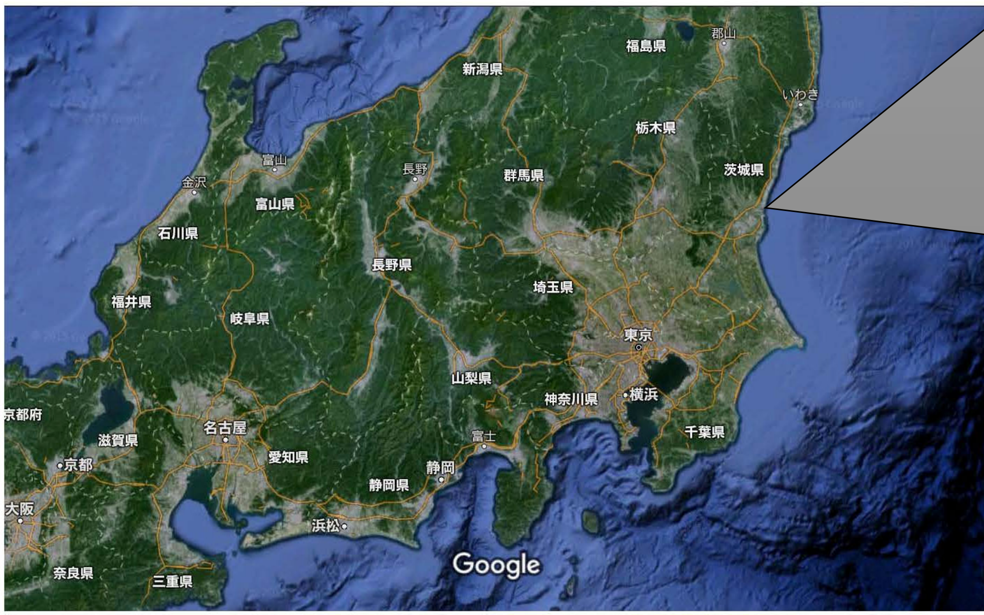
BRIDGE2025, 20 Oct 2025

J-PARC MLF Facility Overview

Naritoshi Kawamura

Deputy Head of Materials and Life Science Division

J-PARC
Japan Proton Accelerator Research Complex



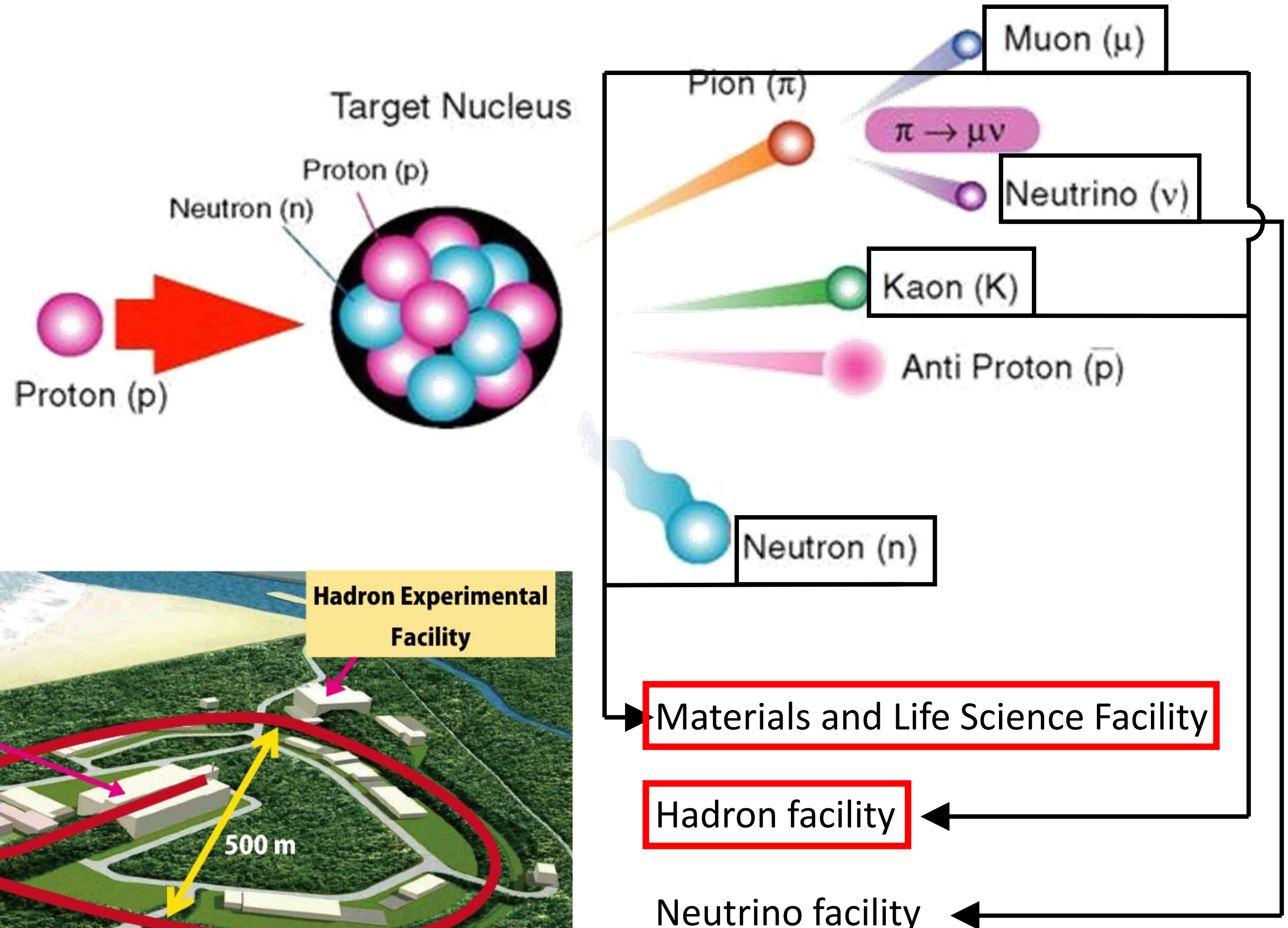
画像 ©2015 Data SIO, NOAA, U.S. Navy, NGA, GEBCO、Data Japan Hydrographic Association、Landsat、地図データ ©2015 Google、ZENRIN 50 km

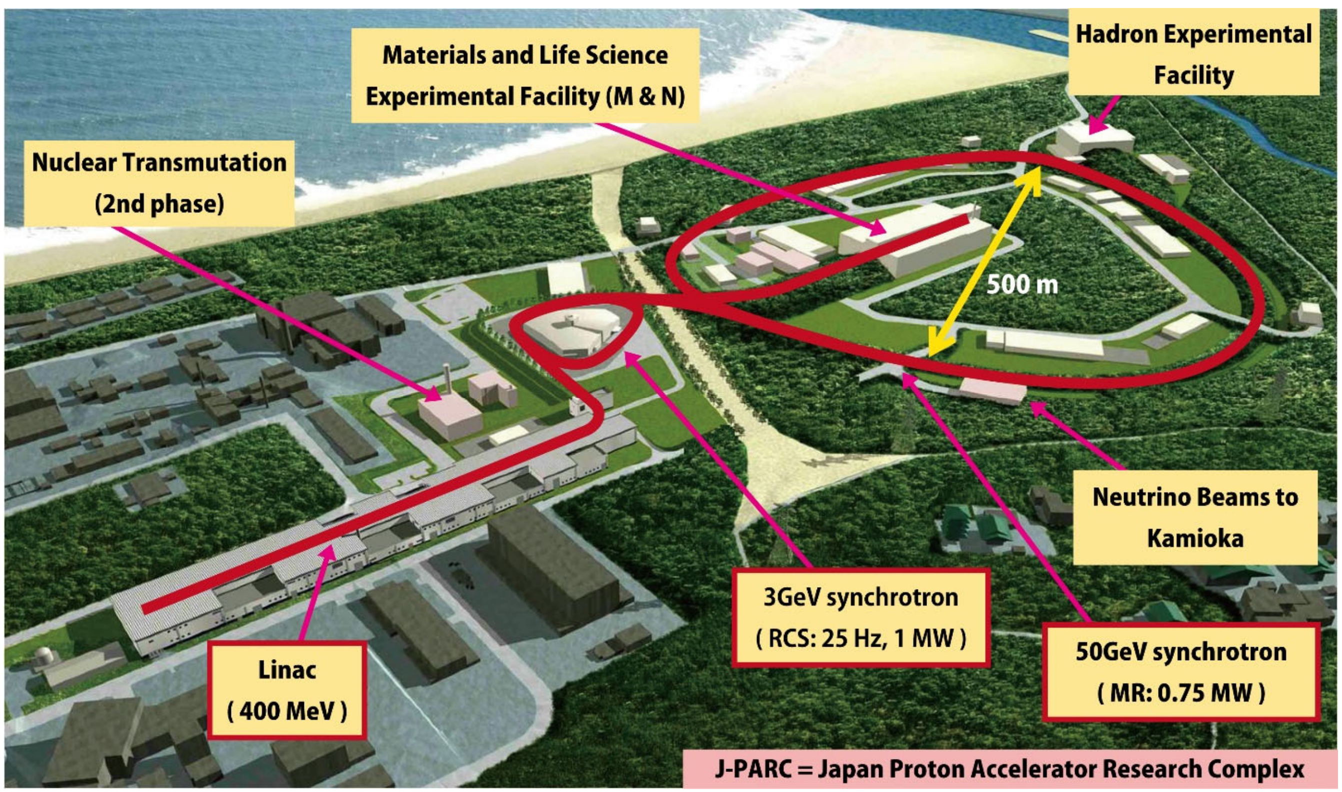
J-PARC is an accelerator complex funded by KEK and JAEA.
The construction started in 2008 toward the world's strongest beam.

J－PARC

3 accelerators

400 MeV linac
3GeV synchrotron (RCS)
30GeV synchrotron (MR)

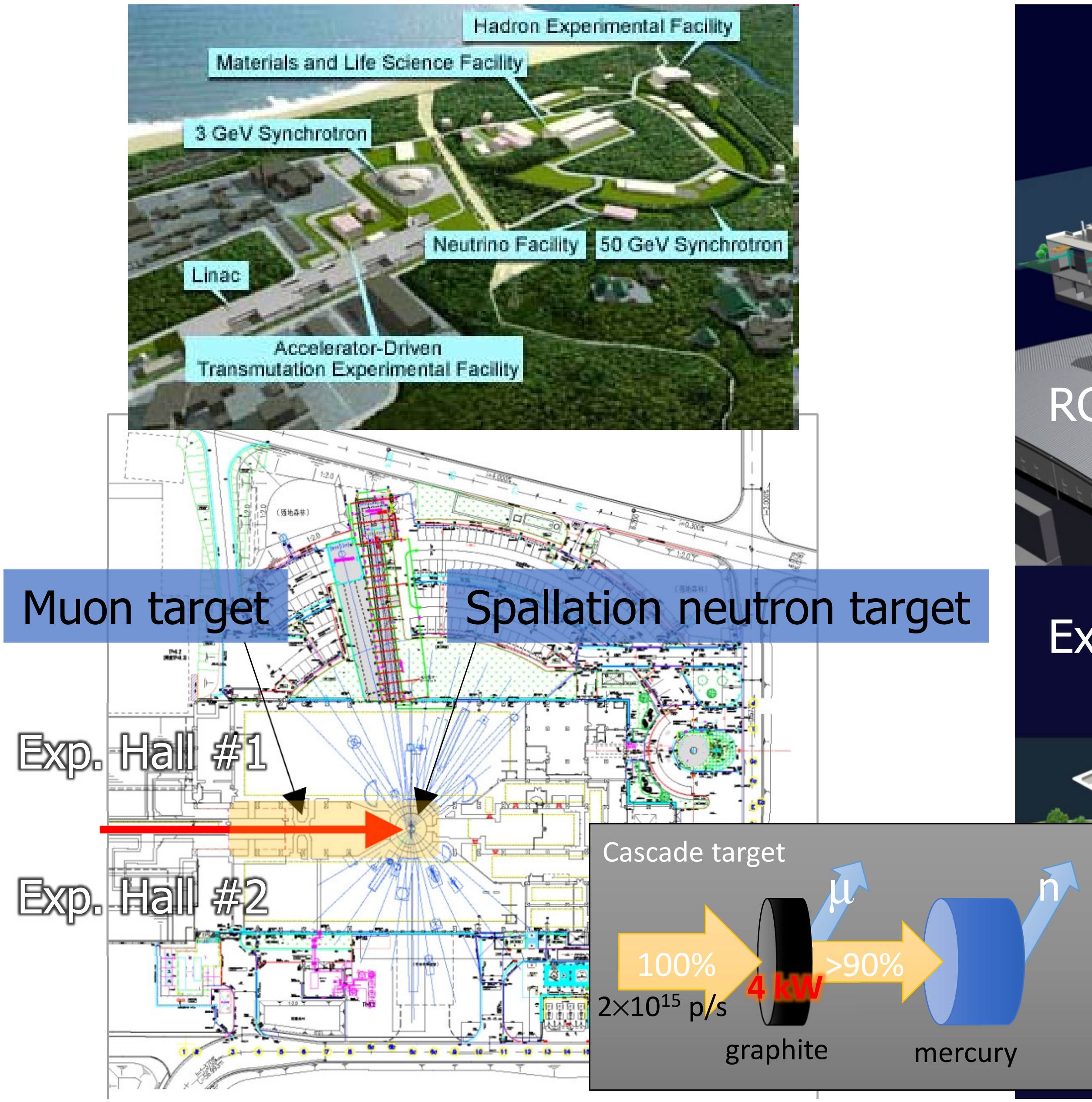


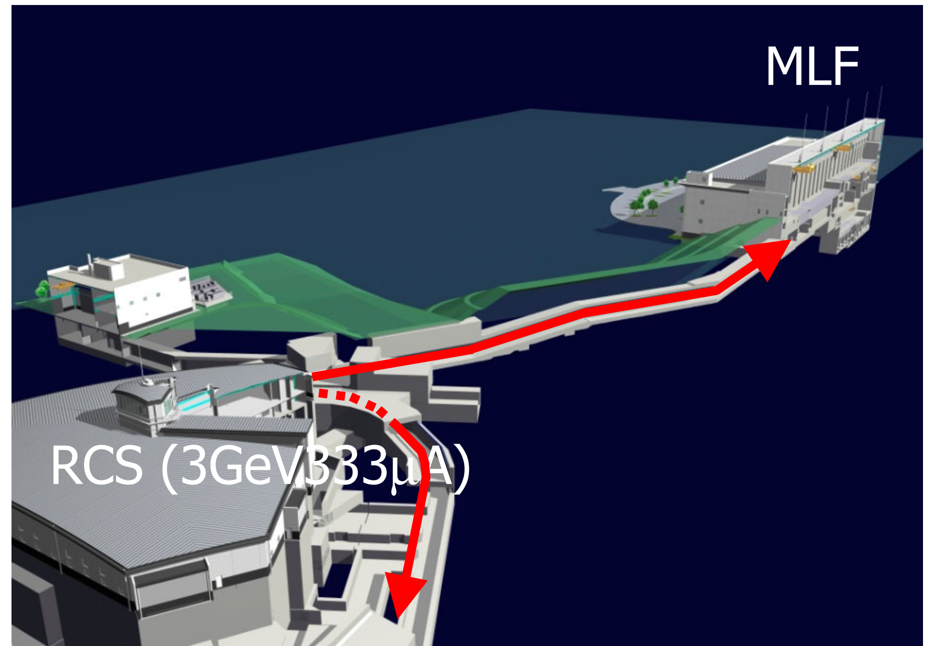


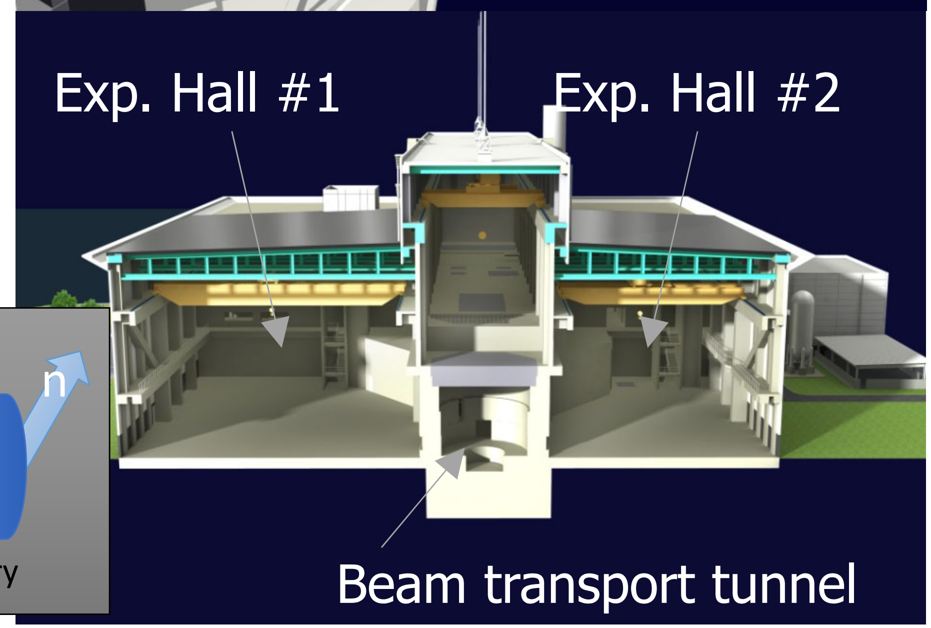
Nuclear transmutation research (under design)

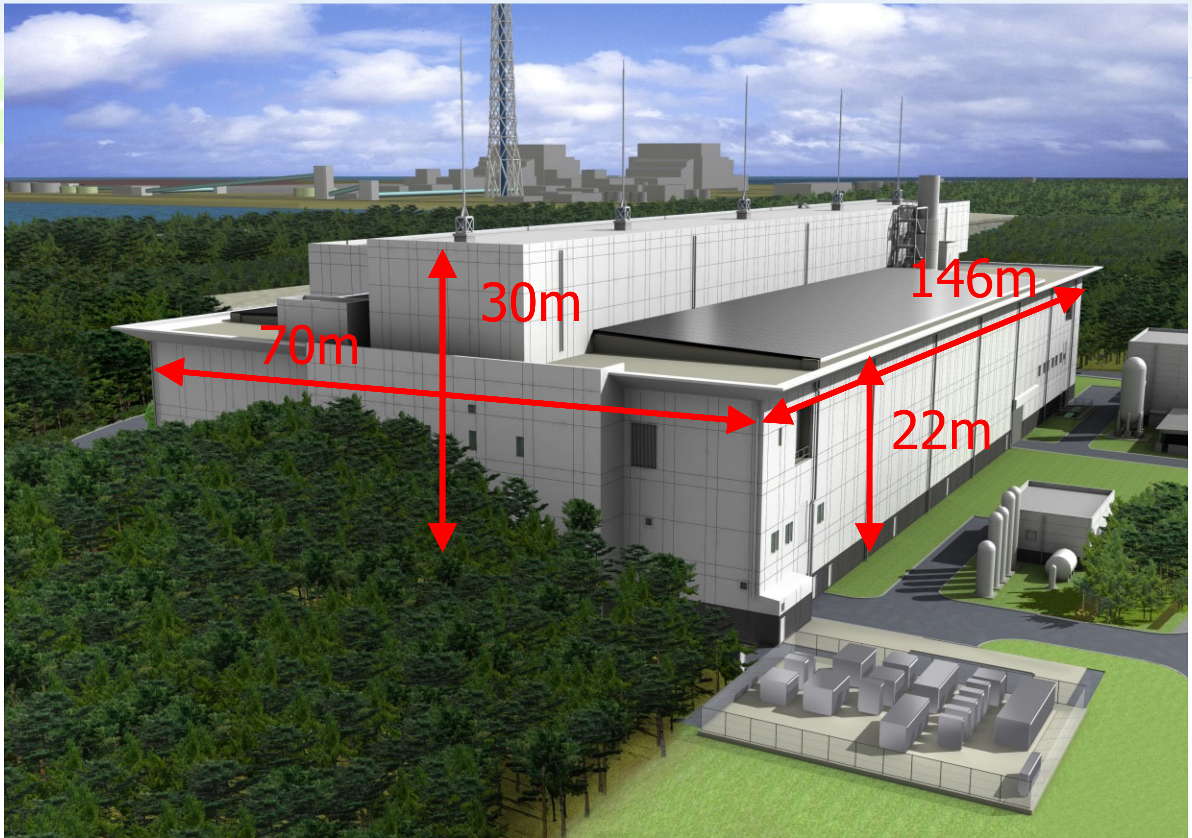
4 facilities

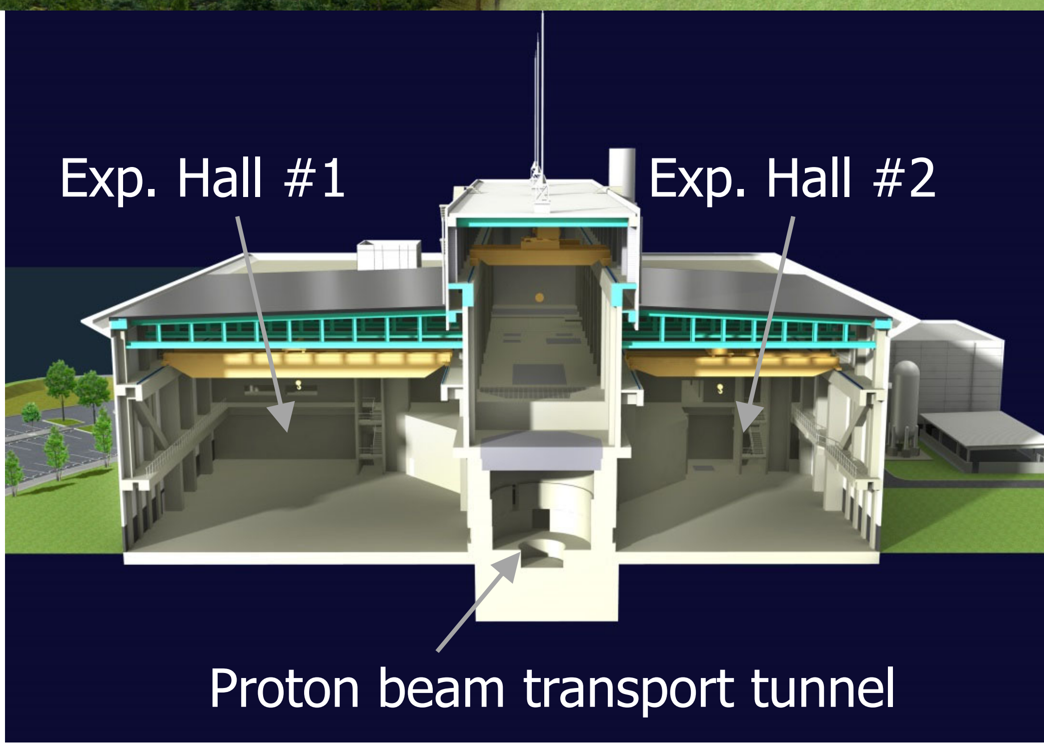
Materials and Life Science Facility

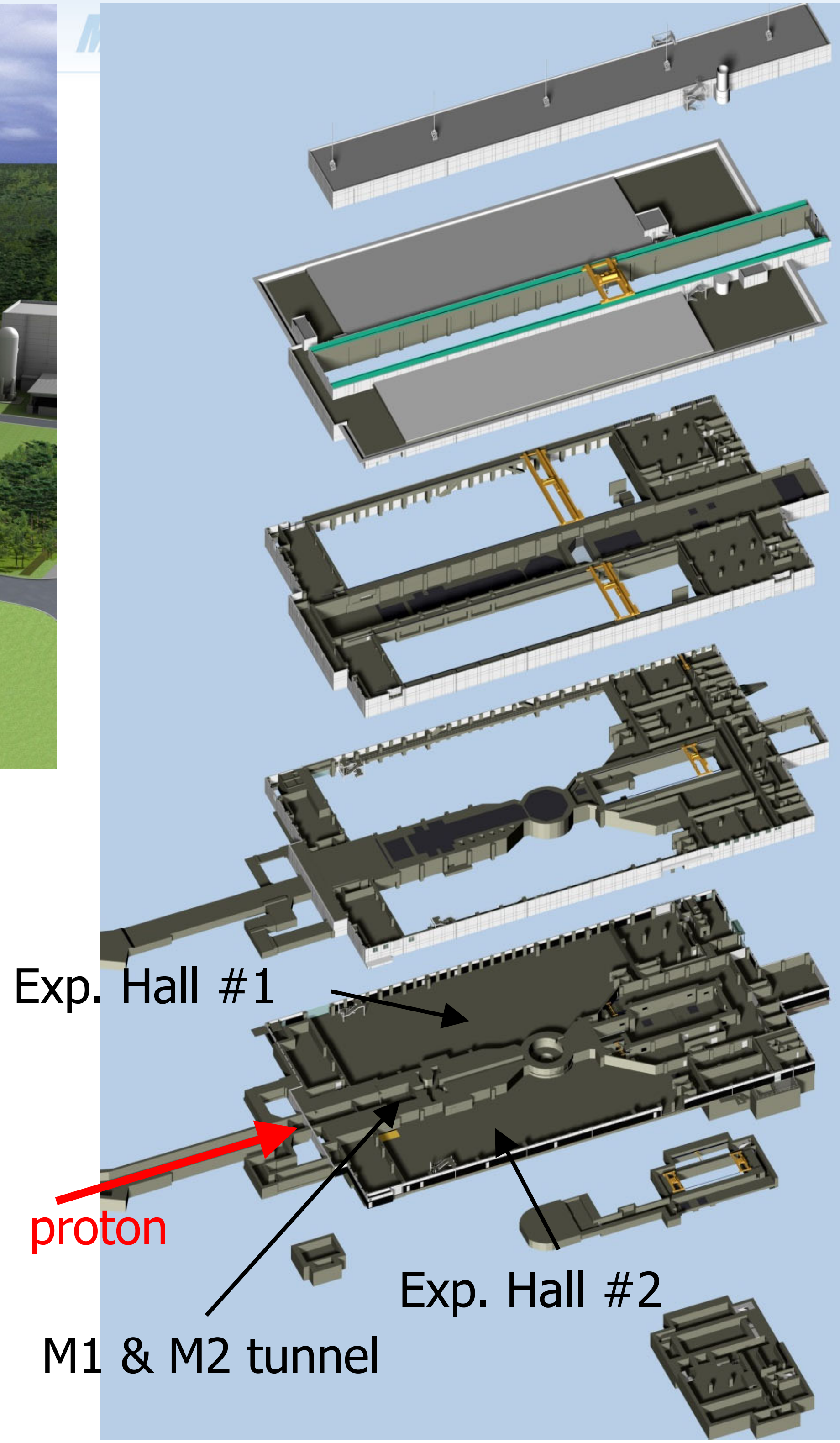






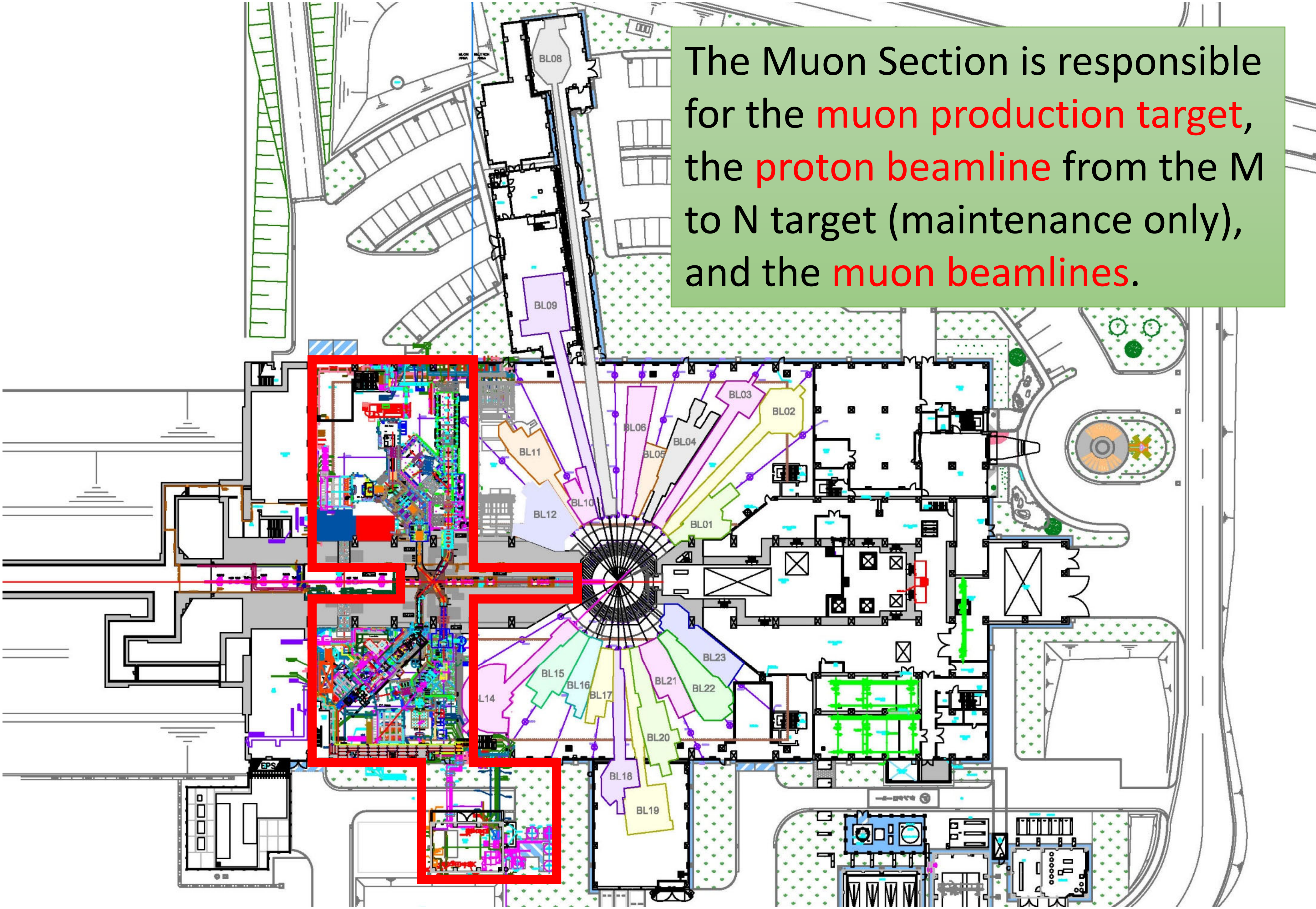

30m
146m
70m
22m


Exp. Hall #1
Exp. Hall #2
Proton beam transport tunnel


Exp. Hall #1
proton
Exp. Hall #2
M1 & M2 tunnel

Muon Facility

The Muon Section is responsible for the muon production target, the proton beamline from the M to N target (maintenance only), and the muon beamlines.



Muon beamlines

S-line μ^+

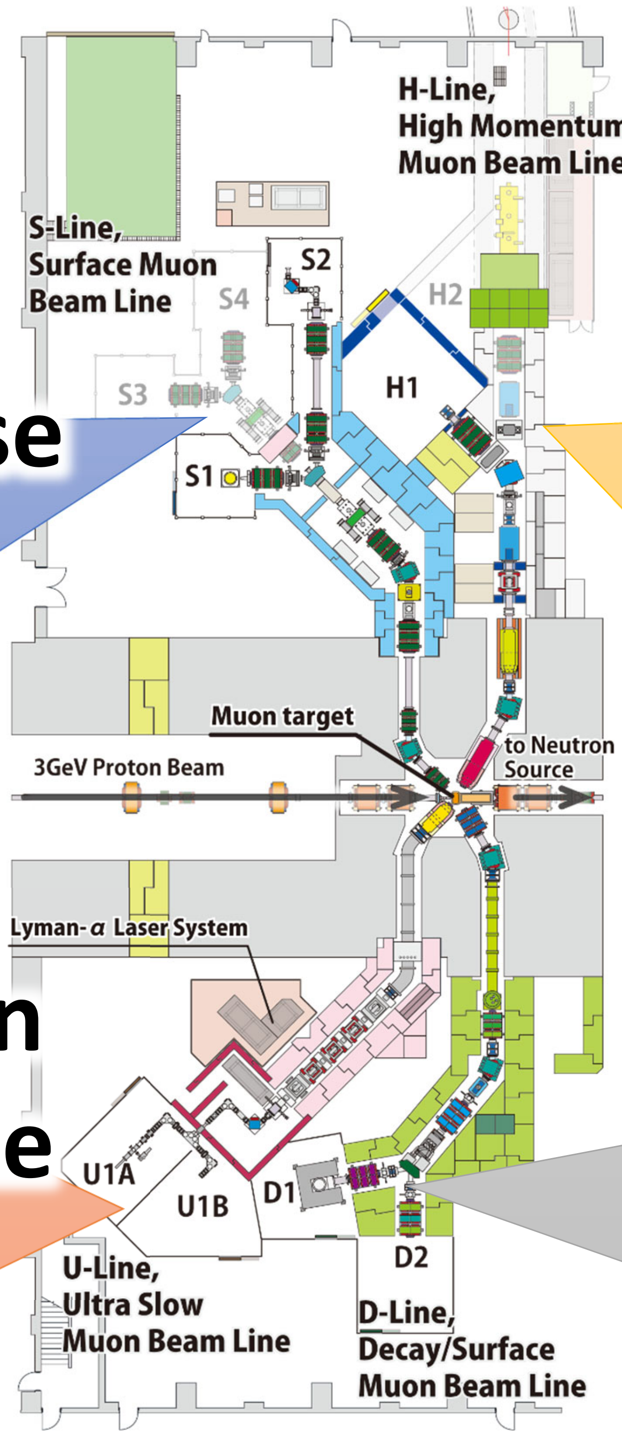
Surface muon (4 MeV)
dedicated to bulk μSR
in 4 experimental areas
w/ various sample env.
ultra-low temperature
high magnetic field
pulsed excitations *etc.*

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

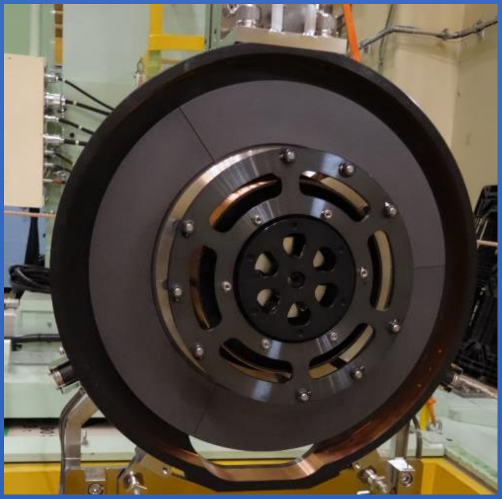
D-line μ^+/μ^-

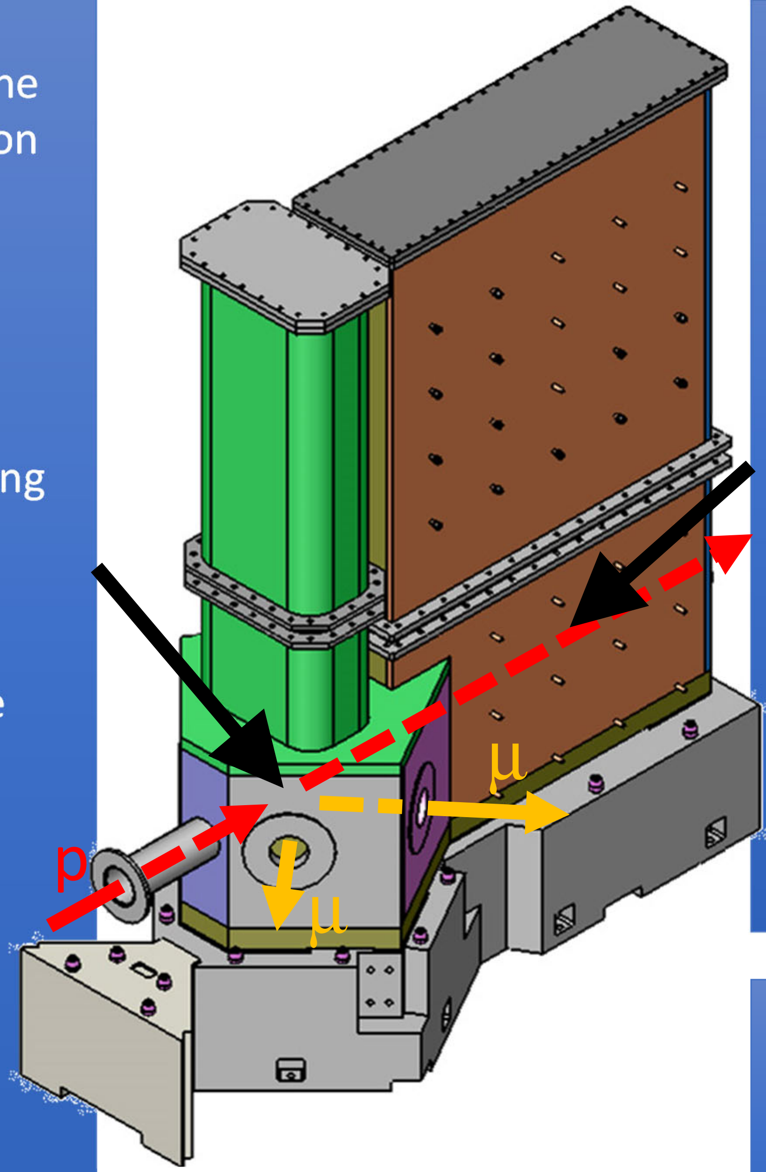
Decay and surface muon
to answer a variety of
users' demands with
μSR spectrometer (D1)
general purpose (D2)

General Use

Muon Production Target

Rotating target
- To prolong the lifetime of the target against DPA, operation started.
  #1: 2014-2019
  #2: 2019-
- Heat deposit : 4 kW
- Graphite disk: rad. cooling
  Bearing, jacket: water cooling
- Monitors: motor torque, vacuum level, Q-mass for outgas. IR-Radiation thermometer is going to be operated.

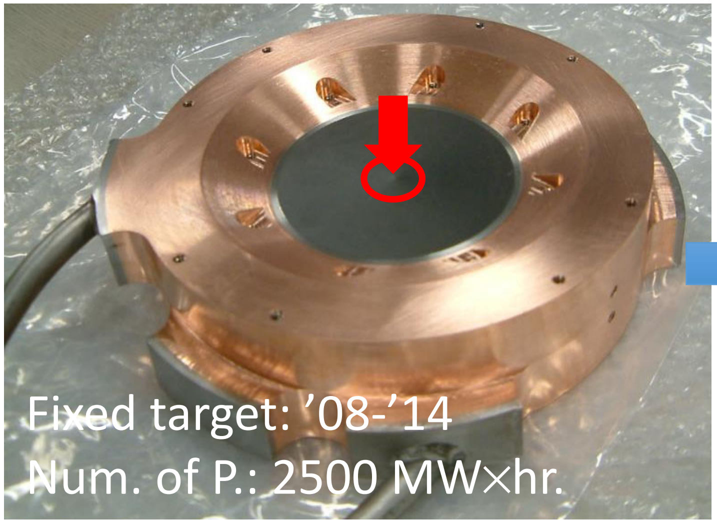


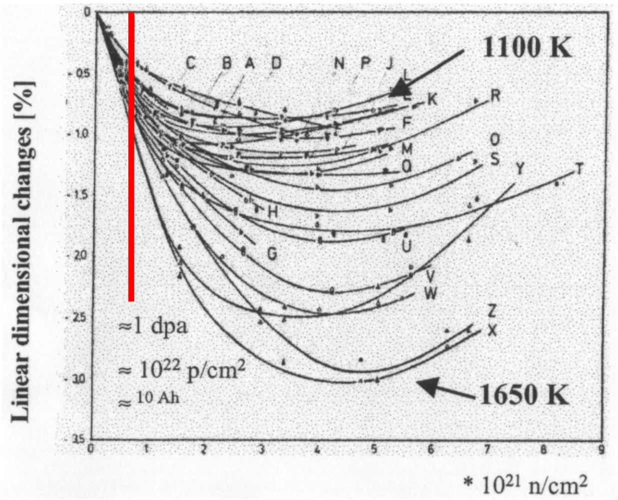


Scraper (proton collimator)
- Scrape the scattered protons by the target
- Renewed in 2015.
- Heat deposit : 20 kW@No1
- Water cooling
- Thermocouple thermometers

Vacuum vessel
- In service since 2008
- Hea deposit : 10 kW
- Water (>90%) and air cooling
- Thermocouple thermometers

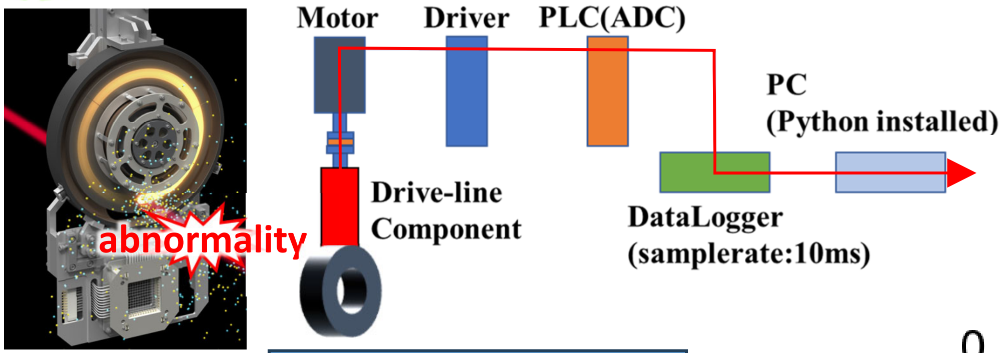
Muon Production Target



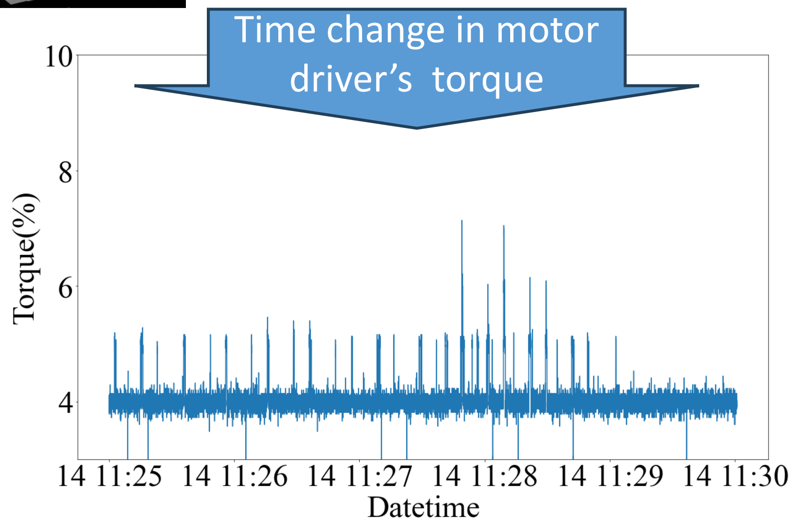


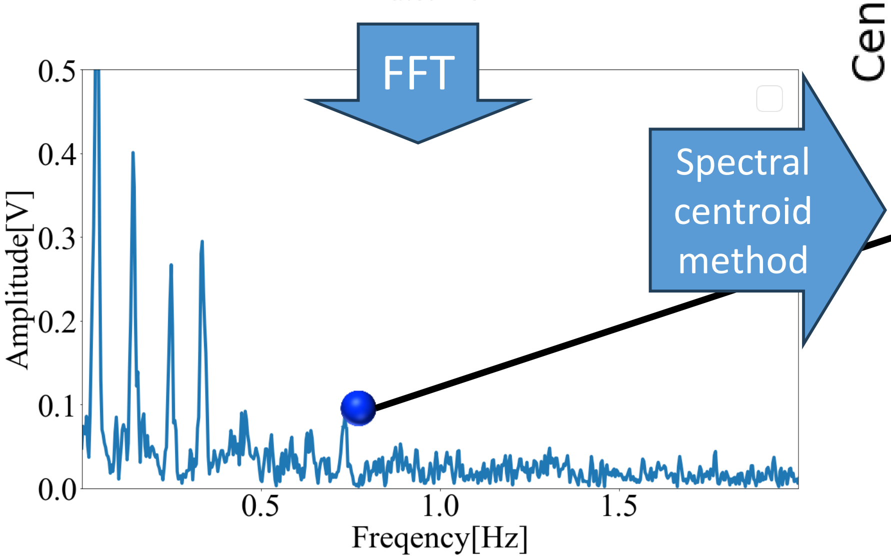
- To disperse the radiation damage, 1% shrinkage / 1DPA (~0.5-year irradiation under 1 MW), and to prolong the lifetime, a rotating system has been applied since 2014.
- Common property
  - 2-cm thick IG-430U from Toyo Tanso Inc., consuming 5% of protons
- Different property
  - direct water cooling (fixed) vs. radiation cooling (rotating)
  - Max temp.: 1500 deg C (fixed) vs. 700 deg C (rotating)

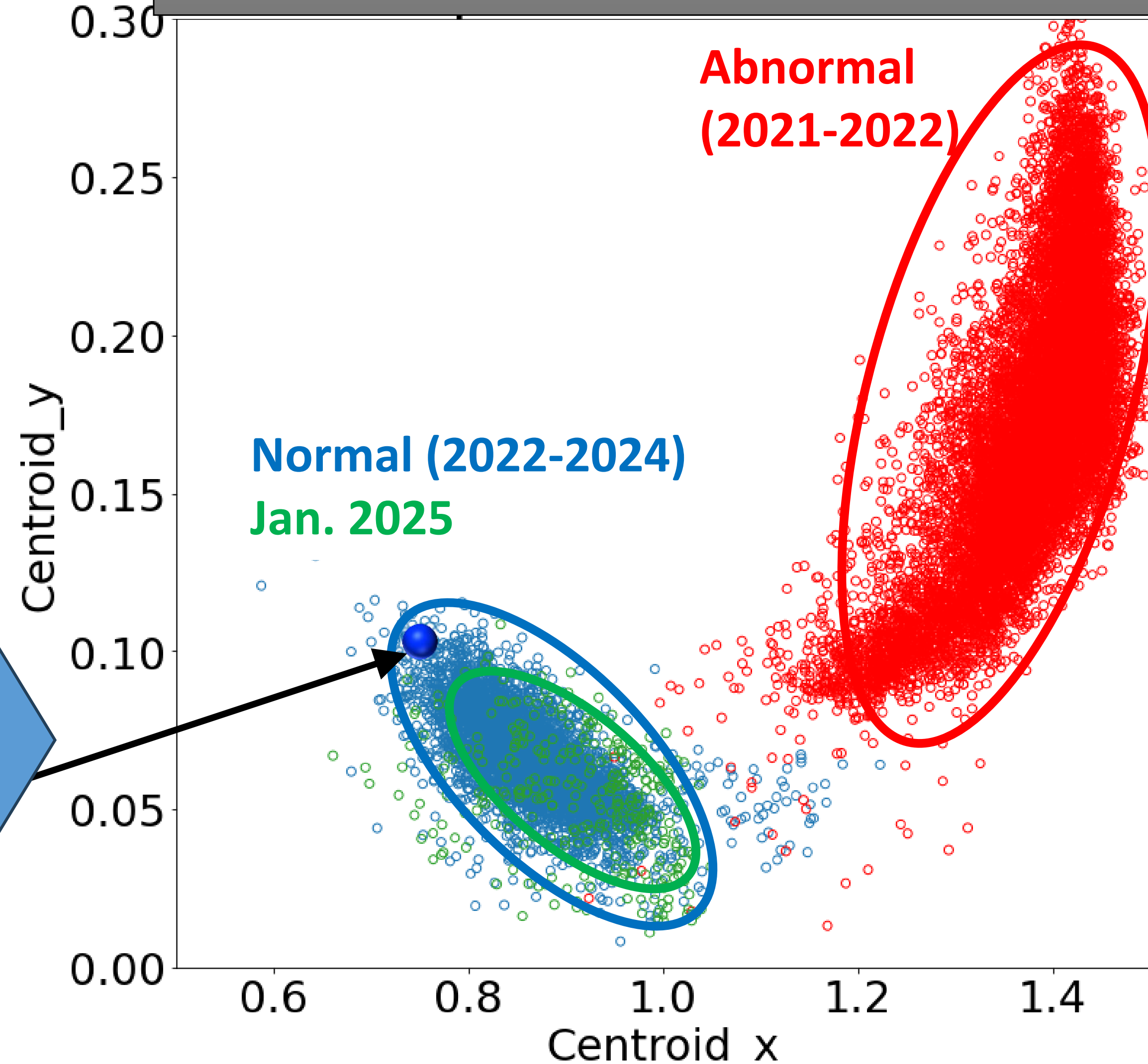
Muon Target: Abnormality Prediction



The target diagnosis is essential for safe and stable operation. We had trouble with the motor in 2022 causing the delay in start of the operation. The abnormality-checking method is established to prevent similar troubles.

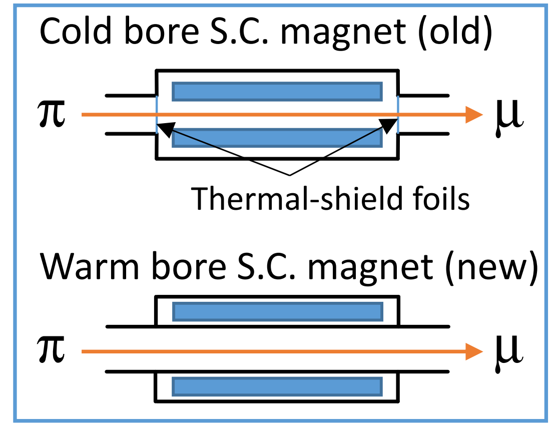




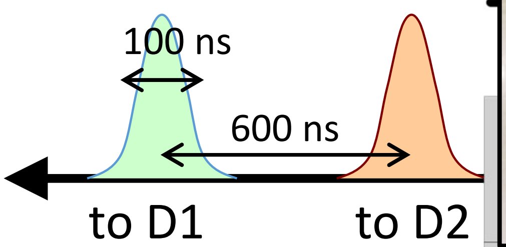


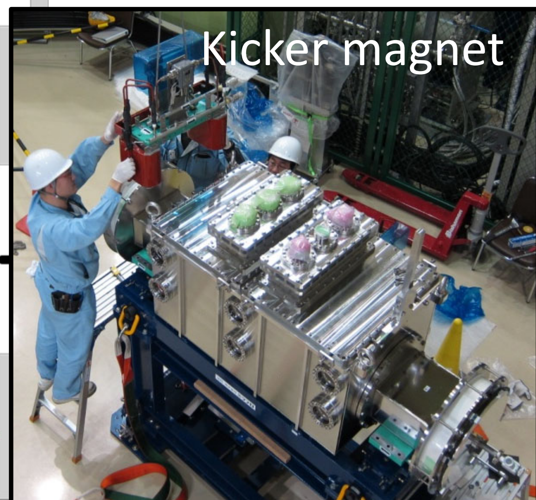
D-line: A decay/surface muon beamline

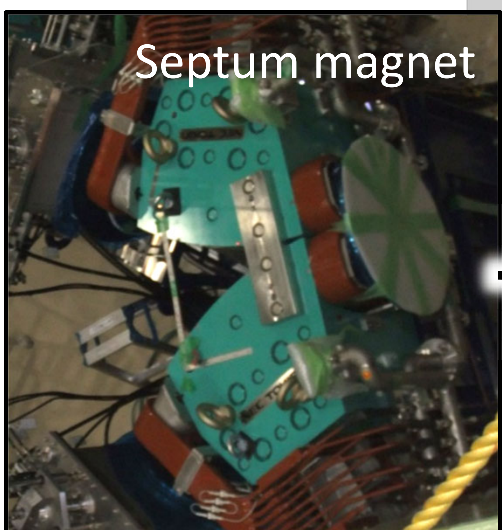
Improved performance with a new superconducting solenoid.
Larger warm bore (ϕ12cm → ϕ24cm) without window foils

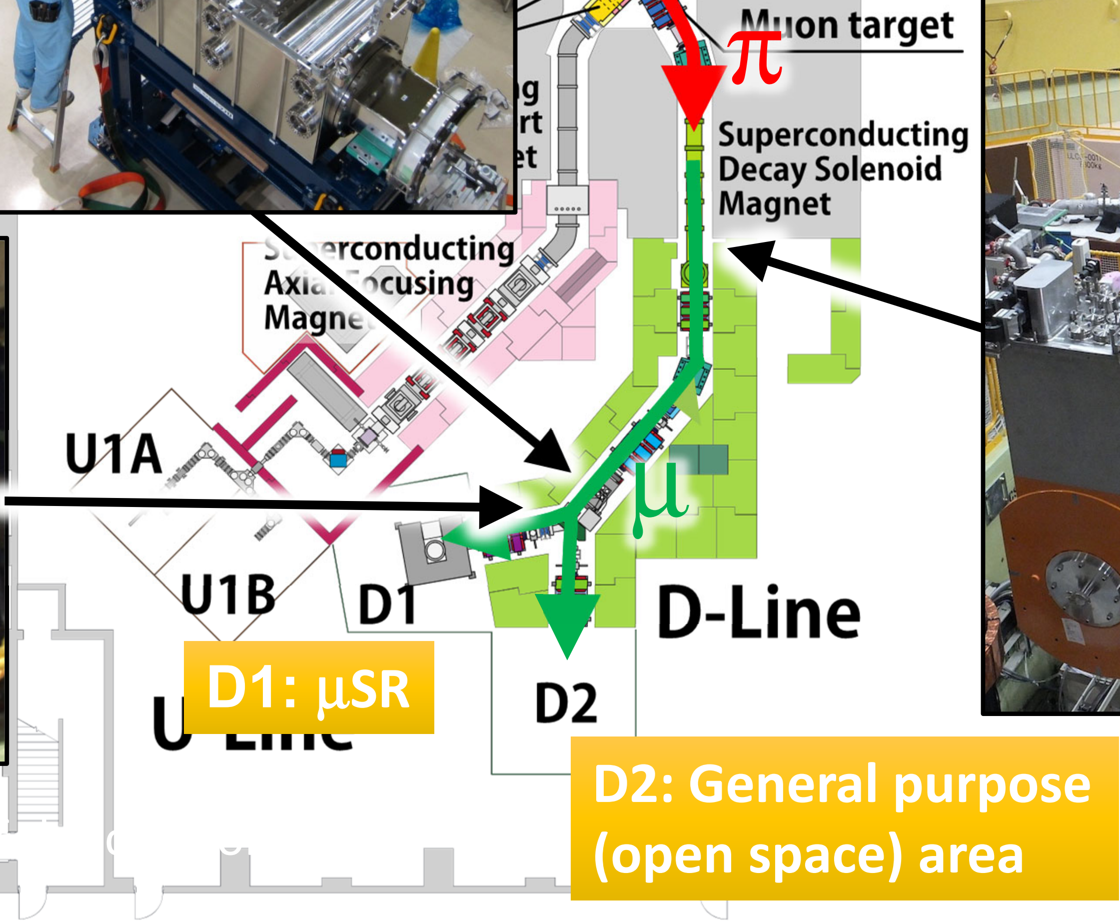


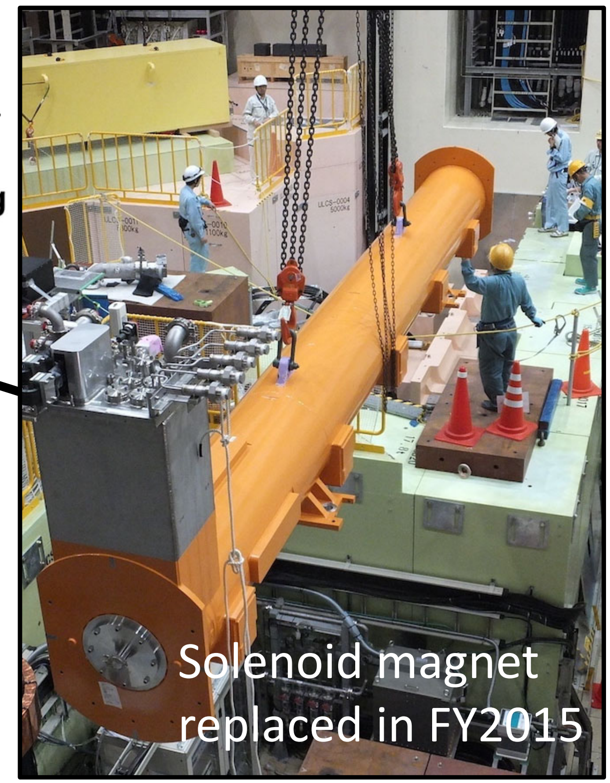
Double pulse structure due to accelerator bunch
Each pulse is distributed to D1 and D2 areas with a kicker magnet.



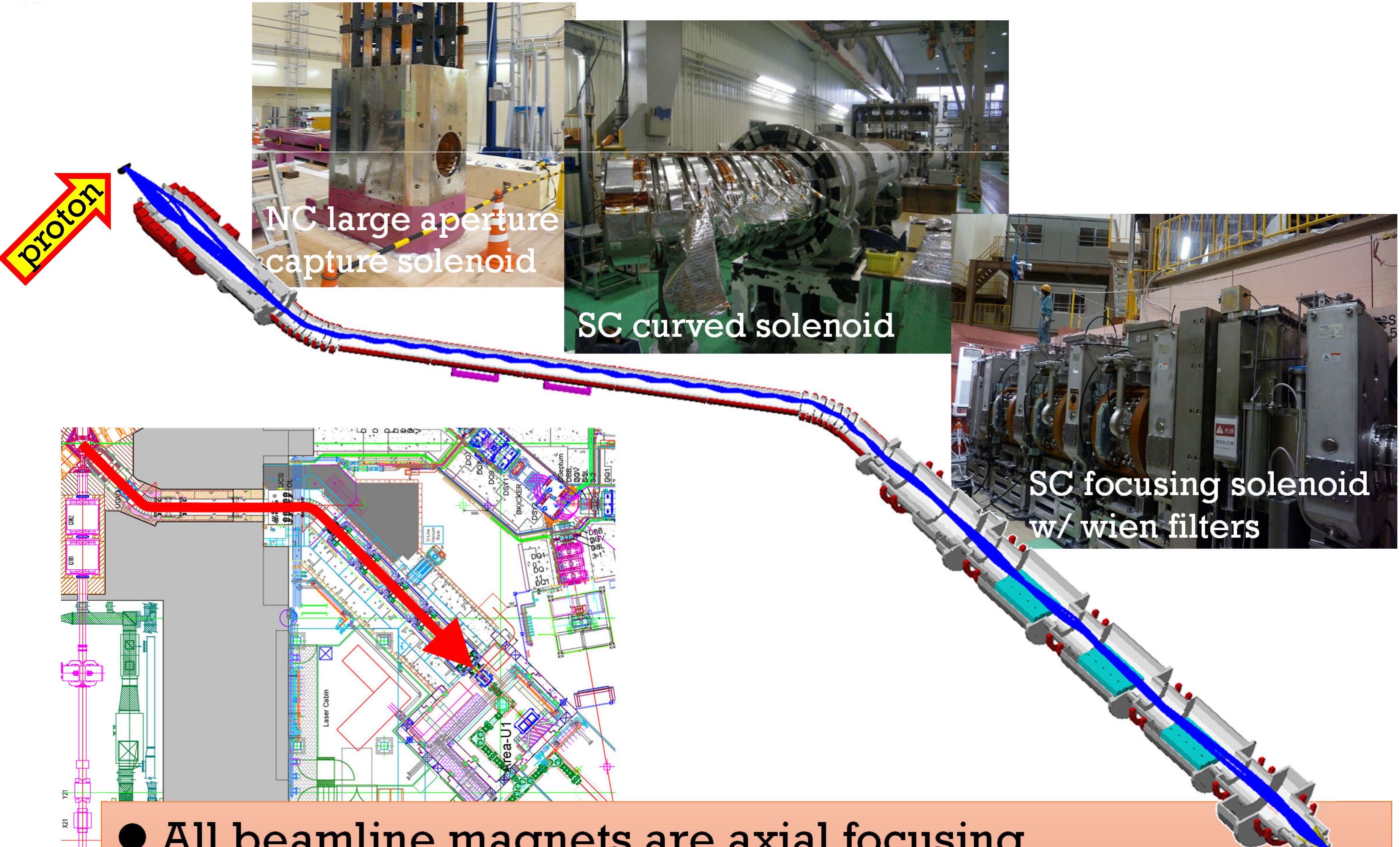






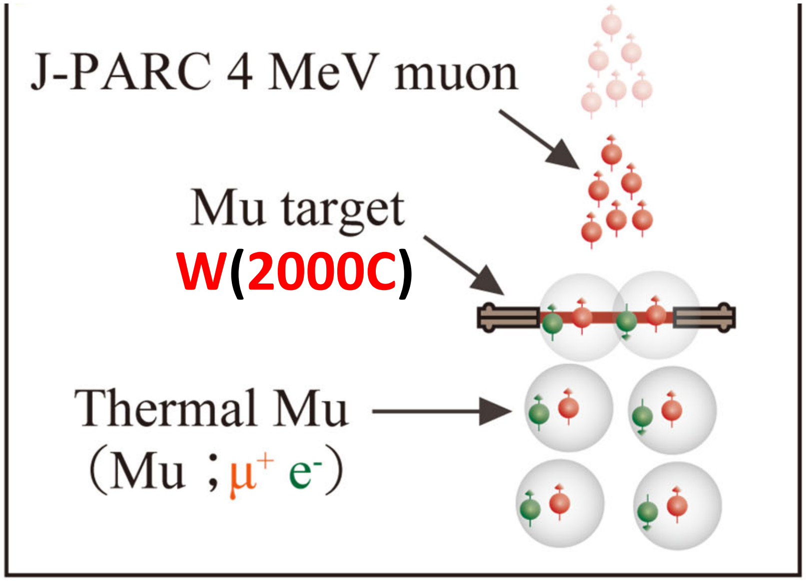


U-line: The highest intensity beamline for USM

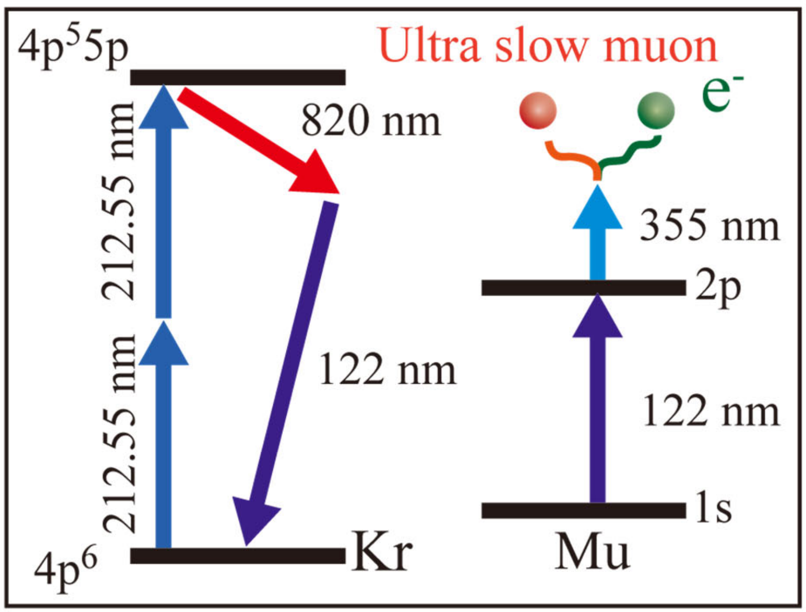


- All beamline magnets are axial focusing
- The world strongest pulsed muon: 2×10^{8} μ^{+}/s, 1×10^{7} μ^{-}/s

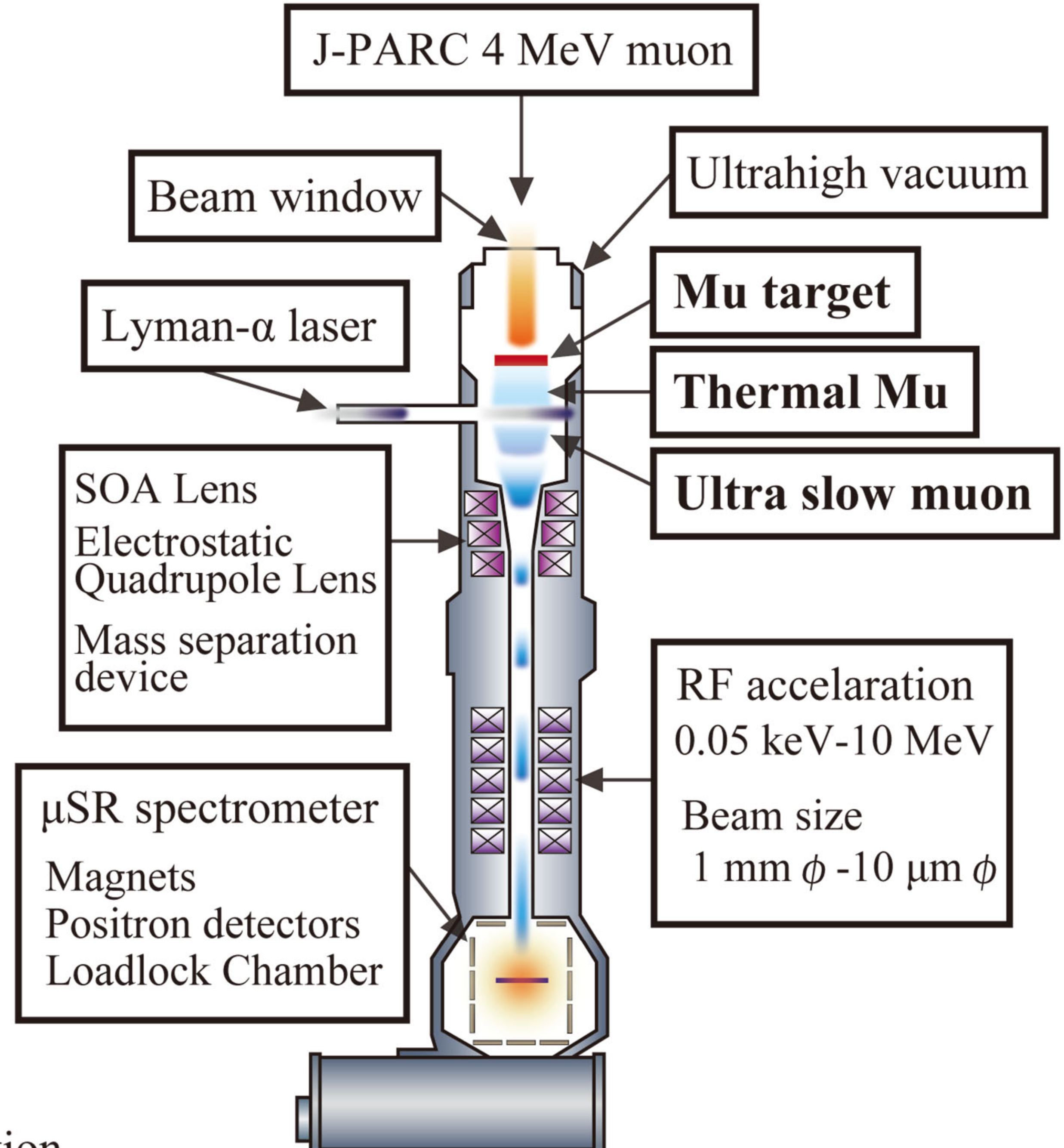
U-line: Generation of Ultra Slow Muon



Mu generator

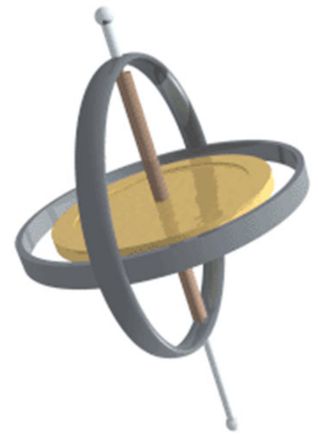


Lyman-α laser generation and Mu dissociation by laser resonant ionization method

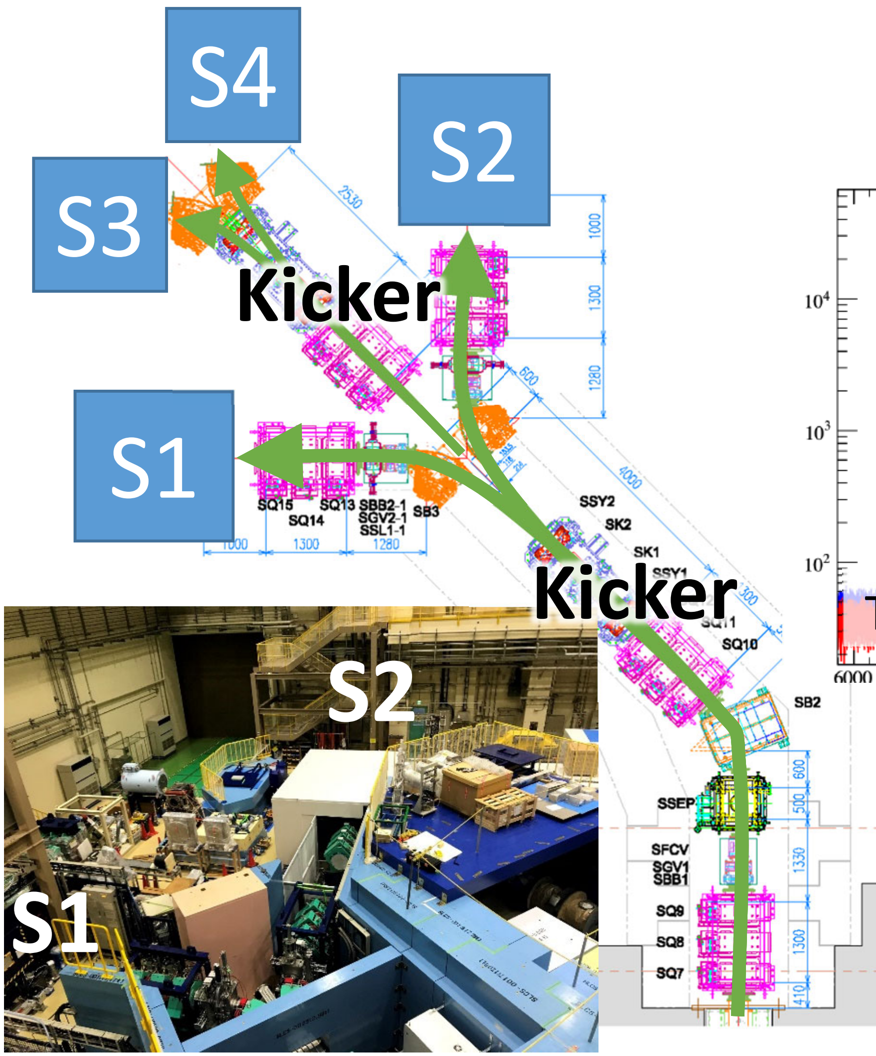


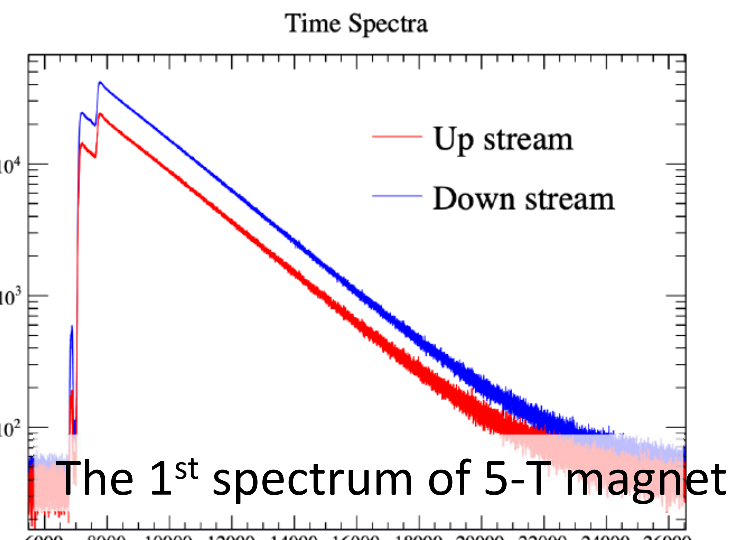
S-line: A Beamline Dedicated to Surface Muon

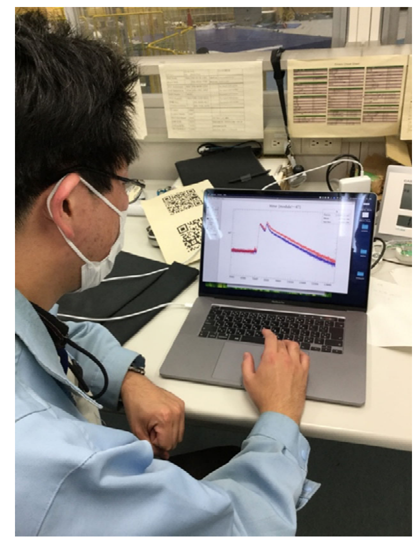
The S line is dedicated to transporting surface muon beams. Using two kicker systems, the S line will provide muon beams to all 4 areas simultaneously, and at present, two experimental areas, S1 and S2 were completed.

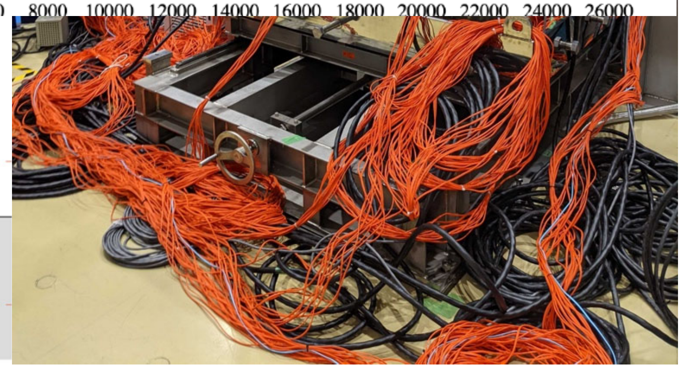


In the S1 area, a μSR spectrometer was placed. The S1 area is one of the busiest instruments.
The S2 area is partially funded by Okayama-univ. group to perform high rescission measurements of the Mu 1s-2s level.





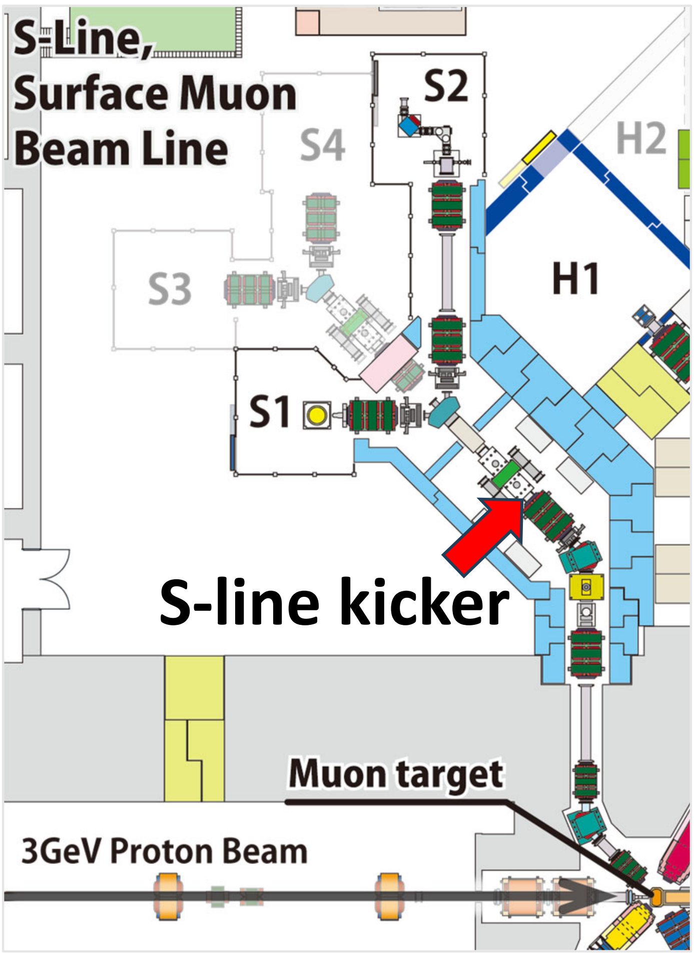


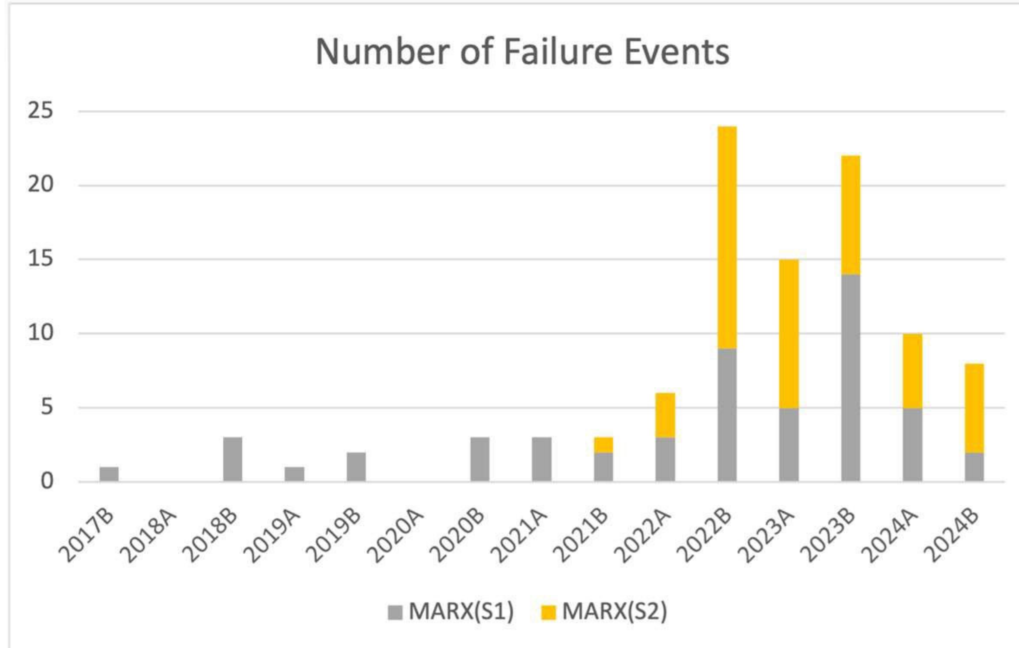


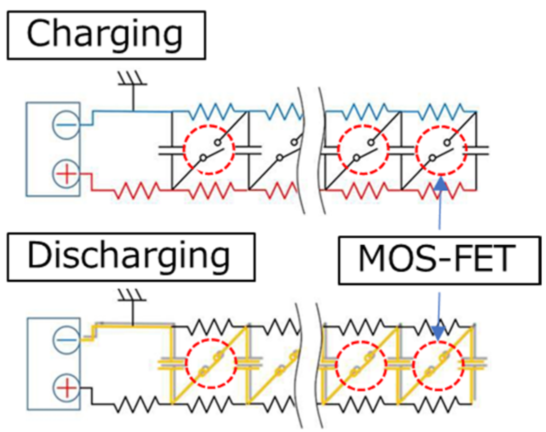
Pulse μSR: Highly segmented spectrometer is necessary to avoid the distortion of the time spectrum due to pileup.
Cf. 5-T magnet needs 3008-ch

S-line: Operation Status of the Kicker

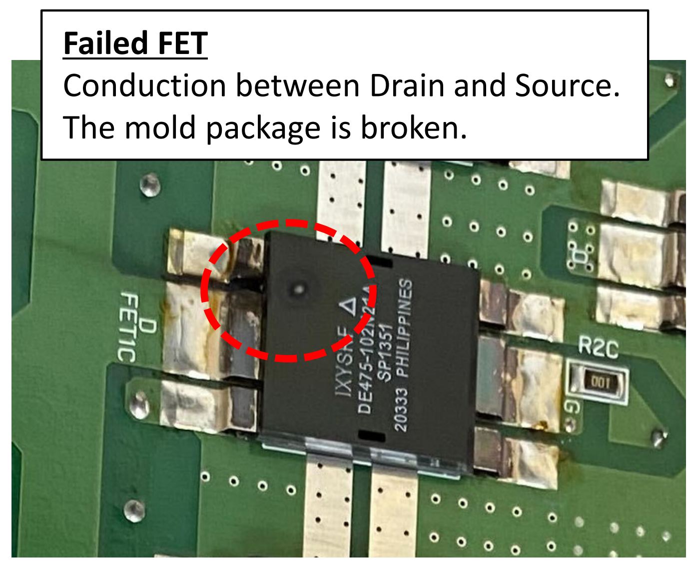
The S-line kicker is a key device to provide single-pulsed beam to S1 and S2 areas simultaneously. However, failure events have occurred in high rate due to FET problem for recent years.
The recovery work takes half a day and obstacle to efficient operation.





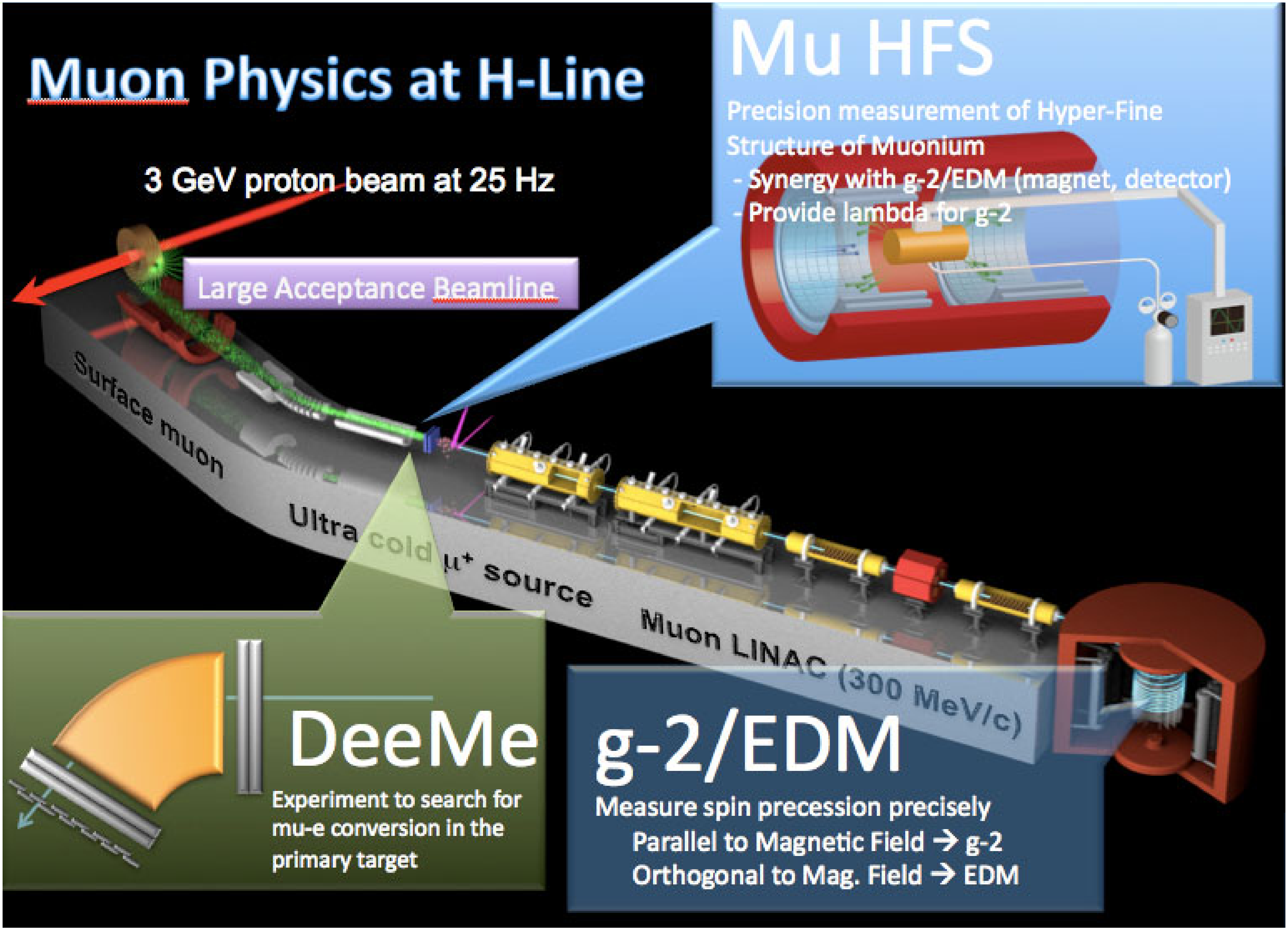


2,304 MOS-FETs are used for high-voltage switch to kick the beam by high voltage pulse of ±50kV with 300 ns.

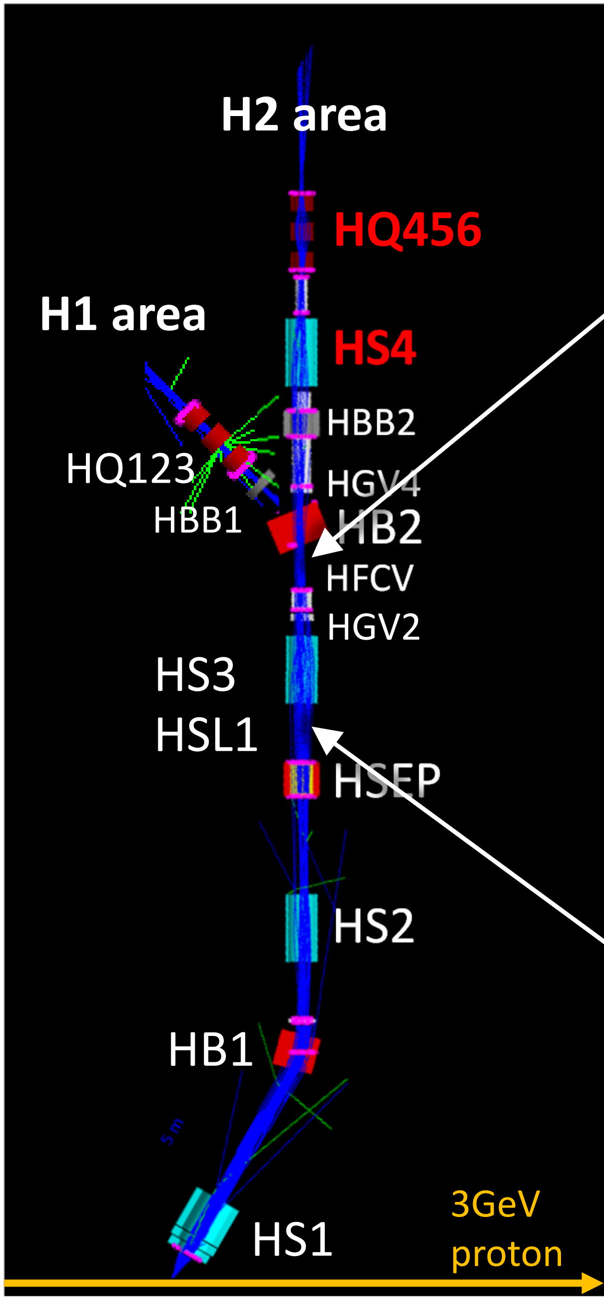


The above used MOS-FET is discontinued. We will replace them with SiC MOS-FET which has higher withstanding voltage.

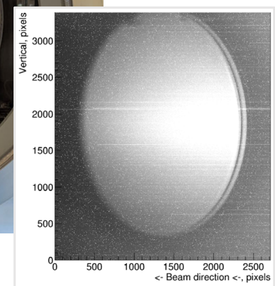
H-line: A beamline for fundamental physics



H-line: Upgrading of beamline

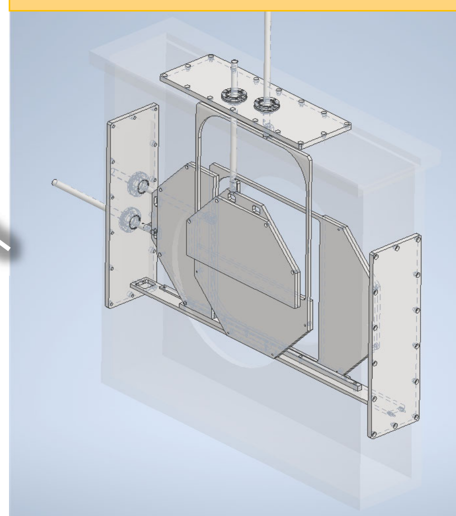


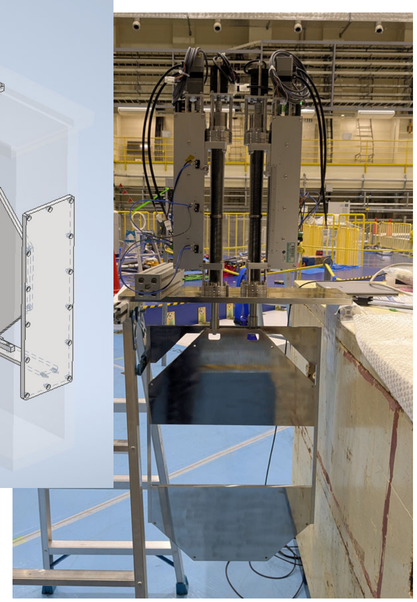
A beam-profile monitor developed at BINP was installed.



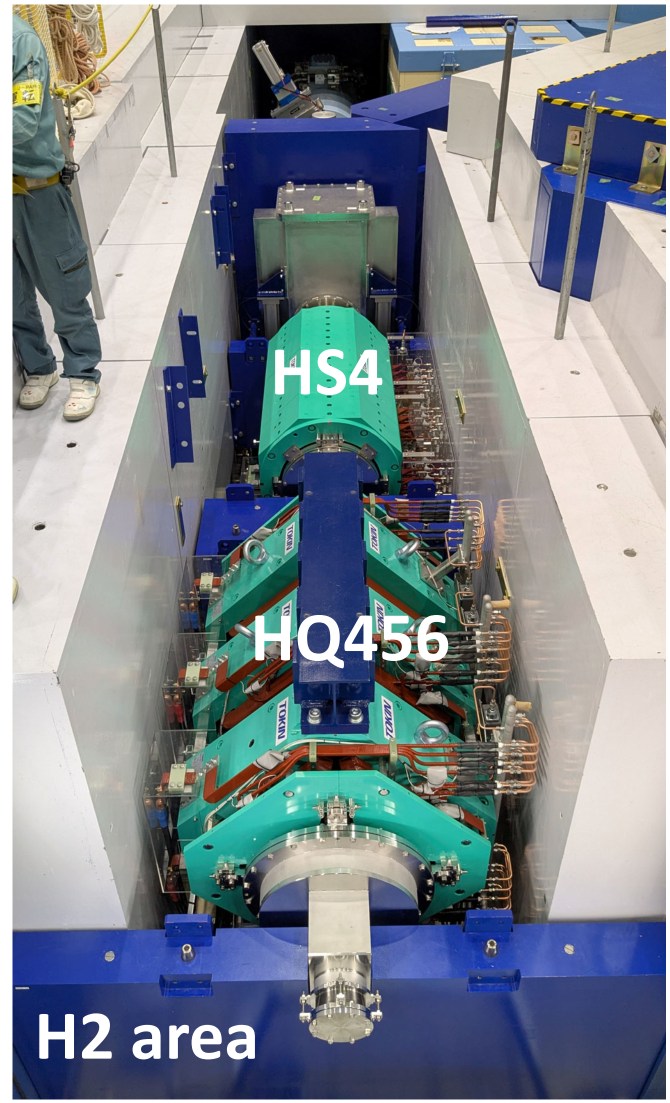
a 3-5-μm CsI film.

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



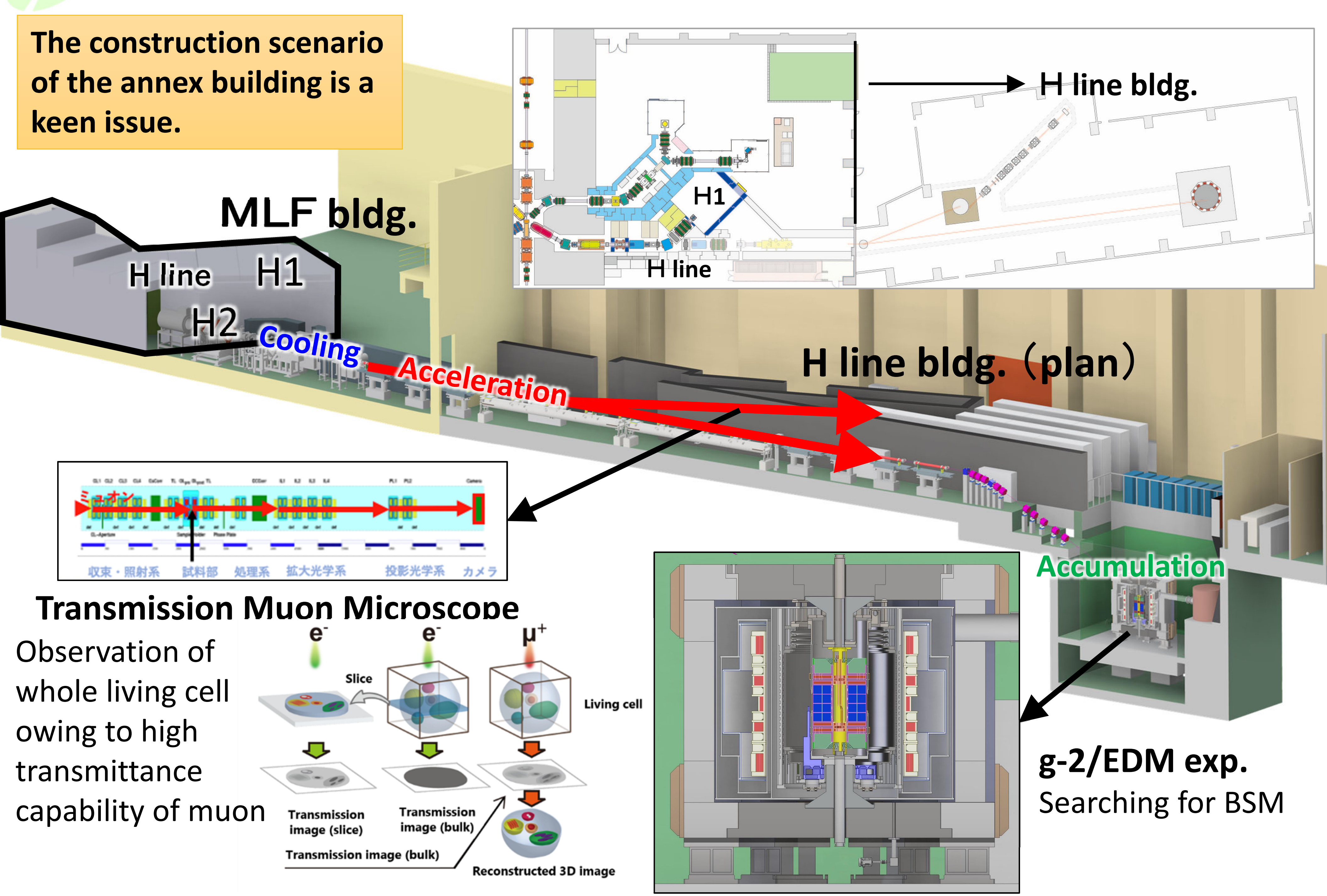


The final focusing magnets were installed.
The beam-commissioning will start in the next FY.



H-line: Extension

The construction scenario of the annex building is a keen issue.



Transmission Muon Microscope

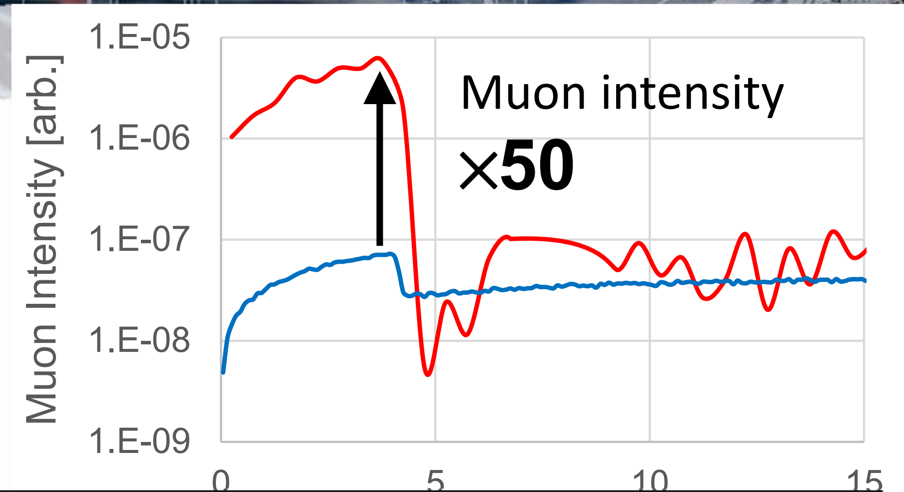
Observation of whole living cell owing to high transmittance capability of muon

g-2/EDM exp.

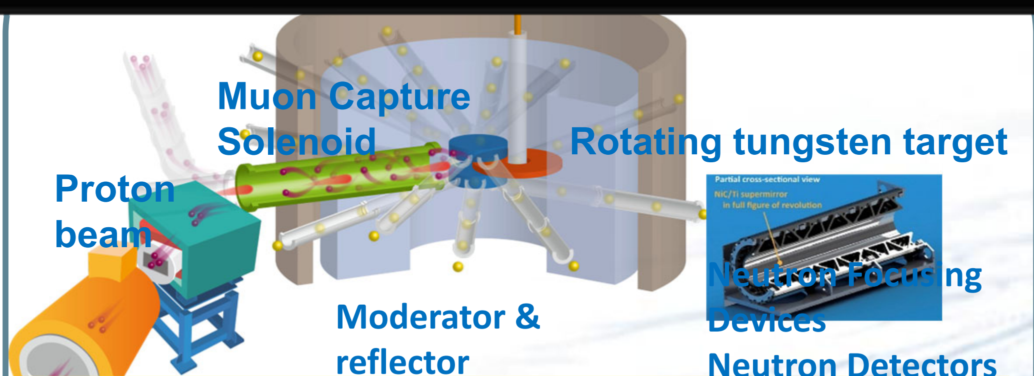
Searching for BSM

Target Station - 2

Courtesy of T. Otomo

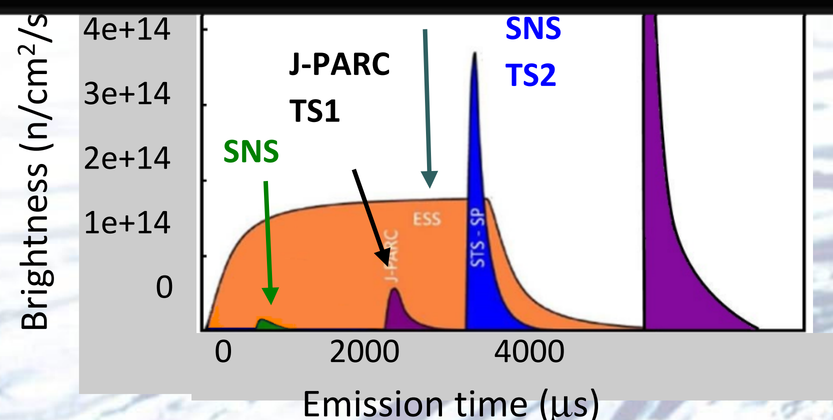


This project was accepted in "The Medium- to the Long Term Academic Research Strategy" by the Science Council of Japan.



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

"Specialties" of MUSE

- High-intensity pulsed beam
  → beam distribution by kicker systems (S line)
  → devices synchronizing the pulse
    → flashlight *etc*. for μSR spectroscopy (SE)
    → ultra slow muon generation by pulse-laser
      → g-2/EDM exp., transmission muon microscope

- pion generation by 3-GeV proton beam
  → relatively high yield of π^- and thus μ^-
    → promotion of non-destructive elemental analysis
      → application to archeological artifacts *etc*.

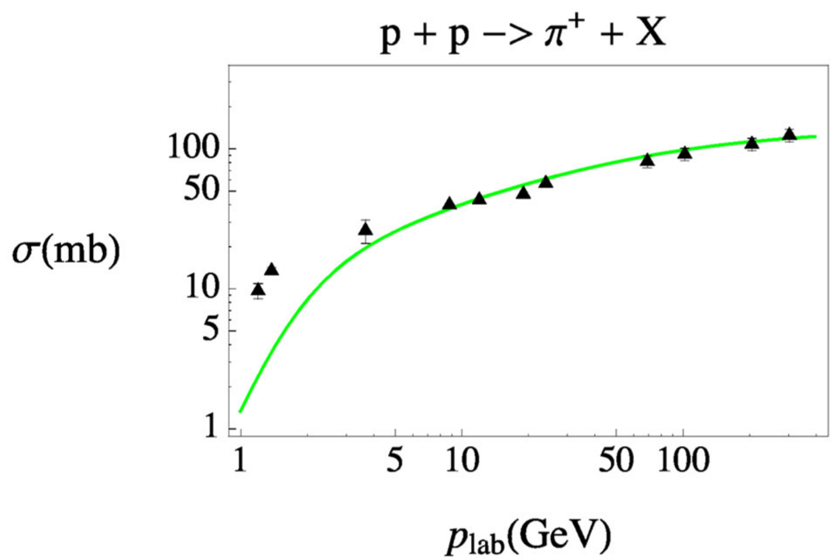


Figure 5: Log - log plot of the π^+ total inclusive cross section parameterization (gr solid line) of equation (1) versus experimental data (triangle symbols) of references [3 6, 7, 9, 14].

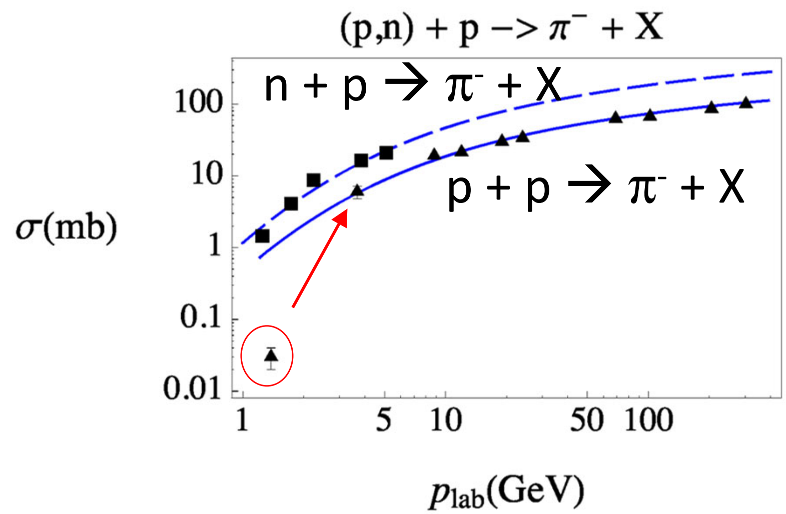


Figure 7: Log - log plot of total inclusive cross section parameterization (blue, solid line) o equation (2) for the reaction $p+p \to \pi^- + X$ versus experimental data (triangle symbols of references [3, 4, 7, 9, 14, ?]. Also shown is the cross section data (solid squares) from Abdivaliev [10], for the reaction $n+p \to \pi^- + X$, compared to the parameterization (blue dashed line) of equation (9).

MUSE utilizes 3GeV proton, and the π^- yield is higher than the other meson factories.

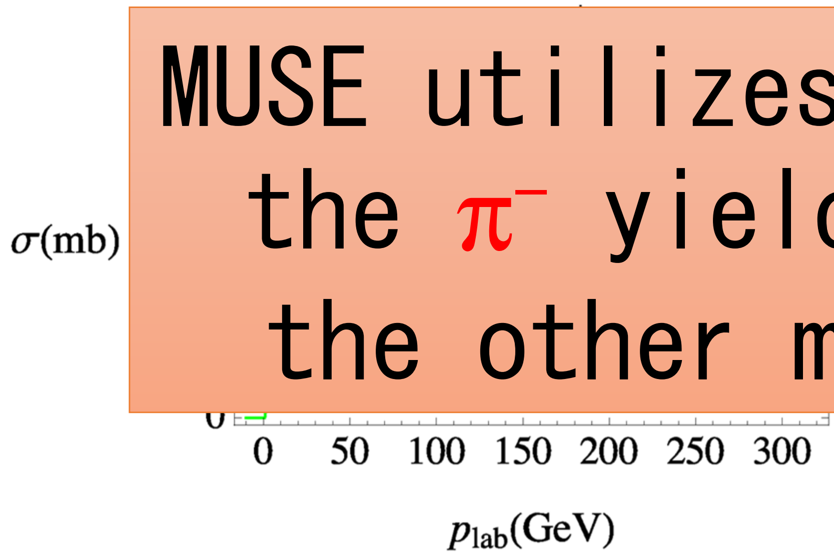


Figure 6: Same as figure 5, except for use of linear axes.

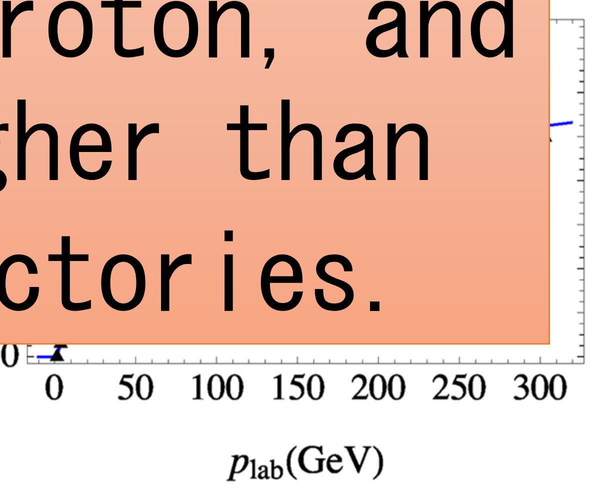
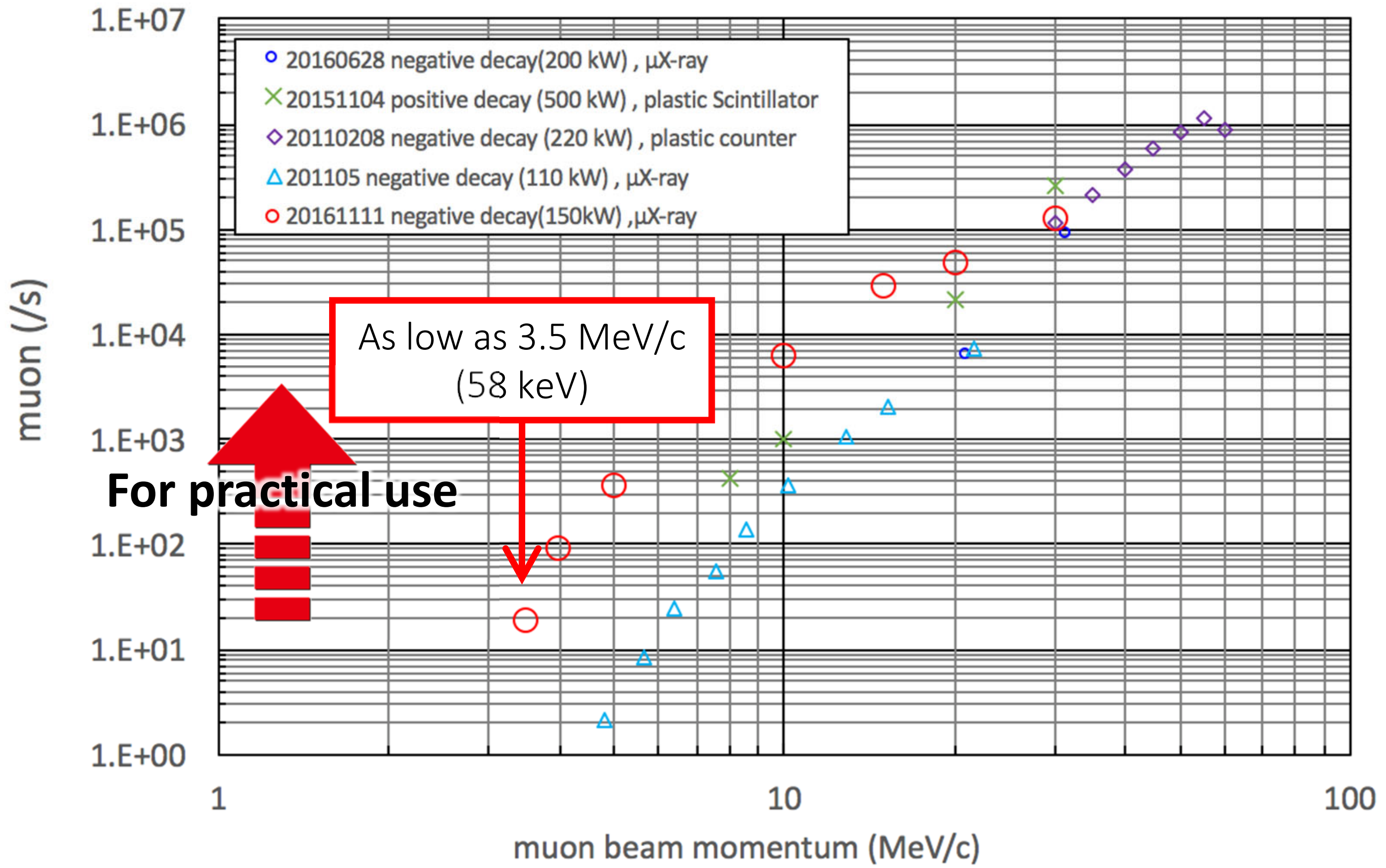


Figure 8: Same as Figure 7, except for use of linear axes and n+p reaction is not shown

Negative muon yield in MLF J-PARC

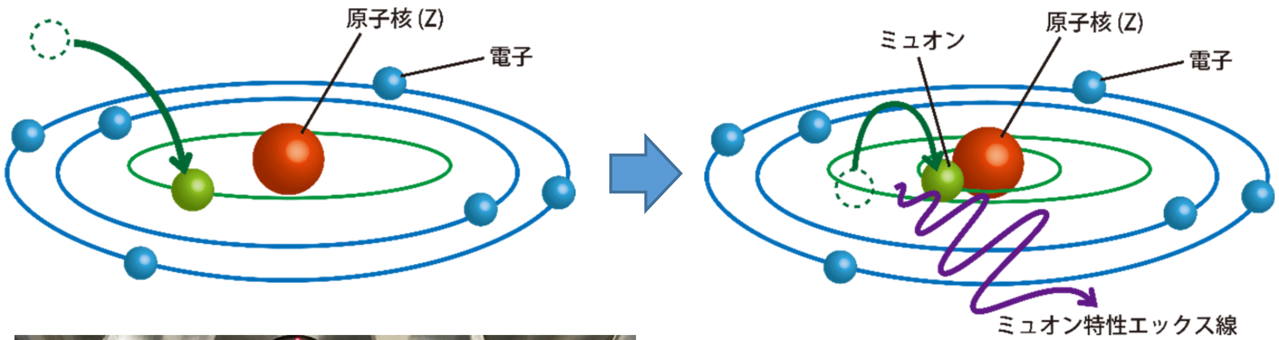
High negative muon yield owing to

- Beam transport with a windowless super-conducting solenoid
- Relatively high negative muon yield by 3 GeV proton

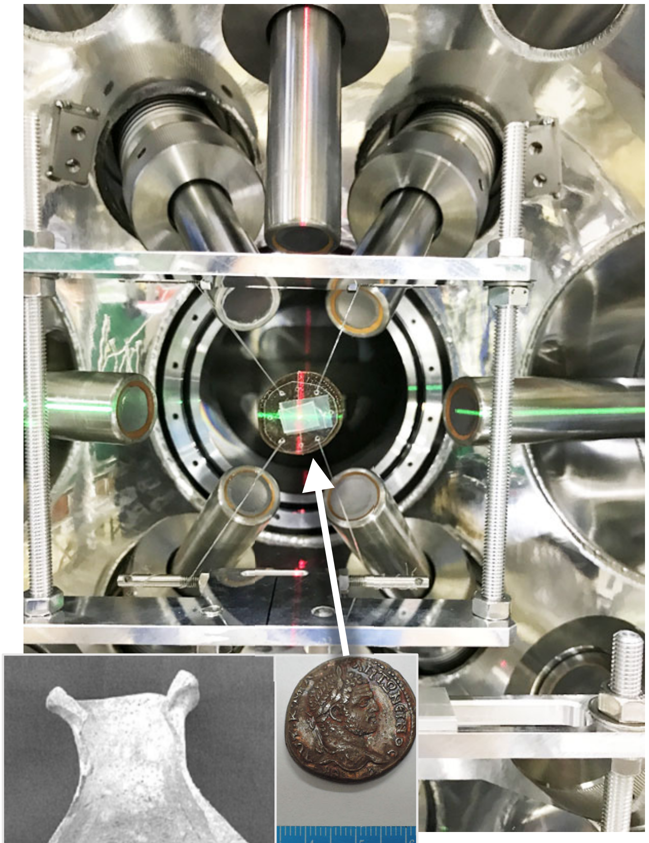


"The world's strongest pulse" and "high negative muon yield" are our specialties that differentiate the other meson factories in the world.

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



To promote this field of study, we made a dedicated panel for heritage science. 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.

Summary

- Detailed information will be provided later in oral and poster presentations.
- Tomorrow, you can enjoy J-PARC, and you can ask any details there.