LHeC

- Design Considerations and Study Fram
- Two options: -Ring-R

  ith Energy Recovery
- Beam
-
- S in Preparation of an ERL Test Facility @ CERN

On behalf of the LHeC Collaboration!

➔ LHeC-Note-2011-003 GEN

LHeC Proposal endorsed by ECFA (30.11.2007)

As an add-on to the LHC, the LHeC delivers in excess of 1 TeV ... **quark cms system**. It accesses high parton densities 'bey... to be the unitarity limit. Its physics is thus fundam... to be further worked out, also with respect to the fi... the final results of the Tevatron and of HERA.

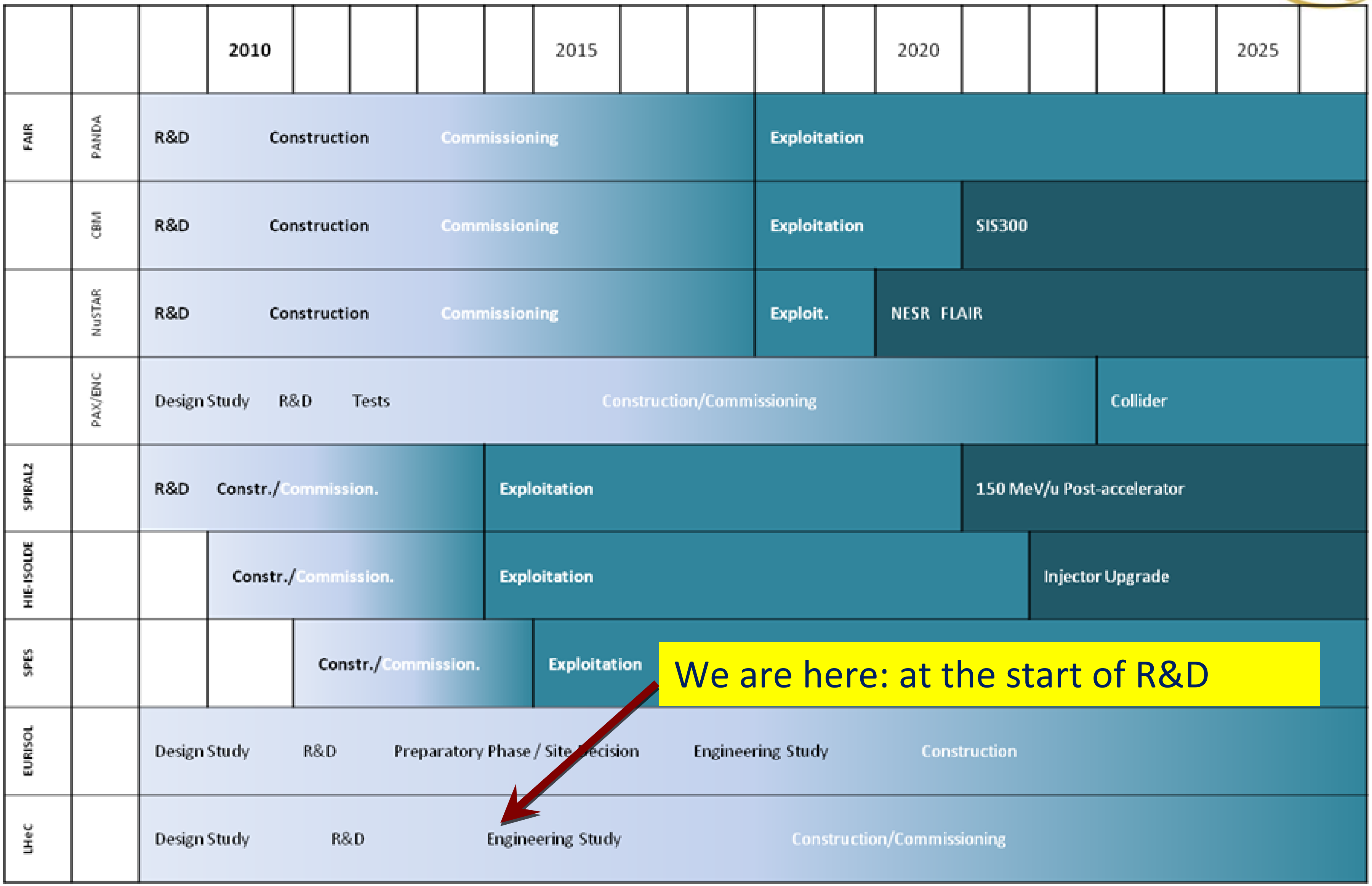
First considerations of a ring-ri... ...celerator layout lead to an unprecedented combin... luminosity in lepton-hadron physics, exploiting th... ...nts in accelerator and detector technology.

It is th... ...d two workshops (2008 and 2009), under the au... CERN, with the goal of having a Conceptual Design ...erator, the experiment and the physics. A Technical Design ...n follow if appropriate.

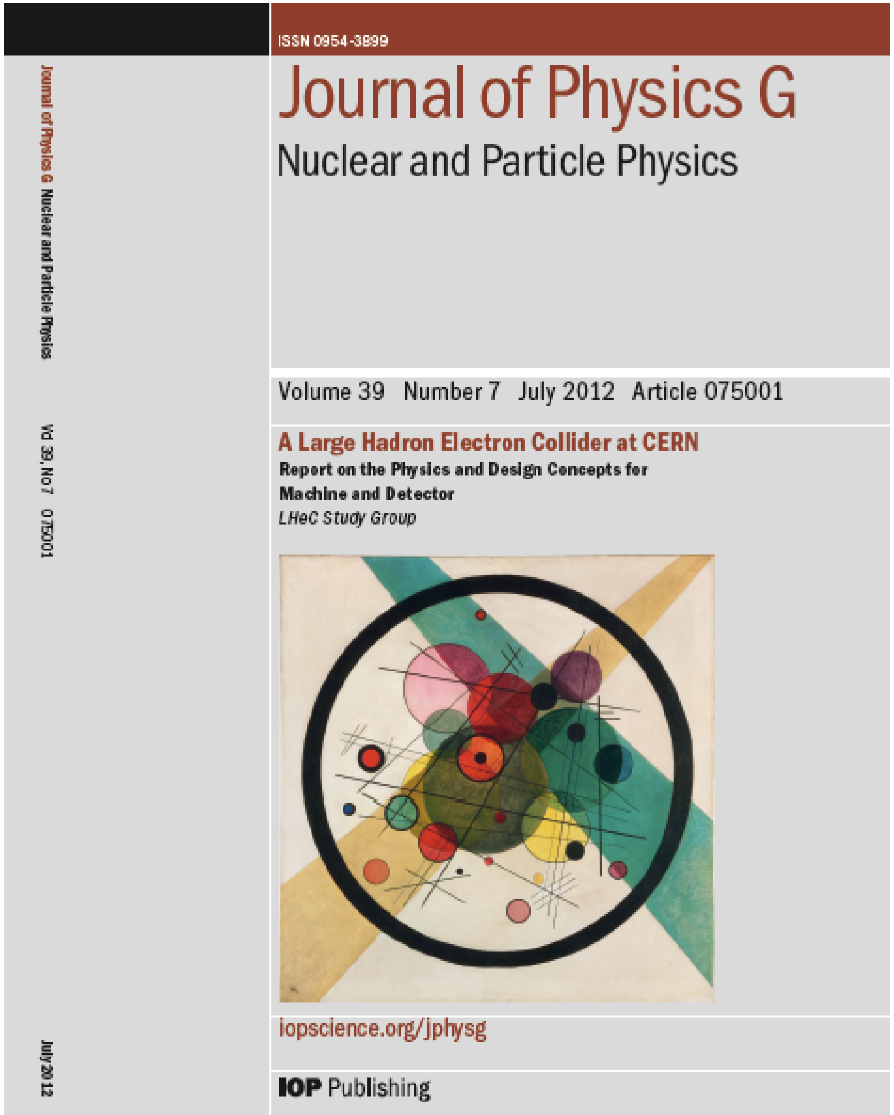
Maximum Exploitation of the LHC infrastructure investment!

Unanimously supported by rECFA and ECFA plenary in November 2007

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



LHeC CDR



1. Design for synchronous ep and pp operation (including eA) → after LS3 which is about 2025 – no firm schedule exists for HL-LHC, but it may operate until ~2035

2. LHeC is a new collider: the cleanest microscope of the world, a complementary Higgs facility, a unique QCD machine with a striking discovery potential, with possible applications as γγ → H or
injector to TLEPP or others
AND an exciting new accelerator project

3. CERN Mandate to develop key technologies for the LHeC for project decision after start of LHC Run II and in time for start parallel to HL LHC phase

CERN Mandate: 5 main points

LHeC

The mandate for the technology development **includes studies and prototyping of the following key technical components**:

•Superconducting RF system for CW operation in an Energy Recovery Linac (high Q_0 for efficient energy recovery) S

•Superconducting magnet development of the insertion regions of the LHeC with three beams. The studies require the design and construction of short magnet models

•Studies related to the experimental beam pipes with large beam acceptance in a high synchrotron radiation environment

•The design and specification of an ERL test facility for the LHeC.

•The finalization of the ERL design for the LHeC including a finalization of the optics design, beam dynamics studies and identificationof potential performance limitations

The above technological developments require close collaboration between the relevant technical groups at CERN and external collaborators.

Given the rather tight personnel resource conditions at CERN **the above studies should exploit where possible synergies with existing CERN studies.**

S.Bertolucci at Chavannes workshop 6/12 based on
CERN directorate's decision to include LHeC in the MTP

Design Considerations

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

Integrated e$^{\pm}$p : O(100) fb^{-1} ≈ 100 * L(HERA) → synchronous c

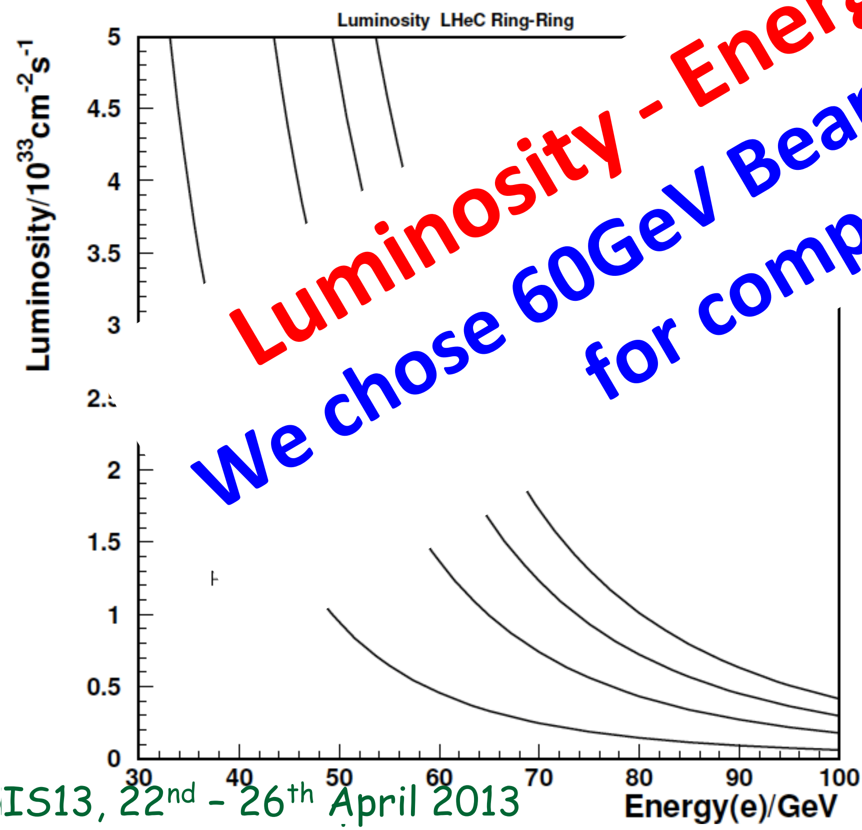
Luminosity O (10^{33}) cm^{-2}s^{-1} with 100 MW power cons

Start of LHeC operation together with HL-LHC

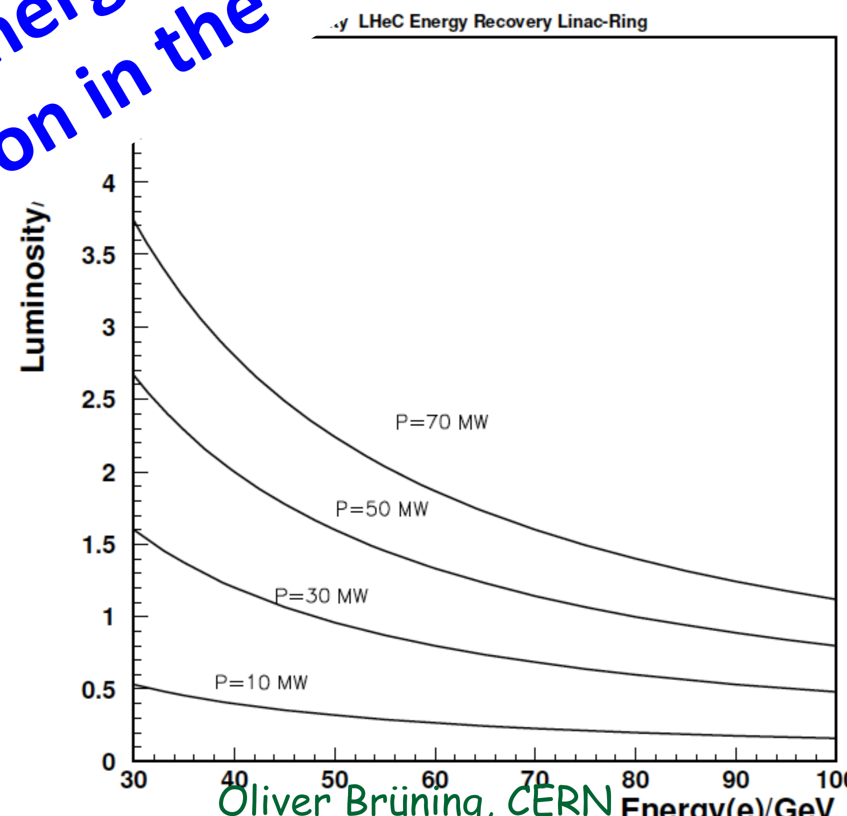
Luminosity - Energy & Power tradeoff

We chose 60GeV Beam Energy as reference case for comparison in the CDR

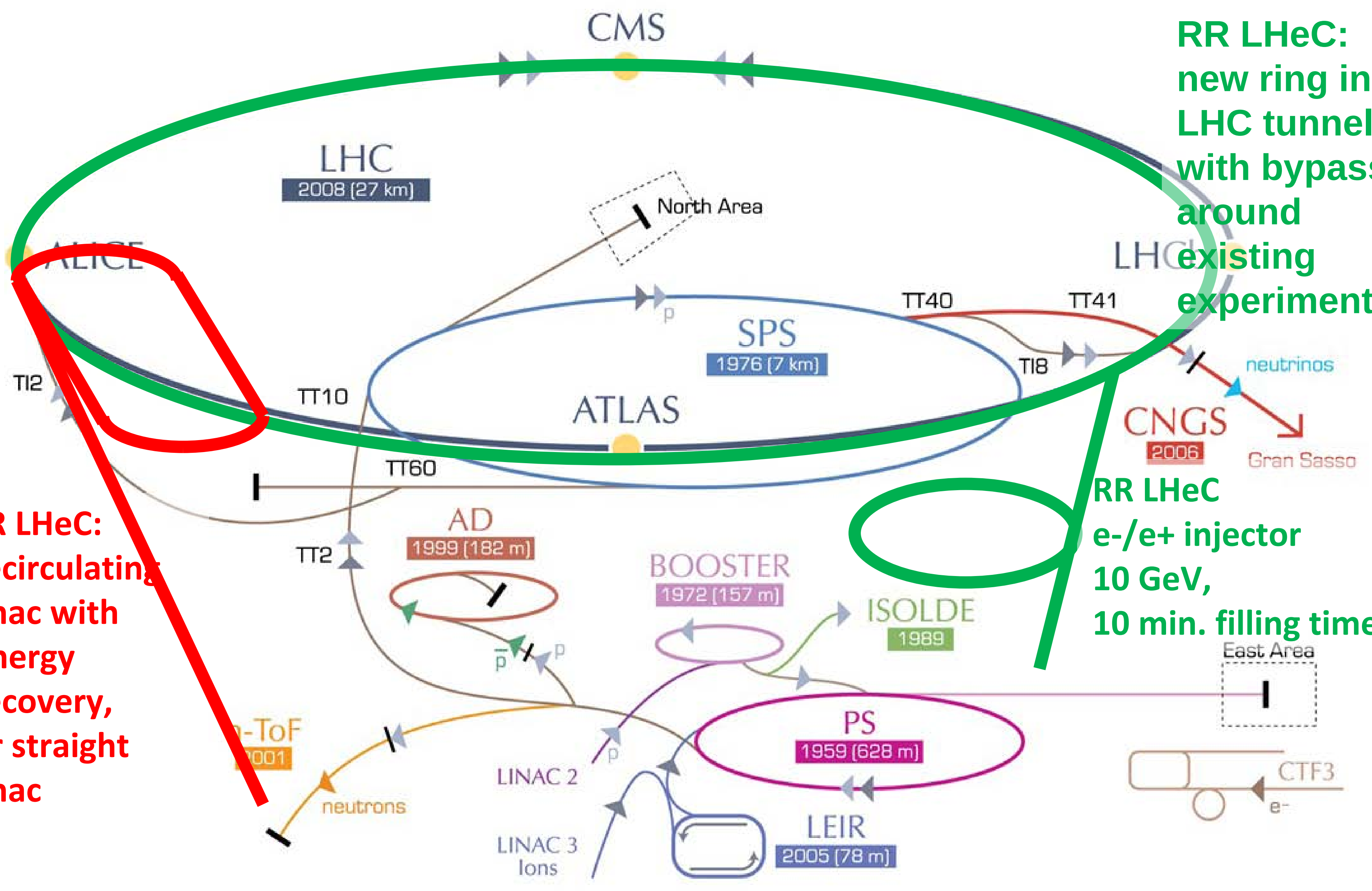
e Ring in the LHC tunnel (Ring-Ring - RR)



ing -LR)



LHeC options: RR and LR

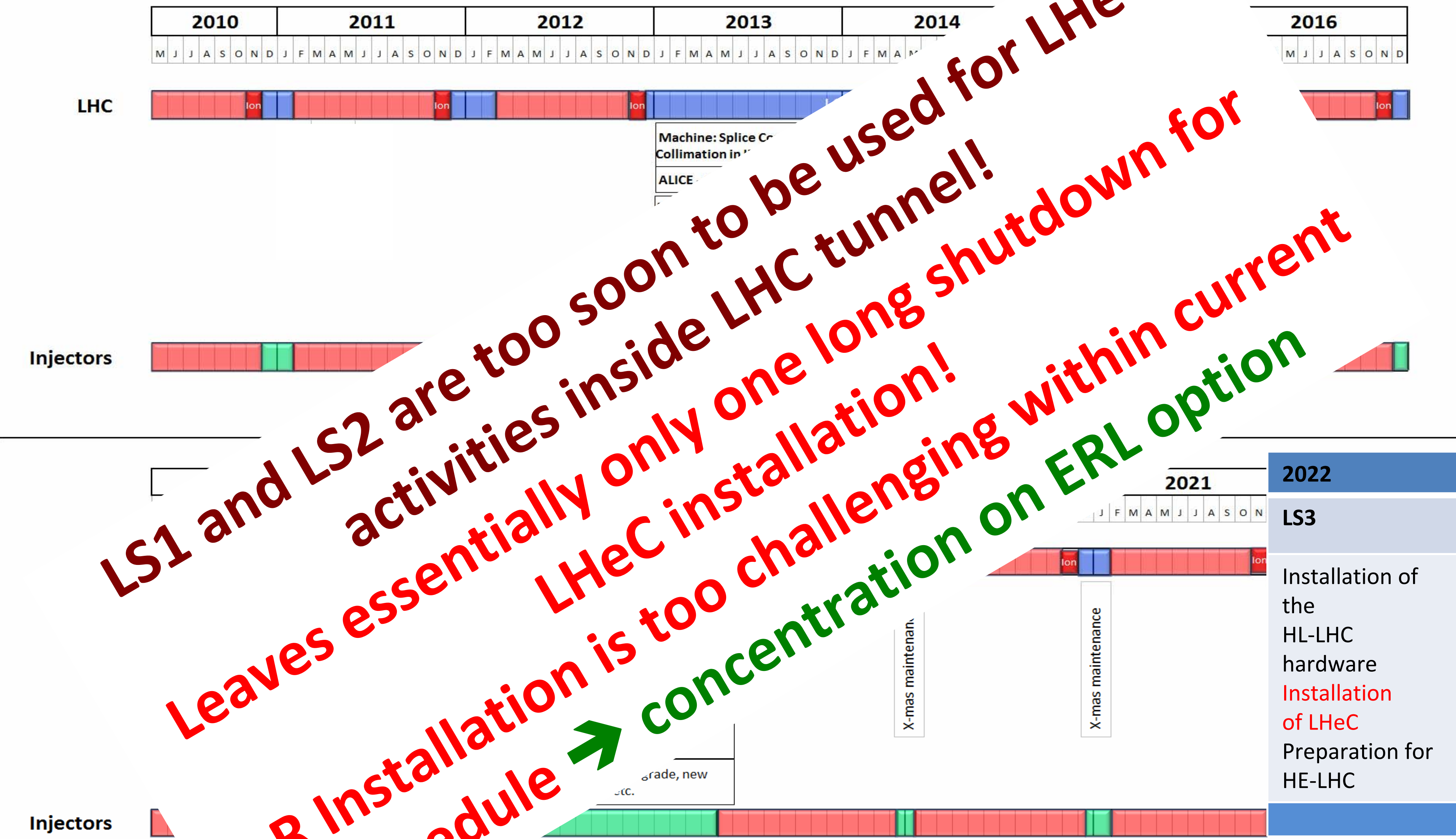


RR LHeC: new ring in LHC tunnel, with bypasses around existing experiments

RR LHeC e-/e+ injector 10 GeV, 10 min. filling time

LR LHeC: recirculating linac with energy recovery, or straight linac

Current 10 Year Plan for LHC Operation



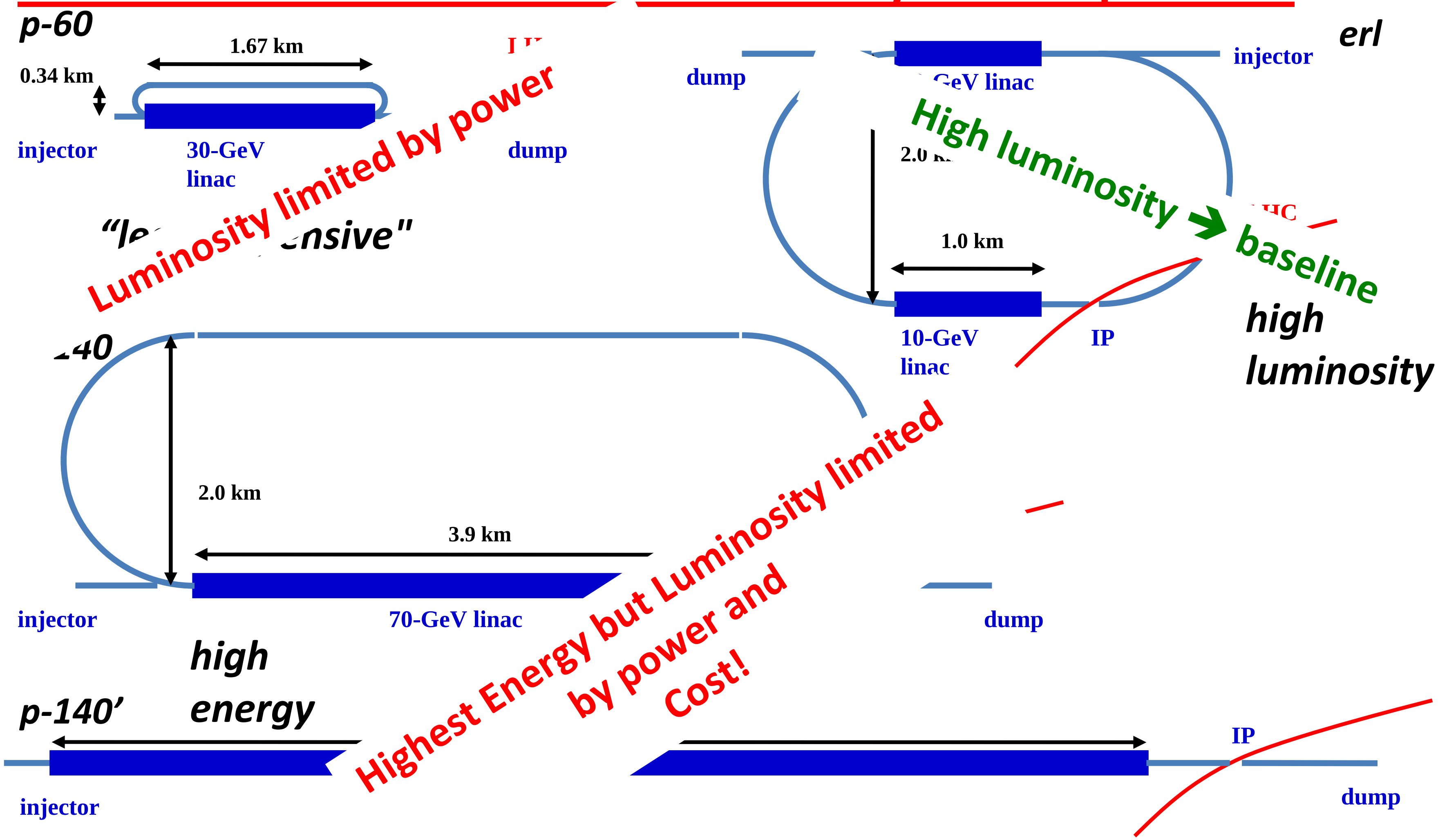
LS1 and LS2 are too soon to be used for LHeC activities inside LHC tunnel!

Leaves essentially only one long shutdown for LHeC installation!

R-R Installation is too challenging within current schedule → concentration on ERL option

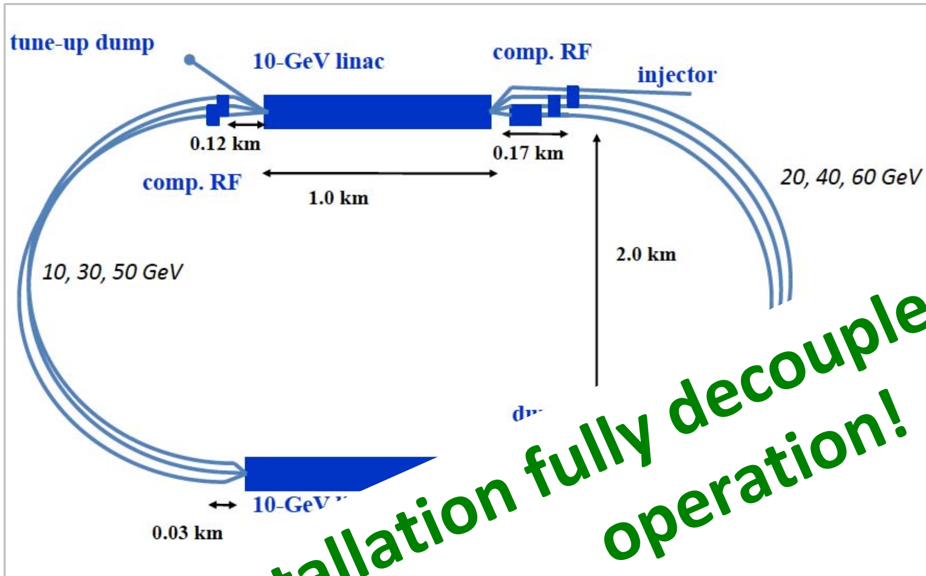
LHeC: Linac-Ring Option

Considered Various Layout Options



LHeC: Baseline Linac-Ring Option

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



Two 1 km long SC lin... CW operation

Installation fully decoupled from LHC operation!

- requires Cryogenic system comparable to LHC system!

Challen... ...atively large return arcs

- ➔ ca. 9 k.. underground tunnel installation
- ➔ total of 19 km bending arcs
- ➔ same magnet design as for RR option: > 4500 magnets

Energy Loss

Energy loss due to synchrotron radiation in arcs (ρ=764m)

Total loss per particle about 1.9GeV

i.e. 12.2MW beam power

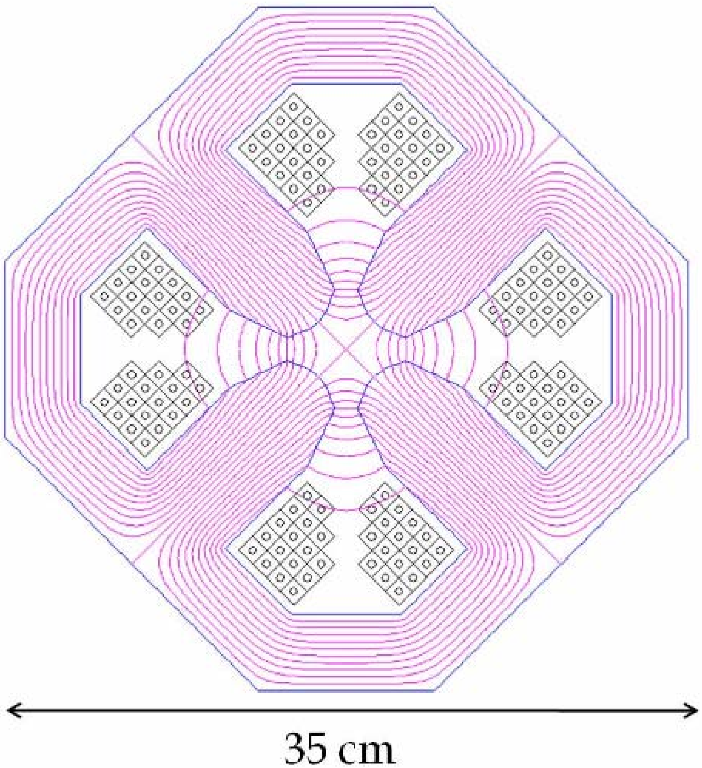
Compensated by additional linacs
60% wall plug to beam efficiency
-> 20.3MW

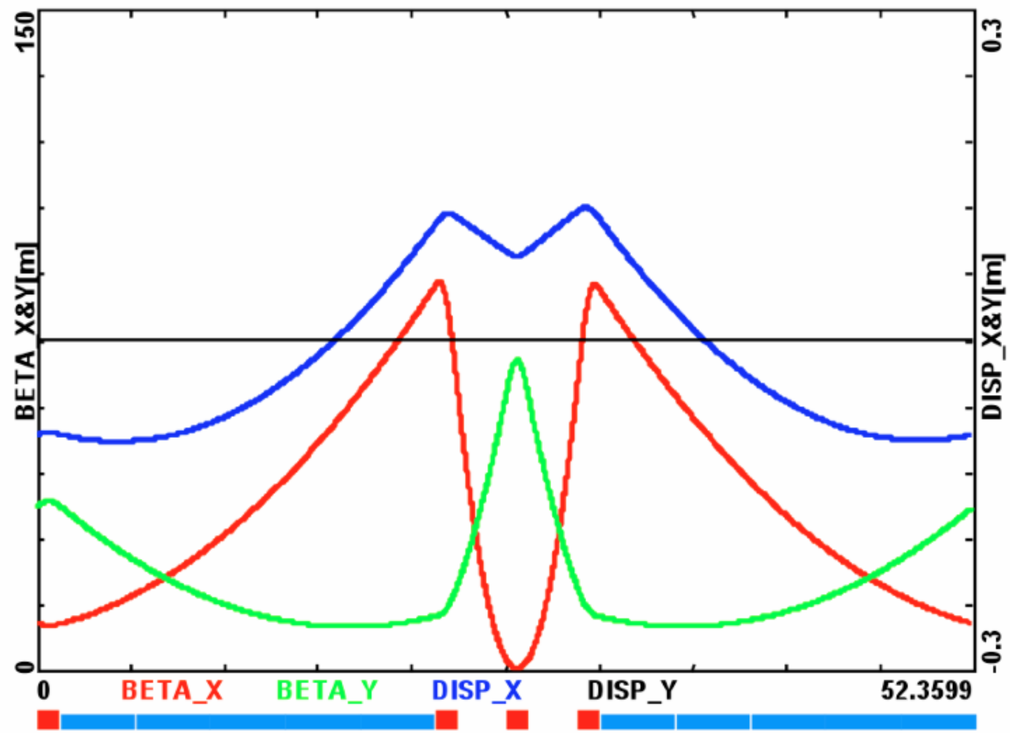
turn no	E GeV	ΔE [MeV]	σ_E/E[%]
1	10.42	0.7	0.00036
2	20.33	9.8	0.0019
3	30.25	48.2	0.0053
4	40.17	150	0.011
5	50.08	362	0.020
6	60.0	746	0.033
7	50.08	362	0.044
8	40.17	150	0.056
9	30.25	48.2	0.074
10	20.33	9.8	0.11
11	10.42	0.7	0.216
dump	0.5	0.0	4.53

ARC Optics Design

Lattice exist for all 6 arcs

Synchrotron radiation is OK for emittance ($\Delta\varepsilon \leq 7\mu m$, before collision)





A. Bogacz

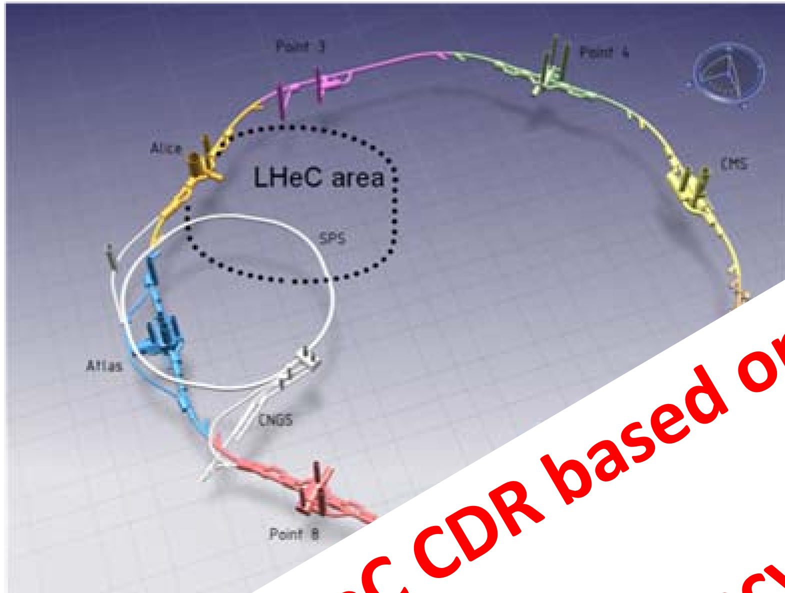
Total of 1440 quadrupoles

3600 4m-long bends

Magnet designs exists

D. Schulte: EPS HEP Stockholm

LINAC – Ring: connection tc



LHeC CDR based on 721 MHz cavity design

But RF Frequency has been re-optimized after publication of the CDR!

→800 MHz chosen after CDR

..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

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

Linac RF Power

Ideally only losses into the wall need to be replaced (Q_0=2.5 10^{10}, P_{loss}≈30W/cavity)
But need to control RF phase (small frequency errors due to mechanical vibrations, beam Phase errors etc.)

Need to couple cavity to the outside (Q_{ext}, Q_L)
This leads to power leaking from the cavity

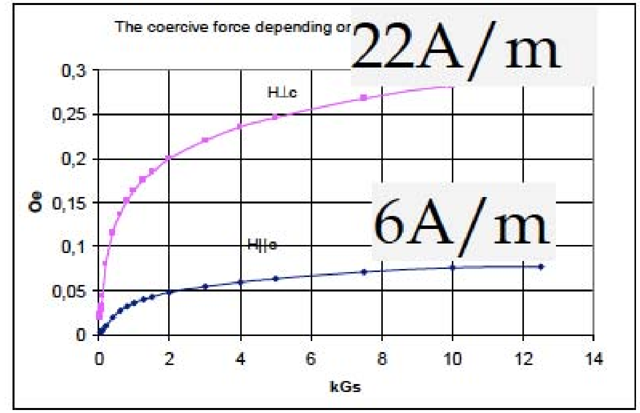
Made relatively conservative assumption (Beam takes/leaves 420kW/cavity, we use 4% to control)

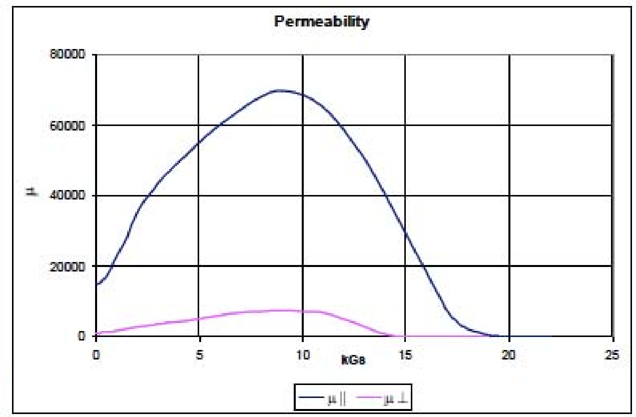
If we can establish more aggressive stability of RF in cavity, we could reduce the power

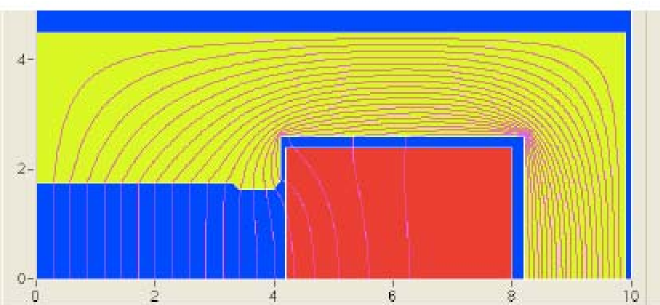
Assumed loaded Q_L	4.7 10^7
Compensating RF power required per cavity	16.8kW
Transmission losses	7%
RF power needed per cavity	17.9kW
Total RF power	17MW
Wall plug to RF power efficiency	70%
Total power	24MW

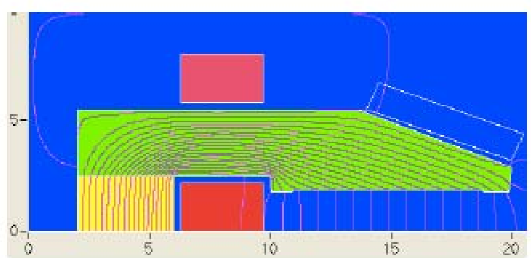
D. Schulte: EPS HEP Stockholm

STATUS OF BINP WORK









3408 grain oriented steel
0.35 mm thick laminations

- after cycles of different amplitude, the remanent field is of about 1 Gauss in all cases
- the reproducibility of the injection field is about ± 0.075 Gauss

LHeC 400 mm long CERN Dipole mod…

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

…asini]

	…th magnet
	70
	5.45
…]	127-763
…ets	3080
…erture [mm]	40
… 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

		$6\cdot10^{-5}$
		$6\cdot10^{-5}$
	$3\cdot10^{-5}$	$3\cdot10^{-5}$
	$4\cdot10^{-5}$	$5\cdot10^{-5}$
…el)	$2\cdot10^{-5}$	$4\cdot10^{-5}$

…ture & tests of 3 models

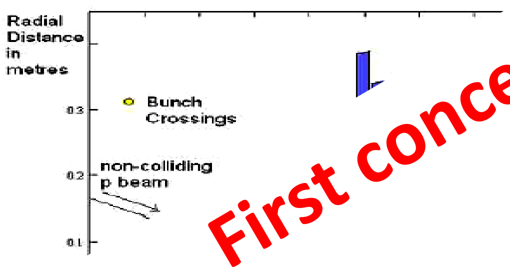
Prototype development in collaboration with Novosibirsk

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

Interaction Region: Accommodat… …eams

Small crossing angle of about 1mrad to avoid firs…
(Dipole in detector? Crab cavities? Design f…
Synchrotron radiation –direct and bac…

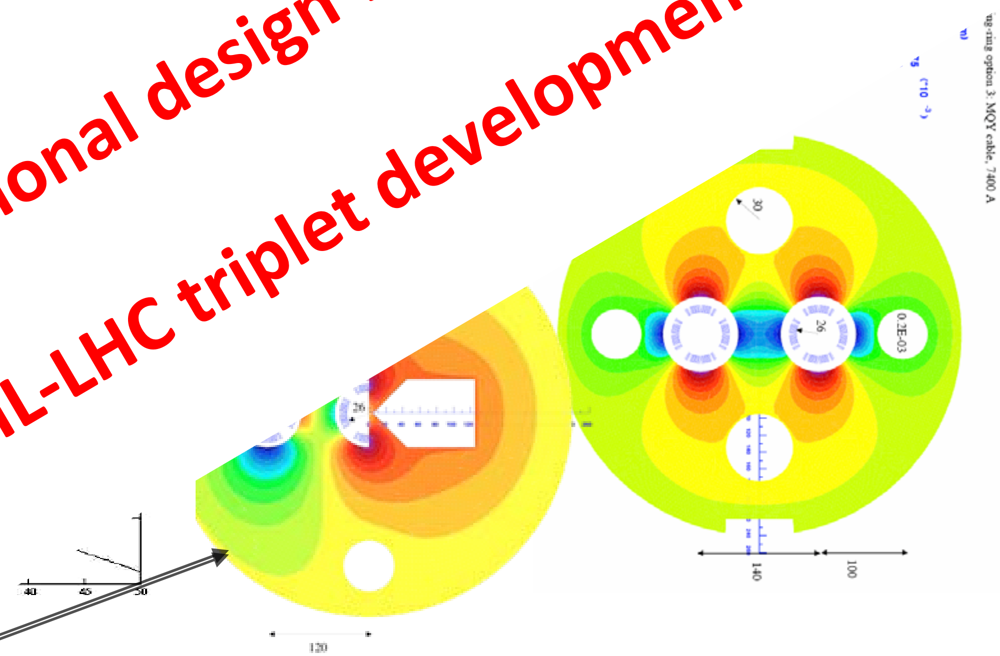
Focus of current activity



First conceptual SC magnet designs exist

But: Still requires additional design work and R&D!

Synergies with HL-LHC triplet development!



1st … …eflect)
sepa… …MQY cables, 4600 A

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

¥: ultimate LHC
*: ATS optics?

Parameters (ERL option)

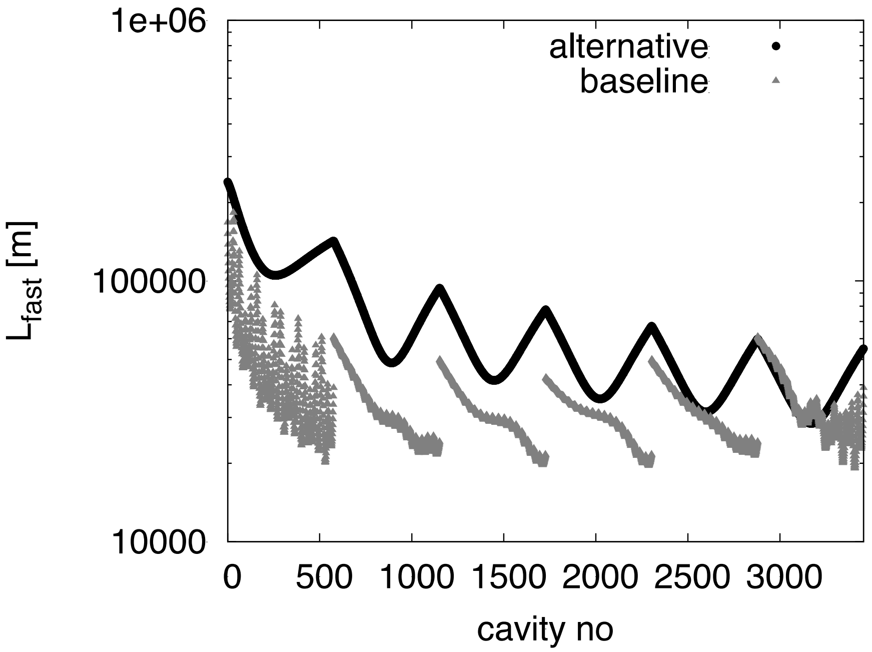
	protons	electrons
beam energy [GeV]	7000	60
Lorentz factor γ	7460	117400
normalized emittance $\gamma\varepsilon_{x,y}$ [μm]	3.75¥	50
geometric emittance $\varepsilon_{x,y}$ [nm]	0.50	0.43
IP beta function $\beta^*_{x,y}$ [m]	0.10*	0.12
rms IP beam size $\sigma^*_{x,y}$ [μm]	7	7
rms IP divergence $\sigma'_{x,y}$ [μrad]	70	58
beam current [mA]	≥430	6.6
bunch spacing [ns]	25 or 50	(25) 50
bunch population	$1.7\mathrm{x}10^{11}$ ¥	($1\mathrm{x}10^9$) $2\mathrm{x}10^9$
Effective crossing angle	0.0	

LINAC Beam Dynamics Issues: Ion trapping

Daniel Schulte @ LHeC Seminar

- Has been studied for the linacs only
  - Arcs need to be included
  - Only analytical estimates used
- Continuous beam would trap ions in the linacs
  - This would lead to unstable beam
- One 10μs long gap in beam prevents long-term trapping
  - Rise time of instability during the train between gaps seems to be acceptable (10 turns)

- Full study needed
  - Arcs will make instability worse
  - Ions are not completely lost during one passage of the gap
  - But the frequency of the induced instability varies along the machine, which helps



Post CDR Studies: ERL Beam Dynamics

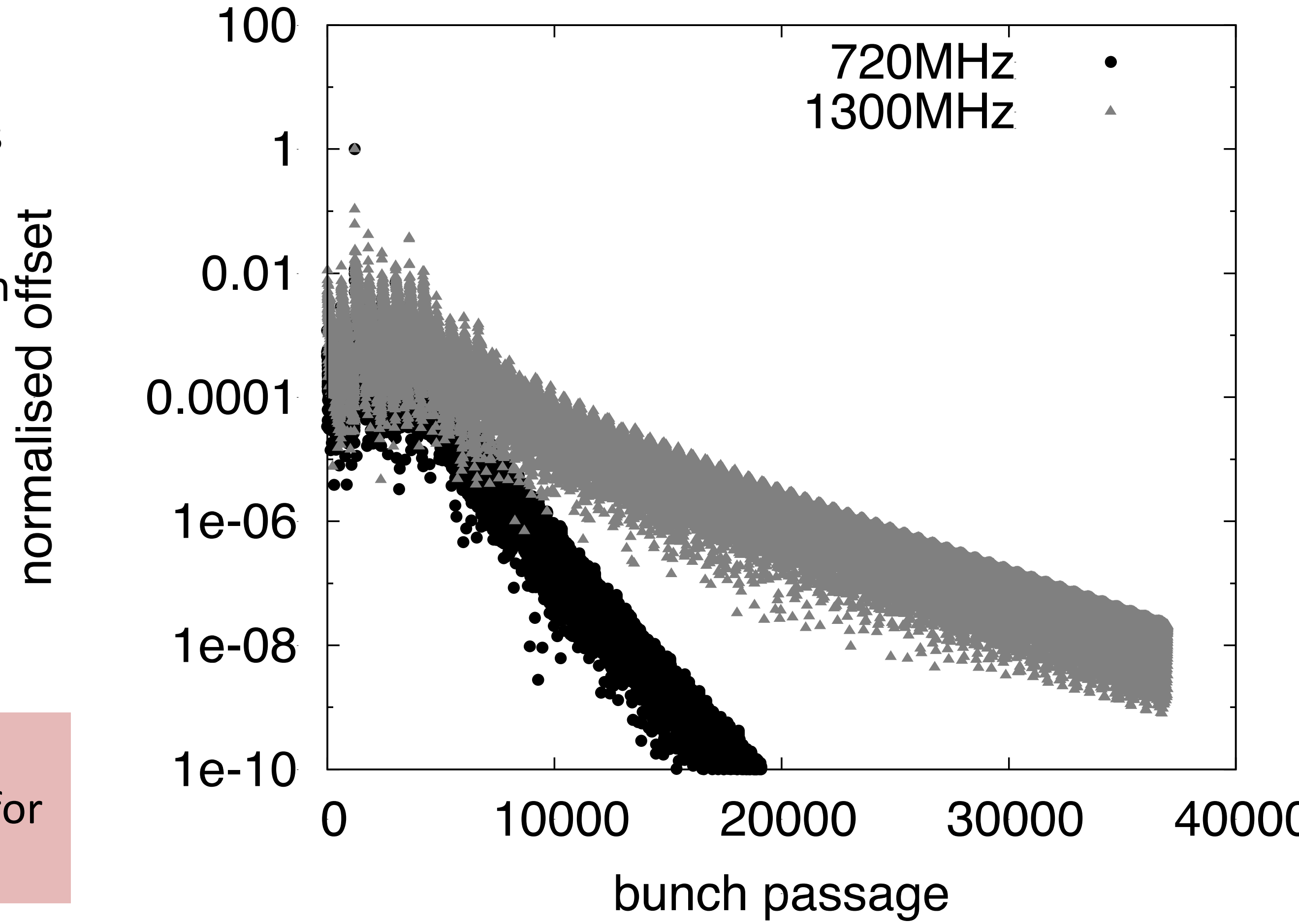
Beam Instabilities:

Daniel Schulte @ LHeC Seminar 12. March 2013

Increased bunch charge
To allow for ion-clearing gaps
N=3 10^9

Note: bunches were placed in the gaps

F_{rms}=1.05 for ILC cavity
F_{rms}=1.001 for SPL cavity



Beam is stable for both cases but more margins for lower RF frequency

➔ Optimum choice for LHeC RF frequency?

Post CDR Studies: ERL Beam Dynamics

LHeC

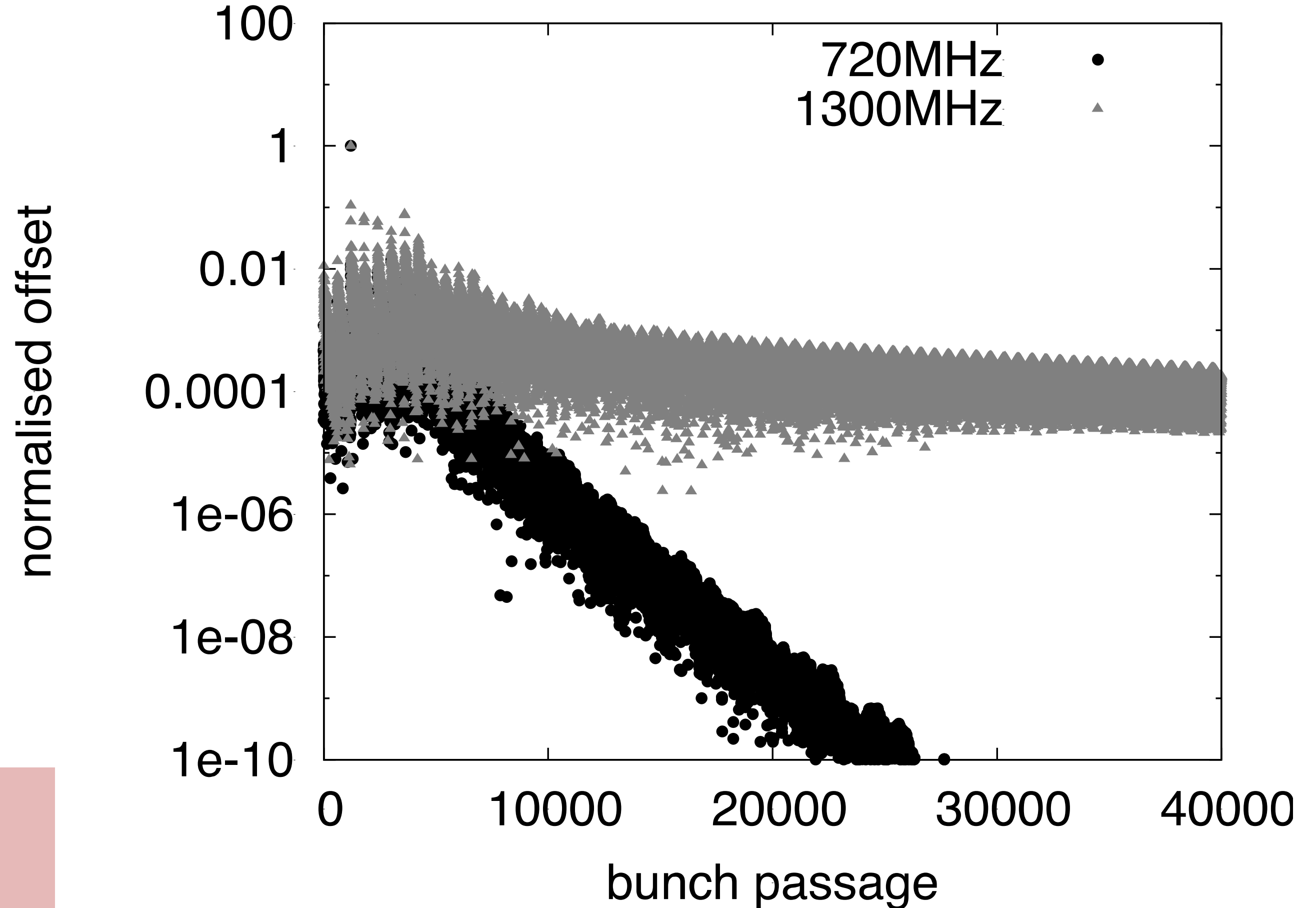
Beam-Beam effects:

Daniel Schulte @ LHeC Seminar 12. March 2013

N=3 10^9
Beam-beam effect included as linear kick

Result depends on seed for frequency spread
"worst" of ten seed shown

F_{rms}=1.135 for ILC cavity
F_{rms}=1.002 for SPL cavity



Beam is stable but very small margin with 1.3GHz cavity ➔ lower RF frequency beneficial

➔ Optimum choice for LHeC RF frequency

Post CDR Studies: RF Frequency

LHeC

Review of the SC RF frequency:

-HL-LHC bunch spacing requires bunch spacing with multiples of 25ns (40.079 MHz)

Frequency choice: *h* * n* 40.079 MHz

Symmetry in ERL: n=3 ➔ h * 120.237 MHz

h=6: 721 MHz or h=11: 1.323GHz

SPL & ESS: 704.42 MHz; ILC & XFEL: 1.3 GHz

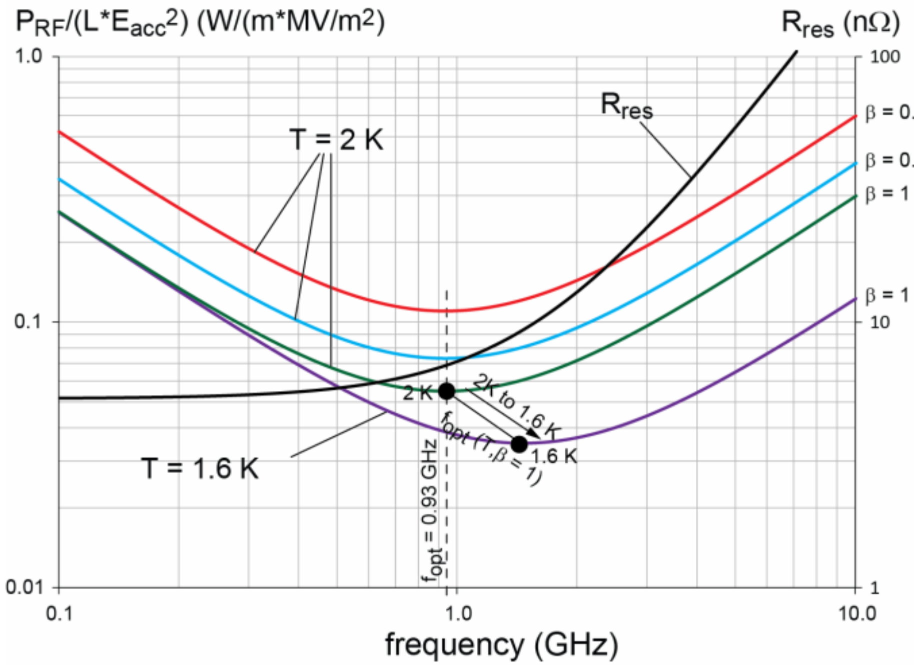
Frequencies are slightly different (20MHz) from existing technologies!
But having the harmonic number be a multiple of the ERL symmetry is not a strong requirement ➔ asymmetric bunch patterns

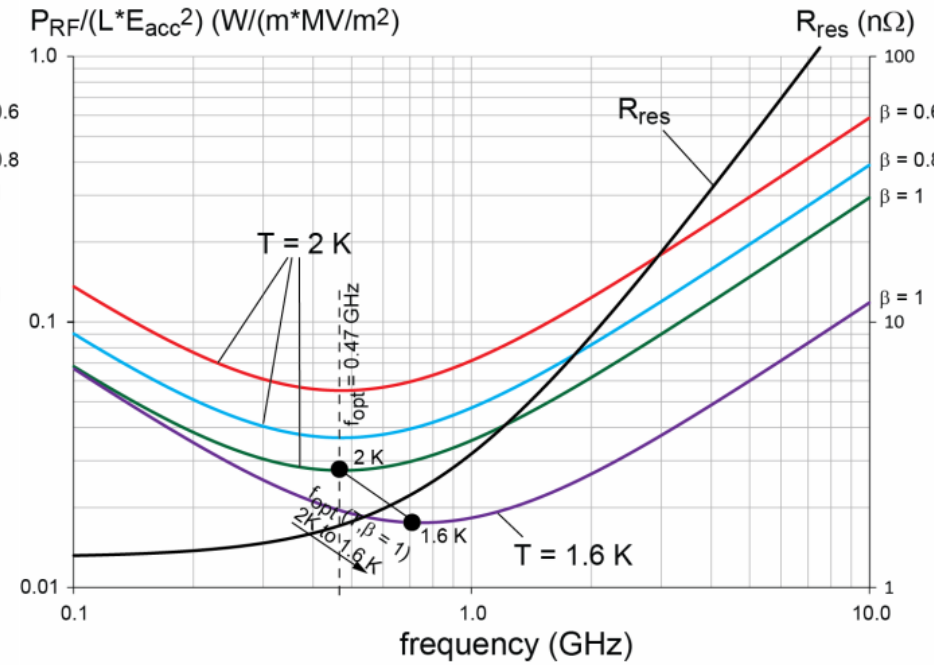
Optimum RF Frequency: Power Considerations

LHeC

Results from F. Marhauser [Muons Inc]

Erk Jensen at Daresbury meeting 12 March 2013





Small-grain (normal) Nb:
Optimum frequency at 2K between 700 MHz and 1050 MHz
Lower T shift optimum f upwards

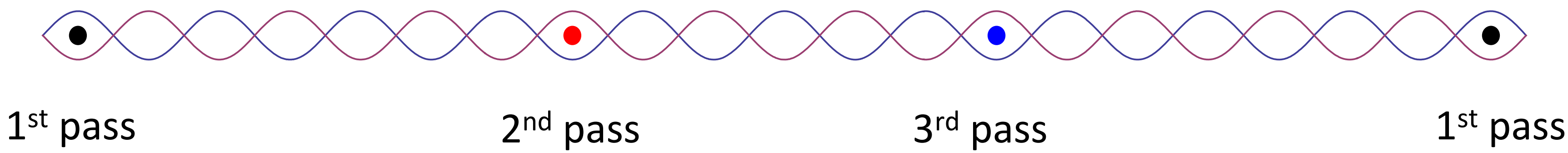
Large-grain Nb:
Optimum frequency at 2K between 300 MHz and 800 MHz
Lower T shift optimum f upwards

Optimum RF Frequency: around 800 MHz

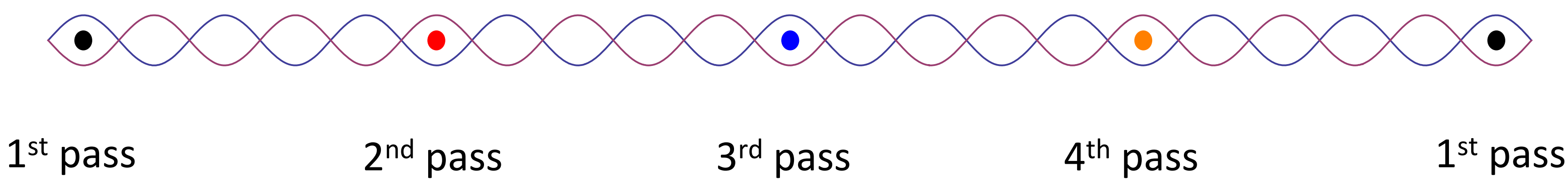
Erk Jensen @ March 2013 LHeC Seminar

- F_{RF} = 20* 40.079 MHz ➔ 801.58 MHz

➔Buckets with slightly unevenly spaced bunches



➔One could vary the number of passes through the ERL:



➔Synergy with HL-LHC: Higher Harmonic RF System and TLEP!

Next Steps: RF Prototype and Test Facility

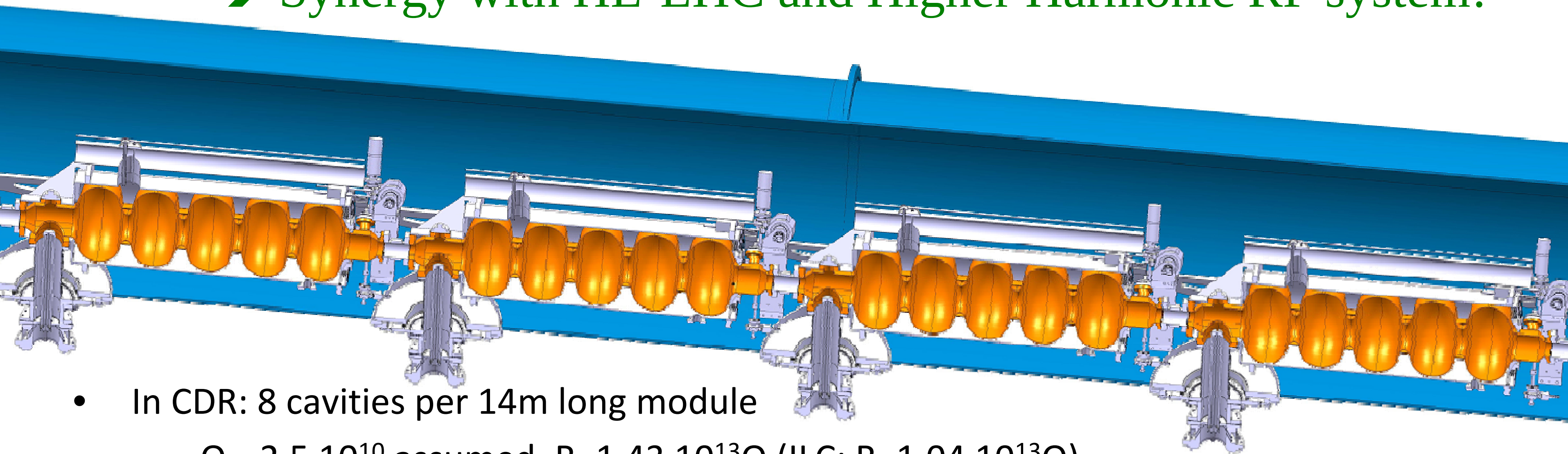
LHeC

Develop 2 RF Cryomodule Prototypes over the next 3 years

-LHeC RF frequency choice driven by power considerations

→ Choice of ERL RF frequency: 801.58 MHz

→ Synergy with HL-LHC and Higher Harmonic RF system!



- In CDR: 8 cavities per 14m long module
  - Q_0=2.5 10^{10} assumed, R=1.43 $10^{13}\Omega$ (ILC: R=1.04 $10^{13}\Omega$)
- 2 modules per quadrupole pack (2m)
- ~60 modules per 1000m long linac
- Beam physicists assumed slightly different parameters (and only 18MV/m)

LHeC: Post CDR Plans

Launch SC RF and ERL R&D and Establish collaborations:

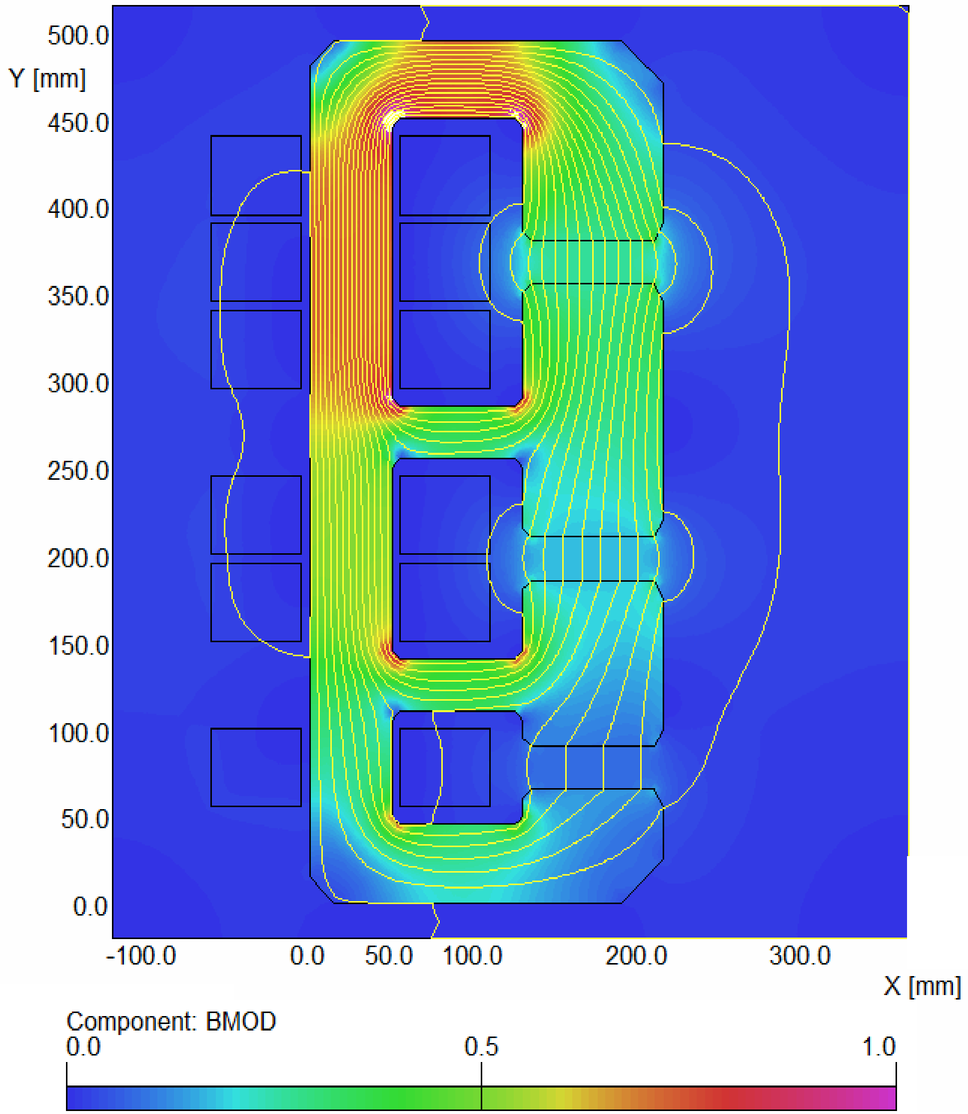
- -SC RF R&D has direct impact on cryo power consumption
  - -Synergy with HL-LHC and TLEP!
- -ERL is a hot topic with many applications
  - -Synergy with national research plans: e.g. MESA

Magnet R&D activities:

- -Normal conducting compact magnet design
- -Design optimization for ERL operation (3-in-1)
- -Superconducting IR magnet design
  - ➔ Detailed magnet design depends on IR layout and optics
  - ➔ Optics & IR magnet design influence experimental vacuum beam pipe

Magnet optimization: 3-in-1 design for ERL

Attilio Milanese and Yuri Pupkov 11/12



First conceptual cross-section

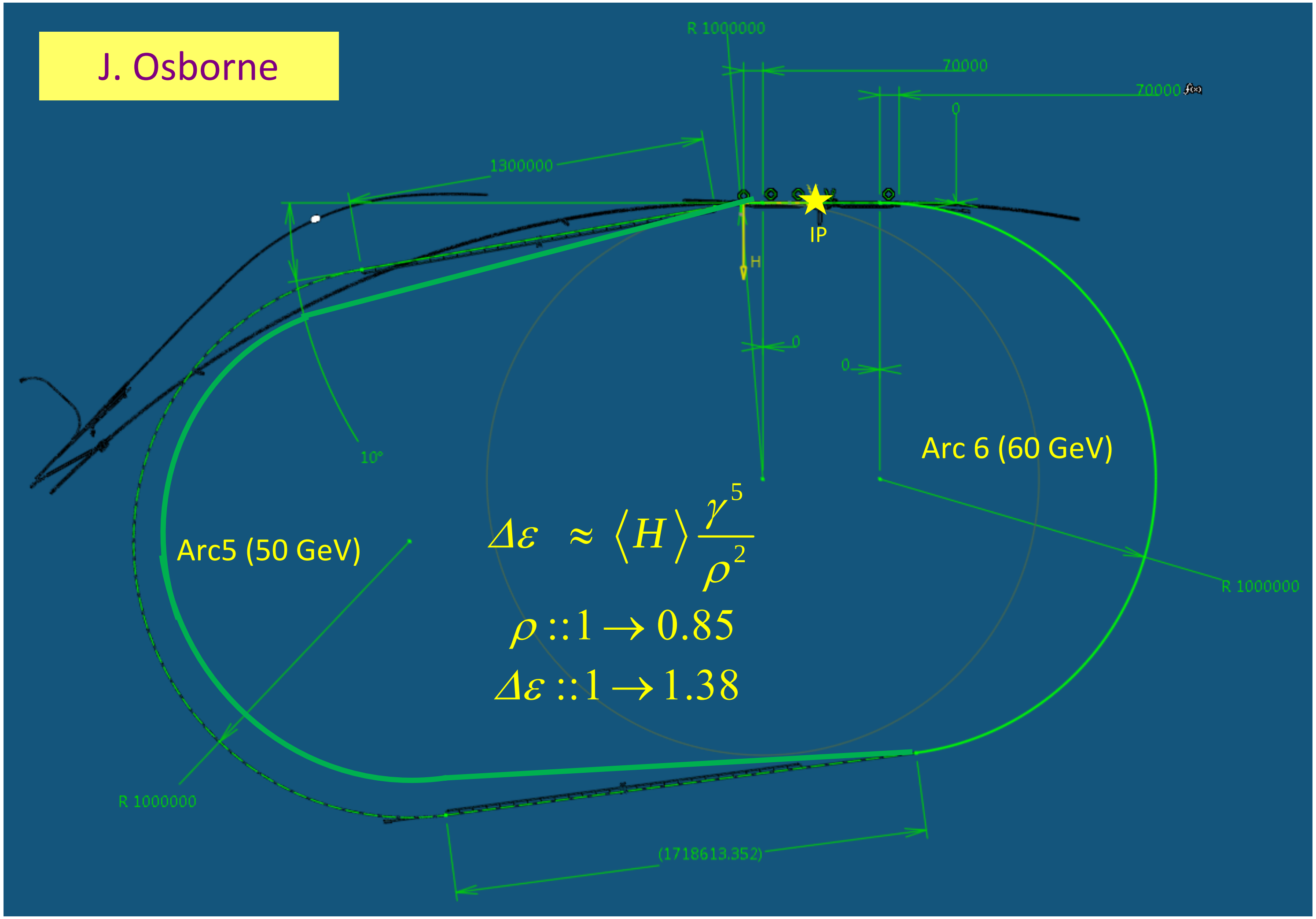
flux density in the gaps	0.264 T 0.176 T 0.088 T
magnetic length	4.0 m
vertical aperture	25 mm
pole width	85 mm
number of magnets	584
current	1750 A
number of turns per aperture	1 / 2 / 3
current density	0.7 A/mm^2
conductor material	copper
resistance	0.36 mΩ
power	1.1 kW
total power 20 / 40 / 60 GeV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

LHeC: Post CDR Plans

LHeC

- Develop 2 RF Cryomodule Prototypes over the nest 3 years
  - -LHeC RF frequency choice driven by power considerations
- Optimize and Iterate on LHeC ERL layout:
  - -Optimization of Civil Engineering layout
  - -Optimization of linac configuration & parameters
  - -Optimization of Interaction Region (L^*) and Synchroton Light
- Develop an ERL test facility @ CERN:
  - -Beam Dynamics for ERL operation ➔ develop expertise at CERN
  - -Synergy with other research plans: SC RF and TLEP
  - ➔ More details in presentation by Erk Jensen

Next Steps: ERL Layout Finalization



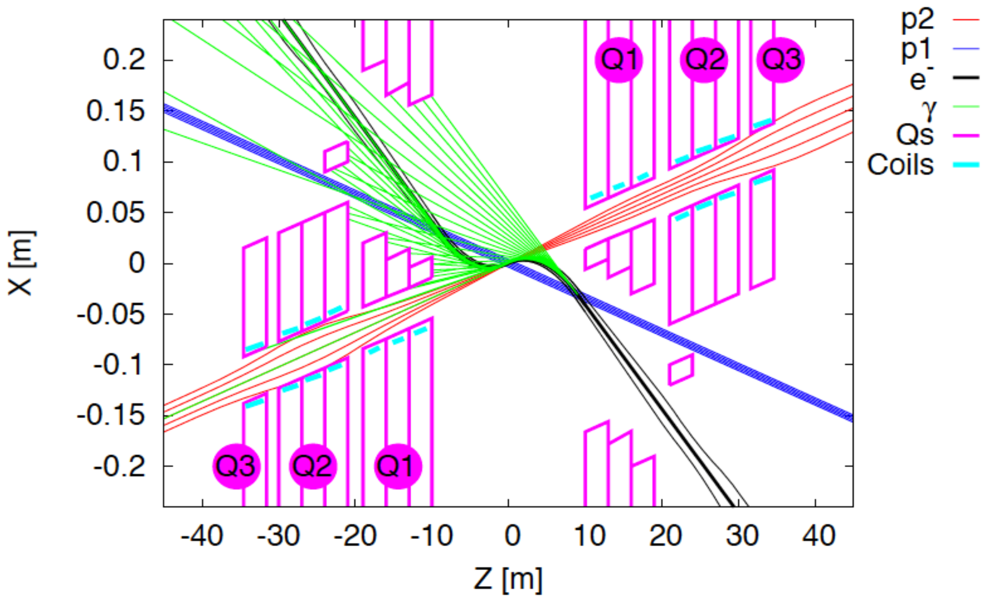
John Osborne

High Luminosity Goal

†: HL-LHC parameter
*: ATS optics?

	protons	electrons
beam energy [GeV]	7000	60
Lorentz factor γ	7460	117400
normalized emittance $\gamma\varepsilon_{x,y}$ [μm]	3.75 -> 2.5†	50
geometric emittance $\varepsilon_{x,y}$ [nm]	0.50	0.43
IP beta function $\beta^*_{x,y}$ [m]	0.10 -> 0.05*	0.12 -> 0.032
rms IP beam size $\sigma^*_{x,y}$ [μm]	7.2 -> 3.7	7.2 -> 3.7
Luminosity [10^{33}]	1 -> 10	
beam current [mA]	1120	12.8
bunch spacing [ns]	25	25
bunch population	$2.2\text{x}10^{11\dagger}$	$2\text{x}10^{9}$
Effective crossing angle	0.0	

Next Steps: Interaction Region Optimization



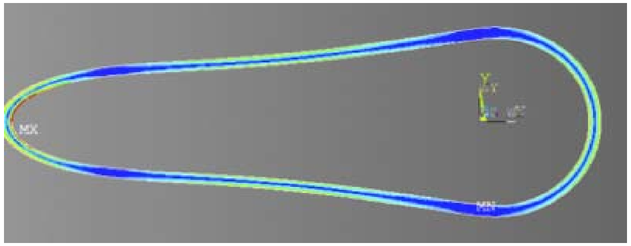
Have optics compatible with LHC ATS optics and β*=0.1m
Head-on collisions mandatory →
High synchrotron radiation load, dipole in detector

Adapt LHeC to LHC ATS optics
Specification of Q1 – NbTi prototype

Revisit SR (direct and backscattered),
Masks+collimators
Beam-beam dynamics and 3 beam operation studies

Beam pipe: in CDR 6m, Be, ANSYS calculations

Composite material R+D, prototype, support..
→ Essential for tracking, acceptance and Higgs



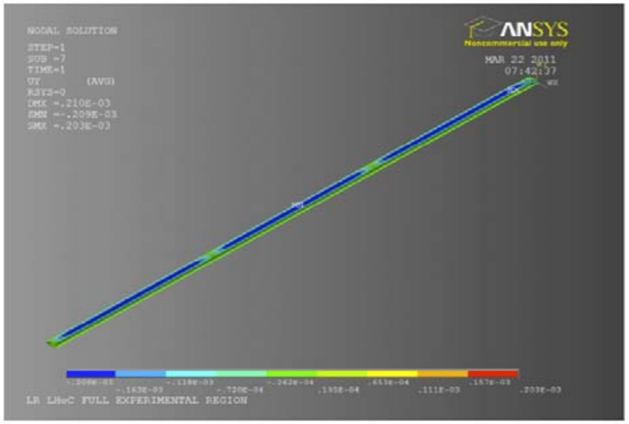
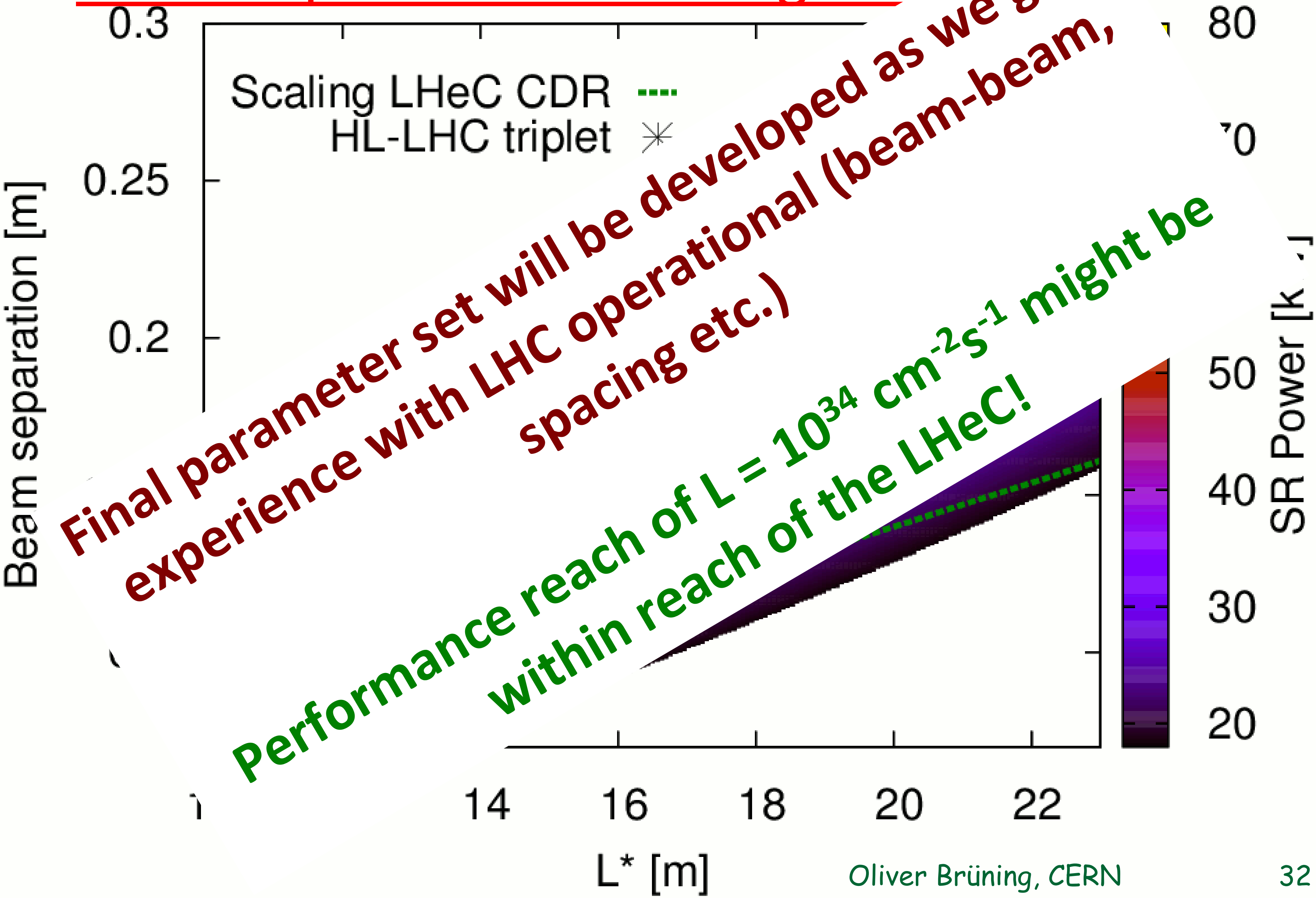


Figure 9.32: 3-D view of the LR geometry showing contours of bending displacement [m].

Next Steps: Interaction Region D



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

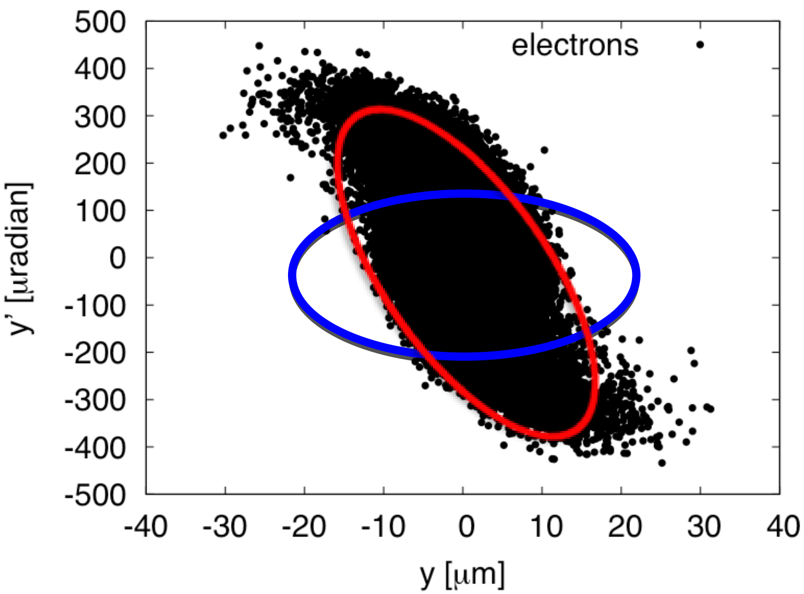
Performance reach of $L = 10^{34}$ $cm^{-2}s^{-1}$ might be within reach of the LHeC!

Post CDR Studies: Beam-beam Effects

The main impact of LHeC on the proton beam

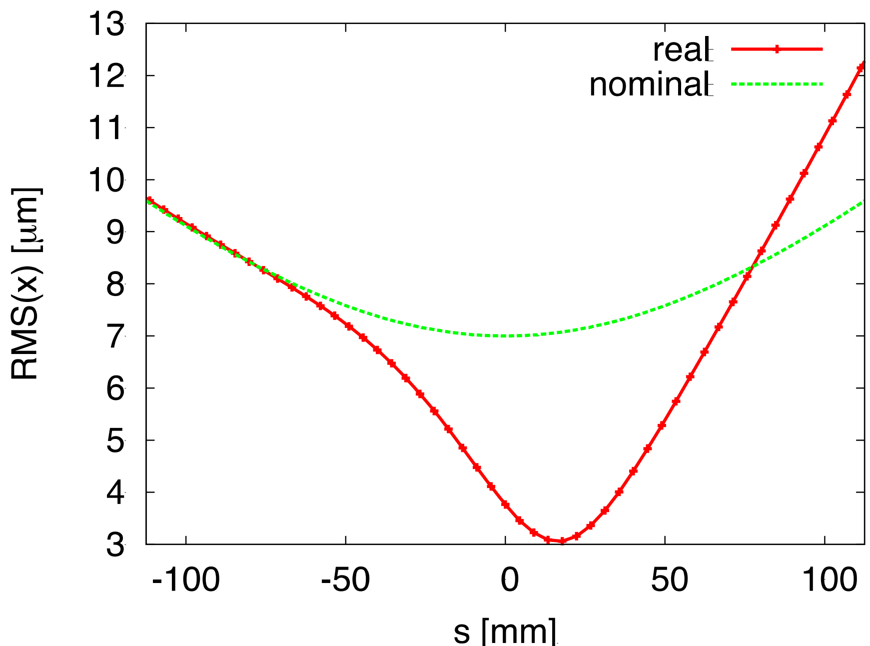
Disruption parameter is 6.2 for electrons
Ratio of focal length to bunch length

$$D_y = \frac{\sigma_z}{f_y} = \frac{2Nr_e\sigma_z}{(E/m_e)\sigma_y(\sigma_x+\sigma_y)}$$



Spent electron beam shown

Need special optics to catch electron beam



Electron beam shrinks during collision
Increases beam-beam tune shift for protons

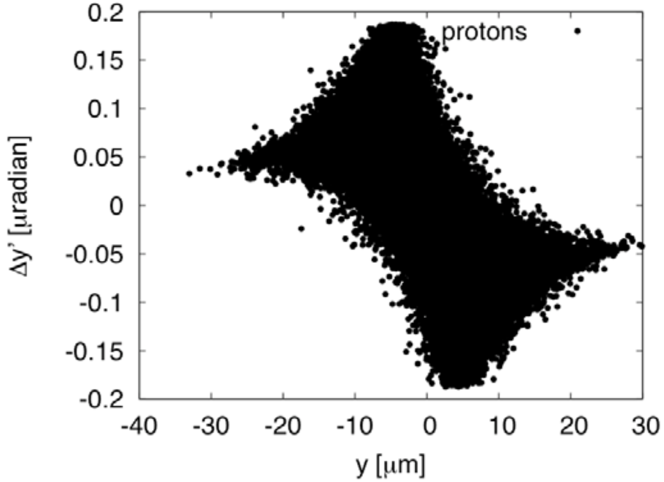
D. Schulte; EPS, Stockholm, July, 2013

Post CDR Studies: Beam-beam Effects

Nominal beam-beam tune shift 1.2×10^{-4} for protons

$$\xi_y = \frac{N r_e \beta_y}{2\pi(E/m_e)\sigma_y(\sigma_x+\sigma_y)}$$

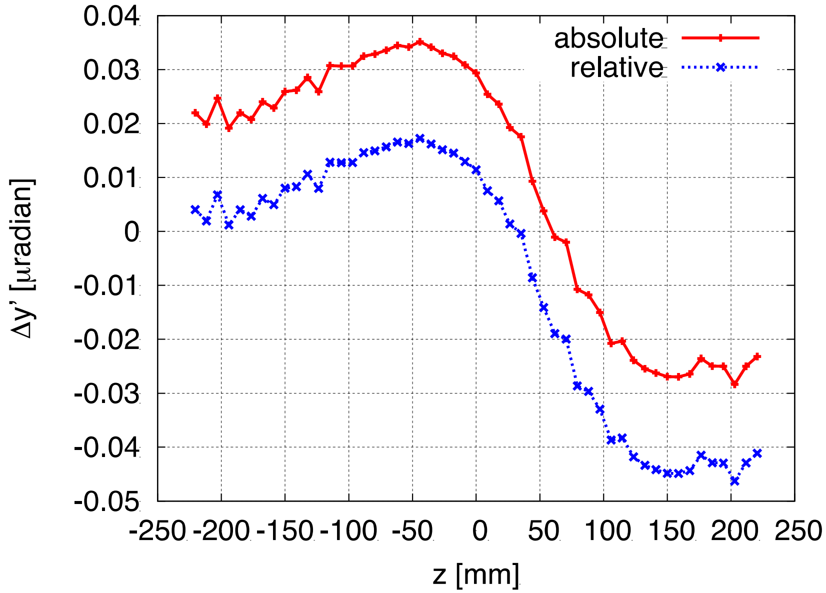
Proton deflection as function of initial offset:



Real beam-beam tune shift is 6×10^{-4} for Protons due to electron beam disruption

Disruption also modifies collision with offsets

Deflection for 1σ offset



Beam-beam offset leads to emittance growth in proton beam

Conservative estimate:

$$\frac{\Delta\varepsilon}{\varepsilon} = O\left(10^{-7}\right)\frac{\sigma_{jitter}^2}{\sigma^2}$$

Cured by limiting beam-beam jitter to O(1%σ)

D. Schulte; EPS, Stockholm, July, 2013

Summary: Next Steps

- Develop 2 RF Cryomodule Prototypes over the nest 3 years

  Choice of ERL RF frequency: 801.58 MHz

  ➔ Synergy with HL-LHC and Higher Harmonic RF system!

- Design an ERL test facility @ CERN:

  -More details in next presentation by Erk Jensen

- Optimize and Iterate on LHeC ERL layout:

  -Optimization of linac configuration & parameters

  -Beam dynamics studies

  -Optimization of Civil Engineering layout

  -Optimization of Interaction Region (L^*) and Synchroton Light

Summary: 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. 10-15 years of HL-LHC operation

  -Current planning based on HL-LHC start in 2023-2024

  ➔ end of LHC lifetime by 2034 to 2039

- LHeC operation:

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

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

LHeC Tentative Time Schedule

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
	RF Proto Type Development												

LHeC Project is still on track for startup with HL-LHC:

-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)

HERA required ca.10 years from proposal to completion

On schedule for launching SC RF development

➔ Synergies with HL-LHC and TLEP

LS3 --- HL LHC

(LEP, LHC and LINAC4 at CERN and the European XFEL at DESY and the PSI XFEL). In

Reserve Transparencies

LHeC CDR:

Total of ca. 500

•Details remain to be addressed

•Decision to focus R&D work on LR technologies over coming 4 years

➔Main Conclusion so far: LHeC can be realized in parallel with HL-LHC if necessary studies are not delayed!

LHeC Options: Executive Summary

Ring-Ring option:

-We know we can do it: → LEP 1.5

-Challenge 1: integration in tunnel and co-existence with LHC HW

-Challenge 2: installation within LHC shutdown schedule

Linac-Ring option:

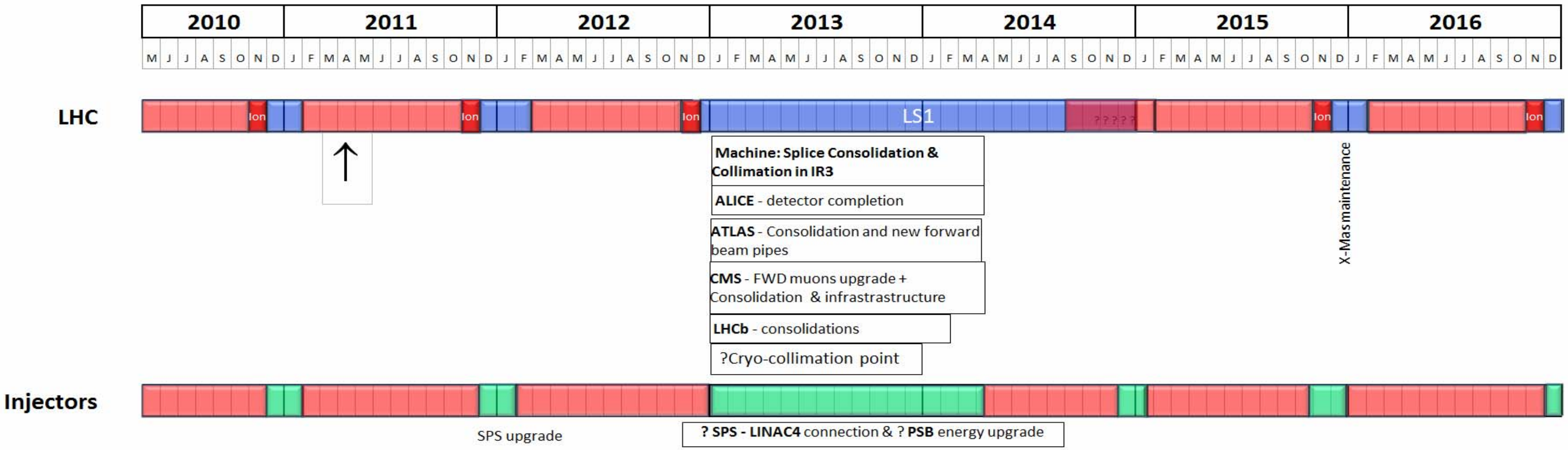
-Installation decoupled from LHC operation and shutdown planning

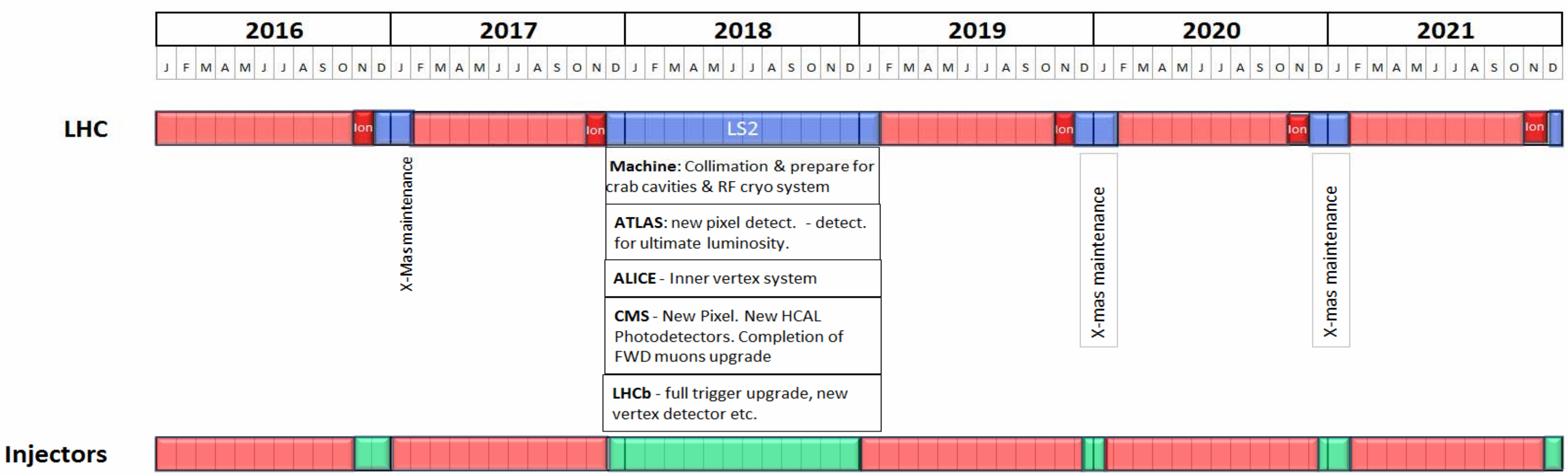
-Infrastructure investment with potential exploitation beyond LHeC

-Challenge 1: technology → high current, high energy SC ERL

-Challenge 2: Positron source

New rough draft 10 year plan





2022

LS3

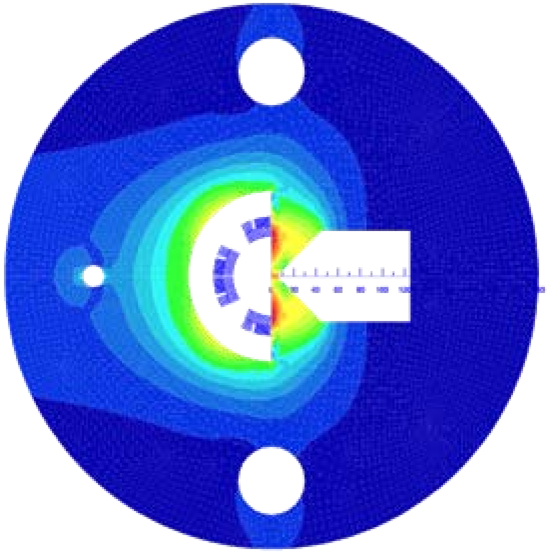
Installation of the HL-LHC hardware

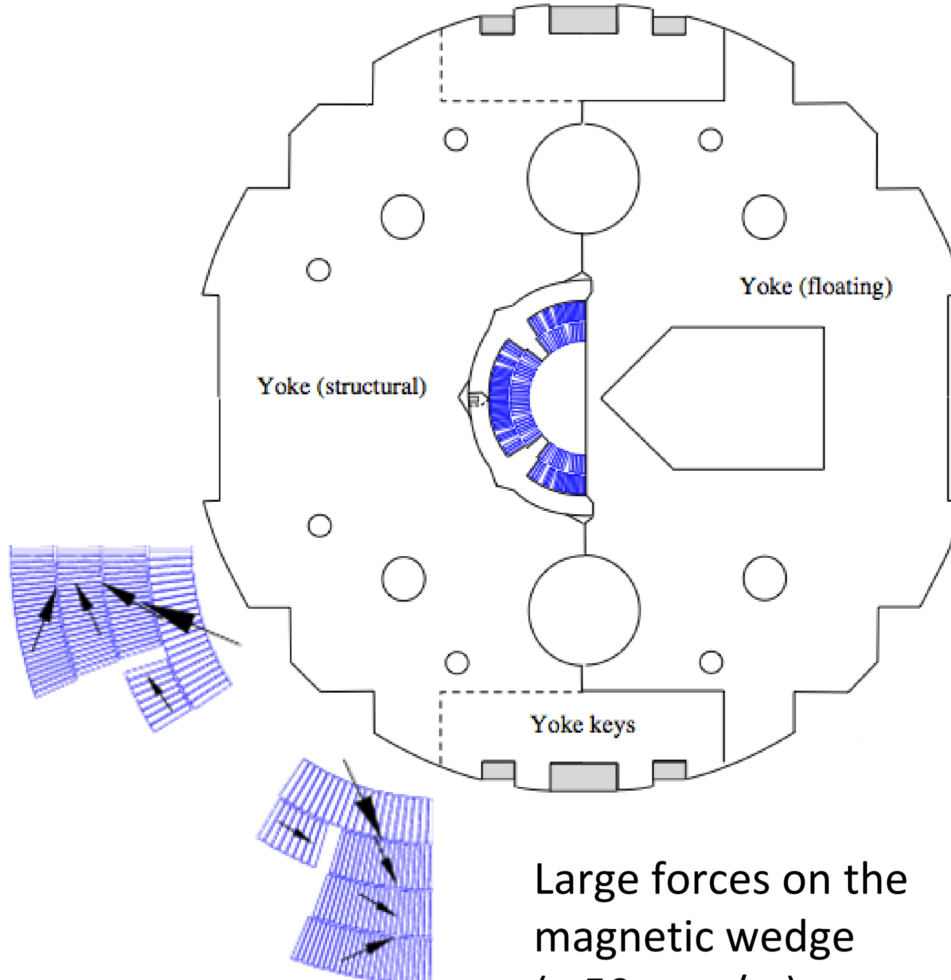
Installation of LHeC

Preparation for HE-LHC

Next Steps: LHeC IR Quadrupole

Luca Bottura @ Chamonix 2012





Large forces on the magnetic wedge (> 50 tons/m)

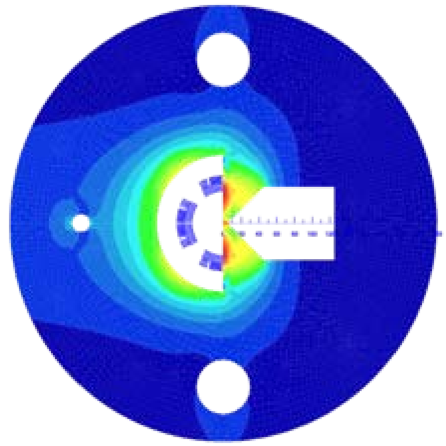
- Half-quad with field-free region, assembled using MQXC coils
  - 2.5 FTE
  - 500 kCHF
  - approx. 2 years till test

IR magnets

- Ring-ring
  - G=140 T/m
  - A=70 mm
  - **B_{fringe} = 30 mT**
  - **O(15) kW SR power in the proton aperture**

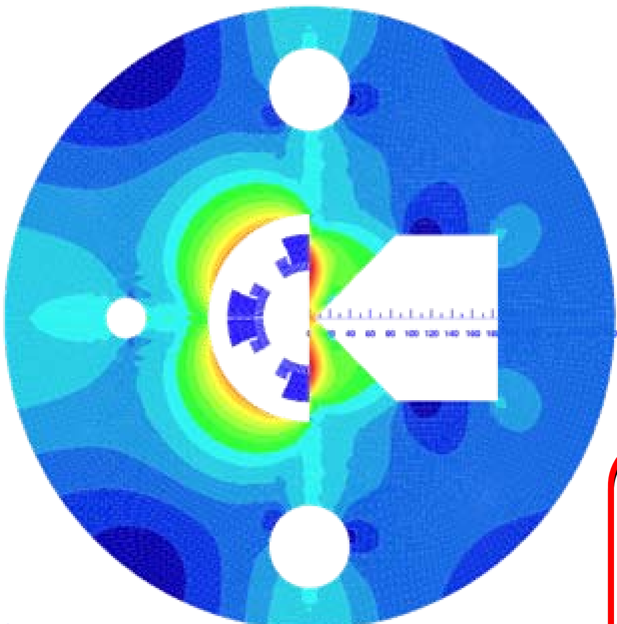
- Linac-Ring
  - **G=250-300 T/m**
  - **A=90 mm**
  - B_{fringe} = 500 mT
  - **O(2) kW SR power in the proton aperture**

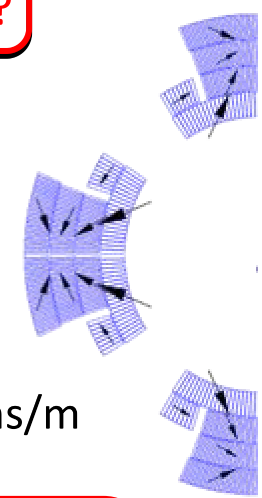
By courtesy of S. Russenschuck



NbTi suitable for this *medium gradient* option

Mechanics ?
Heat removal ?





100 tons/m

NbTi or Nb3Sn ?
Large aperture ?
Mechanics ?
Heat removal ?

LHeC - Participating Institutes: A very rich collaboration

LHeC

CERN

SLAC NATIONAL ACCELERATOR LABORATORY

NTNU Norwegian University of Science and Technology

The Cockcroft Institute of Accelerator Science and Technology

Jefferson Lab Thomas Jefferson National Accelerator Facility

clic

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

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ИНСТИТУТ ЯДЕРНОЙ ФИЗИКИ
им. Г.И.Будкера
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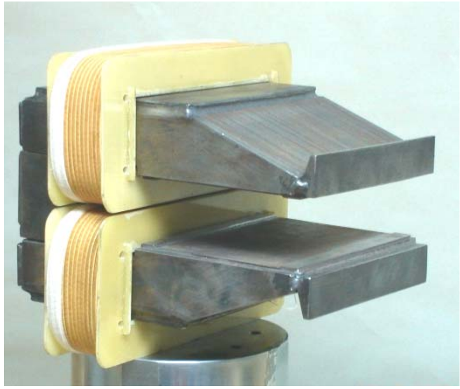
KEK

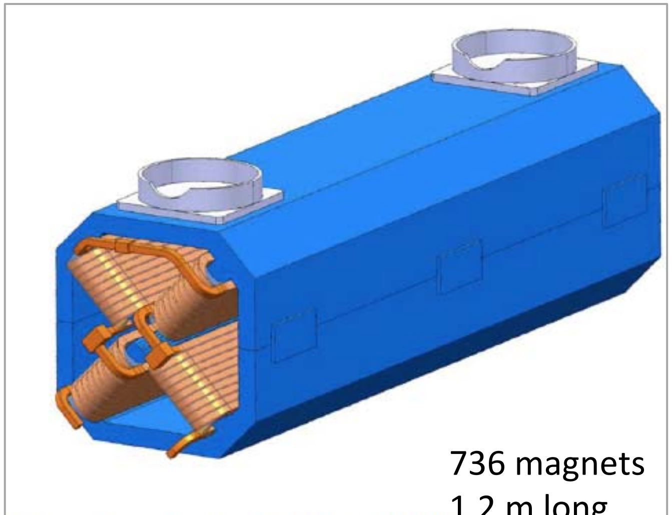
Ring: Dipole + Quadrupole Magnets



BINP & CERN prototypes

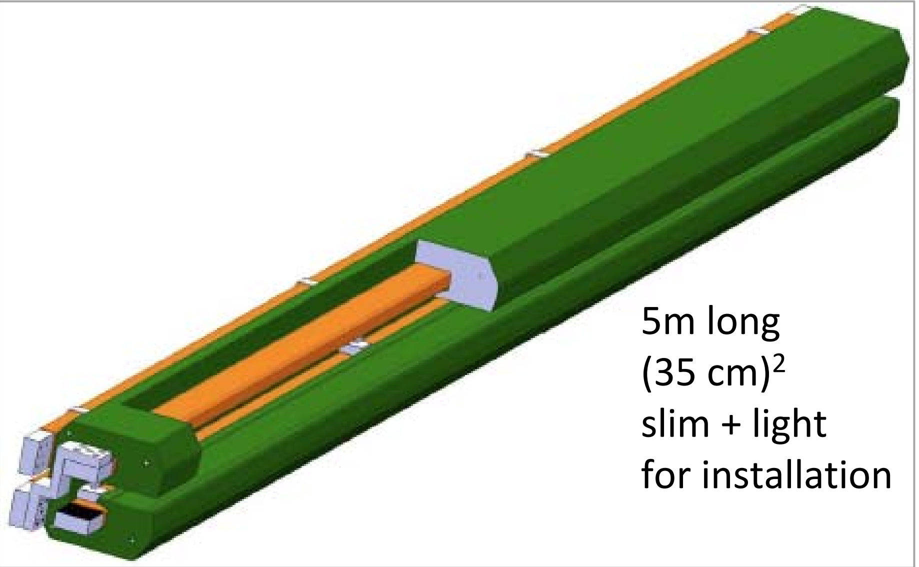
Parameter	Value	Units
Beam Energy	10-60	GeV
Magnetic Length	5.35	Meters
Magnetic Field	0.127-0.763	Tesla
Number of magnets	3080	
Vertical aperture	40	mm
Pole width	150	mm
Number of turns	2	
Current @ 0.763 T	1300	Ampere
Conductor material	copper	
Magnet inductance	0.15	milli-Henry
Magnet resistance	0.16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

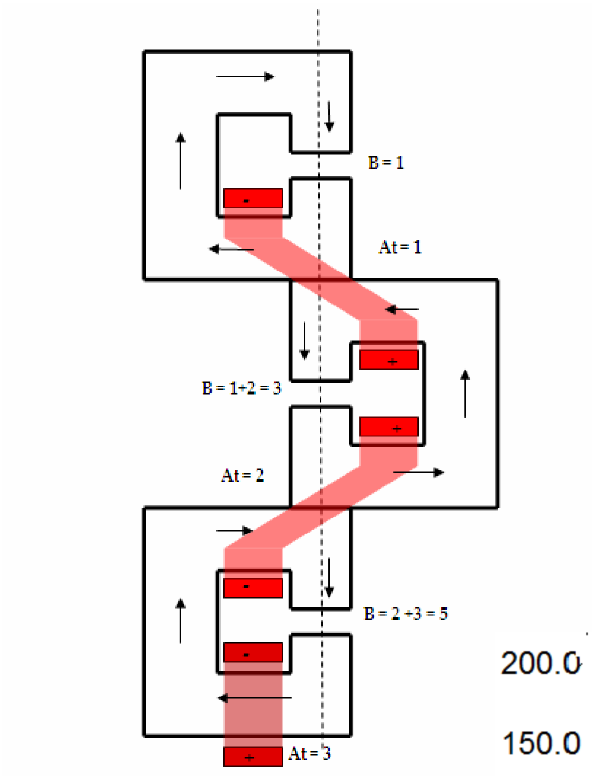


5m long
$(35\ cm)^2$
slim + light
for installation

Next Steps: Test Facility and Magnets

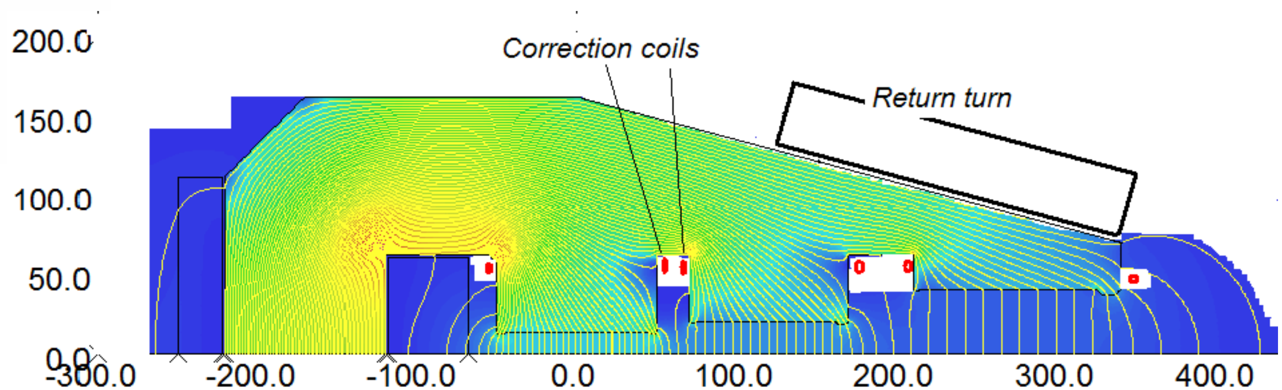
Intend to build Collaboration of CERN Magnet Group for the dipole and possibly further arc magnets for the Test Facility (two turns) and the LHeC.

Initial designs for Linac magnets in CDR and further discussions/thoughts from Daresbury, CERN and BINP colleagues.



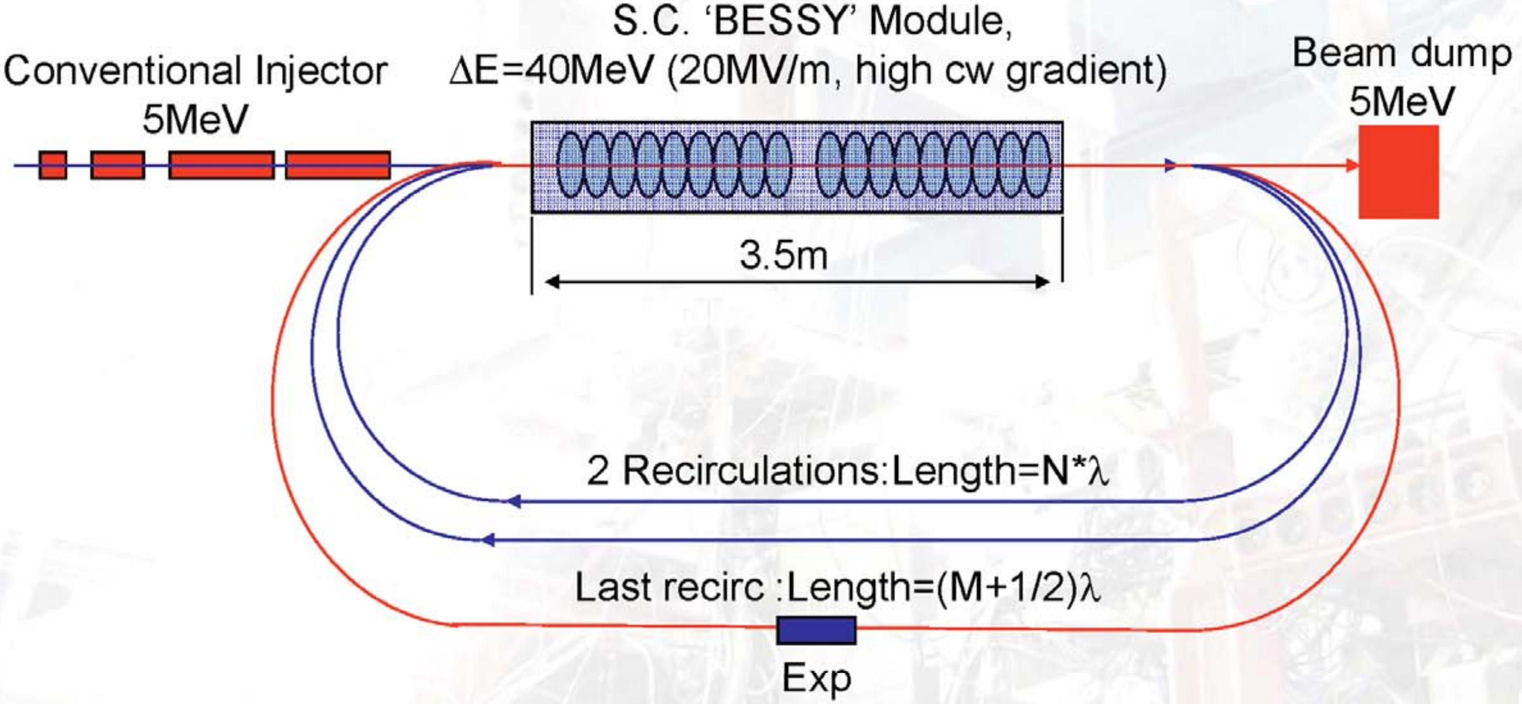
Neil Marks 7/12

Attilio Milanese and Yuri Pupkov 11/12



MESA

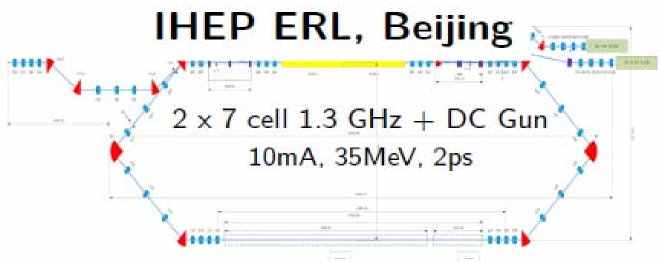
Mainzer Energieeffiziente Supraleitende Anlage
Mainz Energy recovering Superconducting Accelerator

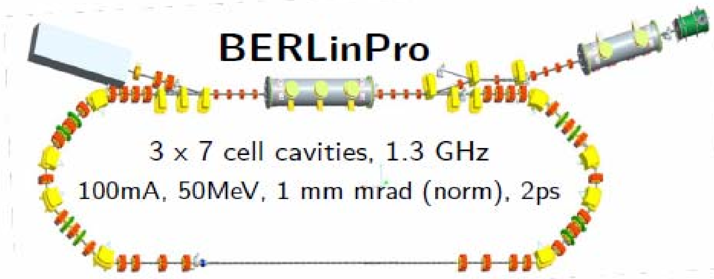


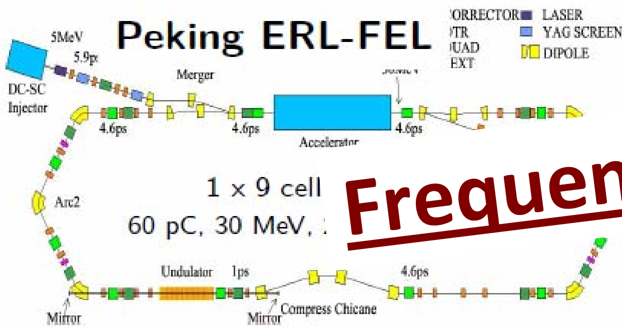
Parameters: (red beam for experiments)
E_{max}= 5-125 MeV; I_{av}=10mA (cw) ; ε_{norm}=10µm, P_{dump}≤50kW, Cost <10M€
Footprint < 20*10m.

ERL Facilities around the World

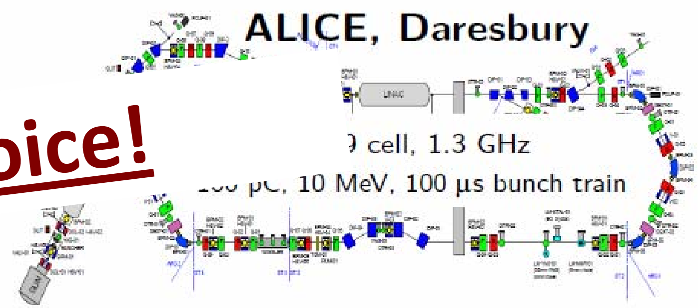
Planned Test Facilities and Installations:

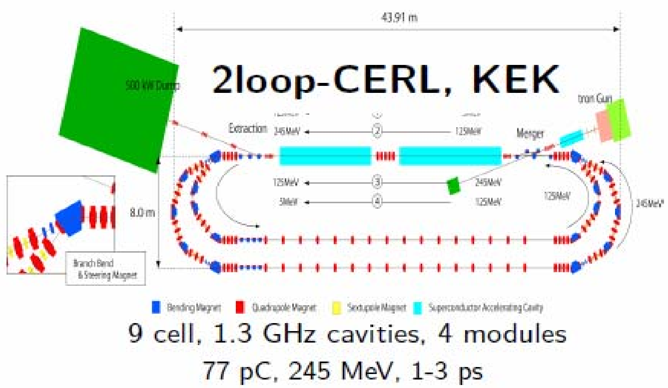


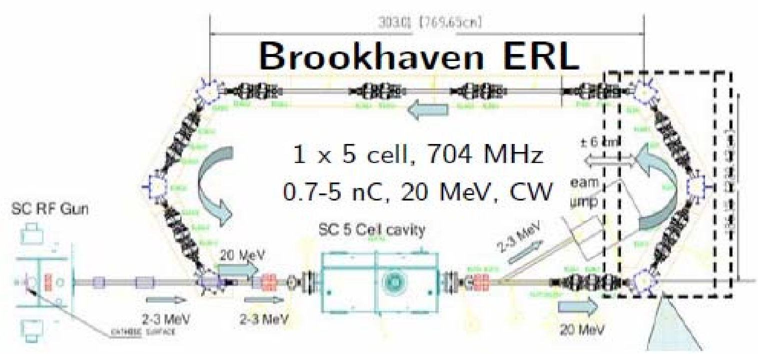




Frequency choice!

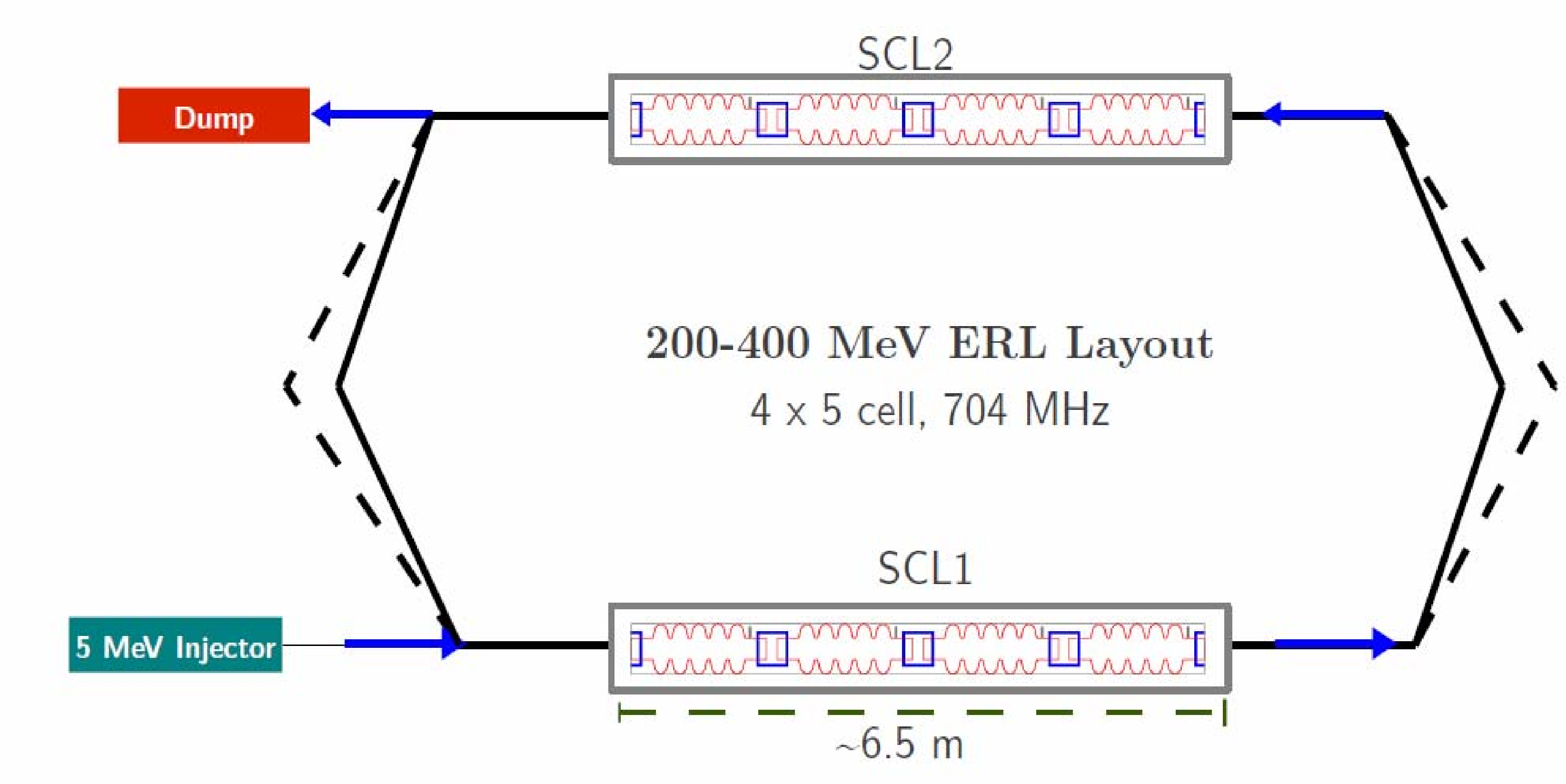






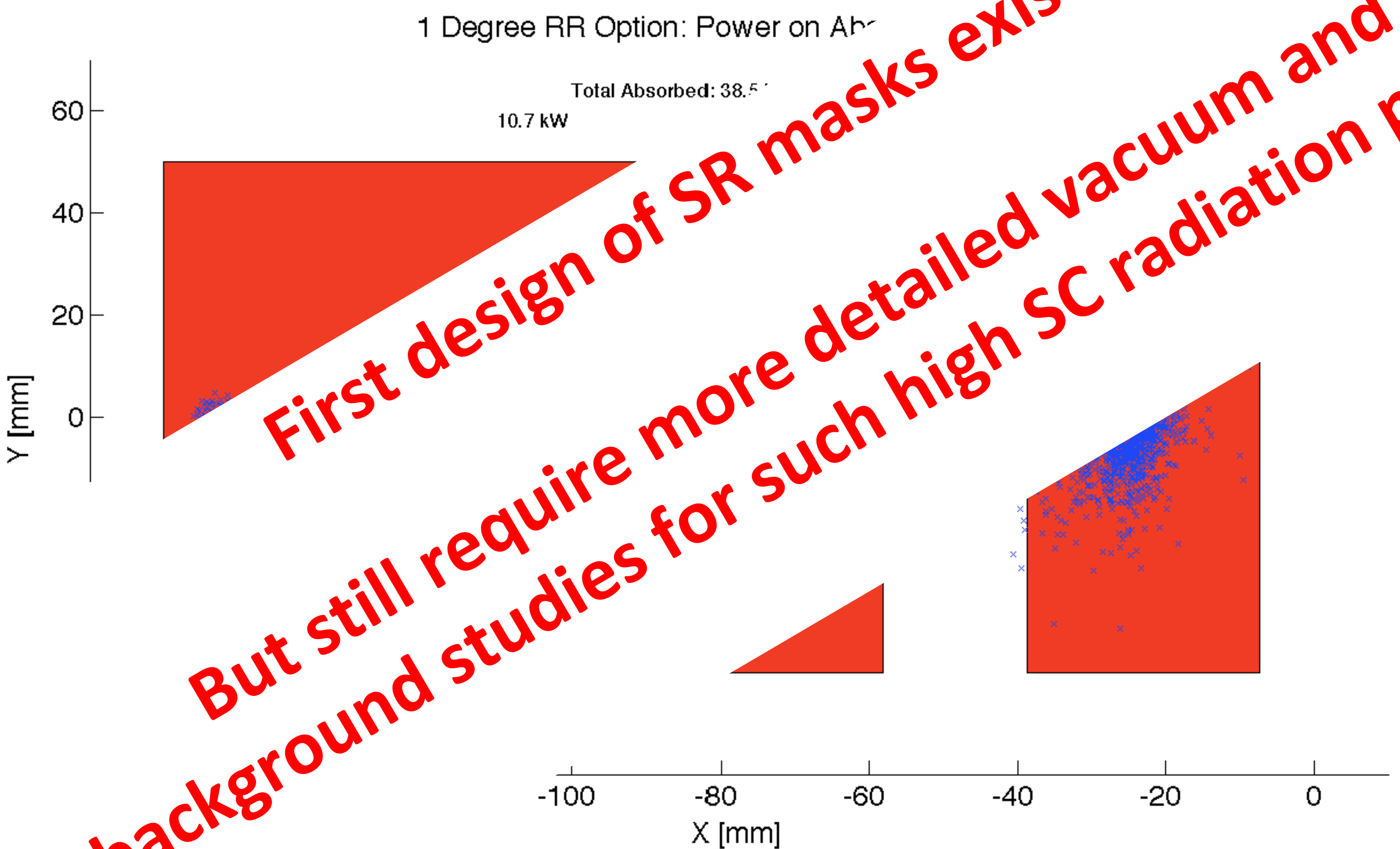
ERL Test Facility at CERN

- Potential layout:



Interaction Region: Synchrotro… tion

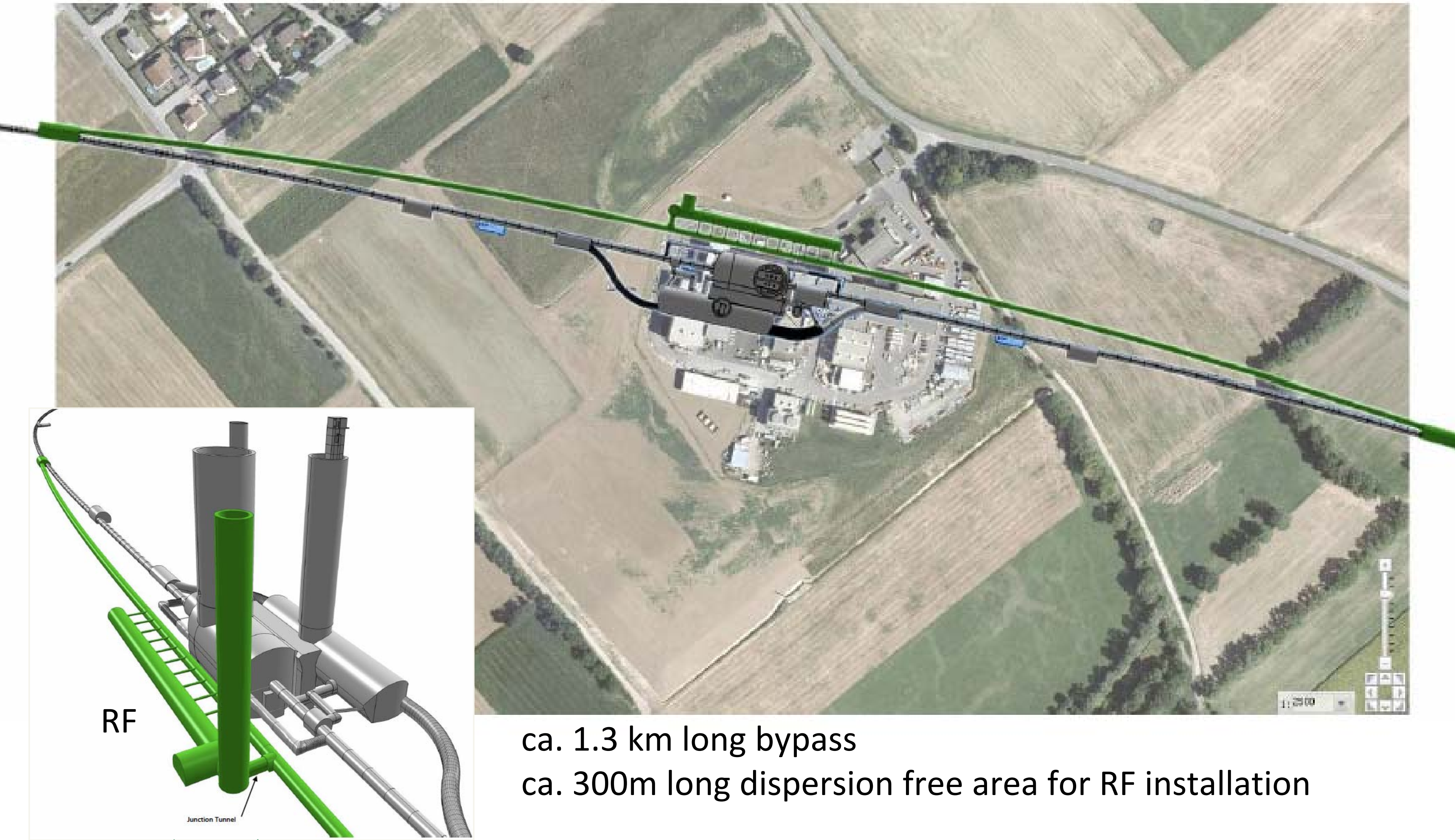
Significant power: > 20 kW. Example Ring-Ring



First design of SR masks exists.

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

Bypassing CMS: 20m distance to Cavern



ca. 1.3 km long bypass

ca. 300m long dispersion free area for RF installation

Design Parameters

electron beam	RR**	LR	LR*		LR
e- energy at IP[GeV]	60	60	140		1.7
luminosity [10^{32} cm^{-2}s^{-1}]	0.9	10			3.75
polarization [%]	40	90			7
bunch population [10^9]	20				
e- bunch length [mm]	6				
bunch interval [ns]					
transv. emit. $\gamma\varepsilon_{x,y}$ [m					
rms IP beam si					
e- IP bet					
full					
geo					
repeti					
beam pu			5		
ER efficien			N/A		
average cur		6.6	5.4		
tot. wall plug	100	100	100		

*) pulsed, but high ene ossible; **) 1° acceptance optics

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

ervative

also for deuterons

w) and lead (exists)

RR= Ring – Ring
LR =Linac –Ring

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

LH*e*C organisation

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Allen Caldwell -chair (MPI Munich)
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Interaction Region Design
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Ring-Ring Design
Kurt Huebner, Sasha Skrinsky, Ferdinand Willeke
Linac-Ring Design
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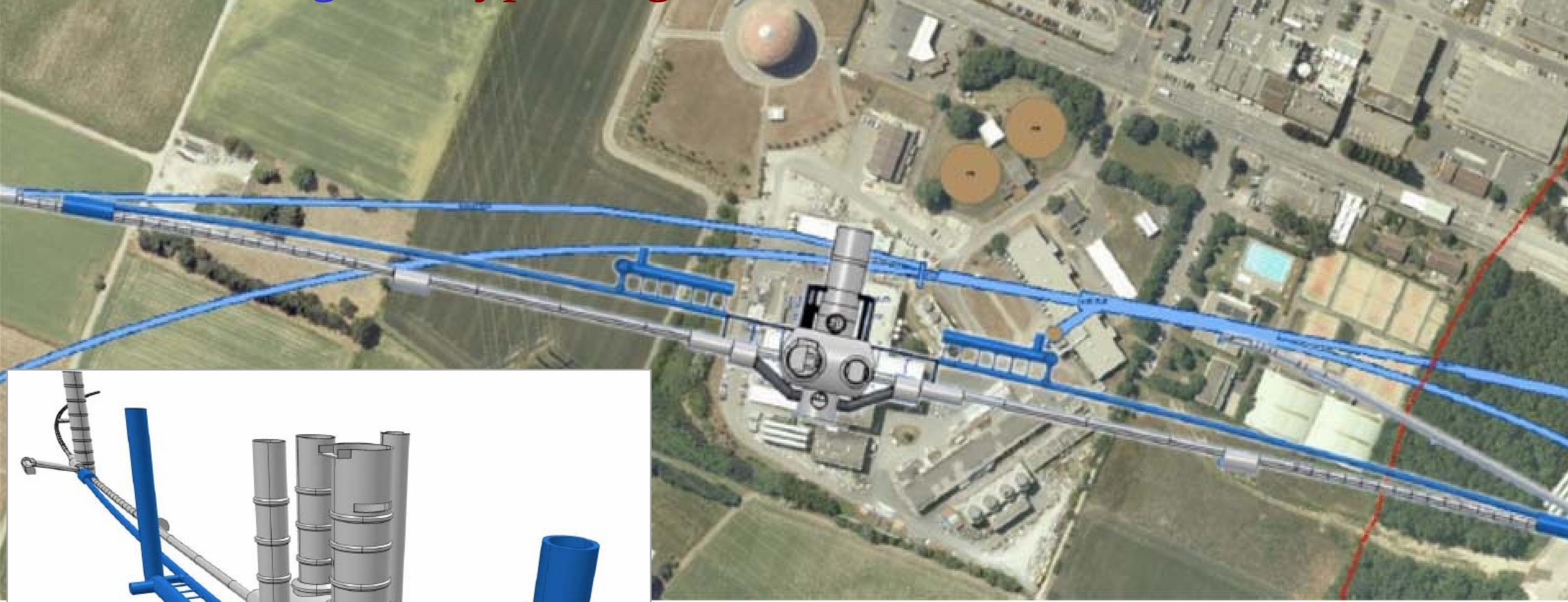
LHeC: Ring-Ring Option

Challenge 1: Bypassing the main LHC detectors



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

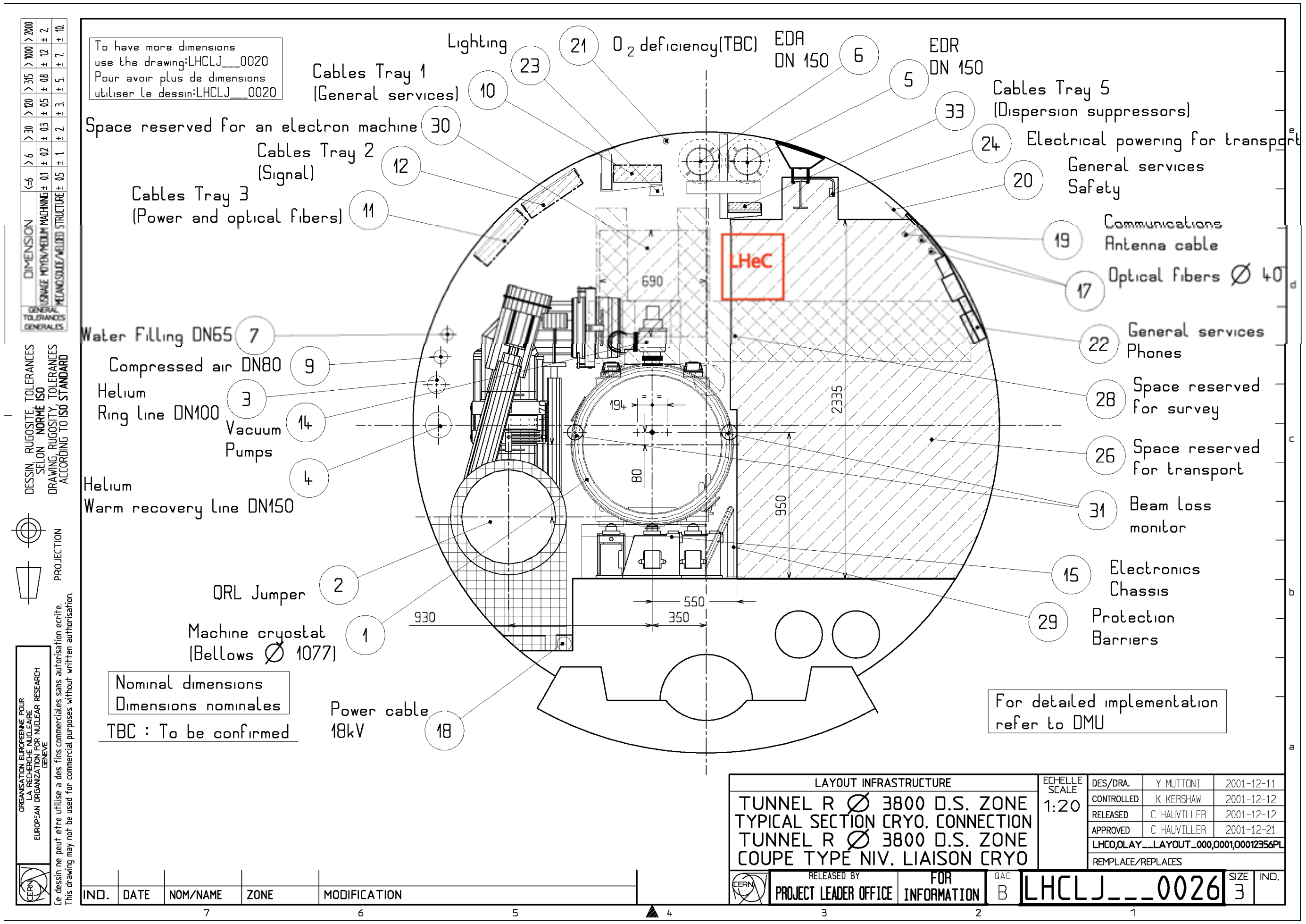
ca. 1.3 km long bypass

ca. 170m long dispersion free area for RF

LHeC: Ring-Ring Option

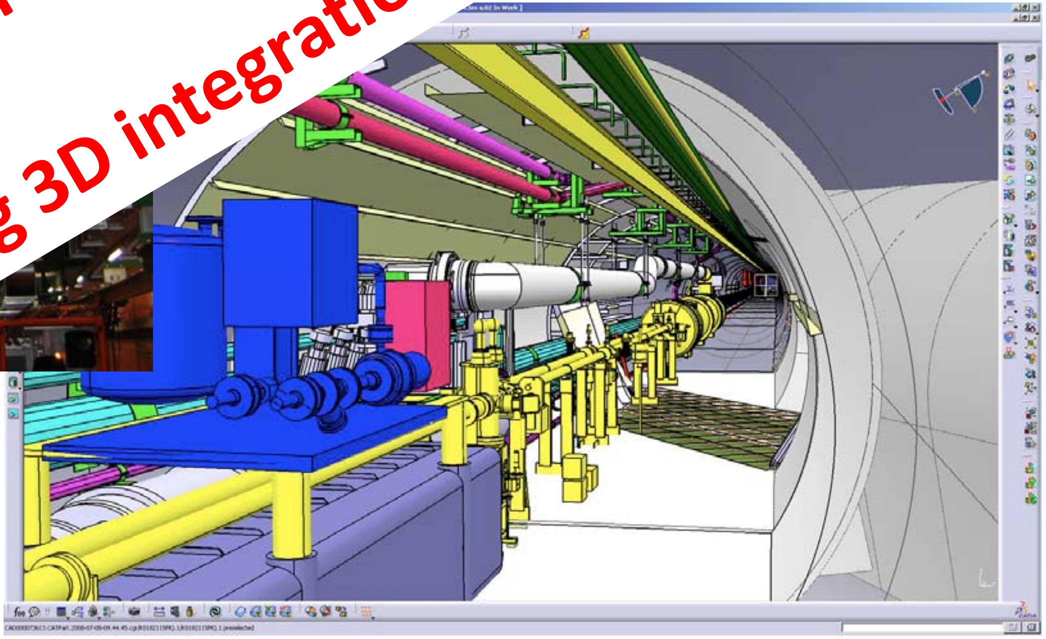
Challenge 3: Installation with LHC circumference:

requires: support structure with efficient montage and compact magnets



LHeC: Ring-Ring Option

Challenge 2: Integration in the LHC tunnel



No principal problem found yet!

(Still missing 3D integration study)

ink in IR3