Presentation of CERN Projects

(Magnets, Superconductors and Materials)

Mike Lamont
on behalf of the Accelerators and Technology Sector

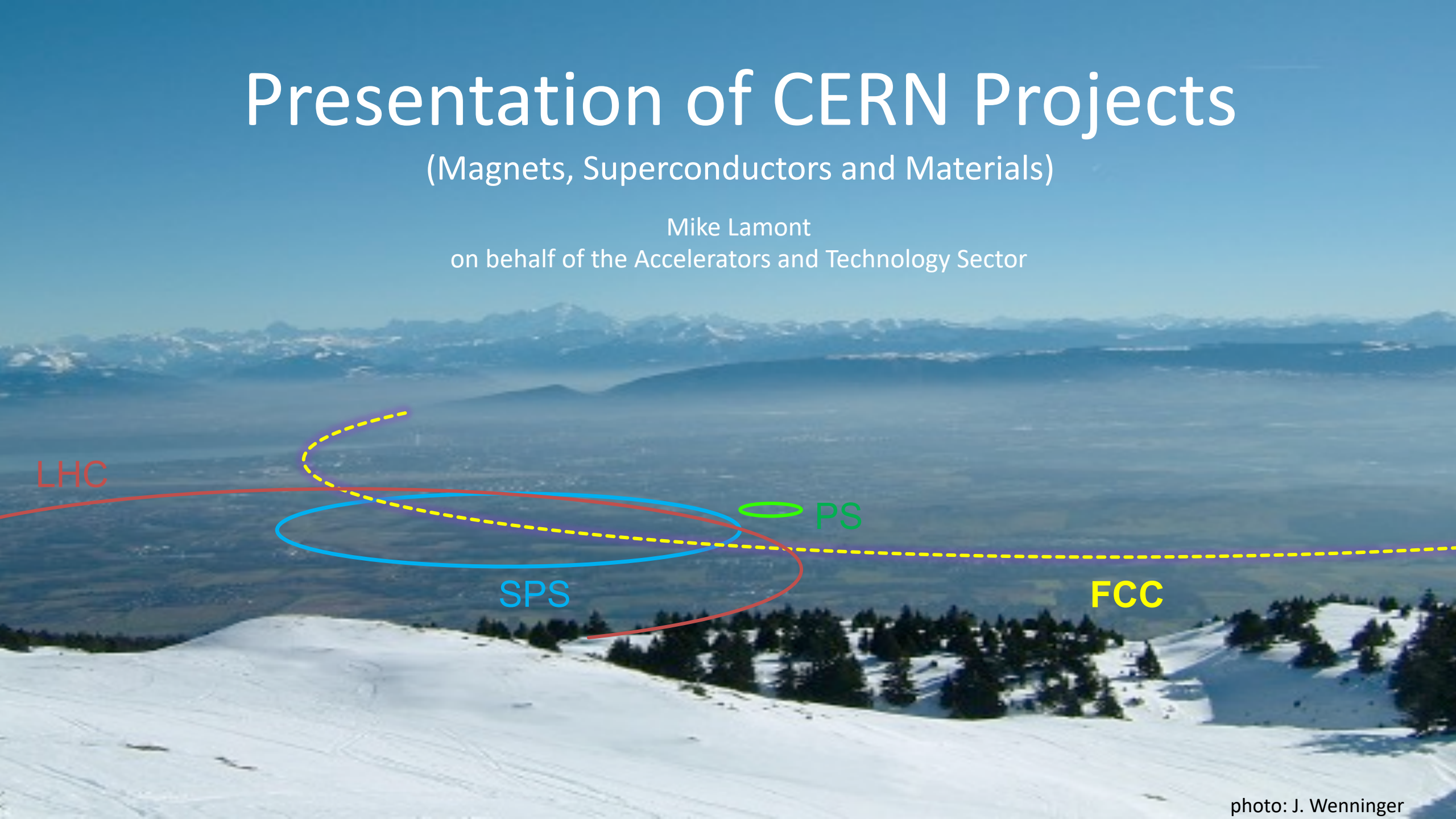
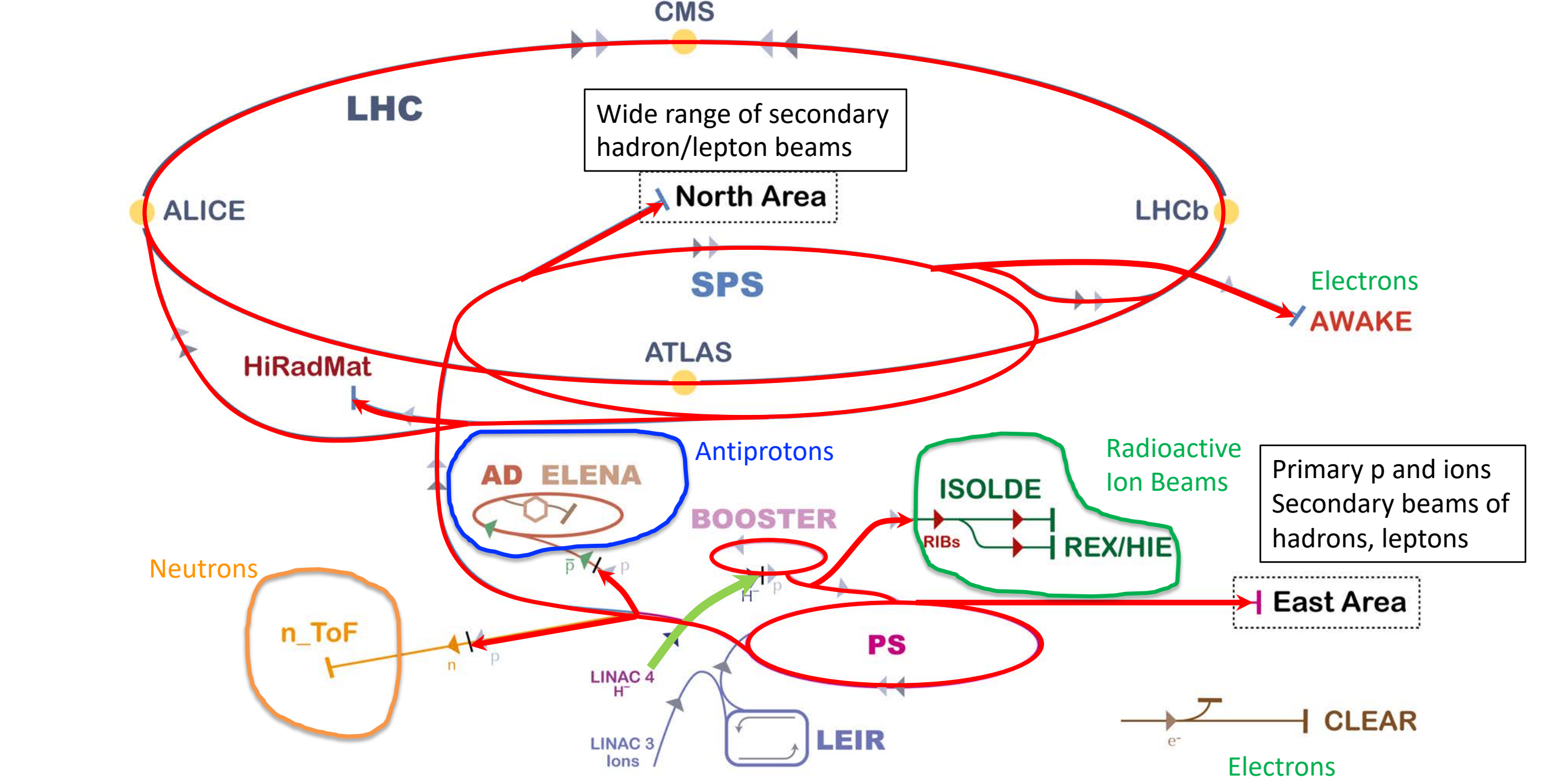


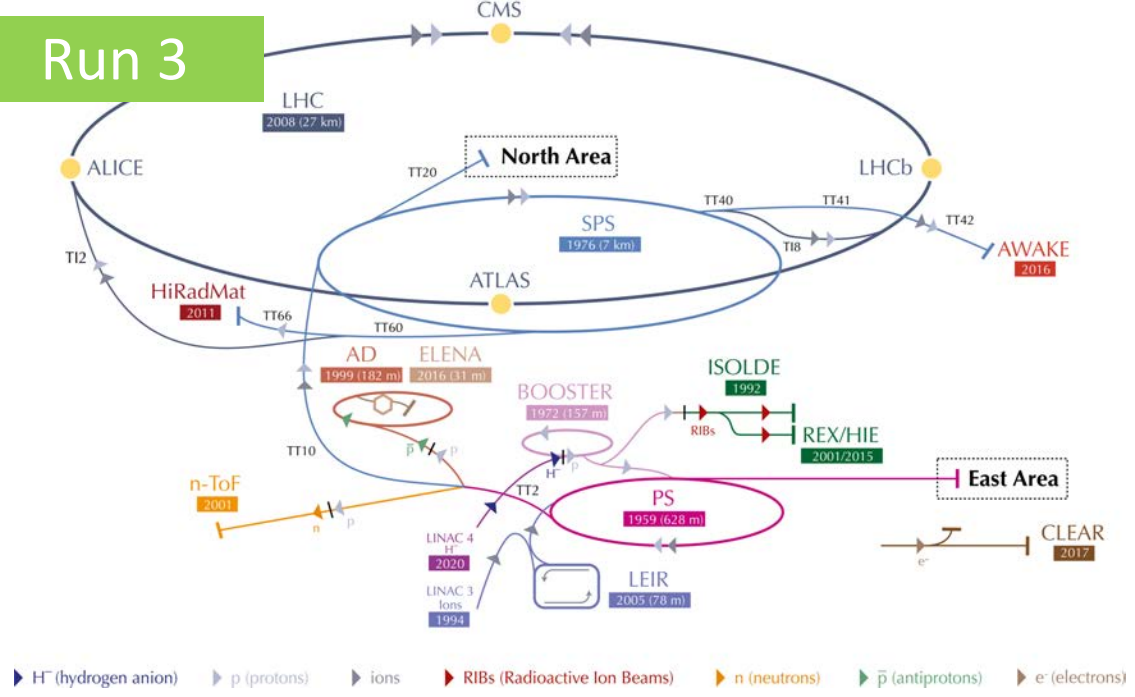
photo: J. Wenninger


CMS
LHC
Wide range of secondary hadron/lepton beams
North Area
ALICE
LHCb
SPS
Electrons
AWAKE
ATLAS
HiRadMat
Antiprotons
AD ELENA
Radioactive Ion Beams
ISOLDE
BOOSTER
Primary p and ions
Secondary beams of hadrons, leptons
RIBs
REX/HIE
Neutrons
East Area
n_ToF
PS
LINAC 4
H⁻
LINAC 3
Ions
LEIR
CLEAR
Electrons
H⁻ (hydrogen anion)
p (protons)
ions
RIBs (Radioactive Ion Beams)
n (neutrons)
p̄ (antiprotons)
e⁻ (electrons)

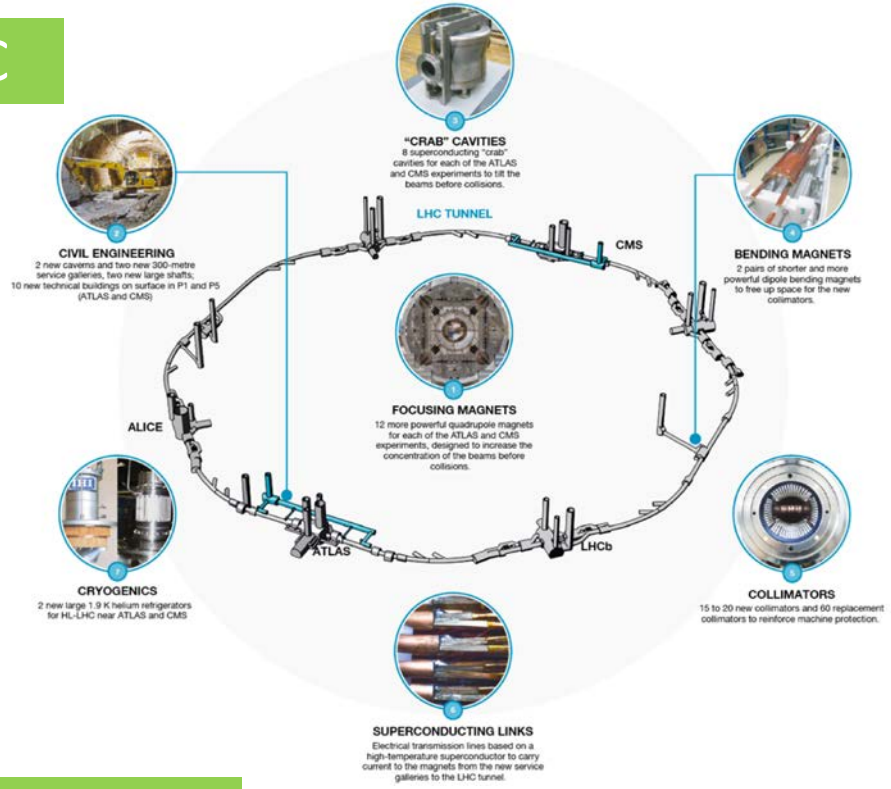
CERN's scientific priorities

- Exploitation
  - LHC
  - High Luminosity LHC (HL-LHC)
  - Potential of the injector complex
- Secure the future
  - bold new energy frontier machine backed by accelerator R&D
- Diversify
  - novel applications of complex and technology

Run 3



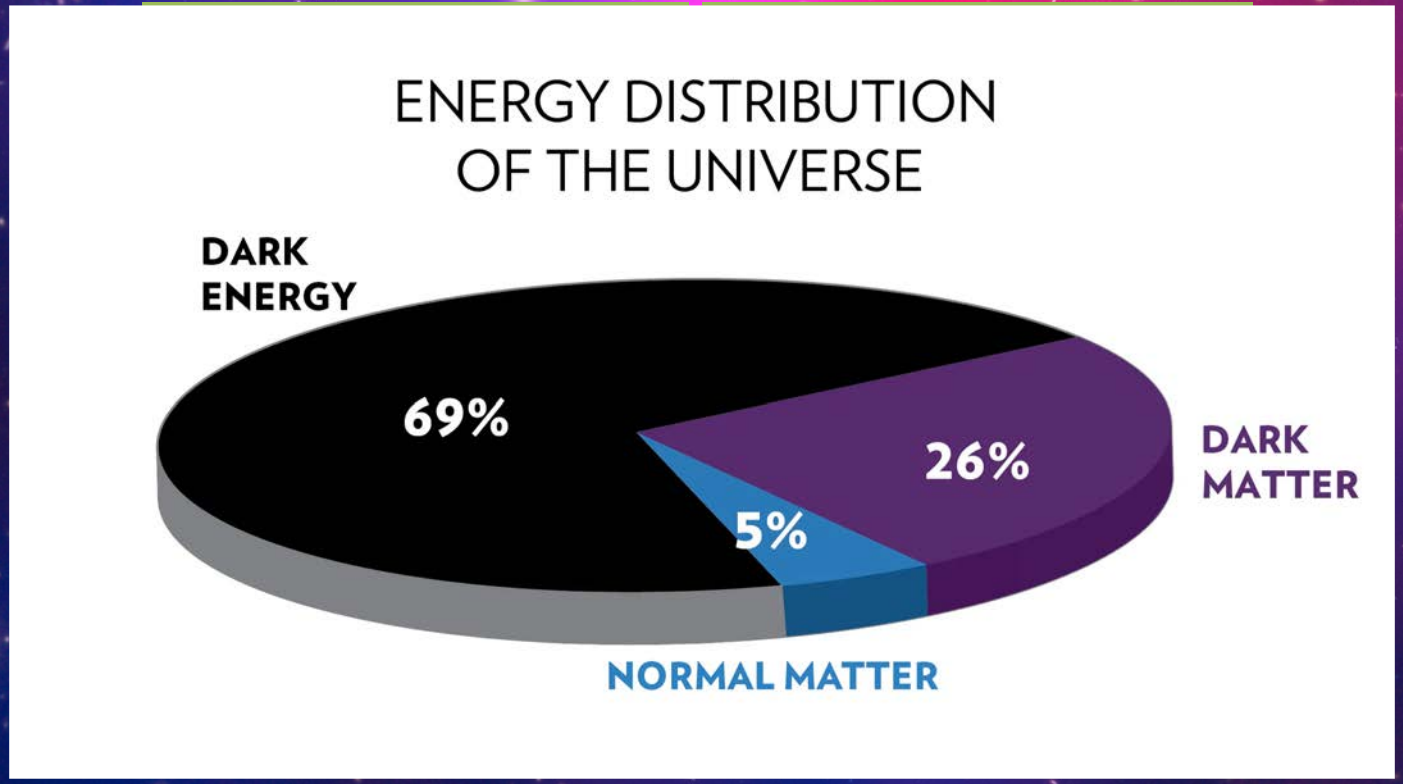
HL-LHC

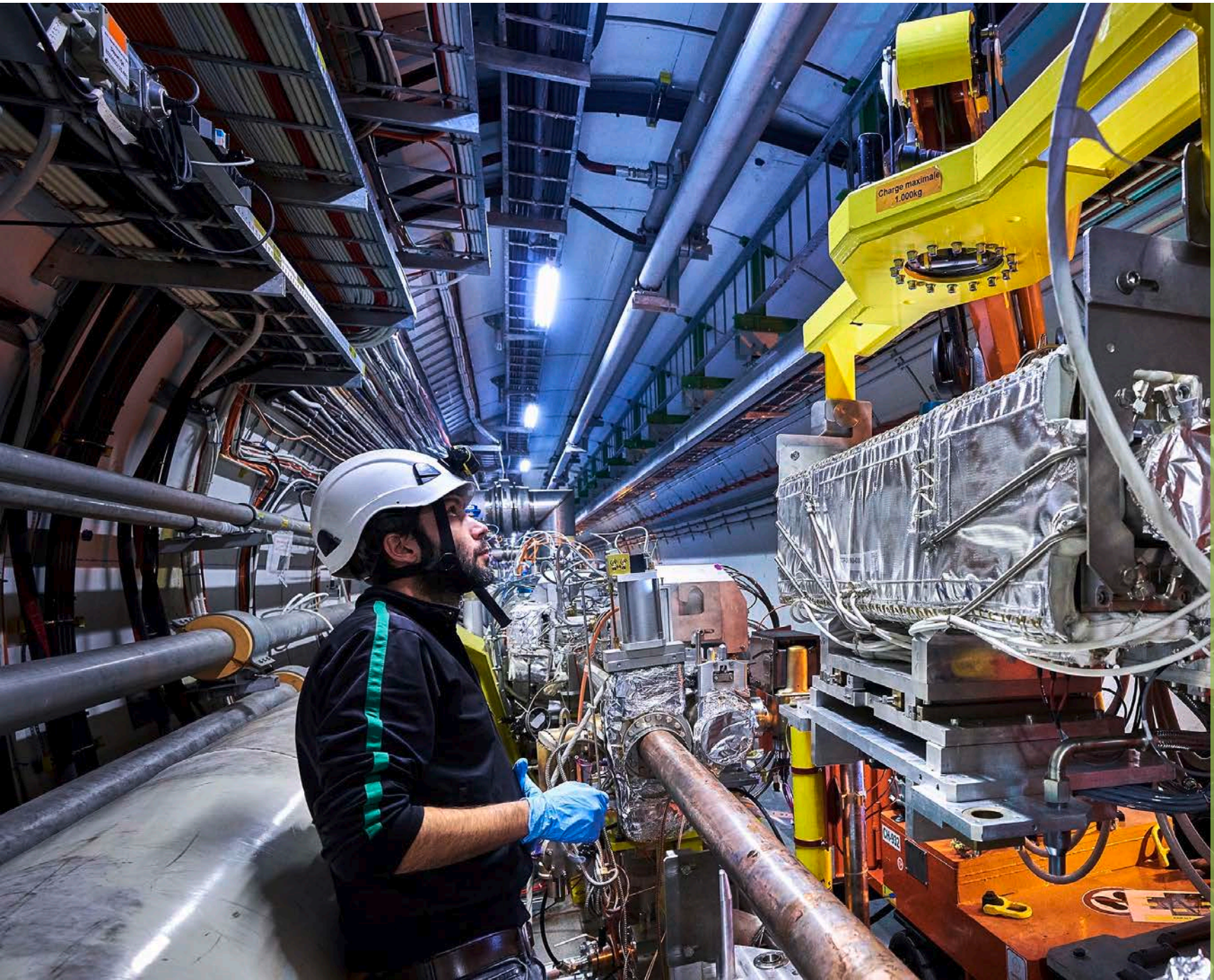


Future Options

Technology/R&D

Interesting times for fundamental physics

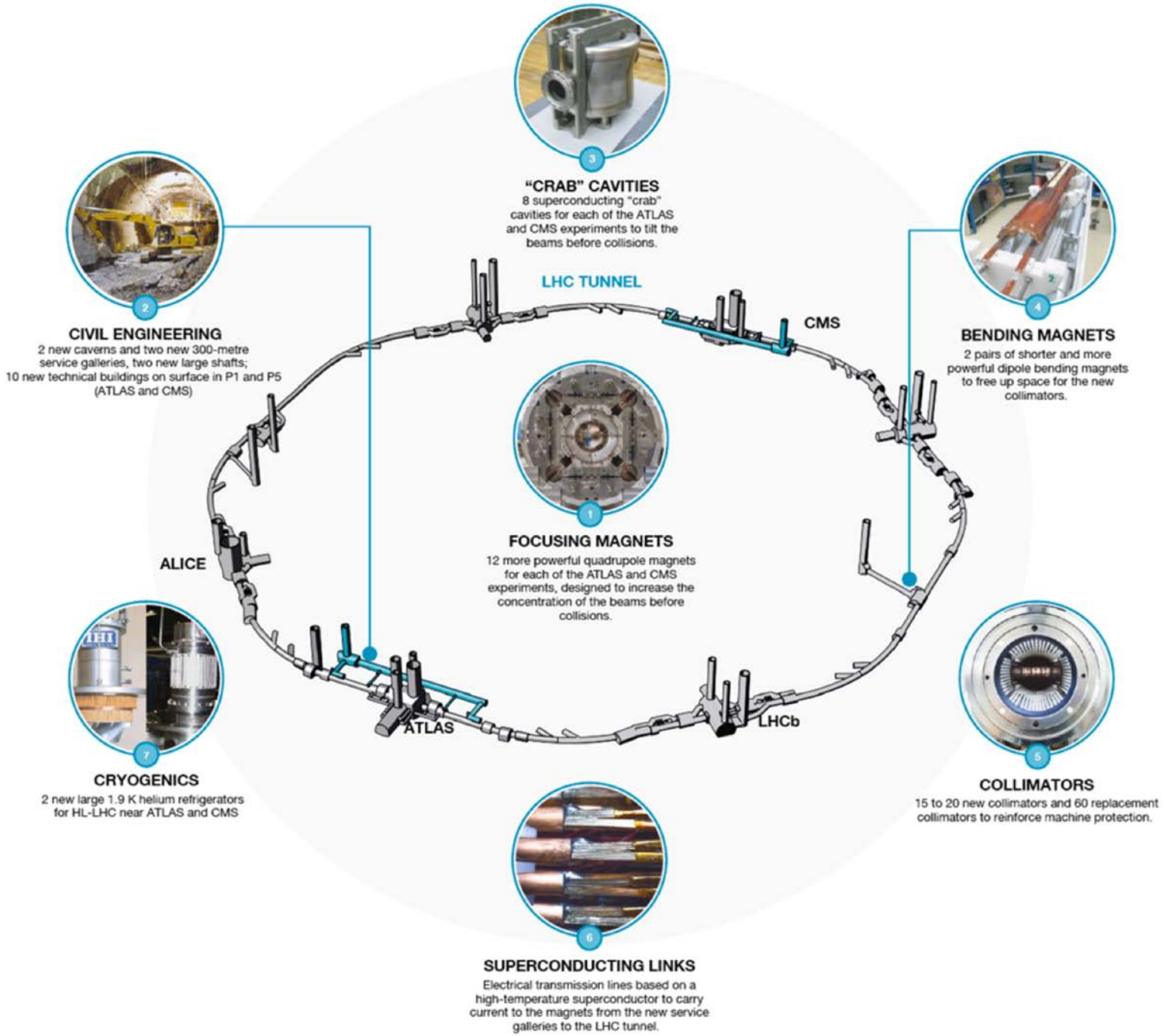




Upgrade to the High-Luminosity LHC is under way

- The HL-LHC will use new technologies to provide 10 times more collisions than the LHC.
- It will give access to rare phenomena, greater precision and discovery potential.
- Deployment 2025 - 2027
- It will start operating in 2027 and run until ~2040.

HL-LHC



Superconducting bulk niobium RF "crab" cavities*

High-field niobium-tin (Nb_3Sn) superconducting magnets

Robust materials for machine protection

High temperature superconducting links

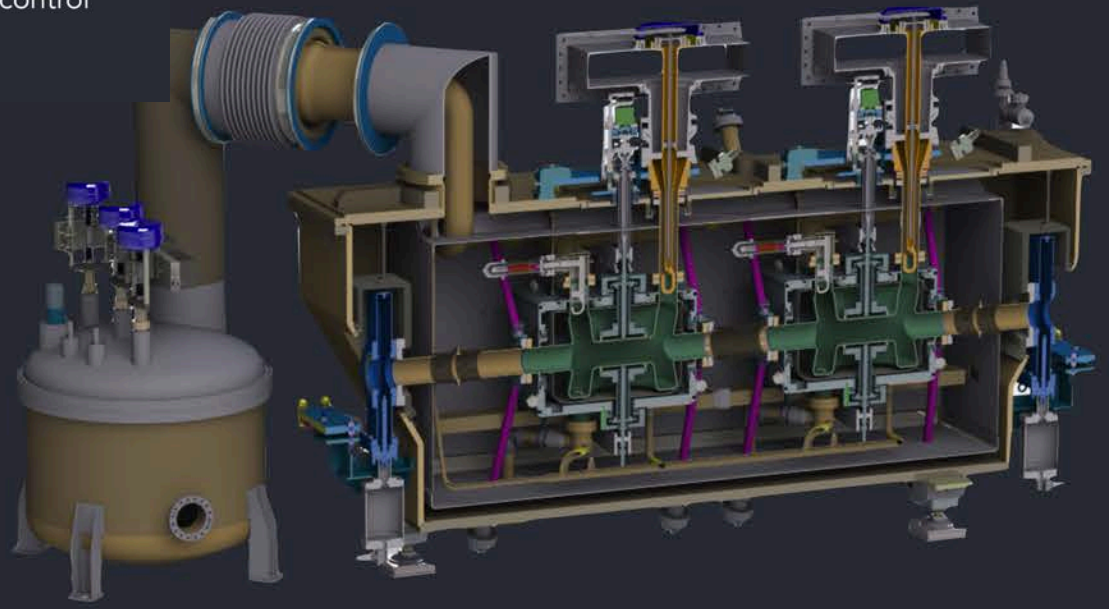
*RI Research Instruments

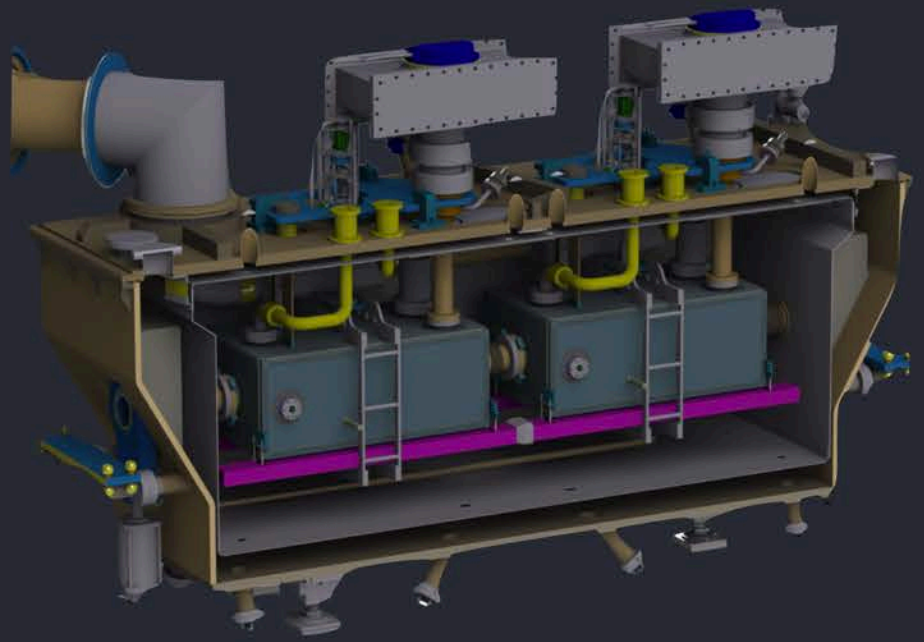
2 types of Crab cavities

- Bulk 400 MHz Nb crab cavities & their cryomodules
- Power couplers, HOM couplers, cavity control
- Low trip rate mandatory!
- Industrialisation for small series

Double Quarter Wave

- Vertical crossing for Atlas
- SPS test in 2018





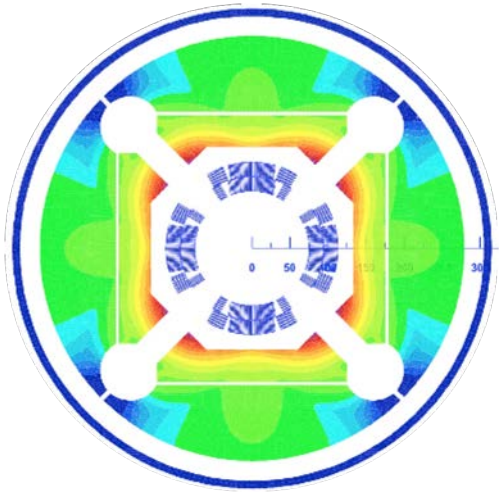
RF Dipole

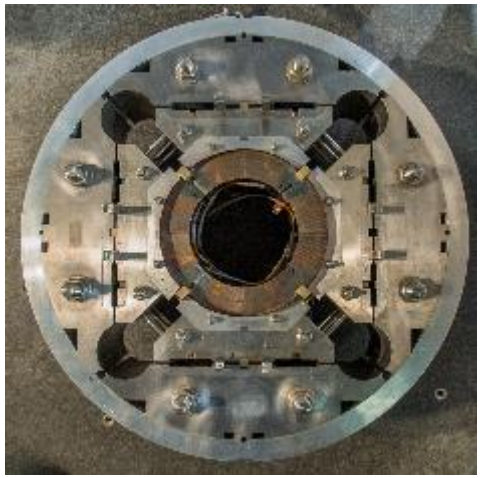
- Horizontal crossing for CMS
- SPS test in 2021

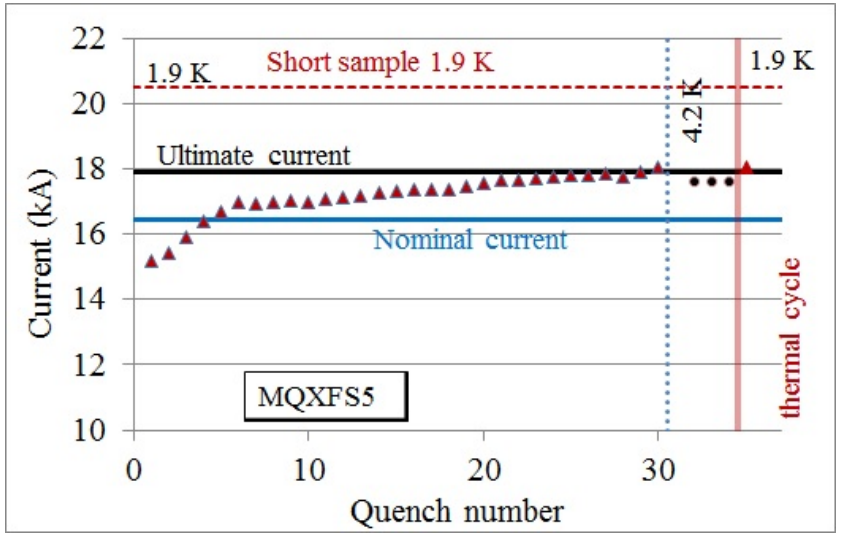
HL-LHC quadrupole R&D

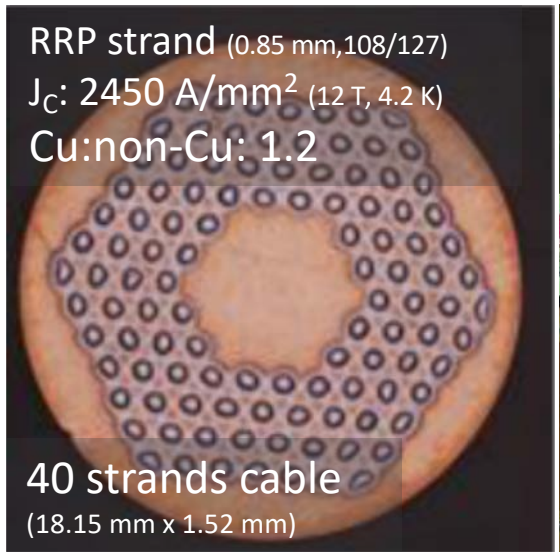
R&D programme started in 2000

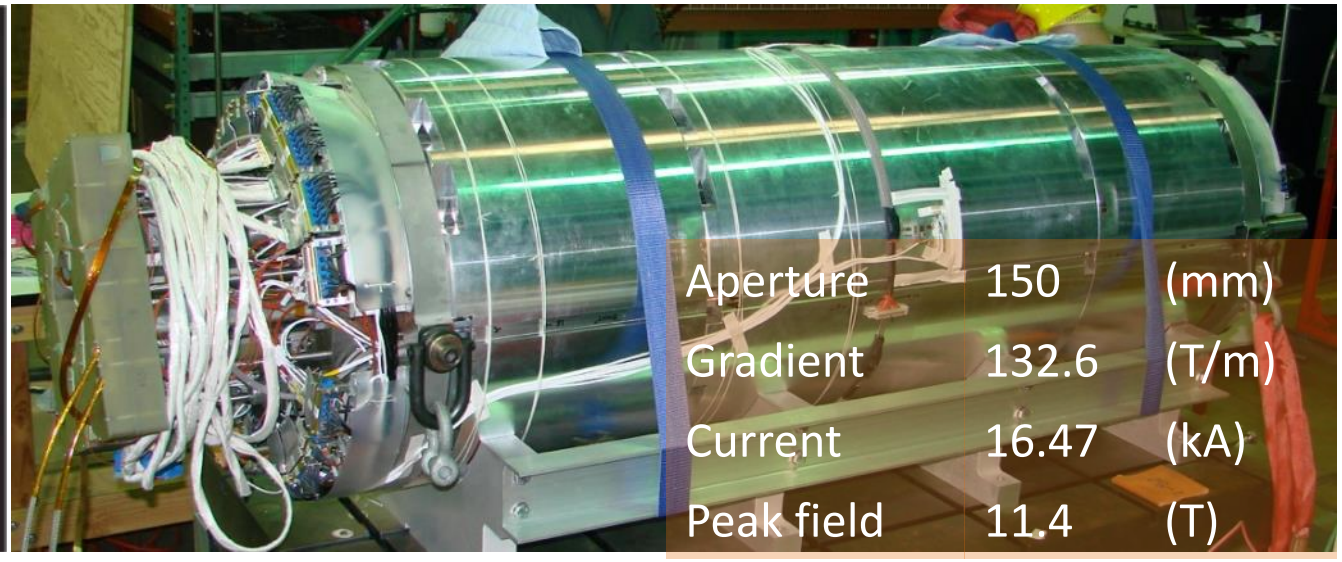
4.2 m 7.15 m

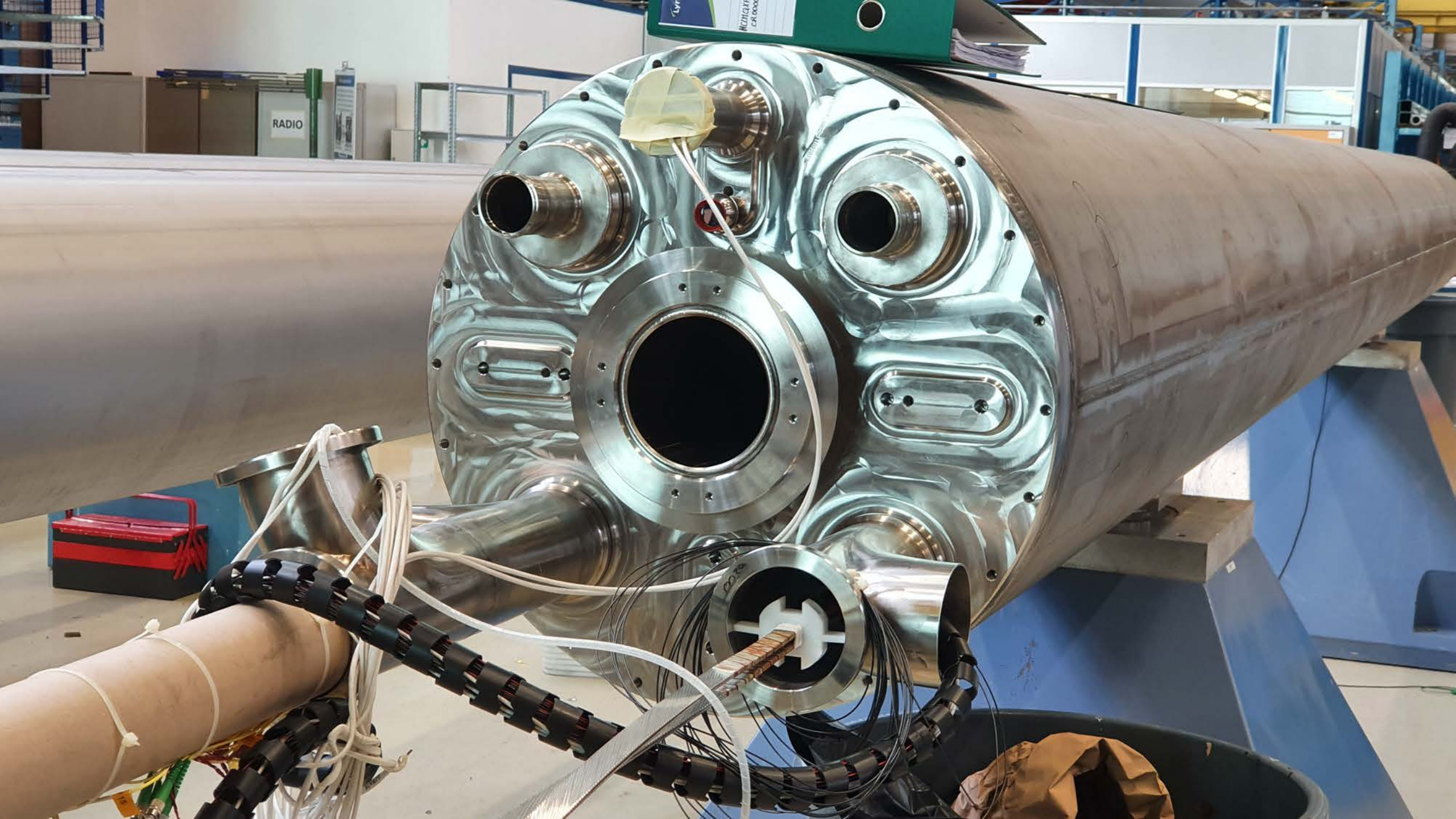






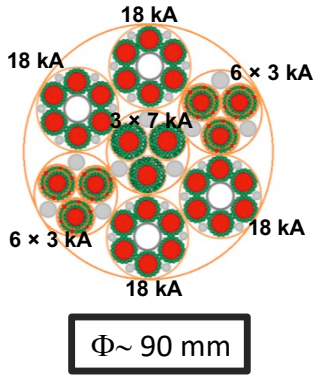


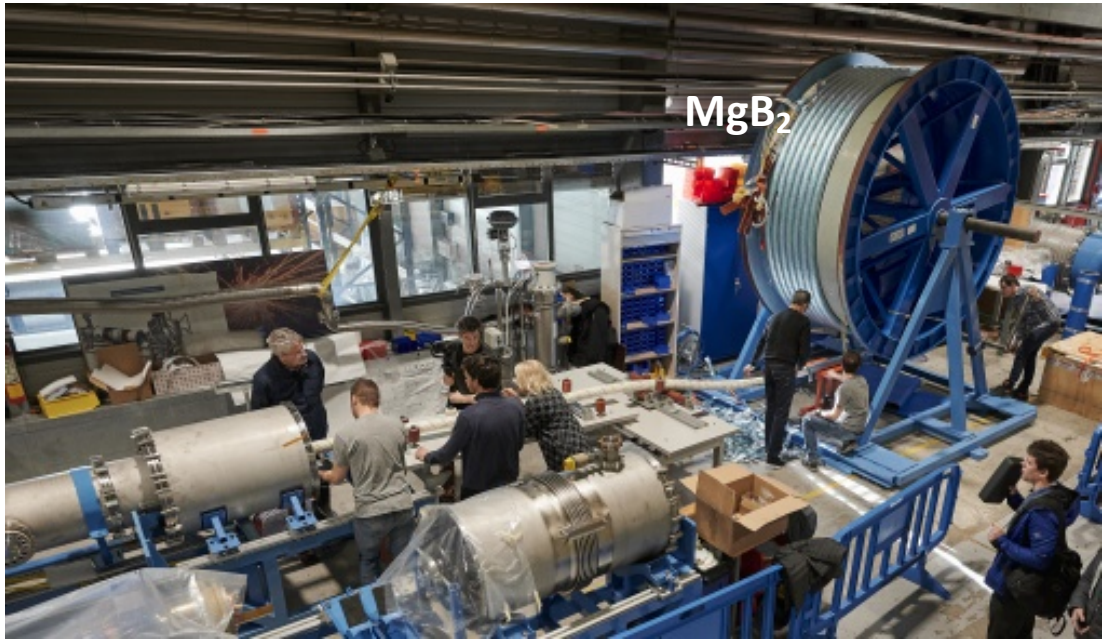


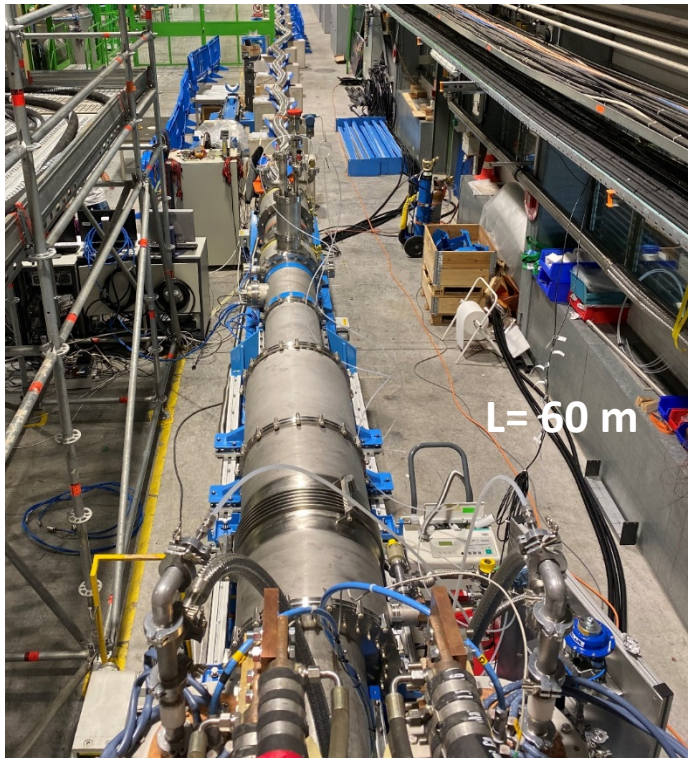

RADIO

HL-LHC: superconducting link

MgB_2 cable:
$\Phi \sim 90$ mm
$|Itot| > 100$ kA @ 25 K







System demonstrator at CERN - DEMO2

Demonstration of:
2 x 20 kA + 2 x 7 kA
[54 kA total]

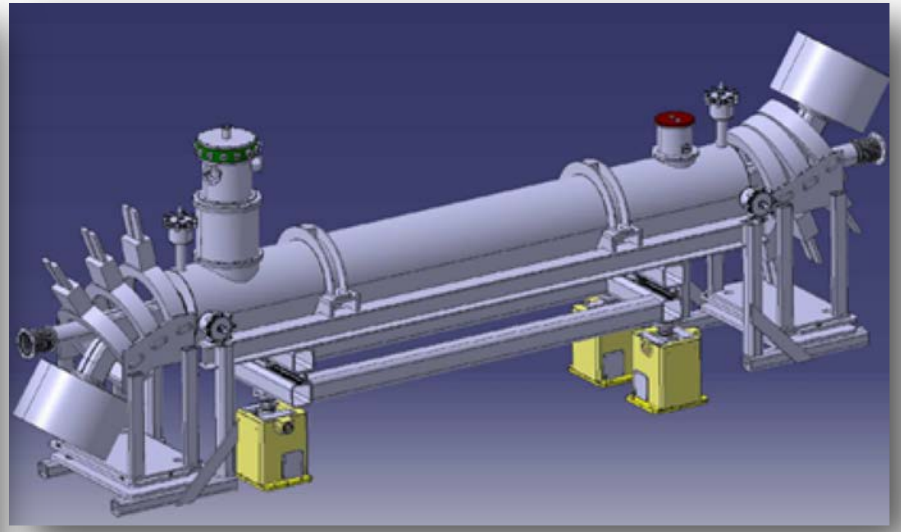
MgB_2 @ 30K in flexible cryostat over 60m

Collimation

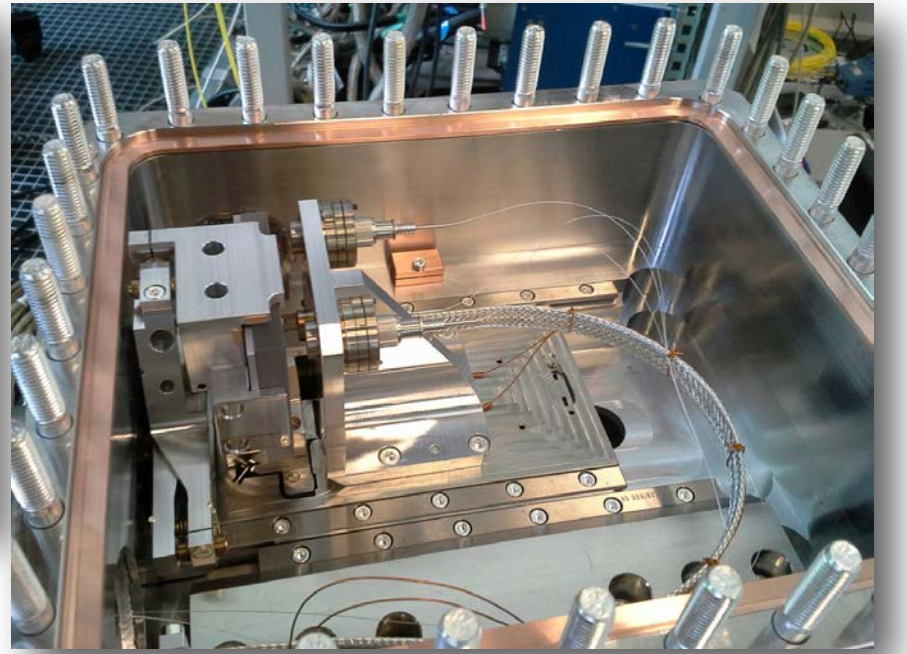
- HL-LHC Collimators, Hollow-electron lens and Crystals

MoGr collimator jaw with BPM

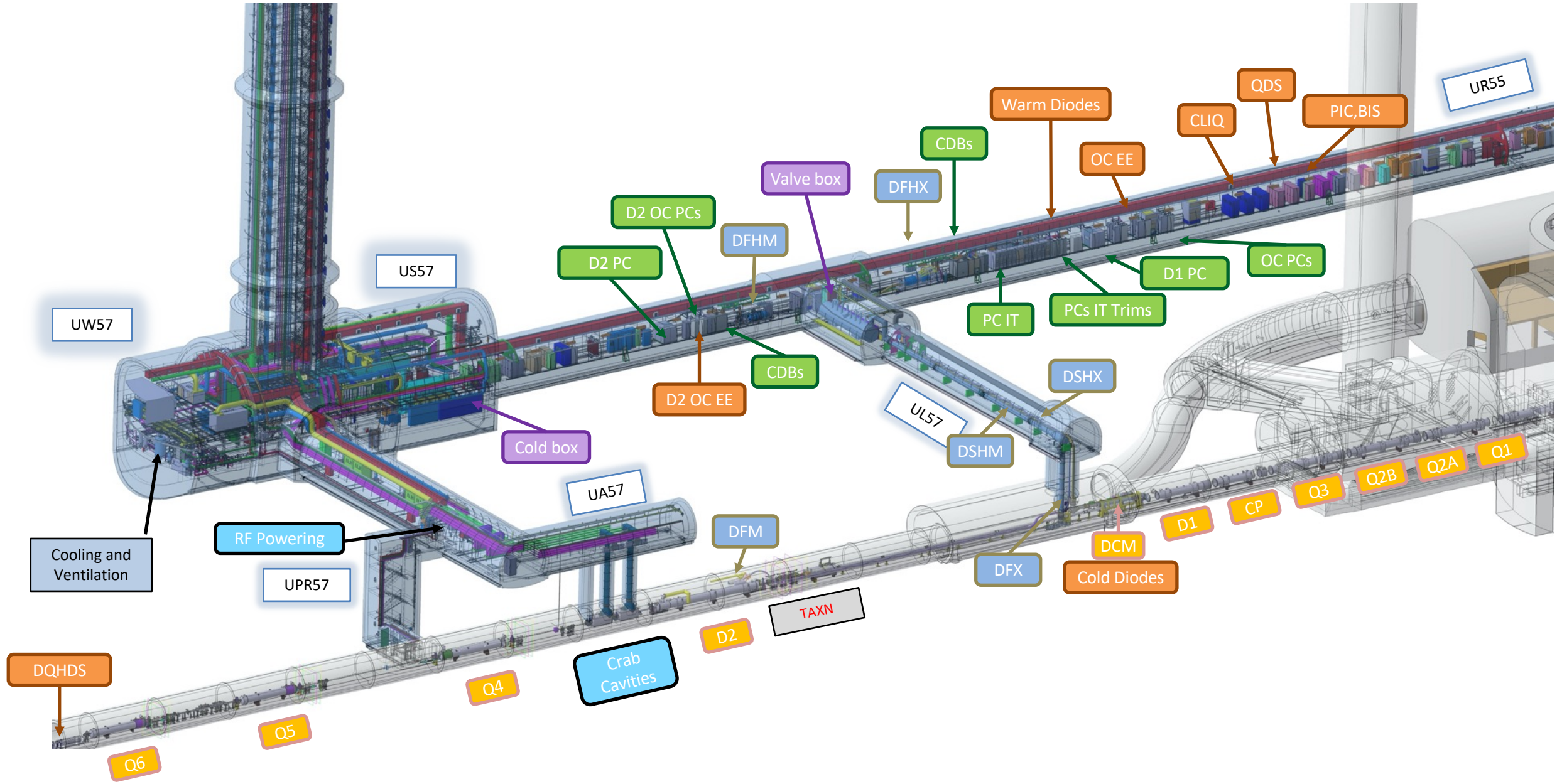
Hollow-electron-lens conceptual design



Prototype LHC bent crystal collimator



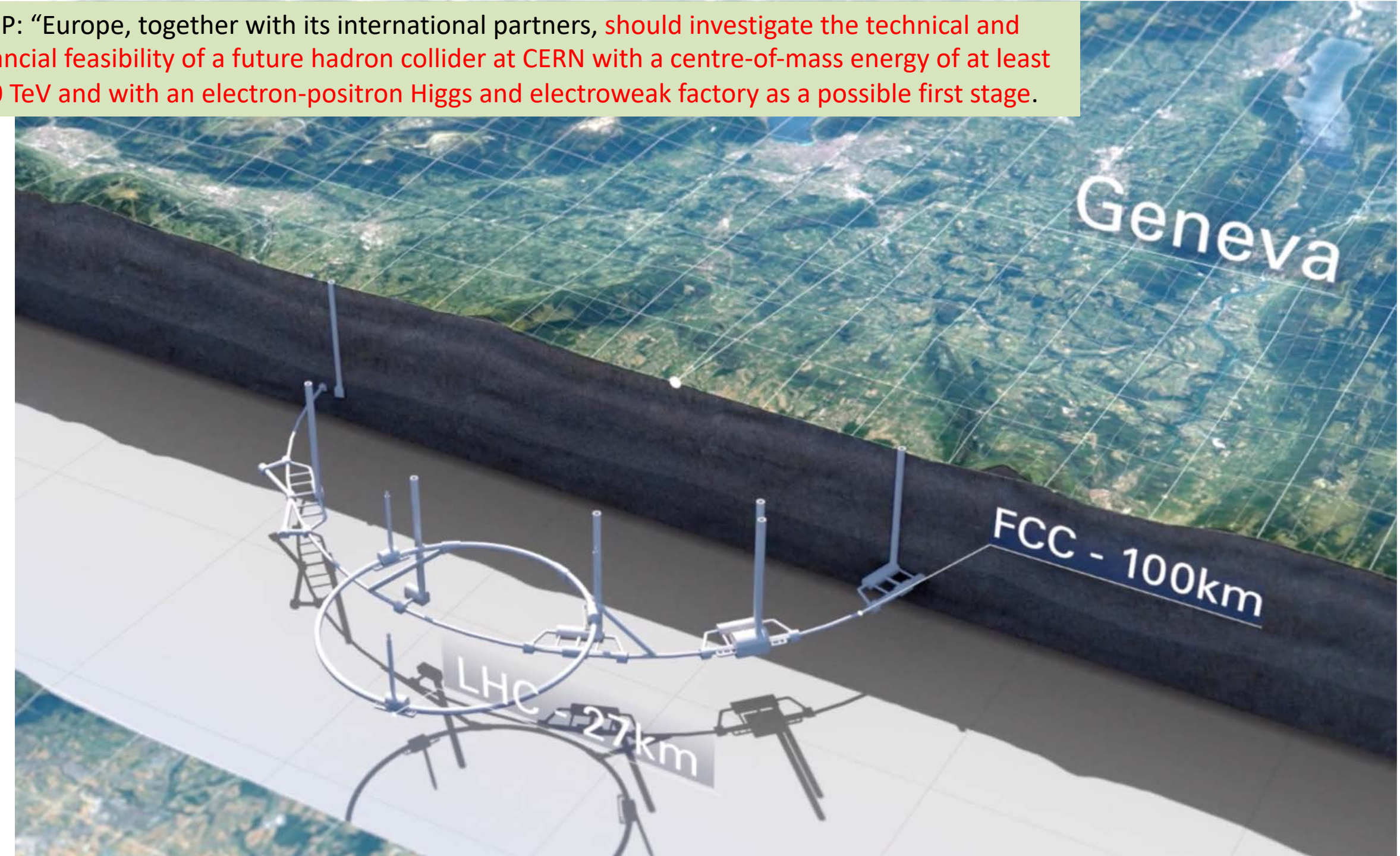
HL-LHC


UR55
QDS
PIC,BIS
CLIQ
Warm Diodes
CDBs
OC EE
Valve box
DFHX
D2 OC PCs
DFHM
D2 PC
US57
UW57
OC PCs
D1 PC
PCs IT Trims
PC IT
CDBs
D2 OC EE
DSHX
UL57
DSHM
Cold box
UA57
Q1
Q2A
Q2B
Q3
CP
D1
DCM
Cold Diodes
DFX
DFM
RF Powering
Cooling and Ventilation
UPR57
TAXN
D2
Crab Cavities
Q4
Q5
Q6
DQHDS

Future options

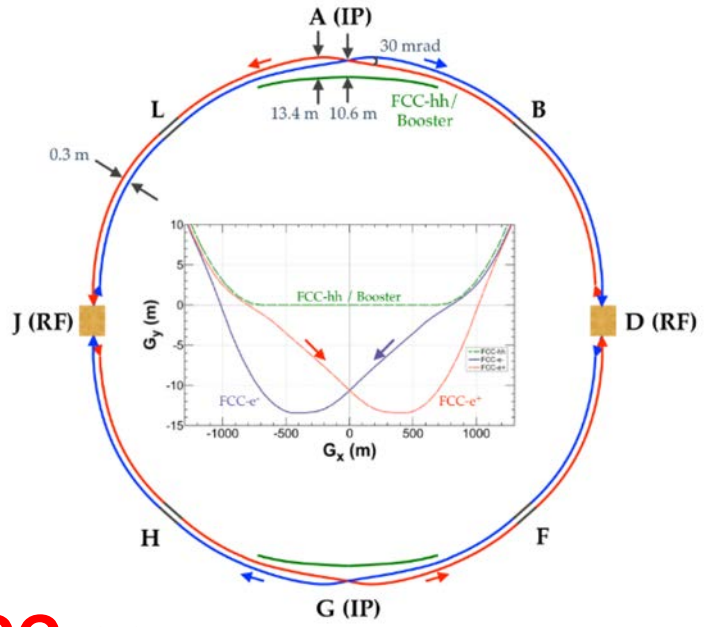
- FCC study to 2027
  - technical, administrative, financial feasibility of tunnel, with due regard to energy and environment, political, societal and scientific community impact and support
- CLIC, Muon Collider, Plasma Wakefield Acceleration
- Accelerator R&D
  - High Field Magnets, RF (warm and superconducting), Vacuum, Cryogenics…
- Physics Beyond Colliders
  - Novel possibilities (complex and technologies)

ESPP: “Europe, together with its international partners, should investigate the technical and financial feasibility of a future hadron collider at CERN with a centre-of-mass energy of at least 100 TeV and with an electron-positron Higgs and electroweak factory as a possible first stage.



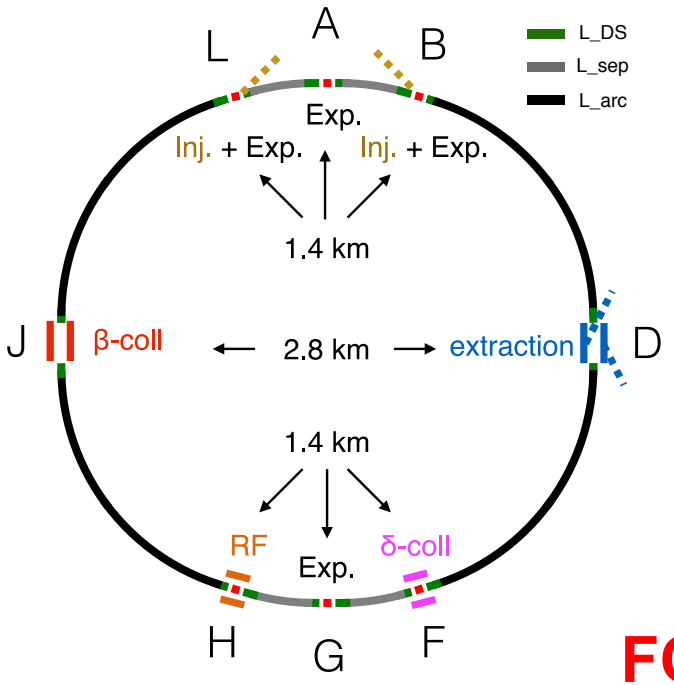
The FCC integrated program

- **Stage 1: FCC-ee (Z, W, H, tt̄)** as Higgs factory, electroweak & and top factory at highest luminosities
- **Stage 2: FCC-hh (~100 TeV)** as natural continuation at energy frontier, with ion and eh options
- Common civil engineering and technical infrastructures
- Building on and reusing CERN's existing infrastructure



FCC-ee

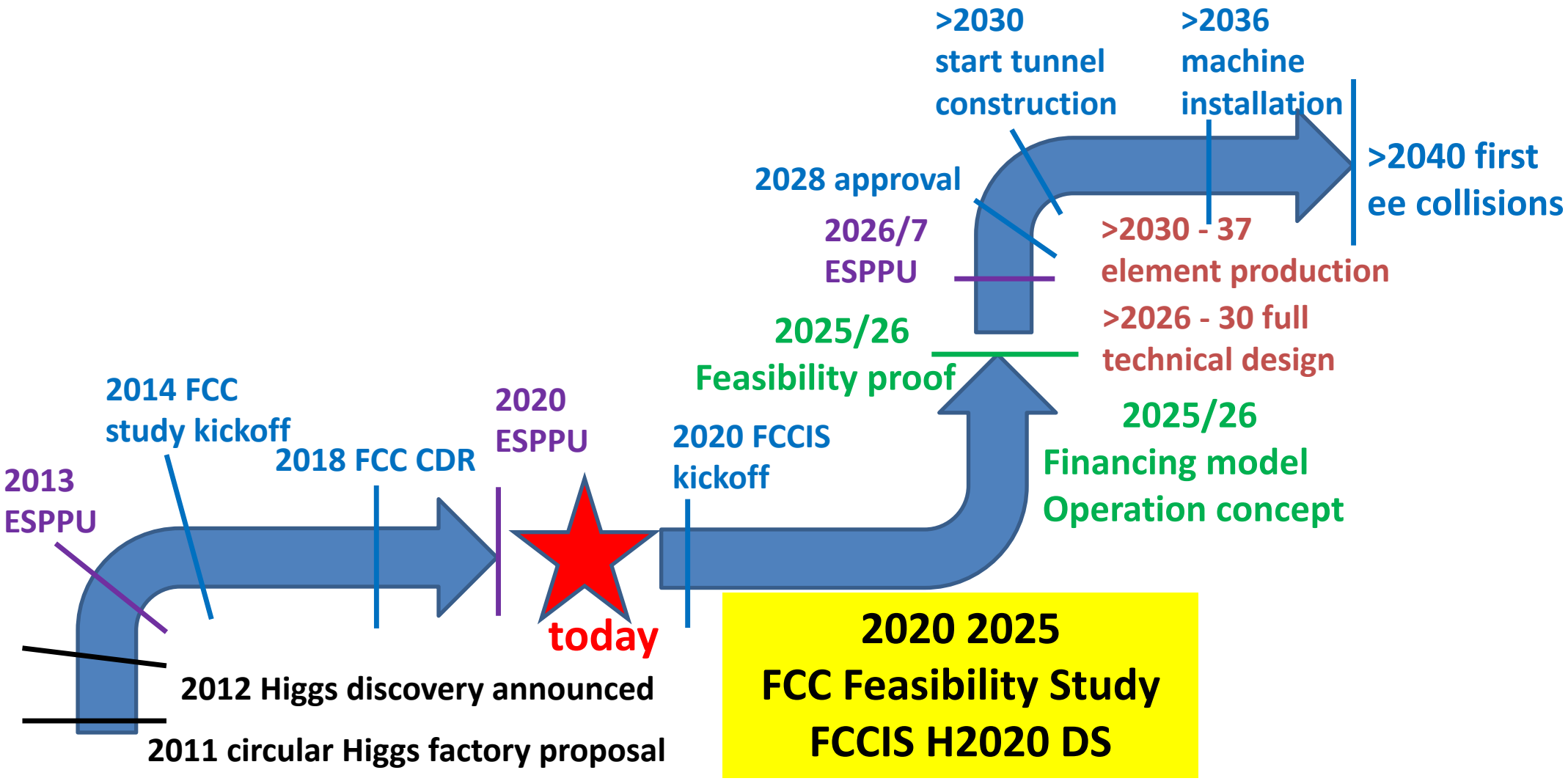
Warm magnets, superconducting RF



FCC-hh

High-field SC magnets

FCC roadmap towards stage 1

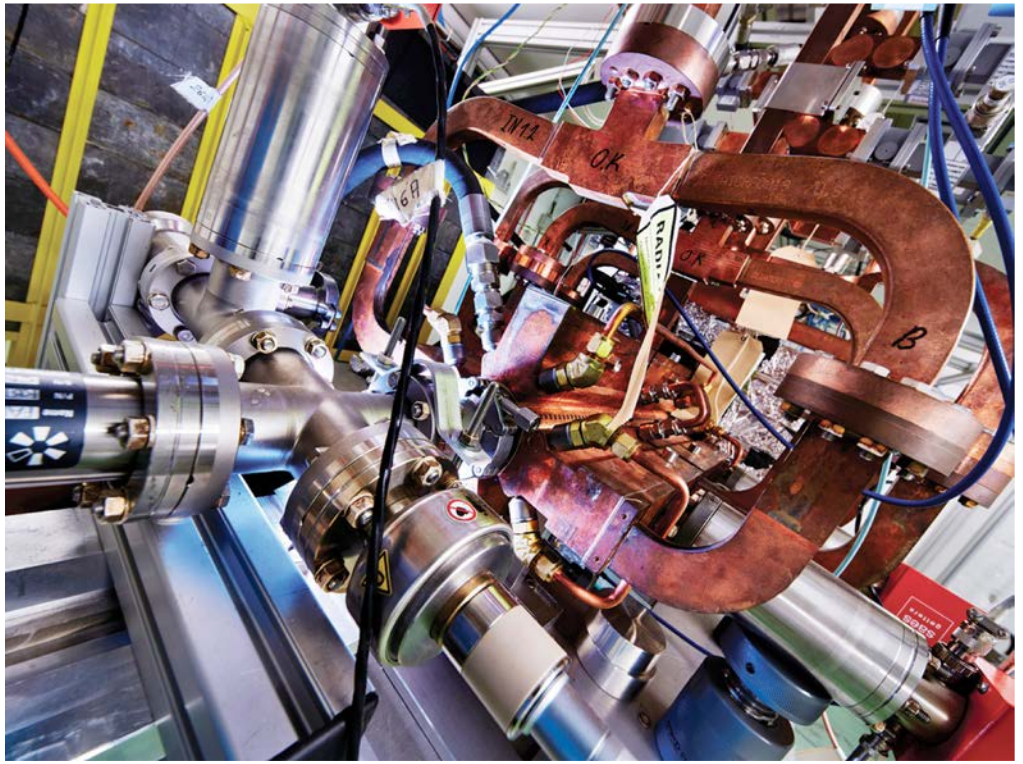


Preliminary!!!

Compact Linear Collider (CLIC)

Compact Linear Collider (CLIC)

Linear e^+e^- collider $\sqrt{s}$ up to 3 TeV

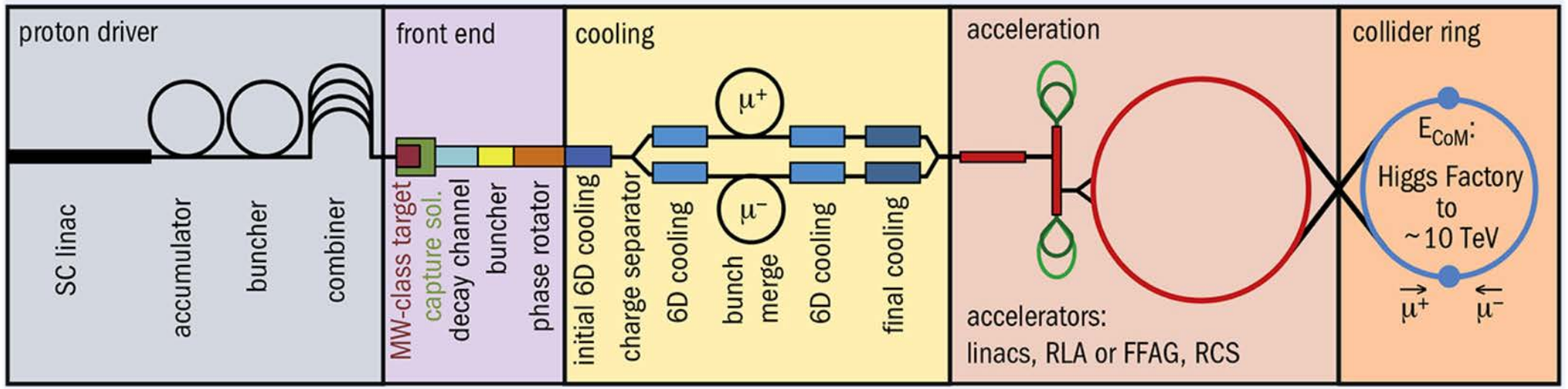


- **X-band core-technology, high efficiency klystrons**
- **High gradient studies using the CLEAR facility** (instrumentation for nano-beams, medical accelerators..)
- **Smaller projects outside CERN using X-band technology** (medical, industrial and research linacs…)

Muon Collider

International Design Study

The study aims to **establish whether the investment into a full CDR and a demonstrator is scientifically justified.**

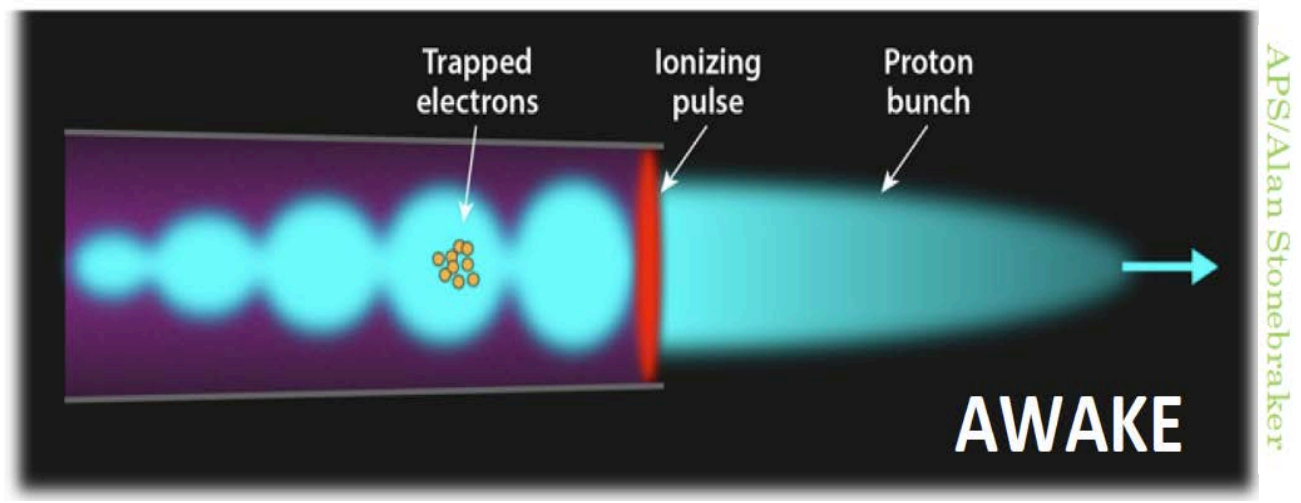


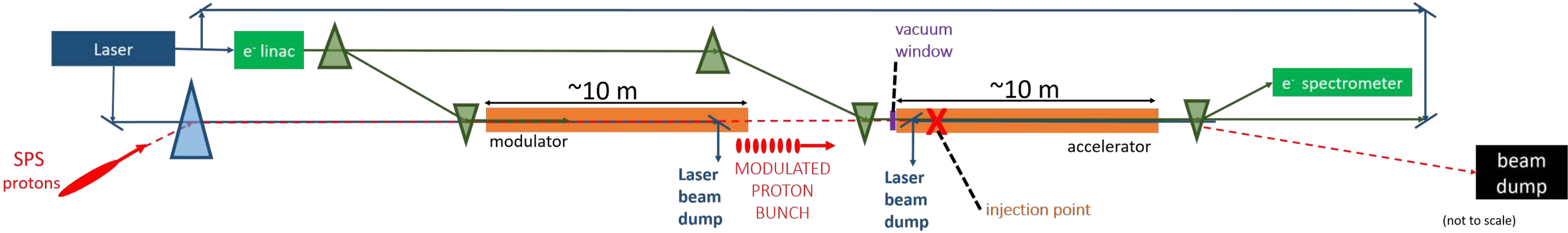
Muon
Mass: 207 x mass of electron
Lifetime: 2.2 microsecond

Many serious technical challenges!

- **High field superconducting magnets**
- **Fast-ramping magnets and efficient energy recovery**
- **Superconducting RF**
- **Normal conducting RF**
- **Target area with high proton beam power**
- **Re-optimization of muon cooling system**

Advanced Acceleration Techniques





Contribute to the global effort on developing the use of plasma wake-fields for accelerating particle beams, in particular the development of **proton driven plasma wakefield acceleration technology.**

Technology/R&D

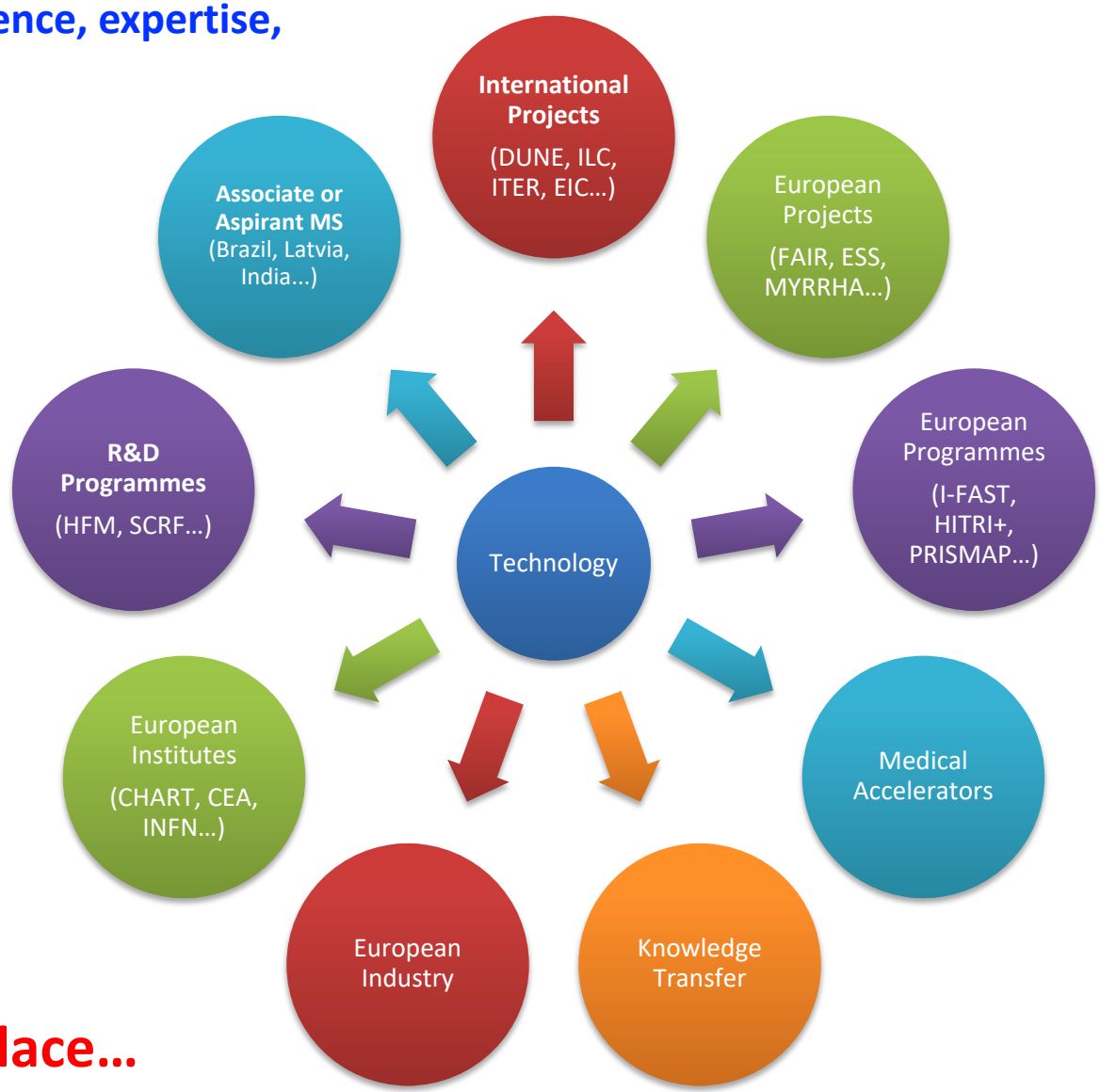
Diverse technical capabilities of the sector: knowledge, experience, expertise, facilities, manufacturing capability…

Developments for in-house applications

New requirements at existing complex (e.g LIU, L4)
New projects (e.g. HL-LHC, FCC)
R&D programmes (HFM, SCRF…)
Improving performance of existing systems
Obsolescence

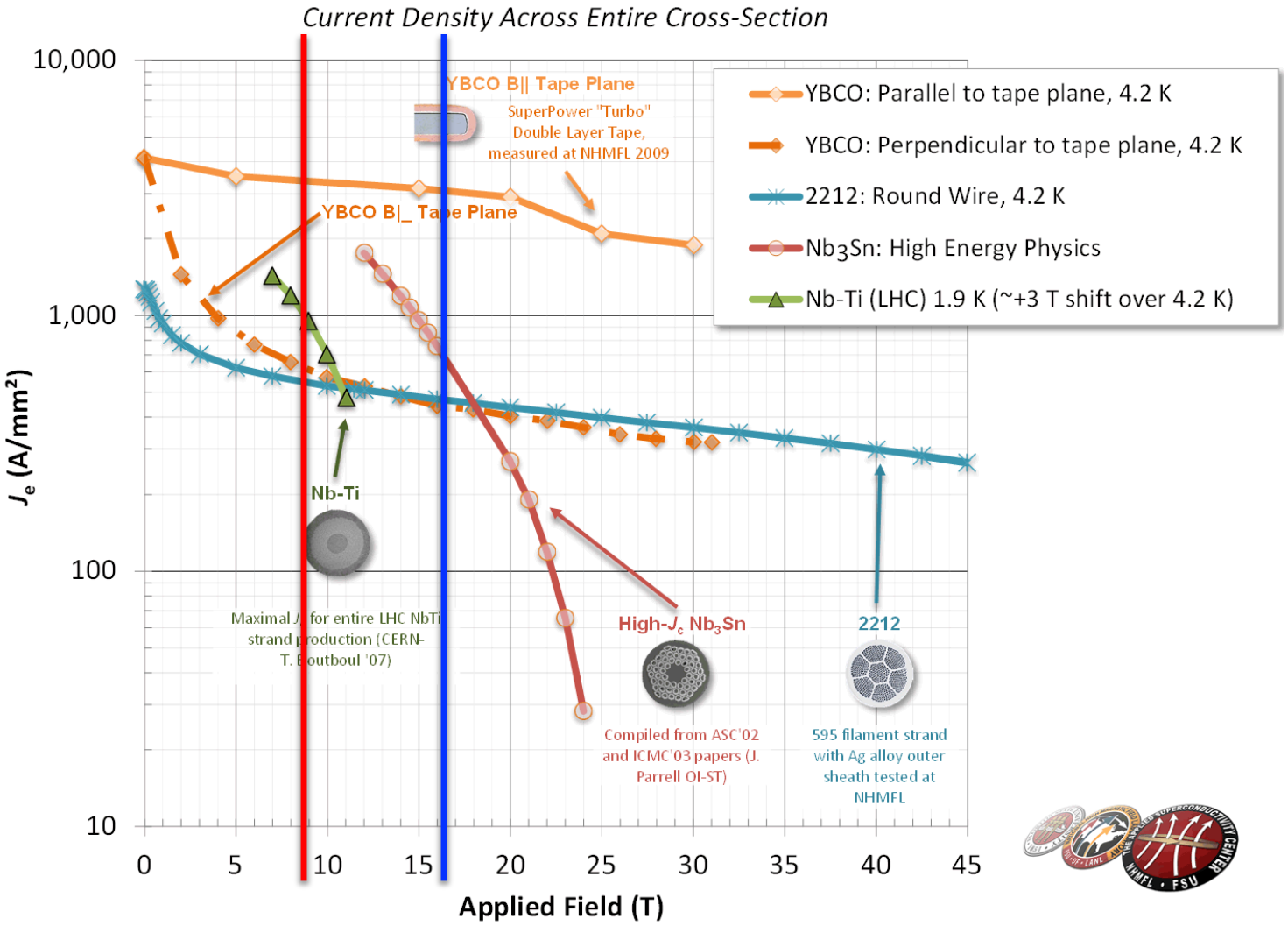
AND… in other institutes/industry:

- Use of CERN technology – leveraging CERN's knowledge base – with further R&D a possibility
- Development of novel applications with CERN's support
- R&D for CERN projects as means of establishing and maintaining in-country expertise



Truly impressive number of collaborations in place…

Superconducting magnet technology



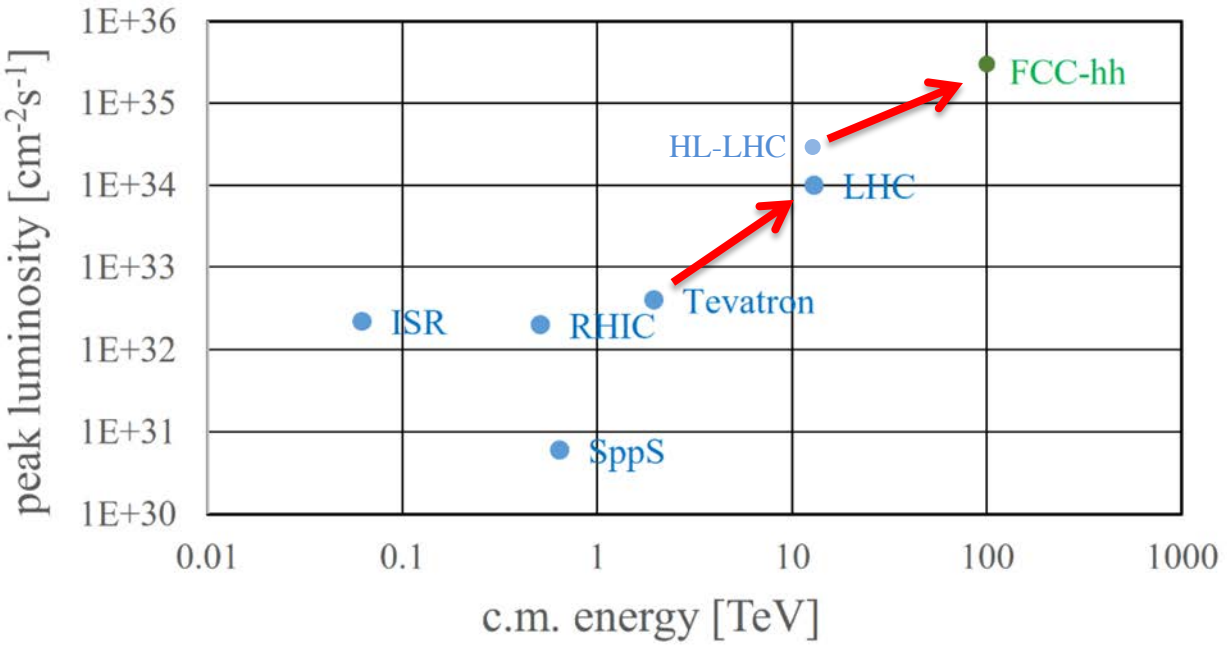
<u>Nb_3Sn</u>

- HL-LHC with 11-12T
- 16 T for HEP
- Almost a commodity!
  - 15-20 t per year for MRI
  - ITER needs 500 t
- ca x5 cost LHC Nb-Ti
- Brittle material

<u>HTS</u> (needed → 20 T)
→ on going R&D!

- Bi-2212: cost today 2-5x Nb_3Sn
- YBCO: cost today 10x Nb_3Sn

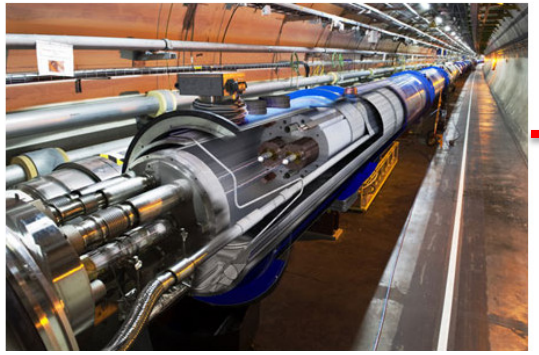
FCC-hh: highest collision energies



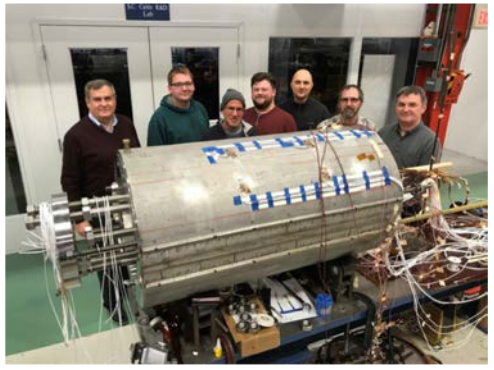
- **Order of magnitude performance increase** in both **energy & collision rate**
- **100 TeV cm collision energy**
- **Key technology: high-field magnets (~16 T)**

Challenging, long-term HFM R&D required

from
LHC technology
8.3 T NbTi dipole



via
HL-LHC technology
12 T Nb_3Sn quadrupole



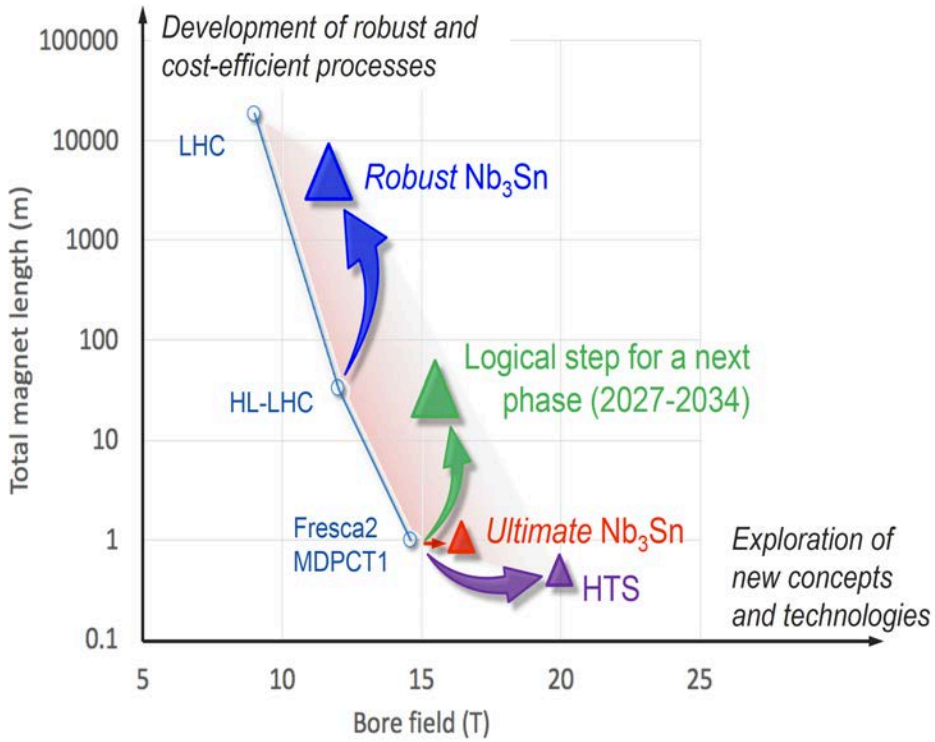
FNAL dipole demonstrator
14.5 T Nb_3Sn

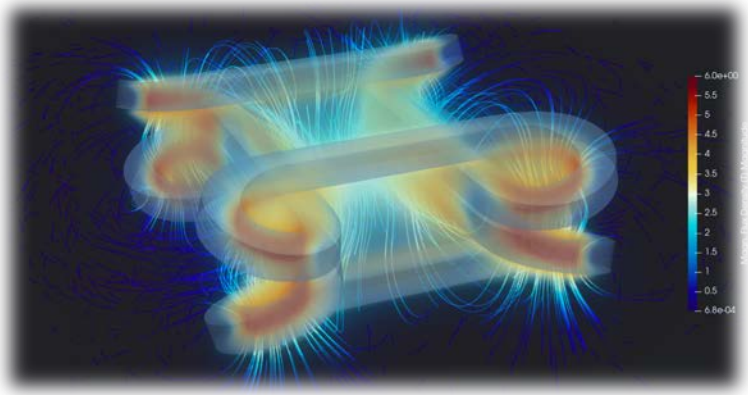
High Field Magnet R&D Programme

2020 saw the launch of a reinforced R&D programme for superconducting high-field magnets, as key technology for future accelerators (hadron colliders, muon colliders, neutrino beams, etc.) and detectors, with great potential for wider societal applications.

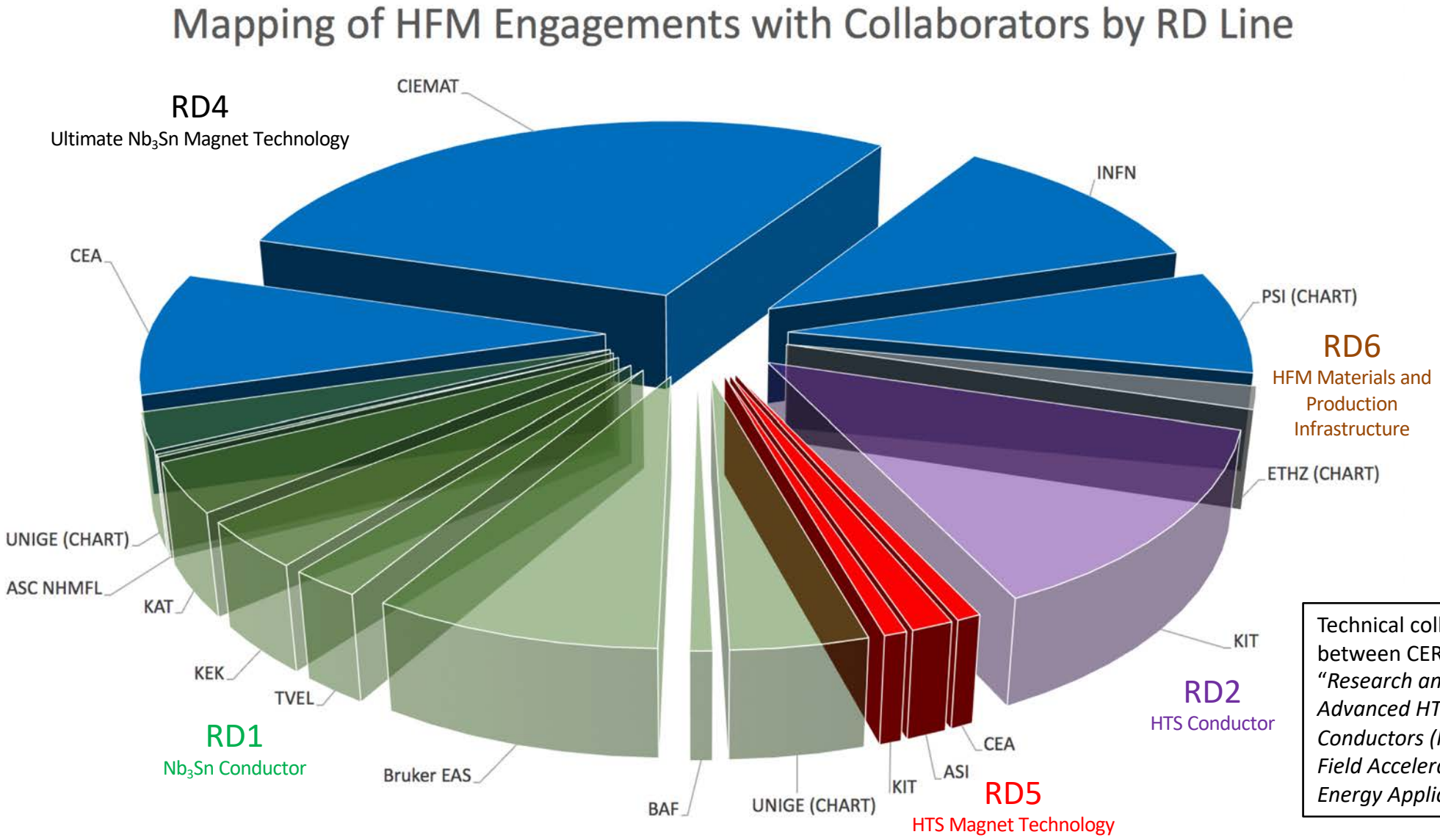
- Nb_3Sn **conductor** R&D
- Nb_3Sn **magnet technology** R&D
- Nb_3Sn **accelerator magnet** development
- HTS **material and conductor** R&D
- HTS **coil technology and accelerator magnet** R&D
- **Insulating materials**, polymers and composites
- **Infrastructure** for development, manufacture, test and measurement

Strong partnership with industry and with Institutes and Universities in Europe, US and beyond



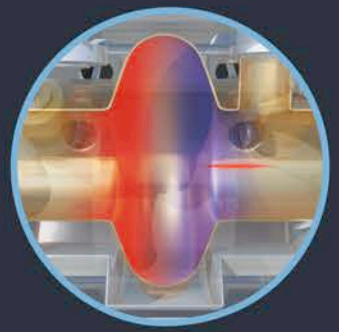


HFM – already a strong collaborative effort

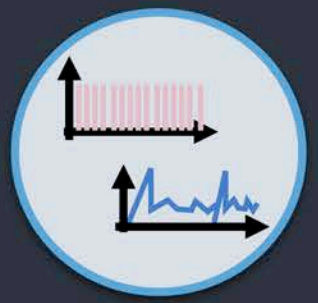


Technical collaboration between CERN and KIT for the "*Research and Development of Advanced HTS Coated Conductors (HTS-CC) for High Field Accelerator Magnets and Energy Applications*"

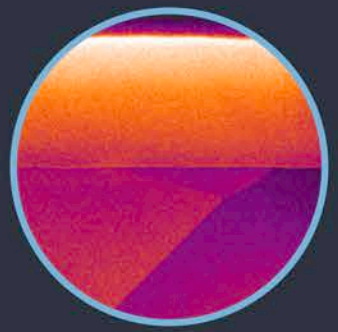
SRF R&D for FCC



optimize cell shapes



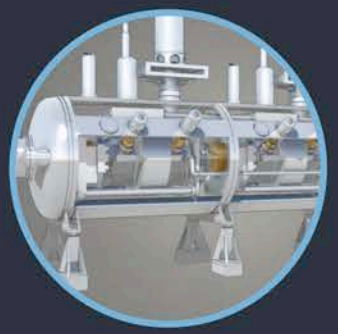
beam dynamics studies



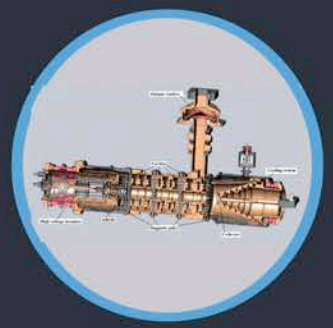
Q-slope mitigation

material & manufacturing

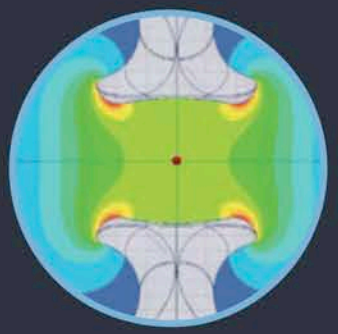
assembly & cost optimisation



ancillaries:
1 MW CW coupler!



efficient RF production



coated crab cavities

Conclusions

- What we are doing here at CERN is not easy…
- …and we want to keep pushing
- As noted by Dr Volker Rieke (BMBF Director-General) in yesterday's Opening Ceremony
  - Fundamental Research drives Innovation
  - Pushes us to the forefront of what is technically feasible (with remarkable results)
- Bold and ambitious future plans
  - technological development in collaboration with industry, fully exploiting the opportunities offered by cutting edge research, is an imperative