ARES Status 2004(JFY)

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High Energy Accelerator Research Organization (KEK)

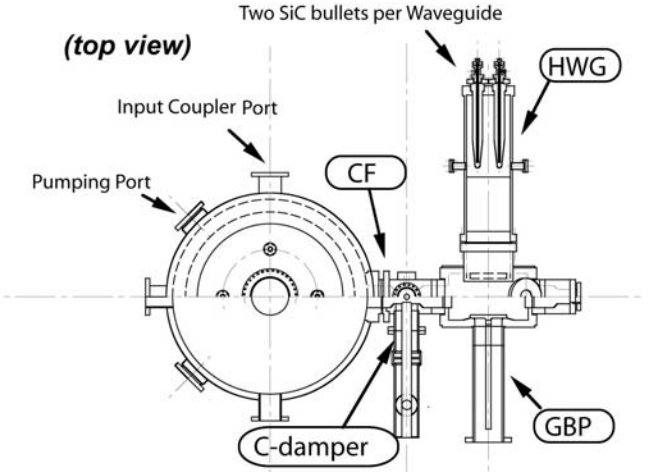
＜Outline＞

1. Fundamentals of the ARES-cavity system
2. Operation status
3. D04C/ARES multipactoring problem
4. Summary

KEKB Review
@KEK
2005.02.21

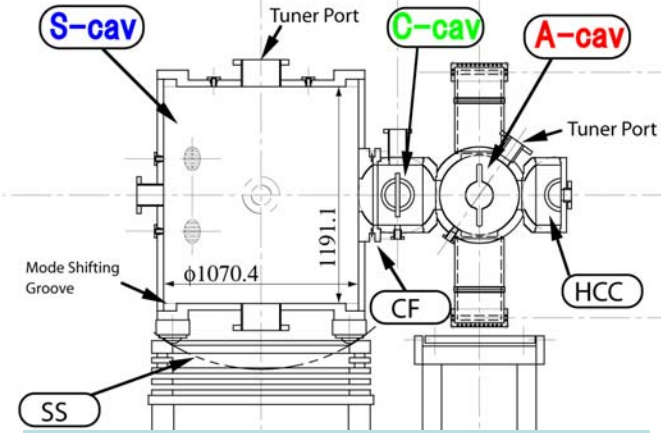
Accelerator Resonantly-coupled with Energy Storage

3-cavity system stabilized with the π/2-mode operation

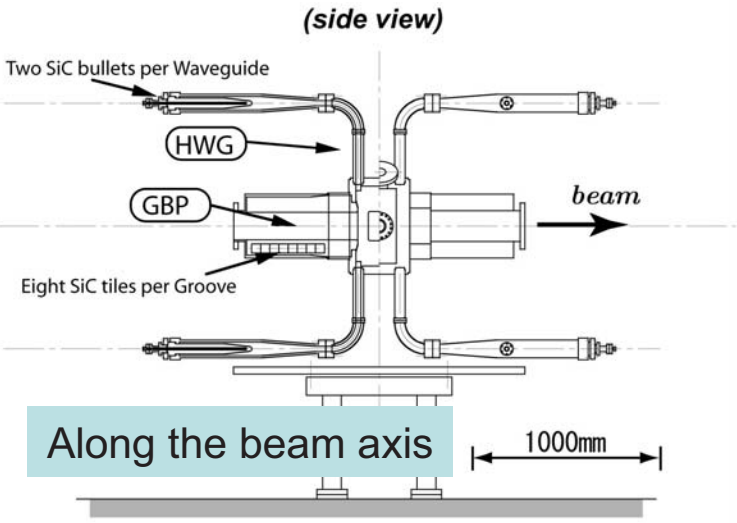


consists of

- HOM-damped accelerating cavity (**A-cav**)
- Energy-storage cavity with TE_{013} (**S-cav**)
- Coupling cavity (**C-cav**)
  with a parasitic-mode damper



Perpendicular to the beam axis



Along the beam axis

Operation with the Accelerating π/2 Mode

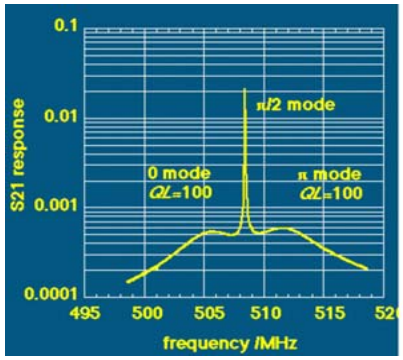
Advantages

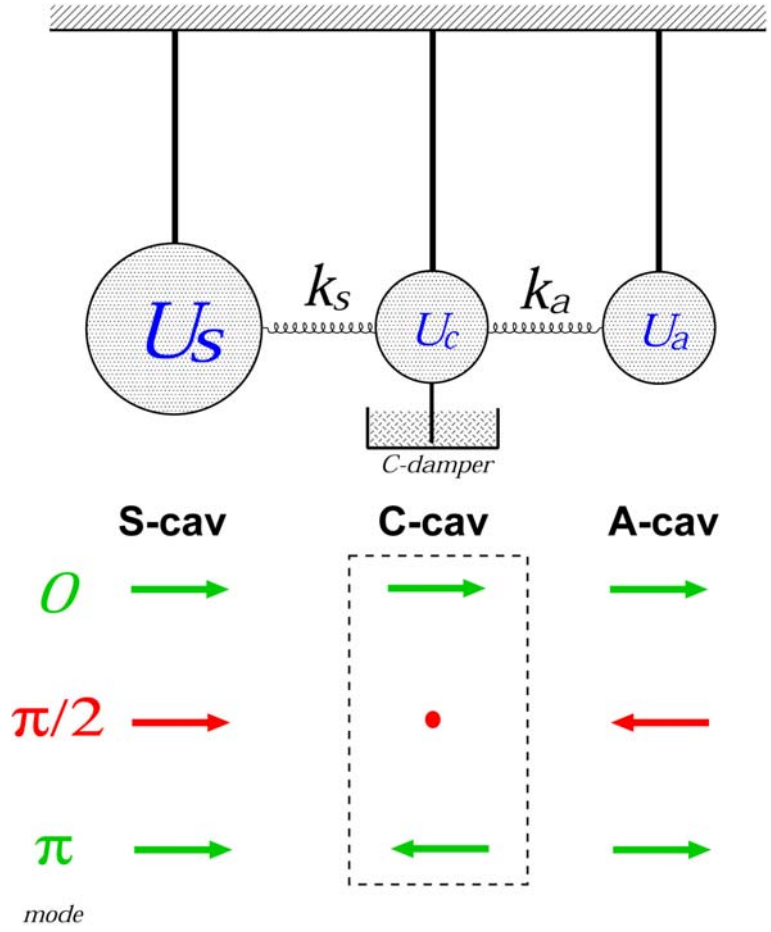
- **The field of the π/2 mode is the stablest against**
  - Beam loading,
  - Detuning of A-cav $(=\Delta f_a)$
- **The stored-energy ratio: Us/Ua**
  - → can be changed

$$\frac{Us}{Ua} = \frac{k_a^2}{k_s^2} \qquad \left(\Delta f_{\pi/2} = \frac{\Delta f_a}{1 + Us/Ua} \right)$$

- **The parasitic 0 and π modes**
  - → can be damped selectively

  out of C-cav (C-damper)





Energy-storage Cavity (S-cav)

- Q_0(S-cav) =~ 1.7x10^5
- Stores large electromagnetic energies in TE_{013}
- To suppress the longitudinal CBIs

$$\text{Optimum detuning } \Delta f = \omega_R - h\omega_0$$
$$= -\frac{I \sin\phi_s}{2V_c}\frac{R_a}{Q_0} f_a$$
$$= -\frac{P_b \tan\phi_s}{4\pi U}$$

$$\Delta f_{\pi/2} = \frac{Ua}{Ua+Us}\Delta f_a = \frac{\Delta f_a}{1+Us/Ua}$$

Ua : energy in A-cav
Us : energy in S-cav

=9 (in KEKB)

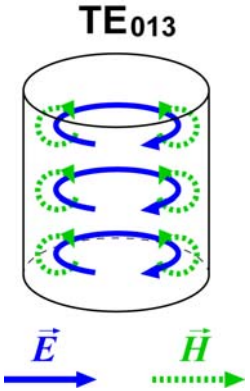
Δf_a: optimum detuning of A-cav

$\Delta f_a = -200$ kHz in KEKB/LER (2.6A, 20 sets)

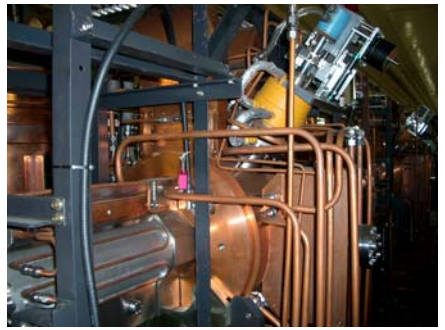
$\Delta f_a = 710$ kHz in SuperKEKB/LER (9.4 A, 28 sets)

Cf. $f_{rev} = 99$kHZ

S-cav's



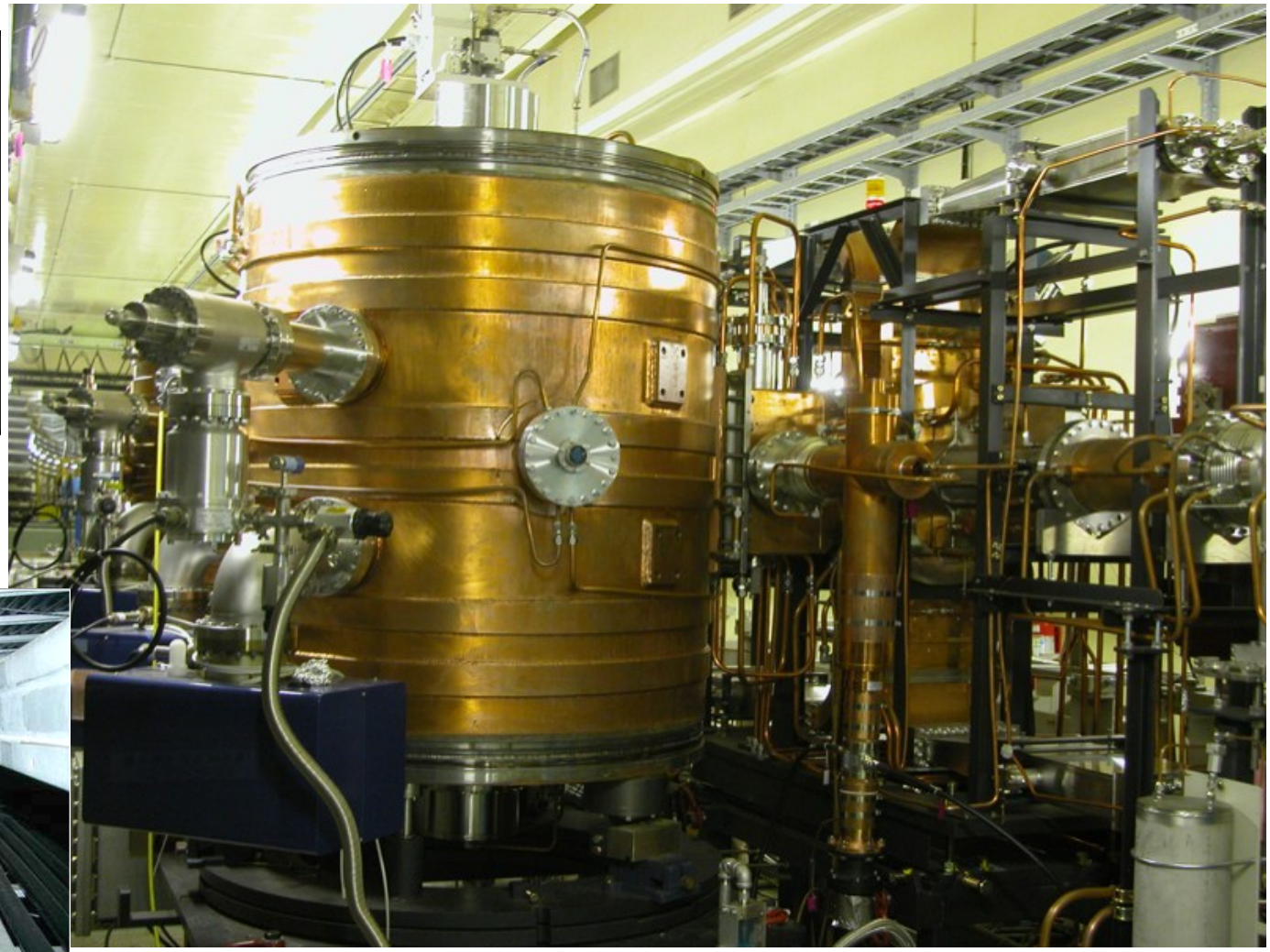
Movable tuner on A-cav



ARES in the KEKB Tunnel

Design Parameters

V_c	0.5MV
R_a/Q_0	15 Ω
Q_0	11x10^5
P_{in}	400kW
P_c	150kW
U_s/U_a	9



(Waveguide from klystron)

Operation Status @ KEKB

(Jan.~Feb., 2005)

- **LER: 20 cavities**
  - Total Vc: 8.0MV (0.4MV/cav)
  - Beam current: ~1.6A
  - Input RF power /cav: ~300kW
  - HOM power: >~ 5kW
  - Trip rate: <1 /cav /3months

- **HER: 12 cavities (+ 8 SCCs)**
  - Total Vc = 15MV (←13MV)
    = 4.09MV(ARES) + 10.91MV(SCC)
    (0.34MV/cav)
  - Beam current: ~1.20~1.27A
  - Trip rate (ARES): < 1 /cav /3months

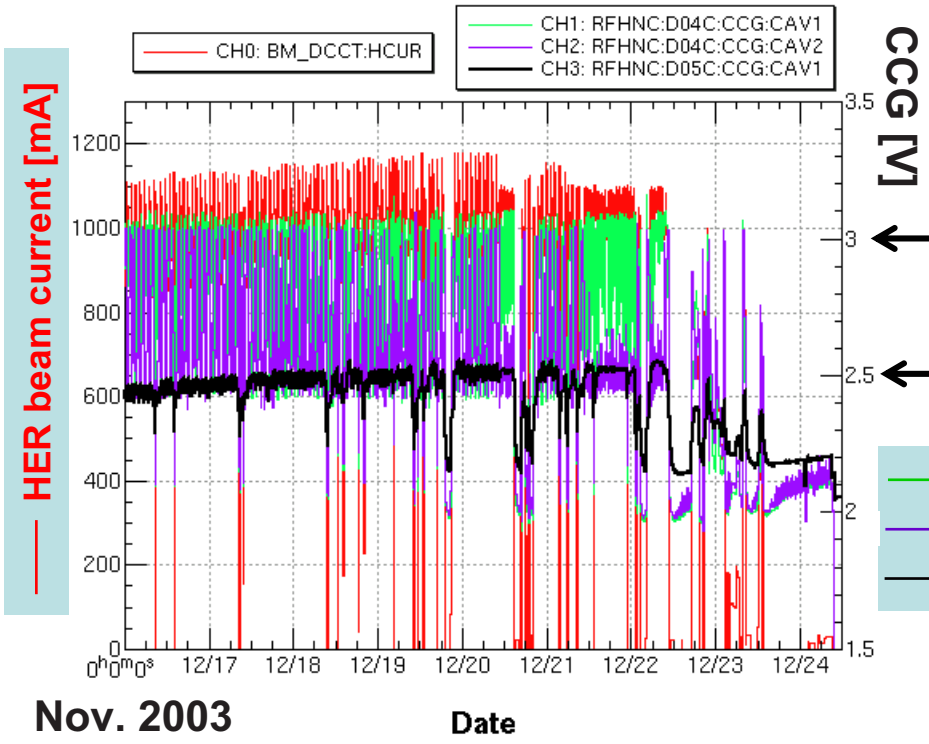
Stable Operation!!!

ARES cavities in the LER RF section

D04C/ARES Multipactoring Problem

--- worse vacuum and discharge ---

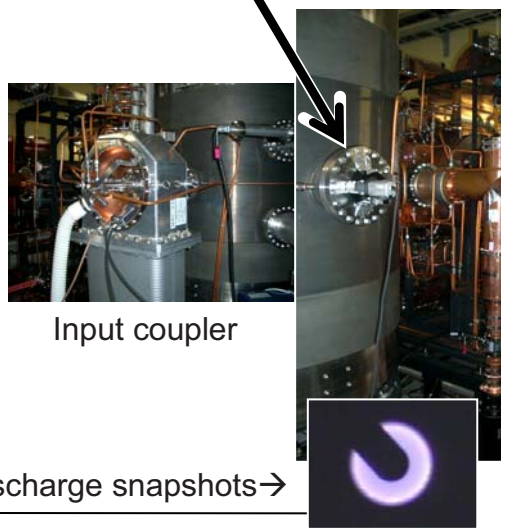
- The *vacuum* in the ARES cavities (No.1 and No.2) of the D04C station became worse significantly (~3 times).
- Even with lower $P_{kly\text{-}out}$ and/or Vc
- No conditioning effect
- Input-power dependence
- *Discharge* in the input couples observed with the TV cameras



6.8x10^-6 Pa

2.3x10^-6 Pa

Vac(D04C-cav1)
Vac(D04C-cav2)
Vac(D05C-cav1)



Input coupler

Example of the discharge snapshots→

The input couplers were wiped with dilute sulfuric acid in Nov. 2003 (winter shutdown)

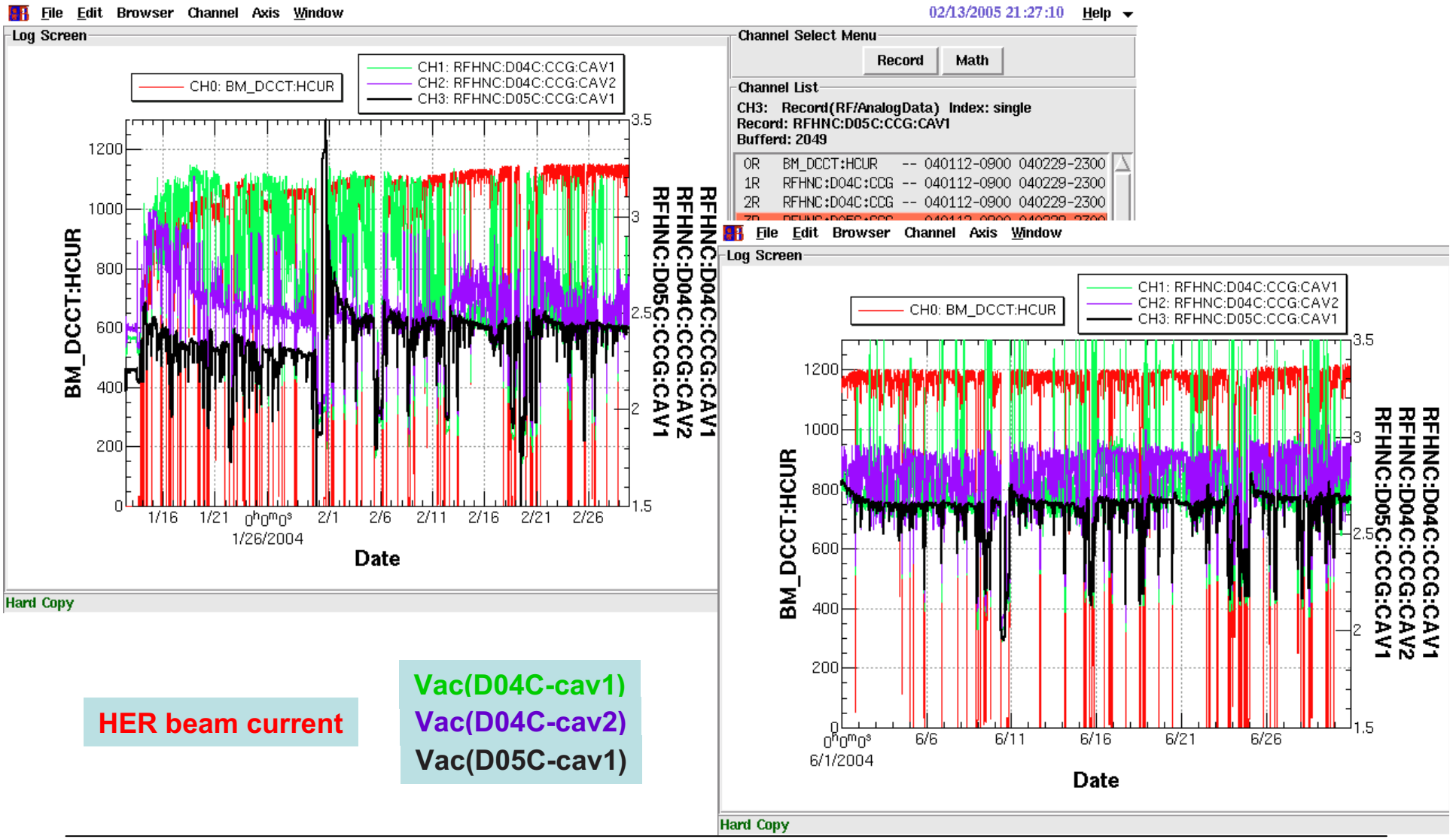
Before

Soot?

After

Clean!

Still bad! (on cav1)



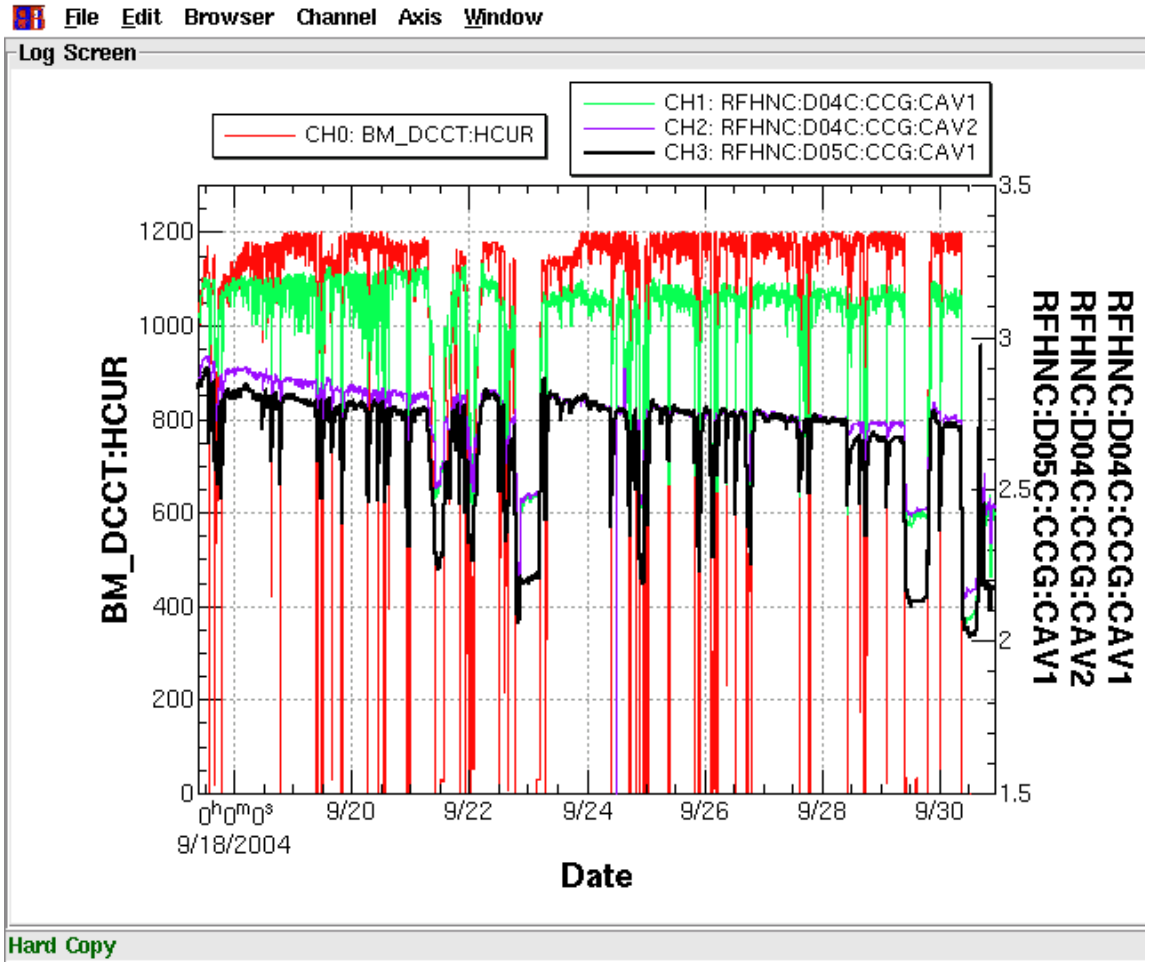
HER beam current

Vac(D04C-cav1)
Vac(D04C-cav2)
Vac(D05C-cav1)

In the summer shutdown 2004

- **Two input-couplers replaced by new ones**
- Input-coupler ports scraped
- Ion pumps replaced by new ones
- High power test (with no beam) →**OK**
  - ✓***The vacuum condition was good.***
  - ✓***No discharge observed***
  - ✓***We reached a target power soon!***

Again bad on Cav1 in the KEKB operation



HER beam current

Vac(D04C-cav1)
Vac(D04C-cav2)
Vac(D05C-cav1)

Options

I. To leave the cavities as they are

→ No effort, no cost and no time to be spent

→ Might cause terrible accidents.

II. To replace the whole ARES cav. by new ones

→ Effort, high cost and long time to be spent

→ No guarantee (?)

III. To do studies, not to replace the cavities

→ Effort and time to be spent, free of cost

→ More scientific

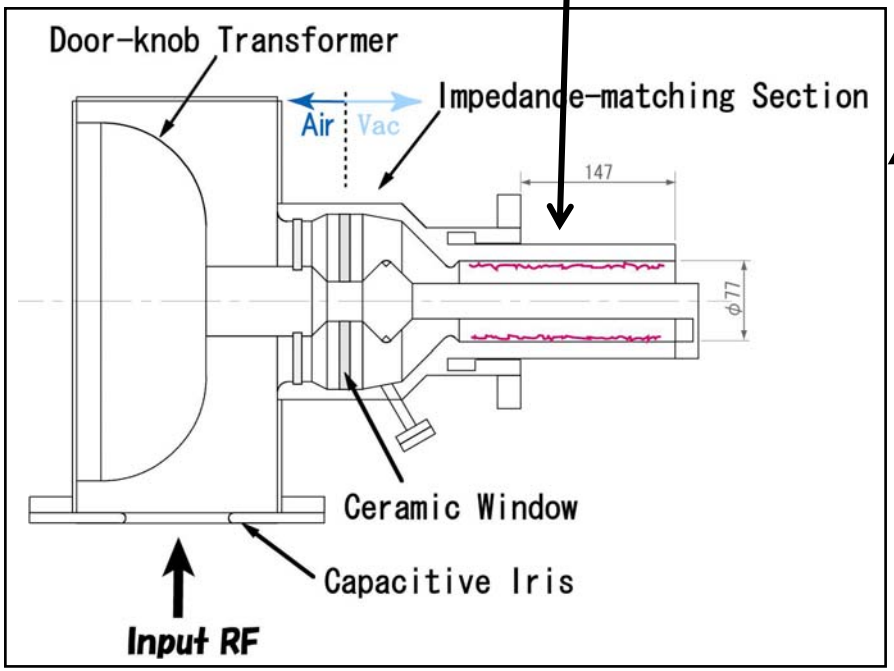
Choice

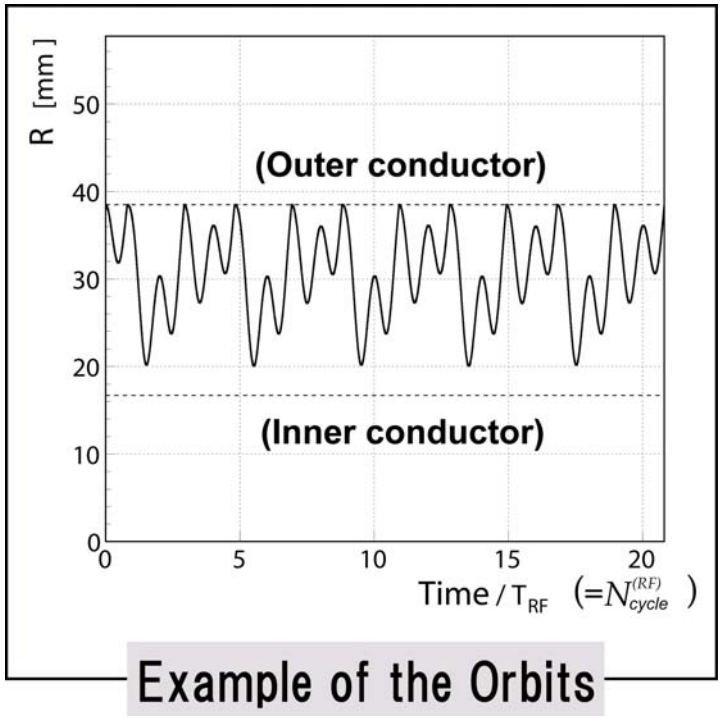
III. To do studies, not to replace the cavities

→ Effort and time to be spent, free of cost

→ More scientific

Simulation Study on the Multipactoring in the coaxial line of the Input Couplers

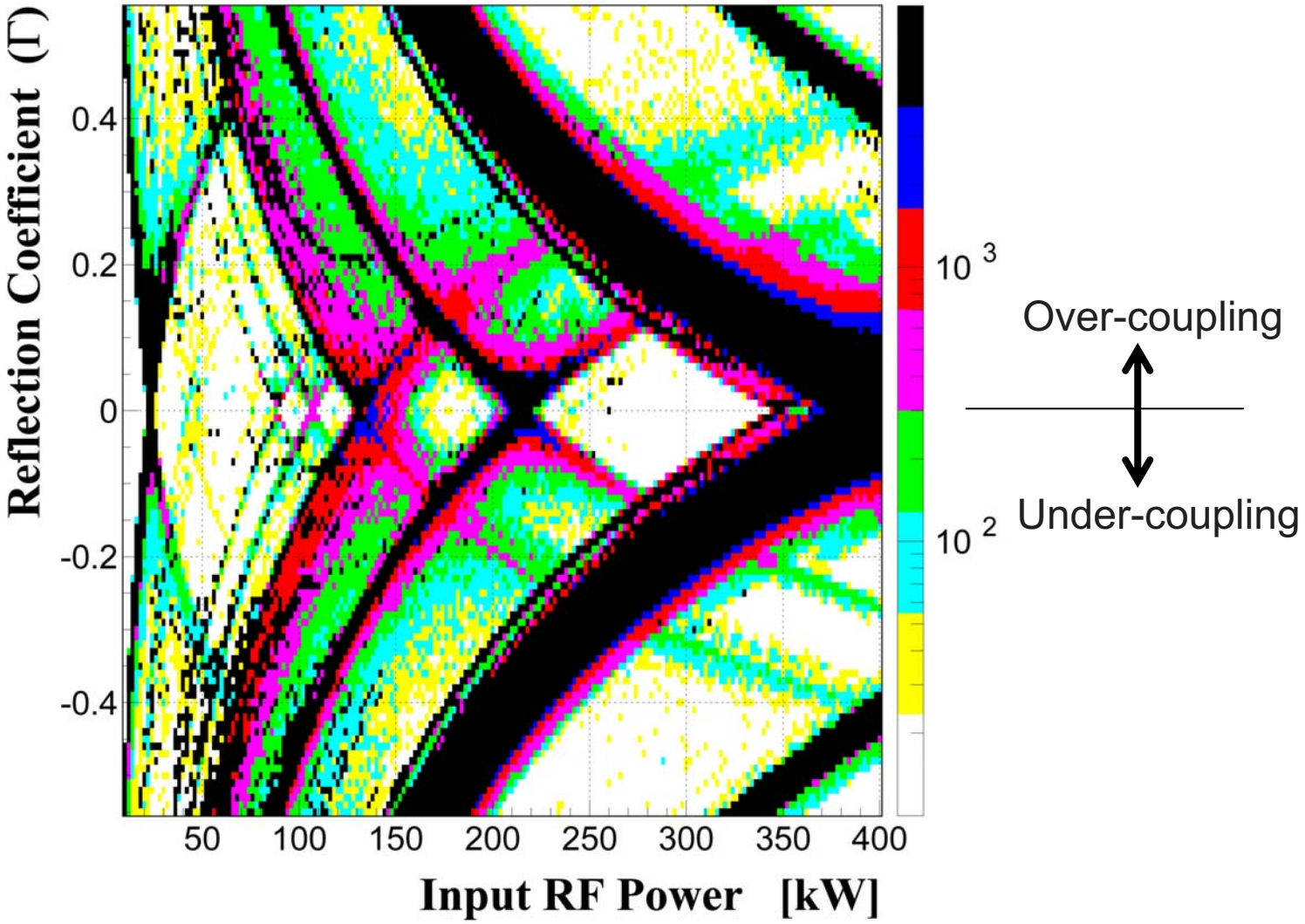




Example of the Orbits

- Solving eq. of motion with the Runge-Kutta method
- Assuming the SEY of conditioned copper
- Count number of collisions.

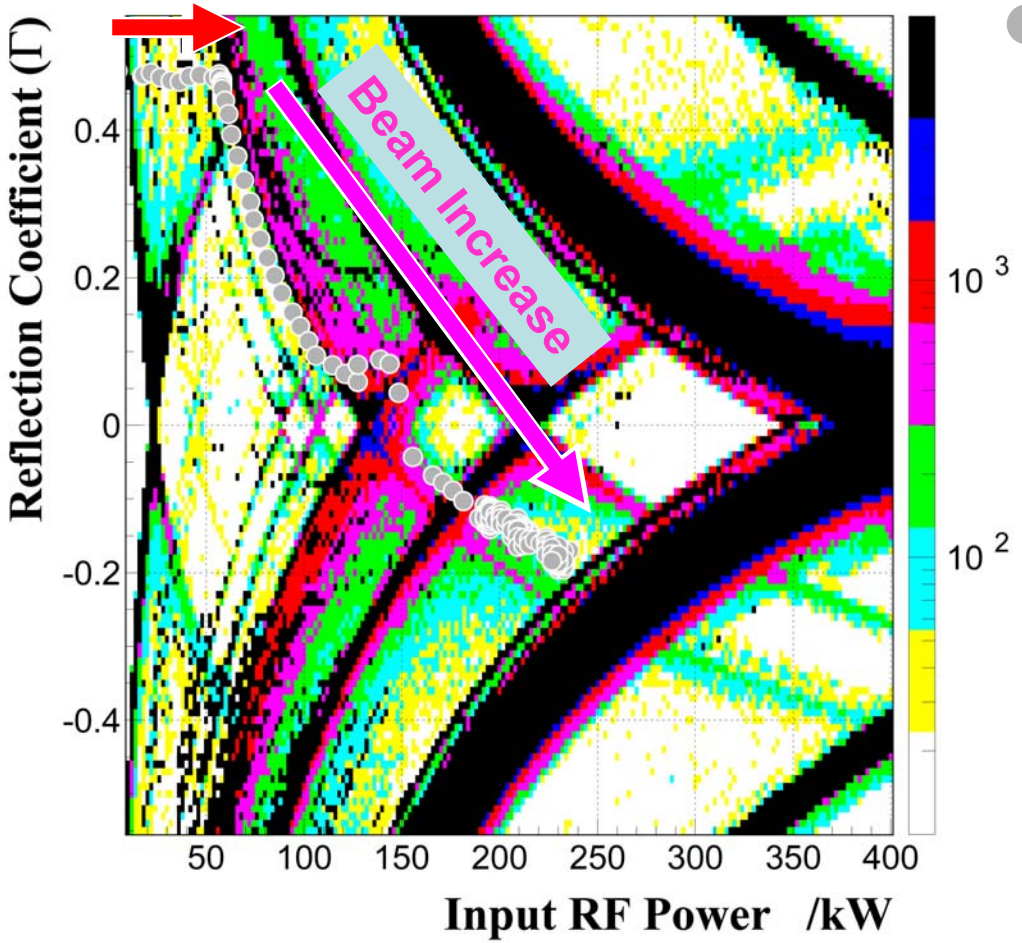
Multipactoring Zone from the Simulation



OLD route before summer 2004

Vc(D04C)=0.54MV

Recovery (no beam)

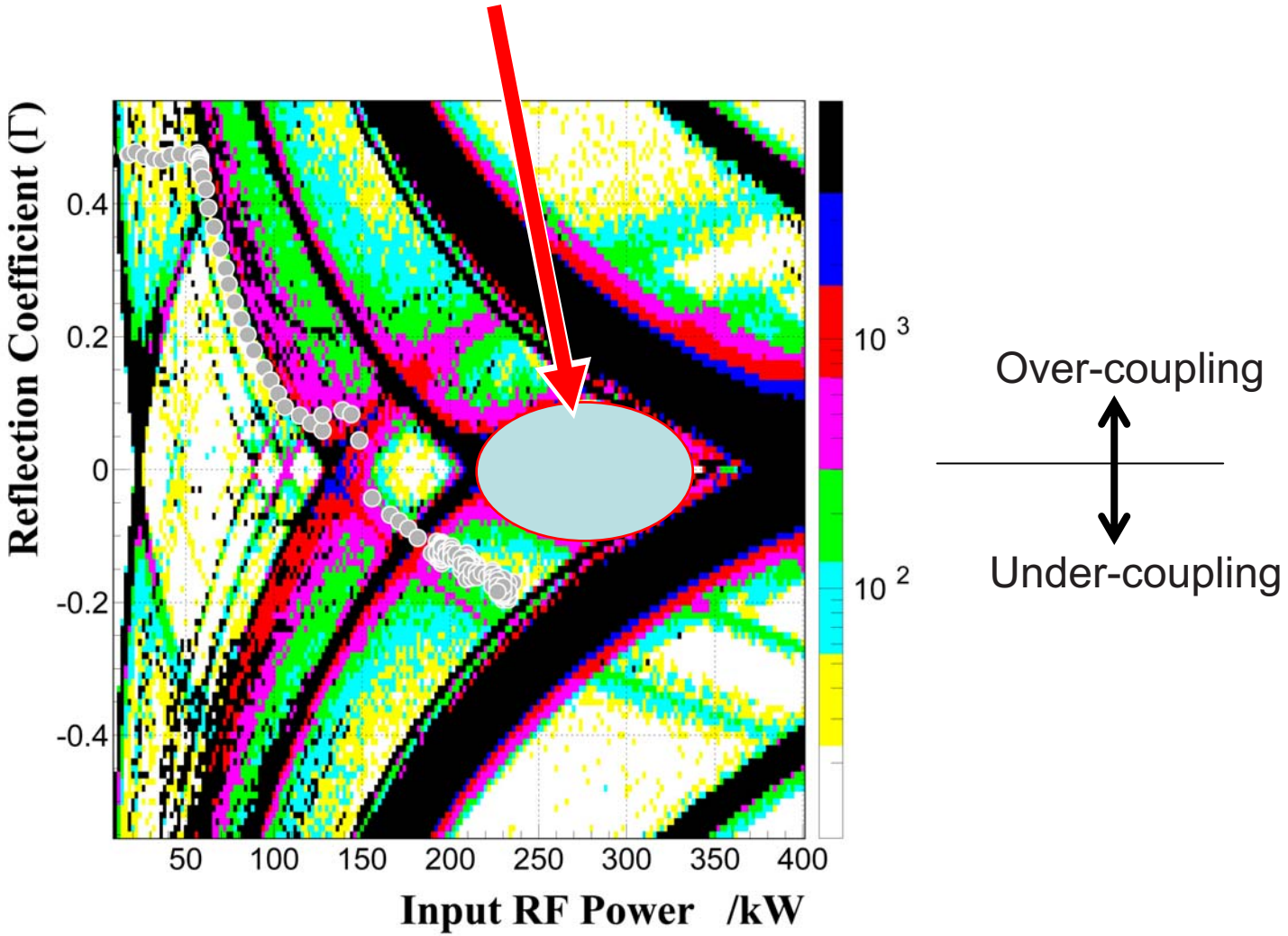


D04C-cav1 data
in 2004.05.09_13:41:45-14:50:00

Over-coupling

Under-coupling

A good operating region must be inside!

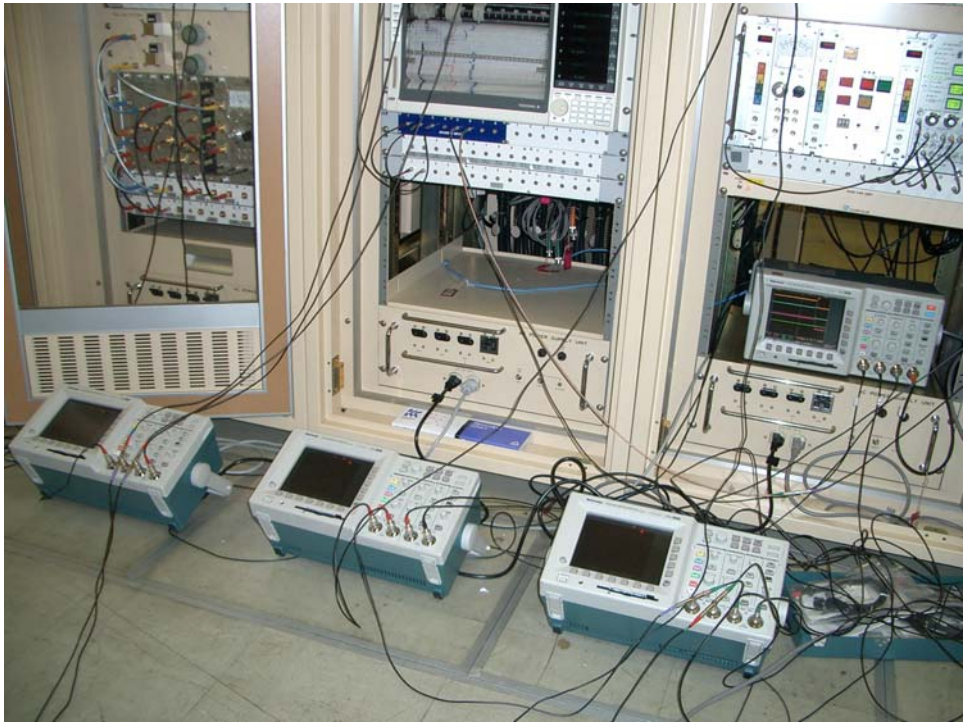


Machine Studies

Search for an operating region with

- *good vacuum,*
- *no discharge,*
- *low trip rate*

based on the simulation results.

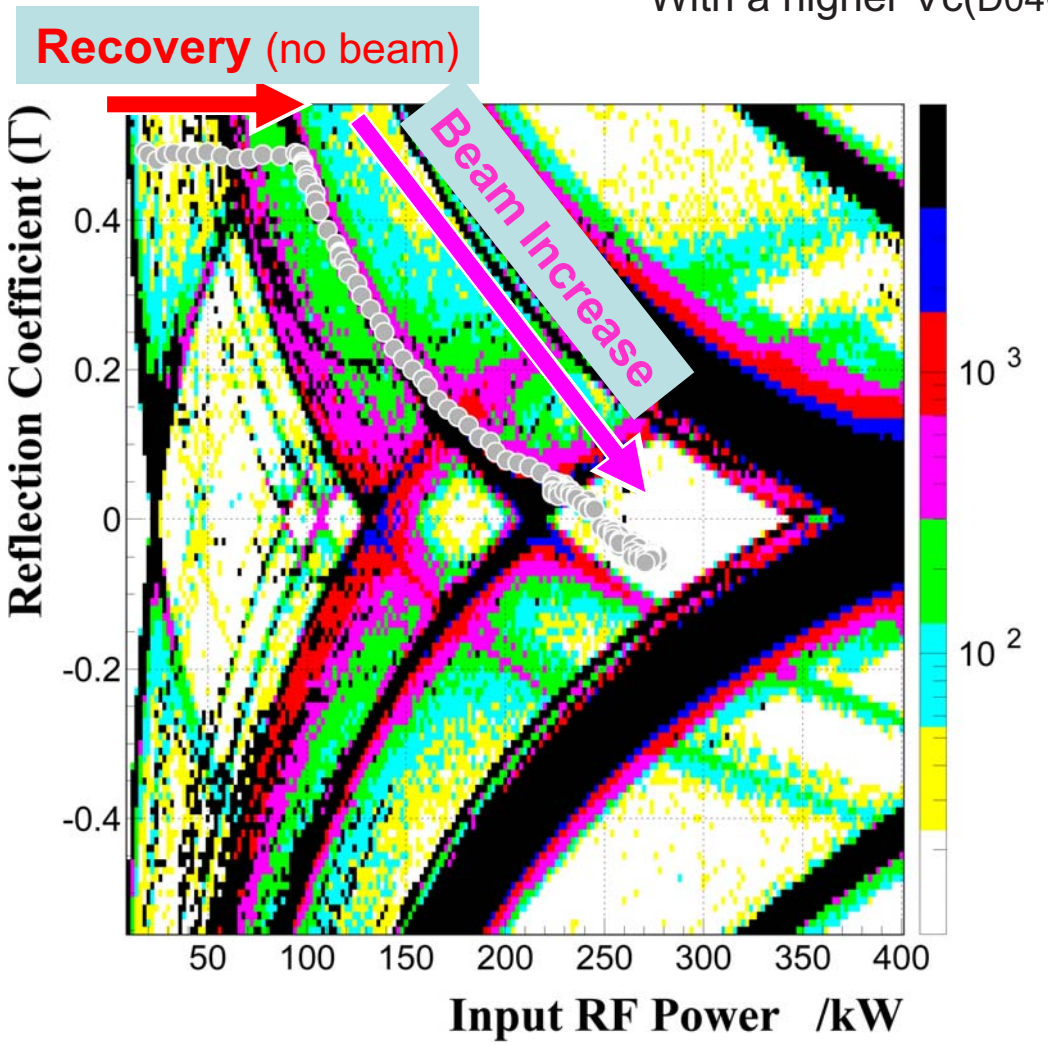


(in the D04 local control room)

(at the D04C klystron)

NEW route in 2005

With a higher Vc(D04C)=0.68MV



Over-coupling

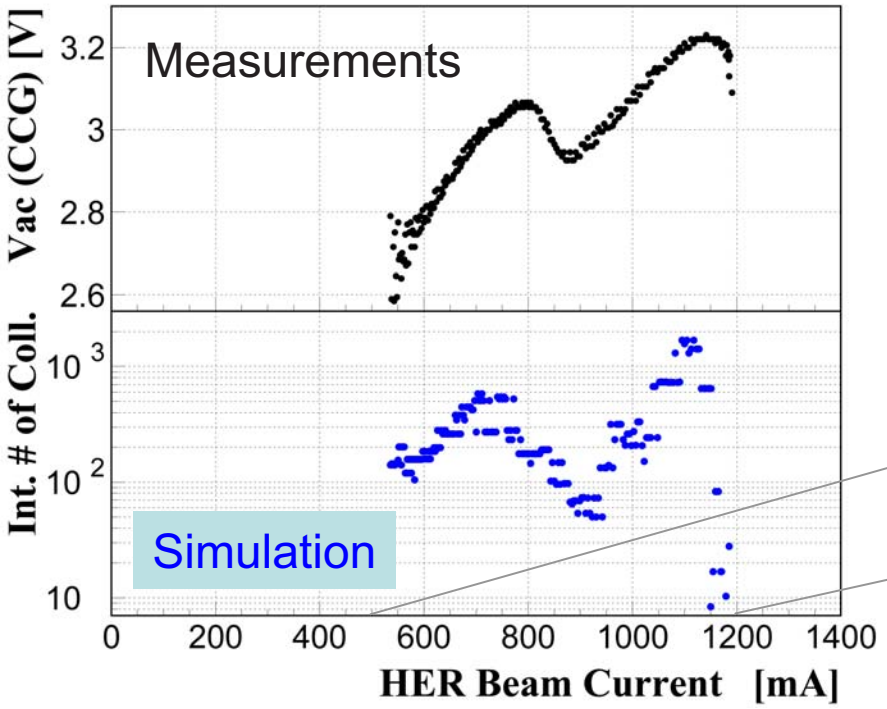
Under-coupling

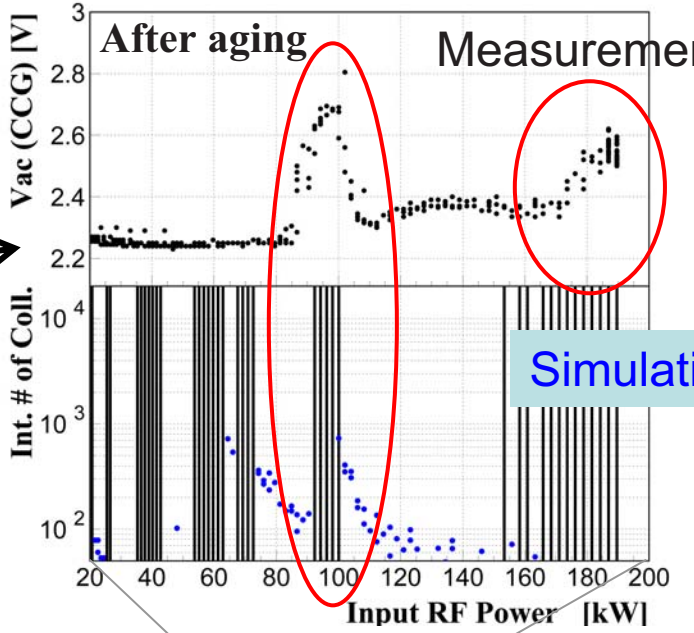
D04C-cav1 data
in 2005.01.30_16:37:45-17:50:00

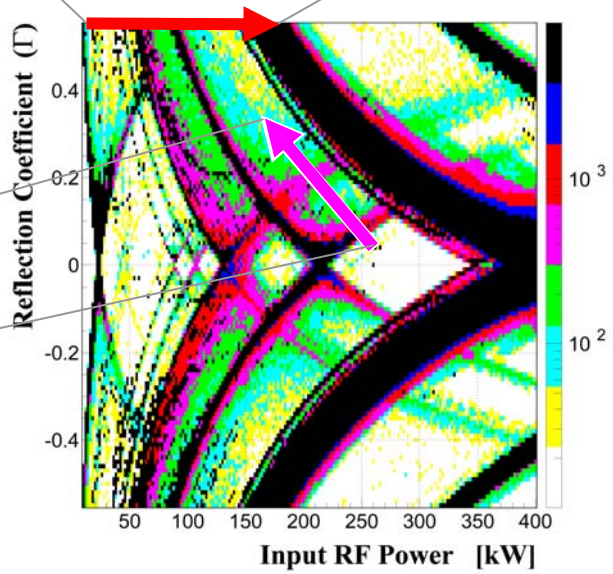
Comparison with the Data

Good Agreement !

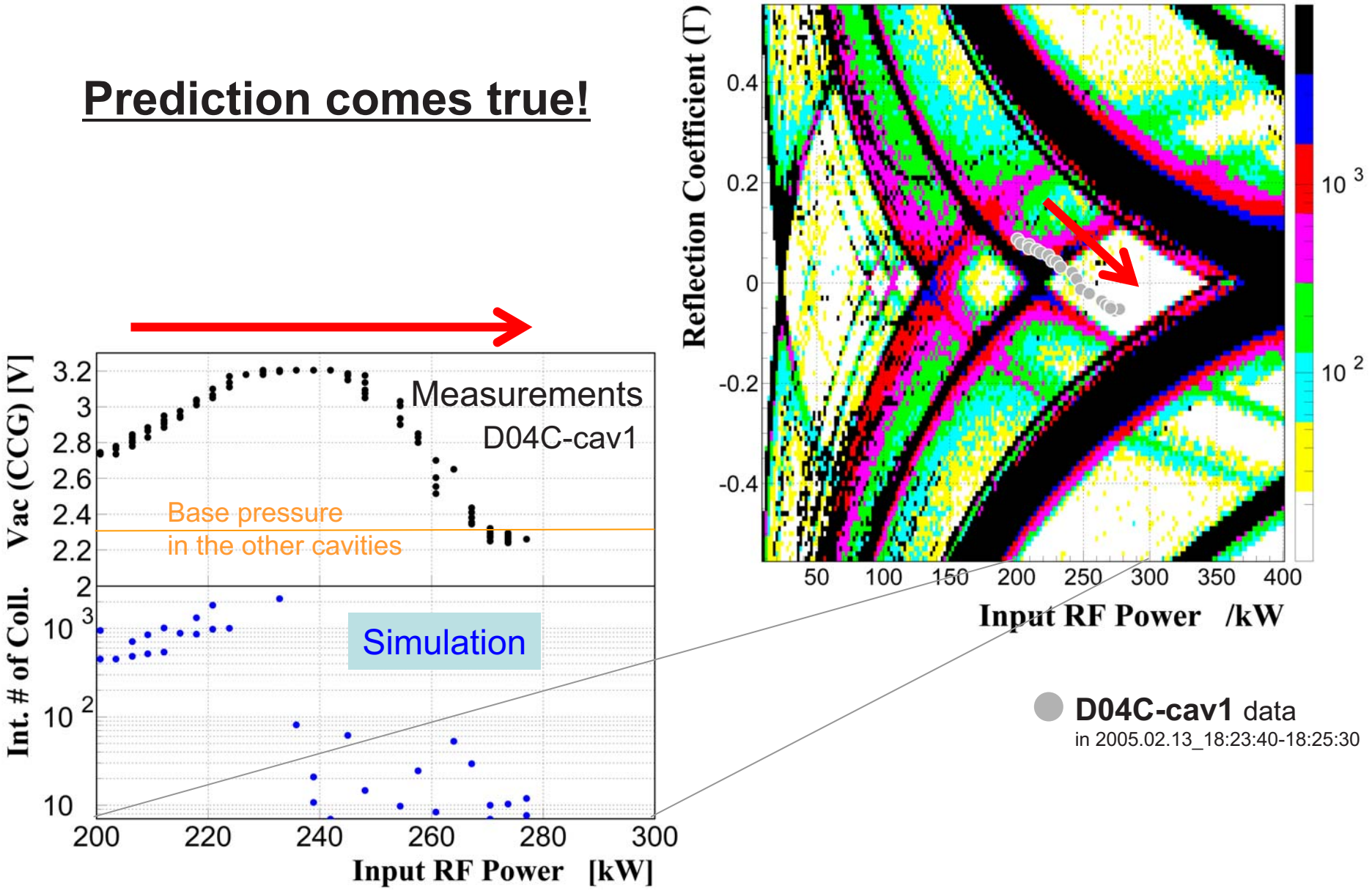
D04C-cav1





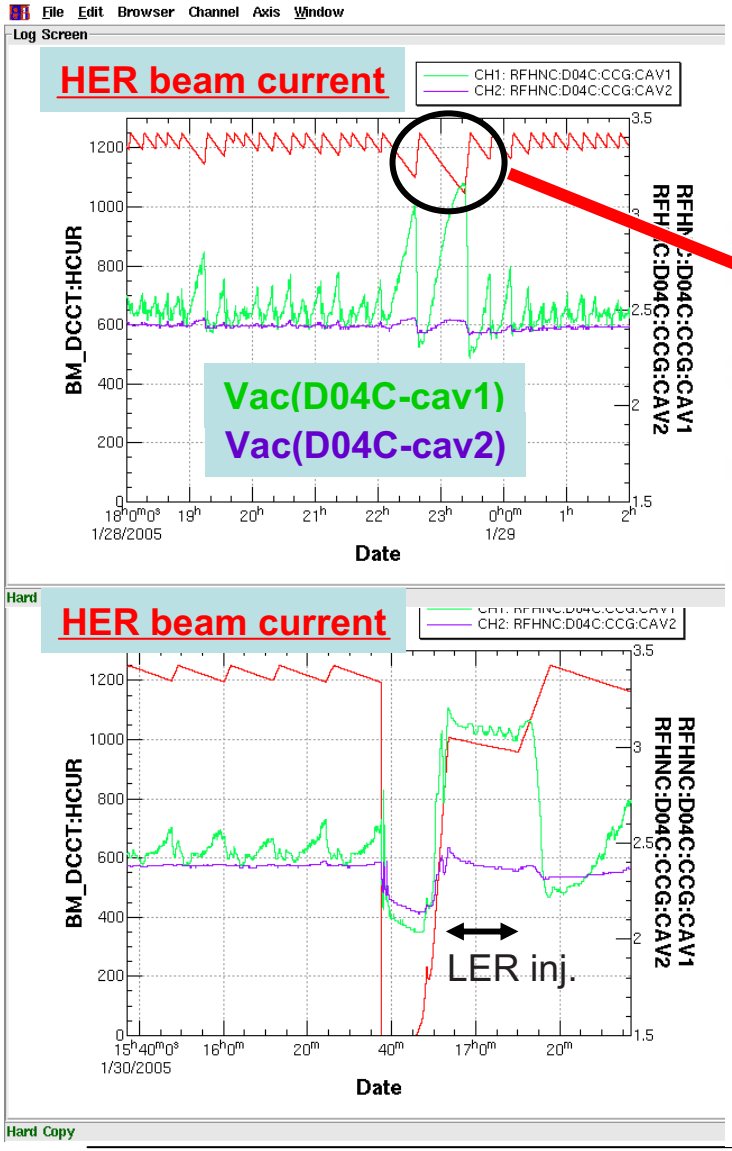


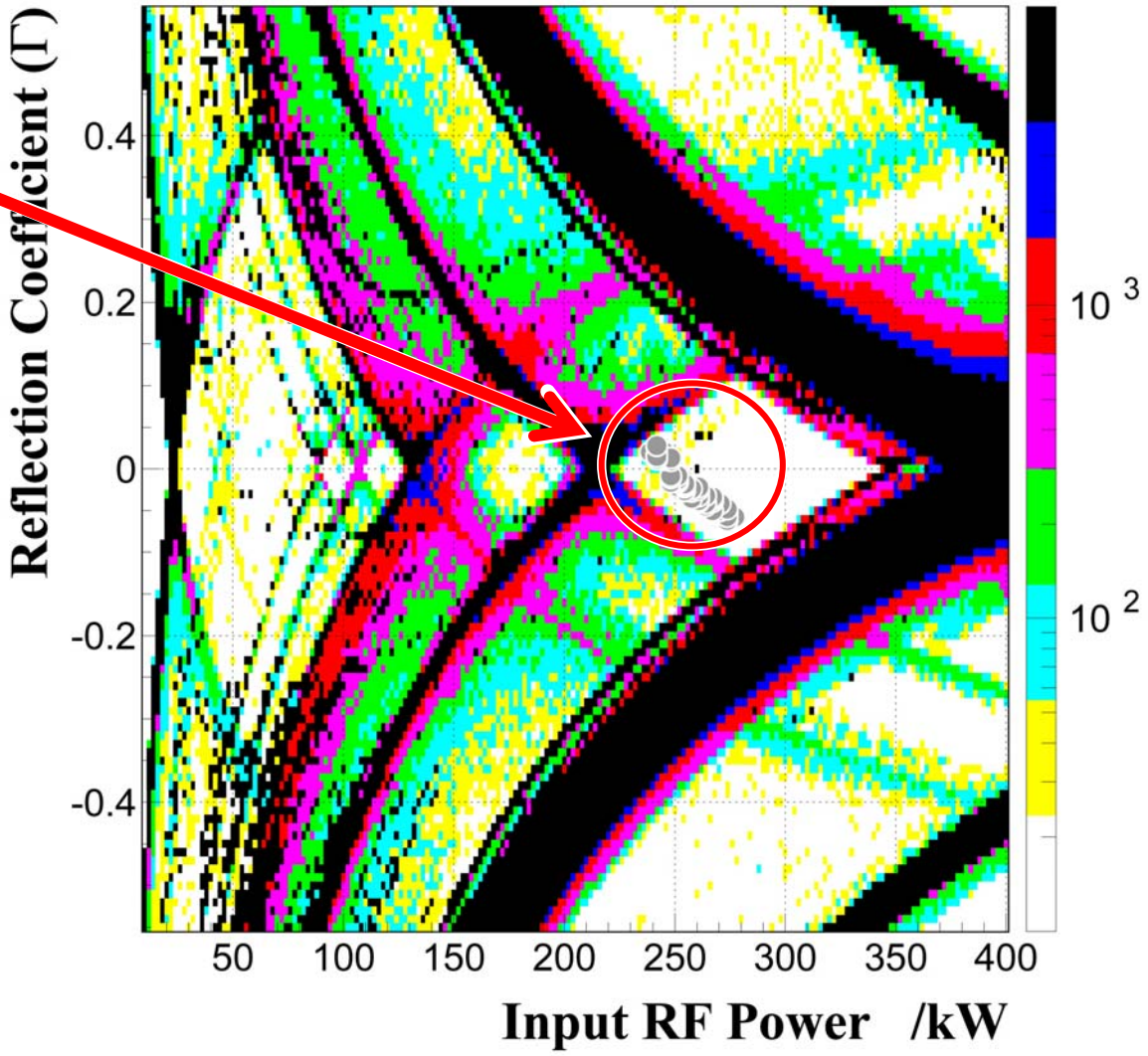
Prediction comes true!



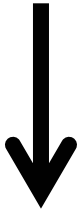
But the region is not so wide.

D04C-cav1 data
in 2005.01.28_22:40:00-23:22:00



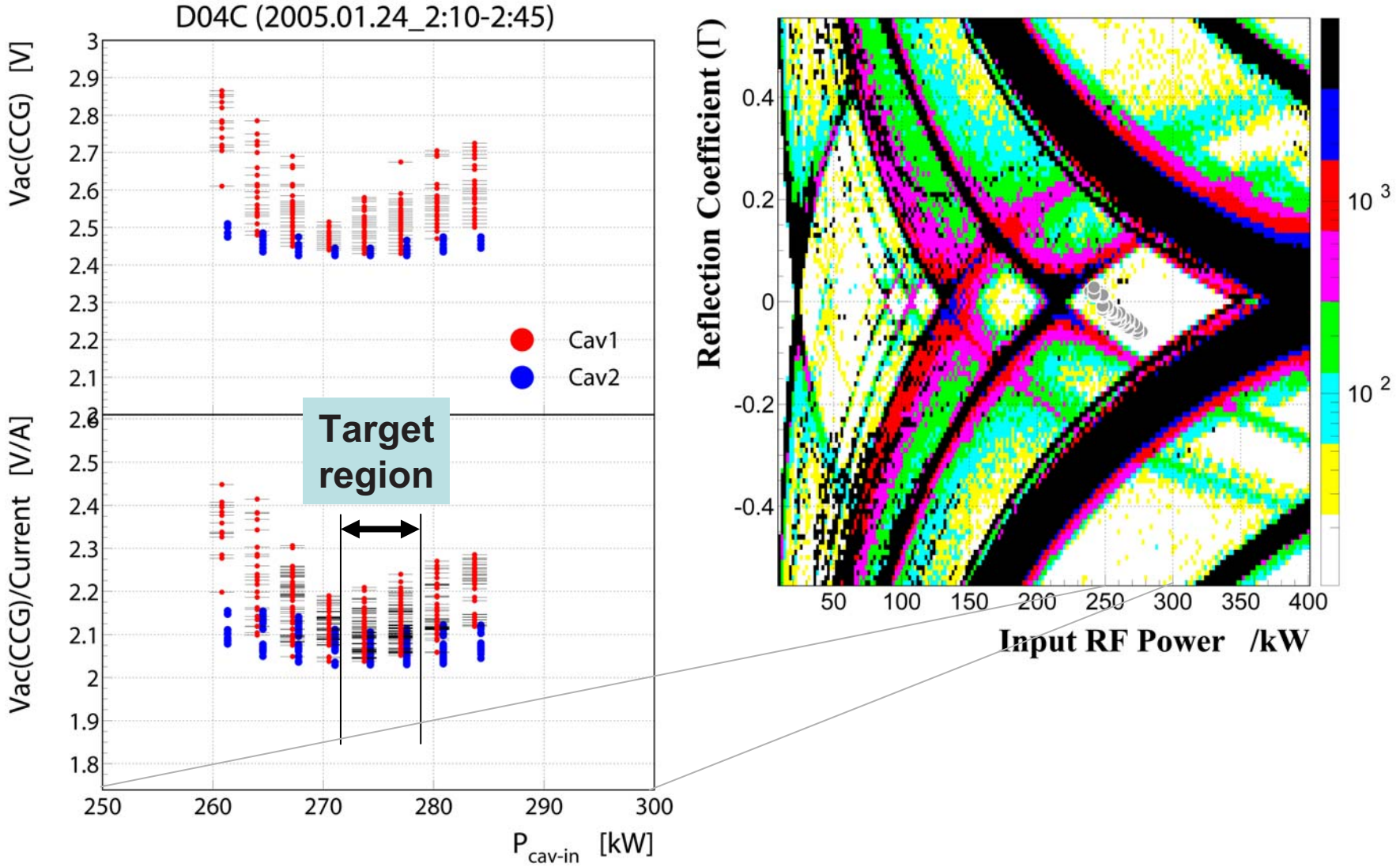


Considering the fact that
"*Cavities out of condition are in a minority*",

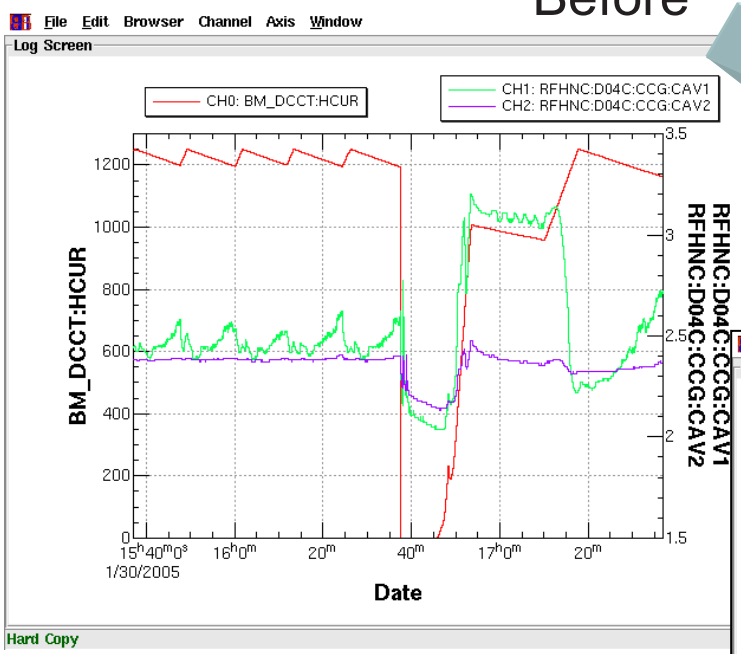


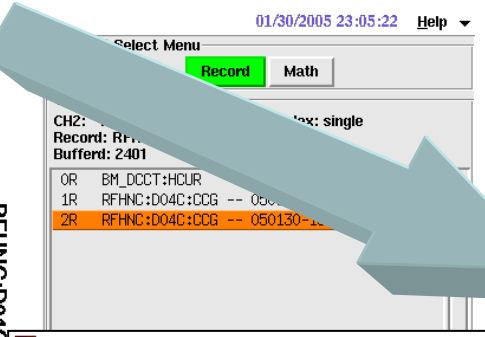
We can keep an input RF power in a region with a good vacuum condition by changing the cavity phase (or beam loading) *automatically.*

Scan of the vacuum pressure and a target power region



Before



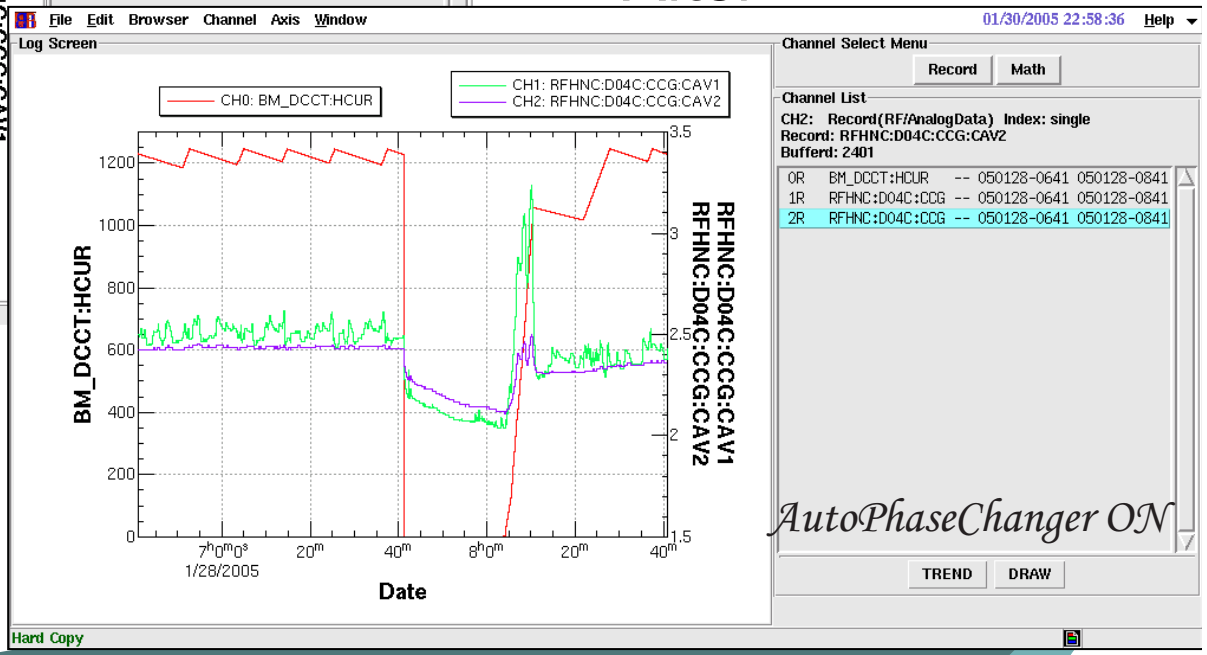


HER beam current

Vac(D04C-cav1)

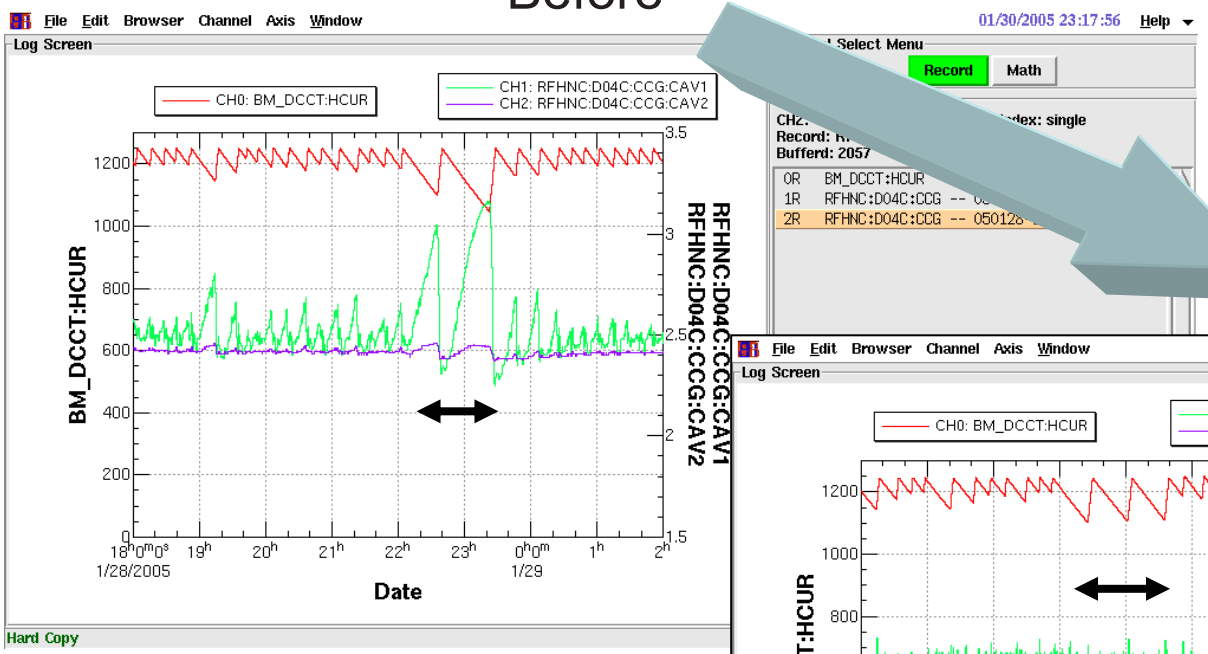
Vac(D04C-cav2)

After

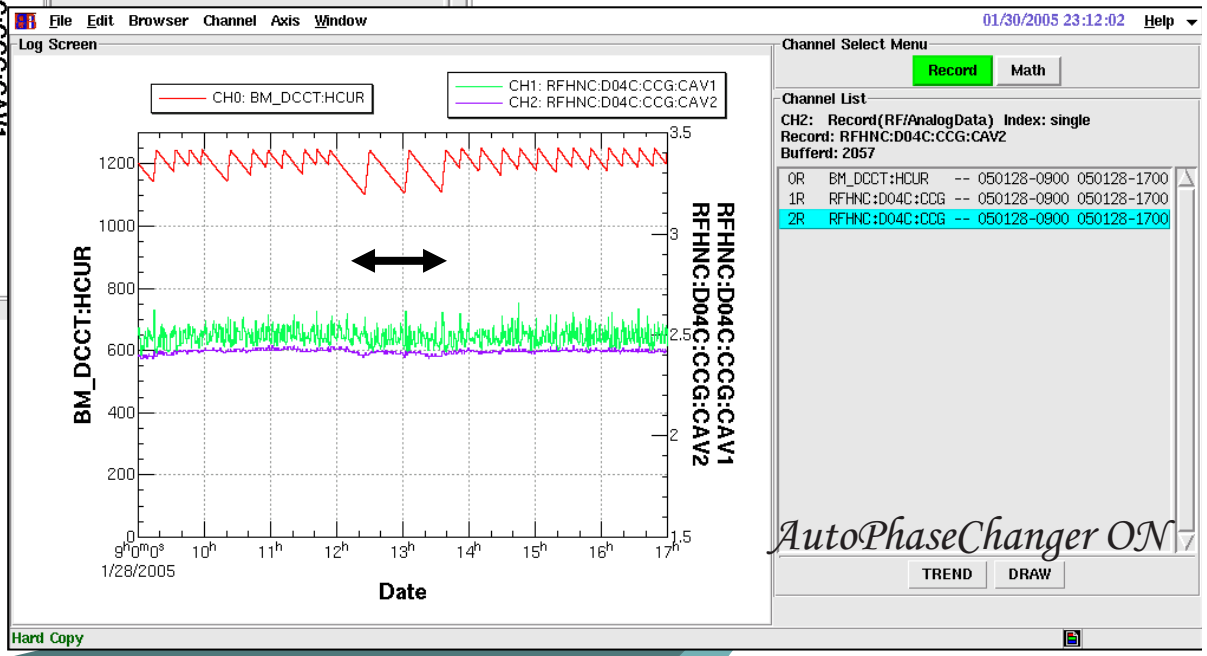


Quick passage through the multipactoring zone!

Before



After



HER beam current

Vac(D04C-cav1)

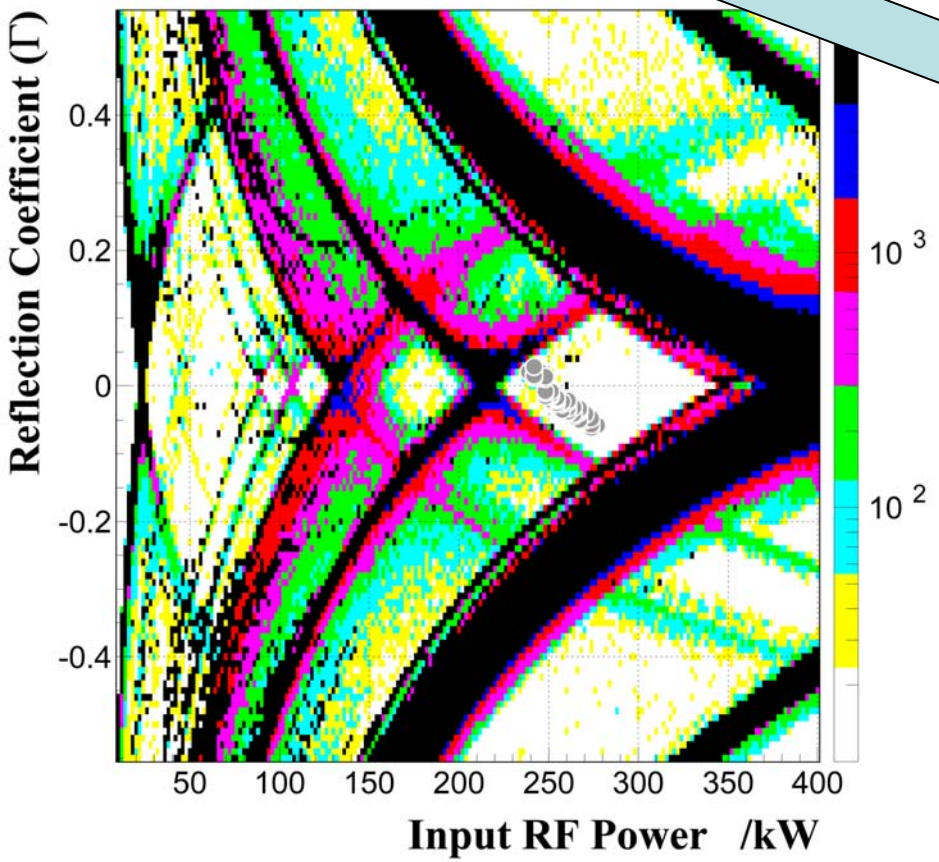
Vac(D04C-cav2)

No beam-current dependence!

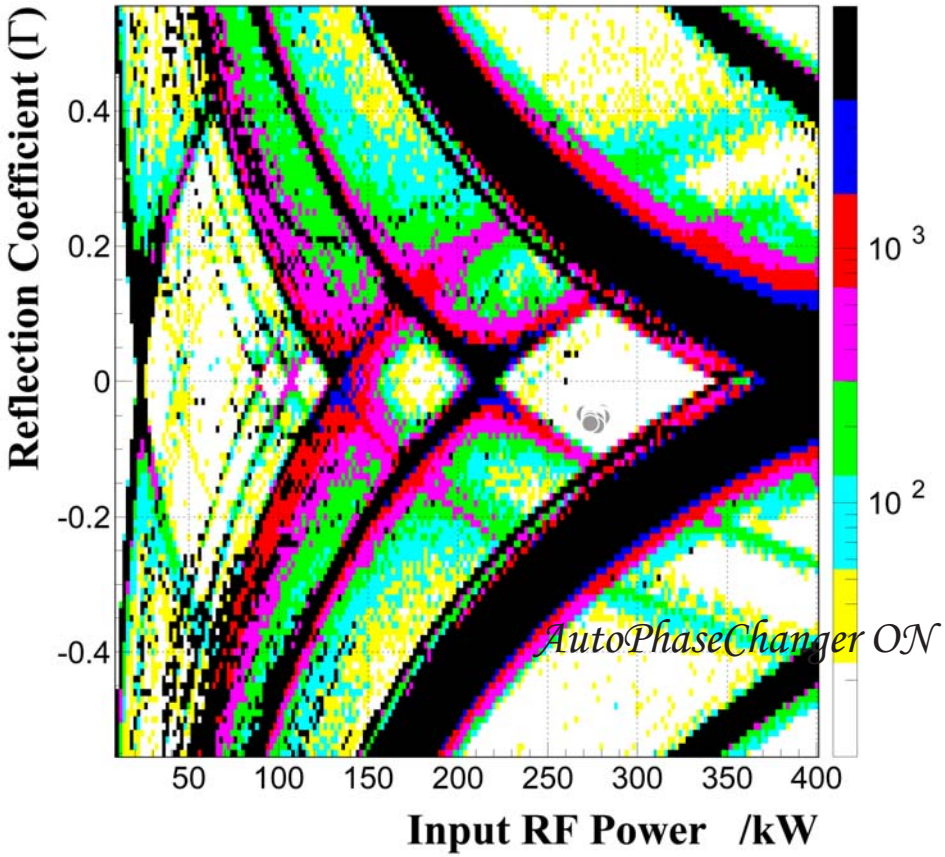
Before

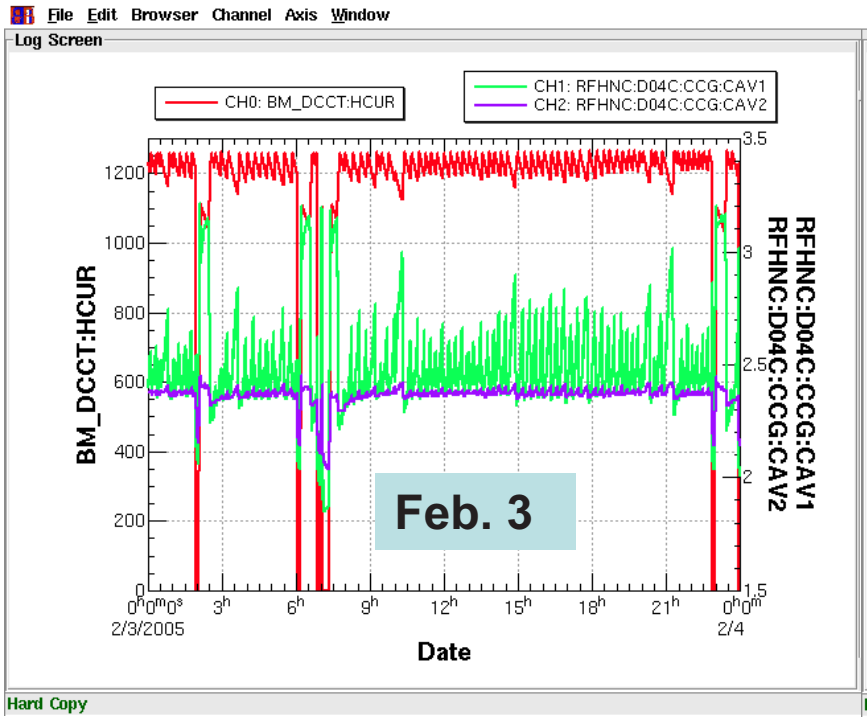
D04C-cav1 data in CIM

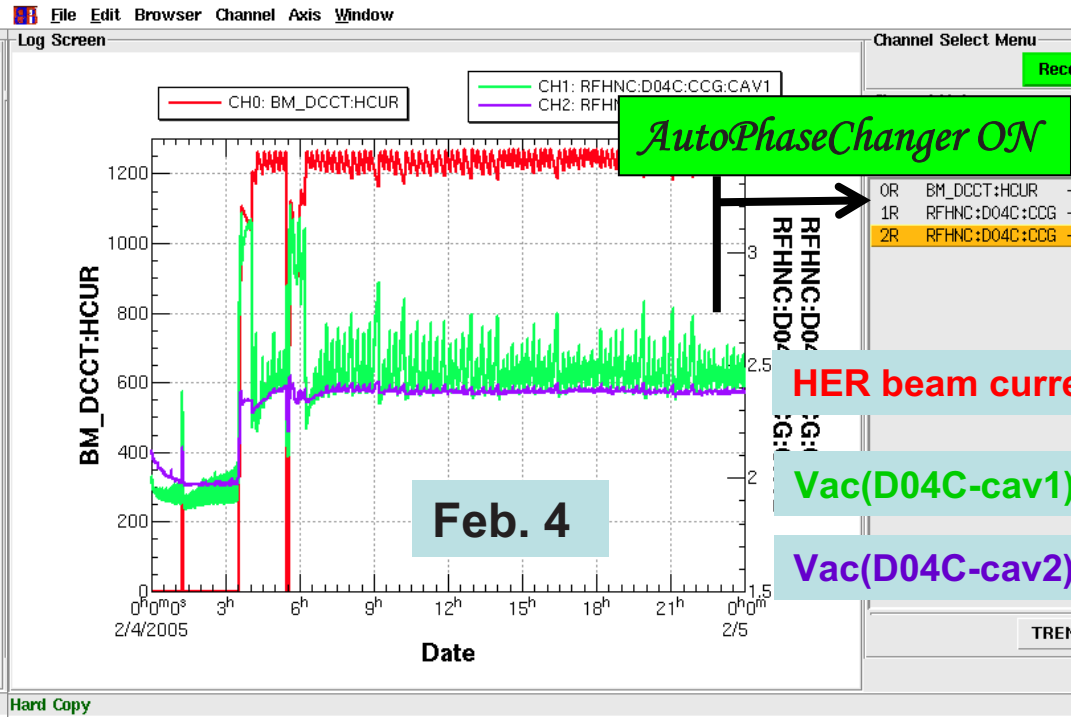
($V_{c(D04C)}$=0.68MV)

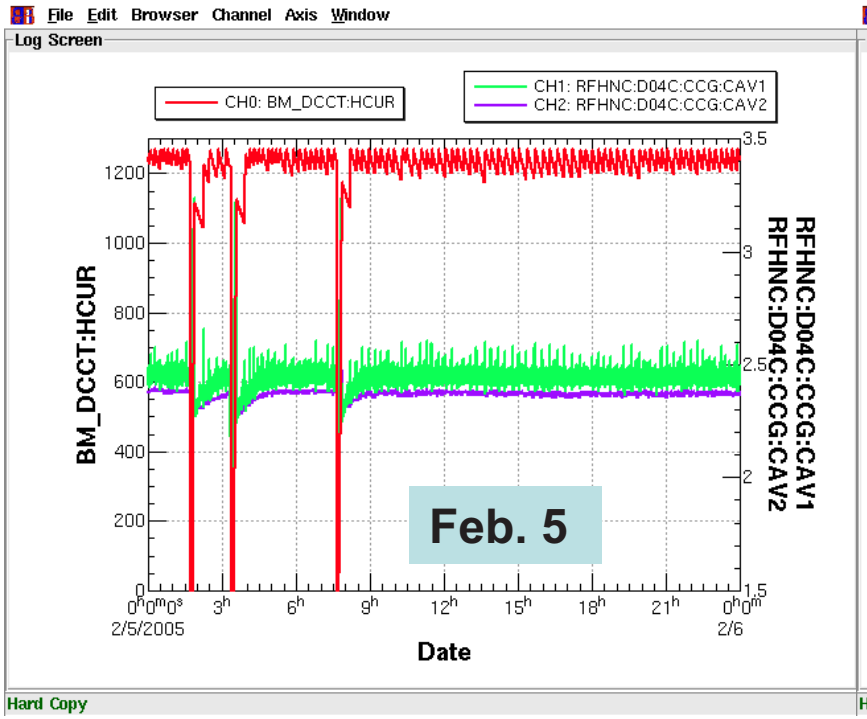


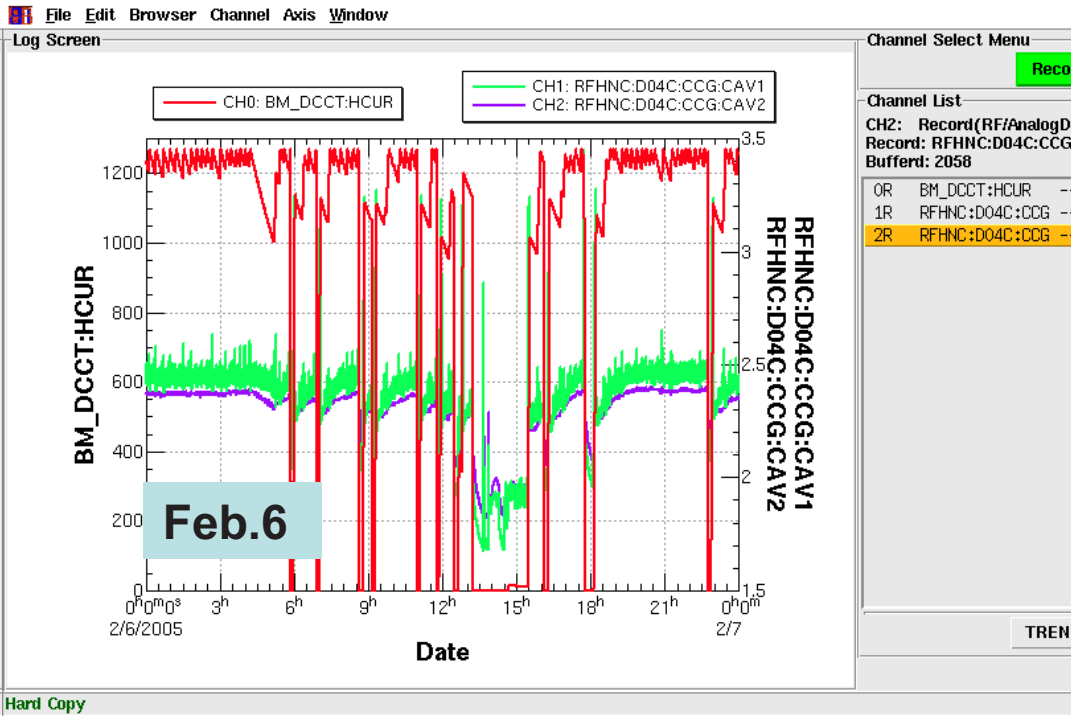
After




File Edit Browser Channel Axis Window
Log Screen
CH0: BM_DCCT:HCUR
CH1: RFHNC:D04C:CCG:CAV1
CH2: RFHNC:D04C:CCG:CAV2
BM_DCCT:HCUR
RFHNC:D04C:CCG:CAV1
RFHNC:D04C:CCG:CAV2
Feb. 3
2/3/2005
2/4
Date
Hard Copy


File Edit Browser Channel Axis Window
Log Screen
CH0: BM_DCCT:HCUR
CH1: RFHNC:D04C:CCG:CAV1
AutoPhaseChanger ON
Channel Select Menu
0R BM_DCCT:HCUR
1R RFHNC:D04C:CCG
2R RFHNC:D04C:CCG
HER beam curre
Vac(D04C-cav1)
Vac(D04C-cav2)
Feb. 4
2/4/2005
2/5
Date
Hard Copy


File Edit Browser Channel Axis Window
Log Screen
CH0: BM_DCCT:HCUR
CH1: RFHNC:D04C:CCG:CAV1
CH2: RFHNC:D04C:CCG:CAV2
BM_DCCT:HCUR
RFHNC:D04C:CCG:CAV1
RFHNC:D04C:CCG:CAV2
Feb. 5
2/5/2005
2/6
Date
Hard Copy


File Edit Browser Channel Axis Window
Log Screen
CH0: BM_DCCT:HCUR
CH1: RFHNC:D04C:CCG:CAV1
CH2: RFHNC:D04C:CCG:CAV2
Channel Select Menu
Channel List
0R BM_DCCT:HCUR
1R RFHNC:D04C:CCG
2R RFHNC:D04C:CCG
BM_DCCT:HCUR
RFHNC:D04C:CCG:CAV1
RFHNC:D04C:CCG:CAV2
Feb.6
2/6/2005
2/7
Date
Hard Copy

Summary and Future

- **20+12 ARES cavities are working well.**
  - → Low trip rate
  - → Stable operation

- **D04C/ARES multipactoring problem**
  - → Good operating region found by the simulation and machine studies
  - → Solution: *keeping an input RF power in a region with a good condition by changing the cavity phase automatically*.
  - → The feedback program has been working well since Feb.4.

- **R&D activities for SuperKEKB**
  - → To be continued on the tomorrow's talk…