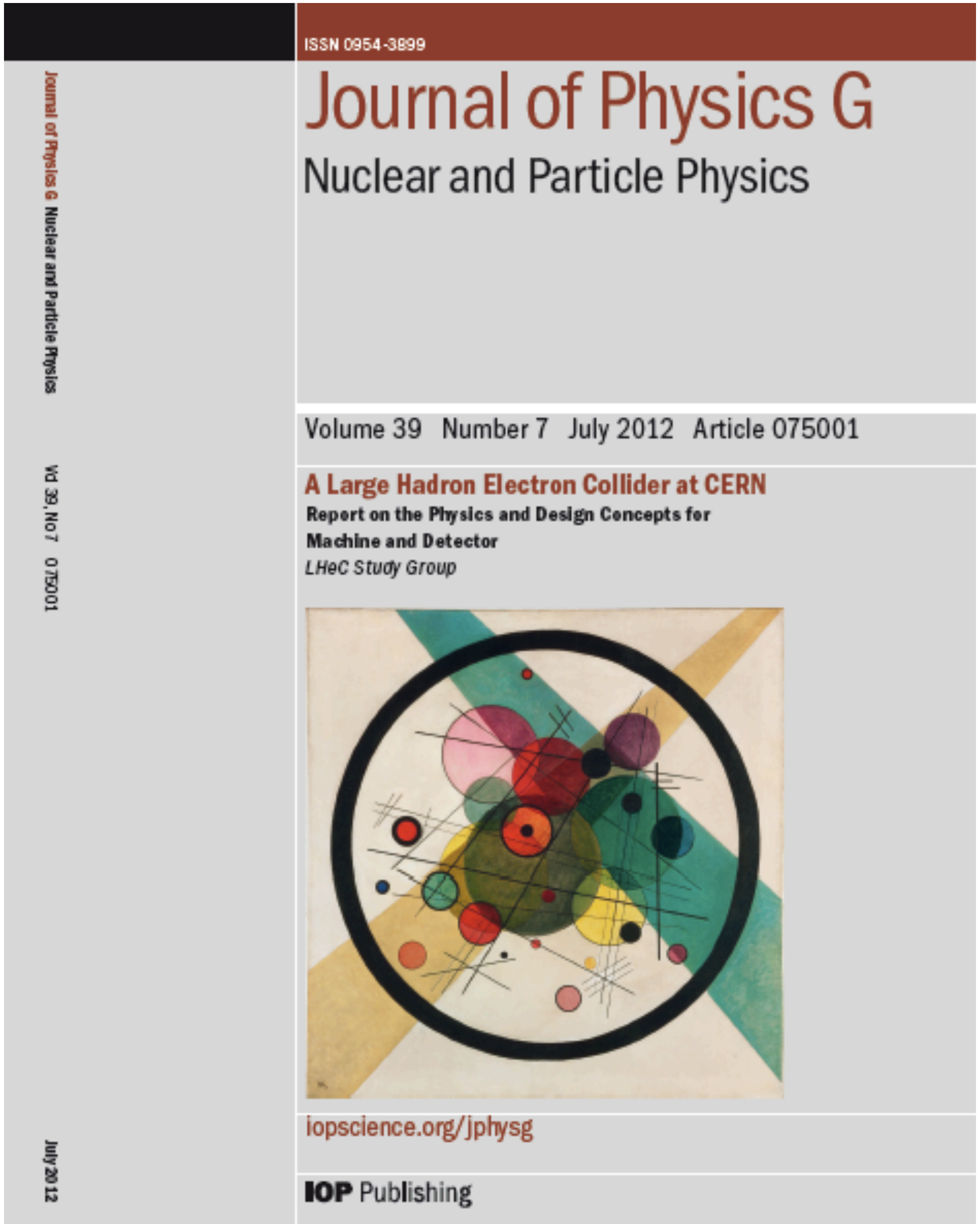
DIS with the LHC

1. LHeC – CDR (Refereed, NuPECC, ECFA)
2. Scaling the Effort and Physics
3. A Next Step

For the DG of CERN, Rolf Heuer.

M.Klein, CERN, 19.2.2013

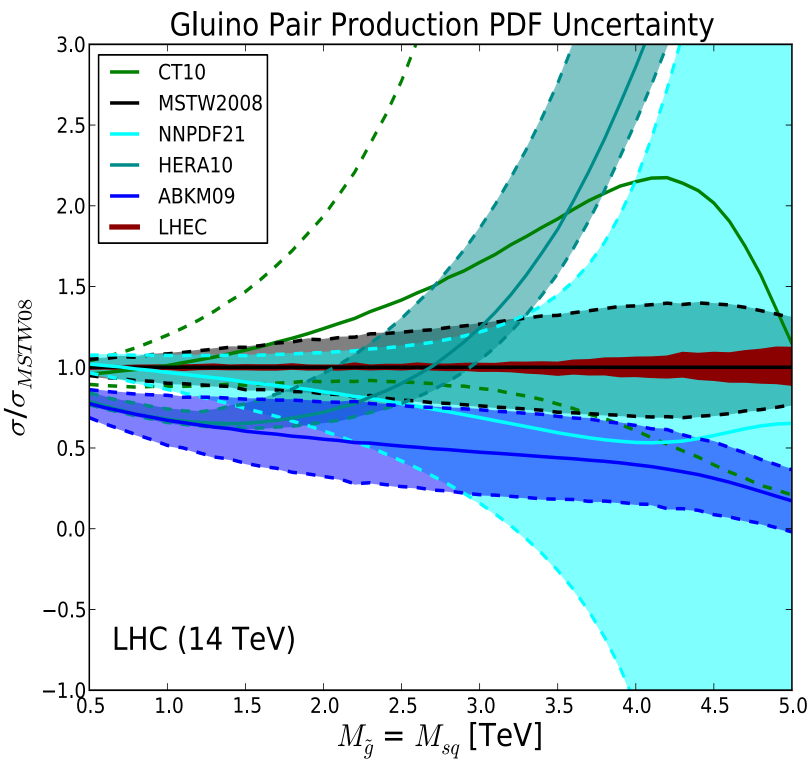


CERN Referees

Ring Ring Design
Kurt Huebner (CERN)
Alexander N. Skrinsky (INP Novosibirsk)
Ferdinand Willeke (BNL)
Linac Ring Design
Reinhard Brinkmann (DESY)
Andy Wolski (Cockcroft)
Kaoru Yokoya (KEK)
Energy Recovery
Georg Hoffstaetter (Cornell)
Ilan Ben Zvi (BNL)
Magnets
Neil Marks (Cockcroft)
Martin Wilson (CERN)
Interaction Region
Daniel Pitzl (DESY)
Mike Sullivan (SLAC)
Detector Design
Philippe Bloch (CERN)
Roland Horisberger (PSI)
Installation and Infrastructure
Sylvain Weisz (CERN)
New Physics at Large Scales
Cristinel Diaconu (IN2P3 Marseille)
Gian Giudice (CERN)
Michelangelo Mangano (CERN)
Precision QCD and Electroweak
Guido Altarelli (Roma)
Vladimir Chekelian (MPI Munich)
Alan Martin (Durham)
Physics at High Parton Densities
Alfred Mueller (Columbia)
Raju Venugopalan (BNL)
Michele Arneodo (INFN Torino)

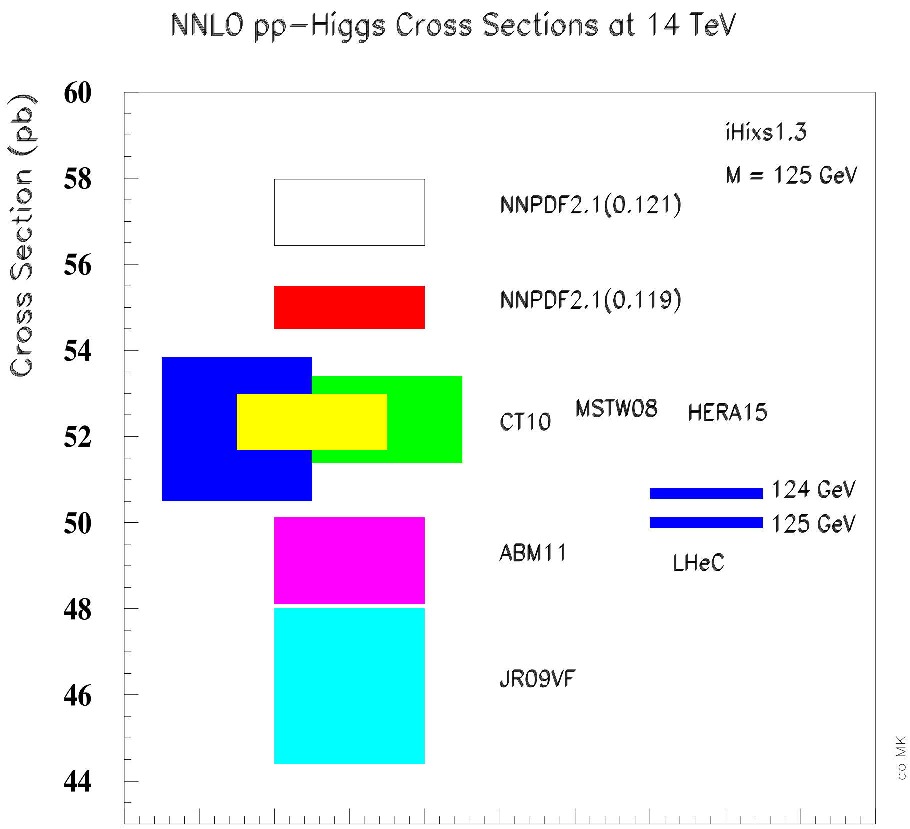
Published 600 pages conceptual design report (CDR) written by 200 authors from 60 Institutes and refereed by 24 world experts on physics, accelerator and detector, which CERN had invited.

Close Link of ep (and eA) to the LHC



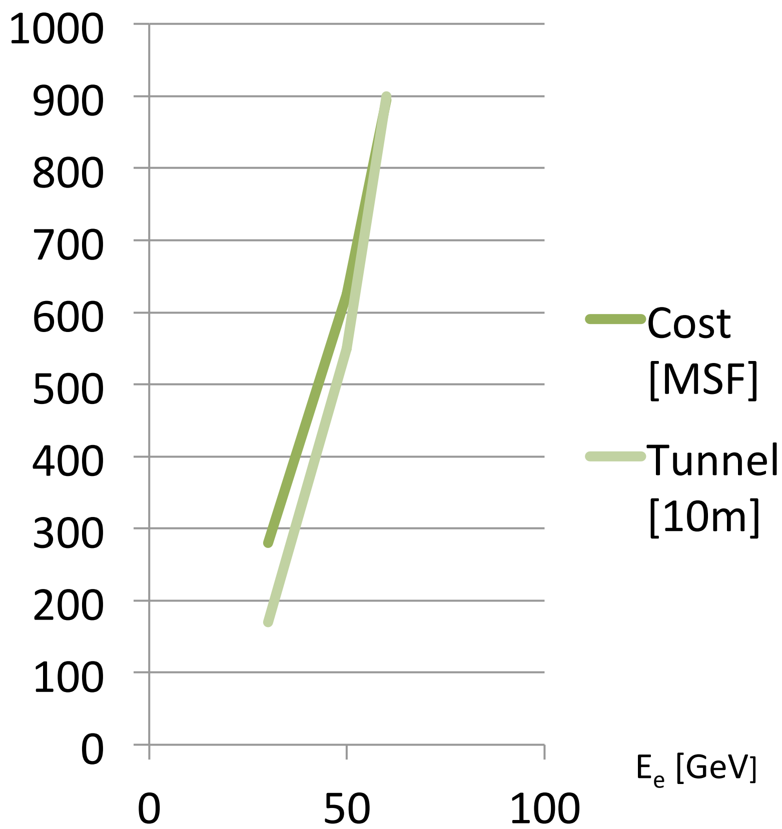
High mass searches (SUSY, ED..)

"Removal" of QCD uncertainties for H at the LHC (PDFs, $\delta\alpha_s$~0.2%, GUT?)



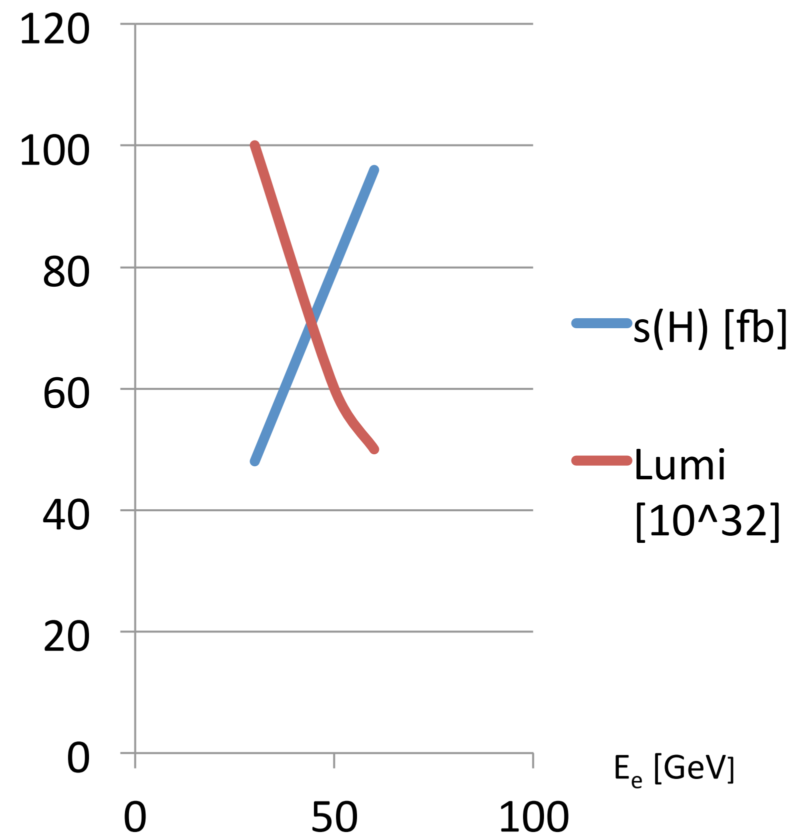
Scaling of the LHeC with the Electron Beam Energy

Cost and Tunnel Length

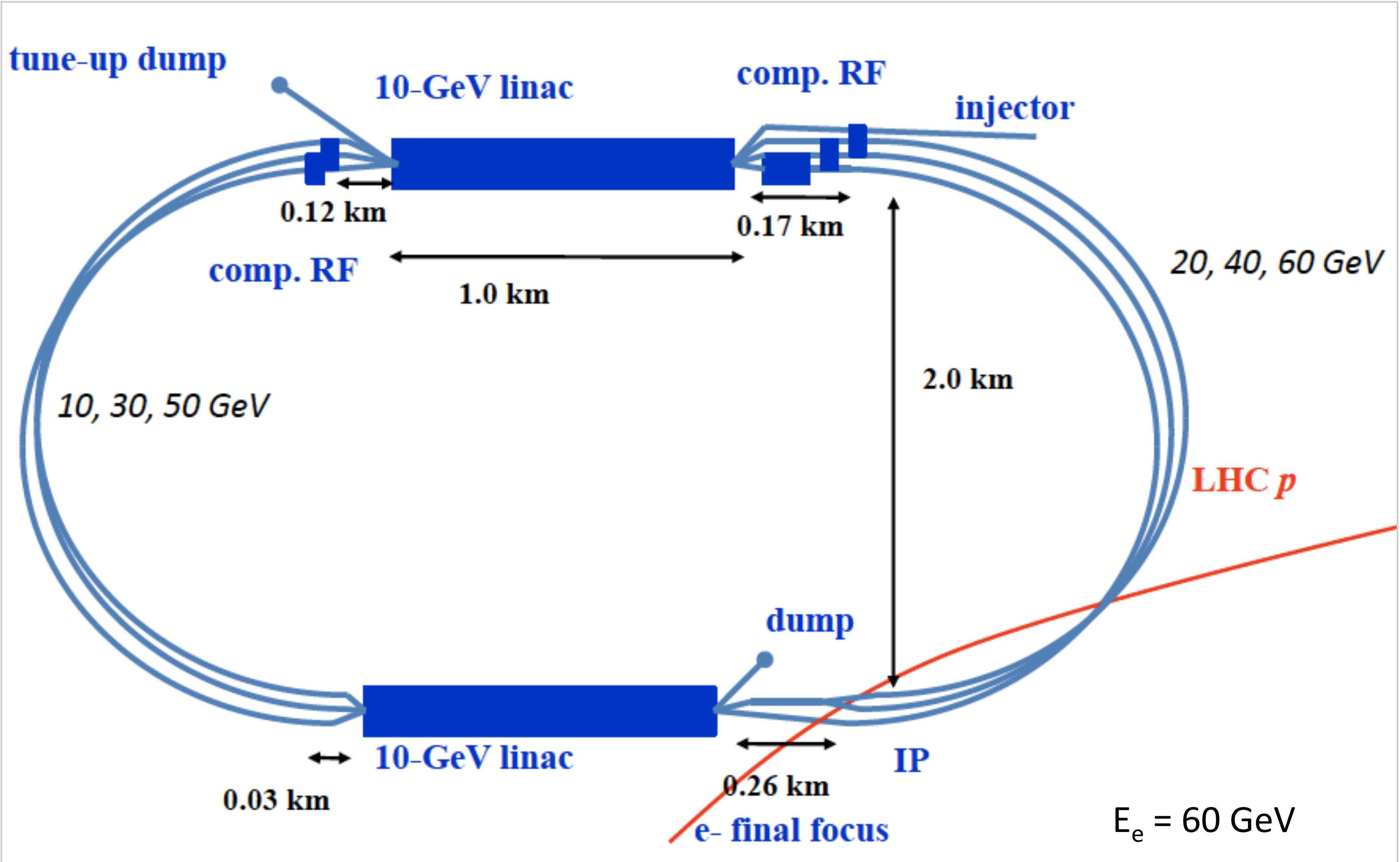


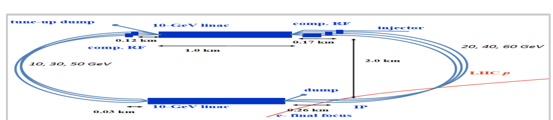
Cost w/o contingency. 80GeV ~ 1.5BSF
The core detector cost is 106 MSF (CDR).

Higgs Cross Section and Luminosity



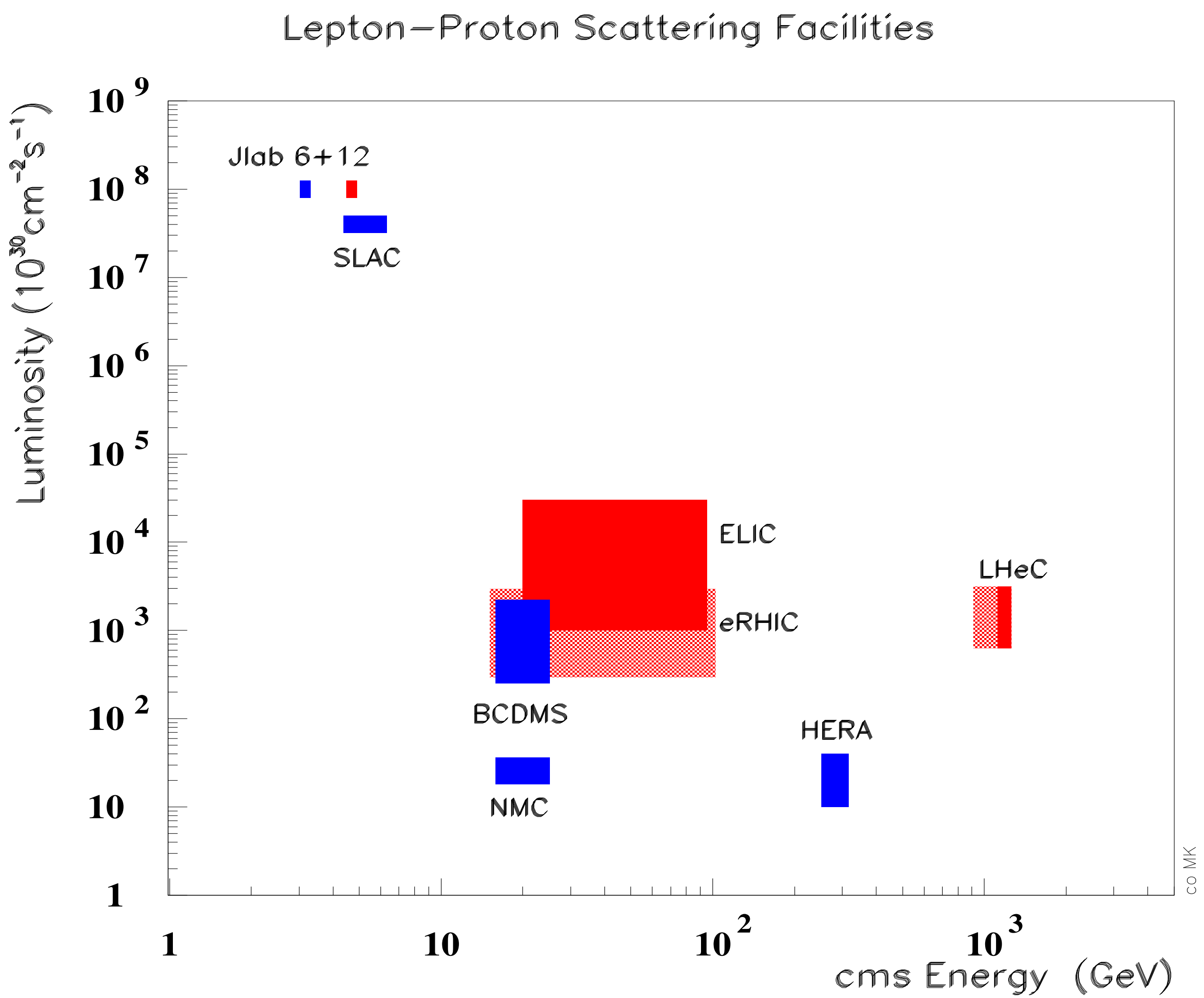
Luminosity at constant power ~ $1/E_e$ while $\sigma(E_e)$ ~ E_e
This corresponds to 5-10k WW→ H in e- CC per year, independently of E_e (modulo acceptance change)





E_e = 30 GeV = 3 * 2 * 5 GeV

[The tunnel length is not only a function of the energy but also dependent on future upgrade capabilities.]



The LHC provides the only, single opportunity to develop DIS as part of HEP for decades

R+D Tasks for LHeC

LHCC
MAC/LMC

2012-2015

ECFA
NuPECC

Coordination
Enable decision by 2015 ("TDR")
Oversight of Physics, Detector, Accelerator Issues. Finances
CERN + International Collaborations on Detector + Accelerator
Response to CERN Directorate and Committees, Conferences etc.

Physics	Detector	Computing	IR	CE	RF+Cryo	ERL	Magnets
Stimulate new DIS physics	Performance (precision, acc.)	Physics processes	Pipe for 1°	Site specific linac design	Cavity-cryo module (Q)	Beam dynamics	Q design and prototypes
t,Higgs,RPV..	Technical design	Computing model, support	Syn.radiation, beam backgrd	Junction of e,p beam lines	Cryogenics system design	Protection, dumps	Return arc magnets
Adjust to LHC	Prototypes	Simulations	Masks, collimators..	Technical integration	Power, coupler	Electron source	Rotator
Tool development	Installation model	DAQ and Trigger	Fwd and bwd detectors	Power, GS..	Test facility	Positron R+D	Integration

LHeC Project Organisation 2012-2015 [13.6.2012]

New LHeC project organisation, as considered at Chavannes (June 2012)

Remark

It is feasible to realise an unchallengeable ep and eA DIS physics programme with the LHC.

An accelerator and detector project organisation would have to be built for preparing such an experiment for the HL phase of operation, following the example of the first MoU's in preparation for the LHeC energy recovery testfacility. A sketch of such an organisation has been considered. Collaborators have expressed interest worldwide but can only be attracted with a declaration of CERN's support.

Reducing the electron beam energy, but using energy recovery techniques, it seems possible to essentially maintain the full physics programme of the 60 GeV LHeC. If the electron beam energy is halved the cost seems to be 1/3 of the full cost, about. The final choice of energy depends on the 13 TeV run, and the developments around the major facilities, the LHC upgrade and the ILC and future considerations. One can imagine also a genuine synergy with the LHeC as a yy collider (to be studied).

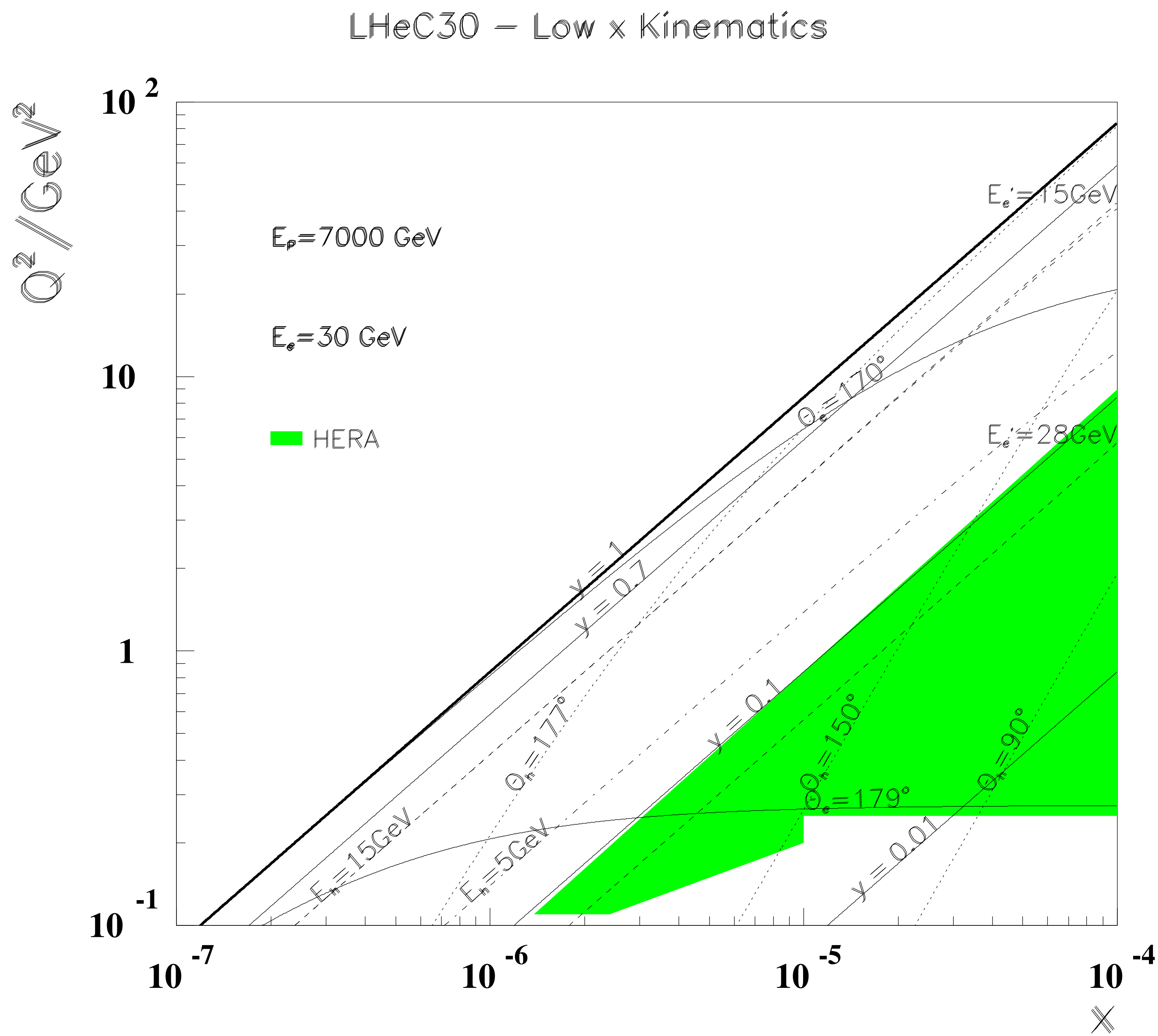
backup

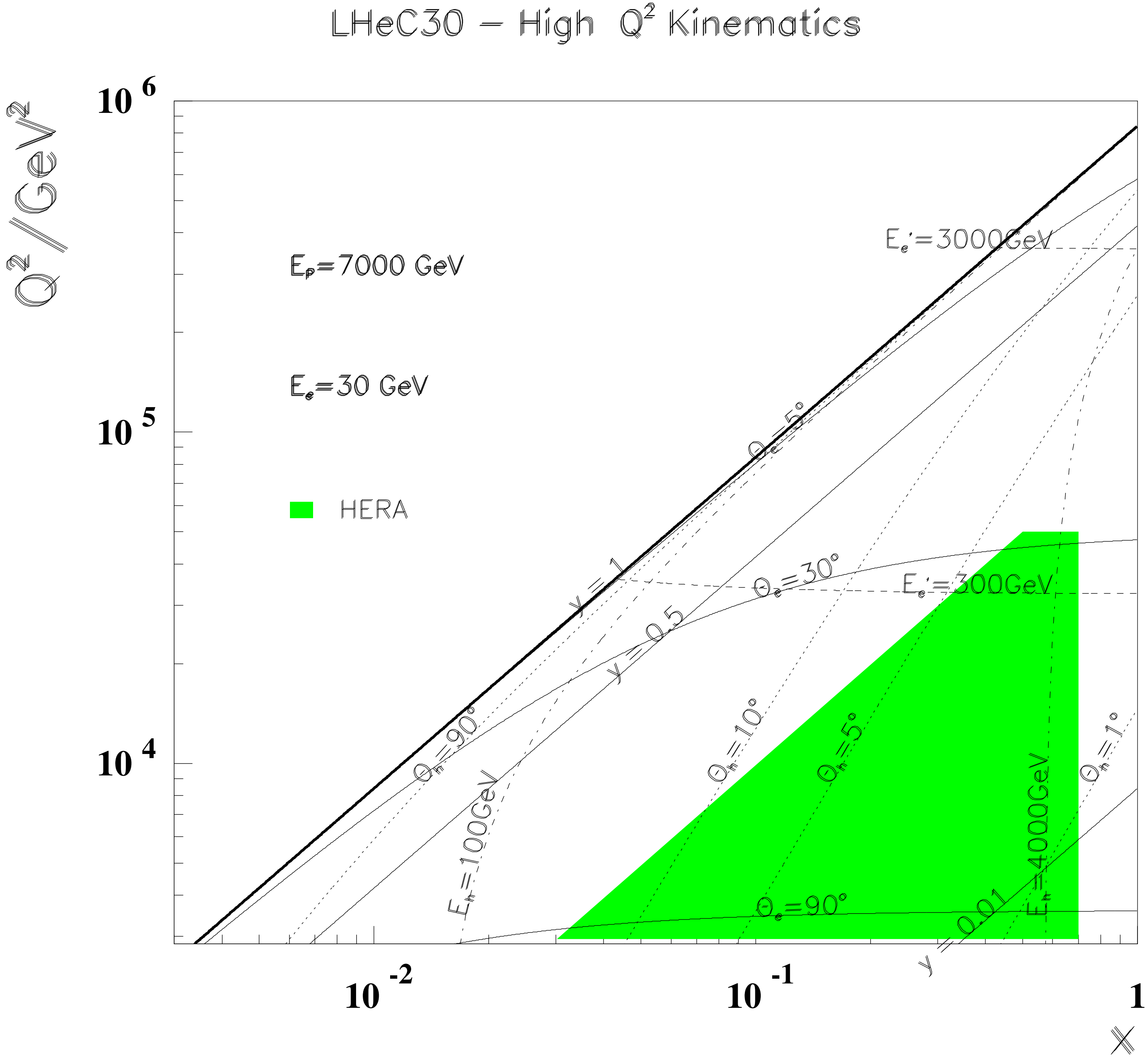
Summary of LHeC Physics [arXiv:1211:4831+5102]

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, $H \to b\overline{b}$, $H \to 4l$, 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, $x \approx 1$, 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.


LHeC30 – Low x Kinematics
Q^2/GeV^2
E_p=7000 GeV
E_e=30 GeV
HERA
E_e'=15GeV
E_e'=28GeV
Θ_e=170°
Θ_e=179°
Θ_h=177°
Θ_h=150°
Θ_h=90°
y = 1
y = 0.7
y = 0.1
y = 0.01
E_h=15GeV
E_h=5GeV
10^{2}
10
1
10^{-1}
10^{-7}
10^{-6}
10^{-5}
10^{-4}
x

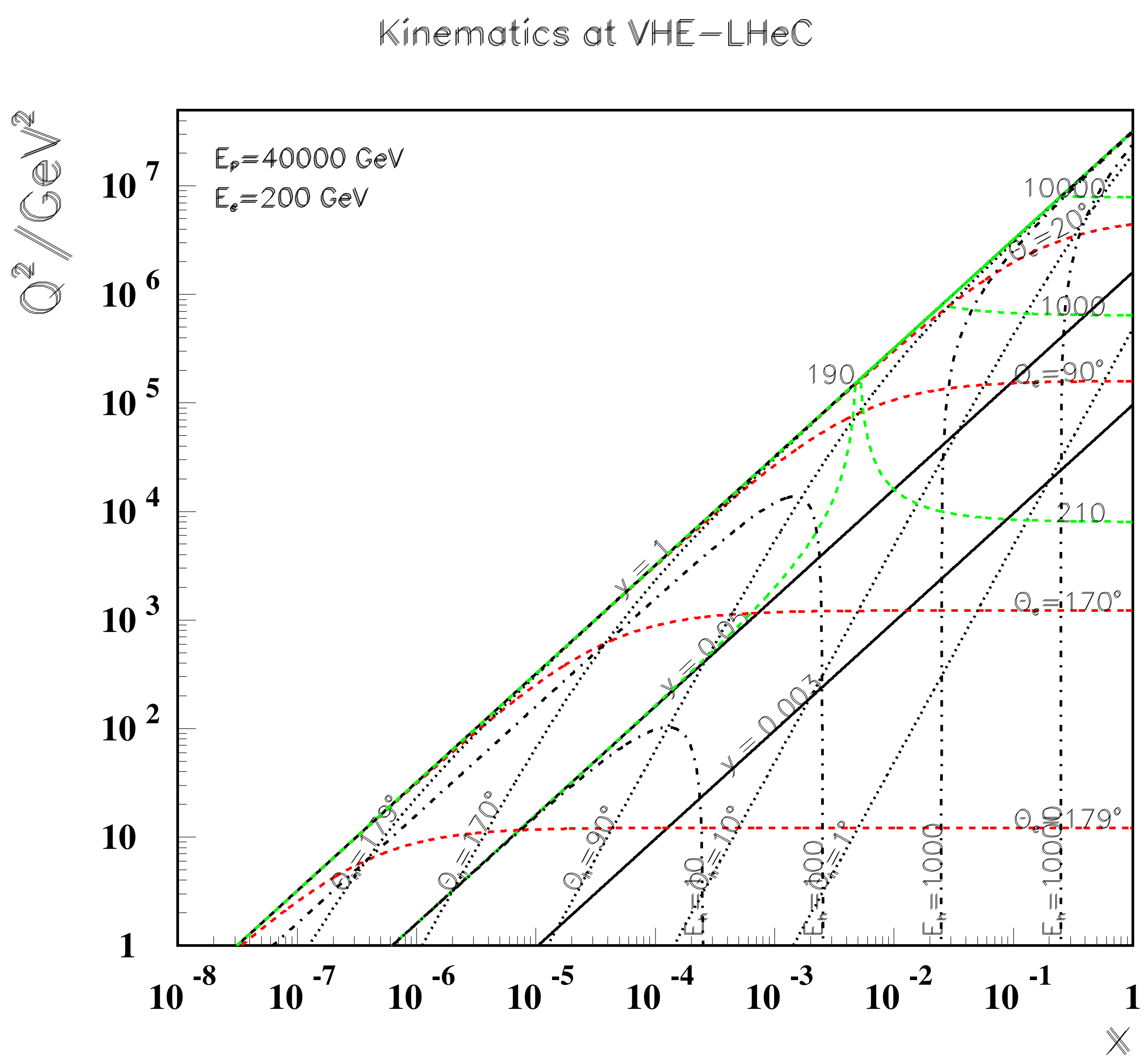

LHeC30 – High Q² Kinematics
Q² /GeV²
10⁶
10⁵
10⁴
10⁻²
10⁻¹
1
x
Eₚ=7000 GeV
Eₑ=30 GeV
HERA
Eₑ'=3000GeV
Eₑ'=300GeV
y = 1
y = 0.5
y = 0.01
Θₑ=5°
Θₑ=30°
Θₑ=90°
Θₕ=90°
Θₕ=10°
Θₕ=5°
Θₕ=1°
Eₕ=100GeV
Eₕ=4000GeV

Ring vs Linac - Tentative "Core" Cost

Only for the CERN Directorate and only indicative 24.1.2012

Item	Ring	Linac	Source of information
Civil Engineering	98+40	240+96	Amber+40% (LHC model)
Rf	50	30	Guess
Magnets +support	22k*3946=87 7k*3000=21	22k*5118=114 10*3600=36	Davide Tommassini
Injector	50	5	Estimate
Cryogenics	15	150	Friedrich Haug
Linac	--	120*1.8=216	Brinkmann
Total	361 → 450	887 → 1100	¼ extra added

Scaling of Linac (and Return Arc) cost leads to 590 instead of 887 for 50 GeV



For the DIS dreams for the very far future an ep/A "bridge" is absolutely crucial.