R&D of the J-PARC muon spin polarization monitor Simulation Development

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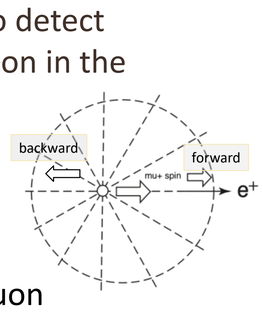
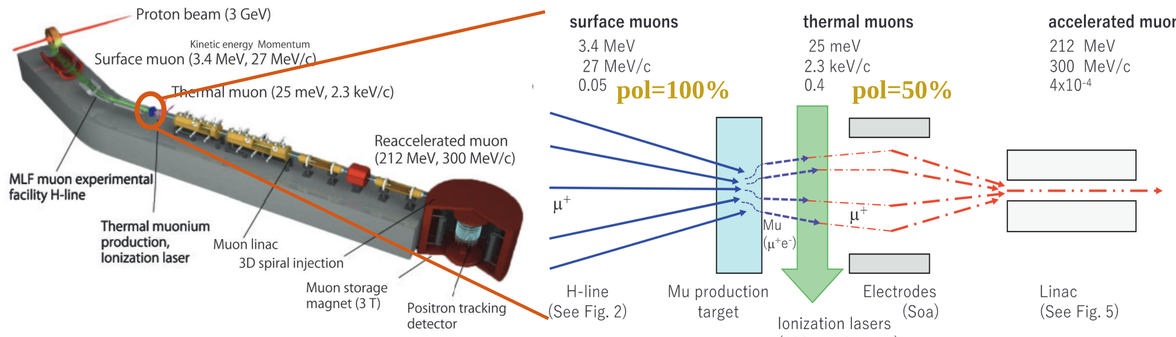
Overview: Muon Polarization Monitor for J-PARC muon g-2/EDM experiment

- The polarization monitor, as an essential part of the DQC, is used to detect the 50% muon spin polarization lost during thermal muon production in the J-PARC muon g-2/EDM experiment[1]
- Polarization can be detected through asymmetric positron angular distribution due to the parity violation of muon decay
- This project is divided into three phases:

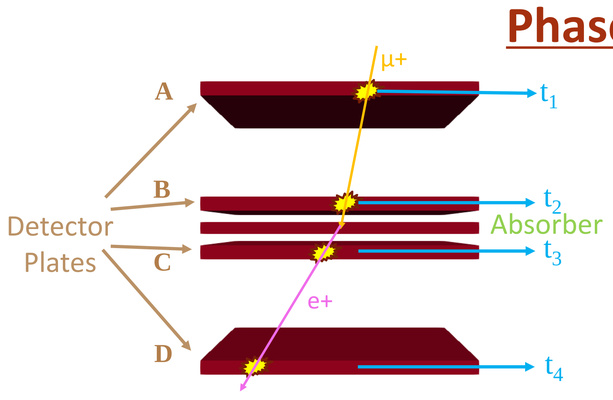
  Phase 1&2: Validate the design and feasibility with atmospheric muon

  Phase 3: Apply our design to the J-PARC muon g-2/EDM experiment





Phase 1: Polarization Measurement with Four Parallel Detector Plates

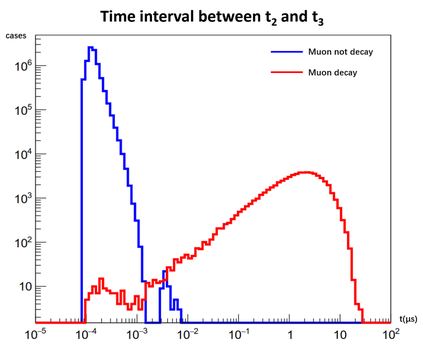


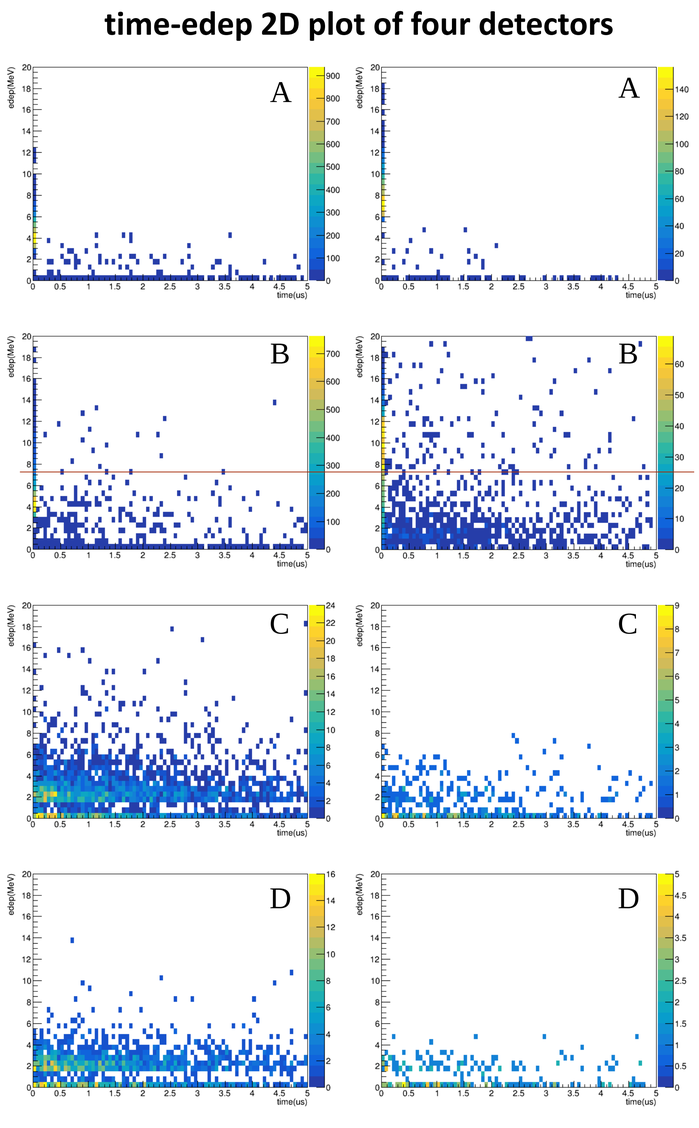
- Particles will deposit energy in scintillator bars of the detector
- Absorber (Cu/Fe) can stop muon, causing it decay in the absorber
- Polarization P is calculated through detected asymmetry A:

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

F=Forward count, B=Backward count

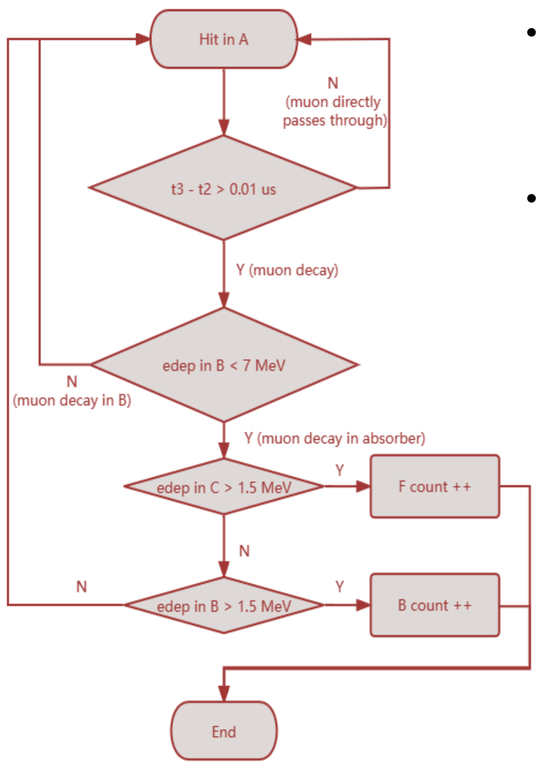
- Time and energy deposition (edep) info. are used to reject background



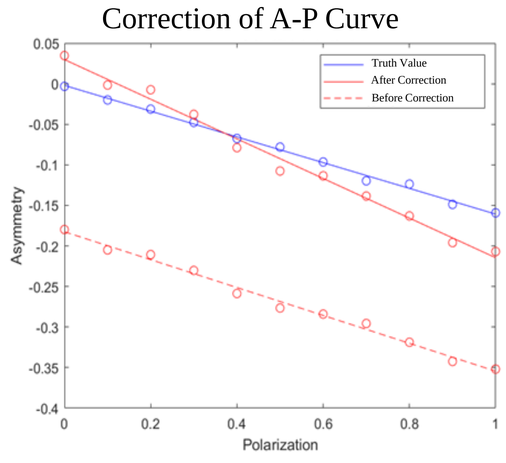


- Left plots show the hit distribution of four detectors in two different cases. The x-axis represents the hit time, and the y-axis represents the energy deposition of each hit
- Left col: muon decays in absorber (forward), right col: muon decays in B (forward)
- To distinguish these two cases, an coincidence energy cut can be applied, as shown in the algorithm

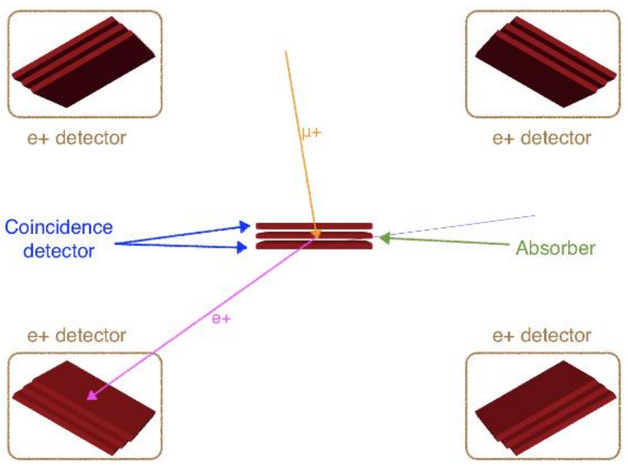
Flow chart of detection algorithm



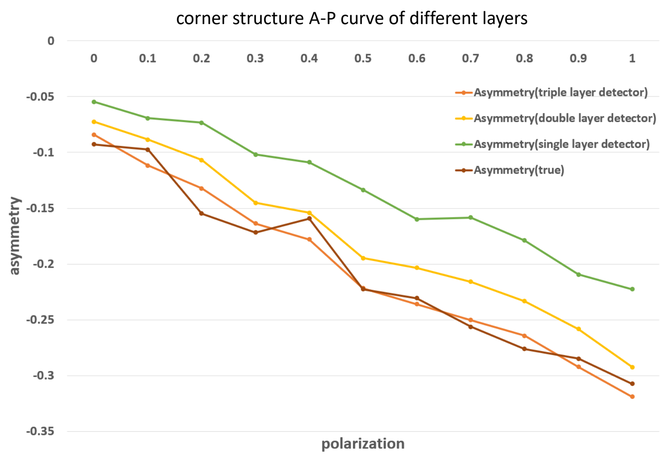
- The relationship between A and P is obtained to measure polarization
- Muons decaying in B act similarly with those decaying in absorber, causing deviation between algorithm output and truth value
- Correction is conducted by another run with absorber removed[2]

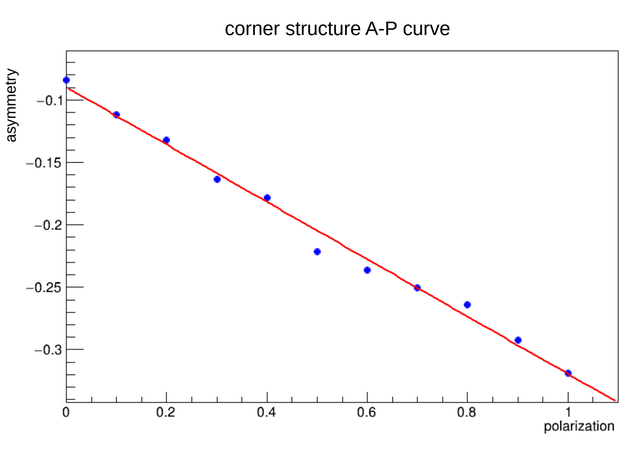


Phase 2: Polarization Measurement with Detectors in Four Corners

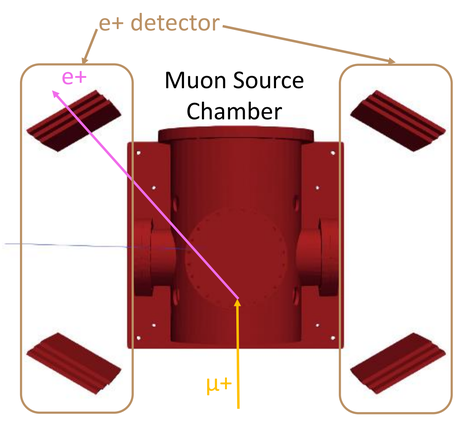


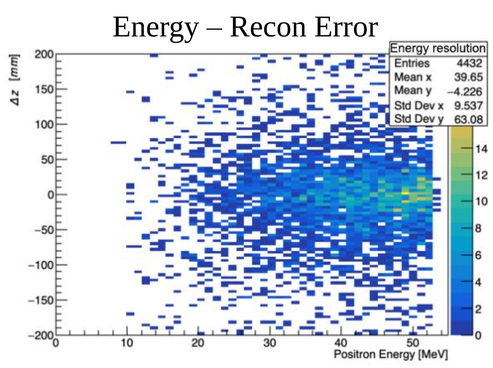
- The detectors are arranged in the four corners in order to implant in J-PARC
- The detectors in four corners serve as positron detector, while the inner ones serve as coincidence detector
- The positron detectors can vary in layers, and three layers result in best accuracy but rather low efficiency



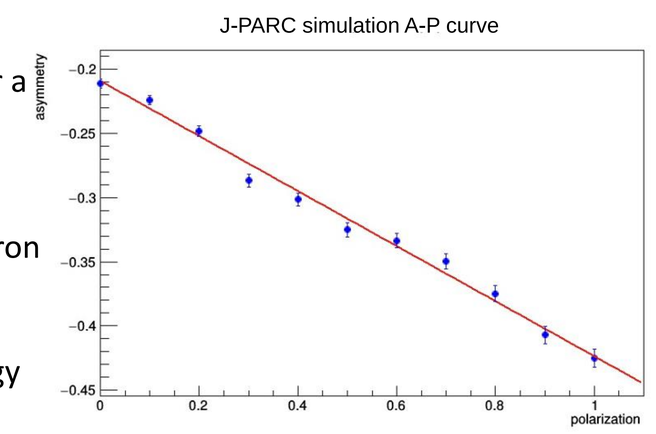


Phase 3: Simulation of J-PARC Thermal Muon





- The muon source chamber at J-PARC is imported for a more realistic simulation result
- Use thermal muon ($p \approx 2.3$ keV/c) and phase 2 detector structure to measure the polarization
- The 3-layer detector can help reconstruct the positron track to determine the muon decay position
- Due to the scattering of the chamber, the reconstruction error decreases when positron energy gets higher



Conclusion

- In Phase !, the correction to algorithm output performs well.
- In Phase 2, three layers of detector results in best accuracy.
- In Phase 3, the position reconstruction has an error of 63 mm std dev.
- All cases present good linearity for A-P curve.

Reference

[1] 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)

[2] *Polarization of low-energy cosmic ray muons at sea level*. (n.d.). Retrieved November 18, 2022, from http://www.jetp.ras.ru/cgi-bin/dn/e_015_04_0654

Acknowledgments: This work is supported by National Natural Science Foundation of China (Grant No. 1211101353) and Zhiyuan Scholars Program (Grant No. 2022-09)