Future Circular Collider

Designing a Future Circular Collider: Challenges & Perspectives

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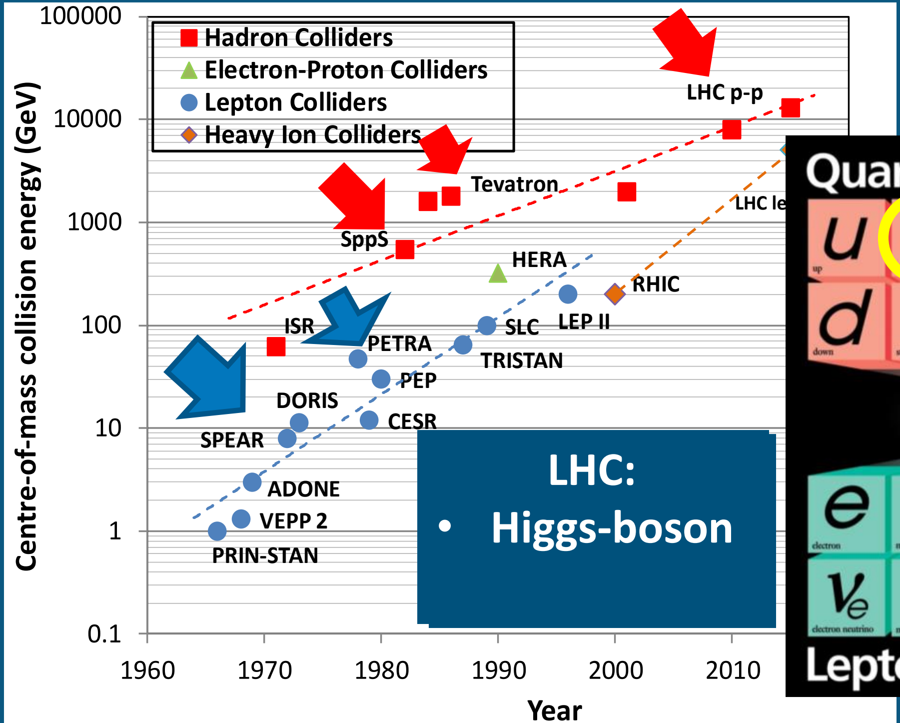
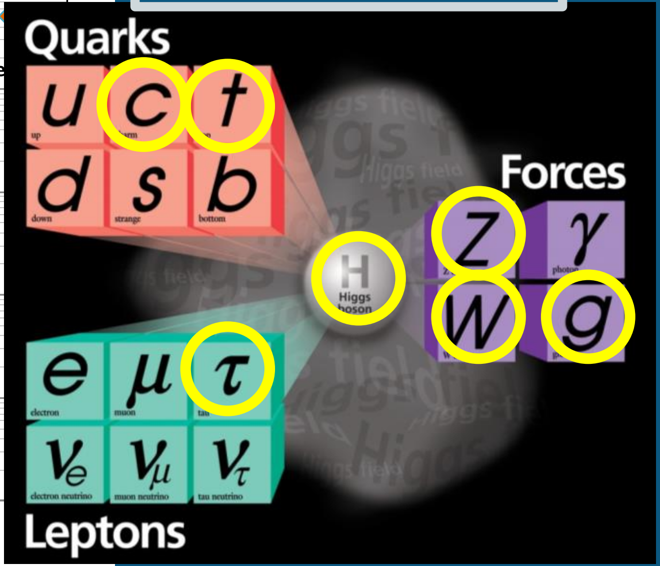
Discoveries by colliders



LHC:
- Higgs-boson

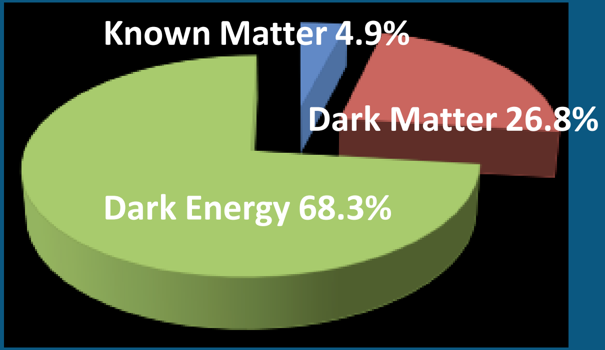
Standard Model Particles and forces

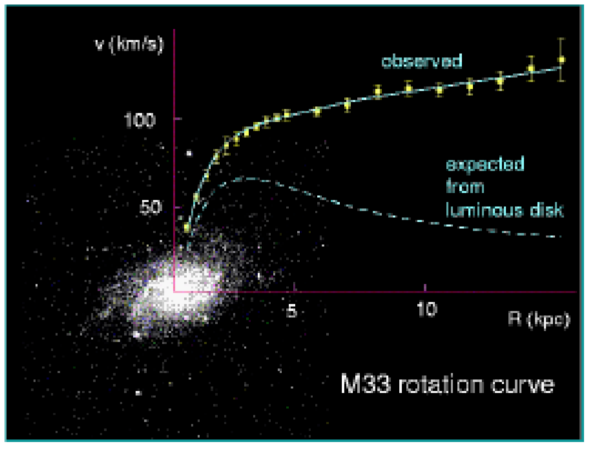


Colliders are powerful instruments in High Energy Physics for particle discoveries and precision measurements

Still many open questions

- Standard model describes known matter, i.e. 5% of the universe!



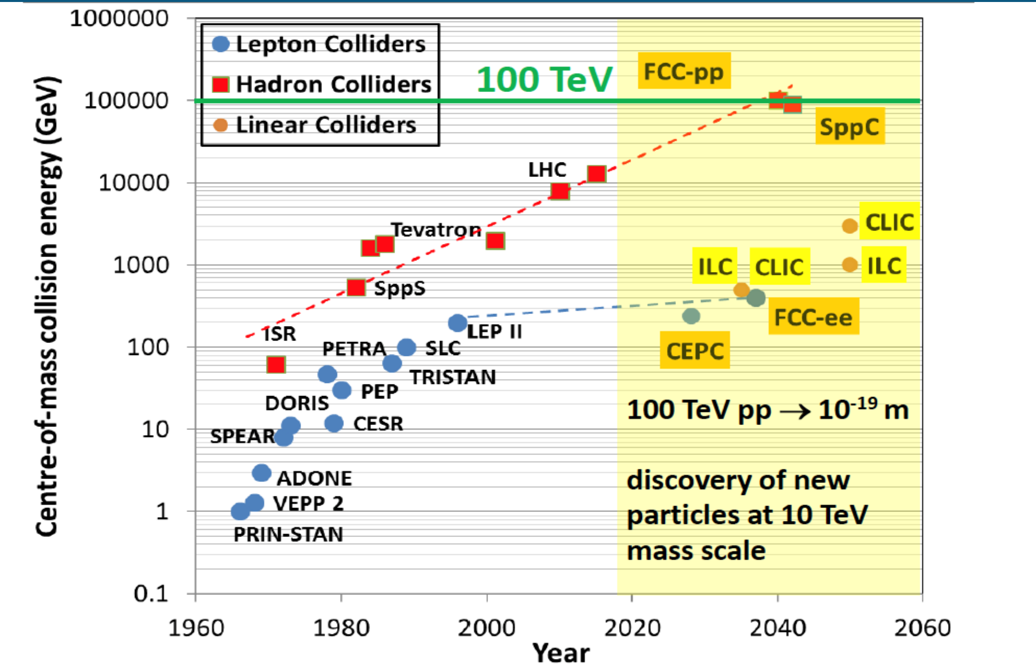


galaxy rotation curves, 1933 - Zwicky

- what is dark matter?
- what is dark energy?
- why is there more matter than antimatter?
- why do the masses differ by more than 13 orders of magnitude?
- …

The exploration continues

Particle colliders are powerful instruments in physics for discoveries and high precision measurements because they provide well controlled experimental conditions in laboratory environment



Global vision for the future of particle physics

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

"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…" -US Particle Physics Strategy (P5)

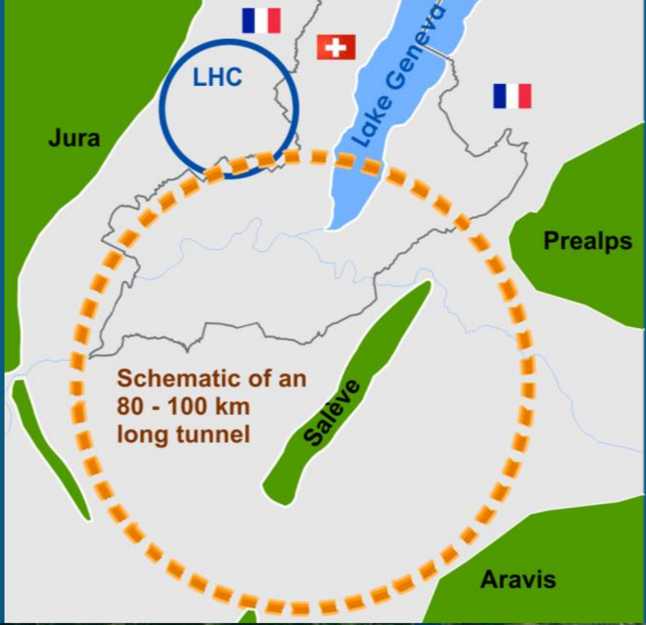
"…ICFA supports studies of energy frontier circular colliders and encourages global coordination…" -ICFA

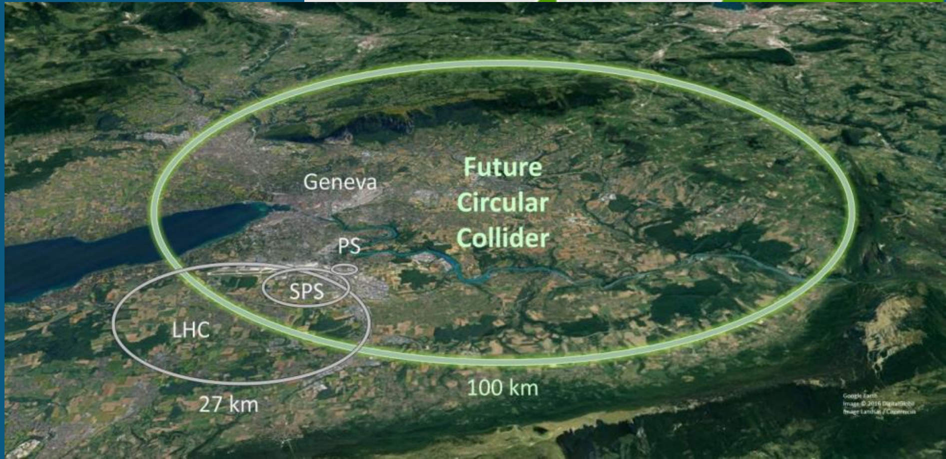
Expanding our Horizons
Future Circular Collider Study

International collaboration with CERN as host laboratory:

exploring the feasibility of several particle collider scenarios with the aim of significantly expanding the current energy and luminosity frontiers.

- Lepton collider as possible first step and 100 TeV proton collider as long-term goal
- 100 km tunnel infrastructure in Geneva area





FCC physics and design goals

FCC-ee:

- **Exploration of 10 to 100 TeV energy scale via couplings with precision measurements**
- **~20-50 fold improved precision on many EW quantities (equiv. to factor 5-7 in mass)**

  ($m_{Z,}$ m_W, m_{top} , $\sin^2 \theta_w^{eff}$, R_b , α_{QED} (m_z) α_s (m_z m_W m_τ), Higgs and top quark couplings)

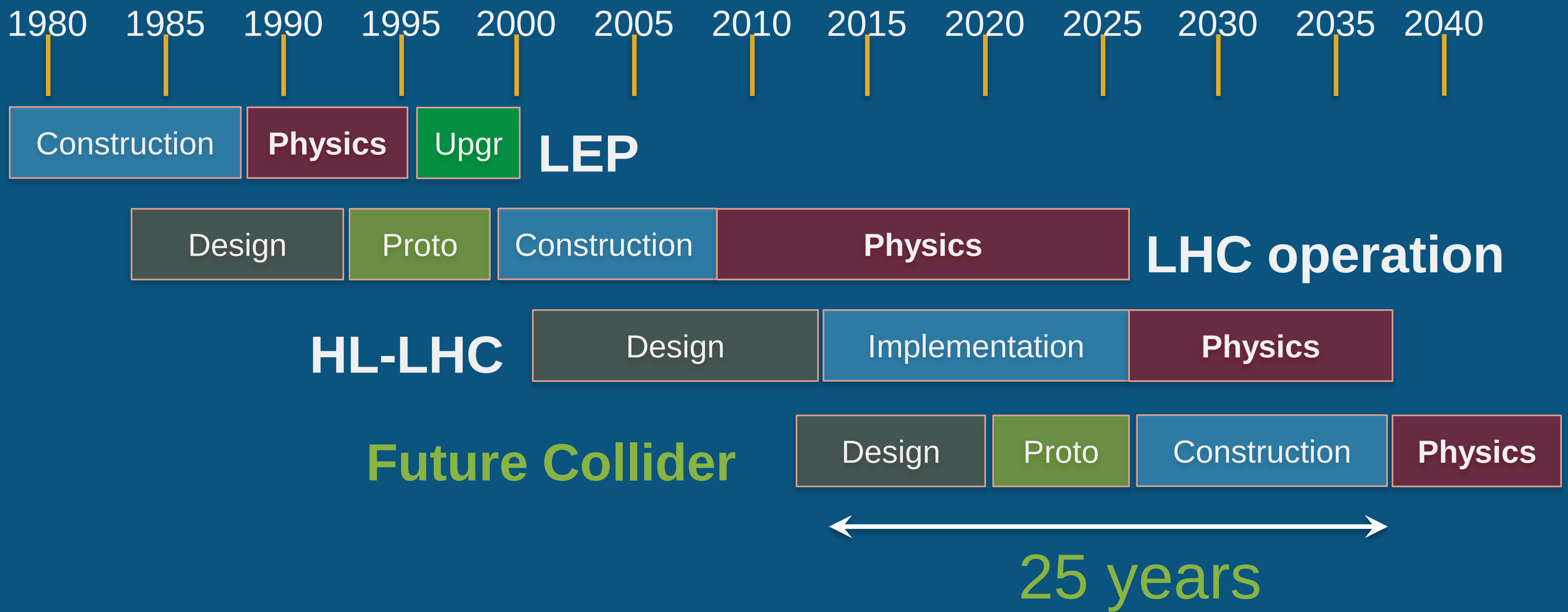
➢ **Machine design for highest possible luminosities at Z, WW, ZH and ttbar working points**

FCC-hh:

- **Highest center of mass energy for direct production up to 20 - 30 TeV**
- **Huge production rates for single and multiple production of SM bosons (H,W,Z) and quarks**

➢ **Machine design for ~100 TeV c.m. energy & integrated luminosity $\sim$ 20ab^{-1} within 25 years**

HEP Timescale



Domains covered by the FCC study:

- Designs for future colliders.

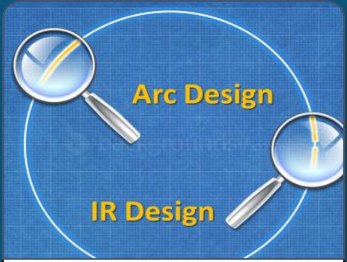
- Tunnel Infrastructure in Geneva area.

- Technologies pushed in dedicated R&D programs.

- Discovery areas.

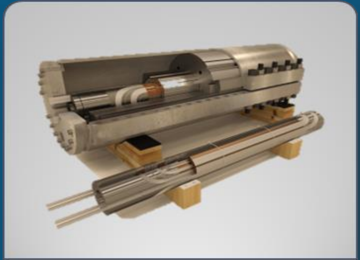
- Design of new detectors.

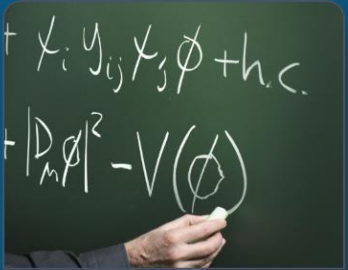
- Overall cost models.

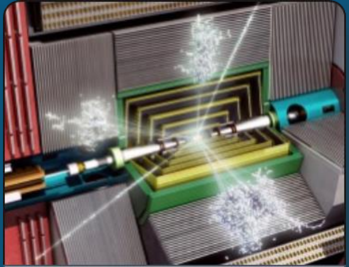


Collider Designs


Infrastructures

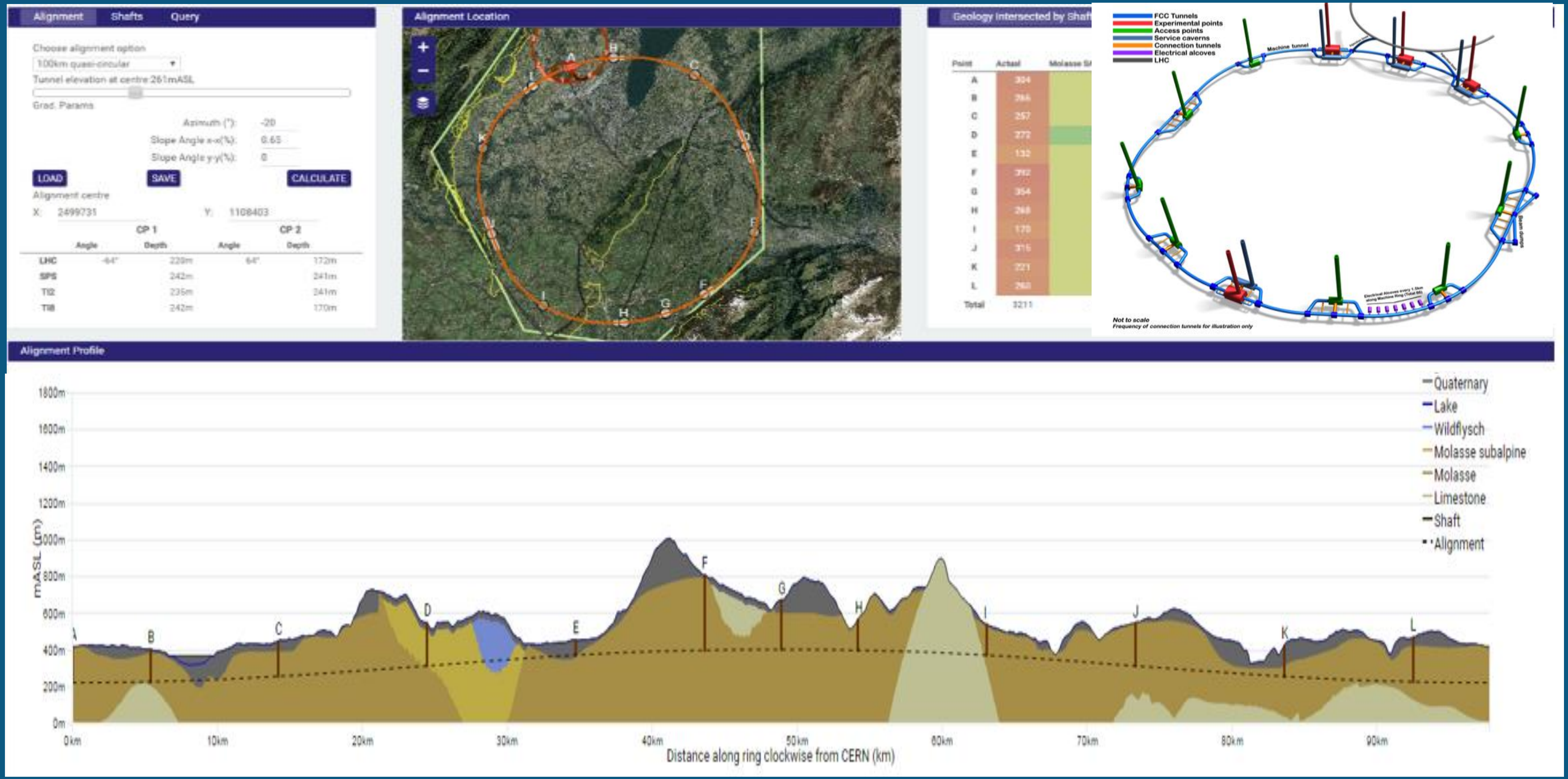

R&D Programs


Physics Cases

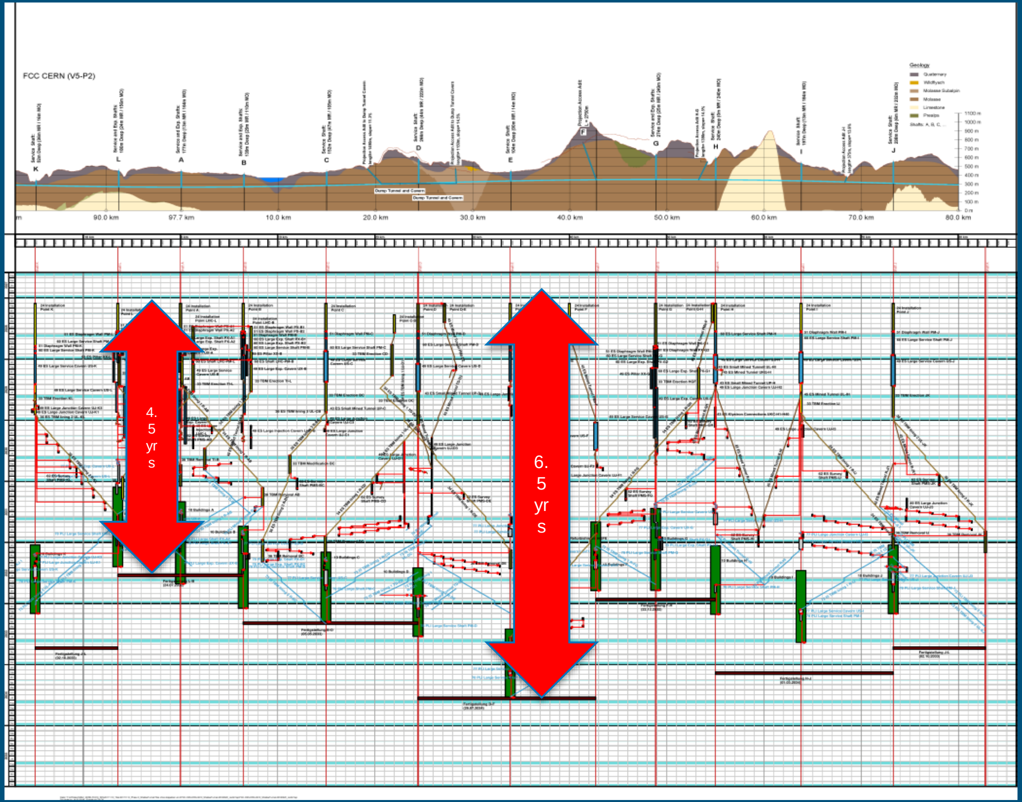

Experiments

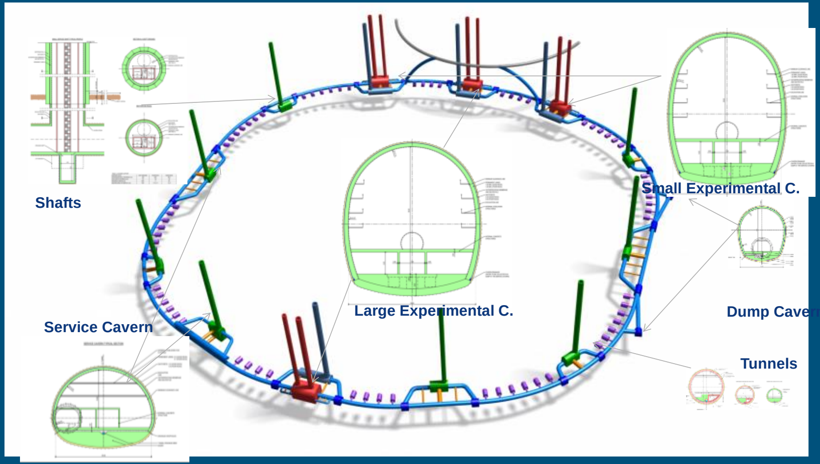
Cost Estimates

Geology and Civil Engineering studies
Implementation of the 100 km tunnel



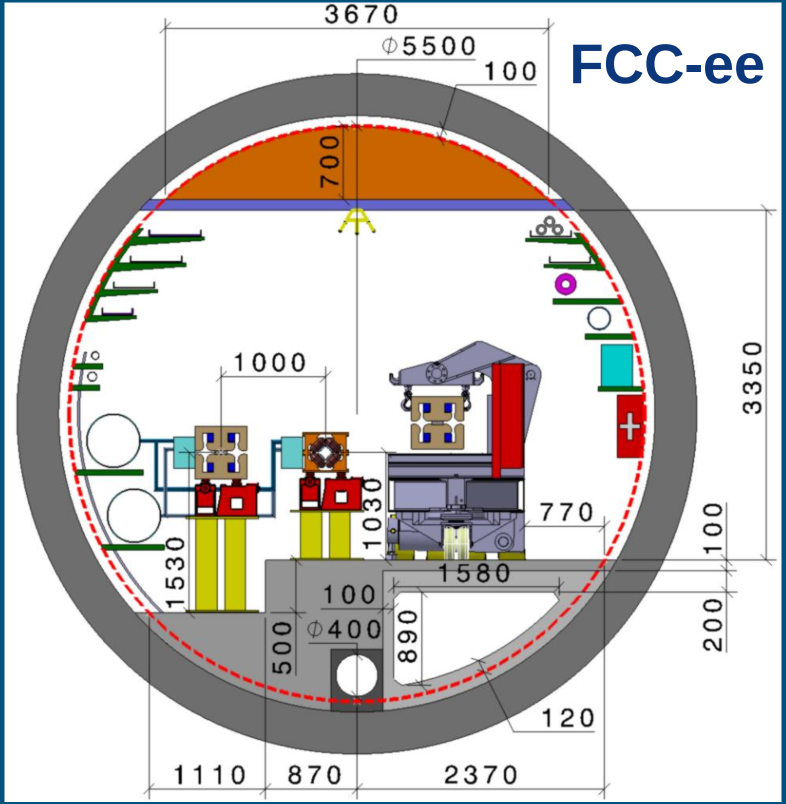
Future Circular Collider - Tunnel Layout

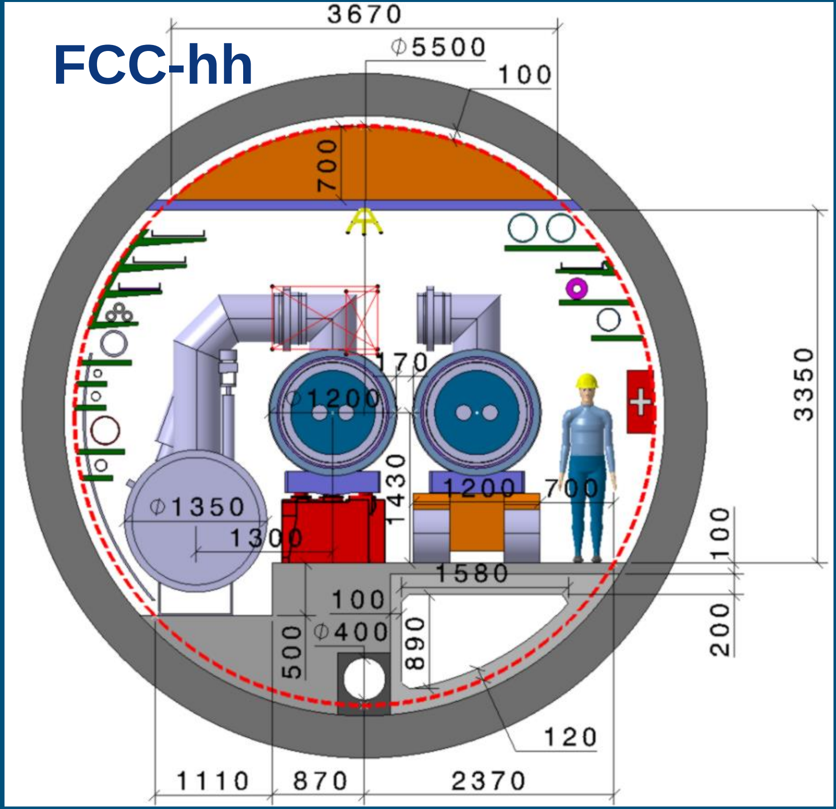




- Total construction duration 7 years
- First sectors ready after 4.5 years

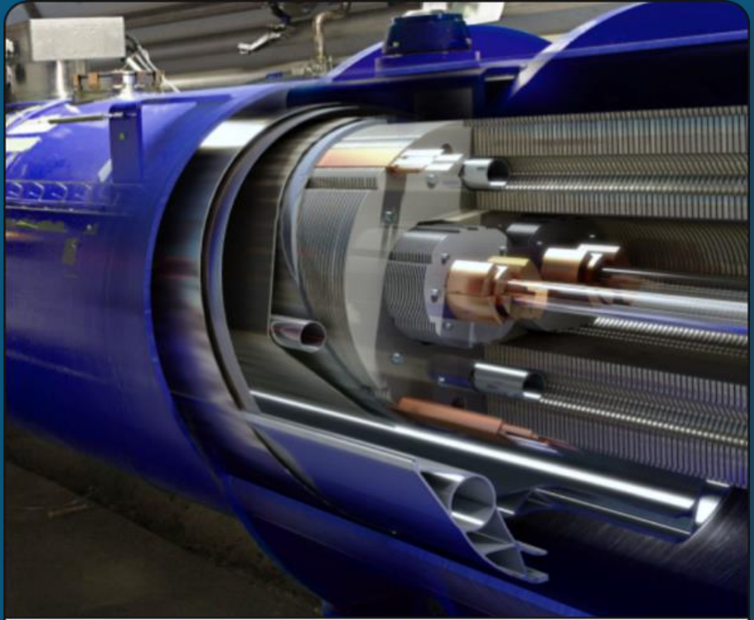
Tunnel Integration



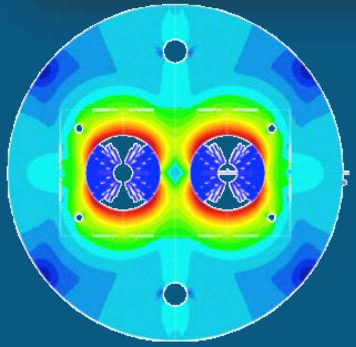


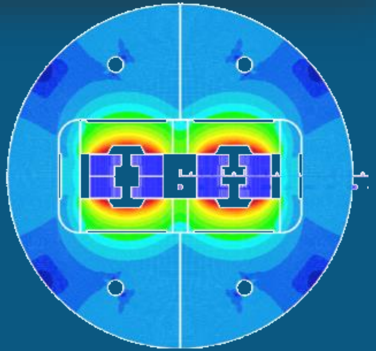
FCC high-field magnets

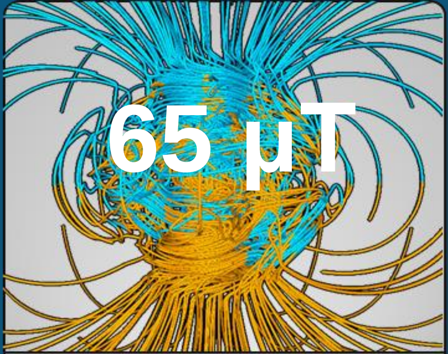
- FCC requires 16 T magnets
- Design with sufficient aperture (50 mm)
- Meet operation requirements
  - margins,
  - field quality and stability,
  - cycled operation,
  - equipment protection,
  - reliability and maintenance



Cut through accelerator magnet





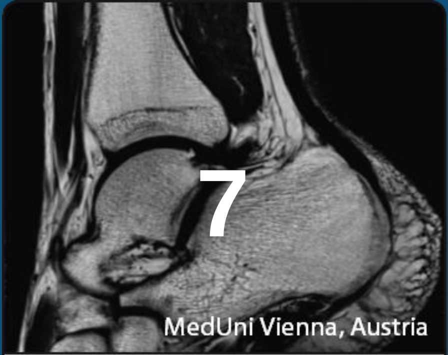


Earth Magnetic Field

Magnetic Button

Iron Magnet

M R I

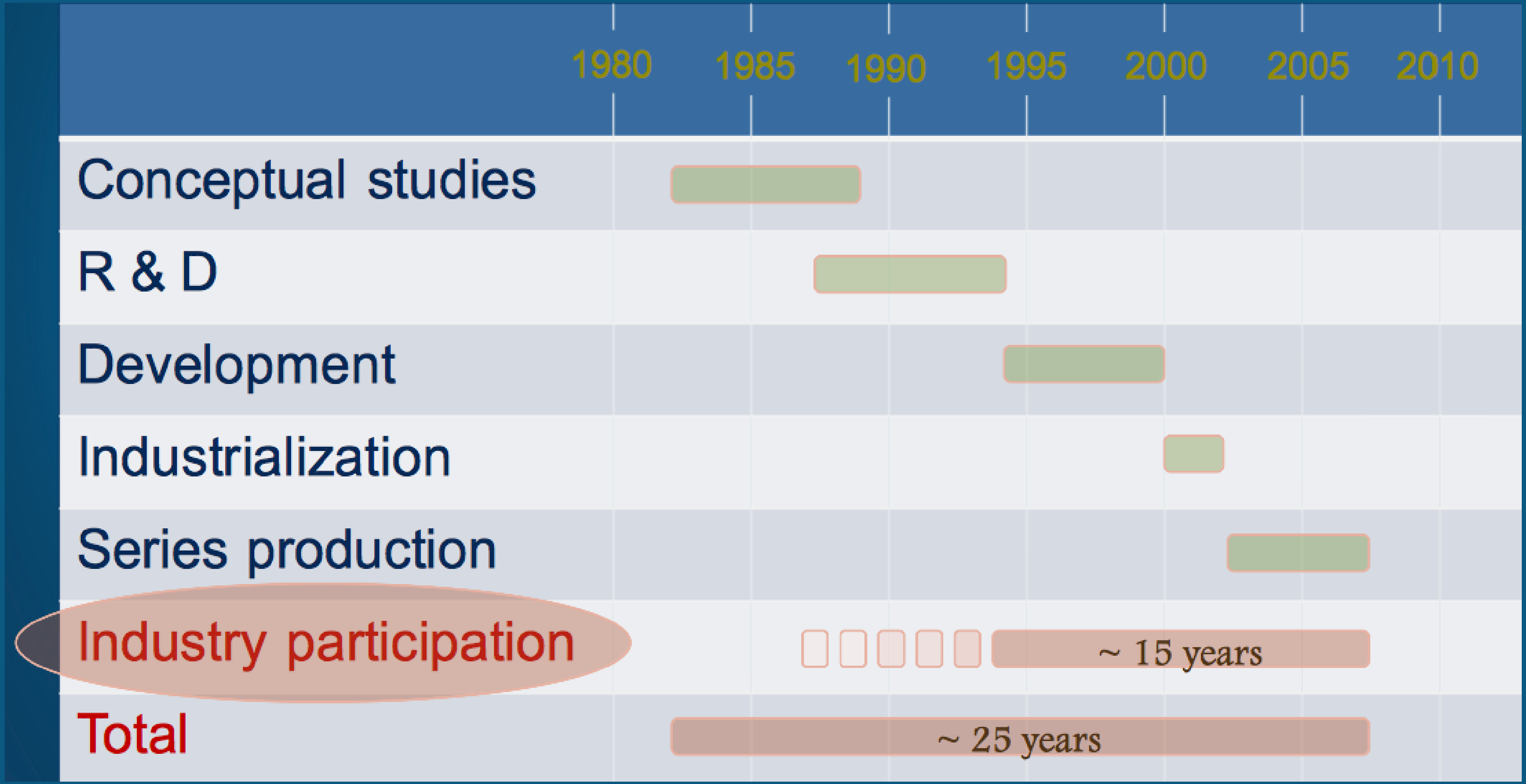


Ultra high-field MRI

LHC Dipole Magnet

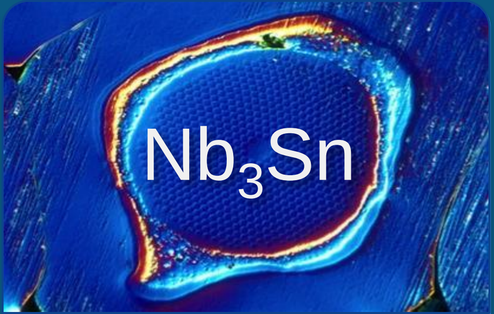
Time indicator superconducting magnets

LHC magnets – from concept to series production



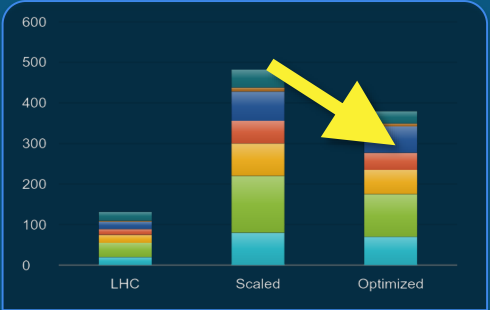
Push Novel Technologies

High-field Magnets



Novel Materials and Processes

Large-scale Cryogenics



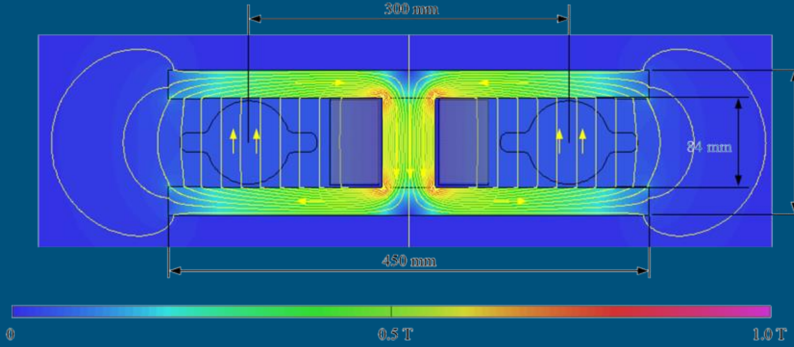
Power Efficiency

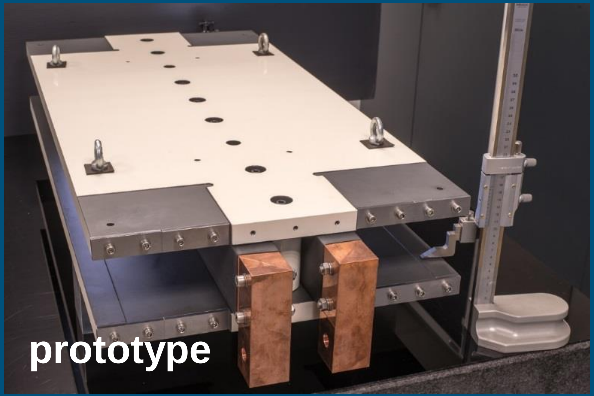
Reliability & Availability

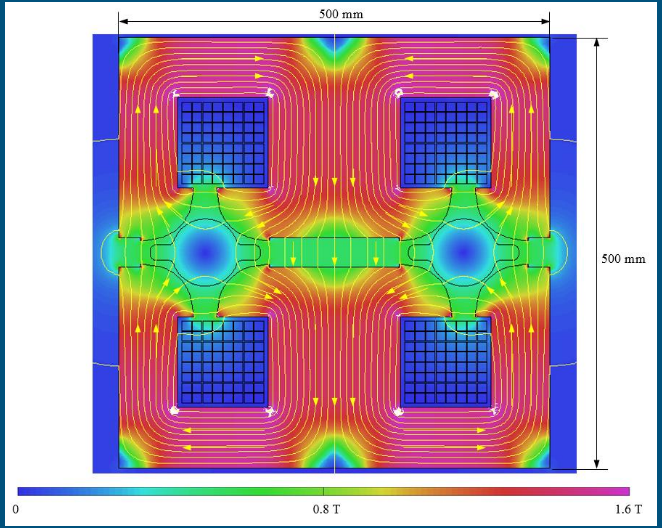
Global Scale Computing

Lepton collider prototype magnets

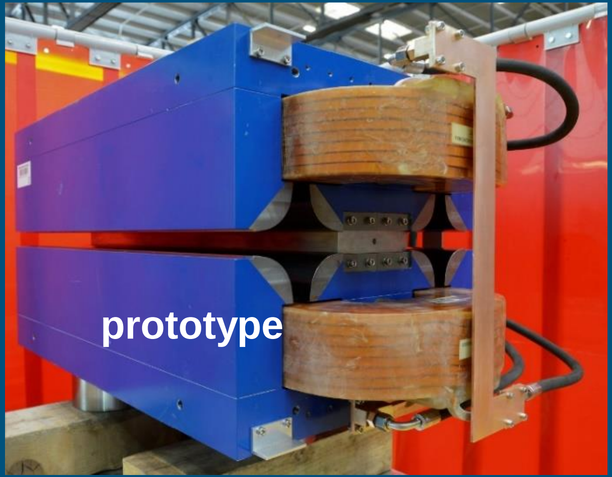
Twin-dipole design with 2× power saving
16 MW (at 175 GeV), with Al busbars





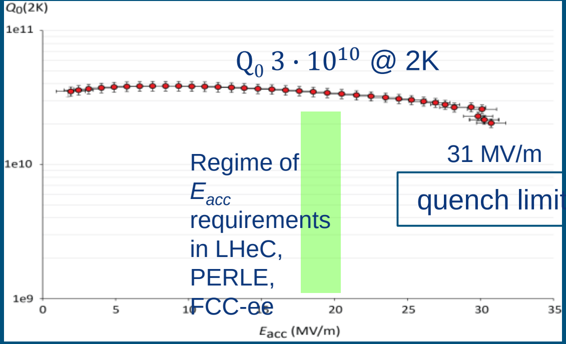


Twin F/D arc quad design with 2× power saving
25 MW (at 175 GeV), with Cu conductor

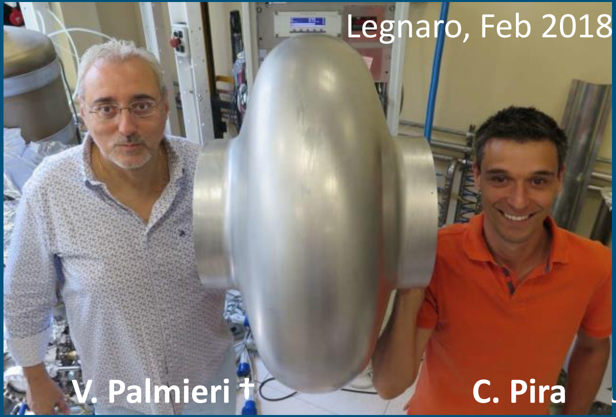


Radiofrequency system prototyping

5-cell 800 MHz cavity, JLAB prototype for both FCC-ee (t-tbar) & FCC-eh ERL (PERLE)



Seamless 400 MHz single-cell cavity formed by spinning at INFN-LNL



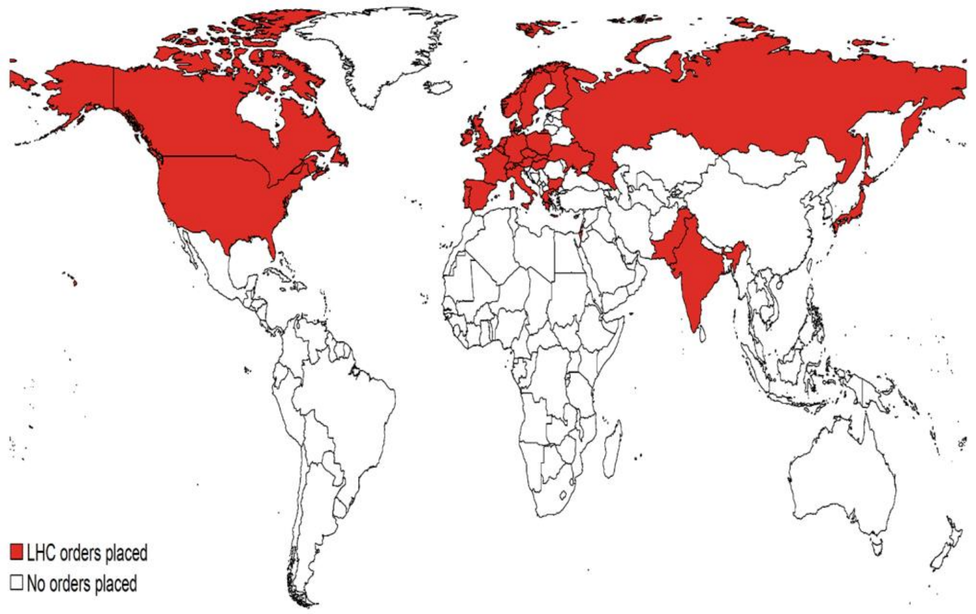
20 mA, 802 MH

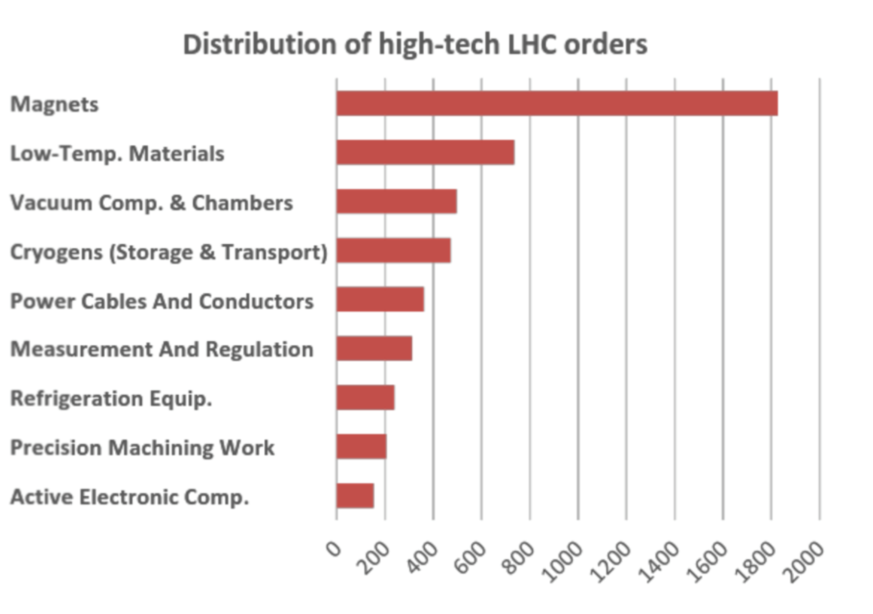
Tooling fabricated and successfully tested with an Aluminium cavity.

CERN half-cells formed using Electro-Hydro-Forming (EHF) at Bmax.

High strain rate technology using shockwaves in water from HV discharge.
EHF investigated for half-cells and seamless Nb and Cu cavities.

Approx. 1400 firms located in 30 countries have collaborated with CERN for the LHC project during 1995-2008





FCC international collaboration status

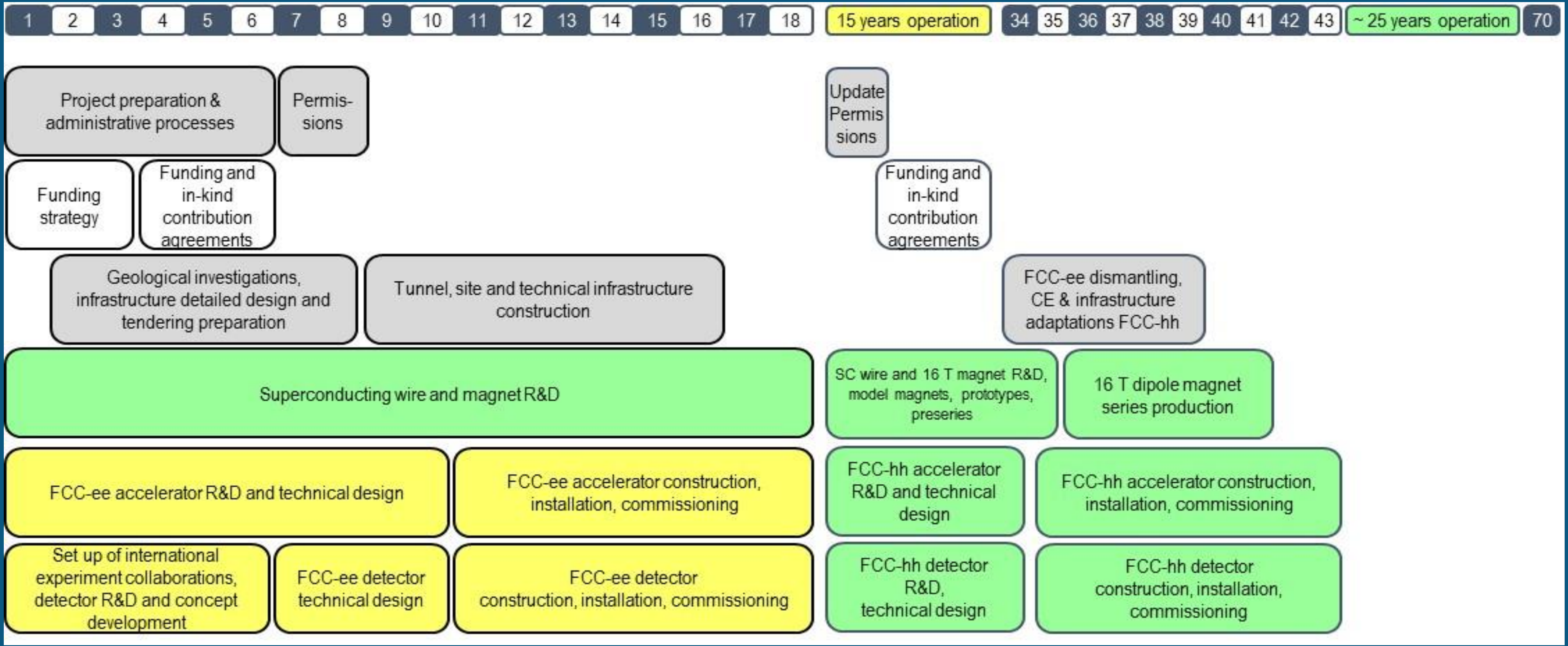
- 133 research centers & universities
- European Commission
- 32 countries
- 25 companies

- Geographically balanced
- Topically complementary
- Promote ownership among Participants

FCC conceptual design report & documentation

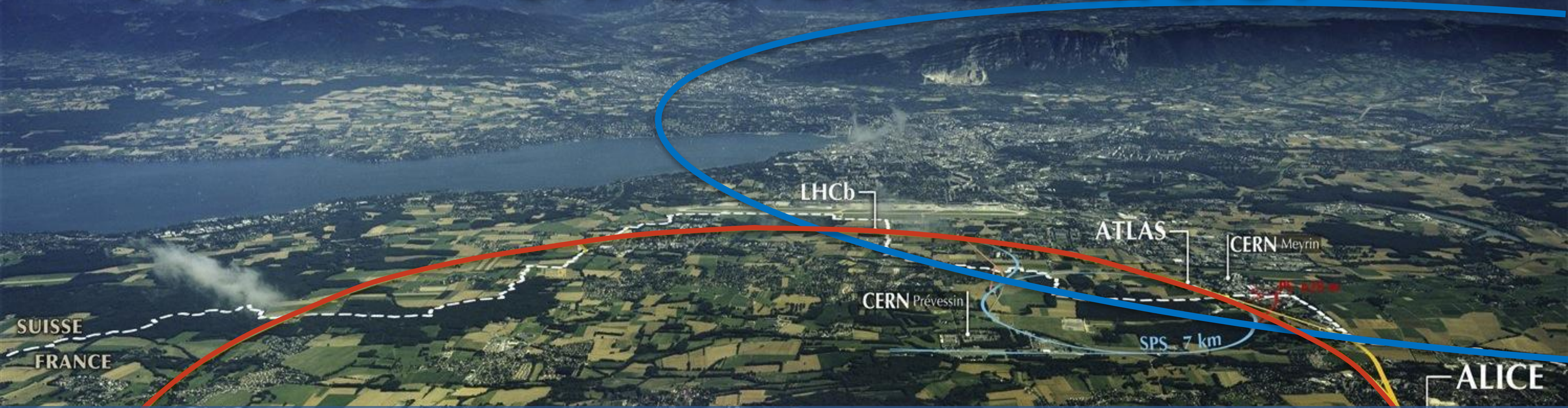
- FCC-Conceptual Design Reports:
- Vol 1 – Physics,   Vol 2 – FCC-ee,   Vol 3 – FCC-hh,   Vol 4 – HE-LHC
- Preprints available since 15 January 2019 on http://fcc-cdr.web.cern.ch/
- CDRs accepted for publication in the **European Physical Journal**
- Summary documents submitted to EPPSU SG in December 2018
- FCC-integral, FCC-ee, FCC-hh, HE-LHC accessible on http://fcc-cdr.web.cern.ch/

FCC integrated project – technical timeline



A coherent HEP program throughout the 21st century

Future Circular Collider



Developing a largest scale research and technical infrastructure

Strengthen long-term attractiveness of Europe as world leading high-energy physics research location

Driven by international contributions and aiming at long-term liaisons for high-tech R&D with industry.

Final thoughts

We are at an important moment in the history of particle physics. The highest priority is to gain an in-depth understanding of the Higgs particle. It is considered the portal to explore the open questions of modern physics such as the origin of dark matter, matter-antimatter asymmetry, neutrino masses and others.

To continue exploring, the next facility must be versatile and powerful.
Future colliders must offer: More Sensitivity, More Precision, More Energy.

CERN is best placed for such a challenging enterprise, given its demonstrated success in delivering international projects and the existing infrastructure.

FCC attracts a diverse community of scientists, engineers and partners from industry, going beyond geographical and cultural boundaries, who collaborate to address these fundamental questions.