Performance of CLIC prototype accelerator structures tested at Nextef

CLIC2014

4 February 2014

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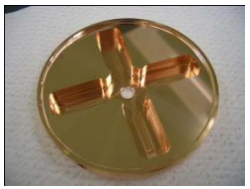
Contents

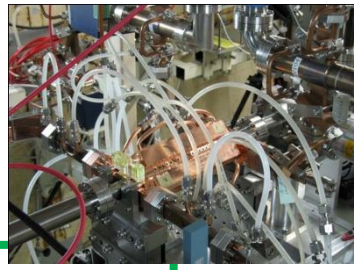
- Overview of Nextef high gradient tests
- Most recent result of TD24R05#4
- Comparison of recent structure result
- Future activities at Nextef
- Issues of Nextef high power test

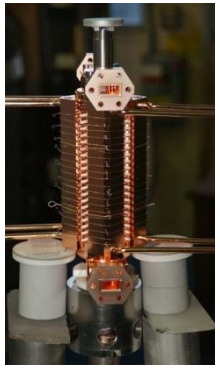
Overview on Nextef high gradient tests

- Idea
  - Test CLIC prototype structures made as twin
  - Fabrication based on SLAC/KEK
  - Independent high gradient tests
- Work share
  - Design by CERN
  - Fabrication & test by SLAC & KEK
- History
  - Started in 2008 to test CLIC prototype structures
  - Has kept running to date and in future as needed

CERN/SLAC/KEK test flow



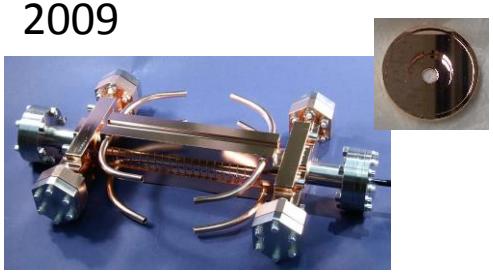




Fabrication and test of LC prototype structures

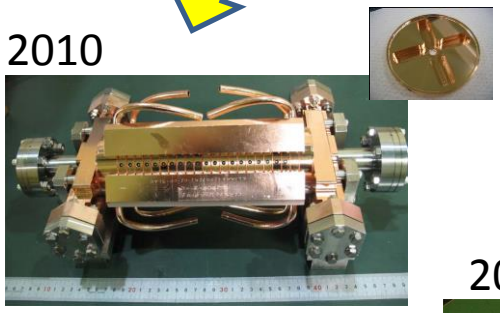
T18 → Quad → TD18 → T24 → TD24 → TD24R05 → TD24R05

2009



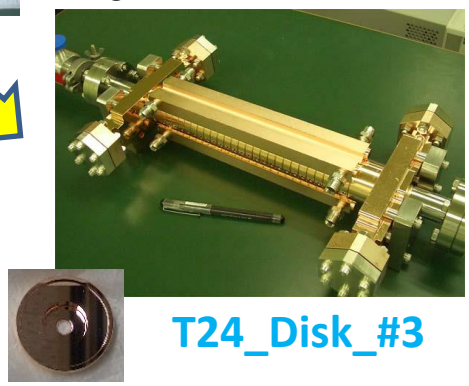
T18_Disk_#2

2010



TD18_Disk_#2

2011

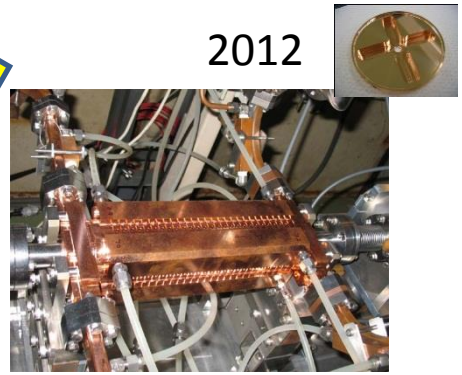


T24_Disk_#3

2011-2012

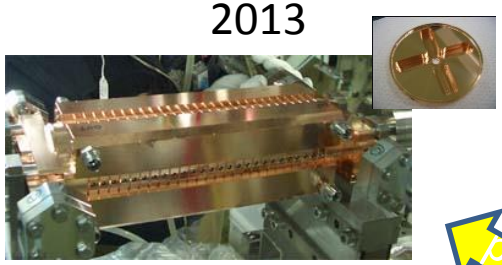
TD24_Disk_#4

2012

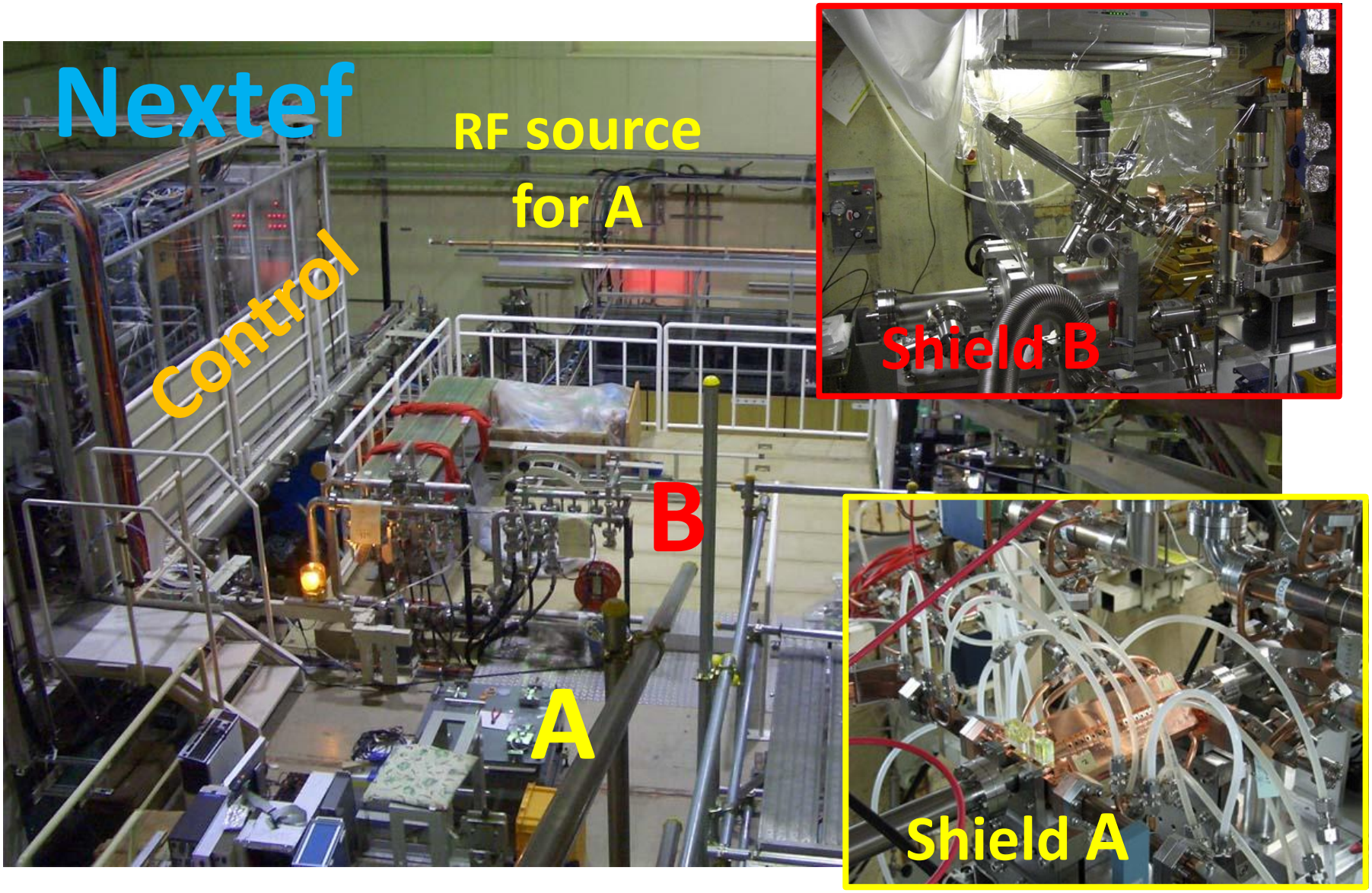


TD24R05_#2

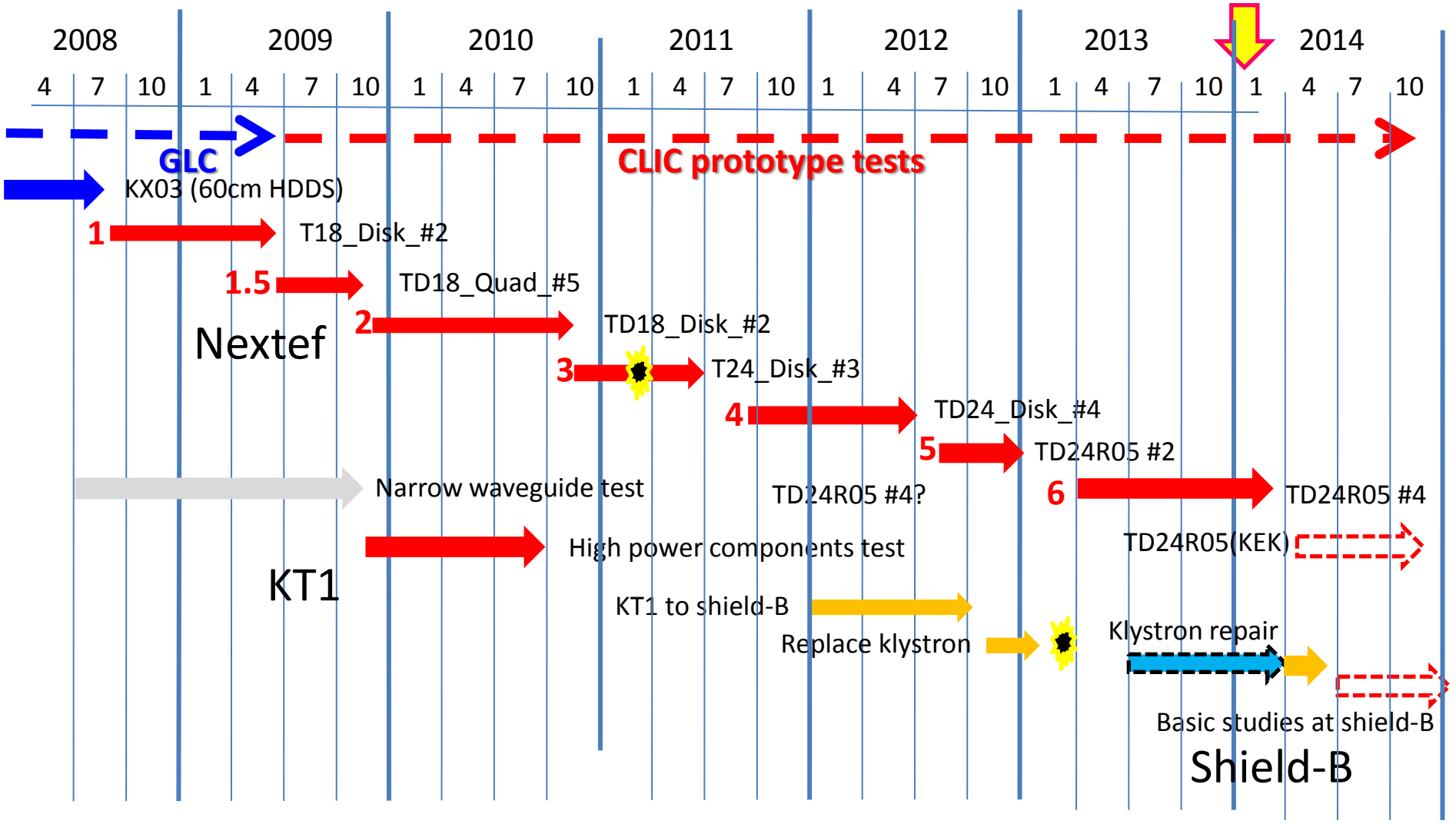
2013



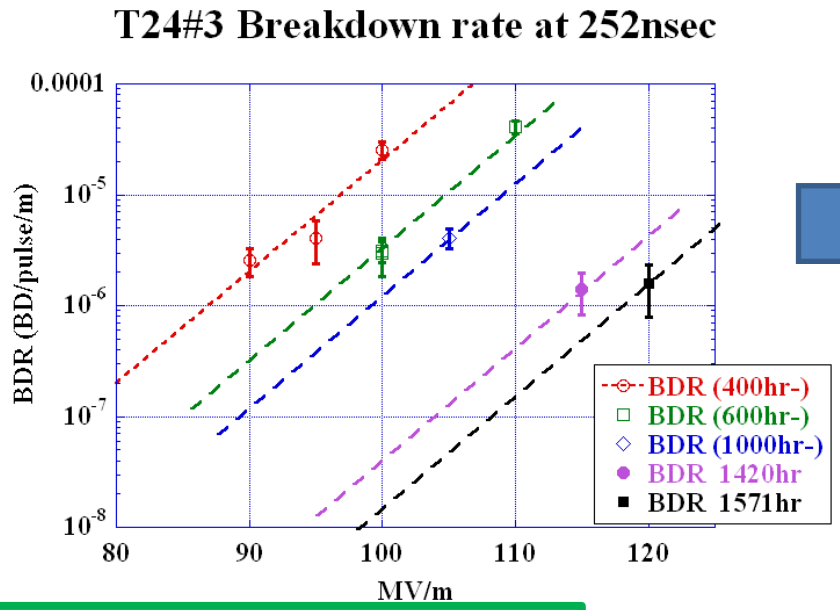
TD24R05_#4

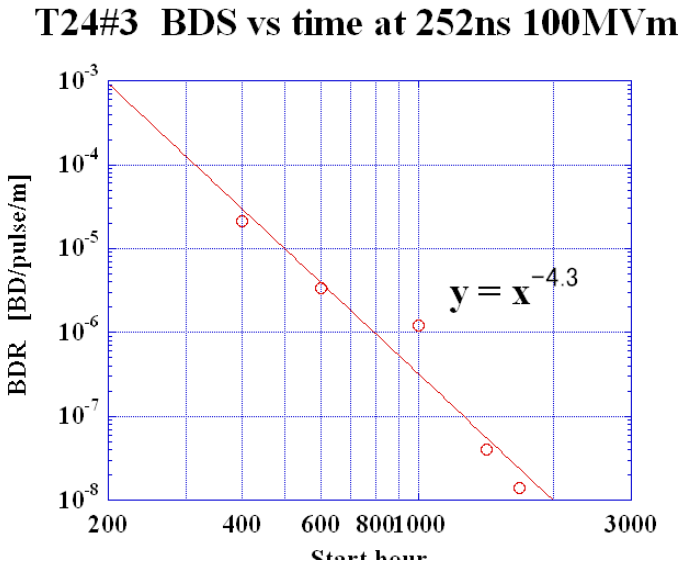

Nextef
RF source
for A
Control
B
A
Shield B
Shield A

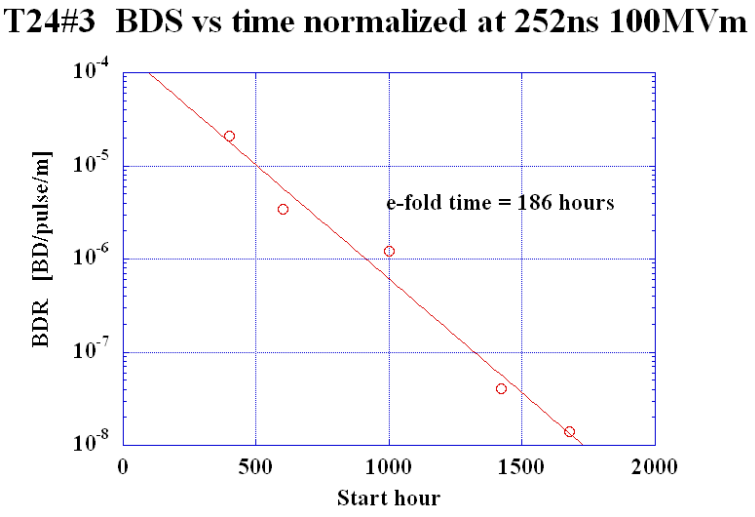
High-gradient test at Nextef



T24#3
BDR evolution at 252ns normalized 100MV/m







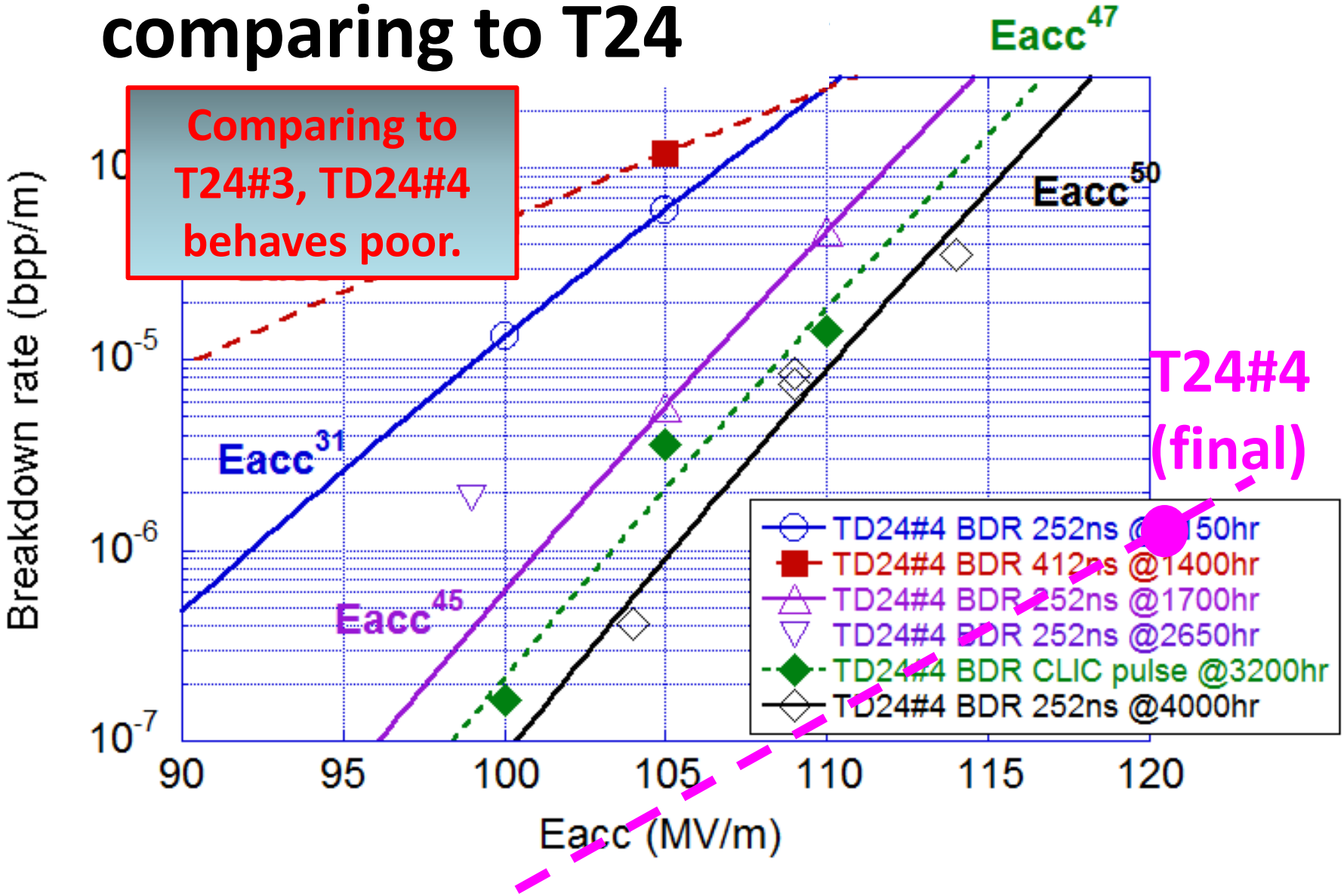
Excellent BDR performance in T24#3.

same exponential
be as that at 400hr

We understand the BDR has been kept decreasing.

BDR summary on TD24 comparing to T24

LCWS2012 at Arlington



Somewhat poor results in the recent damped structures

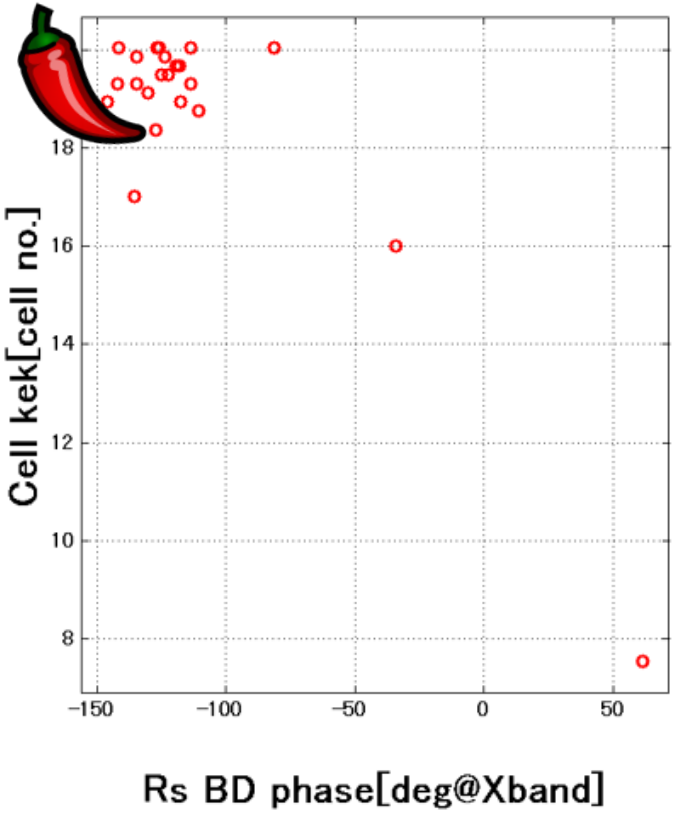
- Started with T24#3 showing excellent performance in 2011.
- TD24#4 in 2012 behaved not so good as estimated from excellent BDR result of T24#3.
- Revised design,TD24R05#2, showed in late 2012 hot spots after going up to 110 MV/m and BDR was stayed poor.
- Tried another TD24R05#4 in 2013.

TD24R05#2 presented in CLIC2013

Hot spots localized in each cell

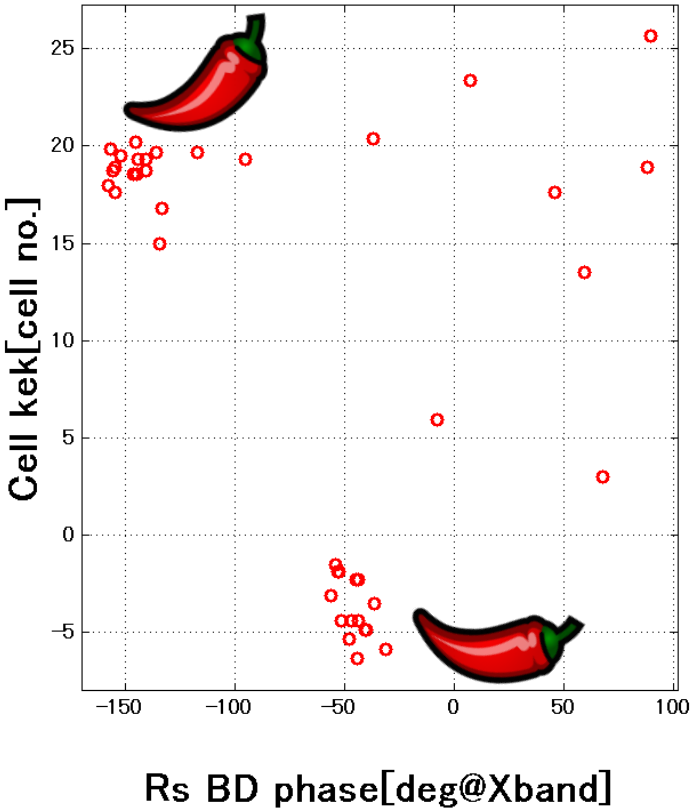
TD24R05#2

Run 27 at 100 MV/m



Only downstream

Run 31 at 110 MV/m



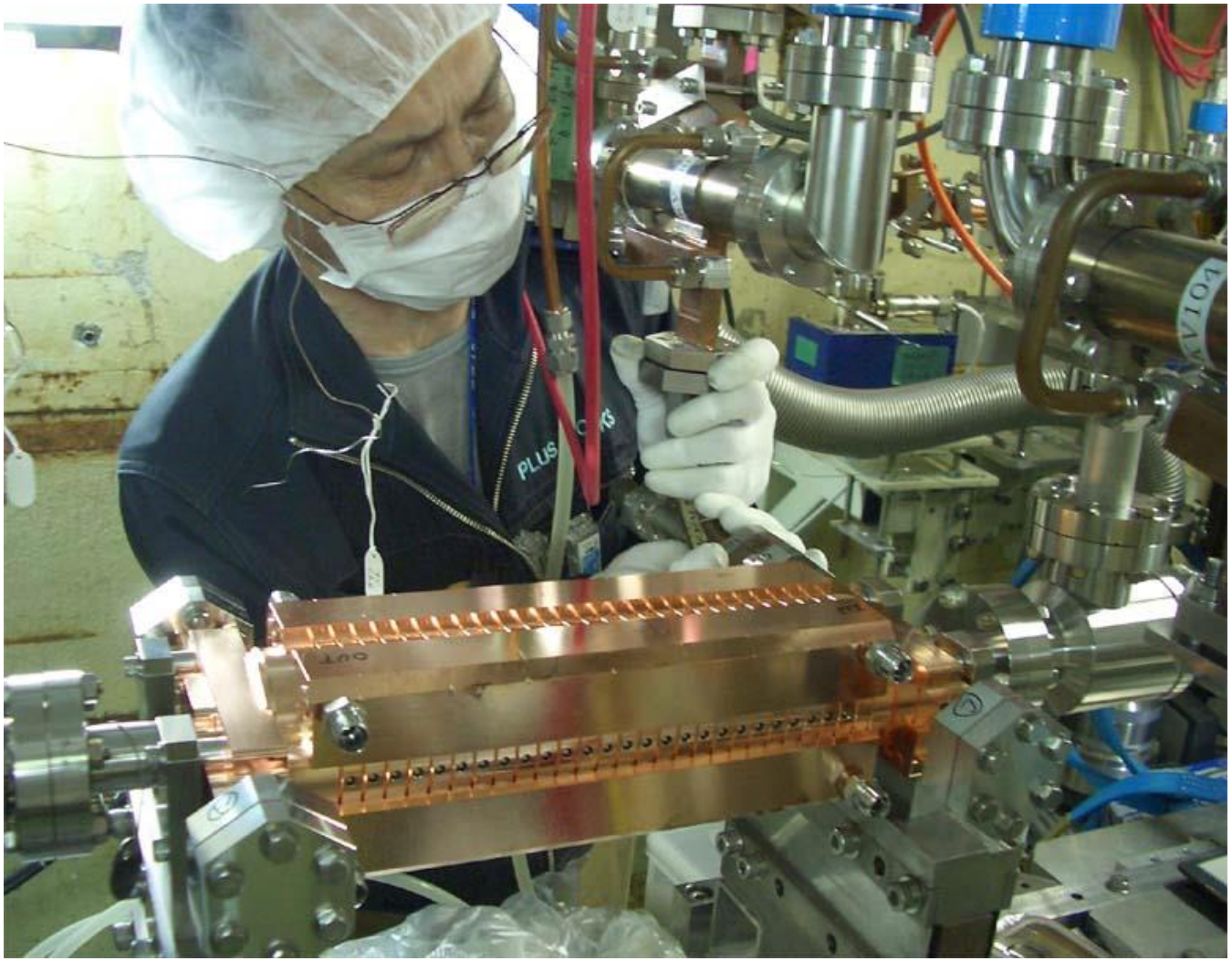
Both up and down

Most recent prototype structure TD24R05#4

- Considering the hot spot appearance in TD24R05#2, we tried to install #4 carefully in cleanness.

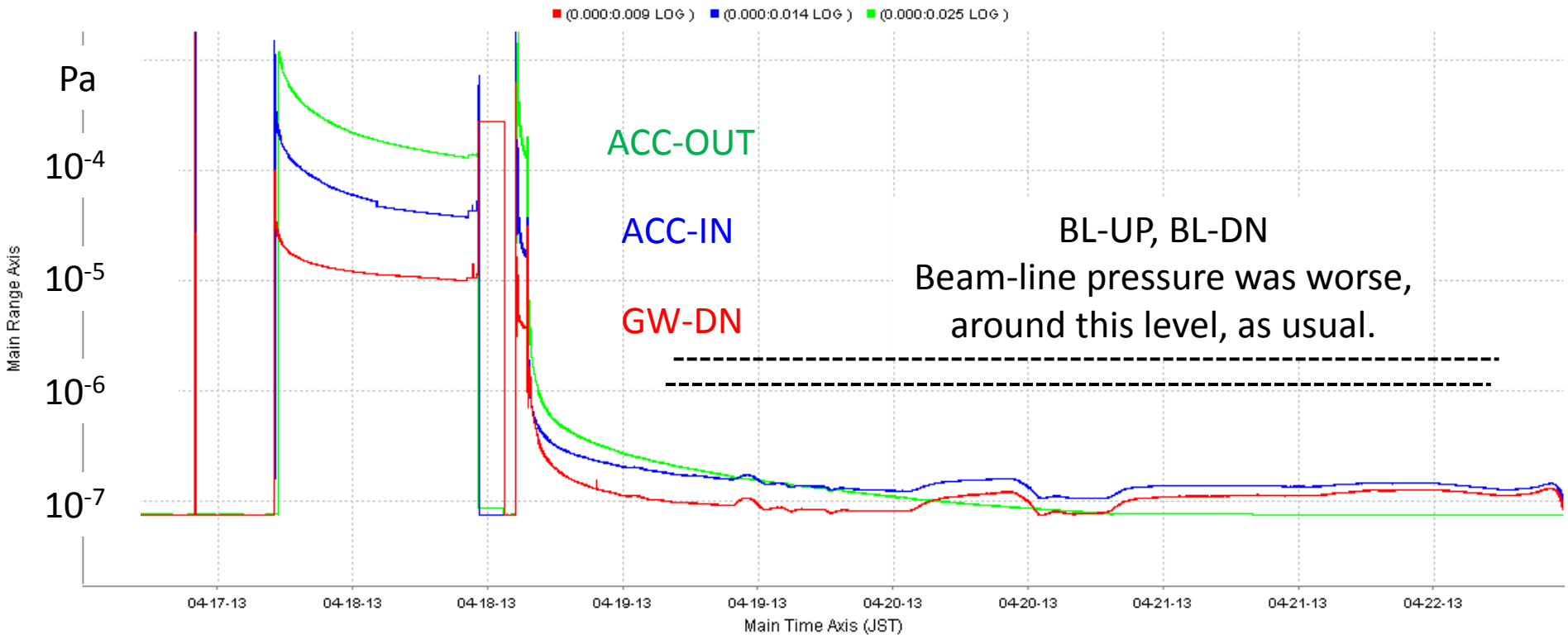
- However, the treatment was probably not well improved, as shown in next page.
- Cleaner treatment may be needed.

TD24R05#4 installation

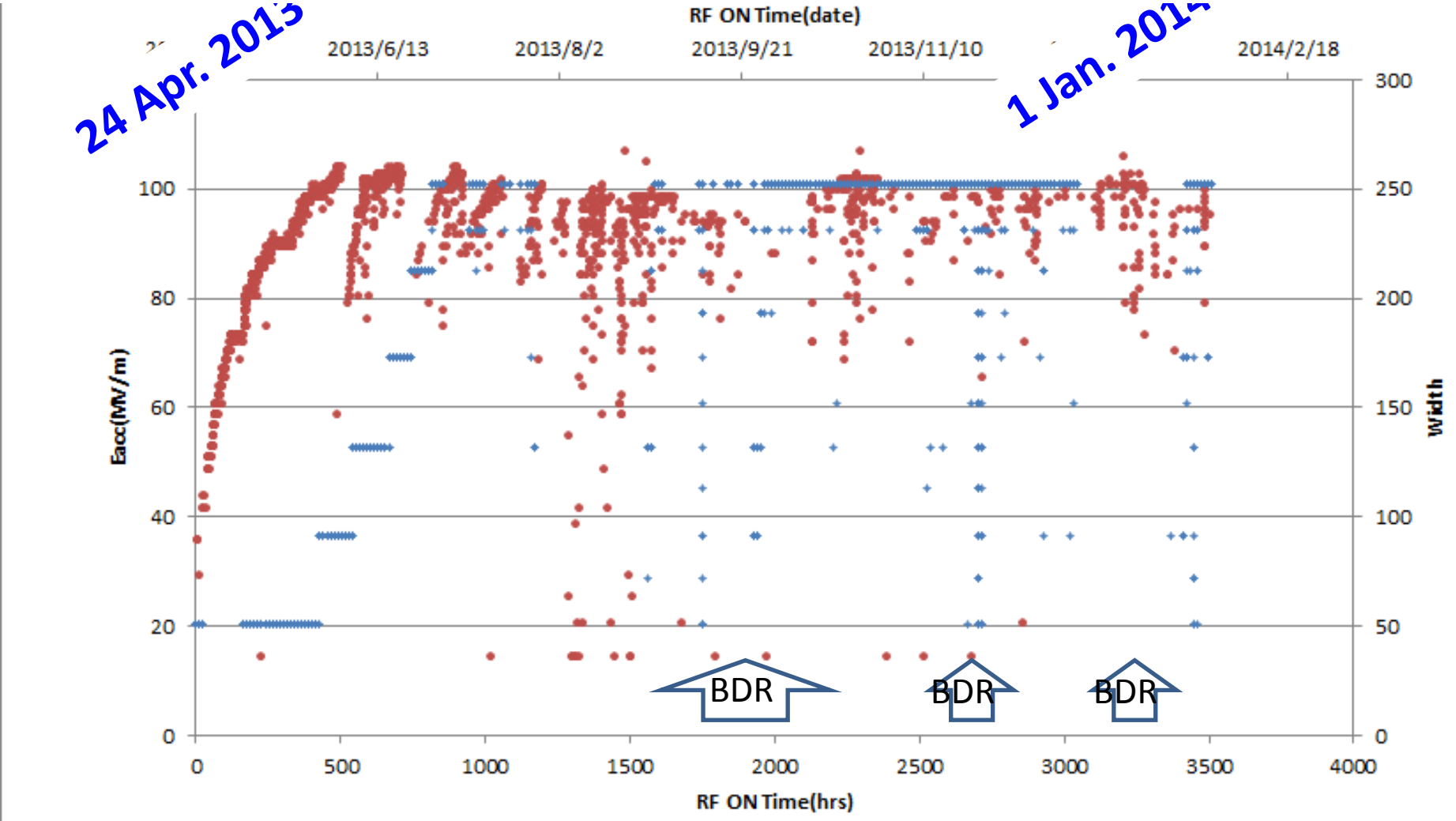


Tried to install in a better situation on dust and environment, though we should admit that it was still in the poor level.

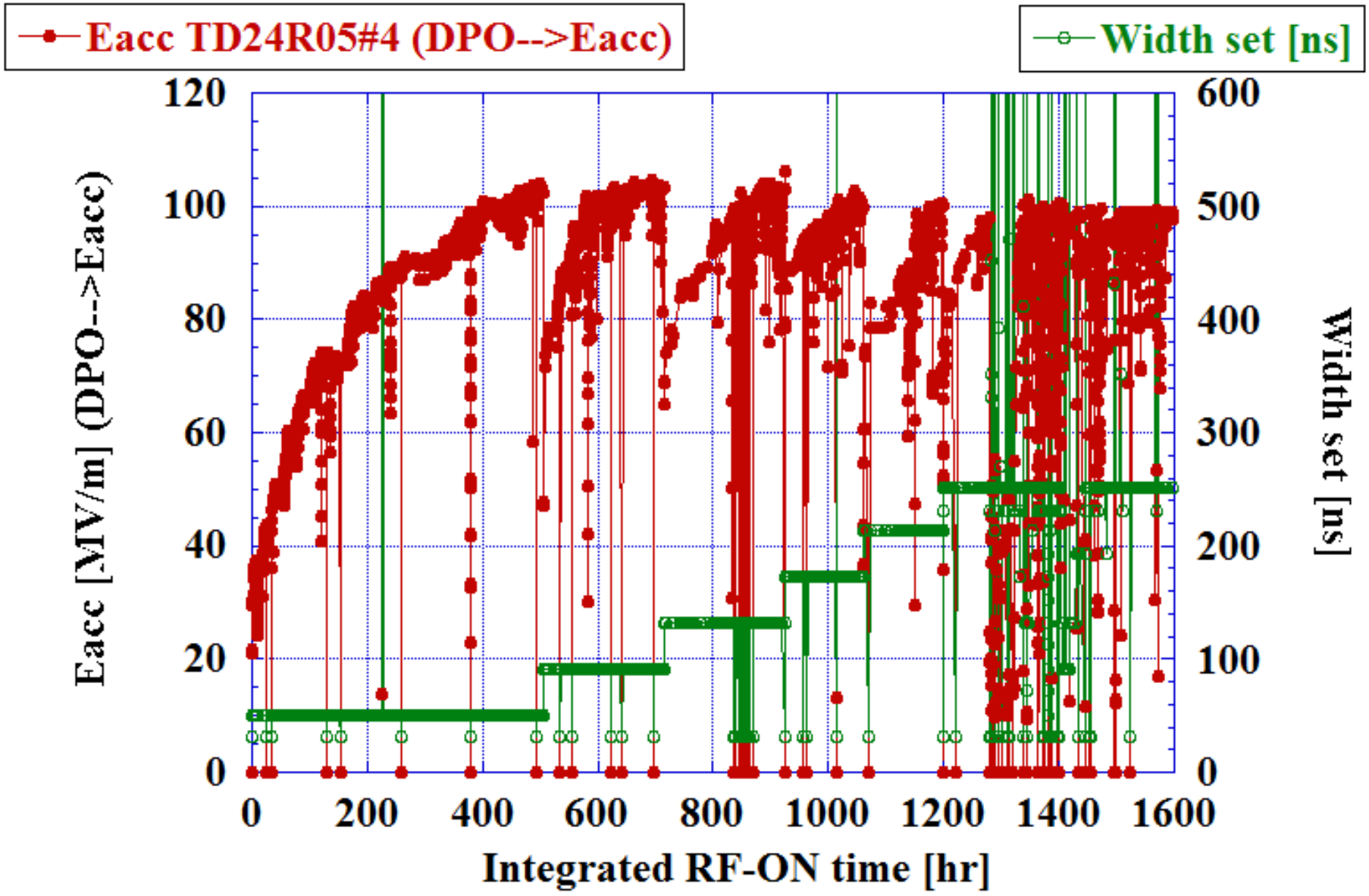
TD24R05#4
Initial vacuum characteristics as usual

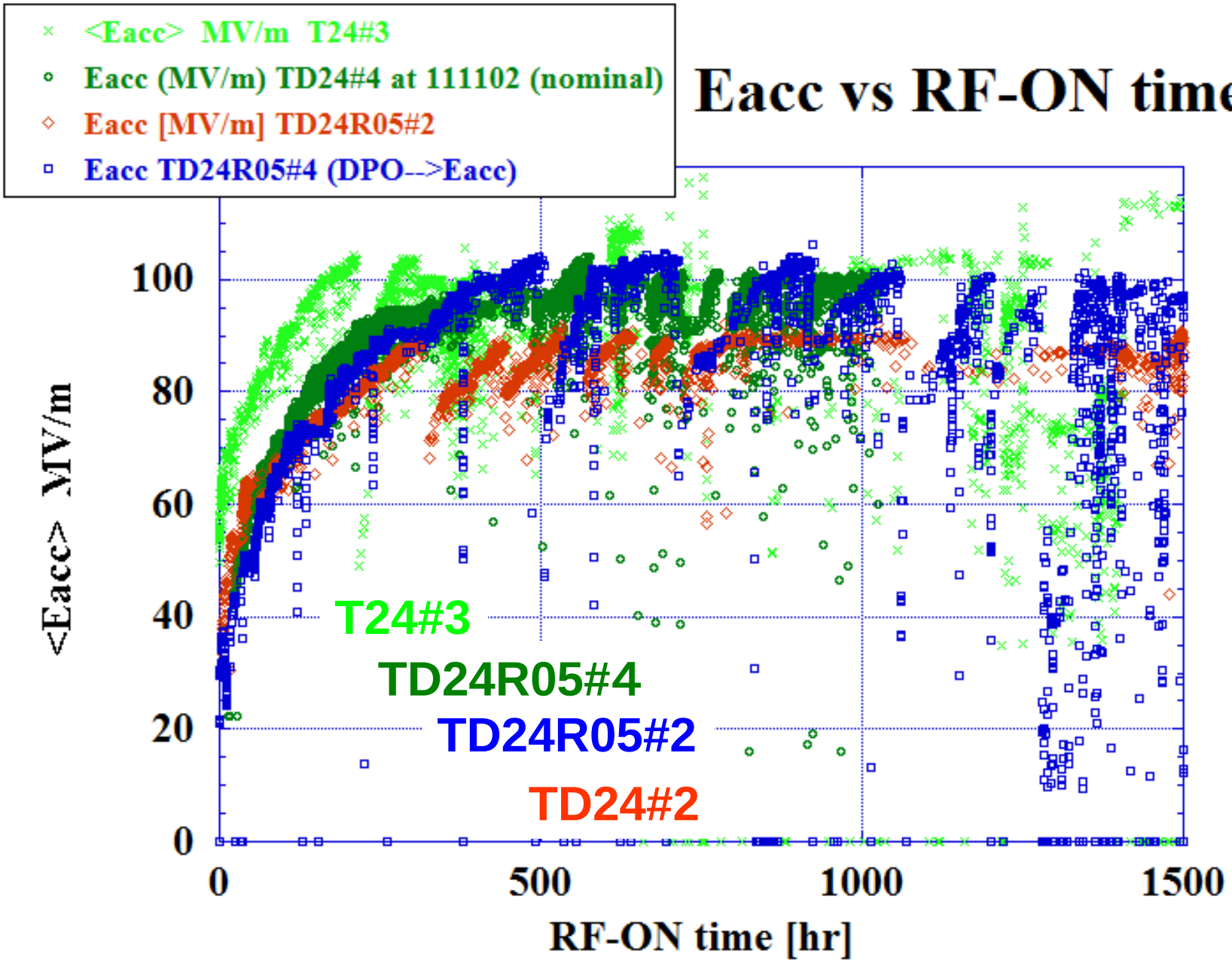


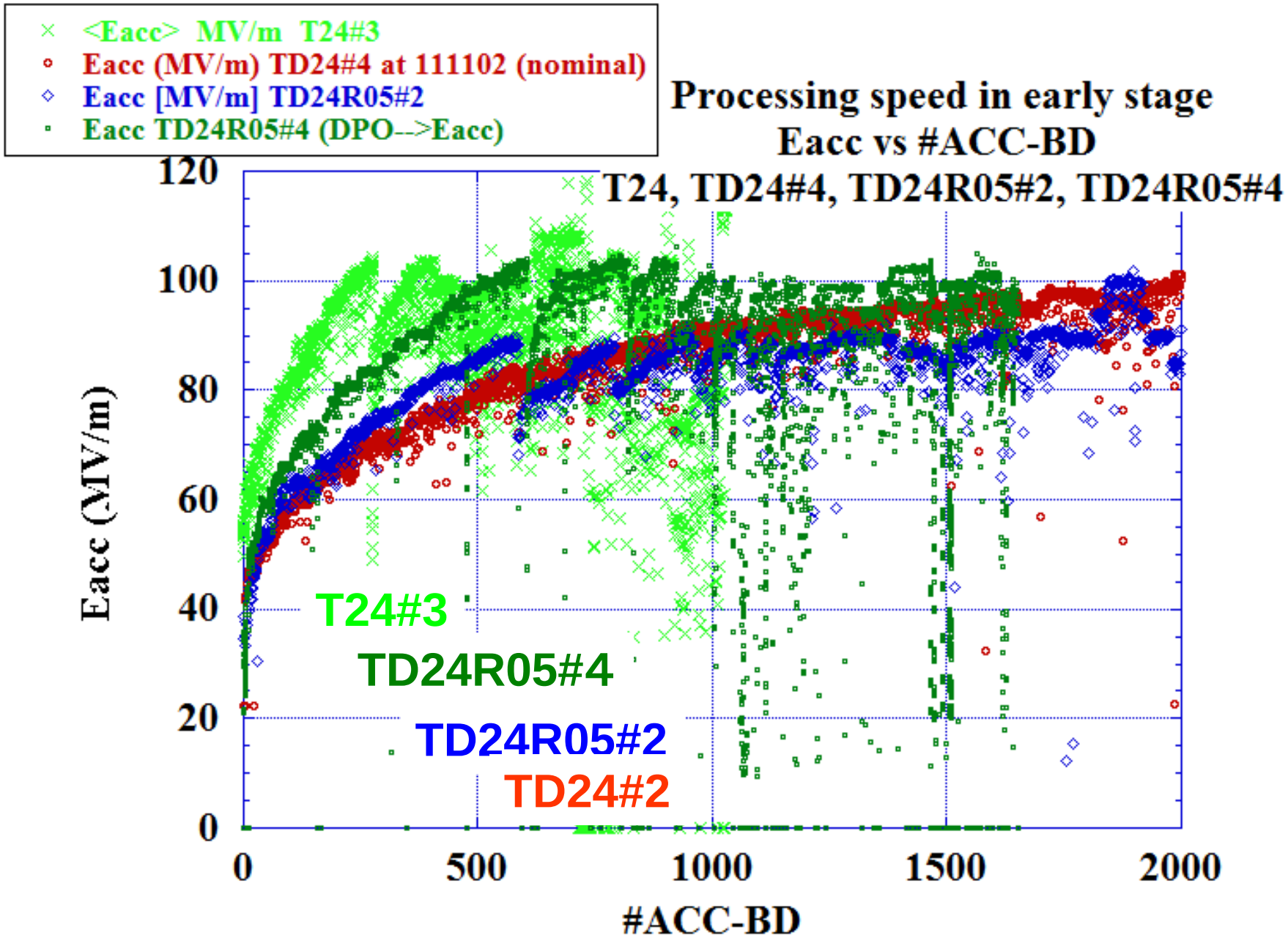
TD24R05#4 Processing whole history



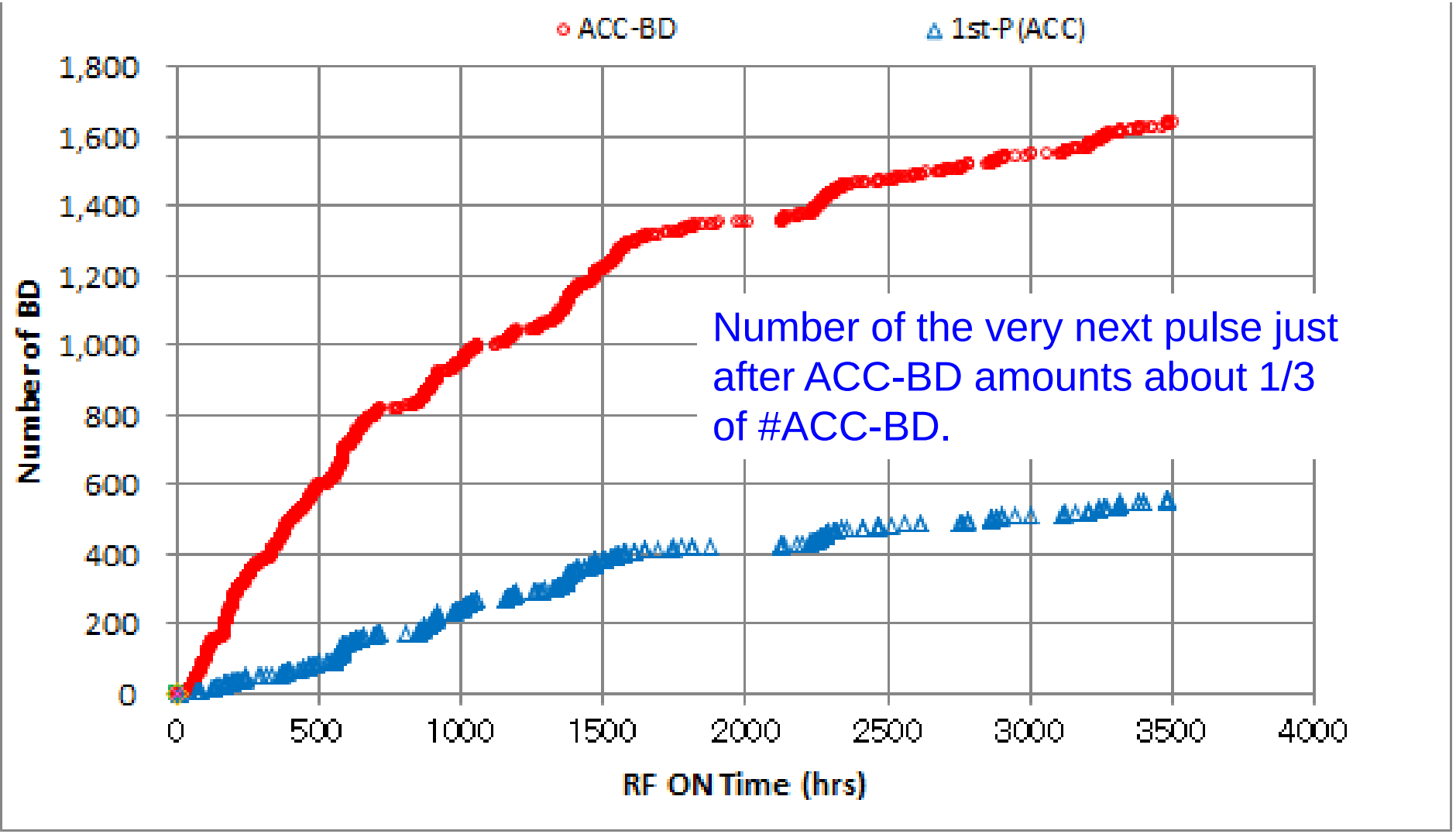
TD24R05#4 processing history




<Eacc> MV/m T24#3
Eacc (MV/m) TD24#4 at 111102 (nominal)
Eacc [MV/m] TD24R05#2
Eacc TD24R05#4 (DPO-->Eacc)
Eacc vs RF-ON time
<Eacc> MV/m
RF-ON time [hr]
0
20
40
60
80
100
0
500
1000
1500
T24#3
TD24R05#4
TD24R05#2
TD24#2


<Eacc> MV/m T24#3
Eacc (MV/m) TD24#4 at 111102 (nominal)
Eacc [MV/m] TD24R05#2
Eacc TD24R05#4 (DPO-->Eacc)
Processing speed in early stage
Eacc vs #ACC-BD
T24, TD24#4, TD24R05#2, TD24R05#4
Eacc (MV/m)
#ACC-BD
0
20
40
60
80
100
120
0
500
1000
1500
2000
T24#3
TD24R05#4
TD24R05#2
TD24#2

TD24R05#4 #AC-BD & 1st-pulse BD

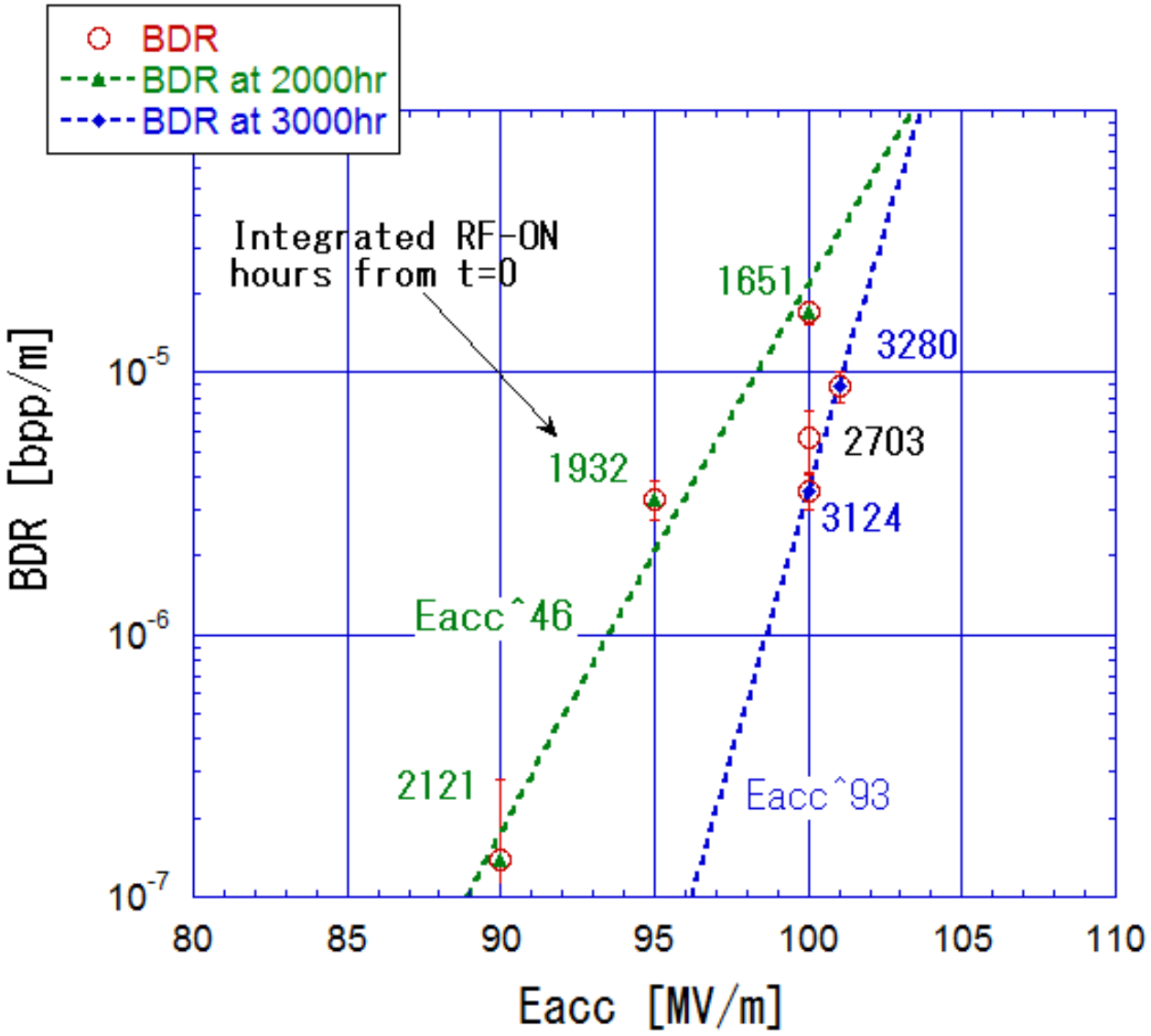


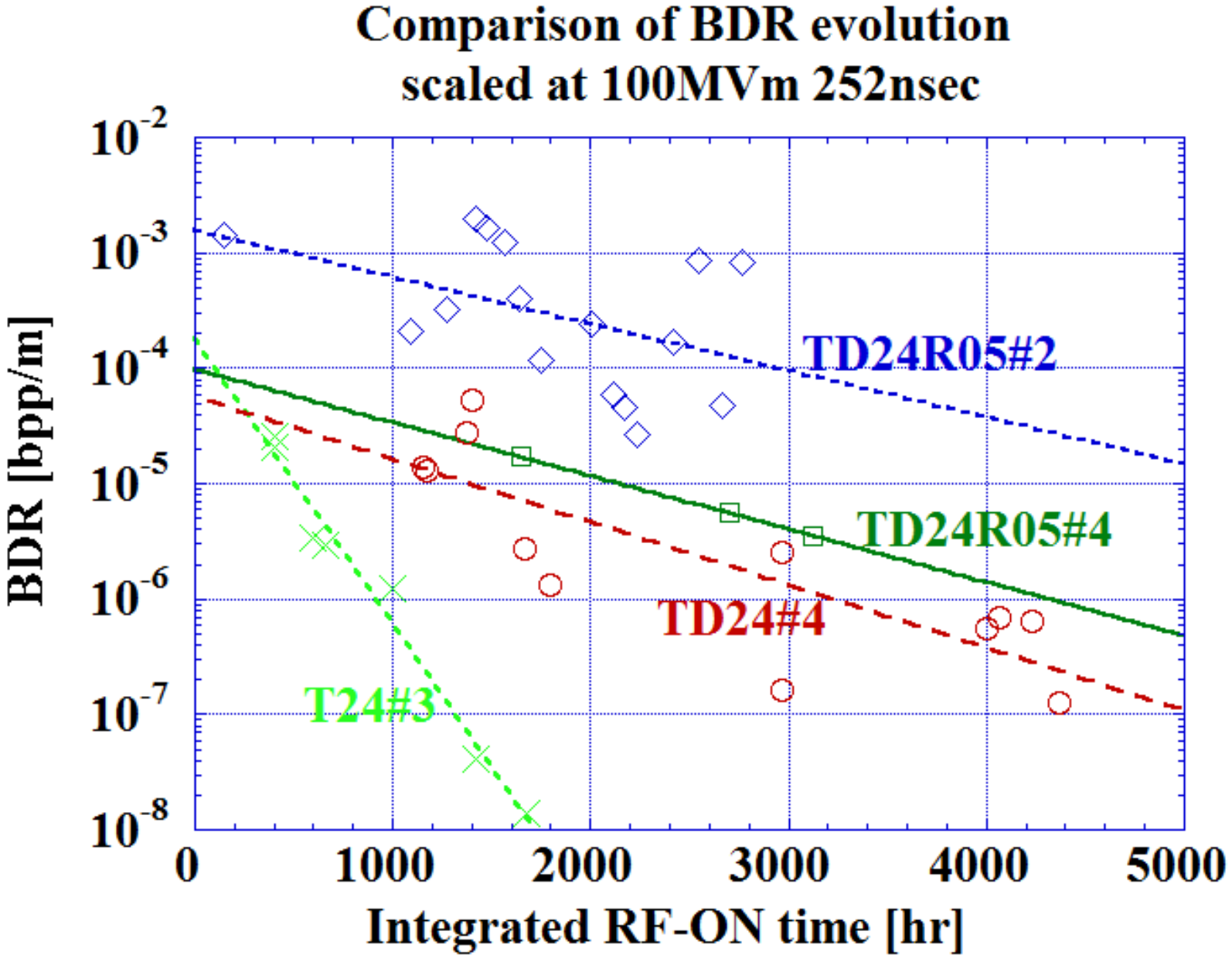
TD24R05#4 BDR (still preliminary)

Run	Integrated RF-ON time	Eacc(MV/m)	#ACC-BD	Period「Hour]	BDR[10^-6 bpp/m]
28	1651	100	97	155.5	17
29	1932	95	35	279.2	3.3
30	2121	90	1	190*	0.14
41	2703	100	14	65.73	5.64
43	3124	100	48	358.17	3.54
45	3280	101	50	142.67	8.90
47	3319	99		16.27	

* Run time and detailed checking of BD pulse should be made for final values.

BDR TD24R05#4 (preliminary)




Comparison of BDR evolution
scaled at 100MVm 252nsec
BDR [bpp/m]
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
0
1000
2000
3000
4000
5000
Integrated RF-ON time [hr]
TD24R05#2
TD24R05#4
TD24#4
T24#3

Further investigation

- Dark current evolution was measured. Waiting for analysis.
- The clear hot spot was not observed, though dull peak was once seen in cell 5-10 area.

- Interesting to see how the BDR evolves.
- Also worthwhile to taste it with special operations in pulse shape etc.
- Want to see the behavior through longer pulse than 252nsec or higher peak power than 100MV/m.

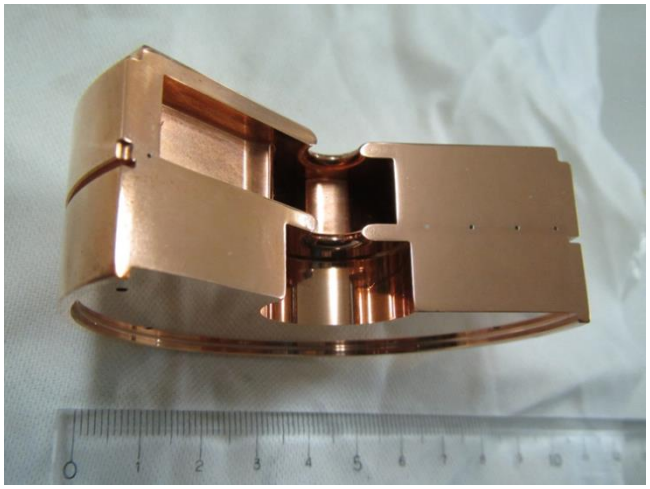
Further activities of Nextef

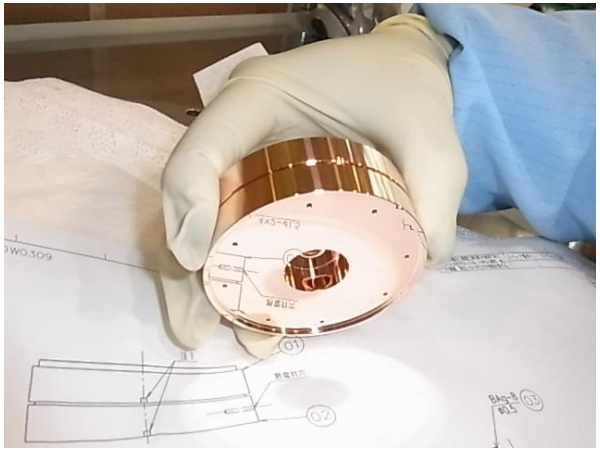
- Prototype structure
  - TD24R05 made by KEK
  - Choke-mode by Tsinghua
  - Actual CLIC prototype
    - Compact coupler, SiC, and so on
- Single-cell SW test
  - TD24 with various fabrication technologies
    - All milling, diamond milling, large grain material, eyc.
    - Quadrant
    - Brazed cavity by MHI

Basic studies with simpler experimental setup

- The shield room is ready once klystron is recovered.
- Idea is to test first the performance around 100 MV/m. Then test at higher gradient.
- And compare various victims from design and technology points of view.

Single-cell SW braze-assembled by MHI





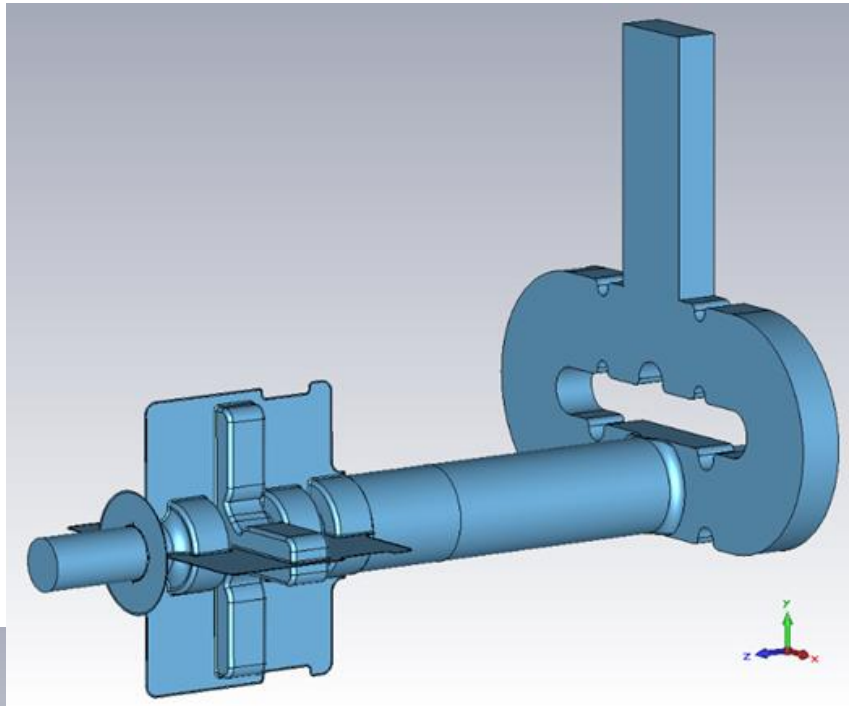
Vacuum tightness was confirmed.

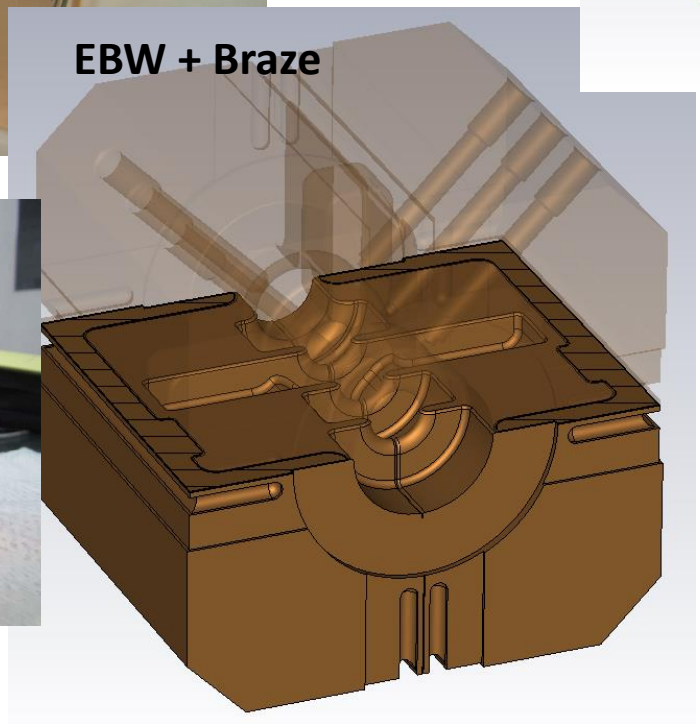
Proceed to actual cavity production by end of March.

Quadrant in preparation

- Features
  - Finite gap (0.1mm) against virtual leak
  - Large radius (R0.4mm) at opening to reduce field enhancement
- High gradient test is foreseen this year
  - Single-cell test setup configuration as SLAC
  - Assembly with EBW followed by brazing

Test on quad-type “singe-cell” cavity





EBW tested

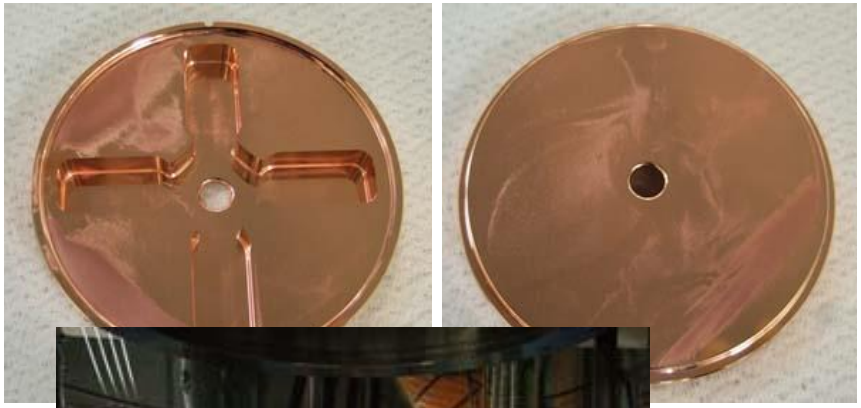
Quad-type single cell cavity connected to mode launcher.

Quad is in production now. Mode launcher is under production by SLAC.

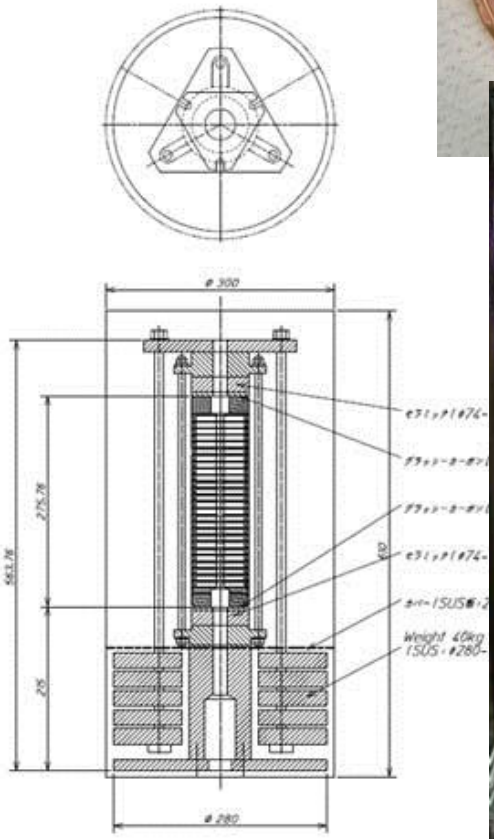
Making prototype structure

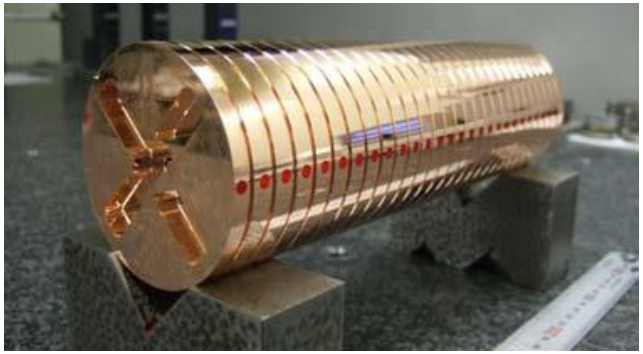
- Re-furbish the fabrication in KEK
  - CP basically followed SLAC procedure
  - Hydrogen furnace for DB
  - Brazing in H2 or vacuum
  - Vacuum baking will be implemented in the brazing step by vacuum furnace (maybe from the 2nd one?)

Diffusion bonding was re-confirmed



T04 the worst appearance





Issues in KEK

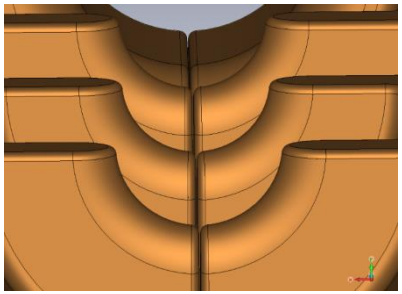
- Biggest issue also in is to have RF power source. We do not have any spare klystron but does not have simple solution.
  - Still PPM? -- XL4? -- medium power + pulse compression? ------- to be discussed
- We want a plan of the fabrication of actual CLIC prototype structure.
  - Better to advance to those, more practical, such as compact coupler, SiC, and so on.
- We want to survive and introduce young colleagues
  - Under the SuperKEKB effort in 2014-2015- ??
  - and the ILC movement in Japan.

Conclusion

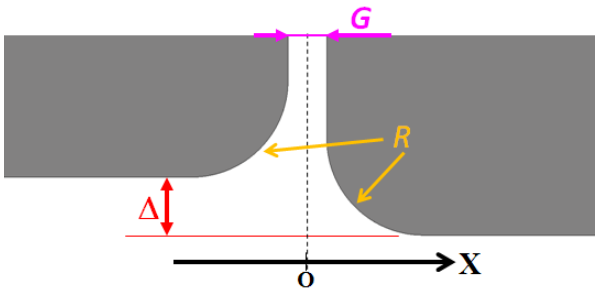
- Recent 24-cell damped structures, showed gradually better performance but there is still room for improvement.
- We continue fabrication of a complete structure by KEK, in addition to SLAC/KEK.
- We keep long-term evaluation study on CLIC prototype structures.
- We will test other structures, such as choke mode, in collaboration with Asian institutes under CLIC collaboration.
- Finally but might be most, we should find a solution against RF source problem.

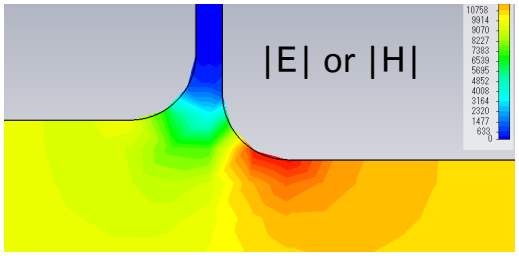
Additional materials

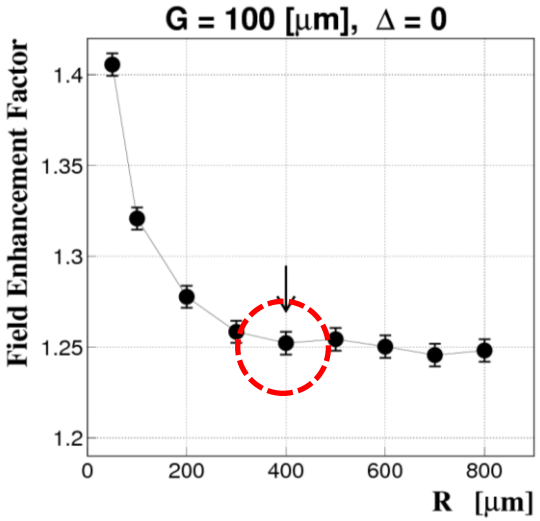
Field Enhancement due to the Concave Structure

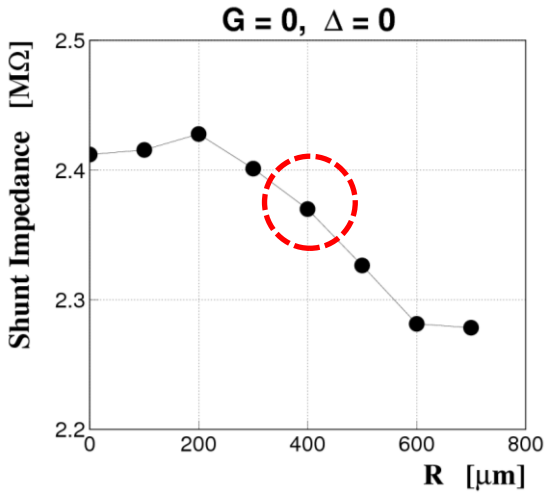


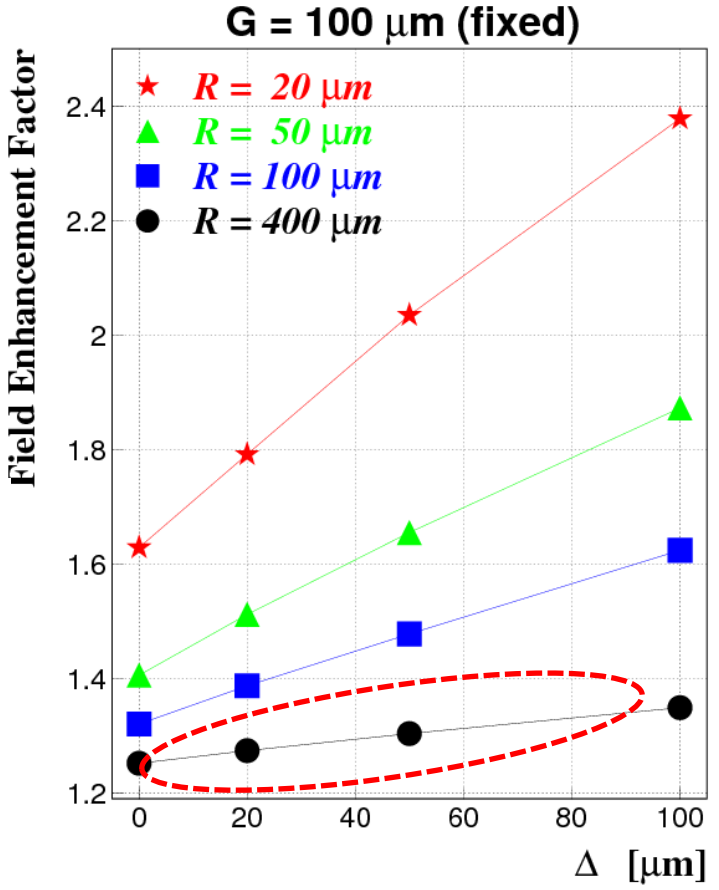
Gap to avoid virtual leaks
Large chamfer to suppress field enhancements



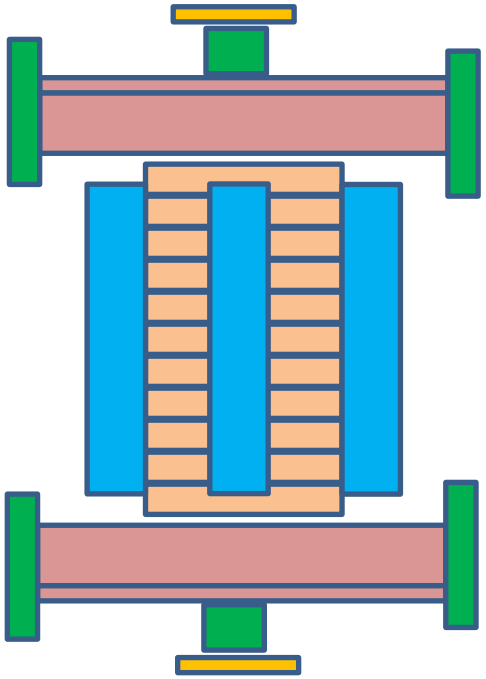


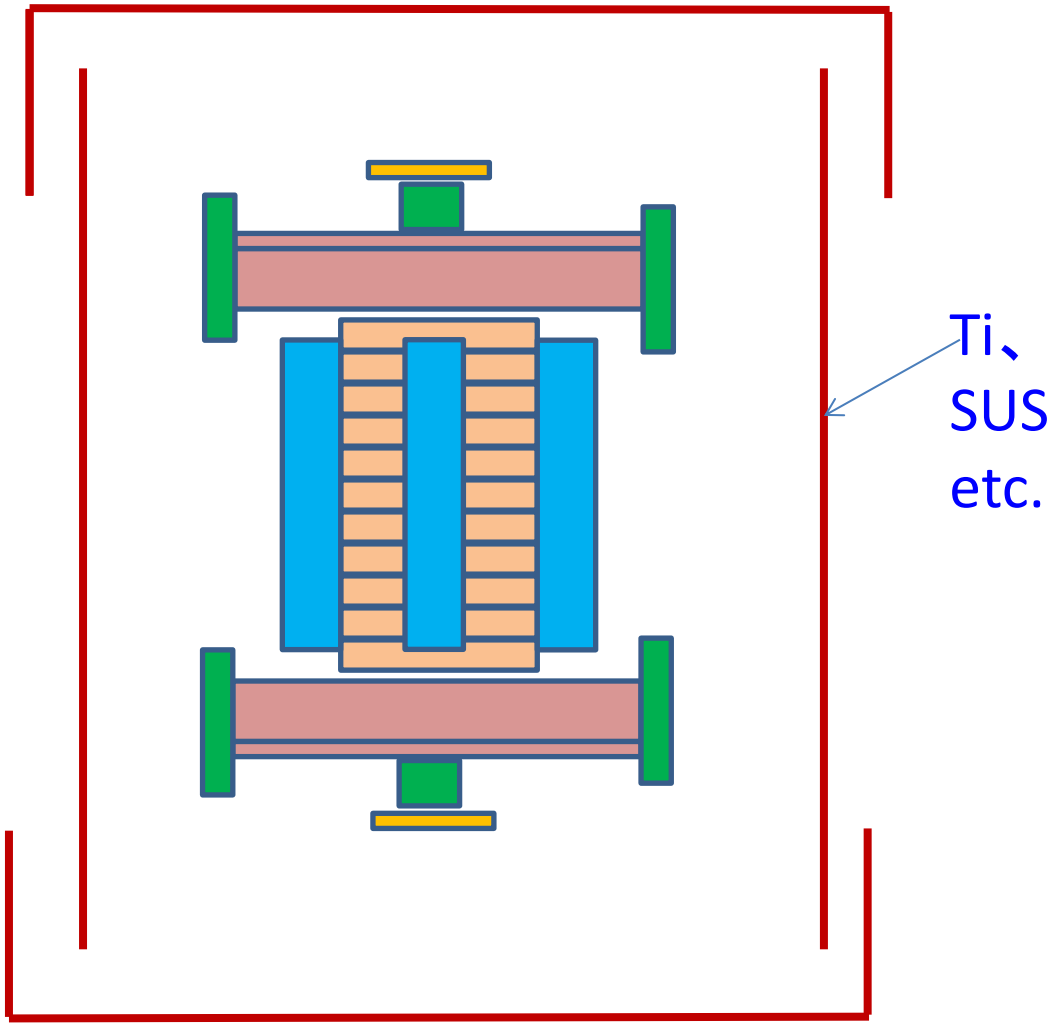






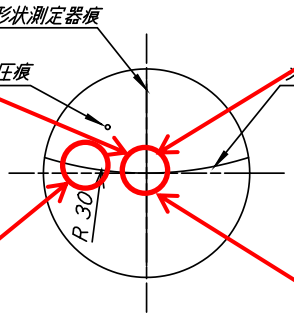
KEK-based vacuum baking in consideration

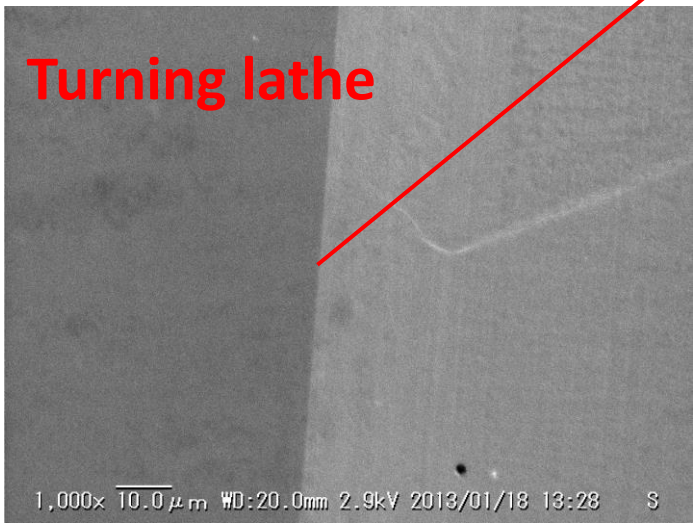


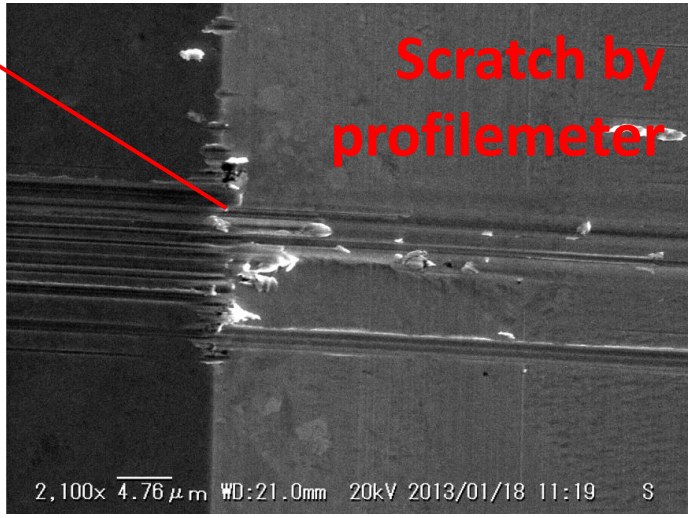


1. VAC 900 degC
2. Partial 1hr?
3. vacuum 1hr?
4. Temp fall
5. Quick extraction
6. Seal

Copper surface evaluation

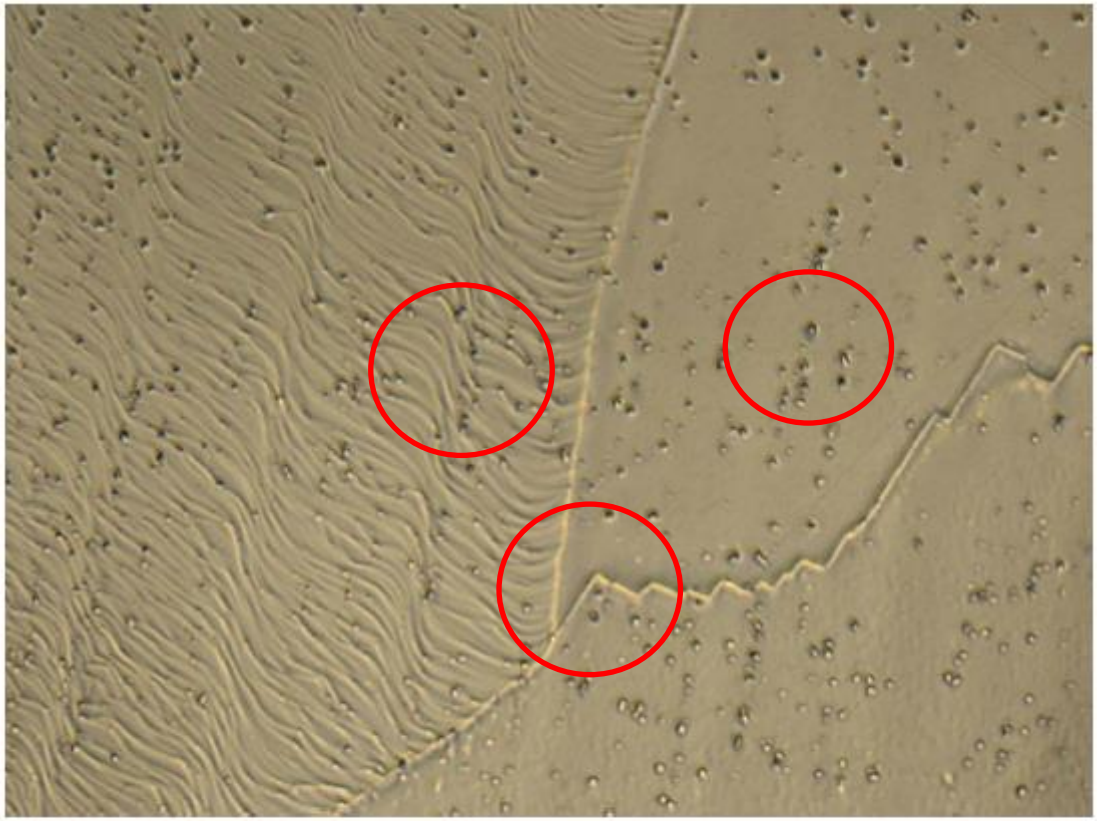






MLG-64（エンドミル）

①水素炉1020℃/60min

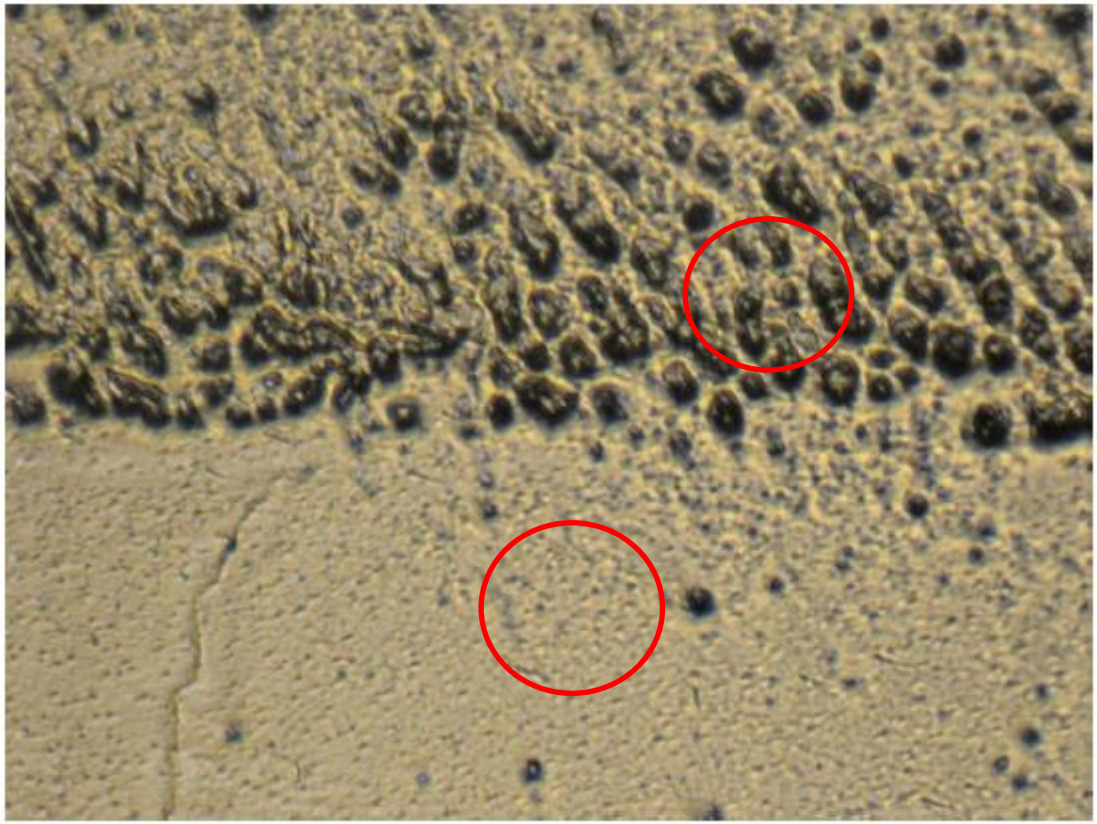


×2000

End mill (without CP) → hydrogen furnace

MLG-29（エンドミル）

⑥真空炉パーシャル1040℃/60min
+真空炉950℃/10min
+真空炉800℃/10min
+真空炉800℃/60min



×2000

End mill (without CP) → vacuum furnace with partial N2