# ARES Status 2004(JFY)

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***High Energy Accelerator Research Organization (KEK)***

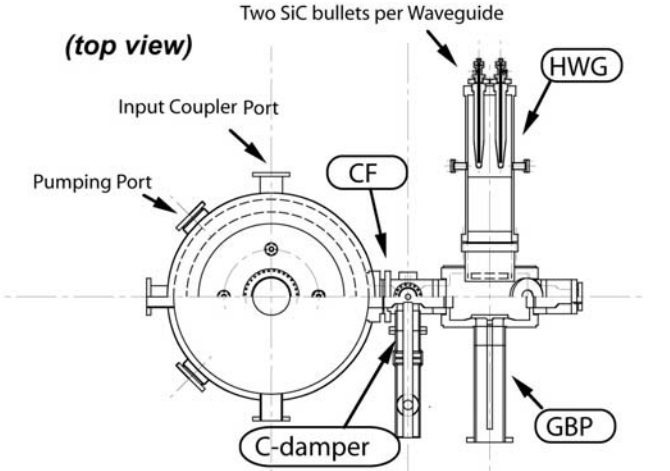
## ＜Outline＞

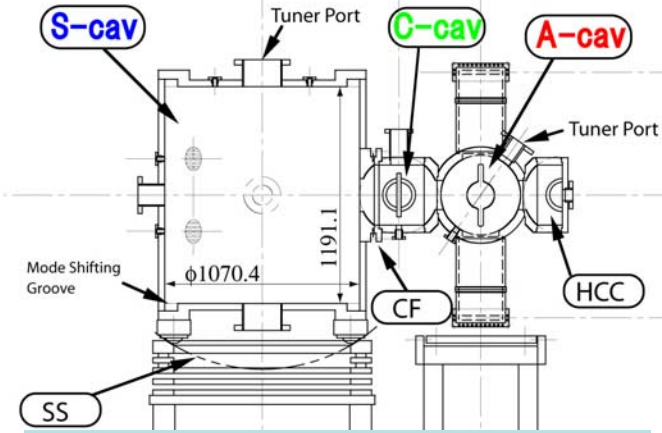
1. Fundamentals of the ARES-cavity system
2. Operation status
3. D04C/ARES multipactoring problem
4. Summary

*KEKB Review*
*@KEK*
*2005.02.21*

# Accelerator Resonantly-coupled with Energy Storage

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

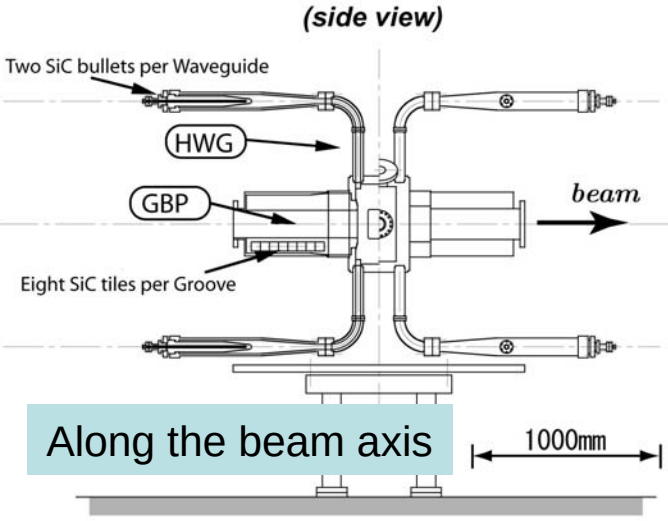



Perpendicular to the beam axis

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




Along the beam axis

# Operation with the Accelerating π/2 Mode

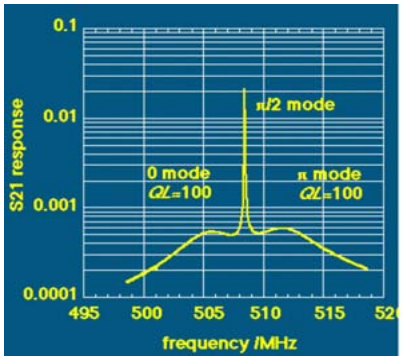
- **The field of the π/2 mode is the stablest against**
  - Beam loading,
  - Detuning of A-cav $(=\Delta f_a)$

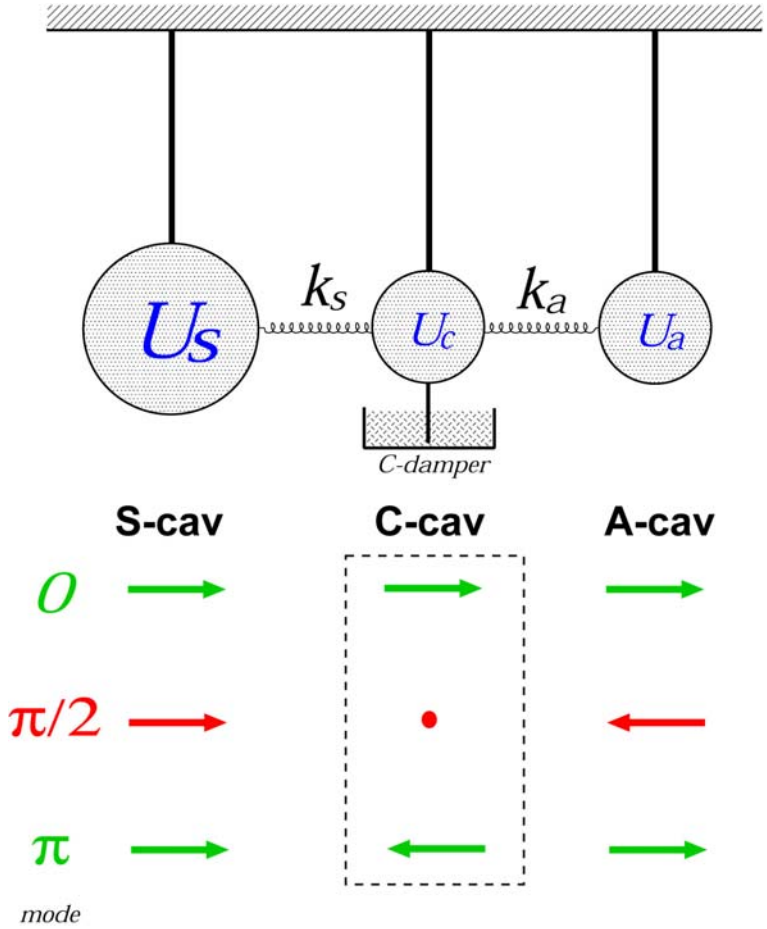
- **The stored-energy ratio: Us/Ua**
  - → can be changed

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

- **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

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)

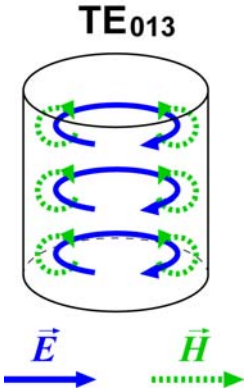
$\Delta f_a$: optimum detuning of A-cav

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

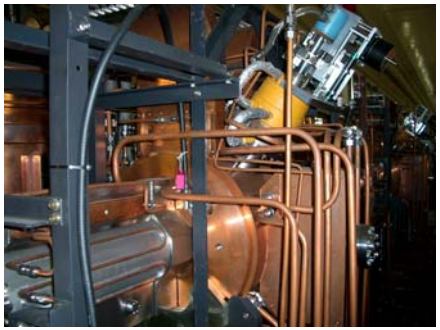
$\Delta f_a = 710$ kHz in SuperKEKB/LER (9.4 A, 28 sets)

Cf. $f_{rev} = 99$kHZ

S-cav's



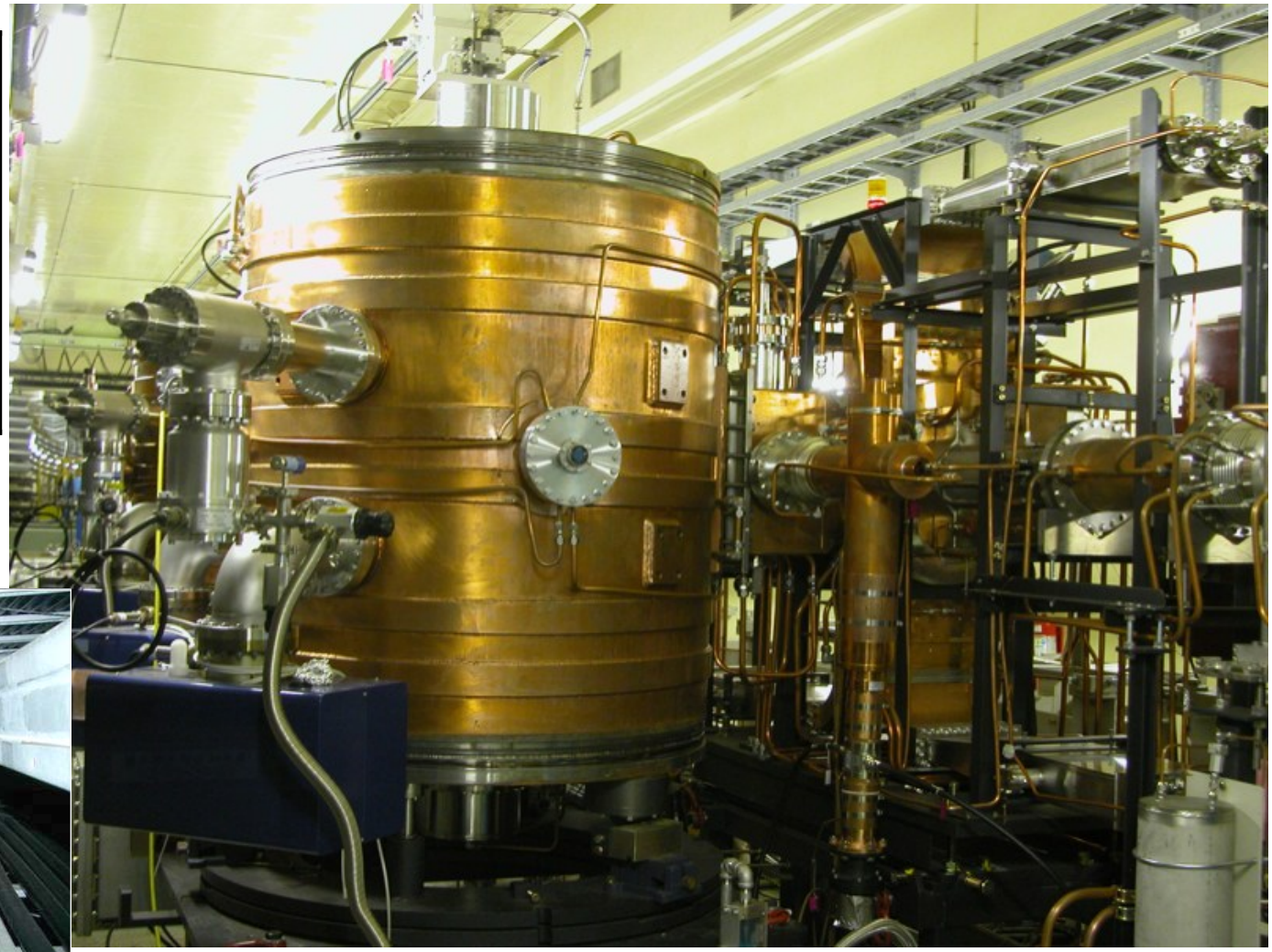

Movable tuner on A-cav



# 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

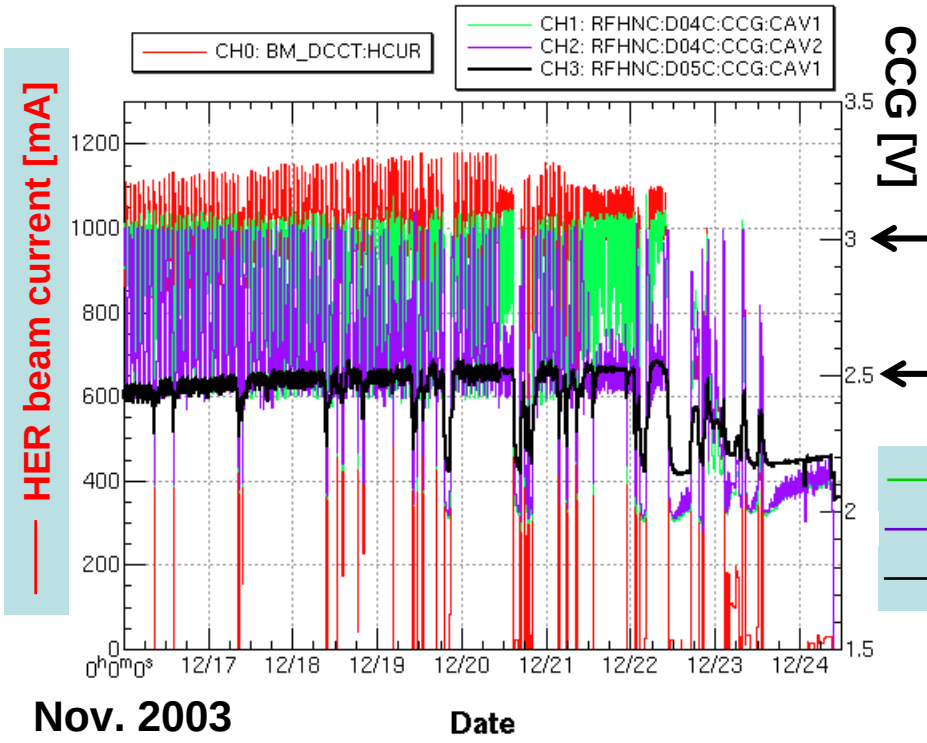
***Stable Operation!!!***

ARES cavities in the LER RF section

# D04C/ARES Multipactoring Problem

*--- worse vacuum and discharge ---*

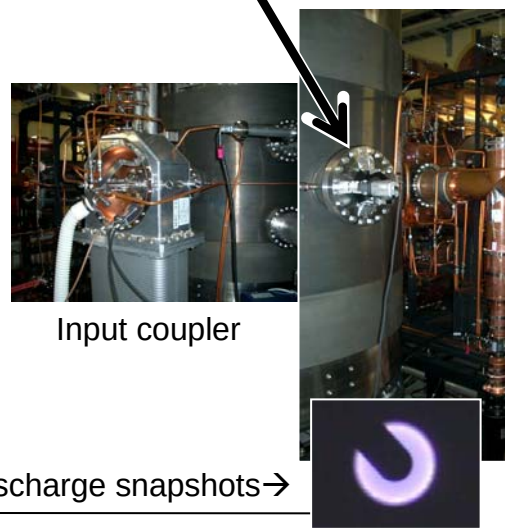
- The *vacuum* in the ARES cavities (No.1 and No.2) of the D04C station became worse significantly (~3 times).
- Even with lower $P_{kly\text{-}out}$ and/or Vc
- No conditioning effect
- Input-power dependence
- *Discharge* in the input couples observed with the TV cameras




6.8x10^-6 Pa

2.3x10^-6 Pa

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



Input coupler

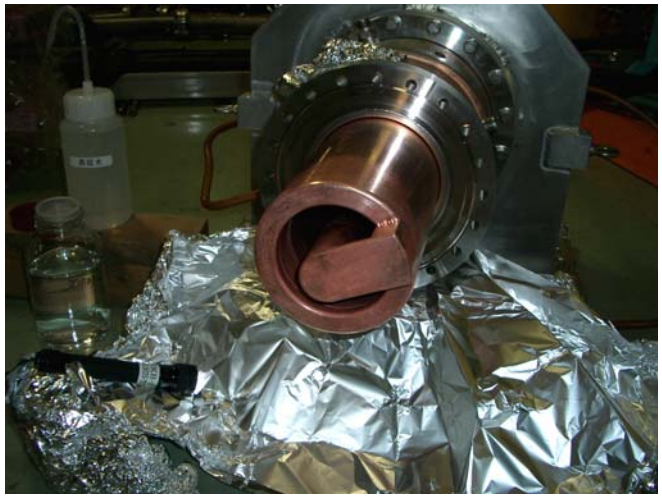
Example of the discharge snapshots→

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

Before

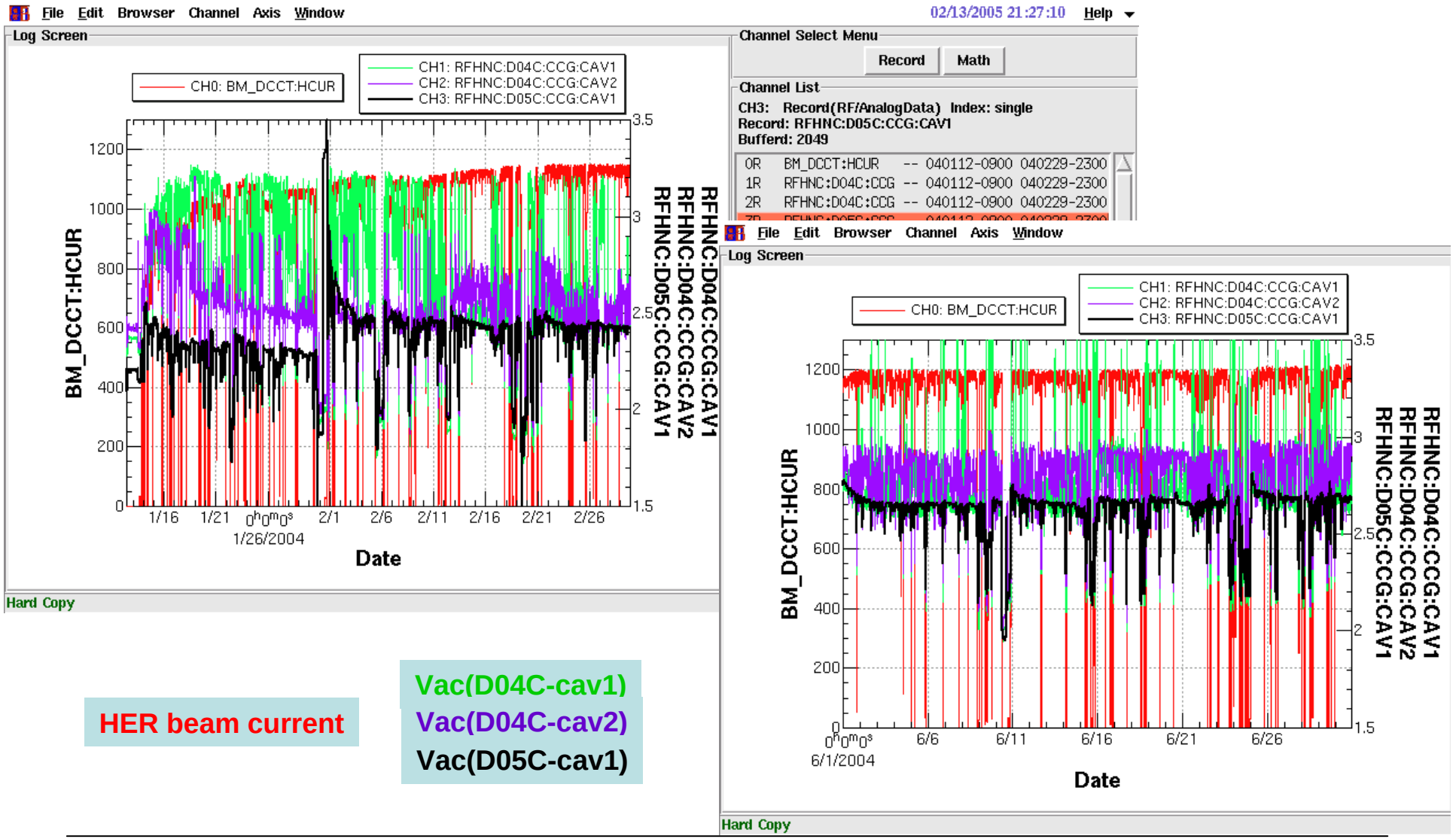
Soot?

After



Clean!

# Still bad! (on cav1)



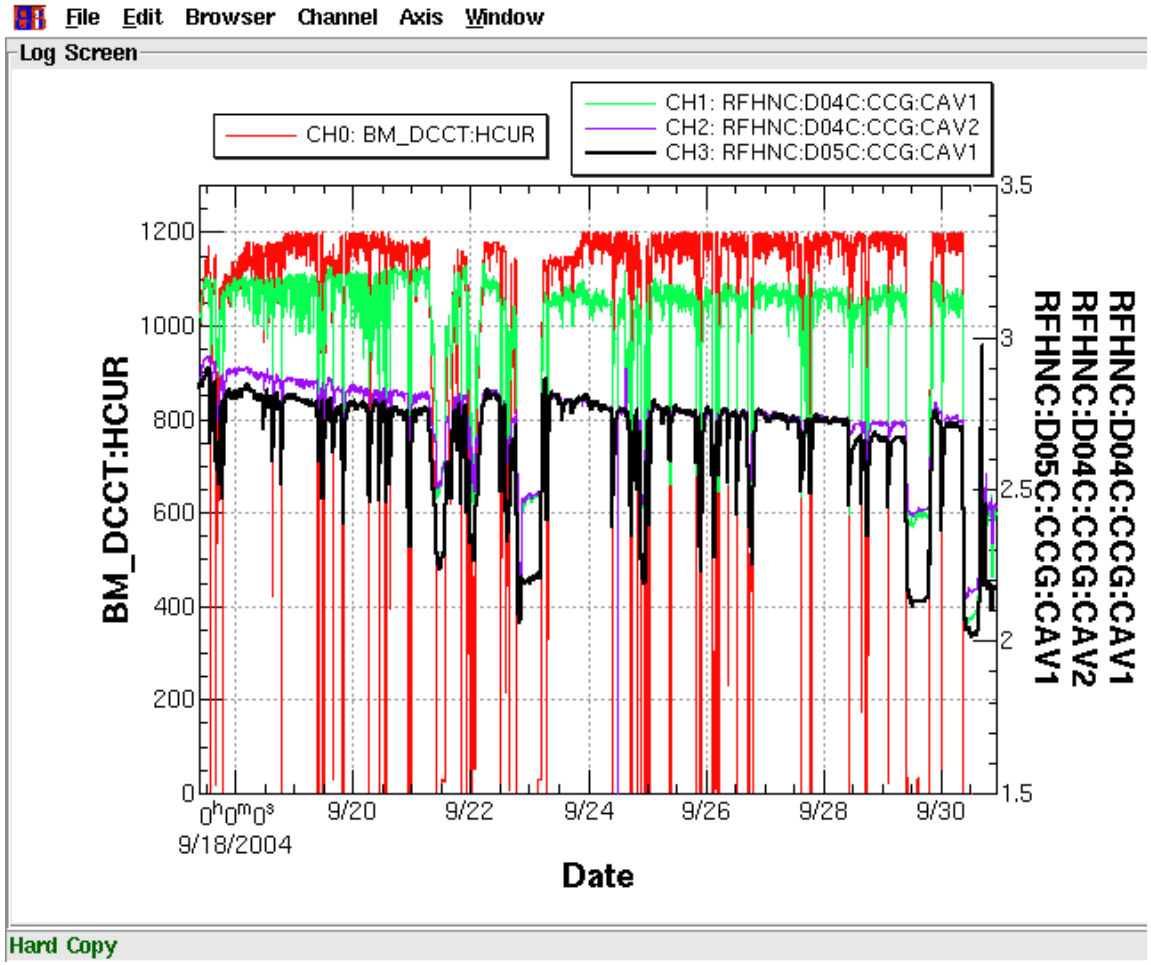

**HER beam current**

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

# In the summer shutdown 2004

- **Two input-couplers replaced**
- Input-coupler ports scraped
- Ion pumps replaced
- 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 cavities**

- → 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

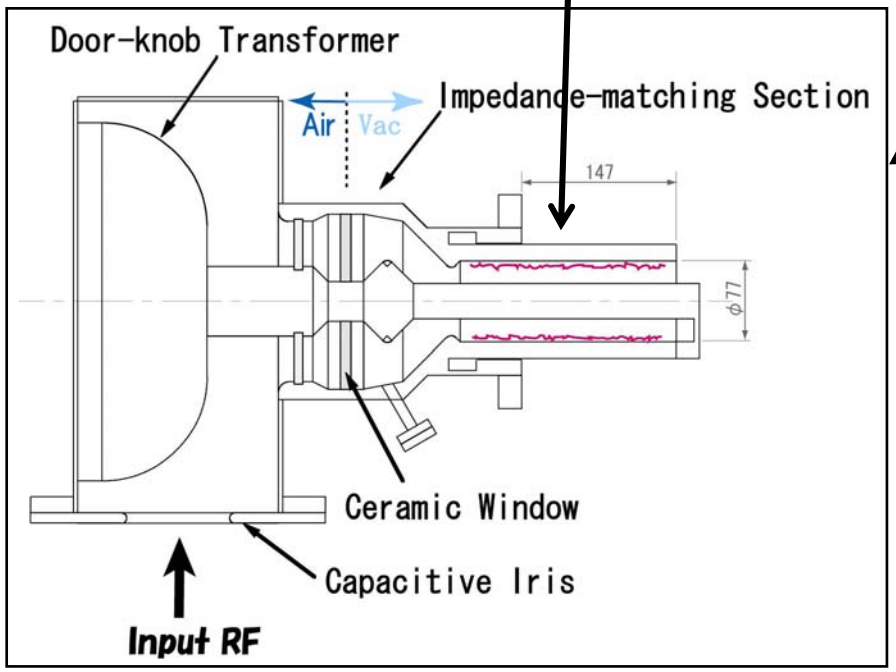
# Choice

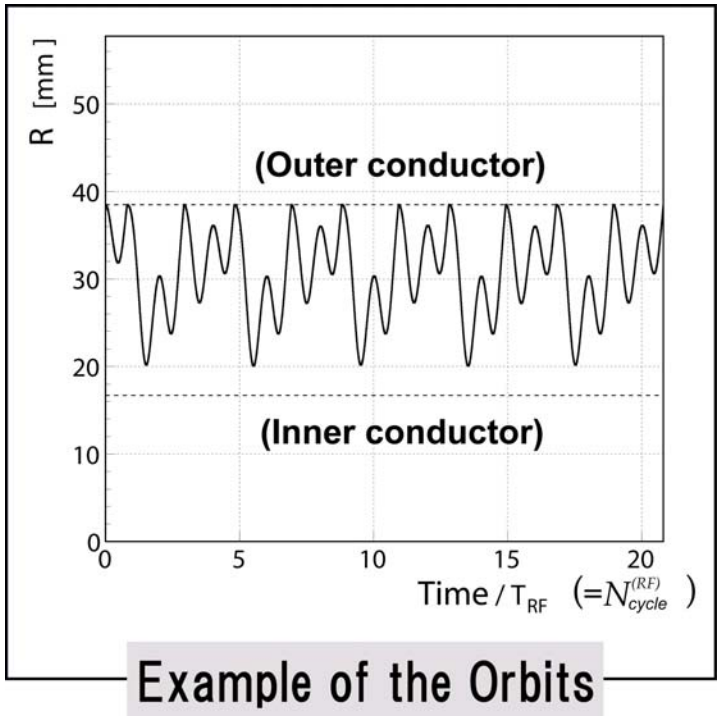
**III. To do studies, not to replace the cavities**

→ Effort and time to be spent, free of cost

→ More scientific

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

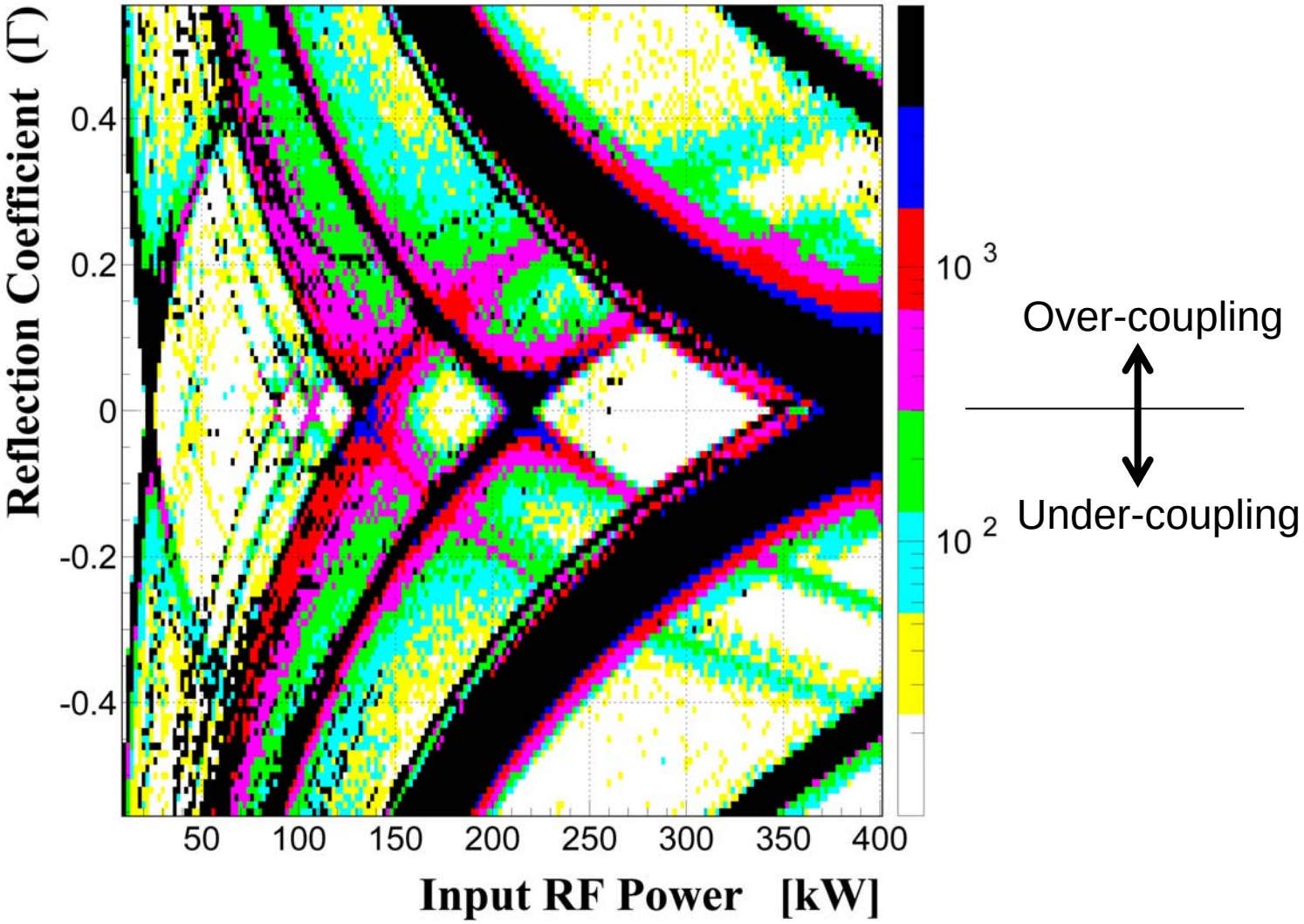



Example of the Orbits

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

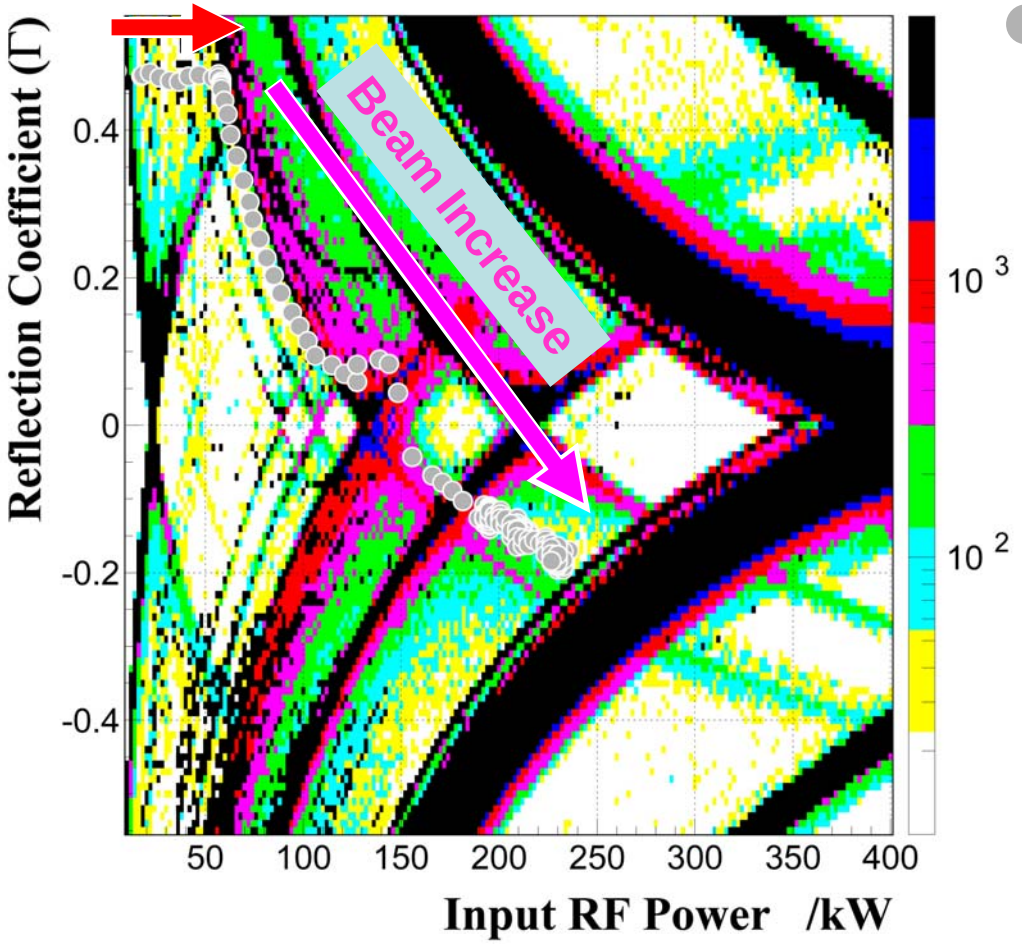
# Multipactoring Zone from the Simulation



# 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

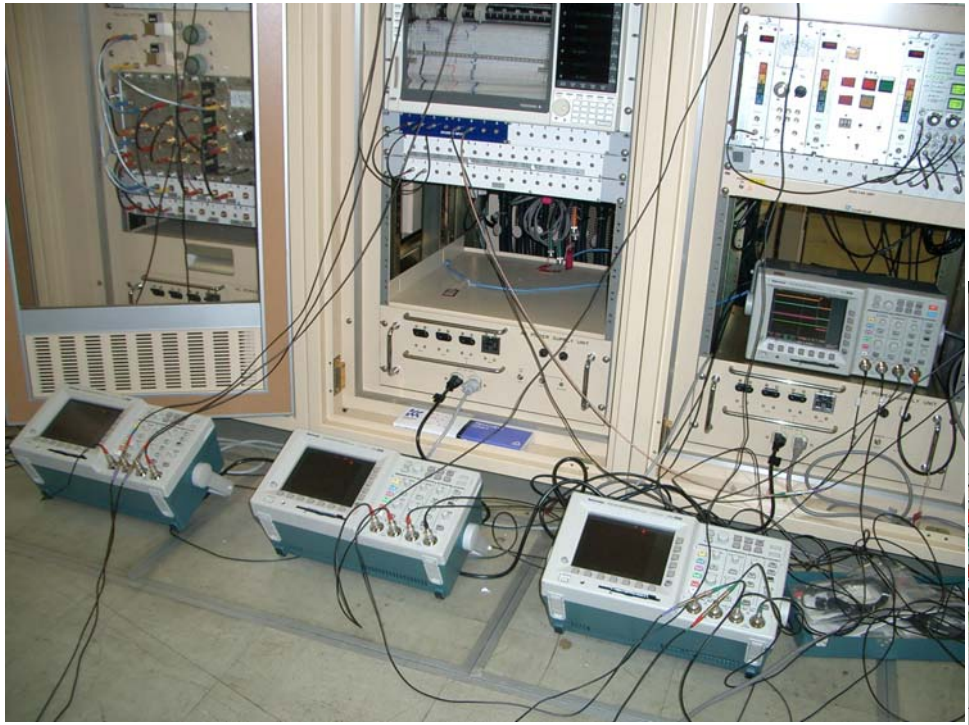
Under-coupling

# Machine Studies

*Search for an operating region with*

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

based on the simulation results.

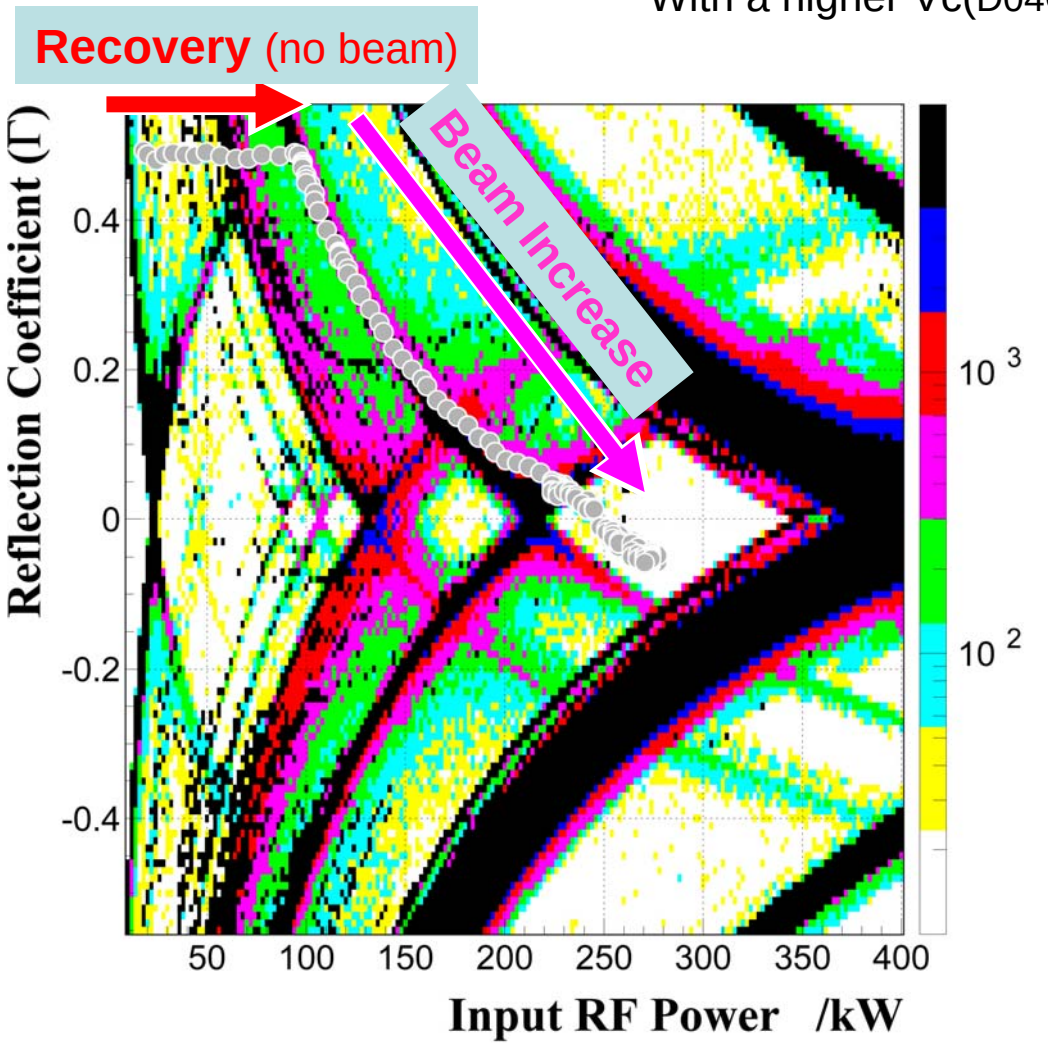


(in the D04 local control room)

(at the D04C klystron)

# NEW route in 2005

With a higher Vc(D04C)=0.68MV




Over-coupling

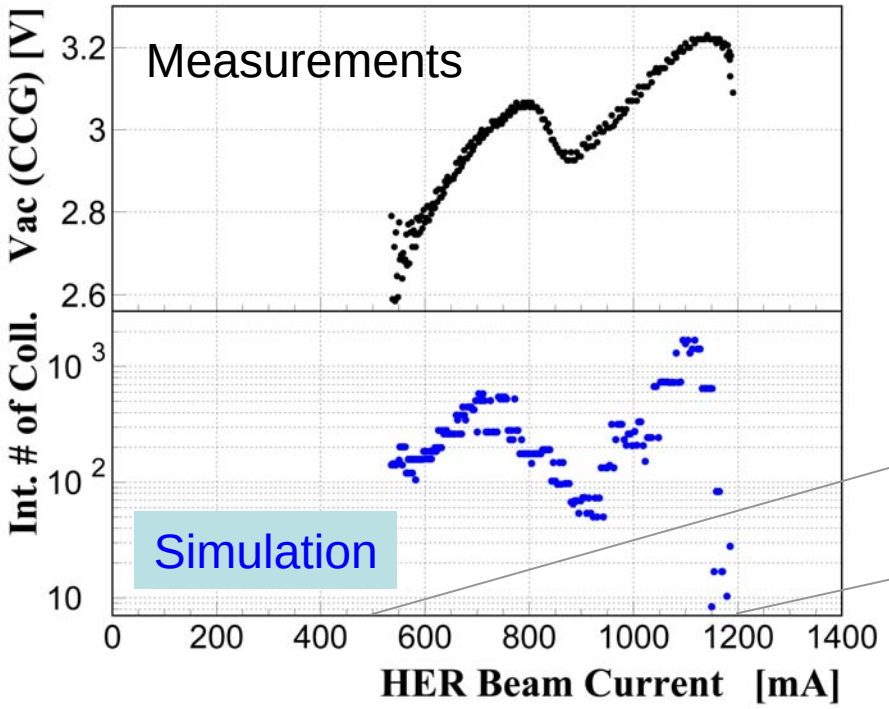
Under-coupling

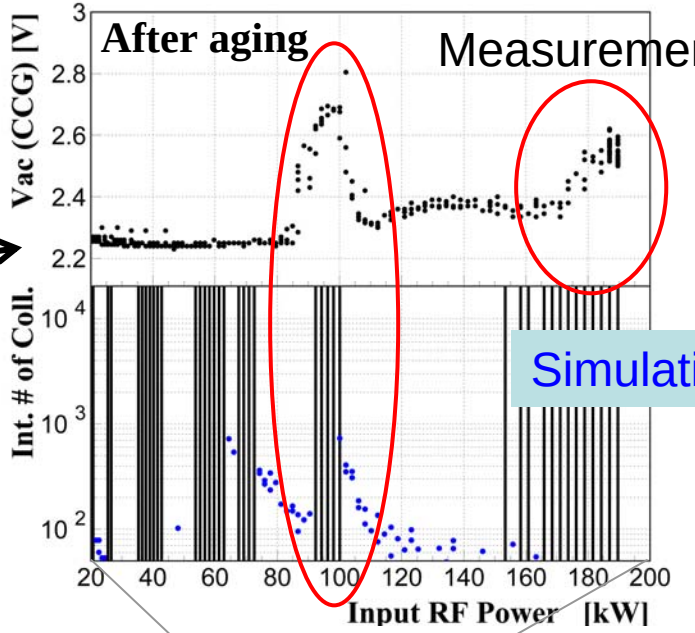
**D04C-cav1** data
in 2005.01.30_16:37:45-17:50:00

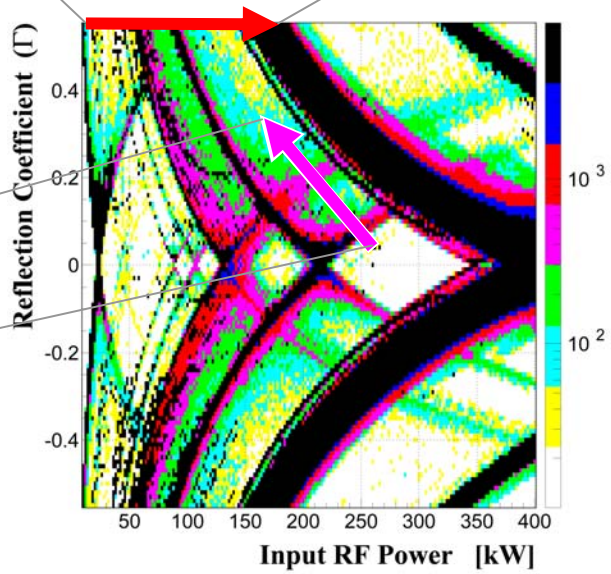
# Comparison with the Data

**Good Agreement !**

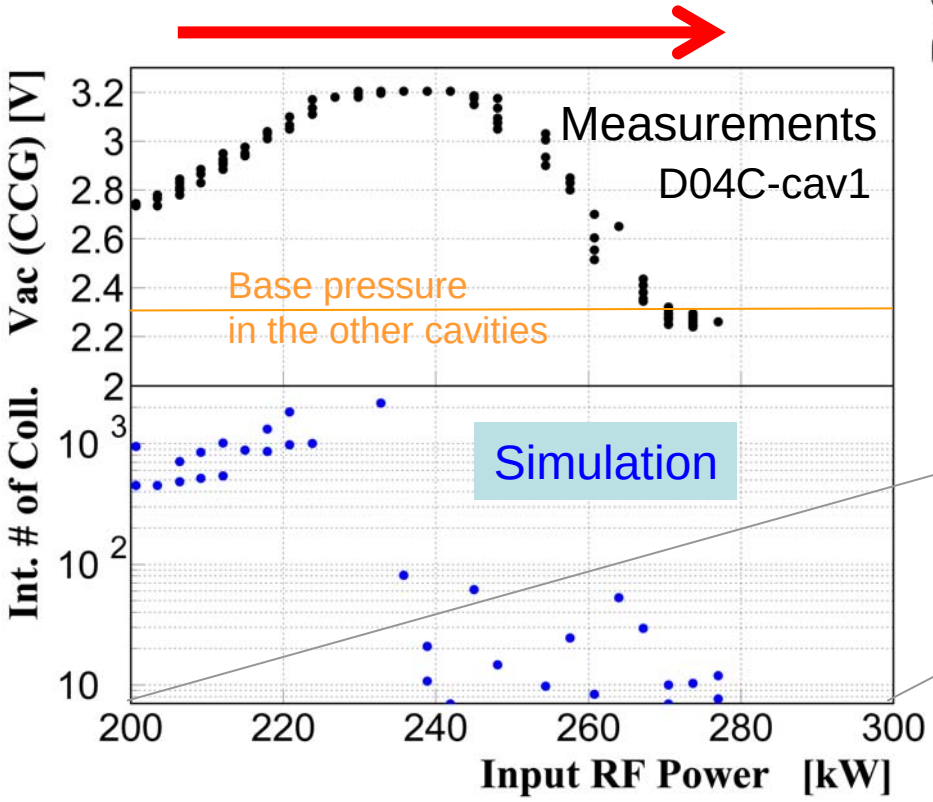
D04C-cav1

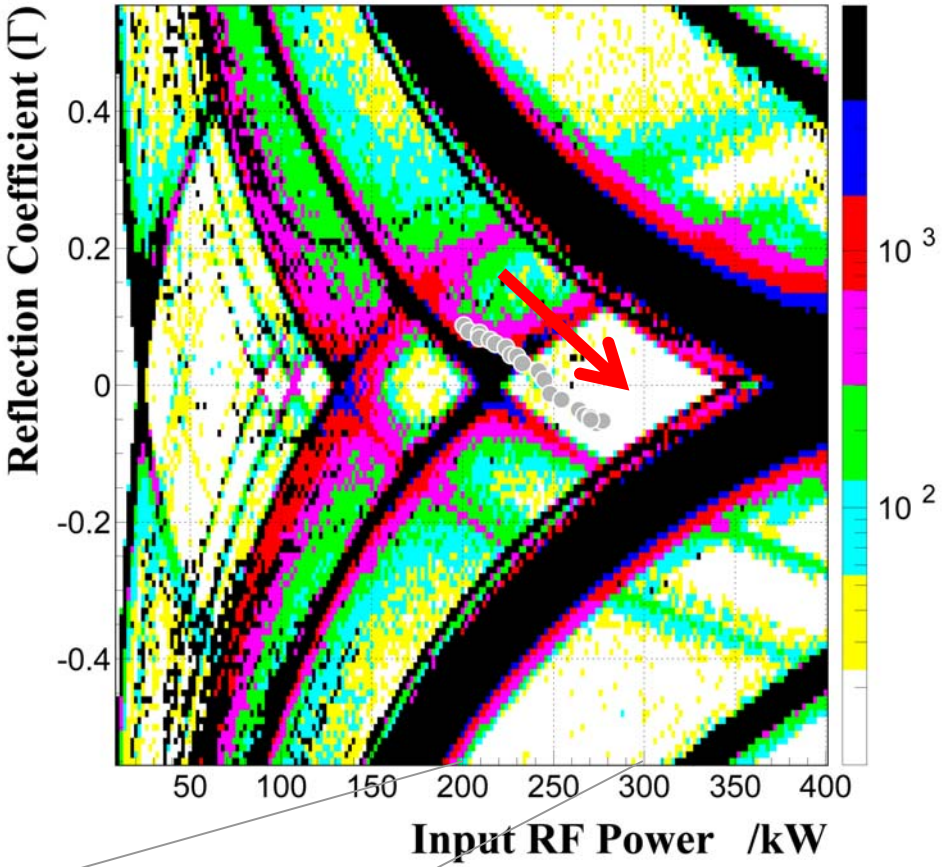


# Prediction comes true!

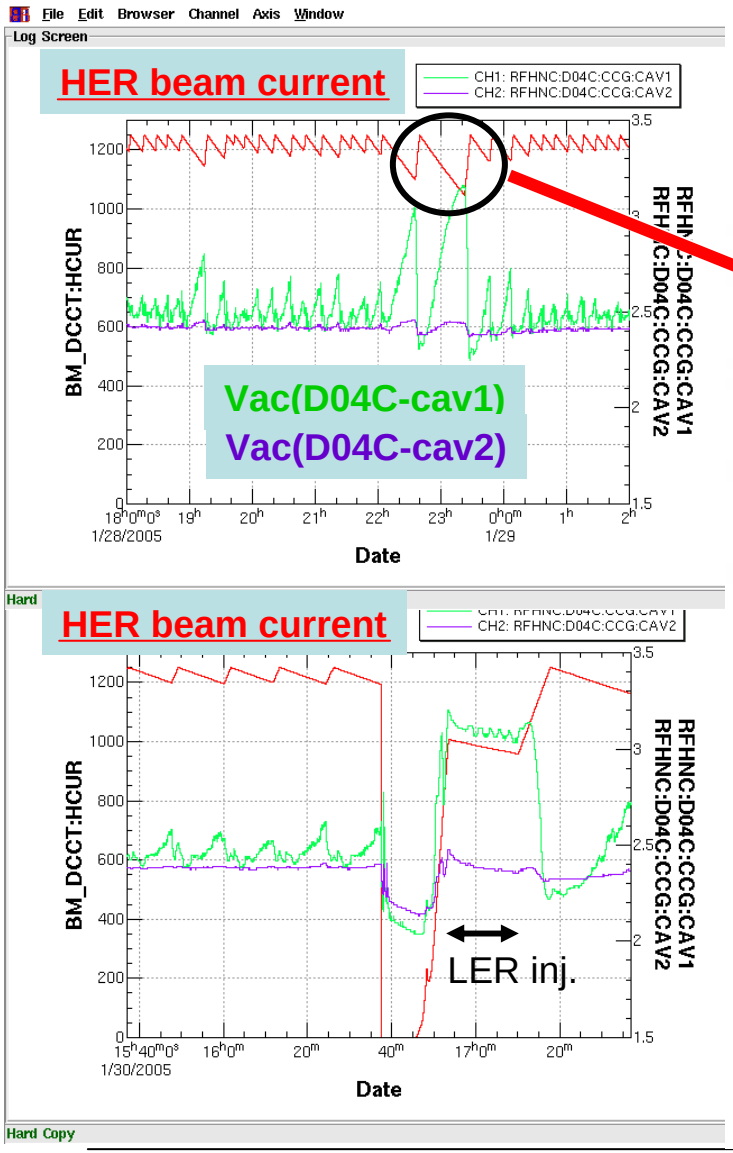


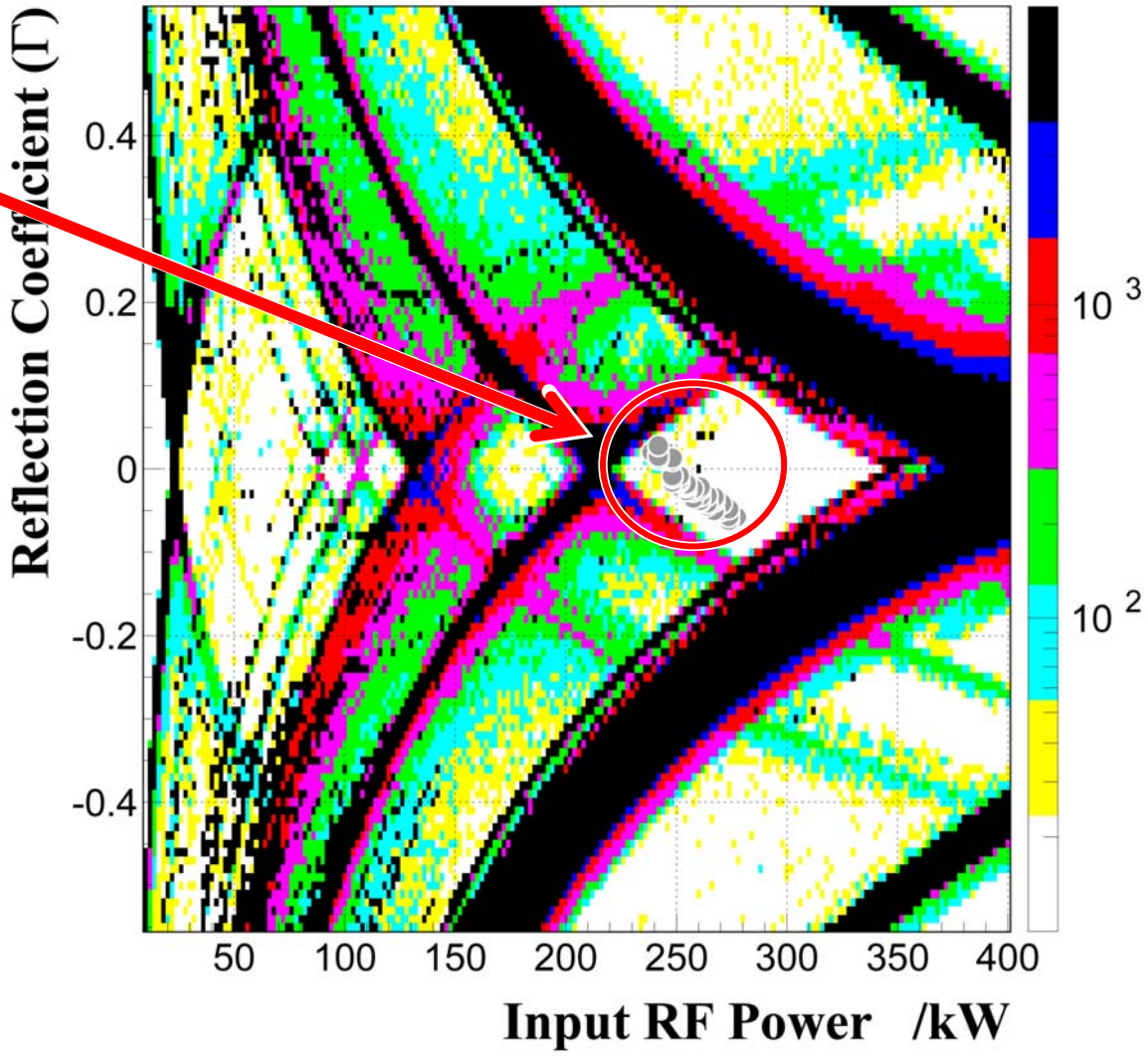




**D04C-cav1** data
in 2005.02.13_18:23:40-18:25:30

# But the region is not so wide.

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

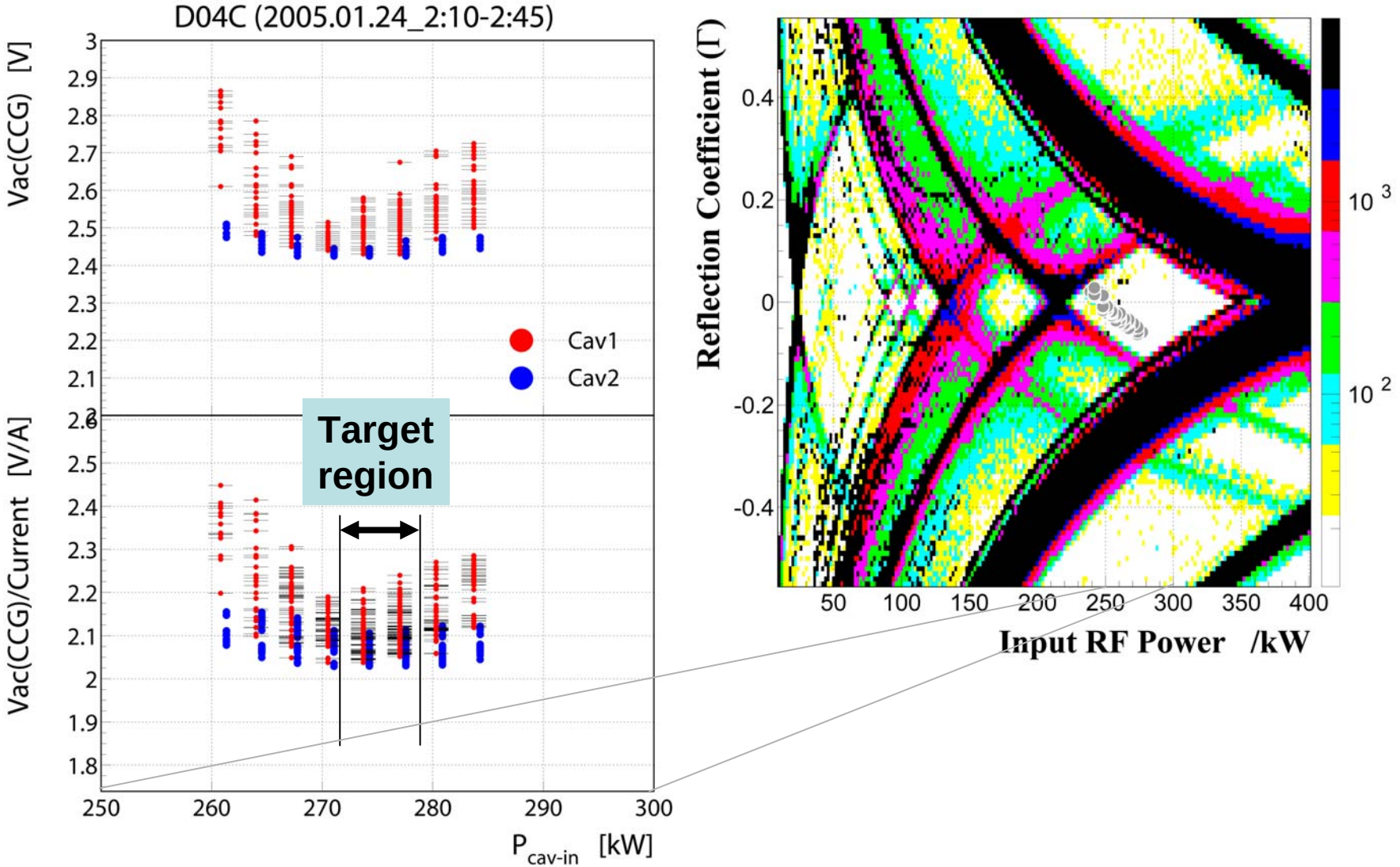


**Considering the fact that**
**"*Cavities out of condition are in a minority*",**

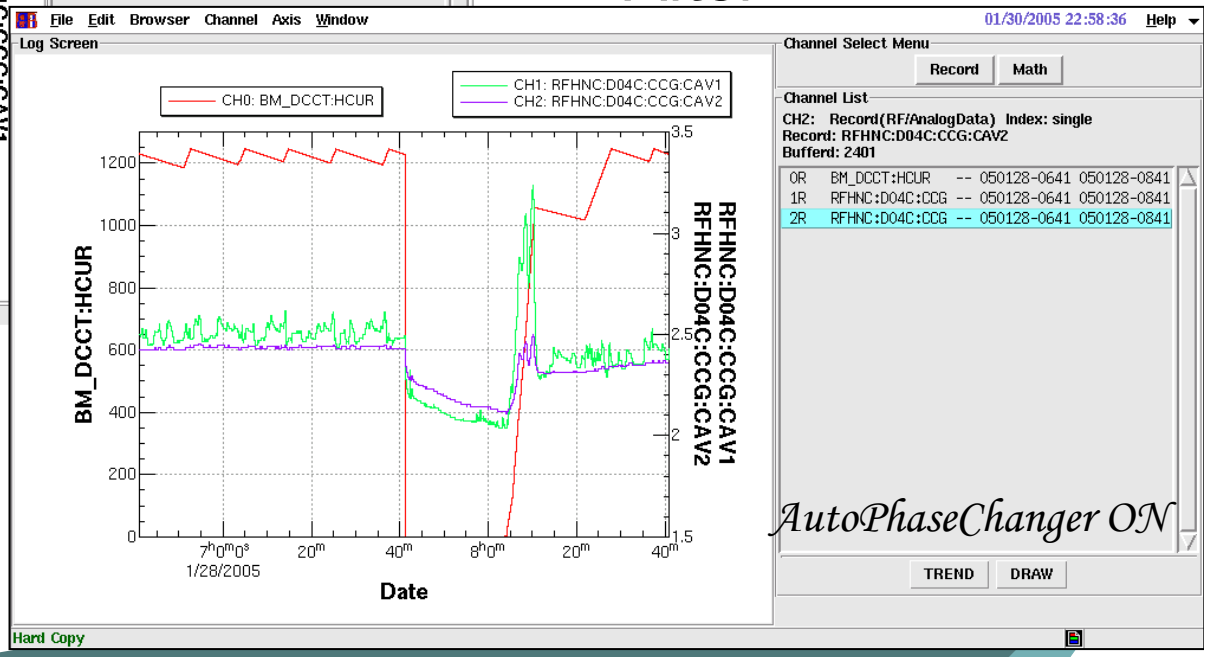
***We can keep an input RF power in a region with a good vacuum condition by changing the cavity phase (or beam loading)*** *automatically.*

# Scan of the vacuum pressure and a target power region



Before


After



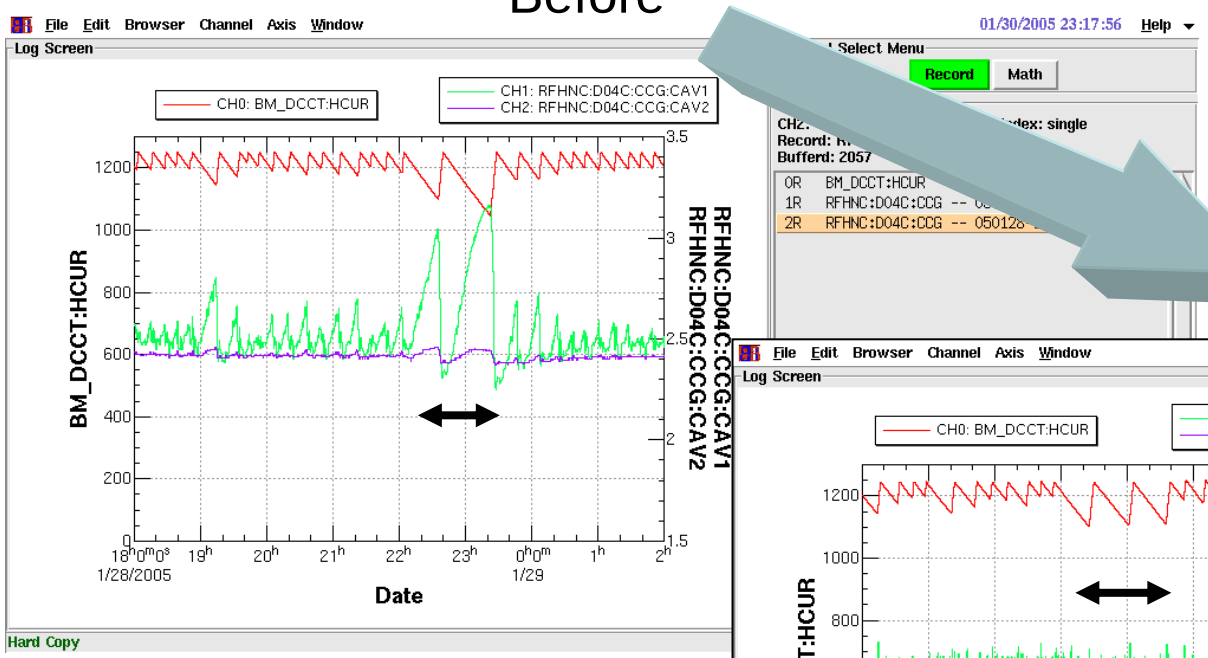

**HER beam current**

**Vac(D04C-cav1)**

**Vac(D04C-cav2)**

**Quick passage through the multipactoring zone!**

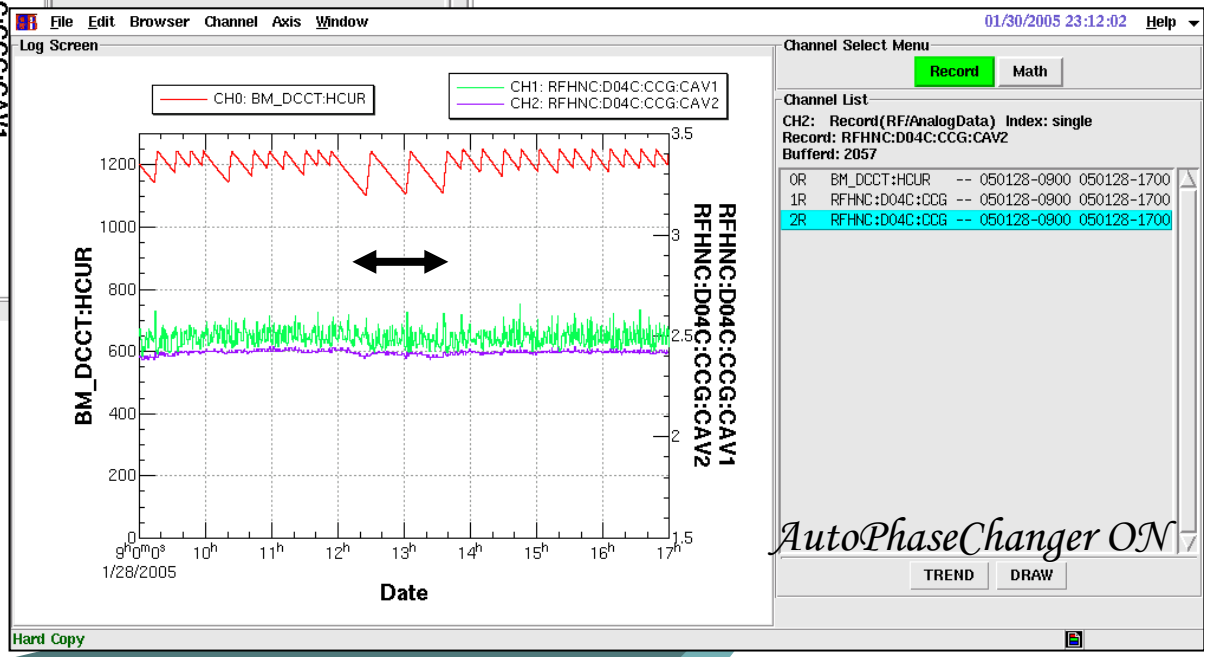
Before







After




HER beam current

Vac(D04C-cav1)

Vac(D04C-cav2)

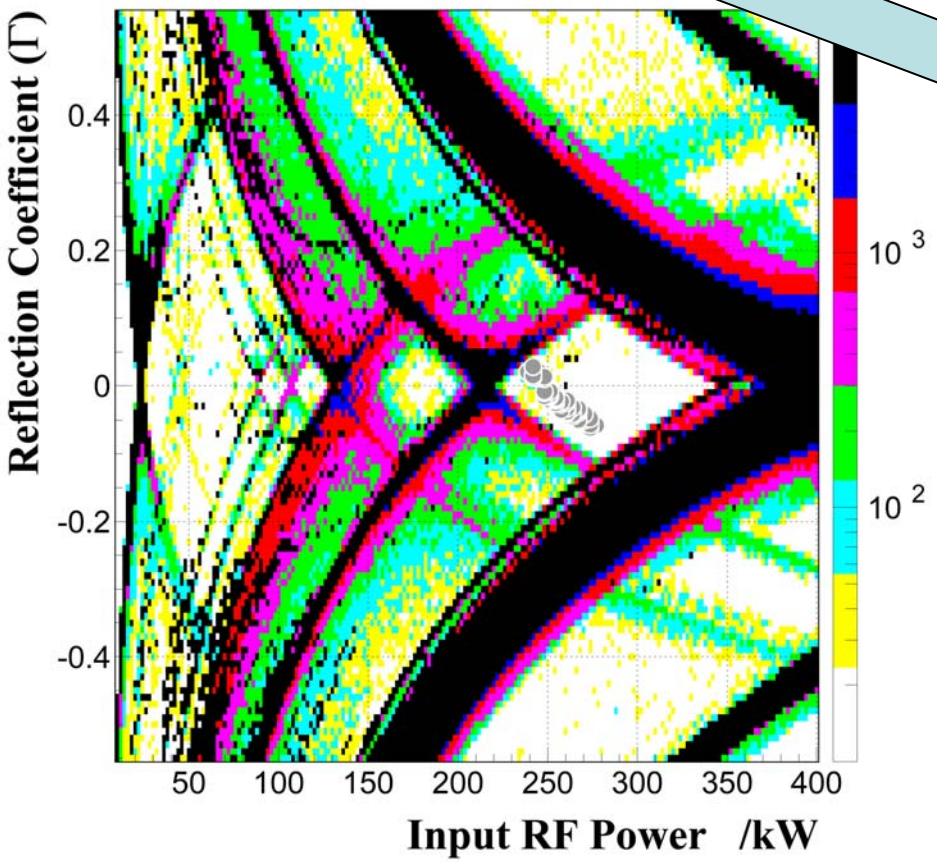
No beam-current dependence!

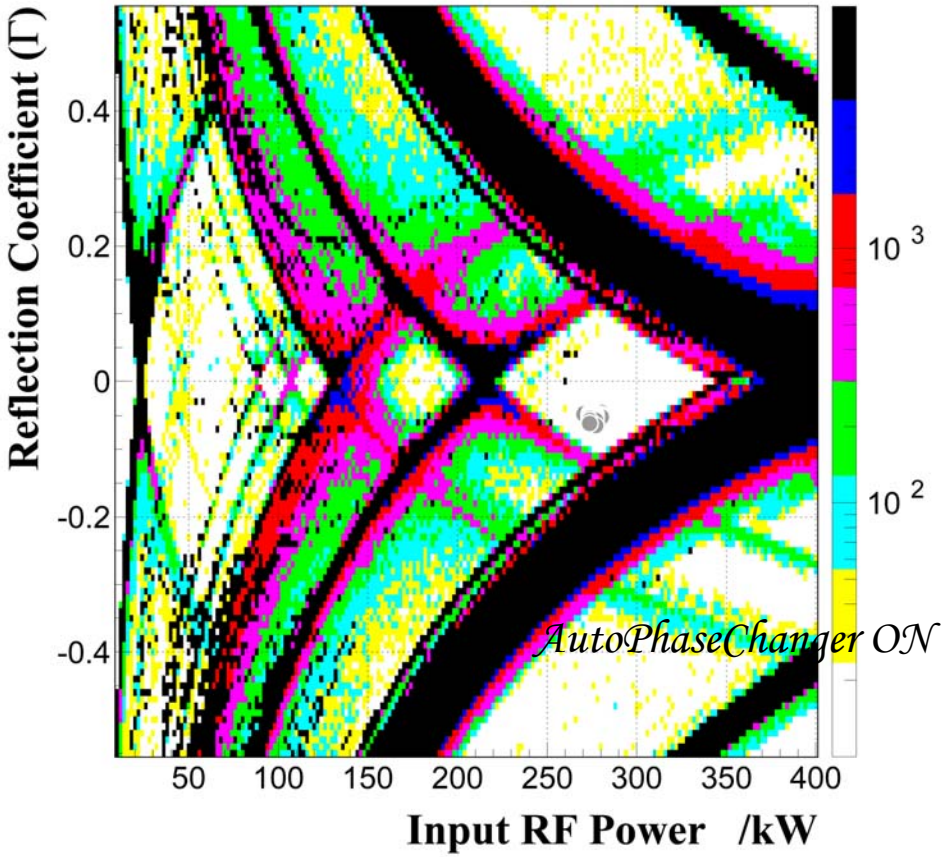
Before

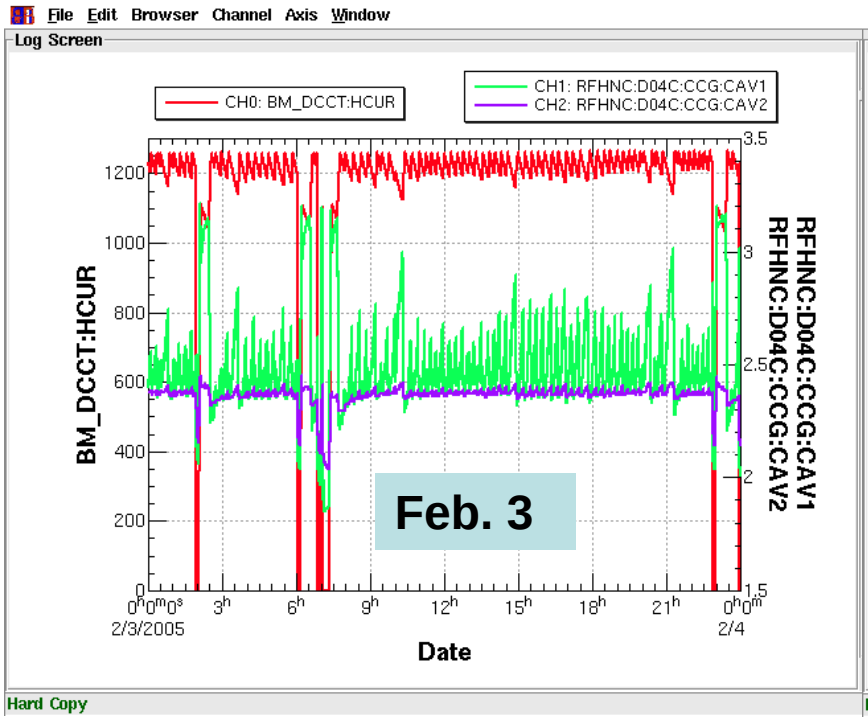
**D04C-cav1 data in CIM**

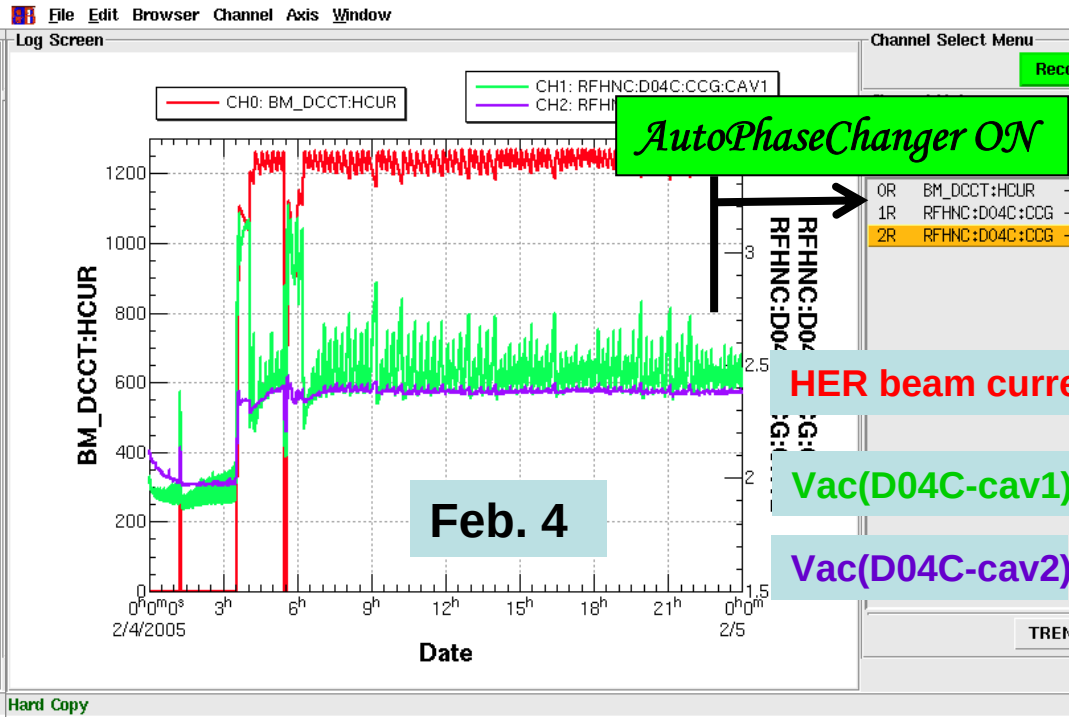
(Vc(D04C)=0.68MV)

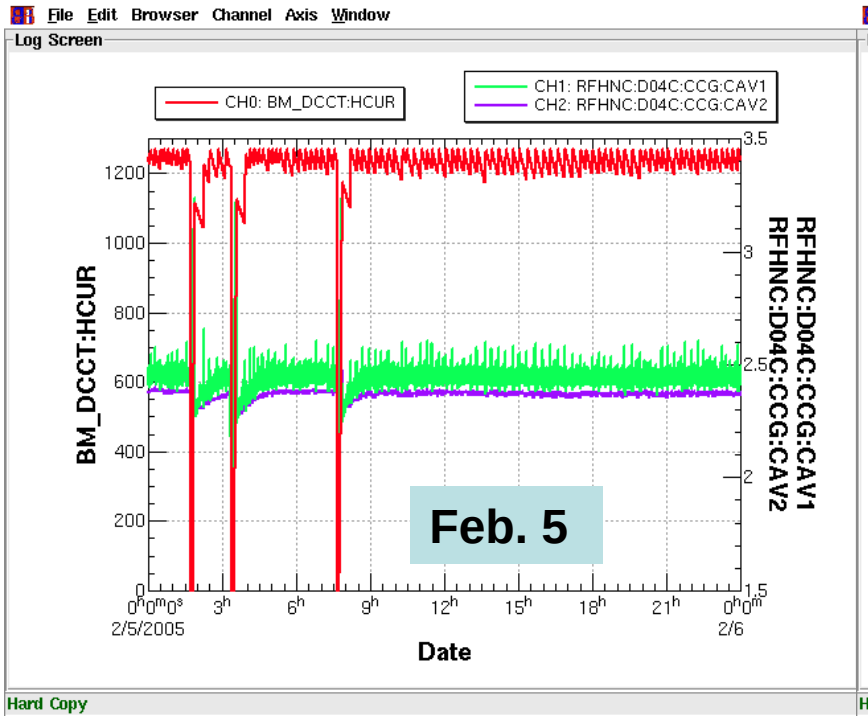
After

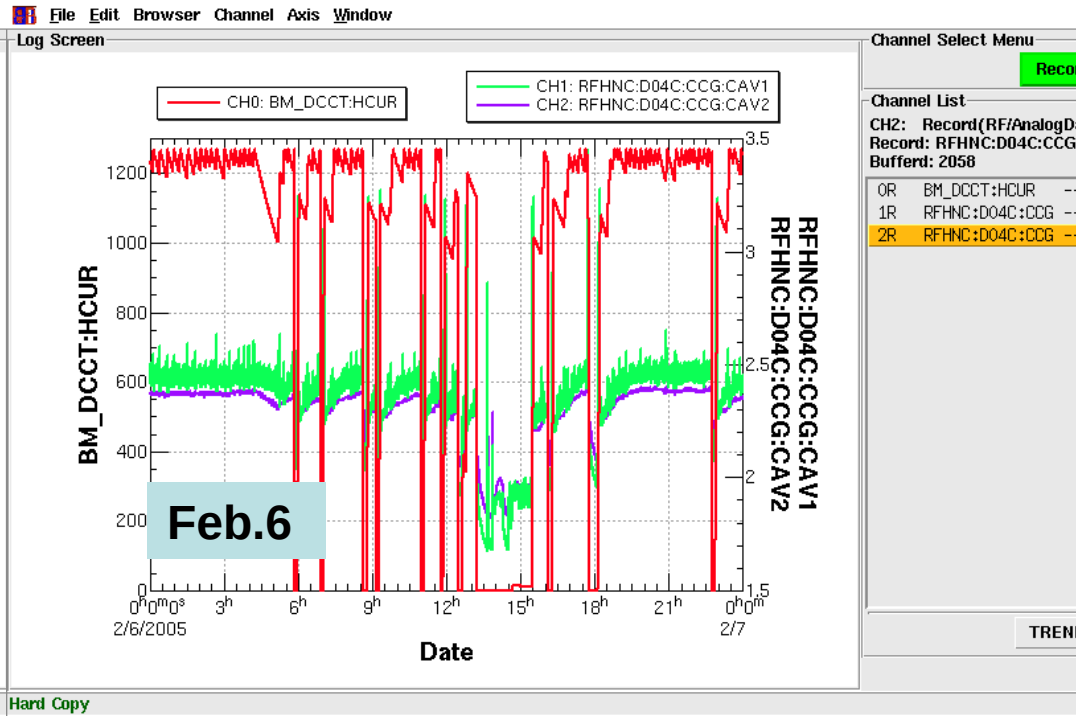



File Edit Browser Channel Axis Window
Log Screen
CH0: BM_DCCT:HCUR
CH1: RFHNC:D04C:CCG:CAV1
CH2: RFHNC:D04C:CCG:CAV2
BM_DCCT:HCUR
RFHNC:D04C:CCG:CAV1
RFHNC:D04C:CCG:CAV2
Feb. 3
2/3/2005
2/4
Date
Hard Copy


File Edit Browser Channel Axis Window
Log Screen
Channel Select Menu
CH0: BM_DCCT:HCUR
CH1: RFHNC:D04C:CCG:CAV1
AutoPhaseChanger ON
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
Channel Select Menu
Channel List
CH0: BM_DCCT:HCUR
CH1: RFHNC:D04C:CCG:CAV1
CH2: RFHNC:D04C:CCG:CAV2
0R BM_DCCT:HCUR
1R RFHNC:D04C:CCG
2R RFHNC:D04C:CCG
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…