2013.3.4
MRC2013
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Superconducting Cavity

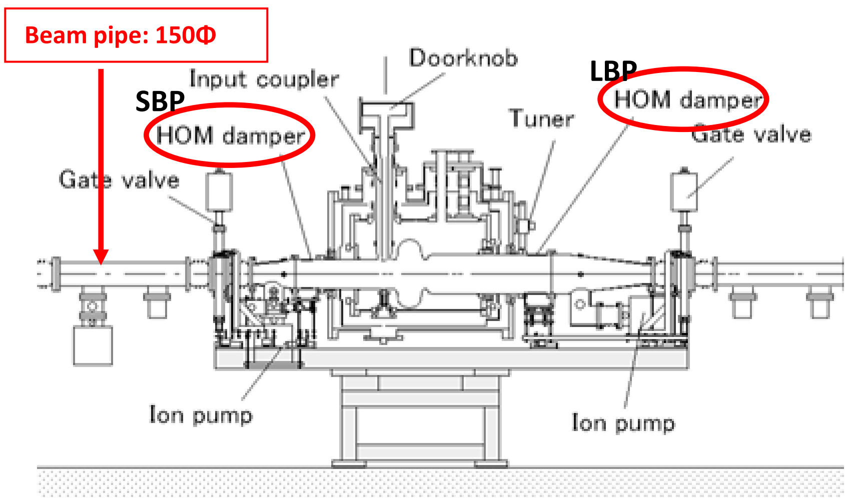
1. Measures for large HOM power
2. Performance recovery

Expected beam-induced HOM power in SuperKEKB/HER

- Machine parameter of SuperKEKB/HER
  - Beam Current : 2.6A/2500 bunches
  - Bunch length : 5mm
- Expected beam-induced HOM power
  - Cavity loss factor : 1.2V/pC @σ=5mm
  - HOM power : 31kW
  - LBP damper load : 26kW
    - Self loss=0.26 V/pC
  - SBP damper load: 20kW
    - Self loss=0.30 V/pC
  - Total HOM load per cavity : 46kW
- Total HOM power at KEKB: 16 kW

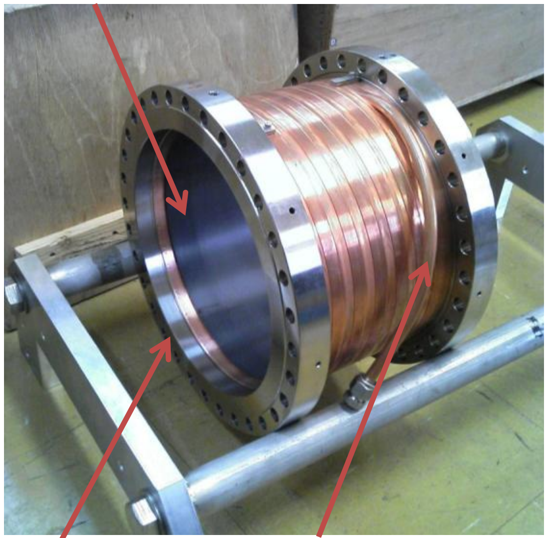
Expected damper loads

Beam current	SBP load	LBP load
(A)	(kW)	(kW)
2	12	15
2.6	20	26



HOM damper

HIPped ferrite（Thickness : 4mm）



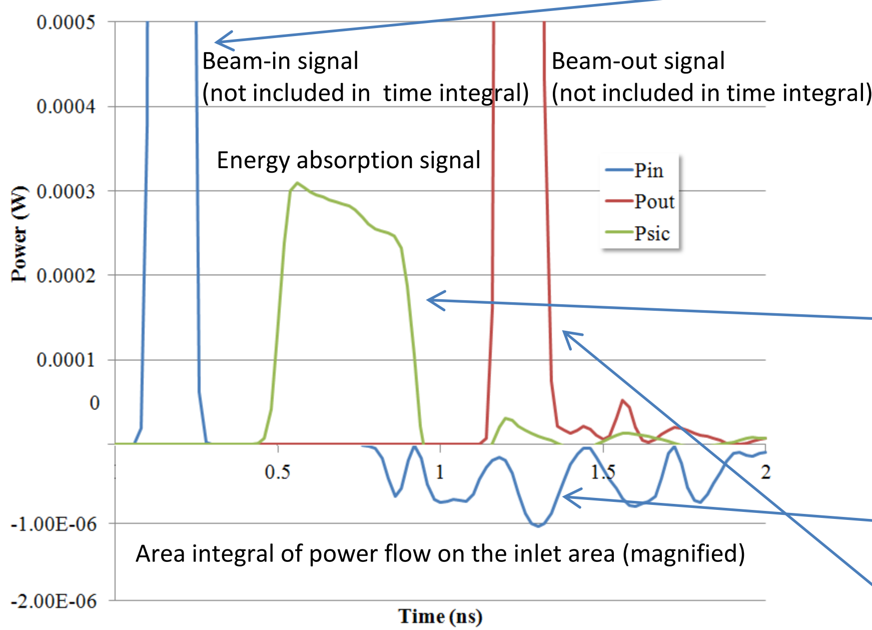
Cupper pipe (3/8”) for water cooling

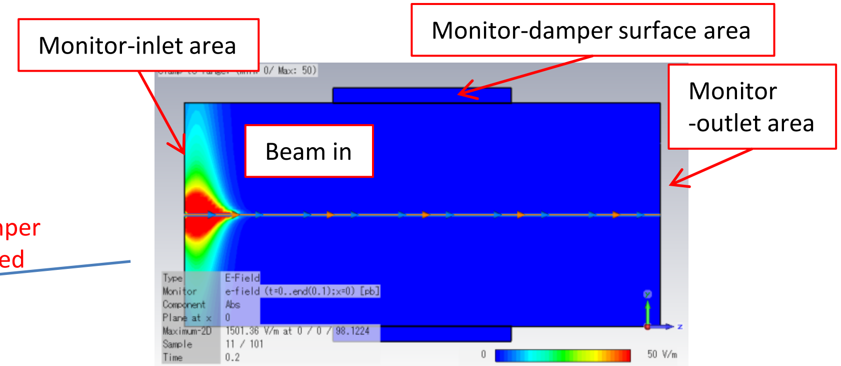
Stainless steel flange

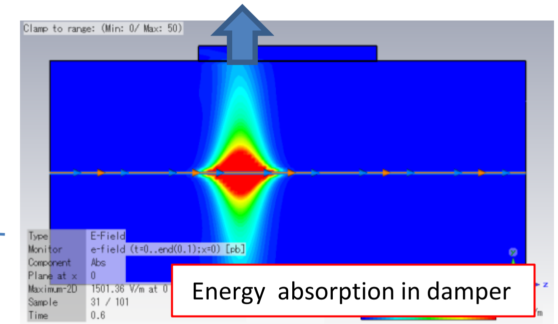
New calculation method for damper load
Power flow monitor (CST-PS wake-field)

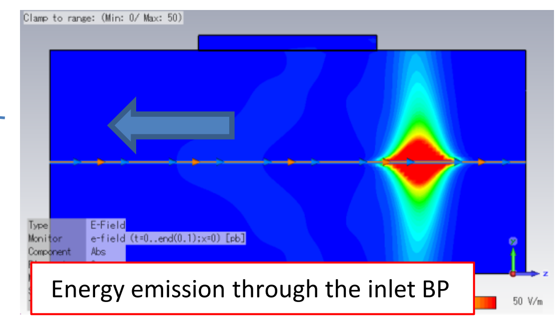
Area integral of power flow on each area

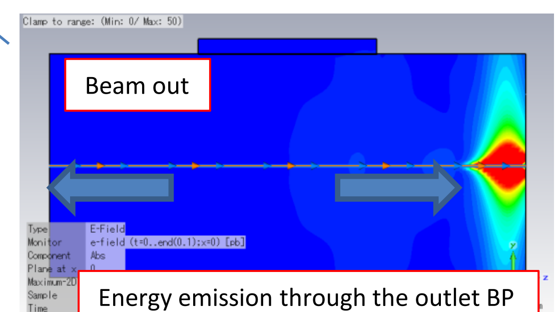
Absorbed power in damper can be directly calculated









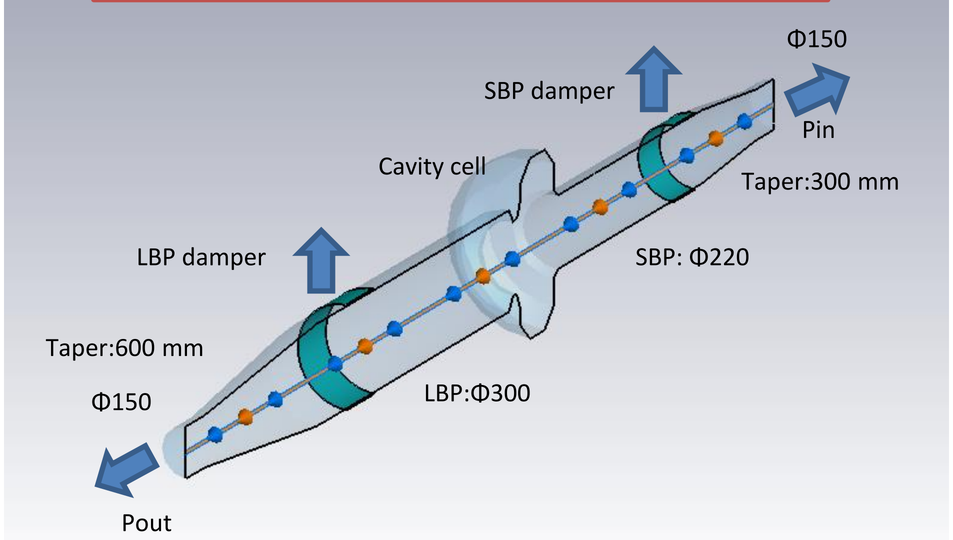


Bunch charge: 1pC

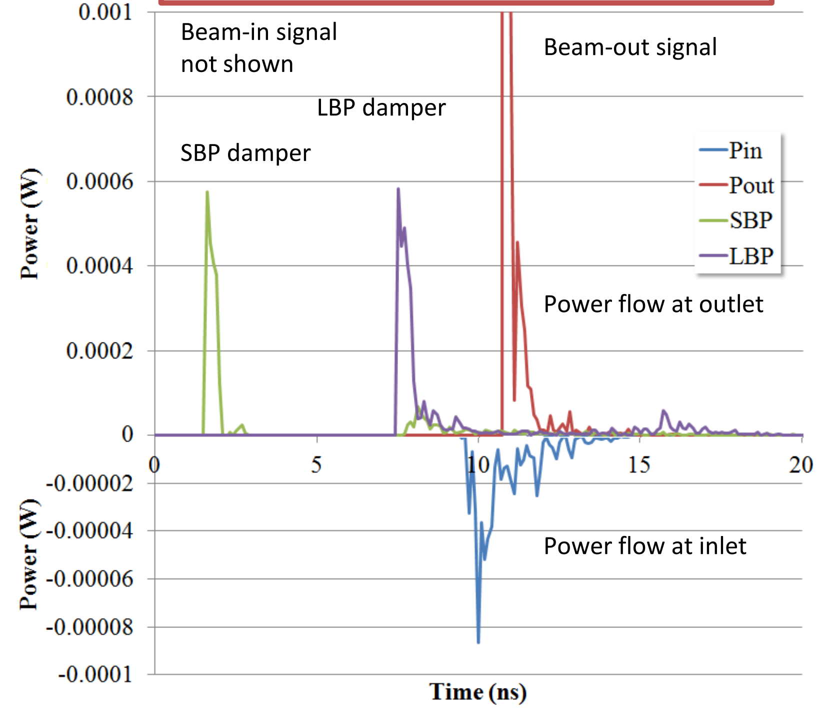
	Time integral (pJ)	Normalized (pJ)	Eq. LF (V/pC)
Inlet area	0.000536	0.000636	0.000636
Outlet area	0.00797	0.00946	0.00946
Damper surface	0.112	0.133	0.133
Stored energy @ 2ns	0.00353	0	0
Total energy	0.124	0.143	0.143
From loss factor	0.143		0.143

Power flow simulation for superconducting cavity module

Wake field simulation using CST Particle Studio
-The damper's shape was approximated by a cylinder



Area integral of power flow on each surface



Emitted/absorbed/stored energy in the cavity

LF (V/pC)	Inlet (pJ)	Outlet (pJ)	SBP (pJ)	LBP (pJ)	Stored energy (pJ)	Total energy (pJ)
1.414	0.06229	0.3573	0.2885	0.3798	0.104	1.192
σ=5 mm, q=1pC Energy deposit of 1pJ corresponds a loss factor of 1V/pC						

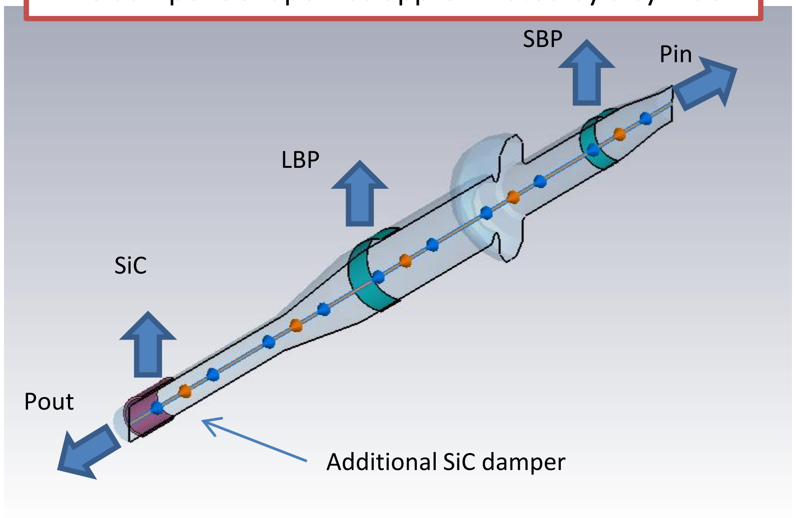
Eq. LF and HOM loads at 2.6A

	Eq. LF (V/pC)	Load@2.6A (kW)
Inlet	0.081	2.2
Outlet	0.464	12.5
SBP	0.375	10.1
LBP	0.494	13.3
Total	1.414	38.2

Total energy is consistent with energy deposit calculated from the loss factor. SBP and LBP damper loads are not large. Those loads can be absorbed by present dampers. On the other hand, large energy is emitted through the beam pipe outlet. The energy becomes additional load to cavities of downstream area. Therefore the energy has to be absorbed by an additional damper.

Effects of additional SiC damper

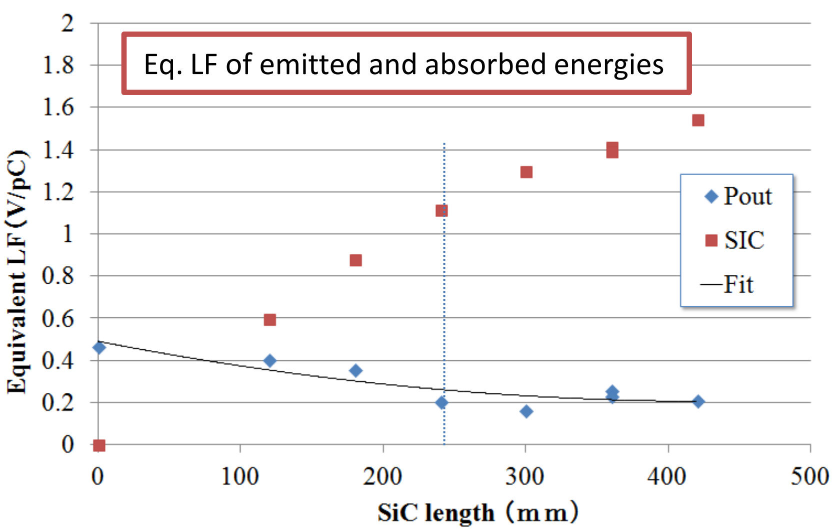
Wake field simulation using CST Particle Studio
-The damper's shape was approximated by a cylinder



Eq. LF and HOM loads at 2.6A

SiC:240mm	Eq LF (V/pC)	Load@2.6A (kW)
Pin	0.09	2.4
Pout	0.22	5.9
SBP	0.31	8.4
LBP	0.44	11.9
SiC	1.10	29.7
Total	2.16	58.4

Eq. LF of emitted and absorbed energies



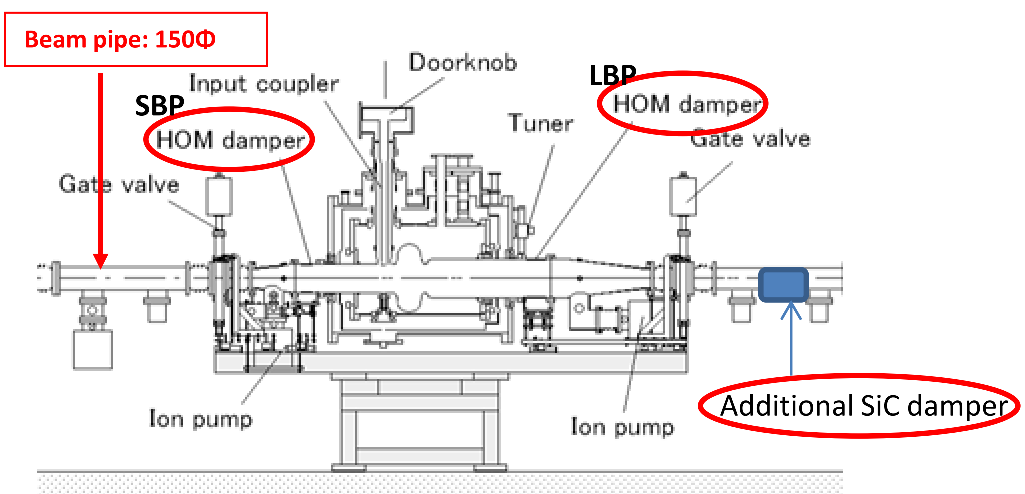
Additional SiC damper can absorbs more energy as the length becomes longer. It also reduces SBP and LBP damper loads. In practice, HOM load of additional SiC damper has to be less than 30kW (1.1 V/pC). 240 mm damper is suitable for our cavities.

Summary of measures for large HOM power

- Established new HOM power calculation method
  - Each damper's load can be calculated
- HOM power calculation
  - SBP and LBP HOM loads are not large (can be absorbed)
  - 30% of beam-induced energy is emitted through BP
- Additional SiC
  - Additional SiC damper can absorb energy emission
  - Also reduce ferrite damper loads
  - 240 mm SiC damper is suitable for our cavity
  - SiC can be set without opening the cavity module
- Fabrication and high power test of SiC dampers

Summary of HOM power loads

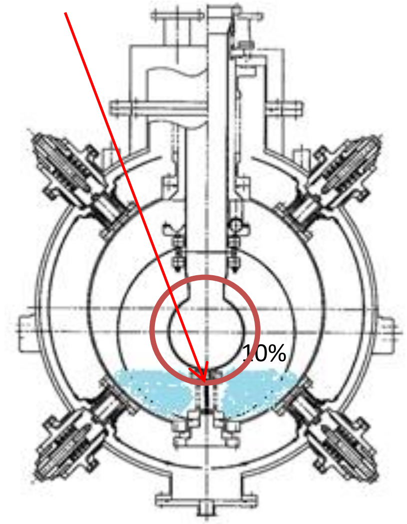
	Load@2.6A (kW)
Inlet	2.4
Outlet	5.9
SBP	8.4
LBP	11.9
SiC(240mm)	29.7
Total	58.4

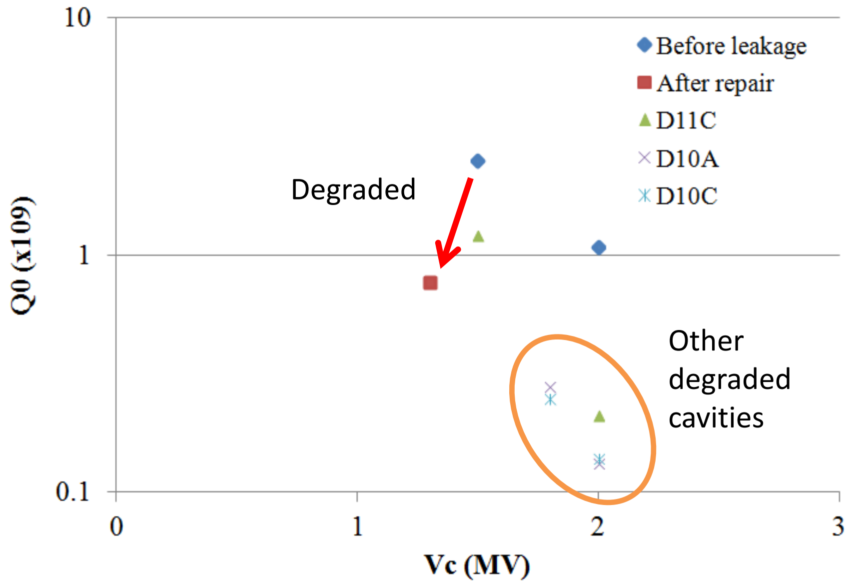


Performance recovery of degraded cavities

- Vacuum leakage happened at cooldown in May 2010
  - Suspected leakage at indium-sealed flange
- Opened the cryomodule, retightened volts.
  - Bolts of the flange were loose (60kgfcm)
  - Those bolts were retightened (150kgfcm)
- High power test
  - No vacuum leakage
  - Q degradation with field emission
    - Voltage reached 1.3 MV with degraded Qo value
    - Limited by the radiation safety rule at test stand
    - Contaminated with micro-particle
- Other degraded cavities
  - D10A, D10C, and D11C at high fields
  - Still acceptable for SuperKEKB operation
  - Performance recovery is desirable
- High pressure rinsing
  - HPR is effective to clean cavity surface
  - HPR in a cryomodule can save time and costs
  - We are developing horizontal HPR (HHPR)

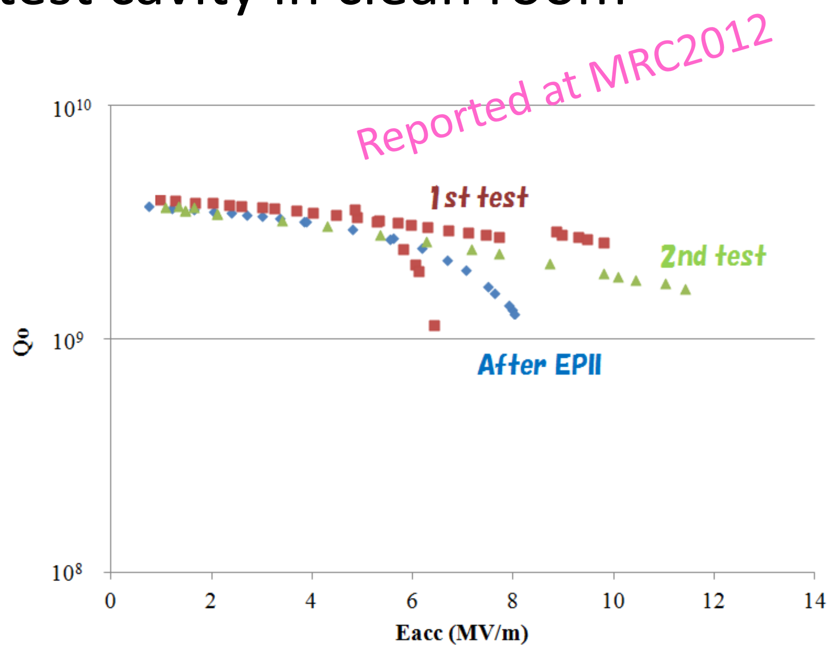
Leakage at indium sealed flange





Horizontal HPR of the test cavity in clean room

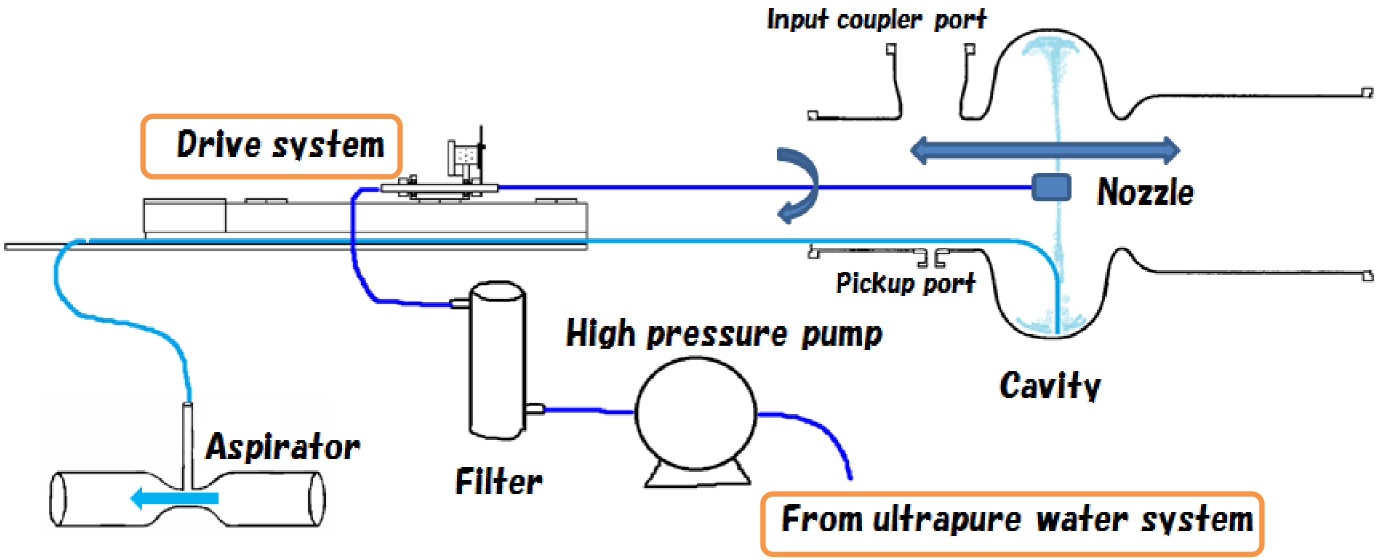
- Horizontal HPR test in clean room
- EPII (10μm)
- Baked at 120 ℃
- Cold test after EPII
- 1st HHPR
  - Rinsed cavity cell, iris and BP
  - Evacuated in vertical position
  - Residual water dropped on BP flange
- Cold test after 1st HHPR
  - Without baking
- 2nd HHPR
  - Evacuated in horizontal position
  - Residual water in cavity cell
- Cold test after 2nd HHPR
  - Without baking
  - Observed no degradation

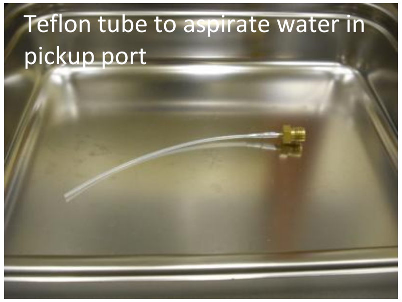


We confirmed that HHPR is applicable to our cavity

Improvement of HHPR for application to cryomodule

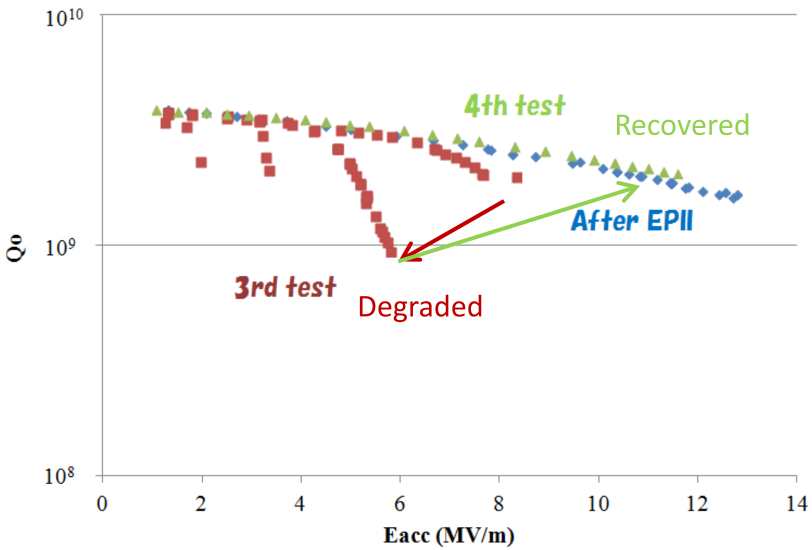
- Developed automated nozzle driving system
- Wasted water is aspirated through stainless steel pipe at equator
- Installed new ultrapure water system at assembly area
- Parameters of HHPR
  - Ultrapure water jet (7MPa) from a stainless steel nozzle
  - Nozzle: 6 holes of 0.54 mm diameter
  - Driving speed: 1mm/sec
  - Rotation speed: 60 deg./10 sec
  - Total time: 15 min
  - Rinsing area: +200/-250mm (cell and iris areas covered)
- After HHPR
  - Aspirate residual water in pickup port

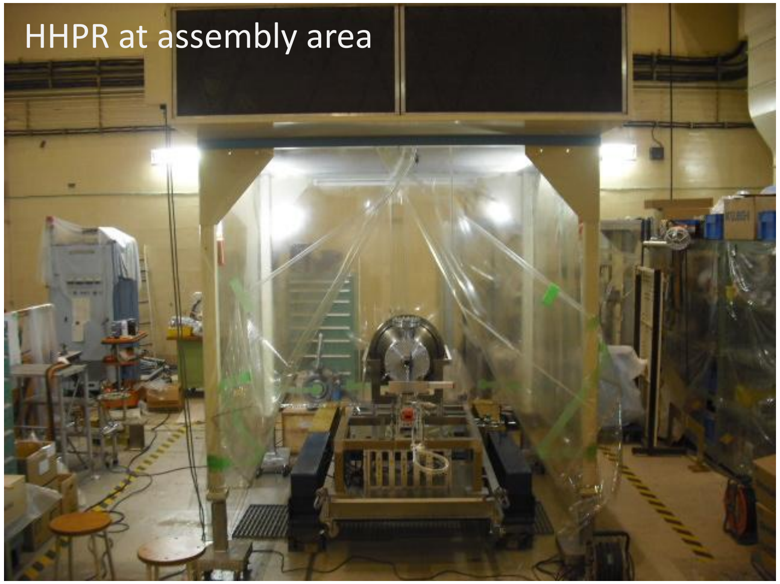




Horizontal HPR in clean booth

- EPII (10µm) and baked at 120℃
- Cold test
  - Fields reached to 13MV/m
- HHPR(3rd HHPR)
  - HHPR in clean booth at assembly area
  - Used new HHPR system
  - Rinsed cell and iris areas for 10 min.
  - Evacuated with residual water
- Cold test after 3rd HHPR w/o baking
  - Fields reached to 8 MV/m after RF processing
  - Fields degraded to 6 MV/m with FE
- Inspected in clean room,
  - Found a small pit <1 mm near LBP iris
- HHPR(4th HHPR)
  - Rinsed cell and iris area for 15 min.
    - Wider SBP iris area
- Cold test after 4th HHPR w/o baking
  - Fields successfully recovered to 12 MV/m
  - No field emission observed



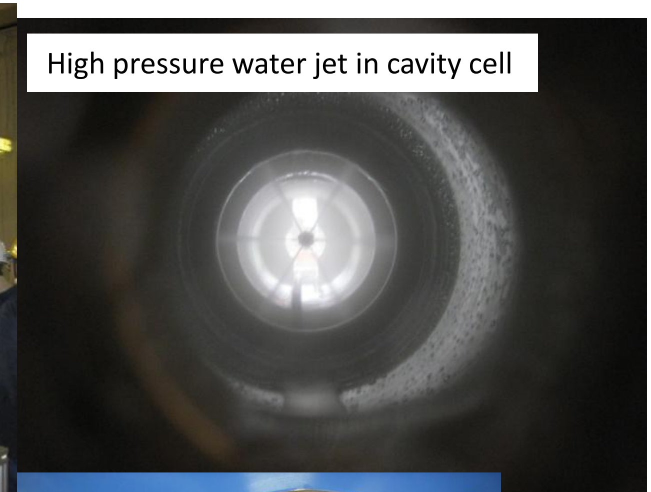


Effectiveness of HHPR was demonstrated.

HHPR application to our spare cavity module

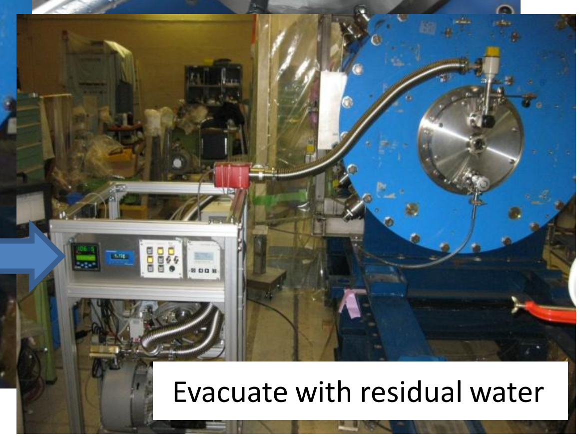

Moved the cavity to assembly area


Dismounted end parts and HPC


High pressure water jet in cavity cell

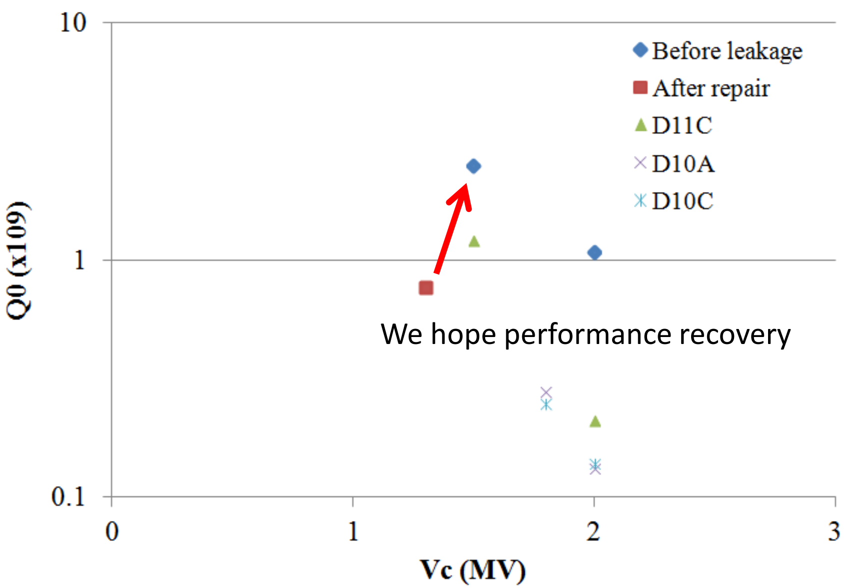

Set HHPR apparatus in clean booth

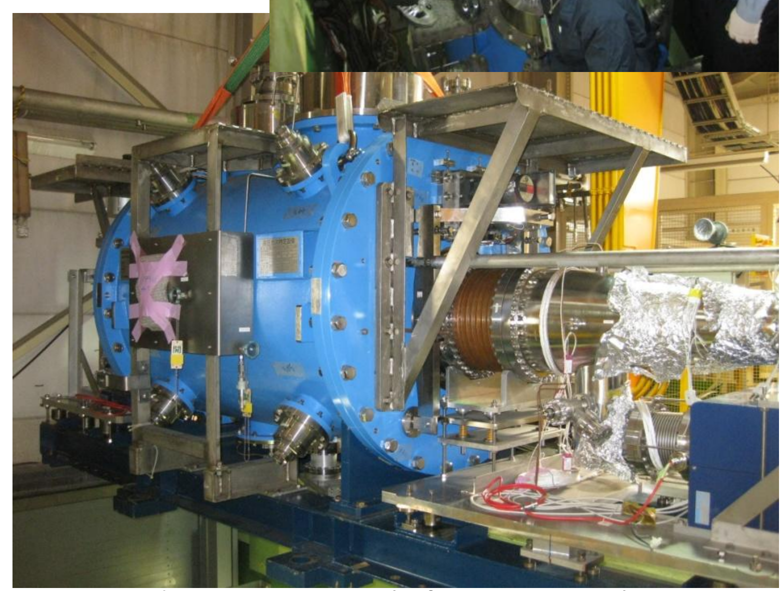

Water jet nozzle and aspirator


Evacuate with residual water

Summary of performance recovery

- Horizontal HPR was established
  - Degraded test cavity recovered its performance after HHPR
  - Rinsed cell and iris areas
  - Evacuated with residual water
  - Cold tested without baking
- We applied HHPR to our spare cavity module
  - High power test will be done this month





HHPRed spare cavity just before setting in the pit

Our plans for the next two years

- Measures for large HOM power
  - Studied additional SiC dampers
  - Fabrication and HPT of SiC dampers
  - Assembly of ϕ200mm beam pipe module (continued)
    - For lower beam-induced HOM power structure
- Performance recovery
  - High power test of HHPRed spare cavity will be done soon
  - Exchange one of installed cavities with the spare cavity
  - Attach ϕ200mm beam pipe module to exchanged cavity
  - If the performance will not recover…
    - Dismount cavity cell from the cryomodule
    - HPR or EP, CT and HPT

	FY2012	FY2013	FY2014
Measures for large HOM power	~~High power test for 4mm thick dampers with double cooling structure~~ ✓Study for additional SiC dampers Assembly of 200ϕ BP modules →	Fabrication and HPT of SiC dampers 200ϕ BP (continued)	Install SiC dampers in the SuperKEKB ring
Performance recovery	✓HHPR in cryomodule ☐High power test	Exchange one of cavities with the spare cavity Attach 200Φ BP for low LF High power test	Install 200ϕ BP cavity Cool-down test of all cavities

If not recover
Dismount cavity cell
HPR or EP