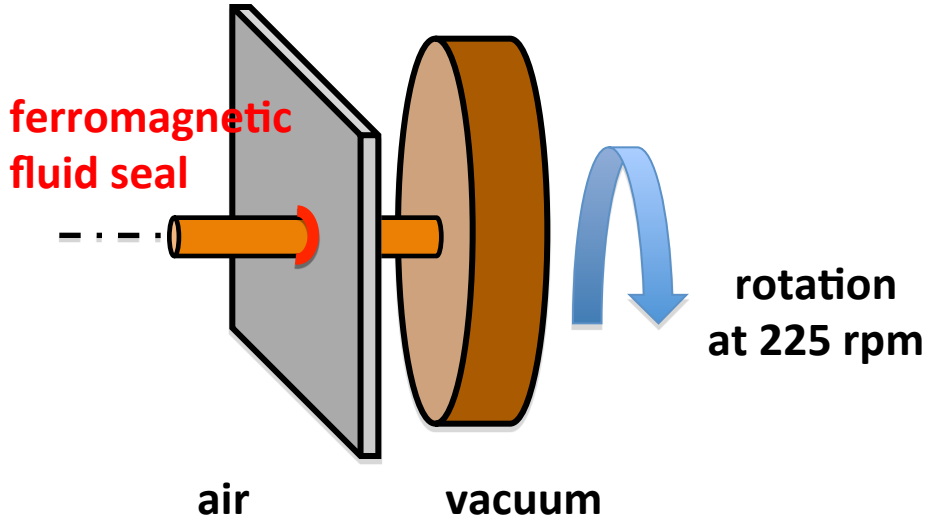
ILC E-driven e+ source
Rotation Target
design and R&D

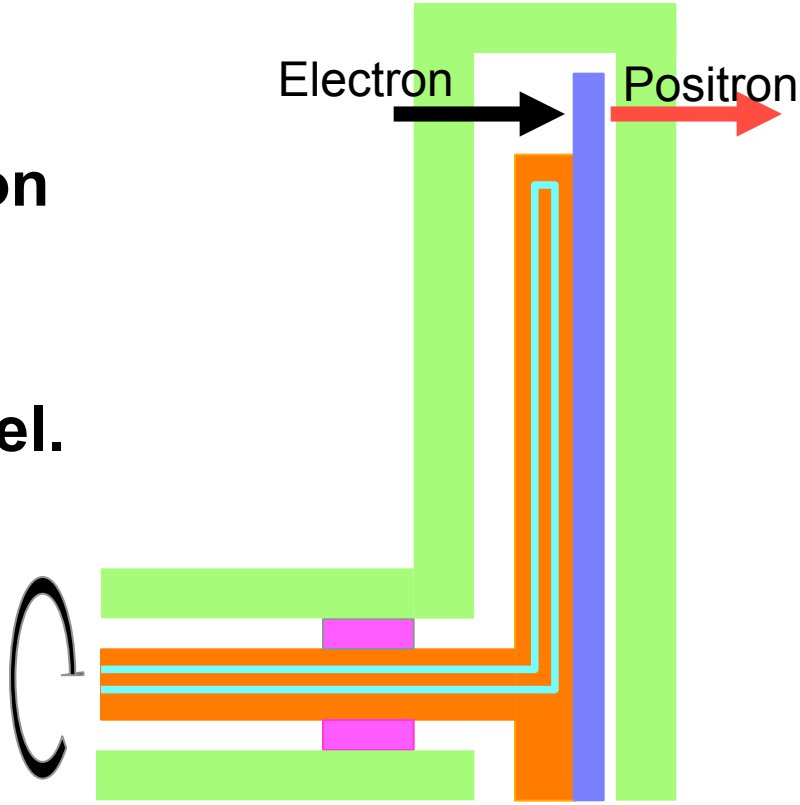


T. Omori, 28-May-2018

**Asian Linear Collider Workshop, ALCW2018, May 28th - June 1st,
Fukuoka International Congress Center, Fukuoka, Japan**

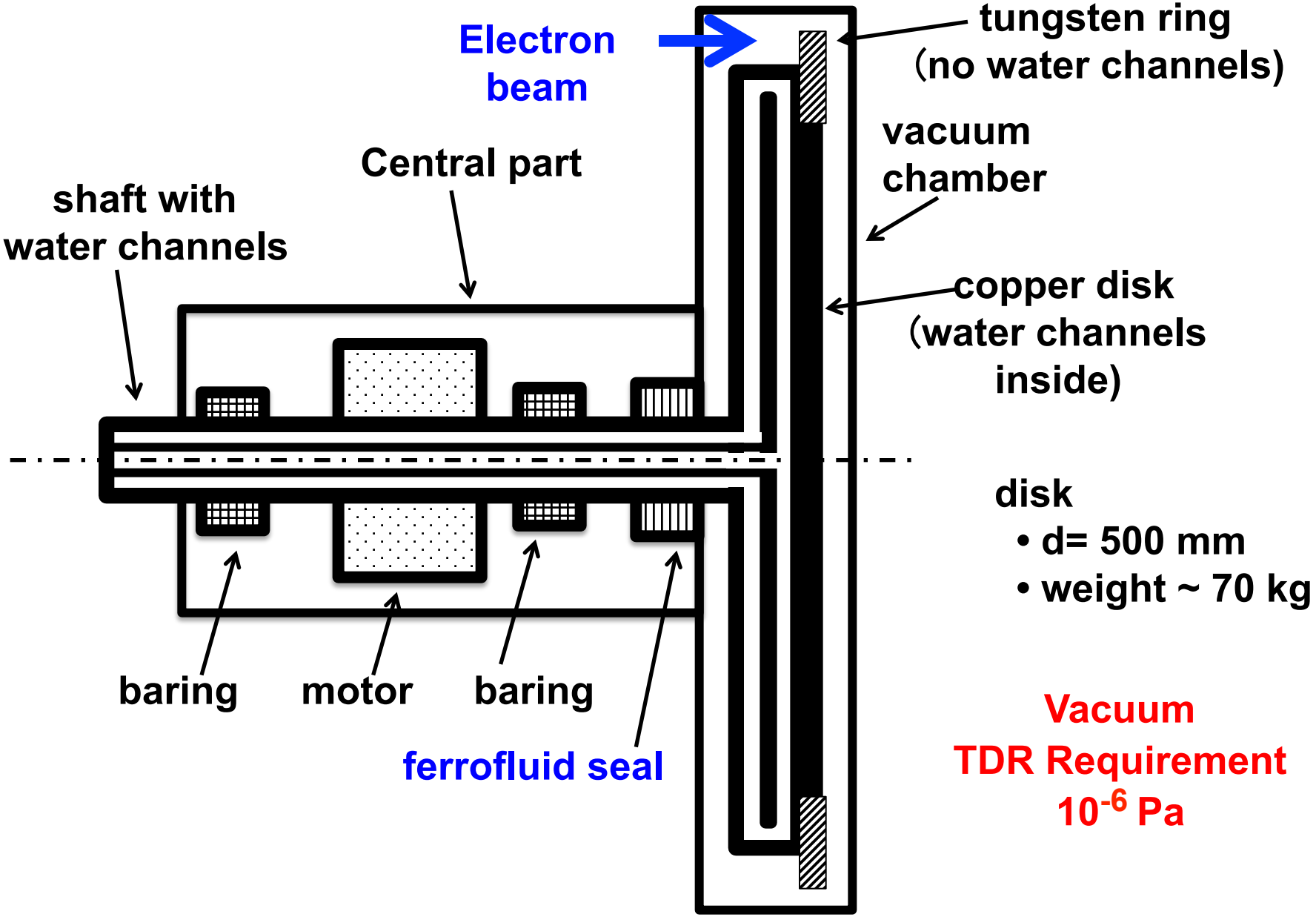
Target

- **W-Re 16mm thick.**
- **5 m/s tangential speed rotation (225 rpm, 0.5m diameter) in vacuum.**
- **Water cooling through channel.**
- **Vacuum seal with ferro-fluid.**

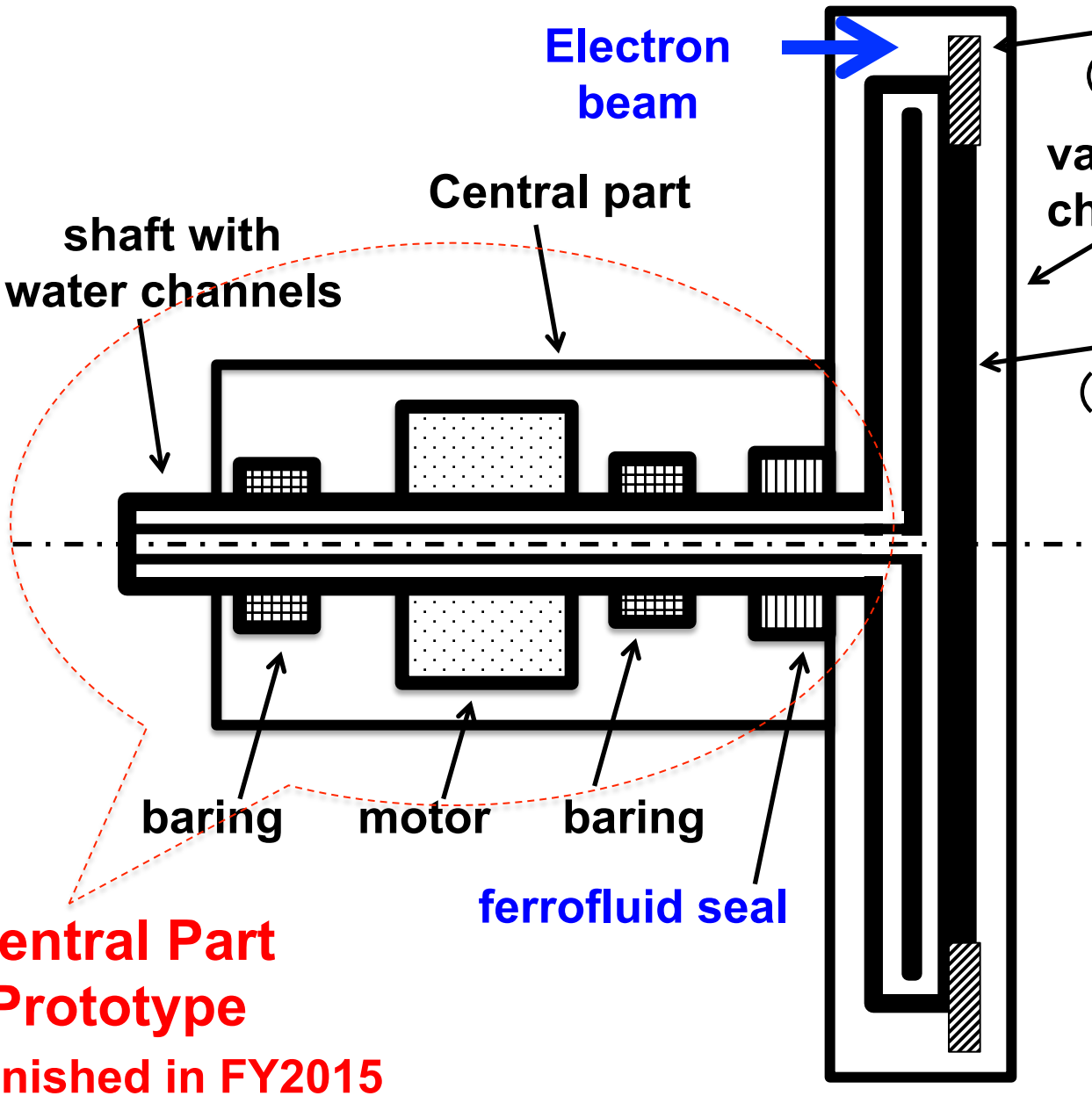


Target
and
Vacuum Test

Rotation Target (E-driven)



Rotation Target (E-driven)

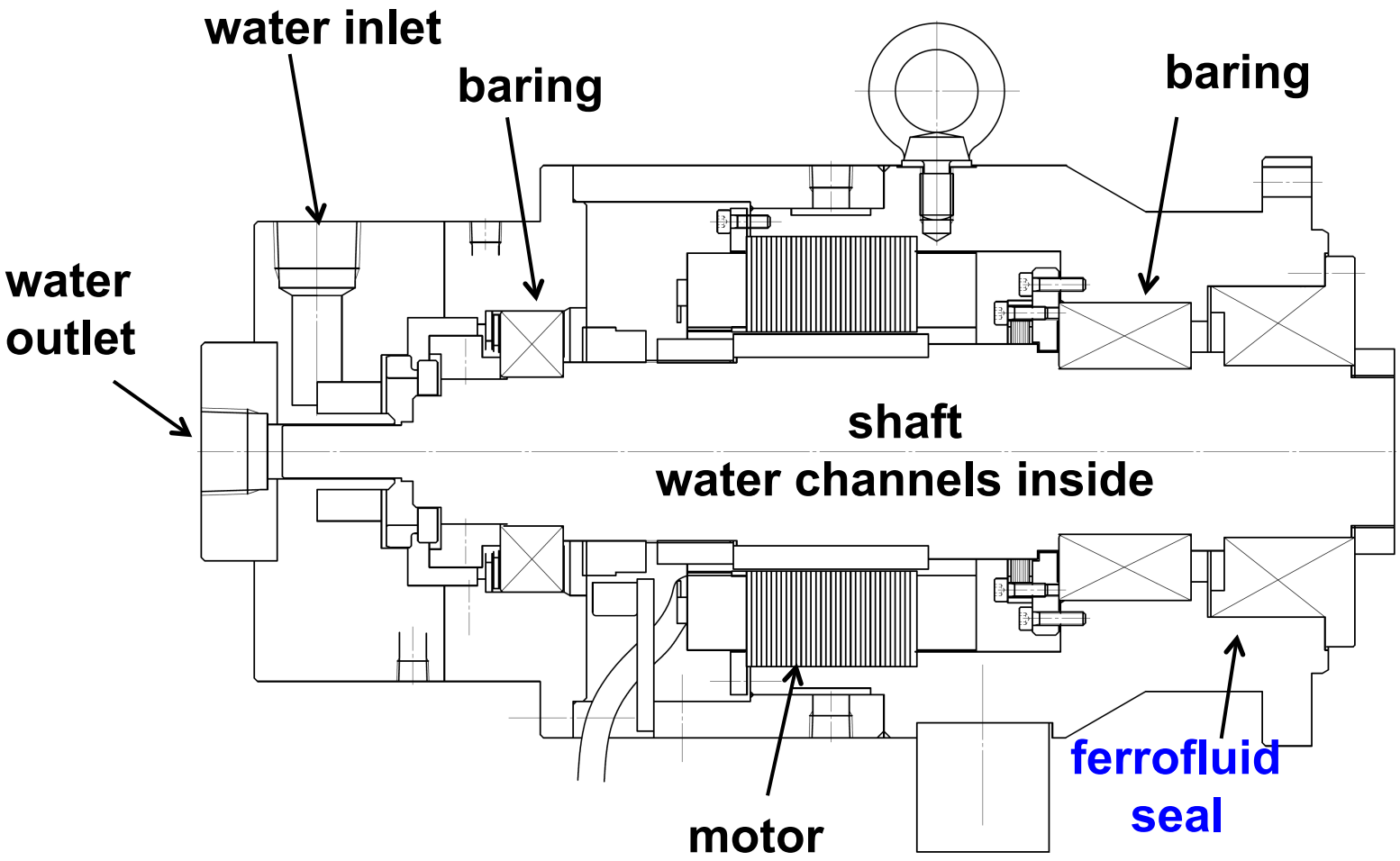


disk
- d= 500 mm
- weight ~ 70 kg

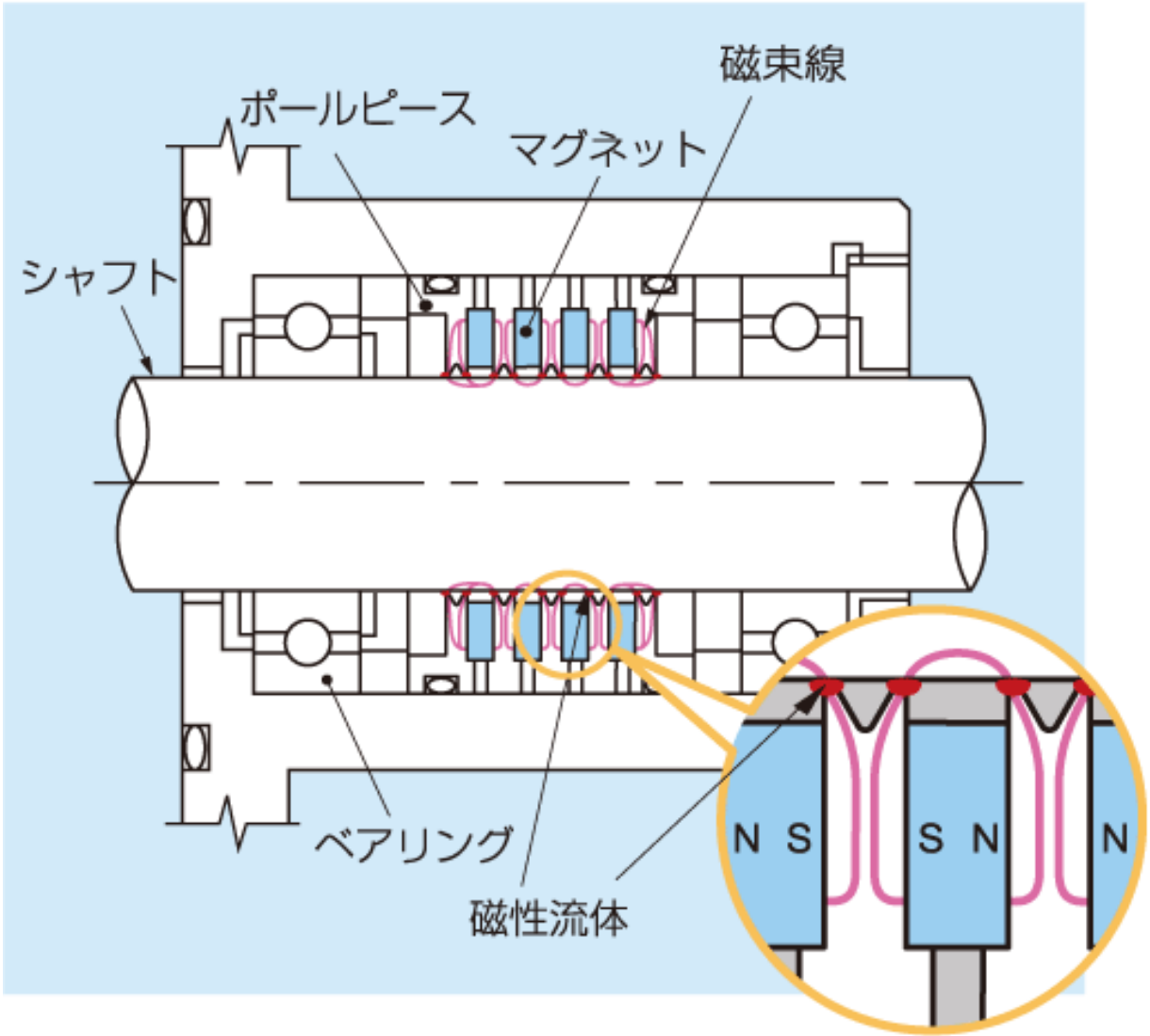
Vacuum
TDR Requirement
10^{-6} Pa

Central Part Prototype
finished in FY2015

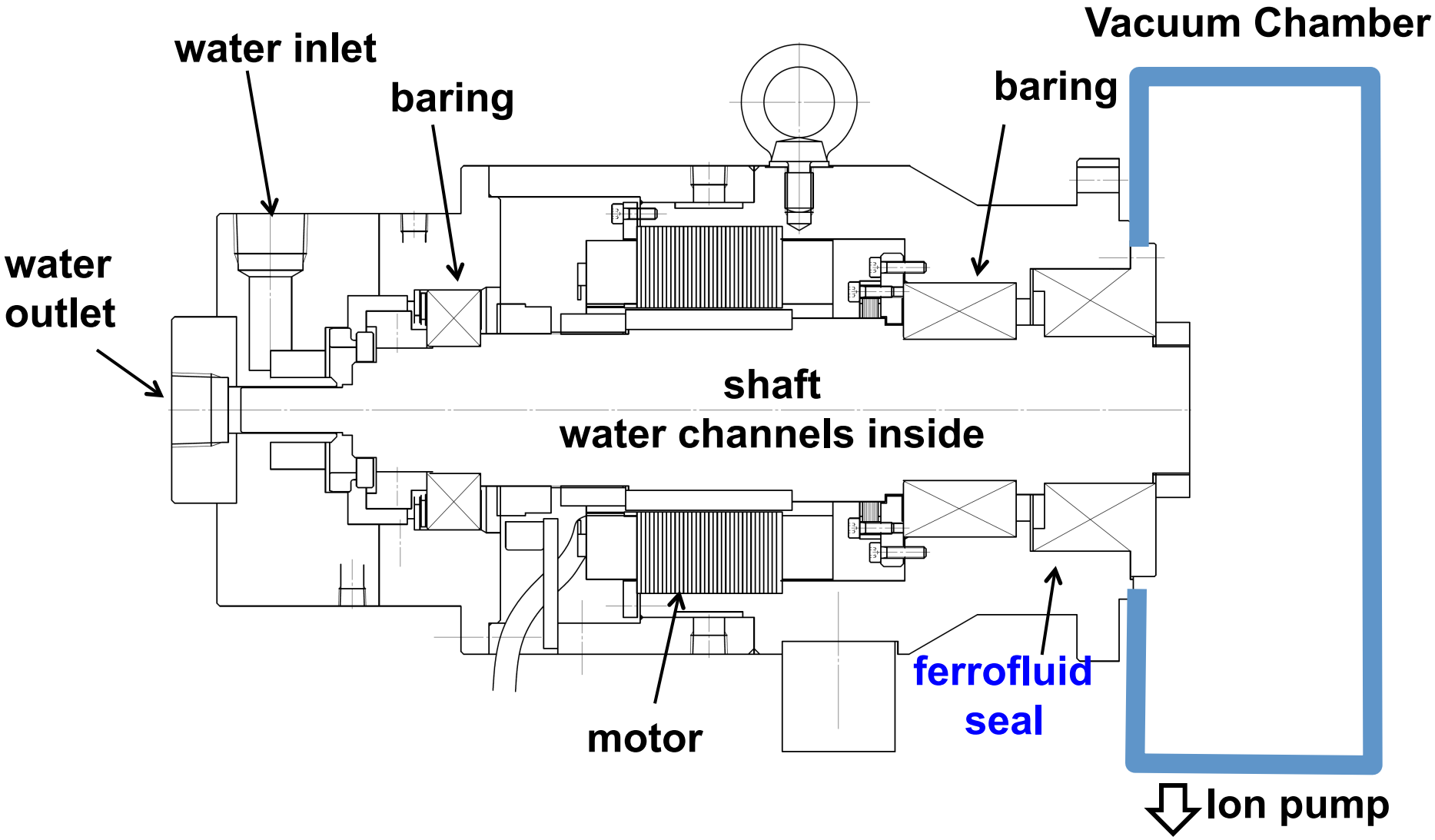
Central Part Prototype



Schematic of ferrofluid seal

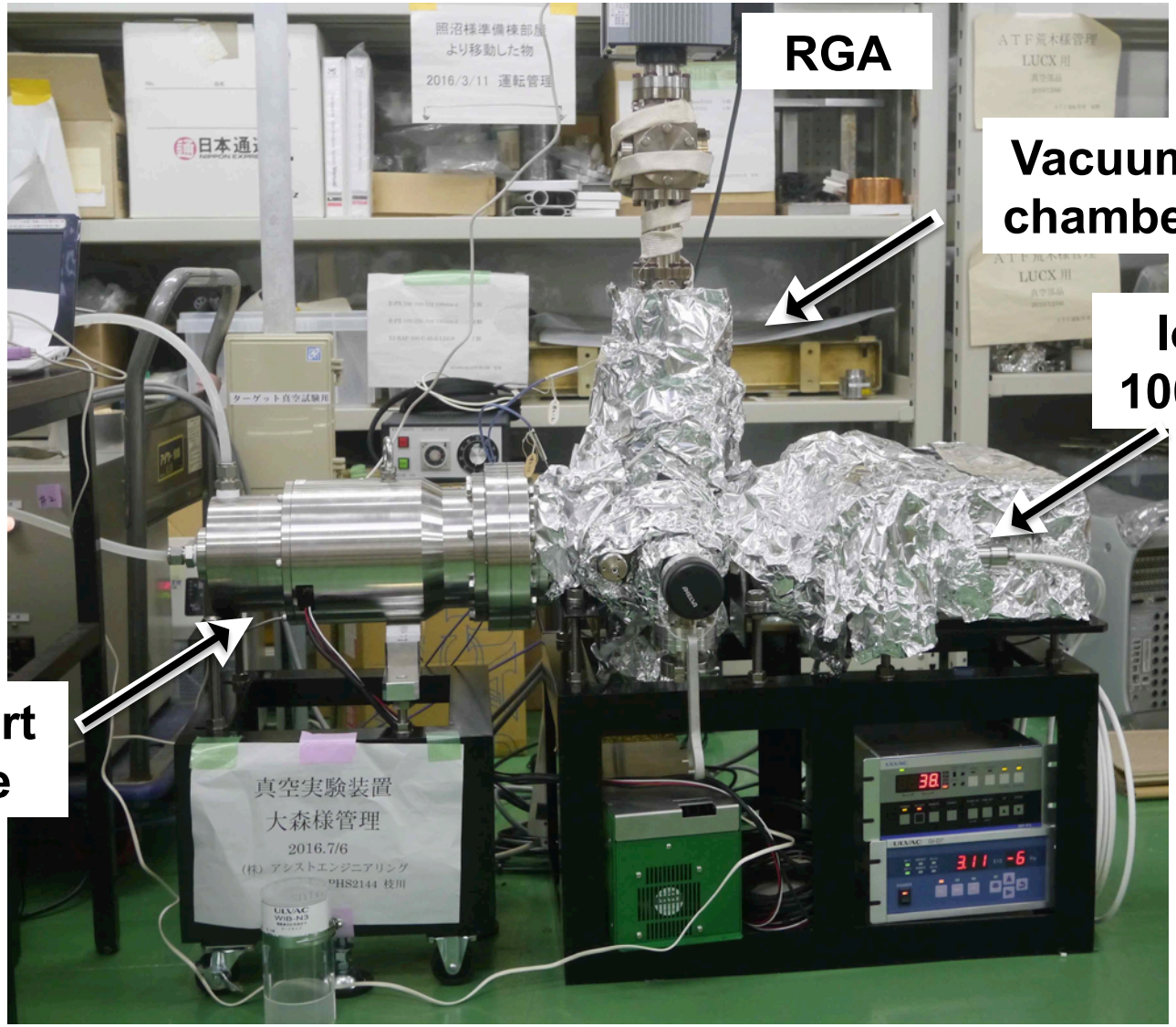


Central Part Prototype Vacuum Test



Central Part Prototype Vacuum Test

Feb/2017



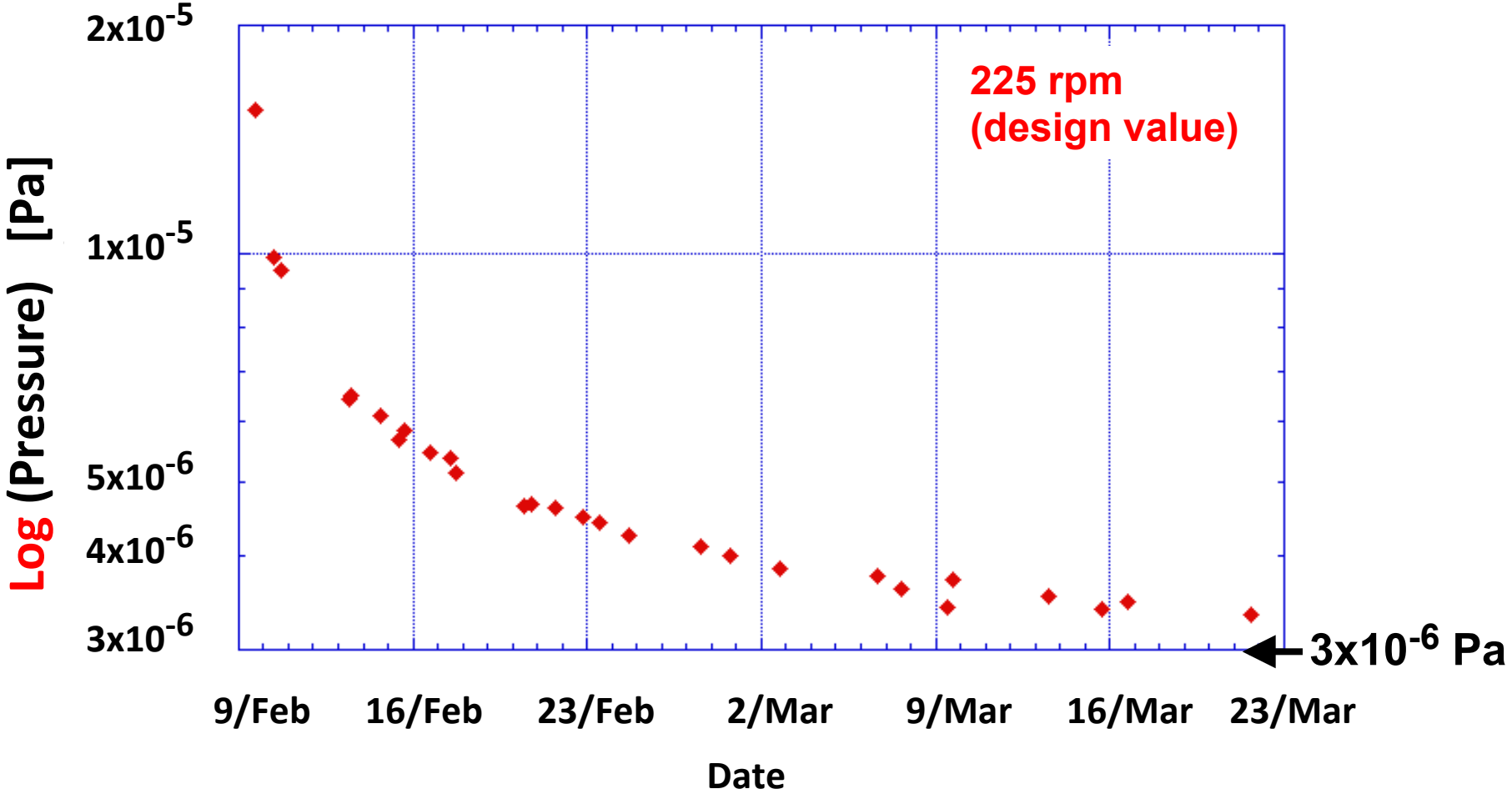
Central Part Prototype: Funded by KEK
Vacuum Test: Funded mostly by Hiroshima Univ.

Central Part Prototype Vacuum Test
Facts and What happened (1)

- **Ion pump 100 litter/sec.**
- **Rotation at 225 rpm (design value).**
- **We started the experiment on February 9th, 2017.**

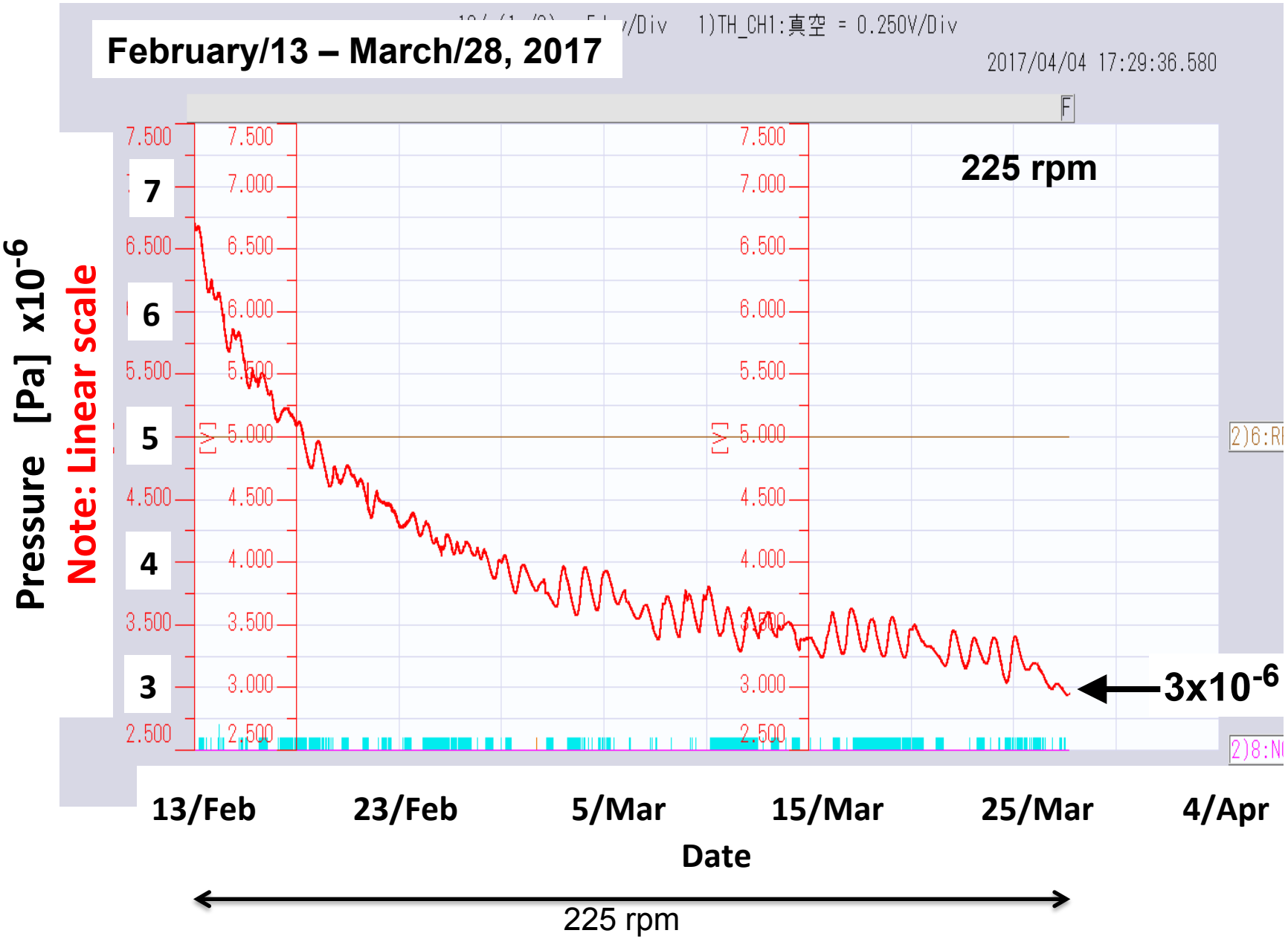
Central Part Prototype Vacuum Test

The test started on February 9th, 2017 with continuous rotation at 225rpm



The vacuum test started on February 9th with continuous rotation at 225 rpm (design value). The vacuum level seems to be reasonable in comparison with the expectation. The vacuum level is as good as the ILC TDR requirement. It seems promising. But the prototype has no disk. We will make further study.

Central Part Prototype Vacuum Test

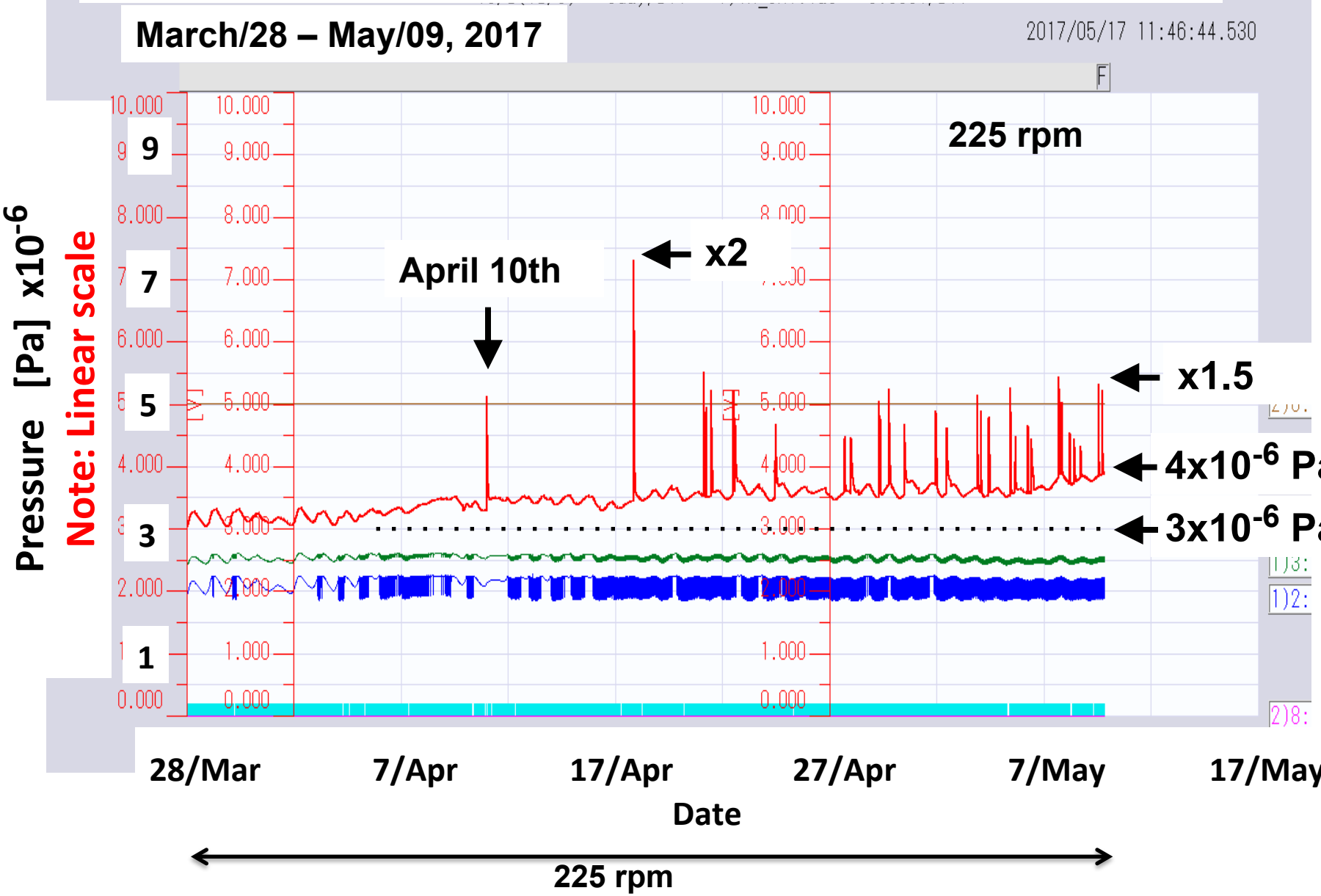


Central Part Prototype Vacuum Test
Facts and What happened (1)

- Ion pump 100 litter/sec.
- Rotation at 225 rpm (design value).
- We started the experiment on February 9th.
- Vacuum level went good monotonically.
- And reached ~ 3×10^{-6} Pa at the end of March.

Central Part Prototype Vacuum Test

Small spikes (x1.5 – x 2) were obsreved



Central Part Prototype Vacuum Test
Facts and What happened

- Ion pump 100 litter/sec.
- Rotation at 225 rpm (value).
- We started the experiment on February 9th, 2017.
- Vacuum level went good monotonically.
- And reached ~ 3x10^{-6} Pa at the end of March.
- Vacuum level was stable at ~ 3x10^{-6} until April 10th.
- Then, we observed small spikes.
  - Height of a spike ~x1.5.

Vacuum Test: ILC Rotation Target
Facts and Concerns at the Prototype

Facts

Vacuum **3×10^{-6} Pa (measurement results)**

Keep good vacuum over five months

Sikes

Vacuum level slowly went worse.

Concerns

Sikes

Aging

Contamination of the accelerator tube

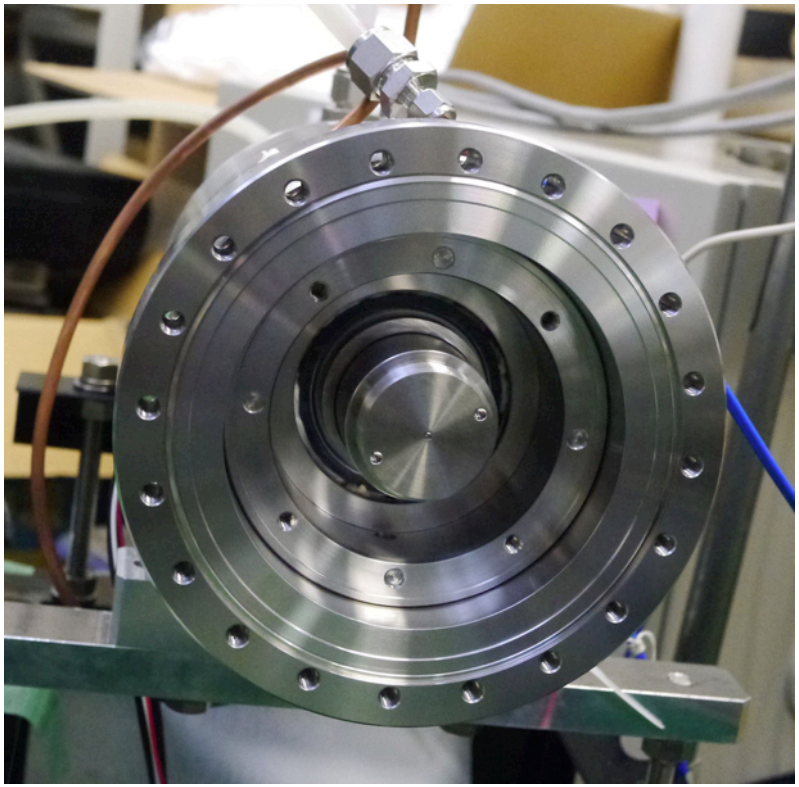
Reinstallation of the Seal Unit

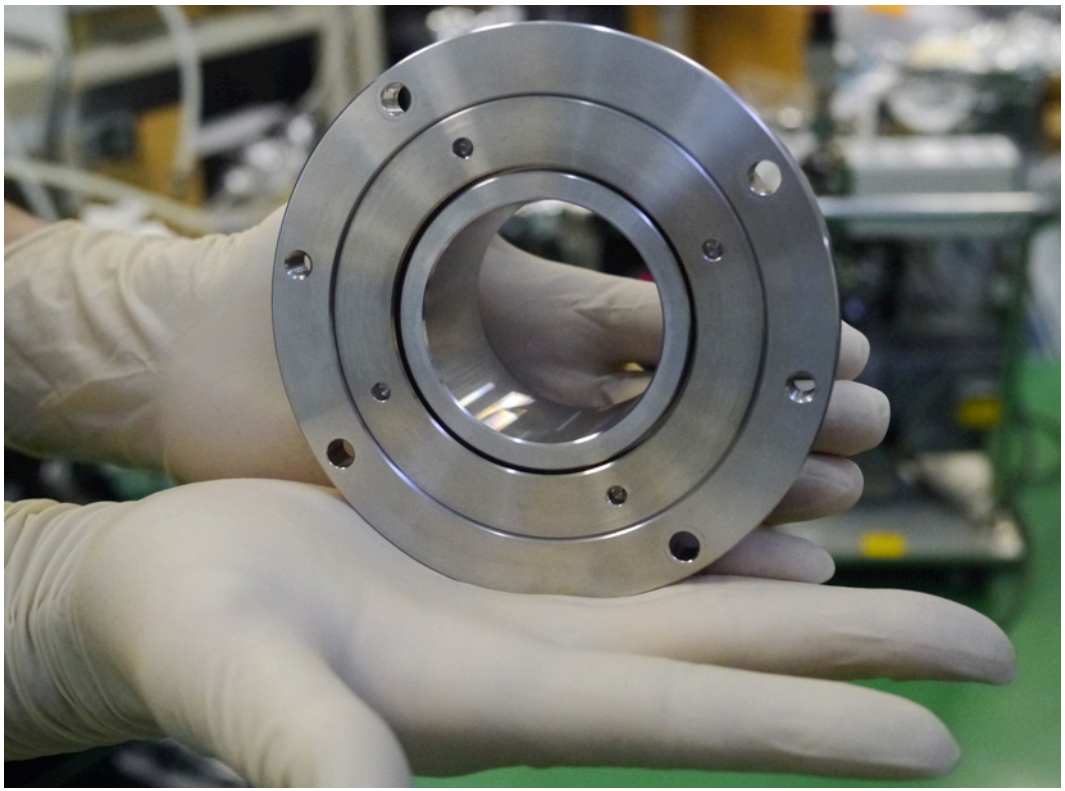
(1) We opened the chamber 19th July 2017.

(2) The seal unit was sent back to the company (RIGAKU). The company checked the unit, washed the unit, and applied fresh ferrofluid.

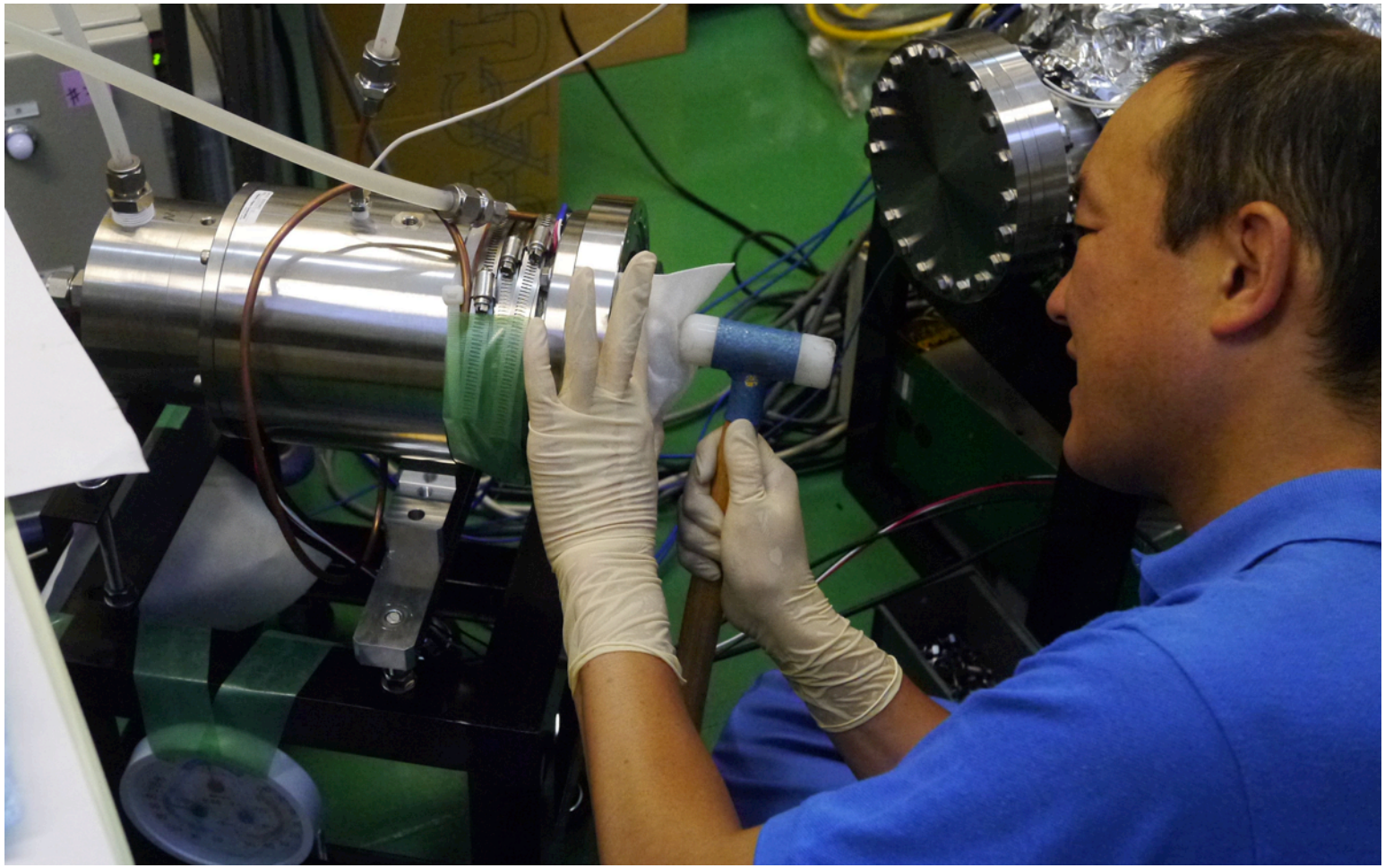
(3) We reinstalled the unit on 31st July 2017.

July 31st, 2017:
We reinstalled the seal unit and closed the chamber again

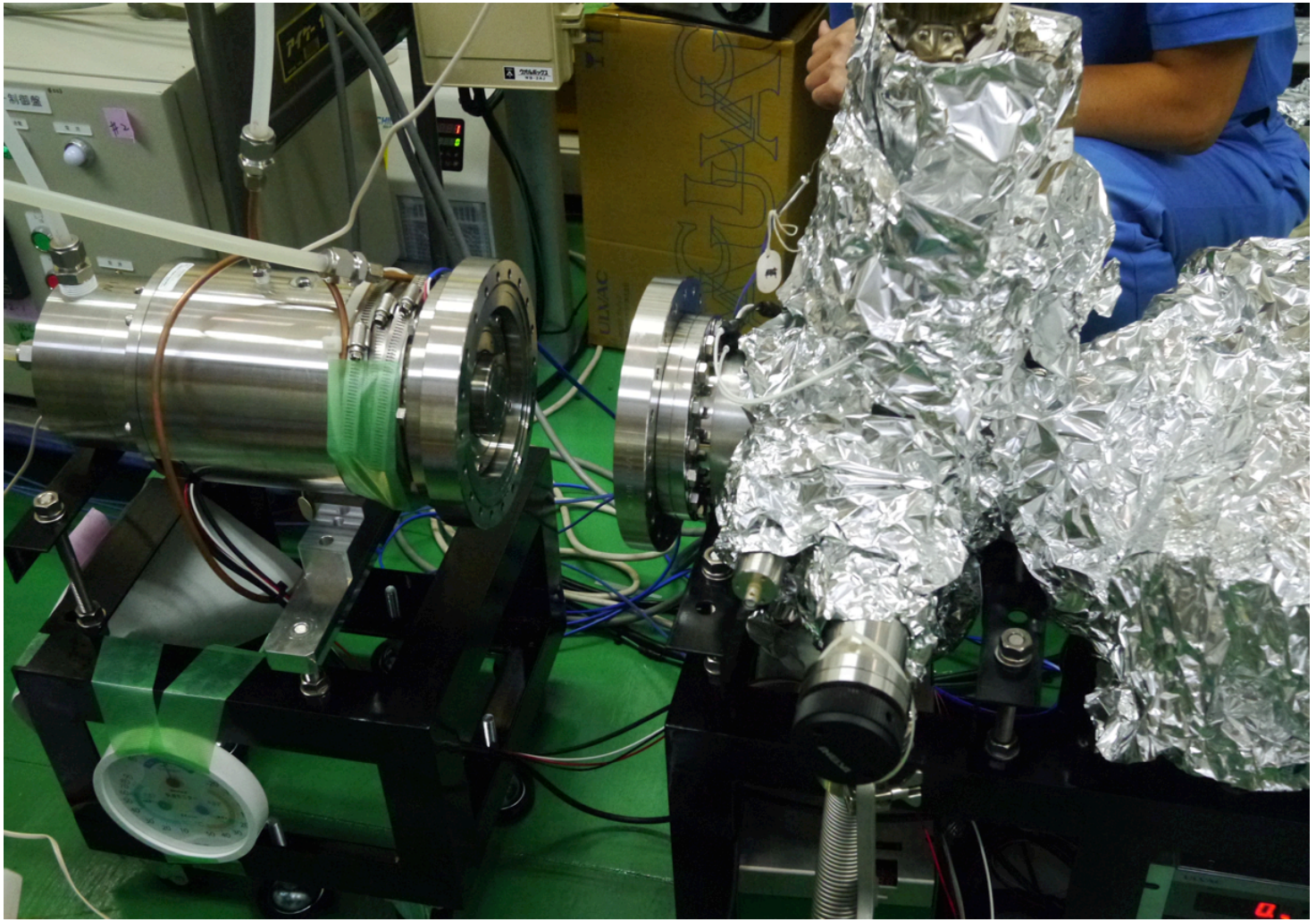




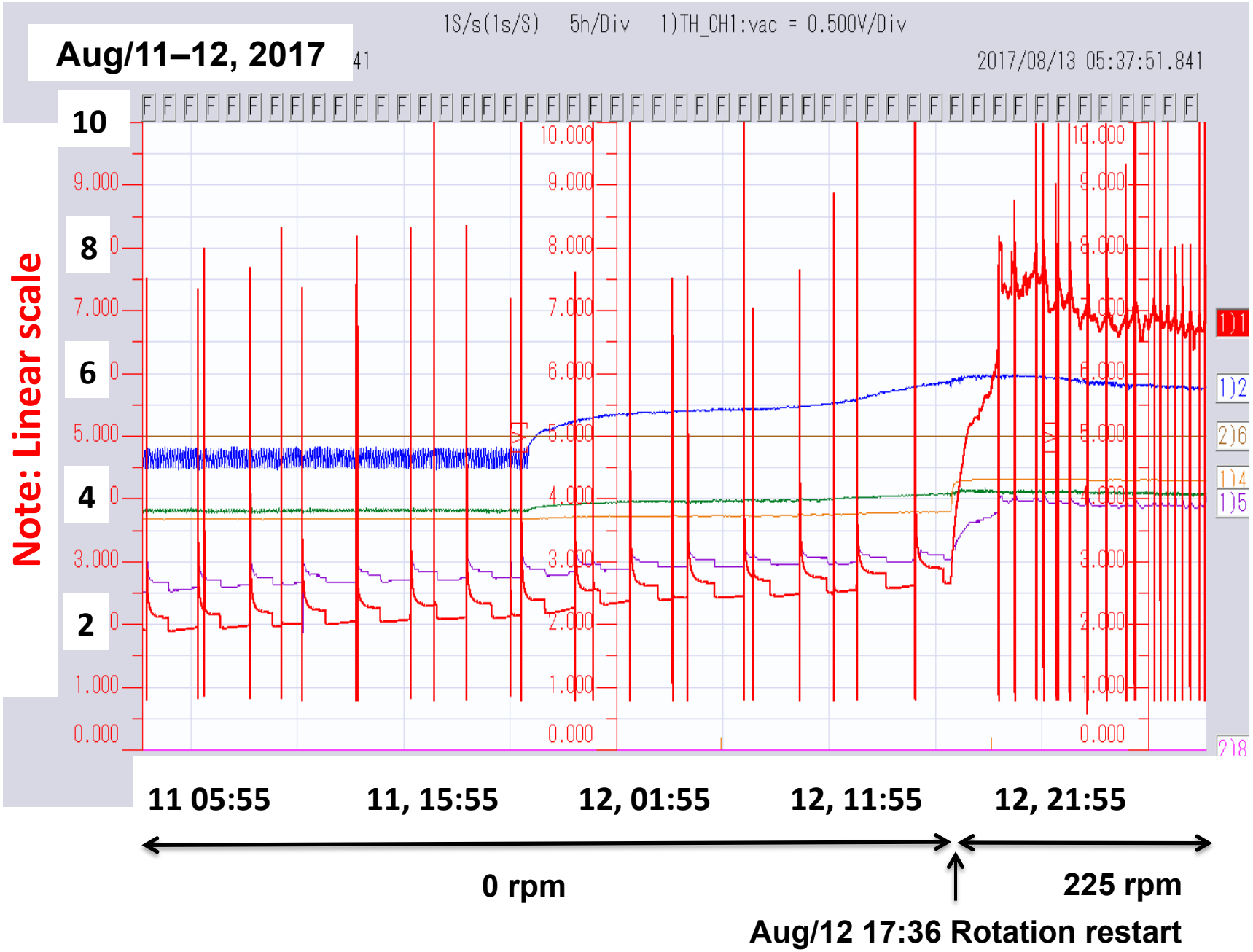
July 31st, 2017:
We reinstalled the seal unit and closed the chamber again



July 31st, 2017:
We reinstalled the seal unit and closed the chamber again



Vacuum Test: After reinstallation



Spikes in August 2017

- We observed spikes again in the operation in August after the reinstallation (the second experiment).

- The frequency of spikes was rather high.
  Every 10-20 minutes.

- Spikes appeared immediately after restart of operation.

  cf. Spikes appeared after 3 months of operation in the first experiment in Febuary-July).

- In the first experiment, we suspected the aging of the ferrofluid was the cause of the spikes. But in the second experiment we observed spikes immediately.

- Quality control is the cause?.

An Event

The air conditioner of the room was broken in early August.

September (2017)

- **September:**

  The air conditioner of the room was broken in early August. Rotation in bad environment may give bad affect on the seal fluid. So we stopped the rotation at the end of August and suspended the experiment.

- **Begging of of October:**

  We restarted the experiment at the begging of October.

  Vaccum: 4-5x10^{-6} Pa at 225rpm

  Spikes: every 10-30 min (height ~x20)

October-November (2017) : New Tests

- **Fast speed rotation**

  We intentionally change the rotation speed to much faster than the rated speed to change the state (condition) of the fluid.

  - rotation at 900 rpm
  - rotation at 1150 rpm
  - change speed every 3 minutes, (225 <-> 900)x20 times

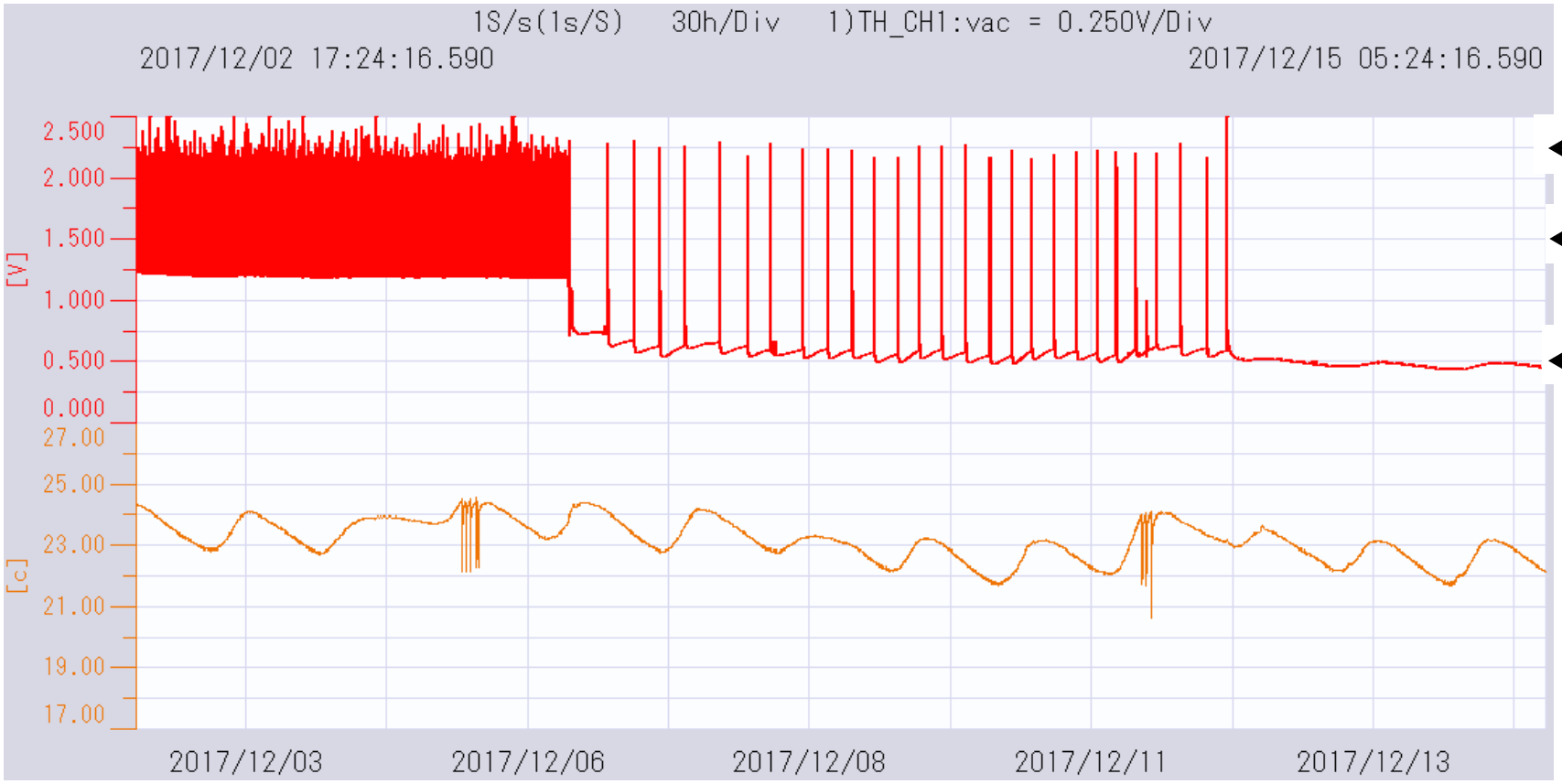
- **End of October**

  Situation at the end of October.
  Vaccum: 3.3×10^{-6} Pa at 225rpm
  Spikes: every 2-3 hours (height ~x20)

November (2017)

We prepared better environment arround the seal.

2017, Dec. 02nd - Dec. 15th



Vac

← 2.5x10^{-5} Pa

← 5x10^{-6} Pa

← 5x10^{-7} Pa

T3 (Room)

1150 rpm
Spikes: every 20 min

225 rpm

Spikes: every 6 hours

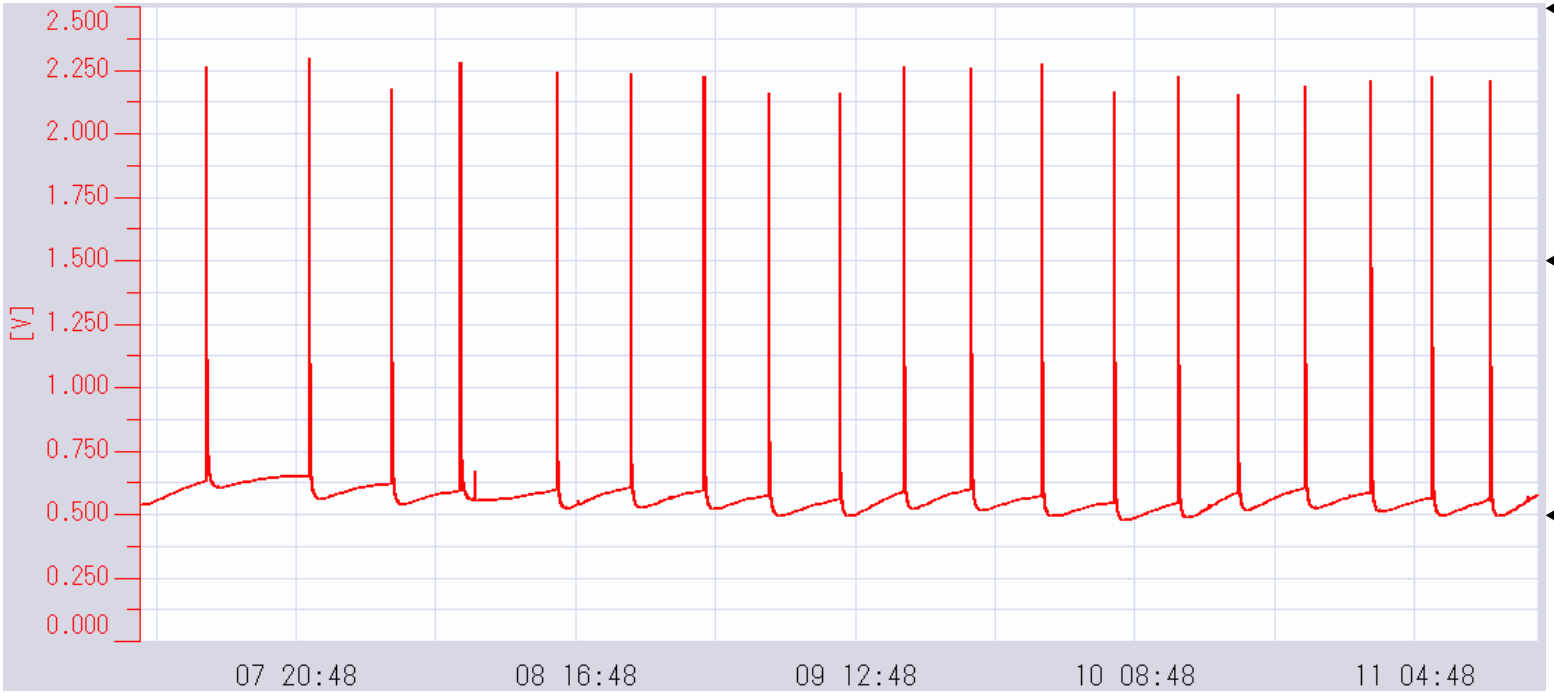
0 rpm

Dec. 06th 13:40
1150 rpm -> 225 rpm

Dec. 12nd 09:32
225 rpm -> 0 rpm
the last spike at the moment of the stop

Vacuum at 225 rpm

2017, December



← $5x10^{-5}$ Pa

← $5x10^{-6}$ Pa

← $5x10^{-7}$ Pa

7^{th}/Dec 8^{th}/Dec 9^{th}/Dec 10^{th}/Dec 11^{th}/Dec

base ~ 5×10^{-7} Pa

peak of spikes ~ 2×10^{-5} Pa

Vacuum TDR Requirement 10^{-6} Pa

Results of December Experiment

We got better results

3×10^{-6} Pa $\rightarrow$ 5×10^{-7} Pa

But we still have spikes

Estimation in ILC e+ source system

* Data measured by the central part prototype (experiment)

  Vacuum (result exp.) 5×10^{-7} Pa (base (NO spike))

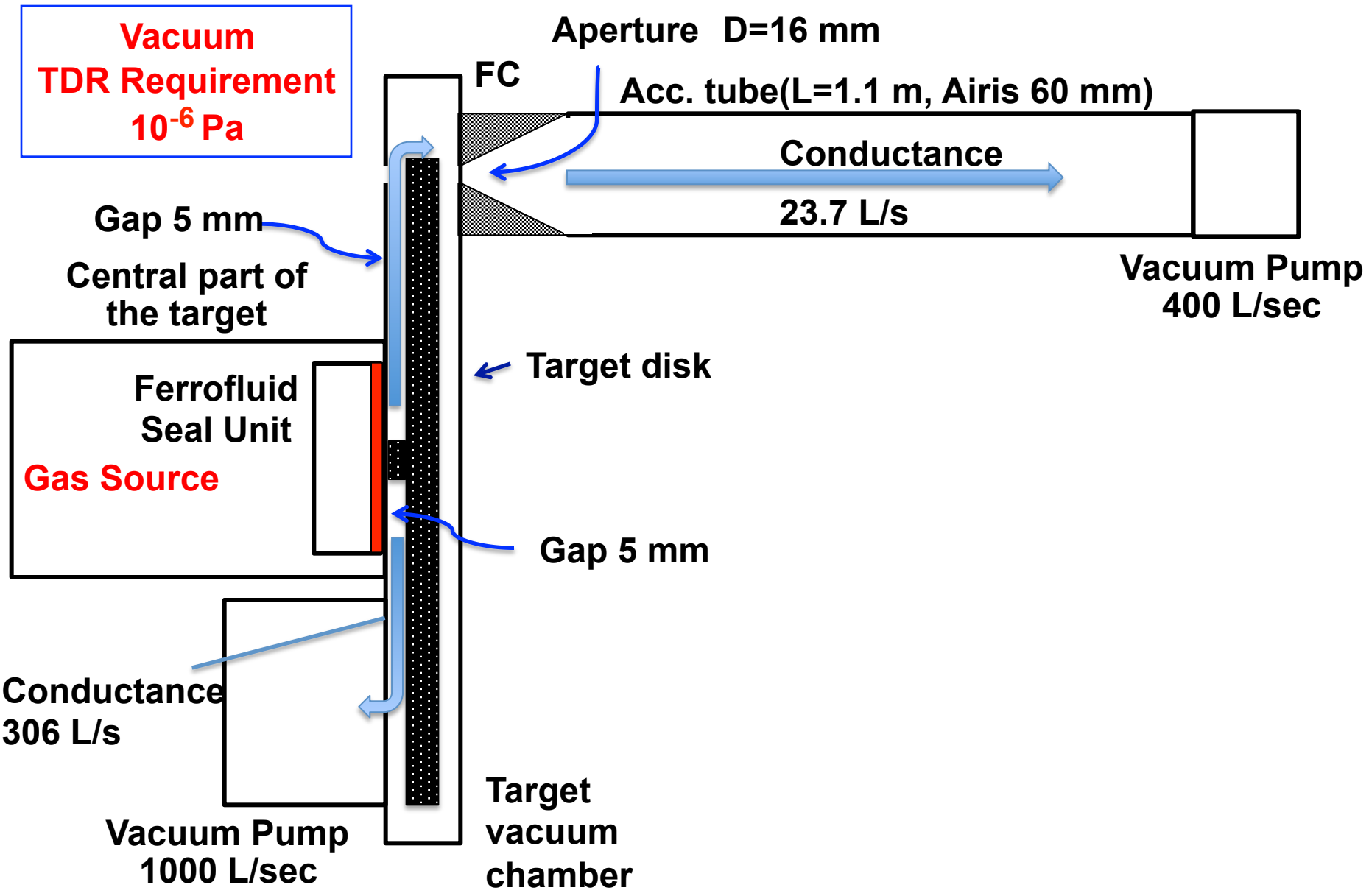
  Vacumm pump used 100 L/s (=100×10^{-3} m^3/sec)(Ion pump)

* Leak rate （calculated from the above）

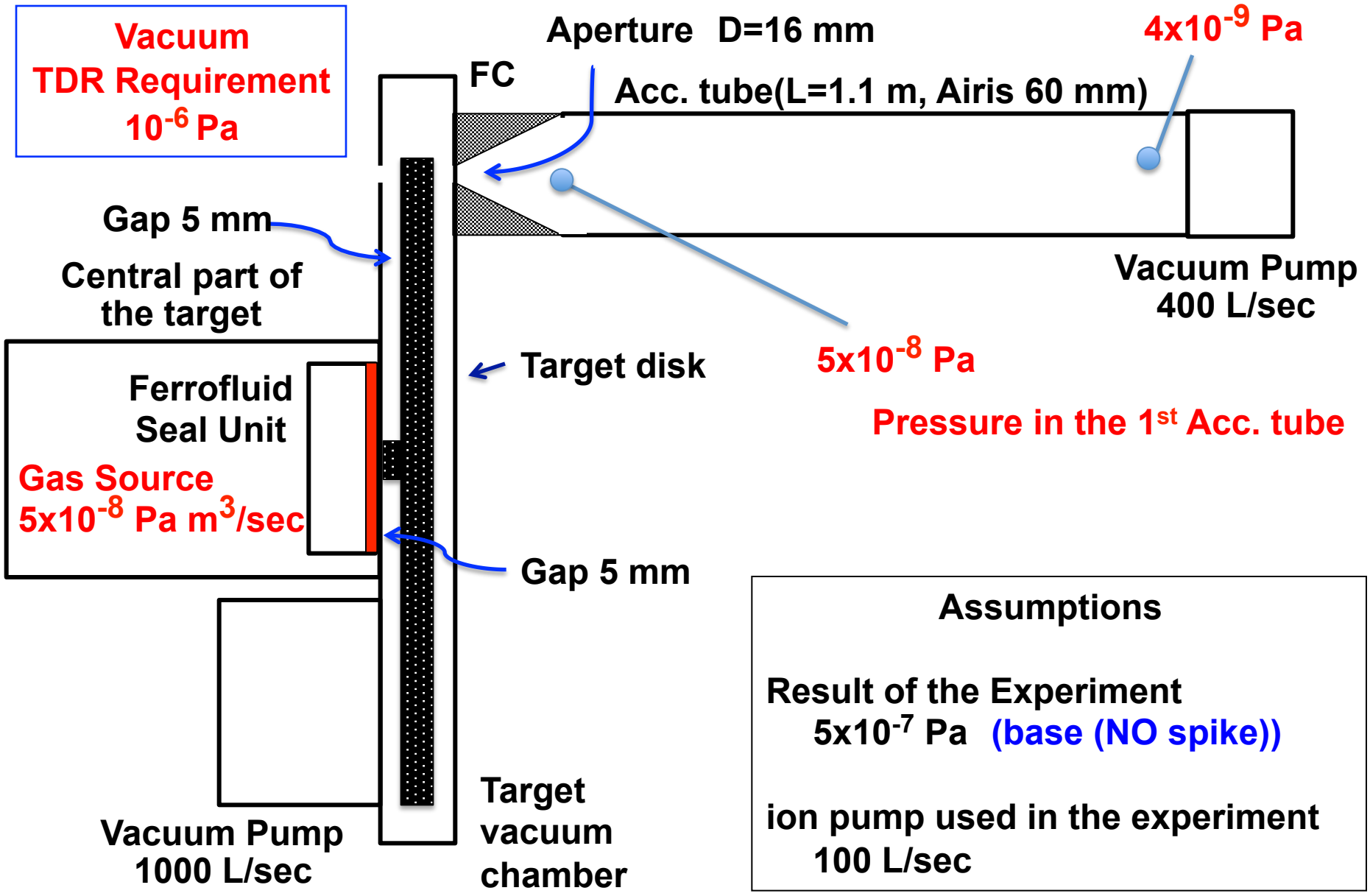
  (5×10^{-7} Pa) x (100×10^{-3} m^3/sec) = 5×10^{-8} Pa m^3/sec

* Estimate expected vacuum levels and gas flows at 1st acc-tube in ILC e+ source system by using the leak rate.

The Model


Vacuum
TDR Requirement
10-6 Pa
Aperture D=16 mm
FC
Acc. tube(L=1.1 m, Airis 60 mm)
Conductance
23.7 L/s
Gap 5 mm
Central part of
the target
Vacuum Pump
400 L/sec
Target disk
Ferrofluid
Seal Unit
Gas Source
Gap 5 mm
Conductance
306 L/s
Vacuum Pump
1000 L/sec
Target
vacuum
chamber

The Calculation based on the Model: 1

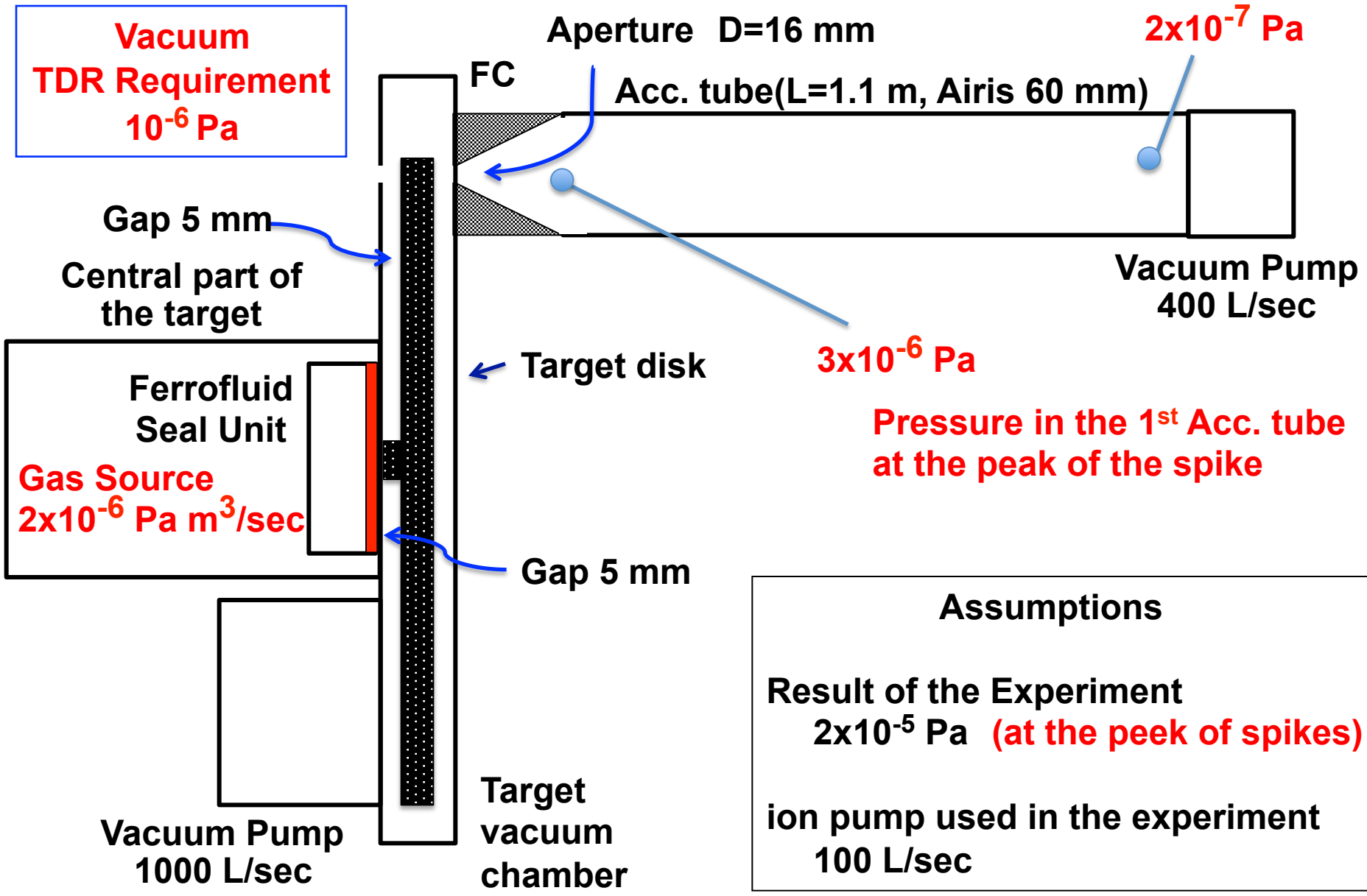


Assumptions

Result of the Experiment
5×10^{-7} Pa (base (NO spike))

ion pump used in the experiment
100 L/sec

The Calculation based on the Model: 2



Assumptions

Result of the Experiment
2×10^{-5} Pa (at the peek of spikes)

ion pump used in the experiment
100 L/sec

Plan on improvements

Result of experiment is promising

Vacuum
TDR Requirement
10^{-6} Pa

Pressure at Base

- **5×10^{-7} Pa at 225 rpm (experiment)**

  Calculation at first Acc. tube :
  from 7×10^{-8} to 4×10^{-9} Pa

Pressure at Peaks of Spike

- **2×10^{-5} Pa at 225 rpm (experiment)**

  Calculation at first Acc. tube :
  from 3×10^{-6} to 2×10^{-7} Pa

Bur we still have spikes

We are planning to make improvements.

"Super Seal" and "Two Stage Seal"

Radiation Test

Tests of Ferrofluid

November 2014

TEST was done: Radiation Tolerance

Takasaki Advanced Radiation Research Institute, JAEA

- The seal dosed up to 4.7 MGy (3 ILC year , 2600 bunch) is examined.
- Rotation : 0-600 rpm.
- No leak was found. GOOD!
- But, viscosity increased.

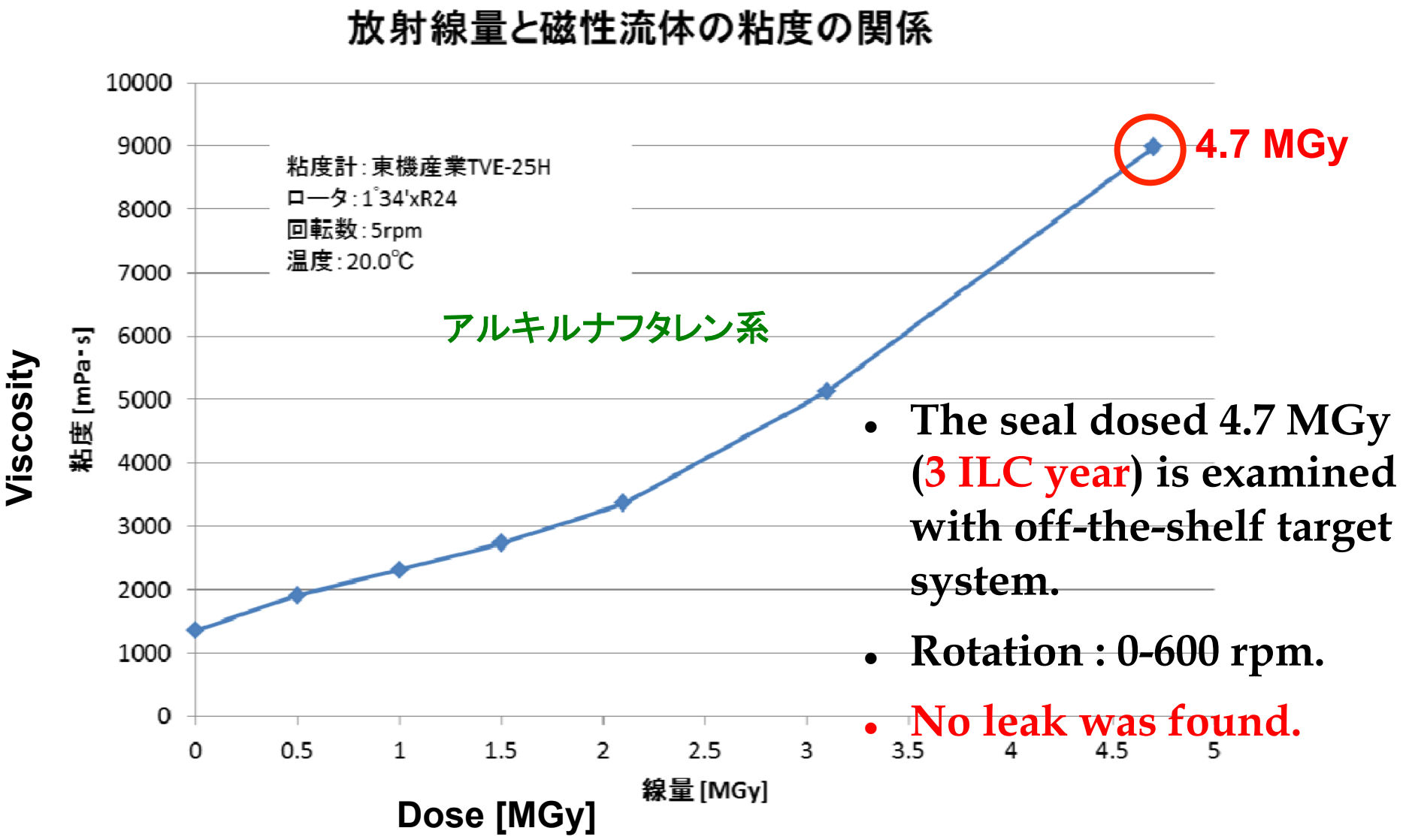
TEST: Radiation Tolerance

November 2014

More systematic study for CN oil

FY2014

Viscosity as a function of dose



- The seal dosed 4.7 MGy (3 ILC year) is examined with off-the-shelf target system.
- Rotation : 0-600 rpm.
- No leak was found.

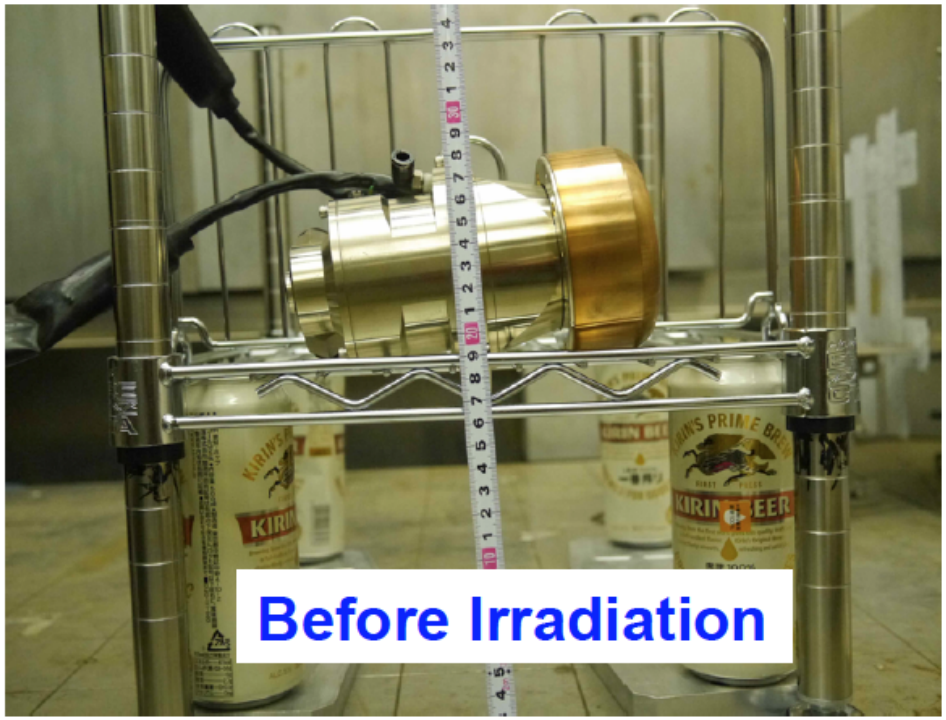
Radiation Test: Entire Target

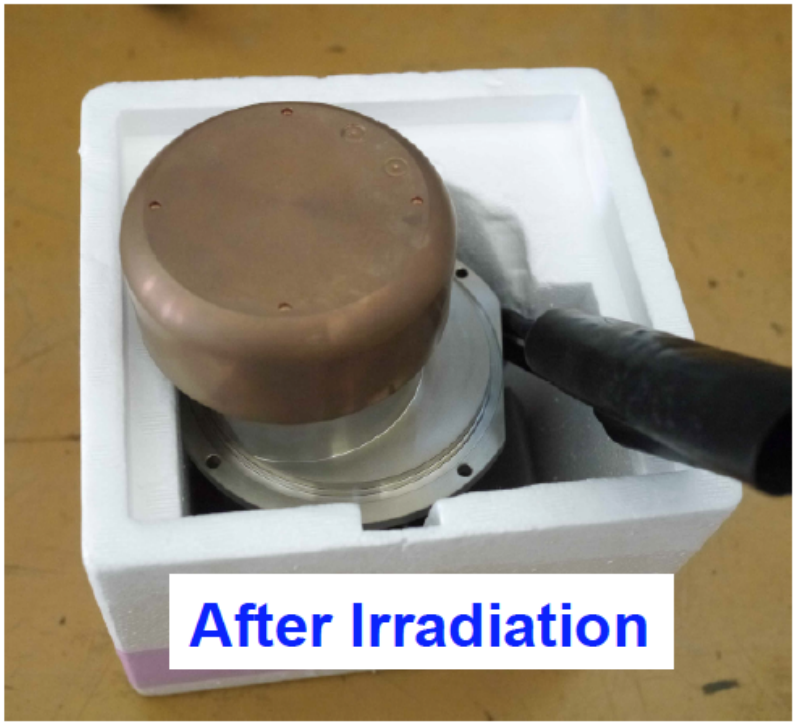
TEST: Radiation Tolerance Mar 2015

Irradiation to the small (d=10 cm) off-the-shelf rotation target

Radiation test of the whole system: motor, bearing, ferrofluid,,,

0.6 M Gy irradiation on the motor.
corresponds 1 ILC year



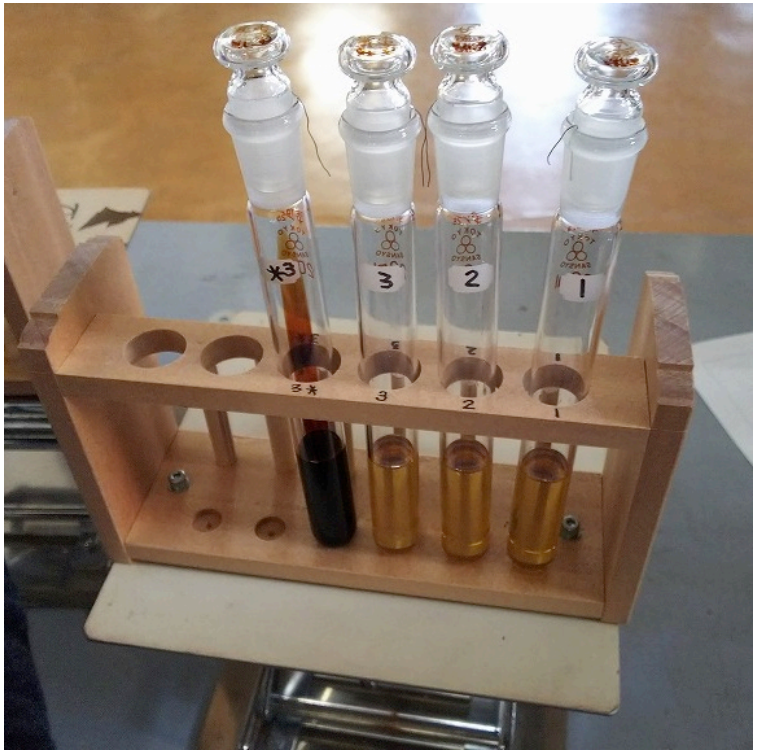


After irradiation, we made rotation and vacuum test.

We found NO problem

T. Omori

New Radiation Test:
Feb 2018 and Summer 2018



Radiation tests with monocular structure analysis by GPC and UV-Vis methods are on going.

GPC: Gel Permeation Chromatography

UV-Vis: Ultraviolet Visible Spectrophotometer

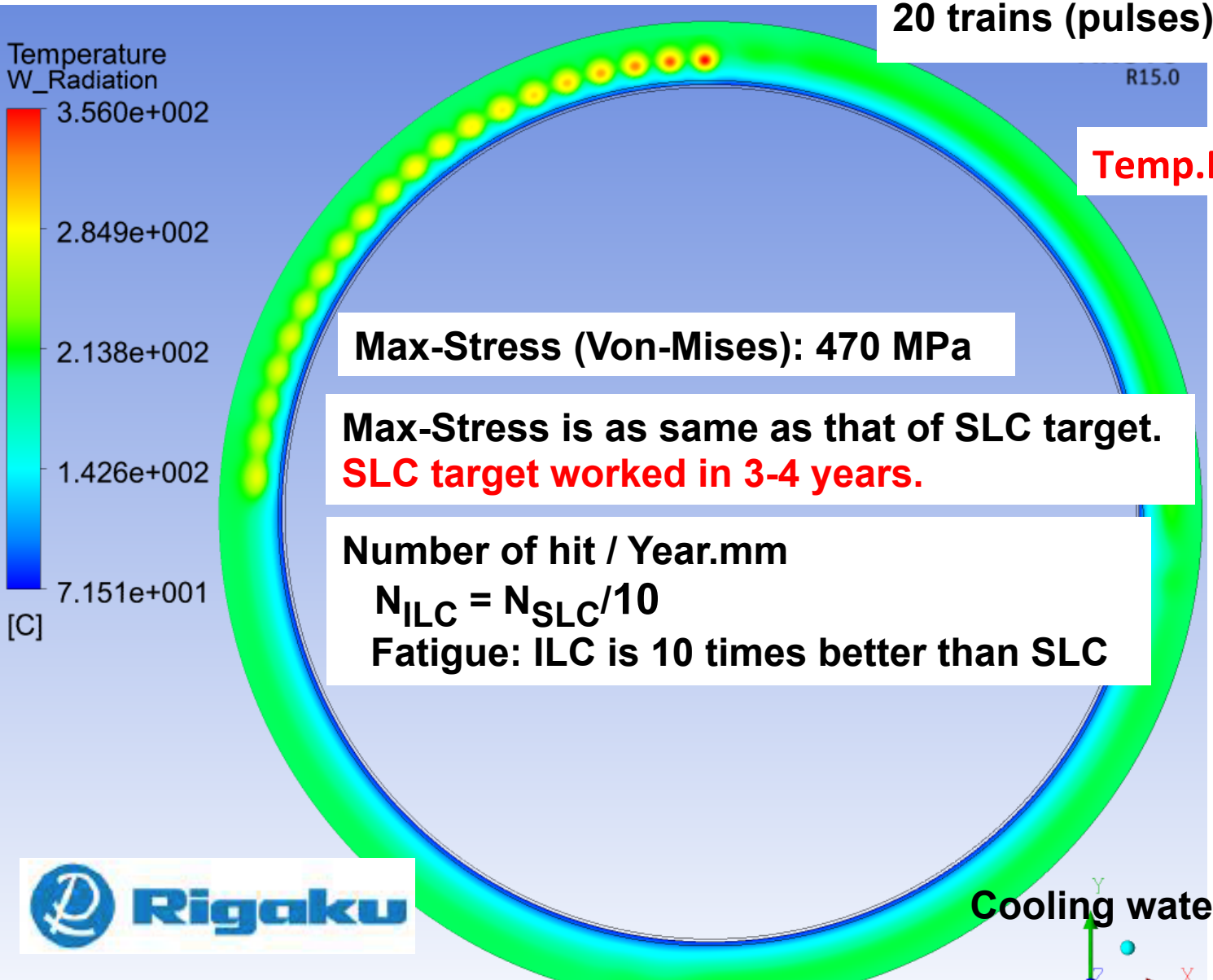
Heat&Stress Simulations

Simulation : target stress and cooling

Pulse#02 225rpm

Pulse beam analysis: step 2

20 trains (pulses) in 63 ms



Temp.Max.; 356.0℃

Max-Stress (Von-Mises): 470 MPa

Max-Stress is as same as that of SLC target.
SLC target worked in 3-4 years.

Number of hit / Year.mm
$N_{ILC} = N_{SLC}/10$
Fatigue: ILC is 10 times better than SLC

Stress: OK
Cooling: OK

$N_b = 2600$

Cooling water: 60 ℓ/min

Rigaku

Summary

Summary of Target Vacuum Test

(1) Results of the experiments (so far)

- 5 x 10^{-7} Pa at 225 rpm
- Spikes

  5 x 10^{-7} Pa → 2 x 10^{-5} Pa (every 6 hours, duration 2 min)
  (225 rpm)

(2) Calculations of Vac. at First Acc. tube(inputs: (1))

- from 7 x 10^{-8} to 4 x 10^{-9} Pa
  (when 5 x 10^{-7} Pa at near seal (base))
- from 3 x 10^{-6} to 2 x 10^{-7} Pa
  (when 2 x 10^{-5} Pa at near seal (peak of spikes))

TDR Requirement
10^{-6} Pa

(3) Plans of Improvements

Try Super Seal (in 2018)

Try two-stage seal (when we get increased budget)

Summary of the Radiation Test

(1) The ferrofluid dosed 4.7 MGy (3 ILC year, 2600b)

We used the ferrofluid in a small target. Rotation : 0-600rpm.

No leak was found. GOOD!

But, viscosity increased, and we need to know the cause.

(2) Test of entire target system

A small target was dosed 0.6 MGy at the motor.

It corresponds 1 ILC year (2600b).

No problem was found in rotation and in vacuum.

(3) Radiation tests with monocular structure analysis

The test is on going

Summary of the Heat&Stress Simulations

- Stress of the ILC target is as same as that of the SLC target.
- Compare Number of hit / Year.mm

  $N_{ILC} = N_{SLC}/10$