

Future of muon science at J-PARC and KEK

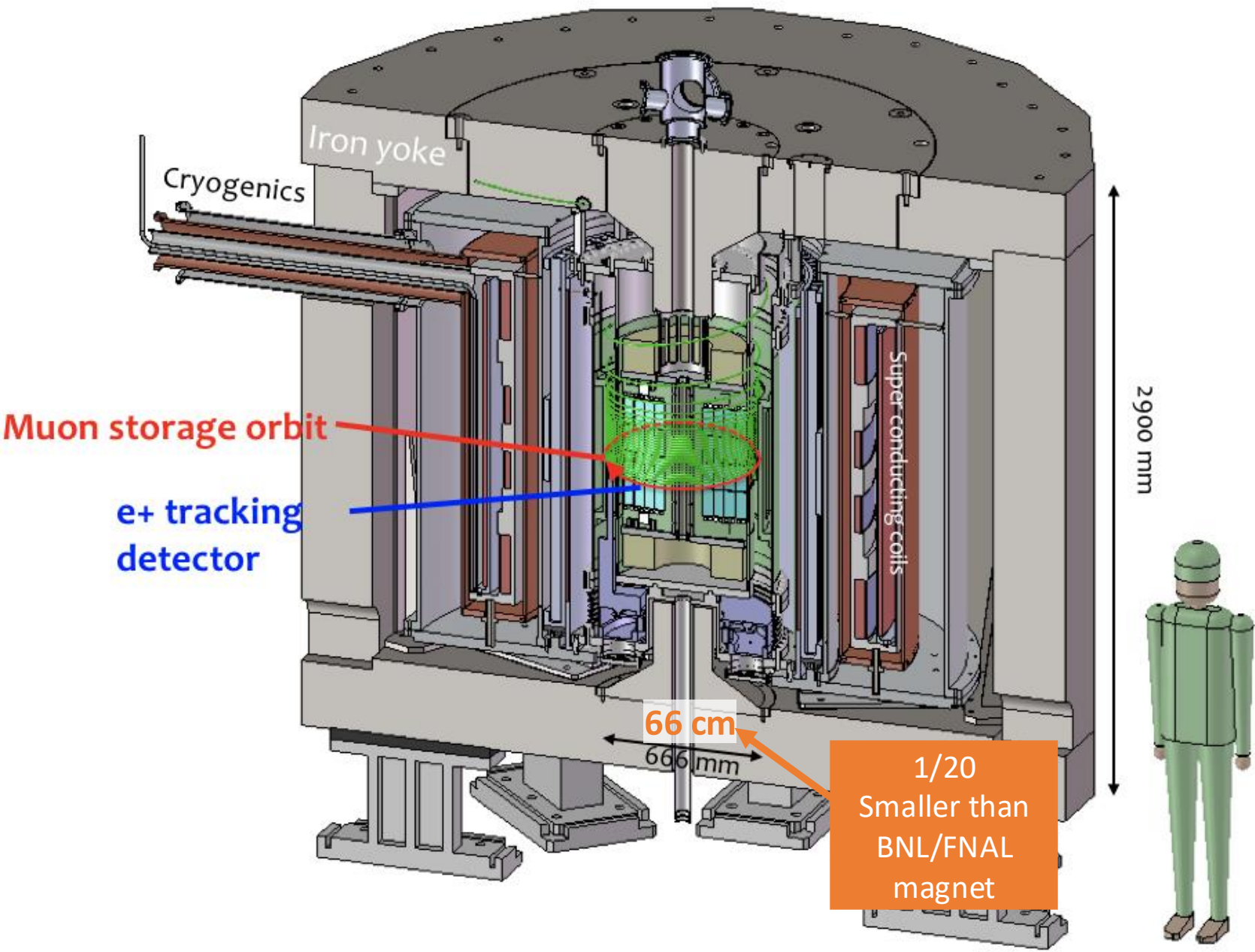
October 31, 2024
Tsutomu Mibe (KEK)

muon g-2 at Fermilab



Science TV show cosmic front (NHK, Nov. 23, 2023)

New g-2/EDM experiment at J-PARC



J-PARC

LINAC
(400 MeV)

Beam power 1MW
Rep. Rate 25 Hz

Rapid Cycle
Synchrotron
(3 GeV)

Neutrino exp. facility

Muonium

g-2/EDM

Materials and Life science
experimental Facility
(MLF)

Main Ring
(30 GeV)

proton
muon
neutron
neutrino
kaon

COMET

Hadron exp. Hall

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

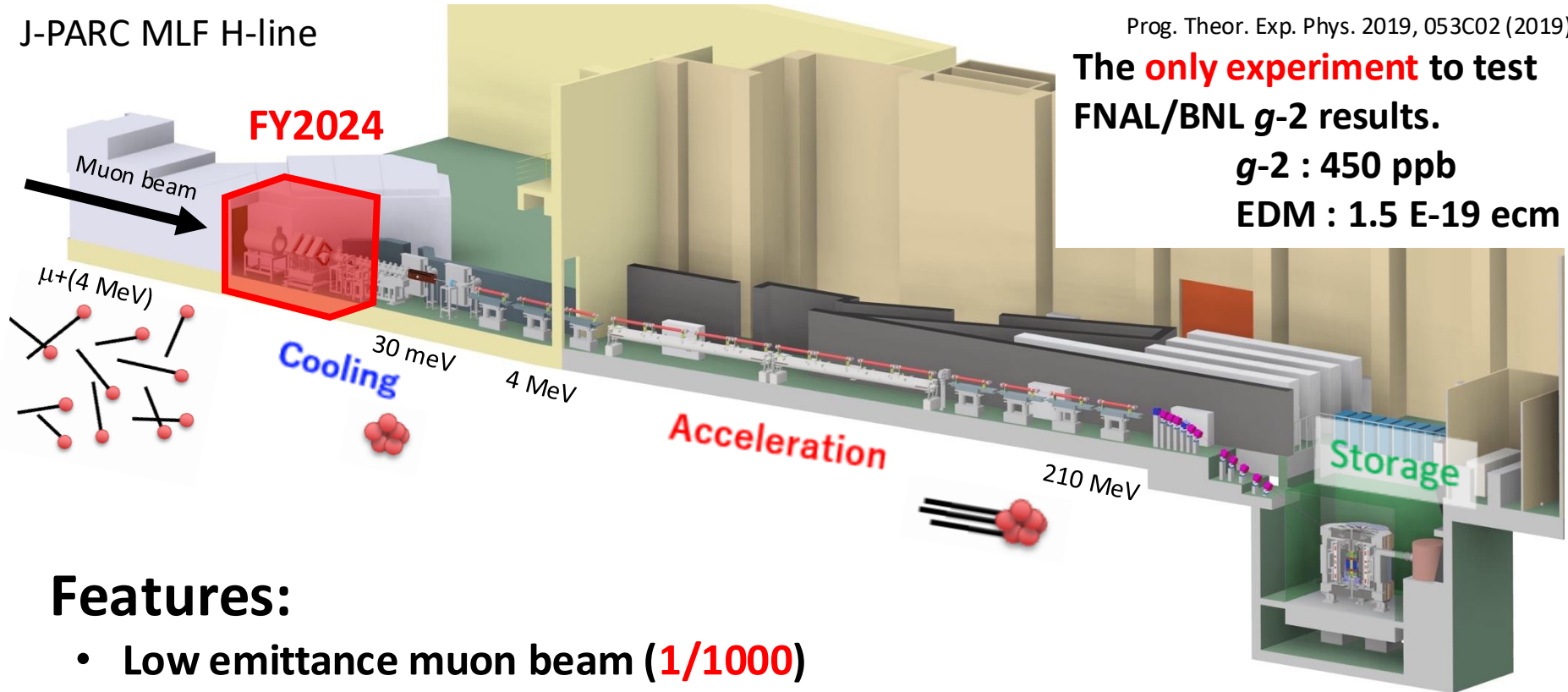
J-PARC MLF H-line

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

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

$g-2$: 450 ppb

EDM : 1.5 E-19 ecm



Features:

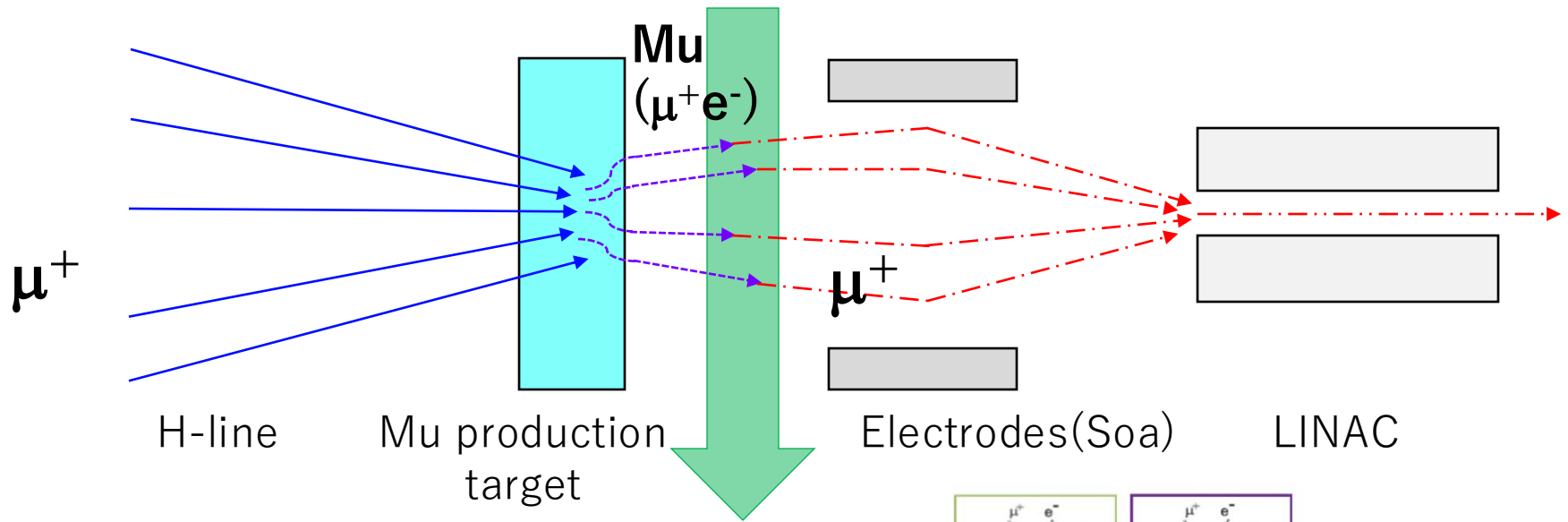
- Low emittance muon beam (**1/1000**)
- No strong focusing (**1/1000**) & good injection eff. (**x10**)
- Compact storage ring (**1/20**)

The only experiment to check FNAL/BNL $g-2$ results

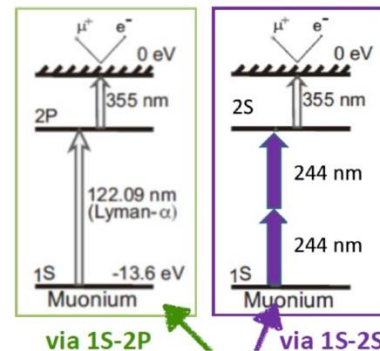
Excellent sensitivity to **muon EDM** about **100 times** better than the
previous limit (sensitivity : **1.5 E-21 ecm**)

Acceleration of thermal muons 6

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

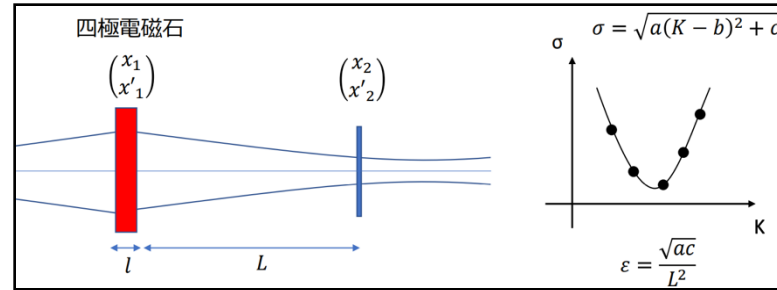


Muonium : a bound state of μ^+ and e^-

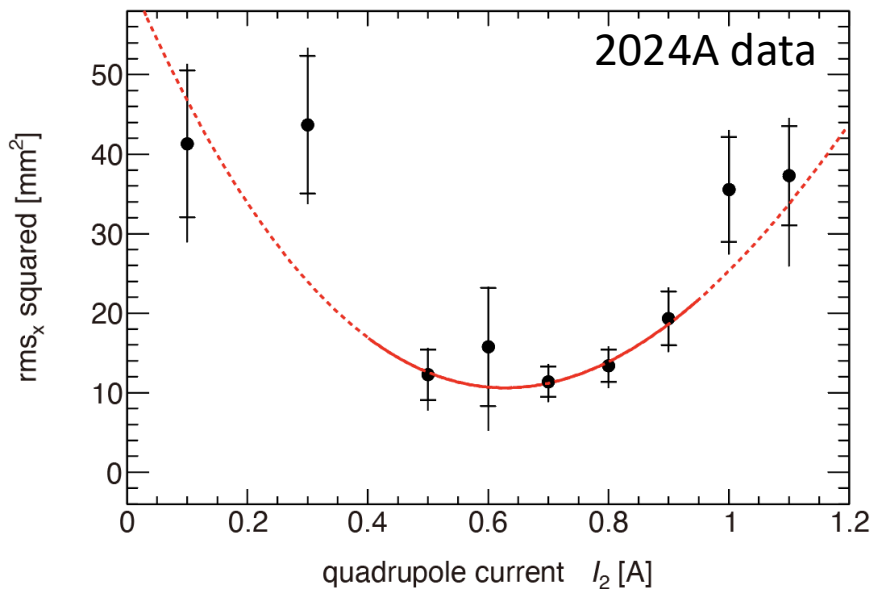


Muon acceleration to 100 keV

[arXiv:2410.11367](https://arxiv.org/abs/2410.11367)



horizontal



before cooling

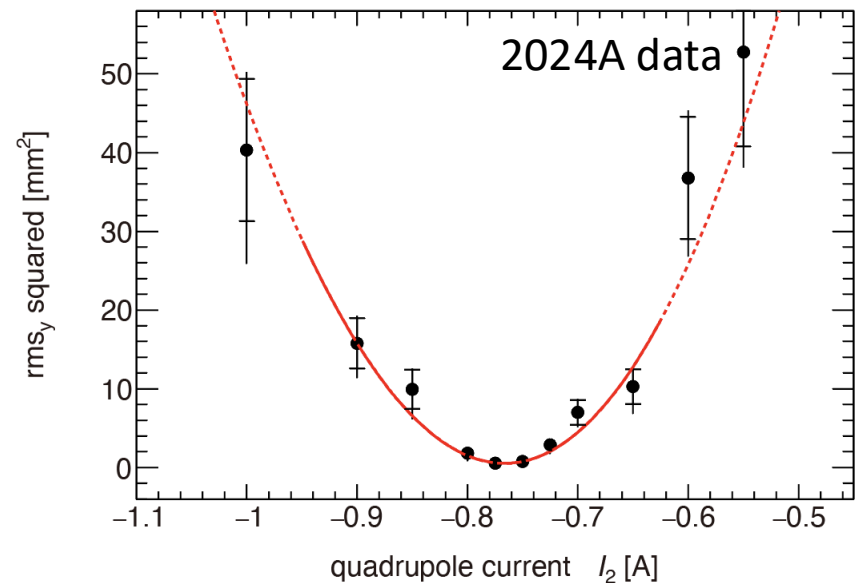
$$\varepsilon_x = 170 \pi \text{ mm mrad}$$

x 1/200

after cooling + acceleration

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

vertical



before cooling

$$\varepsilon_y = 130 \pi \text{ mm mrad}$$

x 1/400

after cooling + acceleration

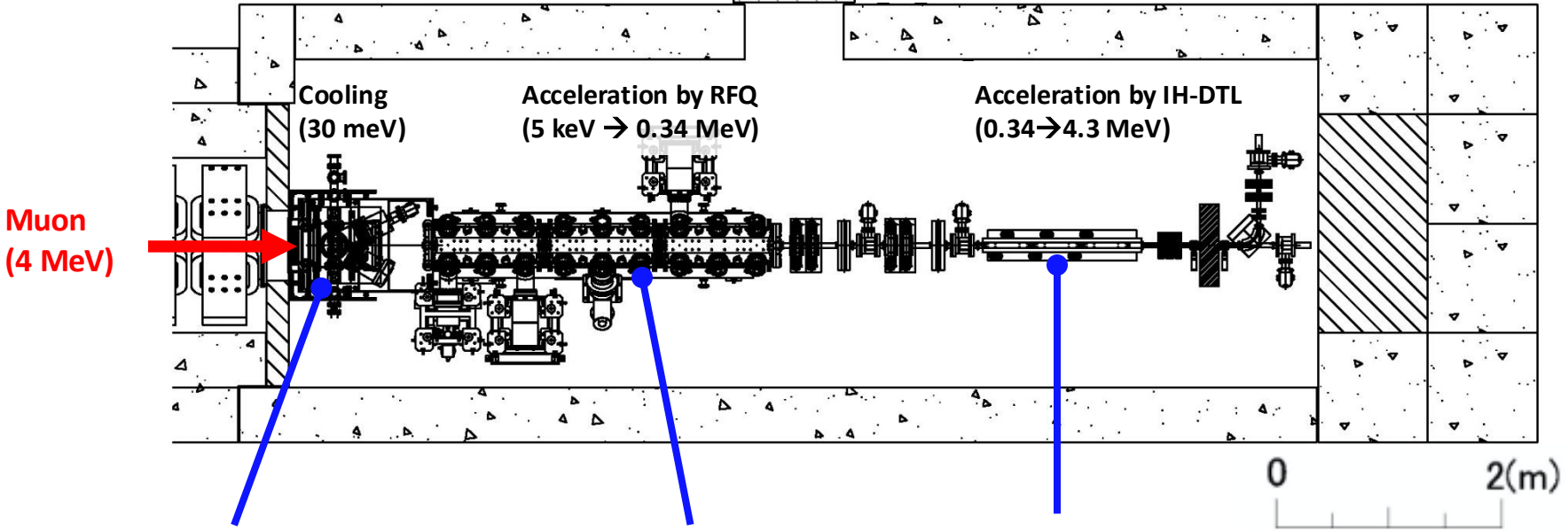
$$\varepsilon_y = 0.23 \pm 0.03^{+0.05}_{-0.02} \pi \text{ mm mrad}$$

The birth of low-emittance muon beam

Next step: Acceleration to 4 MeV

H2 area

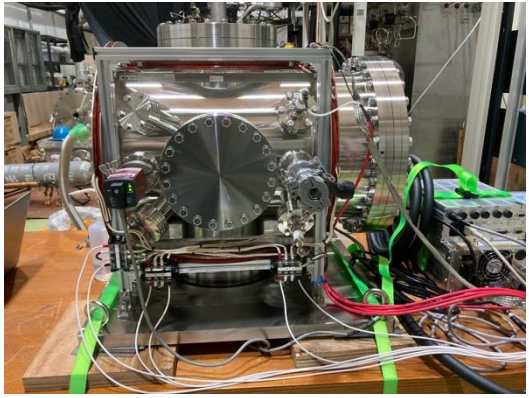
FY2025-2027



Mu production chamber (available)

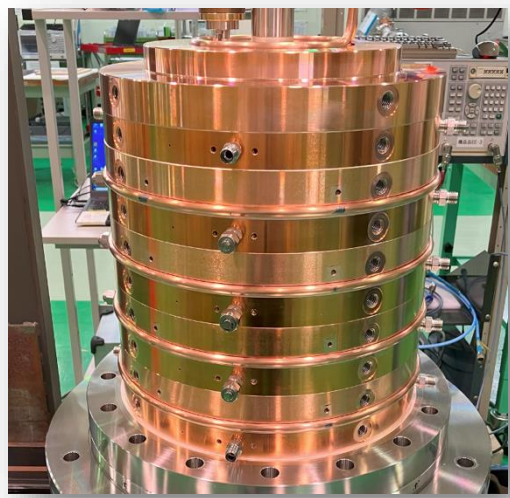
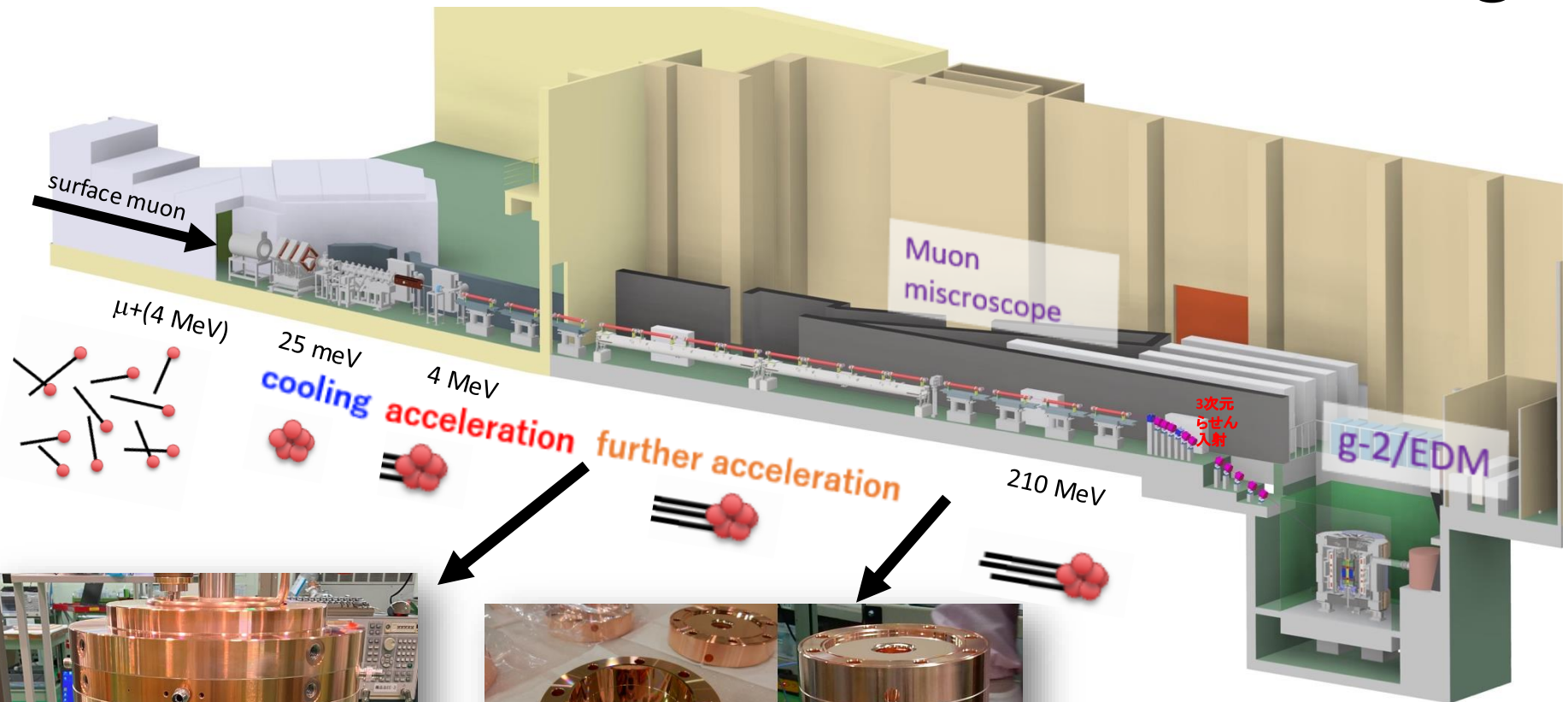
J-PARC LINAC RFQ (available)

IH-DTL (fabricated and evaluated in FY2022)

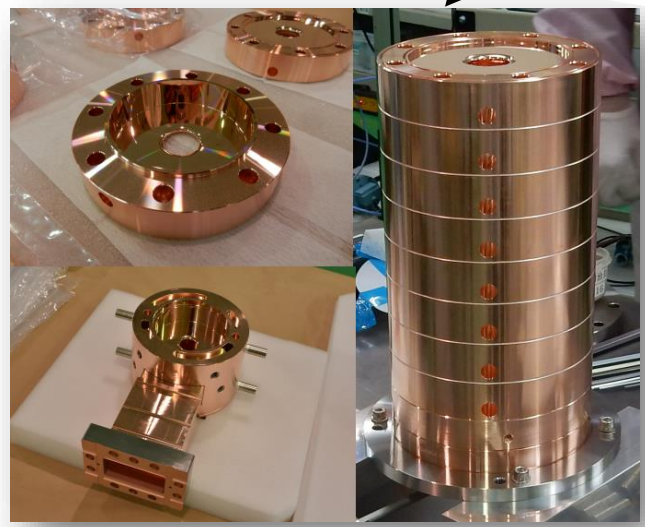


Currently, the cavity is located at J-PARC LINAC.

Further acceleration to 210 MeV



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



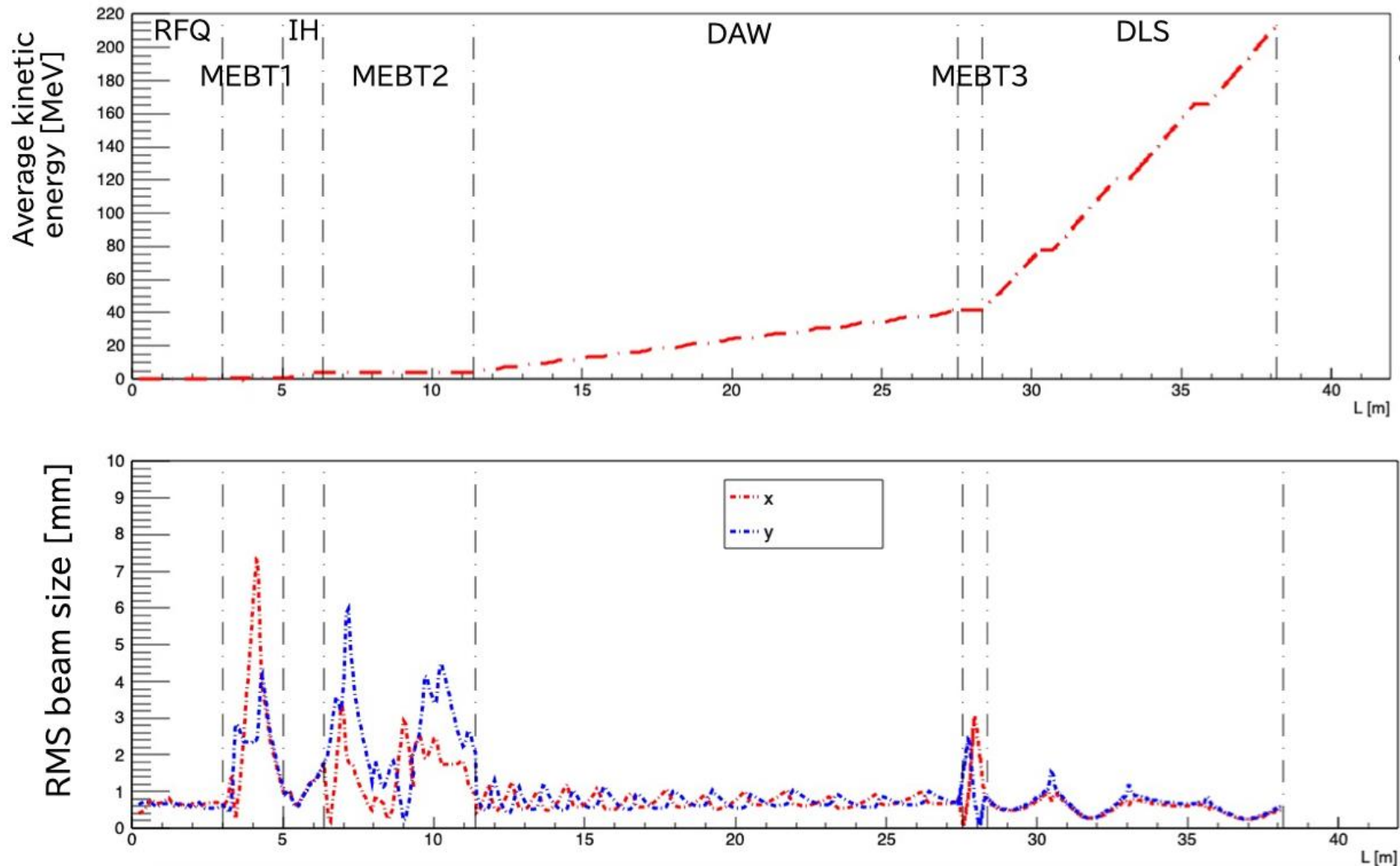
Disk Load Structure (DLS) (from 40 MeV to 210 MeV)

Start-to-end simulation

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Simulated beam in the muon LINAC

Y. Takeuchi

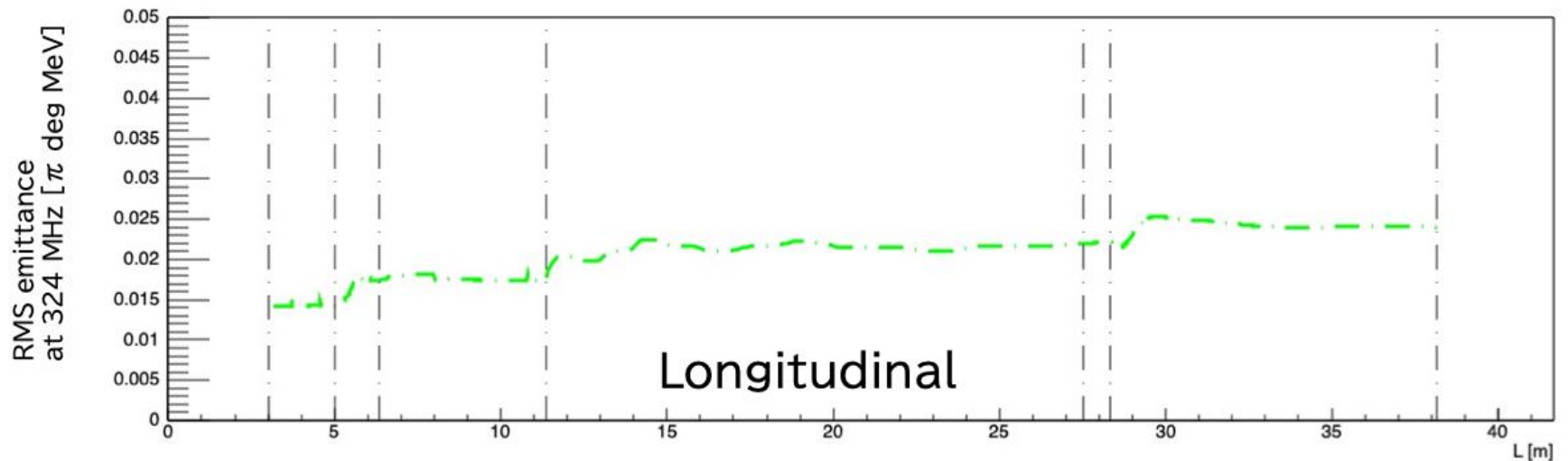
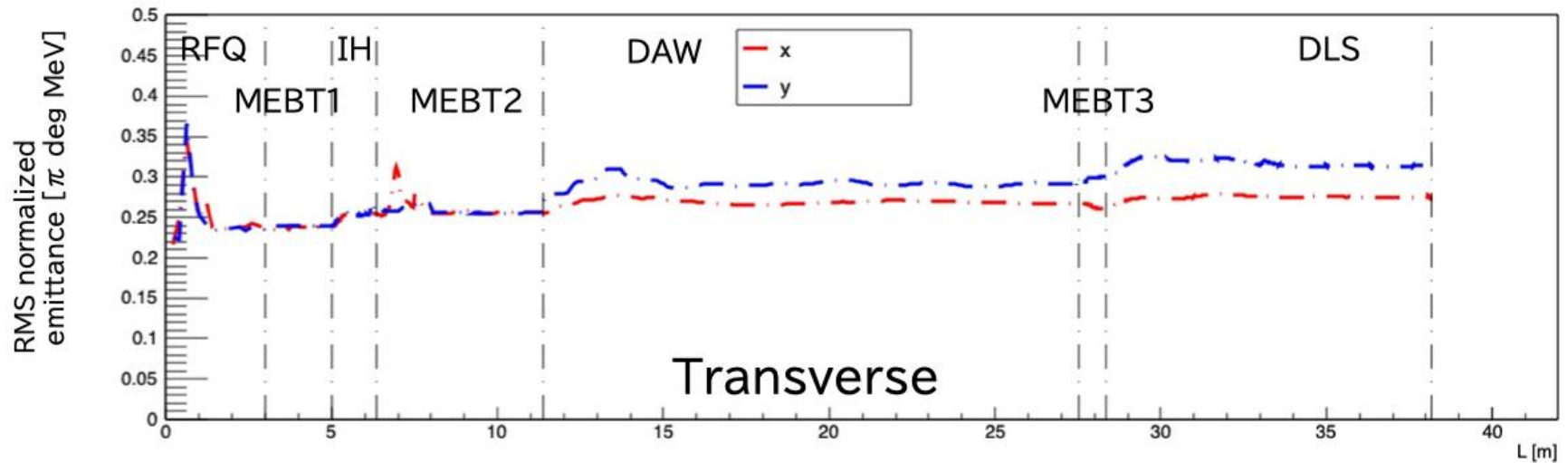


Start-to-end simulation

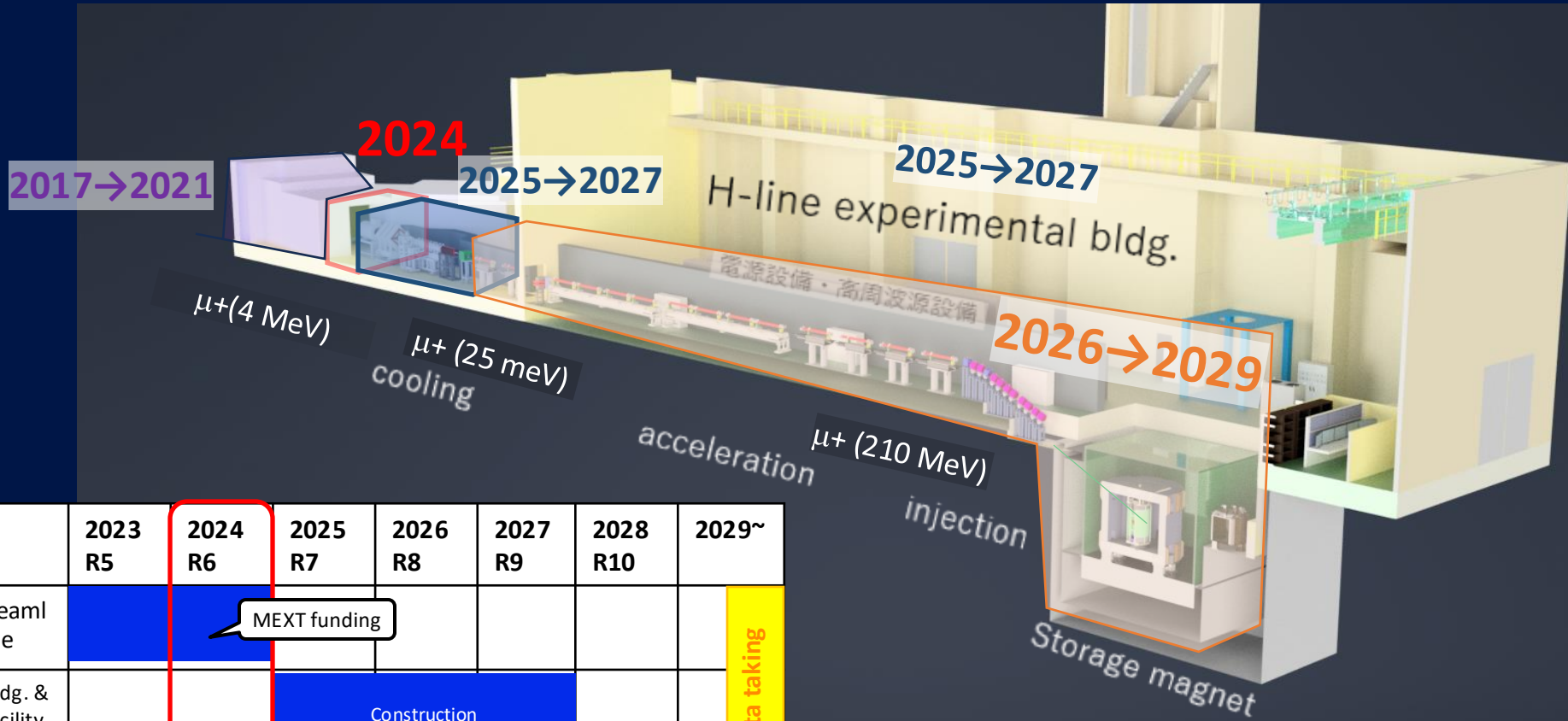
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Simulated beam in the muon LINAC

Y. Takeuchi



Intended schedule



	2023 R5	2024 R6	2025 R7	2026 R8	2027 R9	2028 R10	2029~
Beamline		MEXT funding					
Bldg. & facility		Construction					
Source, LINAC, storage	source	★ cooling @S2	★ cooling @H2				
	LINAC			★ 100 keV@S2	★ 4 Me@H2		
	Storage		procurement			installation ★	
Detector		position tracker magnetic field monitors					

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 (construction)

The collaboration

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114 members from Canada, China, Czech, France, India, Japan, Korea, Netherlands, Russia, USA



Tamaki Yoshioka
(Kyushu)

Collaboration board (CB)

Chair: Seonho Choi

Executive board (EB)

Spokesperson: T. Mibe

2024.3 Shanghai Jiao Tong University
2024.6 Iwate University

Subgroups

Interface coordinators

Committees

Speakers committee

chair: K. Ishida, **Y. Sato**

Publication committee

chair: B. Shwartz

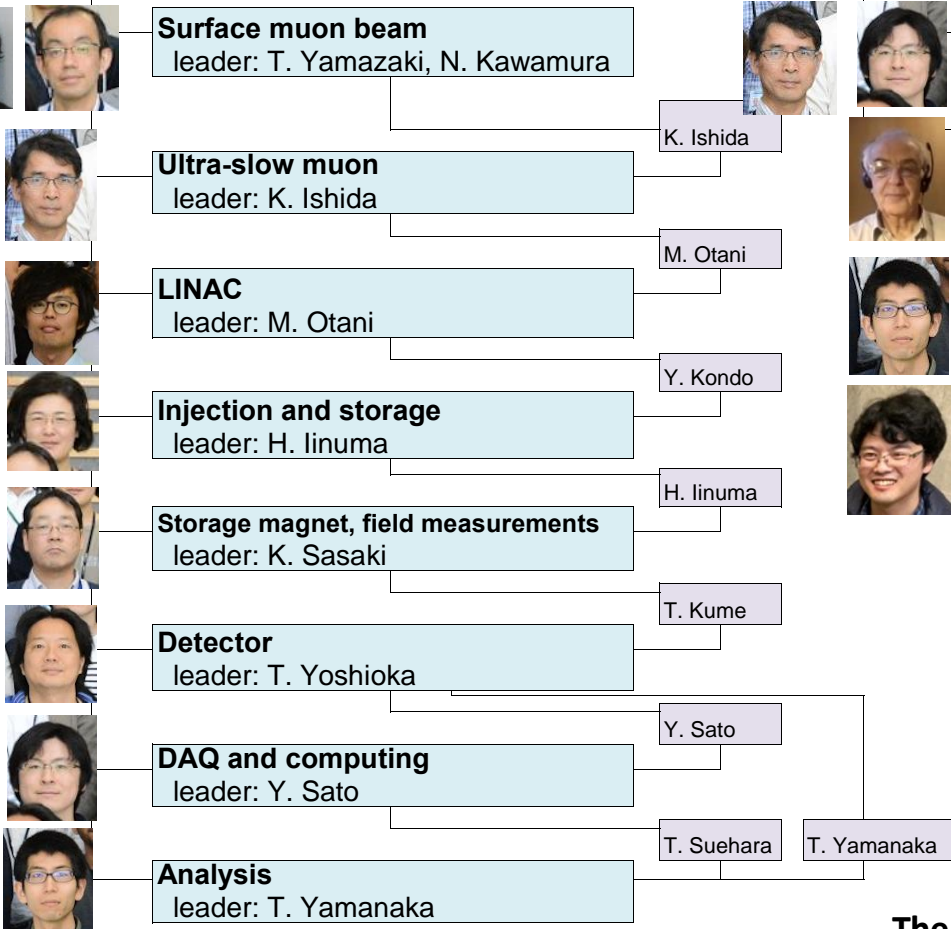
Working groups

physics analysis

T. Yamanaka, S. Ogawa

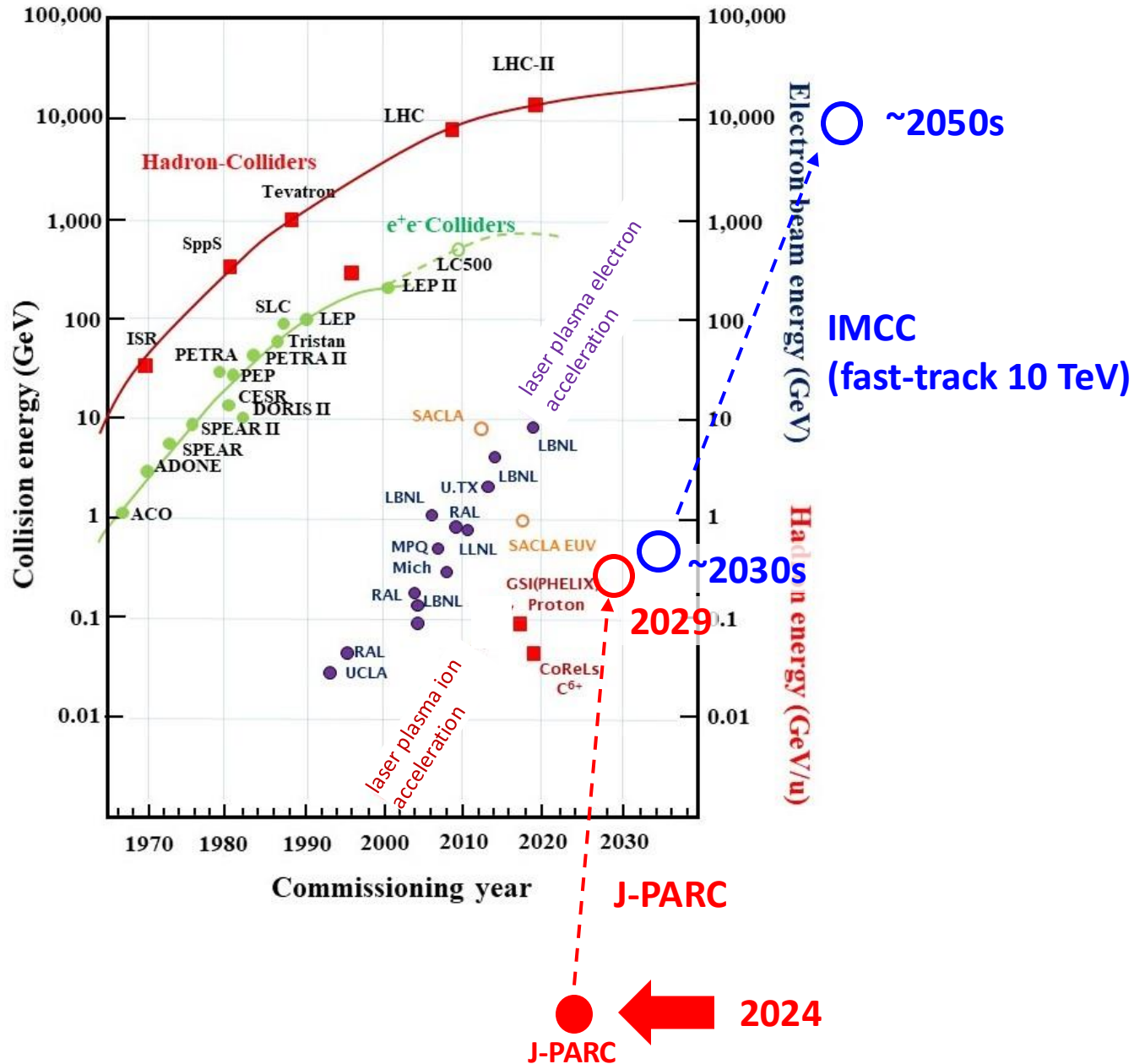
Domestic institutes :

Kyushu, Nagoya, Tohoku, Niigata, Toyama C, Tokyo, Ibaraki, RIKEN, JAEA, etc.
KEK: IPNS, IMSS, ACC, CRY, MEC, CRC



The 28th collaboration meeting at J-PARC, June 26-28, 2024

Future



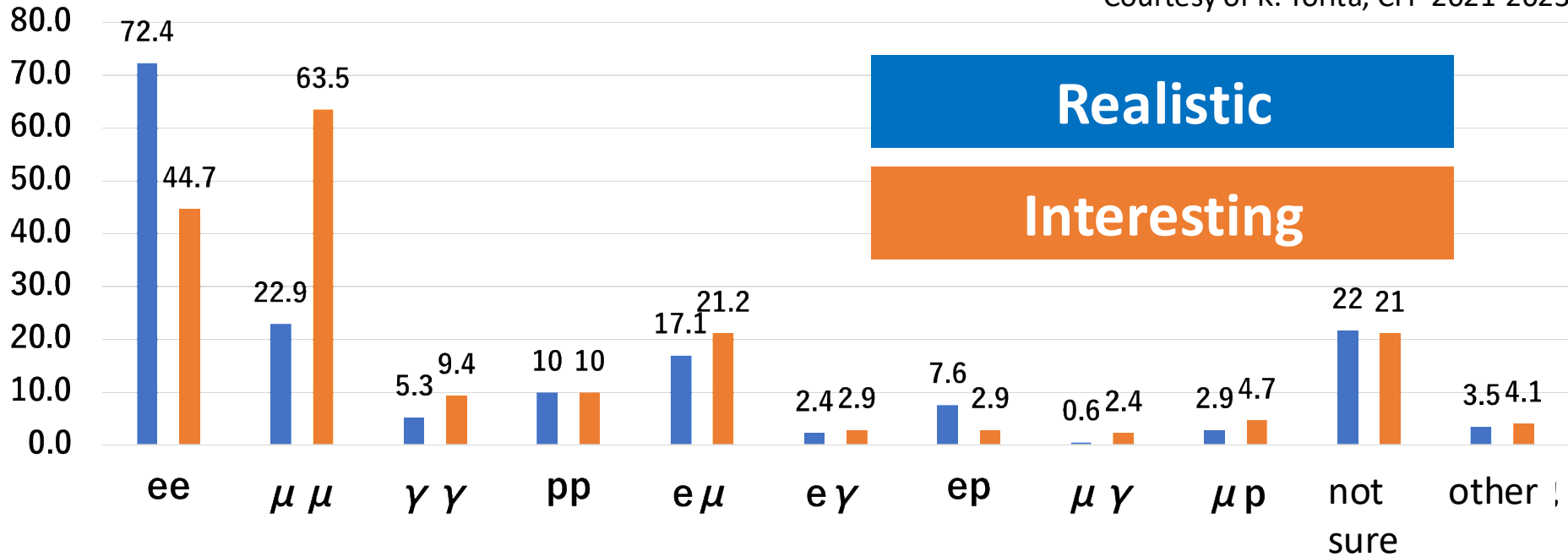
Community survey in Japan (2023)

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for Japanese experimental particle physicists

What do you think the **next-generation collider** would be?

Courtesy of K. Yorita, CFP 2021-2023



Study groups were formed and documented status and prospects.

- e+e- Higgs factory
- non-collider experiments
- **muon acceleration**

Muon acceleration and future colliders

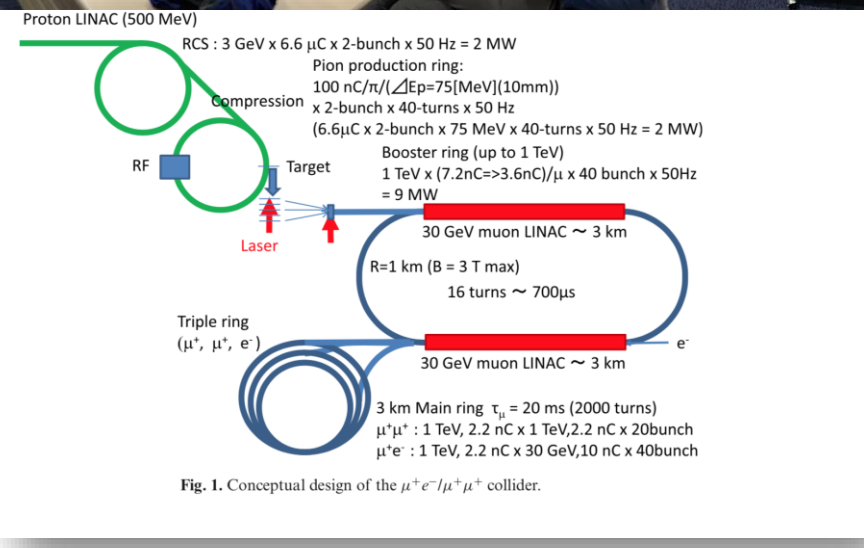
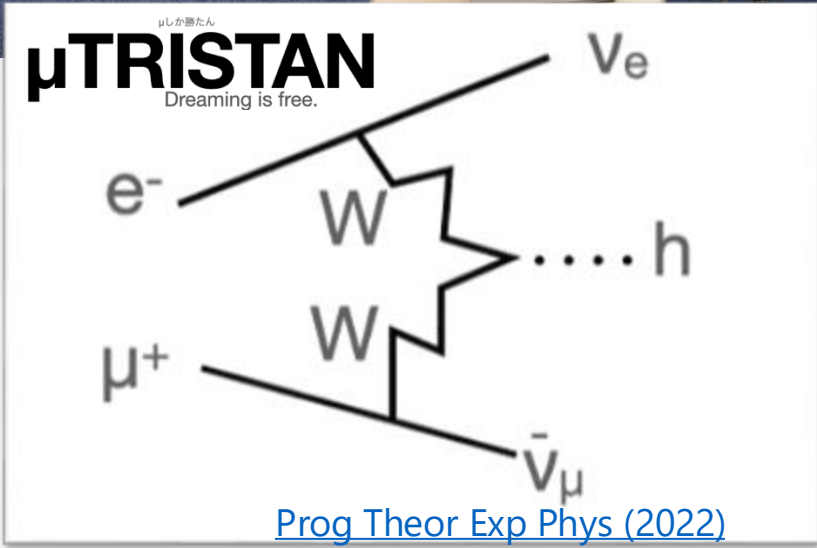
KEK IPNS workshop, Nov. 2, 2023

<https://kds.kek.jp/event/48168/>

$\mu^+ \mu^-$ or $\mu^+ e^-$?



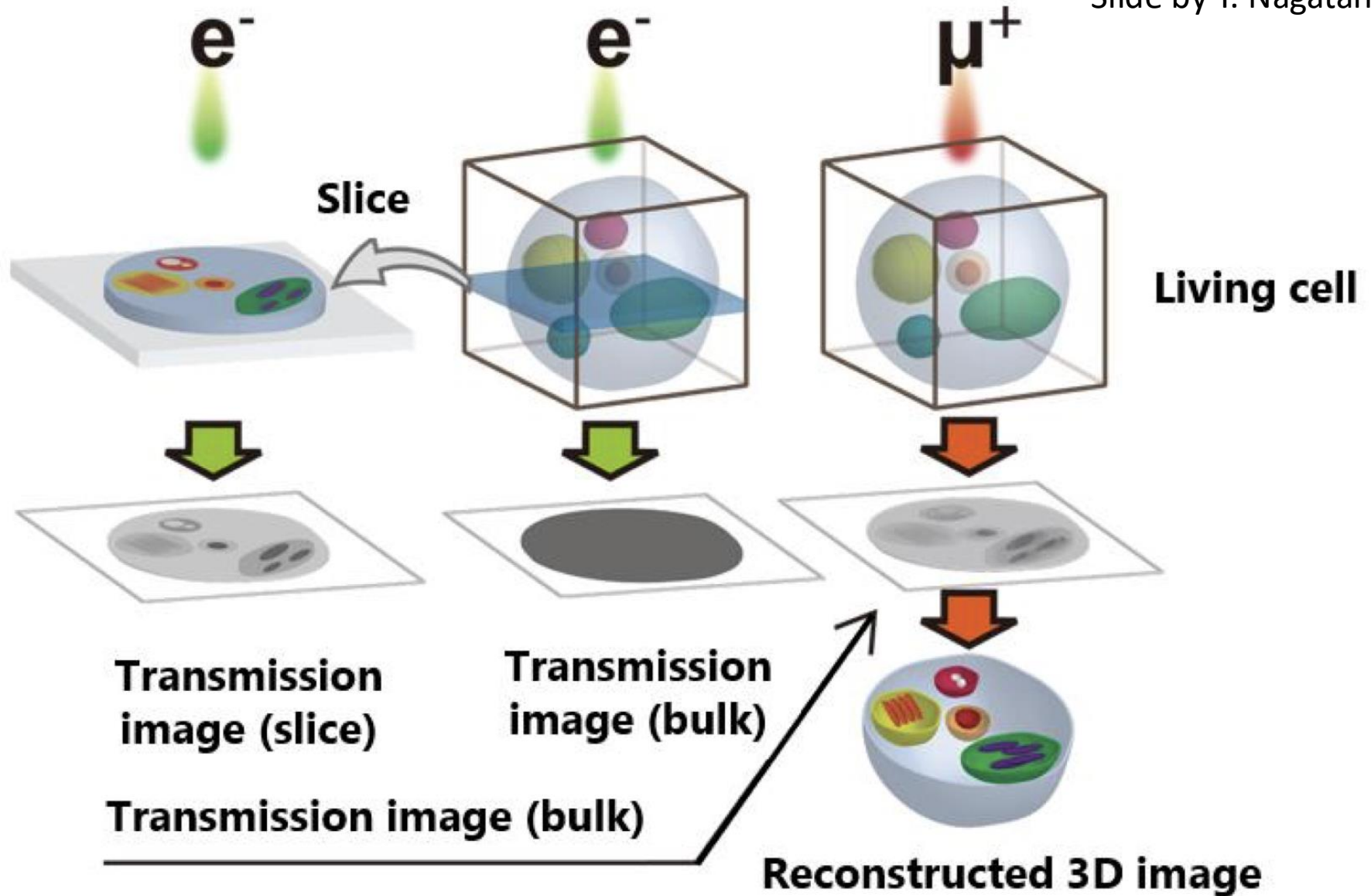
R. Kitano



Transmission muon microscope

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Slide by Y. Nagatani



Drive-thru cargo scanning

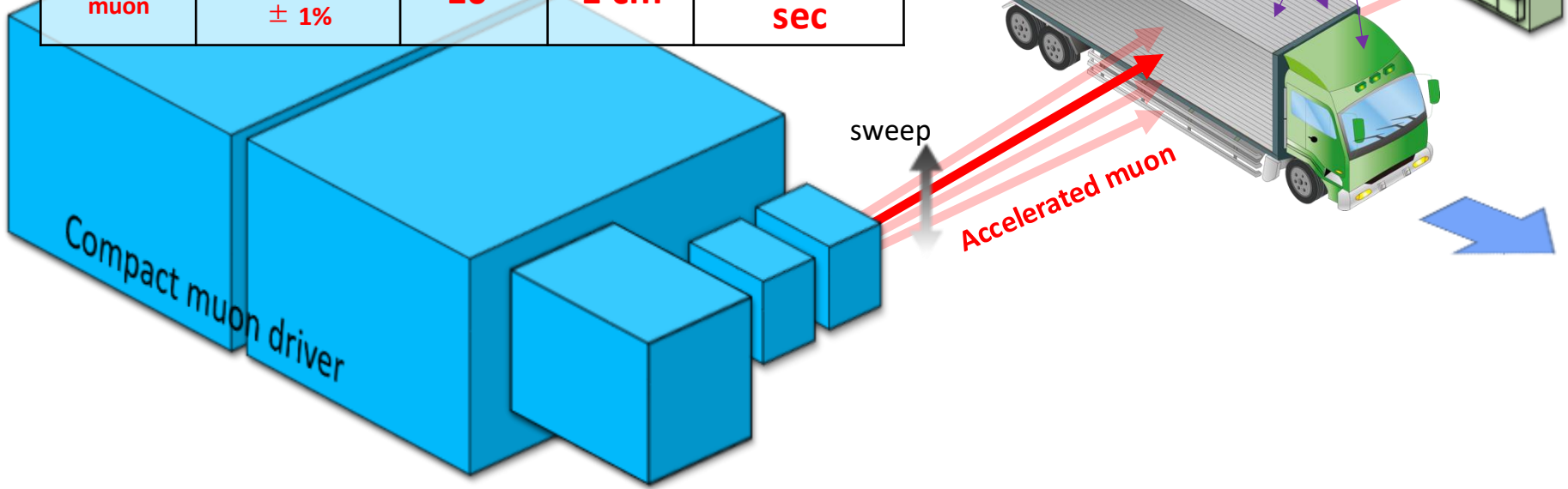


Drive-thru cargo scanning

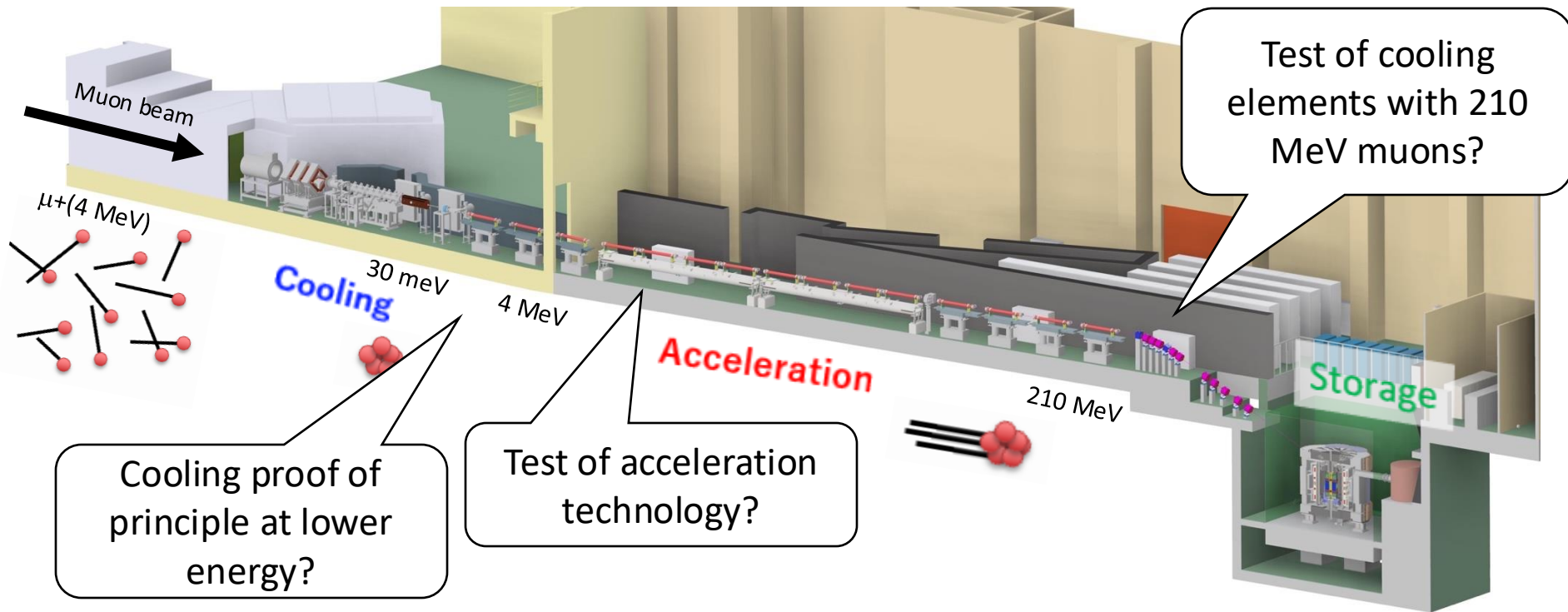
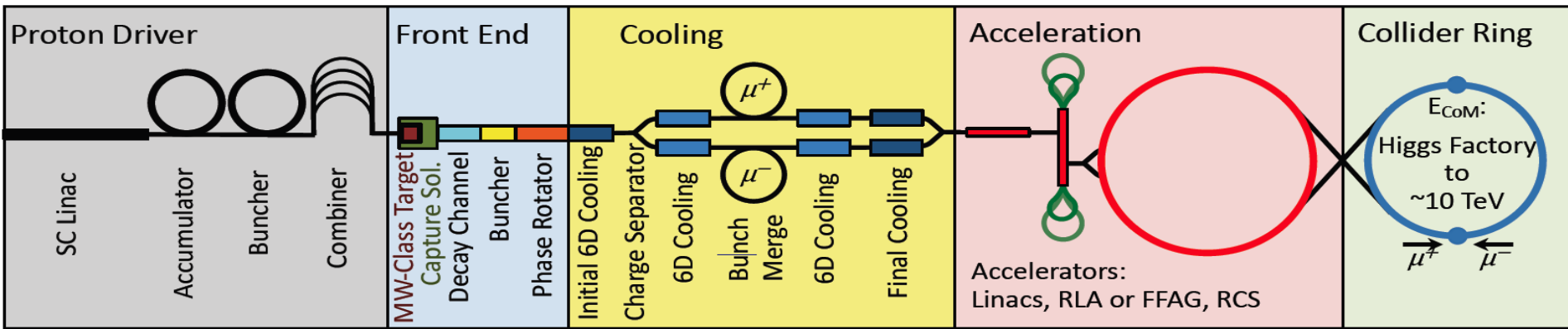
Approved in JST K-program (2024-2029)

Detection of heavy materials (nuclear fuel, weapon, etc) with muon transmission image

	Energy	Flux (/cm ² /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



Synergies with the muon collider?



Summary

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- A new experiment to measure muon g-2 and EDM is under preparation.
 - **Cooling & acceleration of positive muon to 212 MeV**
 - We succeeded in the first ever demonstration of muon acceleration.
 - Expected year of data taking from 2029.
- Future plan is under discussion
 - Japanese community is interested in muon collider.
 - mu-e collider
 - muon microscope
 - cargo scanning

