LHeC Accelerator Development

E. Cruz-Alaniz

on behalf of the LHeC Study Group

DIS 14
Warsaw, Poland

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A.M. Stasto (Penn State)
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F. Zomer (Orsay LAL)

LHeC

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CERN

CLIC

KEK-JAPAN

The Cockcroft Institute
of Accelerator Science and Technology

EPFL
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

SLAC
NATIONAL ACCELERATOR LABORATORY

UNIVERSITY OF
LIVERPOOL

NTNU
Norwegian University of
Science and Technology

DESY

Jefferson Lab

BROOKHAVEN
NATIONAL LABORATORY

ANKARA UNIVERSITY

TOBB
UNIVERSITY OF
ECONOMICS AND TECHNOLOGY

ULUDAĞ ÜNİVERSİTESİ 1975

NİĞDE ÜNİVERSİTESİ 1992

INFN
Istituto Nazionale
di Fisica Nucleare

LAL
LABORATOIRE
DE L'ACCÉLÉRATEUR
LINÉAIRE

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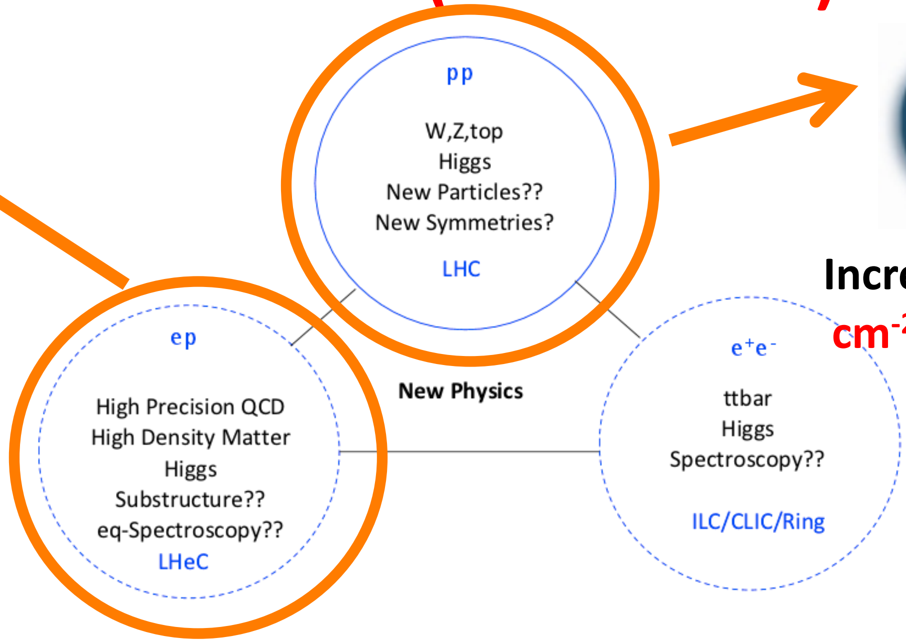
LHC Upgrade Program

TeV Scale (2014-2035..)

Energy ($\sqrt{s}$= 1.2 TeV) 4 times higher Luminosity (10^{33} $cm^{-2}s^{-1}$) 100 higher as HERA

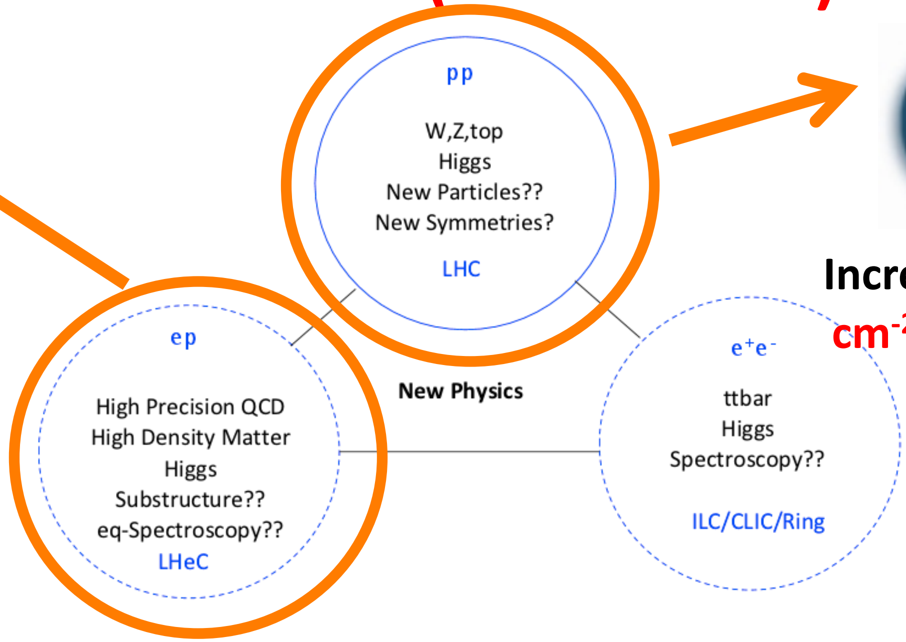


Increase Luminosity(5×10^{34} $cm^{-2}s^{-1}$) in IP1 (ATLAS) and IP5 (CMS)

LHeC Goals

TeV Scale (2010-2035..)

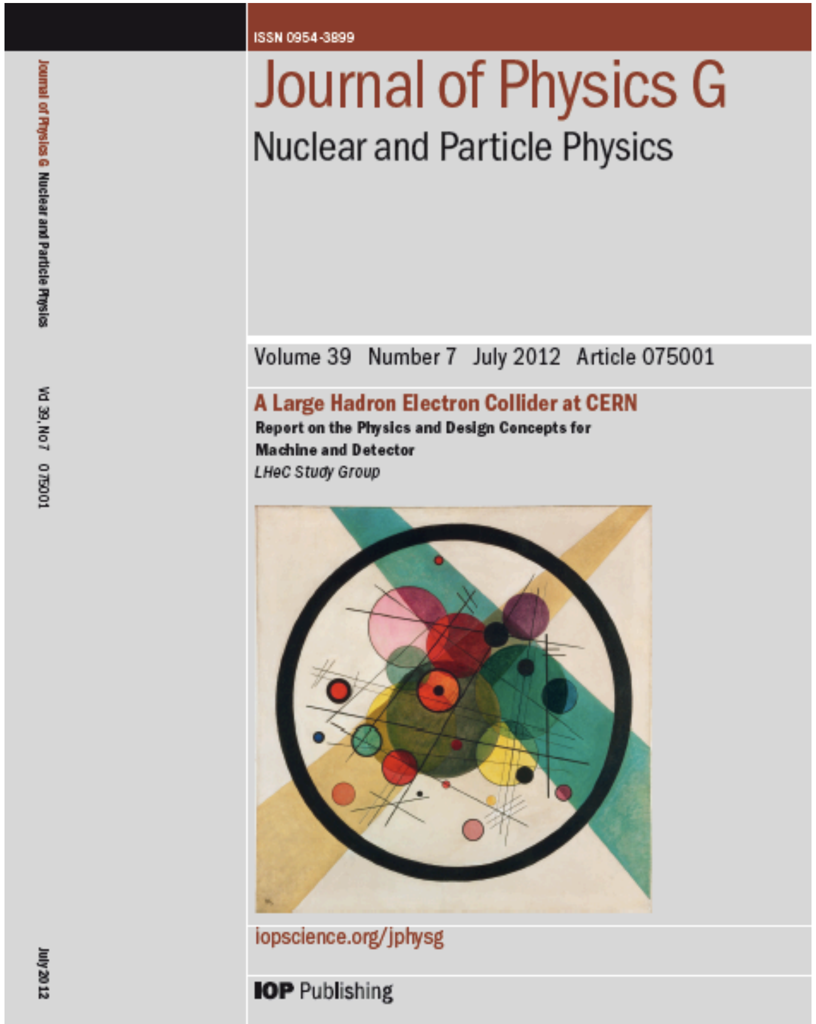
Energy (√s= 1.2 TeV) 4 times higher Luminosity (10^{33} $cm^{-2}s^{-1}$) 100 higher as HERA



Increase Luminosity($5x10^{34}$ $cm^{-2}s^{-1}$) in IP1 (ATLAS) and IP5 (CMS)

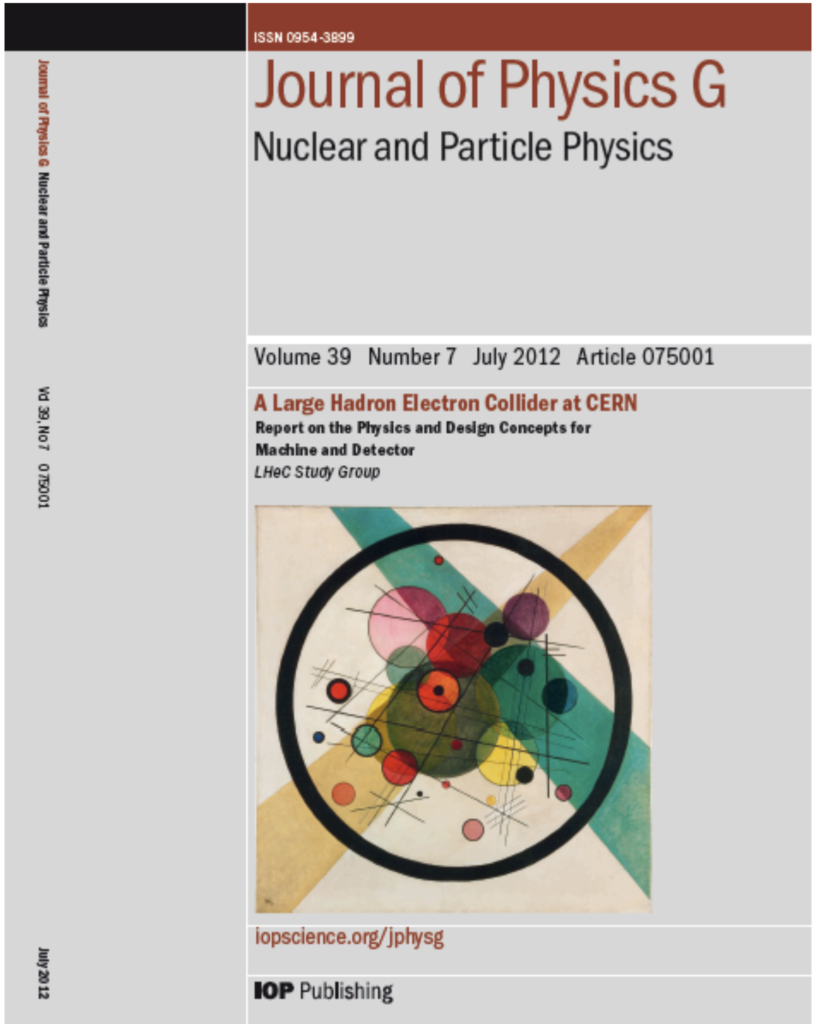
- Synchrotonous pp and ep operation at high Luminosity
- Power consumption for lepton complex ≤ 100 MW

Conceptual Design Report (CDR) July 2012



1. INTRODUCTION
2. PHYSICS
3. ACCELERATOR
4. DETECTOR
5. CONCLUSIONS

CDR



1. **INTRODUCTION**

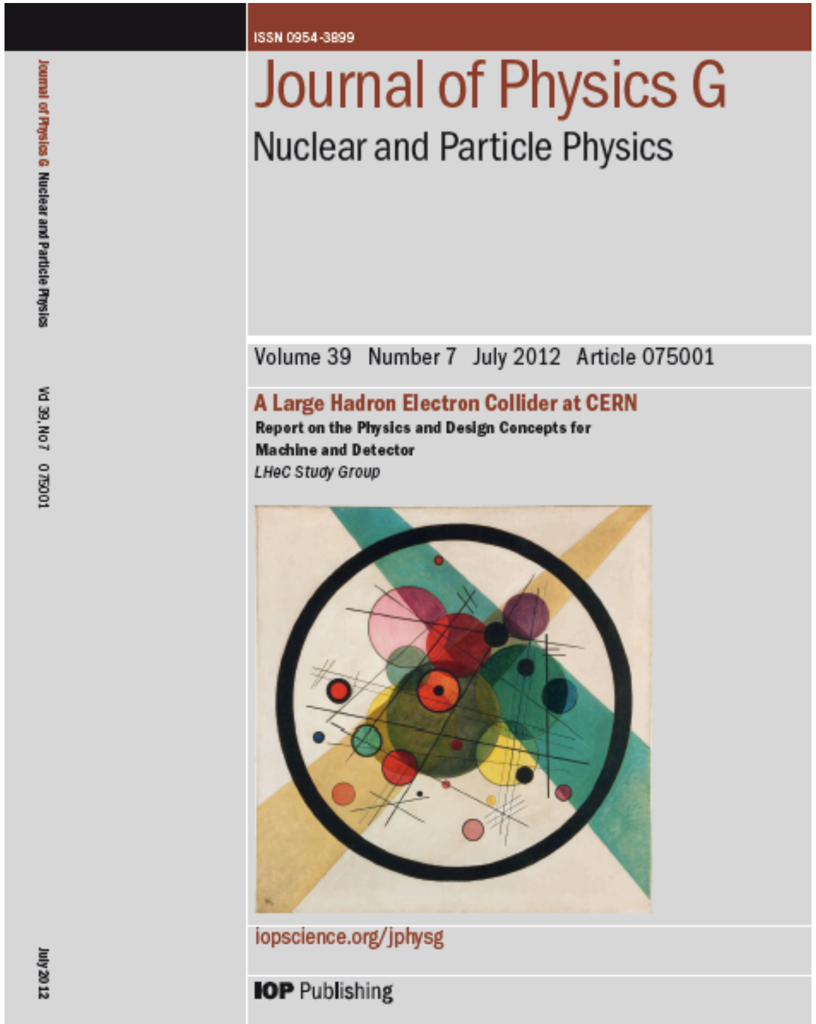
2. **PHYSICS**
   - Precision QCD and Electroweak Physics
   - Physics at High Parton Densities
   - New Physics at high energy

3. **ACCELERATOR**

4. **DETECTOR**
   - Detector Requirements
     - Central Detector
     - Forward and Backward Detector

5. **CONCLUSIONS**

CDR



1. **INTRODUCTION**

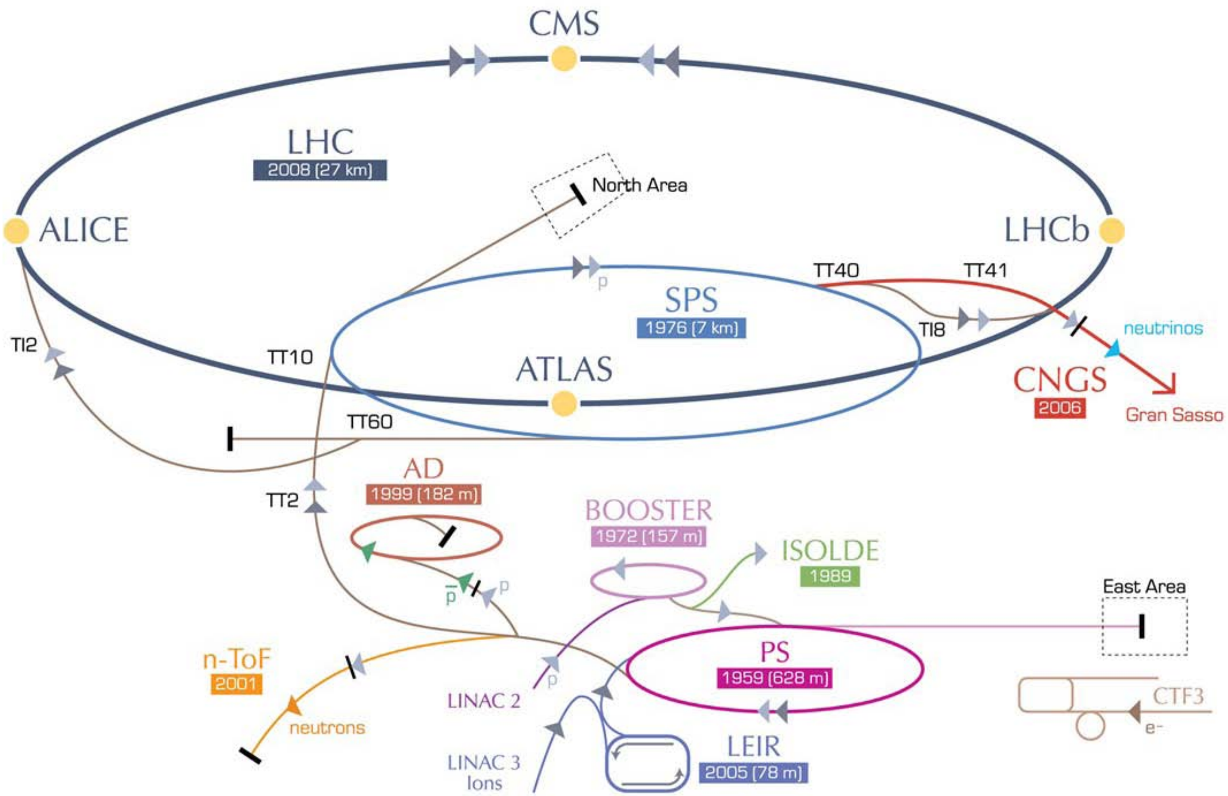
2. **PHYSICS**

3. **ACCELERATOR**
   - Ring-Ring Collider
   - Linac-Ring Collider
   - System Design
   - Civil Engineering and Services

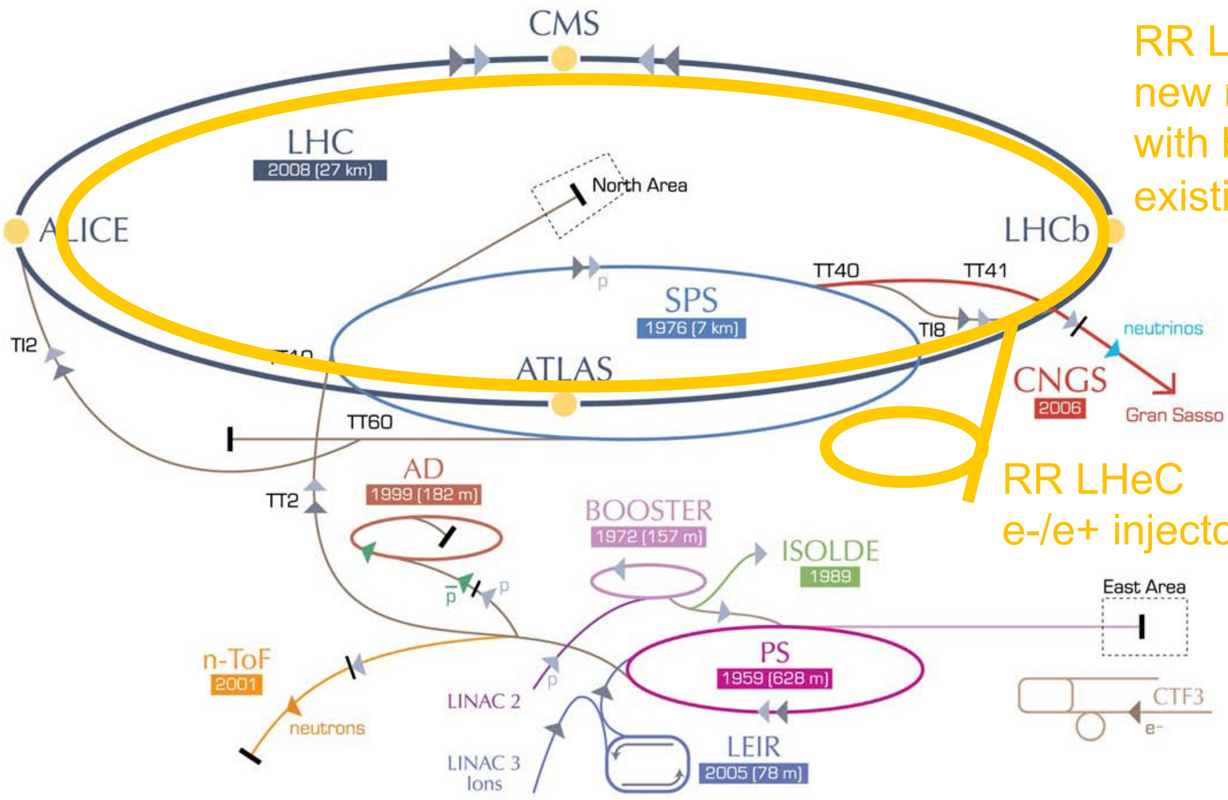
4. **DETECTOR**

5. **CONCLUSIONS**

LHeC Options



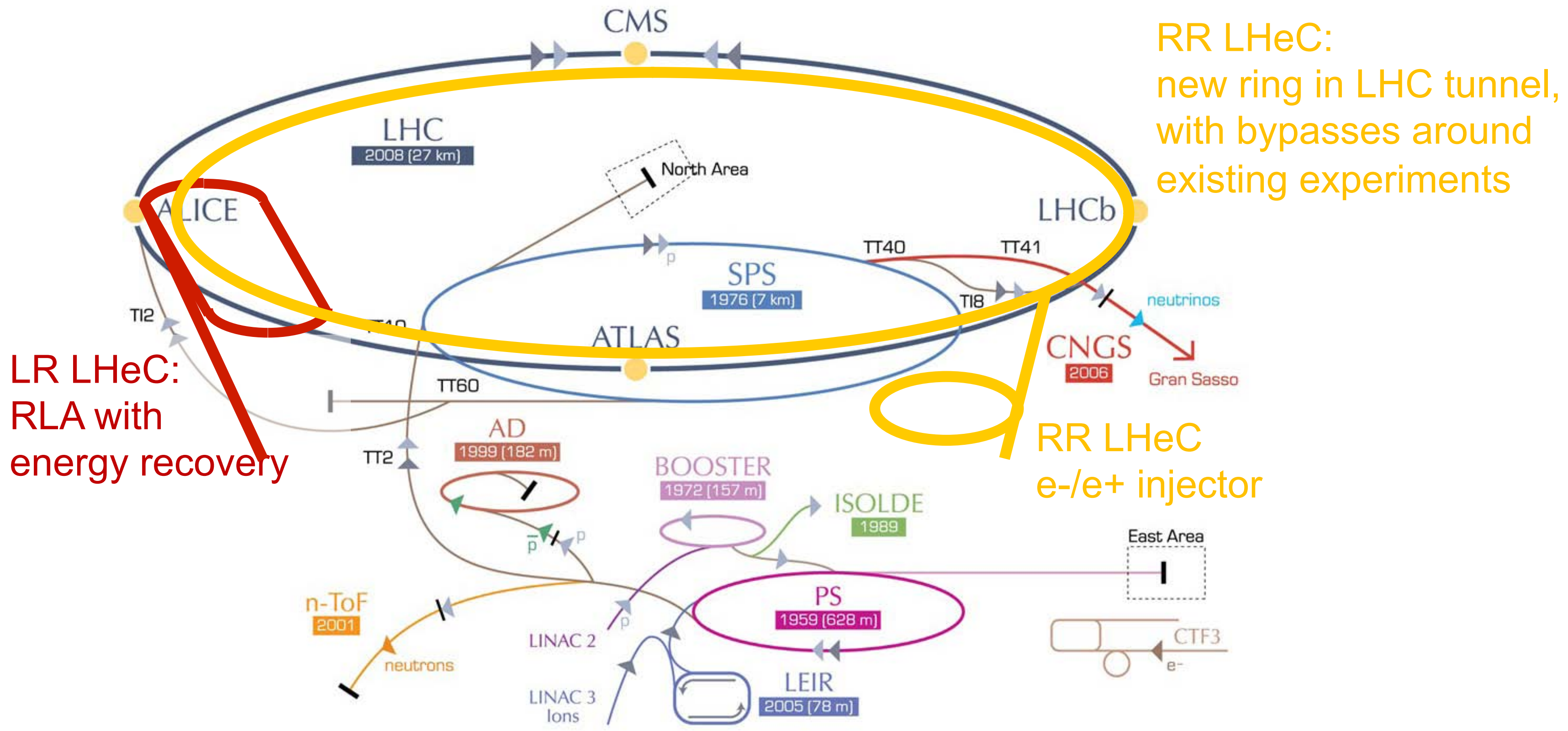
LHeC Options



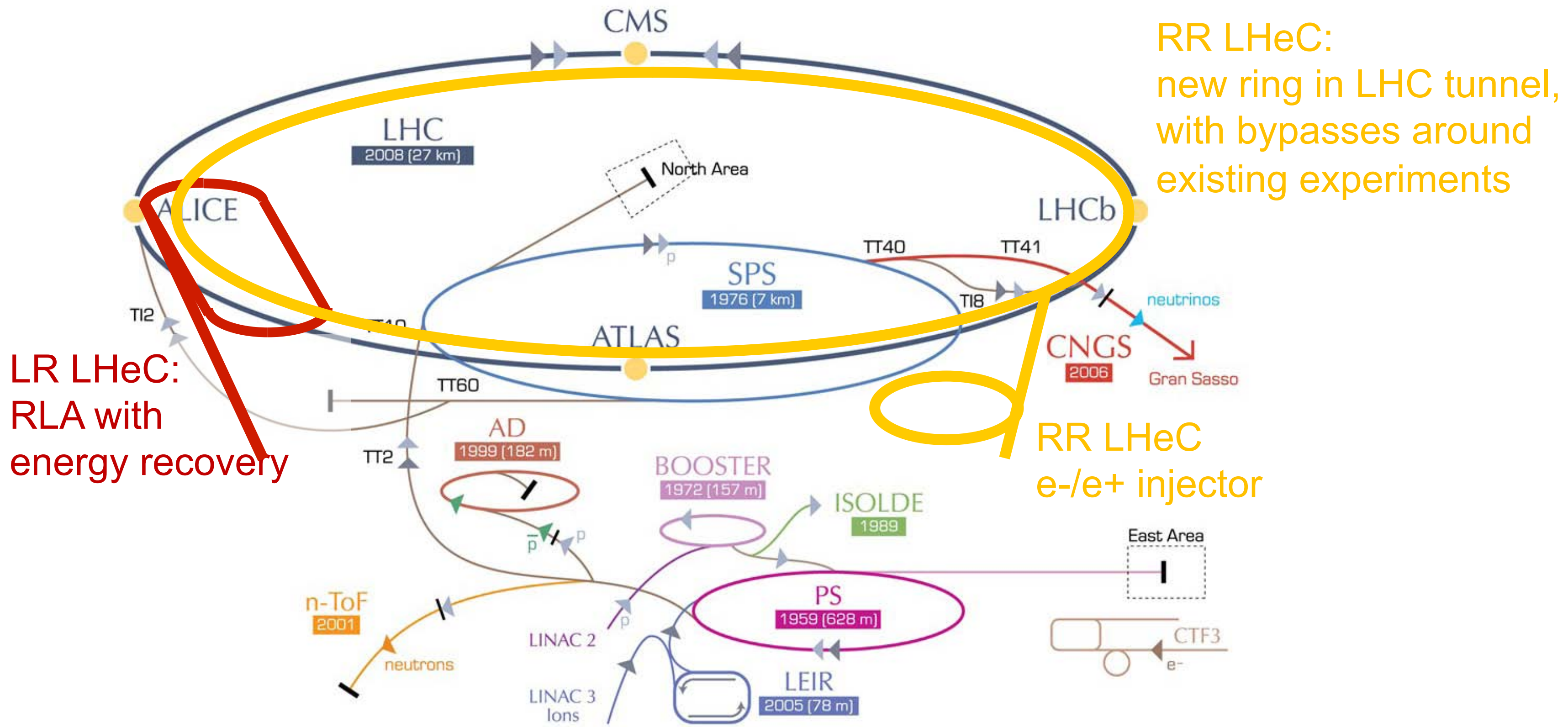
RR LHeC:
new ring in LHC tunnel,
with bypasses around
existing experiments

RR LHeC
e-/e+ injector

LHeC Options



LHeC Options



Ring-Ring option, feasible but impact LHC operation during installation

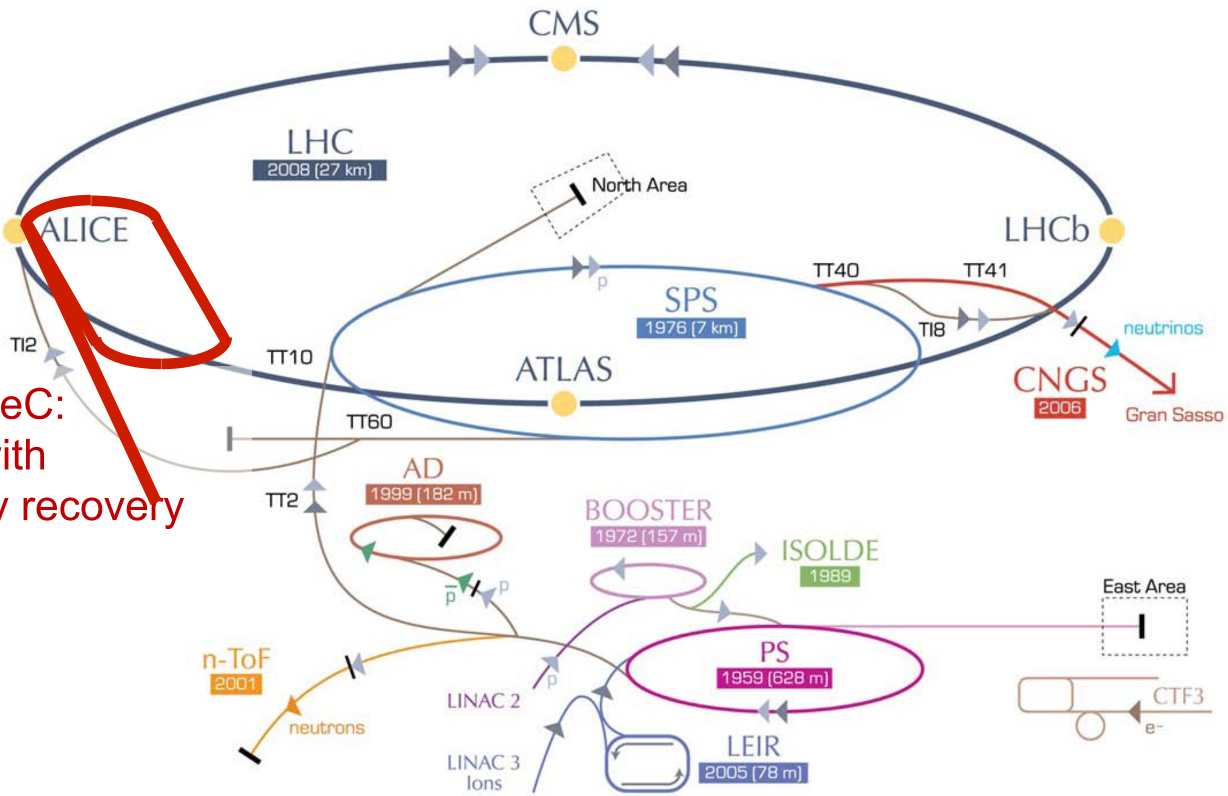
Linac-Ring option, the baseline solution exists, will now have to find the best solution

CERN Mandate

Key Technical Components

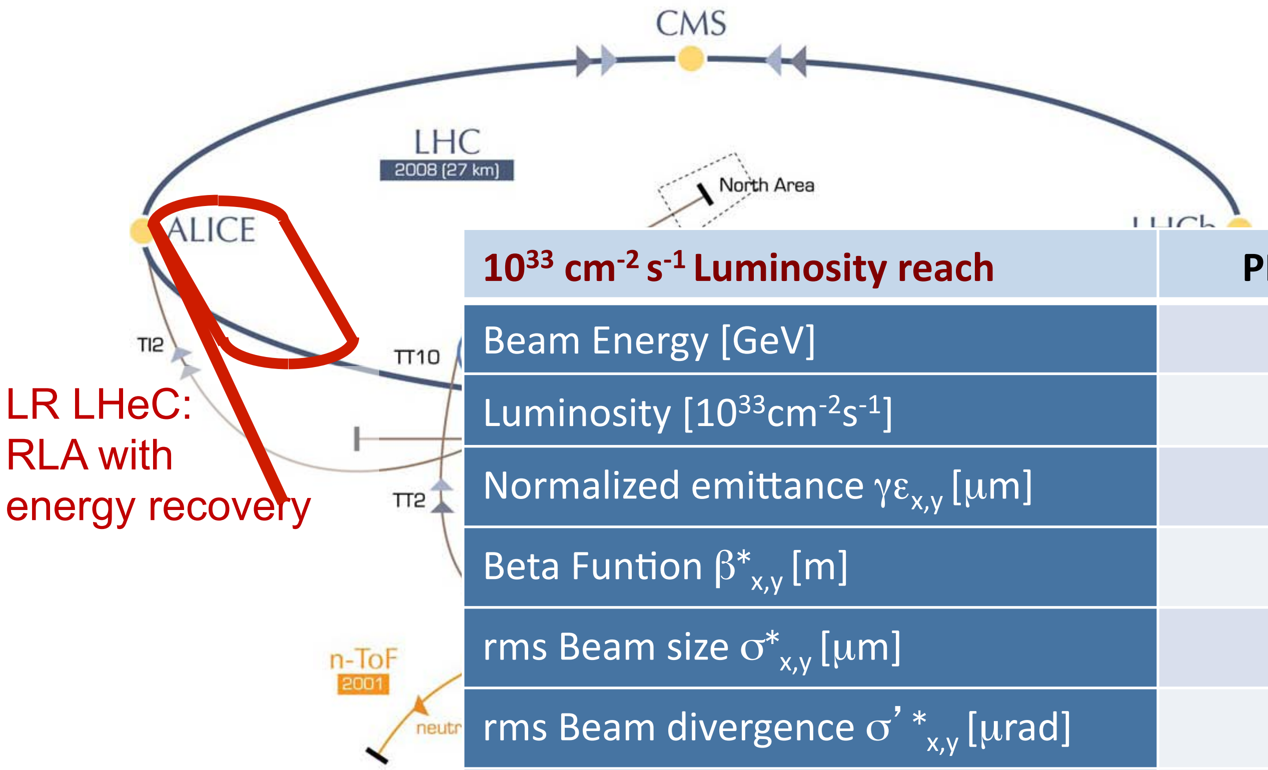
- Superconducting RF System
- Superconducting magnet development
- Pipes with large beam acceptance
- The finalization of the ERL design for the LHeC (optics design, beam dynamics studies and identification of potential performance limitations)
- The design and specification of an Energy Recovery LINAC (ERL) test facility for the LHeC

Linac-Ring LHeC



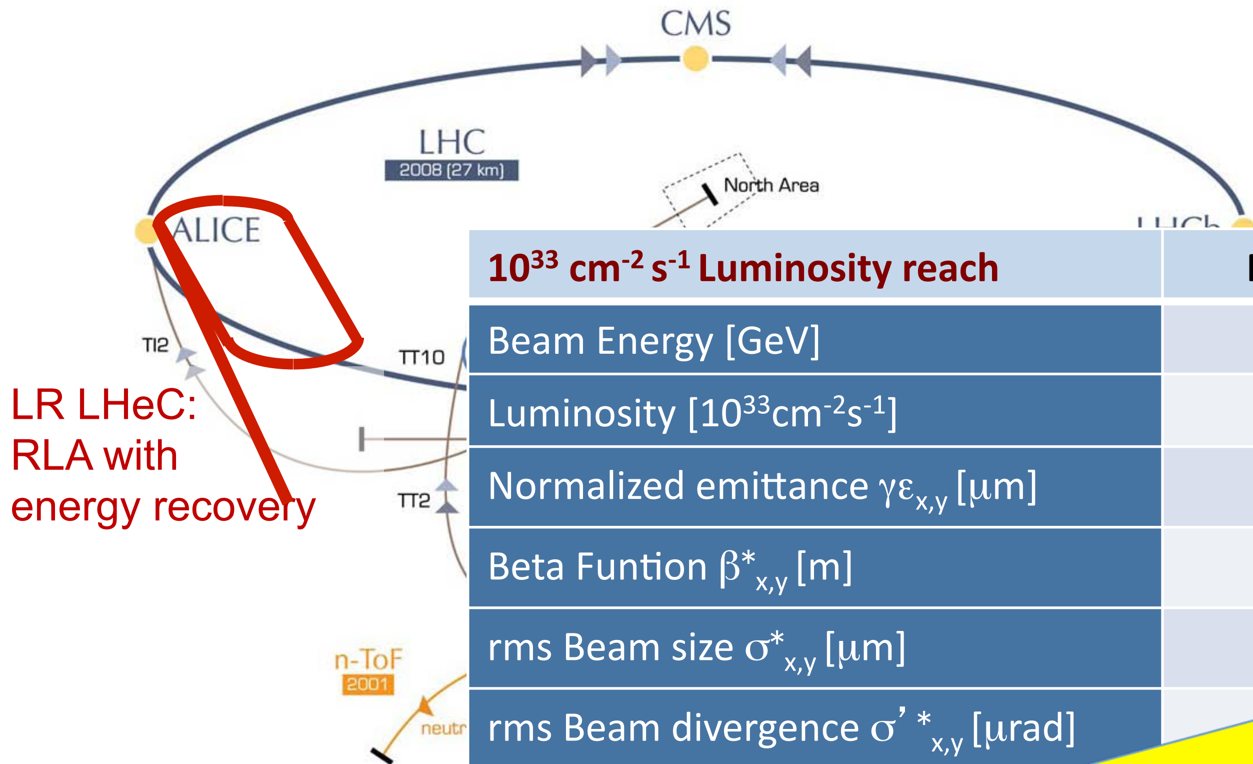
LR LHeC:
RLA with
energy recovery

Linac-Ring LHeC



10^{33} cm^{-2} s^{-1} Luminosity reach	PROTONS	ELECTRONS
Beam Energy [GeV]	7000	60
Luminosity [$10^{33}cm^{-2}s^{-1}$]	1	1
Normalized emittance $\gamma\varepsilon_{x,y}$ [μm]	3.75	50
Beta Funtion $\beta^*_{x,y}$ [m]	0.1	0.12
rms Beam size $\sigma^*_{x,y}$ [μm]	7	7
rms Beam divergence $\sigma'^*_{x,y}$ [μrad]	70	58
Beam Current [mA]	430 (860)	6.6
Bunch Spacing [ns]	25 (50)	25 (50)
Bunch Population	$1.7*10^{11}$	$(1*10^9)$ $2*10^9$
Bunch charge [nC]	27	(0.16) 0.32

Linac-Ring LHeC



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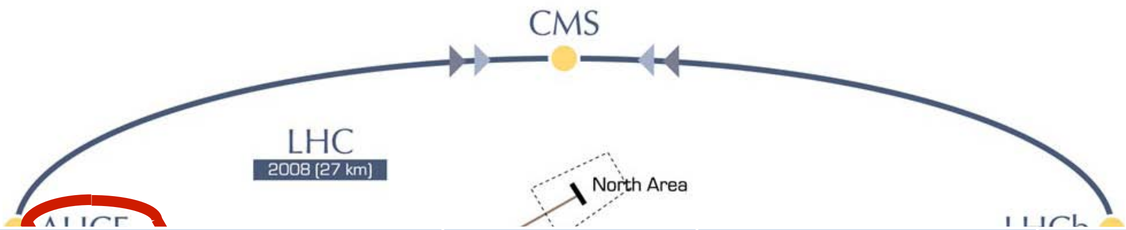
Beam Current [mA]	[illegible]	.6
Bunch Spacing [ns]	[illegible]	)
Bunch Population	[illegible]	[illegible]
Bunch charge [nC]	[illegible]	(0.16) 0.32

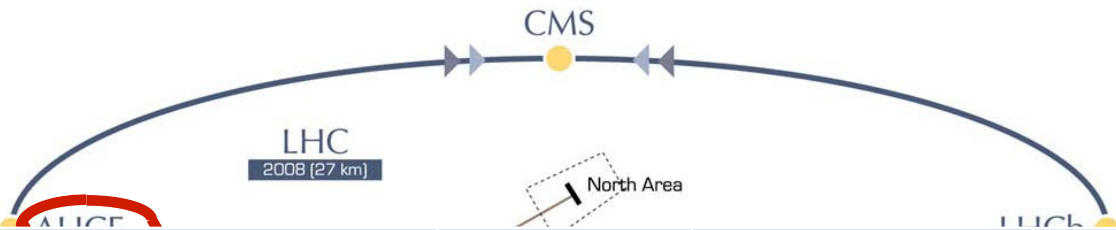
Energy 4 times
Luminosity
100 times larger
than HERA

Linac-Ring LHeC



10^{34} cm^{-2} s^{-1} Luminosity reach	PROTONS	ELECTRONS	PROTONS	ELECTRONS
Beam Energy [GeV]	7000	60	7000	60
Luminosity [$10^{33}cm^{-2}s^{-1}$]	16	16	1	1
Normalized emittance $\gamma\varepsilon_{x,y}$ [μm]	2.5	20	3.75	50
Beta Funtion $\beta^*_{x,y}$ [m]	0.05	0.10	0.1	0.12
rms Beam size $\sigma^*_{x,y}$ [μm]	4	4	7	7
rms Beam divergence $\sigma'^*_{x,y}$ [μrad]	80	40	70	58
Beam Current [mA]	1112	25	430 (860)	6.6
Bunch Spacing [ns]	25	25	25 (50)	25 (50)
Bunch Population	$2.2*10^{11}$	$4*10^{9}$	$1.7*10^{11}$	$(1*10^{9})$ $2*10^{9}$
Bunch charge [nC]	35	0.64	27	(0.16) 0.32

Linac-Ring LHeC



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Bunch Spacing [ns]	25	[illegible]	[illegible]	)
Bunch Population	$2.2*10^{11}$	4*1	[illegible]	[illegible]
Bunch charge [nC]	35	0.6	[illegible]	(0.16) 0.32

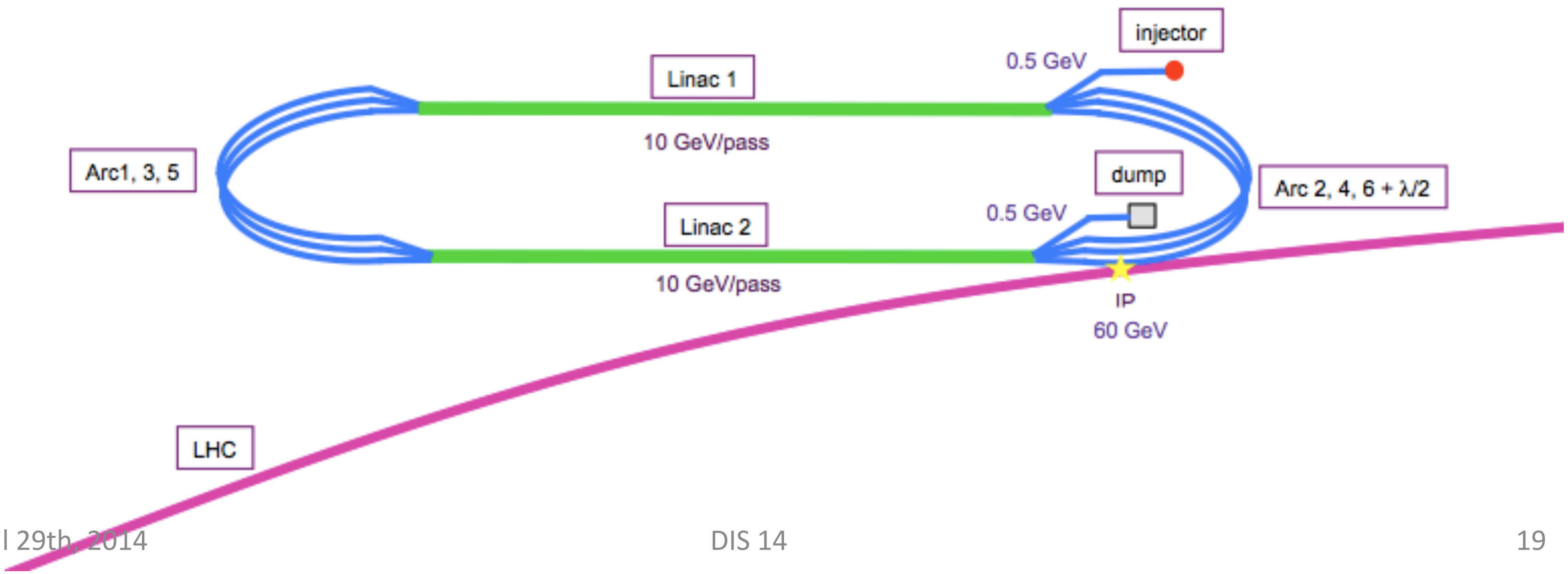
Luminosity 1000 times larger than HERA

Energy Recovery Linac

RECIRCULATOR COMPLEX

1. 0.5 GeV injector
2. 2 linacs (10 GeV per pass)
3. Six 180°, 1 Km arcs
4. Final 60 GeV energy
5. Extraction dump at 0.5 GeV

A. Bogacz



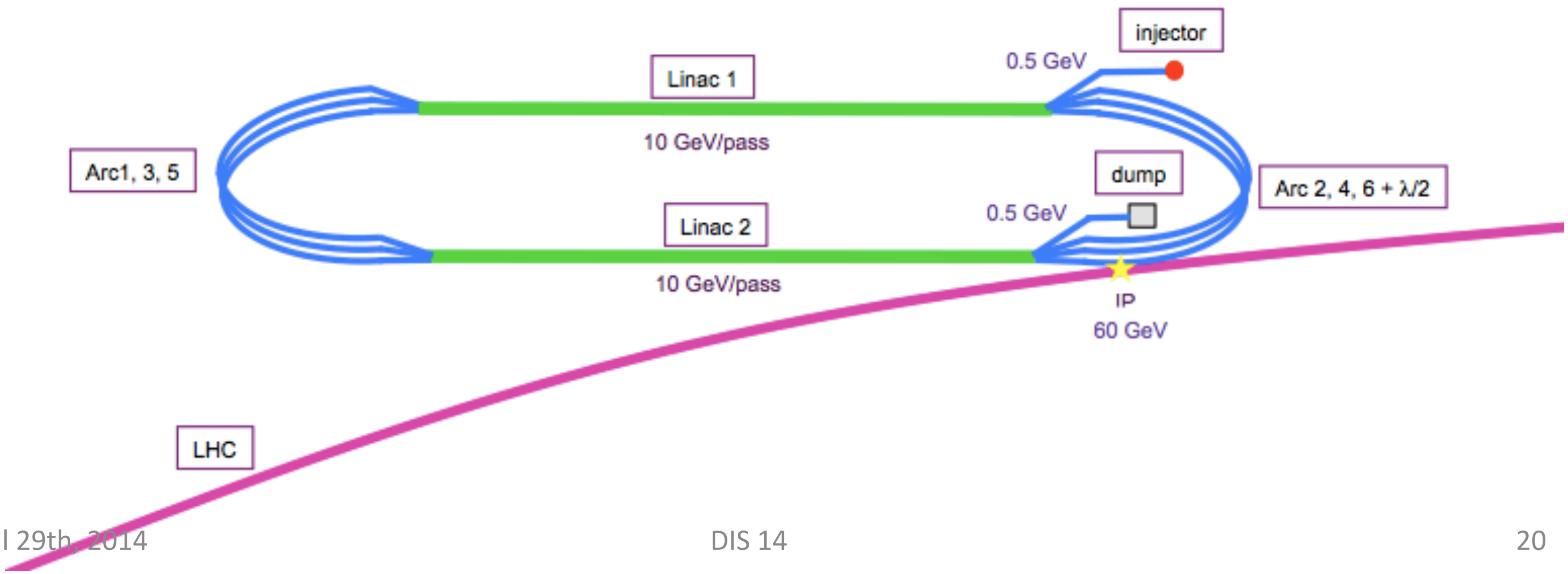
ERL-Post CDR

BEAM ISSUES-SYNCHROTRON RADIATION!

1. Energy loss
2. Emmitance Growth
3. Momentum spread

→ **PROPER LATTICE DESIGN**

A. Bogacz



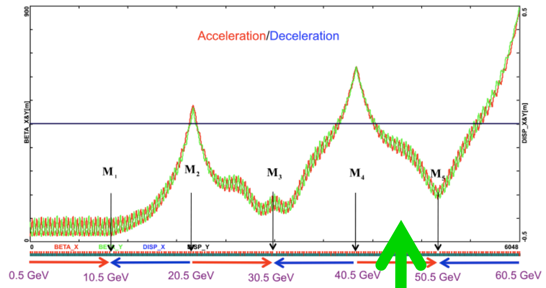
ERL-Post CDR

BEAM ISSUES-SYNCHRTOTRON RADIATION!

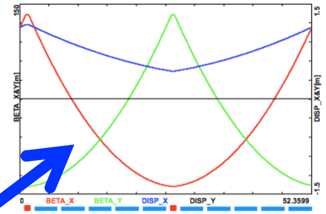
1. Energy loss
2. Emmitance Growth
3. Momentum compaction

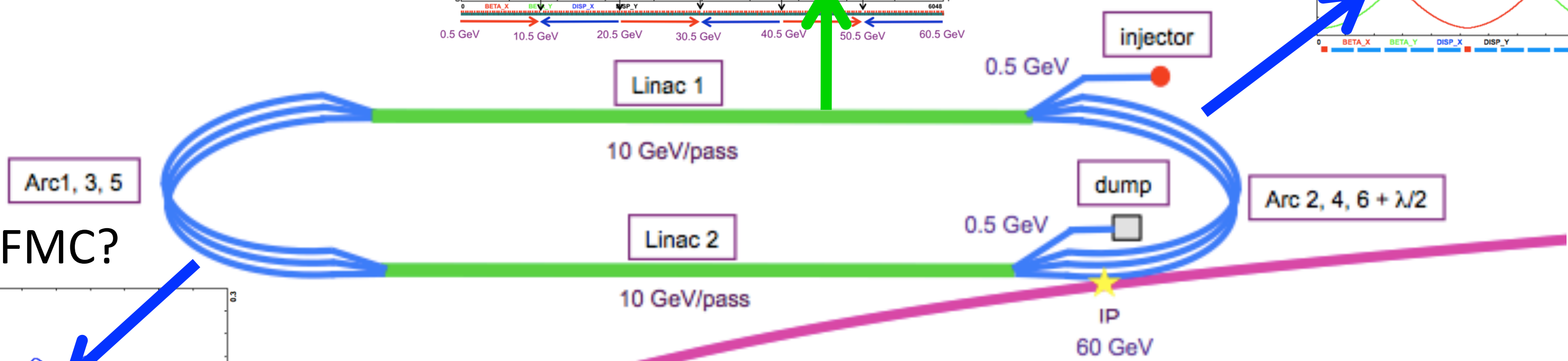
→ **PROPER LATTICE DESIGN**

A. Bogacz

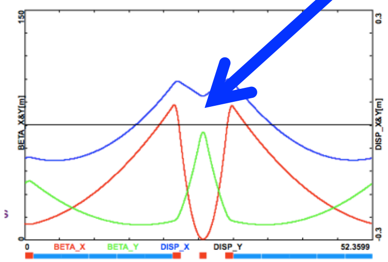


FODO?



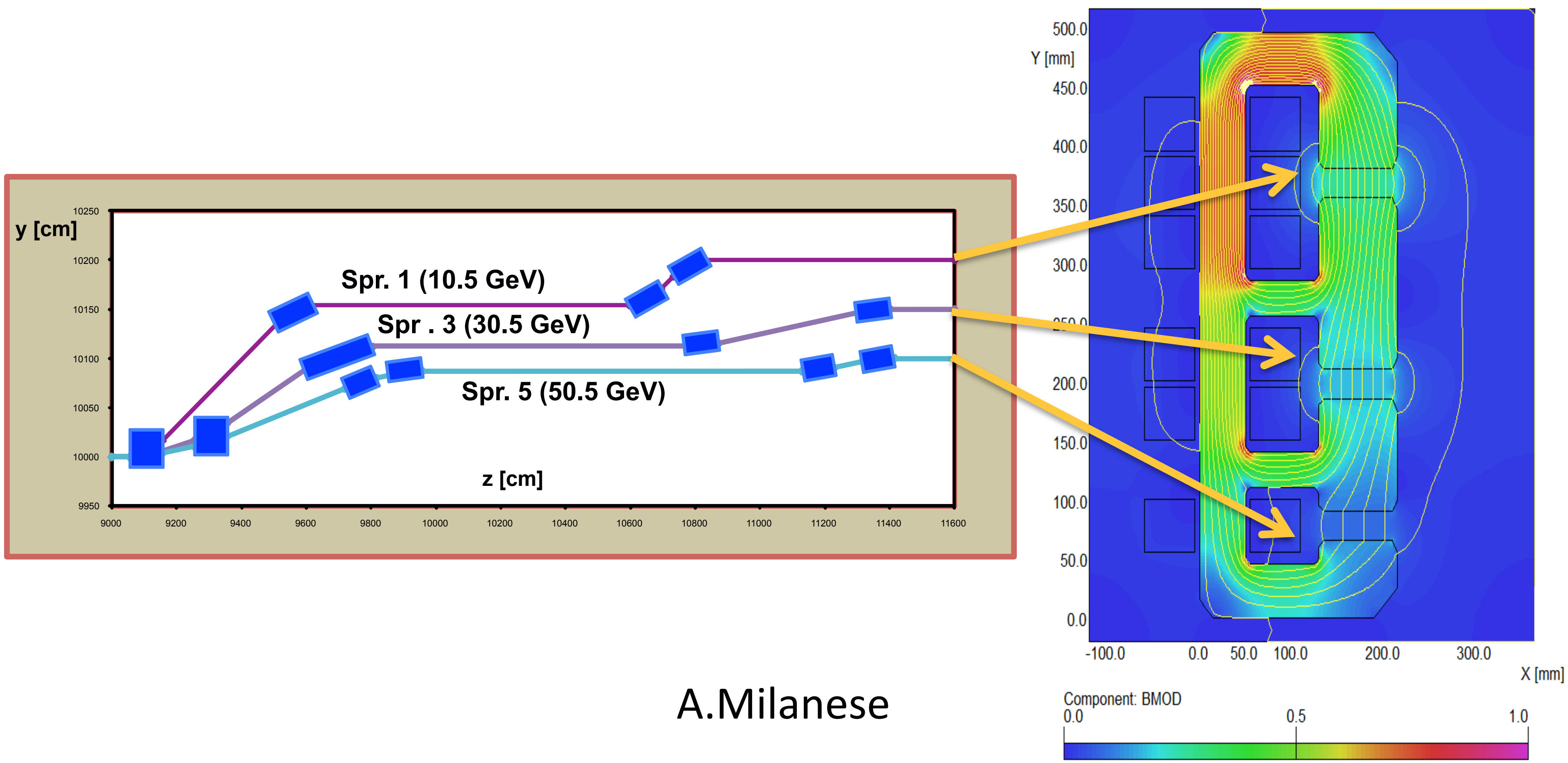


FMC?



Advantages of Flexible Momentum Compaction (FMC) over a FODO cell

Post-CDR Magnets

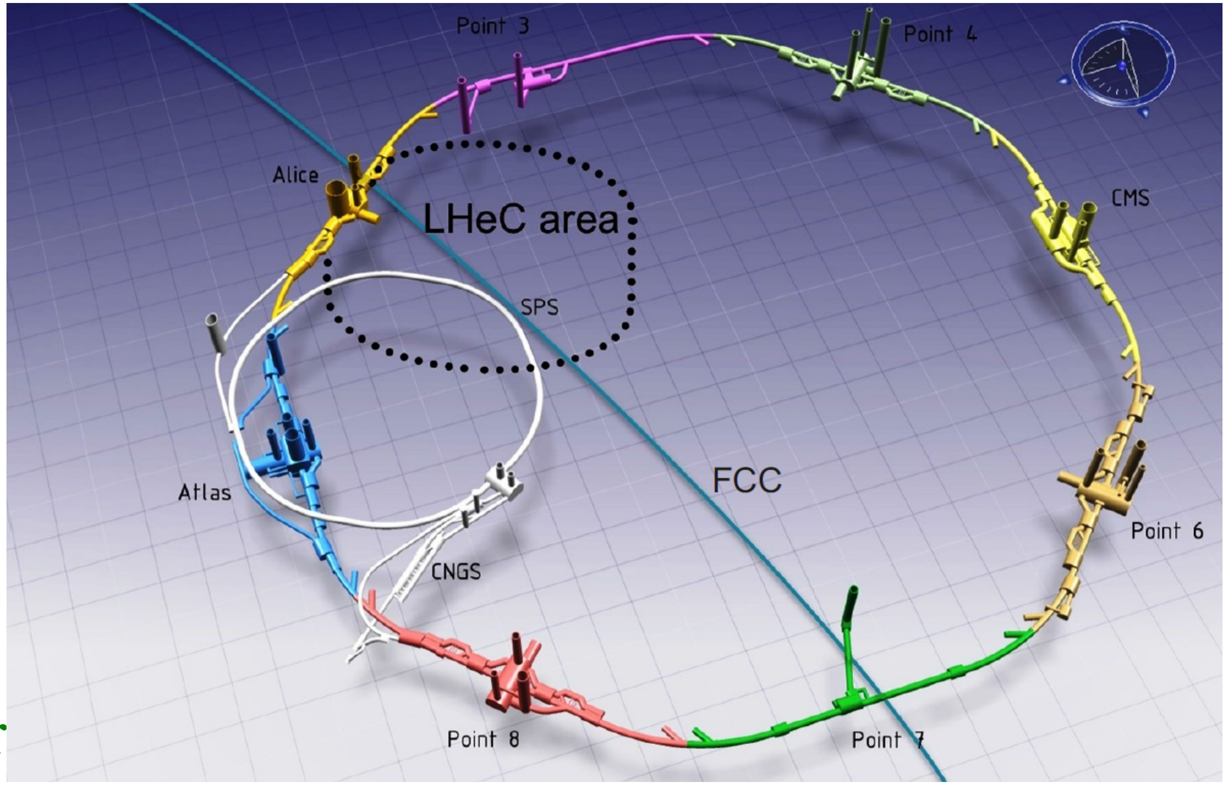


A.Milanese

LHeC in the context of FCC

ERL applications:

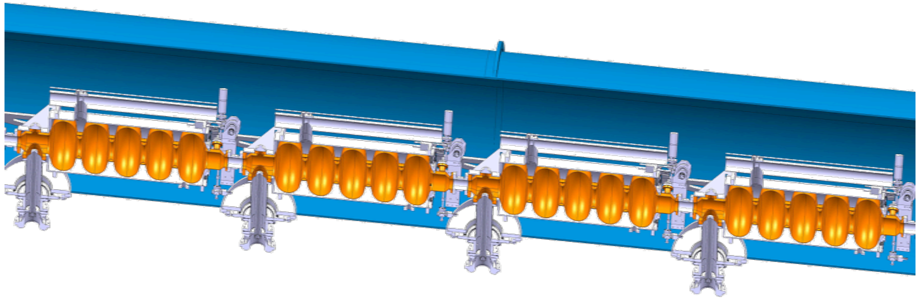
- ➔ LHeC could provide collisions with HL-LHC
- ➔ LHeC could potentially provide collisions with FCC-hh
- ➔ LHeC could operate as injector for FCC-ee



RF Frequency

CDR

8 cavities per 14 m
Choice between **720 MHz** and **1.3 GHz**



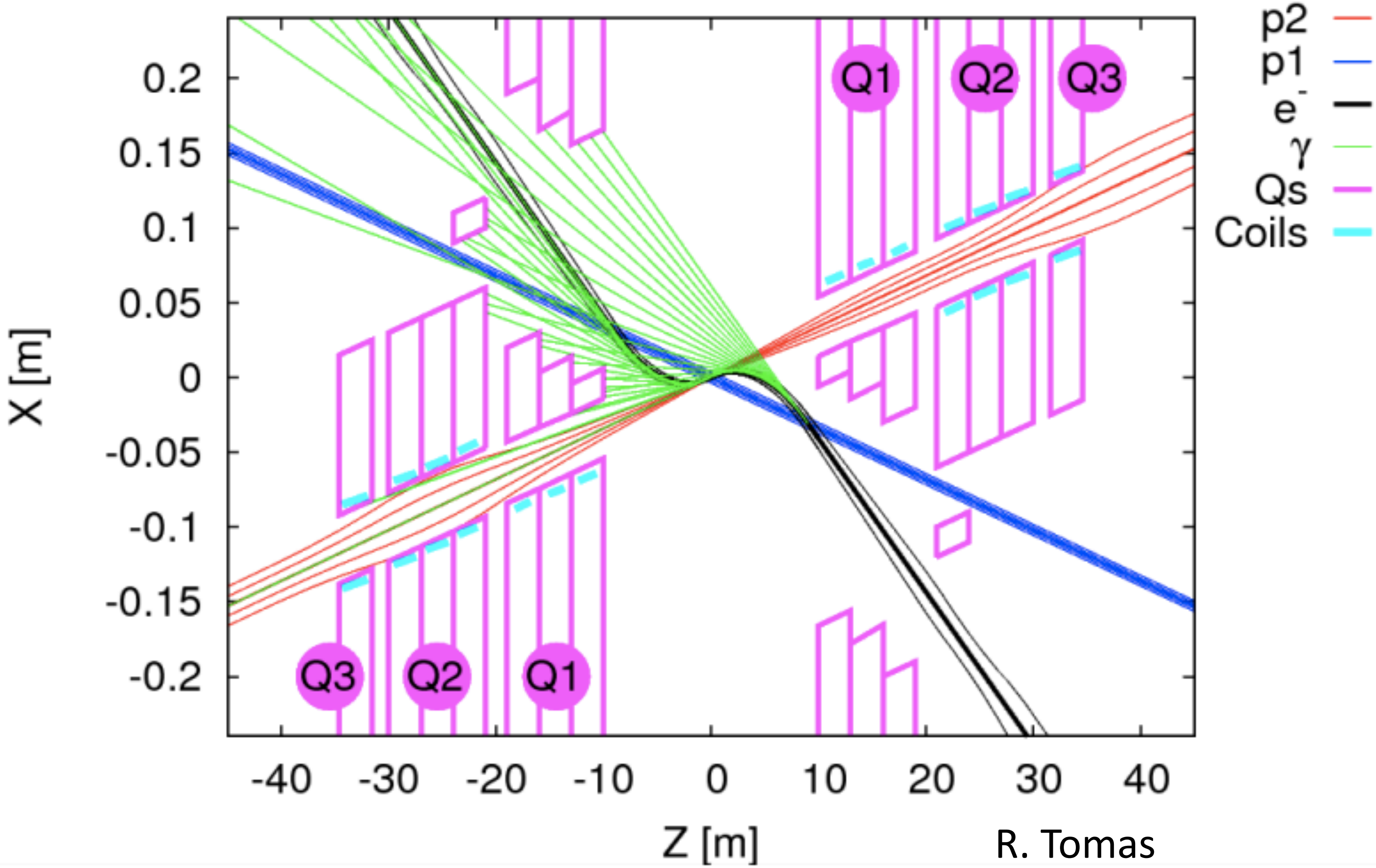
Daresbury Meeting 2013

POST-CDR

FINAL CHOICE: 801.58 MHz

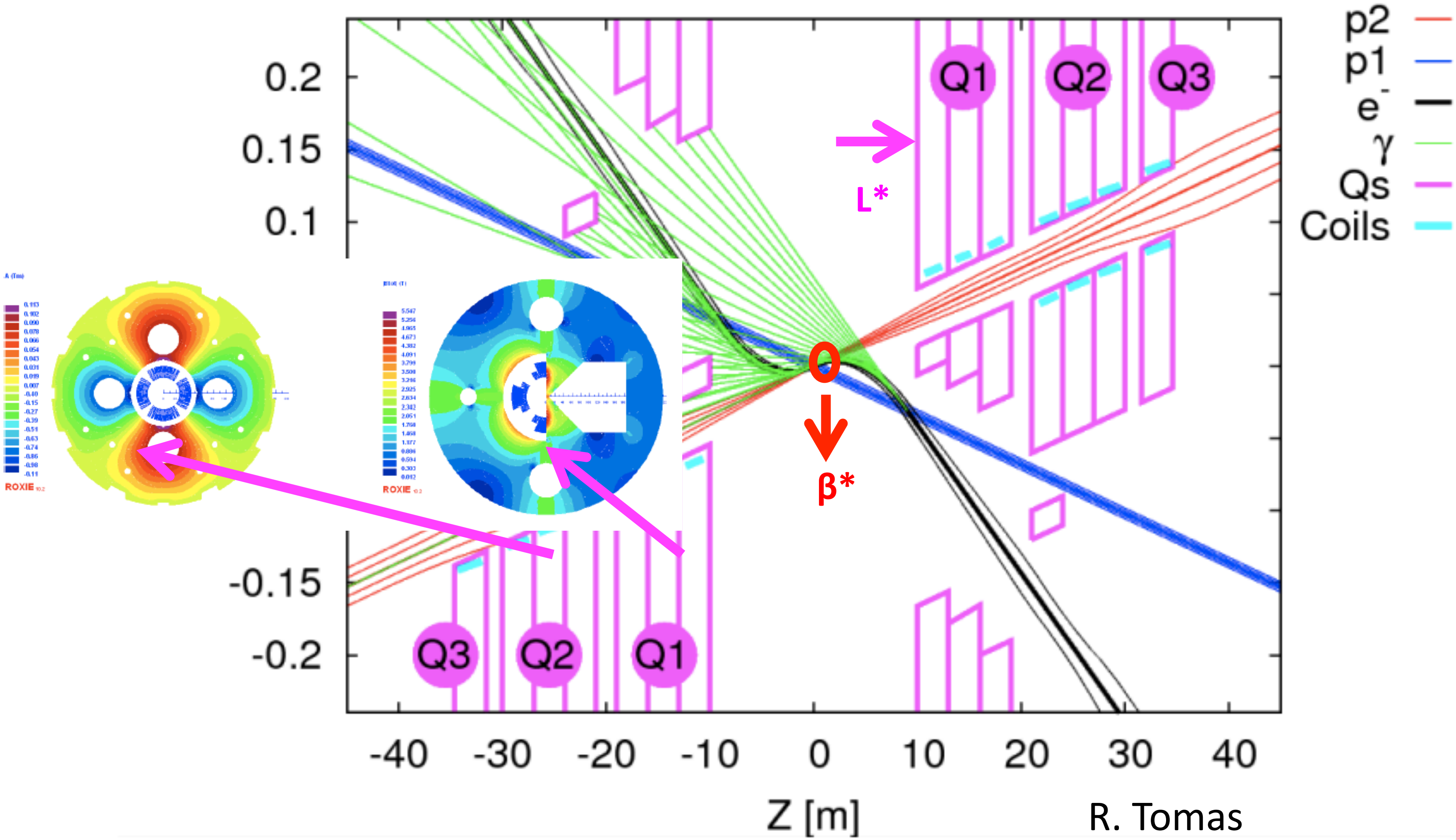
- Synergy with other projects (HL-LHC) and international collaboration option (MESA)
- Optimum frequency for both material options

Interaction Region CDR



R. Tomas

Interaction Region CDR



R. Tomas

IR Post-CDR

Towards Luminosity **≥10^{33} cm^{-2}s^{-1}**

$$L = \frac{1}{4\pi e} \frac{N_{b,p}}{\varepsilon_p} \frac{1}{\beta_p^*} I_e H_{hg} H_D$$

Minimize β* = More Luminosity!

$$\sigma_x = \sqrt{\epsilon \beta(s)}$$

IR Post-CDR

Towards Luminosity **≥10^{33} cm^{-2}s^{-1}**

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Minimize β* = More Luminosity!

$$\sigma_x = \sqrt{\epsilon\beta(s)}$$

Normal way.
Focus 26 quads in IR2 → ***β^*=0.3 m***

Limits quadrupole strengths.
IT causes huge chromatic aberrations

IR Post-CDR

Towards Luminosity ≥10^{33} $cm^{-2}s^{-1}$

$$L = \frac{1}{4\pi e}\frac{N_{b,p}}{\varepsilon_p}\frac{1}{\beta_p^*}I_e H_{hg} H_D$$

Minimize β* = More Luminosity!

$$\sigma_x = \sqrt{\epsilon\beta(s)}$$

Normal way.
Focus 26 quads in IR2 → β^*=0.3 m

Limits quadrupole strengths.
IT causes huge chromatic aberrations

Achromatic Telescopic Squeezing
Focus 3X26 quads in IR1,IR2,IR3 → β^*=0.1 m

IR Post-CDR

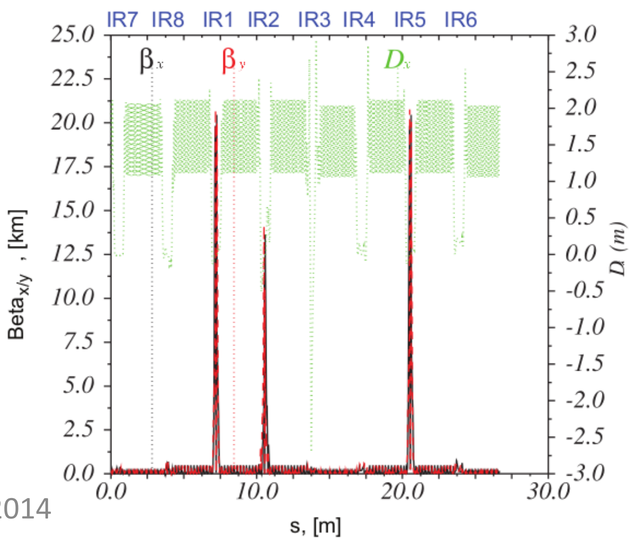
Towards Luminosity **≥10^{33} cm^{-2}s^{-1}**

$$L = \frac{1}{4\pi e}\frac{N_{b,p}}{\varepsilon_p}\frac{1}{\beta_p^*} I_e H_{hg} H_D$$

Minimize β* = More Luminosity!

$$\sigma_x = \sqrt{\epsilon\beta(s)}$$

Achromatic Telescopic Squeezeing (ATS) Scheme



IR2 (LHeC)

β*=10 cm

IR1/IR5 (HL-LHC)

β*=15 cm

M. Korostelev

IR Post-CDR

- ✓ **Chromaticity correction** -> Use of sextupoles.
- ✓ Flexibility Parameters.

Minimize β*. +More luminosity. L*=10-20 m.

-More chromaticity.

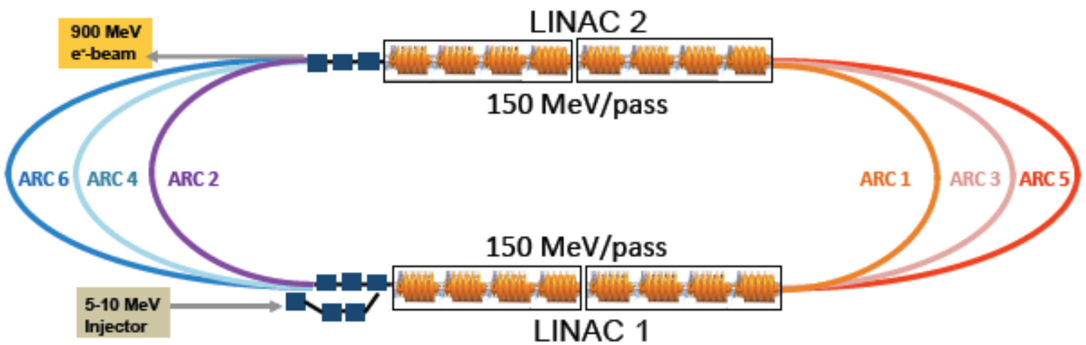
Increase L*. + Less SR.   β*=5-10 cm.

-More chromaticity.

- ✓ How far can we correct the chromaticity?
- ✓ Integration of **e-beam**!

Goals of the ERL Test Facility

- Test facility for SCRF cavities and modules
- Test facility for multi-pass multiple cavity ERL
- Injector studies: DC gun or SRF gun
- Study reliability issues, operational issues!
- Possible use for detector development, experiments and injector
- Could it be foreseen as the injector to LHeC ERL?

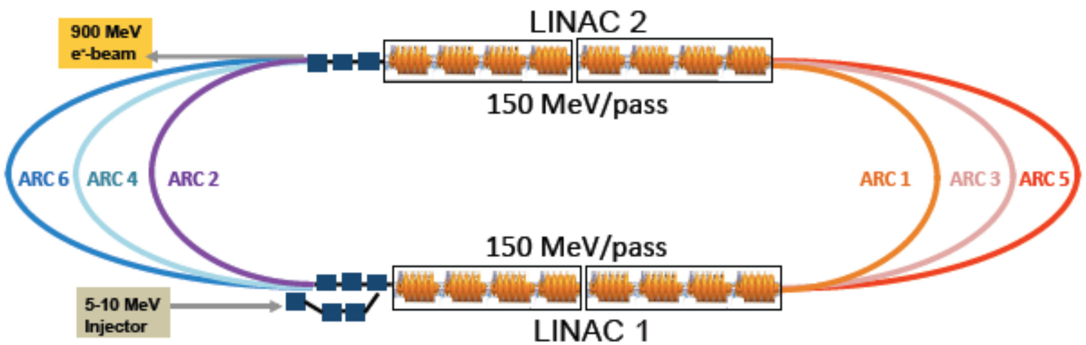


A. Valloni

ERL TF Design

- Injection at 5 MeV
  - 3 turns
  - 150 MeV/linac
  - Final energy 900 MeV

ARC	ENERGY
ARC 1	150 MeV
ARC 2	300 MeV
ARC 3	450 MeV
ARC 4	600 MeV
ARC 5	750 MeV
ARC 6	900 MeV



A. Valloni

LHeC Next Steps

Guido Altarelli (Rome)
Sergio Bertolucci (CERN)
Frederick Bordry (CERN)
Stan Brodsky (SLAC)
Hesheng Chen (IHEP Beijing)
Andrew Hutton (Jefferson Lab)
Young-Kee Kim (Chicago)
Victor A Matveev (JINR Dubna)
Shin-Ichi Kurokawa (Tsukuba)
Leandro Nisati (Rome)
Leonid Rivkin (Lausanne)
Herwig Schopper (CERN) – **Chair**
Jurgen Schukraft (CERN)
Achille Stocchi (LAL Orsay)
John Womersley (STFC)

- Mandate a Coordination group and an **International Advisory Committee**
  - IAC Chair: H. Schopper
  - First IAC meeting at January 2014 LHeC Workshop
- Develop CDR for an ERL test facility at CERN

Work Summary

- Advances in ERL Lattice Choice
- Choice on RF Frequency
- First p-optics, e-optics IR integration into HL-LHC CDR IR
- Ongoing optimization for IR
- Ongoing studies for dynamic studies and beam-beam interactions
- Studies in preparation of the ERL Test Facility at CERN

Thank you!

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