Operating experience of the J-PARC RFQs

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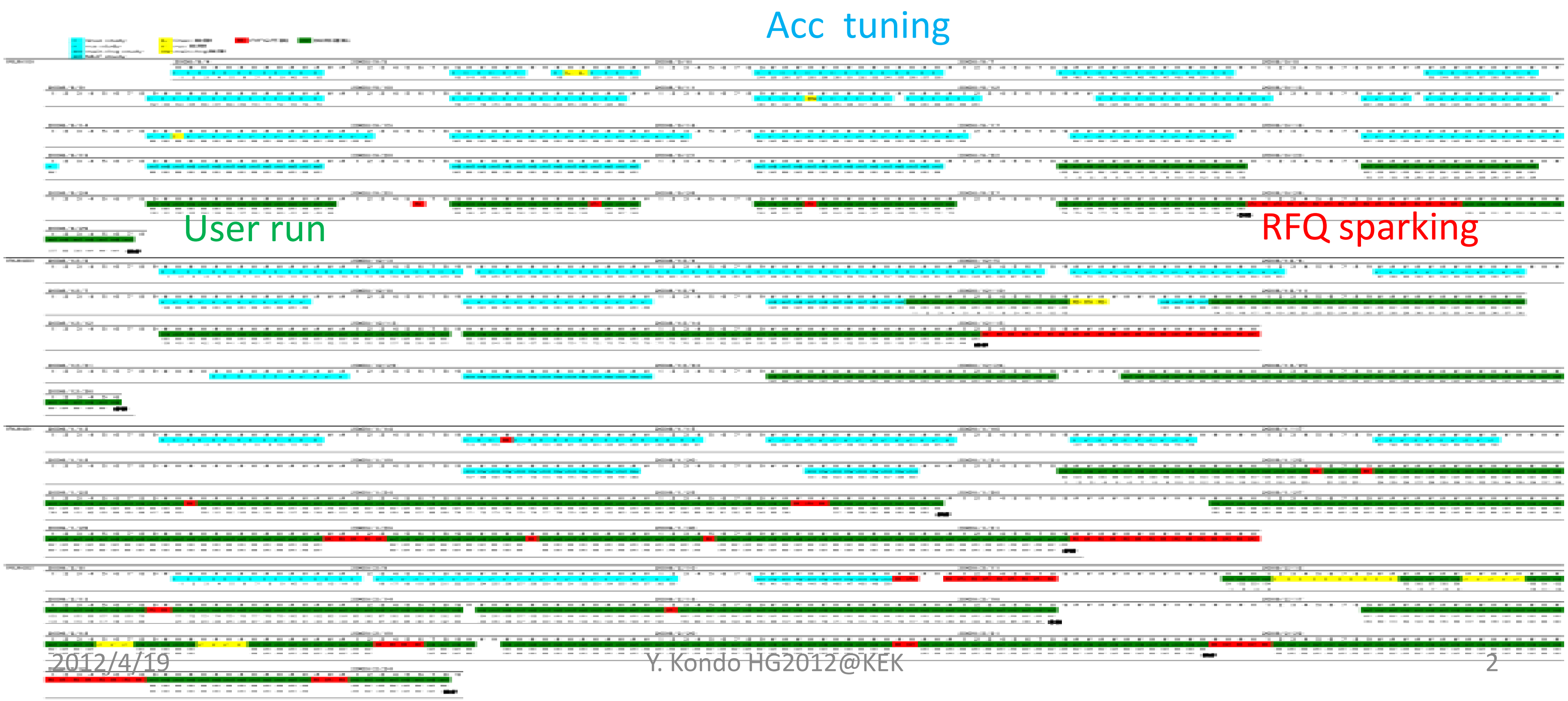
contents

- Breakdown problem of the RFQ since 2008.
- Estimated cause of breakdown
- Improvement in current RFQ and next RFQs

Operation status of 2008

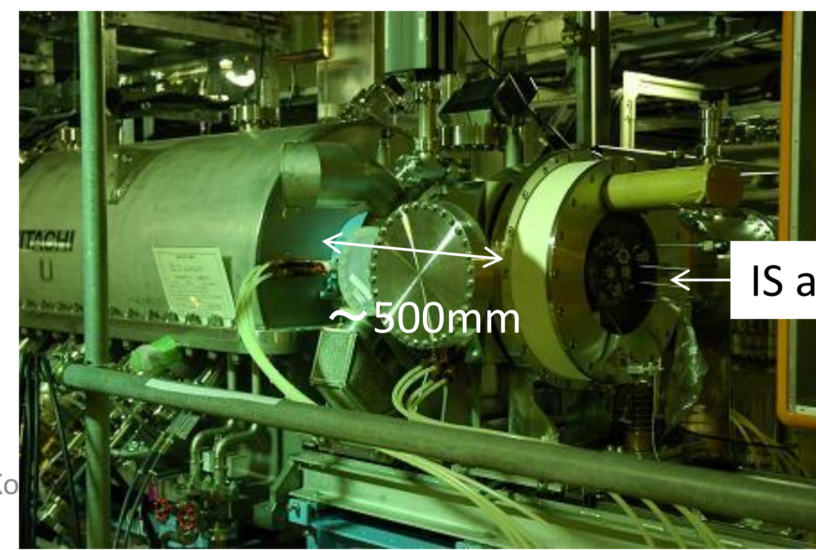
- In 2008, it was revealed that the RFQ cannot withstand long term beam operation. (linac commissioning was started from 2006)
- Critical discharges were started after about 100 hours user operation. (1 box=1 hour, Red: doing RFQ conditioning)



Specifications of the operating RFQ

Beam	H^-
Resonant frequency	324 MHz
Injection energy	50 keV
Extraction energy	3 MeV
Peak beam current	30 mA
Repetition	25 Hz
RF pulse width	600 μs
RF duty factor	3 %
Max. peak surface field	32 MV/m (1.76 Kilpatrick)

- Surface field of the RFQ is at most 32 MV/m, this value is not extremely high, but...
- An ion source (IS) is “attached to” the RFQ.
- Gas flow from IS is extremely high, especially H^- ion source.
- Our RFQ is stable enough just as an RF cavity. (i.e. if there is no beam from IS, the RFQ is stable), however, it is useless as an accelerator.
- There are only two high intensity H^- RFQ, J-PARC’s and SNS’s, under user operation in the world. SNS’s had similar problem.



PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **13**, 070101 (2010)

Stabilized operation of the Spallation Neutron Source radio-frequency quadrupole

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II. RFQ INSTABILITY

When the RFQ enters an unstable region, the typical symptom is that the resonance frequency of the RFQ drops rapidly within a minute by more than 20 kHz and the low level radio-frequency resonance control is lost as shown in Fig. 3, and is sometimes accompanied with structure arcing. We refer to this sudden loss of resonance control as the

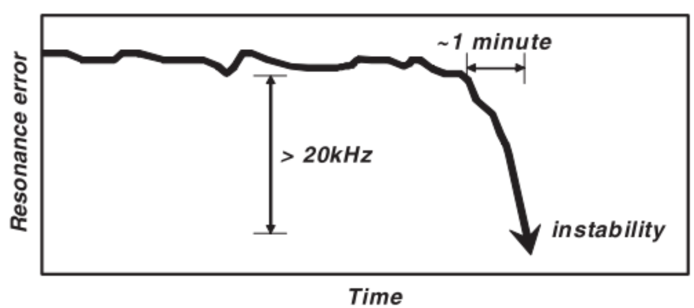
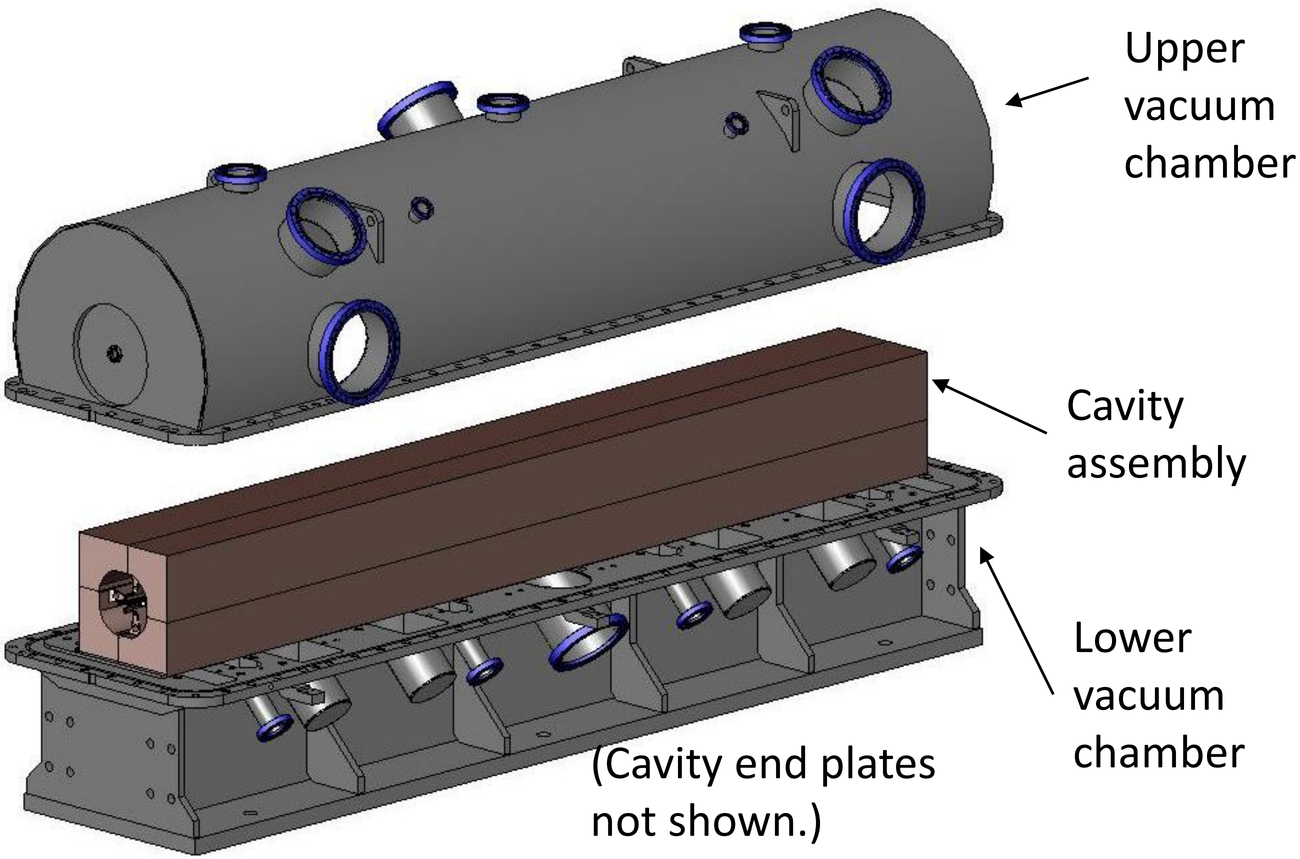


FIG. 3. The typical behavior of the RFQ resonance error when the RFQ shows instability.

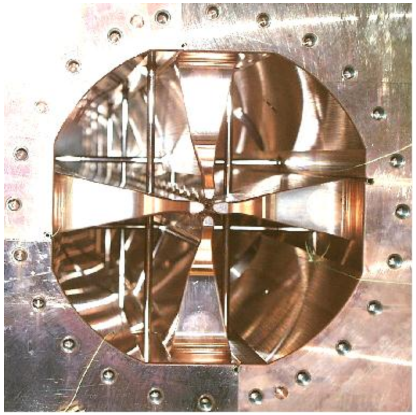
RFQ and rf field. The theory for the instability is as follows; hydrogen from the ion source is continuously absorbed on the surface of the RFQ. At the beam-off state 65 kV negative hydrogen beam is dumped around the upstream part of the RFQ, and at the beam-on state some portion ($< 10\%$) of the negative hydrogen beam will hit the vanes during acceleration by design. Ion beam bombardments are known to be very efficient for gas desorption from metal surfaces [7–9]. The source beam, either at beam-on or beam-off states, enhances hydrogen desorption, which degrades the local vacuum, especially around the vanes even though the vacuum gauge reading at the wall side does not change. Local discharge starts around the vanes where the local vacuum and rf field meet the discharge condition even though it is very mild. This local discharge absorbs the rf power and consequently heats up the vanes, which results in variations of the net rf power at a constant rf field in the closed loop rf control and, consequently, the resonance error changes. Local discharge and vane heating can become even worse if hydrogen desorption increases due to ion beam bombardment and local discharge in the structure. The RFQ can become unstable with a thermal run-away condition causing a sudden dec-[illegible] of the resonance frequency of the RFQ structure.

Structural problems of J-PARC RFQ



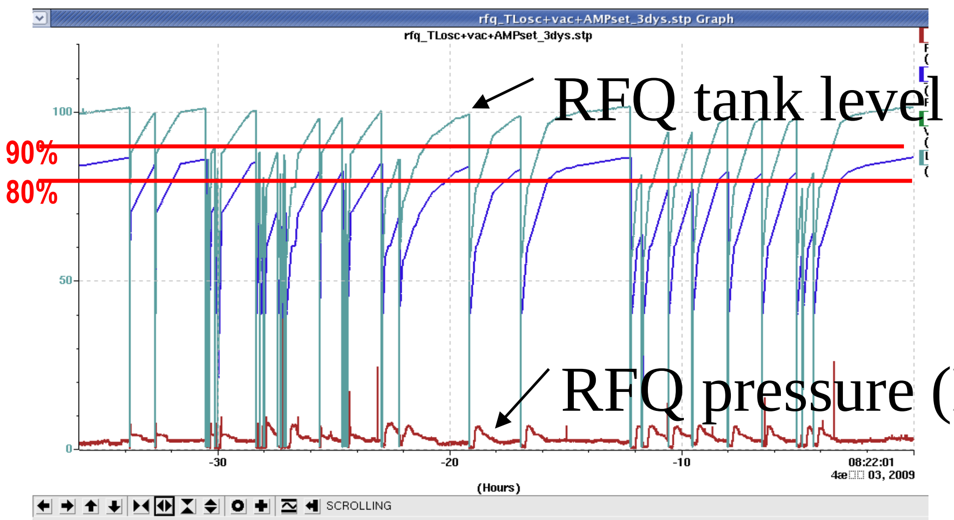
- Volume and especially surface are extremely large.
- Conductance of pumping port is small (pumping speed is slow)

PISL (dipole mode suppresser)

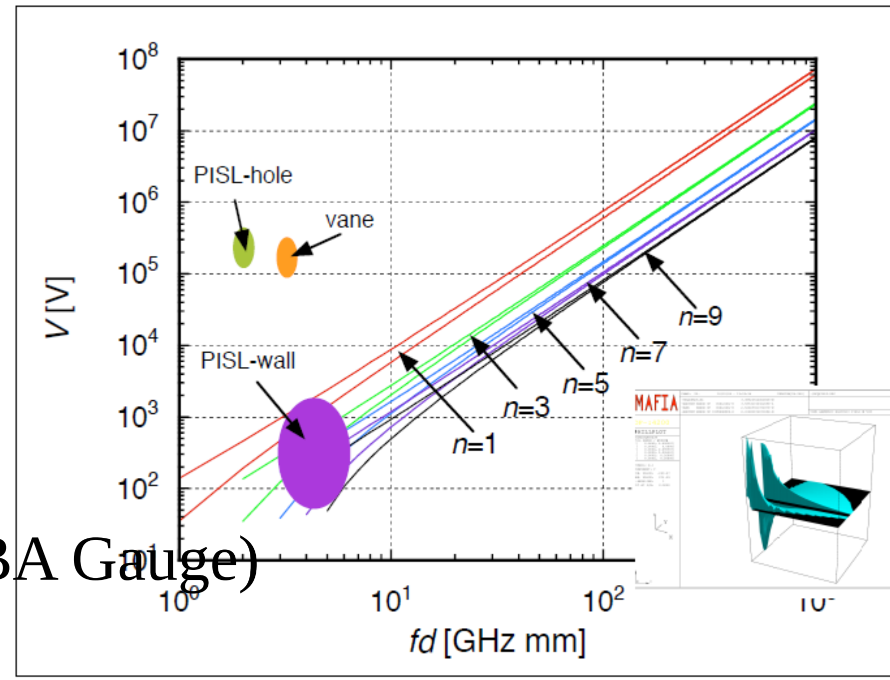


Jungle-gym like structure

- Breakdown: rod-penetration
- Multipacting: rod-cavity wall



There are multipacting region around 80% and 90% tank levels



Rod-cavity wall meets multipacting condition (S. Yamaguchi)

Vacuum system around the RFQ

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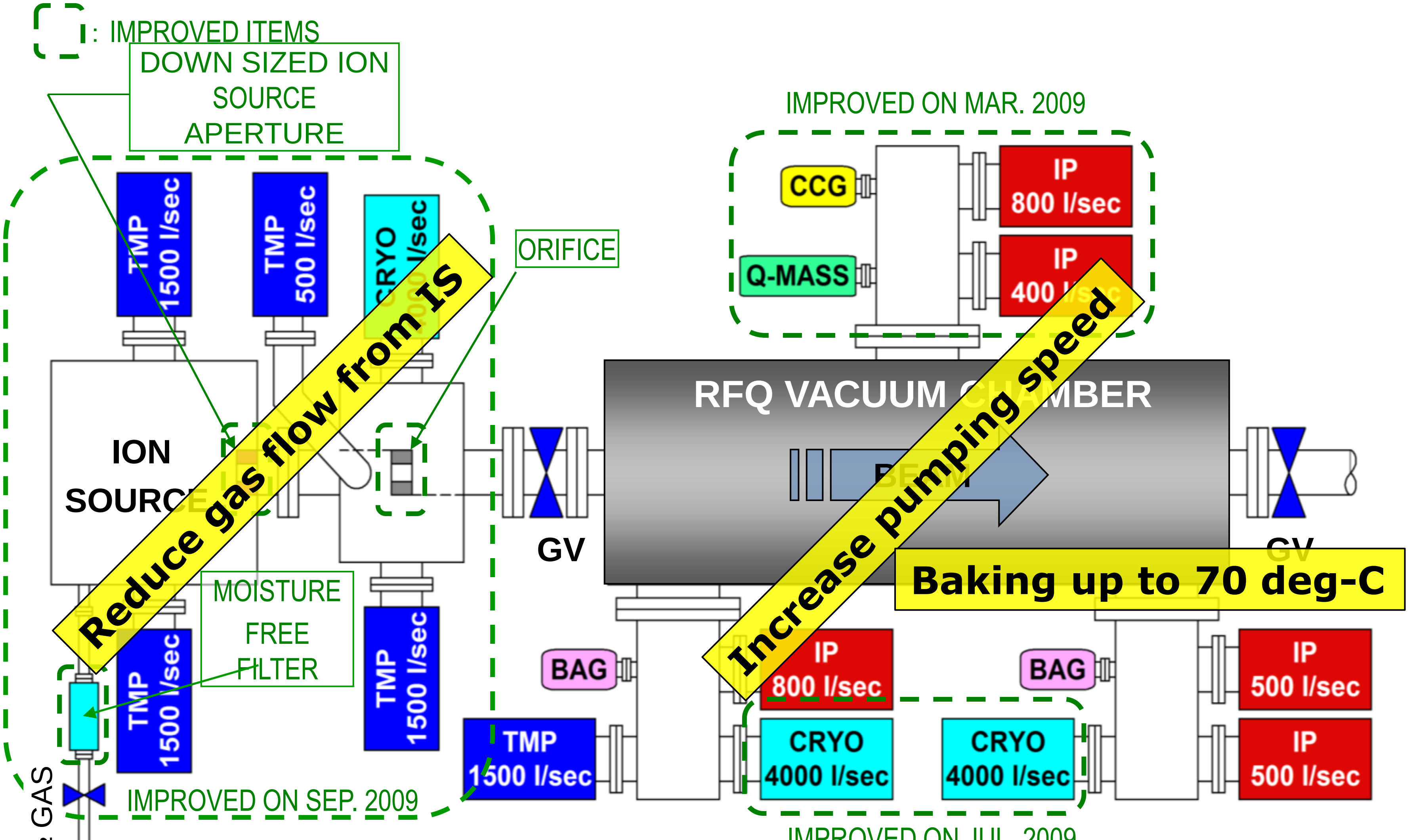


① REDUCE GAS FLOW FROM. UPPER STREAM.

② ADOPT MOISTURE FREE FILTER.

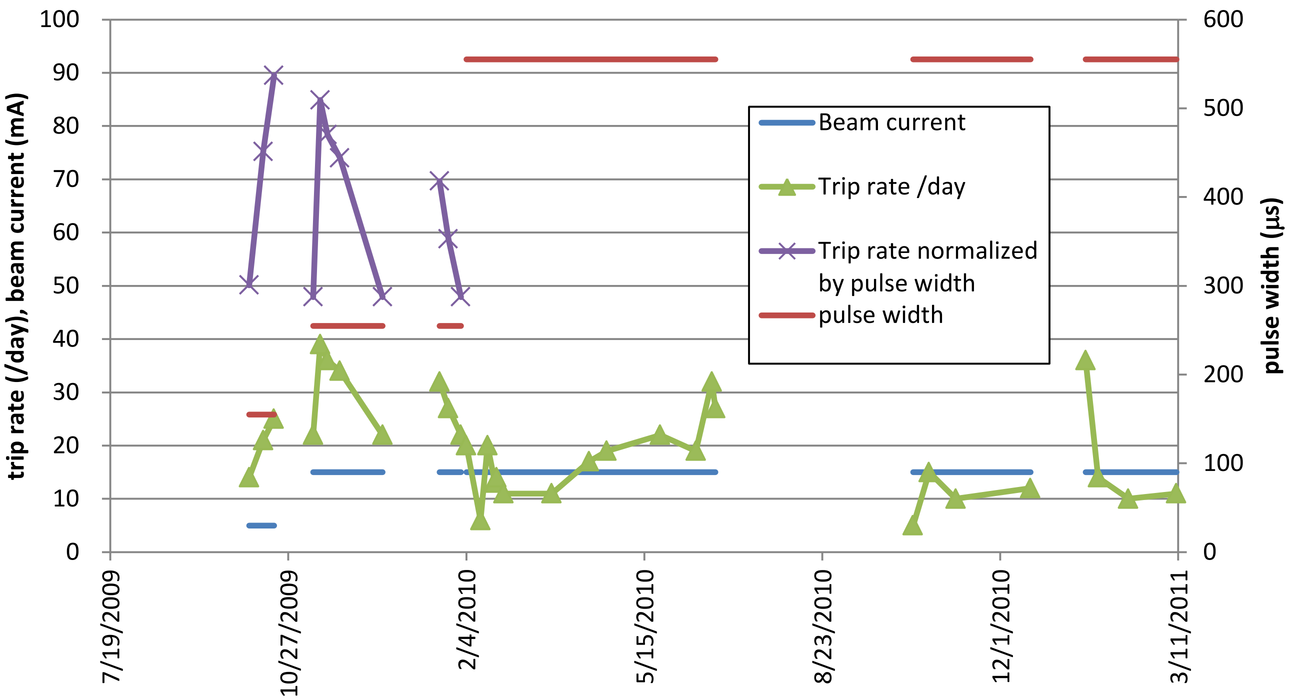
③ OIL FREE ROUGH PUMP SYSTEM.

RFQ PUMP SPEED [l/sec]: 3,300 → 12,500

ION SOURCE PUMP SPEED [l/sec]: 6,000 → 9,000

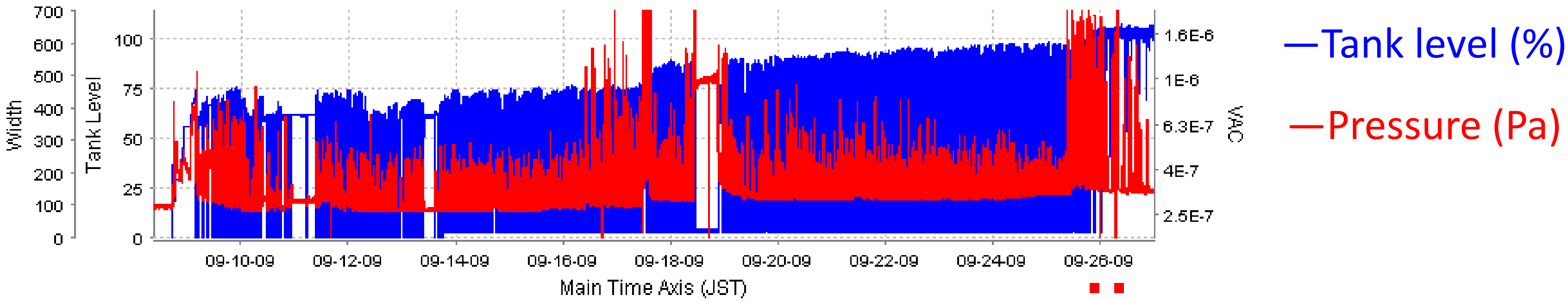
Trip rate before the earthquake

- The series of improvements were effective at a certain level.
- Trip rate had become tolerable level (~1/hour)

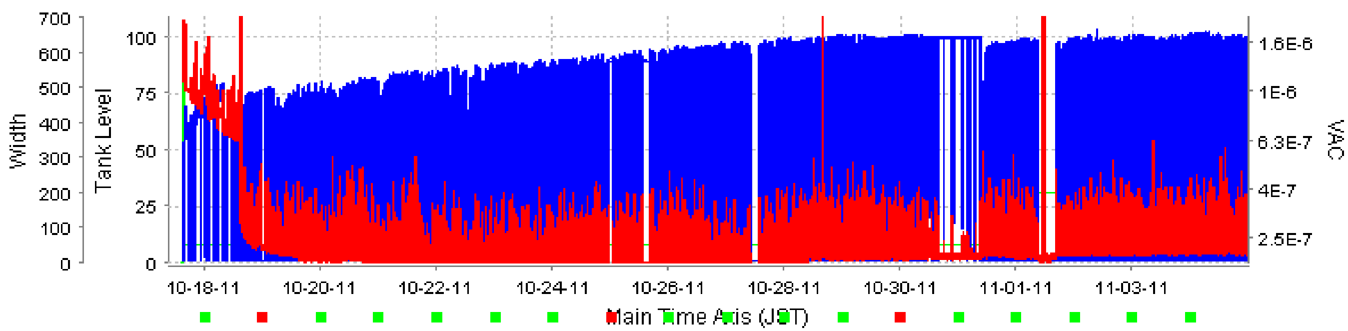


Reconditioning after the earthquake

- Fortunately, there was no damage due to the 3.11 earthquake.
- All vacuum valves kept close (pressure was 6.3 Pa) and continuous pumping was restarted from May 26 2011.
- Nevertheless, conditioning similar to after the pump upgrade was needed.
- In Sep. 2011, baking was done again, because the pressure had been getting worse during two years beam operation.
- We guess, gases baked out from the vessel were absorbed in the vanes.

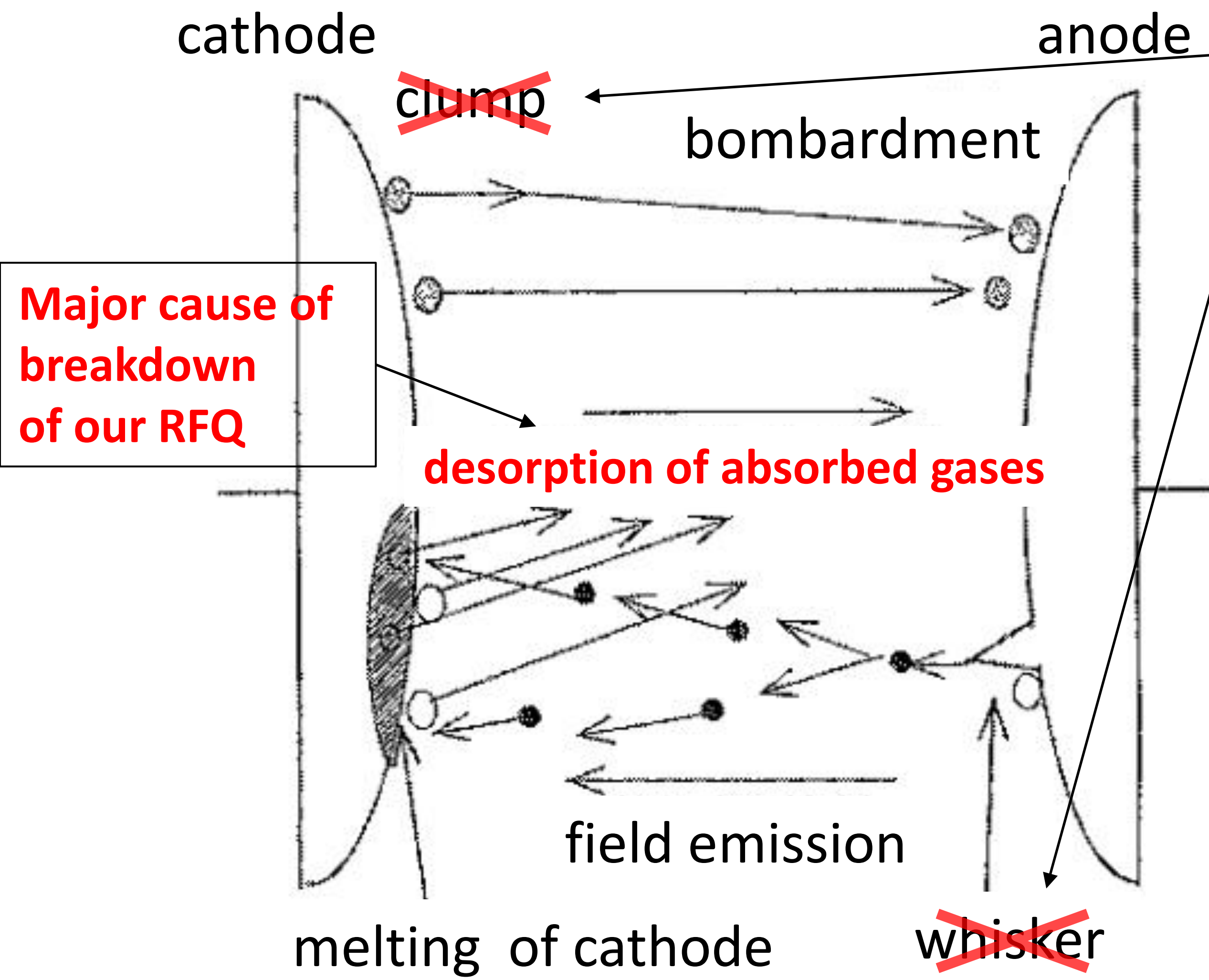


Sep.2009



Oct. 2011

Various causes of breakdown



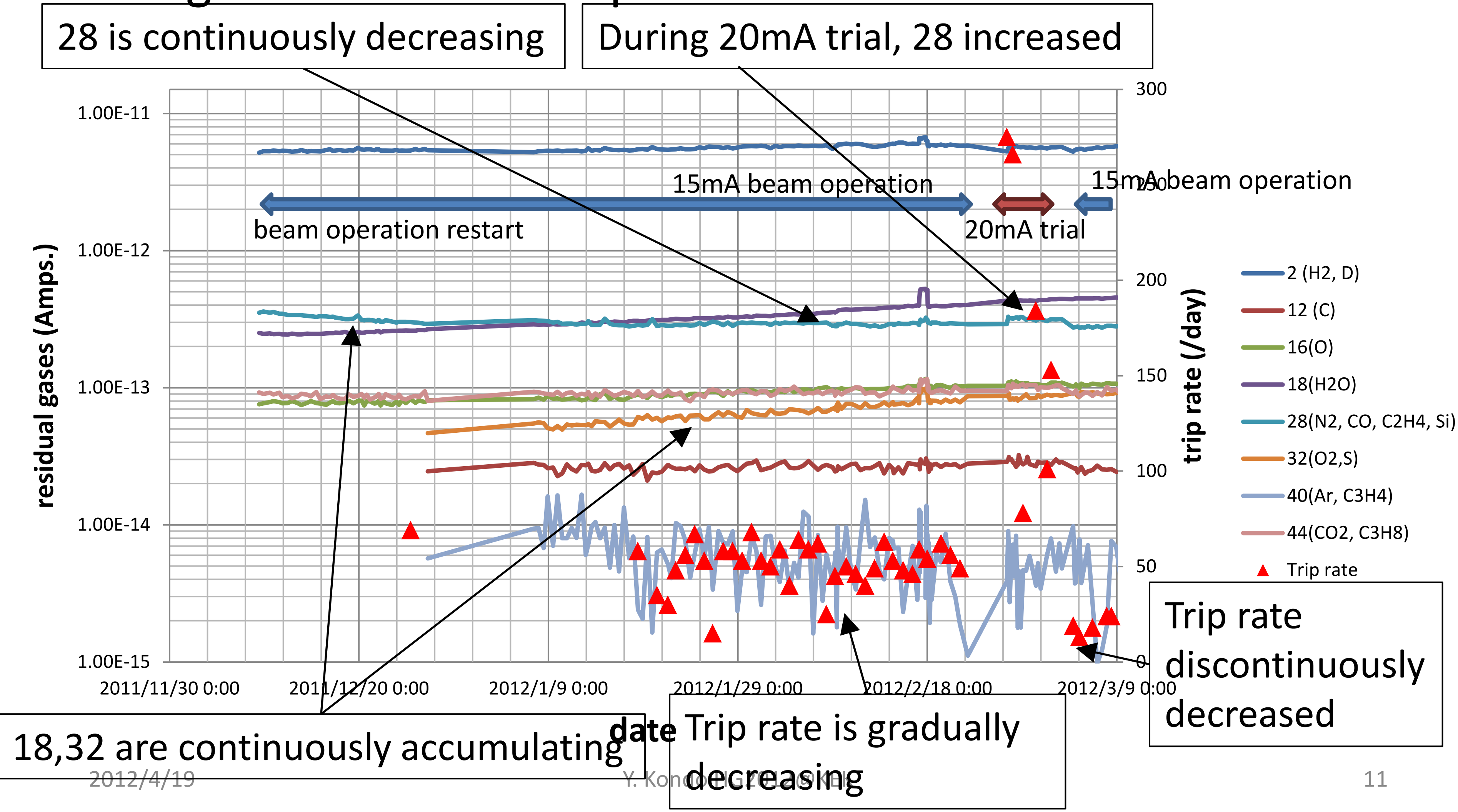
- They can be excluded, because never purged nor operated after the earthquake.
- Absorbed gases cannot be desorbed without spark conditioning.

図1　電界が印加された真空ギャップ電極間で生ずる素過程[12)]

From S. Kobayashi, JPASJ, Vol. 8, No. 4, 2011 (in Japanese)

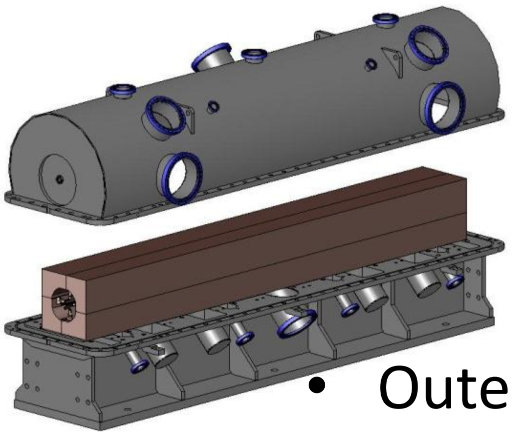
Residual gas analysis

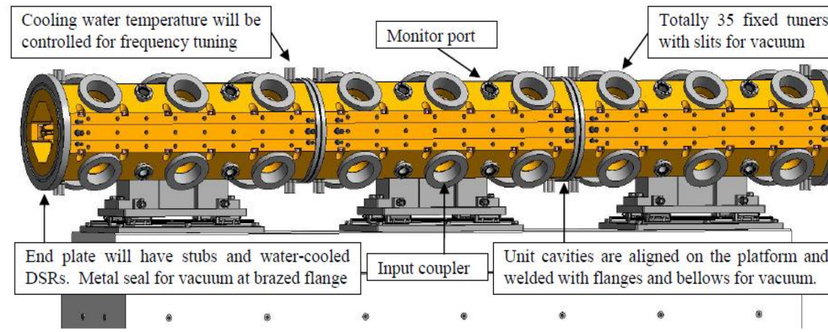
- mass number 28, we guess relating to hydro-carbons, both accumulating in the vanes and directory flowing from IS have strong relation to the trip rate.



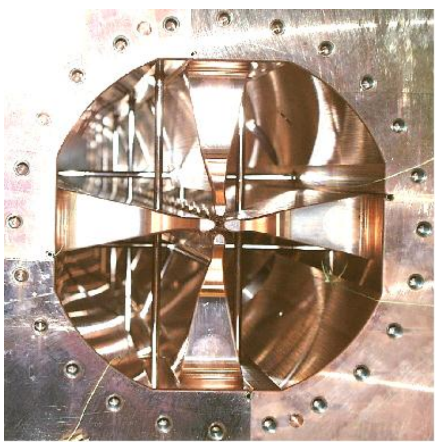
Improvements on new RFQs

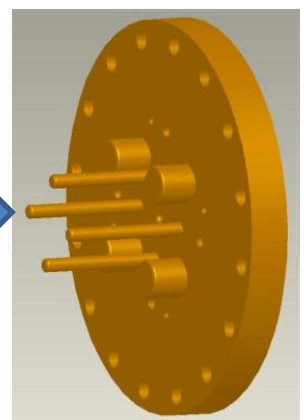
In detail, please visit Morisita-san's poster

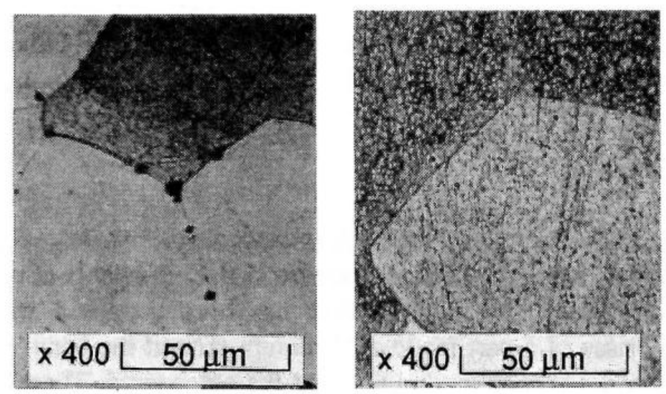




- Outer vacuum vessel -> monolithic structure
  - Reduce volume and surface







H. Matusmoto et. al., PAC1991, p1008

Figure 2. Optical micrograph showing forged OFHC (left) and HIP-OFHC (right) at a temperature of 800 °C and an isostatic

- PISL -> DSR (Dipole stabilizing rod)
  - Reduce high field region and source of multipacting

- HIP (Hot Isostatic Pressing)
  - Reduce voids between grains

Summary

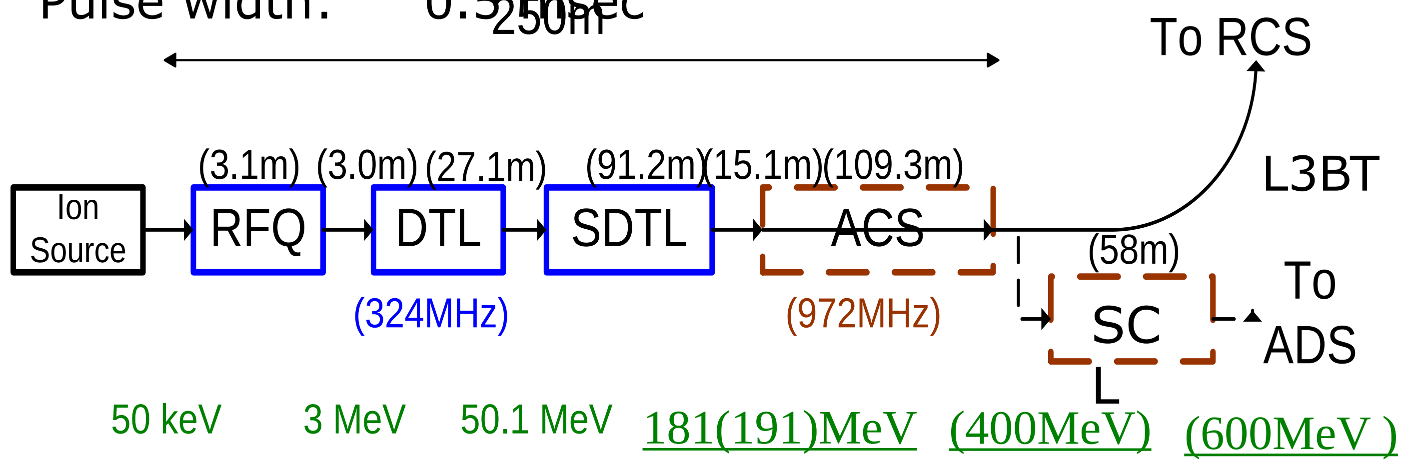
- Major cause of the breakdown in our RFQ is gases from outside (mainly ion sorce).
- The absorbed gases into the vanes can remove only by spark conditioning.
- New RFQs improved against gas absorption are under development. (High-power test will start from next week.)

reserves

Linac Parameters

Major Parameters

- Particles: H- (negative hydrogen)
- Energy: 181 MeV, The last two SDTLs are used as debunchers.
  (400 MeV for ACS, 600 MeV for SCL)
- Peak current: 30 mA (50 mA for 1MW at 3GeV-> Ion source, RFQ)
- Repetition: 25 Hz (additional 25 Hz for ADS application)
- Pulse width: 0.5 msec



Block Diagram of the Linac

Estimated Causes and Measures

Estimated causes

Damage during operation and conditioning

Measures →

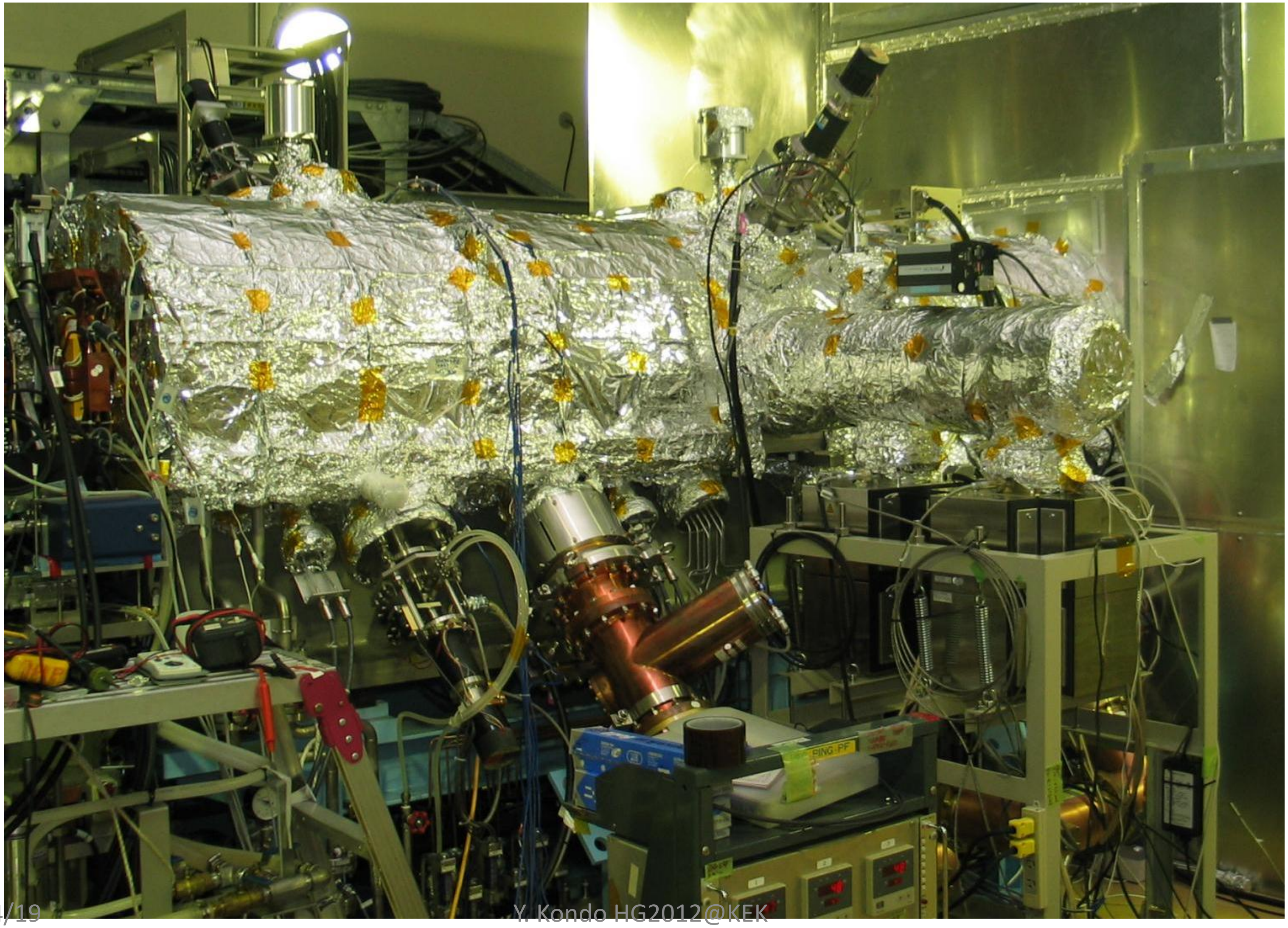
- Improvement of interlock setting
- Suppression of un-expecting beams from the ion source
- Gentle conditioning

Poor vacuum properties:
poor pressure and accumulation of some contaminant from LEBT

→

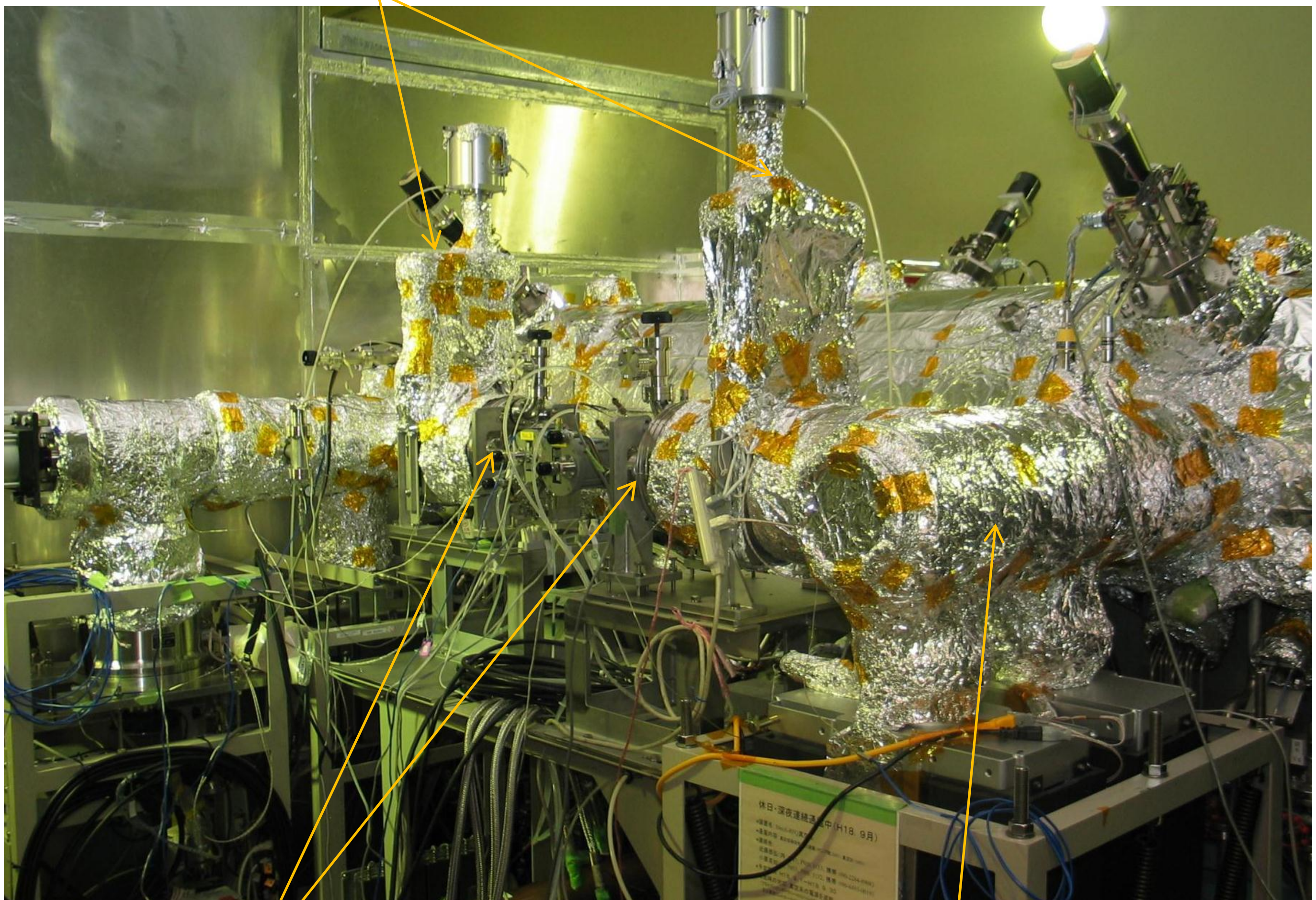
- Addition of vacuum pumps, diagnostics
- Degassing by baking
- Oil free system

RFQ（通路側）



RFQ（ユーティリティ側）

ゲートバルブ（２台）



クライオポンプ（２台）

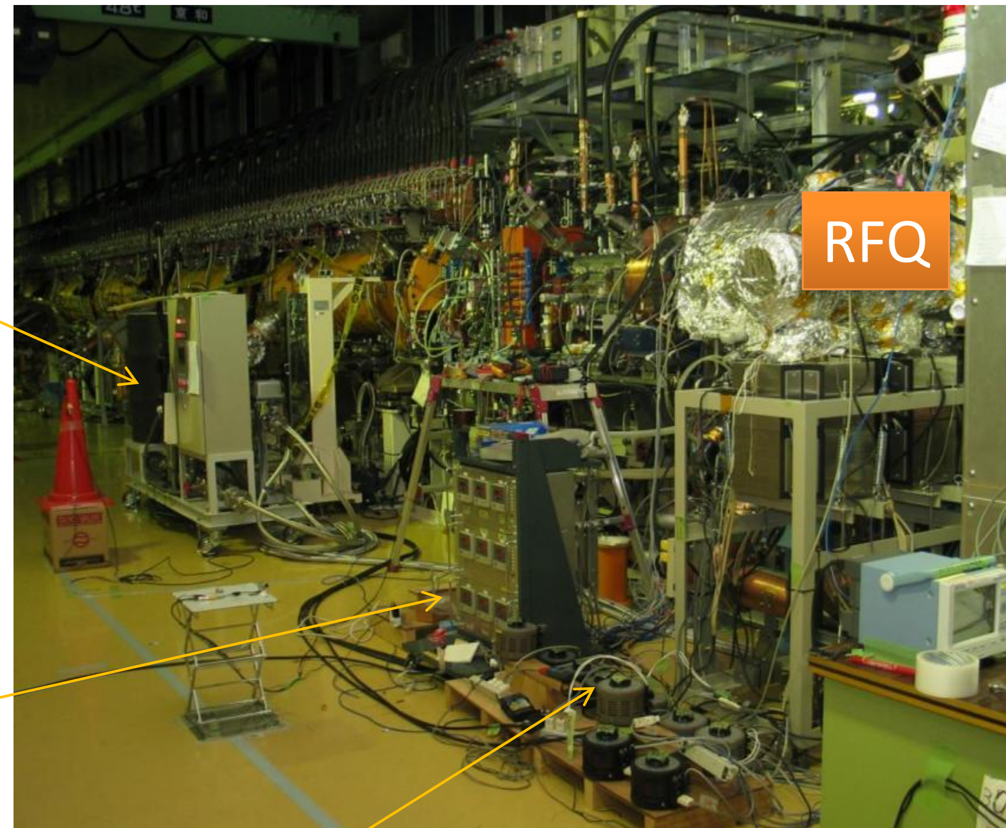
イオンポンプ用マニホールド

Baking

Baking (or warming) was carried out for degassing.

Temperature was changed by 1 deg-C/hour for water and vacuum vessel. The maximum temperature was 67 deg-C.

Water heater

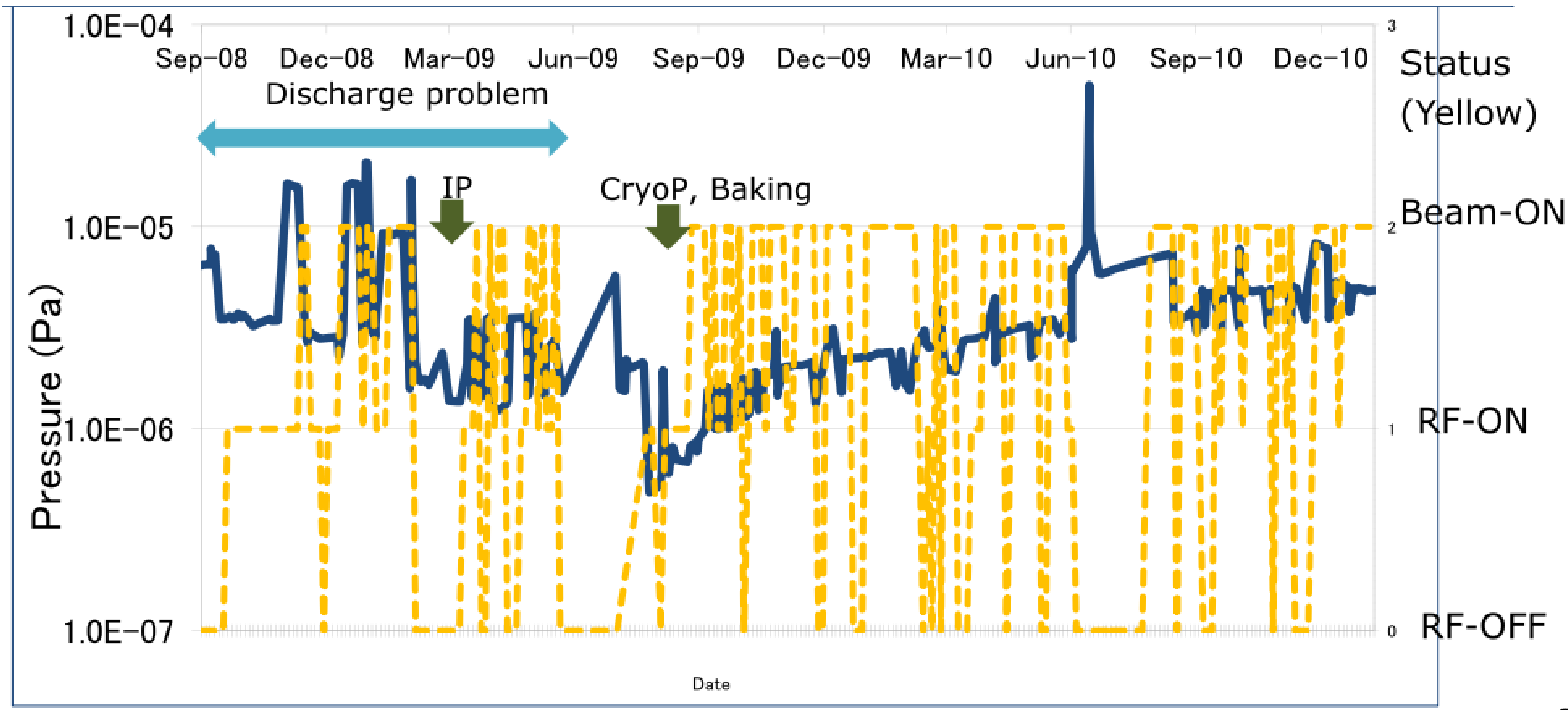


Heater controller for RFQ vacuum vessel

Variable transformers for vacuum pumps and manifold baking control

震災からの復旧

- 震災により、真空リークはなく、ポンプ復旧まで封じ切っていた。



Vacuum pressure at the RFQ in blue, and status of the RF/beam in yellow.