COMET Experiment searching for muon to electron conversion

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Abstract

The COMET is dedicated to searching for charged Lepton Flavor Violation (cLFV) processes with muon to electron conversion in a muonic atom (μN→eN). A staging approach is planed for the COMET experiment . The COMET Phase-I plans to achieve a signal sensitivity of 3×10^{-15} in 2017 followed by the COMET Phase-II with the sensitivity of 10^{-17} in 2020.

Currently COMET Group is preparing the proton beam line, a muon beam section and a detector section for the COMET Phase-I (Fig1). A detector design is fixed by performance tests and constructing a Cylindrical Drift Chamber (CDC) starts.

Physics

The COMET aims at the observation of the neutrinoless muon to electron conversion. Muons are captured by the aluminum stopping target. In the COMET Phase-I, electrons emitted from muon decays are detected by the CDC.

- The μ-e coversion's signal is a mono-energetic (~104.9 MeV) electron.

$$\mu^- + (A,Z) \rightarrow e^- + (A,Z)$$

$$\mathrm{E_e = m_\mu - B_{Al} - R_{Al} \sim 104.9\ MeV}$$

B_{Al} : Binding energy of Al
R_{Al} : Atomic nuclear recoil effect

- Background is an electron emitted from a muon's three body decay with two neutrinos in an Al atomic orbit (Decay In Orbit ; DIO).

$$\mu^- \rightarrow e^- \nu_\mu \bar{\nu}_e$$

(*) Due to an Al atomic nuclear recoil, momentum spectrum of DIO electrons has a long tail near the signal region.

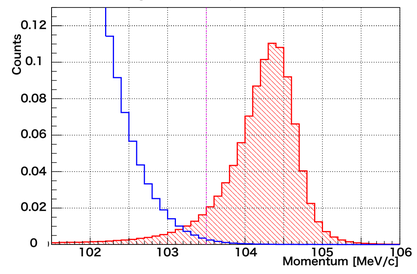


Fig2. Momentum Spectrum

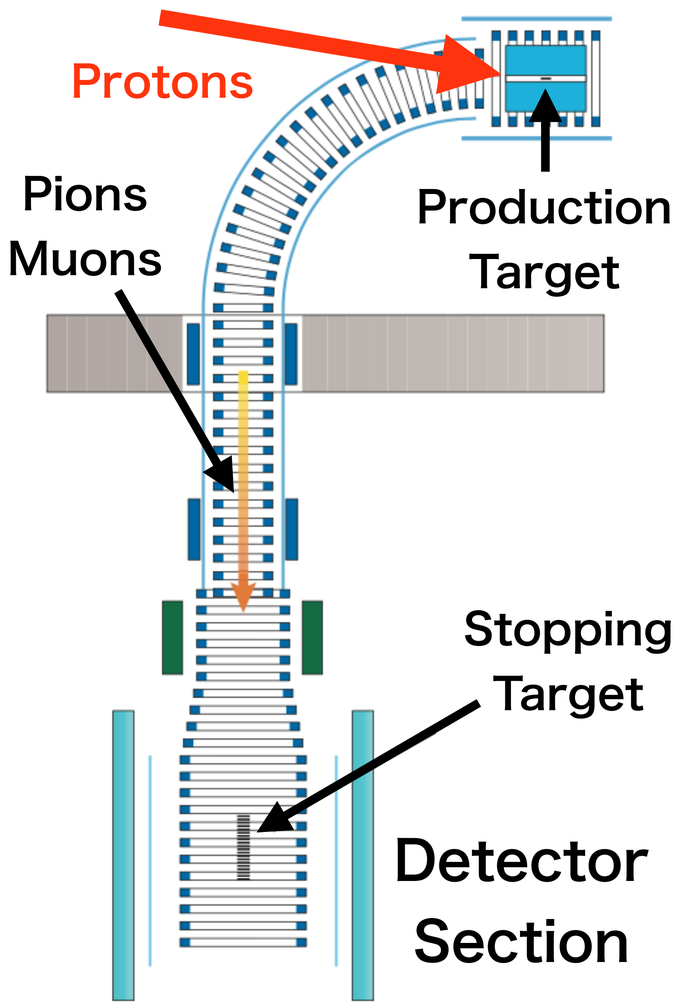


Fig1. Schematic of COMET Phase-I

Cylindrical Drift Chamber (CDC)

A momentum resolution of the CDC must be less than 200 keV/c for achieving an target sensitivity. The detector group is finalizing the CDC design and DAQ system. We start constructing the CDC and DAQ system for the CDC.

CDC → ・Electron Beam Test at Tohoku University (TingSam WONG, Development of Cylindrical Drift Chamber for COMET Phase-I)
CDC → ・Gain Test at Osaka University
DAQ → ・DAQ connection Test at IHEP in China

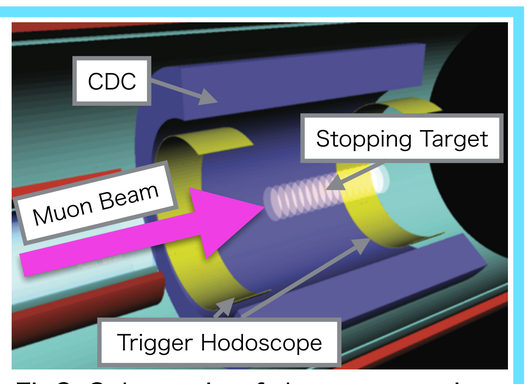
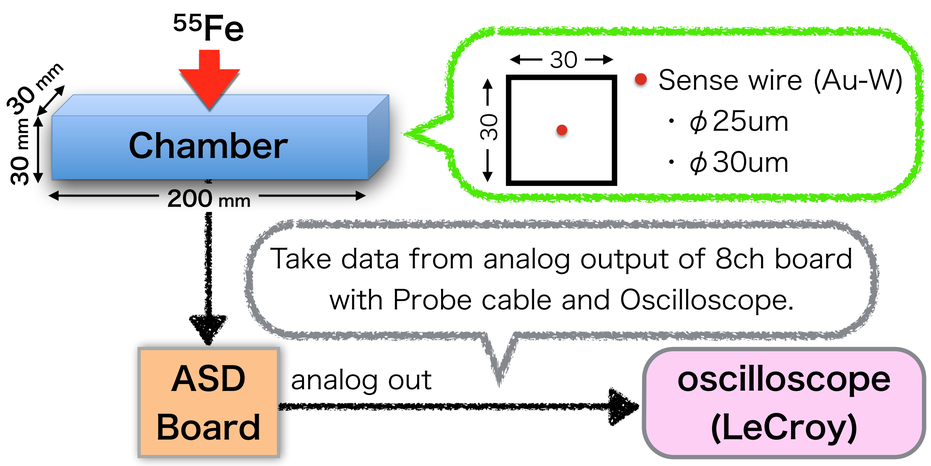


Fig3. Schematic of detector section

Gain Test

Setup



Result

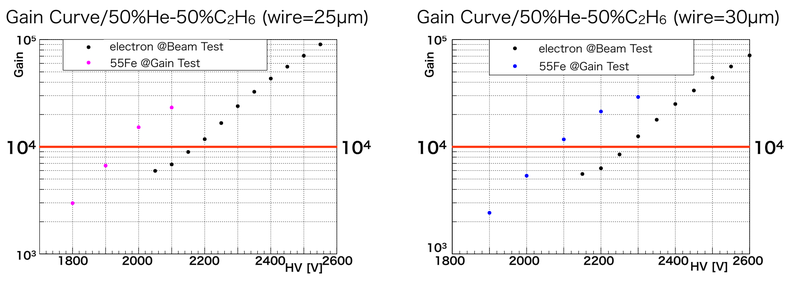


Fig 4. Gain calculation result of two tests

According to a previous design, a candidate of field wire is ϕ80 μm Al wire and sense wire is ϕ25 μm or ϕ30 μm Au-W wire. Wire diameter is decided by Electron Beam Test and Gain Test result.

・Field Wire

To avoid Aging effects, a surface E field on field wire need be less than 20 keV/cm and this corresponds to applied voltage on sense wires less than 1700 V. We want to operate the CDC with the gas gain of 10^4~10^5 for stable working. To satisfy this condition, applied voltage should be higher than ~2000 V. Ant the Beam Test result shows that the highest efficiency is ~96% which is at 2350 V. Therefore field wire is chosen to be ϕ126 μm wire to reduce the surface E field.

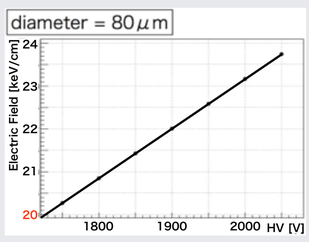


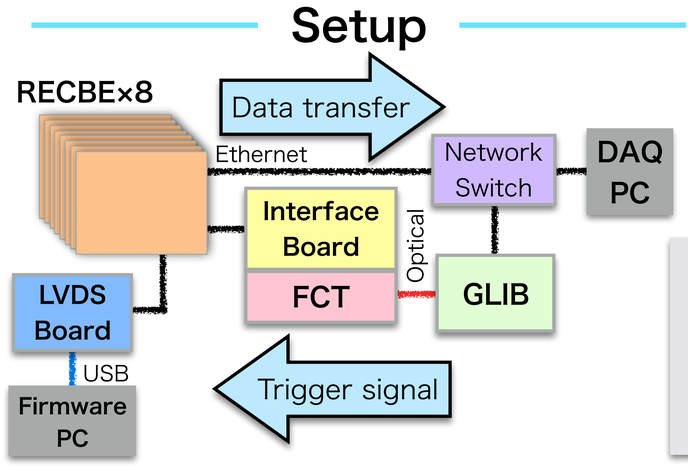
Fig5. Surface E field of field wire

・Sense Wire

For low energy electron search, the momentum resolution of the CDC is dominated by multiple scattering effects. Therefore the CDC must be a low-mass detector. According to two tests, both sense wire candidates can work stability. Therefore the diameter of sense wire is fixed to ϕ25 μm.

DAQ connection Test

Setup



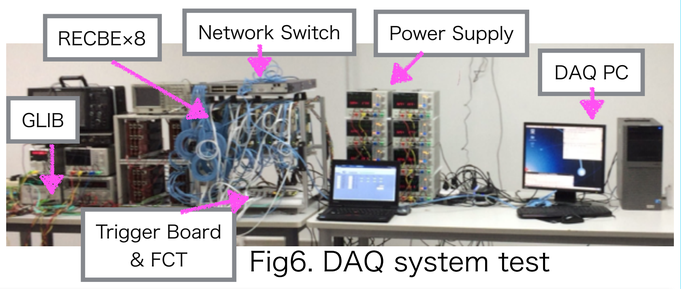


Fig6. DAQ system test

Check List

(1) New RECBE for COMET works or not
(2) Firmware download through Ethernet
(3) RECBE-FCT-GLIB communication

Result

(1) In the COMET Phase-I, the RECBE which is an electric circuit developed by Belle-II Group for data acquisition is used the CDC's DAQ system. We can get a data of waveform made by a function generator from new RECBEs reproduced for COMET at IHEP with using this setup.

(2) Firmware download through Ethernet cables (Cat 7) is successful. So we can download the firmware by remote operation at a beam time.

(3) On the COMET Phase-I, GLIB (Trigger Decision and Timing Control Electronics) connects the CDC with trigger detector. And FCT connects RECBEs with GLIB. So we have to check these communication to send a trigger to RECBEs through GLIB and FCT. Three following tests are successful.

- Send a trigger number from GLIB via FCT and record this number to DAQ PC through SiTCP of RECBEs
- Send busy signals from RECBEs to GLIB via FCT to stop the trigger sending
- Send a 40MHz clock from GLIB via FCT to RECBEs and synchronize among RECBEs

CDC Construction

According to these results, the CDC design is fixed. Thereby Detector Group starts constructing the real CDC at FUJI experimental building in KEK. And a mass-production of RECBEs for the CDC is about to start at IHEP.

Fig7. outside appearance of the CDC

Fig8. Endplate of the CDC

Summary & Prospect

- The COMET Phase-I is searching for the electron emitted from μN→eN with the sensitivity of 10^{-15} to discovery cLFV process.
- A construction of CDC and DAQ system starts. At last a preparation for COMET Phase-I greets the climax.
- The prototype of the CDC was constructed with new design and the final performance test will be done in this summer.