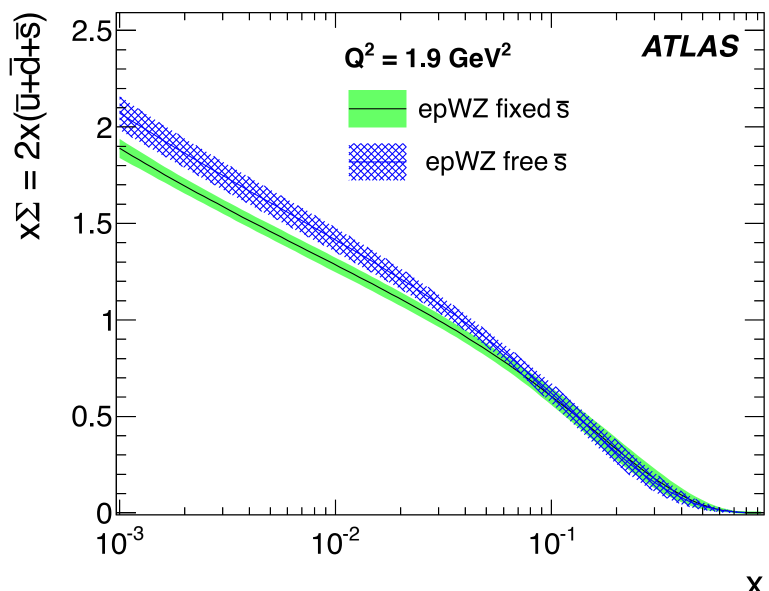
Precision Drell-Yan (W,Z) data constrain PDFs



according to the ATLAS data and HERA+ATLAS QCD analysis: s = d !



ATLAS-CONF-2012-159

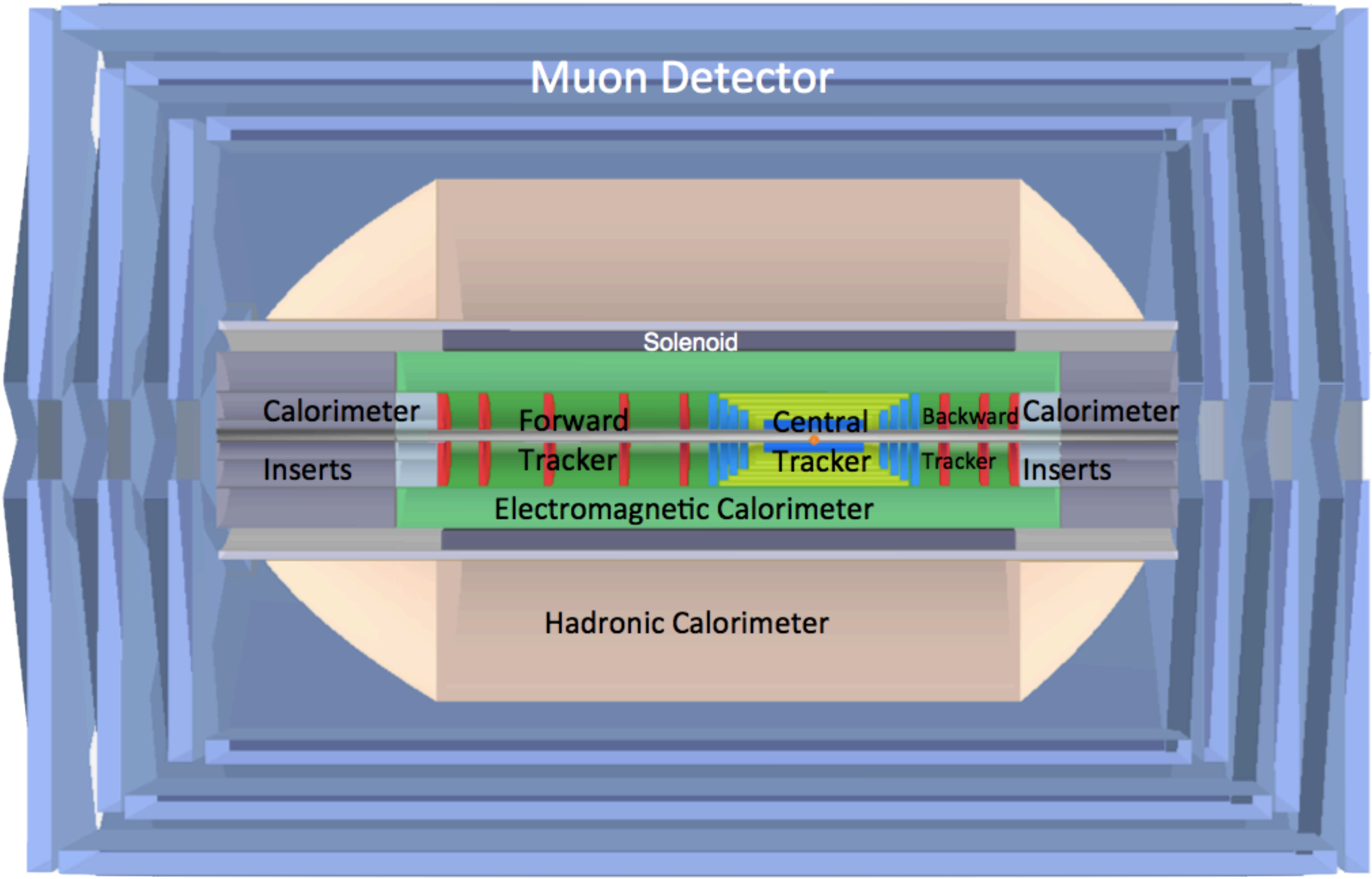


PRL 109(2012)012001

Very high precision required for any constraint on PDFs

Change of strange affects sea - UHE ν

LHeC Detector Overview

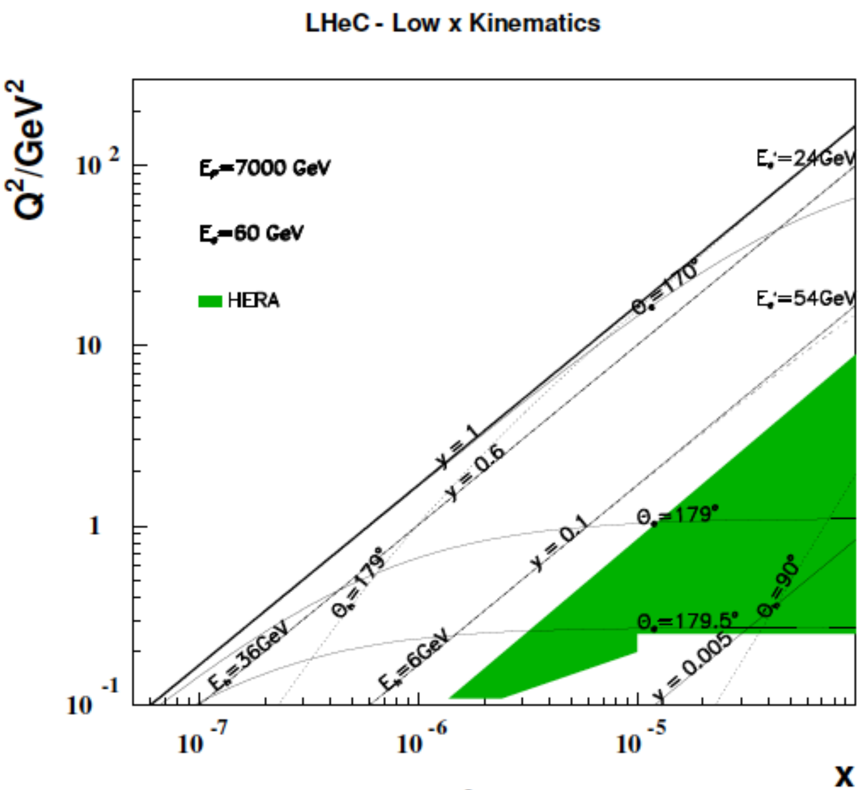


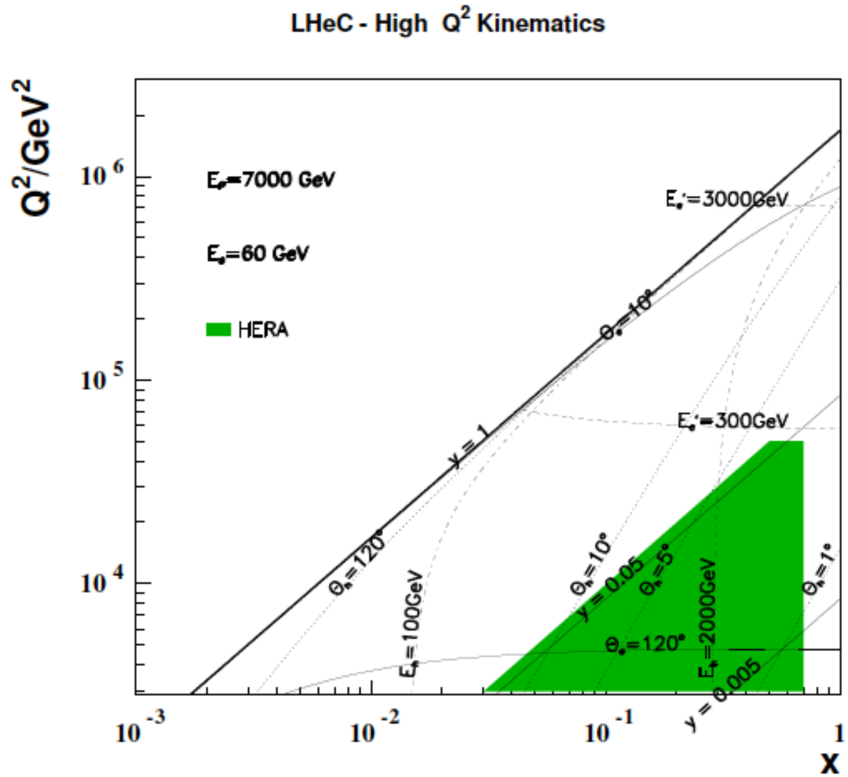
Detector option 1 for LR and full acceptance coverage

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)

Kinematics - LHeC and HERA

Access to "saturation" (?) region in DIS ($Q^2 > 1$ GeV^2) and ep





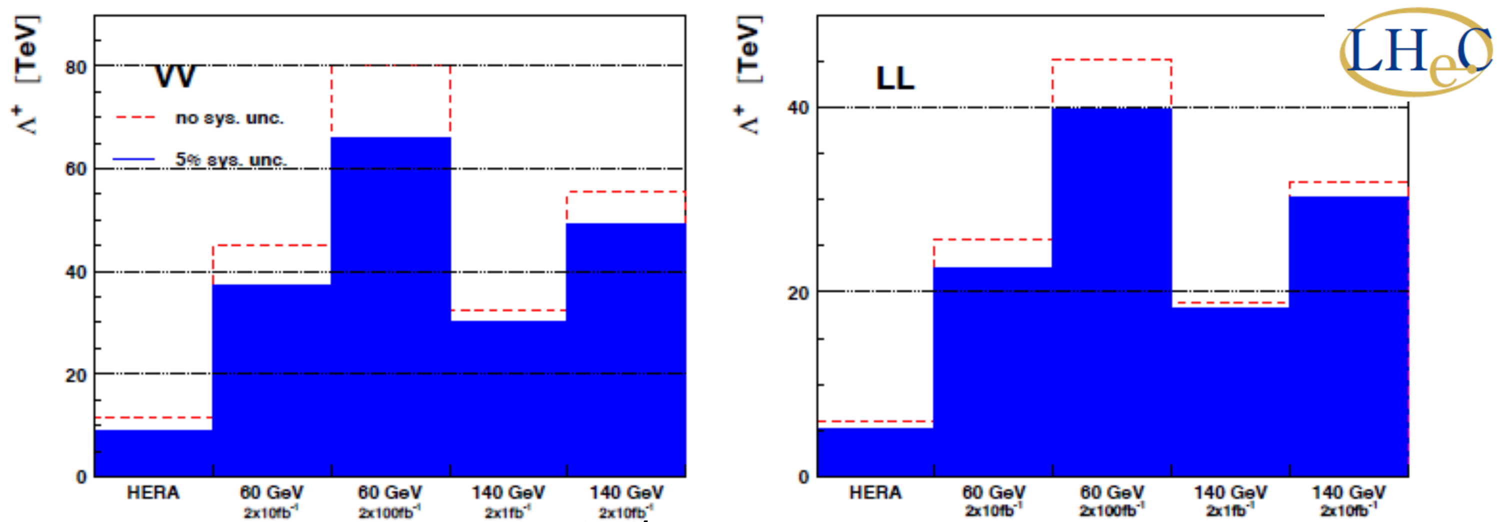
Extending beyond the Fermi scale with precision Z and W exchange data → high x, H, top PDF, flavour & new physics,

What HERA could not do or has not done

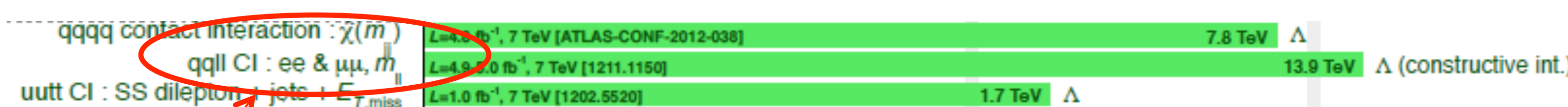
Test of the isospin symmetry (u-d) with eD - no deuterons
Investigation of the q-g dynamics in nuclei - no time for eA
Verification of saturation prediction at low x – too low s
Measurement of the strange quark distribution – too low L
Discovery of Higgs in WW fusion in CC – too low cross section
Study of top quark distribution in the proton – too low s
Precise measurement of F_L – too short running time left
Resolving d/u question at large Bjorken x – too low L
Determination of gluon distribution at hi/lo x – too small range
High precision measurement of α_s – overall not precise enough
Discovering instantons, odderons – don't know why not
Finding RPV SUSY and/or leptoquarks – may reside higher up
…

Contact interactions (eeqq)

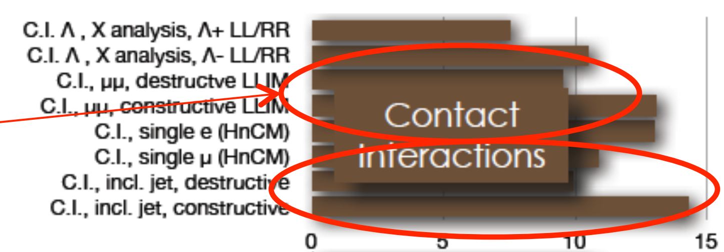
- New currents or heavy bosons may produce indirect effect via new particle exchange interfering with γ/Z fields.
- Reach for Λ (CI eeqq): 25-45 TeV with 10 fb^{-1} of data depending on the model



Similar to LHC

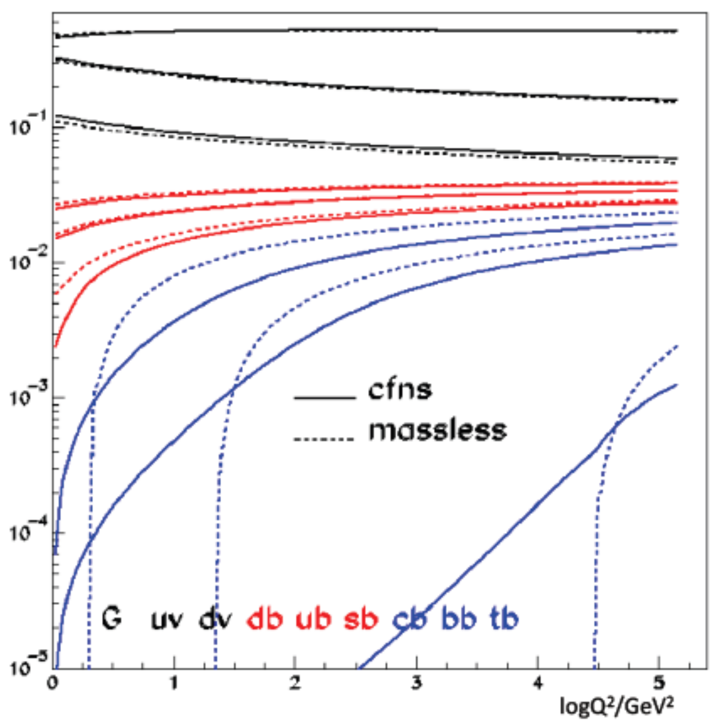


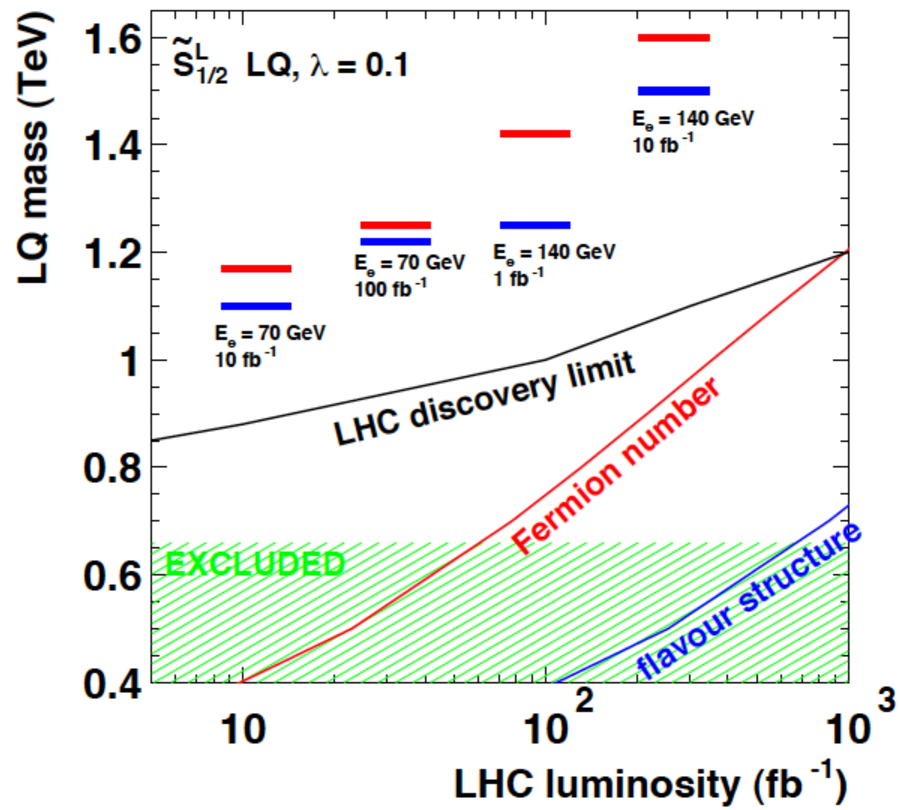
ATLAS and CMS constraints on eeqq CI (expected up to 30-40 TeV at c.o.m. 14 TeV LHC)



Top Quark and Leptoquarks

The LHeC is a (single) top quark production factory, via Wb → t. Top was never observed in DIS. With ep: top-PDF → 6 flavour VFNS, precision M_t direct and from cross section, anomalous couplings [to be studied]





Leptoquarks (-gluons) are predicted in RPV SUSY, E6, extended technicolour theories or Pati-Salam.

The LHeC is the appropriate configuration to do their spectroscopy, should they be discovered at the LHC.

Measurement Simulations

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 %

Table 3.1: Assumptions used in the simulation of the NC cross sections on the size of uncertainties from various sources. These assumptions correspond to typical best values achieved in the H1 experiment. Note that in the cross section measurement, the energy scale and angular uncertainties are relative to the Monte Carlo and not to be confused with resolution effects which determine the purity and stability of binned cross sections. The total cross section error due to these uncertainties, e.g. for $Q^2 = 100\,\mathrm{GeV}^2$, is about 1.2, 0.7 and 2.0 % for $y = 0.84,\ 0.1,\ 0.004$.

Full simulation of NC and CC inclusive cross section measurements including statistics, uncorrelated and correlated uncertainties – checked against H1 MC

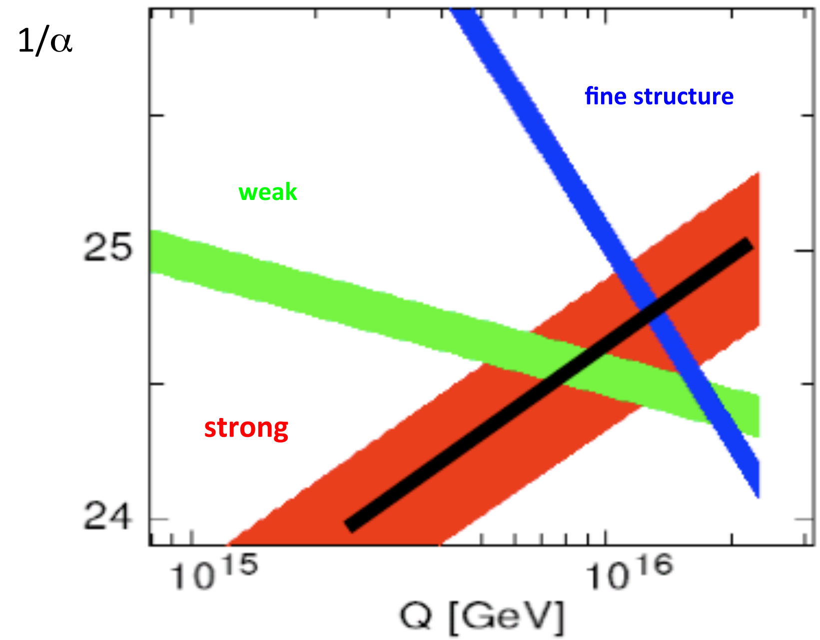
Strong Coupling Constant

α_s least known of coupling constants
Grand Unification predictions suffer from $\delta\alpha_s$

DIS tends to be lower than world average (?)

LHeC: per mille - independent of BCDMS.

Challenge to experiment and to h.o. QCD →
A genuine DIS research programme rather than one outstanding measurement only.



case	cut [Q^2 in 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

Two independent QCD analyses using LHeC+HERA/BCDMS

DATA	exp. error on α_s
NC e^+ only	0.48%
NC	0.41%
NC & CC	**0.23% :=(1)**
(1) $\gamma_h > 5°$	0.36% :=(2)
(1) +BCDMS	0.22%
(2) +BCDMS	0.22%
(1) stat. *= 2	0.35%

α_s

Per mille precision
NNNLO PDFs
Heavy quarks →
Full set of PDFs

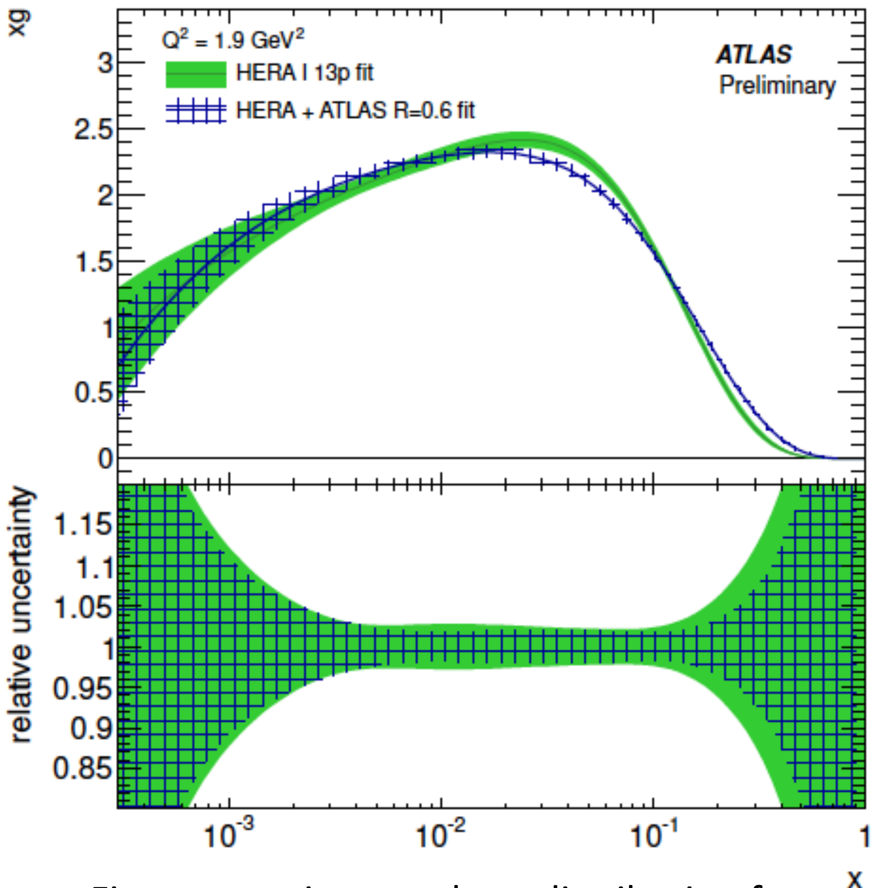
Data input	Experimental uncertainty on m_c [MeV]
HERA: NC+CC	100
HERA: NC+CC+ F_2^{cc}	60
LHeC: NC+CC	25
LHeC: NC+CC+ F_2^{cc}	3

Full exp. error

case	cut [Q^2 (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

From LHeC CDR

PDF constraints from LHC – Jets

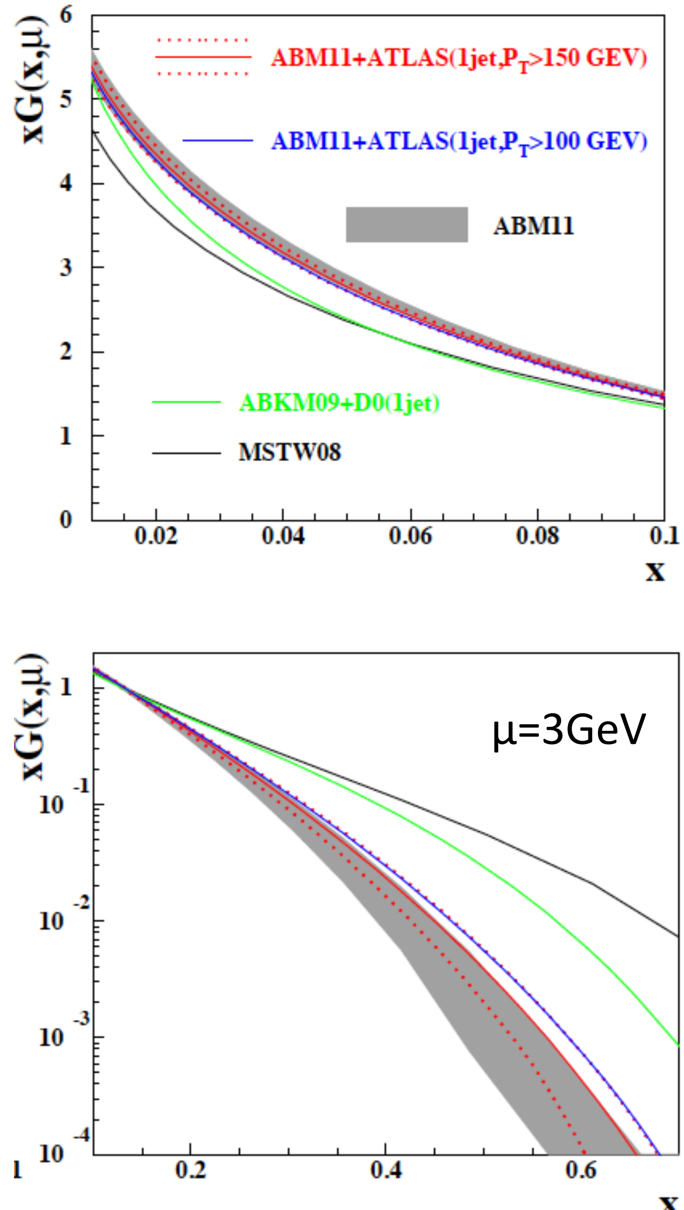


First constraints on gluon distribution from jets: cross sections and ratios 2.7/7 TeV

Will improve, but depends on energy scales, jet definition, non-perturbative effects ..

Similar results from CMS ($W^{\pm}$, DY, top..)

ATLAS-CONF-2012-128

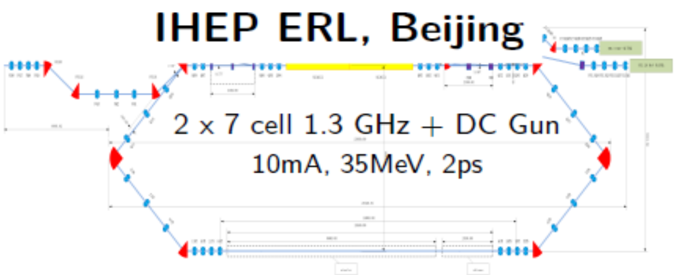


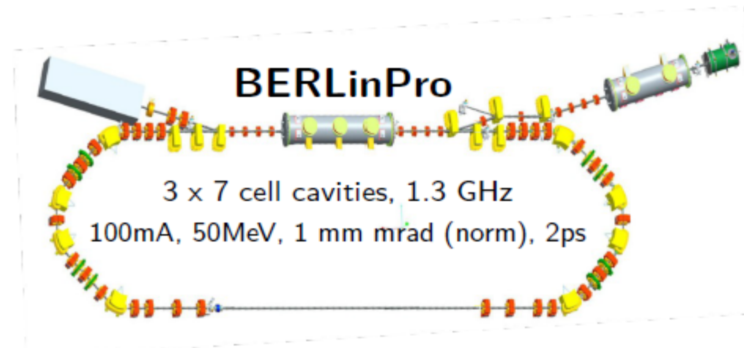
S.Moch 6th Terascale Workshop (Hamburg, 3.12.12)

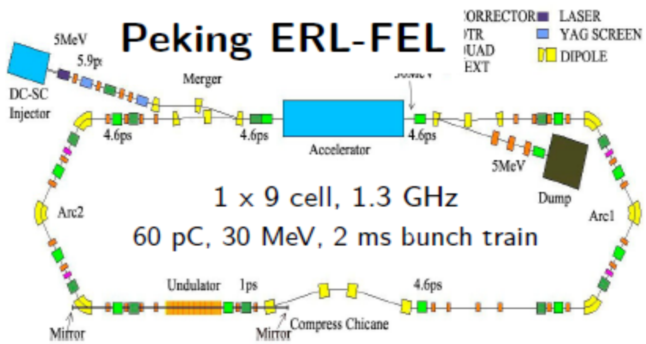
Summary and outlook

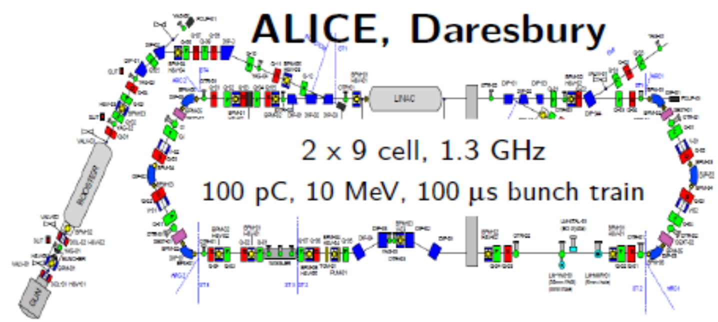
- LHeC provides complementarities to the LHC SUSY search program in the twenties
  - Ideal to search and study properties of new bosons with couplings to electron-quark
  - Direct searches for CI, excited fermions, leptoquark, RPV SUSY, RPC SUSY in specific scenarios such as compressed, non-degeneracy for squarks
  - Interplay with HL-LHC to constraints on PDF crucial for model testing in case of observed deviations → an independent precision measurement of PDFs will be important for an efficient use of the high luminosity for setting reliable high mass limits

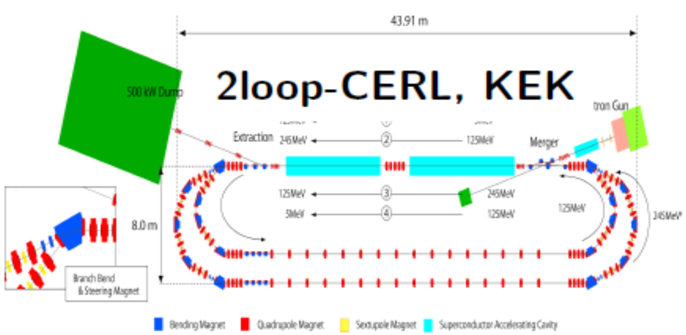
Collaboration on ERL





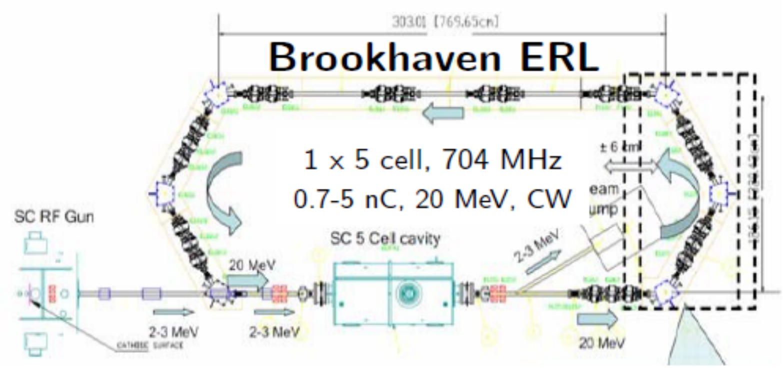






9 cell, 1.3 GHz cavities, 4 modules

77 pC, 245 MeV, 1-3 ps



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End