

# DeeMeスペクトロメータを用いた DIO測定

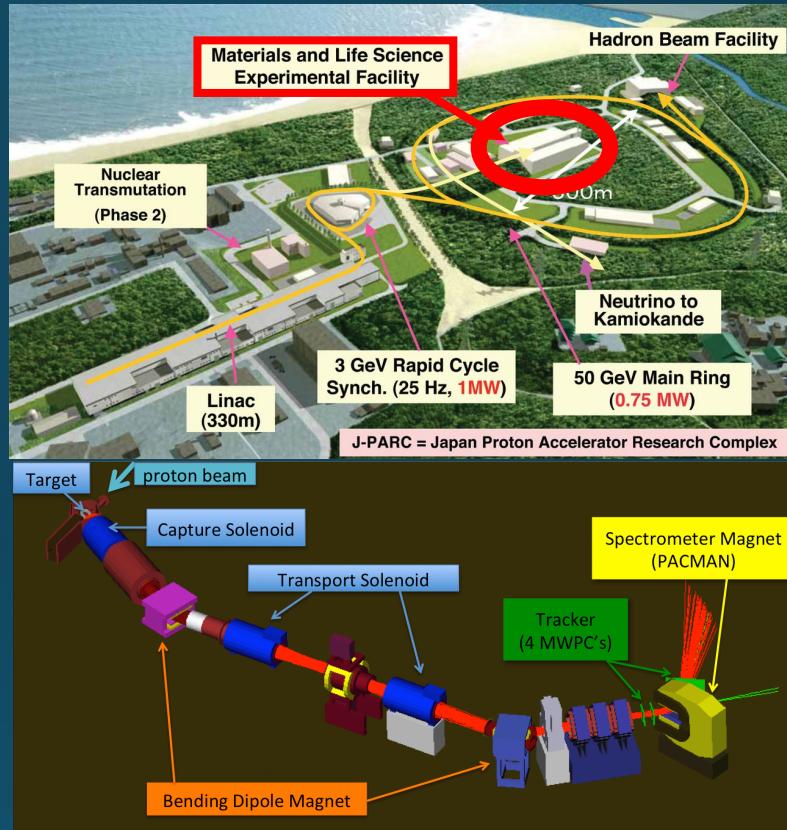
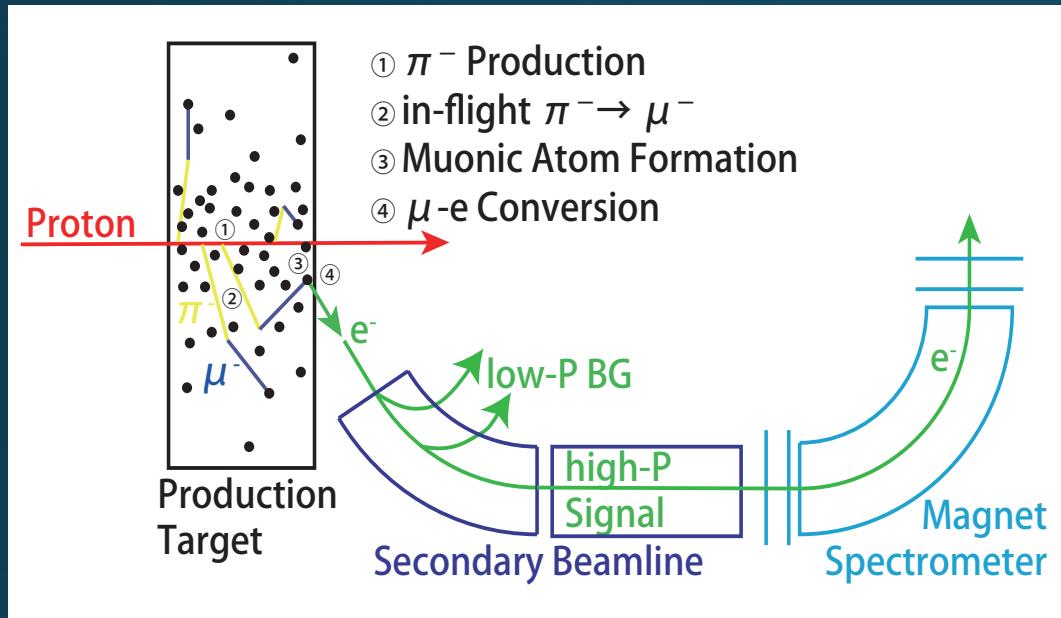
2017/12/28

長尾大樹

# Outline

- Motivation
- Measurement plans
- Analysis
- Tracking
- Summary

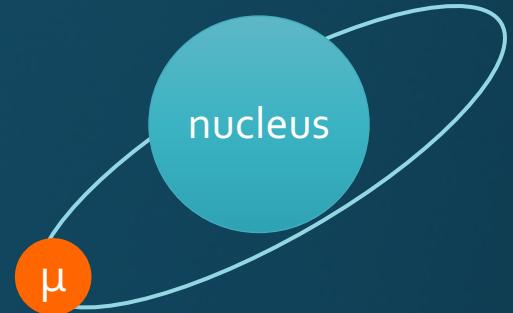
# DeeMe実験概要



C標的を用いて実験を開始する

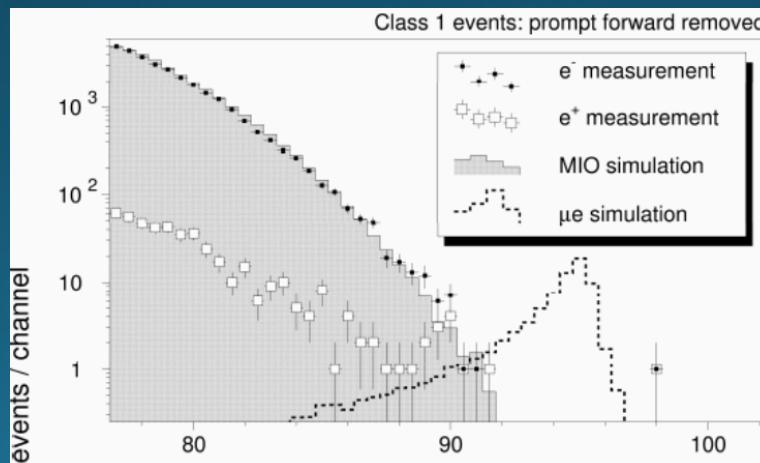
- Lifetime of muonic carbon atom  $\sim 2 \mu\text{s}$
- Energy of electron from  $\mu$ -e conversion = 105.06 MeV
- Single event sensitivity (1 year =  $2 \times 10^7$  sec)
  - C標的
    - $7.9 \times 10^{-14}$  (1 year)
    - $2.1 \times 10^{-14}$  (4 years)
  - SiC標的
    - $2.0 \times 10^{-14}$  (1 year)
    - $5.4 \times 10^{-15}$  (4 years)

# Muon Decay In Orbit



- 自由空間での崩壊と同じ（ただし原子軌道上）
- DIOによって放出される電子は、原子核によって運動量が補償されるため、 $\mu$ -e転換電子に近いエネルギーまで到達しうる
- $\mu$ -e転換探索において最も重要なバックグラウンドの一つ

SINDRUM-II  
(Au 標的)



# Muon Decay In Orbit

- Watanabeらによって <90MeV の運動量領域について計算され、
- Shankerによって recoilを含む形で high momentum 側が計算された

これらを  $\mu$ -e 転換探索実験で用いるため組み合わせたもののを我々は “Watanabe-Shanker spectrum” と呼んでいる

- “Czarnecki” spectrum
  - 原子核の recoil を含む形でより詳細に計算された
  - 相対論的効果をより詳細に導入

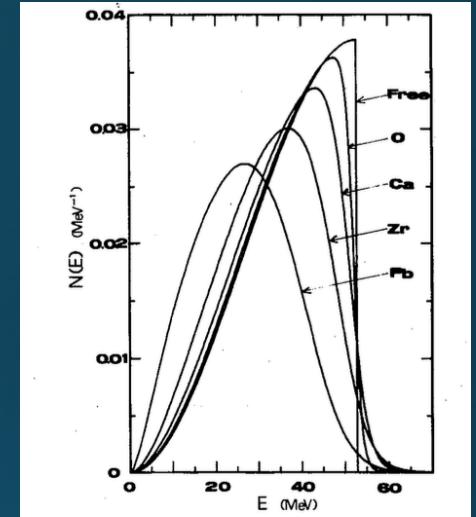
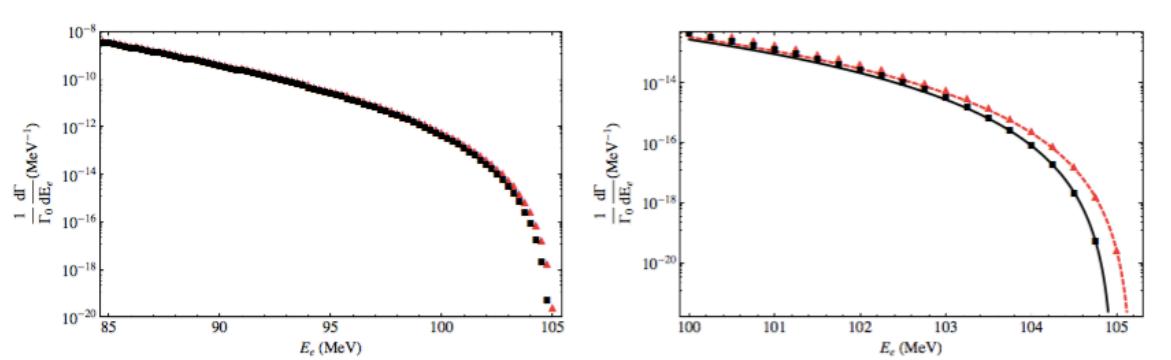


Fig. 1. Energy spectra  $N(E)$  of electrons for the bound muon decays in  $^{16}\text{O}$ ,  $^{40}\text{Ca}$ ,  $^{90}\text{Zr}$  and  $^{208}\text{Pb}$ , and for the free muon decay. They are normalized so that  $\int N(E) dE = 1$  for the free muon decay.

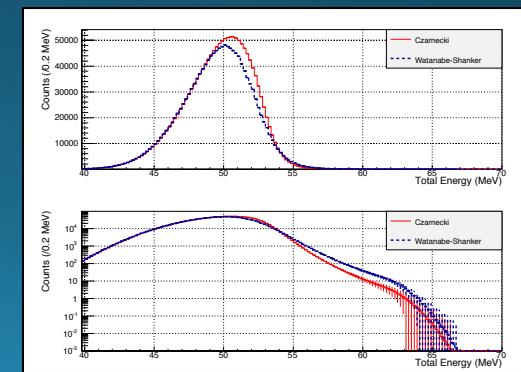
Watanabe 計算



AI原子でのDIOスペクトル  
(赤 : Watanabe spectrum,  
黒 : Czarnecki spectrum)

# Motivation

- Performance test of spectrometer system
  - MWPC development completed
  - Need to check efficiency and resolution of MWPC
  - DAQ test with 4 MWPCs
  - Practice for tracking analysis
- DIO background analysis
  - Difference between Watanabe- and Czarnecki-spectrum
- The difference of measured momenta was estimated
  - D line
  - 4 MWPCs and 90°bending sector magnet
  - Measurement energy = 55 MeV
  - The shape of spectra differed from each other



# Measurement plans

- March 2017

Material of target	polarity	momentum (MeV/c)	purpose
Holmium (Ho)	+	55	Momentum calibration
	+	45	Acceptance measurement
Graphite (C)	+	55	Momentum calibration
	+	45	Acceptance and polarized spectrum measurement
	-	55	DIO spectrum measurement

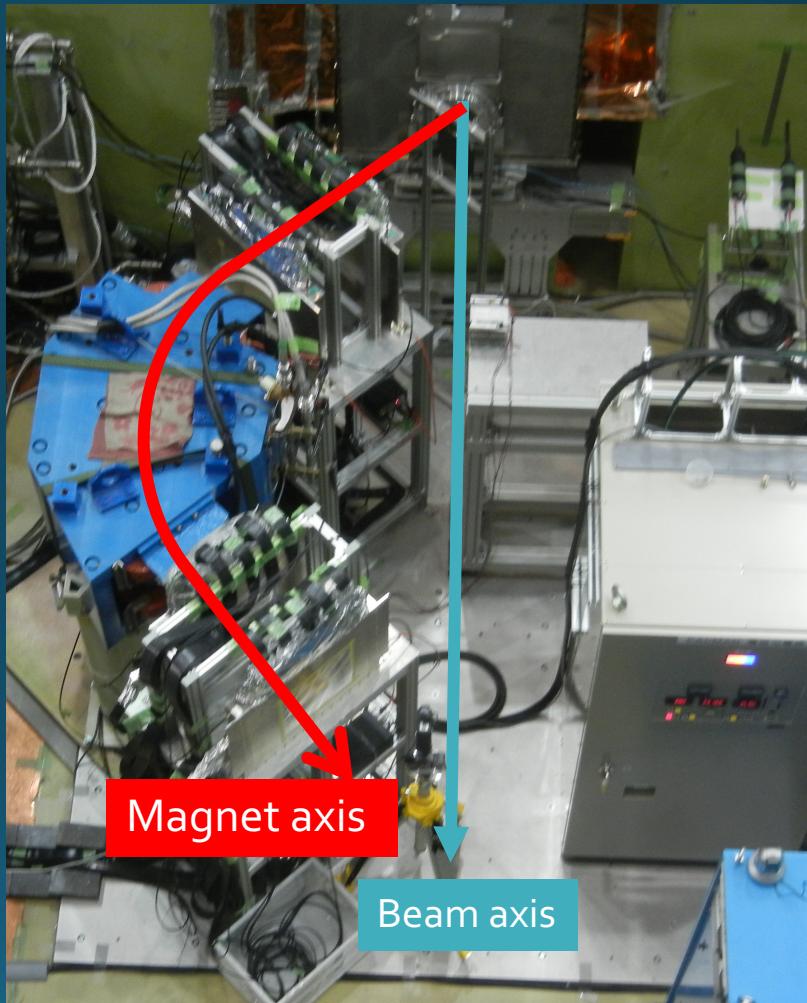
# Measurement plans

- June 2017

Material of target	polarity	momentum (MeV/c)	purpose
Holmium (Ho)	+	60	Momentum calibration
	+	52.5	Momentum calibration
	+	45	Acceptance measurement
	+	40	Acceptance measurement
Graphite (C)	+	52.5	Momentum calibration
	+	45	Acceptance and polarized spectrum measurement
	-	55	DIO spectrum measurement
Si, SiC	-	52.5	Backup
	-	45	Backup
	-	55	DIO spectrum measurement

# Setup

- Beam
  - 30 MeV/c decay muon
- Target
  - Right next to the beam window
  - 45° and 90° against to beam axis and magnet axis
- Spectrometer
  - 4 MWPCs and sector bending magnet
- Hodoscope
  - 2 scintillation counters
  - Counting electron from the target
- Trigger and DAQ
  - Trigger of DAQ synchronized with that of accelerator (25 Hz)
  - Waveform recorded by 12 32ch-100MHz-Flash ADC

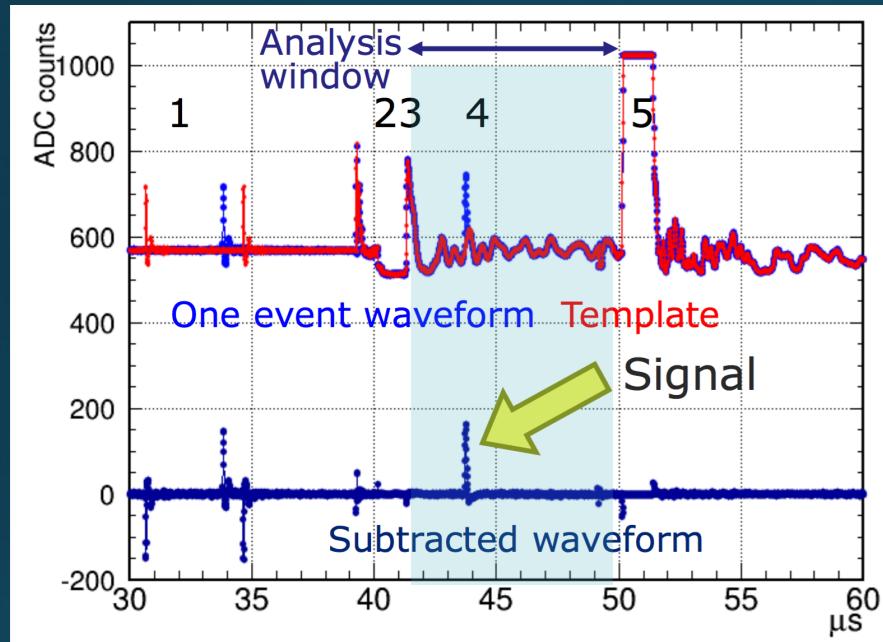


# Analysis

- decode
- baseline subtraction
- pulse finding
- hit position calculation
- tracking
  - by Genfit
  - Calman-filter
  - blind analysis

# Waveform analysis

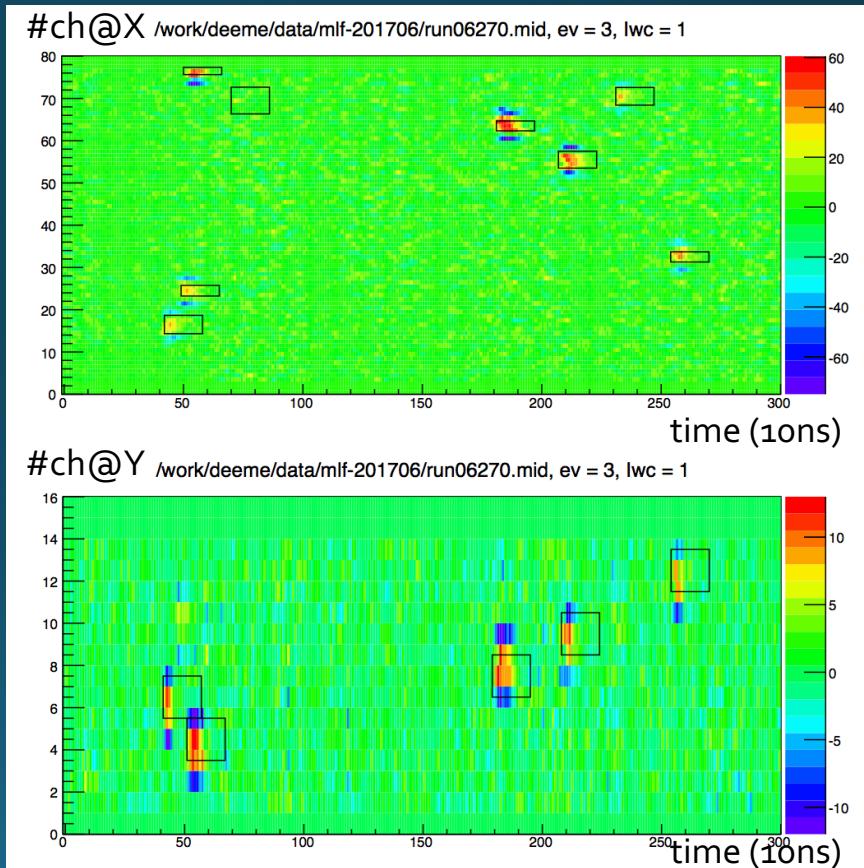
- Baseline subtraction



1. test pulse
2. HV-switching OFF->ON
3. over shoot by PZC circuit
4. signal
5. HV-switching ON->OFF

A template waveform is a set of most frequent value in each sample points

- Pulse finding



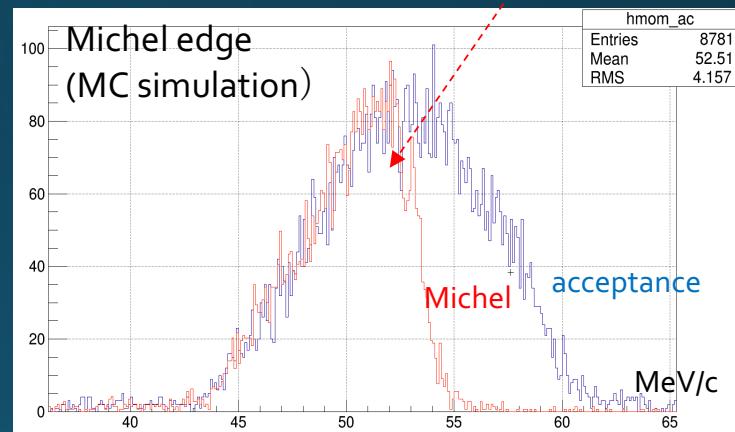
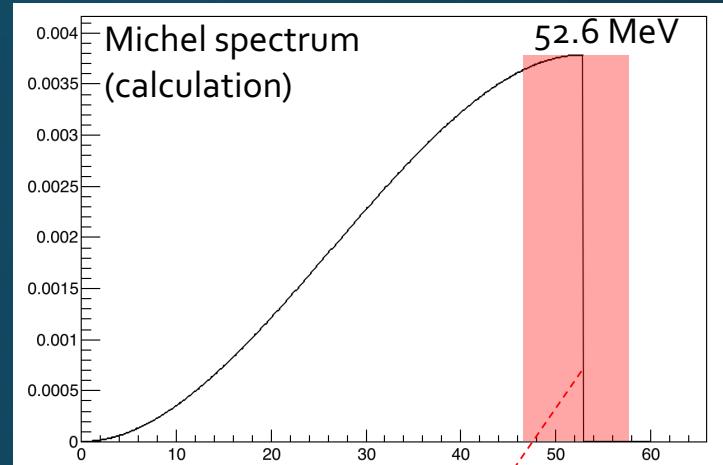
finding condition

- 7 points in 3 continuous strips over threshold
- highest point in the central strip

# Tracking

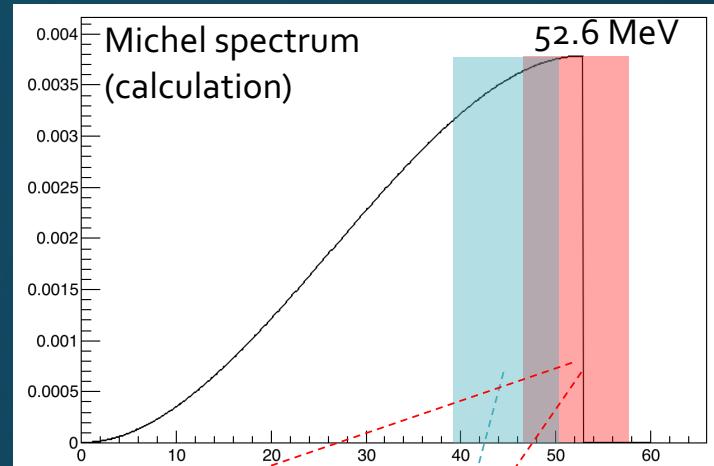
- Calibration
  - by Michel edge observation (52.6 MeV)

Measurement in June (run6256: C, mu+, 52.5MeV)

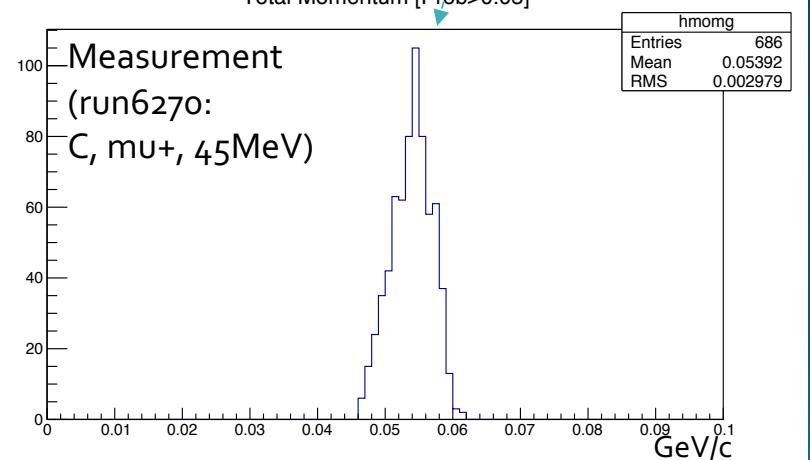
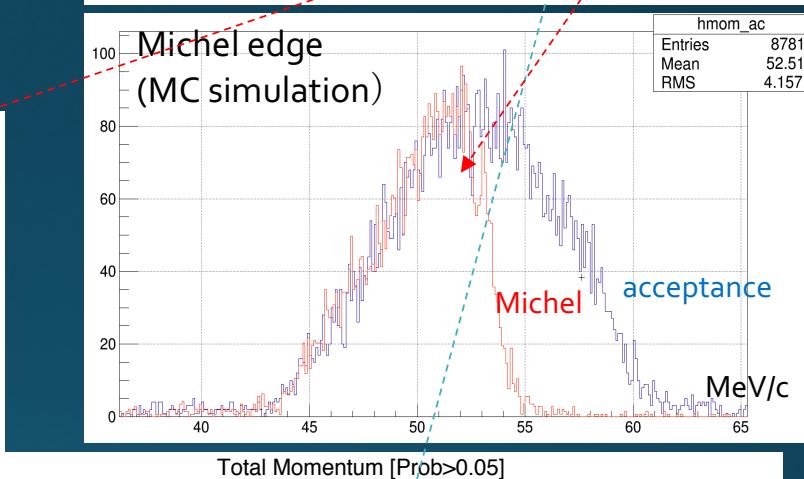
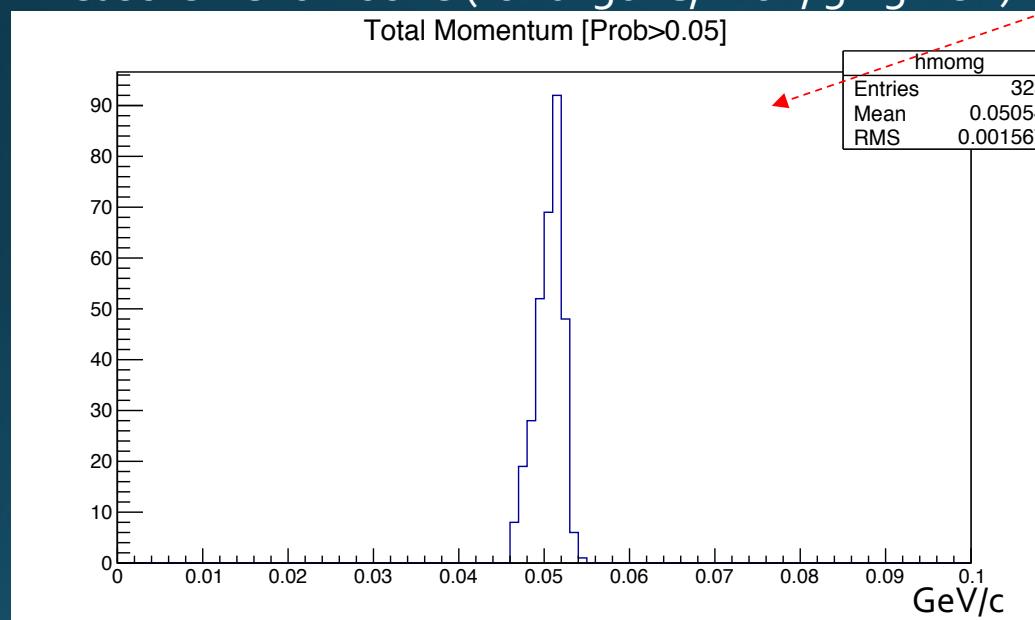


# Tracking

- Calibration
  - by Michel edge observation (52.6 MeV)

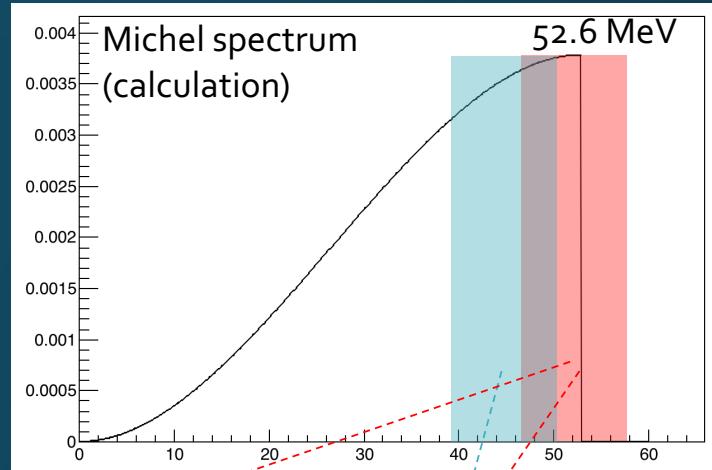


Measurement in June (run6256: C, mu+, 52.5 MeV)

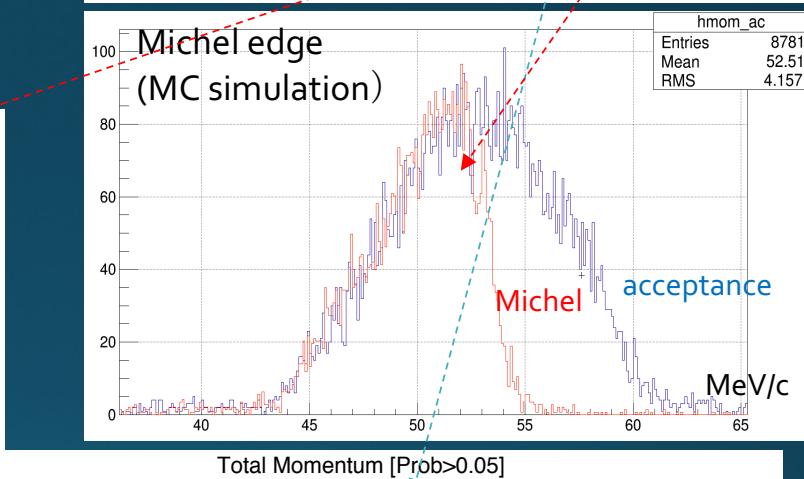
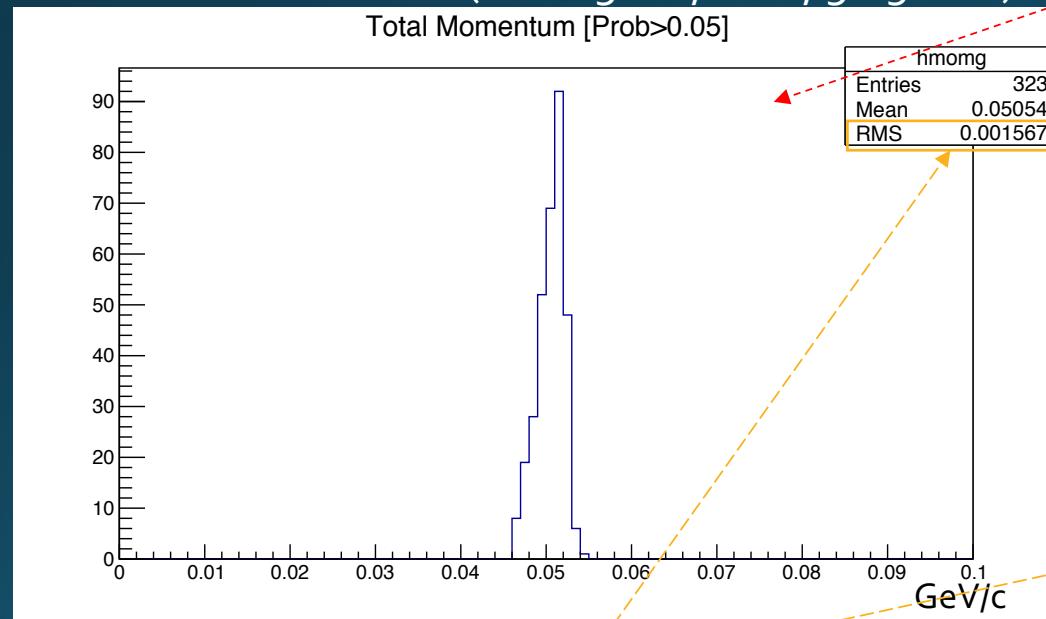


# Tracking

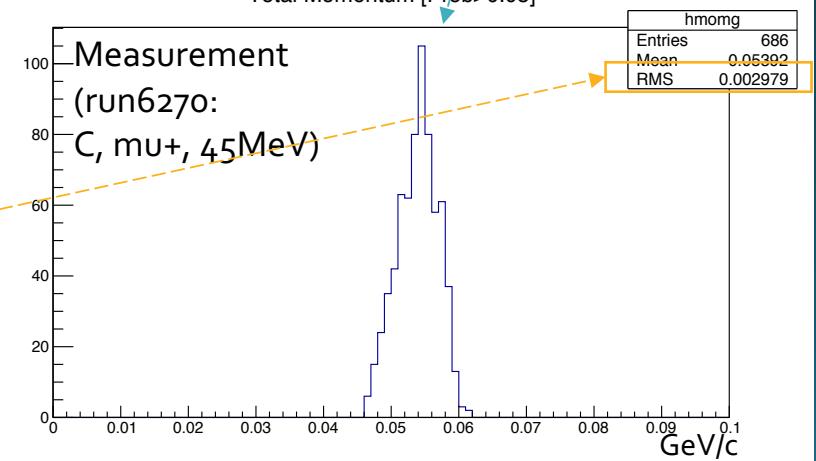
- Calibration
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Measurement in June (run6256: C, mu+, 52.5 MeV)

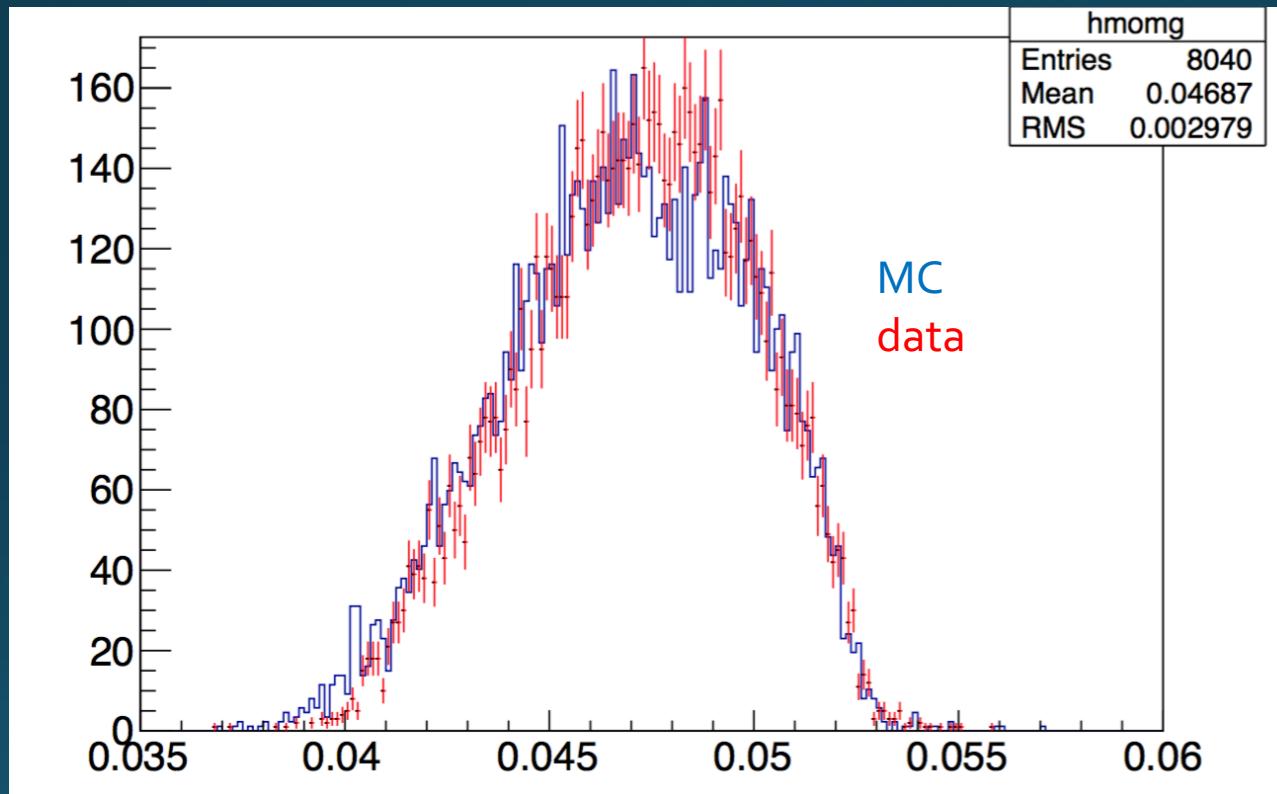


The shapes of momentum depend on strength  
of the magnetic field



# Tracking

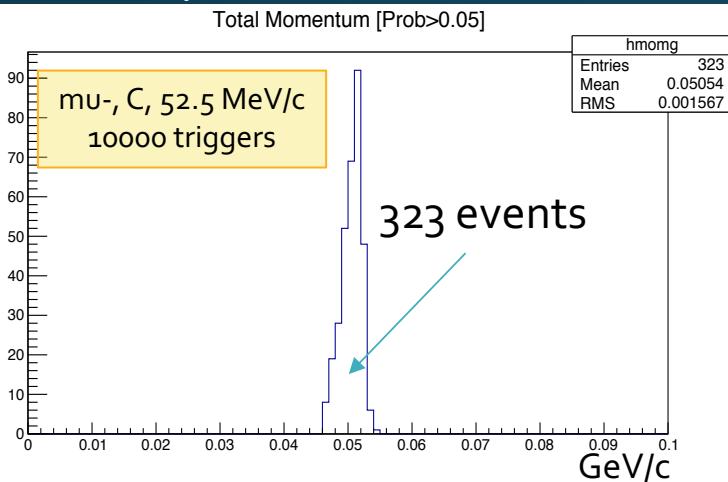
- C, mu+, 45 MeV
  - spectra of data and MC simulation are consistent



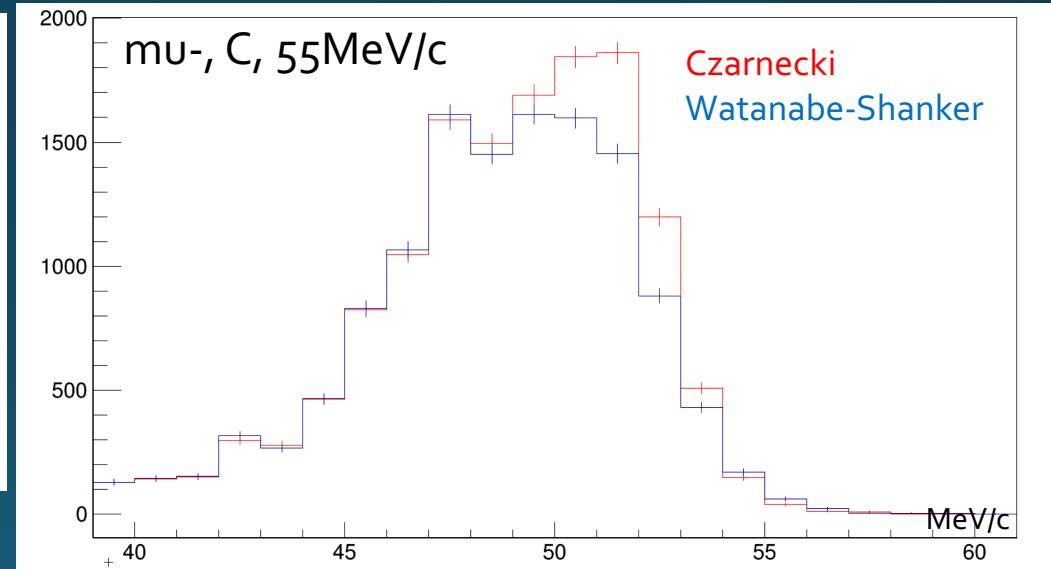
# Estimation

- DIO spectrum measured in June with C target have been estimated from 1-run data (10000 triggers)

analyzed data (1run)



G4BL simulation ( $1.2 \times 10^8$  muons)



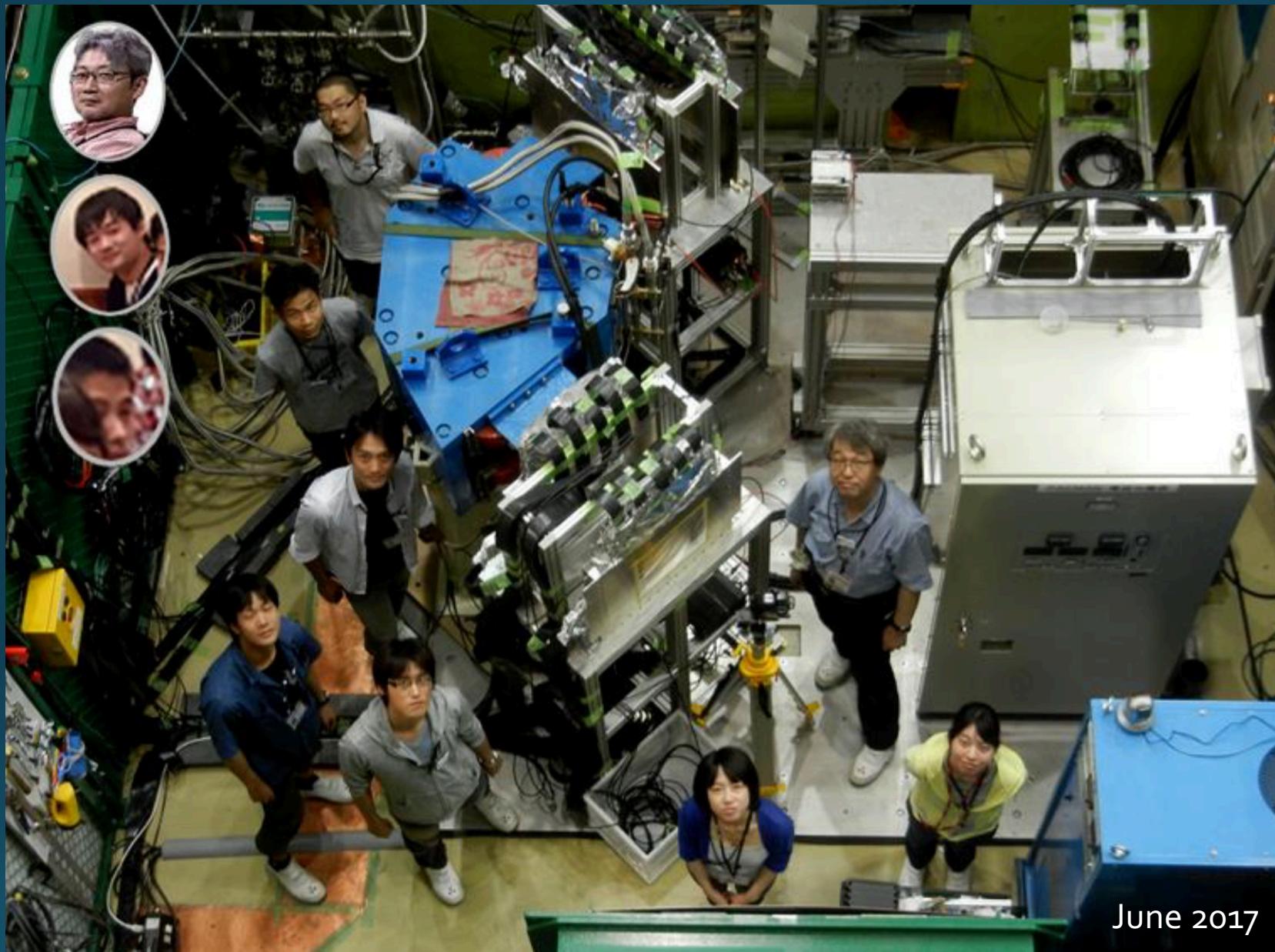
- Blind analysis code will be developed to analyze full DIO data

# Summary

- DIO spectrum was measured in March and June 2017
  - performance test of spectrometer system
- C, mu+, 45 and 52.5 MeV data were analyzed
  - Michel edge observed in 52.5 MeV measurement
  - MC simulation and data are consistent in 45 MeV
- DIO spectrum in June estimated by 1-run (10000 triggers)
  - Enough events to distinguish Watanabe and Czarnecki spectrum
- Blind analysis code will be developed

# To Do

- Tools improvement
  - Pulse finding algorithm
  - Tracking algorithm
  - G4bl simulation
- Efficiency and time dependence analysis
- 52.5 MeV calibration
- Acceptance calibration with 45 MeV data
- Analysis with Si, SiC
- DIO blind analysis
- Watanabe DIO calculation (Uesaka calculation)



end of slides