HIE-ISOLDE cavity production & cryomodule commissioning: lessons learned

W. Venturini Delsolaro

K. Artoos, O. Capatina, Y. Kadi, Y. Leclercq, A. Miyazaki, E. Montesinos, V. Parma, G. J. Rosaz, K. M. Schirm, A. R. M. Sublet, S. Teixeira Lopez, M. Therasse, L.R. Williams,

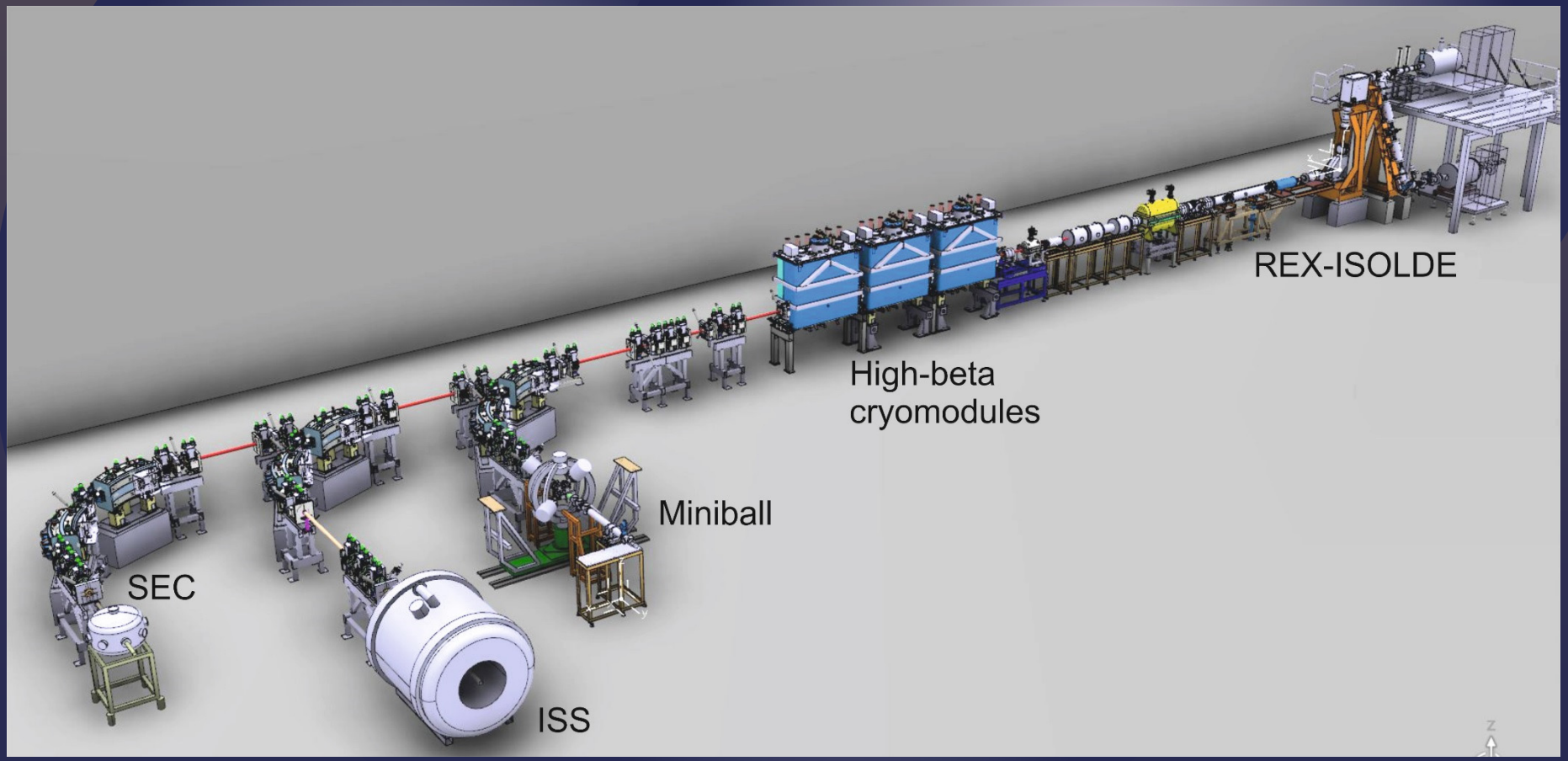
CERN, Geneva, Switzerland

18th International Conference on RF Superconductivity
Lanzhou China
July 17-21, 2017

Contents

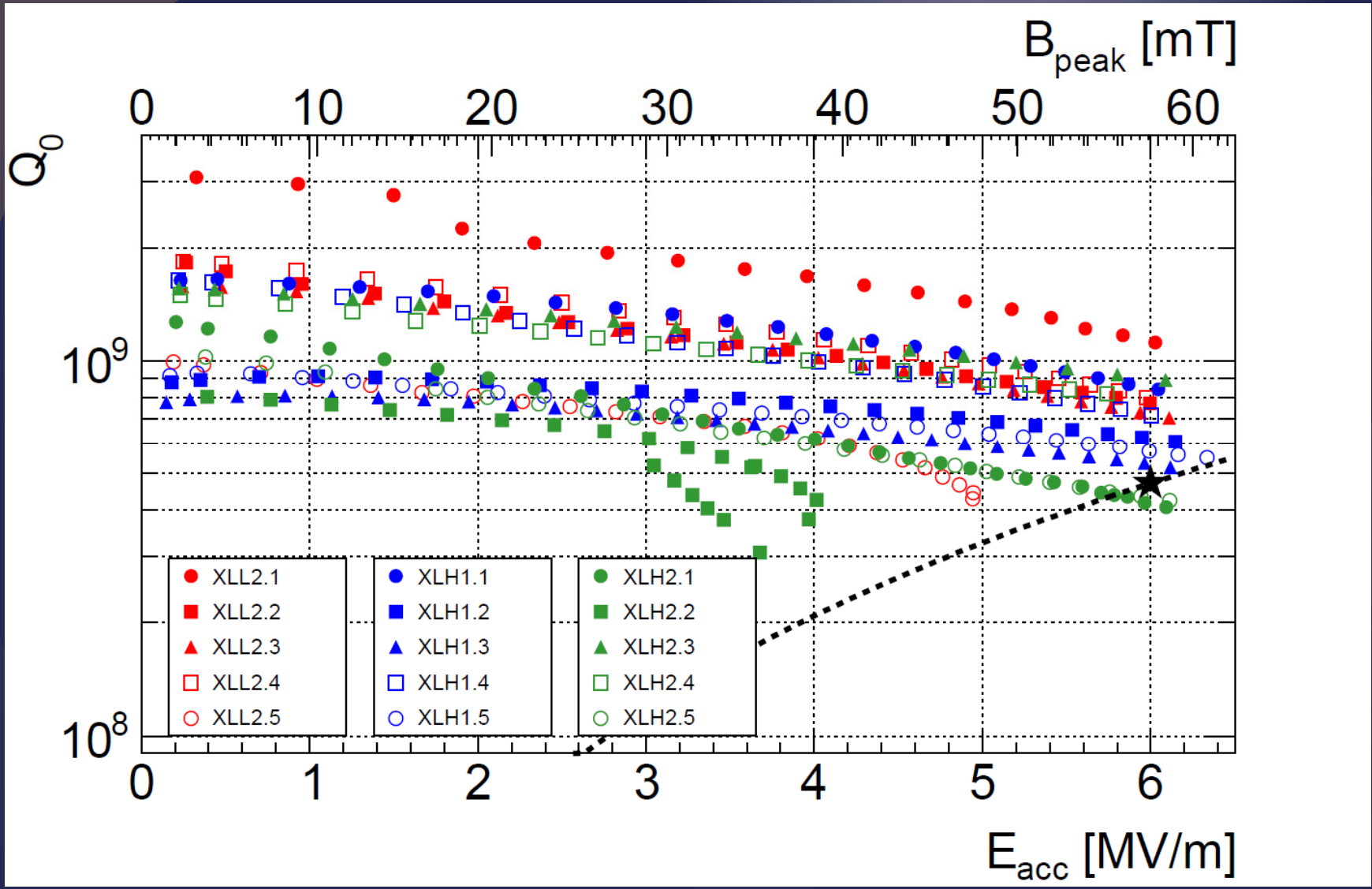
- Status of HIE ISOLDE linac
- Notes on cavity series production
- Notes on cryomodule design and assembly
- Notes on cryomodule commissioning
- Summary

HIE ISOLDE linac in 2017

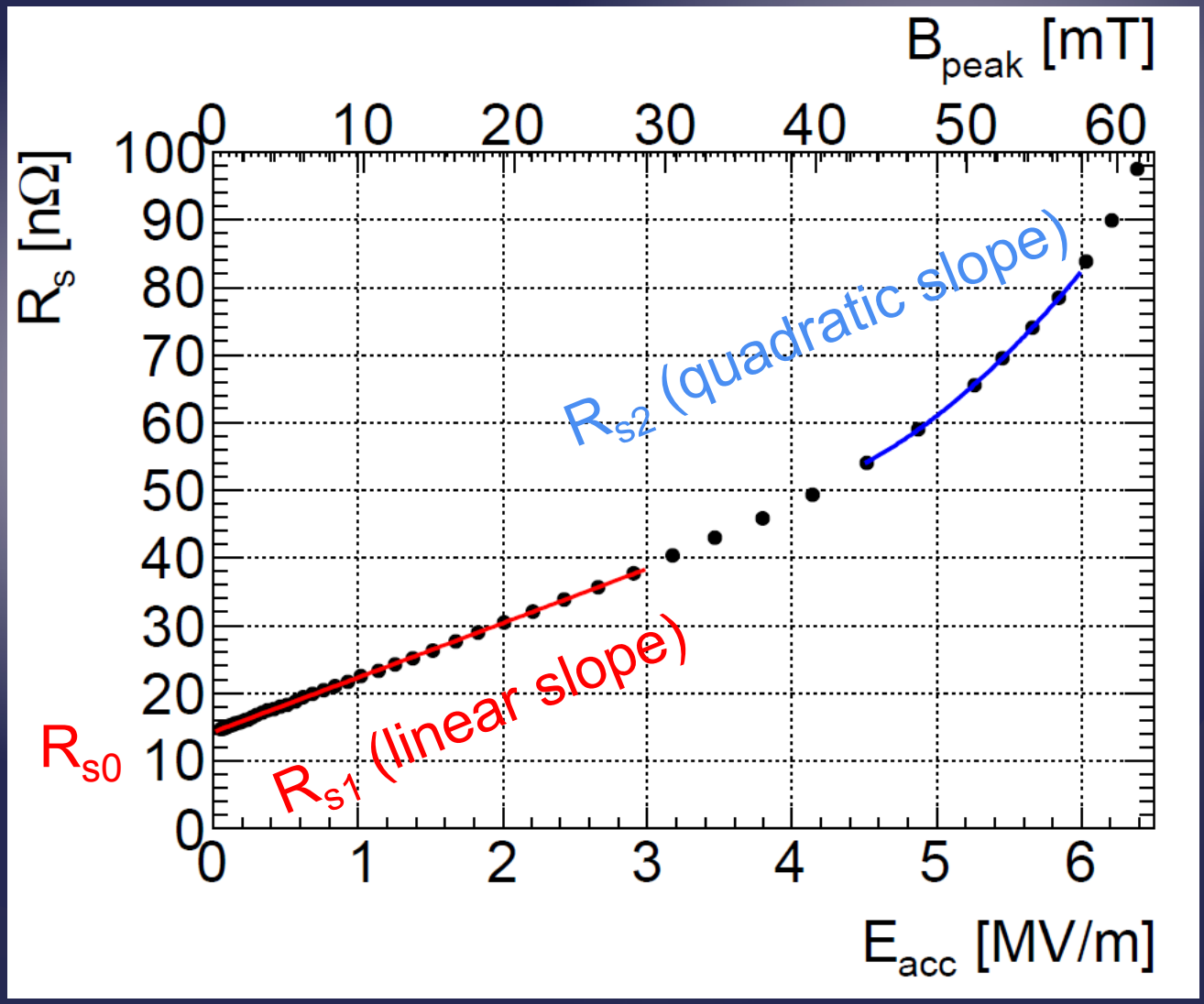


HIE-ISOLDE cryomodule

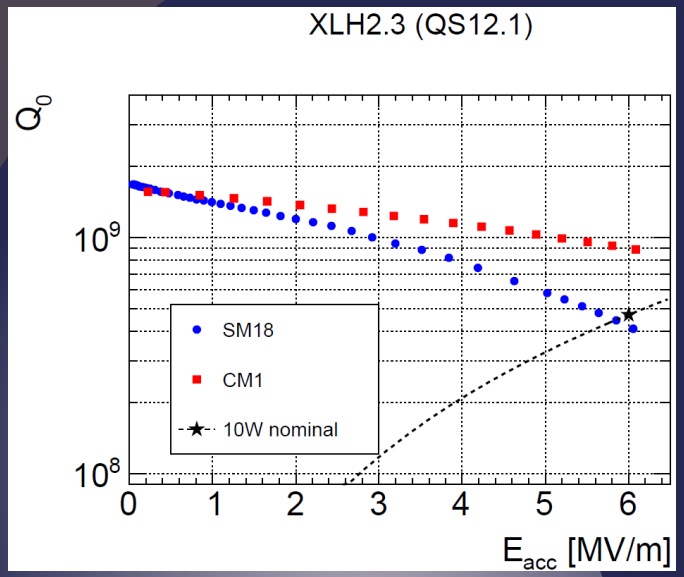
Cavity performance on line (3 CM)

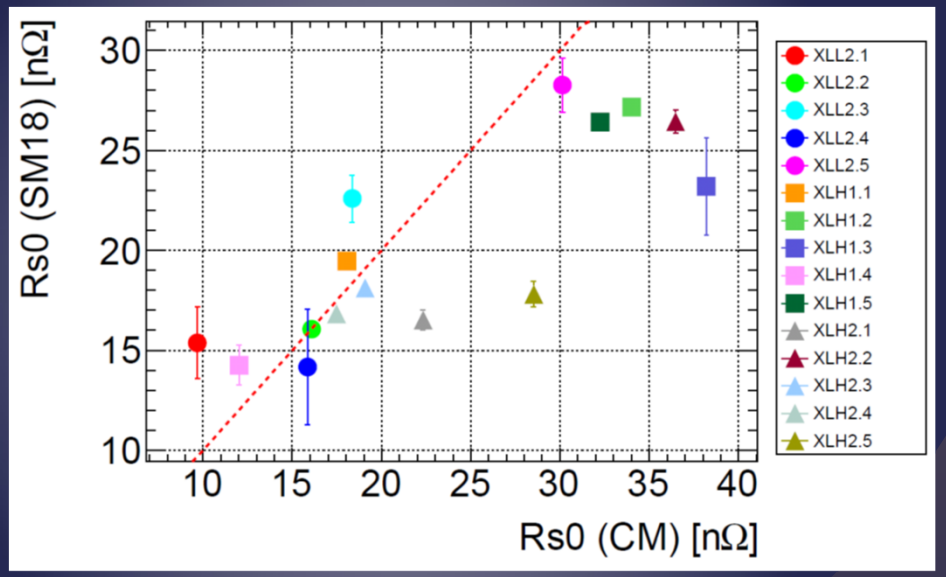


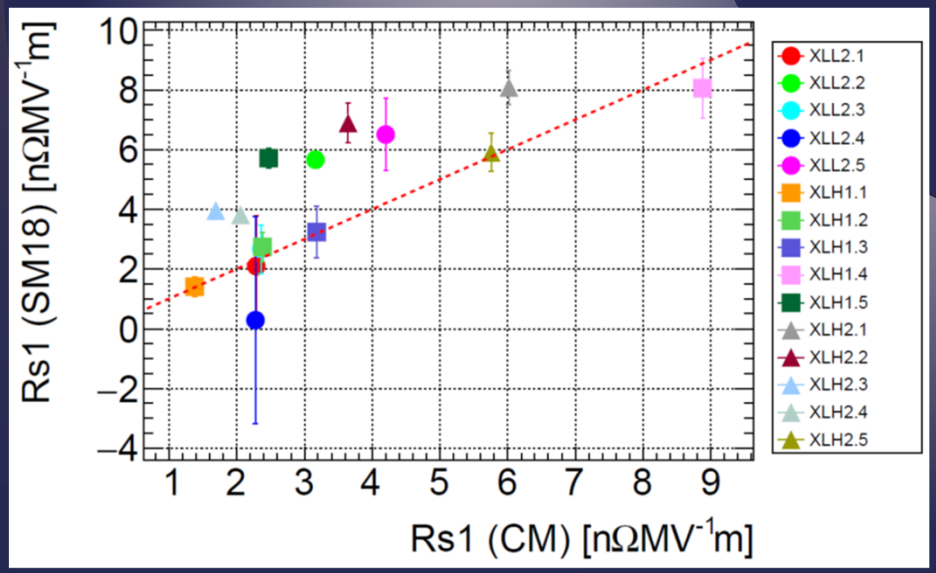
Surface resistance fit parameters

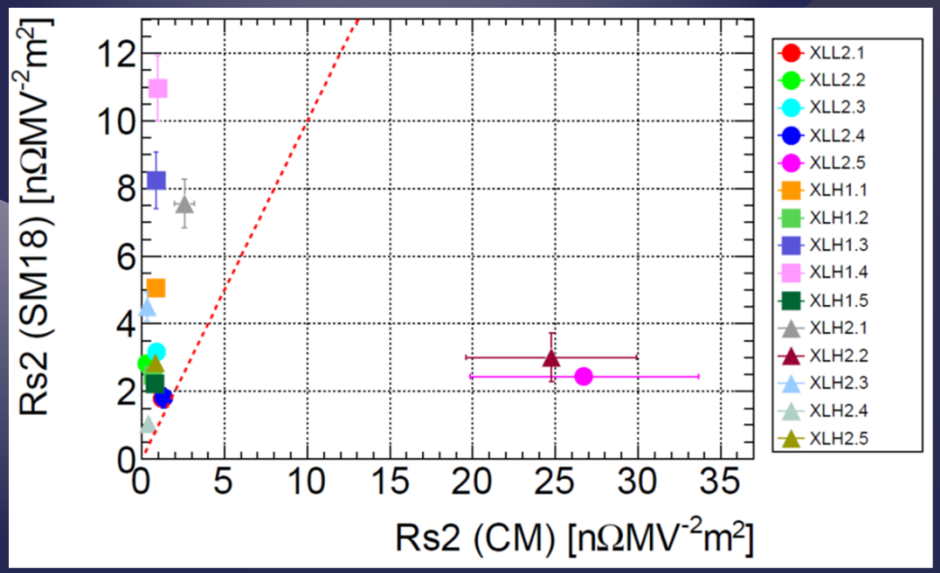


1: performance improvements in linac

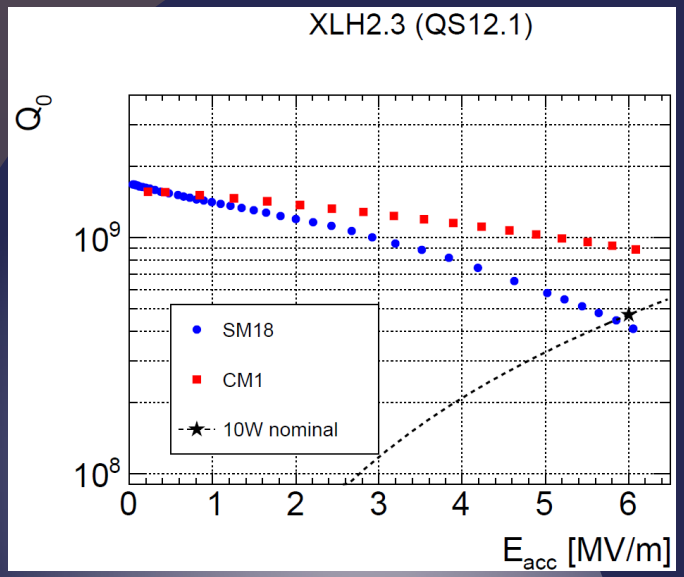


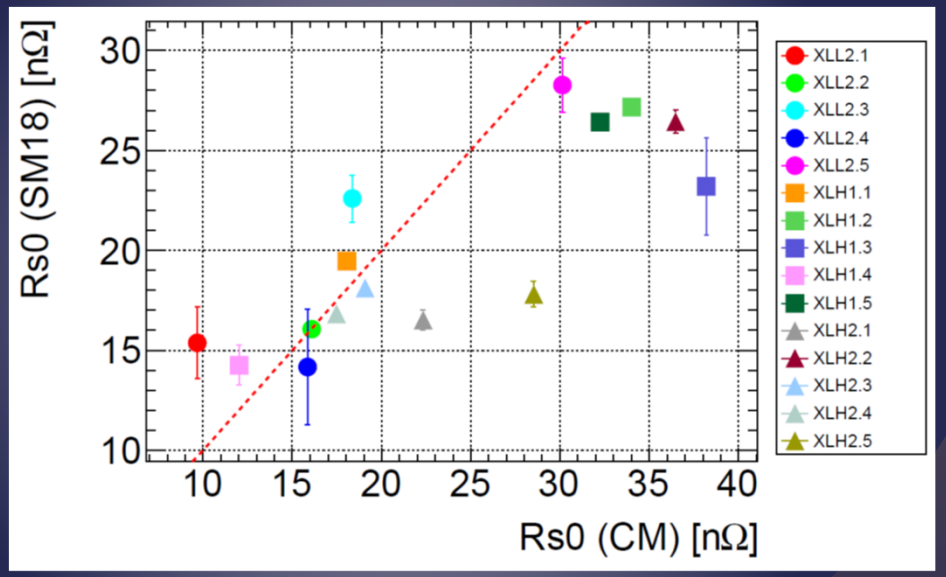


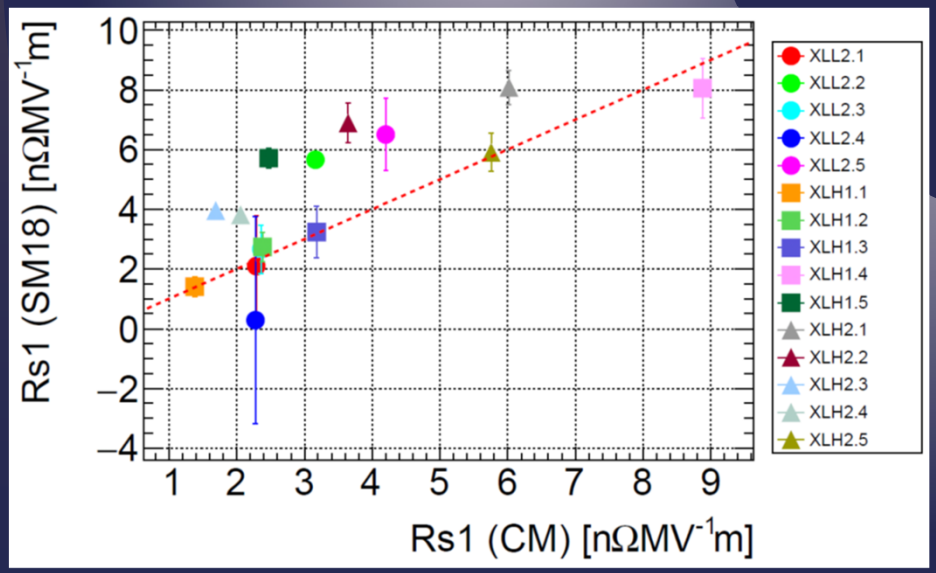


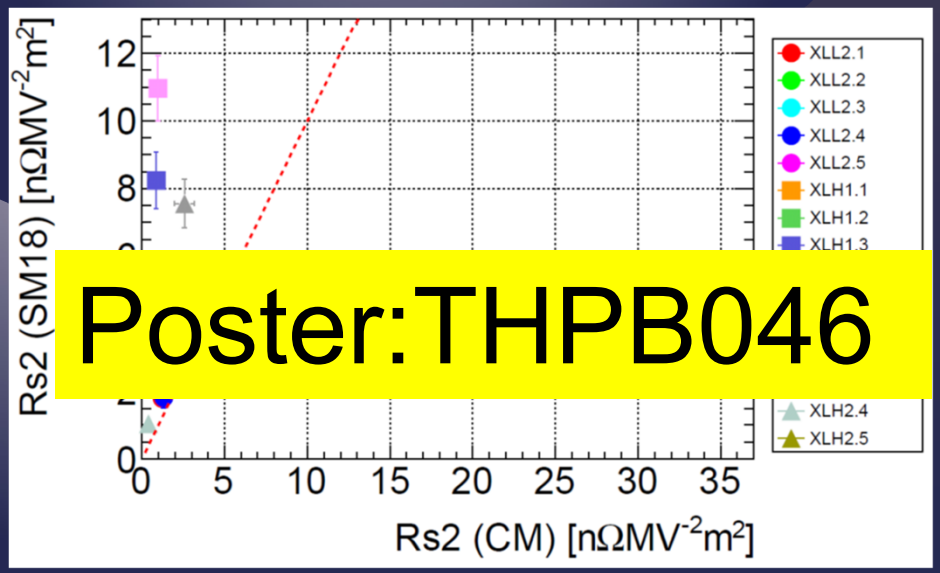


1: performance improvements in linac



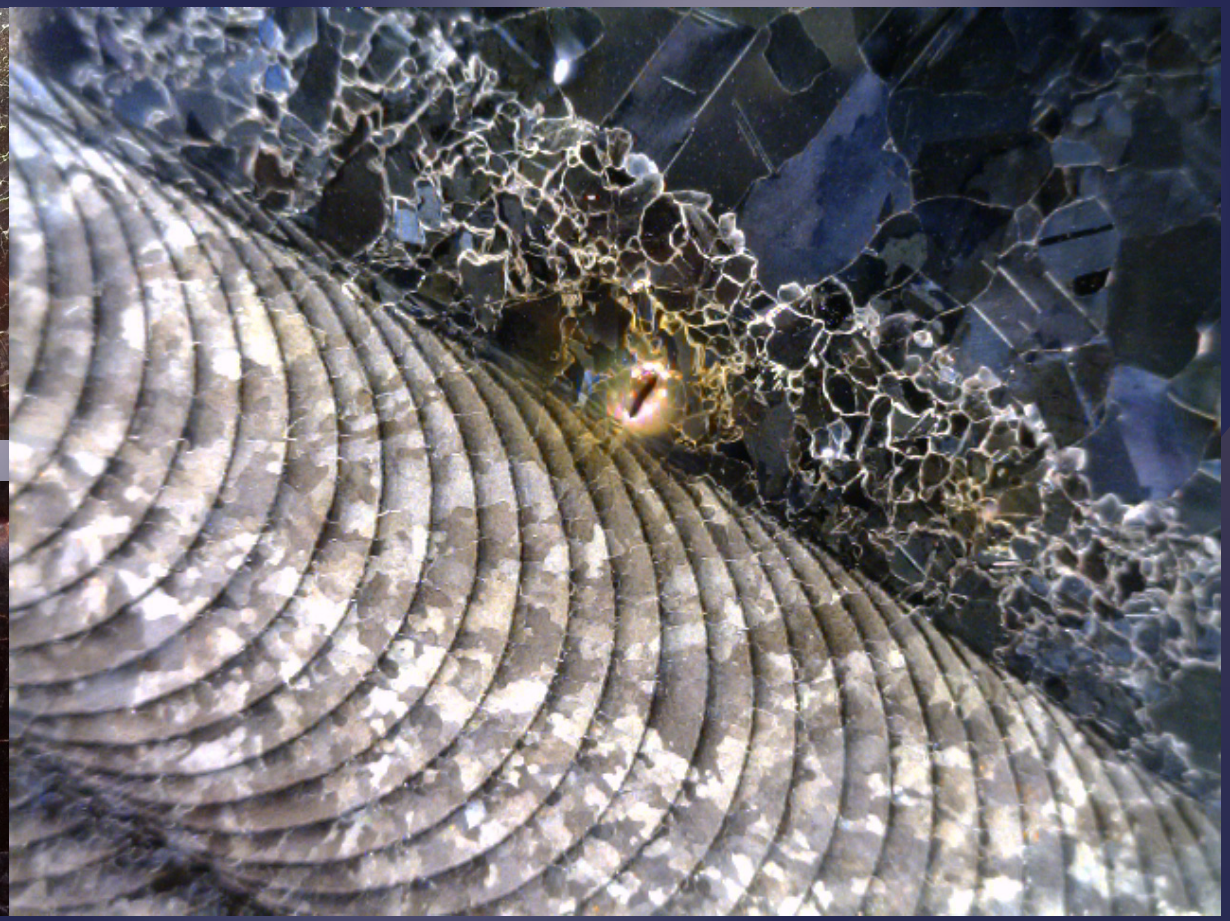




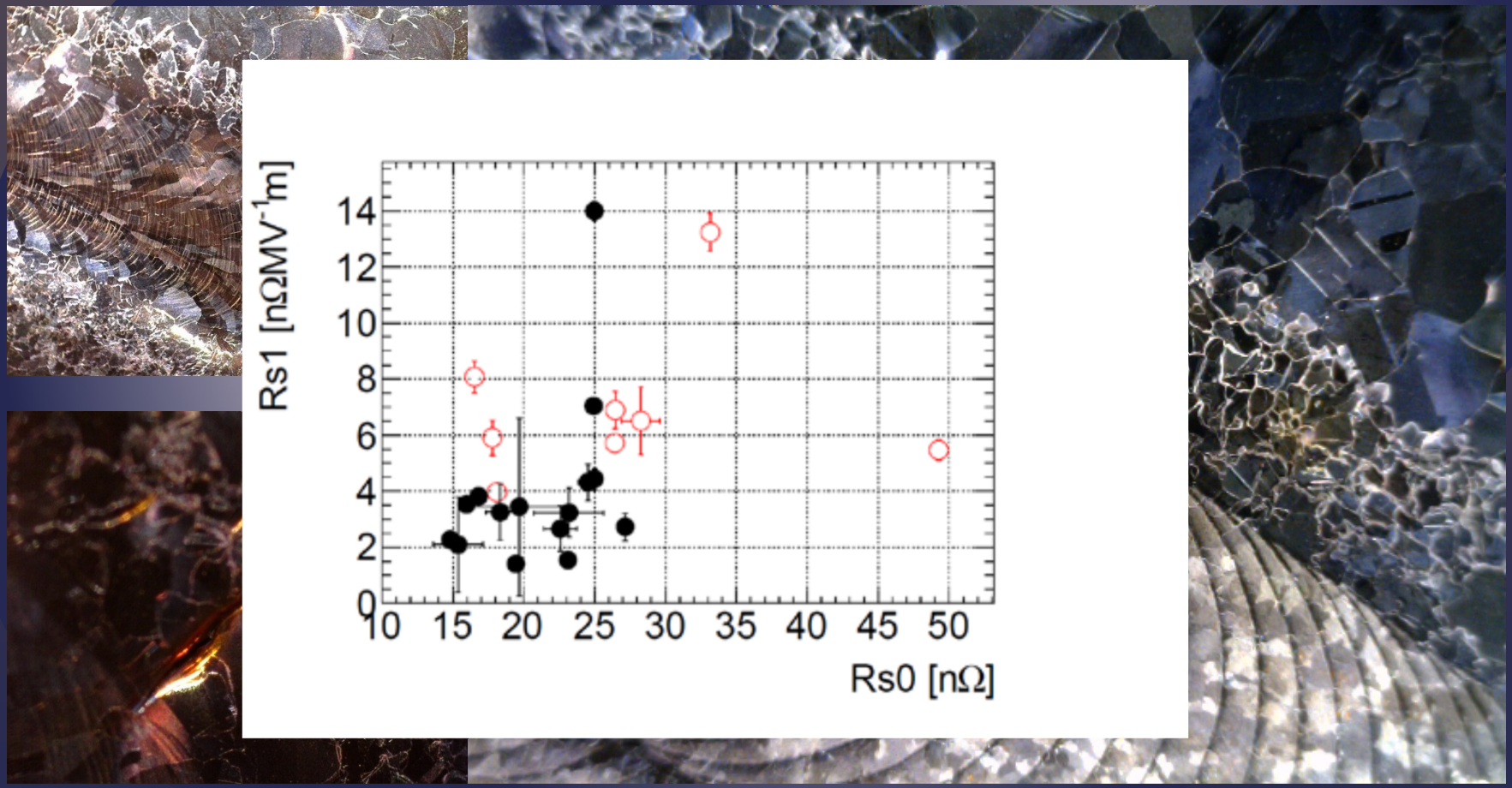


Poster:THPB046

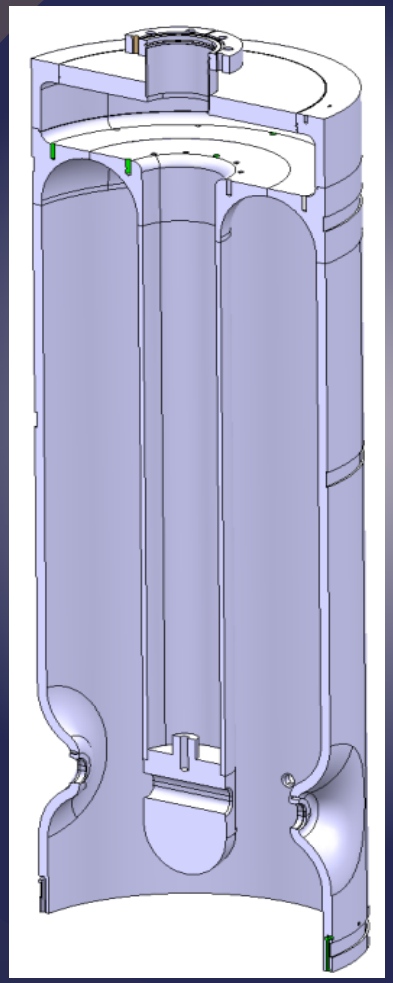
2: crack is evil



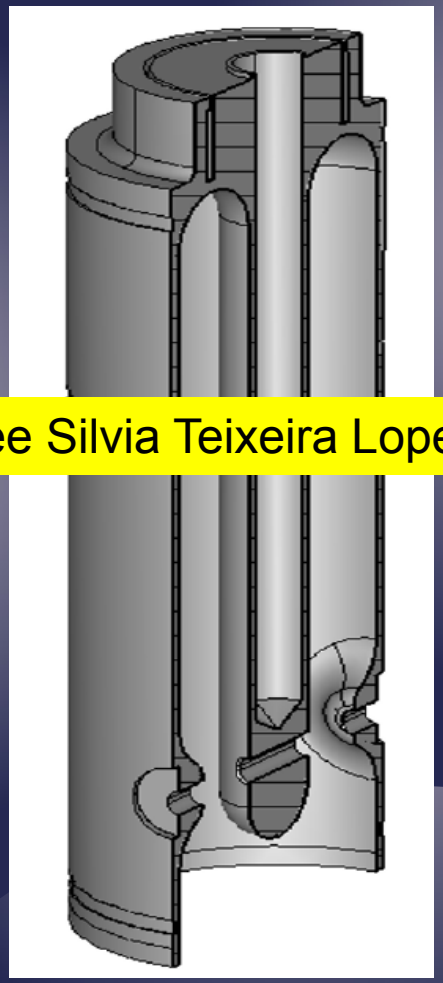
2: crack is evil



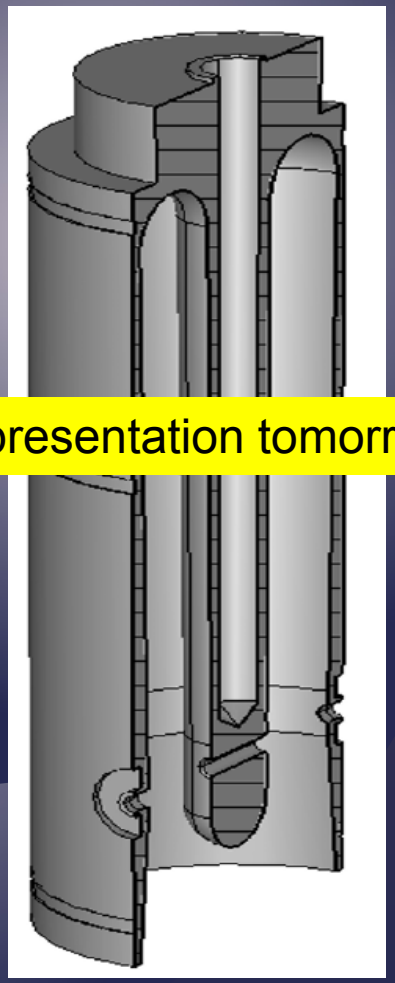
Cavity design evolution



Rolled sheets



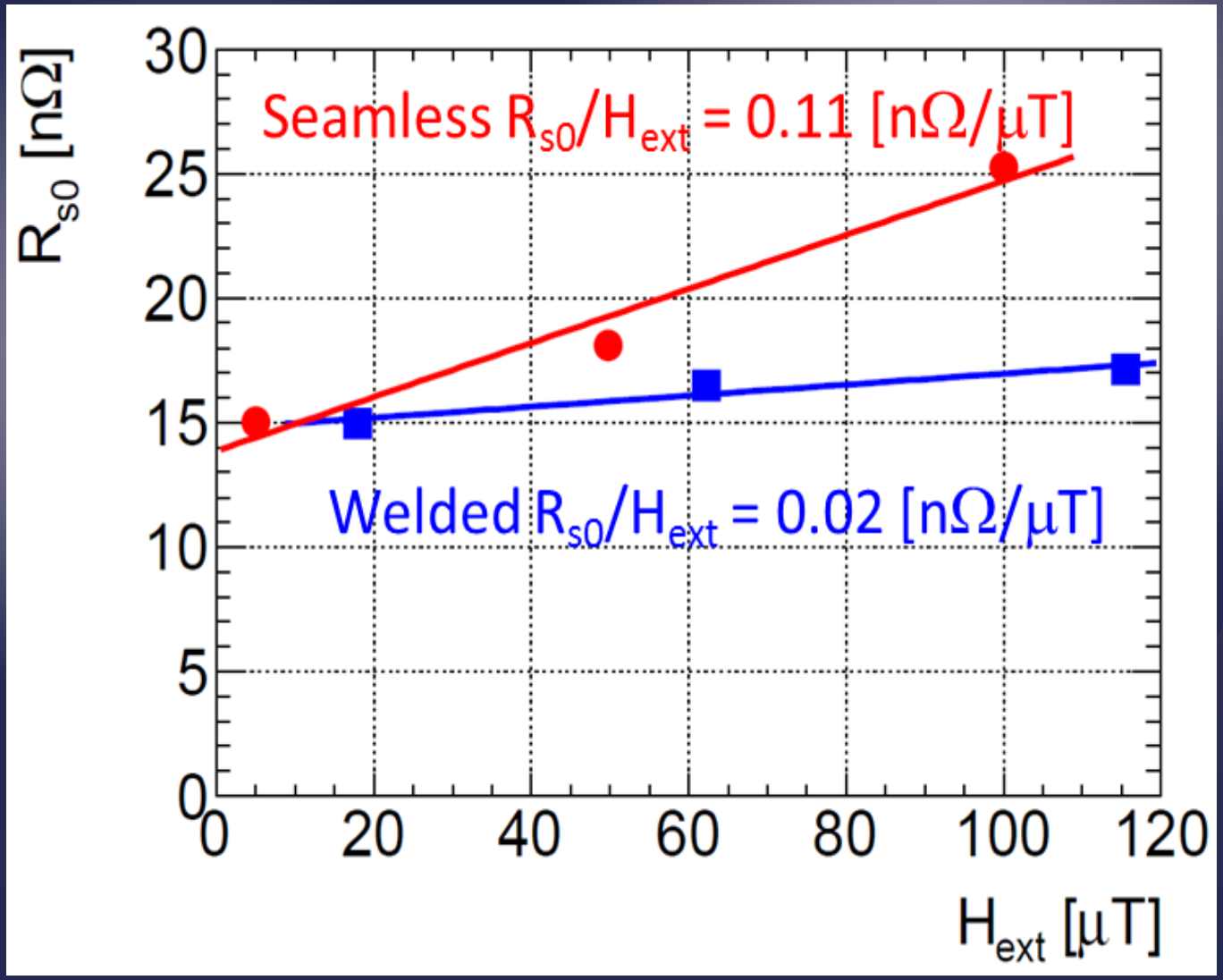
Shrink fit



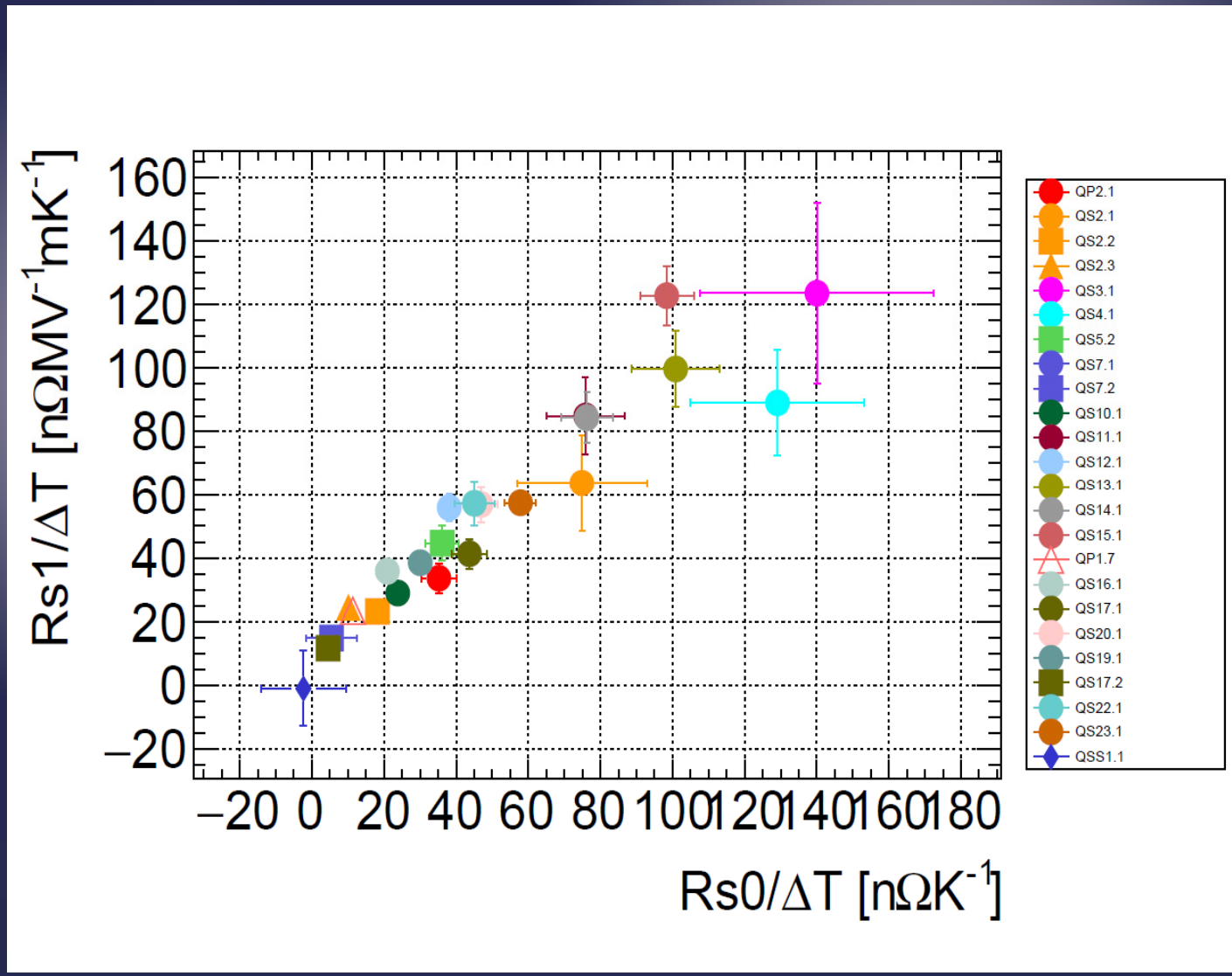
Seamless

See Silvia Teixeira Lopez's presentation tomorrow!

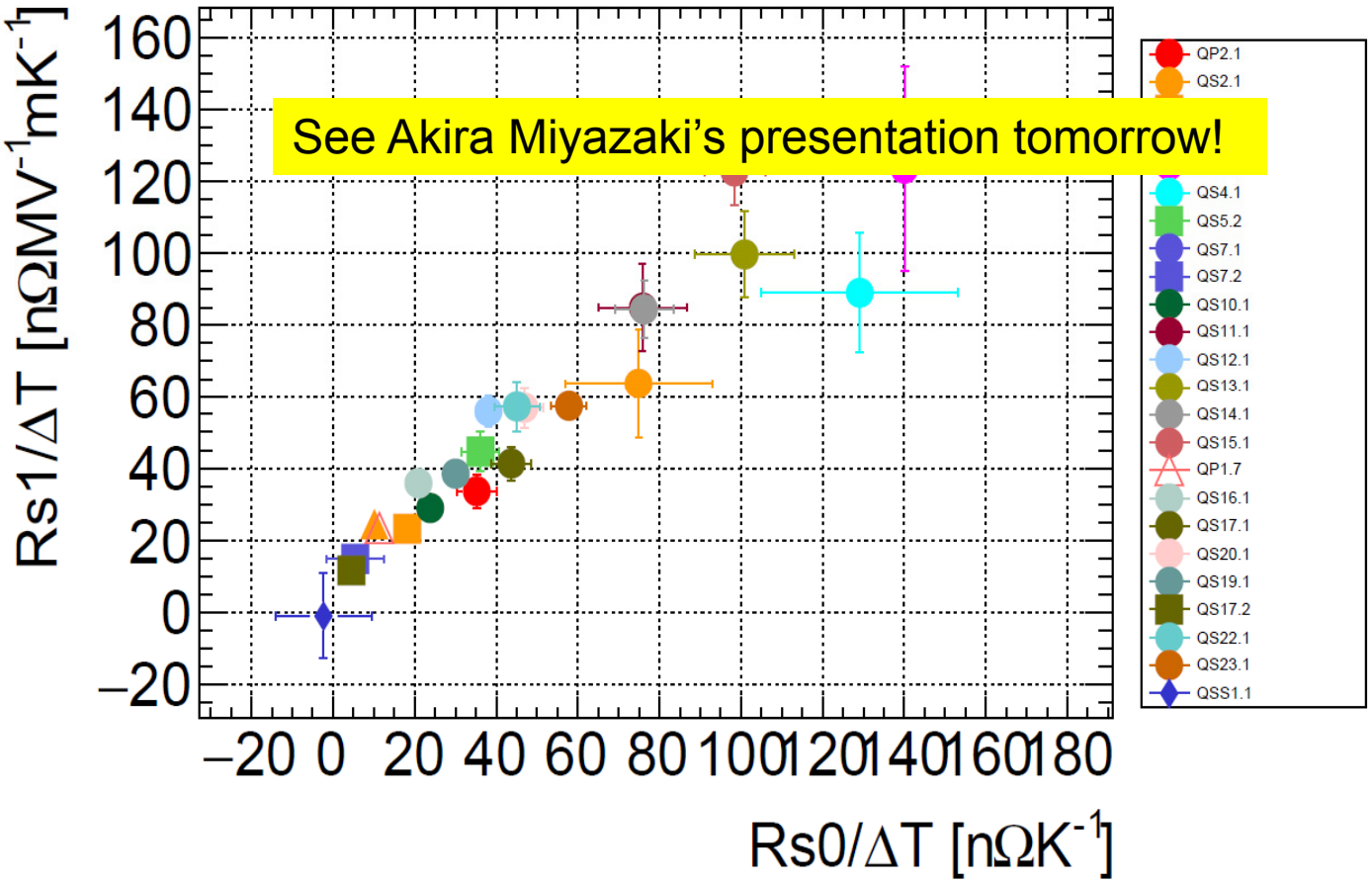
3: R(trapped flux) is higher for the best Nb/Cu cavities



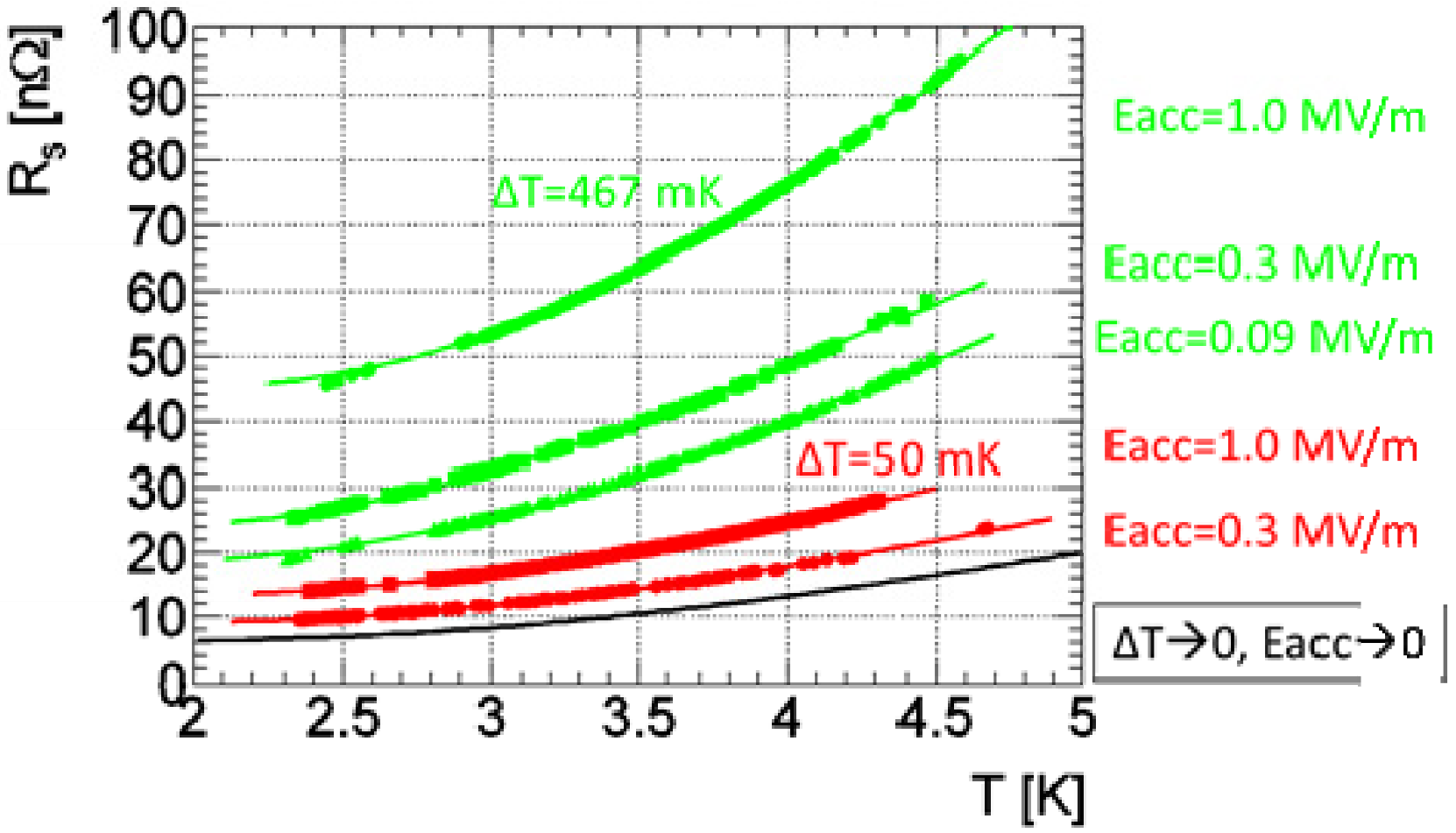
4: Rs dependence on T gradient across Tc is cavity dependent



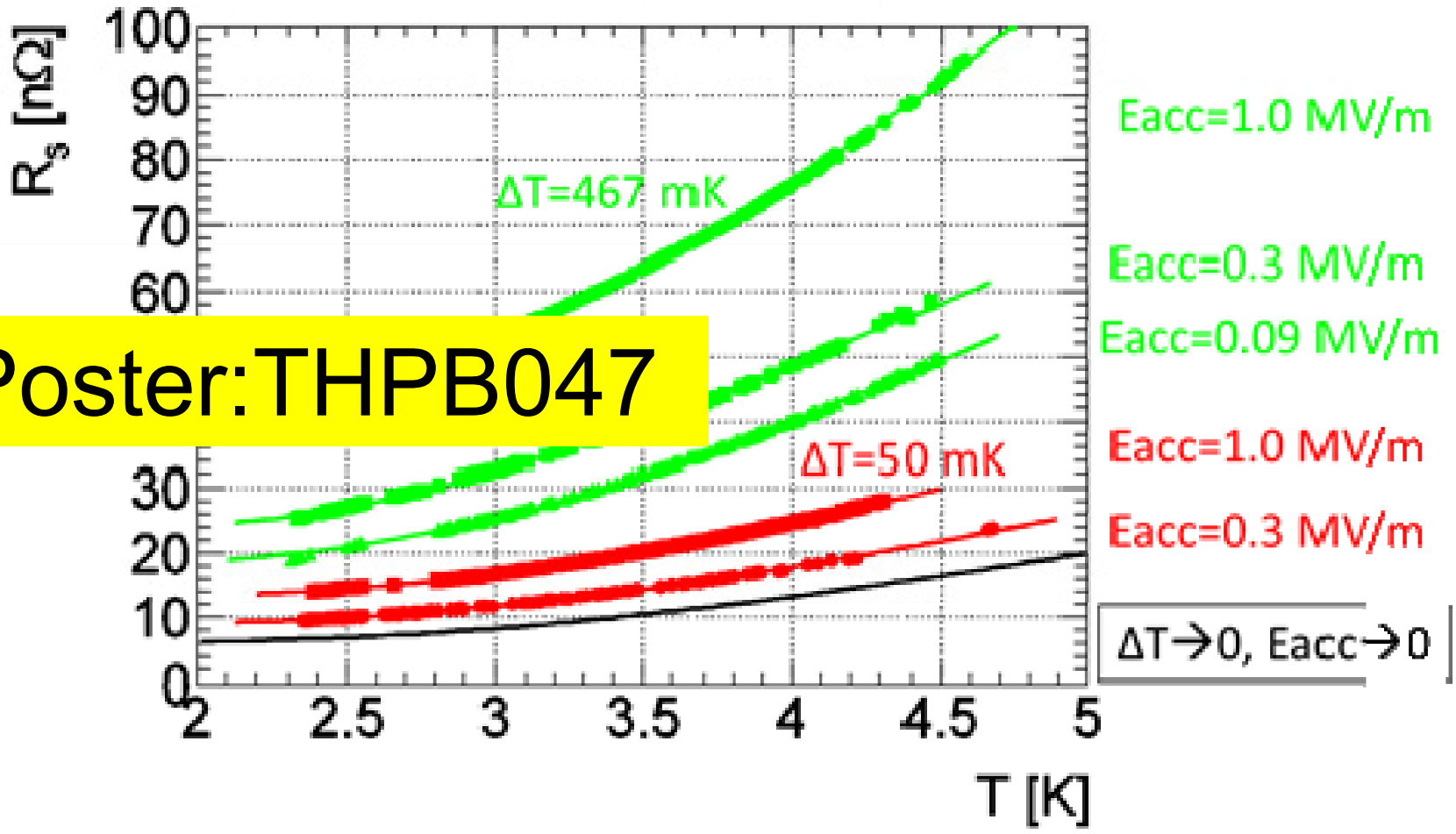
4: Rs dependence on T gradient across Tc is cavity dependent



6: $R(T) \neq R_{BCS}$?

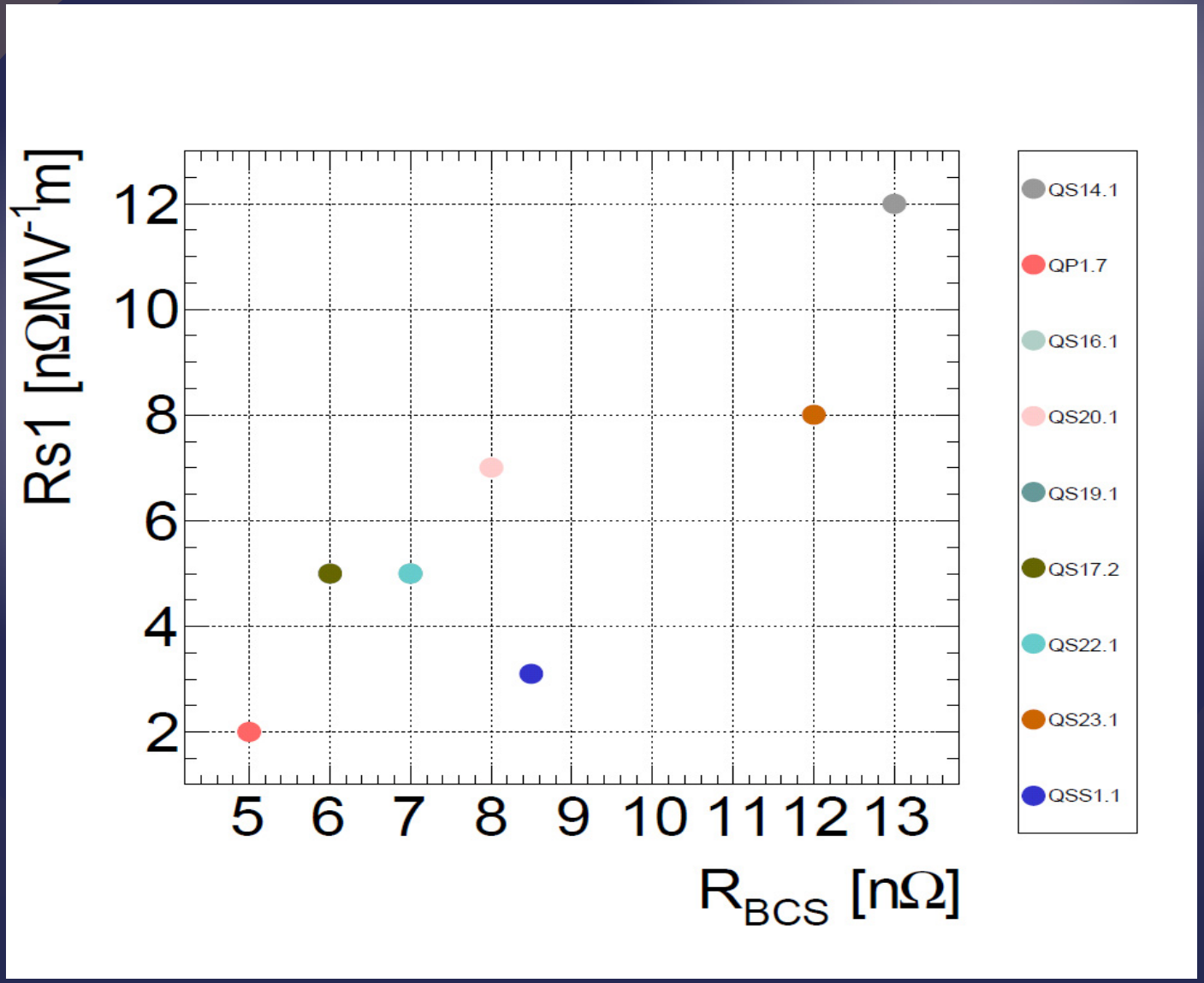

R_s [nΩ]
100
90
80
70
60
50
40
30
20
10
0
2
2.5
3
3.5
4
4.5
5
T [K]
ΔT=467 mK
ΔT=50 mK
Eacc=1.0 MV/m
Eacc=0.3 MV/m
Eacc=0.09 MV/m
Eacc=1.0 MV/m
Eacc=0.3 MV/m
ΔT→0, Eacc→0

6: $R(T) \neq R_{BCS}$?



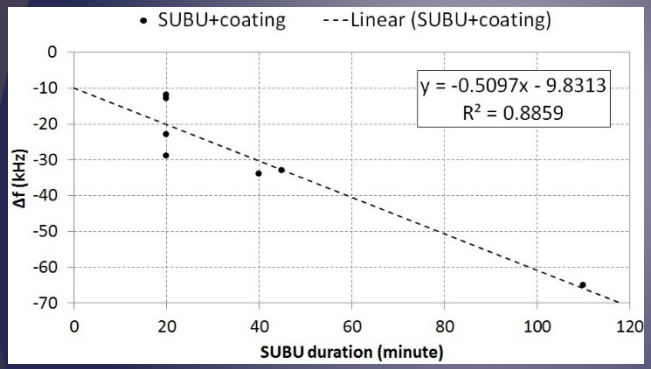
Poster:THPB047

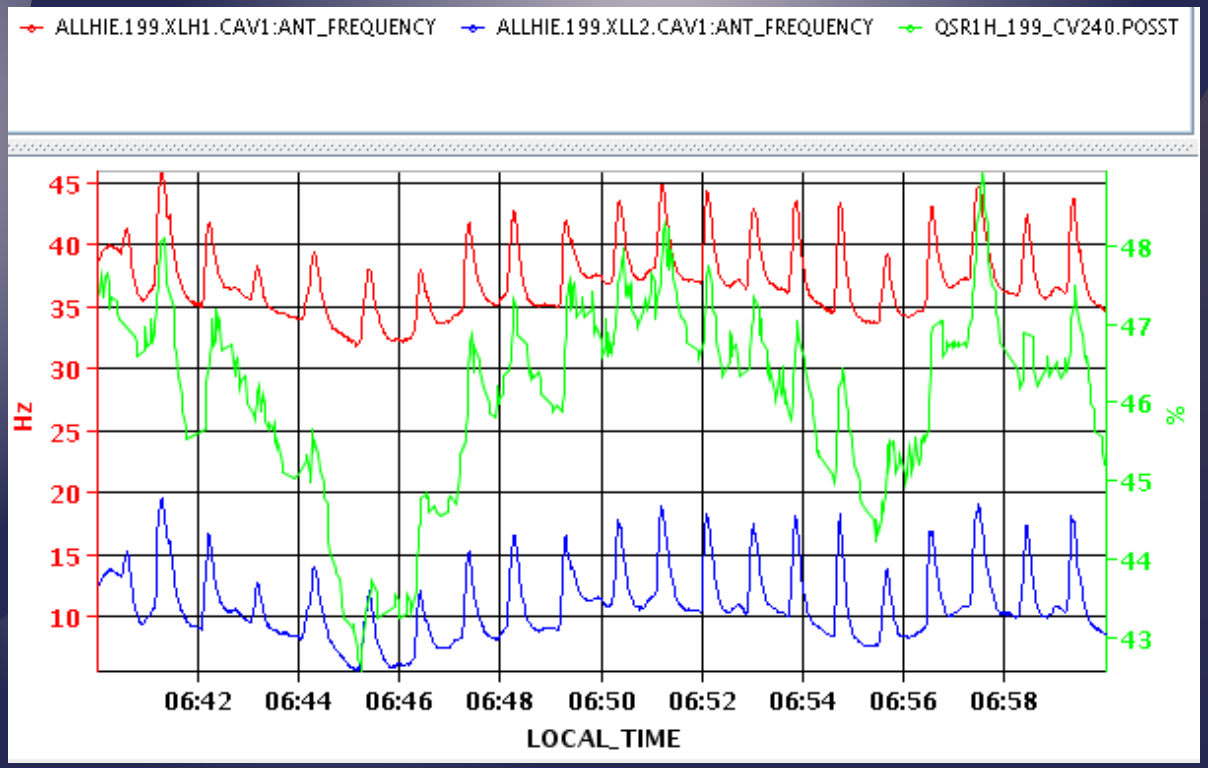
5: Rs(T) and Rs(B) are positively correlated



7: Tuning system

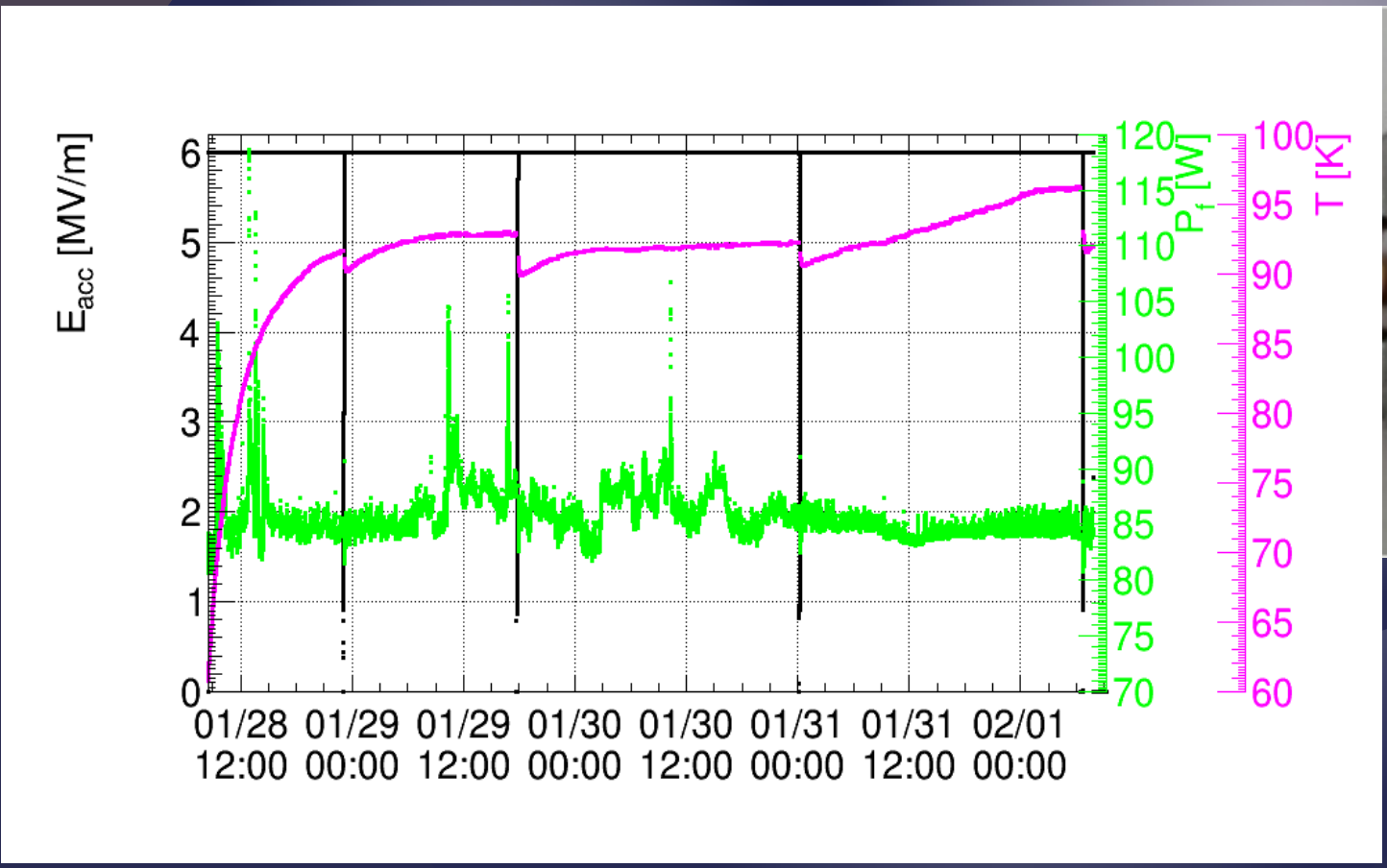
- Carefully gather statistics on Δf (acceptance-operation) for pre-tuning
- Tuning plate: Trojan horse for vibrations.
  Is plastic deformation taboo?



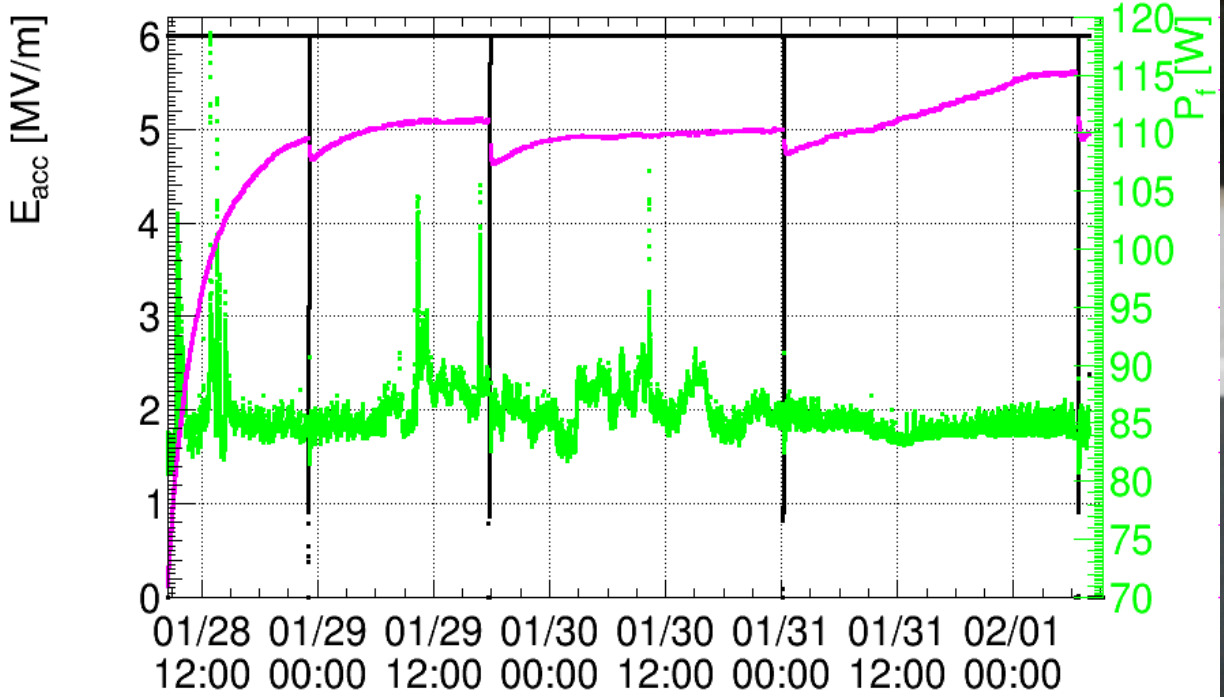


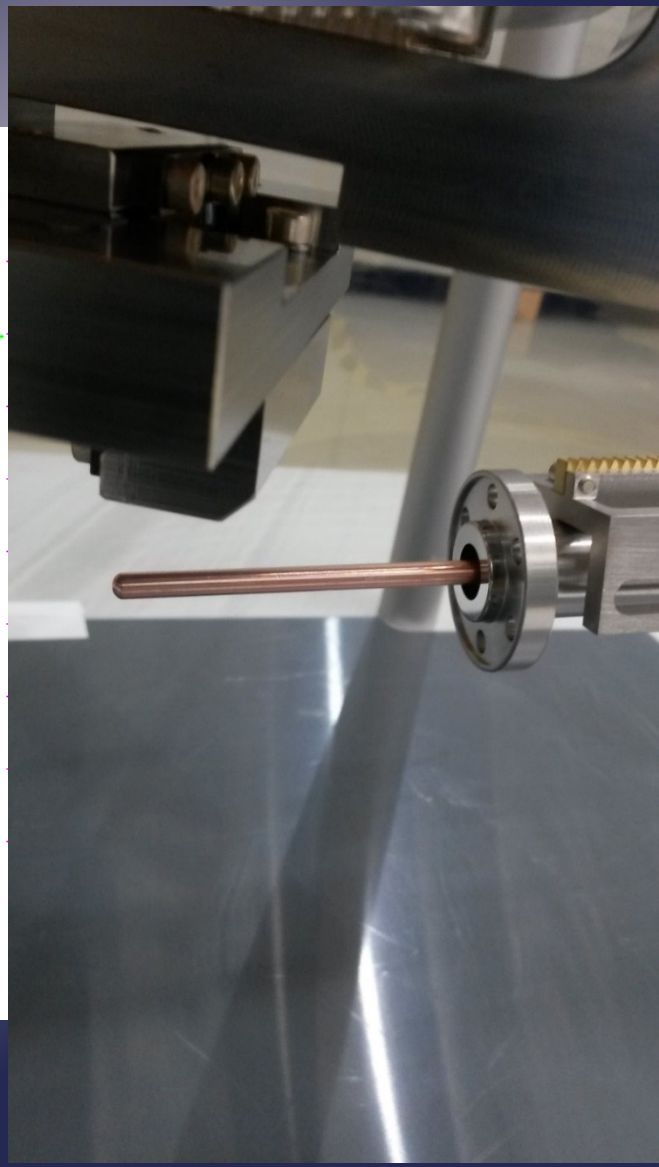
8: Endurance-test couplers in operational conditions!

8: Endurance-test couplers in operational conditions!



8: Endurance-test couplers in operational conditions!





9: Cryomodule design and assembly

Cryomodule design based on common vacuum and supporting system from the top plate:

→ More compact and simpler mechanics, but
→ Longer and more delicate assembly in clean room

- Procedures
- Logistics
- Blank assembly as much as possible
- Quality Assurance

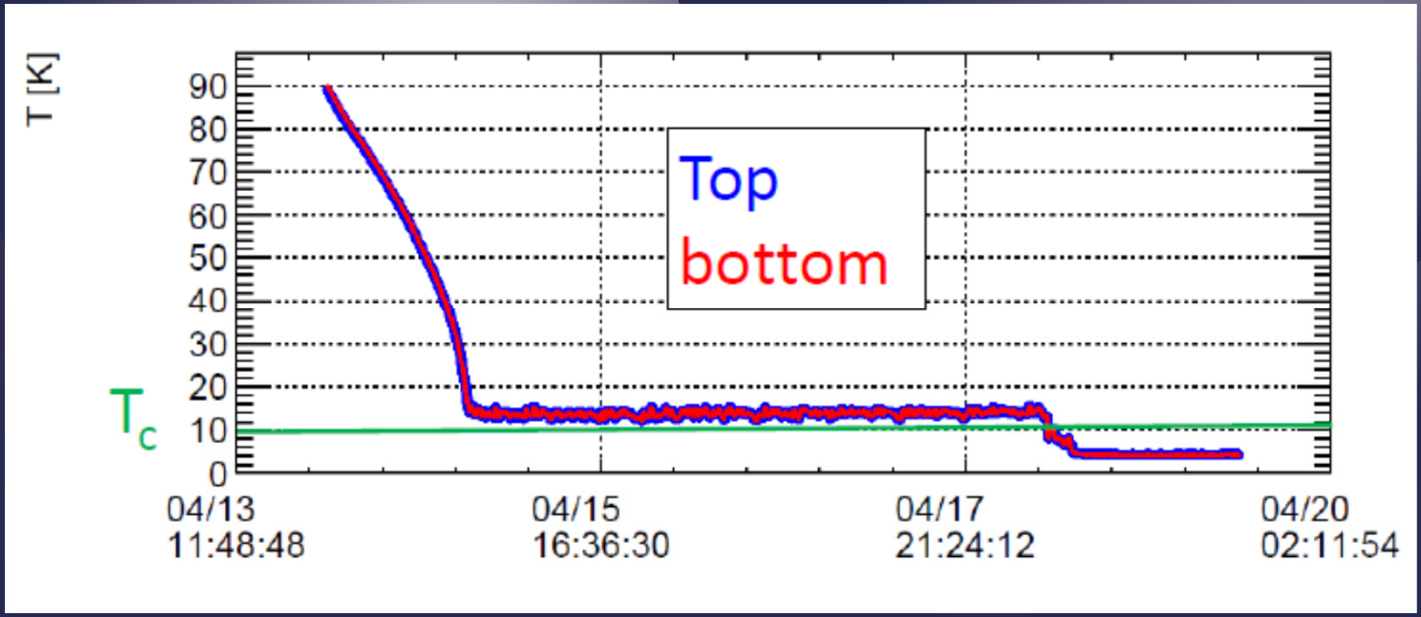
Thermal shield nickel plated to reduce emissivity:
→ May be overkilling
→ Plating difficult to do with required quality

Blank assembly of a seamless cavity, July 2017

Thermal design and alignment concepts fully validated:
~ 10 W @ 4.5 K static; cavity/solenoid positioning < 0.1 mm
No cold leaks p ~ 10^{-11} mbar

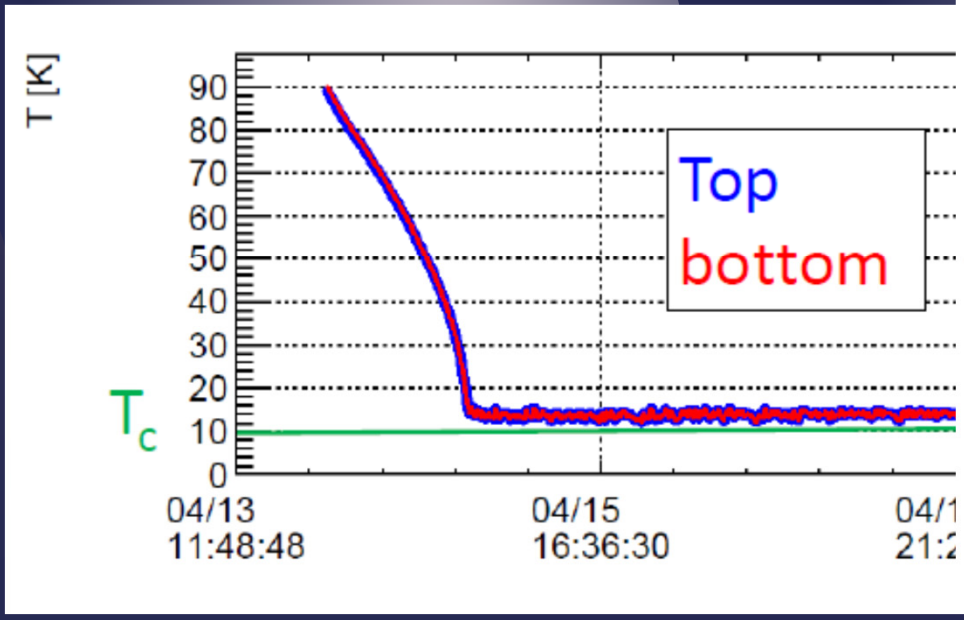
10: cryomodule commissioning

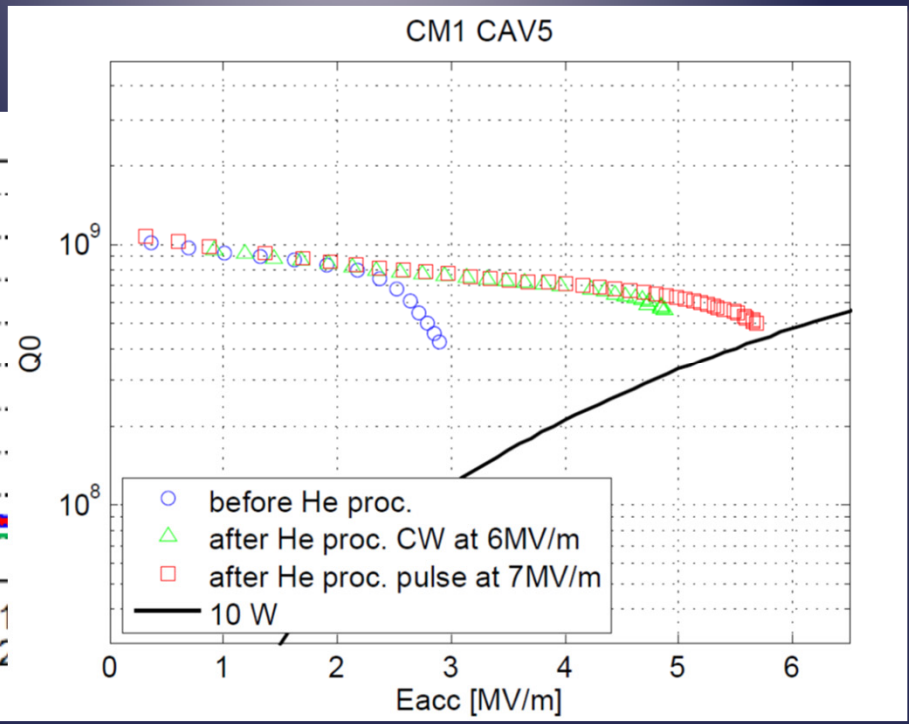
- Horizontal test skipped: commissioning in the linac
- Controlled cool down
- Cryo-plant process→ cavity detuning
- No venting without rinsing!
- He processing in situ works!



10: cryomodule commissioning

- Horizontal test skipped: commissioning in the linac
- Controlled cool down
- Cryo-plant process→ cavity detuning
- No venting without rinsing!
- He processing in situ works!





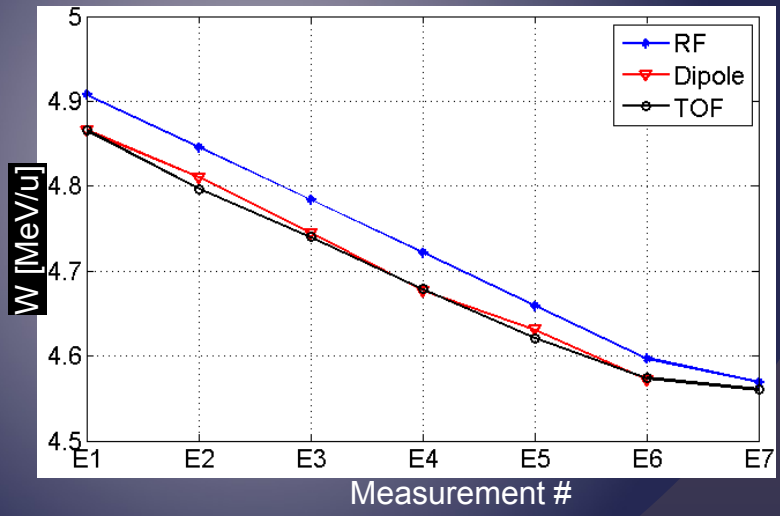
Cavity measurement with beam

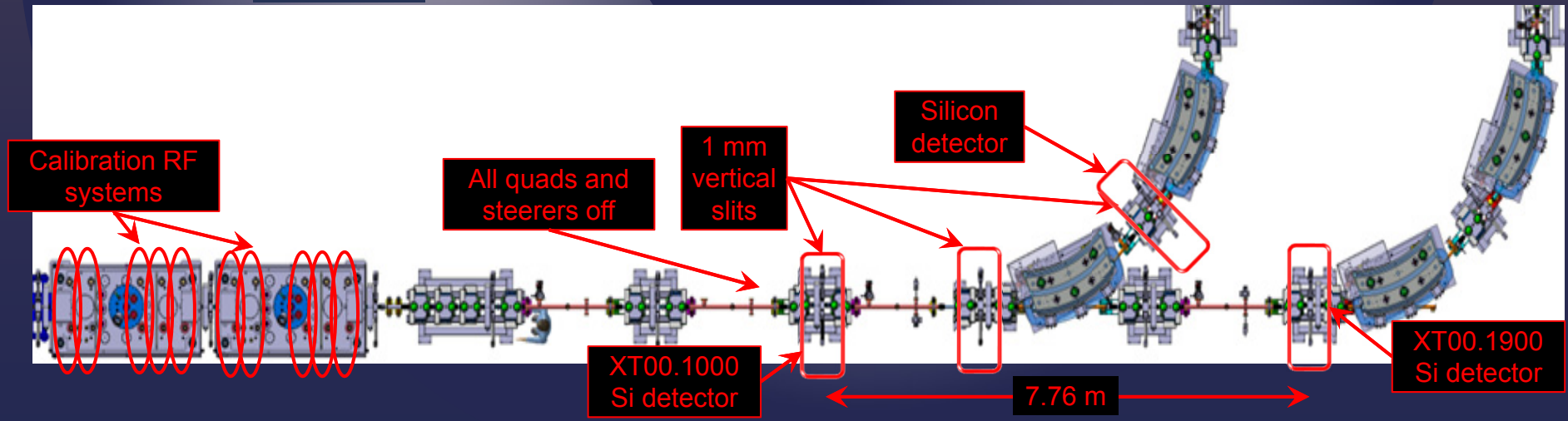
Comparison Energy Measurements:

We can compare the three independent methods to measure the energy of the beam:

- Calibration of the RF systems (W_{RF})
- First dipole of the XT01 HEBT line (W_B)
- TOF between silicon detectors in XT00 (W_{TOF})

#	E_{SRF08} [MV/m]	W_{RF} [MeV/u]	$\frac{W_{RF}-W_{TOF}}{W_{TOF}}$	W_B [MeV/u]	$\frac{W_B-W_{TOF}}{W_{TOF}}$	W_{TOF} [MeV/u]
E1	5.455	4.908	0.9 %	4.866	0.0 %	4.866
E2	4.455	4.846	1.0 %	4.810	0.3 %	4.797
E3	3.455	4.784	0.9 %	4.745	0.1 %	4.740
E4	2.455	4.722	0.9 %	4.677	-0.0 %	4.679
E5	1.455	4.659	0.8 %	4.631	0.2 %	4.621
E6	0.455	4.597	0.5 %	4.572	-0.0 %	4.574
E7	0.000	4.569	0.2 %	--	--	4.560





Summary

- **Nb/Cu technology was successfully used to build HIE-ISOLDE RIB linac serving a large physics community at CERN**

- 15 cavities are running at 4.5 K requiring ~ 100 W RF power for ~ 1.8 MV V_{acc}
- Cavity dissipation in the linac < 10 W at 6 MV/m
- Without magnetic shielding
- No interference from neighbouring superconducting solenoids

- >> 20 cavities coated with same method and cold tested
  - Importance of substrate quality for Nb/Cu
  - Importance of homogeneous ($\Delta T \rightarrow 0$) cool down across T_c
  - Surface resistance displaying intriguing behaviour and correlations
  - Cavity design and sputtering protocol further perfectible

- 3 cryomodules assembled, installed and commissioned in the linac (4^{th} is coming)
  - Design choices validated
  - Importance of stress testing coupler and tuning systems in V tests
  - Nb/Cu QWR could be made insensitive to vibrations by a stiffer tuning plate
  - FE can be processed on line
  - RF measurements cross checked with TOF