



Recent Status of SHINE High-Q Cavities and Cryomodules

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SHINE

 Fermilab
**TESLA Technology
Collaboration Meeting**
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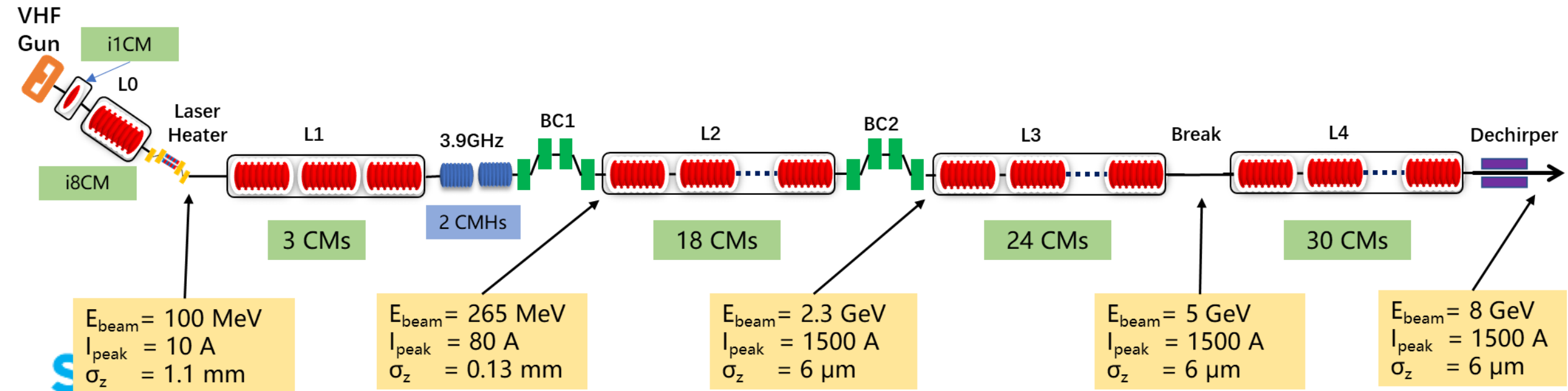
Outline

➤ Introduction

- ◆ High-Q Cavities
- ◆ Cryomodules
- ◆ Upgrade of SRF Infrastructures
- ◆ Summary

Introduction

- **SHINE**, launched in 2017, groundbreaking in 2018, aiming at the first lasing in 2025.
- Accelerator: **an 8 GeV SRF linac**, 3 undulator lines, generating photons from 0.4-25 keV
- Cryomodules (CMs) requirements
 - 1 CM with one twin-FPC cavity
 - 75 CMs with eight 1.3 GHz **high-Q cavities**
 - 2 CMs with eight 3.9 GHz cavities





Outline

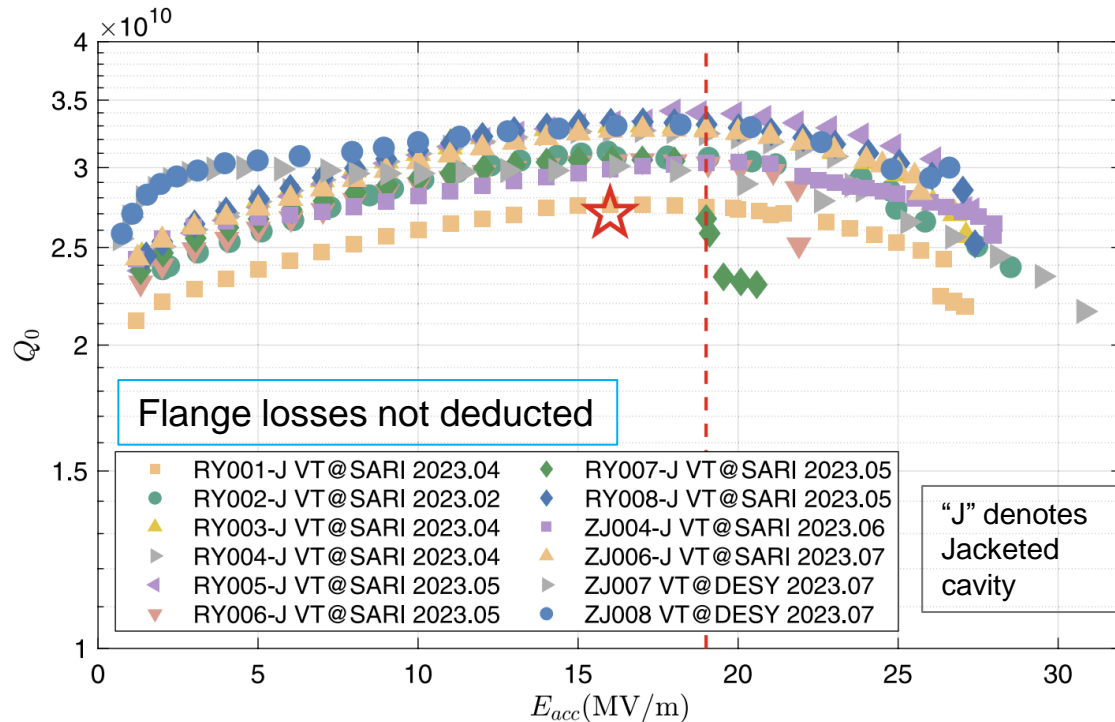
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- ◆ Cryomodules
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SC Cavities Ordered for SHINE Project

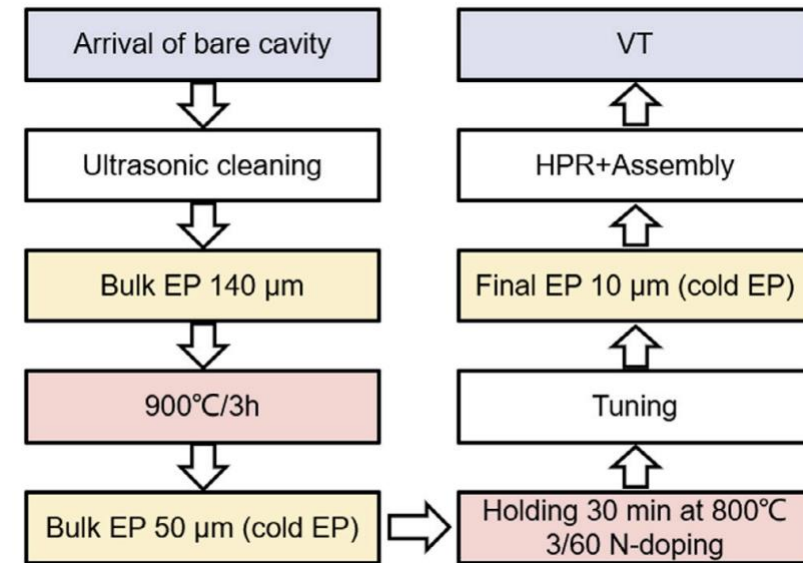
- In total, **4 cavity manufacturers chosen**: two qualified domestic companies, and two mature international companies
- **Cavities contracted**: 264 cavities, in two batches, around **half domestic and half international**
 - Small-batch: 8 cavities each, most fabricated
 - Medium-batch: 40~72 cavities each, fabrication started

| | Domestic | | International | |
|-----------------------------|--|---------------------|------------------|---------------------|
| Nb materials | TD | NX | NX | NX |
| 1.3GHz cavity manufacturing | HERT (8+72) | OSTEC (8+40) | RI (8+60) | ZANON (8+60) |
| High-Q recipes | Mid-T baking, N-doping | | N-doping | |
| Cavity-processing | SHINE facilities at Wuxi Creative | | RI | ZANON |
| VT | Mainly at SHINE | | | |

Small-batch Production – N-doped Cavities



Main preparation steps



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- International manufacturers
- 3/60 N-doping (dressed cavities tested)
 - Average $Q_0 = 3.1E+10$ at 16 MV/m
 - Average max $E_{acc} = 26.0$ MV/m

SHINE



Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/nima



Full Length Article

Accelerating gradient improvement in nitrogen-doped superconducting radio-frequency cavities for SHINE[☆]

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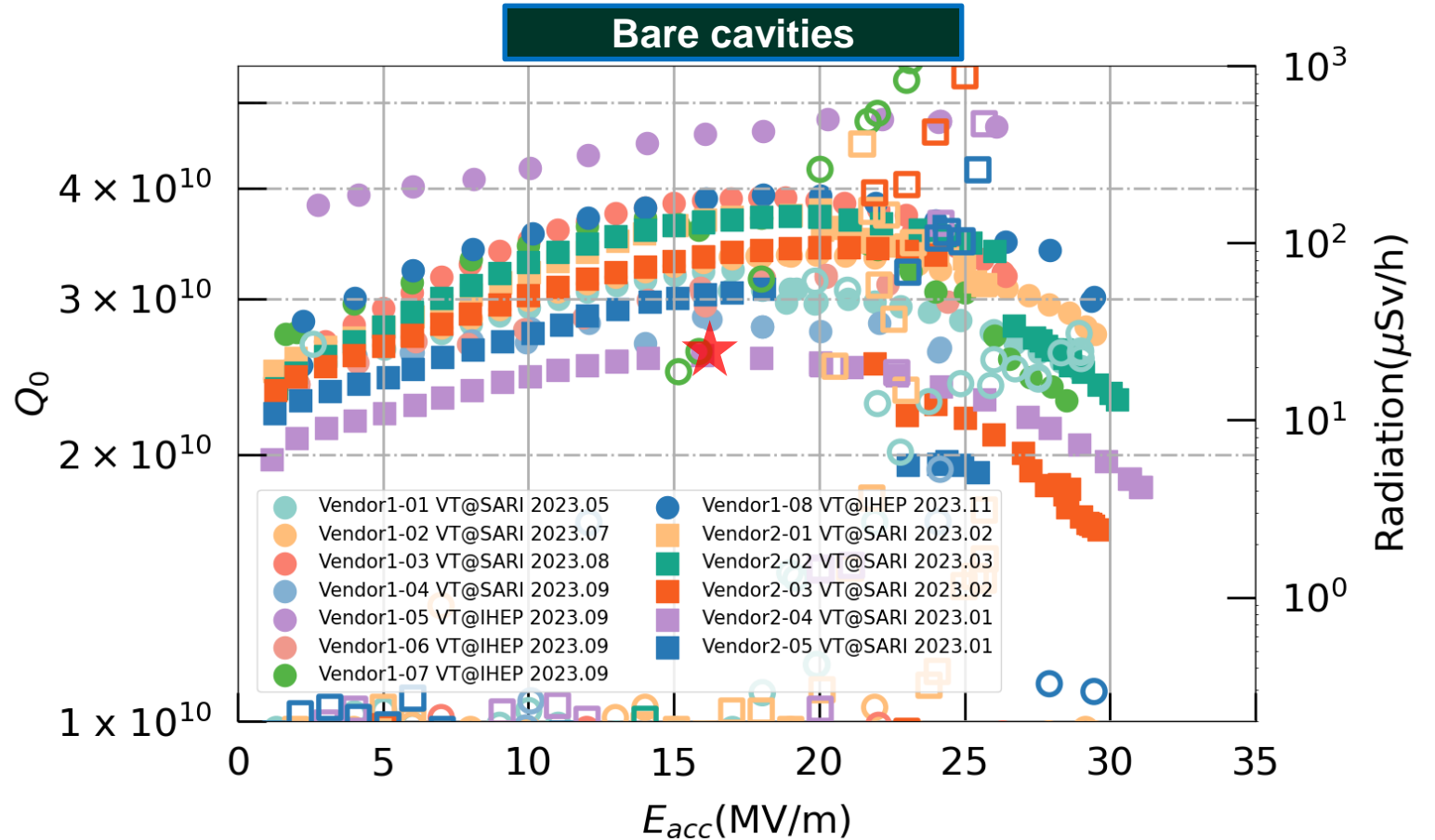
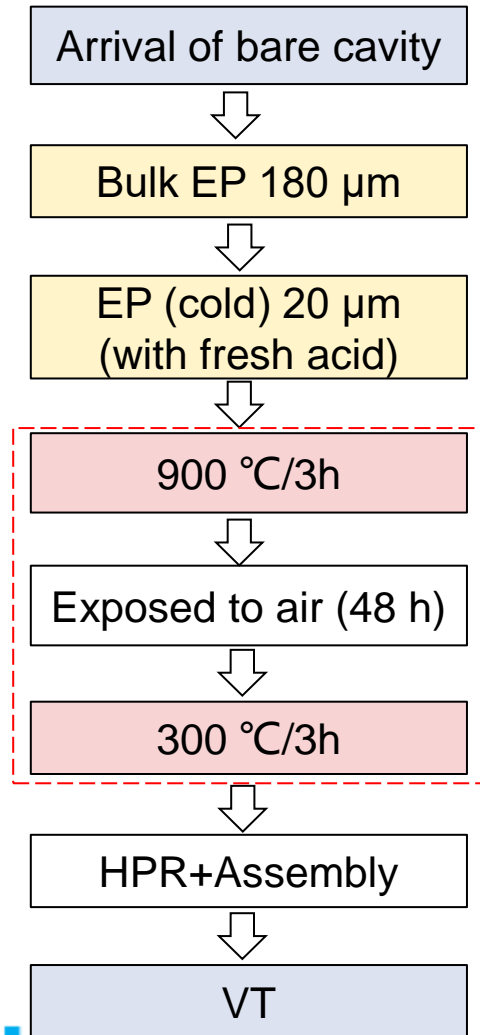
^d ShanghaiTech University, 201210, Shanghai, China

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Small-batch Production – Mid-T Baked Cavities

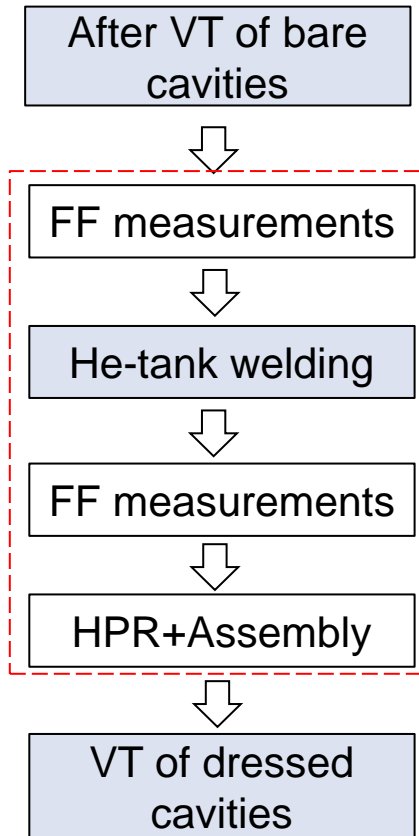
Main preparation steps



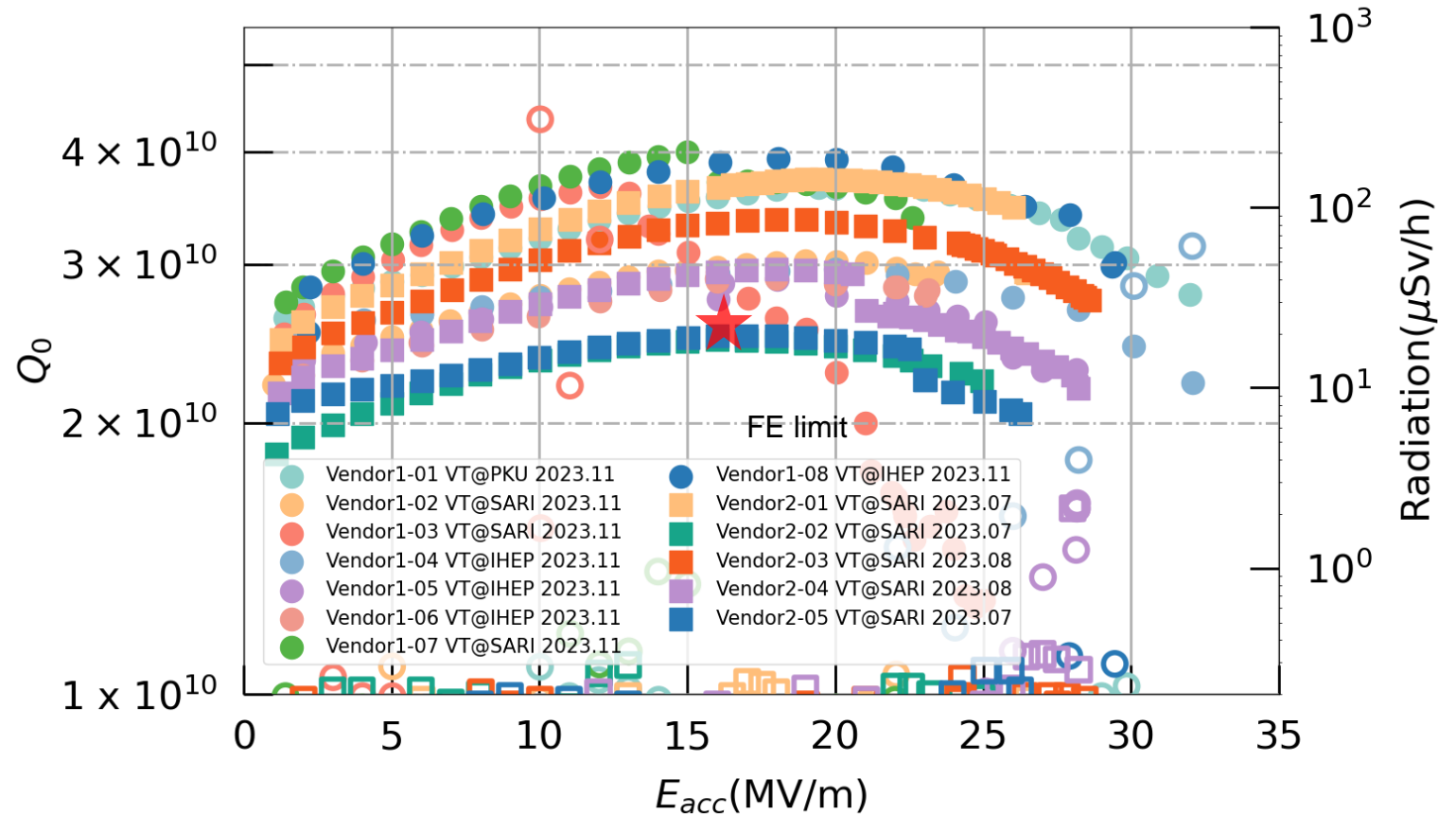
- **Domestic** manufacturers, surface treated by SHINE facilities in Wuxi
- Mid-T baking (bare cavities tested)
 - Average $Q_0 = 3.4\text{E}+10$ at 16 MV/m (Flange losses not deducted)
 - Average max $E_{acc} = 28.0$ MV/m

Small-batch Production – Mid-T Dressed Cavities

Main preparation steps for small-batch **dressed cavities**

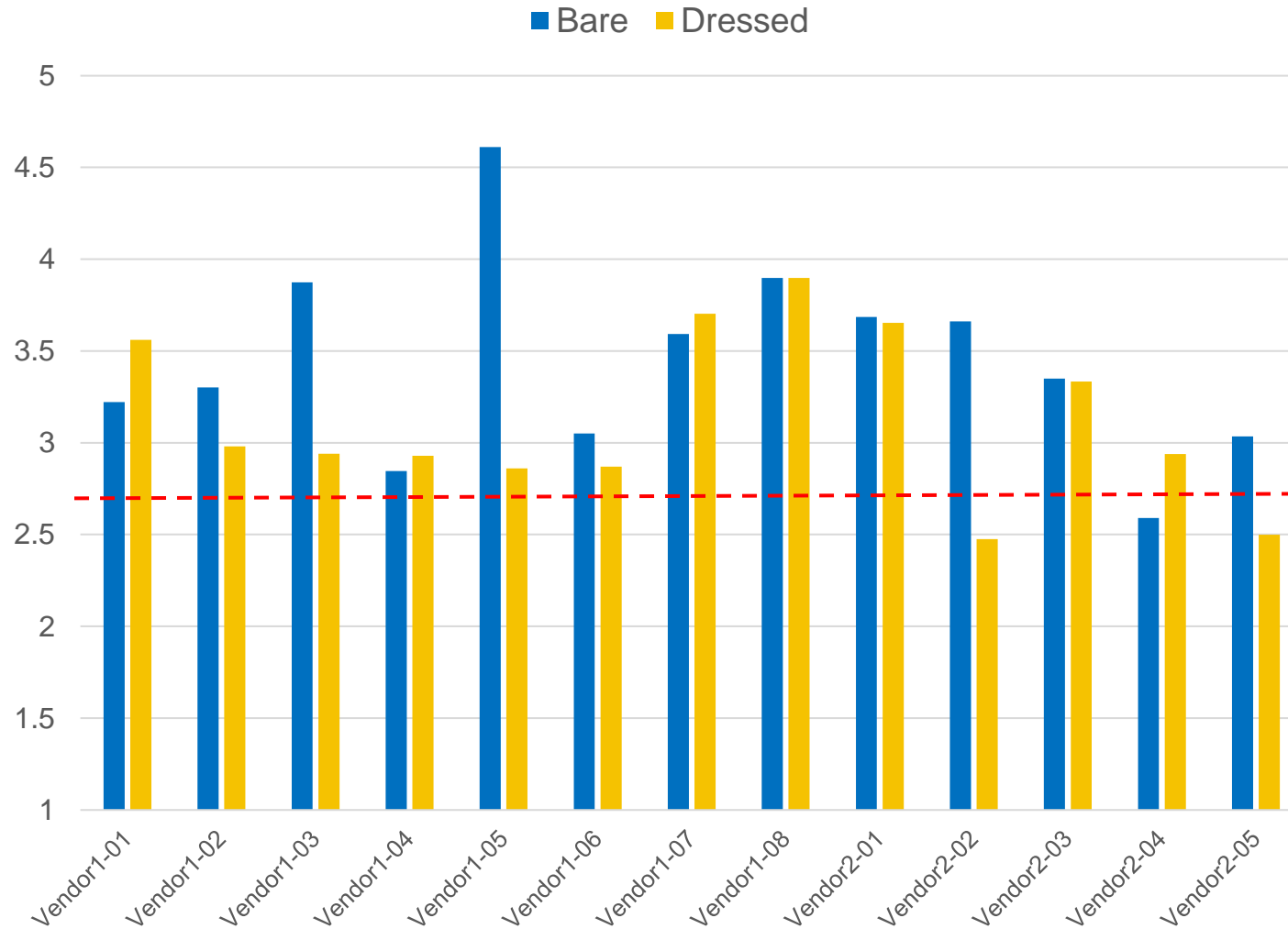


Dressed cavities (Mid-T baking)



- Domestic manufacturers, mid-T baking (dressed cavities tested)
 - Average $Q_0 = 3.1\text{E}+10$ at 16 MV/m
 - Average max $E_{acc} = 27.0$ MV/m

Mid-T baking: Q_0 from Bare Cavities to Dressed Cavities



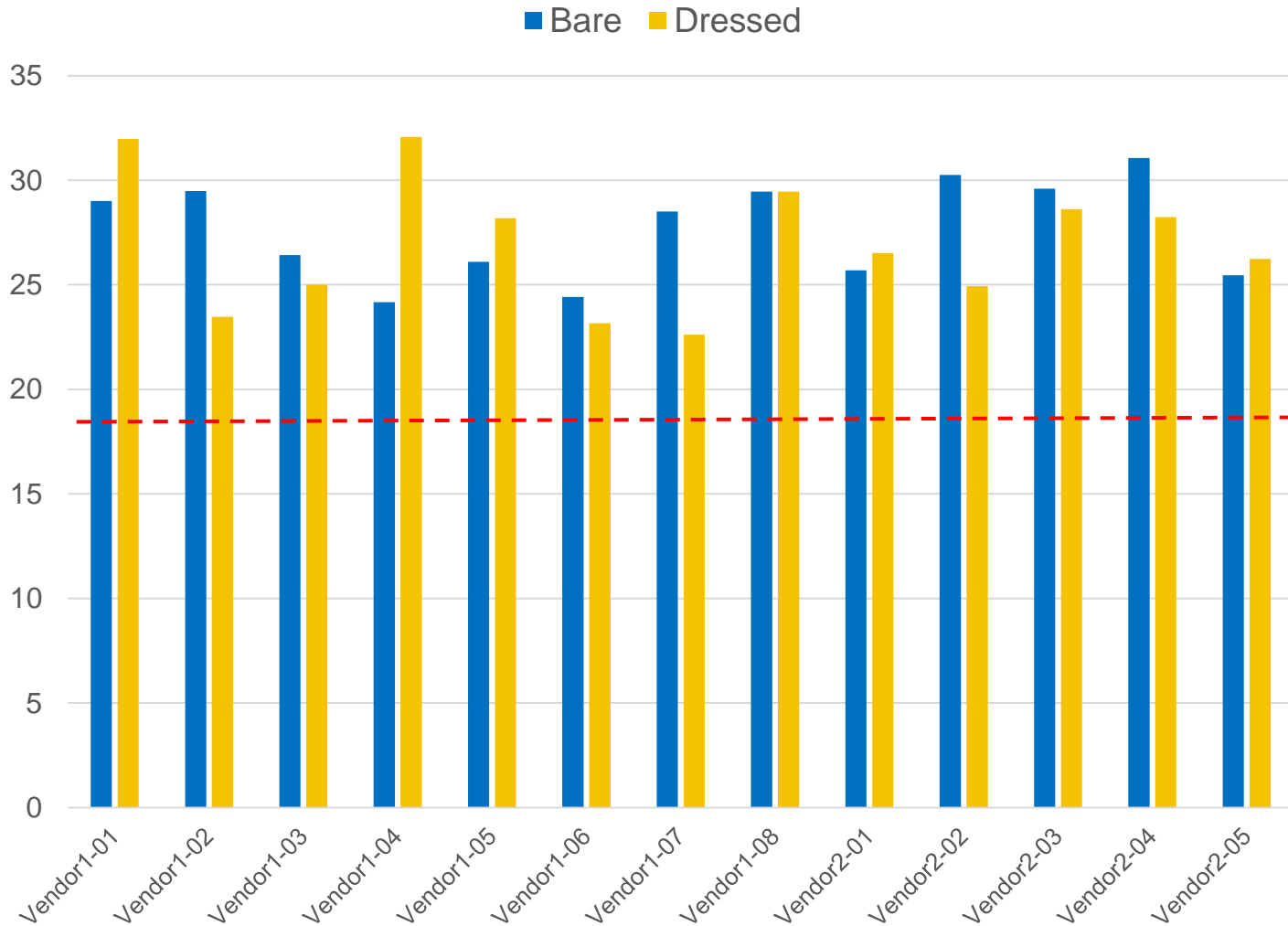
(Flange losses not deducted)

8% ↓ Q_0

Bare cavities → dressed cavities

The average Q_0 @16-20MV/m decreased by 8% , from $3.4E+10$ to $3.1E+10$, non-systematic, It is also associated with the time of the vertical tests (before and after cryogenic upgrade at SARI) and the testing locations (SARI, IHEP, PKU)

Mid-T baking: Max Eacc from Bare to Dressed Cavities



4% ↓ Max Eacc

Bare cavities → Dressed cavities

The average max Eacc decreased by ~4%, from 28 to 27 MV/m, with some showing improvement, such as vendor1-04

All 13 cavities have met the SHINE specifications



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Cryomodules

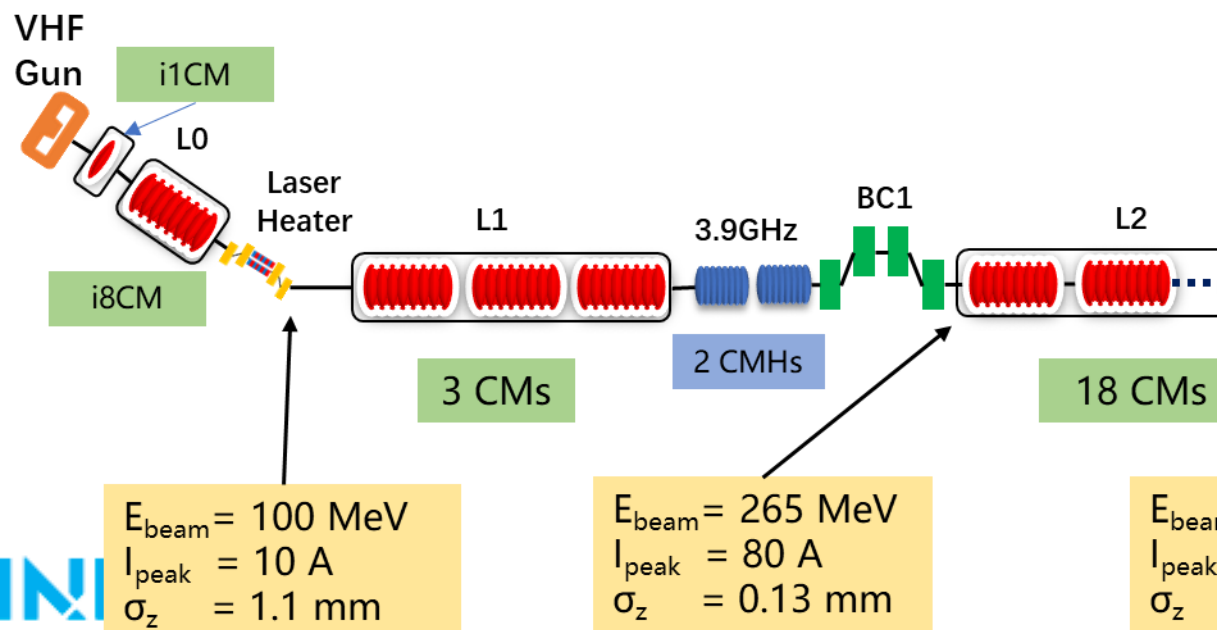
■ Cryomodules (CMs) under development

L0

i1CM (1 twin-FPCs cavity): Waiting for horizontal test
 i8CM (ABBA, 8 mid-T baked cavities): under assembly

L1

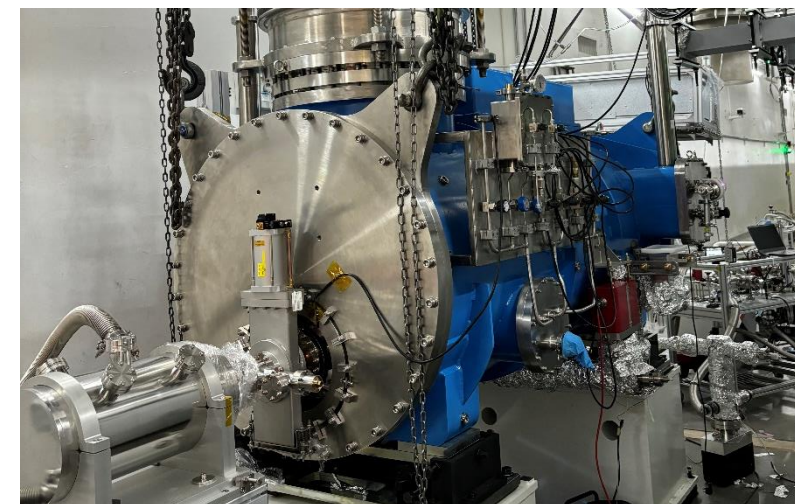
CM01 (standard, 8 N-doped cavities): under horizontal test



Related talks:

1. Design and fabrication of a **twin-FPCs 1.3 GHz 9-cell cavity**, Hongtao Hou (Dec.7, 14:15)
2. Manufacturing studies and RF test results of the 1.3 GHz **FPCs** for SHINE project, Zhenyu Ma (Dec.7, 12:15)
3. **Heat load** measurement and analysis for SHINE 1.3 GHz cryomodules, Yawei Huang (Dec. 6, 16:00)

i1CM at horizontal test stand



Upgrade of SRF Infrastructures

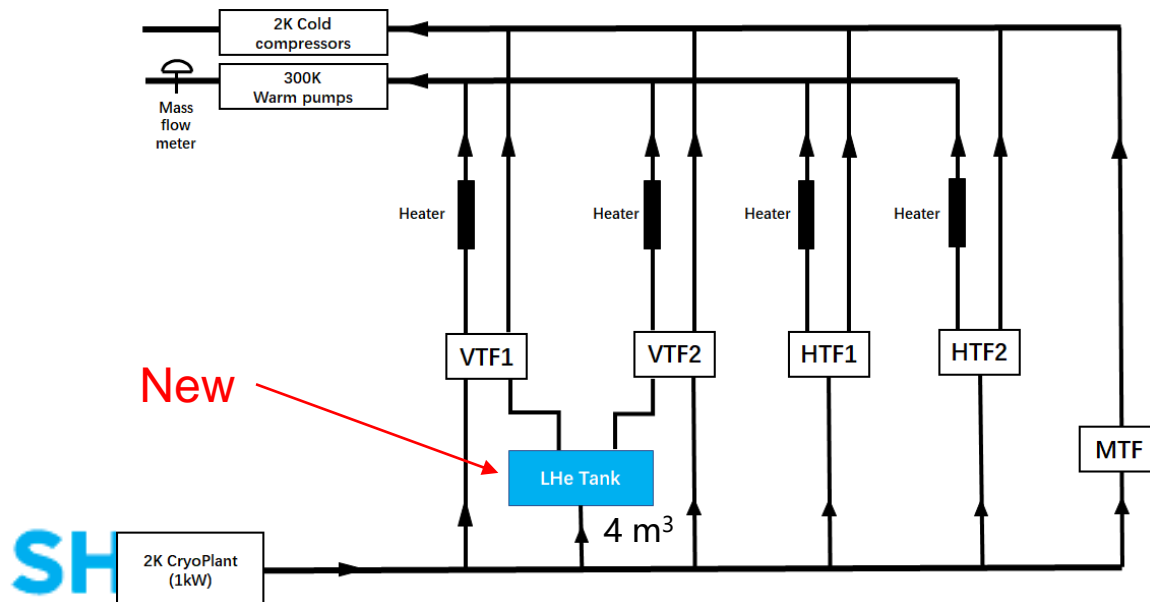
■ Upgrade of **cryogenic system** for vertical test stands (**Aug-Nov, 2023**)

● Fast cooling ways

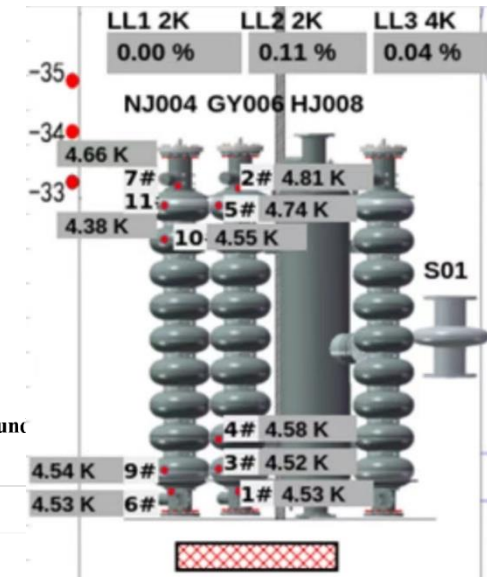
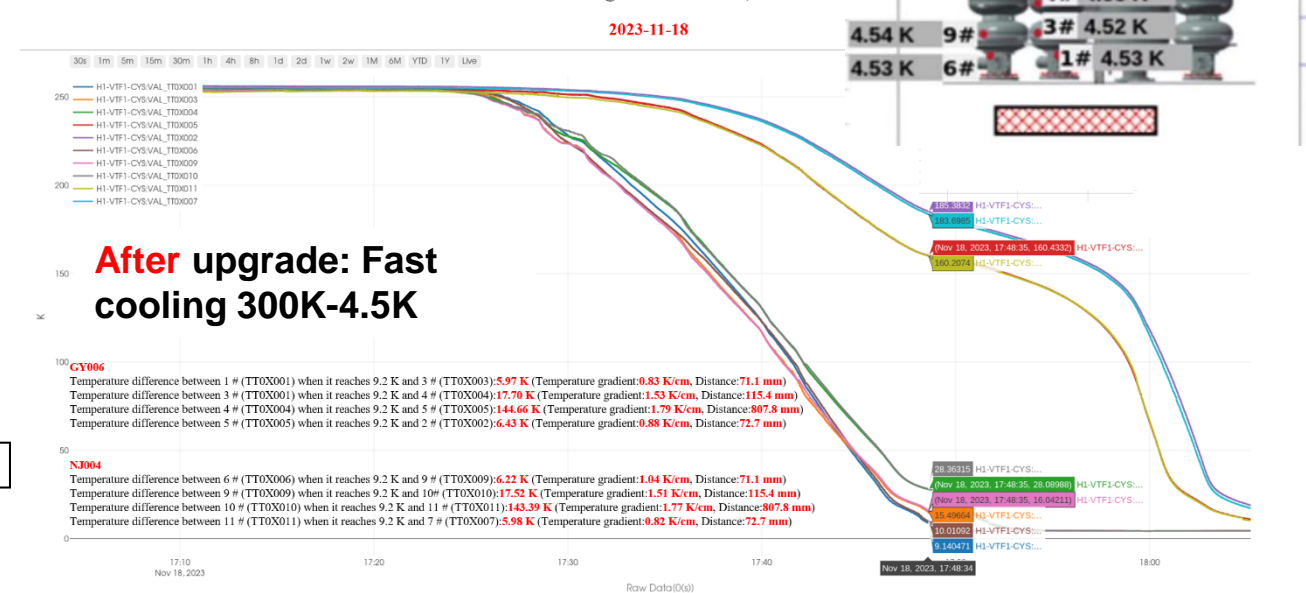
- **Before:** Fast cooling with Refrigerator 150K-4.5K
- **After:** Direct cooling with LHe Dewar 300K-4.5K

● Thermal gradient passing through 9.2 K

- **Before:** 9-cell cavity bottom < 0.4K/cm
- **After:** 9-cell cavity entirely $\geq 0.8\text{K/cm}$



VTF1 Fast Cooling 300 K~4.5 K (50th round)



Summary



- **Mass production** of SHINE high-Q cavities has started. Four manufacturers have been chosen.
- **The small batch cavities** (8 each) with N-doping or mid-T baking recipes, show good performance; some with FE, need re-HPR.
- **Cryogenic system** for vertical test stands has been upgraded since November, with better fast cooling capacity.
- **First cryomodules** are under assembly or test, including the two CMs for the injector, and the standard CM01 for L1.



■ Many thanks to:

- The cooperators: DESY, INFN-LASA, KEK, PKU, IHEP, DICP etc.
- The industrial suppliers both in international and domestic
- The people of SHINE SRF cryomodule team, cryogenic team

Thank you for your attention!