Progress in Nb_3Sn SRF cavity development at KEK after furnace relocation

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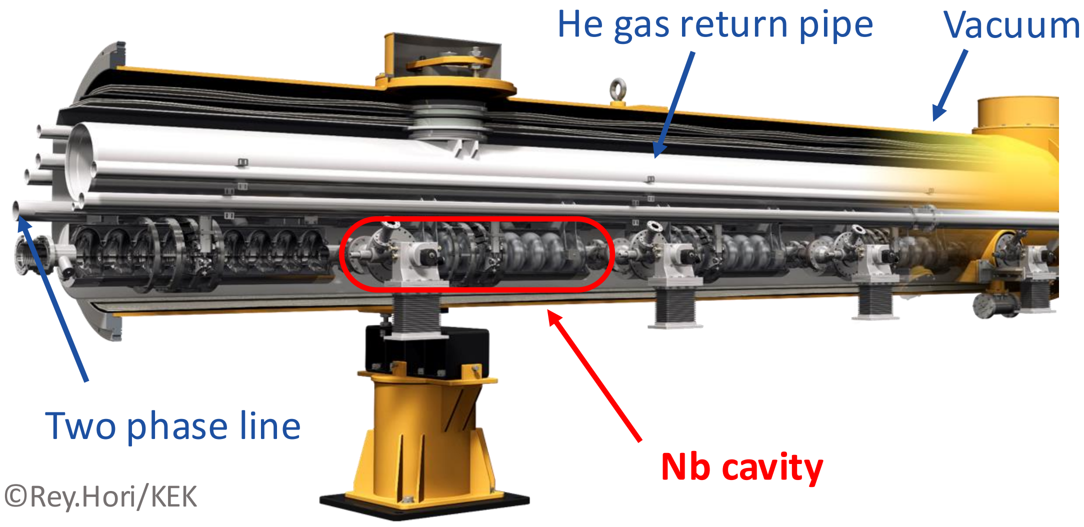
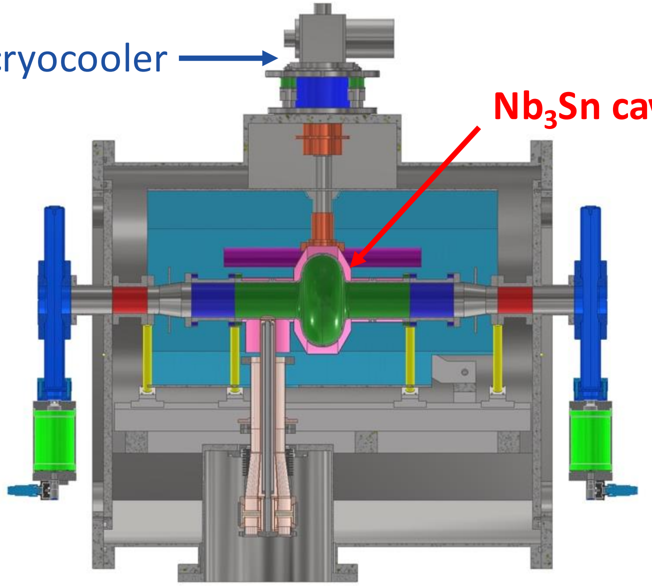
Why Nb_3Sn?

Typical 1.3 GHz Nb cryomodule

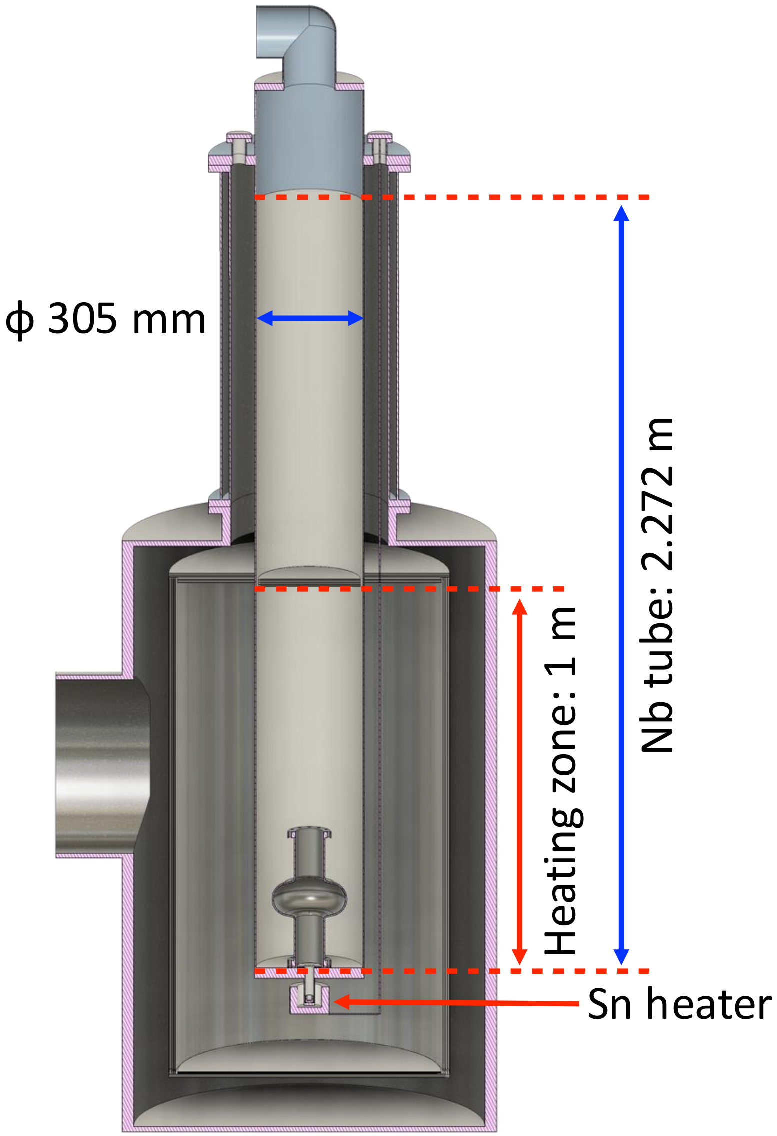


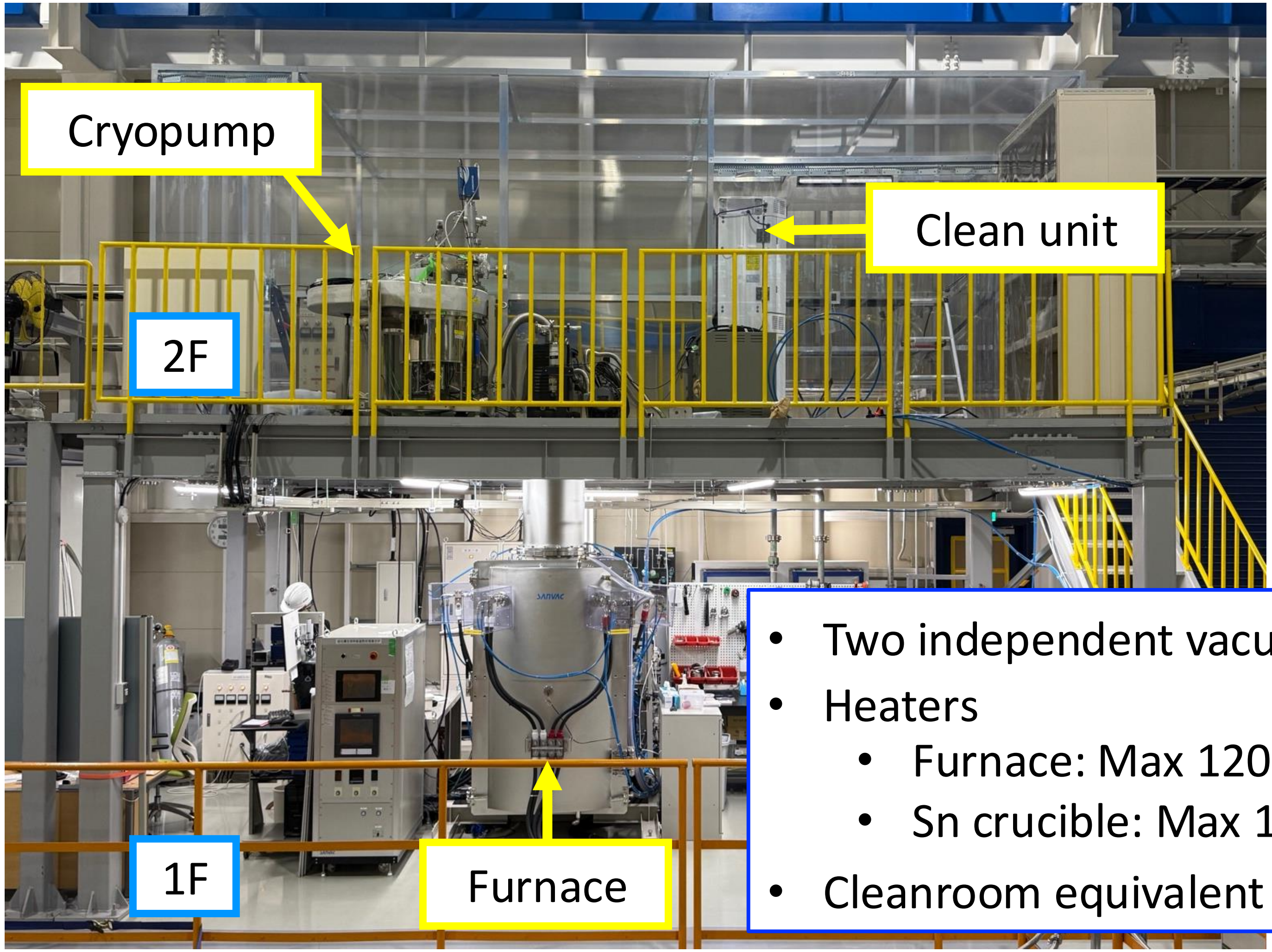
Conduction-cooled Nb_3Sn cryomodule (concept)



- Nb cavities require 2 K liquid-helium cooling to achieve high Q_0.
  → Large and complex cryogenic systems
- Nb_3Sn can achieve a high Q_0 at 4.2 K, comparable to that of Nb cavities operated at 2 K.
  → Compact conduction-cooled SRF accelerators without liquid helium
  → Broadens the applications of SRF accelerators

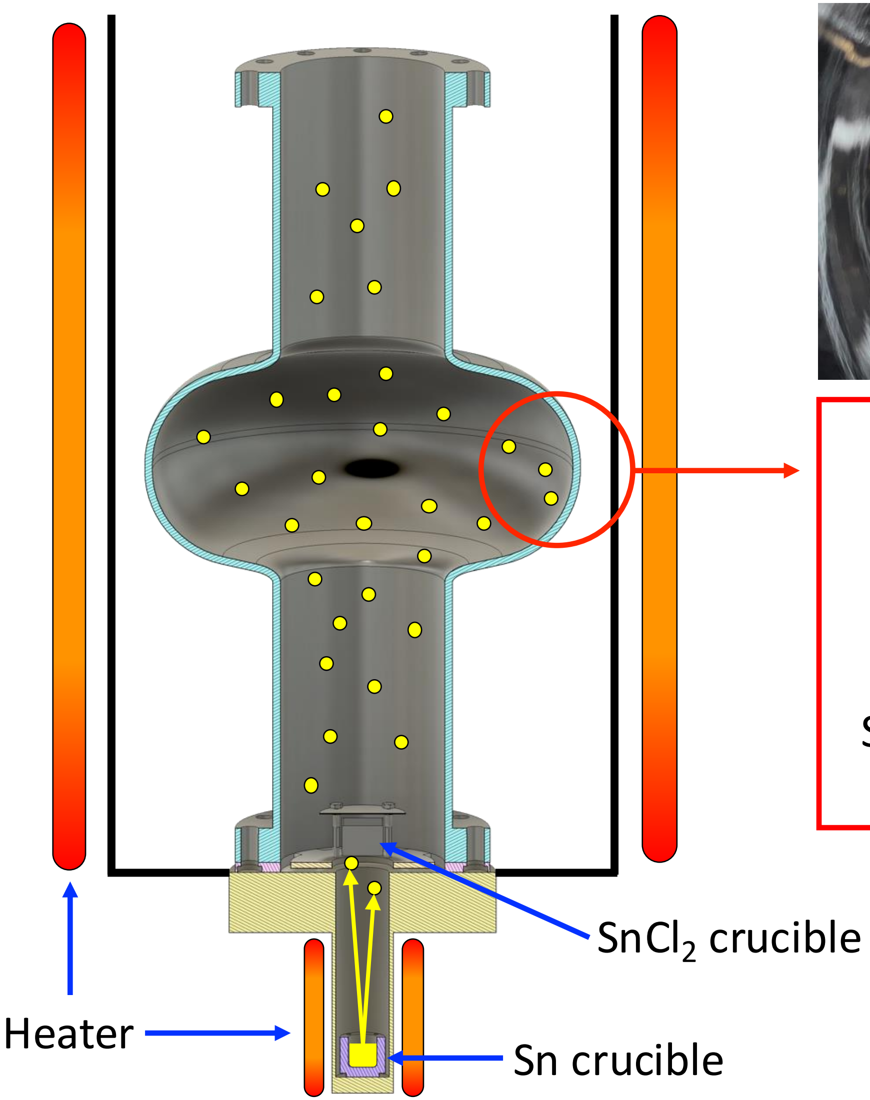
KEK's Nb_3Sn coating system

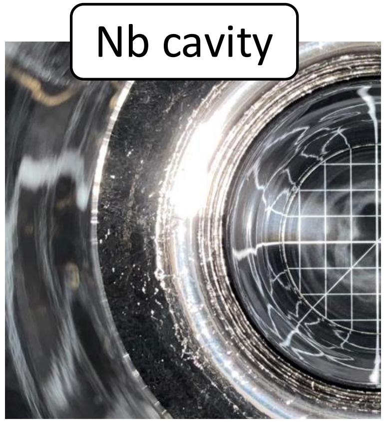


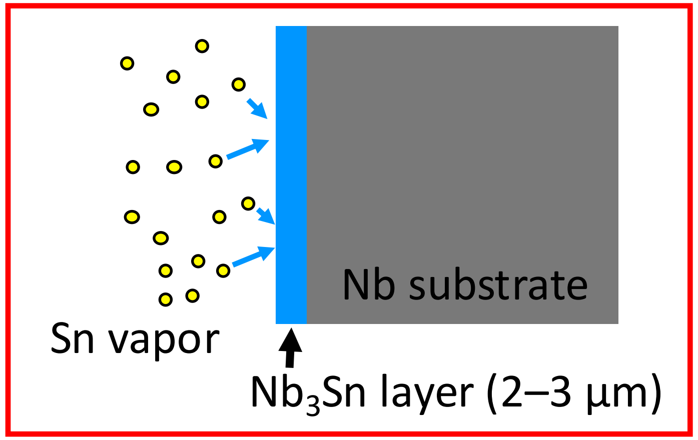


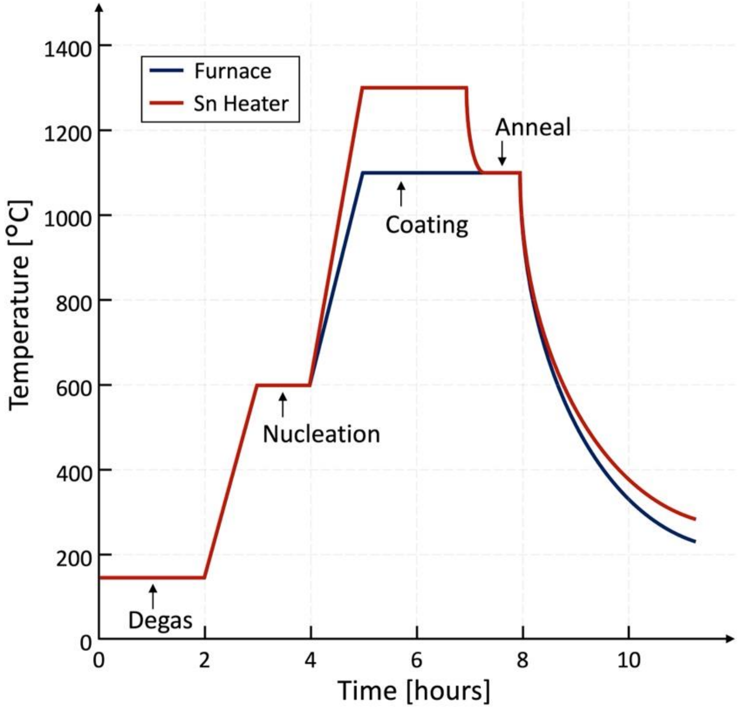
- Two independent vacuum systems
- Heaters
  - Furnace: Max 1200°C
  - Sn crucible: Max 1500°C
- Cleanroom equivalent to ISO class1

Nb_3Sn coating by vapor diffusion



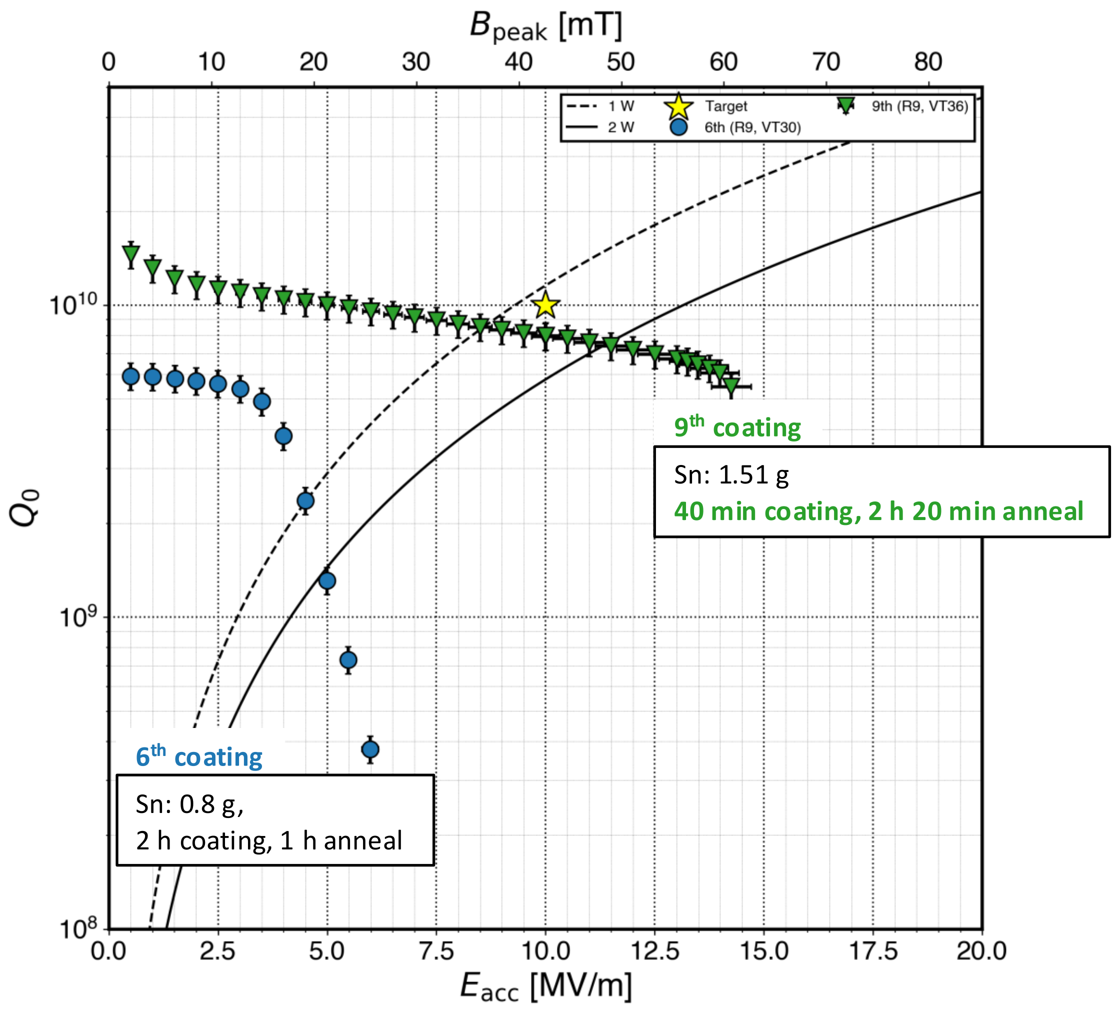






- Nb_3Sn is formed on the inner surface of the Nb cavity.
- A shading plate is installed to suppress the formation of Sn droplets on the upper side.

Nb_3Sn performance – Sn supply balance



No.	Sn source [g]	Sn evaporation [g]	Estimated Sn evaporation [g]
6	0.80	0.80	1.52
8	1.55	1.47	1.52
9	1.51	0.51	0.61
10	1.50	1.06	1.42

Oversupply

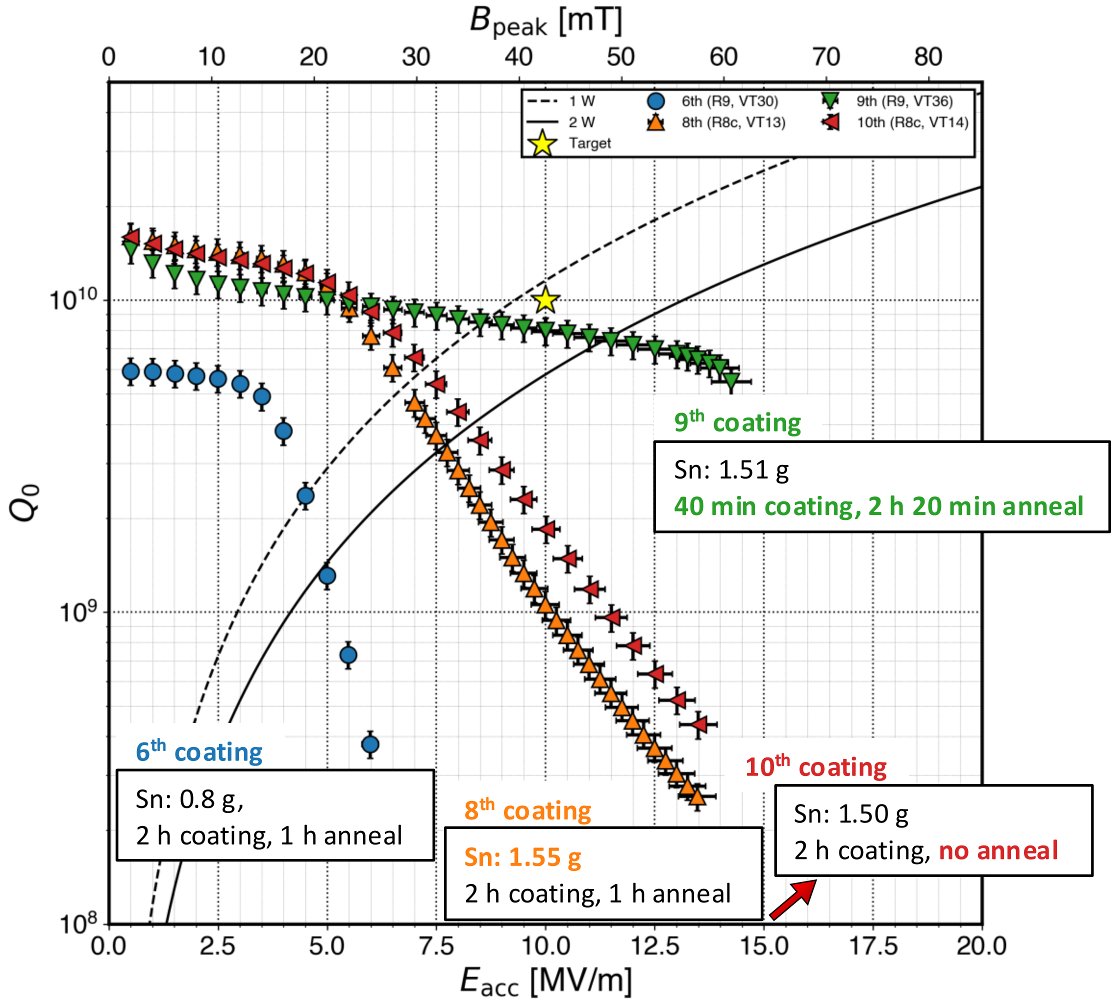
Optimum supply

Undersupply

In the undersupply condition, a strong Q-slope appears even at low accelerating gradients.

In the oversupply condition, a high Q_0 is maintained up to high accelerating gradients.

Nb_3Sn performance – Sn supply balance



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Oversupply

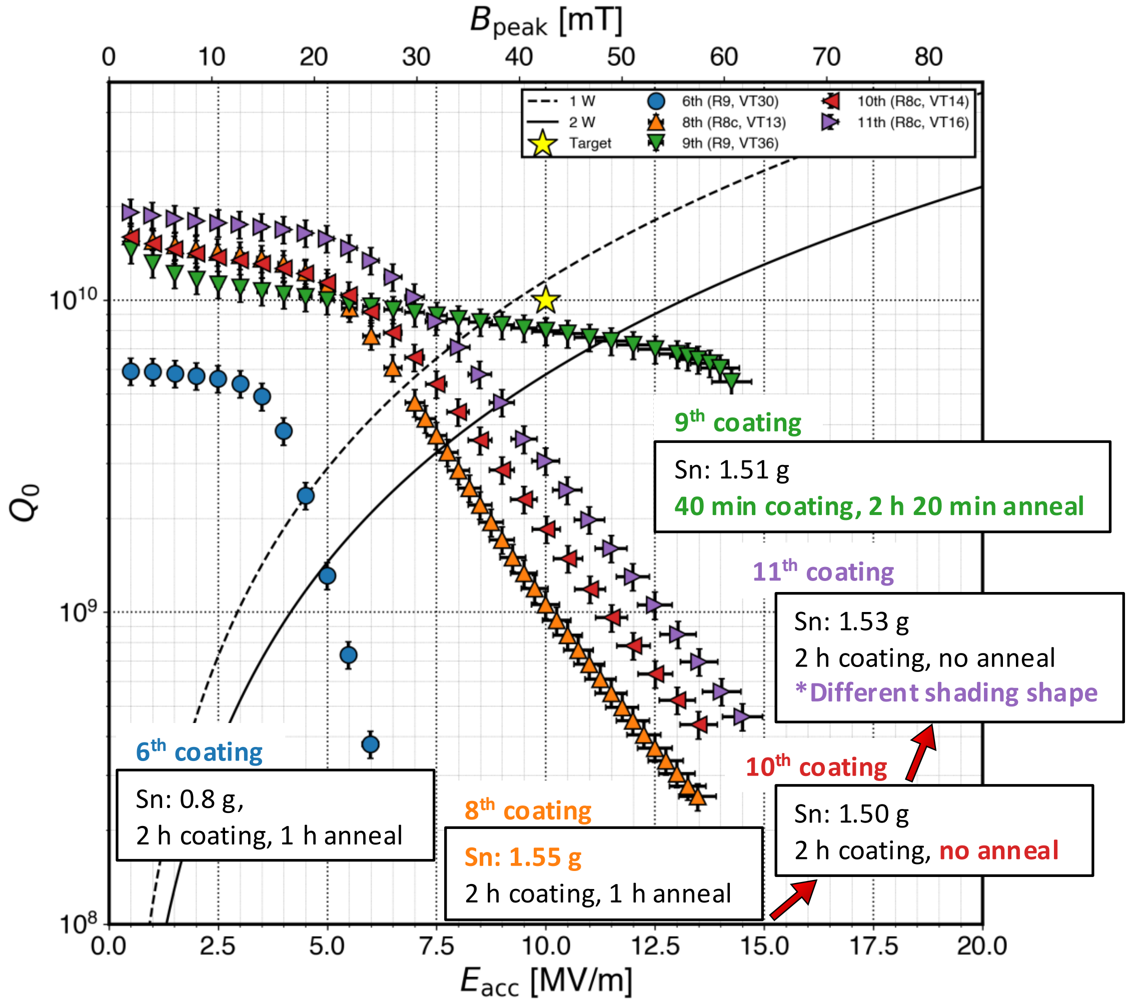
Optimum supply

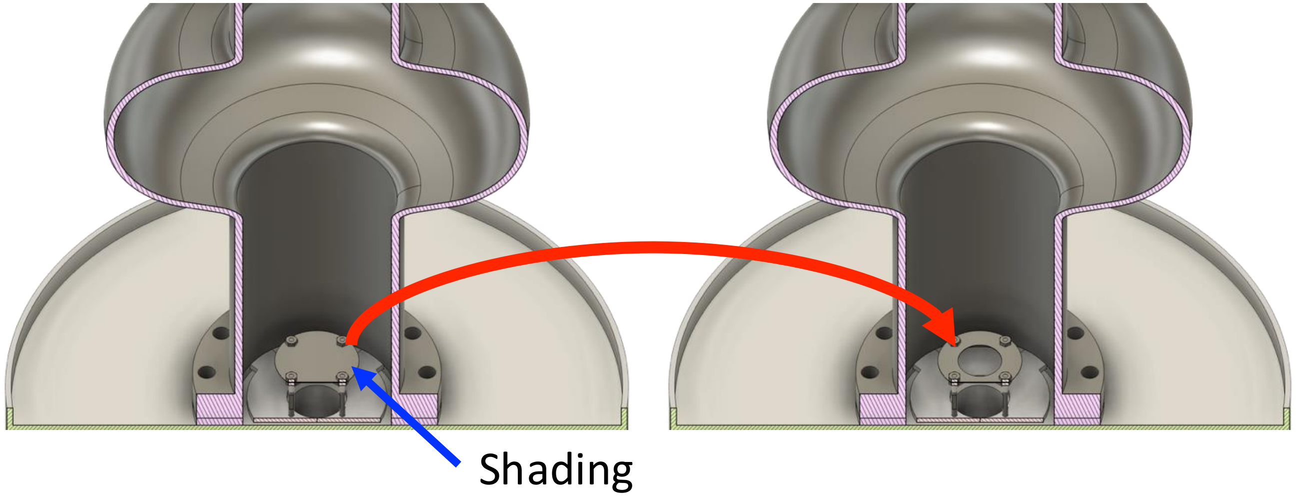
Undersupply

In the optimum supply condition, the Sn supply was optimized without oversupply or undersupply, but the cavity performance was intermediate.
→ The Sn vapor likely became insufficient during the final stage of the coating process.

In the 10th coating, the annealing process was eliminated.
→ Q-slope was slightly reduced.

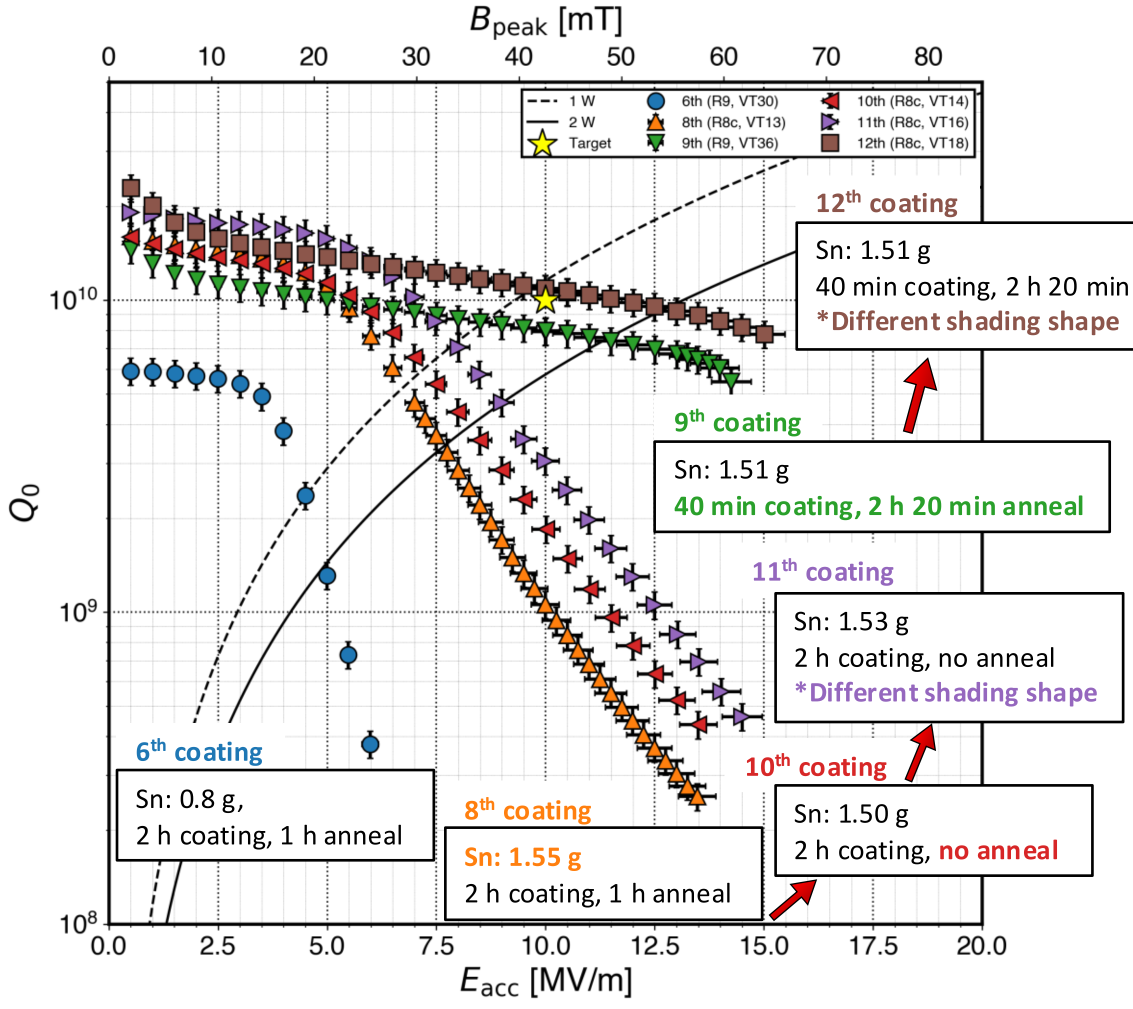
Nb_3Sn performance – effect of shading geometry

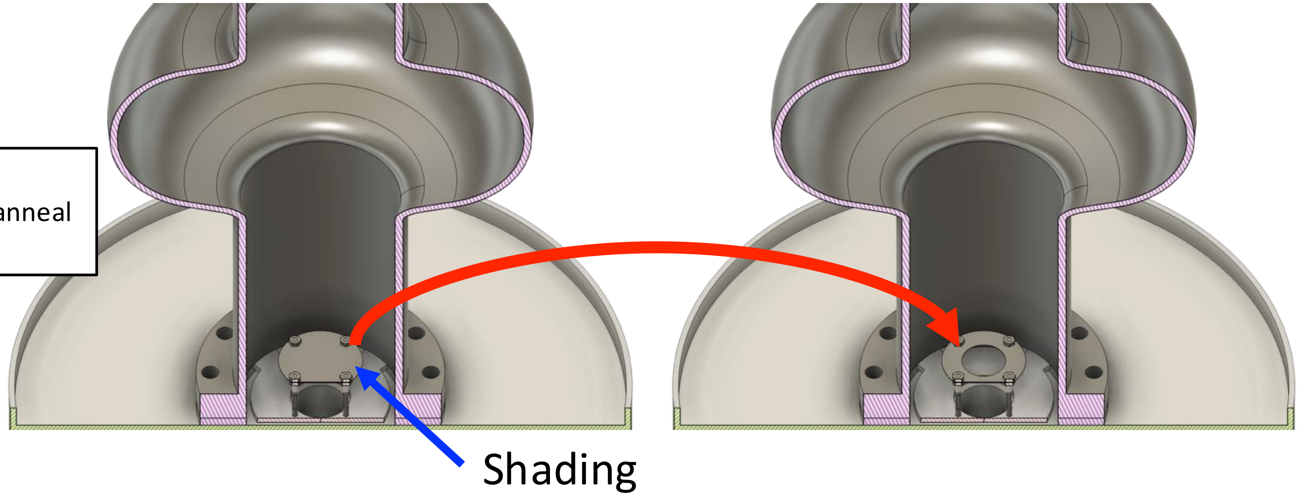




For the 11th coating, only the shading geometry was modified from that used in the 10th coating to improve Sn vapor transport into the cavity.
→ Q_0 was consistently improved over the entire E_{acc} range.

Nb_3Sn performance – effect of shading geometry





For the 11th coating, only the shading geometry was modified from that used in the 10th coating to improve Sn vapor transport into the cavity.

→ Q_0 was consistently improved over the entire E_{acc} range.

For the 12th coating, 9th coating conditions were combined with the improved shading geometry developed for the 11th coating.

→ The target cavity performance was successfully achieved.

Summary

- KEK is developing Nb_3Sn cavities for future superconducting accelerators.
- Optimization of the coating conditions and Sn vapor transport significantly improved cavity performance.
- Achieved our current target:

  $Q_0 > 1 \times 10^{10}$ at 10 MV/m and 4.2 K
- Further optimization of the coating parameters is ongoing to achieve even higher cavity performance.

For more details, please visit Poster **THPO011**.