DE LA RECHERCHE À L'INDUSTRIE

R&D ON FUTURE CIRCULAR COLLIDERS

Detecting radiations from the Universe.

Conseil Scientifique de l'Institut 2015 | Antoine Chance and Maria Durante

www.cea.fr

Irfu

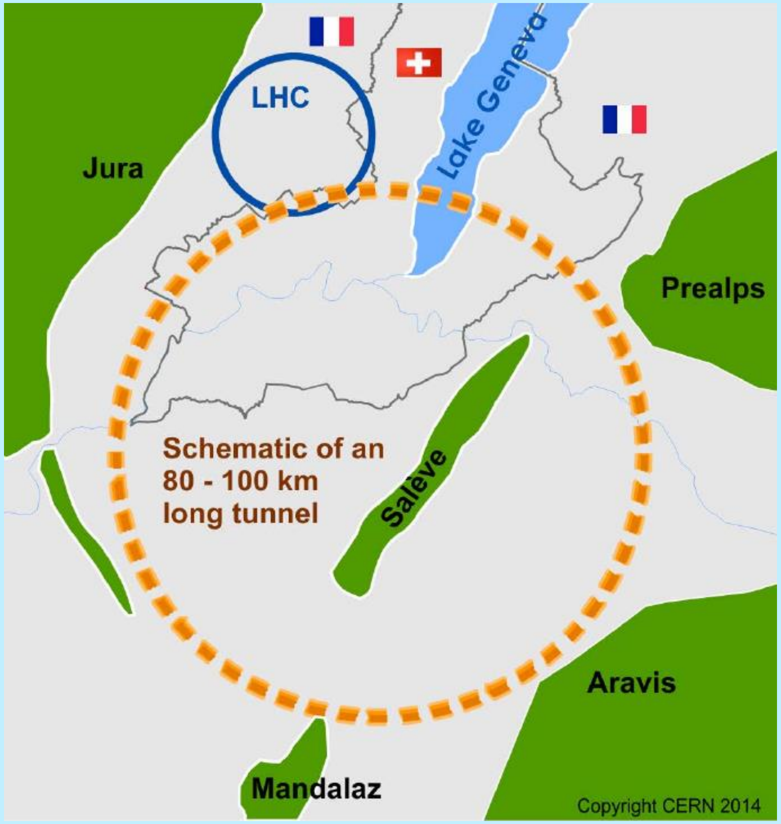
MOTIVATIONS

- Higgs discovery.
- The standard model is confirmed.
- Some questions still remaining:
  - Neutrino mass.
  - Asymmetry matter/antimatter.
  - Dark matter.
  - New physics: supersymmetry…
- European strategy for particle physics (to 2018):

***To stay at the forefront of particle physics**, Europe needs to be in a position to **propose an ambitious post-LHC accelerator** project at CERN **by the time of the next Strategy update**, when physics results from the LHC running at 14 TeV will be available. CERN should **undertake design studies** for accelerator projects in a global context, with emphasis on proton-proton and electron- positron **high-energy frontier machines**. These design studies should be **coupled to a vigorous accelerator R&D programme**, including high-field magnets and high-gradient accelerating structures, in collaboration with national institutes, laboratories and universities worldwide.*

FCC: FUTURE CIRCULAR COLLIDER

Circular collider :
100 TeV center of mass
100 (80) km circumference



Proton-proton : FCC-hh
- Defines the infrastructures.
- Foreseen 2035/2040.
- For new physics.
- **Existing reason of FCC.**

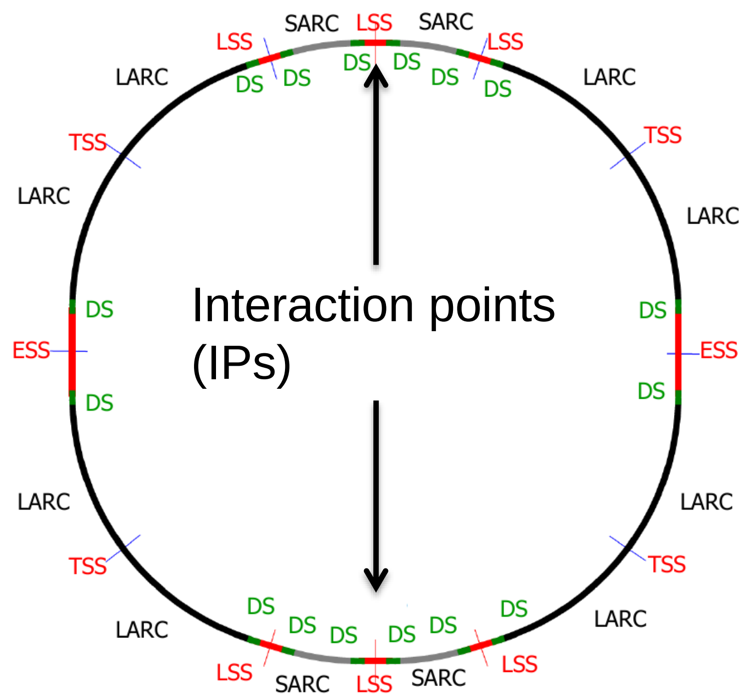
Electron-positron : FCC-ee
- Intermediate step.
- Optional.
- Higgs precision and rare decays of Z, W, H et *t*.

Proton-electron : FCC-he
- Optional.
- Only with FCC-ee.
- Inelastic scattering and Higgs physics.

FCC-HH IN A FEW NUMBERS

Parameters	FCC-hh	LHC	HL-LHC
Energy center of mass [TeV]	**100**	**14**	
Circumference [km]	**100 (80)**	**26.7**	
Dipole field [T]	**16 (20)**	**8.33**	
Number of straight sections	8	8	
Average length straight sections [m]	1400	528	
Number of interaction points	2+2	2+2	
Injection energy [TeV]	3.3	0.45	
Number of bunches [25 ns spacing]	10600	2808	
Peak luminosity [10^{34} $cm^{-2}s^{-1}$]	**5**	**1**	**5**
Integrated luminosity per day [fb^{-1}]	2.2	0.47	2.8
Normalized emittance [μm]	2.2	3.75	2.5
β^* [m]	1.1	0.55	0.15 (min)
Crossing angle [μrad]	74	285	590
Stored energy per beam [GJ]	**8.4**	**0.392**	**0.694**
Synchrotron radiation power per ring [MW]	2.4	0.0036	0.0073
Synchrotron radiation losses per ring [W/m]	**28.4**	**0.17**	**0.33**
Lost energy per turn [MeV]	4.6	0.0067	
Critical energy of the photons [keV]	4.3	0.044	
Dipole aperture [mm]	50	56	

LAYOUT OF THE RING



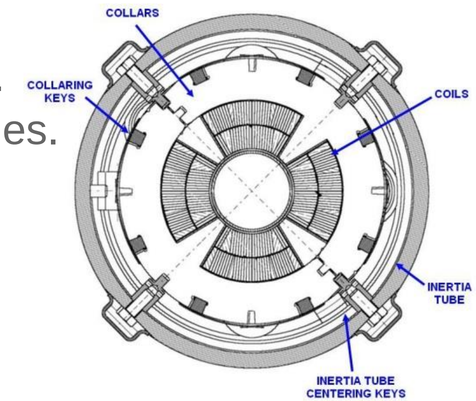
A lot of constraints on the layout :

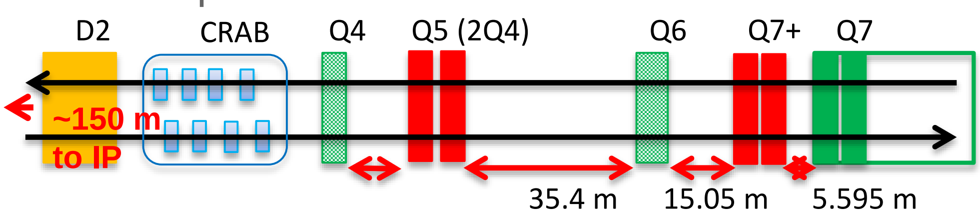
- Geological constraints.
- Luminosity.
- Magnet field.
- Radiation power.
- Cost.

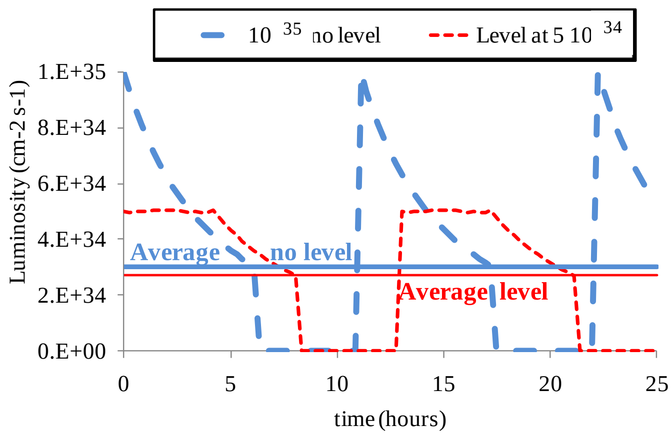
Abbreviation	Generic name	Number	Length [km]
LSS	Long straight section	6	1.4
ESS	Extended straight section	2	4.2
TSS	Technical straight section	4	ε
DS	Dispersion suppressor	16	0.4
SARC	Short arc	4	3.2
LARC	Long arc	8	*depends on P*

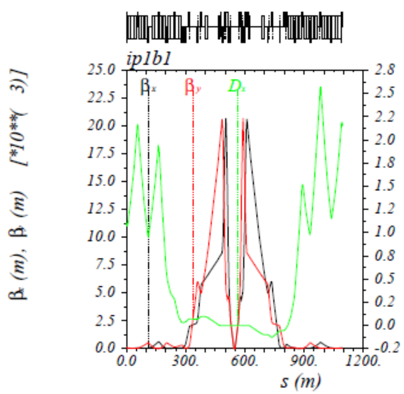
IN THE CONTINUITY OF SACM PROGRAMS

- FCC is in the continuity of the studies for HiLumi LHC.
- The Irfu/SACM has already developed an expertise :
  - In beam dynamics.
    - Design of the interaction region.
    - Dynamic aperture studies → field quality requirements.
    - Fringe field studies and their integration in tracking codes.
  - In high-field magnets.
    - Design and realization of Nb_3Sn Quadrupole
- This expertise will be an asset for FCC.







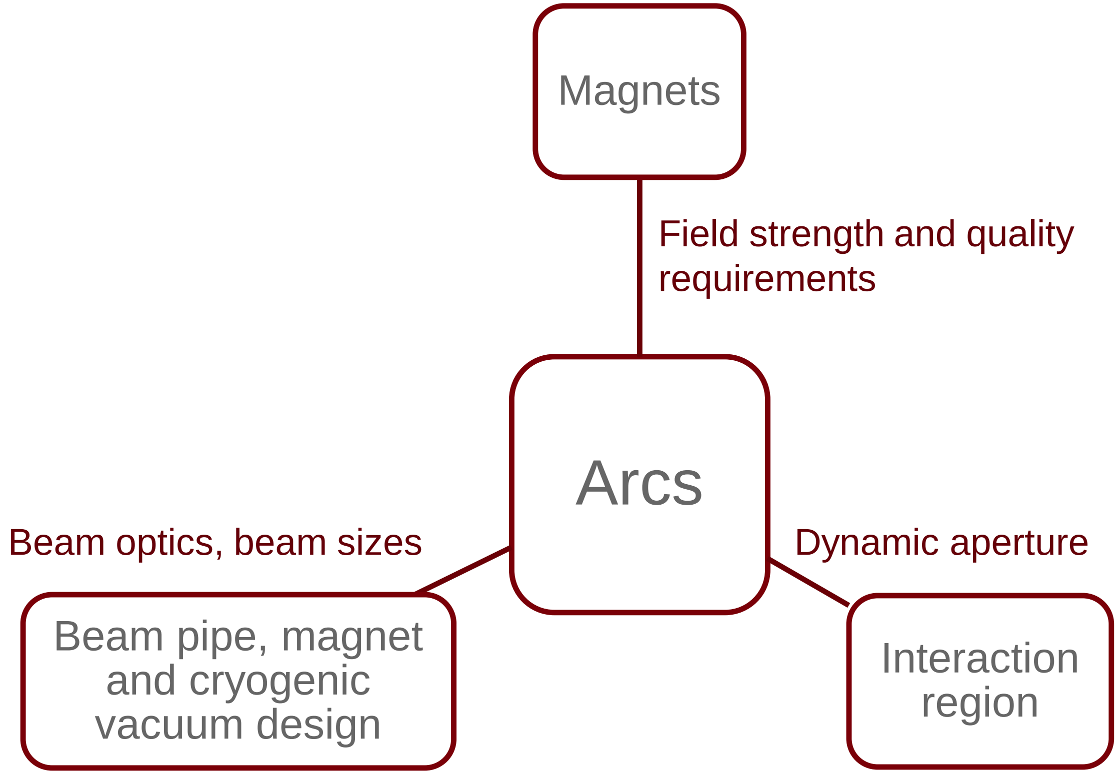


Nb_3Sn Quadrupole cold mass inside SACM SCHEMa facility

THE CHALLENGE OF THE ARCS

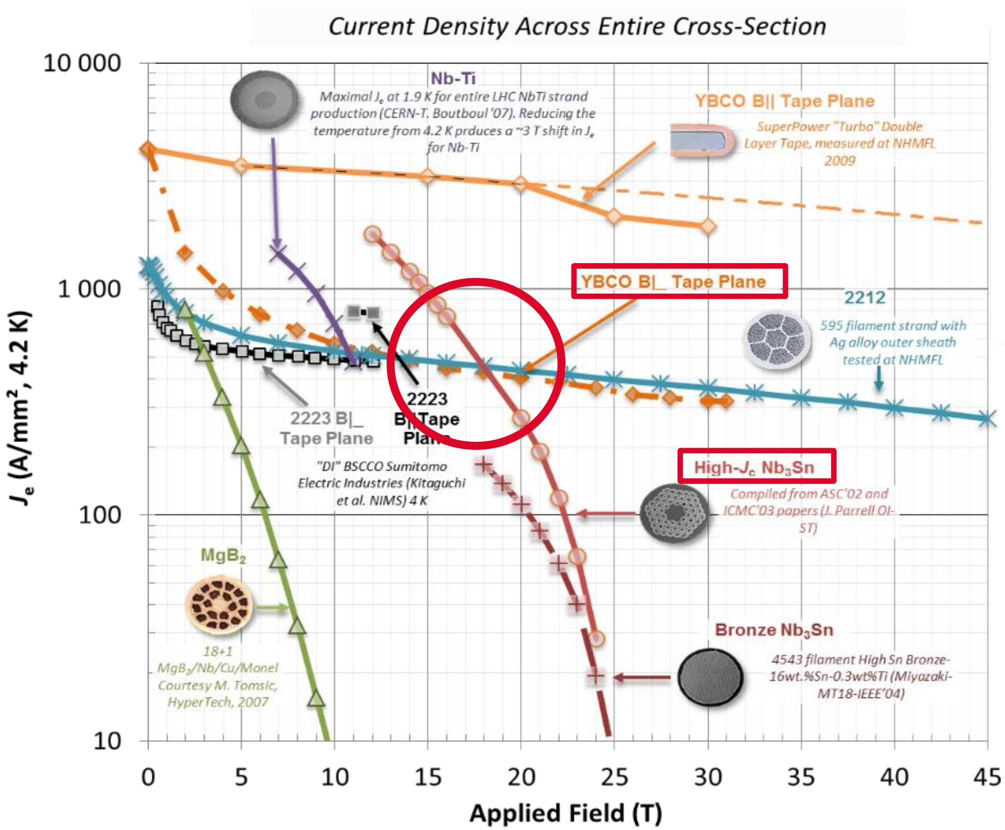
- Arc design is cost driven :
  - 80% of the ring.
  - Tune beam performance vs. cost by optimizing the arc cell.

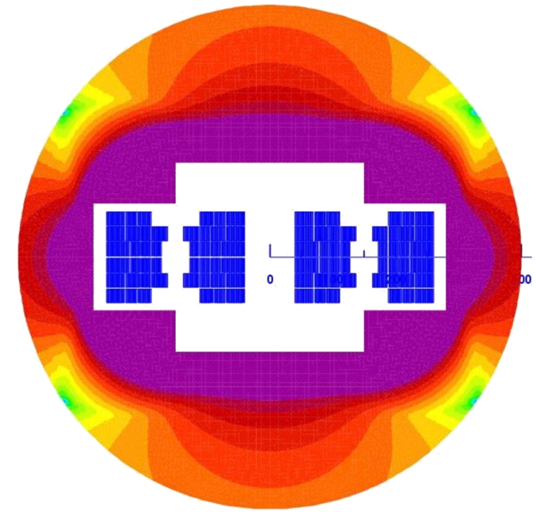
- At the interface with different machine aspects.



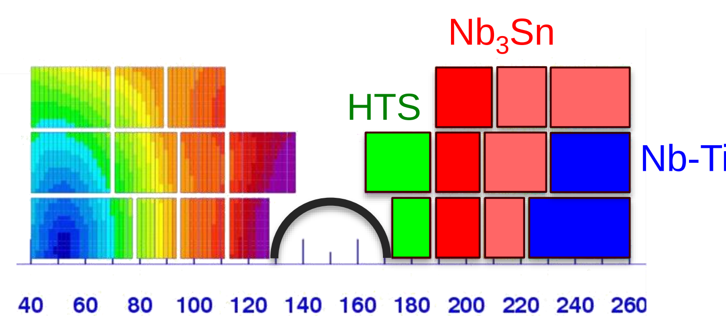
THE CHALLENGE OF THE MAGNETS

- Needs :
  - 16/20 T for the 100/80 km circumference options
  - Cost optimization → graded magnets





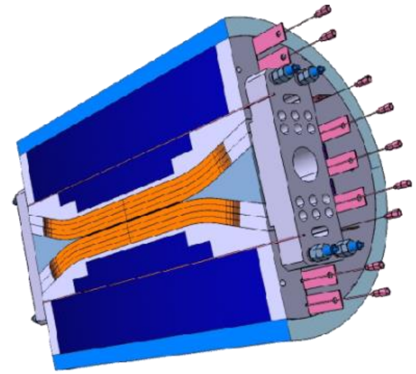
A 20 T HE-LHC dipole
E. Todesco, L. Rossi (CERN)



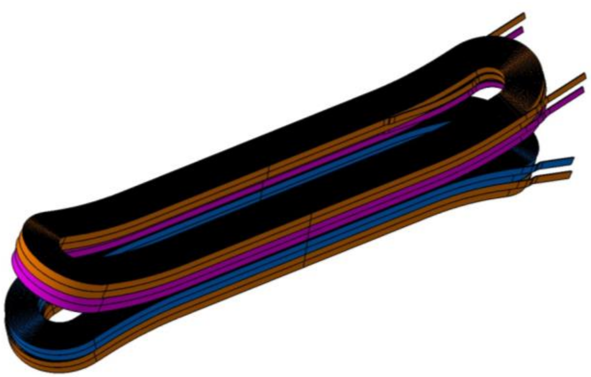
Graded winding : Simultaneous use of Low Temperature and of High Temperature Superconductors

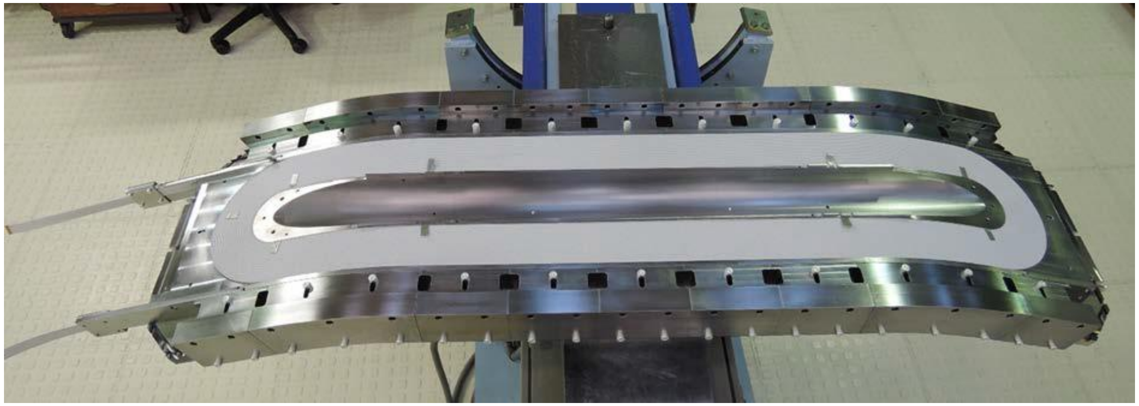
R&D ON HIGH FIELD MAGNETS

- R&D activities on High Field Magnets are ongoing in the framework of a new collaboration agreement between CERN and Irfu.



- R&D on Nb_3Sn :
  - FRESCA2 Nb_3Sn Dipole :
    - 13 T at 4.2 K, 15 T at 1.9 K
    - 100 mm aperture
    - Upgrade of cable test faclity at CERN.

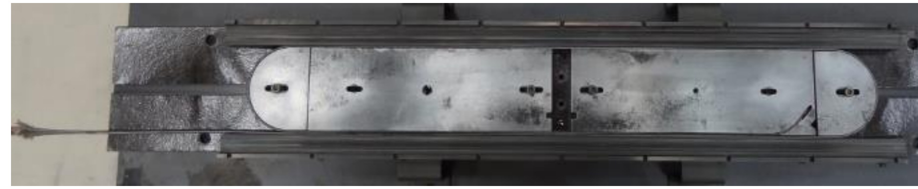




FRESCA2 dipole coil winding at Saclay

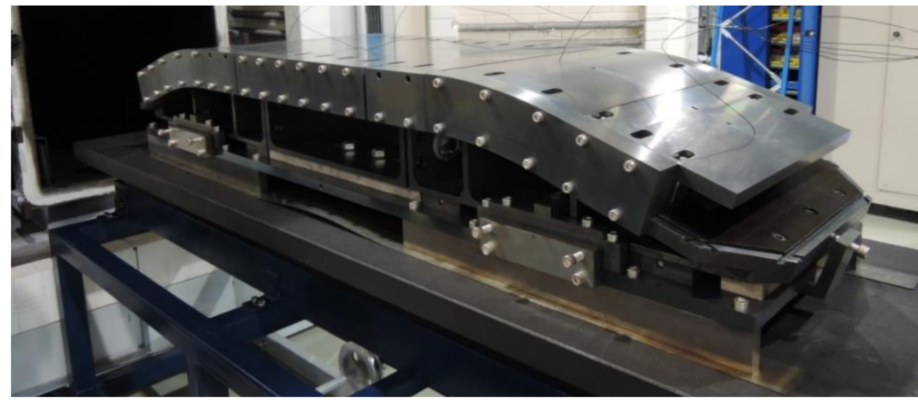
R&D ON HIGH FIELD MAGNETS

- R&D on Nb_3Sn :
  - Nb_3Sn cable behavior studies.

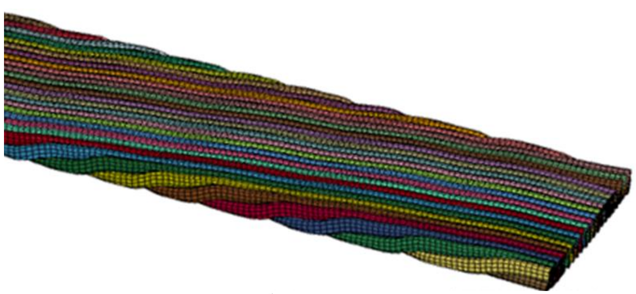


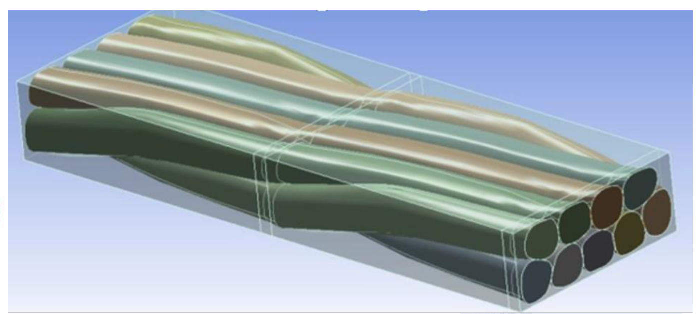
Reaction molds for dimensional changes studies and stress control in Nb_3Sn coils

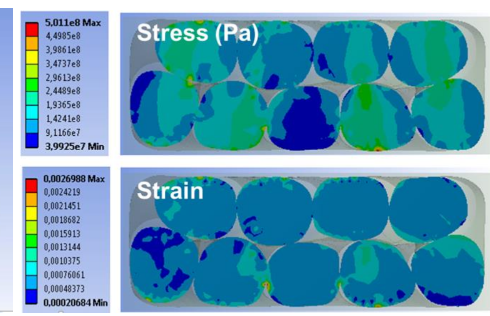
Reaction mold for Nb_3sn cable thickness variation studies



  - Nb_3Sn cable behavior modeling.

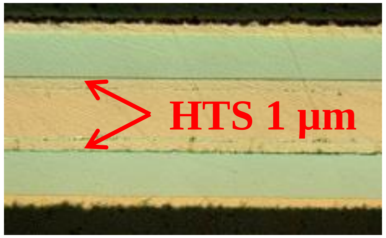




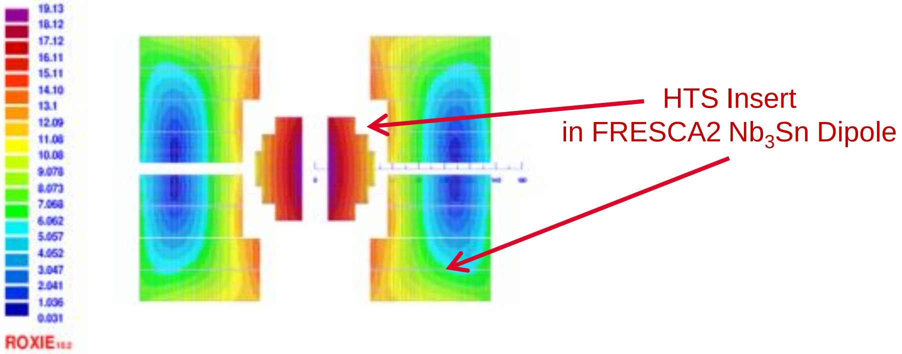


R&D ON HIGH FIELD MAGNETS

- R&D on High Temperature Superconductors :
  - EuCARD HTS Insert, 6T in 13 T bgf, 4.2K, 99 mm outer diameter

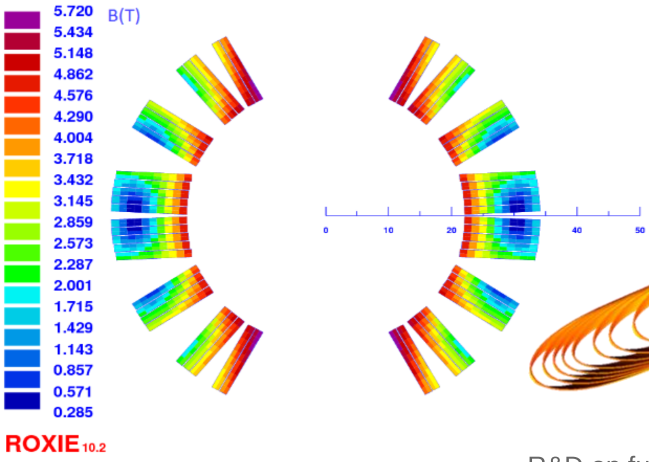


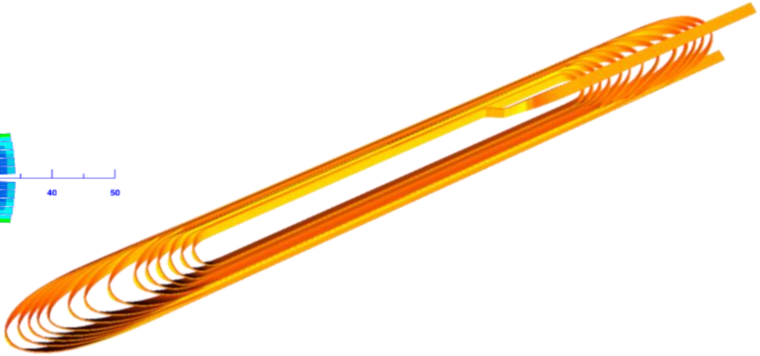
Insert double layer tape
(SuperPower)



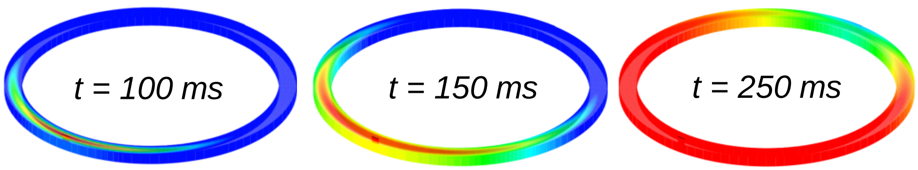
  - EuCARD2 HTS Dipole, 40 mm aperture, 5 T, accelerator field quality

YBCO Roebel cable
(General Cable Superconductors, New Zealand)

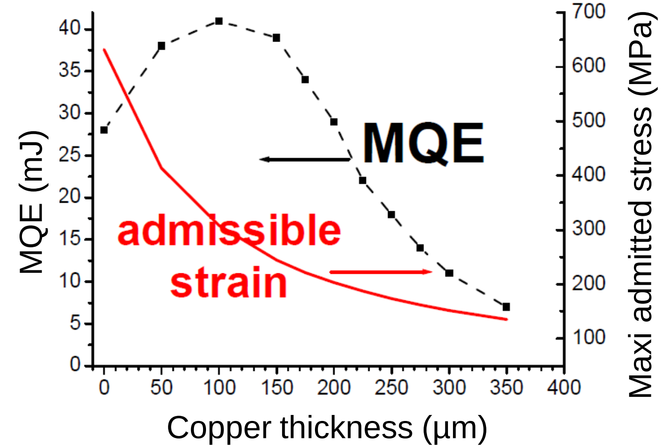




- R&D on HTS :
  - Protection studies

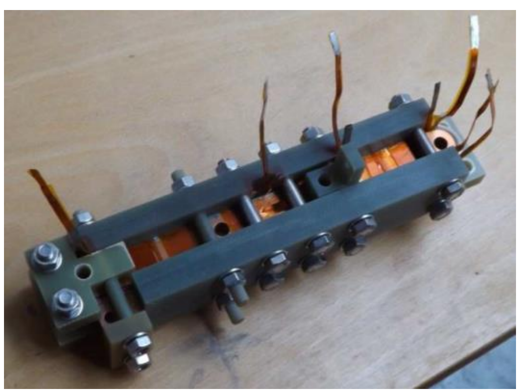


Simulation of quench propagation in a YBCO coil

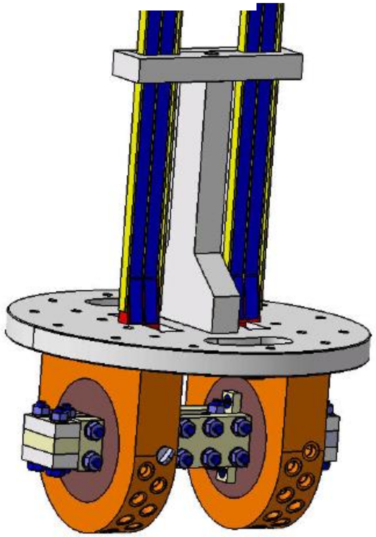


  - Superconducting tapes/cables characterization

Solenoidal pancakes of superconducting tapes for quench propagation studies

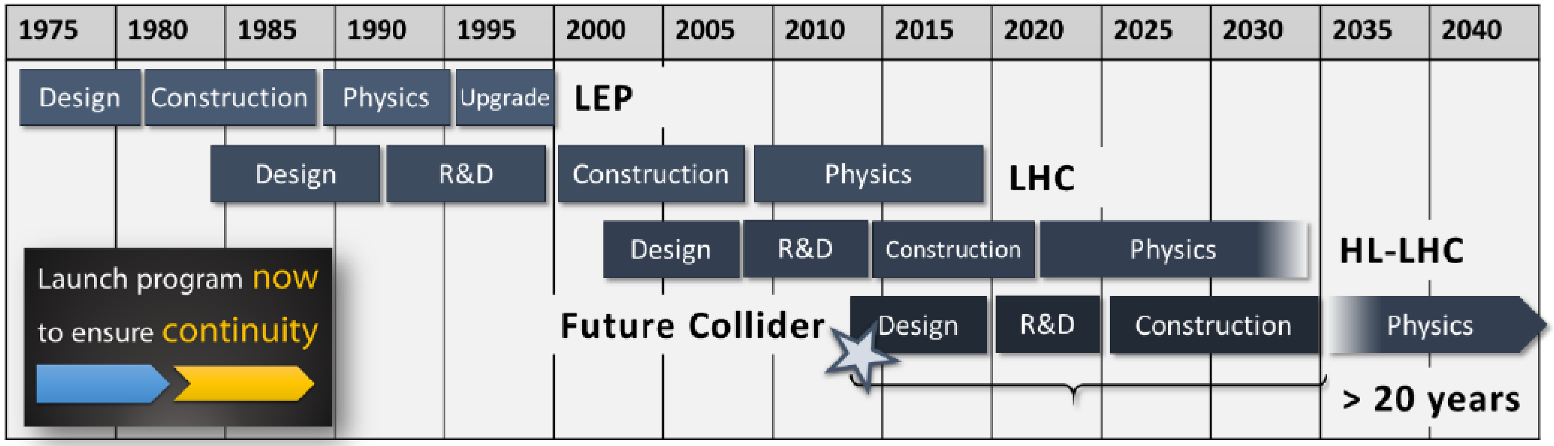


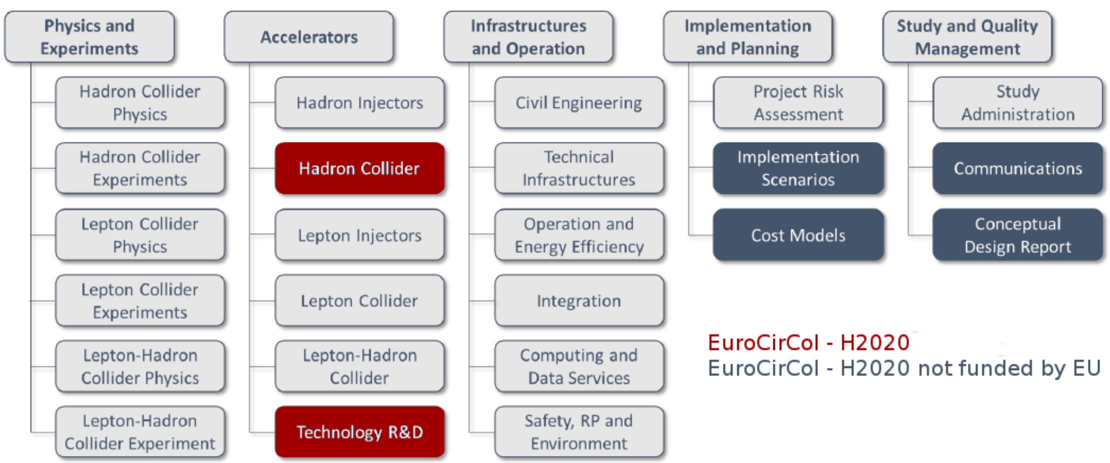
Single tape layer coil set-up for tape performances characterization and quench stability studies



Angular orienting set-up developed for LNCMI Grenoble M10 High Test Facility

EUROCIRCOL FOR FCC-HH



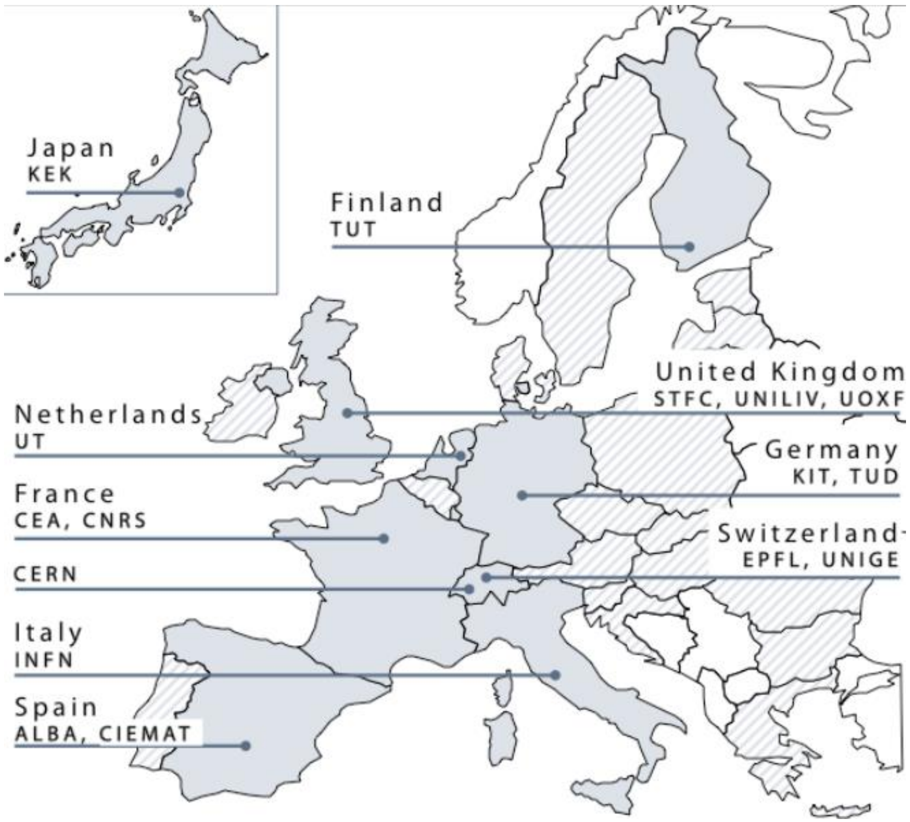


EuroCirCol - H2020
EuroCirCol - H2020 not funded by EU

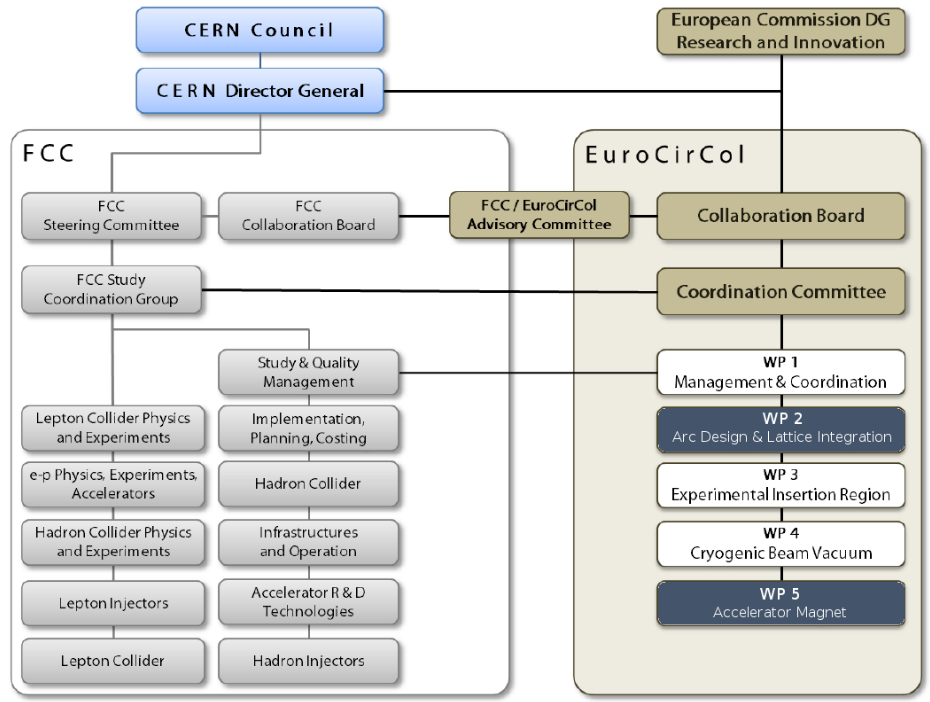
- EuroCirCol: **Euro**pean **Cir**cular **Col**lider
- **Aim:** make a design study (with CDR) for end 2018 (milestone for the European strategy for particle physics).
- 3 M€ asked to H2020.
- Only a part of the study will be funded.

EUROCIRCOL IN H2020

Partner countries



5 work packages



SACM and SIS are involved in 2 work packages:

- Arc design and Lattice Integration
- Accelerator Magnet

CONCLUSIONS

- FCC is an answer to the European strategy for particle physics
- Design and realization of such a collider lasts 20 years.
- Beginning studies now is of utmost importance to have the next collider running in 2035.

- China has an aggressive schedule with a 52-km-long e^+/e^- collider at 240 GeV for 2020.

- EuroCirCol corresponds to a design study of a h-h collider on the key-points:
  - Feasibility and performance of the collider,
  - Cost.
- Milestone: Conceptual Design Report for end 2018.

- SACM and SIS are involved in 2 work packages
  - The arc design. It consists in optimizing the arcs (cost and performance), studying the dynamic aperture and defining the magnet quality requirements.
  - The high-field magnet design. It consists in making the electromagnetic and mechanical design of the arc dipoles magnet and contributing to a cost model of the collider.

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