CHAIR WELCOME

Perspectives for SRF Thin Films

A.-M. Valente-Feliciano

SRF Thin Films Workshop Series

- The first event was organized at JLab in 2005, as a spin-off of the SRF conference (1.5 days).
- In 2006, Enzo Palmieri organized the 2nd edition under "International Workshop on Thin Films and New Ideas for Pushing the Limits of RF Superconductivity".
- Since then, the Workshop has taken place bi-annually.
- Over the years, the SRF Thin Films landscape has changed significantly:
  - Some materials and techniques that appeared promising time ago, look less promising at the moment.
  -Some research lines revealing their potential
  -New topics are becoming relevant. The SRF Thin Films scientific community has also expanded significantly.

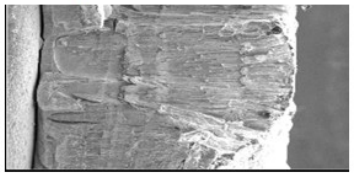
We had to say goodbye to dear colleagues, others are now focusing on other endeavors but we also have gained many other collaborators.

SRF Thin Films in the World: 1998 Landscape

CERN

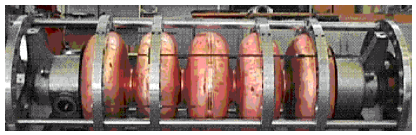
JLab

CEA



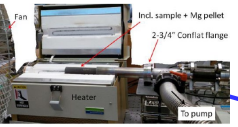
INFN

SRF Thin Films in the World: 2005 Landscape



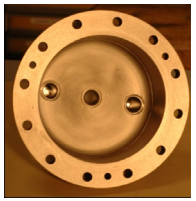
CERN

Cornell



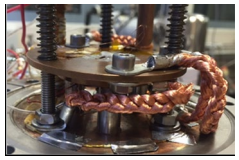
LANL

AASC

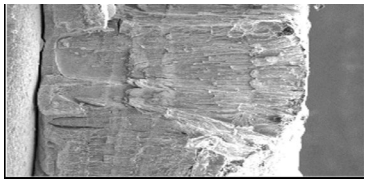


ANU

JLab

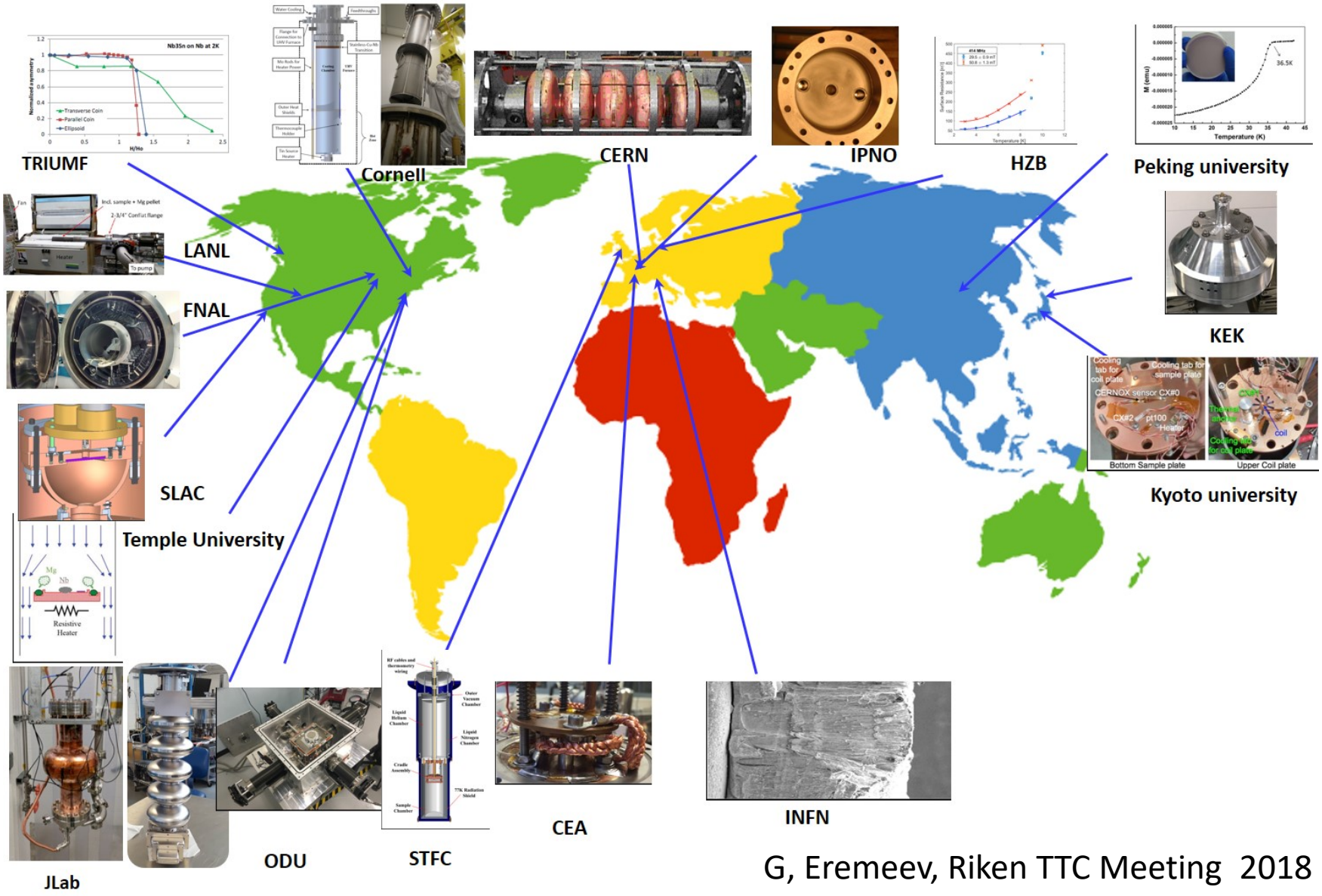


CEA



INFN Legnaro & Roma

SRF Thin Films in the World: Today's Landscape

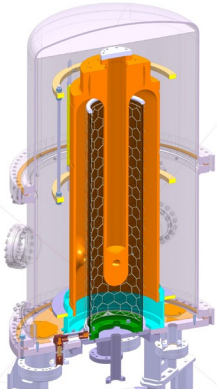


G, Eremeev, Riken TTC Meeting 2018

CURRENT PROJECTS

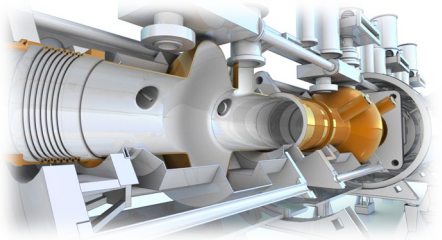
Hie-ISOLDE Nb/Cu QWR cavities

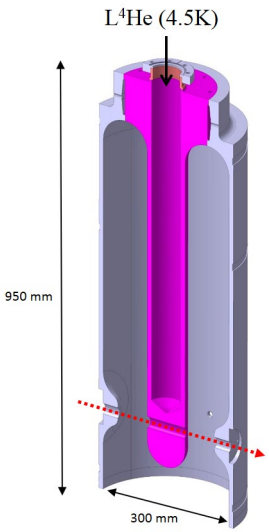
25 Nb/Cu 100 MHz QWR cavities

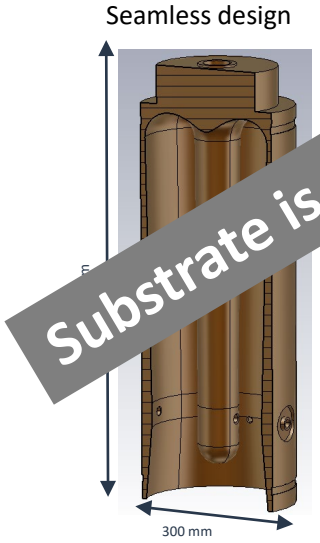


A. Sublet et al.

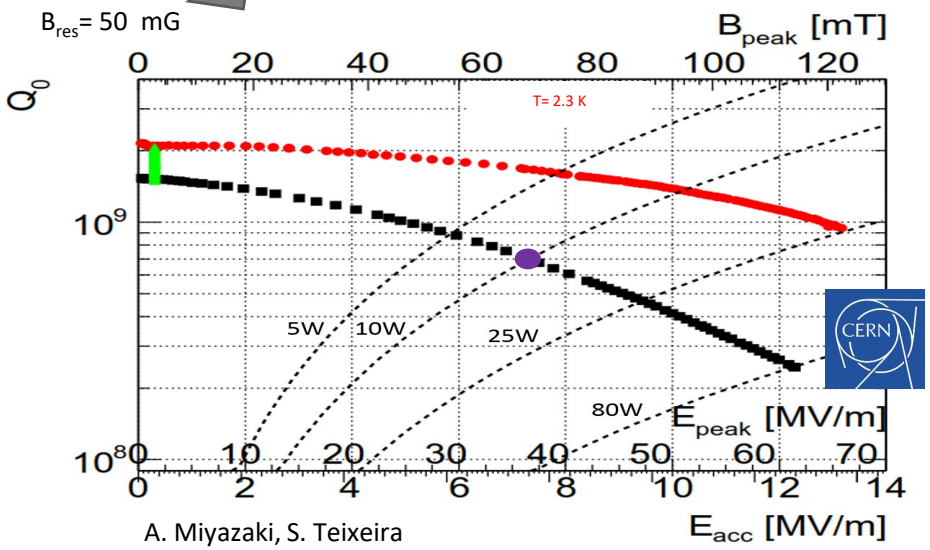
DC-bias diode sputtering, biased
@high temperature (650 °C), in steps
Nb film : 1.5 µm to 12 µm, multilayered
Spare cavities coated







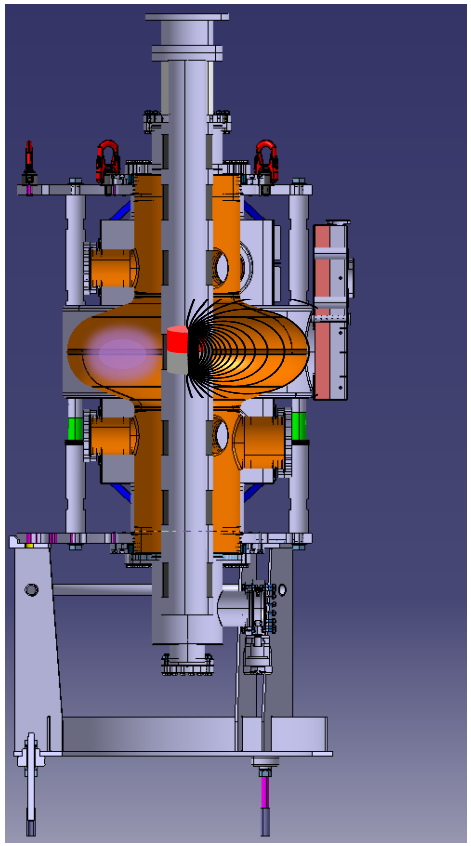
Substrate is KEY



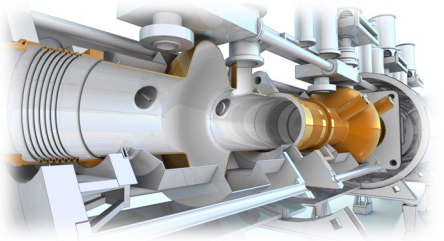
A. Miyazaki, S. Teixeira

Highest field ever reached for Nb/Cu cavity
(~30MV/m in elliptical shape)

LHC 400 MHz elliptical Nb/Cu cavity spares

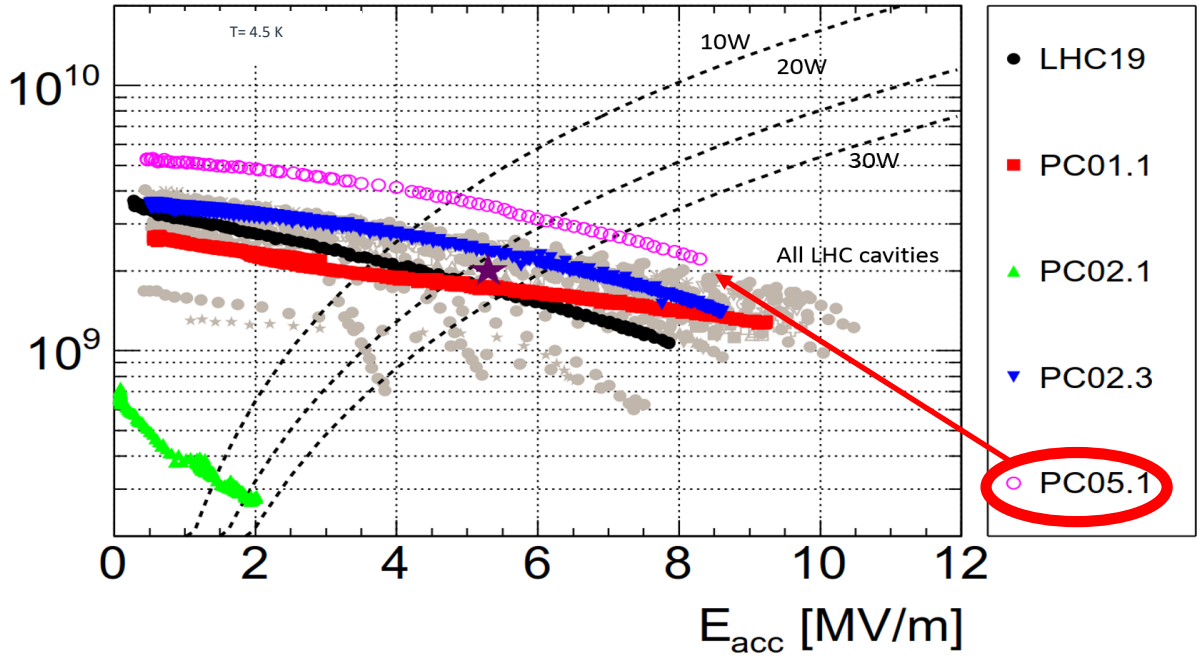


6 spares



Cylindrical DC magnetron sputtering @ (180 °C), in 7 sections

Nb film : ~2 µm



A. Miyasaki, K. Turaj, A. Zwozniak, M. Therasse

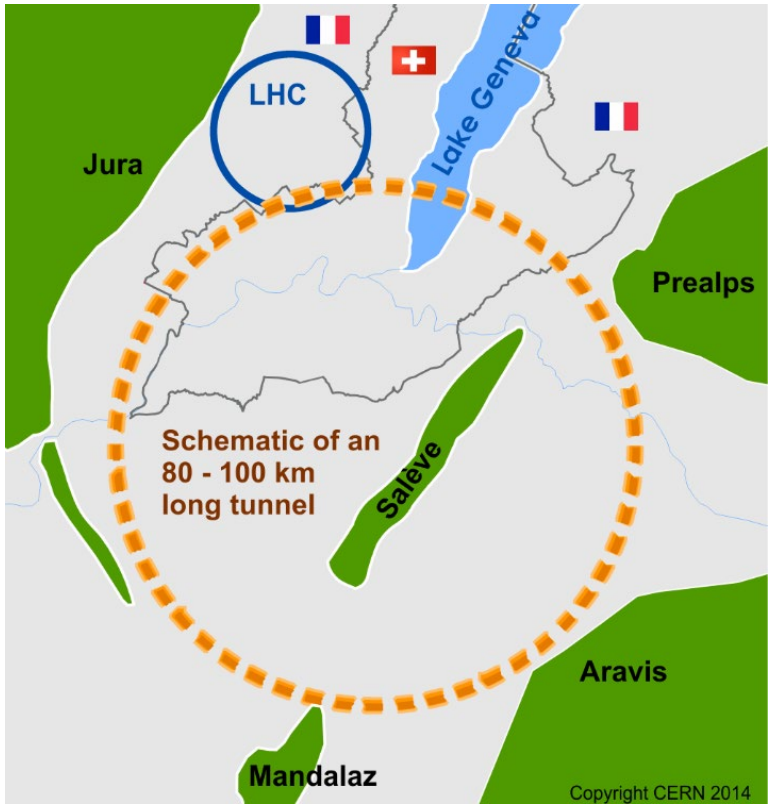
G. Rosaz et al.

Spare cavities coated

Best RF performance achieved

FUTURE PROJECTS

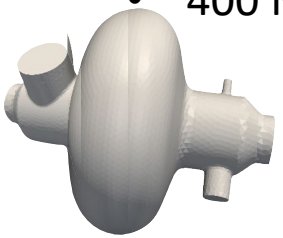
FCC Studies



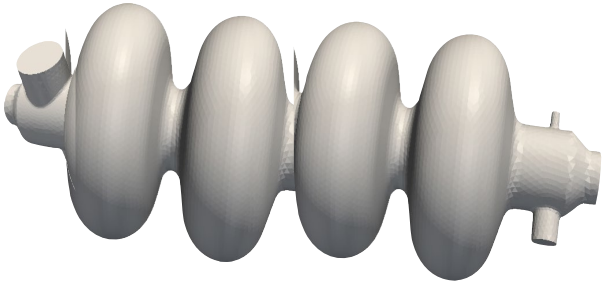
FCC study

Future Circular Collider, ~ 100 km (~2030)

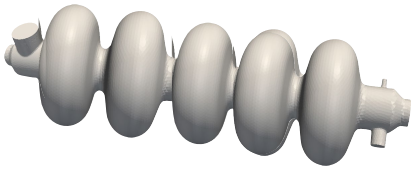
- 400 MHz single cell cavities, **quantities ~ 208**



- 400 MHz 4-cells, **quantities ~ 408**

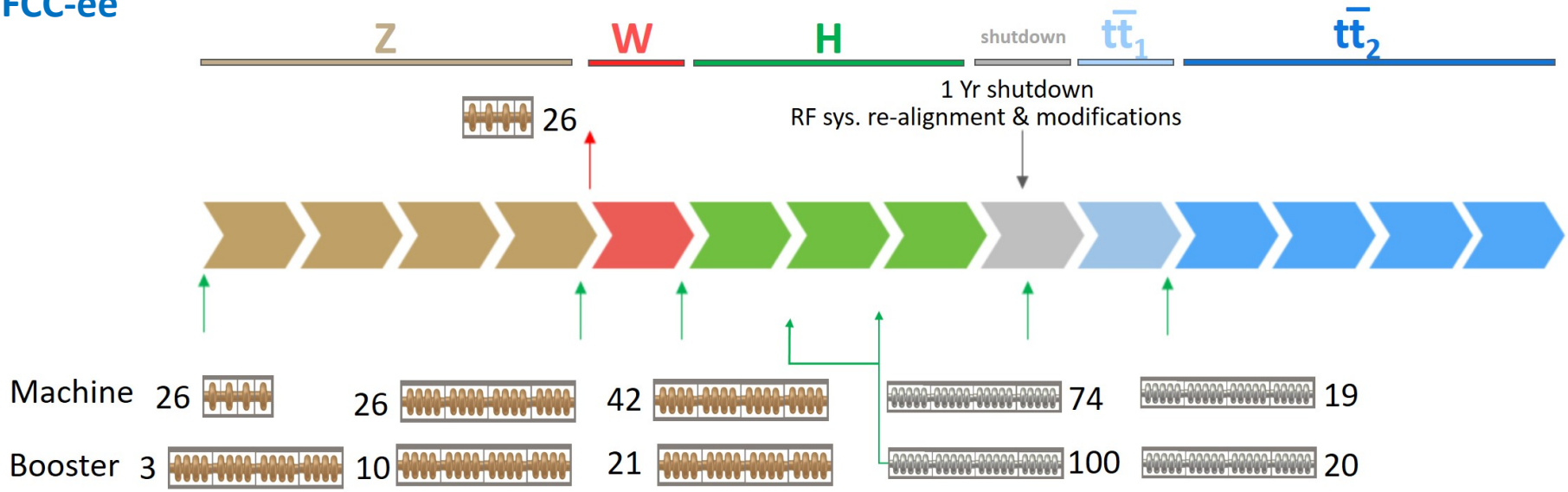


- 800 MHz 5-cells, **quantities ~ 892**



FCC Studies

FCC-ee



FCC-hh

RF will be similar to LHC (injector} Nb/Cu 400MHz
Consider adding 800MHz for operational stability

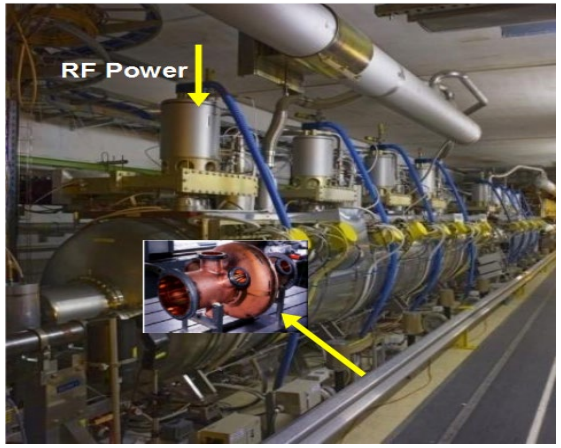
Can re-use systems &infrastructure from FCC-ee

Parameter	Value
Circumference [km]	97.75
Energy (injection/collision) [TeV]	3.3/50
Transition gamma	99 & 71
Energy loss per turn [MeV]	4.6
Bunch spacing [ns]	25 (5)
RMS bunch length during physics [cm]	8
4σ bunch length during physics [ns]	1.07
Bunch intensity [ppb]	10^{11}

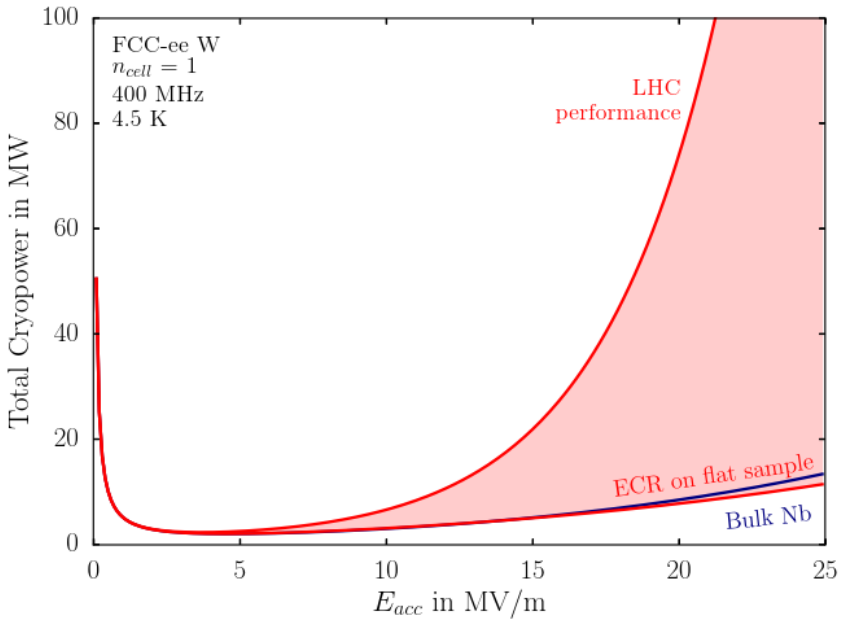
Installed voltage of 48 MV
Bucket forming voltage 12 MV at injection

- 32 MV at collision
- Synchrotron tune and energy spread smaller than in LHC

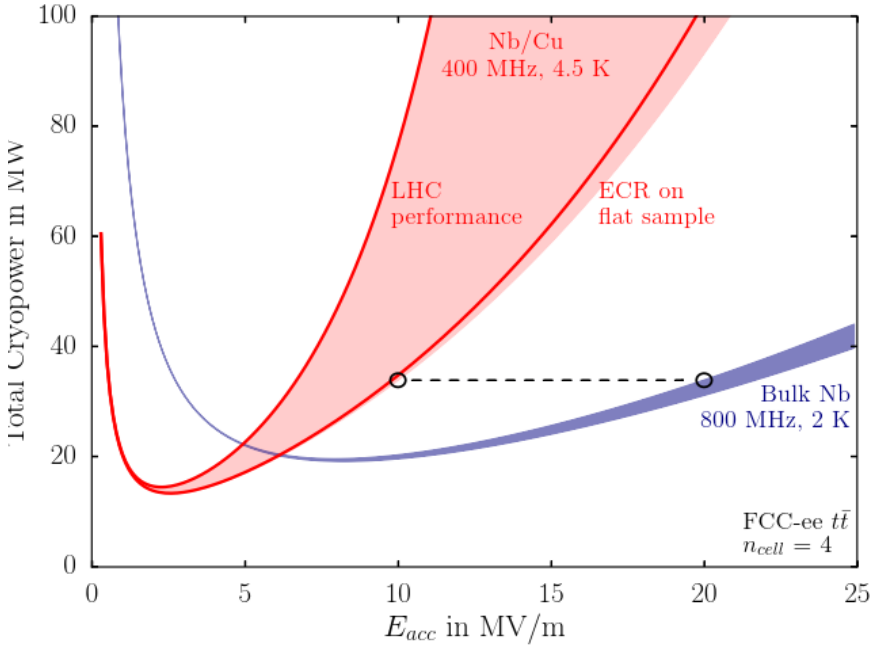
400 MHz(Nb-Cu)



Perspectives for SRF Nb Thin Film Cavity for FCC



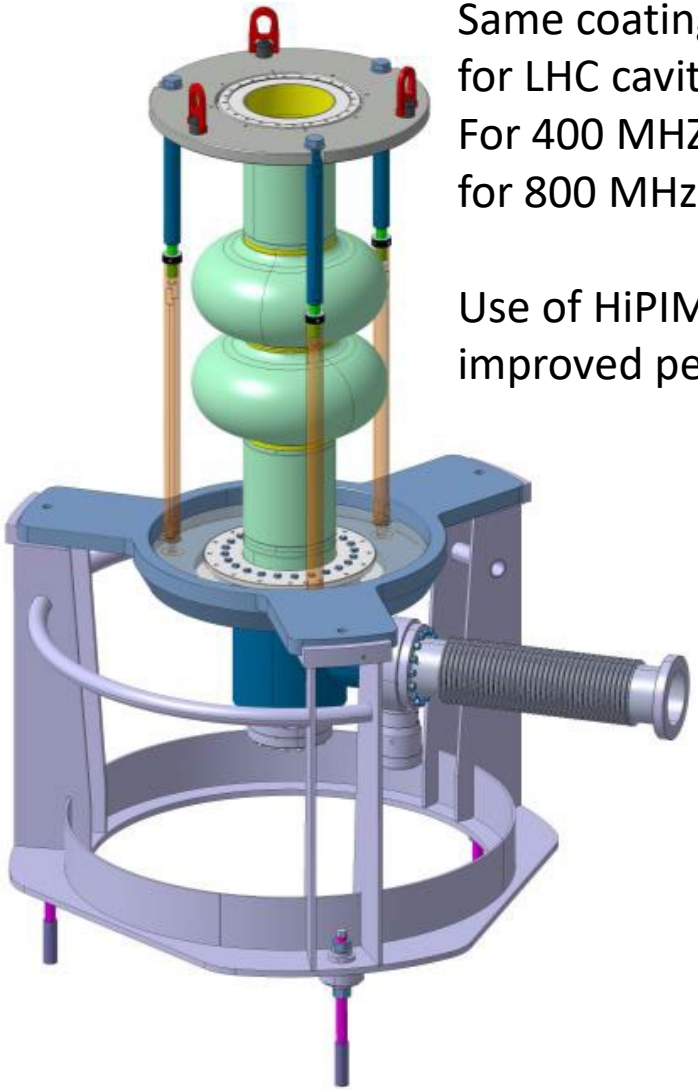
Courtesy of S. Aull, *FCC week 2017*



S. Aull, and co. *FCC-DRAFT-TECH-2017-002* (2017)

The perspective of cavity performances based on EC Nb RF behavior yields similar cryogenic losses for Nb/Cu at 400 MHz and 4.5 K and bulk Nb at 800 MHz and 2.0 K.

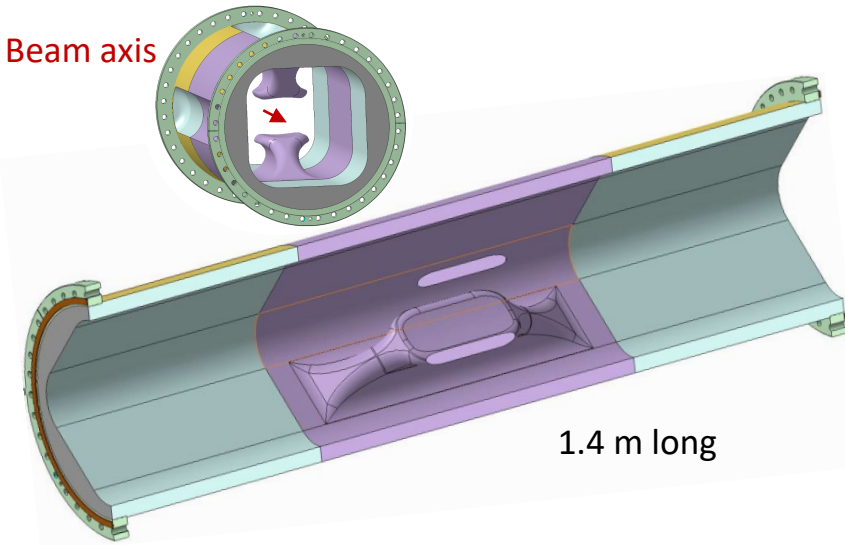
FCC cavities



Same coating hardware as for LHC cavities
For 400 MHZ and scaled for 800 MHz

Use of HiPIMS for improved performance

Wide Open Waveguide
Particle deflected by transverse TE-111 like field between 2 mushroom-shaped ridges



- low longitudinal and transverse impedances
- natural damping for HOMs

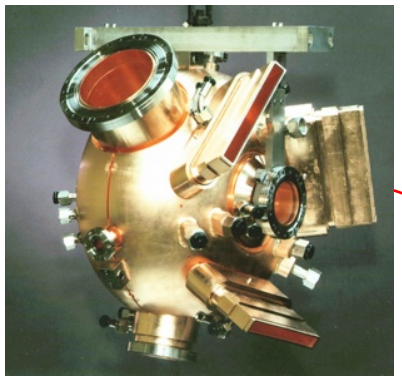
A. Grudiev **Innovative crab cavity design for FCC hh**
https://indico.cern.ch/event/656491/contributions/2932264/

Coating feasibility under study
by A. Sublet &F. Avino (CERN, TE/VSC)

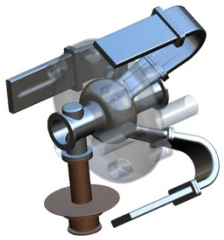
Electron-Ion Collider in US (EIC)

- Electron ring: PEP-II warm 476MHz RF adopted
  - Proven technology with low cost
  - Use CEBAF as injector, frequency matched by 1497×7/22=476.3MHz
  - Enough cavities and klystrons available as the total beam SR power is similar
  - Will upgrade to 952.6MHz SRF cavities for future high rep-rate operation
- Ion ring: new 952.6MHz SRF cavities to provide bunching voltage
  - Plus low frequency cavities for capture, acceleration and bunch formation.
- Crab cavity system: 952.6MHz
- Cooler:
  - 952.6MHz cavities for source and ERL (20-55MeV)
  - Cooler baseline with circulator ring, using RF harmonic kickers
- Ion injector chain:
  - An SRF linac with warm front end as developed by ANL
  - A booster with a series of low frequency for capture, acceleration and bunch split

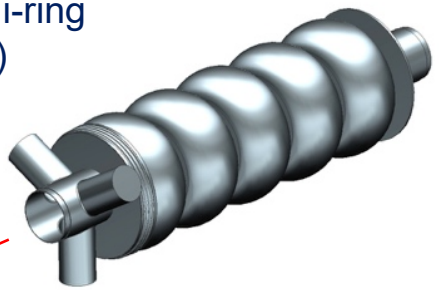
Electron-Ion Collider in US (EIC)



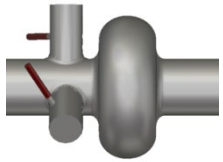
476.3 MHz e-ring
(NCRF PEP-II)



952.6 MHz i-ring
(SCRF)



952.6 MHz cooler
ERL (SCRF)



952.6 MHz cooler
booster (SCRF)

952.6 MHz crab
(SCRF)

JLEIC
Collider
Rings

i-SRF +
NCRF

BB cooler

Crab

IP

e-RF

Crab

e-RF

Future IP

Booster

SRF Linac

Ion Source

Electron Injector

12 GeV 1497MHz CEBAF

Hall D

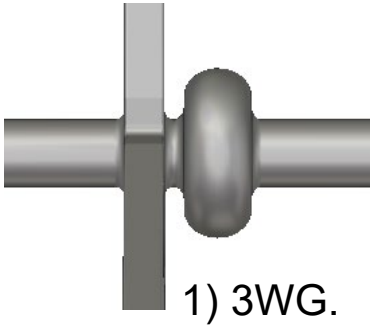
Halls A, B, C

Harmonic Fast kicker
for cooling ring

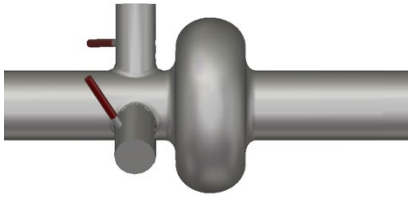
Not including ion acceleration and bunch formation

EIC 952MHz SRF Cavity Family (JLab)

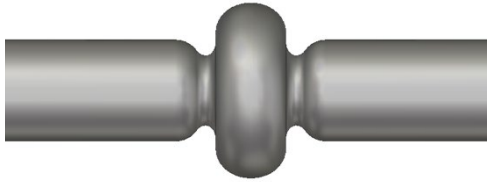
- New 952.6MHz High-current cavity shape
- 4 different HOM damping schemes under evaluation
- 1, 2, 5 cells for different sub-systems
  - 1-cell, on-cell damper for e-ring 952MHz upgrade and possibly for i-ring and ERL booster
  - 2-cell possibly for i-ring and ERL booster
  - 5-cell for ERL linac
- Prototype in progress (without end-groups)



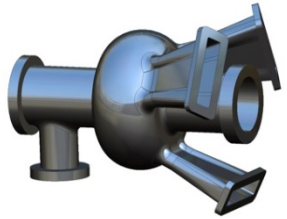
1) 3WG.



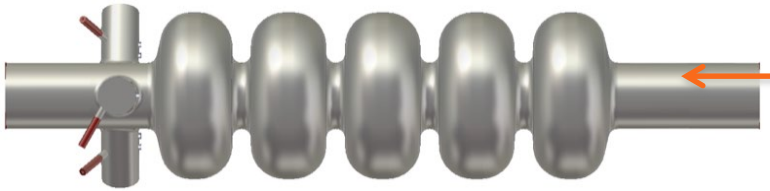
2) 3 x coax dampers.



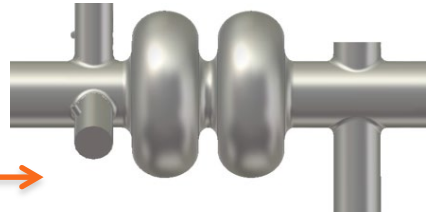
3) enlarged beam pipes (ref)



4) on-cell dampers

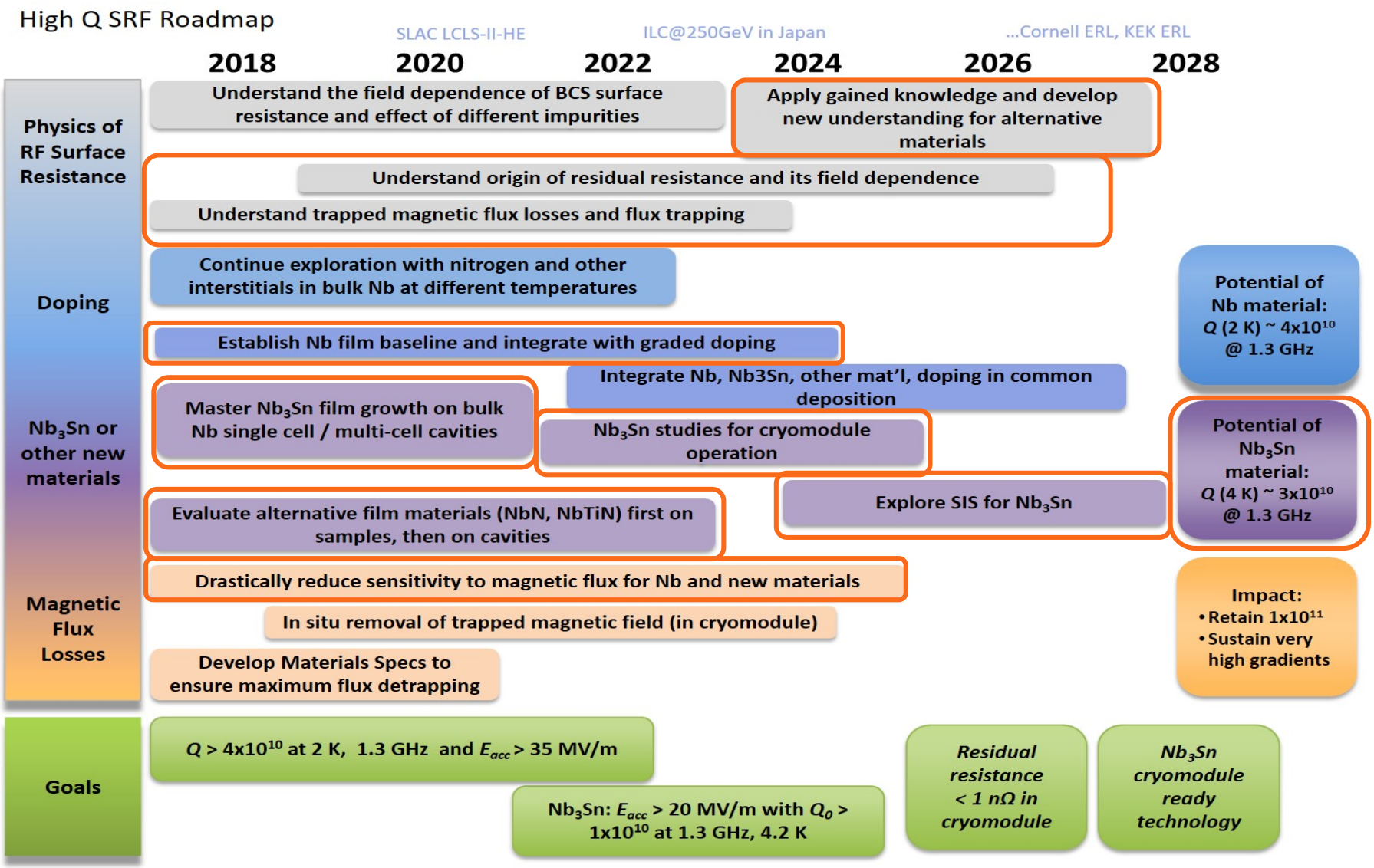


Cooler needs **5-cells** in the ERL, 1 or 2 -cells in the injector.
Ion ring might use **2-cells** with TM010 π mode R/Q tuned close to 0



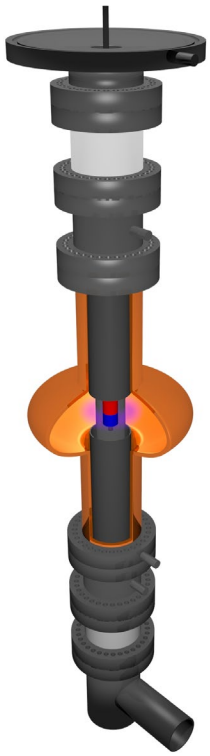
SRF ROADMAP – GARD Meeting 2017

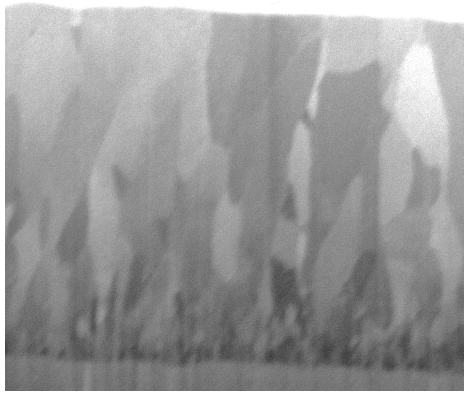
S. Belomestnykh, FNAL

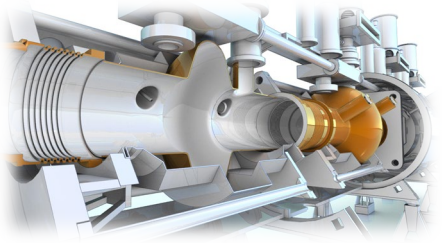


Recent successes in R&D Developments

Nb/Cu Technology - HiPIMS Nb/Cu cavities - 1.3 GHz elliptical



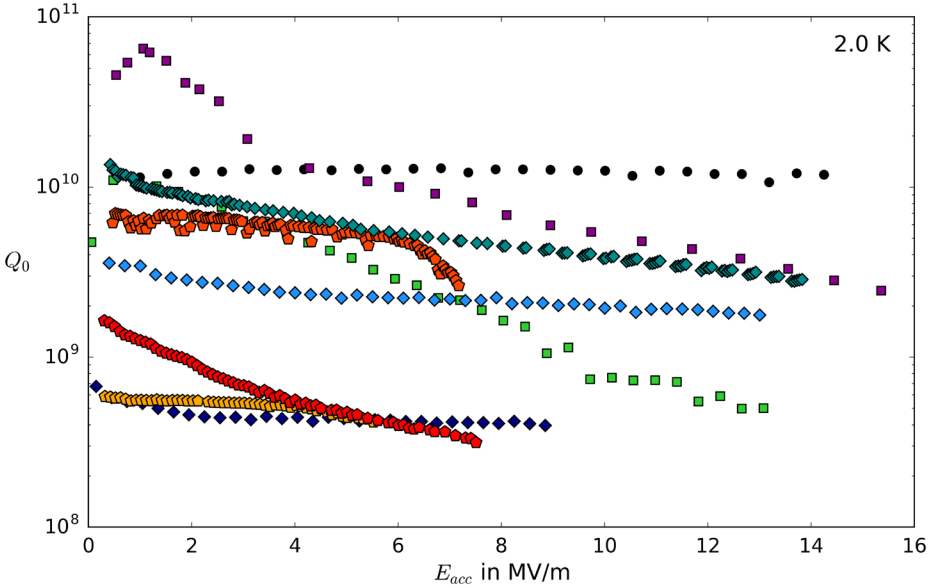


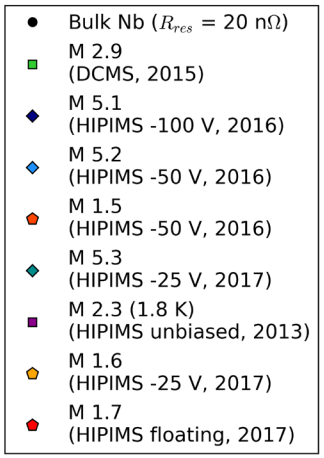


HiPIMS (high power impulse magnetron sputtering)

- ❑ Higher level of stress in HiPIMS vs. DCMS
- ❑ Biased HiPIMS produces denser films

Study on going to qualify, quantify and mitigate residual stress





G. Rosaz et al.

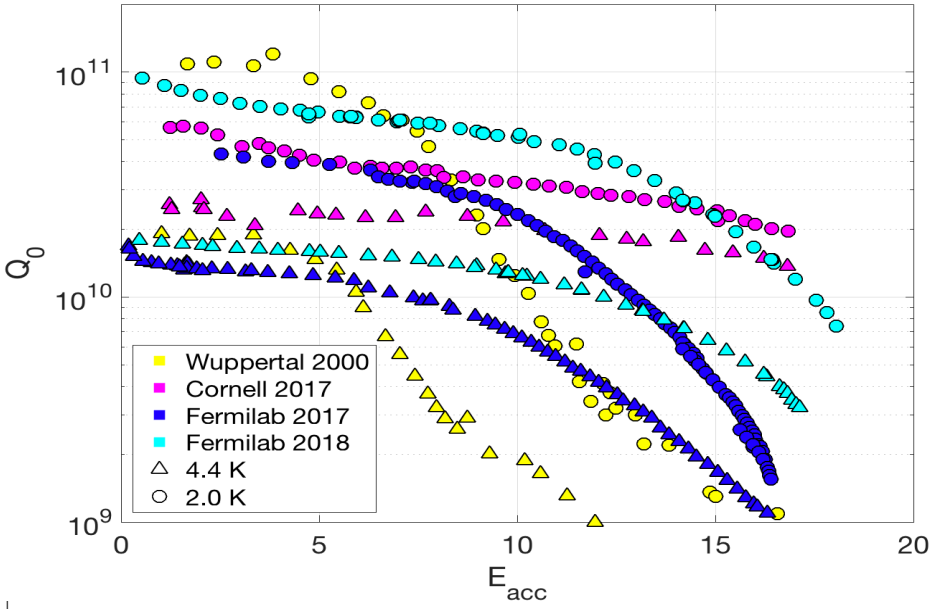
S. Aull, M. Arzeo

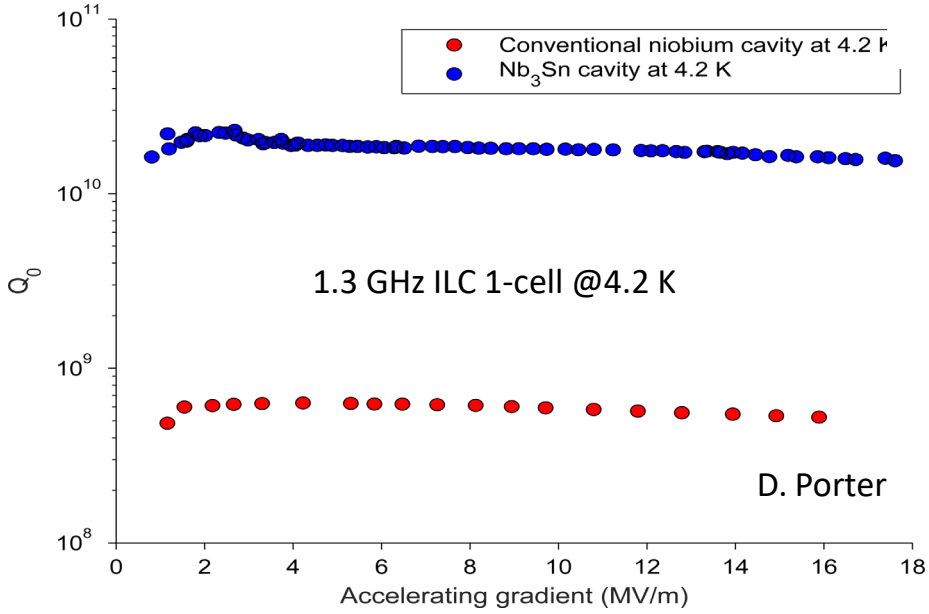
R_{res}

- down to 5 nΩ with Q-slope (unbiased)
- 20nOhm with mitigated Q-slope (biased)

At the level of the best DCMS ones but not yet better

Nb_3Sn by Sn diffusion





Other techniques development

- Electrochemical deposition
- Sequential multilayer sputtering & diffusion
  for Nb_3Sn/Nb

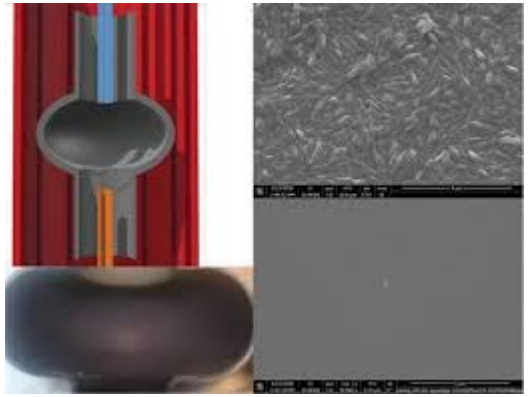
- Sputtering (DC, pulsed) of Nb_3Sn/Cu

1st RF measurements by QPR

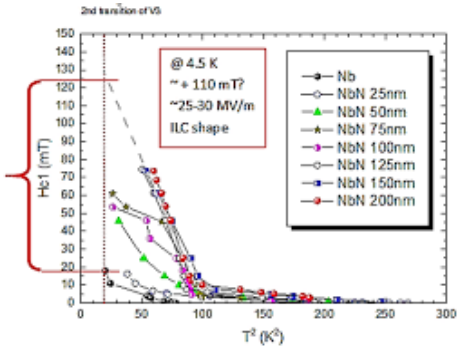
Other materials

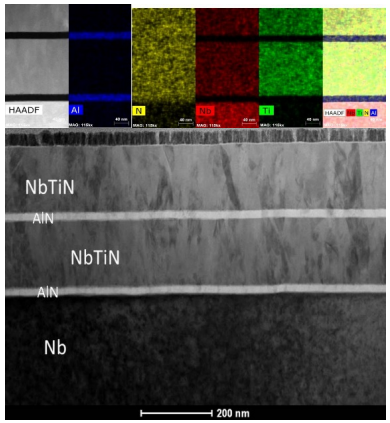
- MgB_2

Steadily progressing towards cavity coating

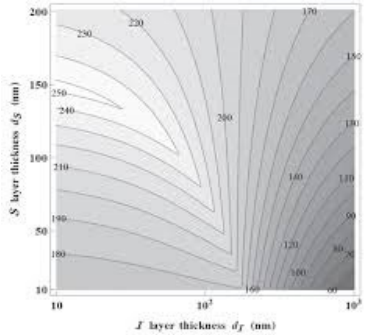


- NbTiN, NbN and multilayers





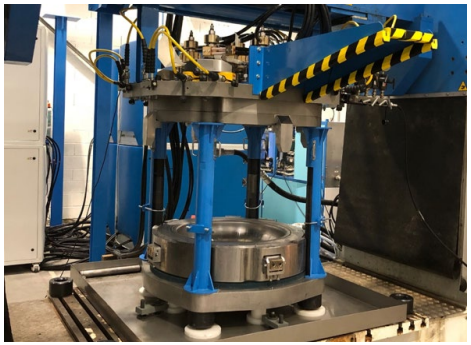
- Theoretical understanding of SRF thin films and multilayers



Other R& D Developments

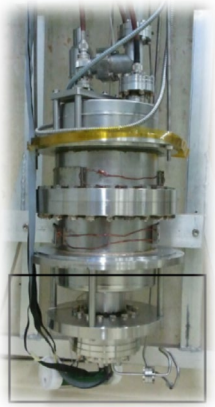
Substrate Developments

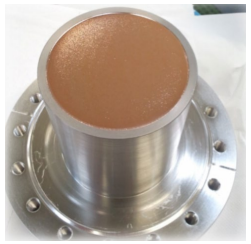
-Electrohydraulic forming (EHF), 3D manufacturing, spinning improvements

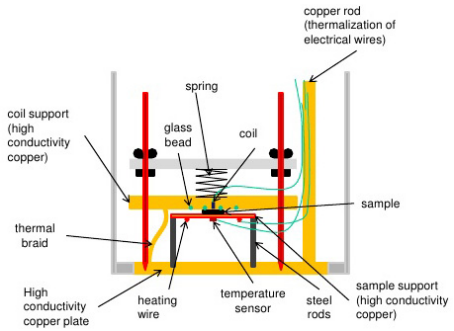


-Chemical processes development for Cu and Nb: reverse pulse electropolishing, standard electropolishing

Characterization Techniques: DC, RF and microscopy







CONCLUSION

- Significant improvements have been achieved with Nb/Cu and Nb_3Sn/Nb cavities
- Steady progress with new techniques and materials
- Progress may be slower than funding agencies and external observers would like but it is THERE
- Major projects around the World will rely or would benefit from performing SRF films matching or beyond bulk Nb

  FCC, CEPC, EIC. …
- With progress in development of alternative materials, existing machine future upgrades become feasible at longer tem: retrofit existing machines with new SRF materials Nb3Sn, SIS…for higher efficiency & performance within the same footprint

Principal goals of the workshop

Forum for new initiatives in innovative thin films and related technology to advance future generations of superconducting RF accelerators. Present superconducting RF accelerator technology is based on predominately bulk niobium, for which the state of the art in performance is reaching the theoretical limit.

Intensive and coordinated R&D effort is of decisive importance for the scientific community.

The primary aim of the workshop is to support this initiative by providing an opportunity to bring together individuals and institutions working in this effort and infusing expertise of specialists from related disciplines (superconductivity, plasma physics, material science, nanotechnology, RF engineering and industry).

Aim to offer a **collaborative environment as open, inclusive and diverse** as possible.

Finally…

During these 3 days, we hope you will make the most of the contributions, interactions during the discussions and breaks, will foster existing collaborations and expand them.

Each day will conclude with a round table on the subjects treated in the session. The conveners will be the chairs of the different sessions

We hope you enjoy the program & we are wishing for a very successful workshop