

Recent High-gradient test result at KEK

Linear Collider Workshop 2012
Arlington, Texas (WebEx)

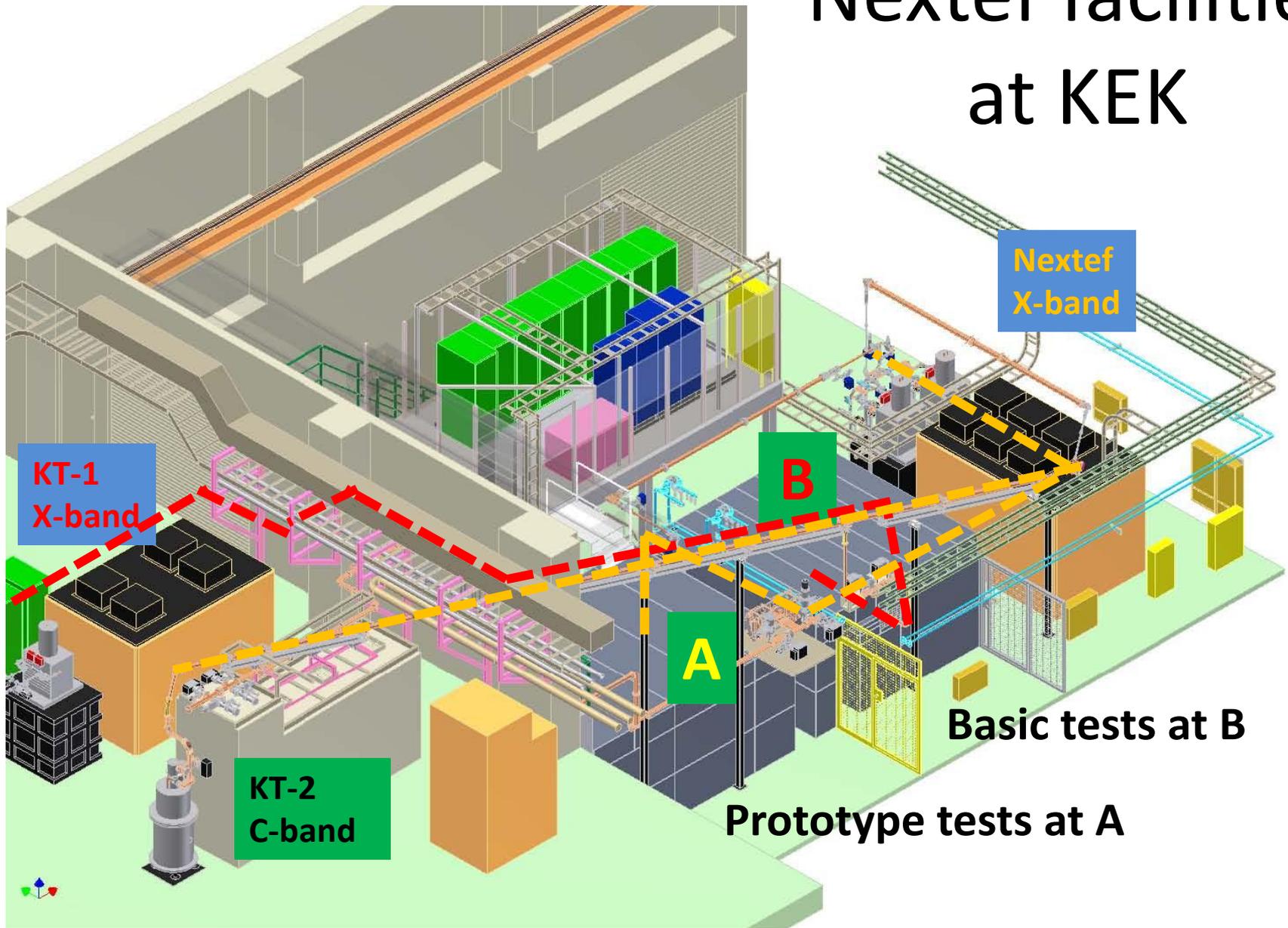
25 October, 2012

Toshi Higo and X-band group of KEK

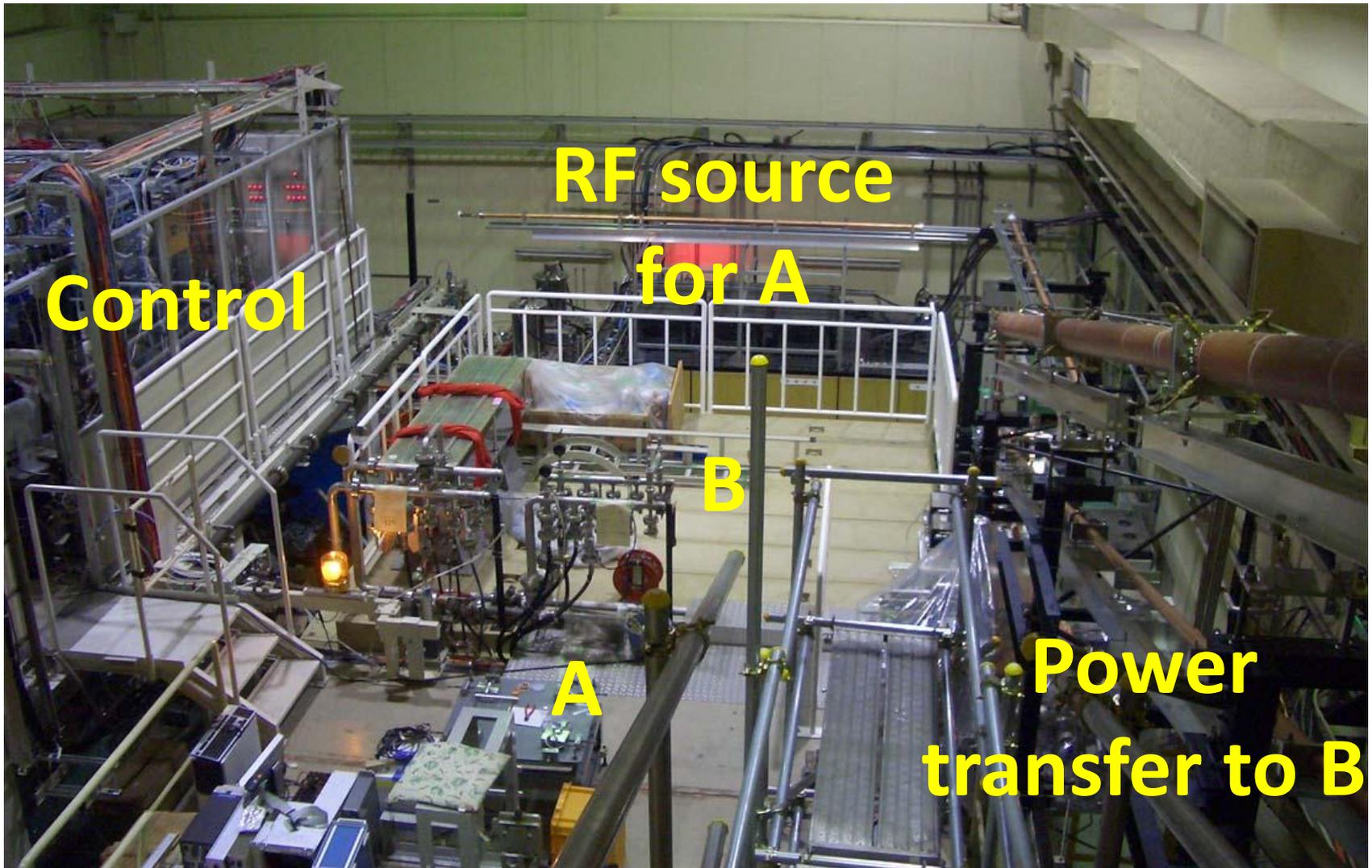
Contents

- Performance comparison of **prototype CLIC structures**
 - Processing speed
 - Design parameters
 - Breakdown rate
- Proof with **CLIC pulse** operation
- **Some effort** for understanding breakdown
- **Near-future studies** in mind

Nextef facilities at KEK



Nextef

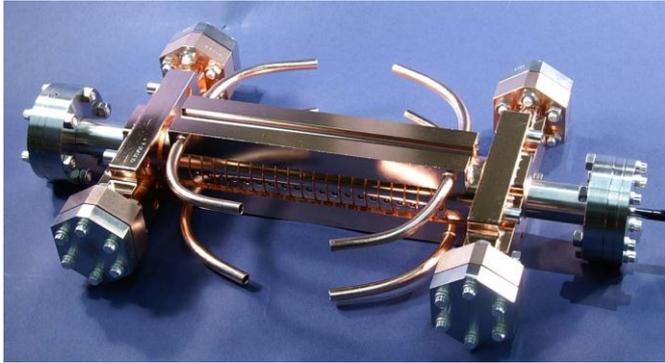


Comparison of CLIC prototype structures in initial processing

Comparison of CLIC prototype structures

- Collaboration from 2007 ---
- → T18 2008 --- 2009
- → TD18 2009 --- 2010
- → T24 2010 --- 2011
- → TD24 2011 --- 2012
- → TD24R05 2012 ----

CLIC test structures; T18 → TD18 → T24 → TD24 a series of nominal fabrication by KEK+SLAC



T18_Disk_#2 2009



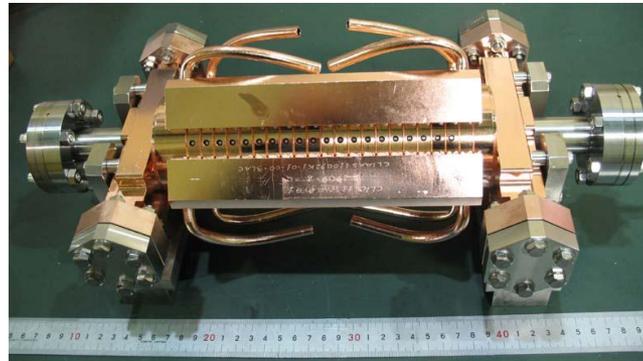
undamped



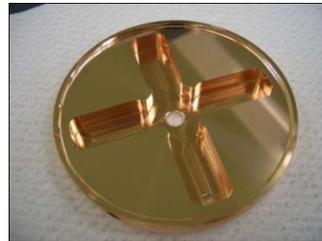
T24_Disk_#3

2011

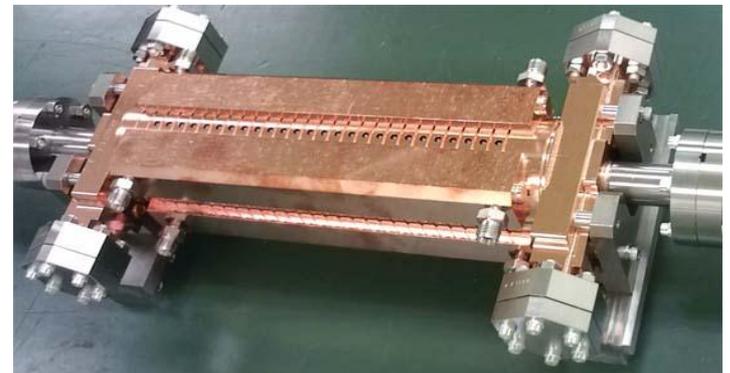
2011~12



TD18_Disk_#2



damped



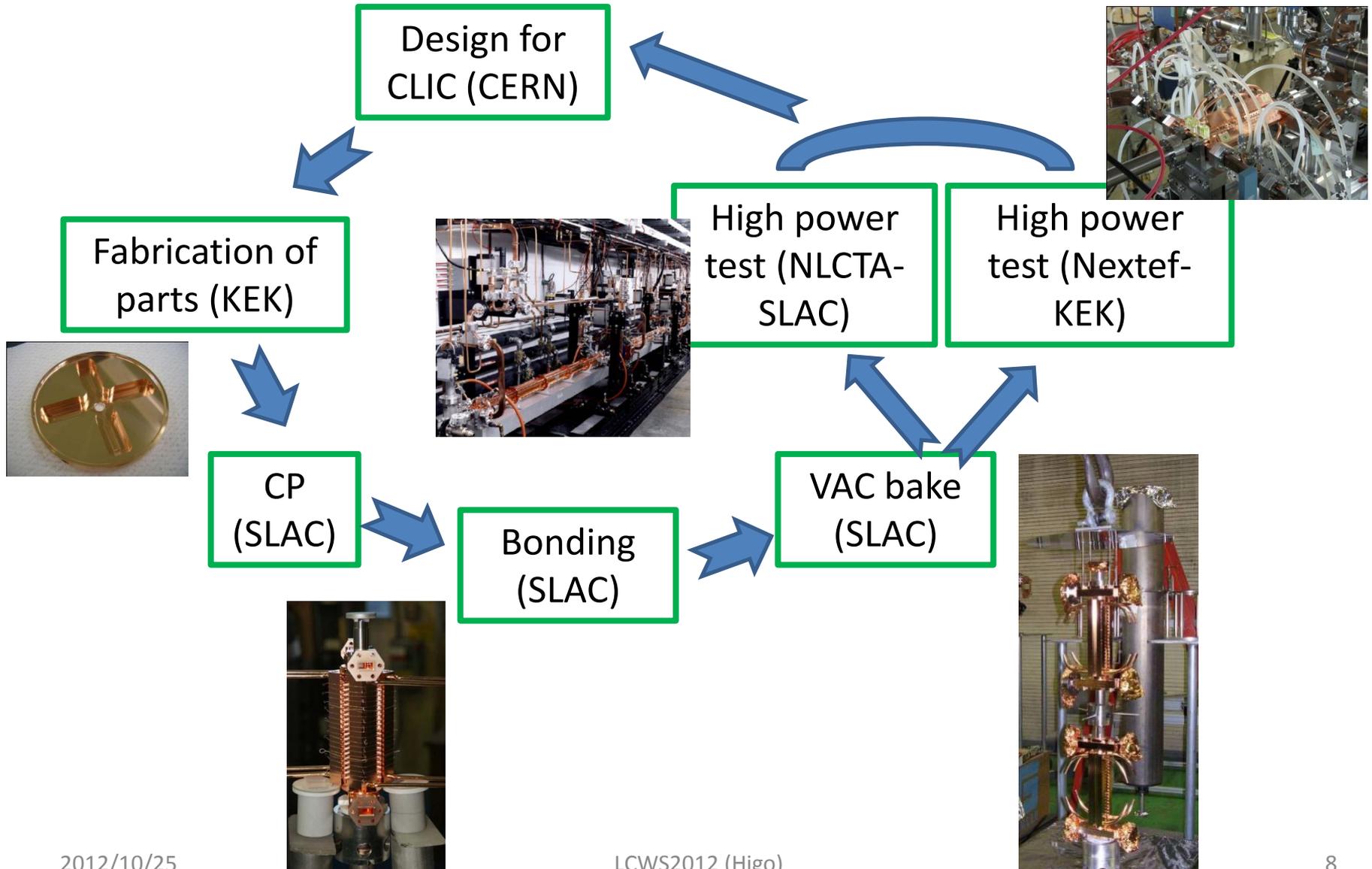
TD24_Disk_#4



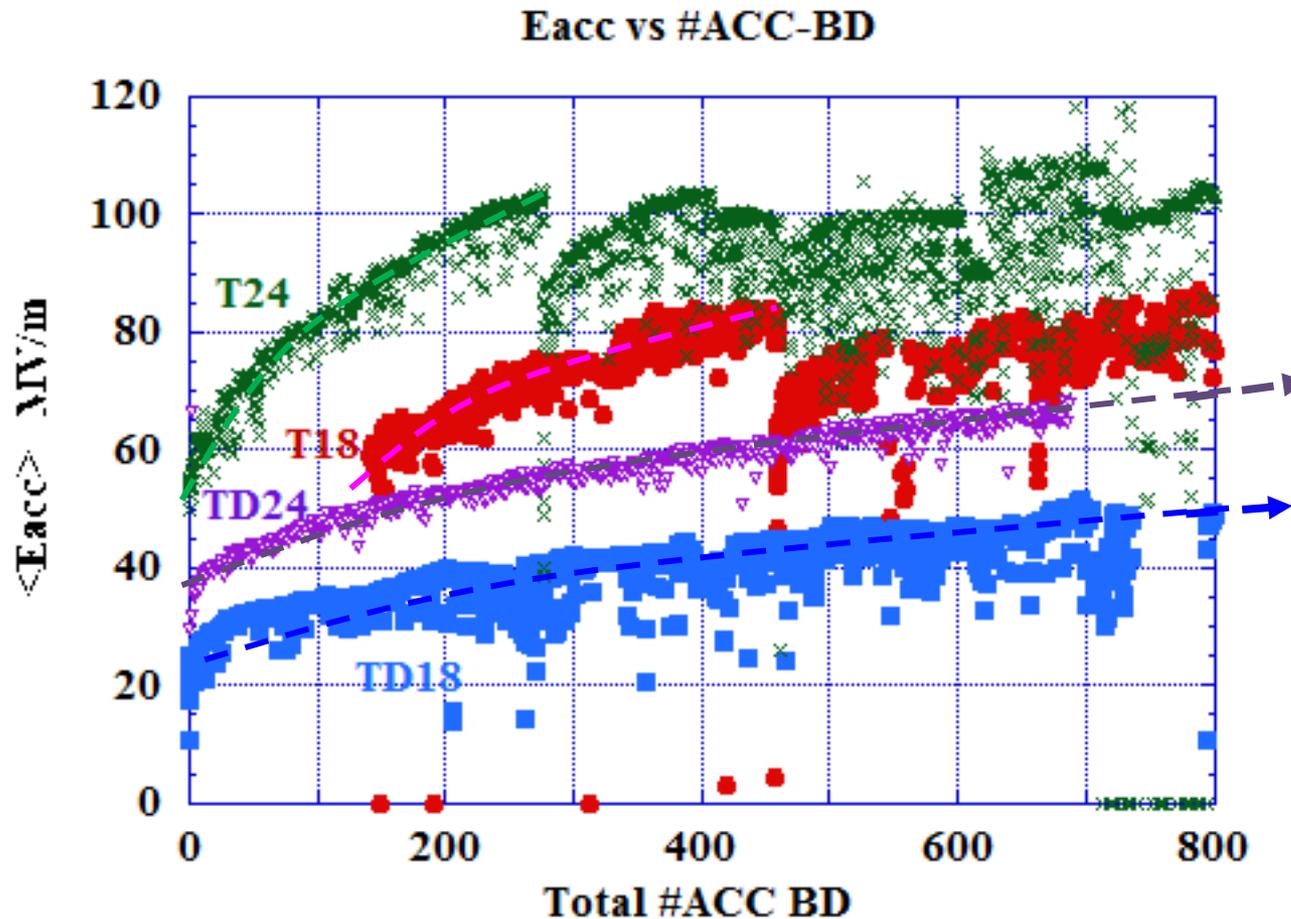
2010



SLAC/KEK typical fab/test flow

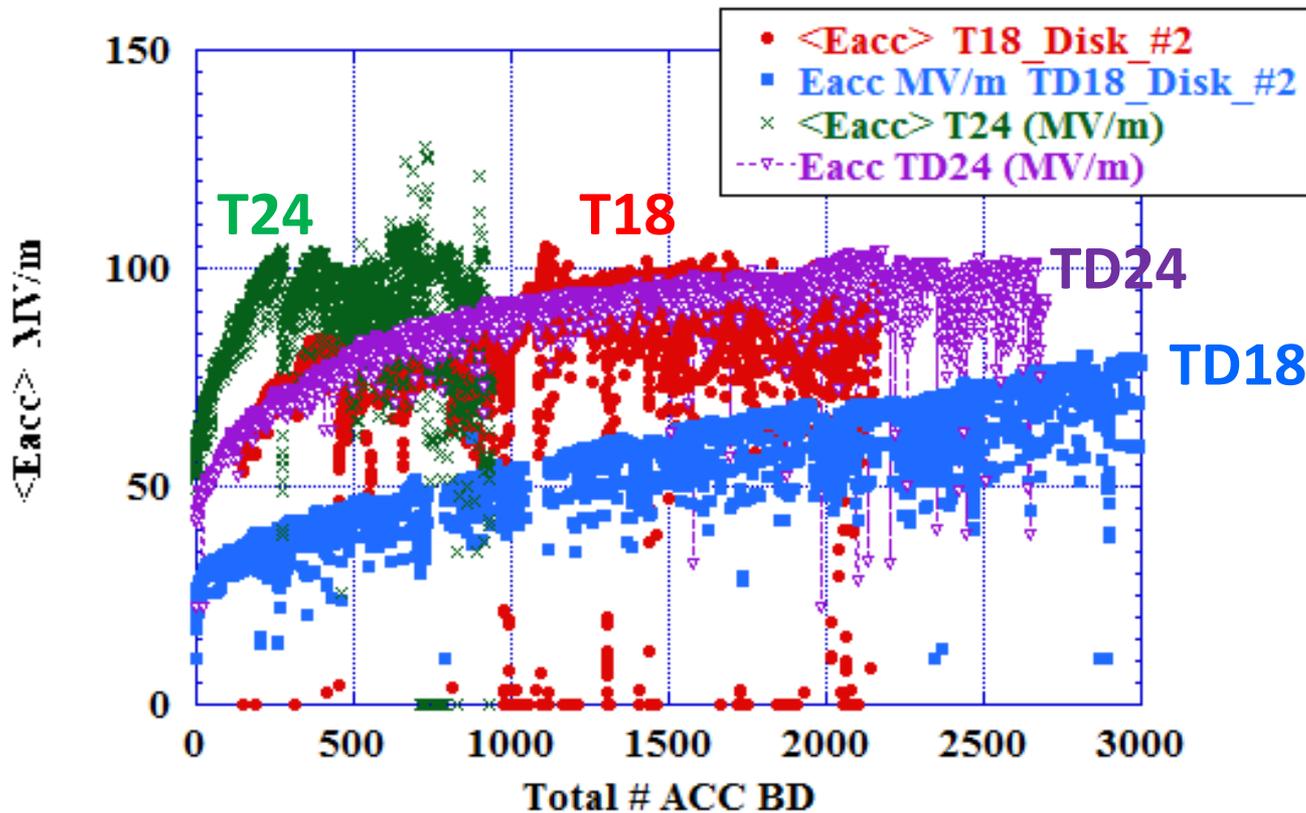


Comparison of initial processing starting at 51nsec



Difference in processing speed among four structures

Eacc vs #ACC-BD

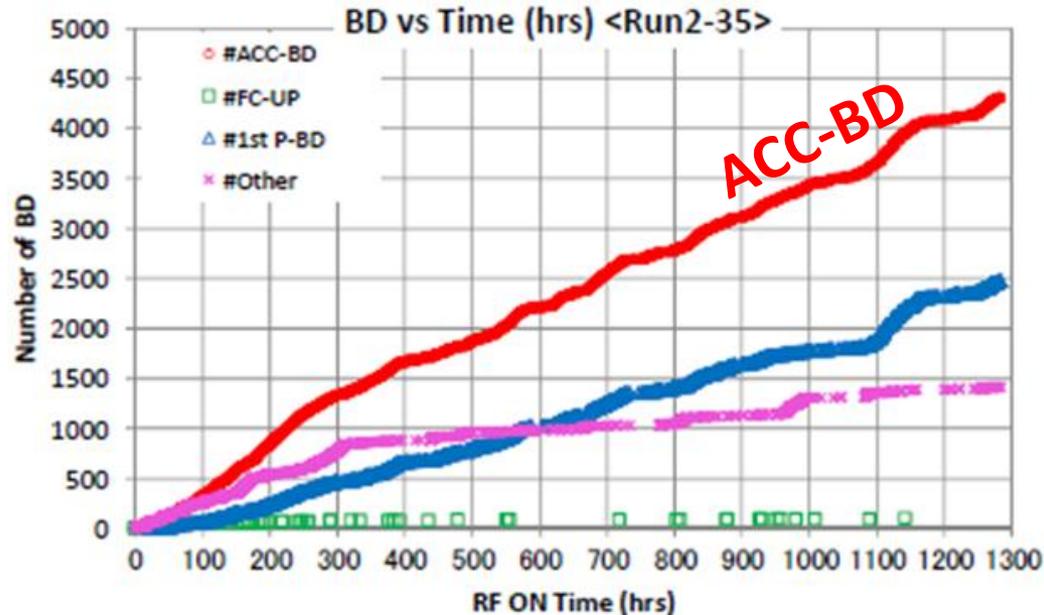
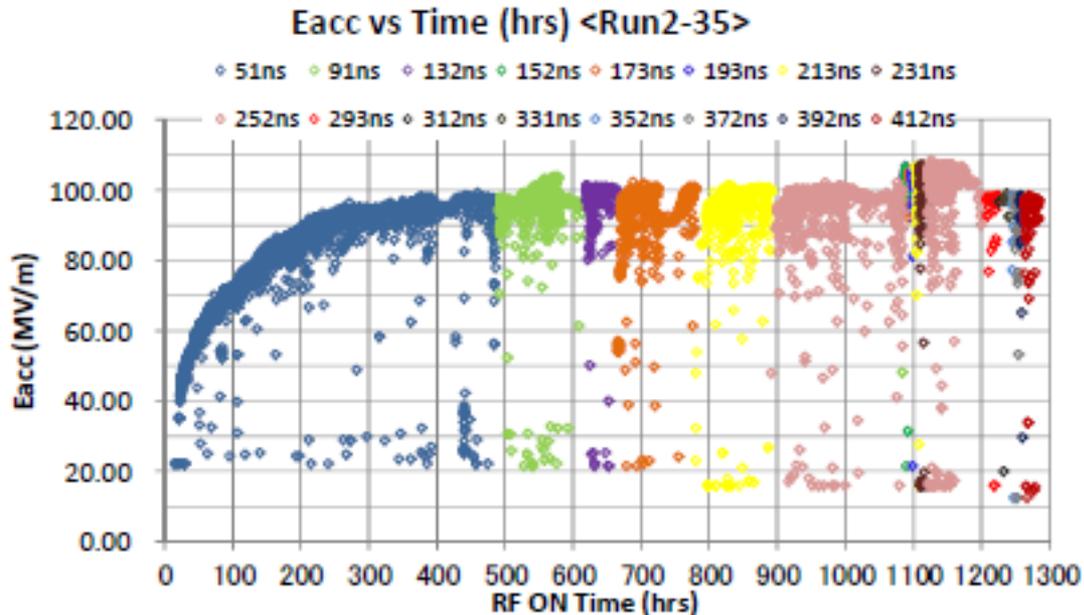


More BD's are required for damped!

BD's are needed for processing?

Can it be reduced?

TD24#4 initial processing

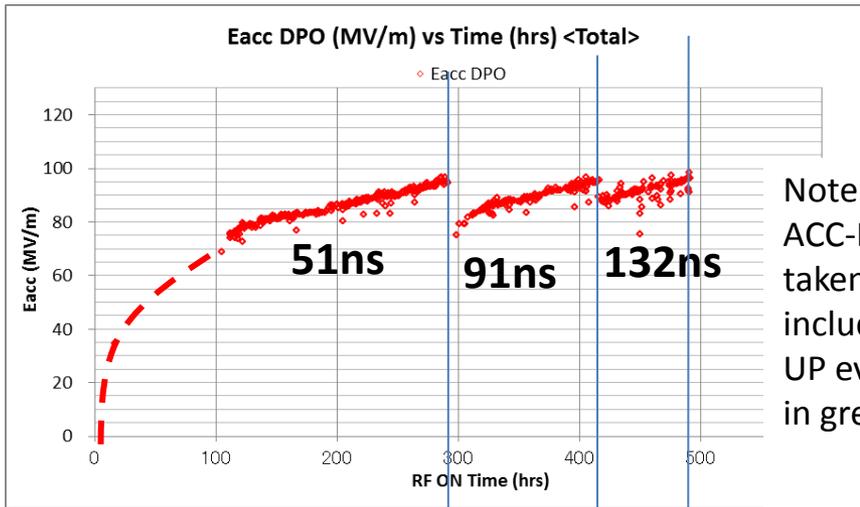


132ns, 100MV/m

Through

ACC-BD = 2400
and
670 hours

TD24R05 initial processing now

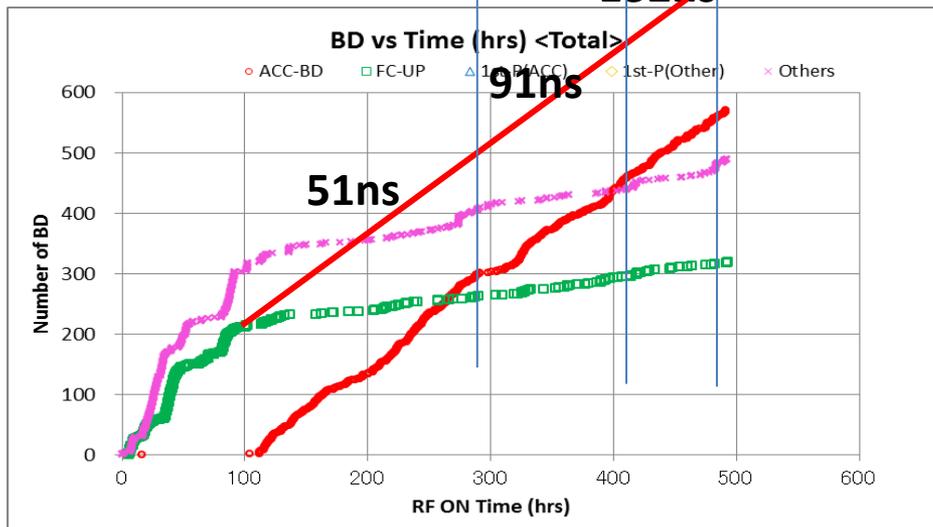


Note: Most of ACC-BD were not taken. Those are included in FC-UP events shown in green dots.

It has been processed to ~100MV/m at 132ns

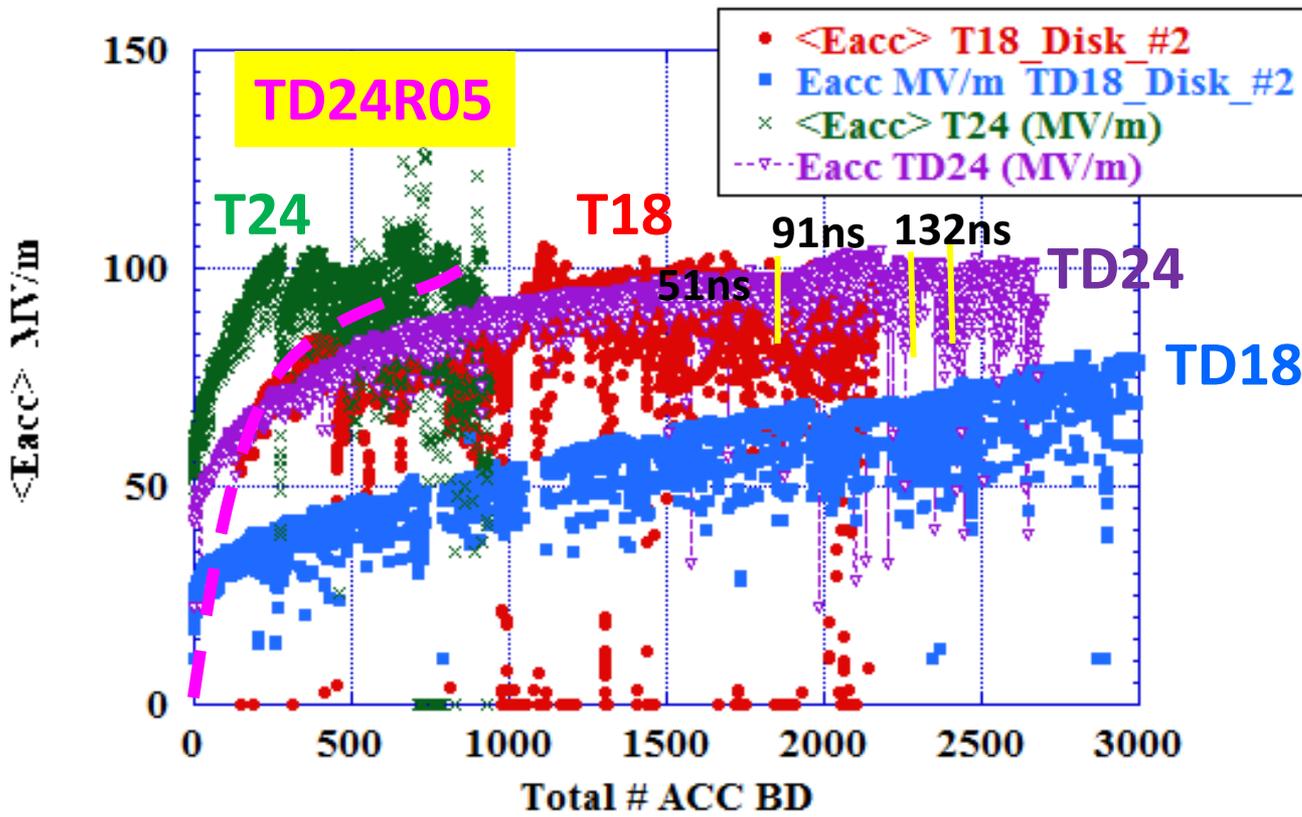
in 500 hours at 50Hz

Accumulated ACC-BD events amounts only 800, much smaller than the early-tested structures.



Difference in processing speed among four+1 structures

Eacc vs #ACC-BD



Number of ACC-BD's until reaching the same level in (T_p , Eacc)

Ranking

- T24
- TD24R05?
- T18
- TD24
- TD18



Magnetic field!?!?

Structure parameter choice

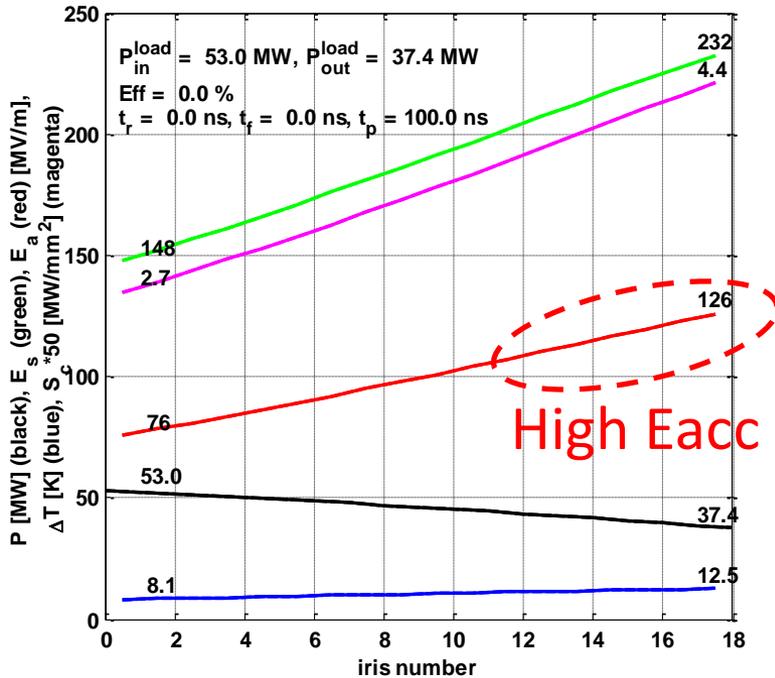
Reduced electric field 18 → 24

T18
Undamped

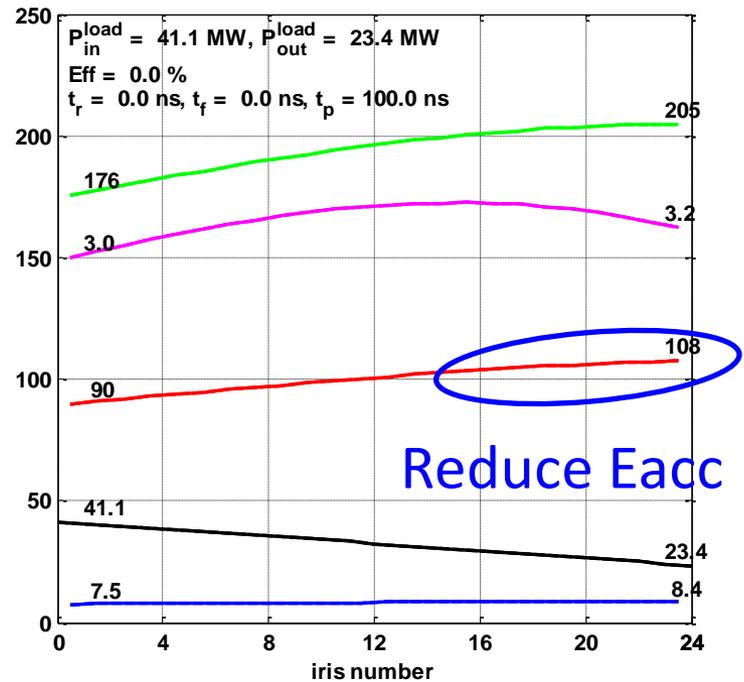


T24
Undamped

P (MW), Es (MV/m), Ea (MV/m), $\Delta T(C)$, Sc*50 (MW/mm²)



P (MW), Es (MV/m), Ea (MV/m), $\Delta T(C)$, Sc*50 (MW/mm²)

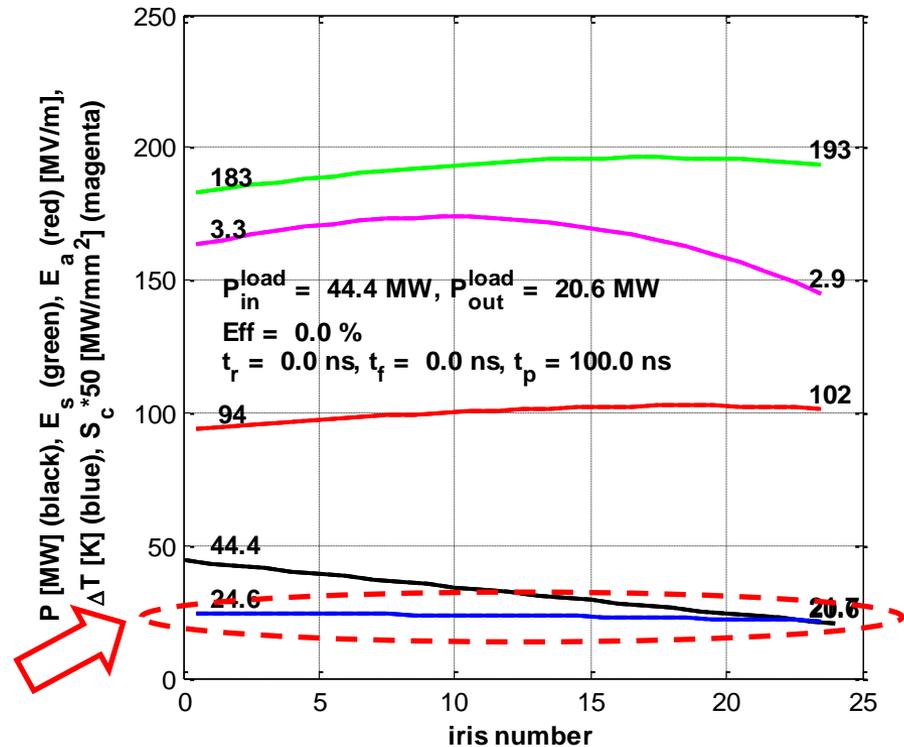
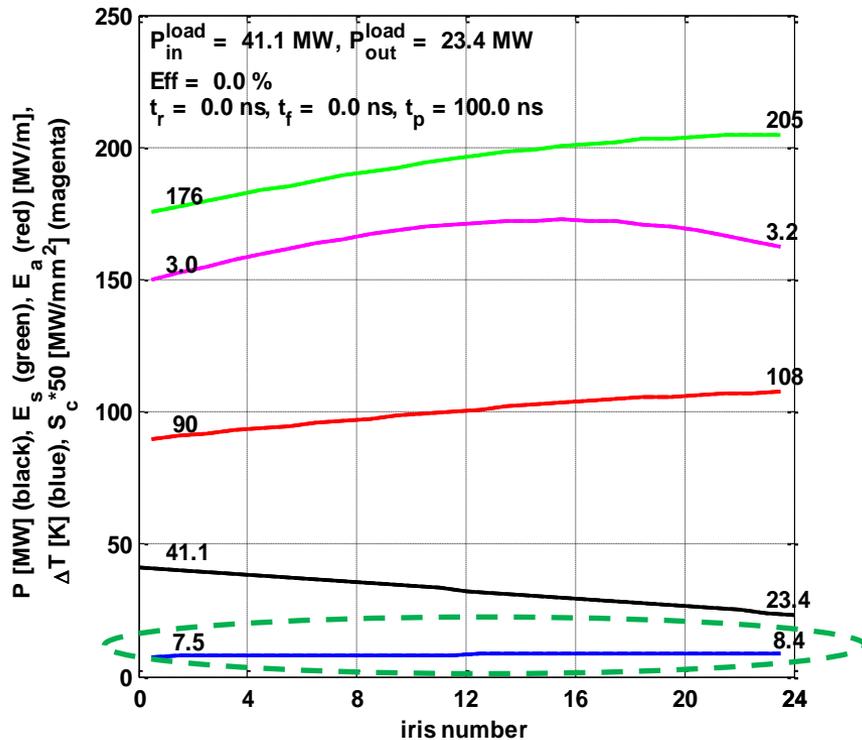


T24



TD24

Average unloaded of 100 MV/m



Increase of pulse heating $\Delta T \sim (H_p/E_a)^2$
 due to damping feature

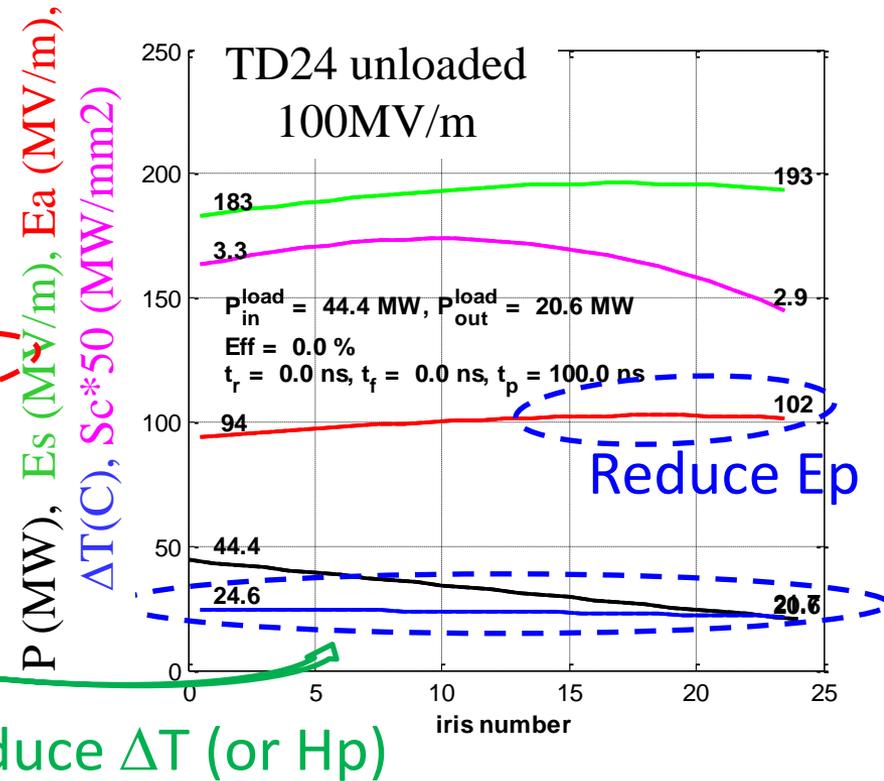
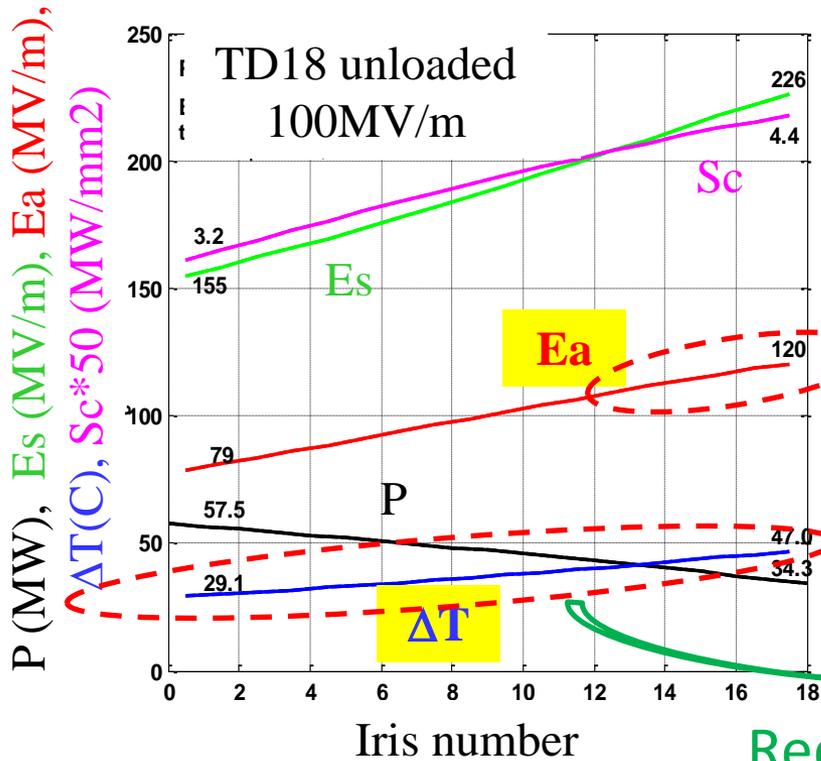
Reduced magnetic field 18 → 24



TD18
Damped



TD24
Damped

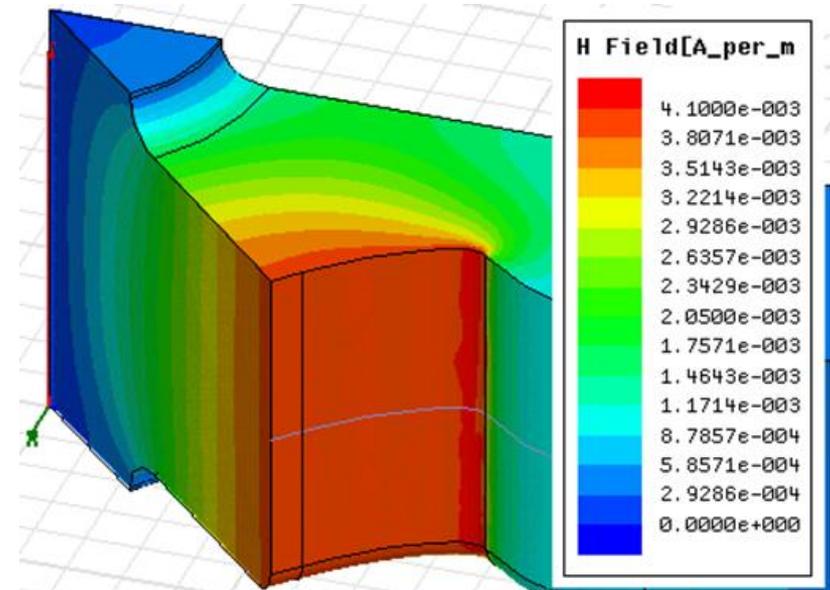
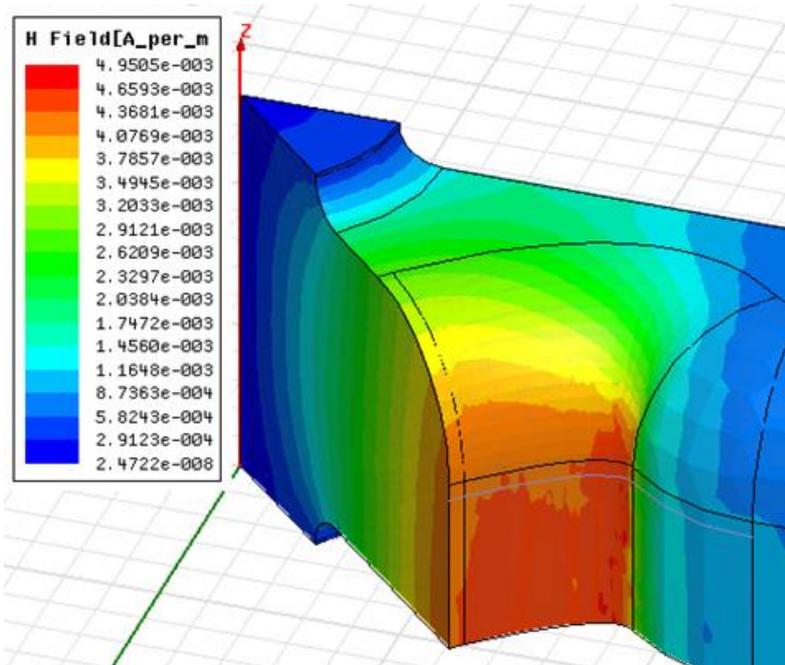


Reduce H_p/E_a and DT by reducing corner radius in the cell

TD24



TD24R05



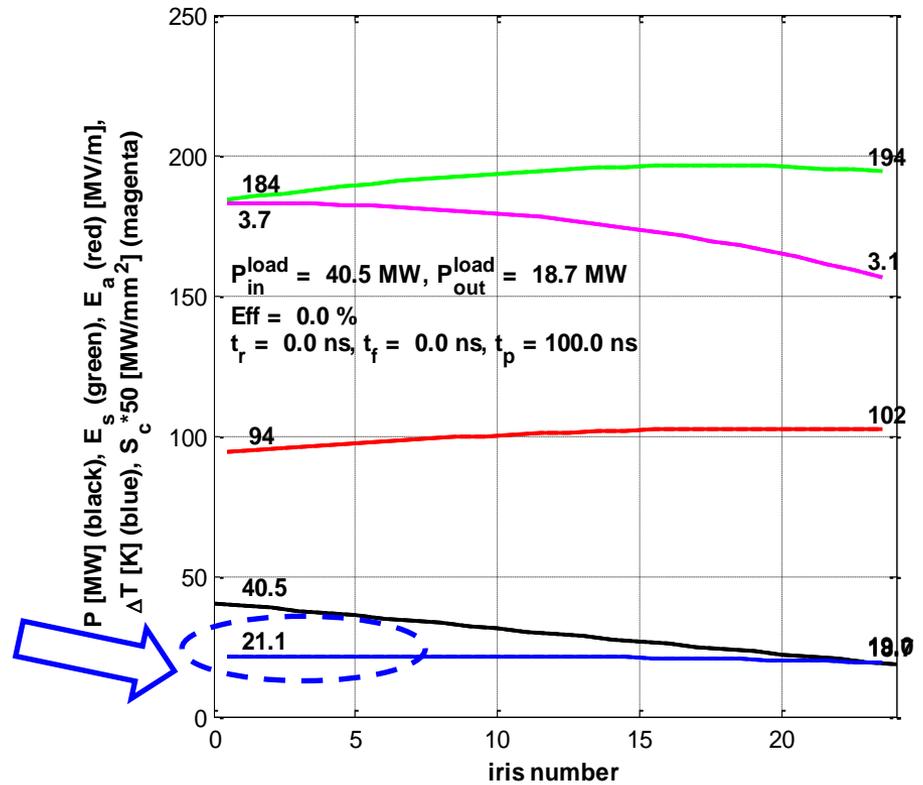
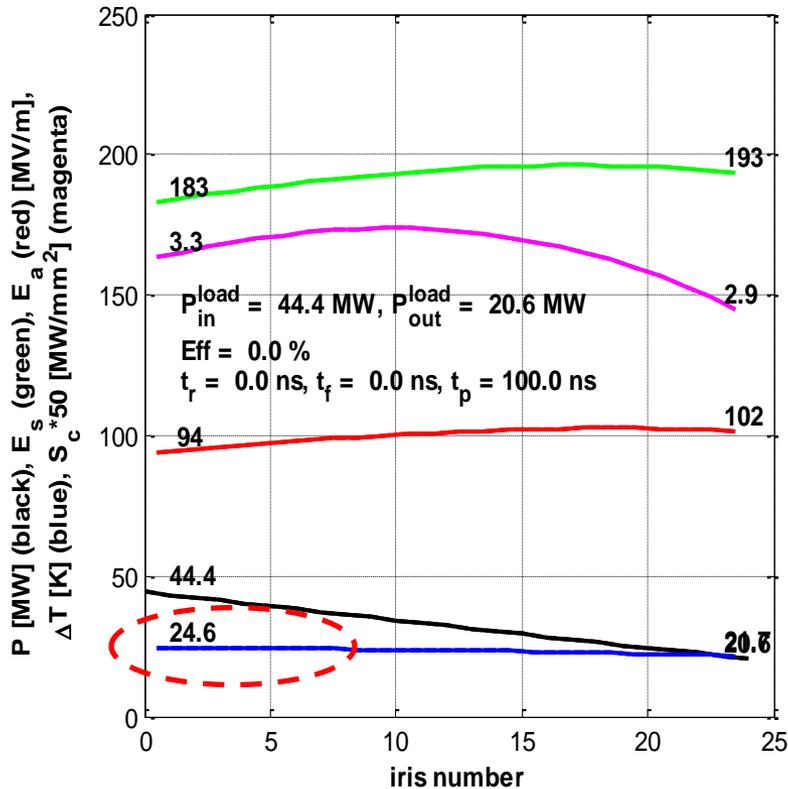
Further reduce Hp/Ea

TD24



TD24R05

Average unloaded of 100 MV/m



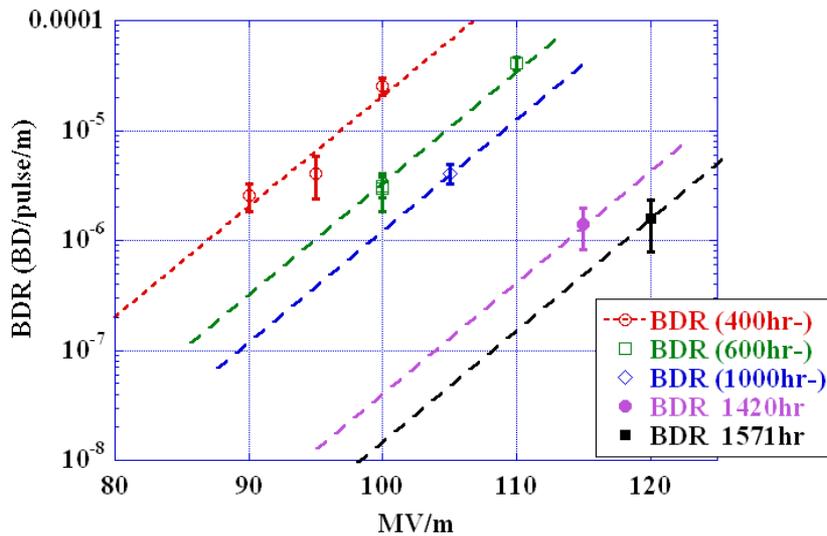
Max field and temperature rise

	E_p/E_a	H_p/E_a	Sc/E_a^2
TD18	1.97	5.9	0.52
TD24	1.95	4.5	0.37
TD24R05	1.95	4.1	0.41
T18	1.95	3.2	0.47
T24	1.95	2.6	0.37

Breakdown rate and flat or CLIC pulse

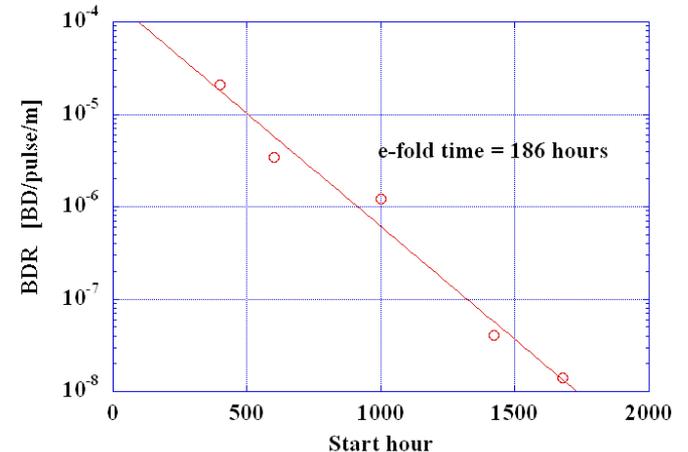
T24#4 BDR evolution at 252ns normalized 100MV/m

T24#3 Breakdown rate at 252nsec



Assuming the same exponential slope as that at 400hr

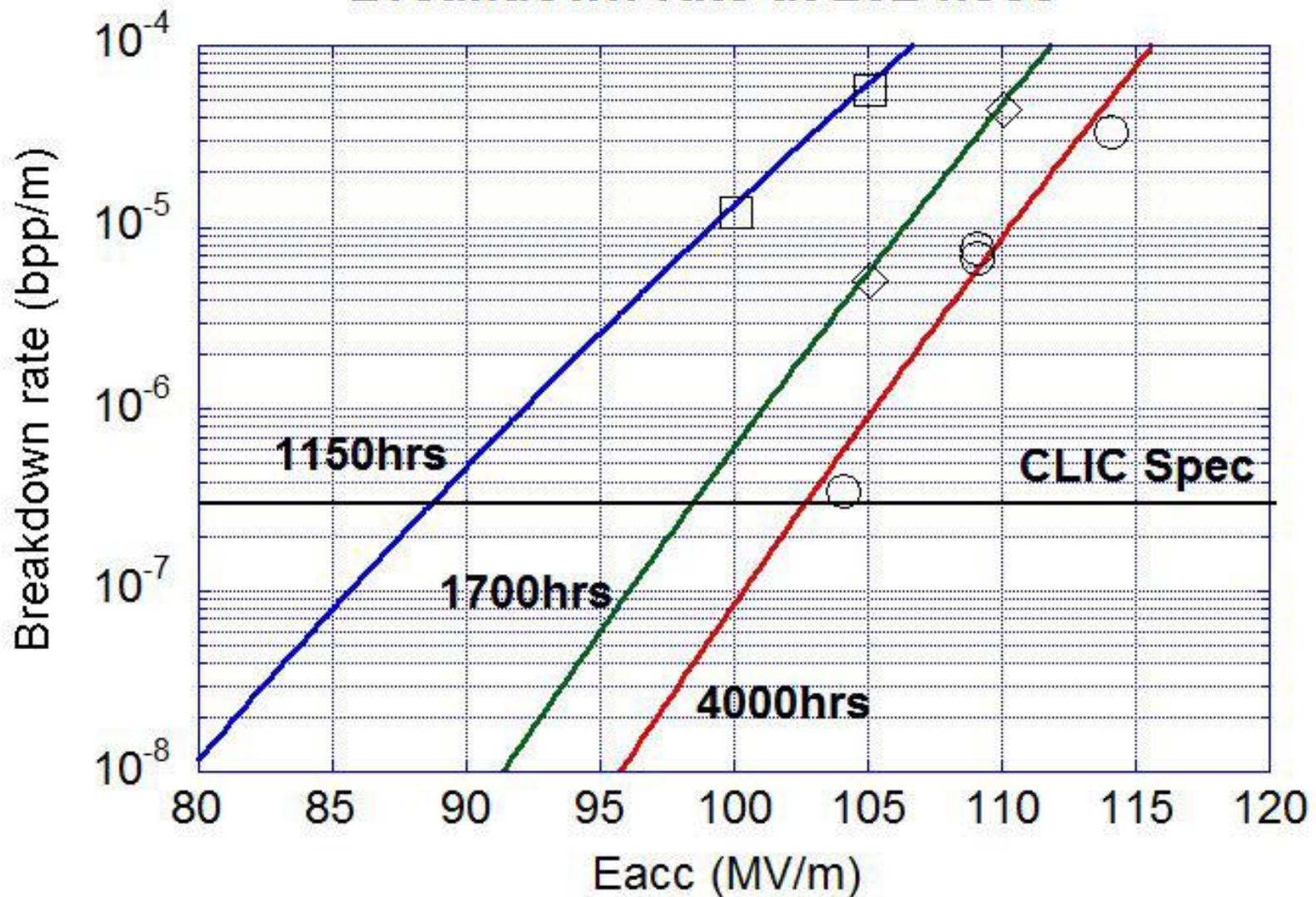
T24#3 BDS vs time normalized at 252ns 100MVm



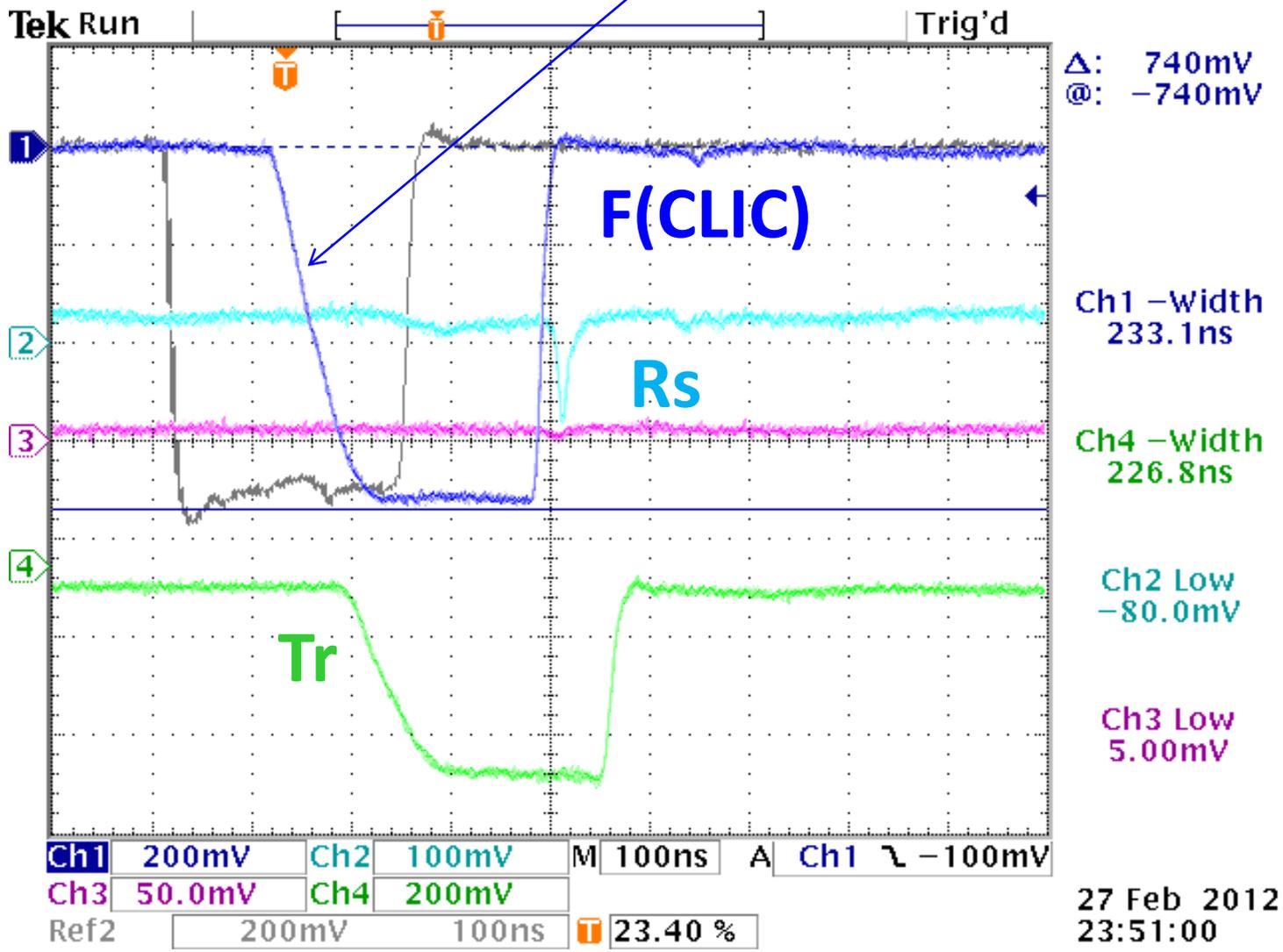
BDR has kept decreasing.

CLIC prototype structure; TD24#4

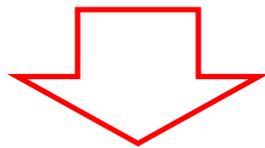
Breakdown rate at 252 nsec



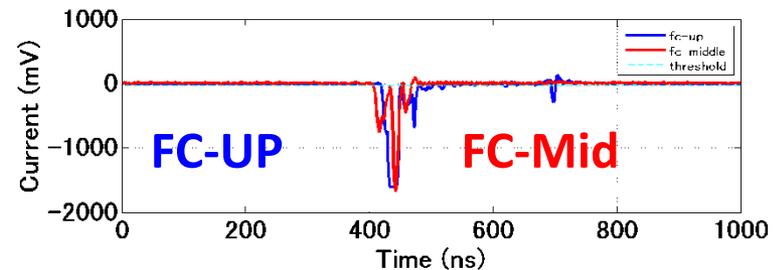
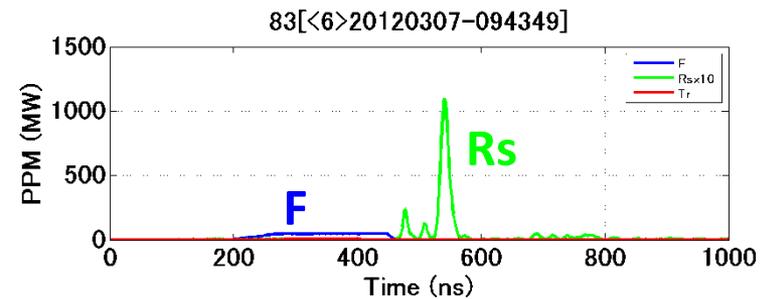
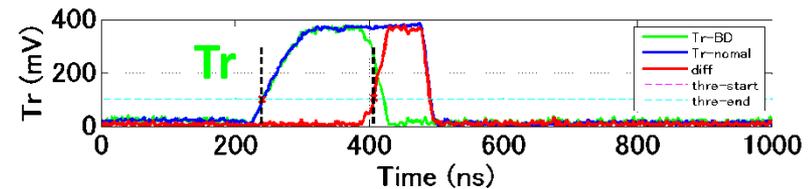
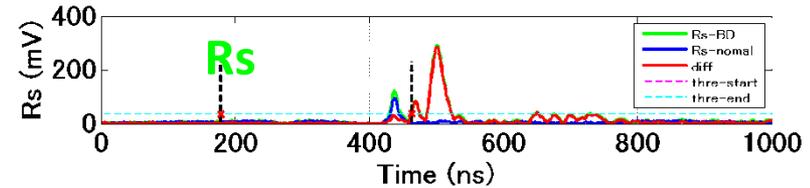
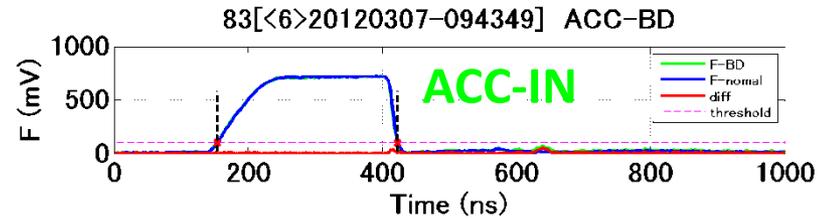
Nominal CLIC pulse



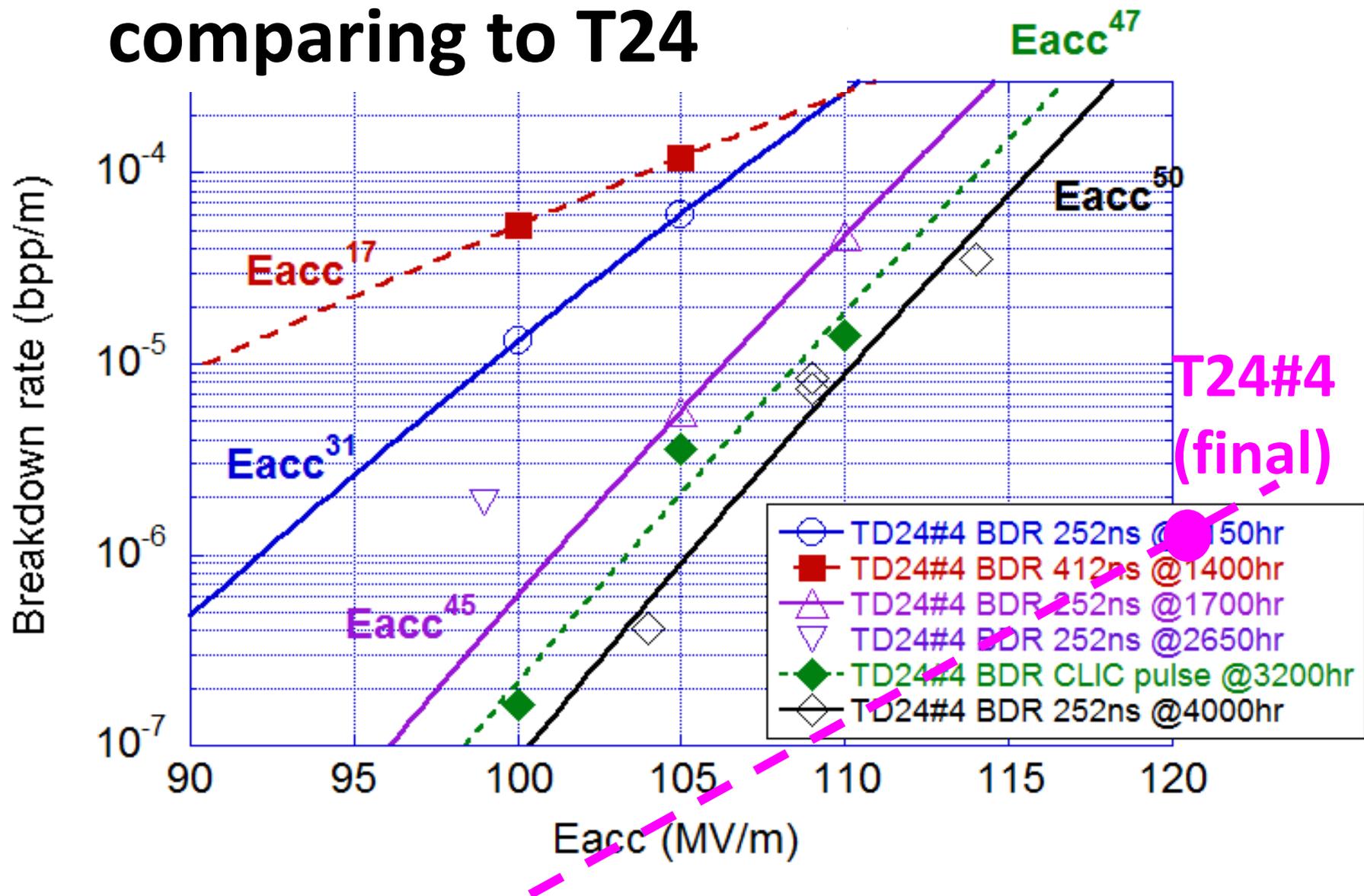
Only 3 breakdowns
 in 484 hour
 operation with CLIC
 pulse at
 FLT=100MV/m



1.6×10^{-7} bpp/m



BDR summary on TD24 comparing to T24



BDR results of TD24#4

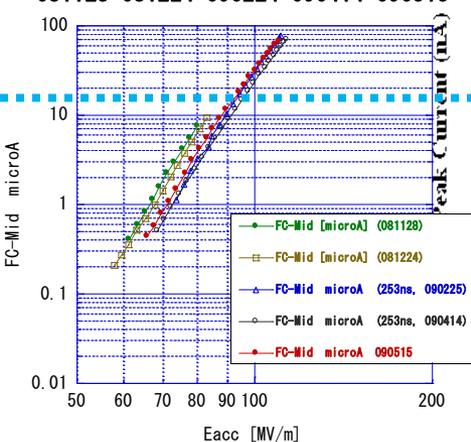
- BDR decreases as processing, as usual
- Larger BDR than T24 but much less than TD18
- CLIC requirement is met through 2000 hours processing
- BDR seems still keep decreasing
- CLIC requirement (3×10^{-7} bpp/m) was actually confirmed in CLIC pulse

Various studies toward understanding of vacuum breakdowns

Comparison of dark current

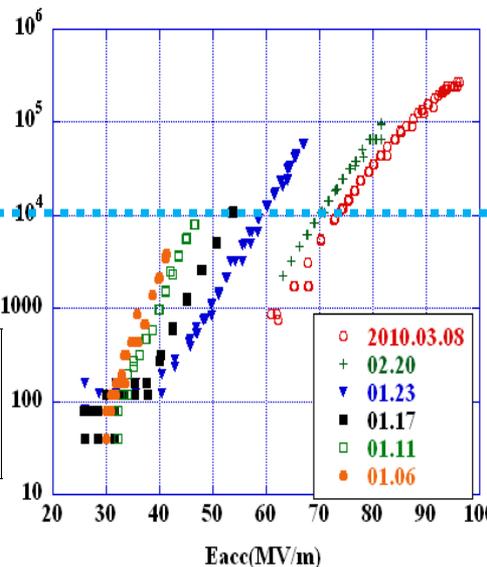
T18_Disk

T18_#2 Dark Current evolution
081128-081224-090224-090414-090515



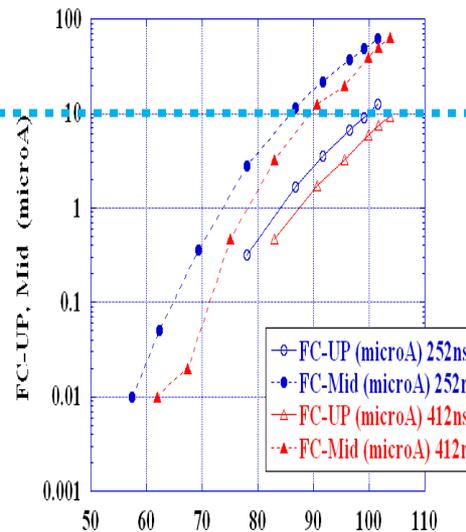
TD18_Disk

Dark Current FC-Mid TD18_Disk_#2



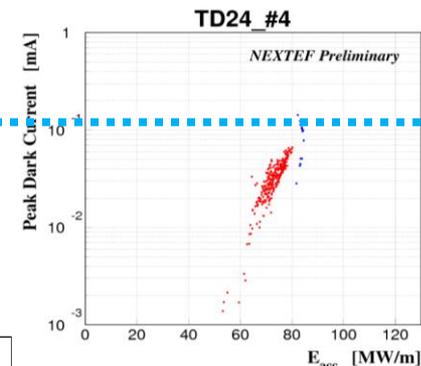
T24_Disk

T24#3 Dark current 110209



TD24_Disk

(51ns processing)



Eacc for peak dark current of 10μ

90MV/m

70MV/m

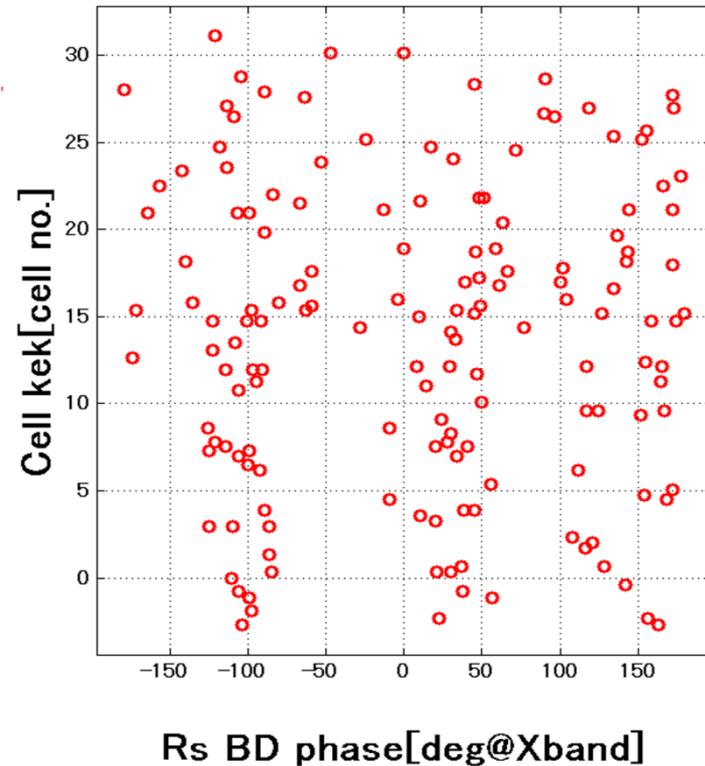
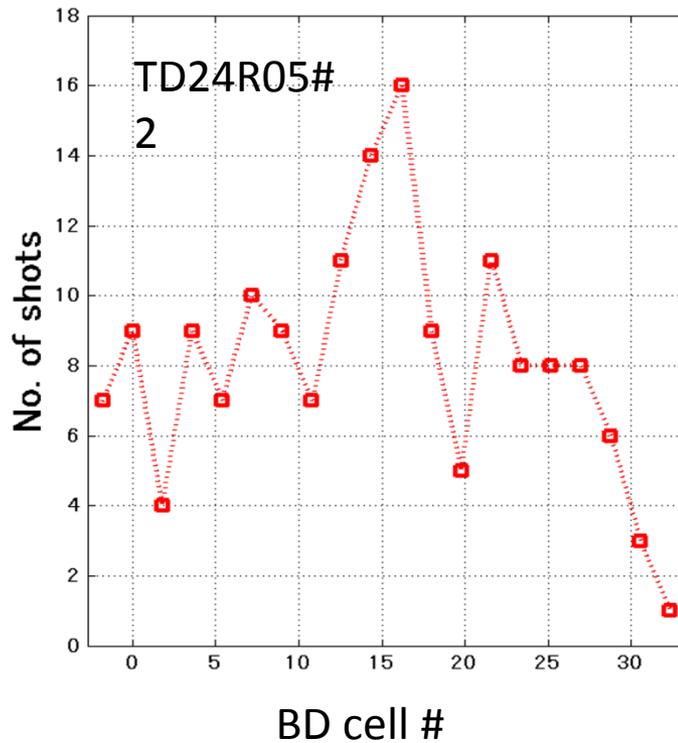
100MV/m

(80MV/m)

Undamped 90~100 MV/m

damped 70~80MV/m

Identification of BD location from RF pulse shape and reflected phase

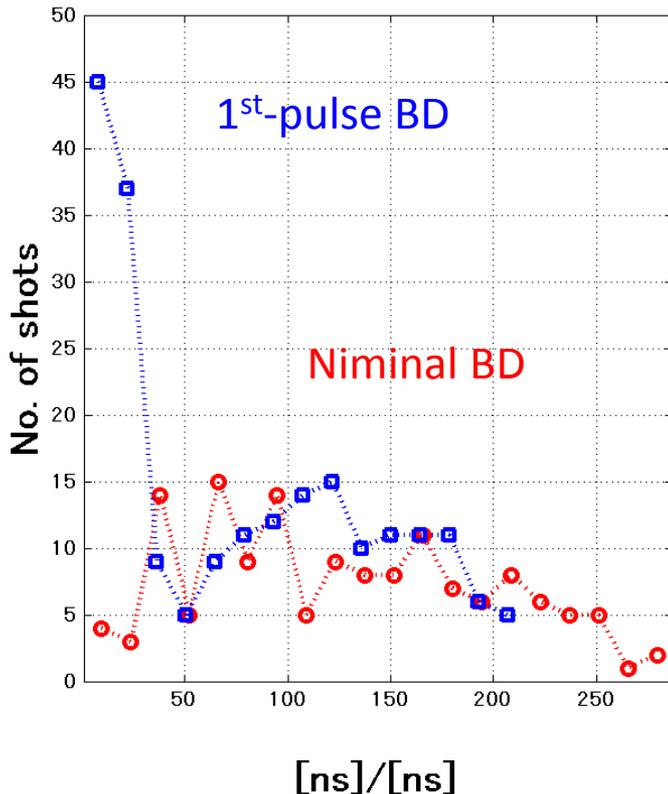


No special location nor steep variation along the structure.

→ Probably surface related mechanism is important to study.

BD timing in pulse evaluated by decay timing of transmission

BD Histogram Plot
Overlay Mode (Up to 5 pieces available)



Uniformly distributed in the pulse
for nominal ACC-BD.

High probability at the beginning
of pulse for the 1st-pulse BD.

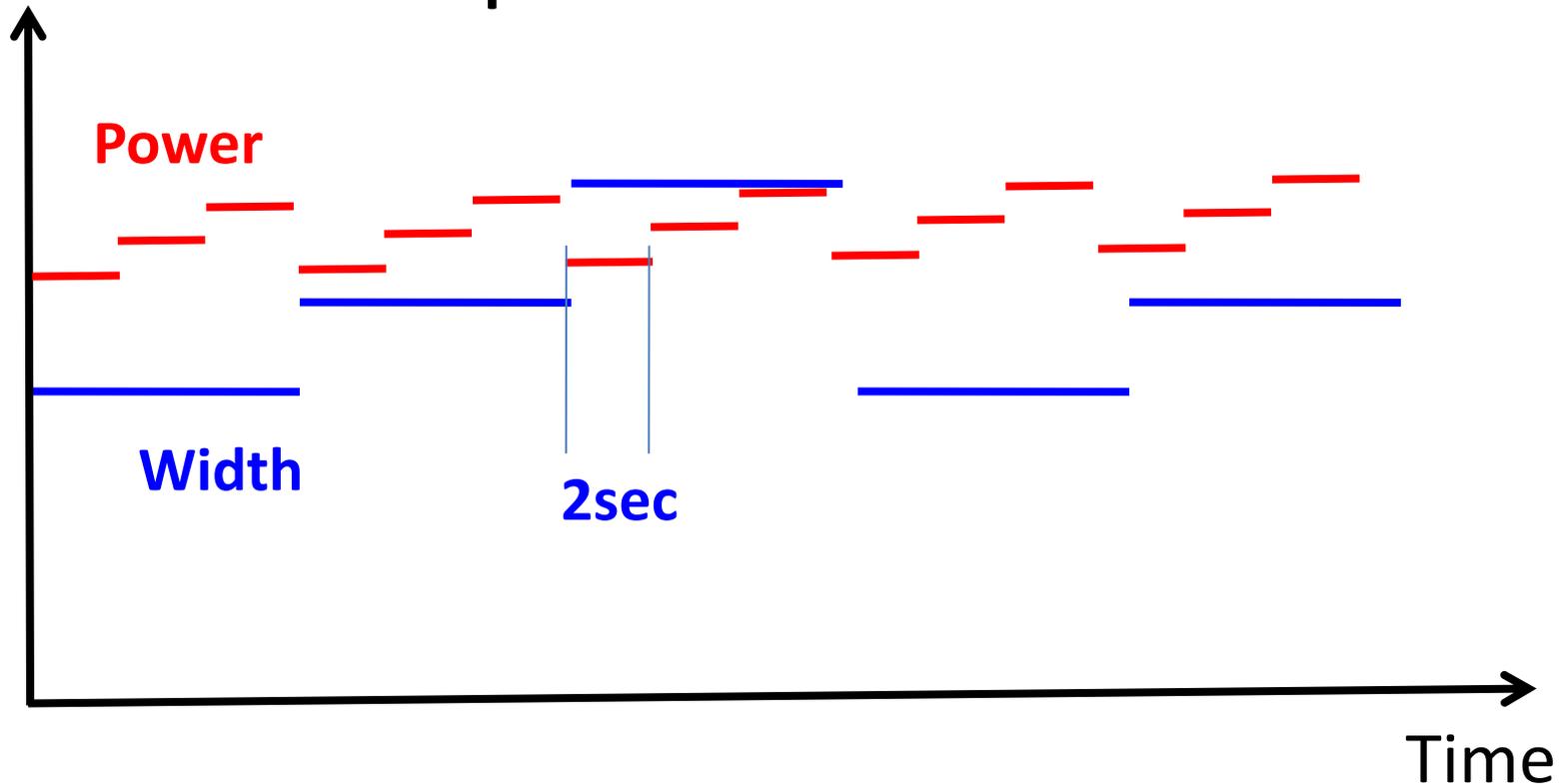
No BDR increase was observed in time in
the pulse!!

Is it usual?

Is it naturally understood?

We see in many cases in structure test,
but contradictory to the result we
observed in the waveguide experiment!?

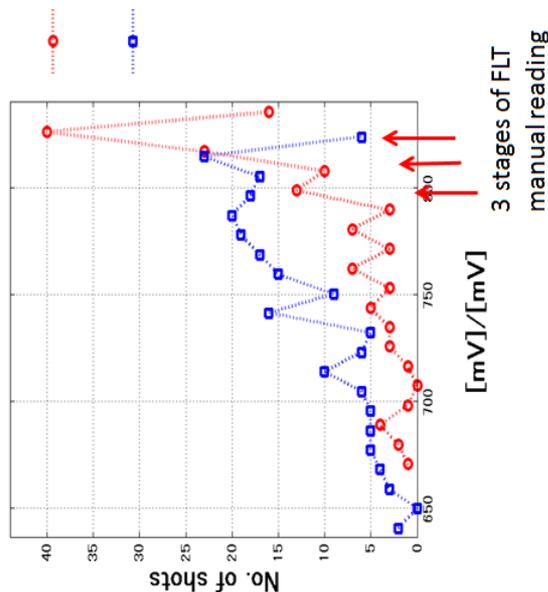
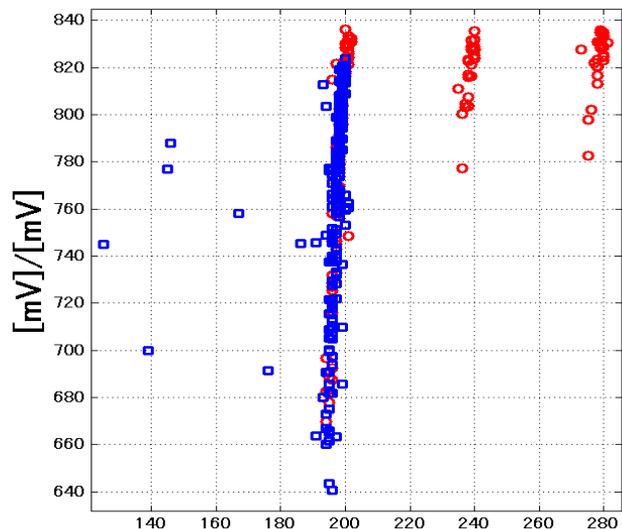
Switching mode operation in power and width



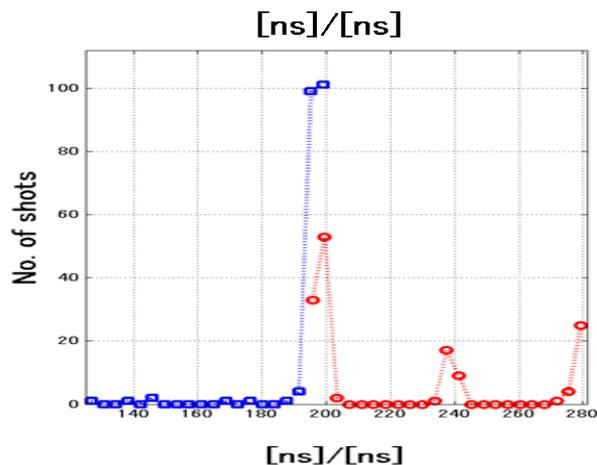
As one of the trials to study memory on following pulses.

Width and Power → Failed!

BD Correlation Plot
Overlay Mode (Up to 5 pieces available)



Need more sophisticated experimental programming!



More BD's in higher Eacc.

→ Obvious!

Power dependence was not well resolved.

→ need more spacing in power level.

→ need more time to study in this mode.

Lower power BD's in 1st-pulse BD

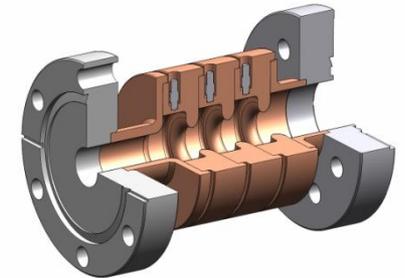
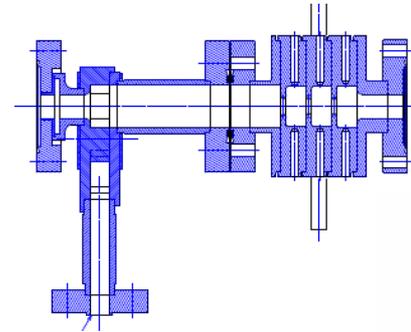
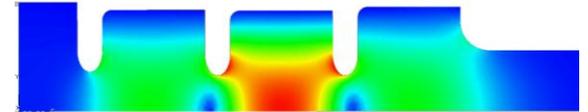
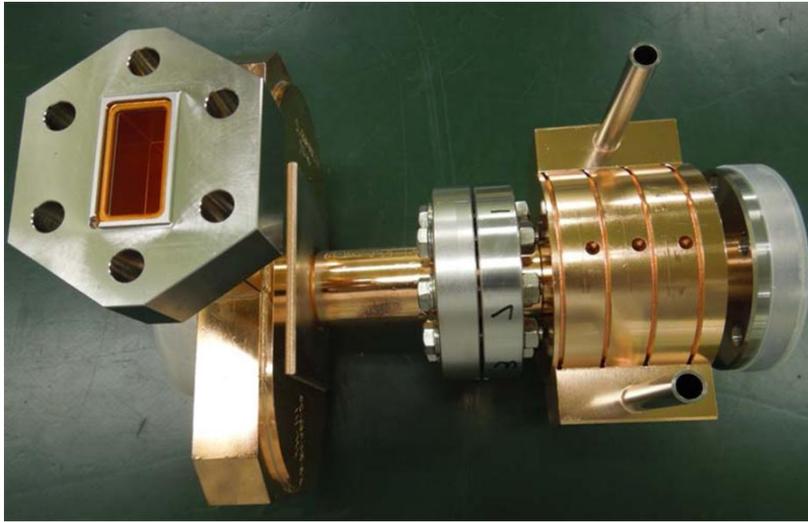
→ Because startup with less power setting for recovery routine.

BDR characteristics on width is not evident.

→ Need more statistics.

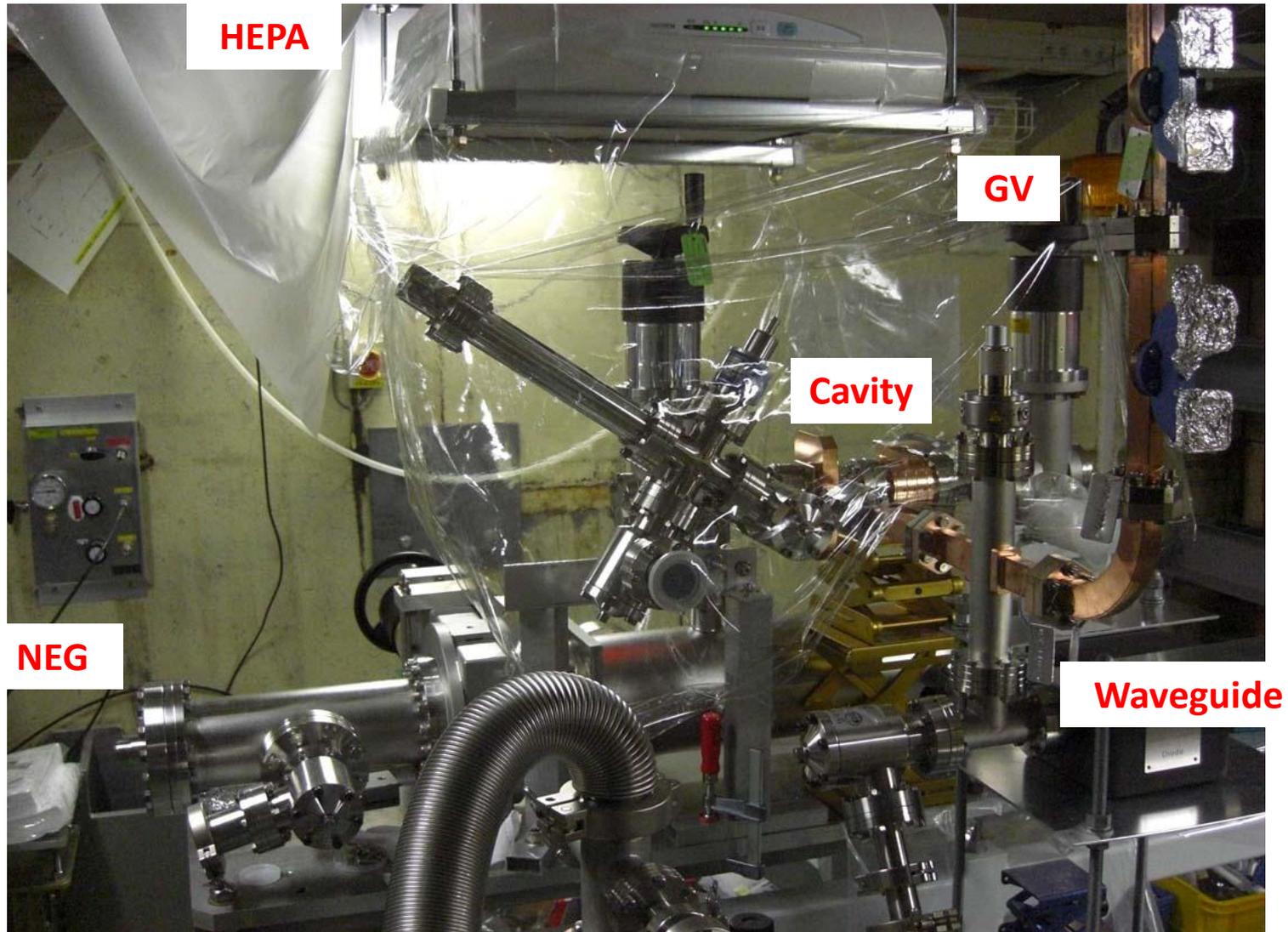
Setups being prepared to study basic characteristics and mechanism of vacuum breakdowns in RF

Single-cell setup just as that established by SLAC



We will study breakdown characteristics taking much focus on the **initial processing stage** appearing at medium field, 60-100 MV/m

Preparation of setup in shield-B



Studies in mind

- Explore **basic research** in a simple geometry
- Center cell is such as the following

1. **Standard**: KEK made – SLAC test

2. Nominal: **Heavily-damped**

3. Made of **large-grain material**

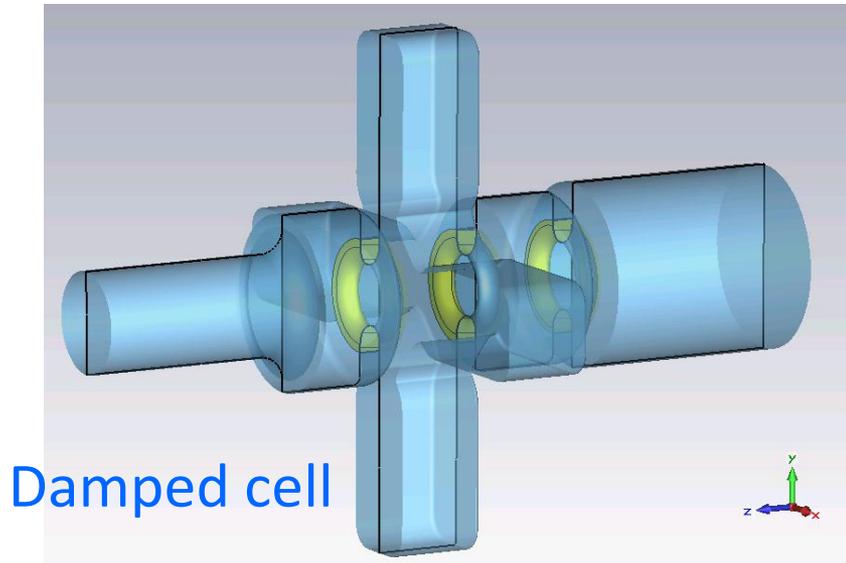
4. Undamped but **all-milled**

5. All milled **quadrant** type

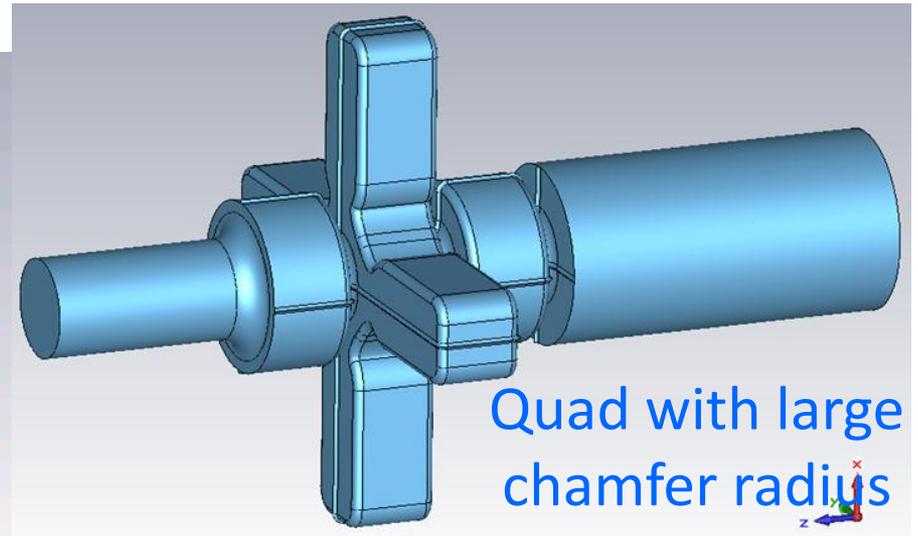
These are under
preparation

6. **Choke-mode** type (take Tsinghua design?)

Some studies in mind



Damped cell



Quad with large chamfer radius



Crystal characteristics



Clean surface

Conclusion

- Finished high gradient test of four CLIC prototype structures.
- TD24 closest to actual CLIC3000 has estimated to meet CLIC BDR requirement in full-flat pulse. CLIC pulse operation was actually confirmed to meet CLIC BDR requirement.
- Processing of TD24R05 recently started. Initial processing speed as function of # of ACC-BD showed better than TD24, and even better than T18, up to 132nsec . (preliminary)
- Basic study test stand is ready to start. The klystron for it is being evaluated whether to be recovered from water leakage into waveguide.