Nb-coated copper crab cavity alternative for FCC

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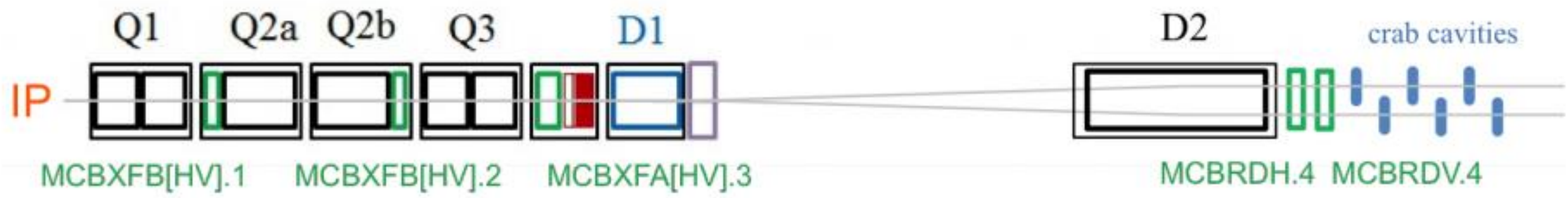
Outline

- Crab cavity system for FCC-hh
- Motivation for Nb-coated crab cavity
- Cavity design and parameters
- Budget and time line

Crab cavity system for FCC-hh (april 2017)



Schematic layout:
E. Cruz-Alaniz,
Nov. 2016, Barcelona

	FCC-hh		HL-LHC (R. Calaga, Chamonix 2012)
RF frequency [MHz]	400		400
Total voltage V [MV]	18 (uncertainty ±20%)		6 ÷ 10
Available length [m]	20		
Beam separation [mm]	250 (maybe 204 soon)		194
Average beta in the ring [m]	(339+67)/2 = 203		200
Beta* [m]	0.3	0.1	15 ÷ 25
Crossing angle [urad]	89	154	235 ÷ 290
Beta at CC location [m]	10100 ÷ 10900	30300 ÷ 32700	4000

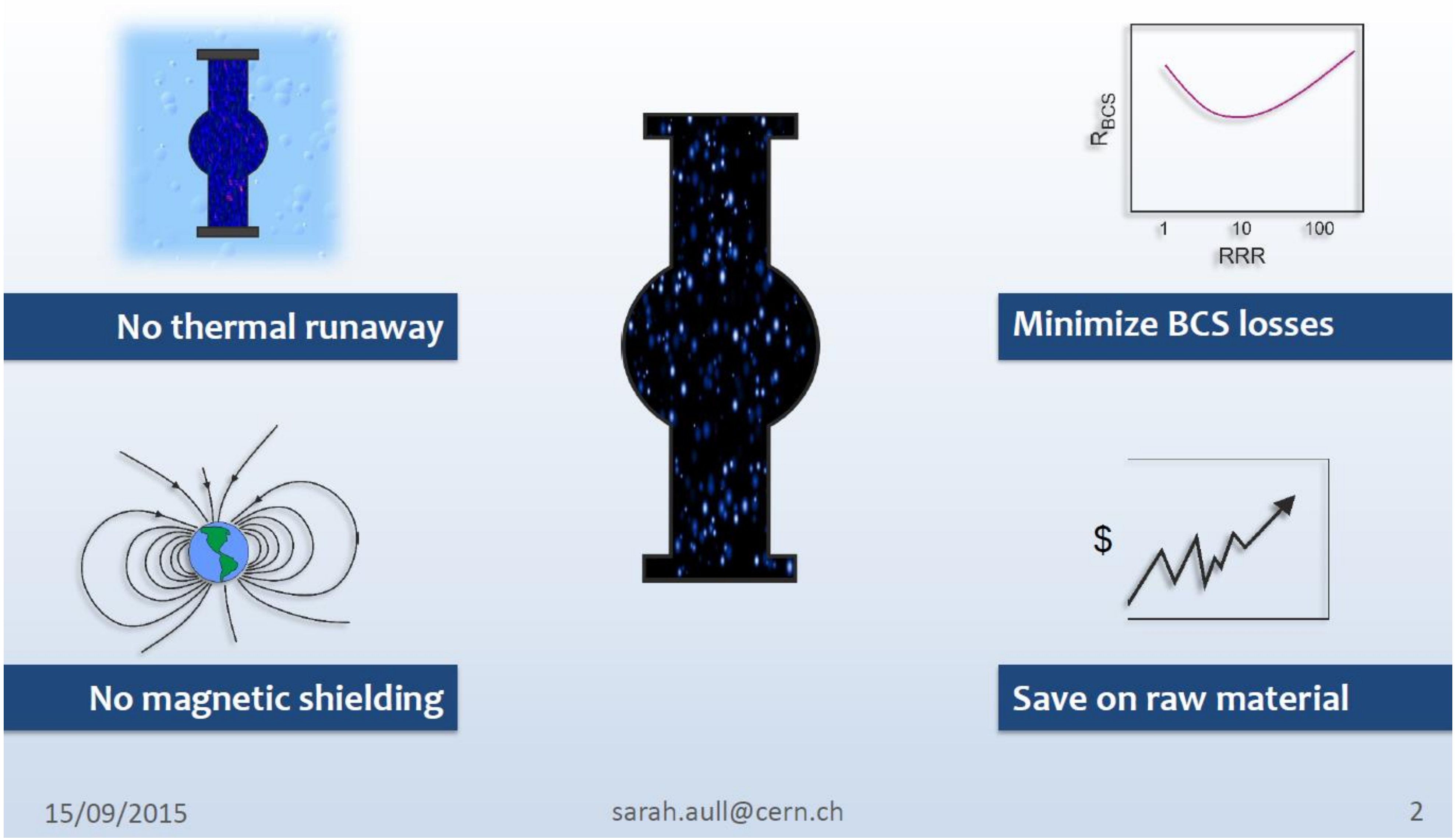
Information for FCC-hh provided by FCC-hh general design WG: D. Schulte, E. Cruz-Alaniz, A. Seryi, R. Martin, R. T. Garcia

Comparing CC pars for FCC-hh to the HL-LHC

- MORE CCs: Total voltage is 3 (2) times higher => **6** cavities per beam/side/IP
- Available length: 20m/(6x2) = 1.7 m per cavity is sufficient even for longer alternatives (WOWCC)
- Larger beam separation 250 vs 194 may give some advantages in case of redesign
- EFFECTIVE TRANSVERSE IMPEDANCE IS MUCH (up to 3x8=**24** times) HIGHER than for HL-LHC:
  - Beta function at the CC location is 2.5 -> **8** times higher for the same <beta>
  - Number of cavities per beam 2-**3** times higher
- Low impedance CC are desirable
- In Conclusion: larger number of cavities, larger beam coupling impedance and different beam separation justifies looking into new alternatives for FCC-hh CC system

Motivation

S. Aull, SRF2015



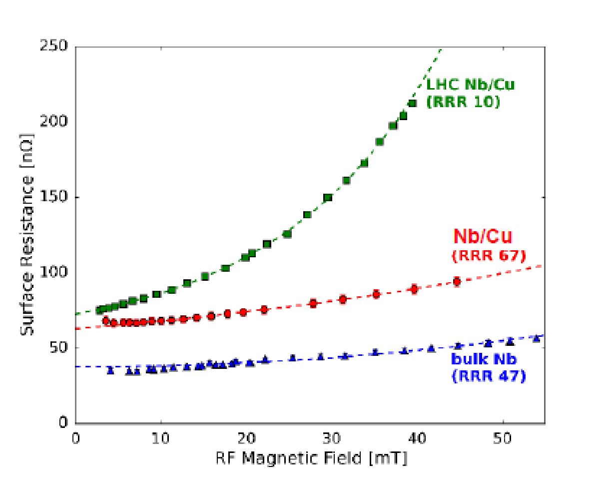
Motivation

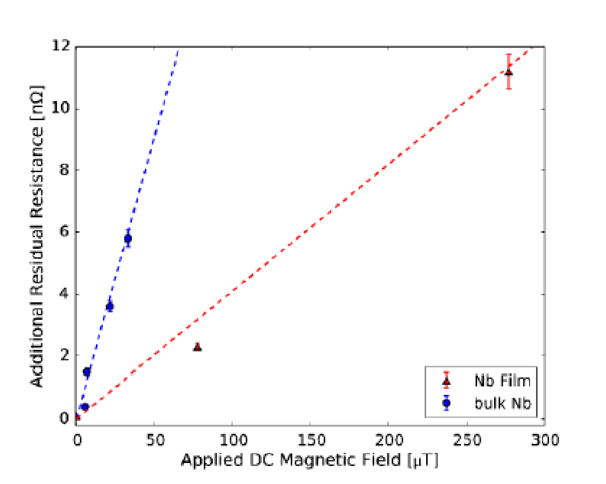
Can we apply the state of the art coating technique to 400 MHz crab cavity?

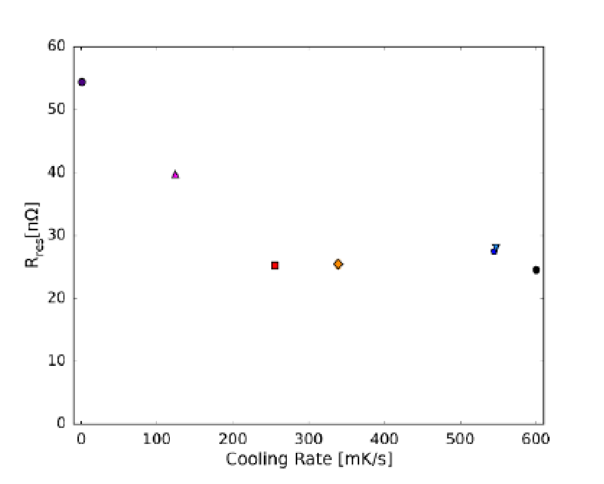
Summary

S. Aull, SRF2015

We have a bulk-like Nb/Cu film…







with a Q-Slope comparable to bulk niobium at 4 K

still less sensitive to trapped flux

severely affected by thermal currents?

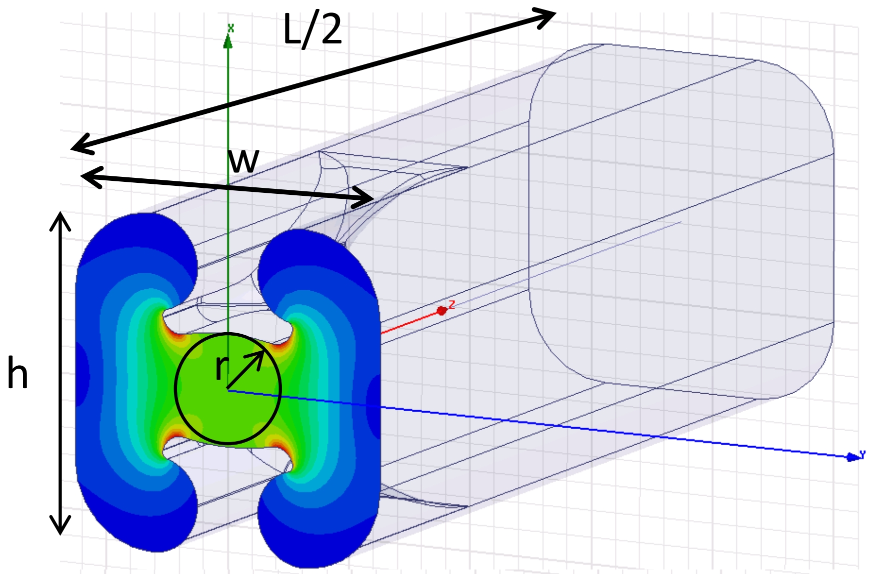
Introduction

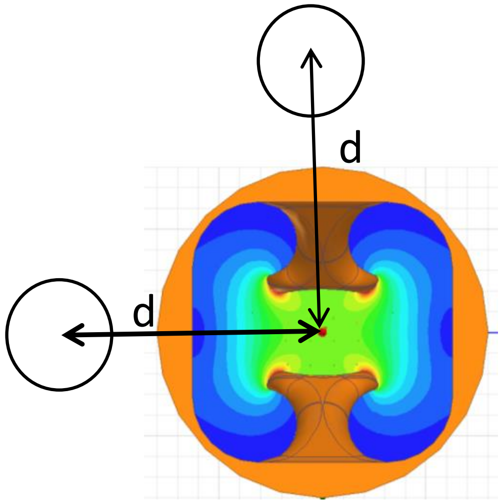
- This work package covers design, construction and testing of 2 prototypes of a compact superconducting crab-cavity for LHC using Nb-on-Cu-coating technique.
- The cavity shape is based on the ridged waveguide resonator with wide open apertures to provide access to the inner surface of the cavity for coating.
- It also provides natural damping for HOMs and rather low longitudinal and transverse impedances.
- **The final goal is to validate the fabrication and coating of the cavity prototypes and to characterize its high gradient performance in a vertical test at 4K**

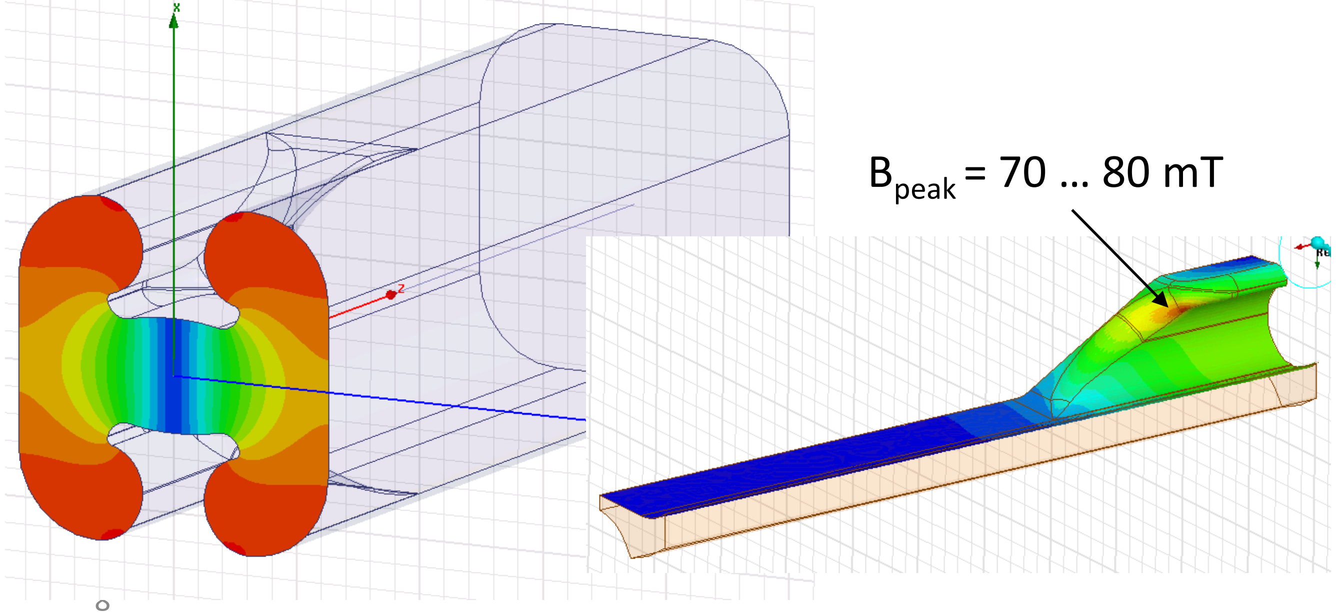
Main Parameter

w [mm]	251.70
h [mm]	251.70
r [mm]	42.00
L [mm]	1400.00
d [mm]	192.00

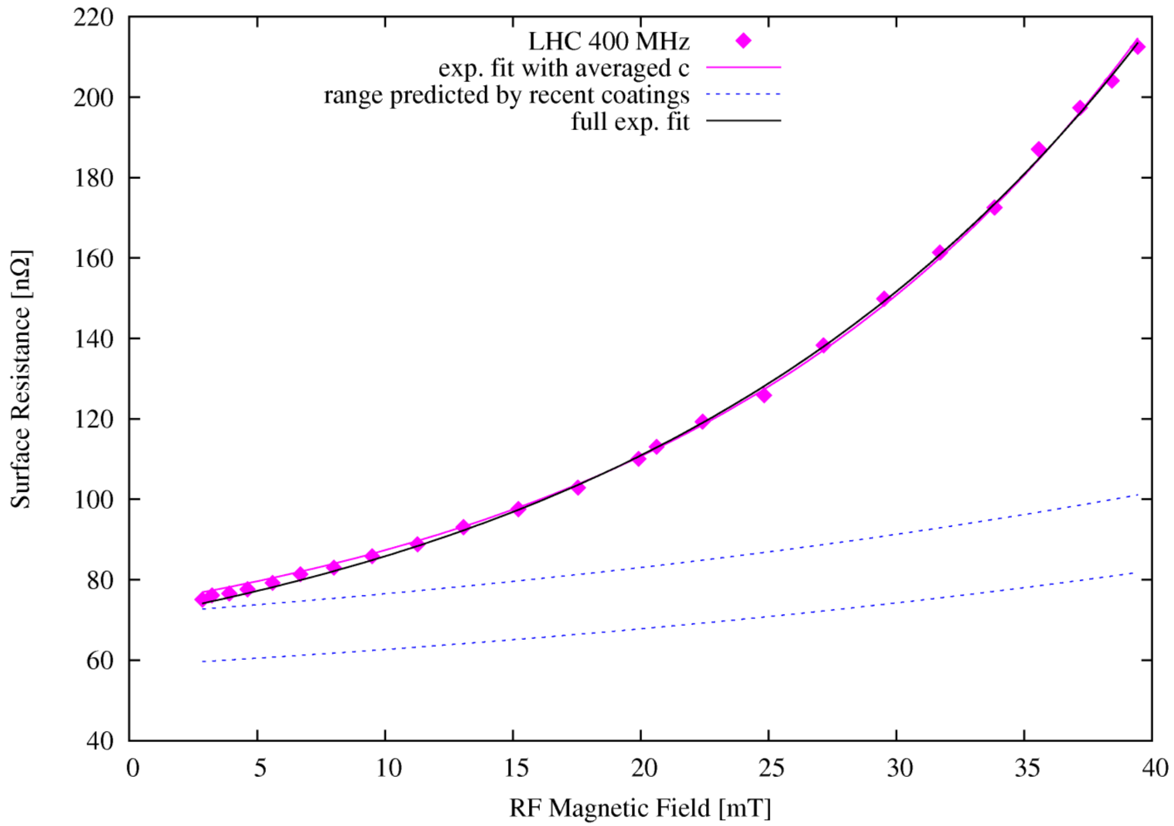
Frequency [MHz]	400.000
G [Ω]	109
Vx [MV]	3.0
Total Energy [J]	10.4
Rx/Q [Ω]	343.5
E_{peak} [MV]	50
B_{peak} [mT]	78







Non-linear behaviour of surface resistance (S. Calatroni, S. Aull)

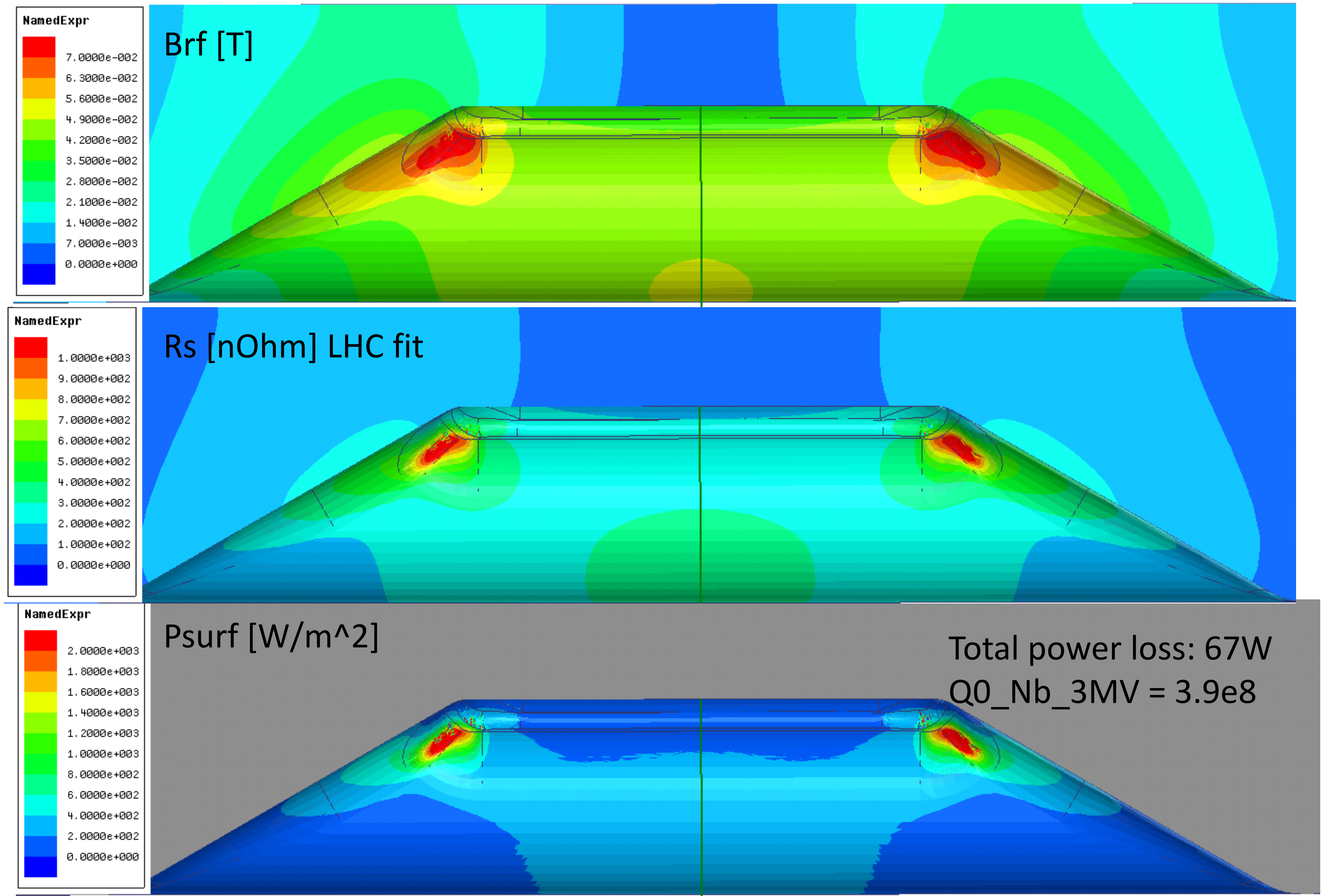


LHC: Rs(Brf)[nOhm] = 54.7 + 19.0*exp(0.054*Brf[mT])

ECR: Rs(Brf)[nOhm] = 46.9 + 17.1*exp(0.023* Brf[mT])

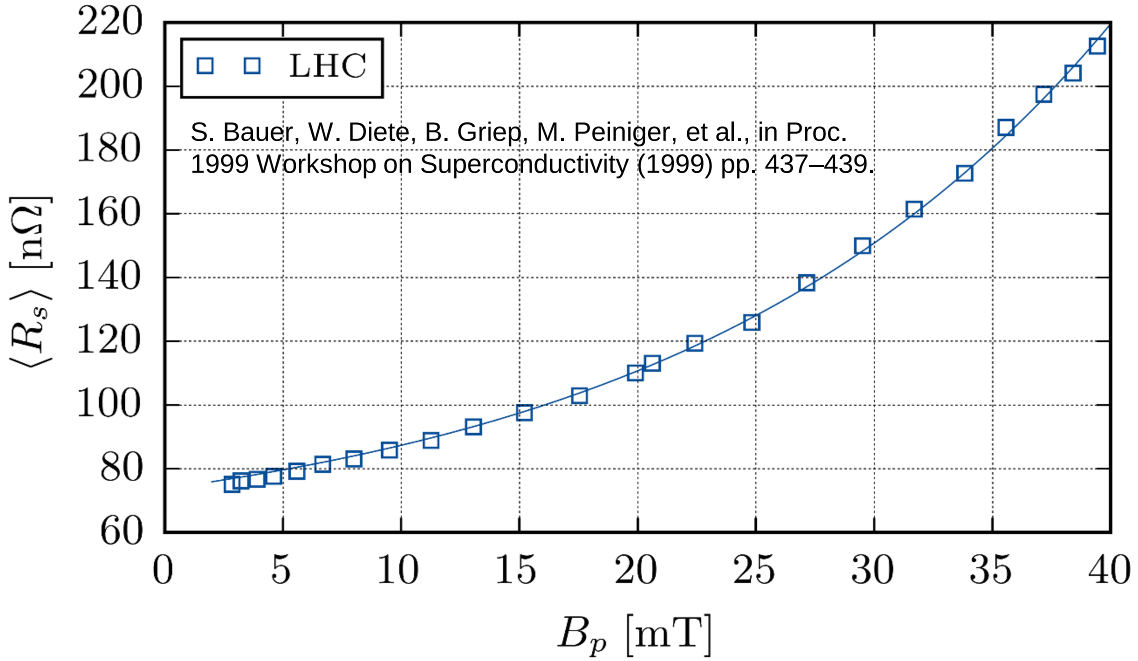
There is a big potential in the new coatings but let's be conservative and take LHC cavity data.

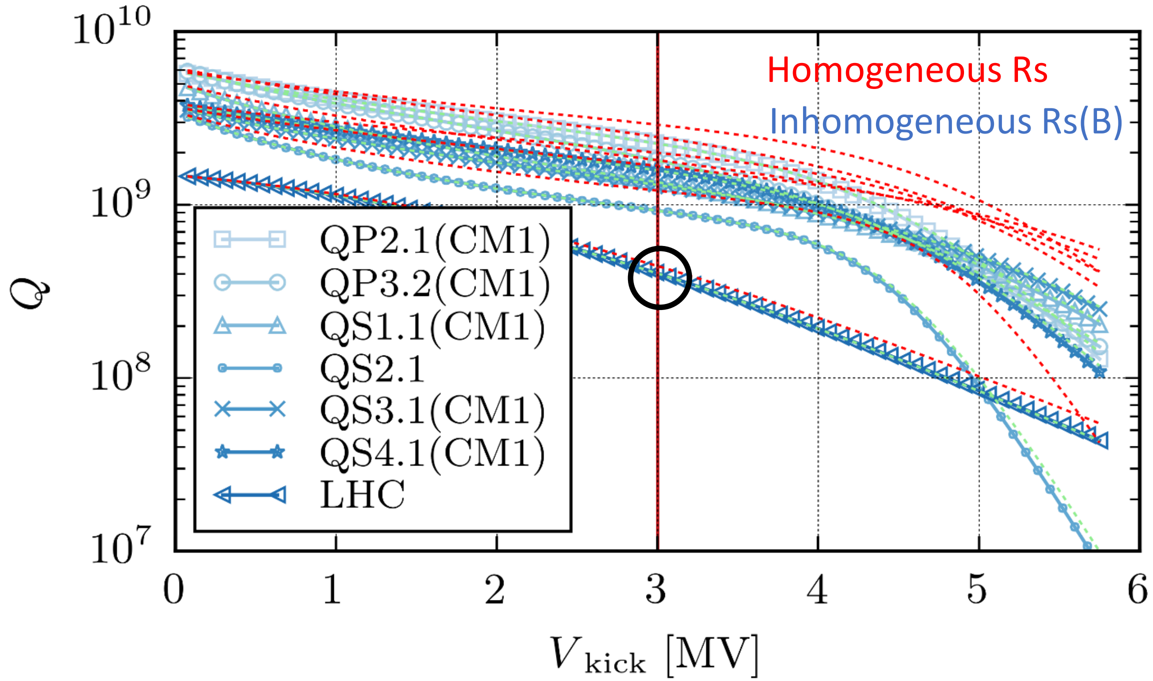
Power loss distribution on the surface for 30 degree taper at 3 MV



Q_0 calculation

- Nominal kick voltage 3 MV → B_{peak} up to 80 mT
- Results above 40mT for LHC uncertain due to lack of measurement data
- Q based on extrapolation of Rs from the LHC data
- Q_0 (Rs=const.) = 4.45e8
- Q_0 (Rs=Rs(B)) = 4.05e8





Wake Field and Impedance Calculation

Monopole

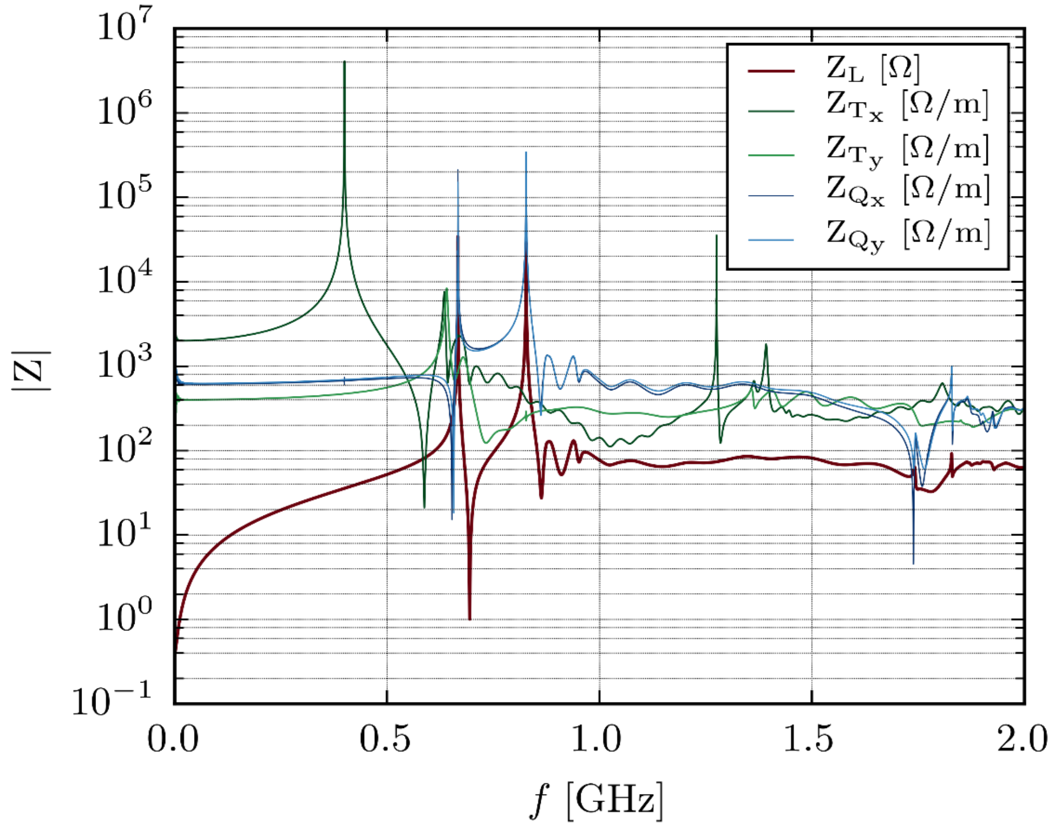
Loss factor [V/pC]	0.012
$(Z_L/N)_{eff}$ [mΩ]	**0.974**

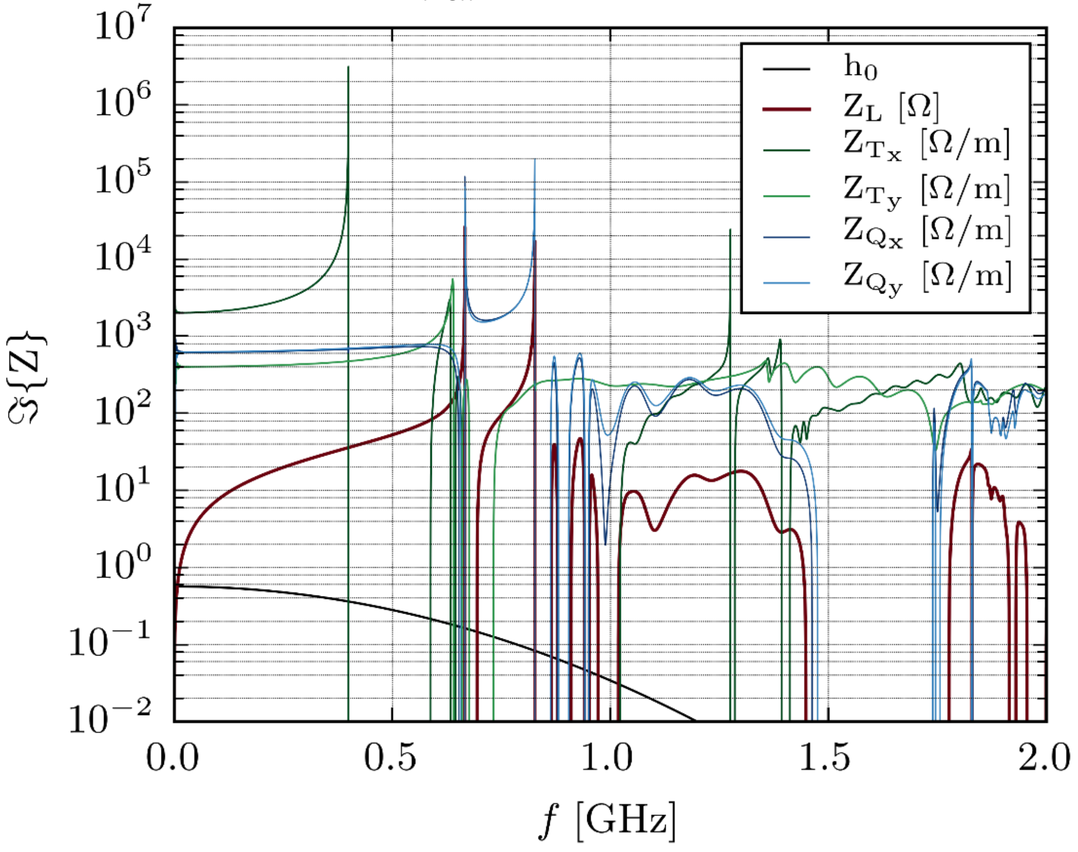
Dipole

Kick factor x [V/pC/m]	1.673
Kick factor y [V/pC/m]	0.460
$(Z_T)_{eff}$ x [Ω/m]	**1562.8**
$(Z_T)_{eff}$ y [Ω/m]	437.6

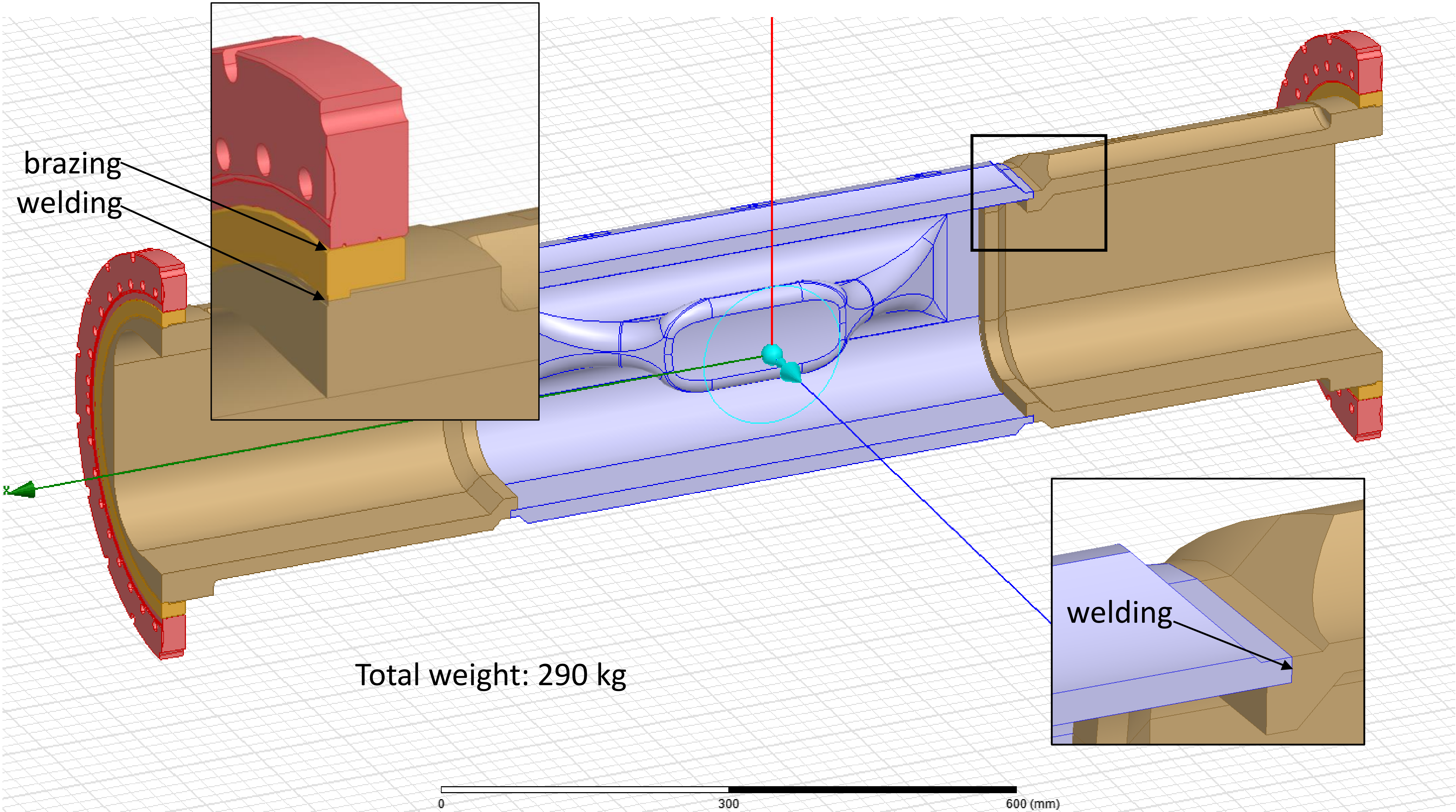
Quadrupole

Kick factor x [V/pC/m]	0.733
Kick factor y [V/pC/m]	0.769
$(Z_T)_{eff}$ x [Ω/m]	631.9
$(Z_T)_{eff}$ y [Ω/m]	791.9

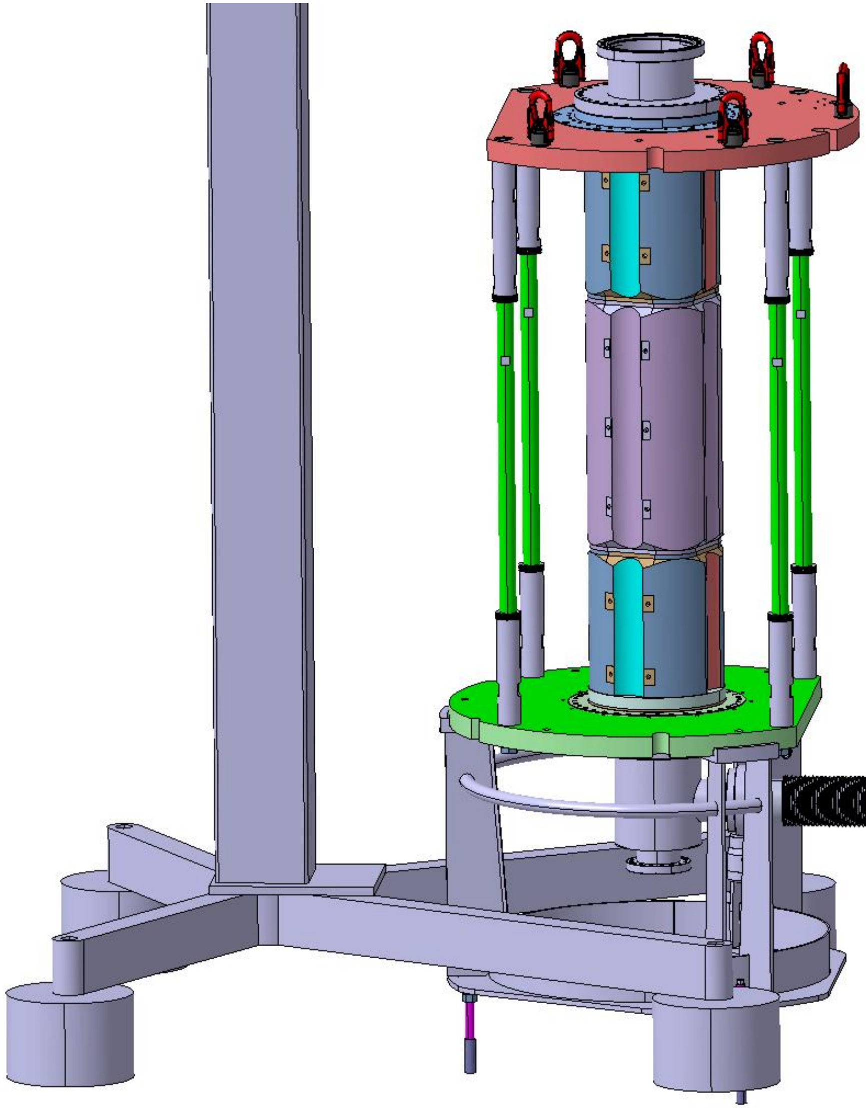


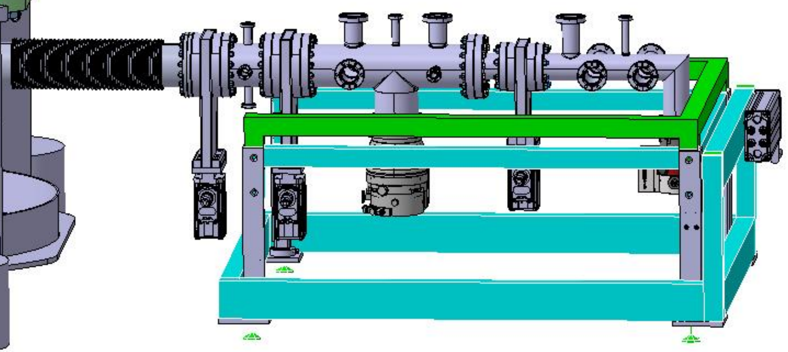


Assembly concept of the WOWCC copper substrate



Integration of WOWCC into LHC-coating setup

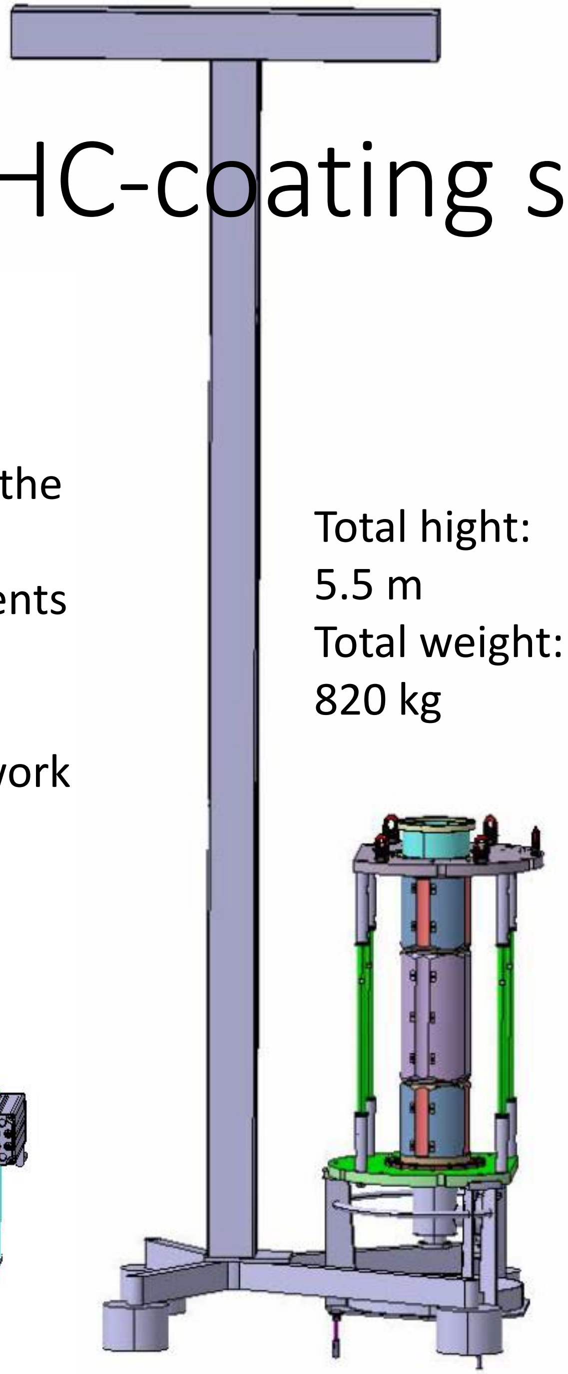




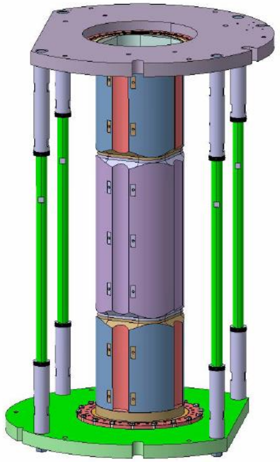
<u>Aim of the integration study:</u>

- Get overall dimensions and weight of the setup
- Formulate requirements for the infrastructure in the B252
- Communicate the requirements to the responsible for the infrastructure in B252
- Pave the way to the future work on the design of the coating setup

Total hight:
5.5 m
Total weight:
820 kg



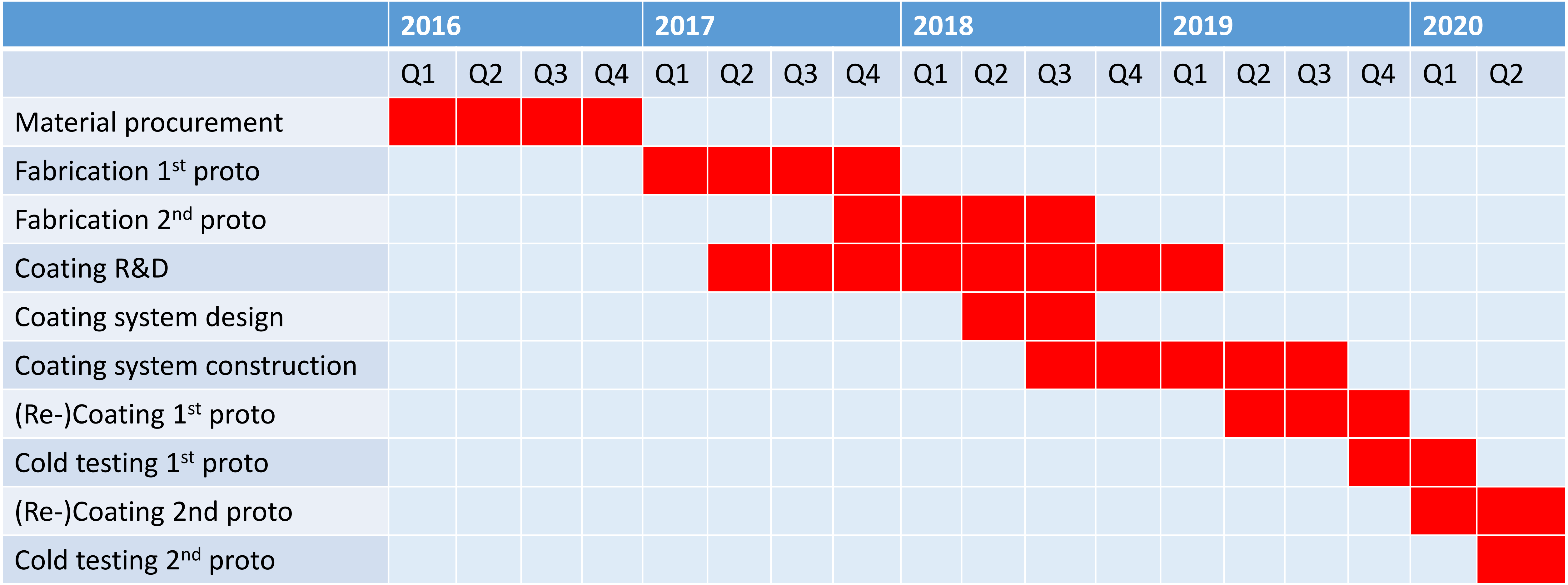
WOWCC +
frame
weight:
517 kg



Work package structure:

- Task 1: RF design (Alexej Grudiev (RF))
- Task 2: Mech. Design of the prototype and tooling (Ofelia Capatina (MME))
- Task 3: Fabrication of the “substrates” (Pierre Naisson (MME))
- Task 4: Surface treatment (Leonel Ferreira (VSC))
- Task 5: Coating system and coating (Alban Sublet (VSC))
- Task 6: Rinsing and clean room assembly of the prototypes for testing (Mikko Karppinen (RF))
- Task 7: Cold Testing in cryostat (Mikko Karppinen (RF))

Schedule


2016
2017
2018
2019
2020
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Material procurement
Fabrication 1st proto
Fabrication 2nd proto
Coating R&D
Coating system design
Coating system construction
(Re-)Coating 1st proto
Cold testing 1st proto
(Re-)Coating 2nd proto
Cold testing 2nd proto

Budget and manpower profile (end of 2016)

		2016	2017	2018	Total
Budget [kCHF]	Design	20	20	?	
	Material	80	~0	?	
	Fabrication	0	150	50	
	Chemistry	0	100	50	
	Coating	0	150	50	
	RF infrastructure	**?**	**?**	?	
	Total	**100**	**420**	150	670
Manpower [FTE]					
	Engineer (ENG)	0.33	0.85	0.5	1.7
	Technician (TEC)	0	1.5	1.5	3.0
	Fell/PJAS (FEL)	0.45	0.25	0.25	1.0

← 20% less cost for coating system

Reduction of manpower for coating
2PM-ENG
3PM-FEL
3PM-TEC

The resources for SRF infrastructure modification in order to accommodate the WOWCC prototypes are not included

Summary
why would we do coated crab

- No thermal run-away (operation, machine protection)
- Potential to reach 5 MV per cavity if coating is (2-3 times) better than for LHC 400 MHz main RF cavities (cost, impedance)
- Lower impedance (x2, Z/n; x3 Z_x,y)
- No magnetic shielding (cost)
- Material (cost)