High Q/Gradient R&D based on the completely new Wuxi platform

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/SHINE project
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Recipe references

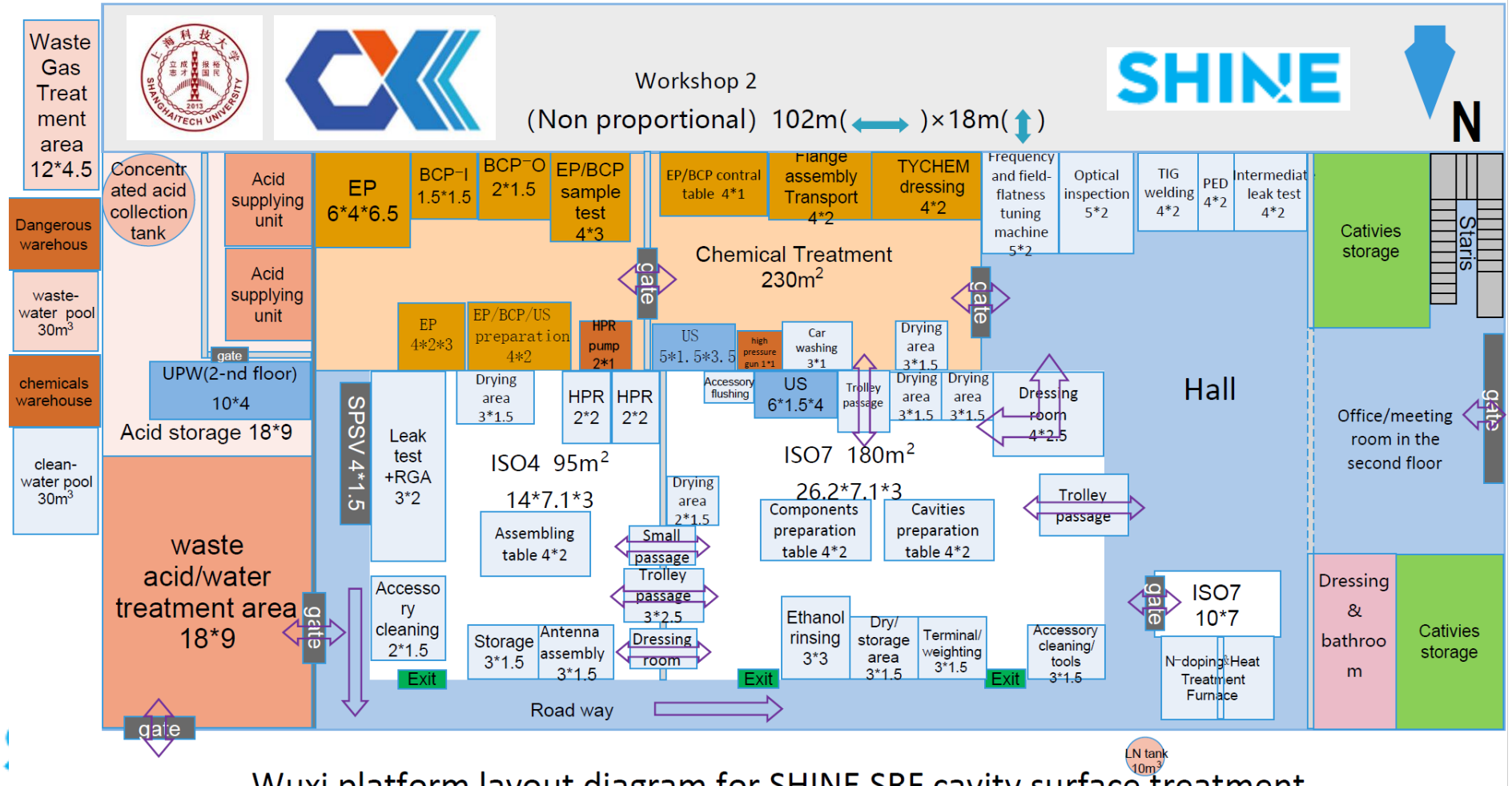
- **Ari Palczewski's talk**, A Novel Approach to Producing High Gradient and Q0Cavities in "Non-Ideal Furnaces" post furnace treatment, SRF'21
- **Dan Gonnella's talk**, The LCLS-II-HE R&D Program - New Insights into Improving the Performance of Nitrogen-Doped SRF cavities, IPAC'21
- **Anna Grassellino et al.**, Accelerating fields up to 49 MV/m in TESLA-shape superconducting RF niobium cavities via 75C vacuum bake, https://arxiv.org/abs/1806.09824, 2019
- **Feisi HE, et al.,** Experimental study of simplified mid-T furnace baking at IHEP, Supercond. Sci. Technol. 34 (2021)

OUTLINE

- **Wuxi platform**
- **High Q/G R&D on single-cell cavities**
- **High Q R&D on 9-cell cavities**
- **Summary**

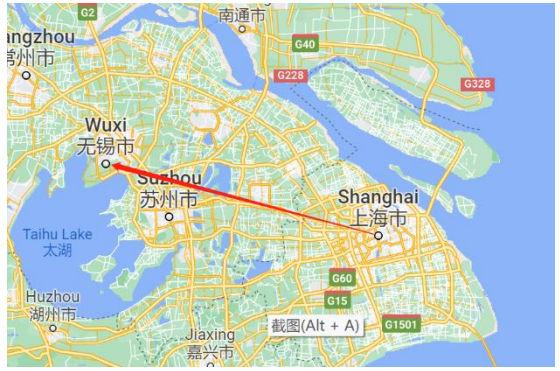
Wuxi platform for SRF cavity surface-treatments

- **Goal**: R&D and mass production for cavity surface treatment
- **Design:** Dealing with all the procedures after cavity fabrication, and before vertical test.



Wuxi platform layout diagram for SHINE SRF cavity surface treatment

Co-construction:
ShanghaiTech University (SHINE) and
Wuxi Creative Tech. Co., Ltd.



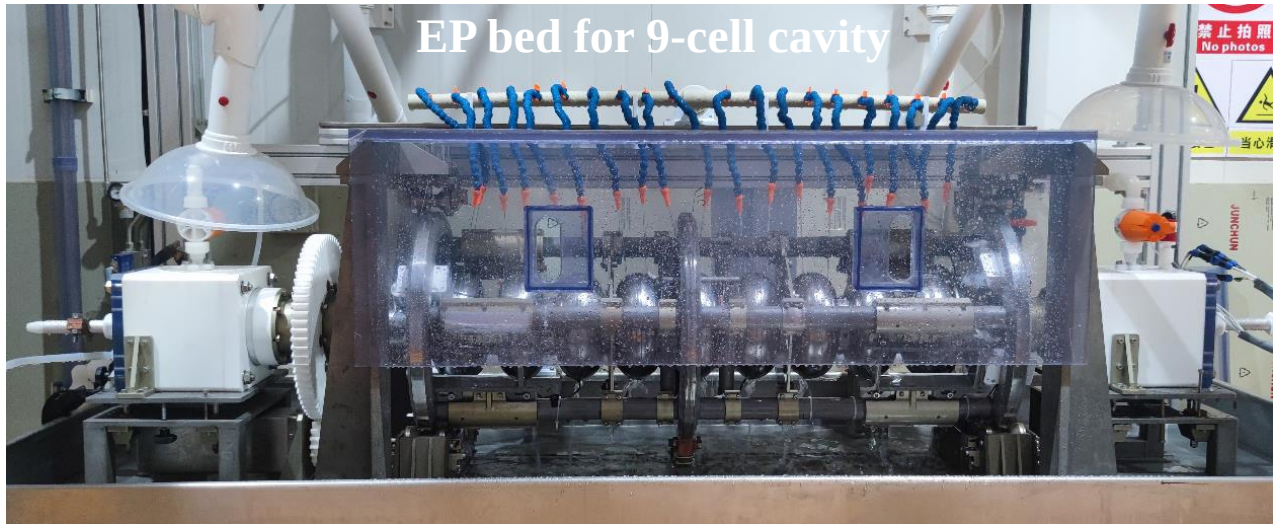
Location: in Wuxi city, ~150 km northwest from Shanghai.

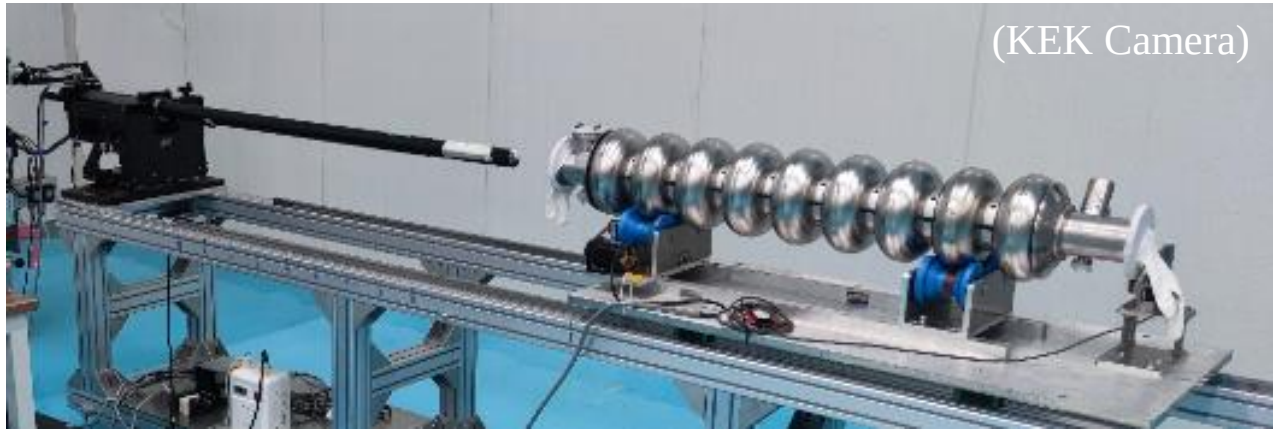
Construction history

Main devices in operation (1)

- EIA permit and acid use qualification achieved;
- Main devices, gradually commissioned and put into operation since 2021.

A lot of support from KEK! Many thanks!





Main devices in operation (2)

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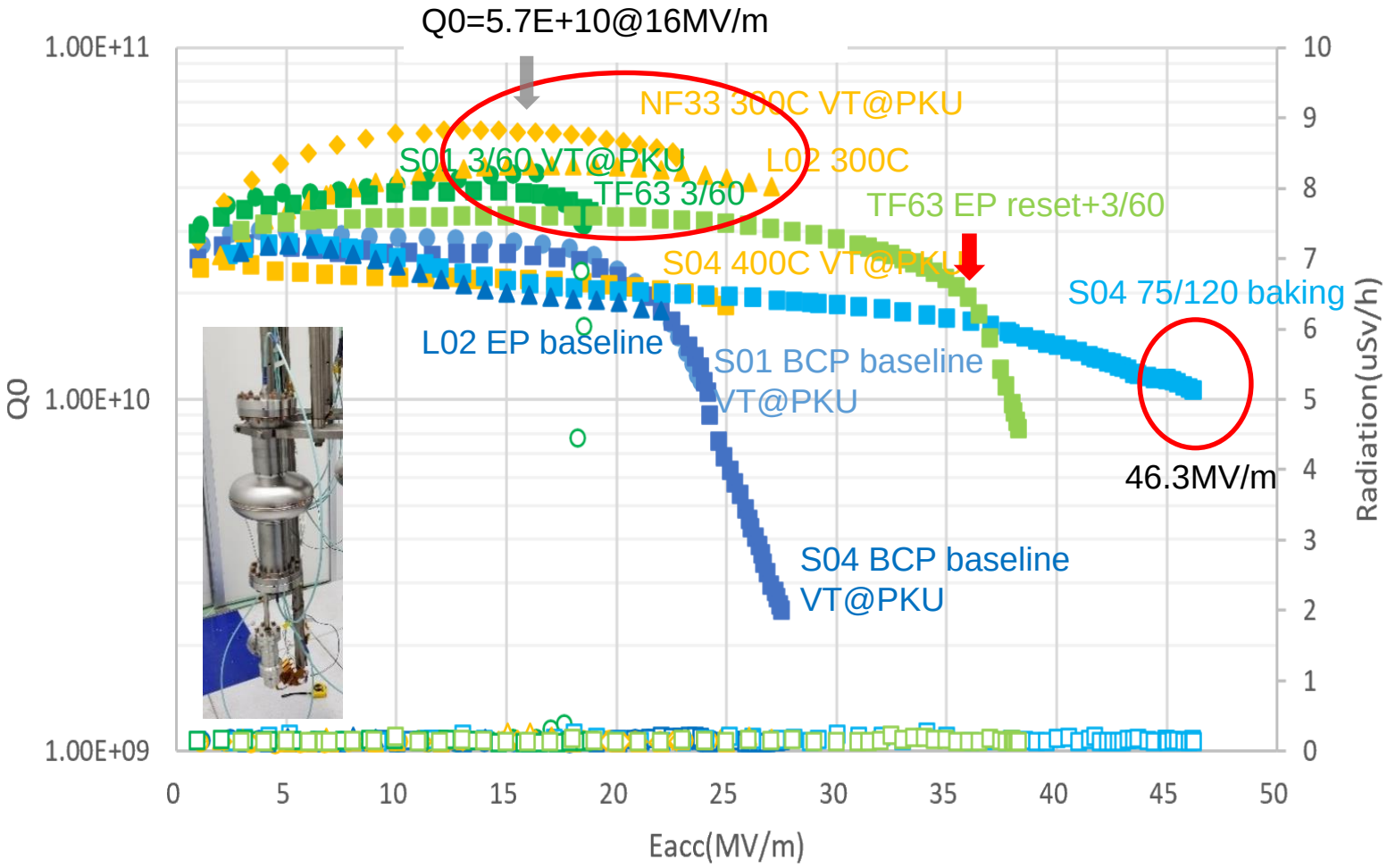
High Q/G R&D on single-cell cavities

- **Test run of the new facilities, as well as preliminary High Q/G R&D**

- **Recipes studied**
  - BCP/EP baseline
  - N-doping, 3/60
  - Mid-T baking
  - 2steps baking, 75C*4+120C*48
  - Nitric soak

Single-cell cavities treated at Wuxi platform in 2021



Lager temperature gradient at PKU; others tested at SARI

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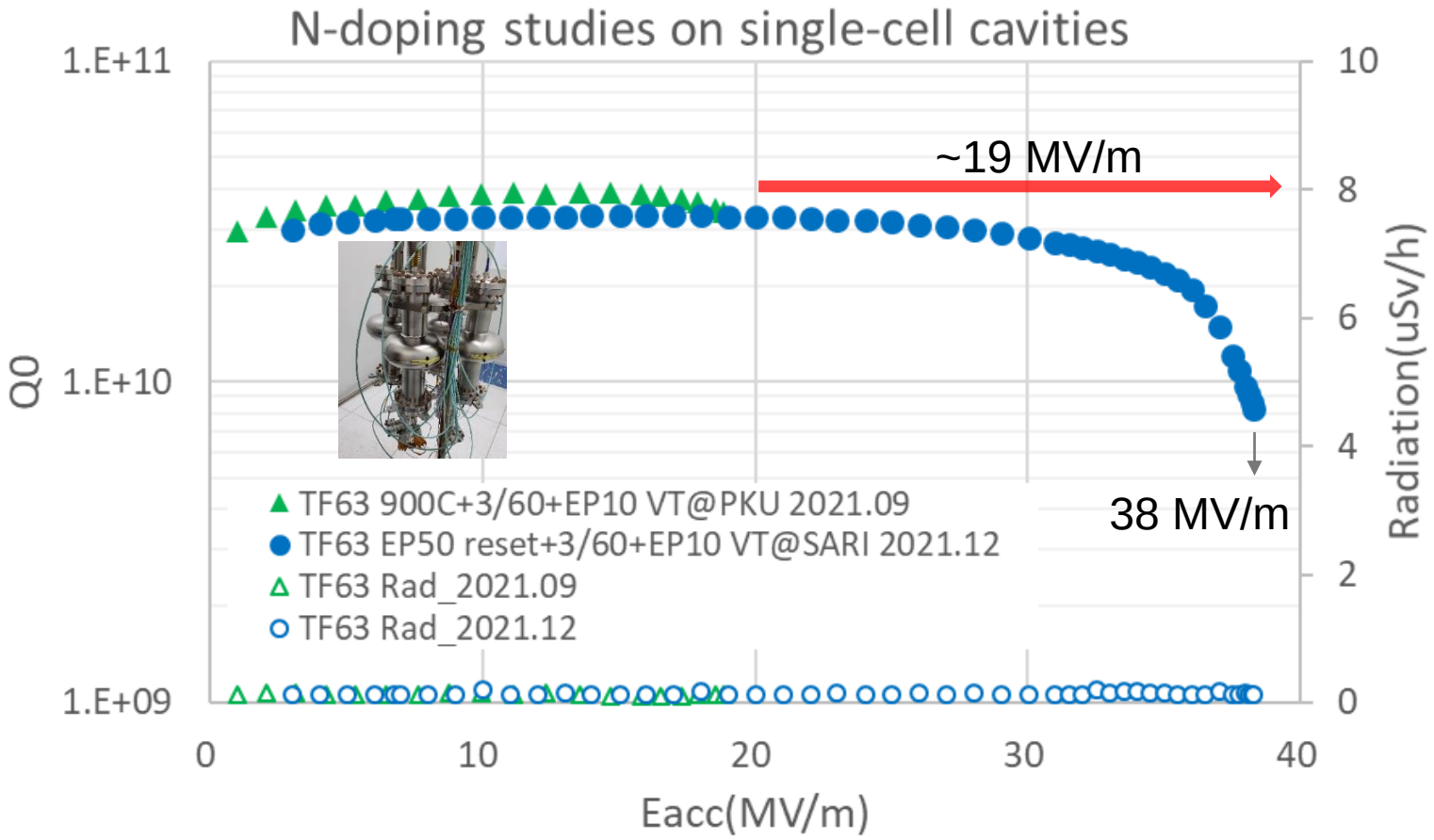
N-doping: improving max Eacc (1)

- **An EP between: max Eacc doubled, reached 38 MV/m; Q_0>2.0E+10 @ 35MV/m**
- **Q_0 difference, max ~20%, likely due to different fast cooling at PKU and SARI.**

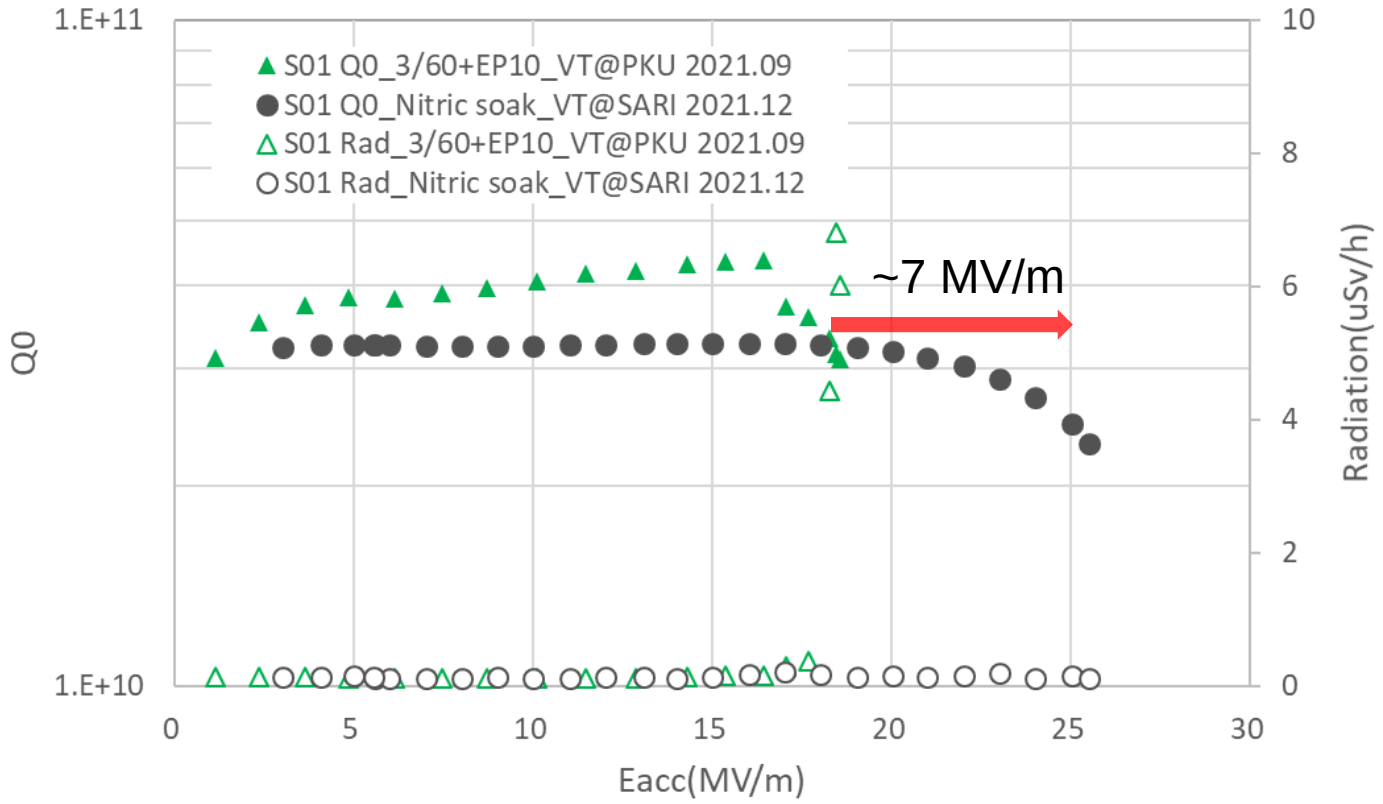


Main processes:

- EP 50um reset, acid T≤10℃
- Ramp up to 800C, hold 30mins
- 3 mins N2 injection, 60 mins annealing
- EP 10um, acid T≤10℃

Nitric soak: improving max Eacc (2)

- **Nitric soak: HNO3 (68%) for 1h**
- **Single-cell cavity S01: max Eacc increased 7MV/m**

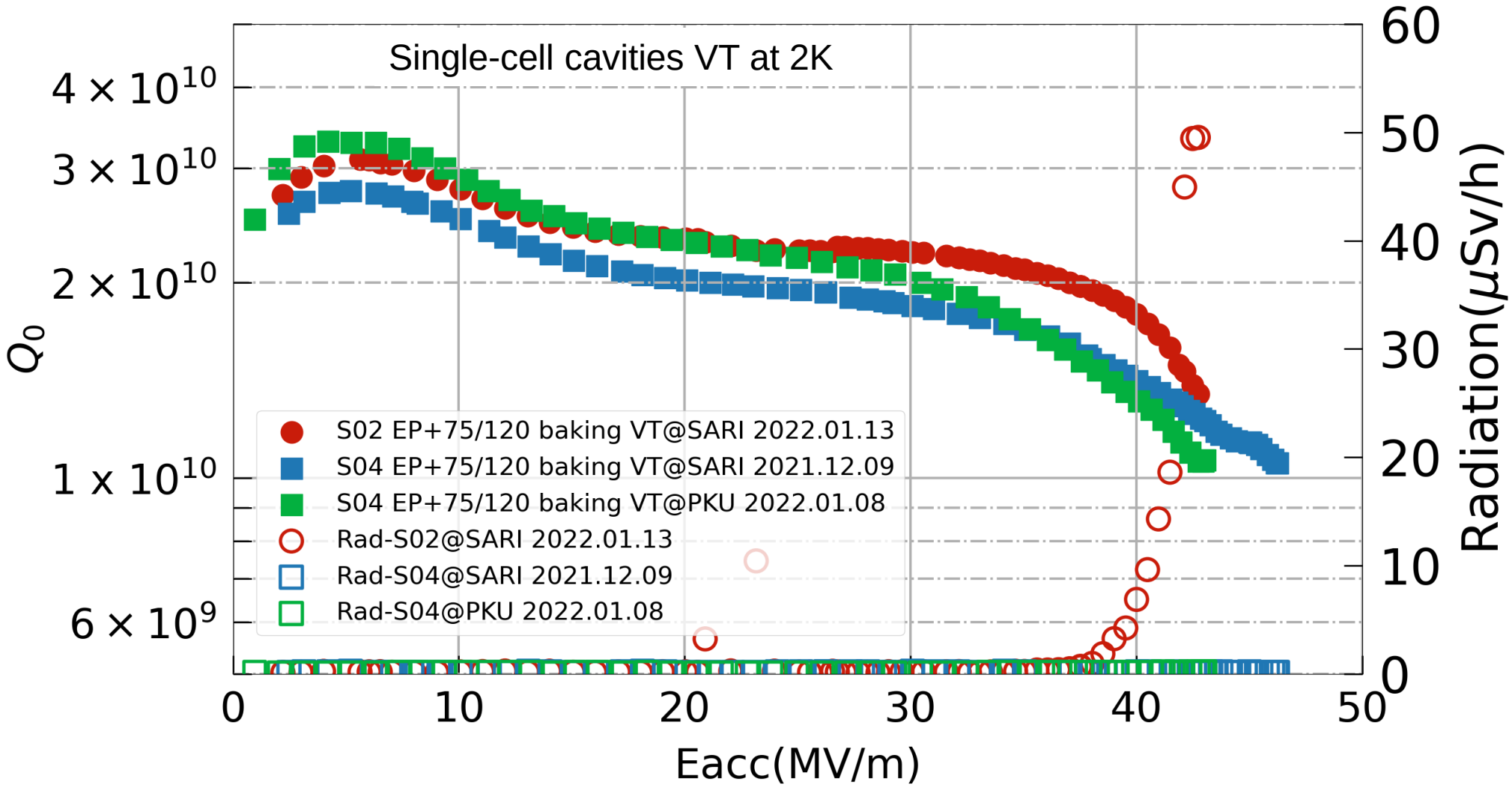


- **Q_0 difference**, max~30%, likely due to fast cooling

- **Temperature gradient:**
  VT@PKU 2021.09.17: ~ 1.20 K/cm
  VT@SARI 2021.12.29: ~ 0.28 K/cm

High-G studies: 2-steps baking

- **High gradient achieved:** max Eacc ≥43 MV/m, with Q0≥1.0E+10;
- **Double checked:** S04 re-tested at PKU, difference of max Eacc <10%.



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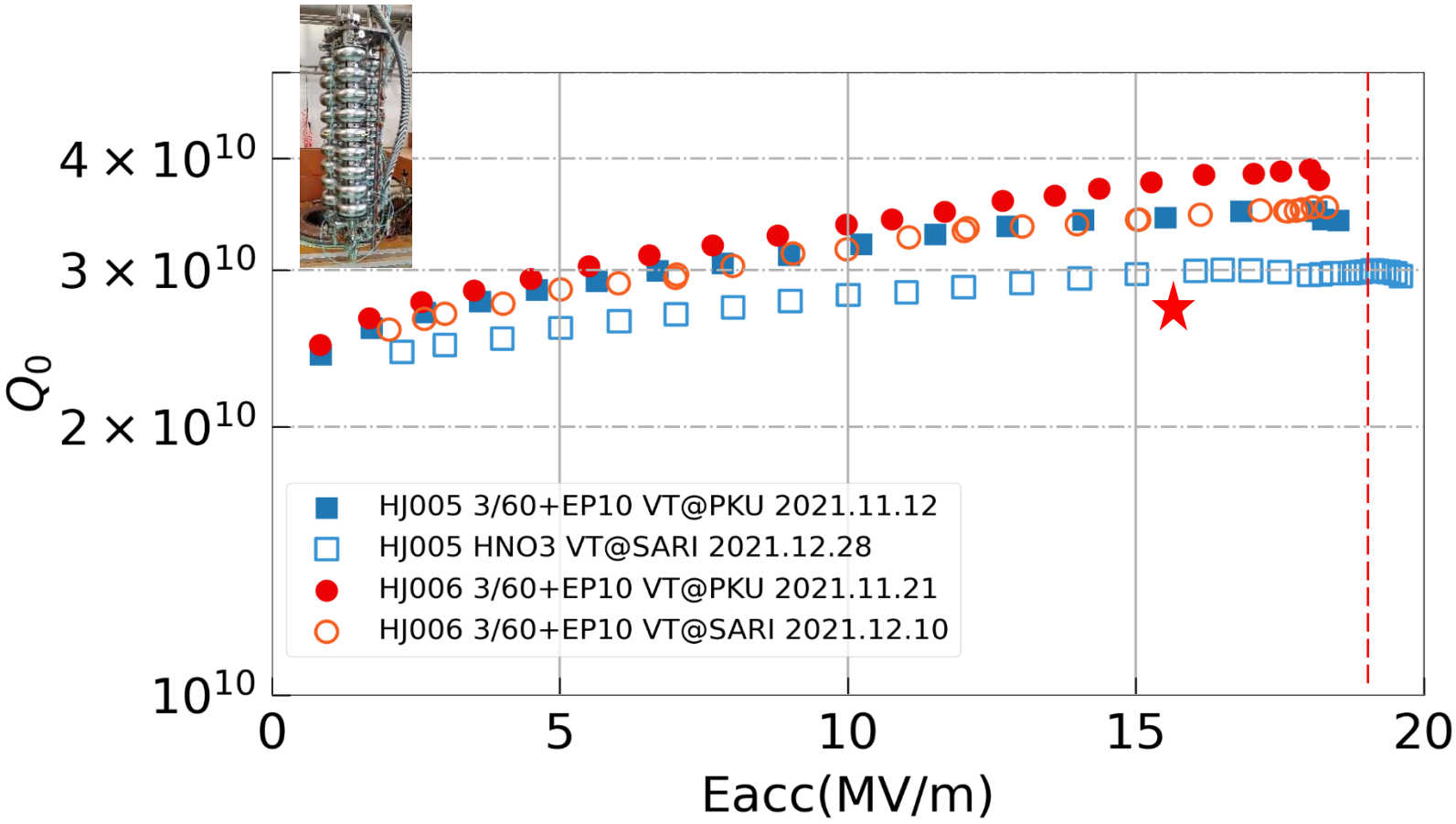
High-Q R&D on 9-cell cavities – N-doping

- **Surface treatments**
  - Bulk BCP (60/100 um) to remove welding splatters
  - EP 100um，acid T≤10℃
  - 900℃/3h + 3/60@800℃
  - EP 10 um，acid T≤10℃

- **Nitric soak (68% 1h):** max Eacc improved ~ 1 MV/m, Q0 difference is likely due to different fast cooling

- **Next step: try split bulk EP**



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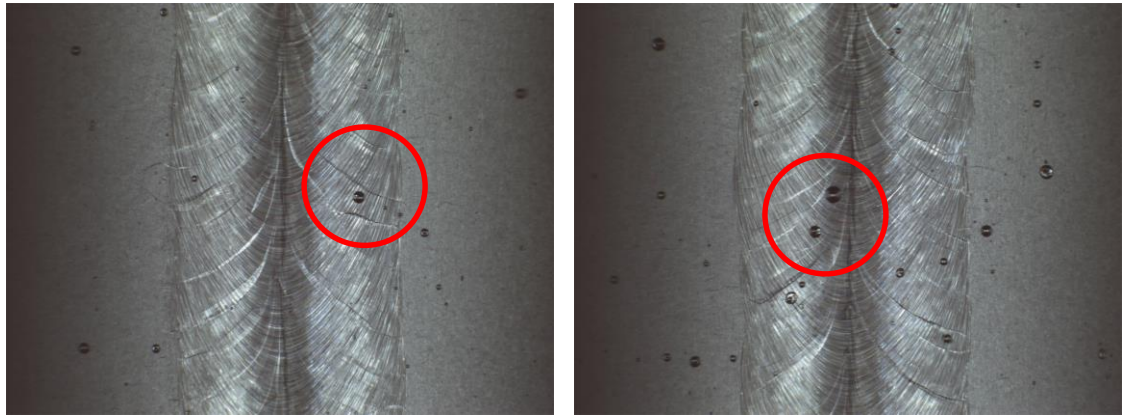
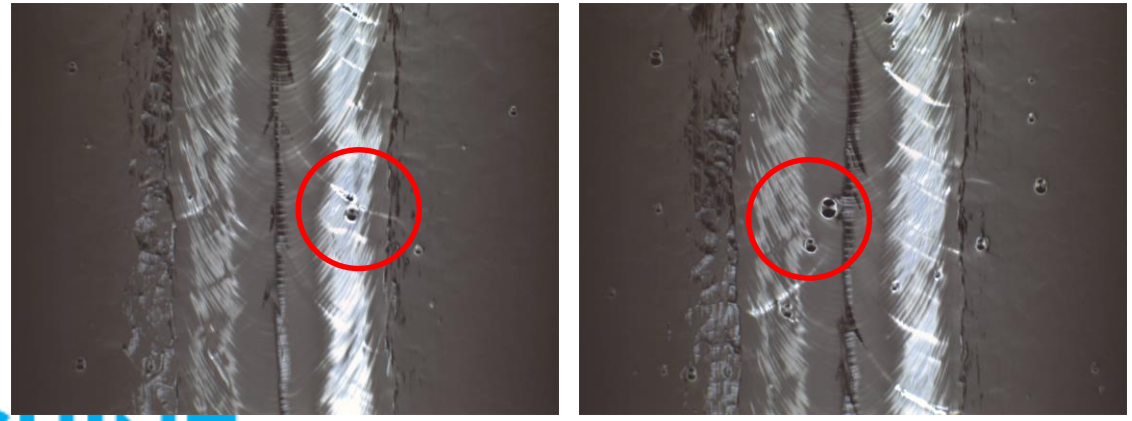
Welding splatters removal: EP vs BCP

- We found BCP is more effective than EP to remove welding splatters (without grinding).

Received **HJ004-cell6**

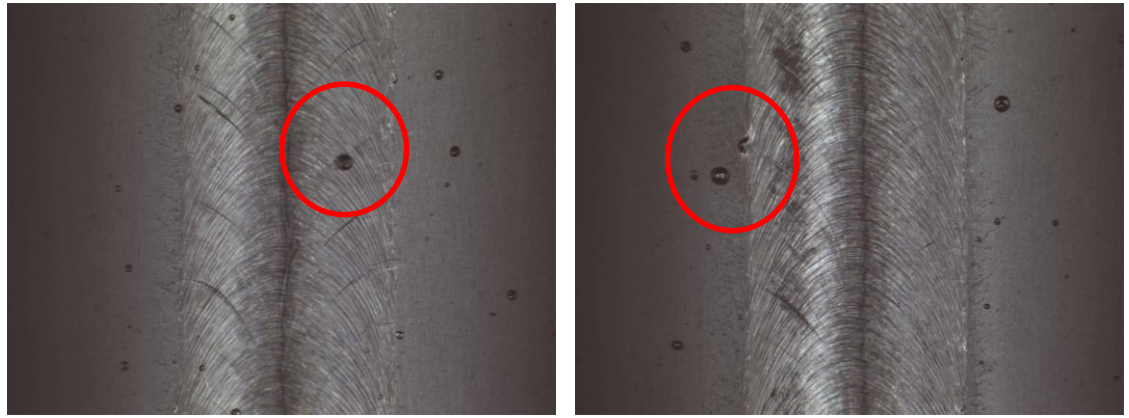


After EP 110 um

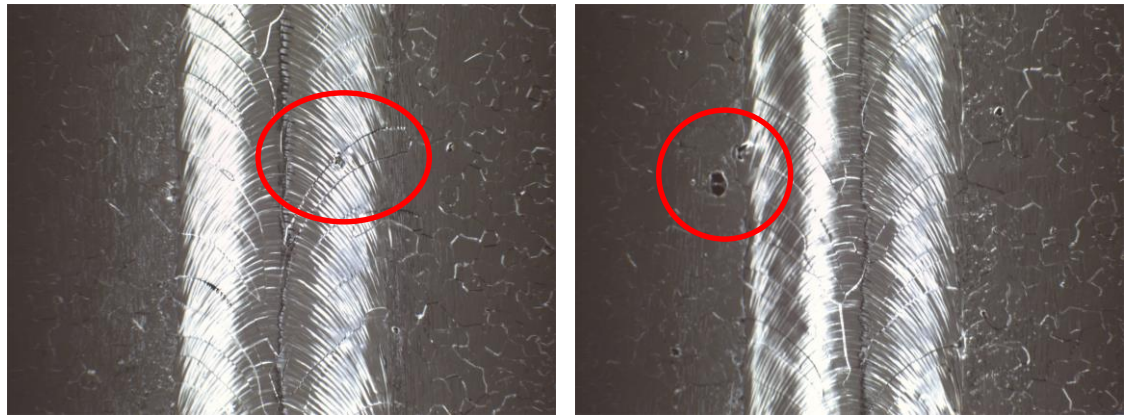


0° 8°

Received **HJ005-cell2**



After BCP 100 um



4° 192°

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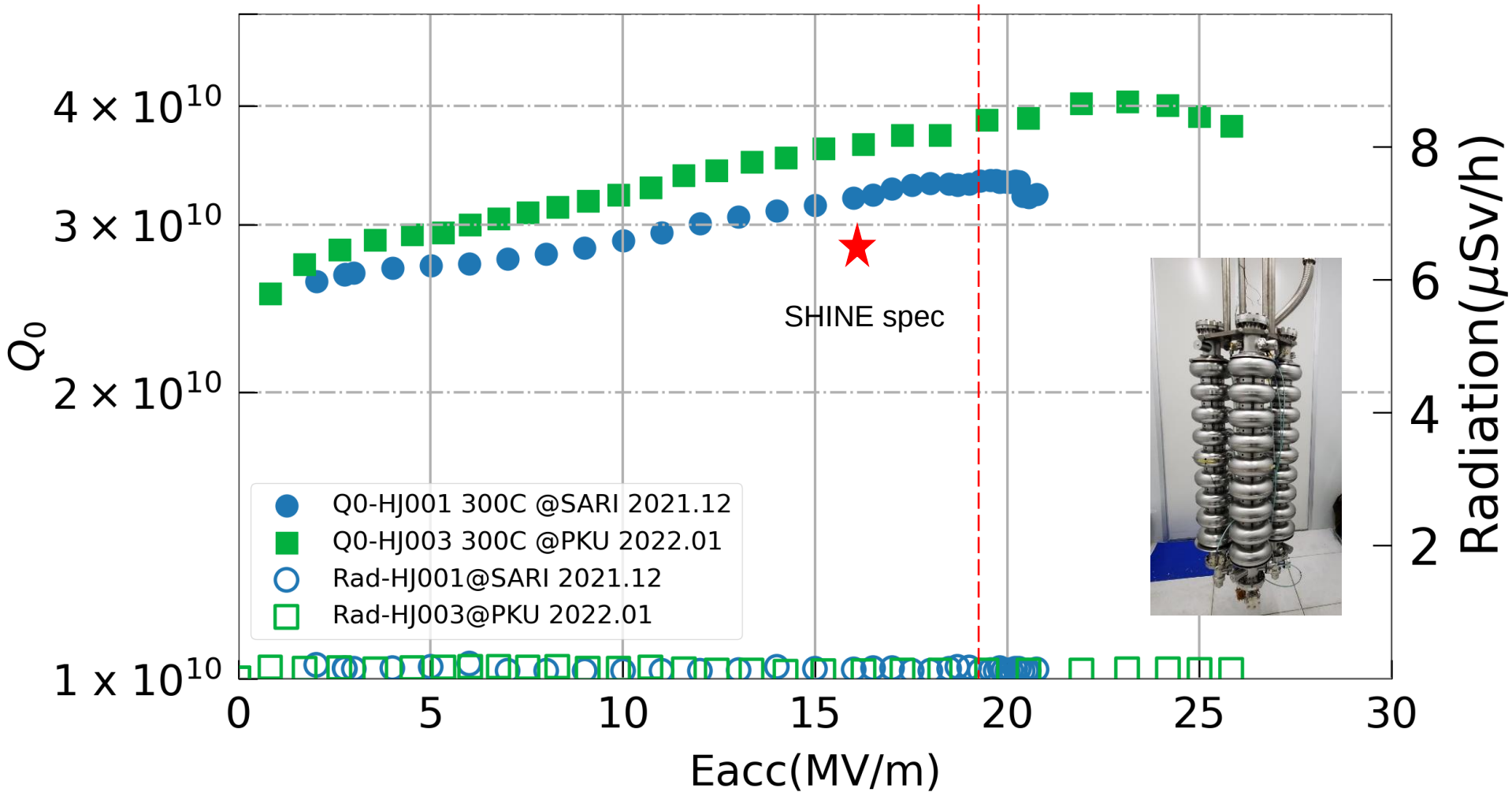
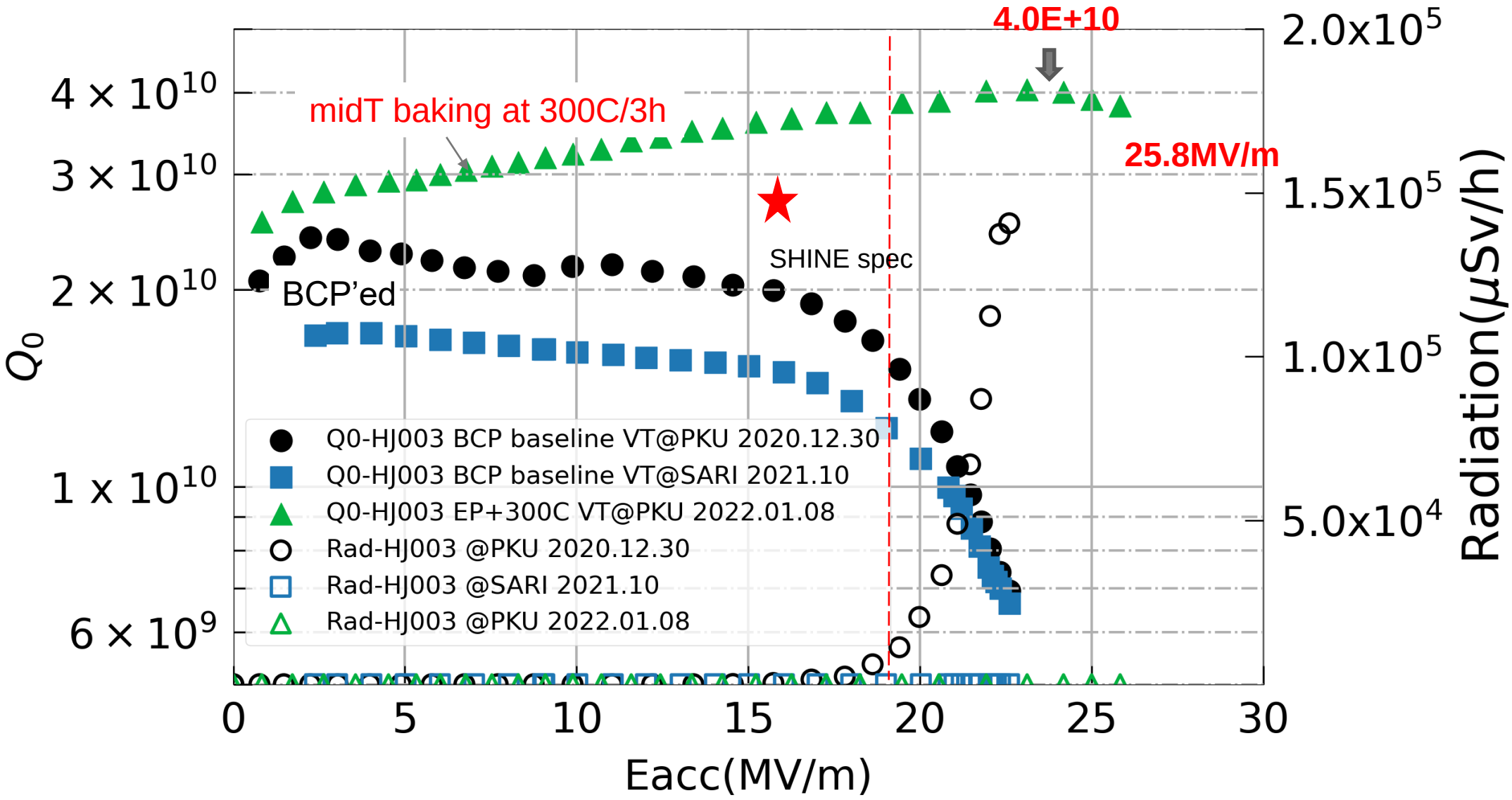
High Q R&D on 9-cell cavities – midT baking

- **Treatments:** BCP baseline +EP 50um + 900C/3h + air exposure/3days + 300C/3h
- Q_0 difference likely due to different fast cooling at PKU and SARI

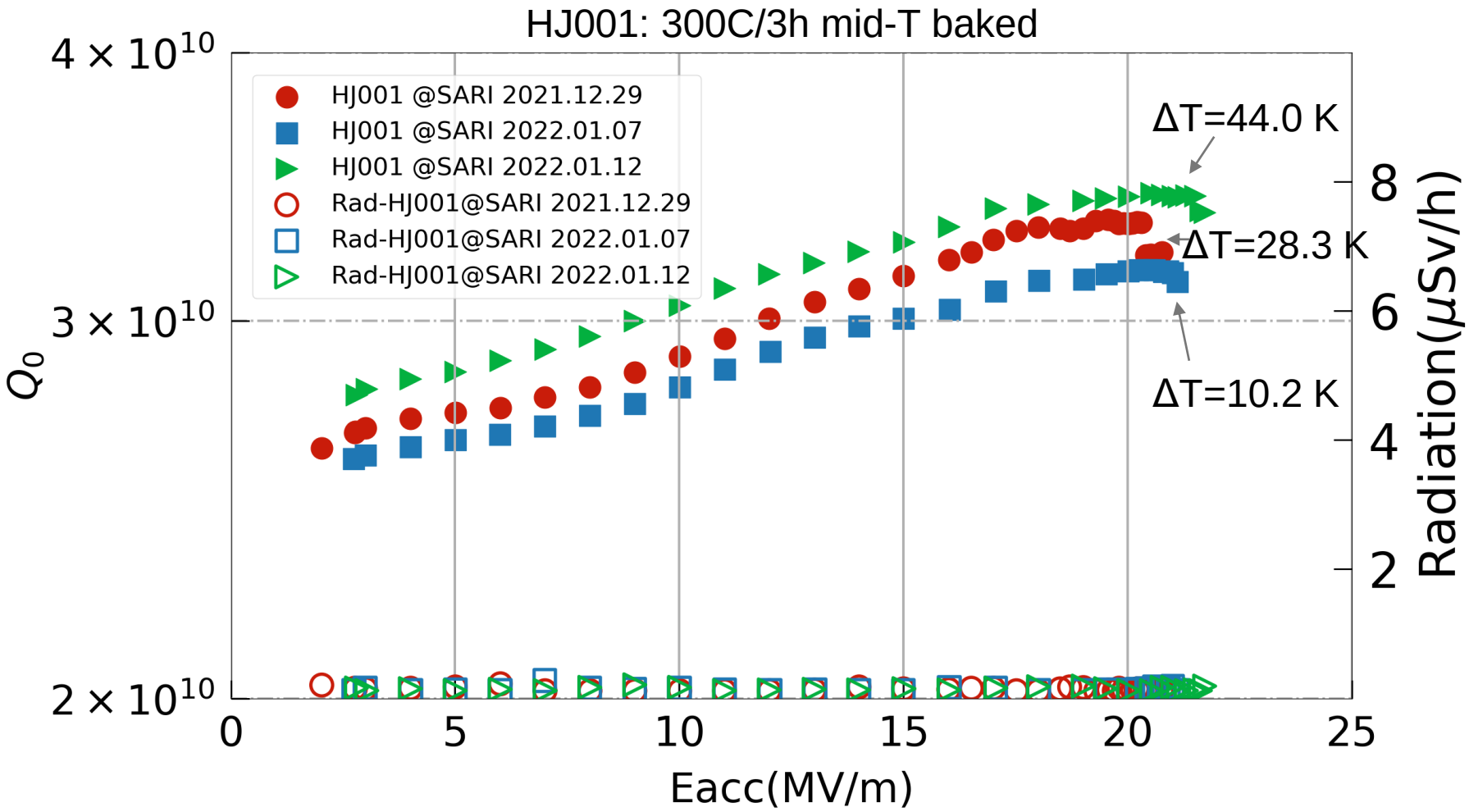


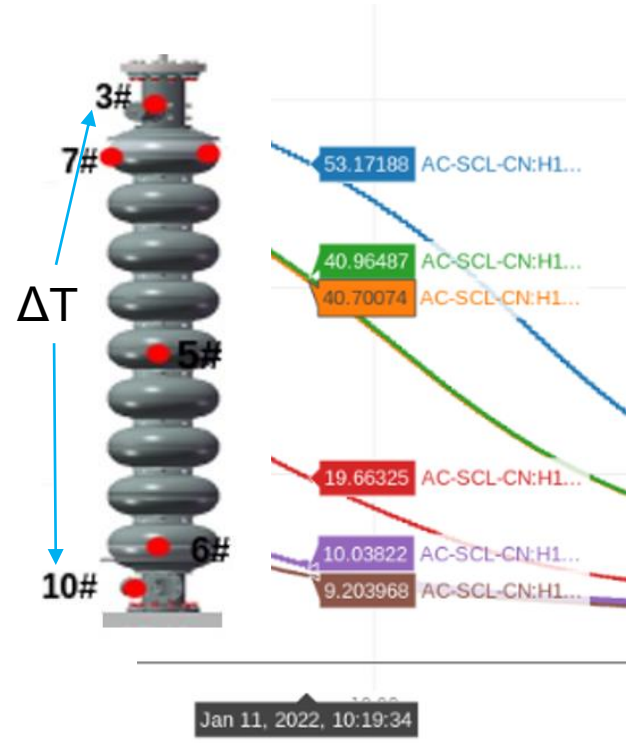
Mid-T baking (2)



Studies on fast cooling

- **Q0 vs ΔT:** Clear trend found, but ΔT=44.0 K in VT is likely still not enough for flux expulsion
- **Question:** How much temperature gradient is enough? [ΔT~120 K at PKU]





More studies on going.

Summary

- The newly constructed Wuxi platform, including many facilities, has been gradually commissioned and put into operation for cavity surface-treatment since the spring of 2021.

- Based on this platform, several preliminary studies on high Q and high gradient have been carried out. High-Q is achieved on both single-cell (highest Q_0=5.7E+10@16MV/m) and 9-cell cavities (Q_0=4.0E+10@~25 MV/m). High gradient is achieved on single-cell cavities (max Eacc=46.3MV/m).

- More R&D on high Q and high gradient will be continued, based on these new SRF infrastructures.

Acknowledgements

Many thanks

- To this open and friendly TTC community
- To INFN-LASA, KEK for supports on platform/facilities construction
- To PKU, especially J.K. Hao, for supports on vertical tests of cavities
- To Wuxi Creative, OSTEC and many other cooperative institutions and companies
- To RF-test group, Cryostat/Cryogenic groups and many other SHINE colleagues, as well as to Zhi Liu's group in ShanghaiTech University.

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Thank you for your attention!

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