Overview of SRF activities at CERN

Frank Gerigk (CERN), SLHIPP-6, 23 May 2016, Daresbury

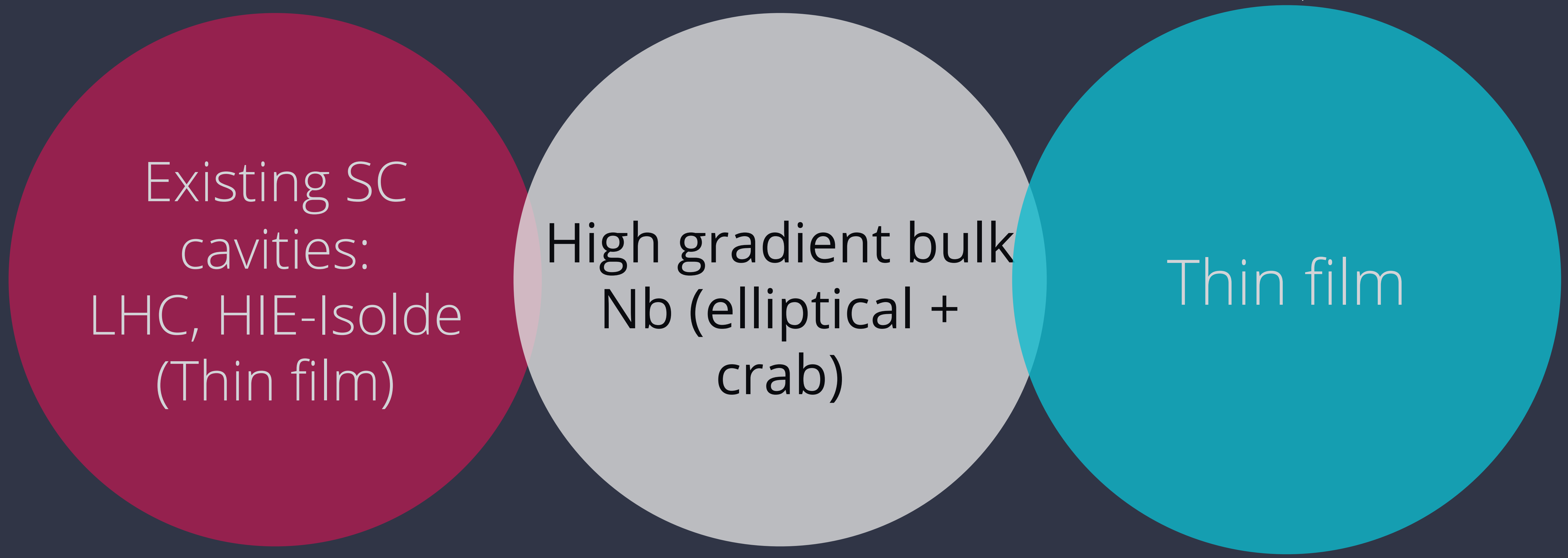
Outline

- SRF in major CERN Projects:
  - HL-LHC
  - HIE ISOLDE
  - LHC
- SRF R&D:
  - FCC
  - Thin Film R&D: deposition and el.magn. properties (QPR II,...)
  - High Gradient (704 MHz)
  - WOW cavity
- SRF infrastructure

SRF at CERN: general strategy

Maintain Nb on Cu technology & infrastructure used for **operational machines**.

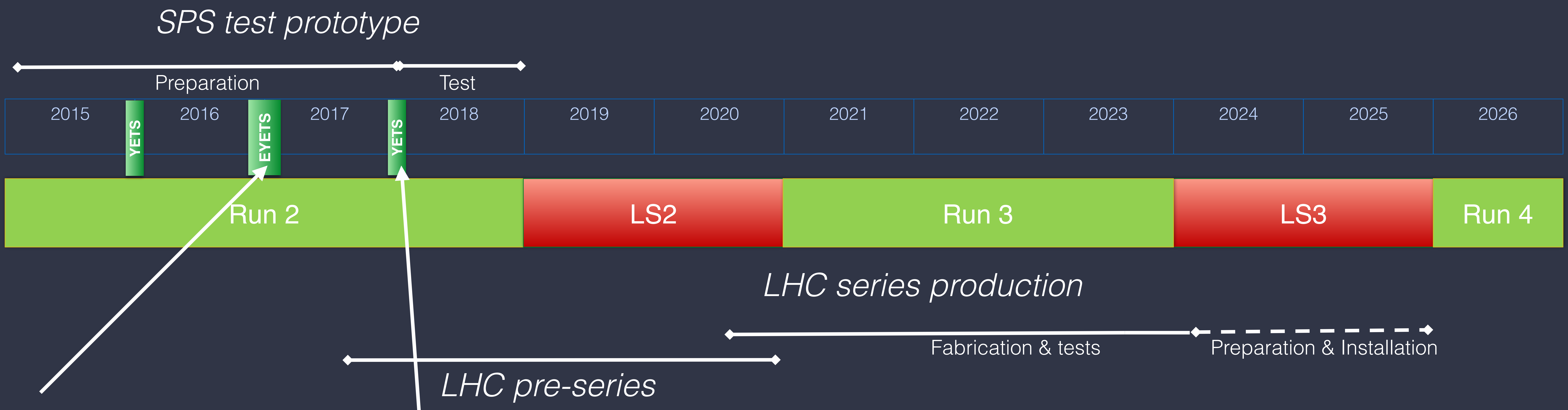
R&D: Explore full potential of Nb on Cu, new films, multi-layer, etc.



Establish **state of the art** infrastructure and performance of bulk Nb elliptical and crab cavities using existing recipes.

High Luminosity LHC

Test of a proof-of-principle cryo module in the SPS



EYETS 16/17: Main time slot for infrastructure installation

YETS 17/18: Main time slot for cryo-module installation

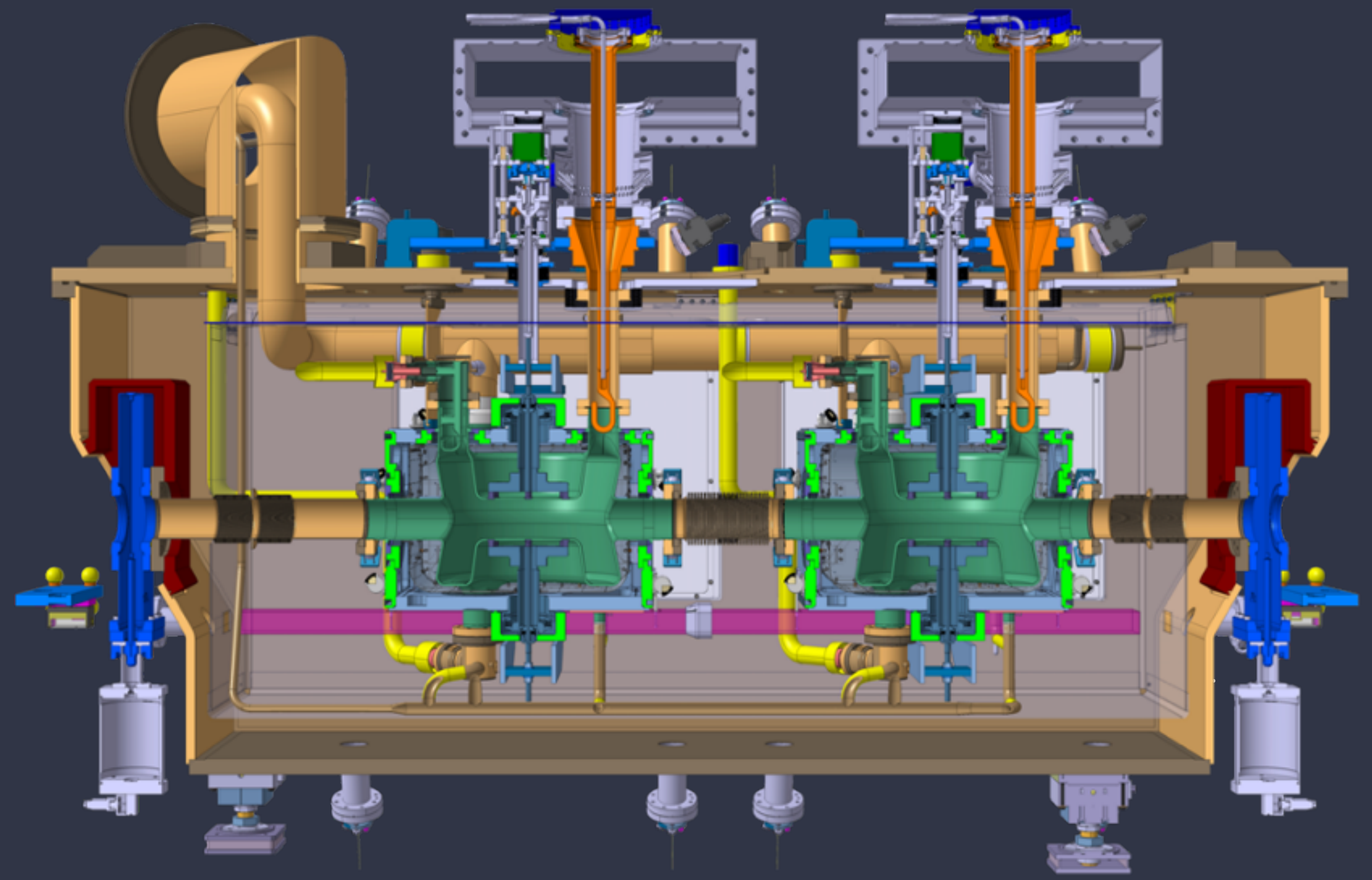
- **Scope:** test one cryo module in the SPS with beam before LS2.
- **Beam tests in 2018:** i) show that CRAB cavities can be made invincible for the beam, ii) demonstrate crabbing effect.
- Demonstrate cavity and CM technology.

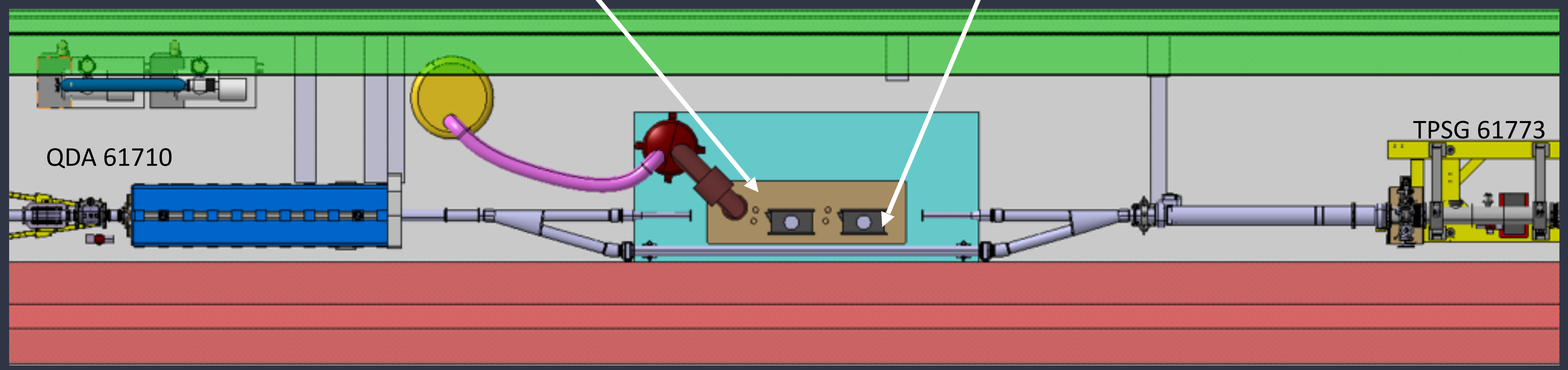
High Luminosity LHC

Test of a proof-of-principle cryo module in the SPS

- Two double quarter wave (DQW) 400 MHz cavities including couplers, tuners, and all accessories and the complete cryo-module are constructed and assembled at CERN.
- A movable table with 510 mm displacement can move the CM into or out of the beam within 20 min.

> **!** Everything needs to be ready for installation by end of 2017

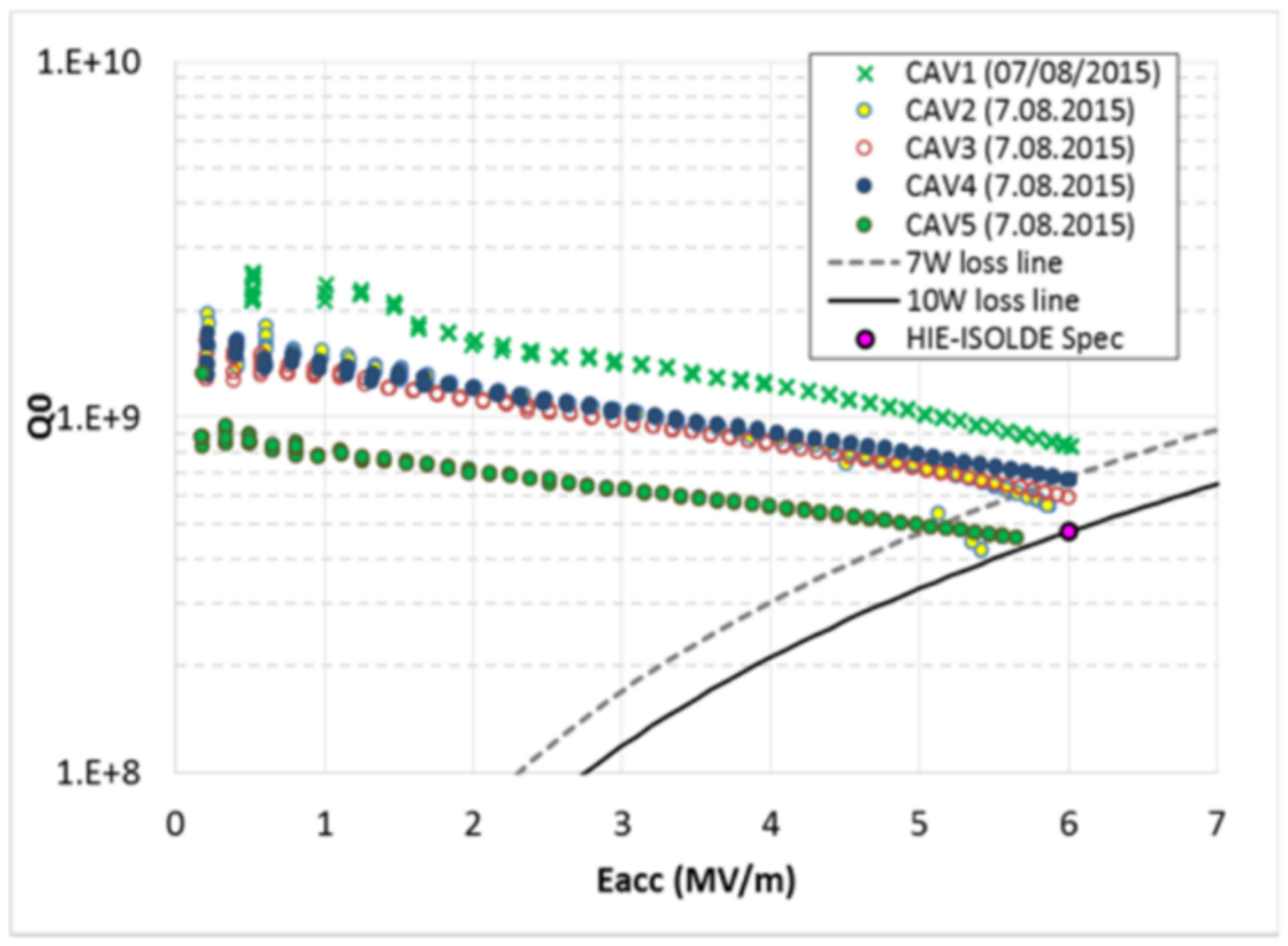




f	400.8 MHz
V_{kick}	3.4 MV
R/Q	400 Ω
T	2 K

- 5 QWR + 1 SC solenoid per cryo-module
- CM1 installed in 2015, first physics run in November 2015 (see WEOBA01, J.A. Rodriguez, IPAC16).
- CM2 is installed, first beam in June, physics run from August 2016 (11 weeks).
- CM3 scheduled for installation: 1/2 - 2017, physics run from May 2017 (25 weeks), followed by CM4.

f	101.3 MHz
E_{acc}	6 MV/m
Q	5×10^8
T	4.5 K



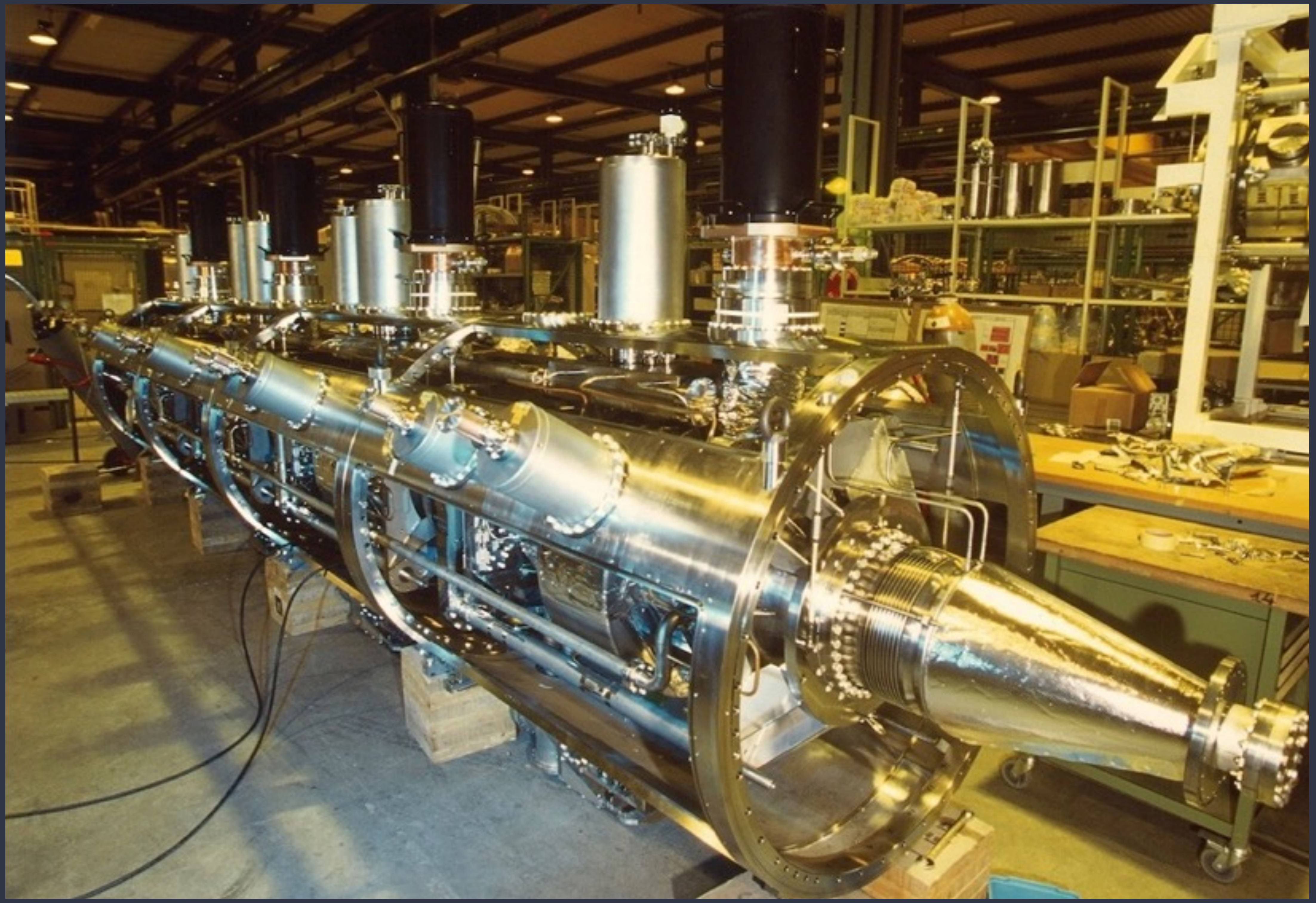
Cavity performance in 1st cryo-module
(WEPMB051, IPAC16, W. Venturini)

- The production was interrupted after the observation of what looks like micro-cracks (linear indications).
- Not fully understood but they appear after the shrink-fit and welding process.
- There seems to be an influence on the RF performance, but we don't know for sure if these indications also appear in the first CM (which exceeds nominal performance).

- CM3 will be assembled with already produced cavities.
- For CM4 the cavity production (and design) will be changed in order to suppress the shrink-fit and welding process (seamless cavities).
- CM4 will be constructed with 3 "seamless" and 2 "normal" cavities.

LHC spare cavities

.. or the reverse engineering of vital LHC technology



LHC cryo-module with 4 Nb on Cu, 400 MHz single-cell cavities.

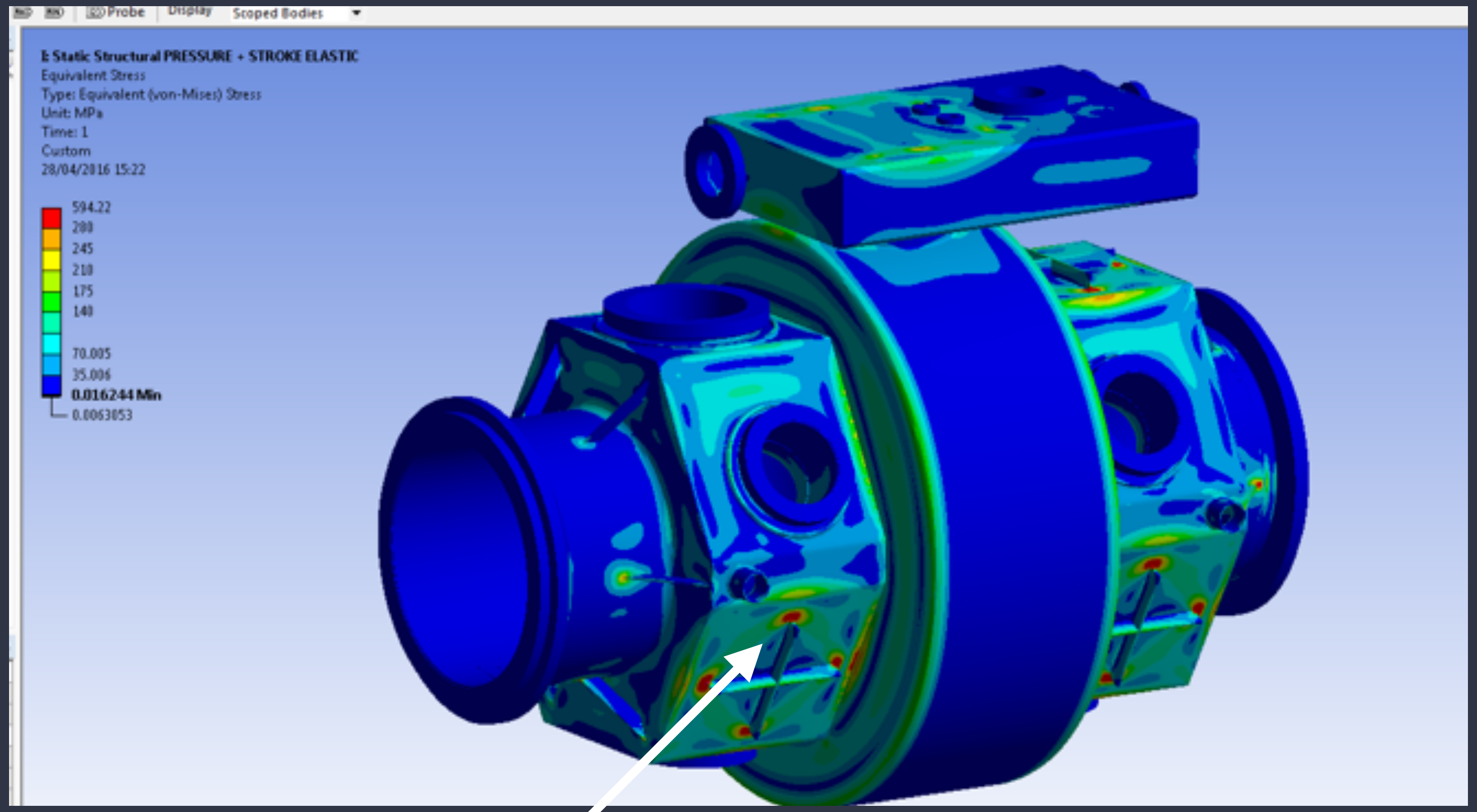
Since the design and construction of the LHC cavities:

- Most people who were involved have retired.
- Tooling is no longer available (e.g. to weld cavity half cells from the inside, or to tune cavities to their target frequency).
- The safety rules have changed (e.g. pressure vessel code).
- The reasoning for certain mechanical choices (e.g. material thickness, Cu type, heat treatments, etc) is not documented and needs to be re-understood.
- Assembly procedures are lost.

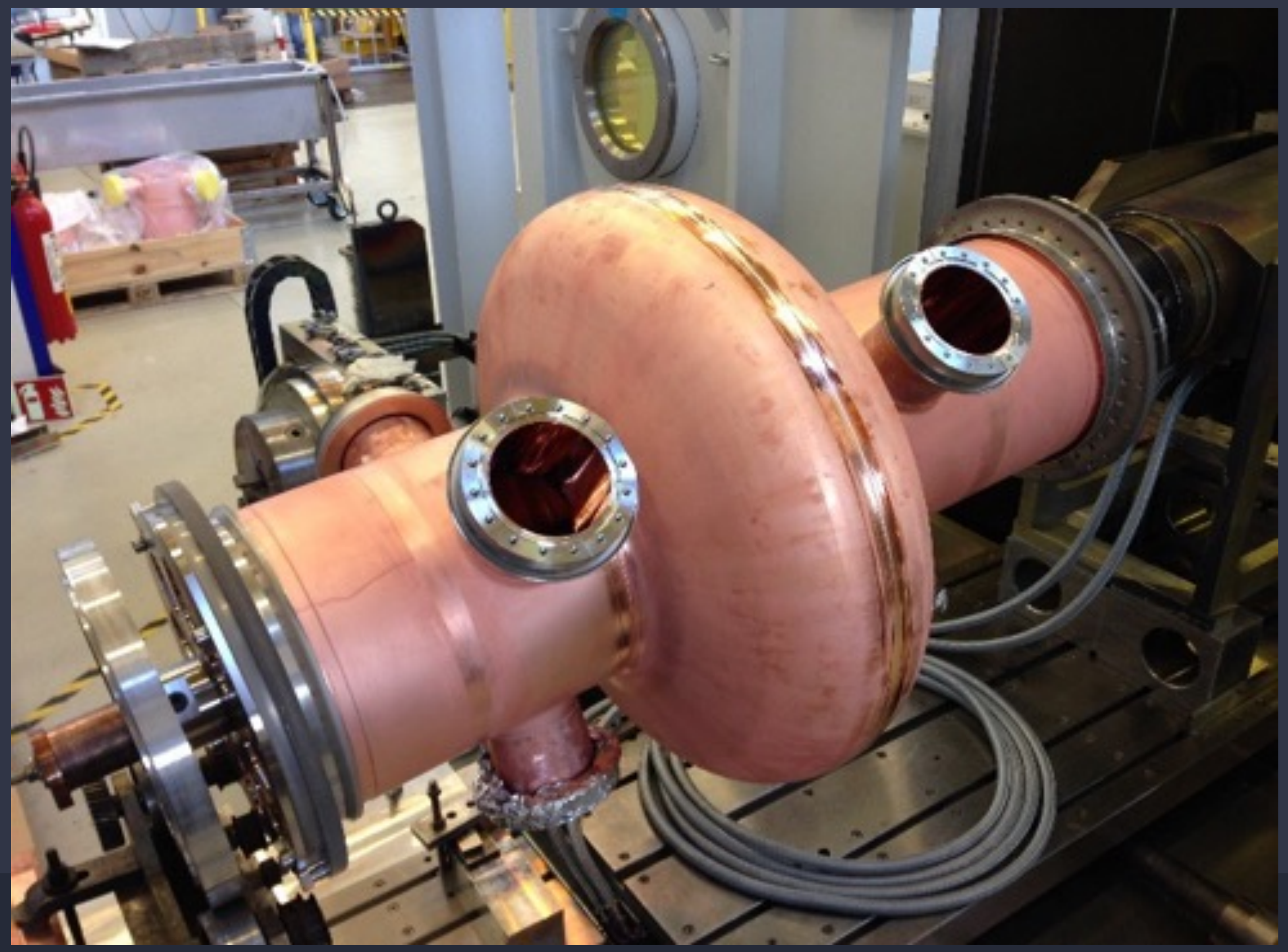
f	400.8 MHz
E_{acc}	5.5 MV/m
Q	$>2 \times 10^9$
T	4.5 K

LHC spare cavities

.. or the reverse engineering of vital LHC technology



Modern FEA reveals spots with too high mechanical stress



One complete spare module is available and the strategy is to re-establish (and document) the know-how instead of having a 2nd spare as quickly as possible:

- This will provide knowledge for the mechanical and RF teams to intervene and repair.
- A complete documentation will be available once the spares are produced.
- A staged process has been defined:
  I. Production of 2 dressed cavities and 4 bare cavities in 2017
  II. Production of missing tooling and a complete cavity string for 2018/2019
  III. Potentially: complete 2nd spare CM (to be confirmed)
- Recent coating of first CERN produced cavity successful.
- First vertical cold test on bare cavity imminent.

High priority SRF projects

core activities

- HL-LHC: Crab cavities
- HIE-ISOLDE
- LHC spare cavities

SRF R&D programs

what we do whenever we find the time...

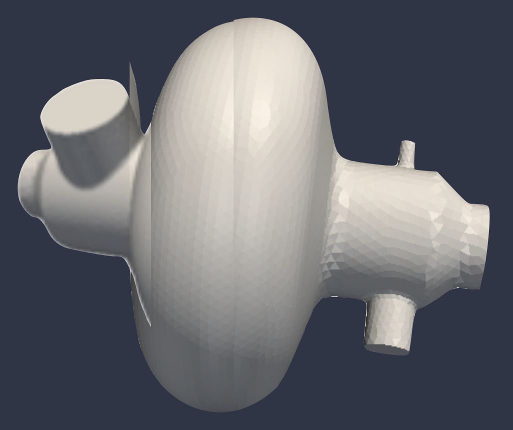
- FCC
- Thin Film R&D: deposition and el.magn. properties (QPR II, etc.)
- High Gradient (704 MHz)
- WOW cavity

FCC study: general parameters

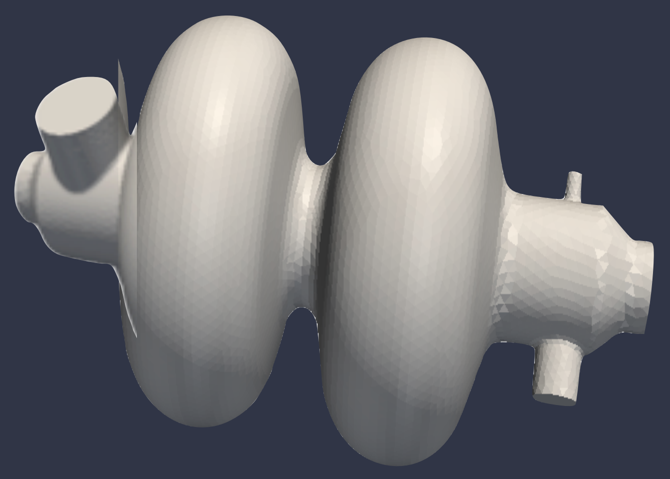
FCC-hh, Z, W, H, $t\bar{t}$

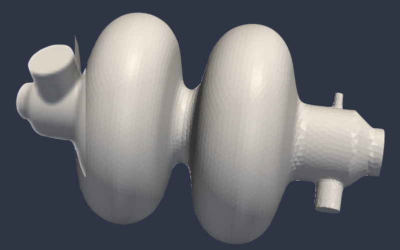
	FCC-hh	Z	Z	W	H	$t\bar{t}$
Beam energy [GeV]	**50,000**	**45.6**		**80**	**120**	**175**
Beam current [mA]	0.5	1450		152	30	6.6
Bunches / beam		30180	91500	5260	780	81
Bunch spacing [ns]	25	7.5	2.5	50	400	4000
Bunch population [10^{11}]	1.0	1.0	0.33	0.6	0.8	1.7
Crossing angle at IP [mrad]		30				
Bunch length [mm] (total)	300	6.7	3.8	3.1	2.4	2.5
Energy loss / turn [GeV]		0.03		0.33	1.67	7.55
Total RF voltage [GV]	0.032	0.4	0.2	0.8	3	10
RF frequency [MHz]	400					
cells×cavities×beams	1×25×2	1×150×2	1×75×2	2×150×2	2×400×2	2×1340
Luminosity/IP for 2IPs [10^{34} $cm^{-2}s^{-1}$]	5…30	207	89.4	19.1	5.1	1.3
SR power (total) ≈ total RF power [MW]	**5**	**100**				
Electric power for RF [MW]	**≈ 10**	**≈ 165**				
Total cryogenic power [MW]	**0.4**	**2**	**2**	**5**	**23**	**39**

400 MHz single cell



400/800 MHz 2-cell





Designs converge towards 2 cavity types to cover all FCC-ee machines and FCC-hh:

- FCC-hh, Z, W: 400 MHz single cell
- W,H,$t\bar{t}$: 400/800 MHz multi-cell (most likely 2-cell)

see O. Brunner, FCC Week Rome 2016

FCC study

SRF Cavity R&D

SCRF Cavity Technologies (CERN-INFN-STFC collaboration)

- surface processing & coating infrastructure for 800 MHz (CERN)
- RF test bench (CERN)
- Seamless 800 MHz cavities (INFN)
- 6 GHz cavities for coating R&D (INFN)
- 400 MHz cavity fabrication techniques (INFN)
- Microscopic and surface characterisation of samples (STFC)

CM challenges

Electro-Hydraulic Forming (development started in the frame of the SPL study)

see E. Cantergiani, FCC Week Rome 2016

SCRF Cavity Material and Performance (CERN, UNIGE, HZB, TUW)

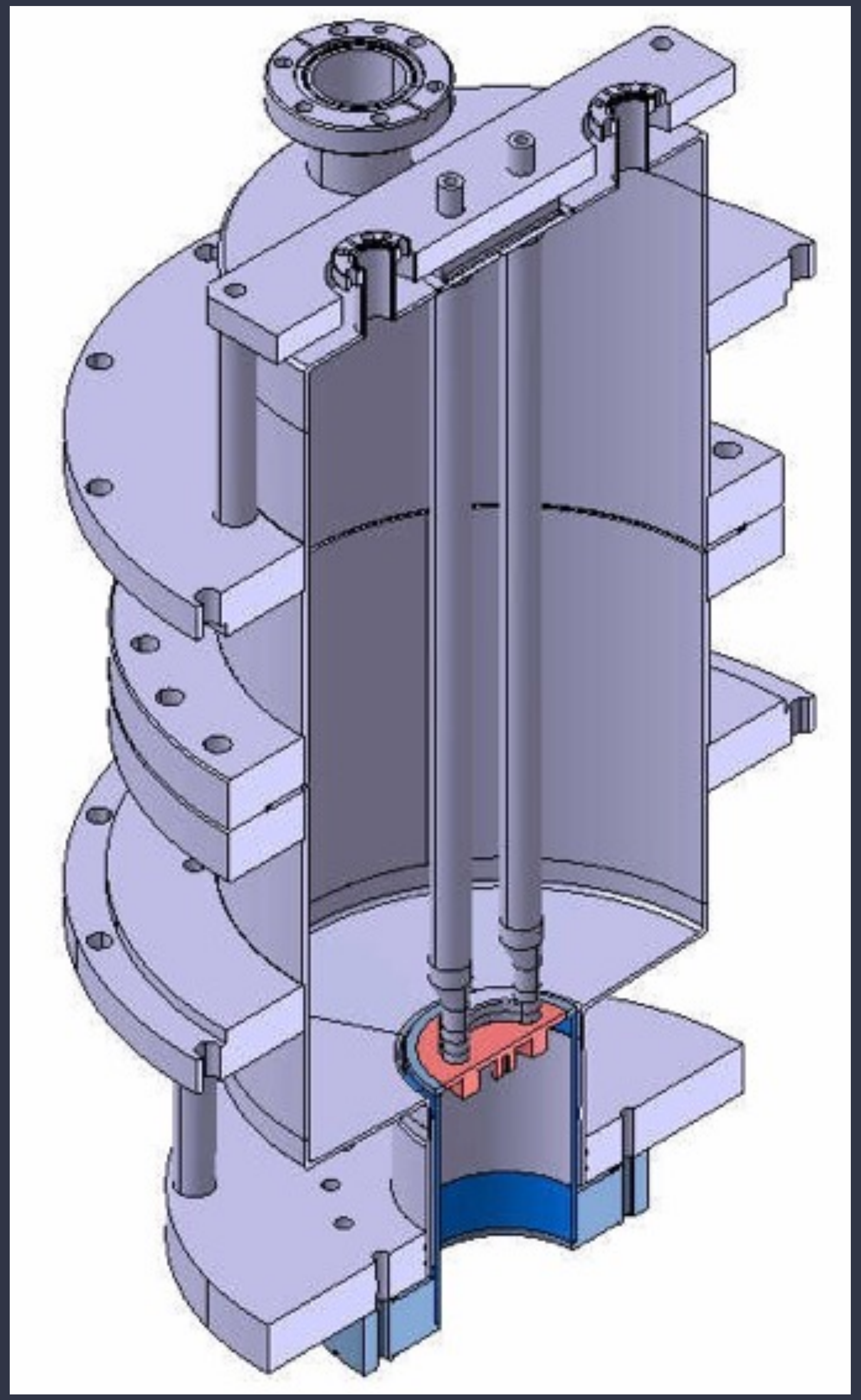
- CU surface preparation,
- DC and AC sample testing,
- RF measurements and diagnostics
- Nb-Cu coatings
- A15 coatings (alternative materials)
- Preparation and test of bulk Nb surfaces

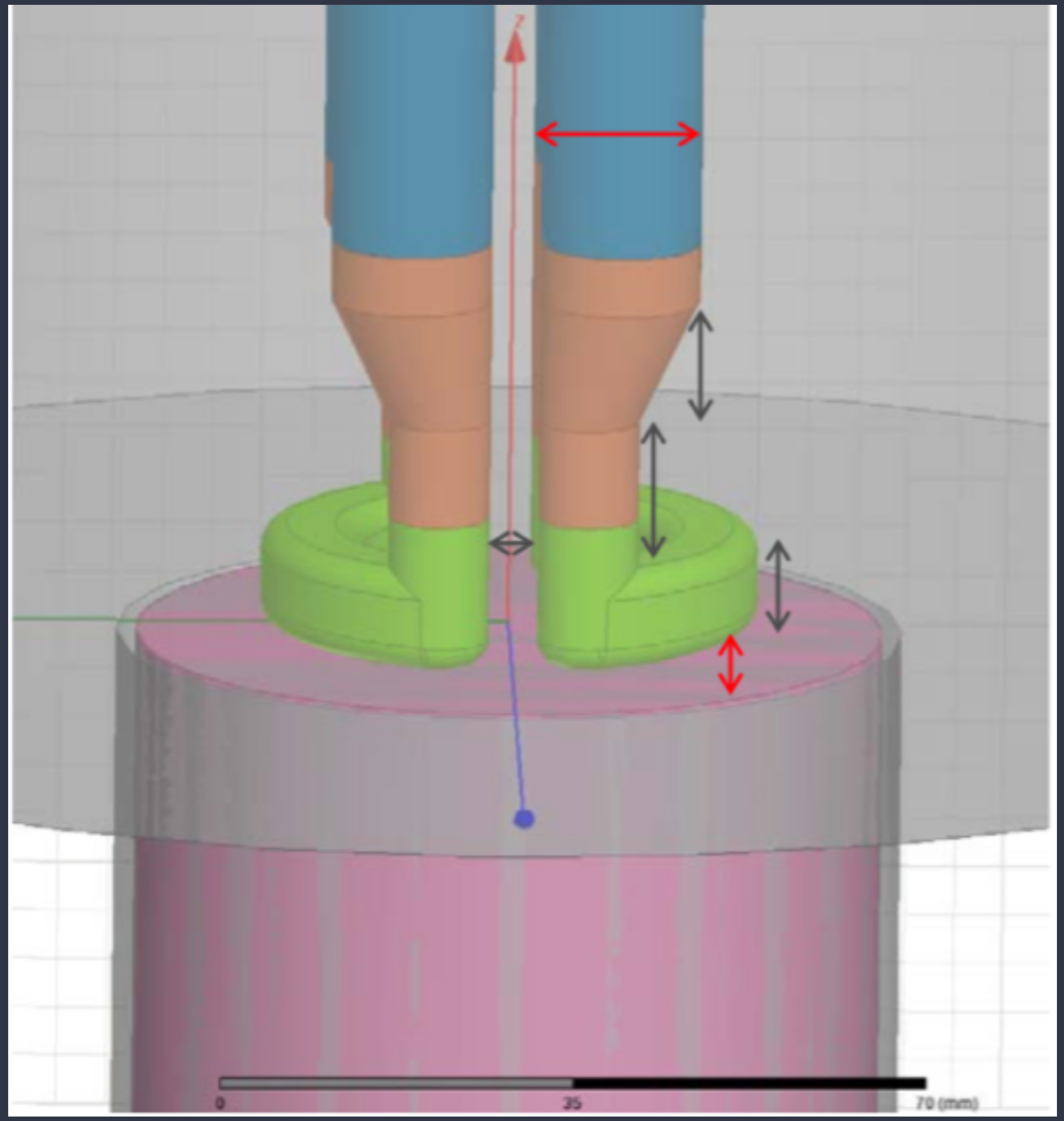
Cavity design and HOM couplers (CERN-Rostock)

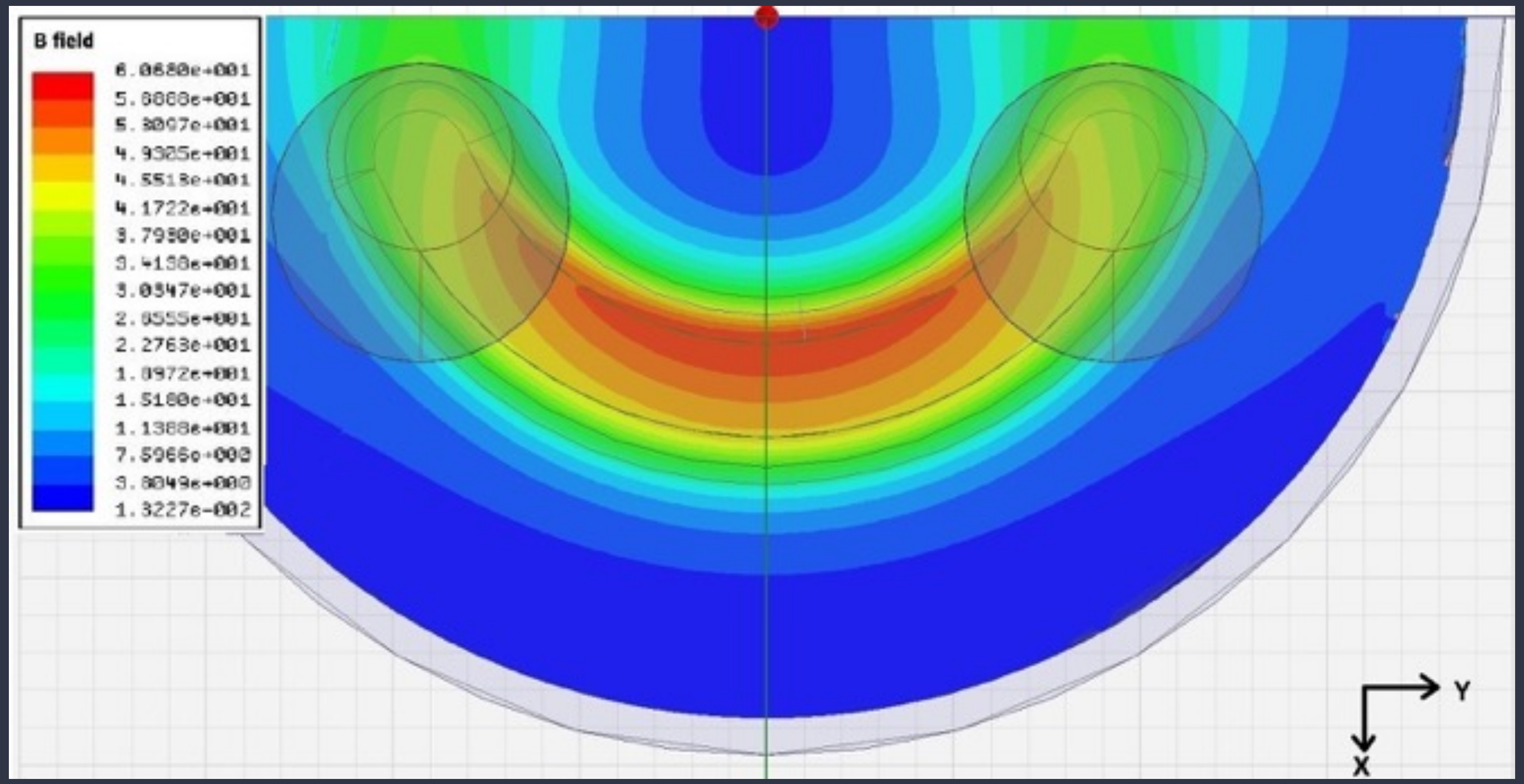
- 400/800 MHz cavity design for the different physics cases
- HOM coupler design

Quadrupole Resonator (QPR)

testing of thin film samples



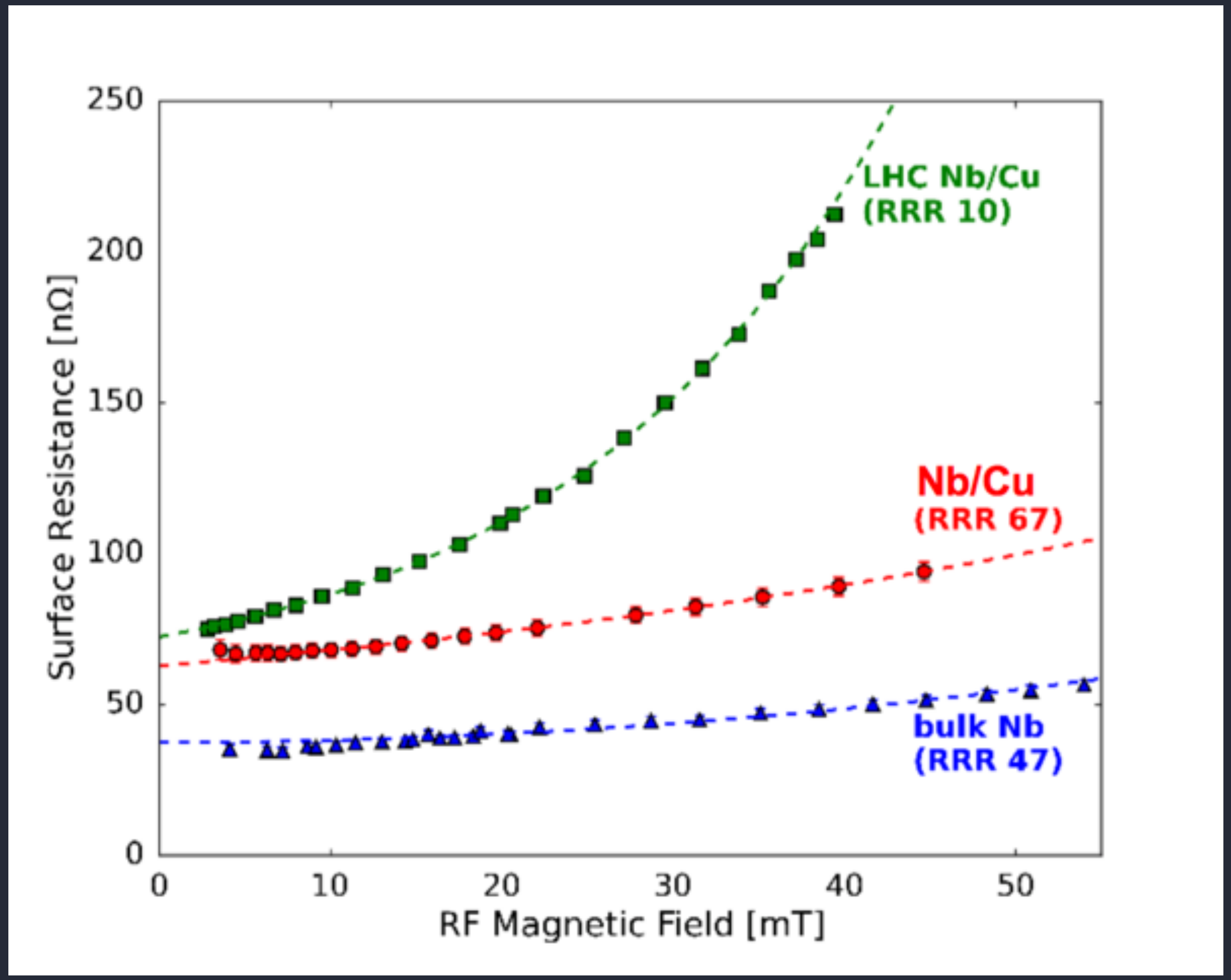




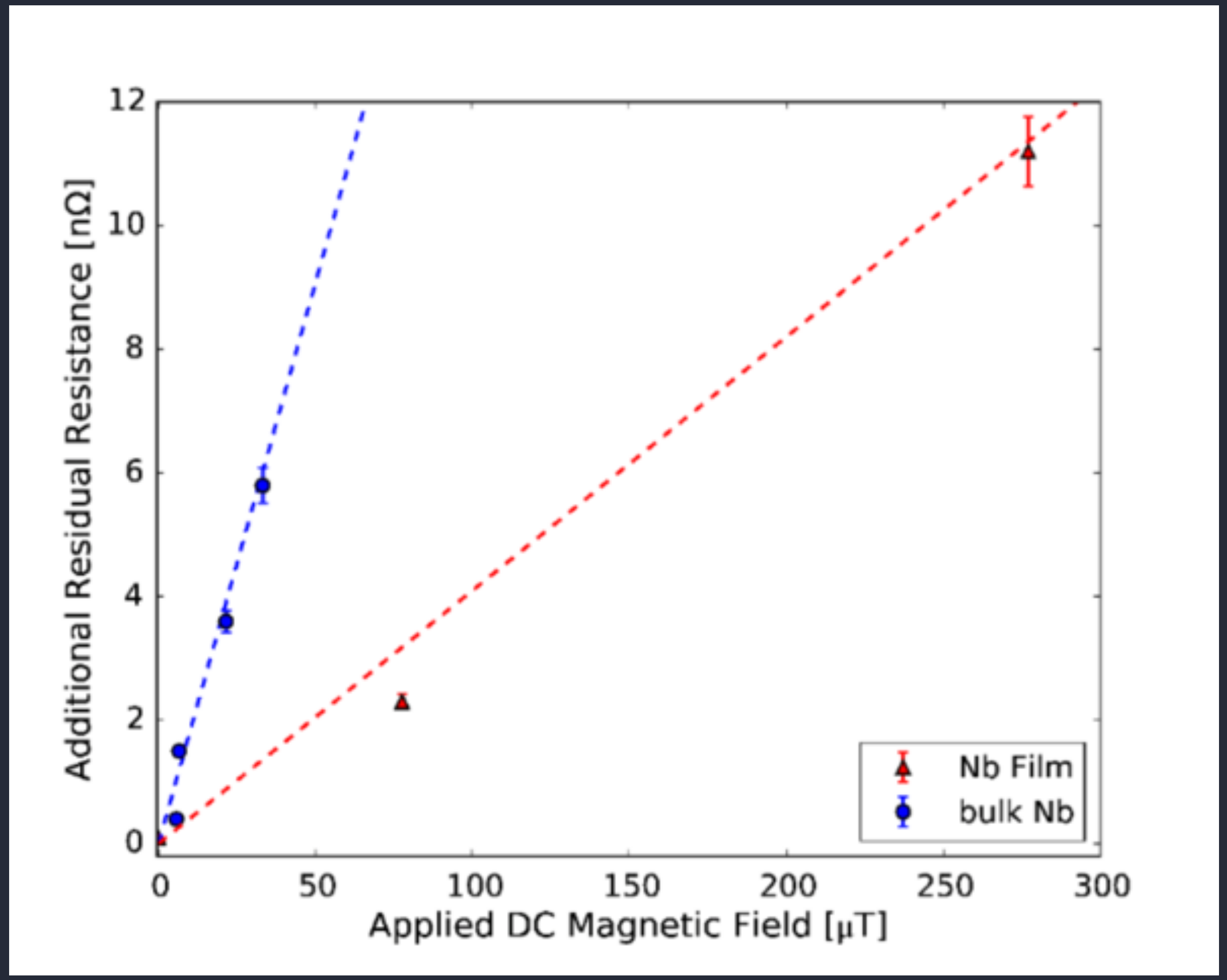
- Testing of Nb on Cu samples at 400 MHz, 800 MHz, and 1200 MHz with magnetic fields on the samples > 100 mT
- The pole shoes focus magnetic field on the sample surface
- 1st generation developed at CERN (60 mT), 2nd generation under commissioning at HZB (120 mT), 3d generation under development at CERN, (fabrication in 2017)

First thin film samples without Q-slope

testing of thin film samples



Q-slope comparable to bulk Nb at 4 K

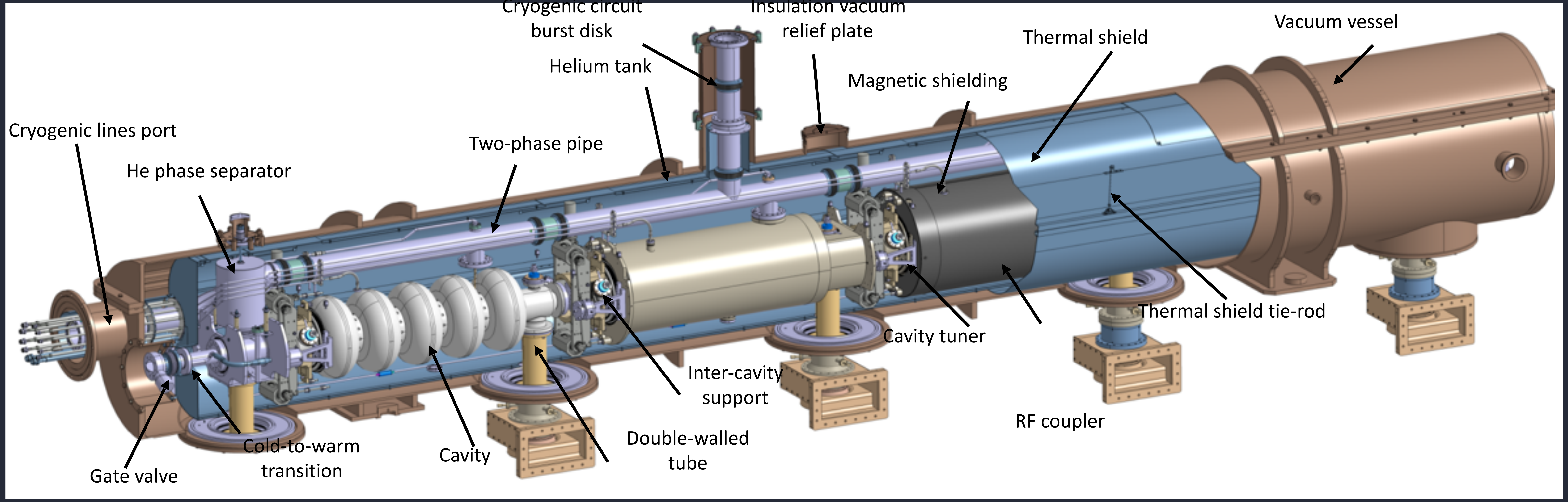


Less sensitive to external magnetic field

see S. Aull, SRF 2015

704 MHz High-gradient cavities

from the former SPL study



- Goal: 25 MV/m at $Q_0=1\times10^{10}$
- Stainless steel helium tanks.
- Power couplers support the cavities.
- Four 5-cell cavities produced in industry.
- He tanks, vacuum tank, couplers are ready.
- 3 cavities are electropolished, 2 have been cold-tested repeatedly (more later).
- CM assembly can only be done after the assembly of the CRAB cavity CM for the SPS test: 2018

704 MHz High-gradient cavities

from the former SPL study

More detailed news will be presented:

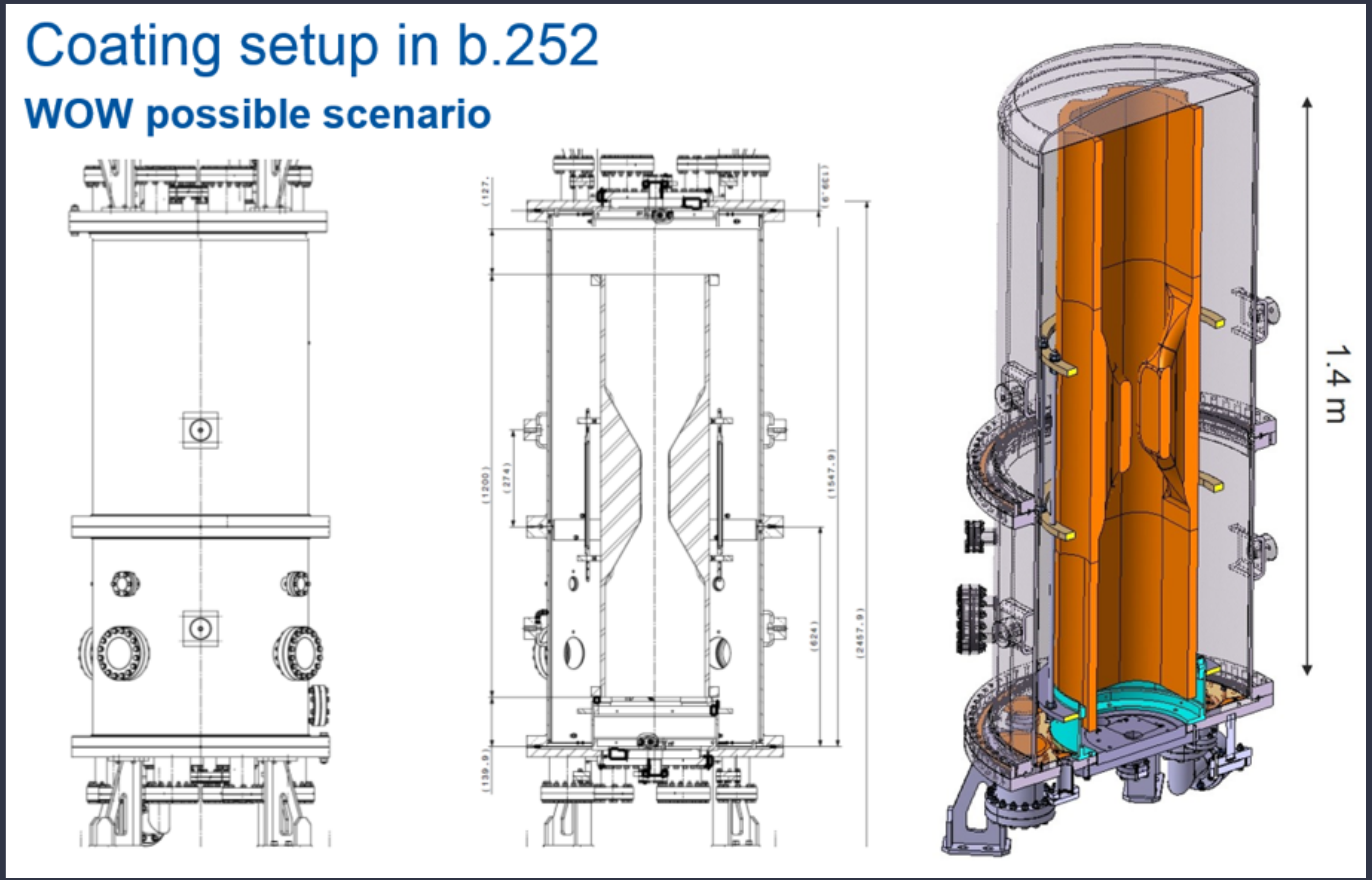
- Cold measurements and tests (Katazyna Turaj & Hernandez Chahin)
- Couplers (Eric Montesinos)
- HOM couplers (Kai Papke)
- Cryo-module status (Luca Dassa)
- Magnetic shielding (Sotirios Papadopoulos)
- Cavity shaping with Electro-Hydro-Forming (Elisa Cantergiani)

Vacuum vessel, designed and procured via CEA collaboration (special French contribution)

WOW cavity

Wide Open Waveguide Crab Cavity

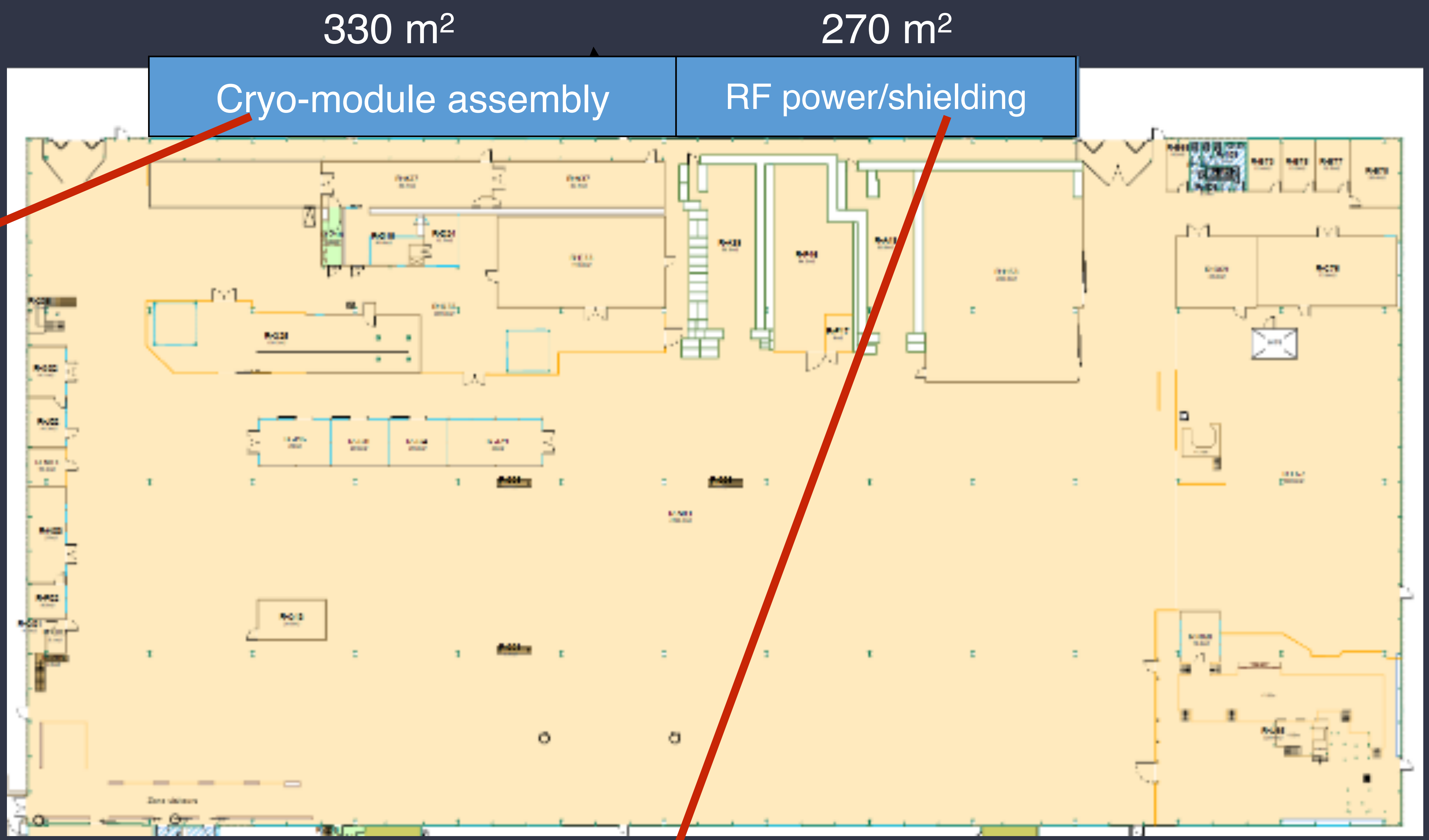
- Nb on Cu coating using a geometry that has been optimised for coating. Coating remains challenging!
- 2 prototypes are foreseen
- Potential alternative solution in case bulk Nb cavities are not viable. Advantages are:
  - natural HOM damping, low longitudinal and transverse impedances,
  - operation at 4K
- Not part of the HL-LHC project.



SRF infrastructure

extension of SM18

- Space outside the clean rooms needed for pre-assemblies and for preparation of clean room assemblies.
- Having several assembly lines for the different projects will enable a more efficient use of the clean rooms.
- Storage of assembly tooling



- Space for coupler assembly and testing in bld. 864 will also be increased

- To extend the area of the RF stations. Today there is only space for the LHC RF system + one more (e.g. CRAB). There is no space to fit RF for 200 MHz, 800 MHz, or any other frequency. Today the 2 horizontal bunkers cannot be used to full capacity because we have not enough space for high-power RF.
- To increase the shielding towards the outside of the building in the area of the horizontal/vertical bunkers.
- Funding exists, green light given by the directorate for accelerators and technology.

Thank you