SRF cavity tests at CALIFES

CALIFES workshop, 10-12 October 2016, CERN

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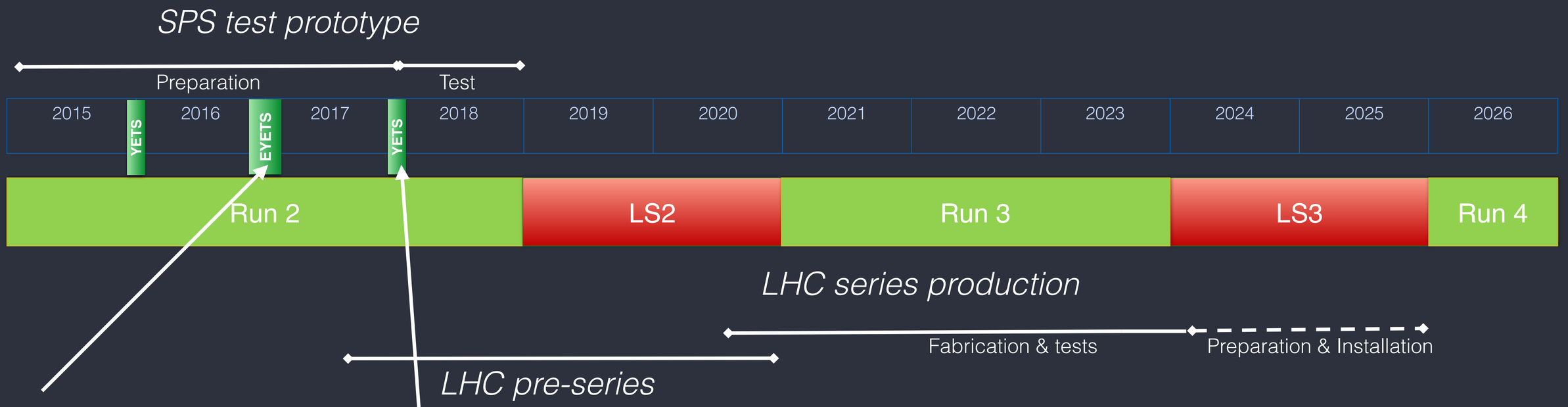
High priority projects

Crab Cavities for HL-LHC
HIE ISOLDE
LHC spare cavities

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

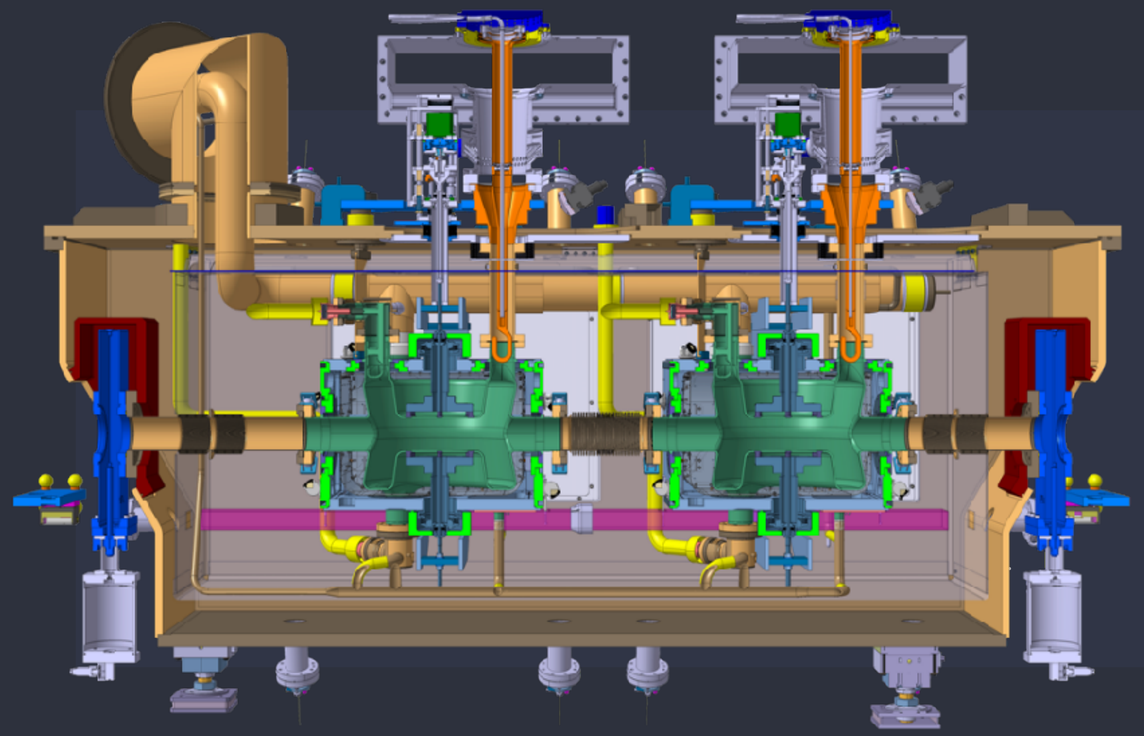
- **Scope:** test one cryo module in the SPS with beam before LS2.
- **Beam tests in 2018:** i) show that CRAB cavities can be made invincible for the beam, ii) demonstrate crabbing effect.
- Demonstrate cavity and CM technology.

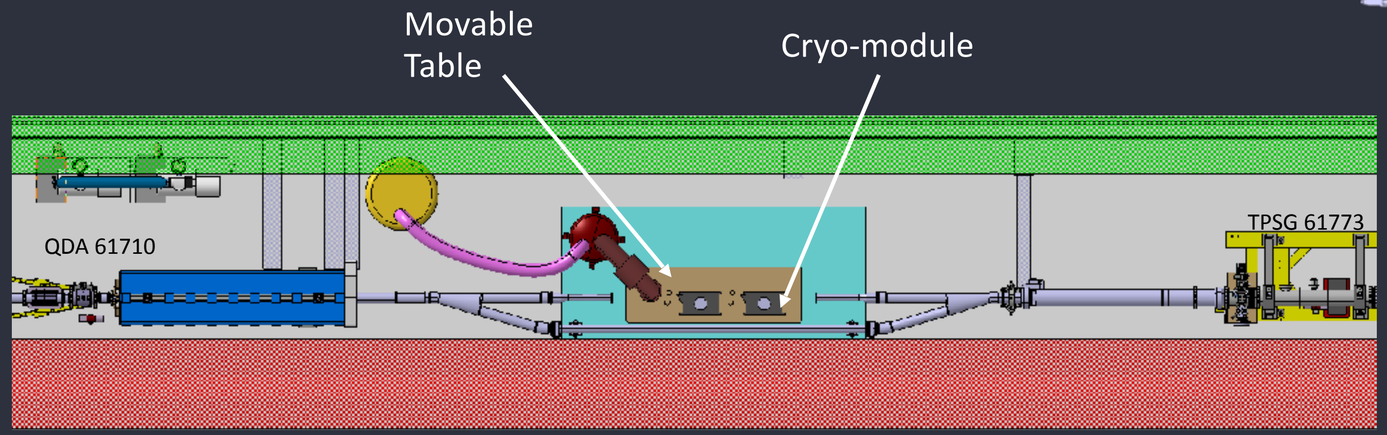
High Luminosity LHC

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

High Luminosity LHC

- Crab cavities have been tested on electron machines before (e.g. KEKB)
- No test so far on hadron machines —> interest in SPS test, verify if Crabs can be made invincible for the beam.
- Verify crabbing effect.

What could be done at CALIFES:

- CALIFES 3 GHz vs 400 MHz,
- **single bunch wakefield measurements**,
- advantage not to be bound to SPS operational schedule,
- **CALIFES cannot replace SPS test**
- but still needs the same infrastructure (cryogenics and RF) as in the SPS test stand

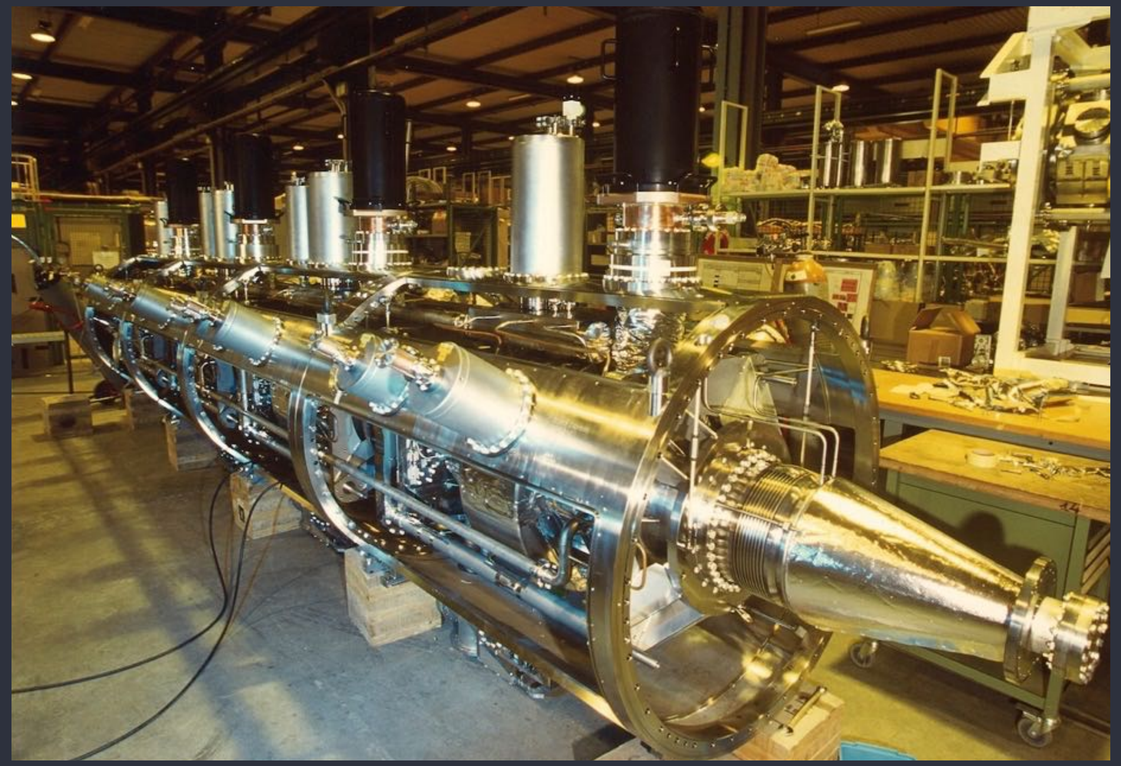
HIE ISOLDE

- 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.

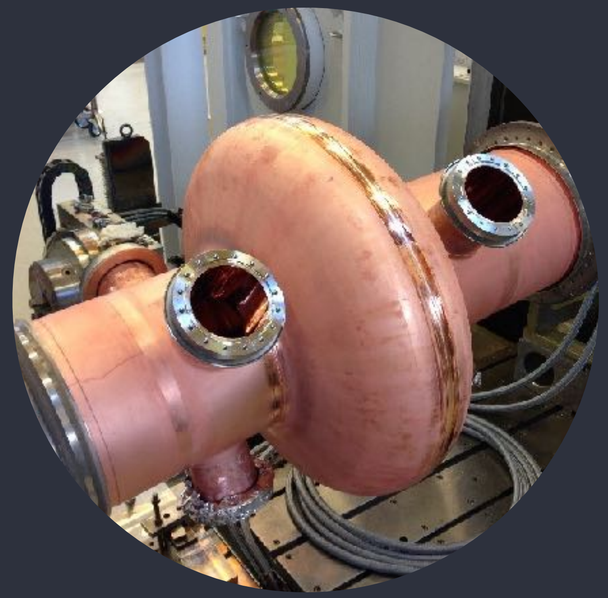
f	101.3 MHz
E_{acc}	6 MV/m
Q	5 x 10^8
T	4.5 K

No scope for any tests at CALIFES

LHC spare cavities



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



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

- 2 trains of 4 cavities will be produced until mid 2019
- same geometry as original
- known behaviour, **no need for beam tests at CALIFES**

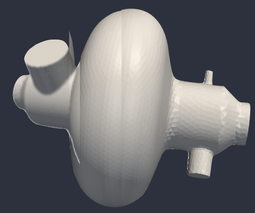
R&D projects

FCC
High Gradient Bulk Nb
WOW

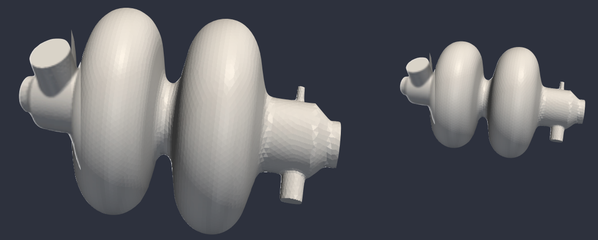
FCC cavities

	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 cavities

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)

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

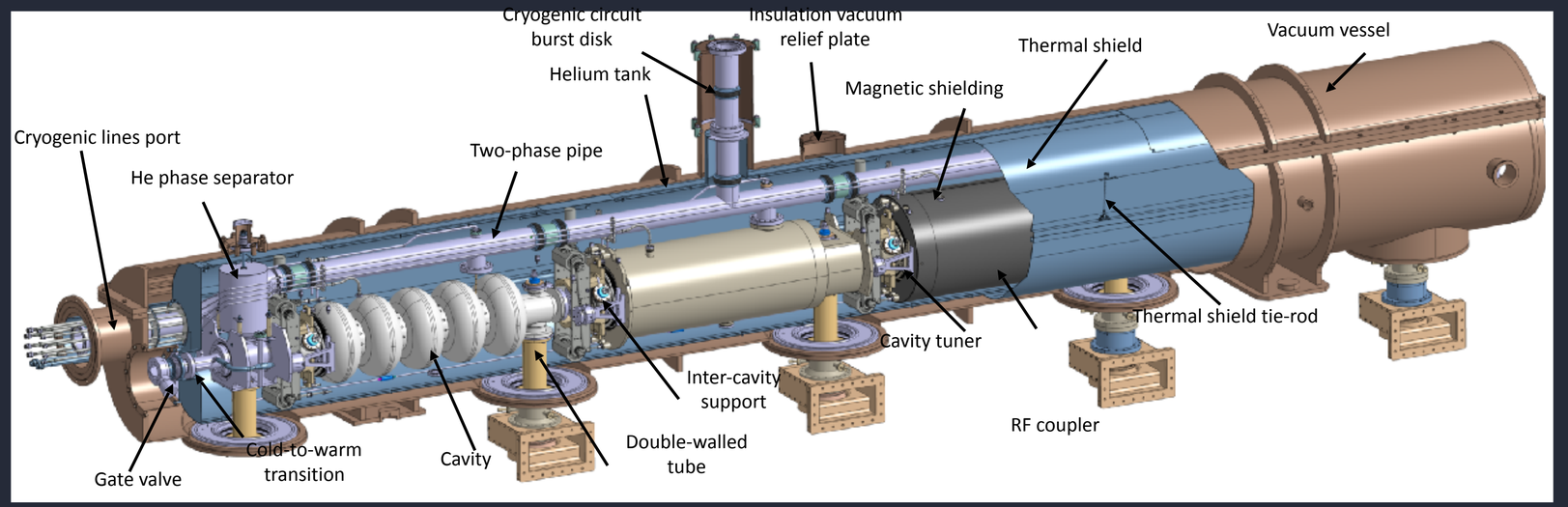
see E. Cantergiani, FCC Week Rome 2016

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

- present effort mostly on coating and forming technologies,
- HOM's will be a serious issue,
- **wakefield measurements at CALIFES could help to optimise cavity shapes and to test HOM couplers**

High gradient 704 MHz module

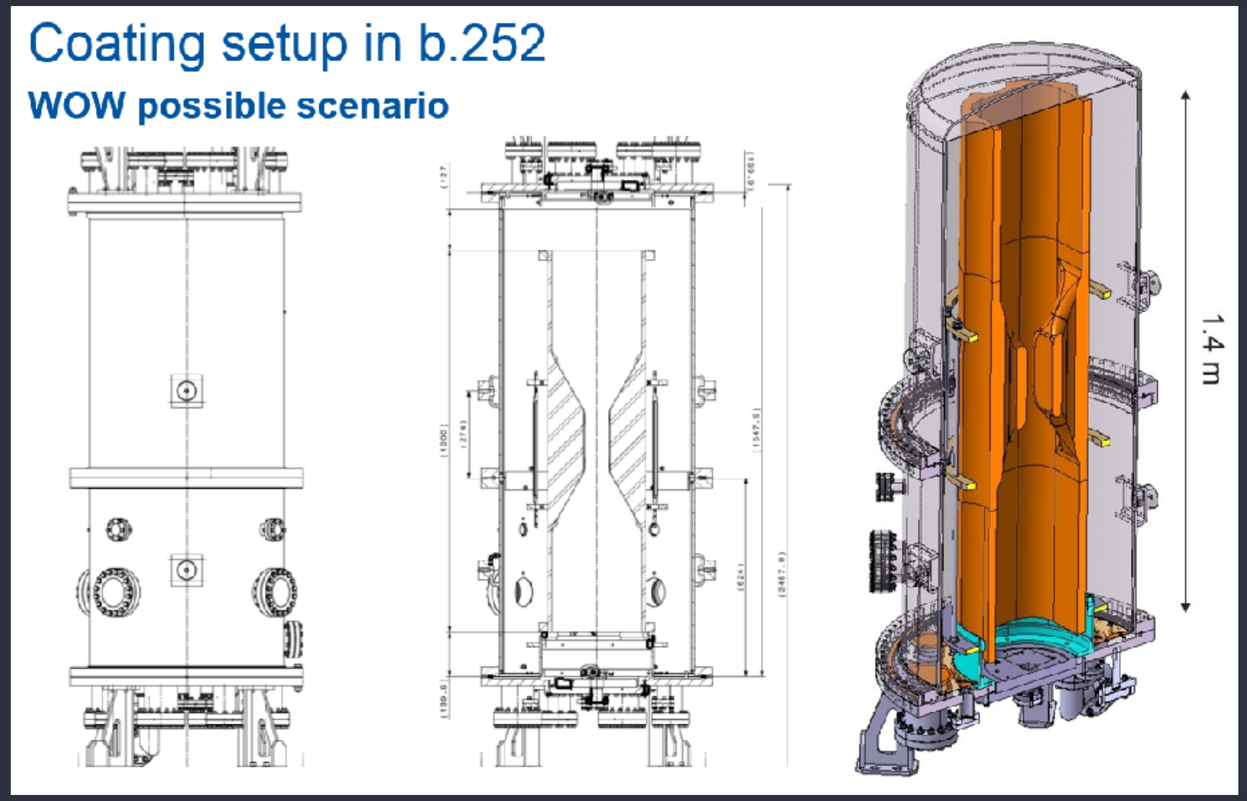


- Legacy of the SPL study
- Goal: 25 MV/m at Q_0=1x10^{10}
- advance CM design and assembly know-how
- Bulk Nb performance is the reference for comparison with Nb on Cu coatings

- Assembly foreseen for 2018.
- **Beam tests would be interesting.**
- **Module could be used for a small ERL** (CERN management refused to have an 800 MHz ERL test facility at CERN, and now CEA is interested)

Wide Open Waveguide Cav.

- Potential alternative solution in case bulk Nb cavities are not viable. Advantages are:
  - natural HOM damping, low longitudinal and transverse impedances,
  - operation at 4K
  - no coupler feed throughs needed in helium vessel
  - potentially very cheap
- Not part of the HL-LHC project.
- Currently under evaluation, if the study continues.
- **Beam tests could be interesting on the 2nd generation of these cavities** (which should include power coupler, HOM damping), > 2019



Infrastructure

RF
Cryogenics

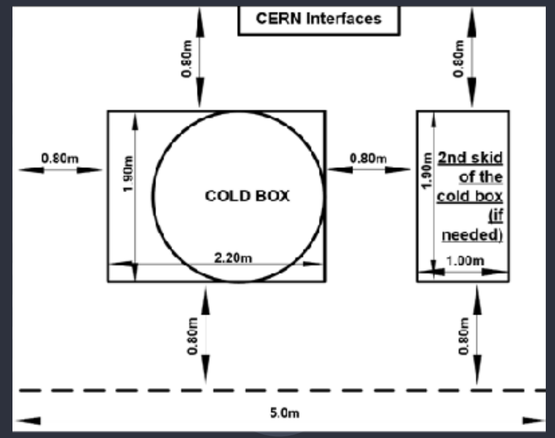
Example: RF at 704 MHz

U_k	-110 kV
I_k	25 A
P_{pulse}	2.6 MW
f_{rep}	1-50 Hz
Z_k	4.4 kΩ
$T_{pulse}/T_{flat\text{-}top}$	1/0.8
droop	1%

- Modulator for one 704 MHz klystron, probably enough for single bunch beam tests with 4 cavities,

- New compact 704 MHz klystron from Thoshiba

Example: Cryo for SPS Crab Test

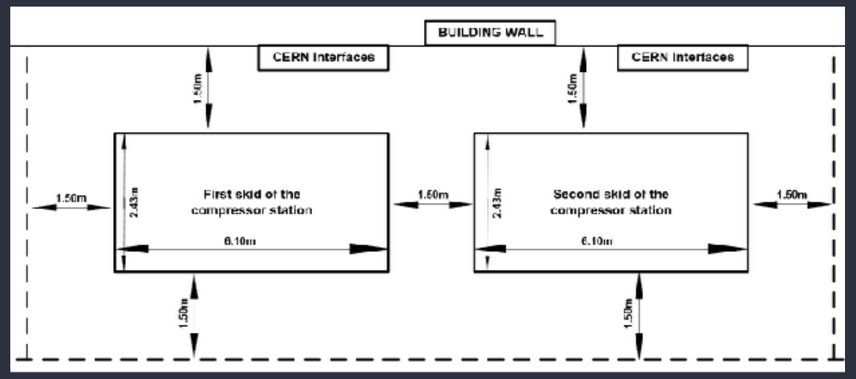


Cold Box & ancillaries

1.9 m x 2.2 m

1.9 m x 1 m

plus handling space

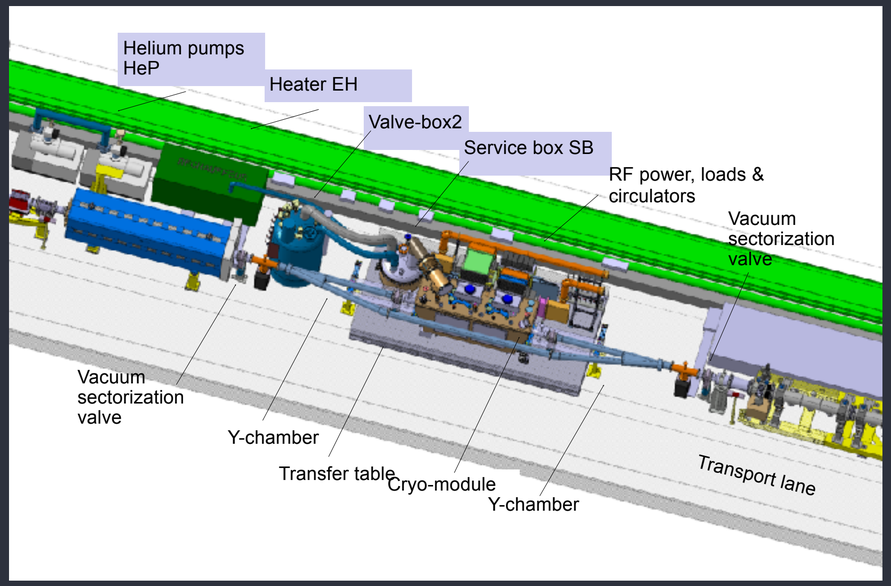


Warm compressor & ancillaries

2.4 m x 6.1 m

2.4 m x 6.1 m

plus handling space



Proximity to CM

Valve box & service box

helium pumps & piping

heater

plus handling space

plus Helium storage: 15 m high, 2.5 m in diameter

Summary

- Califes would be of limited use for CERN's high-priority SRF projects, (CRAB cavities wake field measurements)
- It would be interesting for some of the low-priority R&D projects (e.g. FCC, WOW crab cavity, high-gradient program, ERL)
- Substantial infrastructure investment needed (RF, cryogenics, local mobile clean rooms for connections)
- Synergies with VELA and CLARA at Daresbury should be explored (SRF infrastructure already in place)

THANKS

FOR

LISTENING