Construction and performance tests of the COMET CDC

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On behalf of the COMET Collaboration

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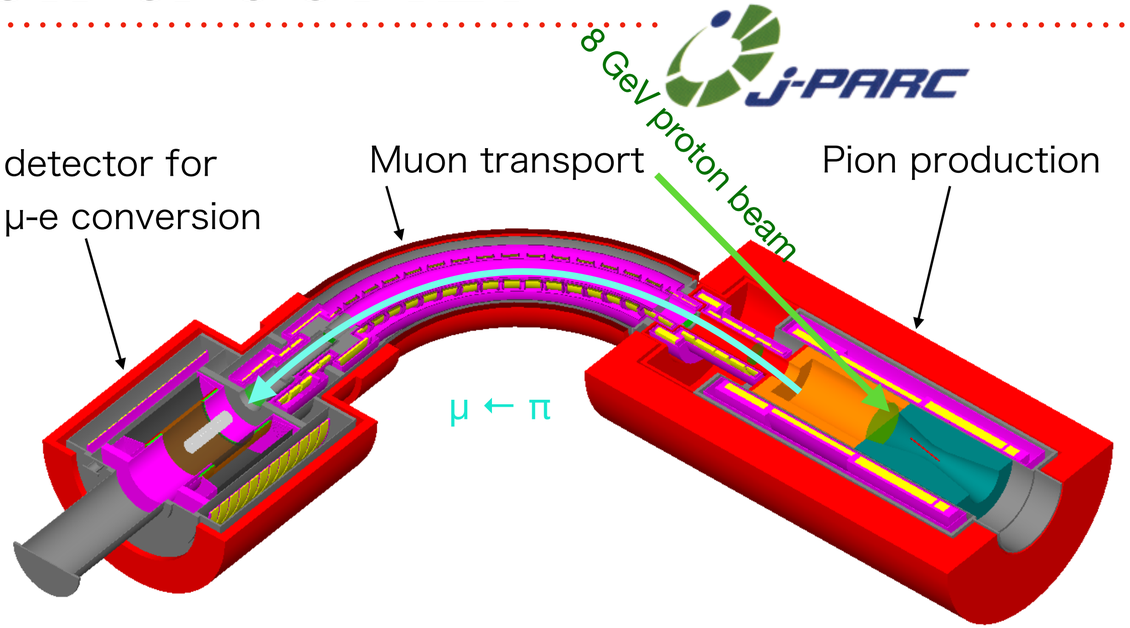
μ-e conversion & COMET

COMET talk by D.Grigoriev
15:40, 7 July @102

COMET Phase-I Layout



- The COMET experiment at J-PARC searches for the neutrinoless coherent transition of a muon to an electron in the field of an aluminum nucleus, which violates the lepton flavor conservation and has never been observed yet thus far.

$$\mu^- N \rightarrow e^- N$$

- The conversion rate is predicted to be enhanced in new physics models beyond the Standard Model, while the process is extremely suppressed in the Standard Model.
- The goal of the COMET is to explore the μ-e conversion with single event sensitivity of 3×10^{-15} and 3×10^{-17} in Phase-I and Phase-II, respectively, which is 100 and 10,000 times better than the current limit.
- COMET Phase-I:
  - J-PARC 8GeV-3.2 kW proton beam → Capture Solenoid → Transport Solenoid (90-deg bend) —> Cylindrical Detector System

Signal & background

- The signal of the μ-e conversion is **~105 MeV** mono-energetic electrons,

$$E_{\mu e} = m_{\mu} - B_{\mu} - E_{\mathrm{rec}} = 104.97 \text{ MeV for Al}$$

- while the backgrounds are
  1. Decay-in-orbit (DIO) electrons
  2. Prompt beam-related BG
  3. Cosmic-ray induced BG.

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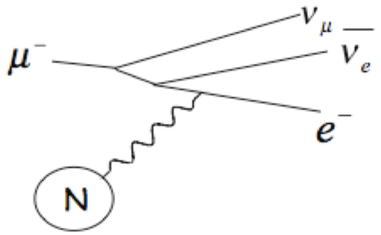
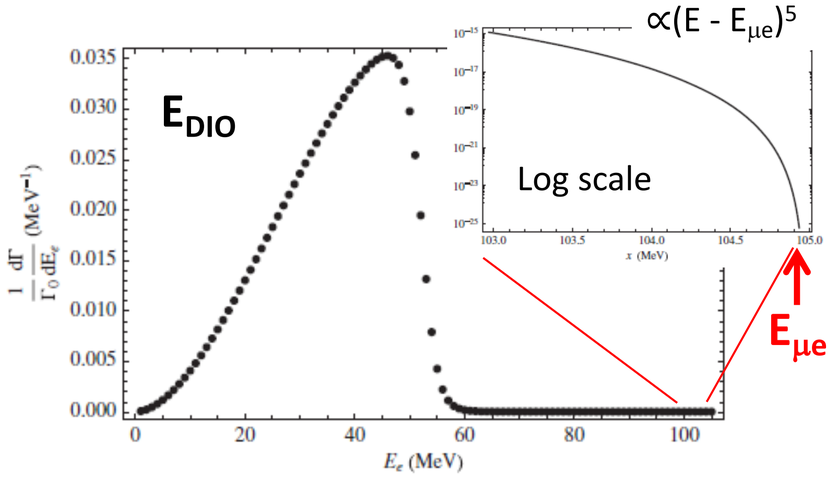
Inevitable physical BG

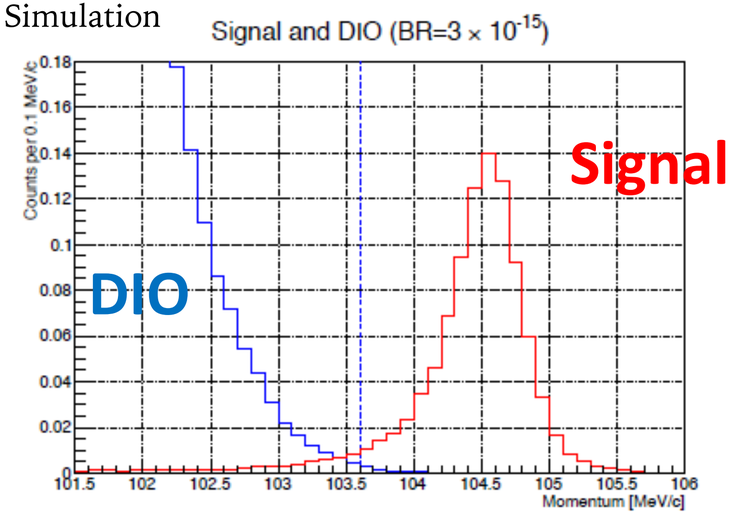
- In order to distinguish the signal from the background, good momentum resolution of **200 keV/c** is required.



Muon Decay in Orbit (DIO)



Simulation

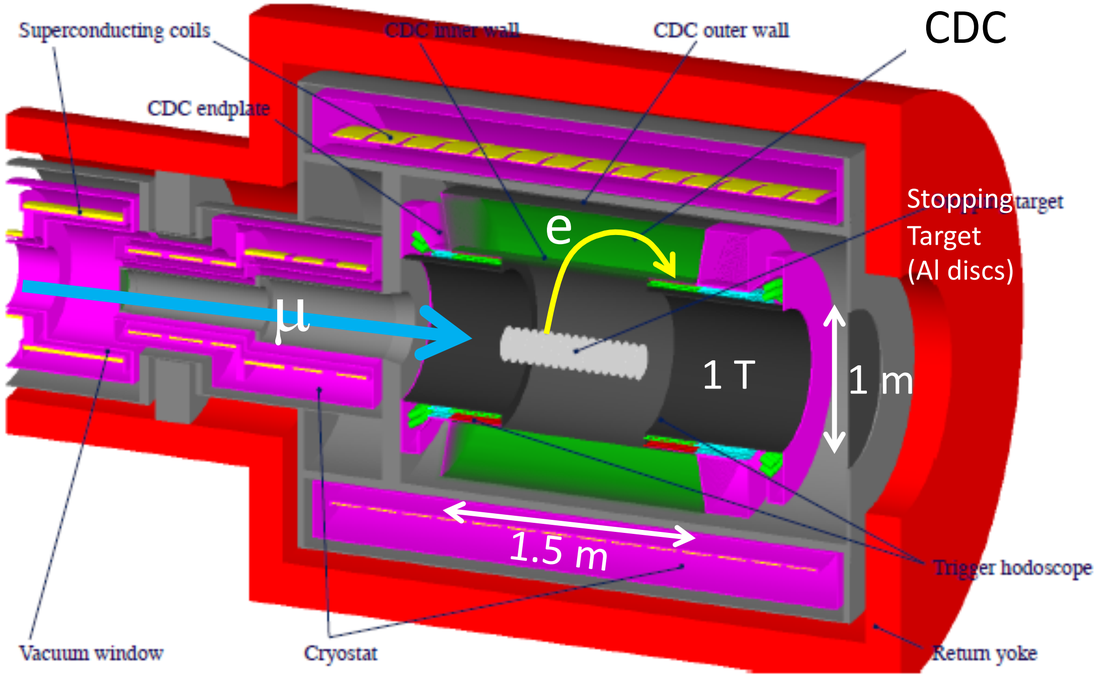


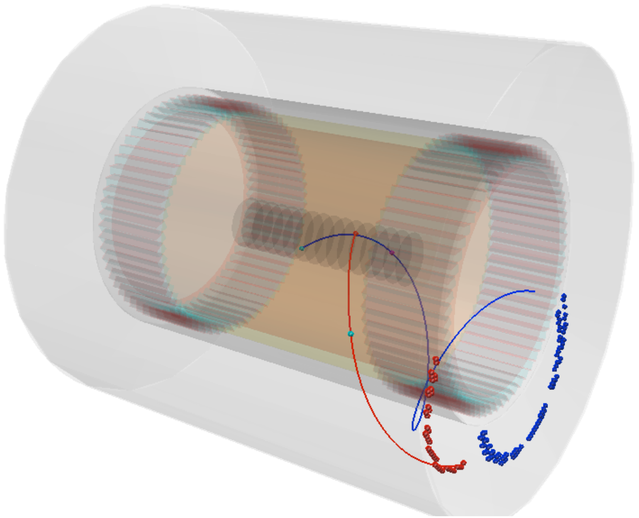
E_{DIO} can have a high-energy tail, which is in principle reach $E_{\mu e}$.

COMET CDC

- In the COMET Phase-I, the converted electrons, which possess monochromatic momentum of 105 MeV/c, are detected with a **cylindrical drift chamber (CDC)** in a solenoidal magnetic field of **1 T**.
- Trigger signals are issued by a combination of **scintillation & Cherenkov hodoscopes** placed at inner side both upstream & downstream of CDC.
- In this low momentum region around 105 MeV/c, momentum resolution is dominated by the multiple-scattering effect.
- In order to realize the excellent resolution of **200 keV/c**, low-mass tracking region is essential.

- **He:i-C_4H_{10} (90:10)** gas mixture for CDC
- **Al field wires** with 126-μm diameter
- Thin CFRP inner wall with **0.5 mm**





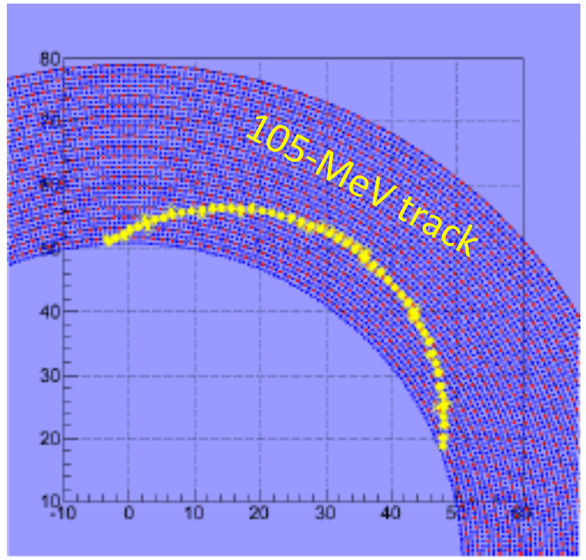
#Note: target volume is filled with He gas.

Al target consists of 17 discs with 100-mm radius, 0.2-mm thickness, & 50-mm spacing.

Design of CDC

Feature of CDC Specification:

- **Large inner diameter of ~1 m**
  - Most of DIO electrons (< 60 MeV/c) do not reach CDC
- Cell structure
  - **Alternating all stereo layer**: 64~75 mrad
    - for good resolution in longitudinal direction



Electron drift lines

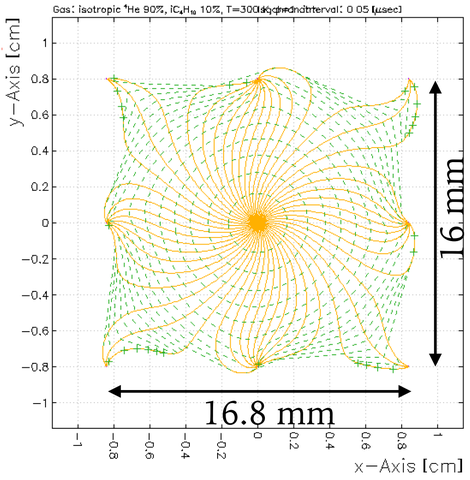
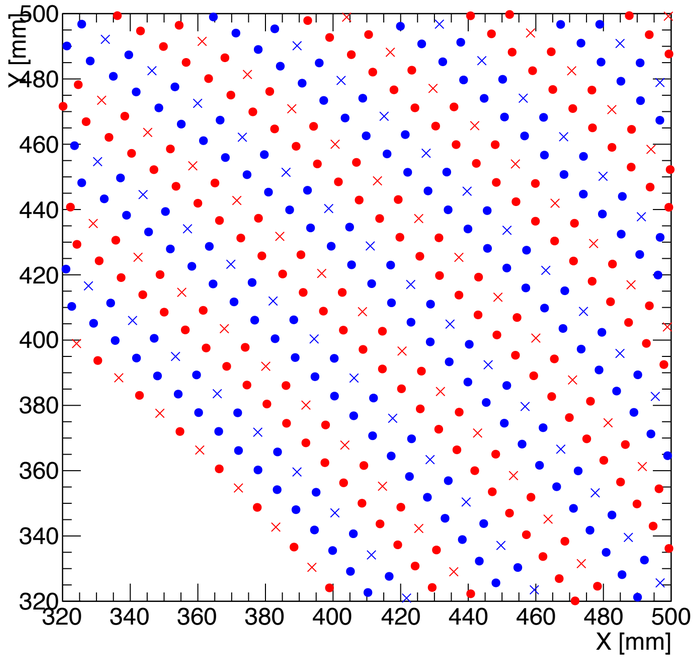


Table 7.1: Main parameters of the CDC.

Inner wall	Length	1495.5 mm
	Radius	496.0~496.5 mm
	Thickness	0.5 mm
Outer wall	Length	1577.3 mm
	Radius	835.0~840.0 mm
	Thickness	5.0 mm
Number of sense layers		20 (including 2 guard layers)
Sense wire	Material	Au plated W
	Diameter	25 μm
	Number of wires	4986
	Tension	50 g
Field wire	Material	Al
	Diameter	126 μm
	Number of wires	14562
	Tension	80 g
Gas	Mixture	He:i-C_4H_{10} (90:10)
	Volume	2084 L

Z=0



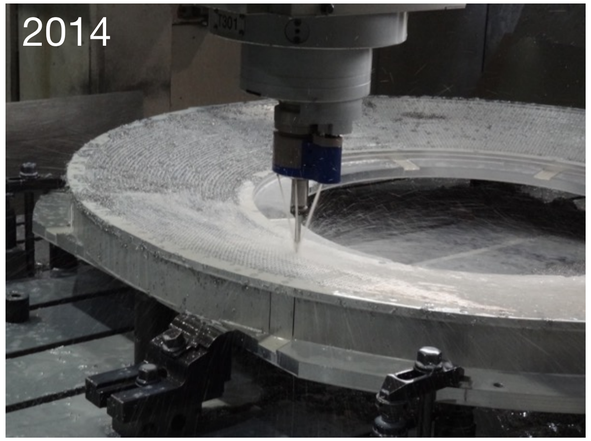
× sense wire

• field wire

Stereo angle:

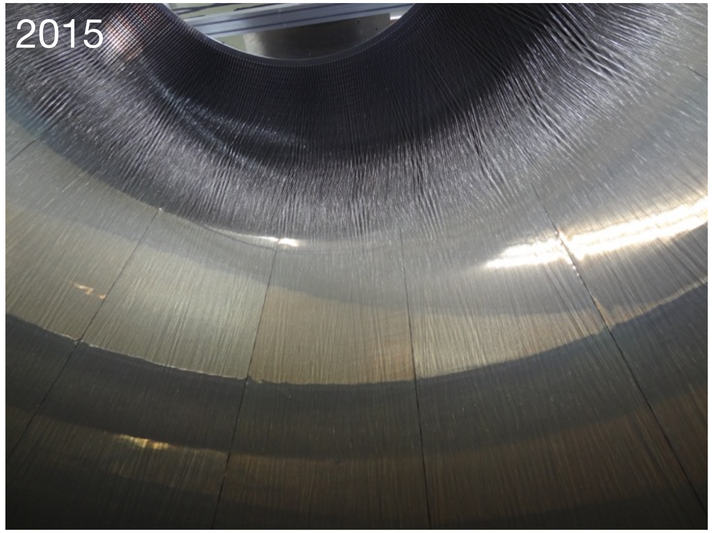
\+ -

Construction of CDC

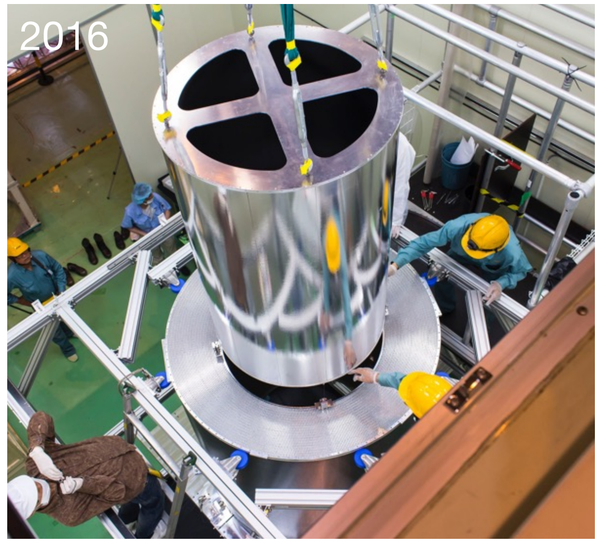


Drilling holes on endplates
with precision of 50 μm

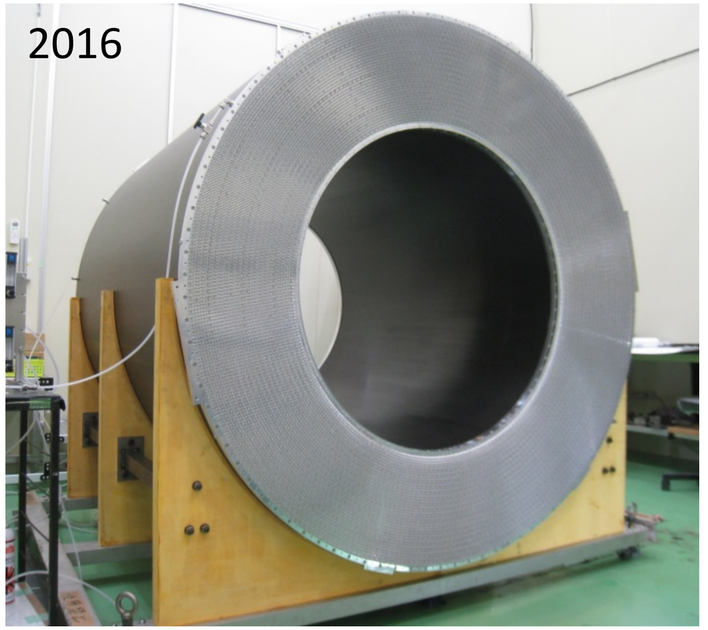
Outer structure was transported to a KEK assembly hall,
and set on a wire stringing cradle.



Wire stringing and tension measurement
for 19,548 wires were carried out in a half year.

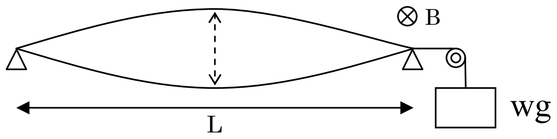


Installation of inner wall
made of 0.5-mm thick CFRP



Completion of COMET CDC

Wire tension assurance



Resonant Frequency: $f = \frac{1}{2L}\sqrt{\frac{wg}{\rho}}$,

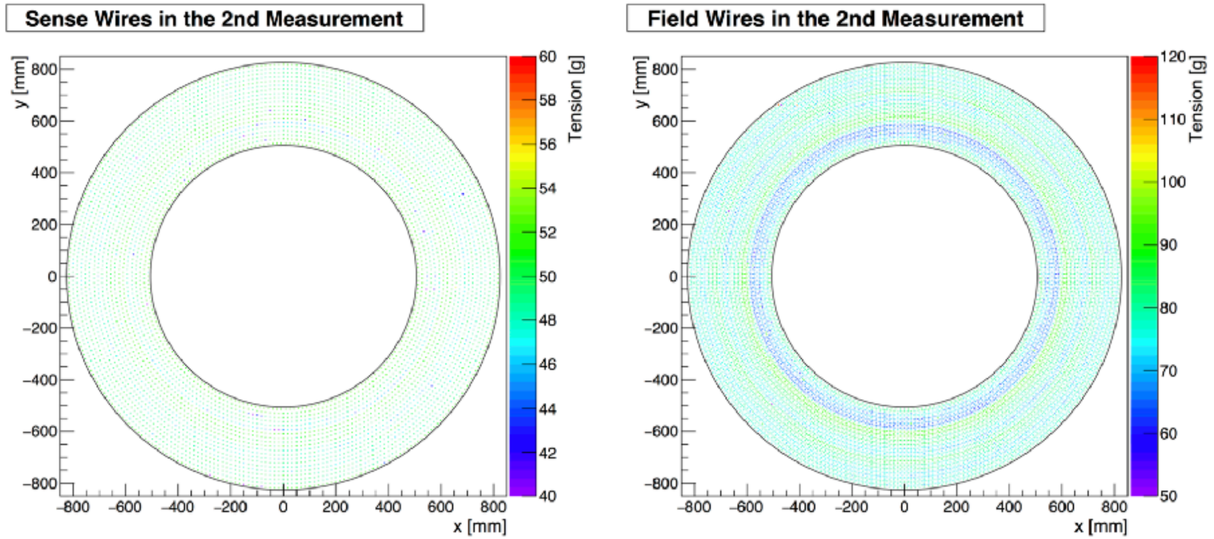
ρ = wire linear density

Nominal value	Material	Diameter	Tension	Sag
Sense	(Au-)W	25 μm	50 g	~50 μm
Field	Al	126 μm	80 g	~120 μm

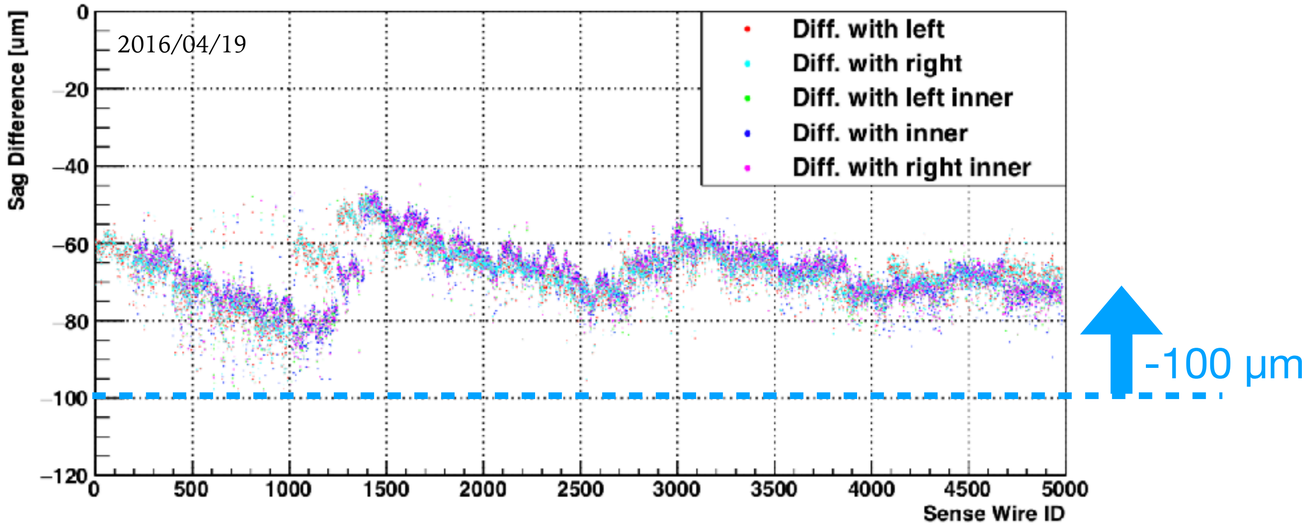
L = 1477~1593 mm

Gravitational Sag: $s = \frac{\rho L^2}{8wg}$.

Criteria
- Sag for sense wire < 70 μm
- Sag difference with neighbor wires < 100 μm



(b) Sag differences between a sense wire and surrounding field wires

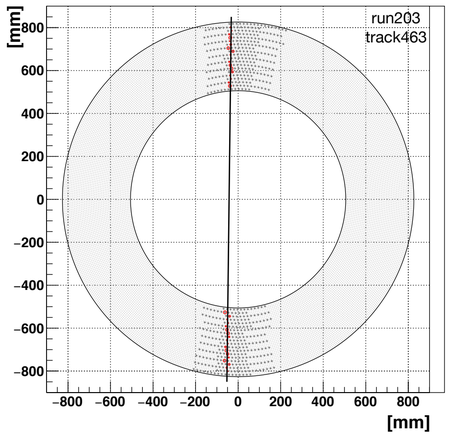


After replacing bad wires, all the wires satisfy the criteria.

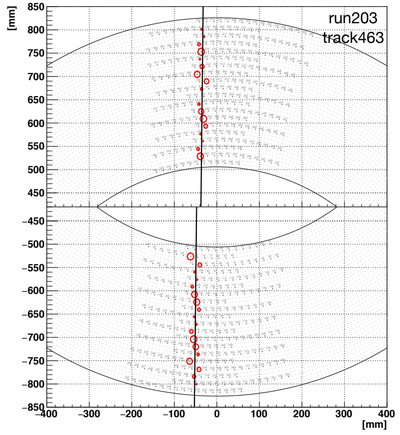
Performance tests

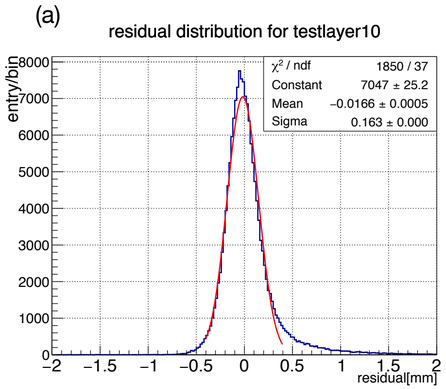
- CDC performance tests using cosmic rays are being carried out with step-by-step upgrade of readout & surrounding systems as well as analysis scheme.
- We have obtained spacial resolution of **170 μm** & efficiency of **95%** so far.
- The performance tests will be continued in this year to precisely investigate whole region of the CDC.

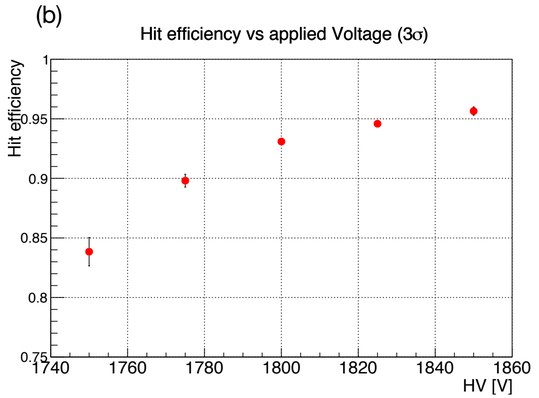
(a) Event Display

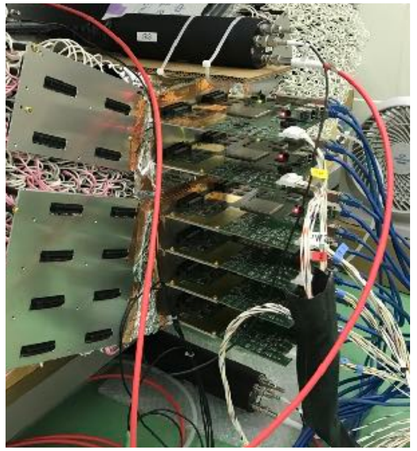


(b) Zoom view









Summary

- The COMET experiment aims to search for the μ-e conversion. Preparation for the COMET Phase-I is intensively in progress.
- Cylindrical detector system is used for the Phase-I physics measurement.
- COMET CDC is designed to achieve 200-keV/c momentum resolution for 105-MeV/c signal electrons.
- Construction of CDC was successfully completed.
- Performance tests are ongoing and reasonable resolution & efficiency are obtained so far.

Prospects

- Performance tests will be finished in this fiscal year.
- We plan to transport CDC from KEK to J-PARC and install to Detector Solenoid in 2019.
- Integrated cosmic-ray BG measurement will start from 2020.