Development of a muon spin polarization monitor for J-PARC Muon g-2/EDM experiment

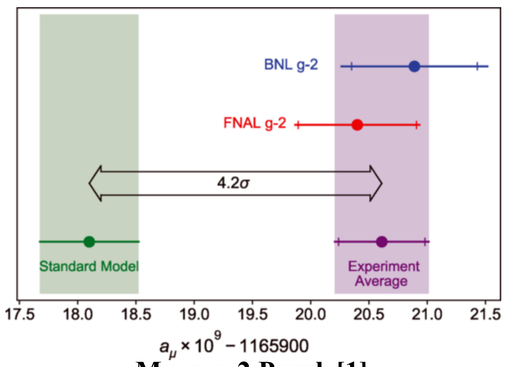
Meng Lv*, Xintong Cai, Fangyuan Yu, Siyuan Chen, Kim Siang Khaw

Email: meng.lv@sjtu.edu.cn

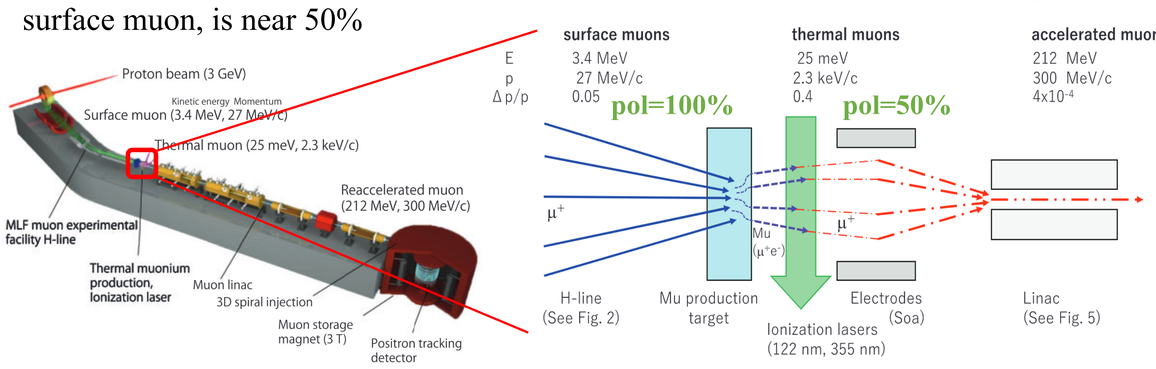
Shanghai Jiao Tong University

Introduction to J-PARC muon g-2/EDM experiment

- Current measurement on muon g-2 has 4.2σ compared with standard model prediction[1]
- J-PARC at KEK, Japan plans to measure both muon g-2 and EDM using ultra-slow muon stored in a relatively smaller storage ring[2] to search for physics beyond the Standard Model
- A muon polarization monitor is needed in data quality control to make sure the polarization of the thermal muon, which is converted from the surface muon, is near 50%



Muon g-2 Puzzle[1]



J-PARC Slow Muon Production[2]

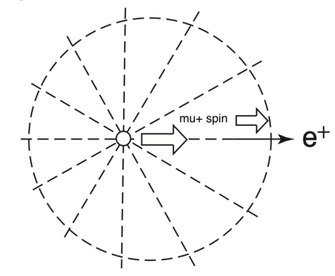
Principle of muon polarization monitor

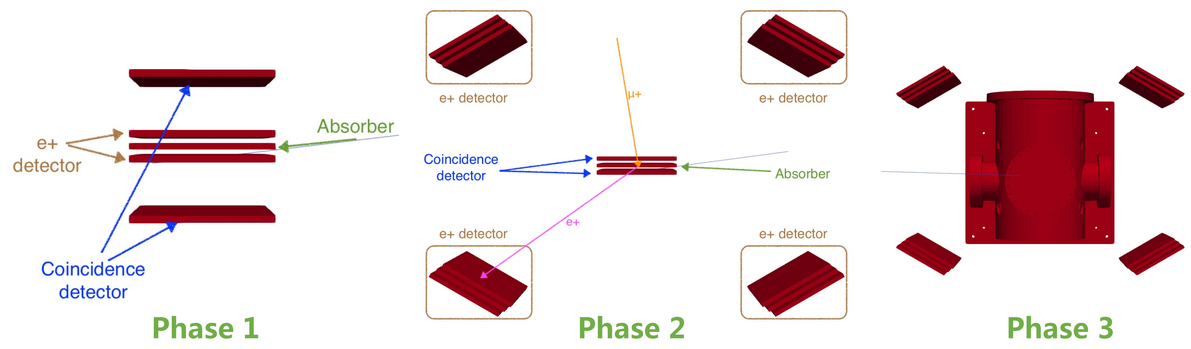
- $\mu \rightarrow e$ decay shows asymmetry with regard to muon spin direction
- Polarization is calculated through detected asymmetry A:

$$A = \frac{F - B}{F + B}$$

F = Forward count, B = Backward count

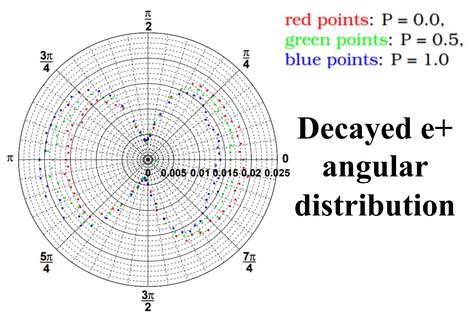
- The whole project is devided into three phases:
- Phase 1&2: validate design with atmospheric muon
- Phase 3: Apply our design to J-PARC experiment





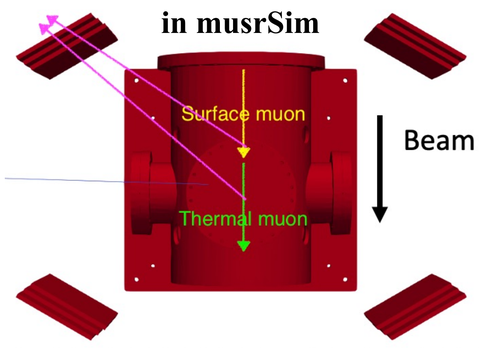
Thermal muon simulation

- Thermal muon in the chamber ($p = 2.3$ keV/c) still shows decay positron asymmetry
- Positron trach reconstruction is conducted to exclude those from surface muon decay

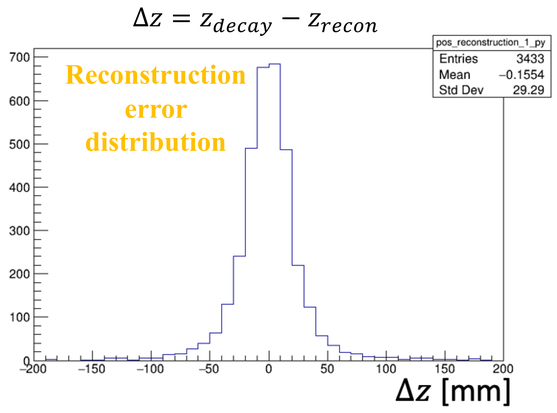


Decayed e+ angular distribution

Chamber and detector 3D Model in musrSim



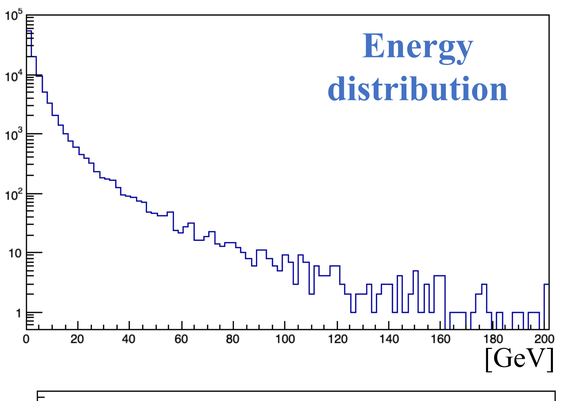
$$\Delta z = z_{decay} - z_{recon}$$

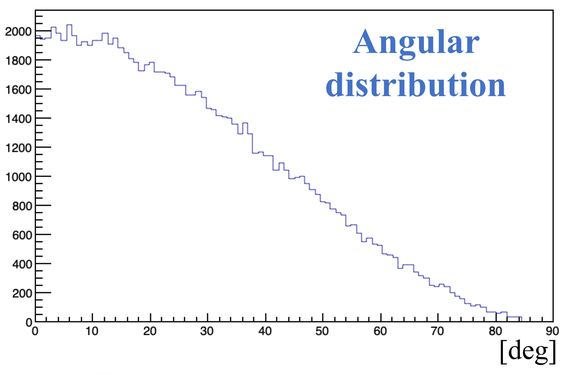


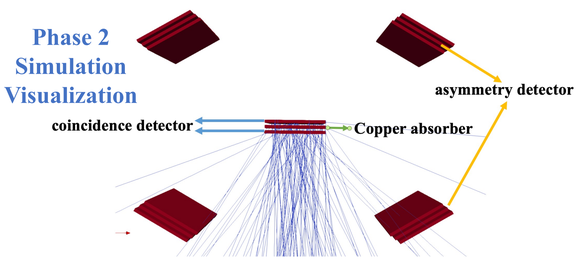
Atmospheric muon simulation

$$\frac{dI_\mu}{dE_\mu} = 0.14\left[\frac{E_\mu}{GeV}\left(1+\frac{3.64GeV}{E_\mu(\cos\theta^*)^{1.29}}\right)\right]^{-2.7} \times\left[\frac{1}{1+\frac{1.1E_\mu\cos\theta^*}{115GeV}}+\frac{0.054}{1+\frac{1.1E_\mu\cos\theta^*}{850GeV}}\right]$$

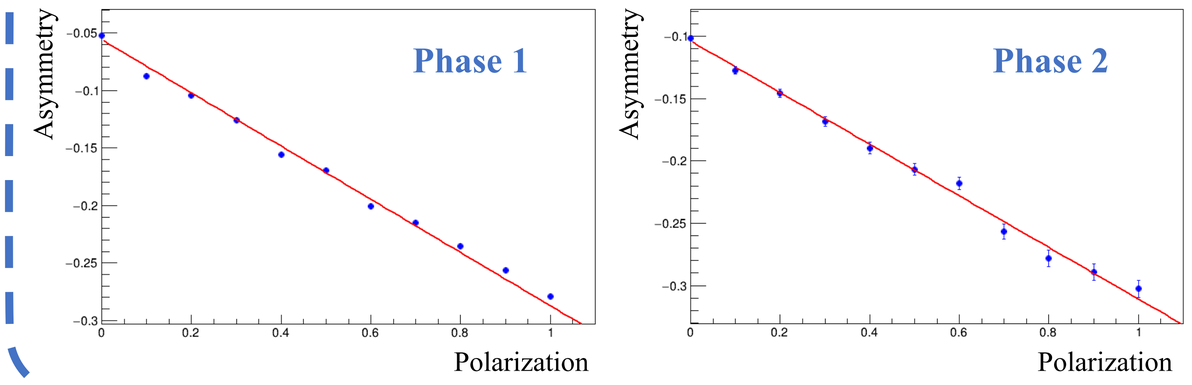
- Get atmospheric muon distribution model equation from Ref. [4]
- Achieve atmospheric muon energy and angular distribution in musrSim
- Get a good linearity in asymmetry-polarization calibration





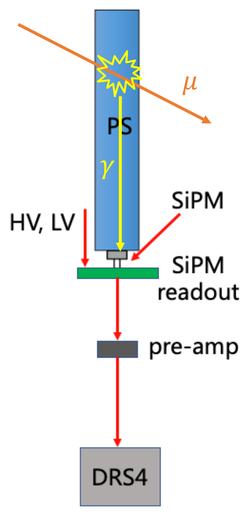


Polarization-Asymmetry Calibration

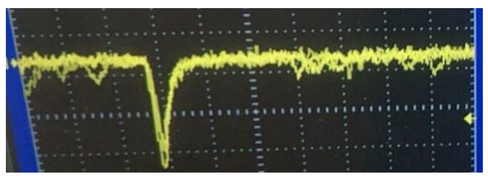


Atmospheric muon detection

Plastic Scintillator photo



- A detector plate is composed of several scintillator bars
- When μ/e hits the scintillator, the photon it produces will be received by SiPM
- The signal will be amplified and analysis by digital system DRS4



Typical signal shape in oscilloscope

Conclusion & Future prospects

- We use asymmetric spatial distribution of positron decayed from muon to monitor the muon polarization
- We've simulated both energy and angular distribution of atmospheric muon and achieved good linearity in polarization-asymmetry calibration
- Thermal muon track reconstruction can help select position from thermal muon
- A muon detection system has been realized, which will be applied to build a detector and validate our simulation in the future

References

[1] Muon g-2 collaboration, Measurement of the Positive Muon Anomalous Magnetic Moment to 0.46 ppm, Phys. Rev. Lett. 126, 141801 (2021)

[2] Abe, M. et al. A New Approach for Measuring the Muon Anomalous Magnetic Moment and Electric Dipole Moment. *arXiv*. https://doi.org/10.48550/arXiv.1901.03047 (2019)

[3] K. Nagamine, Introductory Muon Science, Cambridge University Press (2003)

[4] Guan, M., Chu, M., Cao, J., Luk, K., & Yang, C. A parametrization of the cosmic-ray muon flux at sea-level. *arXiv*. https://doi.org/10.48550/arXiv.1509.06176 (2015)