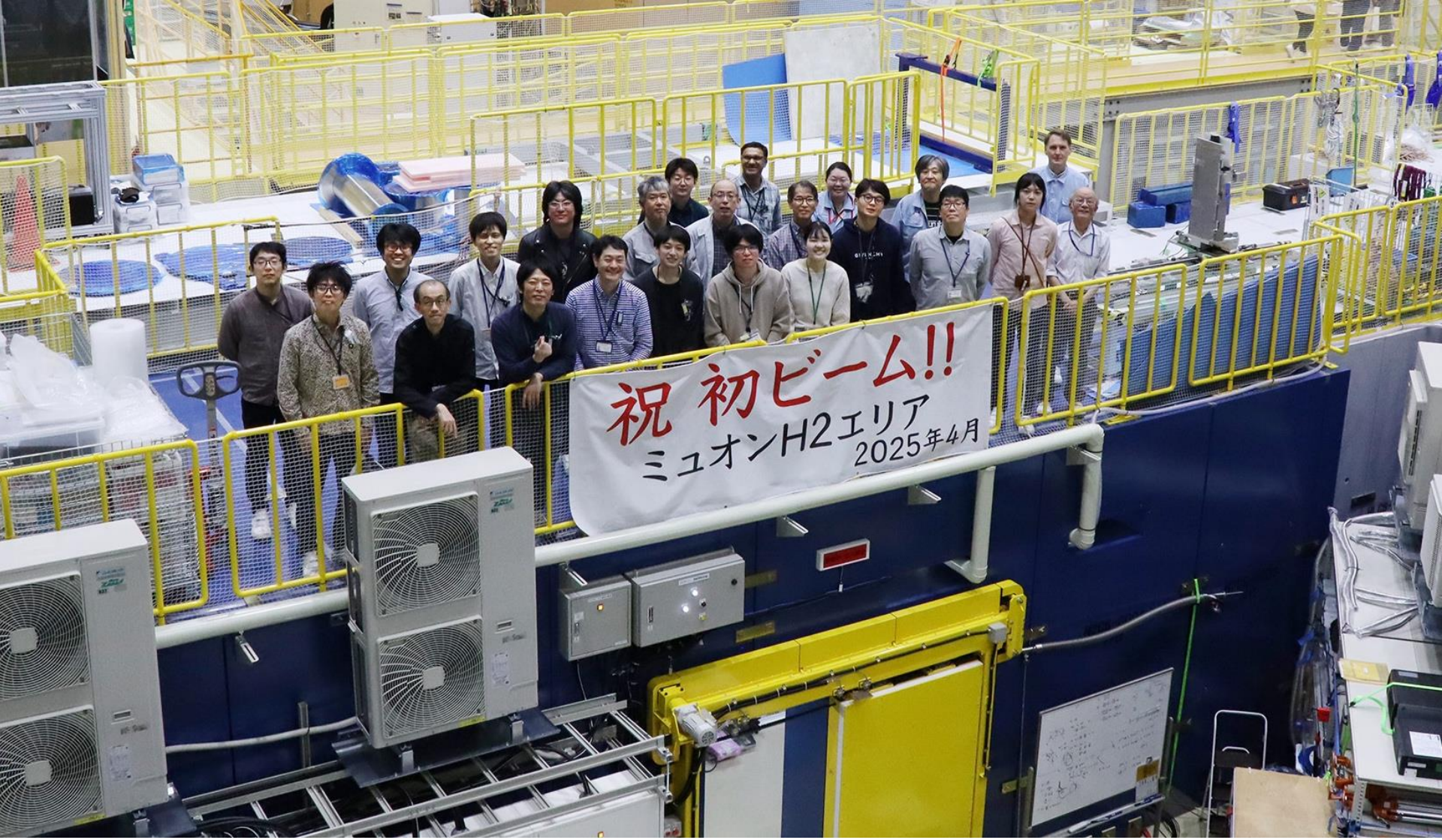


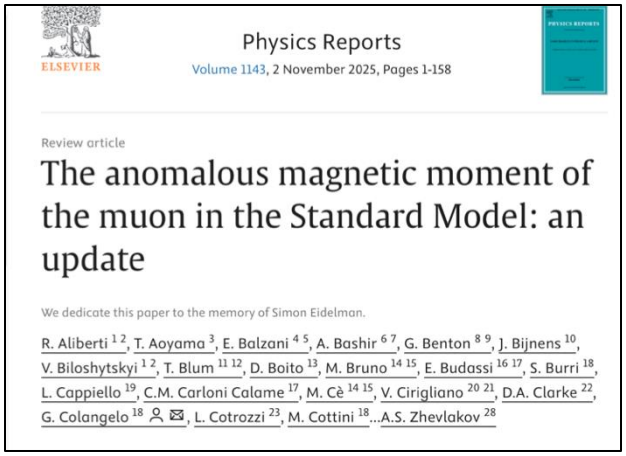
Muon g-2 and EDM in the post FNAL era

September 24, 2025

Tsutomu Mibe（KEK）

Muon *g*-2 at present

On Sep. 10, 2025, **the updated white paper** was published in Physics Report
https://doi.org/10.1016/j.physrep.2025.08.002



ELSEVIER
Physics Reports
Volume 1143, 2 November 2025, Pages 1-158

Review article

The anomalous magnetic moment of the muon in the Standard Model: an update

We dedicate this paper to the memory of Simon Eidelman.

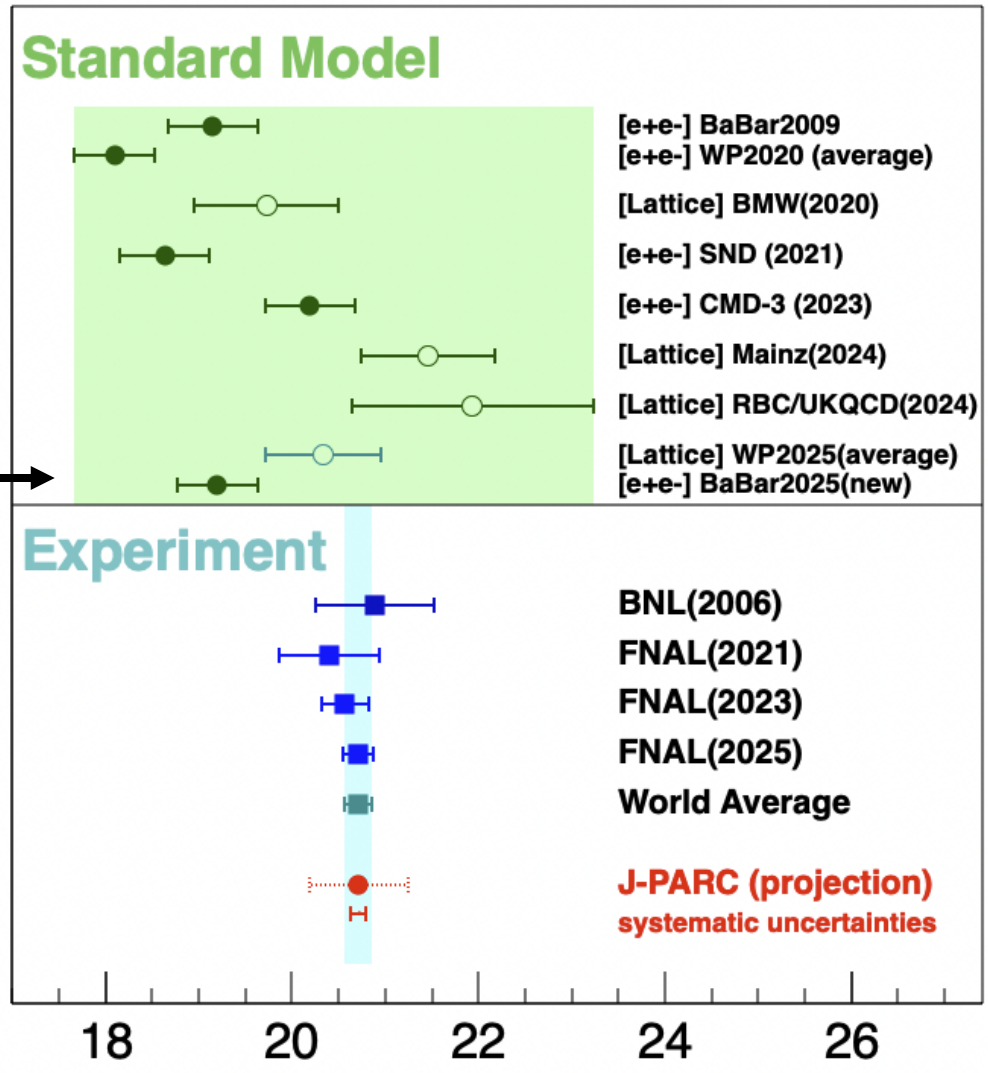
R. Aliberti [1,2], T. Aoyama [3], E. Balzani [4,5], A. Bashir [6,7], G. Benton [8,9], J. Bijnens [10], V. Biloshytskyi [1,2], T. Blum [11,12], D. Boito [13], M. Bruno [14,15], E. Budassi [16,17], S. Burri [18], L. Cappiello [19], C.M. Carloni Calame [17], M. Cè [14,15], V. Cirigliano [20,21], D.A. Clarke [22], G. Colangelo [18] ✉, L. Cotrozzi [23], M. Cottini [18]...A.S. Zhevlakov [28]

The community already moves forward to **next steps**

theory initiative workshop in Orsay, Sep 8-12; **https://indico.ijclab.in2p3.fr/event/11652/**

Muon *g*-2 at present

The NEW BaBar measurement confirmed their 2009 result.



$a_\mu \times 10^9 - 1165900$

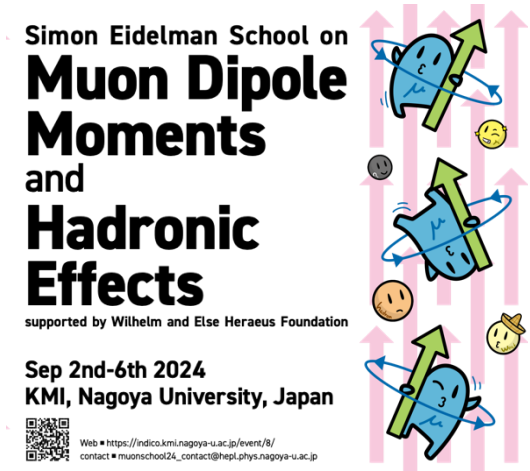
Anomalous magnetic moment of muon

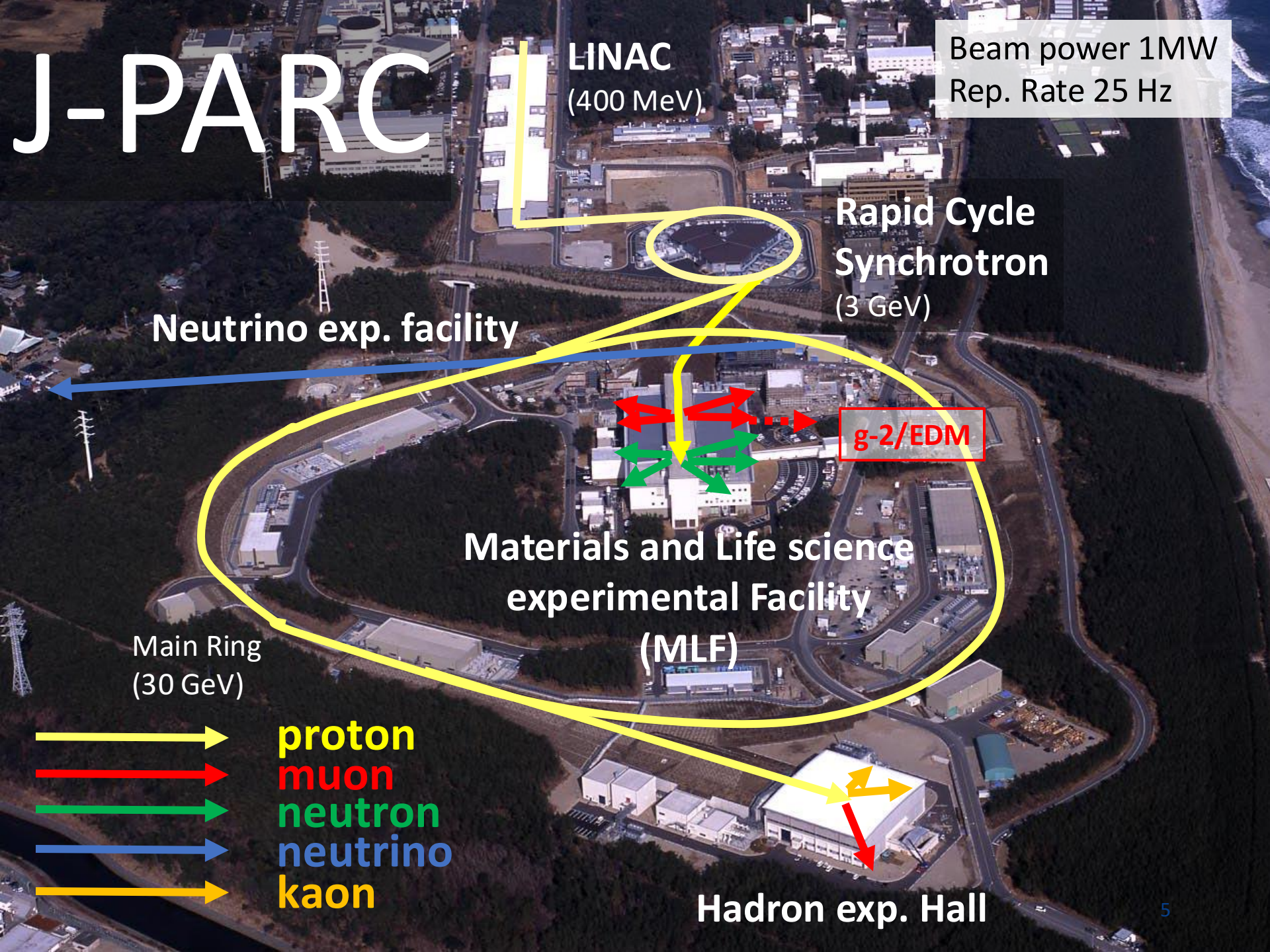
More to come from SND, KLOE, BES III, Belle II and MuonE

Community growth at around Japan

The seventh plenary workshop at KEK (Sep 9-13, 2024) https://conference-indico.kek.jp/event/257/

Simon Eidelman school on muon dipole moments and hadronic effects (Sep 2-6, 2024) supported by Wilhelm and Else Heraeus Foundation https://indico.kmi.nagoya-u.ac.jp/event/8/

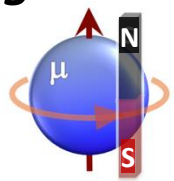



J-PARC
LINAC
(400 MeV)
Beam power 1MW
Rep. Rate 25 Hz
Rapid Cycle
Synchrotron
(3 GeV)
Neutrino exp. facility
g-2/EDM
Materials and Life science
experimental Facility
(MLF)
Main Ring
(30 GeV)
proton
muon
neutron
neutrino
kaon
Hadron exp. Hall

J-PARC muon *g*-2/EDM experiment

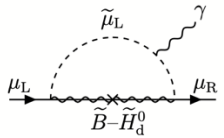
Studies on physics beyond the standard model in quantum loops

***g*-2**

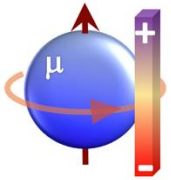


C, P, T conserved

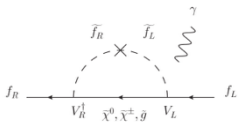
Examples: Super Symmetric particles



EDM

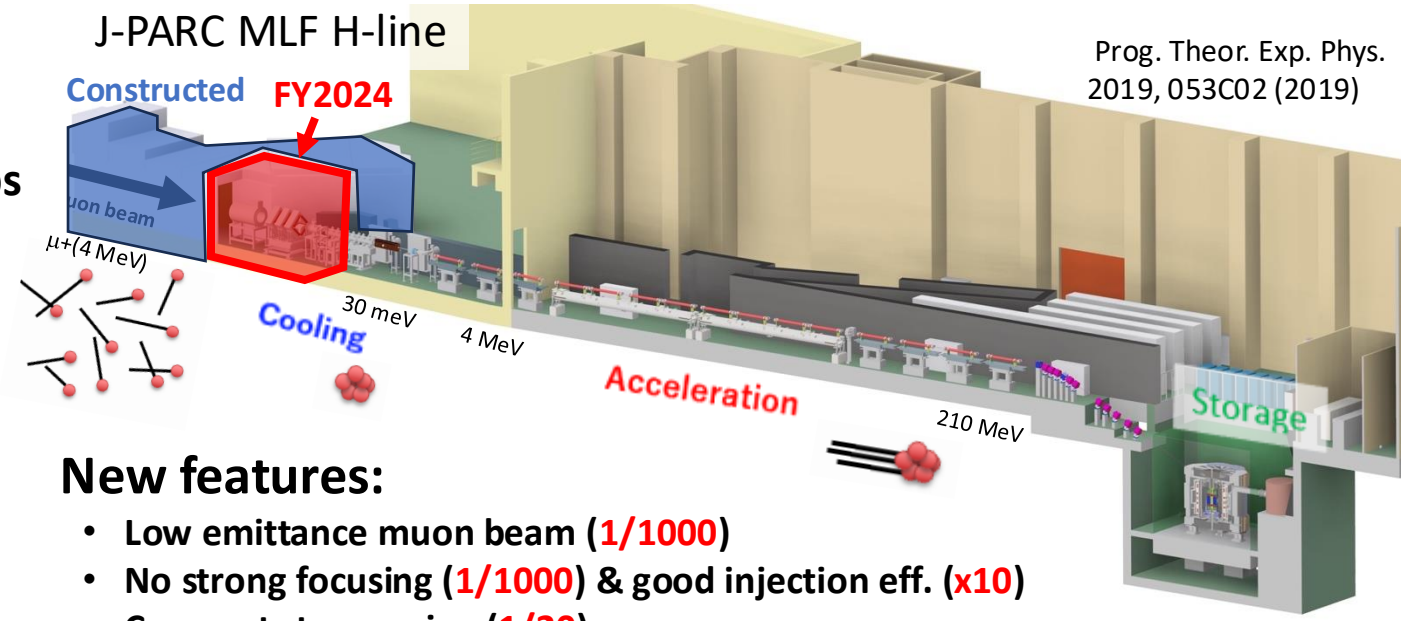


P & T-violating



J-PARC MLF H-line

Prog. Theor. Exp. Phys. 2019, 053C02 (2019)



New features:

- **Low emittance muon beam (1/1000)**
- **No strong focusing (1/1000) & good injection eff. (x10)**
- **Compact storage ring (1/20)**

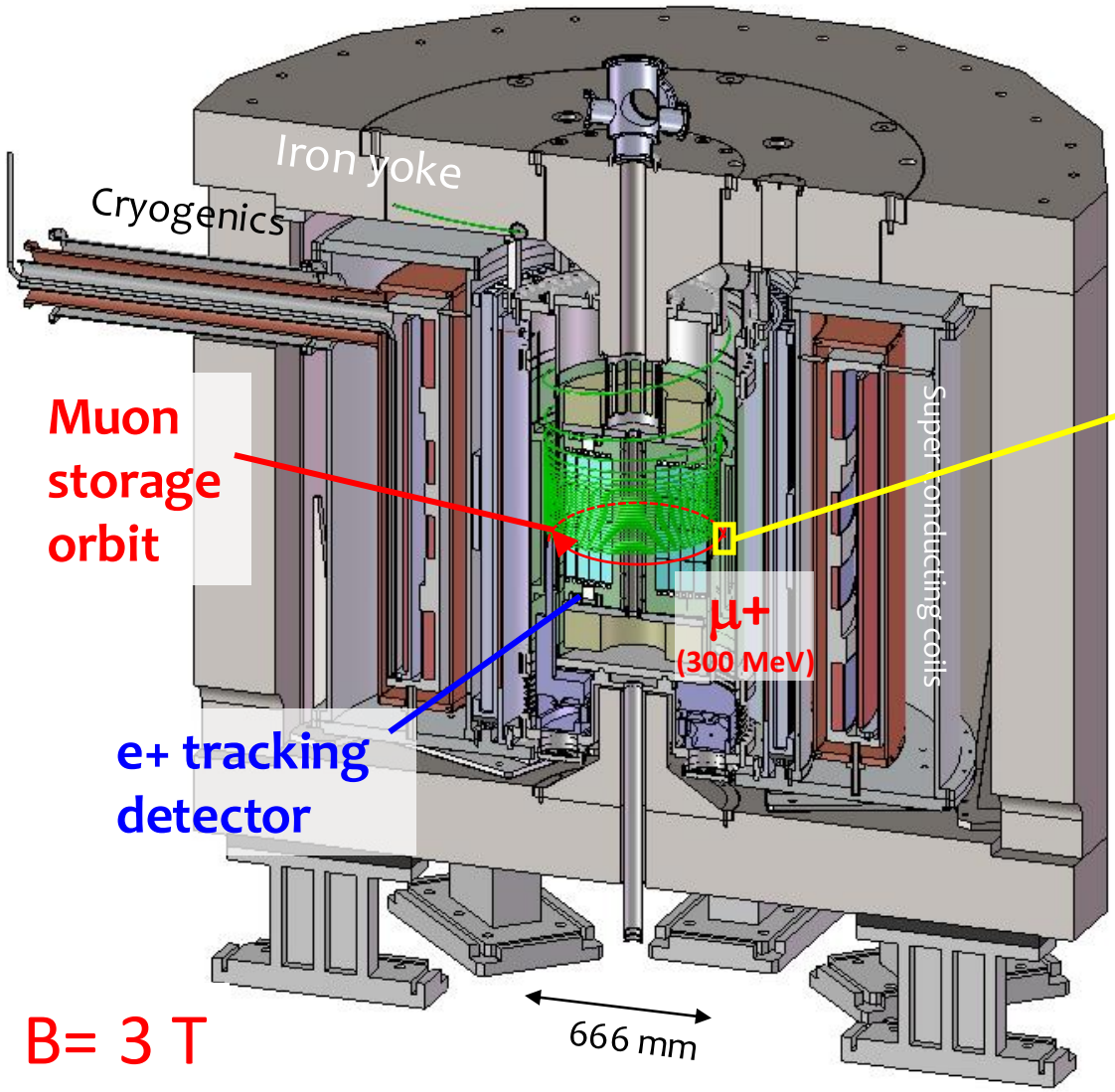
The only experiment to test FNAL/BNL *g*-2 results.

***g*-2 : 450 ppb**

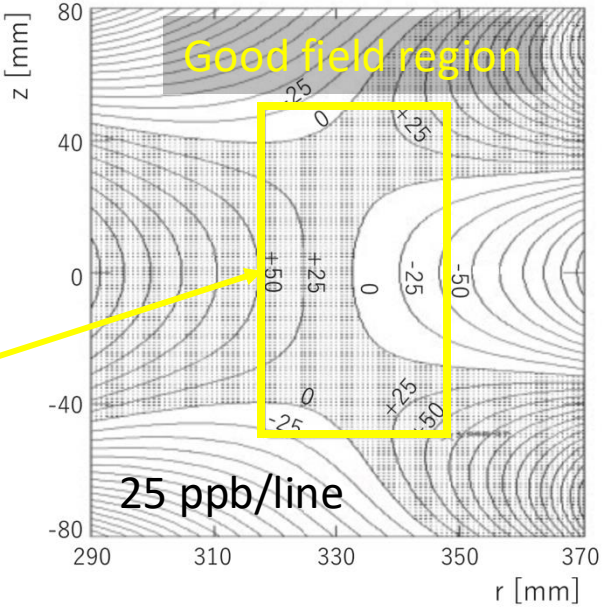
EDM : 1.5 E-21 ecm

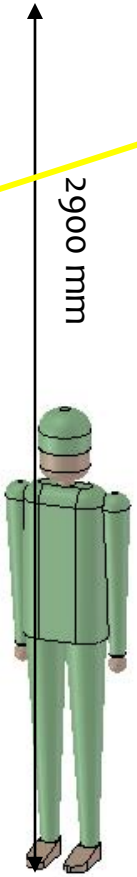
Welcome U. Liverpool group in Dec, 2024 !!

The muon storage ring

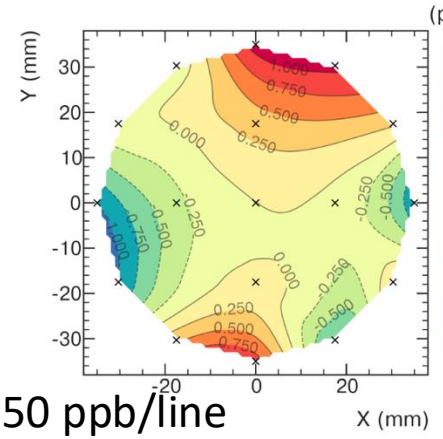


Calculated average field uniformity





FNAL Run 1 PRA 103, 042208 (2021)



M. Abe et. al., NIM A 890, 51 (2018)

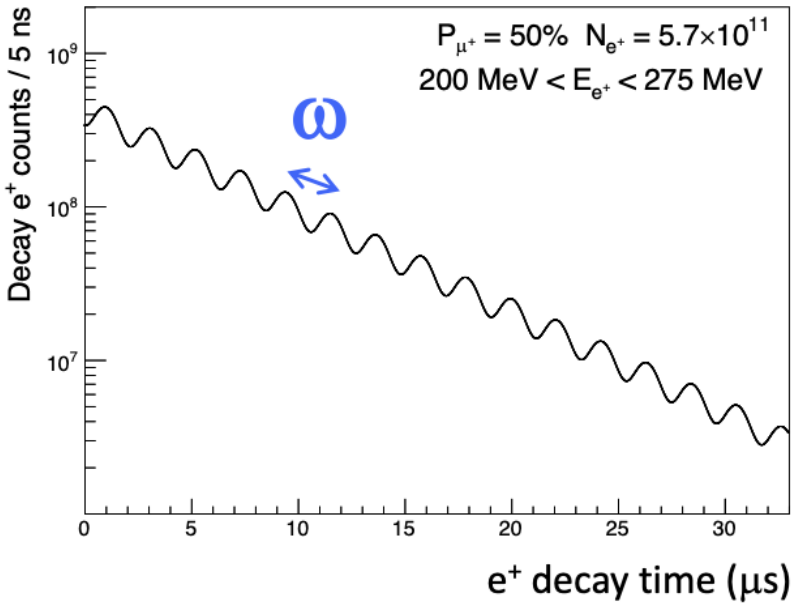
Expected data

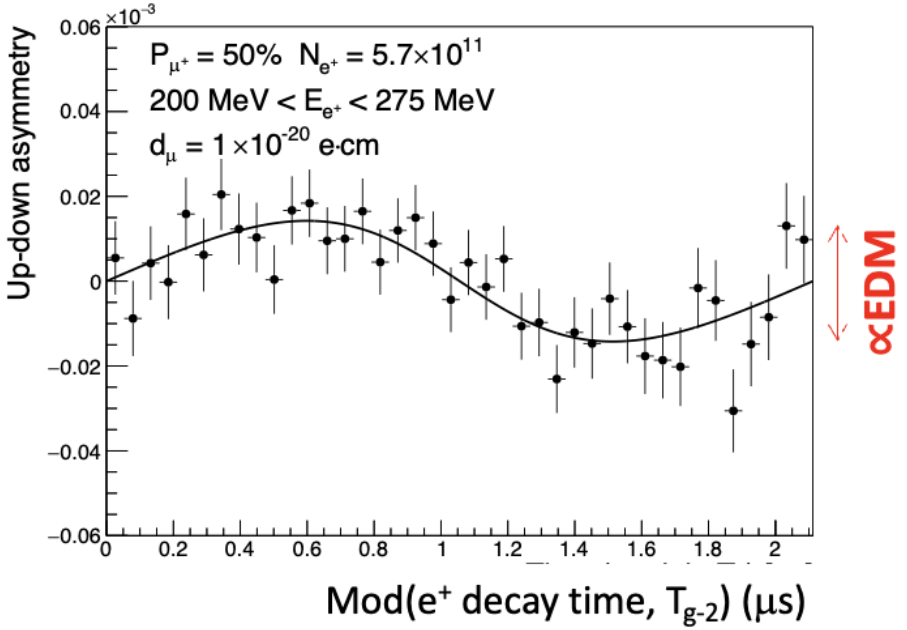
Spin precession w.r.t. momentum

$$\vec{\omega} = -\frac{e}{m}\left[a_\mu \vec{B} + \frac{\eta}{2}\left(\vec{\beta}\times\vec{B}\right)\right]$$

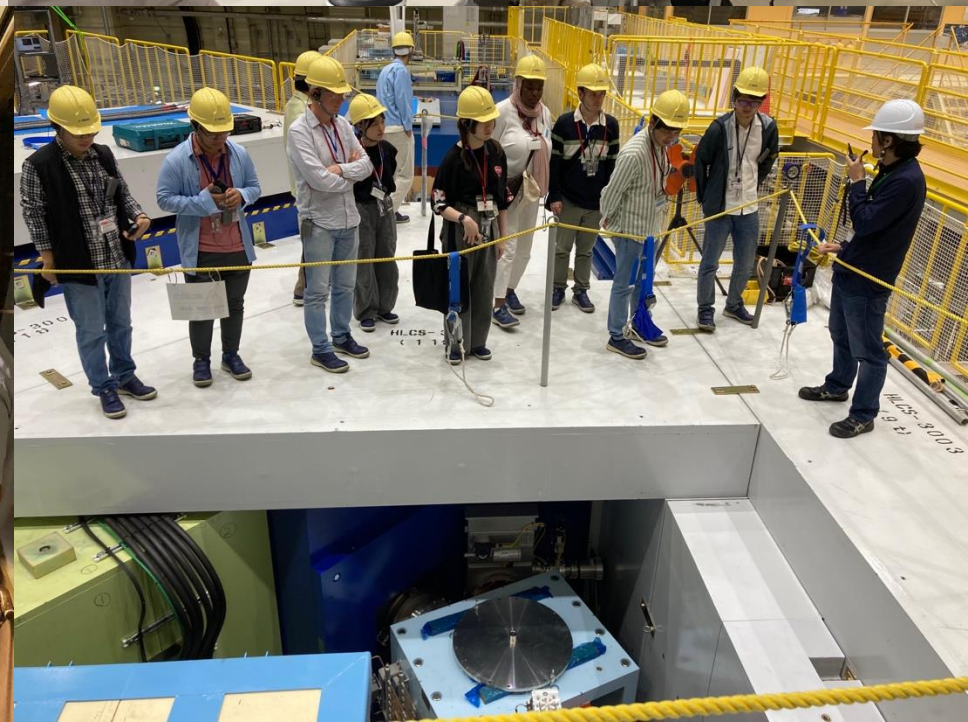
g-2 EDM

Time spectrum of e^+ in $\mu \rightarrow e^+\nu\nu$ decay

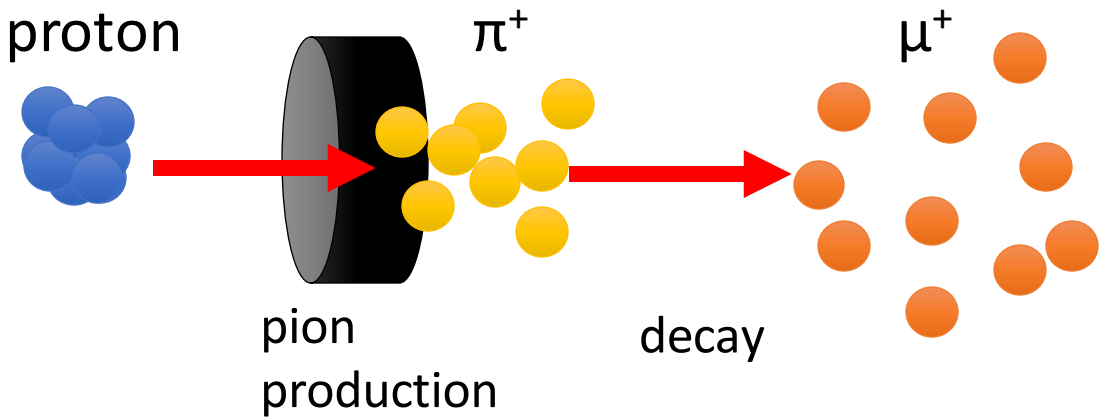




Pictures from the recent collaboration meeting in June 2025



Conventional muon beam



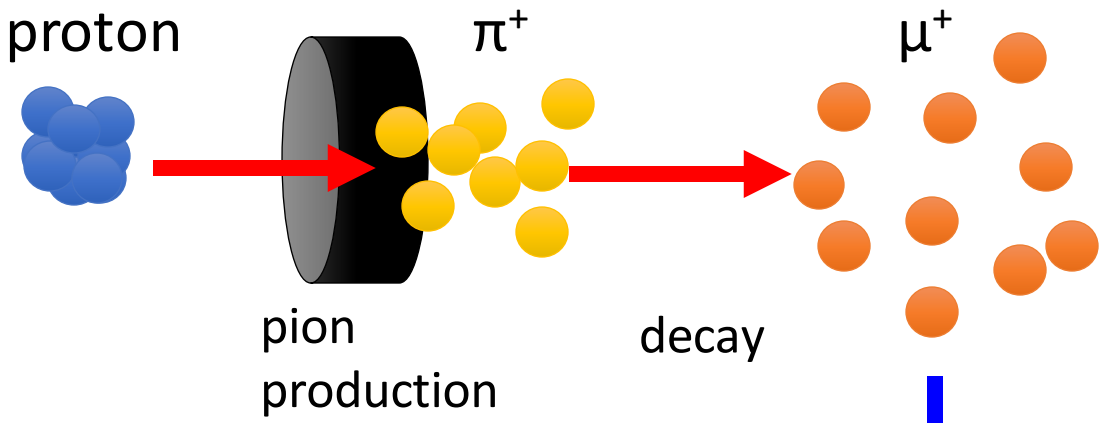
emittance

~1000π mm·mrad

Strong focusing
Muon loss
BG π contamination

Source of systematic uncertainties

Muon beam at J-PARC



emittance
~1000π mm･mrad

Strong focusing
Muon loss
BG π contamination

Source of systematic uncertainties

cooling

μ+

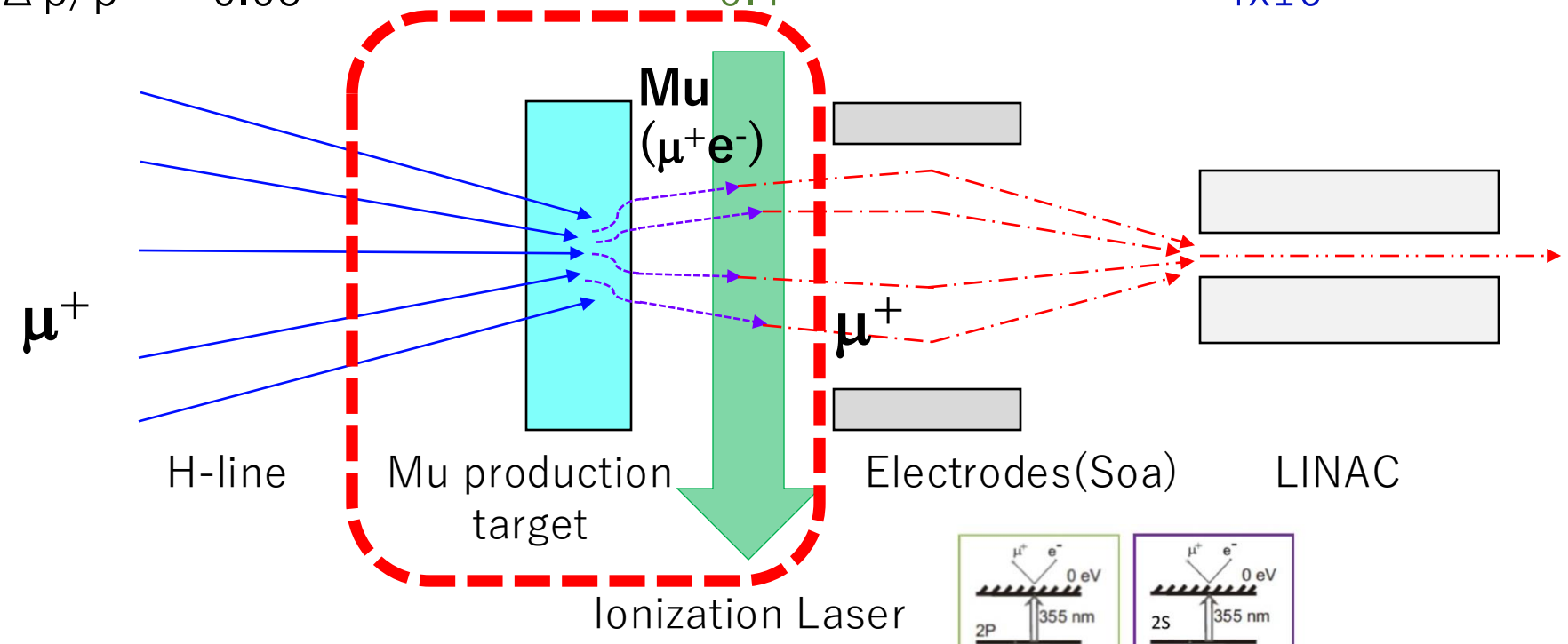
emittance
1π mm･mrad

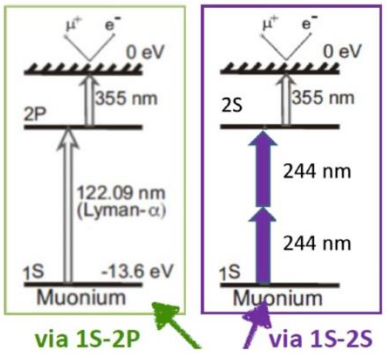
Reaccelerated thermal muon

Free from any of these

Acceleration of thermal muons

	surface muon	thermal muon	accelerated muon
E	4 MeV	30 meV	212 MeV
p	30 MeV/c	2.3 keV/c	300 MeV/c
Δ p/p	0.05	0.4	4×10^{-4}





Muonium : a bound state of μ^+ and e^-

Efficient Muonium production demonstrated in TRIUMF

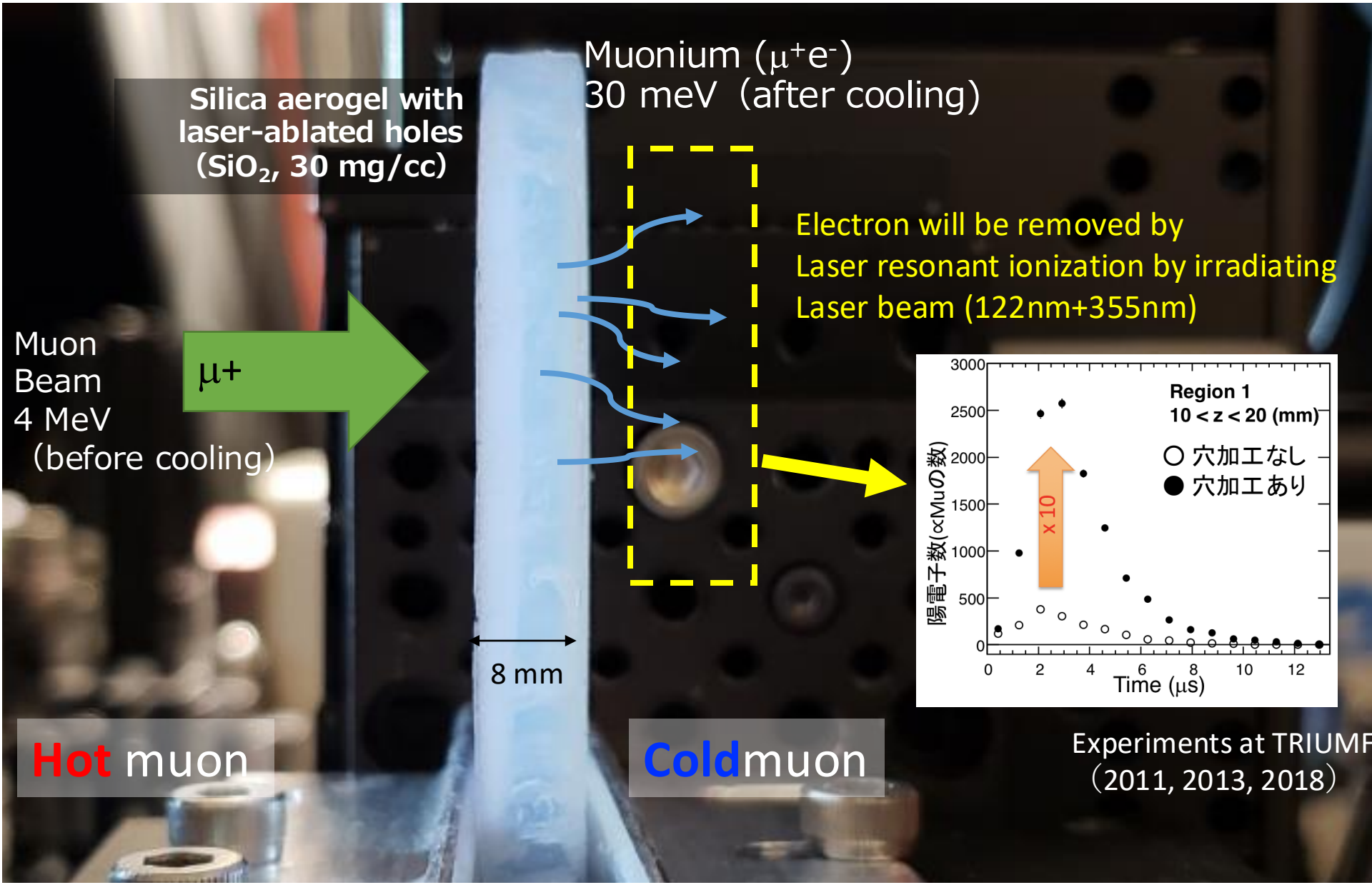
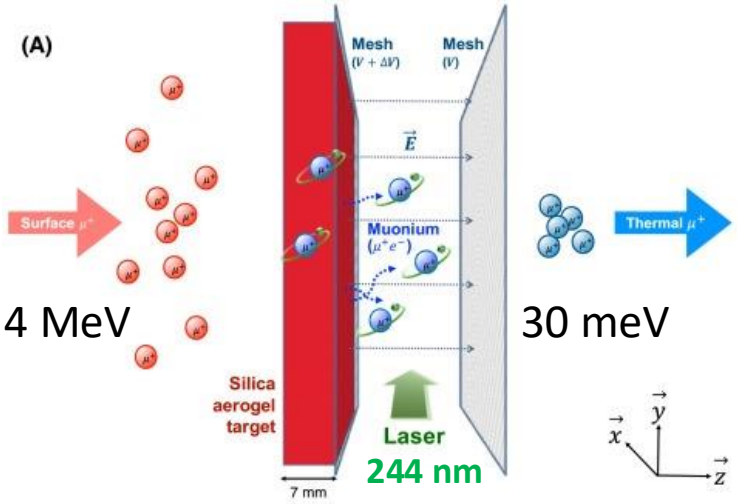
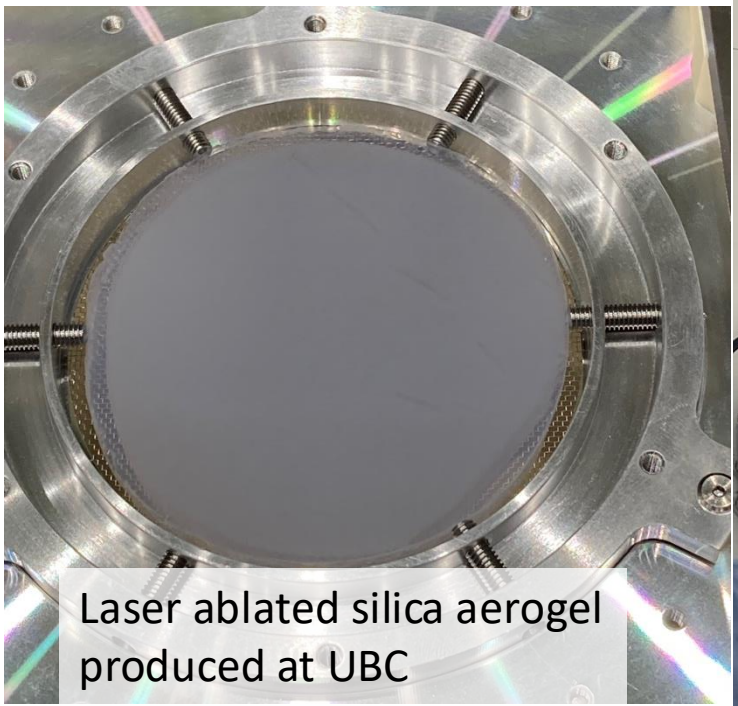


Photo by Saeid Kamal (UBC)

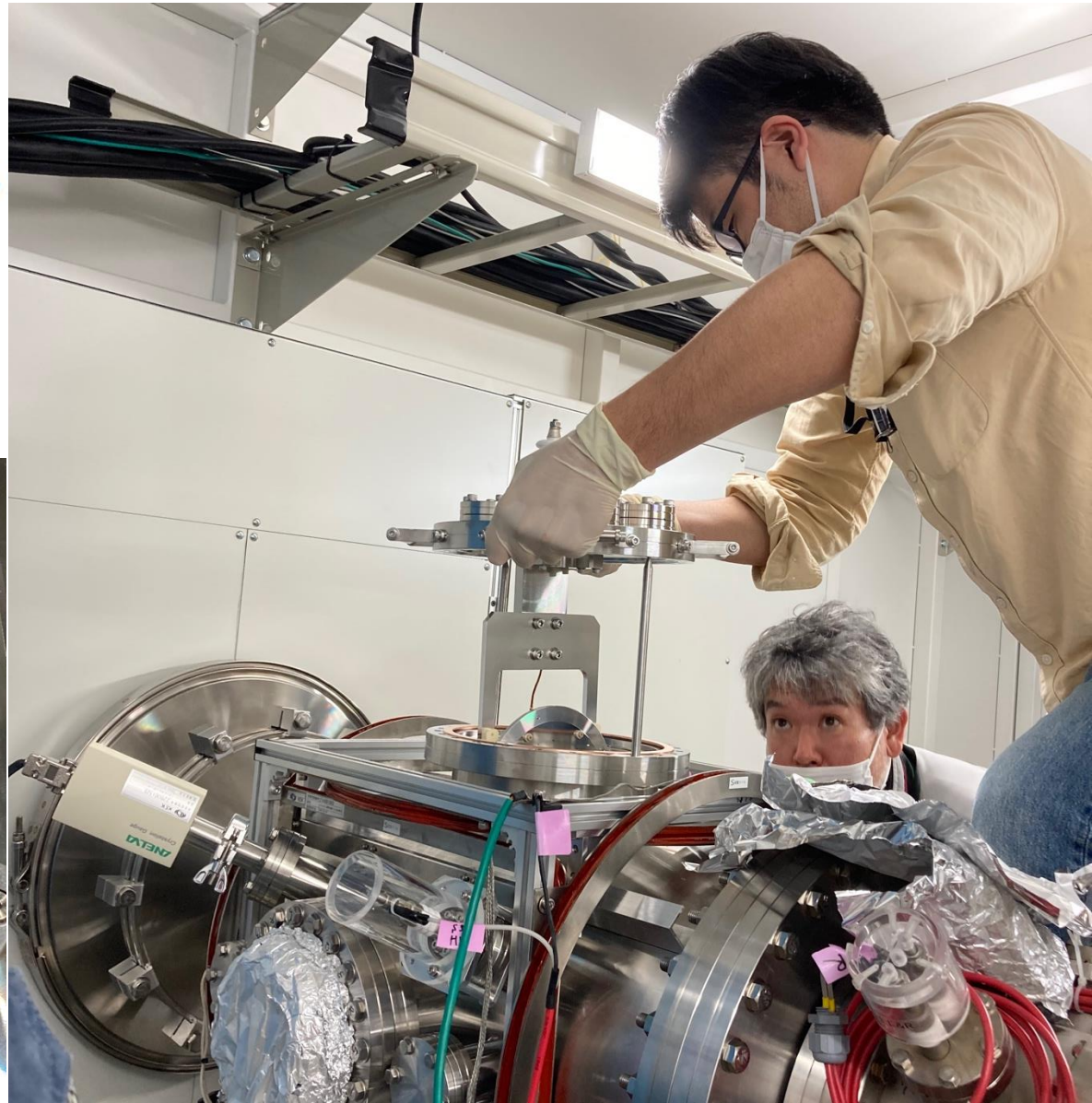
Implementation at J-PARC (2023)





Laser ablated silica aerogel produced at UBC

J-PARC S2 area

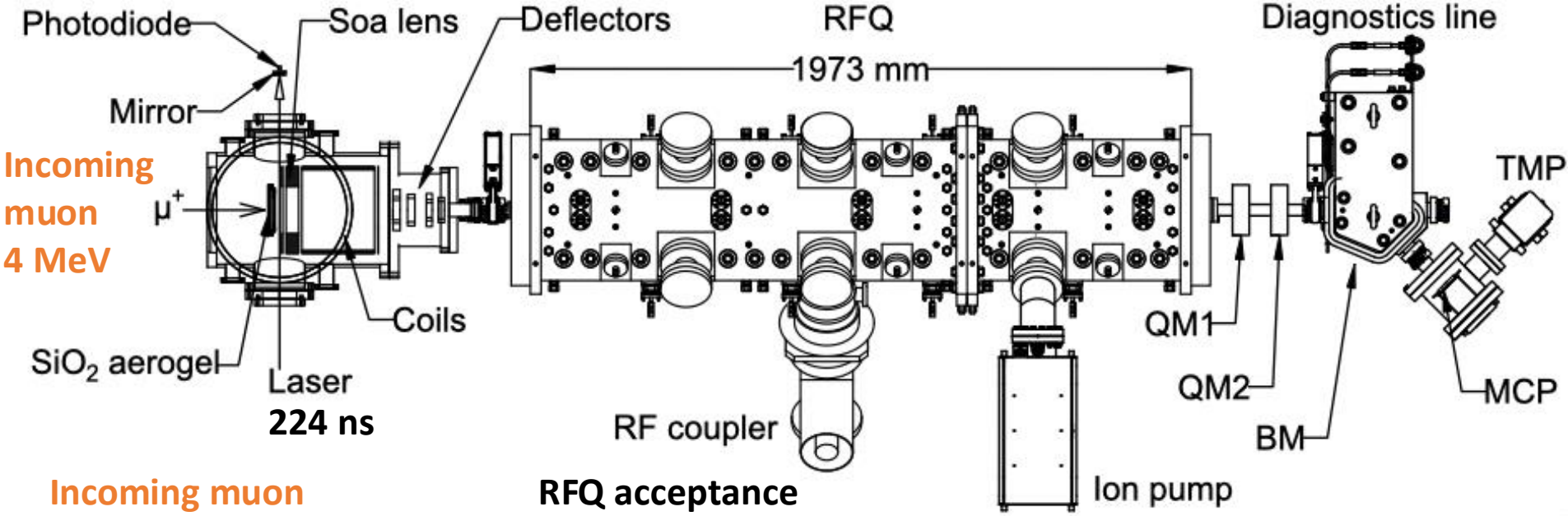


Demonstration of acceleration to 100 keV (2024)

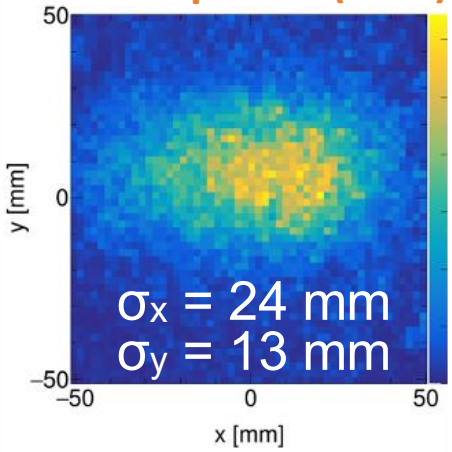
Cooling
30 meV

Acceleration
100 keV

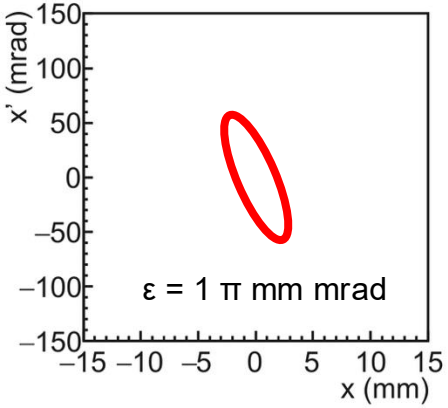
Diagnosis



Incoming muon beam profile (data)

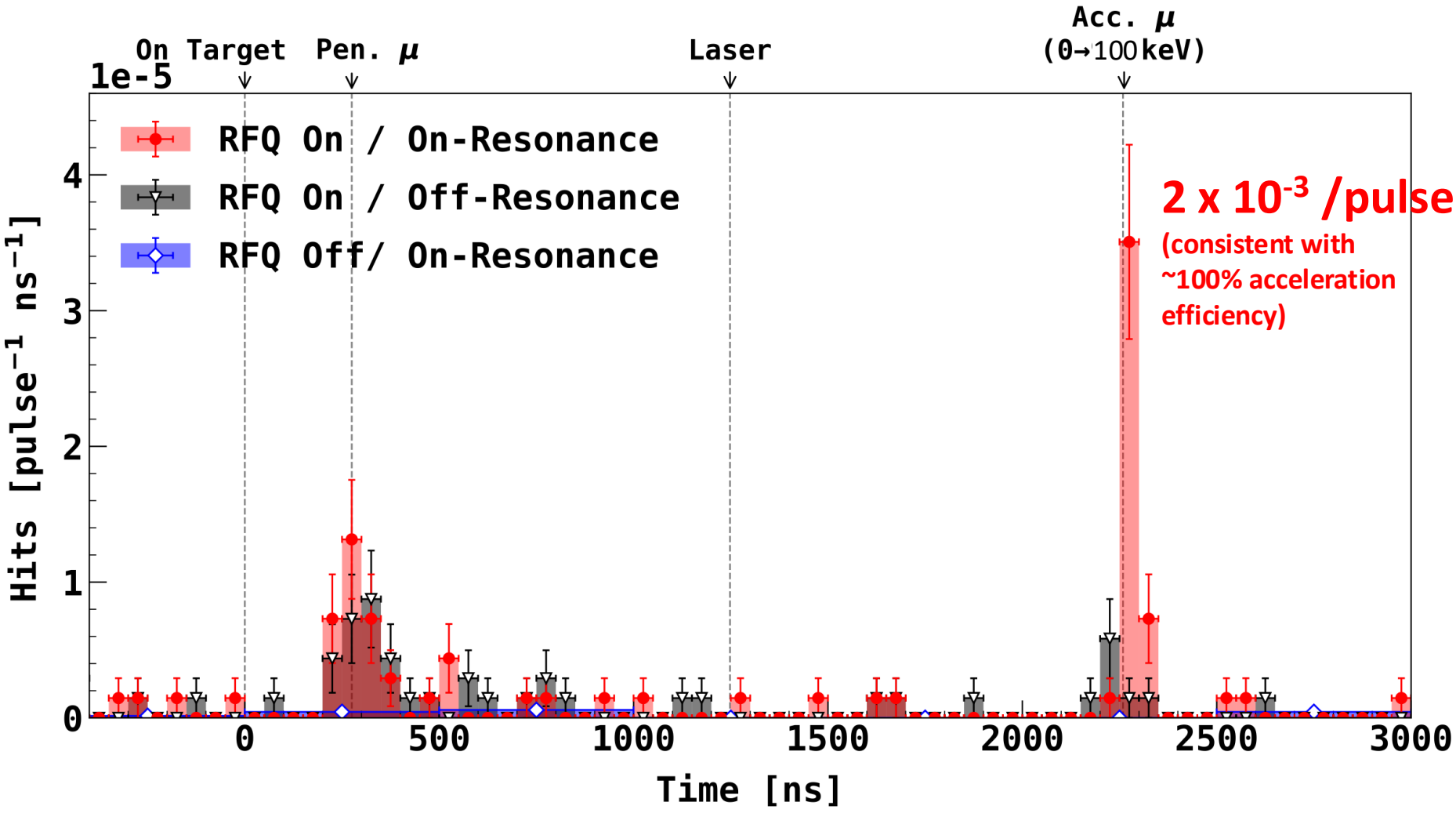


RFQ acceptance (simulation)



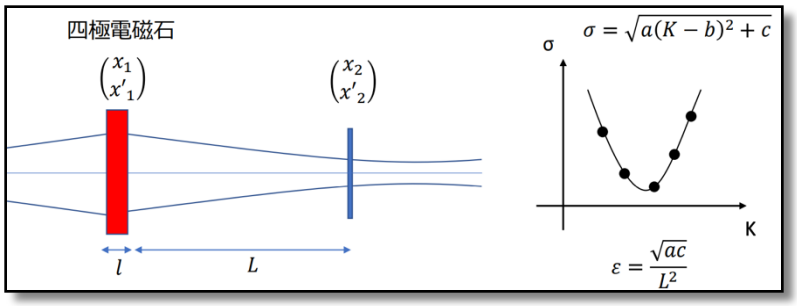
RF frequency: 324 MHz
RF power: 2.6 kW
RF pulse width: 40 μs
Acceleration energy: 100 keV

Results: time of flight

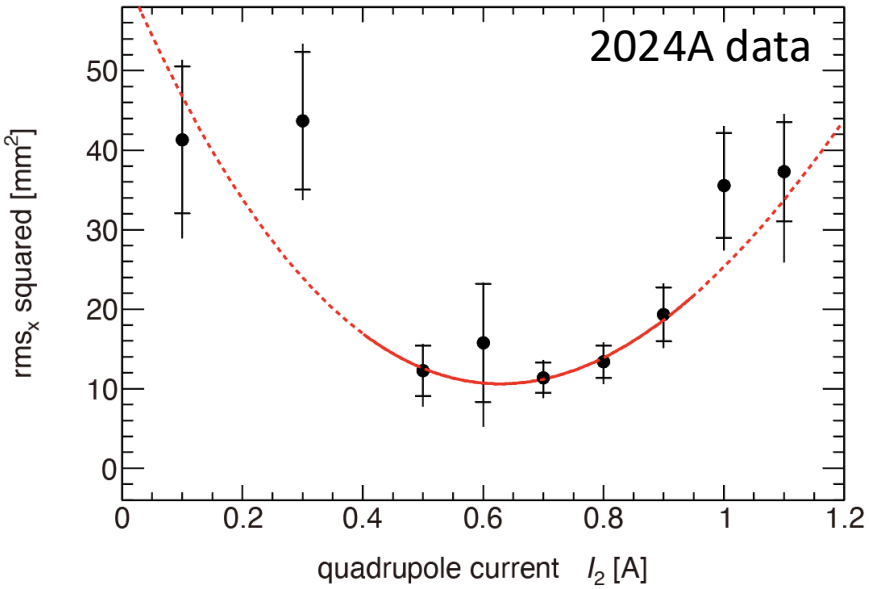


Results: transverse emittance at 100 keV

arXiv:2410.11367



horizontal



before cooling

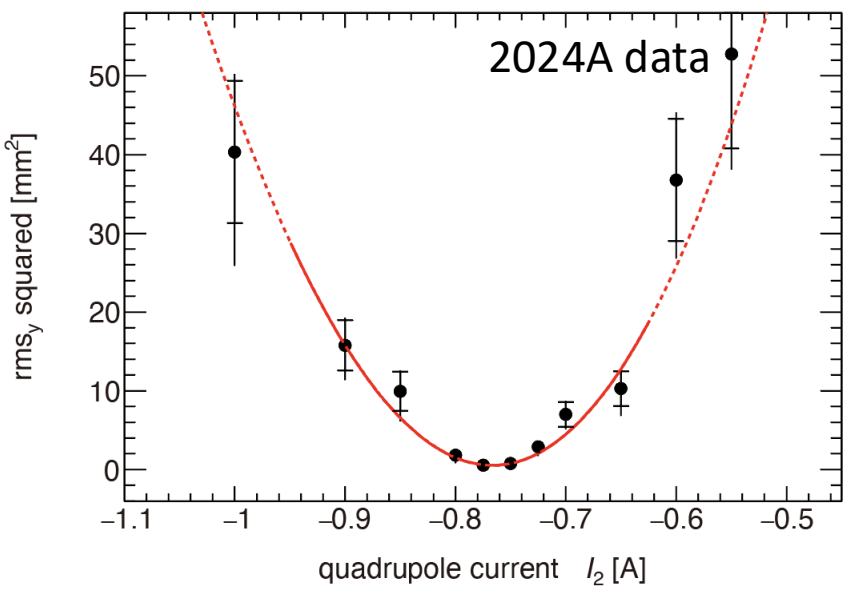
ε_x = 170 π mm mrad

x 1/200

after cooling + acceleration

$\varepsilon_x = 0.85 \pm 0.25^{+0.22}_{-0.13}$ π mm mrad

vertical



before cooling

ε_y = 130 π mm mrad

x 1/400

after cooling + acceleration

$\varepsilon_y = 0.23 \pm 0.03^{+0.05}_{-0.02}$ π mm mrad

The birth of low-emittance muon beam

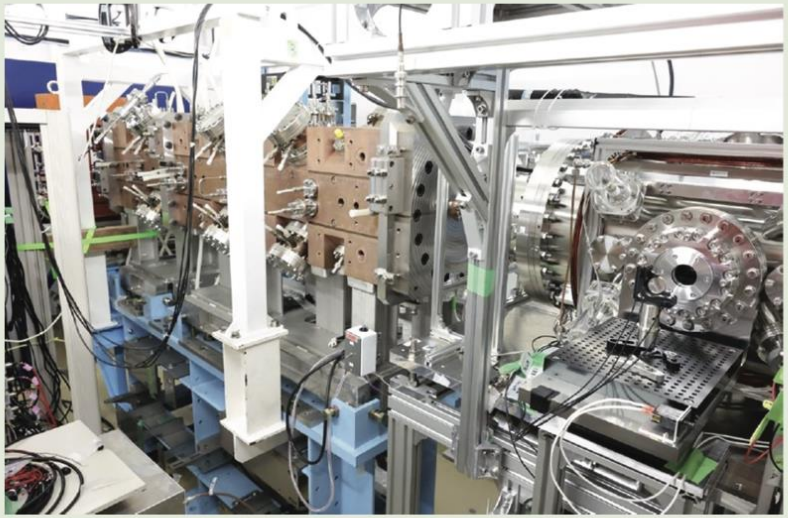
Acceleration of positive muons

Muon acceleration to 100 keV

134

PHYSICAL REVIEW LETTERS

Published week ending 20 JUNE 2025



PRL 134 (24), 240001–249901, 20 June 2025 (440 total pages)

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Published by
American Physical Society

Volume 134, Number 24

https://doi.org/10.1103/PhysRevLett.134.245001

PHYSICAL REVIEW LETTERS **134,** 245001 (2025)

Editors' Suggestion | Featured in Physics

Acceleration of Positive Muons by a Radio-Frequency Cavity

S. Aritome,[1] K. Futatsukawa,[2] H. Hara,[3] K. Hayasaka,[4] Y. Ibaraki,[5] T. Ichikawa,[5] T. Iijima,[5,6] H. Iinuma,[7] Y. Ikedo,[2] Y. Imai,[3] K. Inami,[5,6] K. Ishida,[2] S. Kamal,[8] S. Kamioka,[2,*] N. Kawamura,[2] M. Kimura,[2] A. Koda,[2] S. Koji,[5] K. Kojima,[6,‡] A. Kondo,[5] Y. Kondo,[9] M. Kuzuba,[7] R. Matsushita,[1] T. Mibe,[2] Y. Miyamoto,[3] J. G. Nakamura,[2] Y. Nakazawa,[7,‡] S. Ogawa,[10,‡] Y. Okazaki,[2] A. Olin,[11,12] M. Otani,[2] S. Oyama,[1] N. Saito,[2] H. Sato,[7] T. Sato,[1] Y. Sato,[4] K. Shimomura,[2] Z. Shioya,[13] P. Strasser,[2] S. Sugiyama,[5] K. Sumi,[5,†] K. Suzuki,[6] Y. Takeuchi,[13,§] M. Tanida,[13] J. Tojo,[13,10] K. Ueda,[5] S. Uetake,[3] X. H. Xie,[14,15] M. Yamada,[13] S. Yamamoto,[3] T. Yamazaki,[2] K. Yamura,[4] M. Yoshida,[2] T. Yoshioka,[10,13] and M. Yotsuzuka[5]

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(Received 16 October 2024; accepted 21 April 2025; published 16 June 2025)

“Editor’s suggestion”
“Featured in Physics”
“Cover image”

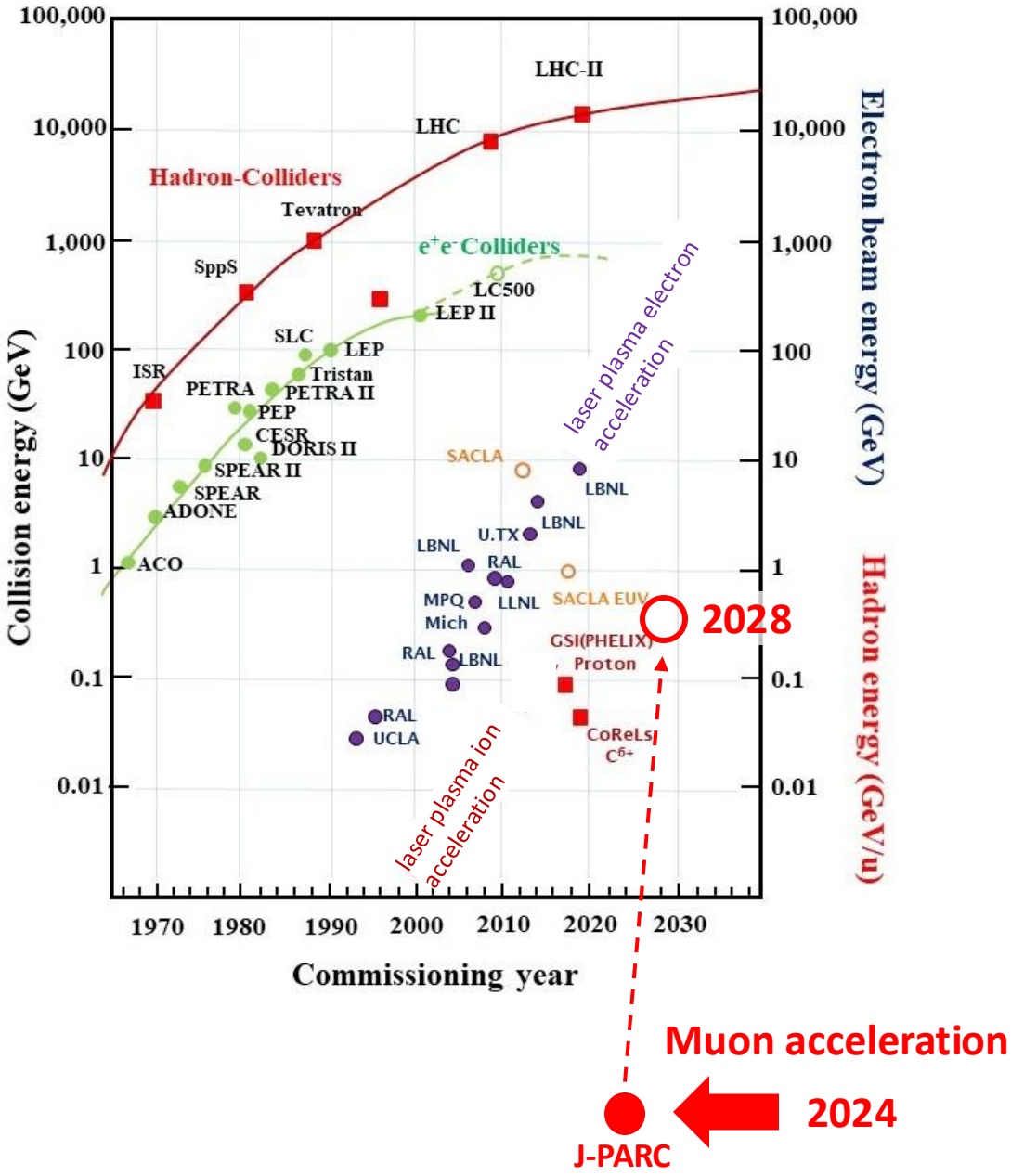
Acceleration of positive muons

Muon acceleration to 100 keV

https://doi.org/10.1103/PhysRevLett.134.245001

Regret : Duct tape …

History of accelerator technology

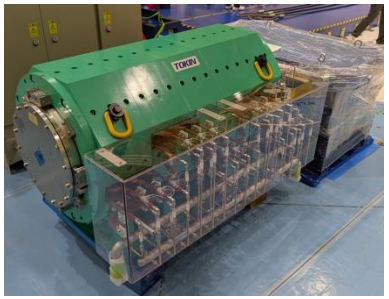


New beamline : MLF H2 area

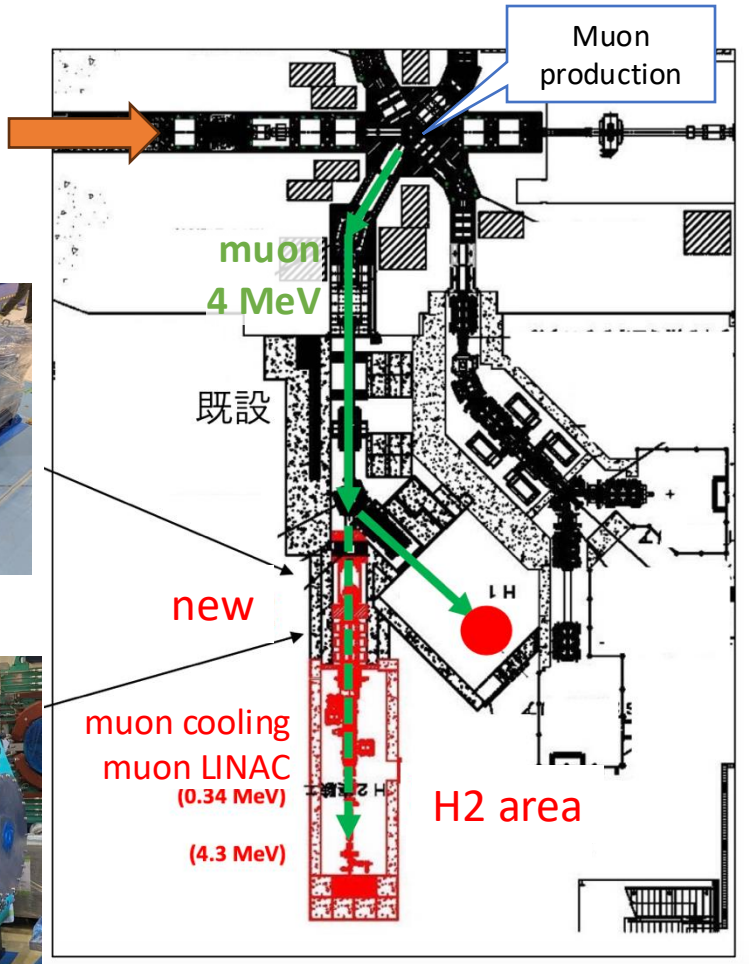
Dedicated beamline for the muon cooling and acceleration
Surface muon rate : 1 x 10^8/sec

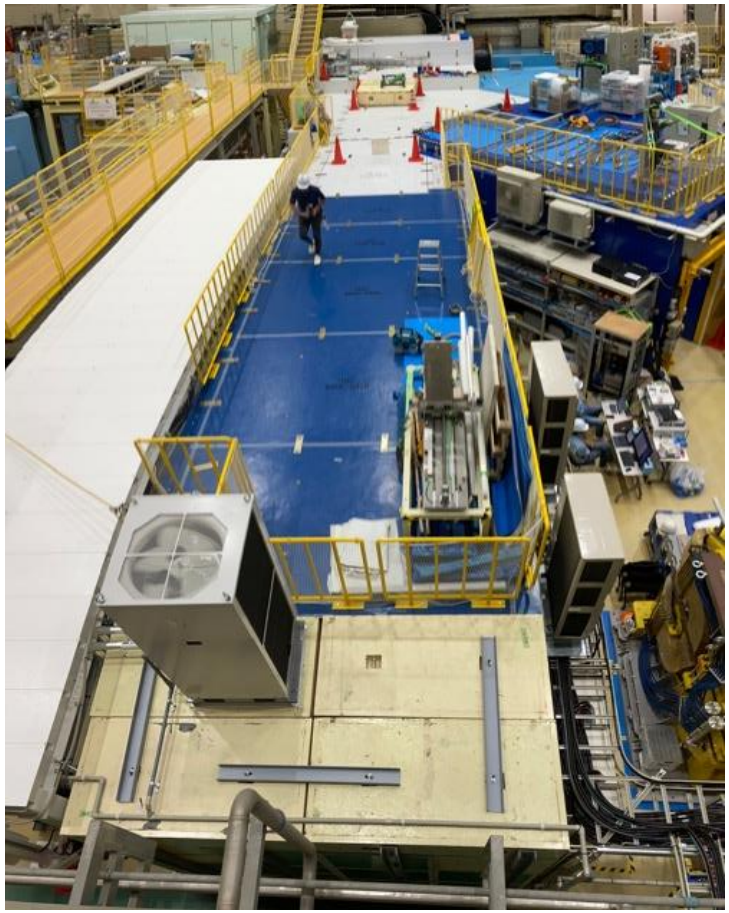
3 GeV
proton

solenoid



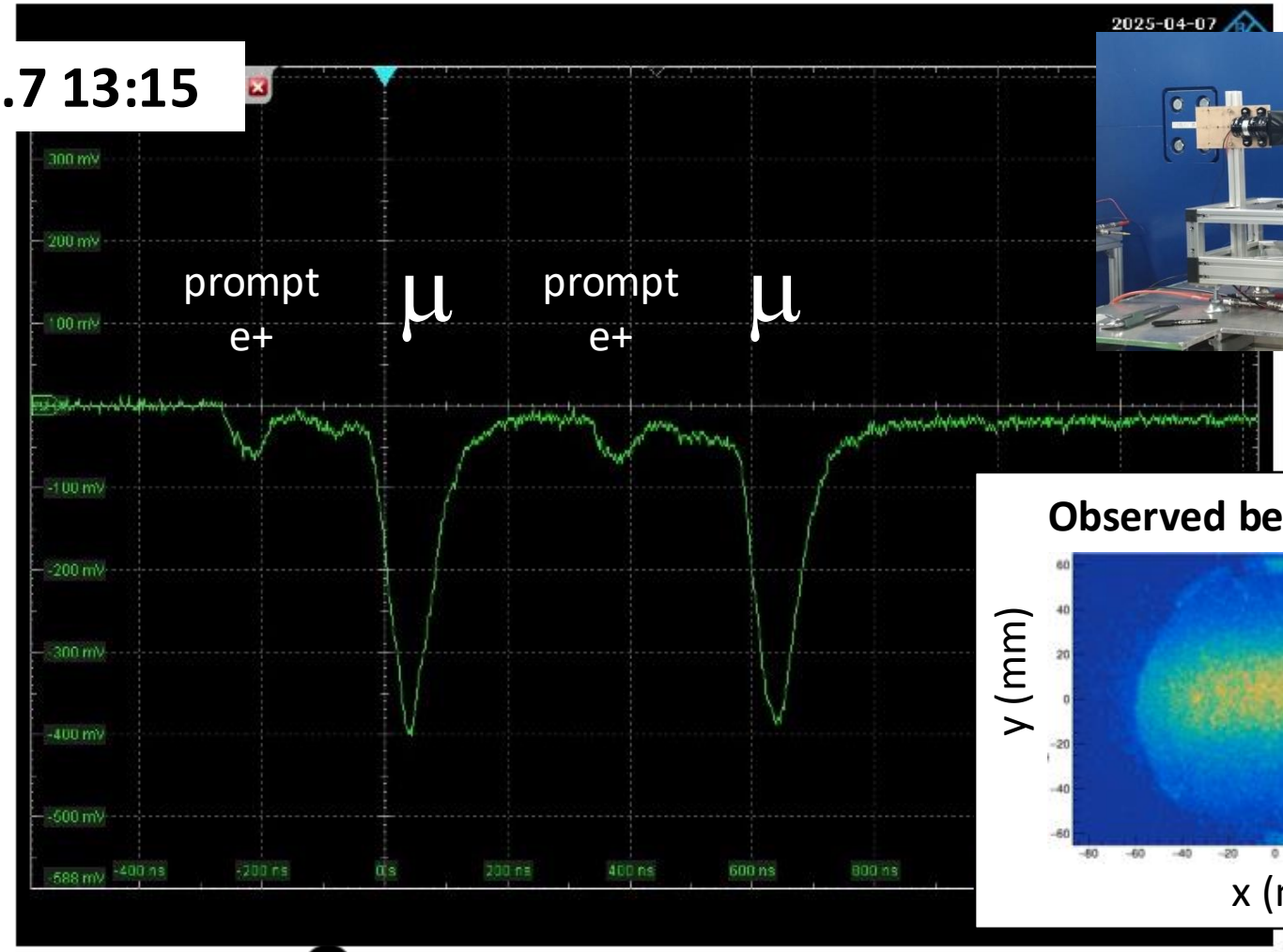
quadrupole magnets

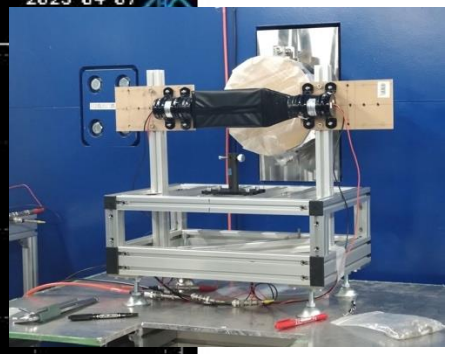


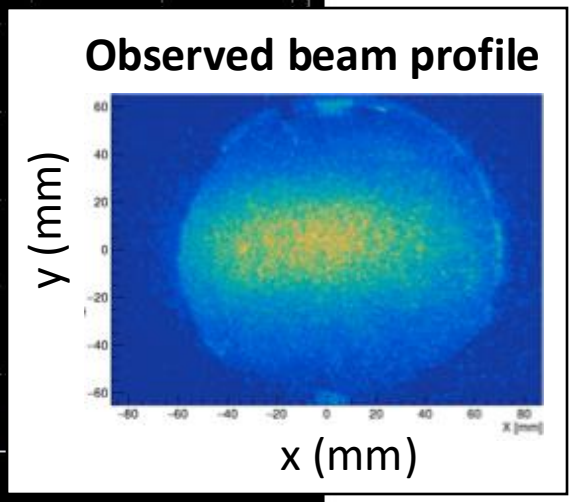


New beamline : MLF H2 area

2025.4.7 13:15

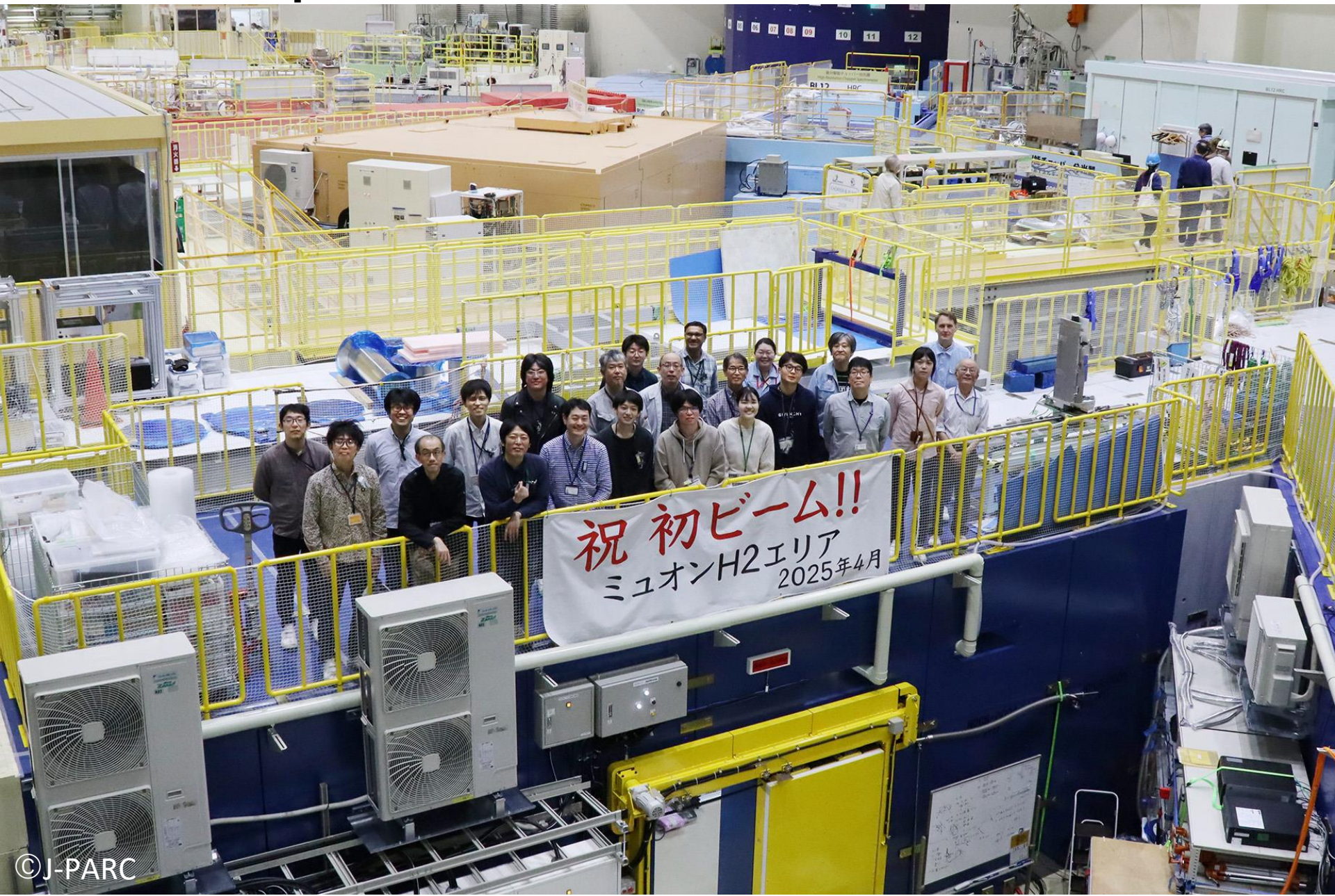






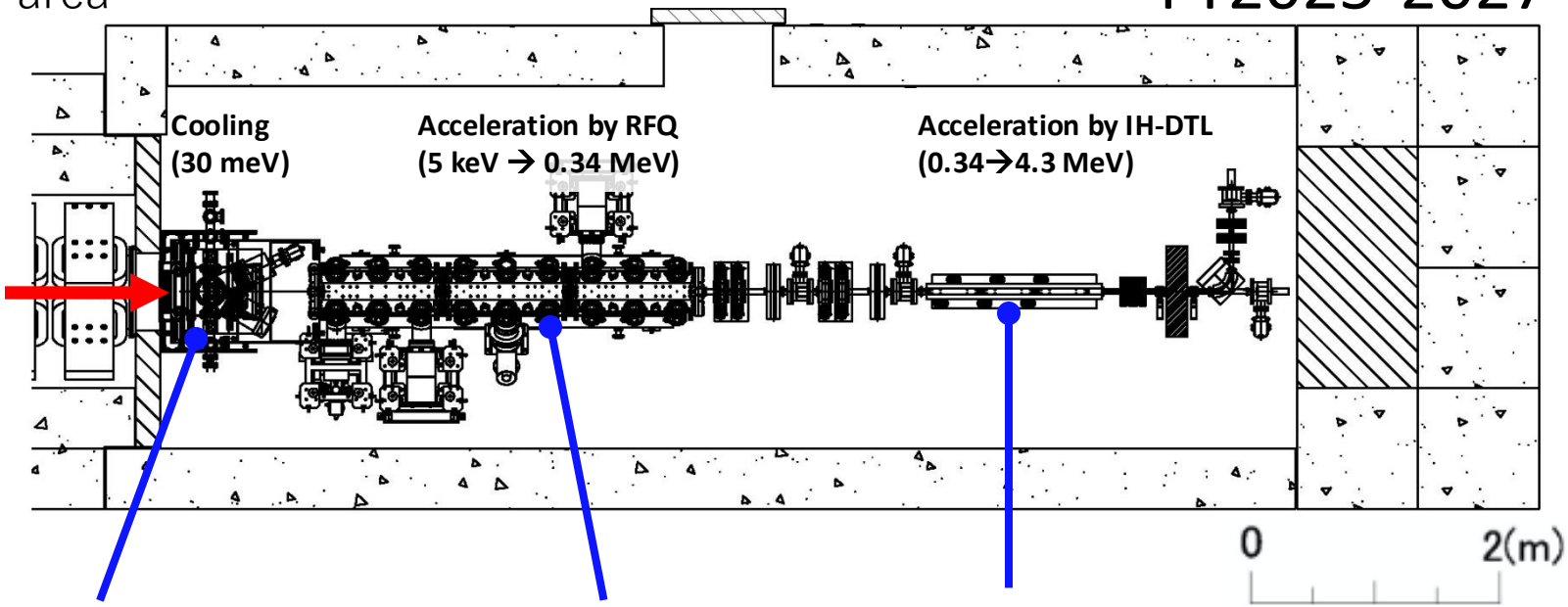
Successful delivery of the beam on April 7, 2025

Group photo on top of the new experimental area (H2 area)



Next step: Acceleration to 4 MeV

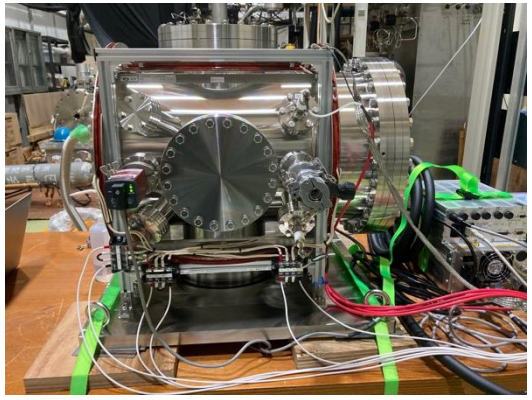
FY2025-2027



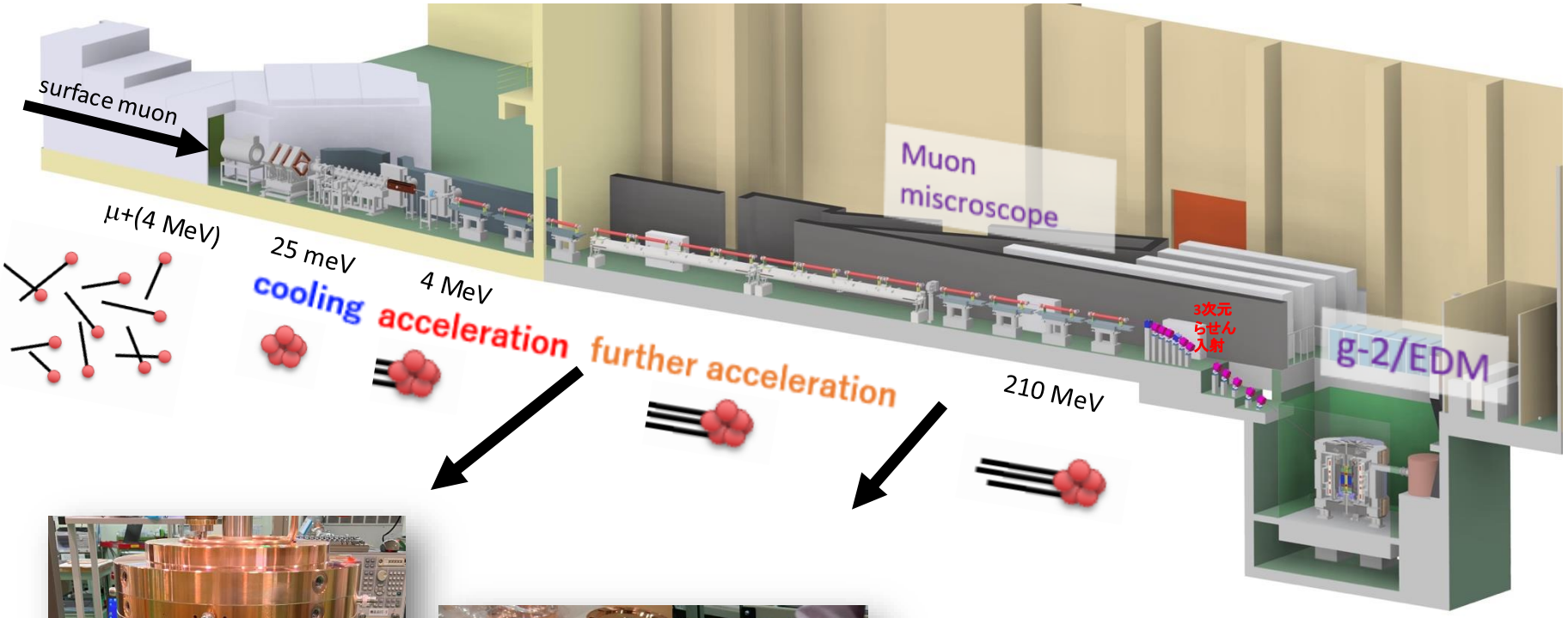
Mu production chamber
(available)

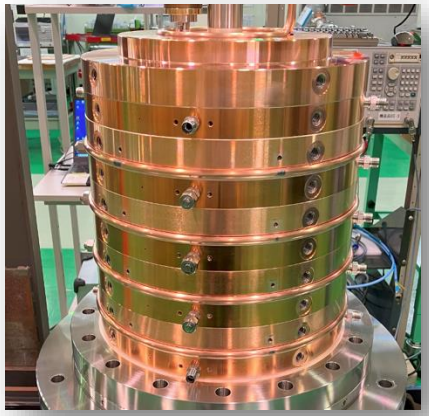
J-PARC LINAC
RFQ (available)

IH-DTL
(fabricated and evaluated in FY2022)

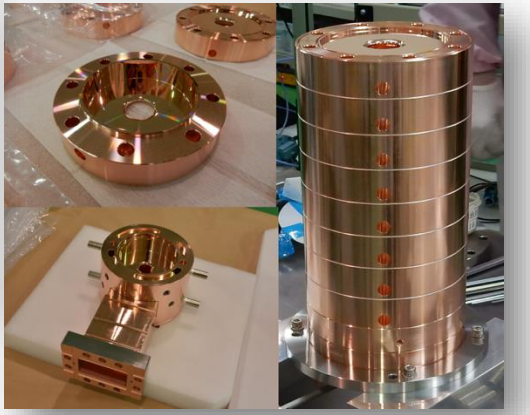


Future: acceleration to 210 MeV



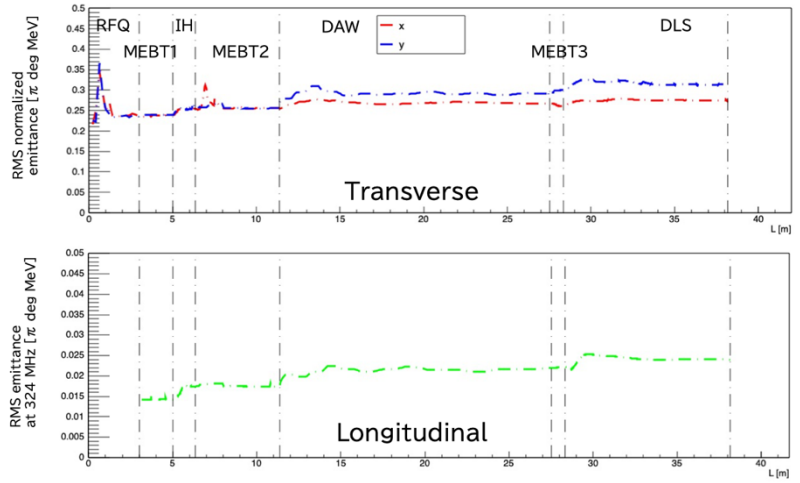


Disk And Washer (DAW)
(from 4 MeV to 40 MeV)

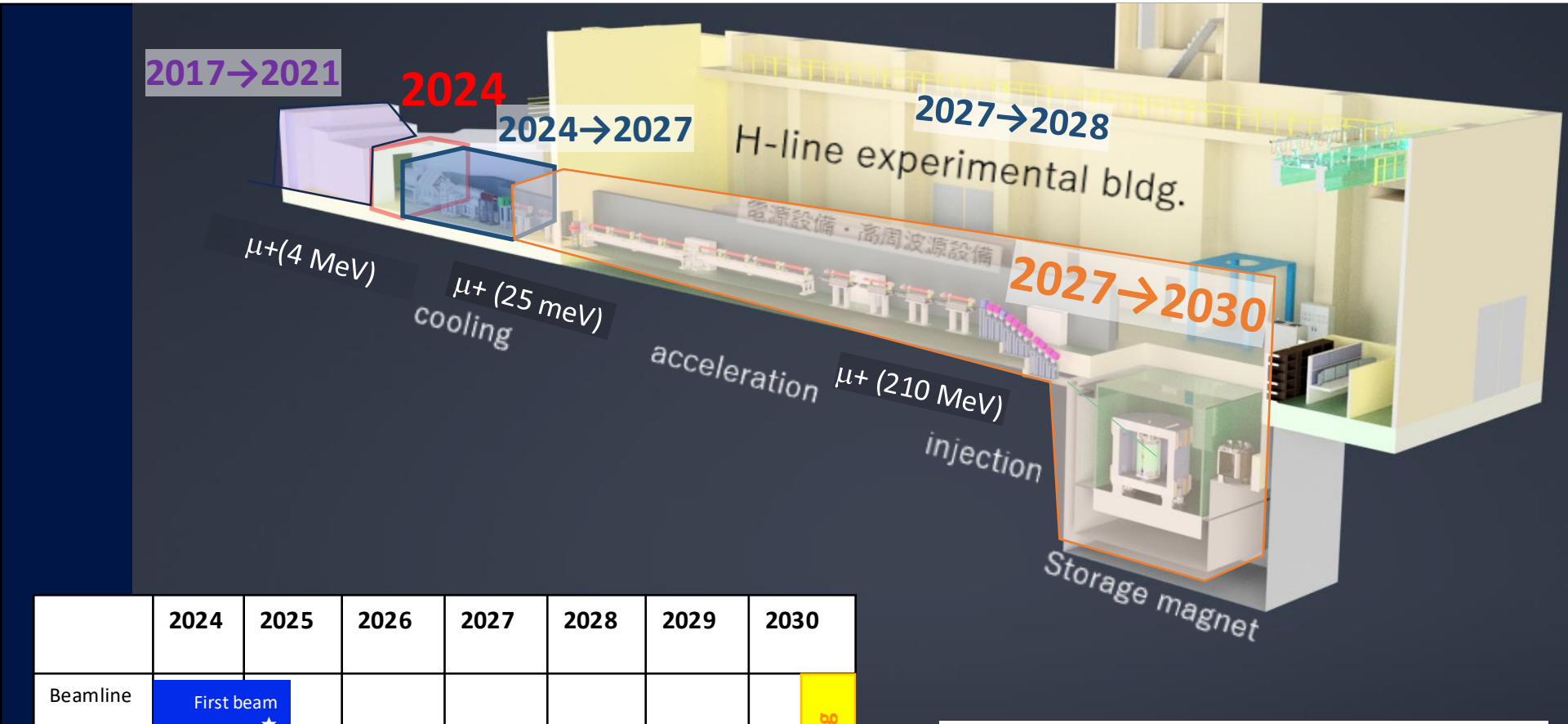


Disk Load Structure (DLS)
(from 40 MeV to 210 MeV)

Evolution of emittance



Muon g-2/EDM : intended schedule



	2024	2025	2026	2027	2028	2029	2030
Beamline	First beam ★						
Bldg. & facility	design refinement			Construction			
Source, LINAC, storage	source: ★ Ionization test at H2 area						
	LINAC: ★4.3 Me@H2					210 MeV ★	
	Storage: procurement					Installation ★	
Detector	positron tracker, magnetic field monitors						Installation ★

Commissioning, data taking

History

- 2009 proposal
- 2015 TDR
- 2016 IPNS focused review
- 2016 SAC (priority #3)
- 2019 KEK-IPNS stage-2, KEK-IMSS stage-2
- 2024 MEXT funding (partial construction)
- 2025 MEXT funding (partial construction)

Towards higher experimental precision

$$\frac{\Delta\omega_a}{\omega_a} = \frac{1}{\omega_a \gamma \tau P}\sqrt{\frac{2}{NA^2}}$$

$$\omega_a = a_\mu \frac{eB}{m}$$

current precision

450 ppb

valuable	definition	value
ω_a	anomalous spin precession frequency, $a_\mu \cdot (eB/m)$	$2\pi/2\ \mu$s
B	magnetic field strength	3 T
γ	Lorentz gamma factor, E/m	3
p	momentum of muon	300 MeV/c
τ	muon lifetime at rest	2.2 μs
P	muon polarization	50%
N	number of detected decay positron	6×10^{11}
A	average analyzing power of positron	0.42

Possibilities of higher precision

$$\frac{\Delta\omega_a}{\omega_a} = \frac{1}{\omega_a \gamma \tau P}\sqrt{\frac{2}{NA^2}}$$

$$\omega_a = a_\mu \frac{eB}{m}$$

1. Higher polarization (P)
2. Higher energy (γ)
3. Stronger magnetic field (B)

Being studied by the collaboration

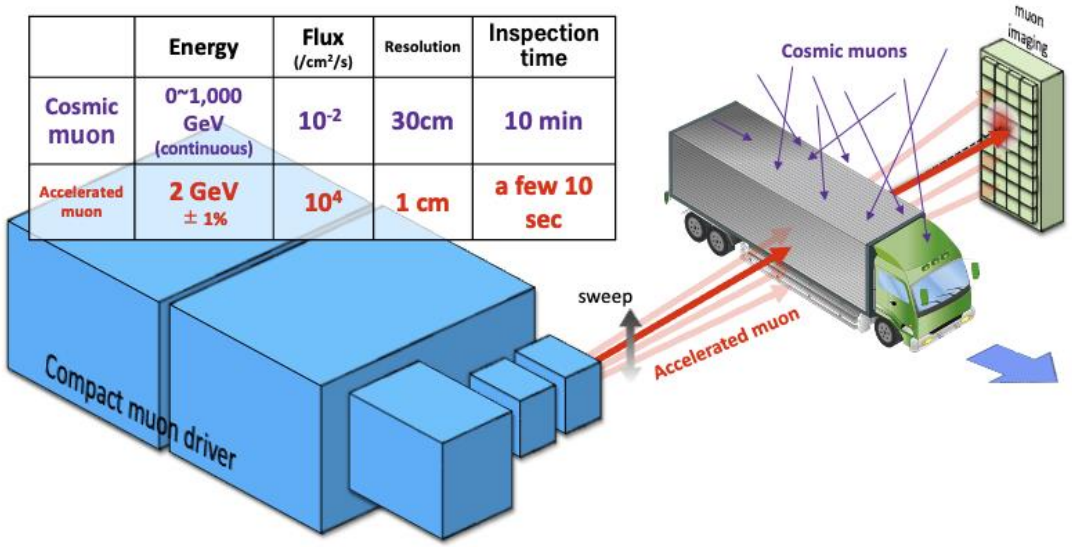
Applications of accelerated muon beam

Drive-thru cargo scanning

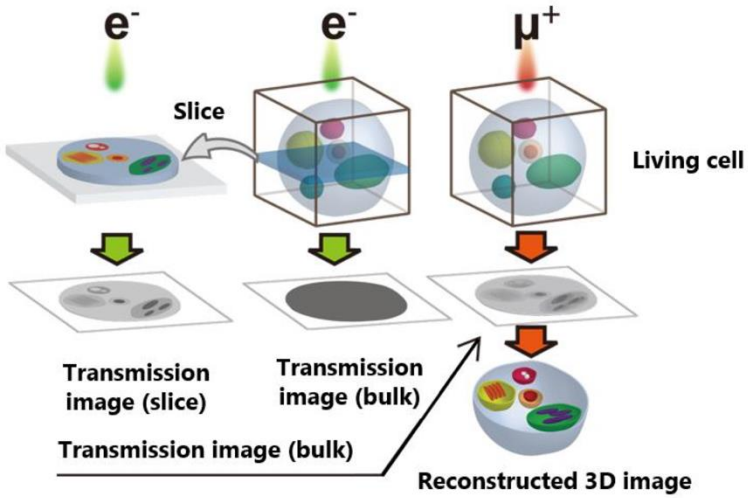
K. Shimomura

Funded by JST K-program (2024-2029)

	Energy	Flux (/cm²/s)	Resolution	Inspection time
Cosmic muon	0~1,000 GeV (continuous)	10^{-2}	30cm	10 min
Accelerated muon	2 GeV ± 1%	10^{4}	1 cm	a few 10 sec

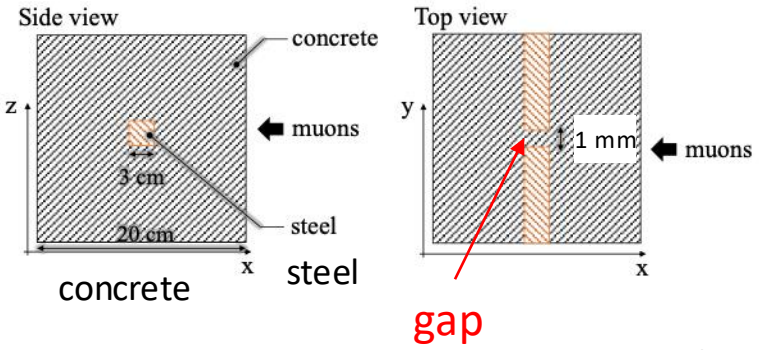


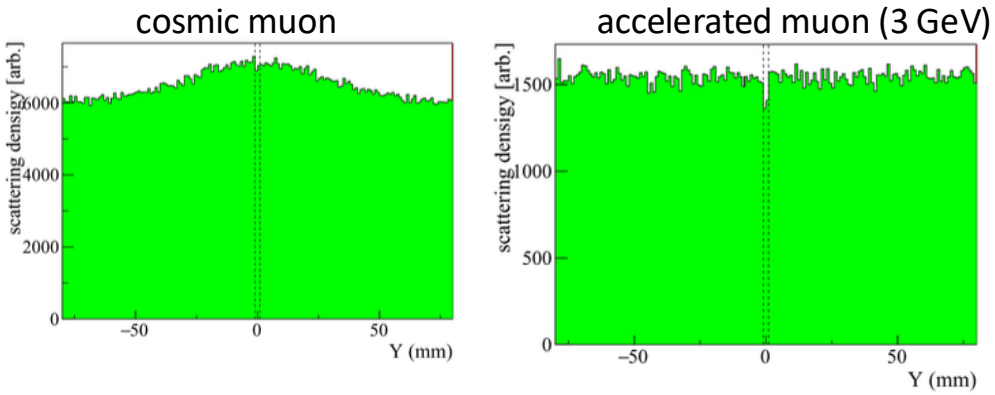
Transmission muon microscope



slide by Y. Miyake et al.

Imaging of large infrastructure

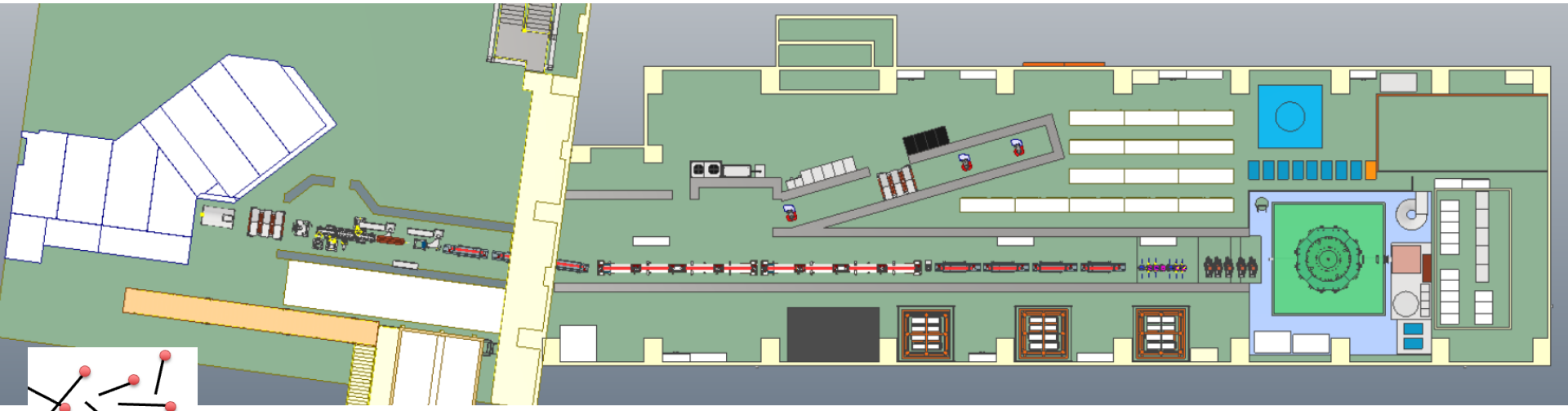




M. Otani, H. Miyadera, T. Shiba, OSA Imaging and Applied Optics Congress 2021 (3D, COSI, DH, ISA, pcAOP)

Summary

- The muon g-2/EDM experiment at J-PARC is **the only experiment** testing the FNAL results.
- **Significant achievements** in 2024 and 2025
  - Demonstration of the room temperature positive muon source
  - First-ever demonstration of positive muon acceleration to 100 keV
  - Completion of the surface muon beamline and first beam delivery
- **Coming up**
  - **Acceleration to 4 MeV**
  - **Studies on higher precision**
- We are open to **new ideas to use the unique muon beam from the first-ever muon LINAC**.



cooling

acceleration

storage
& measurement