HIE ISOLDE Cavity Developments

Walter Venturini Delsolaro

On behalf of

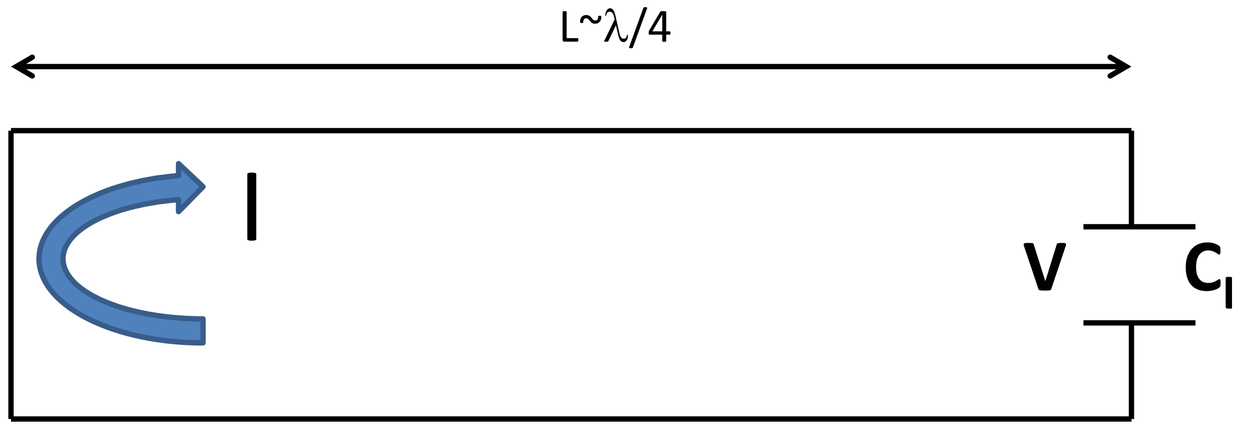
L. Alberty, G. Arnau Izquierdo, O. Brunner, S. Calatroni, O. Capatina, B. Delaup, A. D'Elia, P. Garritty, N. Jecklin, P. Maesen, M. Malabaila, I. Mondino, E. Montesinos, M. Gourragne, G. Pechaud, T. Renaglia, K. M. Schirm, A. Sublet, M. Therasse, D. Valuch

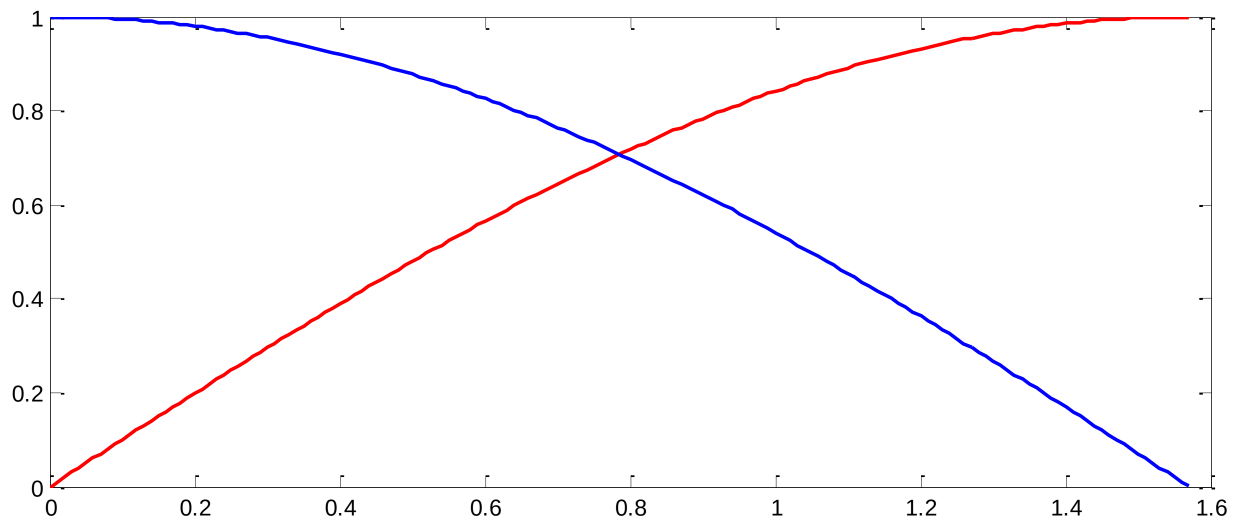
ISOLDE Workshop, 19 December 2012

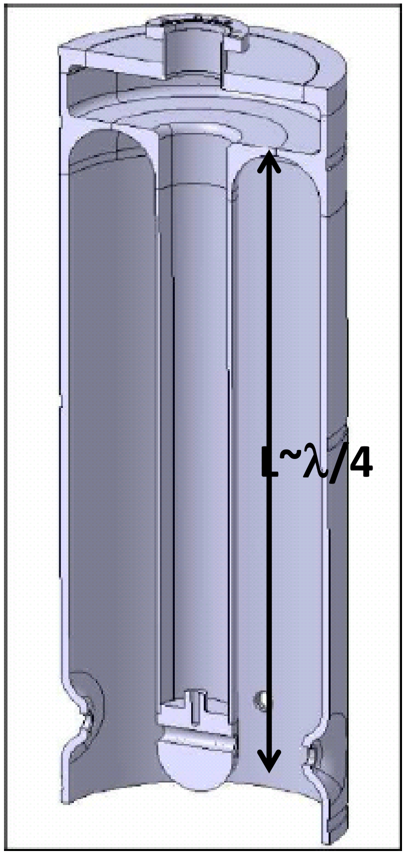
Overview

- **Cavity specifications and design**
- **Prototype cavity developments in 2012**
- Strategy and actions taken
- Test cavities and results
- Q switch issues
- Last two prototype cavity results
- Remaining issues and next steps

HIE ISOLDE accelerating cavities







HIE ISOLDE cavities

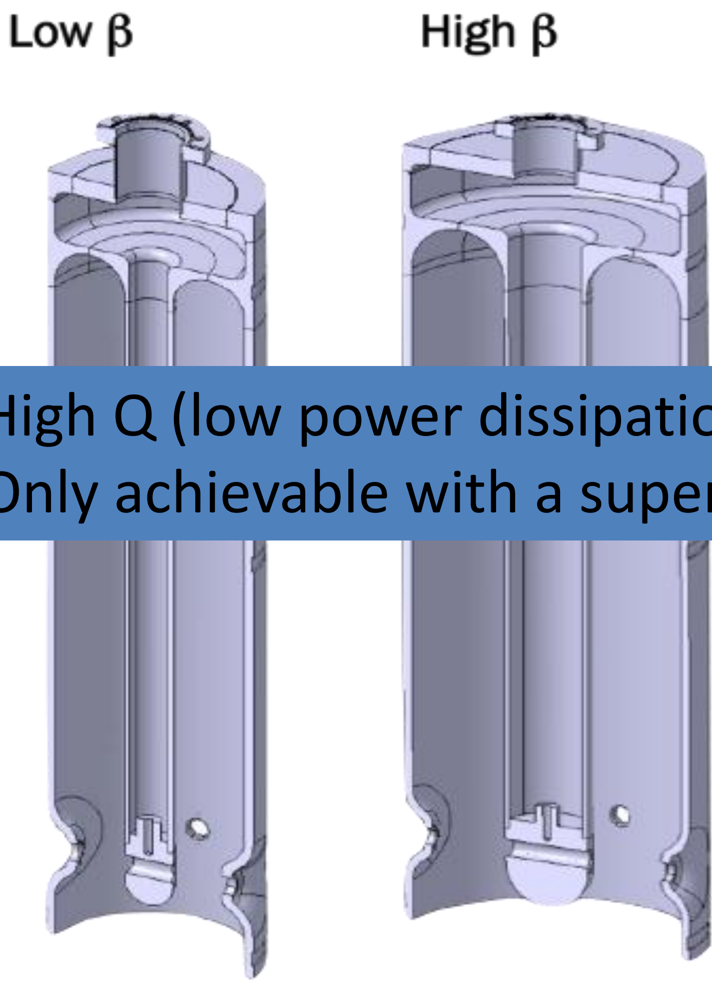


Table 1: Cavity design parameters

Cavity	Low β	highβ
No. of Cells	2	2
f (MHz)	101.28	101.28
β_0 (%)	6.3	10.3
Design gradient E_{acc}(MV/m)	6	6
Active length (mm)	195	300
Beam aperture diameter (mm)	20	20
$U/E_{acc}{}^2$ (mJ/(MV/m)^2	73	207
E_{pk}/E_{acc}	5.4	5.6
H_{pk}/E_{acc} (Oe/MV/m)	80	100.7
R_{sh}/Q (Ω)	564	548
$\Gamma = R_s \cdot Q_0$ (Ω)	23	30.6
Q_0 for 6MV/m	$3.2 \cdot 10^8$	$5 \cdot 10^8$
TTF max	0.85	0.9
No. of cavities	12	20

High Q (low power dissipation) for several MV/m accelerating field
Only achievable with a superconducting structure

Technologies for SC QWR

- **Bulk Nb with high RRR and EB welds**
  - Available from industry:
  - High gradients at low dissipated power are easier
  - Difficulties in operation (microphonics, high RF power needs)

- **Superconducting coatings** (mechanical and thermal stability, lower cost)

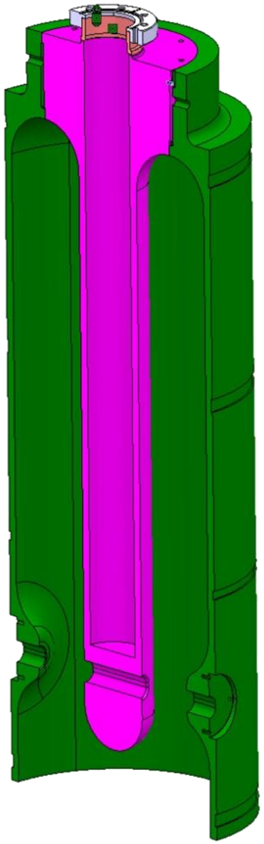
  - **Electroplating of Pb on Copper** (limited to few MV/m due to low B_c of lead)

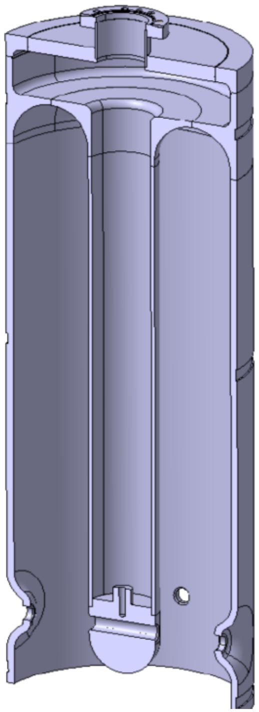
  - **Nb sputtering on copper**

  - **Higher performance than lead plating, competitive with bulk Nb at these frequencies and temperatures**
  - **Multidisciplinary technology (surface science, vacuum, sputtering, clean room, superconductivity, RF engineering Never industrialized on the QWR shape**
  - **Several LINAC projects after HIE ISOLDE could profit from an industrialization**

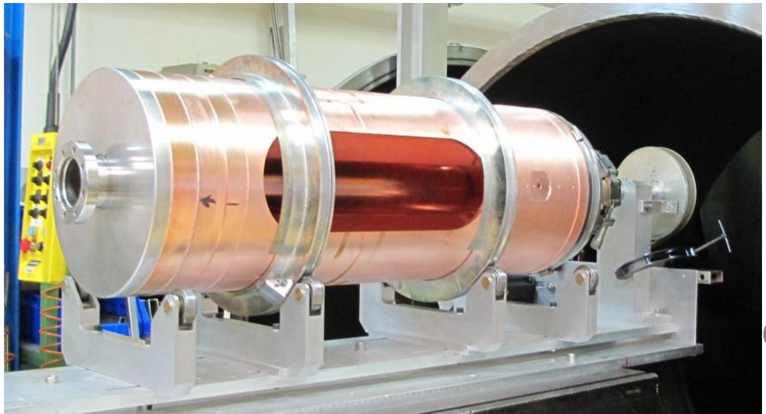
Cavity prototypes designed and built at CERN

- 4 units "old design": Q1-Q2-Q3-Q5 (rolling, EB welding, deep-drawing)
- 1 new design: QP1+ 2 more in pipeline (3D machining in bulk copper, EB welding)





- 1 cavity (Q4) manufactured for sputtering tests on samples

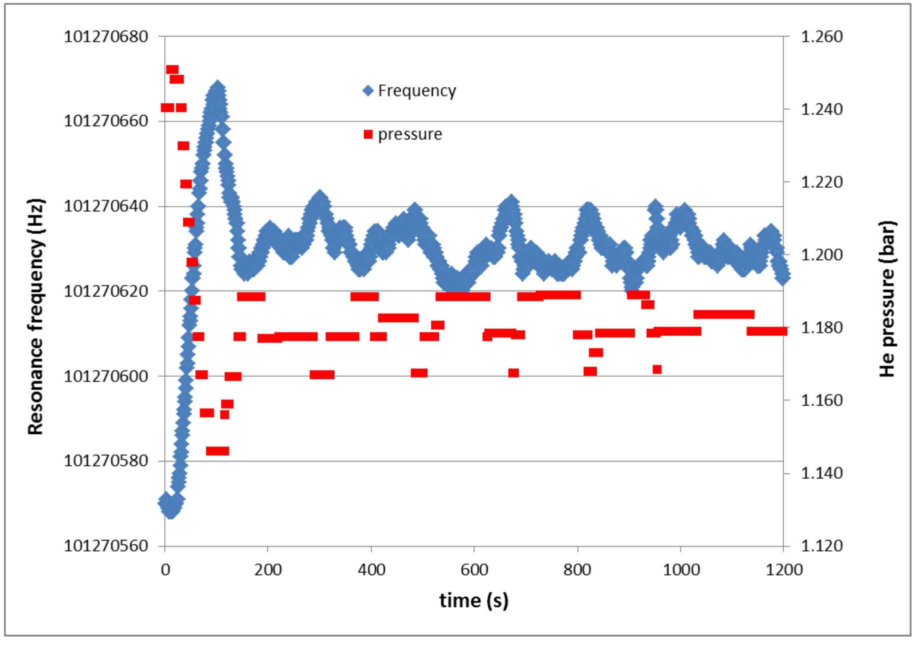


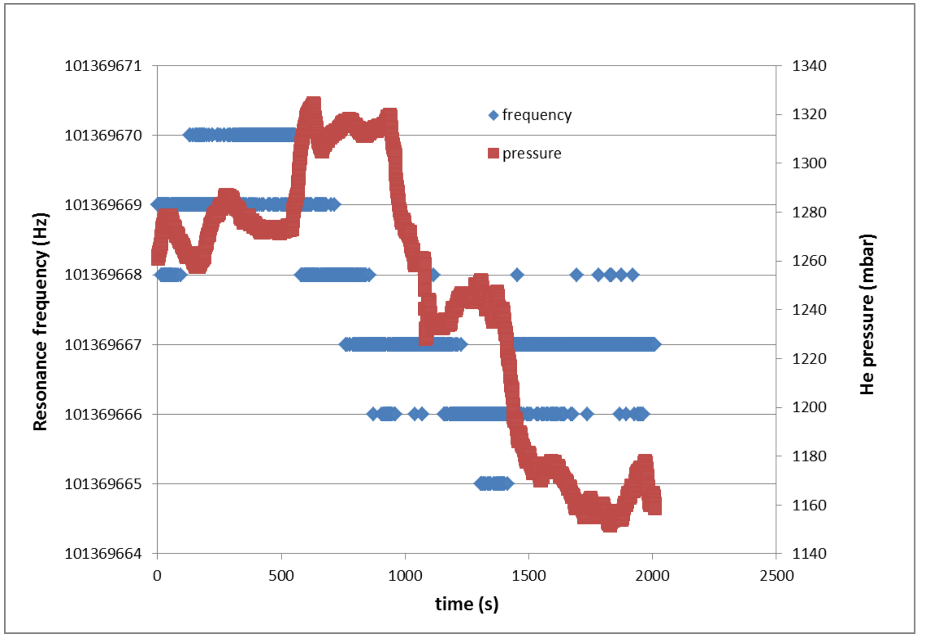
Note: Q3 and QP1 were left longer to reduce B on RF contact with tuning plate

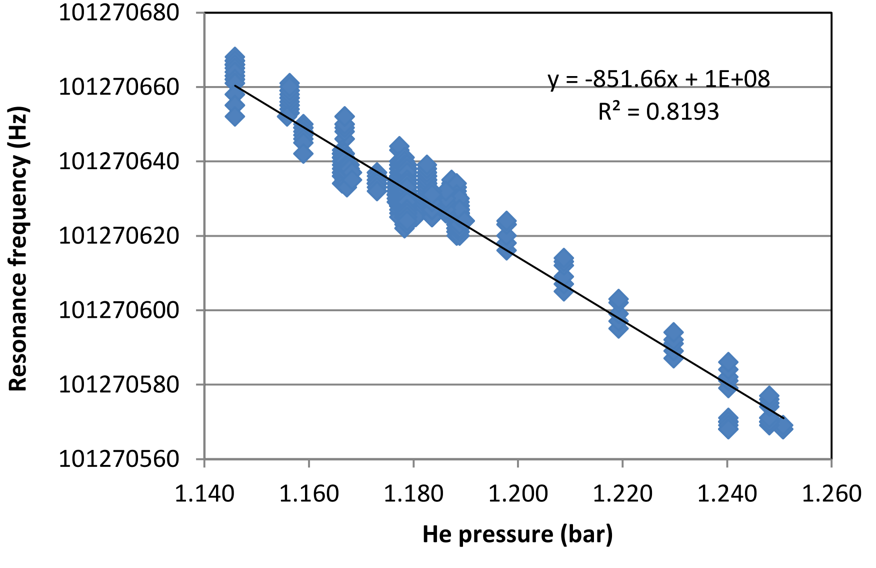
QP1: sensitivity to He pressure

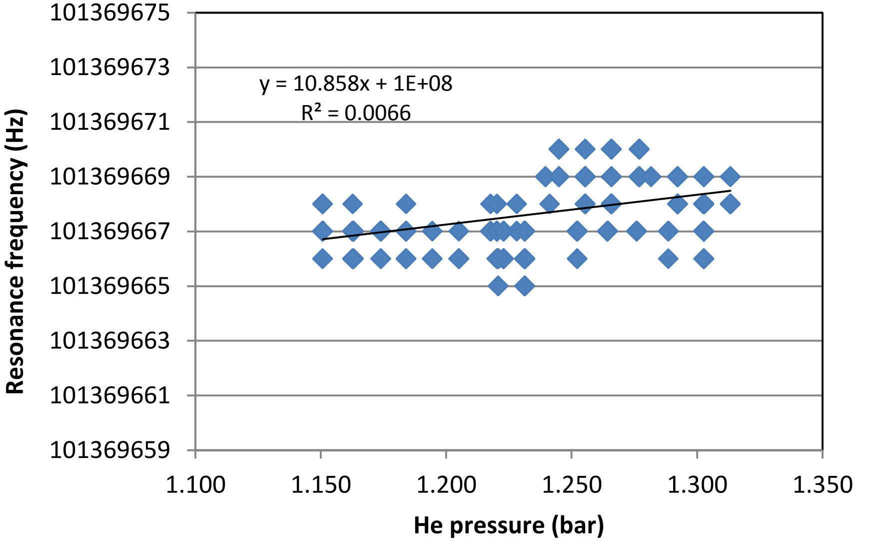
Q2 (old design) ~ 1 Hz/mbar

QP1 (new design) ~ 0.01 Hz/mbar





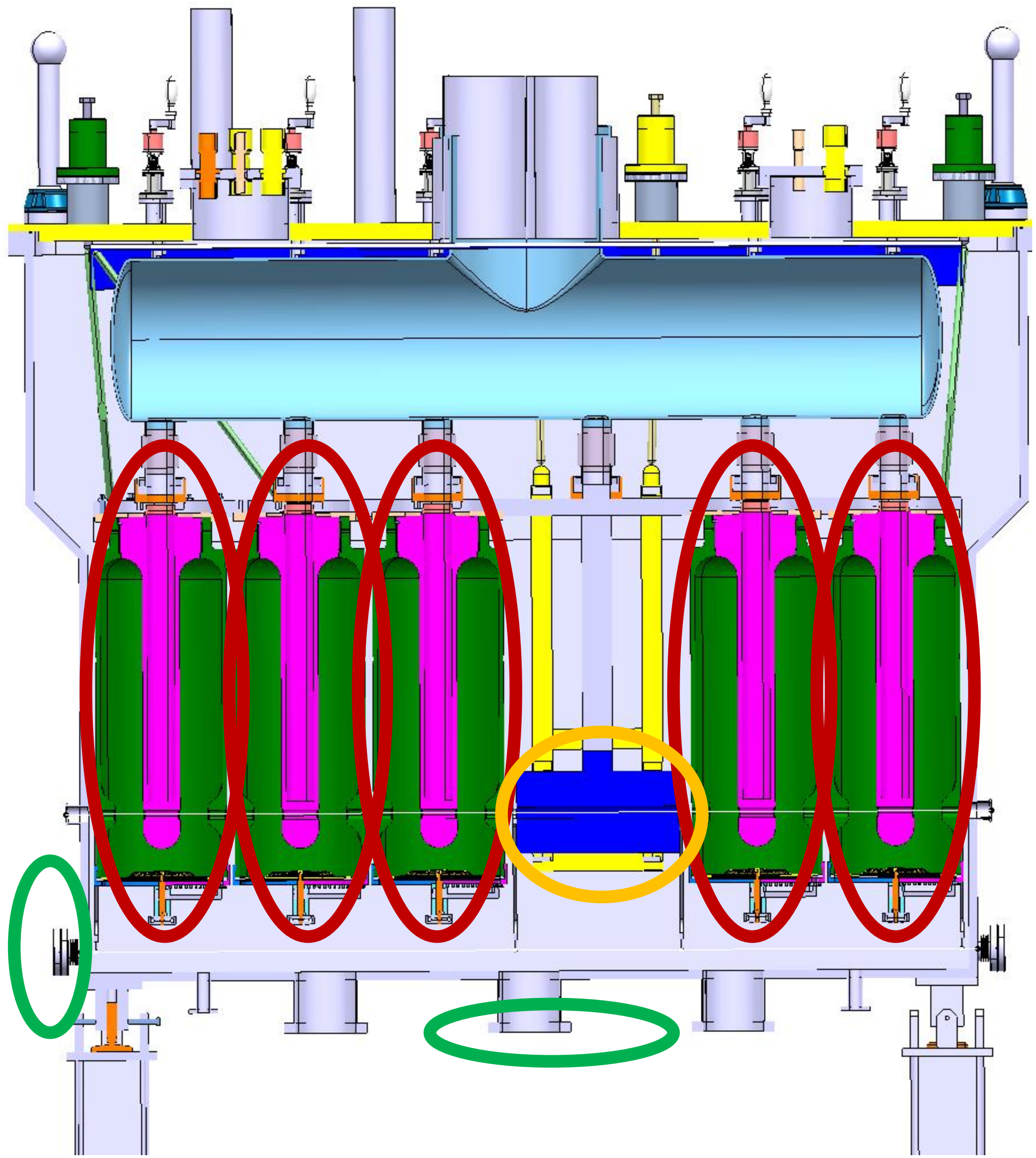




HIE ISOLDE Cryomodule
Side view

Optics → Compactness →
→ Common vacuum

- RF cavities (5 or 6)
- SC (Nb_3Sn) solenoid (1 or 2)
  Up to 600 A
- Supporting frame
- Alignment / monitoring system
  0.15 mm at cold !
- Cryogenics reservoir and piping
- Vacuum system (valves, pumps)
- Thermal shield (50-80 K)
- Vacuum vessel



Common vacuum

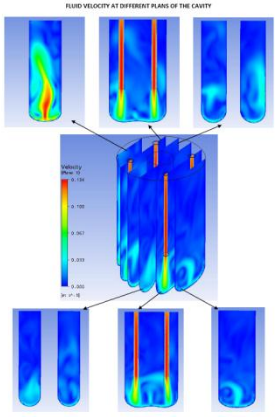
↓

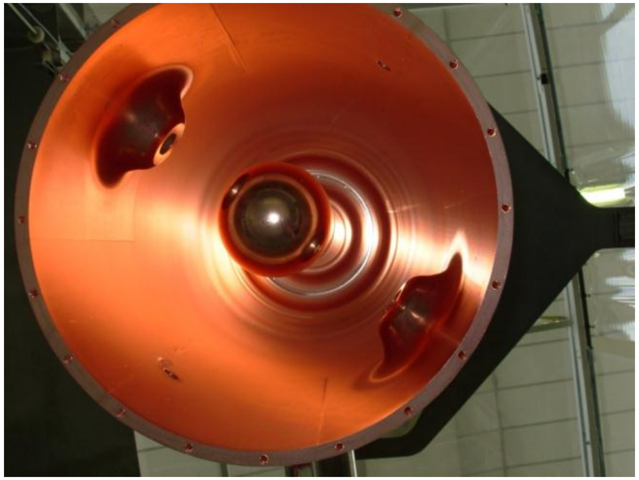
risk of cavity contamination

↓

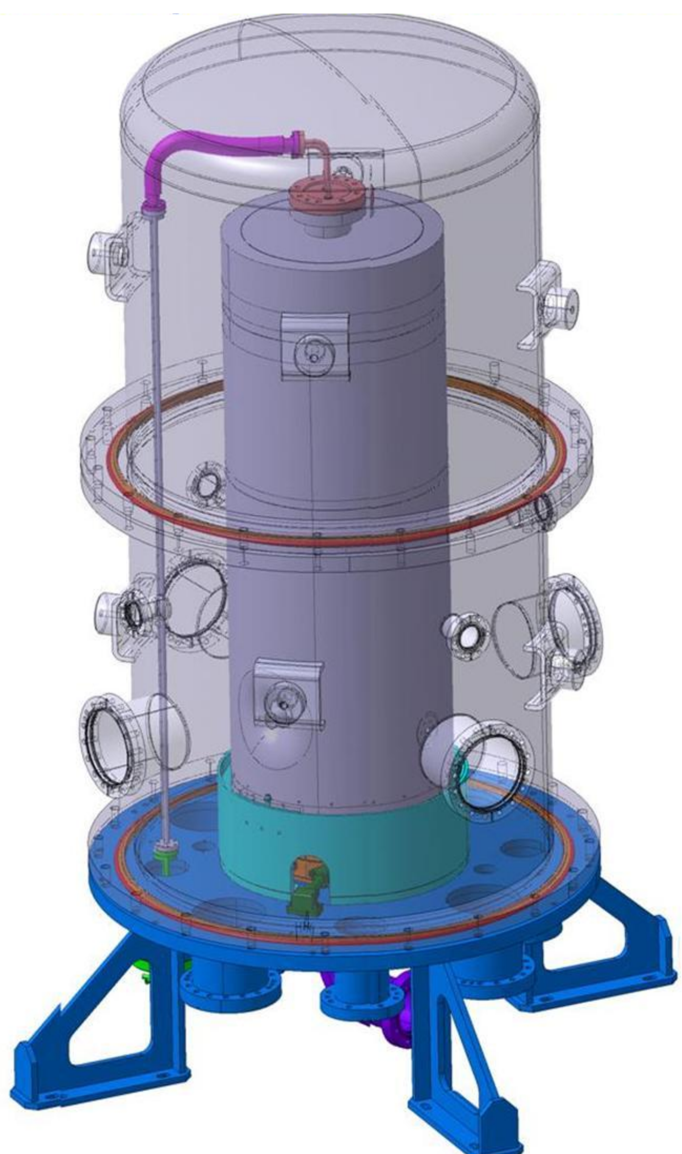
Cleanliness

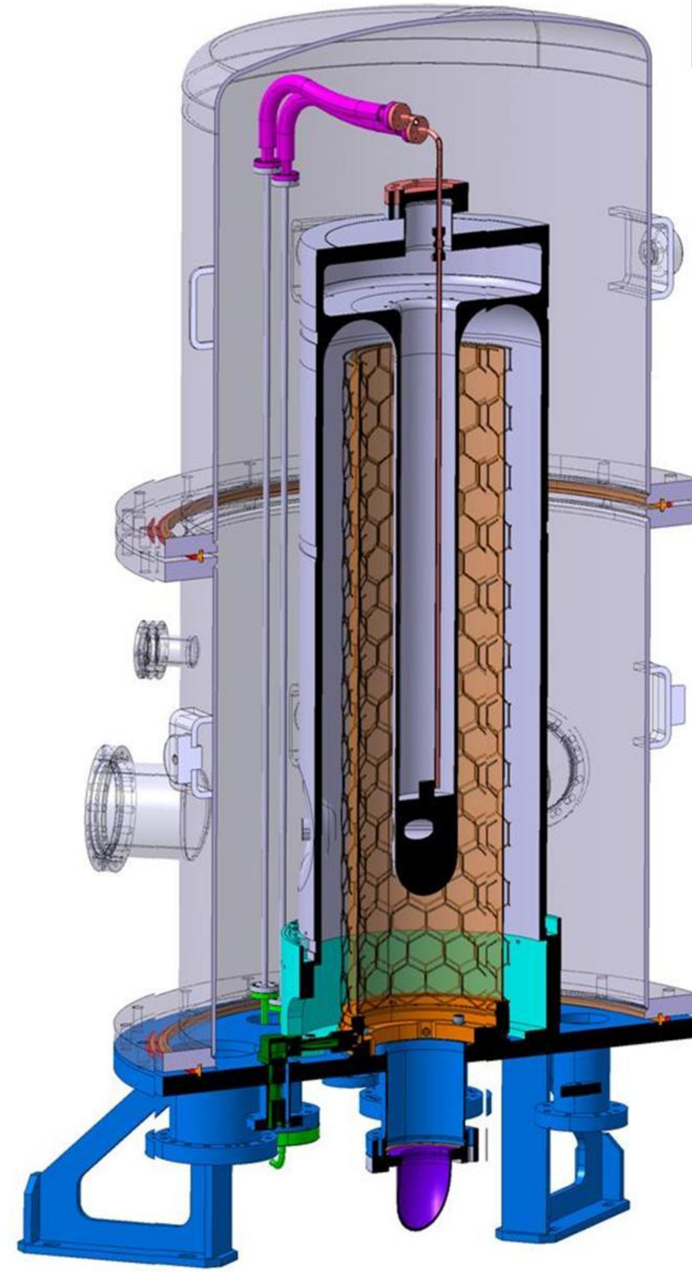
Surface treatment (dummy and real cavity)



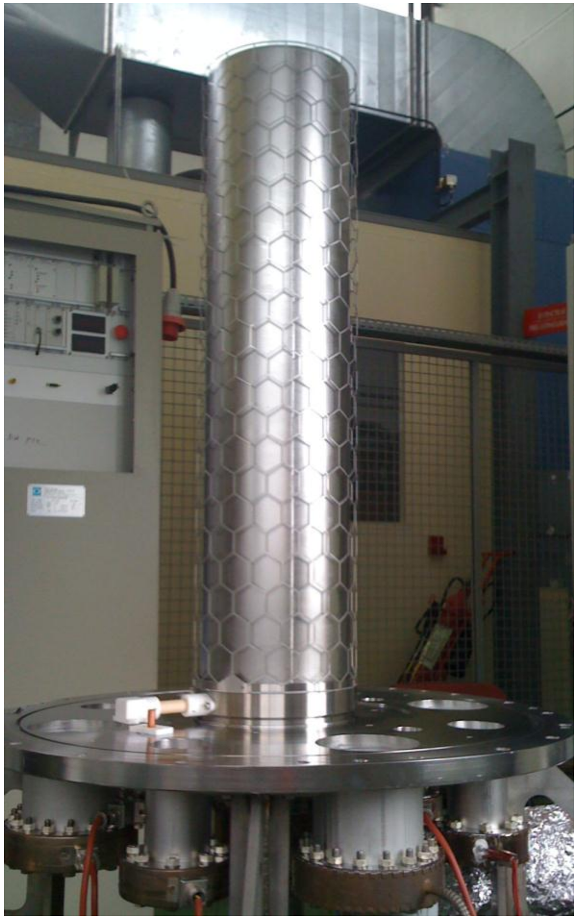


Sputtering system





Diode sputtering



Niobium sputter coatings: 9 test cavities produced in 2012

Focusing on the DC bias sputtering method (INFN-LNL)

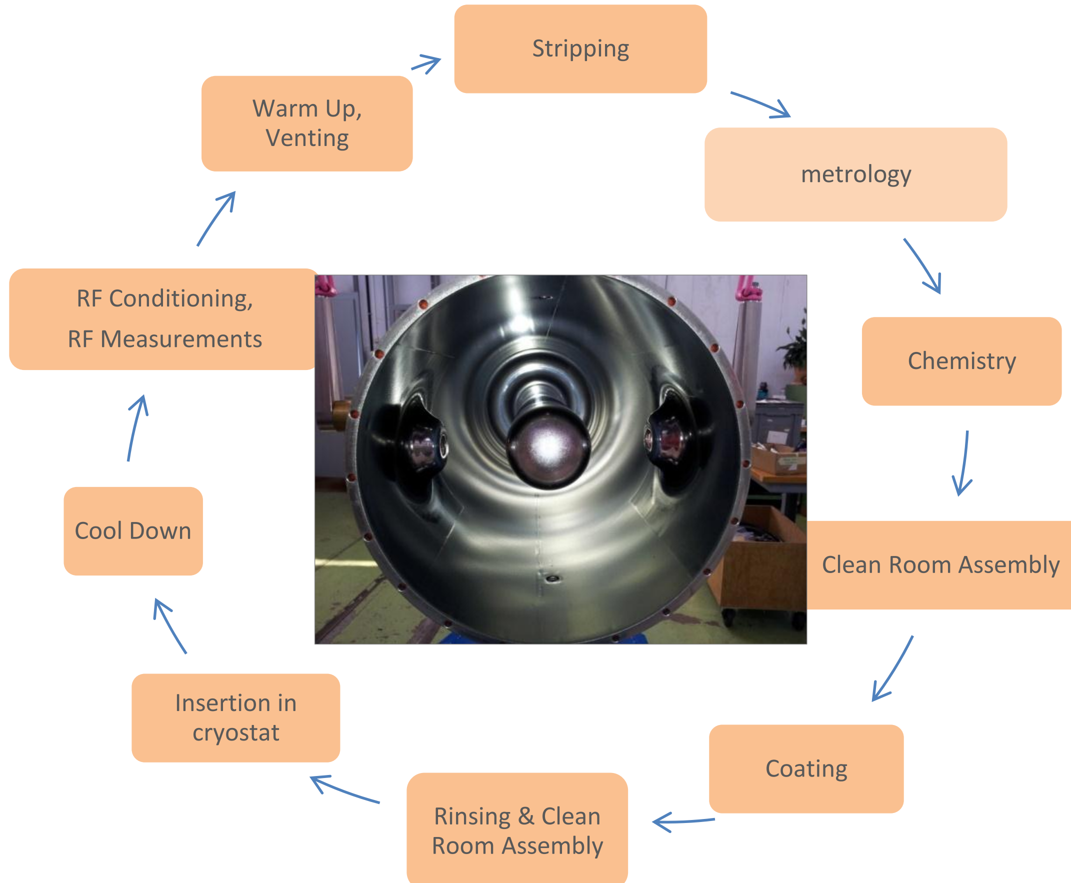
Substrate preparation	Tumbling, EP then SUBU
Rinsing water pressure	100 bar
Bake out temperature	600 ° C (higher than sputtering T)
Sputtering temperature	300-500 ° C
Heating system	IR lamps inside vacuum chamber and QWR
Number of layers	12-20 layers
Sputtering Power	5 kW for 160 MHz structure→ 12.5 KW assumed from scaling of areas
Auxiliary electrode	4 cm diameter, rounded, bias potential
Film minimum thickness	2 µm
Cathode edge profile	sharpened
Sputtering gas	Argon
Venting gas	Nitrogen

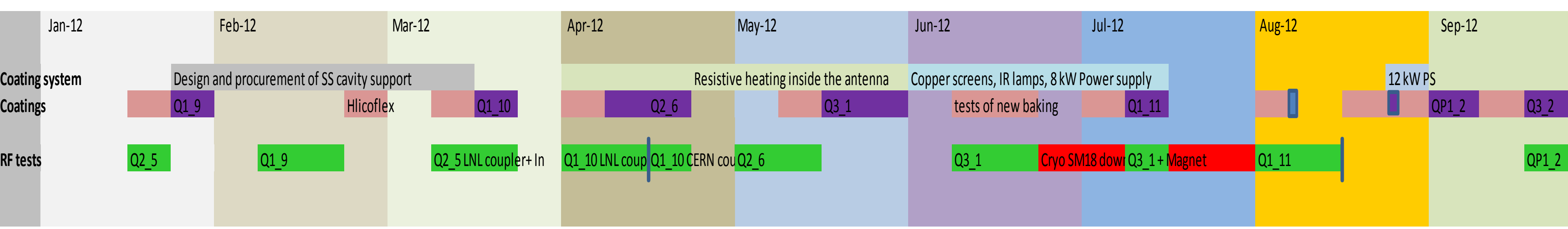
Hardware modifications to the system were required to approach the desired sputtering parameters:

- Cavity support in coating chamber redesigned
- Infra red lamps baking system inside chamber with radiation shields
- Discharge power increased from 2 kW to 10 kW : new power supplies

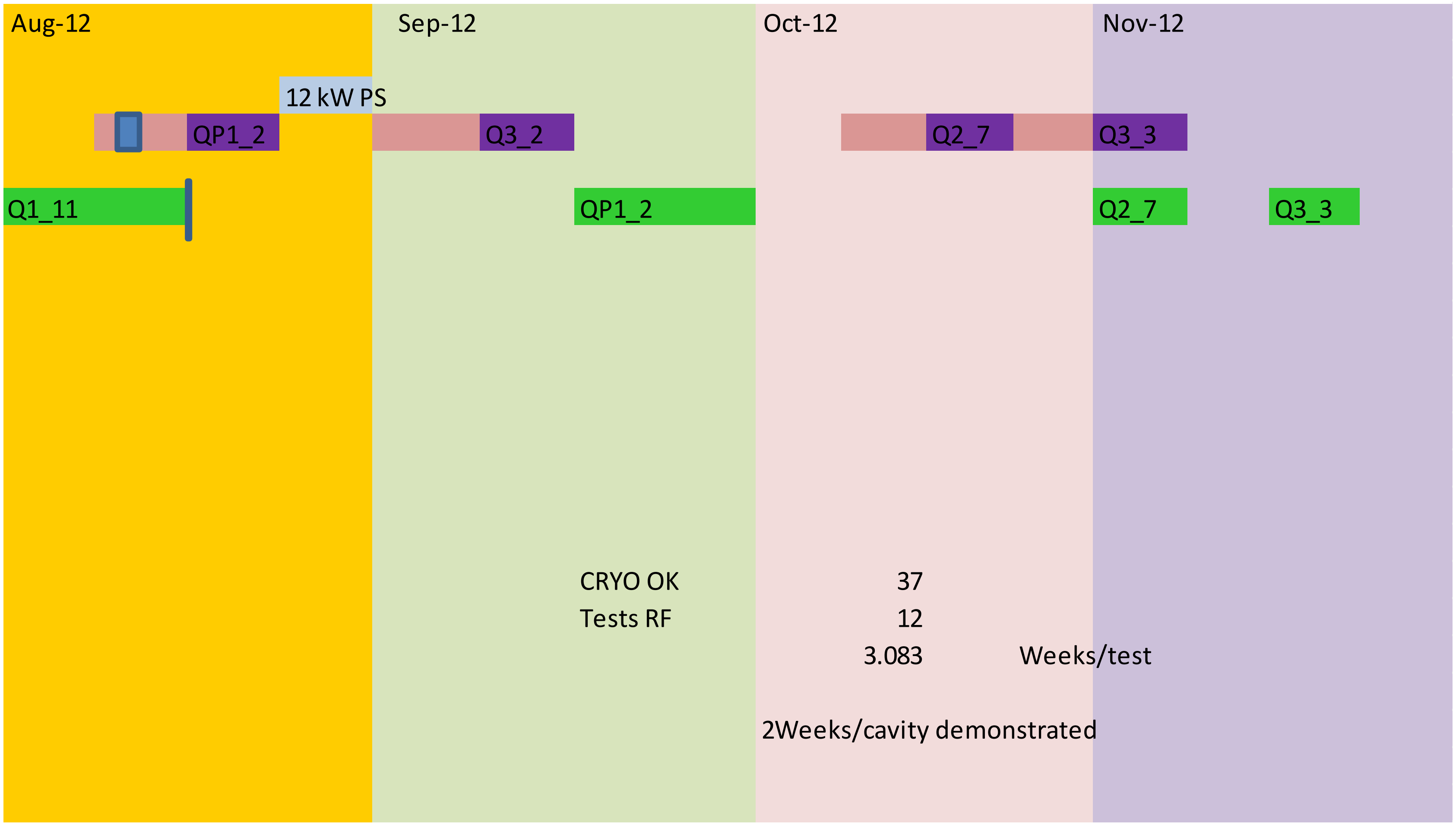
QWR workflow, tests in 2012

Effective turnaround for cold RF tests: 3 weeks

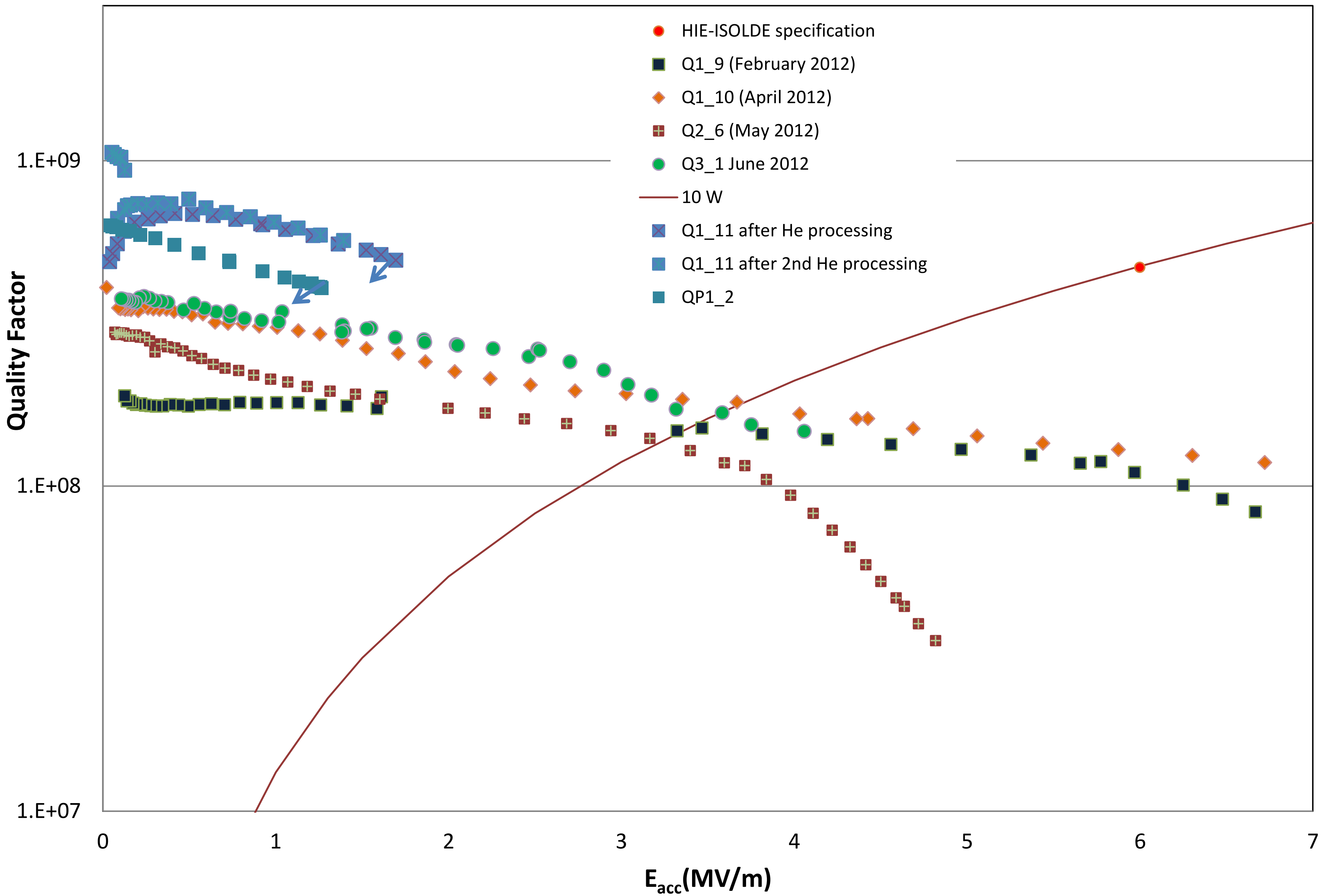




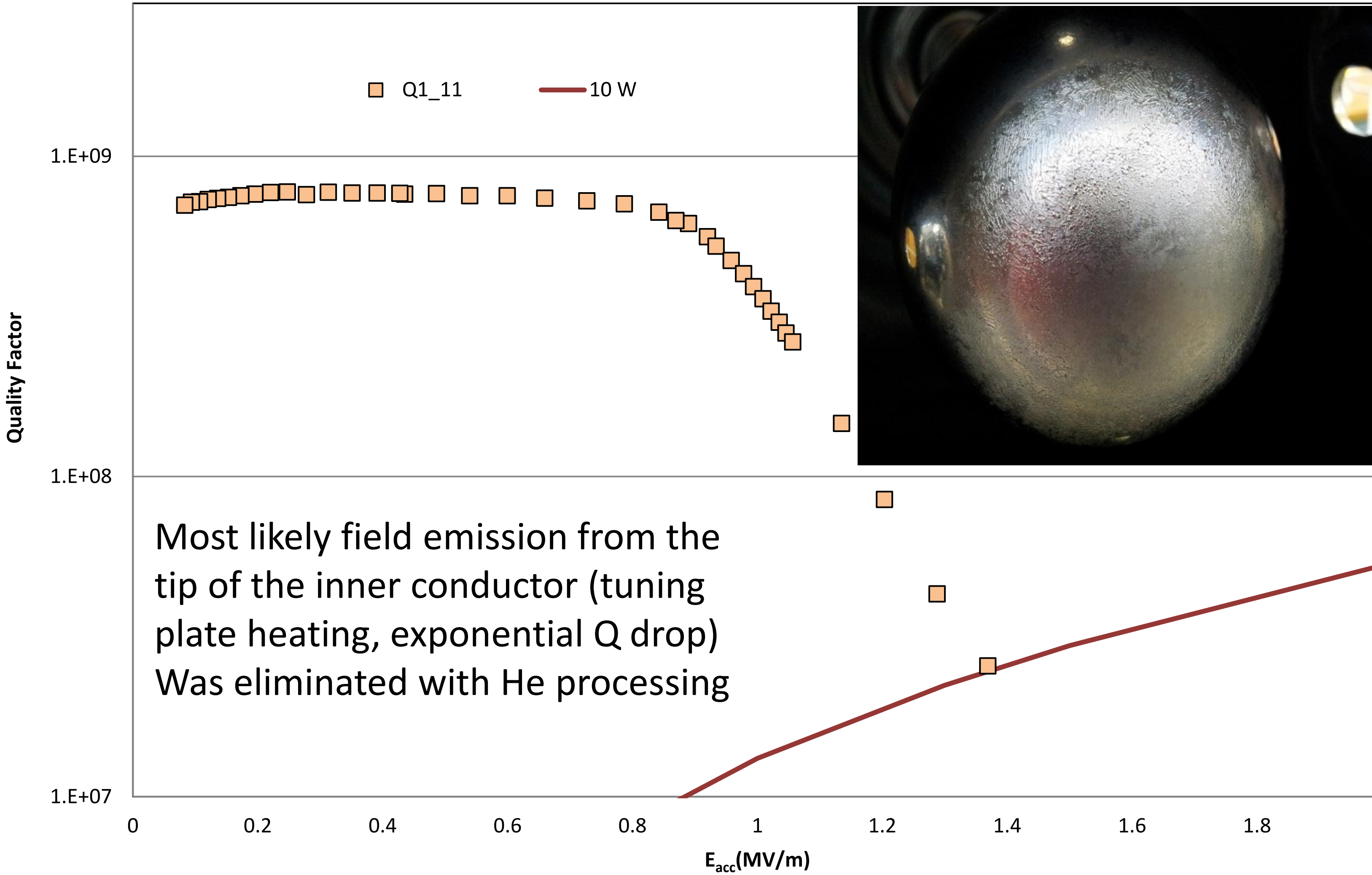
Increasing test rate at end 2012



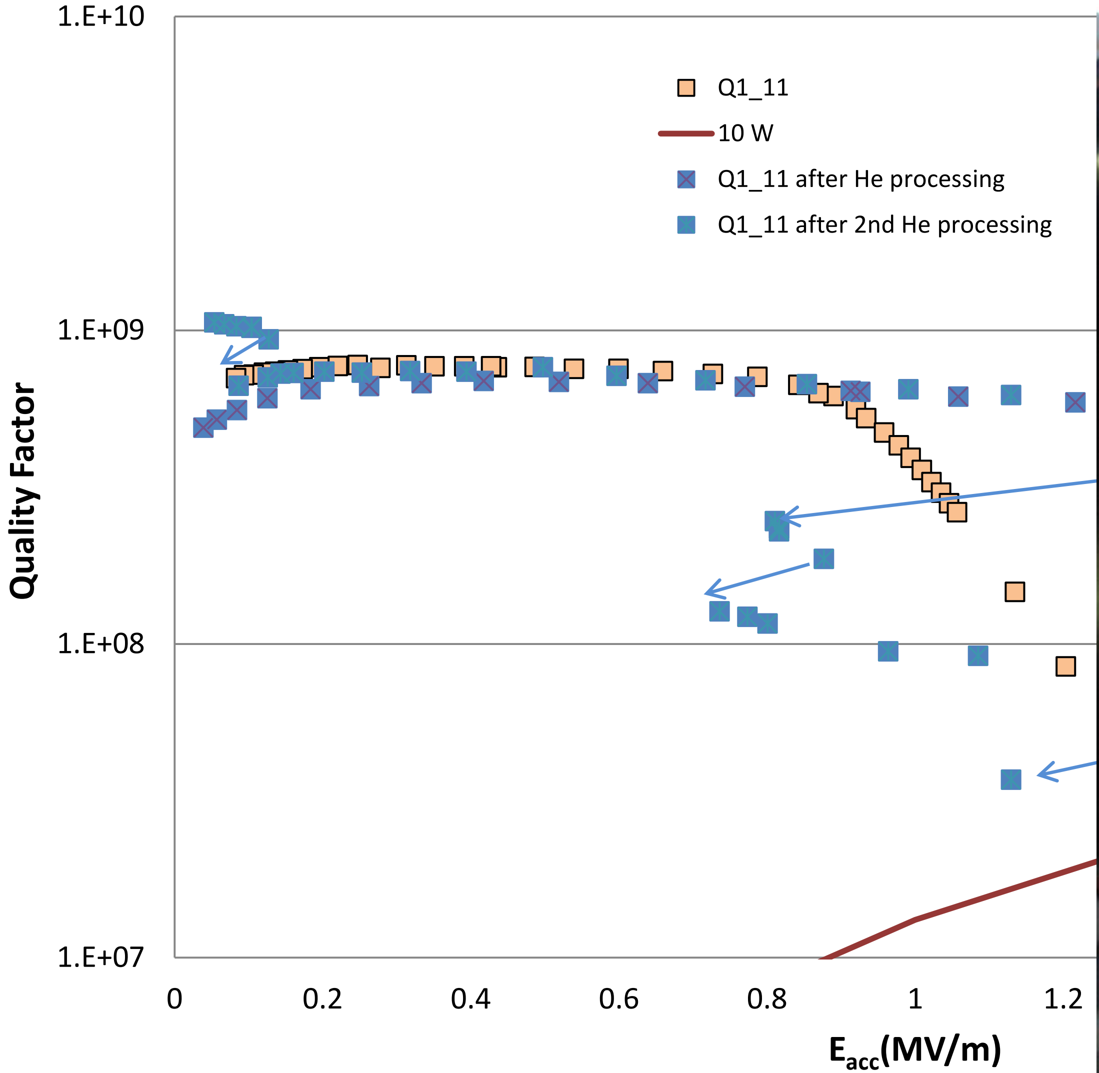
Test cavity performances in 2012

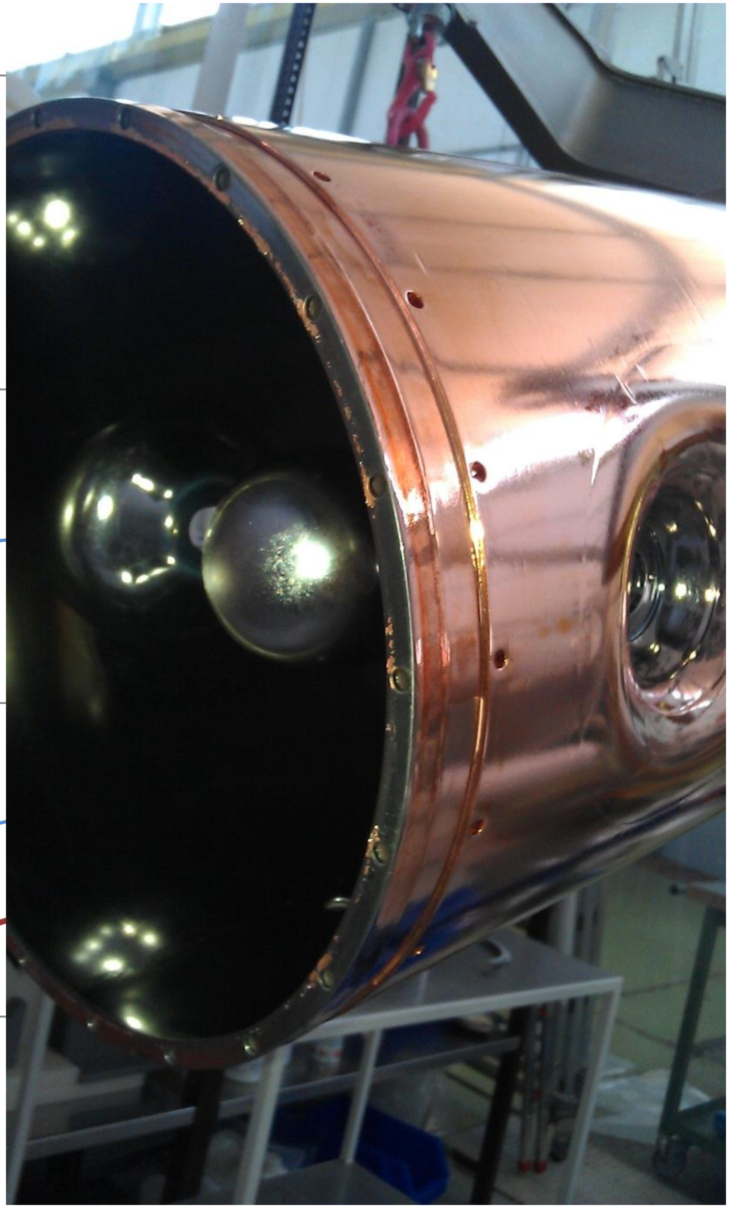


Q1_11 first test results at 4.5 K

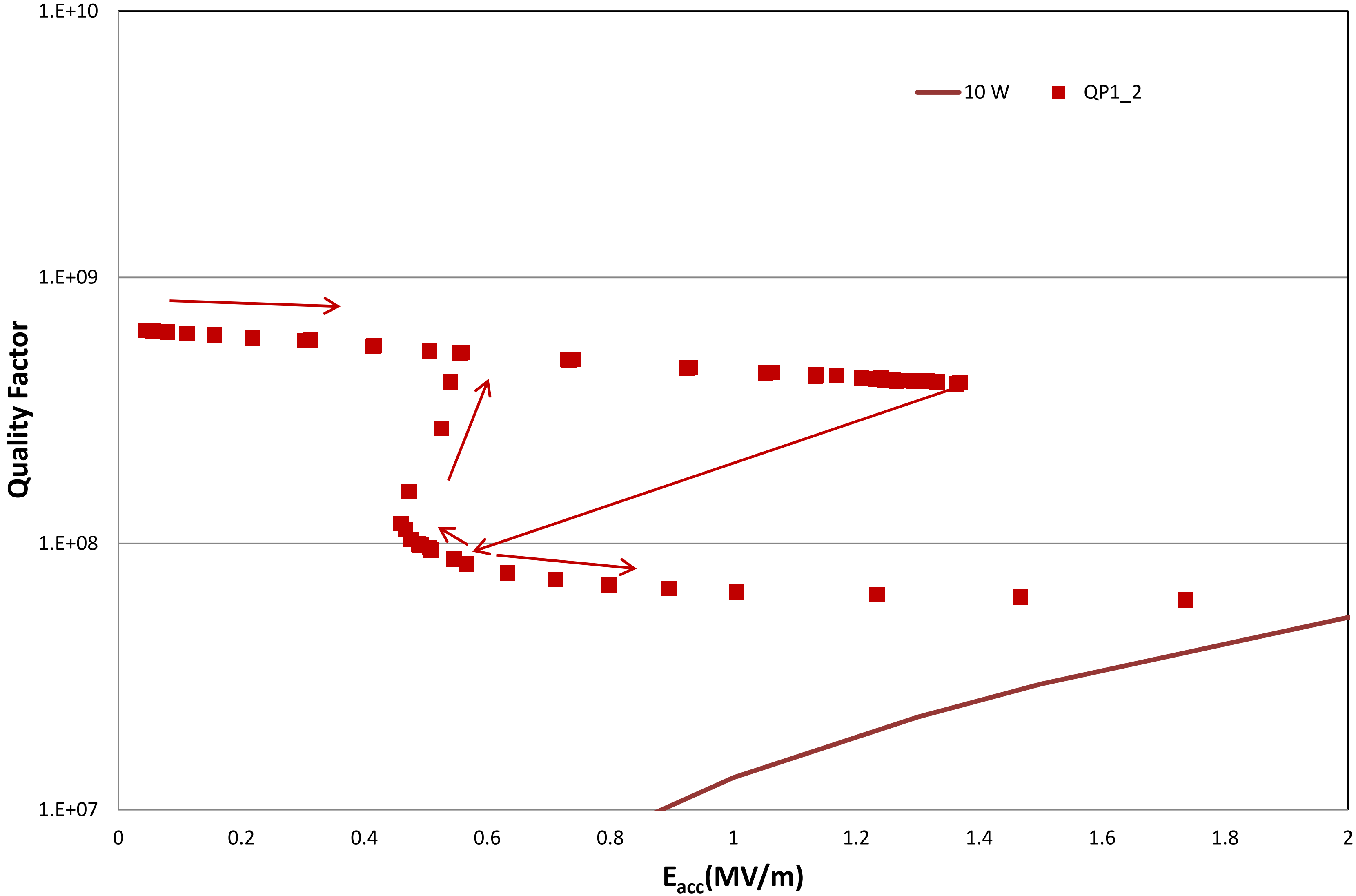


Q1_11 test results after He processing: Q switches





QP1 test results: before He processing, similar behaviour as Q1_11 after He processing. Onset al lower fields. Slight gain in field at 3 K



Observations on “Q switches”

Happen at a determined value of field, not correlated with direct power (checked by changing coupling)

Associated with temperature increase at tuning plate

Deterministic hysteresis paths in Q-E plane

Can jump on upper branch by switching off and on RF (very fast recovery if power is switched off and restored at a level below onset threshold)

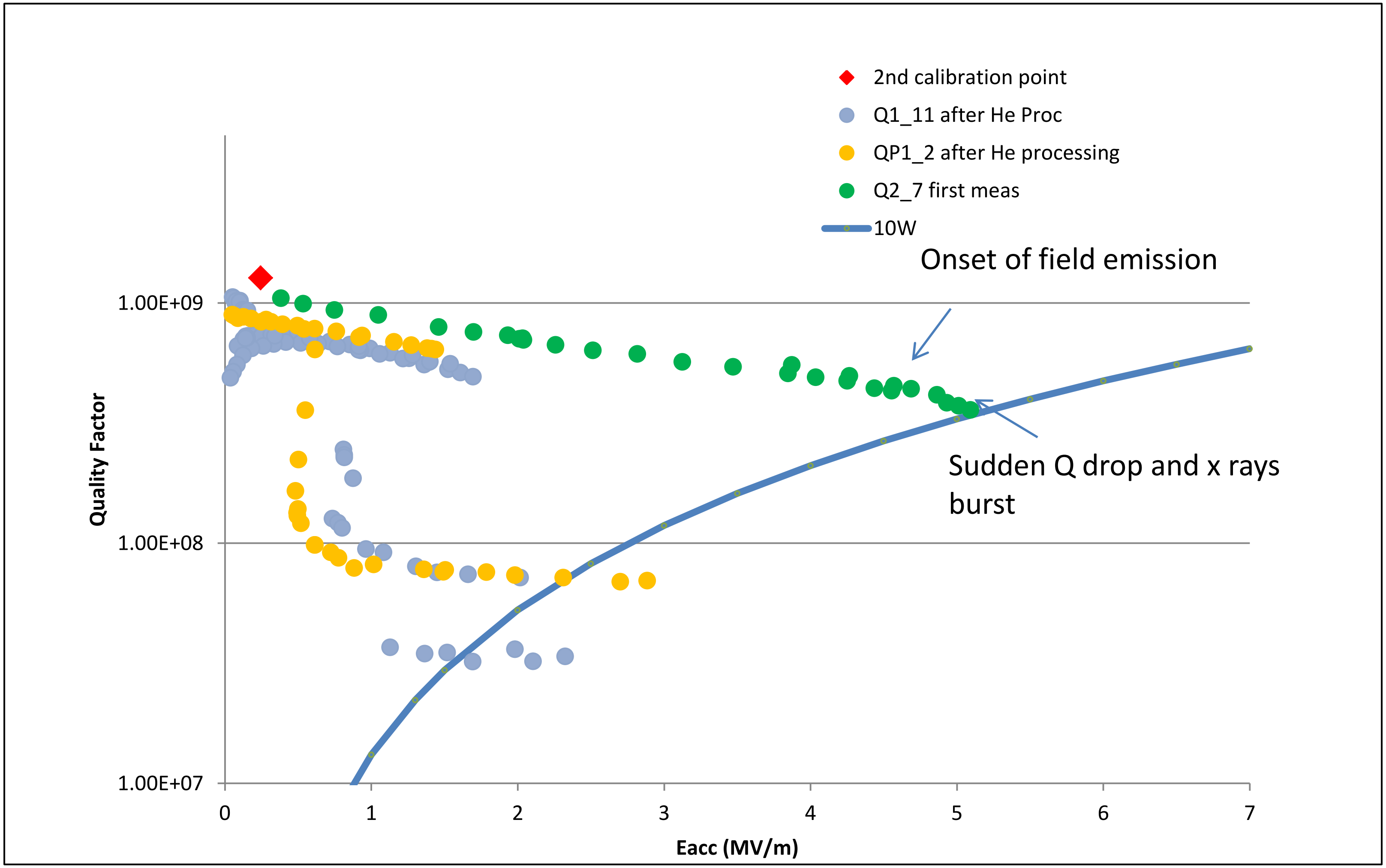
Very low Q slopes (contrary to classical field emission)

Actions taken after Q1_11 and QP1_2

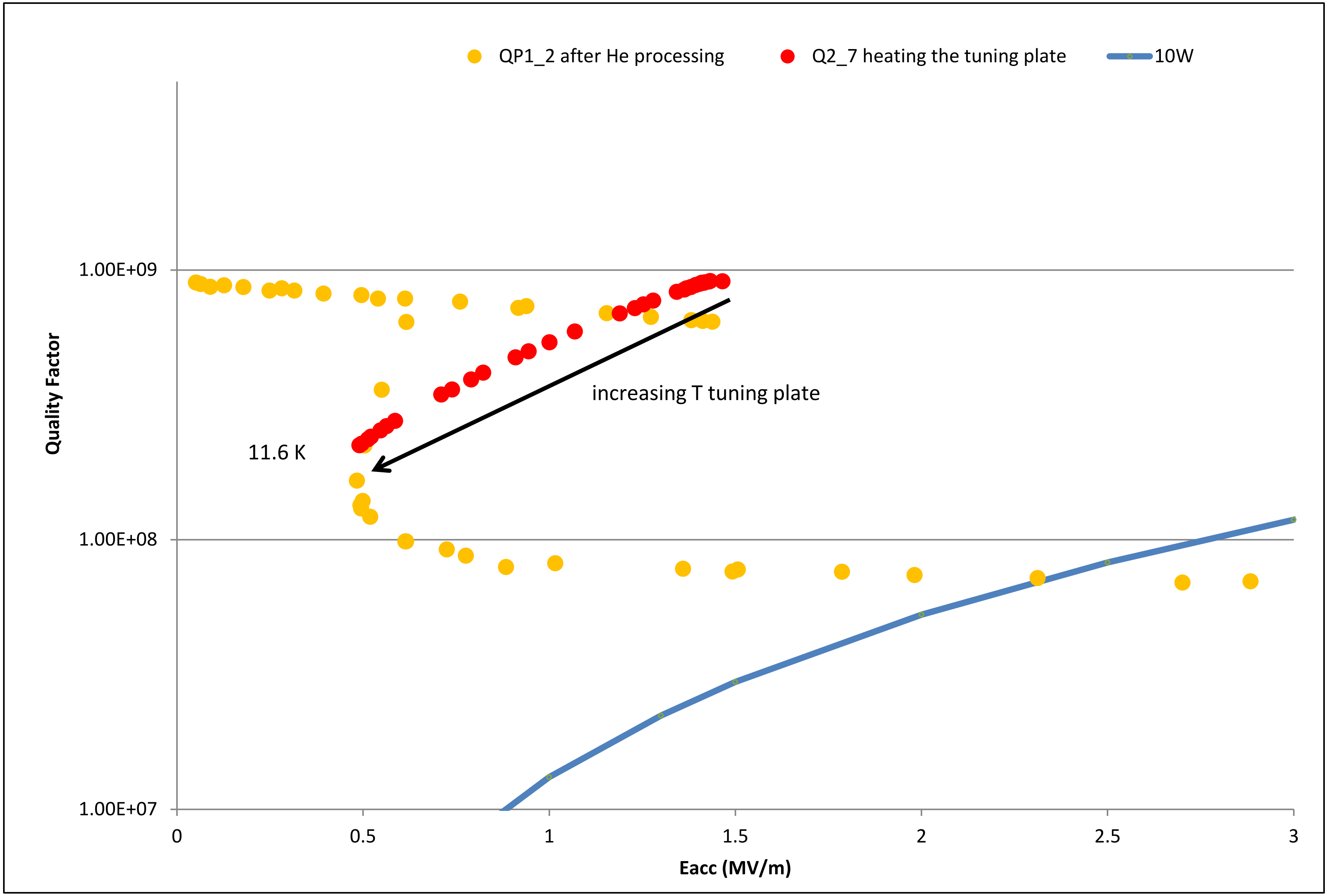
- Electrical heater installed on the bottom plate
- Double check RF contact at the bottom plate
- Increase the thickness of the Nb film by 25%
- Plan incremental stripping on the cavities with Q switch
- Plan systematic thickness measurements on cavity and on samples

First measurement at 4.5 K before He processing

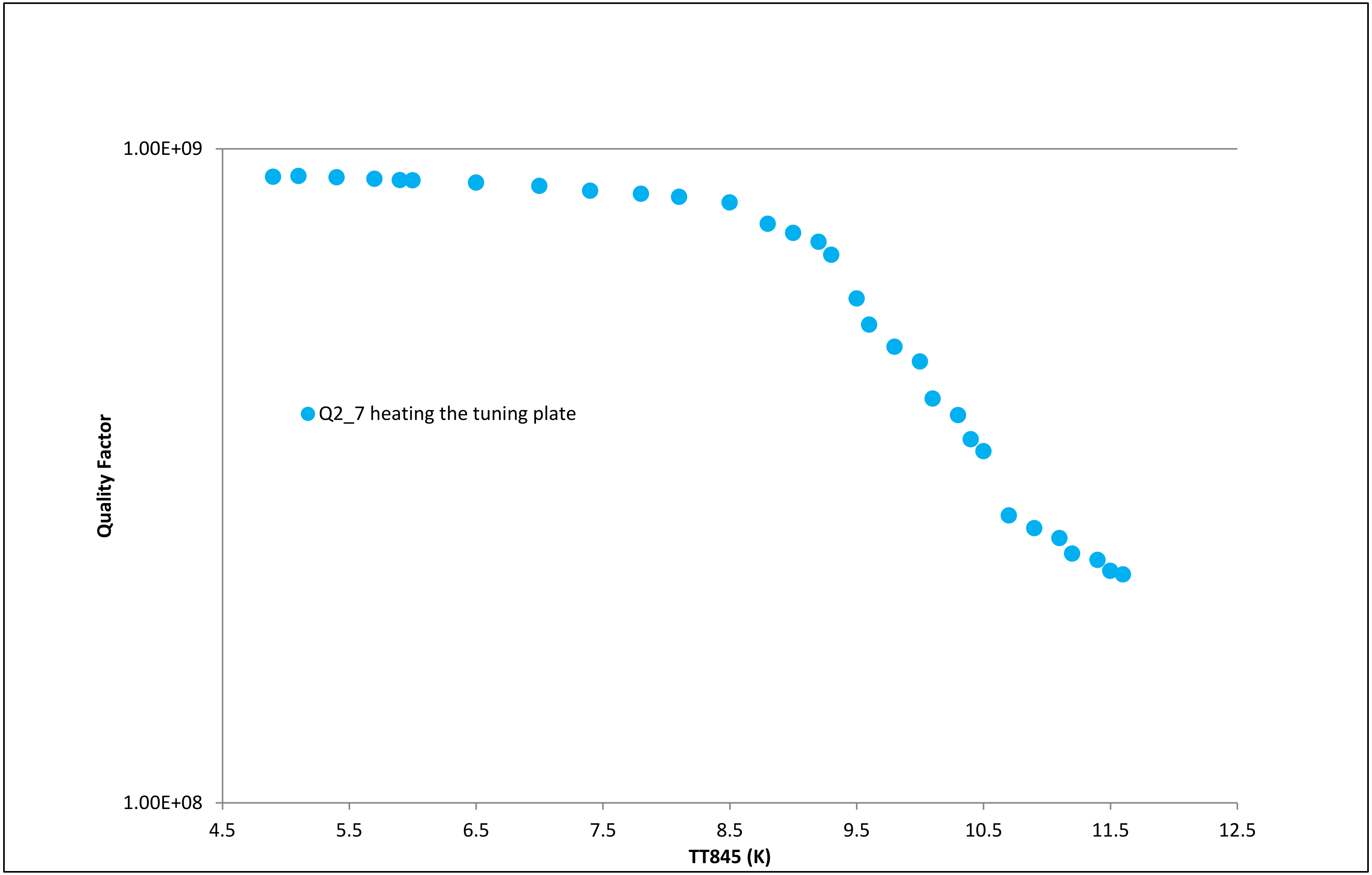
Q_0 is of the order of 1.2 10^9 and on the first powering the cavity reached 5 MV/m at 10 W
The curve very much resembles that of Q1_11 but it does not have any Q switch.



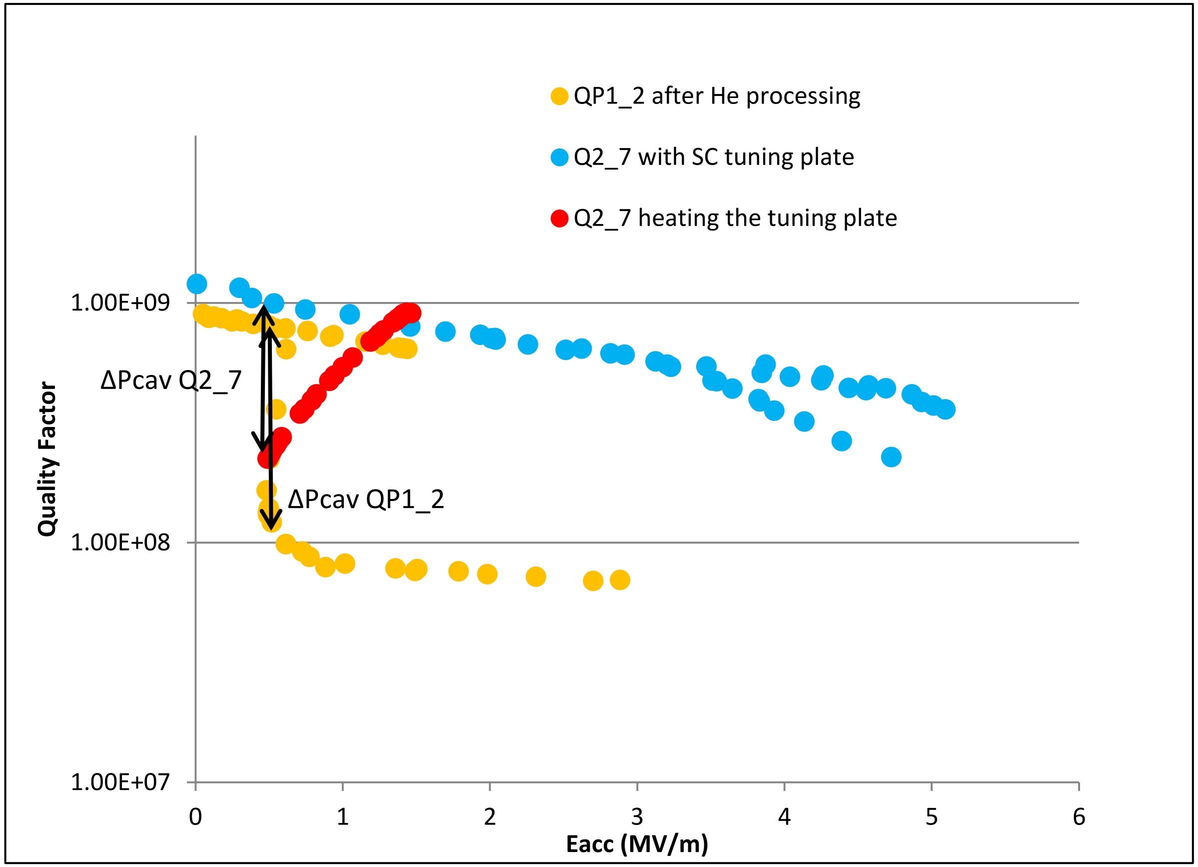
Measurement at 4.5 K when heating the tuning plate



Q vs tuning plate temperature



Power dissipation of normal conducting bottom plate



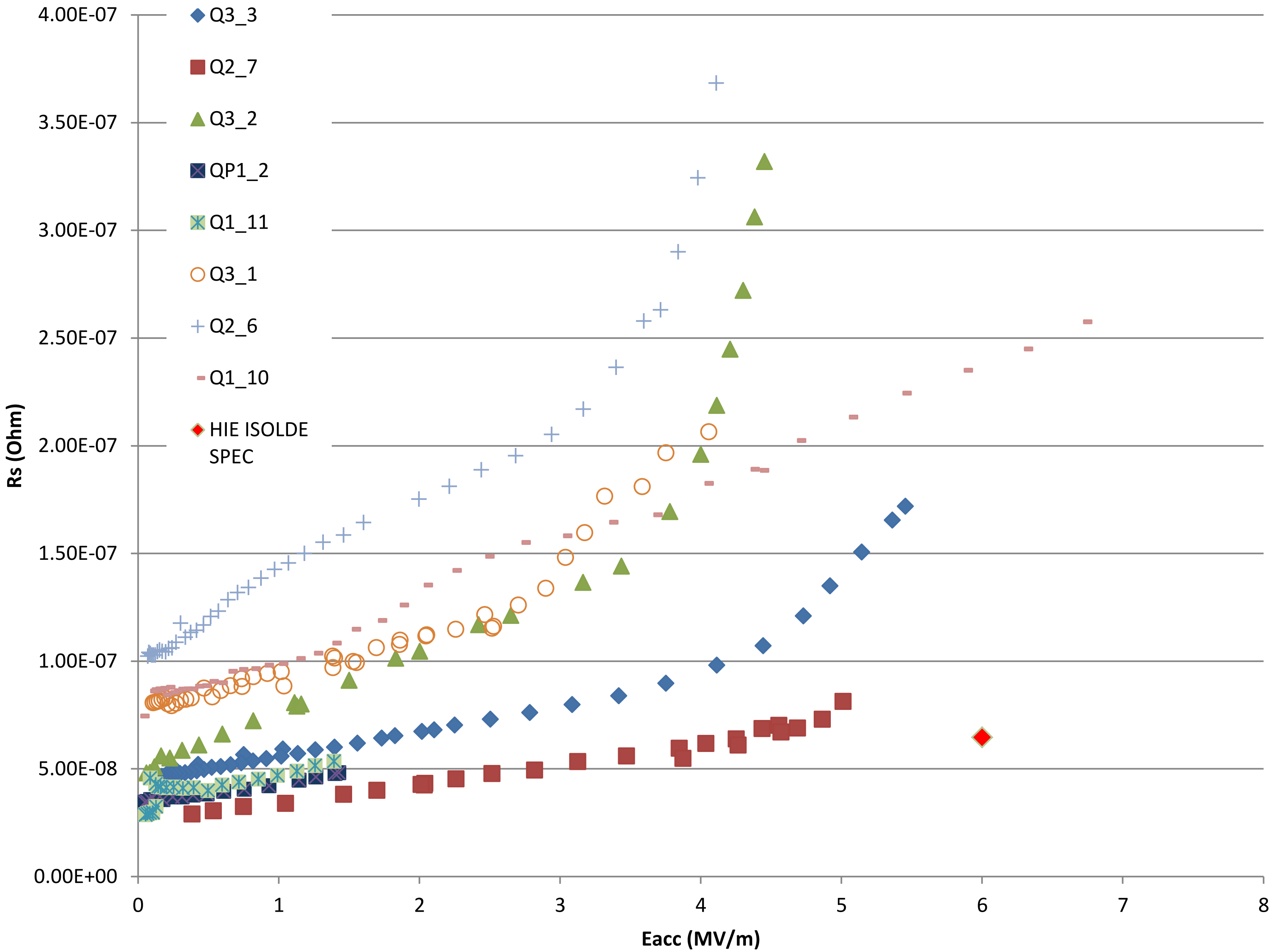
Power dissipation due to a normal conducting bottom plate (flat plate Tipgap70)@0.55MV/m: calculated value
Δpcav@0.55MV/m= 0.11455W*

QP1_2
Pcav@0.55MV/m = 0.041W before the Qswitch
Pcav @0.55MV/m = 0.45W after the Qswitch
Δpcav@0.55MV/m= 0.409W

Q2_7
Pcav@0.55MV/m = 0.035W before the Qswitch
Pcav @0.55MV/m = 0.15W after the Qswitch due to NC tuning plate
Δpcav@0.55MV/m= 0.115W

The power dissipated during the experiment on Q2_7 matches with the simulated value, while the one dissipated in QP1_2 Qswitch is 4 times bigger.

* A.D`Elia



Rs (Ohm)
4.00E-07
3.50E-07
3.00E-07
2.50E-07
2.00E-07
1.50E-07
1.00E-07
5.00E-08
0.00E+00
0
1
2
3
4
5
6
7
8
Eacc (MV/m)
Q3_3
Q2_7
Q3_2
QP1_2
Q1_11
Q3_1
Q2_6
Q1_10
HIE ISOLDE SPEC

Conclusions and outlook

- HIE ISOLDE cavities performances greatly progressed in 2012
- Q2_7 reached 5 MV/m at 10 W → 5.3 MeV/u for A/q=4.5
- Cavity optimization will continue in the first half of 2013
- Cavity review requested by IAP will be held on 21 January 2013