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Development of Silicon Strip Detector for J-PARC Muon *g*-2/EDM Experiment

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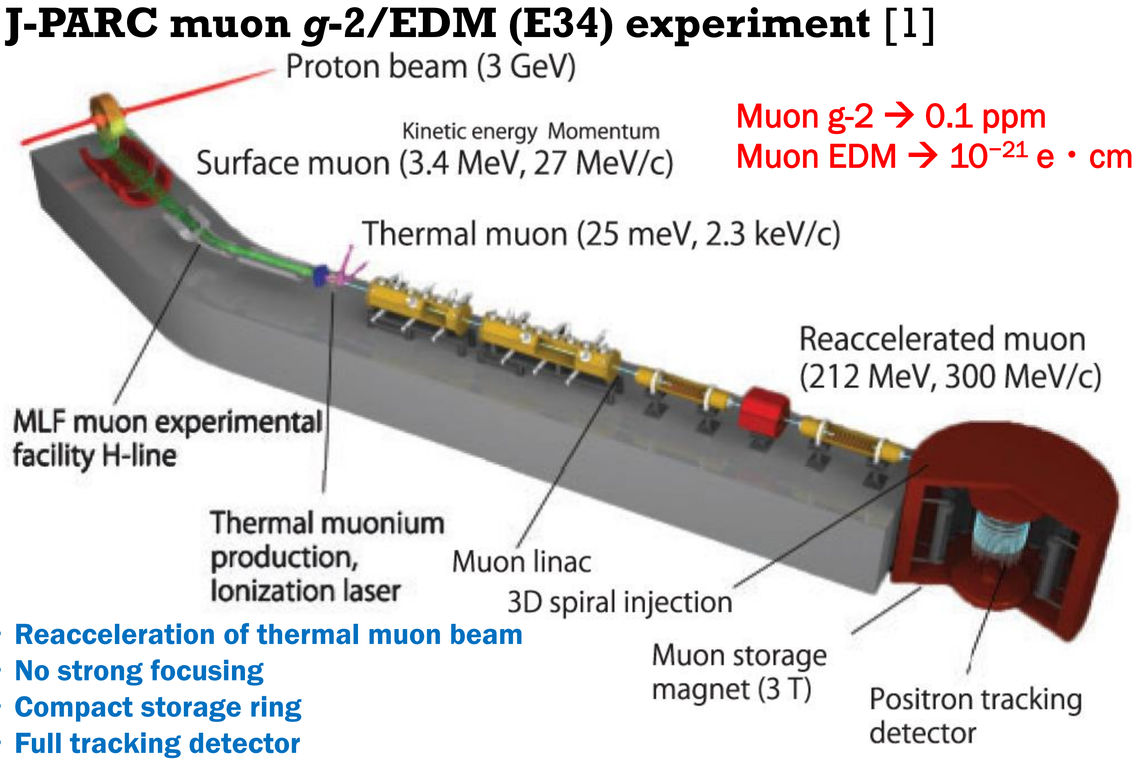
Abstract The positron tracking detector is being developed for the J-PARC muon g−2/EDM (E34) experiment. It uses silicon strip sensors for positron detection and signals from sensors are transferred to the front-end readout system via flexible printed circuit (FPC) boards glued on the sensors. The front-end readout system consists of ASICs on FPCs and the FPGA-based readout boards. The status of these fabrications and developments are presented.

J-PARC muon *g*-2/EDM (E34) experiment [1]



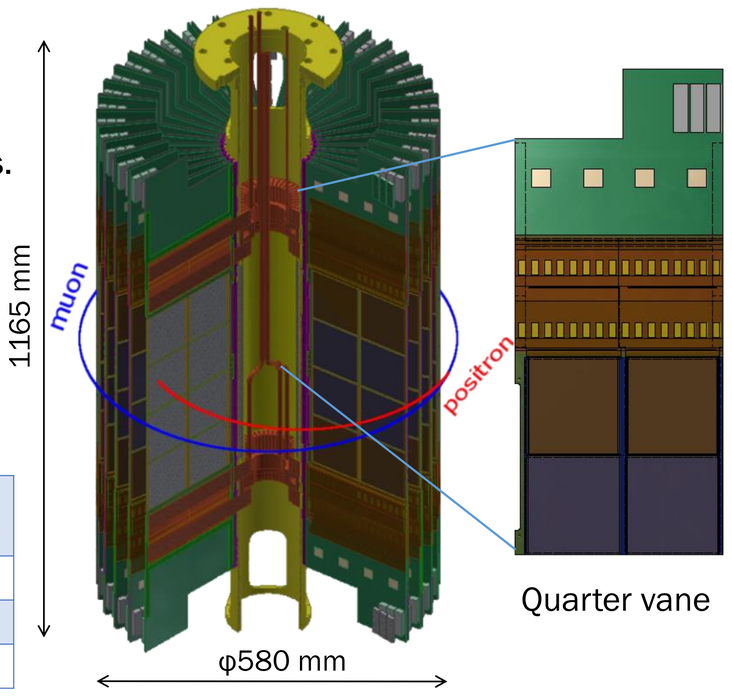
Muon g-2 → 0.1 ppm
Muon EDM → 10^{-21} e・cm

- **Reacceleration of thermal muon beam**
- **No strong focusing**
- **Compact storage ring**
- **Full tracking detector**

Positron Tracking Detector

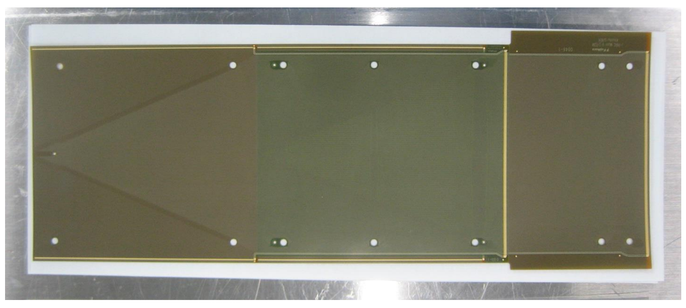
Positrons from muon decays are detected by the tracking detector inside of the storage magnet. It consists of 40 modules called vanes. Each vane has 16 single-sided silicon strip sensors. Half of which measure the radial coordinate and the other half measure the axial coordinate. The smallest unit of the module is a quarter vane.

Geometrical coverage	± 200 mm (axial) 90-290 mm (radial)
Number of vanes	40
Number of sensors	640
Number of strips	655,360



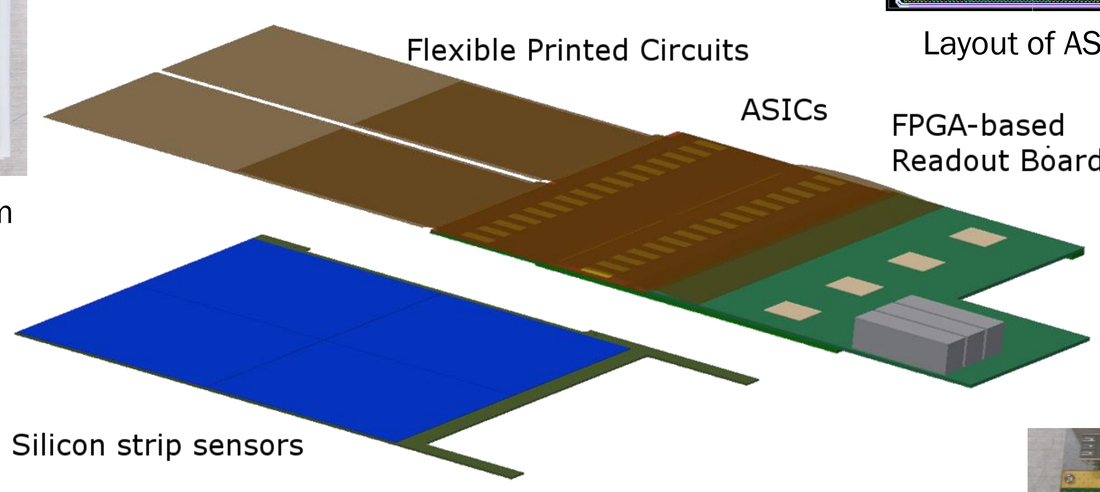
Flexible Printed Circuit (FPC) Board

It is used for transporting signals from sensors to front-end ASICs and installing ASICs.
Mass production of FPCs on sensors was finished. Designing of the rest of FPCs is ongoing.

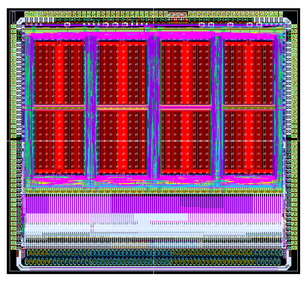


Sensor FPC (Fujikura Ltd.), Line pitch: 84 μm

Quarter Vane Structure



Front-end ASIC



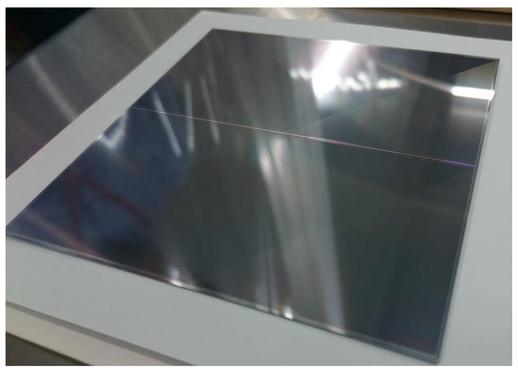
Layout of ASIC

CMOS Process	Silterra 0.18 μm
Size	7200 μm × 6540 μm
Time sampling	5 ns (typical)
Time buffer	8192
Number of channels	128

Not to cause a systematic effect on g-2 measurement, timing stability is important. To constrain timing shift due pile-up hits, test ASIC chips with small time-walk have been studied [2]. Based on this test, the production version of ASIC was designed.

Silicon Strip Sensor

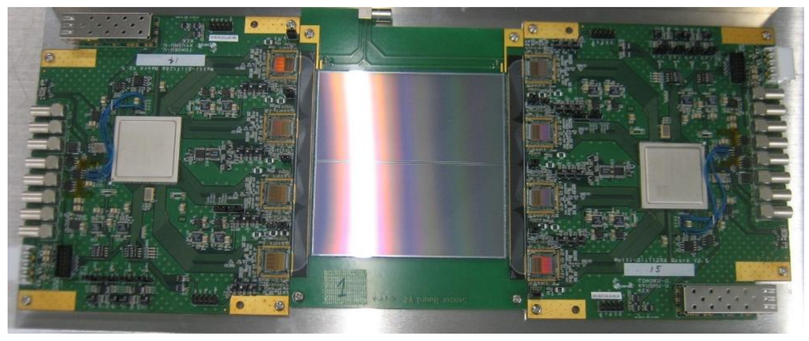
It is used for charged particle detection.
Mass production is ongoing.



Sensor (Hamamatsu Photonics K.K.)

Sensor type	p^+ on n
Size	98.77 mm × 98.77 mm
Active area	97.28 mm × 97.28 mm
Thickness	320 μm
Strip pitch	190 μm
Number of strips	512 × 2 blocks

Readout Board

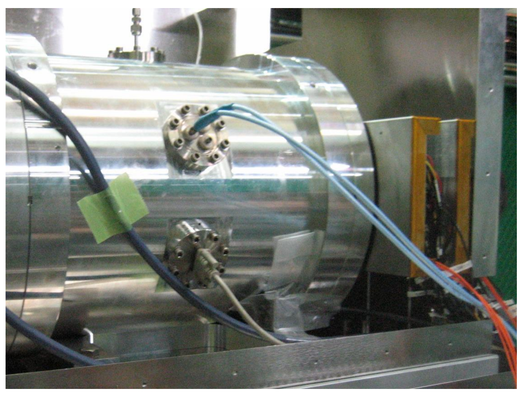


Test detector module with one sensor

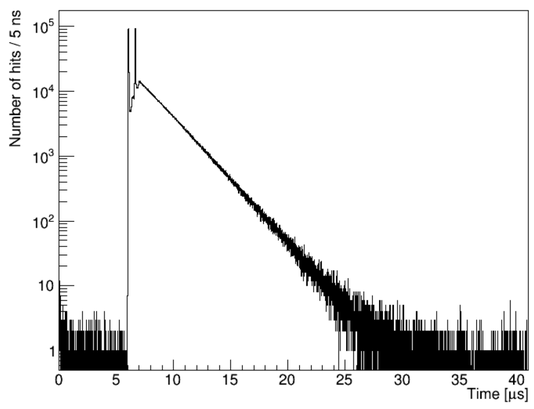
FPGAs process digital output of ASICs and send data through the SFP transceiver. Development is ongoing by constructing the test version of the detector module [3].

Detector Operation

Test detector modules were used at the MuSEUM experiment which measures the muonium hyperfine structure constant [4]. The number of positrons from muon decay is counted in this experiment and detector modules were stably operated under the high hit rate condition.



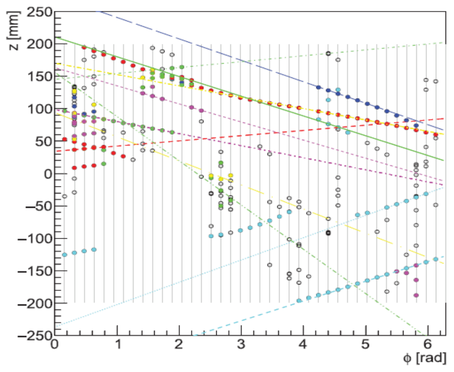
Test detector modules installed at the MuSEUM experiment



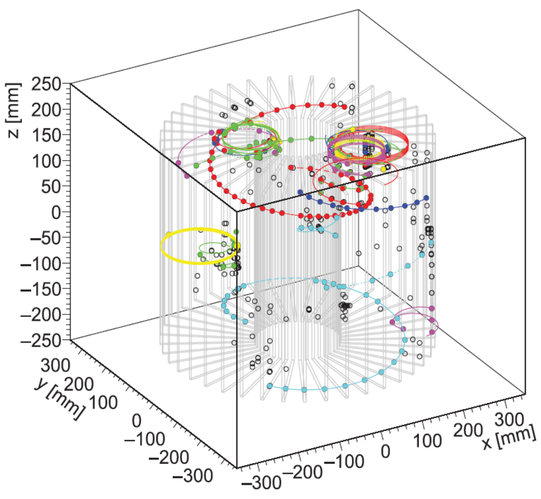
Time distribution of positron hits obtained by test detector modules

Tracking Algorithm

To reconstruct positron tracks in high hit rate condition, tracking algorithm is being developed.
For track finding, Hough transform will be used utilizing a property that high-momentum tracks leave straight lines in φ-z plane.
Track momentum will be obtained from a fitting with a Kalman filter.



Detector hits with straight lines used for track fining in φ-z plane



Detector hits with reconstructed track orbits in 3D space

Summary The positron tracking detector for the J-PARC muon g-2/EDM experiment has been developed and its design was almost fixed. Mass production of sensors is ongoing and production of FPCs on sensors was finished. Their performance evaluation and development of tracking algorithm are also ongoing.

References

[1] M. Abe *et al.*, "A New approach for Measuring the Muon Anomalous Magnetic Moment and Electric Dipole Moment", PTEP2015, 053C02 (2019), DOI: 10.1093/ptep/ptz030
[2] Y. Tsutsumi *et al.*, "Prototype Front-end ASIC for Silicon-strip Detectors of J-PARC Muon g-2/EDM Experiment", arXiv:1901.10181 (proceeding of TWEPP2018)
[3] Y. Sato *et al.*, "Performance of Front-end ASIC and its evaluation with Silicon Strip Sensor for J-PARC Muon g-2/EDM Experiment", DOI: 10.1109/NSSMIC.2017.8532754
[4] K. Shimomura, "Muonium in J-PARC; from fundamental to application", Hyperfine Interact. 233, 89 (2015).