IPAC23

DEVELOPMENT OF THE DIAGNOSTIC BEAMLINE FOR MUON ACCELERATION TEST WITH APF IH-DTL

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acceleration

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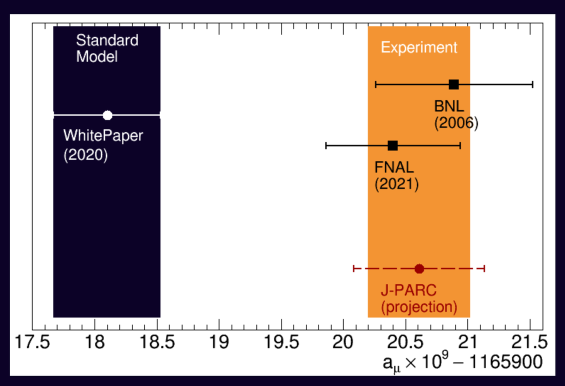
Abstract

The muon-dedicated linear accelerator is being developed for the muon g-2/EDM experiment at J-PARC. To suppress the decay loss during acceleration, the Alternating Phase Focusing (APF) method inter-digital H-mode drift tube linac (IH-DTL) is adopted in the low-velocity region following a radio-frequency quadrupole linac (RFQ). We are planning to accelerate muons in 2025 using the RFQ and the IH-DTL which will accelerate muons from β=0.08 to 0.28 with an operating frequency of 324 MHz. After the IH-DTL, a diagnostic beamline will be placed to measure the beam energy and quality after acceleration, and its design, which consists of magnets and bunchers, is underway. In this poster, we will report on the development status of the diagnostic beamline.

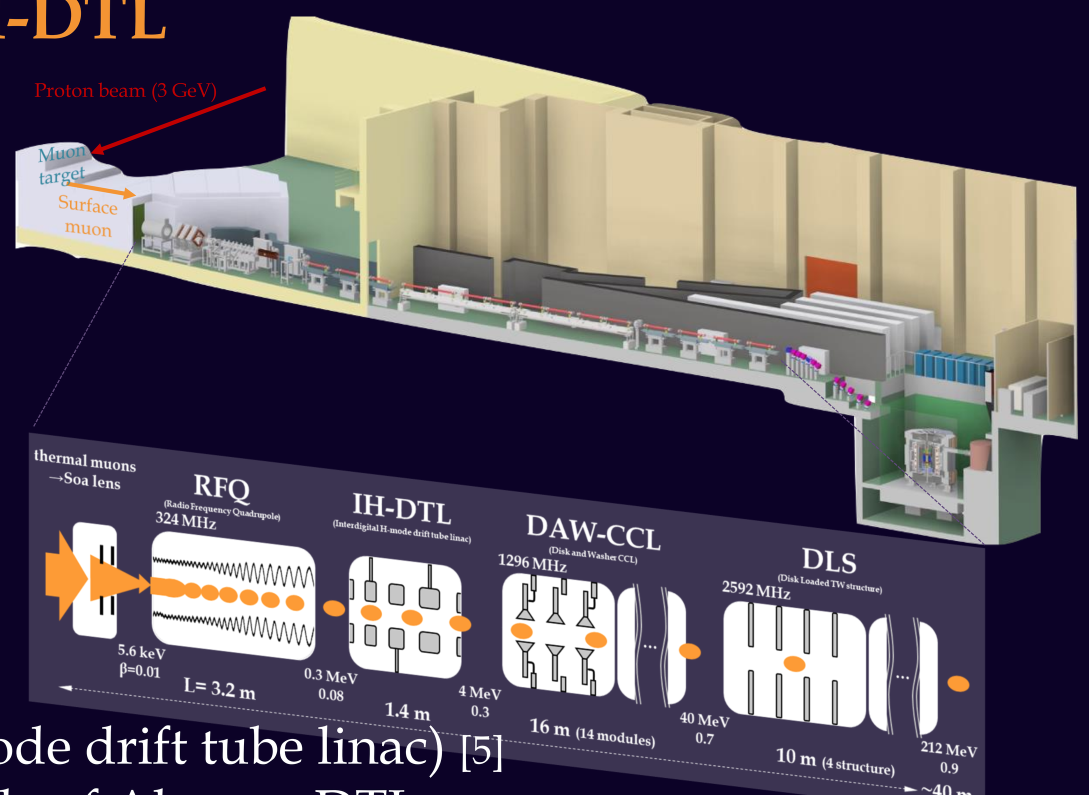
Muon g-2/EDM experiment at J-PARC

- The muon anomalous magnetic moment shows a divergence of 4.2 σ between theoretical and experimental values [1].
- The muon g-2/EDM experiment is planned at J-PARC to precisely measure the anomalous magnetic moments and the electric dipole moments of the muon with a new method [2].
- It is key to produce a low-emittance muon beam [3,4].



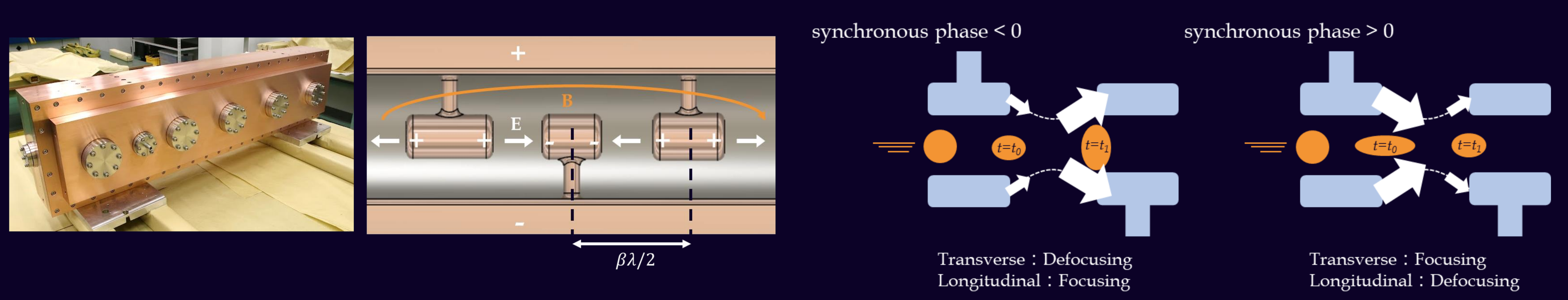
Muon LINAC and IH-DTL

- The cavity is changed to match the velocity β of the muon, and the linac consists of four types of cavities.
- In Low-velocity muon acceleration, high efficiency, and short-range acceleration are necessary.



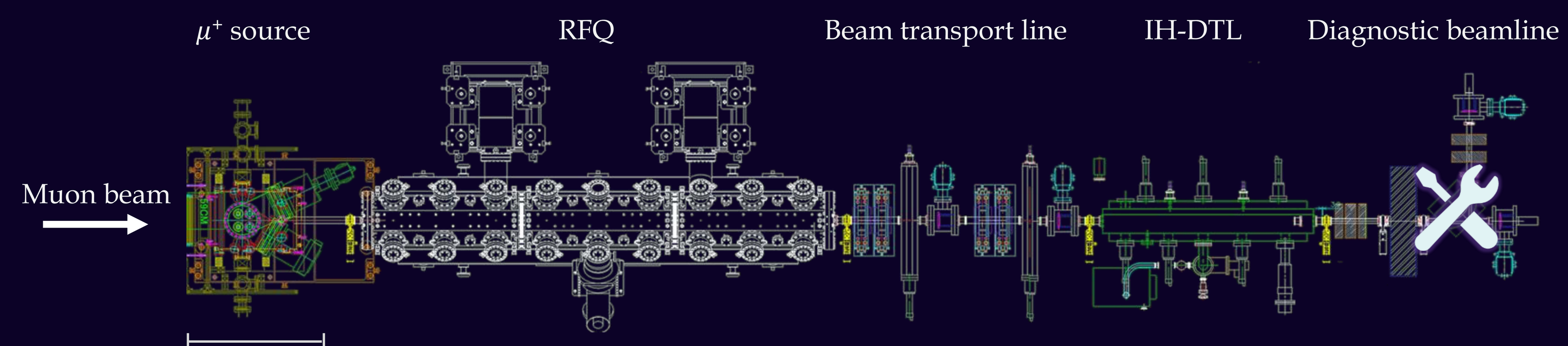
IH-DTL (Inter-digital H-mode drift tube linac) [5]

- Accelerate at the half cycle of Alvarez-DTL
- Use the Alternating Phase Focusing (APF) method
  →Both longitudinal and transverse focusing with only RF field



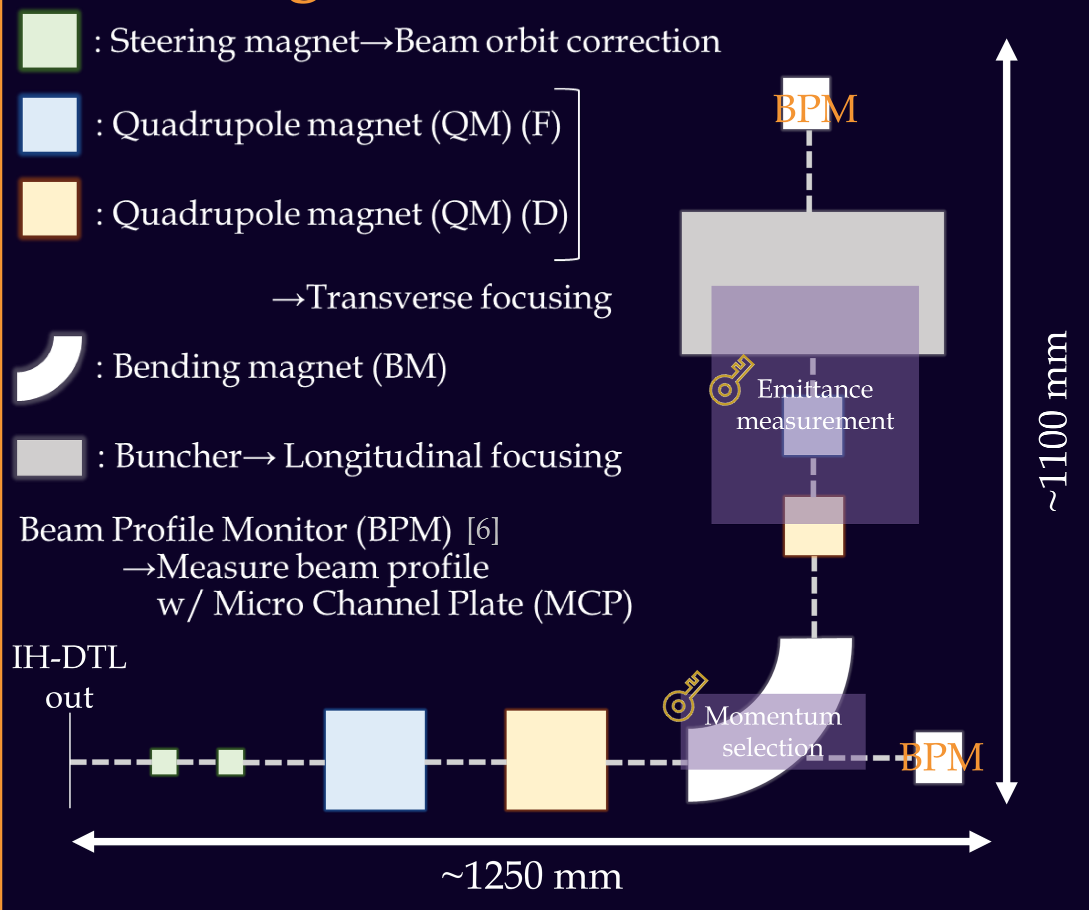
Acceleration Test with APF IH-DTL

- It is the first case to adapt 324 MHz APF IH-DTL for muon acceleration, it is necessary to demonstrate an accelerating muon.



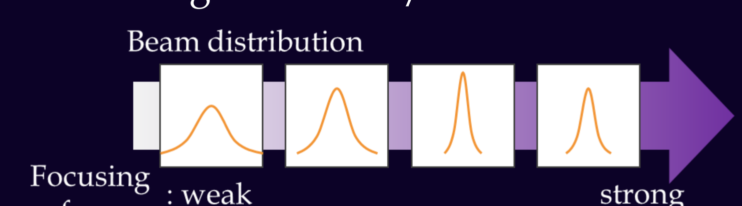
- We will
  check if the muon can accelerate up to 4.3 MeV
  measure beam emittance
  →A beamline to diagnose these is needed.

The Diagnostic Beamline and Beam Diagnostic Methods



Beam Diagnostic Methods

1. Varying focusing force of the QMs and the buncher.
2. The beam width changes as the focal length varies w/ 1.



3. Emittance is derived by fitting an equation relating beam width (σ) to focusing force.

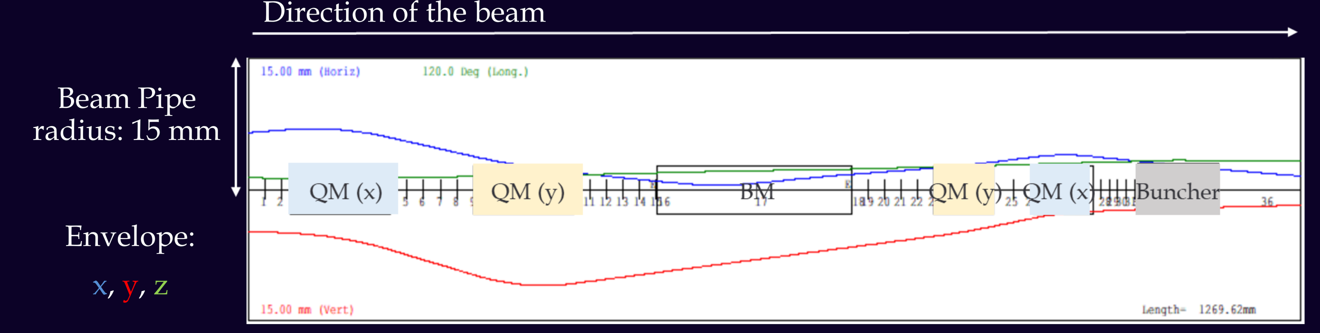
$$\sigma_y^2 = \beta_y \varepsilon_y R_{33}^2 - 2\alpha_y \varepsilon_y R_{33} R_{34} + \frac{1+\alpha_y^2}{\beta_y} \varepsilon_y R_{34}^2$$

$$\sigma_x^2 = \beta_x \varepsilon_x R_{11}^2 - 2\alpha_x \varepsilon_x R_{11} R_{12} + \frac{1+\alpha_x^2}{\beta_x} \varepsilon_x R_{12}^2 + \frac{1+\alpha_z^2}{\beta_z} \varepsilon_z R_{16}^2$$

*ε: Emittance, **α, β: Twiss parameters
***R : The coefficient which represents the components of the transfer matrix and includes the focusing forces of QMs and bunchers.

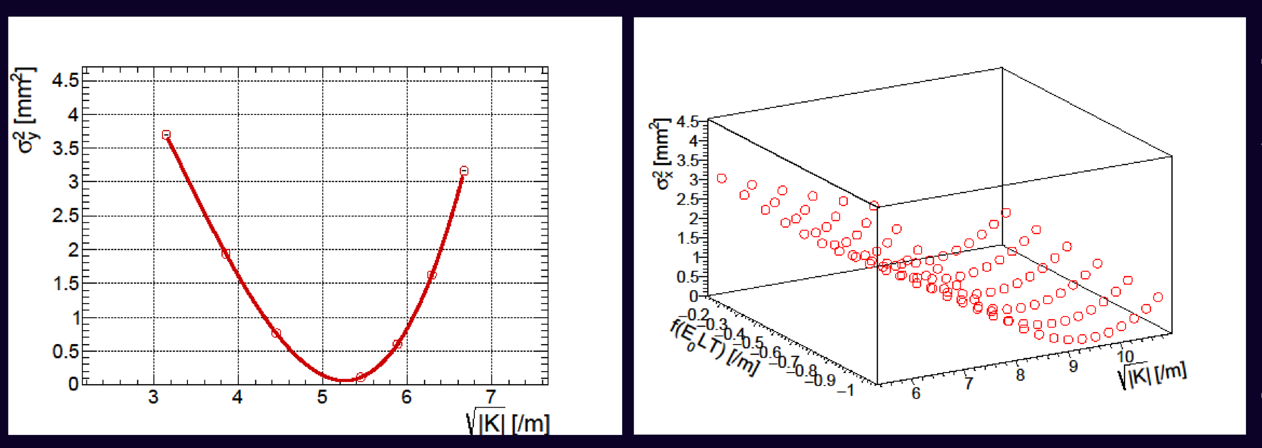
Results

- The QMs and buncher focusing force were optimized in Trace3D [7].
  - Losses due to beam pipes were reduced to about 1%.
  - Small beam spread just before QM and buncher which perform Q-scan.



Emittance measurement accuracy

- Using the optics determined by Trace3D, a simulated scan was performed using the GPT (General Particle Tracer) [8].



Parameters	Sim.	Scan results
ε_x (unnorm., rms) [π mm mrad]	1.235	1.239 (+0.3%)
ε_y (unnorm., rms) [π mm mrad]	0.706	0.648 (-8.2%)
ε_z (rms) [π deg keV]	0.0961	0.0963 (+0.2%)

*$\sqrt{|K|}$: a value proportional to the focusing force of the QM.
** f(E₀LT): a value proportional to the focusing force of the buncher.

- ε_y : 8% lower than the simulation input.
  → The beam in the y-direction is shaved off about 1% by the beam pipe, resulting in an underestimation of emittance.
- $\varepsilon_x, \varepsilon_z$: Diagnostic error of emittance is within 1%.

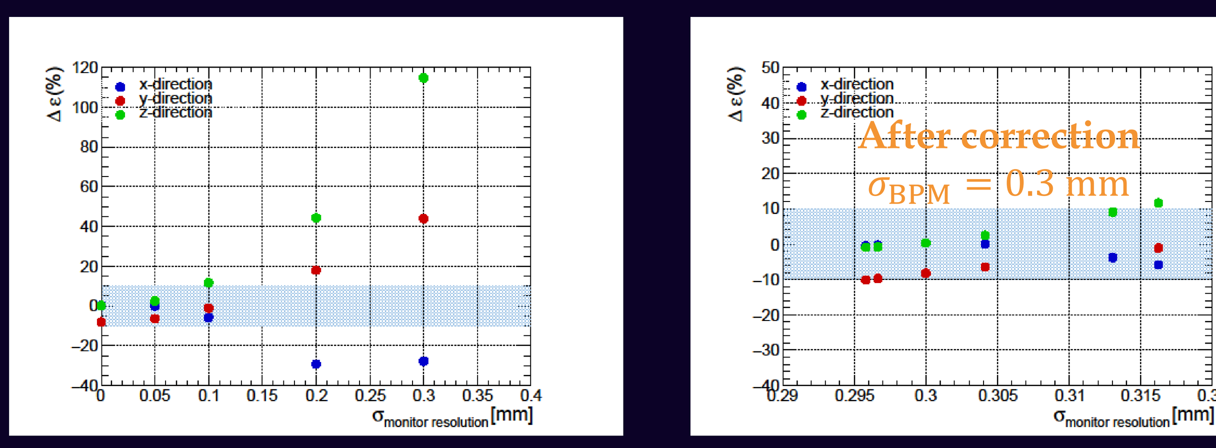
Requirements for beam monitor

- The requirement of emittance error is less than 10% for the acceleration test [9], and need to consider the effect of the BPM resolution.

$$\sigma_{\text{exp.}}^2 = \sigma_{\text{sim.}}^2 + \sigma_{\text{BPM}}^2$$

- The measured beam width can be corrected if the BPM resolution is known;

$$\sigma_{\text{corr.}}^2 = \sigma_{\text{exp.}}^2 - \sigma_{\text{BPM}}^2$$



Conclusion

- A diagnostic beamline was designed for world's first demonstration of the muon acceleration test with IH-DTL.
  - The beam energy and quality can be measured.
- Emittance measurements can be made with an accuracy that meets the requirements using quadrupole magnets and buncher together.
- In actual measurements, the position resolution of the monitor must be taken into account, and a detailed evaluation of the resolution is required.

Acknowledgements

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