Recent Activity on TESLA 9-cell SRF Cavities

IHEP-KEK SCRF Meeting

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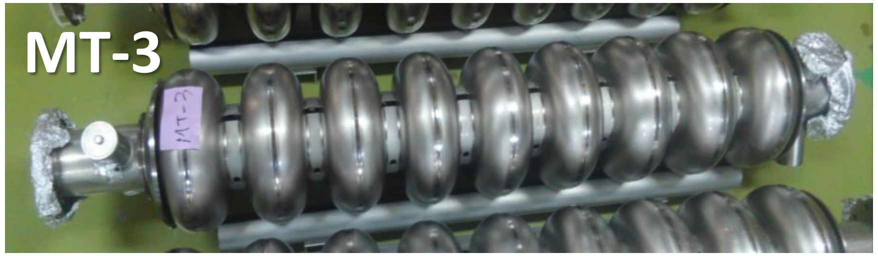
Introduction

- Four 9-cell TESLA-type 1.3 GHz SRF cavities
- Produced my Mitsubishi Heavy Industries
- RRR > 300
- Fine grain
- Cost reduction R&D for ILC



Cavity Histories

MT-3	MT-4	MT-5	MT-6
100 µm EP1 900 °C 3h 20 µm EP2 120 °C 48h **VT1 (16.3 MV/m)**	100 µm EP1 900 °C 3h 30 µm EP2 120 °C 48h **VT1 (cold leak)**	100 µm EP1 900 °C 3h 20 µm EP2 120 °C 48h **VT1 (35.1 MV/m)**	100 µm EP1 900 °C 3h 30 µm EP2 120 °C 48h **VT1 (28.7 MV/m)**
HPR 120 °C 48h **VT2 (cold leak)**	HPR **VT2 (4.1 MV/m)**	20 µm cold EP 75 °C 4h & 120 °C 48h **VT2 (34.0 MV/m)**	30 µm EP2 120 °C 48h **VT2 (26.0 MV/m)**
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20 µm EP2 120 °C 48h **VT4 (36.9 MV/m)**	HPR **VT4 (39.2 MV/m)**	5 µm cold EP **VT4 (26.3 MV/m)**	
10 µm cold EP 75 °C 4h & 120 °C 48h **VT5 (35.4 MV/m)**	5 µm cold EP 75 °C 4h & 120 °C 48h **VT5 (36.0 MV/m)**	100 µm EP1 900 °C 3h 10 µm cold EP 75 °C 4h & 120 °C 48h **VT5 (30.9 MV/m)**	

Cavity Histories – VT after Surface Contamination

MT-3	MT-4	MT-5	MT-6
100 µm EP1 900 °C 3h 20 µm EP2 120 °C 48h **VT1 (16.3 MV/m)**	100 µm EP1 900 °C 3h 30 µm EP2 120 °C 48h **VT1 (cold leak)**	100 µm EP1 900 °C 3h 20 µm EP2 120 °C 48h **VT1 (35.1 MV/m)**	100 µm EP1 900 °C 3h 30 µm EP2 120 °C 48h **VT1 (28.7 MV/m)**
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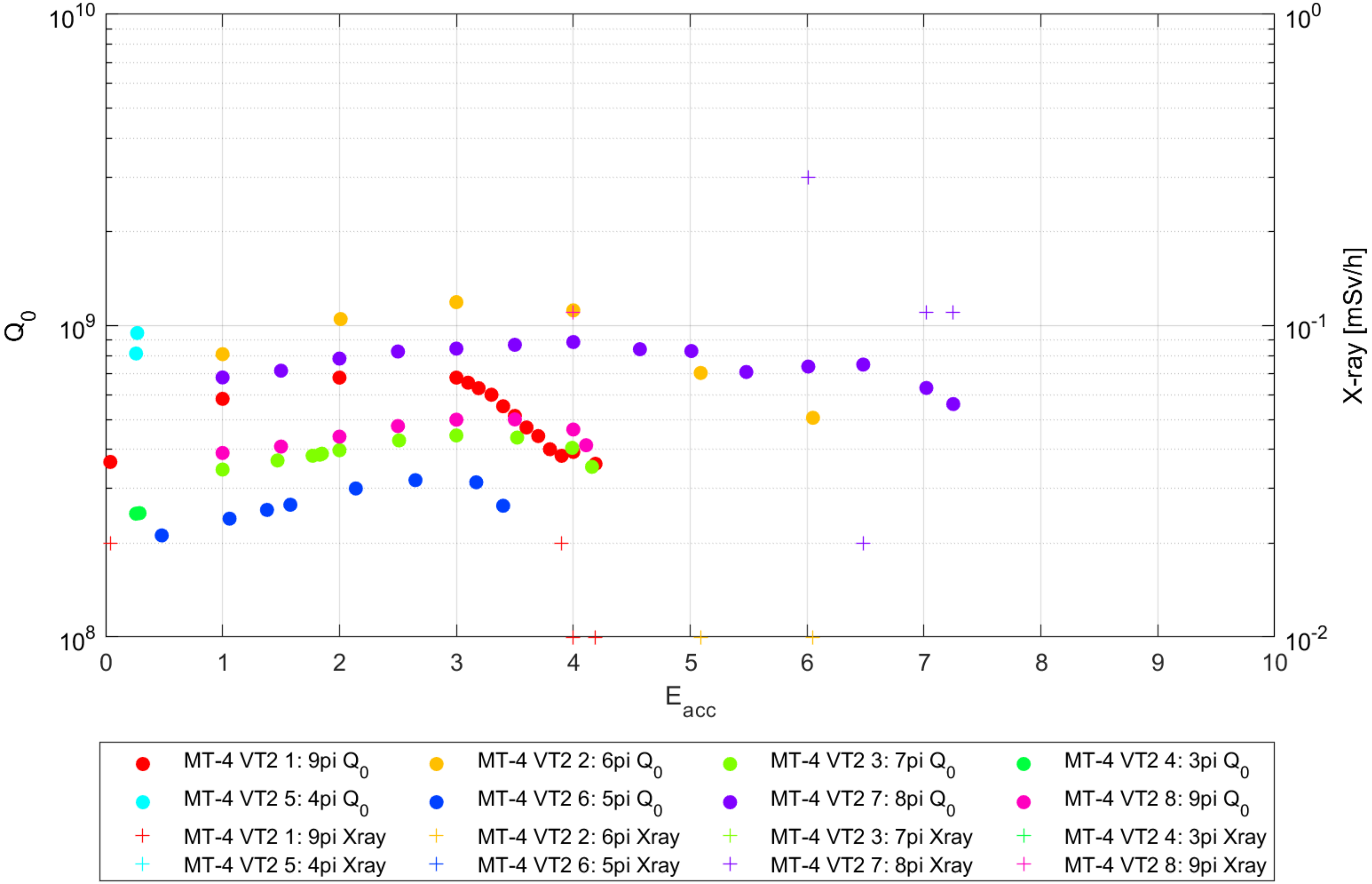
Fuse Blew During Pumping and Heating with Two Heater Fans after Assembly

- 120 °C baking for 48h
- VT1 canceled due to cold leak
- HPR
- Assembly
- Pumping for leak check
  - Vacuum incident: connected heater fan to same power circuit as vacuum pump → unscheduled power down of pump due to blown fuse
- VT2

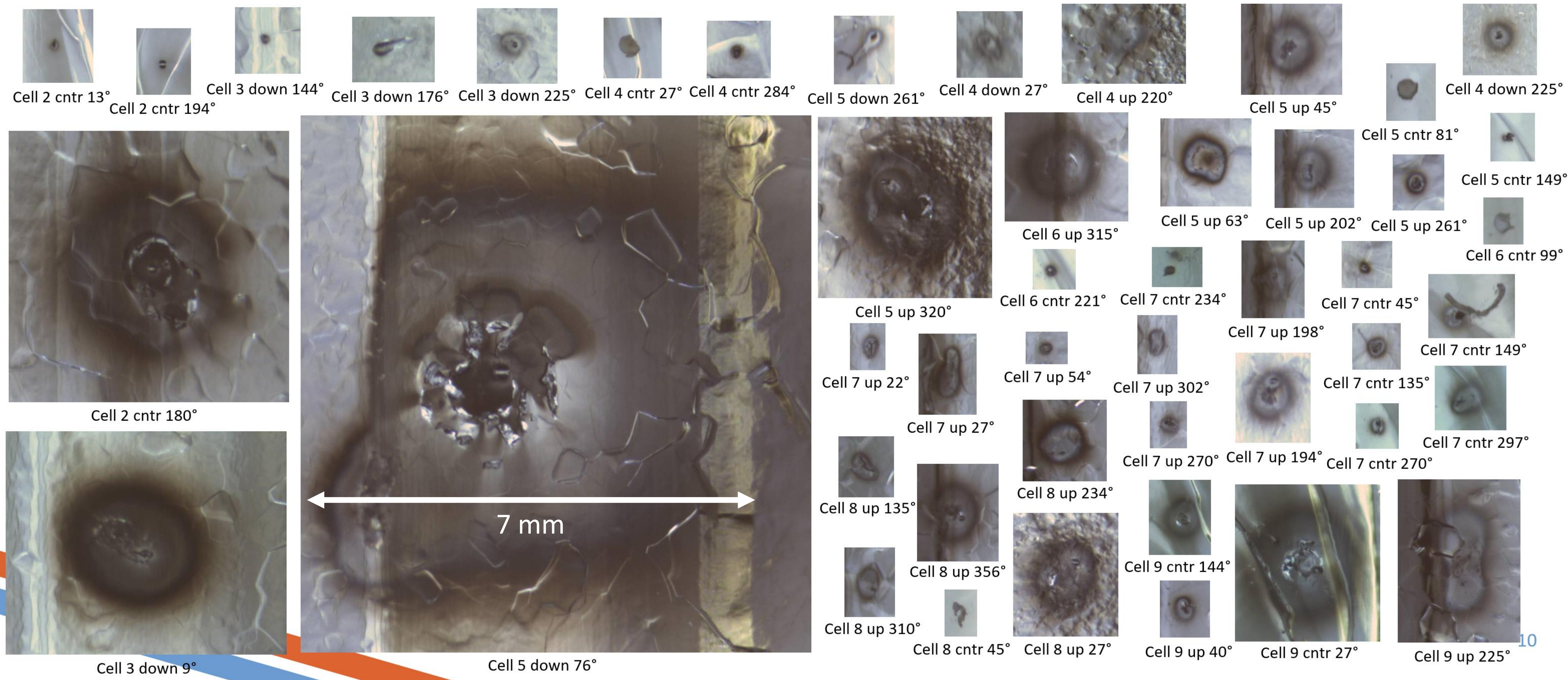
MT-4 VT2 Result

- Eacc,max = 4.1 MV/m
- Quench
- Slight heating observed in:
  - Cell 2 162° & 180° eq.
  - Cell 5 60° eq.



Optical Inspection of the Inner Surface of MT-4 after VT2

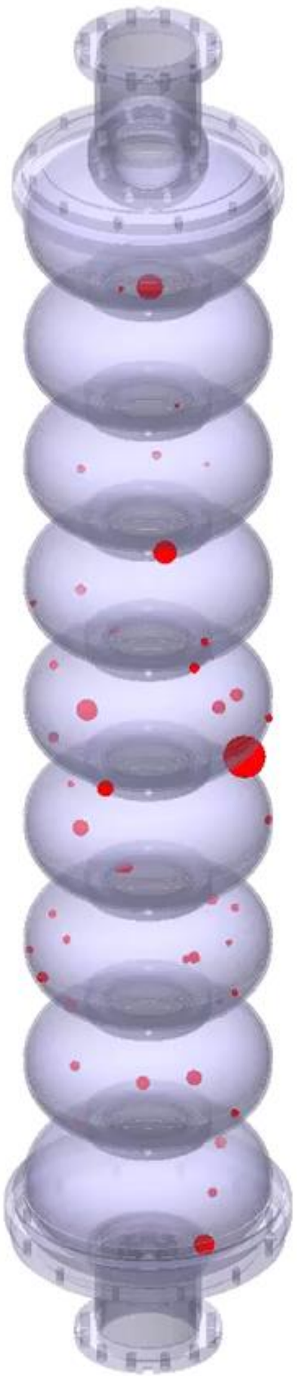
All pictures are at the same scale



Investigation of Defects

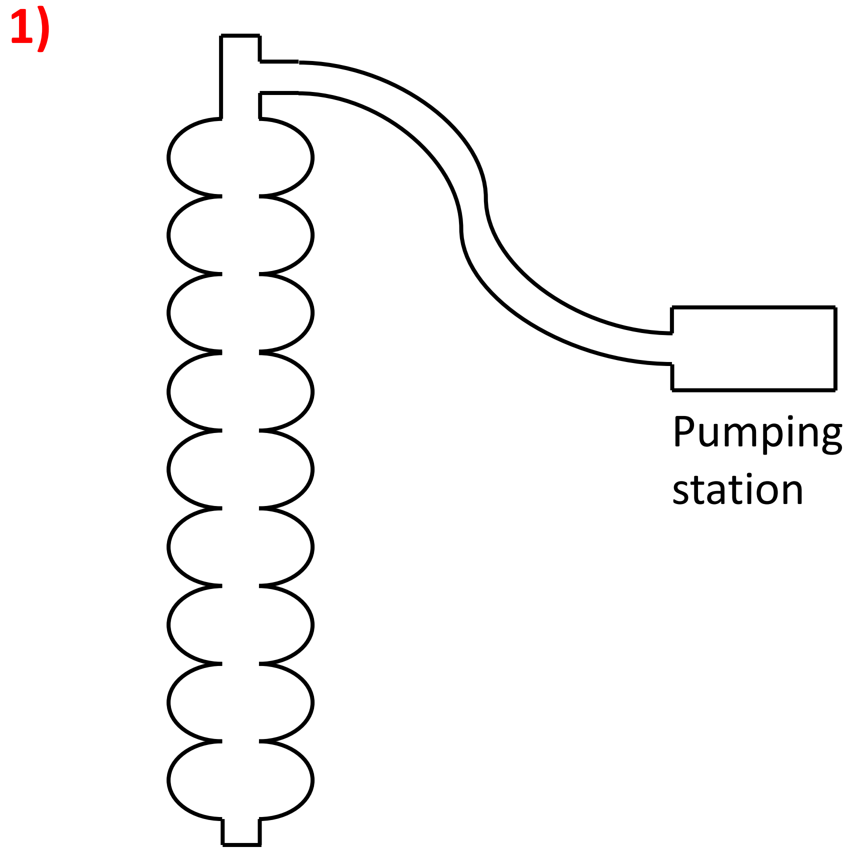
- Center of red disks indicate the position of the defects
- No defect found in cell 1
- Biggest one in cell 5
- Observed slight heating in:
  - Cell 2 eq. 162° & 180°
  - Cell 5 eq. 60°

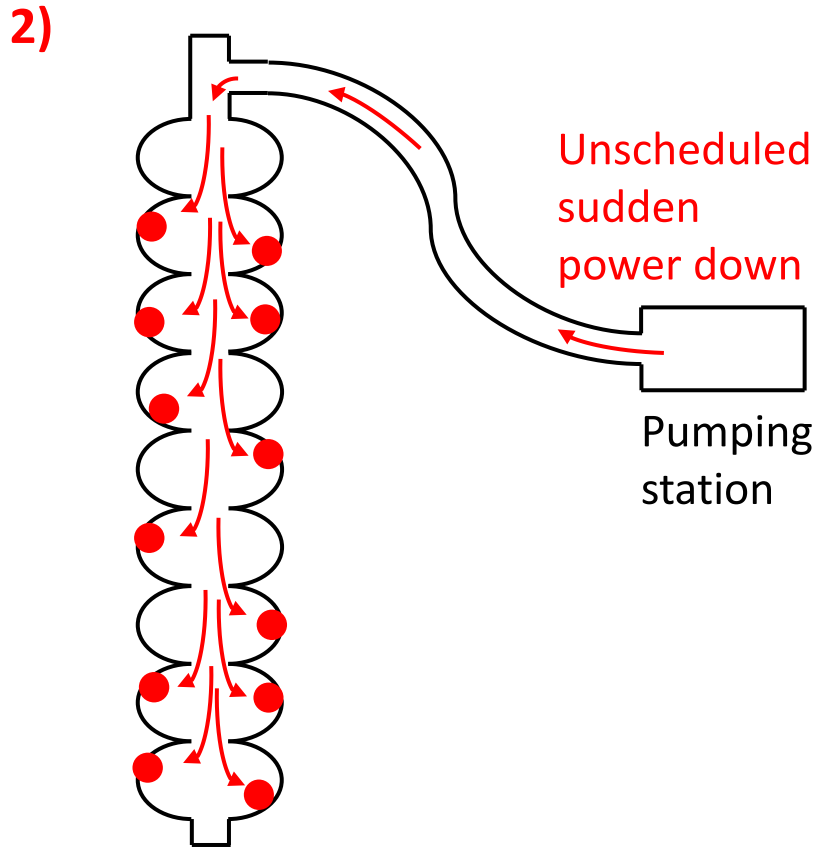
  (highlighted in orange in table)
- Composition of defect material:
  - Iron, Carbon, Chromium, Oxygen, Aluminum, Silicon



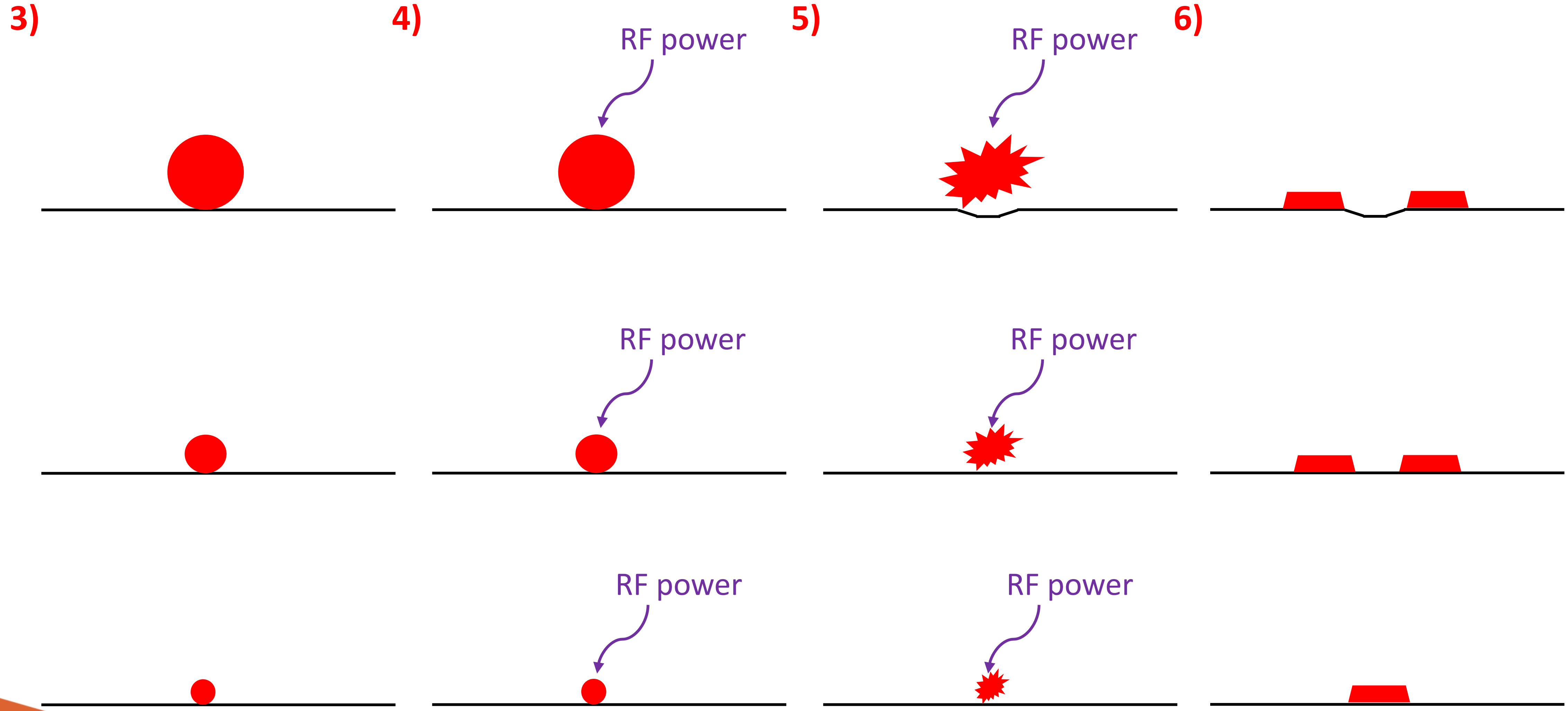
Cell	Position	Angle [°]	Defect width [mm]	Defect height [mm]	Area [mm²]
2	center	13	0.116	0.140	0.016
2	center	180	2.481	2.589	6.422
2	center	194	0.132	0.136	0.018
3	down	9	2.115	1.927	4.075
3	down	144	0.120	0.116	0.014
3	down	176	0.421	0.269	0.113
3	down	225	0.341	0.309	0.105
4	center	27	0.249	0.277	0.069
4	center	284	0.165	0.161	0.026
4	down	27	0.361	0.425	0.154
4	down	225	0.438	0.454	0.198
4	up	220	0.514	0.502	0.258
5	center	81	0.261	0.245	0.064
5	center	149	0.149	0.112	0.017
5	down	76	6.916	6.149	42.525
5	down	261	0.413	0.474	0.196
5	down	333	0.995	0.951	0.947
5	up	45	0.666	0.726	0.484
5	up	63	0.622	0.654	0.407
5	up	202	0.562	0.558	0.314
5	up	261	0.301	0.325	0.098
5	up	320	1.577	1.822	2.874
6	center	99	0.261	0.257	0.067
6	center	221	0.193	0.189	0.036
6	up	315	1.015	0.991	1.007
7	center	45	0.157	0.189	0.030
7	center	135	0.289	0.301	0.087
7	center	149	0.759	0.574	0.435
7	center	234	0.165	0.124	0.020
7	center	270	0.189	0.221	0.042
7	center	297	0.506	0.450	0.227
7	up	22	0.237	0.325	0.077
7	up	27	0.433	0.654	0.284
7	up	54	0.181	0.177	0.032
7	up	194	0.658	0.654	0.431
7	up	198	0.530	0.526	0.279
7	up	270	0.277	0.265	0.073
7	up	302	0.221	0.329	0.073
8	center	45	0.177	0.325	0.057
8	up	27	0.867	0.987	0.856
8	up	135	0.389	0.373	0.145
8	up	234	0.726	0.710	0.516
8	up	310	0.333	0.466	0.155
8	up	356	0.630	0.775	0.488
9	center	27	1.521	1.658	2.522
9	center	144	0.486	0.522	0.253
9	up	40	0.301	0.373	0.112
9	up	225	0.662	1.381	0.914

Interpretation of Available Data





Interpretation of Available Data



Cavity Histories – Reference Measurements

MT-3	MT-4	MT-5	MT-6
100 µm EP1 900 °C 3h 20 µm EP2 120 °C 48h **VT1 (16.3 MV/m)**	100 µm EP1 900 °C 3h 30 µm EP2 120 °C 48h **VT1 (cold leak)**	100 µm EP1 900 °C 3h 20 µm EP2 120 °C 48h **VT1 (35.1 MV/m)**	100 µm EP1 900 °C 3h 30 µm EP2 120 °C 48h **VT1 (28.7 MV/m)**
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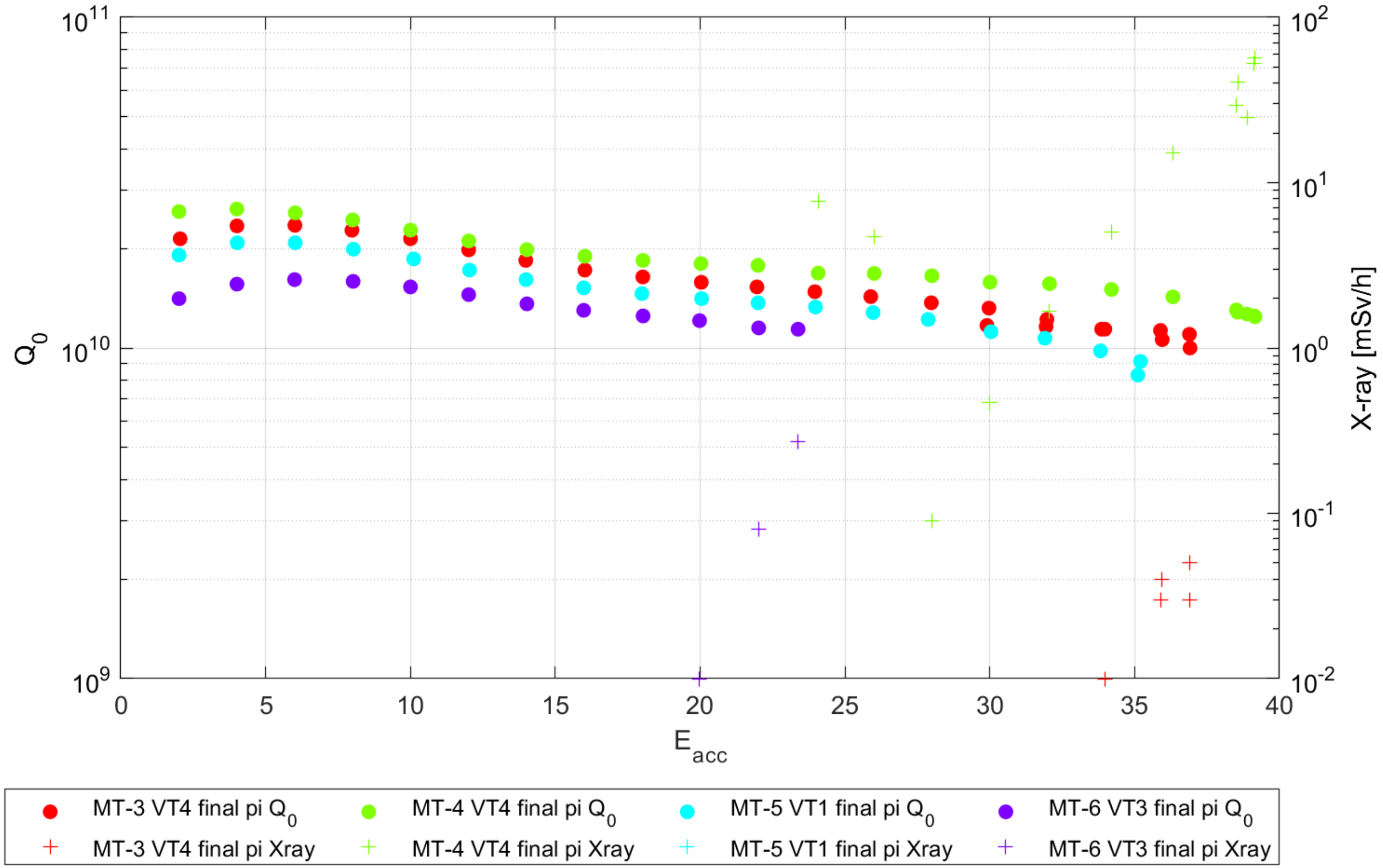
20 µm EP2 120 °C 48h **VT4 (36.9 MV/m)**	HPR **VT4 (39.2 MV/m)**	5 µm cold EP **VT4 (26.3 MV/m)**	
10 µm cold EP 75 °C 4h & 120 °C 48h **VT5 (35.4 MV/m)**	5 µm cold EP 75 °C 4h & 120 °C 48h **VT5 (36.0 MV/m)**	100 µm EP1 900 °C 3h 10 µm cold EP 75 °C 4h & 120 °C 48h **VT5 (30.9 MV/m)**	

Reference Measurements

- Standard recipe:
  120 °C baking for 48h
- Final π-mode measurements for latest reference measurements
- MT-4 was reset
- MT-6 will be retested with an improved assembly procedure

Test	Limitation
MT-3 VT4	Quench: C6 60° eq
MT-4 VT4	Quench: C3 150° down
MT-5 VT1	Quench: C1 90°-120° eq
MT-6 VT3	Quench: C8 240° eq



Cavity Histories – Two-step Baking

MT-3	MT-4	MT-5	MT-6
100 µm EP1 900 °C 3h 20 µm EP2 120 °C 48h **VT1 (16.3 MV/m)**	100 µm EP1 900 °C 3h 30 µm EP2 120 °C 48h **VT1 (cold leak)**	100 µm EP1 900 °C 3h 20 µm EP2 120 °C 48h **VT1 (35.1 MV/m)**	100 µm EP1 900 °C 3h 30 µm EP2 120 °C 48h **VT1 (28.7 MV/m)**
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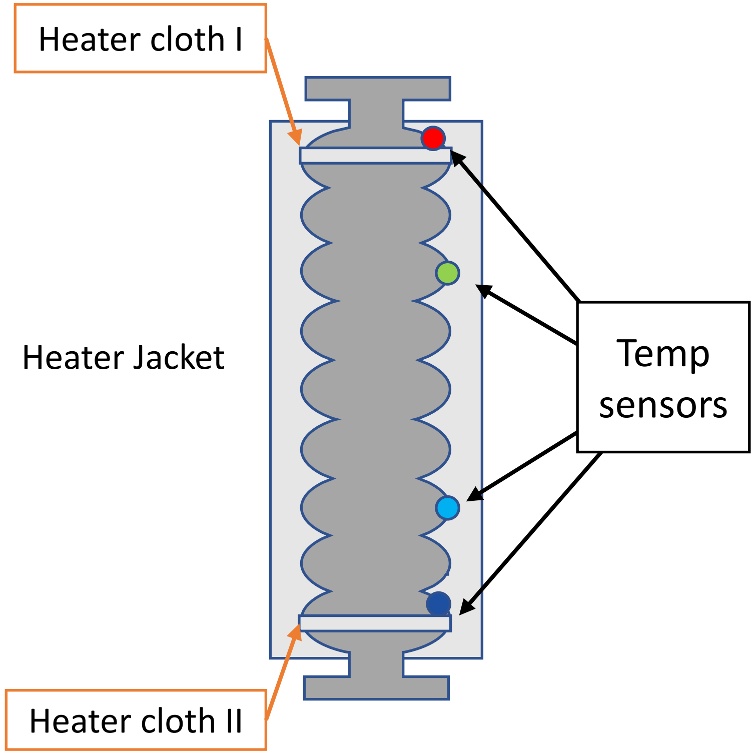
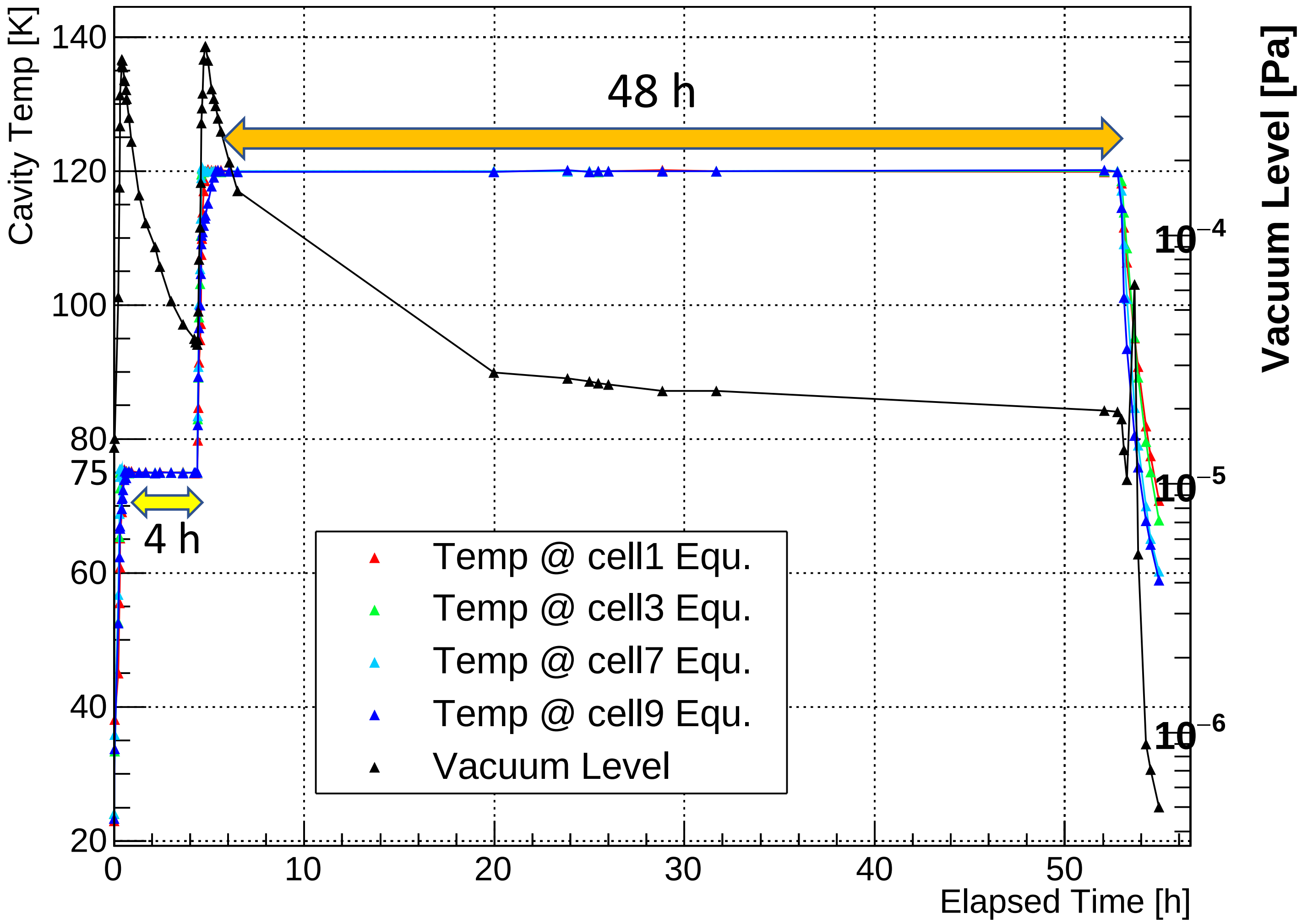
10 µm cold EP 75 °C 4h & 120 °C 48h **VT5 (35.4 MV/m)**	5 µm cold EP 75 °C 4h & 120 °C 48h **VT5 (36.0 MV/m)**	100 µm EP1 900 °C 3h 10 µm cold EP 75 °C 4h & 120 °C 48h **VT5 (30.9 MV/m)**	

Two-step Baking Procedure Example: MT-5 VT2



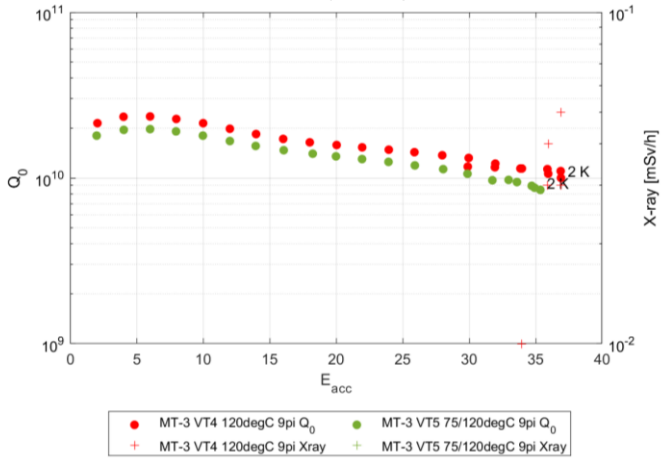


Two-step Baking VT Results

- Final π-mode measurements are shown
- Reference measurements: red
- Tow-step backing results: green
- No improvement in all cases*

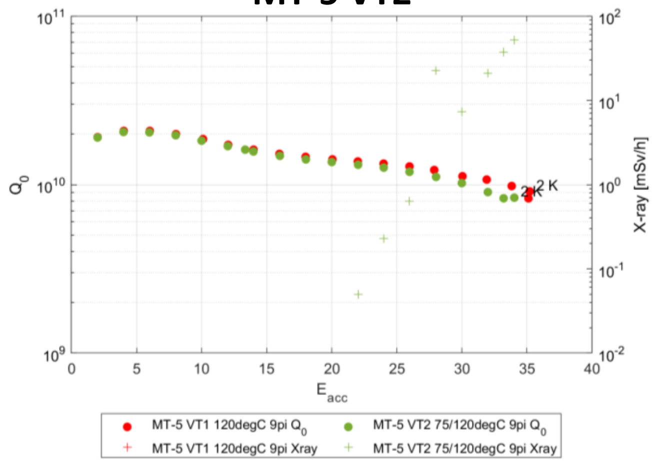
Test	Limit after two-step baking
MT-3 VT5	Quench: C1 240°-280° eq
MT-4 VT5*	Power / FE*
MT-5 VT2	Quench: C2 150° down
MT-5 VT5	Quench: C4 198°-270° eq & down

MT-3 VT5



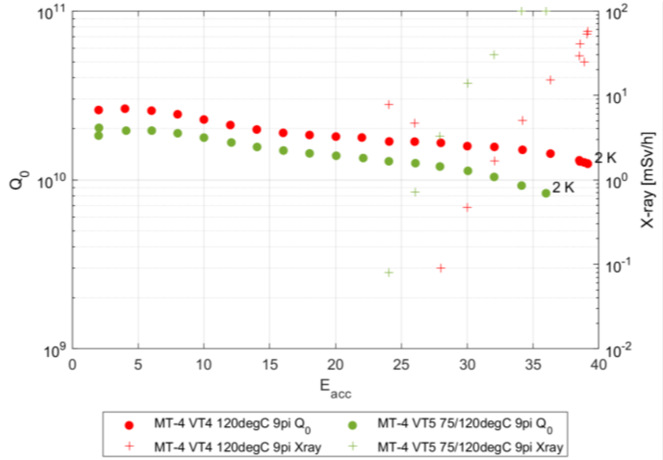
Eacc,max: 36.9 MV/m → 36.6 MV/m

MT-5 VT2



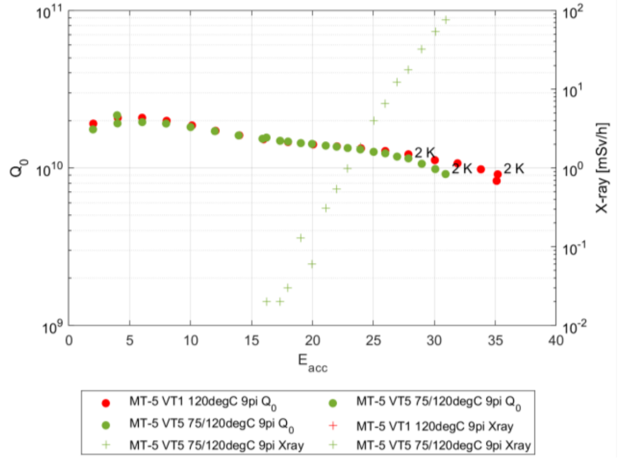
Eacc,max: 36.3 MV/m → 35.3 MV/m

MT-4 VT5



Eacc,max: 39.2 MV/m → 36.0 MV/m*

MT-5 VT5



Eacc,max: 36.3 MV/m → 30.9 MV/m

MT-4 VT5 Passband Mode Summary

	Cells 1&9	Cells 2&8	Cells 3&7	Cells 4&6	Cell 5	Comment
Initial π	22.73	22.73	22.73	22.73	22.73	C1 210° eq
Final π	35.98	35.98	35.98	35.98	35.98	Power limit due to heavy FE
6π/9	41.33	0	41.33	41.33	0	C9 60° eq
Initial 3π/9	20.68	41.36	20.68	20.68	41.36	C1 150° eq
Final 3π/9	20.82	41.64	20.82	20.82	41.64	C2 210° eq
Eacc,max	**41.33**	**41.64**	**41.33**	**41.33**	**41.64**	**Ave Eacc,max 41.454**

- MT-4 will be HPR'ed and retested

Cavity Histories – N-doping (2/0)

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100 µm EP1 900 °C 3h 20 µm EP2 120 °C 48h **VT1 (16.3 MV/m)**	100 µm EP1 900 °C 3h 30 µm EP2 120 °C 48h **VT1 (cold leak)**	100 µm EP1 900 °C 3h 20 µm EP2 120 °C 48h **VT1 (35.1 MV/m)**	100 µm EP1 900 °C 3h 30 µm EP2 120 °C 48h **VT1 (28.7 MV/m)**
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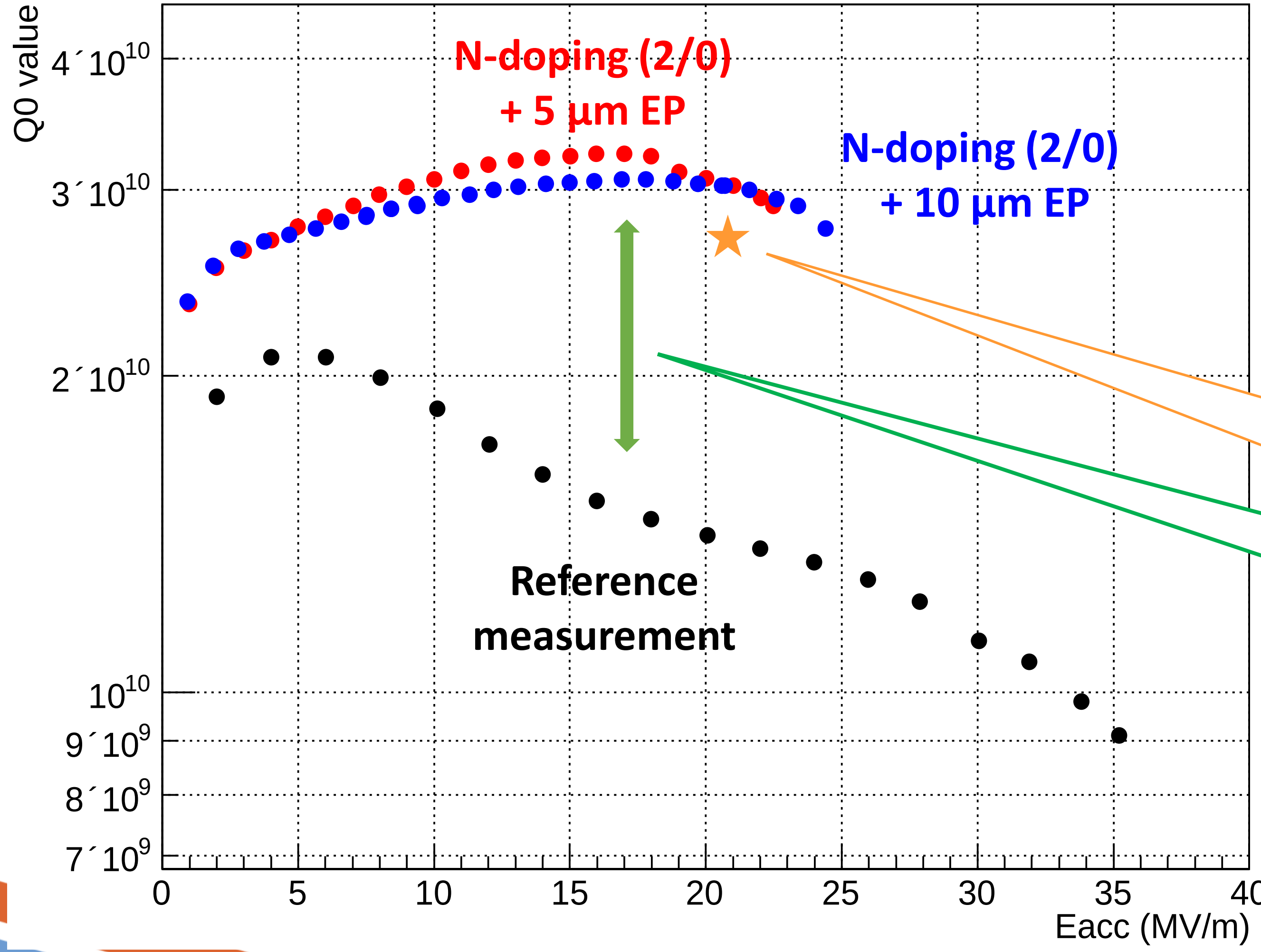
N-doping (2/0) Results (MT-5 VT3 & VT4)



Test	Limit for reference measurement
MT-5 VT1	Quench: C1 90°-120° eq

Test	Limit after N-doping
MT-5 VT3	Quench: C6 108° eq, 60° & 120° down
MT-5 VT4	Quench: C9 60° eq

Requirement for LCLS-II HE
Q_0 = 2.7x10^{10}
Eacc = 20.8 MV/m

An anti-Q slope clearly occurs for N-doped cavity

The first 9π-mode measurements are shown for VTs of the N-doped cavity

Summary

- ILC cost reduction R&D is performed on four TELSA SRF cavities
- Reference measurement: 120 °C 48h
- After generating severe defects on the inner surface of MT-4, the cavity could be reset and reach 39.2 MV/m
- Two-step baking did not show the anticipated improvements, only one case out of four looks promising
- N-doping (2/0) was applied to MT-5, exceeded LCLS-II HE requirements in both VTs (removal of 5 µm and 10 µm)

Thank you very much for your attention! Questions?