Deep Inelastic Scattering with the LHC*

Overview
Ring
LINAC
Physics
Detector
Status

Max Klein
ATLAS and H1

UNIVERSITY OF LIVERPOOL

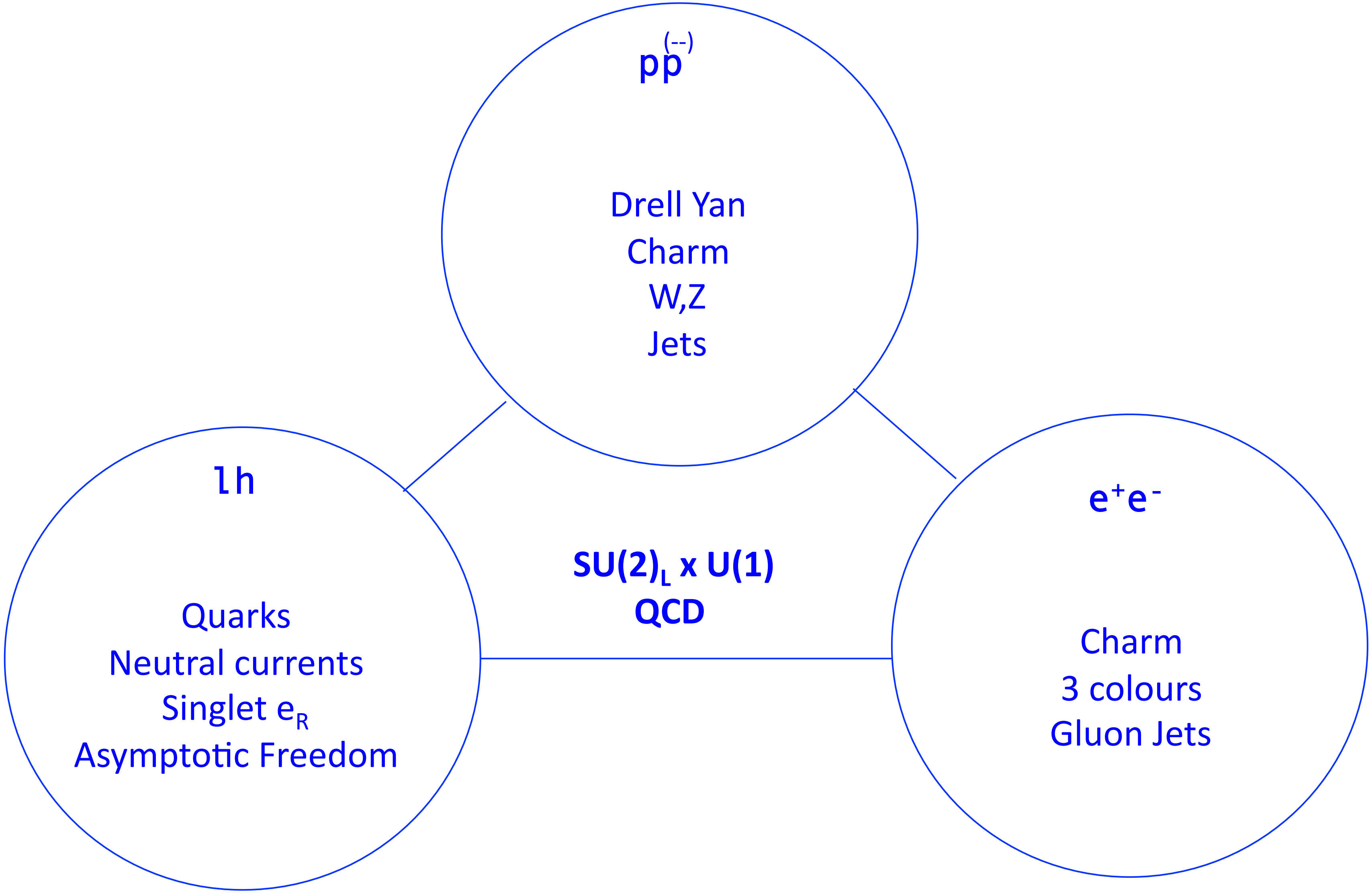
An Introduction to the LHeC

Seminar at MPI Munich, 22.3.11

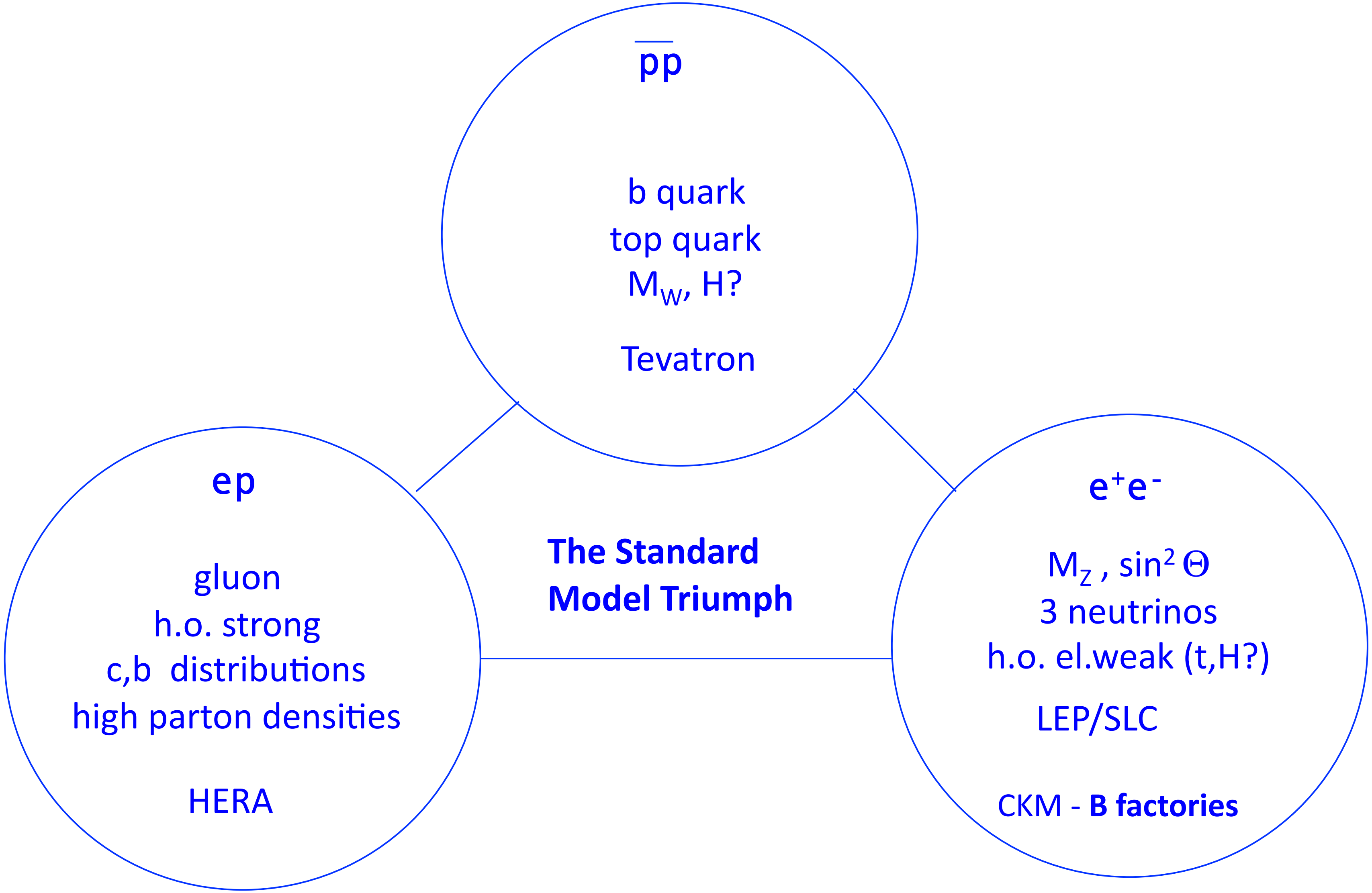
http://cern.ch/lhec

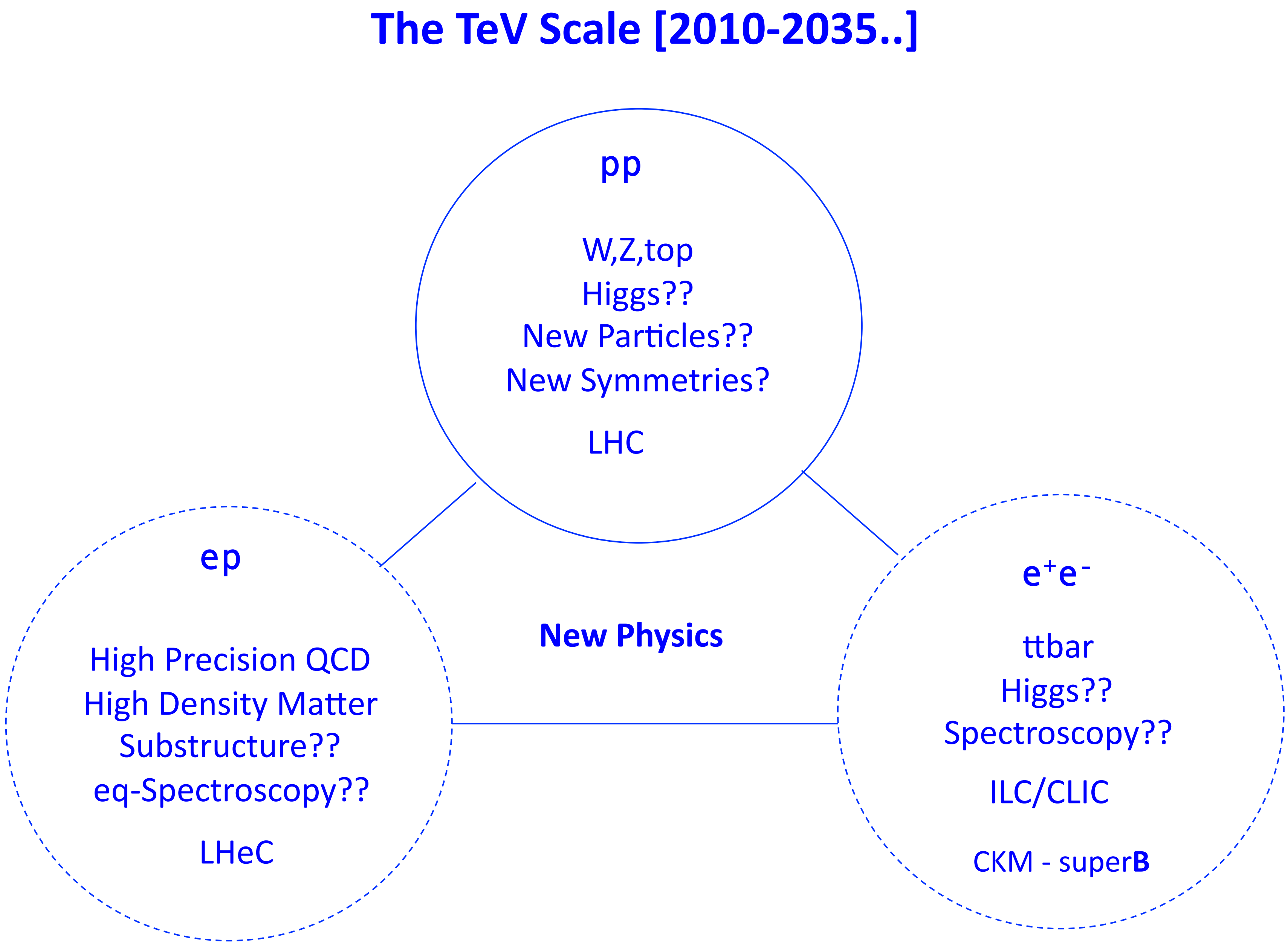
*All tentative - work in progress - prior to CDR publication..

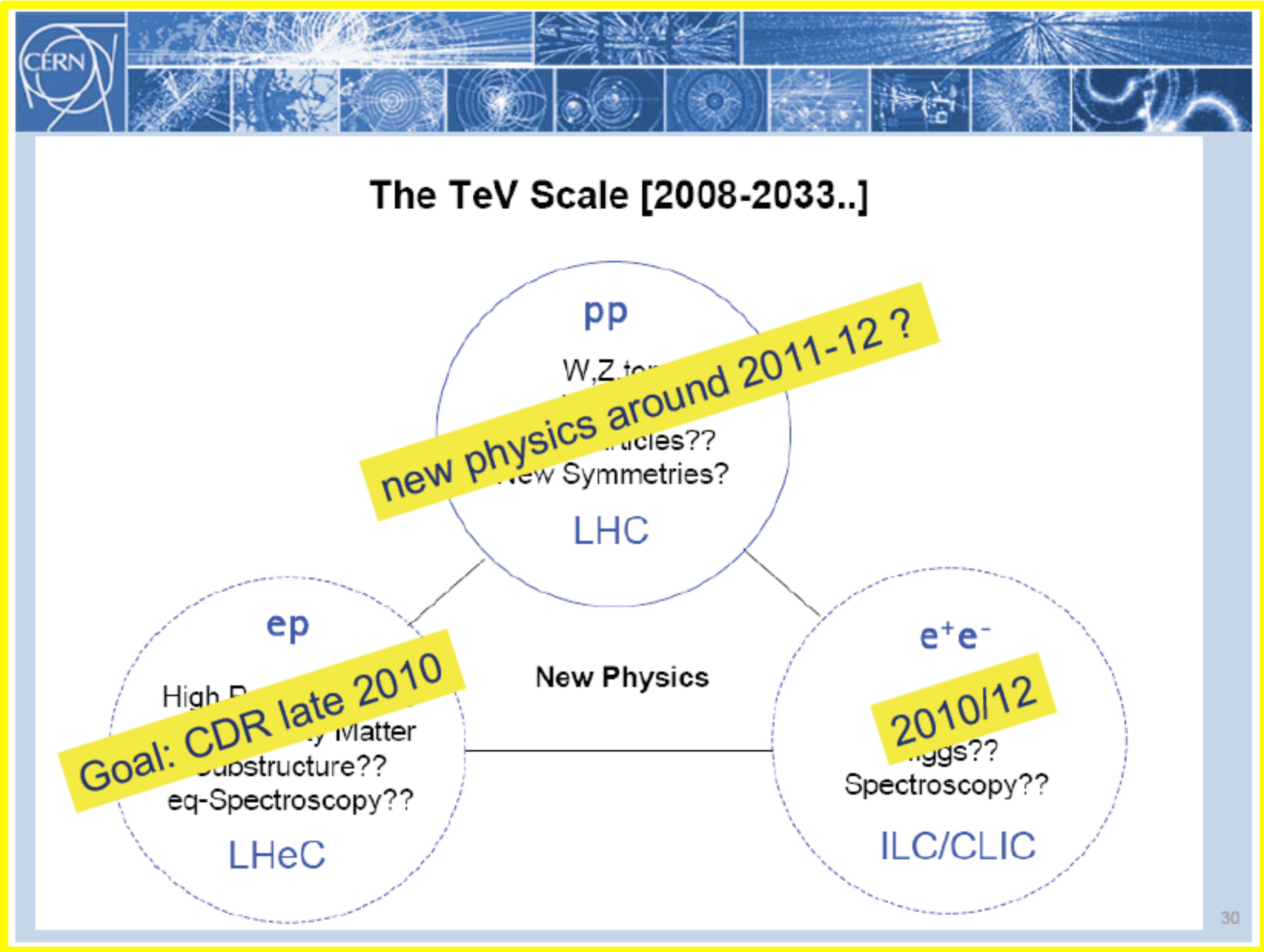
The 10-100 GeV Energy Scale [1968-1986]



The Fermi Scale [1985-2010]

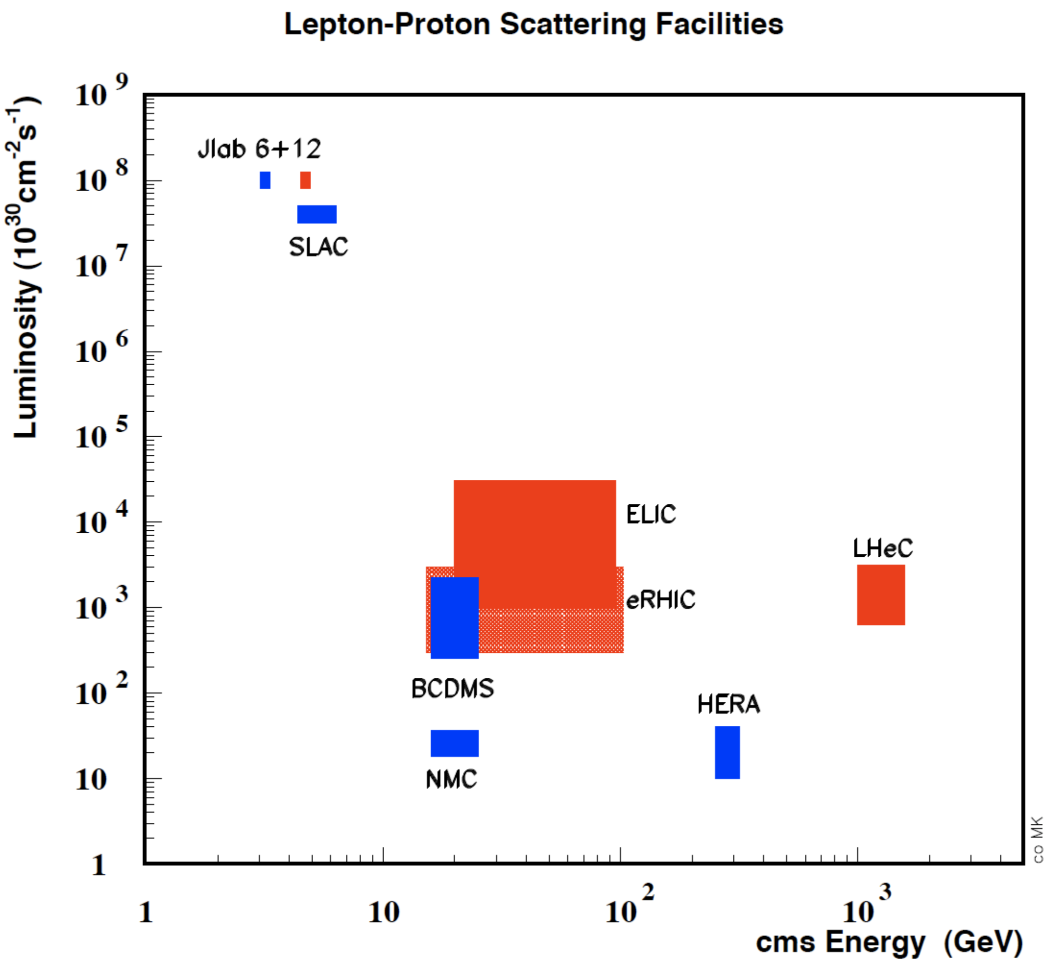


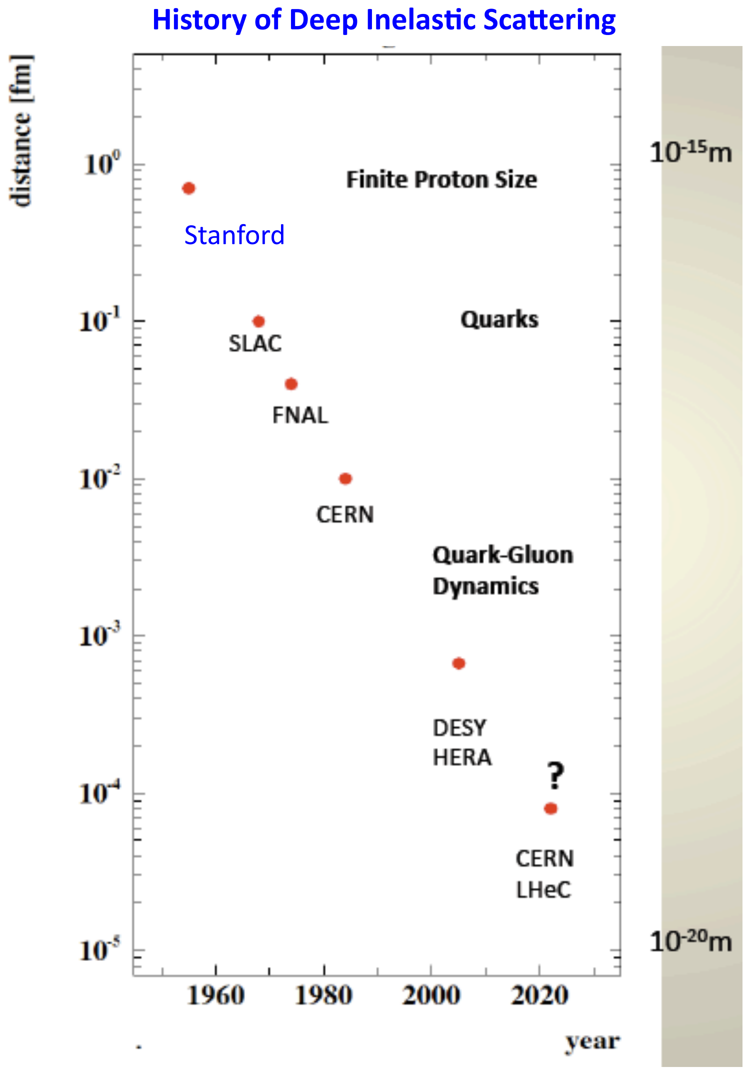

The TeV Scale [2010-2035..]
pp
W,Z,top
Higgs??
New Particles??
New Symmetries?
LHC
ep
High Precision QCD
High Density Matter
Substructure??
eq-Spectroscopy??
LHeC
New Physics
e+e-
ttbar
Higgs??
Spectroscopy??
ILC/CLIC
CKM - superB



Rolf Heuer: 3/4. 12. 09 at CERN: From the Proton Synchroton to the Large Hadron Collider
50 Years of Nobel Memories in High-Energy Physics

Deep Inelastic Scattering - **History and Prospects**





LHeC Physics -1

1. Grand unification? α_s to per mille accuracy: jets vs inclusive
   ultraprecision DIS programme: N^kLO, charm, beauty, ep/eD,..

2. A new phase of hadronic matter: high densities, small α_s
   saturation of the gluon density? BFKL-Planck scale
   superhigh-energy neutrino physics (p-N)

3. Partons in nuclei (4 orders of magnitude extension)
   saturation in eA ($A^{1/3}$?), nuclear parton distributions
   black body limit of F_2, colour transparency, …

4. Novel QCD phenomena
   instantons, odderons, hidden colour, sea=antiquarks (strange)

5. Complementarity to new physics at the LHC
   LQ spectroscopy, eeqq CI, Higgs, e^*

6. Complete unfolding of partonic content of the proton,
   direct and in QCD

LHeC Physics - 2

1. Neutron structure free of Fermi motion
2. Diffraction – Shadowing (Glauber). Antishadowing
3. Vector Mesons to probe strong interactions
4. Diffractive scattering “in extreme domains” (Brodsky)
5. Single top and anti-top ‘factory’ (CC)
6. Gluon density over 6 orders of magnitude in x
7. GPDs via DVCS
8. Unintegrated parton distributions
9. Partonic structure of the photon
10. Electroweak Couplings to per cent accuracy

….

For numeric studies and plots see recent talks at DIS10, ICHEP10, EIC and LHeC Workshops [cern.ch/lhec]

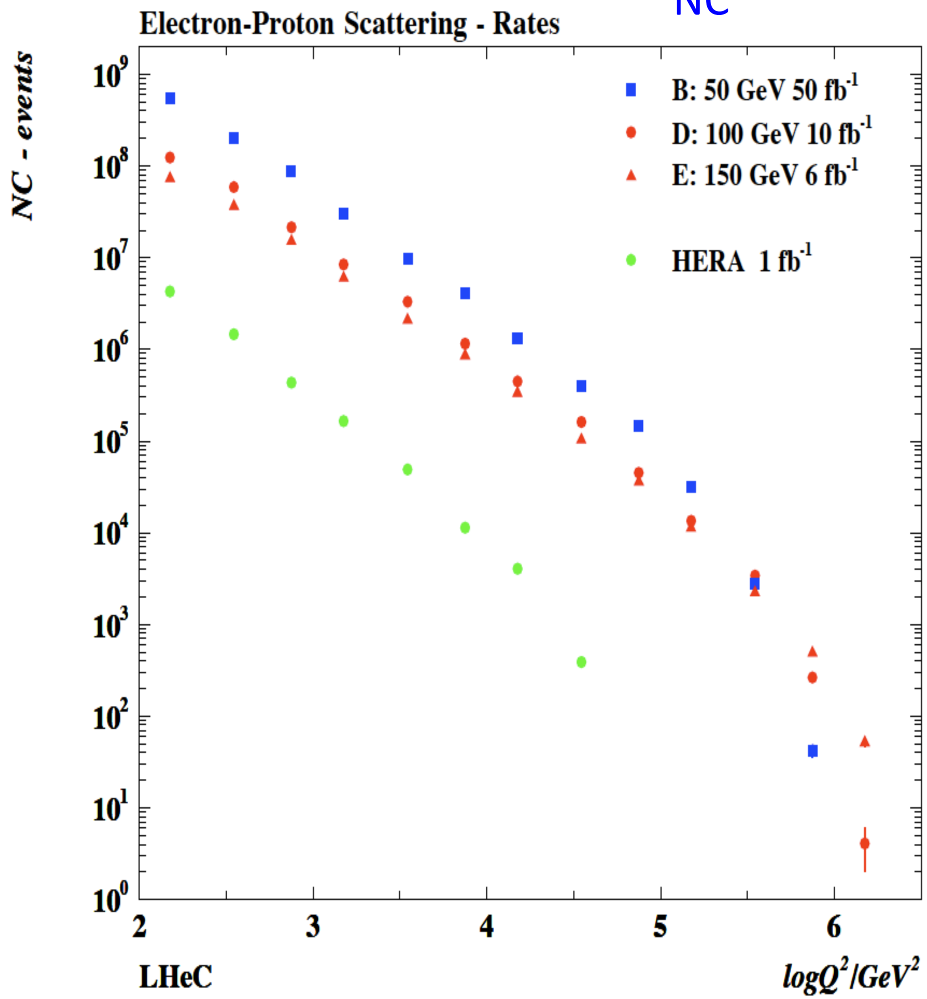
Every major step in energy can lead to new unexpected results, ep: SLAC, HERA

Requires: High energy, $e^{\pm}$, p, d, A, high luminosity, 4π acceptance, high precision (e/h)

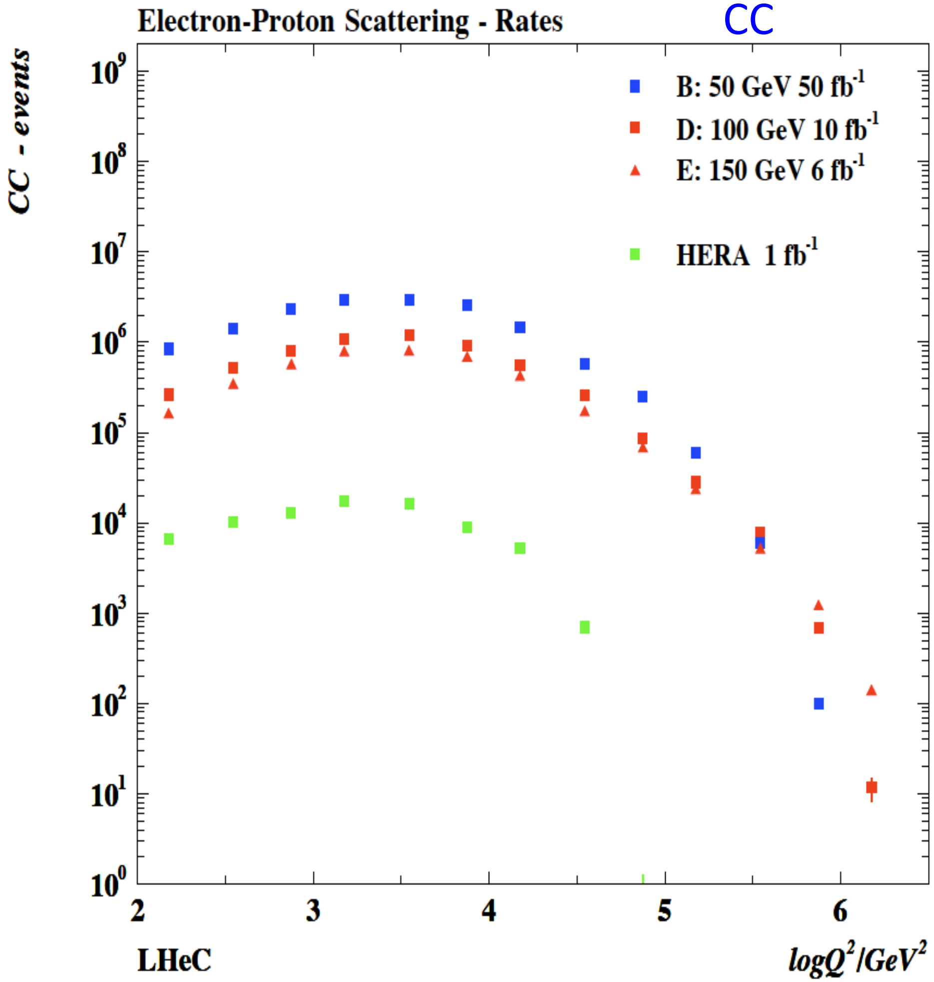
↳ TeV scale physics, electroweak, top, Higgs, low x unitarity

Statistics and Range

NC



CC



Need much higher luminosity than HERA to cover largest Q^2. Huge rates in electroweak region.

Two Options

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

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

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

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

Ring-Ring

Power Limit of 100 MW wall plug

"ultimate" LHC proton beam

60 GeV $e^{\pm}$ beam

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

LINAC Ring

Pulsed, **60 GeV**: ~10^{32}

High luminosity:

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

$\beta^*=0.1m$

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

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

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

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

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

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

Synchronous ep and pp operation (small ep tuneshifts)

The LHC p beams provide 100 times HERA's luminosity

LHeC Accelerator: Participating Institutes

CERN

SLAC NATIONAL ACCELERATOR LABORATORY

NTNU Norwegian University of Science and Technology

clic

The Cockcroft Institute of Accelerator Science and Technology

Jefferson Lab Thomas Jefferson National Accelerator Facility

ANKARA ÜNİVERSİTESİ

NİĞDE ÜNİVERSİTESİ 1992

ULUDAĞ ÜNİVERSİTESİ 1975

TOBB ETU

INFN Istituto Nazionale di Fisica Nucleare

Laboratori Nazionali di Legnaro

DESY

LAL Physique des accélérateurs

ECFA

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

UNIVERSITY OF LIVERPOOL

BROOKHAVEN NATIONAL LABORATORY

СИБИРСКОЕ ОТДЕЛЕНИЕ РАН ИНСТИТУТ ЯДЕРНОЙ ФИЗИКИ им. Г.И.Будкера

630090 Новосибирск

KEK

2. Ring

Luminosity $10^{33}cm^{-2}s^{-1}$ rather ‘easy’ to achieve
Electrons and Positrons
Energy limited by synchrotron radiation
Polarisation perhaps 40%
Magnets, Cryosystem no major R+D, just D
Injector using ILC type cavities
Interference with the proton machine
Bypasses for LHC experiments (~3km tunnel)
Fully on CERN territory
Cost will be estimated
…

A 60 GeV Ring with 10 GeV LINAC Injector

Lattice Design dominated by geometry:

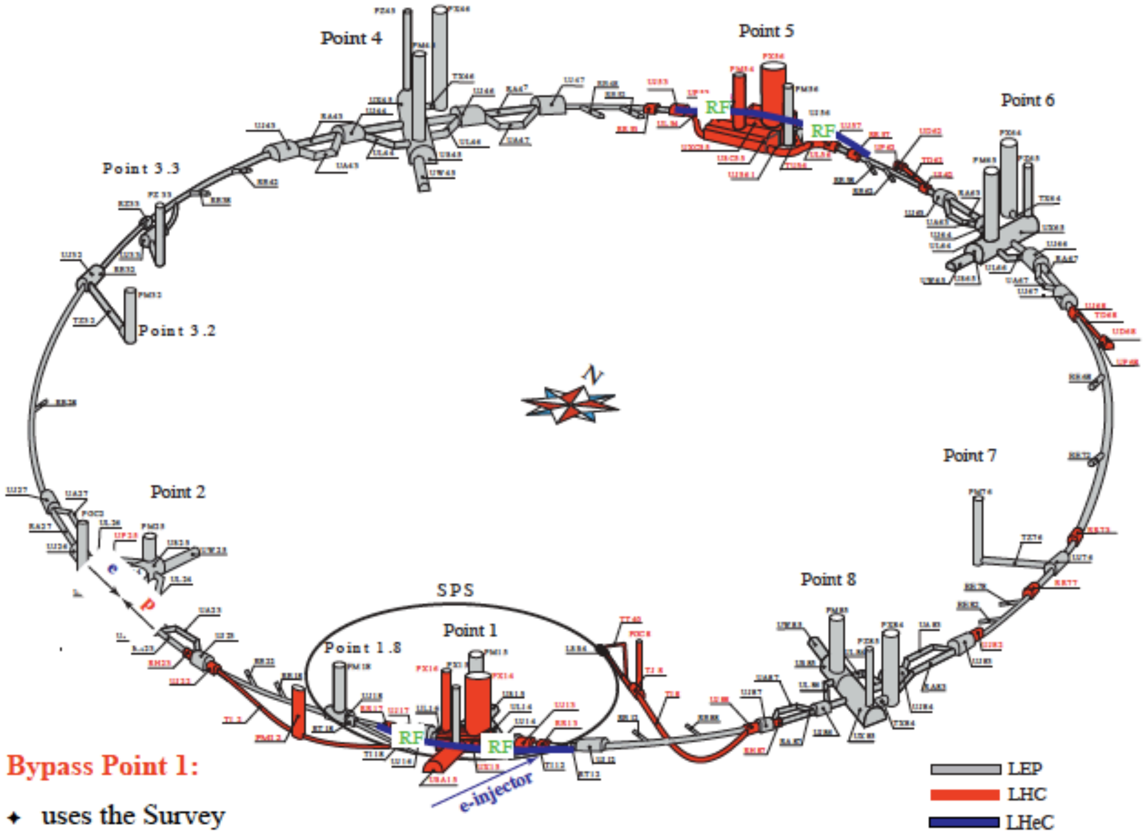
- forbidden space (usually DFBMs) induces an asymmetric lattice
- asymmetric lattice needs to be matched to the symmetric LHC lattice
- ➡ most choices for the LHeC lattice structure are made due to integration

Bypass Design:

- Bypasses increase the circumference of the ring
- ➡ Compensation of the increase in circumference by placing the electron ring 0.61 cm to the inside of the LHC (Idealized Ring)

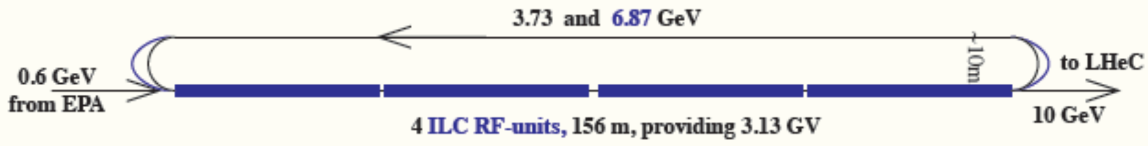
Bypass Point 5:

- adjustment of the circumference by varying the separation
- Δ=20.56 Meter



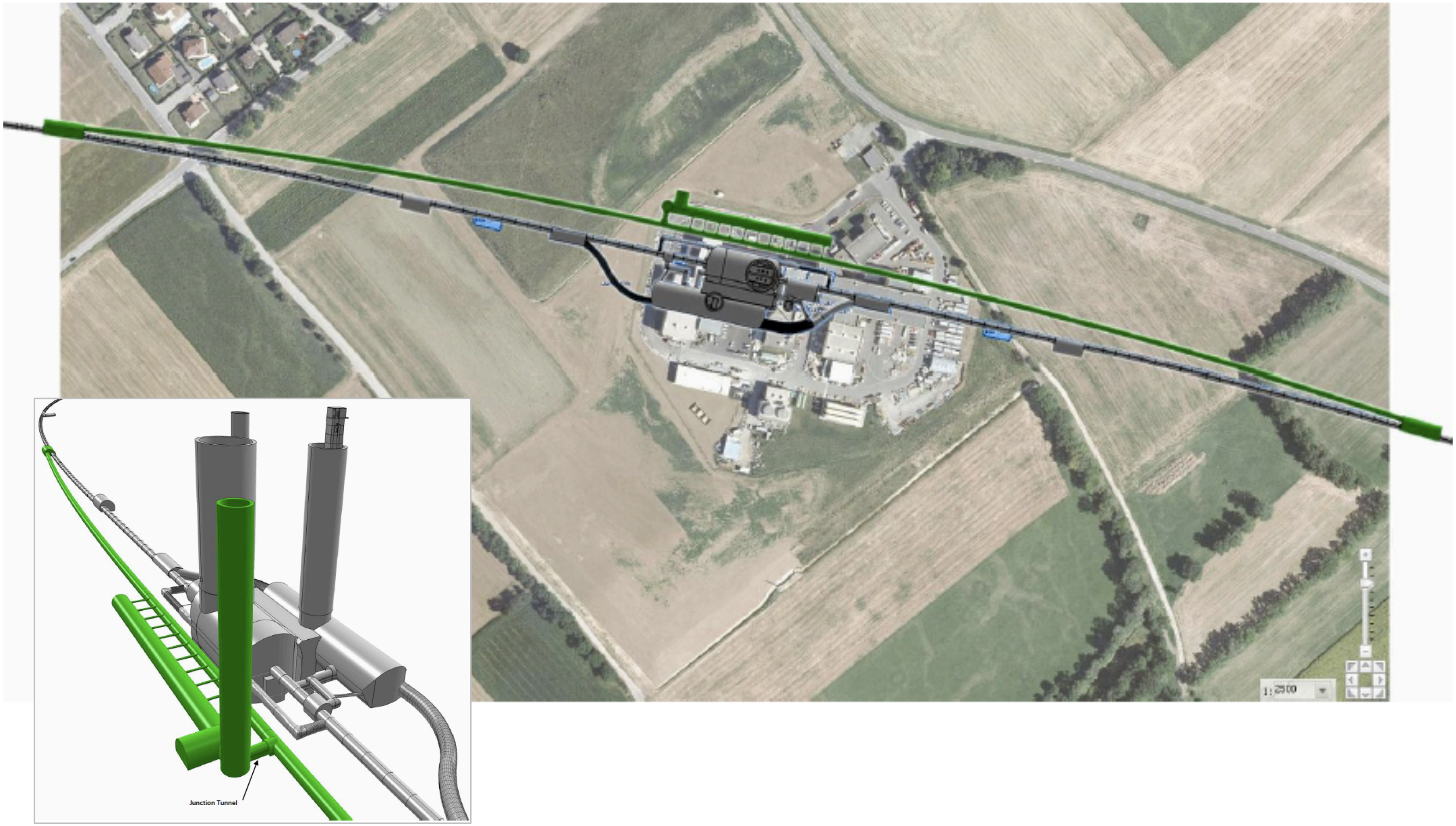
Bypass Point 1:

- uses the Survey Gallery
- Δ=16.25 Meter

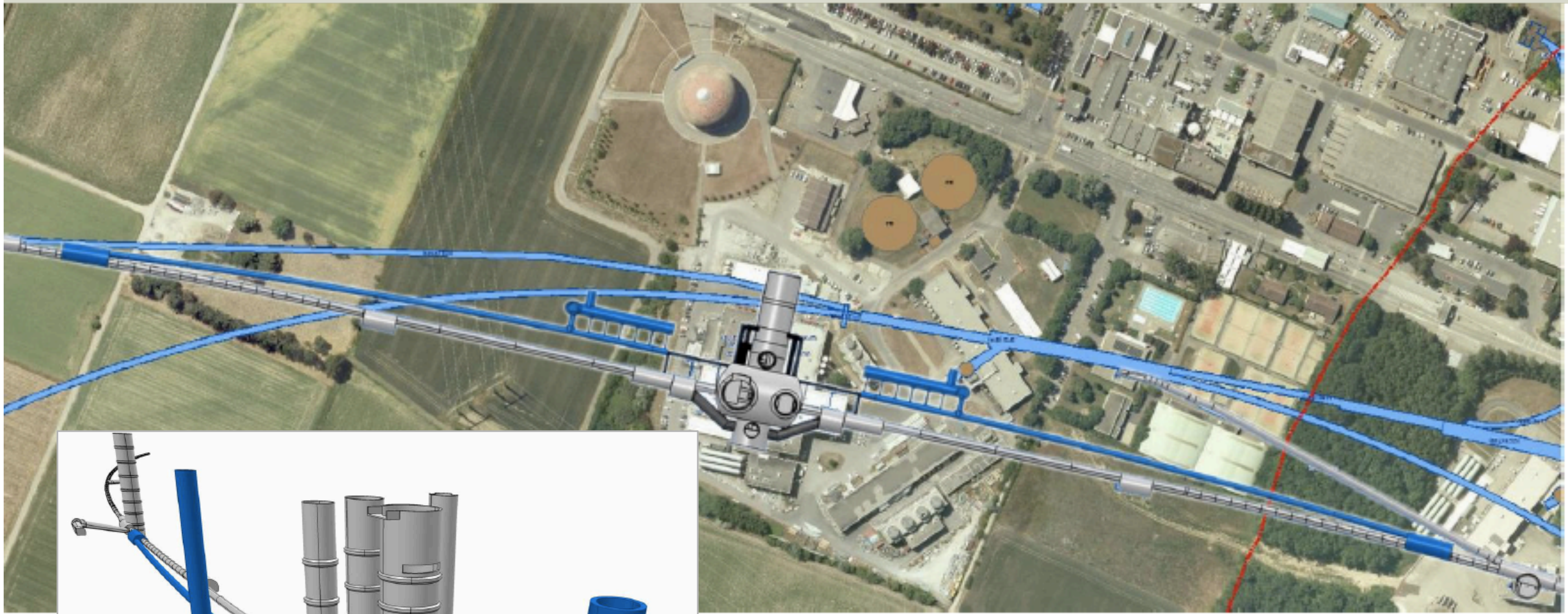


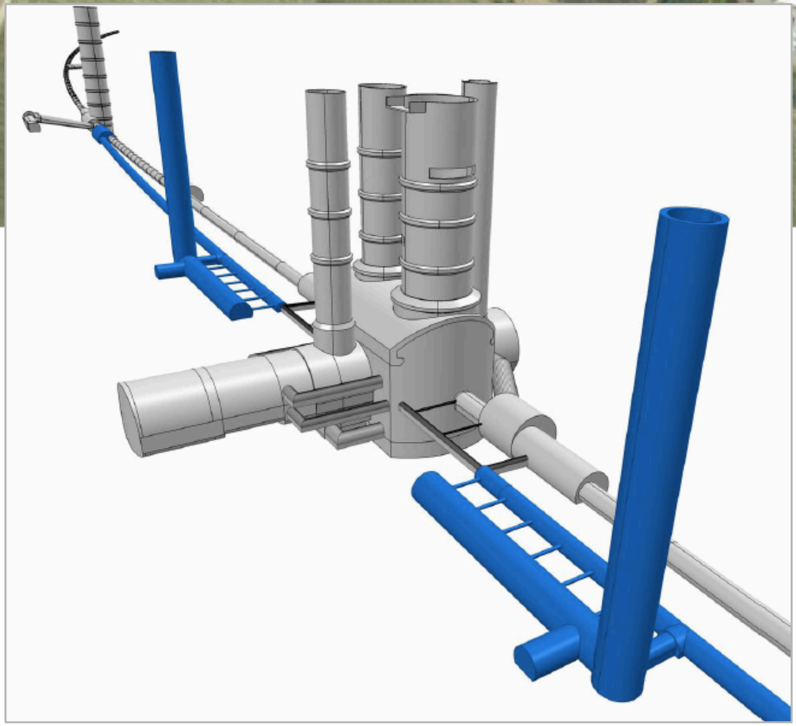
5min filling time

Bypassing CMS



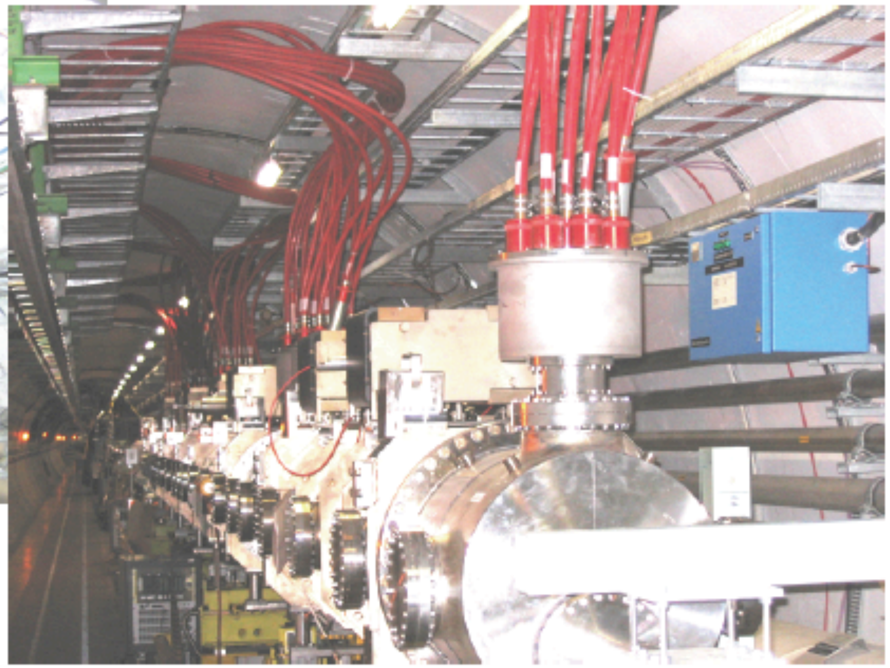
Bypassing ATLAS





For the CDR the bypass concepts were decided to be confined to ATLAS and CMS which is no statement about LHCB or ALICE

Ring Installation Study



- Installation of an e ring is challenging
- Modifications of the existing installations will be necessary
- No show stopper

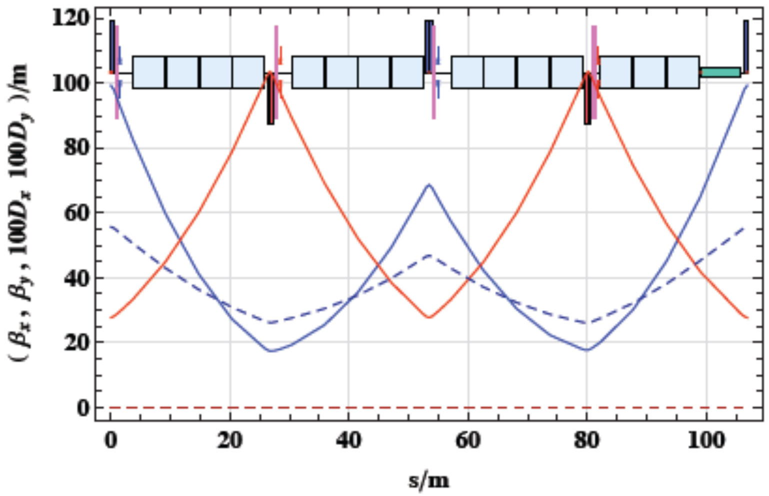
This is the big question for the ring option (interference, activation,..)

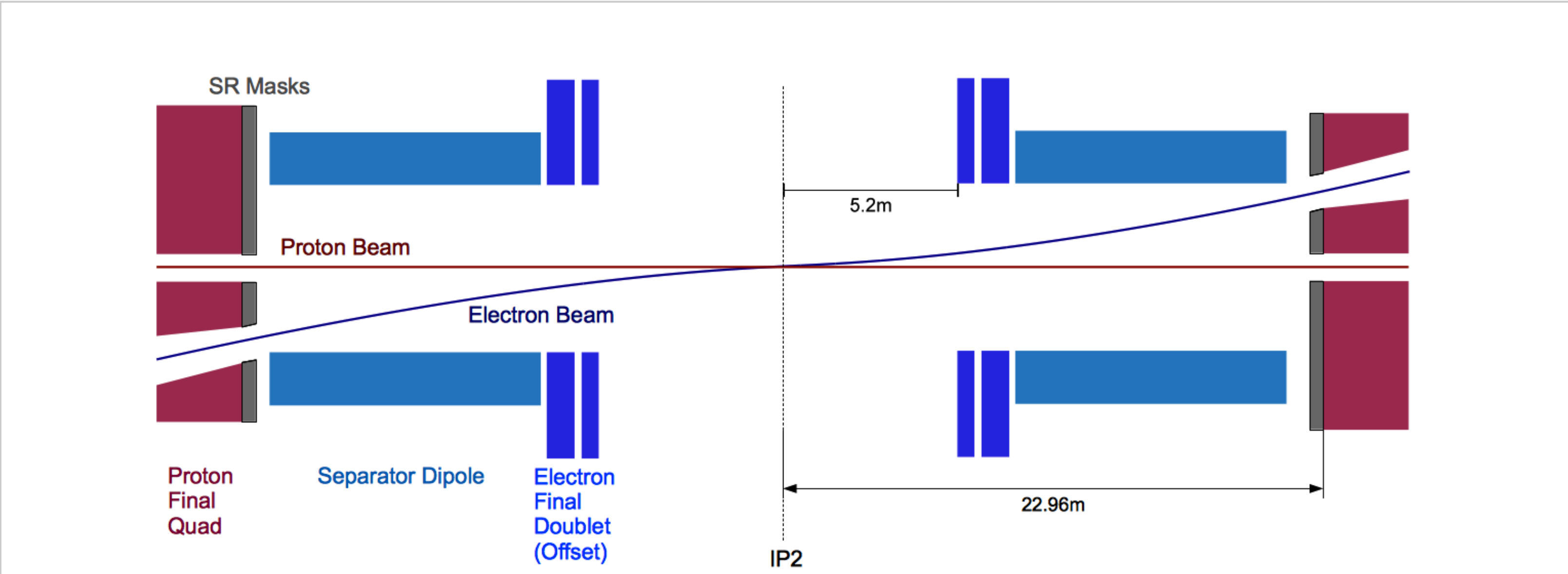
Ring - Arc Optics and matched IR

Optics:

Beam Energy	60 GeV
Phase Advance per FODO Cell	$\approx 90°/60°$
Cell length	106.881 m
Dipole Fill factor	0.75
Damping Partition $J_x/J_y/J_e$	1.5/1/1.5
Coupling constant κ	0.5
Horizontal Emittance (no coupling)	4.70 nm
Horizontal Emittance ($\kappa = 0.5$)	3.52 nm
Vertical Emittance ($\kappa = 0.5$)	1.76 nm

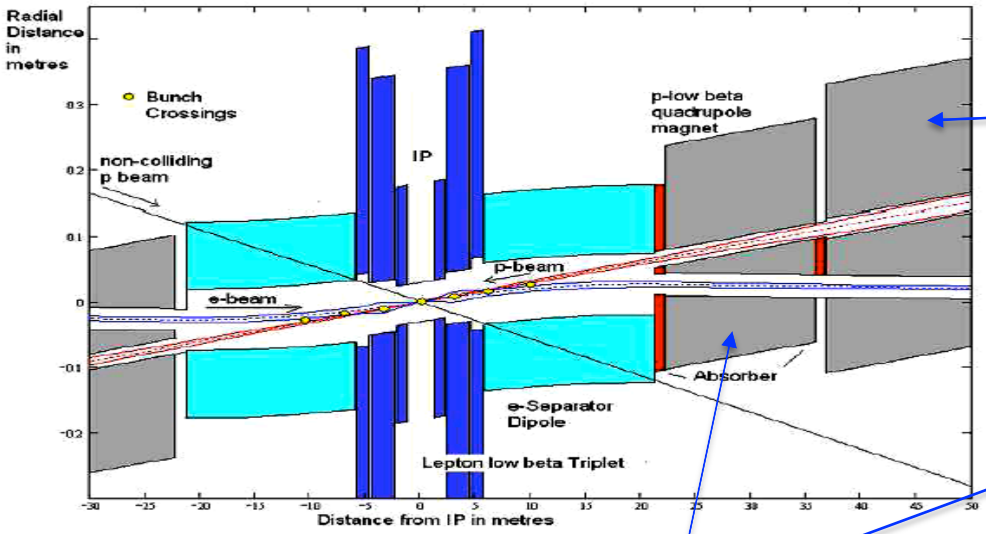
23 arc cells, L_{Cell}=106.881 m

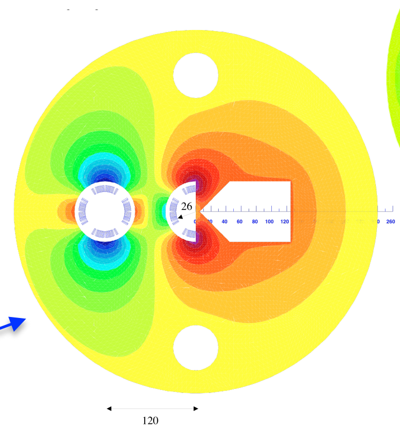


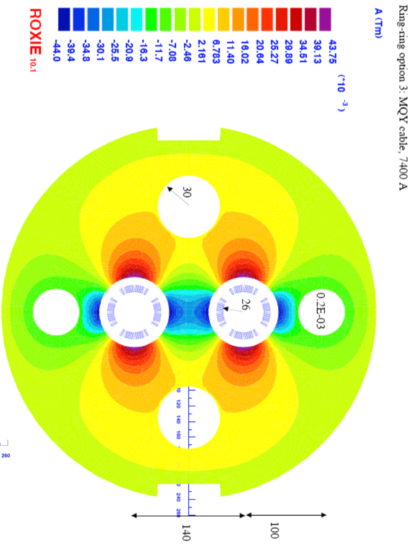


Interaction Region(s)

RR -Small crossing angle ~1mrad (25ns) to avoid first parasitic crossing (L x 0.77)
LR – Head on collisions, dipole in detector to separate beams
Synchrotron radiation –direct and back, absorption simulated (GEANT4) ..





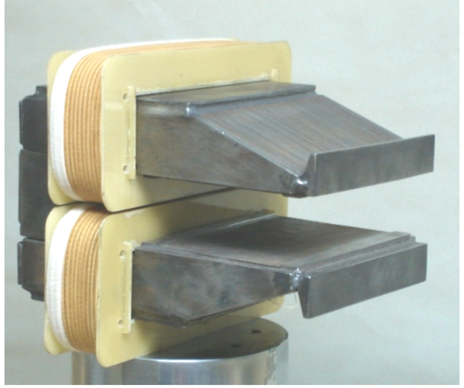


[July 2010]

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

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

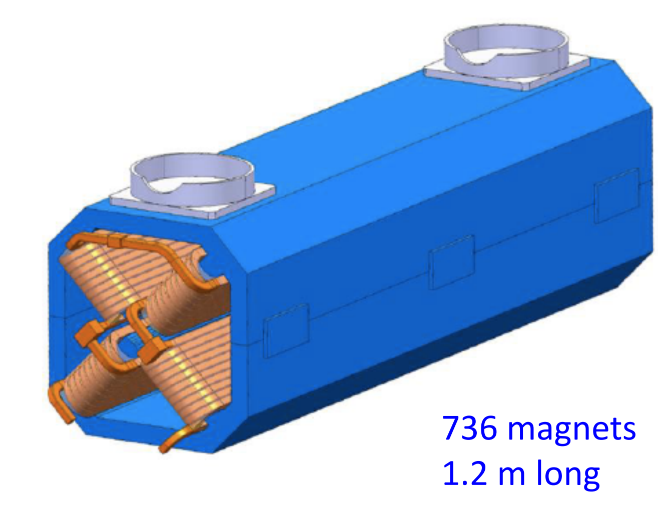
Ring Dipole + Quadrupol Magnets



BINP & CERN prototypes

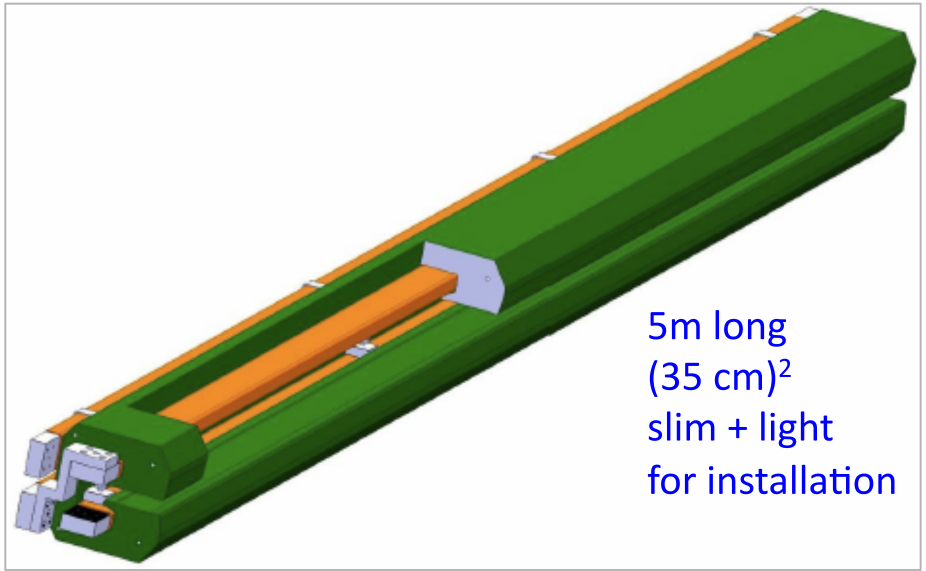
Parameter	Value	Units
Beam Energy	10-60	GeV
Magnetic Length	5.35	Meters
Magnetic Field	0.127-0.763	Tesla
Number of magnets	3080	
Vertical aperture	40	mm
Pole width	150	mm
Number of turns	2	
Current @ 0.763 T	1300	Ampere
Conductor material	copper	
Magnet inductance	0.15	milli-Henry
Magnet resistance	0.16	milli-Ohm
Power @ 60 GeV	270	Watt
Total power consumption @ 60 GeV	0.8	MW
Cooling	air or water	depends on tunnel ventilation

Table 3.2: Main parameters of bending magnets for the RR Option.



736 magnets
1.2 m long

Arc quadrupole magnets for the RR Option

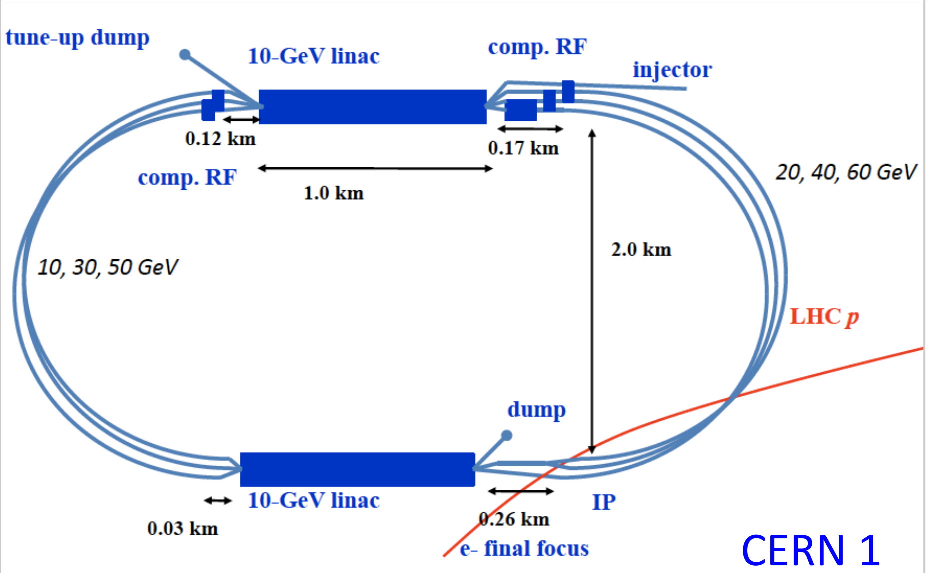


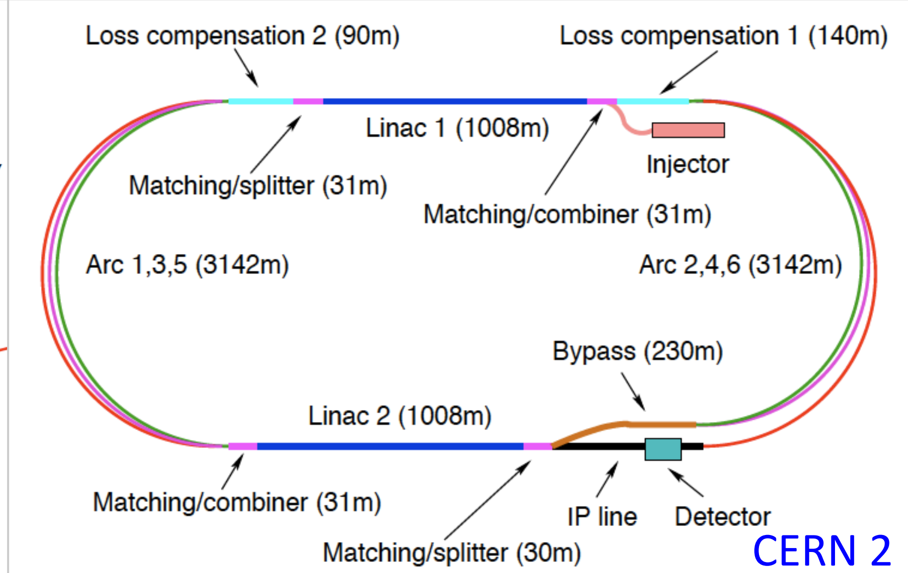
5m long
(35 cm)^2
slim + light
for installation

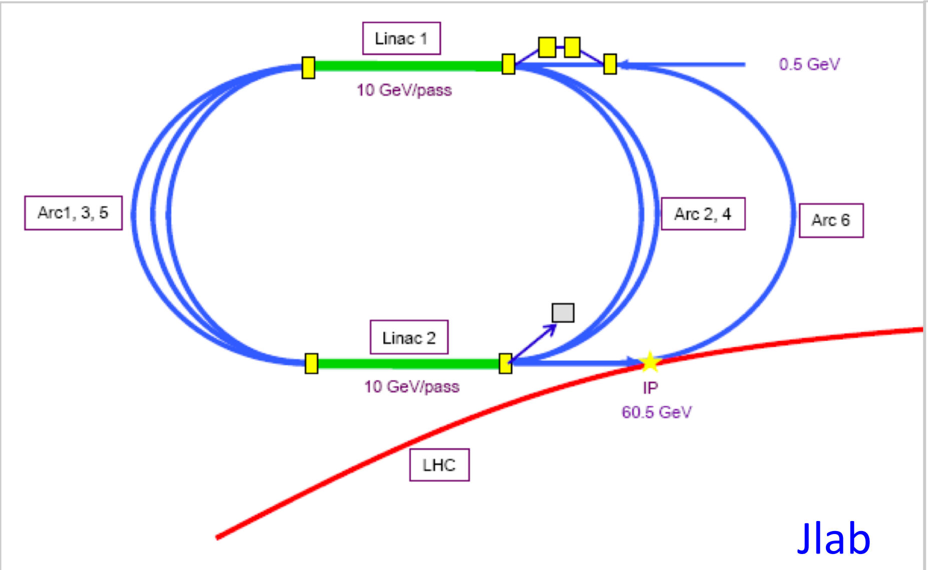
3. LINAC

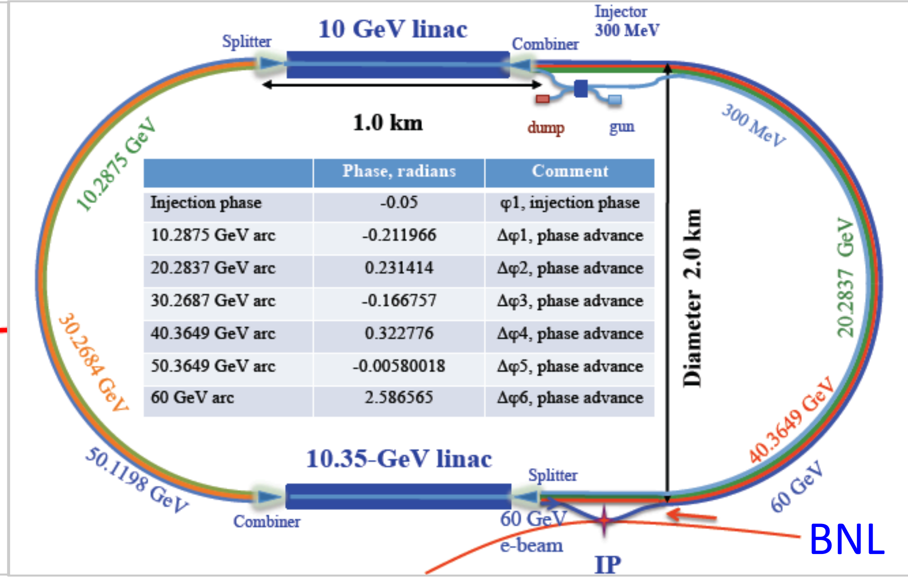
Luminosity $10^{33}cm^{-2}s^{-1}$ possible to achieve for e^-
Positrons require E recovery AND recycling, L+ < L-
Energy limited by synchrotron radiation in racetrack mode
Two beam recovery for high energy LINAC may be a long term option
Polarisation 'easy' for e^- ~90%, rather 0 for e^+
Cavities: Synergy with SPL, ESS, XFEL, ILC
Cryo: fraction of LHC cryo system
Energy Recovery (CI, Cornell, BINP, ..) to be developed for LHeC
Small interference with the proton machine
Bypass of own IP
Extended dipole at ~1m radius in detector
Outside CERN territory (~9km tunnel below St Genis for IP2)
Cost will be estimated
…

LINACs





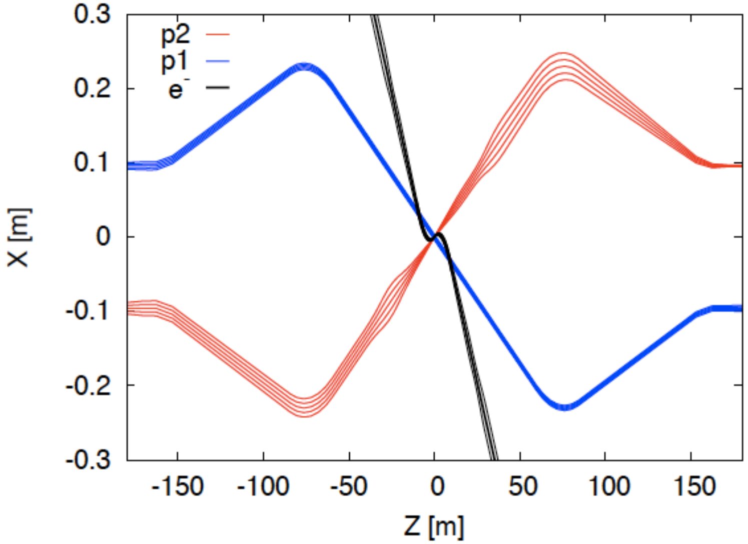




	Phase, radians	Comment
Injection phase	-0.05	φ1, injection phase
10.2875 GeV arc	-0.211966	Δφ1, phase advance
20.2837 GeV arc	0.231414	Δφ2, phase advance
30.2687 GeV arc	-0.166757	Δφ3, phase advance
40.3649 GeV arc	0.322776	Δφ4, phase advance
50.3649 GeV arc	-0.00580018	Δφ5, phase advance
60 GeV arc	2.586565	Δφ6, phase advance

Two 10 GeV Linacs, 3 returns, ERL, 720 MHz cavities, rf, cryo, magnets, injectors, sources, dumps…

LR Interaction Region



3 beams, head-on collisions

p and e optics done

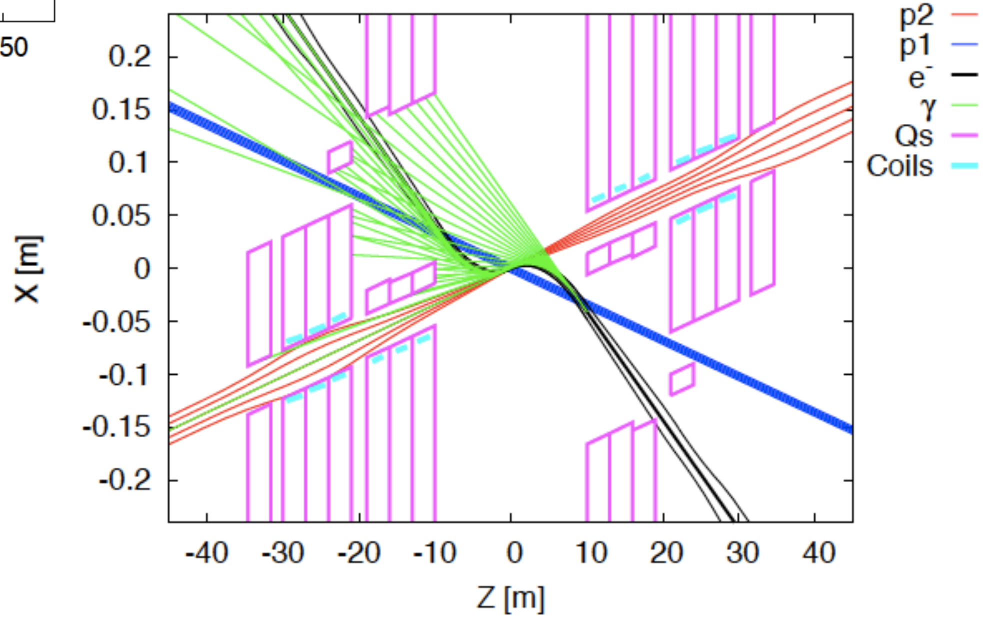


Figure 9.14: LHeC interaction region with a schematic view of synchrotron radiation. Beam trajectories with 5σ and 10σ envelopes are shown.

Three Pass ERL RF system at 721 MHz

Energy = 3 * 20 GeV, 2 x 10 GeV Linacs, 6.6 mA. 721 MHz, allow for 25 ns bunches

Take SPL type cavity @18 MV/m (Close to BNL design for eRHIC)

- 1.06 m/cavity => 19.1 MV/cav => **1056 cavities total** (=132 x 8)
- Take 8 cavities in a 14 m cryomodule (cf SPL) => **66 cryo modules/linac**

  Total length = 924 m/linac + margin ~10%
- Power loss in arcs = 9.5 MW, 9 kW/cavity, Take P_{rf} = 20 kW/cavity with overhead for feedbacks, **total installed RF 21 MW.**
- No challenge for power couplers, power sources – could be solid state
- However, still need adjacent gallery to house RF equipment (high gradient = radiation !) 4-5 m diameter sufficient
- Synchrotron radiation losses in arcs: need re-accelerating 'mini'-linacs

ERL Electrical Site Power

The cryopower for two 10-GeV accelerating SC linacs is 28.9 MW, assuming pessimistically 37 W/m heat load at 1.8 K and 18 MV/m cavity gradient (this is a pessimistic estimate since the heat load could be up to 3 times smaller; see Table 9.1), and 700 "W per W" cryo efficiency as for the ILC. The RF power needed to control microphonics for the accelerating RF is estimated at 22.2 MW, considering that 10 kW/m RF power may be required, as for eRHIC, with 50% RF generation efficiency. The electrical power for the additional RF compensating the synchrotron-radiation energy loss is 24.1 MW, with an RF generation efficiency of 50%. The cryo power for the compensating RF is 2.1 MW, provided in additional 1,44 GeV linacs, and the microphonics control for the compensating RF requires another 1.6 MW. In addition, with an injection energy of 50 MeV, 6.4 mA beam current, and as usual 50% efficiency, the electron injector consumes about 6.4 MW. A further 3 MW is budgeted for the recirculation-arc magnets [?]. Together this gives a grand total of 88.3 MW electrical power, some 10%.below the 100 MW limit.

60 GeV Energy Recovery Linac

U=1/3 U(LHC)

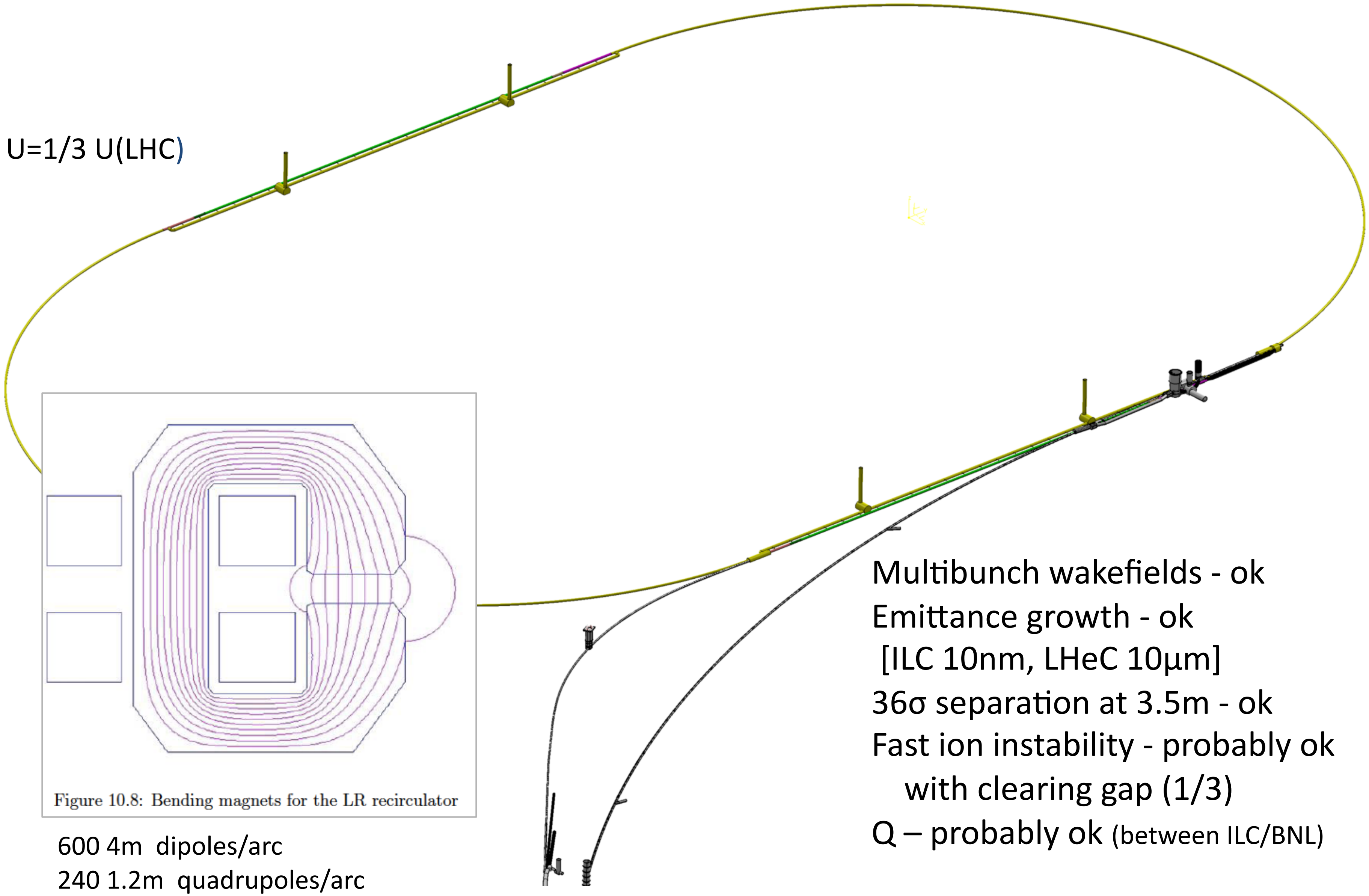
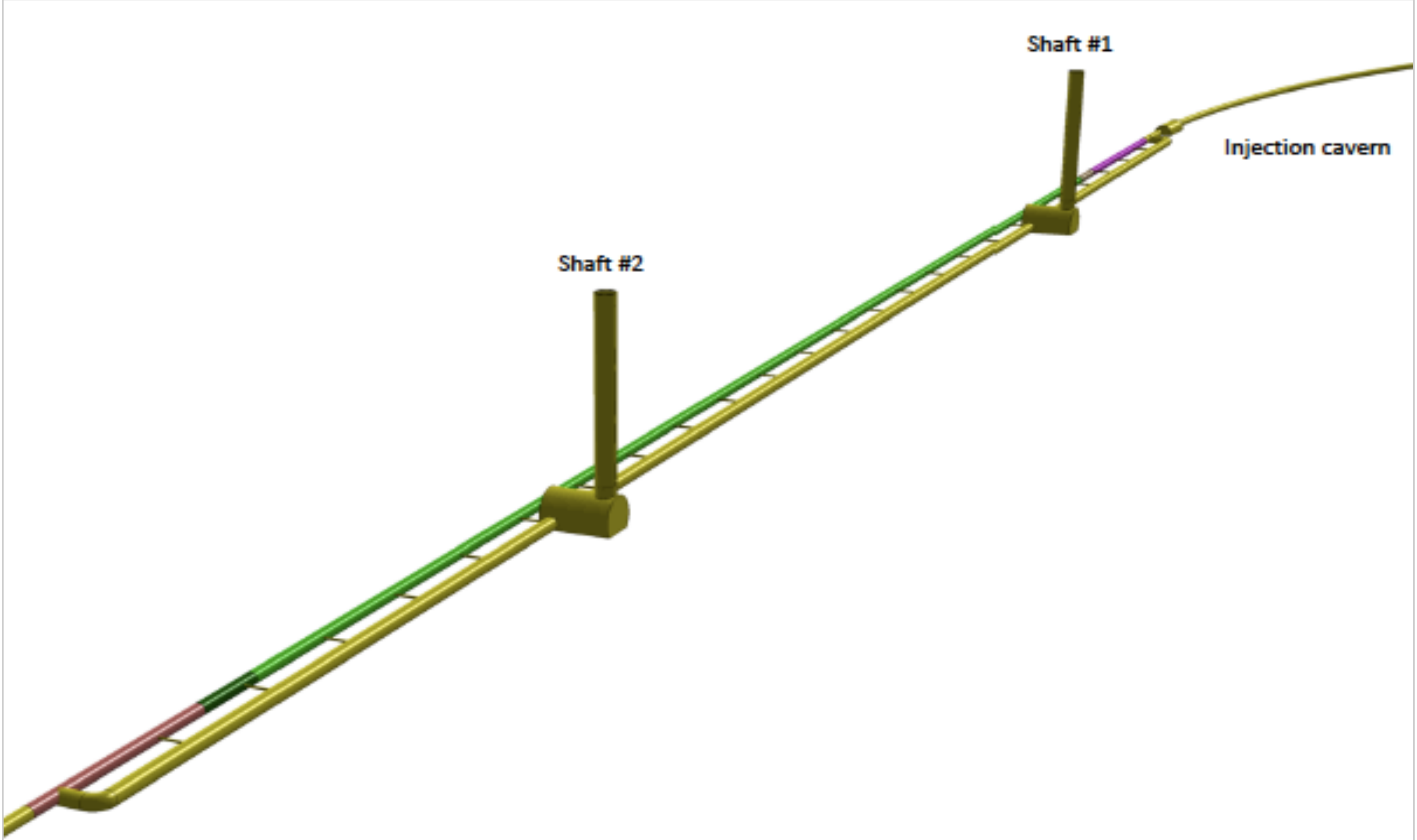


Figure 10.8: Bending magnets for the LR recirculator

600 4m dipoles/arc
240 1.2m quadrupoles/arc

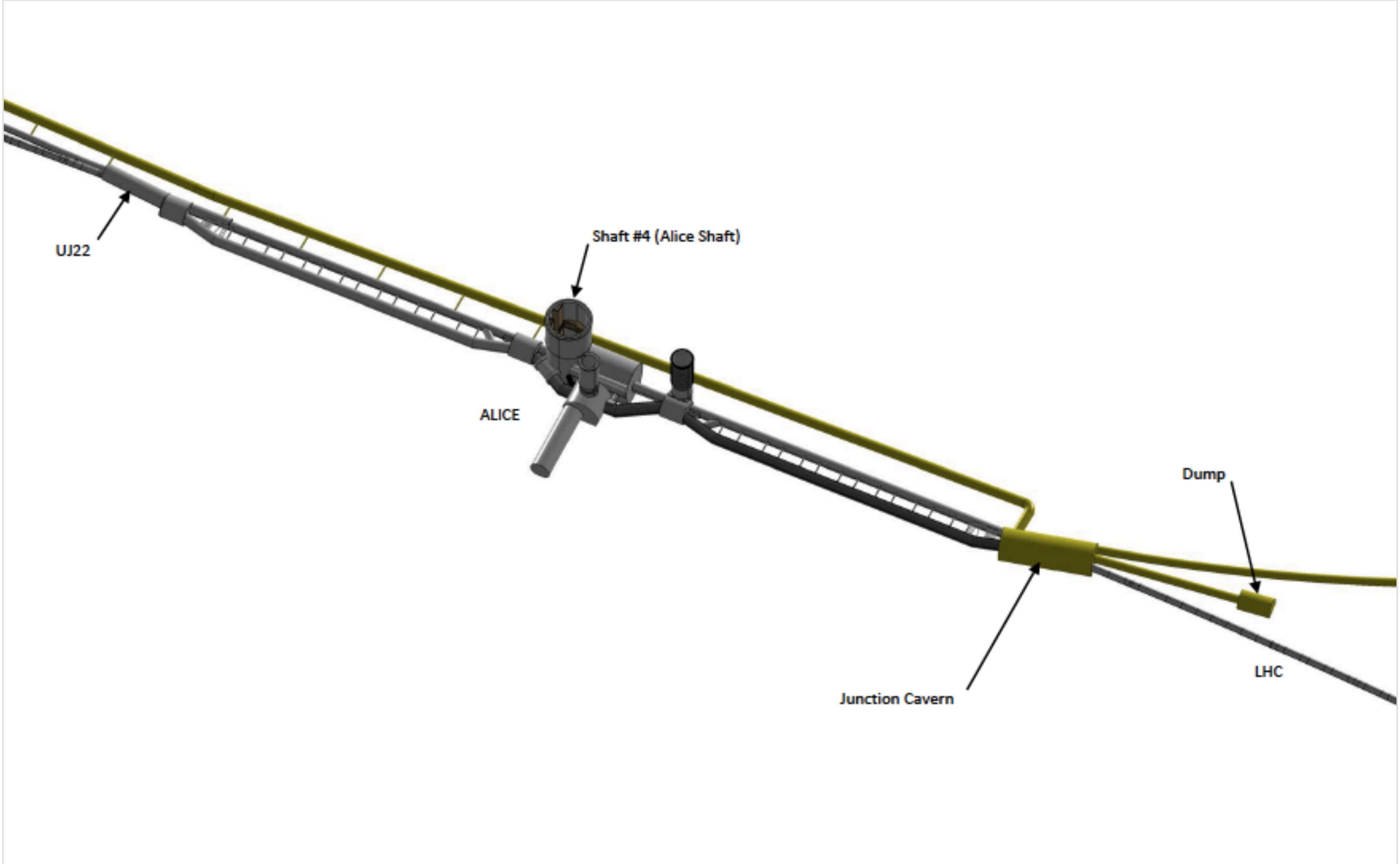
Multibunch wakefields - ok
Emittance growth - ok
[ILC 10nm, LHeC 10µm]
36σ separation at 3.5m - ok
Fast ion instability - probably ok
with clearing gap (1/3)
Q – probably ok (between ILC/BNL)

LINAC – injector side



18.1.11 -All civil engineering drawings tentative!

LINAC – near the IR



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"
1.7 probably conservative

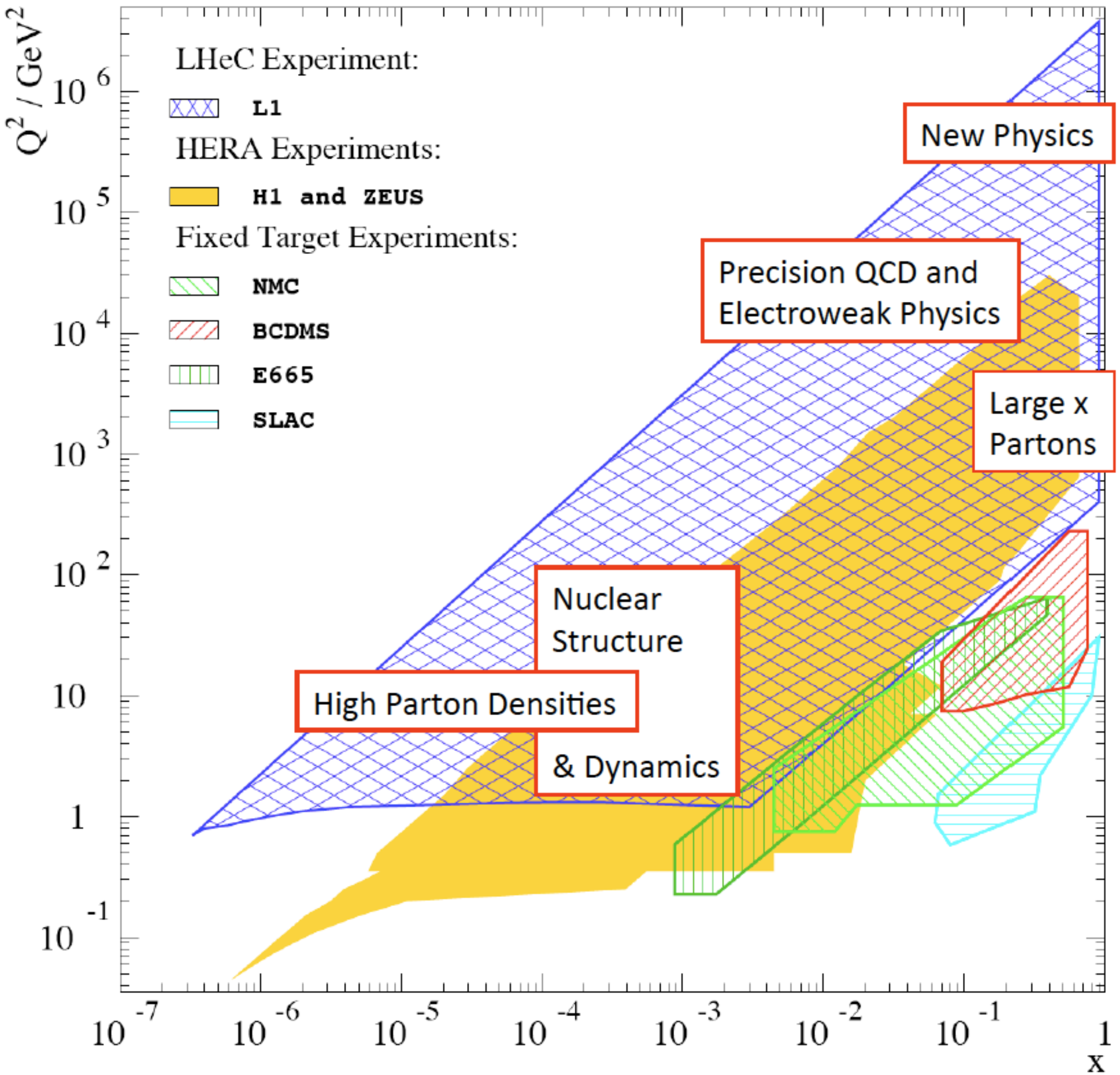
Design also for deuterons (new) and lead (exists)

RR= Ring – Ring
LR =Linac –Ring

Parameters from 8.7.2010
New: Ring: use 1° as baseline : L/2
Linac: clearing gap: L*2/3

4. Physics

Глубоко-неупругое Рассеяние



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**

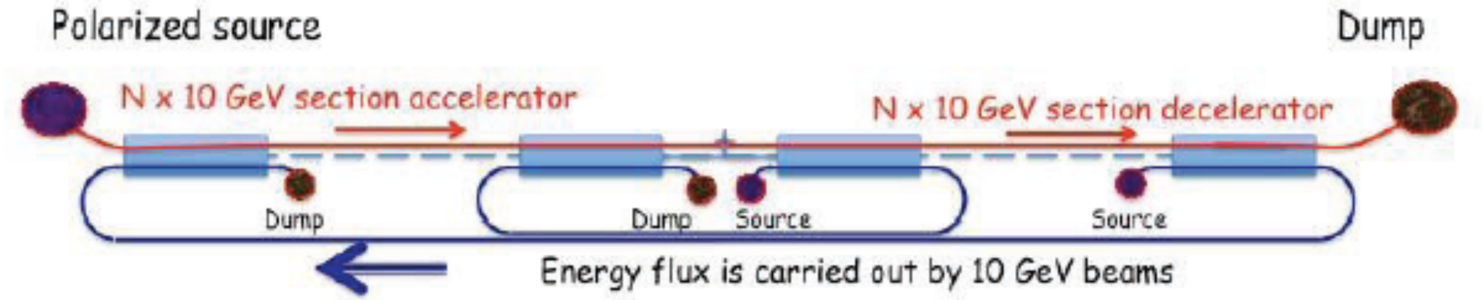
Broad physics goals (to be discussed at the Workshop)

- 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

Towards Higher E_e and Luminosity



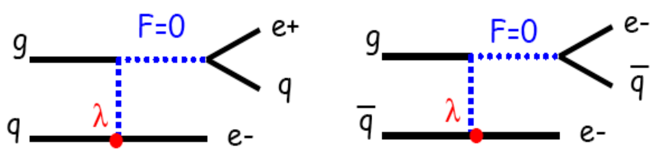
4.1.5 Highest-Energy LHeC ERL Option

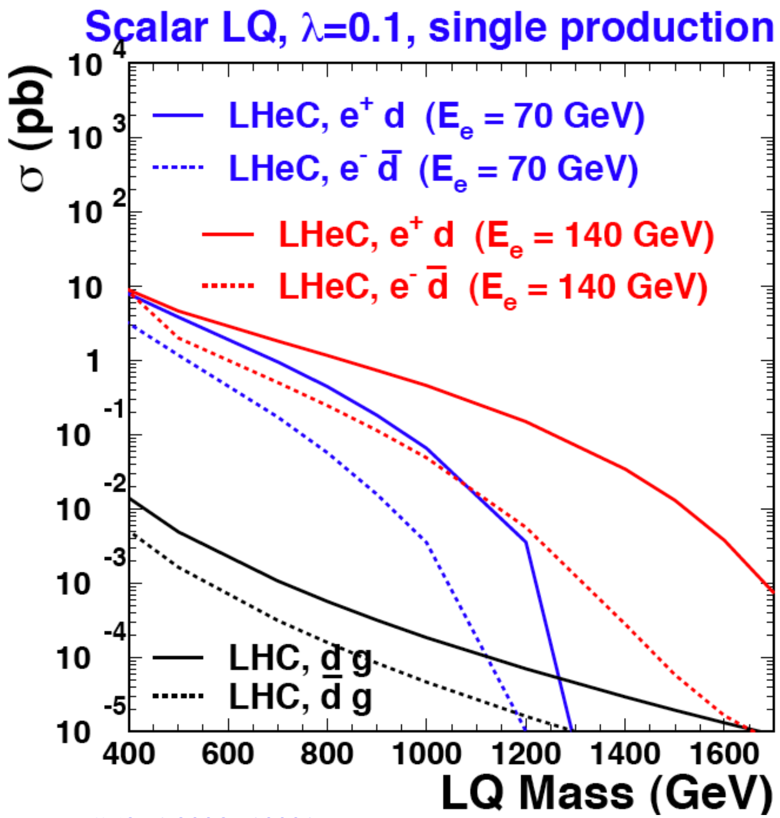
The simple straight linac layout of Fig. 3.8 can be expanded as shown in Fig. 3.9 [29]. The main electron beam propagates from the left to the right. In the first linac it gains about 150 GeV, then collides with the hadron beam, and is then decelerated in the second linac. By transferring the RF energy back to the first accelerating linac, with the help of multiple, e.g. 15, 10-GeV "energy-transfer beams," a novel type of energy recovery is realized without bending the spent beam. With two straight linacs facing each other this configuratiom could easily be converted into a linear collider, or vice versa, pending on geometrical and geographical constraints of the LHC site. As there are no synchrotron-radiation losses the energy recovery can be nearly 100% efficient. Such novel form of ERL could push the LHeC luminosity to the 10^{35} $cm^{-2}s^{-1}$ level. In addition, it offers ample synergy with the CLIC two-beam technology.

The LINAC concept has a possible evolution to say 150 GeV colliding with 16 TeV in the HE LHC, > 2030
This is 10^6 times the Q^2 reach of the SLAC experiment which discovered quarks using a 2 mile LINAC.

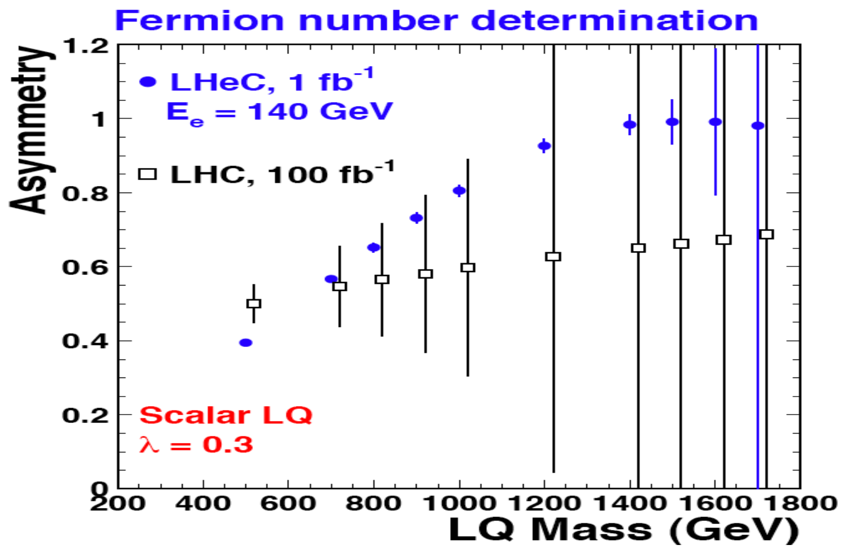
From CDR draft, courtesy V. Litvinenko, Divonne 2008

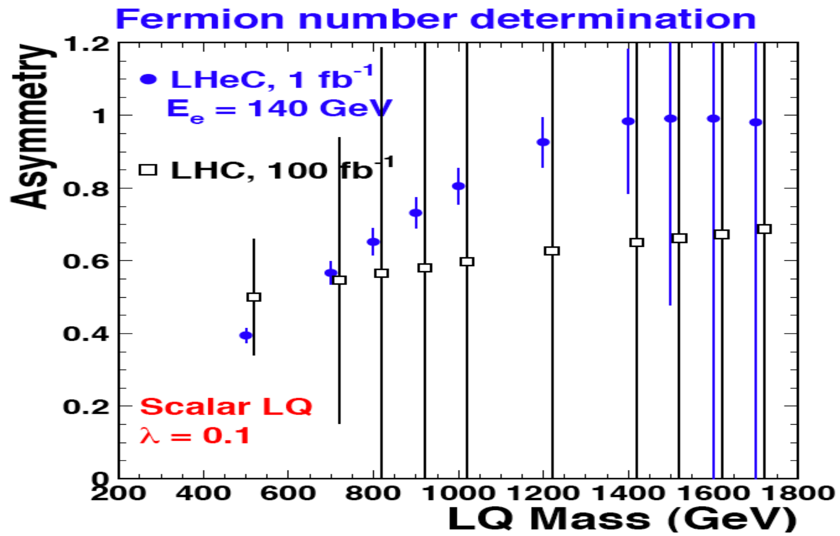
LQ Quantum Numbers





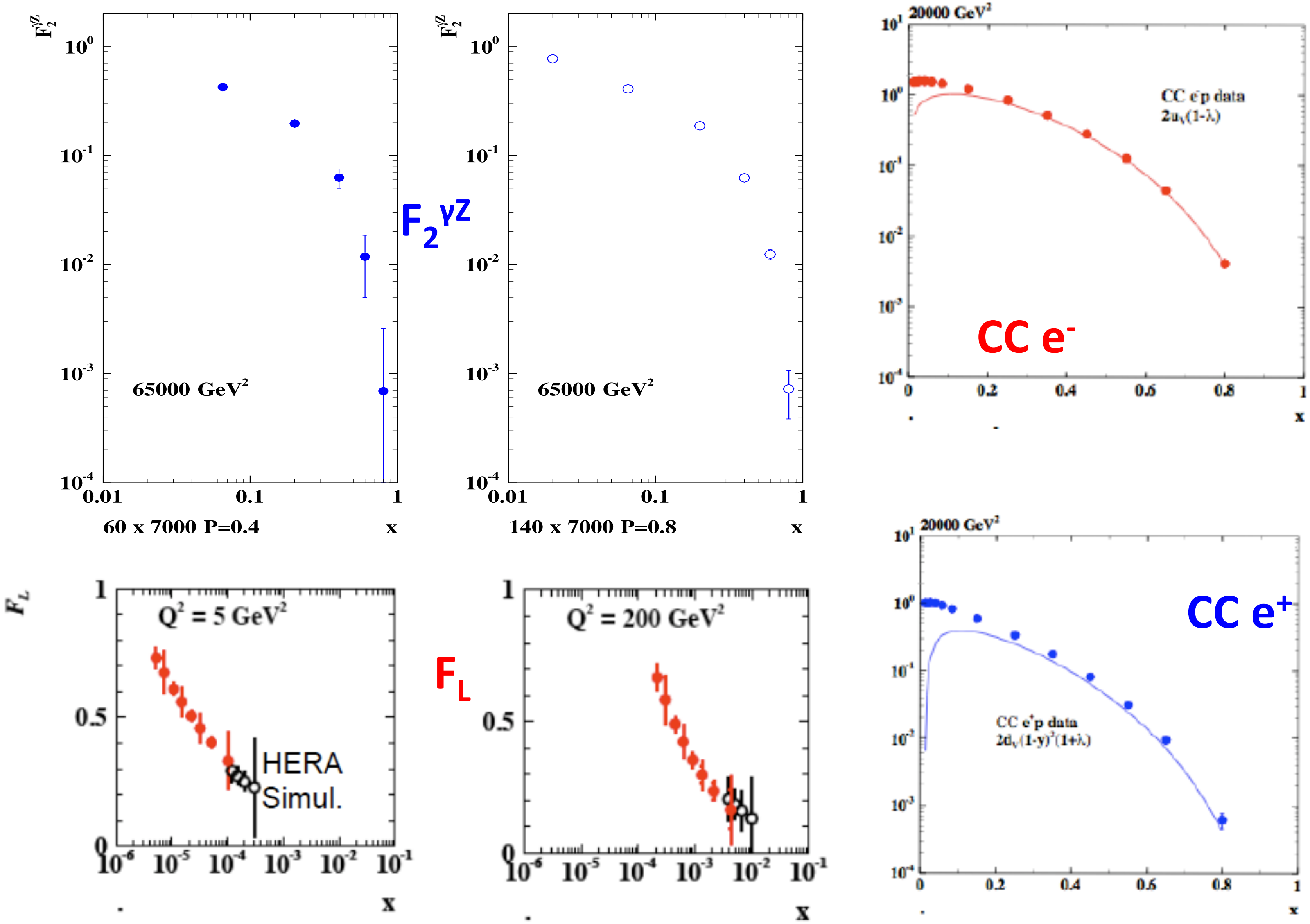
JINST 1 2006 P10001



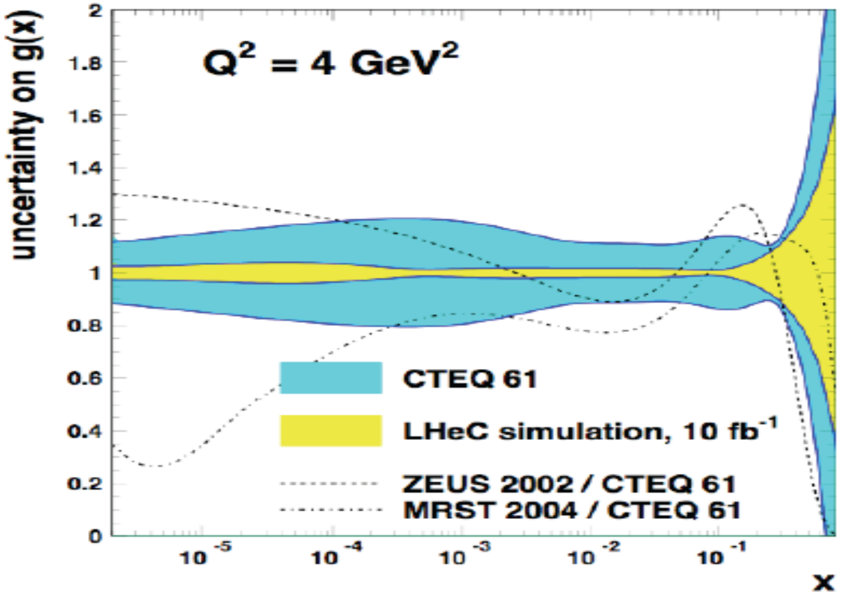


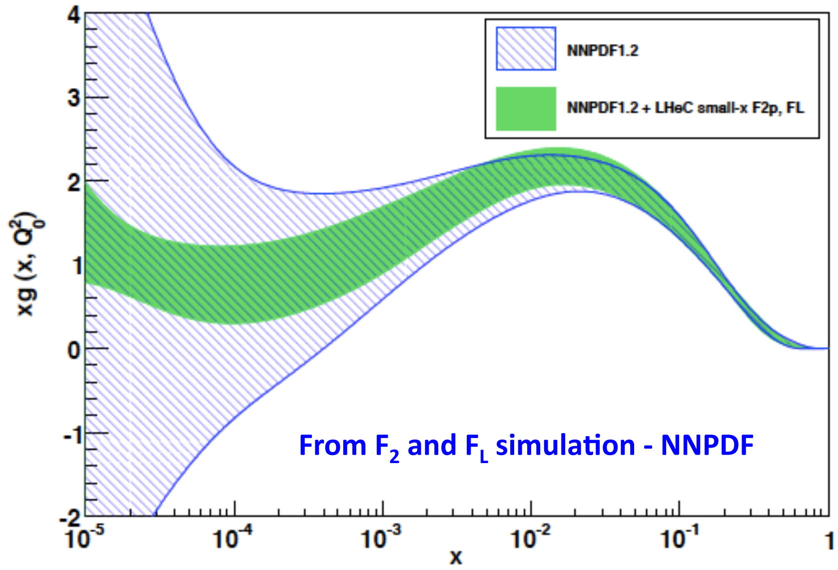
Charge asymmetry much cleaner in ep [in] than in pp [out]. Similar for simultaneous determination of coupling and quark flavour. Polarisation for spectroscopy

Structure Functions – Examples:

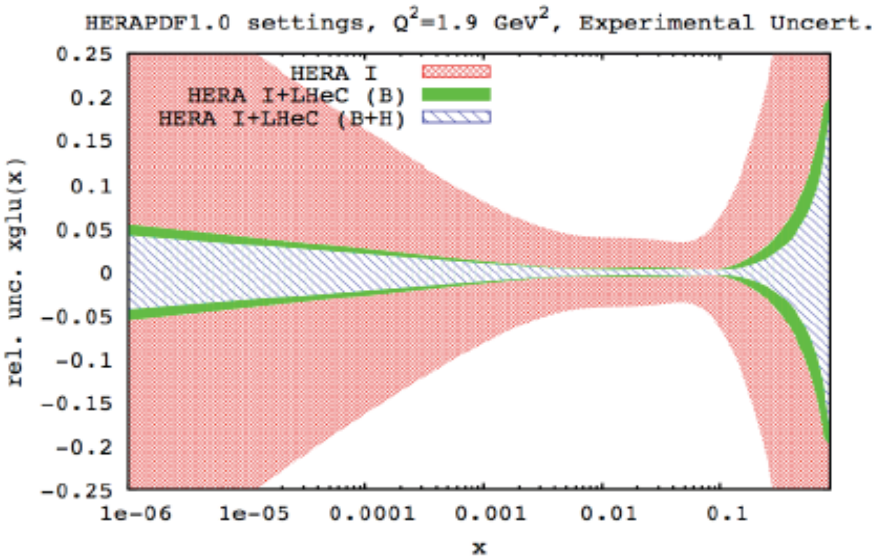


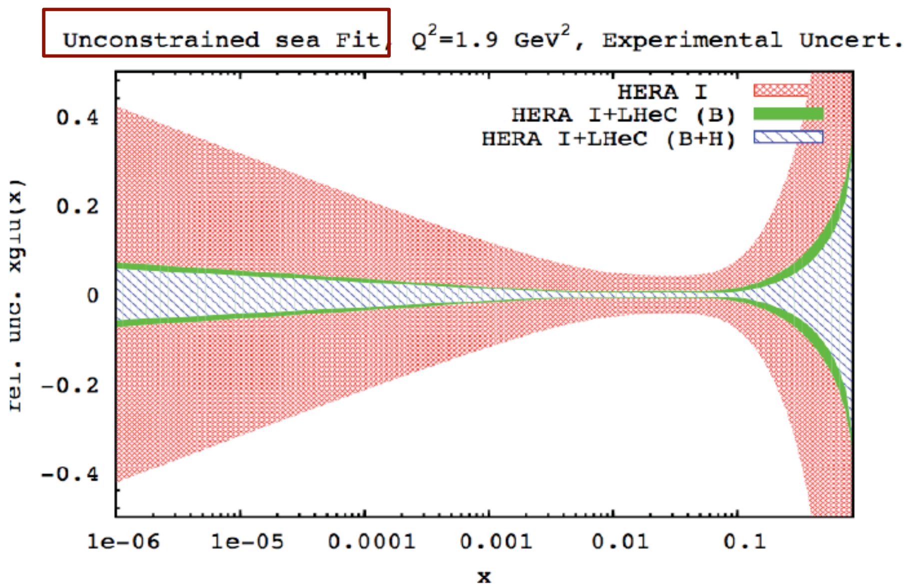
Gluon Distribution





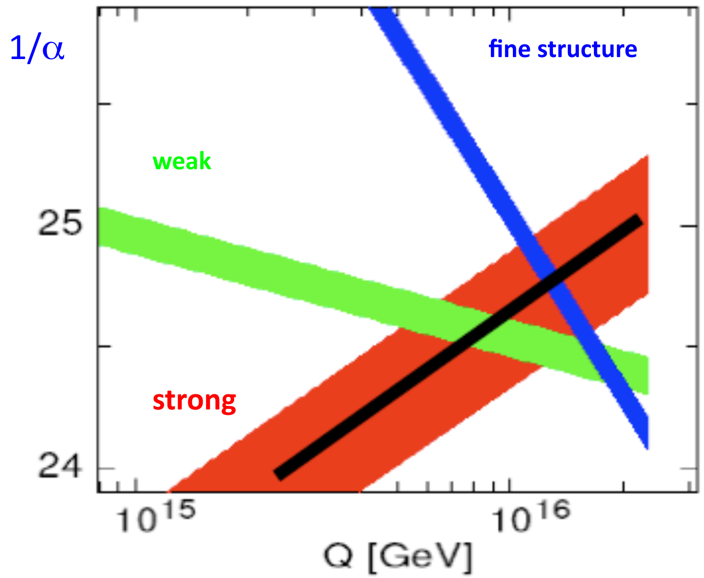
NLO QCD "Fits" of LHeC simulated data





Strong Coupling Constant

Simulation of α_s measurement at LHeC



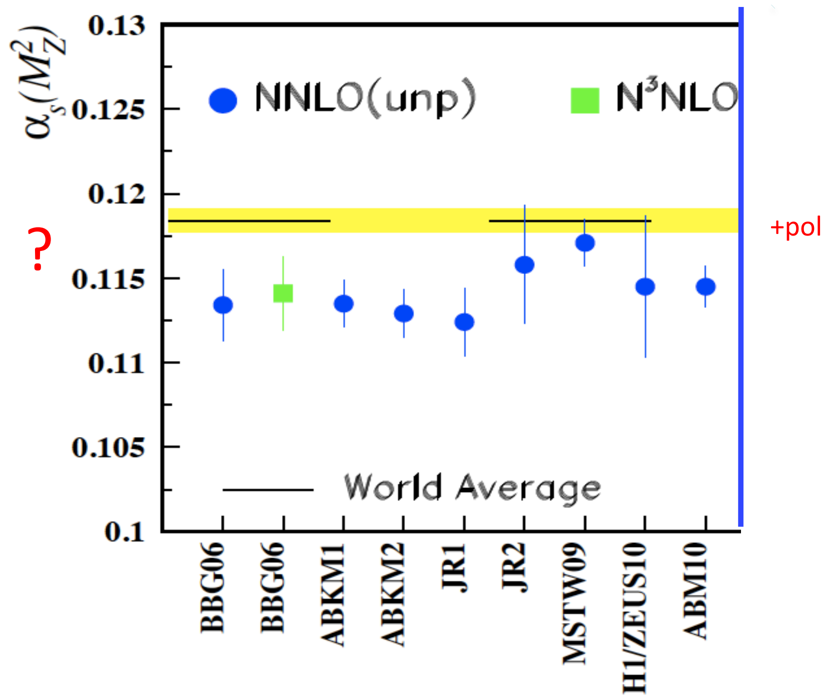
MSSM - B.Allnach et al, hep-ex/0403133

DATA	exp. error on α_s
NC e^+ only	0.48%
NC	0.41%
NC & CC	**0.23% :=(1)**
(1) $\gamma_h > 5°$	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 $\delta\alpha_s$

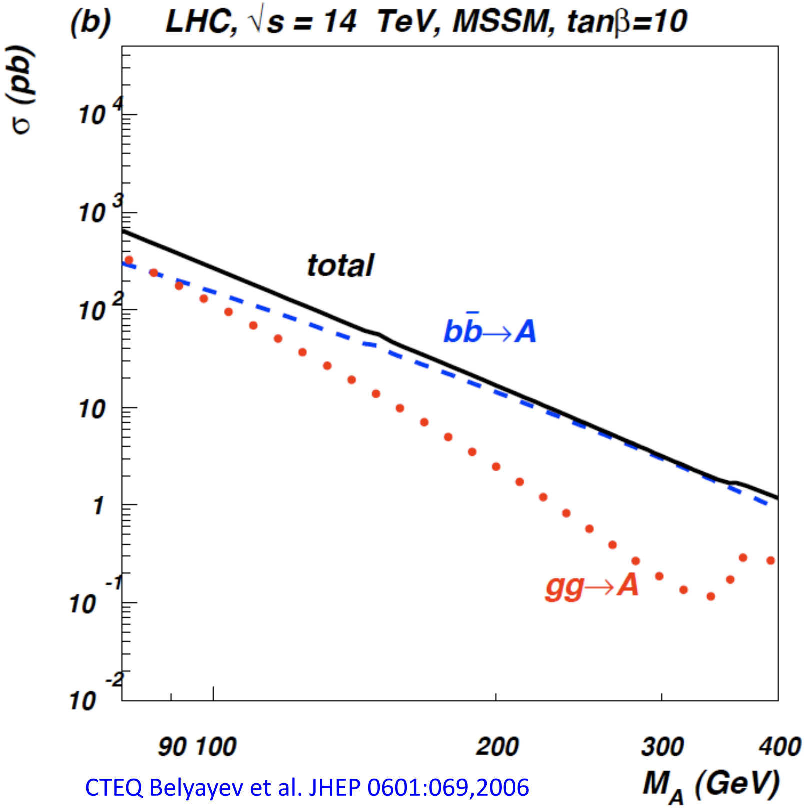
DIS tends to be lower than world average

LHeC: per mille accuracy indep. of BCDMS.
Challenge to experiment and to h.o. QCD



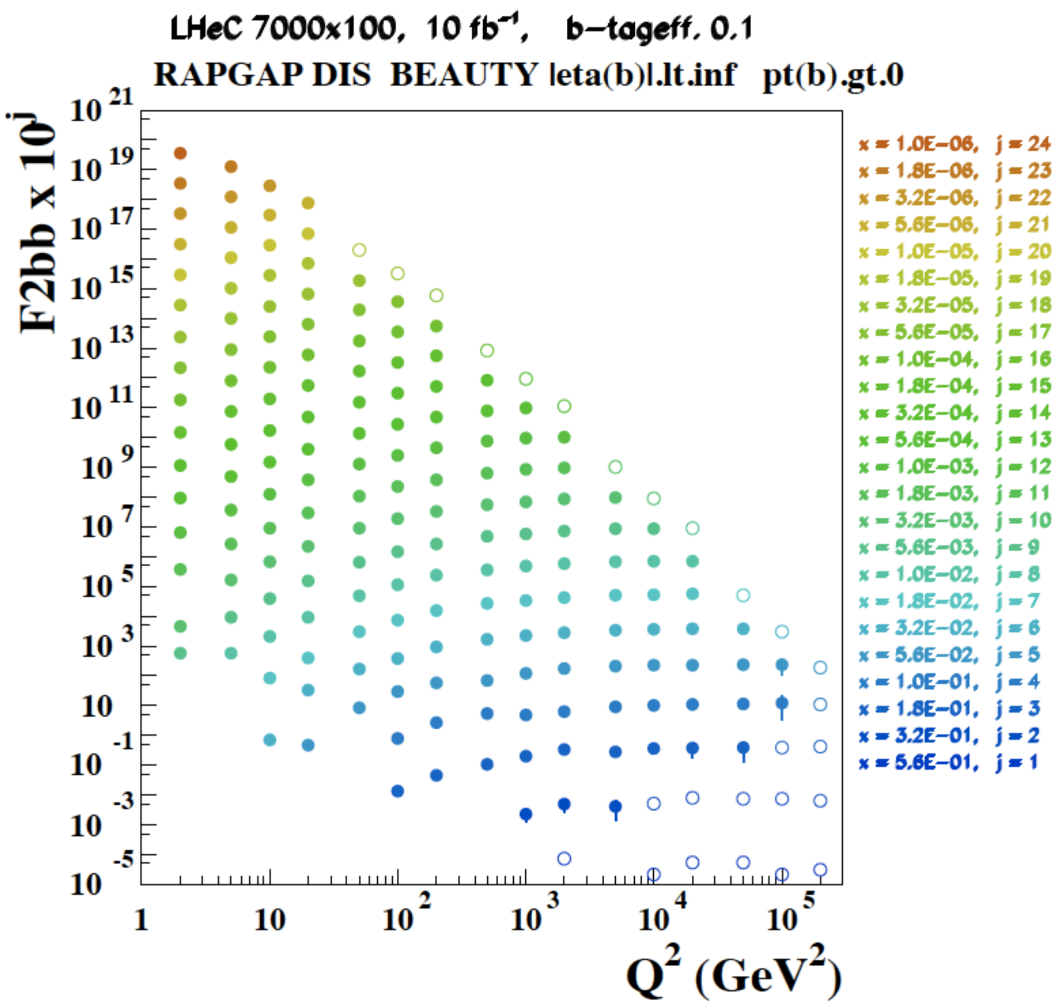
J.Bluemlein and H. Boettcher, arXiv 1005.3013 (2010)

Beauty - MSSM Higgs



CTEQ Belyayev et al. JHEP 0601:069,2006

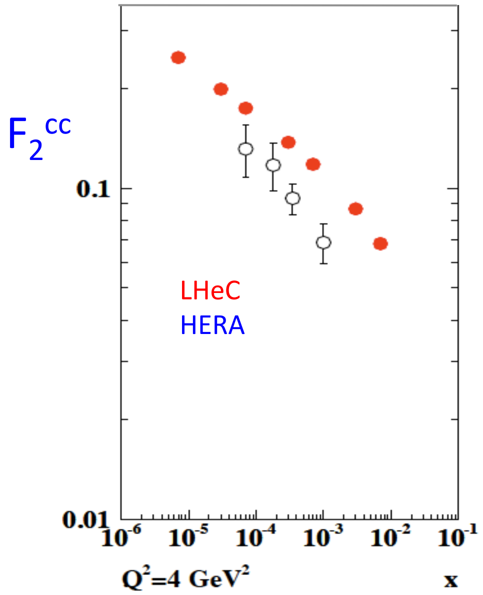
In MSSM Higgs production is b dominated

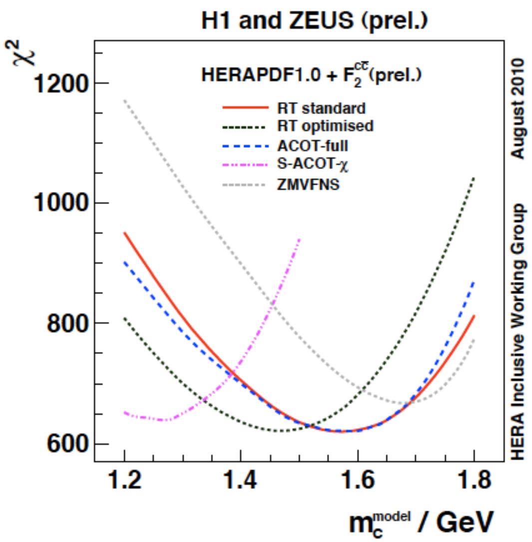


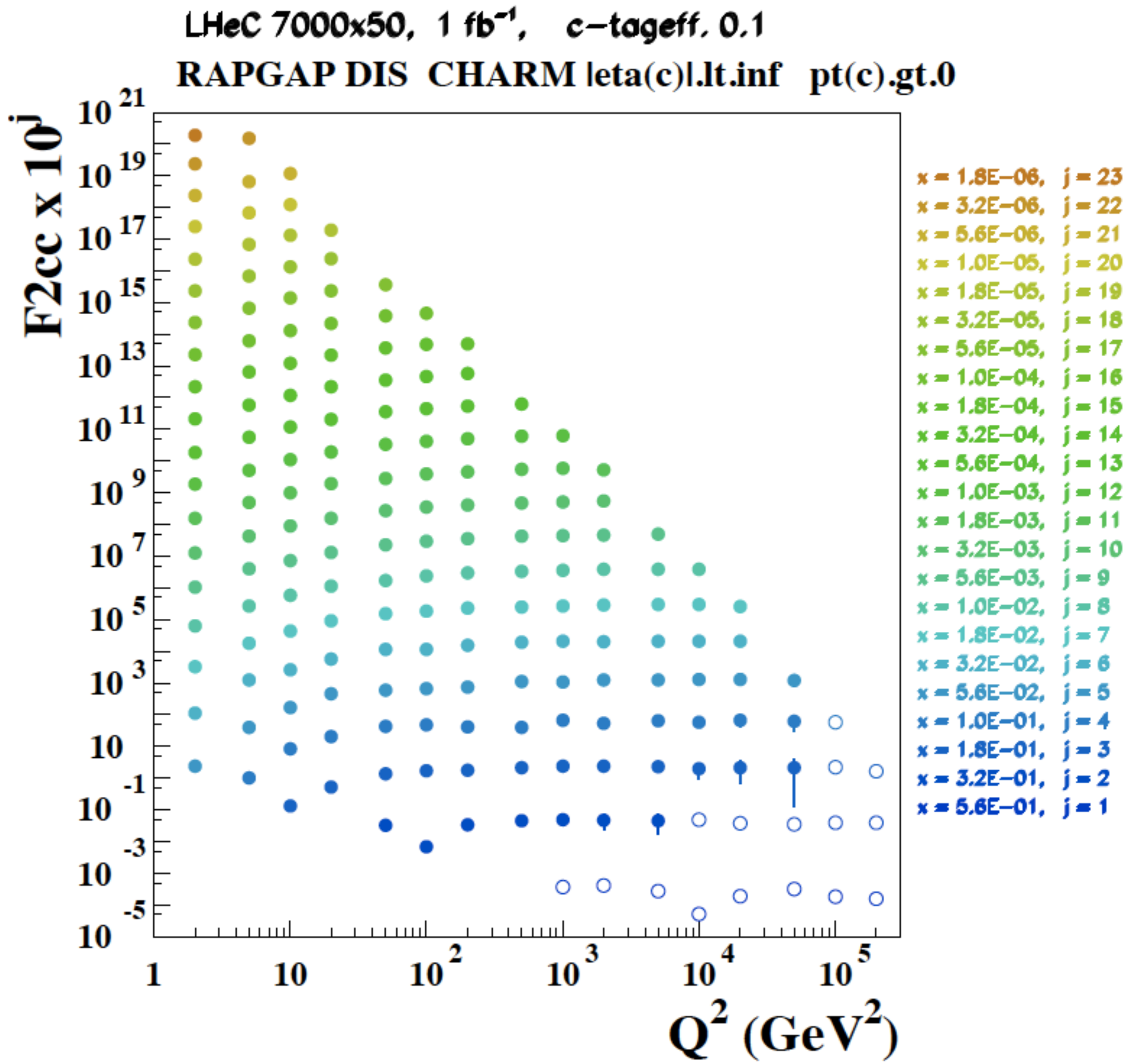
HERA: First measurements of b to ~20%
LHeC: precision measurement of b-df

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

Charm – α_s

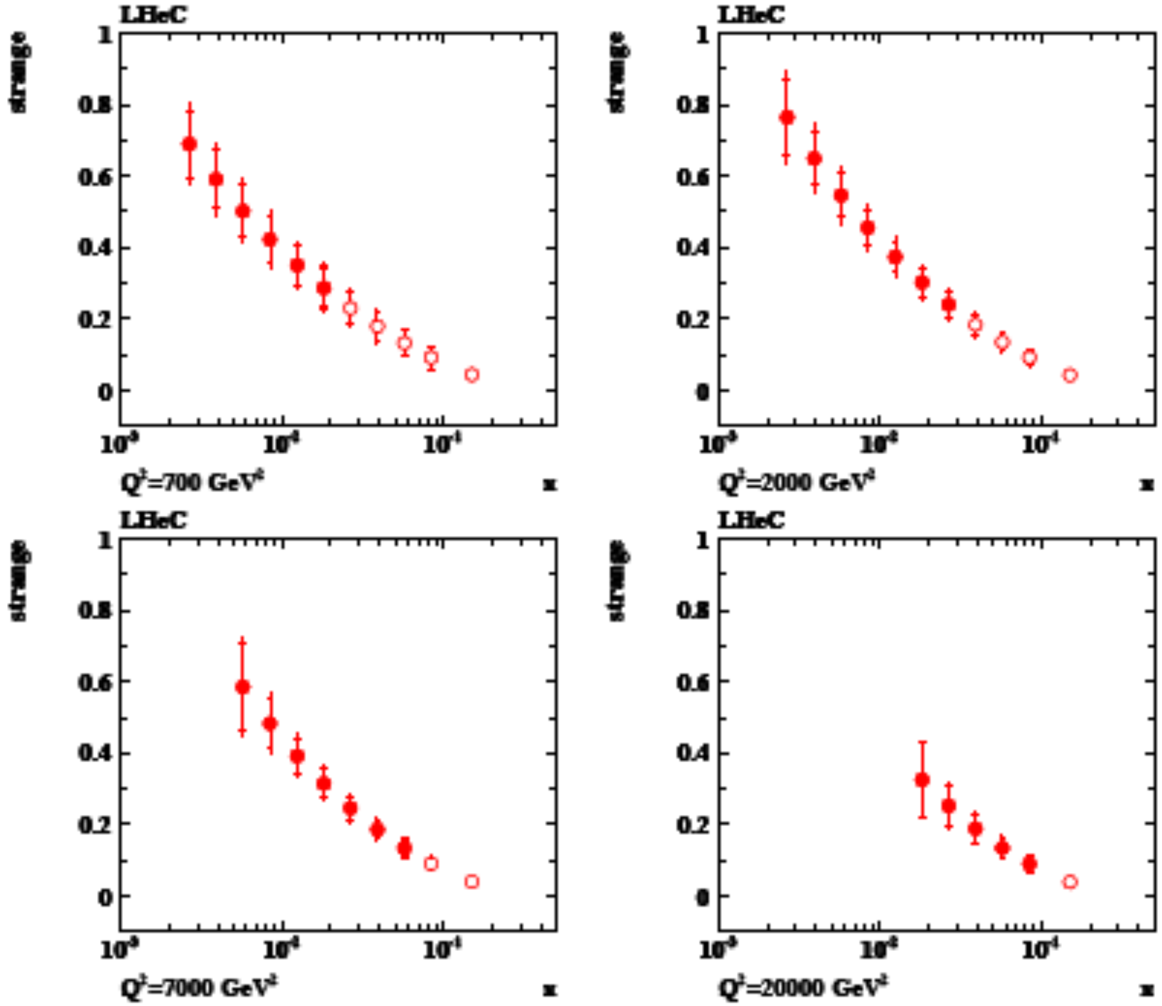






LHeC: higher fraction of c, larger range, smaller beam spot, better Si detectors

Strange (=? anti-strange) Quark



$W^{+}s \rightarrow c$

$1\,fb^{-1}$

$\varepsilon_c = 0.1$

$\varepsilon_q = 0.01$

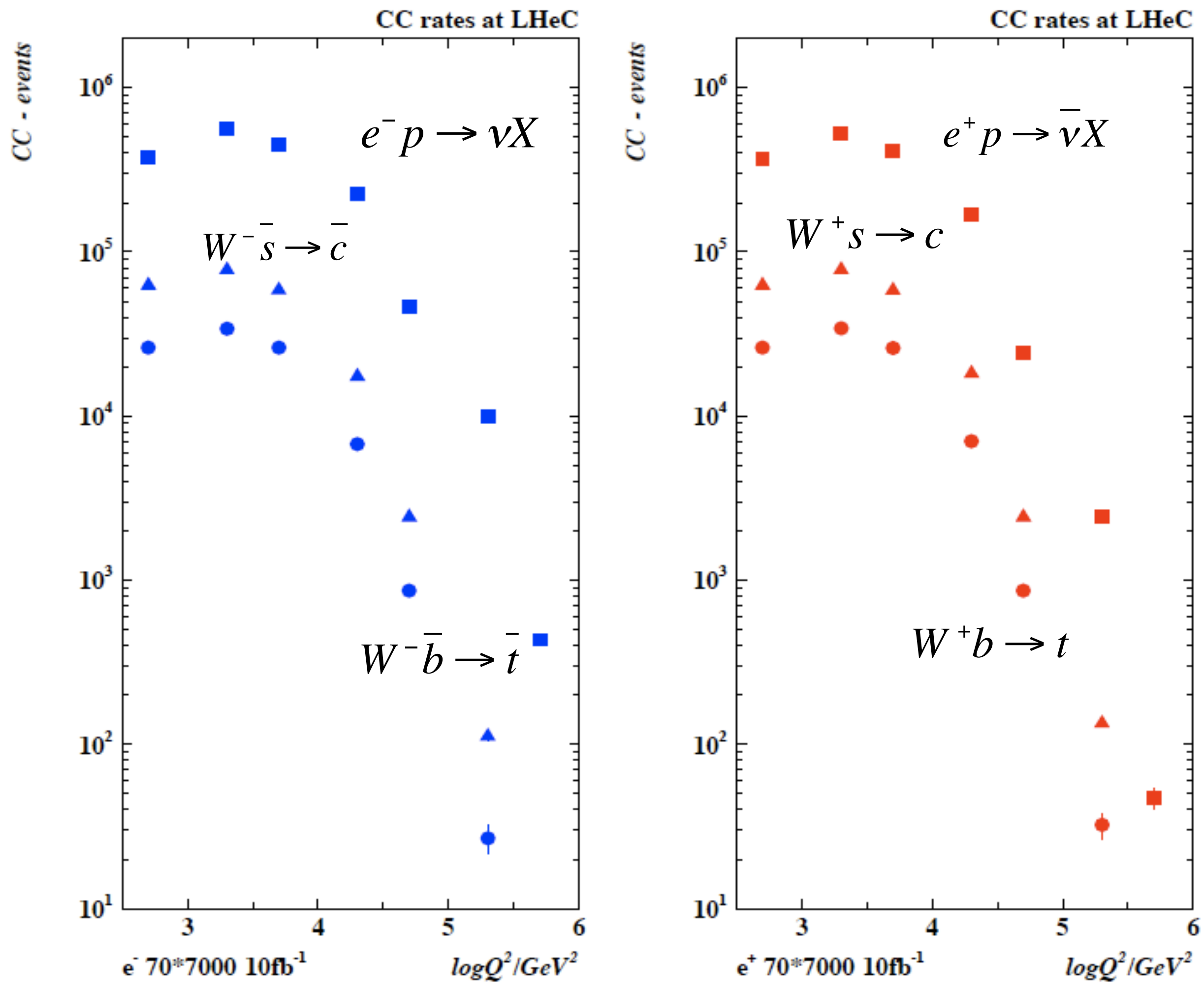
$\delta_{syst} = 0.1$

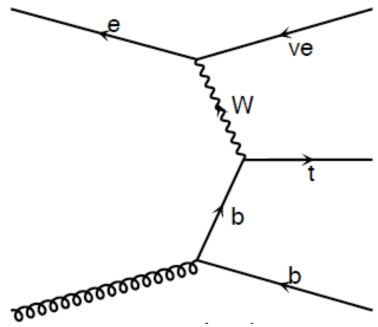
$\circ - \vartheta_h \geq 1^o$

$\bullet - \vartheta_h \geq 10^o$

Some dimuon and K data
never properly measured

$\overline{\text{Top}}$ and Top Production in Charged Currents



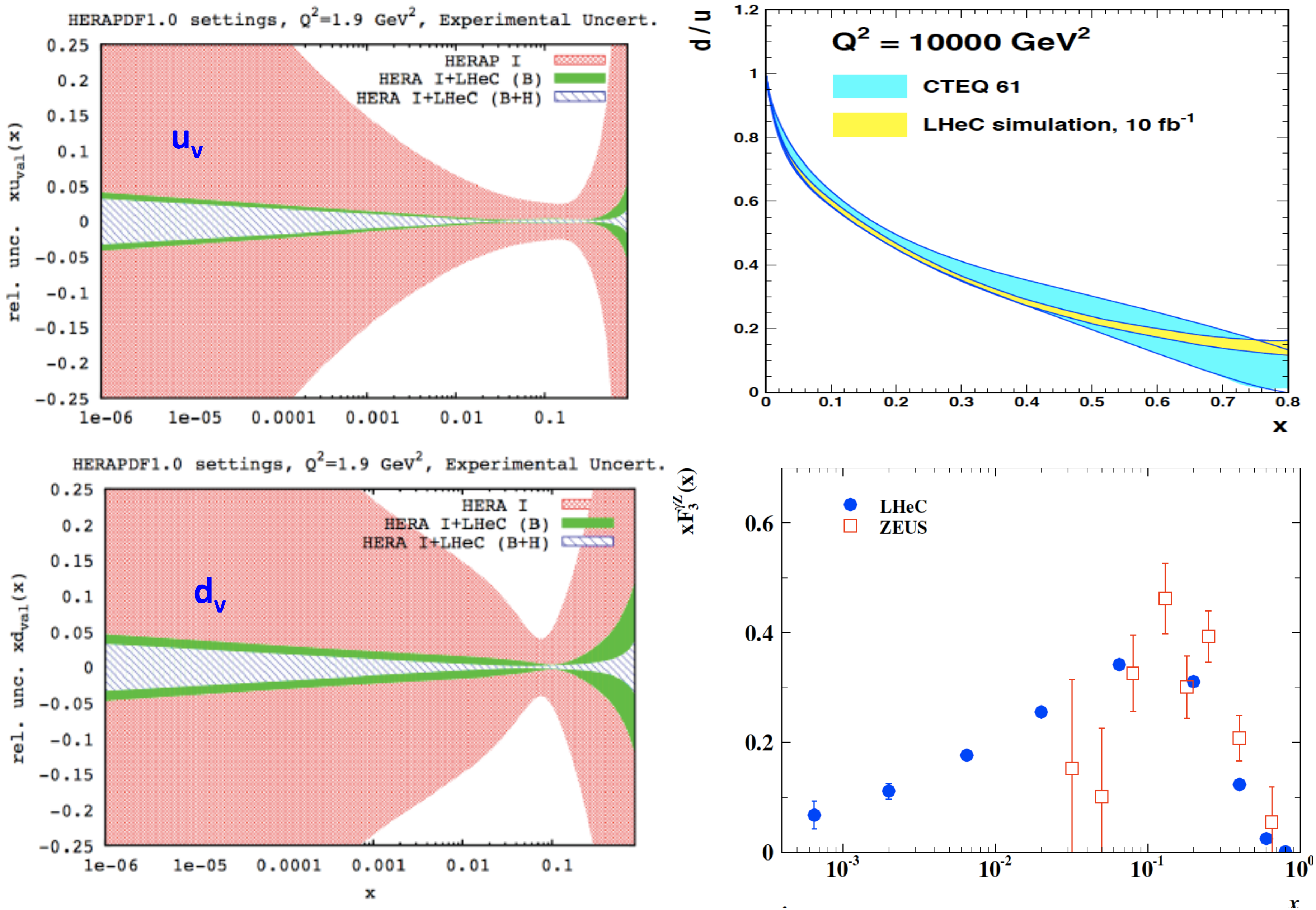


LHeC is a single top and anti-top quark factory

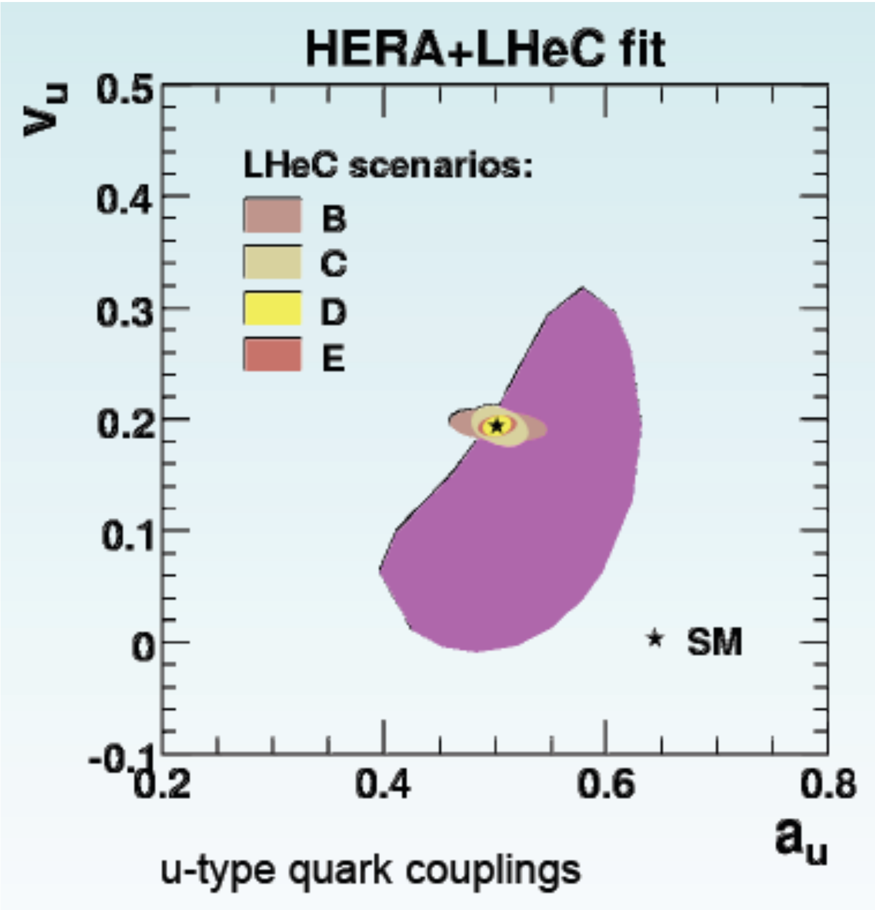
with a CC cross section of O(10)pb

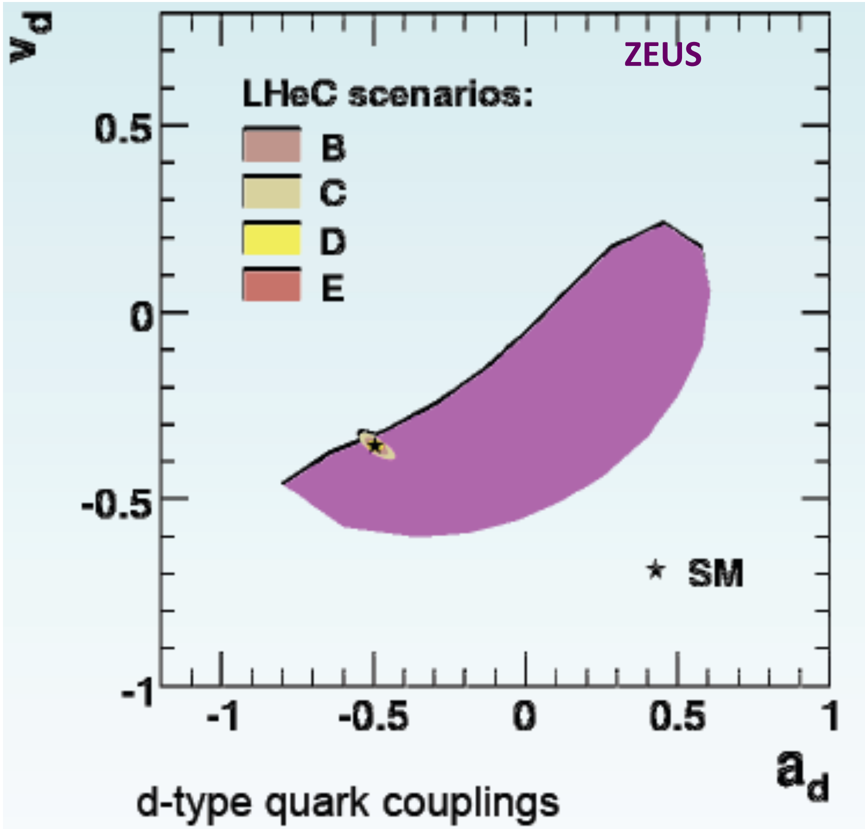
Study Q^2 evolution of top quark onset – 6 quark CFNS

Valence Quarks



Weak NC Couplings of Light Quarks

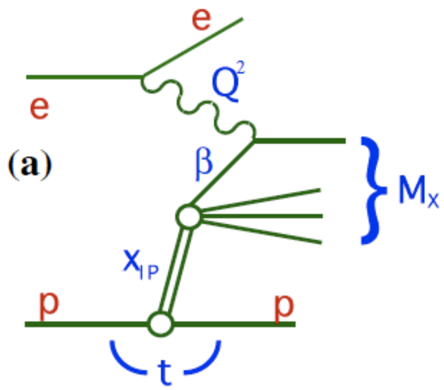




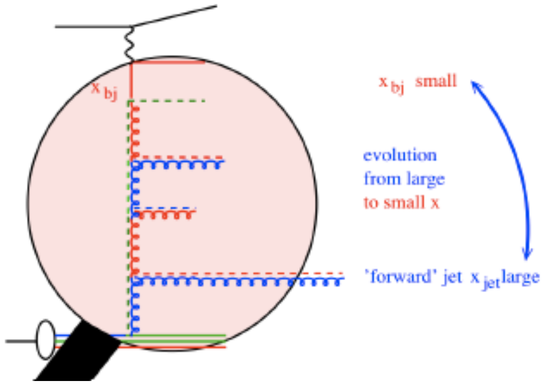
For H1, CDF, LEP cf Z.Zhang DIS10

Per cent accuracy of NC couplings
$\sin^2\Theta$ still to be estimated

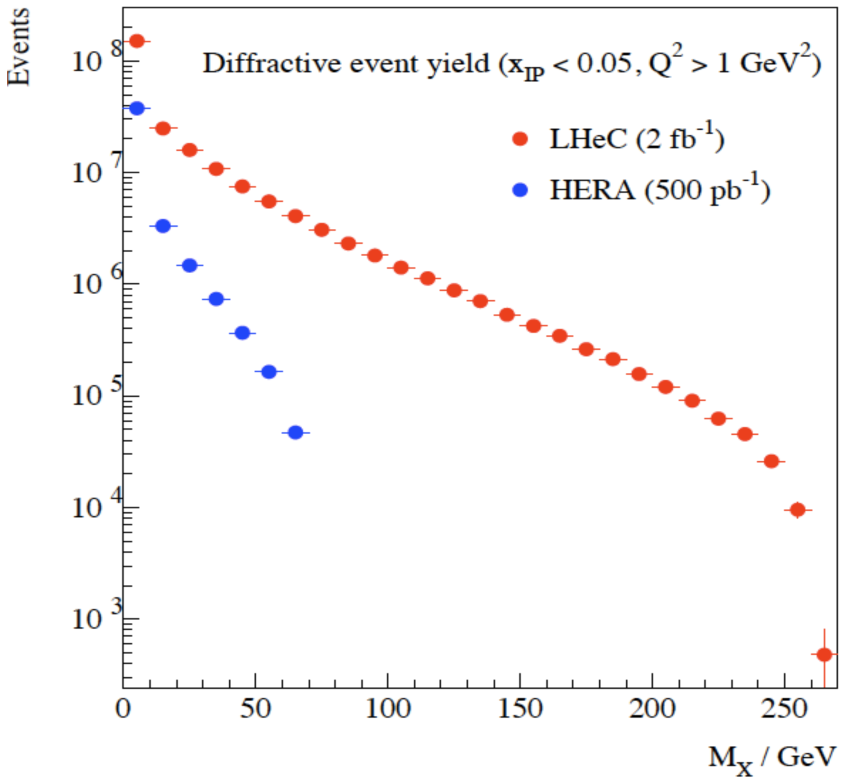
Quark-Gluon Dynamics - Diffraction and HFS (fwd jets)

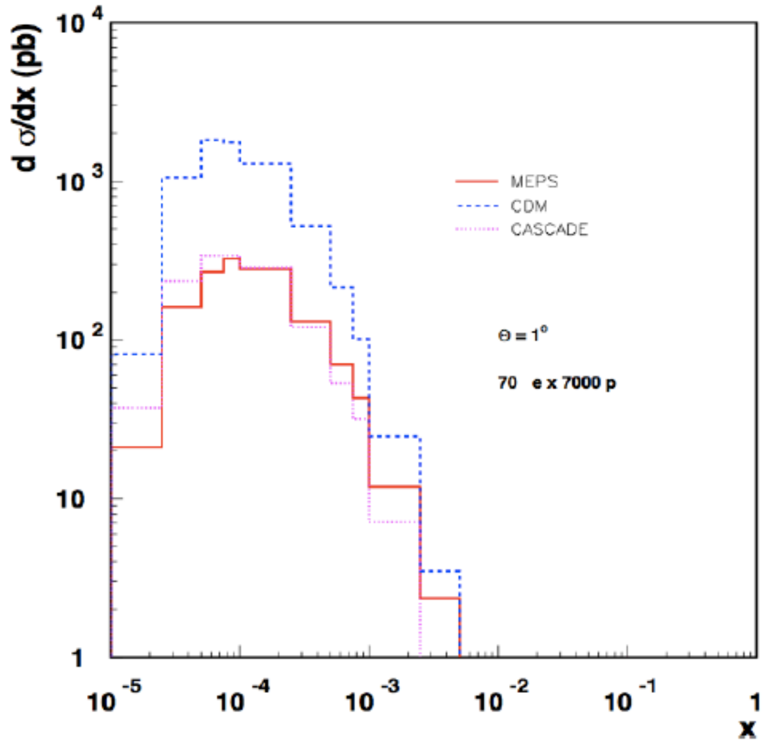


Production of high mass 1^- states



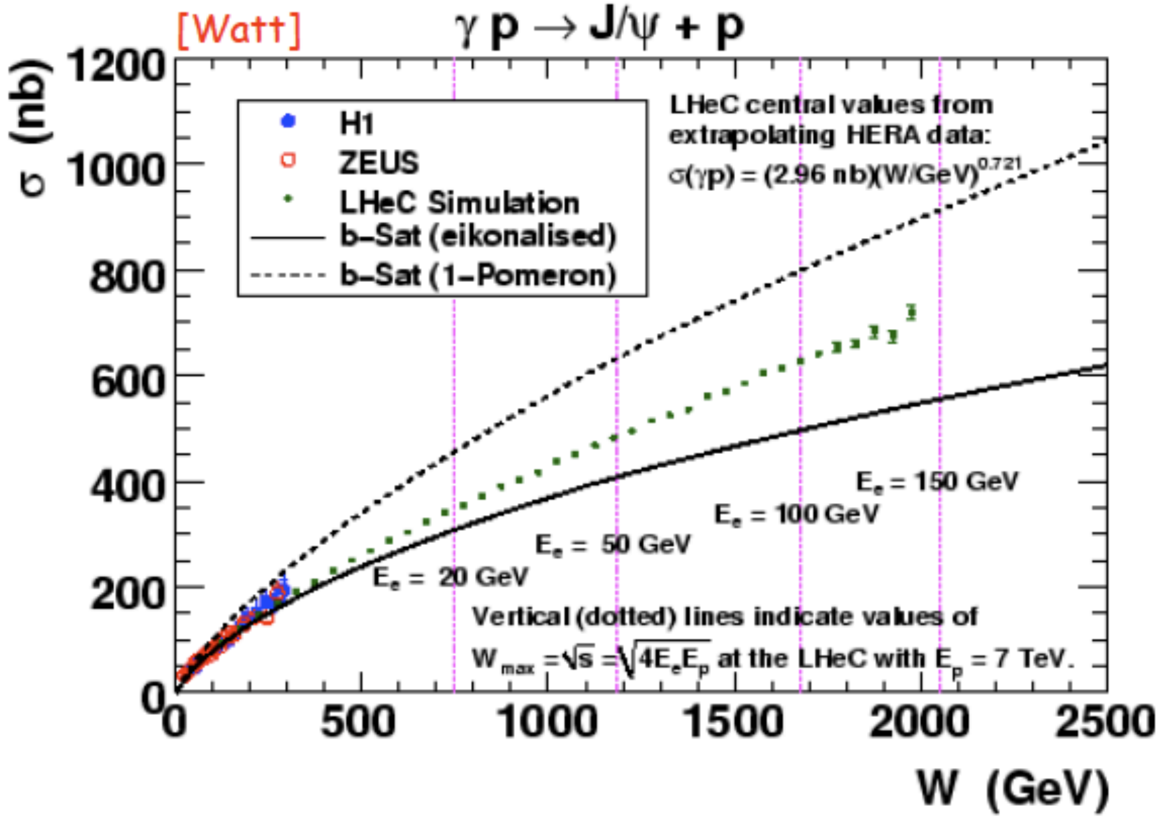
Understand multi-jet emission (unintegr. pdf's), tune MC's

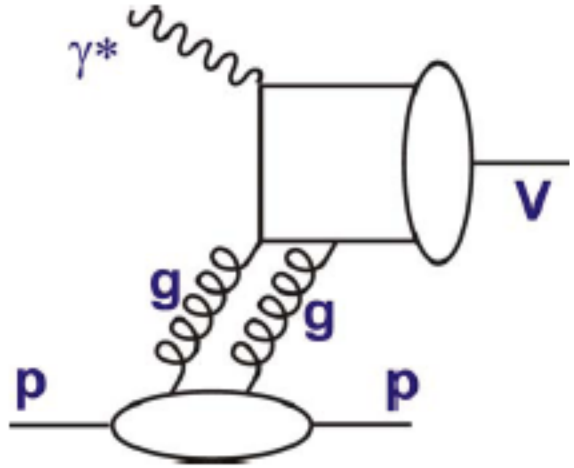




At HERA resolved γ effects mimic non-kt ordered emission

J/ψ – golden channel

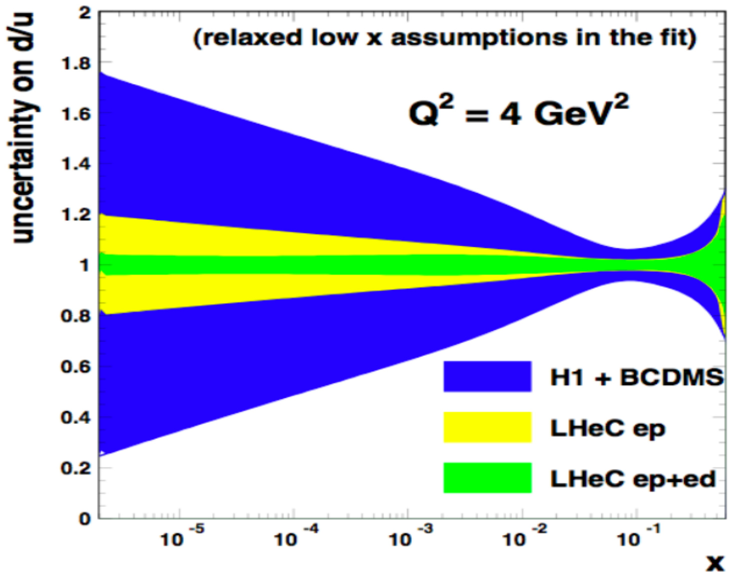




cf also:
A.Caldwell, H.Kowalski
PR C81:025203,2010
Investigation of nuclear
matter with J/Psi

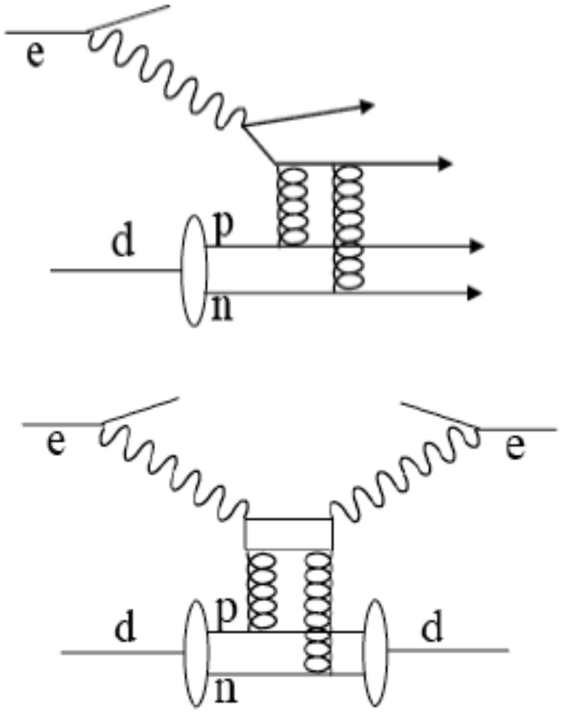
Neutron Structure (ed → eX)

d/u at low x from deuterons



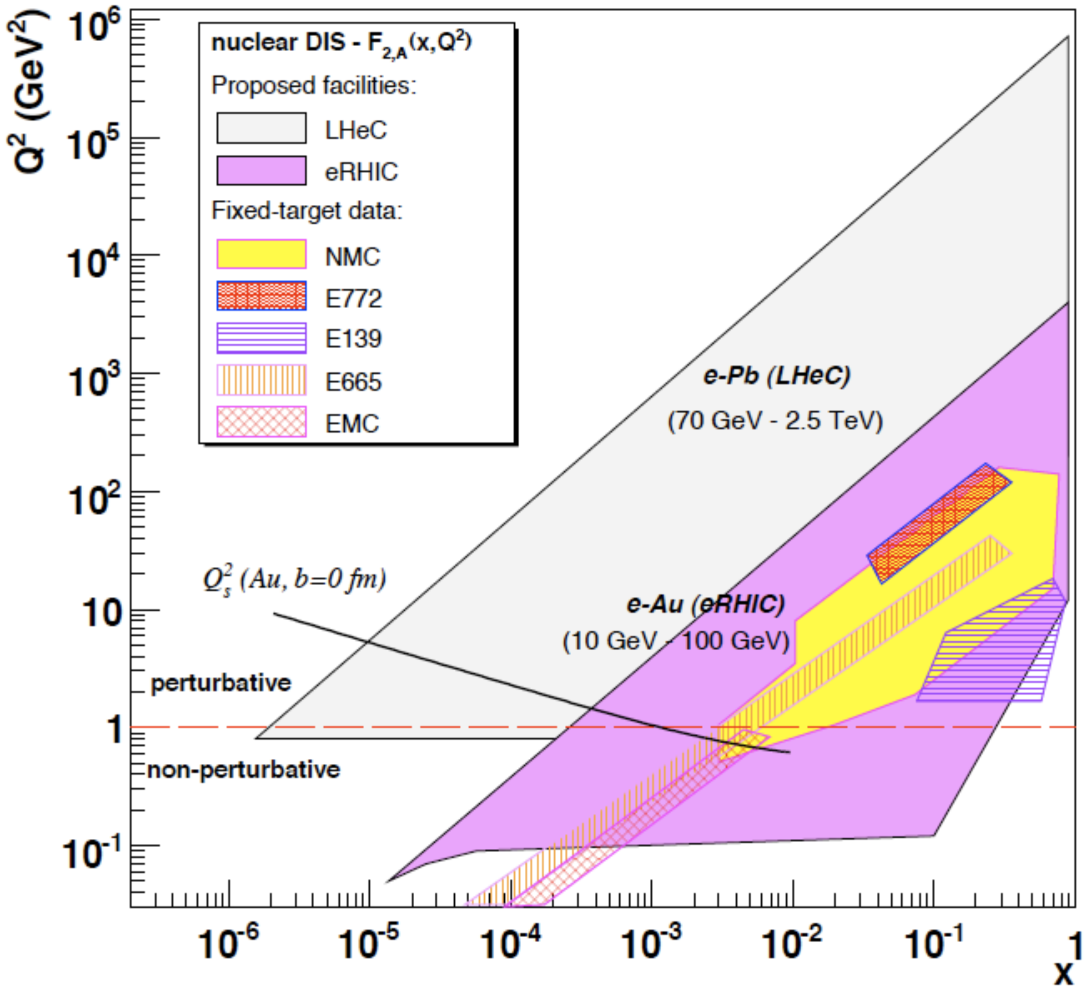
(13) There are five color-singlet combinations of the deuteron wavefunction in QCD, only one of which is the standard proton-neutron state. The "hidden color" [13] components will lead to high multiplicity final states in deep inelastic electron-deuteron scattering.

crucial constraint on evolution (S-NS), improved α_s



In eA at the collider, test Gribovs relation between shadowing and diffraction, control nuclear effects at low Bjorken x to high accuracy

Electron-Ion Scattering: eA → eX

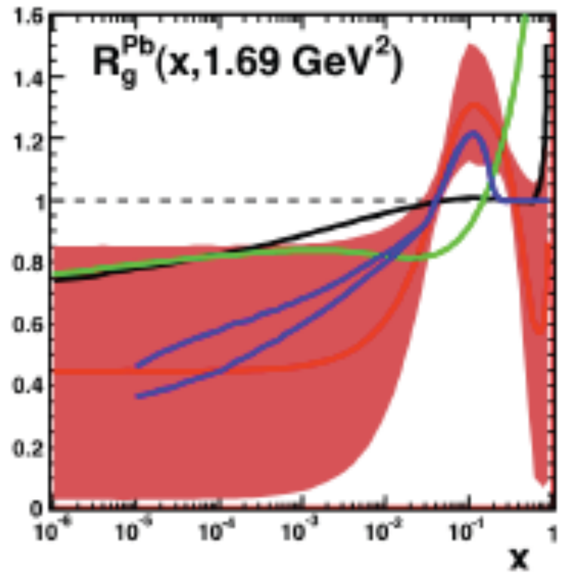


Extension of kinematic range by 3-4 orders of magnitude into saturation region **(with p and A)**

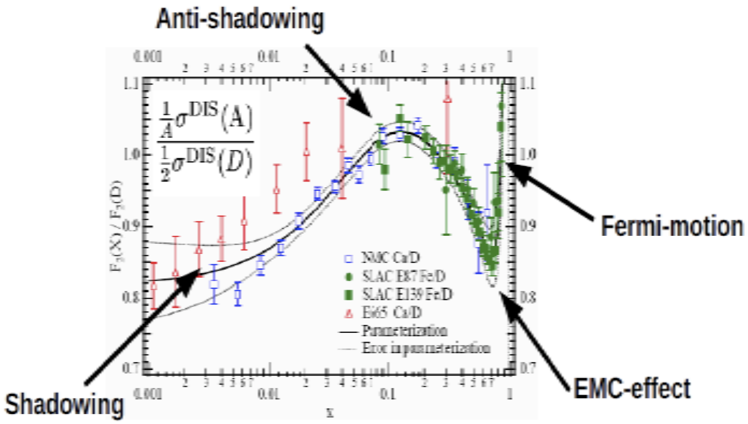
Like LHeC ep without HERA.. (e.g. heavy quarks in A)

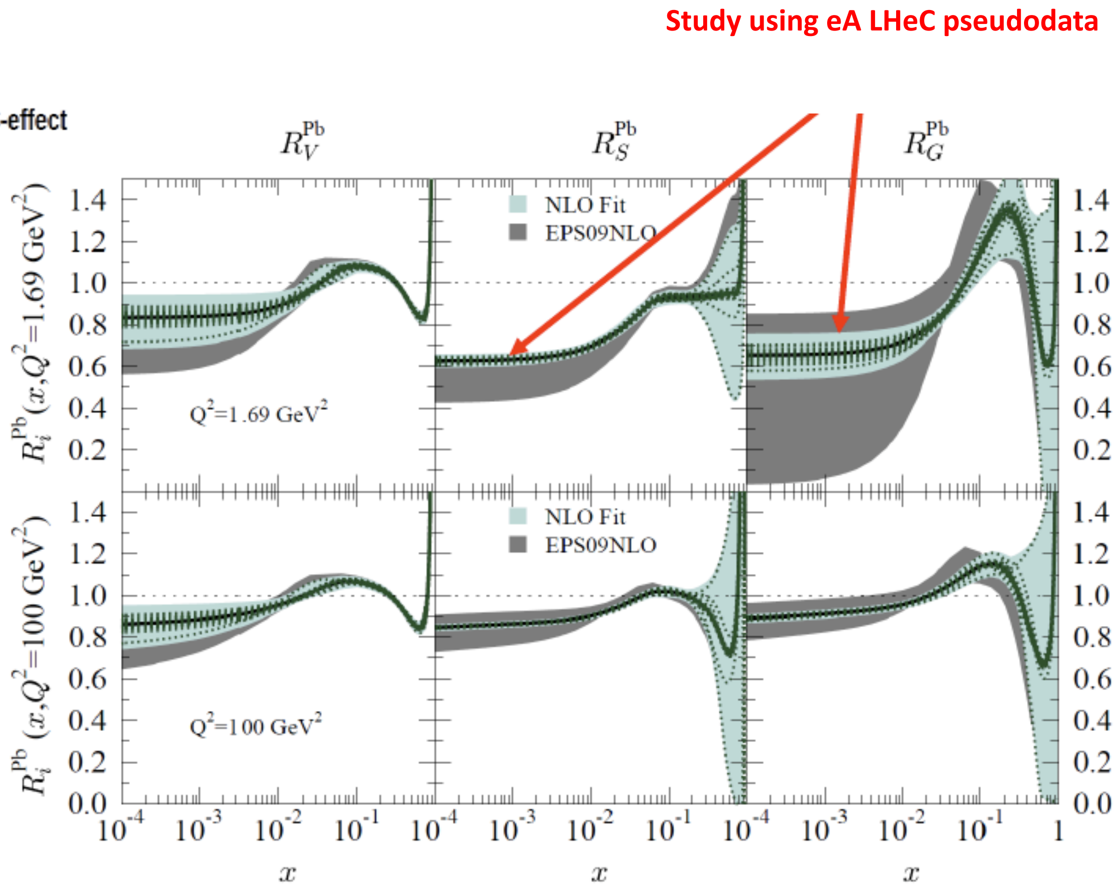
Qualitative change of behaviour

- **Bb limit of F_2**
- **Saturation of cross sections amplified with $A^{1/3}$ (A wider than p)**
- **Rise of diffraction to 50%**
- **hot spots of gluons or BDL?**



Nuclear Parton Distributions





K.Eskola, H.Paukkunen, C.Salgado, Divonne09

→**A complete determination of nPDFs in grossly extended range, into nonlinear regime**
certainly more diverse than in V,S,G terms

5. Detector

Acceptance and Calibration

High luminosity to reach high Q^2 and large x

10^{33} | $1\text{-}5\ 10^{31}$

Largest possible acceptance — Acceptance

1-179° | 7-177°

High resolution tracking — Modern Si

0.1 mrad | 0.2-1 mrad

Precision electromagnetic calorimetry — DA, kin peak, High statistics

0.1% | 0.2-0.5%

Precision hadronic calorimetry — may be possible track+calo, e/h

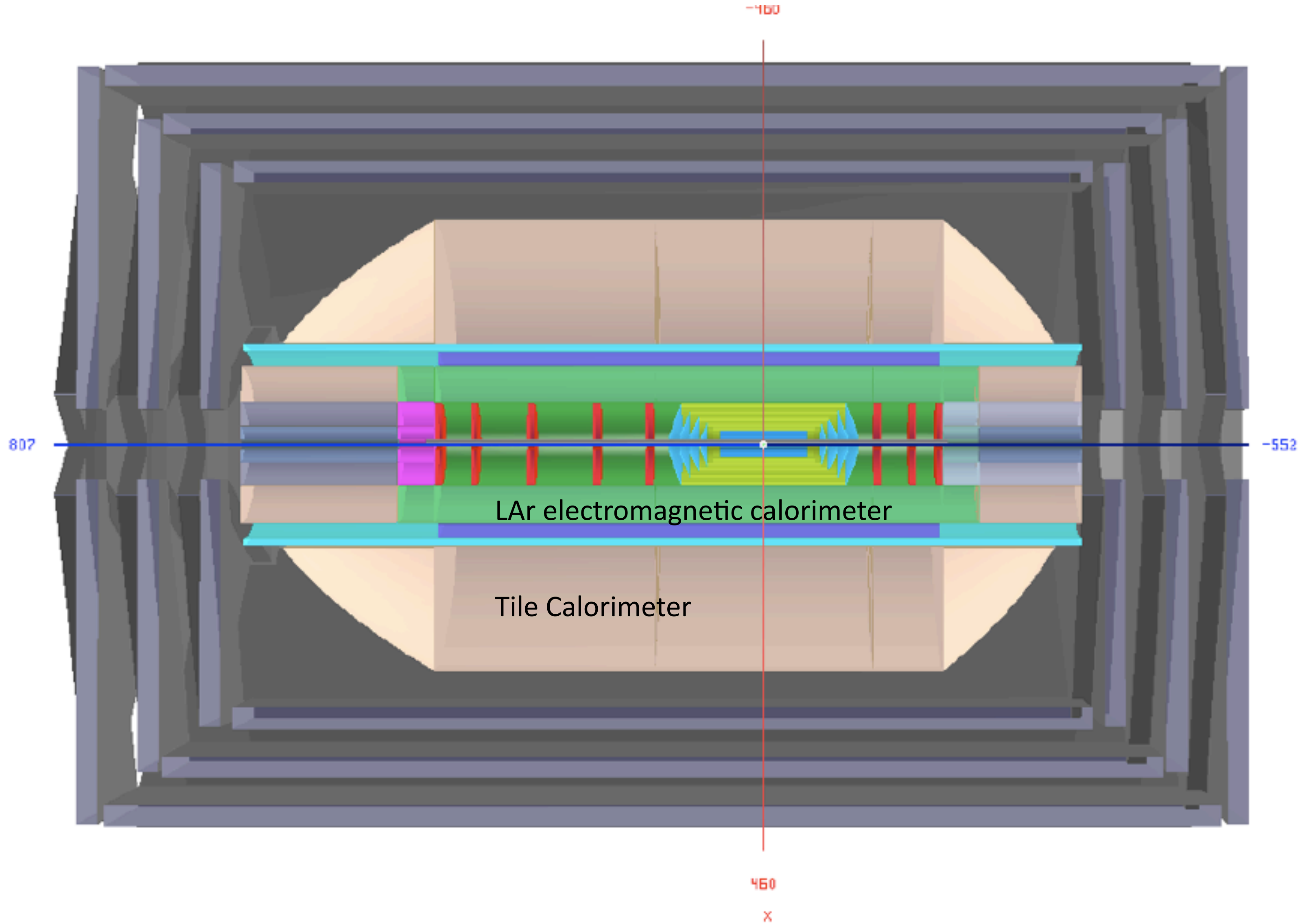
0.5% | 1%

High precision luminosity measurement — Lumi will be hard

0.5% | 1%

LHeC | H1

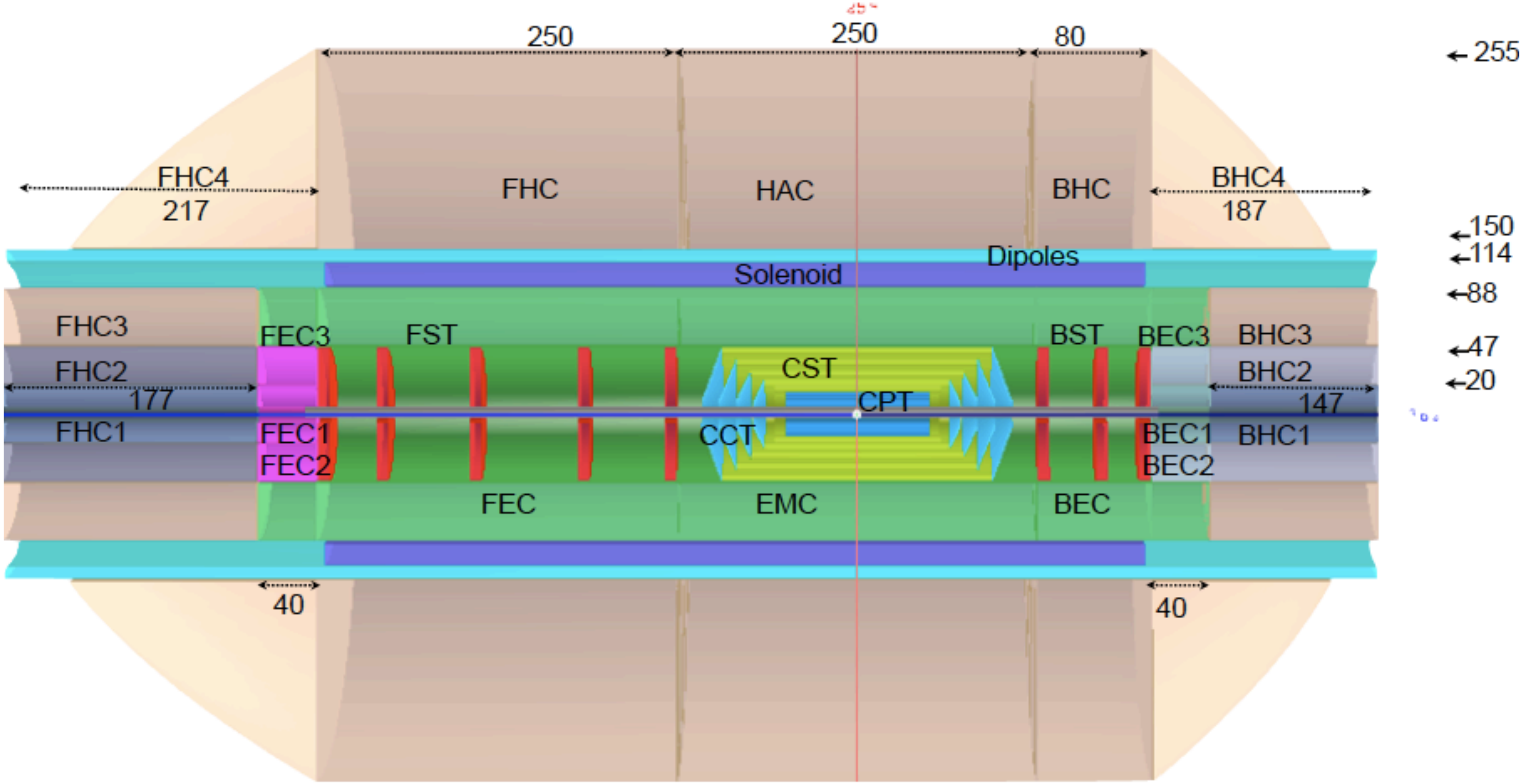
LHeC Detector Overview



Fwd/Bwd asymmetry in energy deposited and thus in geometry and technology [W/Si vs Pb/Sc..]
Present dimensions: LxD =13x9m^2 [CMS 21 x 15m^2 , ATLAS 45 x 25 m^2]

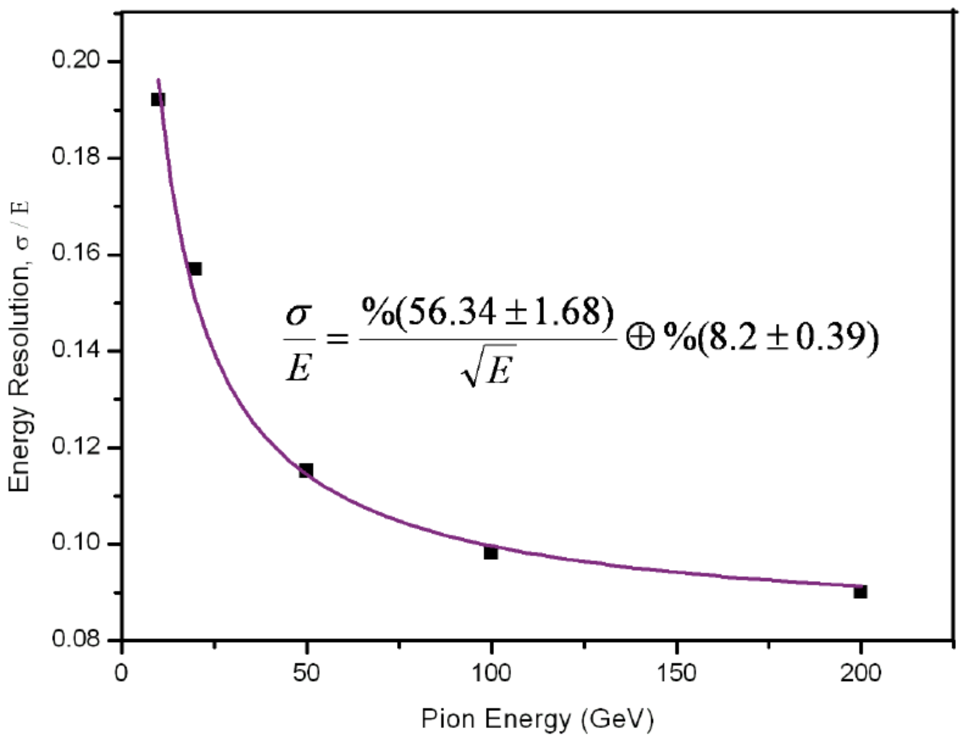
Tentative 21.3.11 **Taggers at -62m (e),100m (γ,LR), -22.4m (γ,RR), +100m (n), +420m (p)**

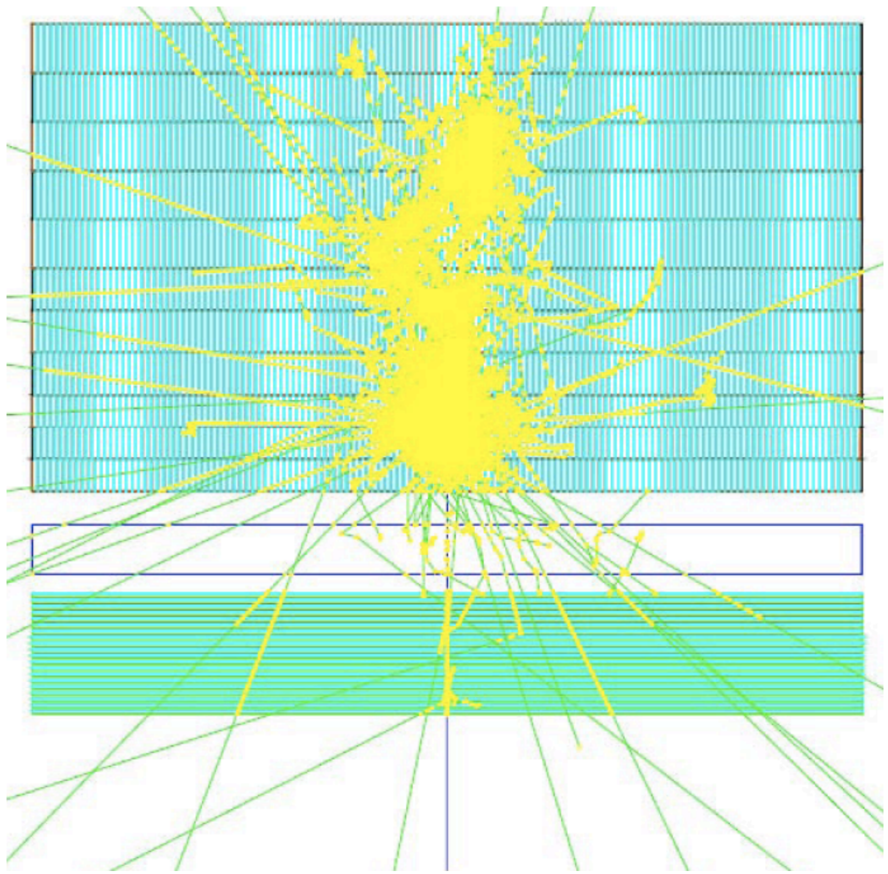
LHeC Detector Overview



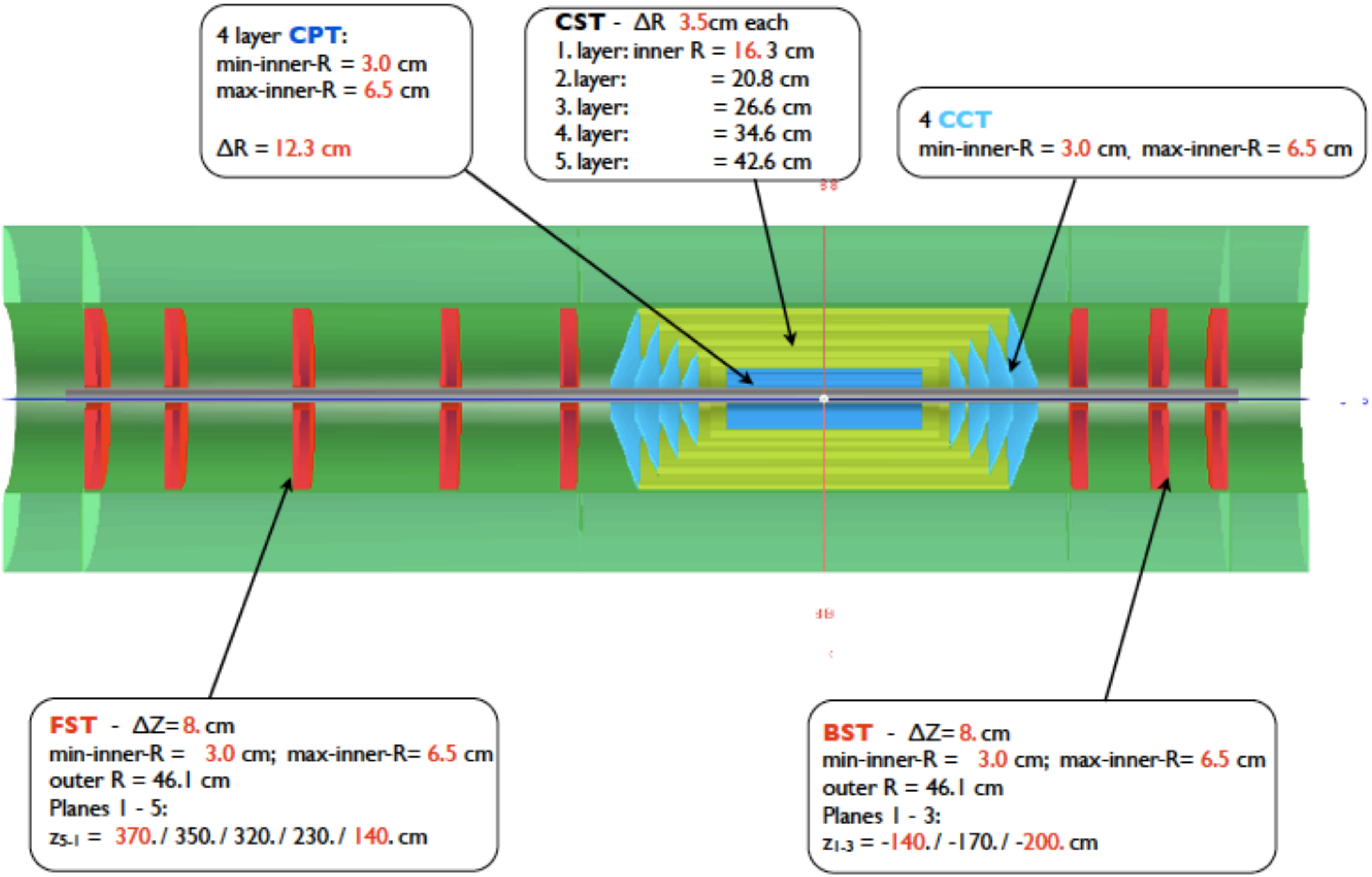
Fwd/Bwd asymmetry in energy deposited and thus in geometry and technology [W/Si vs Pb/Sc..]
Present dimensions: LxD =13x9m^2 [CMS 21 x 15m^2 , ATLAS 45 x 25 m^2]
Tentative 21.3.11 **Taggers at -62m (e),100m (γ,LR), -22.4m (γ,RR), +100m (n), +420m (p)**

Detector Performance (HCAL)



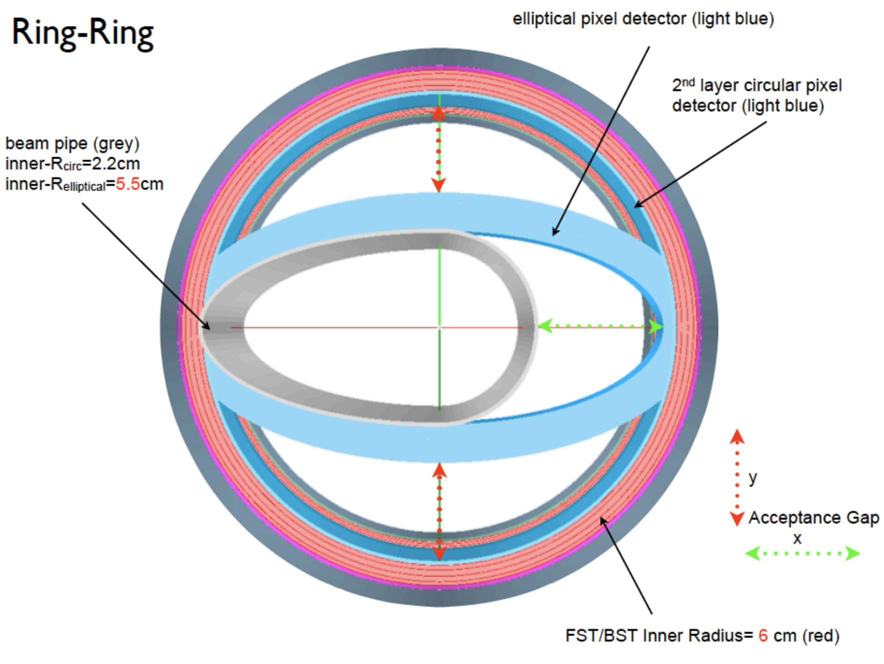


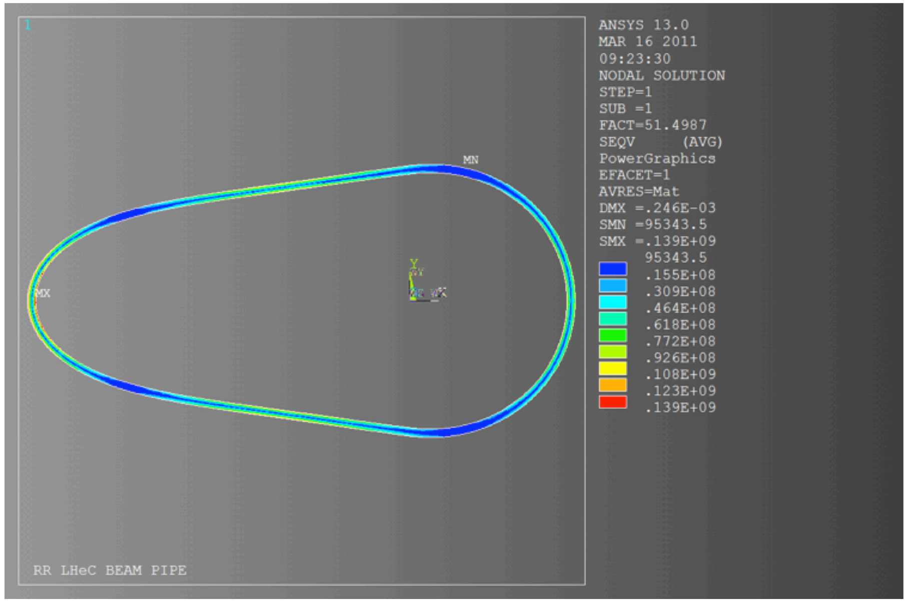
Track Detector Concept



Beam Pipe

Ring-Ring





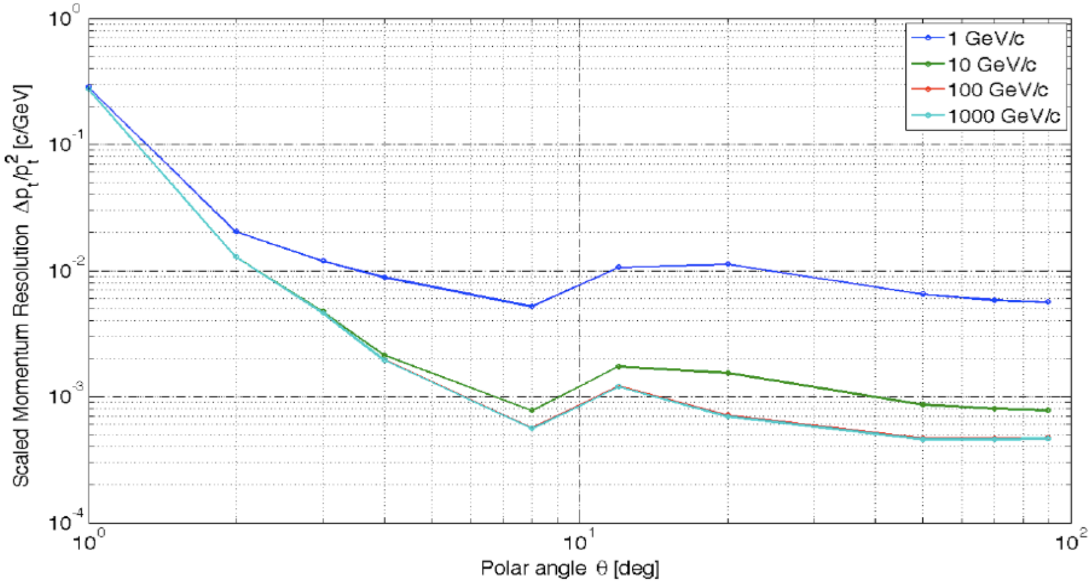
Beam pipe design – work in progress

LR more challenging than RR due to extended synchrotron radiation fan

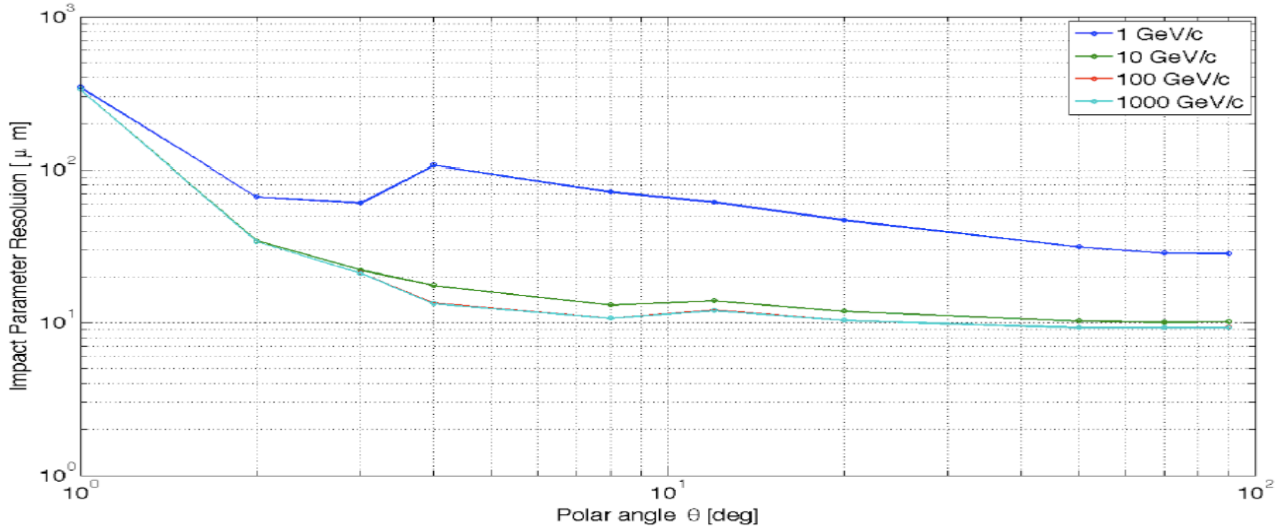
R. Veness et al CERN

Tentative 21.3.11

Detector Performance (Tracker)



transverse momentum
$\Delta p_t/p^2_t \rightarrow 6\ 10^{-4}\ GeV^{-1}$



transverse
impact parameter
→ 10μm

6. Final Remarks

LHC 2010-2012

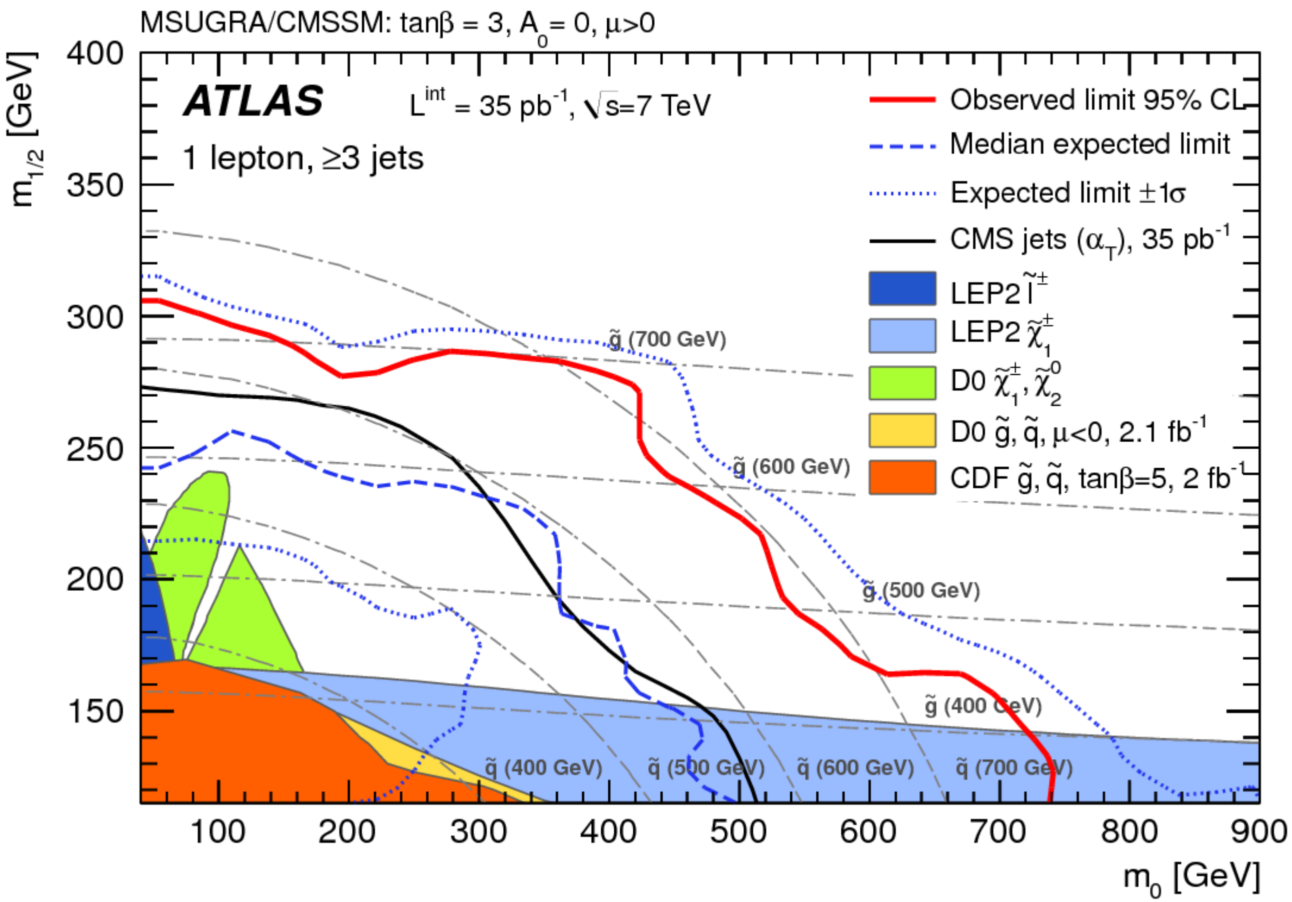
- Great new *limits*, beyond Tevatron on:
  - q*, Quark substructure
  - New massive particles
  - SUSY
  - W', Z', lepto-quarks, b', stable heavy particles, stopped gluinos

- $m_{W'}$>1.36TeV and $M_{Z'}$>1.14TeV

2011 should probe to ~2.5TeV

Extra dimensions

B. Murray Chamonix 1/2011



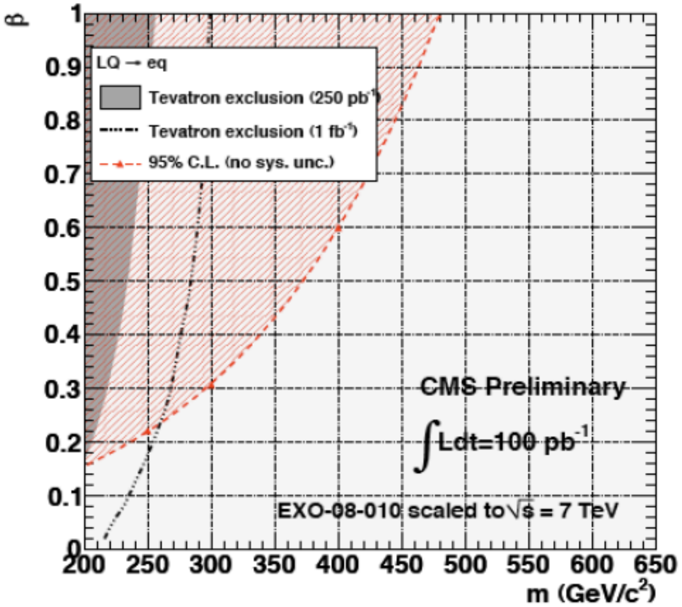
If m_{squark}=m_{gluino} exclude < 700 GeV

No SUSY in 0,1,2 lepton searches so far..

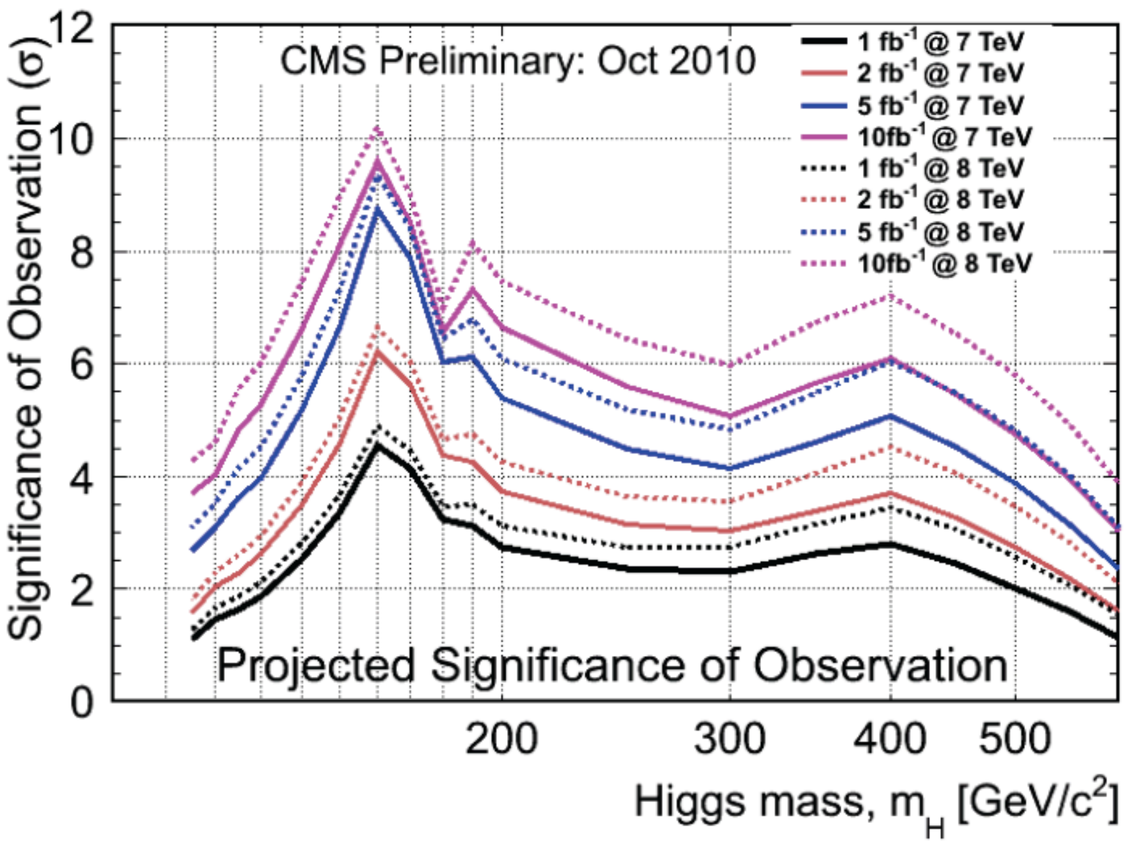
M.D'Onofrio ATLAS
CERN seminar 8.3.11

LHC 2010-2012

Leptoquarks



Brown-Englert-Higgs-Kibble..

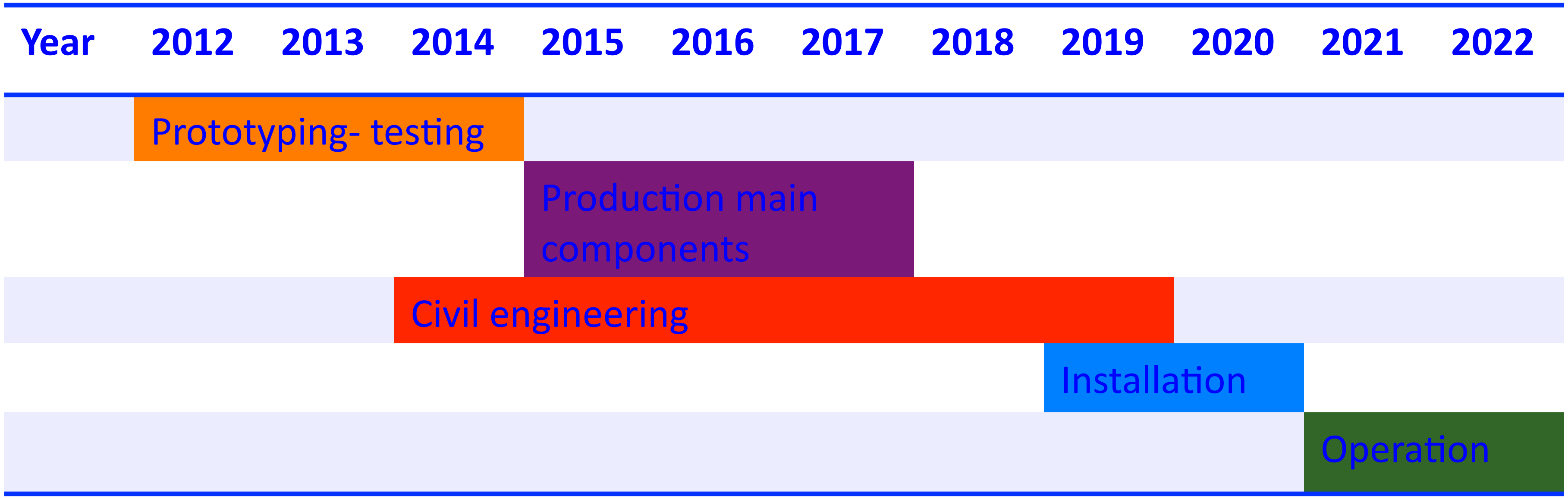


Can expect to settle the SM Higgs question by latest 2012 – no major decision will be taken before

G.Rolandi Paris 12/2010

LHeC_DRAFT_Timeline

Based on LHC constraints, ep/A programme, series production, civil engineering etc



Variations on timeline:

- ➔ production of main components can overlap with civil engineering
- ➔ Installation can overlap with civil engineering
- ➔ Additional constraints from LHC operation not considered here
- ➔ in any variation, a start by 2020 requires launch of prototyping of key components by 2012

[shown to ECFA 11/2010: mandate to 2012]

NuPECC – Roadmap 2010: New Large-Scale Facilities

			201 0					201 5					202 0					202 5	
FAIR	PANDA	R&D	Construction			Commissioning					Exploitation								
	CBM	R&D	Construction			Commissioning					Exploitation			SIS300					
	NuSTAR	R&D	Construction			Commissioning					Exploit.		NESR FLAIR						
	PAX/ENC	Design Study		R&D	Tests			Construction/Commissioning								Collider			
SPIRAL2		R&D	Constr./Commission.				Exploitation							150 MeV/u Post-accelerator					
HIE-ISOLDE			Constr./Commission.				Exploitation								Injector Upgrade				
SPES				Constr./Commission.				Exploitation											
EURISOL		Design Study		R&D	Preparatory Phase / Site Decision					Engineering Study			Construction						
LHeC		Design Study		R&D			Engineering Study				Construction/Commissioning								

G. Rosner, NuPECC Chair, Madrid 5/10

Organisation + Status for the CDR

Scientific Advisory Committee

Guido Altarelli (Rome)
Sergio Bertolucci (CERN)
Stan Brodsky (SLAC)
Allen Caldwell -chair (MPI Munich)
Swapan Chattopadhyay (Cockcroft)
John Dainton (Liverpool)
John Ellis (CERN)
Jos Engelen (CERN)
Joel Feltesse (Saclay)
Lev Lipatov (St.Petersburg)
Roland Garoby (CERN)
Roland Horisberger (PSI)
Young-Kee Kim (Fermilab)
Aharon Levy (Tel Aviv)
Karlheinz Meier (Heidelberg)
Richard Milner (Bates)
Joachim Mnich (DESY)
Steven Myers, (CERN)
Tatsuya Nakada (Lausanne, ECFA)
Guenther Rosner (Glasgow, NuPECC)
Alexander Skrinsky (Novosibirsk)
Anthony Thomas (Jlab)
Steven Vigdor (BNL)
Frank Wilczek (MIT)
Ferdinand Willeke (BNL)

Steering Committee

Oliver Bruening (CERN)
John Dainton (Cockcroft)
Albert DeRoeck (CERN)
Stefano Forte (Milano)
Max Klein - chair (Liverpool)
Paul Laycock (secretary) (L'pool)
Paul Newman (Birmingham)
Emmanuelle Perez (CERN)
Wesley Smith (Wisconsin)
Bernd Surrow (MIT)
Katsuo Tokushuku (KEK)
Urs Wiedemann (CERN)
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 (U Zurich),
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)

Today: writing … for the

Referees of CERN

QCD/electroweak:
Guido Altarelli, Alan Martin, Vladimir Chekelyan

BSM:
Michelangelo Mangano, Gian Giudice, Cristinel Diaconu

eA/low x
Al Mueller, Raju Venugopalan, Michele Arneodo

Detector
Philipp Bloch, Roland Horisberger

Interaction Region Design
Daniel Pitzl, Mike Sullivan

Ring-Ring Design
Kurt Huebner, Sasha Skrinsky, Ferdinand Willeke

Linac-Ring Design
Reinhard Brinkmann, Andy Wolski, Kaoru Yokoya

Energy Recovery
Georg Hoffstatter, Ilan Ben Zvi

Magnets
Neil Marx, Martin Wilson

Installation and Infrastructure
Sylvain Weisz

Expect CDR in spring 2011

Summary

The LHeC has the potential to become an exciting 5th big experiment at the LHC

It needs a new polarised electron/positron beam, and two options are under consideration, a 'Linac' and a ring, with a 'linear' injector.., both promising to deliver O(50) fb^{-1} thus reaching Q^2 = 1 TeV^2, high x = 0.8 and $x=10^{-6}$ in DIS..

The LHeC physics programme is broad, unique and complementary to the LHC

The CDR will be open to expressions of interest in pursuing the project further.

Steps in 2010: DIS11, CDR, EPS, Accelerator Workshop to decide(?) LR-R

…. Adapt organisation for international accelerator project and for LHeC Collaboration in order to arrive in time for an exploitation for 10 years, about, assuming the LHC lives until ~2030.

Very much depends on the findings in the 2011/2012 LHC run and on us.

Envisage update on LHeC physics programme by spring 2012 (DIS12 ??)

THANKS to the whole study group on LHeC : **http://cern.ch/lhec**

LHeC

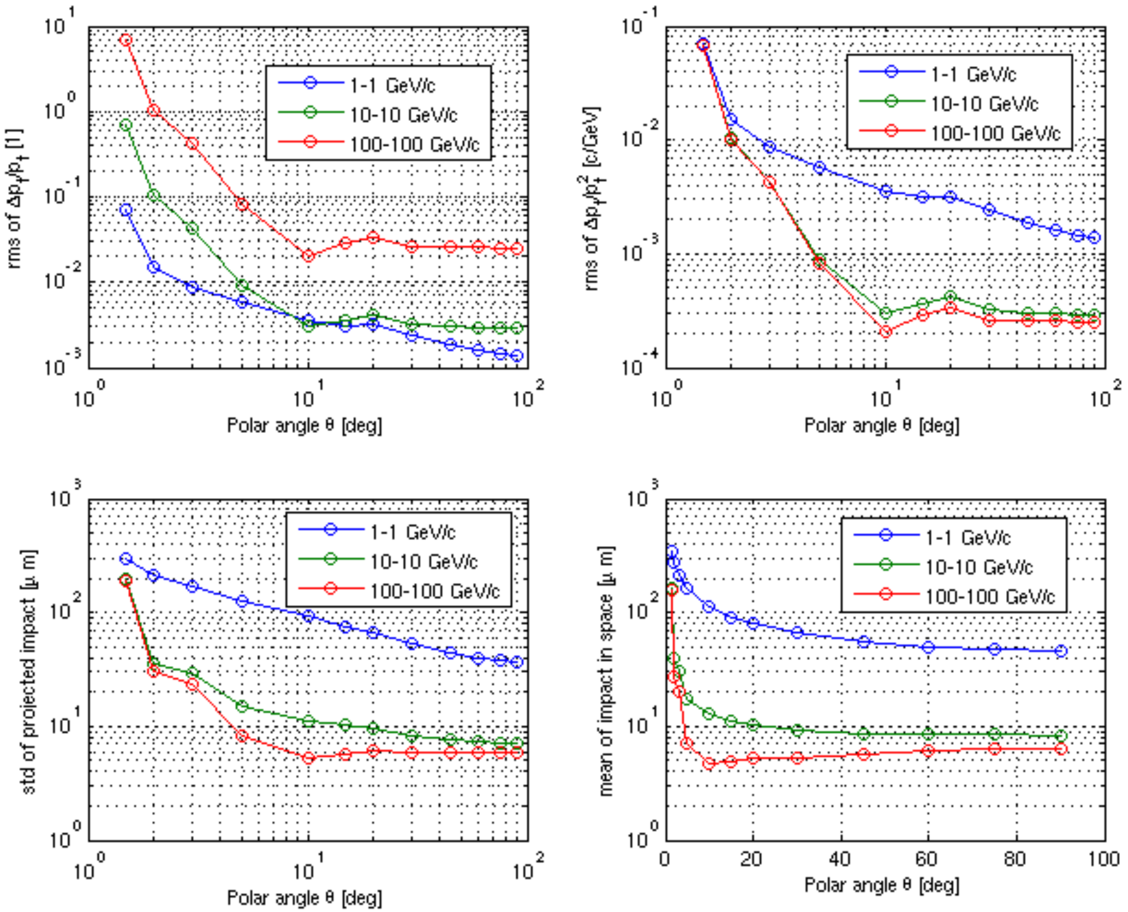
backup

Calorimeter - Resolutions and Scales

approximate angular range / degrees	backward 179 - 135	barrel 135 -45	forward 45-1
electron energy/GeV	3-100	10-400	50-5000
x_e	$10^{-7} - 1$	$10^{-4} - 1$	$10^{-2} - 1$
elm scale calibration in %	0.1	0.2	0.5
elm energy resolution $\delta E/E$ in $\% \cdot \sqrt{E/GeV}$	10	15	15
hadronic final state energy/GeV	3-100	3-200	3-5000
x_h	$10^{-7} - 10^{-3}$	$10^{-5} - 10^{-2}$	$10^{-4} - 1$
hadronic scale calibration in %	2	1	1
hadronic energy resolution in $\% \cdot \sqrt{E/GeV}$	60	50	40

Table 6.1: Summary of calorimeter kinematics and requirements for the default design energies of $60 \times 7000\,\mathrm{GeV}^2$, see text. The forward (backward) calorimetry has to extend to $1^\circ(179^\circ)$.

Momentum Resolution



$$H1:CJC:\frac{\delta p_T}{p_T^2}:=3\cdot 10^{-3}GeV^{-1}$$

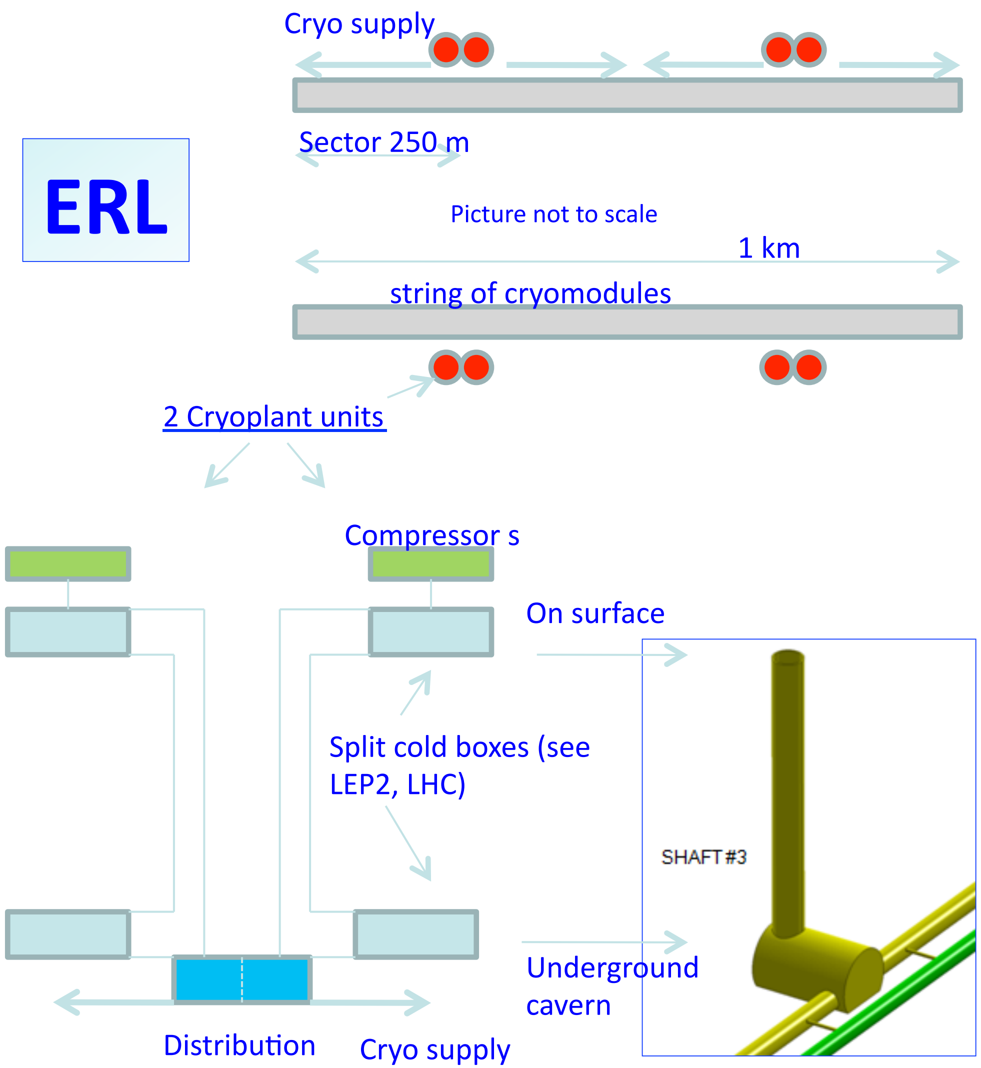
$$B=1.2T,\Delta\approx 200\mu m,N\approx 20:L=1m$$

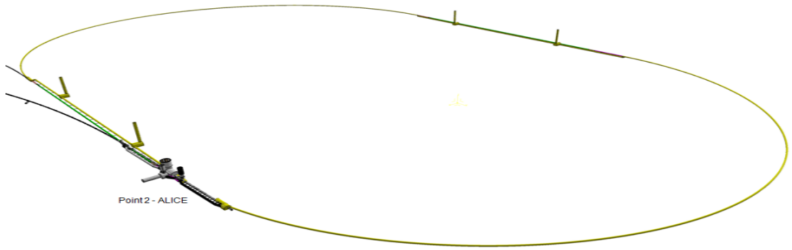
$$\frac{\delta p_T}{p_T^2}=\frac{\Delta}{0.3BL^2}\cdot\sqrt{\frac{720}{N+4}}=1.7\cdot 10^{-4}GeV^{-1}$$

$$B=3.5T,\Delta\approx 10\mu m,N\approx 2*5+3:L=0.6m$$

Linac-Ring Cryogenics

ERL





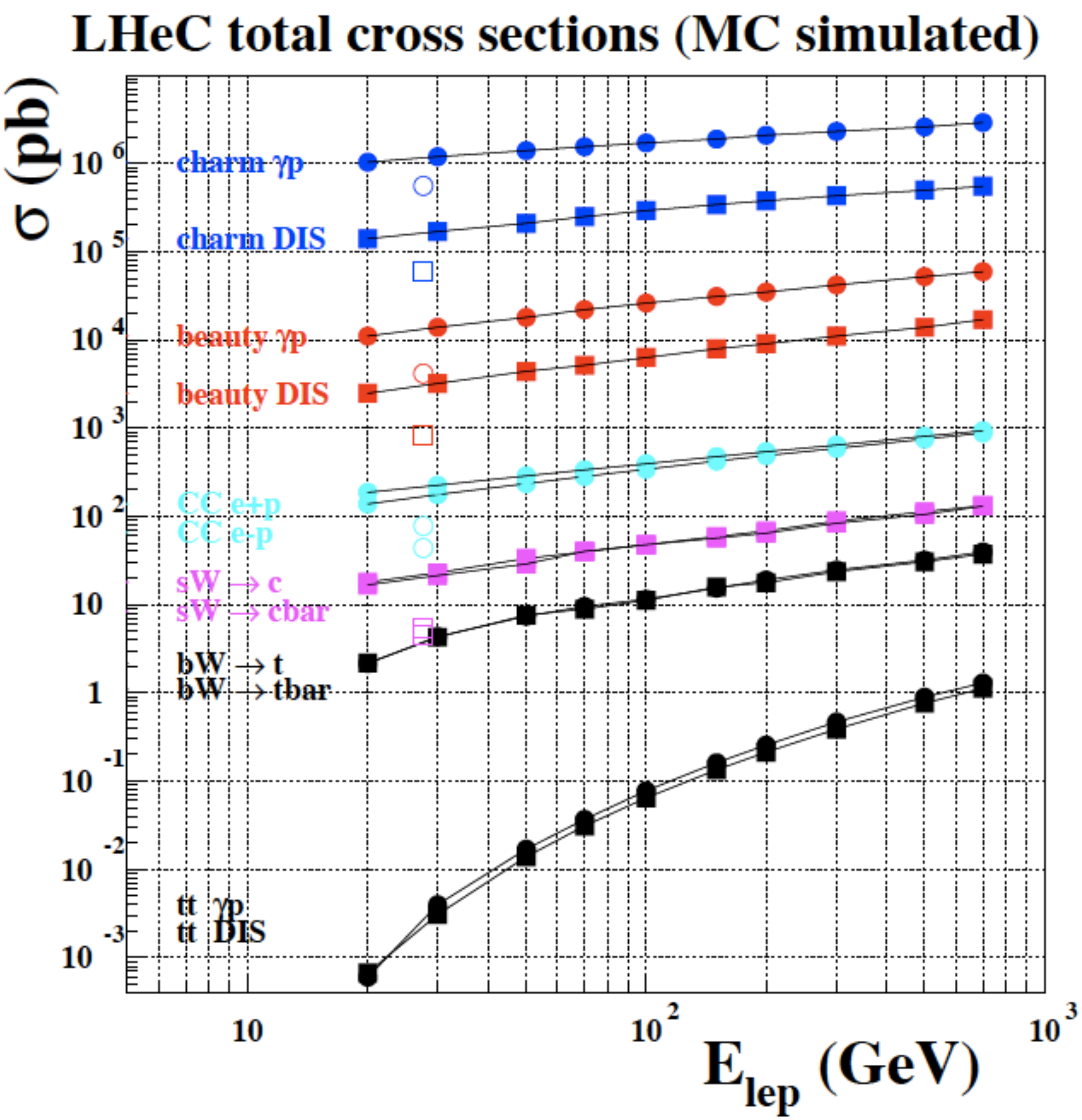
CW operation, 18 MV/m
2 K thermal load: 37 W/m (for active length)
2 K total therma l load: 42 kW @ 2 K
Electric power: 30 MW
(with a COP of 700)

Cooling requirements dominated by dynamic losses at 2 K
(other loads neglected here for simplicity)

Lay-out is based on LHC cryogenic principles with split cold boxes (surface cold box and underground cold box with cold compressors).

Refrigerator units of approx. 5 kW @ 2 K assumed. To be designed. Technology and experience: LHC, CEBAF (JLAB).

Heavy Flavours at the LHeC



HERA - 'an unfinished business'

Low x: DGLAP holds although ln1/x is large
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
- heavy quarks

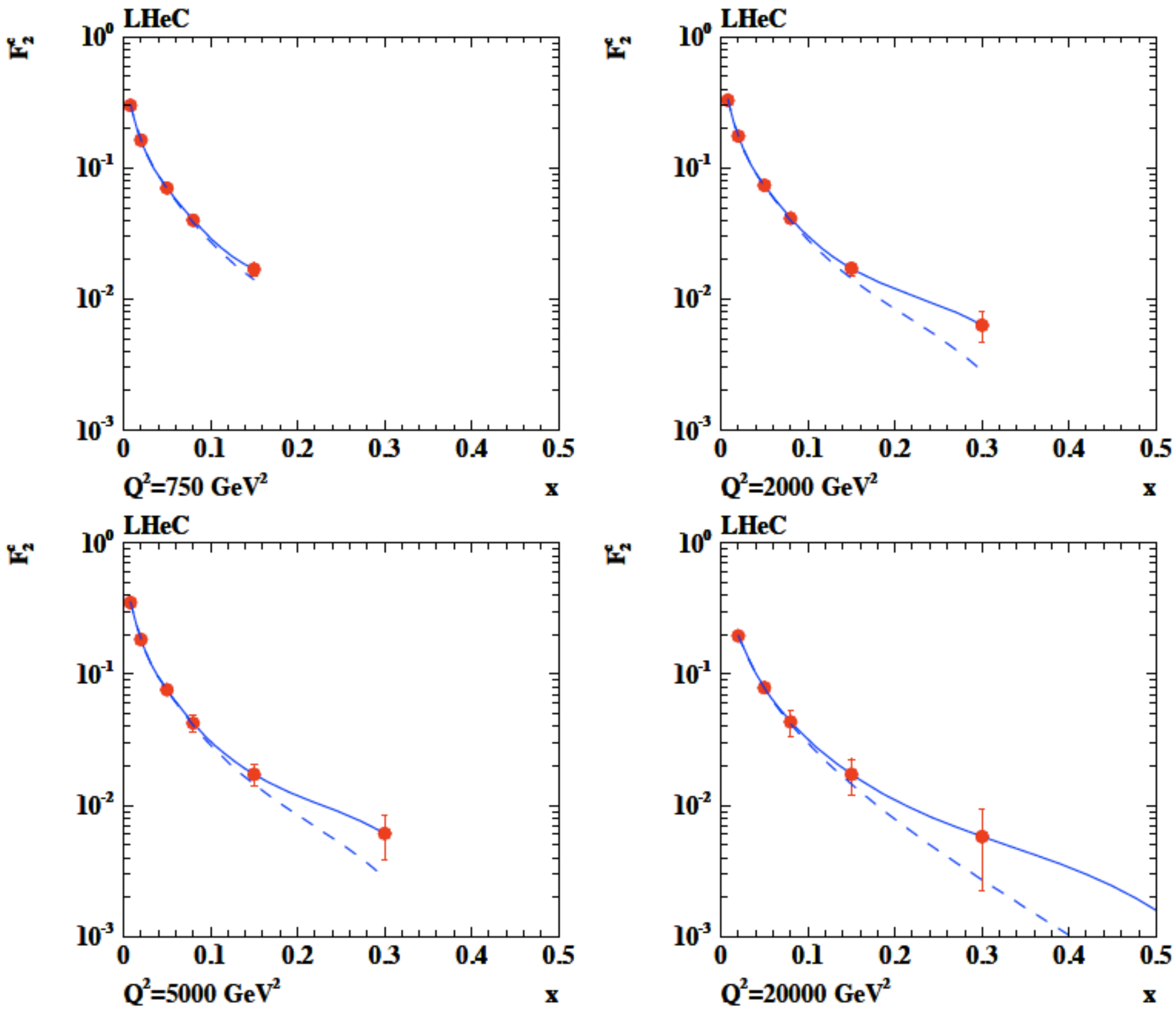
Instantons not observed

Odderons not found

…

Lepton-quark states not observed

Intrinsic Charm ??



CTEQ6 with (solid) and w/o (dashed) intrinsic charm

To access the high x region one needs to tag charm in fwd direction and lower the proton beam energy and get high luminosity.

LR Parameters

Table 9.2: IP beam parameters

	protons	electrons
beam energy [GeV]	7000	60
Lorentz factor γ	7460	117400
normalizwed emittance $\gamma\epsilon_{x,y}$ [μm]	3.75	50
geometric emittance $\epsilon_{x,y}$ [nm]	0.,40	0.43
a IP beta function $\beta^*_{x,y}$ [m]	0.10	0.12
rms IP beam size $\sigma^*_{x,y}$ [μm]	7	7
initial rms IP beam divergence $\sigma^*_{x',y'}$ [μrad]	70	58
beam current [mA]	$\geq$430	6.4
bunch spacing [ns]	25 or 50	(25 or) 50
bunch population [ns]	1.7×10^{11}	(1 or) 2×10^9

6. Final Remarks