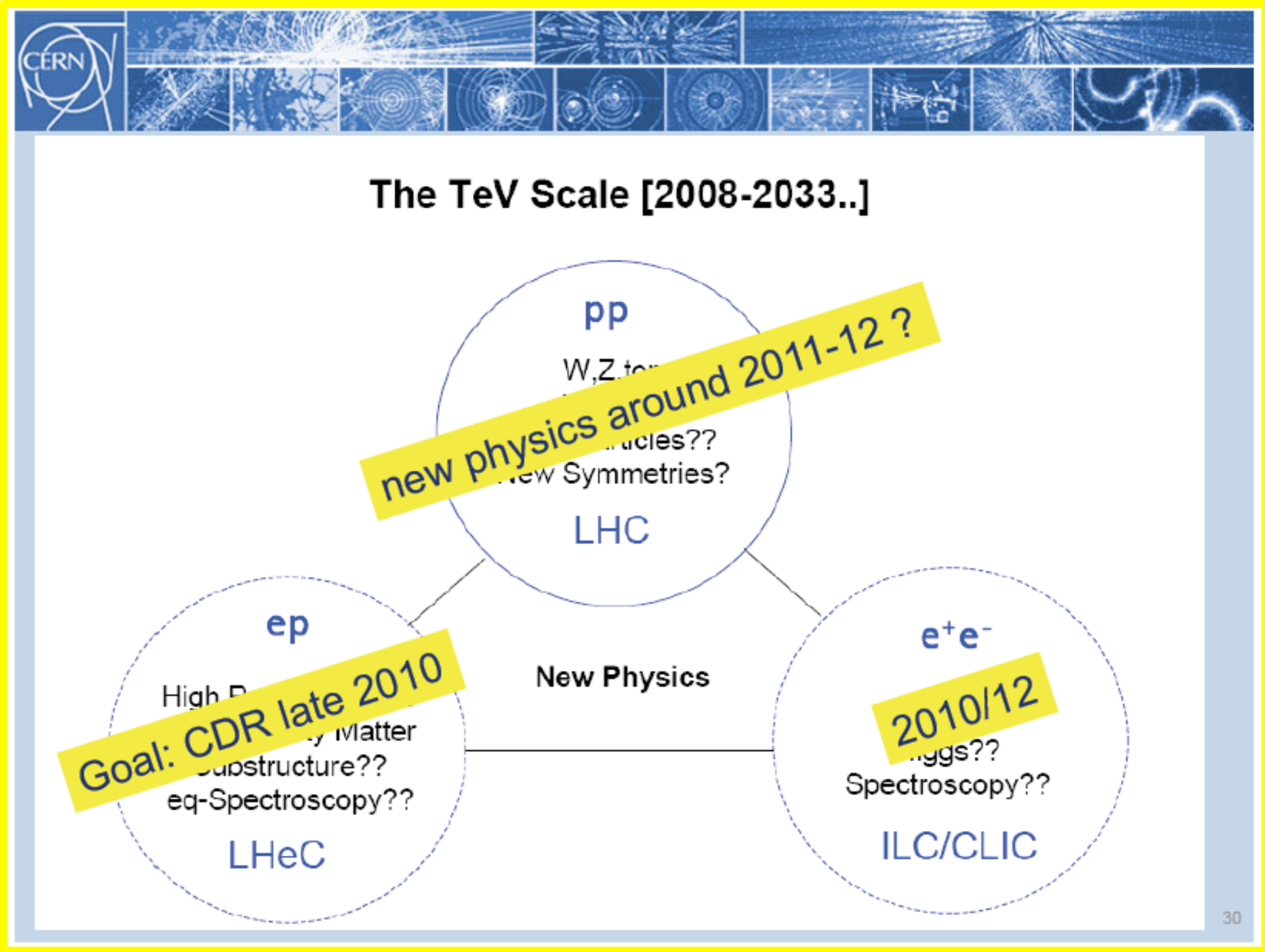
Report on the Design Concepts for the LHeC

Physics
Accelerator
Components
Detector
Conclusion

Max Klein
for the LHeC Study Group

ECFA, CERN, 26.11.10

http://cern.ch/lhec



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

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

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

LINAC Ring

Pulsed, **60 GeV**: ~10^{32}
High luminosity:
Energy recovery: $P=P_0/(1-\eta)$
$\beta^*=0.1$m
[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)

A 60 GeV Ring with 10 GeV LINAC Injector

Lattice Design dominated by geometry:

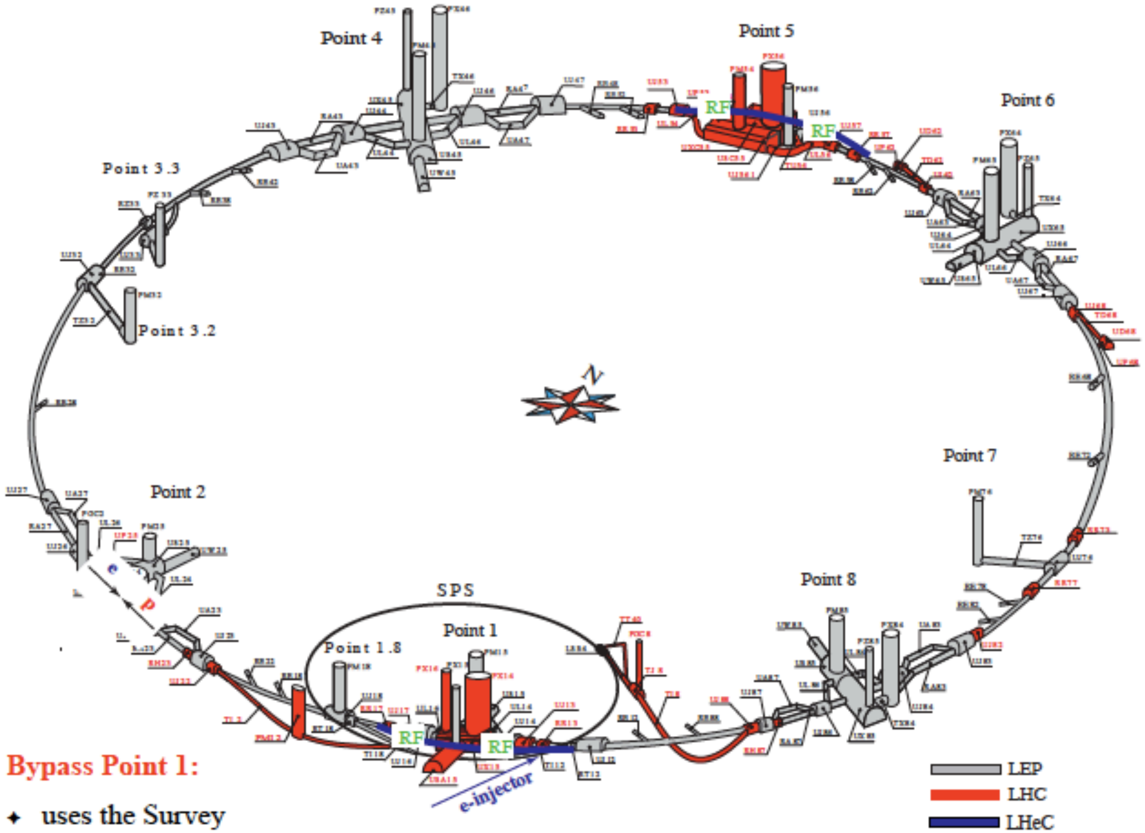
- forbidden space (usually DFBMs) induces an asymmetric lattice
- asymmetric lattice needs to be matched to the symmetric LHC lattice
- ➡ most choices for the LHeC lattice structure are made due to integration

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)

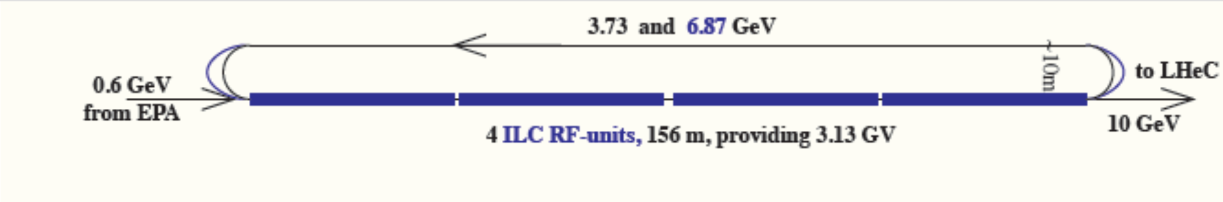
Bypass Point 5:

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



Bypass Point 1:

- uses the Survey Gallery
- Δ=16.25 Meter



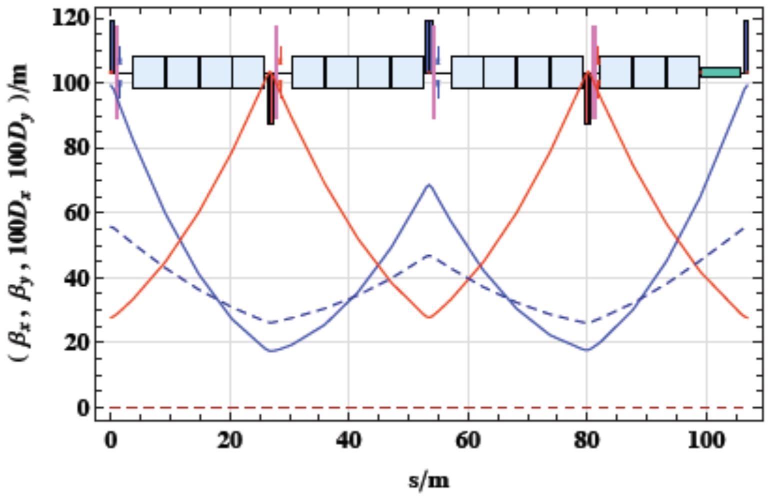
5min filling time

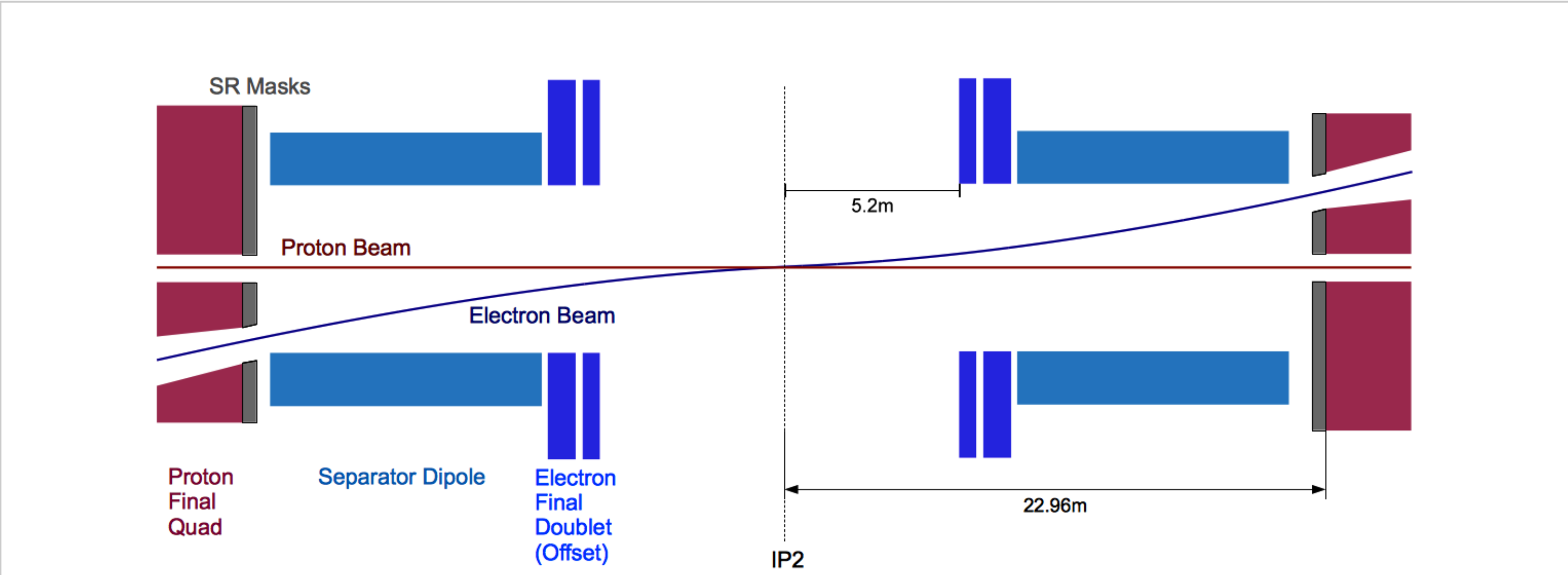
Ring - Arc Optics and matched IR

Optics:

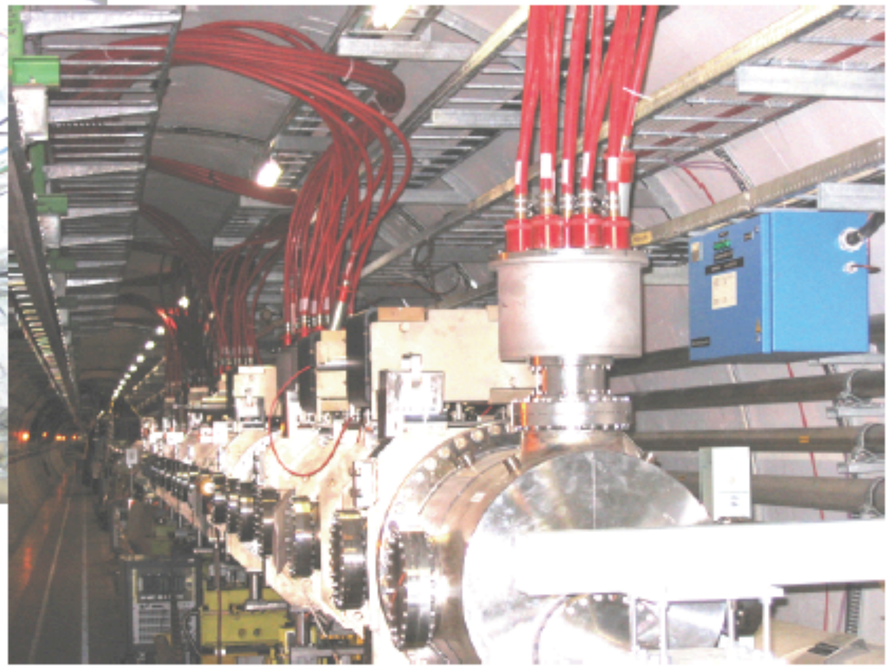
Beam Energy	60 GeV
Phase Advance per FODO Cell	$\approx 90°/60°$
Cell length	106.881 m
Dipole Fill factor	0.75
Damping Partition $J_x/J_y/J_e$	1.5/1/1.5
Coupling constant κ	0.5
Horizontal Emittance (no coupling)	4.70 nm
Horizontal Emittance ($\kappa = 0.5$)	3.52 nm
Vertical Emittance ($\kappa = 0.5$)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

23 arc cells, L_{Cell}=106.881 m





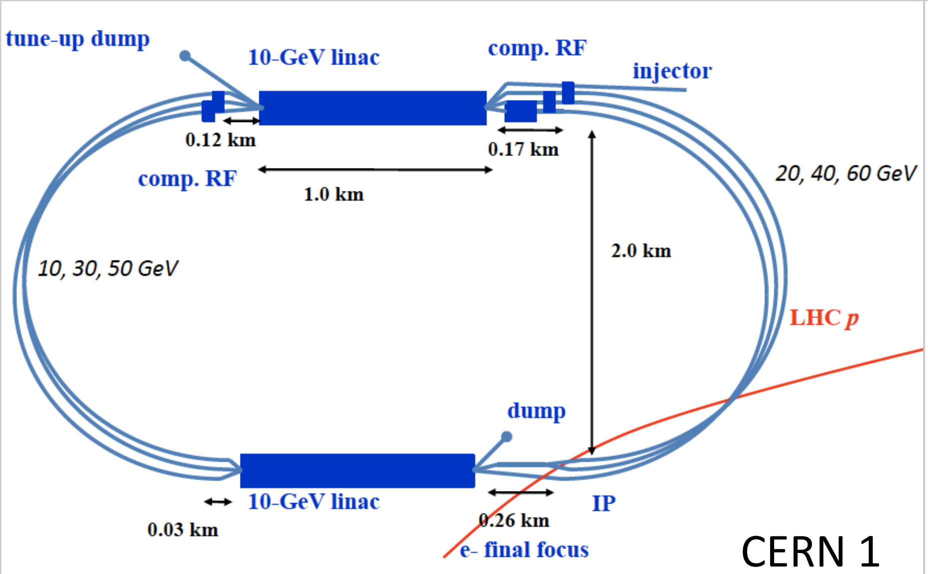
Ring Installation Study



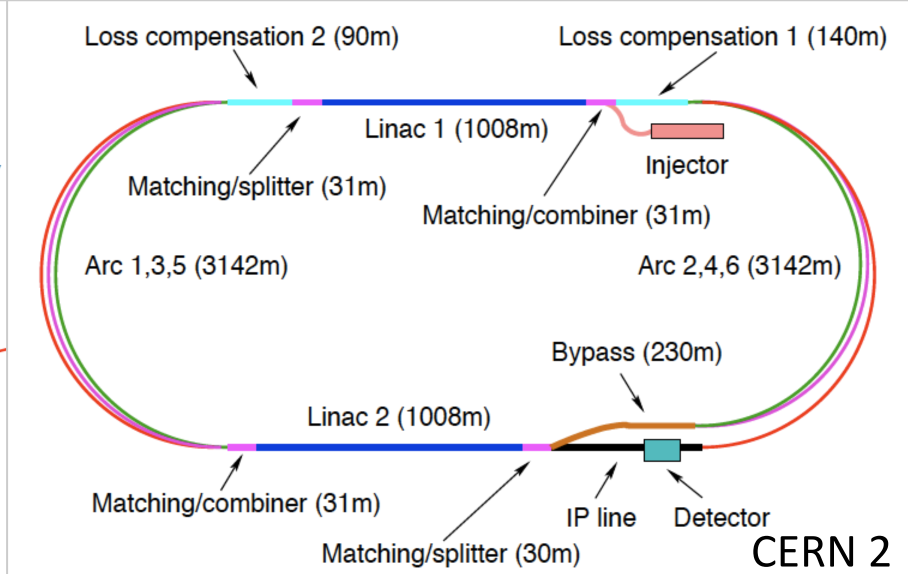
- Installation of an e ring is challenging
- Modifications of the existing installations will be necessary
- No show stopper

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

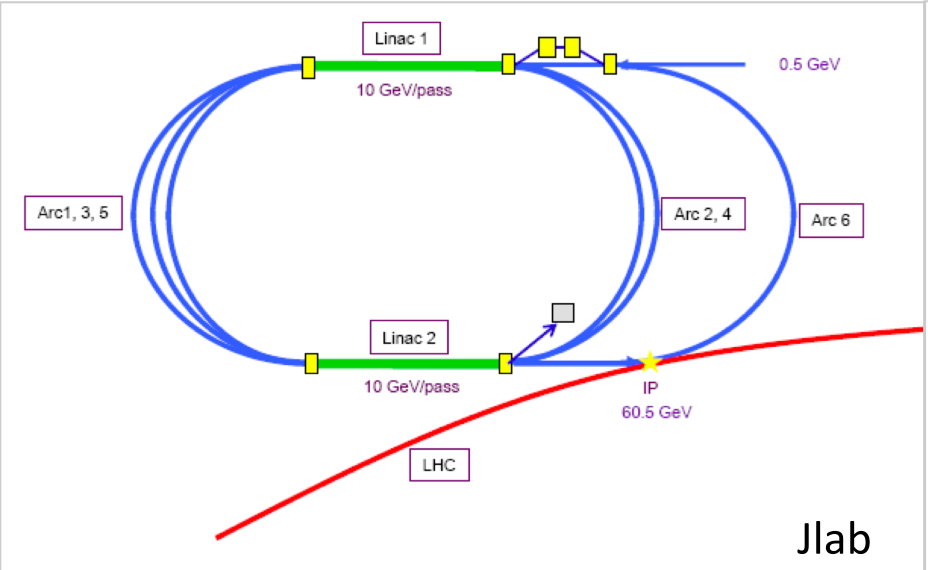
LINACs



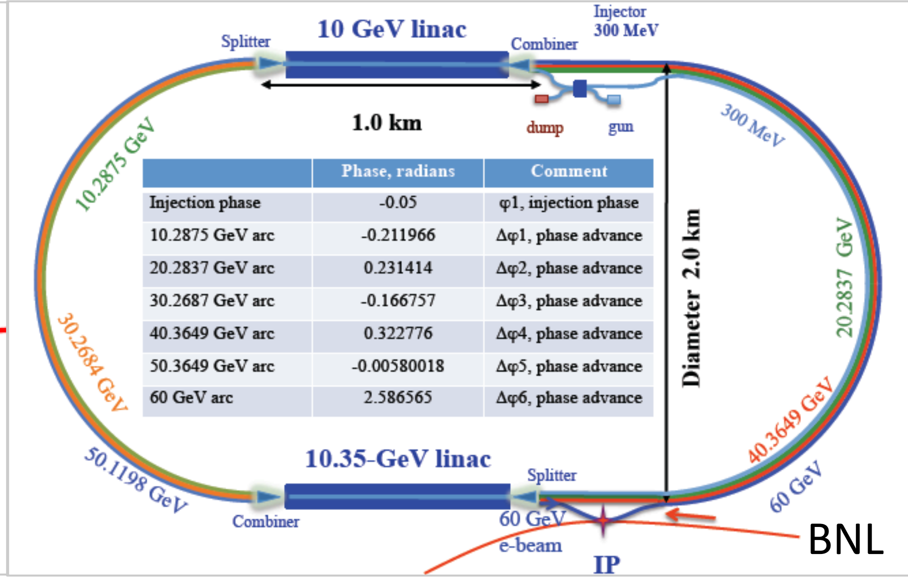
CERN 1



CERN 2



Jlab



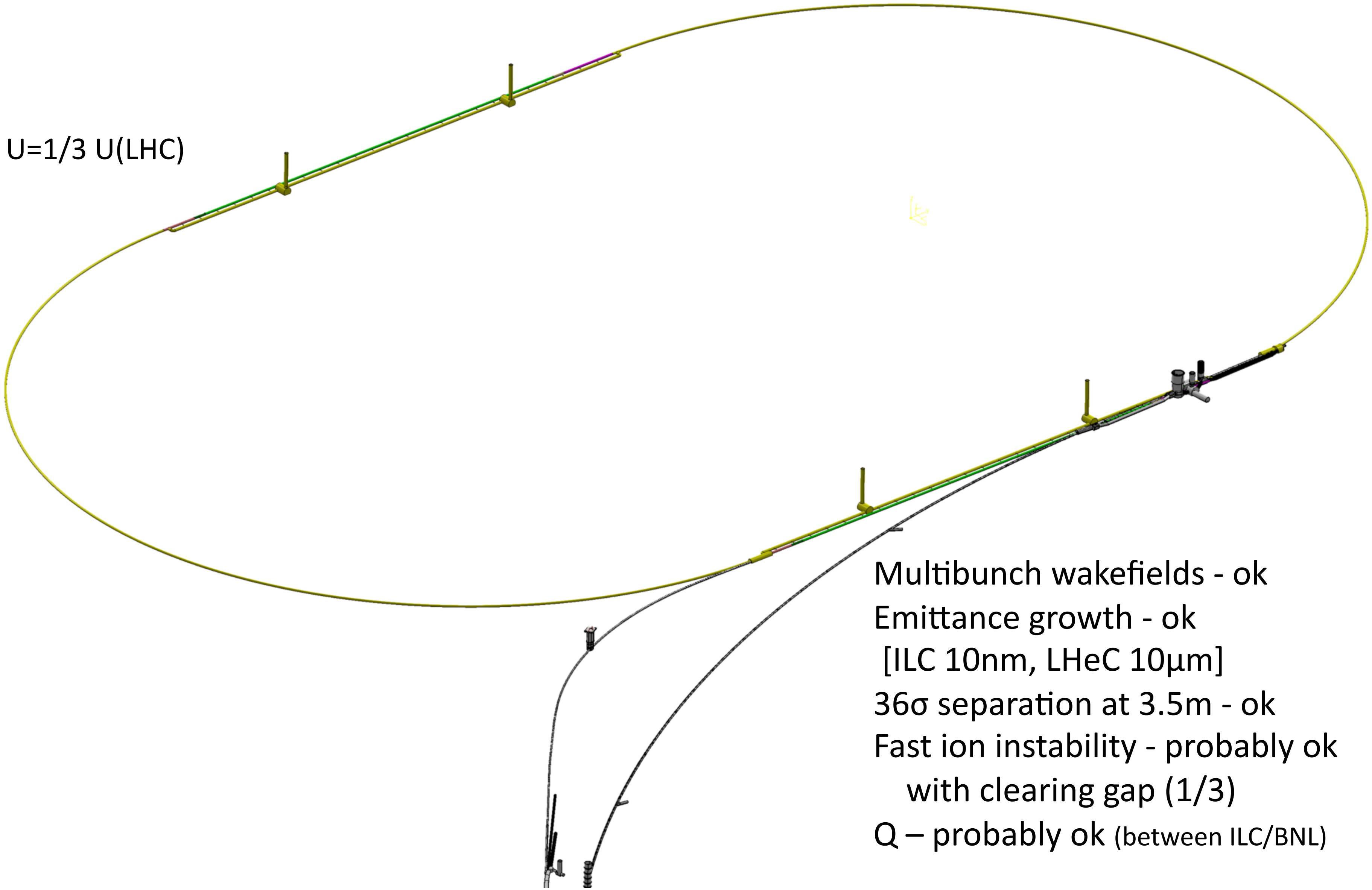
	Phase, radians	Comment
Injection phase	-0.05	φ1, injection phase
10.2875 GeV arc	-0.211966	Δφ1, phase advance
20.2837 GeV arc	0.231414	Δφ2, phase advance
30.2687 GeV arc	-0.166757	Δφ3, phase advance
40.3649 GeV arc	0.322776	Δφ4, phase advance
50.3649 GeV arc	-0.00580018	Δφ5, phase advance
60 GeV arc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

BNL

Two 10 GeV Linacs, 3 returns, compensation for synchrotron radiation losses, recovery of power

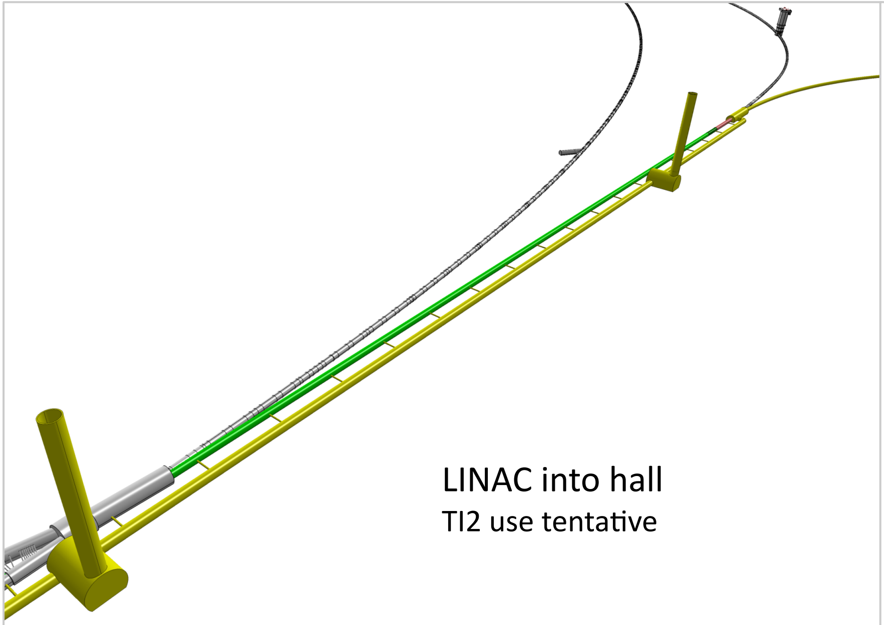
60 GeV Energy Recovery Linac

U=1/3 U(LHC)

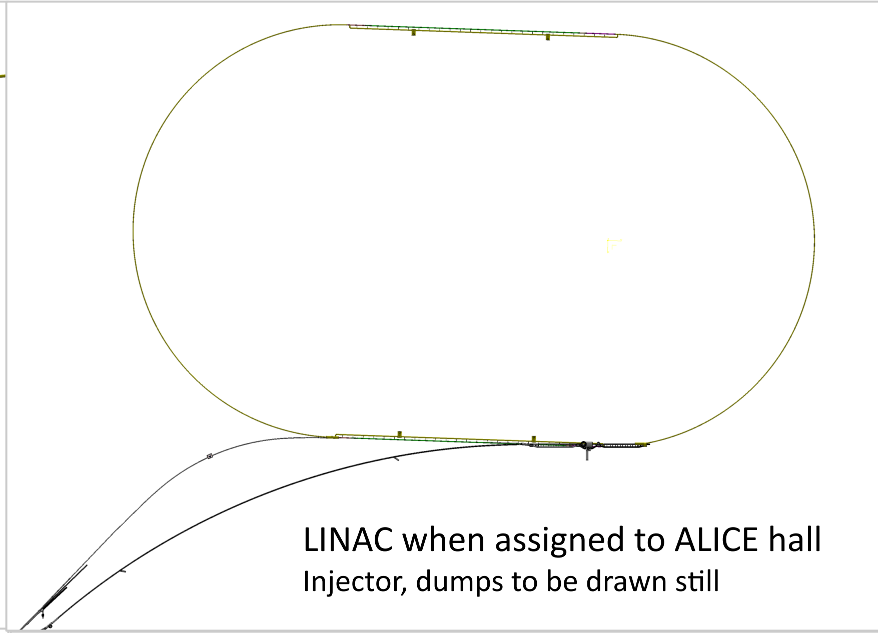


Multibunch wakefields - ok
Emittance growth - ok
[ILC 10nm, LHeC 10µm]
36σ separation at 3.5m - ok
Fast ion instability - probably ok
with clearing gap (1/3)
Q – probably ok (between ILC/BNL)

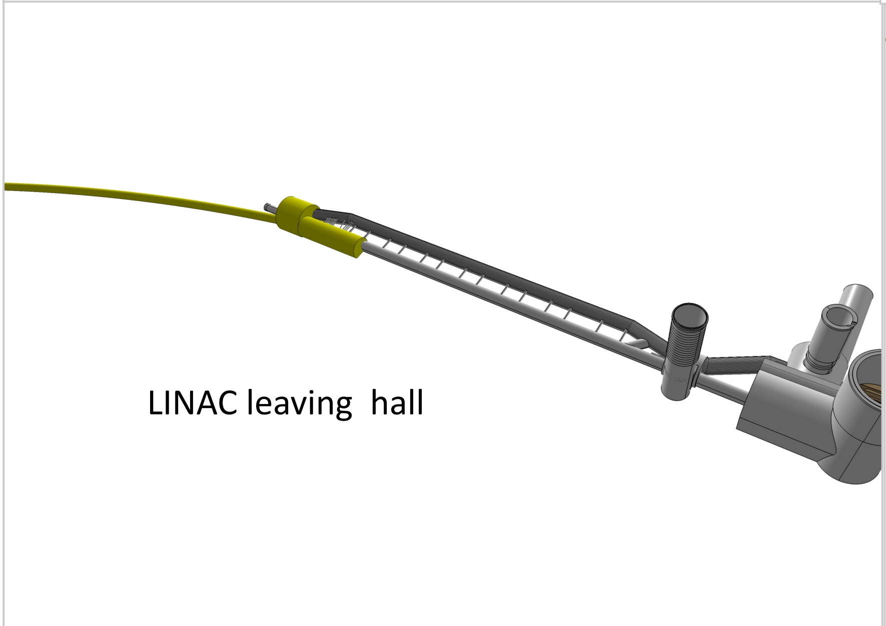
LINAC Views



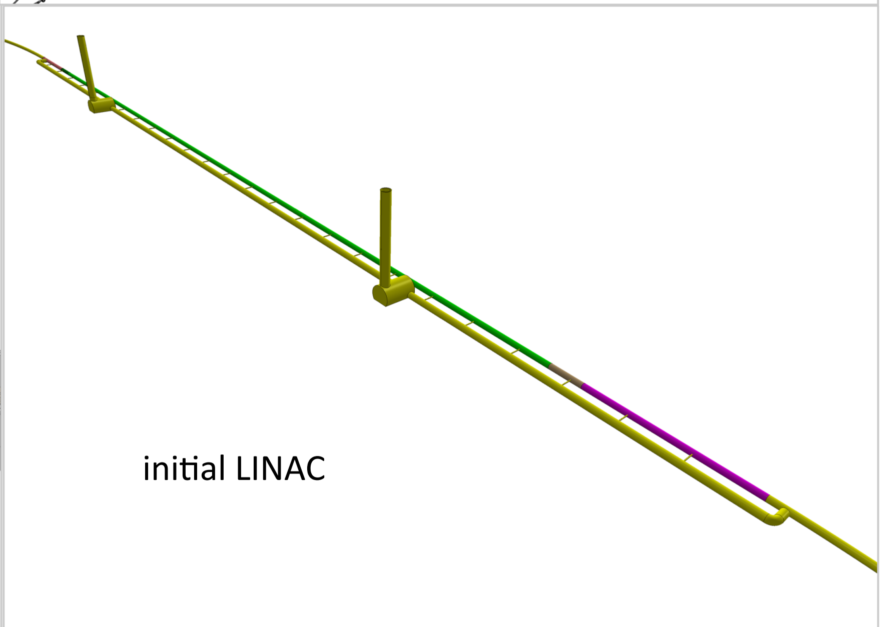
LINAC into hall
TI2 use tentative



LINAC when assigned to ALICE hall
Injector, dumps to be drawn still



LINAC leaving hall



initial LINAC

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

Ring RF system at 721.4 MHz.   60 GeV 100 mA

Synchrotron losses ≈400 MeV: 500 MV => 43 MW rated RF system (RF Feedback margin)

Efficiency: take 40% => < 100 MW mains power.

SPL like 700 MHz cavity, but at harmonic that allows 25 ns bunch spacing (40.08 MHz multiple -> 721 MHz)
= > Synergy with ongoing SPL cavity prototyping work. Here limitation is not gradient but input power !

- Assume 225 kW per coupler, 2 couplers per cavity, => 96 cavities (reasonable number)
- 5.2 MV/cavity only needed; SPL cavity is 25 MV/m in 5 cells length 1.06 m i.e. use 2 cell cavity.

=> 8 double cell cavities in 12 x 10 m cryomodules, Total Length 144 m, Incl. quads, vacuum, BI equipment.

- Two cavities per one 1 MW Klystron - (Less space, "Only" 48 klystrons...)

Install all cavities in the IR bypass sections

208 m available (124 + 2 *42)

6 modules at CMS bypass = 72m

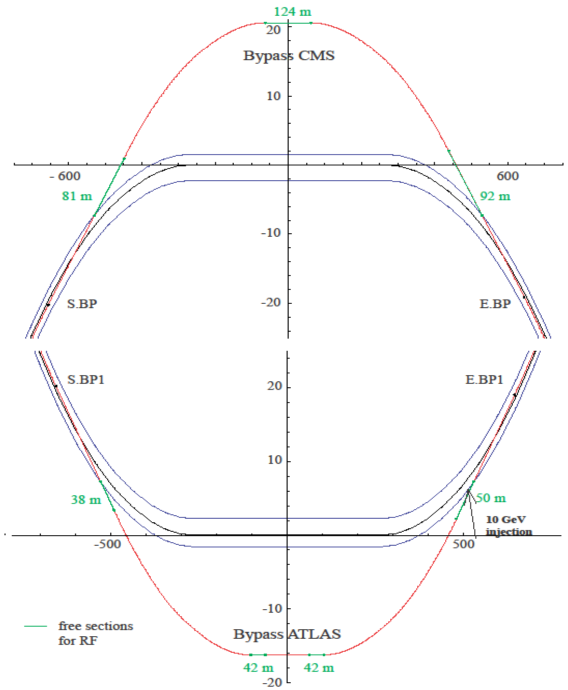
2 x 3 modules at ATLAS bypass = 2 * 36m

RF Power System underground

Need 100m^2 per 8 cavity module in adjacent RF gallery, i.e. 7-8 m wide over the module length

Surface: Need one HV Power Converter rated 6-8 MVA per 4 klystrons on surface.. (12)

Cryogenics: Split cold boxes: on surface and underground



3 – Pass ERL RF system at 721 MHz

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

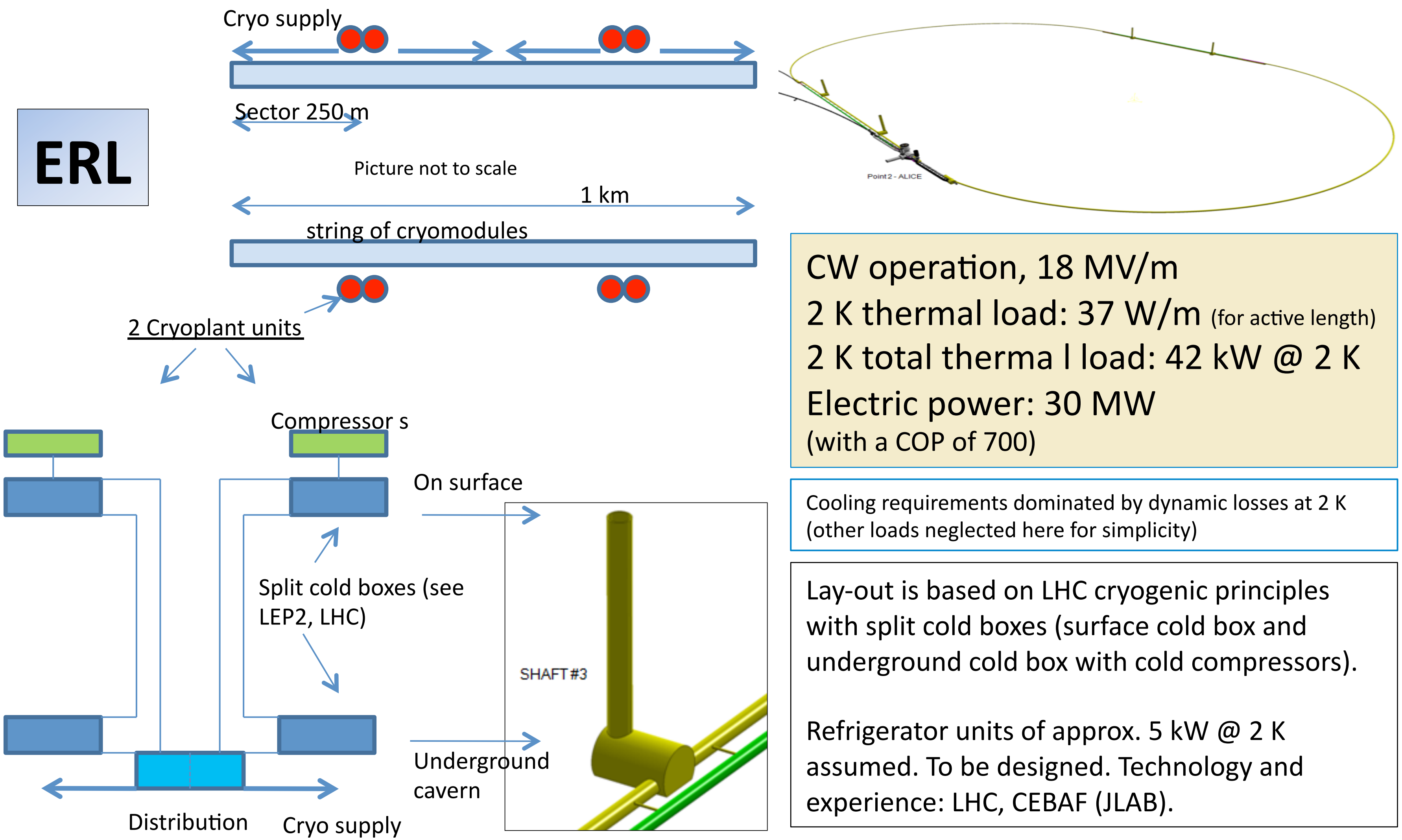
Take SPL type cavity @18 MV/m (Close to BNL design for eRHIC)

- 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

- Future: could **hardware prototyping be initiated, on SC cavities**, - good synergy with SPL Proton Driver study which is well underway. => Possibility of test of ERL concept at CERN ?

Linac-Ring Cryogenics



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).

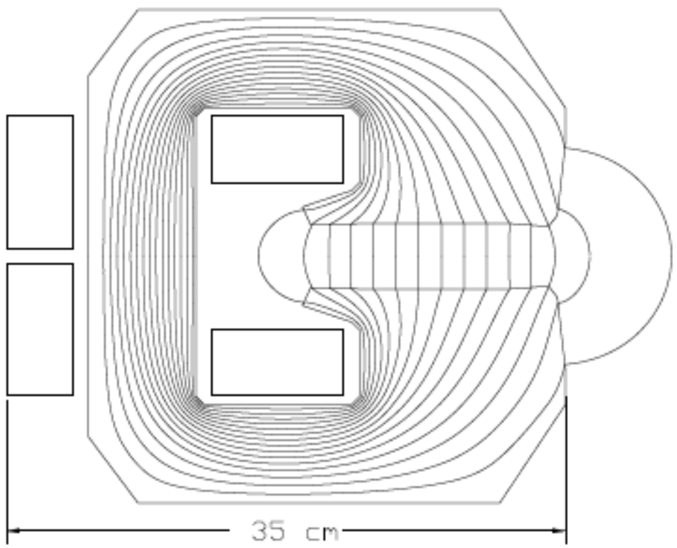
Refrigerator units of approx. 5 kW @ 2 K assumed. To be designed. Technology and experience: LHC, CEBAF (JLAB).

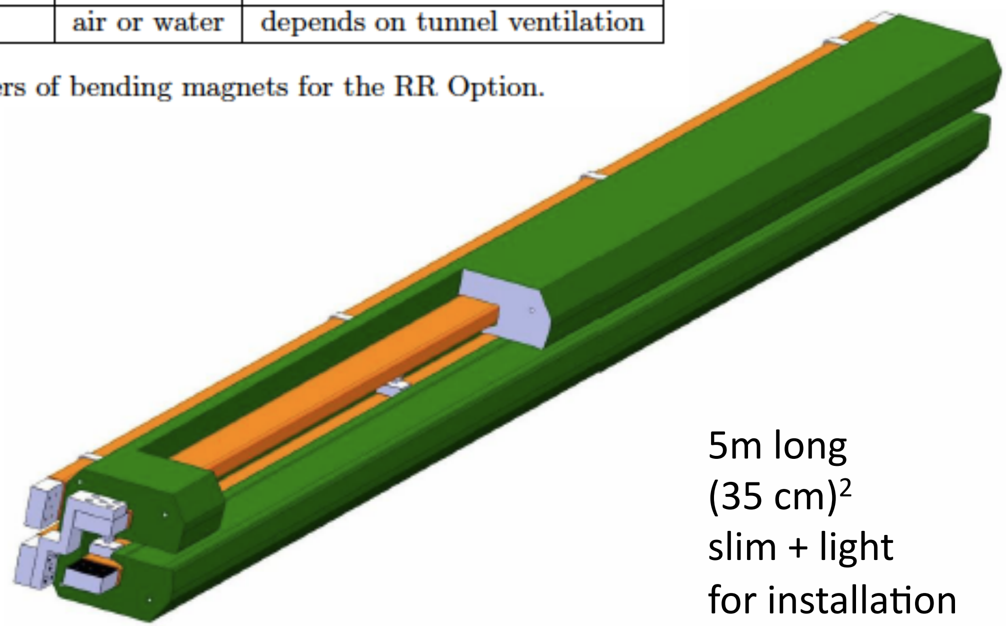
Ring Dipole Magnets

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

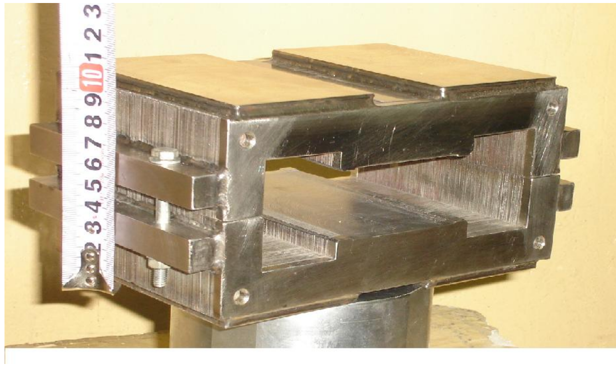
Table 3.2: Main parameters of bending magnets for the RR Option.

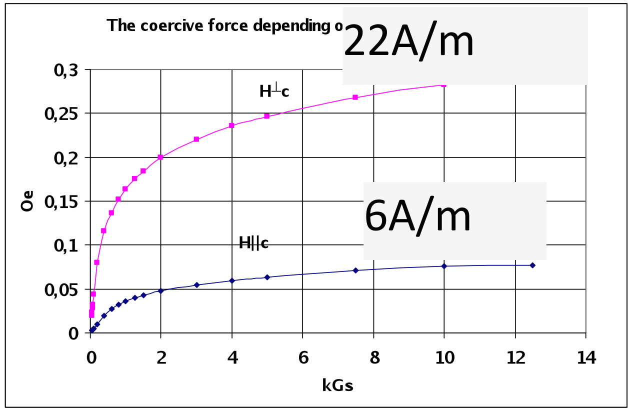


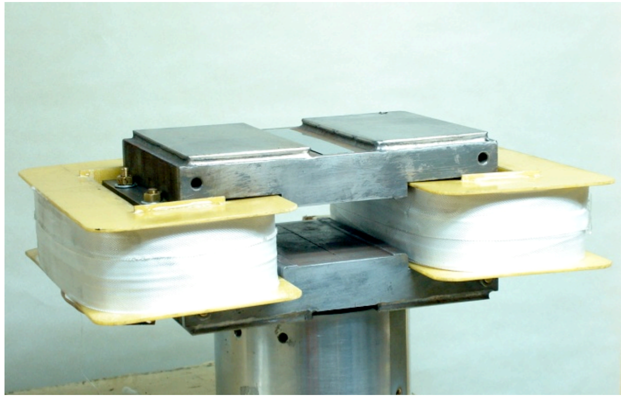


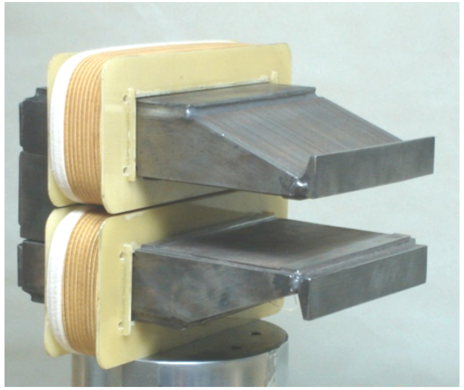
5m long
$(35\ \text{cm})^2$
slim + light
for installation

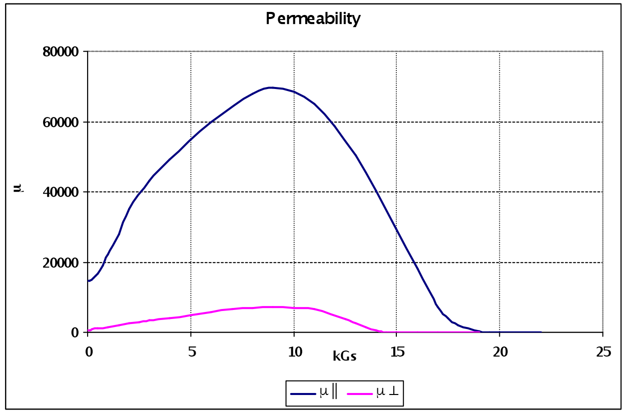
Dipole Prototype- BINP

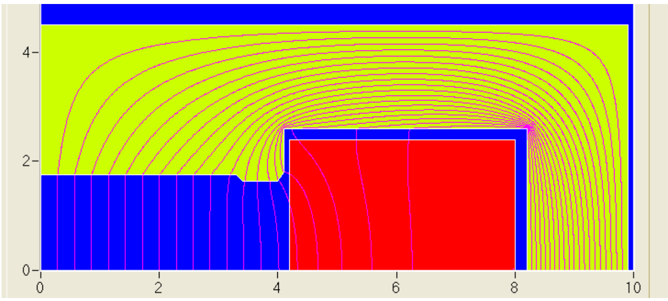




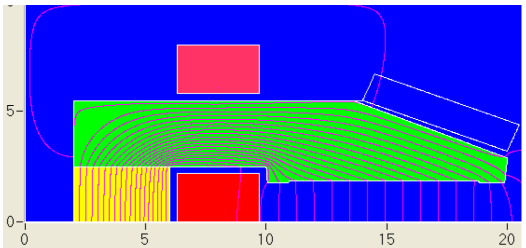






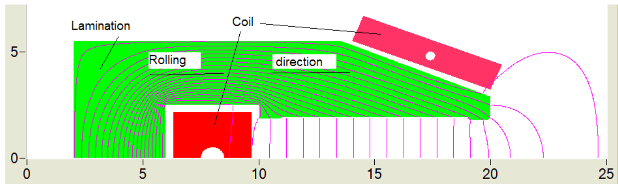


laminations of alternated rolling



same results for the two alternatives

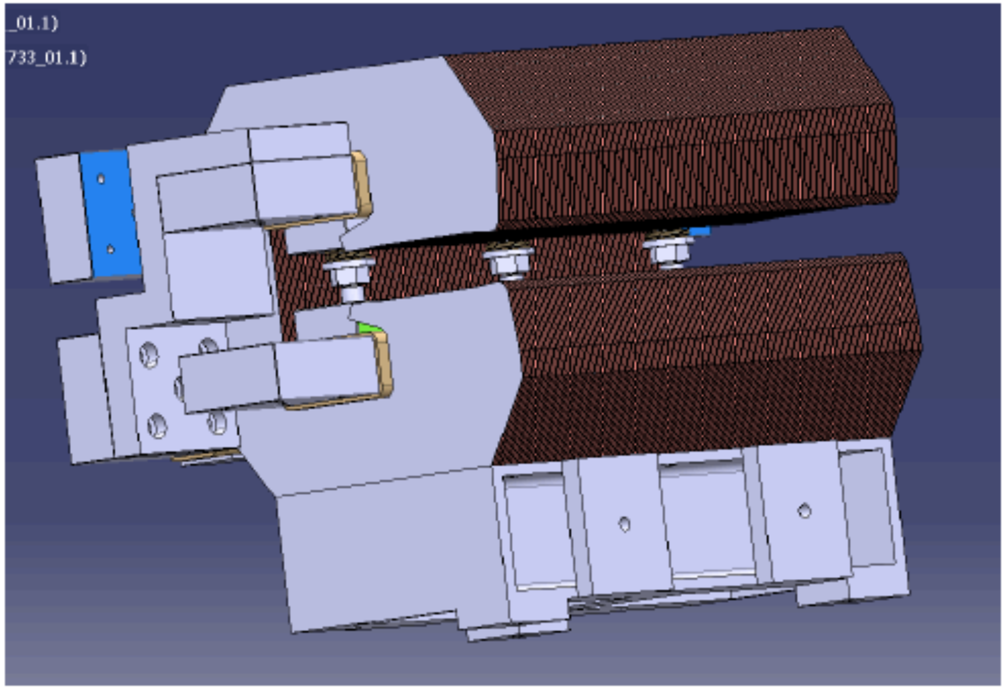
3408 grain oriented steel
0.35 mm thick laminations



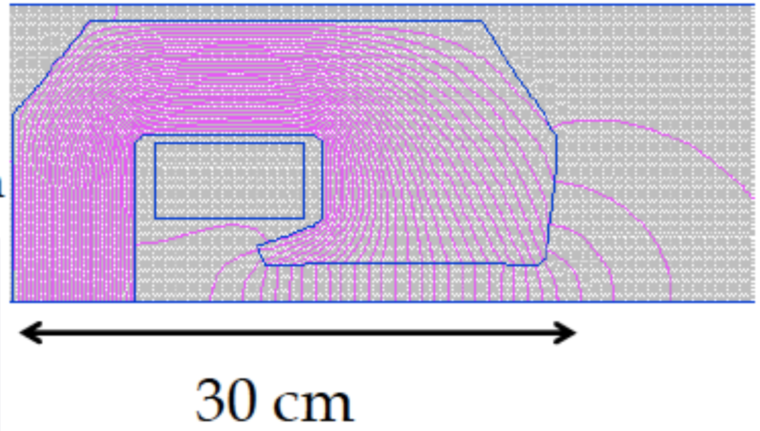
Reproducibility of injection field is below 0.1 Gauss!

Status of CERN Dipole Prototype

- interleaved, low-coercivity iron (H_c<25A/m)
- low resistance conductor, air cooled
- two turns only, bolted bars
- 400 mm long models with different types of iron



- design completed
- spacers under manufacture (phenolic)
- NiFe 50 steel (H_c = 3 A/m,) as reference
- low carbon iron (H_c=20 A/m) is available
- first model expected before Christmas



Magnet Parameters	
Beam Energy [GeV]	70
Magnetic Length [m]	5.45
Magnetic field [Gauss]	874
Number of magnets	3080
Vertical aperture [mm]	40
Pole width [mm]	150
Number of coils	2
Number of turns/coil	1
Current [A]	1500
Conductor section [mmxmm]	92x43
Conductor material	aluminum
Magnet Inductance [mH]	0.15
Magnet Resistance [mΩ]	0.2
Power per magnet [W]	450
Cooling	air

Ring-Arc Quadrupoles Linac

Parameter	Value	Units
Beam Energy	10-60	GeV
Magnetic Length	1.0	Meters
Field gradient @ 60 GeV	10.28 (QF) - 8.40 (QD)	T/m
Number of magnets	368 + 368	
Aperture radius	30	mm
Total length	1.2	meters
Weight	700	kg
Number of turns/pole	9	
Current @ 10.28 T/m	430	Ampere
Conductor material	copper	
Current density	2	A/mm2
Magnet inductance	4	milli-Henry
Magnet resistance	8	milli-Ohm
Power @ 60 GeV	1500	Watt
Cooling	water	

Table 3.3: Main parameters of arc quadrupole magnets for the RR Option.

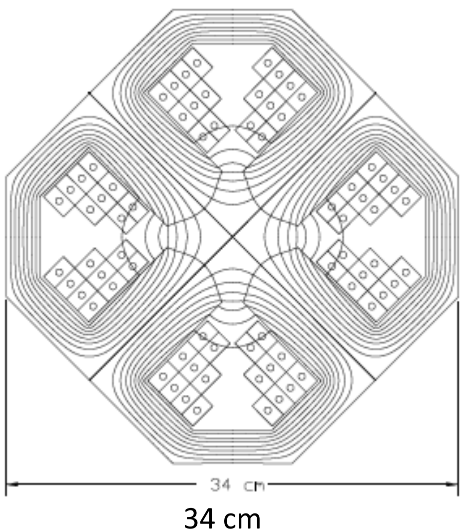
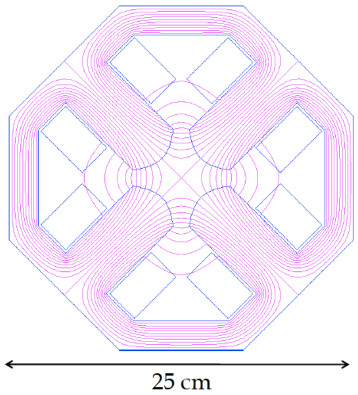
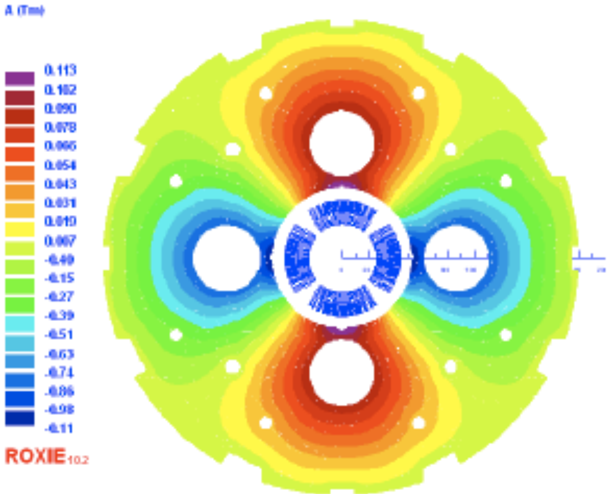


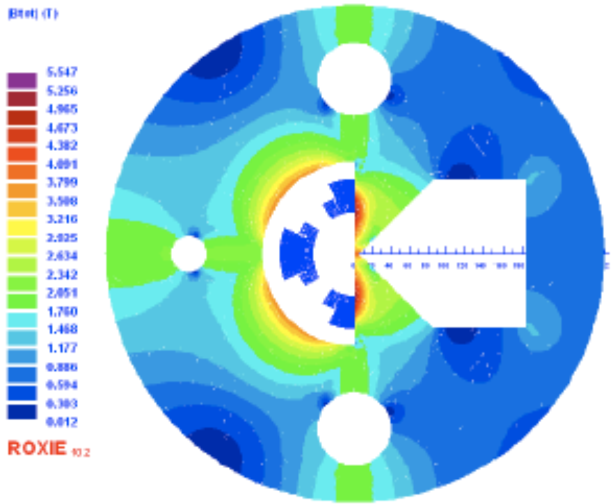
Figure 3.3: Arc quadrupole magnets for the RR Option



Number of magnets	72
Aperture radius [mm]	20
Field gradient [T/m]	4.4
Magnetic Length [mm]	500
Weight [kg]	150
Number of turns/pole	18
Current [A]	40
Conductor material	Copper
Current density [A/mm²]	1.5
Resistance [mΩ]	60
Power [kW]	0.1
Inductance [mH]	9
Cooling	air

Final Proton Quadrupoles





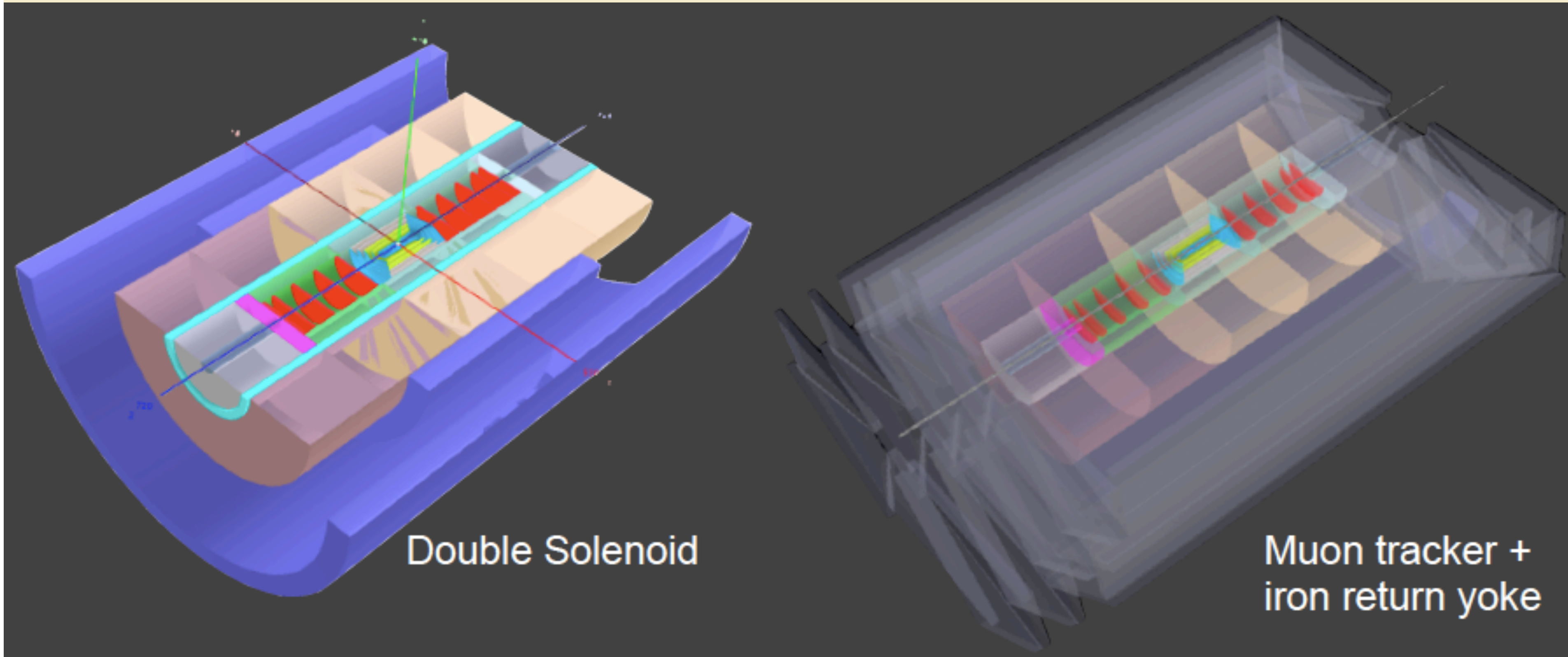
NbTi: 6700 A, 248 T/m at 88% LL Nb3Sn: 8600 A, 311 T/m, at 83% LL	NbTi: 4500 A, 145 T/m, 3.6 T at 87% Nb3Sn: 5700 A, 175 T/m, 4.7 T at 82% on LL (Four layer coil !)
23 mm aperture 87 mm septum	46 mm (half) aperture 63 mm septum (space for p and e-beams)
0.03 T, 3.5 T/m in e-beam pipe 0.09 T, 9 T/m in e-beam pipe	0.37 T, 18 T/m 0.5 T, 25 T/m

NbTi at 1.8 K, Nb3Sn at 4.2 K

3 beams in horizontal plane

Focus and deflect

Double Solenoid Detector



- 2 big Solenoids +5T/-1.5T outside HCAL (evaluated by H.Ten Kate) saving ~10kTons steel for return yoke (~10M$)
- superior muon track measurement in between the 2 magnets

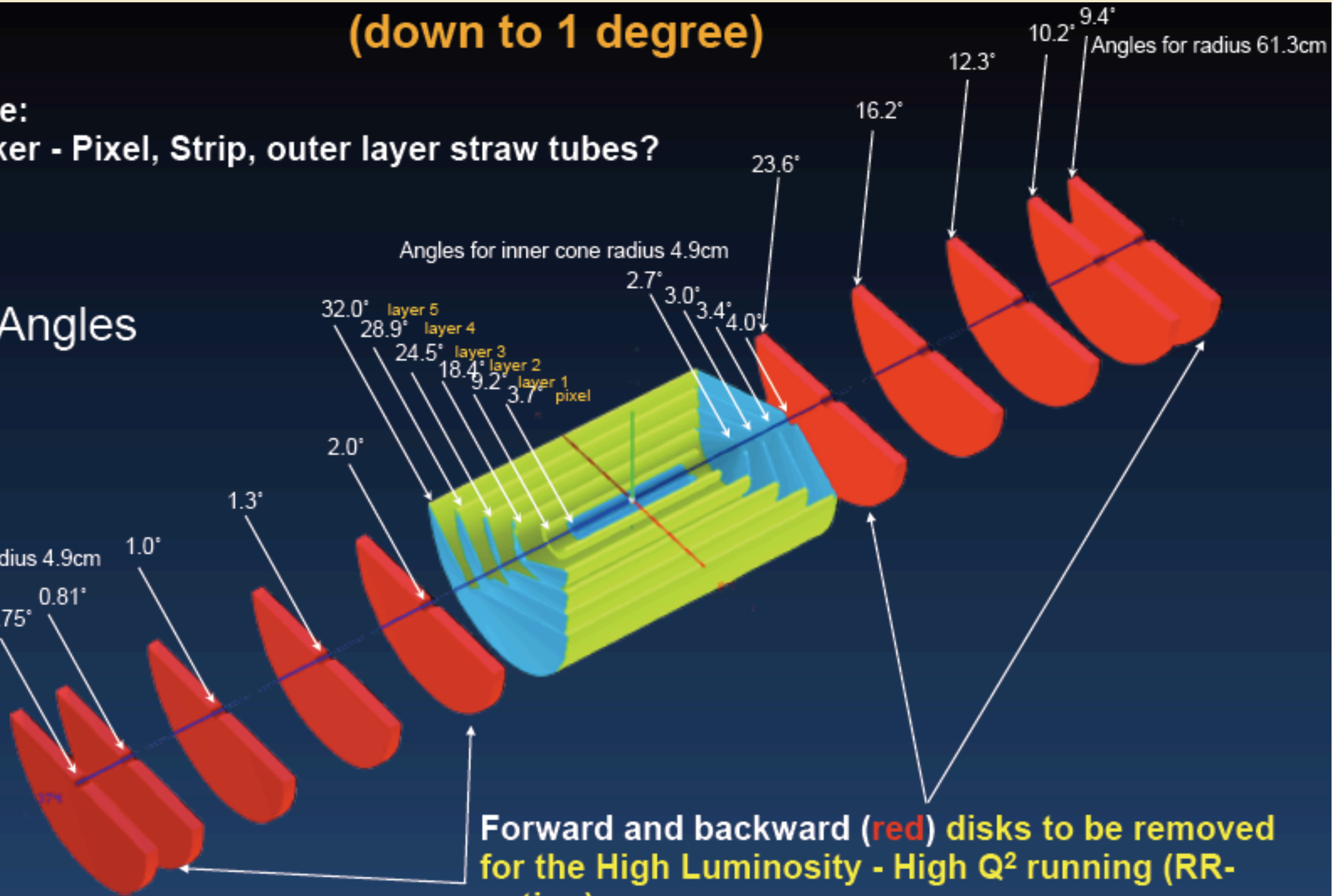
Fwd/Bwd asymmetry in energy deposited and thus in technology [W/Si vs Pb/Sc..]
Present dimensions: LxD =17x10m^2 [CMS 21 x 15m^2 , ATLAS 45 x 25 m^2]
Taggers at -62m (e),100m (γ,LR), -22.4m (γ,RR), +100m (n), +420m (p)

Track Detector Concept

(down to 1 degree)

Baseline:
Si Tracker - Pixel, Strip, outer layer straw tubes?

Track Angles

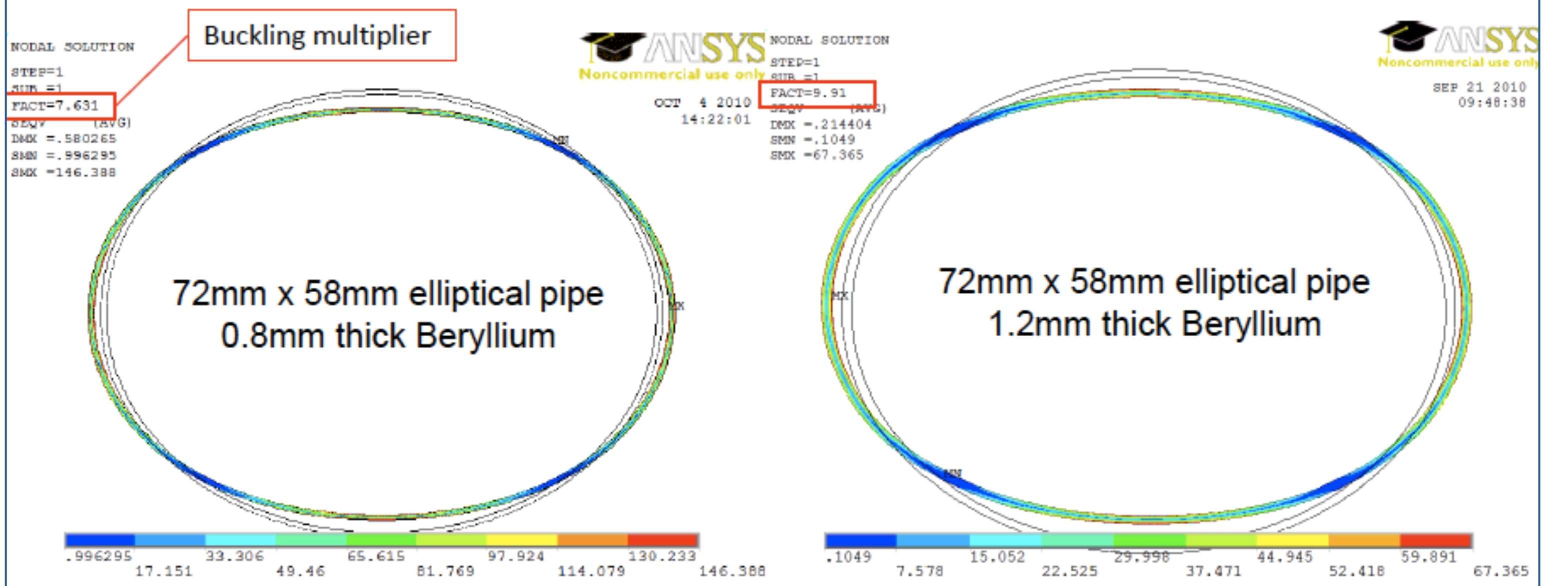


Forward and backward (red) disks to be removed for the High Luminosity - High Q² running (RR-option)

Alternative technologies: MAPS, DEPFET, GOSSIP* (talk of H.van de Graf)

*Gas On Slimmed Silicon Pixels (or Strixels/Pads) - *NIKHEF*

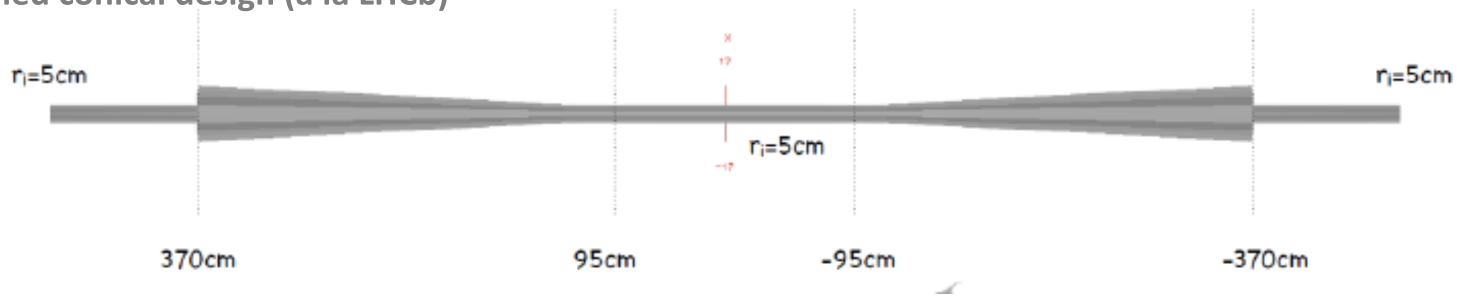
Beam Pipe Design



Equivalent Stress Contours
+
Deformed/Undeformed Shapes

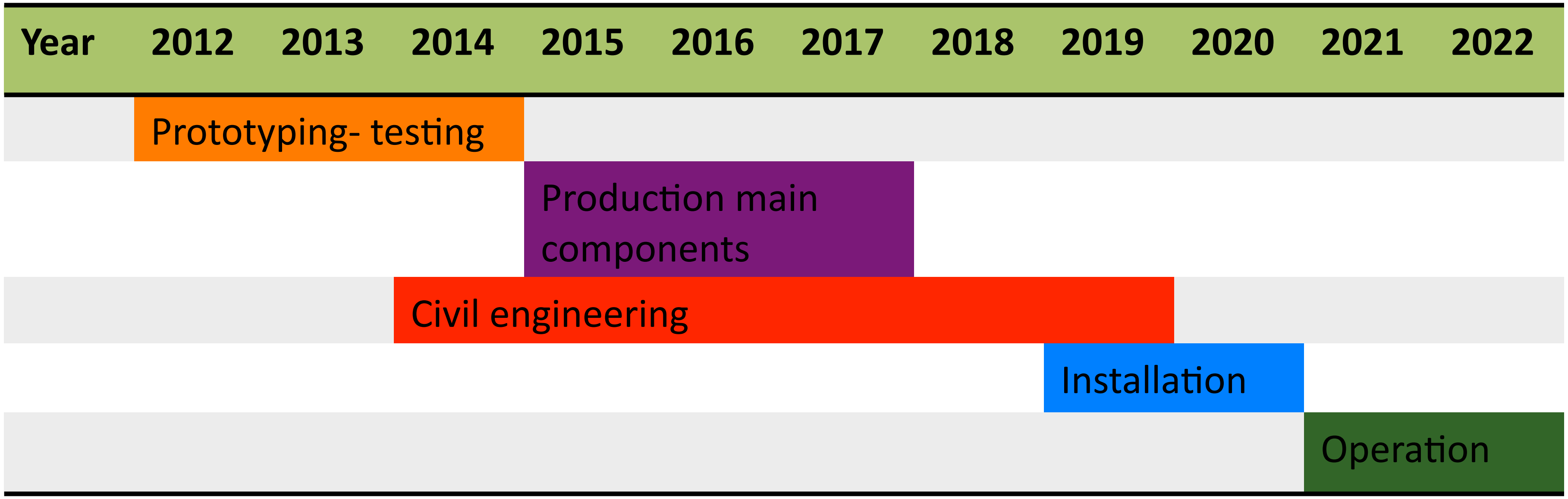
Minimum thickness for Be, elliptical (constant geometry) pipe in order of 1mm

Also studied conical design (a la LHCb)



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

Organisation 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)

Referees of CERN

<u>QCD/electroweak:</u>
Guido Altarelli, Alan Martin, Vladimir Chekelyan

<u>BSM:</u>
Michelangelo Mangano, Gian Giudice, Cristinel Diaconu

<u>eA/low x</u>
Al Mueller, Raju Venugopalan, Michele Arneodo

<u>Detector</u>
Philipp Bloch, Roland Horisberger

<u>Interaction Region Design</u>
Daniel Pitzl, Mike Sullivan

<u>Ring-Ring Design</u>
Kurt Huebner, Sasha Skrinsky, Ferdinand Willeke

<u>Linac-Ring Design</u>
Reinhard Brinkmann, Andy Wolski, Kaoru Yokoya

<u>Energy Recovery</u>
Georg Hoffstatter, Ilan Ben Zvi

<u>Magnets</u>
Neil Marx, Martin Wilson

<u>Installation and Infrastructure</u>
Sylvain Weisz

Final Remarks

The CDR draft is currently being written (140 pages on svn) by perhaps 100 authors.
November 12/13: 3rd LHeC Workshop. December and January for completion and updates
February/March for referees to comment, followed by updating the CDR
Cost estimate organised by CERN Print in spring 2011

Issues of present concern and attention: Coherence, plots, text for all chapters.
Detailed IR layout with masks and absorbers – finalisation of detector concept
Understanding and write-up of necessary R+D steps

For the continuation of the project, **a new mandate/expressions of interest** by ECFA and NuPECC are essential, which allow to adapt the organisation of the further work, together with CERN.

The Ring (which has Linac elements) has high lumi with both charges, reserve for high luminosity and estimated lepton polarisation between 25 and 40%. It looks easier to build but is hard to install.

The Linac (which has arcs..) with ER has high lumi for e^- and >80% polarisation, yet is much less luminous for e^+. It is challenging to build but easier to install.

It has been decided early on to **first conclude the design work and then choose L vs R**. This is not unrelated to the LHC. The CDR also has a section on a 140 GeV straight LINAC, which would need more than 100 MW to exceed 10^{32} luminosity (and thus extraordinary physics reasons to be built).

The detector will and can be based on 'existing' technology, but it **needs 10 years** too.

The LHeC is worth an intensified, broadened effort, but cannot ignore **the pace of the LHC clock**.

Thanks

To the many experts in engineering, accelerators, detectors, experimental physics, software, theory and politics for their engagement in this project, which was launched in 2007 by the SPC, CERN and ECFA and approaches completion of its first phase in the attempt to reach the real world.

Particular thanks to the directors of CERN, to ECFA and NuPECC for their attention and support.

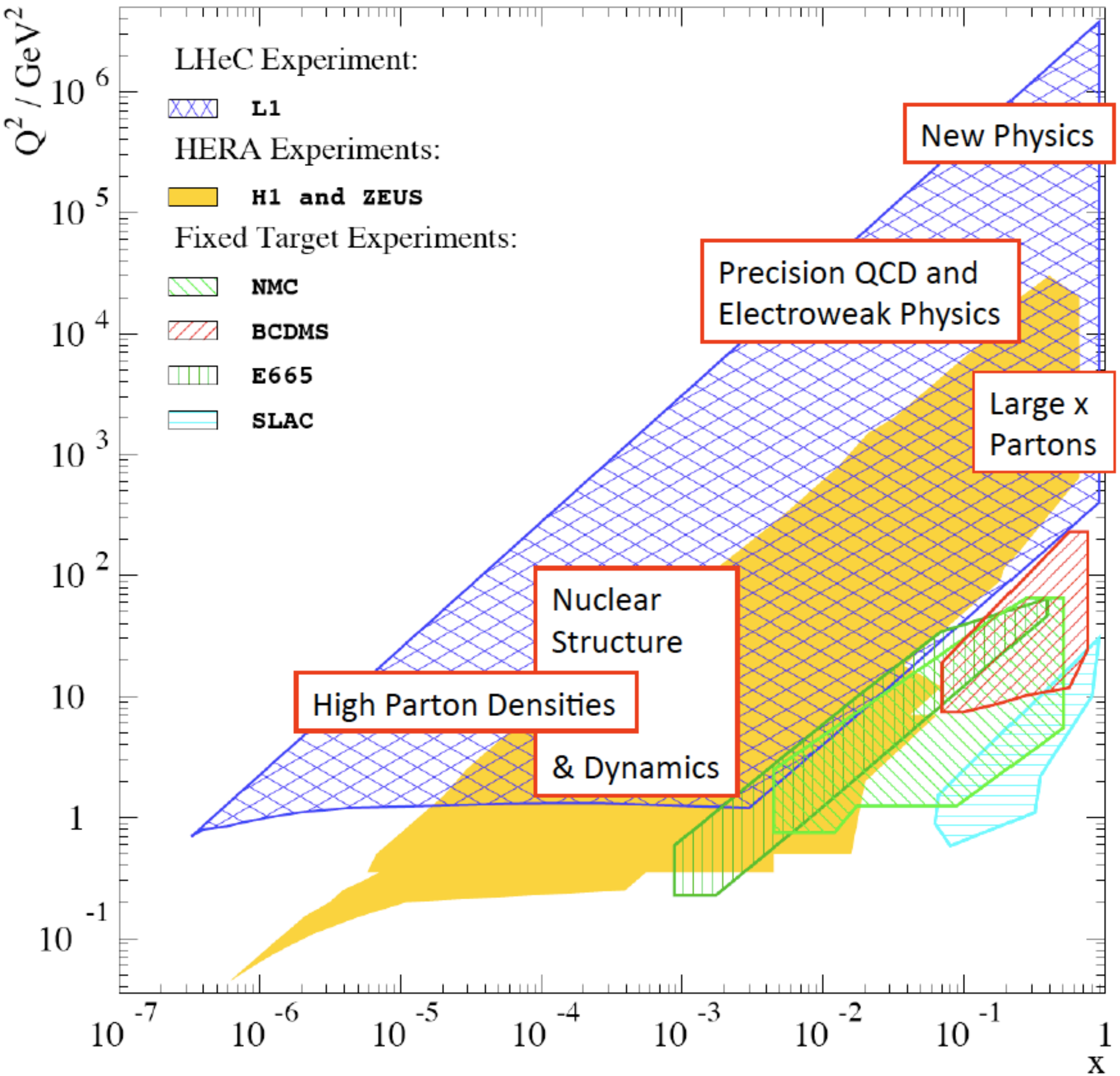
Personal thanks to Patricia Mage, to my Liverpool colleagues for extending their understanding of academic freedom to my 'hobby' and many old and new friends.

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

be better if all the efforts that we expend on the discussions on which form of field theory one should use were devoted to arguing for a higher-energy accelerator so that we can do more experiments over the next generation and really learn more about the basic structure of matter.

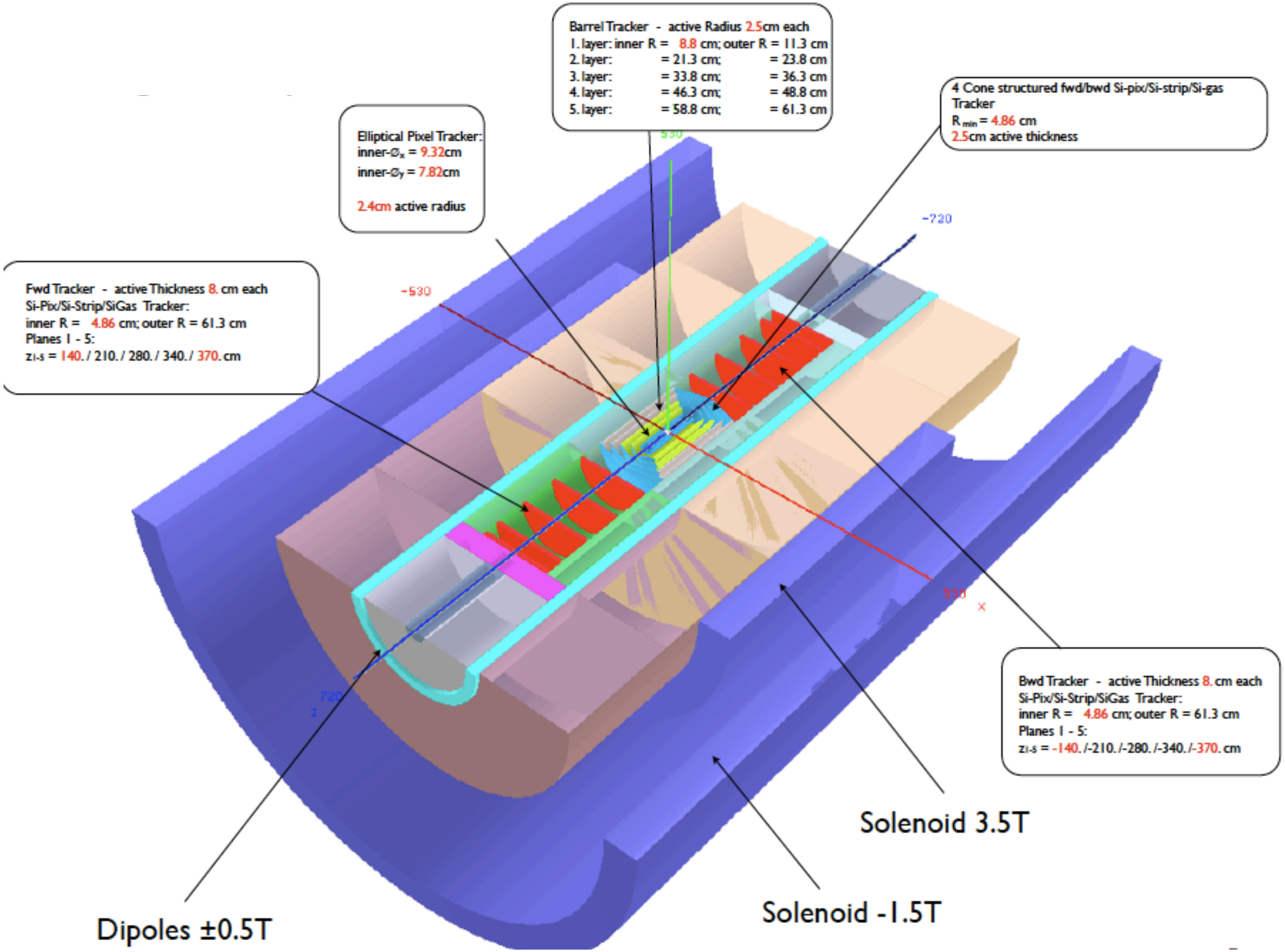
Gell-Mann 1966

RF



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 & Dynamics
High Parton Densities
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

2 solenoid detector concept



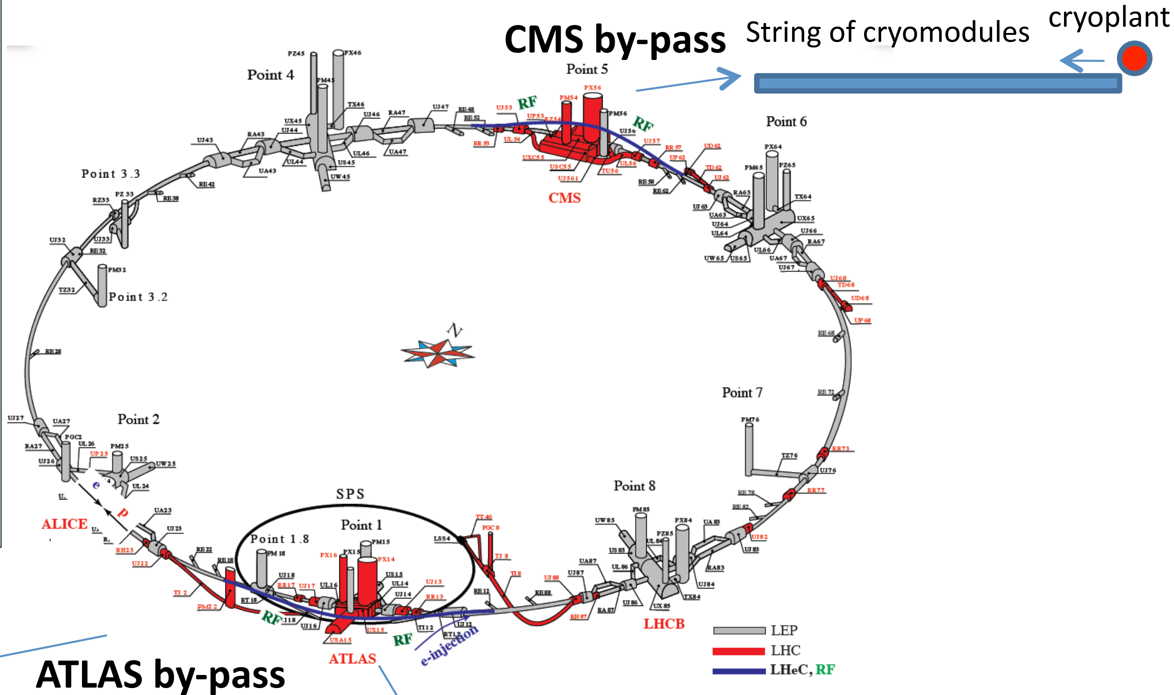
Ring-Ring Cryogenics (basics)

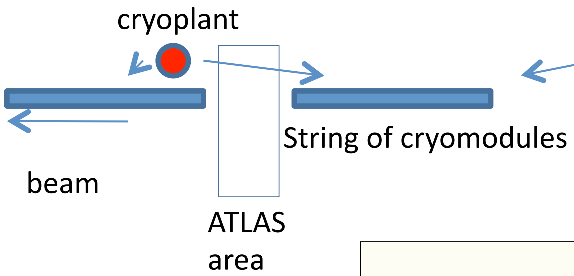
For the CMS and ATLAS bypasses are considered:

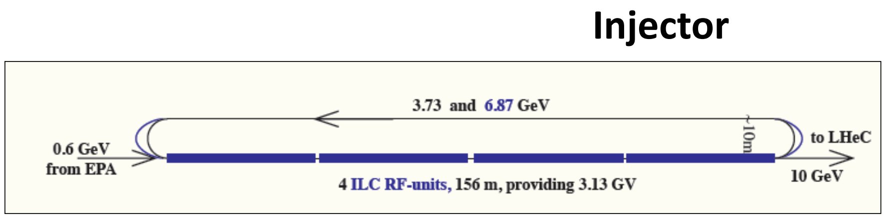
1. LHC type cryomodules (400 MHZ)
2. SPL type cryomodules (704 MHz)

Cryogenics requirements

1. 4.5 K operation. Two cryoplants of approx. 10 kW @ 4.5 K each. El. power approx. 5 MW total.
2. 2 K operation. The installed power of the cryoplants is a function of acc. field (to be determined). (El. power comparable to 1.)







Injector:
12 ILC (XFEL) cryomodules.
Intermittend operation.
Operation temp. 2K.
Cryoplant of modest size
(0.2 kW @ 2 K)

Time Considerations for an LHeC Installation:

LHC upgrade plans:

- ➔ HiLumi upgrade planned for 2020 with goal of
  - ➔ an average luminosity of 5 10^{34} cm^{-2} sec^{-1}
  - ➔ an integrated luminosity of 250fb^{-1} per year and
  - ➔ a total of 3000 fb-1 over the lifetime of the LHC.
- ➔ With the HiLumi parameters the LHC will reach the lifetime goal of 3000 fb^{-1} by 2030 to 2035 depending on the efficiency of the HiLumi commissioning performance ramp up.
- ➔ Aiming for a minimum of 10 years of exploitation for the LHeC this requires start of LHeC operation by about 2020
- ➔ Based on the experience of other projects (e.g. LEP, XFEL and LHC), a large facility like the LHeC will require 1-2 years of installation; ca. 3 years of production including pre-series production; plus ca 1-2 years of test bench operation of the key components
- ➔ Total installation time of 5 to 7 years.

Civil Engineering Requirements

Energy recovery linac option for linac-ring design:

total tunnel length of ca. 10km (similar to 500 GeV CLIC option):

- ➔ 4 years for civil engineering
- ➔ 2 years of service installation (piping, cabling, EL general services)
- ➔ 2 years of actual machine installation
- ➔ Total of 6 years with partial overlap of some of these activities

  (Not counting any time for legal preparations for construction on communal property!)

Bypass for ring-ring option:

Total tunnel length of ca. 2km (ca. 500 on either side of experiment)
But also requires two access shafts (safety)
Requires dedicated alcoves for Klystrons and RF system

- ➔ perhaps slightly shorter intervention time as for Linac-Ring options
- ➔ Total of 5 years with partial overall of some of these activities

  (Civil engineering for injector complex not considered here)

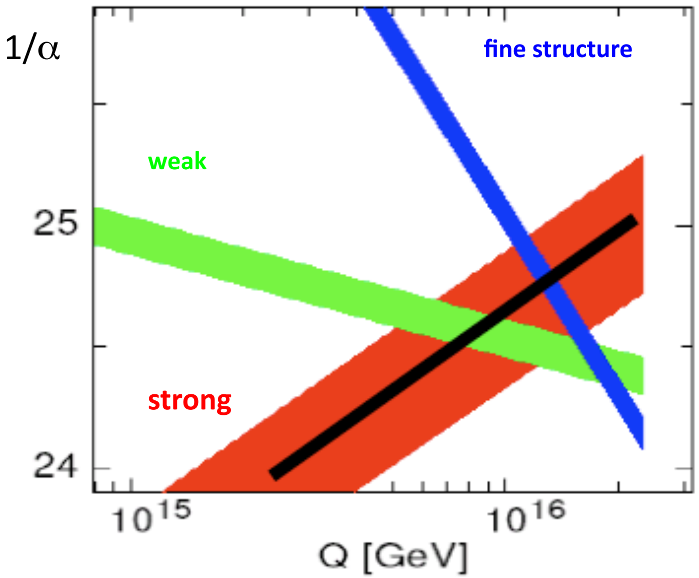
CDR in 2010/2011

April - DIS and QCD Workshop at Florence (DIS10)
May - KEK IPAC
NuPECC at Madrid → LHeC on Long Range Plan (Roadmap)
June - CERN SPC → Reported to Council
July - ICHEP at Paris
October – Dipole Prototype (Novosibirsk) successfully tested
November – 3rd CERN-ECFA-NuPECC Workshop (12/13.11.) http://cern.ch/lhec

December/January – Completion/editing of CDR
February/March – Refereeing
April/May – Update and Print

Strong Coupling Constant

Simulation of α_s measurement at LHeC



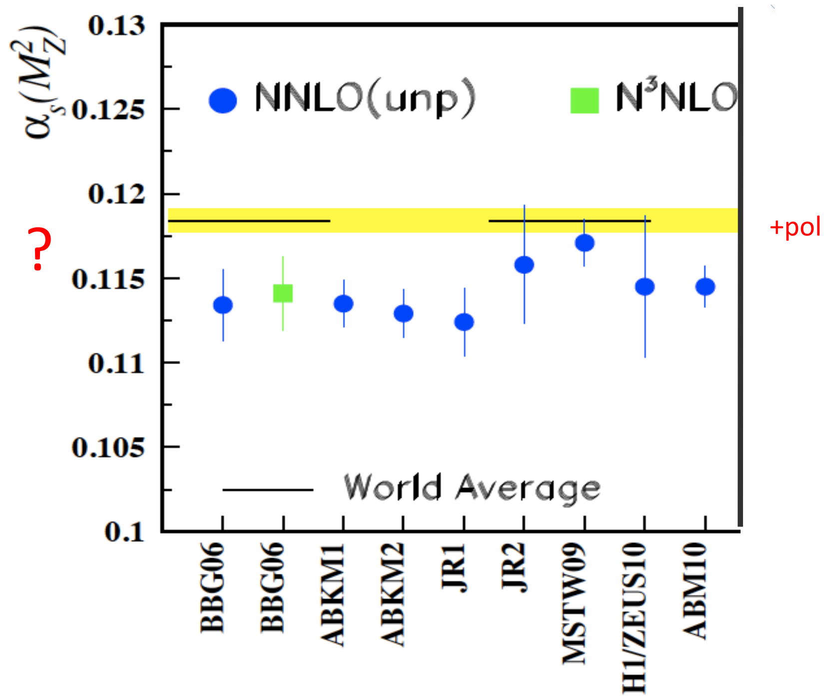
MSSM - B.Allnach et al, hep-ex/0403133

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 $\delta\alpha_s$

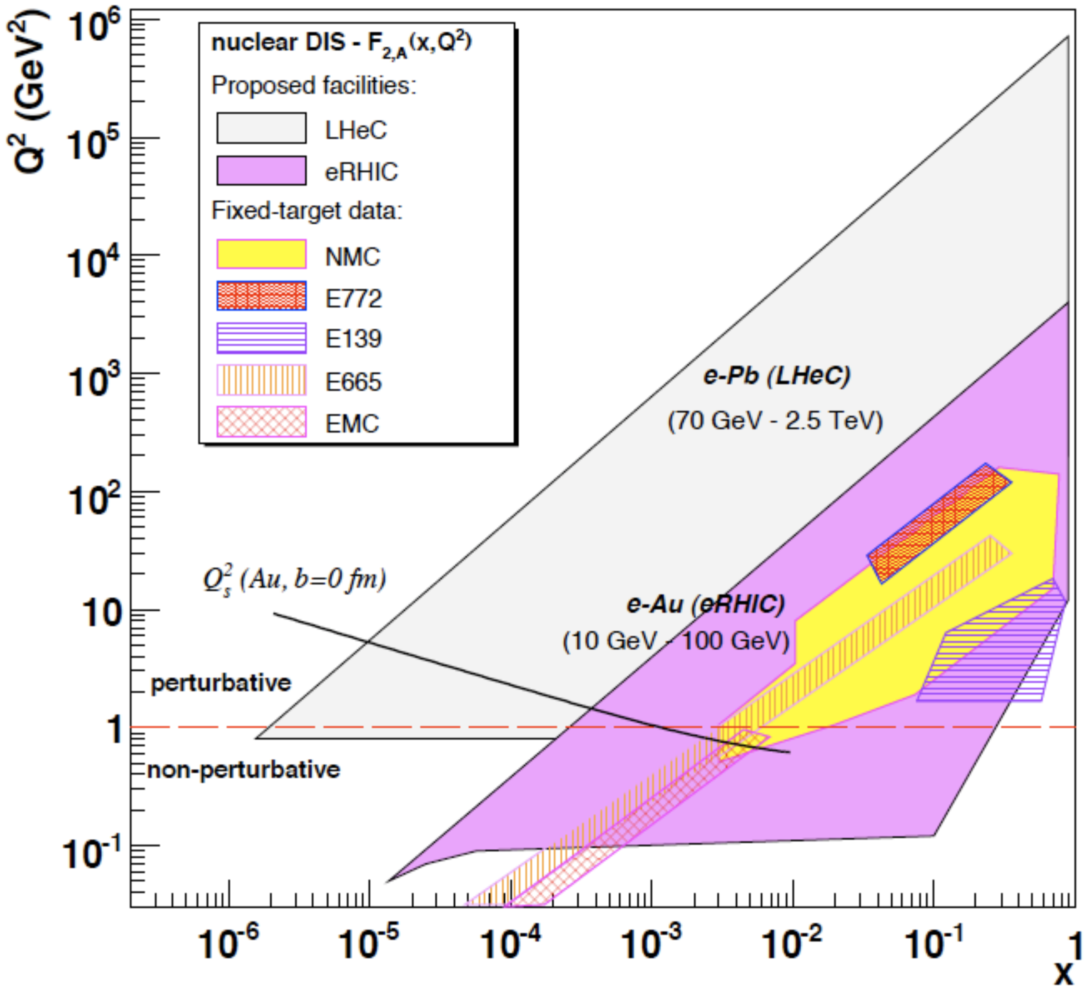
DIS tends to be lower than world average

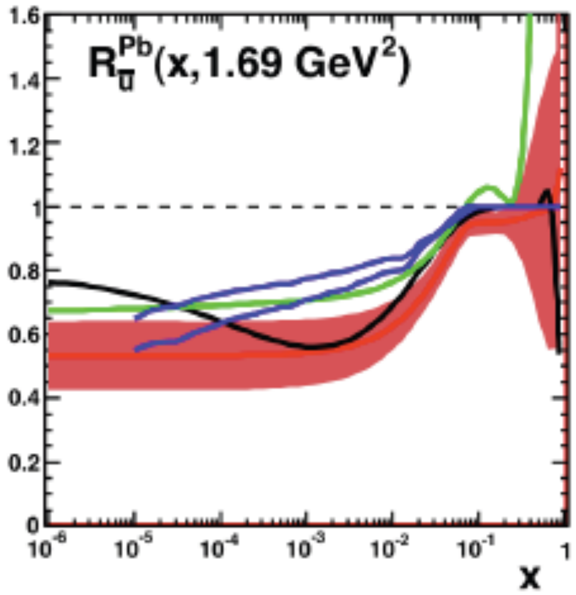
LHeC: per mille accuracy indep. of BCDMS.
Challenge to experiment and to h.o. QCD

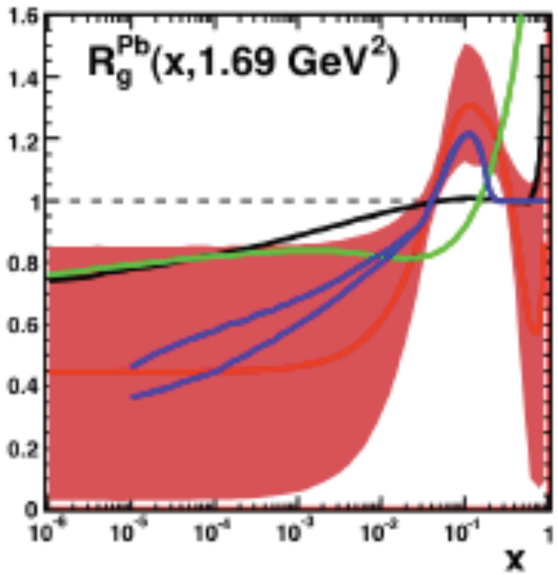


J.Bluemlein and H. Boettcher, arXiv 1005.3013 (2010)

eA → eX

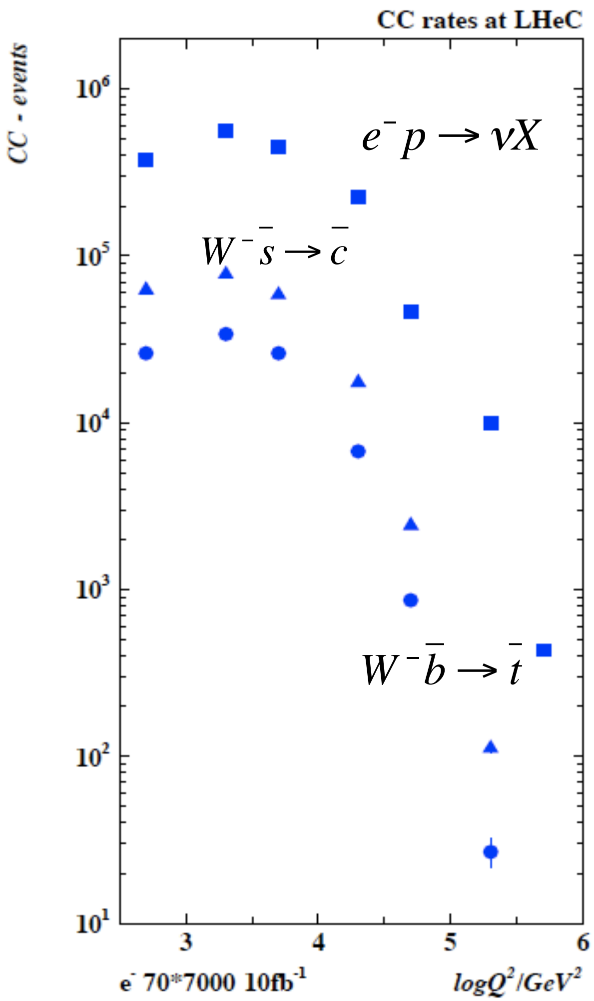


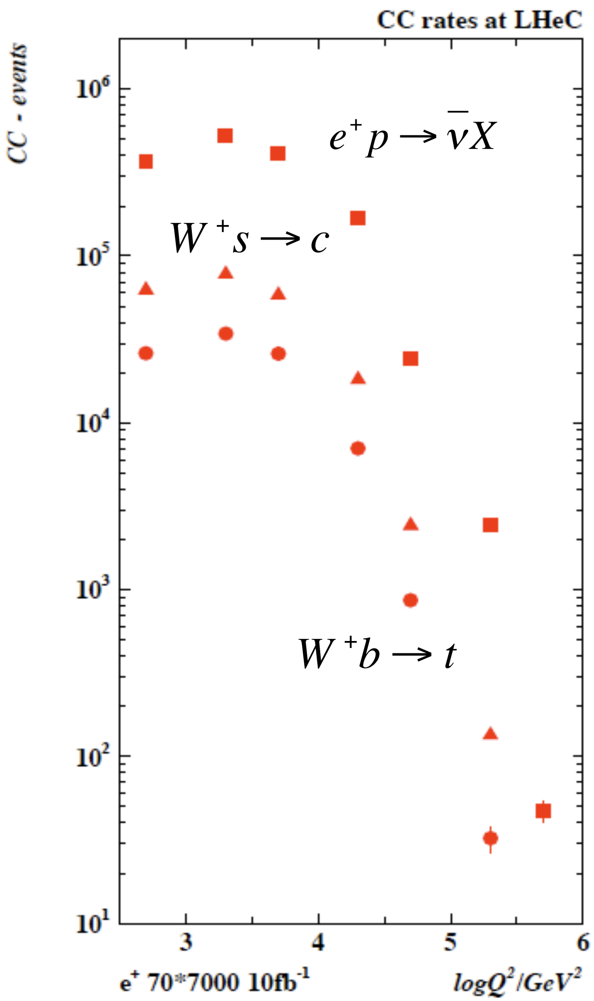


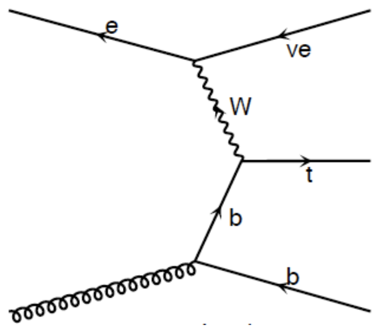


Extension of kinematic range by 3-4 orders of magnitude into saturation region (with p and A)
Like LHeC ep without HERA.. (e.g. heavy quarks in A)

Single top and anti-top Production in Charged Currents







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

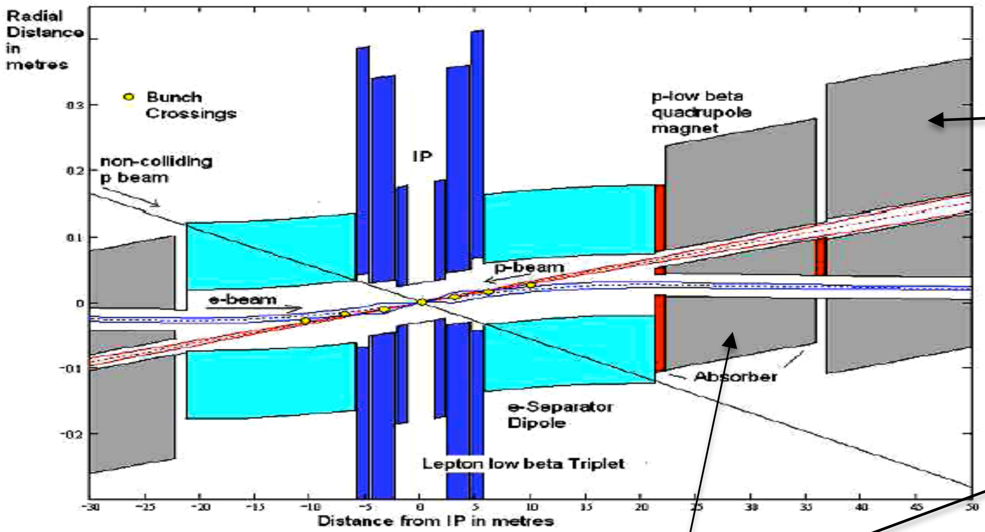
CC t cross section O(5)pb

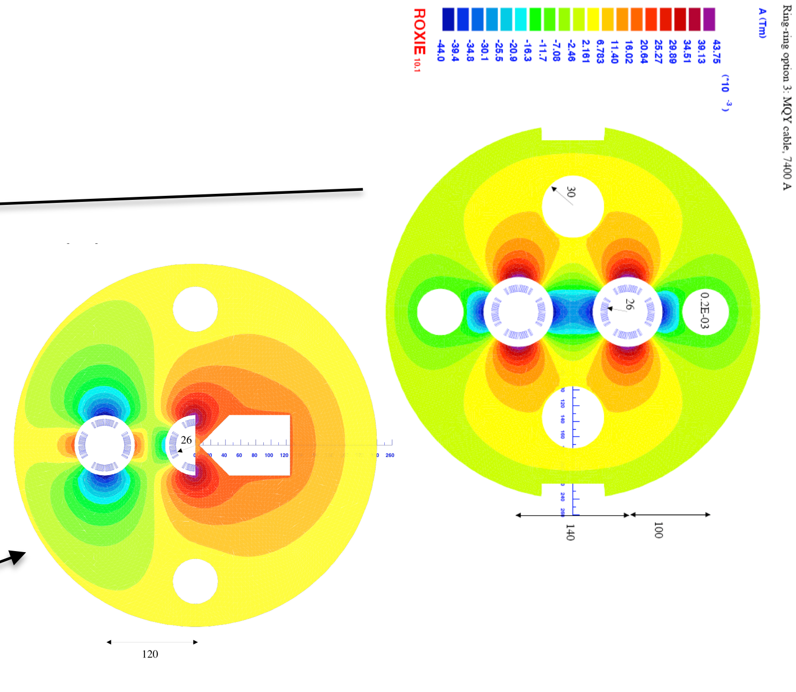
CC events for 10 fb^{-1}

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





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