Research and Development of the COMET trigger counter

Feb 18th 2024　30th ICEPP Symposium

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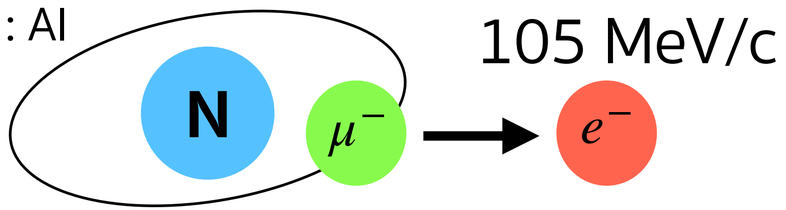
Contents

COMET experiment

COMET (COherent Muon to Electron Transition)

Search for Charged Lepton Flavour Violation @J-PARC



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

μ-e conversion rate

$< O(10^{-54})$ in the Standard Model (SM)

$\sim O(10^{-15})$ in BSM

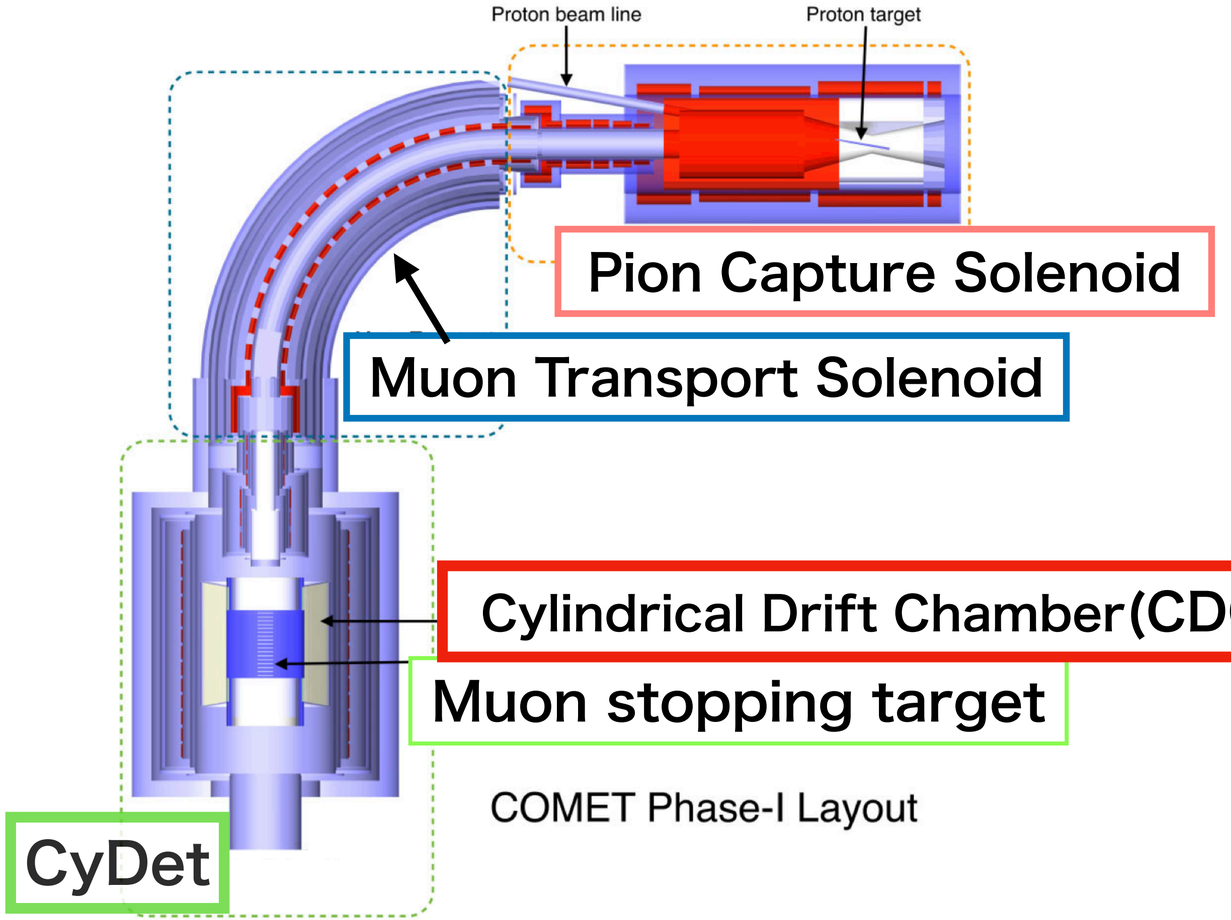
COMET Phase-I (2026?)

Single event sensitivity : 3×10^{-15}

COMET Phase-II (203X)

Single event sensitivity : 3×10^{-17}

Cf) SINDRUM II (Au target): 7×10^{-13}



CyDet (Cylindrical Detector system)

CDC (Cylindrical Drift Chamber)

Specifications

- Drift chamber with 4967 sense wires

Purpose

- Tracking particles
- Measuring momentum of particles

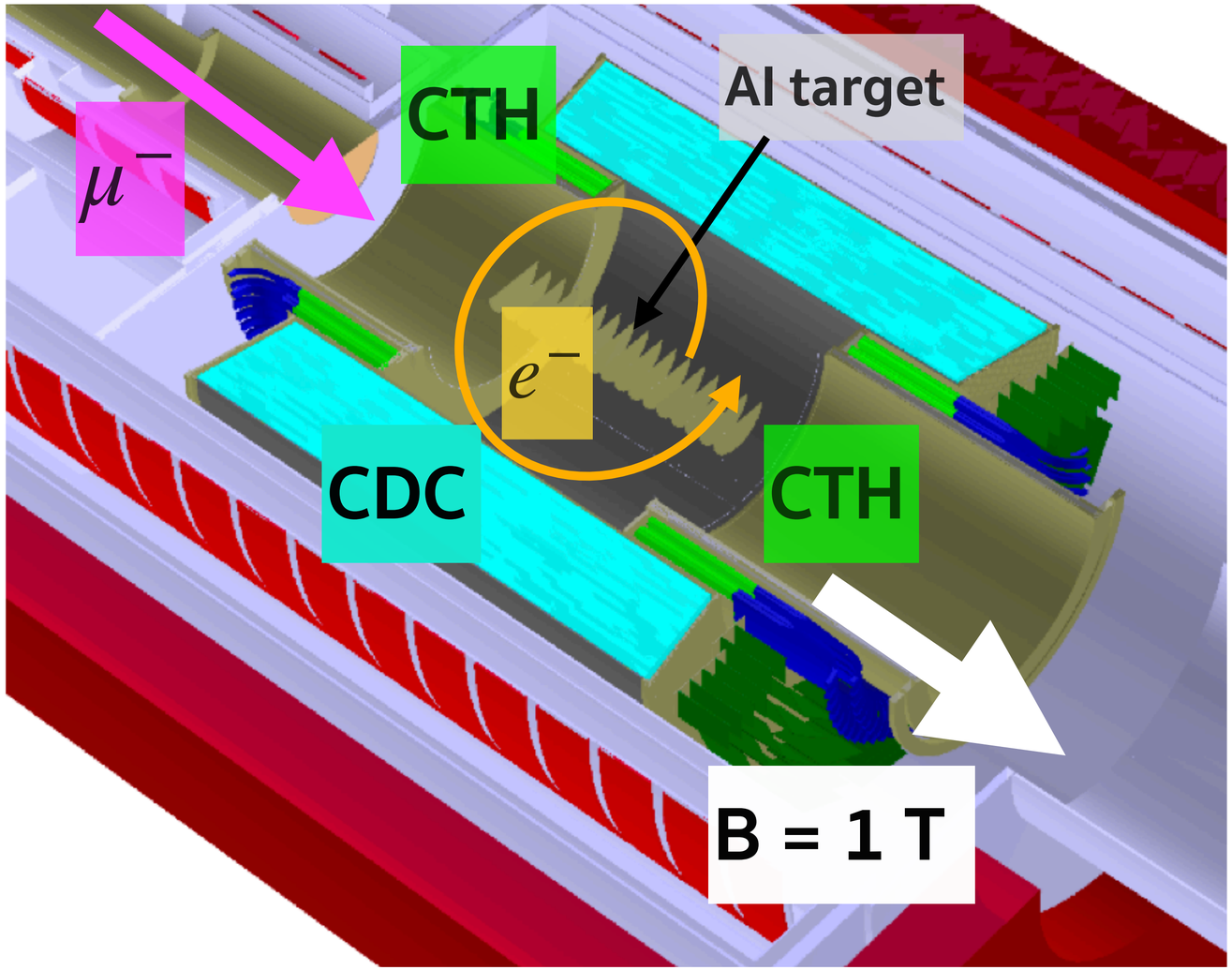
CTH (Cylindrical Trigger Hodoscope)

Specifications

- 4-fold coincidence

Purpose

- Timing of signal event and trigger signal
- Make CDC to start taking data



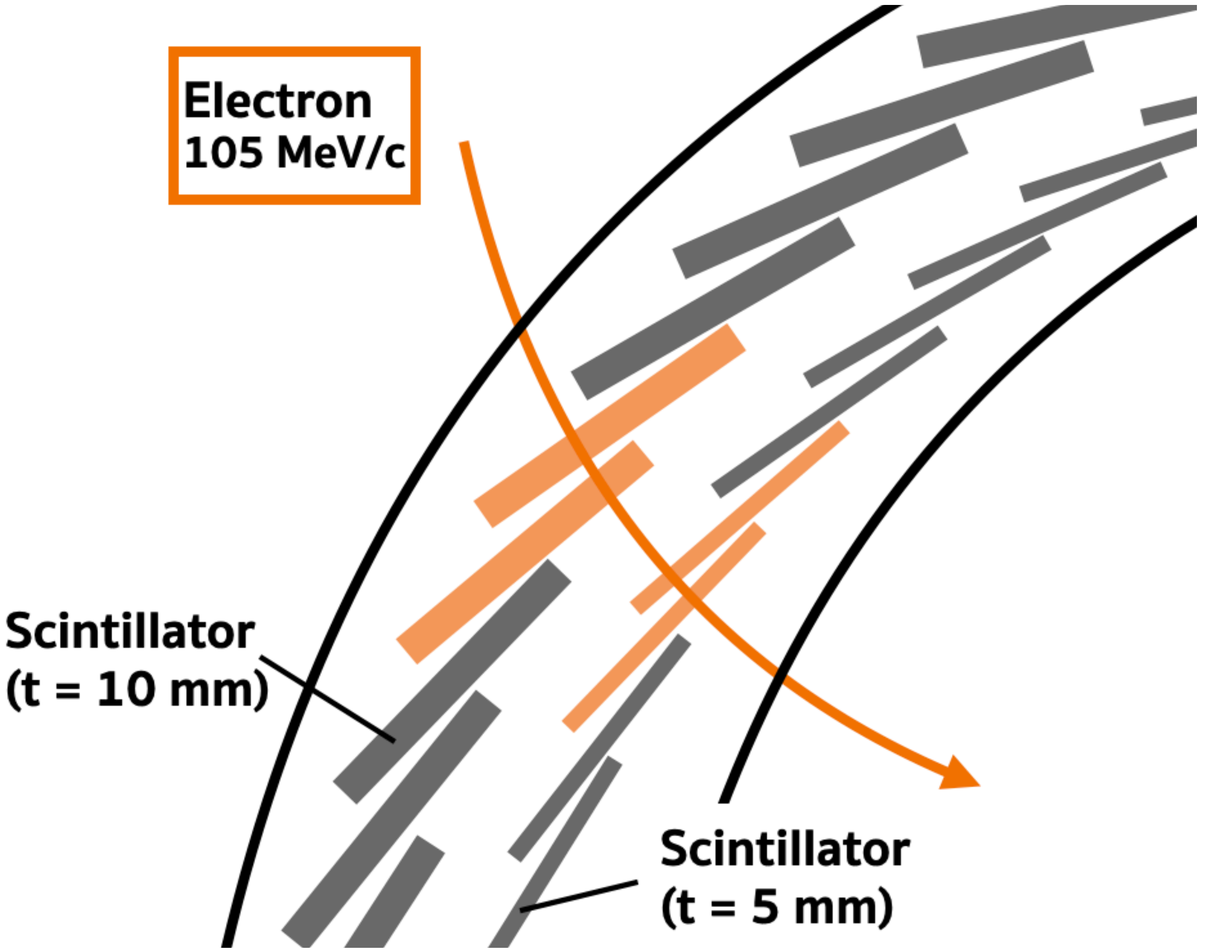
CTH (Cylindrical Trigger Hodoscope)

The requirements

- Time resolution ≦ 1 ns
- **~40 p.e. for electrons around 105 MeV/c**

SiPM will be damaged by neutron in physics run
-> increasing dark pulse

To making a trigger properly,
sufficient amount of light output is needed.



Situation

The design of CTH is almost finalized.

->We made a part of CTH with optical fibre, SiPM, scintillators for performance evaluation.

Making the realistic CTH prototype

Same as actual setup :

- **Scintillator** : Saint Gobain crystals BC-408

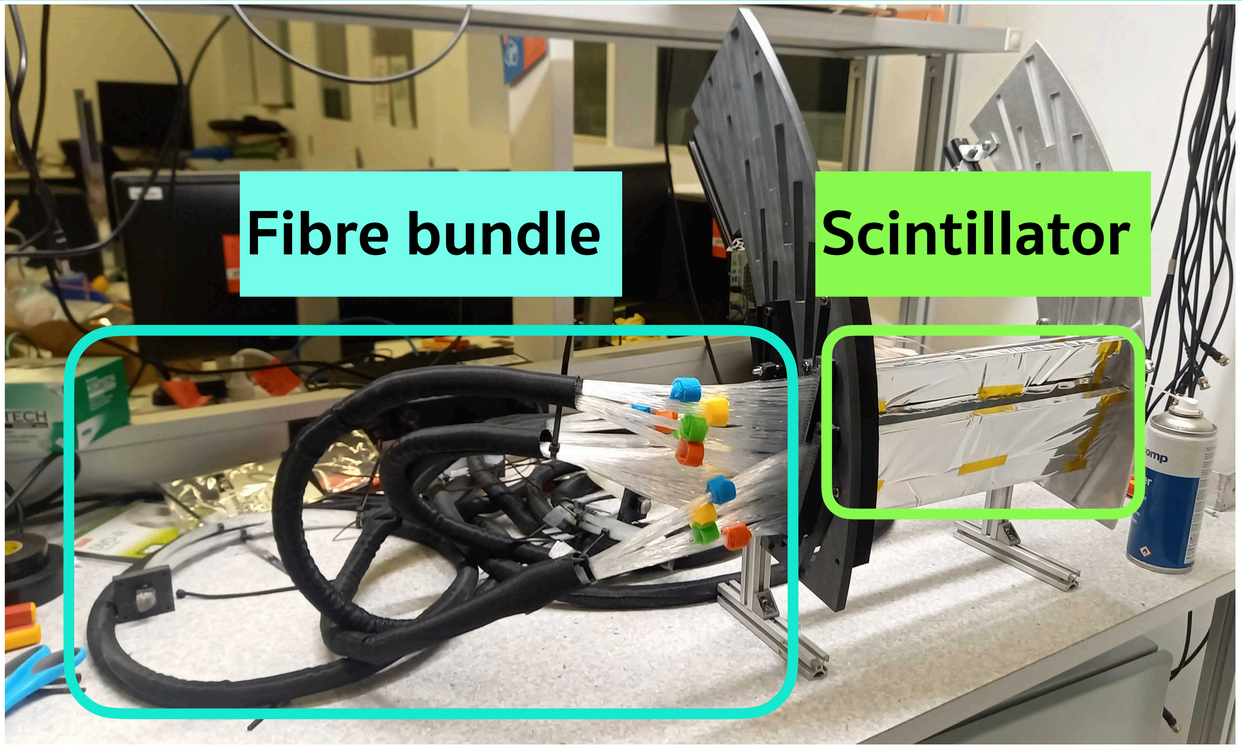
  A,B 370 mm x 80 mm x **5 mm**

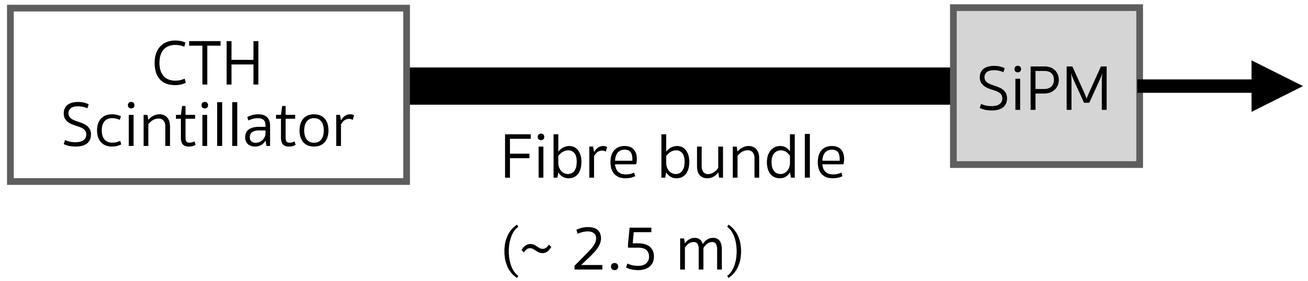
  C,D 340 mm x 88 mm x **10 mm**

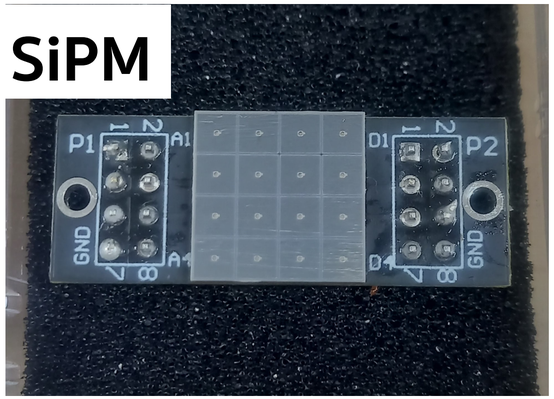
- **Optical fibre** 124 per a counter

  In the real experiment, 5.0 m and 7.5 m fibre will be used.

- **SiPM** : HAMAMATSU S14161-3050HS-04







Performance evaluation

The requirements

- Time resolution ≦ 1 ns
- **~40 p.e. for electrons around 105 MeV/c**

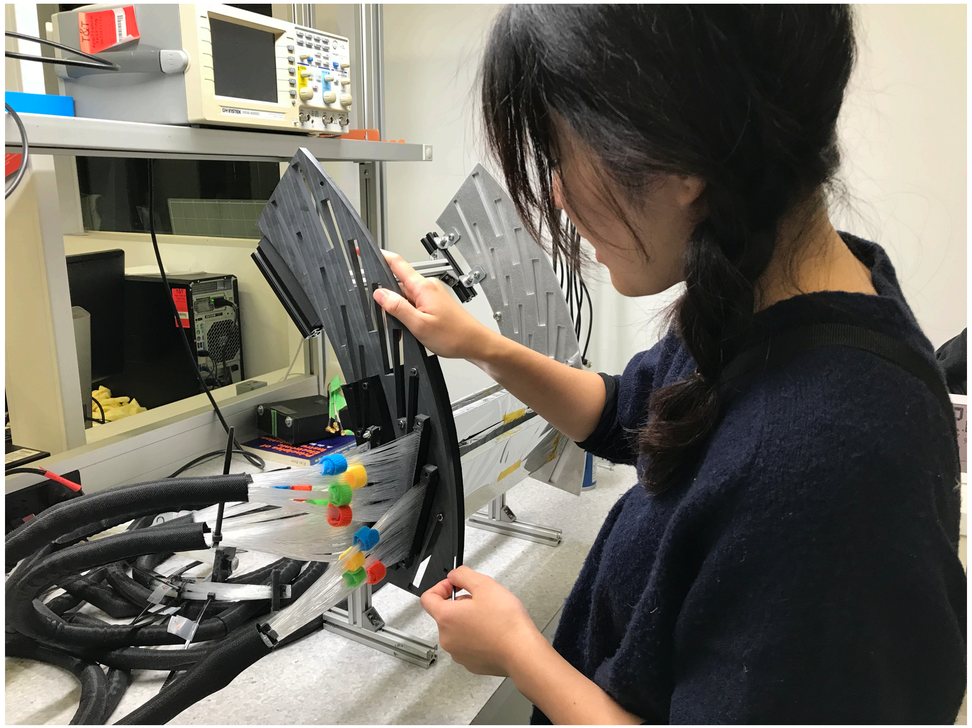
Motivation

Understanding the response for particles

Checking the detector response in detail

Reducing muon background

Muon around 105 MeV/c can be background.



Making the realistic CTH partly

The detector performance was evaluated at PSI (Paul Scherrer Institut)

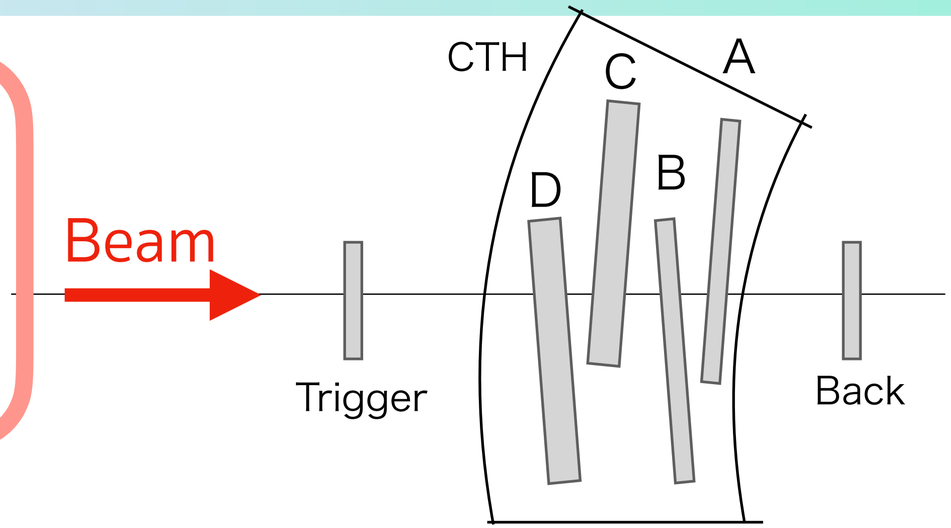
Beam time at PSI

πM1 beam line

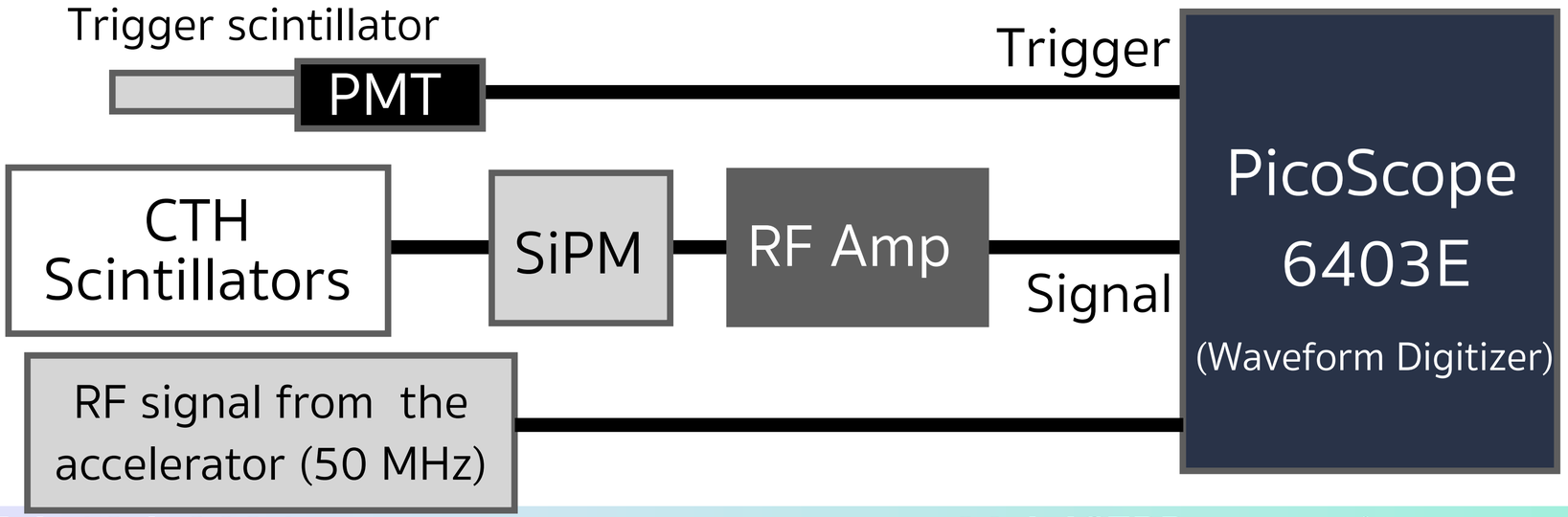
Negative beam e^-, μ^-, π^-

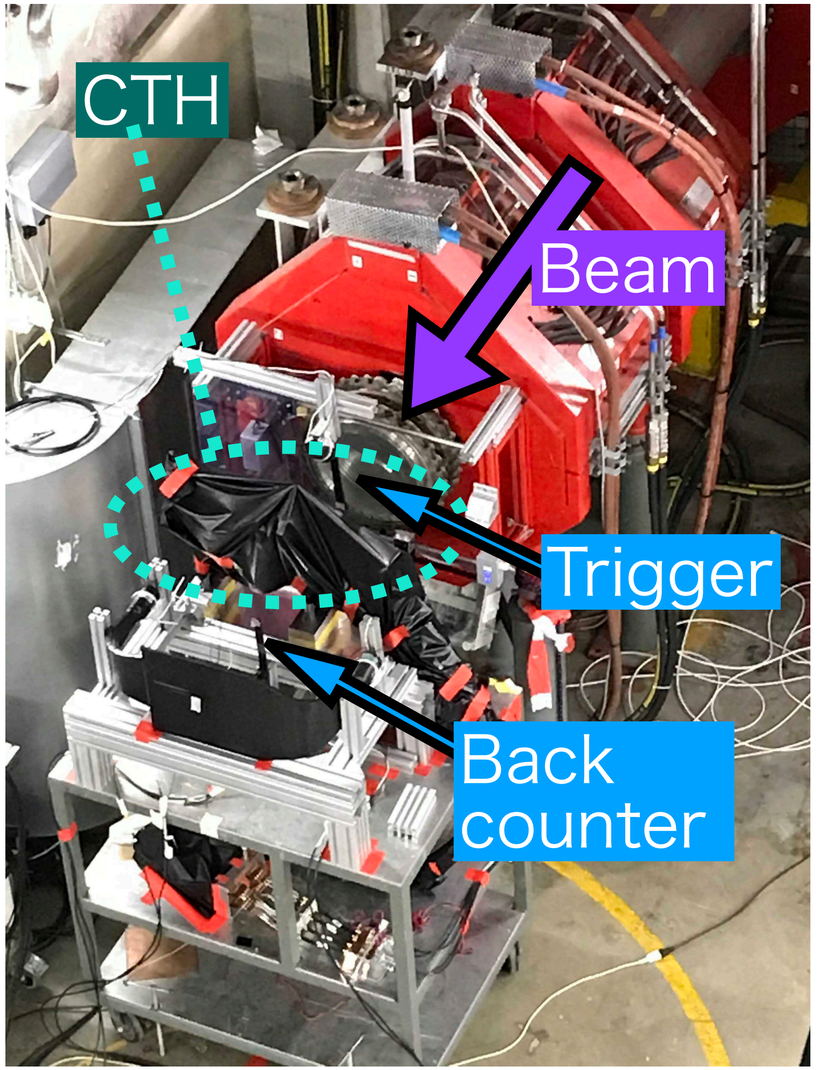
Positive beam e^+, μ^+, π^+

105 MeV/c, 125 MeV/c

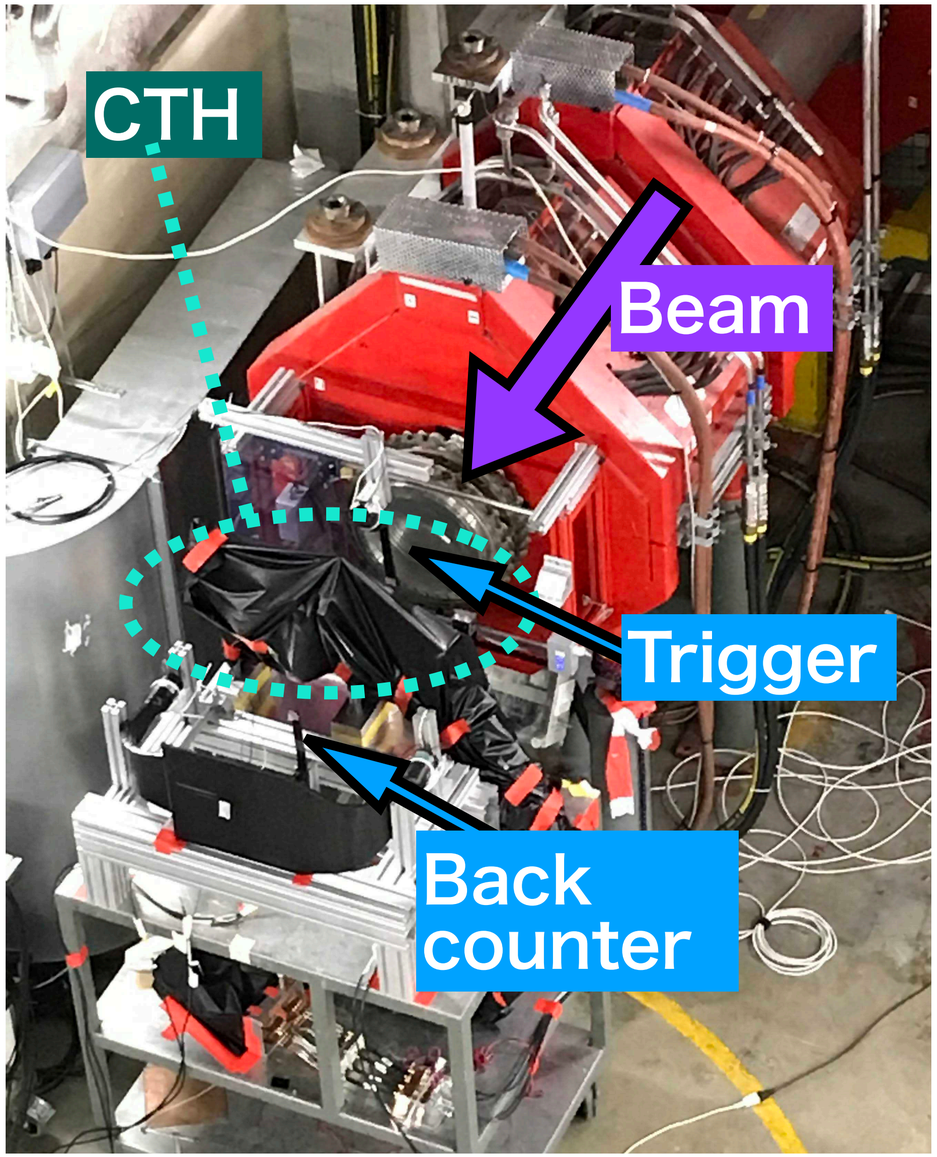


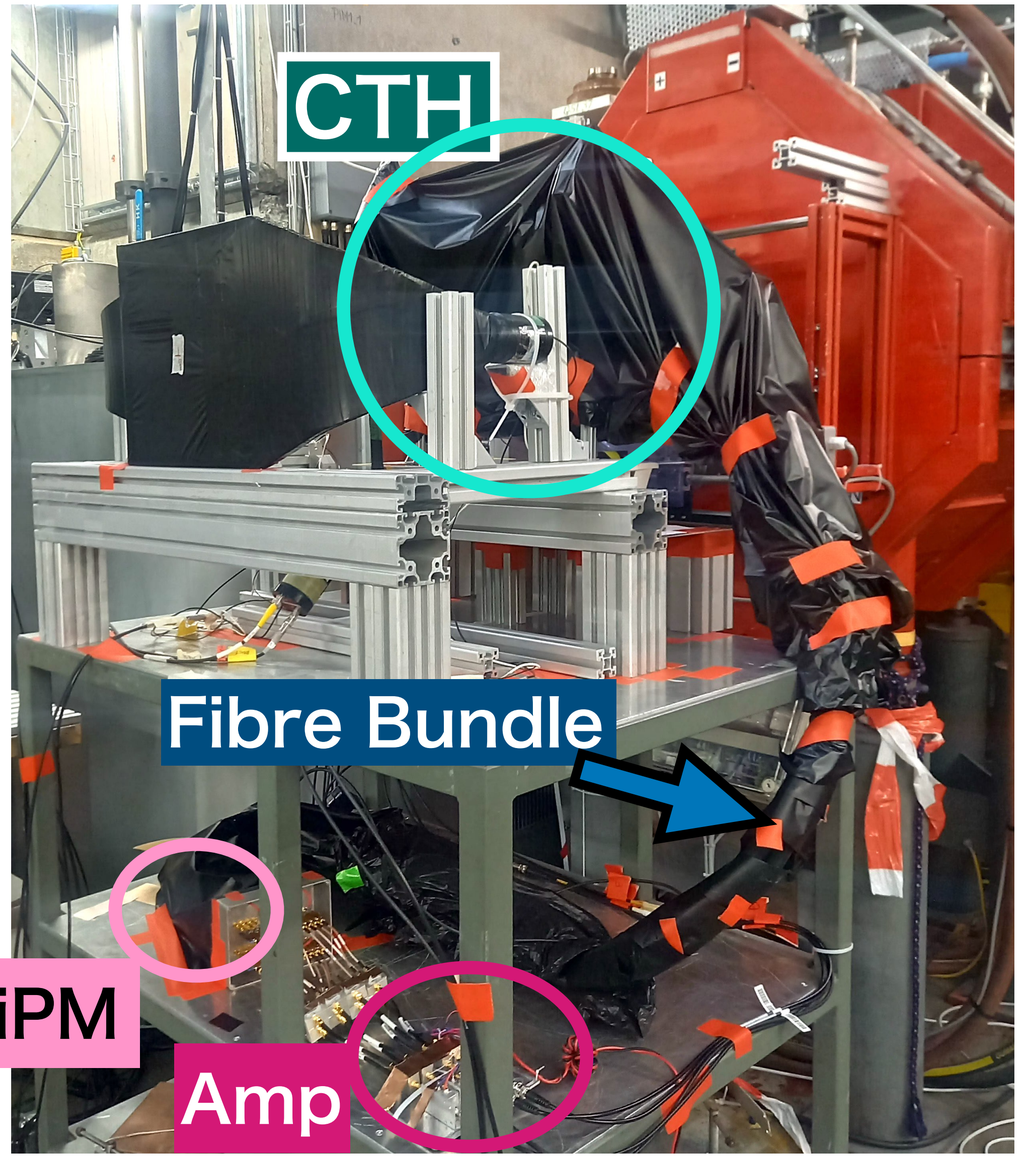
Back counter is a thin plastic scintillator which is placed to check scattered particles.





Pictures of the beam time

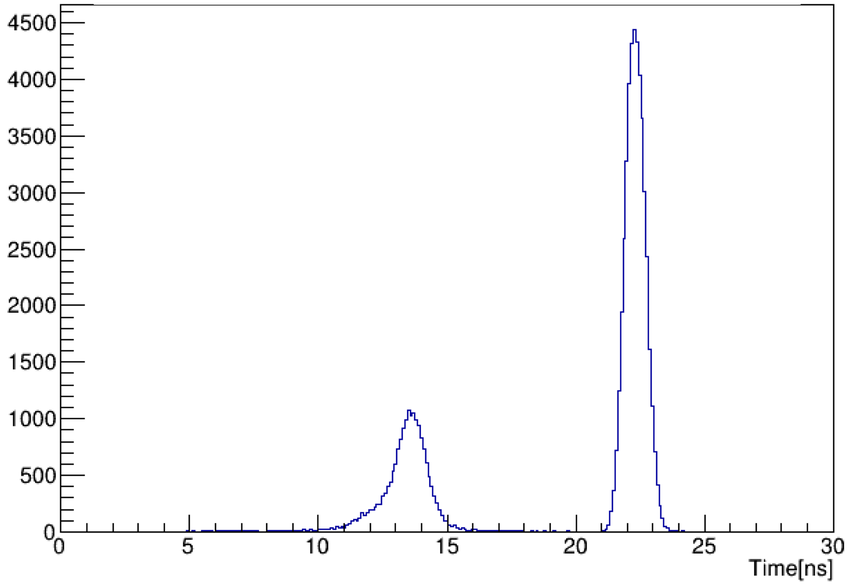




Definition of TOF

Time of flight (TOF)

TOF at trigger counter

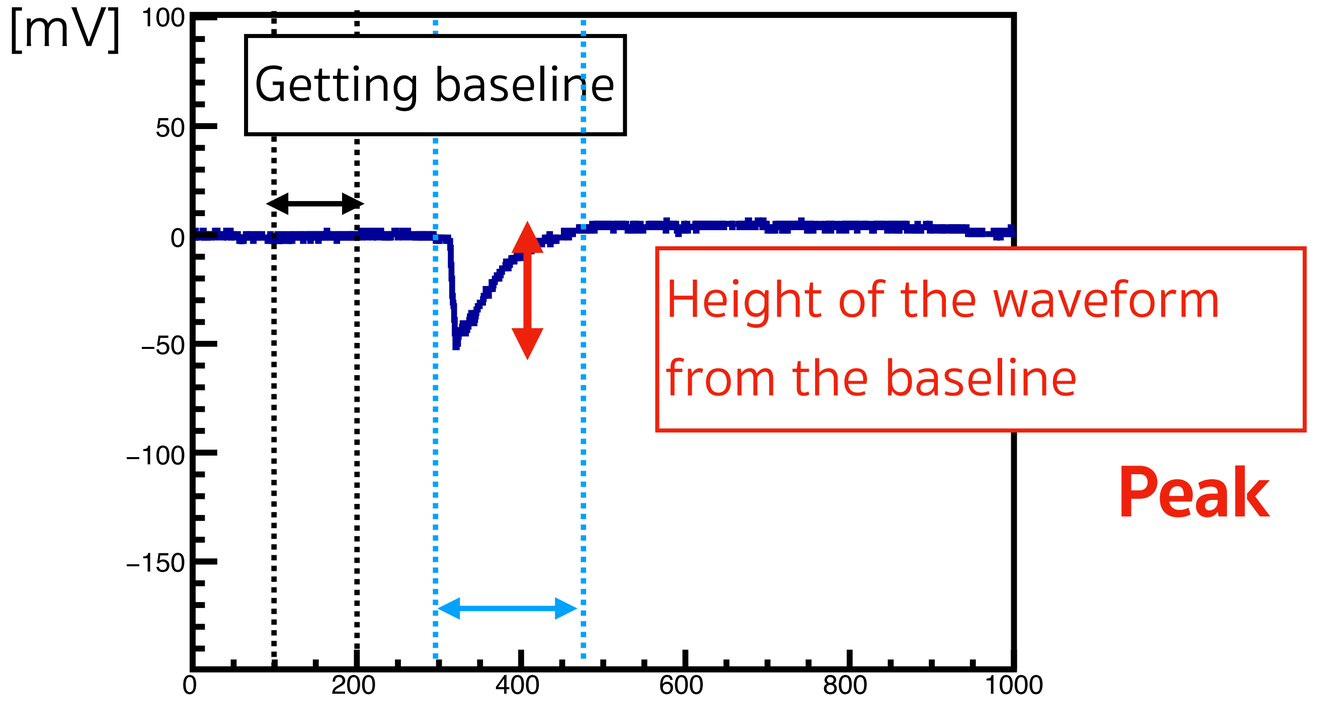


50 MHz (1 period = 20ns)

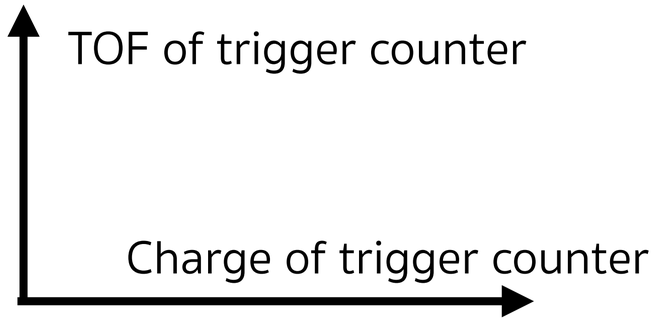
Time of flight is defined as t_{trig} - t_{RF}, where t_{RF} is an RF signal timing given by the accelerator.

Peak and Charge

A waveform of CTH counter



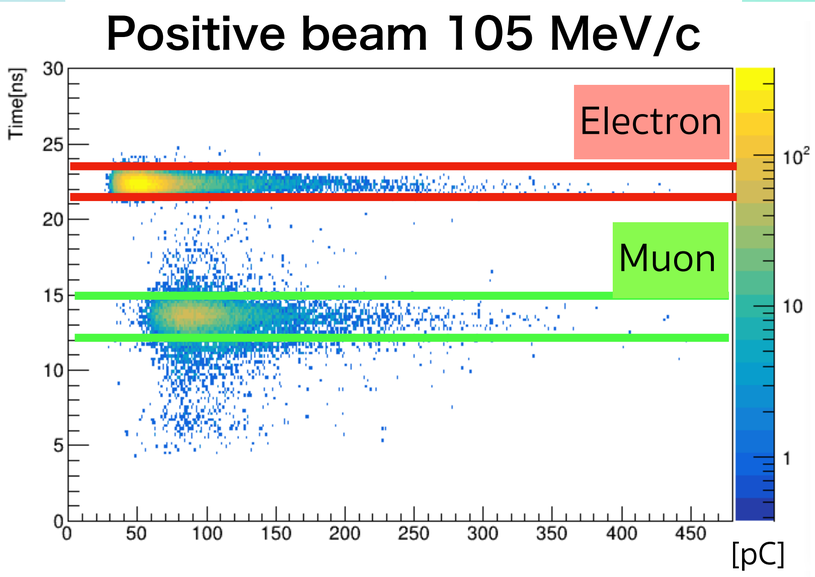
Particle identification by using TOF

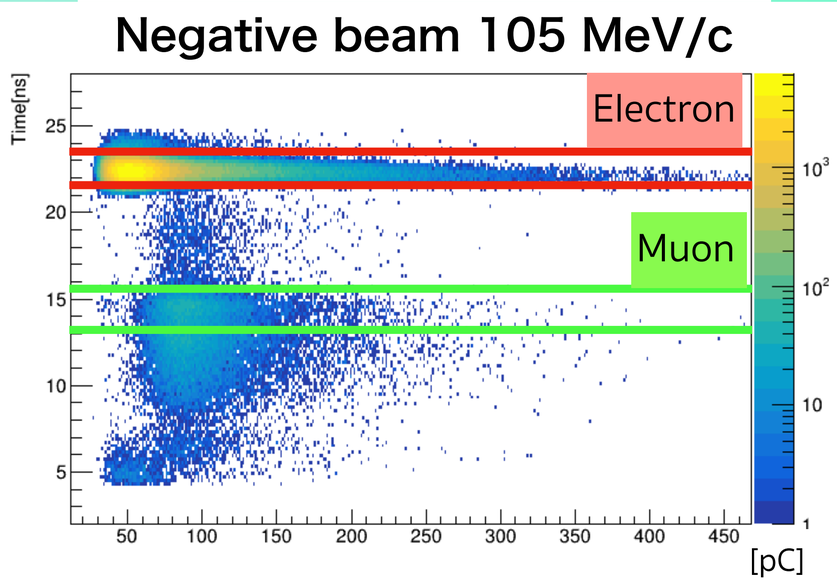


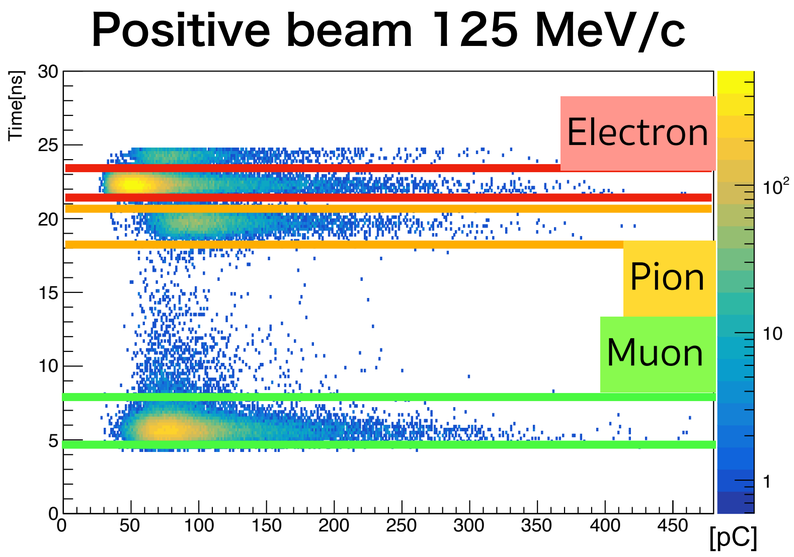
The particles with the same PID and momentum have the same TOF

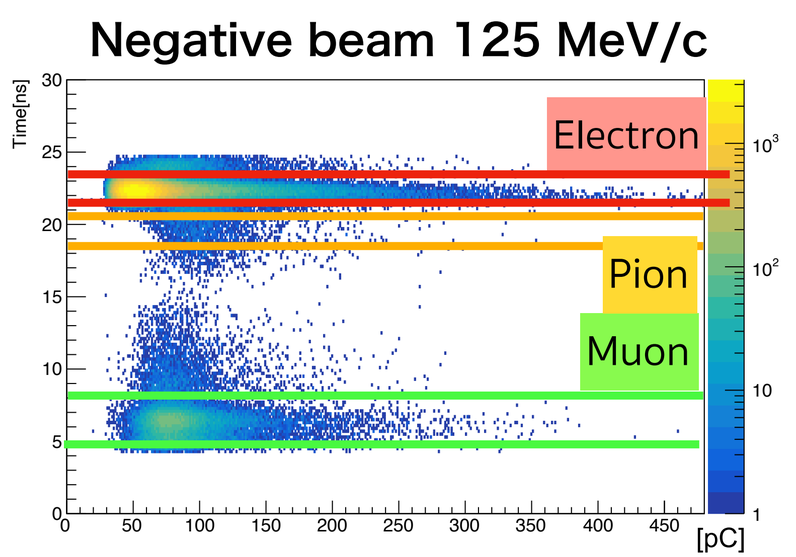
Both positive/negative particles showed the same TOF at the same momentum.

Setting the time range shown by colour lines to sort the particles.









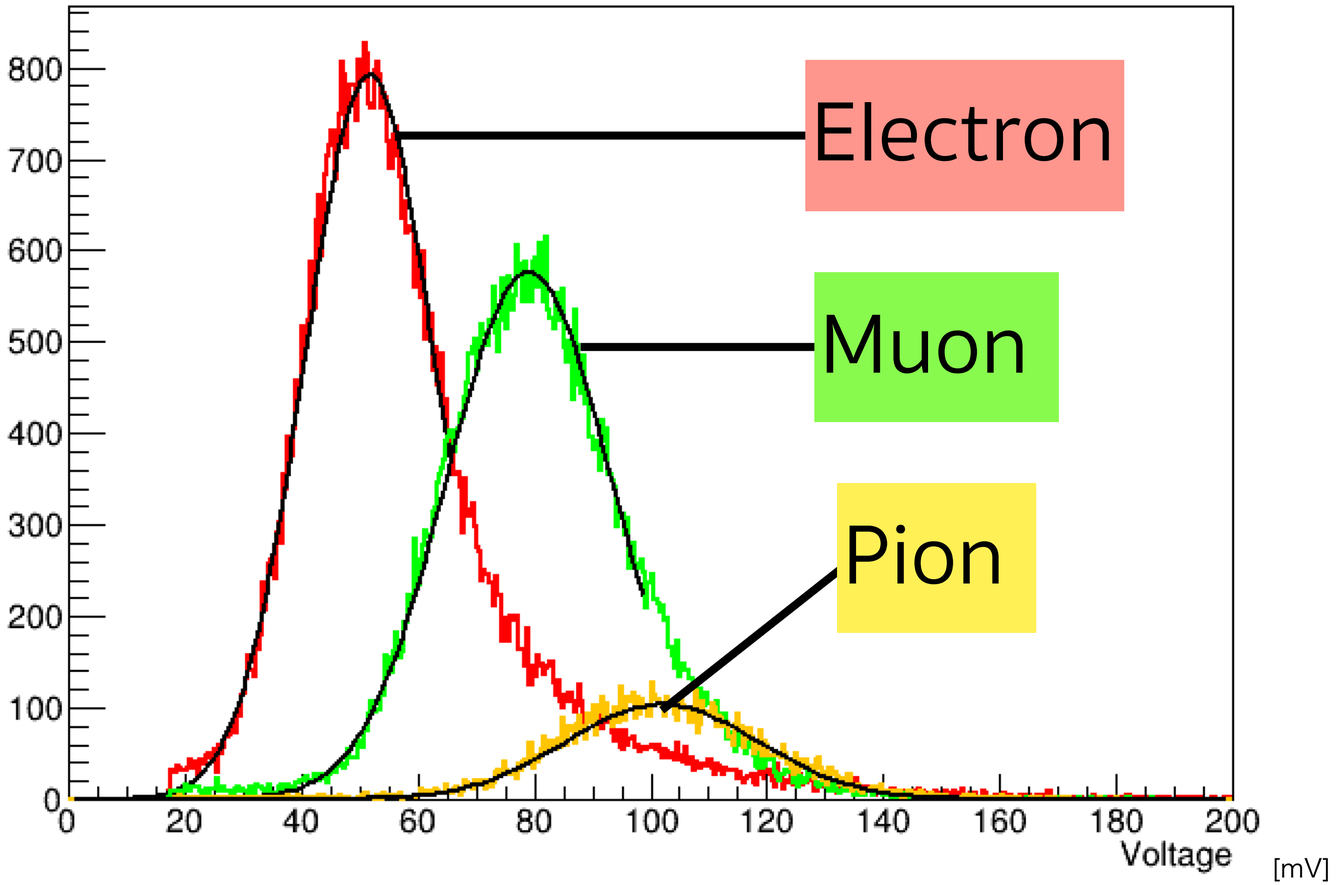
Evaluation of light output

Fitting the histogram of each particle with Gaussian

Using the peak of the fit for calculating the light output

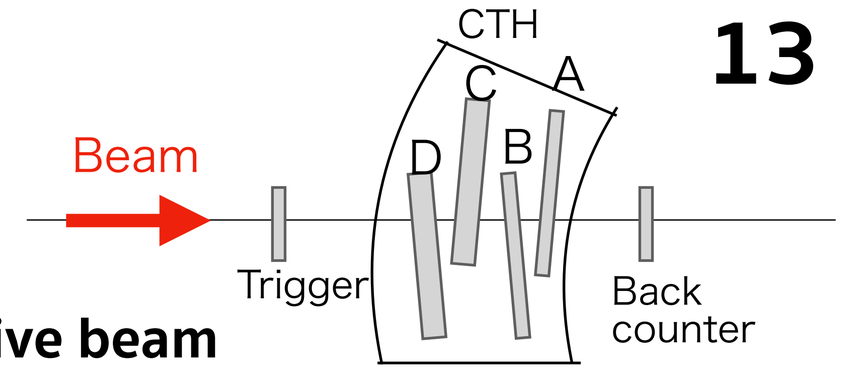
In this presentation,

we assume that **1 p.e. ~ 2.5 mV**.



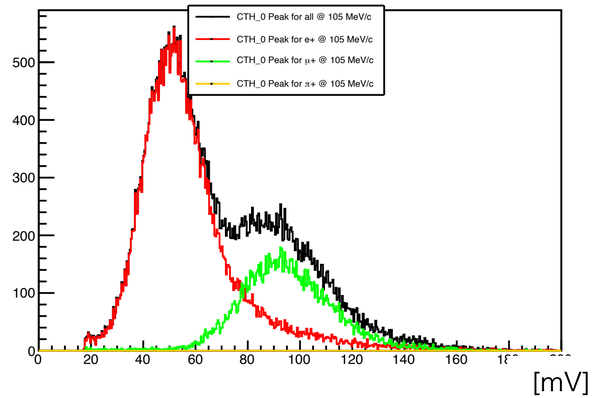
An example of peak distribution

Results of two datasets

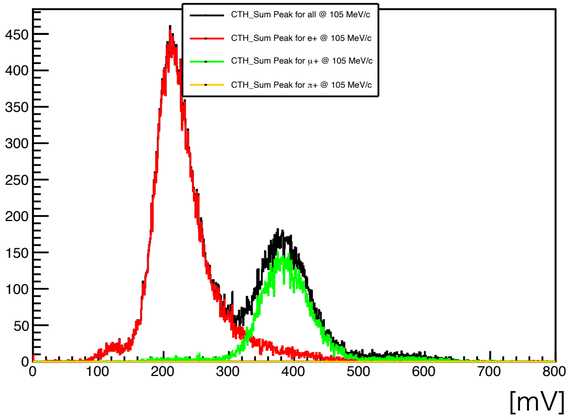


105 MeV/c positive beam

Peak of Counter A

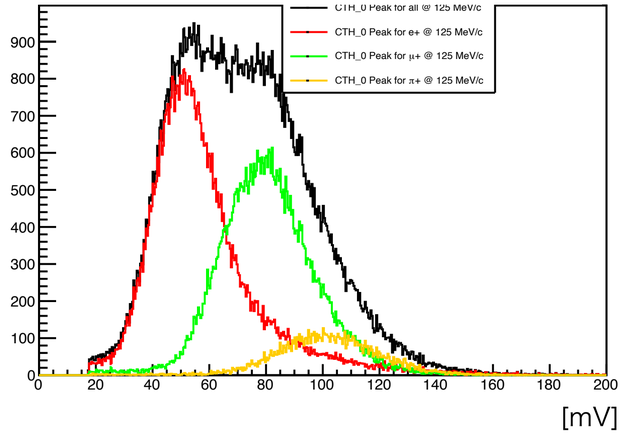


Sum of all counter's peak

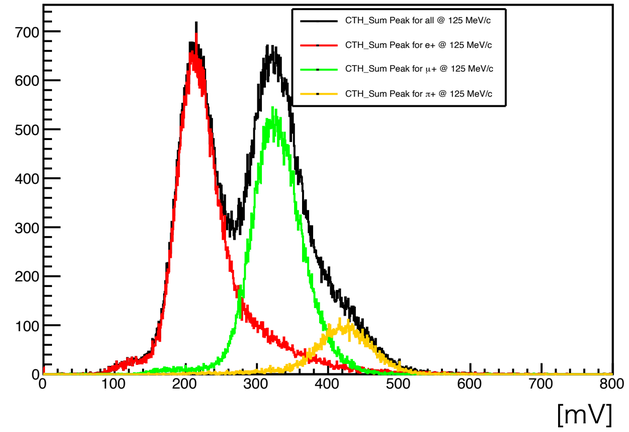


125 MeV/c positive beam

Peak of Counter A



Sum of all counter's peak



Counter	Electron(105 MeV/c)	Electron(125 MeV/c)
A	20.5	20.6
B	21.0	21.1
C	15.8	15.8
D	24.3	24.3

(p.e.)

- In sum of all counter's peak histograms, there are clear separations between electrons and muons at 105 MeV/c.
- The light yield was <u>smaller than requirement.</u>

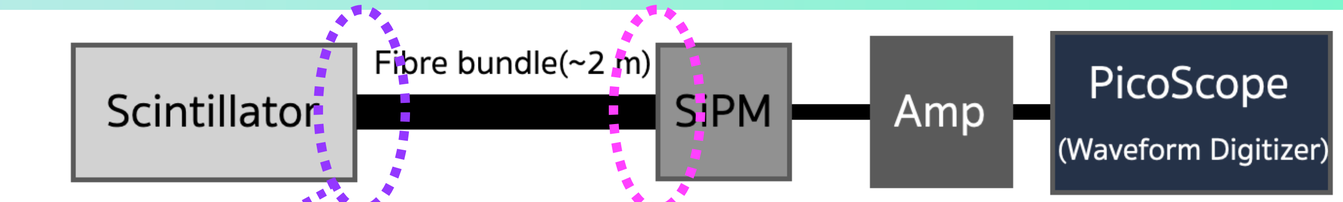
-> Discussion

Discussion

Optical coupling of the setup

The connection between SiPM and fibre bundle may cause low light yield.

- The surface of fibre bundle was not flat.
- The fibre arrangement was not uniform.
- A few fibres were broken.



Light reflector for scintillator

Lower reflectance near the wavelength of light emission of BC-408

Accuracy of jig position

Jigs for fixing fibre are made with a 3D printer.

More investigations are needed to get sufficient light output !

Summary

- The COMET experiment searches for the μ-e conversion with the world's best sensitivity.
- The CTH is currently under development for the COMET Phase-I physics measurement.
- The first beam test for the realistic CTH prototype was carried out to evaluate the detailed detector response.
- We found that electrons and muons are separated around 105 MeV/c.
- The number of photo electrons was fewer than the requirements for the CTH.
- Additional investigations and improvement in fibre couplings are needed to increase light output.

Back up

Datasets ->Backup

Measurement with 3 types of momentum of beam, different positions of CTH, beam polarity

Run No.	Category	Beam polarity	Momentum(MeV/c)
278-280	Momentum scan	Negative	105,125,150
281-284	Move the counter : ±12.5 cm shift (along x axis)	Negative	105,125
285-287	Move the counter : 2.5 cm up (along y axis)	Negative	105,125
288-291	Angle the counter : 15 deg and 30 deg along y axis	Negative	105,125
292-293	Test of positive beam	Positive	105,125
294-295	Positive beam (same setup as Momentum scan)	Positive	105,125
296-297	Reproducibility check	Negative	105,125
298-301	Back side (particles go through A→B→C→D)	Neg/Pos	105,125
302	SAM's amplifier test	Positive	105,125

Measurement for 1 p.e.

- Quick measurement to see 1 p.e.

- Need to make a firmly measurement