acceleration

Muon acceleration for the muon g-2/EDM experiment at J-PARC

NuFact 2022 : The 23rd International Workshop on Neutrinos from Accelerators WG3 : Accelerator physics Ibaraki Univ. Yuga Nakazawa and J-PARC E34 Collaboration

Muon anomalous magnetic moment "g-2"

Standard Model (2020)







4.2σ discrepancy.

B.Abi etal., Phy. Rev. Lett., vol. 126, no. 14, p. 141801 (2021) T.Aoyama etal, Physics Reports, vol. 887, pp. 1–166 (2020)

New physics beyond the Standard Model is expected.

On the other hand, another method of verification is needed. \rightarrow J-PARC method

Experimental method



Precise measurement of ω_a and *B* is critical.

How to eliminate the extra term in ω_a ?

BNL/FNAL : storage magnet

J-PARC : storage magnet



BNL/FNAL

Utilize muon beam decayed at a specific y

- \rightarrow Large emittance
- \rightarrow Strong focusing by E-field is essential

Large magnetic field region is needed.



No E field focus + Compact magnetic field region

 \rightarrow Requires a low emittance beam of 1/1000 of conventional.



Reduction of beam-derived systematic error (ω_a) and high-precision magnetic field



$$\vec{p} = -\frac{q}{m} \left[a_{\mu} \vec{B} + \frac{\eta}{2} \left(\vec{\beta} \times \vec{B} + \frac{E}{c} \right) \right]$$

- There is no contribution from \vec{E} term.
- a_{μ} and EDM can be measured simultaneously.

J-PARC - Japan Proton Accelerator Research Complex

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@ MLF

- 3 GeV proton beam —
- μ target and n target
- Beam power 1MW (First half of 2022 : 830 kW)
- Double pulses, 25 Hz

Neutrino beam to Kamioka

Materials and Life Science Experimental Facility (MLF)

The beamline for g - 2/EDM experiment will be constructed at the J - PARC MLF H - line.

30 GeV MR

JAPAN, Ibaraki, Tokai-mura

Hadron Experimental Hall

Four Muon beam lines in MLF https://slowmuon.kek.jp/index_e.html **U-line** S-line Muon targ D-line H-line to Neutron target



Muon Accelerator (4-stage)

 $0.46 \rightarrow 0.1 \text{ ppm}$ g-2 accuracy

> 10⁻²¹ e·cm **EDM** sensitivity

transport line (26 deg. bend)

Storage Magnet

Positron detector

Must suppress emittance growth during acceleration + transport (~40 m) 8/25

DLS

target

DAW

PDTL

RFQ

~ 40 m

Overview talk by Ce Zhang.

(π)*

187. Status of the Muon g-2/EDM experiment at J-PARC Le Zhang (Peking University) () 8/5/22, 2:50 PM

WG4: Muon Physics Talk WG4: Muon Physics

Muon cooling for g-2/EDM experiment



Muon acceleration

Develop a new accelerator dedicated to muons using electron/proton accelerator technology.



Need to develop a new muon linear accelerator and demonstrate acceleration.

Basic design



Designed muon LINAC performance satisfies experimental requirements.

History / schedule



Beam test

Muon cooling for acceleration test

In 2016~2017, a compact muon source was developed to demonstrate muon RF acceleration quickly.





Mu- acceleration with RFQ (Nov. 2017)

14/25



RF-on : event rate = $(5 \pm 1) \times 10^{-4}/s$

RF-off : (no significant signal)

The world's first muon RF acceleration

[Next] μ + acceleration



μ + acceleration test is planned in 2023.

IH-DTL (Inter-digital H-mode Drift Tube Linac)

High efficiency and short-range acceleration are necessary to suppress muon decay loss during acceleration in the low-velocity region.



APF IH-DTL accelerates and focuses using only an RF electric field.

Emittance growth due to APF

Since the APF method uses the RF field for beam focusing, the field error of the on-axis electric field significantly affects the beam dynamics.



We should suppress the field error to less than \pm 2%.

Development items





19/25 IH-DTL prototype

IH-DTL prototype was fabricated to demonstrate a high-power operation.



Successful stable operation with nominal peak power!



IH-DTL cavity is ready!

 \rightarrow [Next] μ + acceleration test with RFQ and IH-DTL is planned in 2024.

DAW CCL (Disk and Washer Coupled Cavity Linac)



DAW (1st tank)

After processing tests with the prototype, some components for the real DAW were fabricated.

22/25



Fabrication of DAW 1st tank is ongoing.

DLS (Disk Loaded Structure [Traveling wave])



- DLS is often used in electron linac (β=1).
- However, muon velocity increases rapidly (β=0.7–0.94).

\downarrow new DLS dedicated to muons

23/25

- Disk spacing (cell length) varies proportionally to muon velocity.
- A quasi-constant gradient type with linear tapering iris apertures is adopted.

The dynamics and cavity design of the 2592 MHz S-band DLS were completed*.

Prototype DLS

We plan to fabricate the <u>four components</u> as the prototype DLS1.

• for RF performance measurement, error study



The prototype DLS will be fabricated in 2022-2023.

Summary

• We are currently developing the muon linac for the muon g-2/EDM experiment.



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