The LHeC Conceptual Design

A status report on behalf of the LHeC Study Group

Physics
Machine
Organisation

Max Klein

UNIVERSITY OF LIVERPOOL

ICHEP Paris: Future Machines and Projects 24.7.2010

http://cern.ch/lhec

Electron-proton colliders open new horizons on all three of the fundamental questions: the spectroscopy of fundamental fermions, the spectroscopy of gauge bosons, and the problem of hadron structure. In addressing these issues, the ep collider is approaching the same physics as is studied in e^+e^- and $\bar{p}p$ colliders, but in a complementary way, with emphasis on the t-channel. Each technique has its own strengths and weaknesses, which I leave you to contemplate.

Chris Quigg

FERMILAB-Conf-81/52-THY

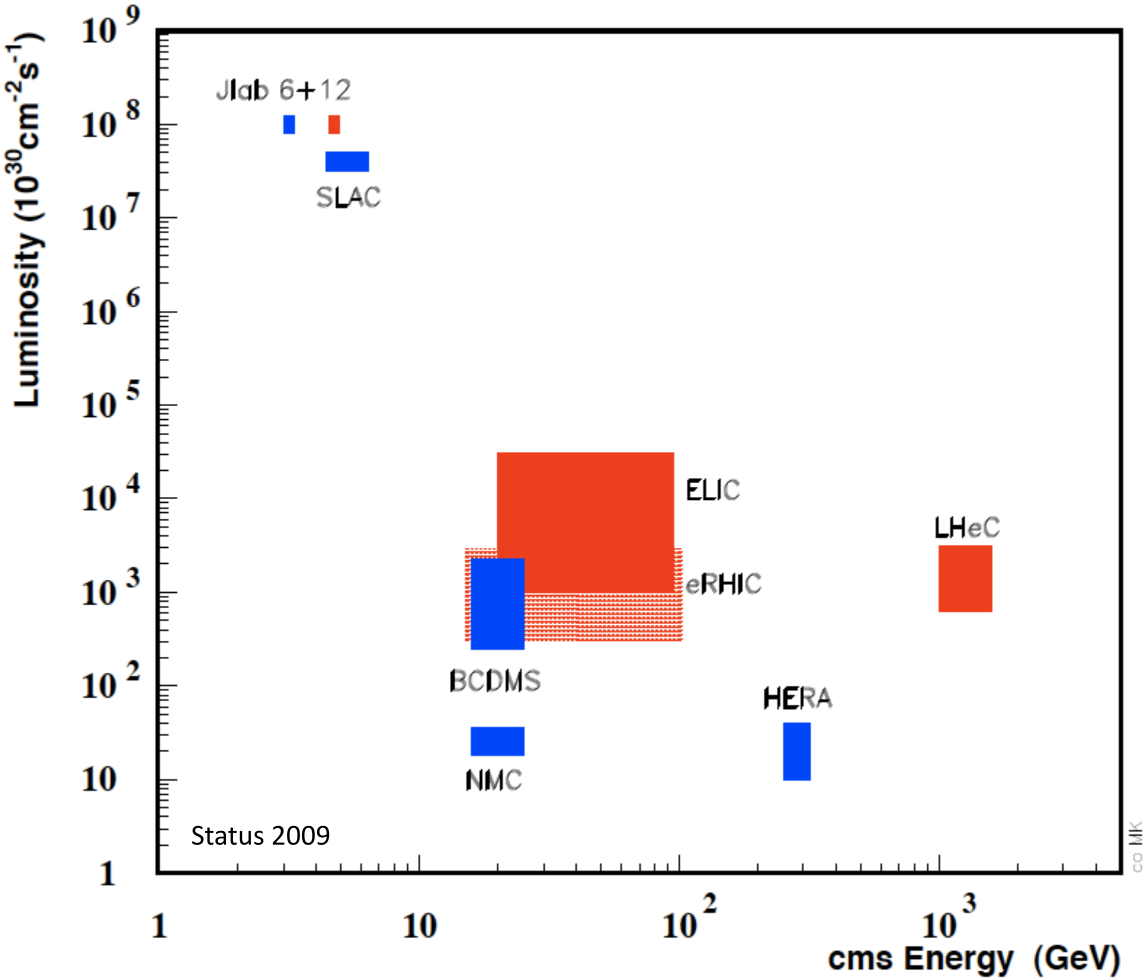
LEP*LHC (1984, 1990) - Lausanne, Aachen
E.Keil LHC project report 93 (1997)
Thera (2001),
QCD explorer (2003)
J.Dainton et al, 2006 JINST 1 10001

LHeC at DIS conferences since Madison 2005

2007 CERN SPC and [r]ECFA
2008 Divonne I, ICFA,ECFA
2009 Divonne II, NuPECC, ECFA

2010 Divonne III, ECFA - CDR

Lepton-Proton Scattering Experiments



done

planned

Tevatron/LEP/HERA (Fermiscale) → LHC/LC/LHeC (Terascale)
100 fold increase in luminosity, in Q^2 and $1/x$ w.r.t. HERA

Luminosity

$$L = \frac{N_p \gamma}{4\pi e \varepsilon_{pn}} \cdot \frac{I_e}{\sqrt{\beta_{px}\beta_{py}}}$$

$$N_p = 1.7 \cdot 10^{11}, \varepsilon_p = 3.8\mu m, \beta_{px(y)} = 1.8(0.5)m, \gamma = \frac{E_p}{M_p}$$

$$L = 8.2 \cdot 10^{32} cm^{-2} s^{-1} \cdot \frac{N_p 10^{-11}}{1.7} \cdot \frac{m}{\sqrt{\beta_{px}\beta_{py}}} \cdot \frac{I_e}{50mA}$$

$$I_e = 0.35mA \cdot P[MW] \cdot (100/E_e[GeV])^4$$

Ring-Ring

Power Limit of 100 MW wall plug

"ultimate" LHC proton beam

→L = 2 10^{33} $cm^{-2}s^{-1}$ → O(100) fb^{-1}

HERA 0.5fb^{-1} with 100 times less L

LINAC Ring

Pulsed, 60 GeV: ~10^{32}

High luminosity:

Energy recovery: $P=P_0/(1-\eta)$

β*=0.1m

[5 times smaller than LHC by reduced l*, only one p squeezed and IR quads as for HL-LHC]

L = 10^{33} $cm^{-2}s^{-1}$ → O(100) fb^{-1}

$$L = \frac{1}{4\pi} \cdot \frac{N_p}{\varepsilon_p} \cdot \frac{1}{\beta^*} \cdot \gamma \cdot \frac{I_e}{e}$$

$$N_p = 1.7 \cdot 10^{11}, \varepsilon_p = 3.8\mu m, \beta^* = 0.2m, \gamma = 7000/0.94$$

$$L = 8 \cdot 10^{31} cm^{-2} s^{-1} \cdot \frac{N_p 10^{-11}}{1.7} \cdot \frac{0.2}{\beta^*/m} \cdot \frac{I_e/mA}{1}$$

$$I_e = mA \frac{P/MW}{E_e/GeV}$$

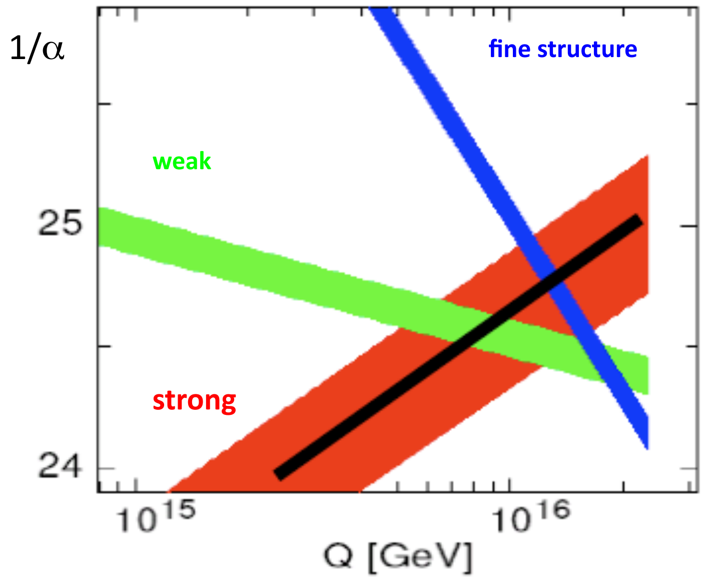
Precision QCD and Electroweak Physics

Based on weak = electromagnetic cross sections, p, d, $e^{\pm}$,P_e and high precision and full acceptance

Structure functions [F_2,F_L,xF_3^{gZ},F_2^{gZ}; F_2^{cc},F_2^{bb},F_2^{ss}] in p/d and A
Quark distributions from direct measurements and QCD fits
Strong coupling constant α_s to per mille accuracy
Gluon distribution in full x range to unprecedented precision
Standard Model Higgs
Single top and anti-top quark production at high rate (5pb)
Electroweak couplings (light and heavy quarks and mixing angle)
Heavy quark fragmentation functions
Charm and beauty below and way beyond threshold at per cent accuracy
Heavy quarks in real photon-proton collisions [LR option]
Jets and QCD in photoproduction and DIS
Gluon structure of the photon
….

Strong Coupling Constant

Simulation of α_s measurement at LHeC



MSSM - B.Allnach et al, hep-ex/0403133

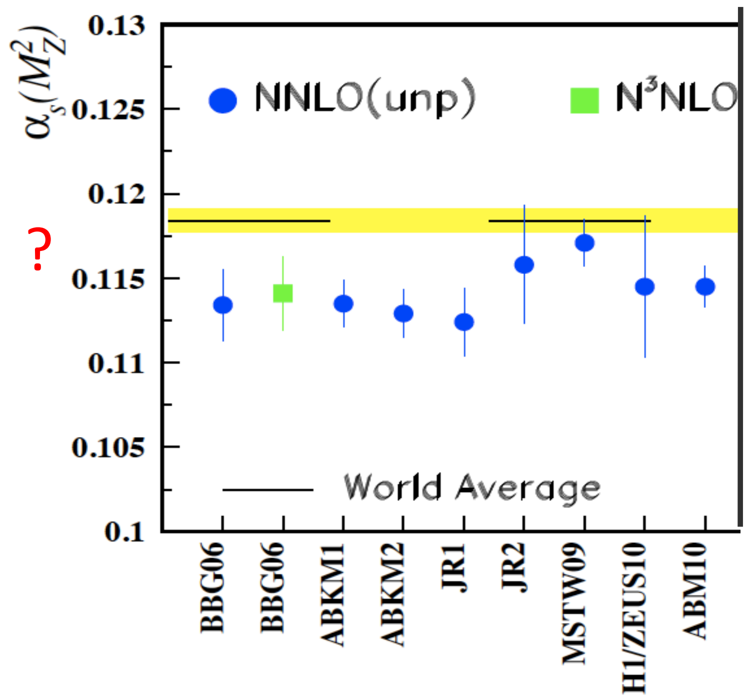
DATA	exp. error on α_s
NC e⁺ only	0.48%
NC	0.41%
NC & CC	**0.23% :=(1)**
(1) γ_h>5°	0.36% :=(2)
(1) +BCDMS	0.22%
(2) +BCDMS	0.22%
(1) stat. *= 2	0.35%

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 accuracy indep. of BCDMS.
Challenge to experiment and to h.o. QCD

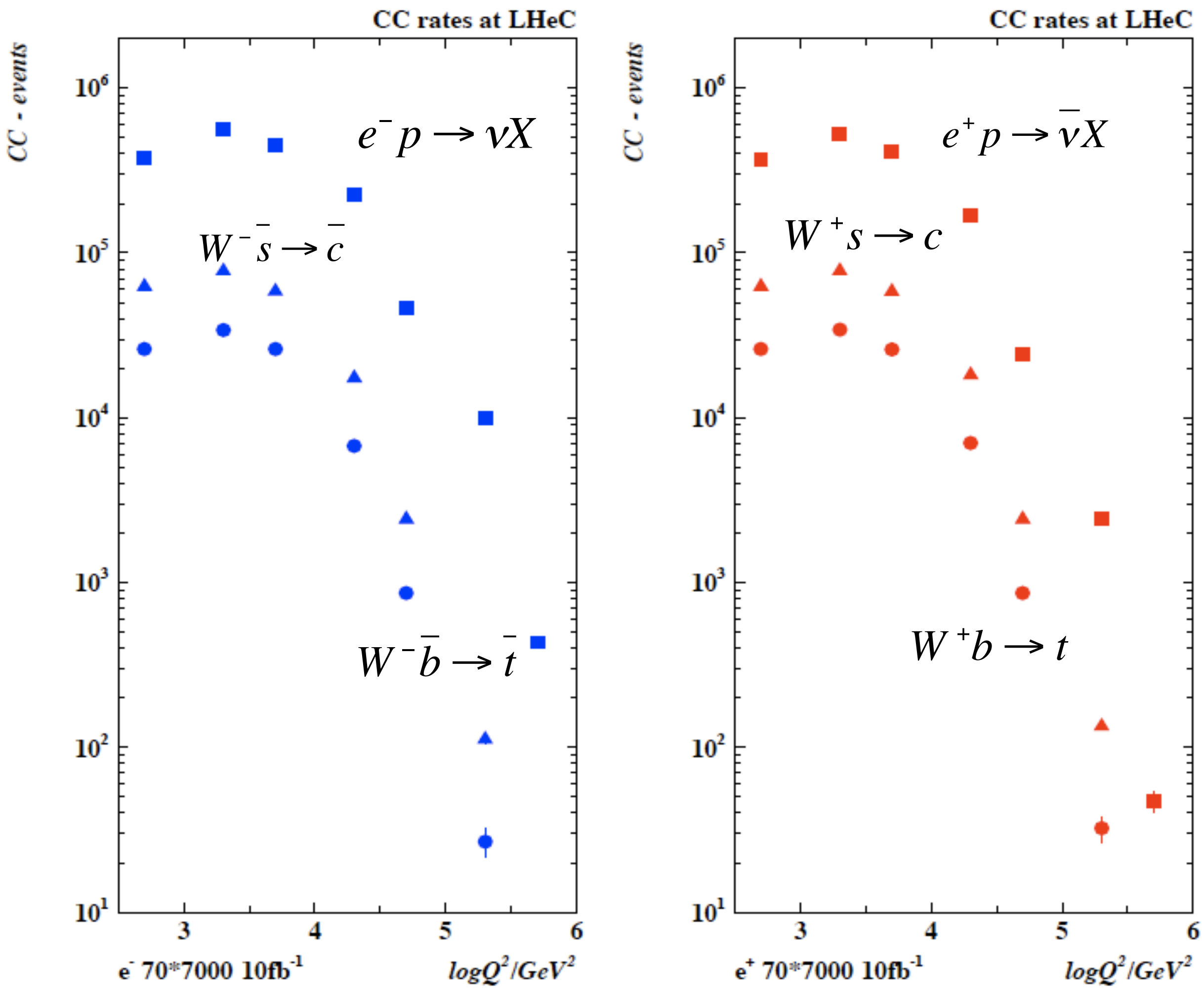
?

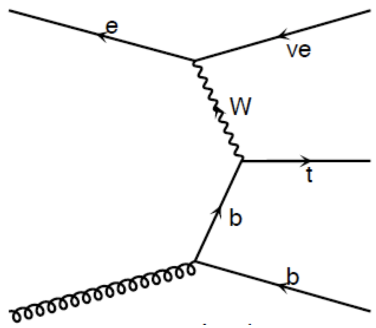


+pol

J.Bluemlein and H. Boettcher, arXiv 1005.3013 (2010)

Single top and anti-top Production in Charged Currents





LHeC is a single top and single tbar quark `factory'

CC t cross section O(5)pb

CC events for 10 fb^{-1}

New Physics at the LHeC

Divonne 08

- **Lepto-Quark Production and Decay (s and t-channel effects)**

Maximum $W < 1.4$ TeV
for $E_e = 140$ GeV, $E_p = 7$ TeV

- **Squarks and Gluinos**
- **ZZ, WZ, WW elastic and inelastic collisions**
- **Technicolor**
- **Novel Higgs Production Mechanisms**
- **Composite electrons**
- **Lepton-Flavor Violation**
- **QCD at High Density in ep and eA collisions**
- **Odderon**

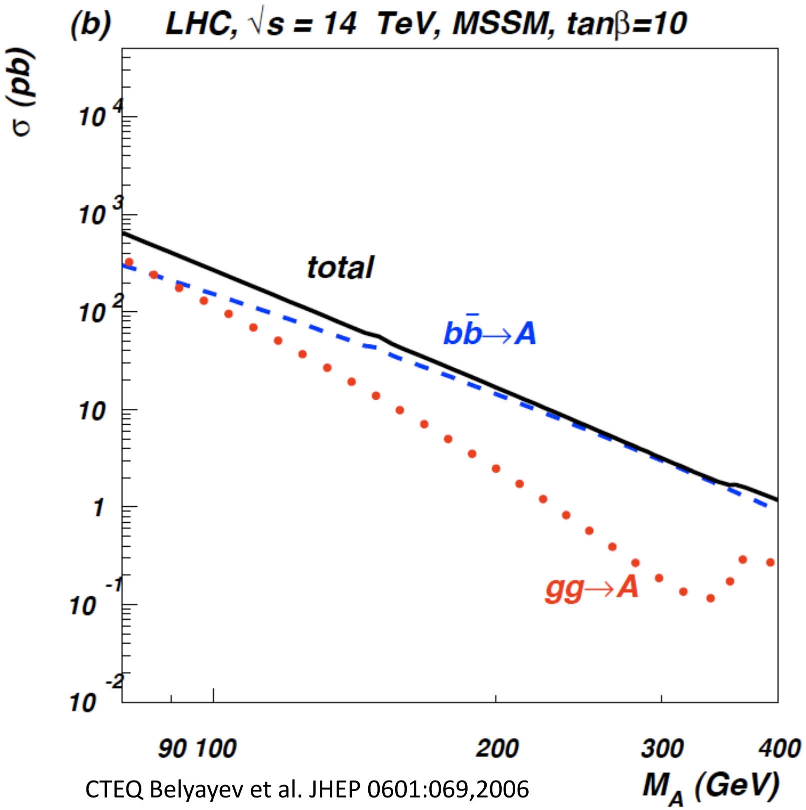
Broad physics goals (to be discussed at the Workshop)

- Proton structure and QCD physics in the domain of x and Q^2 of LHC experiments
- Small-x physics in eP and eA collisions
- Probing the $e^{\pm}$-quark system at ~TeV energy
  eg leptoquarks, excited e*'s, mirror e, SUSY with no R-parity......
- Searching for new EW currents
  eg RH W's, effective eeqq contact interactions...

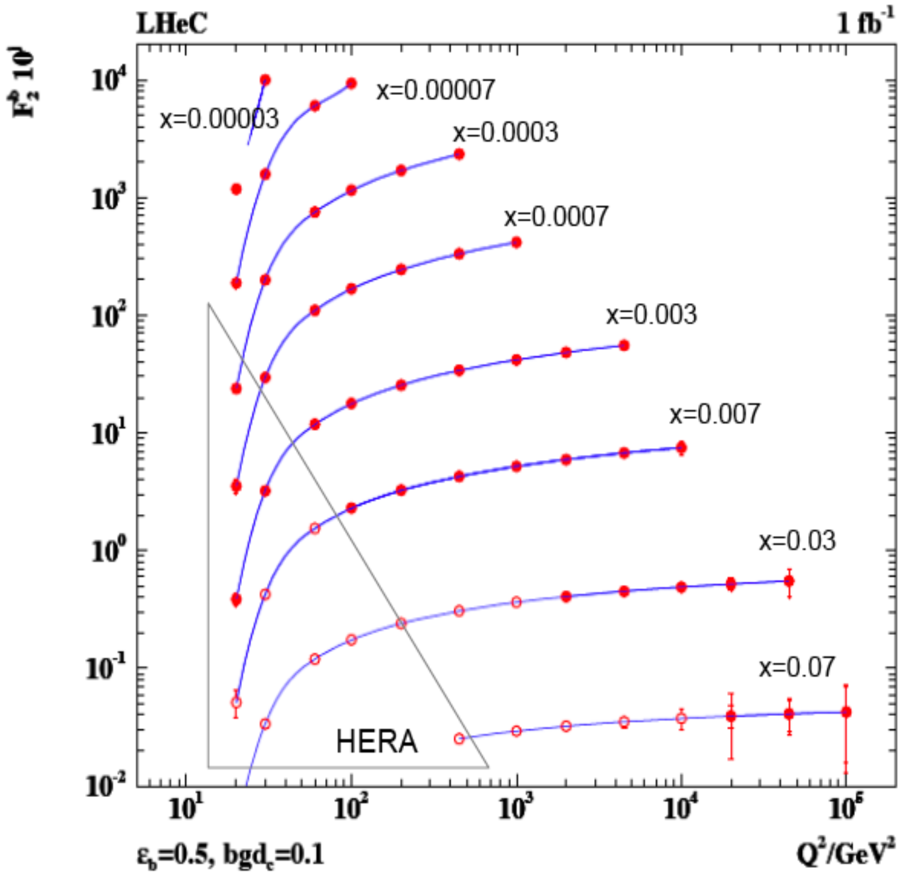
G. Altarelli

J.Bartels: Theory on low x

Beauty - MSSM Higgs



CTEQ Belyayev et al. JHEP 0601:069,2006



In MSSM Higgs production is b dominated

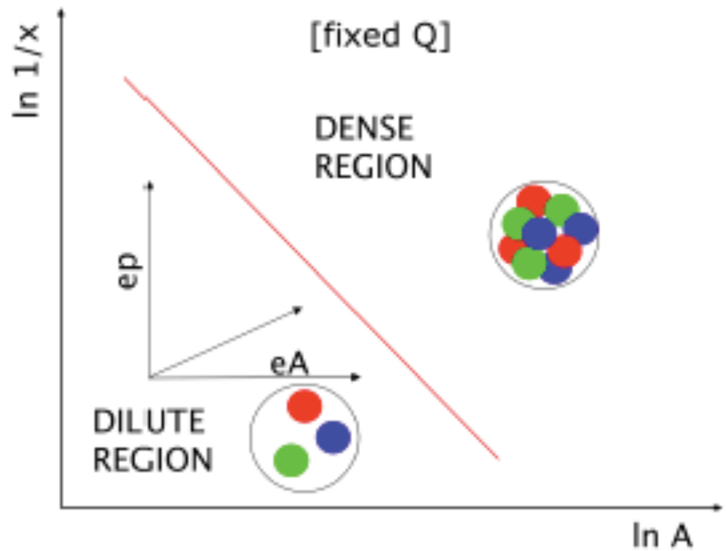
First measurements of b at HERA can be turned to precision measurement of b-df.

LHeC: higher fraction of b, larger range, smaller beam spot, better Si detectors

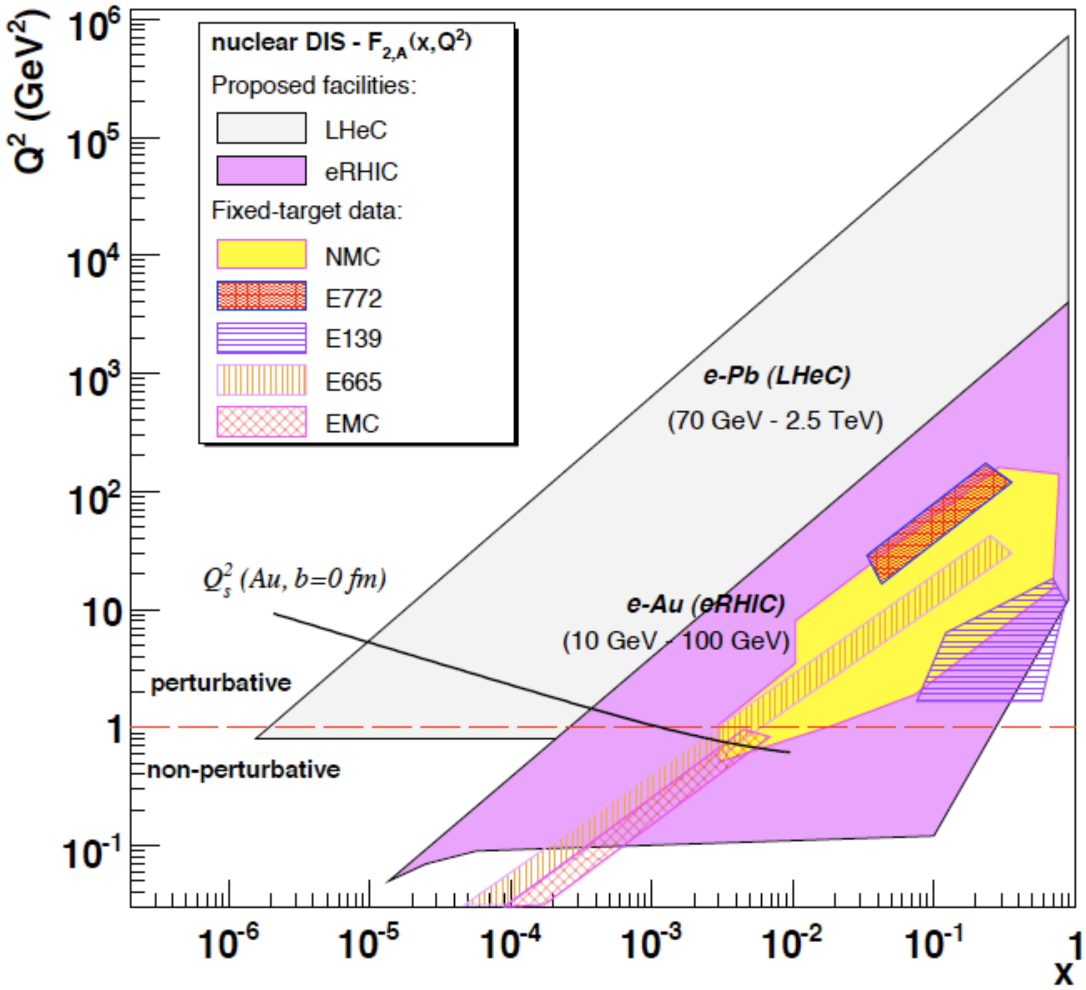
Low x Physics: non-linear parton evolution (ep/eA)

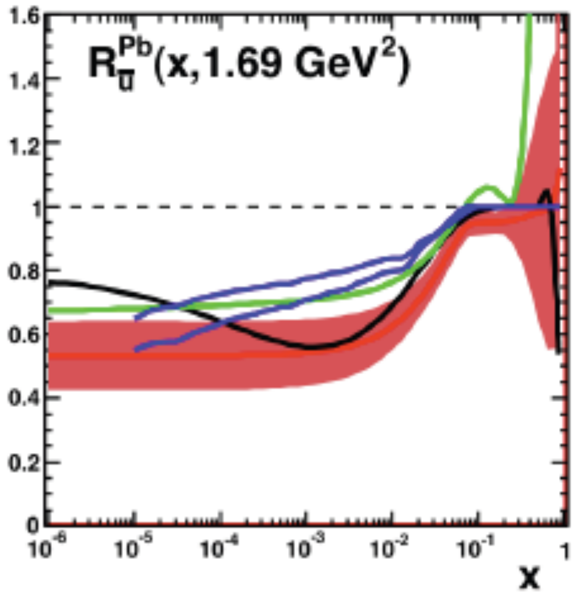
Based on p/A [$e^{\pm}$,P_e] and high precision and full acceptance in forward and backward region

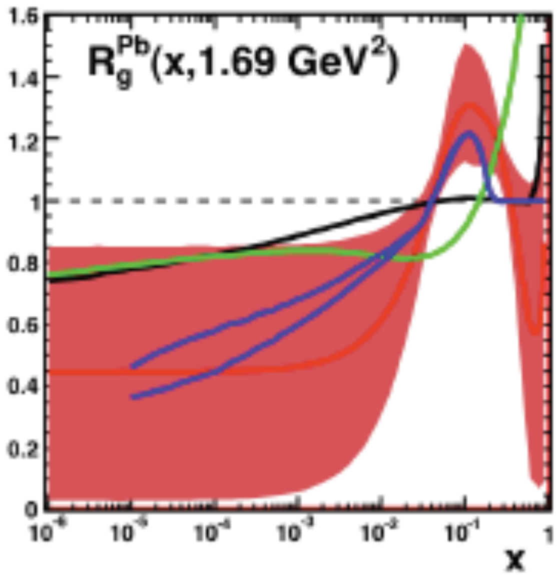
Unitarity and QCD
Expectations from LHC
Nuclear Parton Distributions
New physics at low x
Diffraction
Vector Mesons
Deeply Virtual Compton Scattering
Jets and Parton Dynamics
Forward jets and parton emission
Initial QGP [AA-eA]
UHE Neutrino Scattering and LHeC



eA → eX

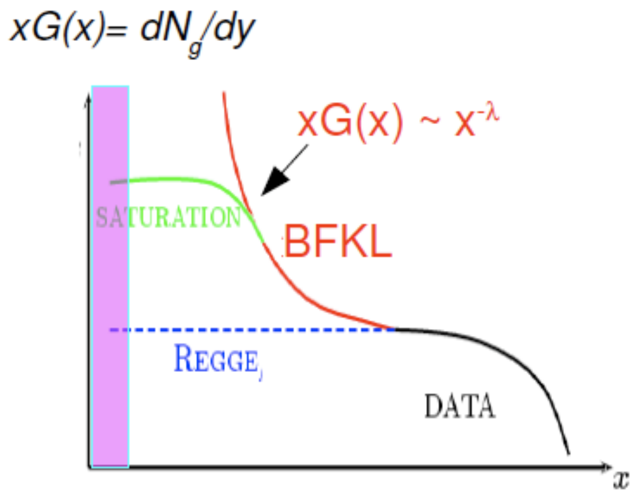


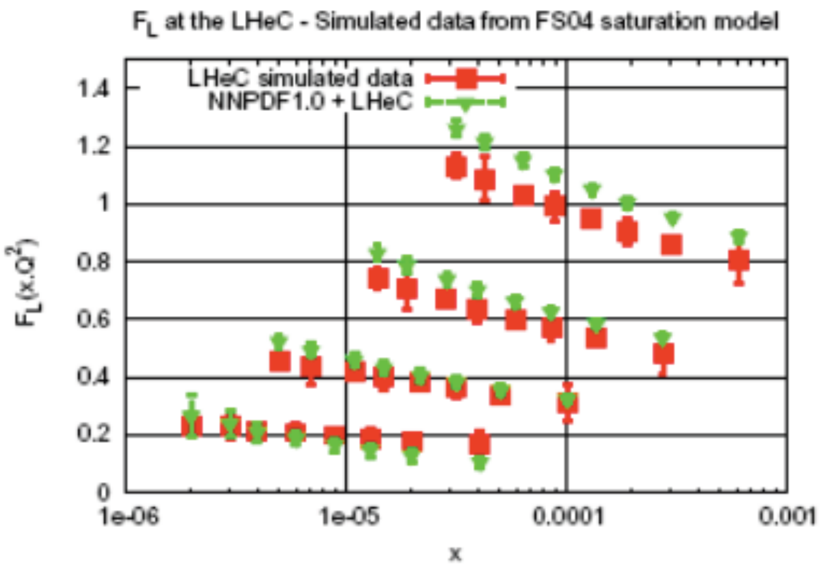


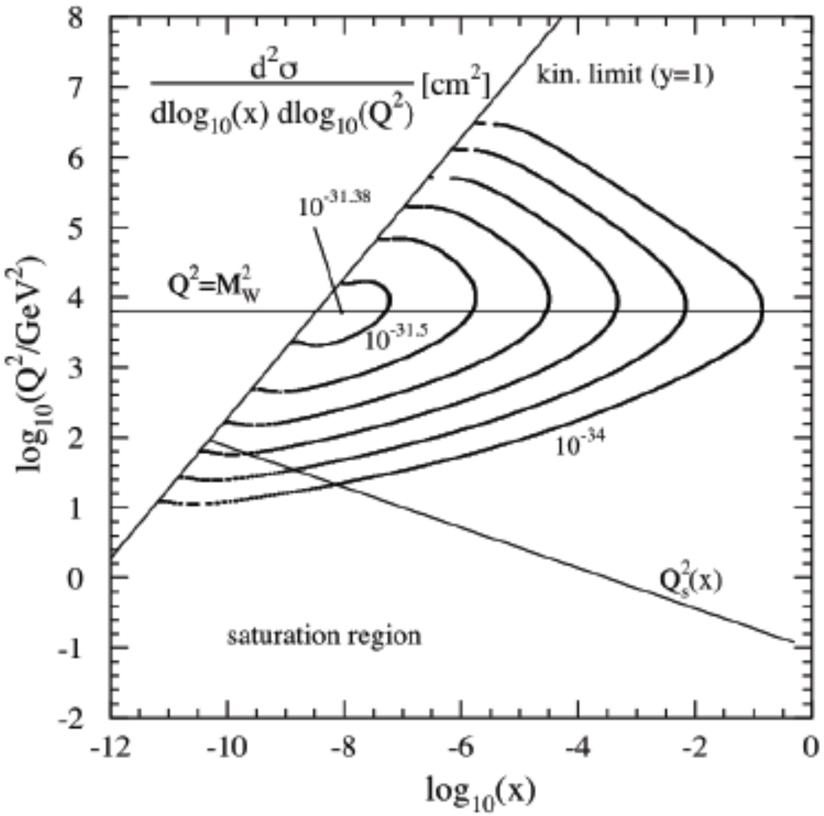


Extension of kinematic range by 3-4 orders of magnitude into saturation region (with p and A)
Like LHeC ep without HERA.. (e.g. heavy quarks in A)

Saturation of Gluon Density



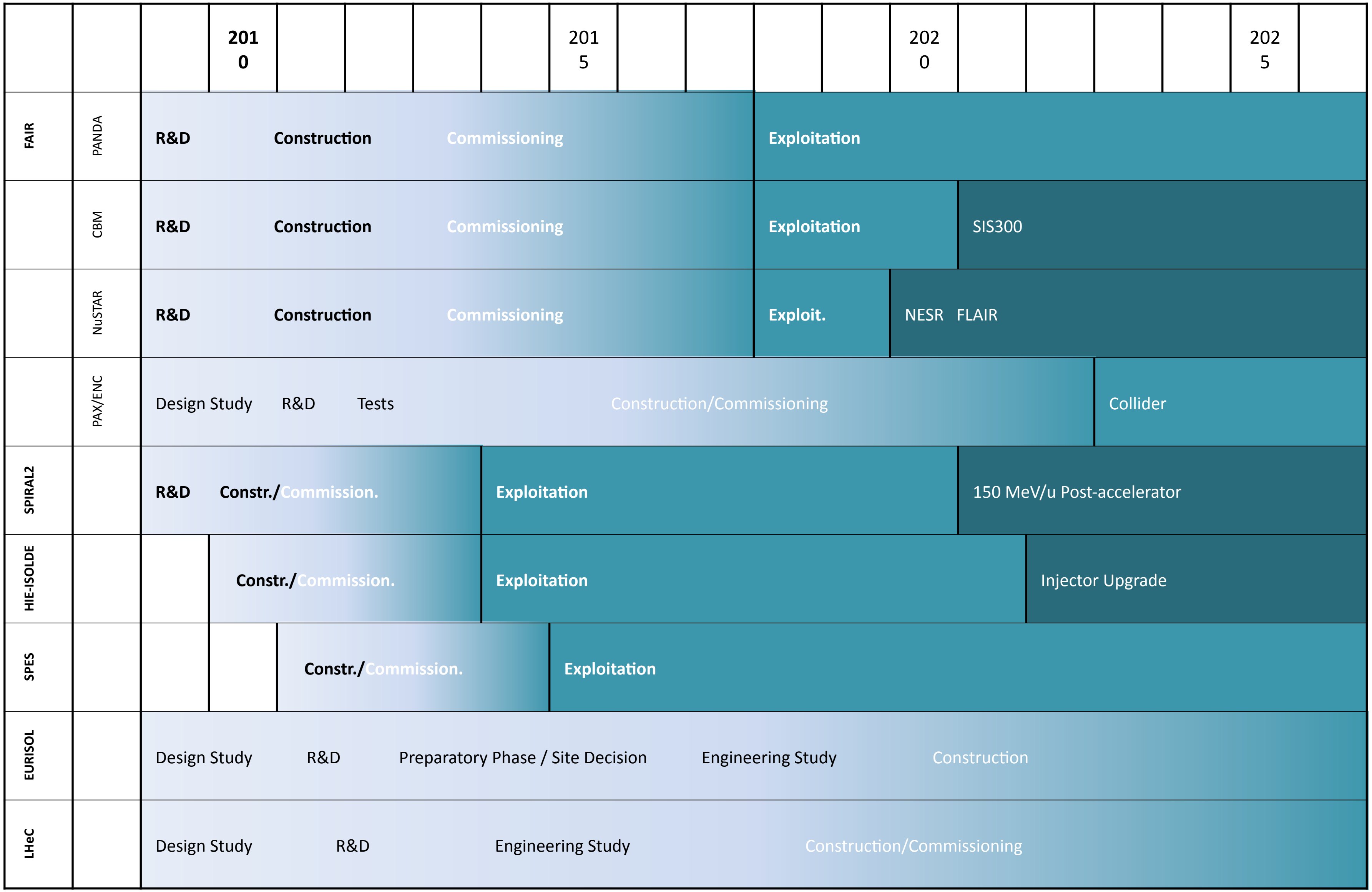




MUST show up as LHeC measures in unitarity limited region. Can be uniquely identified (inclusive F_2/F_L, diffraction, J/ψ).

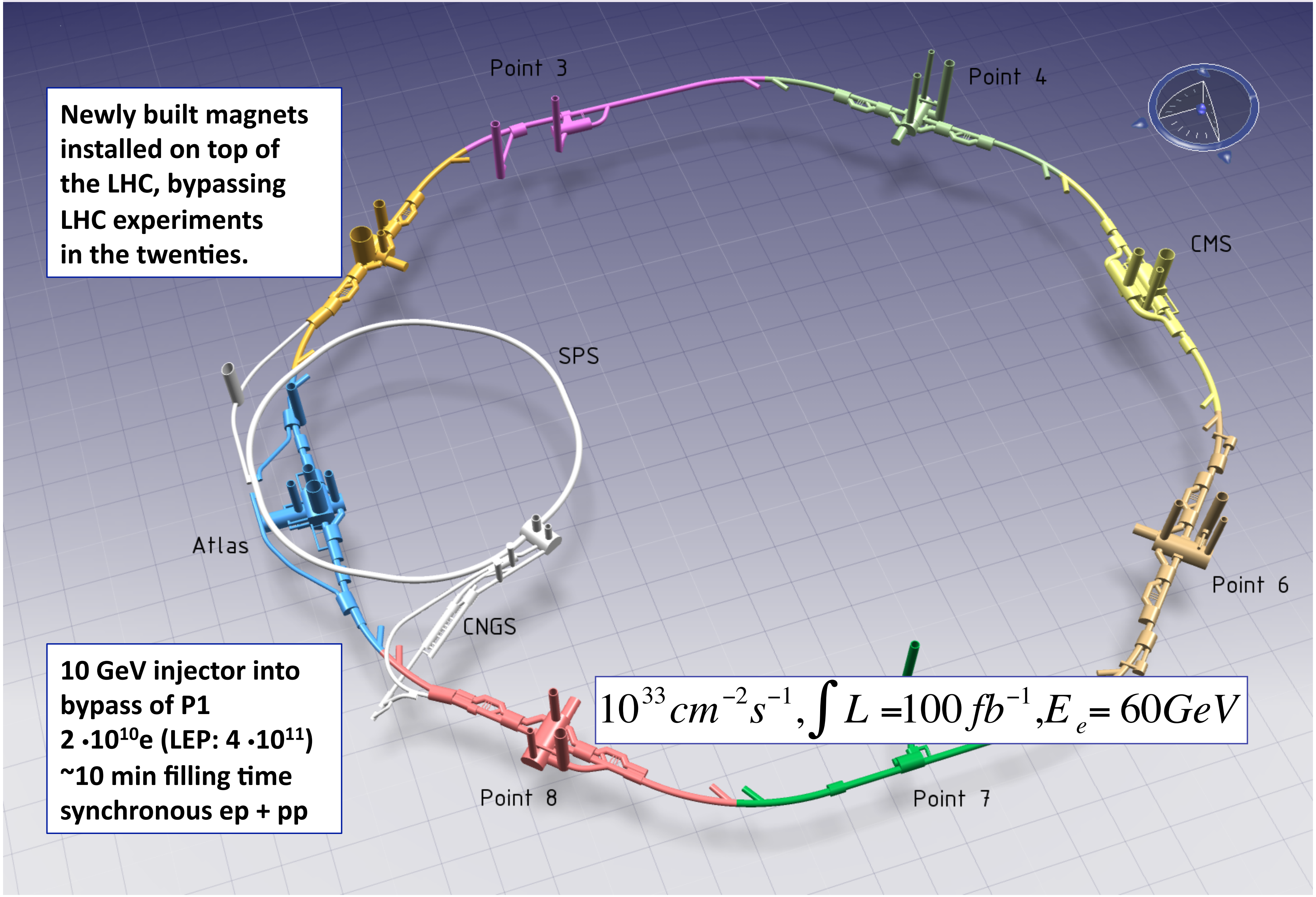
With eA reach effectively x of 10^{-8} (UHEν)

NuPECC – Roadmap 5/2010: New Large-Scale Facilities



G. Rosner, NuPECC Chair, Madrid 5/10

Ring-Ring configuration

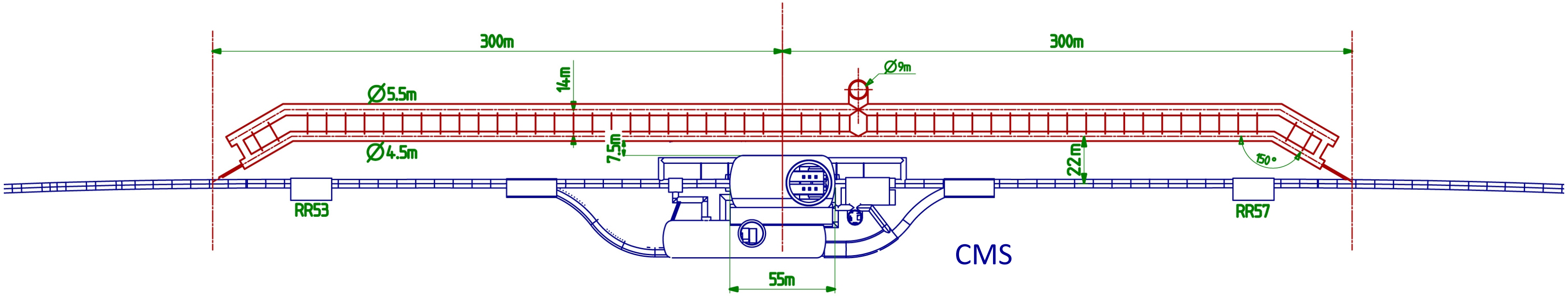


Newly built magnets installed on top of the LHC, bypassing LHC experiments in the twenties.

$$10^{33} cm^{-2} s^{-1}, \int L = 100\, fb^{-1}, E_e = 60 GeV$$

10 GeV injector into bypass of P1
$2 \cdot 10^{10}$e (LEP: $4 \cdot 10^{11}$)
~10 min filling time
synchronous ep + pp

Bypasses



Away from galeries

Double tunnel (?): use to install rf [typically 0.5-1km]

Aim to keep $U_e=U_p$

Tunnel connection (CGNS, DESY)

Possibly in line with P1,5 redesigns

Accelerator: Ring - Ring

Based on HERA, LEP and LHC Experience

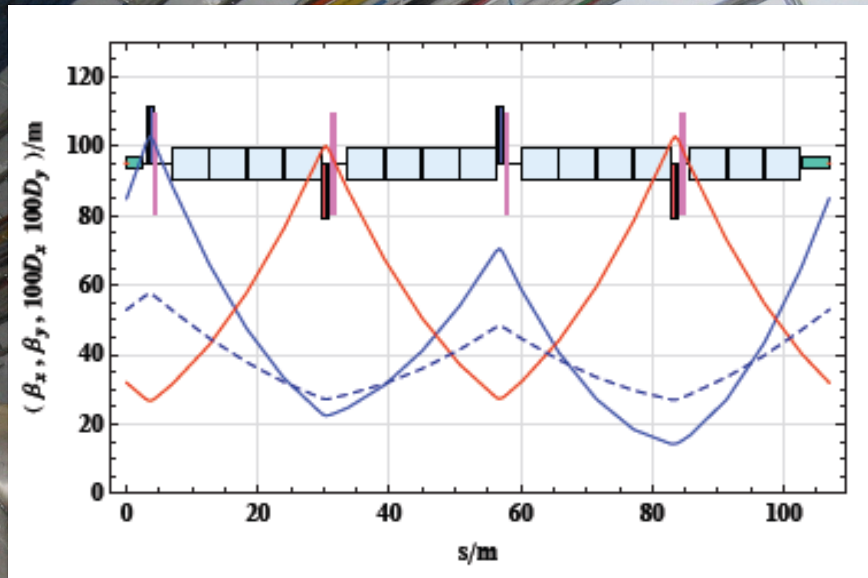
Workpackages for CDR

Baseline Parameters and Installation Scenarios
Lattice Design [Optics, Magnets, Bypasses, IR for high L and 1^o]
Rf Design [Installation in bypasses, Crabs]
Injector Complex [Sources, Injector]
Injection and Dump
Beam-beam effects
Impedance and Collective Effects
Vacuum and Beam Pipe
Integration and Machine Protection
Powering Issues
e Beam Polarization
Deuteron and Ion Beams

BINP Novosibirsk
BNL
CERN
Cockcroft
Cornell
DESY
EPFL Lausanne
KEK
Liverpool U
SLAC
TAC Turkey

e Ring Design

Arc cell design: $L_{FODO}(e)=L_{FODO}(p)/2$



LHC Cryo jumpers accounted for in asymmetric FODO.

Further interferences mapped and being studied.

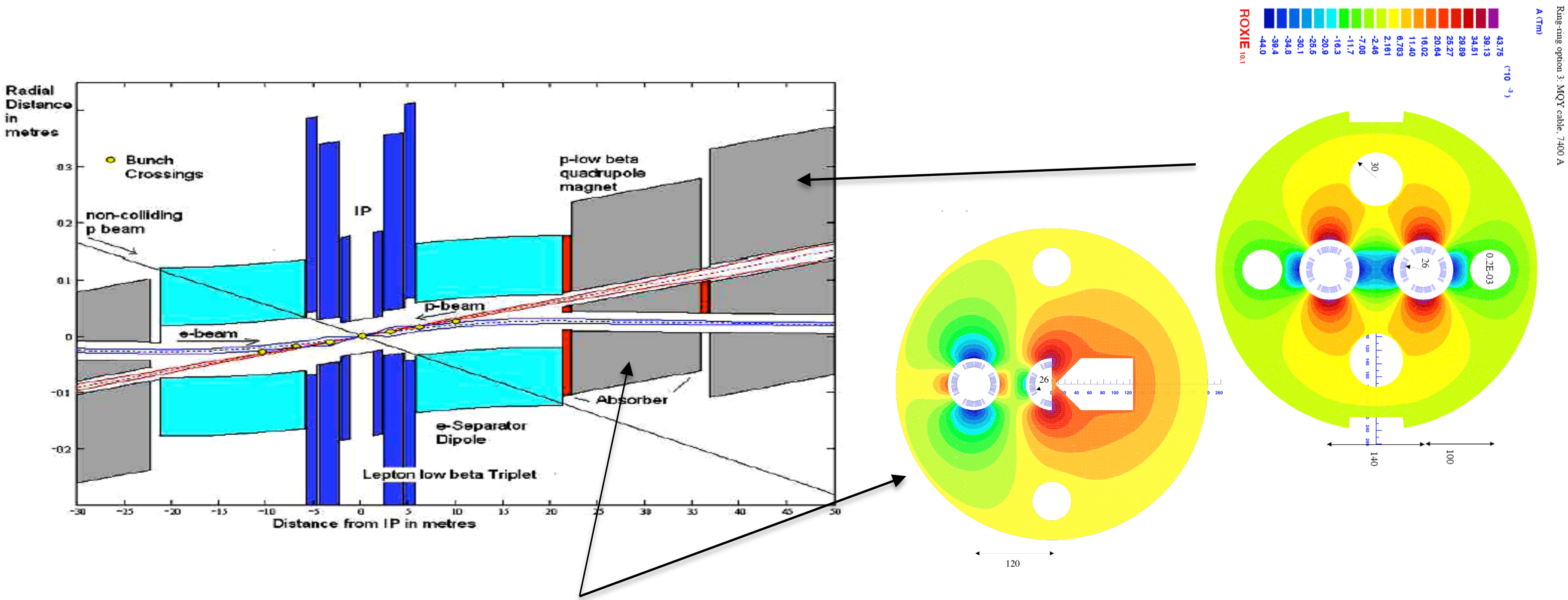
Experiments bypassed in new tunnels which houses rf.

Meets spatial LHC constraints
Synchrotron radiation < 50MW
Two types of quadrupoles
Reasonable sextupole parameters
Dipoles: 4x lighter/slimmer than LEP
Prototypes: Novosibirsk and CERN

Interaction Region

Small crossing angle of about 1mrad to avoid first parasitic crossing (L x 0.77)
(Dipole in detector? Crab cavities? Design for 25ns bunch crossing [50ns?]
Synchrotron radiation –direct and back, absorption … recall HERA upgrade…)

Focus of current activity

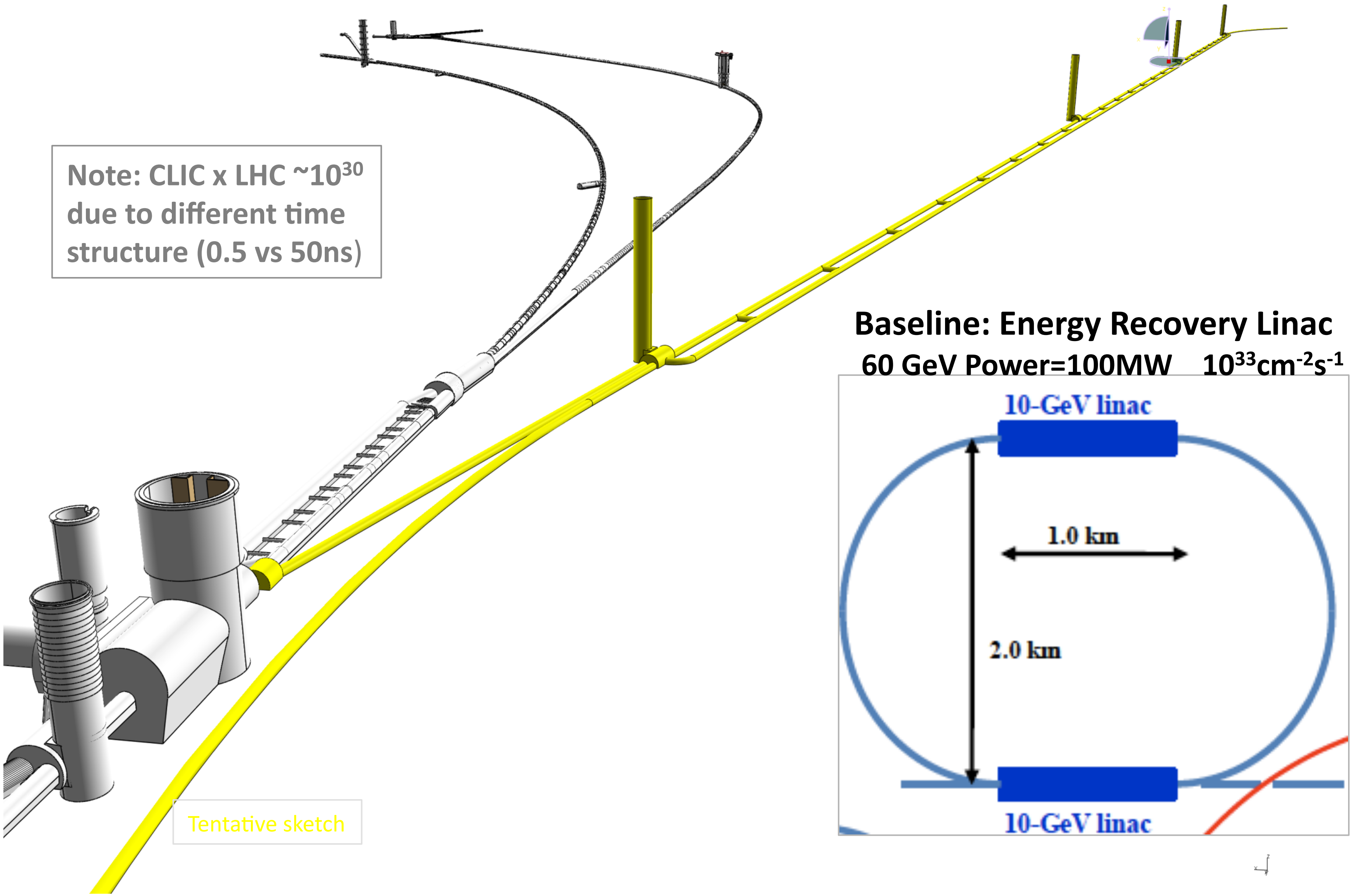


1^{st} sc half quad (focus and deflect)
separation 5cm, g=127T/m, MQY cables, 4600 A

2^{nd} quad: 3 beams in horizontal plane
separation 8.5cm, MQY cables, 7600 A

Linac-Ring configuration

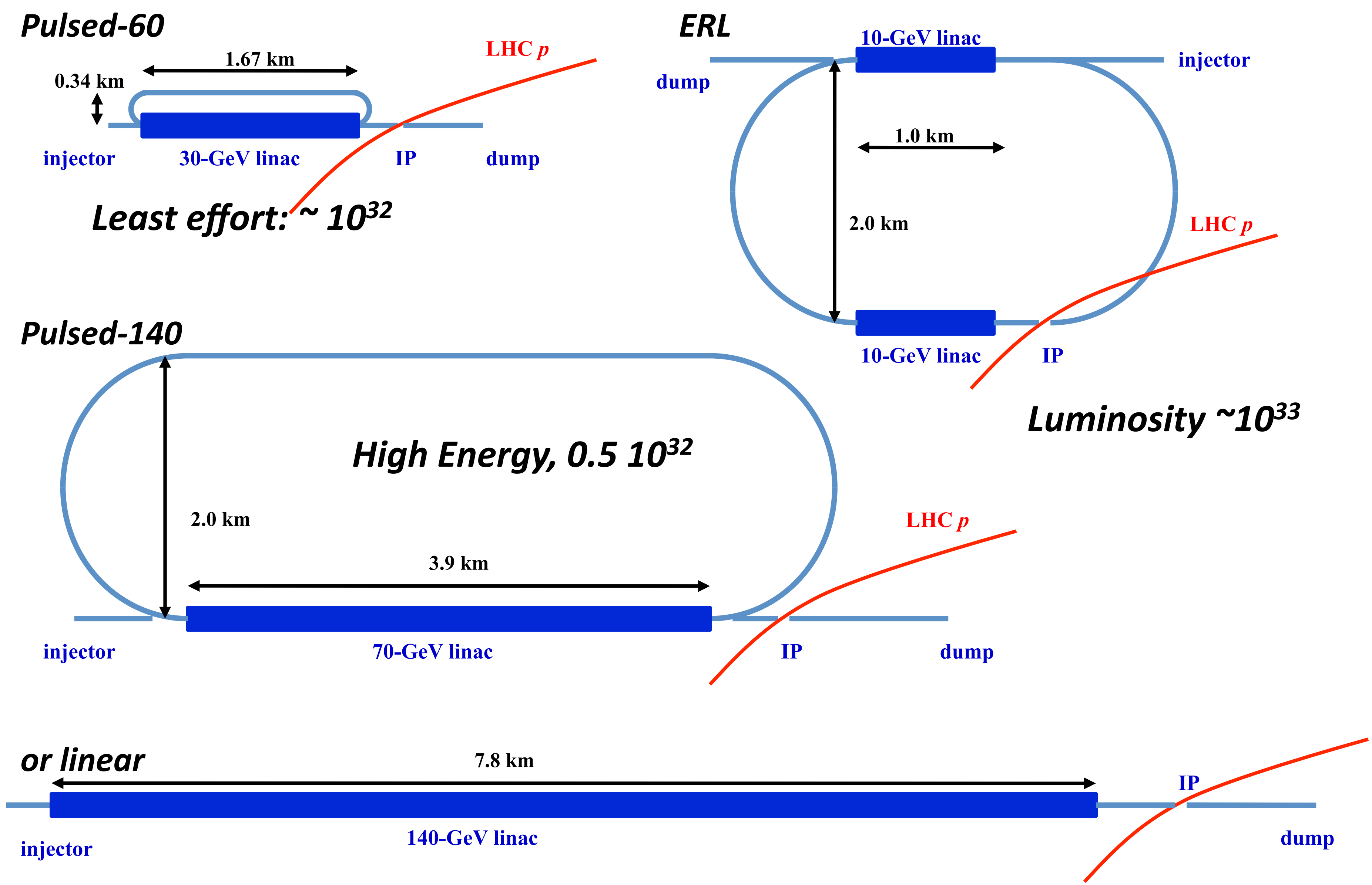
Note: CLIC x LHC ~10^{30} due to different time structure (0.5 vs 50ns)



Baseline: Energy Recovery Linac

60 GeV Power=100MW $10^{33}cm^{-2}s^{-1}$

Linac-Ring Configurations



Accelerator: LINAC - Ring

Based on ILC, SLC and LHC Experience

Workpackages for CDR

Baseline Parameters [Designs, Real photon option, ERL]
Sources [Positrons, Polarisation]
Rf Design
Injection and Dump
Beam-beam effects
Lattice/Optics and Impedance
Vacuum and Beam Pipe
Integration and Layout
Interaction Region
Powering Issues
Magnets
Cryogenics

BINP Novosibirsk
BNL
CERN
Cockcroft
Cornell
DESY
EPFL Lausanne
KEK
Liverpool U
SLAC
TAC Turkey

LINAC-Ring Parameters

Table 4: Lepton beam parameters and luminosity.

	p-60	erl	p-140
e^- energy at IP [GeV]	60	60	140
luminosity [10^{32} $cm^{-2}s^{-1}$]	1.1	10.1	0.4
polarization [%]	90	90	90
bunch population [10^9]	4.5	2.0	1.6
e^- bunch length [μm]	300	300	300
bunch interval [ns]	50	50	50
transv. emit. $\gamma\epsilon_{x,y}$ [μm]	50	50	100
rms IP beam size [μm]	7	7	7
hourglass reduction H_{hg}	0.91	0.91	0.94
crossing angle θ_c	0	0	0
repetition rate [Hz]	10	CW	10
bunches/pulse [10^5]	1	N/A	1
pulse current [mA]	16	10	6.6
beam pulse length [ms]	5	N/A	5
ER efficiency η	0	94%	0
total wall plug power [MW]	100	100	100

For ERL version:
2 x 560, 1m long cavities
25 MW cryo power

Table 2: SC linac parameters. *RT: room temperature.

	p-60	erl	p-140
RF frequency [MHz]	700	700	700
cavity length [m]	1	1	1
energy gain / cavity	31.5	18	31.5
R/Q [Ω]	403	403	403
Q_0 [10^{10}]	1	2.5	1
power loss, stat [W/cav.]	5	5	5
power loss, RF [W/cav]	12.3	32	12.3
power loss, total [W/cav]	17.3	37.2	17.3
real-est. gradient [MeV/m]	17.8	10.26	17.8
length/GeV [m]	55.7	97.5	55.7
#cavities/(1 GeV)	31.8	55.6	31.8
power loss/GeV (2 K) [kW]	0.55	2.06	0.55
"W per W" (1.8 K to RT*)	600	600	600
power loss/GeV (RT*) [MW]	0.33	1.24	0.3
final energy [GeV]	60	60	140
# passes for acceleration	2	3	2
# passes for deceleration	0	3	0
total linac length [km]	1.67	1.95	3.90
tot. cryo power (RT) [MW]	9.9	24.75	23.1
av. beam current [mA]	0.74	6.6	0.27
beam power at IP [MW]	45	396	39
RF power [MW]	89	(22)	75.6
cryo + RF power [MW]	99	(47)	98.4

Cf recent papers to IPAC10 at Kyoto (from LHeC web page)

Design Parameters

electron beam	RR	LR	LR
e- energy at IP[GeV]	60	60	140
luminosity [10^{32} $cm^{-2}s^{-1}$]	17	10	0.44
polarization [%]	40	90	90
bunch population [10^9]	26	2.0	1.6
e- bunch length [mm]	10	0.3	0.3
bunch interval [ns]	25	50	50
transv. emit. $\gamma\varepsilon_{x,y}$ [mm]	0.58, 0.29	0.05	0.1
rms IP beam size $\sigma_{x,y}$ [μm]	30, 16	7	7
e- IP beta funct. $\beta^*_{x,y}$ [m]	0.18, 0.10	0.12	0.14
full crossing angle [mrad]	0.93	0	0
geometric reduction H_{hg}	0.77	0.91	0.94
repetition rate [Hz]	N/A	N/A	10
beam pulse length [ms]	N/A	N/A	5
ER efficiency	N/A	94%	N/A
average current [mA]	131	6.6	5.4
tot. wall plug power[MW]	100	100	100

proton beam	RR	LR
bunch pop. [10^{11}]	1.7	1.7
tr.emit.$\gamma\varepsilon_{x,y}$ [μm]	3.75	3.75
spot size $\sigma_{x,y}$ [μm]	30, 16	7
$\beta^*_{x,y}$ [m]	1.8,0.5	0.1
bunch spacing [ns]	25	25

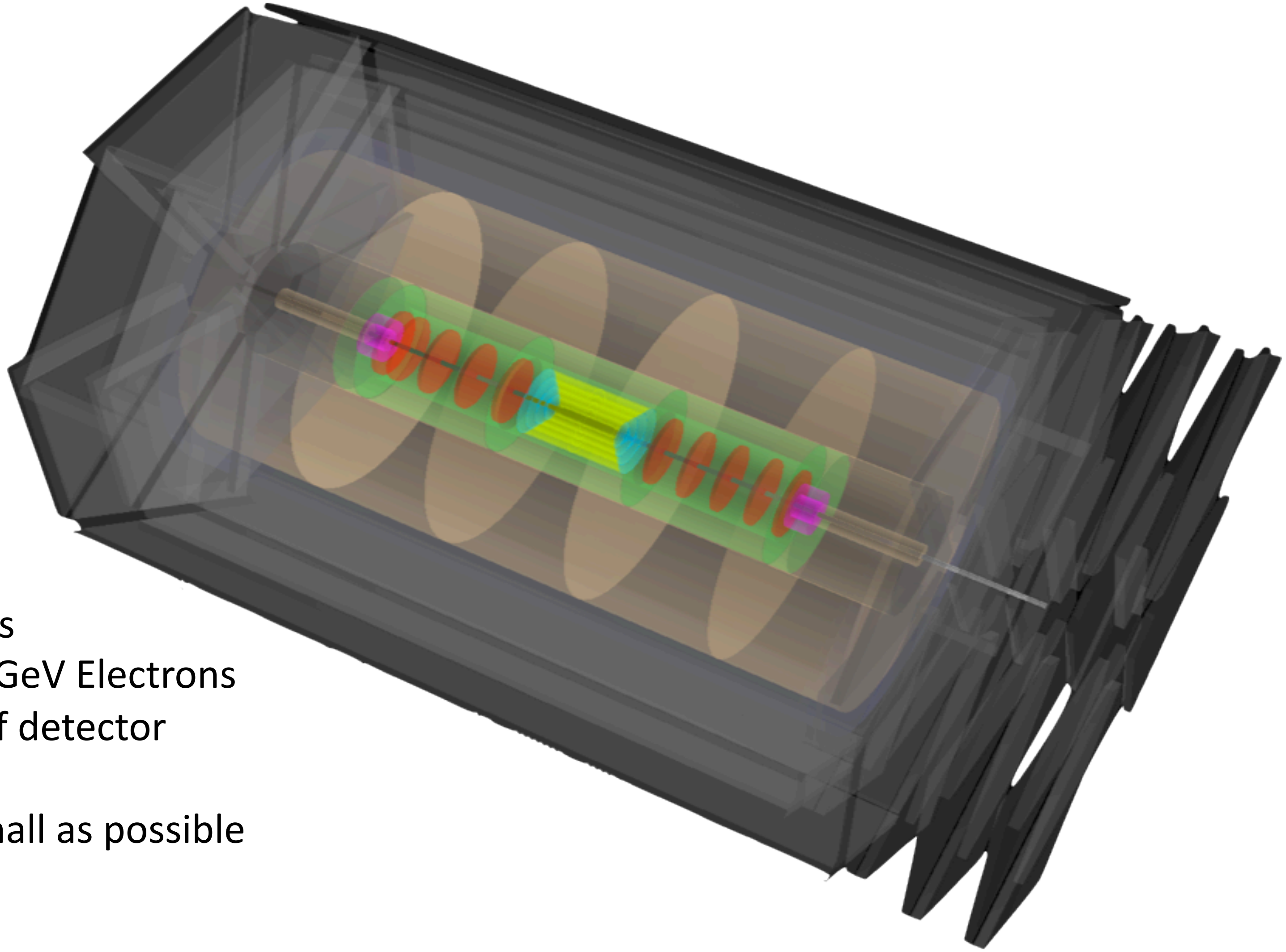
"ultimate p beam"
present record N_p=1.3 10^{11}
1.7 probably conservative

Design also for deuterons (new) and lead (exists)

RR= Ring – Ring
LR =Linac –Ring

Tentative: 8.7.2010

Detector



Calibration:
H1/2

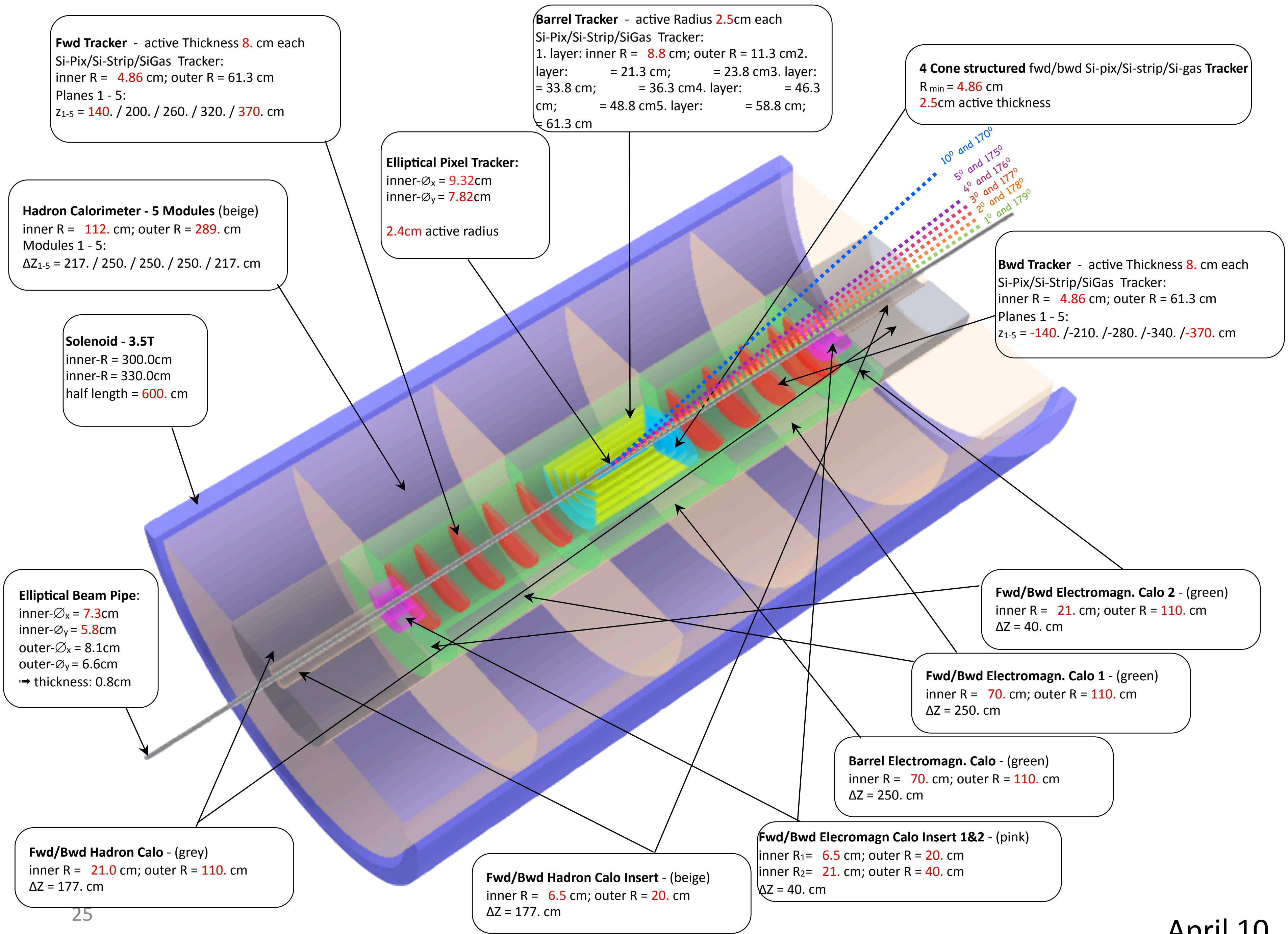
Resolution:
H → bbar

Acceptance:
Down to 1-179^{o}

Forward: TeV Jets
Backwards: 100 GeV Electrons
FB Asymmetry of detector

Beampipe: as small as possible

Modularity for installation in ‘short’ times


Fwd Tracker - active Thickness 8. cm each
Si-Pix/Si-Strip/SiGas Tracker:
inner R = 4.86 cm; outer R = 61.3 cm
Planes 1 - 5:
z_{1-5} = 140. / 200. / 260. / 320. / 370. cm
Barrel Tracker - active Radius 2.5cm each
Si-Pix/Si-Strip/SiGas Tracker:
1. layer: inner R = 8.8 cm; outer R = 11.3 cm2.
layer: = 21.3 cm; = 23.8 cm3. layer:
= 33.8 cm; = 36.3 cm4. layer: = 46.3
cm; = 48.8 cm5. layer: = 58.8 cm;
= 61.3 cm
4 Cone structured fwd/bwd Si-pix/Si-strip/Si-gas Tracker
R_{min} = 4.86 cm
2.5cm active thickness
10^0 and 170^0
5^0 and 175^0
4^0 and 176^0
3^0 and 177^0
2^0 and 178^0
1^0 and 179^0
Elliptical Pixel Tracker:
inner-$\varnothing_x$ = 9.32cm
inner-$\varnothing_y$ = 7.82cm
2.4cm active radius
Hadron Calorimeter - 5 Modules (beige)
inner R = 112. cm; outer R = 289. cm
Modules 1 - 5:
ΔZ_{1-5} = 217. / 250. / 250. / 250. / 217. cm
Solenoid - 3.5T
inner-R = 300.0cm
inner-R = 330.0cm
half length = 600. cm
Bwd Tracker - active Thickness 8. cm each
Si-Pix/Si-Strip/SiGas Tracker:
inner R = 4.86 cm; outer R = 61.3 cm
Planes 1 - 5:
z_{1-5} = -140. /-210. /-280. /-340. /-370. cm
Elliptical Beam Pipe:
inner-$\varnothing_x$ = 7.3cm
inner-$\varnothing_y$ = 5.8cm
outer-$\varnothing_x$ = 8.1cm
outer-$\varnothing_y$ = 6.6cm
➞ thickness: 0.8cm
Fwd/Bwd Electromagn. Calo 2 - (green)
inner R = 21. cm; outer R = 110. cm
ΔZ = 40. cm
Fwd/Bwd Electromagn. Calo 1 - (green)
inner R = 70. cm; outer R = 110. cm
ΔZ = 250. cm
Barrel Electromagn. Calo - (green)
inner R = 70. cm; outer R = 110. cm
ΔZ = 250. cm
Fwd/Bwd Hadron Calo - (grey)
inner R = 21.0 cm; outer R = 110. cm
ΔZ = 177. cm
Fwd/Bwd Hadron Calo Insert - (beige)
inner R = 6.5 cm; outer R = 20. cm
ΔZ = 177. cm
Fwd/Bwd Elecromagn Calo Insert 1&2 - (pink)
inner R_1= 6.5 cm; outer R = 20. cm
inner R_2= 21. cm; outer R = 40. cm
ΔZ = 40. cm

Organisation for the CDR

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Swapan Chattopadhyay (Cockcroft)
John Dainton (Liverpool)
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Frank Zimmermann (CERN)

Working Group Convenors

Accelerator Design [RR and LR]
Oliver Bruening (CERN),
John Dainton (CI/Liverpool)

Interaction Region and Fwd/Bwd
Bernhard Holzer (DESY),
Uwe Schneeekloth (DESY),
Pierre van Mechelen (Antwerpen)

Detector Design
Peter Kostka (DESY),
Rainer Wallny (UCLA),
Alessandro Polini (Bologna)

New Physics at Large Scales
George Azuelos (Montreal)
Emmanuelle Perez (CERN),
Georg Weiglein (Durham)

Precision QCD and Electroweak
Olaf Behnke (DESY),
Paolo Gambino (Torino),
Thomas Gehrmann (Zuerich)
Claire Gwenlan (Oxford)

Physics at High Parton Densities
Nestor Armesto (Santiago),
Brian Cole (Columbia),
Paul Newman (Birmingham),
Anna Stasto (MSU)

Steps towards completion of CDR

CERN invites referees for

QCD/electroweak:

BSM:

eA/low x

Detector

Interaction Region Design

Ring-Ring Design

Linac-Ring Design

Energy Recovery

Magnets

Cost

Installation and Infrastructure

Project Position in HEP

Presentation to Science Policy Committee June 10

Invitation of Referees July/August 2010

Draft of CDR by October 2010

CERN-ECFA-NuPECC Workshop (November)

Report to ECFA: 26.11.2010

Finalisation of design involving referees

Ready for print: March 2011

Evaluation

possibly a TDR with dedicated groups at CERN

Towards a Tentative Schedule

CDR printed in spring 2011

Study of installation and interference issues still to be done

Installation of (ring or linac) LHeC towards 2021

Make maximum use of LHC shutdowns (~50 months).

2021-30: ~10 years of operation with LHC [p/A]

colliding with $E_e \approx 60$ GeV [e^-/e^+]: ~100fb^{-1} in ep

later: possible extension to high E_e LHeC

During HE-LHC upgrade shutdown and long term operation

With 16 TeV p colliding with e.g. $E_e = 140$ GeV [e^-/e^+]

$Q^2_{max}= 9$ TeV^2 $x_{min} =10^{-7}$ in DIS region

The time schedule of the LHeC is linked to the LHC, ep has to be doable as an upgrade or 5th experiment to the LHC, so far that looks feasible

Thanks to

Machine and detector experts

CERN: Simona Bettoni, Frederick Bordry, Chiara Bracco, Oliver Bruning, Helmut Burkhardt, Rama Calaga, Edmond Ciapala, Miriam Fitterer, Massimo Giovannozzi, Brennan Goddard, Werner Herr, Bernhard Holzer, John M. Jowett, Trevor Linnecar, Karl Hubert Mess, Steve Myers, Yvon Muttoni, John Andrew Osborne, Louis Rinolfi, Stephan Russenschuck, Daniel Schulte, Rogelio Tomas, Davide Tommasini, Joachim Tuckmantel, Alessandro Vivoli, Uli Wienands, Frank Zimmermann

BNL: Ilan Ben Zvi, Vladimir Litvinenko, Ferdinand Willeke

BINP: Eugene B. Levichev, Ivan Morozov, Yuriy Pupkov, Pavel Vobly, Alexander Skrinsky

Bologna University: Alessandro Polini

University of Antwerp: Pierre Van Mechelen

Cockcroft Institute: Rob Appleby, Ian Bailey, Graeme Burt, Maxim Korostelev, Neil Marks, Luke Thompson

Cornell University: Georg Hofstaetter

DESY: Desmond P. Barber, Sergey Levonian, Alexander Kling, Peter Kostka, Uwe Schneekloth

Liverpool University: John B. Dainton, Tim Greenshaw, Max Klein

KEK: Tsunehiko Omori, Junji Urukawa

SLAC: Chris Adolphsen, Tor Raubenheimer, Michael Sullivan, Yipeng Sun

TAC: A. Kenan Ciftci, Saleh Sultansoy,

ITEP, Moscow: Vladimir Andreev

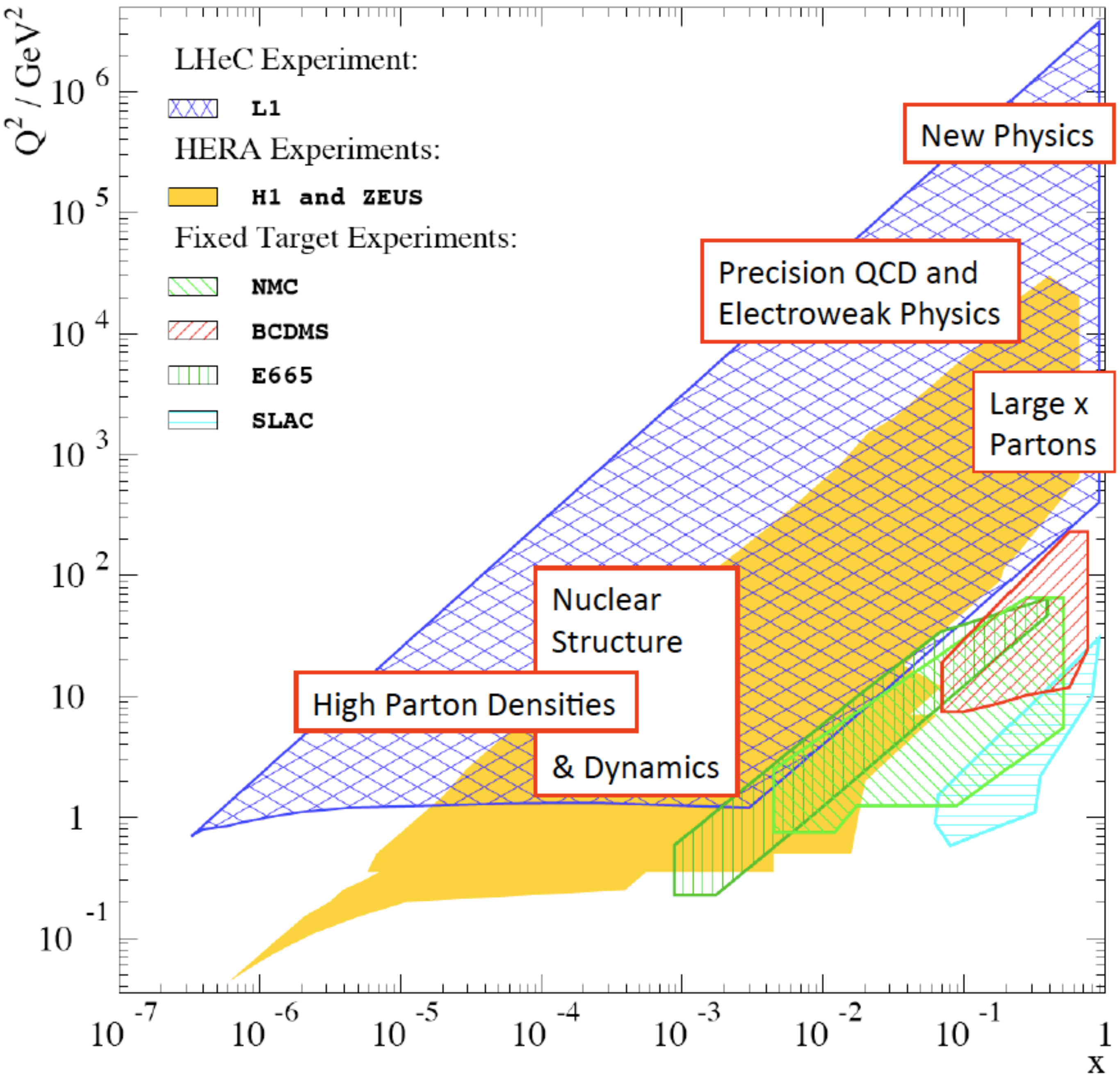
UCLA: Rainer Wallny

EPFL: Leonid Rifkin

Forgotten someone ? … apologies!

and a similar number of particle physicists engaged in this study **to CERN, ECFA, NuPECC** and my UK

Backup slides



LHeC Experiment:
L1
HERA Experiments:
H1 and ZEUS
Fixed Target Experiments:
NMC
BCDMS
E665
SLAC
New Physics
Precision QCD and
Electroweak Physics
Large x
Partons
Nuclear
Structure
High Parton Densities
& Dynamics
Q^2 / GeV^2
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
x

HERA - an unfinished programme

Low x: DGLAP seems to hold though ln1/x is large
Gluon Saturation not proven

High x: would have required much higher luminosity
[u/d ?, xg ?]

Neutron structure not explored

Nuclear structure not explored

New concepts introduced, investigation just started:
-parton amplitudes (GPD's, proton hologram)
-diffractive partons
-unintegrated partons

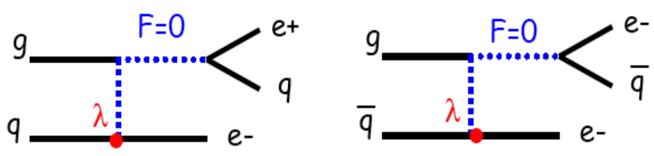
Instantons not observed

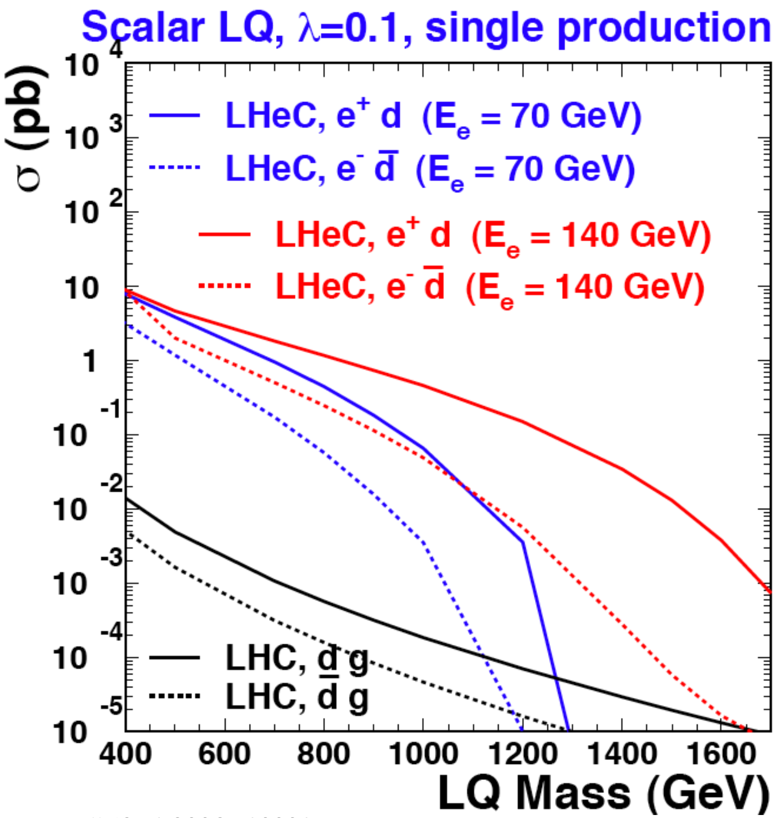
Odderons not found
...

Fermions still pointlike
Lepton-quark states (as in RPV SUSY) not observed

*) For an experimental review see:
M.Klein, R.Yoshida, **"Collider Physics at HERA"**
arXiv 0805.3334, Prog.Part.Nucl.Phys.61,343(2008)
HERA II analysis still ongoing

LQ Quantum Numbers





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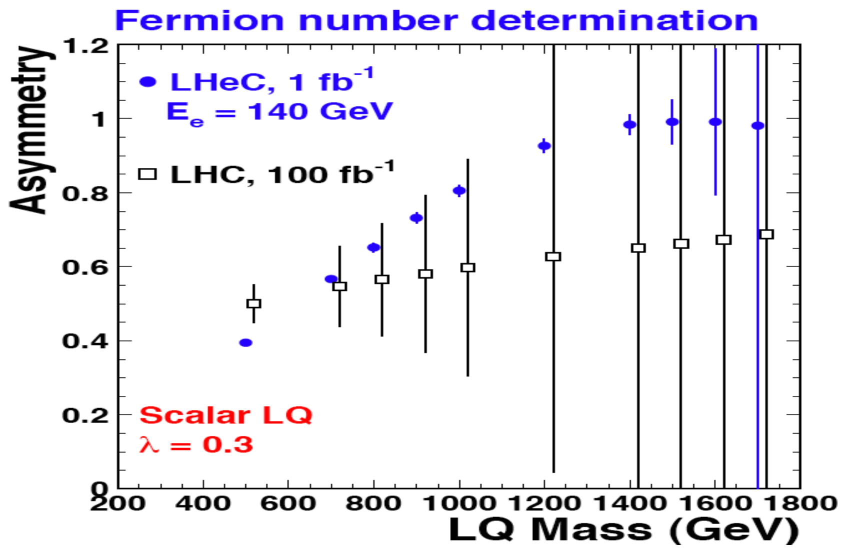
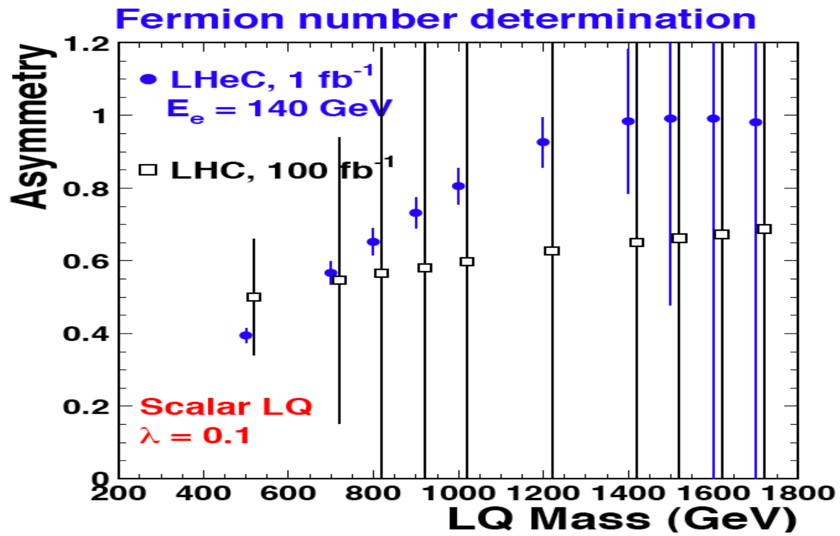
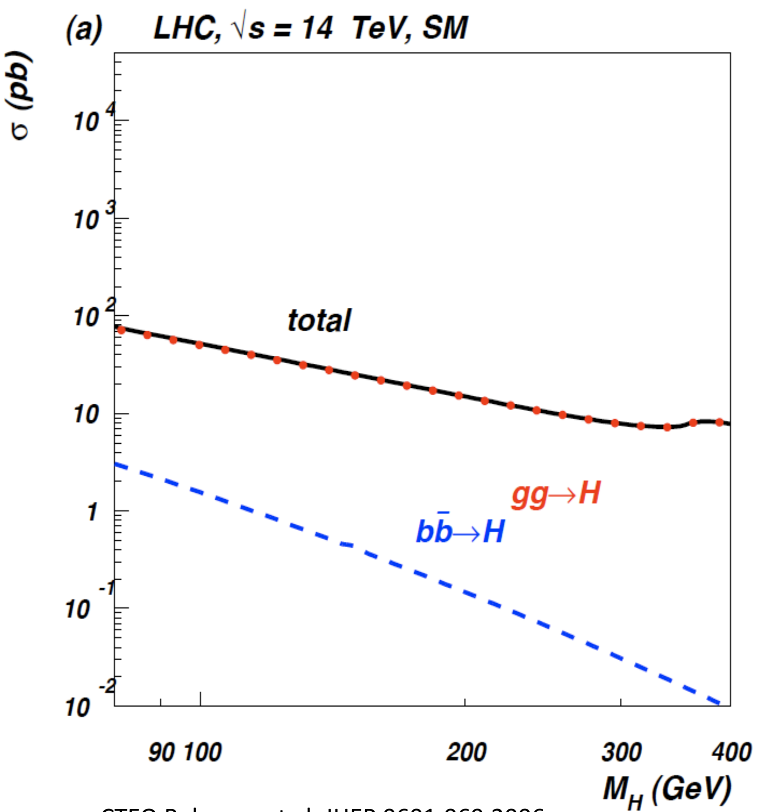


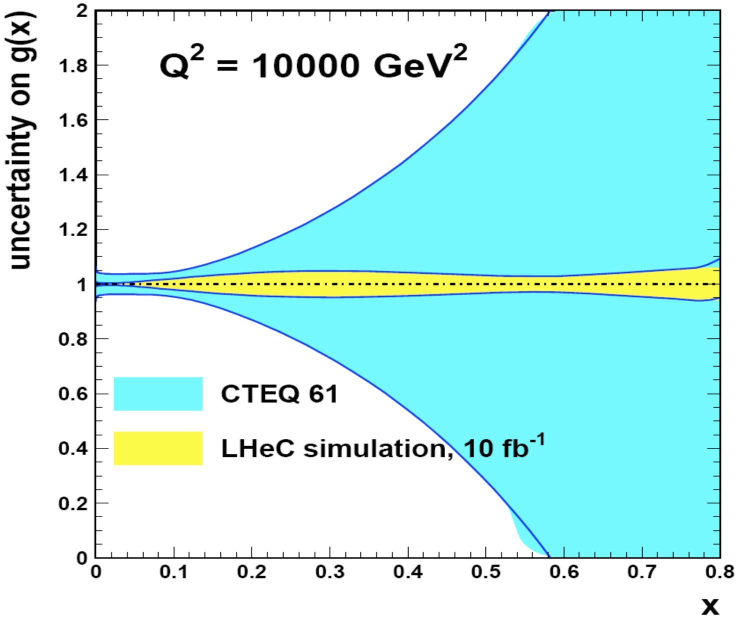


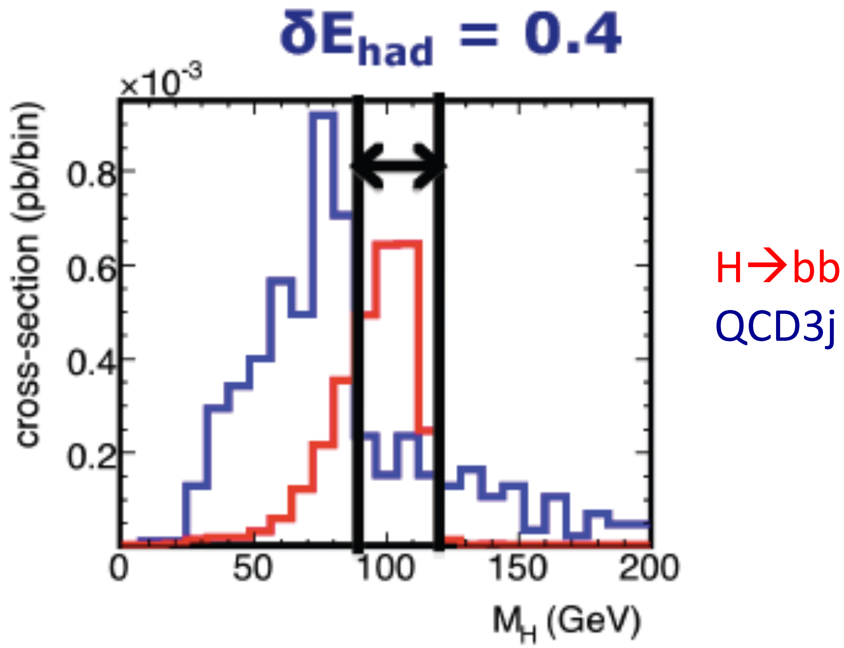
Charge asymmetry much cleaner in ep [in] than in pp [out].
Similar for simultaneous determination of coupling
and quark flavour. Polarisation for spectroscopy

Gluon - SM Higgs



CTEQ Belyayev et al. JHEP 0601:069,2006



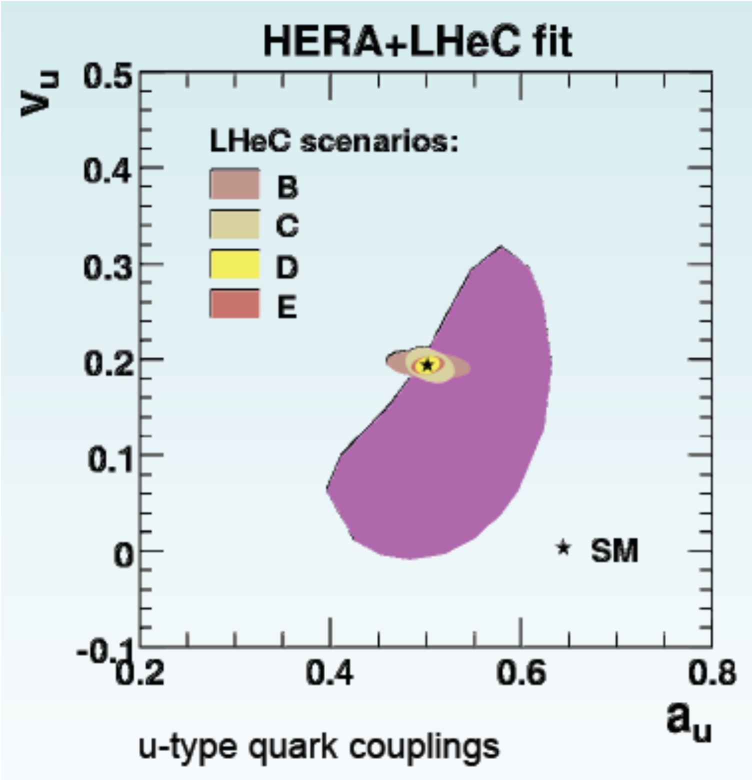


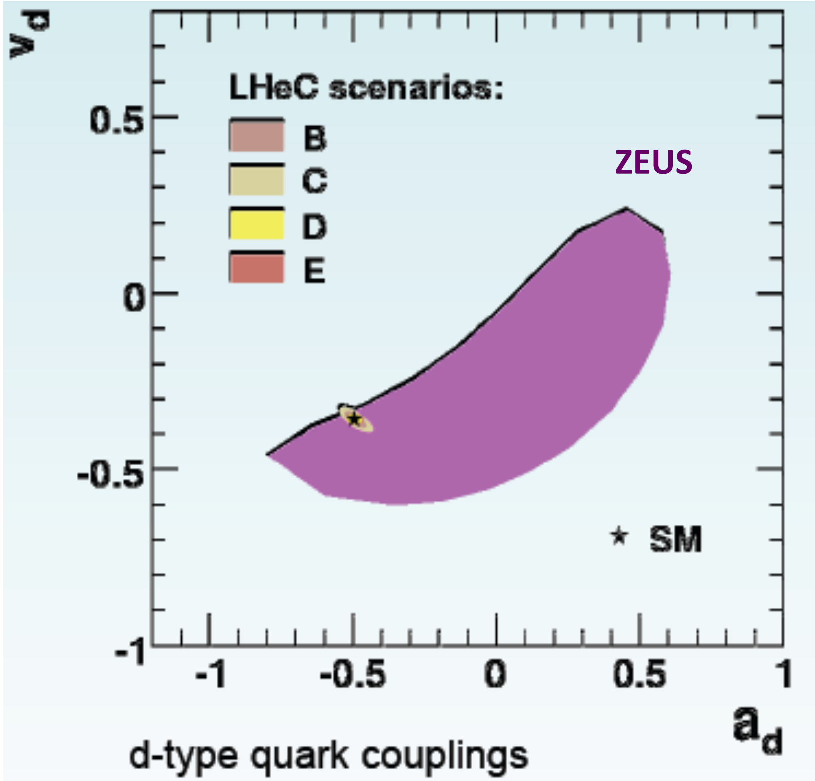
In SM Higgs production is gluon dominated

LHeC: huge x,Q^2 range for xg determination

WW to Higgs fusion has sizeable ep xsection

Electroweak Couplings





CDF: qq' → e+e- (Drell-Yan), A_{FB}

Phys.Rev. D71 (2005) 052002, hep-ex/0411059

LEP/SLC: ee→qq(γ), $a^2_q+v^2_q$

Phys.Rept.427:257,2006, hep-ex/0509008

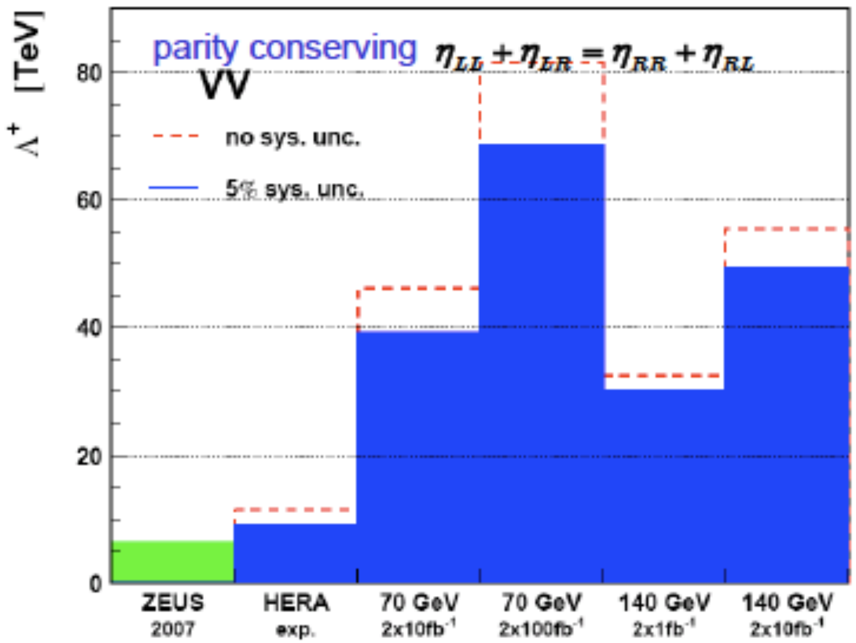
For H1, CDF, LEP cf Z.Zhang DIS10

Contact Interactions

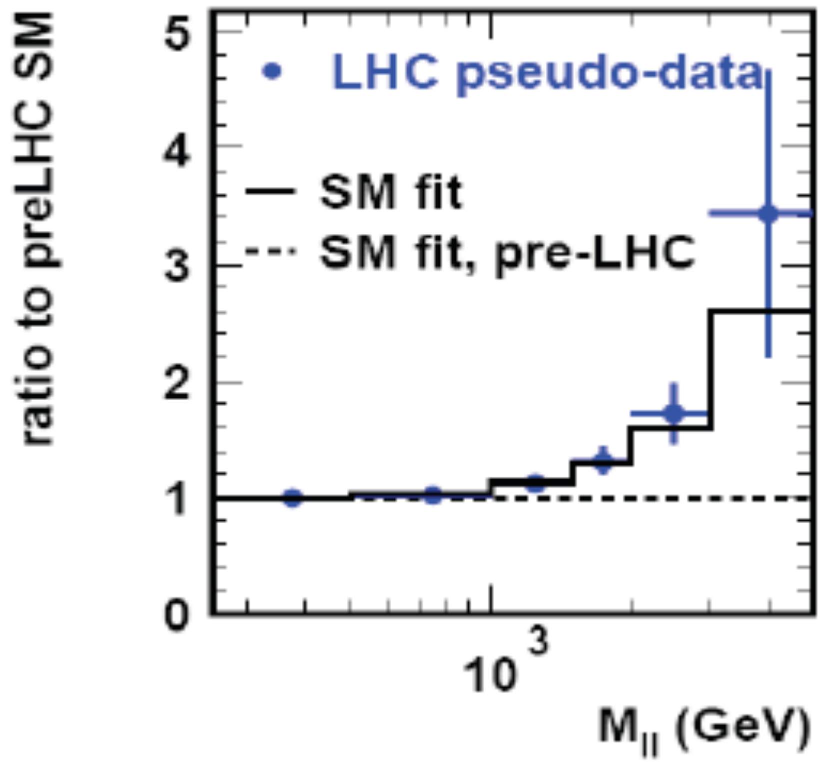
$$\mathcal{L} = \frac{4\pi}{2\Lambda^2} j_\mu^{(e)} j^{\mu(q)};$$

$$j_\mu^{(f=e,q)} = \eta_L \, \bar{f}_L \gamma_\mu f_L + \eta_R \, \bar{f}_R \gamma_\mu f_R + h.c.$$

$\Rightarrow$ all combinations of couplings $\eta_{ij} = \eta_i^{(e)} \eta_j^{(q)}$; $\quad q = u, d$

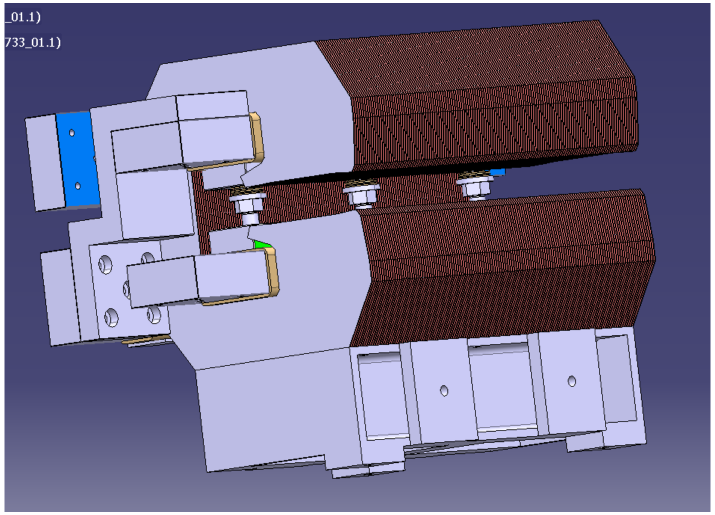


High luminosity vs high energy

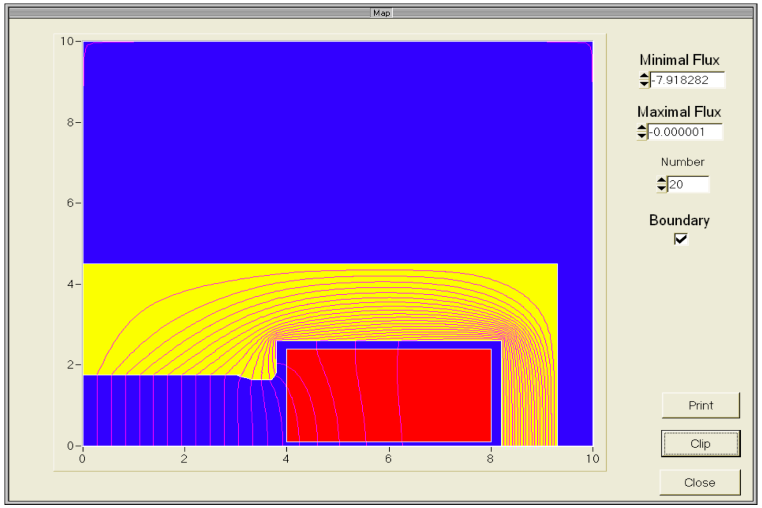


CI study:
LHeC freezes the pdfs which allows new physics to be revealed.
HERA+BCDMS reshuffle the sea…

CERN: 40cm model design



Novosibirsk: Hysteresis loop measurements



Dipole Magnets

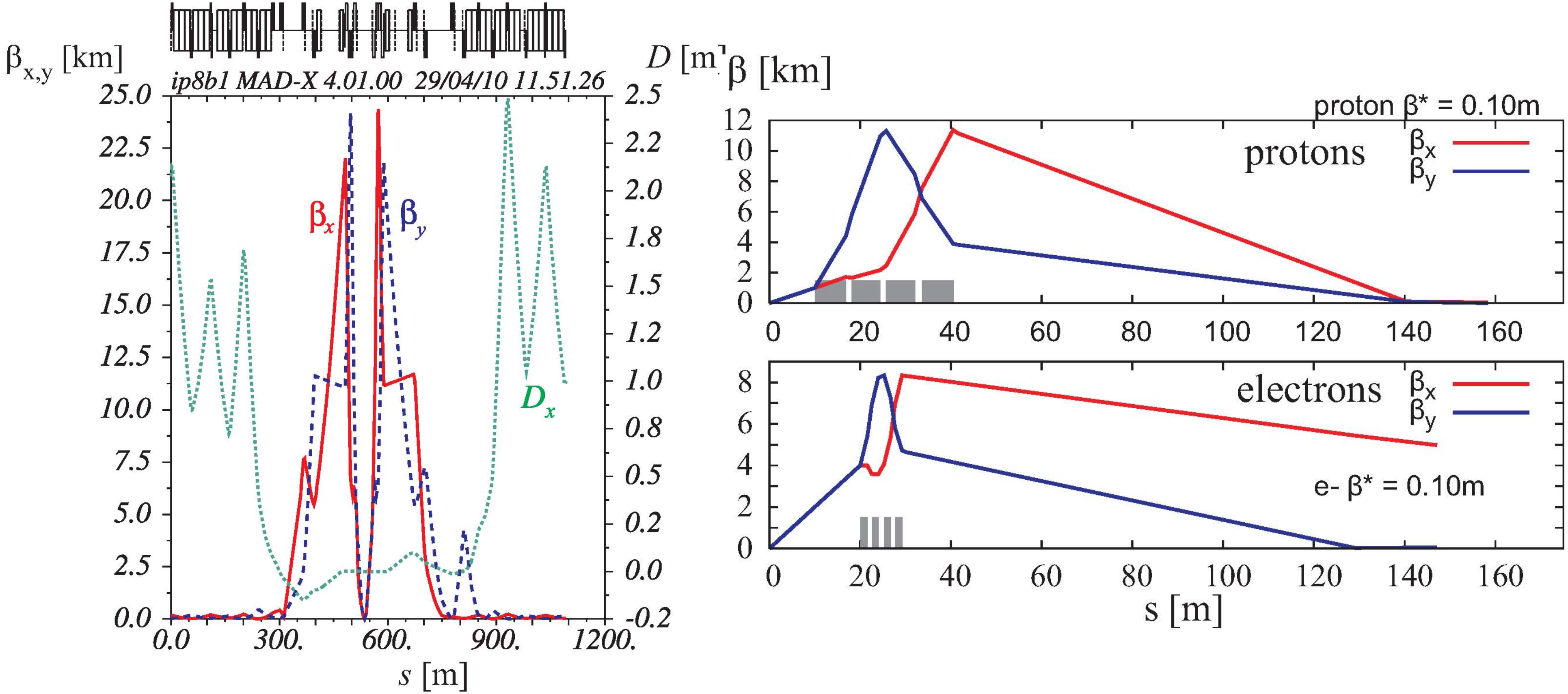
Accelerator	**LEP**	**LHeC**
Cross Section/ cm^2	**50 x 50**	**20 x 10**
Magnetic field/ T	**0.02-0.11**	**0.01-0.10**
Energy Range/GeV	**20-100**	**10-80**
Good Field Area/cm^2	**5.9 x 5.9**	**6 x 3.8**
FODO length/m	**76**	**107 [double]**
Magnet length/m	**11.5**	**5.5**
segmentation	**8x31x6**	**8x23x15**
Number of magnets	**1488+192 [DS]**	**3080+320**
Weight / kg/m	**800**	**200**

Fe based magnet prototypes [BINP-CERN] → CDR

challenges:
compact design for installation
good reproducibility at injection: 0.01T to $10^{-3..-4}$

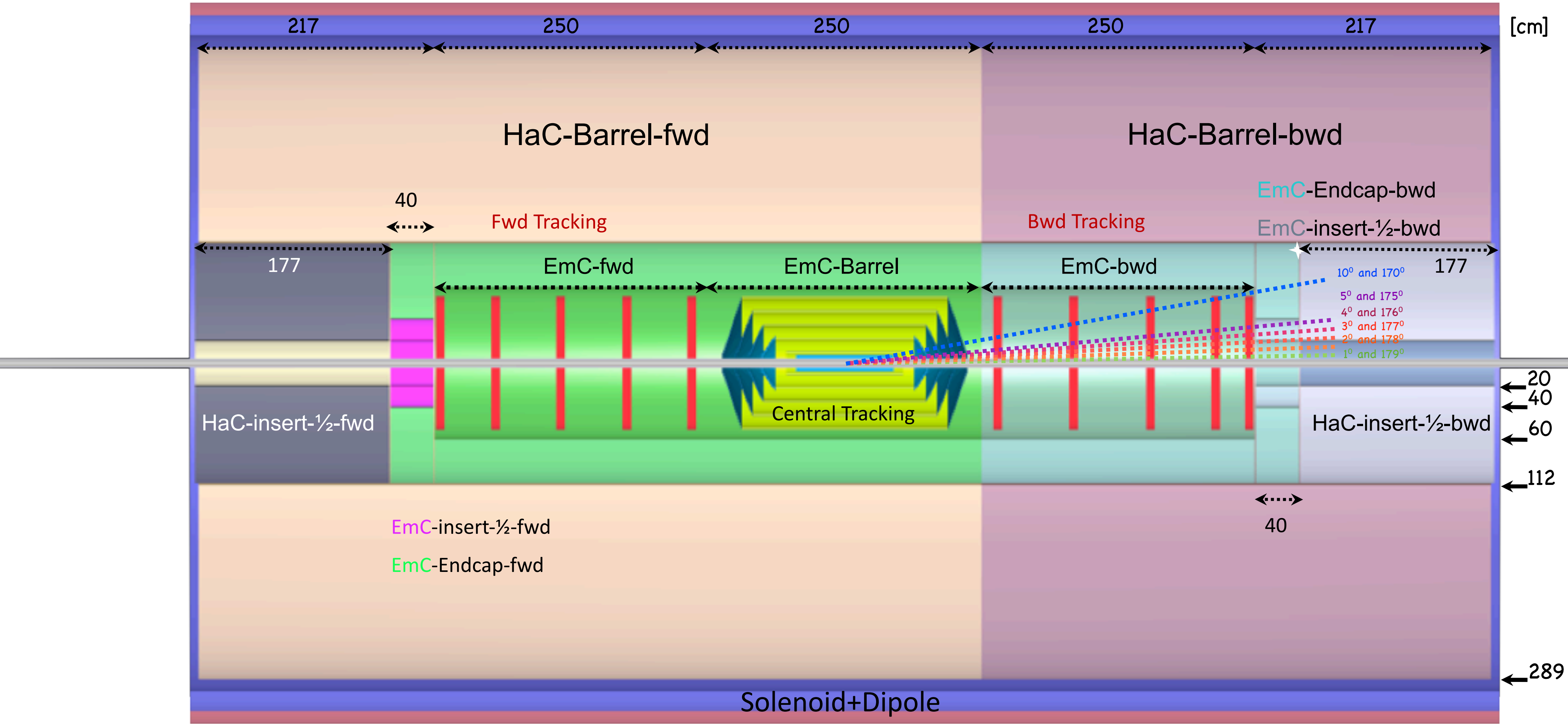
Table 2: Parameters of the first two proton quadrupoles [4].

magnet	pipe radius	gradient	field at pipe
Q1	26 mm	318.6 T/m	8.4 T
Q2	36 mm	250.0 T/m	9.1 T



LHC proton interaction-region optics for $\beta^*_{x,y}$=0.1 m, scaled from the nominal IR optics (left) [5],
and a new IR optics with $\beta^*_{x,y}$=0.1 m for protons [l^*=10 m] (top right) and electrons [l^*=20 m] (bottom right) [4]

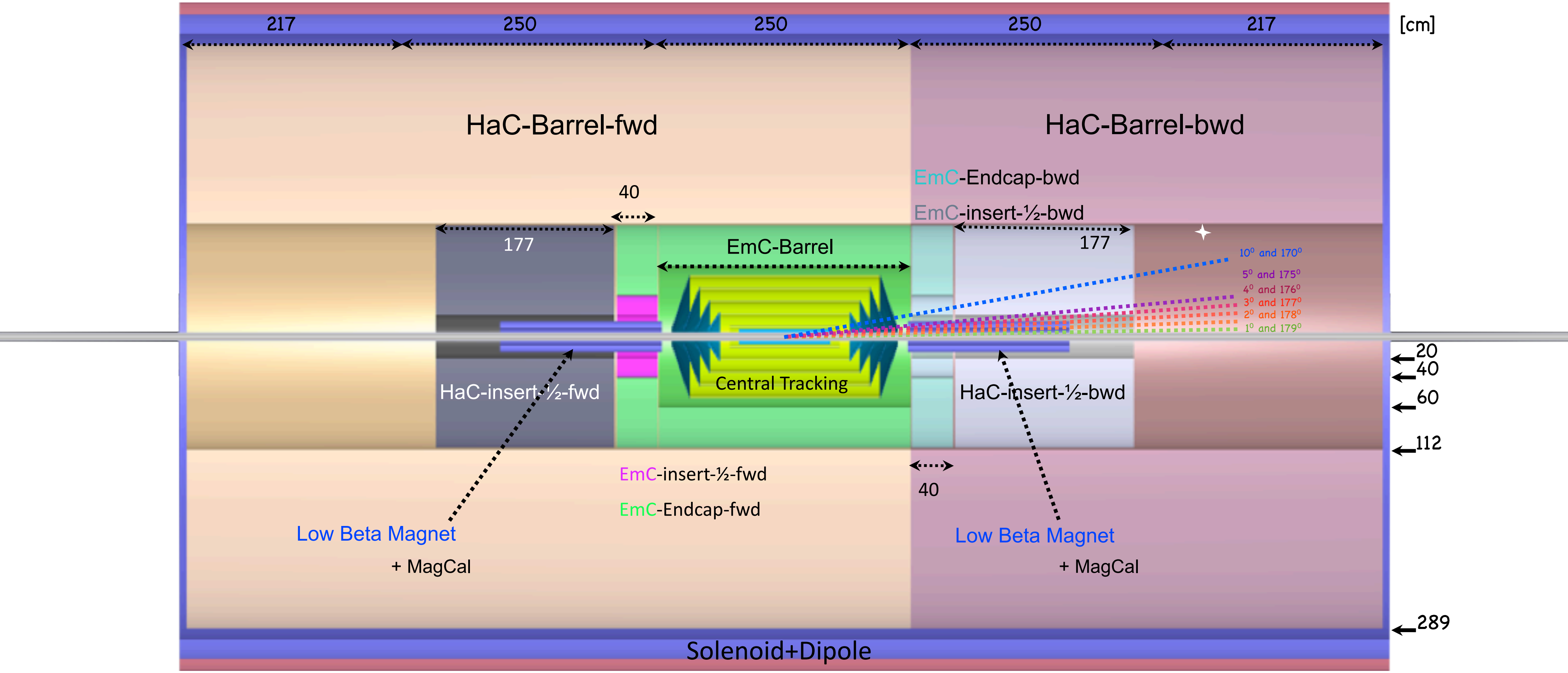
The Detector - Low Q^2 Setup



Fwd/Bwd asymmetry in energy deposited and thus in technology [W/Si vs Pb/Sc..]

Present dimensions: LxD =17x10m^2 [CMS 21 x 15m^2 , ATLAS 25 x 45 m^2]

The Detector - High Q^2 Setup



Aim of current evaluations: avoid detector split in two phases: time and effort

Motivation and Status

motivation:

•rich physics program: eq physics at TeV energies

❑ precision QCD & electroweak physics

❑ complementing LHC physics results

❑ beyond the Standard Model

❑ high density matter: low x and eA

Tevatron/LEP/HERA (Fermiscale) → LHC/LC/LHeC (Terascale)

100 fold increase in luminosity, in Q^2 and $1/x$ w.r.t. HERA

status:

•CERN-ECFA-NuPECC workshops (2008, 2009, 2010: 28.-30.October)

•Conceptual Design Report in print by spring 2011

e-Pb Collisions (RR)

- Assume present nominal Pb beam in LHC
  - Same beam size as protons, fewer bunches

$$k_b = 592 \text{ bunches of } N_b = 7\times10^7 \ {}^{208}\text{Pb}^{82+} \text{ nuclei}$$

- Assume lepton injectors can create matching train of e^-

$$k_b = 592 \text{ bunches of } N_b = 1.4\times10^{10} \ \text{e}^-$$

- Lepton-nucleus or lepton-nucleon luminosity in ring-ring option at 70 GeV

$$L = 1.09\times10^{29} \ \text{cm}^{-2}\text{s}^{-1} \quad \Leftrightarrow \quad L_{en} = 2.2\times10^{31} \ \text{cm}^{-2}\text{s}^{-1}$$

gives 11 MW radiated power

  - May be possible to exploit additional power by increasing electron single-bunch intensity by factor 592/2808=4.7.

title