中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

SRF2011 CHICAGO
15th International Conference on RF Superconductivity

IHEP 1.3 GHz Low Loss Large Grain 9-cell Cavity R&D

Jiyuan Zhai (IHEP, China)

On behalf of the IHEP 1.3 GHz SRF Team

SRF2011, Chicago

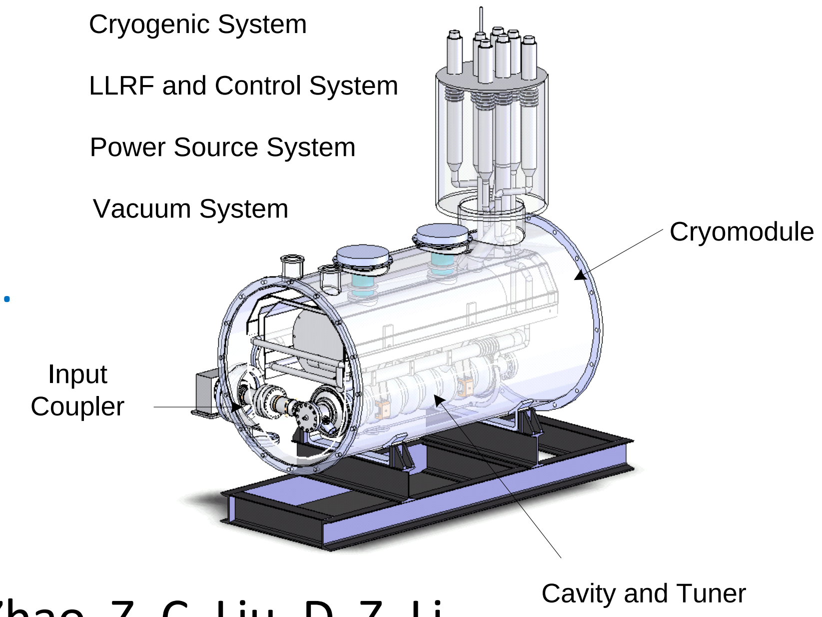
July 27, 2011

Outline

- IHEP 1.3 GHz SRF Program
- Large grain low loss 9-cell cavity
- Other components progress
- Summary

IHEP 1.3 GHz SRF R&D Program

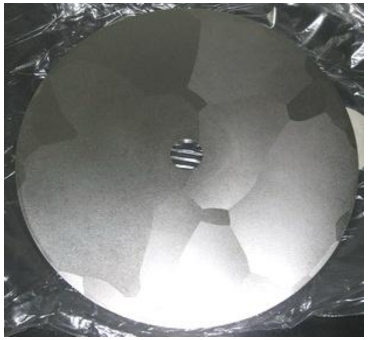
- Develop 1.3 GHz SRF Tech
  - key components and infrastructures
  - short cryomodule (HTS) with ILC spec.
  - 2009-2012

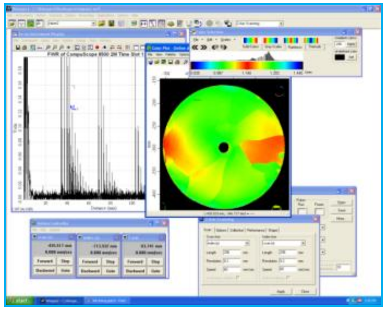


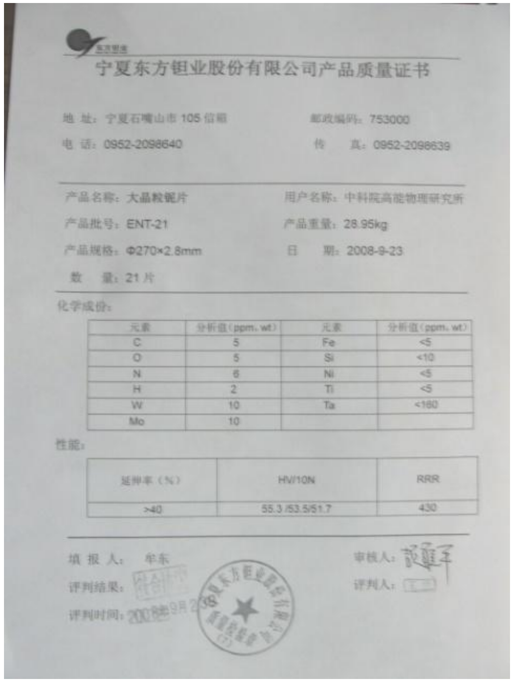
- Team (*led by J. Gao*)
  - Cavity: J. Gao, J. Y. Zhai, Z. Q. Li. T. X. Zhao, Z. C. Liu, D. Z. Li
  - Input coupler: W. M. Pan, T. M. Huang, Q. Ma
  - Tuner & LLRF: Y. Sun, G. W. Wang, H. S. Guo, F. Qiu, H. Y. Liu
  - Cryomodule: S. P. Li, R. Ge, C. H. Li
  - RF Power Source: Y. L. Chi
  - SRF Infrastructure: J. P. Dai, Q. Y. Wang

Large Grain Niobium

- ultrasonic and eddy current scanning tests
- mechanical behavior sample test at room temp. and 4K







宁夏东方钽业股份有限公司产品质量证书

地 址：宁夏石嘴山市 105 信箱　　邮政编码：753000

电 话：0952-2098640　　传 真：0952-2098639

产品名称：大晶粒铌片　　用户名称：中科院高能物理研究所

产品批号：ENT-21　　产品重量：28.95kg

产品规格：Φ270×2.8mm　　日 期：2008-9-23

数 量：21 片

化学成份：

元素	分析值（ppm，wt）	元素	分析值（ppm，wt）
C	5	Fe	<5
O	5	Si	<10
N	6	Ni	<5
H	2	Ti	<5
W	10	Ta	<180
Mo	10		

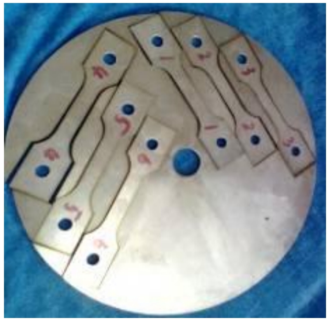
性能：

延伸率（%）	HV/10N	RRR
>40	55.3 /53.5/51.7	430

填 报 人：　牟东　　审核人：

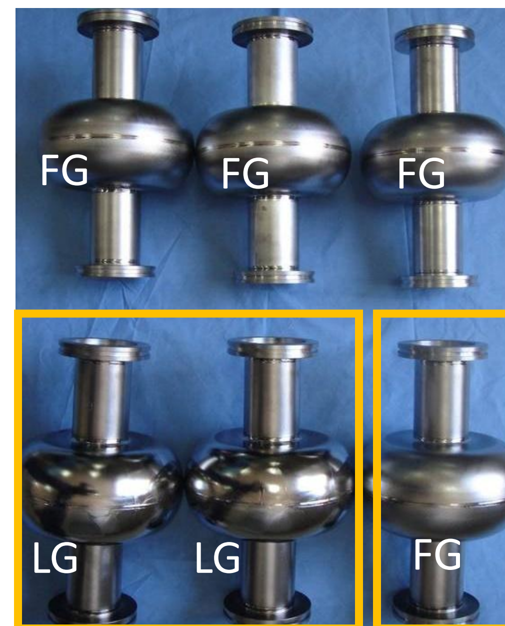
评判结果：　　评判人：

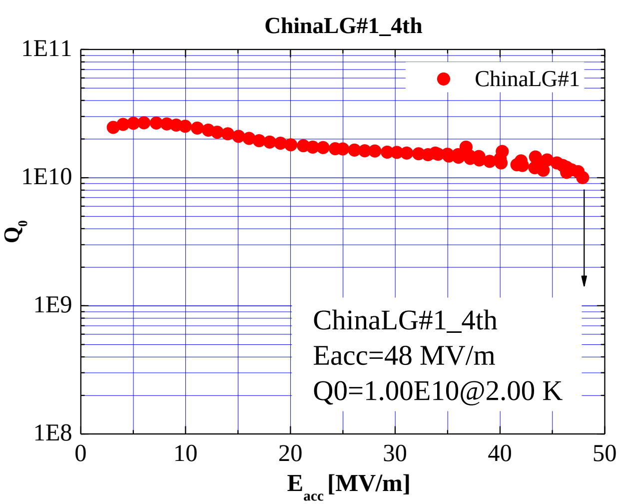
评判时间：2008年9月23

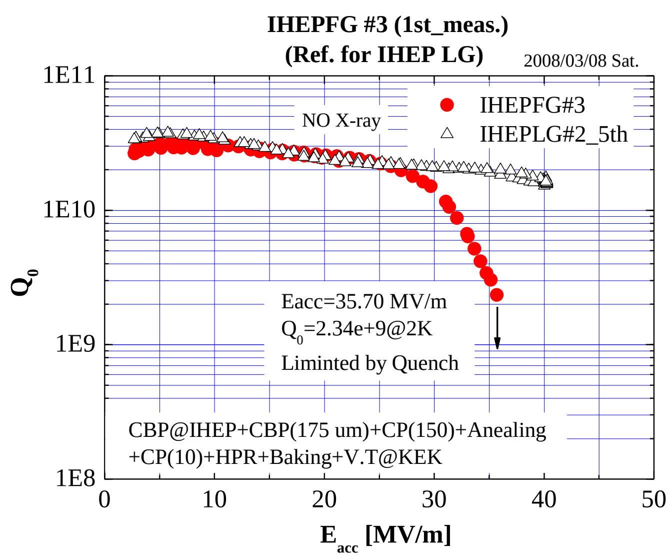


Single Cell Cavities

- 3 Ningxia large grain cavities, made by KEK, in 2007: 48 MV/m (CBP + EP)
- 2 Ningxia large grain cavities, fabricated and processed in IHEP, tested at KEK in 2008
  40 MV/m (CBP + BCP)
- 1 fine grain cavity for reference study







Low Loss large grain 9-cell Cavity

- Research frontier
  - Low loss shape : KEK 40 MV/m with end groups (FG, EP)
  - Large grain EP: DESY 46 MV/m with end groups
  - Large grain BCP : ~ 30 MV/m (DESY and KEK)
- IHEP-01 without end groups
  - Fabricated in Beijing with Ningxia OTIC large grain Nb
  - 2009 ~ 2010

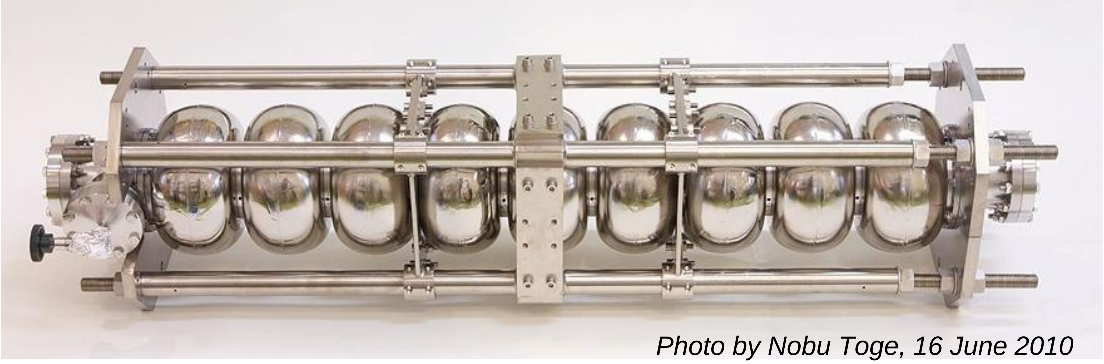
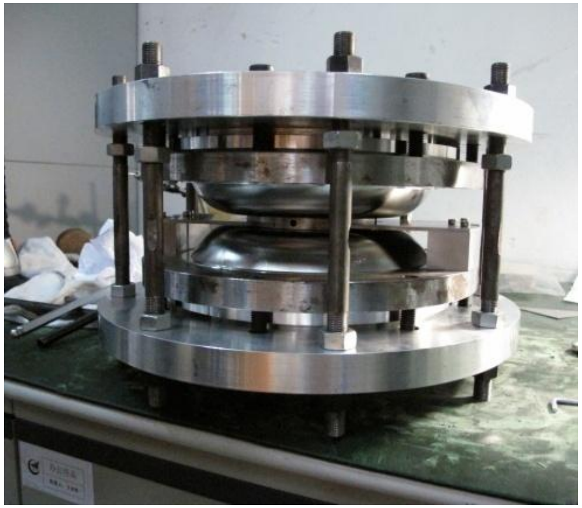
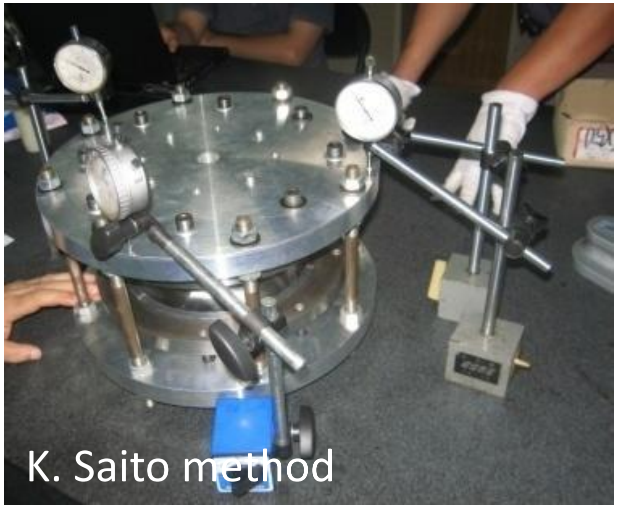
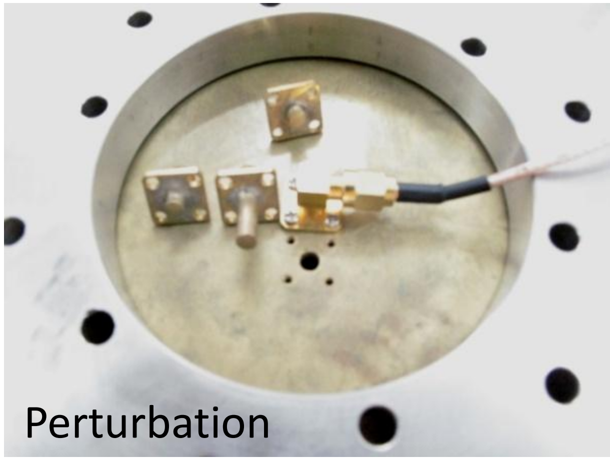


Photo by Nobu Toge, 16 June 2010

Fabrication







- Fabrication and EBW challenges
  - Low loss shape
  - Large grain
- Precise freq. and length control

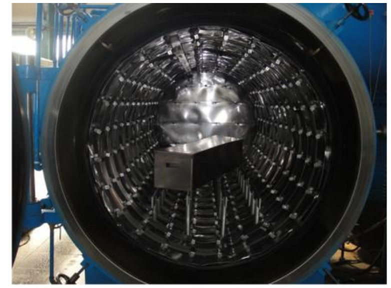
Processing

- CBP + bulk BCP + anneal + tune + light BCP + HPR + bake
  - 1st pass: CBP 190 µm + BCP 130 µm
  - 2nd pass: CBP 150 µm + BCP 110 µm (10 µm in JLAB)
  - totally ~ 600 µm removed in the equator area, 4 kg Nb
  - annealing: 750 C, 3 hours, 1E-4 Pa
  - field flatness
    - 1st pass: 98 % vertical bare, 94 % v. with jig, 92 % horizontal with jig after VT
    - 2nd pass: 99 % h. bare, 92 % v. bare, 90 % after VT
    - 10 µm BCP < 1 % F.F. reduction, flip up and down to reduce F. F. change
    - relative passband frequency change in VT2: RT to 2 K 4%, 2 K to RT 50%
    - passband field profile measurement after VT2, cell gradient correction?

1st Pass Processing

CBP

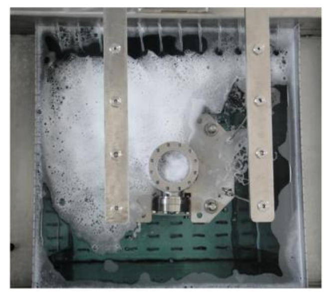
1st BCP



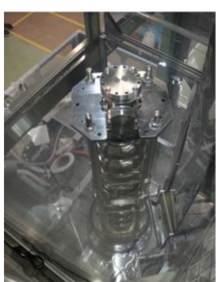
Annealing

(IHEP)

Pre-tuning & 2nd BCP



Ultrasonic Cleaning (at IHEP & KEK)



HPR

Assembly and Pumping

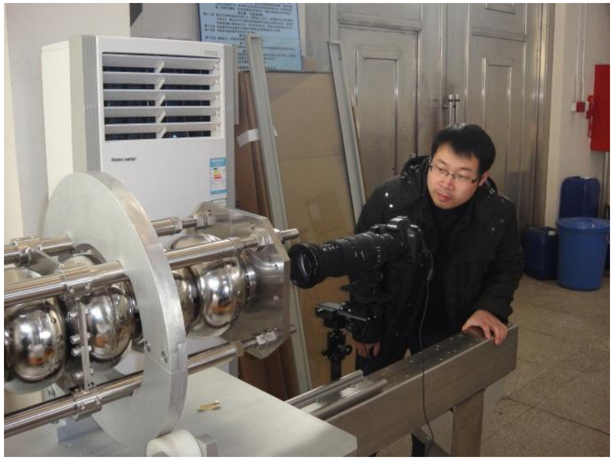
Baking

(KEK)

1st Vertical Test at KEK on July 2010

STF T-mapping system

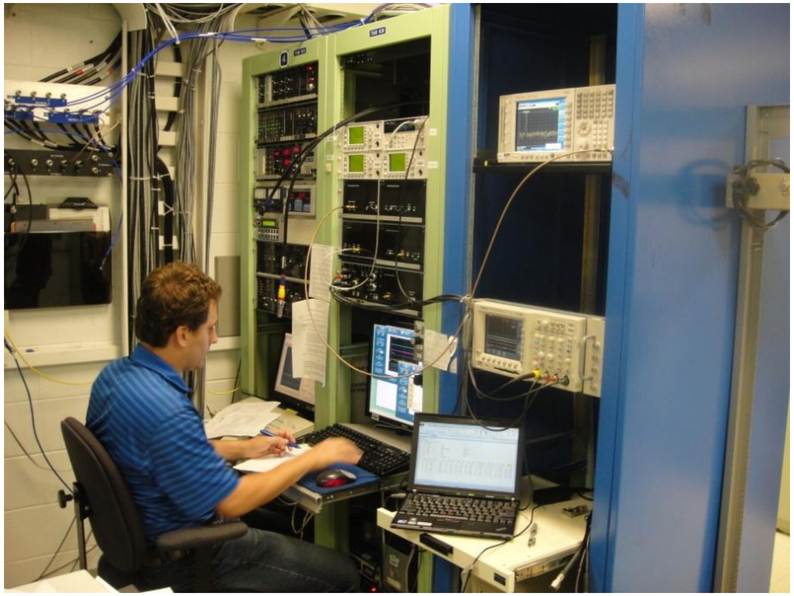
2nd Pass Processing



CBP, bulk BCP, Annealing, Pretuning, Inspection, Ultrasonic, light BCP, HPR at IHEP

Field flatness check, Ultrasonic, flash BCP, HPR, Assemble, Baking at JLAB

2nd Vertical Test at JLAB, July 2011



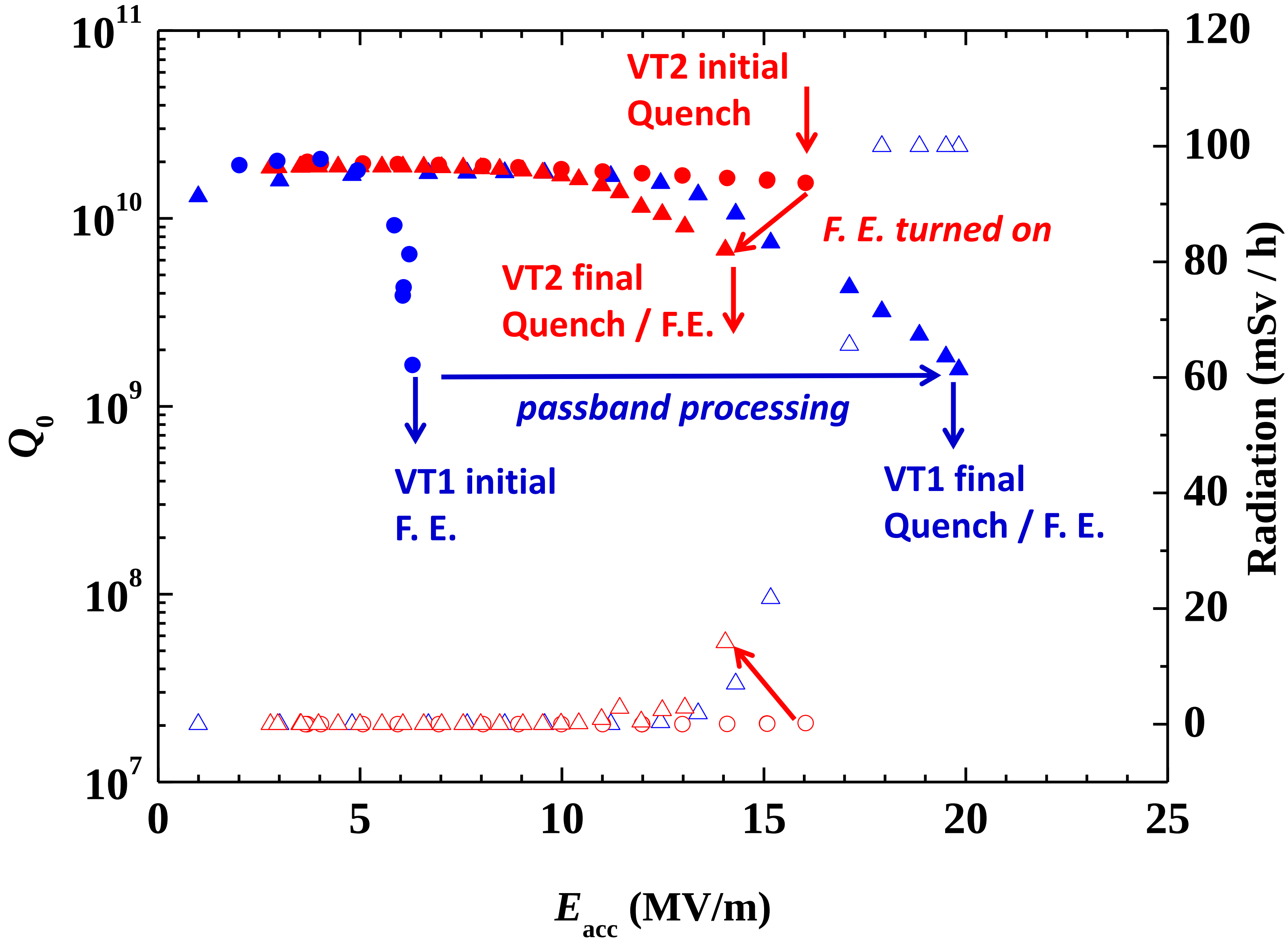
Thermometry near VT1 quench location

OST (2nd Sound) setup

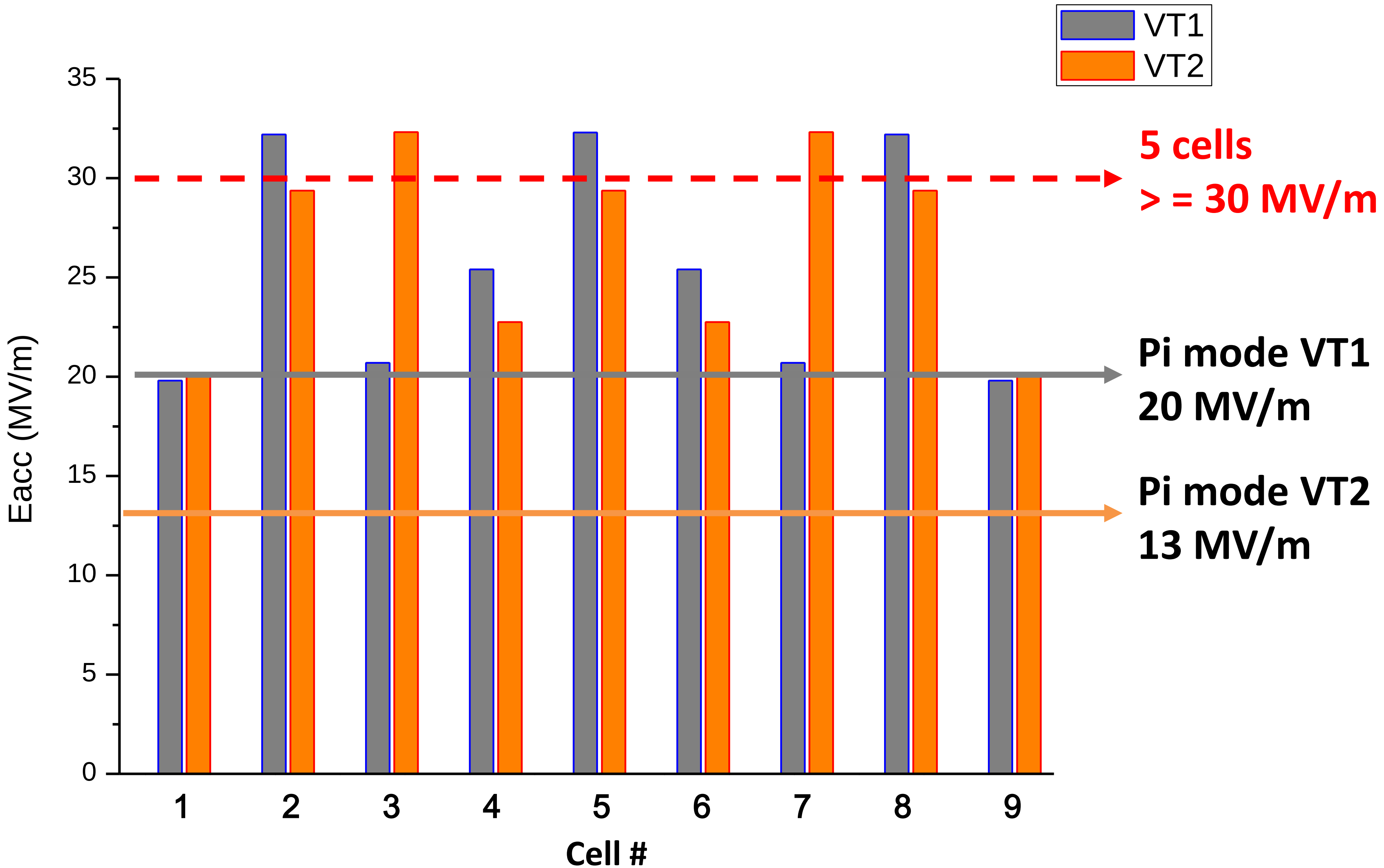
He Pressure Frequency: 335 Hz / Torr

Lorentz detuning factor: 6 Hz / $(MV/m)^2$

1st and 2nd Test Results



Cell Gradient and Analysis



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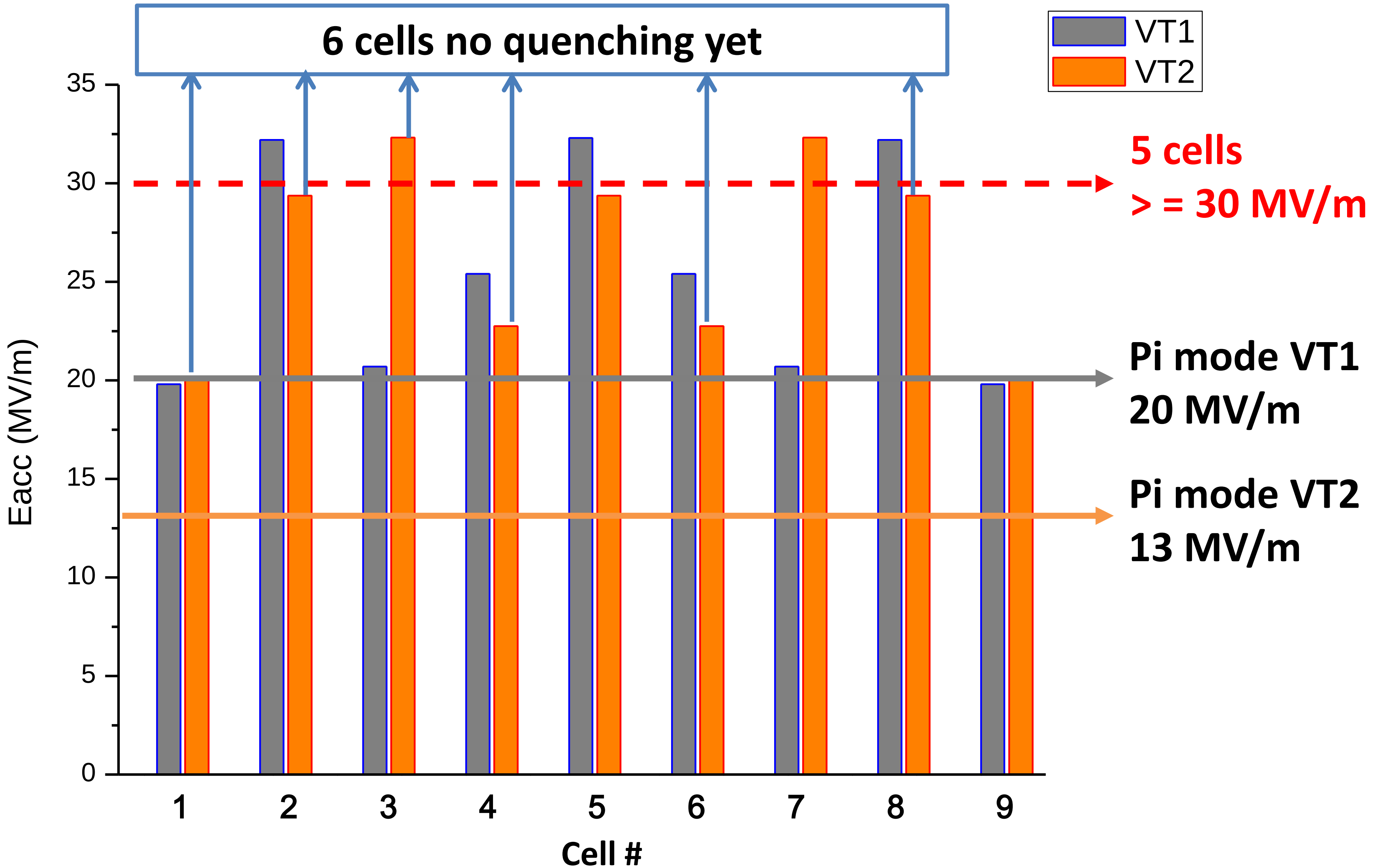

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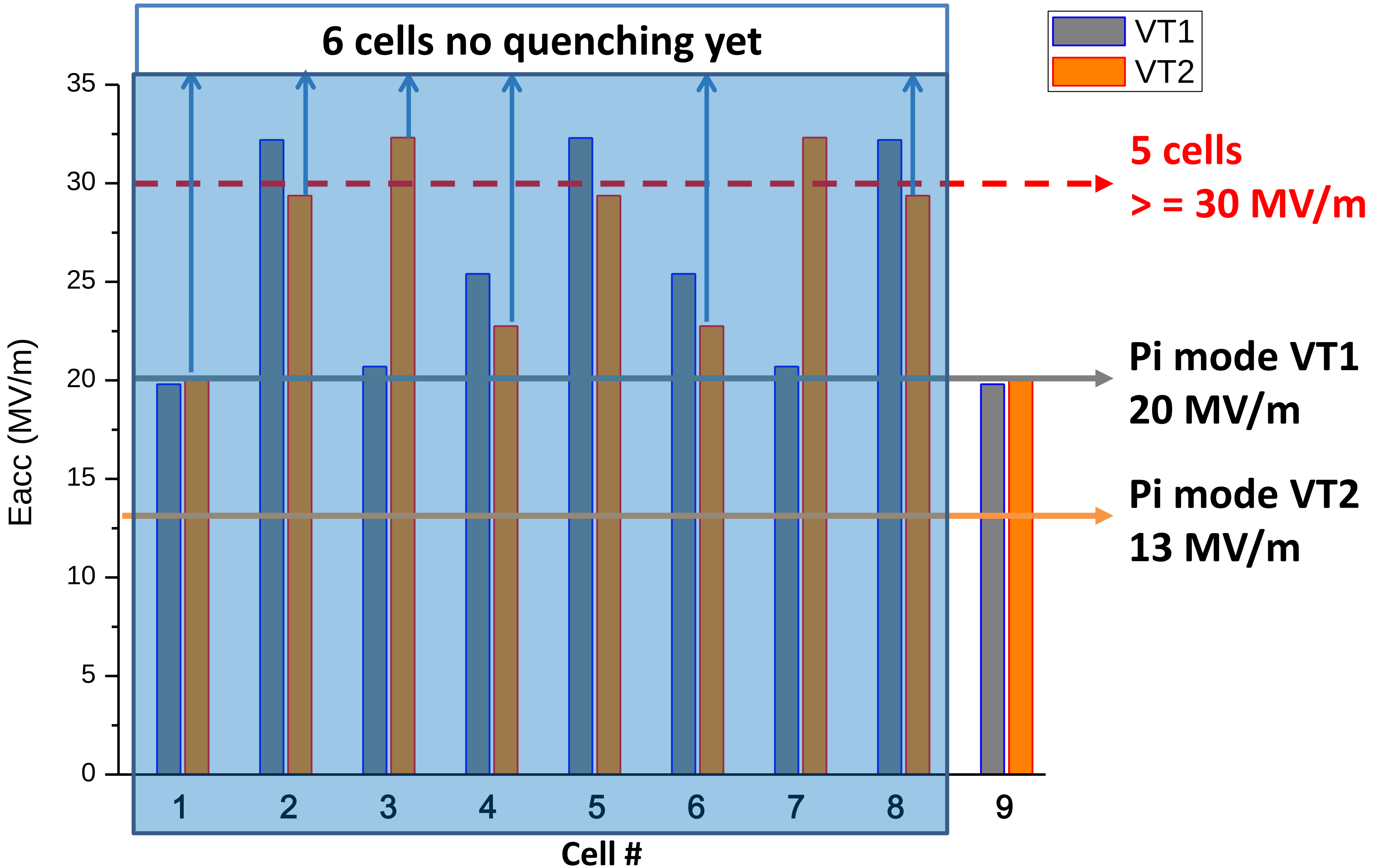
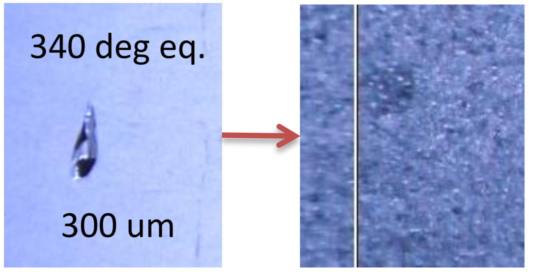
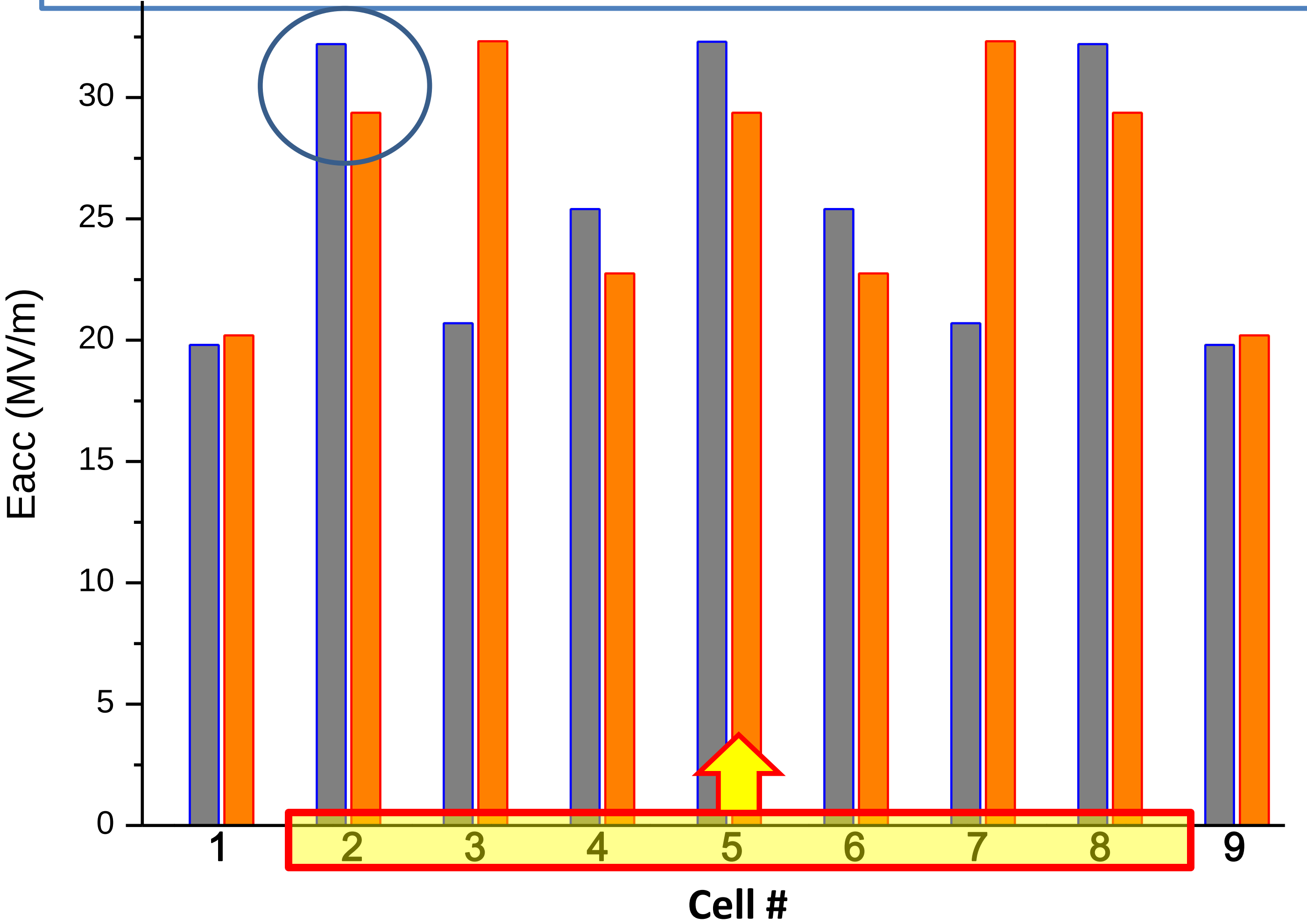


- cell#2 quenched in VT1 at 32 MV/m
- bump found by T-mapping & inspection
- eliminated by CBP
- cell#5 quenched first in VT2
- no way to push cell#2 higher





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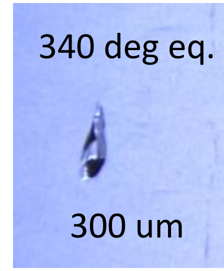
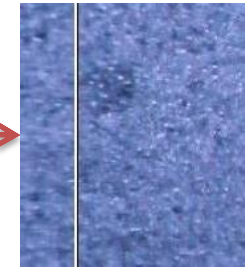
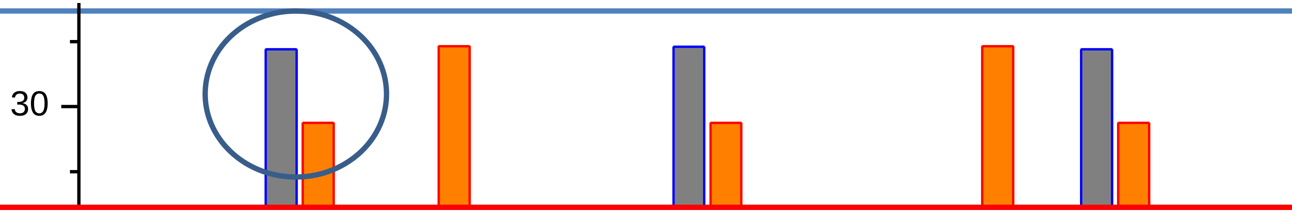
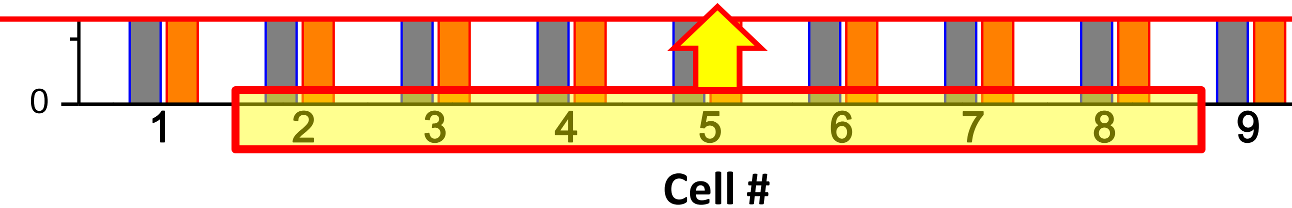
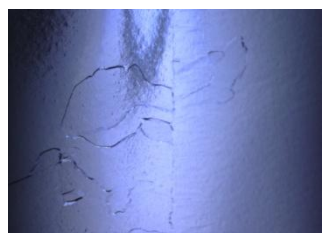








Typical equator pictures for cell #2, 3, 4, 5, 6, 7, 8

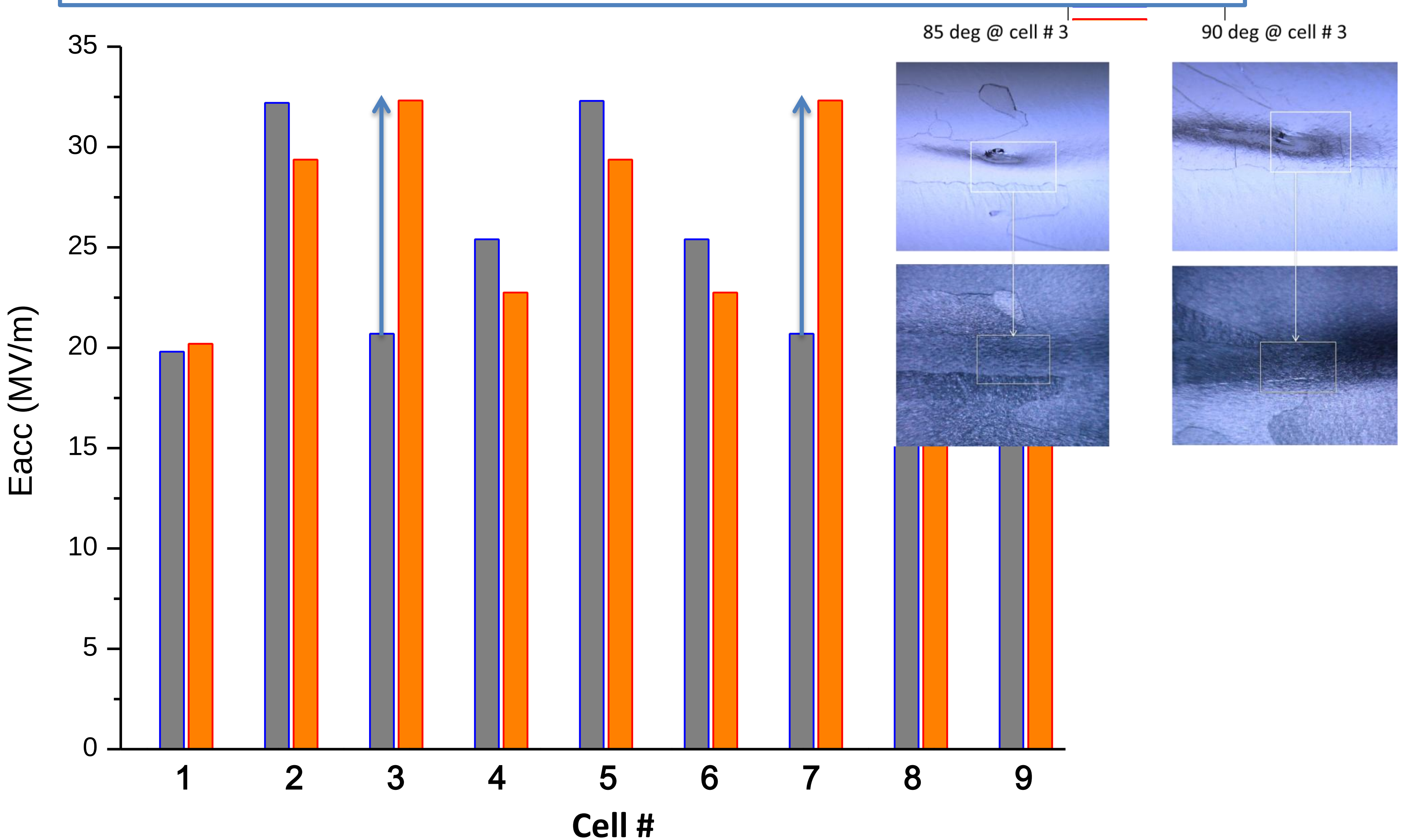


EBW company asked us to anneal the dumbbells to get rid of hydrogen. But why cell #1 & 9 equators, single cell equators and dumbbell iris EBW no sputtering?

Although so many sputtering spots, we can reach 30 MV/m in at least five cells by CBP. No underneath bubbles.

#3 & 7 increased because we didn't test 2Pi/9 mode in VT1.

Two defects were removed after VT1 by CBP, but we will never know it matters or not above 20 MV/m. At least for 20 MV/m is OK.



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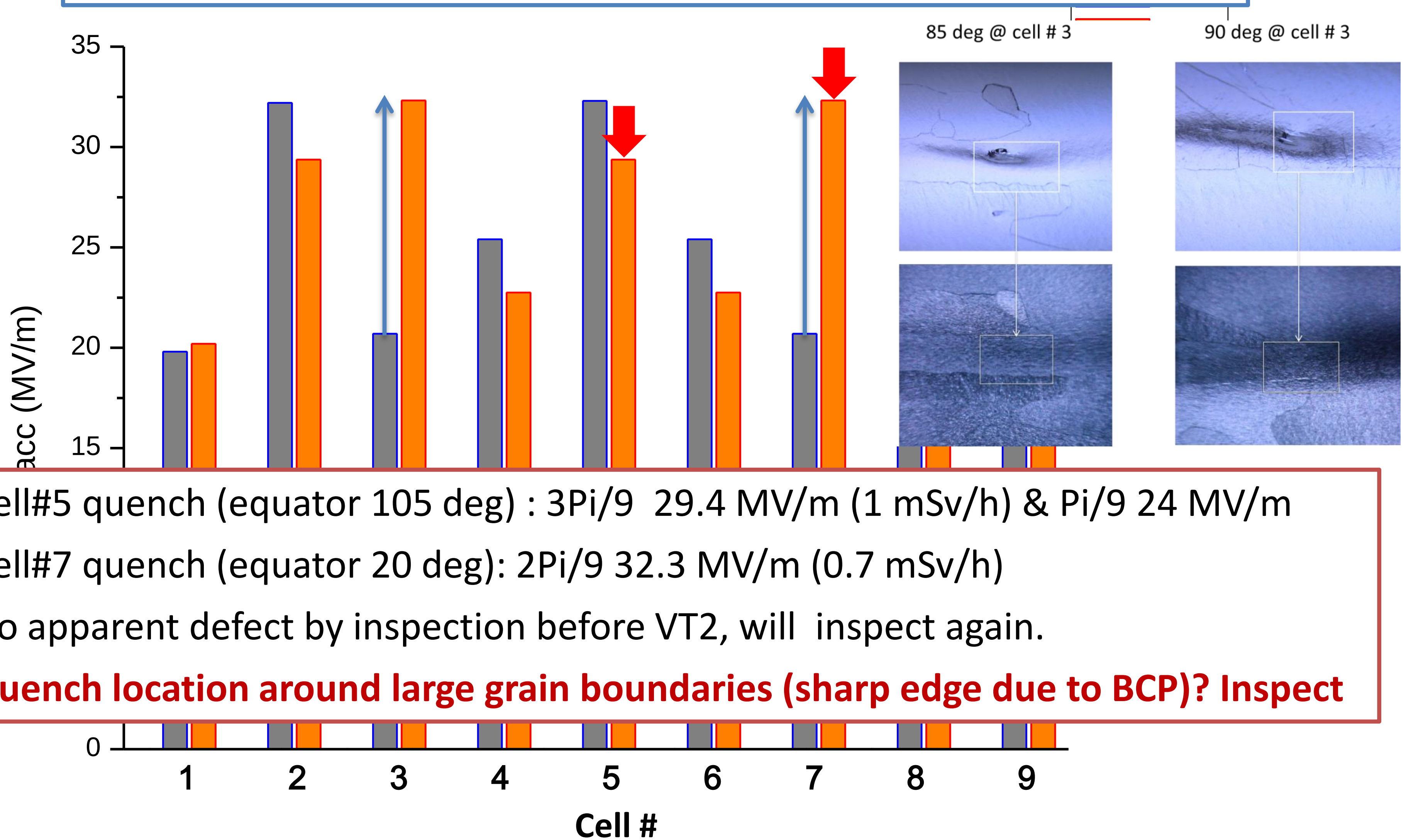
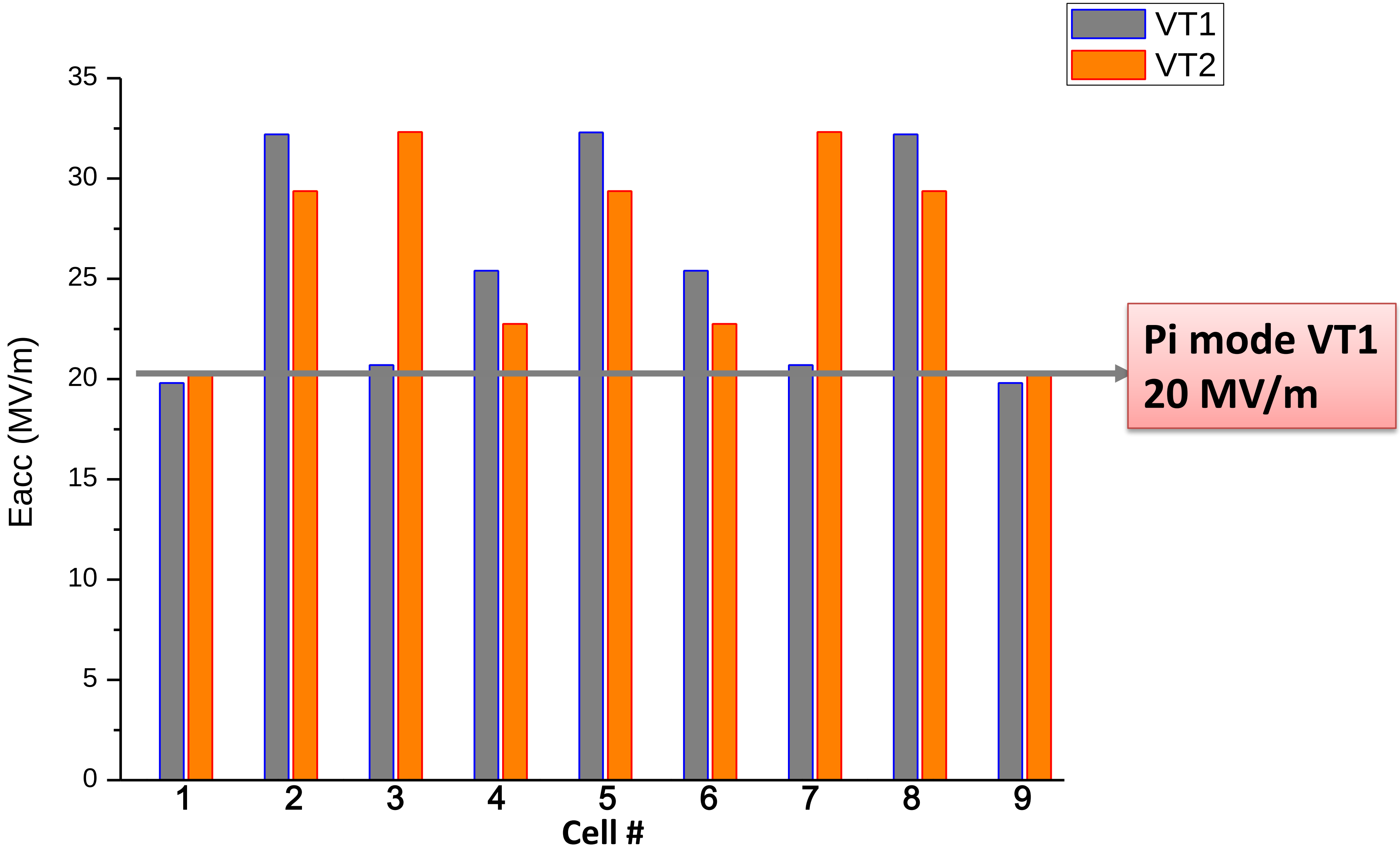


Cell#5 quench (equator 105 deg) : 3Pi/9 29.4 MV/m (1 mSv/h) & Pi/9 24 MV/m

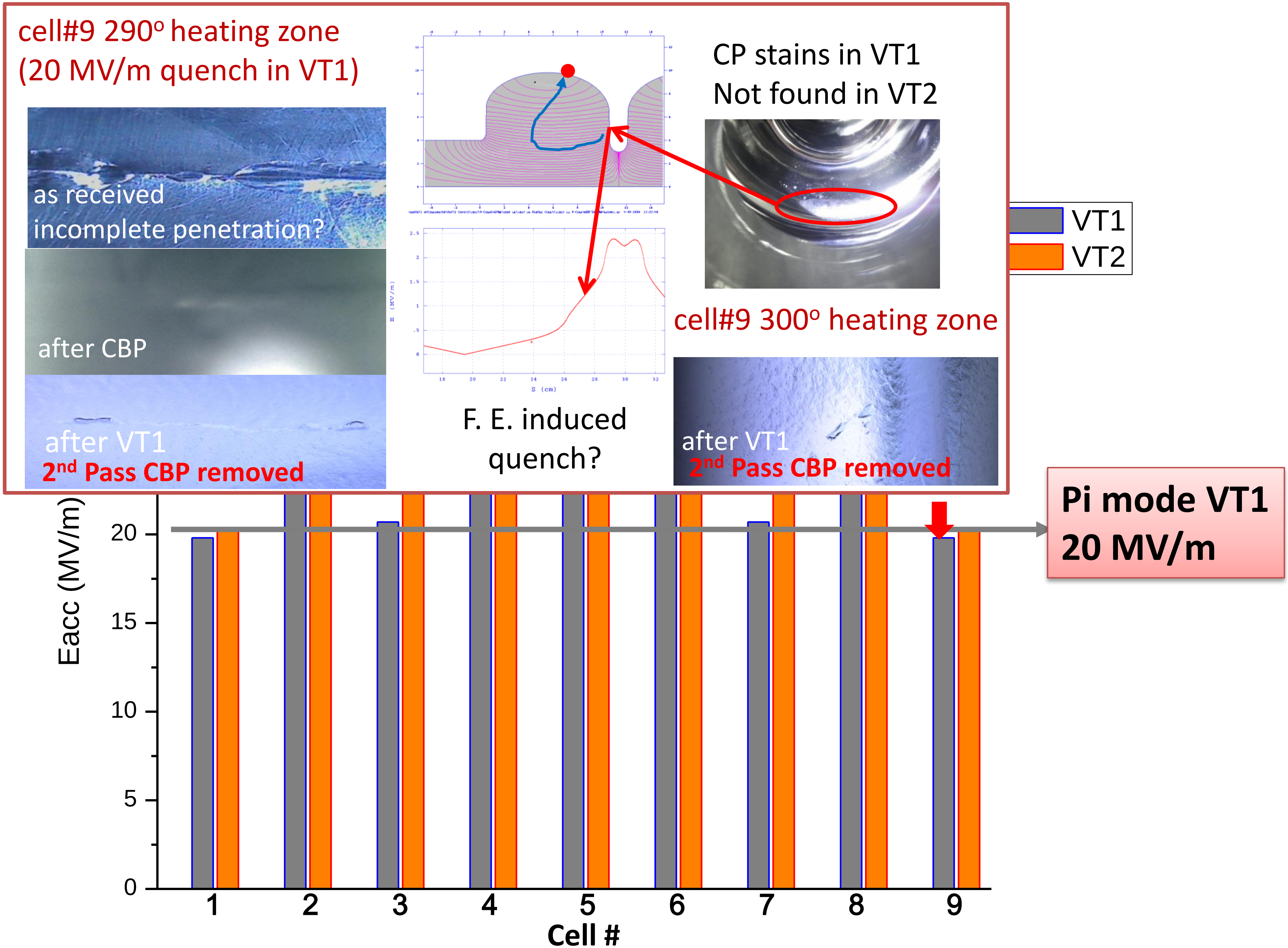
Cell#7 quench (equator 20 deg): 2Pi/9 32.3 MV/m (0.7 mSv/h)

No apparent defect by inspection before VT2, will inspect again.

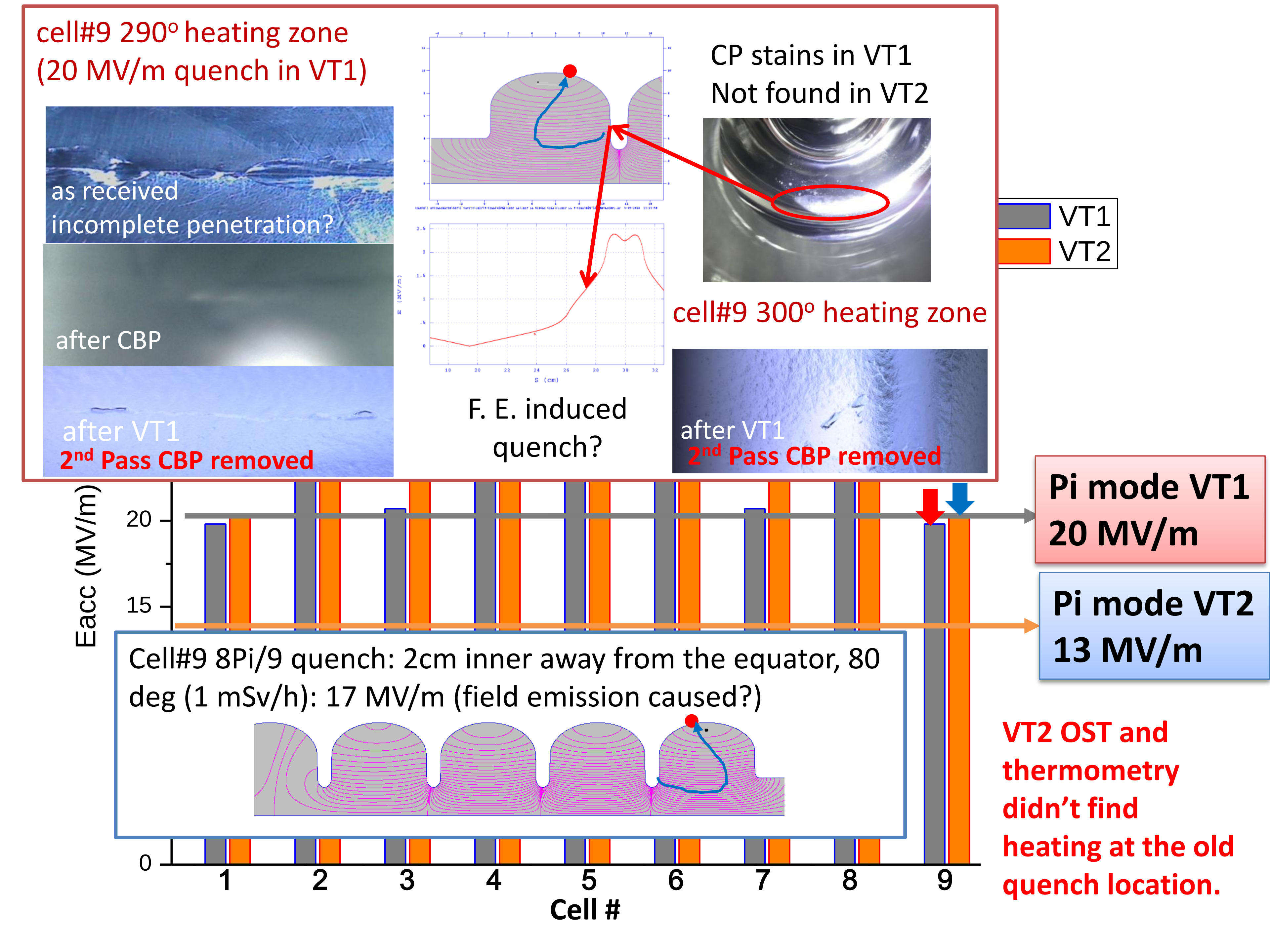
Quench location around large grain boundaries (sharp edge due to BCP)? Inspect



VT1
VT2
35
30
25
20
15
10
5
0
Eacc (MV/m)
1
2
3
4
5
6
7
8
9
Cell #
Pi mode VT1
20 MV/m



cell#9 290° heating zone
(20 MV/m quench in VT1)
as received
incomplete penetration?
after CBP
after VT1
2nd Pass CBP removed
F. E. induced
quench?
CP stains in VT1
Not found in VT2
cell#9 300° heating zone
after VT1
2nd Pass CBP removed
VT1
VT2
Pi mode VT1
20 MV/m
Eacc (MV/m)
Cell #
0
5
10
15
20
1
2
3
4
5
6
7
8
9



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(20 MV/m quench in VT1)
as received
incomplete penetration?
after CBP
after VT1
2nd Pass CBP removed
F. E. induced
quench?
CP stains in VT1
Not found in VT2
cell#9 300° heating zone
after VT1
2nd Pass CBP removed
VT1
VT2
Pi mode VT1
20 MV/m
Pi mode VT2
13 MV/m
Eacc (MV/m)
20
15
0
Cell#9 8Pi/9 quench: 2cm inner away from the equator, 80 deg (1 mSv/h): 17 MV/m (field emission caused?)
1
2
3
4
5
6
7
8
9
Cell #
VT2 OST and thermometry didn't find heating at the old quench location.

Field Emission Induced Iris Quenches

- <u>OST</u>: iris cell#7&8, ~ 90 - 120 deg
  - T-mapping can't reach iris area
- <u>Passband test</u> quench gradient*:

Pi : 12.9 MV/m (5 mSv/h)

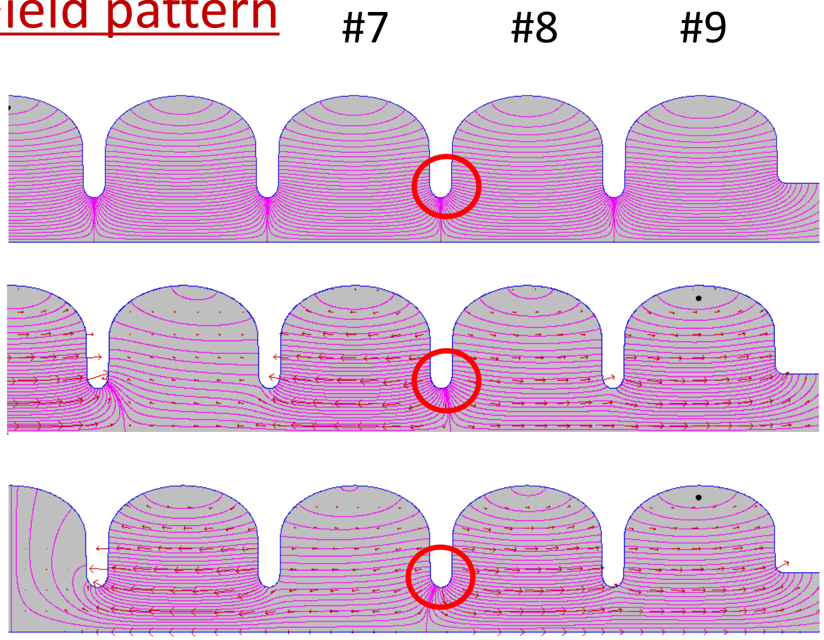
5Pi/9 : 14.6 MV/m (0.3 mSv/h)

4Pi/9 : 13.8 MV/m (5 mSv/h**)

* for 5Pi/9 and 4Pi/9 mode, the gradient is equivalent Pi mode gradient of the end cell (#9)

** highest radiation of the passband modes

<u>Field pattern</u>



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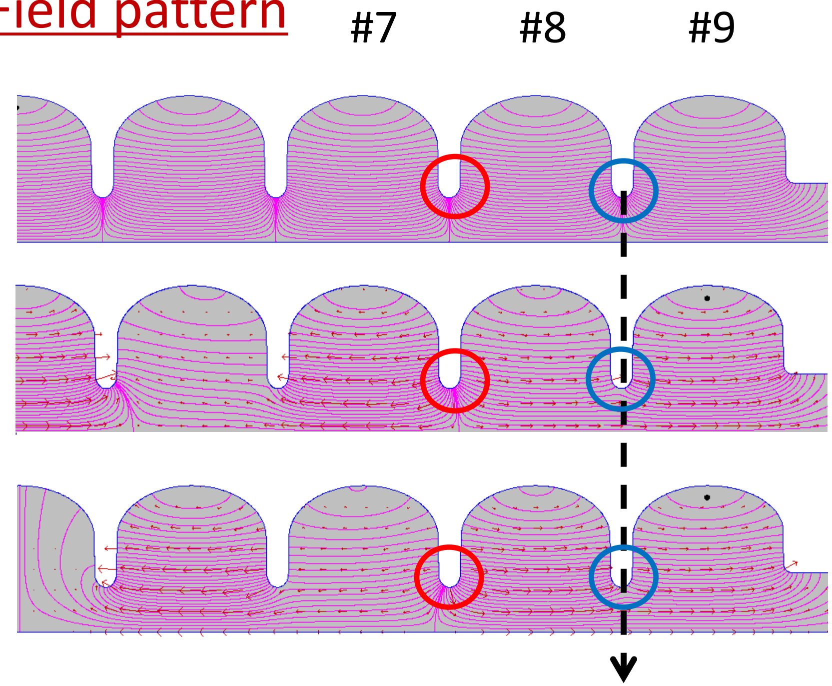
- Inspection: iris pit cell#8&9, 90 deg

Field pattern



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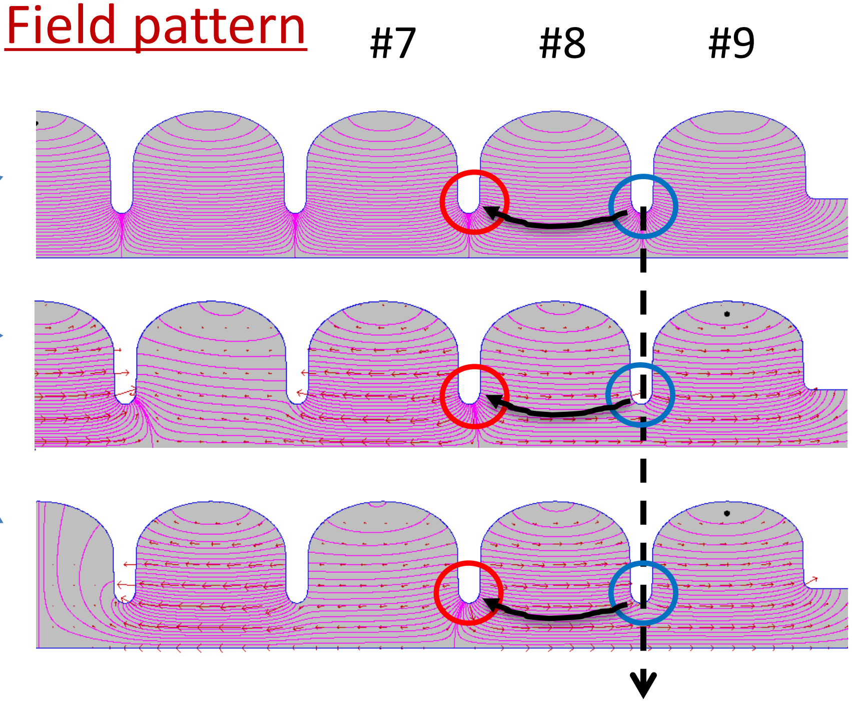

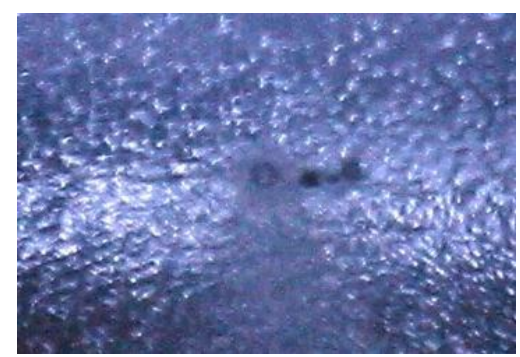

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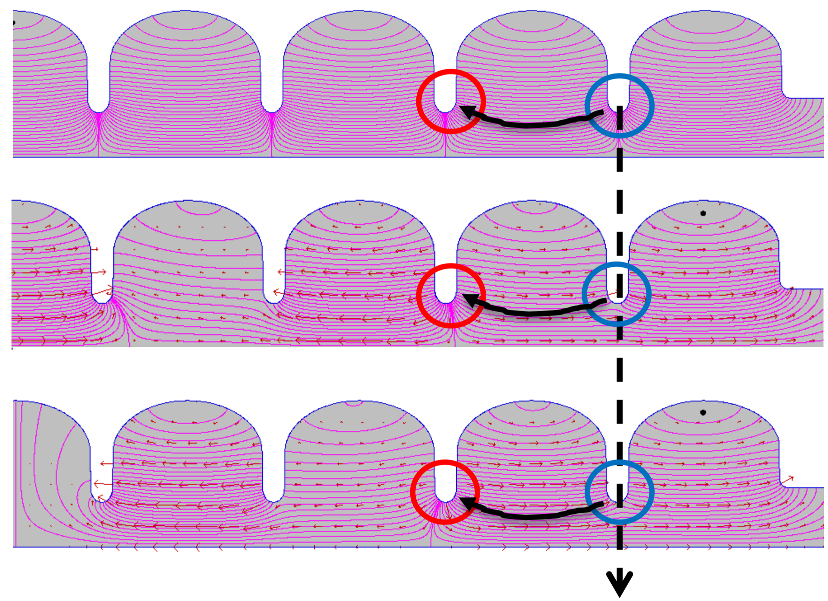
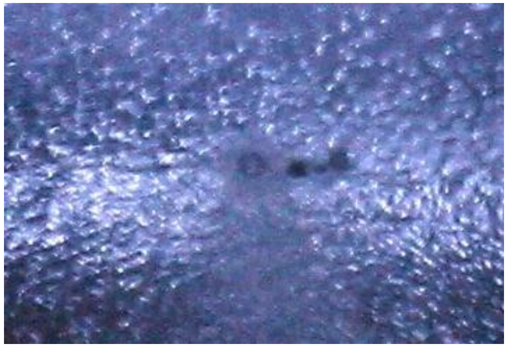
** highest radiation of the passband modes

Field pattern

#7 #8 #9



- Inspection: iris pit cell#8&9, 90 deg
- Pit azimuthal positions, cell gradients, field patterns & radiation levels are correlated, pointing to field emission induced iris quench. The defects may be uncovered after intensive hand and machine grinding and BCP.
- This is why the Pi mode gradient is limited at 13 MV/m, while all cells are higher than 20 MV/m .



Cavity Quench and Defects Summary

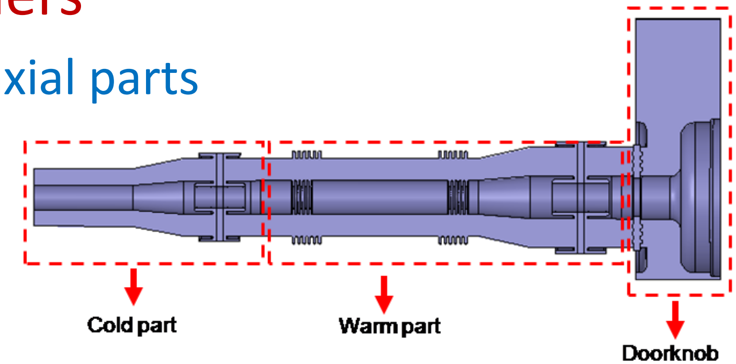
1. quench around 40 MV/m (in BCP single cell)
2. 30 MV/m quench without F.E. (cell#2 defect, VT1)
3. 30 MV/m quench with F.E. (cell#5&7, VT2)
4. 20 MV/m equator quench with F. E. (cell#9, VT1)
5. 13 MV/m iris quench with F.E. (iris#7-8, VT2)

Next Steps

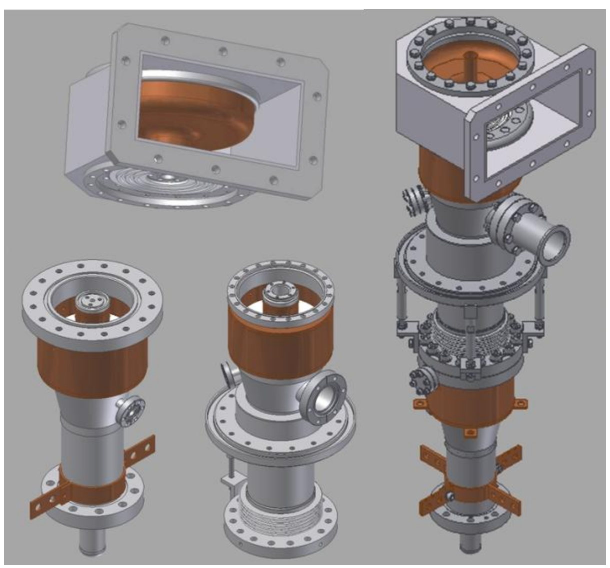
- Inspect to identify defects (iris and equator)
- Reduce low field field emission
  - HPR again and test
  - EP
  - iris repair (?)
- Higher gradient
  - BCP limit: 30 MV/m or 40 MV/m?
  - EP
- IHEP-02 large grain low loss with end groups
  - will finish fabrication in Nov. 2011, test in Feb. 2012

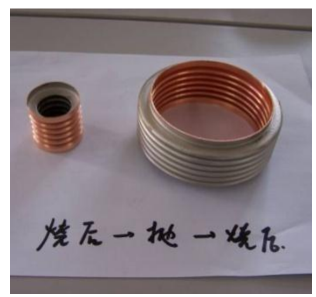
High Power Input Coupler

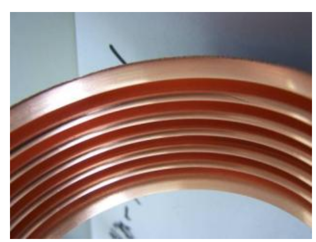
- Two double-choke-window input couplers
  - uniform copper plating on bellows and coaxial parts
  - TiN coating on ceramics
  - finished fabrication of two couplers
  - high power test: October 2011



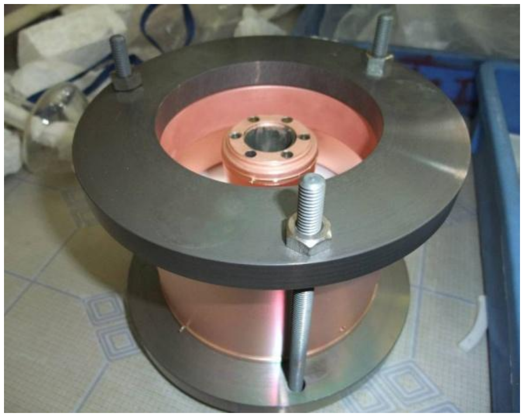
Refer to E. Kako (KEK)



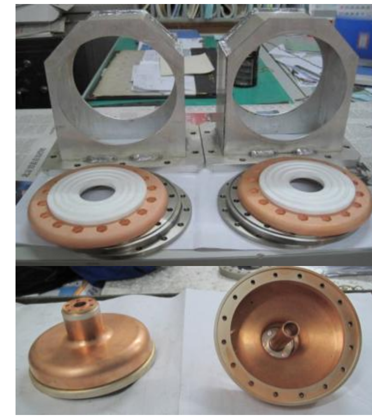




Welded Coupler Parts



Warm and Cold Window, based on the experience of BEPCII 500 MHz 400 kW CW power input coupler (W. M. Pan etc.)



Door knob

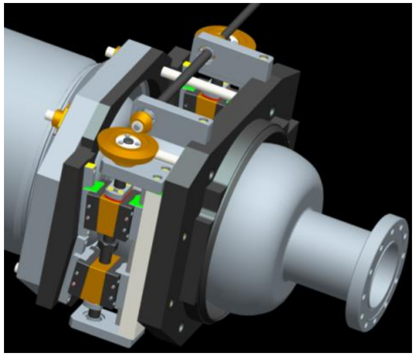
Warm outer part

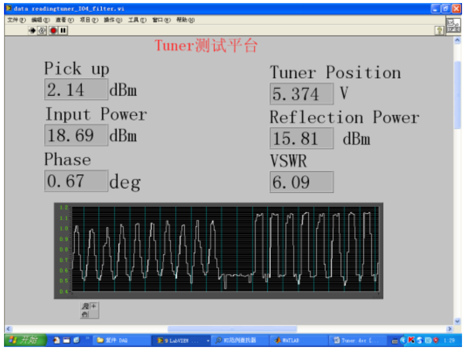
Warm inner part

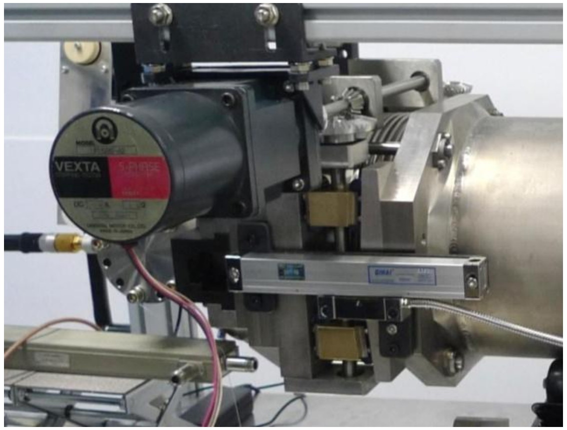
Cold outer and inner parts

Tuner and LLRF

- Home-made slide jack tuner
- Performance test with MHI-04 from KEK
  - Tuner stroke
  - Piezo
  - Stability
- Cold test planned
- Motor inside cryomodule

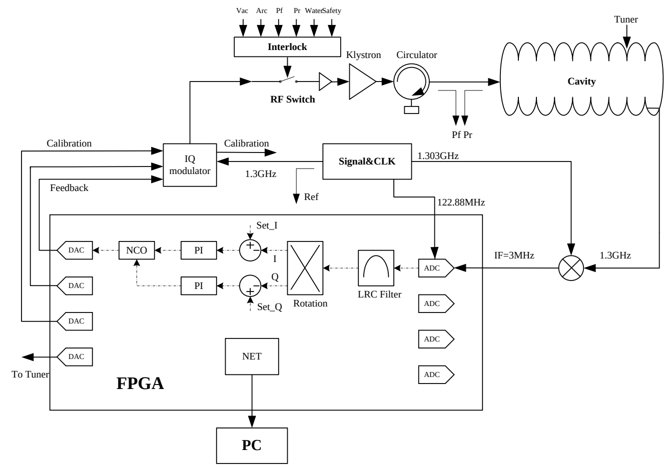


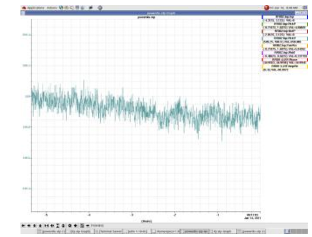


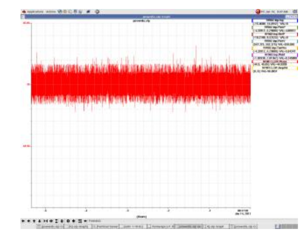


Refer to S. Noguchi (KEK)

LLRF Performance @ RT

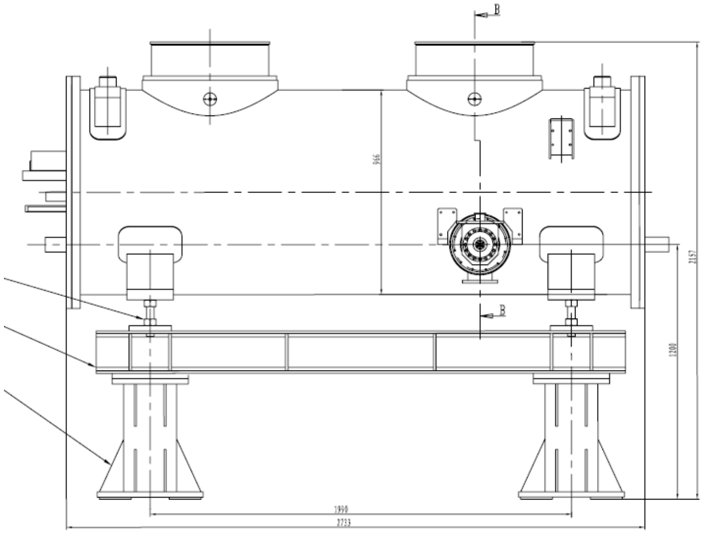


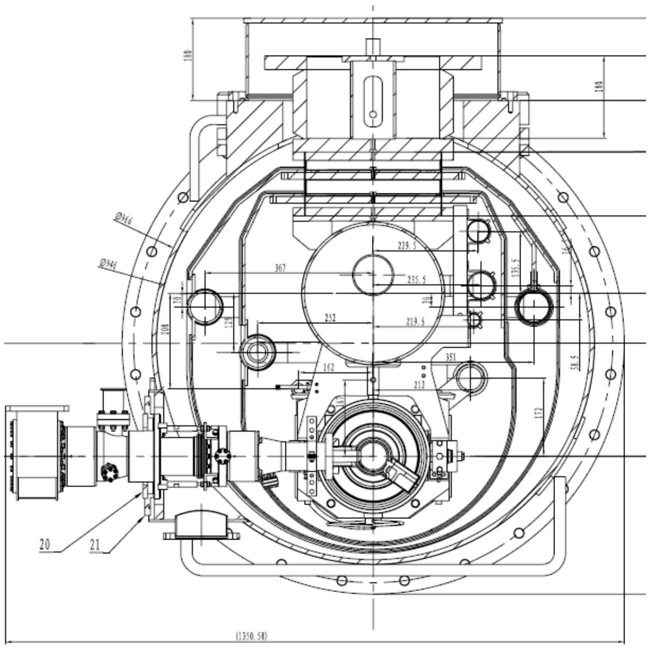




Frequency stability	±1 kHz (room temperature)
Amplitude stability	±0.05 % (peak to peak)
Phase stability	±0.035° (peak to peak)
Response time	70 μs
Dynamic range	20 dB

Cryomodule for the 9-cell Cavity





- Based on PXFEL1 success and XFEL cryomodule mass production
- Design finished, fabricate and assemble in 2011-2012
- Horizontal test with IHEP’s new cryogenic system

IHEP SCRF Infrastructures





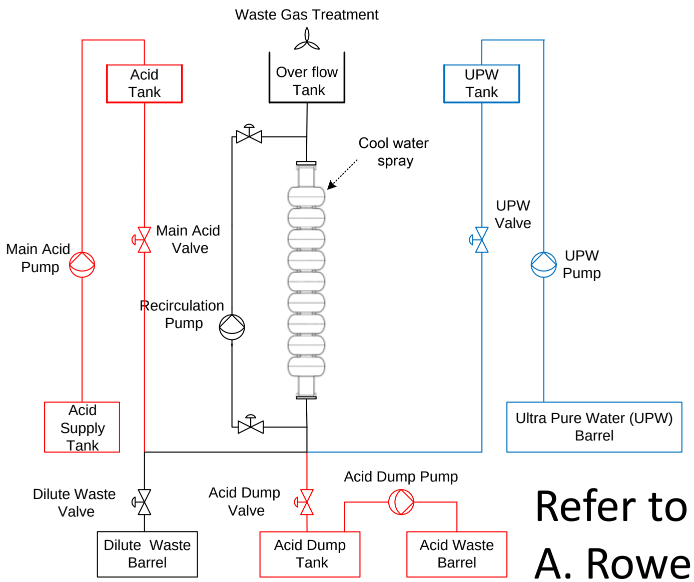






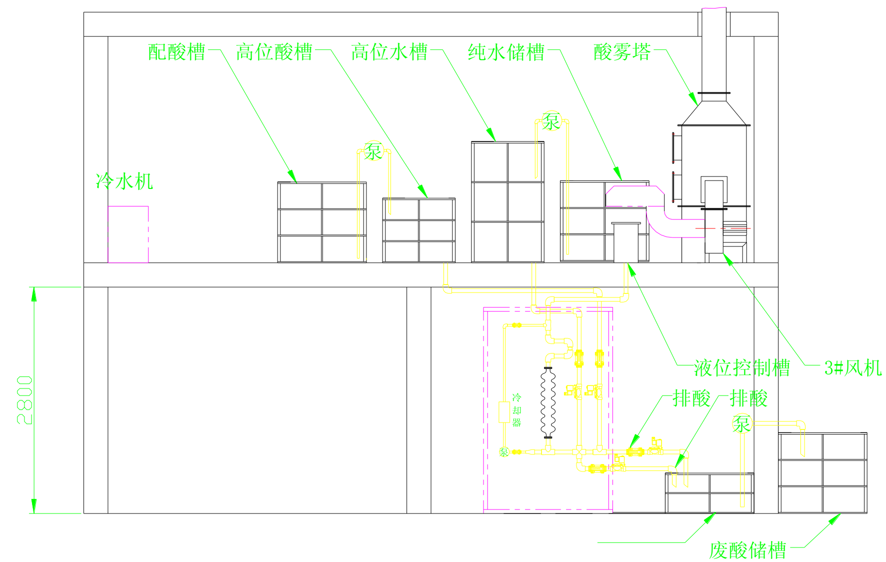


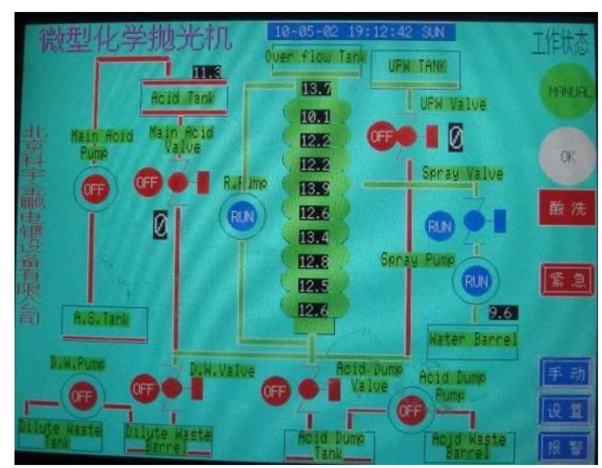
BCP



Refer to

A. Rowe of FNAL



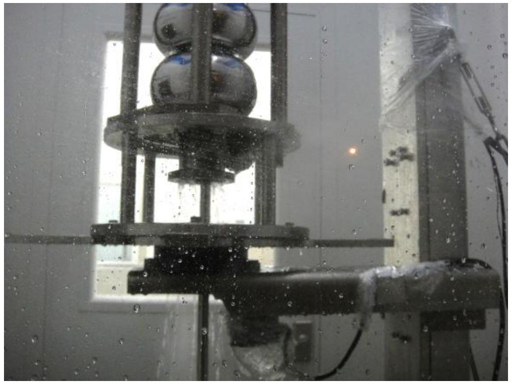


High Pressure Water Rinsing (HPR)

- Nozzle fixed, Cavity rotate and move

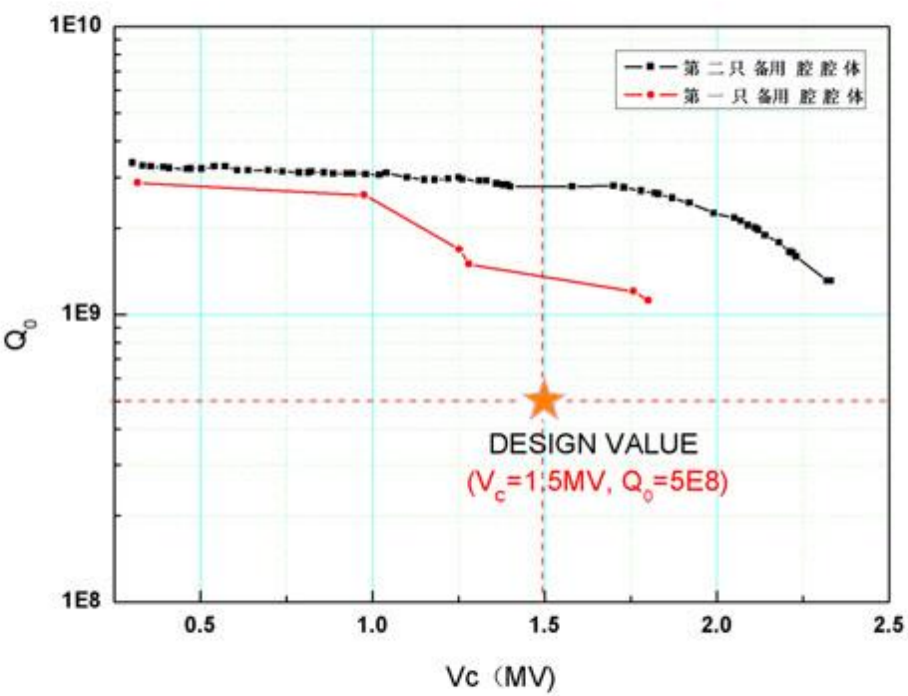




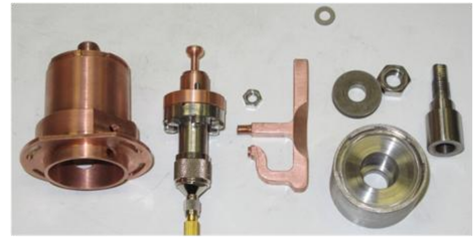


Cavity process and test with IHEP SRF Facility

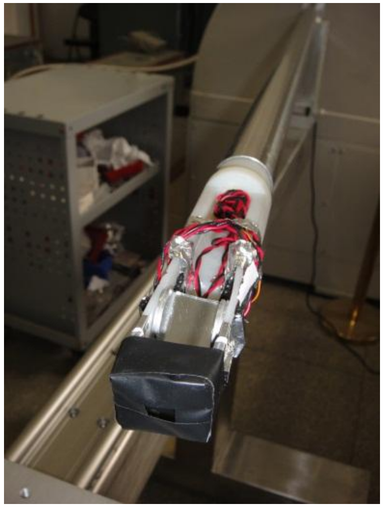
- BCP, HPR, clean room and vertical test system were verified by the BEPCII 500 MHz cavity processing and test at IHEP
- Facilities may need improvement for higher gradient cavity

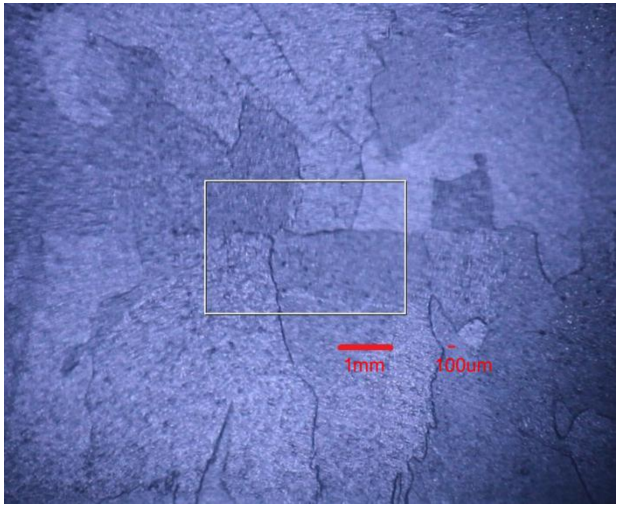


Cavity RF and LLRF Lab



High Resolution Inspection Camera





NEXT STEPS

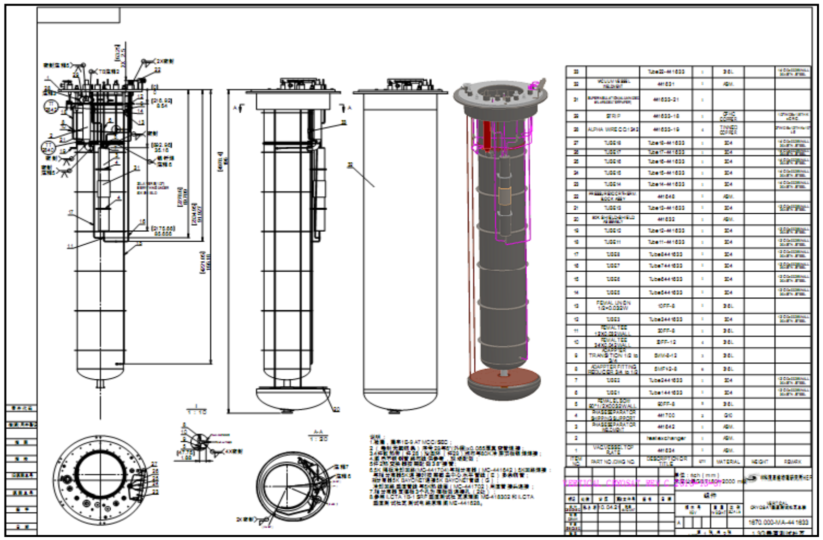
Better image: clearer

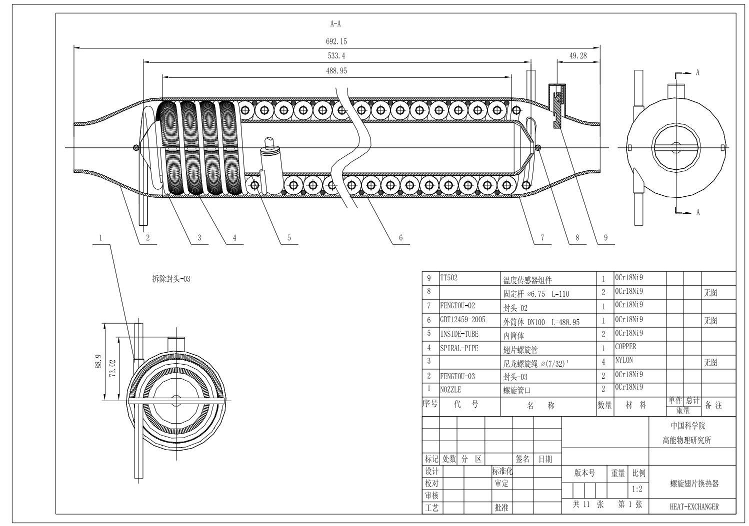
•improve the lighting and optical lens system

Automatic:

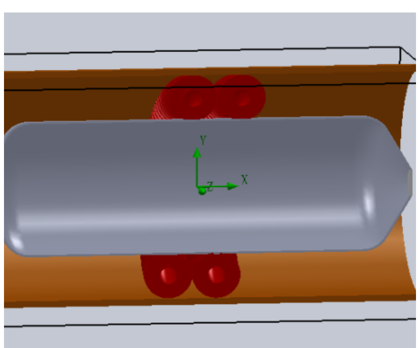
•install motors for cavity moving & rotation
•better camera moving base
•auto photo-taking and focusing

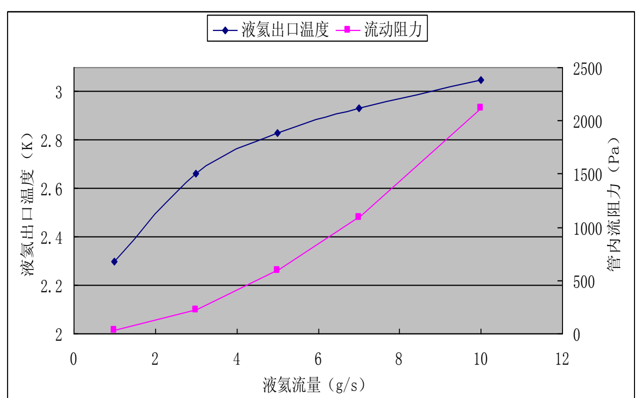
Vertical Test Dewar and Heat Exchanger

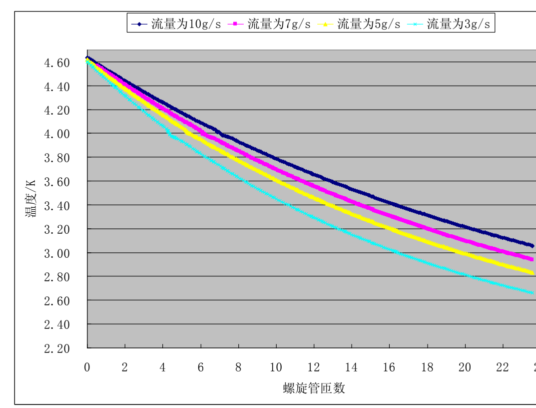




Refer to FNAL







Summary

- Three 9-cell cavities (LG LL, FG TESLA-like) R&D
  - IHEP-01 two tests, continue to lower F. E. and higher gradient
  - IHEP-02 1st VT in 2012, install to IHEP cryomodule for HT
  - IHEP-03 in fabrication, for beam test
- Various SRF facilities were developed
- International collaborations with KEK, FNAL and JLAB are productive.

Acknowledgement

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Thank you!

And welcome to the TTC meeting

IHEP, Beijing, December 5-8, 2011