Future Circular Collider study

18th EPPCN meeting
5 November 2015
CERN

W. Riegler, P. Charitos for the FCC study group

Strategic Motivation

- **European Strategy for Particle Physics 2013:**

  "…to propose an ambitious post-LHC accelerator project….., CERN should undertake design studies for accelerator projects in a global context,…with emphasis on proton-proton and electron-positron high-energy frontier machines..…"

- **ICFA statement 2014:**

  ".… ICFA supports studies of energy frontier circular colliders and encourages global coordination.…."

- **US P5 recommendation 2014:**

  ".…A very high-energy proton-proton collider is the most powerful tool for direct discovery of new particles and interactions under any scenario of physics results that can be acquired in the P5 time window.…"

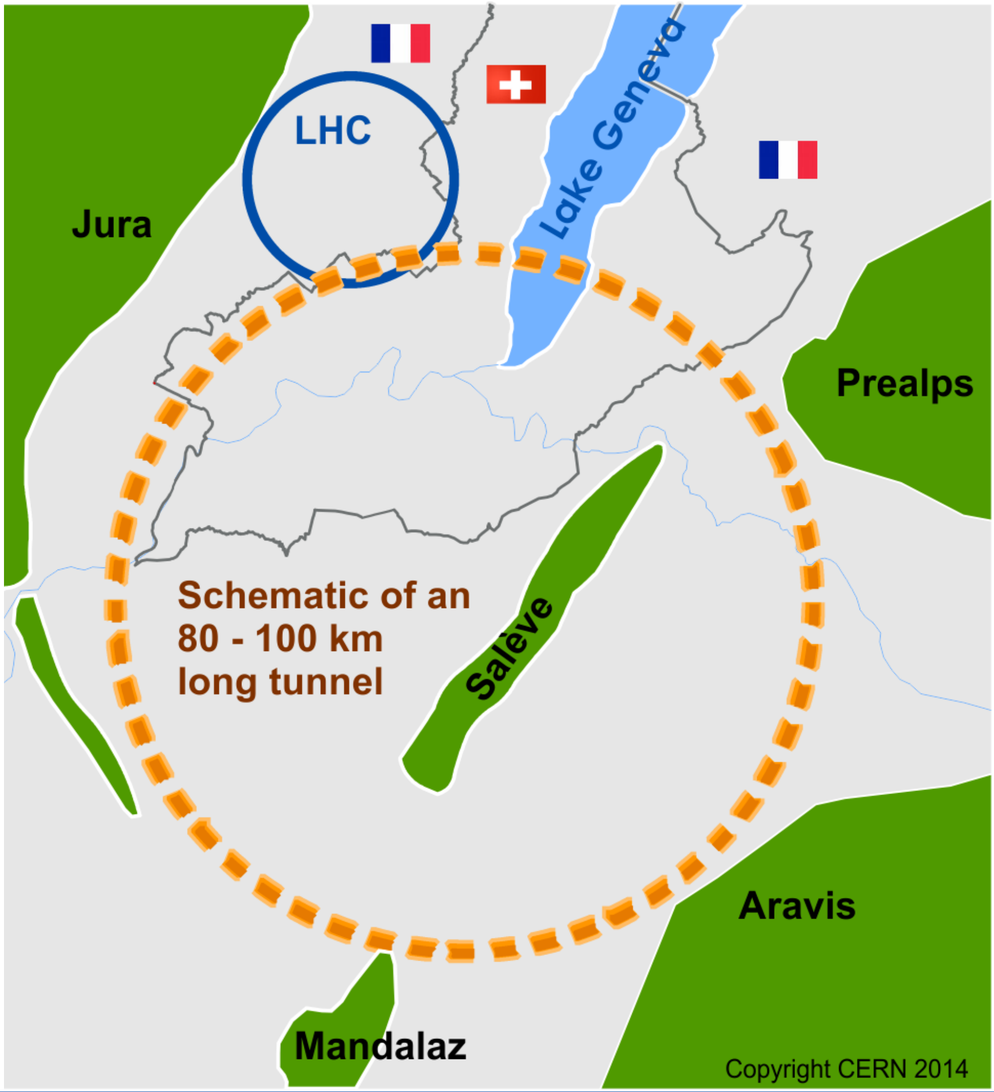
Future Circular Collider Study

International FCC collaboration (CERN as host lab) to study:

- ***pp*-collider (*FCC-hh*)**
  → main emphasis, defining infrastructure requirements

~16 T ⇒ 100 TeV *pp* in 100 km

- **80-100 km infrastructure** in Geneva area
- ***e^+e^-* collider (*FCC-ee*)** as potential intermediate step
- ***p-e* (FCC-he) option**
- **HE-LHC** with FCC-hh technology



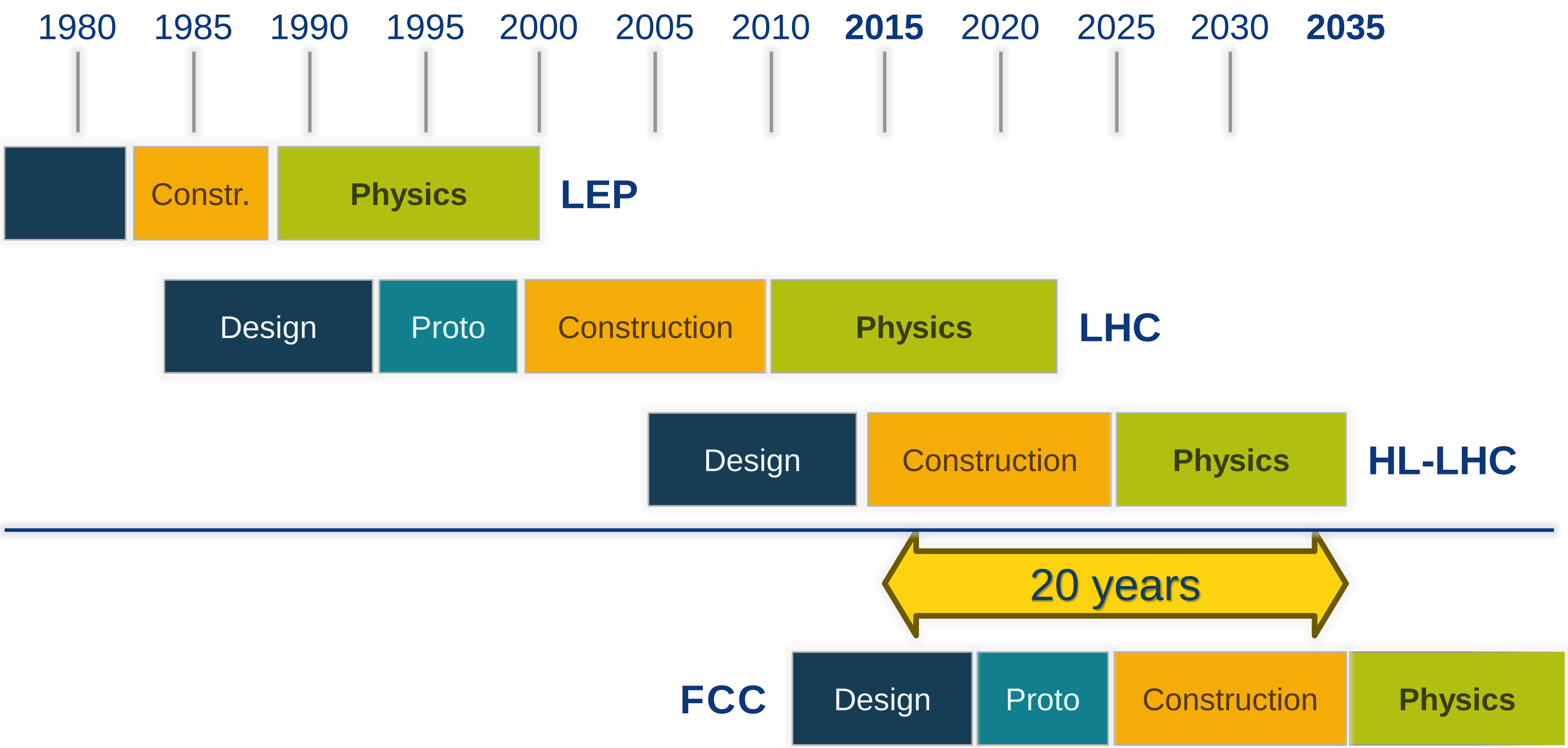
FCC motivation: pushing the energy frontier

The name of the game of a hadron collider is **energy reach**

$$E \alpha B_{dipole} \times R_{bending}$$

Cf. LHC: factor ~4 in radius, factor ~2 in field → **O(10) in E_{cms}**

CERN Circular Colliders and FCC



FCC Conceptual Design Report by end 2018 for the European strategy update

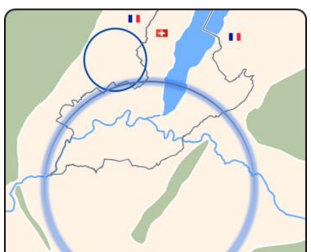
FCC Scope: Accelerator and Infrastructure

Collider Designs

FCC-hh: **100 TeV pp collider as long-term goal**
→ defines infrastructure needs
FCC-ee: **e^+e^- collider**, potential intermediate step
FCC-he: **integration aspects** of pe collisions

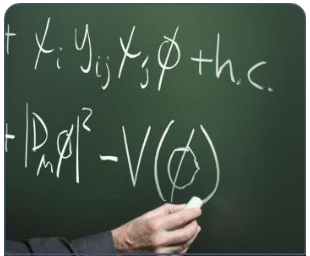

R&D Programs

Push key technologies
in dedicated R&D programmes e.g.
16 Tesla magnets for **100 TeV** pp in **100 km**
SRF technologies and RF power sources


Infrastructures

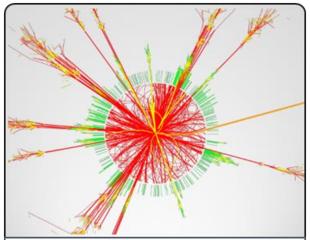
Tunnel infrastructure in Geneva area, linked to CERN accelerator complex
Site-specific, requested by European strategy

Scope: Physics & Experiments



Physics Cases

Elaborate and document
- Physics opportunities
- Discovery potentials



Experiments

Experiment concepts for hh, ee and he
Machine Detector Interface studies
Concepts for worldwide data services

Cost Estimates

Overall cost model
Cost scenarios for collider options
Including infrastructure and injectors
Implementation and governance models

FCC-hh luminosity goals & phases

- **Two parameter sets for two operation phases:**
  - **Phase 1 (baseline): 5 x 10^{34} $cm^{-2}s^{-1}$ (peak),**
    250 fb^{-1}/year (averaged)
    2500 fb^{-1} within 10 years
  - **Phase 2 (ultimate): ~2.5 x 10^{35} $cm^{-2}s^{-1}$ (peak),**
    1000 fb^{-1}/year (averaged)
    ➔ 15,000 fb^{-1} within 15 years
  - **Yielding total luminosity O(20,000) fb^{-1} over ~25 years of operation**

Luminosity goals for a 100-TeV pp collider

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Abstract

We consider diverse examples of science goals that provide a framework to assess luminosity goals for a future 100-TeV proton-proton collider.

An integrated luminosity goal of 20 ab^{-1}

matches very well the 100TeV c.m. Energy

LEP – highest energy e^+e^- collider so far

circumference 27 km
in operation from 1989 to 2000
maximum c.m. energy 209 GeV
maximum synchrotron radiation power 23 MW

FCC-ee physics areas

- highest possible luminosities at all working points
- *beam energy range from 35 GeV to ≈200 GeV*
- **physics programs / energies:**

Z (45.5 GeV) Z pole, 'TeraZ' and high precision M_Z & Γ_Z

W (80 GeV) W pair production threshold, high precision M_W

H (120 GeV) ZH production (maximum rate of H's)

t (175 GeV): $t\bar{t}$ threshold, H studies

Site investigations

Alignment | **Shaft Tools**

Choose alignment option

93km quasi-circular ▾

Tunnel depth at centre: 299mASL

Gradient Parameters

Azimuth (°): -15

Slope Angle x-x(%): .5

Slope Angle y-y(%): 0

CALCULATE

Alignment centre

X: 2499812 Y: 1106889

LHC Intersection	CP 1	CP 2
Angle		
Depth	589m	589m

Alignment Location

Geology Intersected by Shafts | **Shaft Depths**

	Shaft Depth (m)				Geology (m)			
Point	Actual	Min	Mean	Max	Quaternary	Molasse	Urgonian	Calcaire
A	203	200	204	212	93	111	0	0
B	227	219	226	231	41	185	0	0
C	218	208	217	225	75	143	0	0
D	153	150	154	158	19	134	0	0
E	247	233	249	261	24	223	0	0
F	262	251	269	304	32	230	0	0
G	396	392	393	396	177	220	0	0
H	266	231	274	322	0	325	0	0
I	146	141	144	149	26	120	0	0
J	248	247	251	258	6	242	0	0
K	163	153	159	164	76	87	0	0
L	182	182	184	187	17	165	0	0
Total	2711	2607	2724	2867	585	2185	0	0

Alignment Profile

- 90 – 100 km fits geological situation well
- LHC suitable as potential injector

FCC-hh preliminary layout

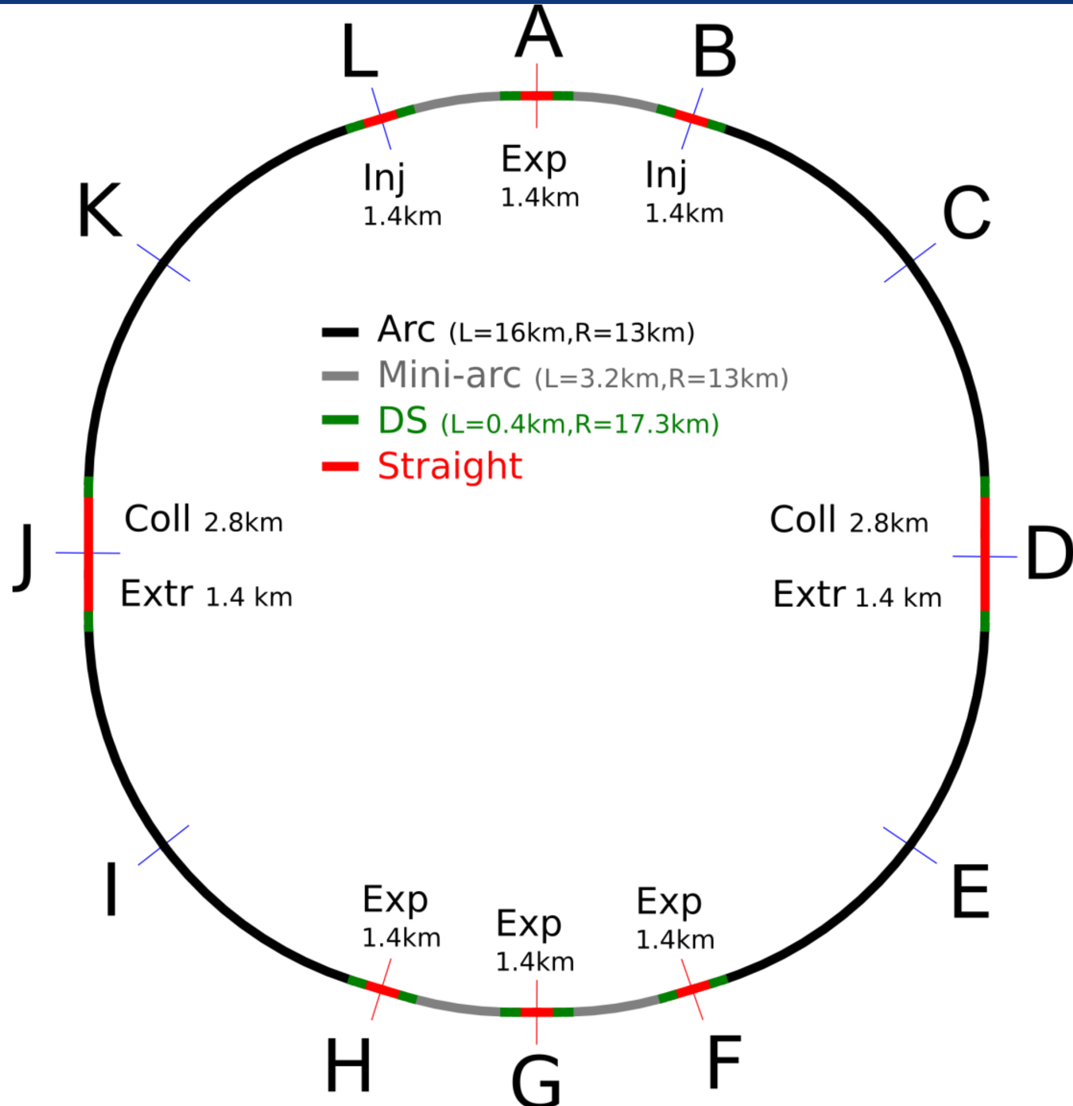
100 km layout for FCC-hh (different sizes under investigation)

⇒ **Two high-luminosity experiments (A and G)**

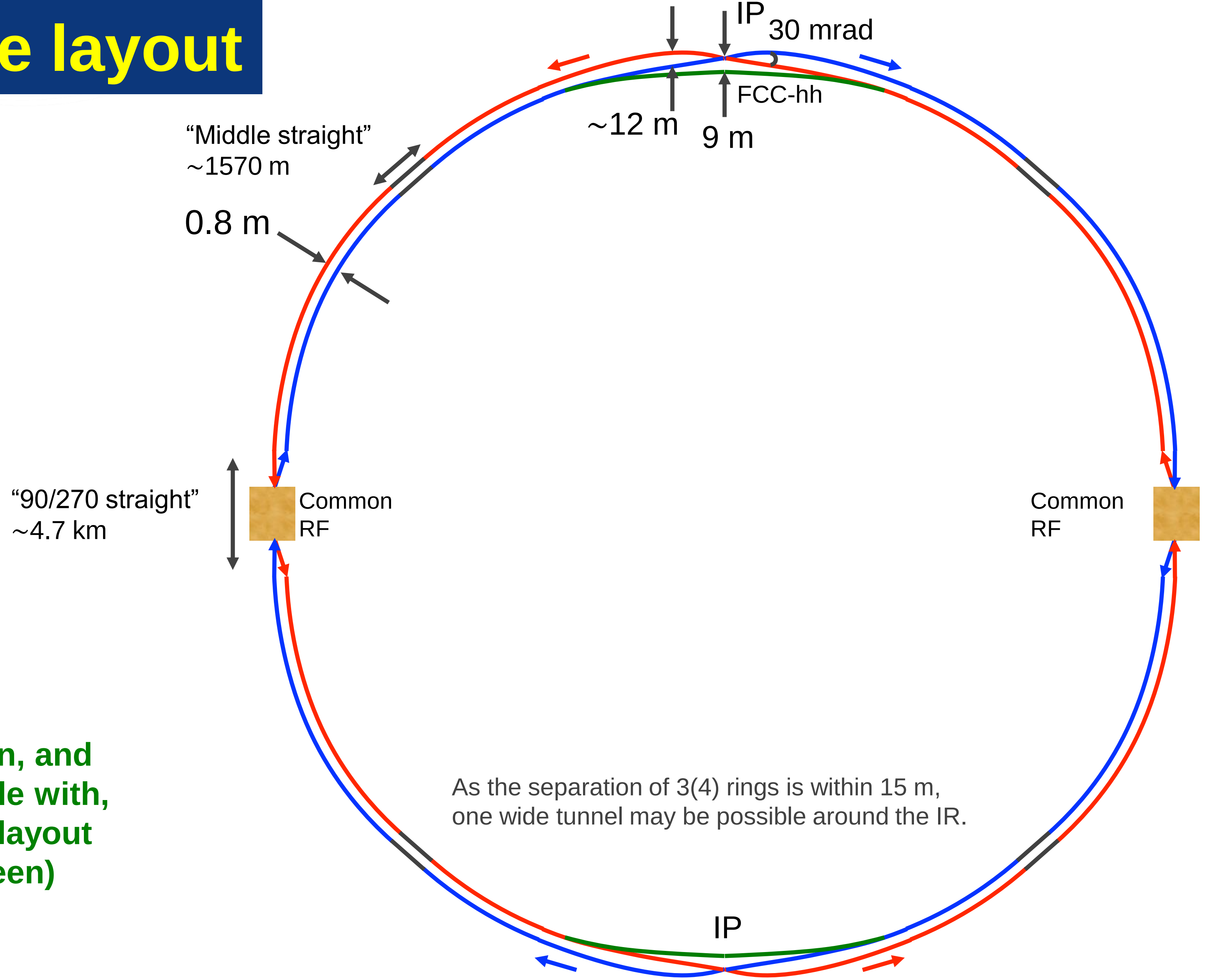
⇒ **Two other experiments (F and H) grouped with main experiment in G**

⇒ **Two collimation lines**

⇒ **Two injection and two extraction lines**



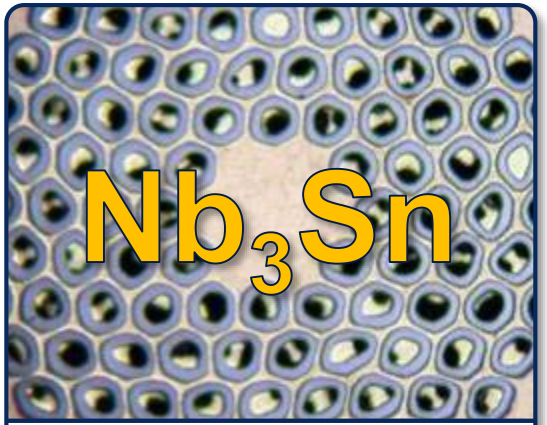
FCC-ee layout



As the separation of 3(4) rings is within 15 m, one wide tunnel may be possible around the IR.

Based on, and compatible with, FCC-hh layout (in green)

Key Technology R&D - HFM



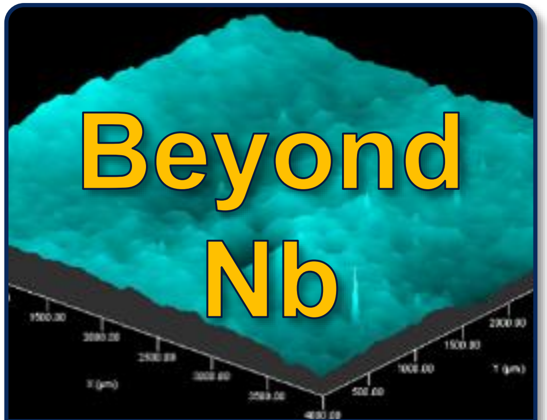
Conductor R&D

- Increase critical current density
- Obtain high quantities at required quality
- Material Processing
- Reduce cost

Magnet Design

- Develop 16T short models
- Field quality and aperture
- Optimum coil geometry
- Manufacturing aspects
- Cost optimisation

Key Technology R&D - RF



Superconducting RF

Power Conversion

- Evaluate new fabrication techniques
- Study novel superconducting materials
- Improve thin film / coating techniques
- Optimise operation temperature to improve energy efficiency

- Push klystron efficiency beyond 75%
- Increase power range efficiency of solid-state amplifiers
- Assess power reach of IOTs

Synchrotron radiation/beam screen

High synchrotron radiation load (SR) of protons @ 50 TeV:

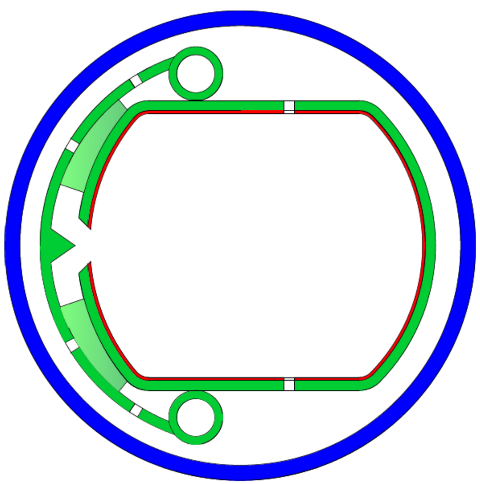
~30 W/m/beam @16 T (LHC <0.2W/m)

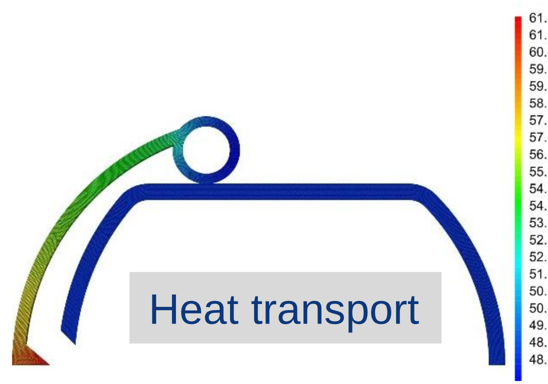
→ 5 MW total in arcs

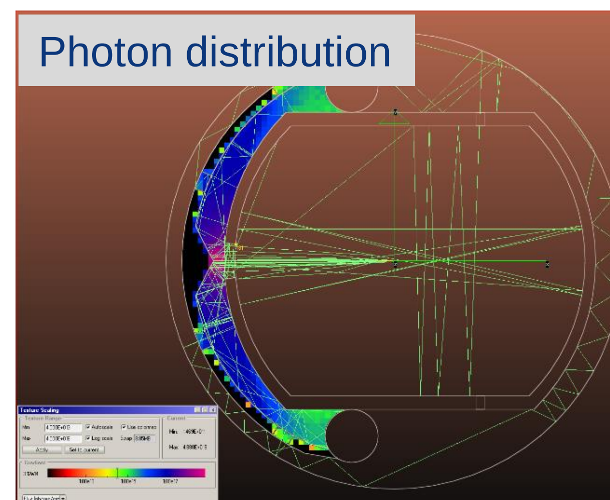
New type of chamber

- absorption of synchrotron radiation
- avoids photo-electrons, helps vacuum

LHC beam screen

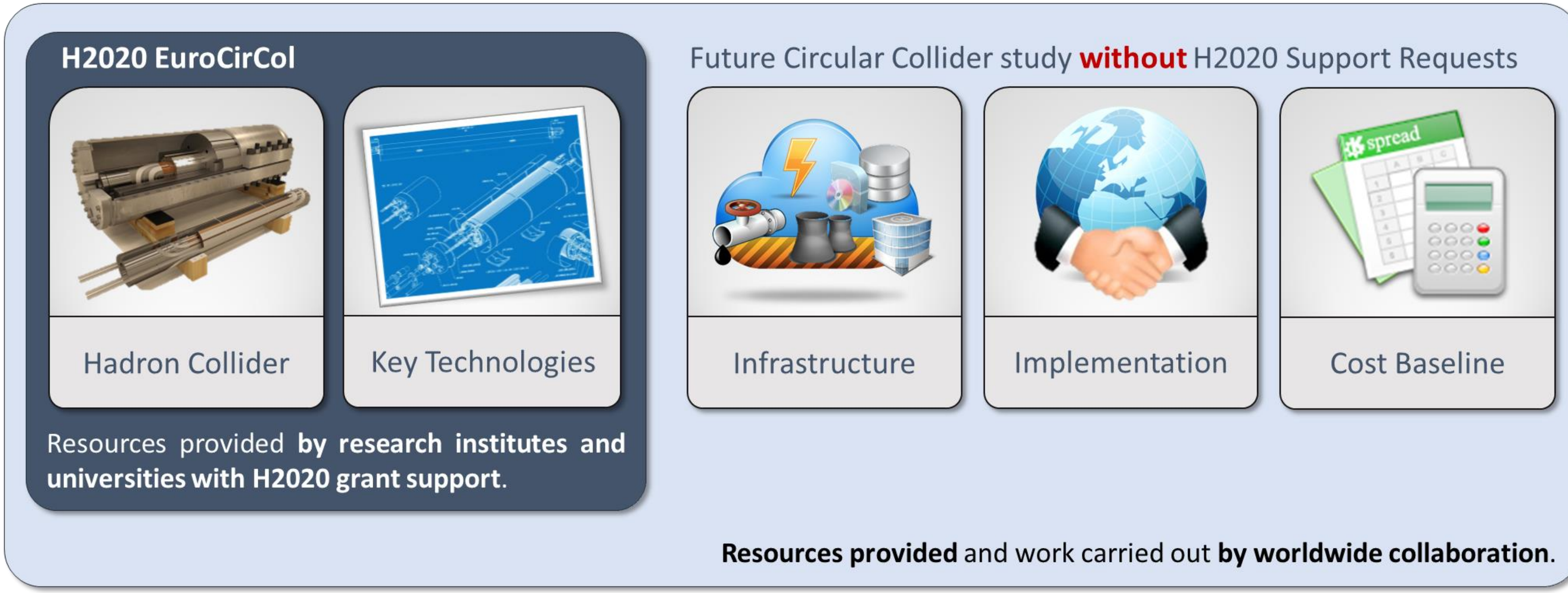






EuroCirCol EU Horizon 2020 Grant

EC contributes with funding to FCC-hh study



- Core aspects of hadron collider design: arc & IR optics design, 16 T magnet program, cryogenic beam vacuum system
- **Recognition of FCC Study by European Commission.**

FCC International Collaboration

- 61 institutes
- 23 countries + EC

Status: 14 September 2015

Conclusions

Main scope of the study [Draft] – **The FCC Communication Strategy is currently revised and a detailed document will be available later this year.**

Even though the LHC programme is already well defined for the next two decades, the time has come to look even further ahead, so CERN has initiated an exploratory study for a future long-term project centred on a new-generation of circular colliders with a circumference of 80 to 100 kilometres. A worthy successor to the LHC, such an accelerator would allow particle physicists to push the boundaries of knowledge far beyond LHC.

The study aims to explore scenarios for different types of colliders (hadron-hadron, electron-electron and hadron-electron). In addition, the detectors needed to study the new physics regime shall determine the basic requirements for the tunnel, surface and technical infrastructures. Finally, the existing CERN accelerator infrastructure and long-term accelerator operation plans are taken into account.

Potential synergies with other international projects for future colliders, including linear colliders, are considered along with the collaboration with organizations and institutes working to promote physics and, more broadly STEM training.

Finally, it should be noted that the study includes cost and energy optimisation, industrialisation aspects and will provide implementation scenarios with detailed schedule and cost profiles.

Key Messages

The following mission statements are at the core of the Future Circular Collider-study.

Science/Physics: Expanding Our Horizons
“Prepare the ground for humankind’s deepening exploration of our Universe through developing opportunities for New Physics breakthroughs.”

Innovation: Pushing Novel Technologies
“To advance innovative technologies beyond state-of-the-art.”

Collaboration: “To forge a globally coordinated strategy of converging activities for frontier particle colliders.”