Progress of the Novel Spiral Injection Test Experiment

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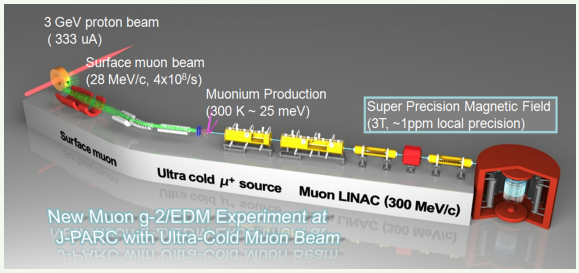
Abstract

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 order to demonstrate the feasibility of this novel injection scheme, the Spiral Injection Test Experiment (SITE) with the electron beam is under construction at KEK Tsukuba campus. The goals of the SITE are divided into two phases. In the first phase of the SITE, 80 keV DC electron beam was injected and detected as a fluorescent light due to the de-excitation of the nitrogen gas into solenoidal storage magnet. In the second phase of the SITE, the pulsed electron beam, and a pulsed magnetic kicker are developed in order to keep the pulsed beam on the very midplane of the solenoidal storage magnet. This paper describes the achievements of the first phase of the SITE and progress towards the second phase.

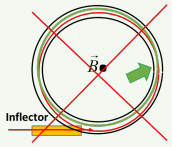
Muon g – 2 Experiment

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.



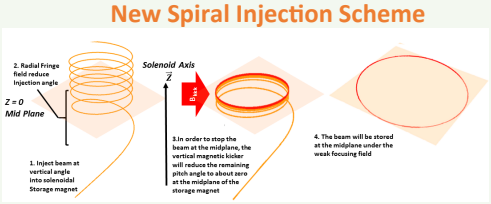
Three-dimensional Spiral Injection Scheme

Conventional Injection Scheme



Not applicable for small storage orbit due technical challenges

New Spiral Injection Scheme



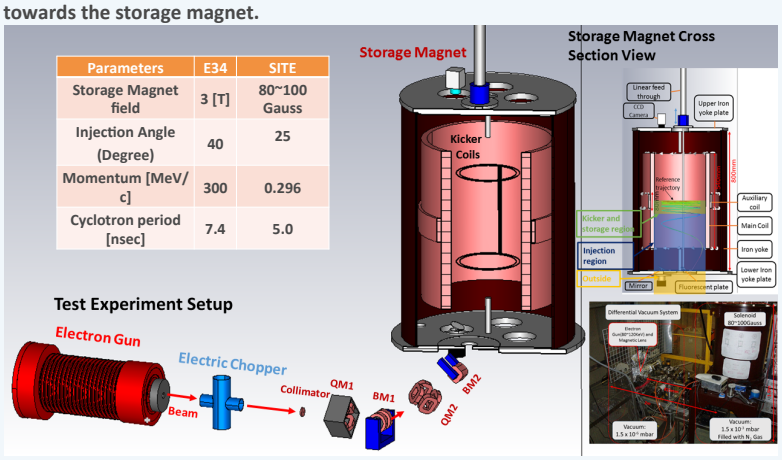
The three-dimensional spiral injection scheme is an unproven idea, therefore, a demonstration experiment to prove the feasibility of this unique scheme is inevitable. A scale down Spiral Injection Test Experiment (SITE) by the use of electron beam is under development at KEK Tsukuba campus.

- 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.

1. Spiral Injection Scheme Test Experiment

The SITE setup contains a 2 m long straight beamline, a solenoid storage magnet to store the electron beam and forty degrees bend section to guide the electron beam towards the storage magnet.

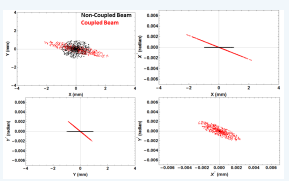
Parameters	E34	SITE
Storage Magnet field	3 [T]	80~100 Gauss
Injection Angle (Degree)	40	25
Momentum [MeV/c]	300	0.296
Cyclotron period [nsec]	7.4	5.0

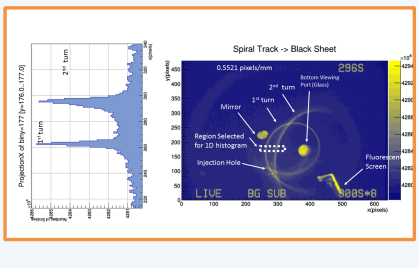


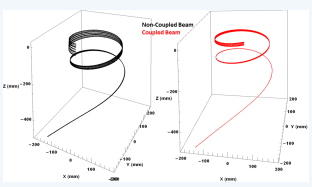
2. Beam Detection in the Storage Magnet

Storage magnet vacuum chamber filled with the nitrogen gas. In order to observe the electron beam as a fluorescent light due the de excitation of nitrogen molecules (390 nm < λ < 470 nm). A chilled CCD-camera is used to observe fluorescence light .

XY-Coupled beam is required





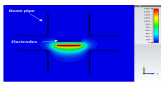


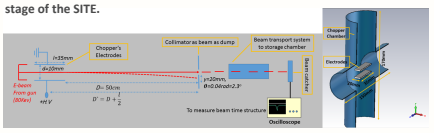
3. Electric Chopper

For the second stage of the SITE, development of pulsed electron beam has been started. Electric chopper has been designed, simulated and fabricated to produce the pulsed beam for the second stage of the SITE.

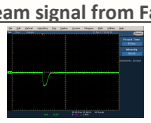
$$Vid = \theta(ymc^2)\beta\gamma^2/ld$$

CST Simulation of Chopper





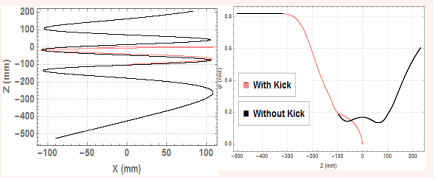
Pulsed beam signal from Faraday Cup



4. Pulsed Magnetic Kicker

A pulsed magnetic kicker is used to decrease the pitch angle (ψ) of the beam. Side figure is illustrating the character of the magnetic kicker.

$$Bikick = Bipeak\,Sin(2\pi/Tikick\ t)$$

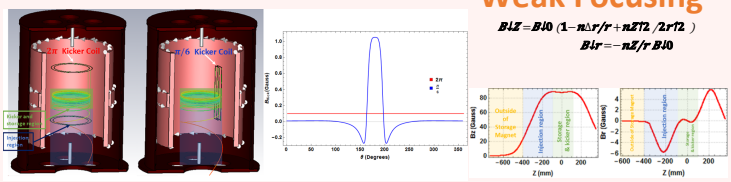


4.1 Kicker Coil Design

Two design of magnetic kicker are under development. In the first design a symmetric (2π) kicker is considered and other possible design is limited region kicker ($\pi/6$).

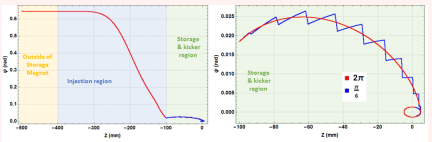
Weak Focusing

$$BiZ = Bi0\,(1 - n\Delta r/r + n\Delta r^2/2r^2)$$
$$Bir = -nZ/r\,Bi0$$



4.2 Tracking in Kicker Field

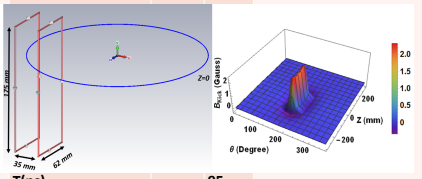
Parameters	2π	$\pi/6$
Pitch angle ψ (rad)	0.95	0.018
T(ns)	95	95



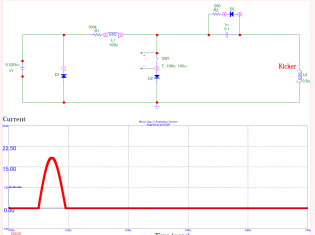
Both types of kicker shapes ($\pi/6$ and 2π) will tested for the SITE.

4.3: $\pi/6$ Kicker Design

The $\pi/6$ kicker coil shape has been optimized to reduce the inductance of coils. The optimization results in the coils of height 175 mm, width 62 mm and the gap between coils was 35 mm with the inductance of 0.8 μH.



4.4: Power Supply Design



Conclusion

A new three-dimensional spiral injection is under development by using the electron beam in order to realize new J-PARC's muon g - 2/EDM experiment.

- The electron beam in the storage magnet was confirmed as fluorescent light due to the de-excitation of nitrogen gas in the storage magnet.
- The required beam phase space for the spiral injection has been calculated and implemented.
- A pulsed magnetic kicker and the power supply is under development to guide the pulsed beam at the midplane of the storage magnet