

CERN-ECFA-NuPECC

Workshop on the LHeC

Electron-proton and electron-ion collisions at the LHC

Steering Group Report

Max Klein (U Liverpool)

14-15 June 2012
Chavannes-de-Bogis, Switzerland

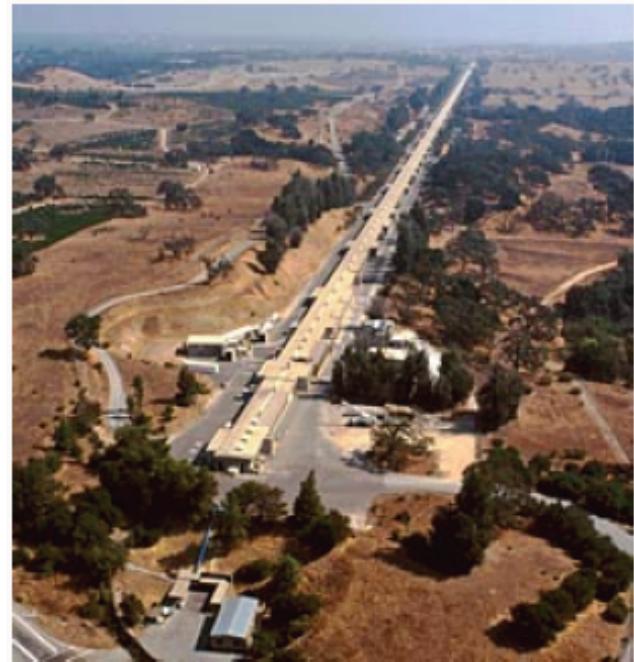
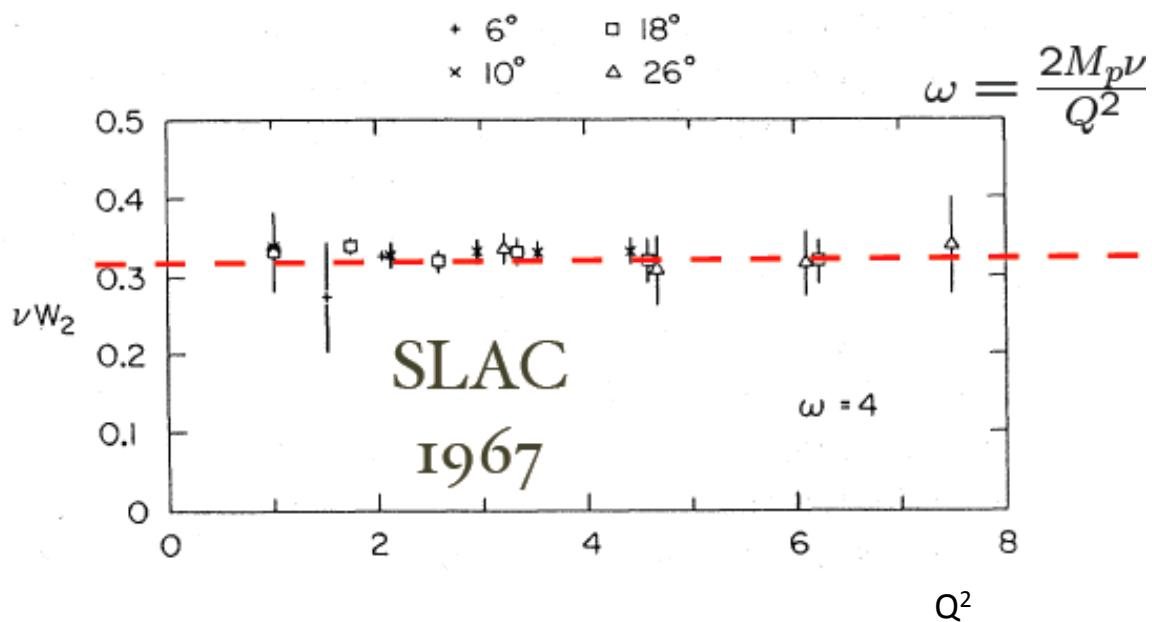
Project Development

- 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 (June 14-15, 2012)



LHeC has some history already ..

Foundation of DIS



SLAC 1967

$$s = 2M_p E_e \approx 20 \text{ GeV}^2$$

LHeC 2025

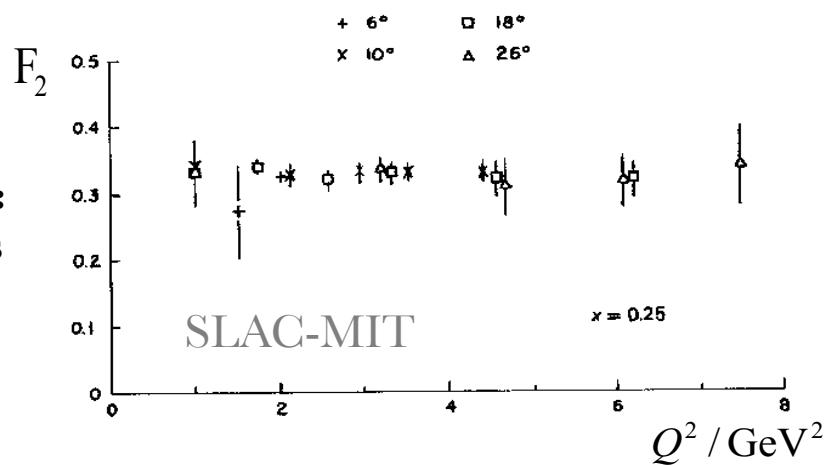
$$s = 4E_p E_e \approx 2 \cdot 10^6 \text{ GeV}^2$$

10⁵ times more Q^2 with the same linac length

"Pief" Panowsky (1919-2007)

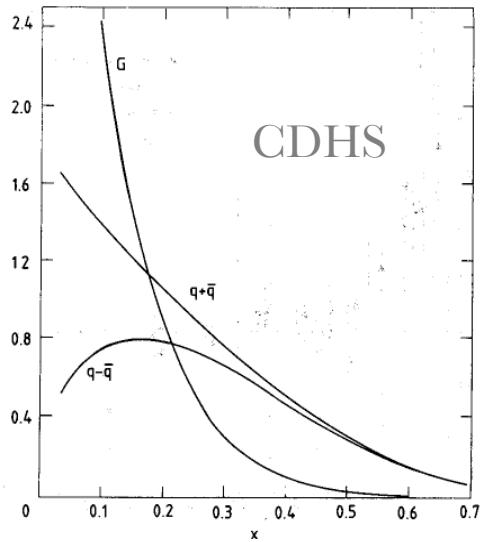
$$\text{DIS} \rightarrow \text{SU}_{2,\text{L}} \times \text{U}_1 \times \text{SU}_{3,\text{c}}$$

**Scaling:
Partons**

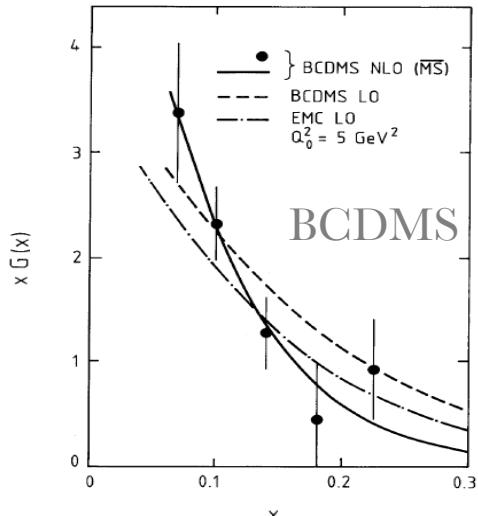


SLAC/GGM
 0.29 ± 0.05
 $= (\mathbf{e}_u^2 + \mathbf{e}_d^2)/2$

Valence and Sea

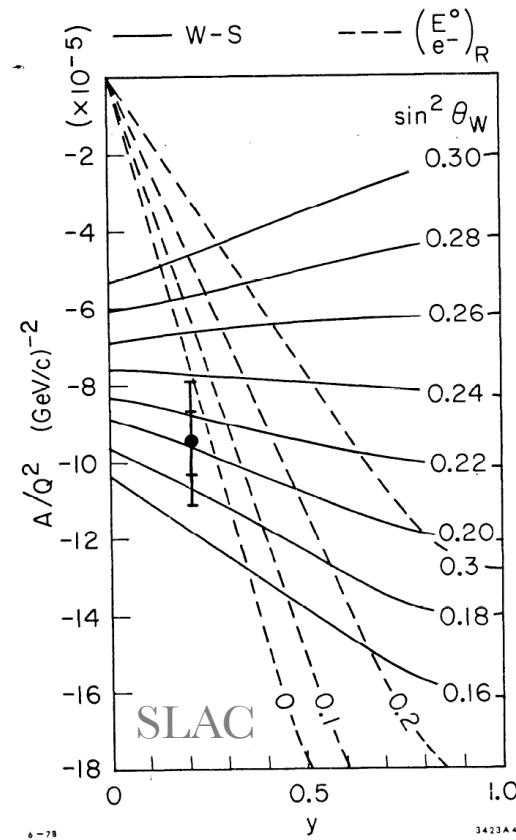


Scaling Violation - Gluon

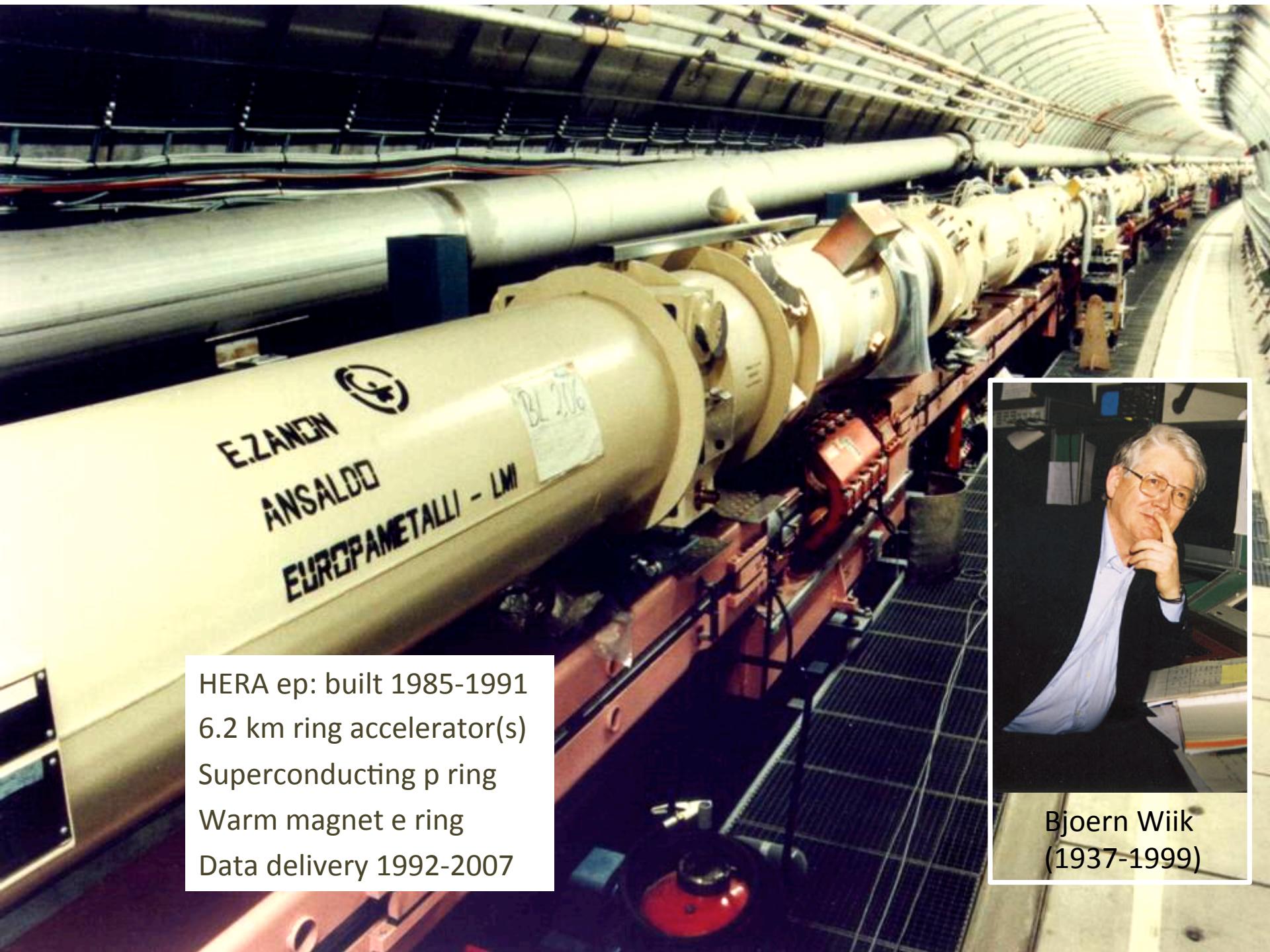


$\alpha_s \approx 0.113 \text{ (AM+MV)}$

PV: \mathbf{Q}_W
 $\mathbf{I}_3^R(\mathbf{e}) = 0$
DEUTERIUM TARGET



CERN housed DIS (μ, v)
and $p\bar{p}$ at the same time..

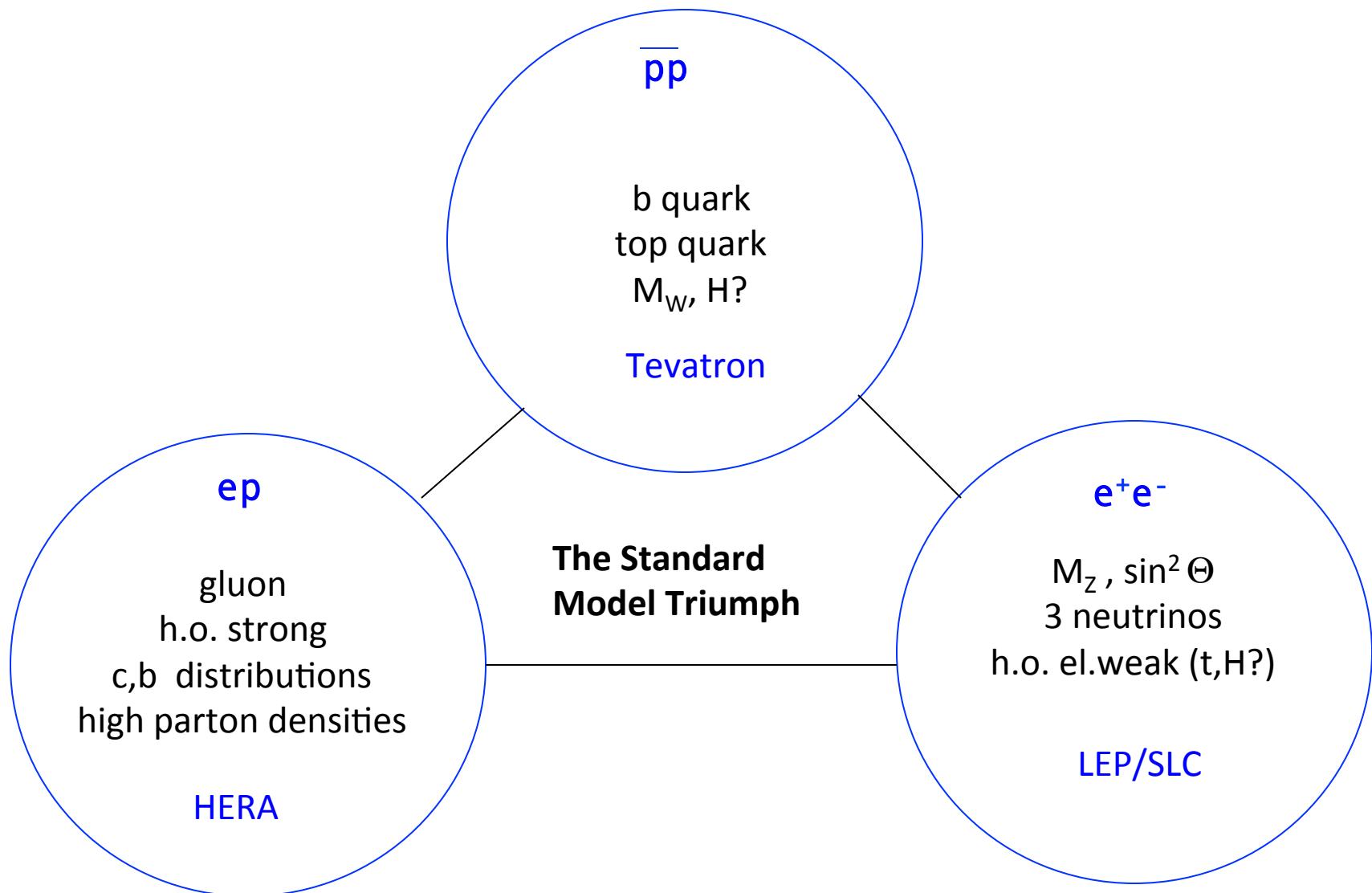


HERA ep: built 1985-1991
6.2 km ring accelerator(s)
Superconducting p ring
Warm magnet e ring
Data delivery 1992-2007



Bjoern Wiik
(1937-1999)

The Fermi Scale [1985-2010]

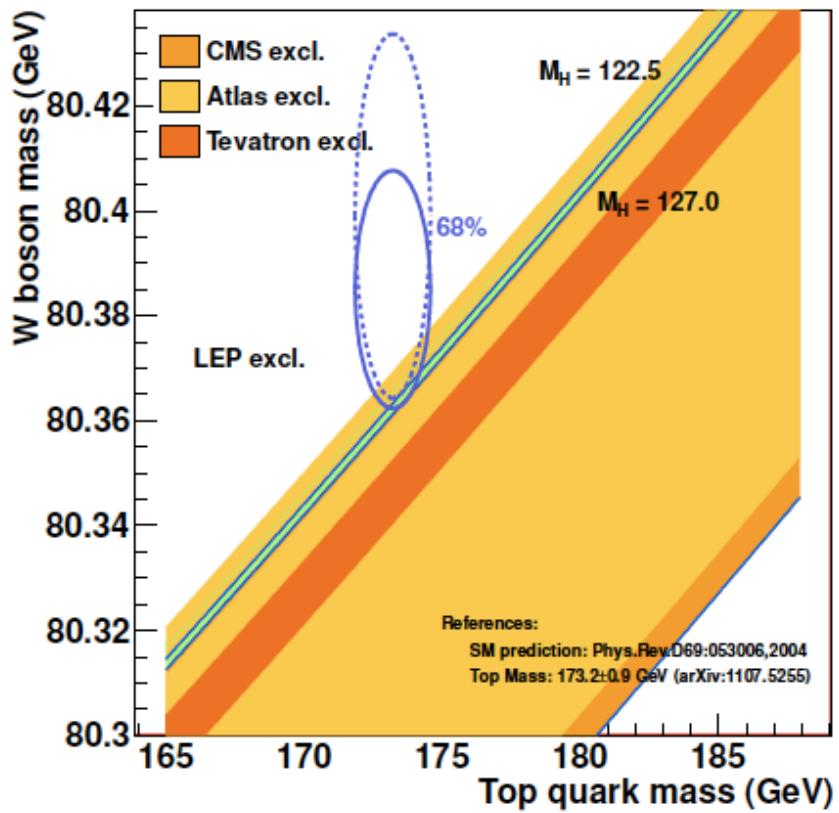


Colliders explored the Fermi Energy Scale

Tevatron to find SUSY and BSM; **LEP/SLC** to find SUSY and the Higgs; **HERA** to find Lepto-Quarks

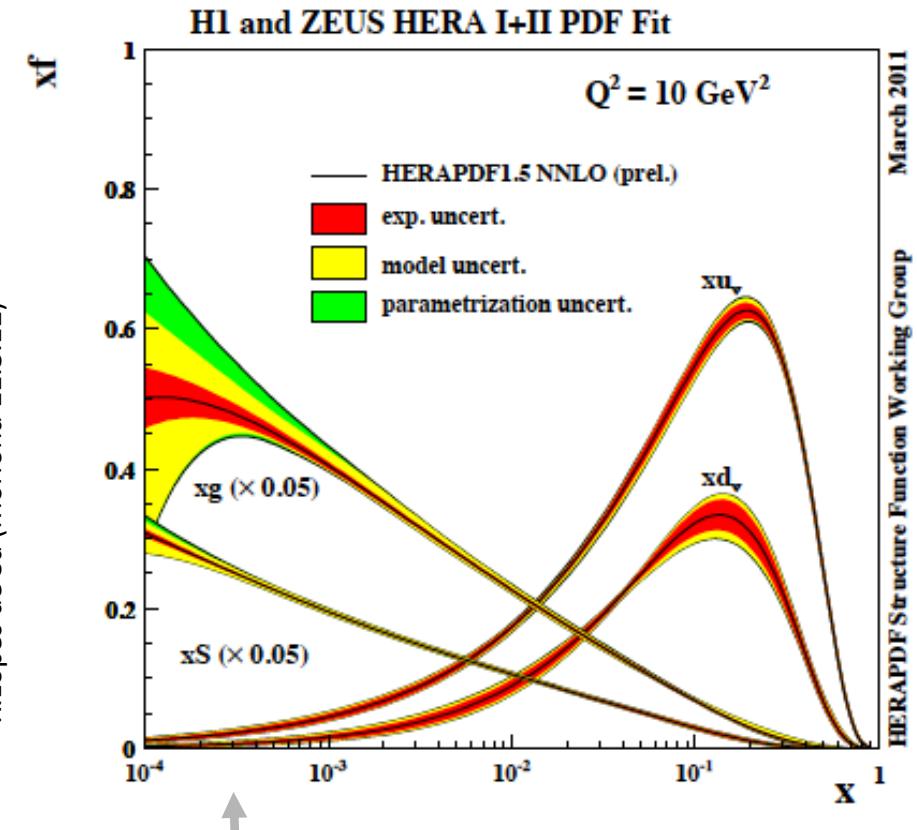
probable legacy plots/numbers

NNLO!



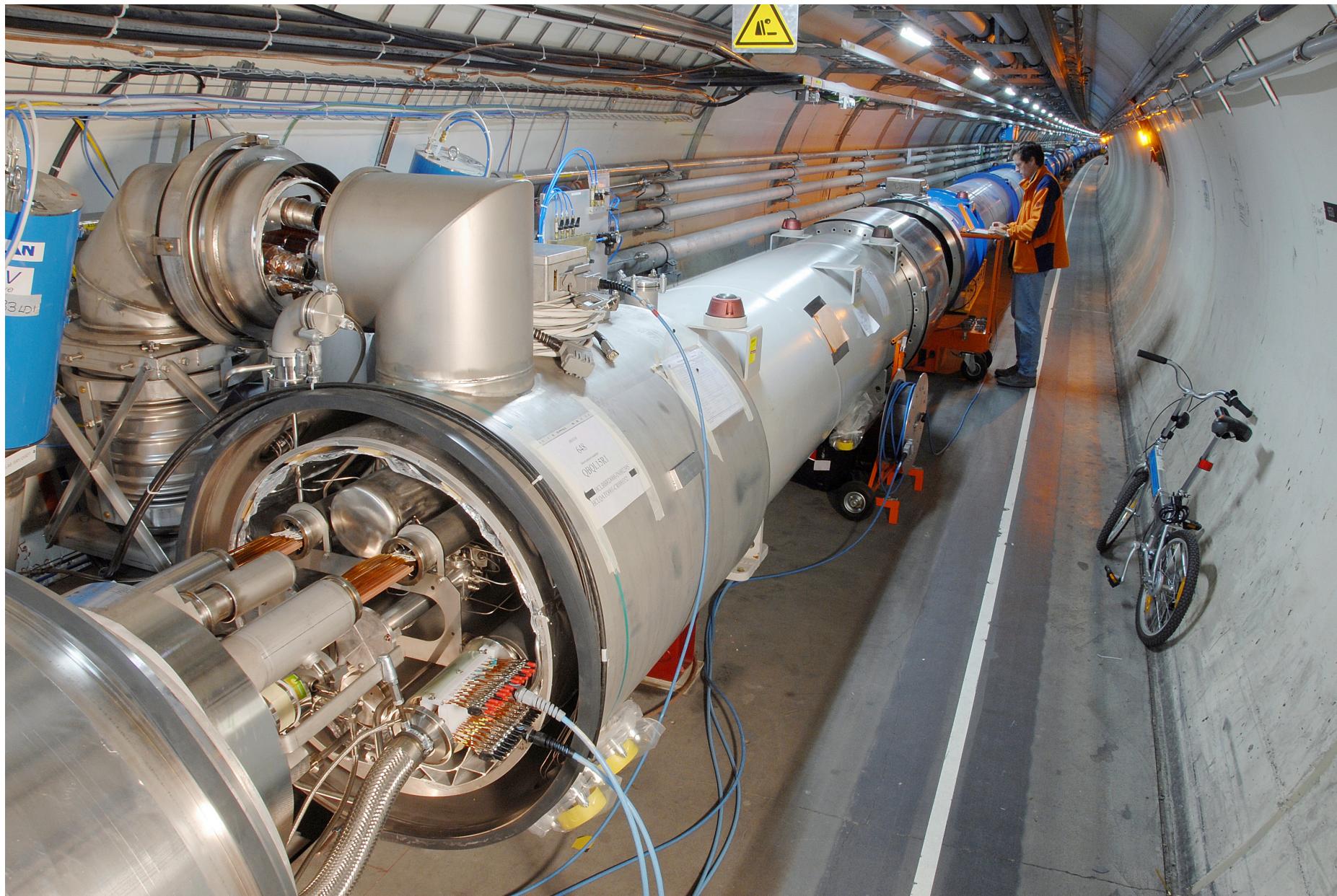
$M_Z = 91.1876 \pm 0.0021$ GeV (PDG2010)

R.Lopes de Sa (Moriond 11.3.12)



Practical end of HERA xg sensitivity

How can we use the LHC for ep/A?



The more expensive half of the LHeC is now built and works well

S.Russenschuck

Summary and Proposal to ECFA

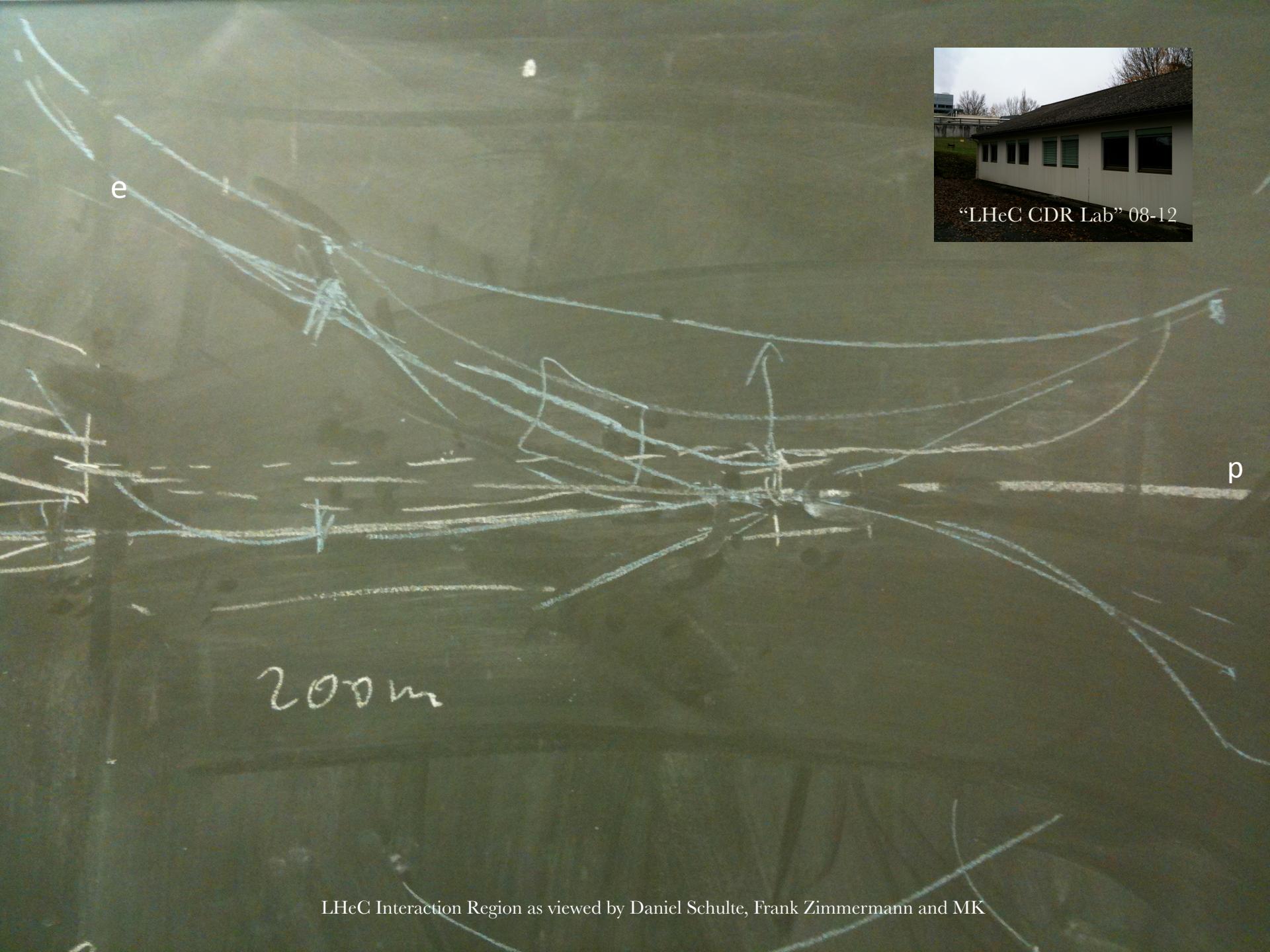
As an add-on to the LHC, the LHeC delivers in excess of 1 TeV to the electron-quark cms system. It accesses high parton densities ‘beyond’ what is expected to be the unitarity limit. Its physics is thus fundamental and deserves to be further worked out, also with respect to the findings at the LHC and the final results of the Tevatron and of HERA.

First considerations of a ring-ring and a linac-ring accelerator layout lead to an unprecedented combination of energy and luminosity in lepton-hadron physics, exploiting the latest developments in accelerator and detector technology.

It is thus proposed to hold two workshops (2008 and 2009), under the auspices of ECFA, with the goal of having a Conceptual Design Report on the accelerator, the experiment and the physics. A Technical Design report will then follow if appropriate.



"LHeC CDR Lab" 08-12



LHeC Interaction Region as viewed by Daniel Schulte, Frank Zimmermann and MK

Magnets

9 System Design	
9.1 Magnets for the Interaction Region	
9.1.1 Introduction	
9.1.2 Magnets for the ring-ring option	
9.1.3 Magnets for the linac-ring option	
9.2 Accelerator Magnets	
9.2.1 Dipole Magnets	
9.2.2 BINP Model	
9.2.3 CERN Model	
9.2.4 Quadrupole and Corrector Magnets	
9.3 Ring-Ring RF Design	
9.3.1 Design Parameters	
9.3.2 Cavities and klystrons	
9.4 Linac-Ring RF Design	
9.4.1 Design Parameters	
9.4.2 Layout and RF powering	
9.4.3 Arc RF systems	
9.5 Crab crossing for the LHeC	
9.5.1 Luminosity Reduction	
9.5.2 Crossing Schemes	
9.5.3 RF Technology	
9.6 Vacuum	
9.6.1 Vacuum requirements	
9.6.2 Synchrotron radiation	
9.6.3 Vacuum engineering issues	
9.7 Beam Pipe Design	
9.7.1 Requirements	
9.7.2 Choice of Materials for beampipes	
9.7.3 Beampipe Geometries	
9.7.4 Vacuum Instrumentation	
9.7.5 Synchrotron Radiation Masks	
9.7.6 Installation and Integration	
9.8 Cryogenics	
9.8.1 Ring-Ring Cryogenics Design	
9.8.2 Linac-Ring Cryogenics Design	
9.8.3 General Conclusions Cryogenics for LHeC	
9.9 Beam Dumps and Injection Regions	
9.9.1 Injection Region Design for Ring-Ring Option	
9.9.2 Injection transfer line for the Ring-Ring Option	
9.9.3 60 GeV internal dump for Ring-Ring Option	
9.9.4 Post collision line for 140 GeV Linac-Ring option	
9.9.5 Absorber for 140 GeV Linac-Ring option	
9.9.6 Energy deposition studies for the Linac-Ring option	
9.9.7 Beam line dump for ERL Linac-Ring option	
9.9.8 Absorber for ERL Linac-Ring option	

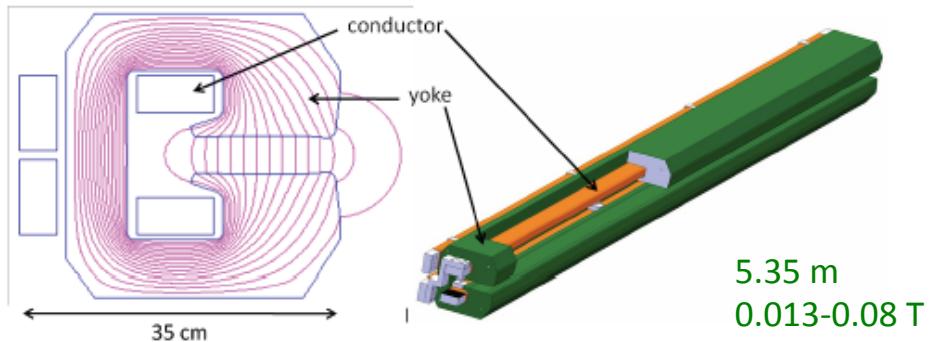


Fig. 2. Field lines and artistic view of a LHeC arc dipole.



TABLE II REPRODUCIBILITY OF MAGNETIC FIELD OVER 8 CYCLES

Model	Low field	High fields
Maximum Relative Deviation from Average		
Model 1 (NiFe steel)	$5 \cdot 10^{-5}$	$4 \cdot 10^{-5}$
Model 2 (Low carbon steel)	$6 \cdot 10^{-5}$	$6 \cdot 10^{-5}$
Model 3 (Grain oriented 3.5% Si steel)	$4 \cdot 10^{-5}$	$6 \cdot 10^{-5}$
Standard Deviation from Average		
Model 1 (NiFe steel)	$3 \cdot 10^{-5}$	$3 \cdot 10^{-5}$
Model 2 (Low carbon steel)	$4 \cdot 10^{-5}$	$5 \cdot 10^{-5}$
Model 3 (Grain oriented 3.5% Si steel)	$2 \cdot 10^{-5}$	$4 \cdot 10^{-5}$

Prototypes from BINP and CERN: function to spec's

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+ F. Wilczek (MIT)



We have done mistakes also

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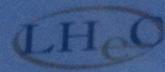
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DRAFT L0
Geneva, August 5, 2011
CERN report
ECFA report
NuPECC report
LHeC-Note-2011-001 GEN

M. Klein

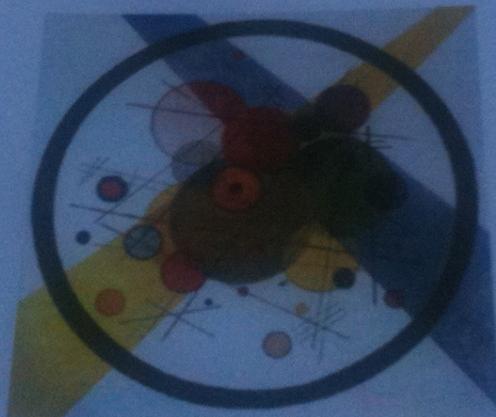


A Large Hadron Electron Collider at CERN

Report on the Physics and Design
Concepts for Machine and Detector

LHeC Study Group

THIS IS THE VERSION FOR REFEREEING, NOT FOR DISTRIBUTION



Draft LHeC Design Report
530 pages refereed →
Publication end of May 12

LHeC-Note-2011-003 GEN

To be submitted for publication

Most of plots from CDR.

“BFKL evolution and Saturation in DIS”



Circles in a circle
V. Kandinsky, 1923
Philadelphia Museum of Art



“Critical gravitational collapse”



Wassily Kandinsky

5d tiny black holes and perturbative saturation
Talk by A.S.Vera at LHeC Workshop 2008

Organisation for CDR

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Accelerator Design

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John Dainton (Liverpool)

Interaction Region

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Pierre van Mechelen (Antwerpen)

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Precision QCD and Electroweak

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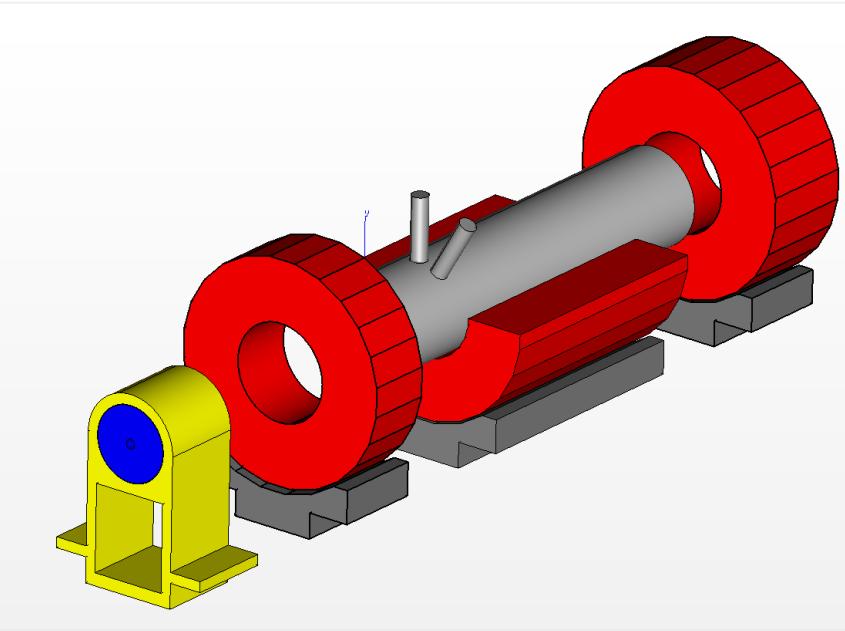
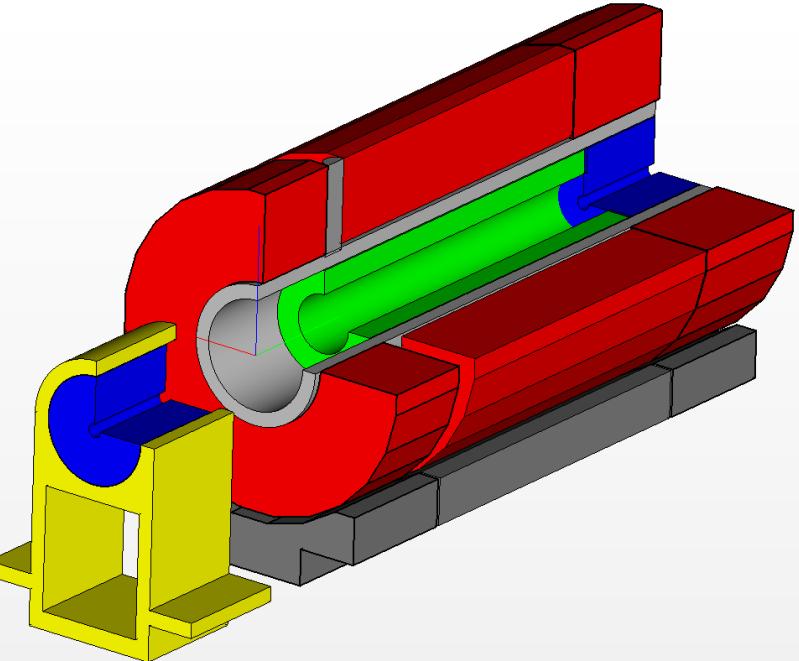
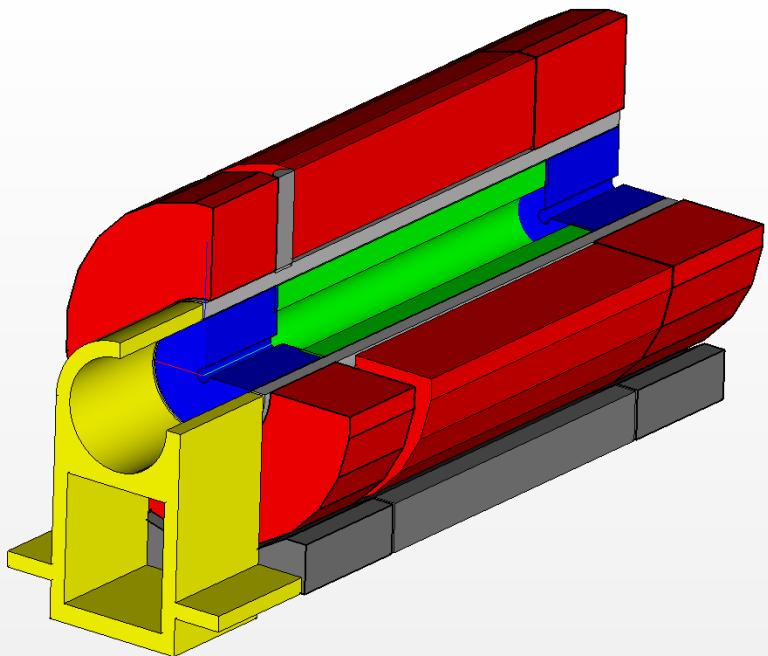
Alan Martin (Durham)

Physics at High Parton Densities

Alfred Mueller (Columbia)
Raju Venugopalan (BNL)
Michele Arneodo (INFN Torino)

In response to ECFA:

Study of Installation of the LHeC Detector A.Gaddi/A.Herve,
Cf talk of Andrea at this workshop





A Large Hadron Electron Collider at CERN

Report on the Physics and Design
Concepts for Machine and Detector

LHeC Study Group



Submitted to J.Phys. G

The CDR is submitted to the arXiv and to J.Phys.G

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- [947] H. Mais and G. Ripken Tech. Rep. 83-62, DESY, 1983. Modern notation: replace \vec{n} by \vec{n}_0 .

LHeC Study Group

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THANK YOU

Candidates for Surprises and Discoveries

PDFs ($t, s, q\bar{q}$, val, xg)
Odderon
Instanton
(no) saturation, QCD
QGP initial state

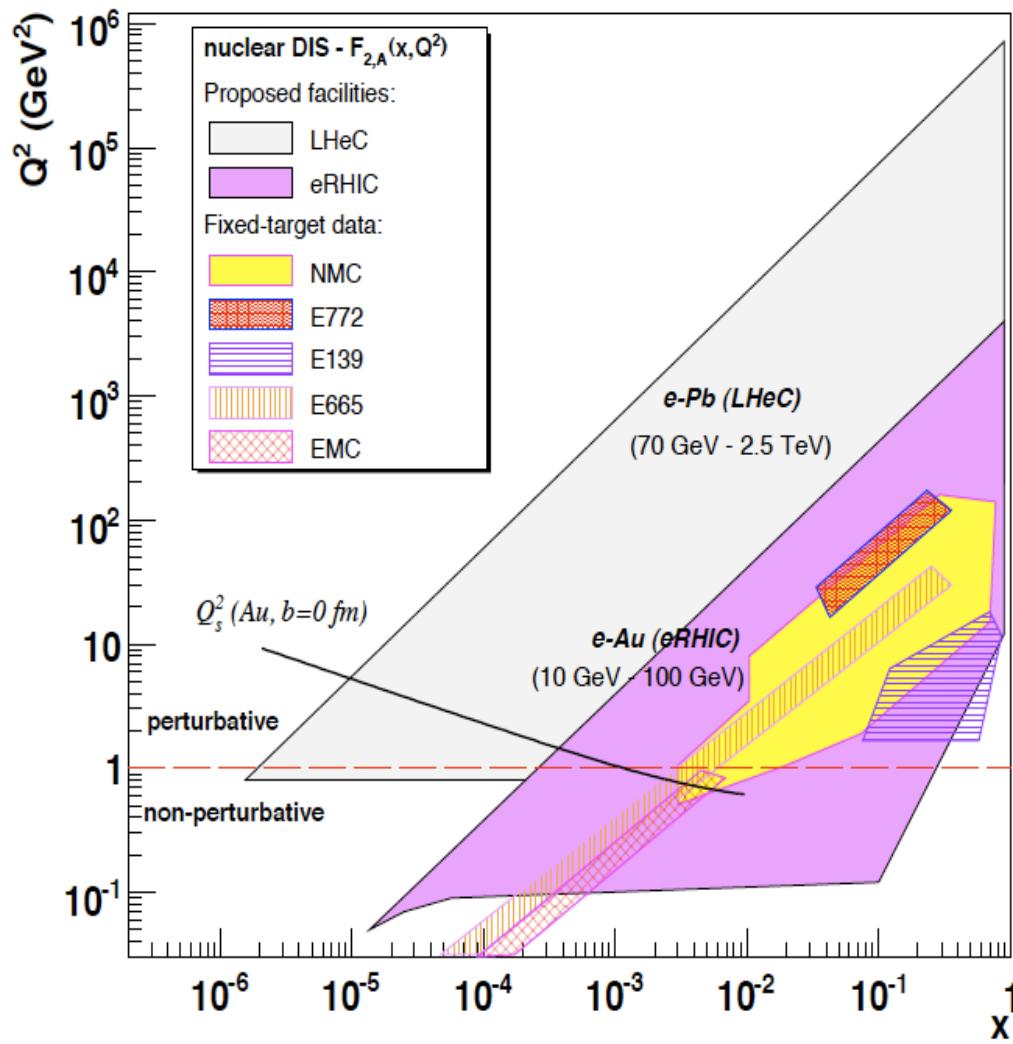
The study of deep inelastic ep scattering is important for the investigation of the nature of the Pomeron and Odderon, which are Regge singularities of the t -channel partial waves $f_j(t)$ in the complex plane of the angular momentum j . The Pomeron is responsible for a growth of total cross sections with energy. The Odderon describes the behaviour of the difference of the cross sections for particle-particle and particle-antiparticle scattering which obey the Pomeranchuk theorem. In perturbative QCD, the Pomeron and Odderon are the simplest colorless reggeons (families of glueballs) constructed from two and three reggeized gluons, respectively. Their wave functions satisfy the generalized BFKL equation. In the next-to-leading approximation the solution of the BFKL equation contains an infinite number of Pomerons and to verify this prediction of QCD one needs to increase the energy of colliding particles. In the $N=4$ supersymmetric generalization of QCD, in the t'Hooft limit of large N_c , the BFKL Pomeron is equivalent to the reggeized graviton living in the 10-dimensional anti-de-Sitter space. Therefore, the Pomeron interaction describing the screening corrections to the BFKL predictions, at least in this model, should be based on a general covariant effective theory being a generalization of the Einstein-Hilbert action for general relativity. Thus, the investigation of high energy ep scattering could be interesting for the construction of a non-perturbative approach to QCD based on an effective string model in high dimensional spaces.

Lev Lipatov in the CDR...

Ultra high precision (detector, e-h redundancy) - new insight
Maximum luminosity and much extended range - rare, new effects
Deep relation to (HL-) LHC (precision+range) - complementarity
→ **LHeC brings a substantial enrichment of LHC physics**

Factorization pp- ep
LQs, RPV SUSY
 e^*
Higgs CP
 α_s indeed small (GUT)

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 ?

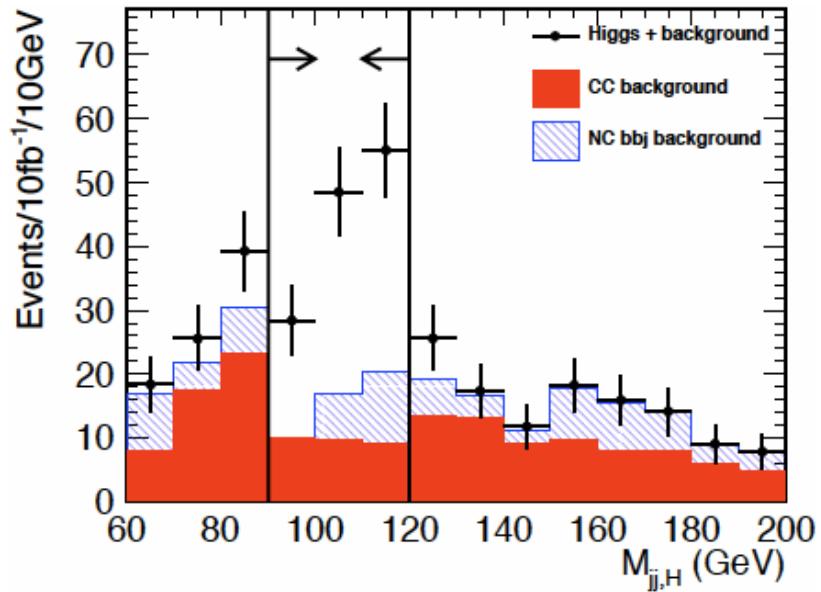
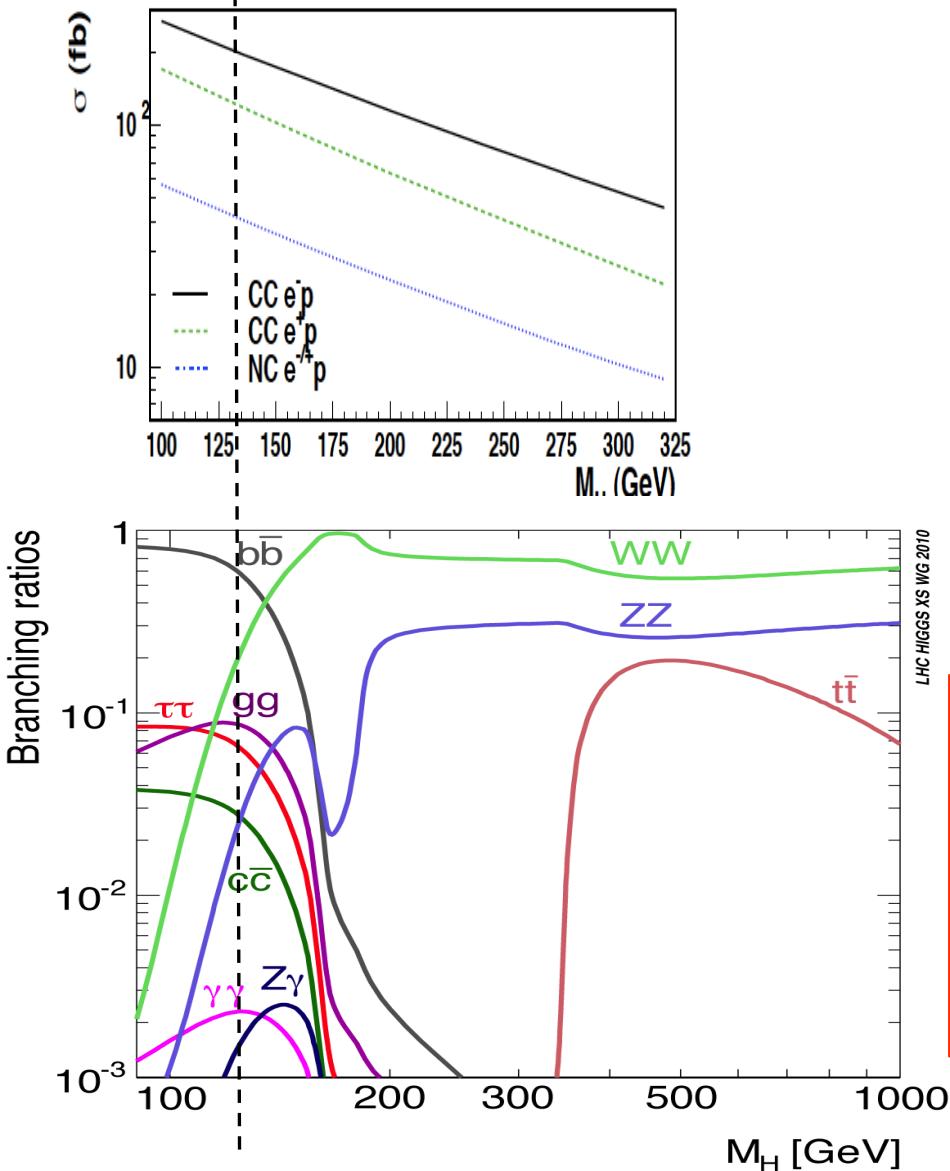
Diffraction in eA scattering

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)

Higgs Boson



Higgs is light (or absent), CC: $WW \rightarrow H \rightarrow ll$
 CP even: SM, CP odd: nonSM, mixture?

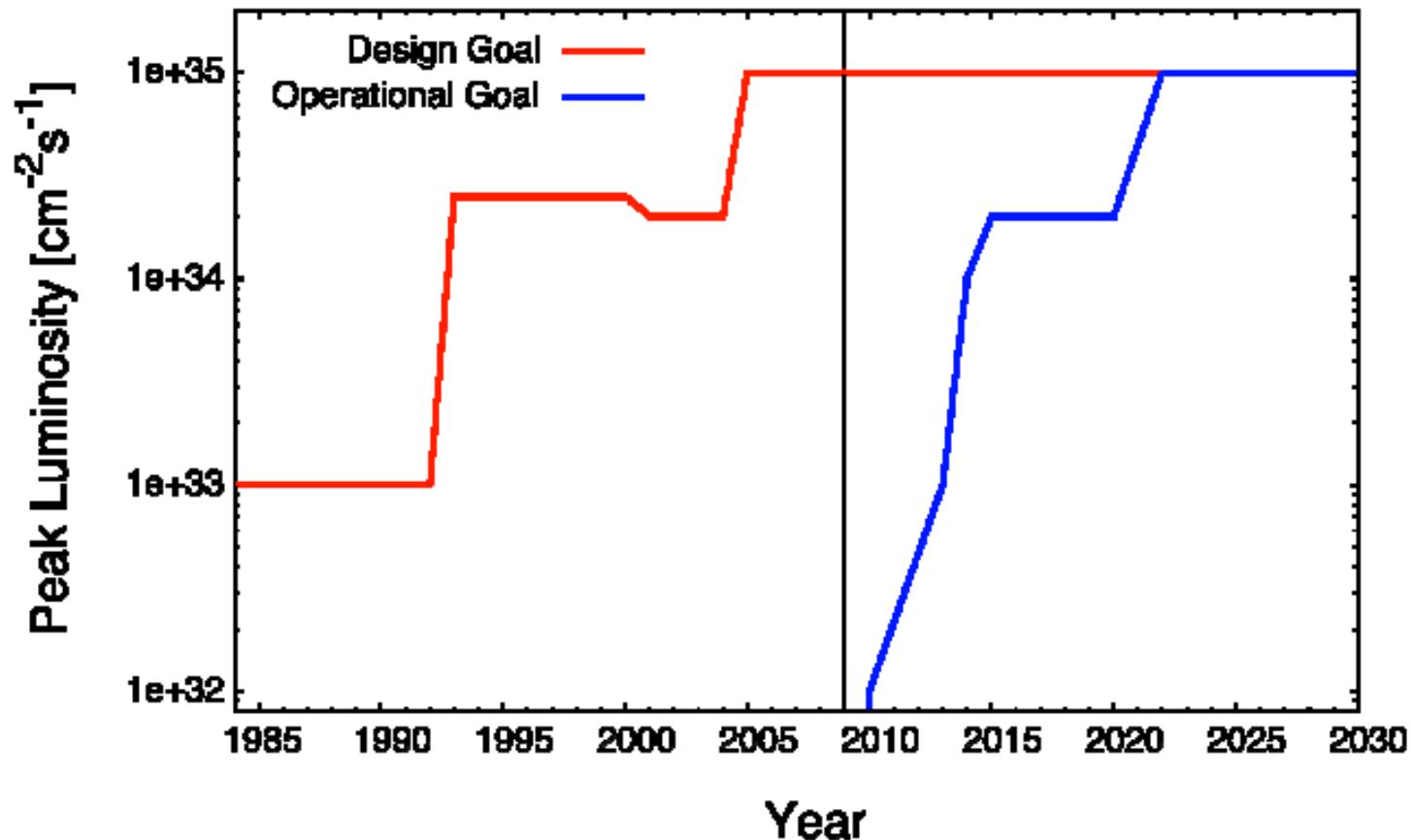
Process determines much of detector acceptance and calibration and b tagging ability (also for single top)

$H \rightarrow bb$ 400 events:
 For 100 fb^{-1} with 60 GeV polarised electron-proton CC

If the Higgs exists or sth similar at ~ 125 GeV, it will
 Become important to reach a luminosity larger than 10^{33}

Luminosity wishes develop with time ..

R.Assmann, Chamonix 2010



→ Nice increase in design luminosity for the experiments...

CDR Model

2008-2012

Scientific
Advisory
Committee

CERN
ECFA
NuPECC

Steering Group

Accelerator	Interaction Region	Detector	New Physics	QCD and Electroweak	High Parton Densities
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Organisation of the LHeC Conceptual Design Report

R+D Tasks for LHeC

2012-2015

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

on Magnet R+D for LHeC + HE-LHC

Magnet Development at CERN

LHeC

	LHeC RR dipole prototype	CRISP and fast cycled SC magnets	MQXC R&D	EUCARD FReSCa-II	DS 11 T MB program	US-LARP IR quadrupole program	EUCARD HTS insert	EUCARD2 HTS model	activated SC magnets handling for	Comments
Low field resistive magnets	field quality and reproducibility	X								demonstrated
	operating cost		X							tests planned in 2012
	integration in the LHC tunnel								X	study launched in 2012 (LS1)
IR magnets	large aperture		X		X					results in 2012...2014
	large gradient				X					
	heat removal	X	X							results in 2012
co-activities and tunnel works								X		integration study and models (BINP); schedule revision

HE-LHC

Very high field magnets	15 T dipole outsert			X						deliverable Q1 2014
	5 T dipole insert					X	X			EuCARD2 proposal
	high gradient quadrupoles				X					US-LARP technology demonstration by 2014
	magnet protection		X	X	X					
	heat loads and removal	X	X							dedicated model tests
	field quality			X	X		X			
Pulsed SC magnets	quench performance and margin	X								
	low-loss cables	X								
Transfer lines										options reviewed at HE-LHC workshop in Malta, 2010
Material availability and cost			X	X	X	x	x			
Installation in 2030									X	study launched in 2012 (LS1)



**Best
Western®**

Welcome to Chavannes 14/15.6.2012

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13-11-2010

Societe / Salle

Horaires

LHeC

Odyssee

09:00
- 12:00



BOIRAUD MINGUET

Venus - 2. floor

09:00
- 18:00



PATTES TENDUES

Mars

08:00
- 18:00



CDR Overview+Celebration, Next Steps towards 2015, how to enjoy EU