SRF R&D 1.3 GHz cavity testing results at CERN

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Status of 1.3 GHz R&D at CERN

Nb-on-Cu is the candidate technology for FCC-ee 400 MHz cavities

- Current LHC cavities do not reach the required performance
- Better low field Q and reduced Q-slope are required

Improvement of the substrate

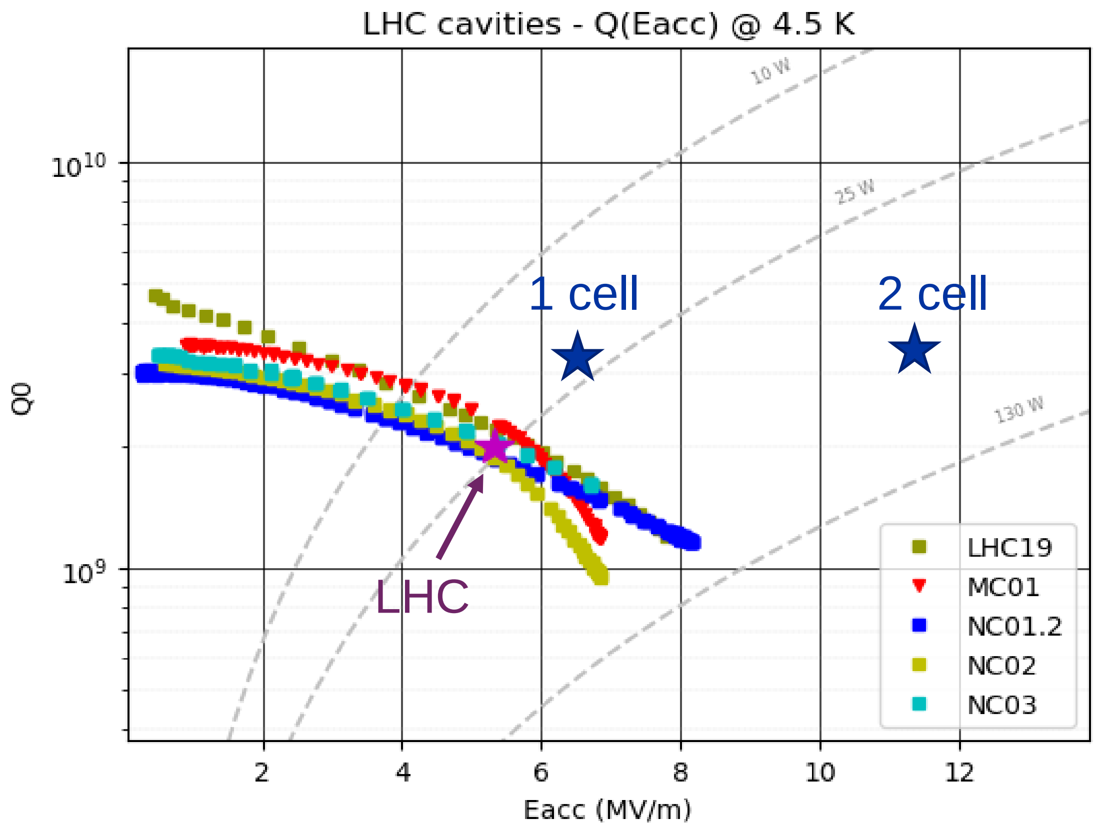
- Seamless cavities

Improvement of the film

- Defect density minimization
- Improving the adhesion to the substrate

Mitigating negative effects

- Thermoelectric currents

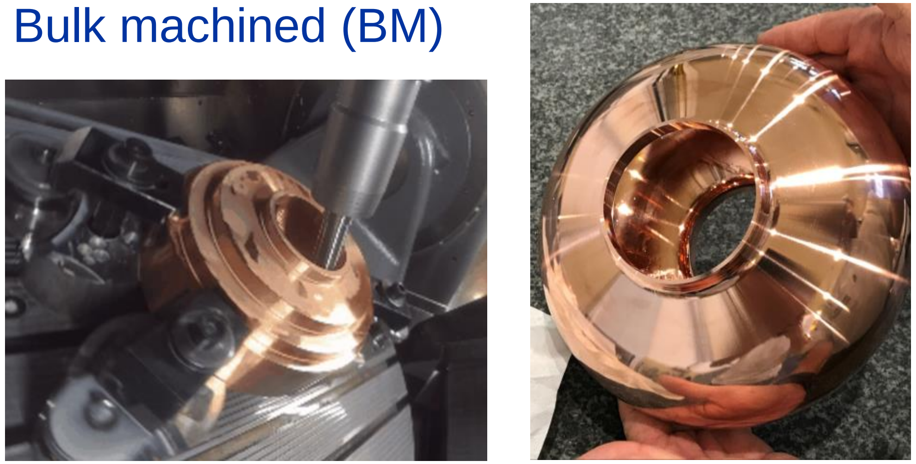


Cavity manufacturing

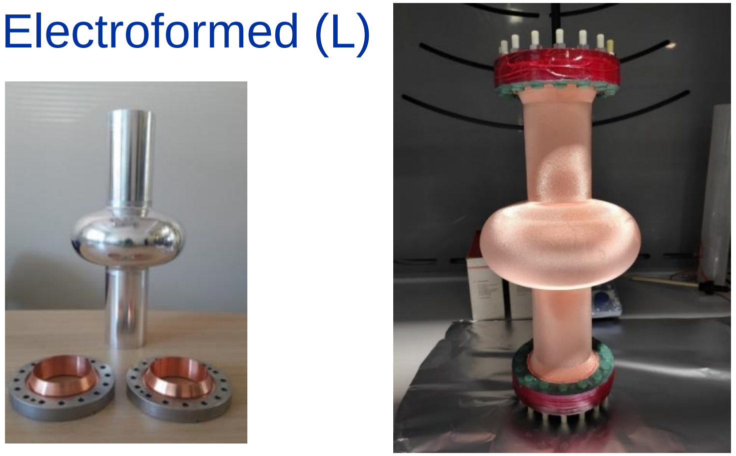
Substrates

- Seamless, or internally welded cavities
- Demonstrated using 1.3 GHz, single cell cavities
  - 400 MHz demonstrators are planned

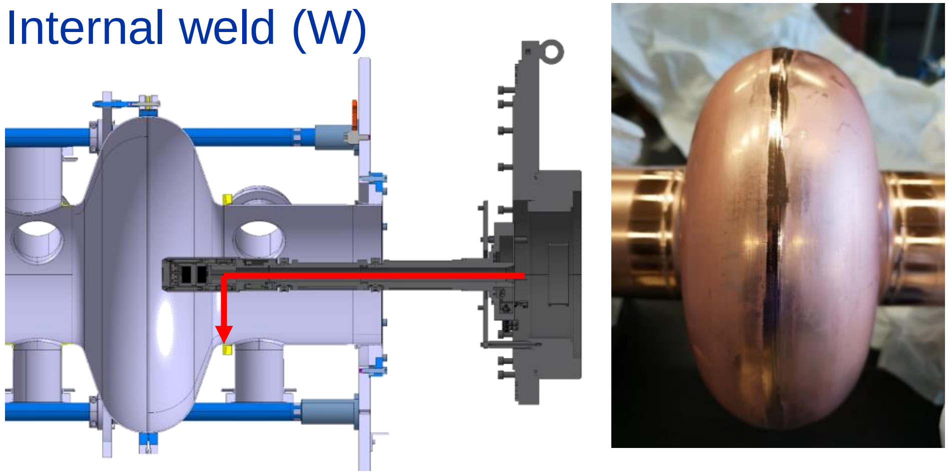
Bulk machined (BM)



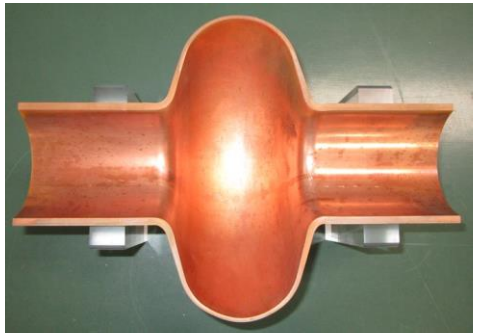
Electroformed (L)



Internal weld (W)



Hydroformed (KEK)

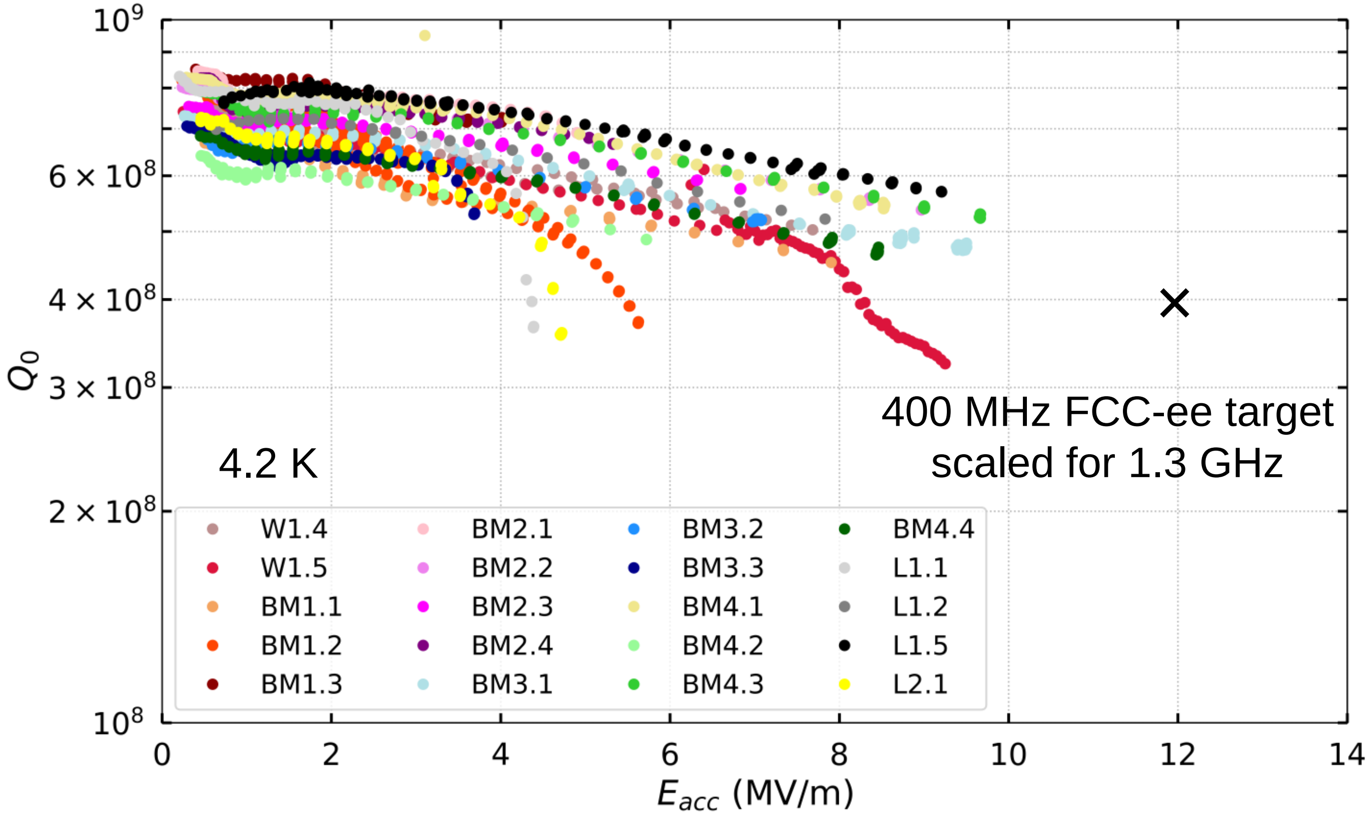


Results of the previous years

Field is limited by test facility

- No radiation allowed
- No He processing

At 4.2 K the FCC-ee requirements are in reach



Results of the previous years

Field is limited by test facility

- No radiation allowed
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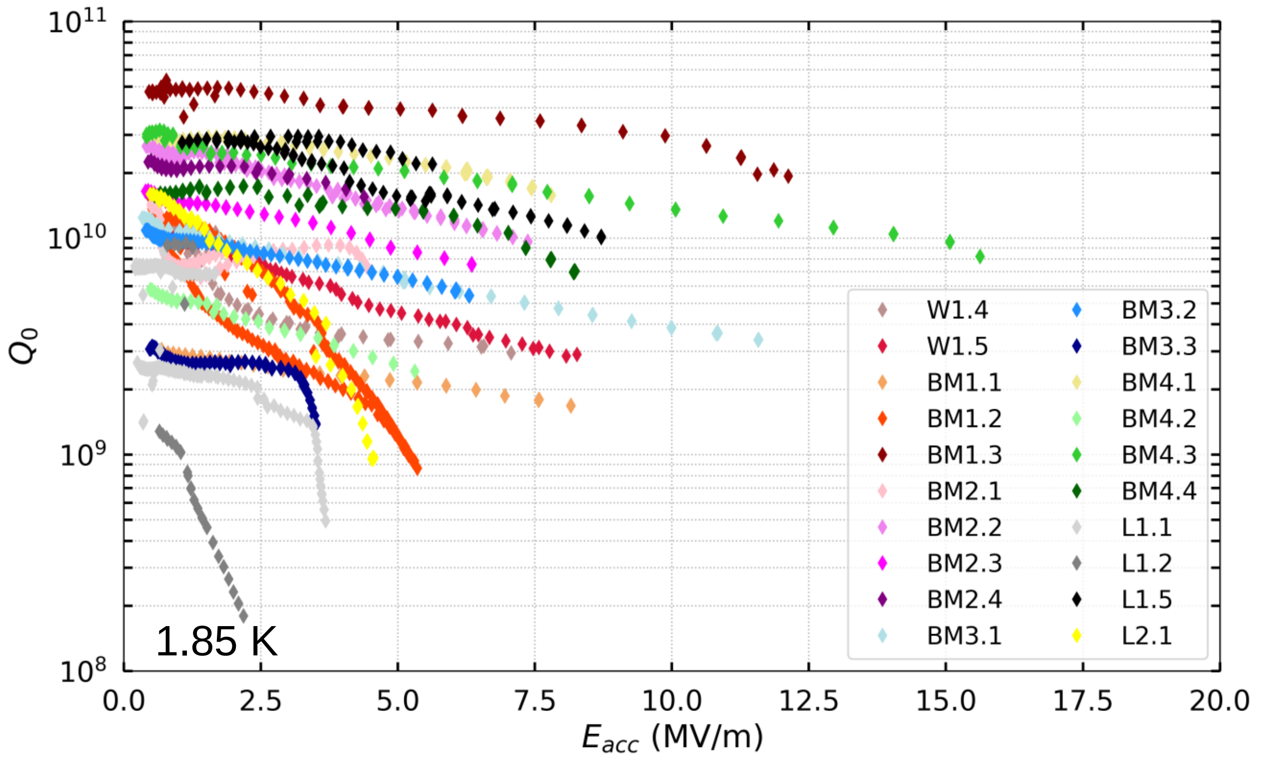
At 4.2 K the FCC-ee requirements are in reach

At 1.85 K the performance has a large spread

- Partially caused by the strong dependence on the coating parameters
- Partially by non-reproducible measurement process



Focus of last year

Thermoelectric current mitigation

Characterization of the first hydroformed Nb-on-Cu cavities

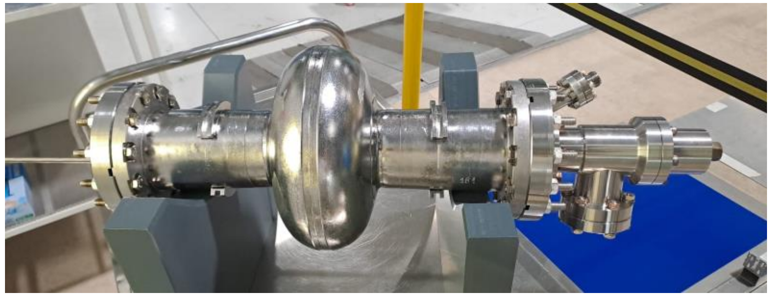
- In collaboration with KEK

Nb-on-Nb cavity measurements

- First tests towards SIS multilayer measurements

Nb-on-Cu cavity tests

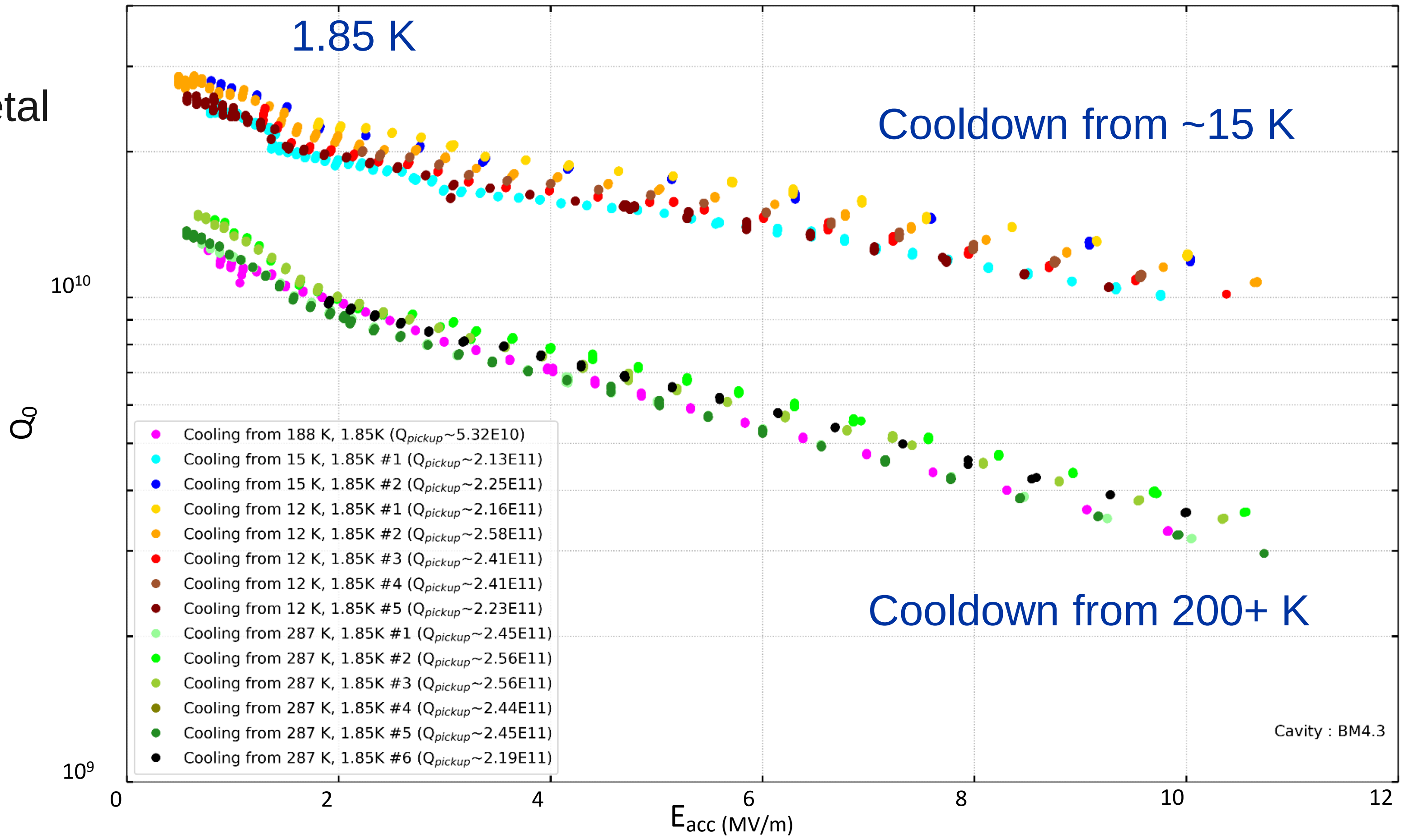
- Slightly varying coating parameters



Thermoelectric currents

Nb – Cu interface

- ΔT drives currents along the bimetal surface
- At the time of the SC transition these currents “freeze in”
- Resulting in an increased surface resistance
- Slow cooldown ≠ Low ΔT
  - But slowing down the CD is necessary to achieve better control



Thermoelectric currents – Mitigation techniques

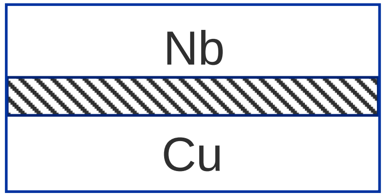
Reducing the thermal gradient

- Modifying the cooldown
  - Thermal shield + heaters
  - Semi-dry cavity cooling
- Improving thermal conduction
  - Thicker cavity

Eliminating the bimetal interface

- Insulating layer between Nb and Cu
  - In situ oxidization, Cu_2O
  - ALD of $\mathbf{Al_2O_3}$

Thermal shield



Insulator

Thermoelectric currents – Mitigation techniques

A copper “shield” was installed

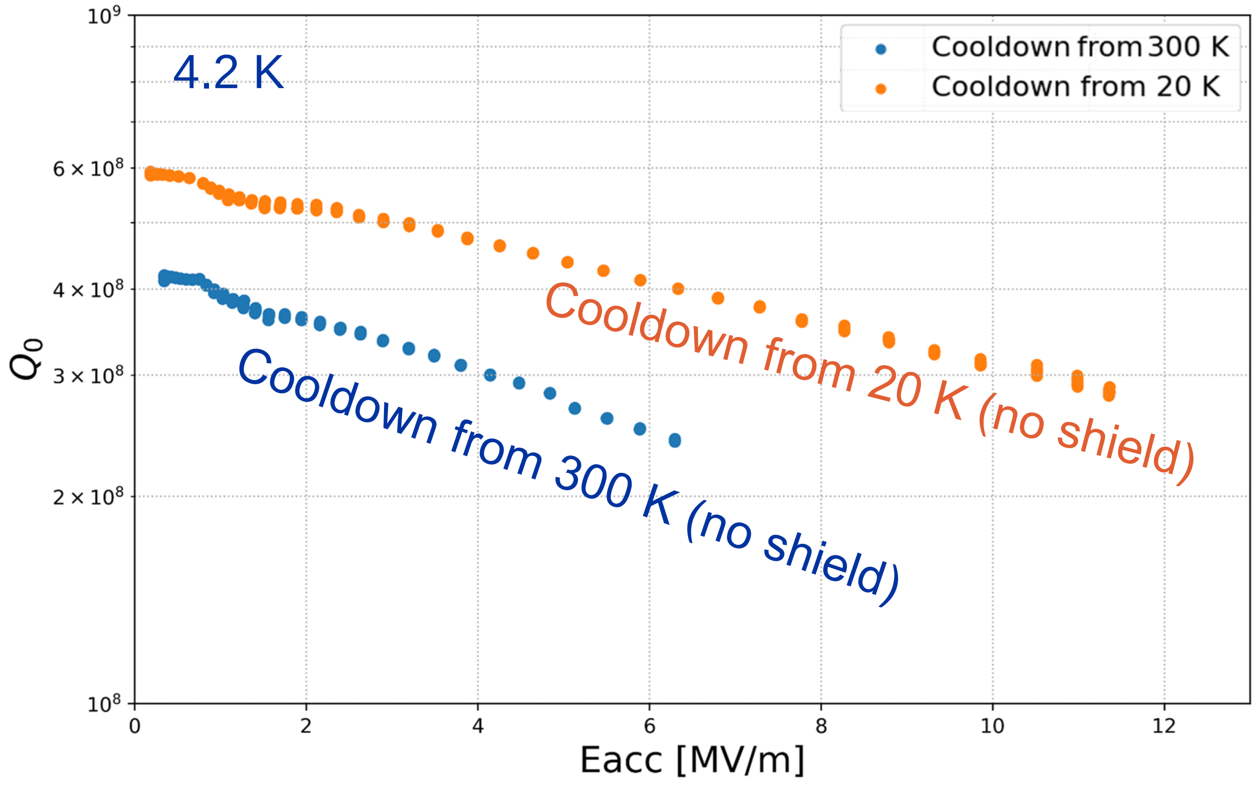
- Closed on the bottom
- The main goal is to shield the cavity from direct “uncontrolled” cooling by the He gas

- Distributed heaters will be used to control the cooldown
  - Reach equilibrium and pause at 10-15 K
  - Slowly reduce heater power
  - Transition with as low of a thermal gradient as possible

Thermoelectric currents – Mitigation techniques

Tests performed using two identical hydroformed cavities (in collab with KEK)

- The first one was measured without the shield
  - It showed significant difference between the first and the second cooldown



Thermoelectric currents – Mitigation techniques

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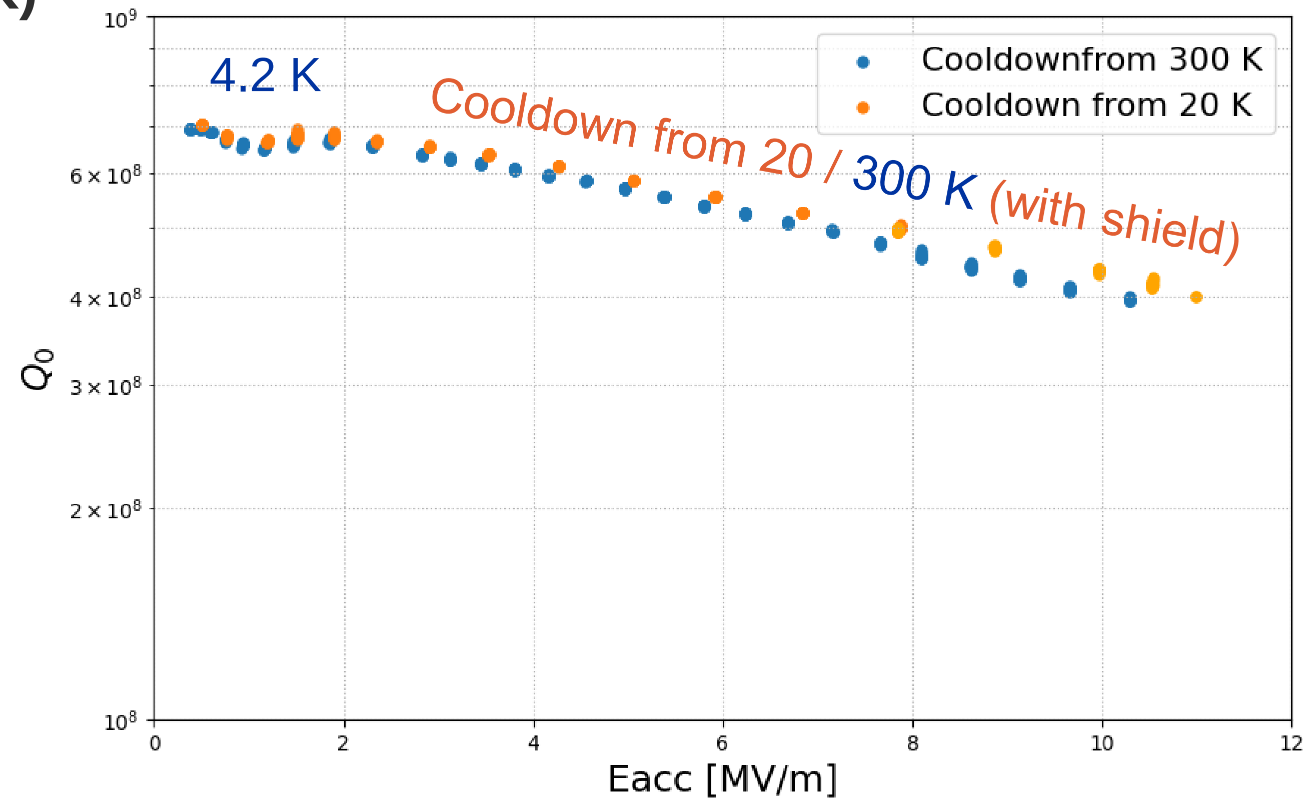
- The second one used the copper shield
  - Increased Q
  - Almost no difference between cooldowns



Thermoelectric currents – Mitigation techniques

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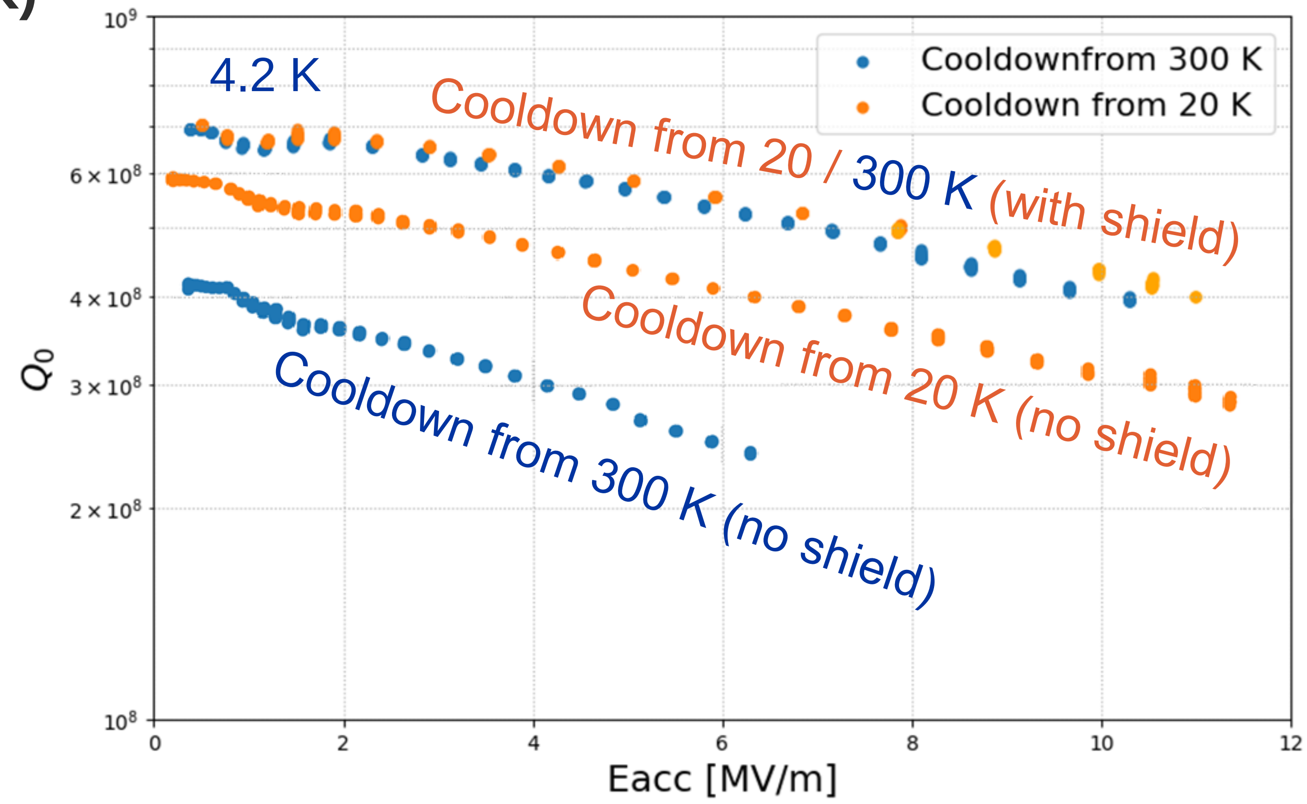
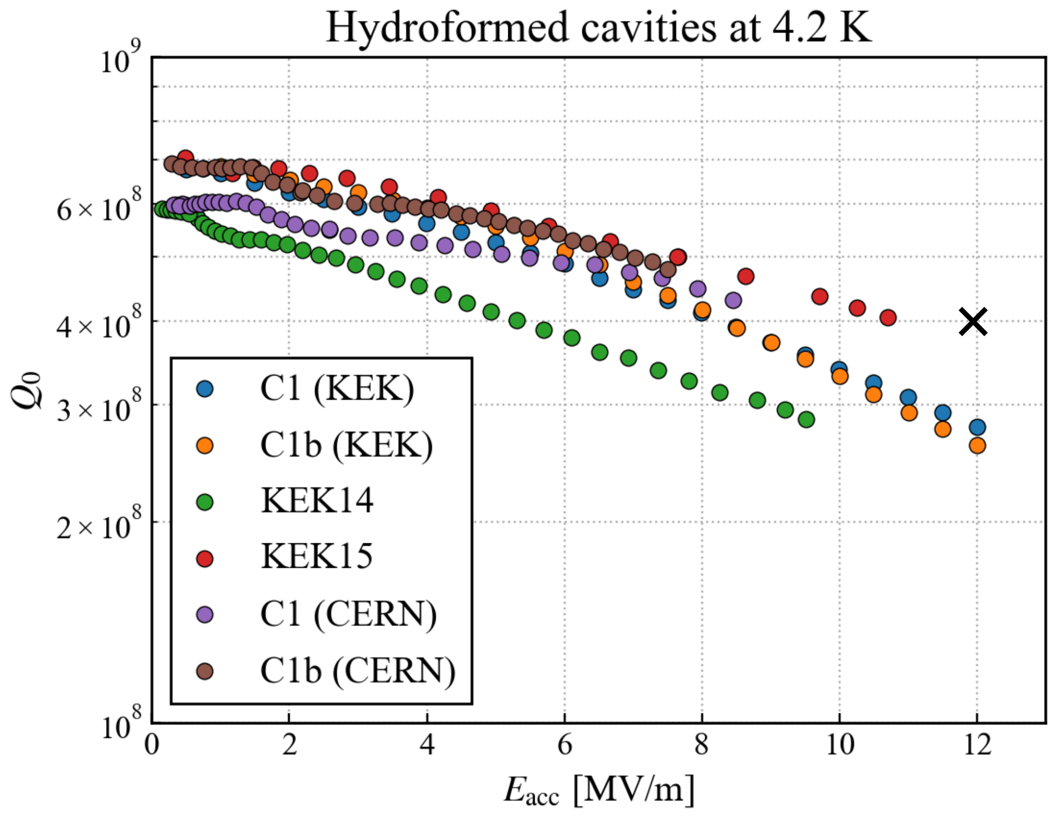


Hydroformed cavity results

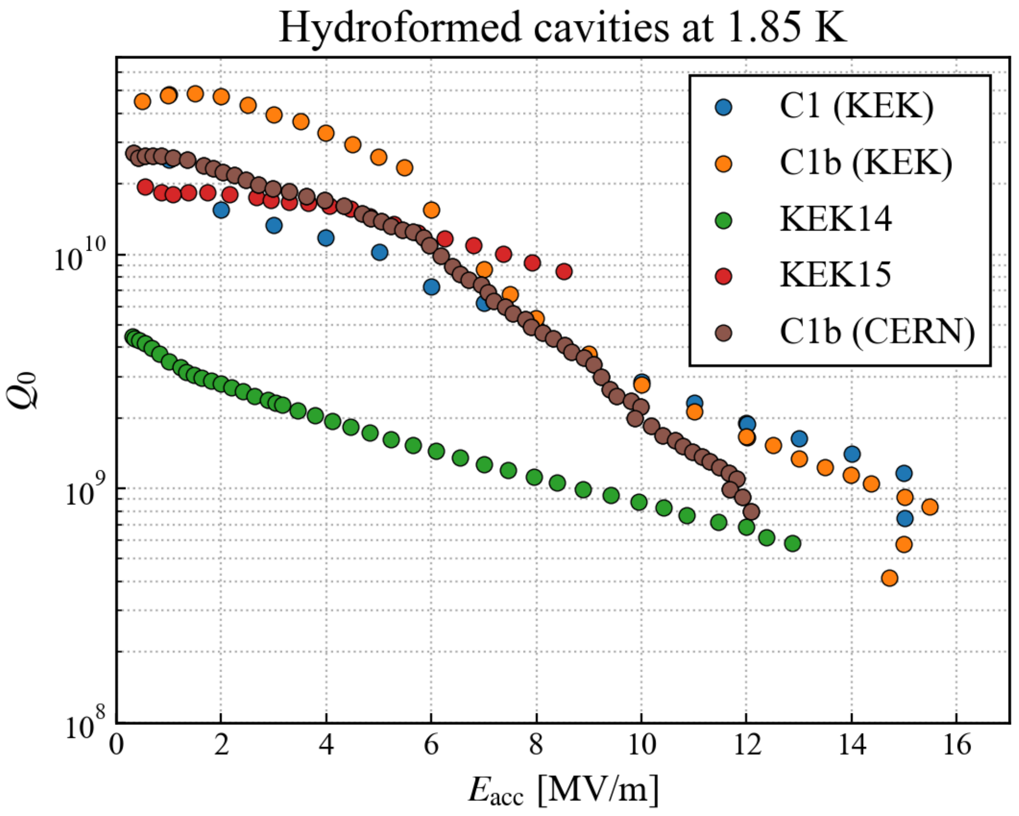
- Four hydroformed cavities
- Two of them (C1 and C1b) measured both at KEK and CERN
- All of them show slightly worse performance than other seamless cavities

- Probably due to the surface roughness of the substrates
- 2 cavities are to be recoated and retested after plasma electron polishing (performed at INFN)



Hydroformed cavity results

- At 1.85 K they all show significant Q slope
- Small “Q switches” are also observed



Nb-on-Nb results

A bulk Nb cavity was coated using HiPIMS

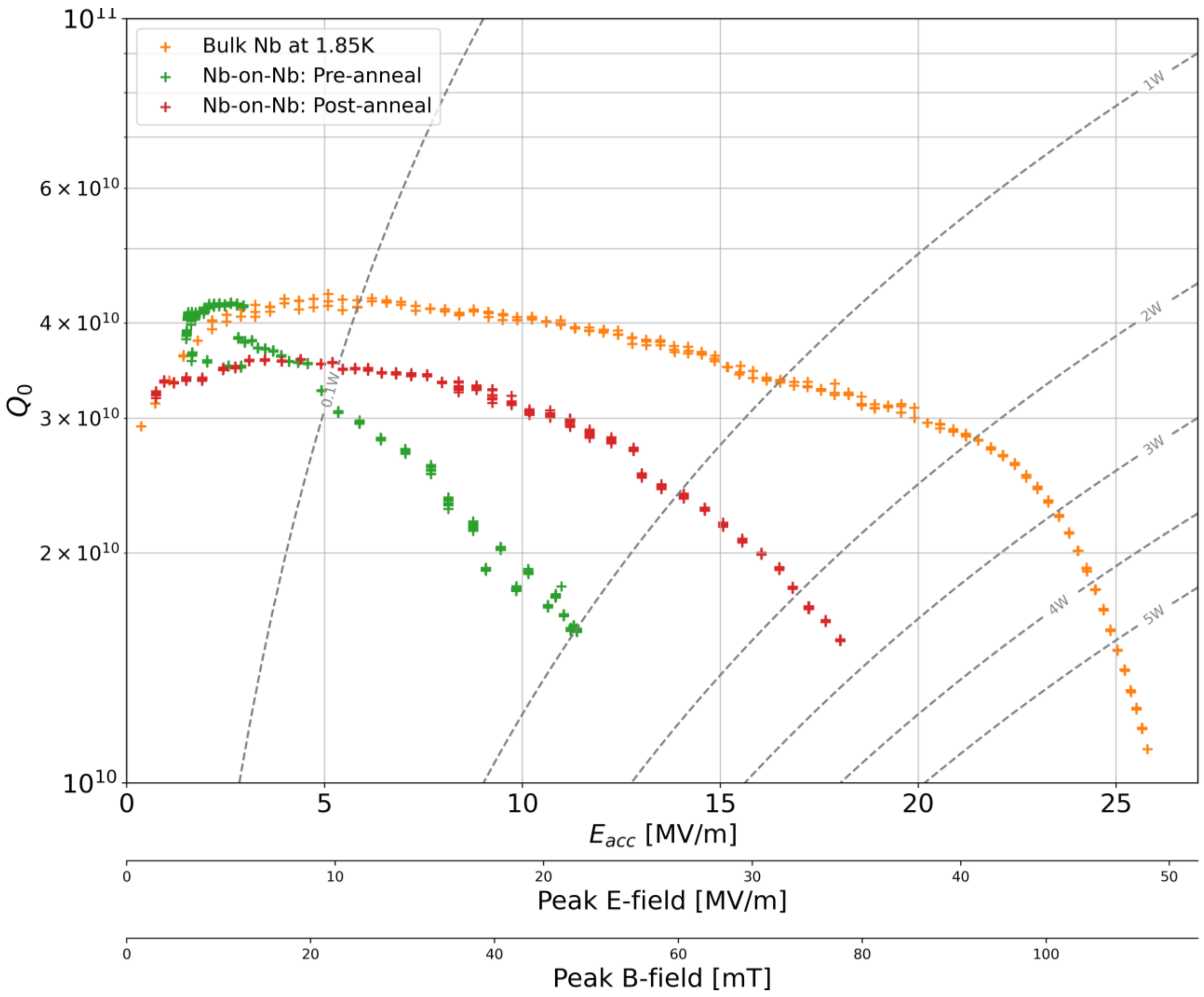
- The cavity showed a Q slope similar to Nb-on-Cu cavities

An 800 °C heat treatment was performed (at DESY)

- The Q slope became significantly less steep

A second heat treatment cycle was performed at 600 °C

- Afterwards the performance dropped unrecoverably



Summary

- **The cryolab measurement stand allows quick turnaround measurements**
  - More extensive testing (higher power) have to be performed in SM18
- **Thermoelectric current mitigation is crucial for reaching peak performance**
  - Simple methods already have significant effects, but proper temperature control will be ideal
  - This will also be relevant for Nb_3Sn-on-Nb/Cu cavities
- **Hydroformed cavities exhibit worse behaviour than other seamless cavities**
  - Surface roughness reduction might improve the results
- **Our test of a Nb-on-Nb cavity showed similar behaviour to a Nb-on-Cu cavity**
  - After a heat treatment the Q slope improved significantly
  - Further testing will be performed on coated bulk Nb cavities (e.g. SS/SIS multilayer tests)

Thank you for your attention!

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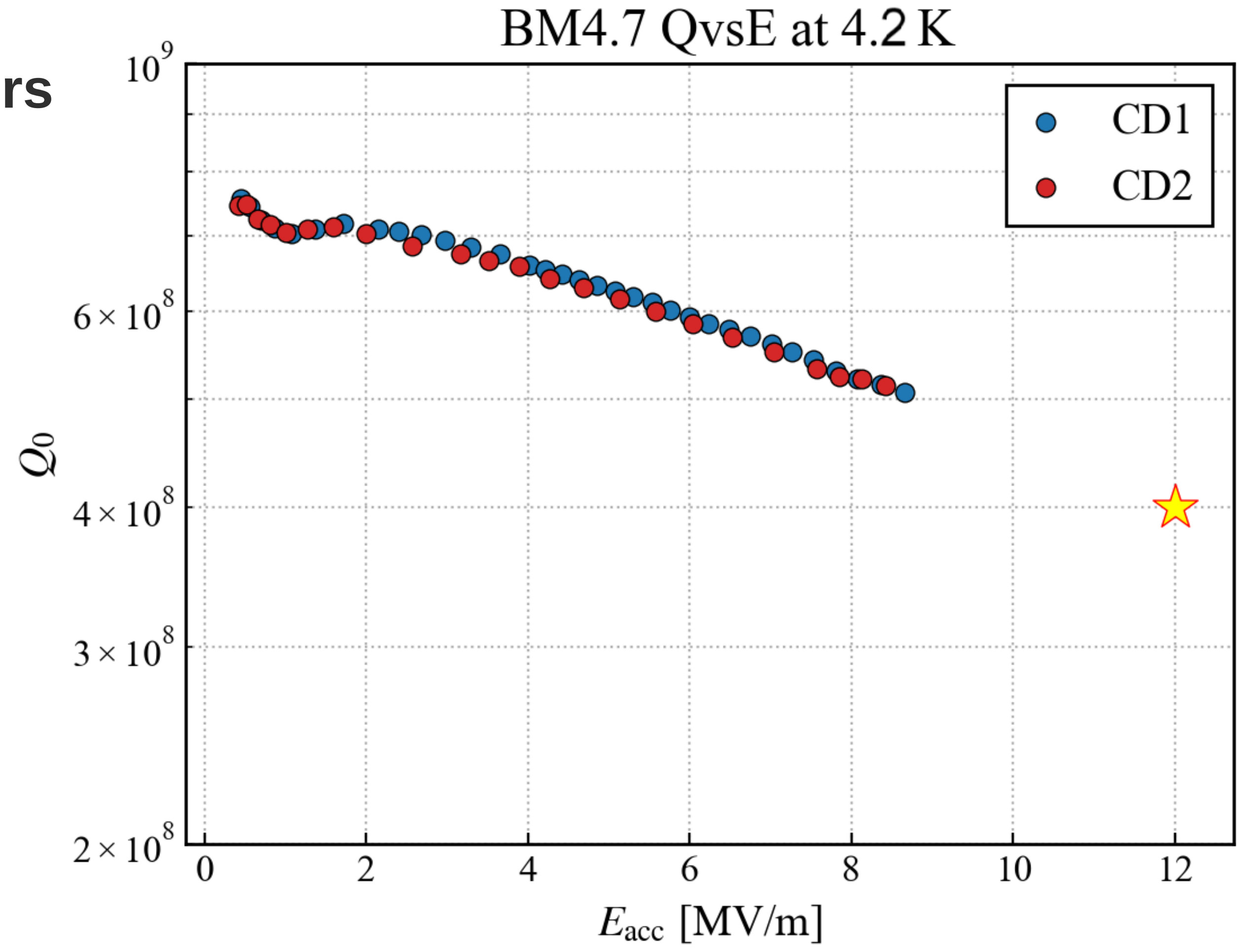
Latest Nb-on-Cu result

HiPIMS with slightly modified parameters

- Expected performance at 4.2 K



Latest Nb-on-Cu result

HiPIMS with slightly modified parameters

- Expected performance at 4.2 K

- At 1.85 K significant Q slope
- But excellent field reach
  - After a thermal cycle 16 MV/m reached without radiation, quench, or Q switch