KEKB long term operation & experience

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On behalf of Takaaki Furuya (KEK)

2014/03/26 at TTC meeting WG8

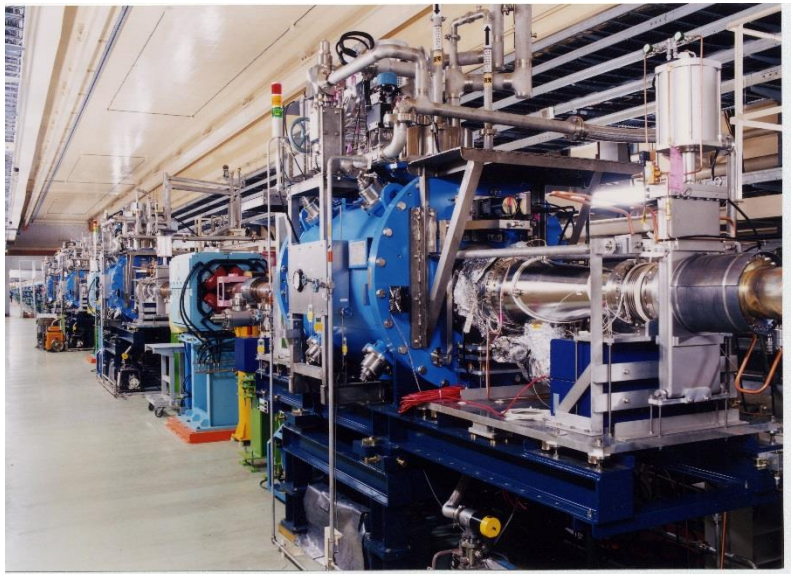
1, SC for KEKB
2, SC performance
3, HHPR

All slide come from「Workshop on Cryomodule Maintenance」2014/3/3@FRIB

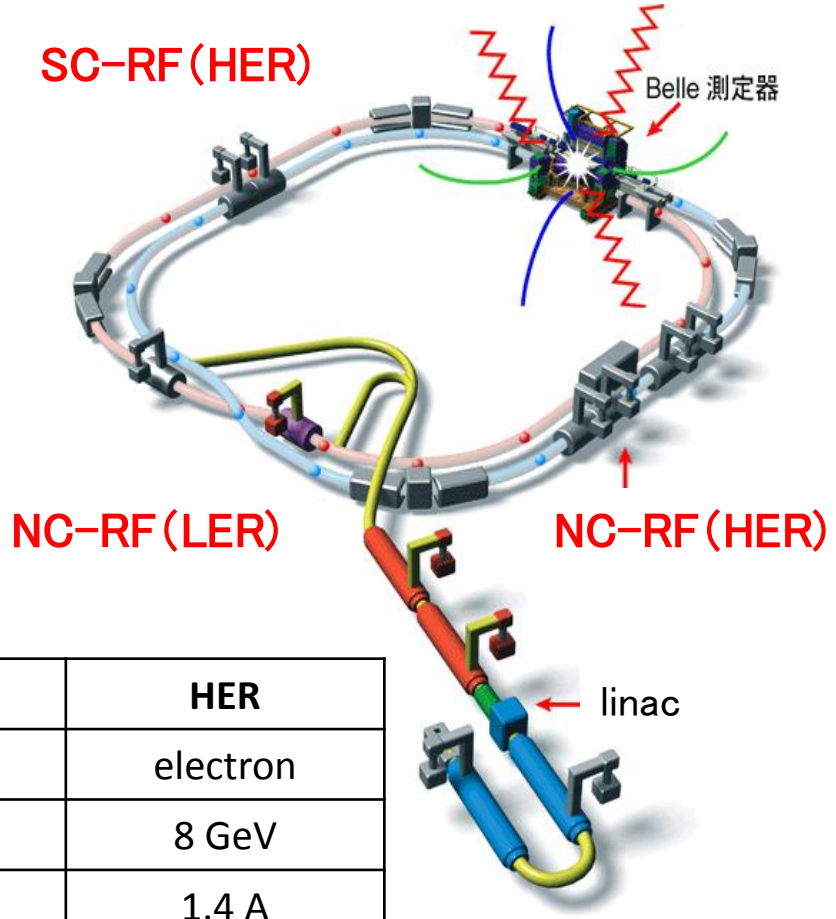
Please contact with Prof. Furuya (takaaki.furuya@kek.jp) for more details.

KEKB Electron Positron Collider

- e-/e+ collider for B meson physics (circumference of 3 km)
- Achieved luminosity of 21 $nb^{-1}s^{-1}$



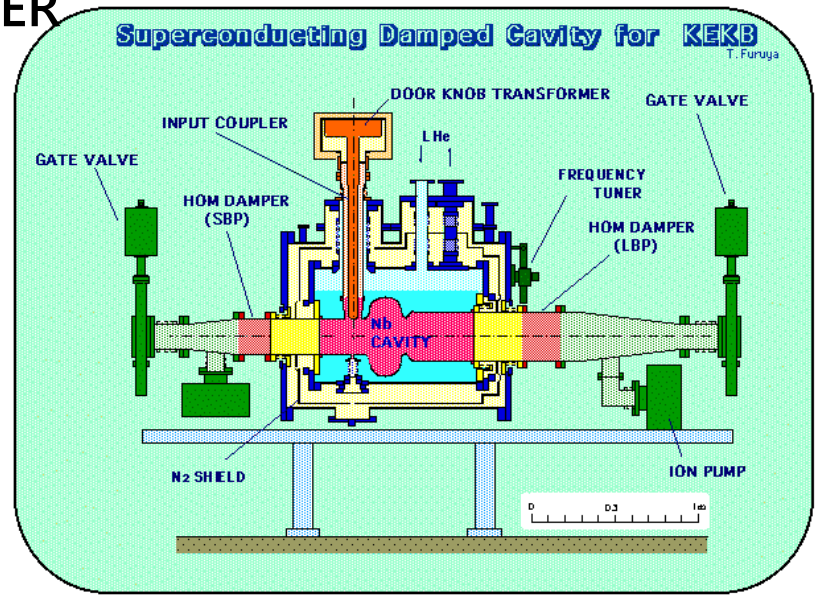
SC-RF modules of HER



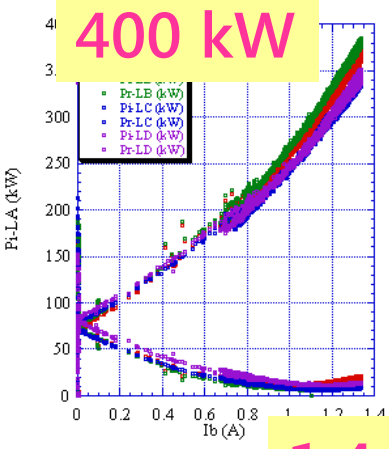
LER	HER
positron	electron
3.5 GeV	8 GeV
2 A	1.4 A

Operation status of KEKB-SC

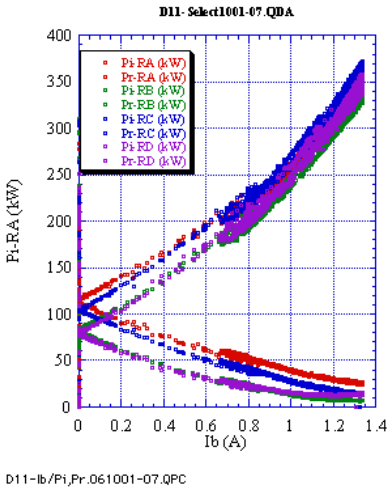
- Hybrid RF of SC(8) + NC(12) for HER
- Since 1998 to 2010
- Top up injection & no ramping
- 509 MHz Nb single-cell cavity
  Voltage: 1-1.5 MV/cav (4-6 MV/m)
  RF power: 350-400 kW/cav
  Qinput=7E+04 → 5E+04
- 4.4K operation: Q0 of 1E+09



400 kW



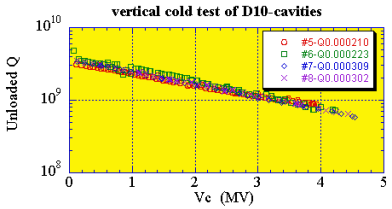
1.4 A

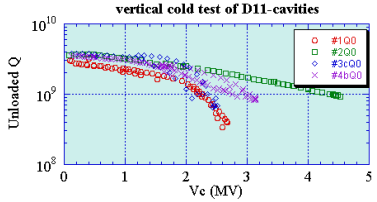


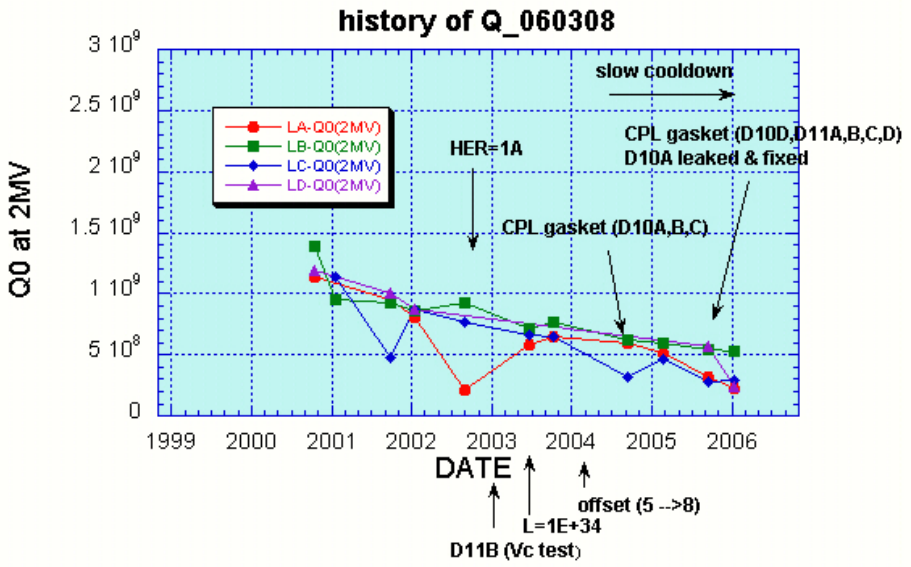
	SC-RF
No. of cavities	8
Max. beam current (A)	1.40
RF voltage (MV/cavity)	1.1 - 2
unloaded Q at 2MV	0.3 -1 E+09
beam loading (kW/cav)	350 - 400
HOM loading (kW/cav)	14 - 16

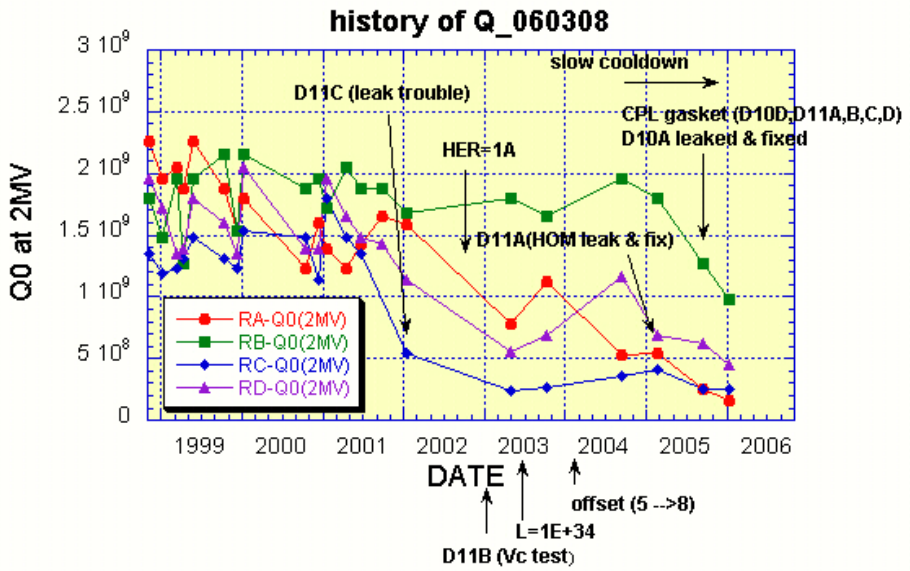
Degradation of Cavity Performance

- Unloaded Q: Q0
- Unloaded Q degraded to 3-5E+08 at 2MV (8 MV/m) by strong electron emission.
- The Q at operating voltage (1.5 MV) still keep the Q of >1E+09.



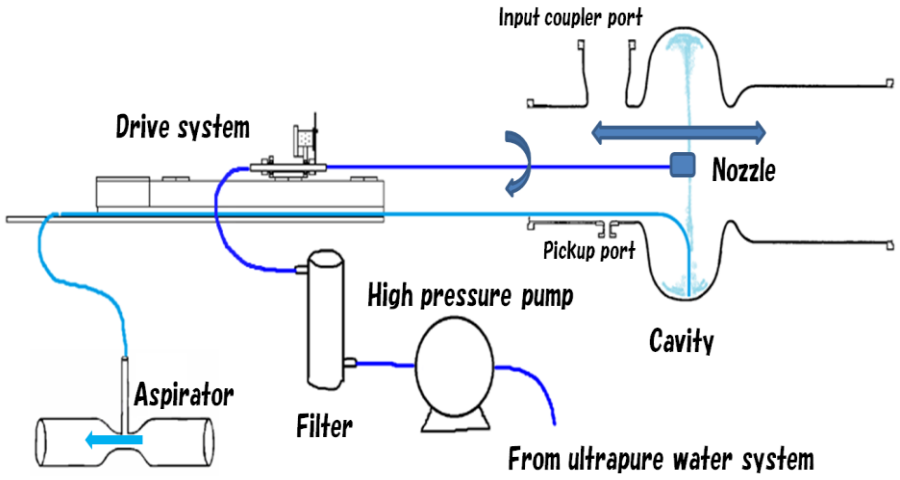


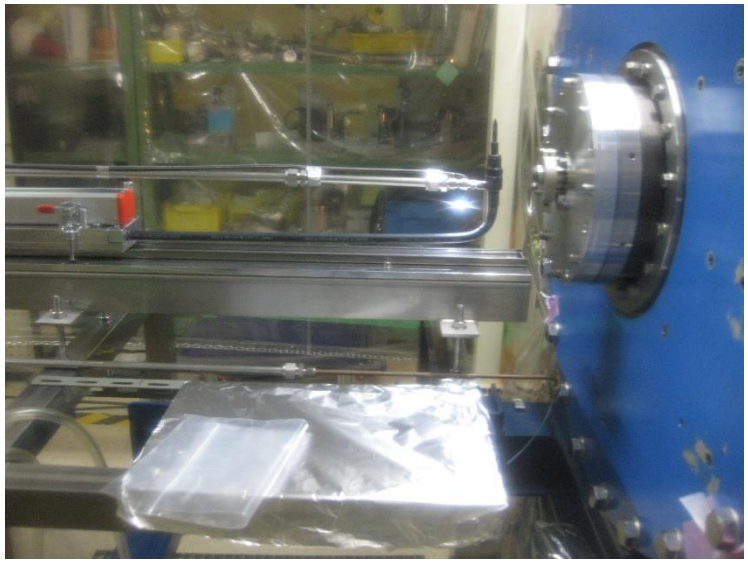




Recovery of Performance by HHPR

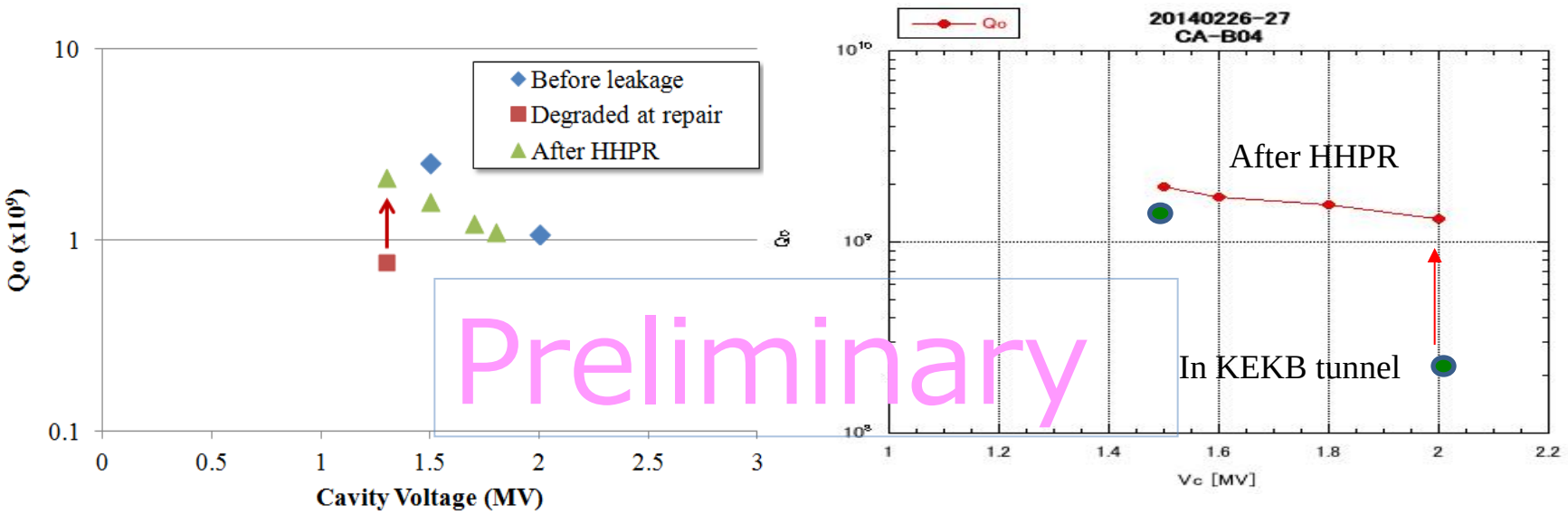
- Horizontal High Pressure Rinsing: HHPR
- For recovering the degraded Q, HPR is given to the cavity inside a horizontal cryostat.
- Saving time, cost, human power and reducing the risk of re-assembling.
- U.P. Water rinsing of 7MPa was given for 15 minutes.





Recovery of Performance by HHPR

- Apply to the real cryomodule
- Applied to two degraded modules.
- CA-B03: He-leaked cavity was degraded by re-assembling.
  CA-B04: Degraded by the vacuum trouble during change coupling.
- In both cases, the Q recovered to >1E+09.



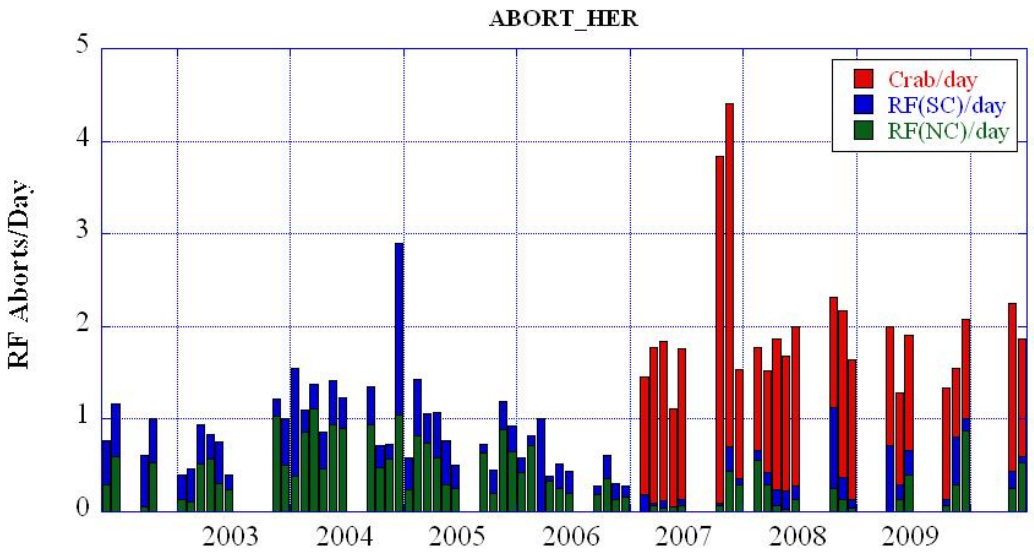
CA-B03

CA-B04

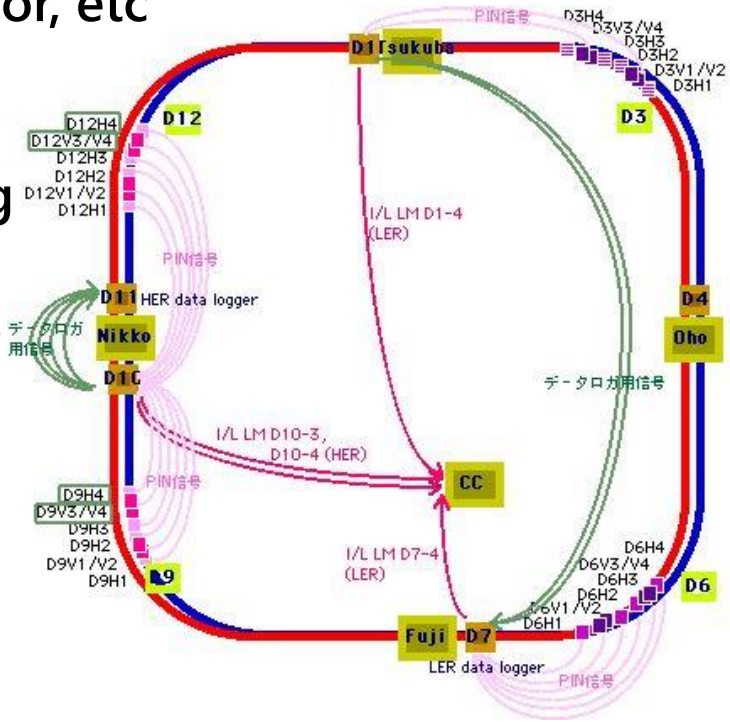
Backup slide

Statistics of Trips

- Collect signals of RF, beam, loss-monitor, etc
- Find a beam dying message to know the real reason of each trip
- SC trip is mainly caused by discharging in the cavity or coupler
- Trip rate of 0.5 times/day for 8 cavities
- 0.1 times/day in 1 A operation



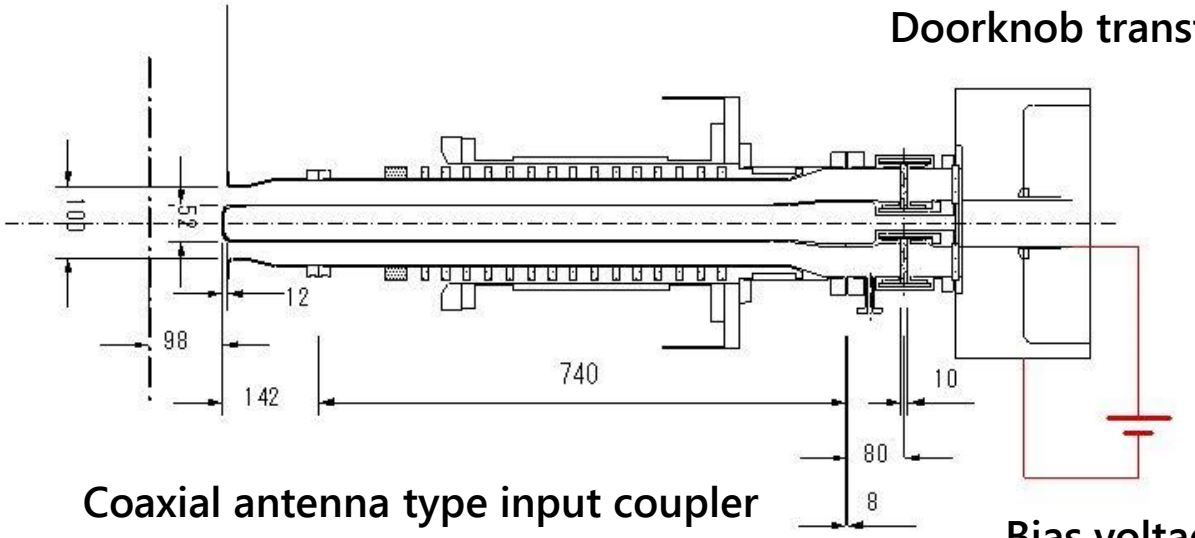
RF trip of HER



Grn: NC-RF (12)
Blu: SC-RF (8)
Red: CRAB cavity (1), since 2007

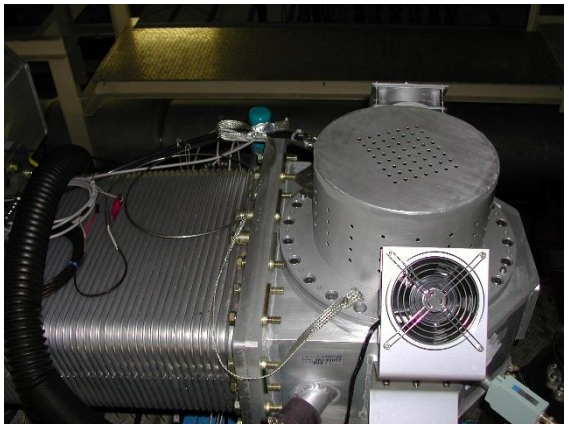
Maintenance Work of SC-RF

- Warming up to RT twice a year
  - Safety inspection of cryogenics; pressure gauge, safety valve, etc
  - Tuner release during cooling down and warming up
  - Coupler conditioning with bias voltage before cooling
- Short stop of every two weeks
  - Visual inspection
  - Cavity conditioning



Coaxial antenna type input coupler

Doorknob transformer



Top view of doorknob

Bias voltage

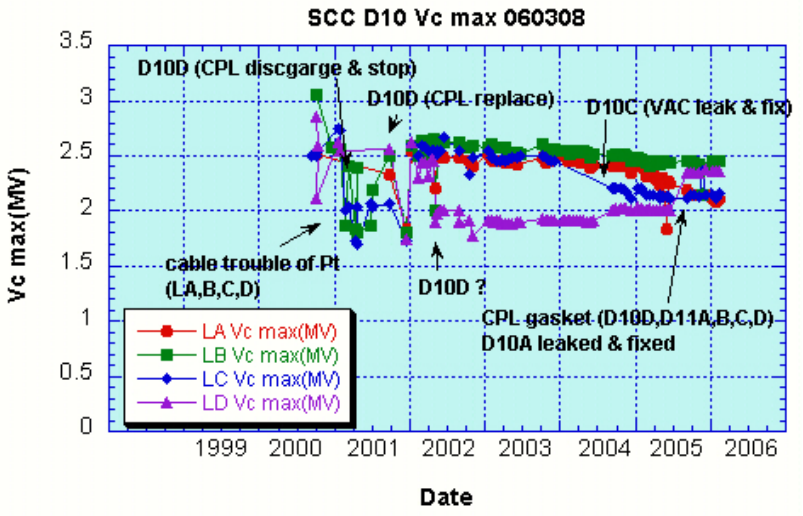
Trouble of Cryomodules

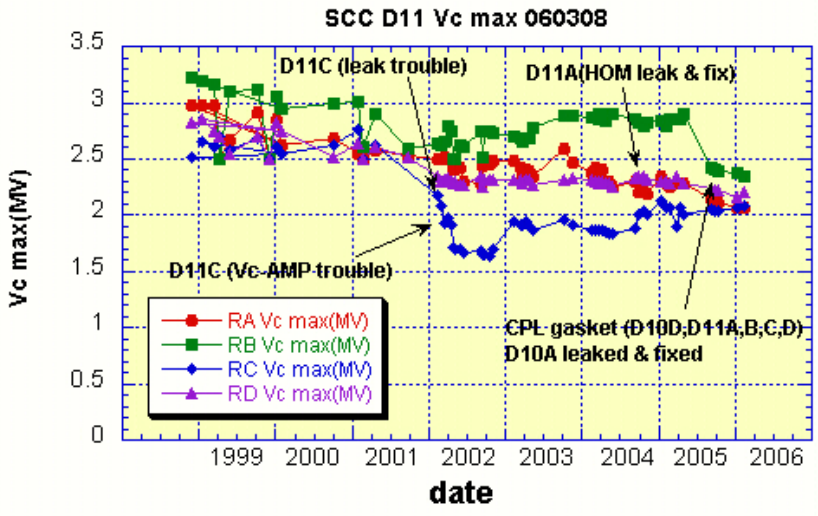
- Trouble of module
  - More than 20 times of heat cycle so far
  - Slow cooling rate of 3K/hr
  - Leaked modules were re-assembled with no additional treatment

Trouble	reason	
Leakage of insulation vacuum	Inferior vacuum gasket	2
Leakage at indium sealing	Inappropriate setting Effect of heat cycle	5
Vacuum leak at HOM damper	Small crack on a welding seam	1
Frequency tuner	Piezo damaged	1

Degradation of Cavity Performance

- Maximum accelerating voltage
- The maximum voltage slightly reduced from 2.5-3MV to 2-2.5MV.
- All cavities can provide a voltage of >2MV (8 MV/m) after 10 years.
- The voltage of D11C degraded by a vacuum trouble. Some amount of dirty air came into the cavity.
- To obtain a strong coupling, the gasket of input coupler was replaced to a thinner one. Qext decreased from 7E+04 to 5E+04.





Summary

- KEKB-SC provided the accelerating voltage of 1-1.5 MV/cavity and the beam power of 350-400 kW/cavity to an ampere class electron beam for 10 years.
- The beam abort caused by SC is ~0.5 times/day for 8 cavities.
- Significant degradation of Q was observed at >2 MV.
- HHPR is considering as a performance recovering method of saving time, cost, manpower and reducing the risk of re-assembling.
- HHPR was applied to two modules. In both cases, it was effective to recover the degraded Q.
- KEKB-SC is re-used in SuperKEKB in which the electron beam of 2.6 A is stored to obtain the luminosity of 800 $nb^{-1}s^{-1}$.