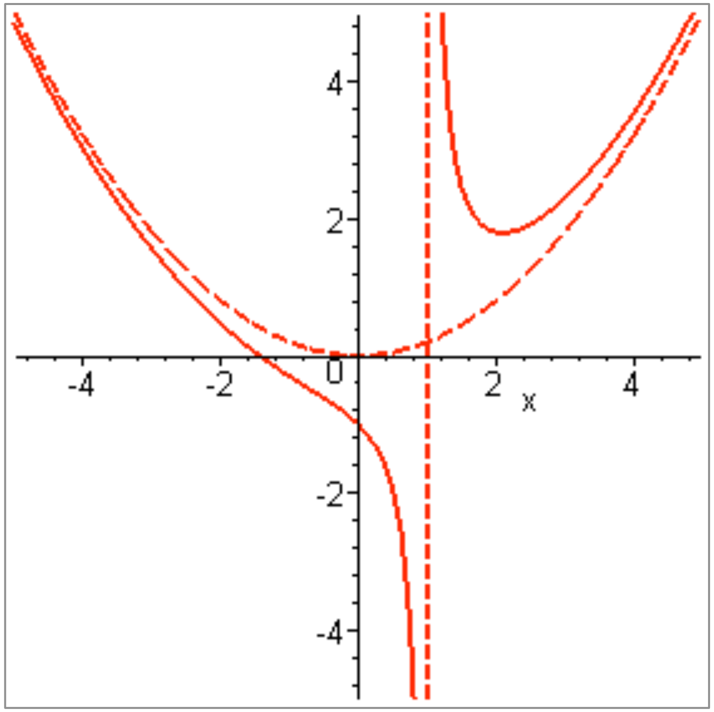
Higgs and eA Physics with the LHeC



A few thoughts on asymptotics in space and time, or
why should pp-ep and AA-pA and eA meet at the LHC?

Max Klein, University of Liverpool, Seminar at the University of Birmingham, November 20th, 2013

Focus on

LHC and some of its Physics
Characteristics of the LHeC
Physics Highlights of ep/eA
Prospects and Detector

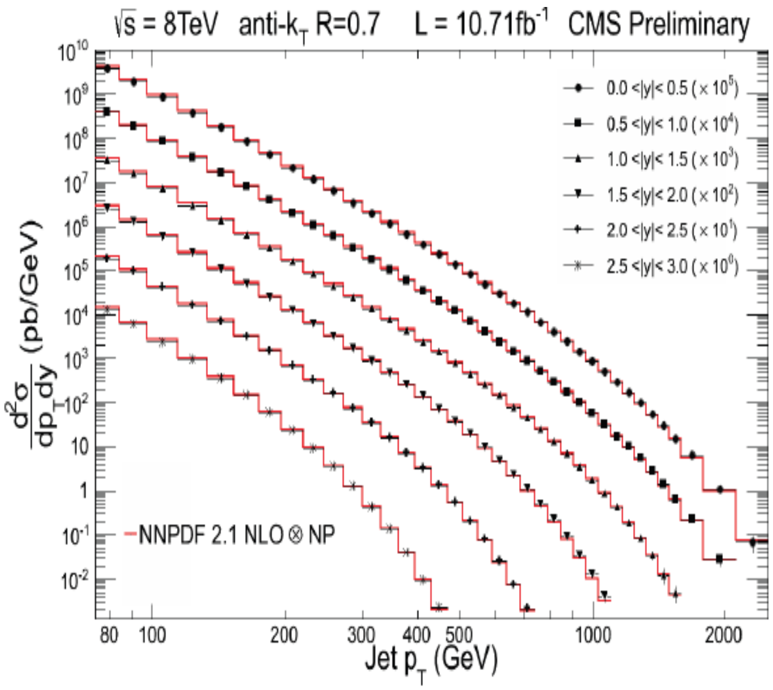
http://cern.ch/lhec

Next Workshop: January 20/21,2014

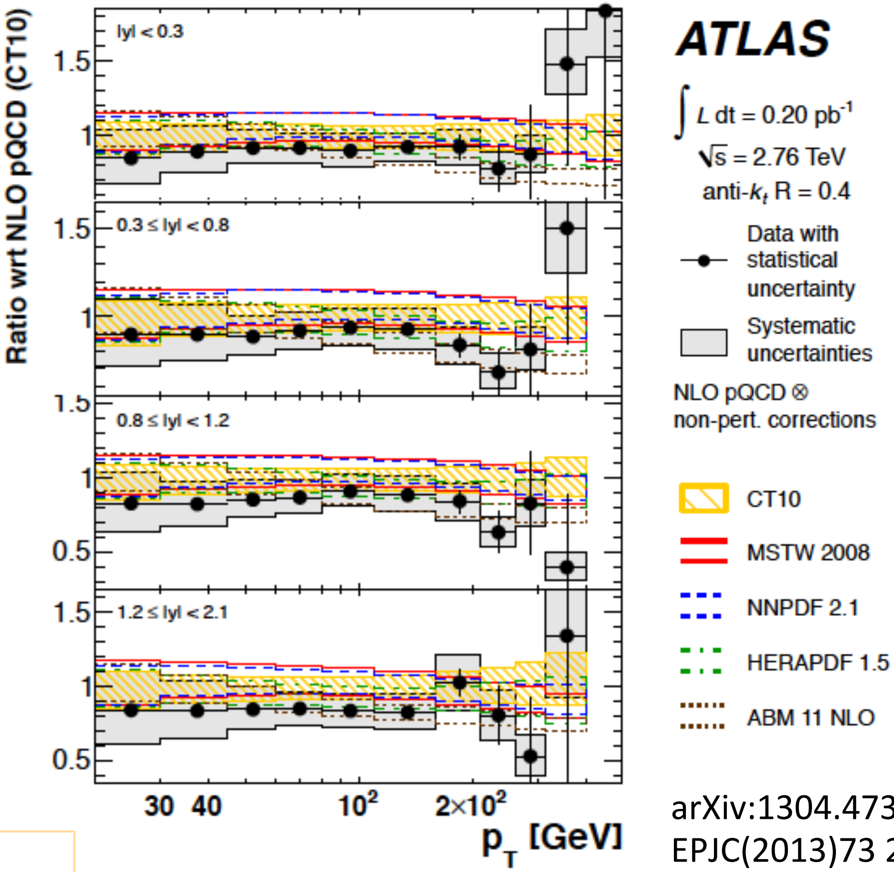
https://indico.cern.ch/conferenceDisplay.py?confId=278903

QCD at the LHC

Jets, Photons, Vector Bosons, Vector Bosons+Jets, Soft QCD [lowx, MPI, diffraction]



CMS-PAS-SMP-12-02



arXiv:1304.4739
EPJC(2013)73 2509
.. extends to 4.4

ATLAS-CONF-2013-041:R3/2
α_s = .111 +- .006 +0.016-0.003 (thy)

Inclusive jet cross sections and their energy dependent ratios well described by NLO QCD

From opening talk “QCD at the LHC and Beyond”, MK, DESY, 9/2013

Possible QCD Developments

AdS/CFT

Instantons

Odderons

Non pQCD

QGP

N^{k}LO

Resummation

Non-conventional PDFs …

Breaking of Factorisation

Free Quarks

Unconfined Color

New kind of coloured matter

Quark substructure

New symmetry embedding QCD

QCD may break .. (Quigg DIS13)

QCD is the richest part of the Standard Model Gauge Field Theory and will (have to) be developed much further, on its own and as background

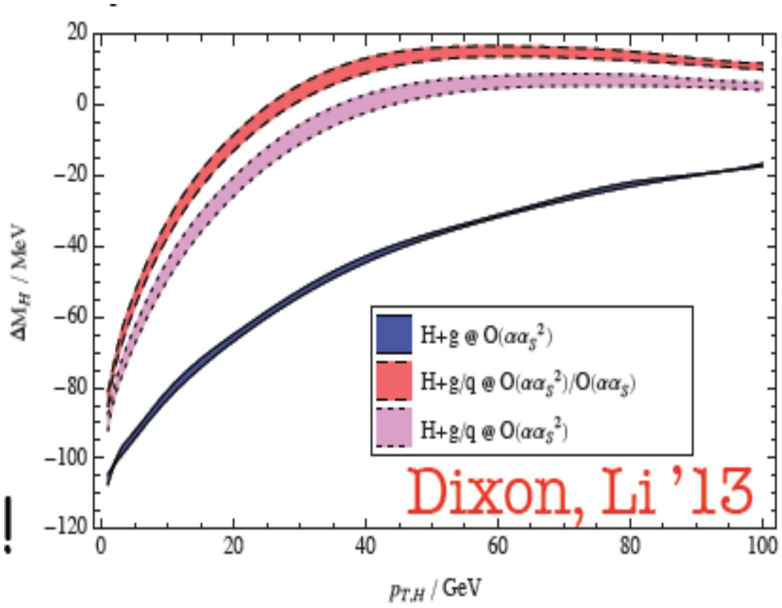
Huge success of the HEP Community

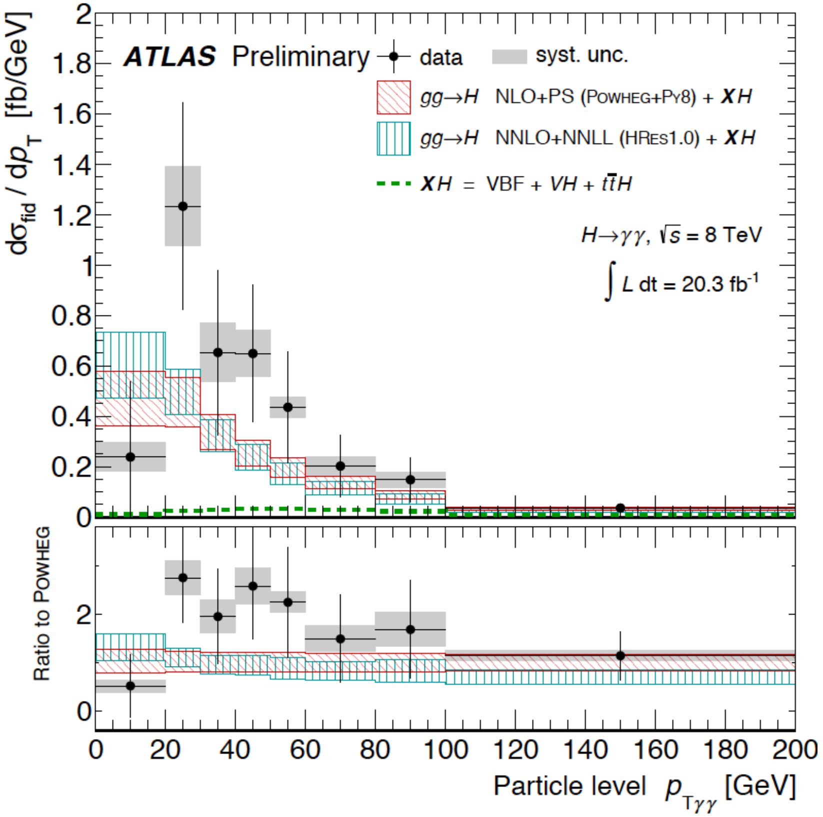
4.7.2012 greeting Melbourne from CERN

“The Higgs: So simple and yet so unnatural” G.Altarelli,arXiv:1308.0545

Higgs and QCD at the LHC

The first pt measurement of H:



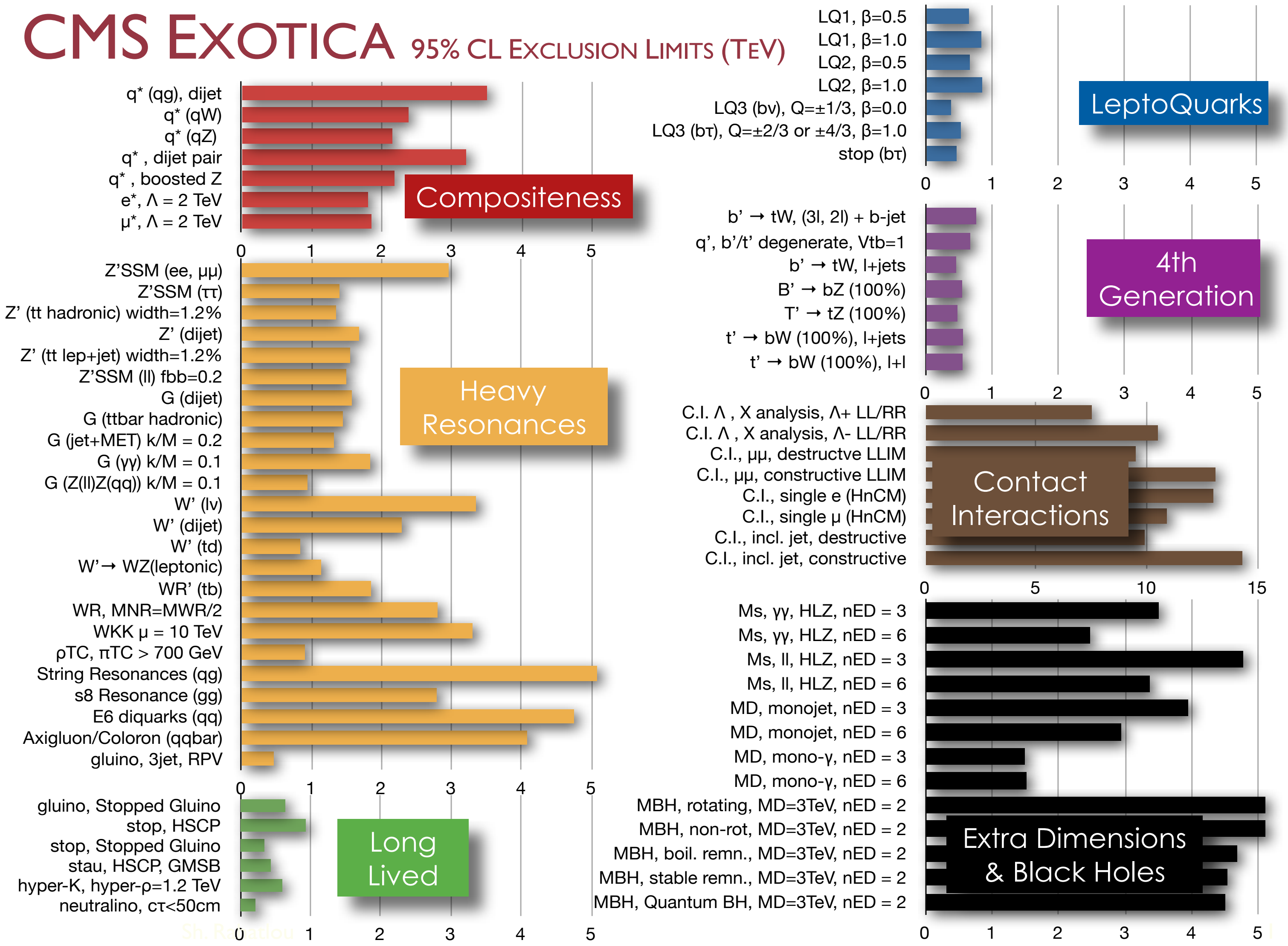


ATLAS-CONF-2013-072

cf C. Grojean at EPS Stockholm

Small width (4 MeV) results in pt(H) dependent reduction of $M_{\gamma\gamma}$. Very high precision required to verify this and thus access Higgs width at the LHC..

Searches for New Physics BSM

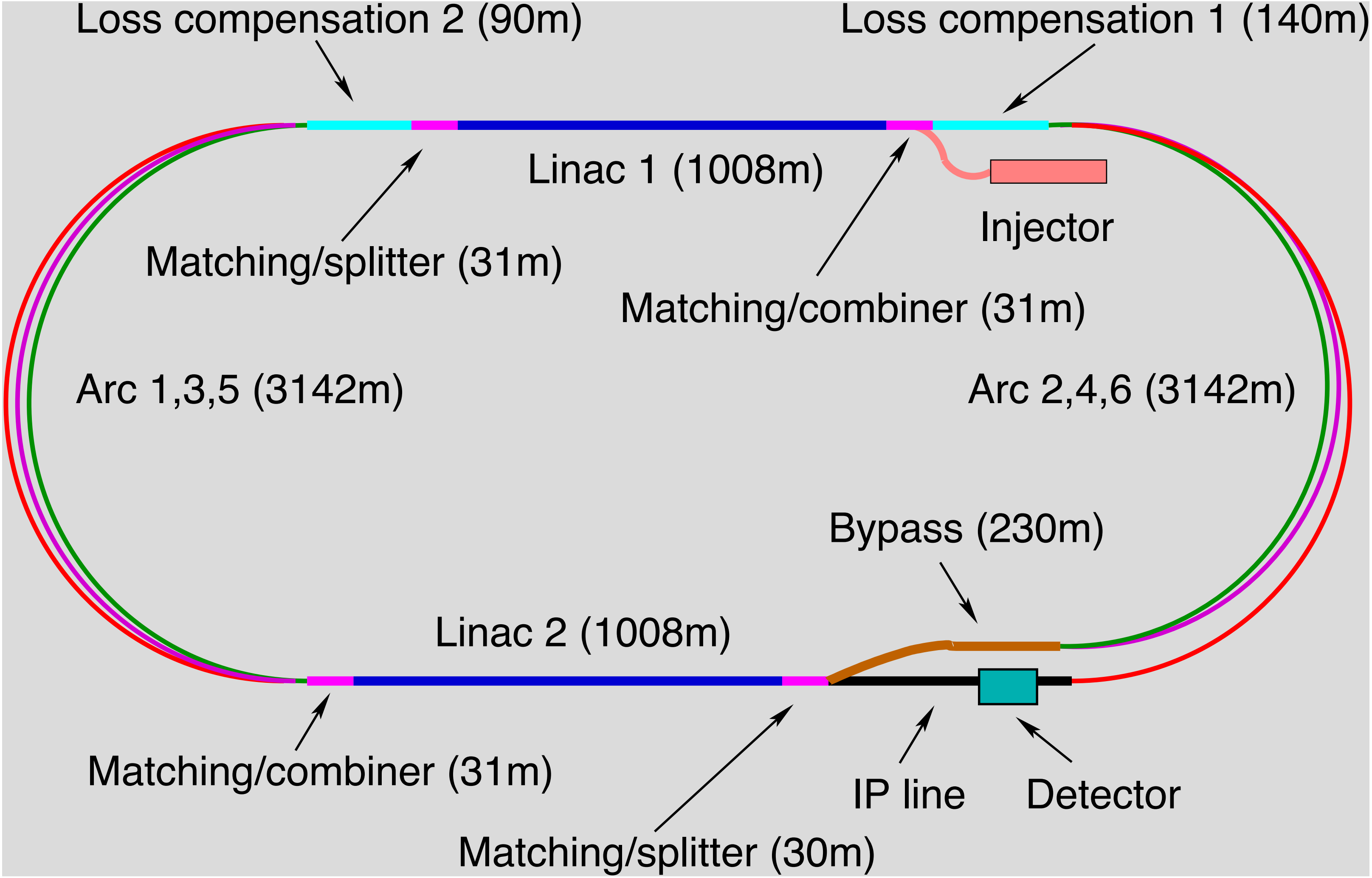


HL-LHC Upgrade Ingredients

- Geometric reduction factor ➔ $\beta^* \geq 10$ cm & Crab Cavities
- Triplet aperture ➔ New large aperture triplet magnets
- Bunch intensity ➔ $N_b = 2.2\ 10^{11}$ (limited in LHC by e-cloud)
  ➔ injector complex upgrade prerequisite for HL-LHC!!!
- Event pile-up in detectors ➔ luminosity leveling
- Beam Losses and Radiation ➔ shielding, Cryo upgrade & relocation of electronics and PC
- Collective effects and impedance ➔ Collimator Upgrade
- Electron cloud effect ➔ beam scrubbing & feedback

LHeC

LHeC - electron beam upgrade



JPhysG:39(2012)075001, arXiv:1206.2913 http://cern.ch/lhec

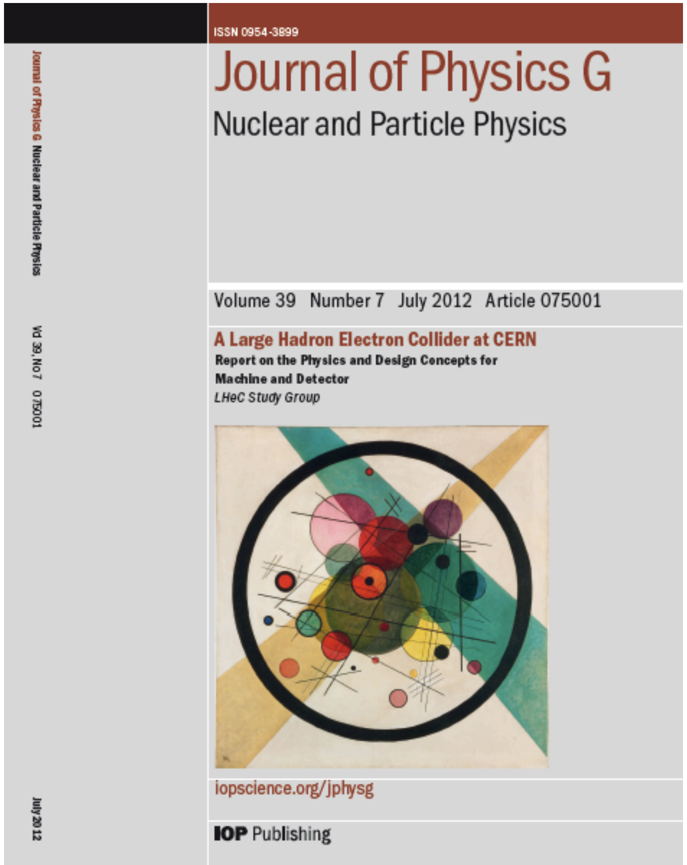
CDR: default design. 60 GeV. $L=10^{33}cm^{-2}s^{-1}$, P< 100 MW → ERL, synchronous ep/pp

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

it has been done before

Courtesy F.Zimmermann

Design Report 2012



ISSN 0954-3899

Journal of Physics G

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

iopscience.org/jphysg

IOP Publishing

Journal of Physics G Nuclear and Particle Physics Vol 39, No 7 075001 July 2012

arXiv:1206.2913 http://cern.ch/lhec

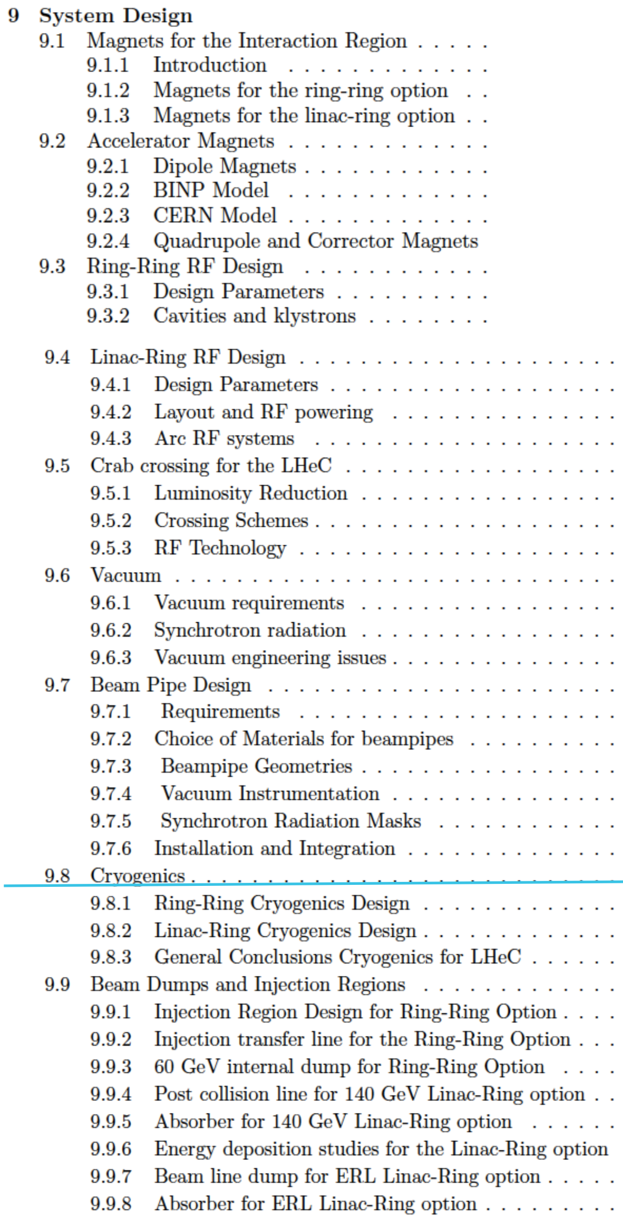
CERN Referees

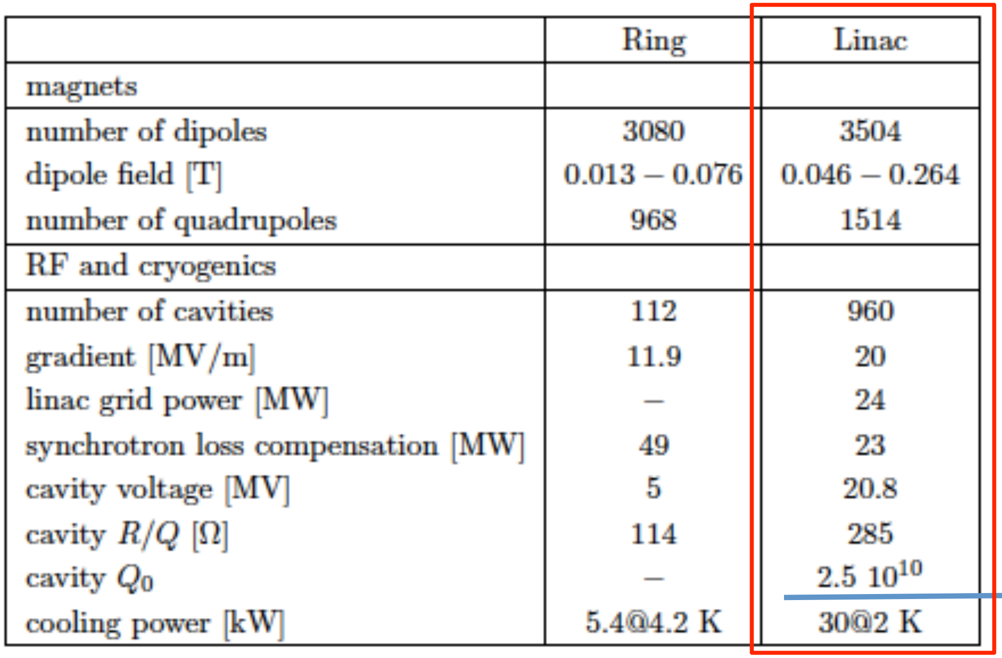
Ring Ring Design
Kurt Huebner (CERN)
Alexander N. Skrinsky (INP Novosibirsk)
Ferdinand Willeke (BNL)
Linac Ring Design
Reinhard Brinkmann (DESY)
Andy Wolski (Cockcroft)
Kaoru Yokoya (KEK)
Energy Recovery
Georg Hoffstaetter (Cornell)
Ilan Ben Zvi (BNL)
Magnets
Neil Marks (Cockcroft)
Martin Wilson (CERN)
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)

The theory of DIS has developed much further: J.Blümlein Prog.Part.Nucl.Phys. 69(2013)28
DIS is an important part of particle physics: G.Altarelli, 1303.2842, S.Forte, G.Watt 1301:6754

Chapter 9 of CDR

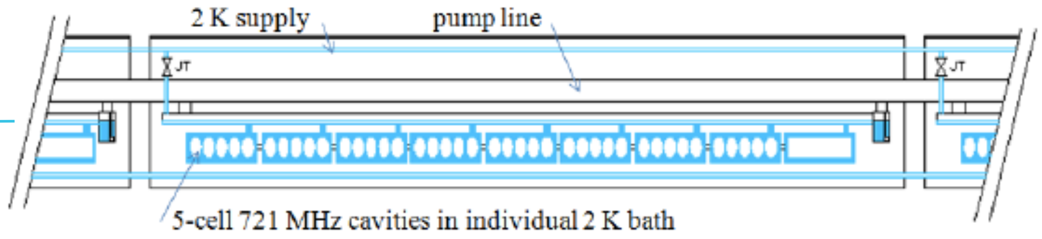
Components and Cryogenics



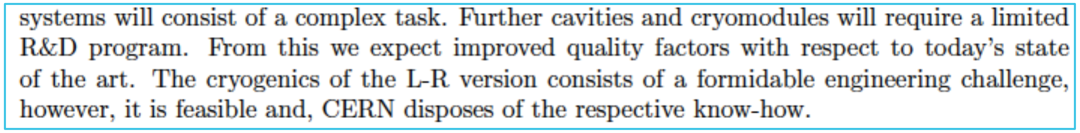


	Ring	Linac
magnets		
number of dipoles	3080	3504
dipole field [T]	0.013 – 0.076	0.046 – 0.264
number of quadrupoles	968	1514
RF and cryogenics		
number of cavities	112	960
gradient [MV/m]	11.9	20
linac grid power [MW]	–	24
synchrotron loss compensation [MW]	49	23
cavity voltage [MV]	5	20.8
cavity R/Q [Ω]	114	285
cavity Q_0	–	2.5 10^{10}
cooling power [kW]	5.4@4.2 K	30@2 K

Jlab:
4 10^{11}



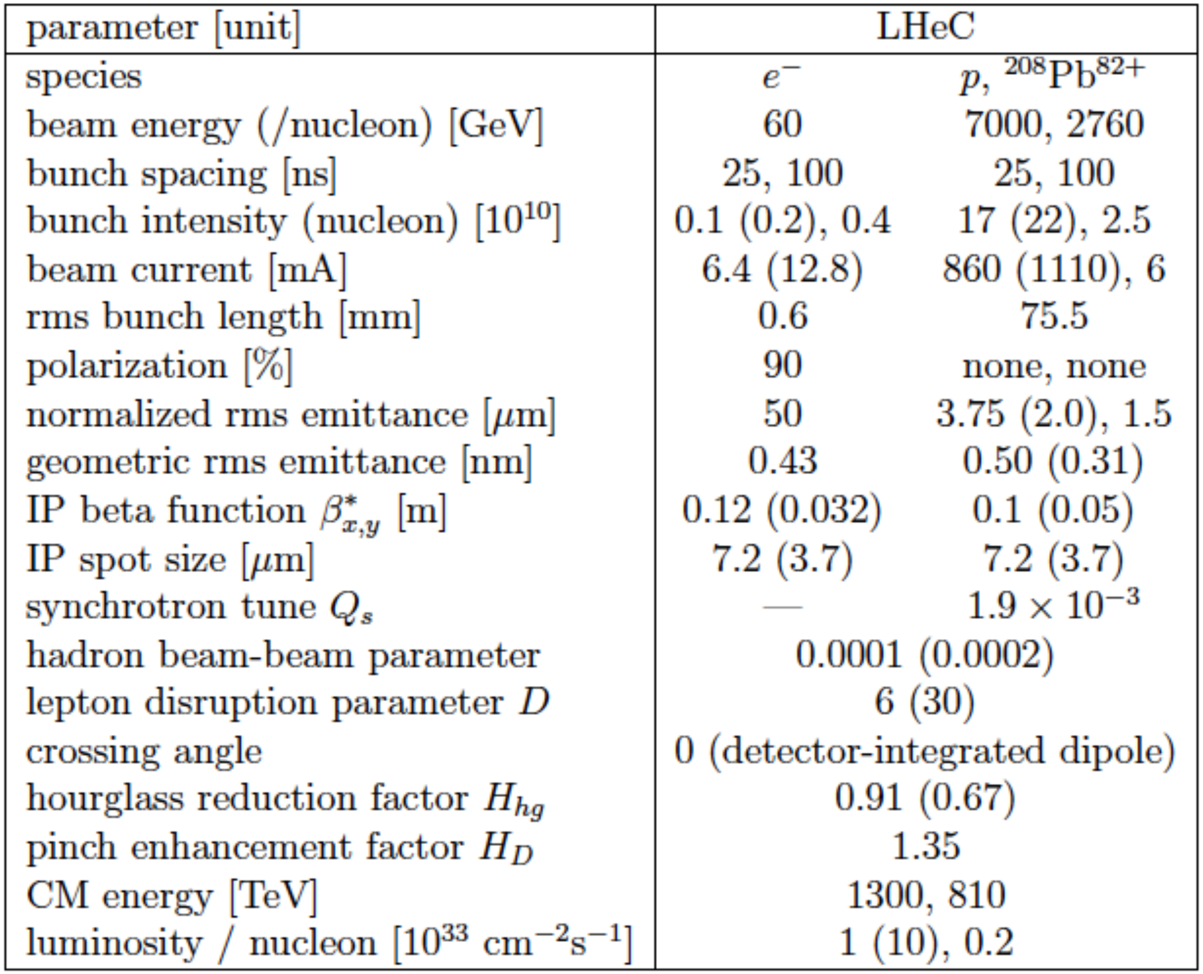
Need to develop LHeC cavity (cryo-module)



systems will consist of a complex task. Further cavities and cryomodules will require a limited R&D program. From this we expect improved quality factors with respect to today's state of the art. The cryogenics of the L-R version consists of a formidable engineering challenge, however, it is feasible and, CERN disposes of the respective know-how.

from CDR LHeC

LHeC at $10^{33(34)}$ Luminosity



parameter [unit]	LHeC	
species	e^-	p, $^{208}\text{Pb}^{82+}$
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	

Key issues:

p brightness

10 mA Ie

Small beta*

High ERL eff

Keep power
P limited

$L \sim P/E_e$

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 and PDG14 F Zimmermann

Steps towards an LHeC ERL Test Facility at CERN

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

Contribution to IPAC13

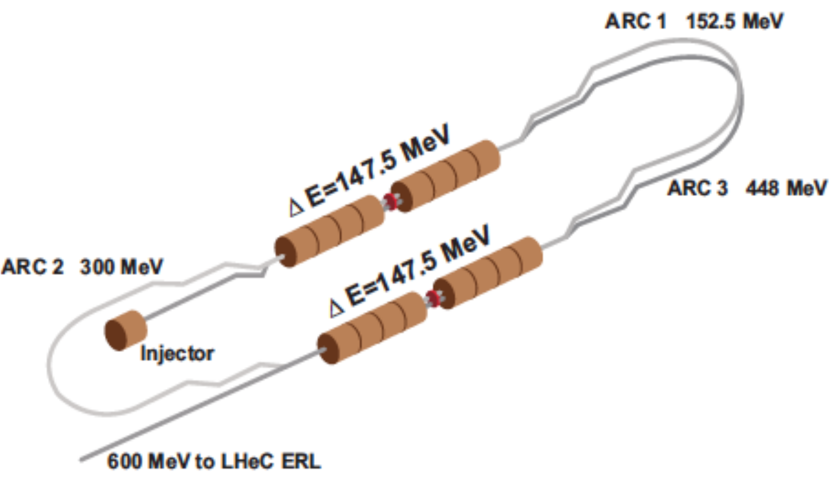


Figure 2: Consequent upgrade to LHeC pre-accelerator. By modifying the machine backleg to include a second full cryomodule, the recirculator can deliver higher beam energy of 600 MeV.

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

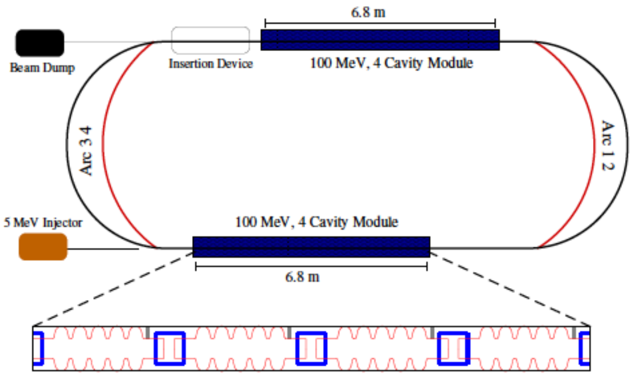
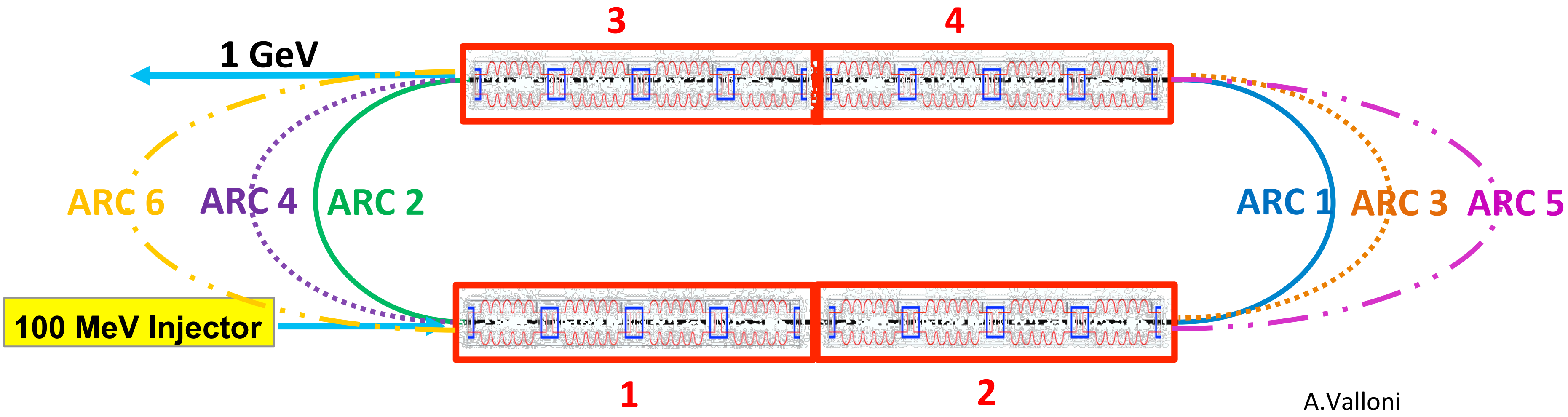


Table 3: Future ERLs for electron-hadron colliders

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

Current Test Facility Design (Final Stage)



A.Valloni

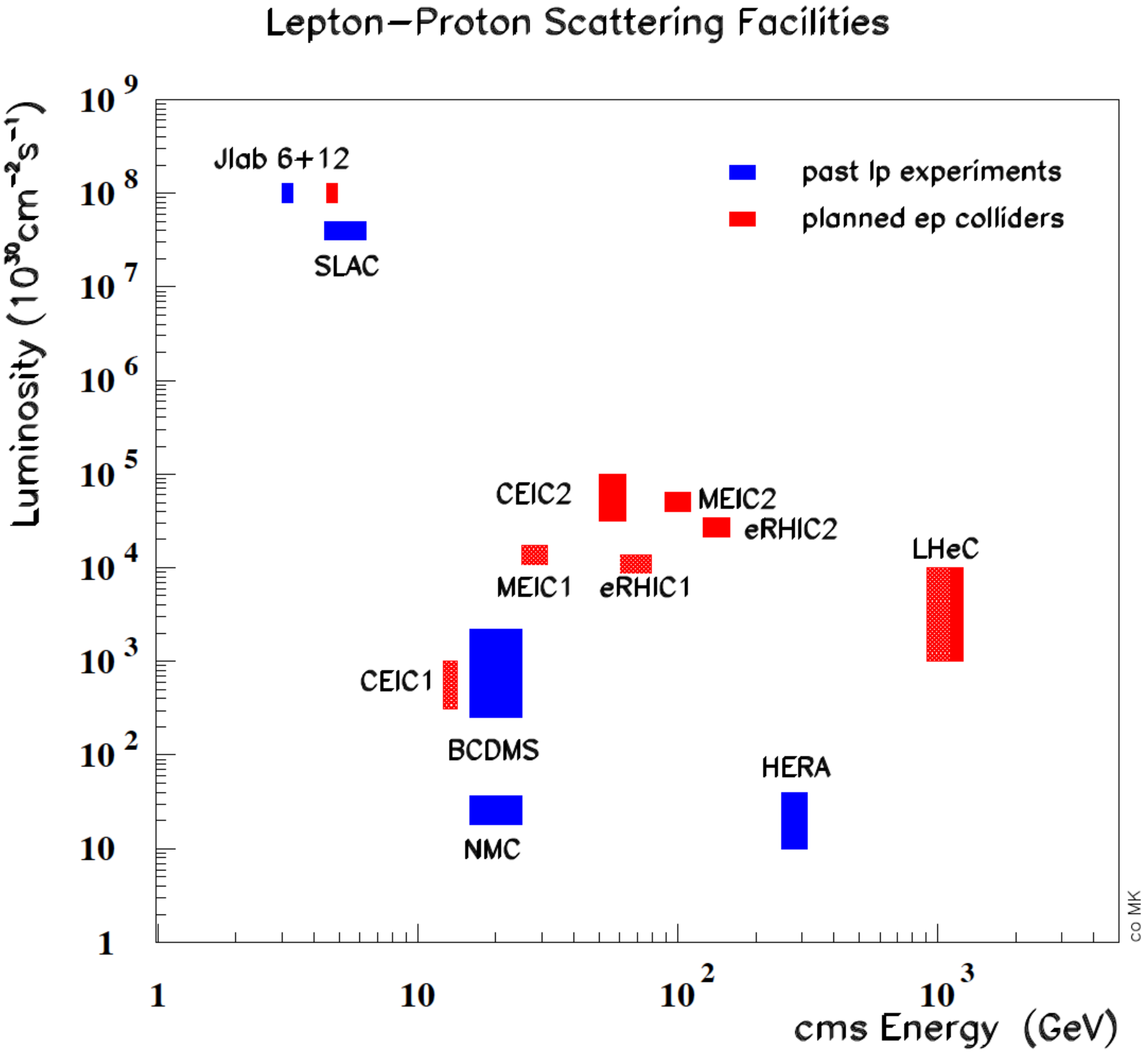
[(75 MeV*2)*2]*3 + 100 MeV = 1000 MeV

Daresbury workshop: January 2013: 802 MHz, basic parameters reviewed

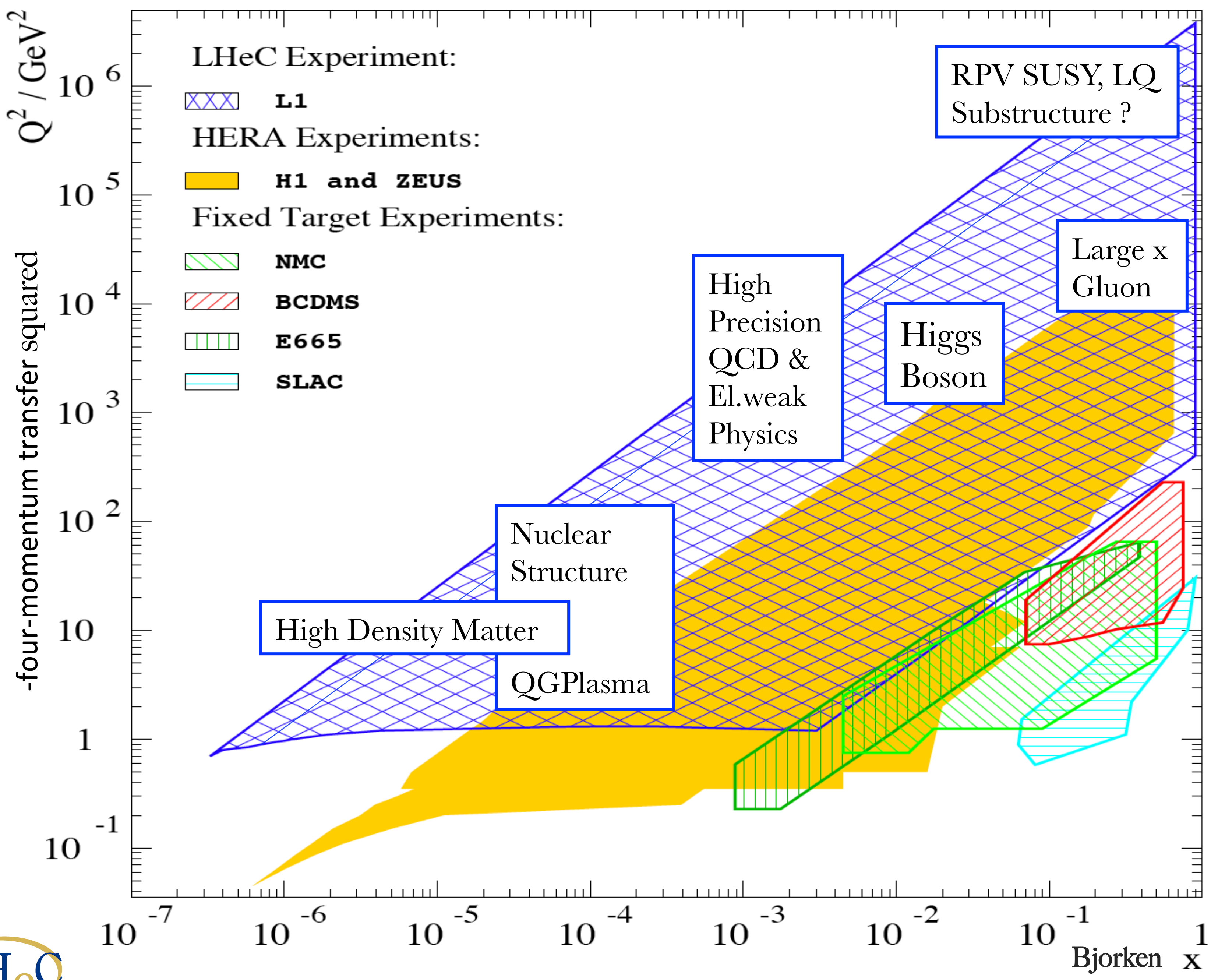
Strong international interest in collaborating:
AsTEC, IHEP Beijing, BINP Novosibirsk, BNL, Cornell, Jefferson Lab, U Mainz..

First step endorsed recently: Development of 2 cavity cryo modules by 2016 and design of the testfacility by 2014 (CDR) and 2016 (“TDR”)

Physics

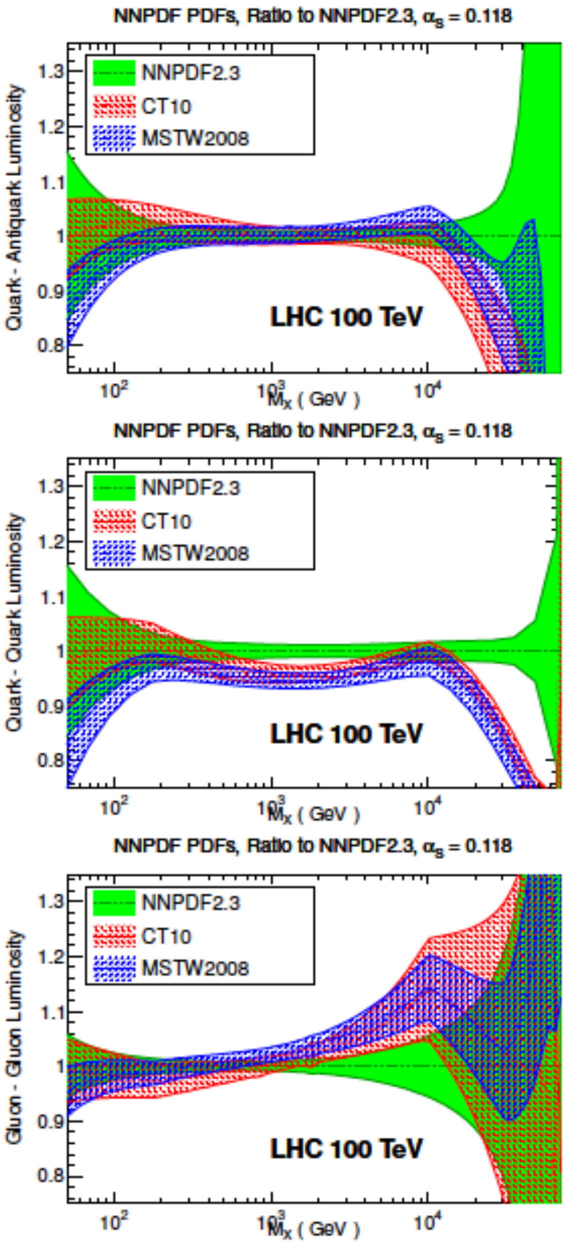


Energy frontier deep inelastic scattering: Higgs, top, searches, PDFs low x, nuclear matter. These and further physics topics require maximum beam energy and high luminosity.

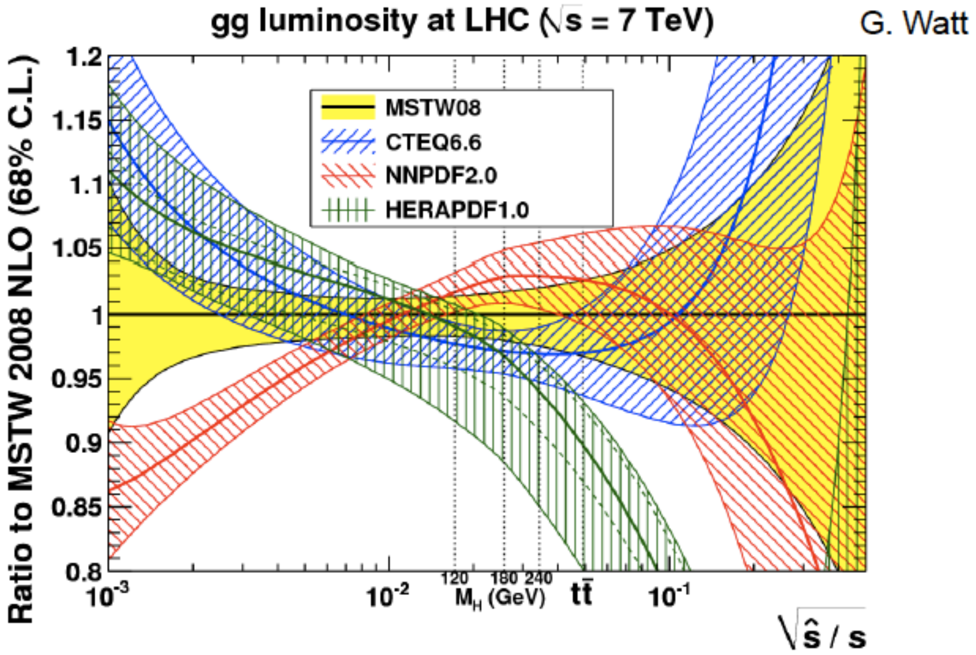

Q^2 / GeV^2
-four-momentum transfer squared
10^6
10^5
10^4
10^3
10^2
10
1
10^{-1}
10^{-7}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
Bjorken x
LHeC Experiment:
L1
HERA Experiments:
H1 and ZEUS
Fixed Target Experiments:
NMC
BCDMS
E665
SLAC
RPV SUSY, LQ
Substructure ?
Large x
Gluon
High
Precision
QCD &
El.weak
Physics
Higgs
Boson
Nuclear
Structure
High Density Matter
QGPlasma

co MK

Parton Distributions

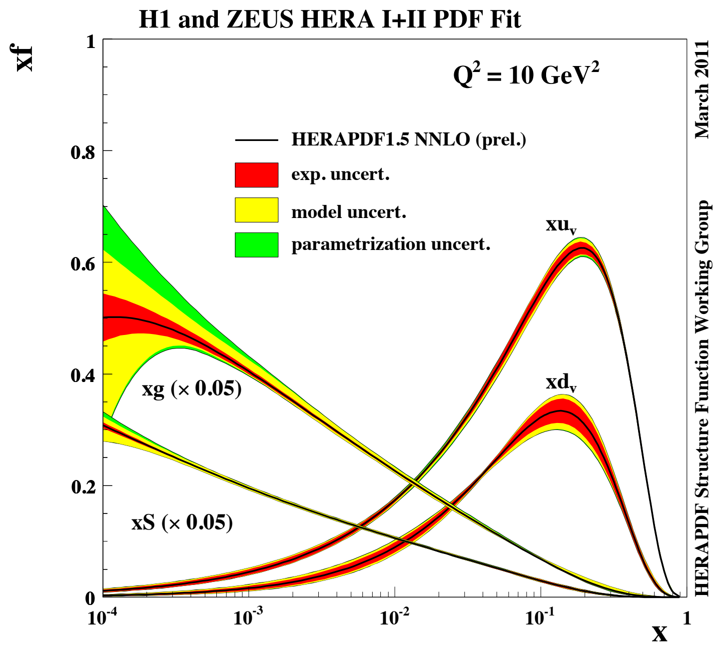


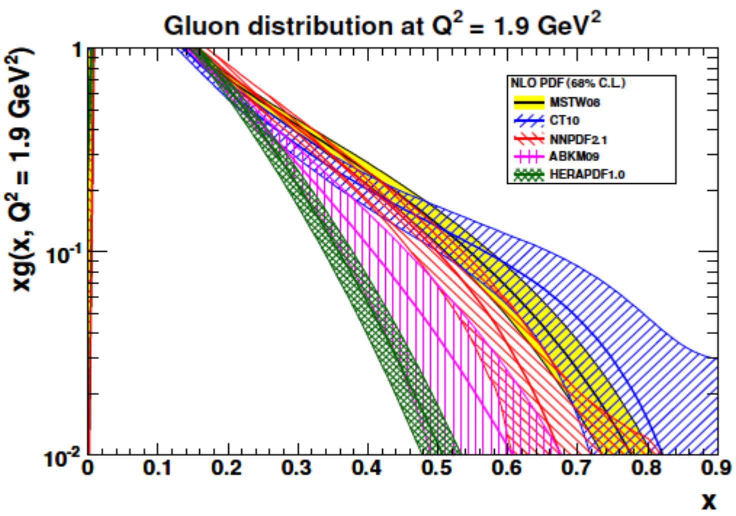
Snowmass13 QCD WG report



Need to know the PDFs much better than so far, for nucleon structure, q-g dynamics, Higgs, searches, future colliders, and for the development of QCD.
The LHC will provide further constraints, but:

(Un)certainty on PDFs





Light Quarks:
valence x < 0.01, u_v x > 0.8, d_v x>0.6
light sea (related to strange) -8% ATLAS/F_2,
light sea quark asymmetry, d/u=?
Isospin relations (en!) ??

Strange: unknown, =dbar? strange valence?

Charm: need high precision to % for α_s
(recent HERA 5%)
Beauty: HERA 10-20%, bb → A?
Top: tPDF at high Q^2 >M_t^2 - unknown

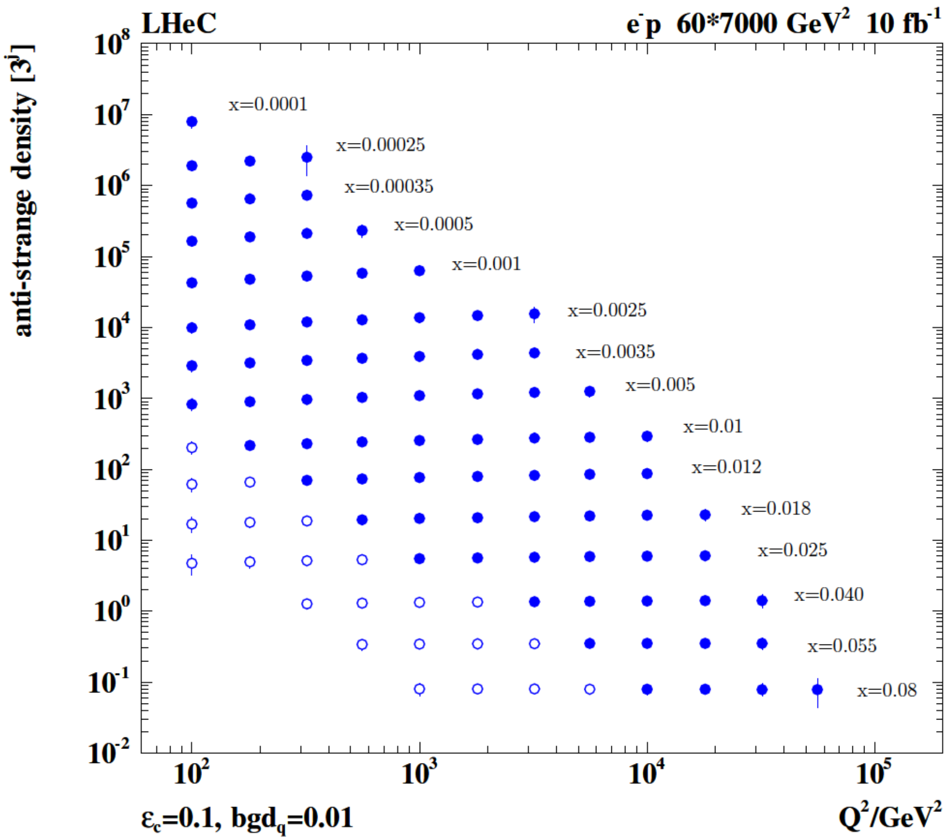
Gluon: low x, saturation?, high x - unknown
medium x: preciser for Higgs!
Recent review: cf E.Perez, E.Rizvi 1208.1178, in RPP

..unintegrated, diffractive, generalised, polarised, photonic, nuclear PDFs ???

A new, required level of determination of PDFs can only be achieved with the LHeC.

Strange Quark Distribution

JPhysG 39(2012)7

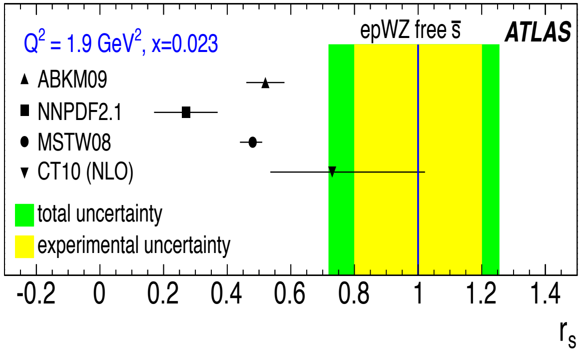


Leads to first (x,Q^2) measurement of the (anti-)strange density, HQ valence?

$x = 10^{-4}$ .. 0.05

$Q^2 = 100 – 10^5\ \mathrm{GeV}^2$

ATLAS+HERA: Recent surprise: s/d =1
PRD85 (2012) 072004; arXiv:1109.5141



cf also HERMES: N_K PLB666(2008)446
W+c measurements from ATLAS+CMS

Important PDF constraints from LHC though no direct determinations (Q^2,x)

Why Precision?

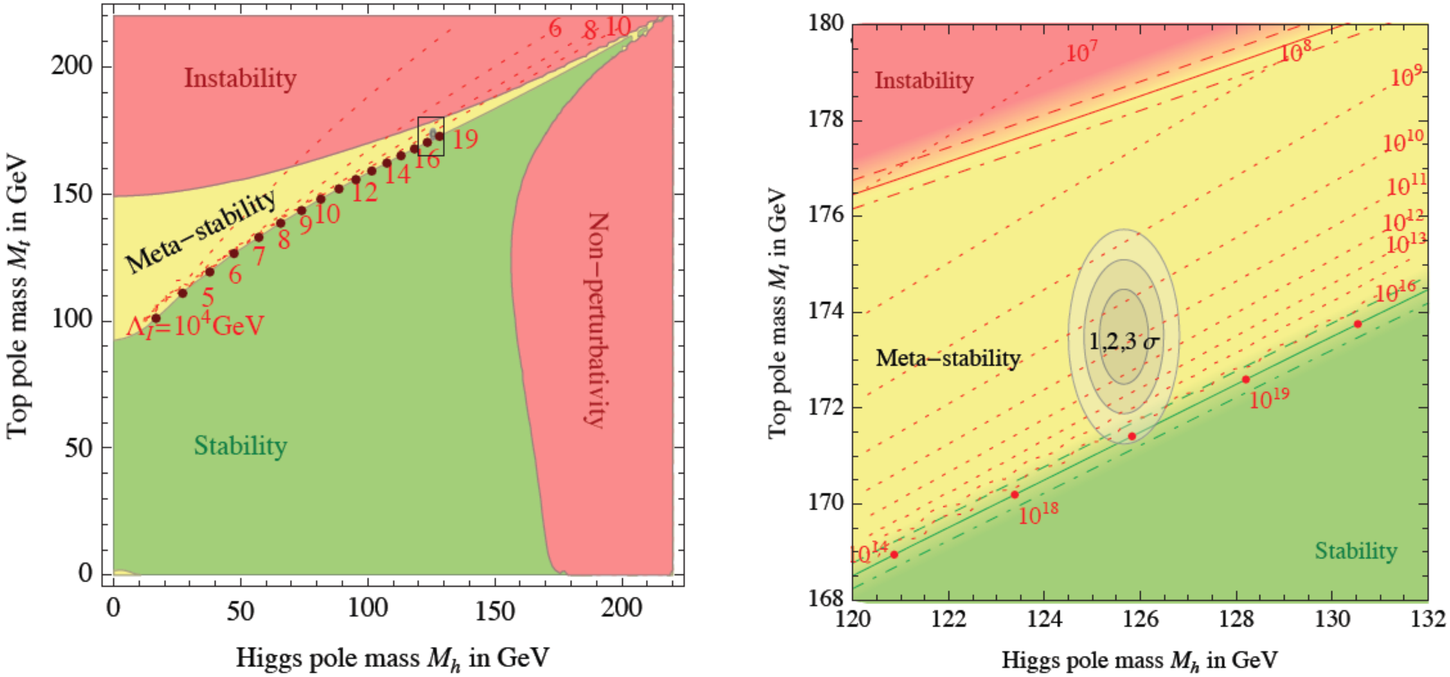
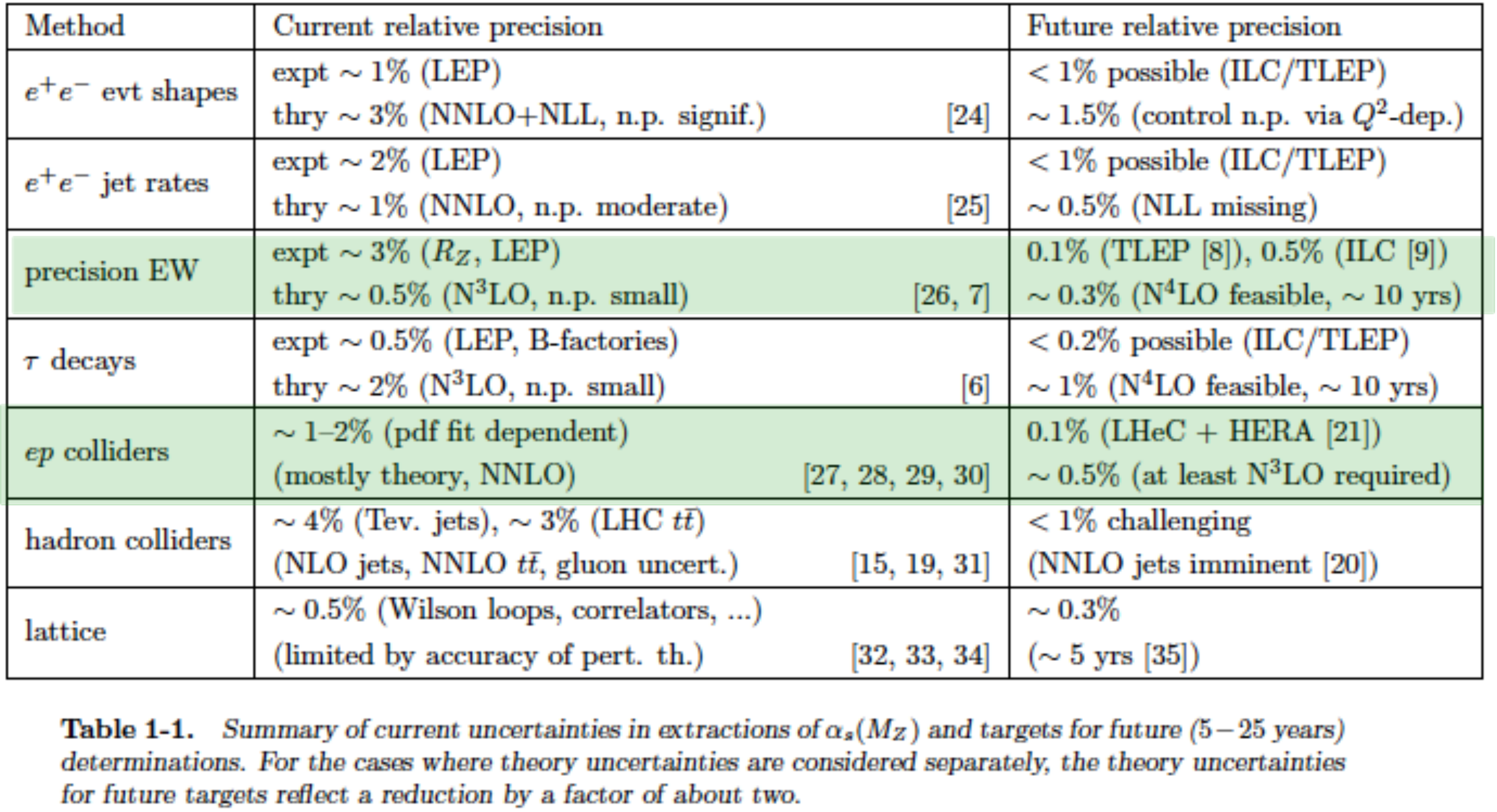


Figure 1: Regions of absolute stability, meta-stability and instability of the SM vacuum in terms of the top and Higgs masses. The frame on the right zooms into the preferred experimental region (the grey ellipses denote the allowed region at 1, 2, and 3σ). The three boundary lines correspond to $\alpha_s(M_Z) = 0.1184 \pm 0.0007$, and the grading of the colours indicates the size of the theoretical error. The dotted contour-lines show the instability scale in GeV, assuming the central value of $\alpha_s(M_Z)$. (For details see refs. [10, 11].)

G Giudice Why Naturalness, arXiv:1307.7879

The strong coupling "constant"



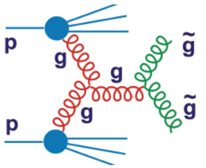
Method	Current relative precision		Future relative precision
e^+e^- evt shapes	expt $\sim 1\%$ (LEP) thry $\sim 3\%$ (NNLO+NLL, n.p. signif.)	[24]	$< 1\%$ possible (ILC/TLEP) $\sim 1.5\%$ (control n.p. via Q^2-dep.)
e^+e^- jet rates	expt $\sim 2\%$ (LEP) thry $\sim 1\%$ (NNLO, n.p. moderate)	[25]	$< 1\%$ possible (ILC/TLEP) $\sim 0.5\%$ (NLL missing)
precision EW	expt $\sim 3\%$ (R_Z, LEP) thry $\sim 0.5\%$ (N^{3}LO, n.p. small)	[26, 7]	0.1% (TLEP [8]), 0.5% (ILC [9]) $\sim 0.3\%$ (N^{4}LO feasible, $\sim$ 10 yrs)
τ decays	expt $\sim 0.5\%$ (LEP, B-factories) thry $\sim 2\%$ (N^{3}LO, n.p. small)	[6]	$< 0.2\%$ possible (ILC/TLEP) $\sim 1\%$ (N^{4}LO feasible, $\sim$ 10 yrs)
ep colliders	$\sim$ 1–2% (pdf fit dependent) (mostly theory, NNLO)	[27, 28, 29, 30]	0.1% (LHeC + HERA [21]) $\sim 0.5\%$ (at least N^{3}LO required)
hadron colliders	$\sim 4\%$ (Tev. jets), $\sim 3\%$ (LHC $t\bar{t}$) (NLO jets, NNLO $t\bar{t}$, gluon uncert.)	[15, 19, 31]	$< 1\%$ challenging (NNLO jets imminent [20])
lattice	$\sim 0.5\%$ (Wilson loops, correlators, ...) (limited by accuracy of pert. th.)	[32, 33, 34]	$\sim 0.3\%$ ($\sim$ 5 yrs [35])

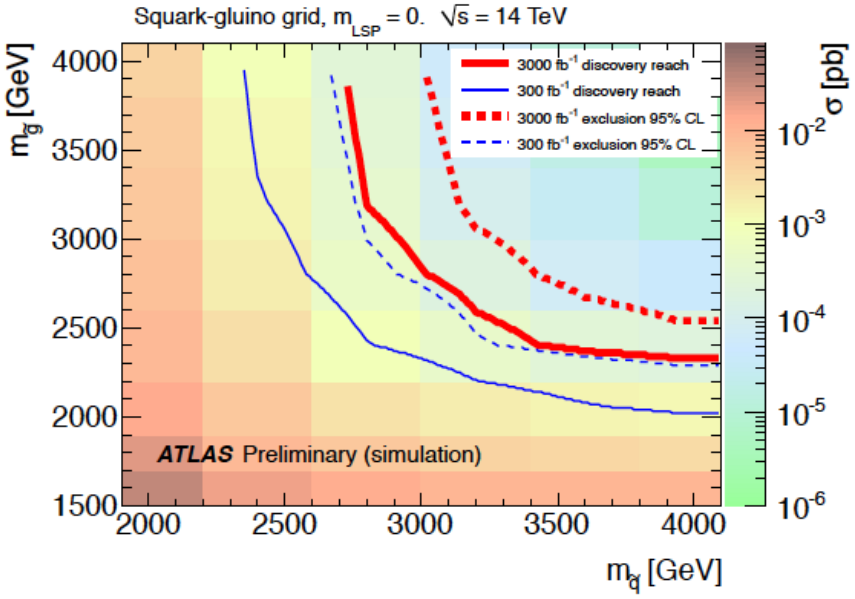
Table 1-1. *Summary of current uncertainties in extractions of $\alpha_s(M_Z)$ and targets for future (5 – 25 years) determinations. For the cases where theory uncertainties are considered separately, the theory uncertainties for future targets reflect a reduction by a factor of about two.*

Snowmass QCD WG report 9/2013

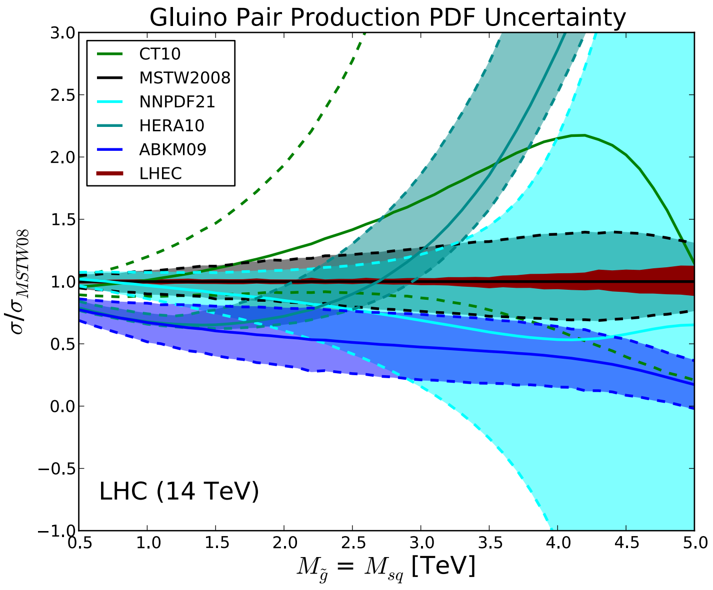
Prospects to measure $\alpha_s(M_Z^2)$ to per mille precision with future ep and ee colliders
Important for gauge unification, precision Higgs at LHC, and to overcome the past..

HL-LHC - Searches





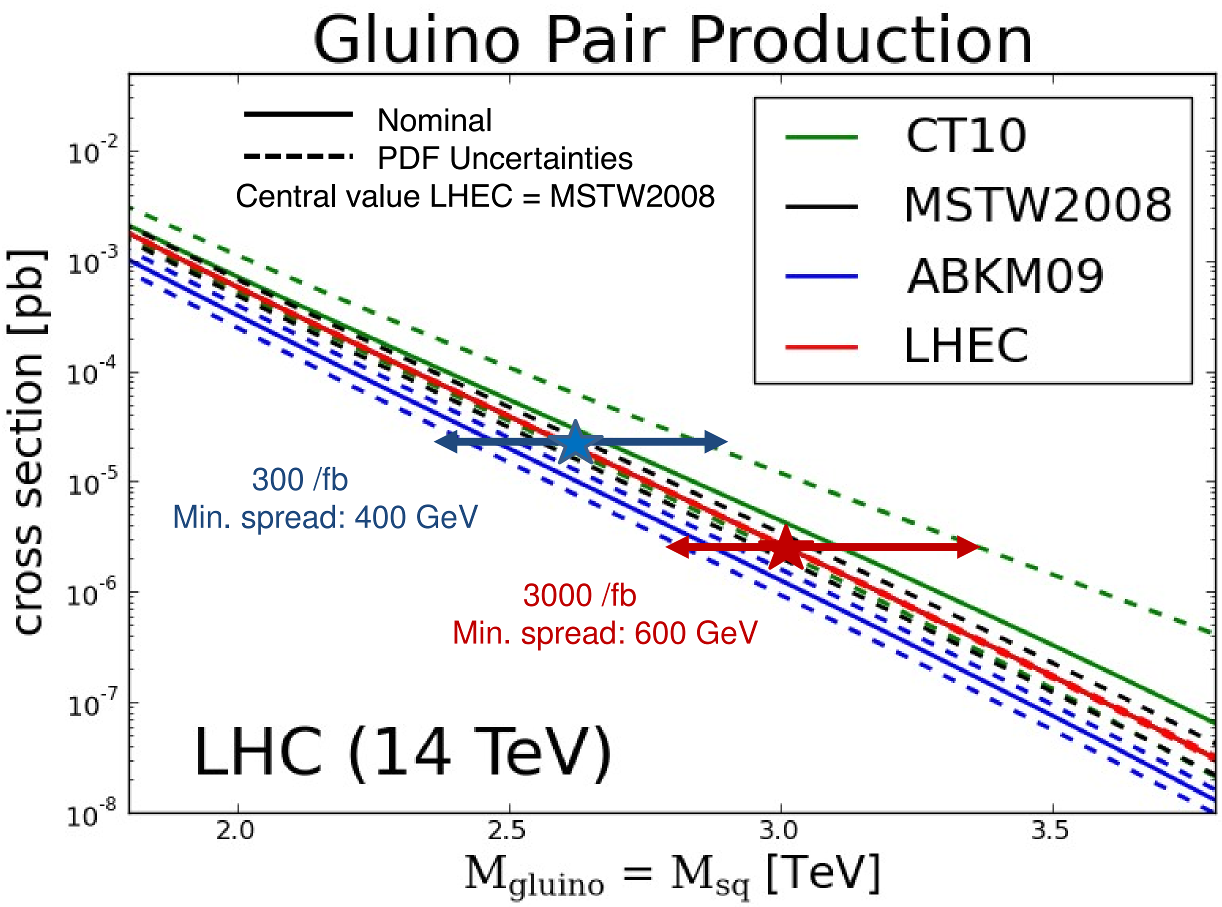
ATLAS October 2012 to EU strategy forum

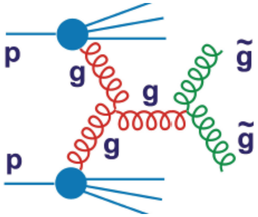


LHeC October 2012 to EU forum arXiv:1211.5102

With high energy and luminosity, the 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?

HL-LHC - Searches





High precision PDFs are needed for the HL-LHC searches in order to probe into the range opened by the luminosity increase and to interprete possibly intriguing effects based on external information.

LHeC BSM poster at EPS13 M.D'Onofrio et al. see also arXiv:1211:5102 Relation LHeC-LHC
Simulated PDFs from LHeC are on LHAPDF (Partons from LHeC, MK, V.Radescu LHeC-Note-2013-002 PHY)

Higgs with HL-LHC

LHC 300 fb^{-1} at 14 TeV:

- Mass: <100 MeV (statistical)
- Coupling κ rel. precision*
  - Z, W, b, τ 10-15%
  - t, μ 3-2 σ observation
  - γγ and gg 5-11%

HL-LHC 3000 fb^{-1} at 14 TeV:

- Mass: << 50 MeV (statistical)
- Couplings κ rel. precision*
  - Z, W, b, τ, t, μ 2-10%
  - γγ and gg 2-5%

**Assuming sizeable (1/2) reduction of theory errors*

- "QCD scale" go to Higher order QCD computation ?
- gg "PDF" from LHC data ?

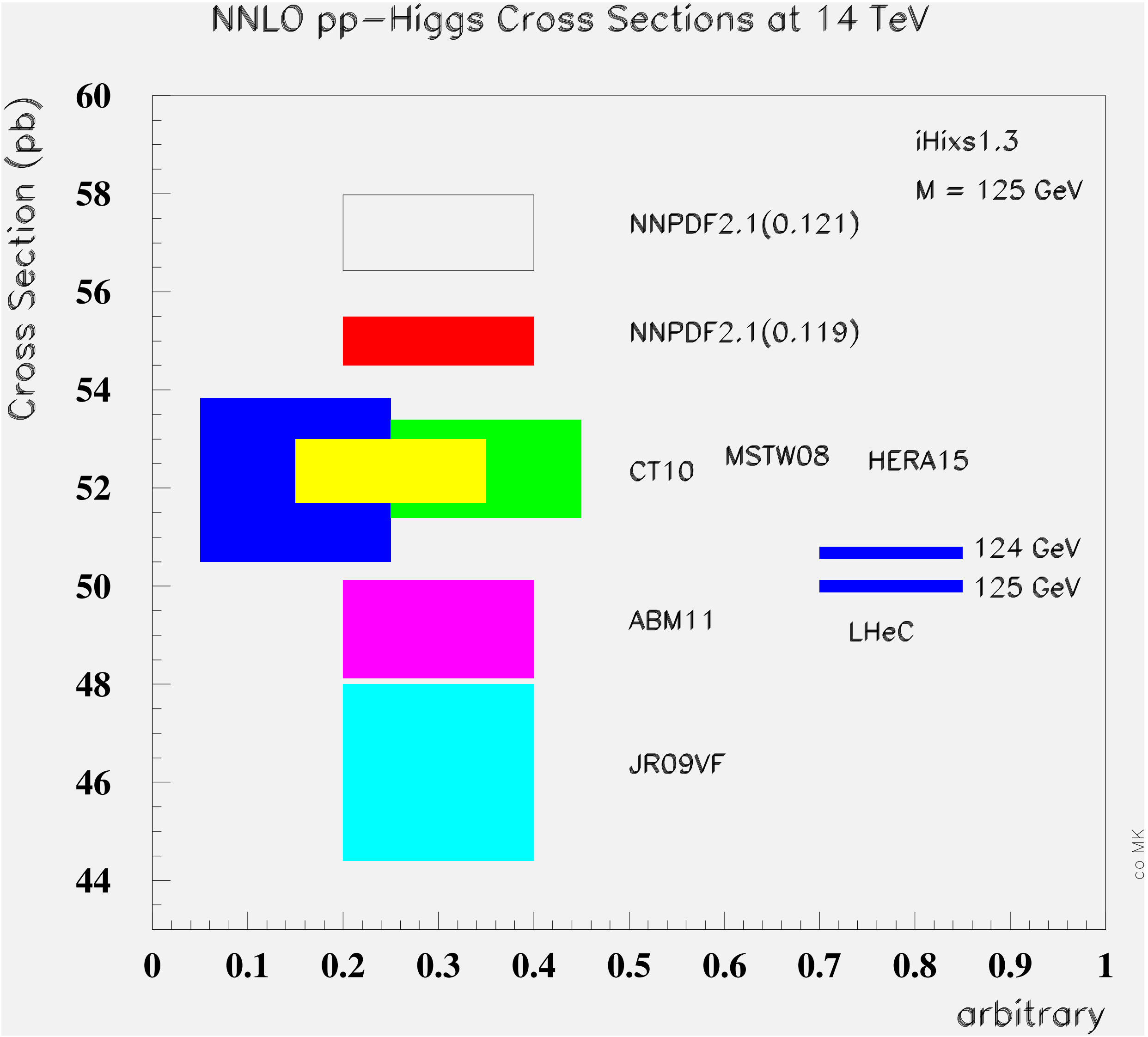
Mass Measurement:

Several exp./theory challenges to reach 50 MeV (e/γ/μ calibration E-scale, Interference, FSR, ..)

F.Cerutti, "Properties of the New Boson" EPS13 Stockholm

Higgs physics at the LHC is a long term challenge [di-H, CP, M, VV damping..]

Precision for Higgs at the LHC



O.Brüning and M.Klein arXiv:1305.2090, MPLA 2013

LHeC:

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

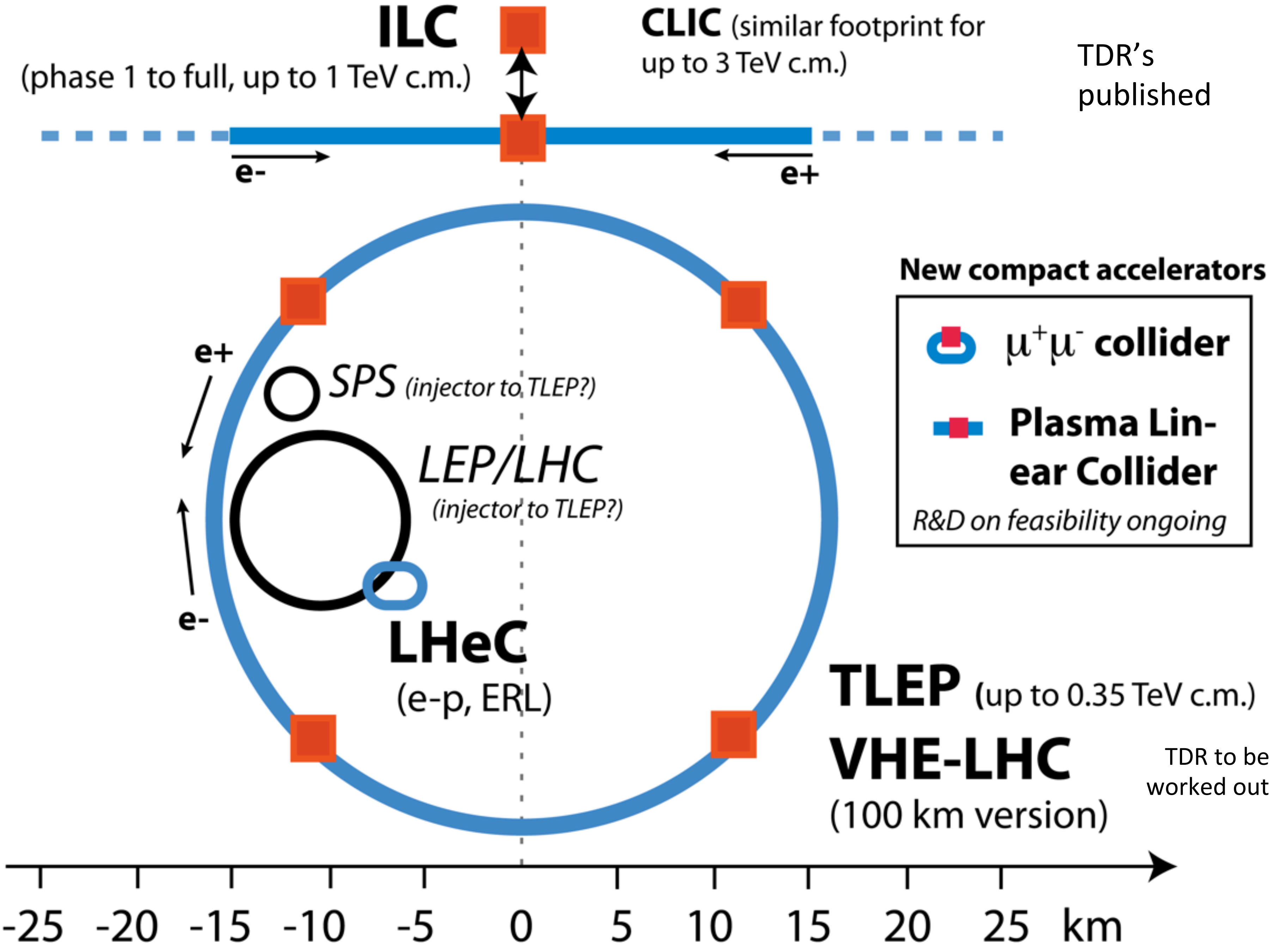
Leads to H mass sensitivity.

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

Needs N^3LO

HQ treatment important …

Lepton collider options beyond LHC



ILC
(phase 1 to full, up to 1 TeV c.m.)

CLIC (similar footprint for up to 3 TeV c.m.)

TDR's published

SPS (injector to TLEP?)

LEP/LHC
(injector to TLEP?)

LHeC
(e-p, ERL)

New compact accelerators

- $\mu^+\mu^-$ **collider**
- **Plasma Linear Collider**

R&D on feasibility ongoing

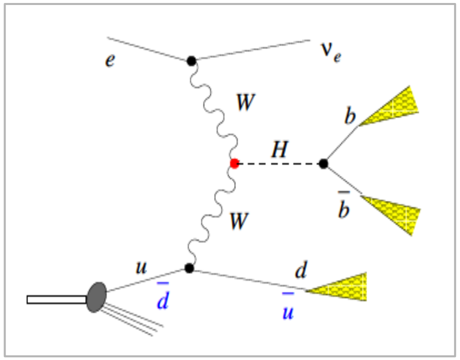
TLEP (up to 0.35 TeV c.m.)

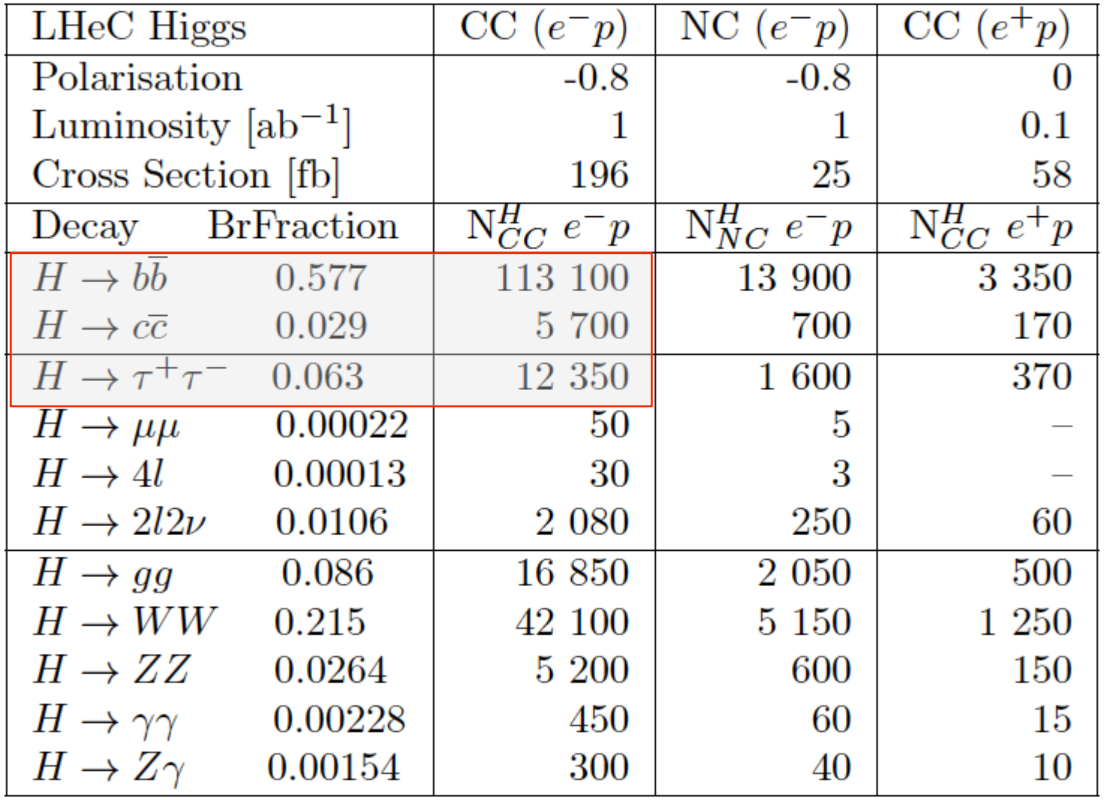
VHE-LHC
(100 km version)

TDR to be worked out

R.Aβmann, EPS13

Luminosity can boost LH(e)C to a precision H facility





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

Polarised electrons
Maximum lumi
Forward tracking
High resolution
No pile-up
Direction asymmetry
…

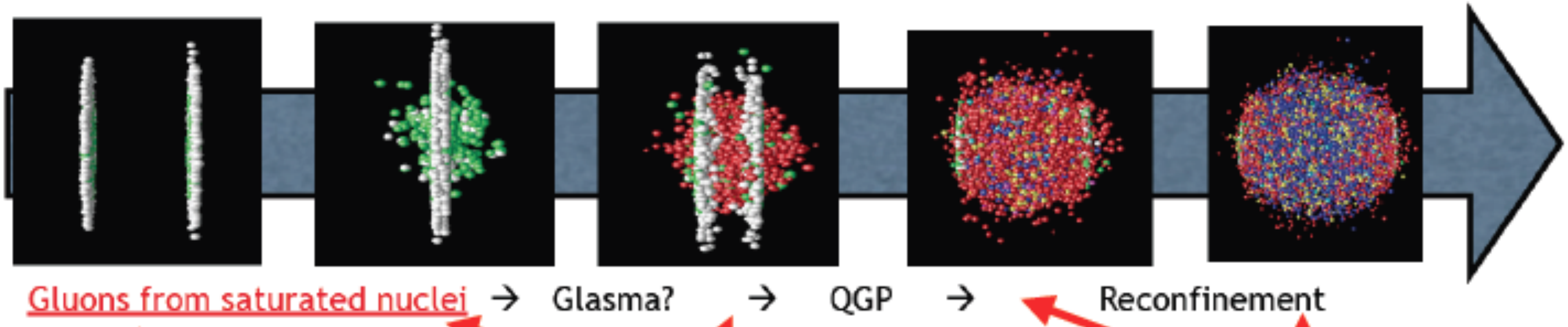
H-bbar coupling to 0.7% precision with 1ab^{-1}, at an S/B of 1 – studies of τ, c, .. to come

The LHeC WW → H cross section is as large as the ILC Z*→ZH cross section (300fb)…

→ 50pb@LHC, hiLumi + ep [H + PDFs] +QCD@h.o. : LHC - a high precision H factory

U.Klein Talk at EPS 7/2013, B.Mellado, Talk at LPCC 3/2013, CDR..

Relation of the LHeC and the LHC HI Program



- Nuclear wave function at small x: nuclear structure functions.

- Particle production at the very beginning: which factorisation in eA?

- How does the system behave as ~ isotropised so fast?: initial conditions for plasma formation to be studied in eA.

- Probing the medium through energetic particles (jet quenching etc.): modification of QCD radiation and hadronization in the nuclear medium.

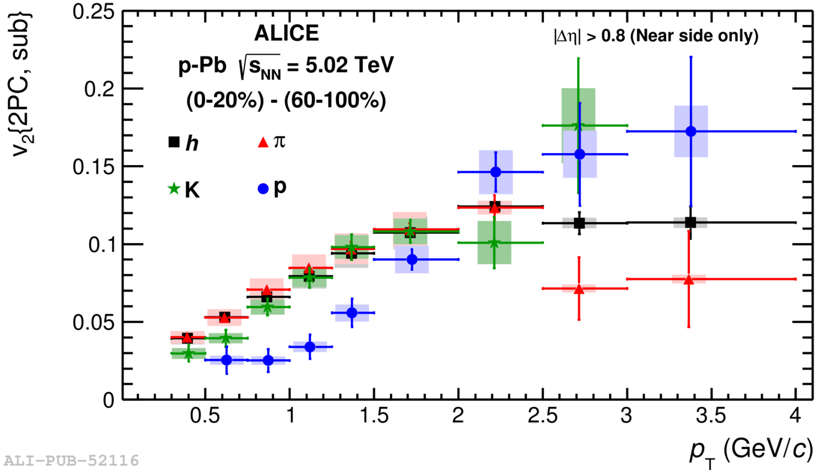
Proton-Lead at the LHC

$$\frac{dN}{d\Phi_Z} \propto \sum_n [1+v_n \cos(n(\Phi_Z - \Phi_{EP}))]$$

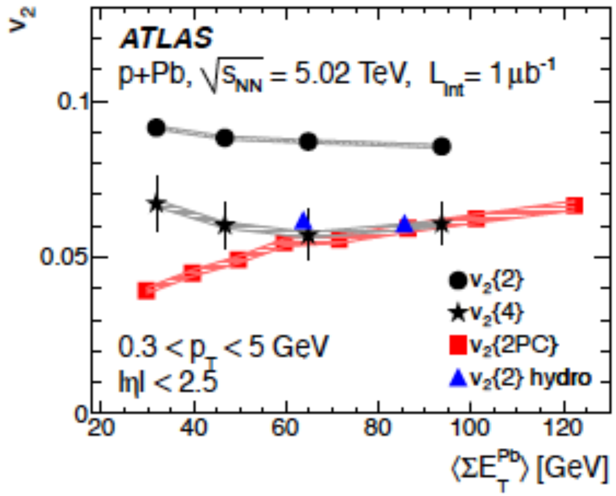
Φ_Z boson azimuthal emission angle
Φ_{EP} event plane azimuth

v_2 for Z is zero, it decays before the plasma is formed ..

1307.3237 – ALICE

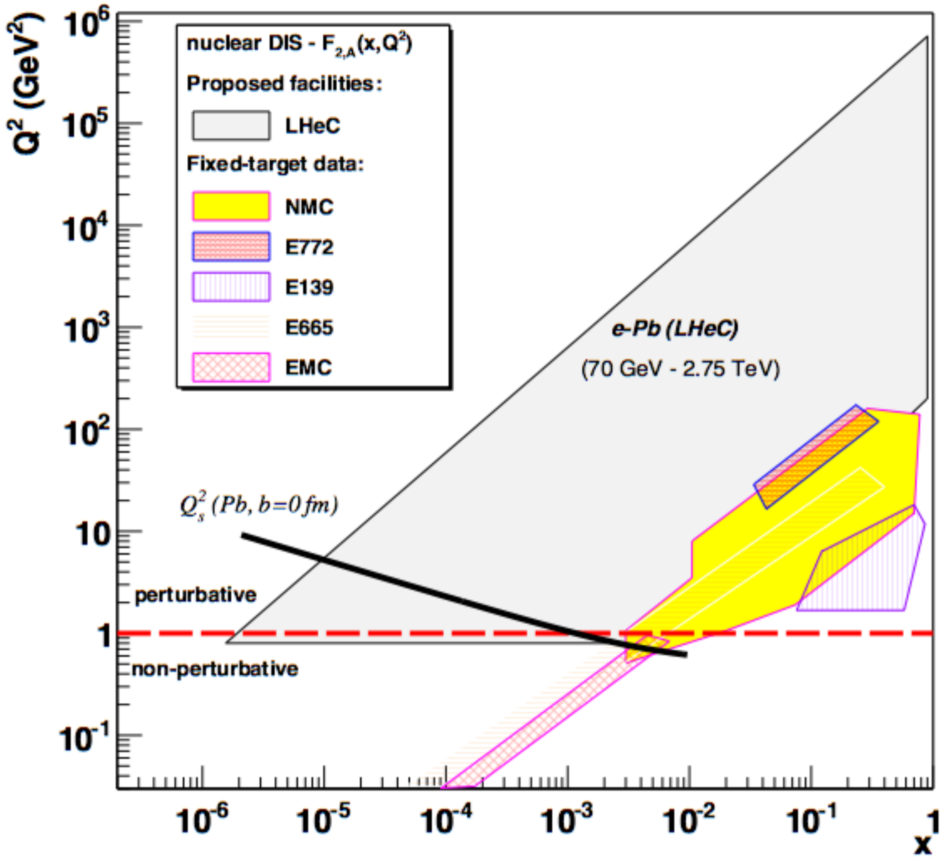


1303.2084 – ATLAS



Perhaps surprising, recent results indicate that the flow in pPb resembles PbPb
Possibly the determination of nPDFs in AA and pA is reduced to W,Z production
[collective effects in final state – rescattering of produced partons – hydrodynamics]

LHeC as Electron Ion Collider



LHeC is part of NuPECCs
long range plan since 2010
$L_{eN} \sim 10^{32}$ cm^{-2} s^{-1}

Extension of kinematic range in lA by FOUR orders of magnitude will change QCD view on nuclear structure and parton dynamics

May lead to genuine surprises…

- No saturation of xg (x,Q^2) ?
- Small fraction of diffraction ?
- Broken isospin invariance ?
- Flavour dependent shadowing ?

Expect saturation of rise at
$$Q^2_s \approx xg\,\alpha_s \approx c\,x^{-\lambda}A^{1/3}$$

Precision QCD study of parton dynamics in nuclei
Investigation of high density matter and QGP
Gluon saturation at low x, in DIS region.

Nuclear Parton Distributions

Data	**DIS lA**	**DIS νA**	**DY ll**	**dAu $\pi^\pm$**	**dAu π^o**	**p Base**	**Ref.**
EPS09	+	-	+	-	+	MSTW	JHEP
DSSZ	+	+	+	+	+	CTEQ6	PRD
nCTEQ	+	-	+	-	-	CTEQ6	Prel.

*)

NLO QCD fits of nuclear correction factors with reference to a proton PDF set

Very restricted range of DIS measurements → "no predictive power below x ~ 0.01" FGS

Single pion data used to constrain the gluon – depends on fragmentation fct., thy uncertain

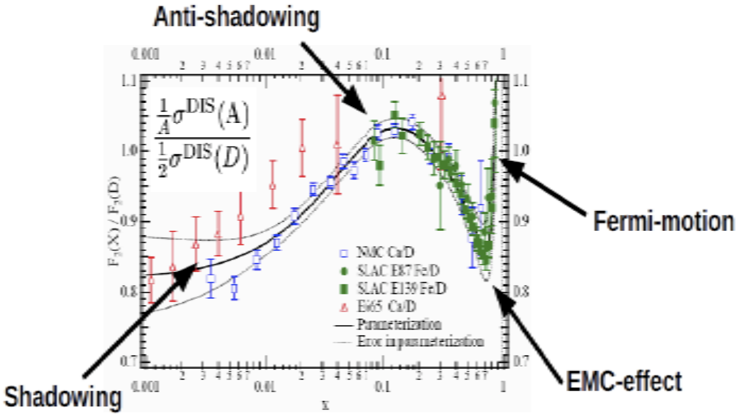
No flavour decomposition (strange may be large, charm, bottom?)

Further assumptions: no nuclear effects in D, isospin invariance, $\Delta\chi^2$ tolerances..

*) see also Hirai, Kumano, Nagai, 0709.3038 (2007)

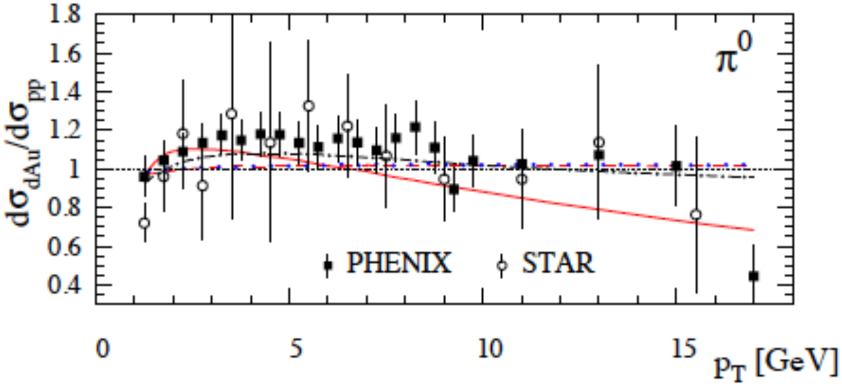
Present nPDFs

DIS input data from NMC and SLAC

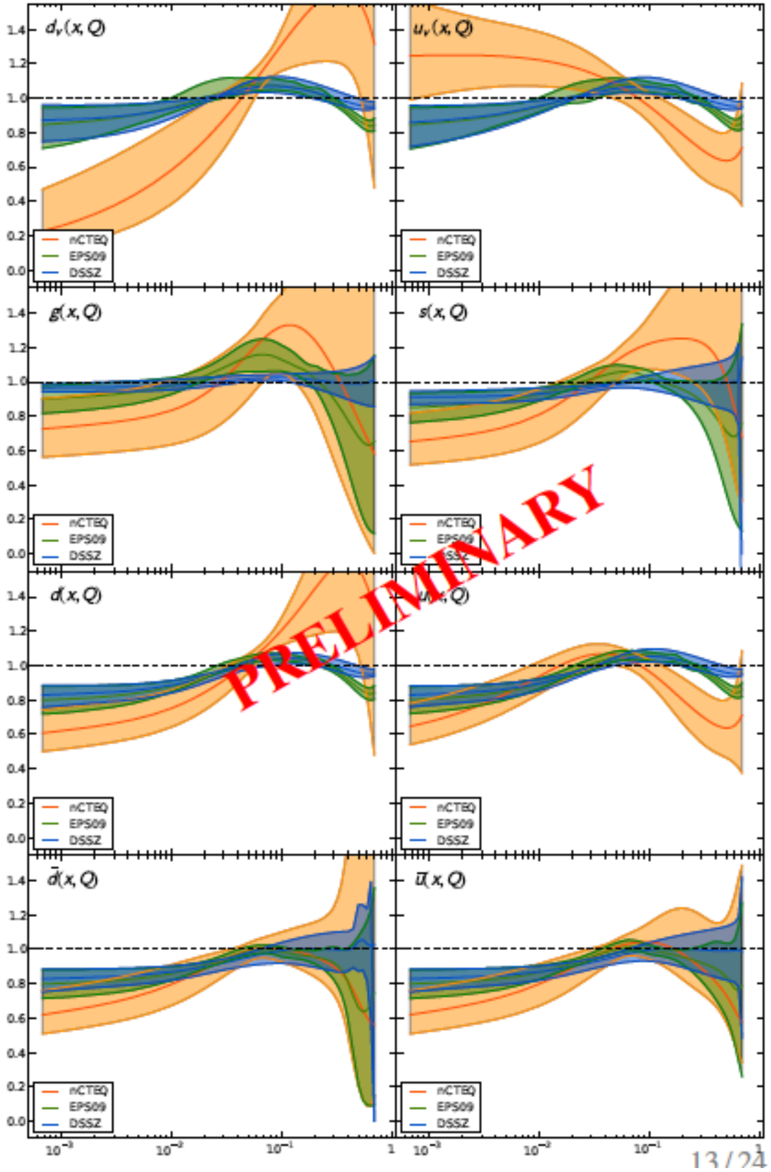


Frankfurt, Guzey, Strikhman, 1106.2091

π^o input from RHIC



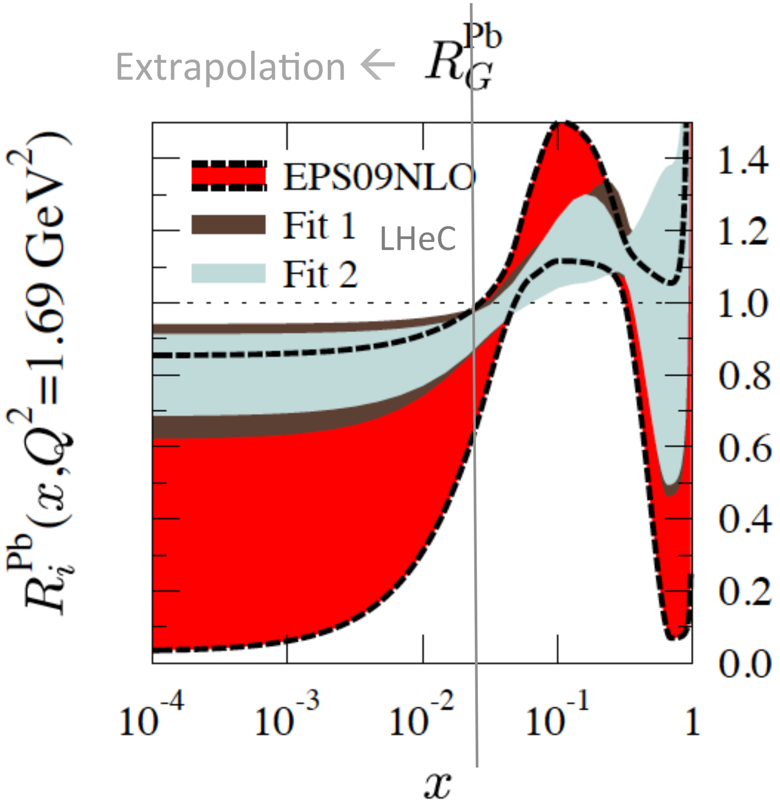
For full set of plots cf D.De Florian 1112.6324

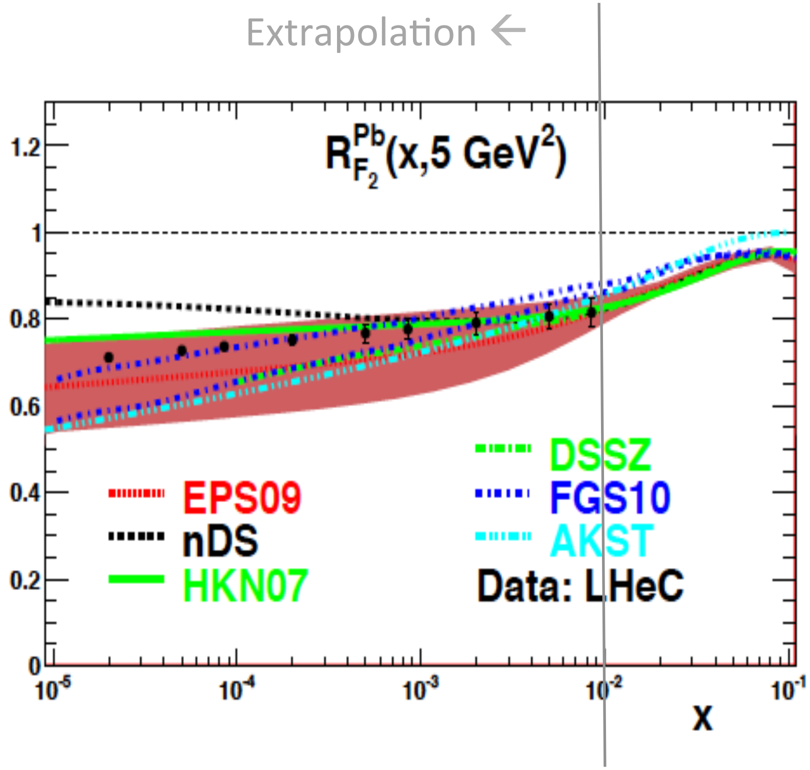


Strong variations of results and just parametric behaviour at $x < 0.01$

A.Kusina May 2013 Pittsburgh

Gluon and Sea at Low x in eA with the LHeC

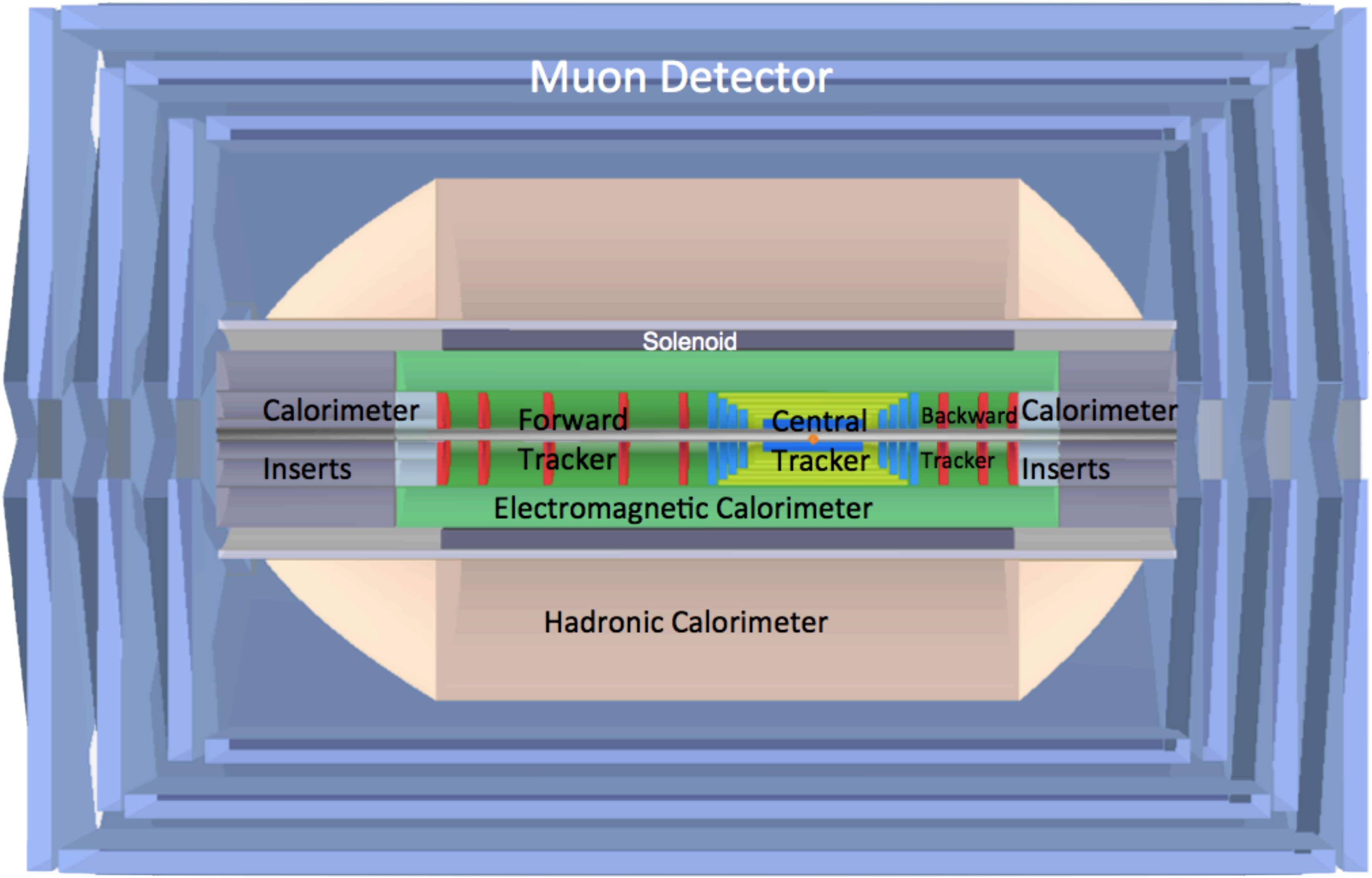




In eA the gluon density may be enhanced proportional to $A^{1/3}$ – yet shadowing.
A proof of saturation requires: ep AND eA to separate nuclear/collective effects from non-linear parton interactions AND $\alpha_s << 1 \rightarrow Q^2 >> M_P^2$
It is a unique program for the LHeC, as it needs high E_A and E_e

Detector

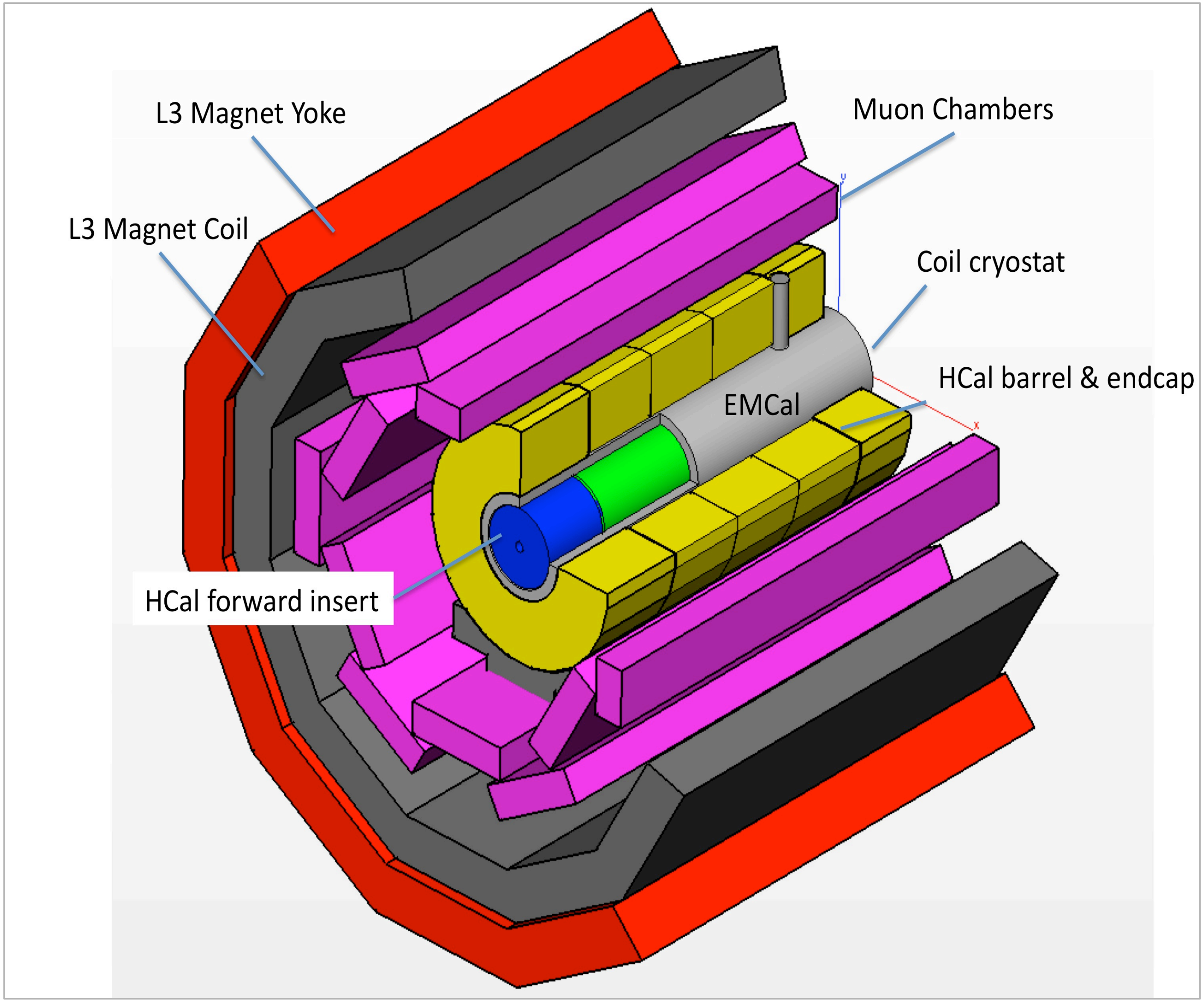
LHeC Detector Overview



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)

Detector installation study for IP2, reuse of L3 magnet as support for LHeC. estimated 30 months cf. LHeC CDR



Detector Magnets

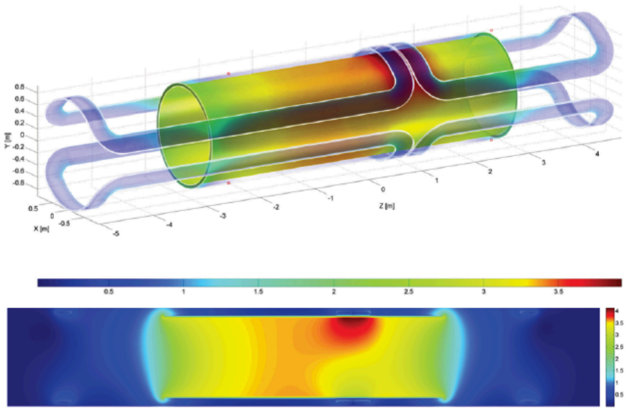


Figure 13.13: Magnetic field of the magnet system of solenoid and the two internal superconducting dipoles at nominal currents (effect of iron ignored). The position of the peak magnetic field of 3.9 T is local due to the adjacent current return heads on top of the solenoid where all magnetic fields add up.

Dipole (for head on LR) and solenoid in common cryostat, perhaps with electromagnetic LAr

3.5T field at ~1m radius to house a Silicon tracker

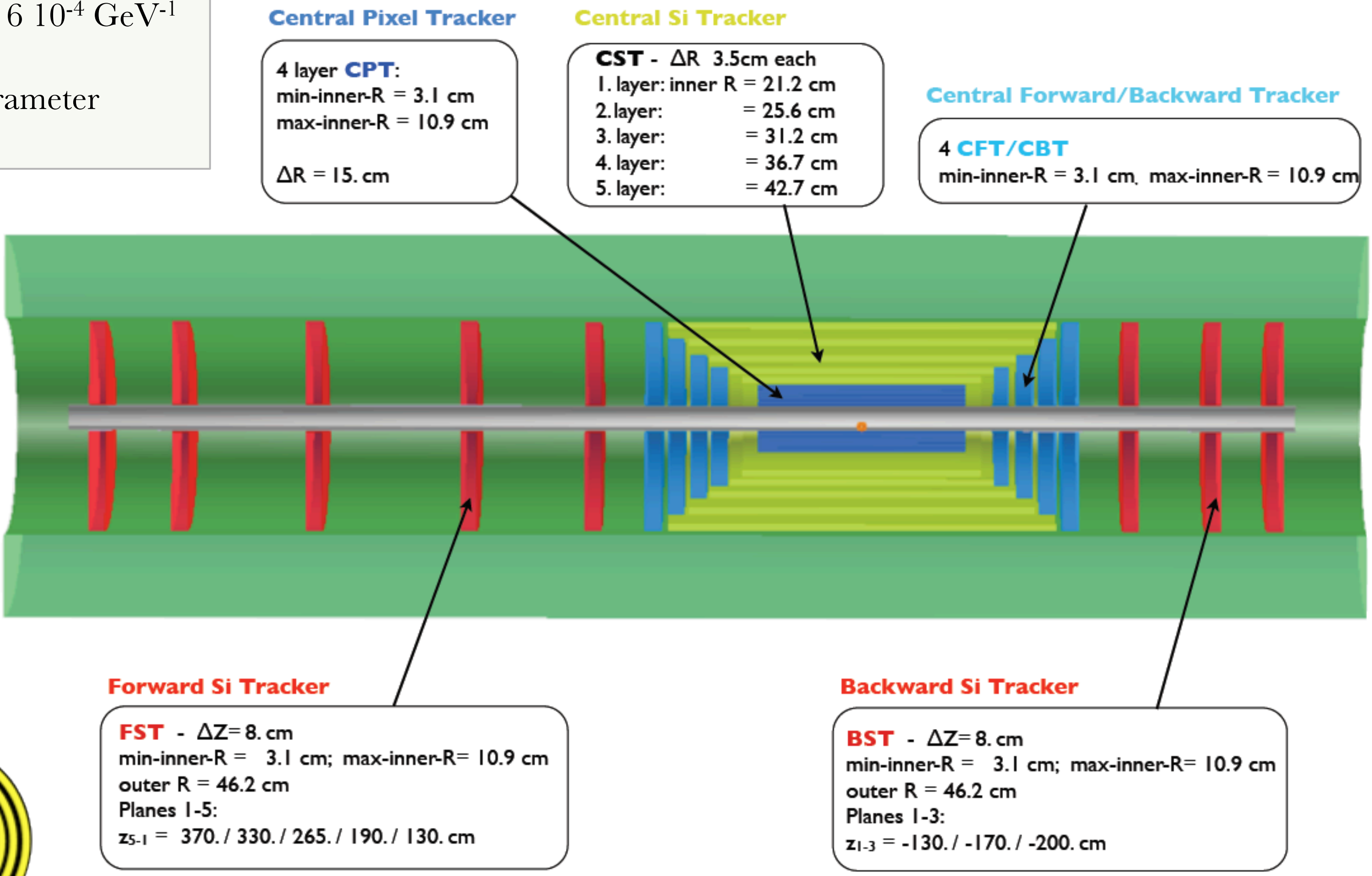
Based on ATLAS+CMS experience

Property	Parameter	value	unit
Dimensions	Cryostat inner radius	0.900	m
	Length	10.000	m
	Outer radius	1.140	m
	Coil windings inner radius	0.960	m
	Length	5.700	m
	Thickness	60.0	mm
	Support cylinder thickness	0.030	m
	Conductor section, Al-stabilized NbTi/Cu + insulation	30.0×6.8	mm^2
	Length	10.8	km
	Superconducting cable section, 20 strands	12.4×2.4	mm^2
	Superconducting strand diameter Cu/NbTi ratio = 1.25	1.24	mm
Masses	Conductor windings	5.7	t
	Support cylinder, solenoid section + dipole sections	5.6	t
	Total cold mass	12.8	t
	Cryostat including thermal shield	11.2	t
	Total mass of cryostat, solenoid and small parts	24	t
Electro-magnetics	Central magnetic field	3.50	T
	Peak magnetic field in windings (dipoles off)	3.53	T
	Peak magnetic field in solenoid windings (dipoles on)	3.9	T
	Nominal current	10.0	kA
	Number of turns, 2 layers	1683	
	Self-inductance	1.7	H
	Stored energy	82	MJ
	E/m, energy-to-mass ratio of windings	14.2	kJ/kg
	E/m, energy-to-mass ratio of cold mass	9.2	kJ/kg
	Charging time	1.0	hour
	Current rate	2.8	A/s
	Inductive charging voltage	2.3	V
Margins	Coil operating point, nominal / critical current	0.3	
	Temperature margin at 4.6 K operating temperature	2.0	K
	Cold mass temperature at quench (no extraction)	~ 80	K
Mechanics	Mean hoop stress	~ 55	MPa
	Peak stress	~ 85	MPa
Cryogenics	Thermal load at 4.6 K, coil with 50% margin	~ 110	W
	Radiation shield load width 50% margin	~ 650	W
	Cooling down time / quench recovery time	4 and 1	day
	Use of liquid helium	~ 1.5	g/s

Table 13.1: Main parameters of the baseline LHeC Solenoid providing 3.5 T in a free bore of 1.8 m.

Silicon Tracker and EM Calorimeter

Transverse momentum
$\Delta p_t/p^2_t \rightarrow 6\ 10^{-4}\ \mathrm{GeV}^{-1}$
transverse
impact parameter
→ 10μm



Central Pixel Tracker

4 layer **CPT**:
min-inner-R = 3.1 cm
max-inner-R = 10.9 cm

ΔR = 15. cm

Central Si Tracker

CST - ΔR 3.5cm each
1. layer: inner R = 21.2 cm
2. layer: = 25.6 cm
3. layer: = 31.2 cm
4. layer: = 36.7 cm
5. layer: = 42.7 cm

Central Forward/Backward Tracker

4 **CFT/CBT**
min-inner-R = 3.1 cm, max-inner-R = 10.9 cm

Forward Si Tracker

FST - ΔZ= 8. cm
min-inner-R = 3.1 cm; max-inner-R= 10.9 cm
outer R = 46.2 cm
Planes 1-5:
$z_{5\text{-}1}$ = 370. / 330. / 265. / 190. / 130. cm

Backward Si Tracker

BST - ΔZ= 8. cm
min-inner-R = 3.1 cm; max-inner-R= 10.9 cm
outer R = 46.2 cm
Planes 1-3:
$z_{1\text{-}3}$ = -130. / -170. / -200. cm

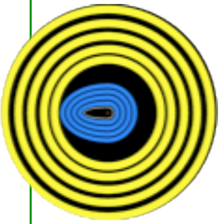
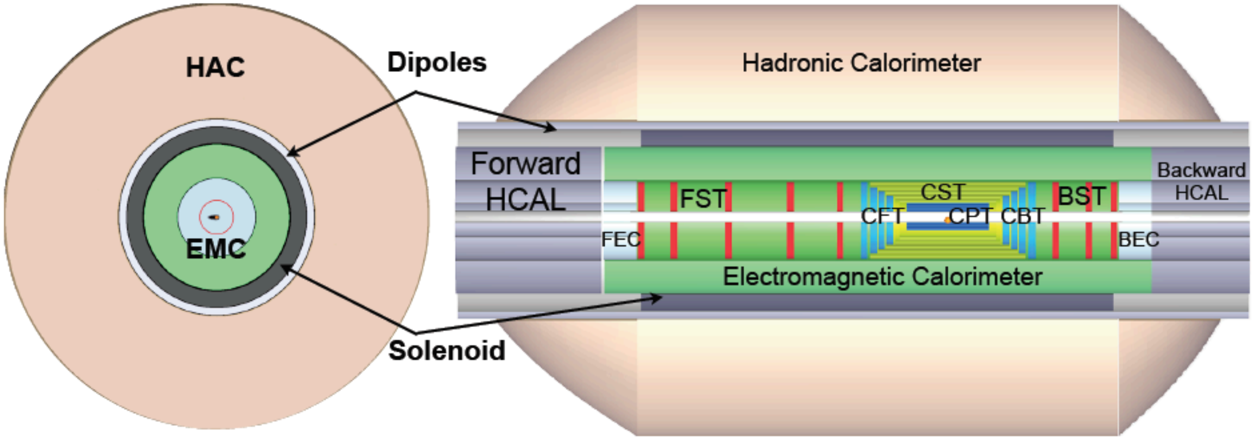


Figure 13.18: Tracker and barrel Electromagnetic-Calorimeter rz view of the baseline detector (Linac-Ring case).

LHeC-LHC: no pile-up, less radiation, smaller momenta apart from forward region

Liquid Argon Electromagnetic Calorimeter



Inside Coil
H1, ATLAS
experience.

Barrel: Pb, $20\ X_0$, $11\mathrm{m}^3$

fwd/bwd inserts:

FEC: Si -W, $30\ X_0$,$0.3\mathrm{m}^3$

BEC: Si -Pb, $25\ X_0$,$0.3\mathrm{m}^3$

Figure 13.30: x-y and r-z view of the LHeC Barrel EM calorimeter (green).

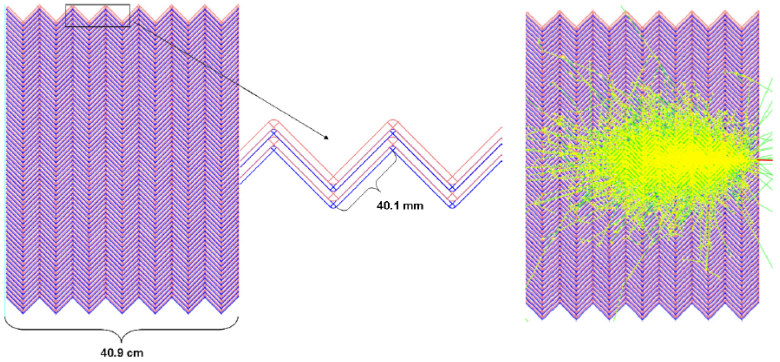


Figure 13.35: View of the parallel geometry accordion calorimeter (left) and simulation of a single electron shower with initial energy of 20 GeV (right).

GEANT4 Simulation

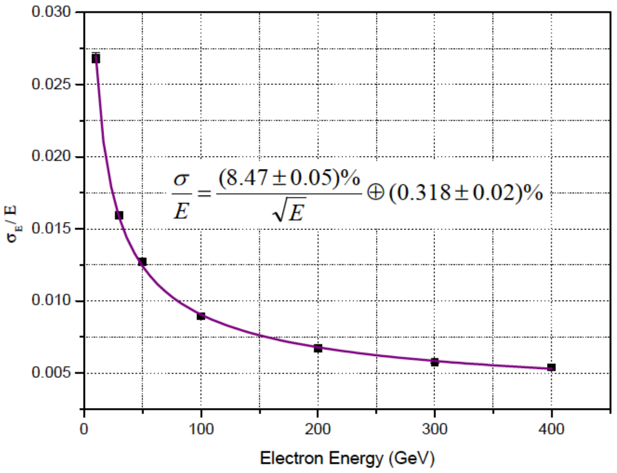
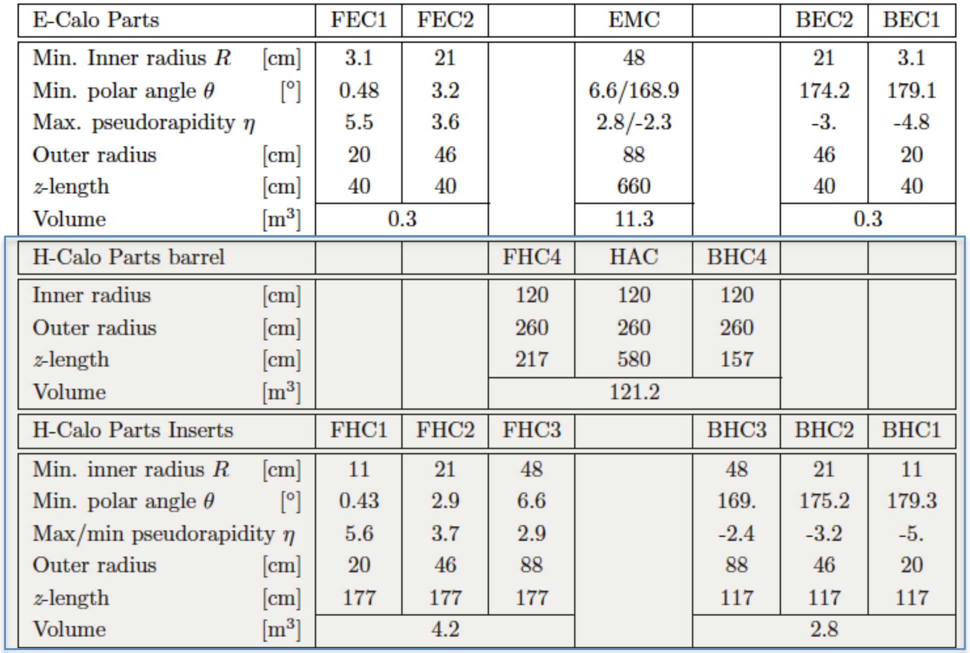


Figure 13.36: LAr accordion calorimeter energy resolution for electrons between 10 and 400 GeV.

Hadronic Tile Calorimeter

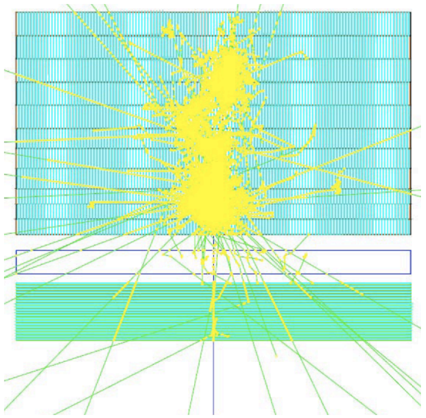
Outside Coil: flux return

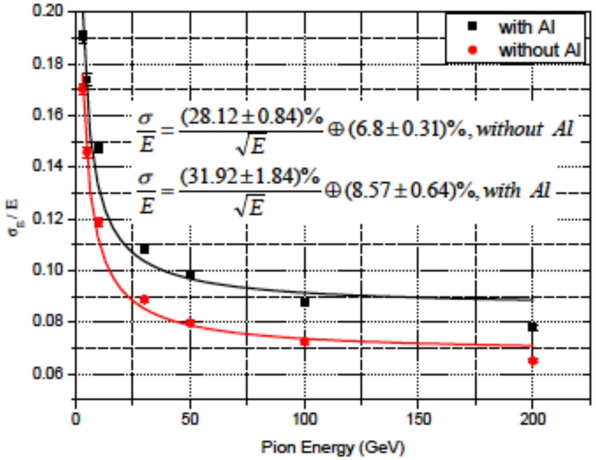
Modular. ATLAS experience.



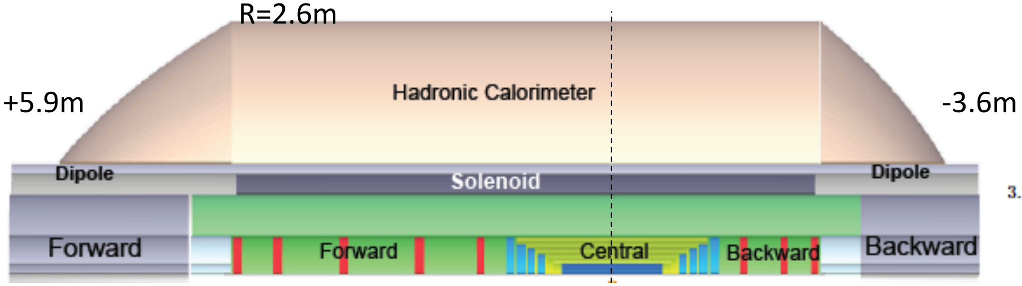
E-Calo Parts	FEC1	FEC2		EMC		BEC2	BEC1
Min. Inner radius R [cm]	3.1	21		48		21	3.1
Min. polar angle θ [°]	0.48	3.2		6.6/168.9		174.2	179.1
Max. pseudorapidity η	5.5	3.6		2.8/-2.3		-3.	-4.8
Outer radius [cm]	20	46		88		46	20
z-length [cm]	40	40		660		40	40
Volume [m^3]	0.3			11.3		0.3	
H-Calo Parts barrel			**FHC4**	**HAC**	**BHC4**		
Inner radius [cm]			120	120	120		
Outer radius [cm]			260	260	260		
z-length [cm]			217	580	157		
Volume [m^3]			121.2				
H-Calo Parts Inserts	**FHC1**	**FHC2**	**FHC3**		**BHC3**	**BHC2**	**BHC1**
Min. inner radius R [cm]	11	21	48		48	21	11
Min. polar angle θ [°]	0.43	2.9	6.6		169.	175.2	179.3
Max/min pseudorapidity η	5.6	3.7	2.9		-2.4	-3.2	-5.
Outer radius [cm]	20	46	88		88	46	20
z-length [cm]	177	177	177		117	117	117
Volume [m^3]	4.2				2.8		

Table 13.6: Summary of calorimeter dimensions.
The electromagnetic barrel calorimeter is currently represented by the barrel part EMC (LAr-Pb module); the setup reaches $X_0 \approx 25$ radiation length) and the movable inserts forward FEC1, FEC2 (Si-W modules ($X_0 \approx 30$) and the backward BEC1, BEC2 (Si-Pb modules; $X_0 \approx 25$).
The hadronic barrel parts are represented by FHC4, HAC, BHC4 (forward, central and backward - Scintillator-Fe Tile modules; $\lambda_I \approx 8$ interaction length) and the movable inserts FHC1, FHC2, FHC3 (Si-W modules; $\lambda_I \approx 10$), BHC1, BHC2, BHC3 (Si-Cu modules, $\lambda_I \approx 8$) see Fig. 13.9.



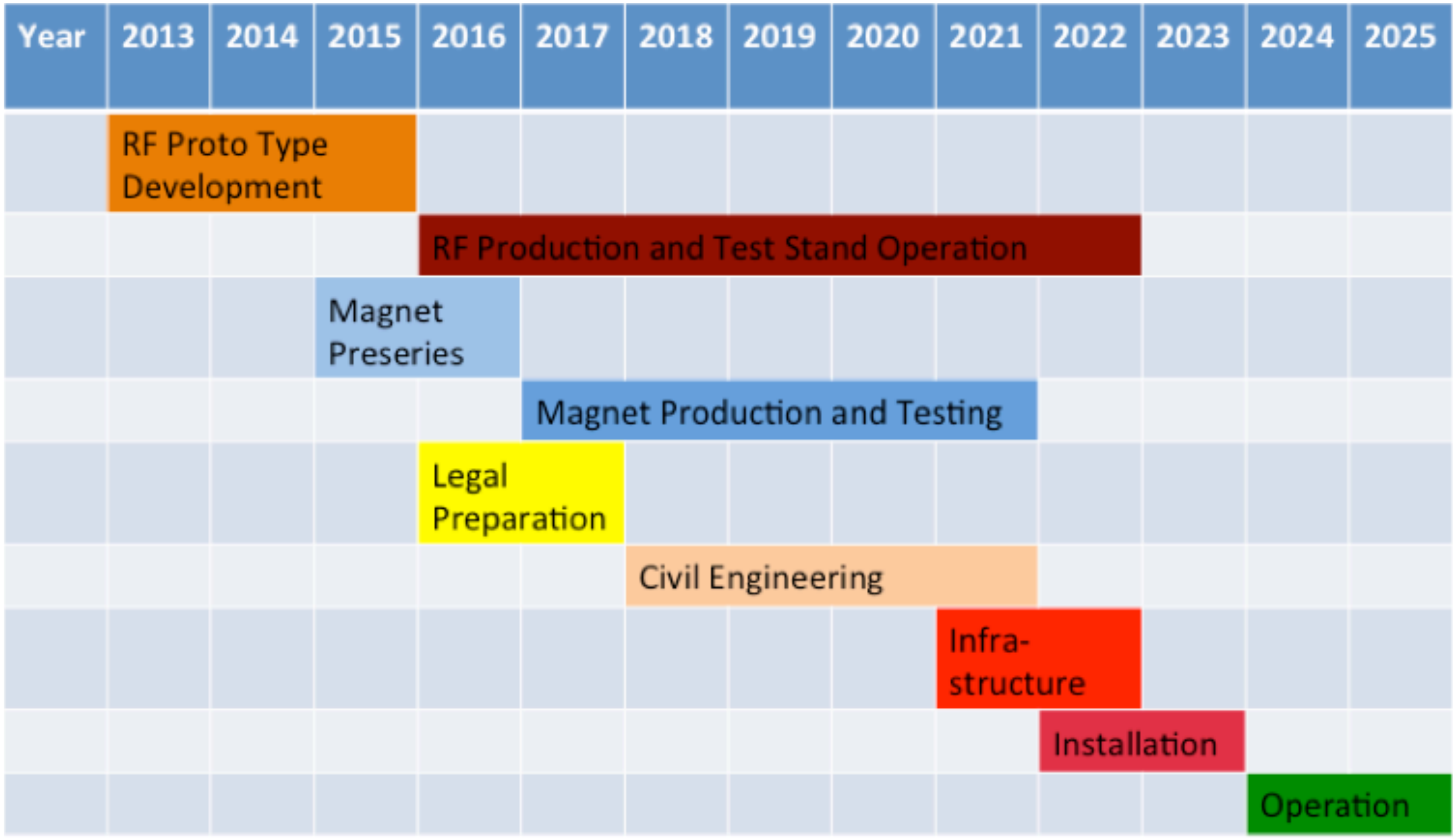


3.37: Accordion and Tile Calorimeter energy resolution for pions with and without 14cm Al block.



Combined GEANT4 Calorimeter Simulation

How long does it take to build the LHeC



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<tr><td></td><td colspan="3">RF Proto Type Development</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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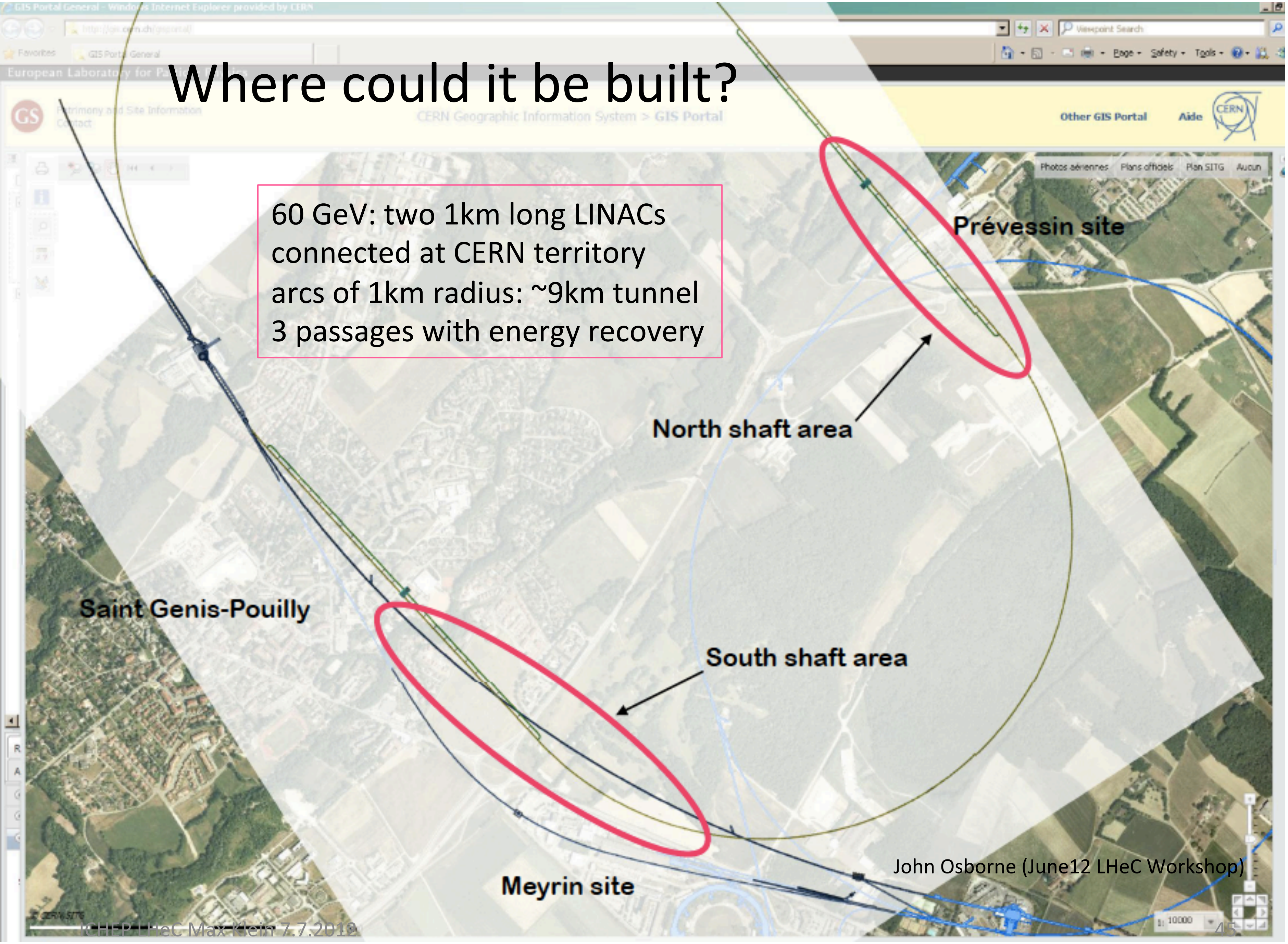
From CDR 2012

Where could it be built?



60 GeV: two 1km long LINACs
connected at CERN territory
arcs of 1km radius: ~9km tunnel
3 passages with energy recovery

John Osborne (June12 LHeC Workshop)

For an overview:

The CDR: J.Phys.G: arXiv:1206.2013

Web page http://cern.ch/lhec

LHeC Meetings: http://indico.cern.ch/categoryDisplay.py?categId=1874

A recent brief overview paper: MPLA: arXiv:1305.2090 (OB,MK)

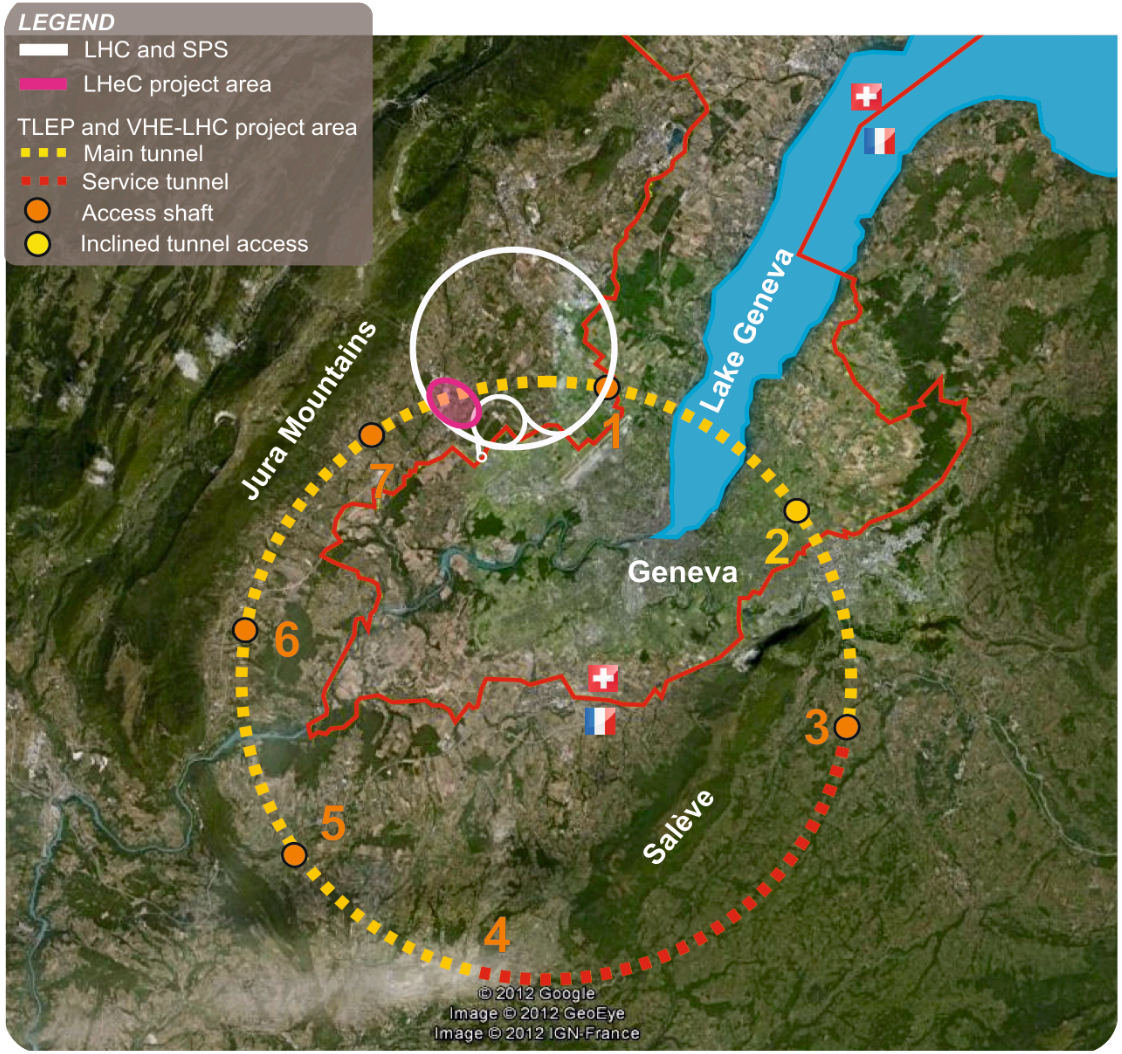
Conferences in 2013: LPCC (April), DIS Marseille, IPAC Shanghai, EPS Stockholm

Next workshop January 21/22 Chavannes - near CERN, no fee, please register:
https://indico.cern.ch/conferenceDisplay.py?confId=278903
Two sessions: Detector+Physics and Testfacility+Accelerator

LHeC

Many thanks to all who participated in this development, not least from Birmingham

Future Rings at CERN*)



100km with 20T
provides 50 TeV
per beam.

80km may not be
clever due to Saleve,
if placed below
Lac Leman → 100km?

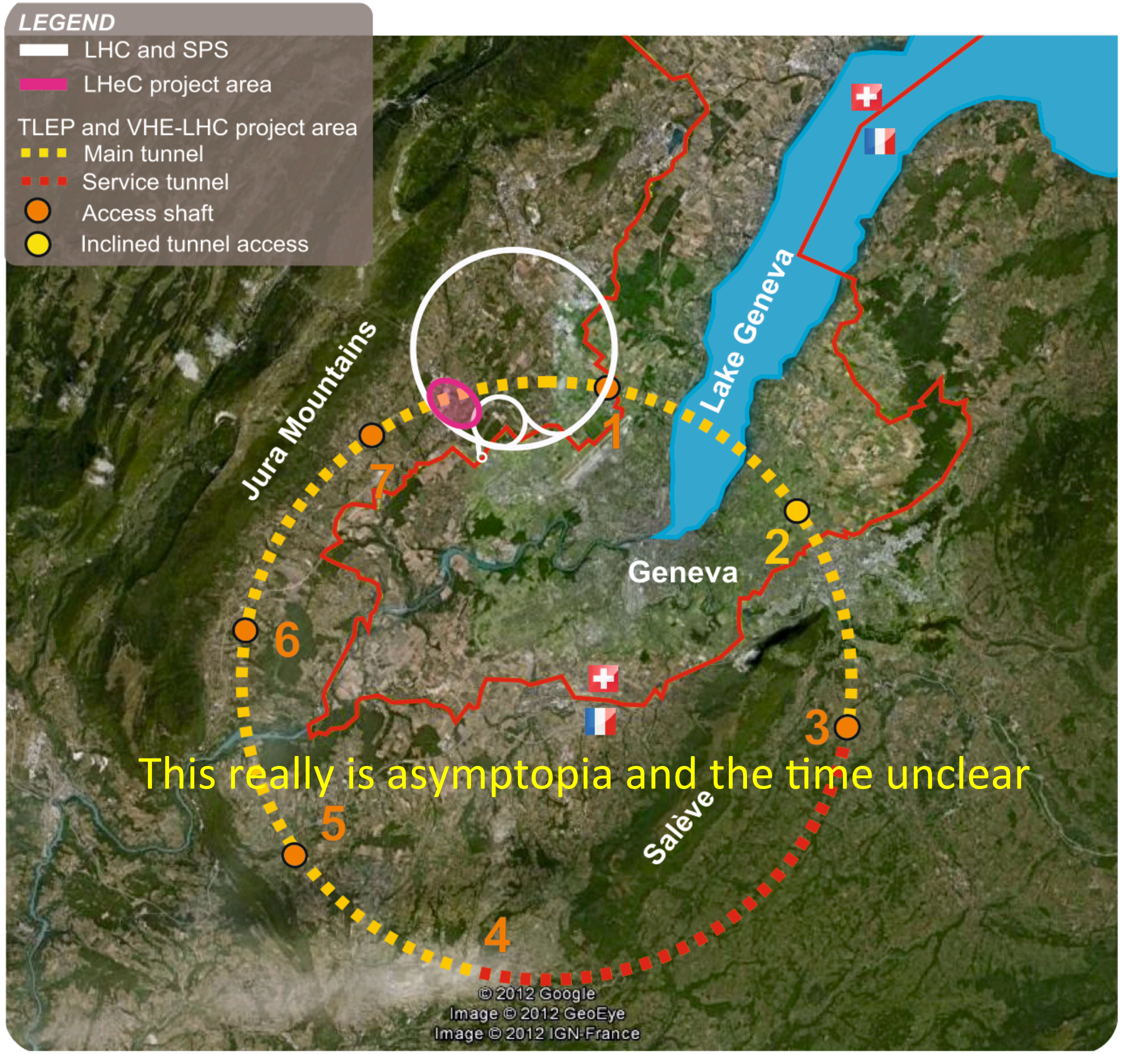
New tunnel may host
a Triple LEP Higgs
facility.

LHeC to run with
LHC and later
with VHE-LHC

---

*) “Civil Engineering Feasibility Studies for Future Ring Colliders at CERN”, Contributed by O.Brüning, M.Klein, S.Myers, J.Osborne, L.Rossi, C.Waaijer, F.Zimmerman to IPAC13 Shanghai

Future Rings at CERN*)



This really is asymptopia and the time unclear

100km with 20T provides 50 TeV per beam.

80km may not be clever due to Saleve, if placed below Lac Leman → 100km?

New tunnel may host a Triple LEP Higgs facility.

LHeC to run with LHC and later with VHE-LHC

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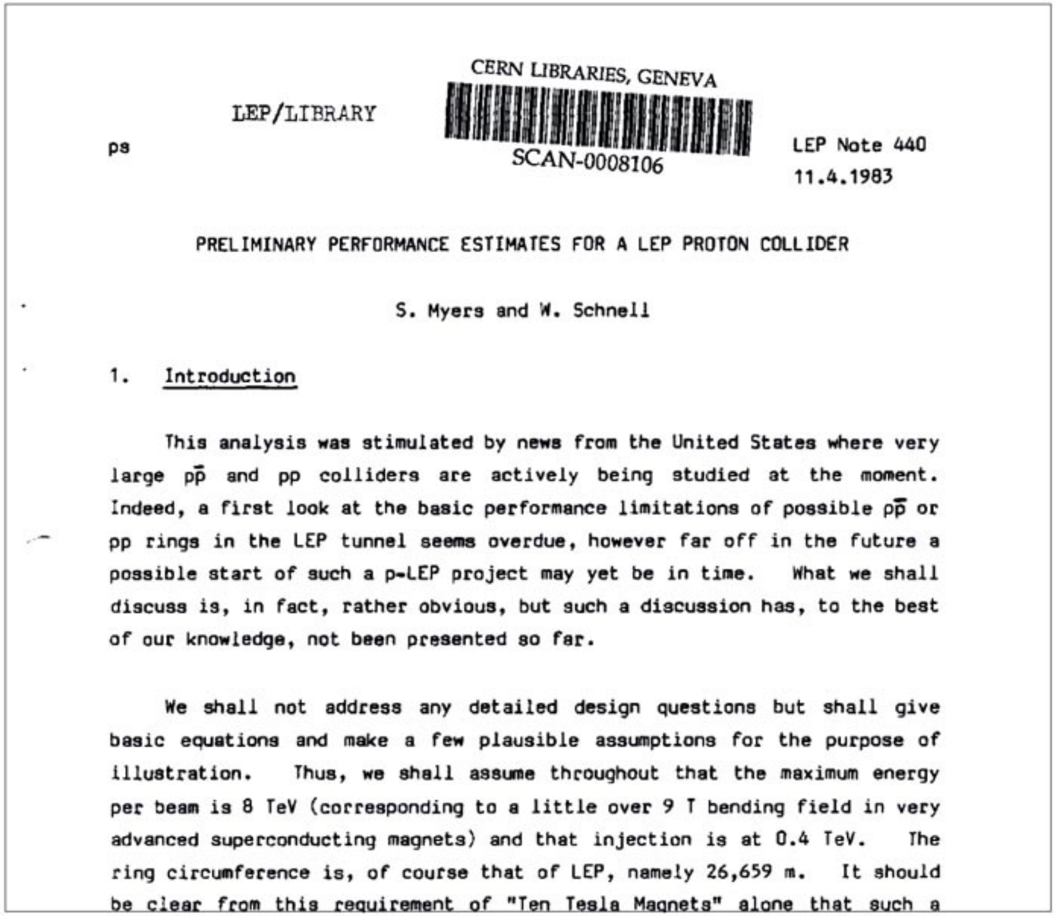
Time



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ps

LEP Note 440
11.4.1983

PRELIMINARY PERFORMANCE ESTIMATES FOR A LEP PROTON COLLIDER

S. Myers and W. Schnell

1. Introduction

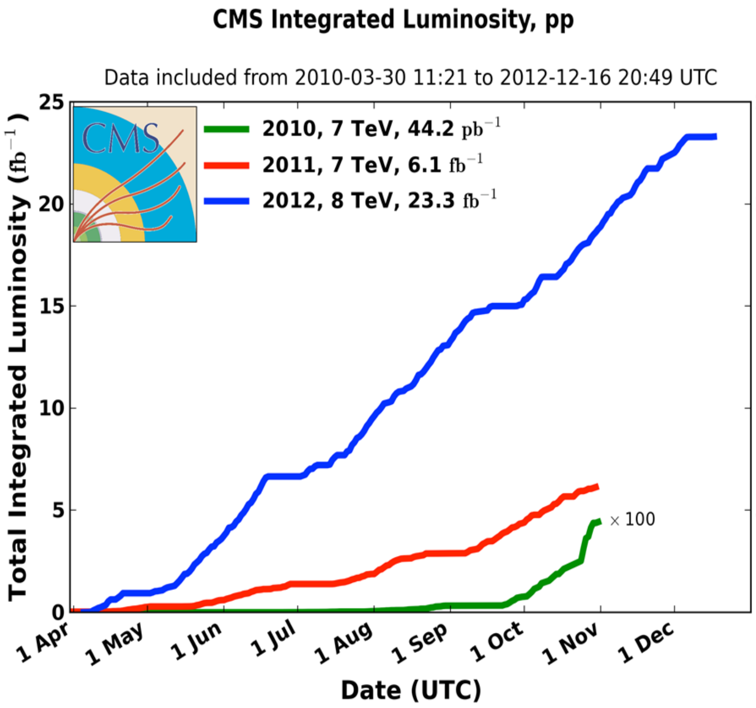
This analysis was stimulated by news from the United States where very large $p\bar{p}$ and pp colliders are actively being studied at the moment. Indeed, a first look at the basic performance limitations of possible $p\bar{p}$ or pp rings in the LEP tunnel seems overdue, however far off in the future a possible start of such a p-LEP project may yet be in time. What we shall discuss is, in fact, rather obvious, but such a discussion has, to the best of our knowledge, not been presented so far.

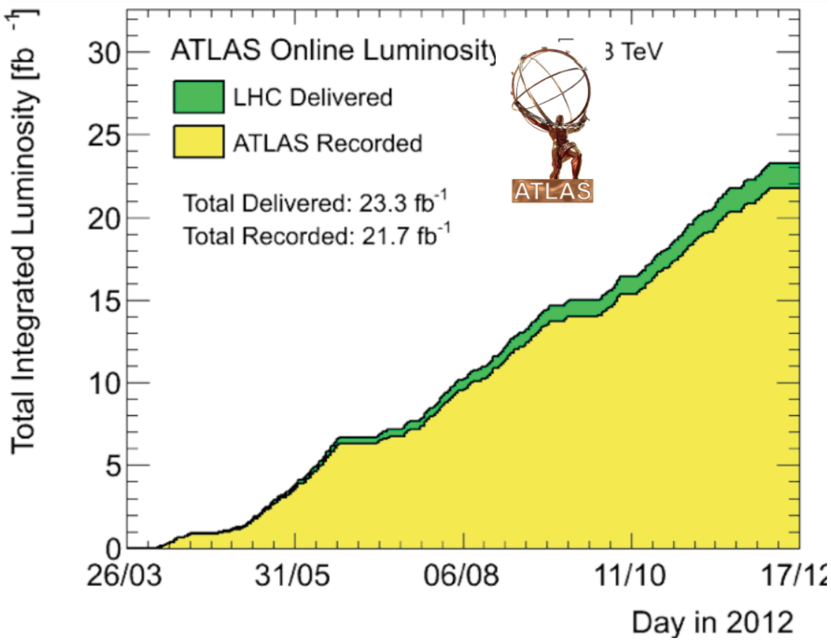
We shall not address any detailed design questions but shall give basic equations and make a few plausible assumptions for the purpose of illustration. Thus, we shall assume throughout that the maximum energy per beam is 8 TeV (corresponding to a little over 9 T bending field in very advanced superconducting magnets) and that injection is at 0.4 TeV. The ring circumference is, of course that of LEP, namely 26,659 m. It should be clear from this requirement of "Ten Tesla Magnets" alone that such a

30 years from the first (p-LEP = LHC) paper to LS1

backup

Run 1 - Accumulation of Luminosity

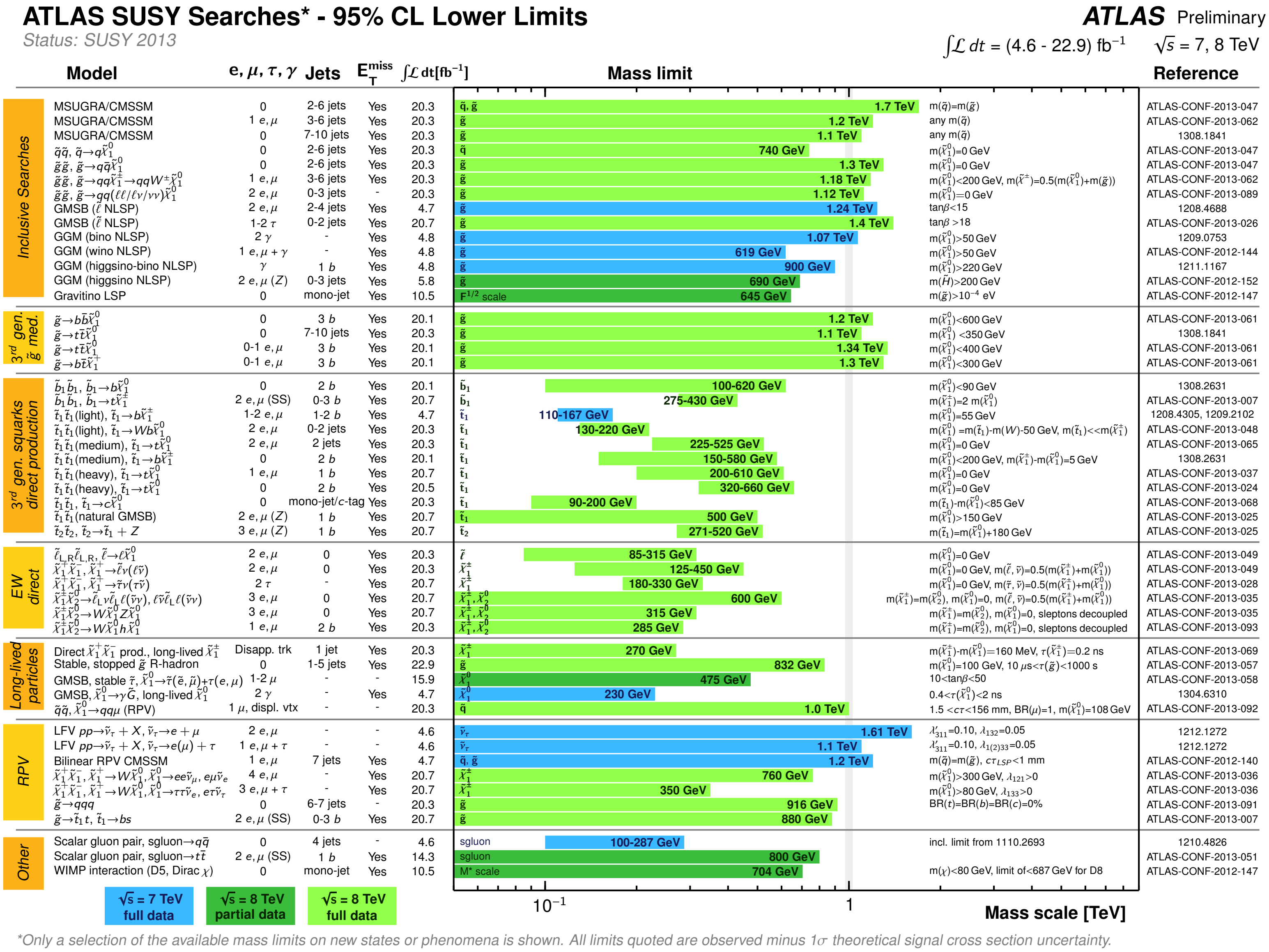




Outstanding efficiency for luminosity recording by the experiments.
Measured with beam scans and forward detectors to 2-4% precision!

Without the LHC there would be no (talking about the) future of HEP
A major achievement by machine, experiments and theoretical PP.

Searches for New Physics BSM



ATLAS SUSY Searches* - 95% CL Lower Limits

Status: SUSY 2013

ATLAS Preliminary

$\int\mathcal{L}\,dt$ = (4.6 - 22.9) fb^{-1} $\sqrt{s}$ = 7, 8 TeV

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int\mathcal{L}\,dt[fb^{-1}]$		Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$	1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.2 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	any $m(\tilde{q})$	1308.1841
	$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$	740 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}$, $\tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq\tilde{\chi}_1^{\pm}\to qqW^{\pm}\tilde{\chi}_1^0$	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.18 TeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}^{\pm})=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e, μ	0-3 jets	-	20.3	$\tilde{g}$	1.12 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e, μ	2-4 jets	Yes	4.7	$\tilde{g}$	1.24 TeV	$\tan\beta<15$	1208.4688
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$	1.4 TeV	$\tan\beta>18$	ATLAS-CONF-2013-026
	GGM (bino NLSP)	2 γ	-	Yes	4.8	$\tilde{g}$	1.07 TeV	$m(\tilde{\chi}_1^0)$>50 GeV	1209.0753
	GGM (wino NLSP)	1 $e, \mu + \gamma$	-	Yes	4.8	$\tilde{g}$	619 GeV	$m(\tilde{\chi}_1^0)$>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$	900 GeV	$m(\tilde{\chi}_1^0)$>220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e, μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$	690 GeV	$m(\tilde{H})$>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale	645 GeV	$m(\tilde{g})>10^{-4}$ eV	ATLAS-CONF-2012-147
3^{rd} gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$	1.2 TeV	$m(\tilde{\chi}_1^0)$<600 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	$m(\tilde{\chi}_1^0)$ <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$	1.34 TeV	$m(\tilde{\chi}_1^0)$<400 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)$<300 GeV	ATLAS-CONF-2013-061
3^{rd} gen. squarks direct production	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$	100-620 GeV	$m(\tilde{\chi}_1^0)$<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to t\tilde{\chi}_1^{\pm}$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$	275-430 GeV	$m(\tilde{\chi}_1^{\pm})=2\,m(\tilde{\chi}_1^0)$	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to b\tilde{\chi}_1^{\pm}$	1-2 e, μ	1-2 b	Yes	4.7	$\tilde{t}_1$	110-167 GeV	$m(\tilde{\chi}_1^0)$=55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	2 e, μ	0-2 jets	Yes	20.3	$\tilde{t}_1$	130-220 GeV	$m(\tilde{\chi}_1^0)=m(\tilde{t}_1)-m(W)$-50 GeV, $m(\tilde{t}_1)<<m(\tilde{\chi}_1^{\pm})$	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}_1^0$	2 e, μ	2 jets	Yes	20.3	$\tilde{t}_1$	225-525 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-065
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to b\tilde{\chi}_1^{\pm}$	0	2 b	Yes	20.1	$\tilde{t}_1$	150-580 GeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}_1^{\pm})-m(\tilde{\chi}_1^0)$=5 GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	1 e, μ	1 b	Yes	20.7	$\tilde{t}_1$	200-610 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.5	$\tilde{t}_1$	320-660 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$	90-200 GeV	$m(\tilde{t}_1)-m(\tilde{\chi}_1^0)$<85 GeV	ATLAS-CONF-2013-068
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e, μ (Z)	1 b	Yes	20.7	$\tilde{t}_1$	500 GeV	$m(\tilde{\chi}_1^0)$>150 GeV	ATLAS-CONF-2013-025
	$\tilde{t}_2\tilde{t}_2$, $\tilde{t}_2\to\tilde{t}_1+Z$	3 e, μ (Z)	1 b	Yes	20.7	$\tilde{t}_2$	271-520 GeV	$m(\tilde{t}_1)=m(\tilde{\chi}_1^0)$+180 GeV	ATLAS-CONF-2013-025
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}$, $\tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e, μ	0	Yes	20.3	$\tilde{\ell}$	85-315 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e, μ	0	Yes	20.3	$\tilde{\chi}_1^{\pm}$	125-450 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^{\pm})+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.7	$\tilde{\chi}_1^{\pm}$	180-330 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}_1^{\pm})+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-028
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu)$, $\ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e, μ	0	Yes	20.7	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$	600 GeV	$m(\tilde{\chi}_1^{\pm})=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^{\pm})+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0Z\tilde{\chi}_1^0$	3 e, μ	0	Yes	20.7	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$	315 GeV	$m(\tilde{\chi}_1^{\pm})=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0h\tilde{\chi}_1^0$	1 e, μ	2 b	Yes	20.3	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$	285 GeV	$m(\tilde{\chi}_1^{\pm})=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	ATLAS-CONF-2013-093
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^{\pm}$	270 GeV	$m(\tilde{\chi}_1^{\pm})-m(\tilde{\chi}_1^0)$=160 MeV, $\tau(\tilde{\chi}_1^{\pm})$=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	22.9	$\tilde{g}$	832 GeV	$m(\tilde{\chi}_1^0)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	ATLAS-CONF-2013-057
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$	475 GeV	10<$\tan\beta$<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	4.7	$\tilde{\chi}_1^0$	230 GeV	0.4<$\tau(\tilde{\chi}_1^0)$<2 ns	1304.6310
	$\tilde{q}\tilde{q}$, $\tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$	1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, $m(\tilde{\chi}_1^0)$=108 GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau+X$, $\tilde{\nu}_\tau\to e+\mu$	2 e, μ	-	-	4.6	$\tilde{\nu}_\tau$	1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\to\tilde{\nu}_\tau+X$, $\tilde{\nu}_\tau\to e(\mu)+\tau$	1 $e, \mu + \tau$	-	-	4.6	$\tilde{\nu}_\tau$	1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	1212.1272
	Bilinear RPV CMSSM	1 e, μ	7 jets	Yes	4.7	$\tilde{q}, \tilde{g}$	1.2 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}$<1 mm	ATLAS-CONF-2012-140
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e, μ	-	Yes	20.7	$\tilde{\chi}_1^{\pm}$	760 GeV	$m(\tilde{\chi}_1^0)$>300 GeV, λ_{121}>0	ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 $e, \mu + \tau$	-	Yes	20.7	$\tilde{\chi}_1^{\pm}$	350 GeV	$m(\tilde{\chi}_1^0)$>80 GeV, λ_{133}>0	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$	916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1t$, $\tilde{t}_1\to bs$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$	880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon pair, sgluon$\to q\bar{q}$	0	4 jets	-	4.6	sgluon	100-287 GeV	incl. limit from 1110.2693	1210.4826
	Scalar gluon pair, sgluon$\to t\bar{t}$	2 e, μ (SS)	1 b	Yes	14.3	sgluon	800 GeV		ATLAS-CONF-2013-051
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale	704 GeV	$m(\chi)$<80 GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

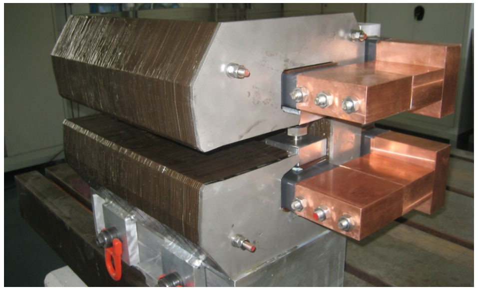
$\sqrt{s}$ = 7 TeV full data

$\sqrt{s}$ = 8 TeV partial data

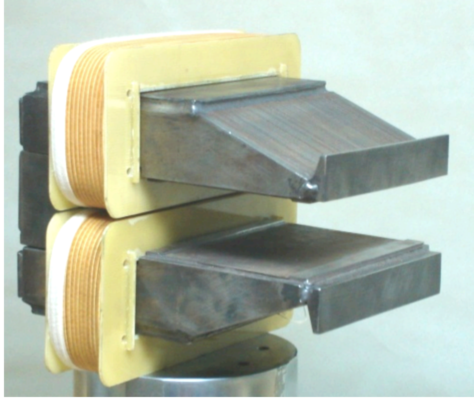
$\sqrt{s}$ = 8 TeV full data

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

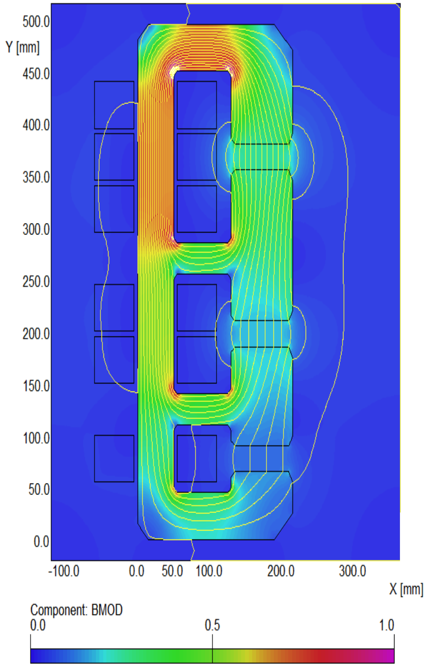
Magnet Developments



Prototypes for Ring dipoles
Fabricated and tested by
CERN (top) and Novosibirsk



LR recirculator dipoles and quadrupoles
New requirements (aperture, field)?
Combined apertures?
Combined functions (for example, dipole + quad)?
LR linac quadrupoles and correctors
New requirements (aperture, field)?
More compact magnets, maybe with at least two families for quadrupoles?
Permanent magnets / superconducting for quads?
A.Milanese, Chavannes workshop



1/2m dipole model
Full scale prototype
Quadrupole for Linac

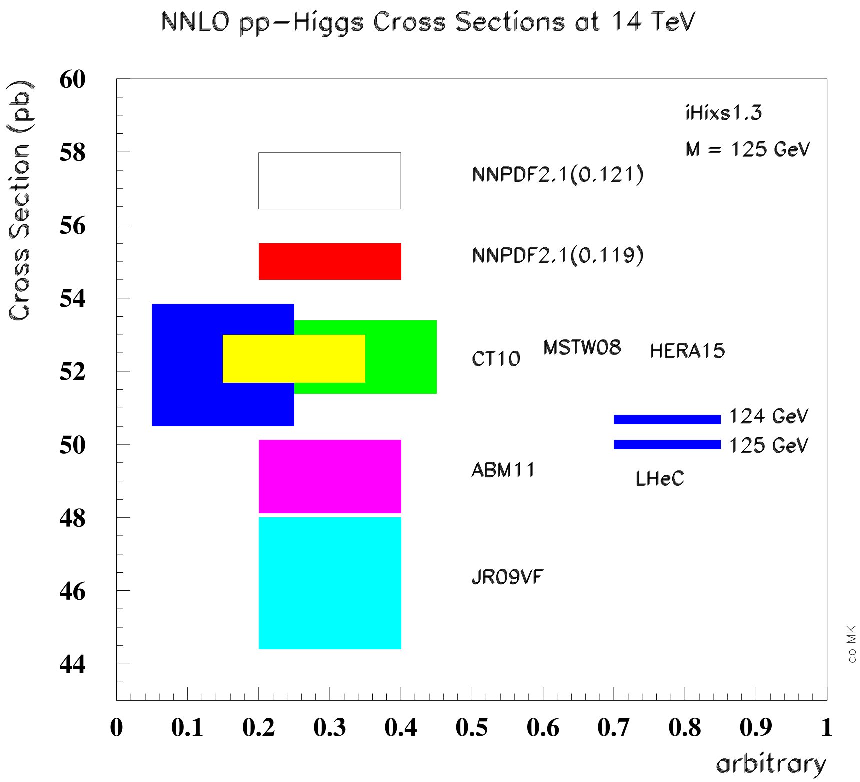
Magnets for ERL test stand

Collaboration of CERN, Beijing, Daresbury, Novosibirsk)

flux density in the gaps	0.264 T 0.176 T 0.088 T
magnetic length	4.0 m
vertical aperture	25 mm
pole width	85 mm
number of magnets	584
current	1750 A
number of turns per aperture	1 / 2 / 3
current density	0.7 A/ mm^2
conductor material	copper
resistance	0.36 mΩ
power	1.1 kW
total power 20 / 40 / 60 GeV	642 kW
cooling	air

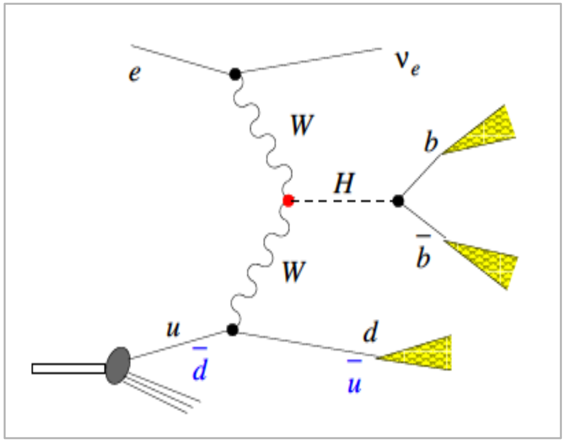
Higgs Physics with the LHeC

High precision partons and strong coupling to NNNLO remove QCD ("thy") uncertainties
→LHC facility may be transformed into precisionHiggs factory [σ(pp→ HX) = 50 pb]



O.Brüning and M.Klein, "The Large Hadron Electron Collider"
arXiv:1305.2090, MPLA A28(2013)16,1330011

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



With L=O(10^{34})cm^{-2} s^{-1} the LHeC becomes a high precision H facility complementary to LHC.

H→ bb to 1%
cc, ττ under study

cf U.Klein. Talk at EPS Stockholm, July 2013

cleaner FS than pp, no pile-up, unique VV→Z!