High energies colliders

Louis Rinolfi

Outlook

- Introduction

- Hadron Colliders

  LHC

  FCC

- Lepton Colliders

  Linear e+e- colliders: ILC and CLIC

  Circular e+e- colliders: TLEP, SuperTristan

  Muon colliders

- Hadron-Lepton Colliders

  LHeC

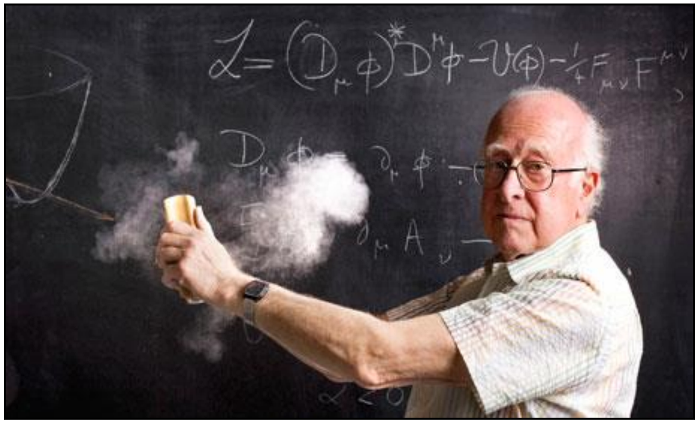
  eRHIC

- Plasma accelerators

General Physics context

LHC discovery:

LHC announced on 4th July 2012 the discovery of a Higgs boson at 126 GeV



Peter Higgs

J. Incaleda
CMS

F. Gianotti
ATLAS

LHC expectation:

LHC continues to investigate what physics is behind this discovery and at what energy scale should considered: Do we need multi-TeV energy ?
Future LHC results would establish the scientific case for High Energy Colliders

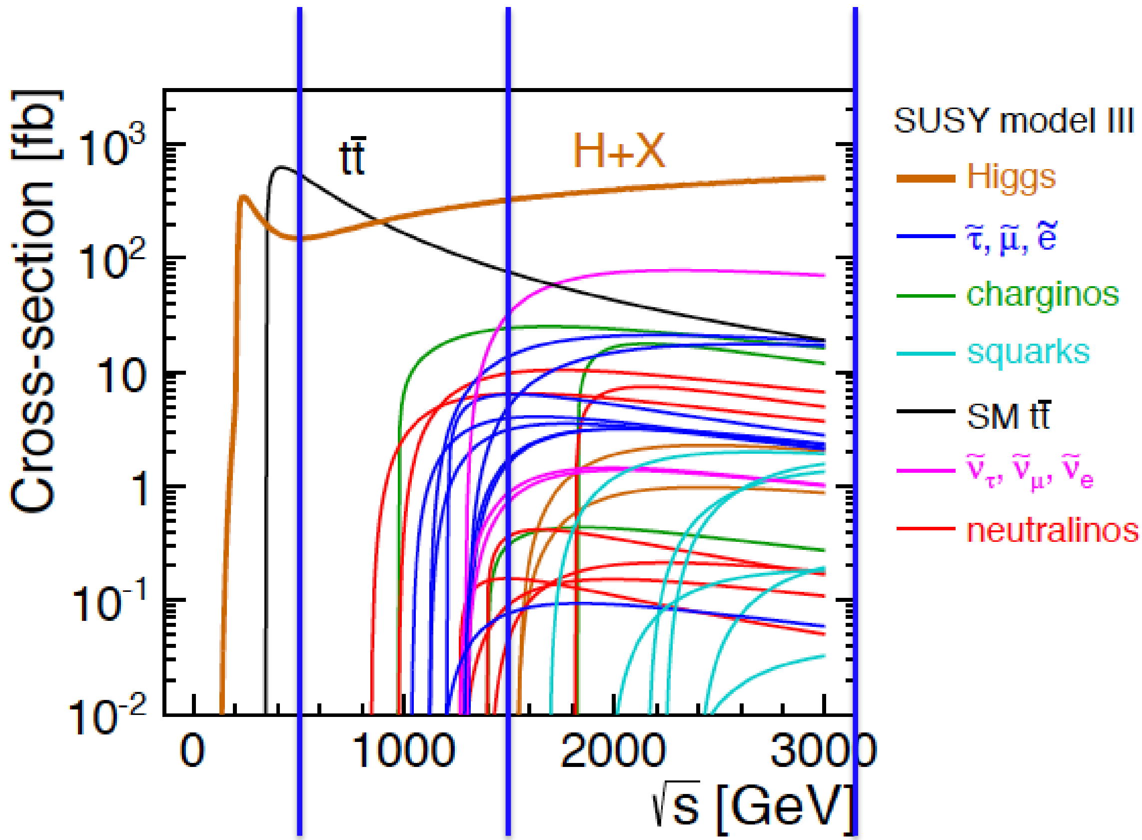
Where to look at ?

S. Stapnes / CERN

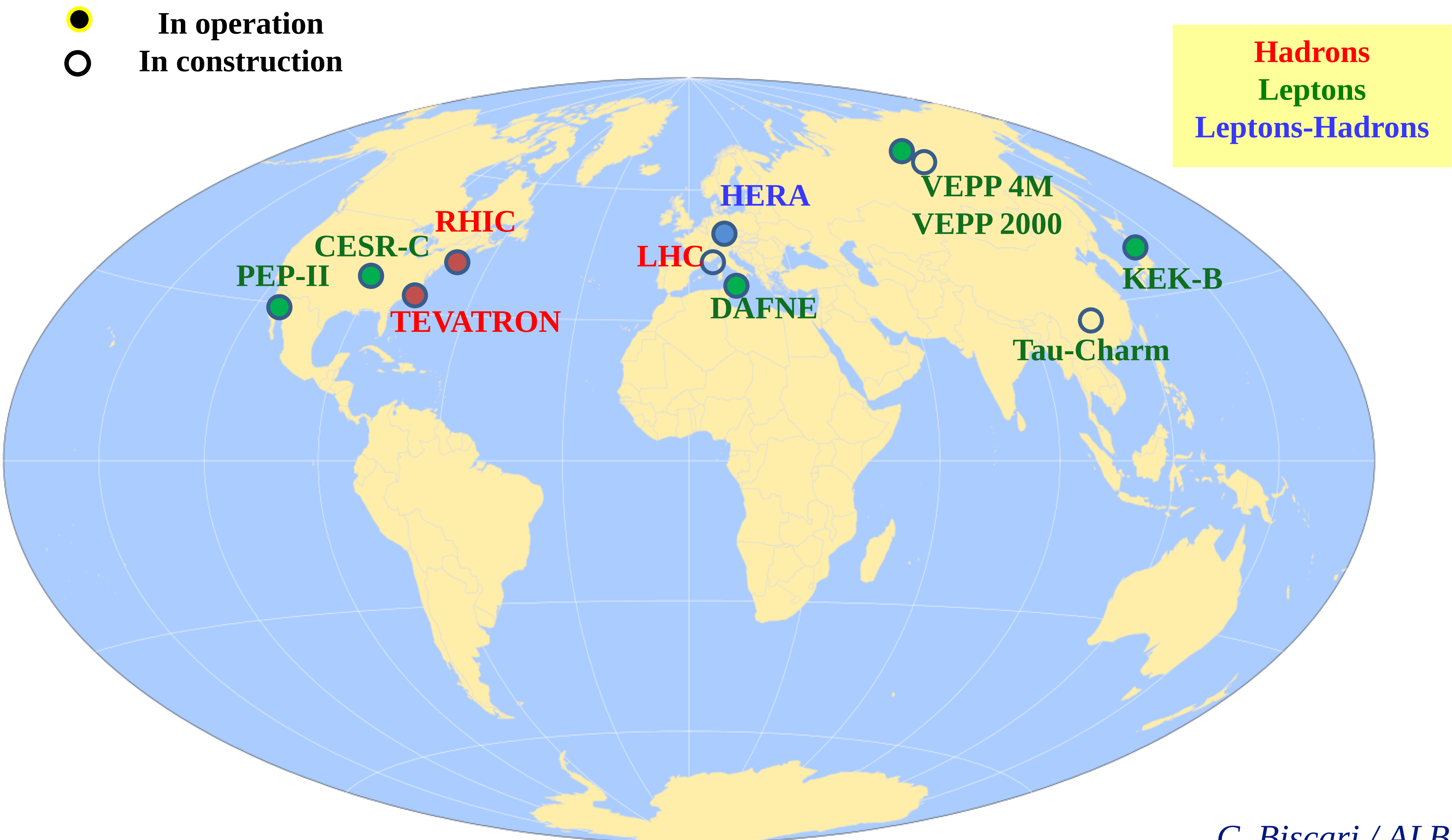
LHC complementarity at the energy frontier:

•How do we build the optimal machine given a physics scenario (partly seen at LHC ?)

- Higgs physics (SM and non-SM)
- Top
- SUSY
- Higgs strong interactions
- New Z' sector
- Contact interactions
- Extra dimensions



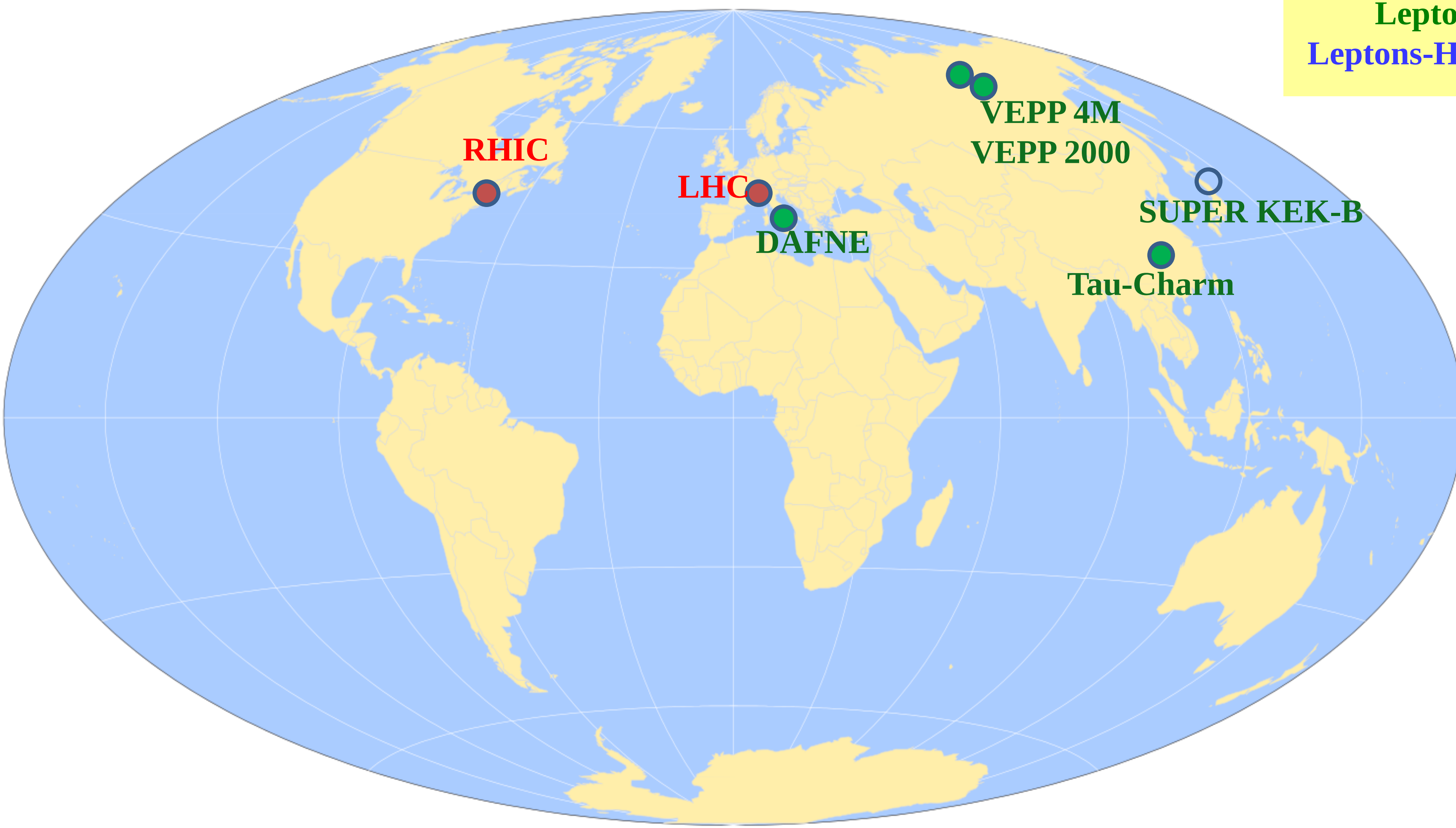
Colliders - 2006



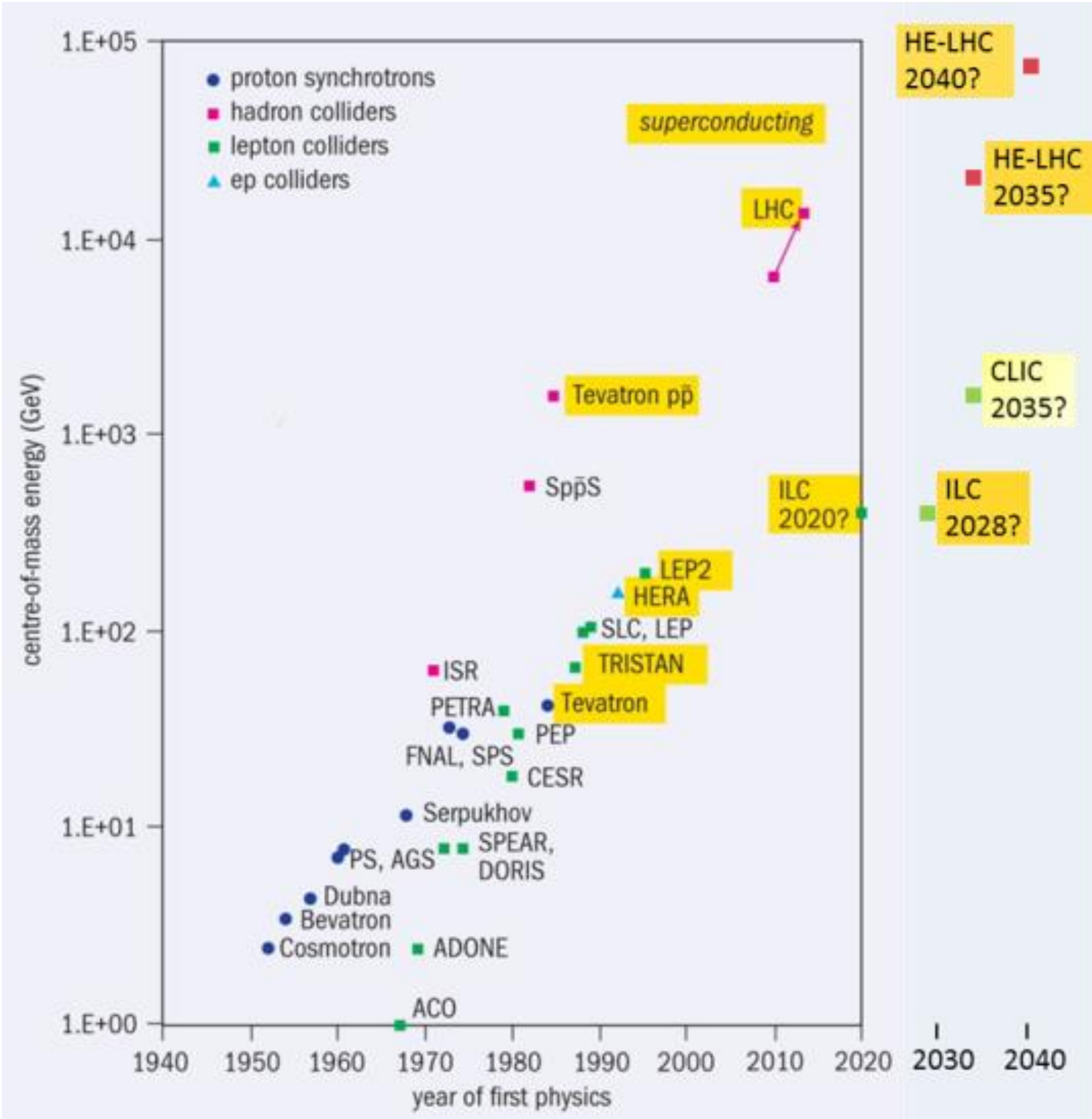
C. Biscari / ALBA

Colliders – 2014

In operation
In construction

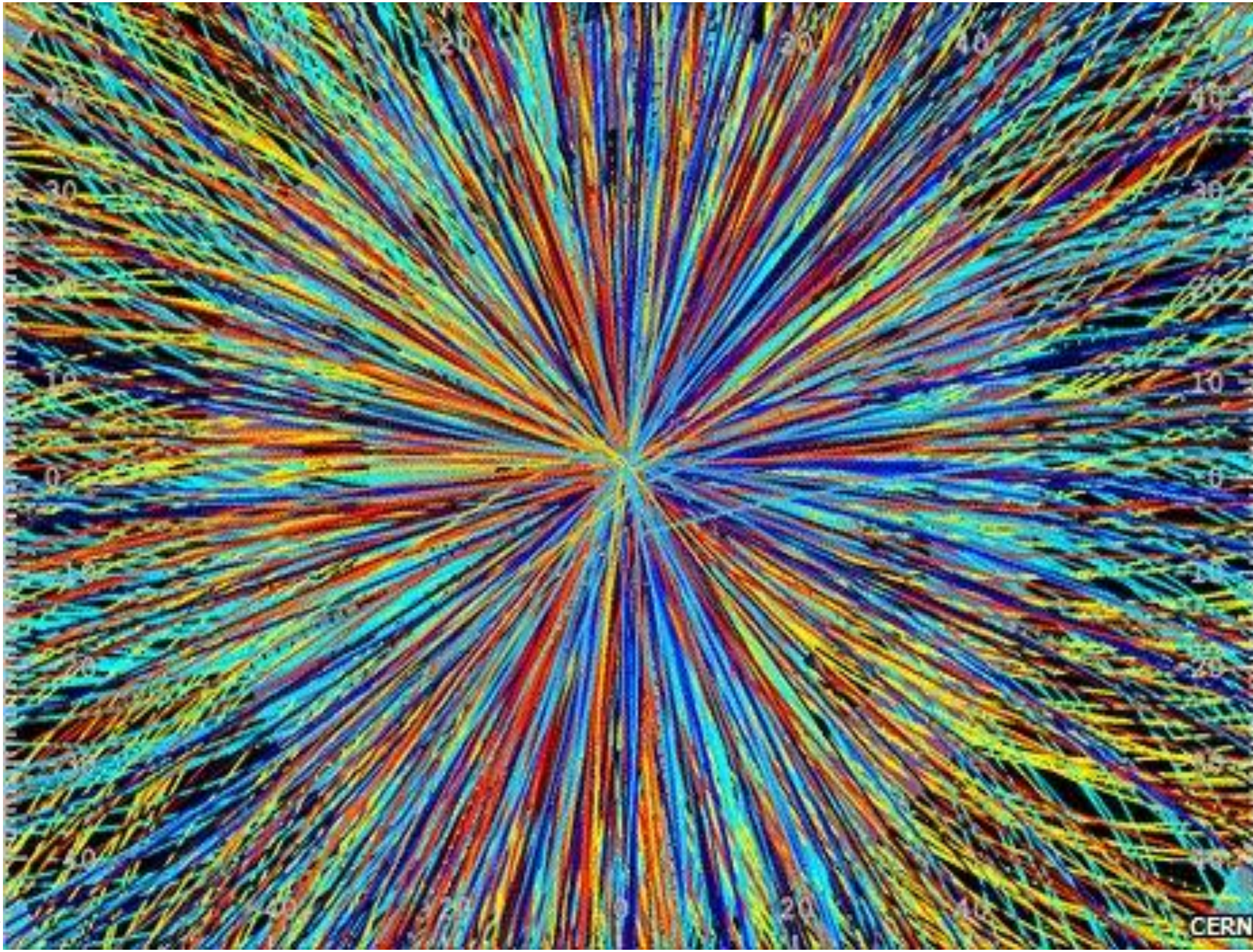


High energy colliders

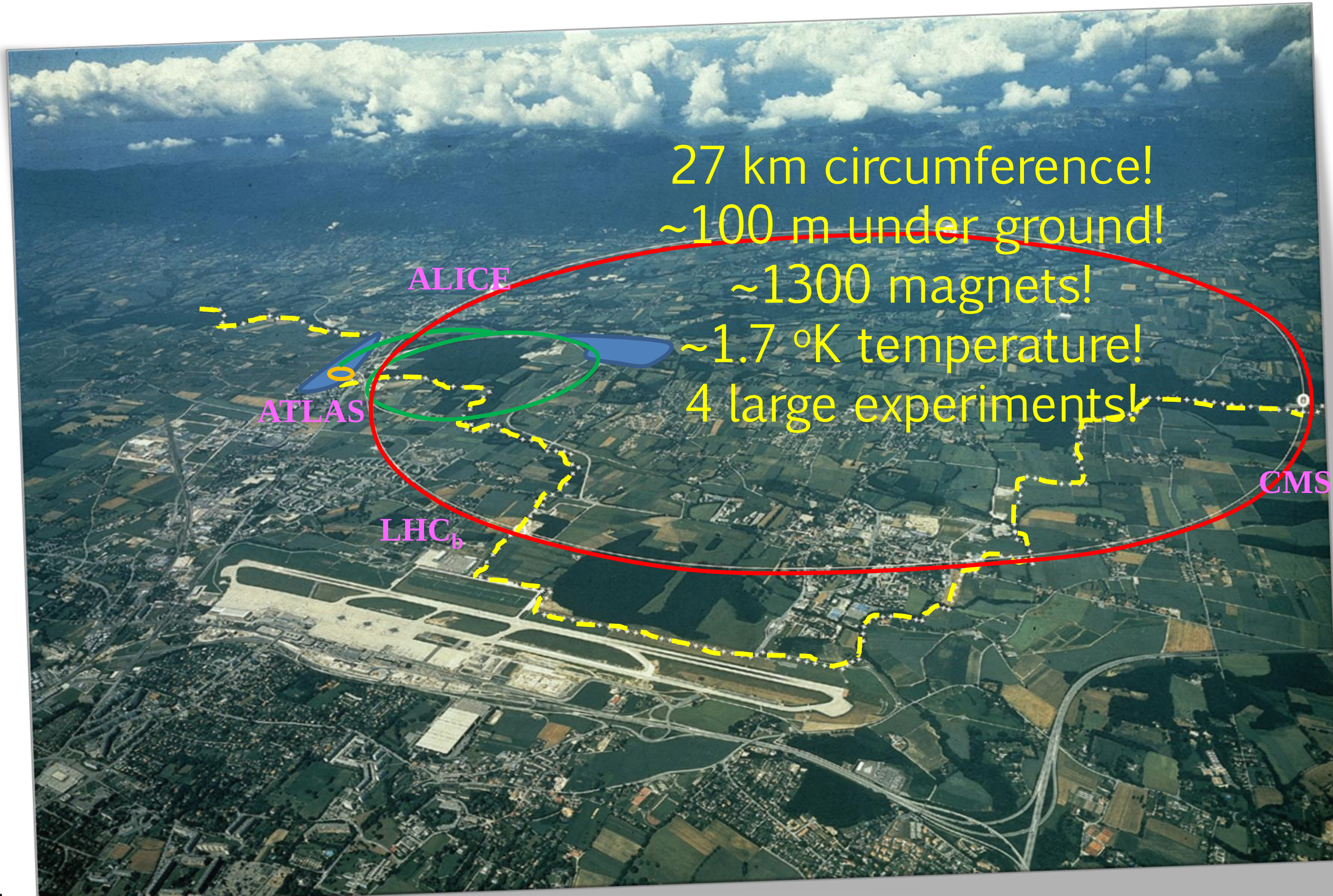


L. Rossi / CERN

Hadron colliders



The LHC (Large Hadron Collider)

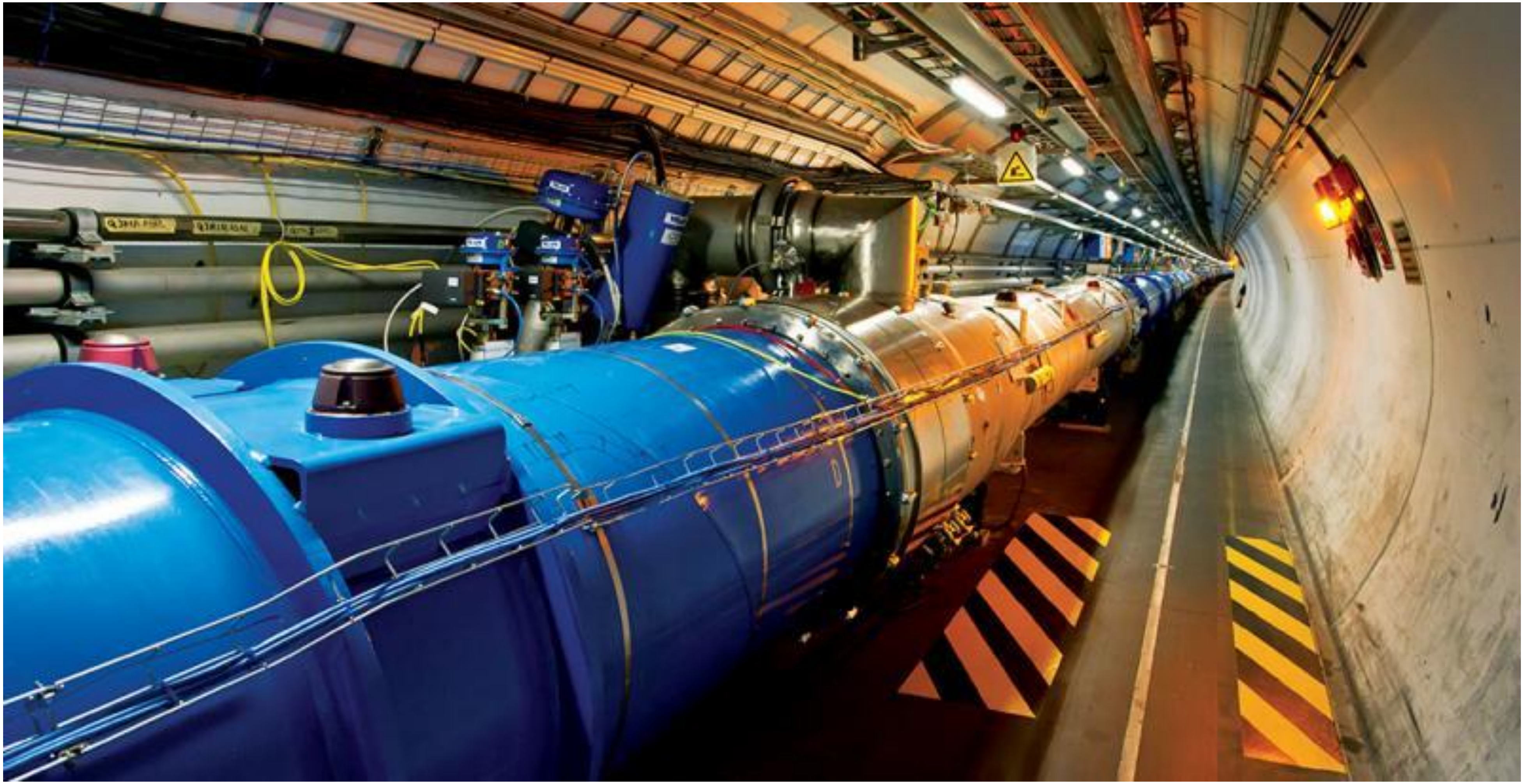


LHC design parameters

Quantity	number
Circumference	26 659 m
Dipole operating temperature	1.9 K (-271.3°C)
Number of magnets	9593
Number of main dipoles	1232
Number of main quadrupoles	392
Number of RF cavities	8 per beam
Nominal energy, protons	7 TeV
Nominal energy, ions	2.76 TeV/u (*)
Peak magnetic dipole field	8.33 T
Min. distance between bunches	~7 m
Design luminosity	10^{34} cm^{-2} s^{-1}
No. of bunches per proton beam	2808
No. of protons per bunch (at start)	1.1 x 10^{11}
Number of turns per second	11 245
Number of collisions per second	600 million

(*) Energy per nucleon

LHC tunnel



FCC scope and structure

Future Circular Colliders - Conceptual Design Study for next European Strategy Update (2018)

Infrastructure

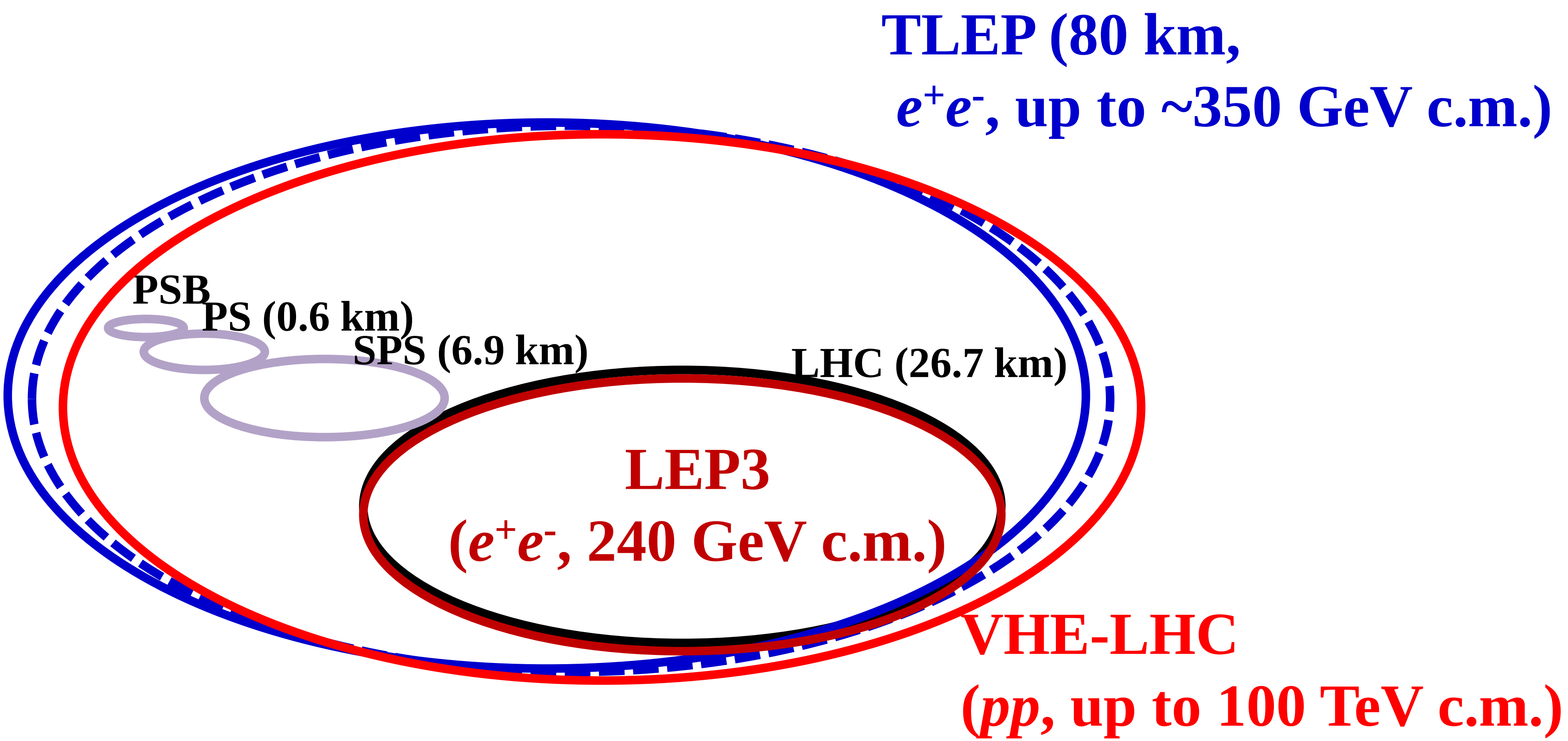
tunnels, surface buildings, transport (access roads), civil engineering, cooling ventilation, electricity, cryogenics, communication & IT, fabrication and installation processes, maintenance, environmental impact and monitoring,

Hadron injectors	Hadron collider	e+ e- collider
Beam optics and dynamics Functional specs Performance specs Critical technical systems Operation concept	Optics and beam dynamics Functional specifications Performance specs Critical technical systems Related R+D programs *HE-LHC comparison* Operation concept Detector concept Physics requirements	Optics and beam dynamics Functional specifications Performance specs Critical technical systems Related R+D programs Injector (Booster) Operation concept Detector concept Physics requirements

e- p option: Physics, Integration, additional requirements

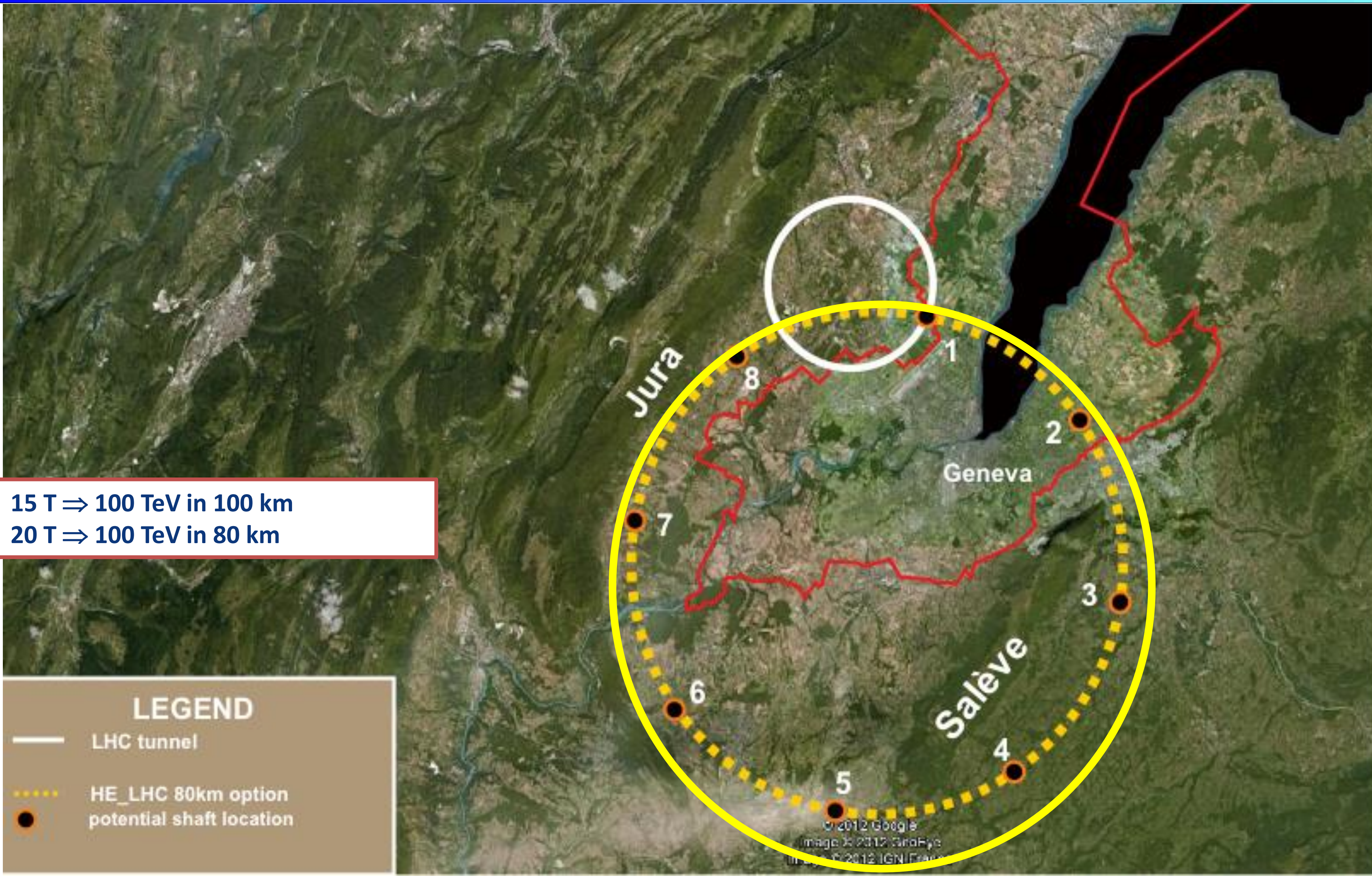
Future Circular Colliders – Conceptual Design Study
Michael Benedikt
6th TLEP Workshop - CERN– 16th October 2013
6

Future Circular Colliders (3 types)



Also collisions: ***e*^± (200 GeV) – *p* (7 & 50 TeV)**

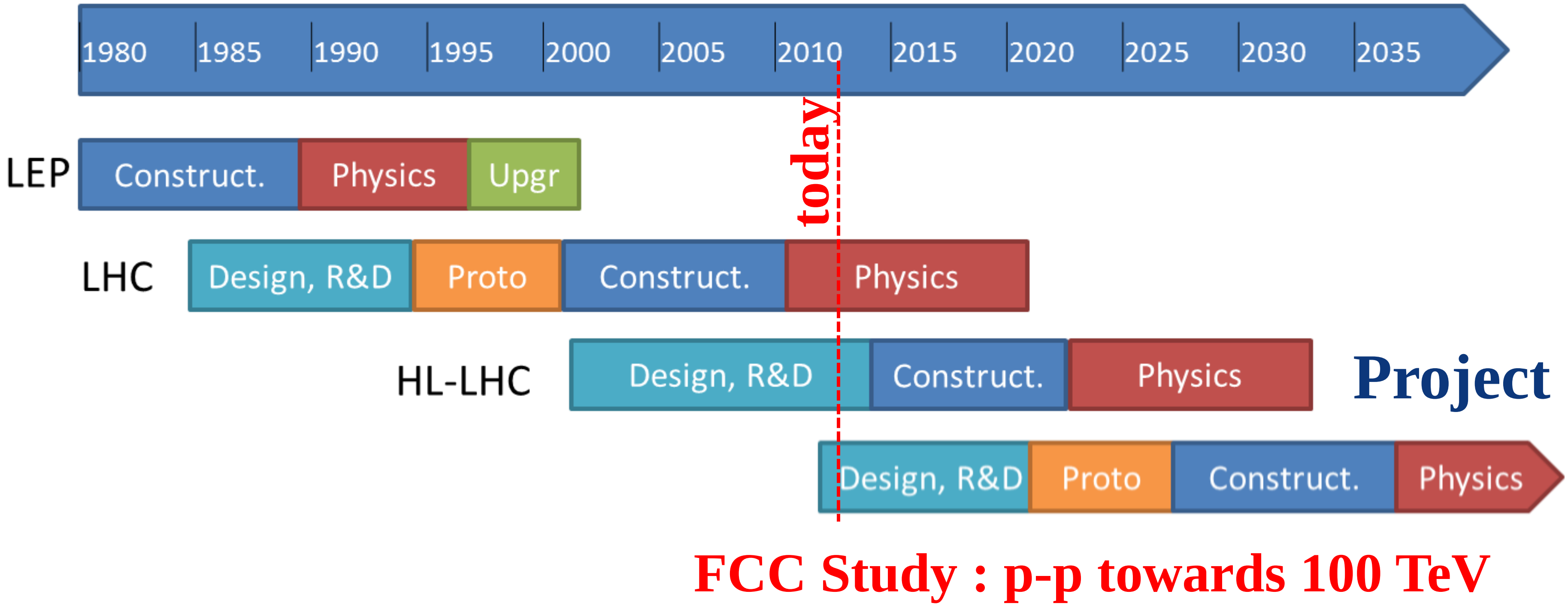
VE-LHC (Very High Energy – LHC)



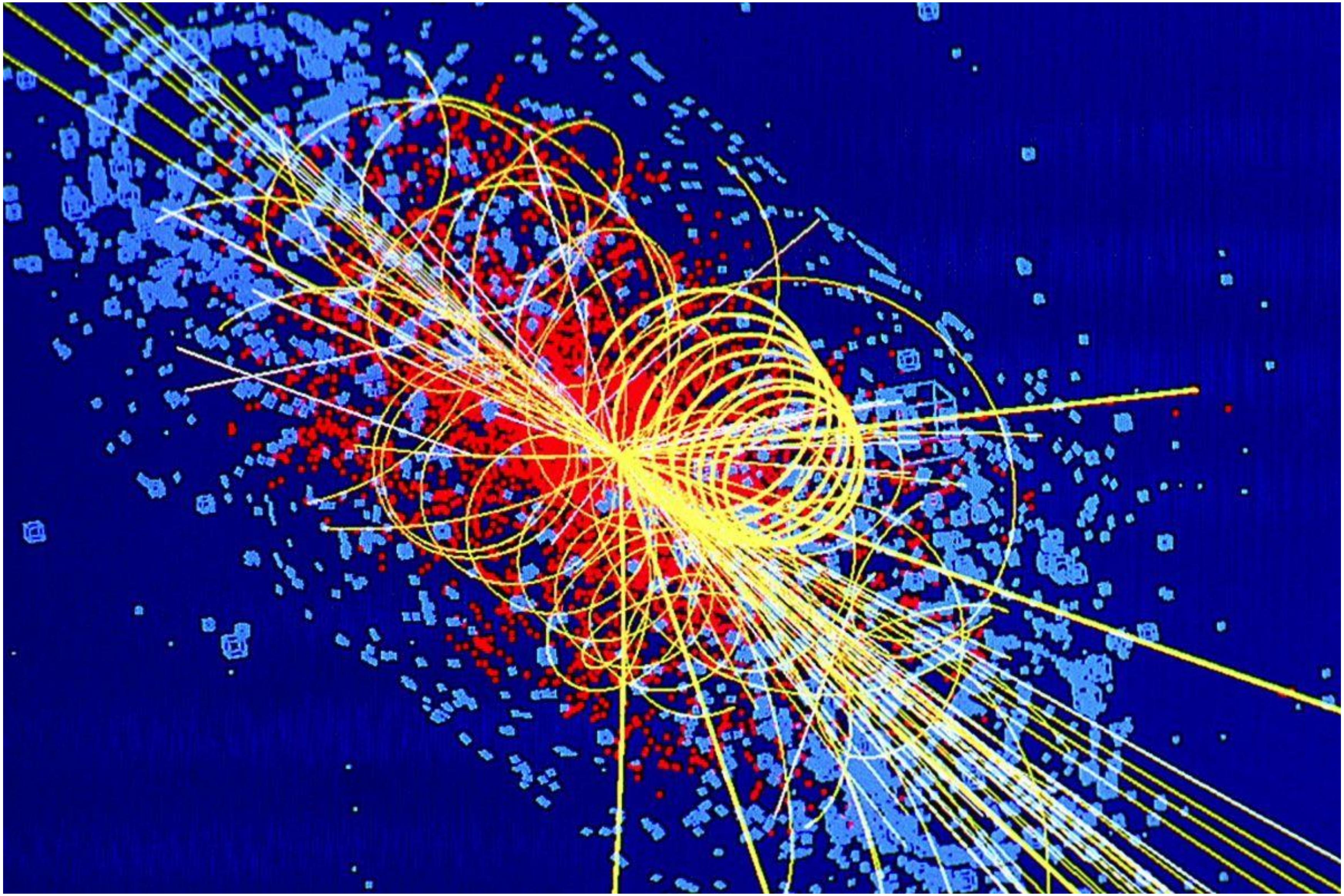
15 T ⇒ 100 TeV in 100 km
20 T ⇒ 100 TeV in 80 km

A possible planning

European Strategy: "CERN should undertake design studies for accelerator projects in a global context, with emphasis on ***proton-proton*** *and electron- positron* ***high-energy frontier machines."***



Lepton colliders



Linear lepton colliders expectations

ILC (International Linear Collider):

ILC nominal energy study is 0.5 TeV.
However the present design is done in order to run up to 1 TeV

"On 24 December 2013, the Japanese cabinet released the government budget proposal for the Japanese Fiscal Year 2014 that will be voted on in the Diet early this year. It includes an official budget line for the ILC. This is highly important as it represents a qualitative change in the status of the ILC in the Japanese government and indicates that it is now a recognized project. …"
LC News Line , Hitoshi Murayama | 23 January 2014

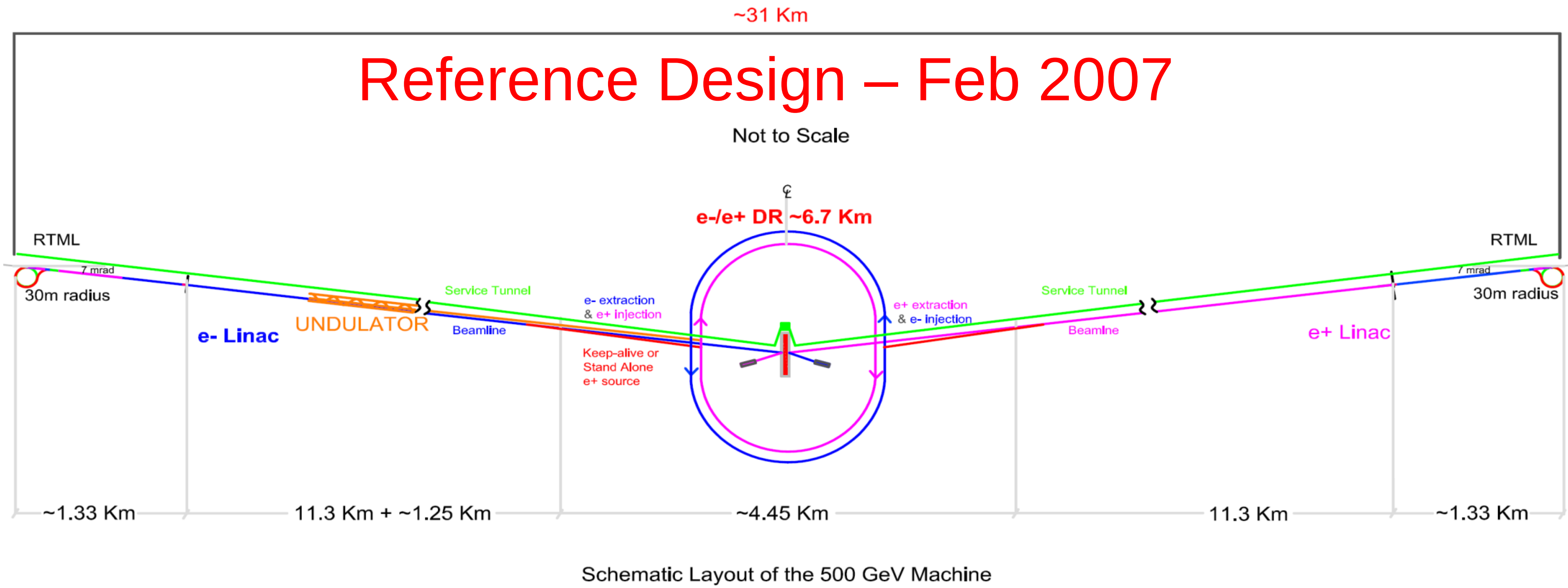
CLIC (Compact Linear Collider):

CLIC nominal energy study is 3 TeV.
However the present design is done in order to run over a wide energy range: 0.5 to 3 TeV (studies have been performed up to 5 TeV).

CLIC Workshop 2014
3-7 February 2014
CERN

International Linear Collider (ILC)

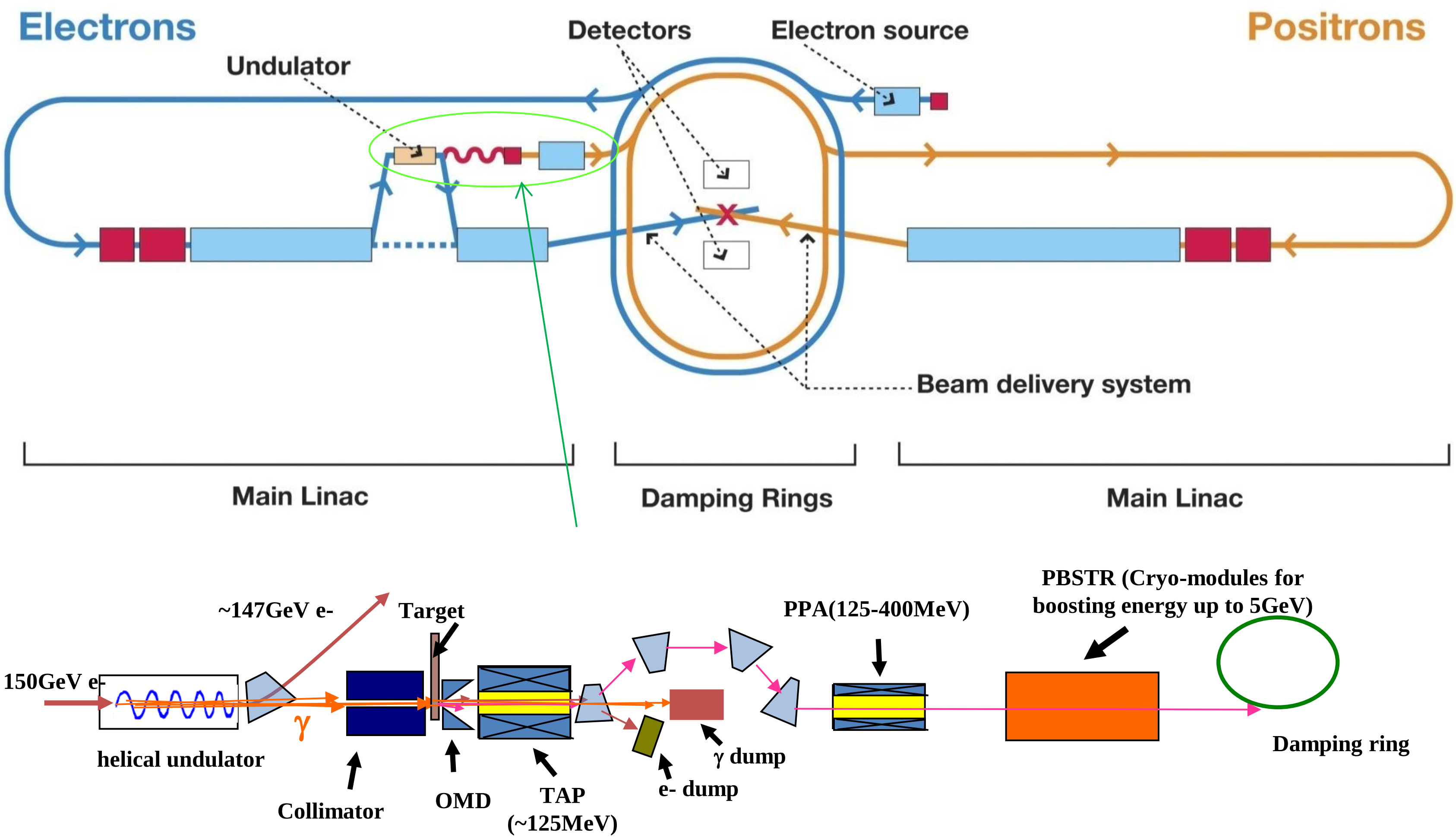
- 11km SC linacs operating at 31.5 MV/m for 500 GeV
- Centralized injector
- Single IR with 14 mrad crossing angle
- Dual tunnel configuration for safety and availability



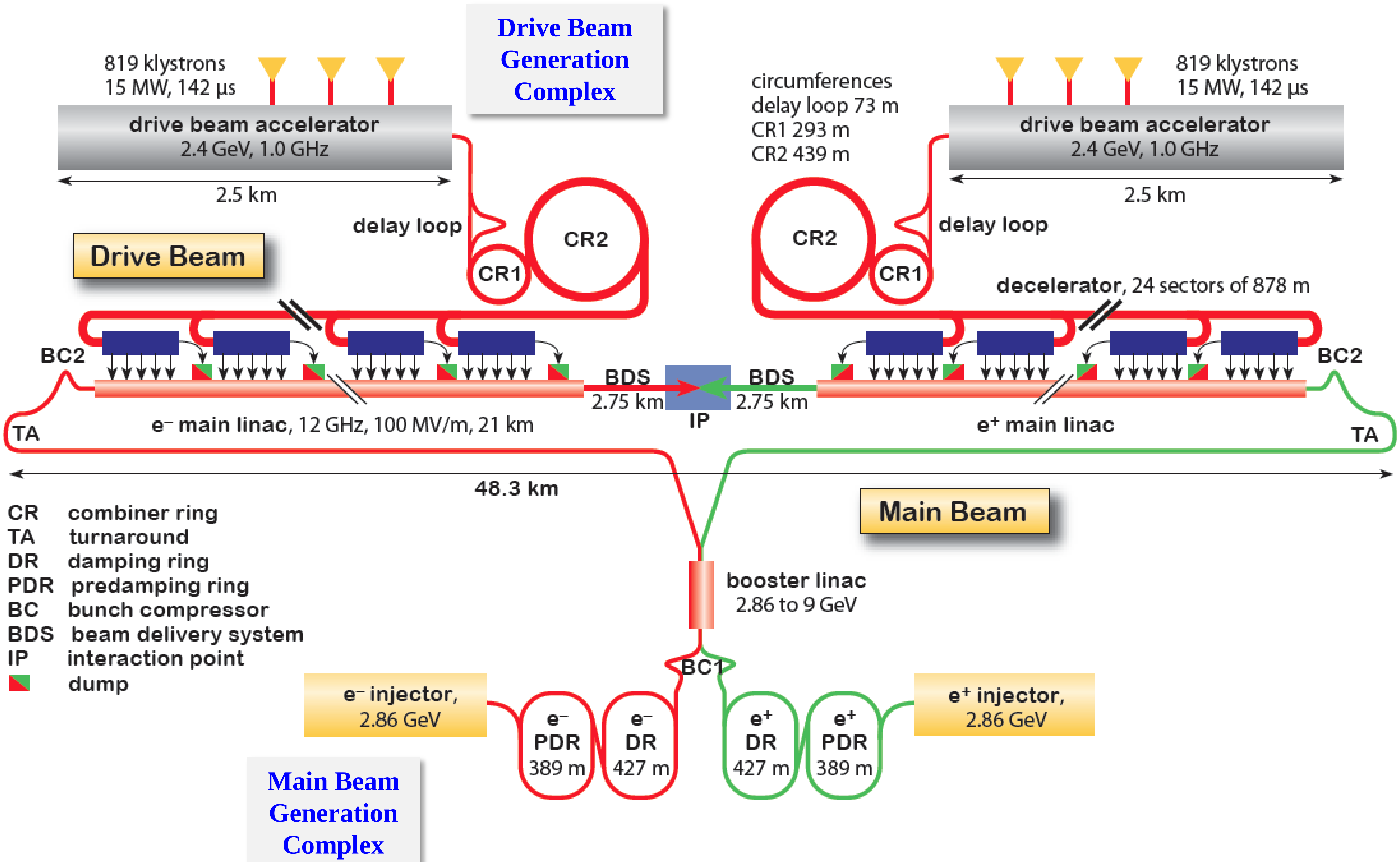
Schematic Layout of the 500 GeV Machine

Documented in Reference Design Report

ILC baseline layout



CLIC Layout at 3 TeV



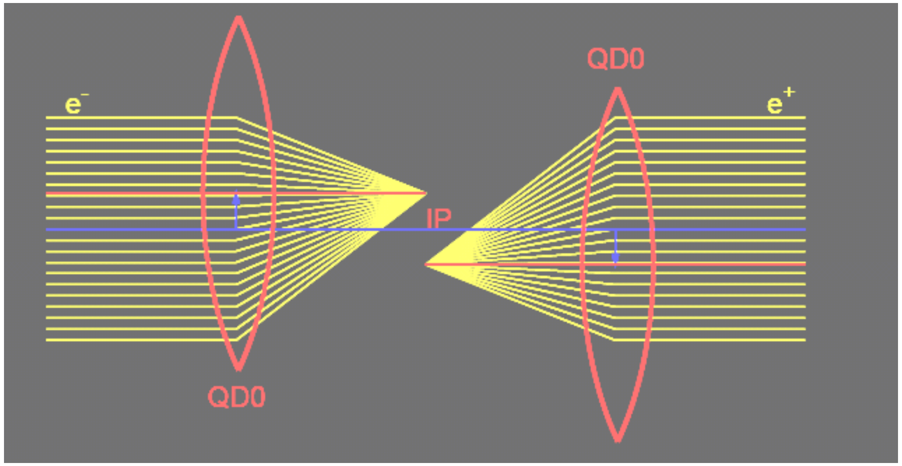
Challenges at the source: flux of e^+

	SLC	CLIC (3 TeV)	CLIC (0.5 TeV)	ILC (RDR)	LHeC (pulsed)	LHeC ERL
Energy	1.19 GeV	2.86 GeV	2.86 GeV	5 GeV	140 GeV	60 GeV
e^+/ bunch (at IP)	40×10^9	3.7×10^9	7.4×10^9	20×10^9	1.6×10^9	2×10^9
e^+/ bunch (aft. capture)	50×10^9	7×10^9	14×10^9	30×10^9	1.8×10^9	2.2×10^9
Bunches / macropulse	1	312	354	2625	100 000	NA
Rep. Rate (Hz)	120	50	50	5	10	CW
Bunches / s	120	15600	17700	13125	10^6	20×10^6
e^+ / second $\times 10^{14}$	**0.06**	**1.1**	**2.5**	**3.9**	**18**	**440**

x 20 x 70 x 7000

Challenges at the Interaction Point: beam size

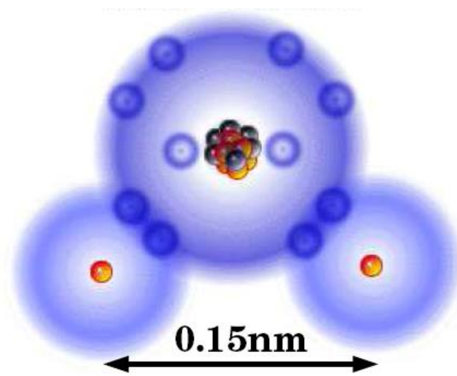
Vertical spot size at IP is 1 nm



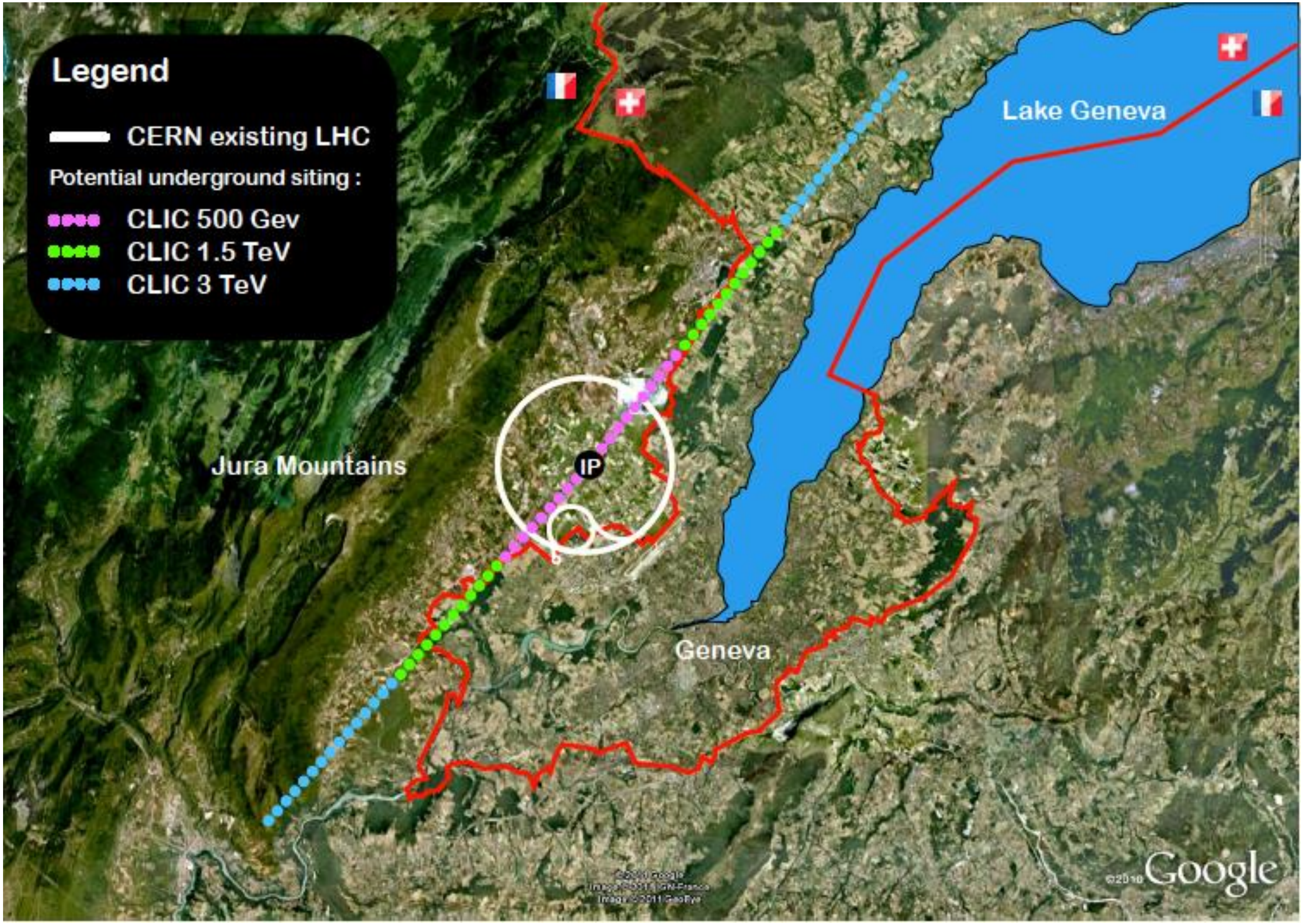
Stability requirements (> 4 Hz) for a 2% loss in luminosity

Magnet	Horizontal jitter	Vertical jitter
Linac (2600 quads)	14 nm	1.3 nm
Final Focus (2 quads) QD0	4 nm	0.15 nm

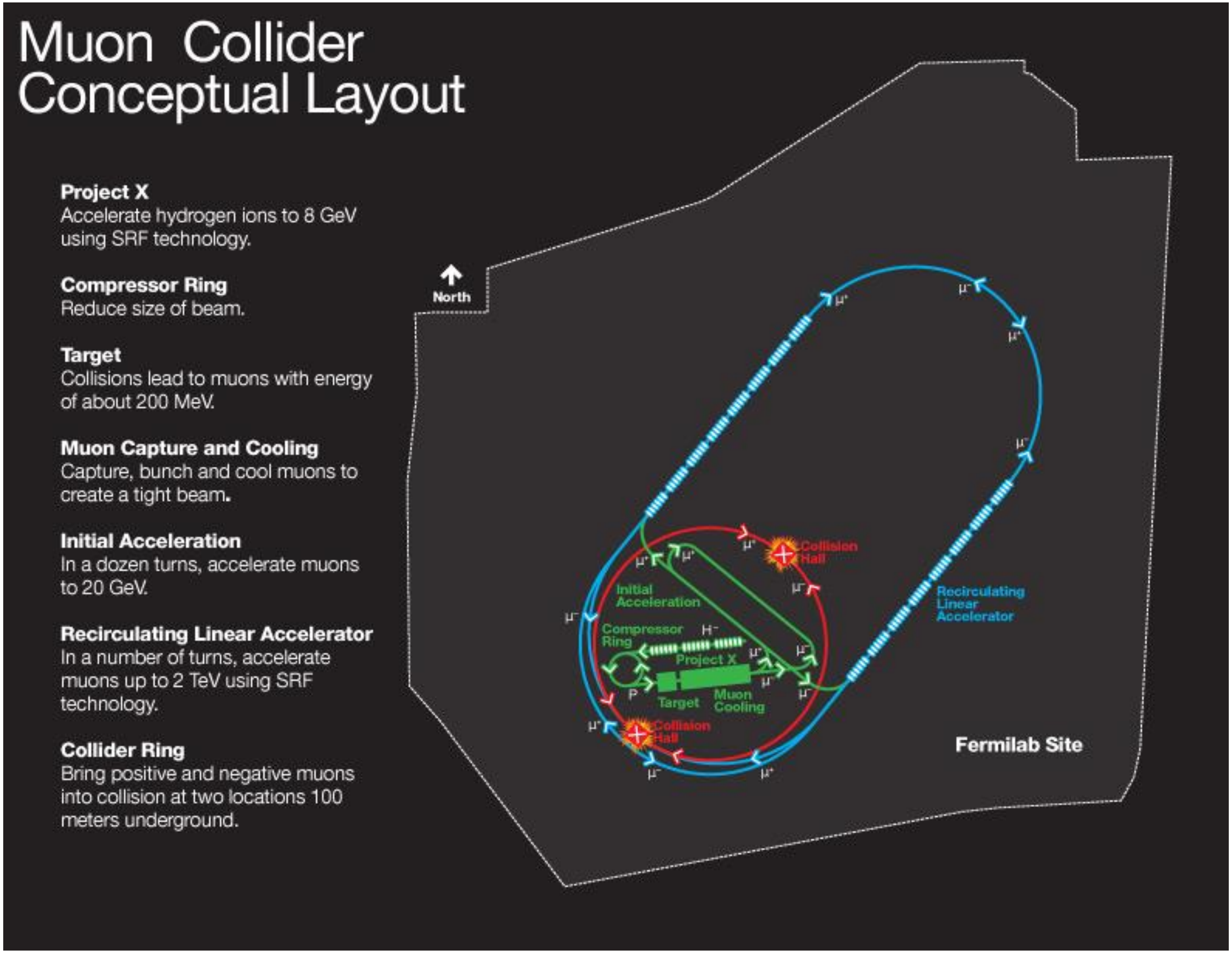
H_2O molecule



Compact Linear Collider (CLIC)



Muon collider



Muon Accelerator Program

Hadron-Lepton colliders

eRHIC (high energy electron-ion collider):

at Brookhaven USA

LHeC (Large Hadron electron Collider):

at CERN - Geneva

eRHIC collider

eRHIC: high energy electron-ion collider

General features

•Species: electrons colliding with protons, ^{3}He or heavy ions (up to Au).

•Energy ranges:

- 5-30 GeV electrons
- 50-325 GeV polarized protons or up to 130 GeV/u gold ions

•Luminosities

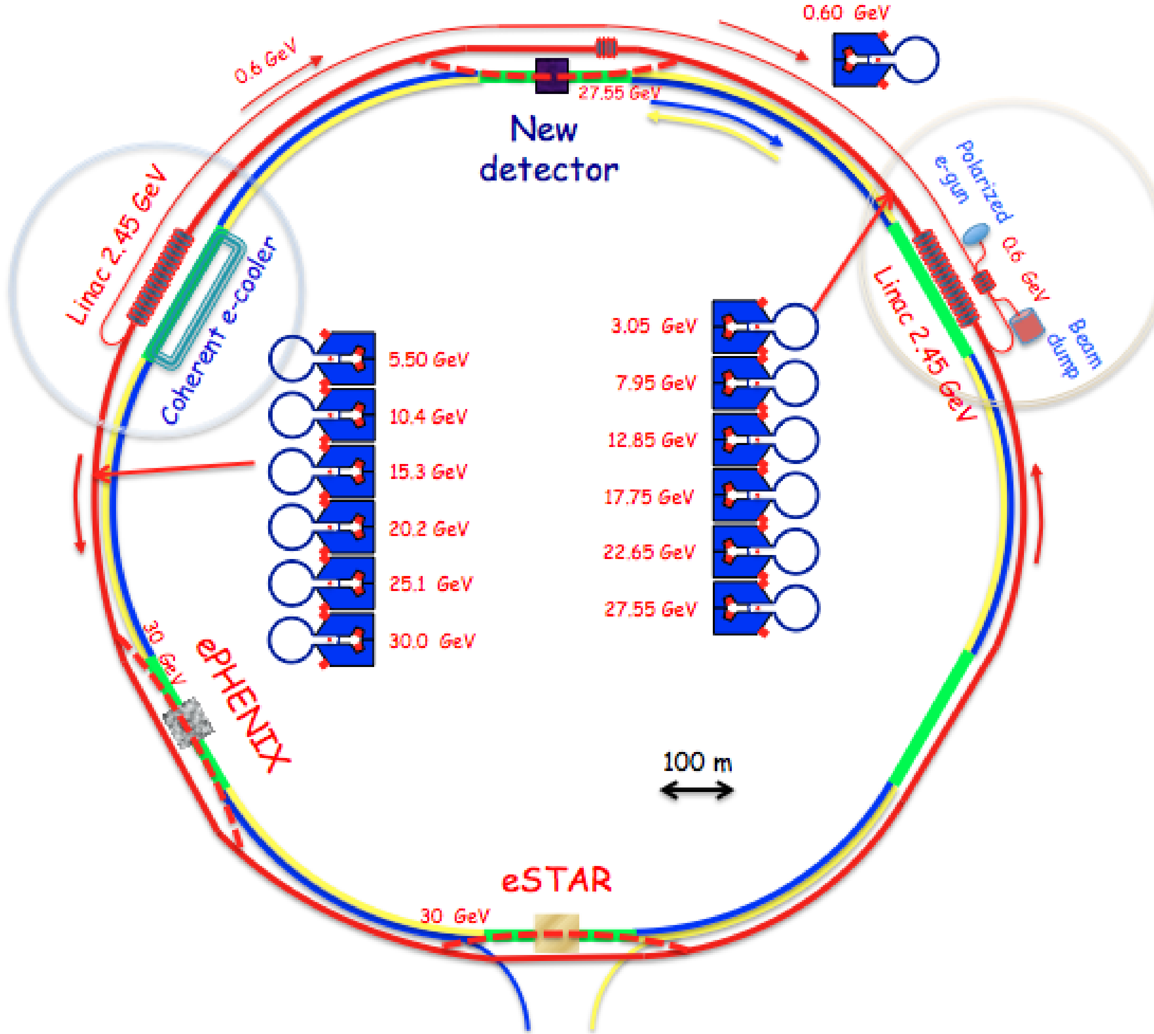
- exceeding 10^{34} cm^{-2}s^{-1} for e-p collisions
- exceeding 10^{32} cm^{-2}s^{-1} for e-Au collisions

•High polarization of electron, proton and ^{3}He beams.

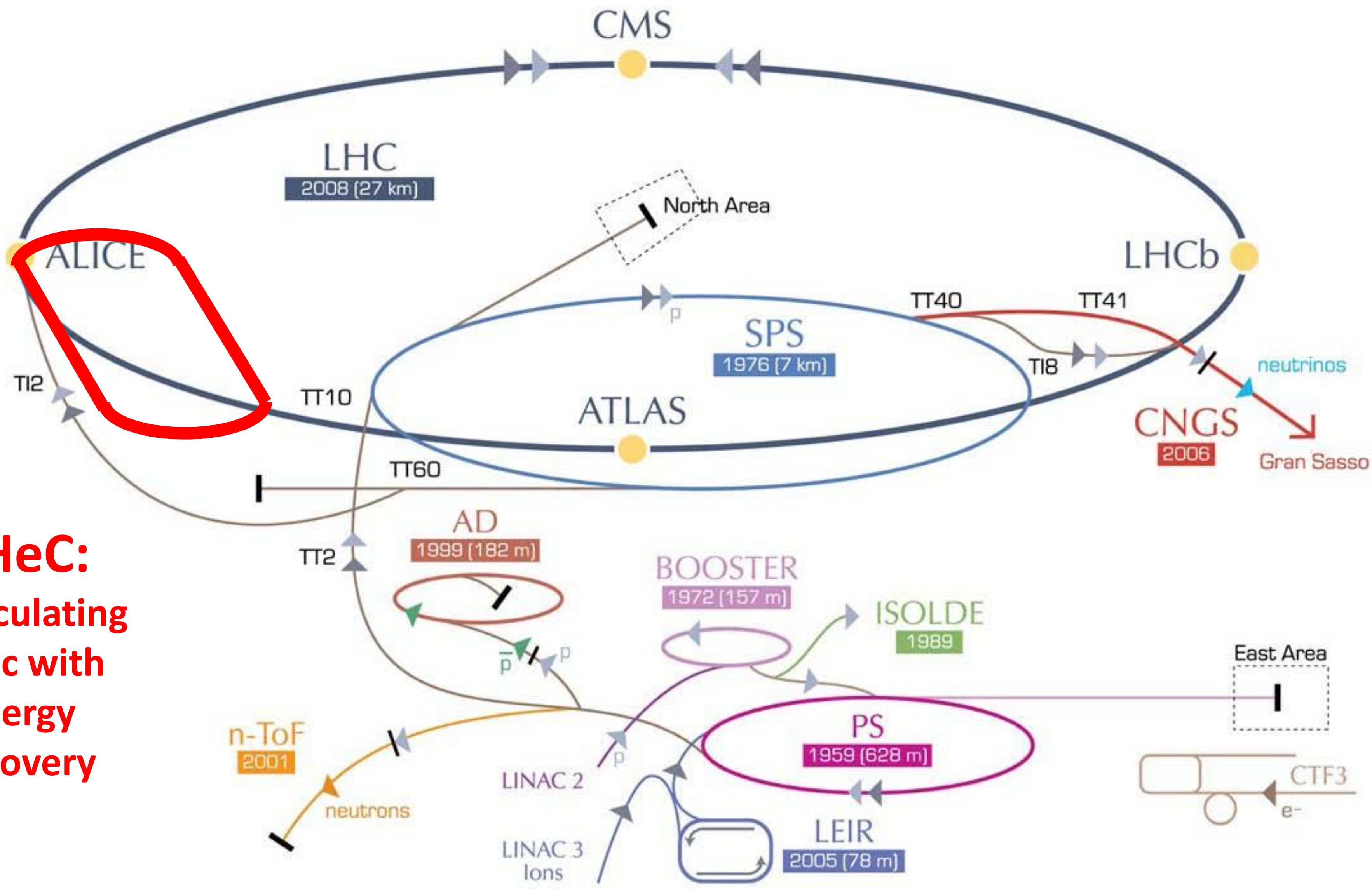
•Electron acceleration in superconducting energy recovery electron linacs.

•Electron beam is used for collisions only on one pass (linac-ring collision scheme).

•IR design with 10 mrad crossing angle and crab-crossing.



LHeC Collider

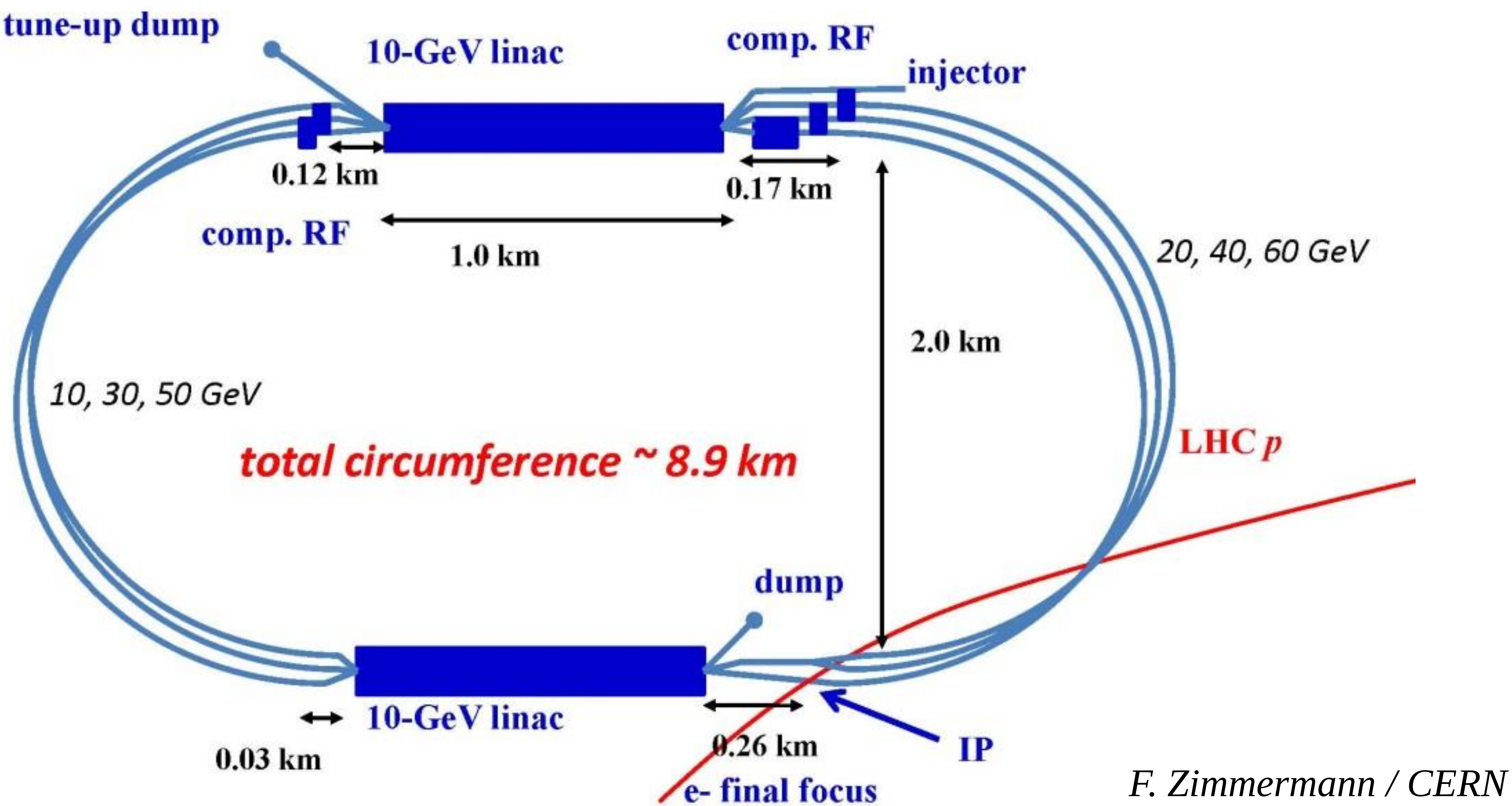


LHeC:

recirculating linac with energy recovery

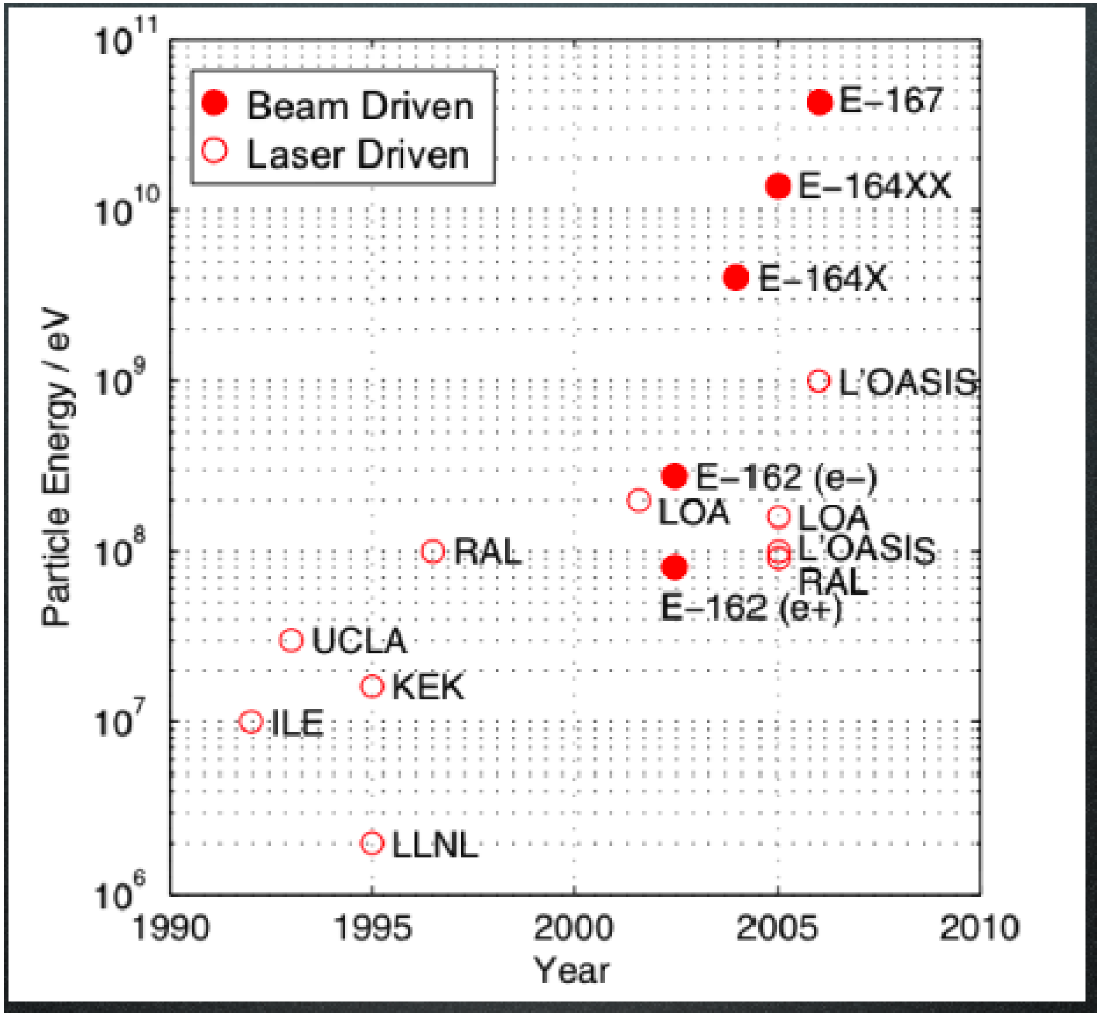
LHeC Layout

two 10-GeV SC linacs, 3-pass up, 3-pass down; 6.4 mA, 60 GeV e-'s collide w. LHC protons/ions



F. Zimmermann / CERN

Plasma accelerator



<u>Laser-Plasma Accelerators:</u>

- Accelerating field of few 100 GeV/m.

- Quasi monoenergetic e-beam, from 100 MeV to 1 GeV, in mm to cm plasma.

- Relative energy spread of 1 %, femtosecond duration.

- Divergence of a few mrad, emittance of π.mm.mrad.

- Charge of about 10-100 pC.

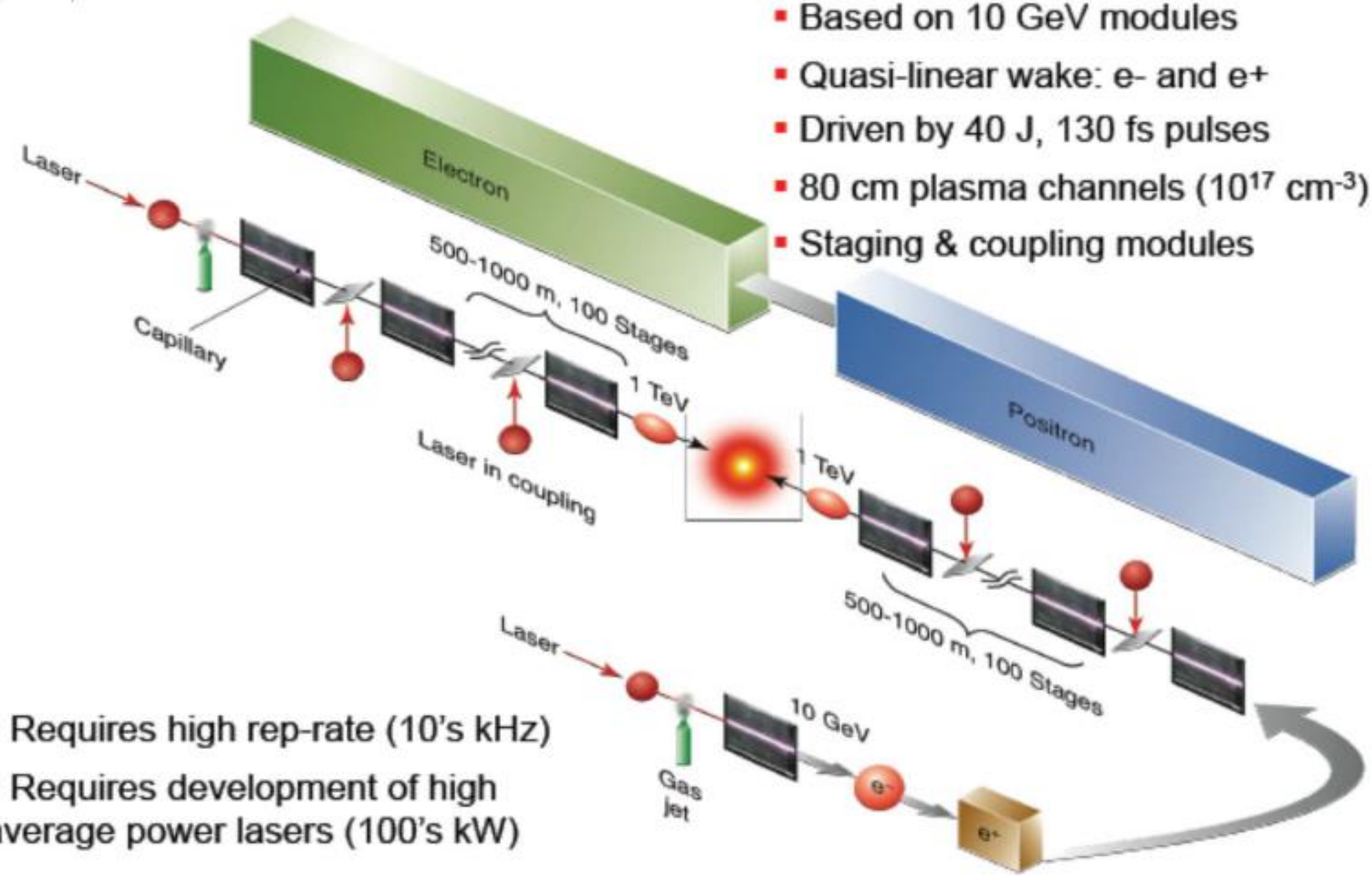
loa

INFN, June 8 (2012)

V. Malka / LOA

Laser plasma collider concept

- Based on 10 GeV modules
- Quasi-linear wake: e- and e+
- Driven by 40 J, 130 fs pulses
- 80 cm plasma channels (10^{17} cm^{-3})
- Staging & coupling modules



- Requires high rep-rate (10's kHz)
- Requires development of high average power lasers (100's kW)

Leemans & Esarey, Physics Today, March 2009

Laser Plasma Acceleration

- LPA currently produce electron bunches of extremely short duration (<10fs), up to 1 GeV, dE/E~2.5% rms
- Laser guiding and increased laser energy should produce electron bunches in the ~10 GeV range in one stage (ex: BELLA project in the USA or APOLLON 10 PW in France)
- Very active and motivating field of research:
  - involving laser, plasma and accelerator physics,
  - several facilites under development,
  - need for students, researchers and engineers

B. Cros/ LPA

Conclusion

Novel ideas are necessary in order to tackle the challenging R&D

The world-wide collaboration is certainly a major asset

Your participation is warmly welcome to the future high energies colliders studies