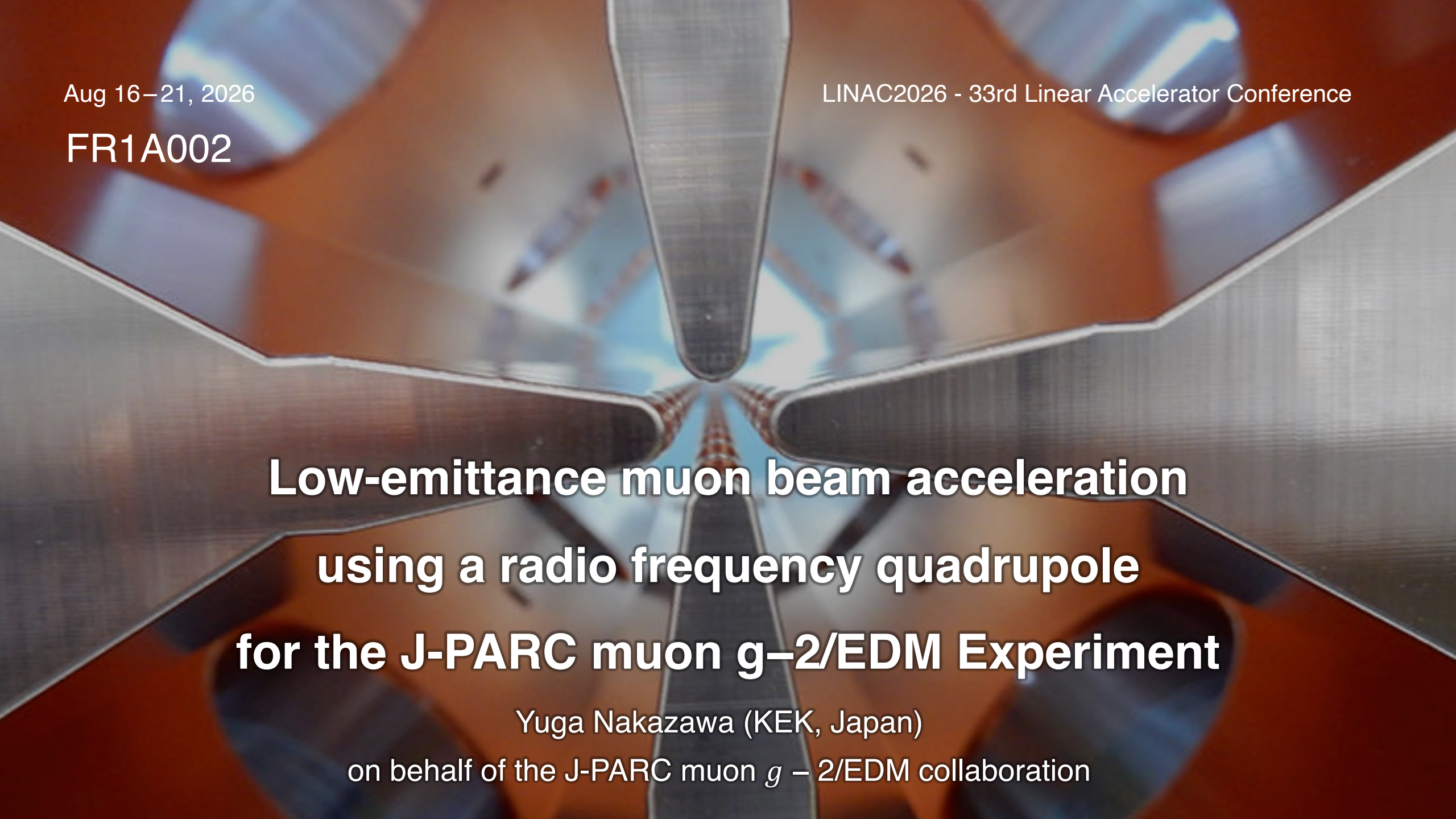
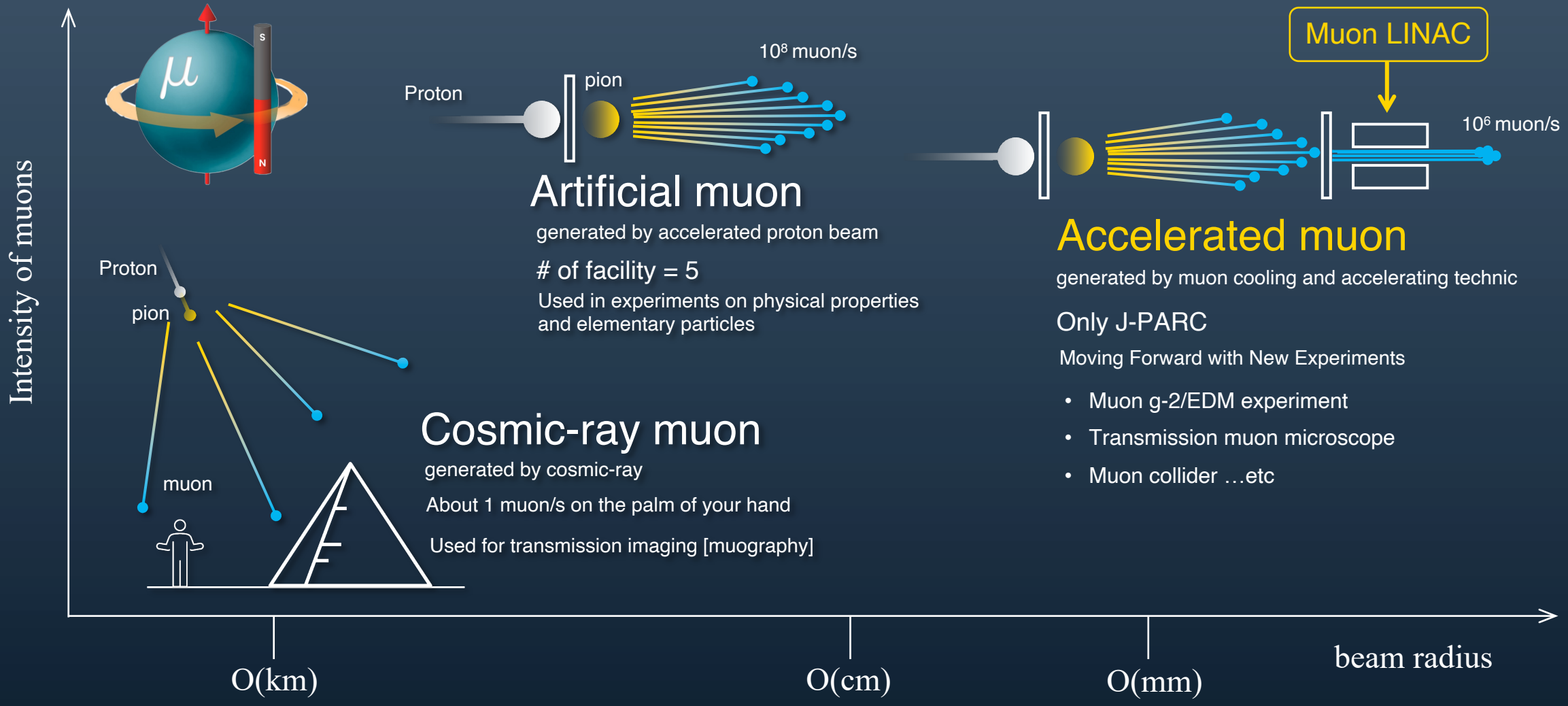
Aug 16–21, 2026
LINAC2026 - 33rd Linear Accelerator Conference
FR1A002



Low-emittance muon beam acceleration using a radio frequency quadrupole for the J-PARC muon g–2/EDM Experiment

Yuga Nakazawa (KEK, Japan)
on behalf of the J-PARC muon g – 2/EDM collaboration

Low-emittance muon beam



Artificial muon

generated by accelerated proton beam

# of facility = 5

Used in experiments on physical properties and elementary particles

Accelerated muon

generated by muon cooling and accelerating technic

Only J-PARC

Moving Forward with New Experiments

- Muon g-2/EDM experiment
- Transmission muon microscope
- Muon collider …etc

Cosmic-ray muon

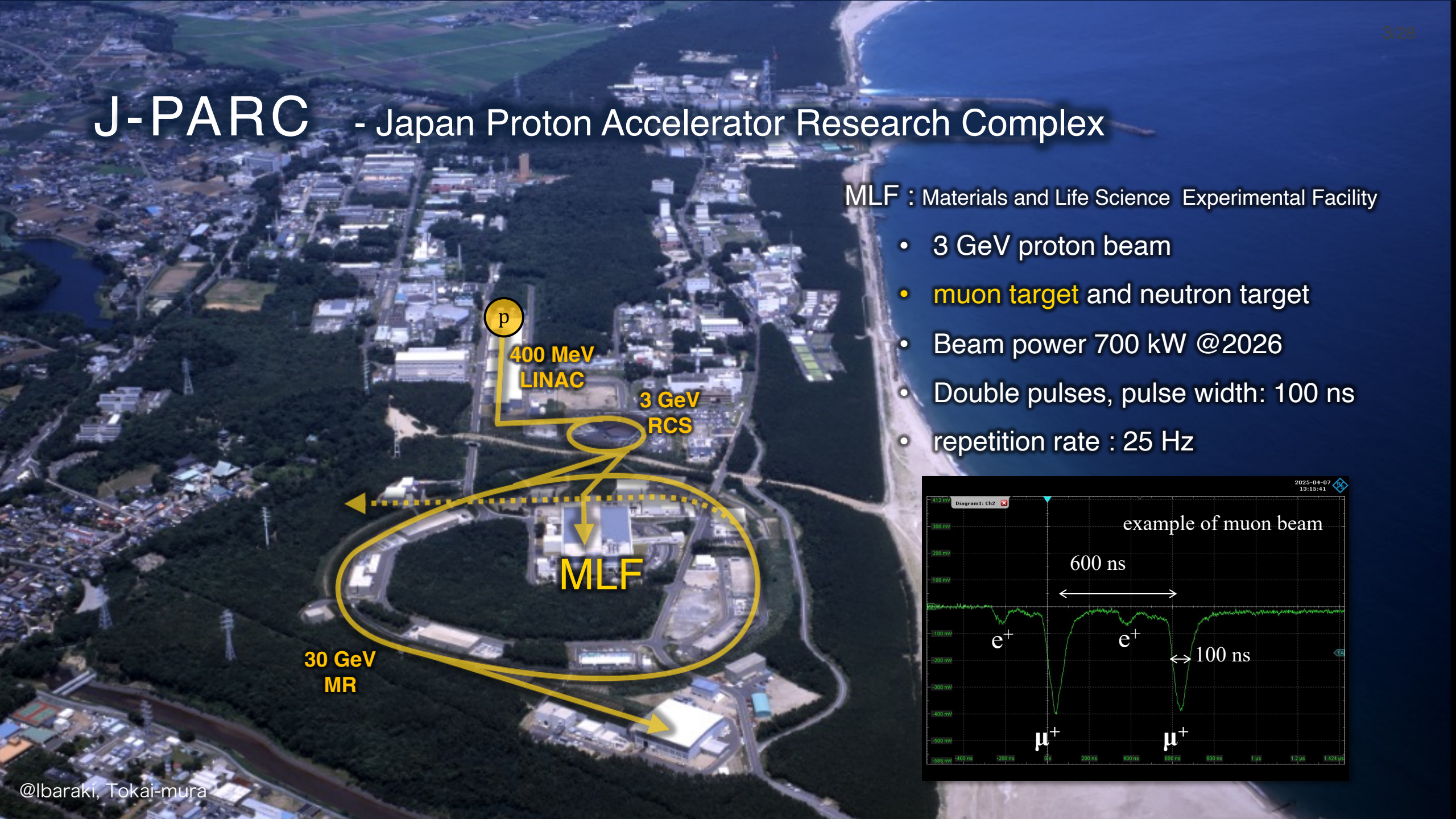
generated by cosmic-ray

About 1 muon/s on the palm of your hand

Used for transmission imaging [muography]

Aiming to realize and apply high-Intensity × low-emittance muon beams

J-PARC - Japan Proton Accelerator Research Complex

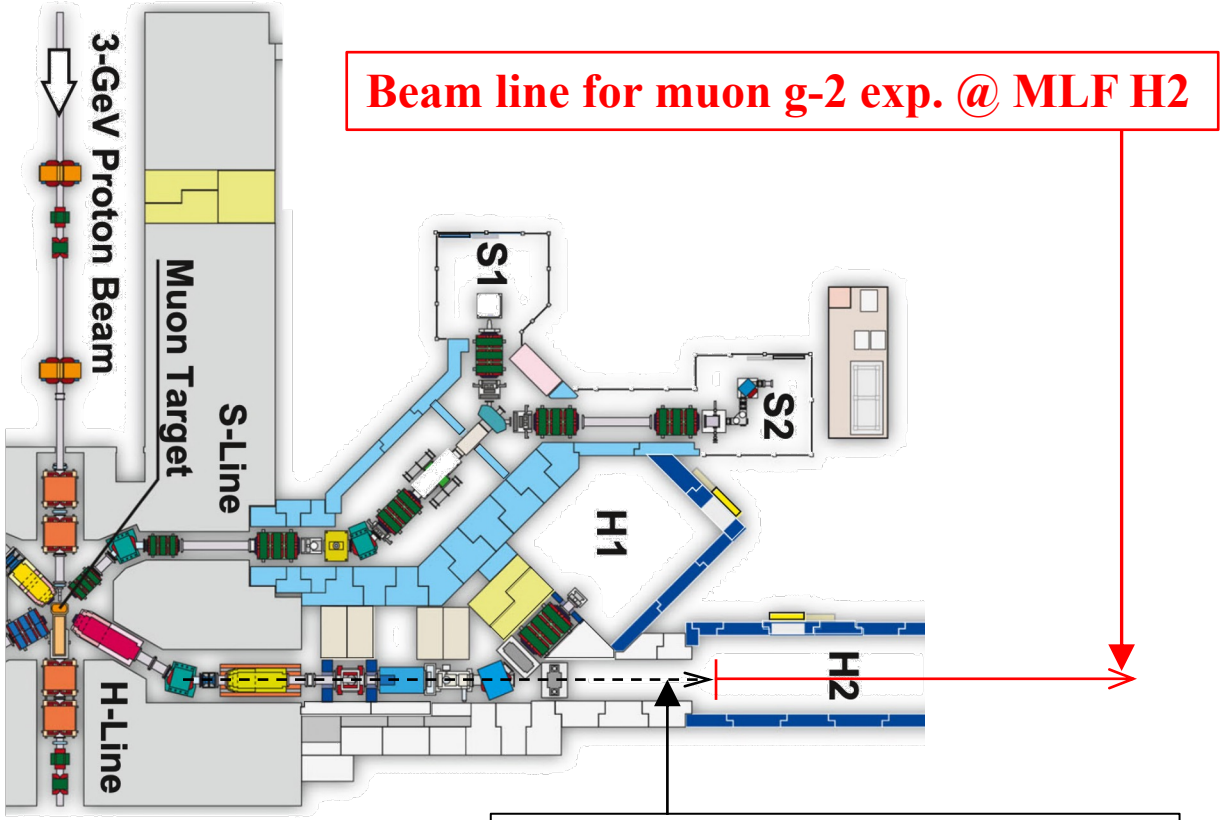


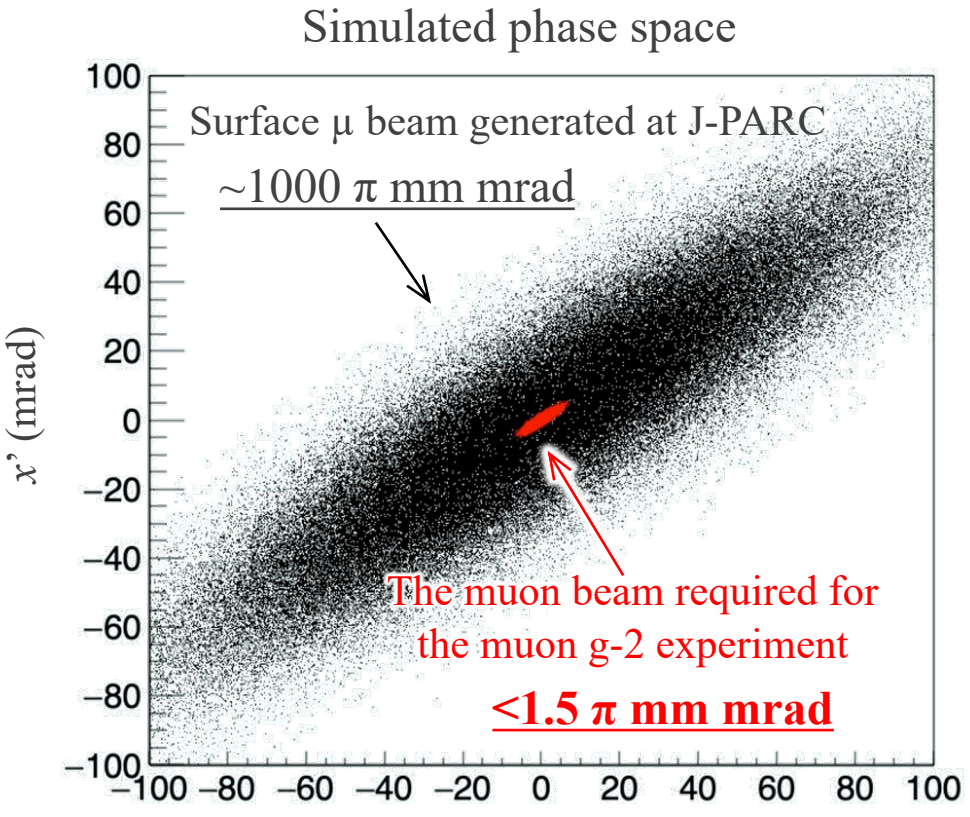
MLF : Materials and Life Science Experimental Facility

- 3 GeV proton beam
- muon target and neutron target
- Beam power 700 kW @2026
- Double pulses, pulse width: 100 ns
- repetition rate : 25 Hz

@Ibaraki, Tokai-mura

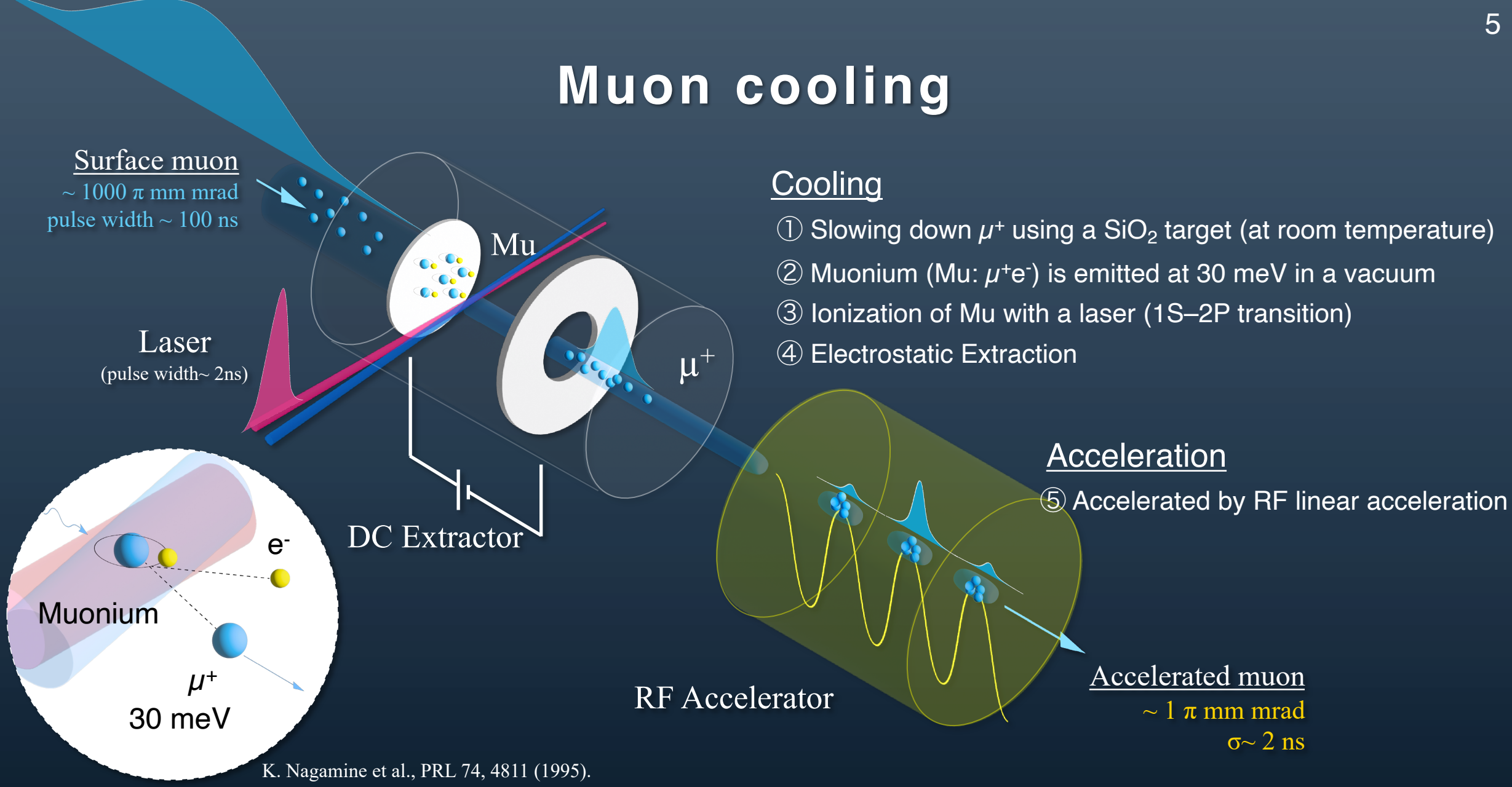
Muon beam generated by J-PARC





How can we reduce the emittance by ~3 orders of magnitude?

Muon cooling



Cooling

① Slowing down μ^+ using a SiO_2 target (at room temperature)

② Muonium (Mu: μ^+e^-) is emitted at 30 meV in a vacuum

③ Ionization of Mu with a laser (1S–2P transition)

④ Electrostatic Extraction

Acceleration

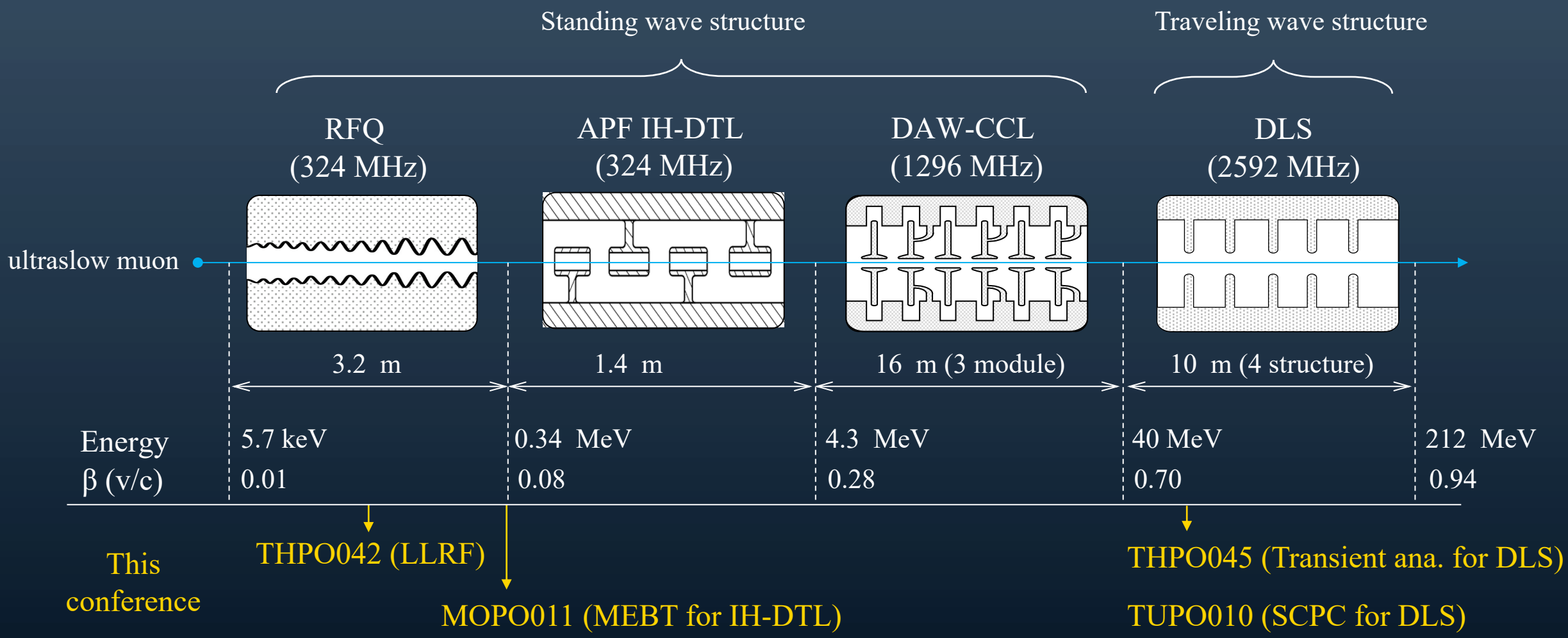
⑤ Accelerated by RF linear acceleration

K. Nagamine et al., PRL 74, 4811 (1995).

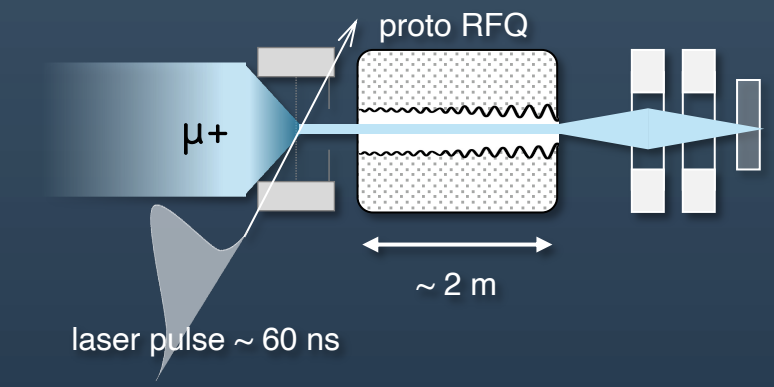
Accelerate the ultraslow muons (USMs) after laser ionization cooling

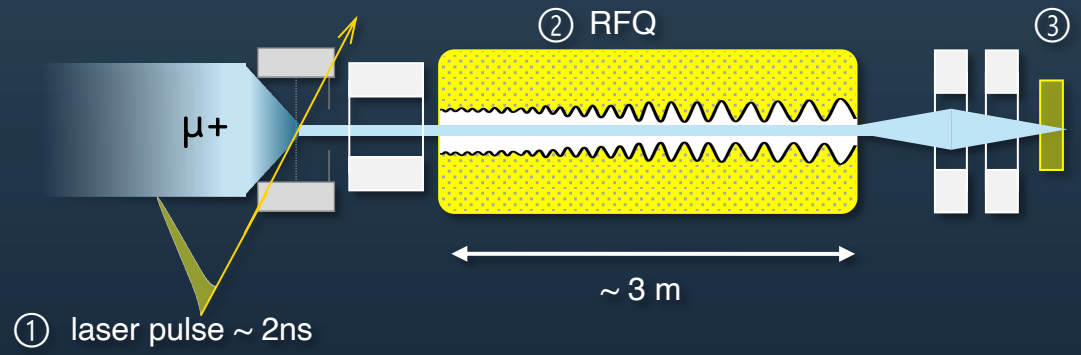
Muon Acceleration

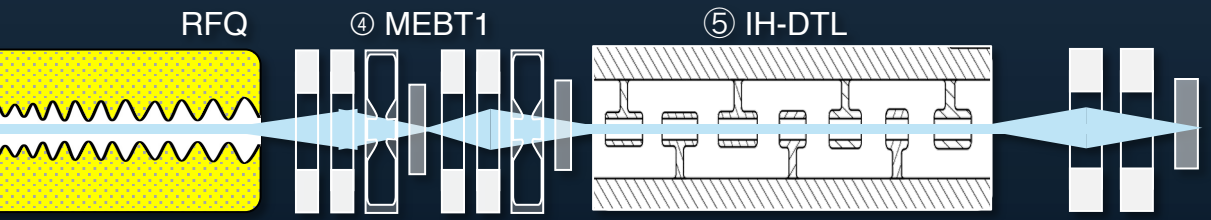
Using proton and electron accelerator technology, we develop a new linac specifically for muons.
Linac is used to minimize muon decay losses.



Strategy of acceleration test







under construction…

Step 1 Demonstration of μ^+ acceleration at user area

- ☑ 100 keV acc. using **prototype RFQ**
- ☑ Measured transverse emittance.

→ Phys. Rev. Lett. 134, 245001 (2025)

Step 2 in-situ implementation for muon g-2 exp.

① Laser upgrade & diagnostic-line → arXiv:2608.02706

② 340 keV acc. using full-scale RFQ. → Today's topic

③ Add the bunch width monitor.

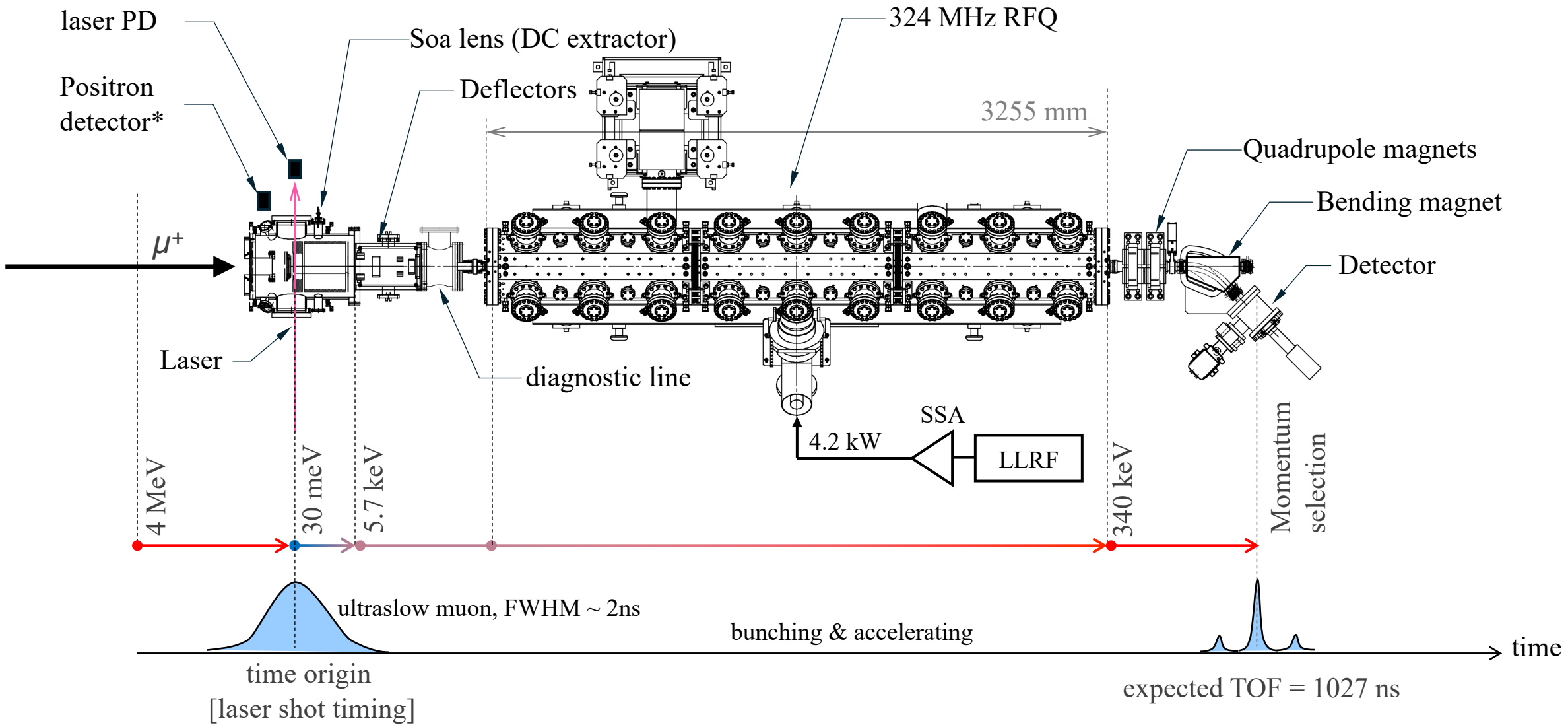
Step 3 Multistage Acceleration w/ 324-MHz IH-DTL.

④ Medium energy beam transport line

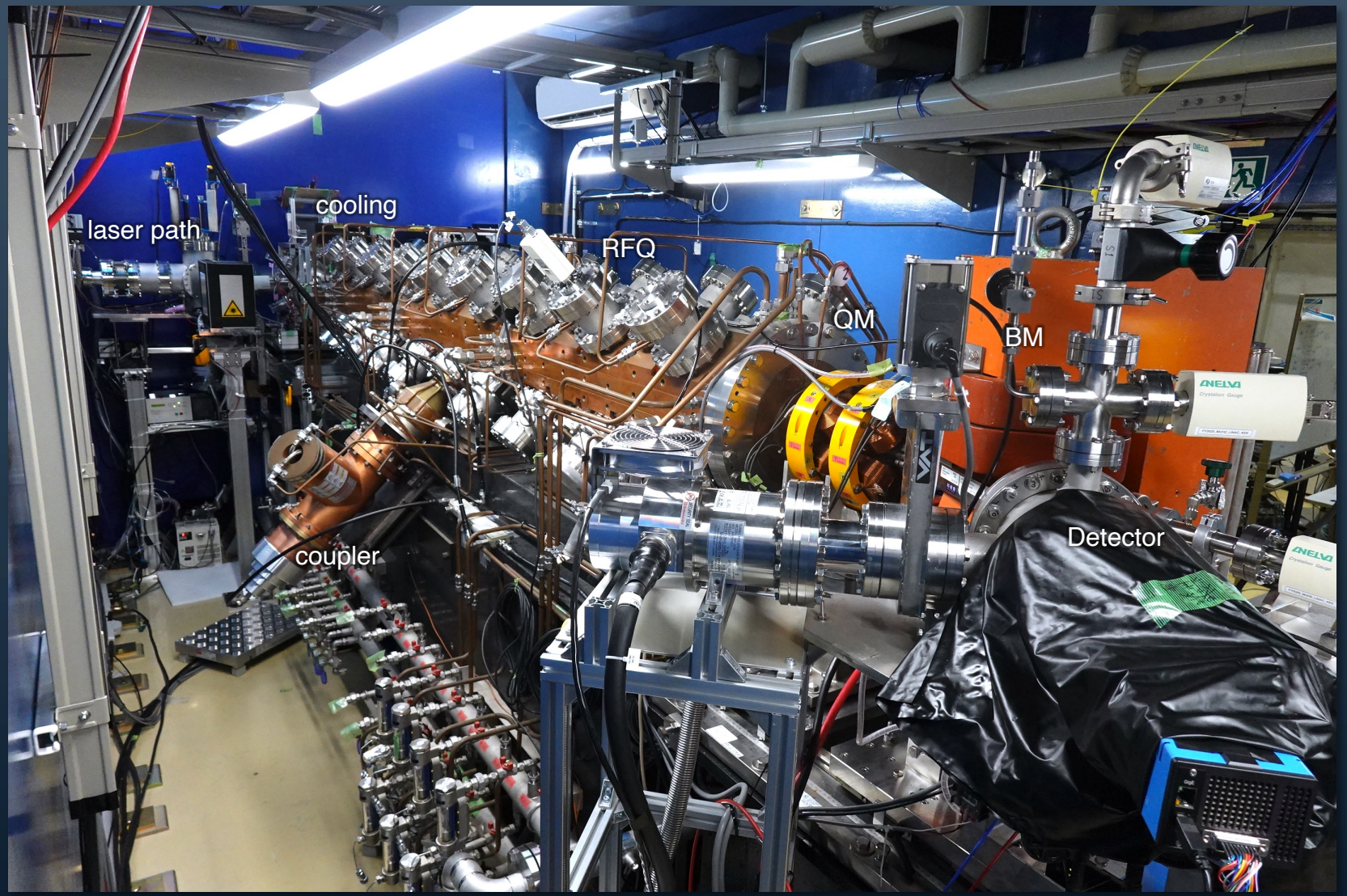
⑤ IH-DTL

→ Future (~2028)

Experimental setup

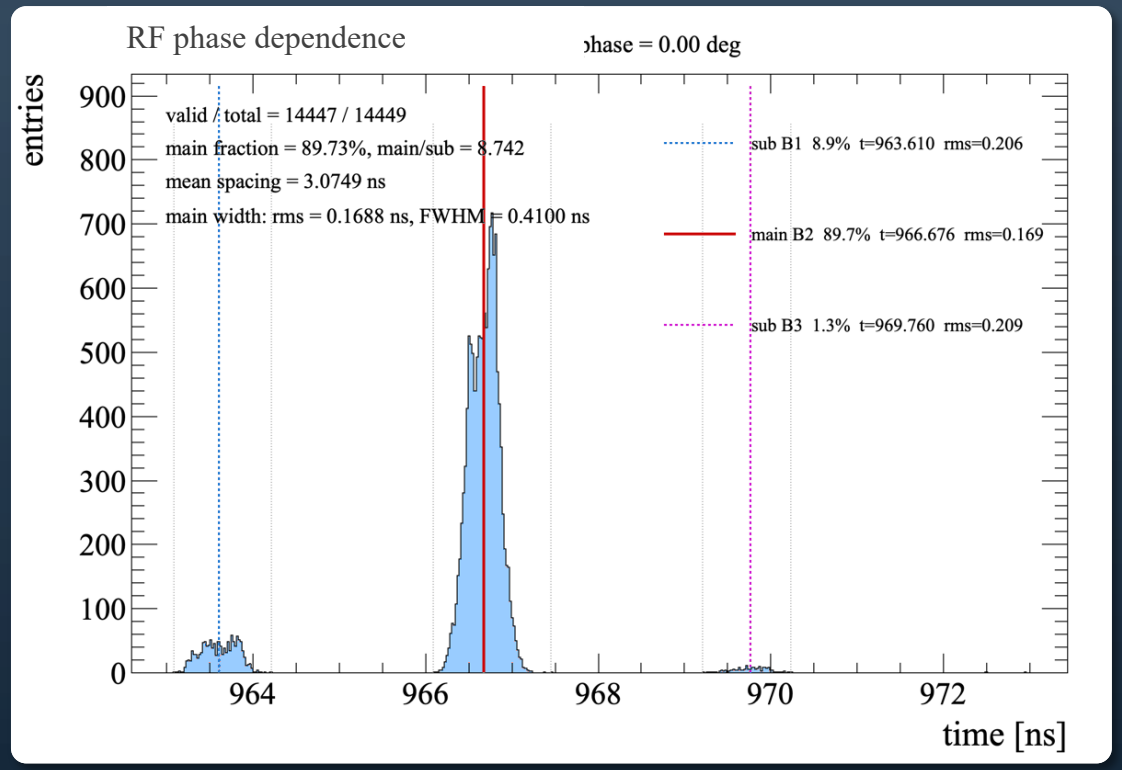


Experimental setup

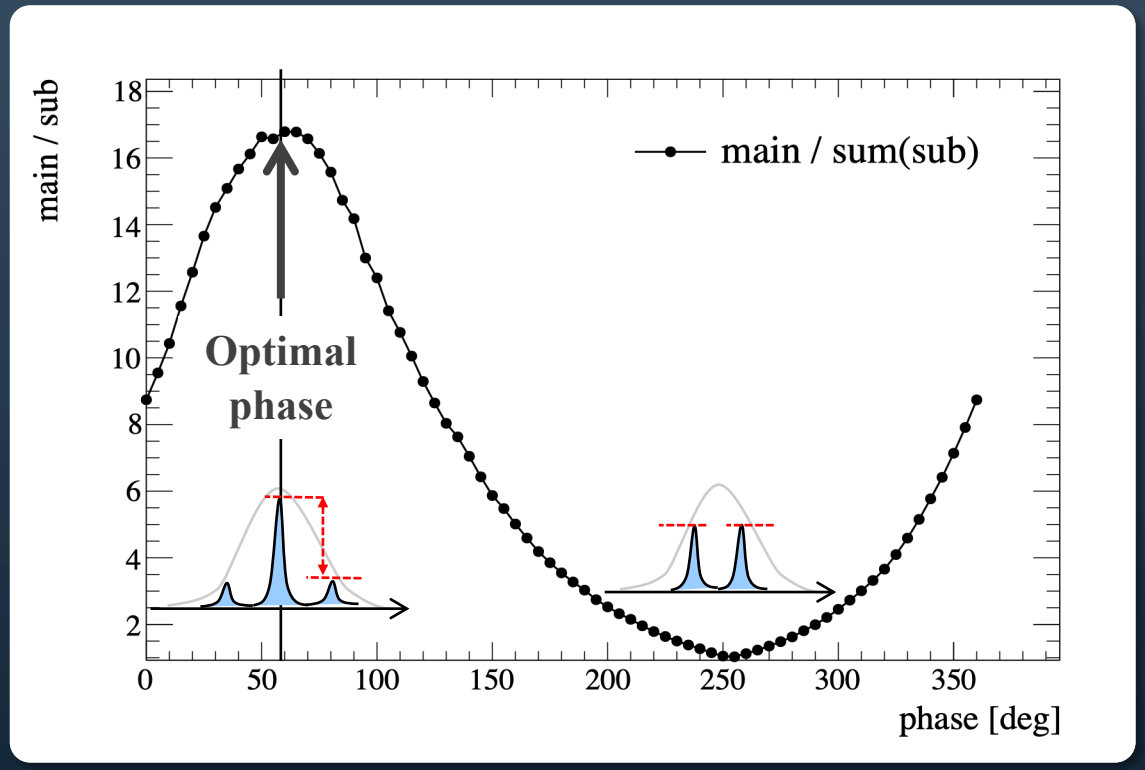


Bunch fraction is determined by RF phase of RFQ.

Simulated time distribution of muons after bunching



Bunch fraction dependent on RF phase

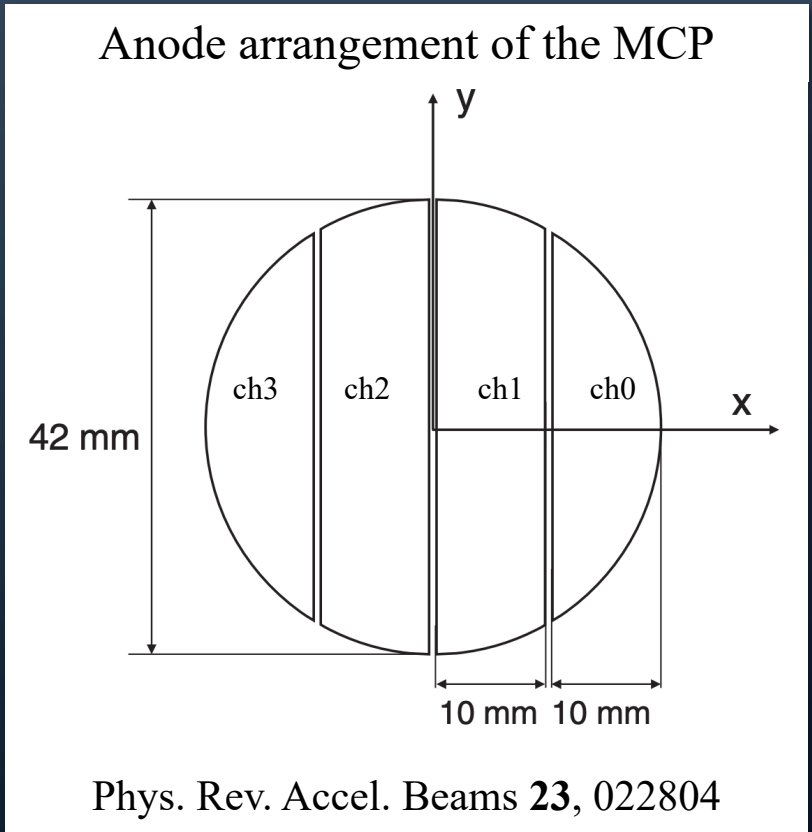


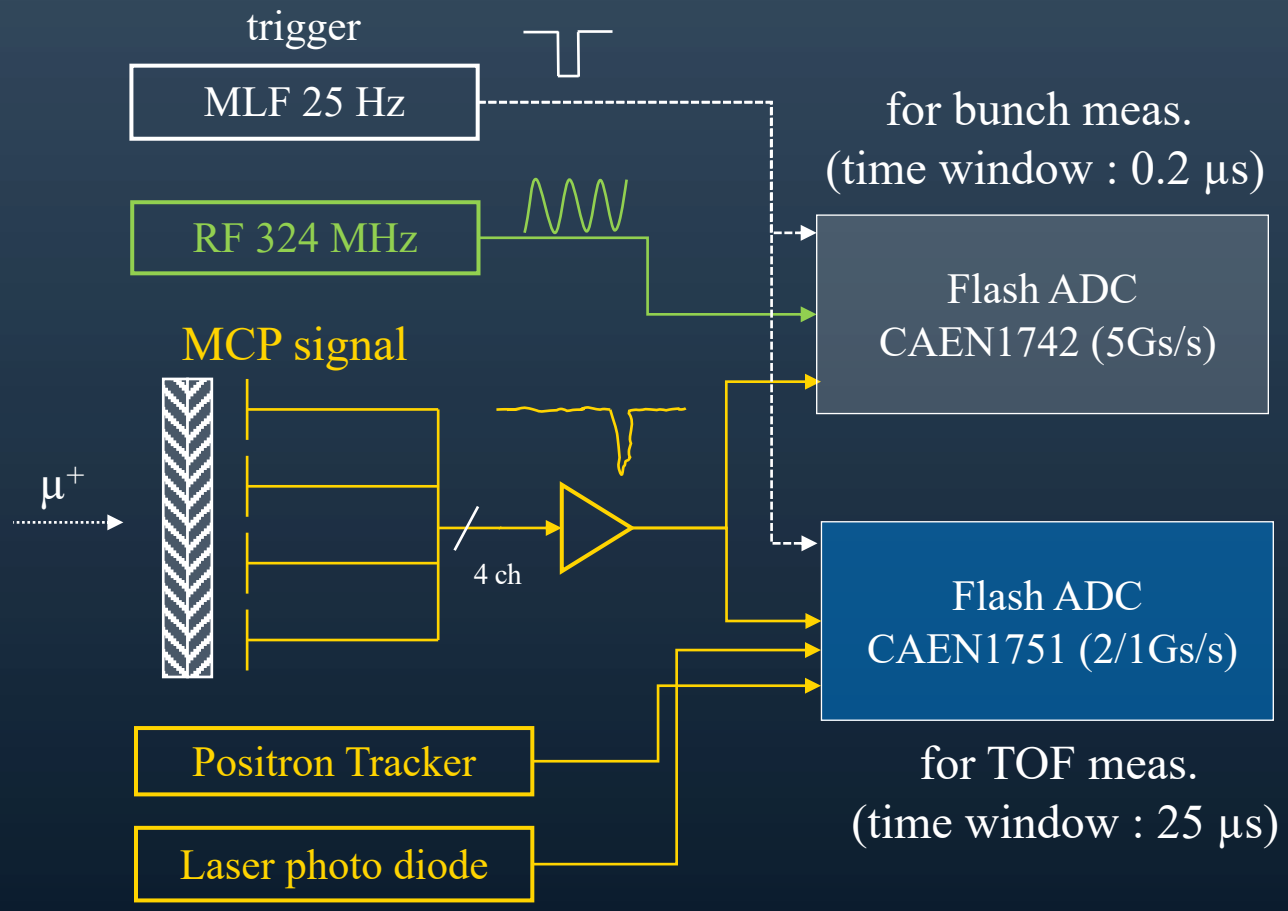
Simulation : General Particle Trace (GPT)

Measuring the time structure is important to maximize the main bunch fraction

Bunch width monitor based on MCP detector

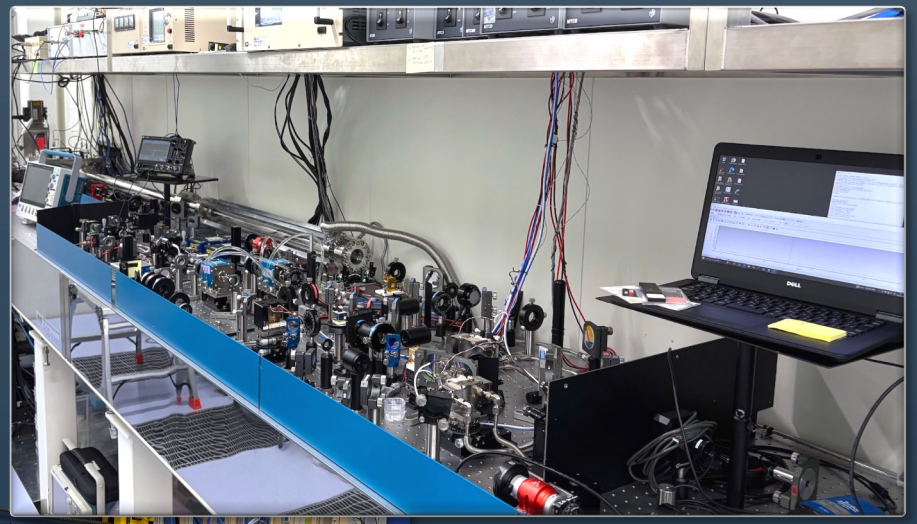
- The micro channel plate (MCP) assembly contained a two-stage MCP and fourstrip anodes.
- Time resolution : 40 ps (w/ CAEN1742)

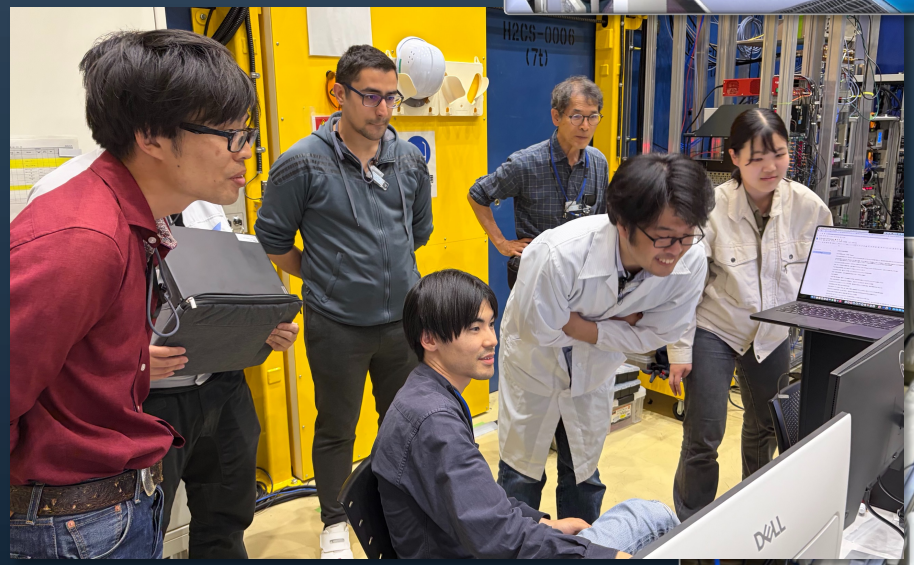




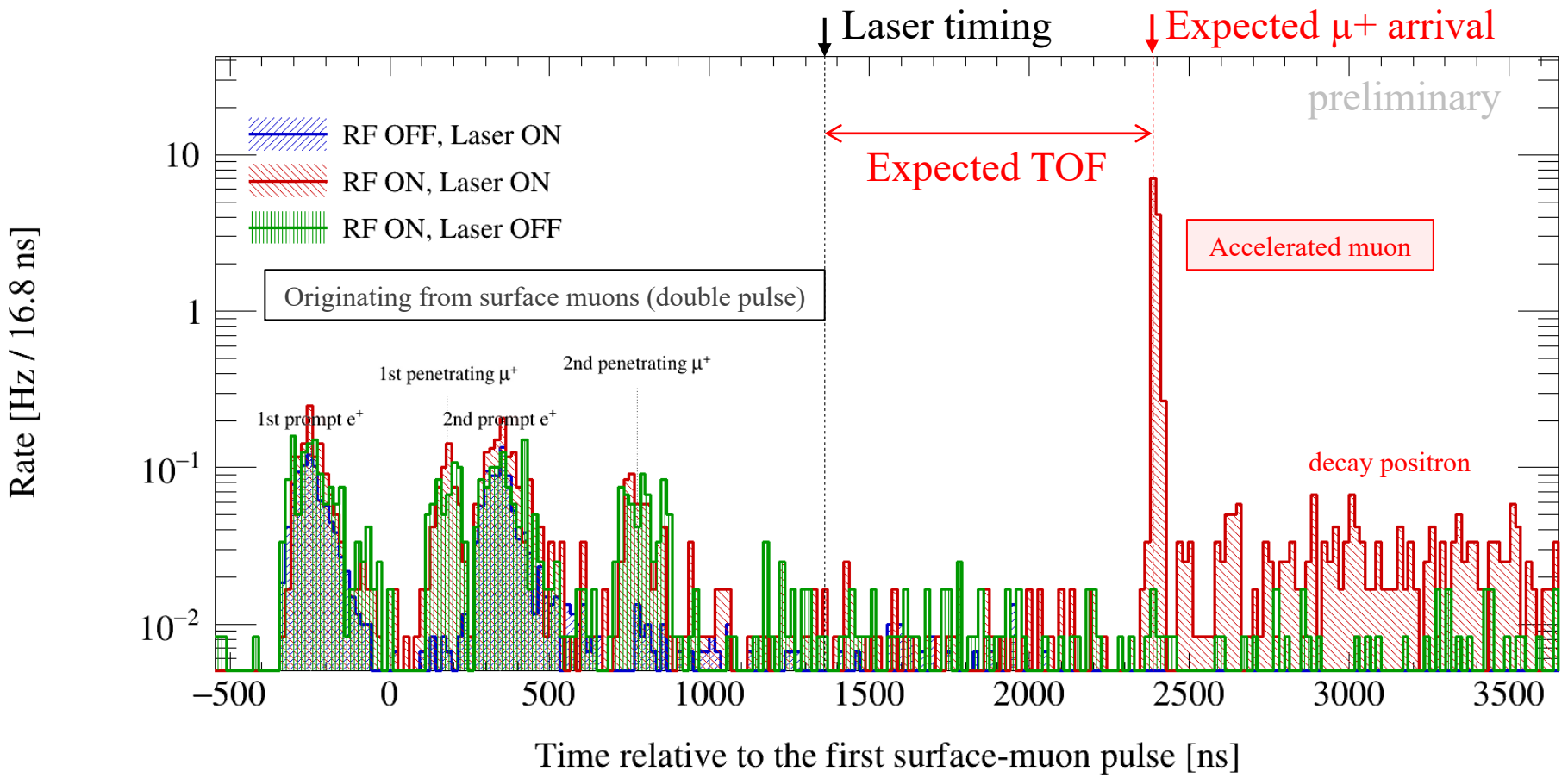
Laser, RF, μ Beam ON!

- Dec. 2025 : RFQ Installation
- Feb. 2026 : Power Line Installation
- Mar. 2026 : RFQ Alignment
  : BM, QM field meas.
  : Detector Installation
  : Control system setup
- Jun. 2026 : LLRF setup
  : First RF-ON (RFQ)
  : Beam test (2 weeks)



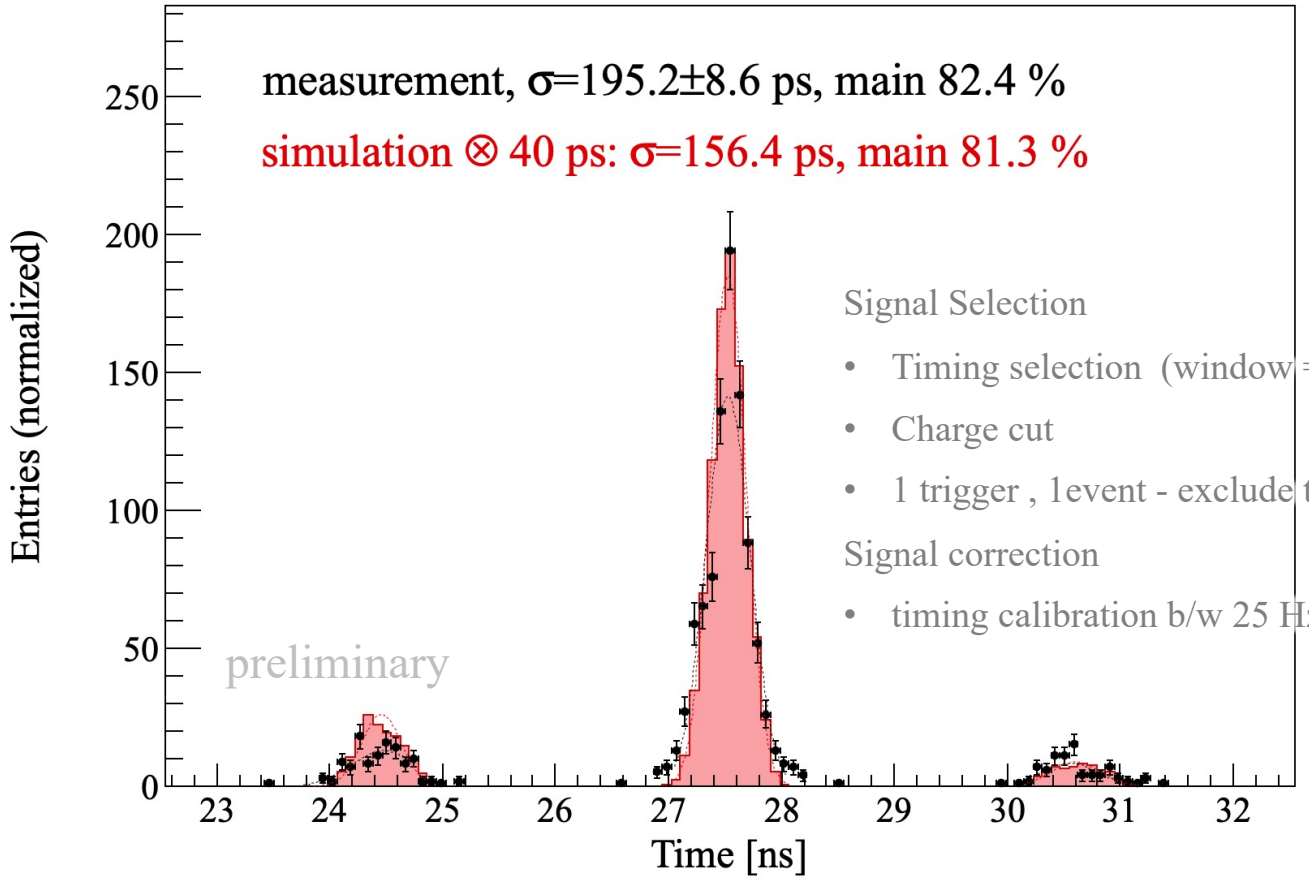


Time of Flight Measurement



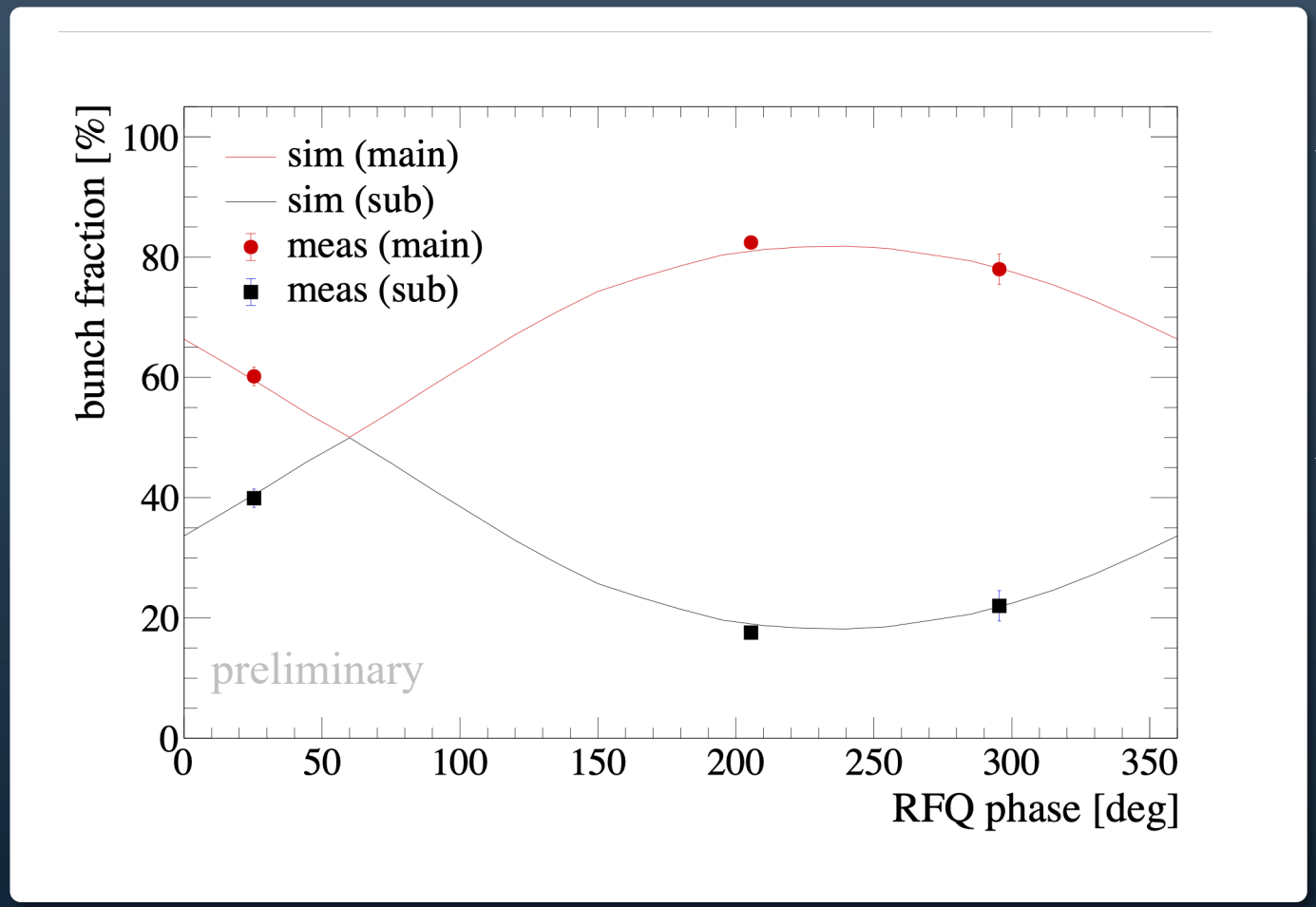
A clear signal was observed only when both RF and Laser were turned on.

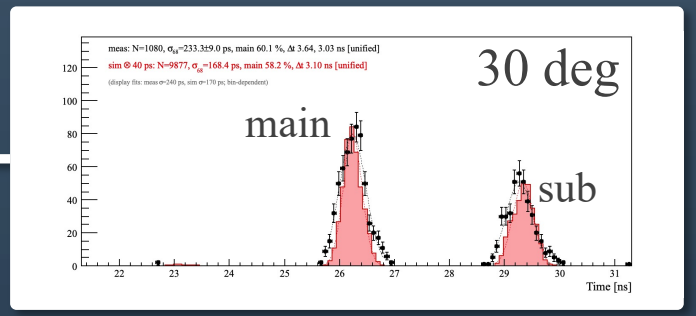
Bunch Width Measurement

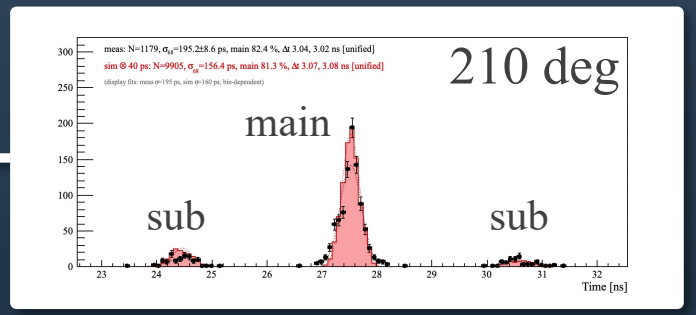


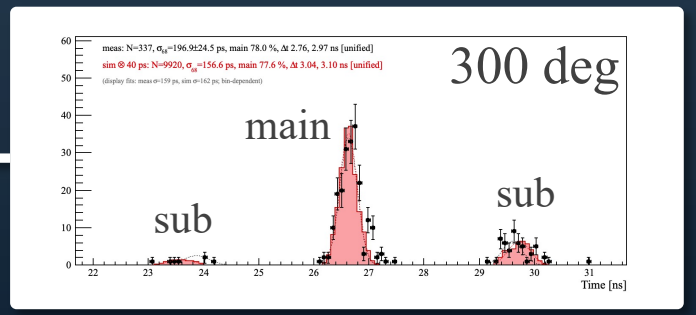
First direct observation of a bunch structure with a 3.09 ns interval at 324 MHz.

RFQ phase scan results





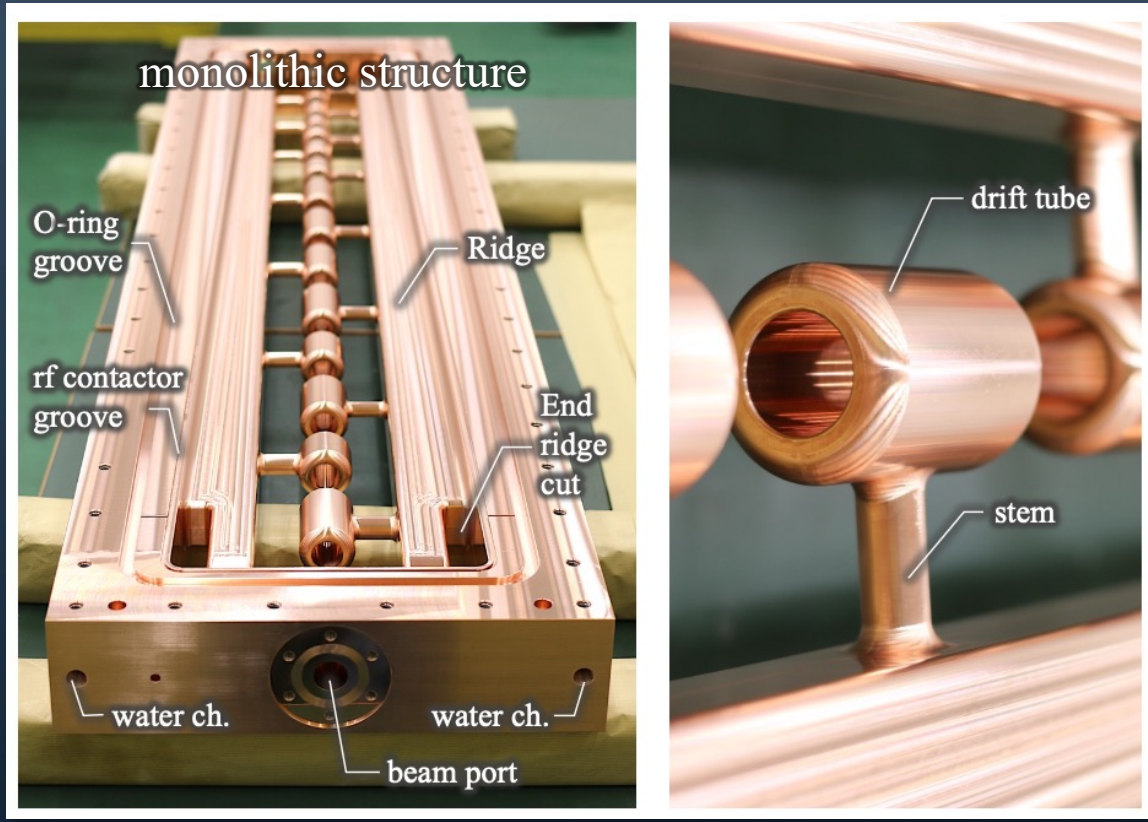




The observed bunch fraction shows the same dependence on RF phase as predicted by the simulation.

Next : APF IH-DTL acceleration

Multi-stage acceleration demonstration tests using the 324 MHz IH-DTL are scheduled for 2028.



Operating frequency	324 MHz
IN/OUT energy	0.34 MeV > 4.26 MeV
Cavity length	1.32 m
Bore radius	11.4 mm
Synchronous phase	−44 ～ −48 deg : APF (Alternating Phase Focusing)
Eff. shunt impedance	68 MΩ (mean)
Maximum surface field	35.6 MV/m (2.0 E_k[1])
Nominal power	310 kW

Development and high-power operation have been completed. → Y. Nakazawa et al., PRAB - Accepted 4 August 2026

Summary

- The full-scale RFQ was implemented in H2 and operated at the nominal power for 340 keV acceleration.
  - The TOF showed a signal at the expected μ+ arrival only with both RF and laser on.
  - We observed a bunch structure at the RF period and phase-dependent bunch fractions.
- These results indicate that we have successfully accelerated muons to 340 keV.
- Next, we will proceed multi-stage acceleration using IH-DTL.