Surface Resistance and Trapped Flux Sensitivity as Function of Baking Temperature

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Outline

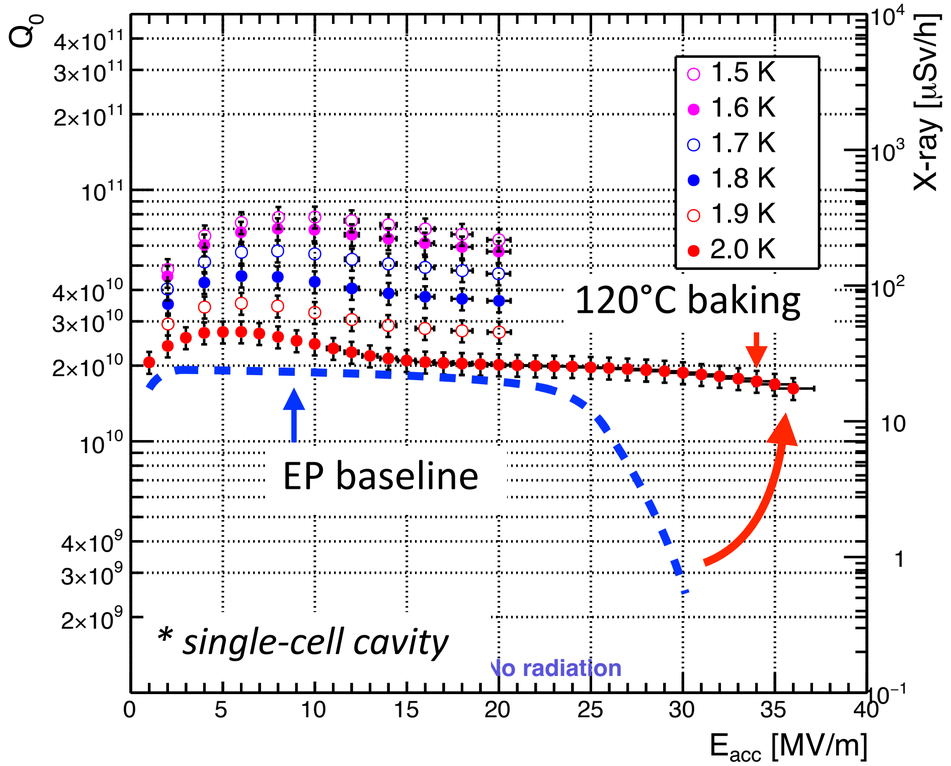
- Baking study at KEK
- Mid-T furnace baking
- Low-T furnace baking
- Summary of baked cavity performance
  - Q-E curve
  - R_{BCS}
  - R_{res}
  - Trapped flux sensitivity
- Reliability of baking method
- Summary

Standard recipe for 1.3 GHz TESLA cavity

Standard treatment

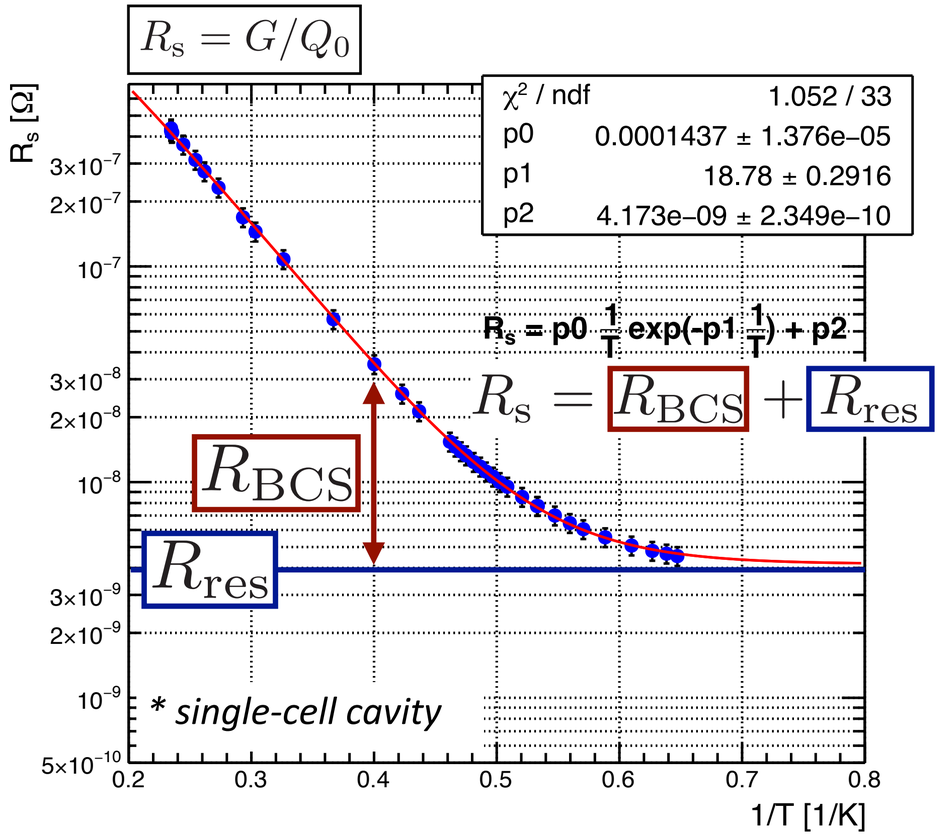
- EP1 ~100 µm — Make clean and flat surface
- Anneal — Hydrogen degassing
- EP2 ~10 µm — Remove polluted layer
- Assembly
- 120°C 48 h baking
- RF measurement

→ w/o HPR
→ w/ HPR



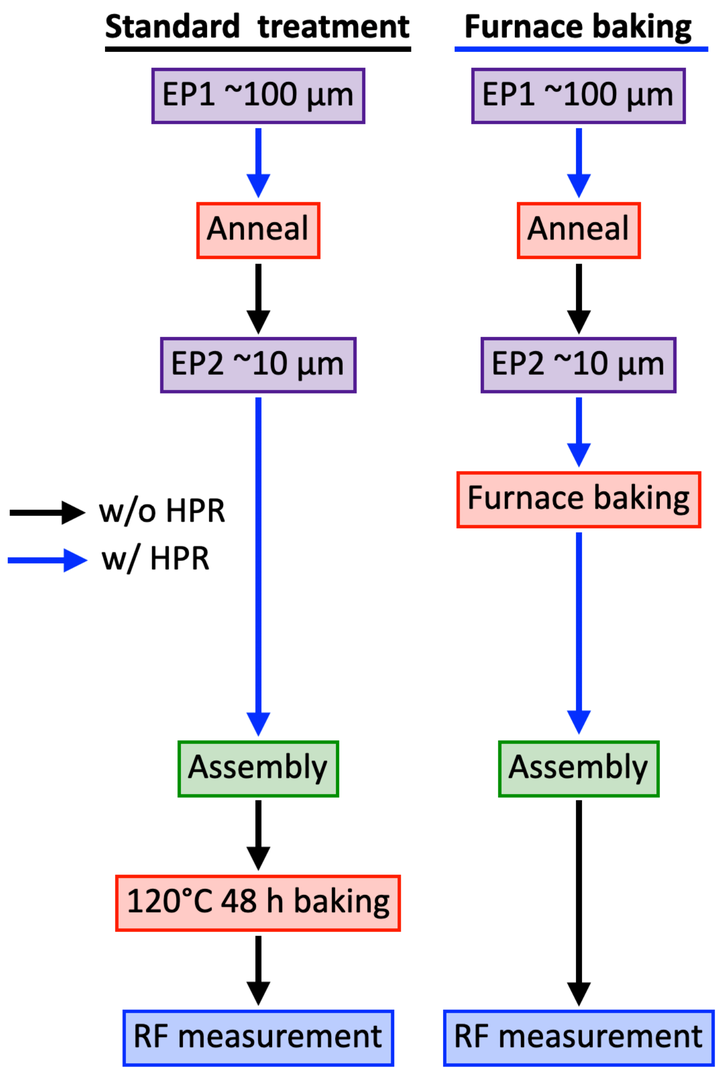
Q_0 = ~2E10 at 2 K

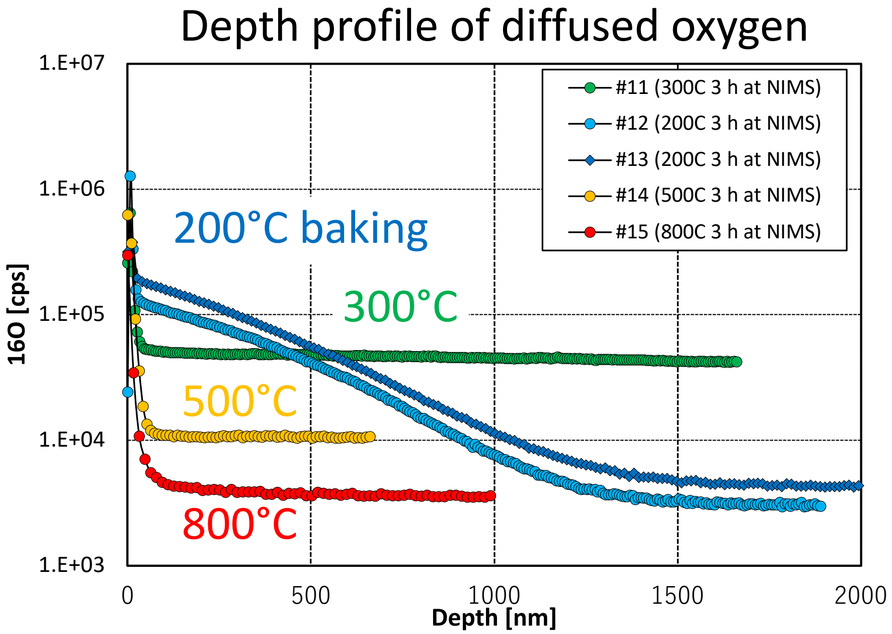
$E_{acc,Max}$ = 35~45 MV/m

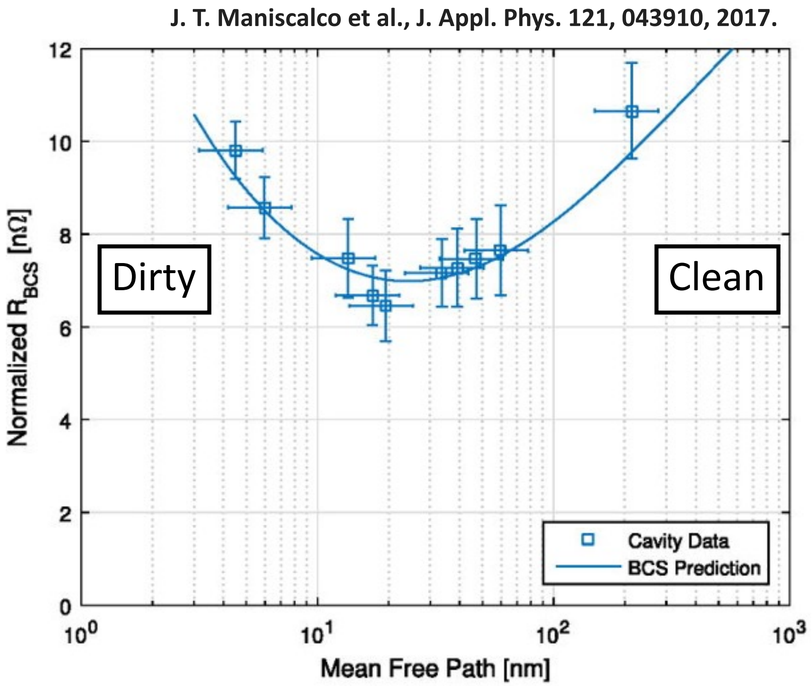


R_s = ~10 nΩ at 2 K

Tuning R_{BCS} by “Furnace baking”





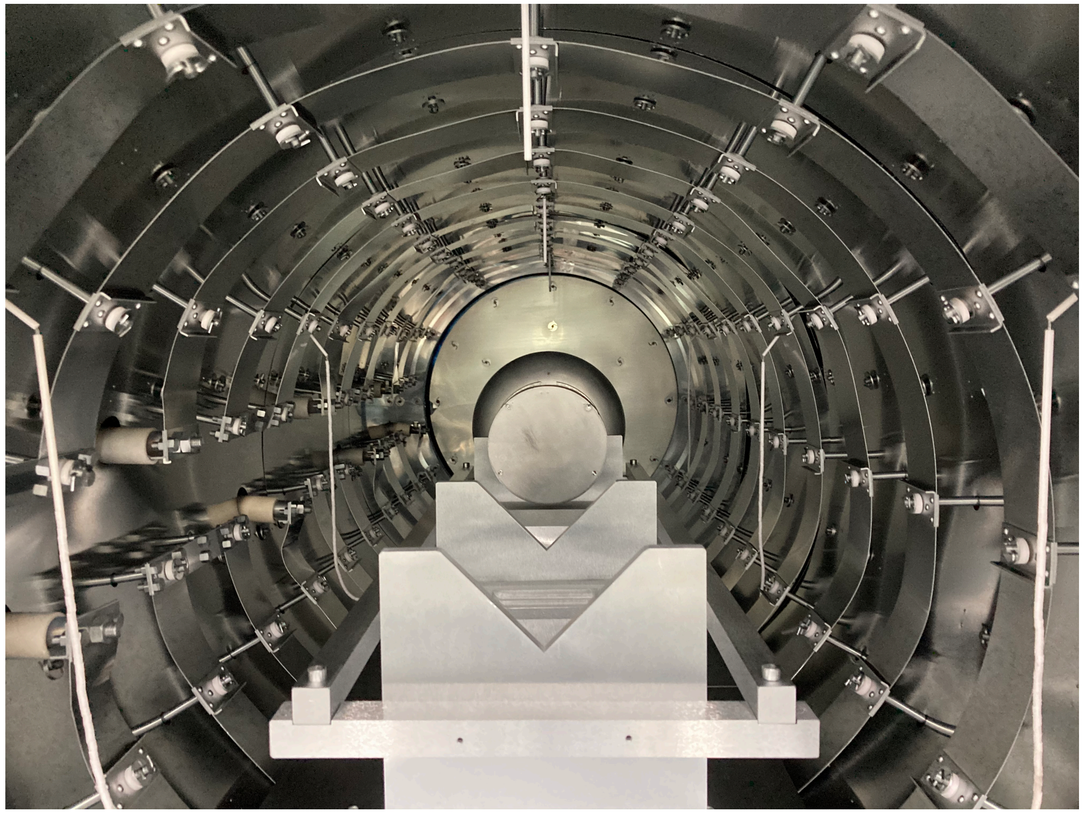


Super clean material is not ideal for SRF cavities.
Optimal surface oxygen concentration minimizes R_{BCS}.

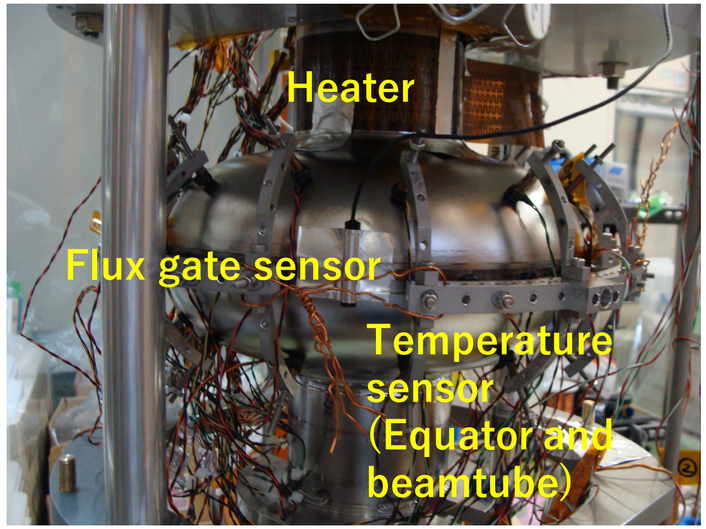
Furnace baking at KEK

light EP → **HPR** → **Furnace baking** → **HPR** → **cleanroom assembly** → **rf test**

- Refresh inner surface
- 200-800°C
- No baking

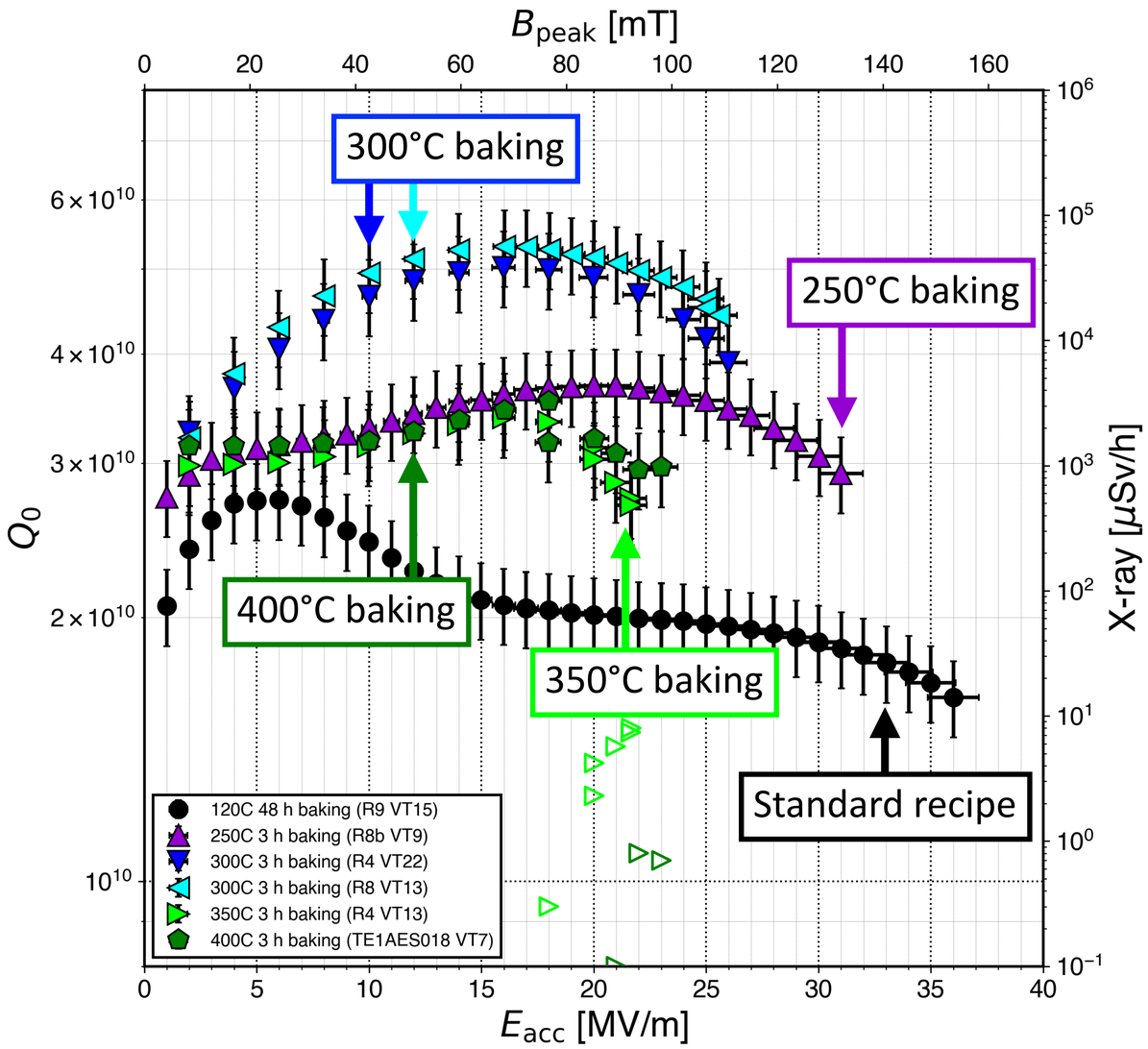


Setup of RF measurement



- Magnetic field is reduced to lower than ~ 1 mG by magnetic shield and solenoid coil
- Flux expulsion is performed to minimize the flux trapping

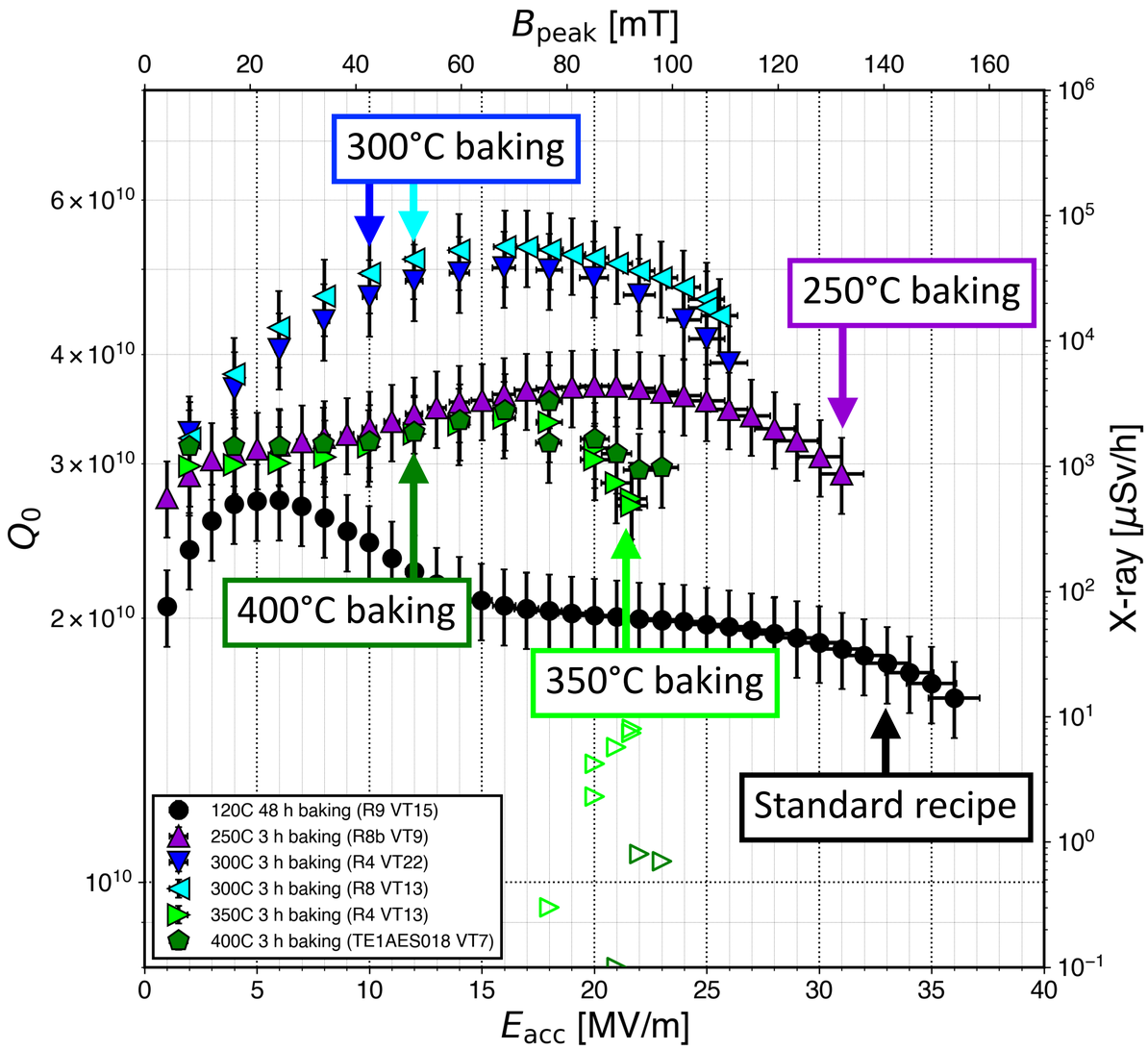
Mid-T furnace baking

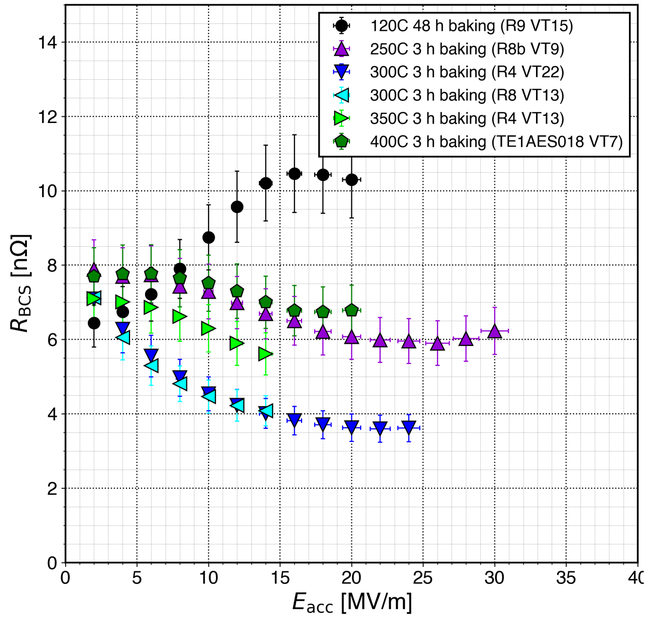


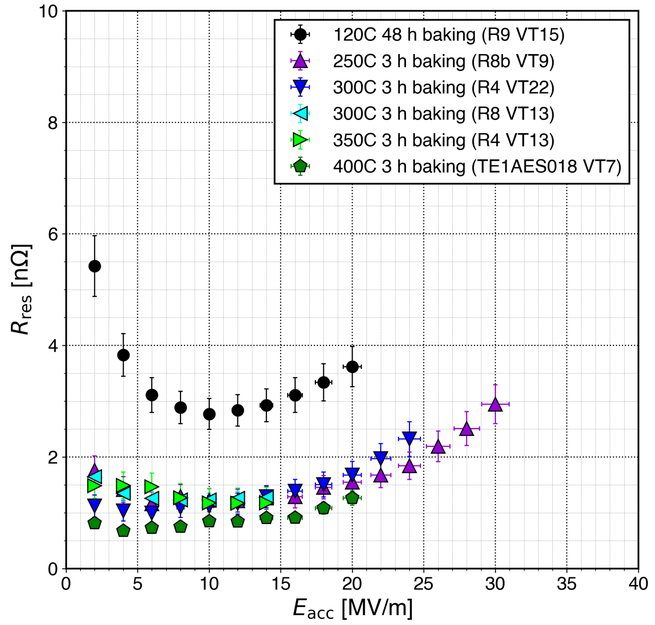
250 ~ 400°C 3 h

- Extremely high Q value and anti-Q slope are observed
- Highest Q value at 2.0 K is ~ 5E10 for 300°C baked cavity
- 250°C baked cavity maintains a high Q-value of over 3E10 at even 30 MV/m

Mid-T furnace baking





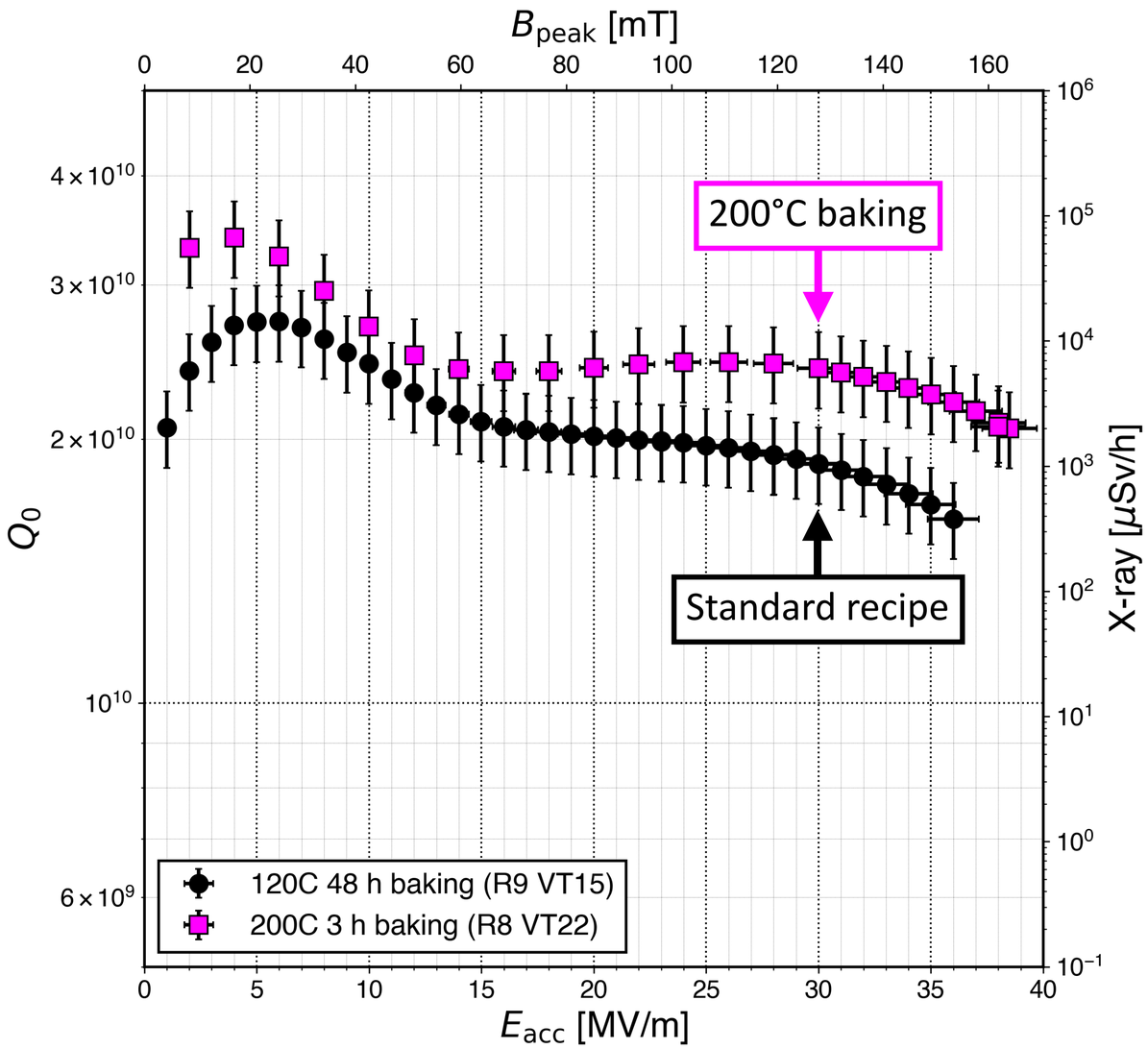


250 ~ 400°C 3 h

- R_{BCS} shows the opposite behavior of the standard treatment
- All R_{res} are lower than standard treatment

Mid-T baking is promising process for CW accelerators.

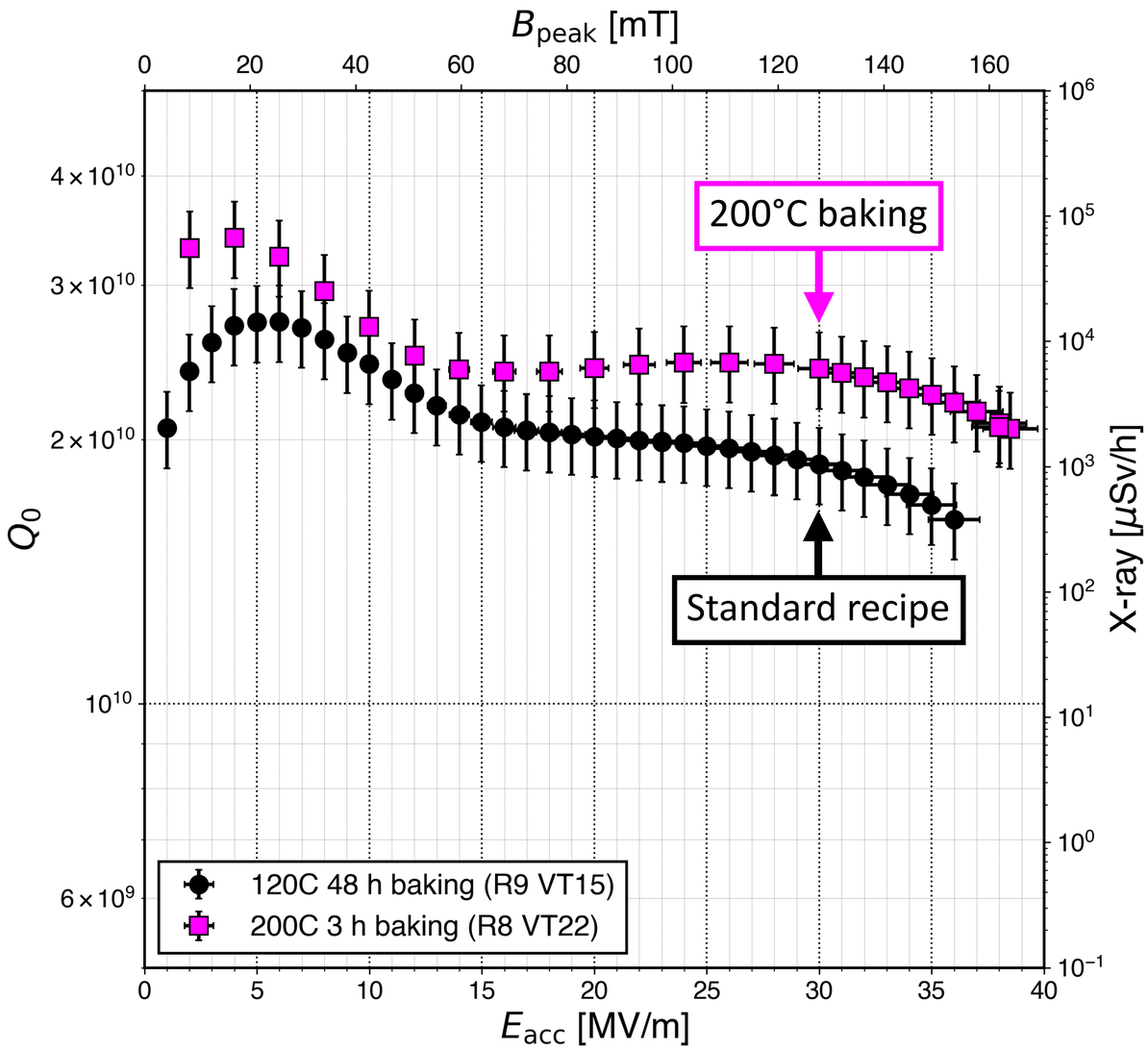
Low-T furnace baking

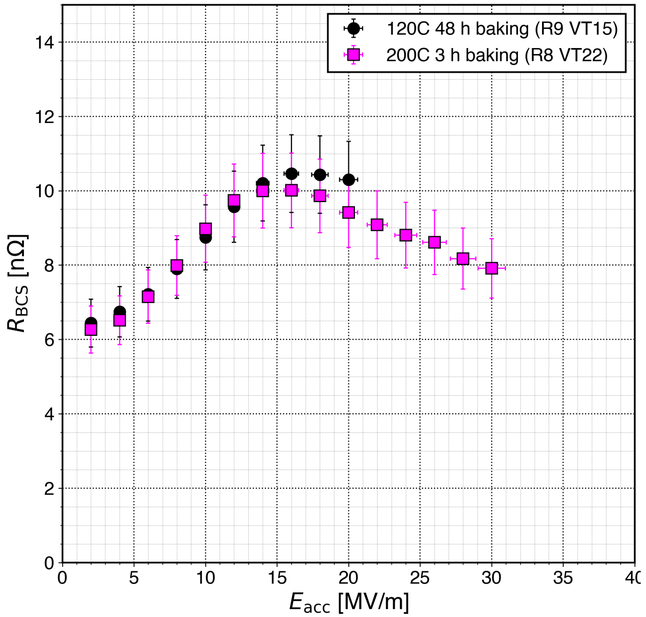


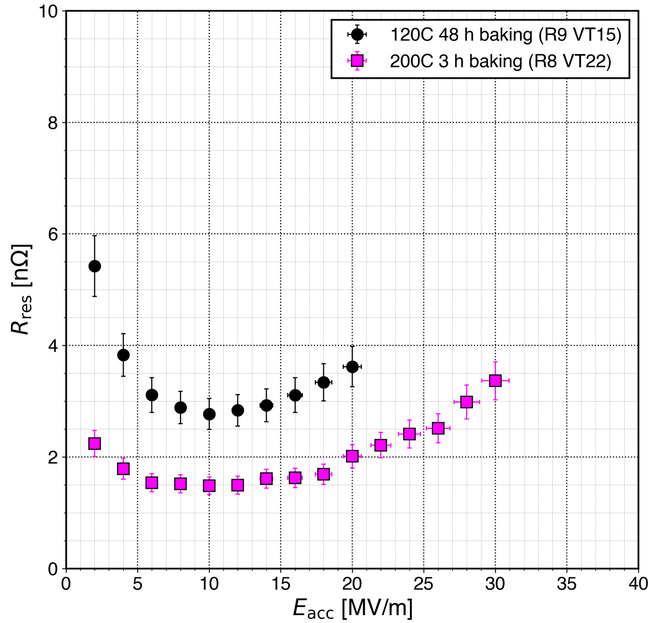
200°C 3 h

- Q value is 1.4 times higher than standard treatment, and E_{acc} performance is comparable to standard treatment
- Q-value is over 2E10 at even 35 MV/m

Low-T furnace baking



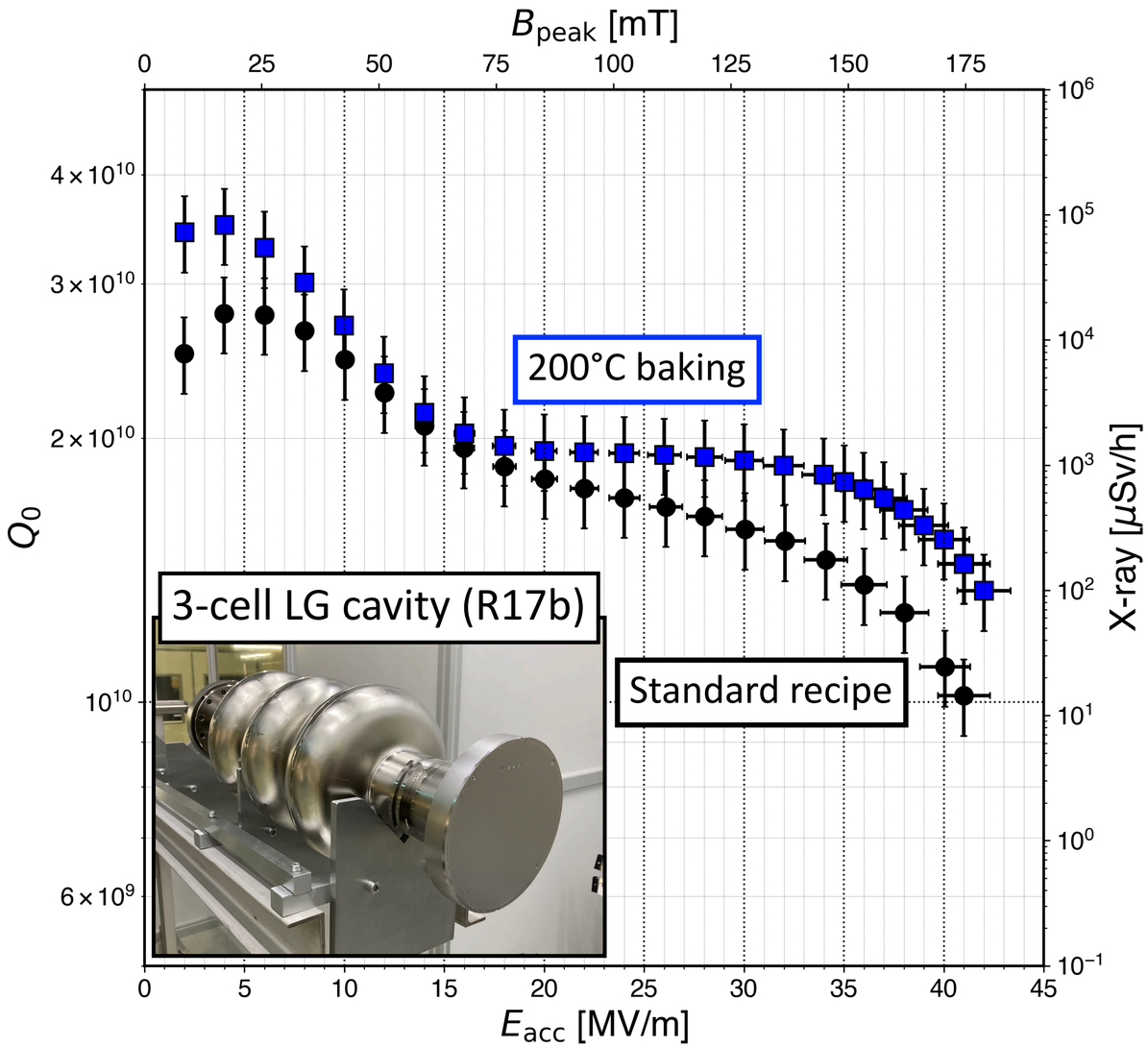




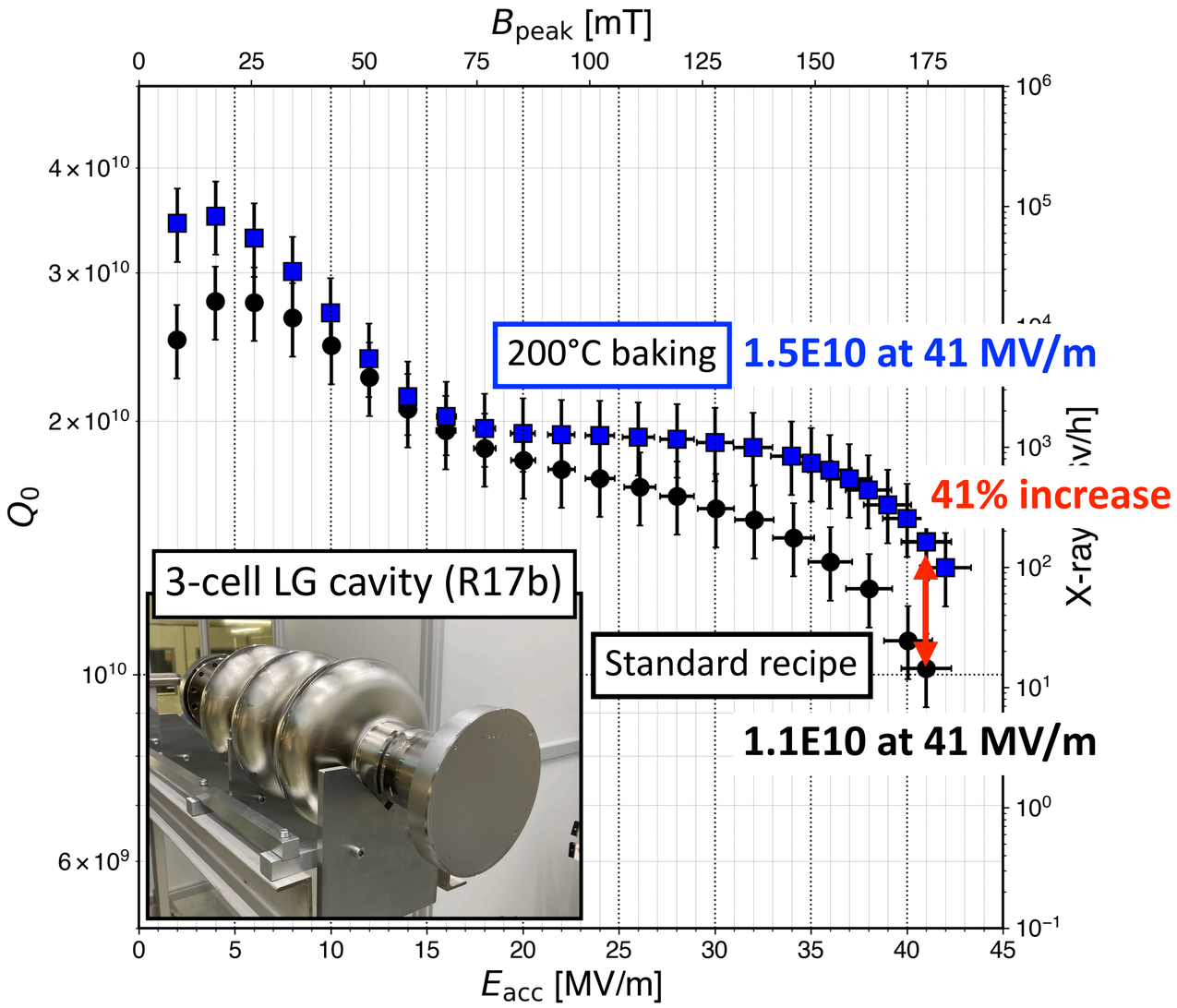
200°C 3 h

- R_{BCS} is little different from standard treatment
- R_{res} is lower than standard treatment
  → Only R_{res} contributes to a higher Q-value of low-T furnace baked cavity

Low-T furnace baking on 3-cell and 9-cell cavities



Low-T furnace baking on 3-cell and 9-cell cavities



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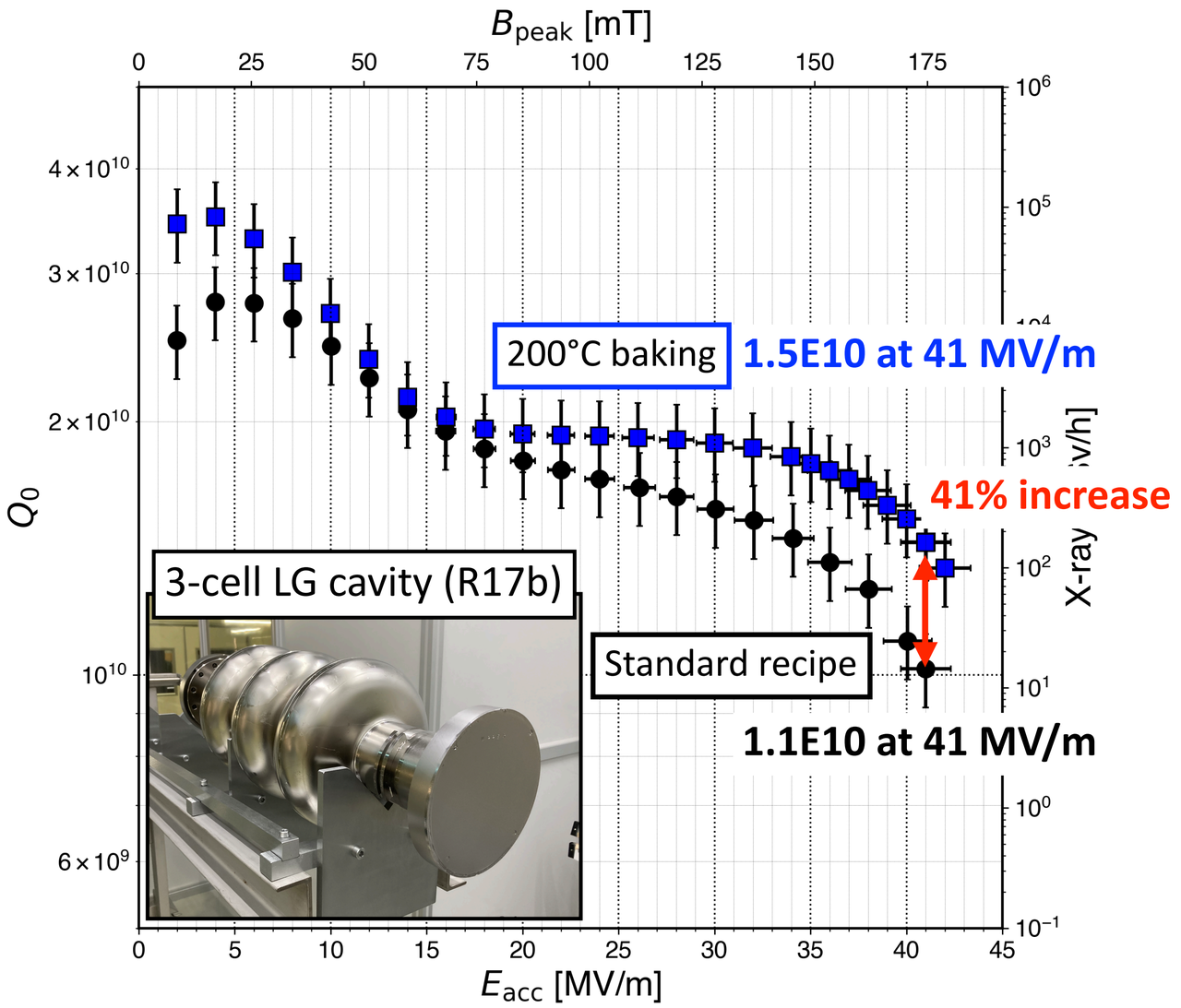
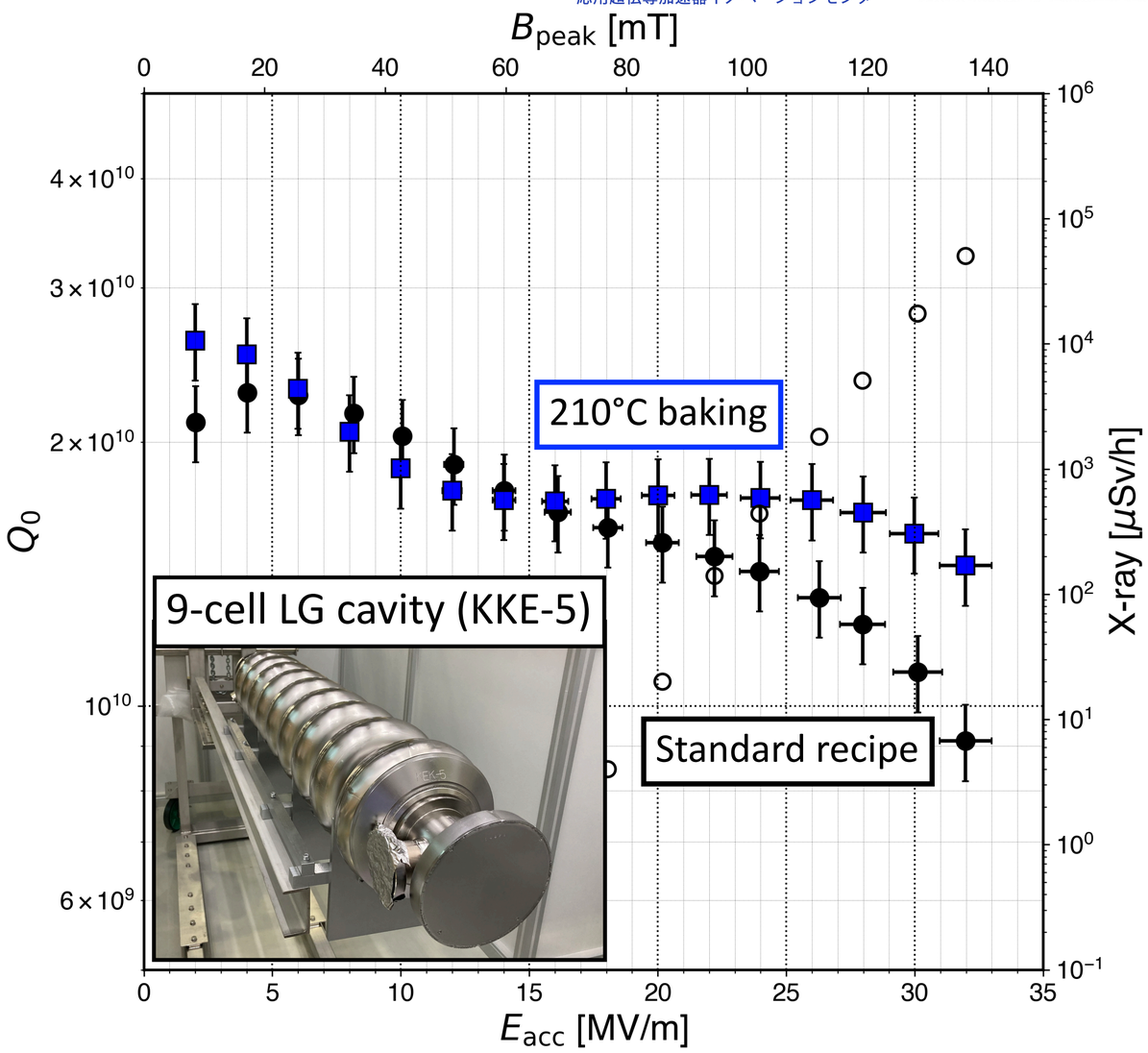
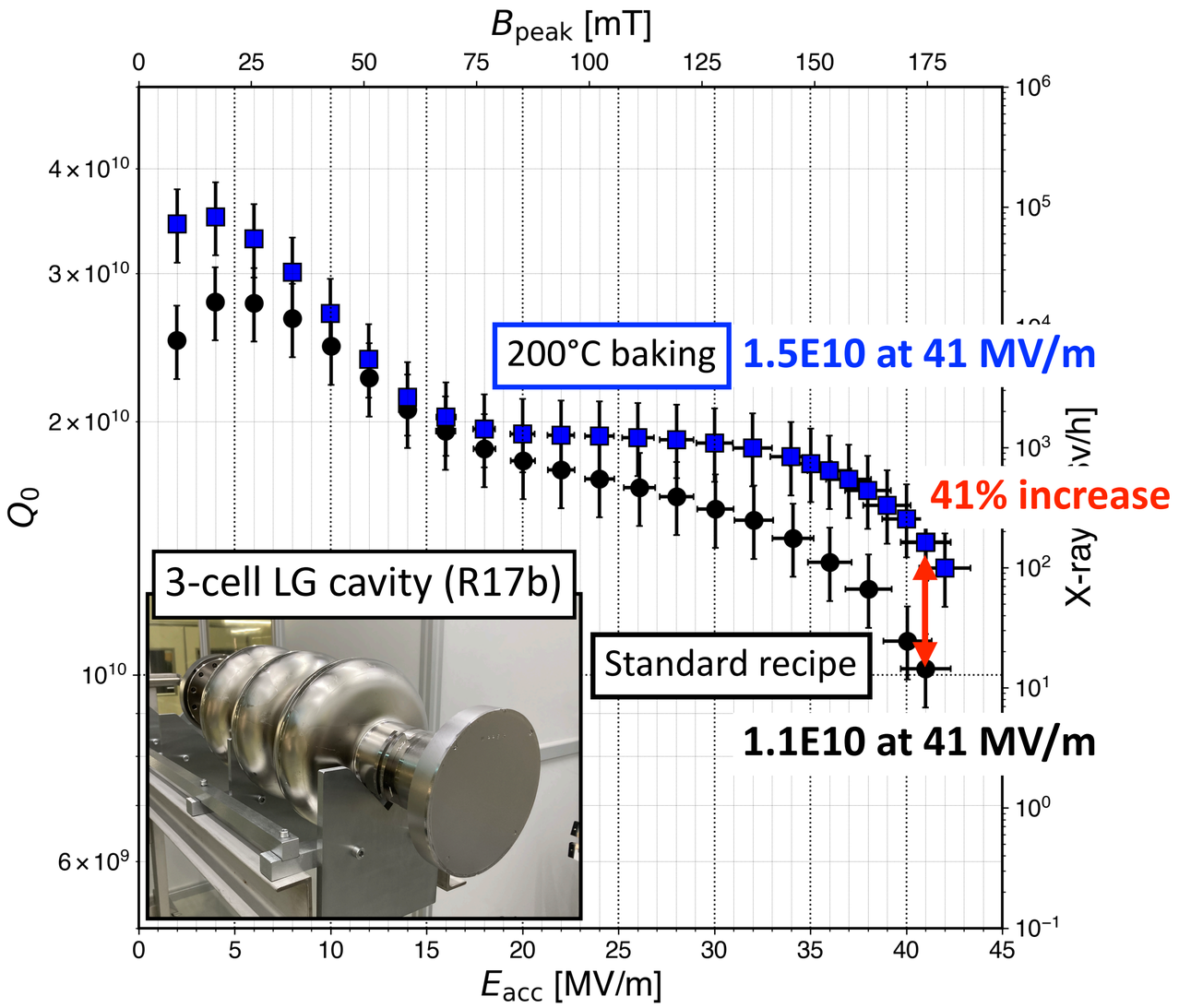
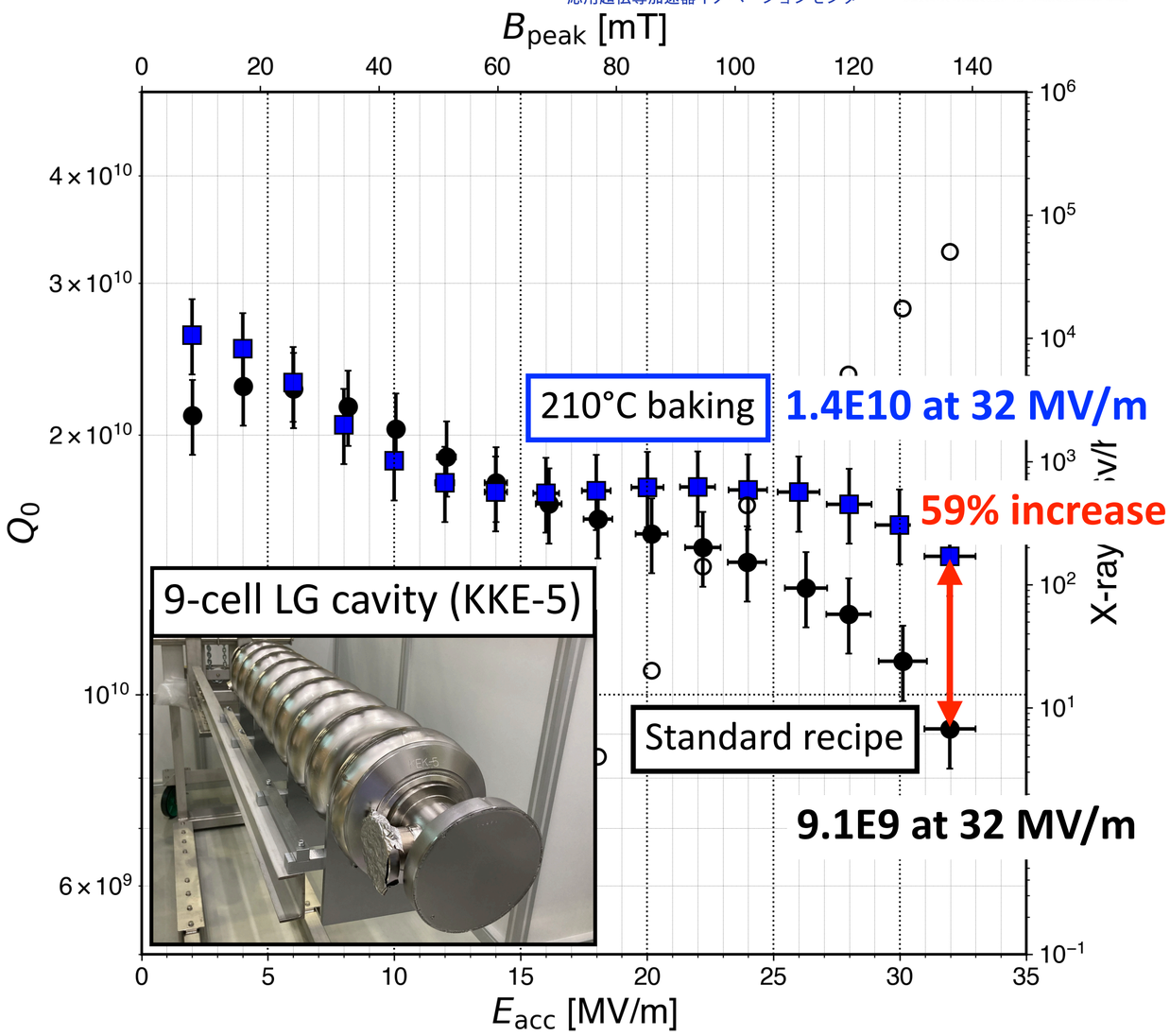


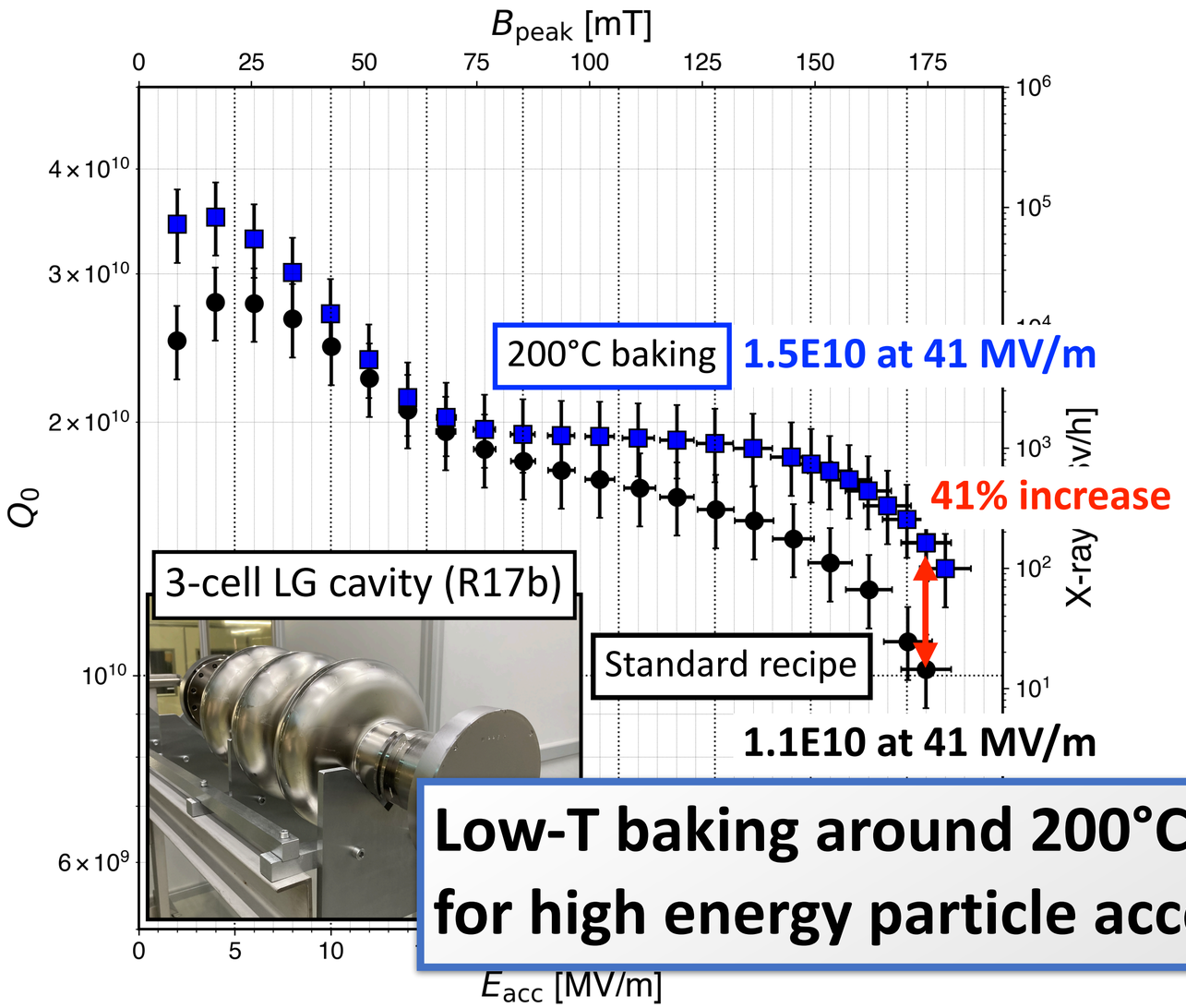


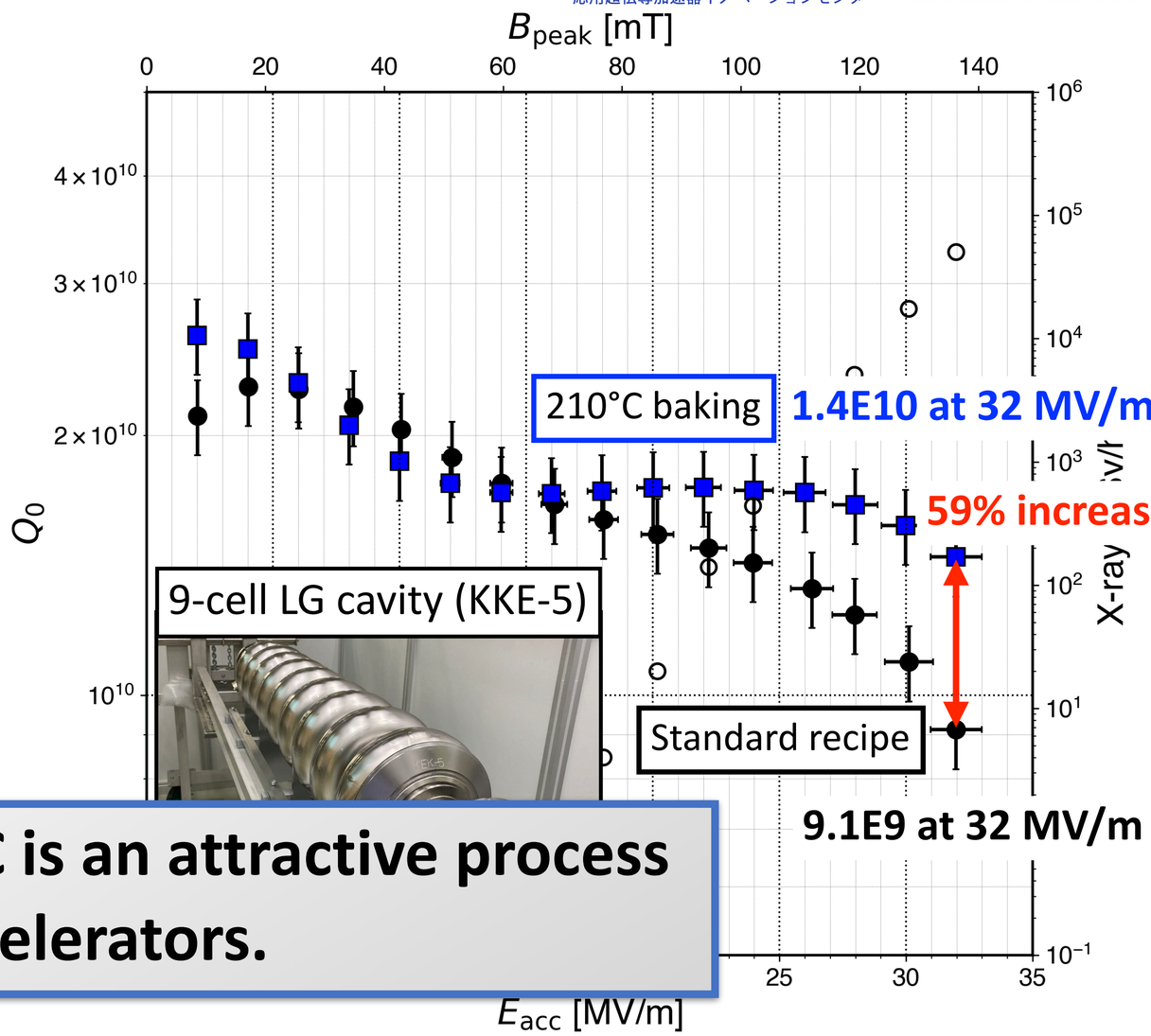
Low-T furnace baking on 3-cell and 9-cell cavities





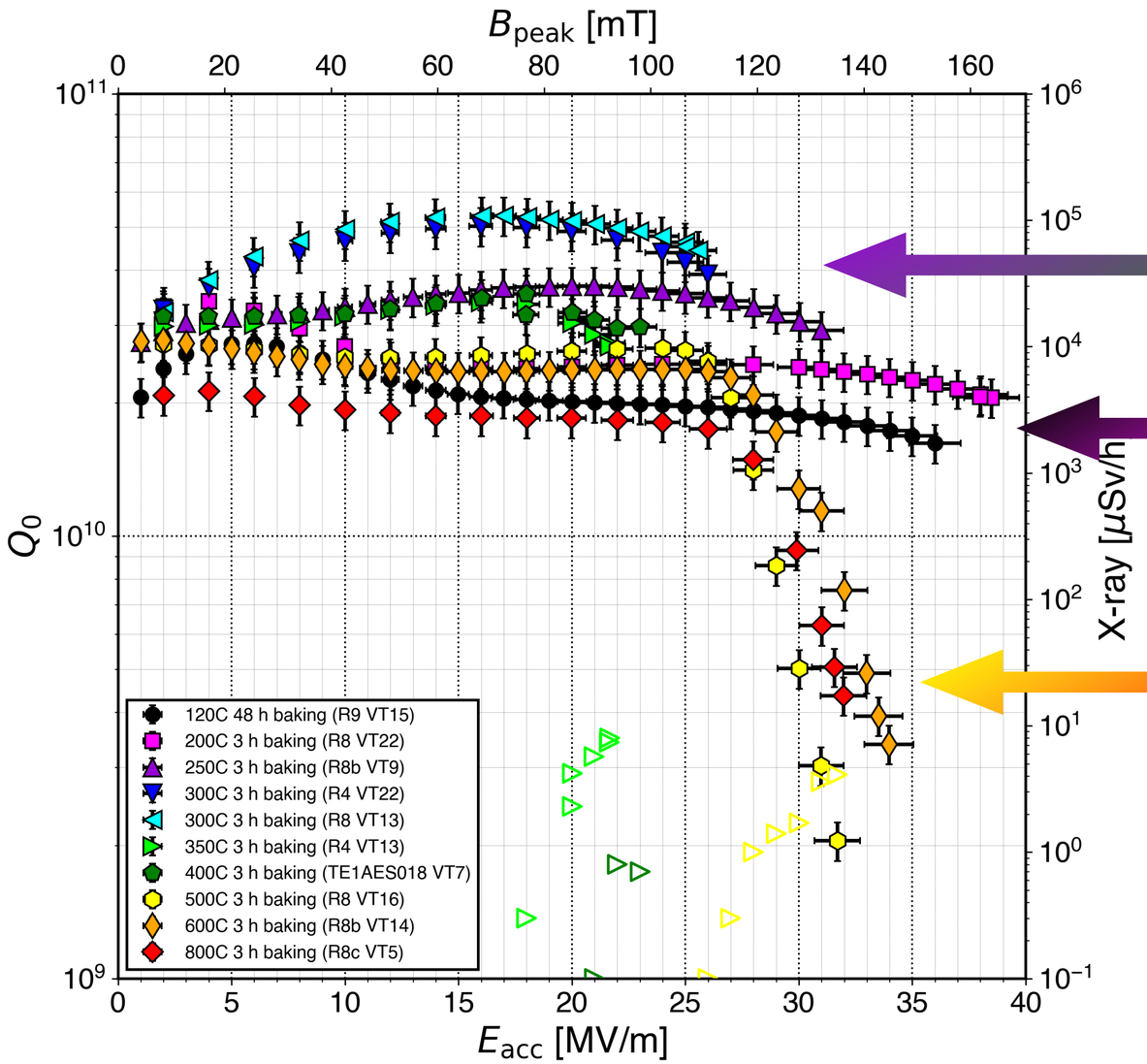
Low-T furnace baking on 3-cell and 9-cell cavities





Low-T baking around 200°C is an attractive process for high energy particle accelerators.

Comparison of Q-E curve



Cavity temperature during measurement

- 120 ~ 600°C baking … at 2.0 K (2.00~2.01 K)
- 800°C baking … at 2.1 K (2.07K)

250 ~ 400°C 3 h

- Extremely high Q value and anti-Q slope are observed
- Highest Q value at 2.0 K is ~ 5E10 for 300°C baked cavity
- 250°C baked cavity maintains a high Q-value of over 3E10 at even 30 MV/m

Standard recipe (120°C 48 h), 200°C 3 h

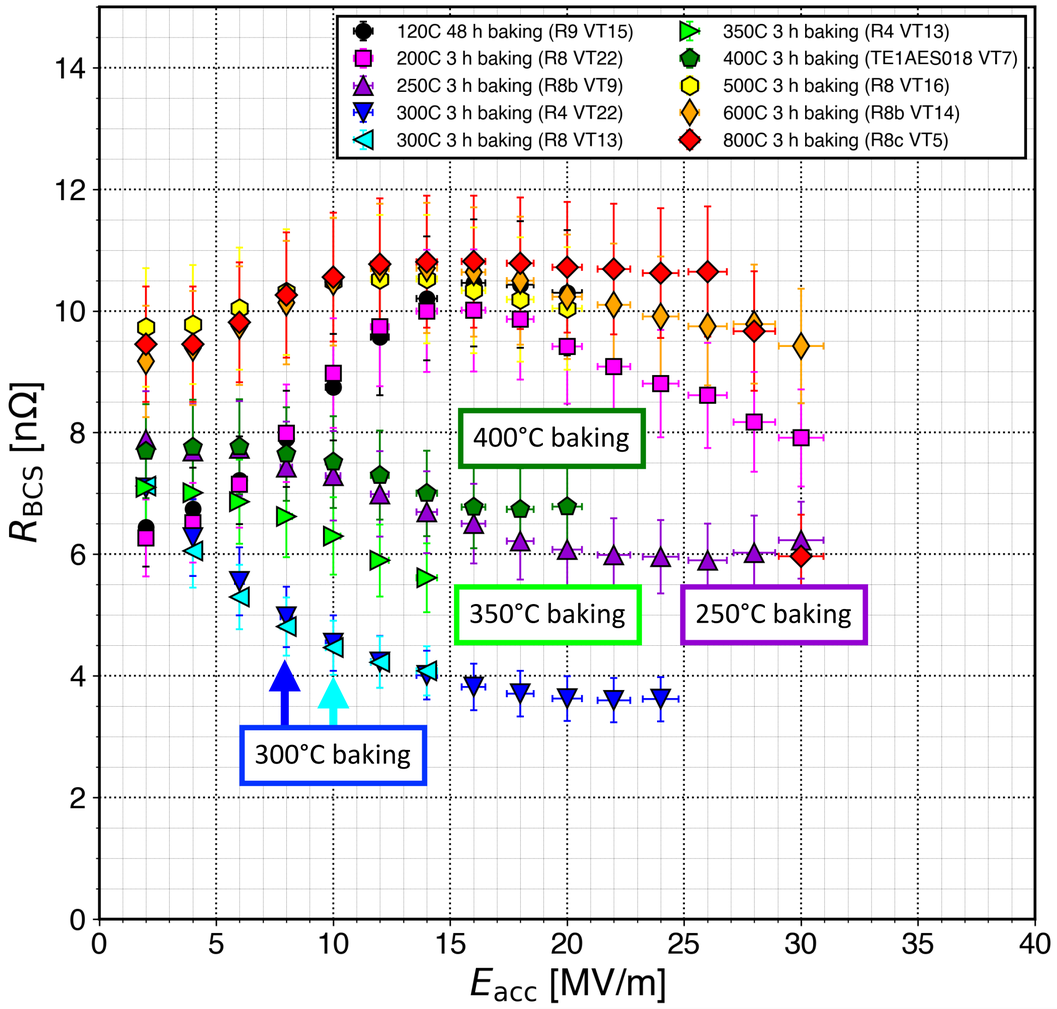
- Q value 1.4 times higher than standard treatment, and E_{acc} performance comparable to standard treatment.

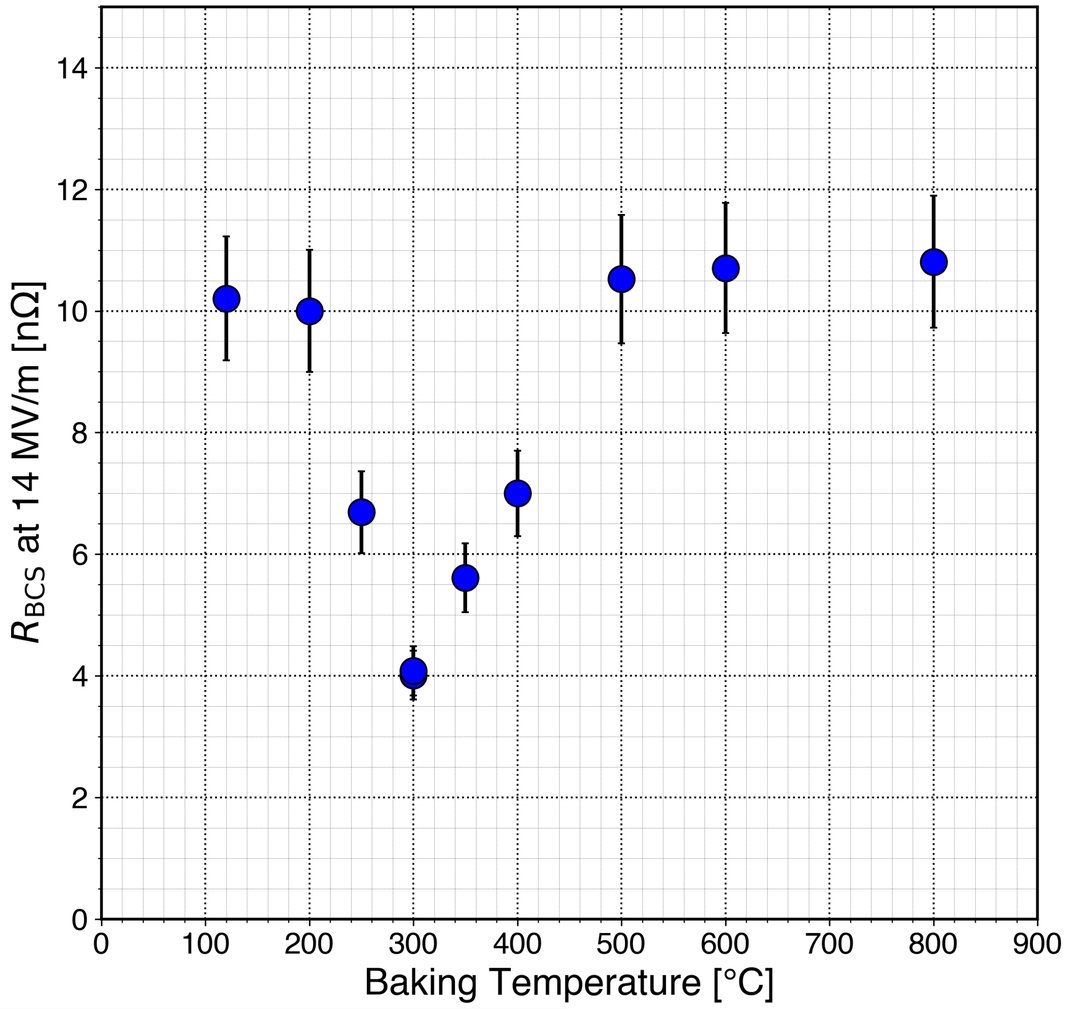
500 ~ 800°C 3 h

- High Q value wasn't observed
- HFQS occurred

Varying the temperature of furnace baking varies Q-E behavior drastically.

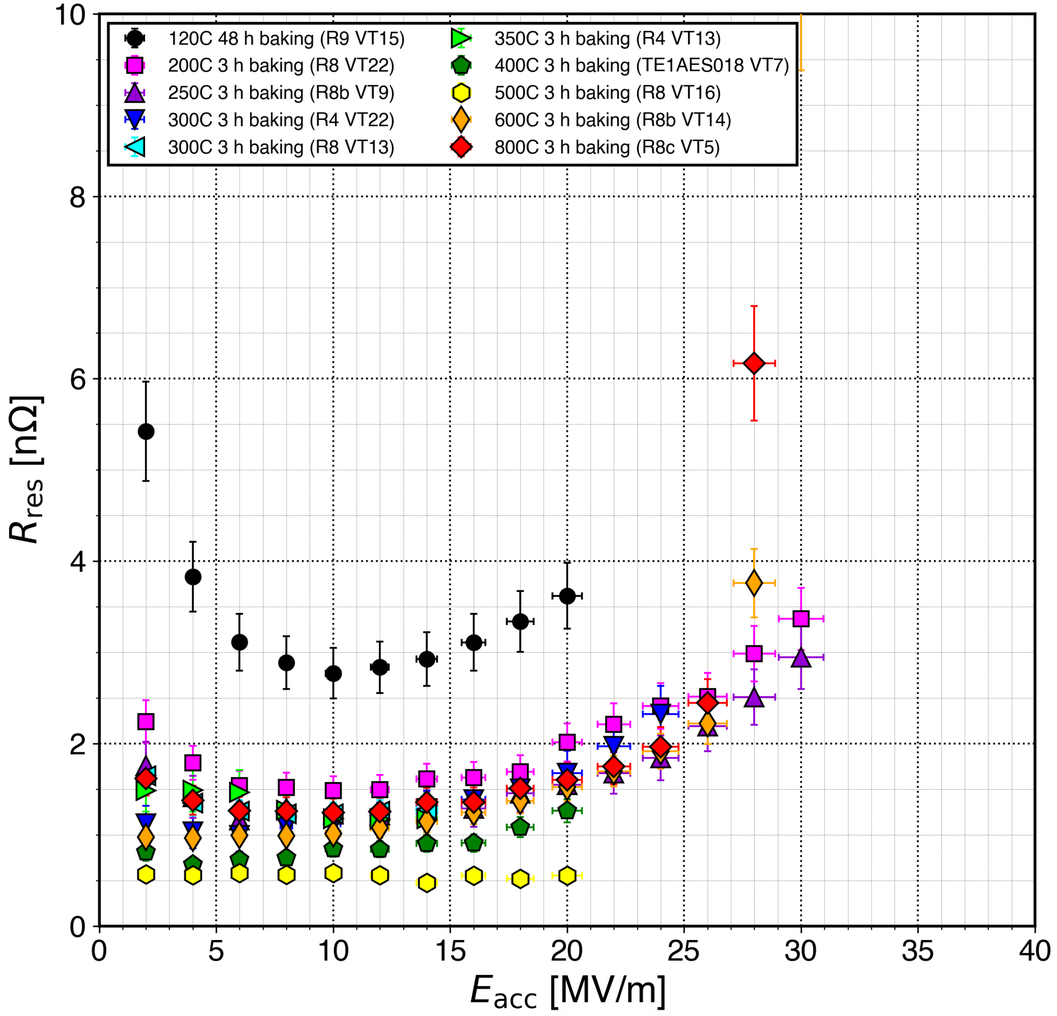
Comparison of R_{BCS}

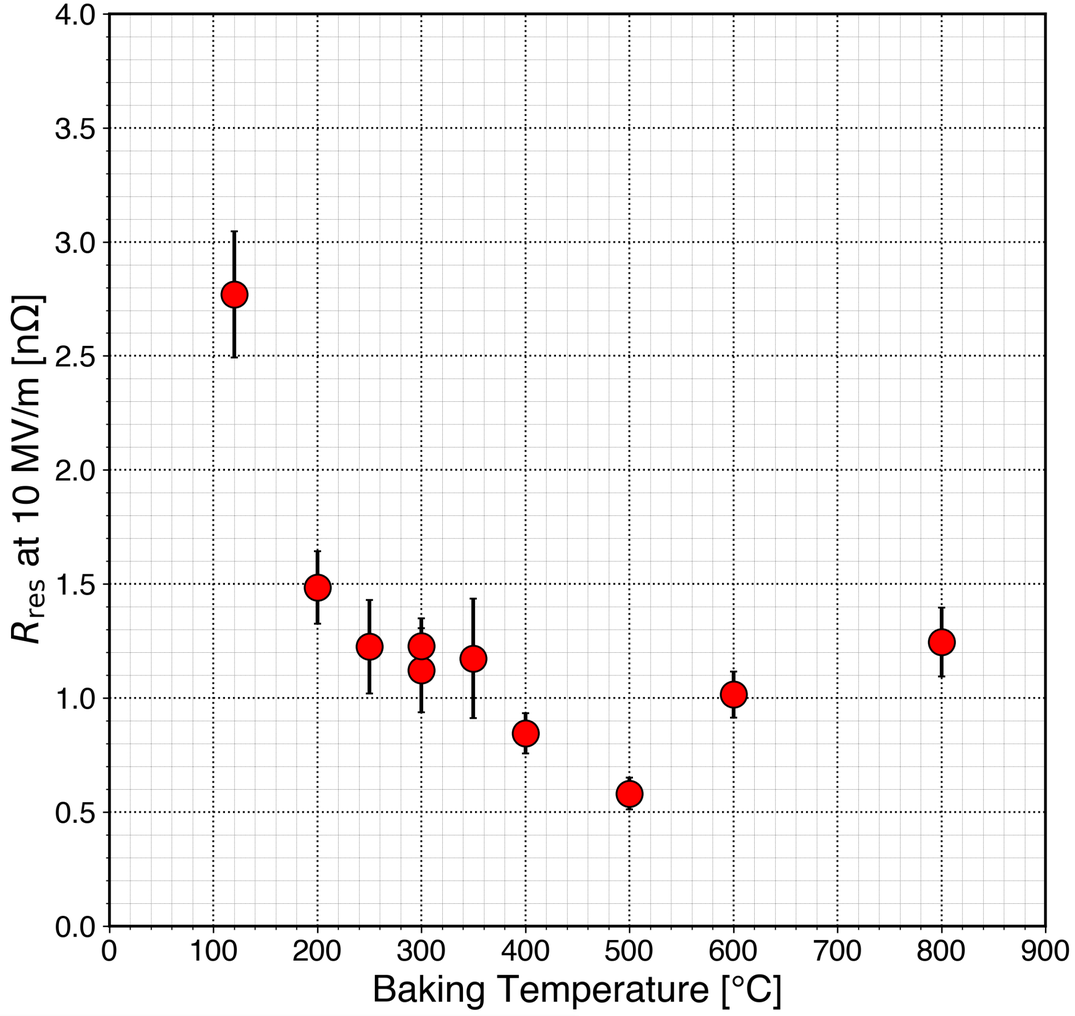




R_{BCS} behavior is changed significantly between 250~400°C.
← related to the decomposition temperature of surface oxide layer

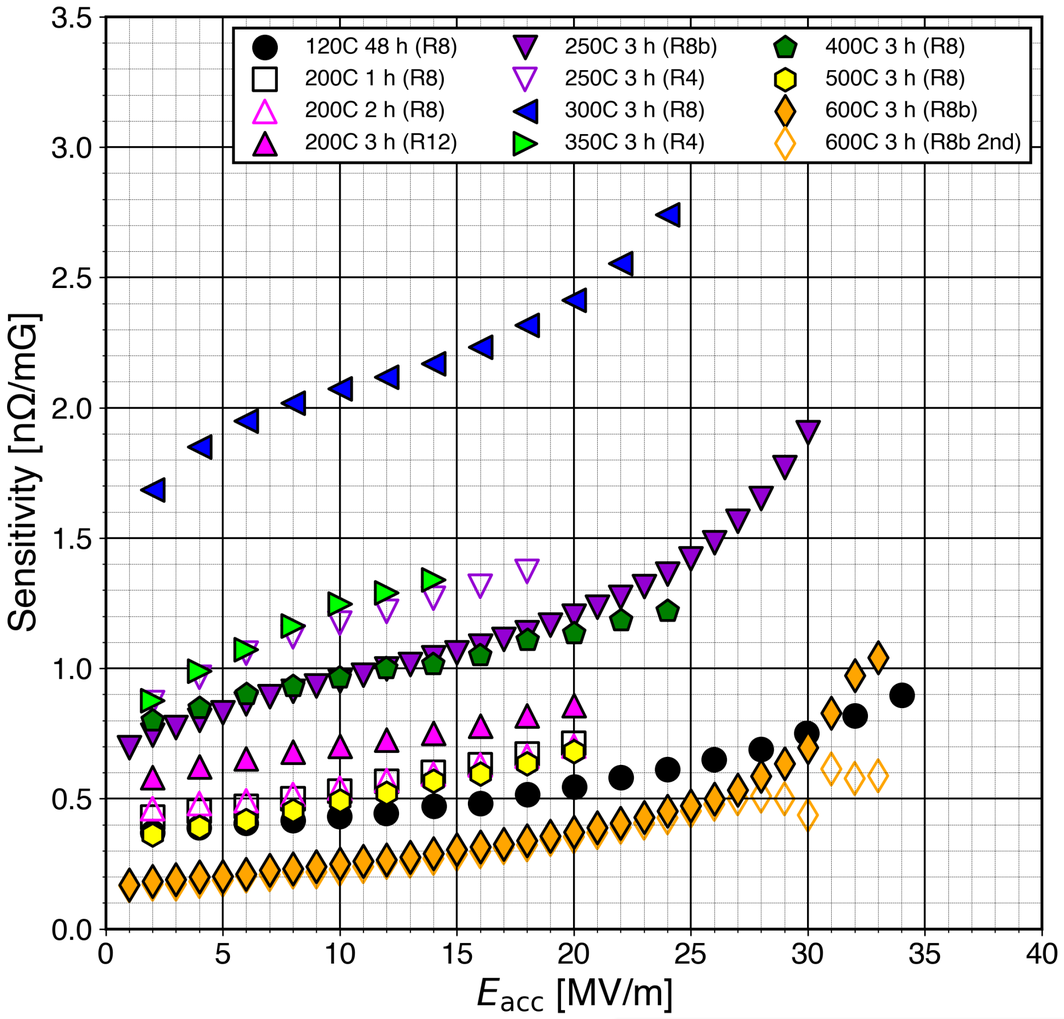
Comparison of R_{res}

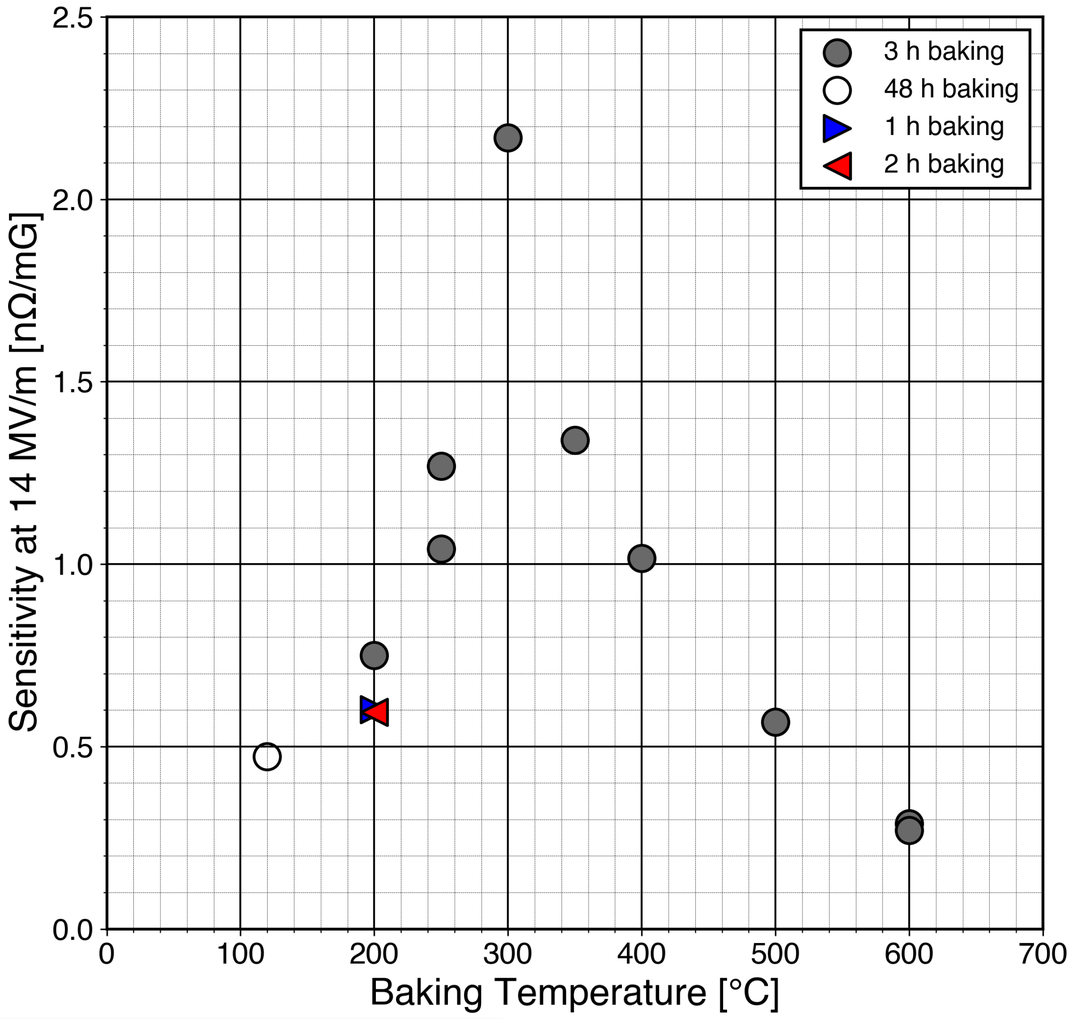




Standard treatment results in higher R_{res}.
R_{res} becomes lower as the heat treatment temperature is increased.

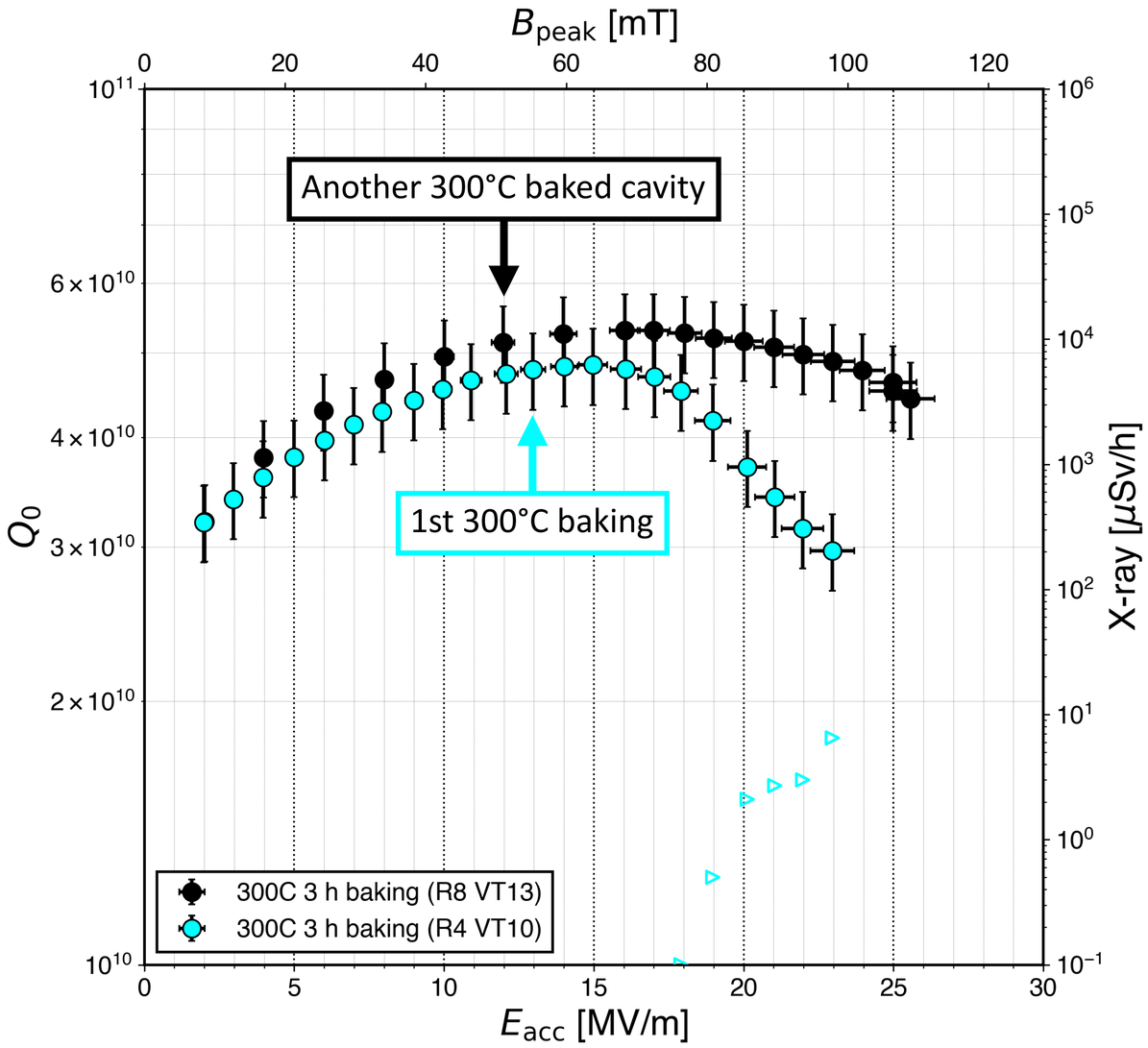
Trapped Flux Sensitivity

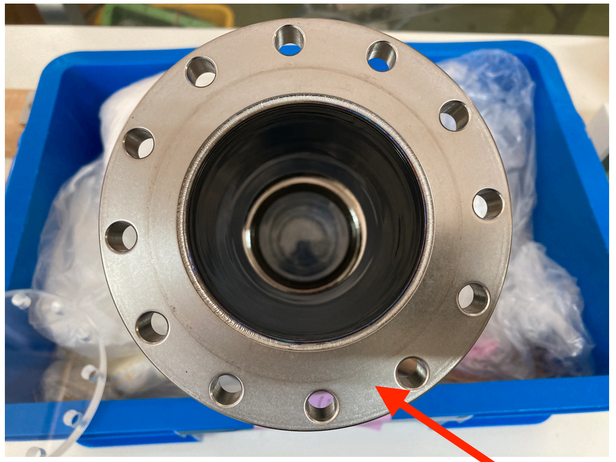


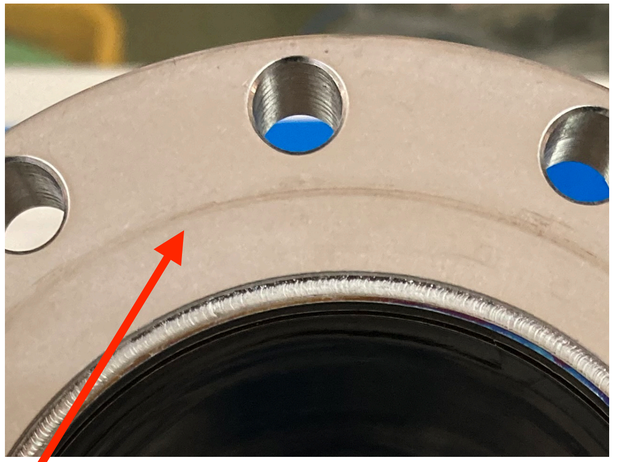


300°C baked cavity shows unusually high sensitivity.
250°C baked cavity would be easier to use for accelerators.

Quality control by eliminating contamination



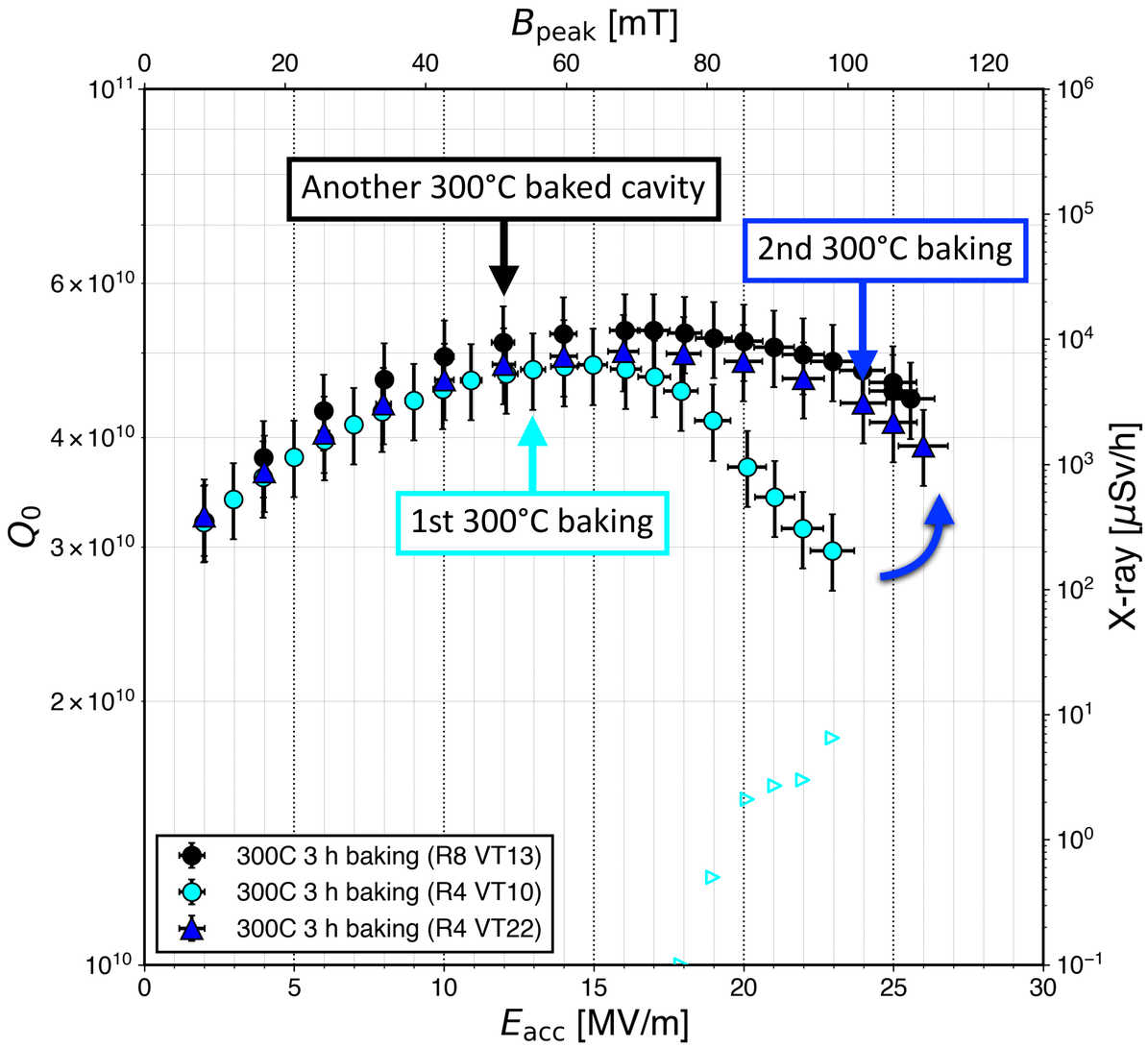




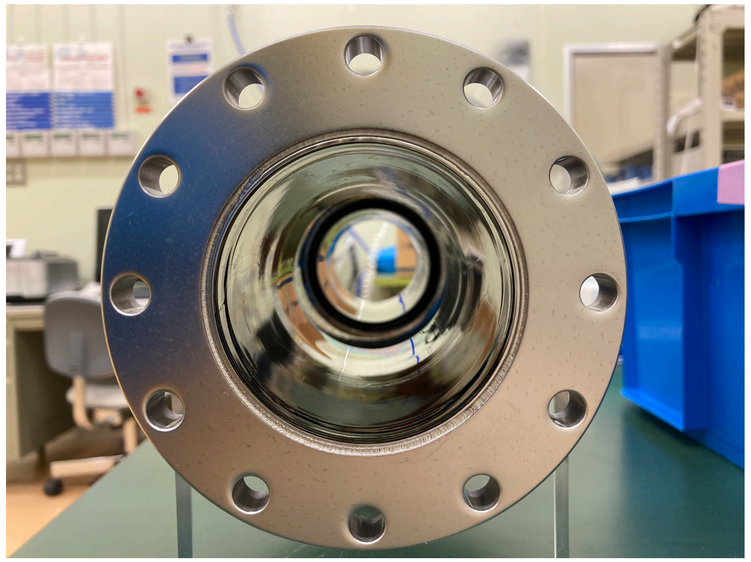
Sn contamination from gasket

We used HELICOFLEX gasket with Sn plating for this cavity.
Sn contamination was deposited on the flange during repeated use in the study.

Quality control by eliminating contamination



After removing contamination



Sn contamination on the flange was removed by polishing and bulk CP, then mid-T furnace baking was applied again.
-> Q degradation from 16 MV/m was overcome

Mid-T baking become more reliable.

Summary

- Furnace baking was applied to the single-cell cavity with various baking temperatures and results in various Q-E behavior
- 300°C baked cavities have an extremely high Q value of over 5E10
- 250°C baked cavity achieve over 30 MV/m while keeping a higher Q value of 3E10
- 200°C baked cavities have good performance in high E_{acc} region
- Sensitivity is unusually high for 300°C baked cavity
- We plan further investigation for furnace baking:
  - Oxygen doping, pre anodization …

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Thank you for your attention.