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MAC2014

Superconducting Cavity

HOM power

Performance recovery

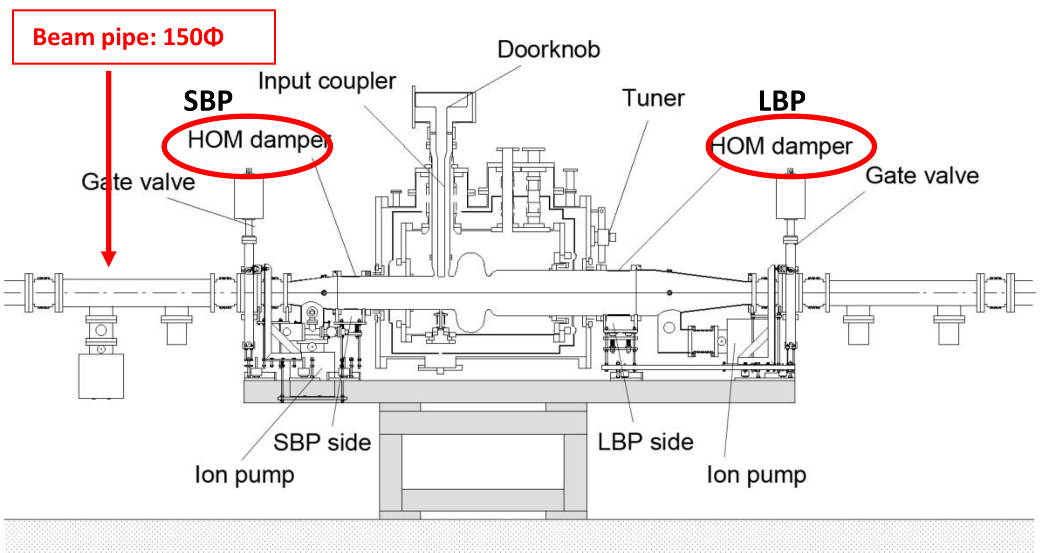
Expected beam-induced HOM power in SuperKEKB/HER

- Machine parameter of SuperKEKB/HER
  - Beam Current : 2.6A/2500 bunches
  - Bunch length : 5mm
- Expected beam-induced HOM power
  - Cavity loss factor : 1.37V/pC @σ=5mm
  - HOM power per cavity : 37 kW
  - at KEKB: 16 kW
- Ferrite HOM damper
  - SBP damper:ϕ220x4x120
  - LBP damper:ϕ300x4x150

HOM power

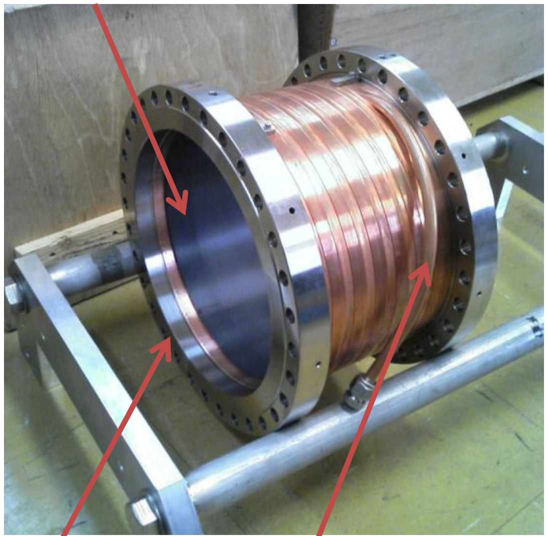
Beam current (A)	HOM power (kW)
2	22
2.6	37

Need to reduce HOM power load



HOM damper

HIPped ferrite（Thickness : 4mm）

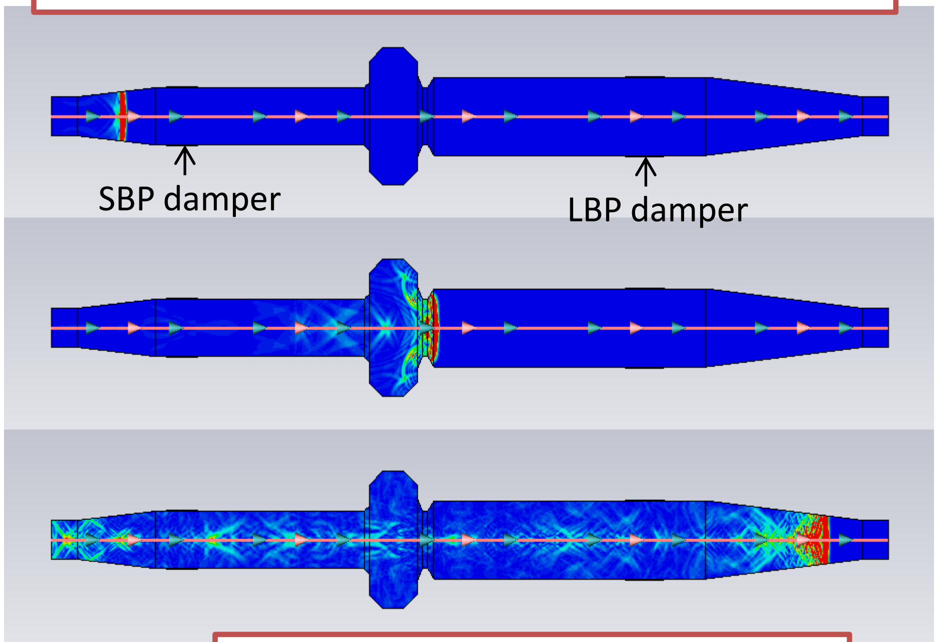


Cupper pipe (3/8”) for water cooling

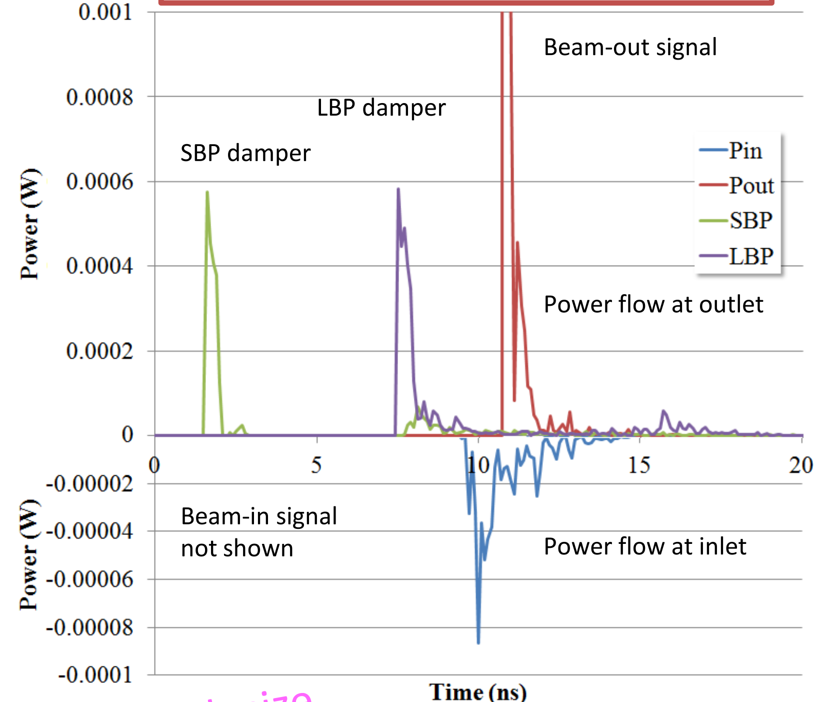
Stainless steel flange

Power flow simulation for superconducting cavity module

Monitor wake fields using CST Particle Studio, wakefield solver



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)
1.367	0.0534	0.5028	0.2755	0.3601	0.1205	1.312
σ=5 mm, q=1pC Energy deposit of 1pJ corresponds a loss factor of 1V/pC						

Fine mesh size

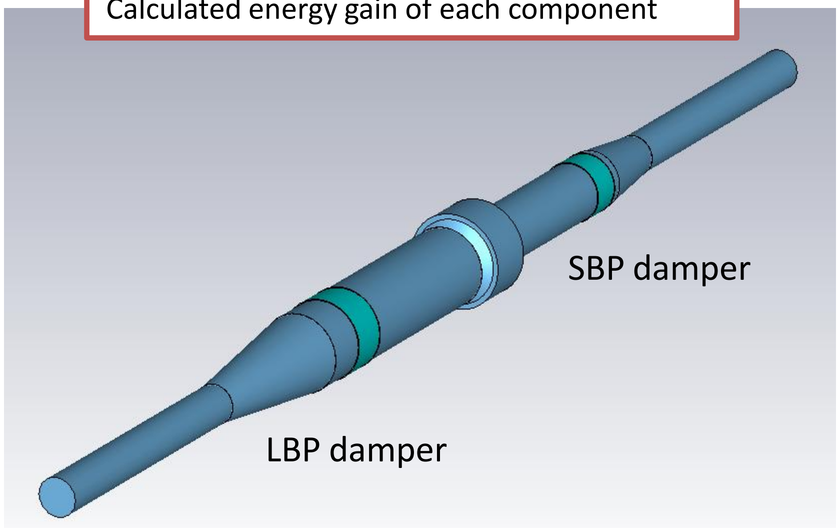
Equivalent LF and HOM loads at 2.6A

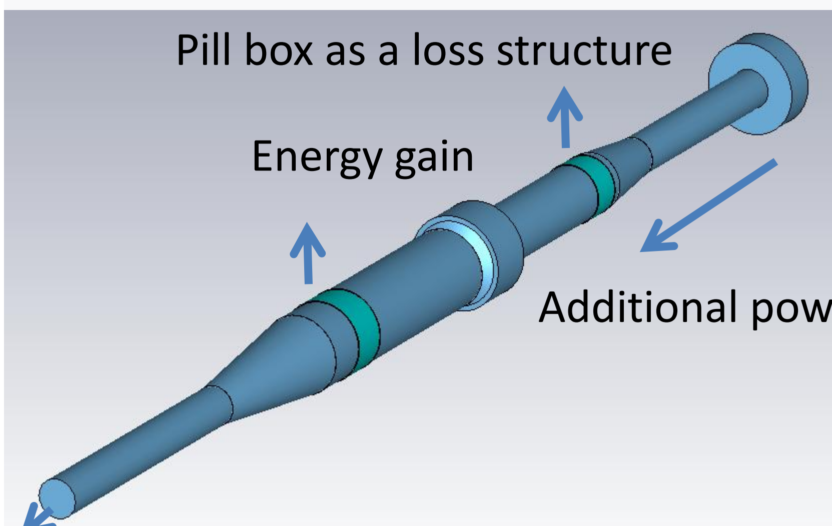
	Eq. LF (V/pC)	Load@2.6A (kW)
Inlet	0.061	1.6
Outlet	0.576	15.6
SBP	0.315	8..5
LBP	0.412	11.1
Total	1.367	36.9

Total energy is consistent with energy deposit calculated from the loss factor.
Results showed SBP and LBP damper loads were not large.
Large amount of HOM power is emitted through the beam pipe outlet.
The energy becomes additional load to cavities in the downstream.

Effects of HOM power emission to the downstream cavity

Wake field simulation using CST Particle Studio
A loss structure introduced in front of cavity
Calculated energy gain of each component





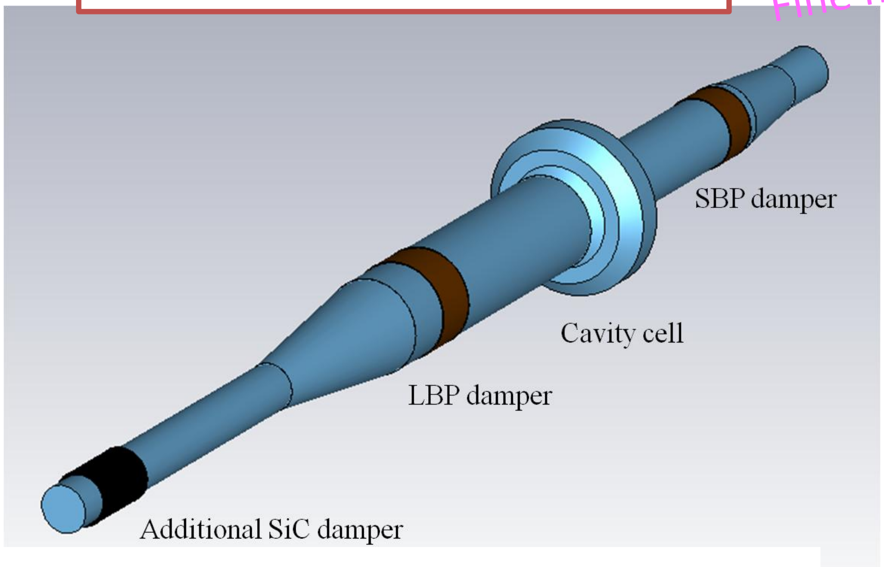
Equivalent LF gain

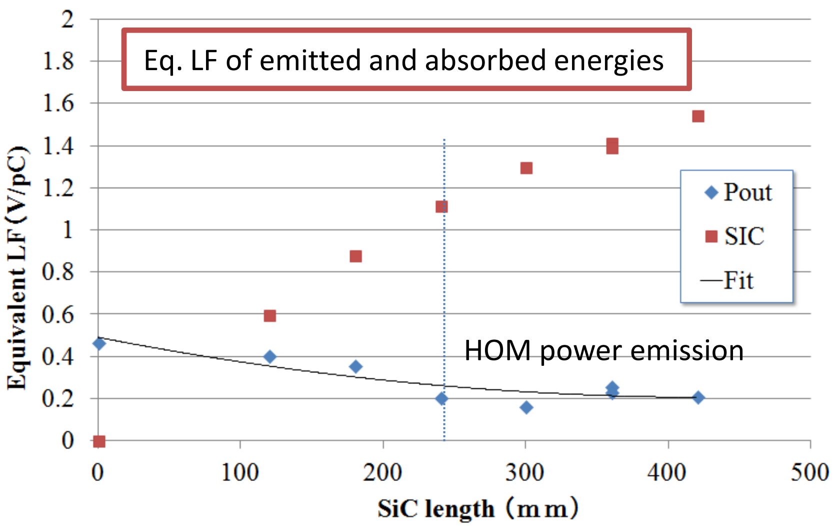
SiC:240mm	Eq LF (V/pC)	Fraction (%)
Outlet	0.1304	59
SBP	0.0885	40
LBP	0.0035	1
Total	0.227	100

40 % of the HOM power is absorbed in the SBP damper while 60 % goes through the cavity. The HOM power emission increases the power load of the SBP damper. The power emission has to be reduced.

Effects of additional SiC damper

Wake field simulation using CST Particle Studio
Additional SiC damper set on the beam pipe





Fine mesh size

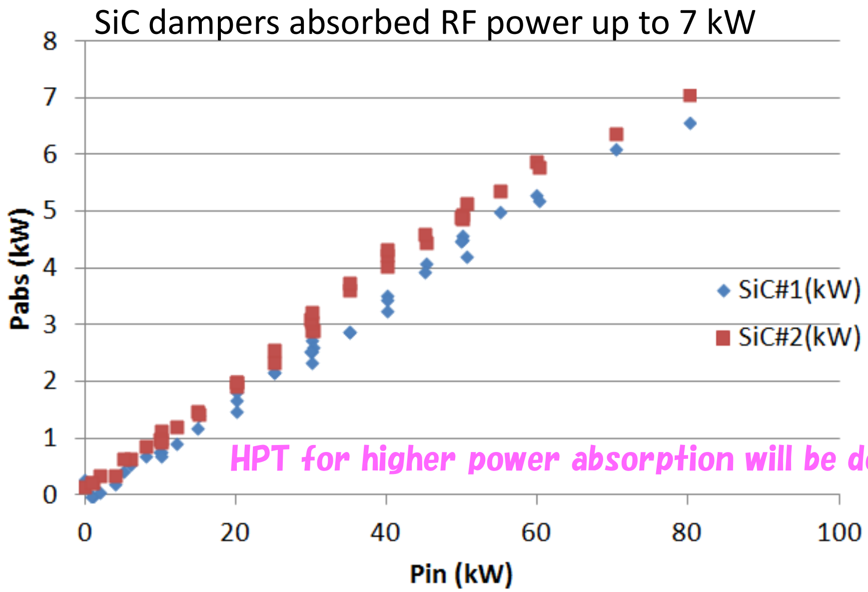
Equivalent LF and HOM loads at 2.6A

SiC:240mm	Eq LF (V/pC)	Load@2.6A (kW)	Overall (kW)
Inlet	0.064	1.7	
Outlet	0.204	5.5	
SBP	0.333	9.0	13.7
LBP	0.436	11.8	12.1
SiC(240mm)	0.905	24.5	26.8
Total	1.942	52.5	

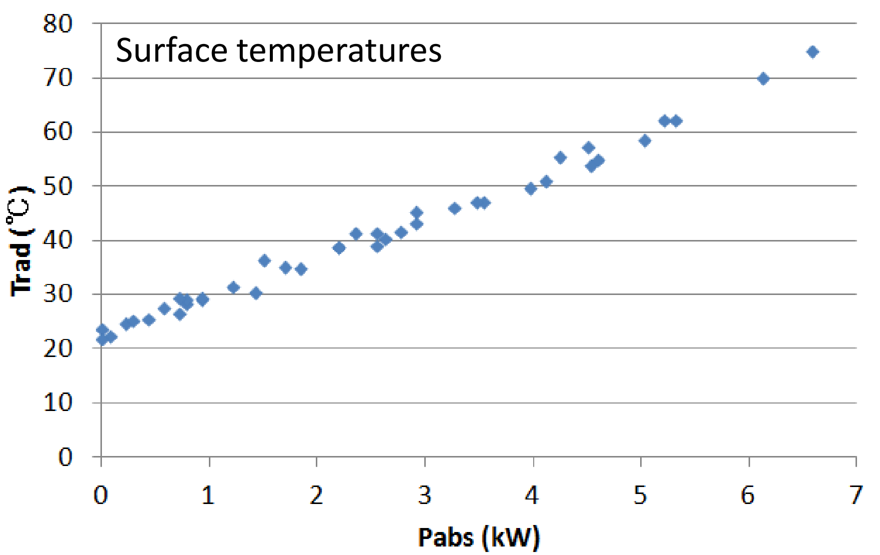
Additional SiC damper can absorbs more HOM power emission as the length becomes longer. In practice, HOM load of additional SiC damper has to be less than 30kW (1.1 V/pC). 240 mm is a good choice.

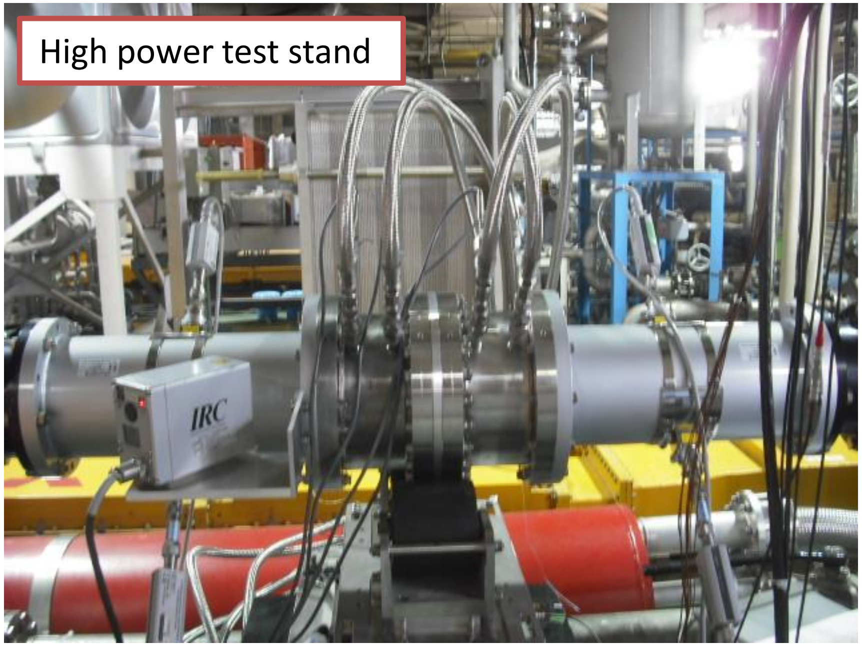
Power emission from the upstream and downstream
Preliminary simulation results showed that 80% of the power emission from the upstream was absorbed in the SBP damper (SiC damper:240 mm), while 5 % goes thorough the cavity. The backward power emission from the downstream was absorbed in the SiC damper. Overall damper loads are given in the table.

Prototype SiC dampers and those high power tests



HPT for higher power absorption will be done soon



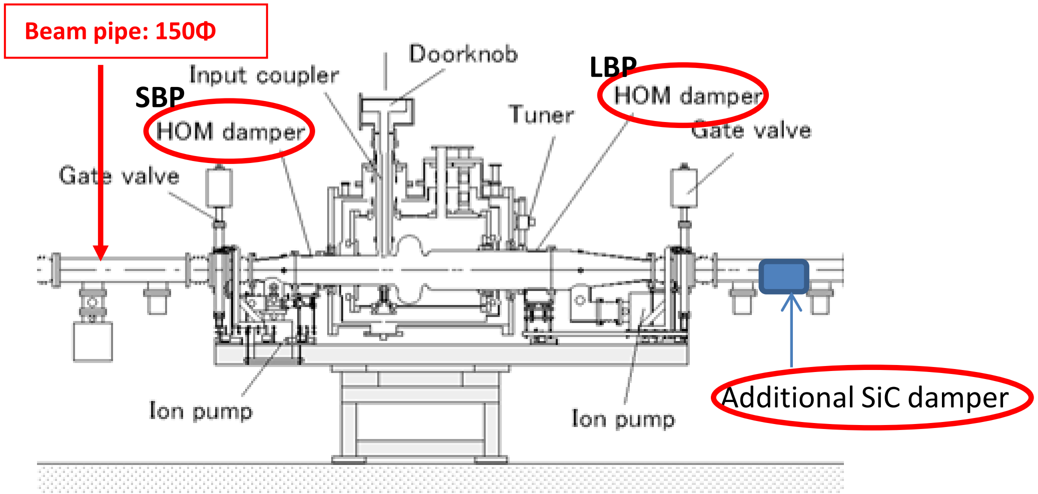


Summary of measures for large HOM power

- Developed a new HOM power calculation method
  - Damper loads can be calculated
- Damper loads
  - SBP and LBP HOM loads are not large
  - Large amount of HOM power is emitted through BP
  - Become SBP damper load
- Additional SiC damper
  - Additional SiC damper can absorb power emission
  - 240 mm SiC damper is suitable for our cavity
  - SiC can be set without vacuum breaking of the cavity
- R&D for SiC dampers is ongoing
  - Fabrication of prototype dampers
  - HPT up to 7 kW

Summary of HOM power loads

	Load@2.6A (kW)
SBP	13.7
LBP	12.1
SiC(240mm)	26.8
Total	52.6



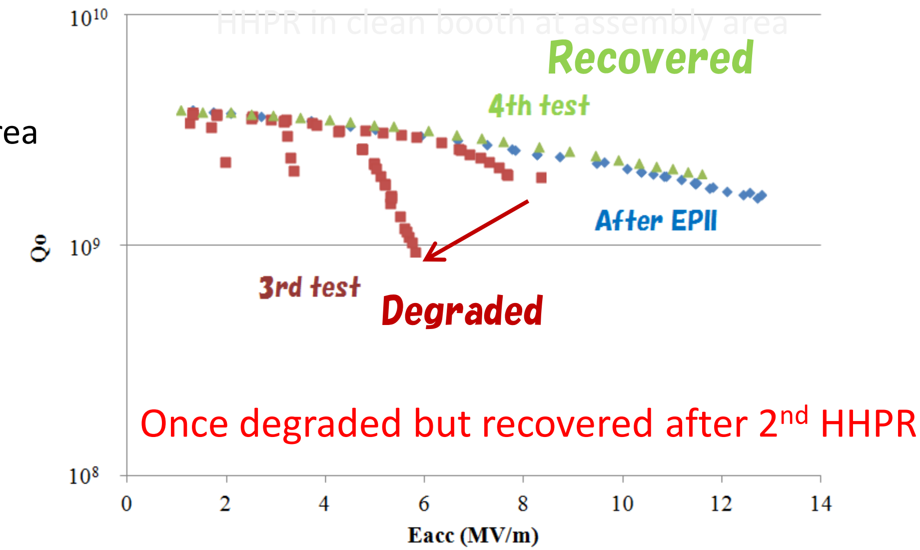
Performance recovery
Motivation to develop HHPR

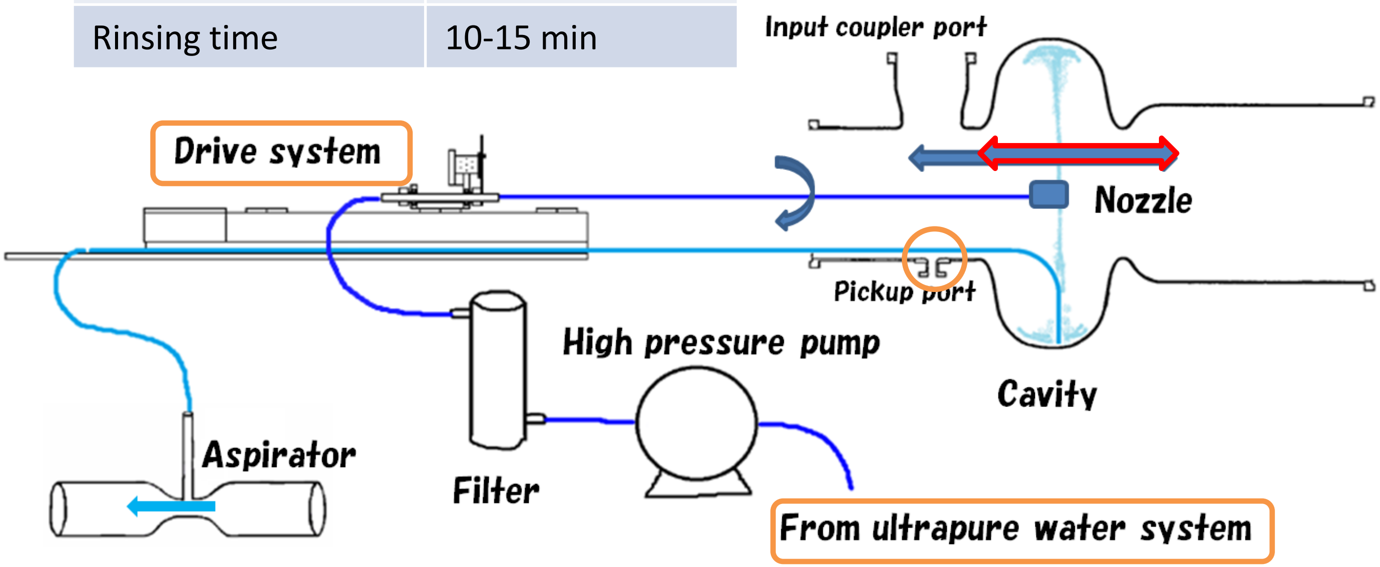
- RF Performance of SRF cavities degraded in the long term operation at KEKB
  - Qo of several cavities significantly degraded at ~2MV with FE
  - Due to particle contamination during
    - repair of vacuum leakage
    - Exchange of coupler gaskets
  - Present degradations are still acceptable for SuperKEKB (1.5MV)
  - Further degradations make the operation difficult
  - Performance recovery is desirable
- HPR is effective to clean the particle contamination
  - If we can apply HPR to the cavity in the cryomodule,
    - We can save time and costs; no need for cavity disassembly
    - We can avoid the risk of leakage; no need for re-sealing at the indium joint
- HHPR was developed for performance recovery
  - Horizontal insertion of the HP water nozzle
  - Water evacuation by the aspirator pump

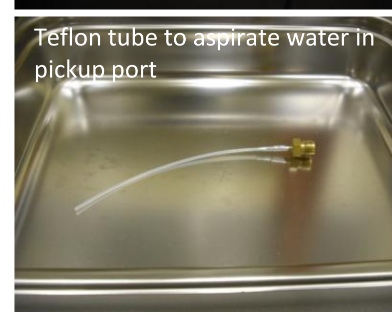
HHPR system

- Developed automatic nozzle driving system
- Water evacuation through the same BP
- Installed new ultrapure water system at assembly area
- Rinsed cell and iris area only
- After HHPR
  - Evacuate residual water in pickup port

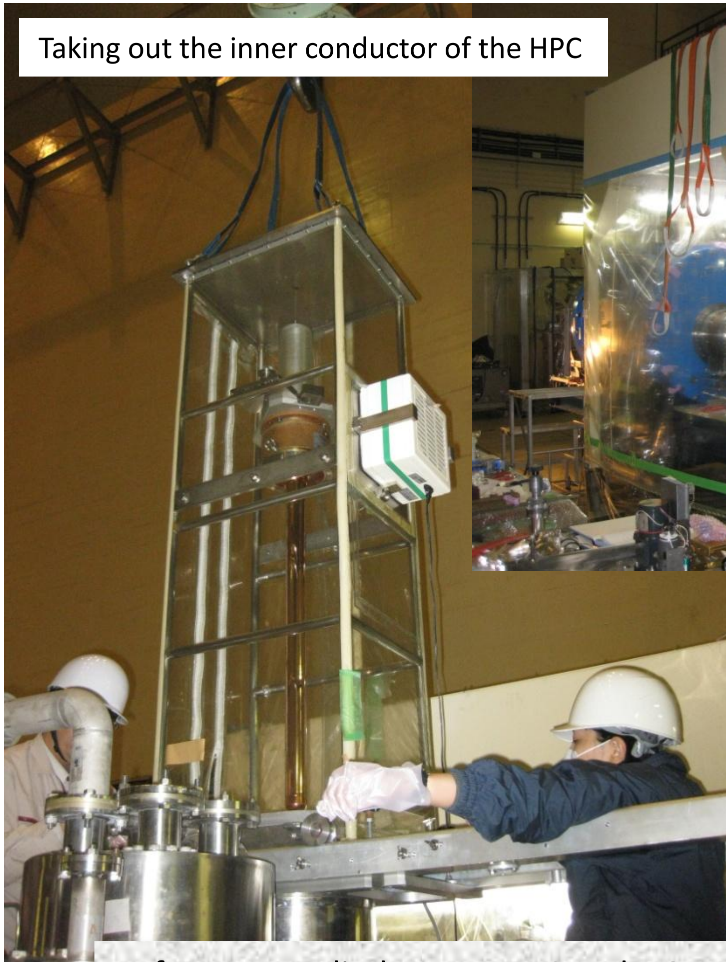
HHPR parameters (automatic operation)	
Water Pressure	7 MPa
Nozzle	Φ0.54mm x 6
Driving speed	1 mm/sec
Rotation speed	6^0/sec
Rinsing time	10-15 min







HHPR application to the spare module



Taking out the inner conductor of the HPC

End beam pipes and HOM dampers were dismounted

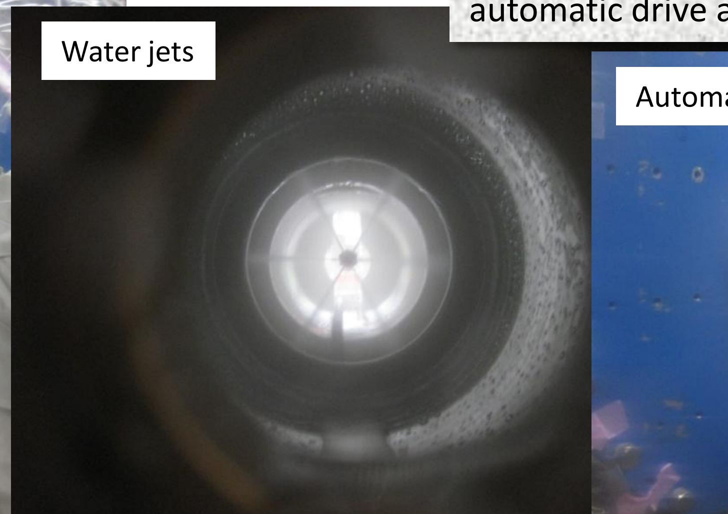
Before we applied HHPR, HPC and HOM dampers were dismounted in a clean booth. Then the HHPR driver was set to the cavity.

Setting the HHPR apparatus

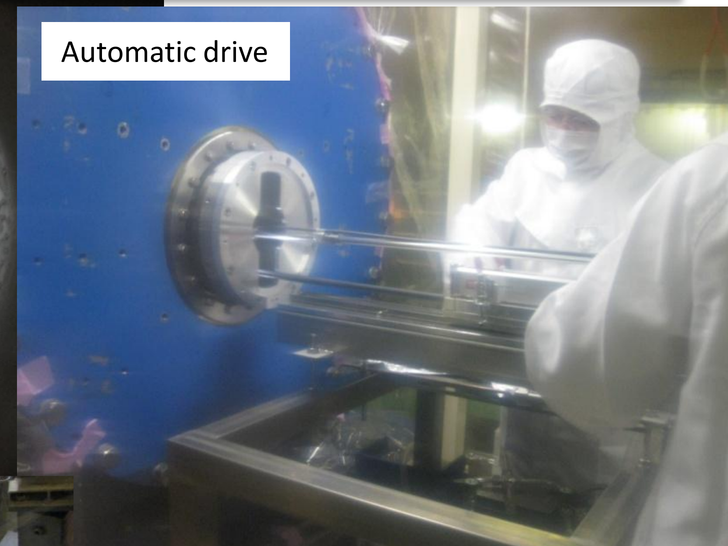
HHPR application to the spare module

The degraded cavity was HHPR'ed with a new automatic drive and water evacuation system

Opening the dummy flange



Water jets



Automatic drive

High pressure water pump

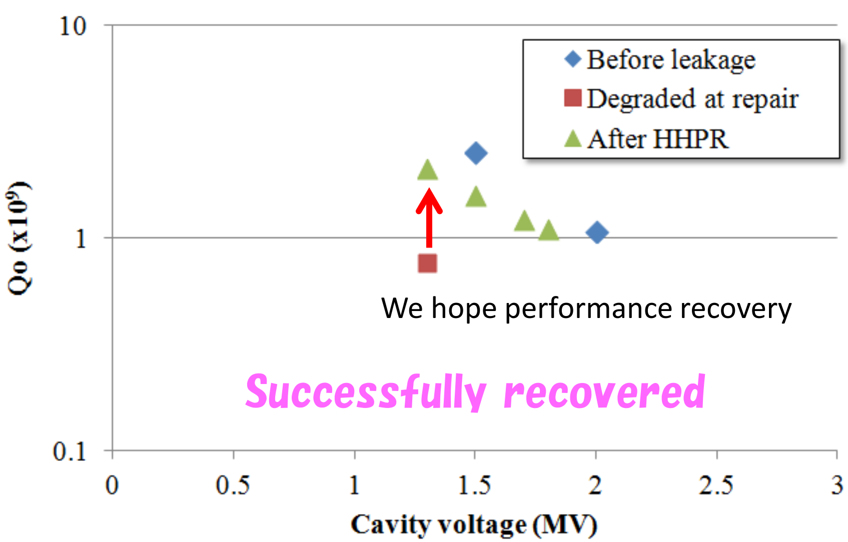
Aspirator pumps

Evacuation after HHPR

Summary of performance recovery

Reported at the last MAC

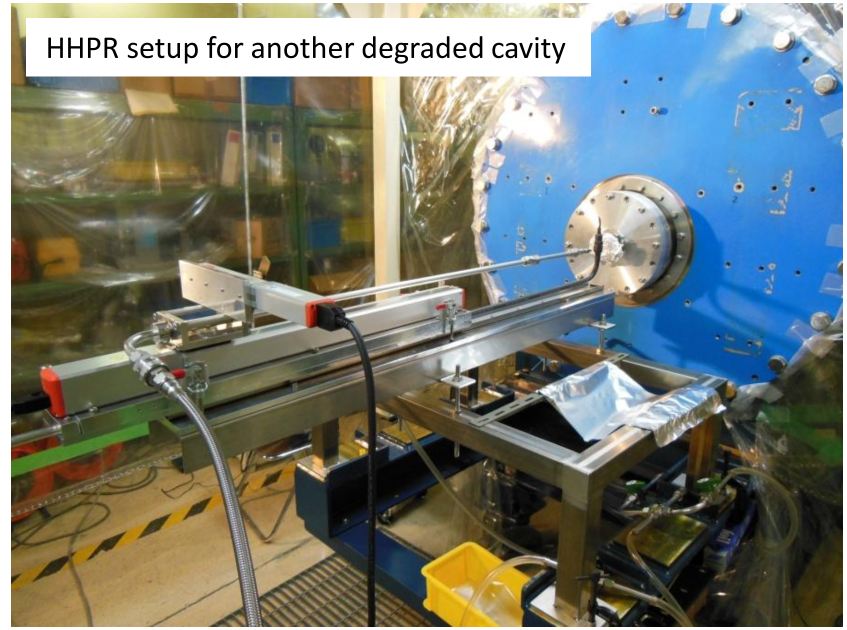
- Horizontal HPR was established
  - Degraded test cavity recovered its performance after HHPR
  - Rinsed cell and iris areas
  - Evacuated with residual water
  - Cold tested without baking
- We applied HHPR to our spare cavity module
  - High power test will be done this month



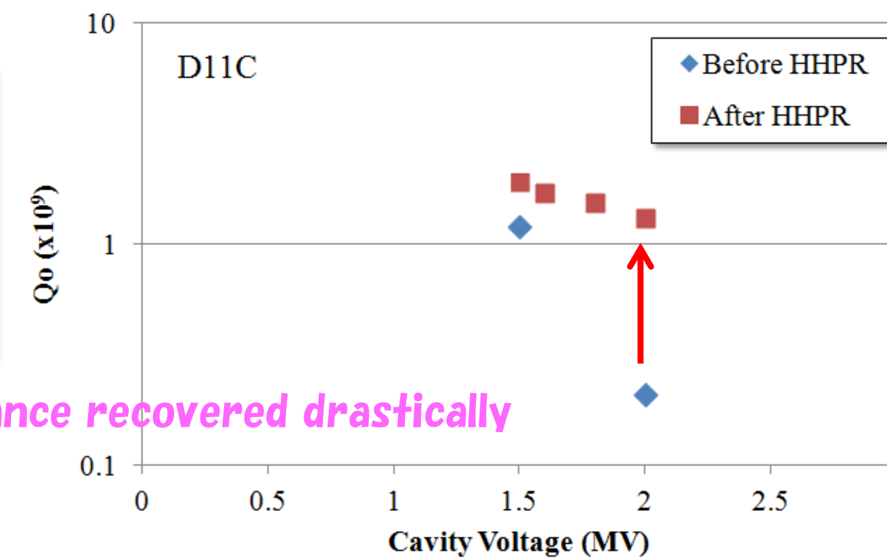
HHPRed spare cavity just before setting in the pit

HHPR to another degraded cavity


Recovered cavity installed into the HER ring


HHPR setup for another degraded cavity

After the successful performance recovery, recovered cavity was installed in the HER ring. On the other hand, another degraded cavity was took out of the ring, then HHPR'ed in the assembly area. This cavity was installed in the test stand. The high power tests of this cavity have been conducted.



Performance recovered drastically

Summary of performance recovery

- We have developed HHPR
  - Horizontal insertion of the HP water nozzle
  - Water evacuation by the aspirator pump
- We applied HHPR to the degraded spare cavity module
  - RF performance recovered successfully
  - The recovery is sufficient for the operation at SuperKEKB
  - However, the recovery is not perfect
    - Further optimization (rinsing time/area)?
    - Re-contamination?
- Recovered cavity: Installed in the HER ring
- Another degraded cavity: HHP rinsed
  - Performance recovered drastically

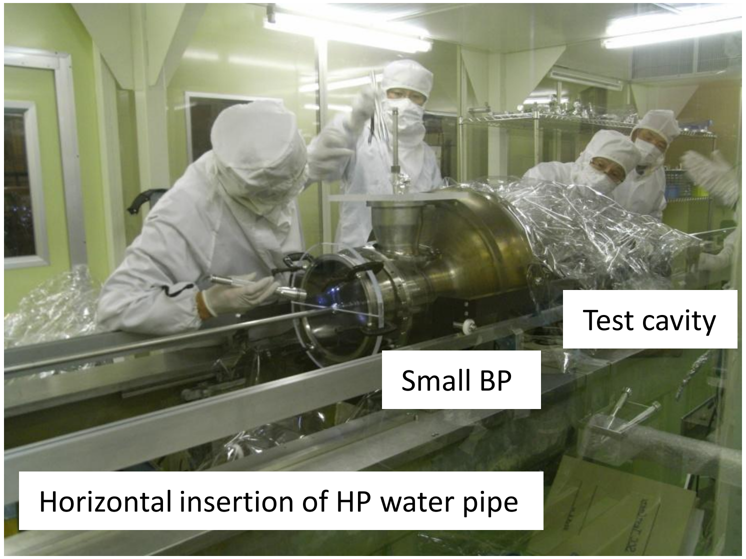
Our plans for the next year

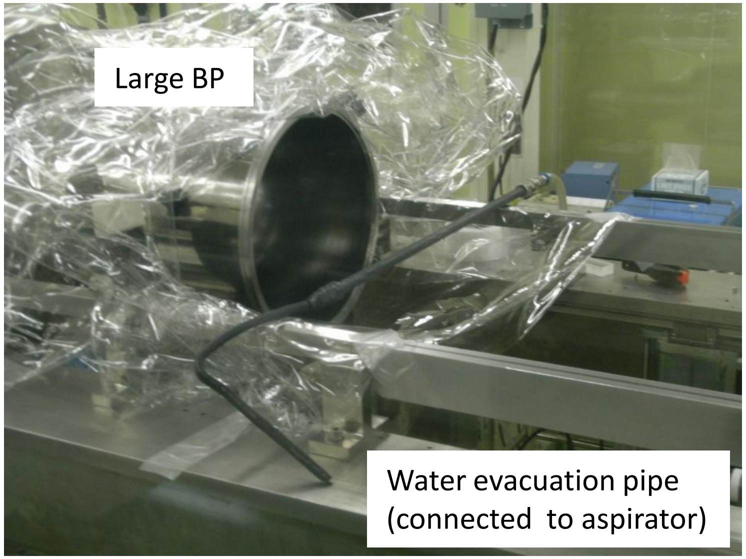
- Measures for HOM power
  - ✓ Fabrication and high power tests of prototype SiC dampers
  - – Continue R&D for additional SiC dampers
  - – Install SiC dampers into HER, if possible
- Performance recovery
  - ✓ High power test of HHPRed spare cavity
  - ✓ Exchange one of installed cavities with the spare cavity
  - ~~– Attach ϕ200mm beam pipe module to exchanged cavity~~
  - ~~– If the performance will not recover…~~
  - ✓ HHPR to another cavity and its high power test
- Cooldown tests of all cavities and then cavity operation for SuperKEKB

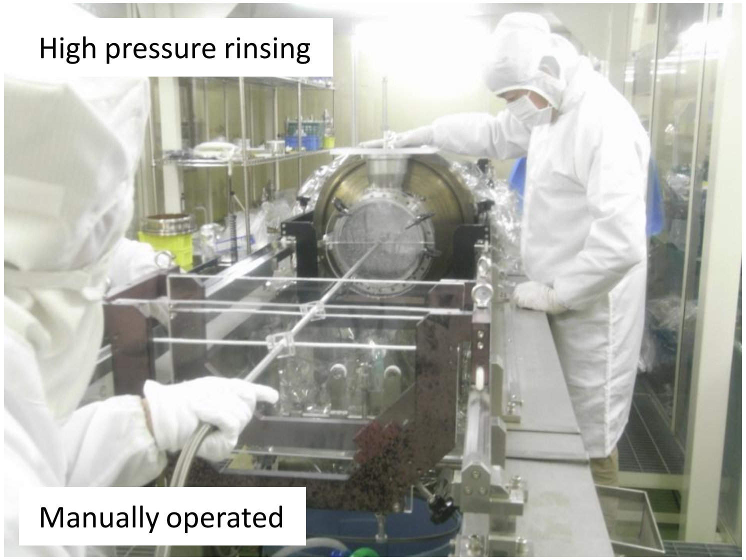
	FY2012	FY2013	FY2014
Measures for large HOM power	~~High power test for 4mm thick dampers with double cooling structure~~ ✔Study for additional SiC dampers ~~Assembly of 200ϕ BP modules~~	✔Fabrication and HPT of SiC dampers ~~200ϕ BP (continued)~~	☐Fablication of SiC dampers ☐Install SiC dampers into HER Cooldown tests of all cavities Cavity operation for SuperKEKB
Performance recovery	✔HHPR in cryomodule ✔High power test	✔Exchange one of cavities with the spare cavity ✔HHPR to another cavity ✔High power test ~~Attach 200Φ BP for low LF~~ ~~High power test~~	~~Install 200ϕ BP cavity~~

Horizontal HPR R&D using prototype test cavity

Horizontal HPR was applied to our test cavity in the clean room







HHPR parameters (manual operation)	
Water Pressure	6 MPa
Nozzle	Stainless steal Φ0.54mm x 6
Driving speed	0.33 mm/sec (cell) 0.66 mm/sec (BP)
Rotation speed	12^0/sec
Rinsing time	20 min

We tried HHPR two times: No degradation occurred