PA01

Control of Rotatable-Quadrupole Magnets Angles for 3-D Spiral Injection Test Experiment

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Abstract

The muon g-2/EDM experiment, which aims to make ultra-precise measurements of muon anomalous magnetic moment (g-2) and electric dipole moment (EDM), is now under planning at J-PARC. In this experiment, muon beams are injected and stored in a solenoid-type magnet with a diameter of 66 cm, which is based on a medical MRI magnet. In this project, an unprecedented beam injection method called 3-D spiral injection is adopted, and the demonstration experiment is being carried out at KEK. In 3-D spiral injection, the horizontal and vertical correlations (X-Y coupling) in the phase space of the beam need to be properly controlled. The X-Y coupling can be adjusted by the rotation angle and current value of the quadrupole magnets on the transport beamline. Currently, we are planning a remote machine controller to precisely adjust the rotation angle and ensure reproducibility of the experiment. In this presentation, we will determine the accuracy required for the rotation angle from the optimal X-Y coupling. In addition, the status of the design and fabrication of the rotation mechanism will be reported.

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J-PARC muon g-2/EDM experiment

- Ultra-precise measurement of the anomalous magnetic moment (g-2) and electric dipole moment (EDM) of muons.

- **Muon g-2**
  There is a 4.2σ difference between the theoretical value from the Standard Model and the experimental value.

- **Muon EDM**
  A nonzero value is forbidden in the Standard Model.
  If a finite value is measured, it would be experimental evidence of T-symmetry breaking.
  Current upper limit: 1.8×10^{-19} e cm

Physics goal

g-2:	Statistical uncertainty of 0.1 ppm over 1 year of measurement
EDM:	Sensitivity of upper limit 1.5×10^{-21} e cm

Measurement method

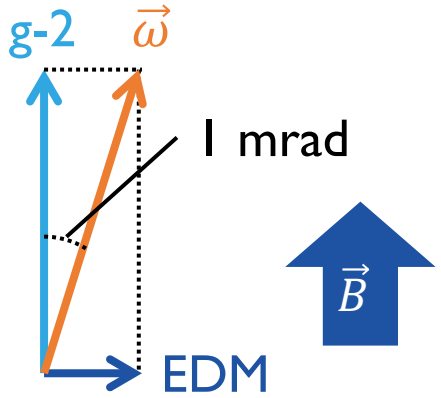
- The muon g-2 and EDM can be determined by measuring the spin precession.

- Equation of spin precession $\vec{\omega}$ (a_μ is g-2, and η is EDM)

$$\vec{\omega} = -\frac{e}{m}\left\{a_\mu \vec{B} - \left(a_\mu - \frac{1}{\gamma^2 - 1}\right)\frac{\vec{\beta} \times \vec{E}}{c} - \frac{\eta}{2}\left(\vec{\beta} \times \vec{B} + \frac{\vec{E}}{c}\right)\right\}$$

Experiment without electric field.

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

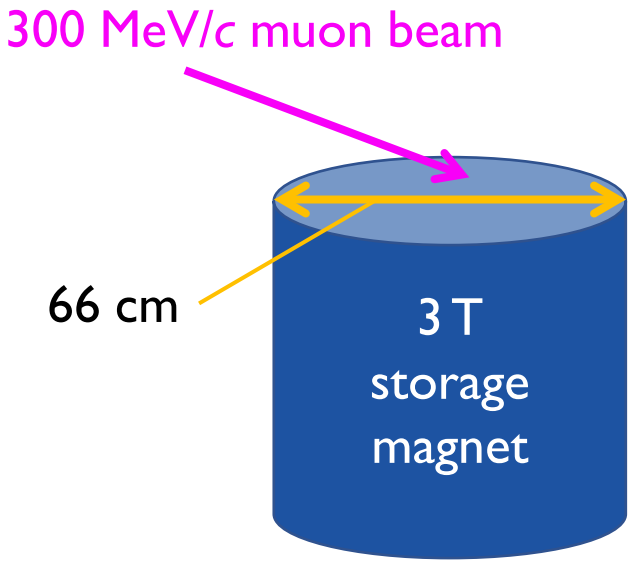


- When a muon decays, it emits positrons in the direction of the spin precession vector.
  ⇒ Measure the time spectrum of decay positrons.

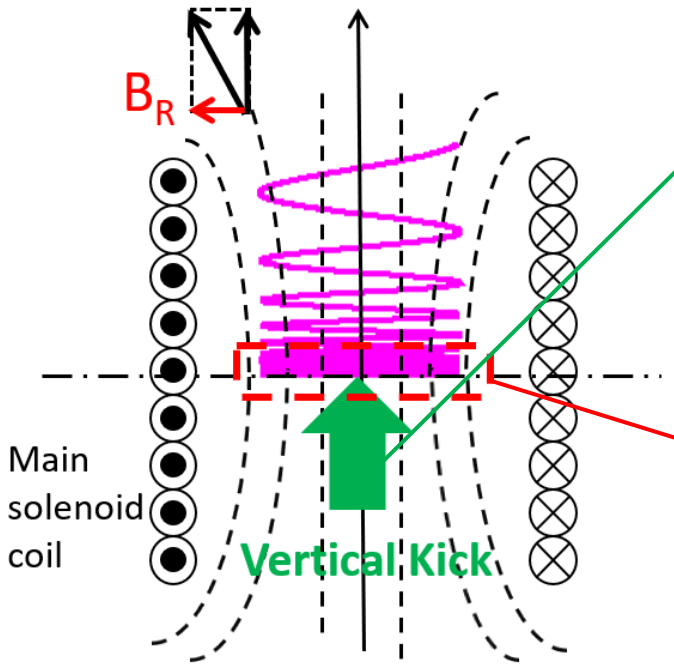
- Magnetic field uniformity of less than 1 ppm is required in the fiducial volume.

Experimental Method

Injection from diagonally above the storage magnet
⇒ 3-D spiral injection



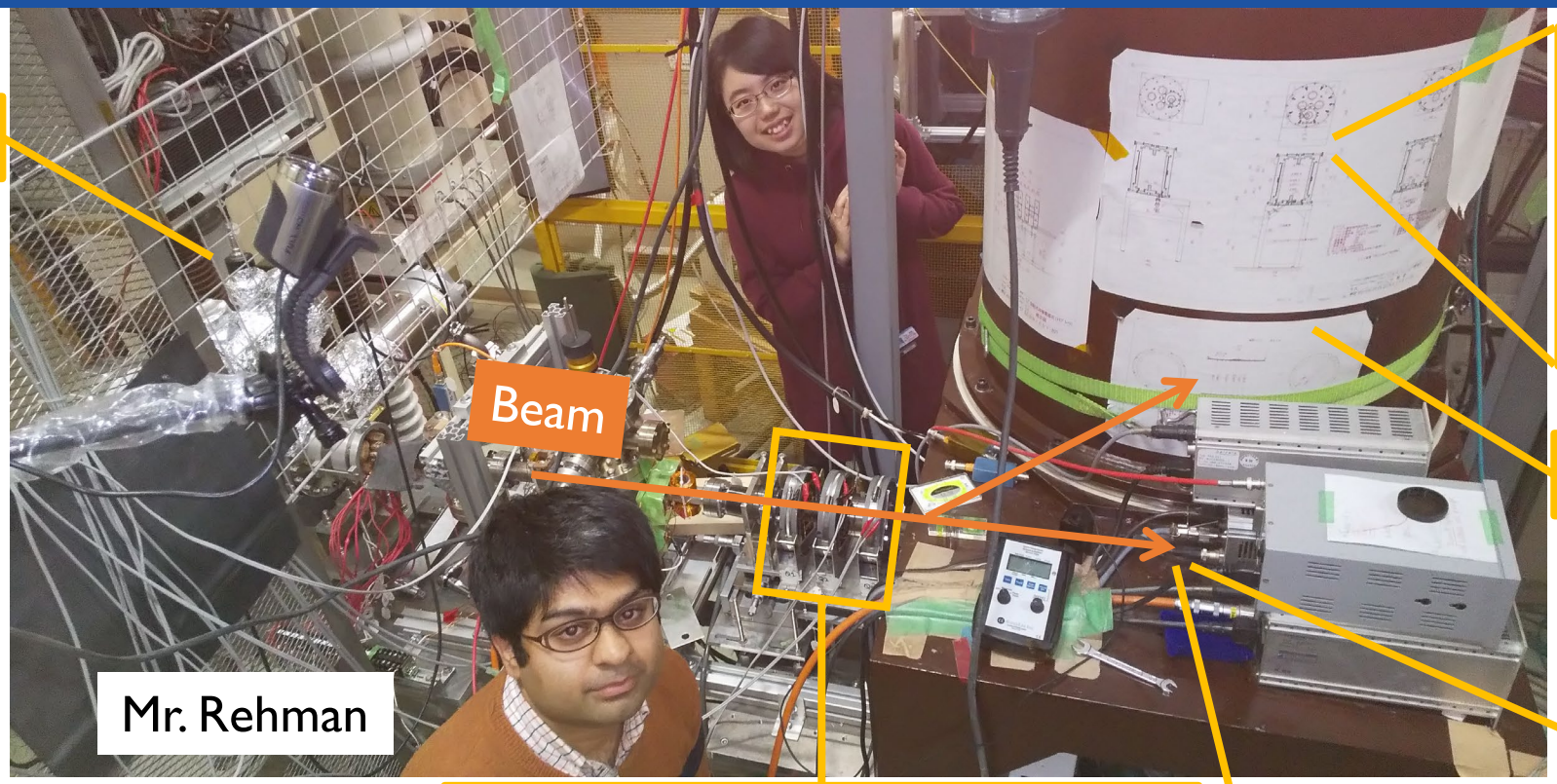
A solenoid-type magnet
based on a medical MRI magnet



Give magnetic field to kick the beam vertically

Store and measure

3-D spiral injection demonstration experiment @KEK



It is manually rotated while measuring the angle.

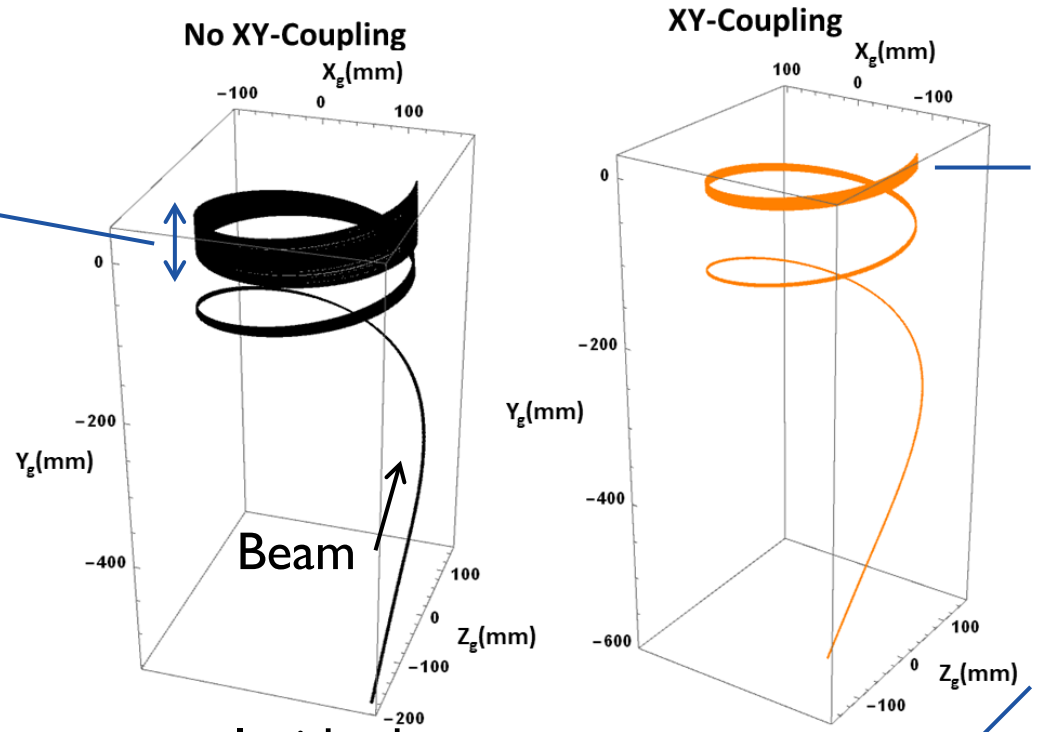
⇒ Create a remote rotation mechanism.

Underway

X-Y coupling

The solenoid axial direction of the beam is not affected by the magnetic field.
⇒ Spread out

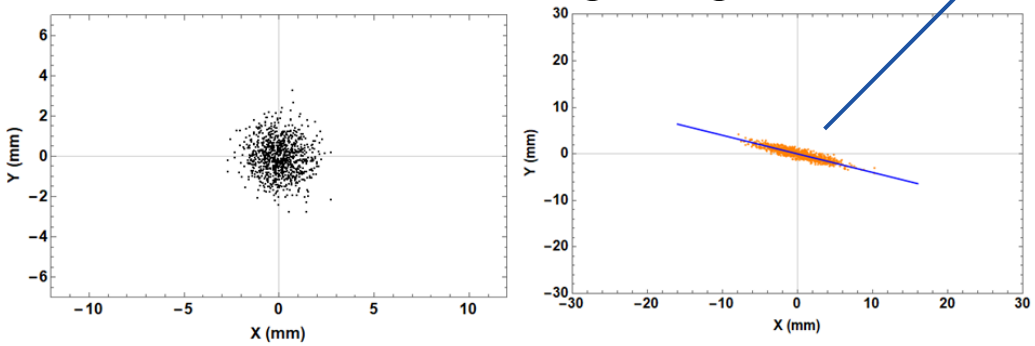
More beams cannot be stored in the axial kick.



The axial spread can be reduced.

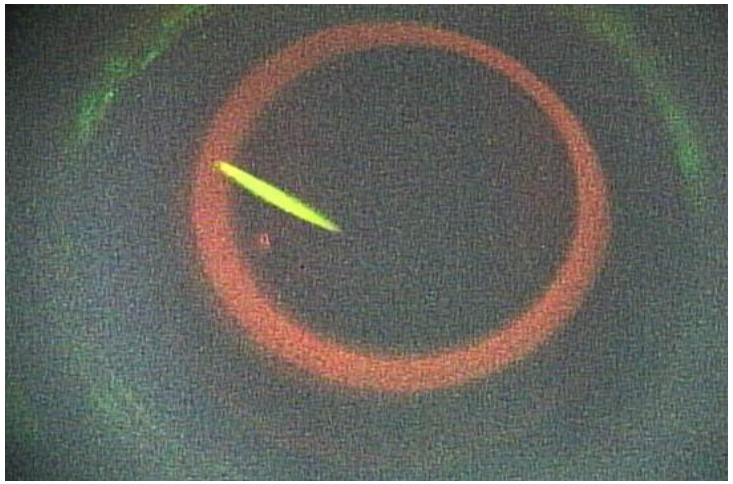
Correlate the motion of the beam in the x and y directions (X-Y coupling).

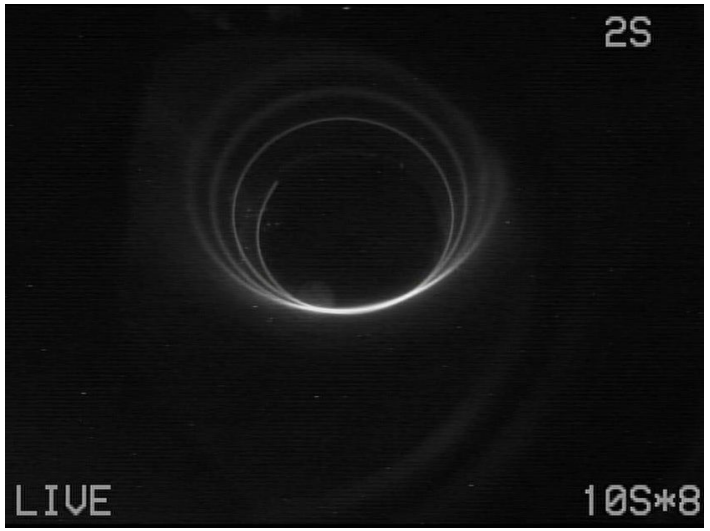
Inside the storage magnet

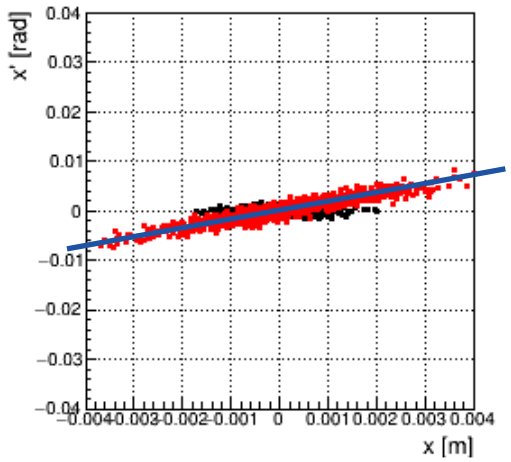


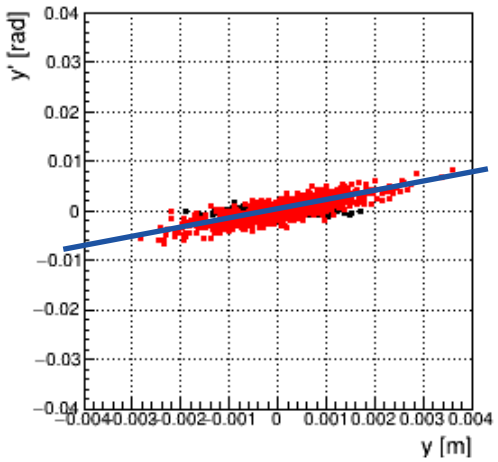
The X-Y coupling can be given by rotating the quadrupole magnets.

Required accuracy of rotatable-quadrupole magnet









Control the slope of the beam in phase space within 5%.

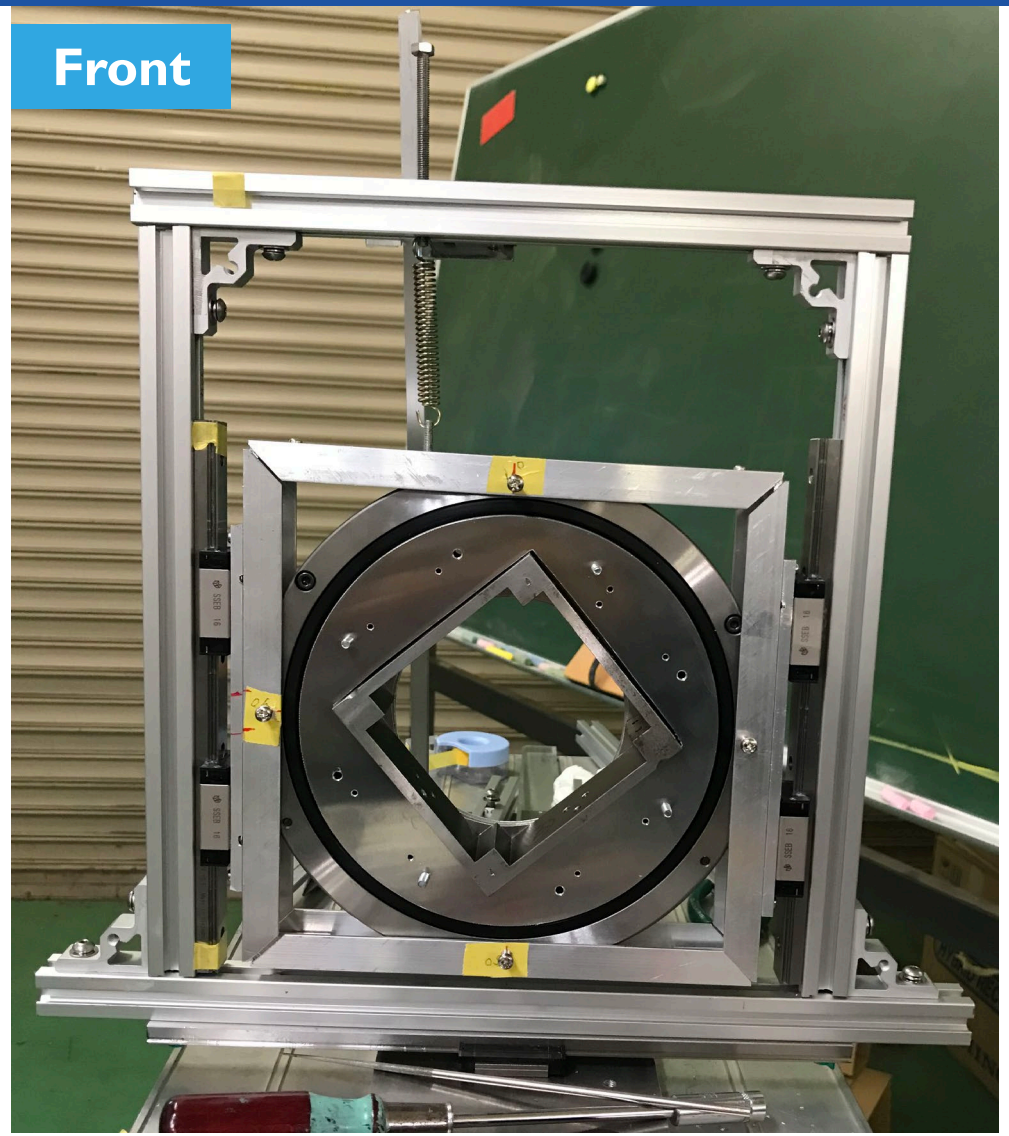
A recipe that gives the best X-Y coupling			
Q-magnet	Q1	Q2	Q3
Current [A]	0.259	-0.719	0.009
±5 % [A]	-0.037 ~ +0.038	-0.052 ~ +0.048	-0.008 ~ +0.043
Angle [degree]	-20.0	25.0	-45.0
±5 % [degree]	-4.0 ~ +3.9	-1.1 ~ +1.2	+45.0

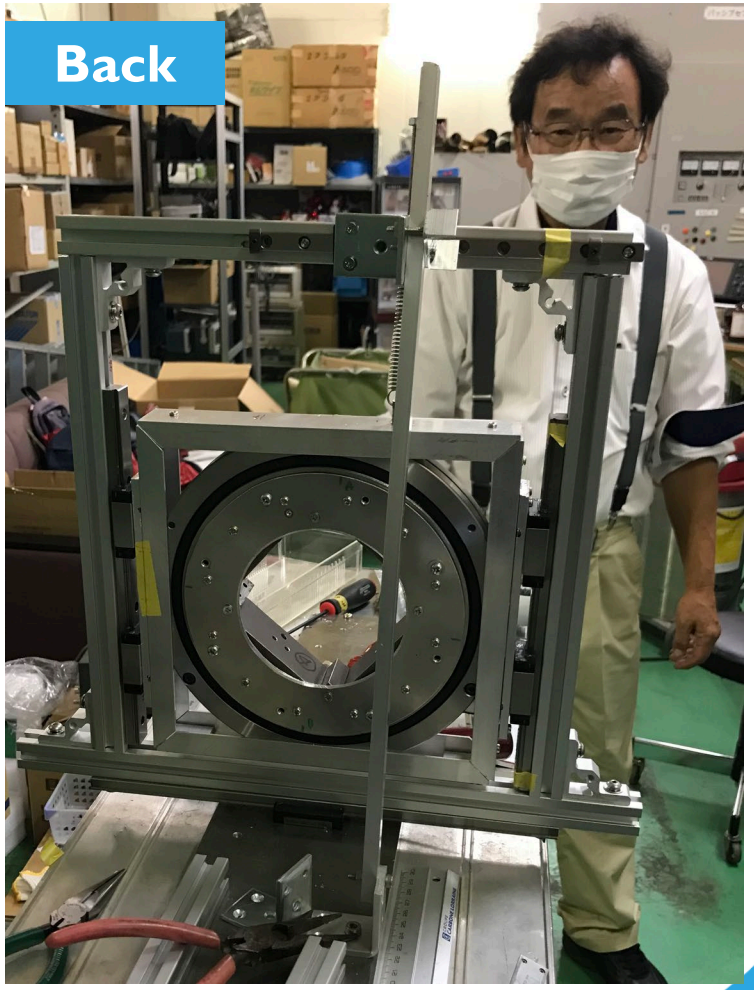
Required accuracy

Current: 0.008 A
Angle: 1.1 degree

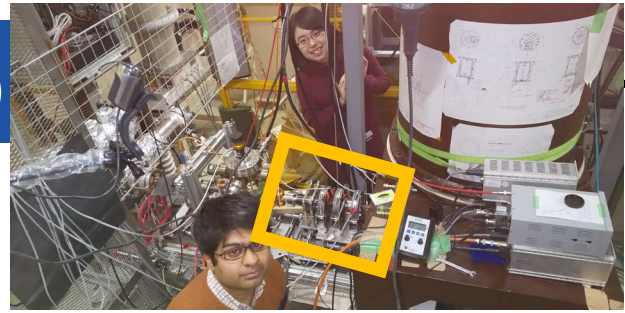
Rotation mechanism (unfinished)

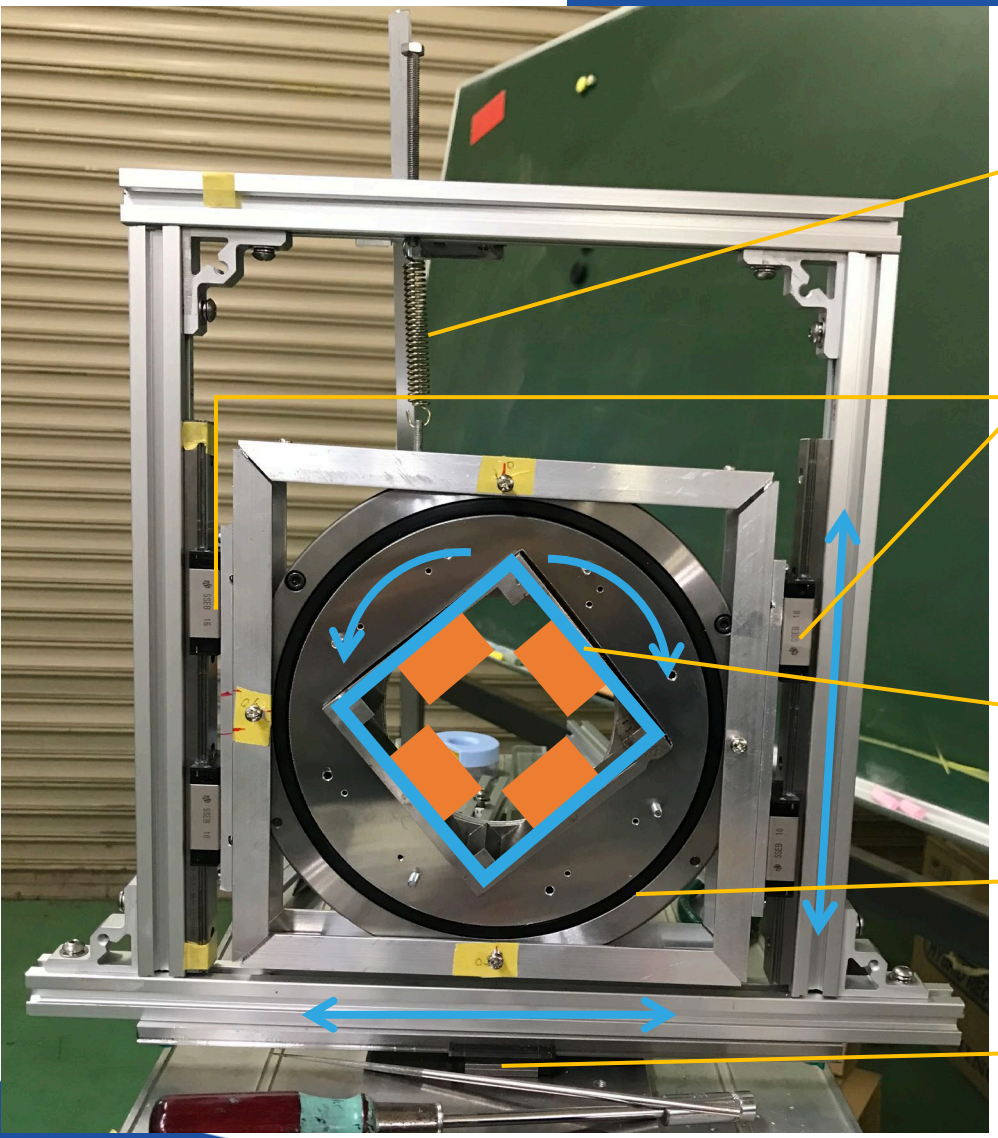
Mr. Someya





Rotation mechanism (unfinished)





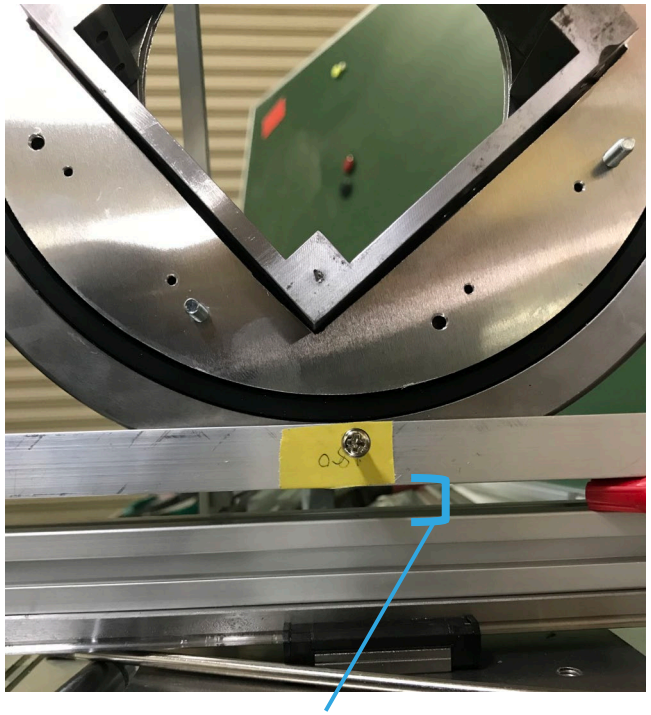
Power spring
- Reduce the load on the motor that moves up and down.
- Doesn't go down when the motor is turned off.

Slide up and down

Quadrupole magnet

Crossed roller bearing
(Rotation around beam axis)

Slide left and right



The spring makes it float a little.

Summary and future

Summary

- Plans are underway for muon g-2/EDM experiment at J-PARC.
- For successful 3-D spiral injection, it is necessary to give the beam appropriate X-Y coupling.
- The X-Y coupling can be adjusted by rotating the quadrupole magnet.
  - The accuracy of the rotation angle and current value was estimated.
  - The rotating mechanism is being created.

Future

- Install motors to move it in rotation, up and down, and left and right directions.
- Make the motor control remotely controllable.