LHeC

LHeC

- Design Considerations
- Two options: -Ring-Ri
- ...th Energy Recovery
- IR La...
- Plan...g and timeline

On behalf of the LHeC Collaboration!

➔ LHeC-Note-2011-003 GEN

Design Considerations

LHC hadron beams: E_p=7 TeV; CM collision energy: $E^2_{CM} = 4\ E_e * E_{p,A}$ → [illegible]GeV

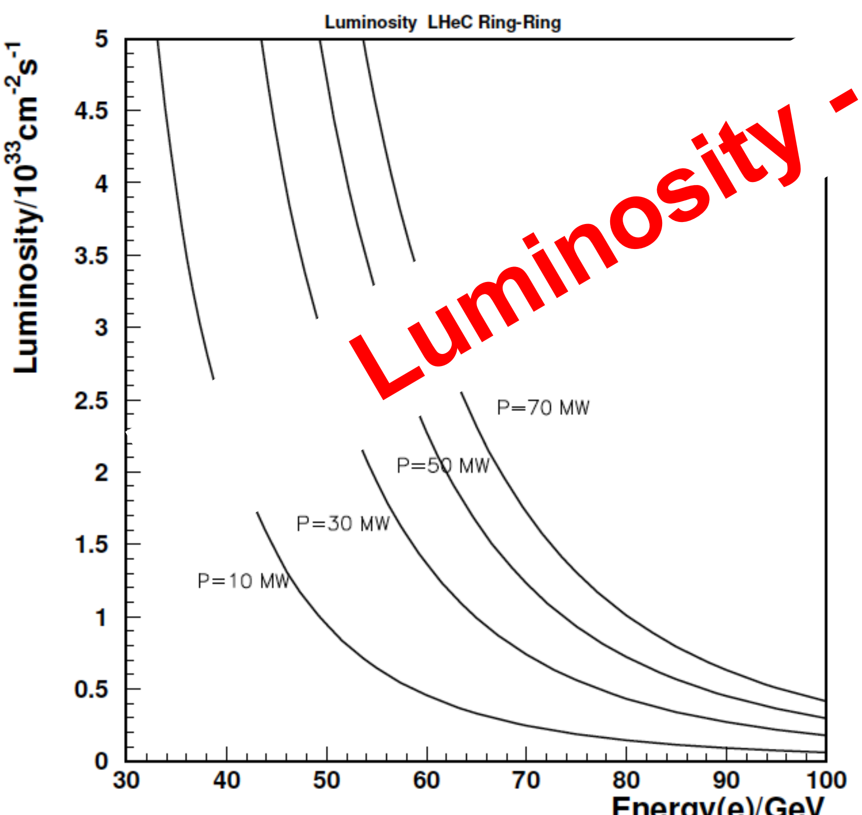
Integrated e±p : O(100) fb^{-1} ≈ 100 * L(HERA) → synchronous ep [illegible]

Luminosity O (10^{33}) $cm^{-2}s^{-1}$ with 100 MW power consumption [illegible] Power < 70 MW

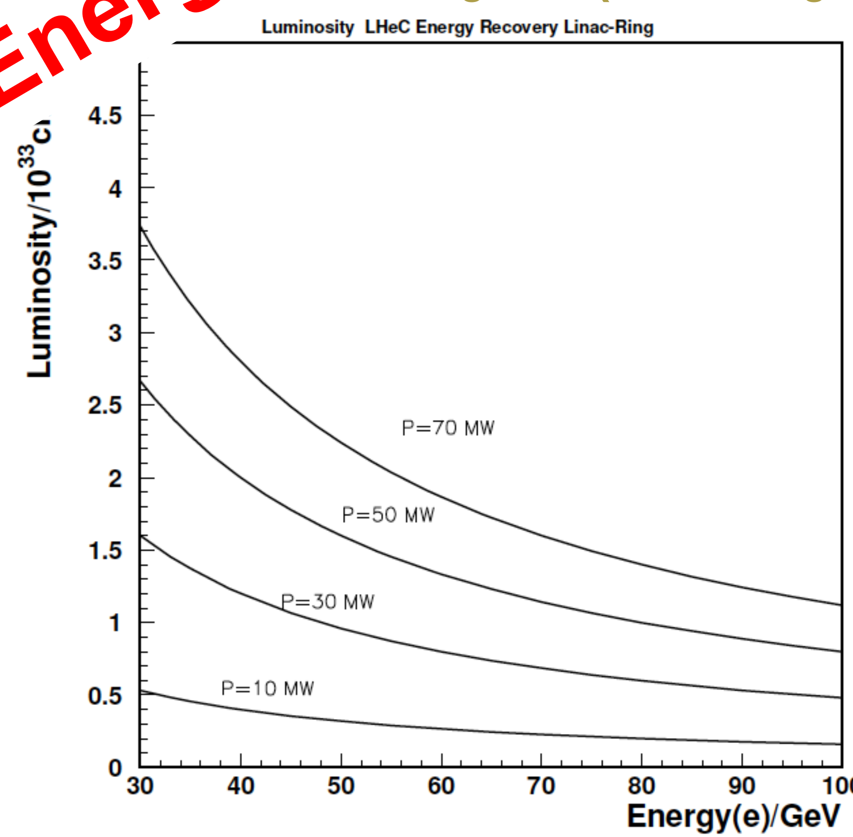
Start of LHeC operation together with HL-LHC in 20[illegible] [illegible] in LS3 in 2022)

Luminosity - Energy tradeoff

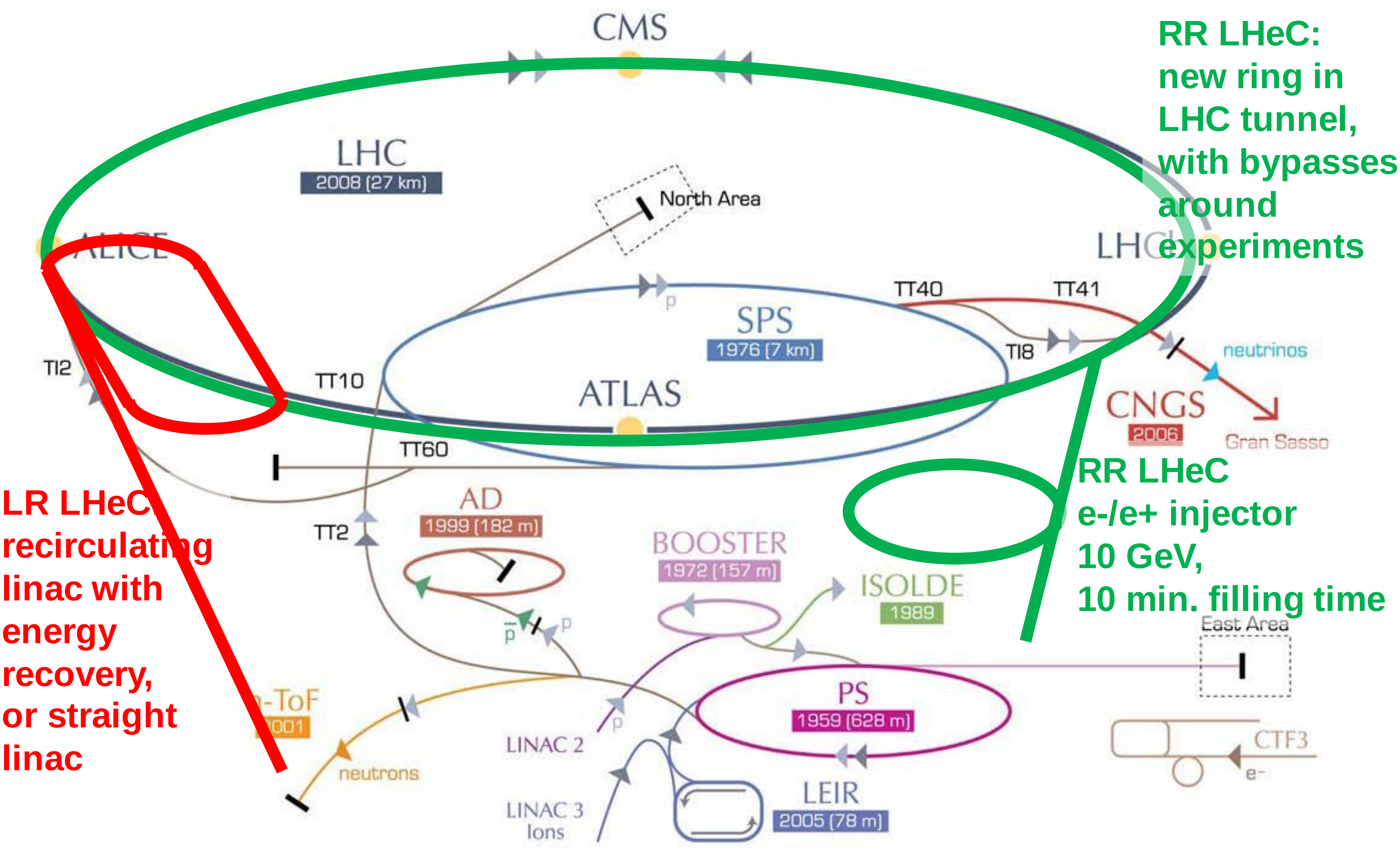
e Ring in the LHC tunnel (Ring-Ring - RR)



[illegible]conducting ERL (Linac-Ring -LR)

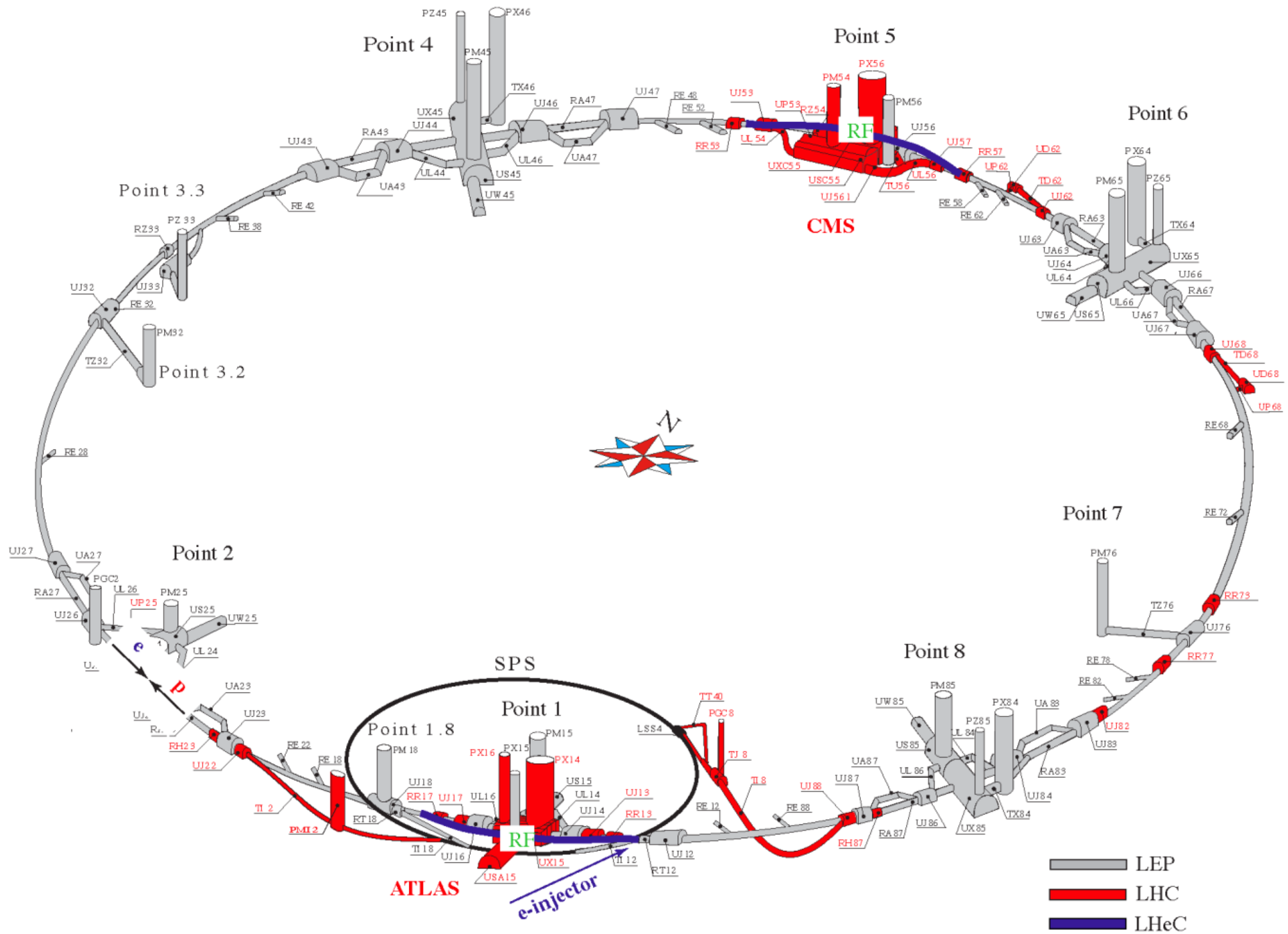


LHeC options: RR and LR

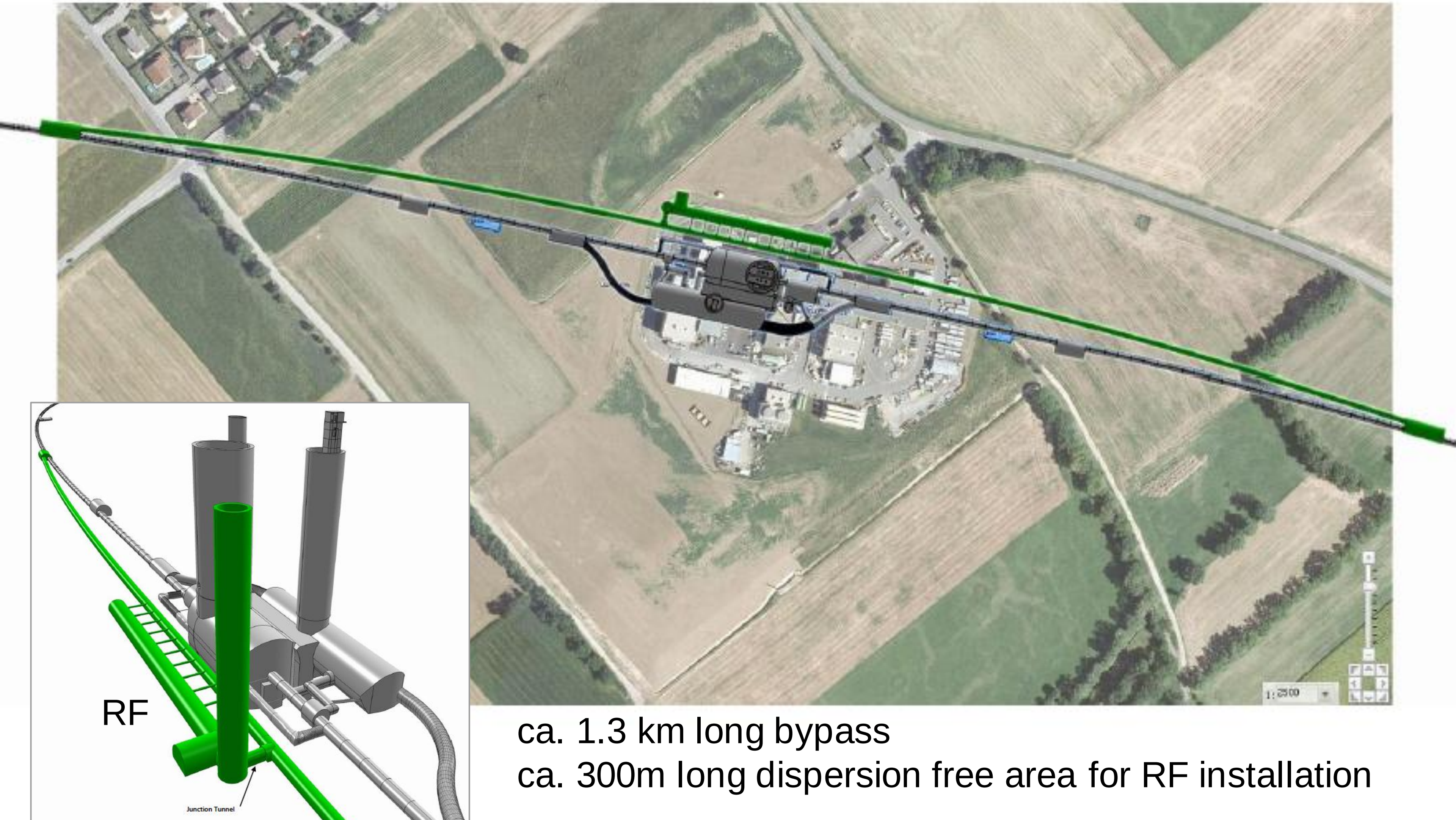


LHeC: Ring-Ring Option

- Challenge 1: Bypassing the main LHC detectors

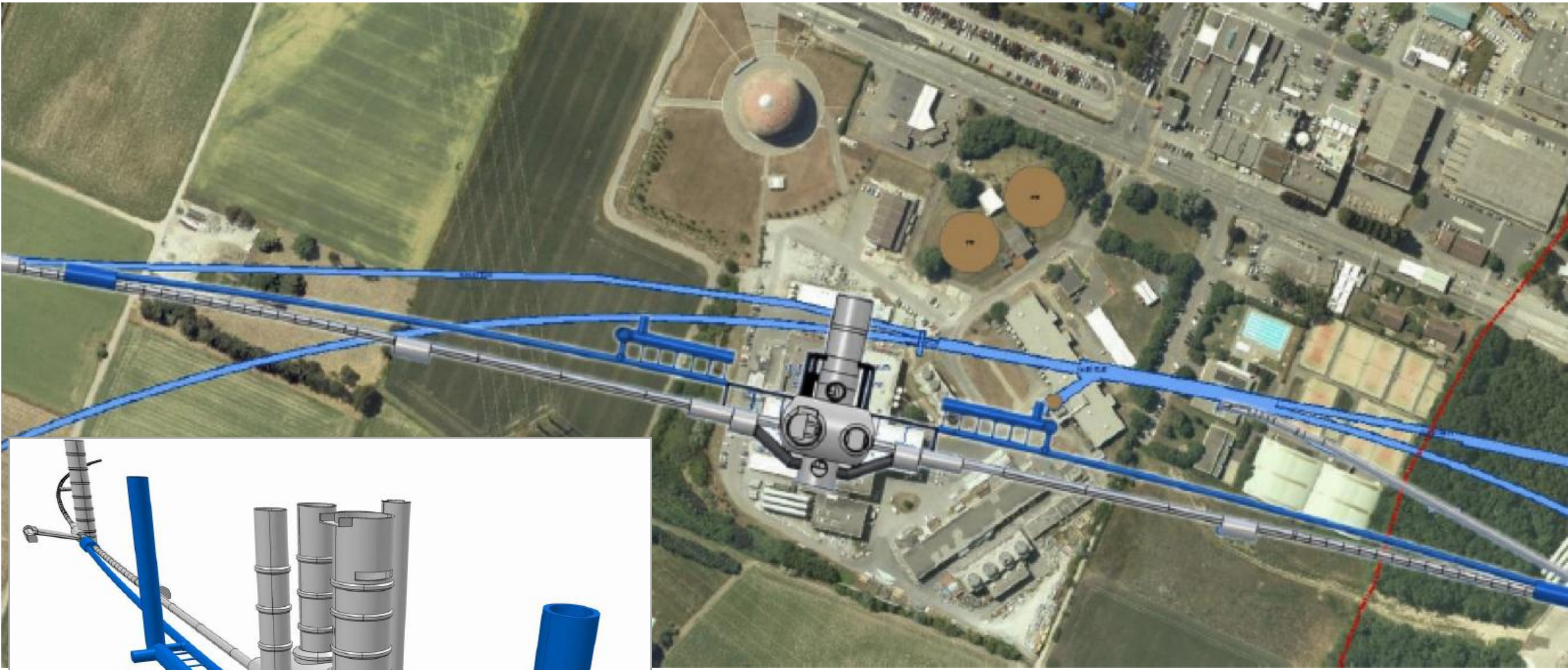


Bypassing CMS: 20m distance to Cavern



ca. 1.3 km long bypass
ca. 300m long dispersion free area for RF installation

Bypassing ATLAS: using the survey gallery



Without using the survey gallery the ATLAS bypass would need to be 100m away from the IP or on the inside of the tunnel!

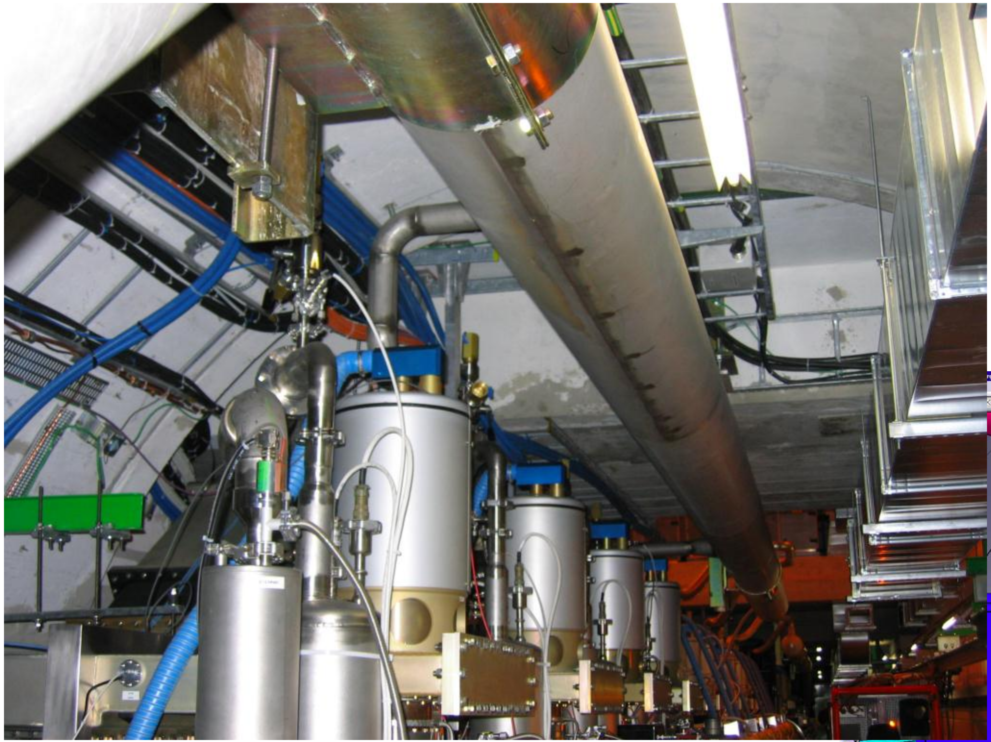
For the CDR the bypass concepts were decided to be confined to ATLAS and CMS

ca. 1.3 km long bypass

ca. 170m long dispersion free area for RF

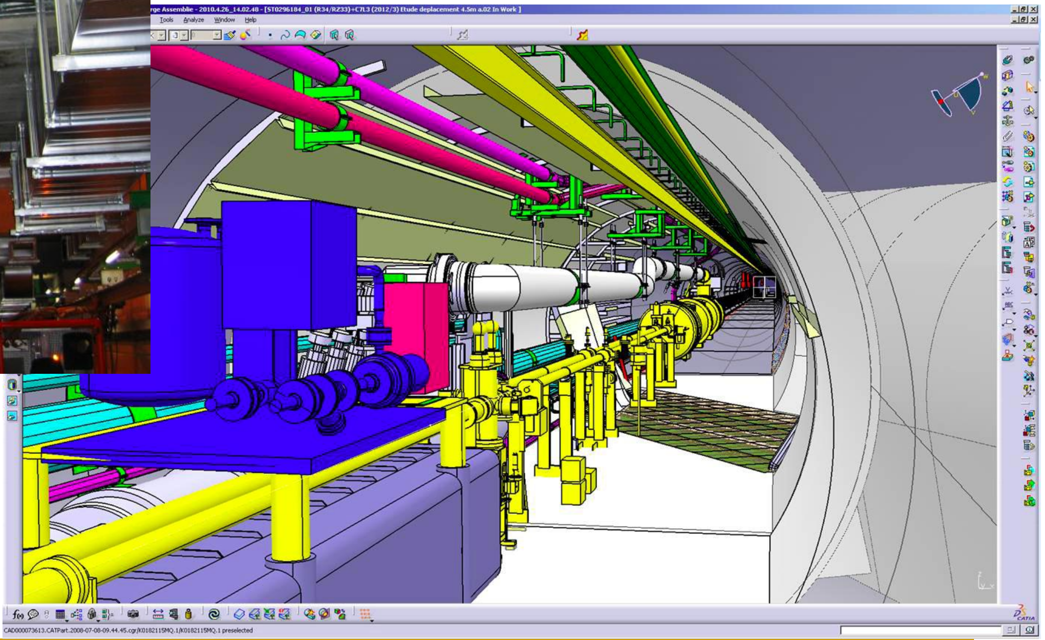
LHeC: Ring-Ring Option

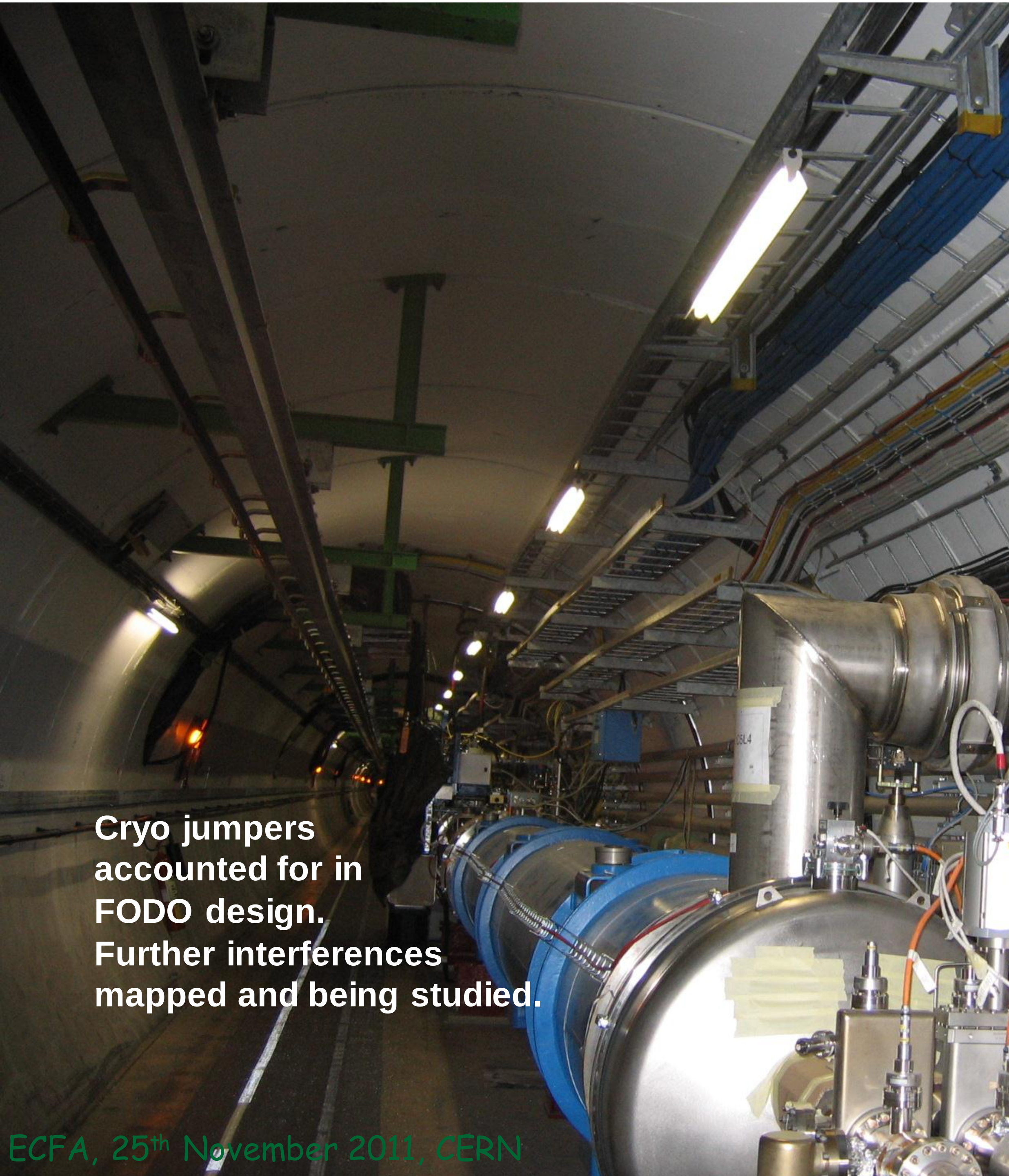
Challenge 2: Integration in the LHC tunnel



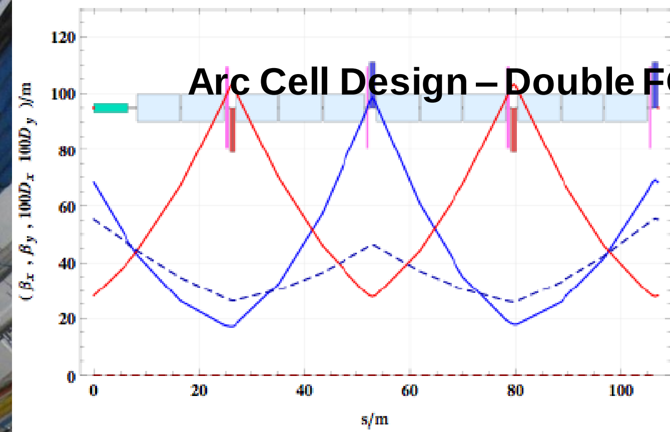
Cryo link in IR3

RF Installation in IR4





Arc Cell Design – Double FO



- No interference with LHC
- meets design parameters
- synchrotron radiation energy loss < 50 MW (maximum dipole filling)
- 2 quadrupoles families
- reasonable sextupole strength and length

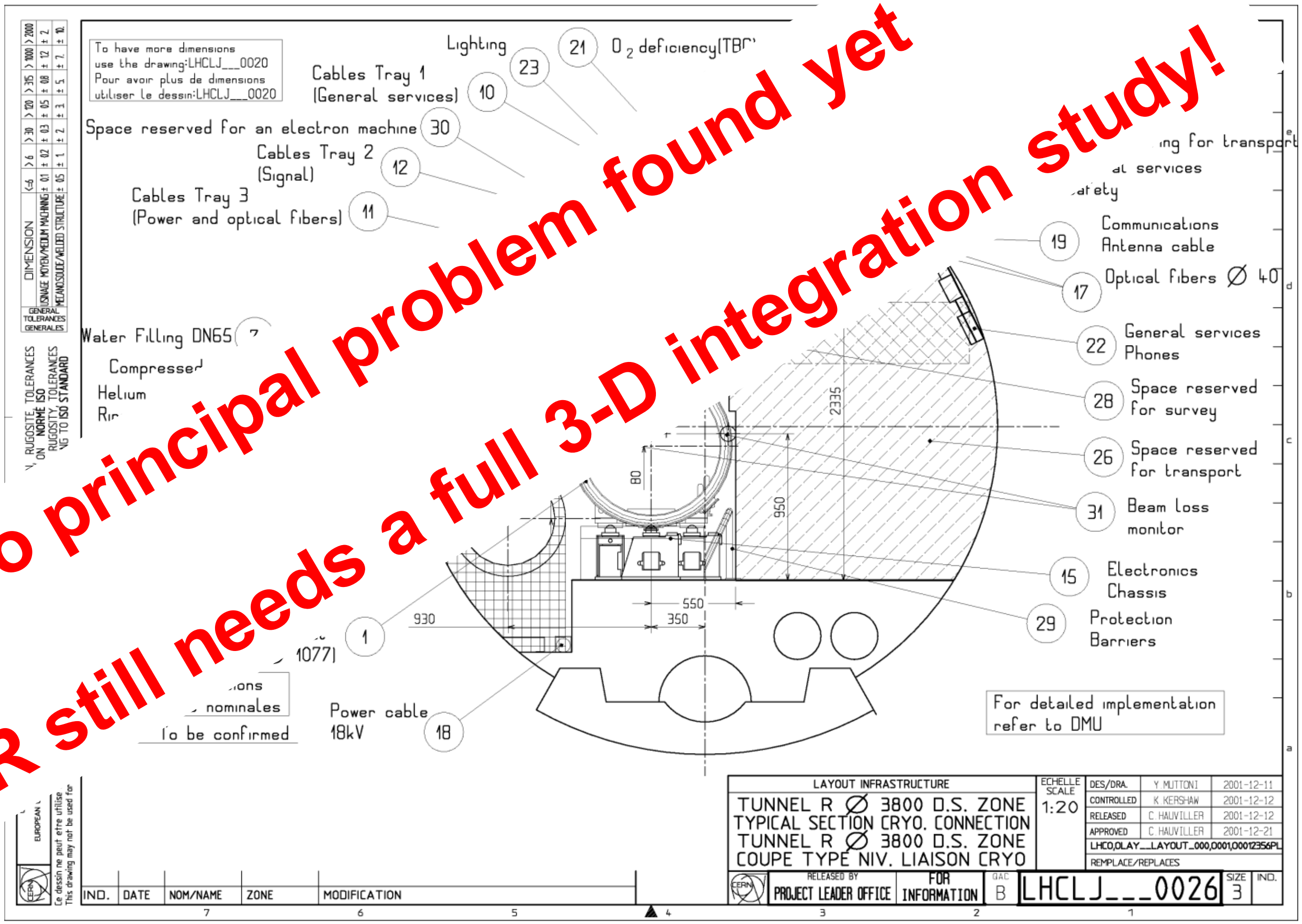
J.M. Jowett, LHeC Design Status, DIS2010, Florence, 22/4/2010

Cryo jumpers accounted for in FODO design. Further interferences mapped and being studied.

LHeC: Ring-Ring Option

Challenge 3: Installation with LHC circumfer...

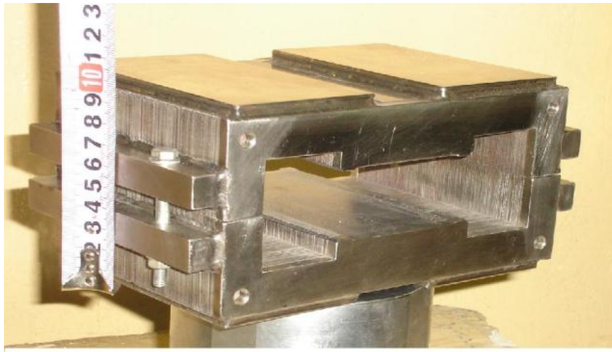
requires:
support
structure
with
efficient
montage
and

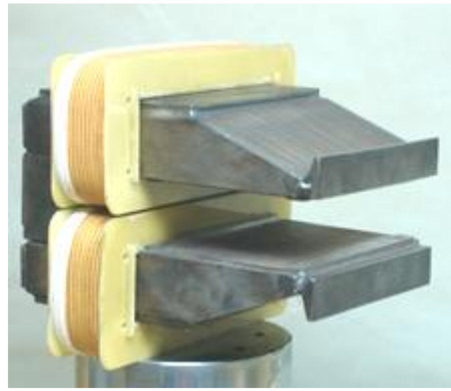


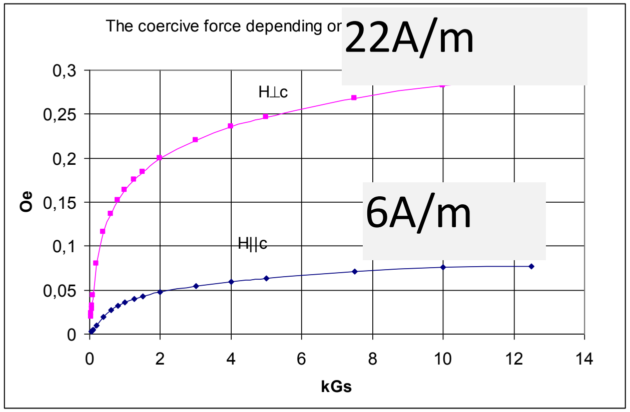
No principal problem found yet

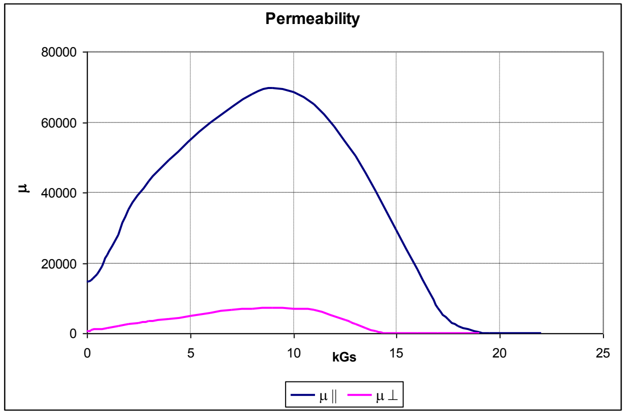
But RR still needs a full 3-D integration study!

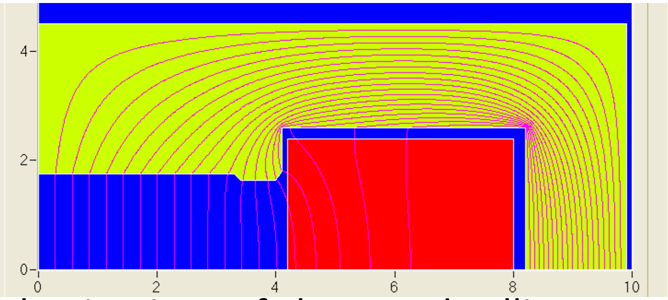
Dipole Prototype- BINP (Novosibirsk)



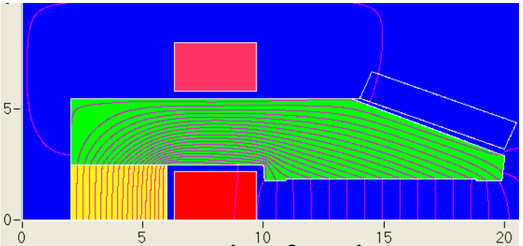








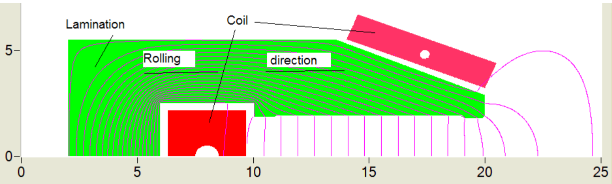
laminations of alternated rolling



same results for the two alternatives

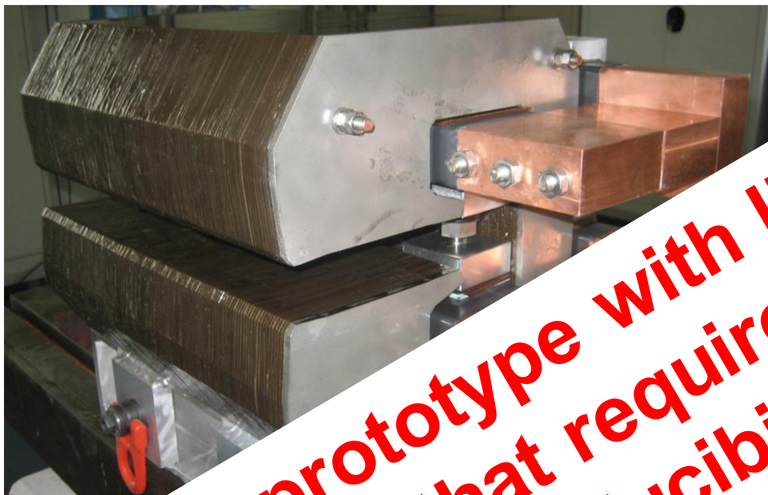
Reproducibility of injection field is below 0.1 Gauss!

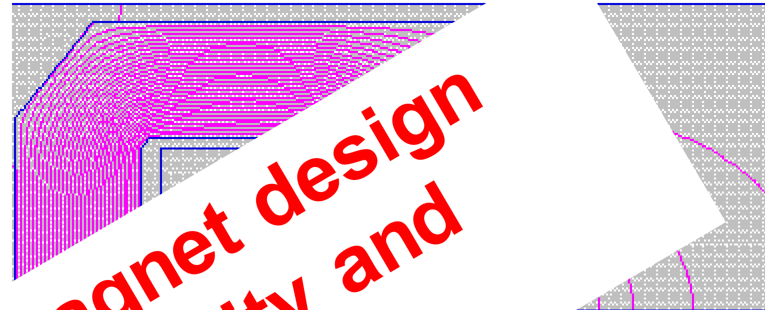
3408 grain oriented steel
0.35 mm thick laminations



LHeC Ring-Ring dipole 400 mm long CERN model

- interleaved ferromagnetic laminations
- air cooled
- two turns only, bolted bars
- 0.4 m models with different types of iron





[Davide Tommasini]

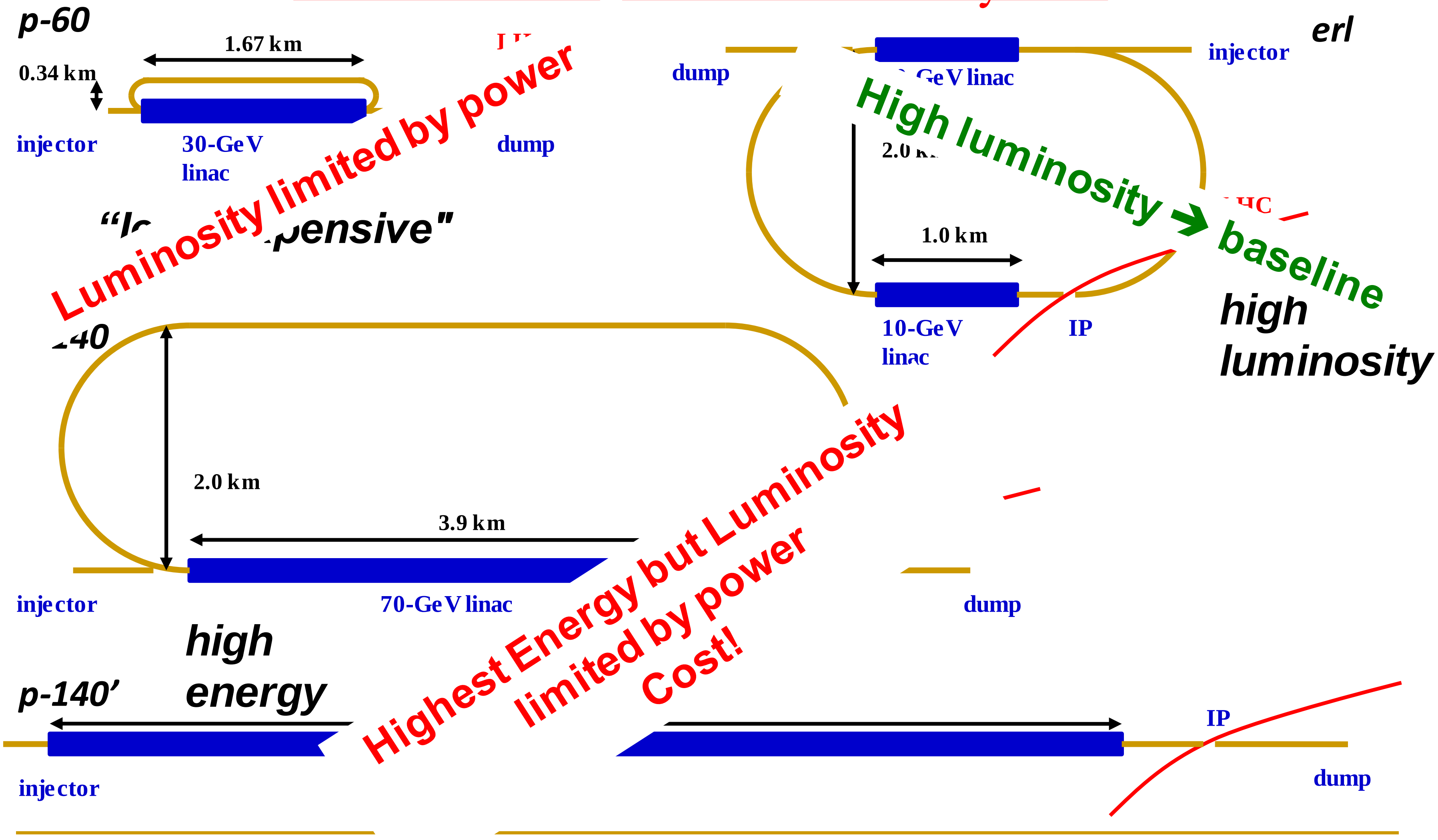
Long prototype with light magnet design shows that required field quality and reproducibility is feasible!

		High fields
Average		
	5·10^{-5}	4·10^{-5}
	6·10^{-5}	6·10^{-5}
…el)	4·10^{-5}	6·10^{-5}
…d Deviation from Average		
	3·10^{-5}	3·10^{-5}
…arbon steel)	4·10^{-5}	5·10^{-5}
N… …rain oriented 3.5% Si steel)	2·10^{-5}	4·10^{-5}

Manufacture & tests of 3 models

…ers of the full length magnet	
… [GeV]	70
… Length [m]	5.45
…gnetic field [Gauss]	127-763
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
Weight [tons]	1.5

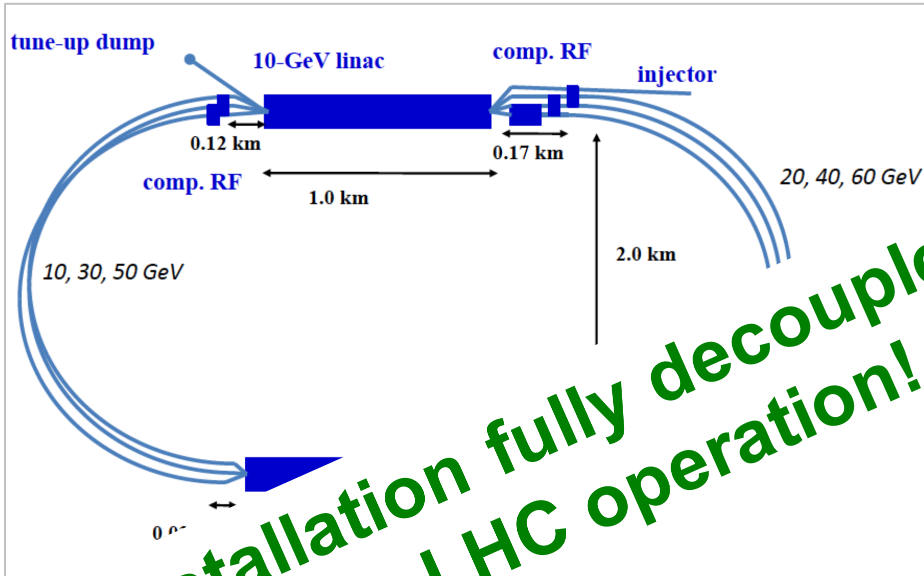
LHeC: Linac-Ring Option ➔ Considered Various Layout



LHeC: Baseline Linac-Ring Option

LHeC

- Challenge 1: Super Conducting Linac with Energy Recovery & high current (> 6mA)



Two 1 km long SC ... in CW operation ... 10)

Installation fully decoupled from LHC operation!

➔ requires Cryogenic system comparable to LHC system!

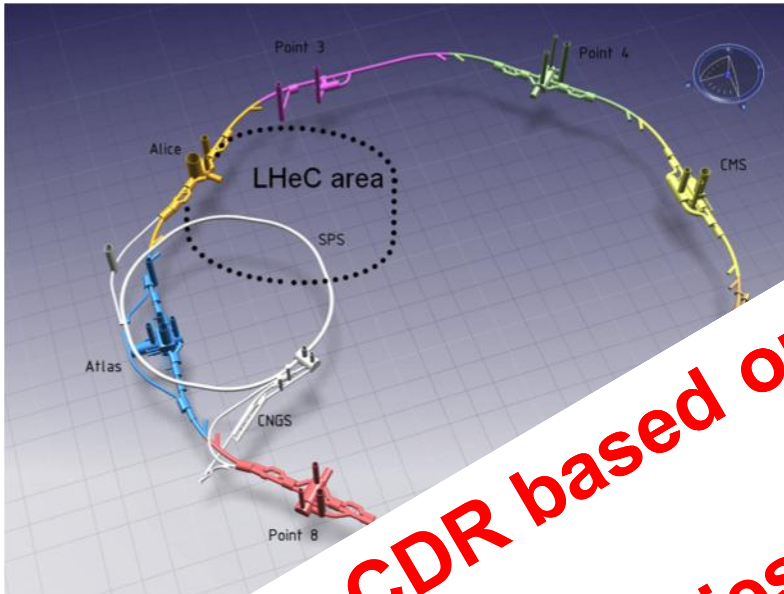
- Chal... Relatively large return arcs

➔ ca. 9 km underground tunnel installation

➔ total of 19 km bending arcs

➔ same magnet design as for RR option: > 4500 magnets

LINAC – Ring: connection to the L...



LHeC CDR based on 721 MHz cavity design

Synergies with ESS and SPL!

1.3 GHz also an option

synergies with TESLA-ILC technology

...ules per linac
...z, 21 MV/m CW
...milar to SPL, ESS, XFEL, ILC, eRHIC, Jlab
-24 - 39 MW RF power
-29 MW Cryo for 37W/m heat load
-4500 Magnets in the 2 * 3 arcs:
600 - 4m long dipoles per arc
240 - 1.2m long quadrupoles per arc

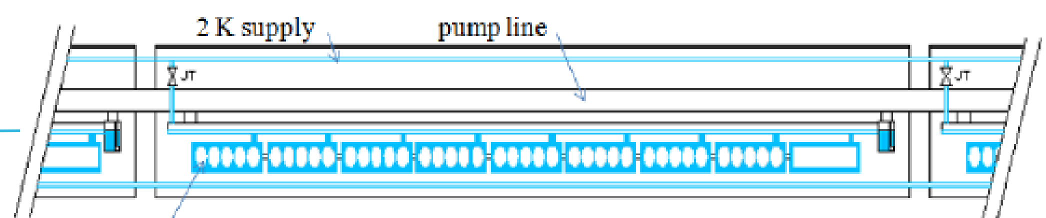
...ck)
... LHC for
...ss at CERN
...erritory
U=U(LHC)/3=9km

9 System Design
9.1 Magnets for the Interaction Region . . . . .
9.1.1 Introduction . . . .
9.1.2 Magnets for the ring-ring option . .
9.1.3 Magnets for the linac-ring option . .
9.2 Accelerator Magnets . . . .
9.2.1 Dipole Magnets . . . .
9.2.2 BINP Model . . . .
9.2.3 CERN Model . . . .
9.2.4 Quadrupole and Corrector Magnets
9.3 Ring-Ring RF Design . . . .
9.3.1 Design Parameters . . . .
9.3.2 Cavities and klystrons . . . .

9.4 Linac-Ring RF Design . . . .
9.4.1 Design Parameters . . . .
9.4.2 Layout and RF powering . . . .
9.4.3 Arc RF systems . . . .
9.5 Crab crossing for the LHeC . . . .
9.5.1 Luminosity Reduction . . . .
9.5.2 Crossing Schemes . . . .
9.5.3 RF Technology . . . .
9.6 Vacuum . . . .
9.6.1 Vacuum requirements . . . .
9.6.2 Synchrotron radiation . . . .
9.6.3 Vacuum engineering issues . . . .
9.7 Beam Pipe Design . . . .
9.7.1 Requirements . . . .
9.7.2 Choice of Materials for beampipes . . . .
9.7.3 Beampipe Geometries . . . .
9.7.4 Vacuum Instrumentation . . . .
9.7.5 Synchrotron Radiation Masks . . . .
9.7.6 Installation and Integration . . . .
9.8 Cryogenics . . . .
9.8.1 Ring-Ring Cryogenics Design . . . .
9.8.2 Linac-Ring Cryogenics Design . . . .
9.8.3 General Conclusions Cryogenics for LHeC . . . . . .
9.9 Beam Dumps and Injection Regions . . . .
9.9.1 Injection Region Design for Ring-Ring Option . . . .
9.9.2 Injection transfer line for the Ring-Ring Option . . .
9.9.3 60 GeV internal dump for Ring-Ring Option . . . .
9.9.4 Post collision line for 140 GeV Linac-Ring option . .
9.9.5 Absorber for 140 GeV Linac-Ring option . . . . . .
9.9.6 Energy deposition studies for the Linac-Ring option
9.9.7 Beam line dump for ERL Linac-Ring option . . . . .
9.9.8 Absorber for ERL Linac-Ring option . . . .

Table 2: Components of the Electron Accelerators

	Ring	Linac
magnets		
beam energy	60 GeV	
number of dipoles	3080	3600
dipole field [T]	0.013 – 0.076	0.046 – 0.264
total nr of quads	866	1588
RF and cryogenics		
number of cavities	112	944
gradient [MV/m]	11.9	20
RF power [MW]	49	39
cavity voltage [MV]	5	21.2
cavity R/Q [Ω]	114	285
cavity Q_0	–	$2.5\ 10^{10}$
cooling power [kW]	5.4@4.2 K	30@2 K



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

from CDR LHeC

Interaction Region: Accommodatin ns

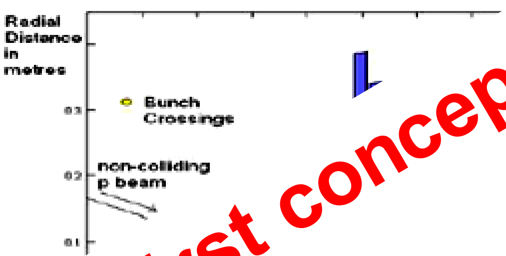
Small crossing angle of about 1mrad to avoid 77)
(Dipole in detector? Crab cavities? Desi
 Synchrotron radiation –direct and b .)

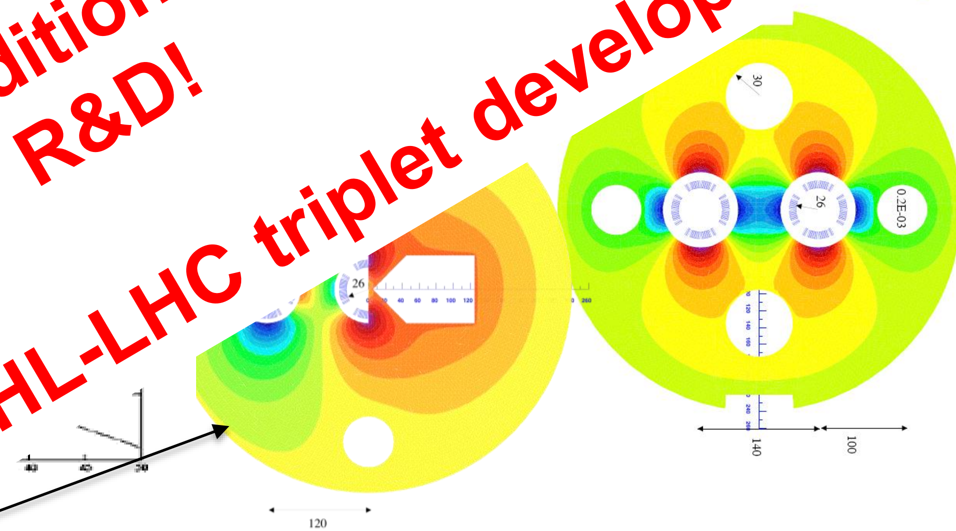
Focus of current activity

First conceptual SC magnet designs exist

But still requires additional design work and R&D!

Synergies with HL-LHC triplet development?



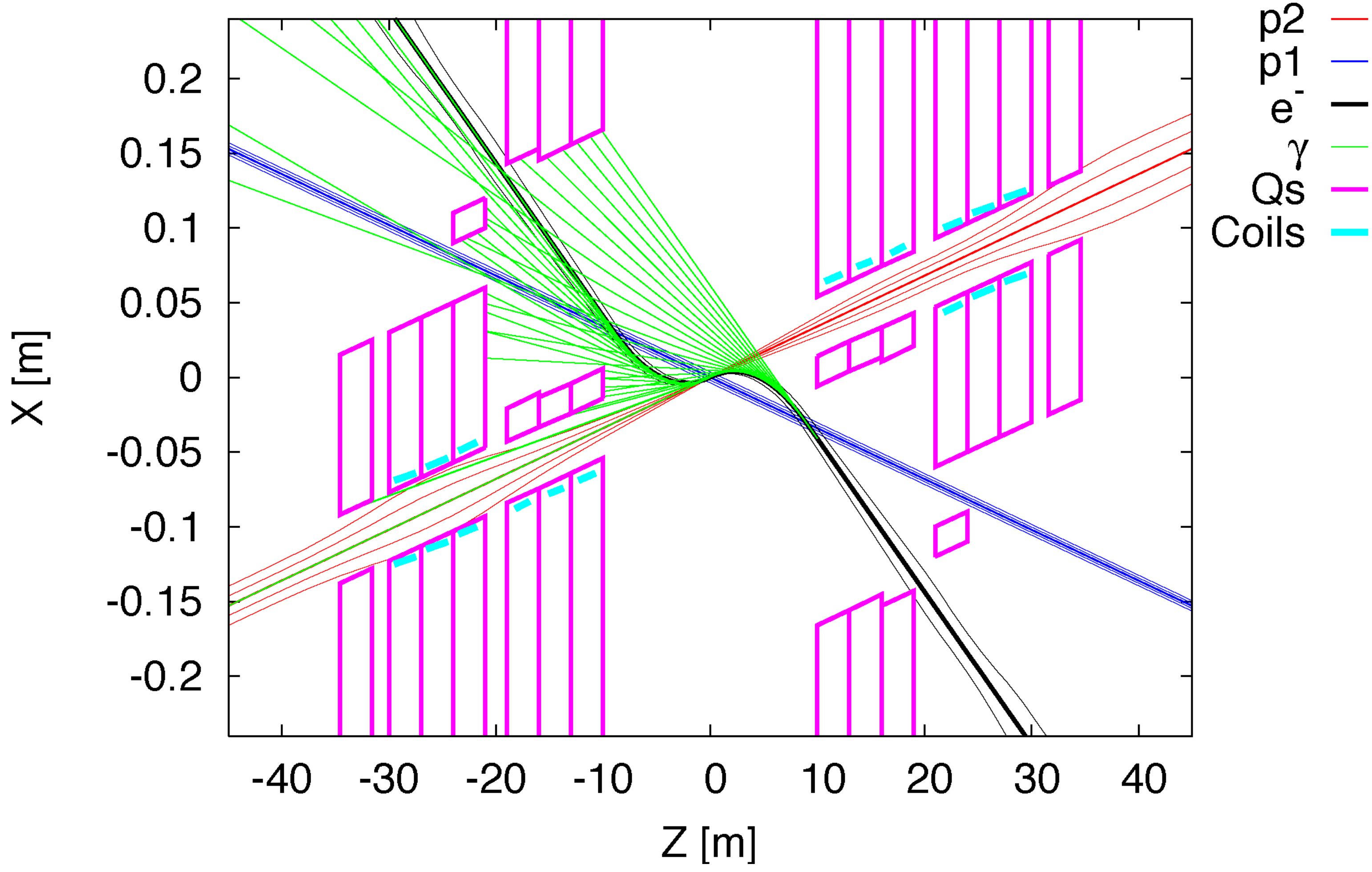


1st d deflect)
sepa n, MQY cables, 4600 A

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

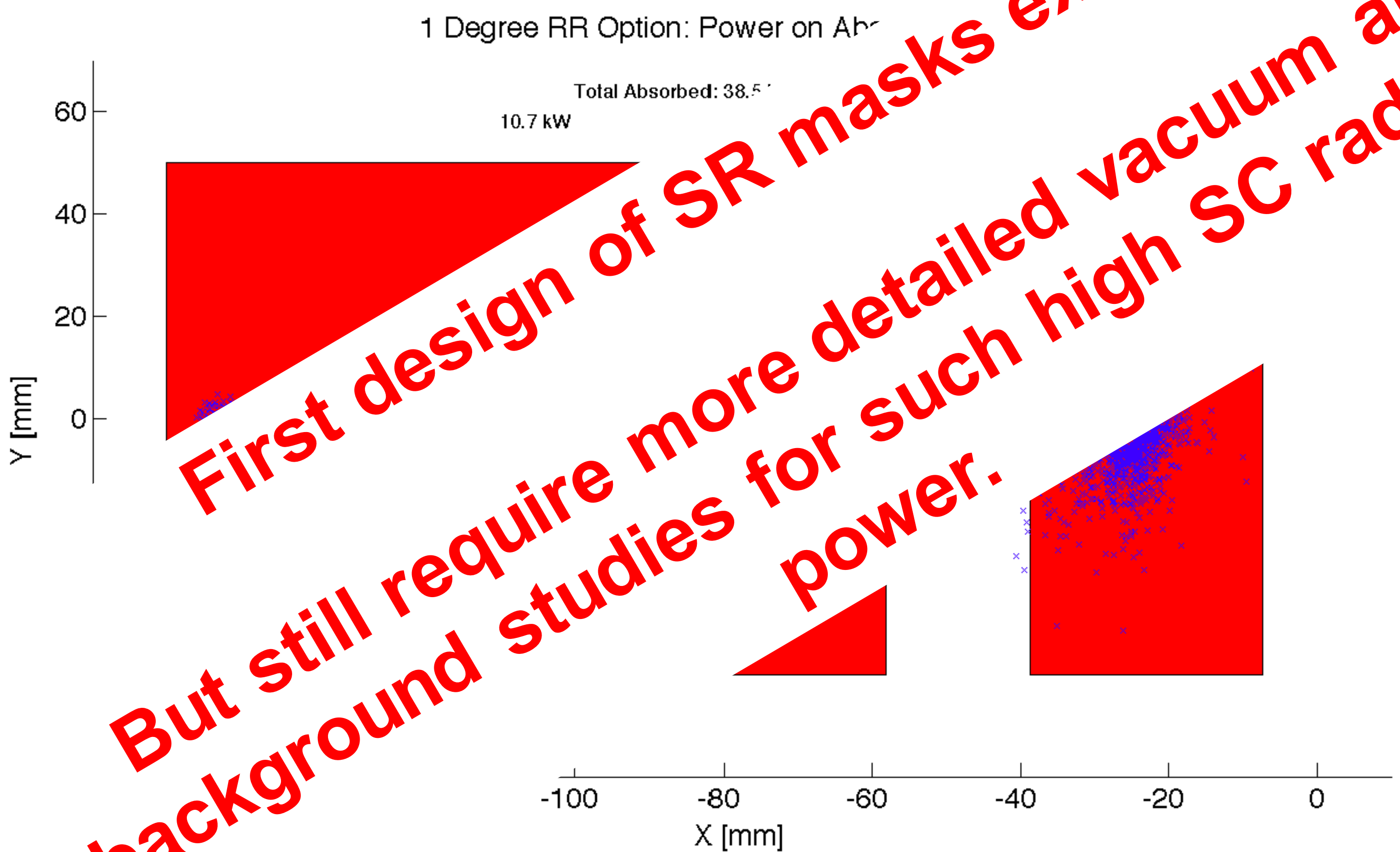
Interaction Region: Synchrotron Radiation

Radiation Fan: Example Linac-Ring



Interaction Region: Synchrotron R... tion

Significant power: > 20 kW. Example Ring-Ring



First design of SR masks exists.

But still require more detailed vacuum and background studies for such high SC radiation power.

Design Parameters

electron beam	RR	LR	LR*
e- energy at IP[GeV]	60	60	140
luminosity [10^{32} $cm^{-2}s^{-1}$]	17	10	[illegible]
polarization [%]	40	90	[illegible]
bunch population [10^9]	26	[illegible]	[illegible]
e- bunch length [mm]	1[illegible]	[illegible]	[illegible]
bunch interval [ns]	[illegible]	[illegible]	[illegible]
transv. emit. $\gamma\varepsilon_{x,y}$ [m[illegible]	[illegible]	[illegible]	[illegible]
rms IP beam si[illegible]	[illegible]	[illegible]	[illegible]
e- IP beta [illegible]	[illegible]	[illegible]	[illegible]
full [illegible]	[illegible]	[illegible]	[illegible]
ge[illegible]	[illegible]	[illegible]	[illegible]
repe[illegible]	[illegible]	[illegible]	[illegible]
beam [illegible]	[illegible]	[illegible]	5
ER effic[illegible]	[illegible]	[illegible]	N/A
average cu[illegible]	[illegible]	6.6	5.4
tot. wall plu[illegible]	[illegible]0	100	100

[illegible]	[illegible]R	LR
[illegible]	[illegible]	1.7
[illegible]	[illegible]	3.75
[illegible]	[illegible]	7
[illegible]	[illegible]	1

Final parameter set to be developed as we gain experience with LHC operational (beam-beam, spacing etc)

The goal here is to demonstrate that realistic sets exist for both LHeC versions

[illegible]servative

[illegible] also for deuterons [illegible]w) and lead (exists)

RR= Ring – Ring
LR =Linac –Ring

Ring uses 1° as baseline : L/2
Linac: clearing gap: L*2/3

[illegible]) pulsed, but high energy ERL not impossible

Disclaimer:

- Very short summary of CDR with ca. 500 pages:
  -Many topics could not be covered here:

Accelerator:

Sources
Damping rings and injector complex
Injection and injector complex
Collective effects and Beam-Beam
Cryogenic system
Polarization
Beam Dump
Vacuum
Power generation and distribution, etc…..

➔ LHeC-Note-2011-003 GEN

LHeC Planning and Timeline

- We assume the LHC will reach end of its lifetime with the end of the HL-LHC project:

  -Goal of integrated luminosity of 3000 fb^{-1} with 200fb^{-1} to 300fb^{-1} production per year ➔ ca. 10 years of HL-LHC operation

  -Current planning based on HL-LHC start in 2022

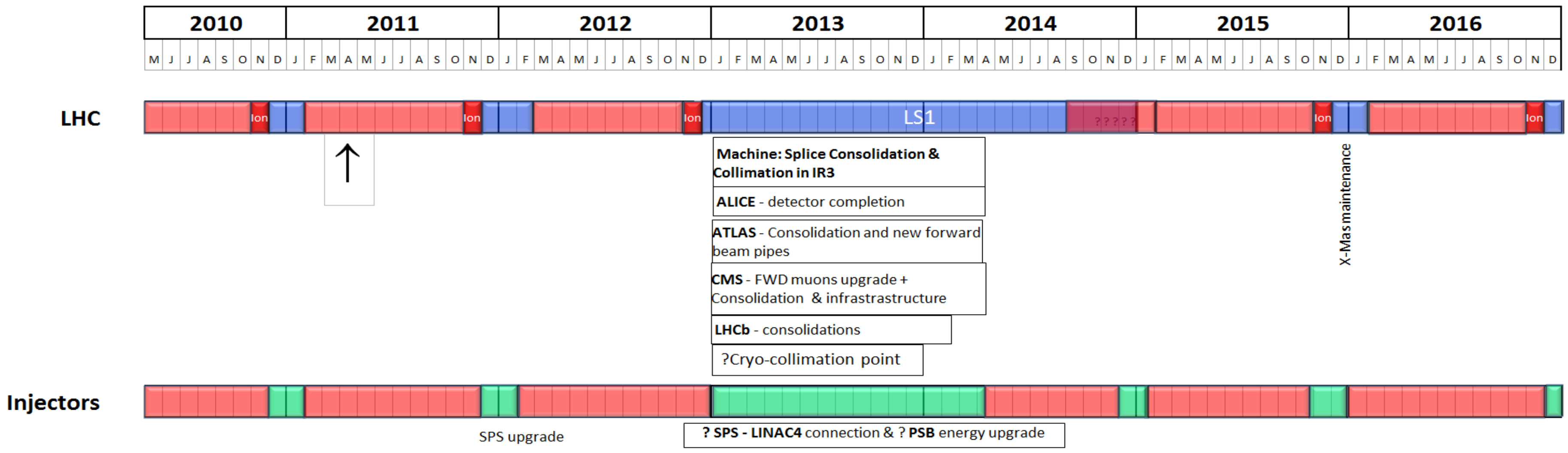
  ➔ end of LHC lifetime by 2032 to 2035

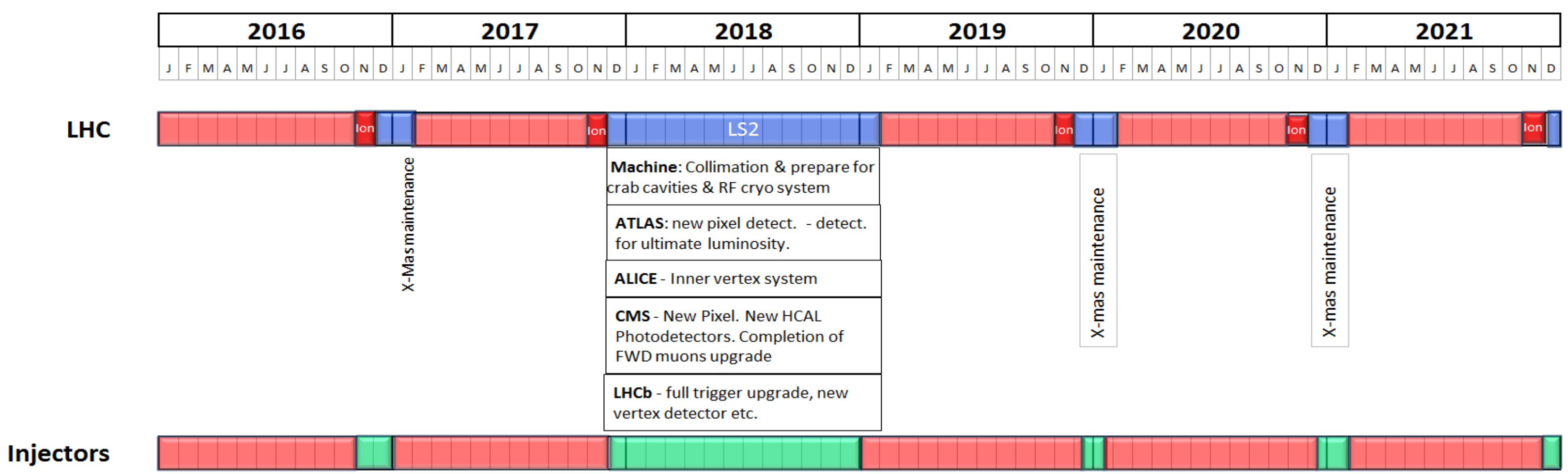
- LHeC operation:

  -Luminosity goal based on ca. 10 year exploitation time (100fb^{-1})

  -LHeC operation beyond or after HL-LHC operation will imply significant operational cost overhead for LHC consolidation

New rough draft 10 year plan





2022

LS3

Installation of the HL-LHC hardware

Installation of LHeC

Preparation for HE-LHC

LHeC Options: Executive Su…

Ring-Ring option:

-We know we can do it: ➔ LEP

-Challenge 1: integration … V

-Challenge 2: ins…

Lin…

…tion and shutdown planning

…otential exploitation beyond LHeC

-C… …ogy ➔ high current SC ERL

-Cha… …ron source

CDR is currently reviewed by Expert Panel

The goal is to identify the best option for the LHeC by the beginning of 2012

LHeC Planning and Timeline

LHeC

CERN Medium Term Plan:

-Only 2 long shutdowns planned before 2022

-Only 10 years for the LHeC from CDR to project start (other smaller projects like ESS and PSI XFEL plan for 8 to 9 years [TDR to project start] and the EU XFEL plans for 5 years from construction to operation start)

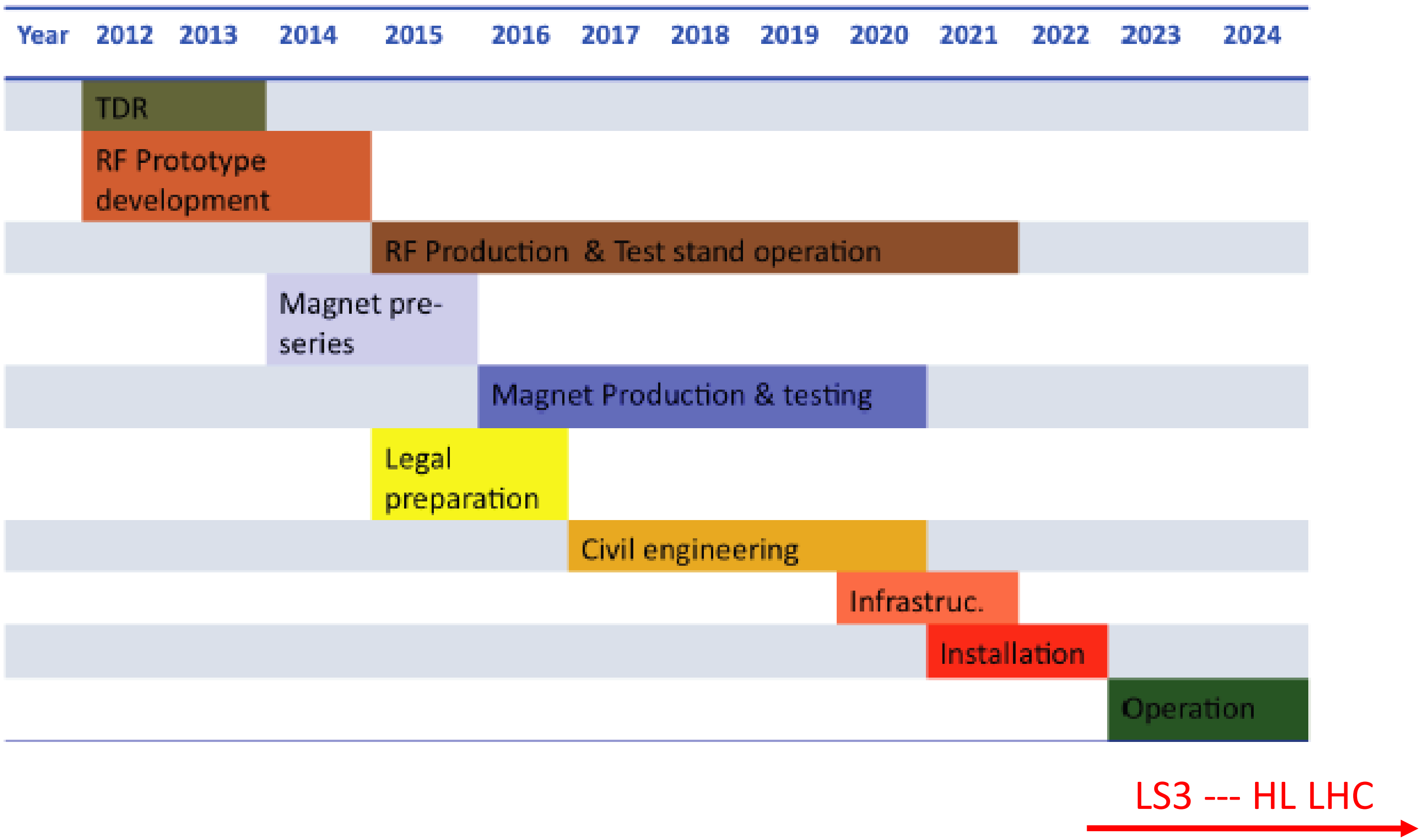
LHeC planning:

-Need to start R&D work as soon as possible

-Need to develop detailed TDR after feedback from review panel

➔ concentrate future effort on only one option

LHeC Tentative Time Schedule



We base our estimates for the project time line on the experience of other projects, such as (LEP, LHC and LINAC4 at CERN and the European XFEL at DESY and the PSI XFEL)

LHeC Planning and Timeline

LHeC

R&D activities:

-Superconducting RF with high Q ➔ 1.3 GHz versus 720 MHz?

-Normal conducting compact magnet design ✔

-Superconducting IR magnet design

➔ synergy with HL-LHC triplet magnet development

-Test facility for Energy recovery operations and – or compact injector complex

-High intensity polarized positron sources

Reserve Transparencies

LHeC - Participating Institutes: A very rich collaboration

LHeC

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

ANKARA ÜNİVERSİTESİ 1946

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

This image cannot currently be displayed.

This image cannot currently be displayed.

KEK

LHeC organisation

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) Inst
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 Conveners

Accelerator Design [RR and LR]
Oliver Bruening (CERN),
Max Klein (Liverpool)
Interaction Region and Fwd/Bwd
Bernhard Holzer (DESY),
Uwe Schneekloth (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)

Review Panel with experts on physics, detector, accelerator, specific systems

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

CDR Authorlist 05.8.2011

C. Adolphsen (SLAC)
S. Alekhin (Serpukhov, DESY)
A.N.Akai (Ankara)
H. Aksakal (CERN)
P. Allport (Liverpool)
J.L. Albacete (IPhT Saclay)
V. Andreev (LPI Moscow)
R. Appleby (Cockcroft)
N. Armesto (St. de Compostela)
G. Azuelos (Montreal)
M. Bai (BNL)
D. Barber (DESY)
J. Bartels (Hamburg)
J. Behr (DESY)
O. Behnke (DESY)
S. Belyaev (CERN)
I. Ben Zvi (BNL)
N. Bernard (UCLA)
S. Bertolucci (CERN)
S. Biswal (Orissa)
S. Bettoni (CERN)
J. Bluemlein (DESY)
H. Boettcher (DESY)
H. Braun (PSI)
S. Brodsky (SLAC)
A. Bogacz (Jlab)
C. Bracco (CERN)
O. Bruening (CERN)
E. Bulyak (Charkov)
A. Bunyatian (DESY)
H. Burkhardt (CERN)
I.T. Cakir (Ankara)
O. Cakir (Ankara)
R. Calaga (BNL)
E. Ciapala (CERN)
R. Ciftci (Ankara)
A.K.Ciftci (Ankara)
B.A. Cole (Columbia)
J.C. Collins (Penn State)
J. Dainton (Liverpool)
A. De Roeck (CERN)
D. d'Enterria (CERN)
A. Dudarev (CERN)
A. Eide (NTNU)
E. Eroglu (Uludag)
K.J. Eskola (Jyvaskyla)
L. Favart (IIHE Brussels)
M. Fitterer (CERN)
S. Forte (Milano)
P. Gambino (Torino)
T. Gehrmann (Zurich)
C. Glasman (Madrid)
R. Godbole (Tata)
B. Goddard (CERN)
T. Greenshaw (Liverpool)
A. Guffanti (Freiburg)
V. Guzey (Jefferson)
C. Gwenlan (Oxford)
T. Han (Harvard)
Y. Hao (BNL)
F. Haug (CERN)
W. Herr (CERN)
B. Holzer (CERN)
M. Ishitsuka (Tokyo I.Tech.)
M. Jacquet (Orsay, LAL)
B. Jeanneret (CERN)
J.M. Jimenez (CERN)
H. Jung (DESY)
J. Jowett (CERN)
H. Karadeniz (Ankara)
D. Kayran (BNL)
F. Kosac (Uludag)
A. Kilic (Uludag}
K. Kimura (Tokyo I.Tech.)
M. Klein (Liverpool)
U. Klein (Liverpool)
T. Kluge (Hamburg)
G. Kramer (Hamburg)
M. Korostelev (Cockcroft)
A. Kosmicki (CERN)
P. Kostka (DESY)
H. Kowalski (DESY)
D. Kuchler (CERN)
M. Kuze (Tokyo I.Tech.)
T. Lappi (Jyvaskyla)
P. Laycock (Liverpool)
E. Levichev (BINP)
S. Levonian (DESY)
V.N. Litvinenko (BNL)
A.Lombardi (CERN)
C. Marquet (CERN)
B. Mellado (Harvard)
K-H. Mess (CERN)
S. Moch (DESY)
I.I. Morozov (BINP)
Y. Muttoni (CERN)
S. Myers (CERN)
S. Nandi (Montreal)
P.R. Newman (Birmingham)
T. Omori (KEK)
J. Osborne (CERN)
Y. Papaphilippou (CERN)
E. Paoloni (Pisa)
C. Pascaud (LAL Orsay)
H. Paukkunen (St. de Compostela)
E. Perez (CERN)
T. Pieloni (CERN)
E. Pilicer (Uludag)
A. Polini (Bologna)
V. Ptitsyn (BNL)
Y. Pupkov (BINP)
V. Radescu (Heidelberg U)
S. Raychaudhuri (Tata)
L. Rinolfi (CERN)
R. Rohini (Tata India)
J. Rojo (Milano)
S. Russenschuck (CERN)
C. A. Salgado (St. de Compostela)
K. Sampai (Tokyo I. Tech)
E. Sauvan (Lyon)
M. Sahin (Ankara)
U. Schneekloth (DESY)
A.N. Skrinsky (Novosibirsk)
T. Schoerner Sadenius (DESY)
D. Schulte (CERN)
N. Soumitra (Torino)
H. Spiesberger (Mainz)
A.M. Stasto (Penn State)
M. Strikman (Penn State)
M. Sullivan (SLAC)
B. Surrow (MIT)
S. Sultansoy (Ankara)
Y.P. Sun (SLAC)
W. Smith (Madison)
I. Tapan (Uludag)
P. Taels (Antwerpen)
E. Tassi (Calabria)
H. Ten Kate (CERN)
J. Terron (Madrid)
H. Thiesen (CERN)
L. Thompson (Cockcroft)
K. Tokushuku (KEK)
R. Tomas Garcia (CERN)
D. Tommasini (CERN)
D. Trbojevic (BNL)
N. Tsoupas (BNL)
J. Tuckmantel (CERN)
S. Turkoz (Ankara)
K. Tywoniuk (Lund)
G. Unel (CERN)
J. Urakawa (KEK)
P. Van Mechelen (Antwerpen)
A. Variola (SACLAY)
R. Veness (CERN)
A. Vivoli (CERN)
P. Vobly (BINP)
R. Wallny (ETHZ)
G. Watt (CERN)
G. Weiglein (Hamburg)
C. Weiss (JLab)
U.A. Wiedemann (CERN)
U. Wienands (SLAC)
F. Willeke (BNL)
V. Yakimenko (BNL)
A.F. Zarnecki (Warsaw)
F. Zimmermann (CERN)
F. Zomer (Orsay LAL)

Magnets

LHeC

7.12.4 10 GeV injector

For the acceleration to 10 GeV we propose a re-circulating LINAC, designed as a downscaled, low energy version of the 25 GeV ELFE at CERN design [?] using modern ILC-type RF-technology.

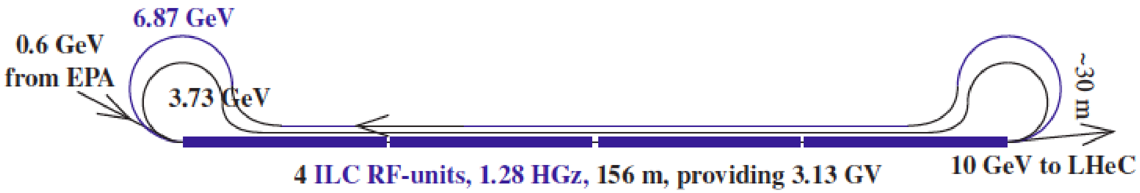


Figure 7.62: Recirculator using 4 ILC modules.

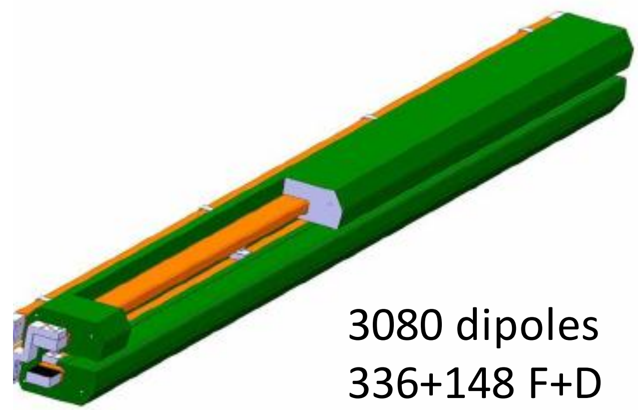
Injector to Ring – similar to Linac design [R+D]

Parameter	Value	Units
Beam Energy	10-60	GeV
Magnetic Length	5.35	Meters
Magnetic Field	0.0127-0.0763	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 9.4: Main parameters of bending magnets for the RR Option.

Novosibirsk dipole prototype measured field reproducible to the required 2 10^{-4}

CERN prototype under test

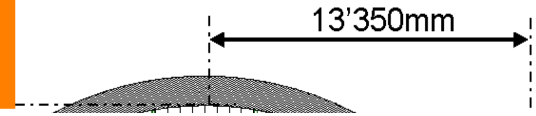


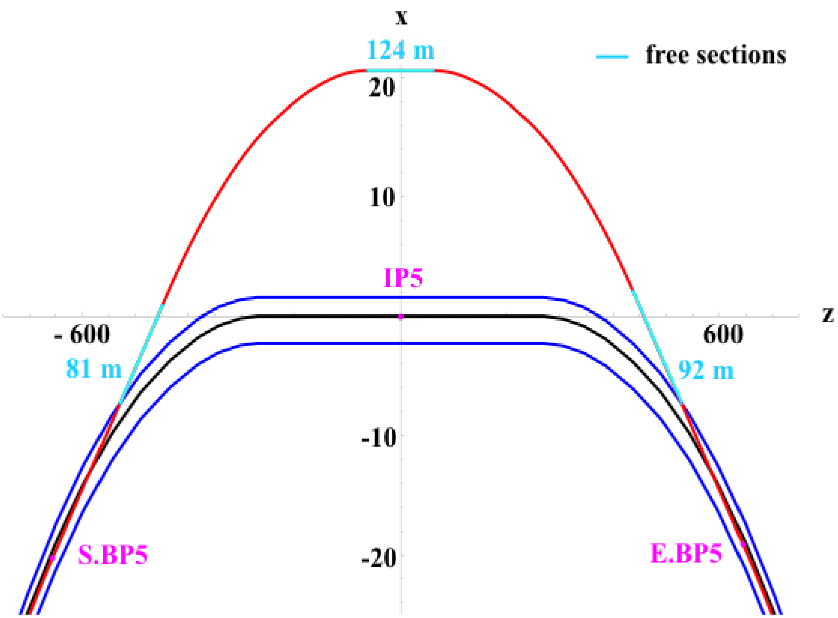
3080 dipoles

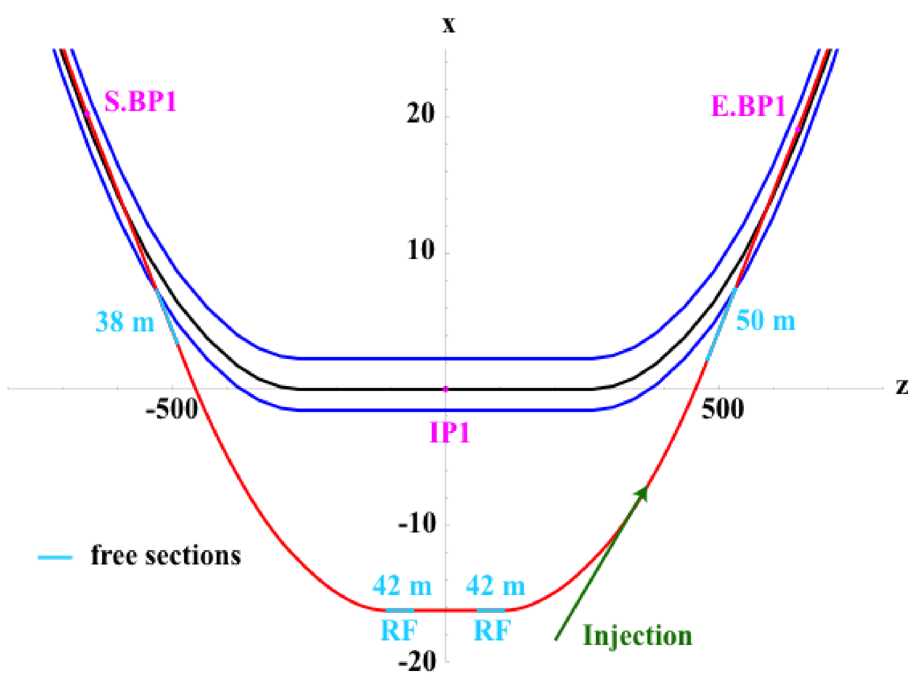
336+148 F+D

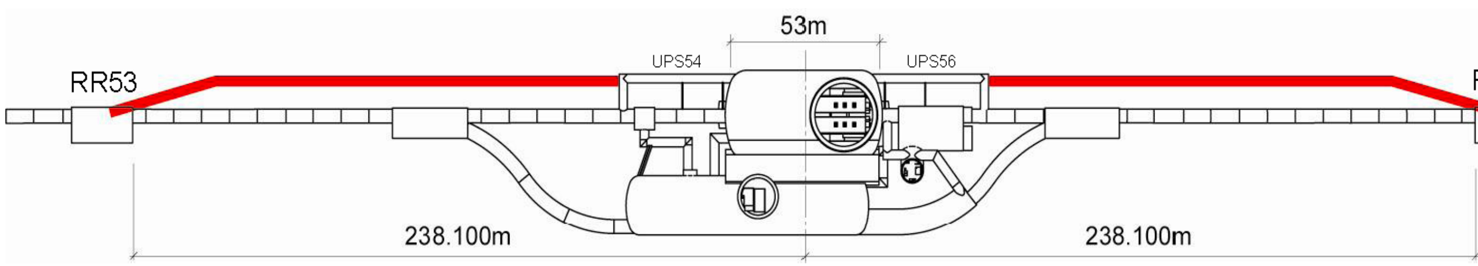
M. F

LHeC
Typical Cross Section through CMS



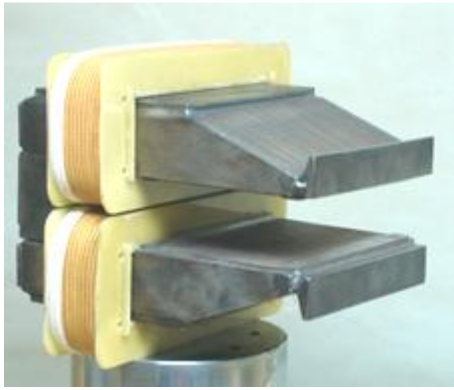






from J.A. Osborne CER

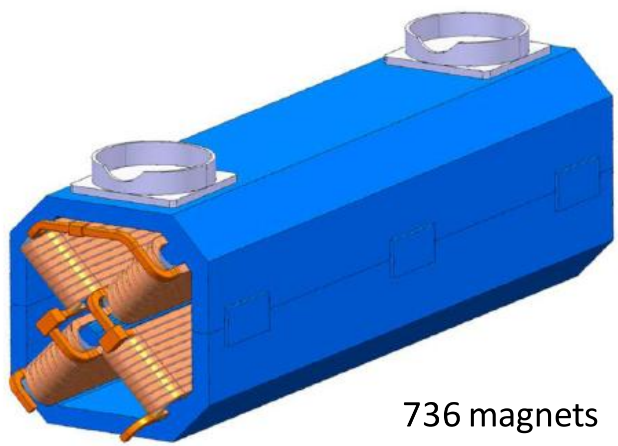
Ring: Dipole + Quadrupole Magnets



BINP & CERN prototypes

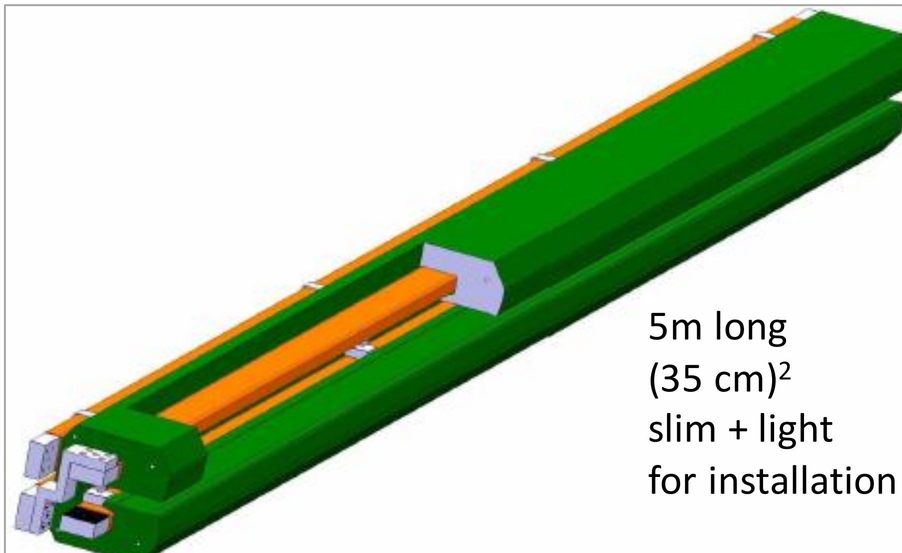
Parameter	Value	Units
Beam Energy	10-60	GeV
Magnetic Length	5.35	Meters
Magnetic Field	0.127-0.763	Tesla
Number of magnets	3080	
Vertical aperture	40	mm
Pole width	150	mm
Number of turns	2	
Current @ 0.763 T	1300	Ampere
Conductor material	copper	
Magnet inductance	0.15	milli-Henry
Magnet resistance	0.16	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.



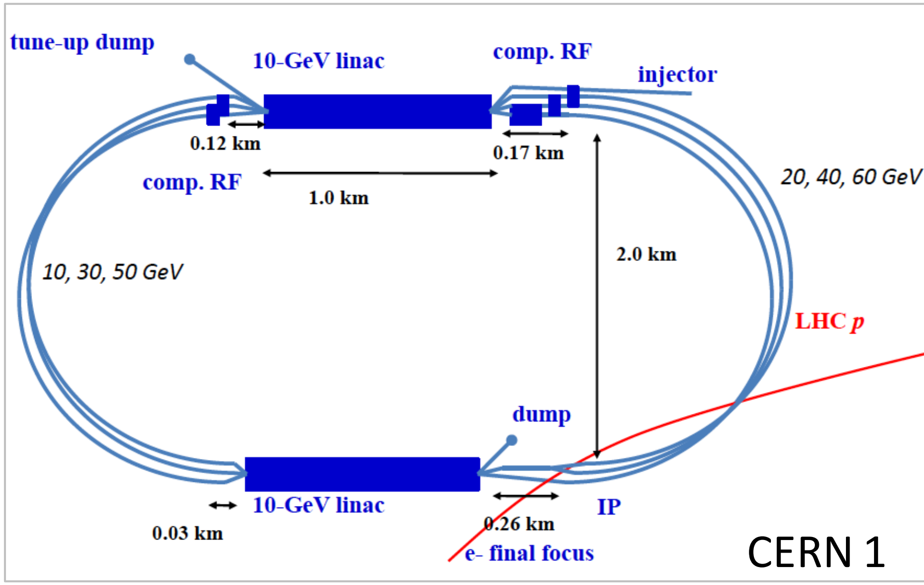
736 magnets
1.2 m long

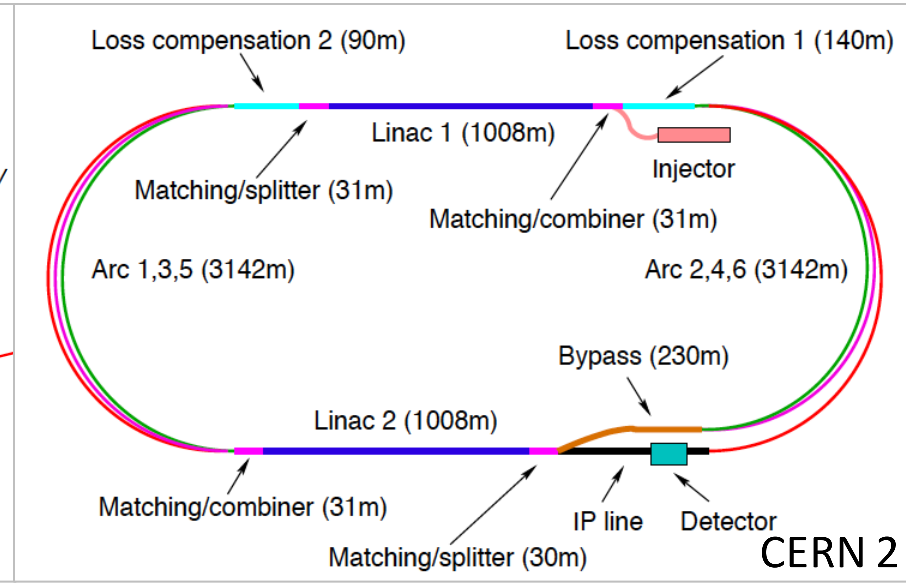
Arc quadrupole magnets for the RR Option



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

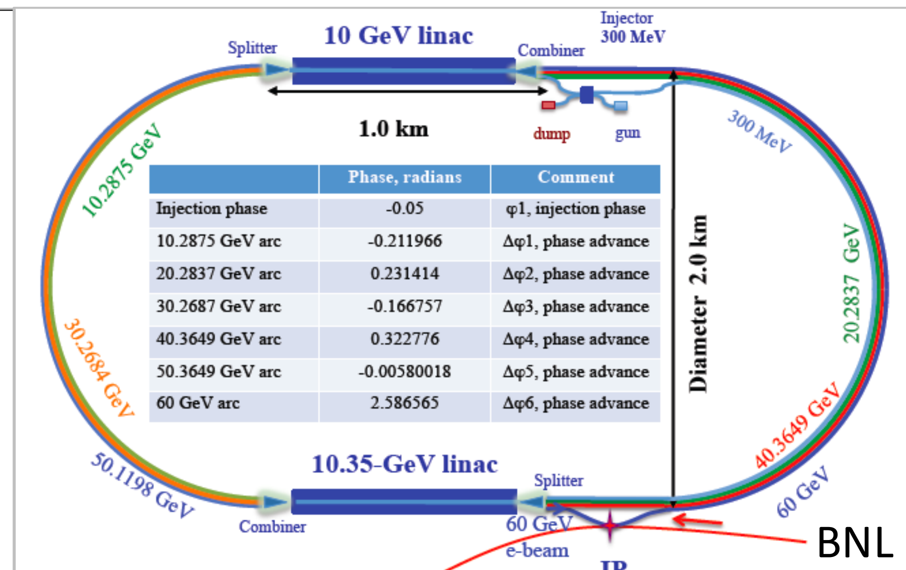
60 GeV Energy Recovery Linac





This image cannot currently be displayed.

Jlab

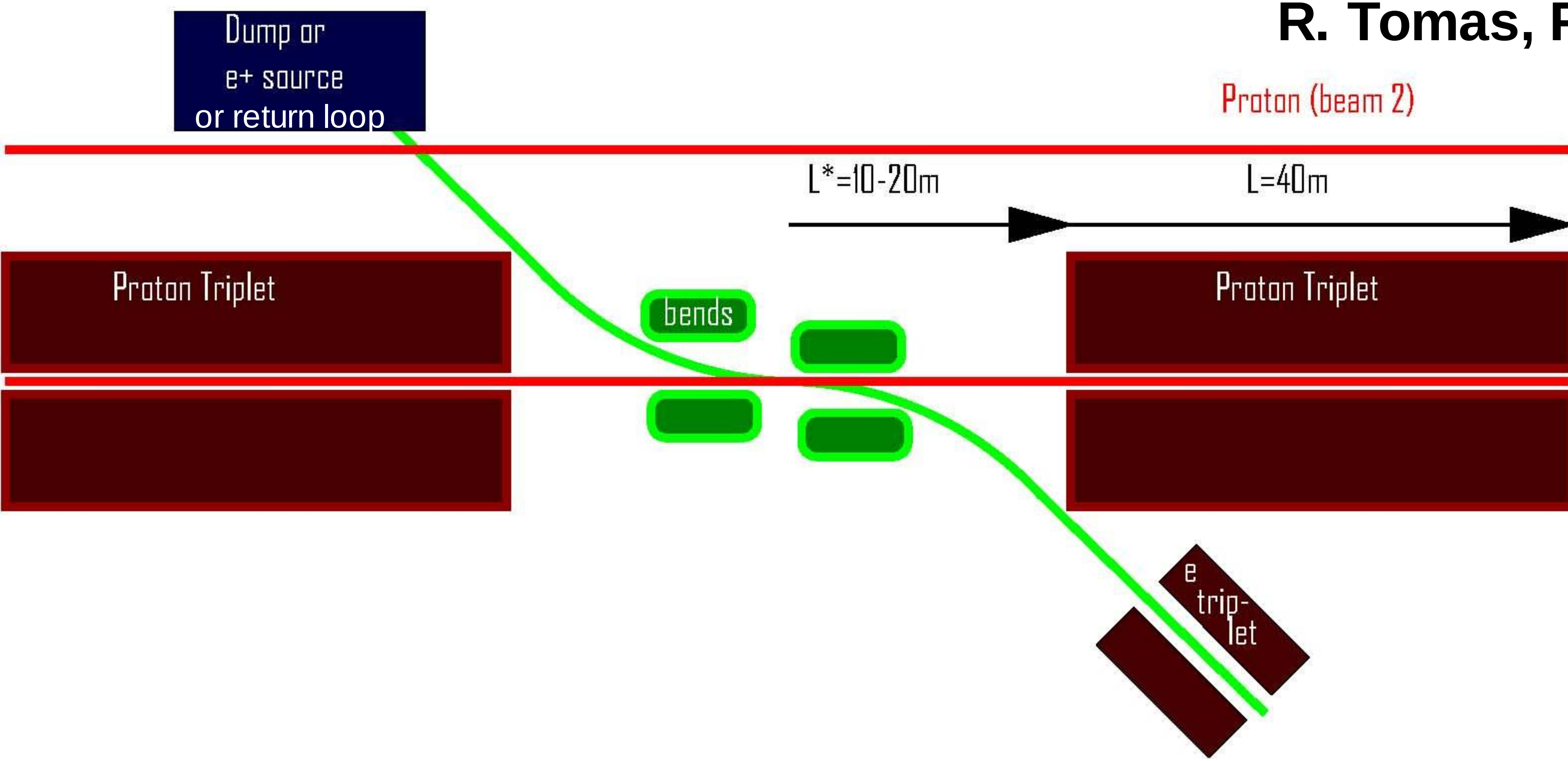


	Phase, radians	Comment
Injection phase	-0.05	φ1, injection phase
10.2875 GeV arc	-0.211966	Δφ1, phase advance
20.2837 GeV arc	0.231414	Δφ2, phase advance
30.2687 GeV arc	-0.166757	Δφ3, phase advance
40.3649 GeV arc	0.322776	Δφ4, phase advance
50.3649 GeV arc	-0.00580018	Δφ5, phase advance
60 GeV arc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

Two 10 GeV energy recovery Linacs, 3 returns, 720 MHz cavities

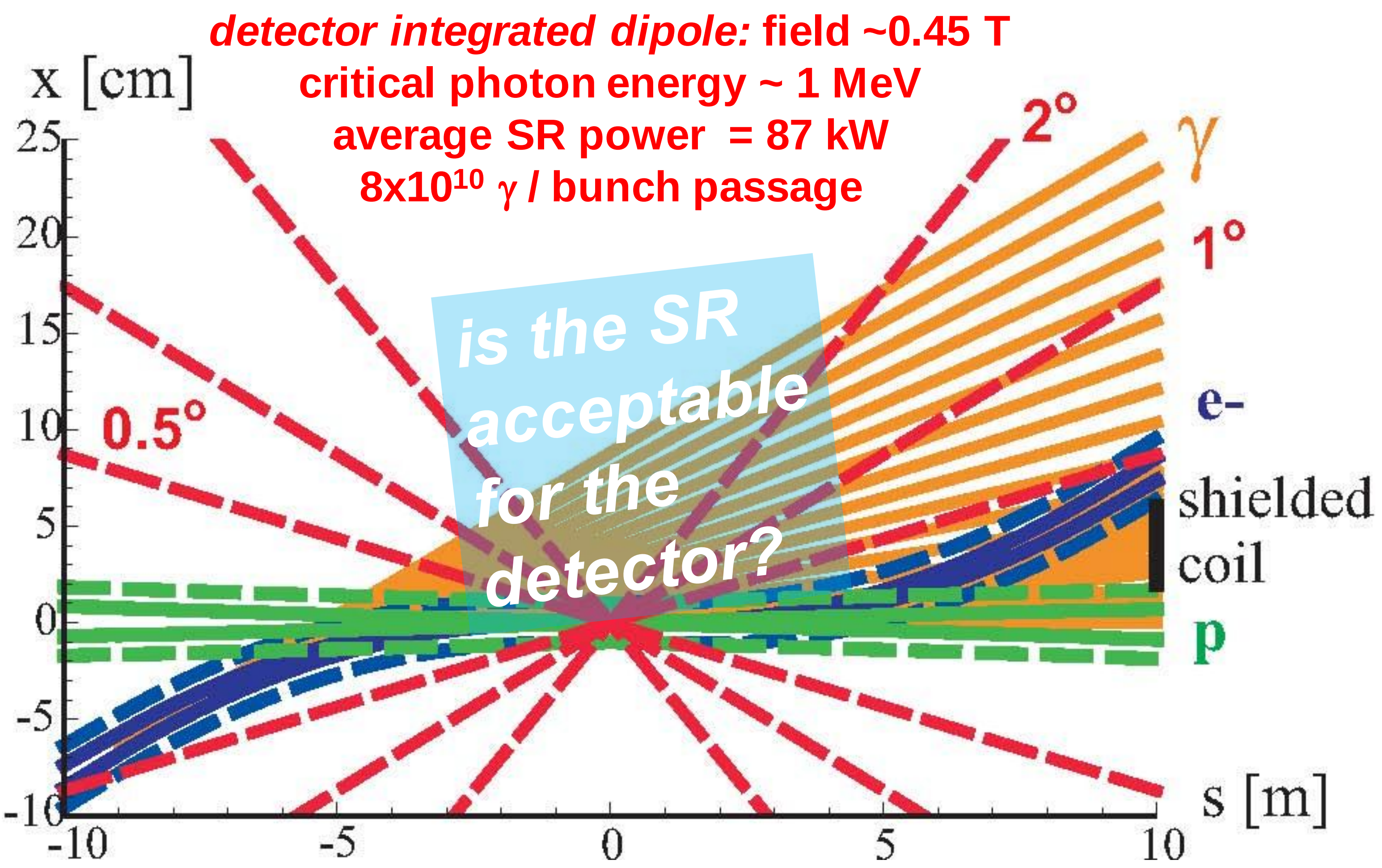
interaction region (2008)

R. Tomas, F.Z.



small e- emittance → relaxed β_e^* → $L_e^* > L_p^*$, can&must profit from $\downarrow\beta_p^*$; single pass & low e-divergence → parasitic collisions of little concern; → head-on e-p collision realized by long dipoles

IR layout w. head-on collision



beam envelopes of 10σ (electrons) [solid blue] or 11σ (protons) [solid green], the same envelopes with an additional constant margin of 10 mm [dashed], the synchrotron-radiation fan [orange], and the approximate location of the magnet coil between incoming protons and outgoing electron beam [black]

8.1 Basic Parameters and Configurations . . . .
8.1.1 General Considerations . . . .
8.1.2 ERL Performance and Layout . . . .
8.1.3 Polarization . . . .
8.1.4 Pulsed Linacs . . . .
8.1.5 Highest-Energy LHeC ERL Option . . . .
8.1.6 γ-p/A Option . . . .
8.1.7 Summary of Basic Parameters and Configurations

CDR draft

Table 8.2: 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

LINAC 60 GeV ERL

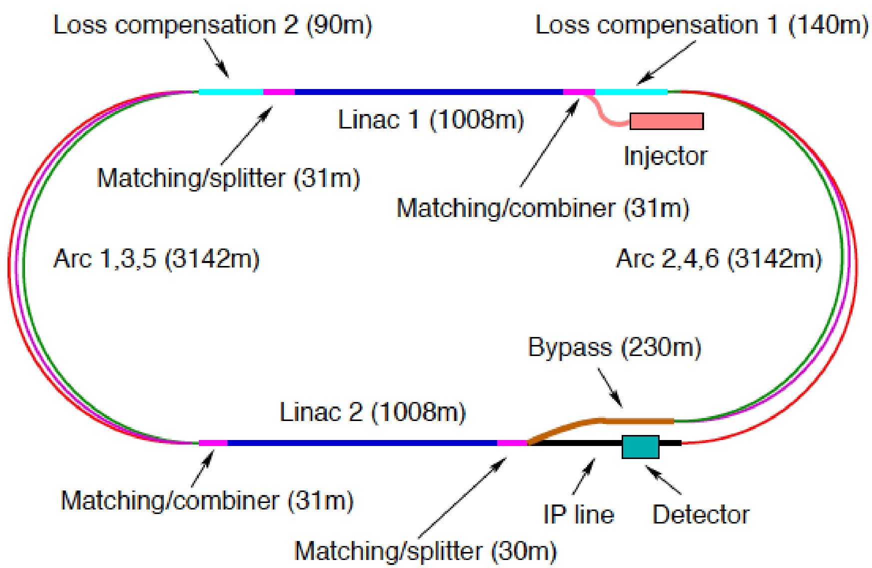
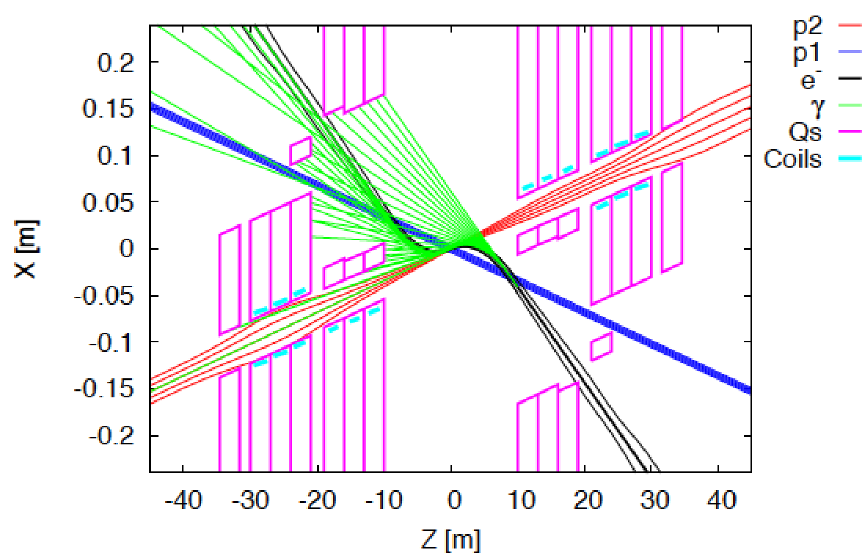


Figure 8.29: The schematic layout of the recirculating linear accelerator complex.



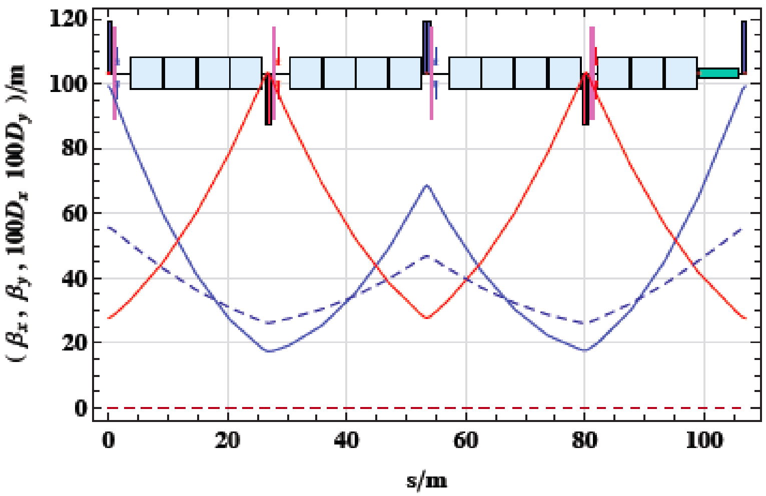
required for high luminosity, the linac must be based on superconducting (SC) radiofrequency (RF) technology. The development and industrial production of its components can exploit synergies with numerous other advancing SC-RF projects around the world, such as the DESY XFEL, eRHIC, ESS, ILC, CEBAF upgrade, CESR-ERL, JLAMP, and the CERN HP-SPL.

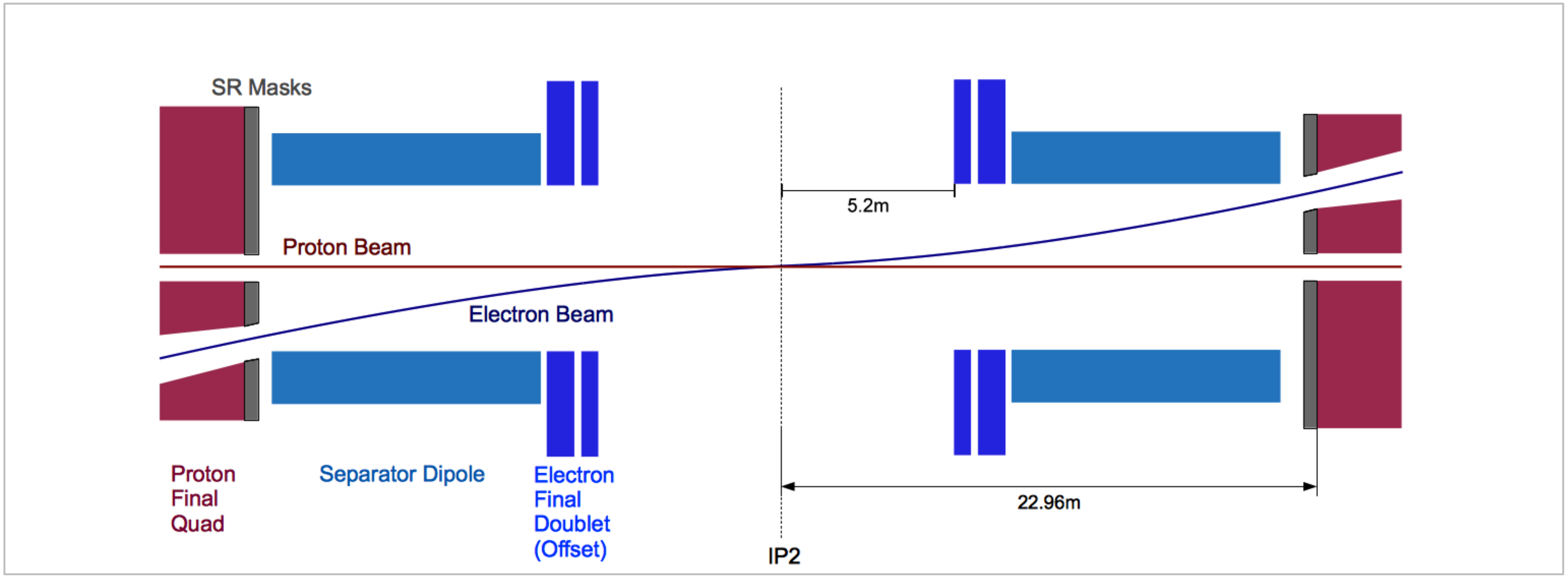
Ring - Arc Optics and matched IR

Optics:

Beam Energy	60 GeV
Phase Advance per FODO Cell	≈ 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



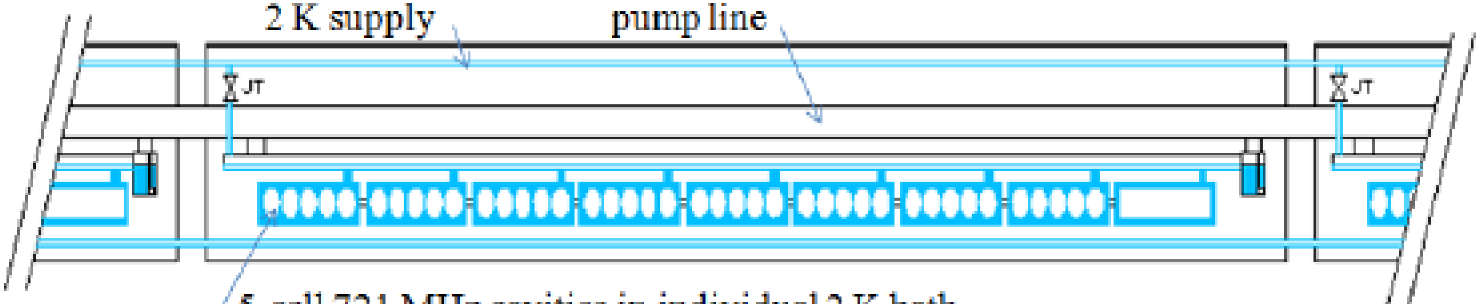


9.2 Ring-Ring RF Design . . . . . .
9.2.1 Design Parameters . . . .
9.2.2 Cavities and klystrons . .
9.3 Linac-Ring RF Design . . . . . .
9.3.1 Design Parameters . . . .
9.3.2 Layout and RF powering
9.3.3 Arc RF systems . . . . .

9.7 Cryogenics . . . .
9.7.1 Ring-Ring Cryogenics Design . . . .
9.7.2 Linac-Ring Cryogenics Design . . . .
9.7.3 General Conclusions Cryogenics for LHeC .

CDR draft

Parameter	Value
Two linacs	length 1 km
5-cell cavities	length 1.04 m
Number	944
Cavities/ cryomodule	8
Number cryomodules	118
Length cryomodule	14 m
Voltage per cavity	21.2 MV
R/Q	285Ω
Cavity Q0	$2.5 \cdot 10^{10}$
Operation	CW
Bath cooling	2 K
Cooling power/cav.	32 W @2 K
Total cooling power (2 linacs)	30 kW @2 K



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