Development of the Pulsed Magnetic Kicker for the Spiral Injection Test Experiment

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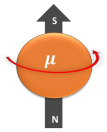
Abstract

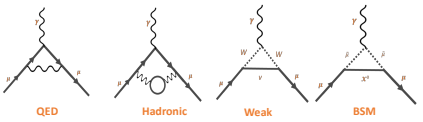
A new muon g – 2 / EDM experiment at J-PARC (E34) is under preparation in order to resolve a 3 sigma discrepancy of muon anomalous magnetic dipole moment between the measurement and the standard model prediction. The E34 experiment will employ a unique three-dimensional spiral injection scheme to store the muon beam into a small storage orbit. In order to demonstrate the feasibility of novel injection scheme, the Spiral Injection Test Experiment (SITE) with the electron beam is under construction at KEK Tsukuba campus. In SITE, 80 keV DC electron beam was injected at forty degree into the storage magnet and detected as a fluorescent light due to the de-excitation of the nitrogen gas. The pulsed electron beam and a pulsed magnetic kicker are developed in order to keep the pulsed beam to the very center of the storage magnet. The magnetic kicker produced the radial field to reduce the pitch angle of the injected beam to keep the beam at the storage region. In this poster, the development of magnetic kicker, tracking studies in kicker field and designs for the SITE's kicker are presented.

1. Introduction

The muon's anomalous magnetic moment is one of biggest discrepancies in elementary particle physics and extremely sensitive to the new physics. The most recent measurement of muon g - 2 results in 3 σ discrepancy between measured and standard model prediction. The J-PARC new muon g – 2 / EDM (E34) experiment is aiming to measure muon g – 2 to the precision of 0.1 ppm and EDM down to the sensitivity of 10^{-21} e.cm.

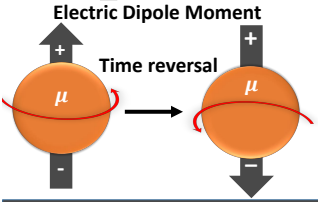


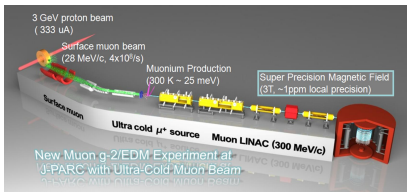
$$a_\mu = \frac{g-2}{2}$$



Electric Dipole Moment

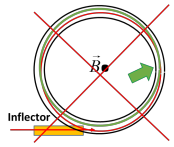
Time reversal





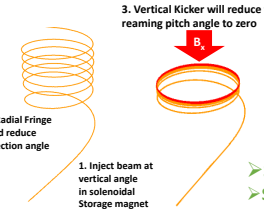
1.1 Three-dimensional Spiral Injection Scheme

Conventional Injection Scheme



Not applicable for small storage orbit due technical challenges

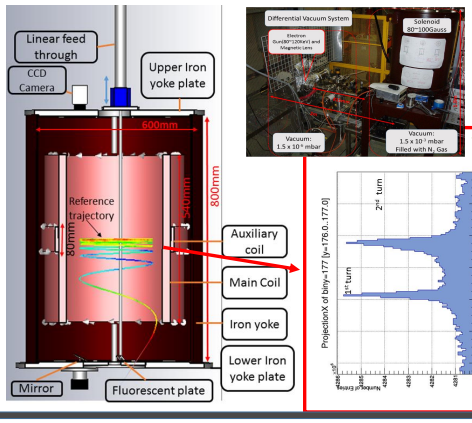
New Spiral Injection Scheme



- Salient Features
- Smooth connection between injection and storage section
- All in one storage magnet, which reduce source of error fields
- No need to kick within a single turn.

The three-dimensional spiral injection scheme is an unproven idea, therefore, a demonstration experiment to prove the feasibility of this unique scheme is inevitable. A scale down Spiral Injection Test Experiment (SITE) by the use of electron beam is under development at KEK Tsukuba campus.

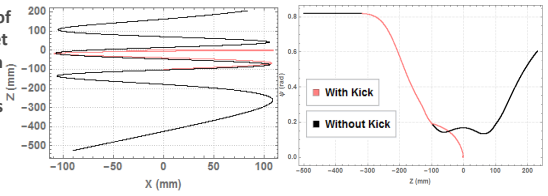
Parameters	E34	SITE
Storage Magnet field	3 [T]	80~100 Gauss
Injection Angle (Degree)	40	25
Momentum [MeV/c]	300	0.296
Cyclotron period [nsec]	7.4	5.0



2.Pulsed Magnetic Kicker

A pulsed magnetic kicker is used to decrease the pitch angle (ψ) of the beam. Below figure is illustrating the character of the magnetic kicker. The black trajectory is showing the motion of the beam inside the storage magnet without kicker, the beam crosses the middle region of the storage magnet without stopping. Pink trajectory represents the situation when an appropriate kick is applied to the beam, which stops the beam in the middle region of the storage magnet.

Radial fringe field of the storage magnet decrease injection to some value remaining angle is decreased by magnetic kicker



The pulsed magnetic kicker have to produce the radial the required magnetic field and stopping volume may calculate as follow

$$B_r = \frac{m_e}{2\,q}\theta_{pitch}\omega \qquad Z_0 = \frac{c}{\gamma_e m_e}\frac{T}{4}P_{z0}$$

Where $\theta_{pitch}(=\frac{P_{z0}}{|P|})$ is the pitch angle of the beam, $\omega(=\frac{2\pi}{T})$ is the angular frequency.

3. Tracking in Kicker Field

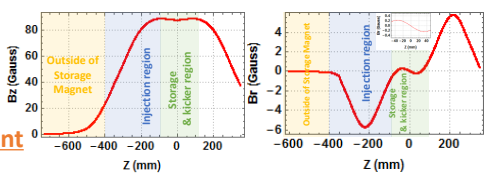
The tracking studies has been carried out in order to find the motion of the particle in the kicker field. Below plots are the shows that how the particle pitch angle decrease in the kicker and particles with residual pitch angle get trapped in the weak focusing field. Even after the kick, there will be residual pitch angle, in order to compensate the effect of the residual pitch angle the weak focusing has been introduced in the storage volume. In the weak focusing field the beam motion will be oscillatory in the storage volume. The weak focusing magnetic field can be defined as follow

$$B_Z = B_0\left(1 - n\frac{\Delta r}{r} + n\frac{z^2}{2r^2}\right)$$

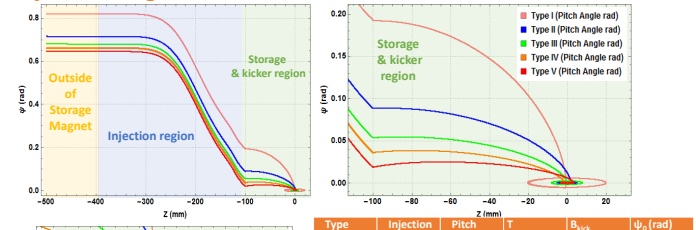
$$B_r = -n\frac{Z}{r}B_0$$

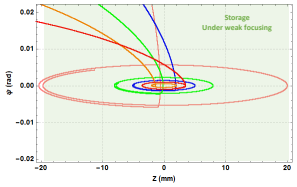
$$n = -\frac{r_0}{B_0}\frac{\partial B_z}{\partial r}$$

SITE Storage Magnet Field Profile



Tracking with different Injection angles

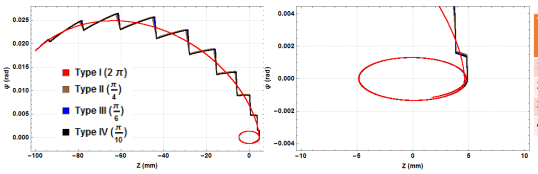




Type	Injection angle (Radian)	Pitch angle Ψ(Radian) at Z = -100 mm	T (ns)	B_{kick} (G)	ψ_0(rad)
1	0.81	0.19	15	2.41	0.005
2	0.71	0.08	31	0.6	-0.003
3	0.67	0.05	48	0.27	-0.004
4	0.66	0.035	62	0.16	10^{-2}
5	0.64	0.018	95	0.07	10^{-3}

4. Alternative Kicker Configurations

In the case of 2π (uniform) kicker with long time period the requirement for the magnetic field reduce drastically. One way to overcome the issue of low magnetic field is to reduce the kick region of the magnetic kicker. The higher magnetic field will be required to kick the beam due to the limited area of the kicker field. Therefore, we considered kicking the beam with π/4, π/6 and π/10 shapes instead of the uniform 2π kick.



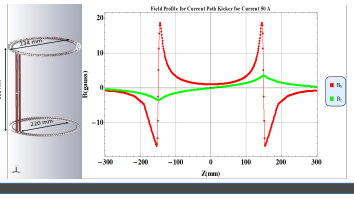
Type	Kicker Shape	T(ns)	B_{kick} (G)	Pitch angle ψ (rad)
1	2π	95	0.079	0.018
2	π/4	95	0.638	0.018
3	π/6	95	0.948	0.018
4	π/10	95	1.58	0.018

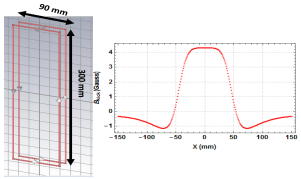
Kicker Design

The kicker shape design and magnetic field calculation has been carried out in CST.

2π kicker, two pairs of circular coils

π/6, Rectangular coils (dipole) will work





Future Plan and Conclusion

A pulsed magnetic kicker is being under development for the SITE to guide the electron beam at the center of the storage magnet. Particle tracking studies have been carried out with the different initial conditions in the kicker and weak focusing field in order to find the required magnetic field and time period for a kicker. From tracking studies it has been found out that the localized kicker will fulfil the requirement for the SITE. We will complete the construction of the pulsed kicker power supply and test our pulsed magnetic kicker with the electron beam within Japanese FY2018.