$\mu^+ \to e^+\gamma$ measurement with polarized μ^+ beam

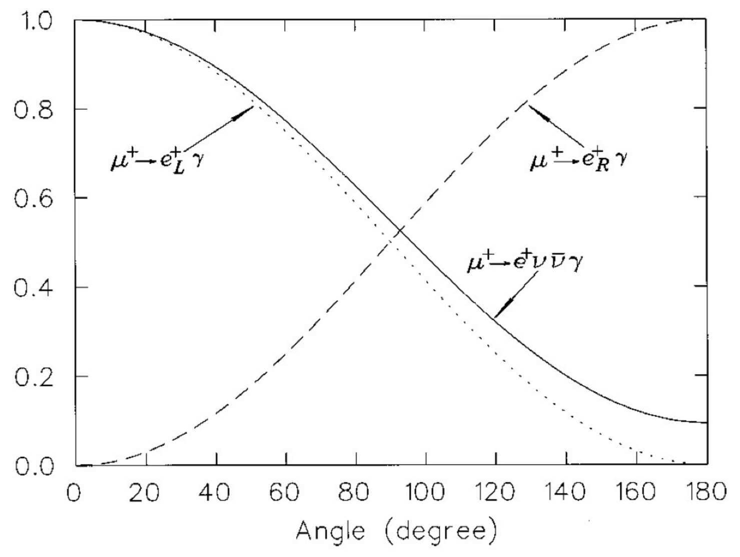
Hajime NISHIGUCHI, University of Tokyo

Workshop on Precision Measurements at Low Energy
18-19, Jan., 2007, Paul Scherrer Institut, Villigen, Switzerland

AFTER the MEG discovering of $\mu^+ \to e^+\gamma$, the experiment can advance from the "*discovery*" to the "*measurement*" phase. By the use of a polarized muon beam and a Suitable target, a polarized MEG can be performed. Based on a sufficient number of observed $\mu^+ \to e^+\gamma$ events, the e^+ angular distribution with respect to the muon spin orientation can be extracted and used to discriminate between different SUSY-GUT extensions to the Standard Model.

Physics Motivation

The measurement of the angular distribution of $\mu^+ \to e^+\gamma$ with respect to the muon polarization direction allows different theoretical models to be tested based on the helicity predictions of the e^+ in $\mu^+ \to e^+\gamma$ [1]. For example, SU(5) supersymmetric grand unification (SUSY-GUT) models only introduce a lepton flavour violation (LFV) in the right-hand slepton sector, therefore, only $\mu^+ \to e_L^+\gamma$ occurs. On the other hand, SO(10) SUSY-GUT models cause LFV in the left-hand as well as in the right-hand slepton sectors, thereby giving rise to both $\mu^+ \to e_R^+\gamma$ and $\mu^+ \to e_L^+\gamma$.



Idea of Measurement

By using a polarized muon beam and a Suitable target together with the MEG detector [2], the asymmetry of the e^+ angular distribution can be measured. When the initial muon is polarized in $\mu^+ \to e^+\gamma$, the angular distribution of the positron is given by

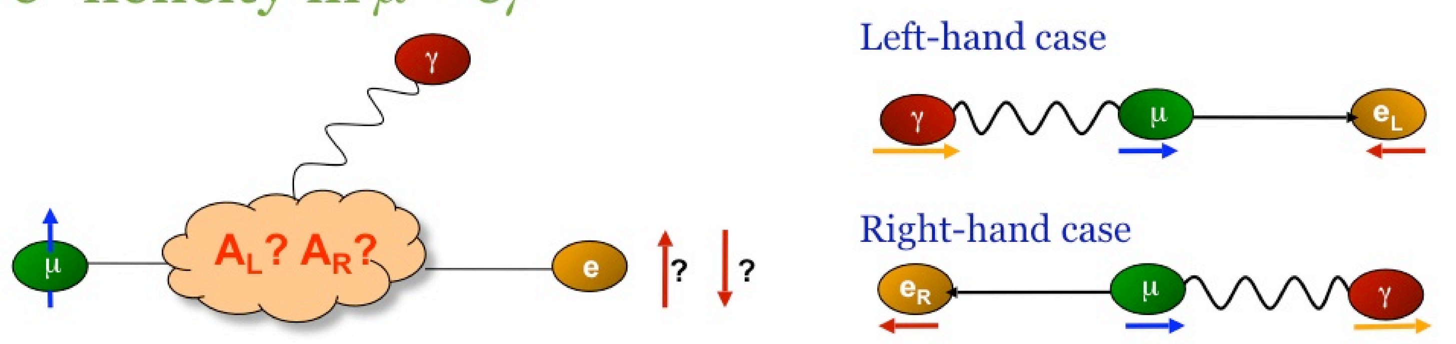
$$\frac{dB(\mu^+ \to e^+\gamma)}{d\cos\theta_e} \propto |A_R|^2\left(1 - P_\mu \cos\theta_e\right) + |A_L|^2\left(1 + P_\mu \cos\theta_e\right)$$

where θ_e is the angle between the muon polarization P_μ and the positron momentum in the muon rest frame. The asymmetry of the e^+ angular distribution

$$A = \frac{|A_L|^2 - |A_R|^2}{|A_L|^2 + |A_R|^2}$$

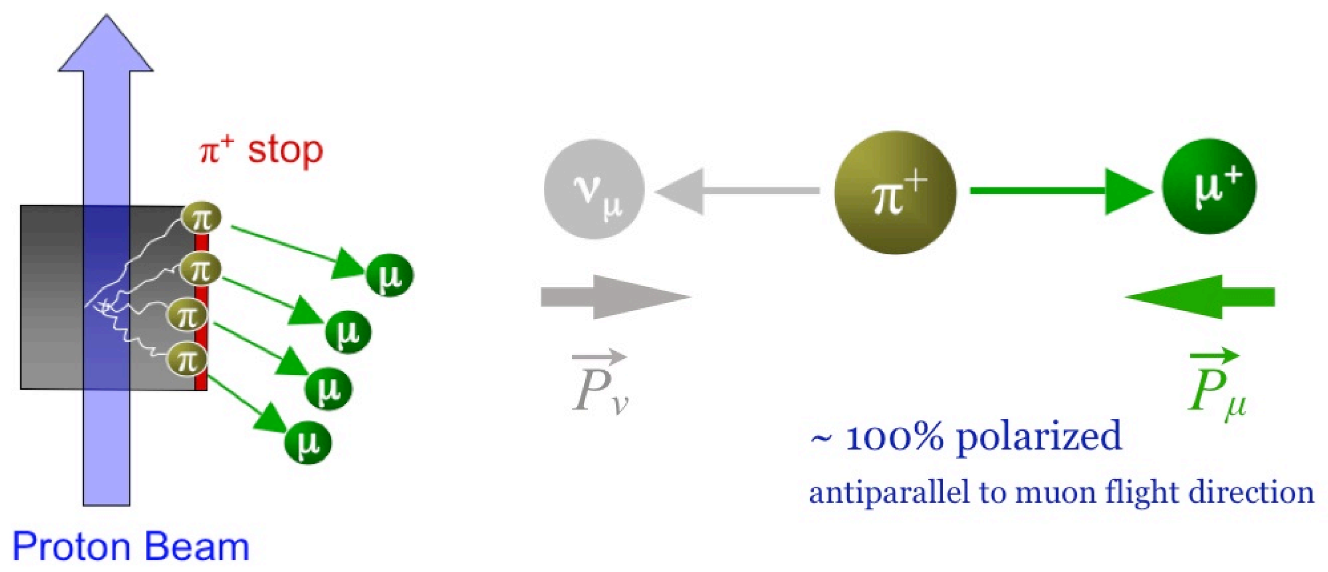
can be determined by just measuring the e^+ emission angle distribution.

e^+ helicity in $\mu \to e\gamma$



Because of their production mechanism, "***surface muons***" are originally 100% polarized, antiparallel to their flight direction.

Surface Muon Beam



From the view point of the most intense source of stopped muons, the PSI cyclotron and the MEG beam line can provide the most intense surface muon beam in the world. Consequently, with a non-depolarization target such as Al, Ag, MEG can measure the angular distribution of $\mu^+ \to e^+\gamma$.

Decay asymmetries and depolarization factors for positive muons [3]

target material	decay asymmetry (*1)	depolarization factor (*2)
Graphite	0.236	1.00
Beryllium	0.222	0.97
Aluminum	0.209	0.91
Lithium	0.201	0.88
Polyethylene (*3)	0.146	0.64

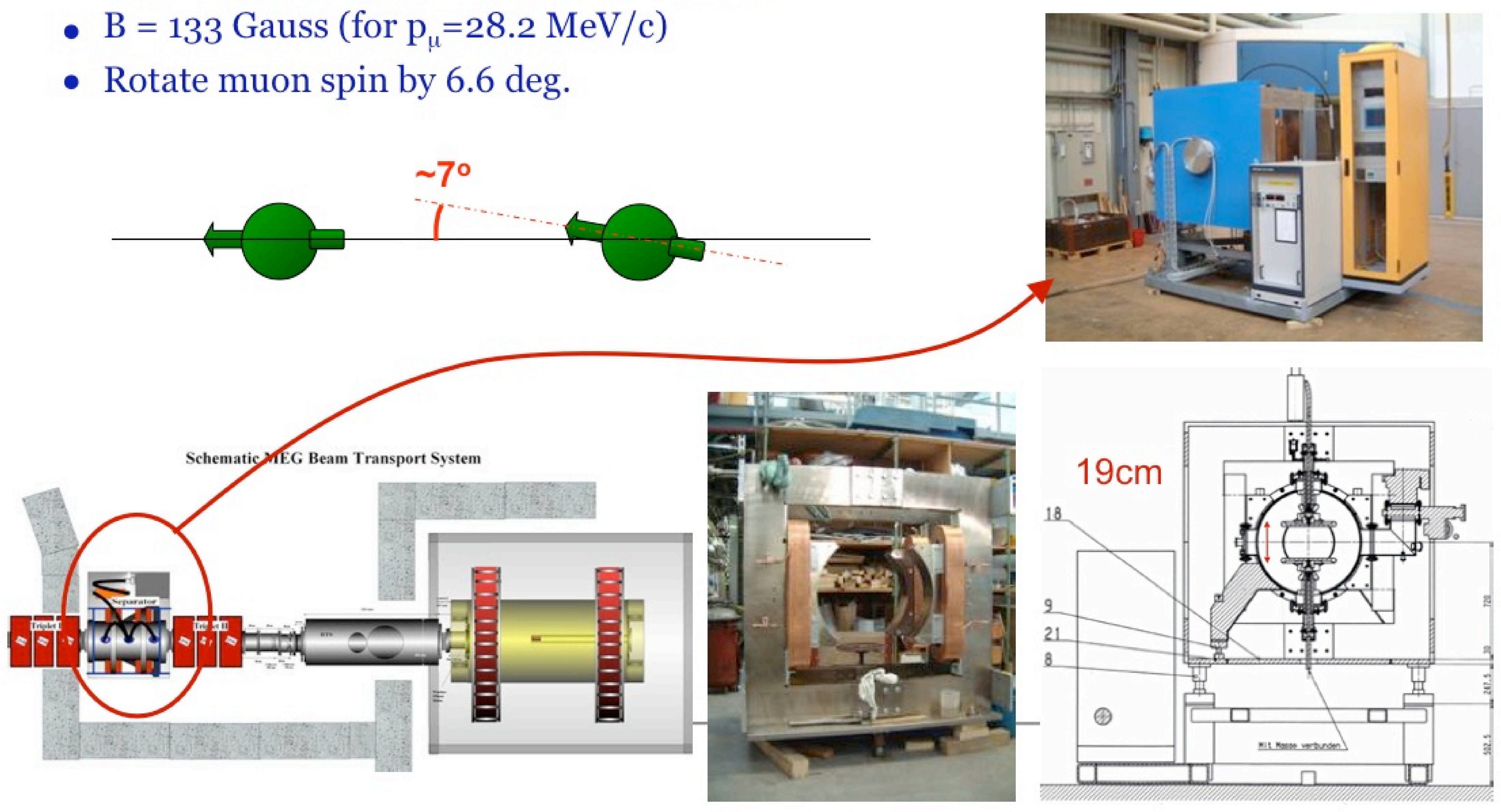
(*1) Asymmetry for beam muons decaying in a target
(*2) Ratio of muon polarization after stopping to that before stopping
(*3) Polyethylene is adopted as muon stopping target in the present MEG detector.

Using MEG detector

The present MEG detector is placed in the πE5 area of PSI. In order to suppress positron contamination in the muon beam, a Wien filter (DC separator) is placed in front of the final beam transport solenoid of the MEG detector. This filter rotates muon spin 6.6 degree.

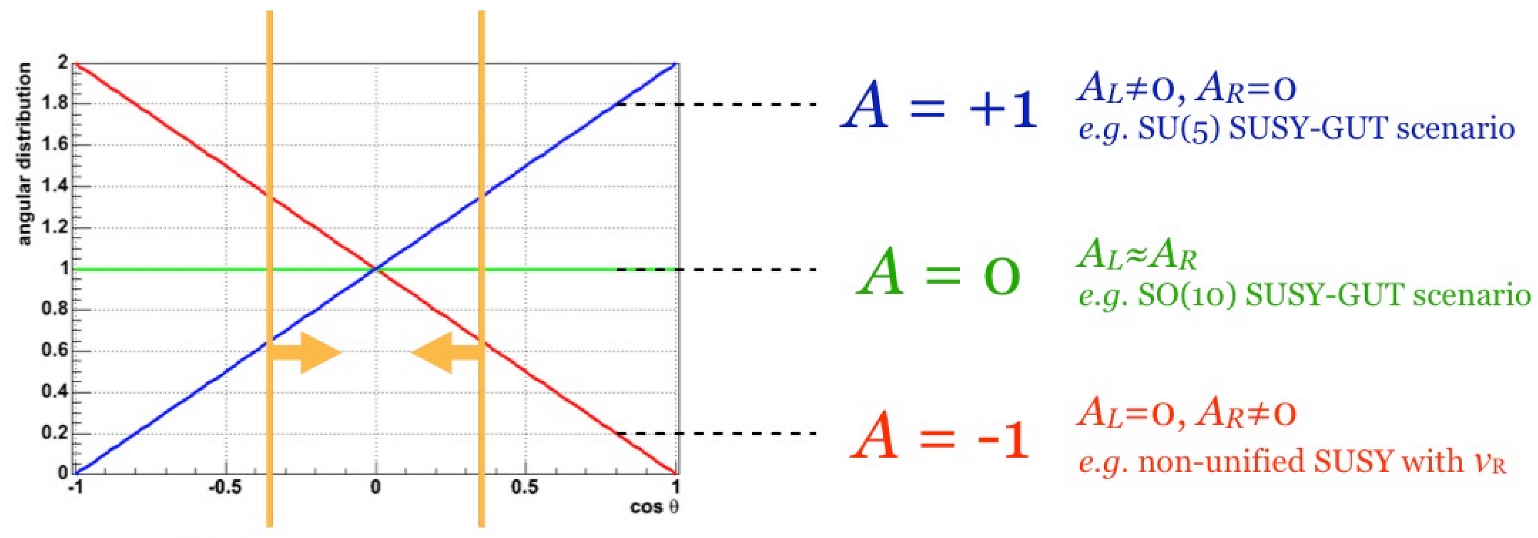
MEG DC separator

- V_{max} = 195 kV, D_{plates} = 19 cm, L_{eff} = 82 cm
- B = 133 Gauss (for p_μ=28.2 MeV/c)
- Rotate muon spin by 6.6 deg.



According to the present MEG detector design, the positron spectrometer has an acceptance of $|\cos\theta| < 0.35$ for e^+ emission angles. Even so a significant measurement can be performed as shown below.

Asymmetry of Angular distribution



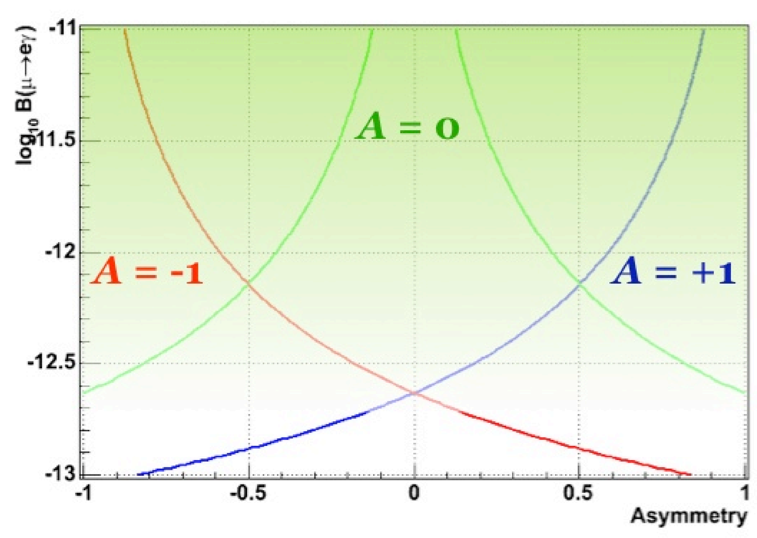
In order to estimate the feasibility, a Monte Carlo study incorporating the present MEG detector was performed [4].

68% C.L. Sensitive Regions

Simulation Assumptions;

- muon beam intensity : 1.0×10^8 /sec
- beam time : 5.2×10^7 sec (2 years)
- muon polarization : 97 %

possible to distinguish A=-1, 0, +1 at 68% C.L. for $Br(\mu \to e\gamma) > 10^{-12.5}$



Conclusion

The observation of a $\mu^+ \to e^+\gamma$ signal and measurement of the e^+ angular distribution would give a clear discrimination of models and a significant test of SUSY-GUT.

References

[1] Y.Kuno and Y.Okada, Rev. Mod. Phys. **73** (2001) 151
[2] T.Mori *et.al.*, Research Proposal to PSI R-99-05 (1999)
[3] R.A.Swanson, Phys. Rev. **12** (1958) 580
[4] S.Yamada, The 12th International Conference on Supersymmetry and Unification of Fundamental Interactions (SUSY2004), KEK, June 17-23, 2004