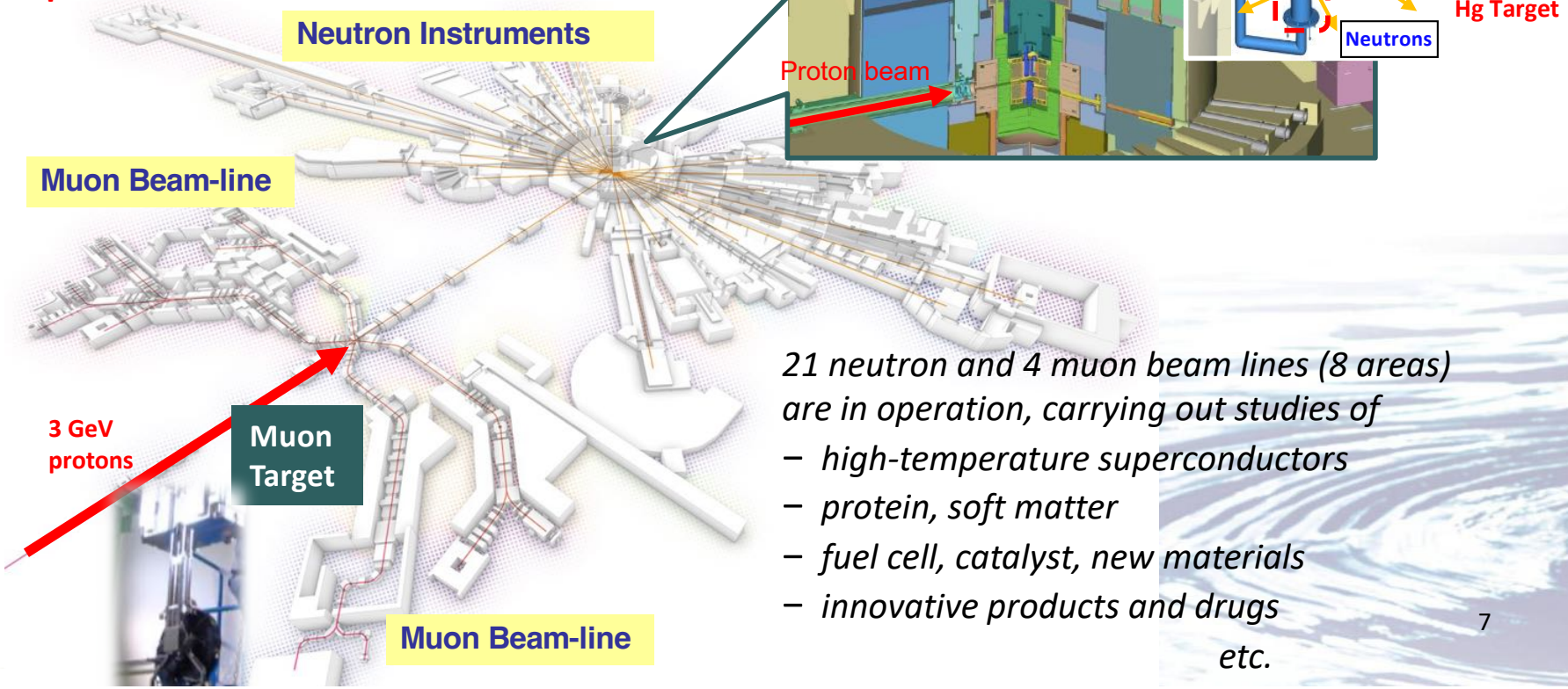
J-PARC muon facility report

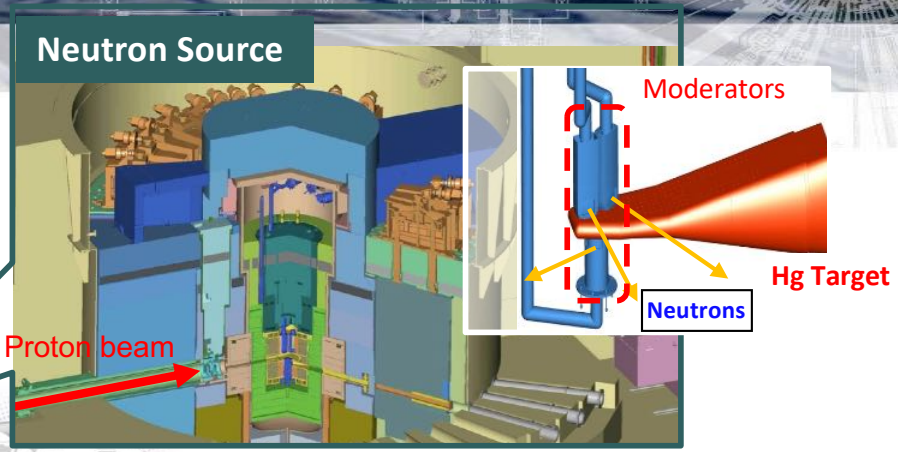
J-PARC/KEK

Akihiro KODA

Materials and Life Science Experimental Facility (MLF)

- **Neutron** and **muon** beams
  - materials science, life science, industrial applications
- **most powerful** neutron and muon sources



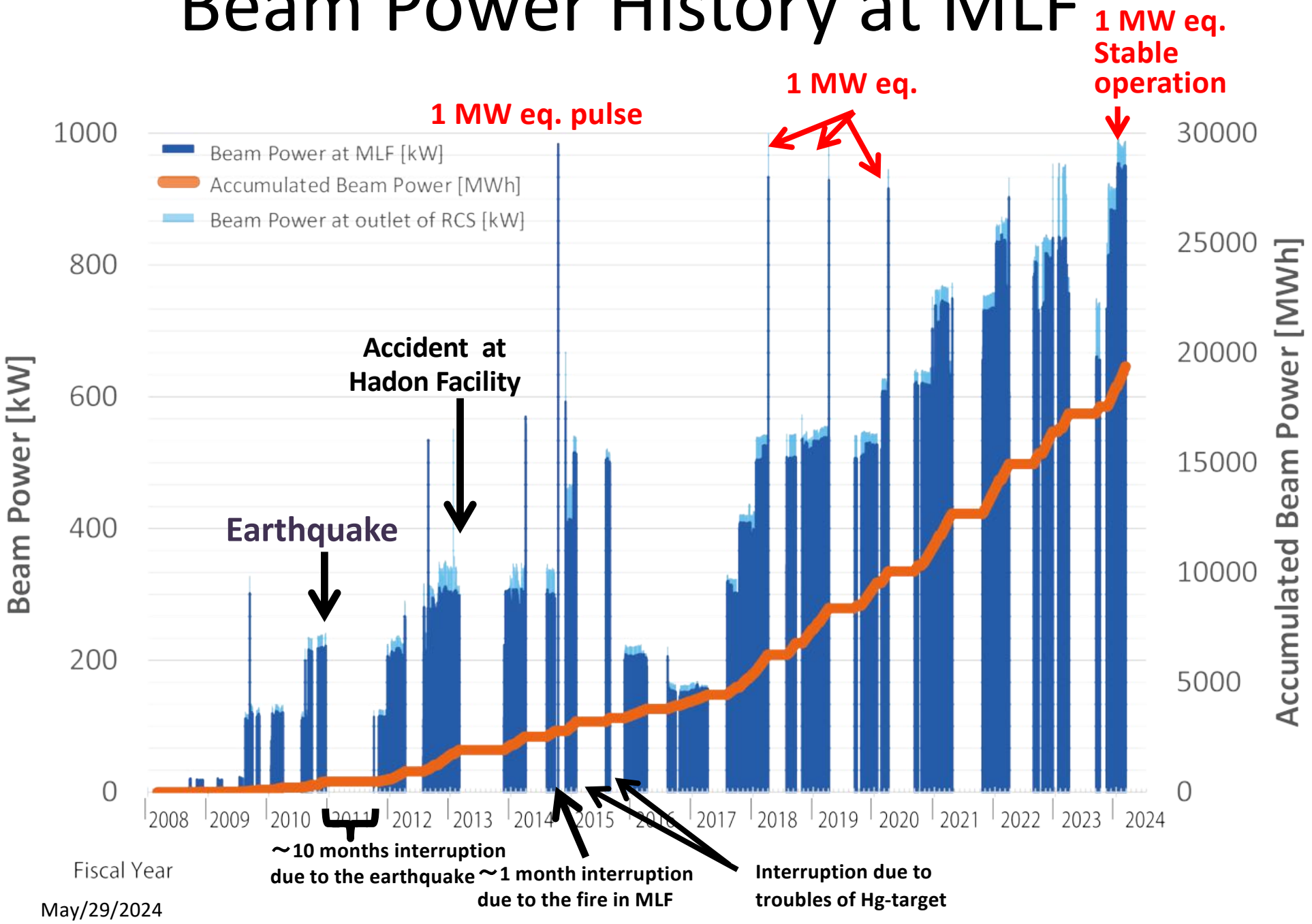


21 neutron and 4 muon beam lines (8 areas) are in operation, carrying out studies of

- *high-temperature superconductors*
- *protein, soft matter*
- *fuel cell, catalyst, new materials*
- *innovative products and drugs*

etc.

Beam Power History at MLF



May/29/2024

MLF numbers

Uniq. No. of Users

~1000

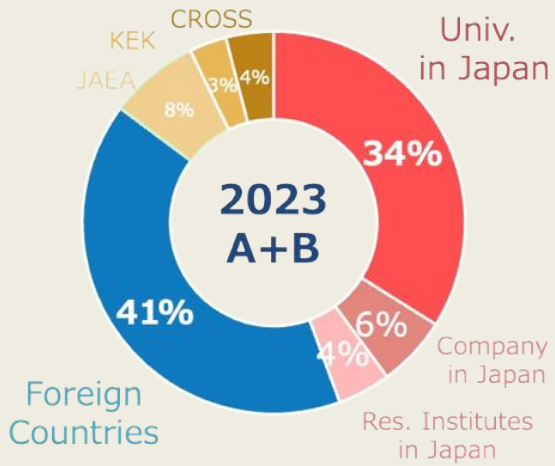
in 2023 JFY

Neutron 932, Muon 155

General proposals

~700

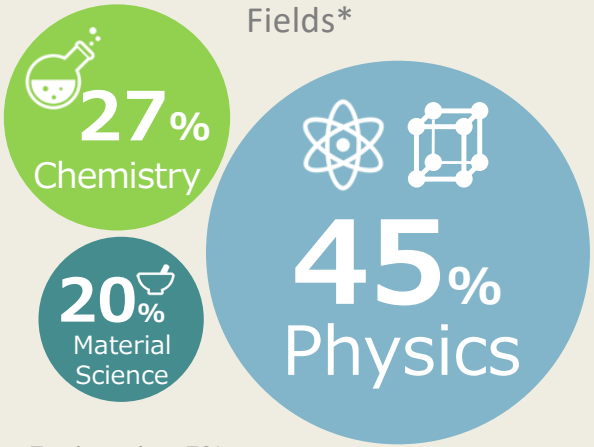
Affiliation of PI



Publications

>250

Fields*



- Engineering 5%
- Biology & Biochemistry 1 %
- Geosciences 1%
- Others 1 %

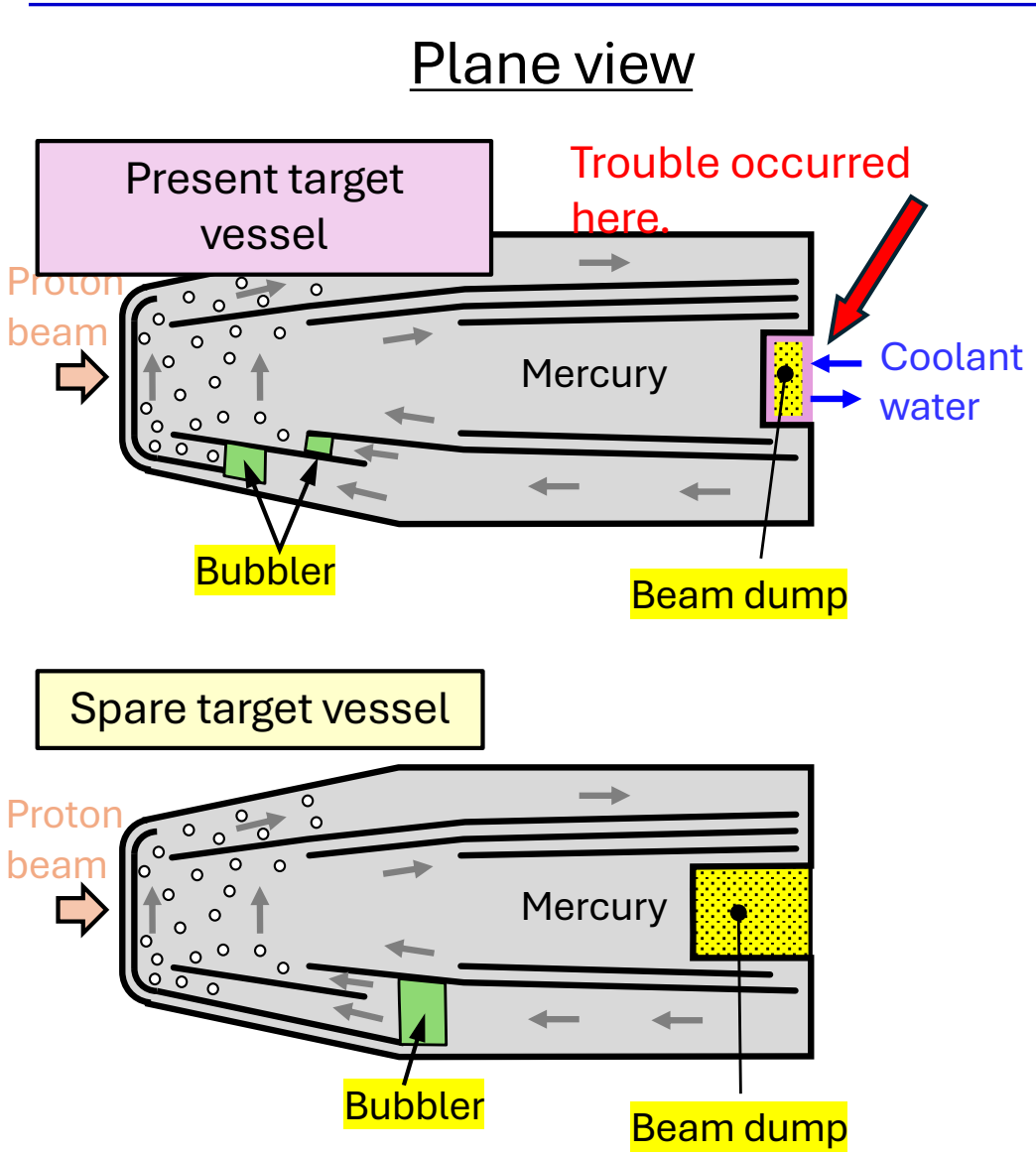
* 2006-2023

Excl. Ibaraki BL

Trouble with beam shutdown at MLF in the last year

- Jun. 2024: Humidity detection in He vessel
- Nov. 2024: Failure of the Power Manipulator in the Hot cell
- Jan. 2025: Leakage from the Hg circulation system
- Jun. 2025: Cooling water leakage of the Neutron production target

Cause of Trouble and Difference of Target Vessel Design



- It is likely that the trouble was induced by localized stress concentration and thermal fatigue at the water-cooled beam dump due to repeated beam operation.
- It has been verified that the spare target does not contain any areas prone to similar failures.
- The beam power for the spare target will be decided taking the safety margin in the thermal fatigue and pitting damage depth into consideration.
  - Around 700 kW is considered a leading candidate.

Muon beamlines

S-line μ^+

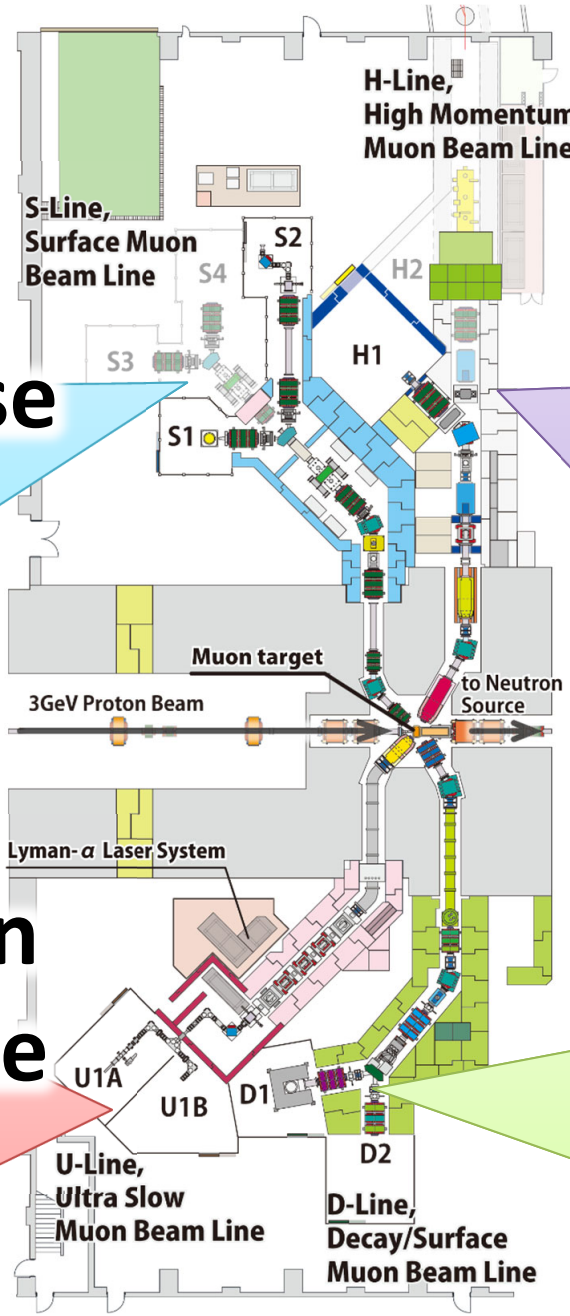
Surface muon (4 MeV)
dedicated to bulk μSR
in 4 experimental areas
w/ various sample env.
ultra-low temperature
high magnetic field
pulsed excitations *etc.*

4 areas
Simultaneous use

H-line μ^+/μ^-

High-intensity surface
muon (<4 - 50 MeV)
"fundamental physics"
requiring high precision,
high sensitivity

High Intensity
General Use



U-line μ^+

(0.1 - 30 keV)
/interface sciences (U1A)
Test-bench for TμM
(U1B)

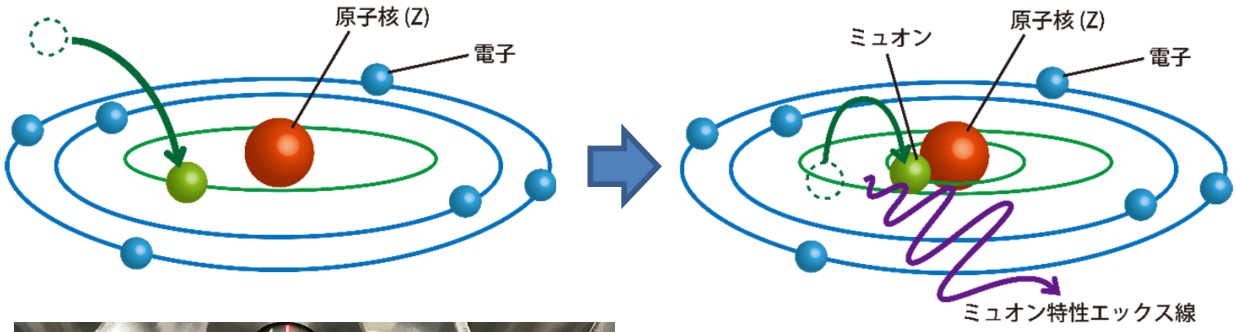
Ultra Slow Muon
Surface/Interface

D-line μ^+/μ^-

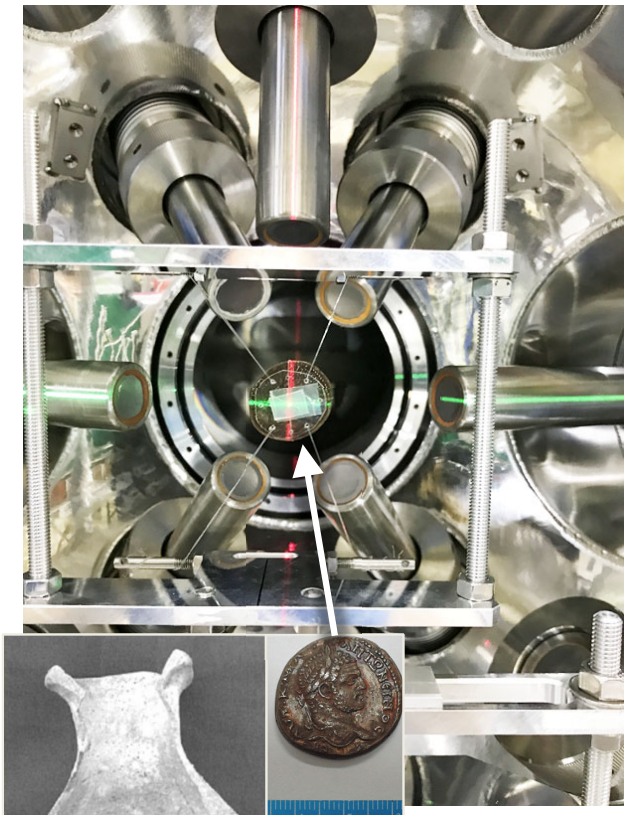
Decay and surface muon
to answer a variety of
users' demands with
μSR spectrometer (D1)
general purpose (D2)

General Use

D-line: Research on the Integration of Arts and Science

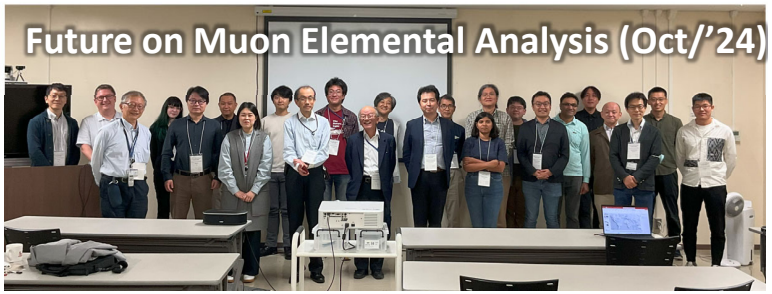


To promote this field of study, we made a dedicated panel for the heritage science in this FY. The reviewers are from museums and the facility.



Caracalla silver coin (AC.188～217, Syria)

Remaining scales from fire of the golden fabulous fish on the roof of Nagoya castle

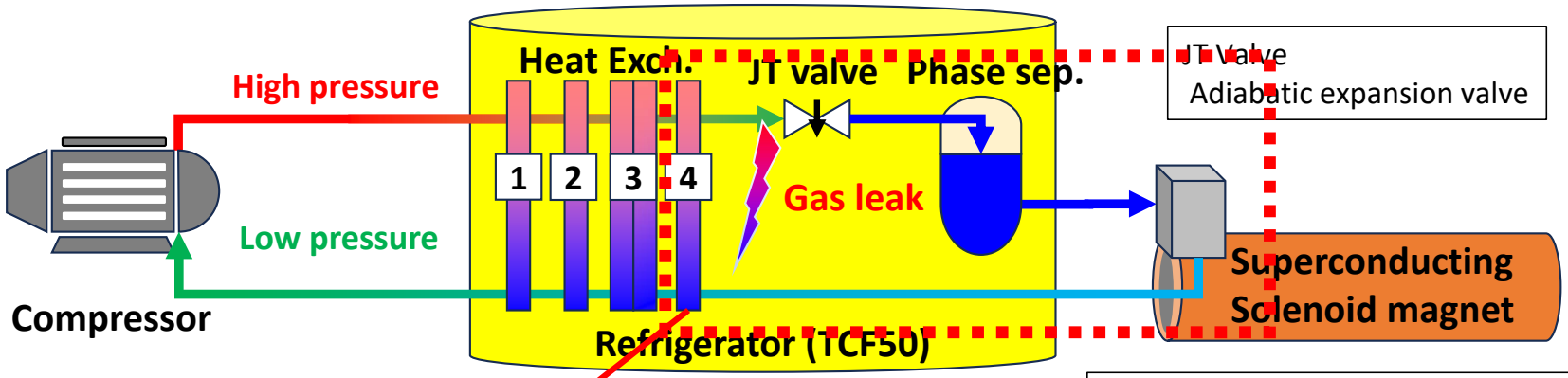


Muon's application to heritage science has become world trend. We hope to form an international relationship to promote this field with neutron and SR as well as μ.

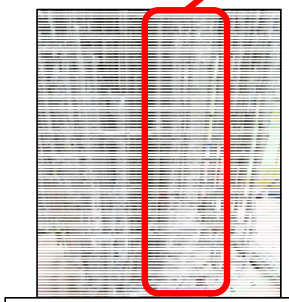
1. Small Gas Leak in Refrigerator for D-line Solenoid

Deterioration

- Small gas leak was found between high pressure- and low pressure-line of the refrigerator for the superconducting solenoid magnet in FY2023.



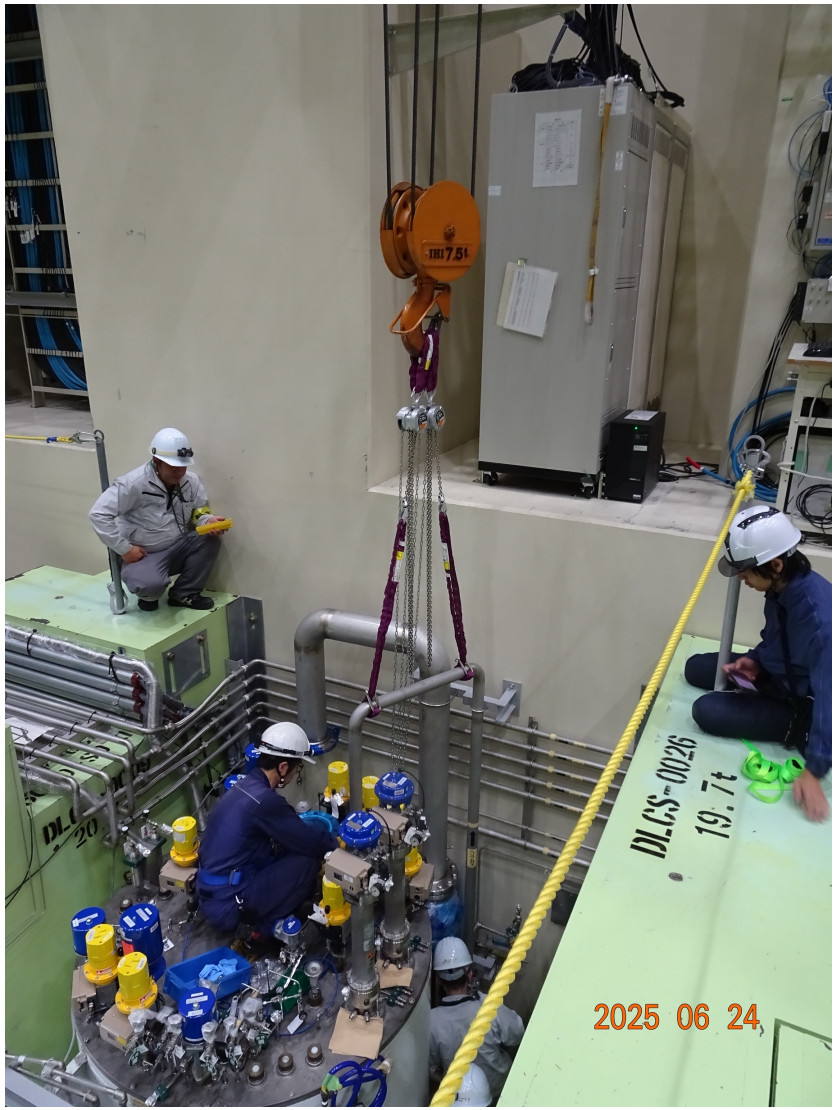
Refrigerator (TCF50)



4th heat exchanger

Investigate the leak with a stethoscope. From the loudness of the sound, it is thought to be leaking at **the 4th heat exchanger or later**.

The refrigerator has been in continuous operation for as long as 24 years since its Tsukuba days.



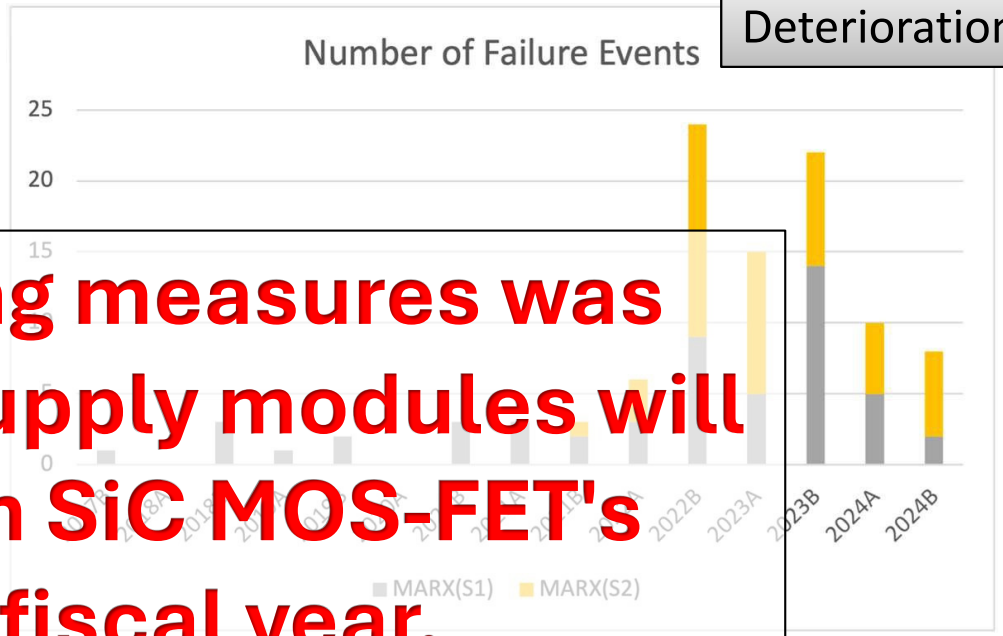
LATEST NEWS:
The leak was found to be caused by unused piping in the 4th heat exchanger. Work is in progress to disconnect unused piping.

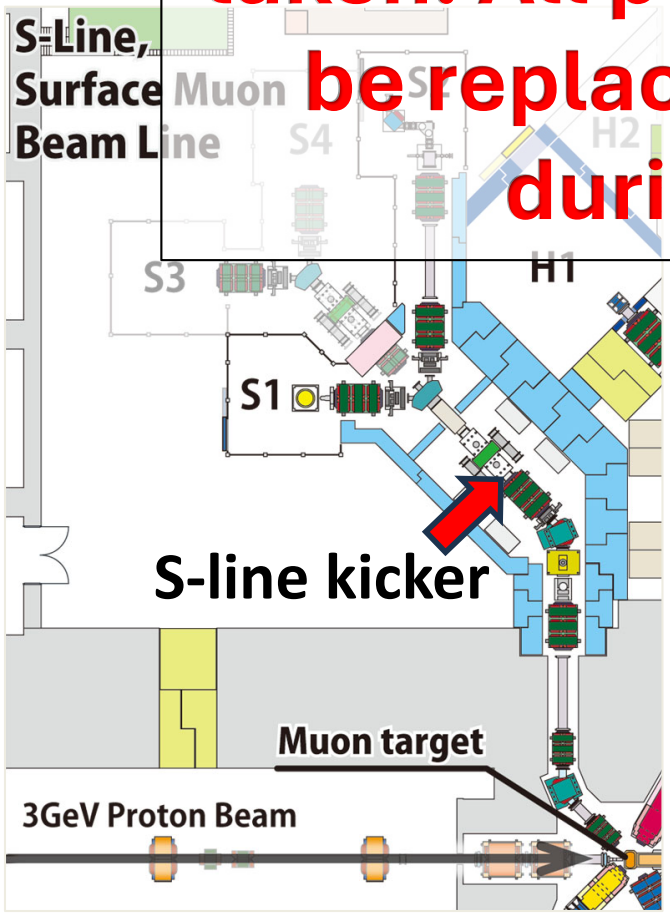
S-line: Operation Status of the Kicker

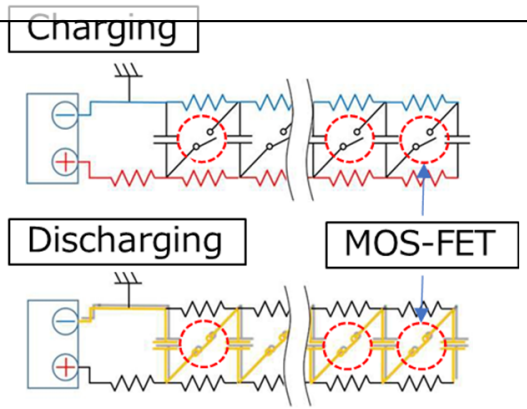
The S-line kicker is a key device to provide single-pulsed beam to S1 and S2 areas simultaneously. However, failure events have occurred in high rate due to FET problem for these years.
The recovery work takes half a day and obstacle to efficient operation.

A budget for aging measures was taken. All power supply modules will be replaced with SiC MOS-FET's during this fiscal year.

Deterioration

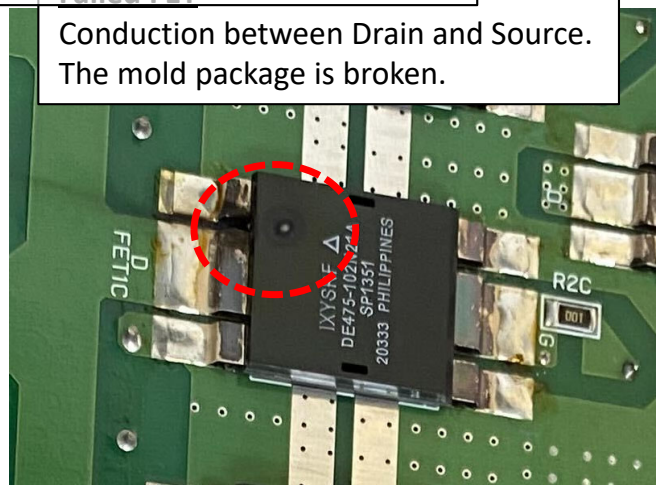






2,304 MOS-FETs are used for high-voltage switch to kick the beam by high voltage pulse of ±50kV with 300 ns.

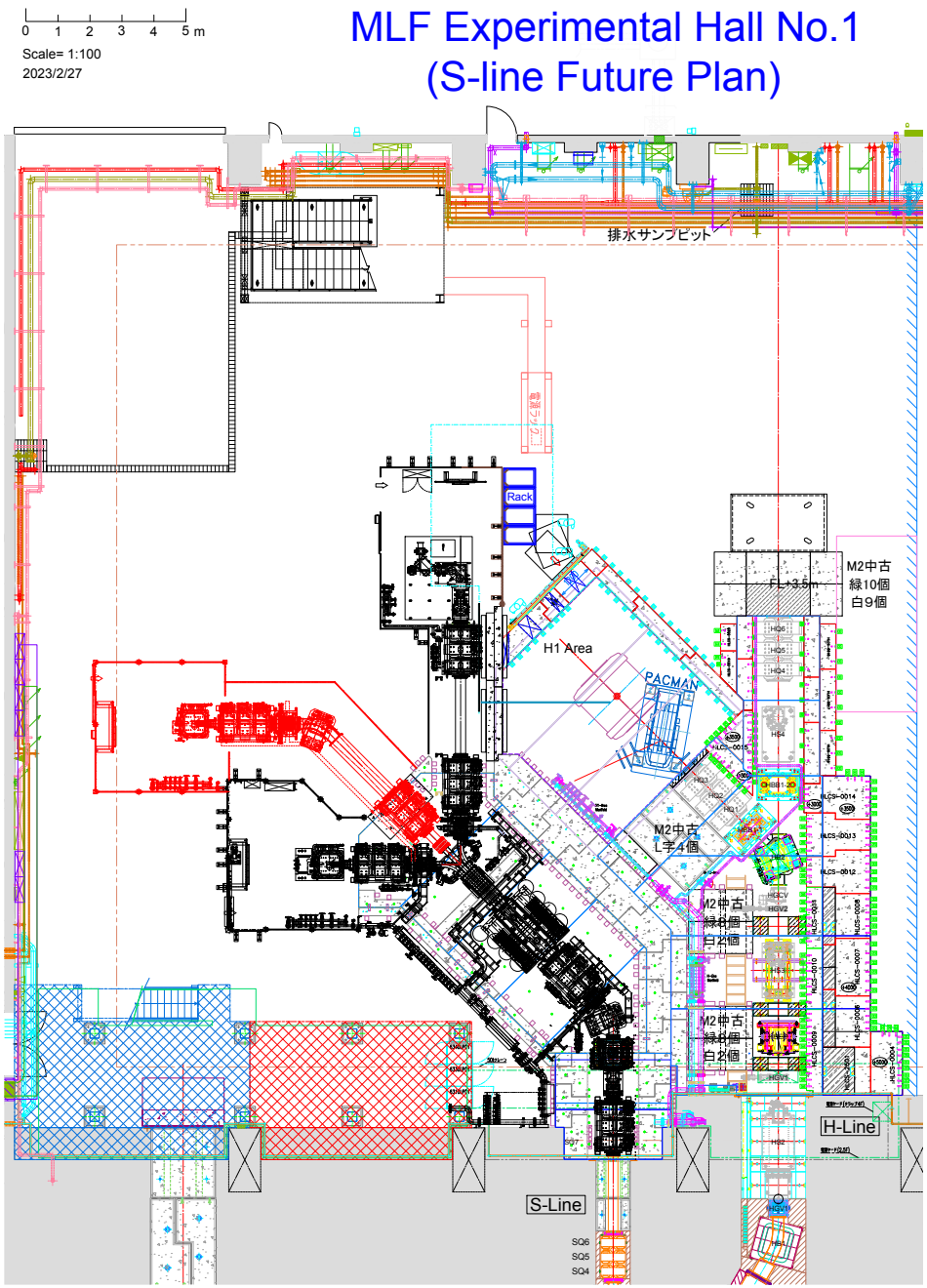
Failed FET
Conduction between Drain and Source.
The mold package is broken.



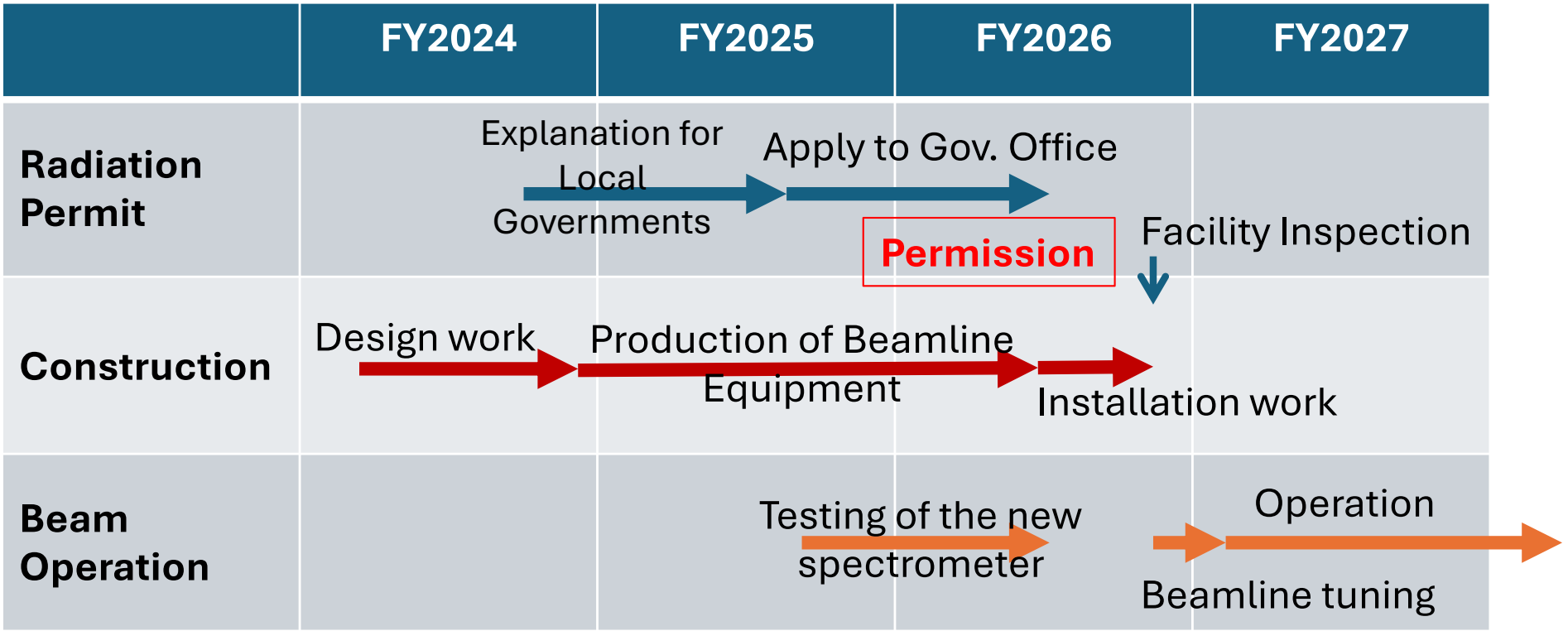
The above used MOS-FET is discontinued. We will replace them with SiC MOS-FET which has higher withstanding voltage.

S3 area

A Grant-in-Aid for Scientific Research on Ion Battery Materials (PI: Prof. M. Hirayama, Inst. of Science Tokyo) has been adopted from FY2024, and the S3 area construction plan has started under the support of CIQuS, KEK-IMSS.



S3: Construction Schedule



A detailed report will be given by Pant san at the Poster session #2 on Thurs day.

U-Line: Project Timeline

First beam of Super-Omega
Y. Ikedo et al., NIM B 317 (2013) 365-368.

USM generation
T. Adachi et al., KEK-MSL Progress Report. 2016-3 (2016) 13.

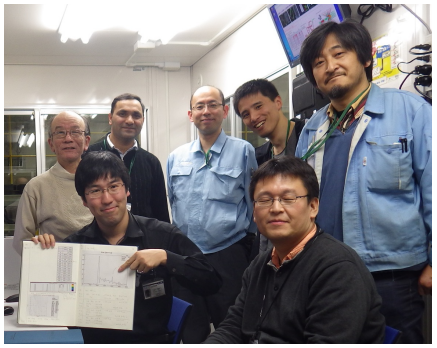
Multilayer USM-μSR
S. Kanda et al, J. Phys.: Conf. Ser. 2462 012030 (2023).

2012 — 2013 — 2016 — 2018 — 2020

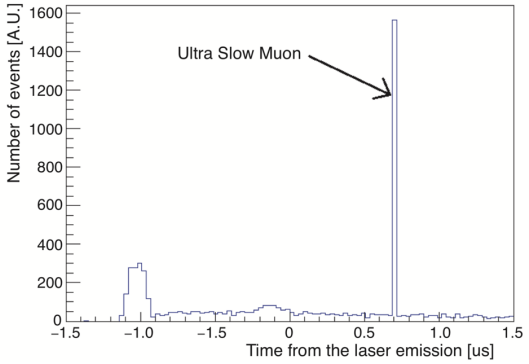
Lyman-α generation with all-solid laser
Y. Oishi et al., JPS Conf. Proc. 2, 010105 (2014).

First USM-μSR
T. Adachi et al., KEK-MSL Progress Report. 2018-2 (2018) 13.

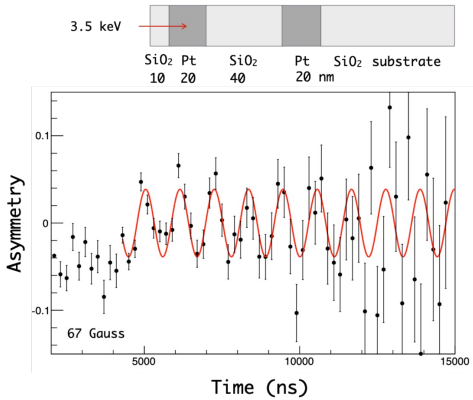
First Ly-α
2013



First USM
2016



USM time-of-flight
2016

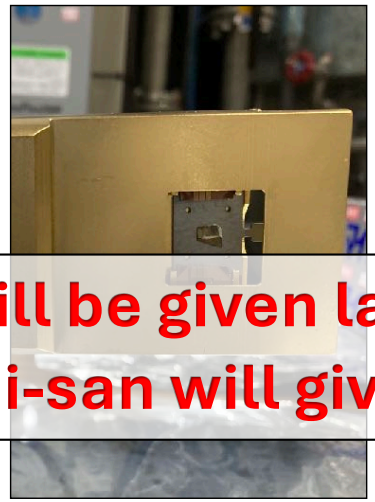


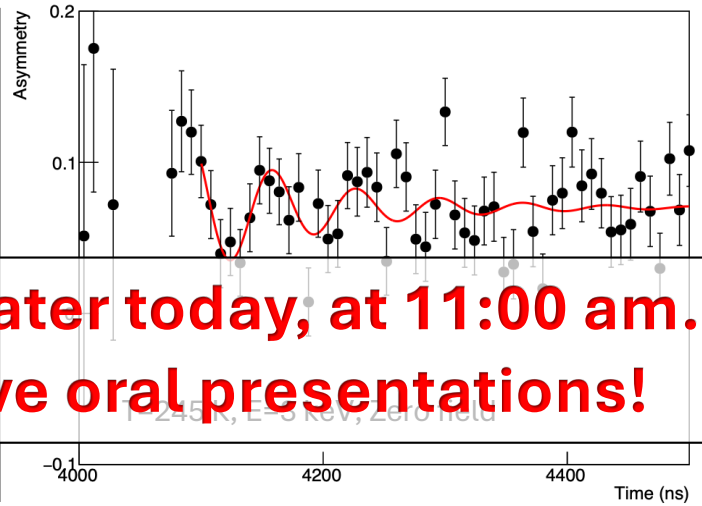
USM-μSR asymmetry
2020

U-Line: First Scientific Campaign

Sample fabrication by pulsed laser deposition.

Thin film sample of $Ca_{0.85}Sr_{0.15}CuO_2$ mounted on the cryostat.





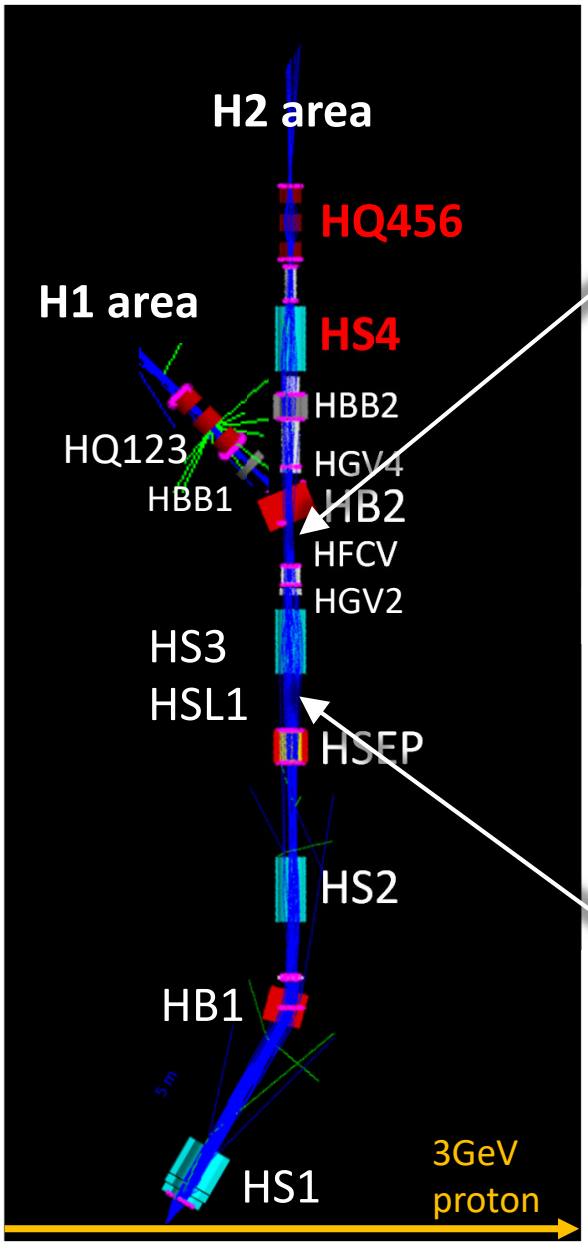
Preliminary result of the zero-field μSR measurement.

Detailed status reports will be given later today, at 11:00 am.
Kanda-san and Nagatani-san will give oral presentations!

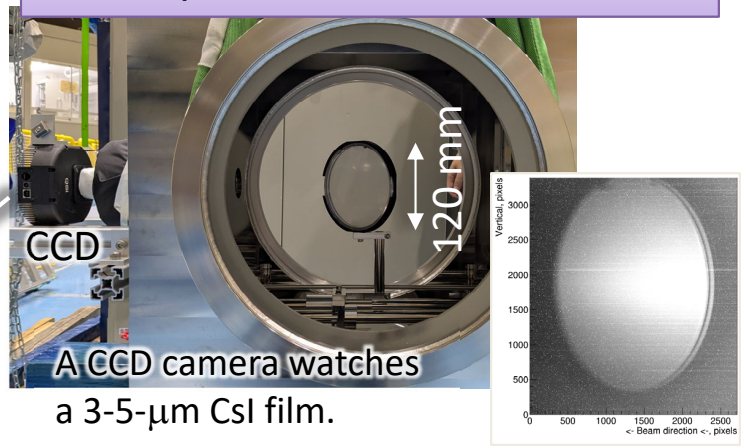
- First scientific measurements of USM-μSR has been started with a cuprate thin-film sample.
- A full-scale physics measurements involving the sample transportation, cooling, and control of implantation energy.
- Muon spin rotation originating from internal magnetic fields inside the sample was successfully observed.

Works with T. Adachi's group of Sophia University,
J. G. Nakamura and H. Okabe(KEK IMSS) .

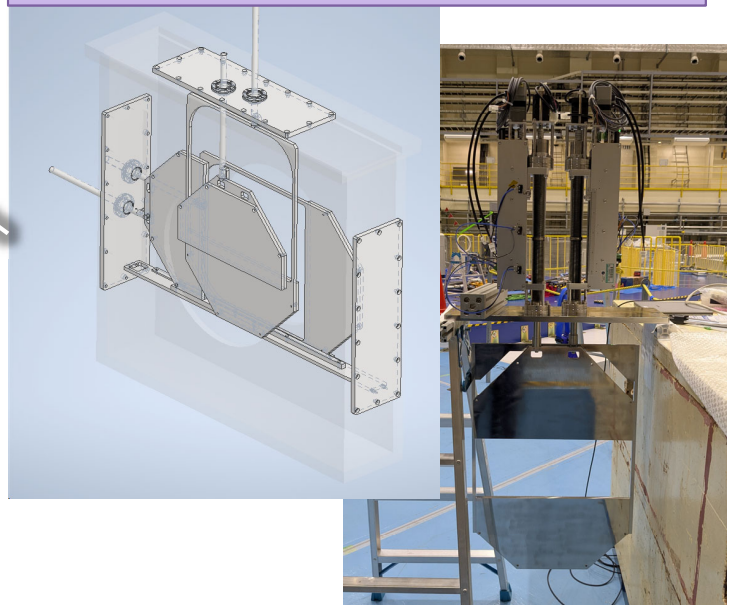
H-line: Upgrading of beamline



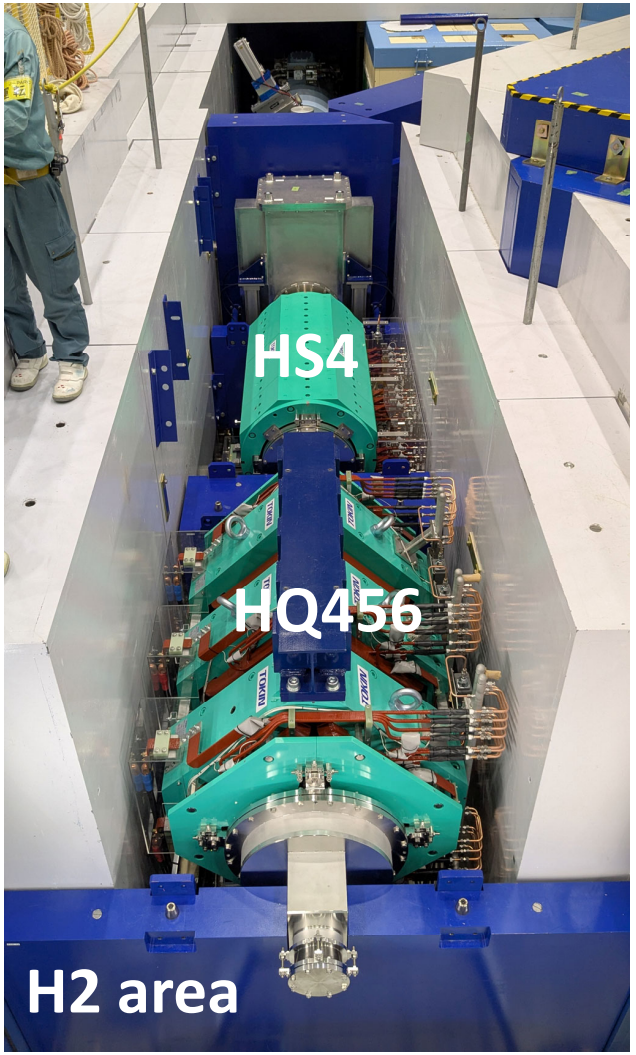
A beam-profile monitor developed at BINP was installed.



A slit was installed by the RIKEN group (new S1-type user)



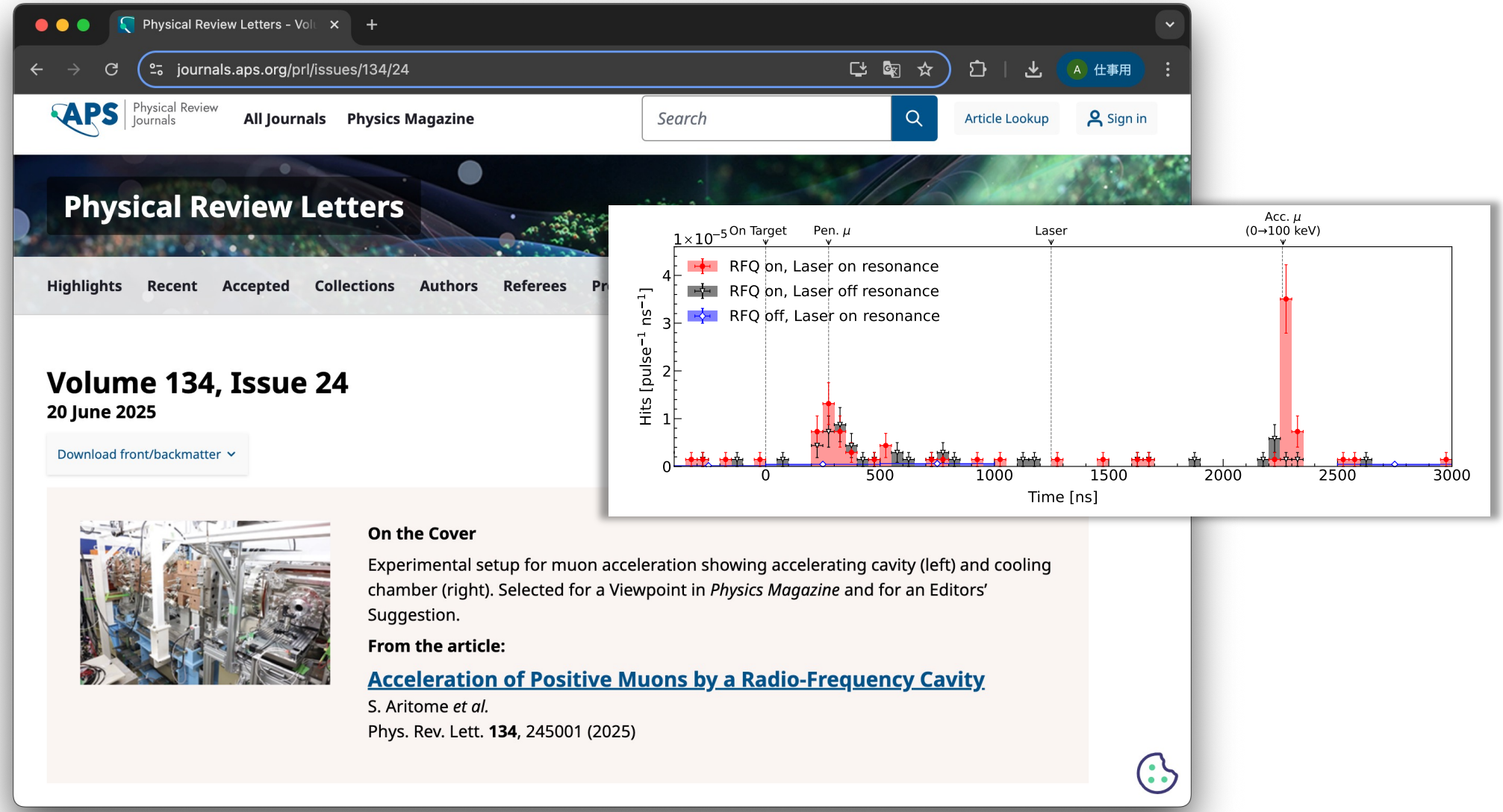
The final focusing magnets were installed.
The beam-commissioning will start in the next FY.



First Beam at the H2 area!

In May 2025, a facility inspection was conducted and a permit was granted for the H2 area. Adjustment of the muon accelerator will begin shortly.

Scientific Topics:
Muon accelaration



Scientific Topics: Observation of Highly Charged Muonic Atoms

PHYSICAL REVIEW LETTERS **134,** 243001 (2025)

Editors' Suggestion

Few-Electron Highly Charged Muonic Ar Atoms Verified by Electronic *K* X Rays

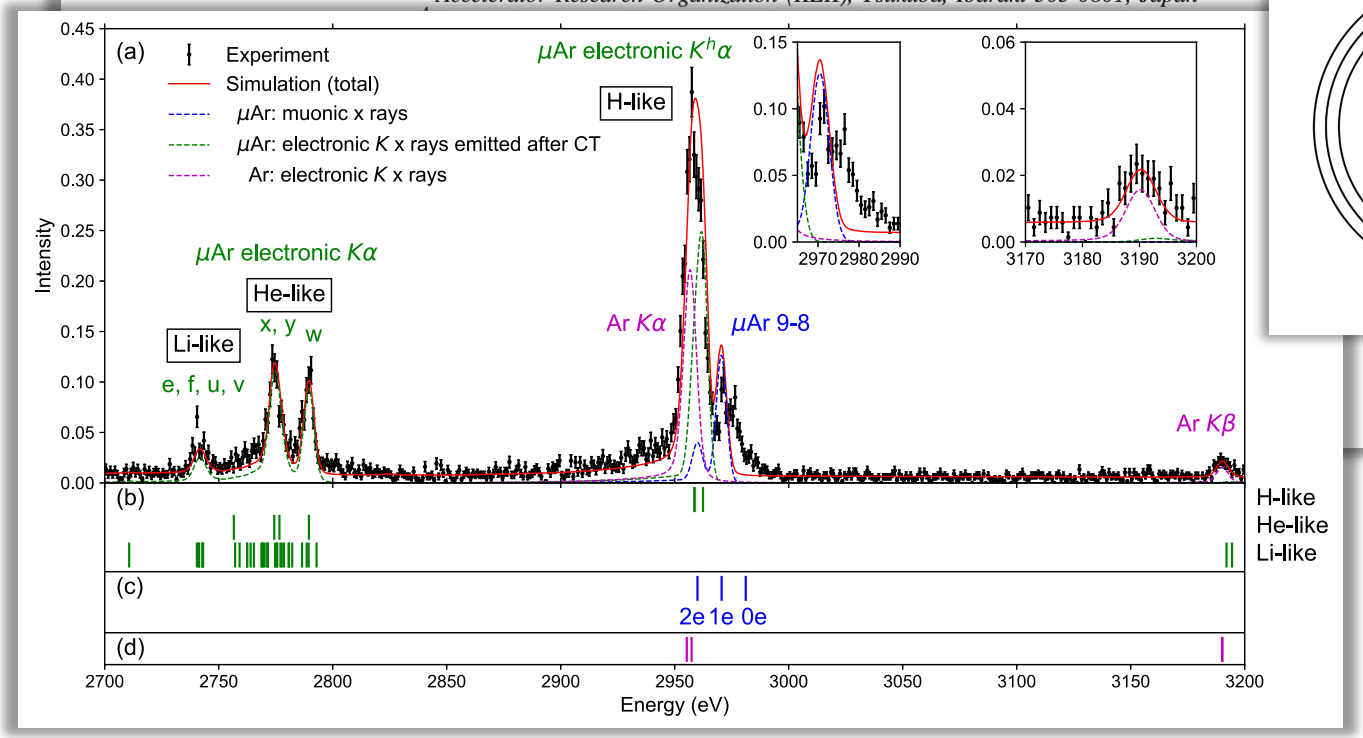
T. Okumura,[1,*] T. Azuma,[2,3,†] D. A. Bennett,[4] W. B. Doriese,[4] M. S. Durkin,[5] J. W. Fowler,[4] J. D. Gard,[5] T. Hashimoto,[6,7] R. Hayakawa,[3] Y. Ichinohe,[7] P. Indelicato,[8] T. Isobe,[7] S. Kanda,[9] D. Kato,[10,11] M. Katsuragawa,[12] N. Kawamura,[9] Y. Kino,[13] N. Kominato,[14] Y. Miyake,[9] K. M. Morgan,[4,5] H. Noda,[15] G. C. O'Neil,[4] S. Okada,[16,17,10,‡] K. Okutsu,[13] N. Paul,[8] C. D. Reintsema,[4] T. Sato,[18] D. R. Schmidt,[4] K. Shimomura,[9] P. Strasser,[9] D. S. Swetz,[4] T. Takahashi,[12] S. Takeda,[12] S. Takeshita,[9] M. Tampo,[9] H. Tatsuno,[19] K. Tőkési,[20] X. M. Tong,[21] Y. Toyama,[17] J. N. Ullom,[4,5] S. Watanabe,[22] S. Yamada,[14] and T. Yamashita[13]

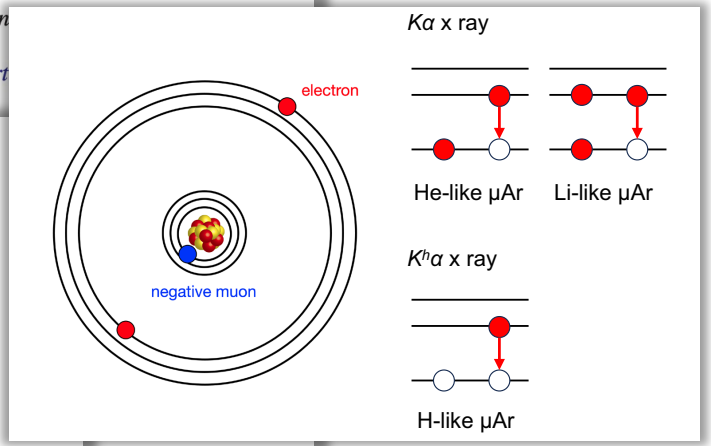
[1]*Department of Chemistry, Tokyo Metropolitan University, Hachioji, Tokyo 192-0397, Japan*

[2]*Atomic, Molecular and Optical Physics Laboratory, RIKEN, Wako 351-0198, Japan*

[3]*WPI-QUP, International Center for Quantum-field Measurement Systems for Studies of the Universe and Part*

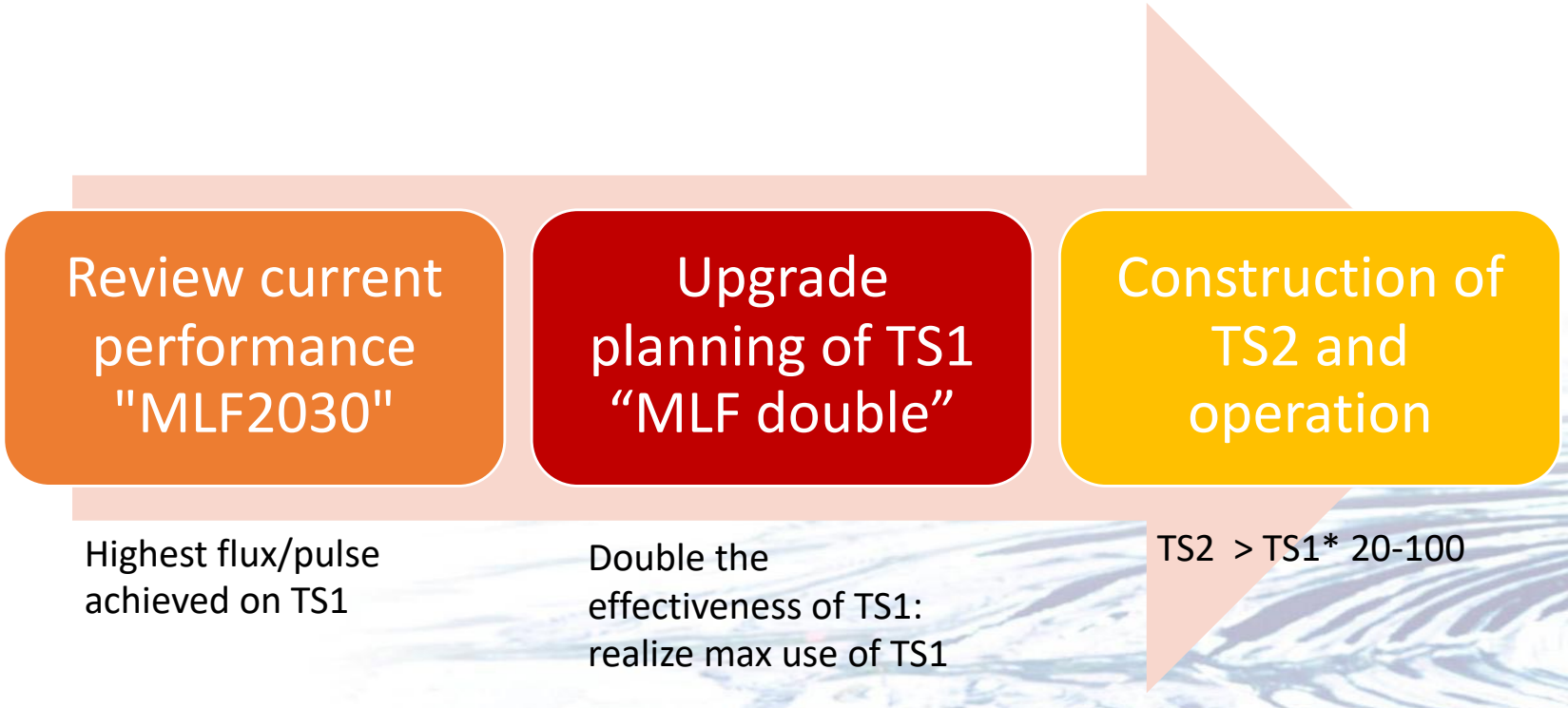
Accelerator Research Organization (KEK), Tsukuba, Ibaraki 305-0801, Japan

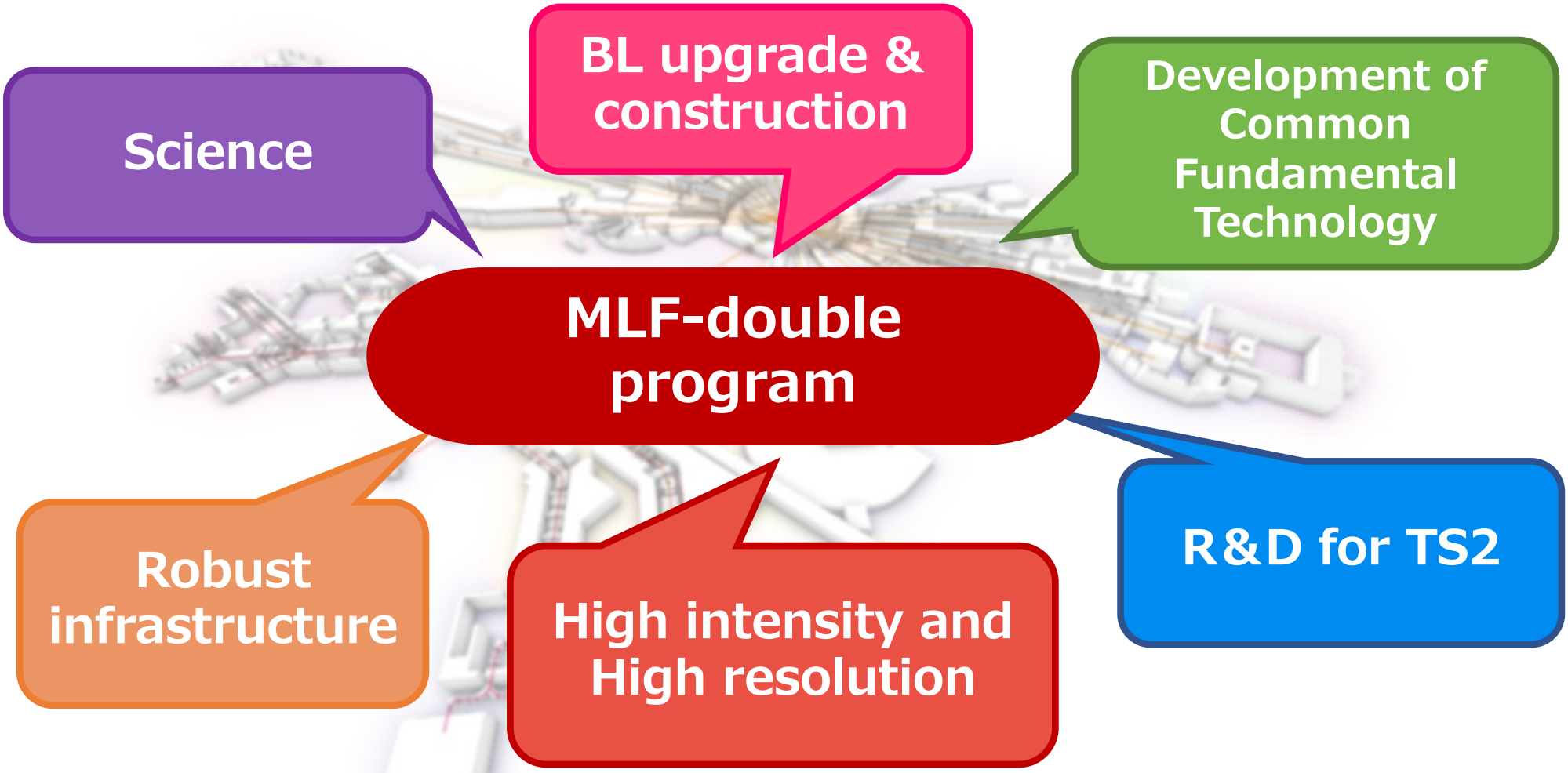




Future J-PARC MLF

MLF roadmap

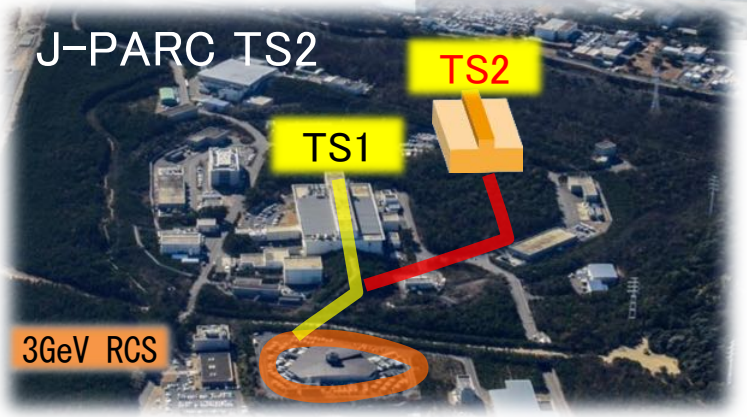

Review current performance "MLF2030"
Upgrade planning of TS1 “MLF double”
Construction of TS2 and operation
Highest flux/pulse achieved on TS1
Double the effectiveness of TS1: realize max use of TS1
TS2 > TS1* 20-100



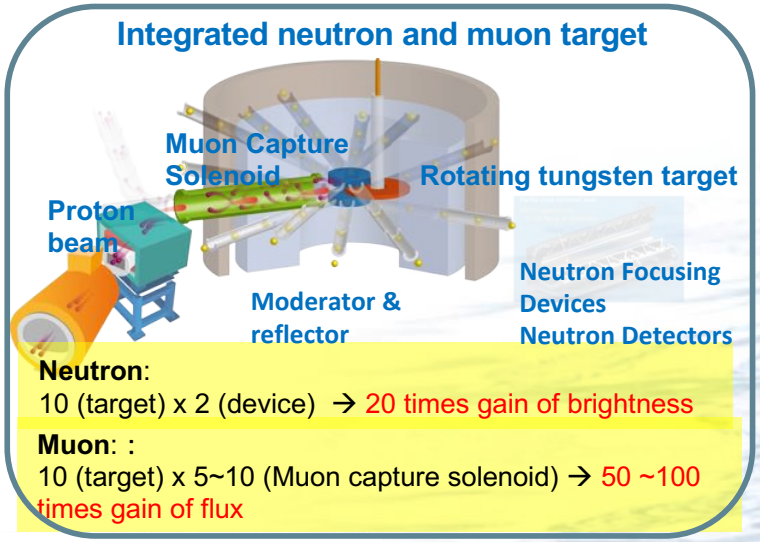
Aiming to double the effectiveness of TS1: realize max use of TS1

Target Station - 2

The Science Council of Japan has decided to formulate a new "Future Science Promotion Plan"

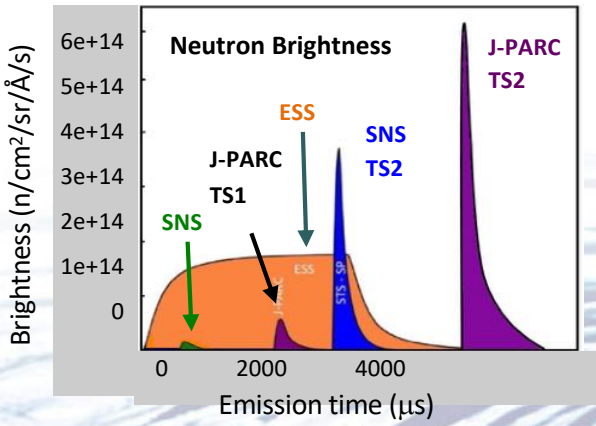


- Integration of neutron and muon sources (world's first)
- J-PARC proton accelerator intensity (1 MW) increased to 1.5 MW
- 1 MW (17 Hz) for TS1 and 0.5 MW (8 Hz) for TS2



Neutron:
10 (target) x 2 (device) → 20 times gain of brightness

Muon: :
10 (target) x 5~10 (Muon capture solenoid) → 50 ~100 times gain of flux



Brightness of MLF TS2 will be the world's highest compared to the next plan of overseas facilities

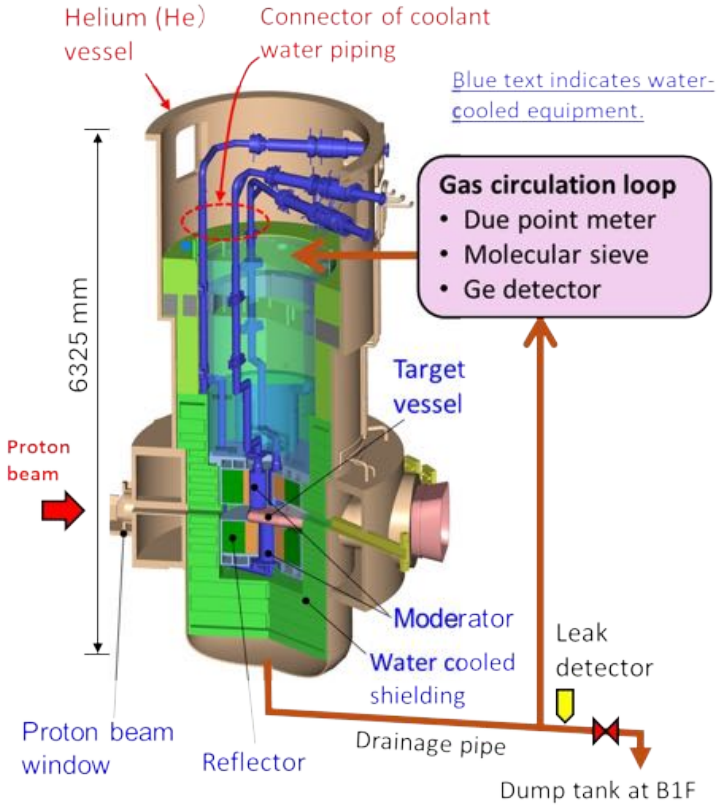
This year, the revision of the Future Science Promotion Plan has begun, and a special workshop on MLF is planned for coming Aug. 26.

Summary

- Since last year, MLF has had to shut down the beam due to various problems.
- The cause of the refrigerator problem that had been a concern on the **D-Line** has been identified, and work is underway to fix.
- Preparations for the construction of a new beam area, S3, have begun on the **S-Line**.
- The **U-Line** is ready for measurement.
- The first beam at the H2 area of the **H-Line** is confirmed.
- Discussions have begun at MLF for future planning.

Fin.

Increase of humidity in the He vessel



Sequence of events

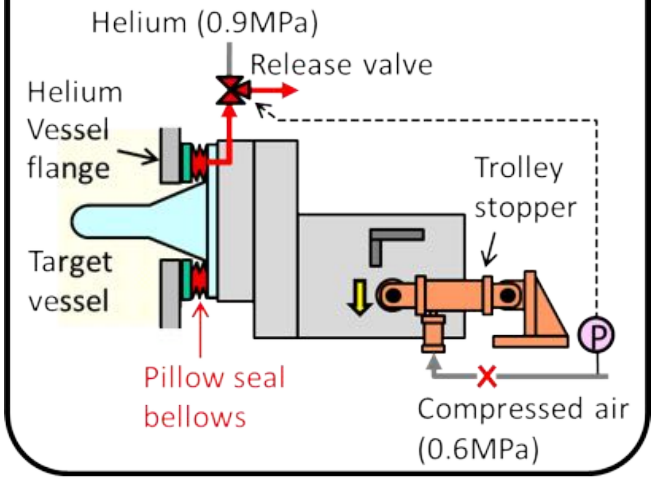
- The due point meter detected the increase of humidity that was higher than usual in the He vessel on Jun. 24, 2024.
- MLF user beam operation was stopped 7 days earlier than scheduled date .

Cause investigation

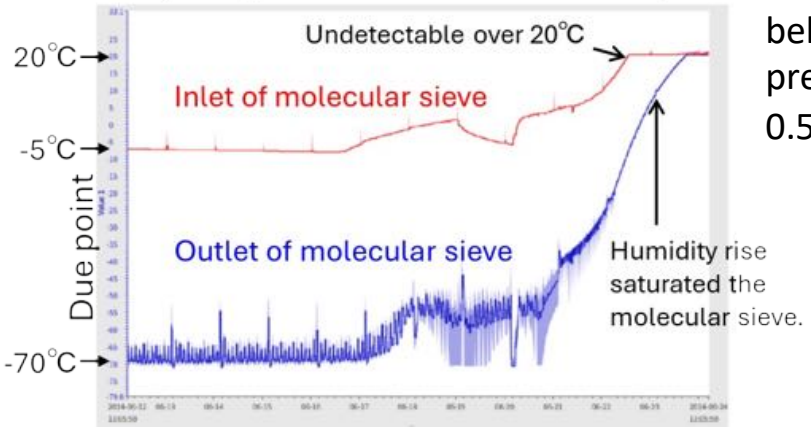
- It was found that the seal performance of the target vessel pillow seal deteriorated repeatedly during June, which might caused intrusion of humid air into the He vessel.

Helium gas in the pillow seal bellows is released when the air pressure goes down less than 0.5MPa.

Interlock to prevent excessive stretching of the pillow seal bellows



Due point data in the He vessel



- The air pressure dropped below 0.5MPa several times due to overuse of compressed air in June.
- Countermeasures were implemented to prevent the functionality reduction of the pillow seal.

Failure of Power Manipulator Caused Delayed Start of Beam Operation

Date : September 18, 2024
Place : Hot cell in MLF
Details

- During the operation of the power manipulator for the replacement of the mercury target vessel, an issue occurred where one axis (the axis that rotates the entire arm) stopped moving.

Influence

- The use program, which was scheduled to start on November 21, was delayed by approximately three weeks, until December 9.

Cause of the Incident

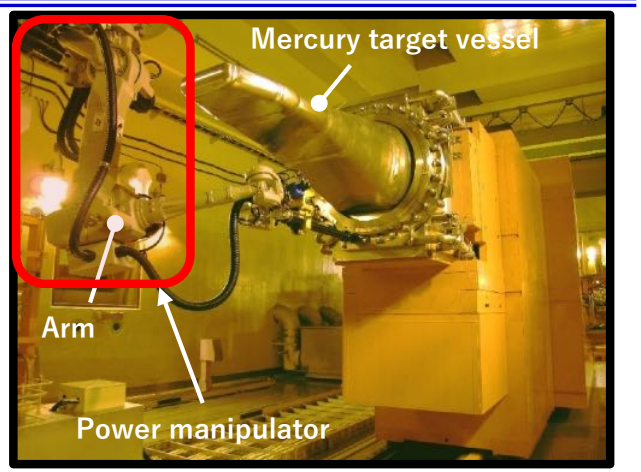
- It was determined that the failure was due to a malfunction in the servo amplifier inside the control panel.

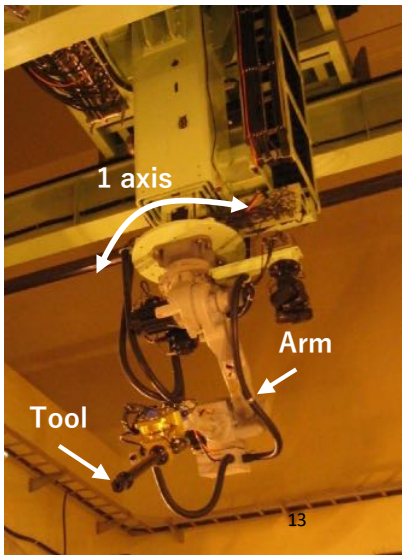
Response

- The faulty servo amplifier was replaced with a spare of the same type that was kept in storage, and the functionality of the power manipulator was restored on October 11.

Long-term Measure

- The control system will be updated in February 2025.

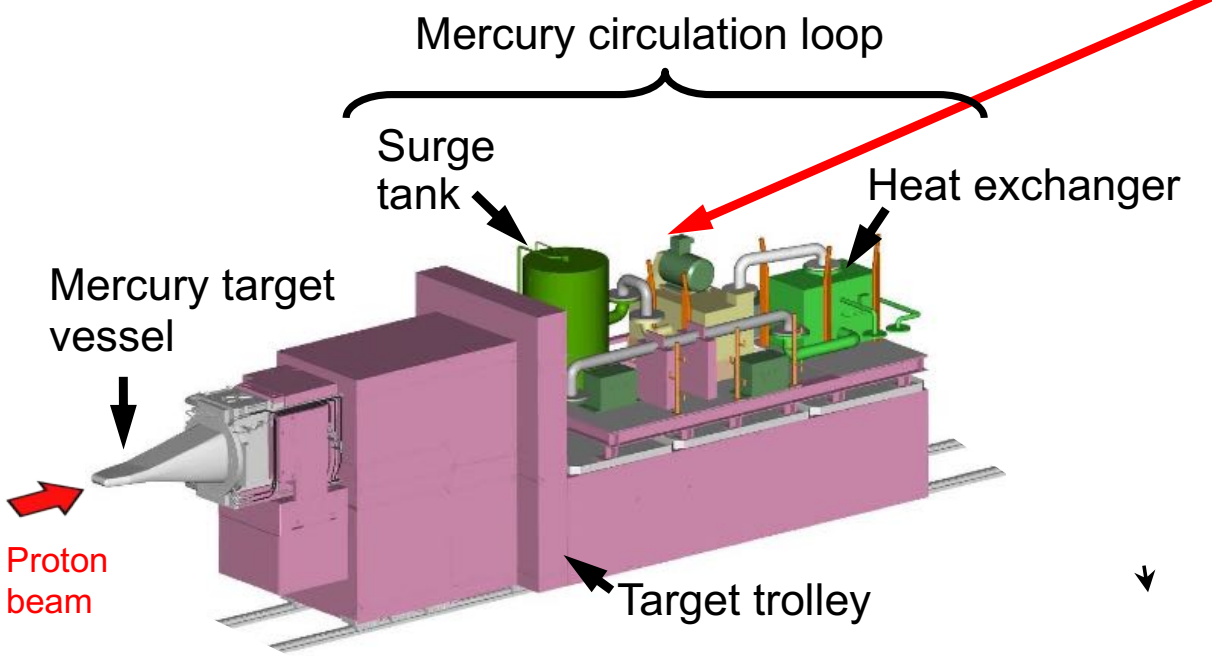




- ◆ This has served as an opportunity to recognize the importance of spare parts management, and a spare parts list for the major devices of neutron source is currently being developed.
- ◆ Impact of obsolescence of the system devices on facility operation is becoming evident.

Outline of Mercury Target System & Mercury Pump

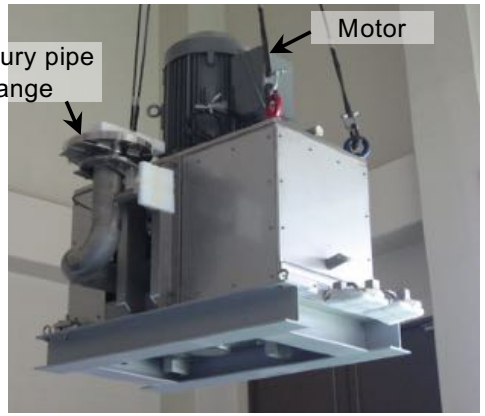
Schematic of mercury target system

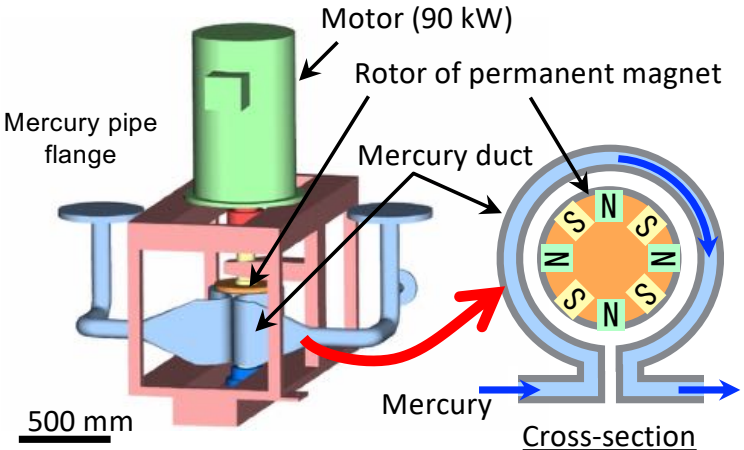


Total length :	12 m
Total weight :	315 ton
Mercury inventory :	1.5 m^3
Mercury flow rate :	38m^3/hr

Mercury is circulated through the mercury target vessel using a mercury pump.

Mercury pump

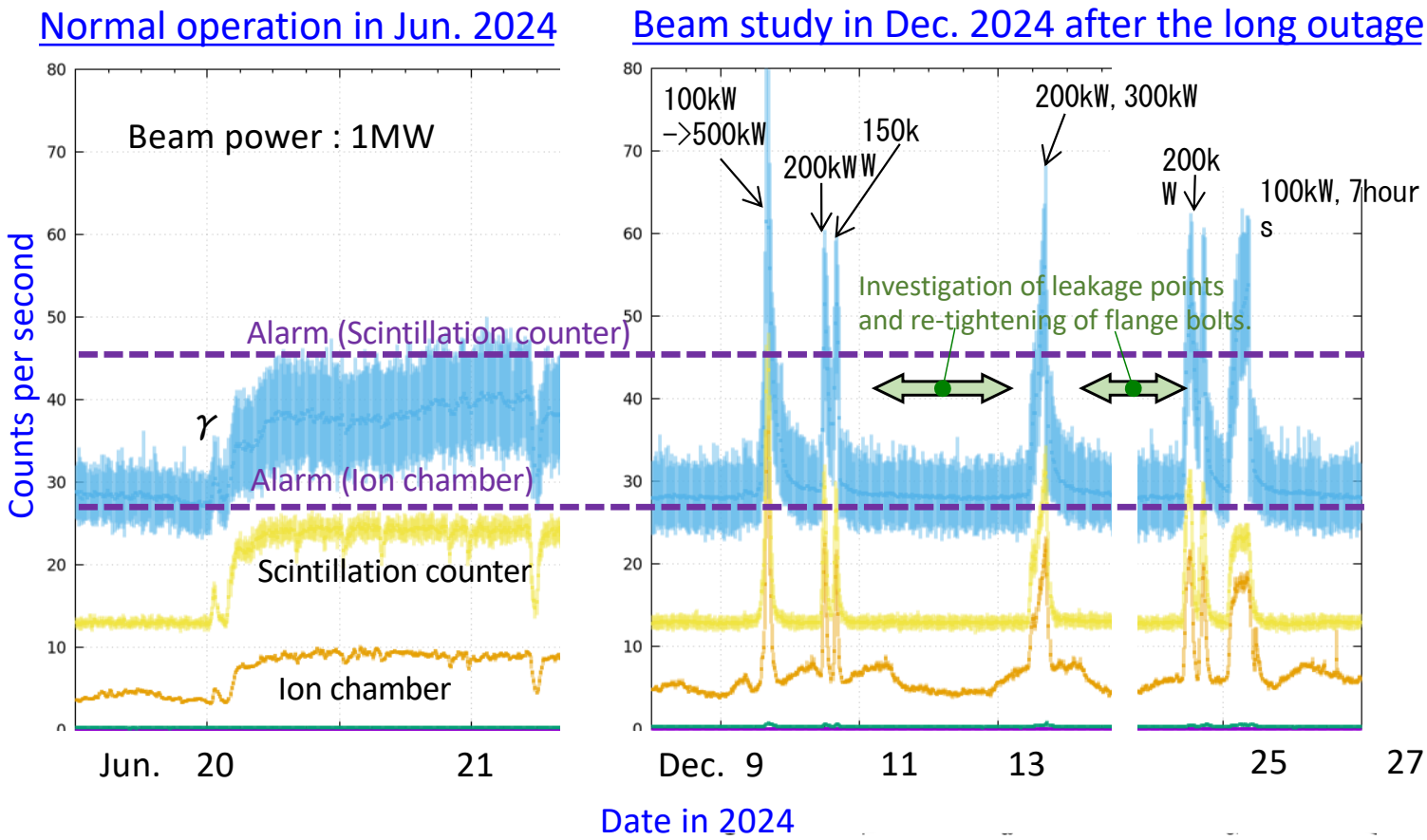




Size : 2m x 2m x 2m
Weight : 3.5 ton

Mercury is driven by the electromagnetic force generated by rotating a permanent magnet with a motor.

Stack Monitor Indication of MLF (In Jun. and Dec. ,2024)



The beam operation of MLF started on Dec. 9, but the stack monitor indication increased sharply over the alarm level, which might be caused by insufficient seal of the mercury loop after the mercury pump replacement.