
CERN

The surface impedance of Nb/Cu coated QWR cavities for HIE-ISOLDE project

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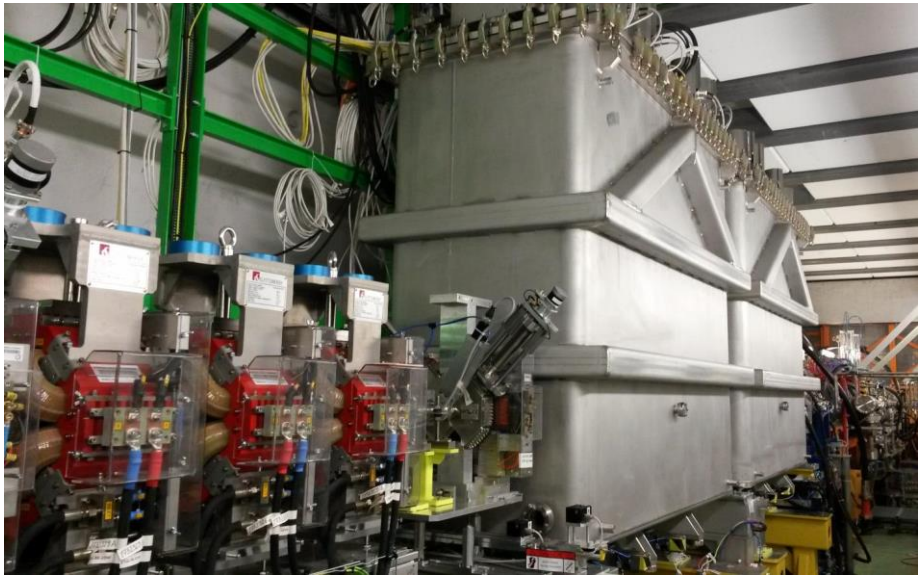
Outline

- HIE-ISOLDE Project
- Quarter-Wave Resonator (QWR)
- Cavity Performance
- Rs0 and Rs1
- Features
  - Optical Inspections
  - Material Studies
- New Cavity Design
- Conclusions

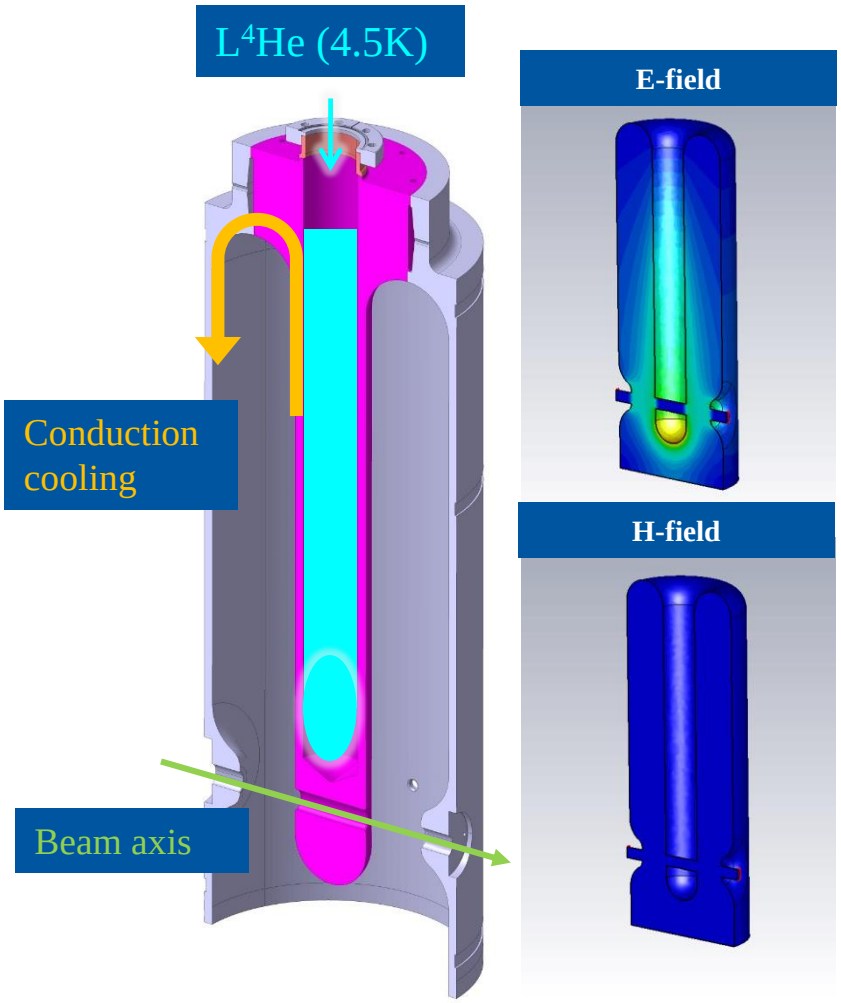
HIE-ISOLDE

- The **High Intensity and Energy ISOLDE** (HIE-ISOLDE) project is a major upgrade of the existing ISOLDE and REX-ISOLDE facilities.
- Energy increase of the delivered radioactive ion beam (RIB) **from 3 MeV/u to 10 MeV/u.**



- SC LINAC based on **Quarter Wave Resonators** (QWRs).
- High-β section consists on **4 cryo-modules** with 5 cavities each.

Quarter Wave Resonator (QWR)

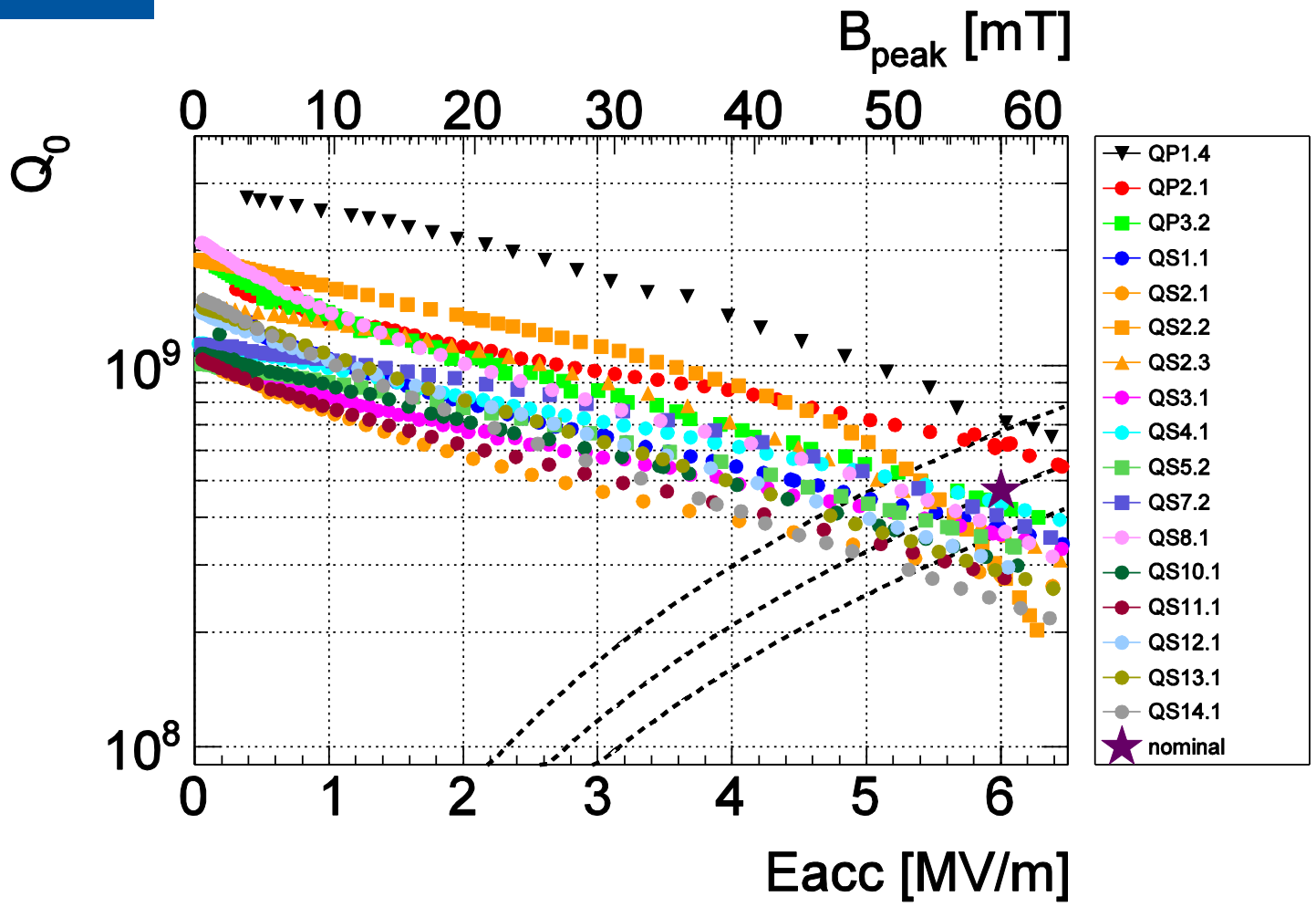


- Superconducting Nb-film cavity at **4.5 K**
- **Conduction cooling** through the copper substrate (good thermal conductivity of Cu)
- **DC bias** sputtering system
- **Welding** in the high magnetic field region
- Surface resistance ***Rs*** has ***non-trivial*** behavior

Frequency	**101.28 MHz**
E_{acc}	**6 MV/m**
$\beta_{optimum}$	**10.9%**
R/Q	**553 Ω**
E_{peak}/E_{acc}	**5.4**
B_{peak}/E_{acc}	**96 G/(MV/m)**
$G=R_sQ$	**30.34 Ω**
U/E_{acc}^2	**0.207 J/(MV/m)^2**
P_c at 6MV/m	**10W**

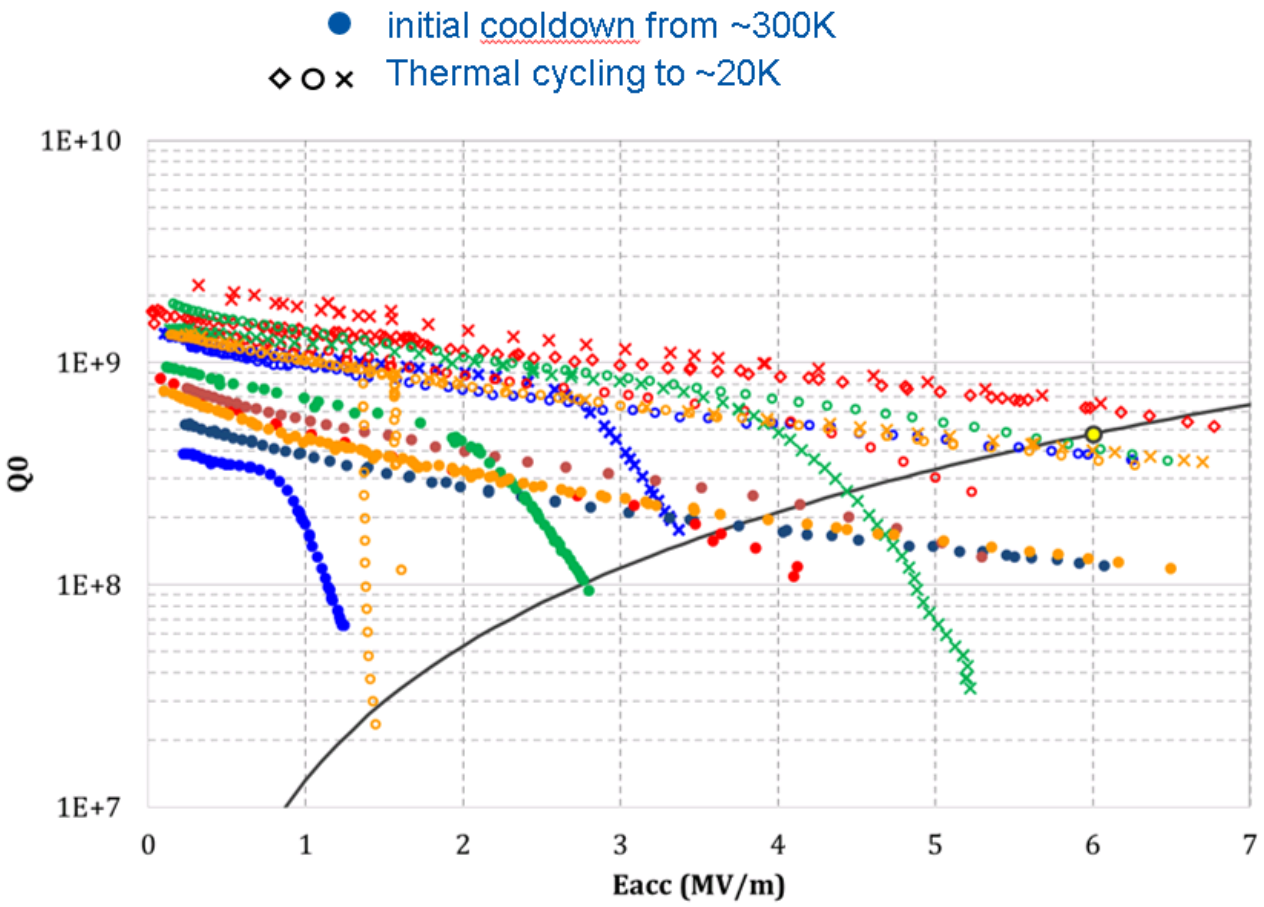
Cavity Performance

Raw data



Presented by Pei in 2014

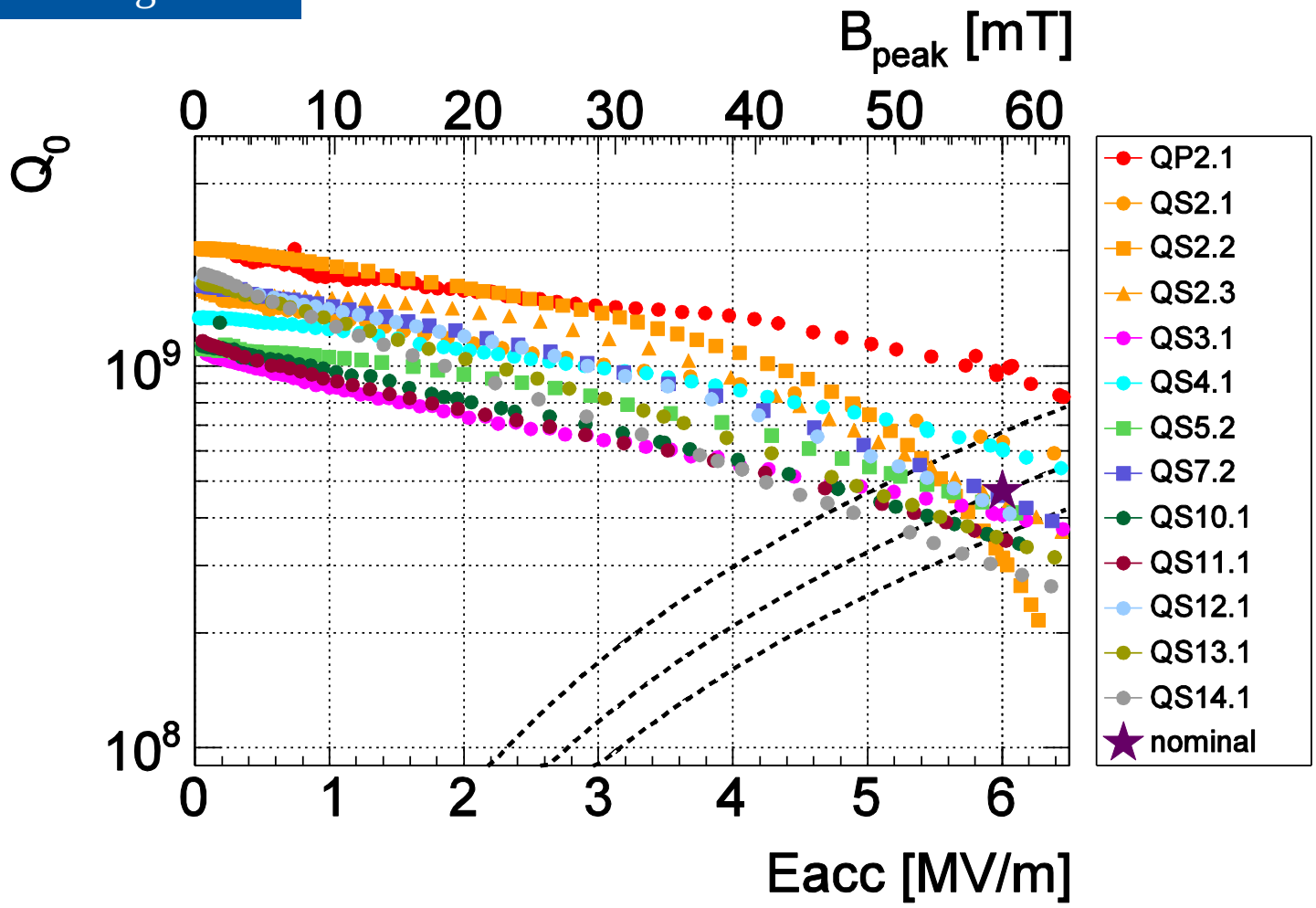
Initial cooldown & thermal cycle



Pei Zhang | Thin film workshop, LNL, Italy | Oct 7th, 2014 | Page 9

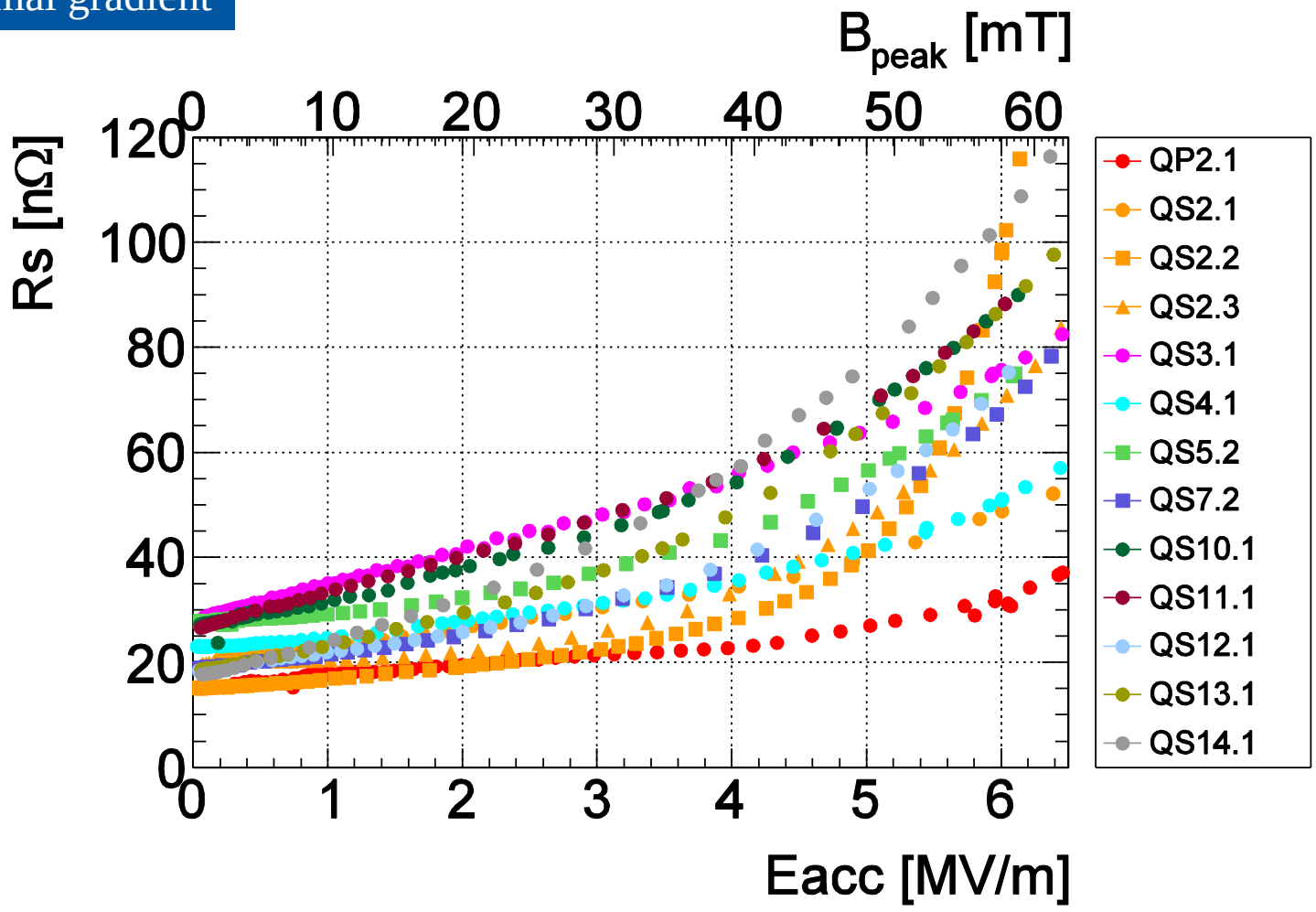
Cavity Performance

Ideal thermal gradient

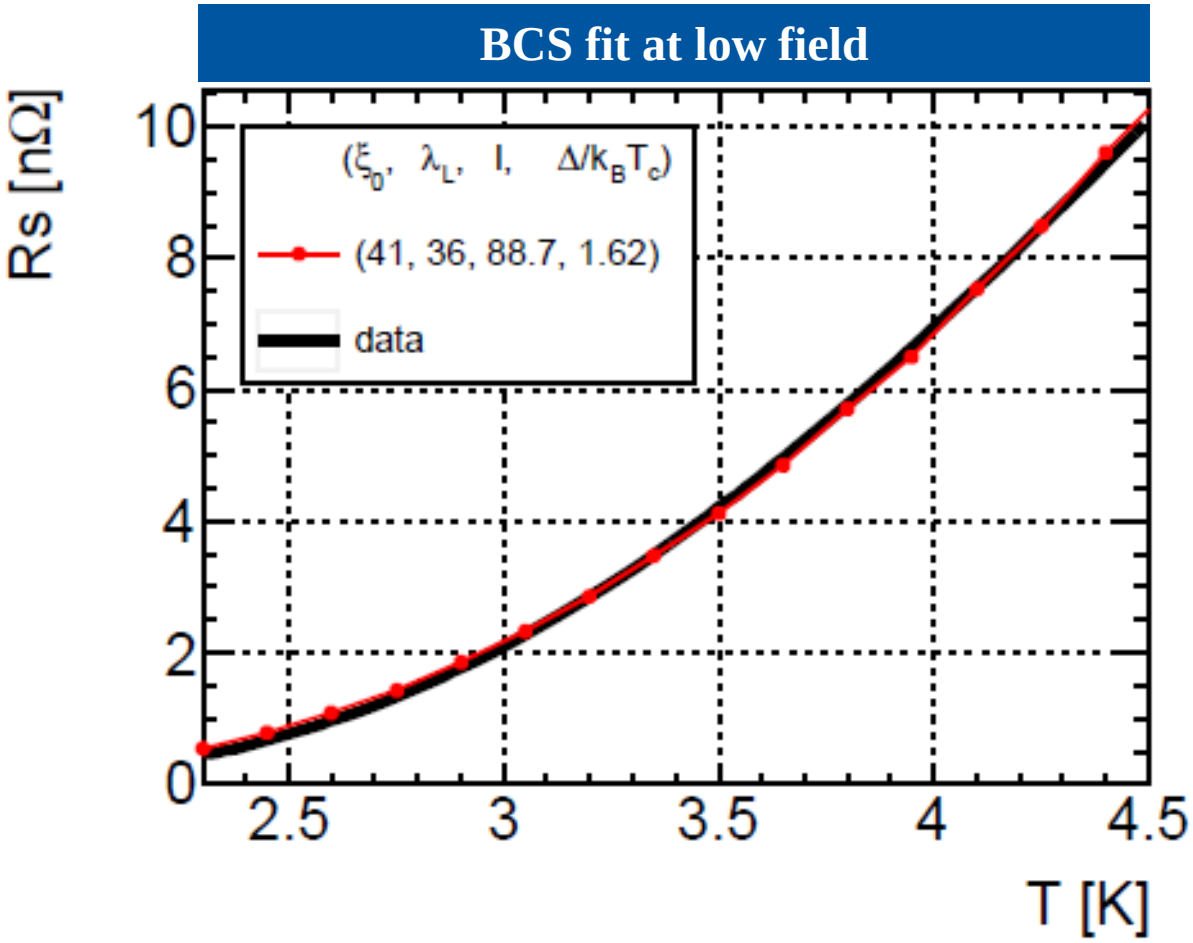


Cavity Performance

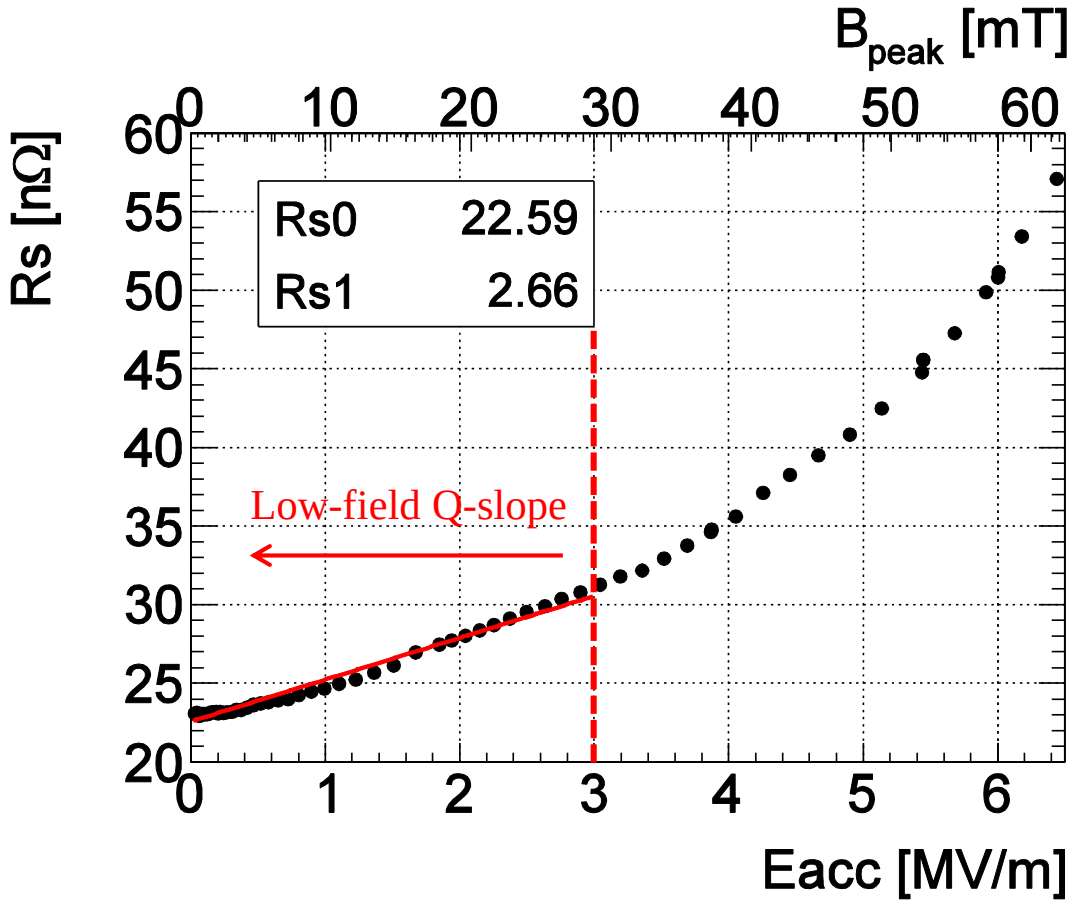
Ideal thermal gradient



Temperature dependent component



Rs0 and Rs1 to evaluate the cavity

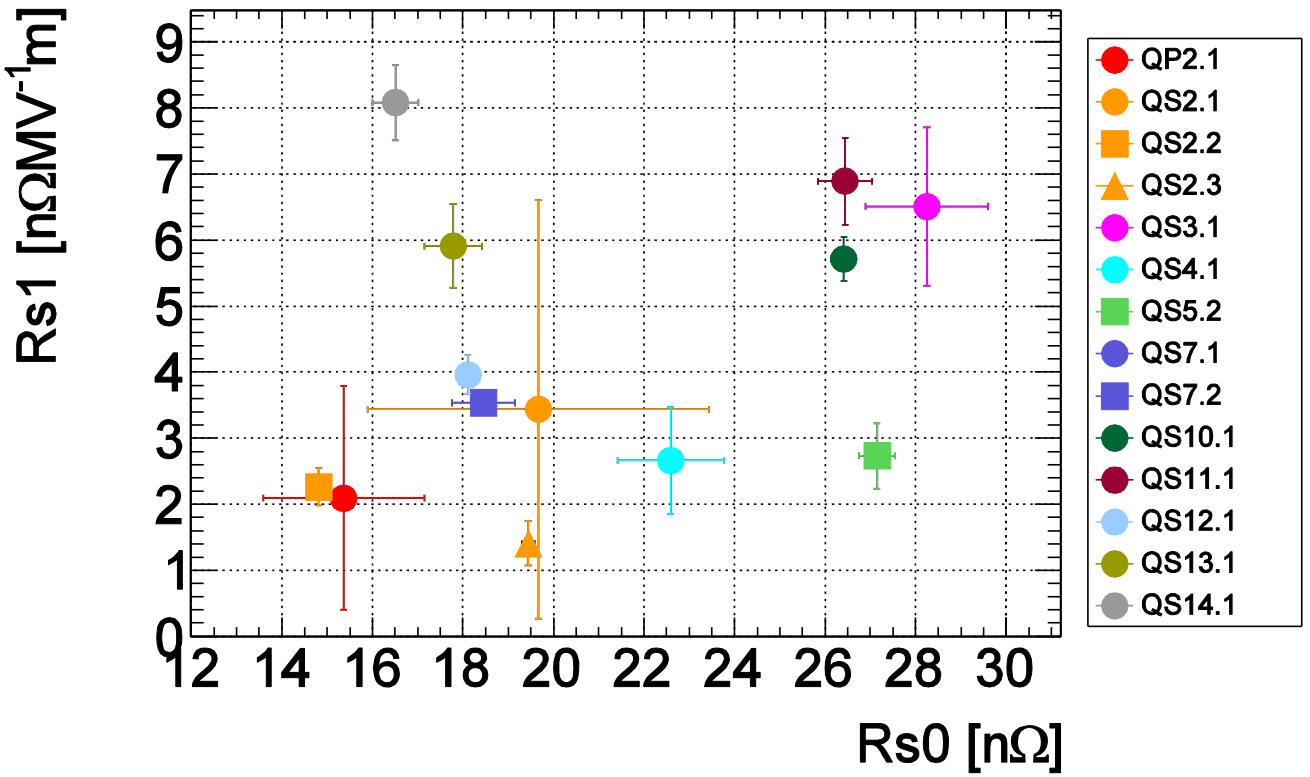


Linear fit: $Rs(E_{acc}) = Rs0 + \underline{Rs1} \cdot E_{acc}$ $(0<E_{acc}<3$ MV/m)

Q-slope

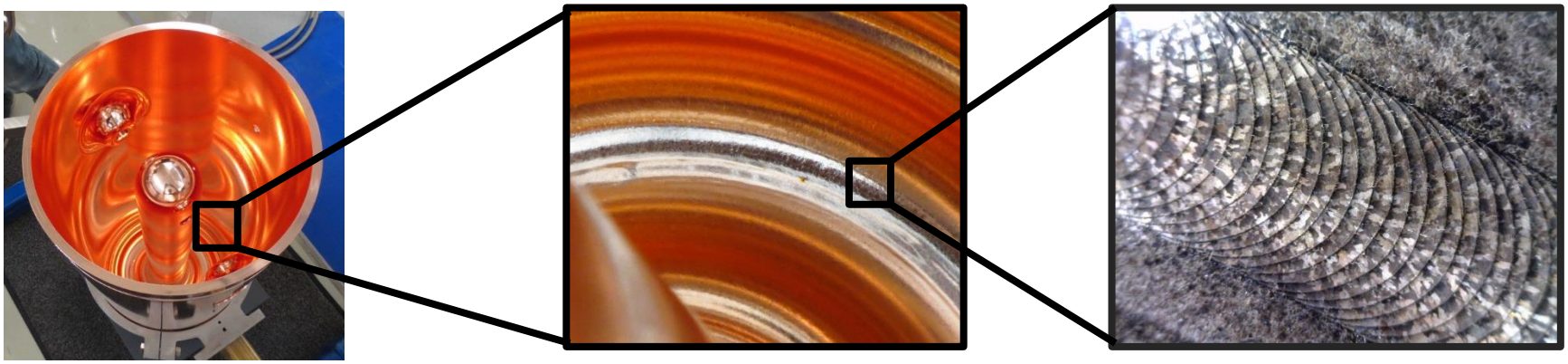
Rs1 vs Rs0 for all cavities

Ideal thermal gradient



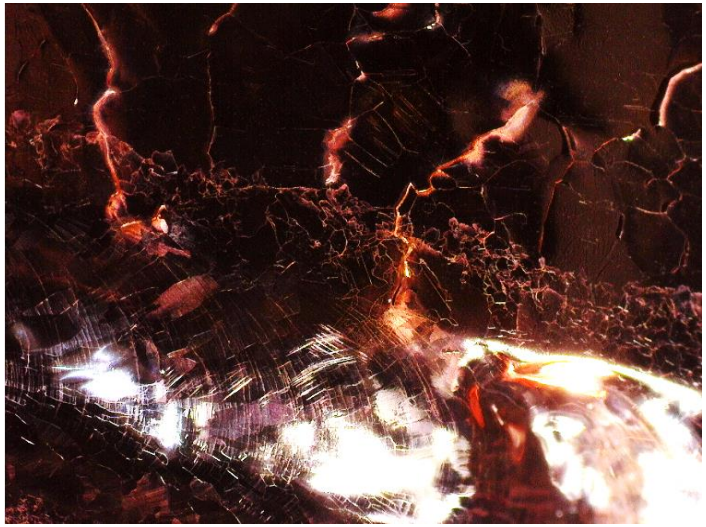
- Rs0 and Rs1 are weakly but **positively correlated** (correlation factor 0.3)

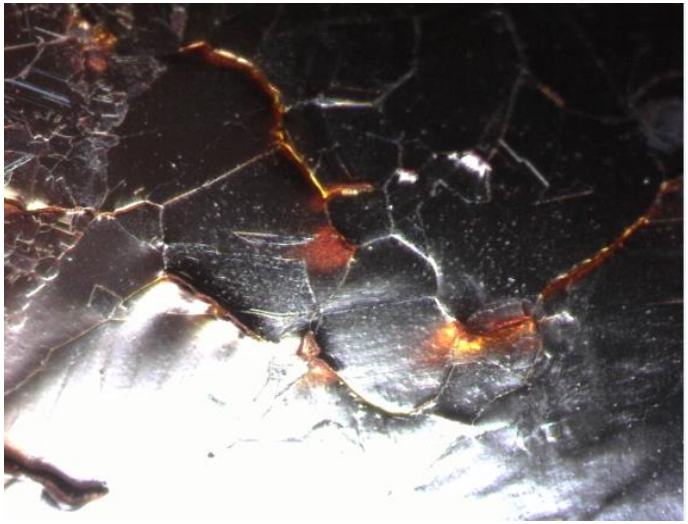
Optical Inspections

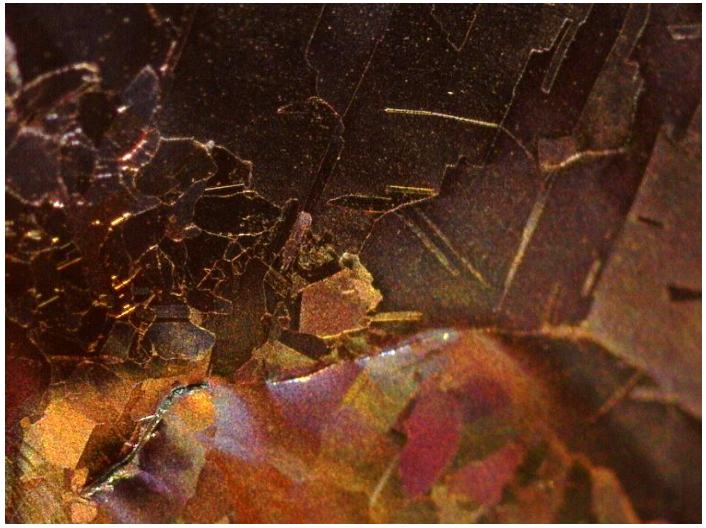


- In most of the substrates of the series production, cracks were observed mainly **near the weld area** (in the outer conductor)
- In most cases they are **identified when revealed by the SUBU** (chemical treatment)

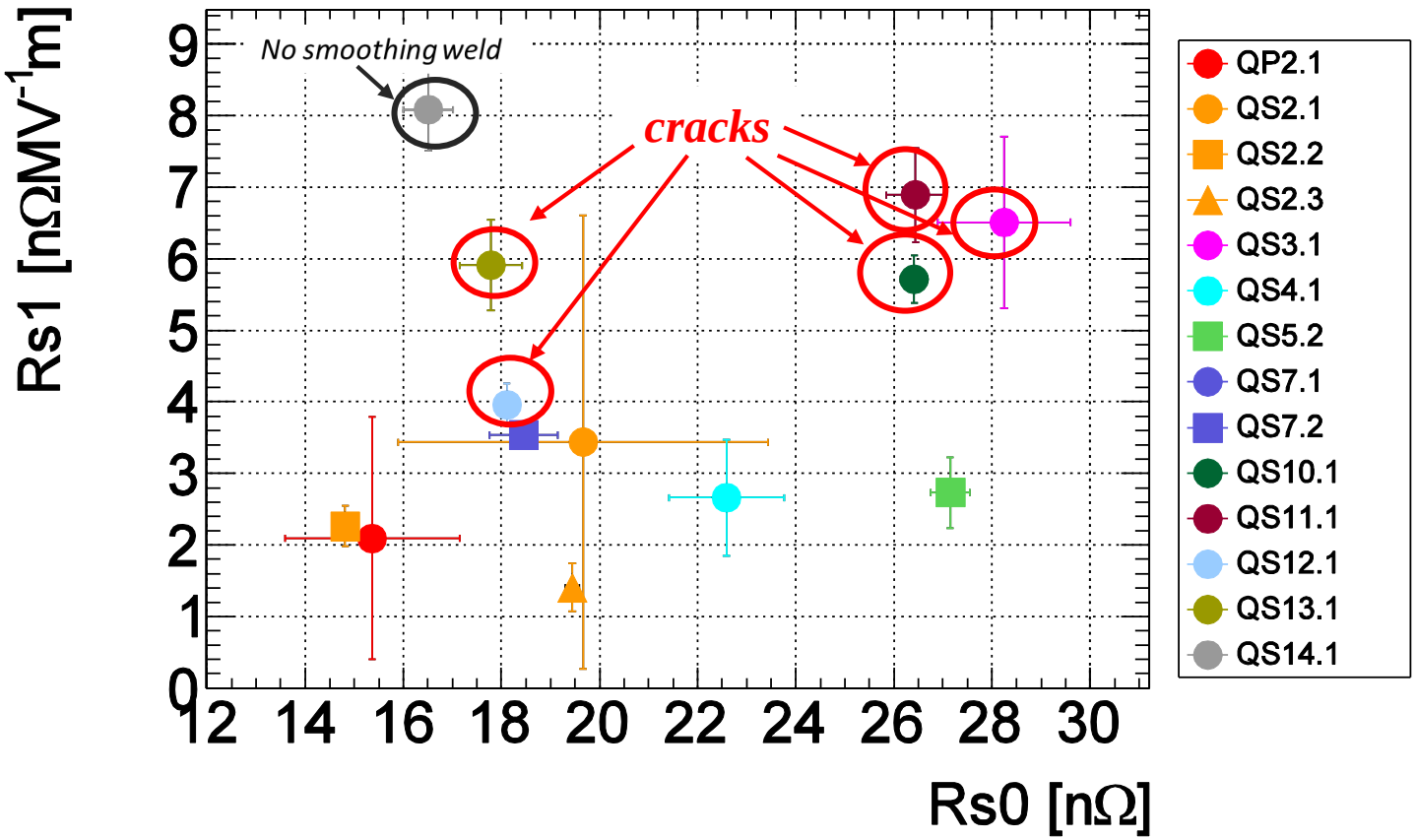
Optical Inspections







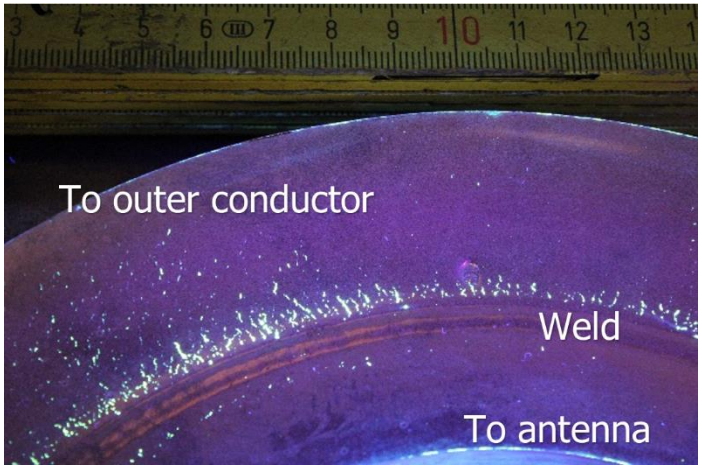
Rs1 vs Rs0 for all cavities



- Rs0 and Rs1 are weakly but **positively correlated** (correlation factor 0.3)
- The substrate with the **cracks tends to have higher Rs1** (Q-slope)
- Removal of the smoothing weld for material investigations

Material Studies

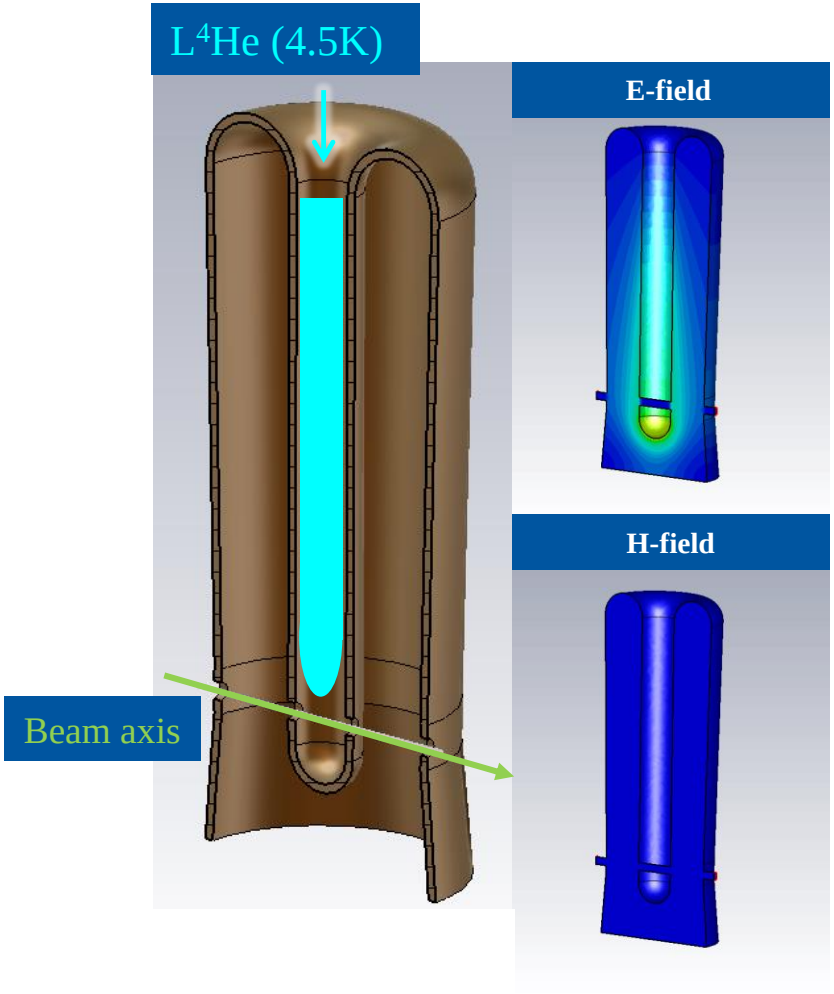
- Linear indications (appearing as cracks and voids) at surface were observed after SUBU etching on QS9, **especially around the EB weld zone.**
- Cracks are not only present in the surface, but in **the bulk material** (OFE copper).
- SUBU doesn't generate the imperfections, but **reveals** them.



Courtesy of M. Crouvizier

- **Hydrogen embrittlement** was discarded as a possible culprit.
- We tried to reproduce the same effect on several kinds of OFE compliant material **without succeeding**.
- **Residual stresses and heat** have probably contributed to the apparition of these imperfections.

Seamless Cavity



Major changes from previous design:

- Cavity machined from **a bulk Cu cylinder**.
- **Antenna length** shorter for frequency tuning
- **Thinner inner conductor** to recover R/Q
- **Cone insertion** to avoid leakage through the beam ports

Frequency	**101.28 MHz**
E_{acc}	**6 MV/m**
$\beta_{optimum}$	**0.12**
R/Q	**525 Ω**
E_{peak}/E_{acc}	**4.9**
B_{peak}/E_{acc}	**98 G/(MV/m)**
$G=R_sQ$	**30.79 Ω**
U/E_{acc}^2	**0.214 J/(MV/m)2**
P_c at 6MV/m	**10 W**

Conclusions

- A set of measurements of **17 HIE-ISOLDE Nb/Cu QWRs** have been presented.
- Part of the surface resistance has been explained by a **BCS fit** with ¨reasonable¨ parameters.
- Rs0 and Rs1 are weakly but **positively correlated**.
- There is a **performance degradation** with time on the production of the cavities. The increase in surface resistance looks correlated to the observed **cracks** at the weld of the Cu substrate.
- The material studies concluded that **residual stresses and heat** might be the origin of the cracks.
- A new design of a **seamless cavity** has been developed in order to avoid the EB welding of the substrate.