Future facilities in muon research at J-PARC

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SSP2022, Vienna, September 2nd, 2022

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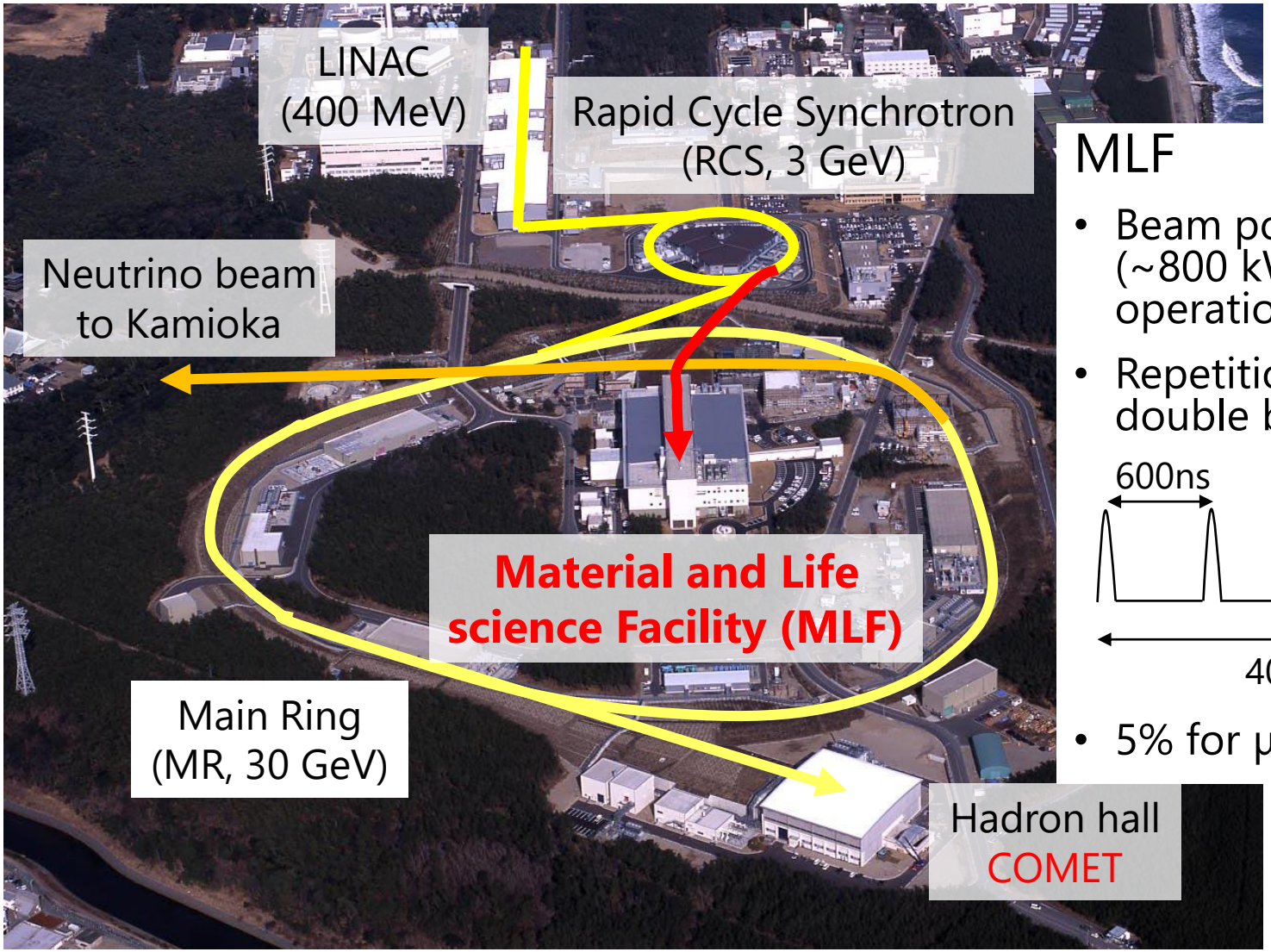
- Future program: 2nd target station of the MLF

J-PARC muon facility

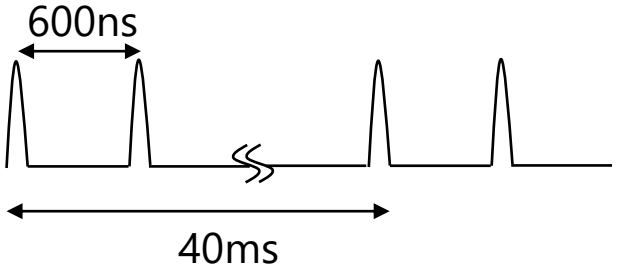
J-PARC

J-PARC (Japan Proton Accelerator Research Complex)



MLF

- Beam power 1 MW (~800 kW stable operation at present)
- Repetition rate 25 Hz, double bunches



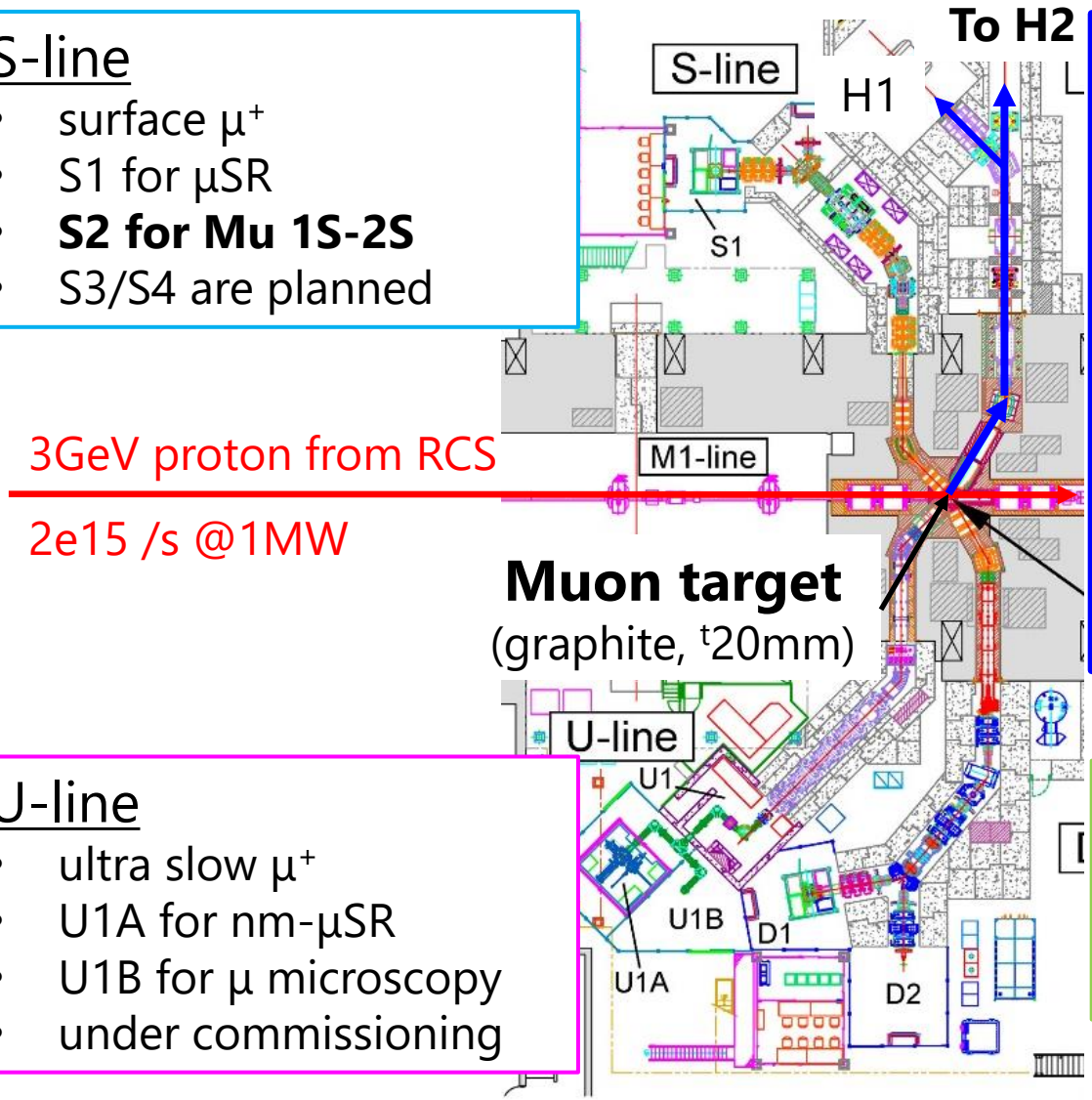
- 5% for μ, 95% for n

J-PARC muon facility

- MUSE (MUon Science Establishment) in the MLF

S-line
- surface μ^+
- S1 for μSR
- **S2 for Mu 1S-2S**
- S3/S4 are planned

H-line
- surface μ^+ (10^8 μ^+/s), cloud μ^+/μ^- (up to 120MeV/c)
- for high intensity & long beamtime experiments
- **H1 for MuSEUM & DeeMe, started operation in Jan. 2022!**
- H2 for g-2/EDM & TμM, under construction



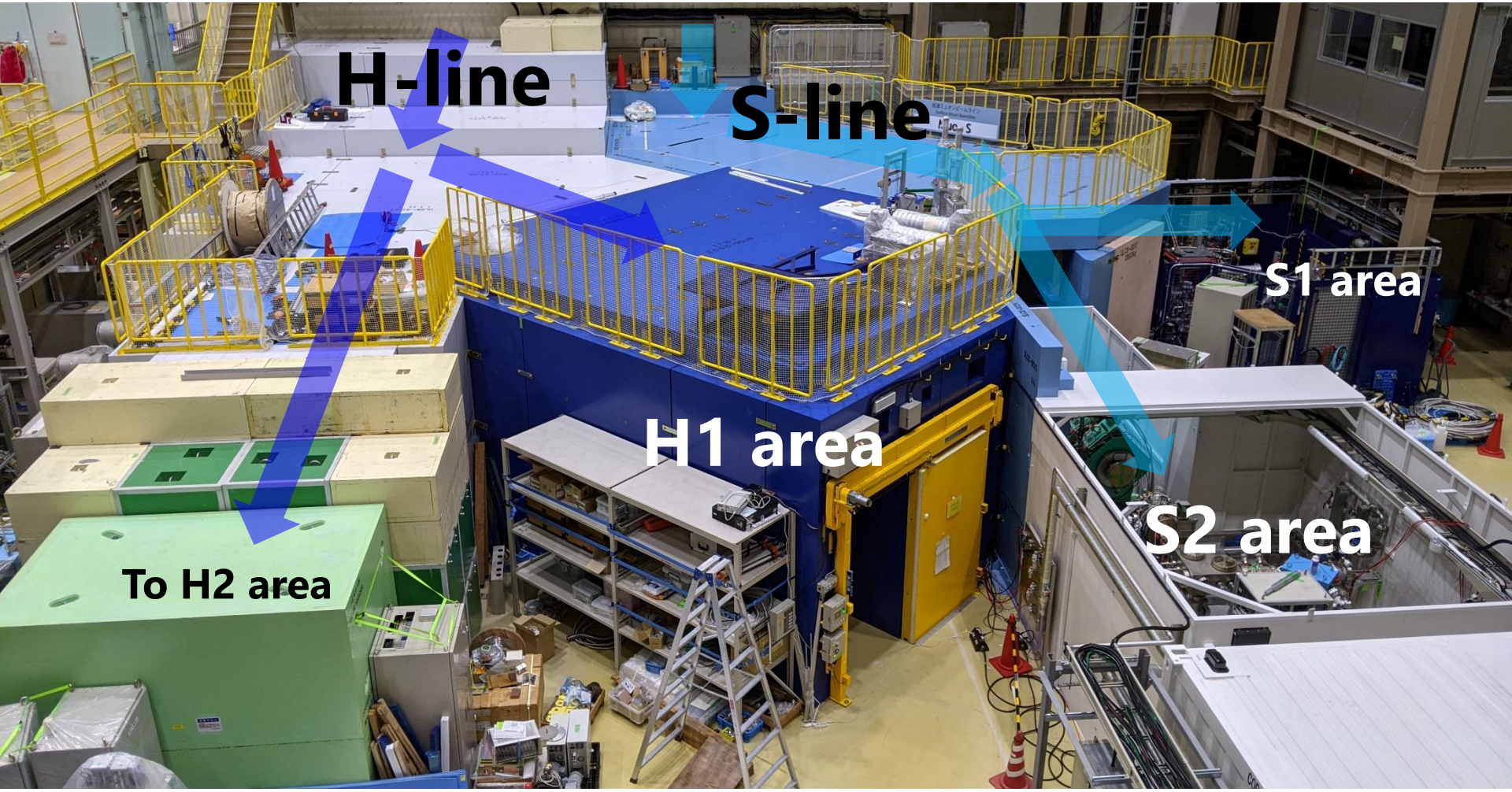
U-line
- ultra slow μ^+
- U1A for nm-μSR
- U1B for μ microscopy
- under commissioning

D-line
- decay μ^+/μ^-, surface μ^+
- D1 area for μSR
- D2 for variety of science

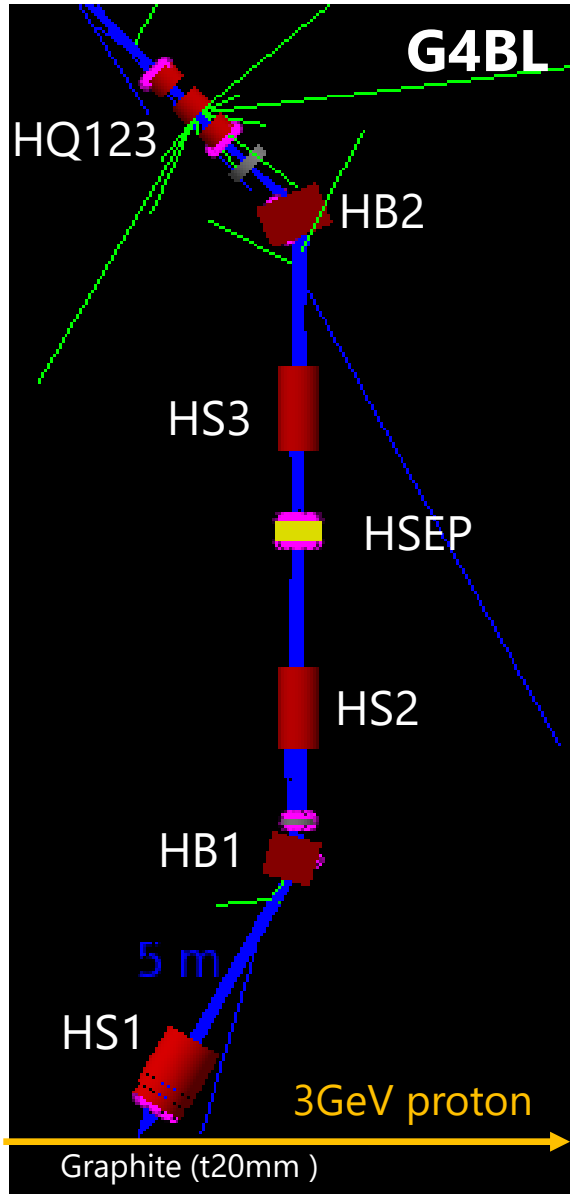
New beamlines for fundamental physics

New two beamlines since JFY2021

- H1 area (1st branch of the H-line) : MuSEUM & DeeMe
- S2 area (2nd branch of the S-line) : Mu 1S-2S



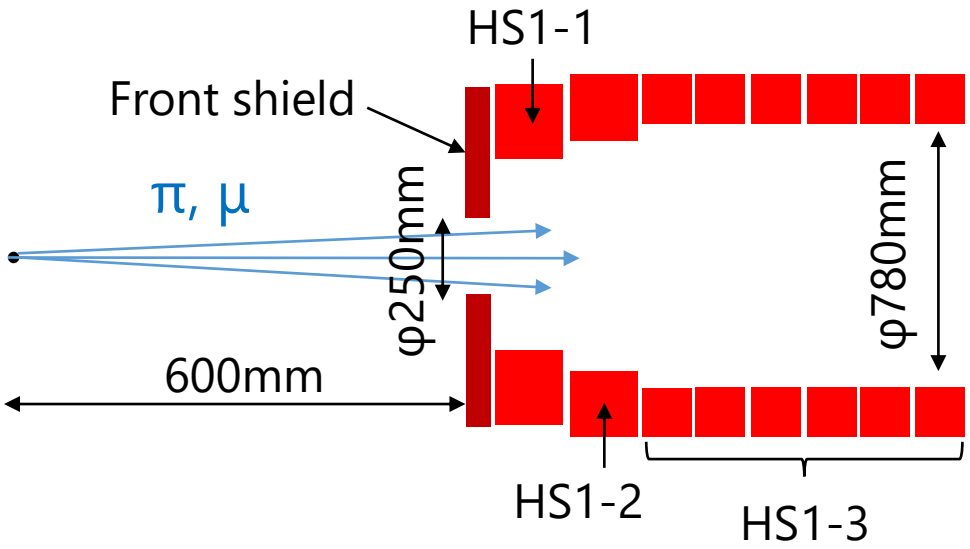
H-line



- H-line is a high intensity muon beamline which can deliver both of surface μ^+ and cloud μ^+/μ^-.
- Beamline optics
  - HS1 : large acceptance (108mSr) capture solenoid
  - HB1,2 : wide gap (300mm) bending magnet
  - HS2,3 : Two superconducting solenoid with opposite polarities
  - HSEP : Wien filter to reduce e^+/e^- background (not installed yet…)
  - HQ123 : Q-triplet for final focusing
- Surface muons of 10^8 μ^+/s are expected to the H1 area with a graphite target and 1MW proton beam.
- **First beam on 15th Jan. 2022!**

π/μ capture solenoid of the H-line

Most important to get intense beams



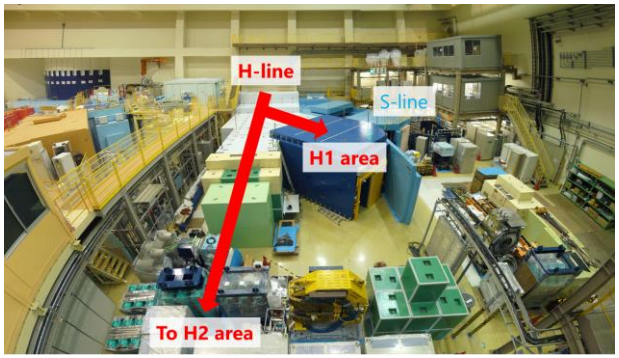
Spec.	Rating	Now
HS1-1 : 0.37T	(3000A) ...	1500A
HS1-2 : 0.31T	(3000A) ...	1500A
HS1-3 : 0.60T	(2600A) ...	900A

- The solenoids are wound with normal conducting Mineral Insulation Cables (MIC) to get enough radiation resistance.
- Due to the failure of the power supplies, maximum currents are limited now...

H-line construction history

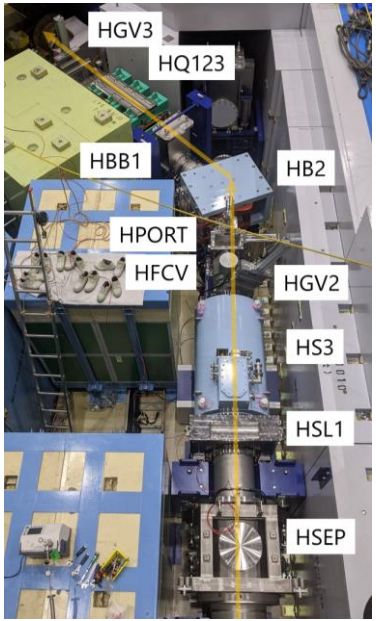
JFY2012
Frontend devices

JFY2016 Radiation shield

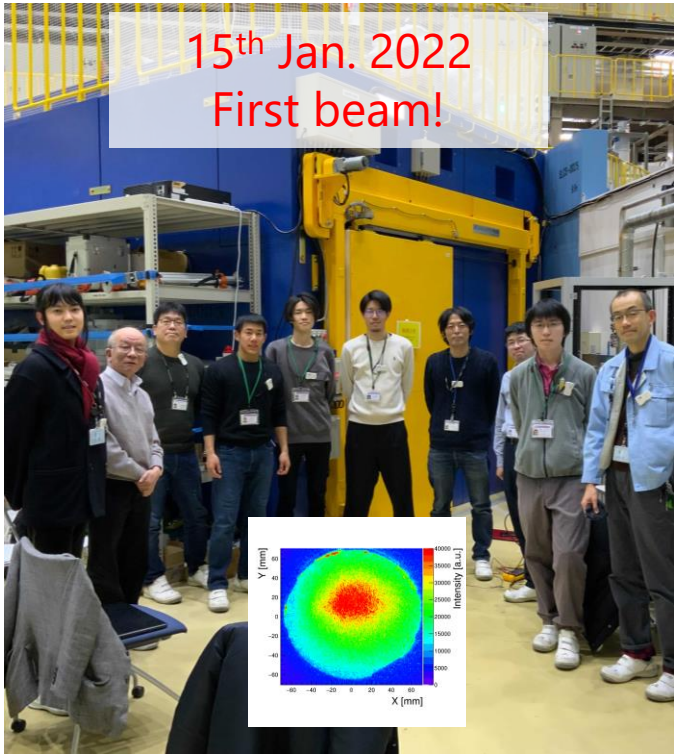


JFY2017~2019: Electric sub-station
* For the NC capture solenoid

JFY2020
Install magnets

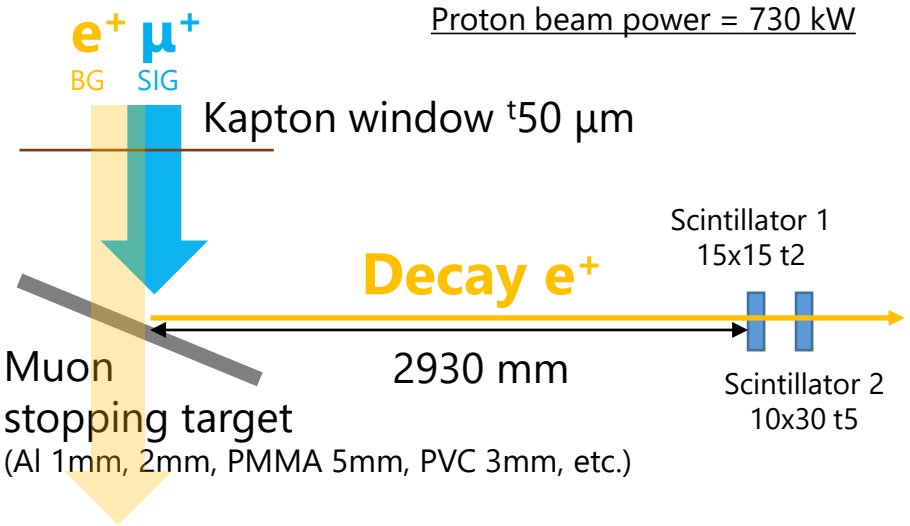


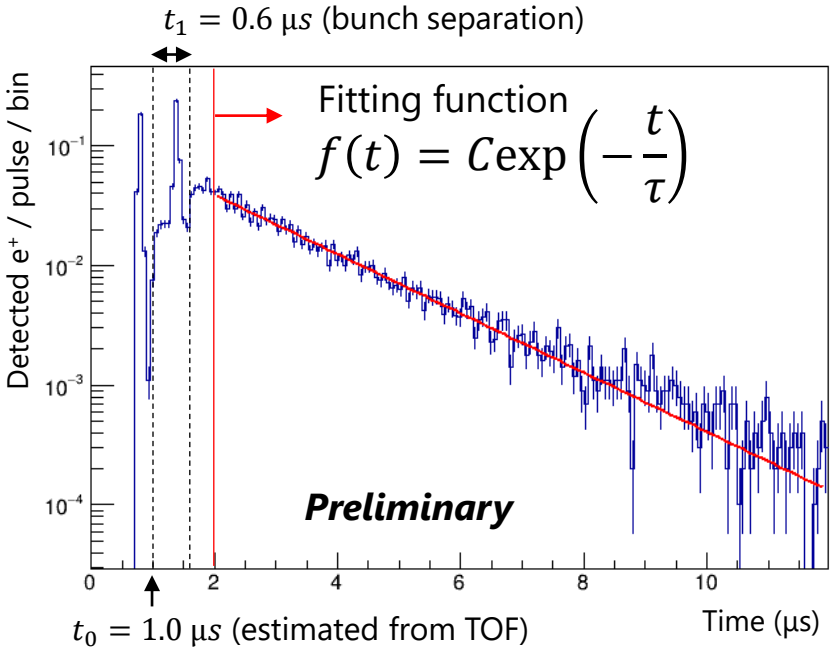
JFY2021
Cabling, plumbing



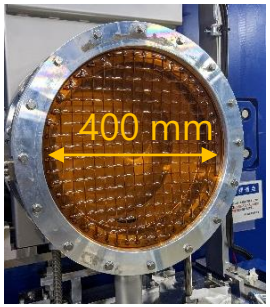
H-line commissioning: Surface μ

Beam intensity measurement





- Number of detected positrons per pulse (25Hz) = 1.6 e^+/pulse
- Detector acceptance (sim.) = 7 x 10^{-7}
- Detection efficiency of scintillators = 0.89
- Transmission efficiency of Kapton window (sim.) = 0.87



The thickness of Kapton = 50 μm, but it is a mesh window to withstand atmospheric stress.

- Proton beam power = 730 kW

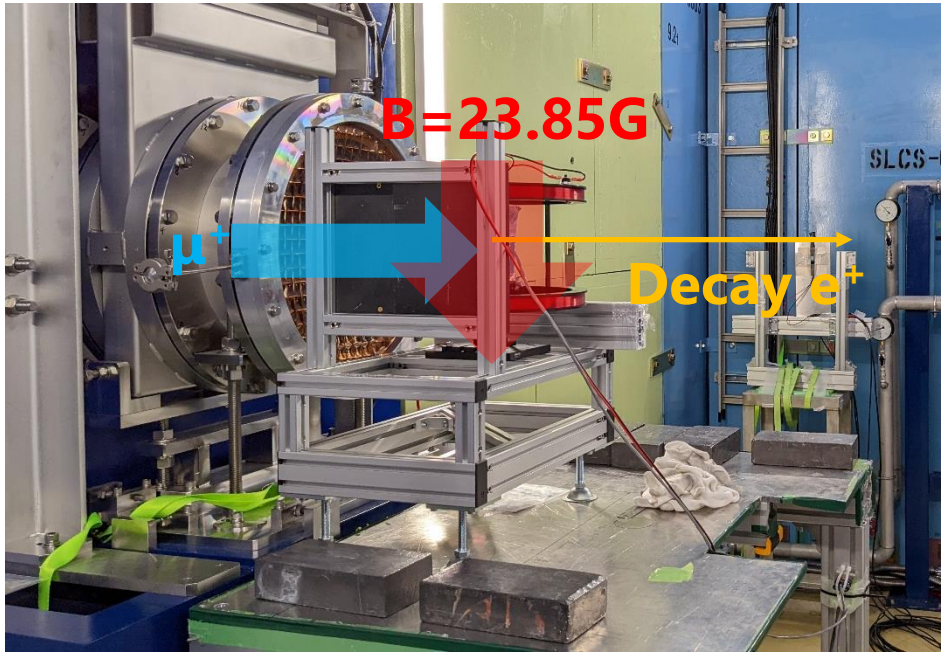
9.9 x 10^7 μ^+/s @1MW (***Preliminary***), almost the same as our expectation.

~10% increase is expected if we fix the power supplies of the capture solenoid.

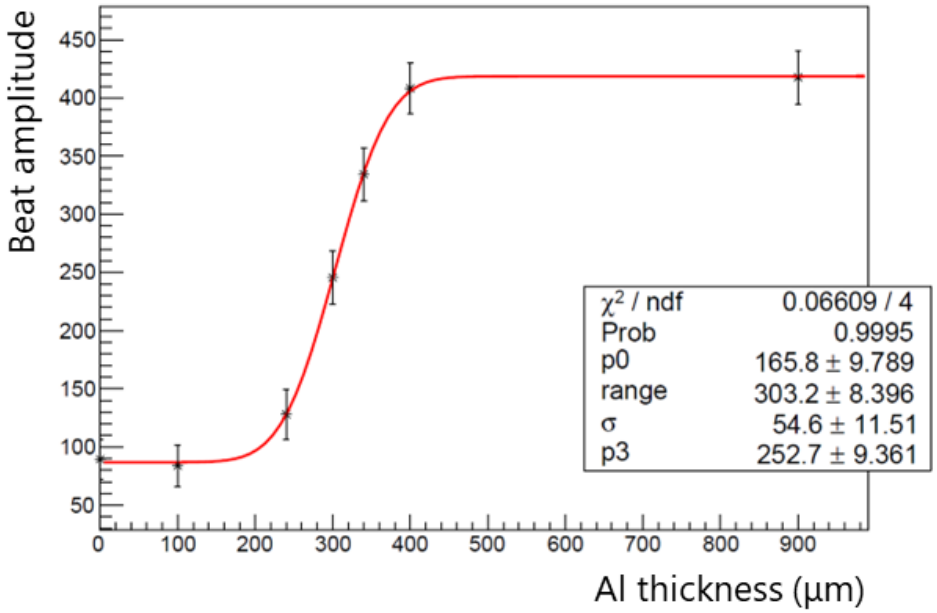
H-line commissioning: Surface μ

Momentum measurement

- Almost the same setup as the intensity measurement
- Al target in a magnetic field of 23.85 G
- Beat amplitude of wiggle plot (∝number of stopped muons) is plotted as a function of Al thickness



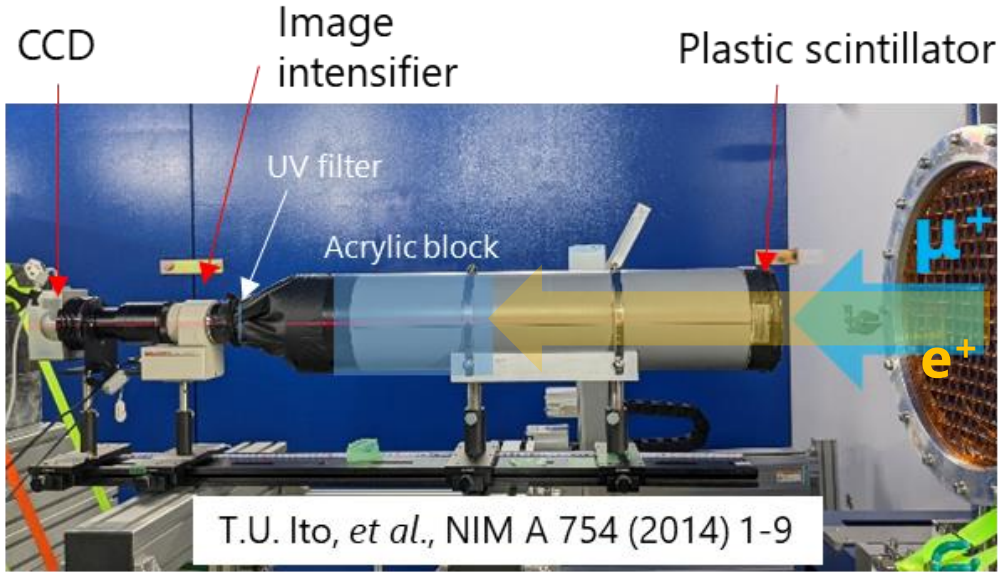
Range measurement

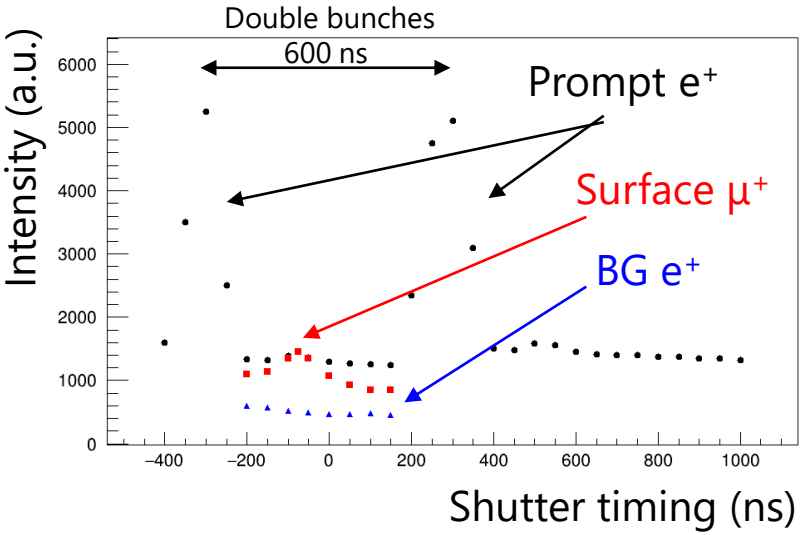


From μ^+ range in Al target, we estimated
P = 28.0 MeV/c (RMS 1.2 MeV/c) in the beamline as expected.

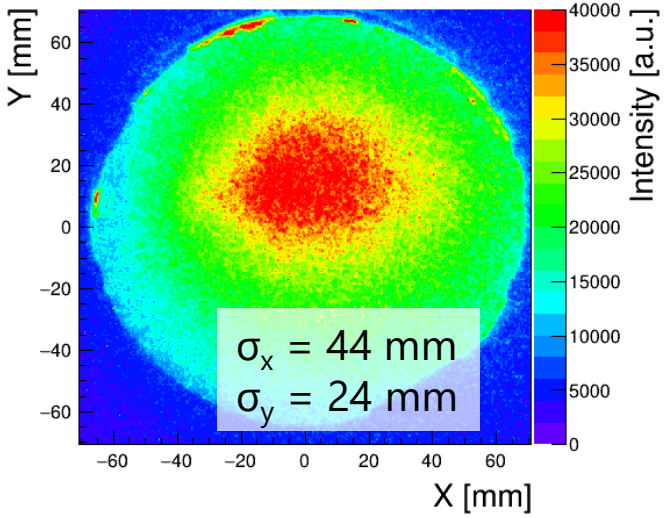
H-line commissioning: Surface μ

Beam profile measurement





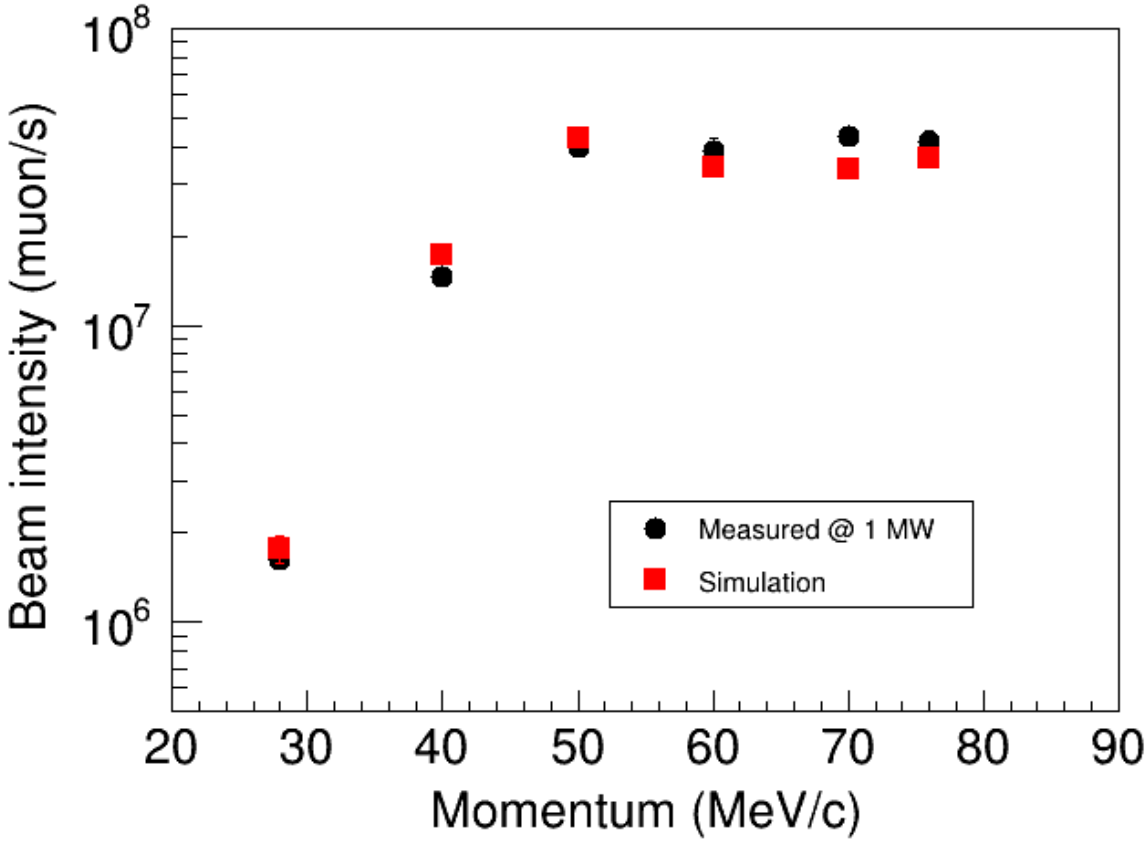
A typical profile of surface μ+



- BG and decay positrons are blocked by the acrylic block.
- Cherenkov lights from the acrylic block cannot pass through the UV filter.
- To select surface μ+, we adjusted the shutter timing.

H-line commissioning: Cloud μ^-

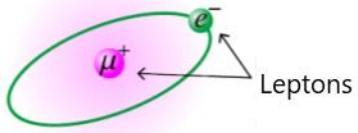
- We measured intensities of cloud μ^- up to 80 MeV/c.
  - ✓ Upgrade of the power supplies, which is scheduled in this JFY, is necessary for higher momentum.



Consistent with Geant4 and G4beamline simulation (Model: QGSP_INCLXX)

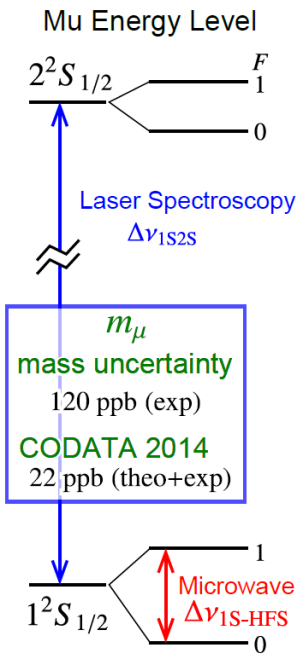
MuSEUM @H1 area

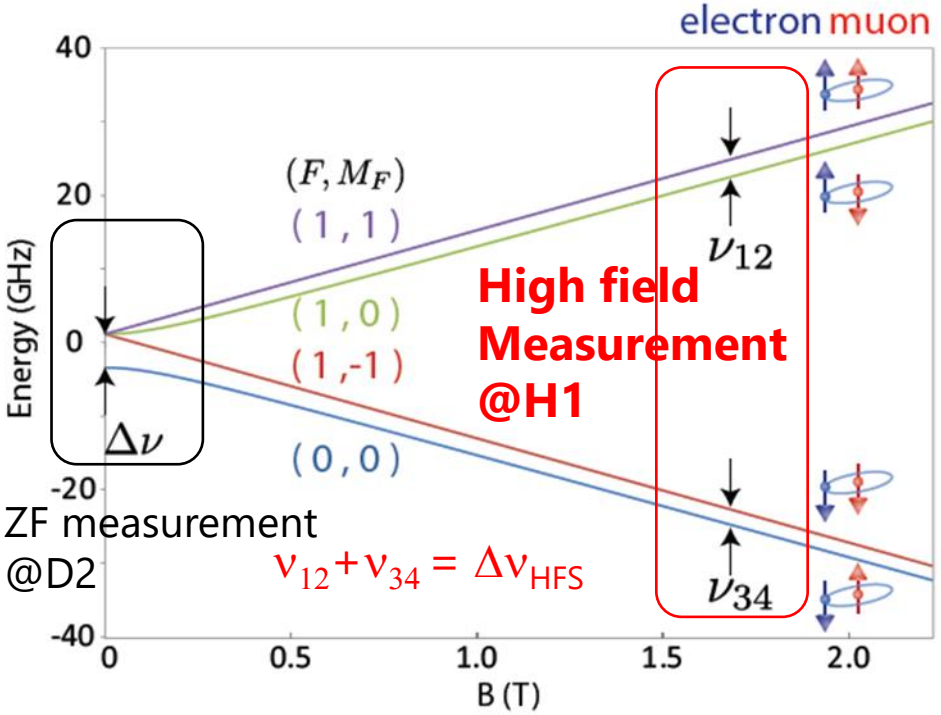
Muonium (Mu)



→ Next talk by K. Shimomura

Precise measurement of the hyperfine structure of muonium





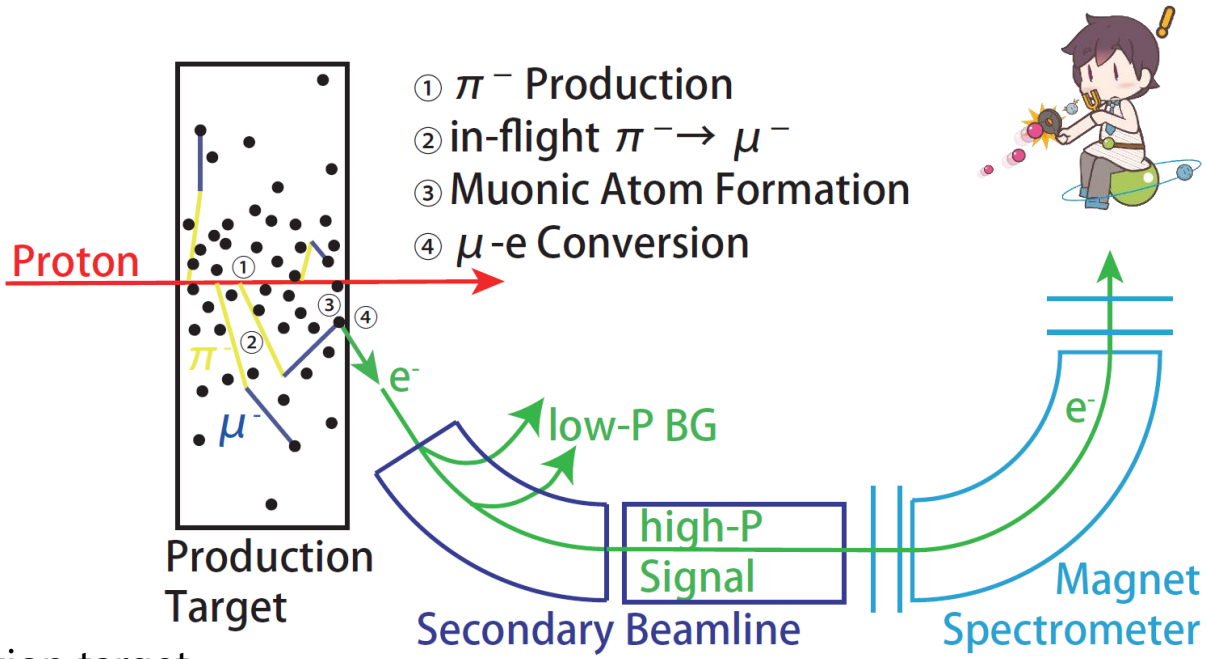
Previous experiment: 4 463.302 765 (53) MHz (LAMPF1999)

Precision of 8 Hz will be reached by a high field measurement at the H-line.

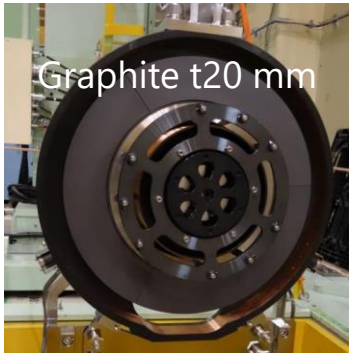
A Wien filter to eliminate e^+ BG is inevitable for this experiment and will be installed in this JFY.

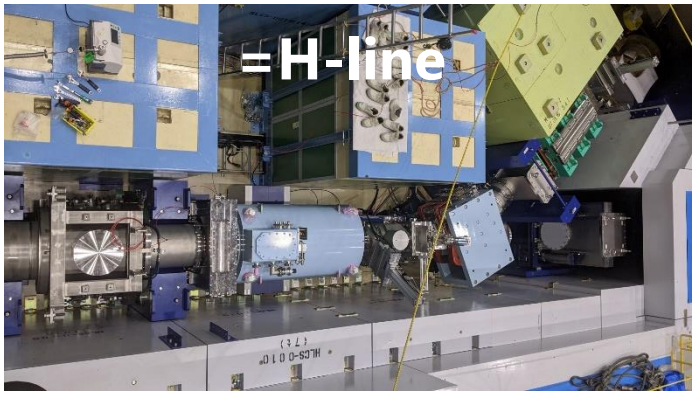
DeeMe @H1 area

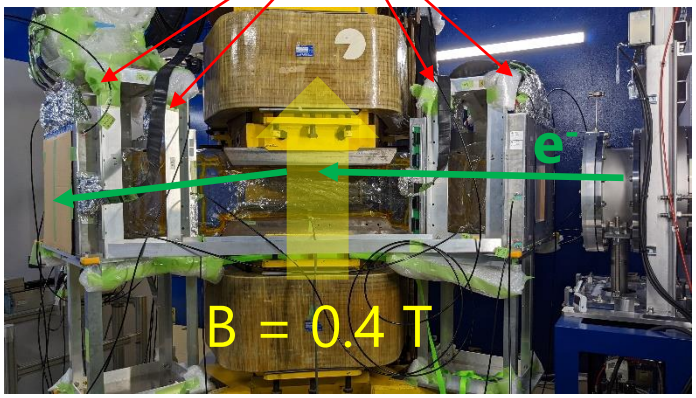
- Search for μ-e conversion (sensitivity ~10^{-14})
  - Pilot RUN was conducted at the H1 area in July 2022.



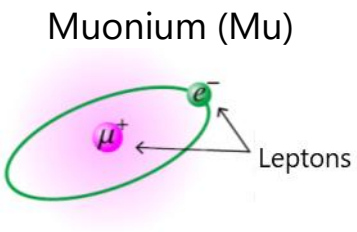
Production target





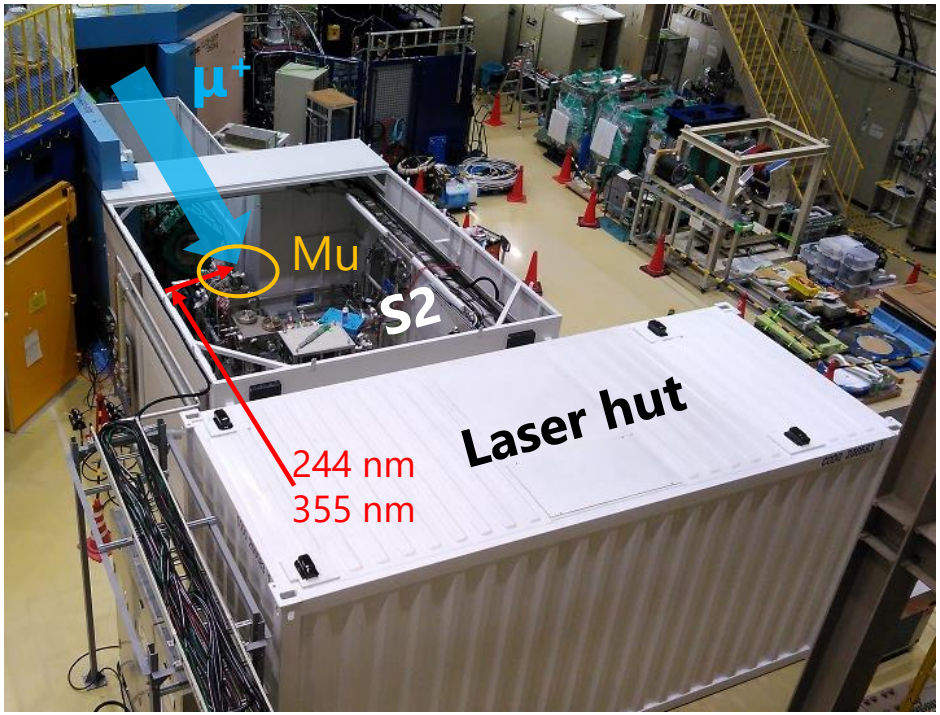


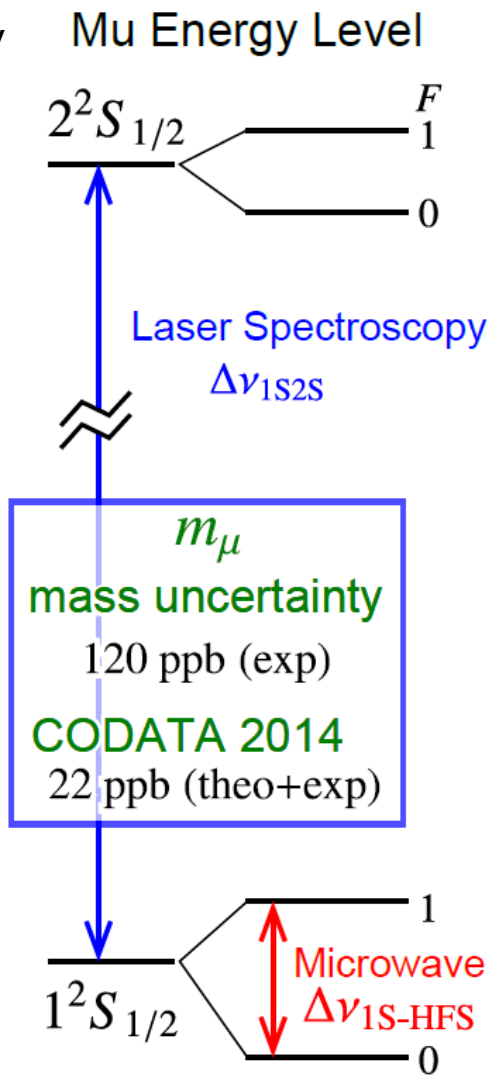
S2 area and Mu 1S-2S



→ Next talk by K. Shimomura

- 2nd branch of S-line dedicated to Mu 1S-2S spectroscopy
  - ✓ Surface muon beamline: 2×10^6 μ^+/s (single bunch)





$$\Delta\nu_{1S2S} \simeq \frac{3\alpha^2}{8h} m_e c^2 \left(1 + \frac{m_e}{\underbrace{m_\mu}_{\text{mass}}}\right)^{-1}$$

10 kHz precision

Δm_μ = 1 ppb

Extension of the H-line (near future)

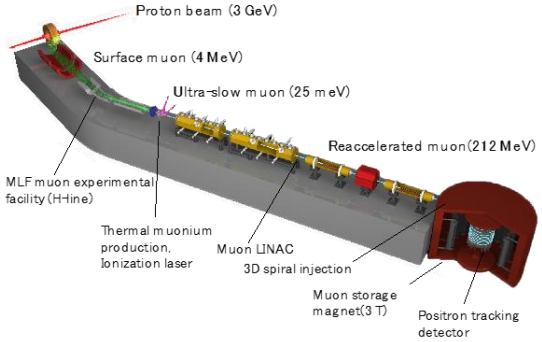
Further extension of the H-line

At the 2nd branch of the H-line, ultra slow muons will be re-accelerated up to 200 MeV to obtain a low-emittance (1 π mm*mrad) muon beam.

Muon g-2/EDM experiment

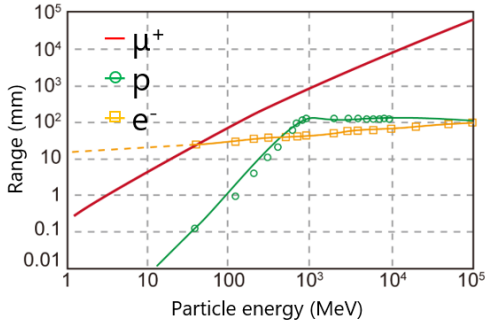
▷ The low-emittance muon beam enables us not to use a strong focusing E-field.

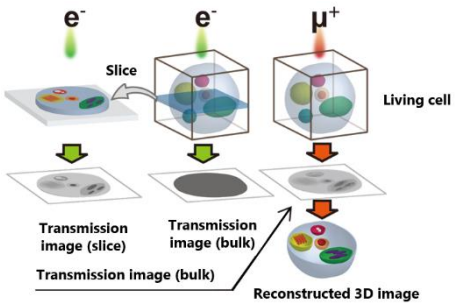
▷ Complementary method to check the discrepancy

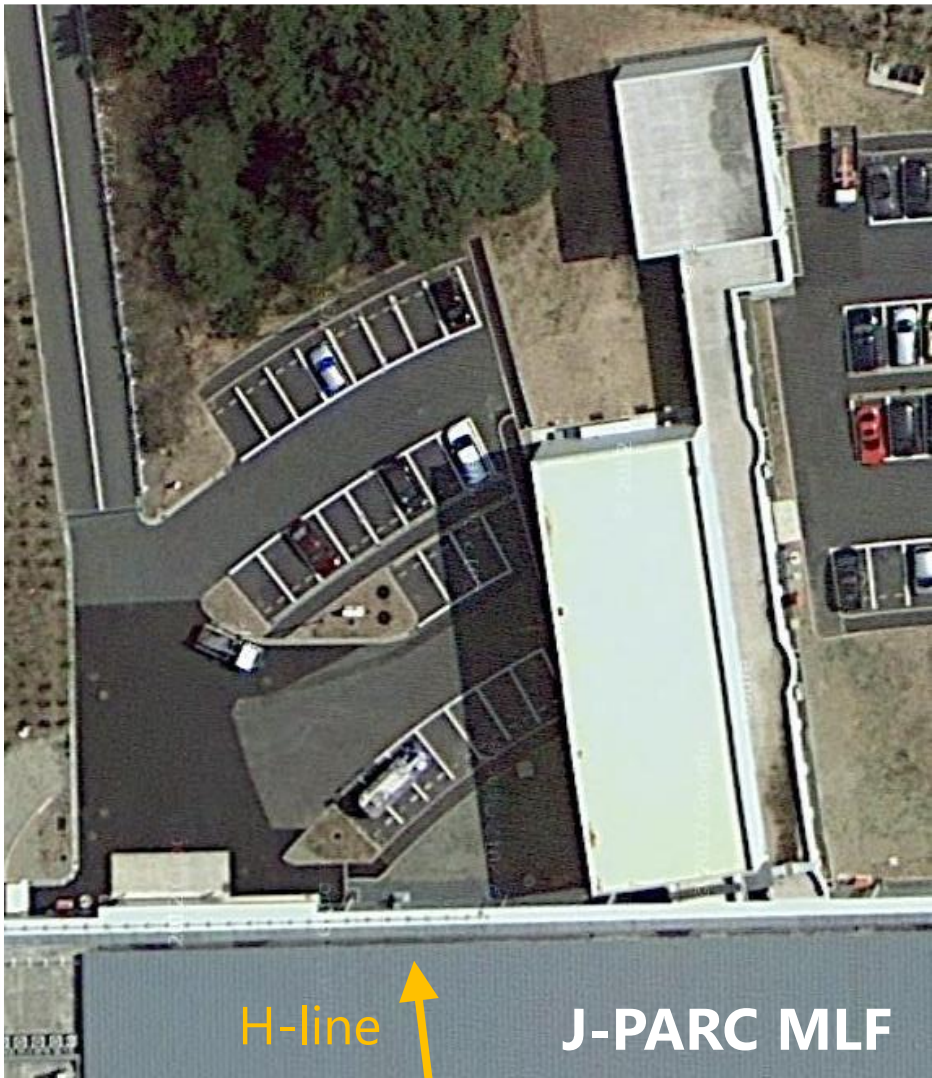


Transmission muon microscope (TμM)

▷ Observe bulk samples utilizing the strong penetrative power of re-accelerated muons







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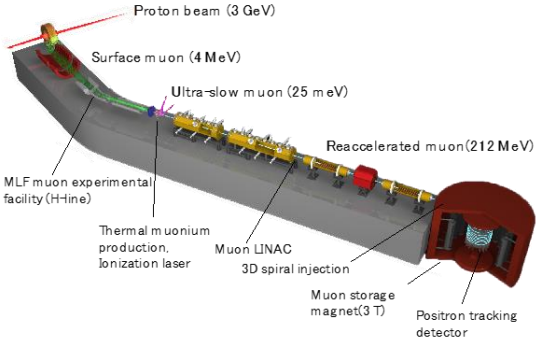

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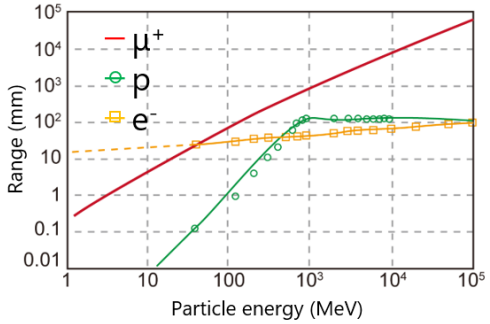
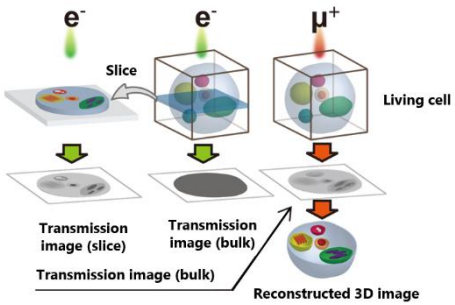
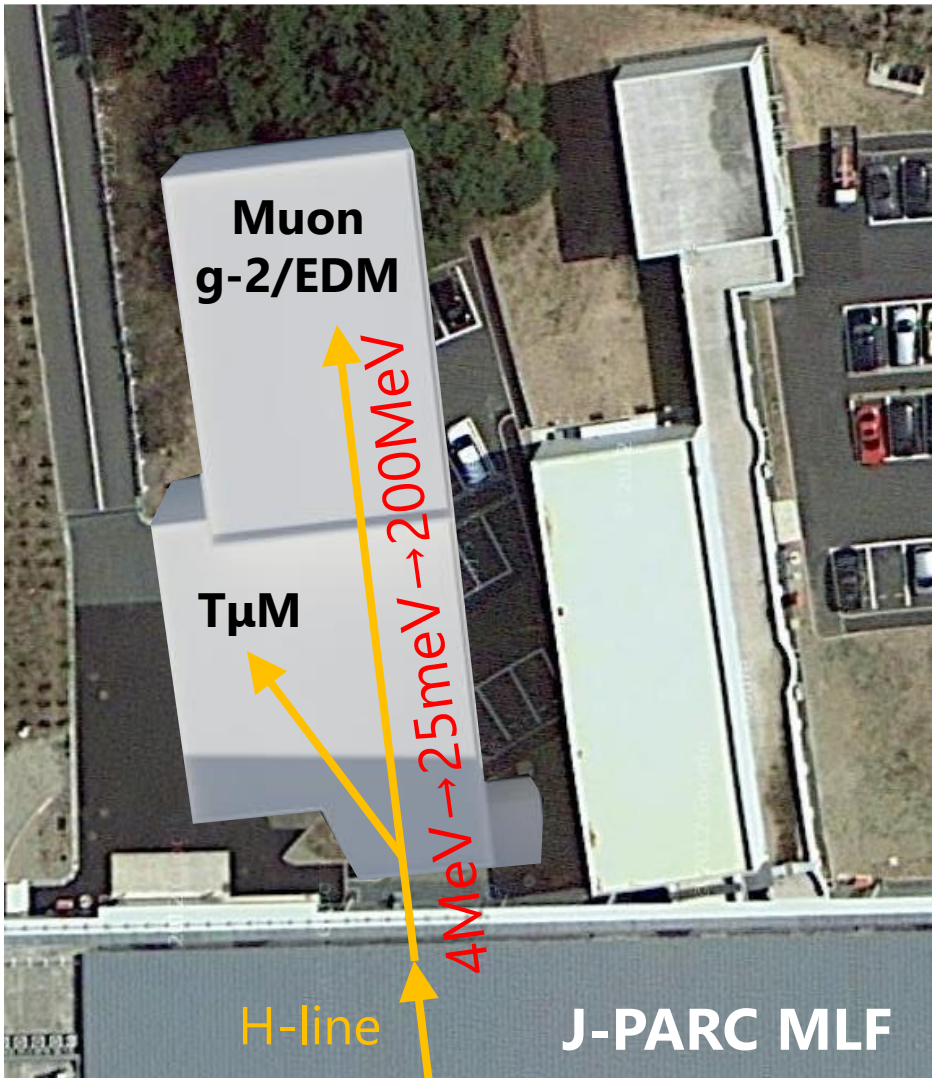
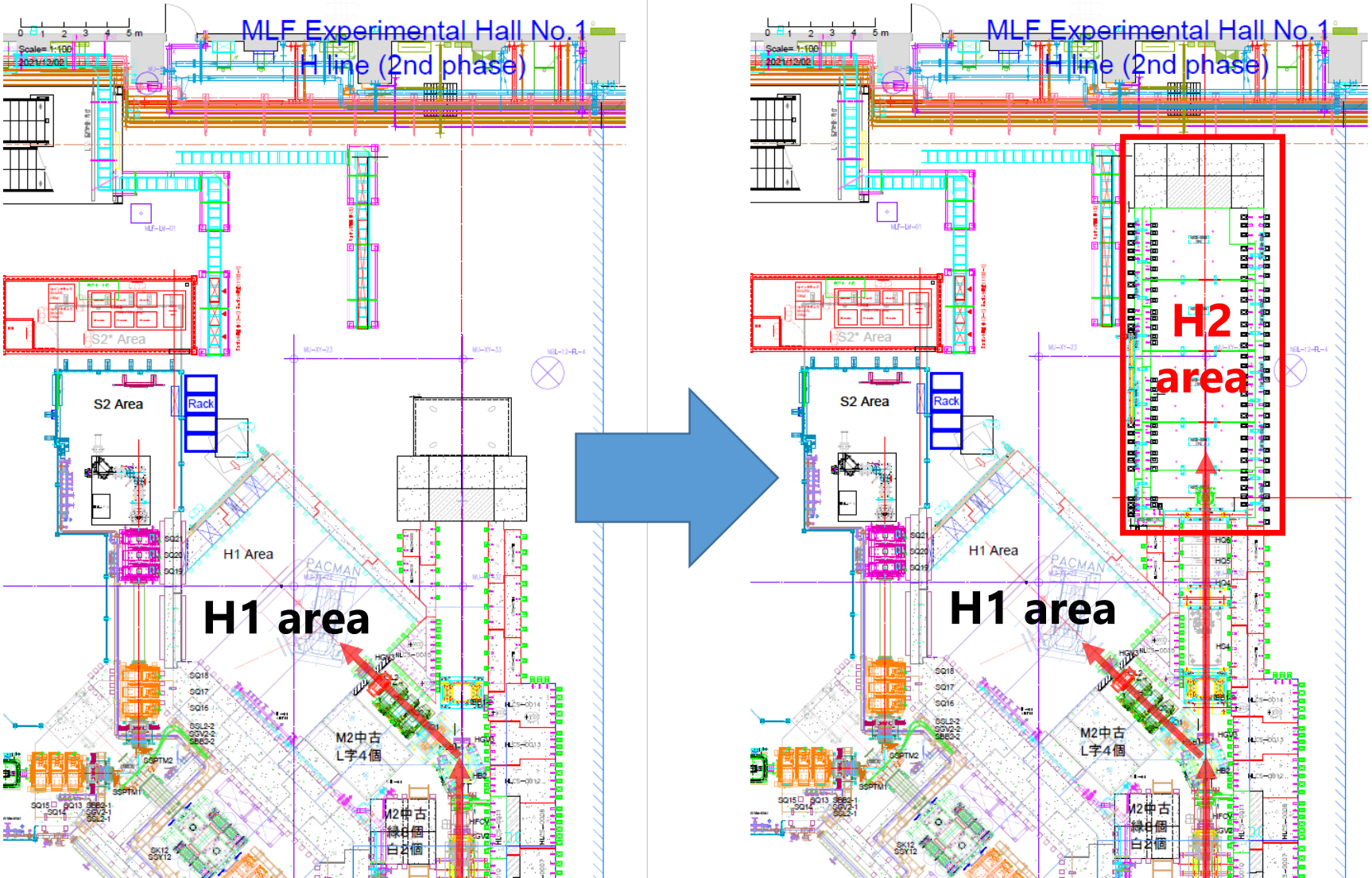






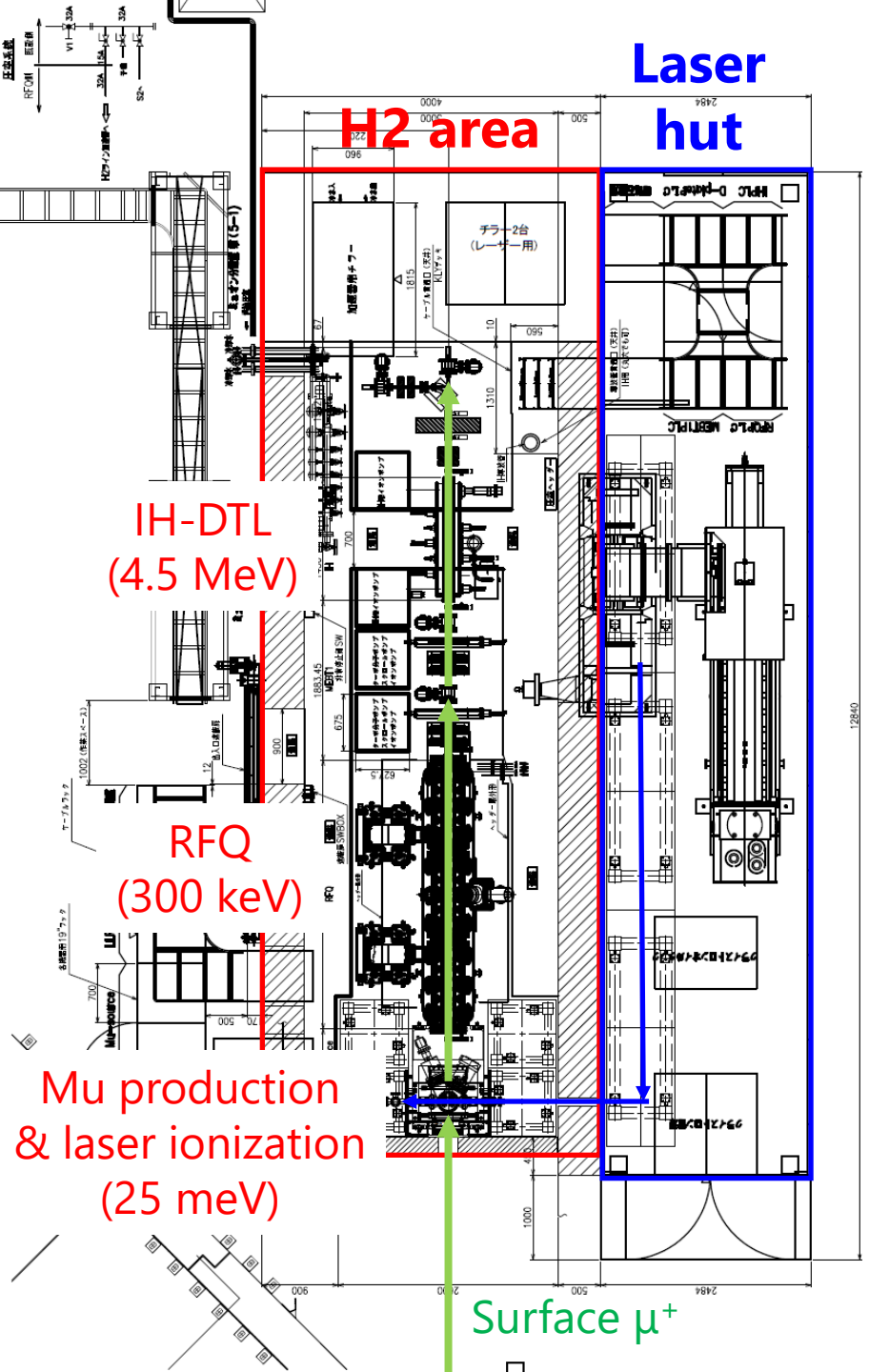
Schedule of the H-line extension

- This JFY: construction of the 2nd branch (H2 area)



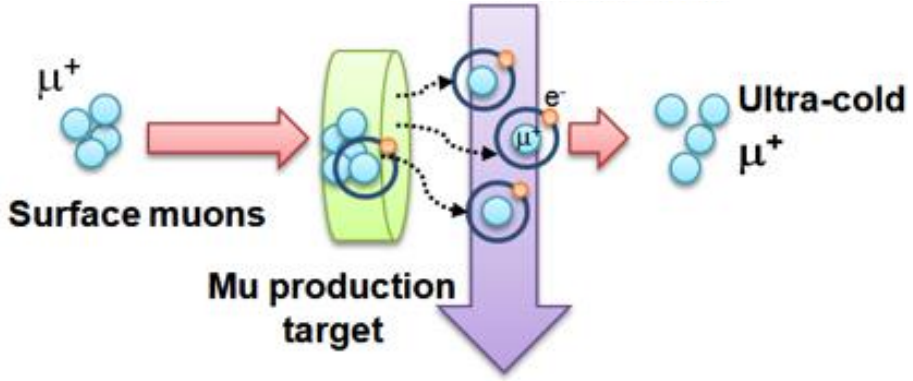
Manufacturing its concrete shields

Schedule of the H-line extension



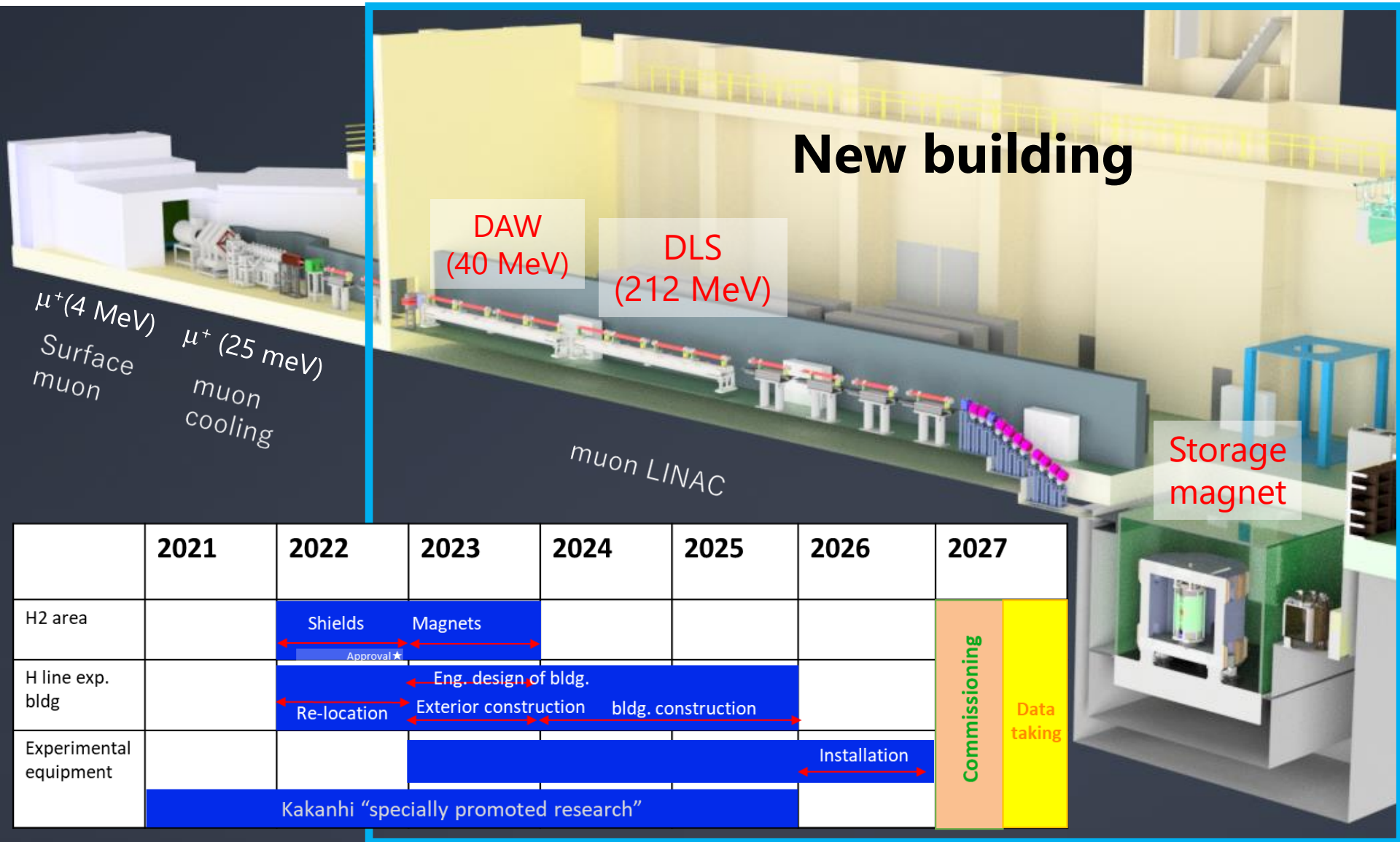
- Apparatuses to produce ultra slow muons (25 meV) and accelerators up to 4.5 MeV will be installed from the next JFY.

1x 122 nm (1S-2P)
or 2x 244 nm (1S-2S)
+ 355 nm (ionization)



Schedule of the H-line extension

Construction of a new building will be started from the next JFY

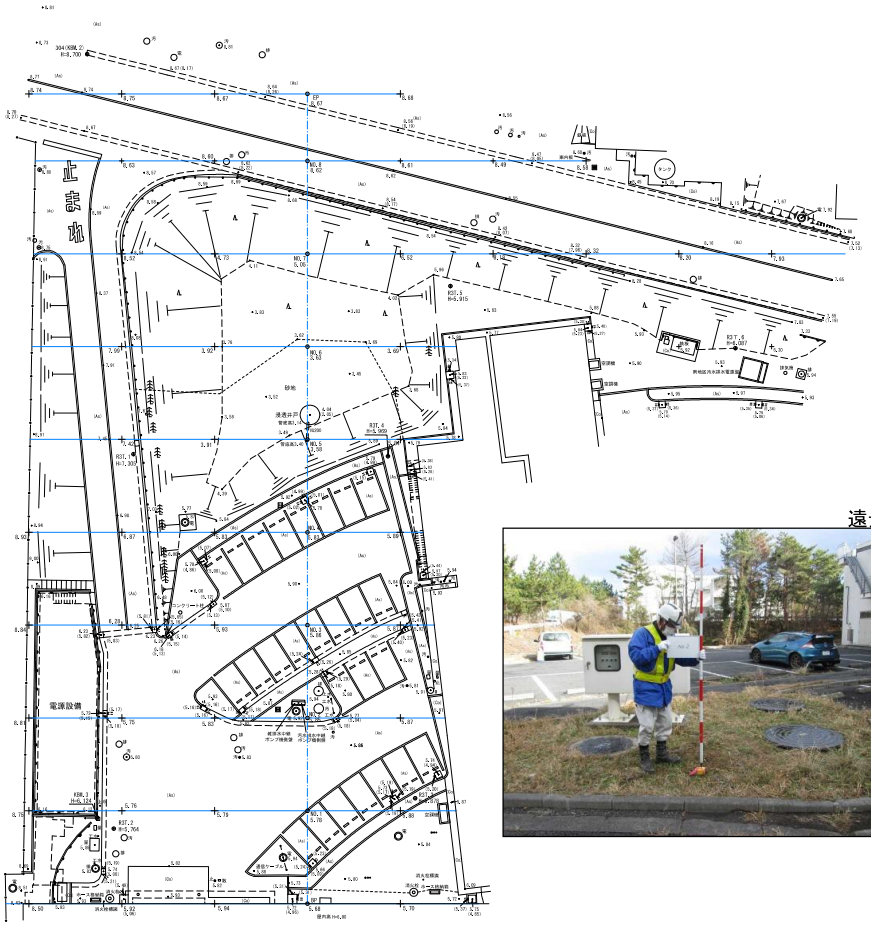


	2021	2022	2023	2024	2025	2026	2027
H2 area		Shields (Approval ★)	Magnets				Commissioning / Data taking
H line exp. bldg		Re-location	Eng. design of bldg. / Exterior construction	bldg. construction			
Experimental equipment						Installation	
	Kakanhi "specially promoted research"						

Preparatory works before construction

Geotechnical investigation

Survey of the construction site



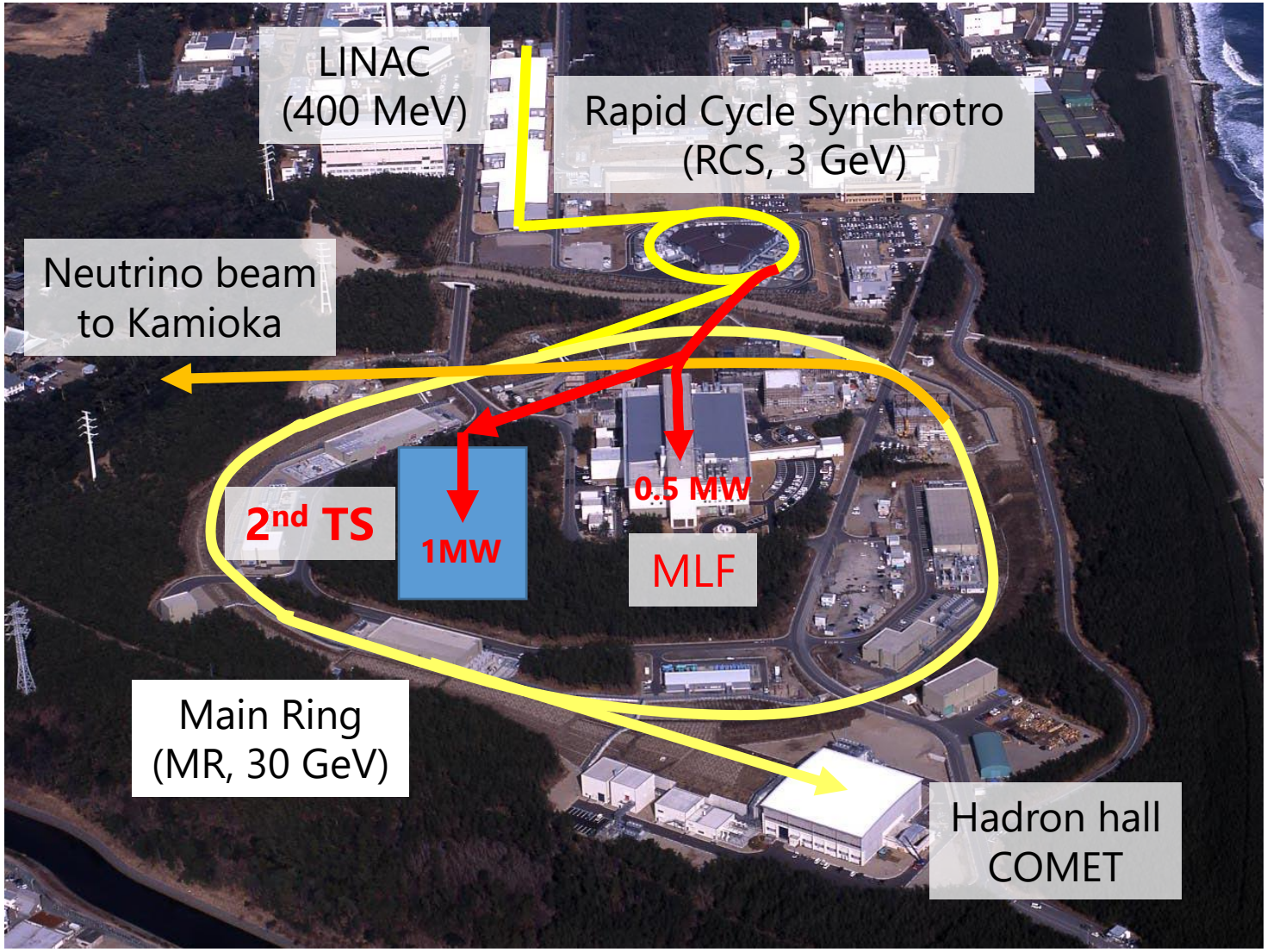
Research of buried cultural properties

…, and the relocation of buried cables is ongoing now.

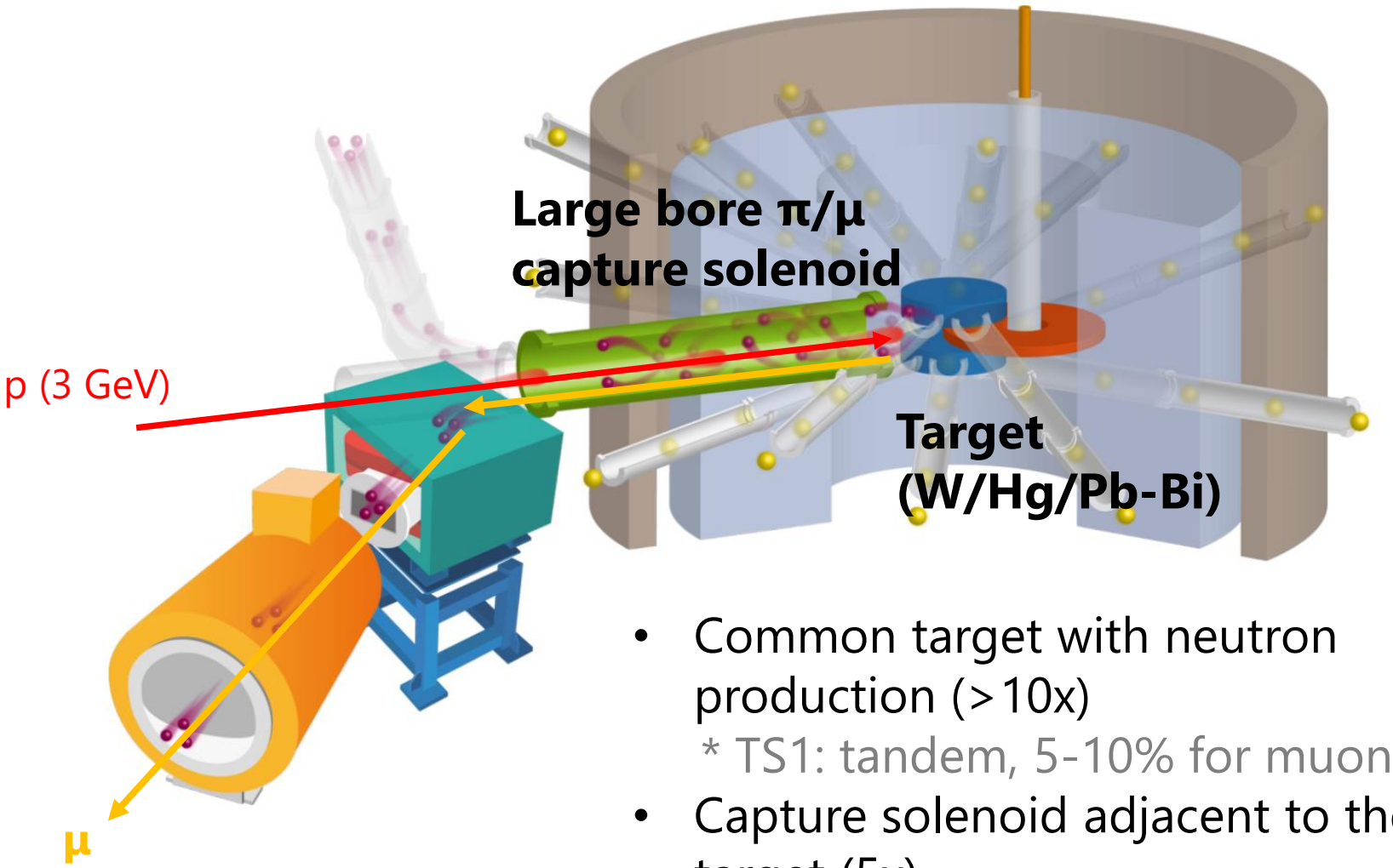
Future program: 2nd target station of the MLF

J-PARC MLF 2nd target station

Conceptual Design report v1.2



Muon beam optics



- Common target with neutron production (>10x)
  * TS1: tandem, 5-10% for muon
- Capture solenoid adjacent to the target (5x)

→ **>50 times higher intensity of μ**

Summary

- New beamlines (H1 and S2) joined the J-PARC muon facility.
  - H-line is a high intense muon beamline (surface $\mu^+ > 10^8$ /s)
  - H1 area: MuSEUM and DeeMe experiments
  - S2 area: Mu 1S-2S
- Further extension of the H-line is ongoing.
  - H2 area is going to be constructed in this JFY.
  - Construction of the low emittance beamline will start from the next JFY, and preparatory works are underway.
- Conceptual design of the 2nd target station of the MLF is in progress.
  - >50 times more intense muons could be available.