Momentum calibration for DeeMe experiment

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Aoki and Yamanaka Group Year-End Presentation

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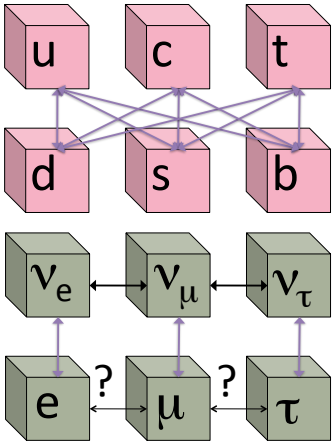
Outline

- Introduction
- J-PARC MLF HLine
- DeeMe Experiment
  - Design
  - HV-Switching MWPC
- Progress
  - Comissionig
  - Momentum calibration
- Summary and prospects

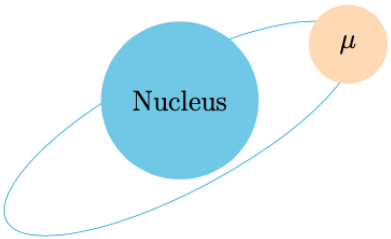
Introduction

- Standard Model



Charged Lepton Family/Flavour Violation(cLFV)

- Muonic Atom



- Upper limit
  - SINDRUM II @2006 (Au) 7.0 $\times 10^{-13}$
  - SINDRUM II @1993 (Ti) 4.3 $\times 10^{-12}$
  - TRIUMF (Ti) @1988 4.6 $\times 10^{-12}$

- Muon Capture(MC)

$$\mu^- + (A, Z) \rightarrow \nu_\mu + (A, Z-1)$$

- Decay in Orbit(DIO)

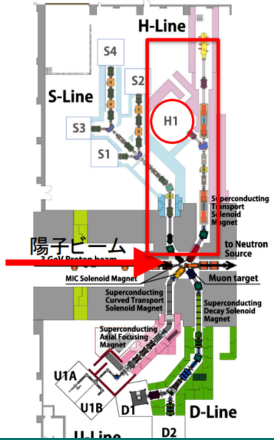
$$\mu^- \rightarrow e^- + \nu_\mu + \bar{\nu_e}$$

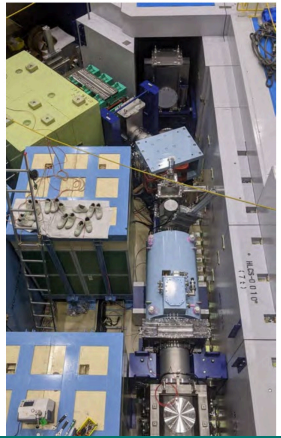
- μ-e conversion

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

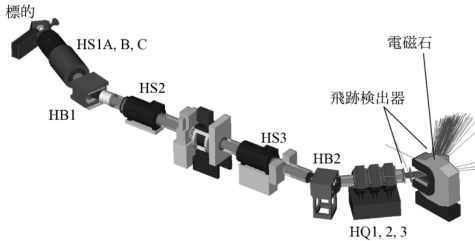
J-PARC MLF HLine

- H Line
  - Large acceptance
  - General purpose beam line
  - In operation since January 2022





- Groups planned to use
  - DeeMe
  - g-2/EDM
  - MuSEUM

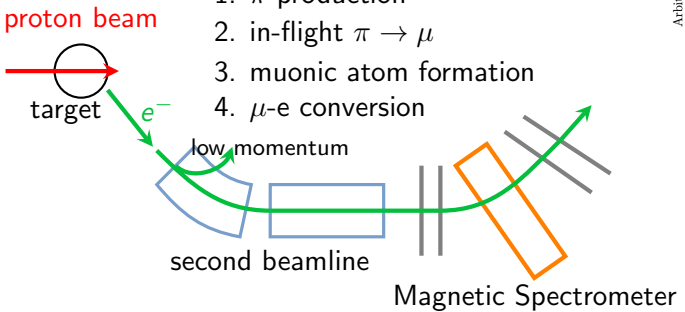


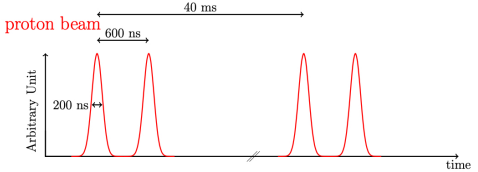
Design of DeeMe Experiment

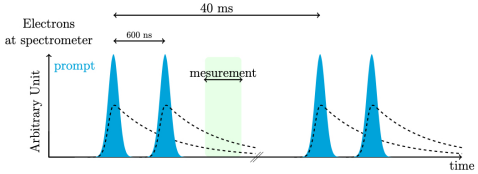
- place : J-PARC MLF H1 Area
- process : $\mu^- + (\mathrm{A}, \mathrm{Z}) \rightarrow e^- + (\mathrm{A}, \mathrm{Z})$
- Single Event Sensitivity : 1×10^{-13} (carbon,1year)

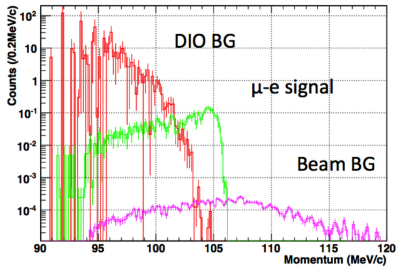
In target

1. π production
2. in-flight $\pi \rightarrow \mu$
3. muonic atom formation
4. μ-e conversion









HV-Switching MWPC

- tracking detector
  - Multi Wire Proportional Chamber(MWPC)

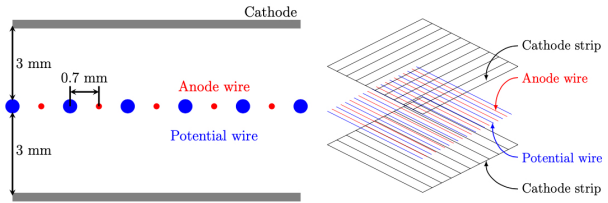
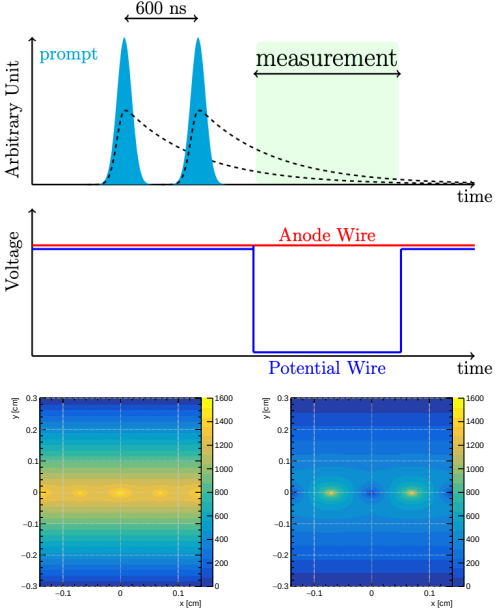


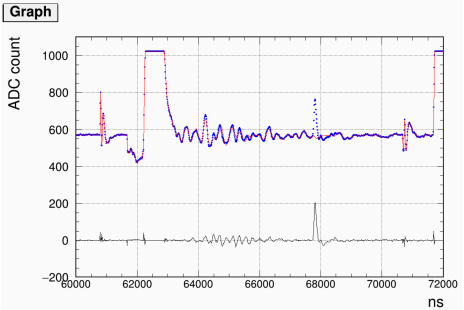
fig 1: Schematic of HV-switching MWPC

- HV switching technique
  - Potential wire voltage quickly switches between approx. 1500 V and 0 V



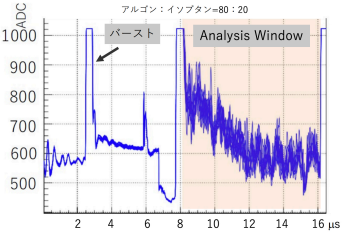
HV-Switching MWPC

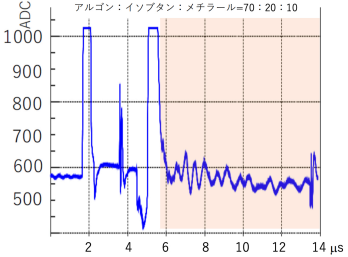
- Create a mode waveform and subtract it from the signal waveform



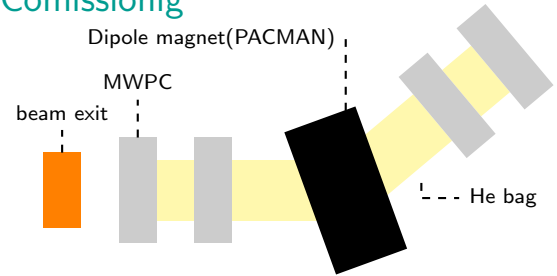
青 : Signal waveform from strip
赤 : Mode waveform
黒 : Subtracted waveform

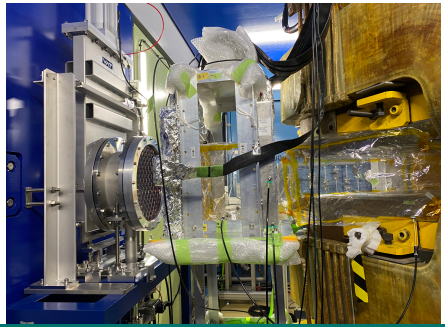
- Delayed noise hits
  - Observation of noise possibly caused by electrons emitted by the large number of argon ions produced at the timing of the incoming prompt burst
    $\Longrightarrow$ Suppressed by addition of methylal(prototype)

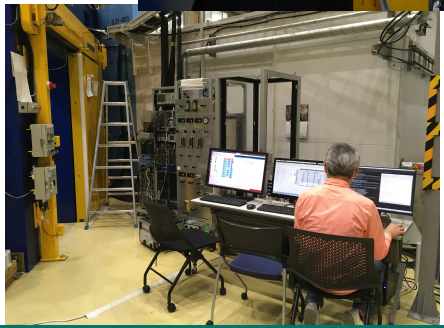




Comissionig



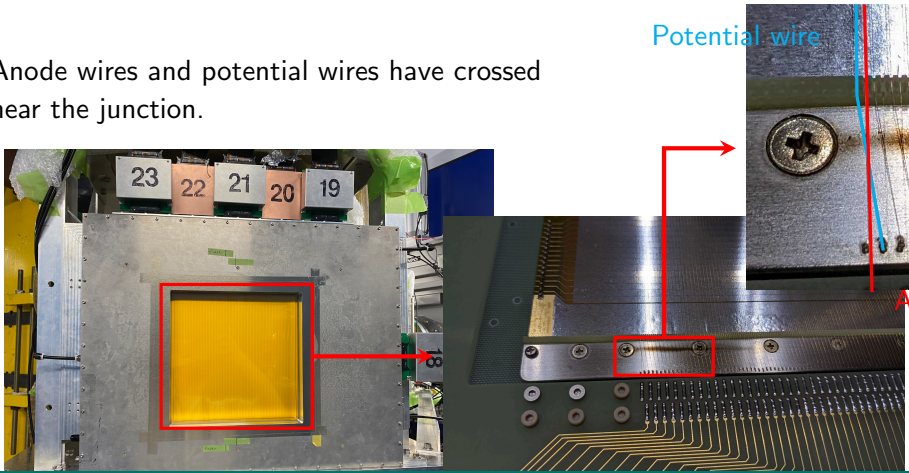




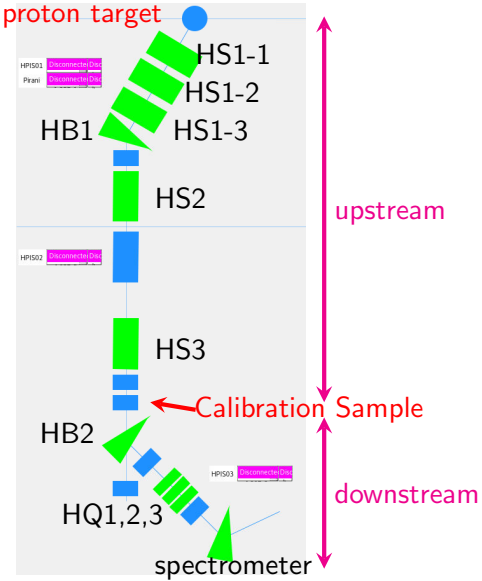
Comissioning

- One MWPC that had been prone to discharges for some time was disconnected during the experiment.
  $\Longrightarrow$ stable operation after repair!

Anode wires and potential wires have crossed near the junction.



Momentum calibration

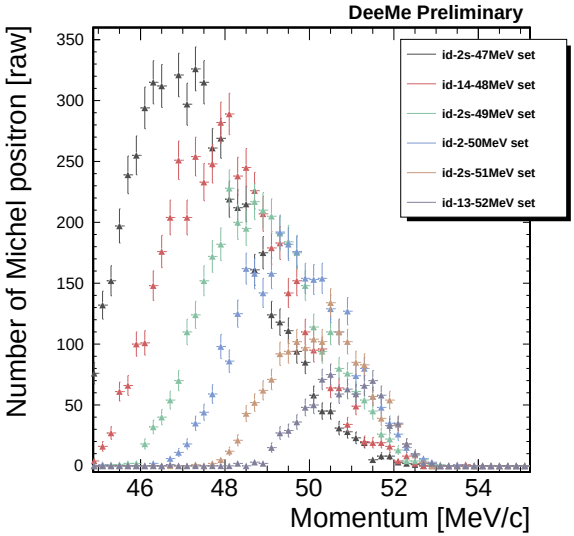


1. Michel decay positron from proton target
   - proton target : carbon
   - $\mu^+ \to e^+\nu\bar{\nu}$
     - ★ continuous momentum(edge : 52.8 MeV/c)
     - ★ lifetime : 2.2 μs
2. Michel decay positron from calibration sample
   - sample : kapton
   - $\mu^+ \to e^+\nu\bar{\nu}$
     - ★ continuous momentum(edge : 52.8 MeV/c)
     - ★ lifetime : 2.2 μs
3. π_{e2} decay positron from calibration sample
   - sample : aluminum
   - $\pi^+ \to e^+\nu$
     - ★ single momentum 69.3 MeV/c
     - ★ lifetime : 26 ns

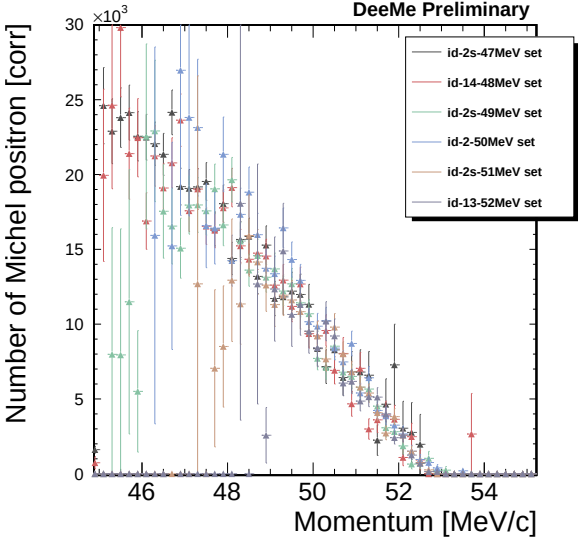
To reduce the number of prompt particles
- upstream : low momentum
- downstream : nominal momentum

Momentum Calibration

- no correction

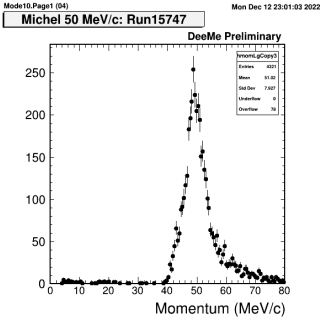


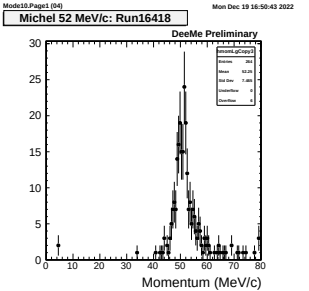
- acceptance correction

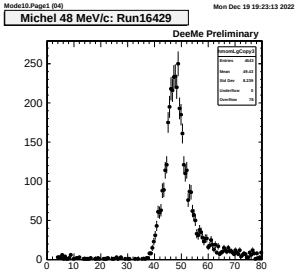


Momentum Calibration

1. Michel from proton target
   - 2022/06
     - ★ 50 MeV/c
     - ★ 55 MeV/c
     - ★ 45 MeV/c
   - 2022/12
     - ★ 50 MeV/c
     - ★ 52 MeV/c
     - ★ 48 MeV/c
2. Michel from calibration sample
   - 10 MeV/c(upstream)
     52.8 MeV/c(downstream)
3. π_{e2} from calibration sample
   - 40 MeV/c(upstream)
     69.3 MeV/c(downstream)
   - 25 MeV/c(upstream)
     69.3 MeV/c(downstream)



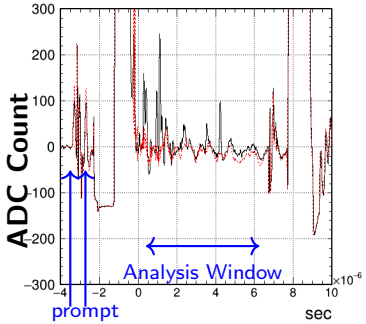


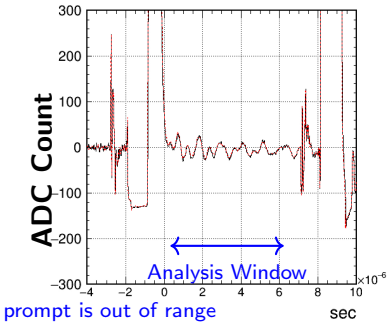


- Momentum reconstruction results obtained
- Understanding of distribution is under analysis

Momentum Calibration

- Addition of methylal
  - First test on a actual machine
- Confirmation of hit rates
  - Tendency for many hits on second and third MWPCs
- Dependent on prompt timing
  - Delayed noise hits or real hits





Summary and Prospects

- DeeMe experiment is underway at J-PARC MLF
  - We confirmed that the device works as a whole.
  - Momentum calibration
    - ★ Michel decay positron from proton target
    - ★ Michel decay positron from calibration target(kapton)
    - ★ π_{e2} decay positron from calibration target(Alminum)
  - Data acquisition in 2022/06 and 2022/12.
    - ★ For the first time, measurements were made using methylal on actual machine.
    - ★ We confirmed that momentum reconstruction by tracking is possible.
- Future Prospects
  - Evaluating the impact of delayed noise hits
  - Understandeing tendency for many hits on second and third MWPCs
  - Understanding momentum distribution

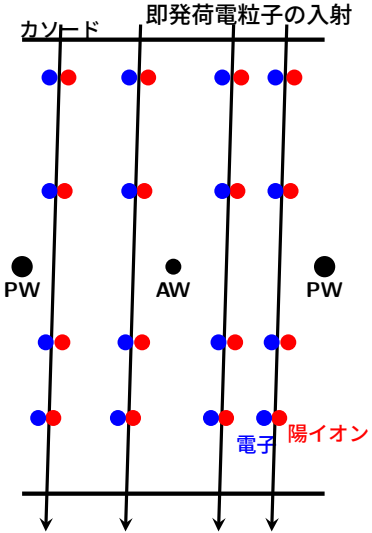
Backup

高レート耐性 MWPC

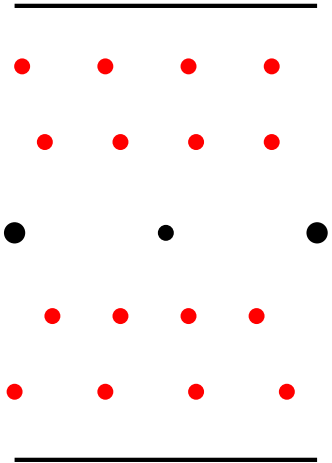
Table 1: 高レート耐性 MWPC の設計値 (713-type/724-type)

アノードワイヤー	物質	金メッキタングステン-レニウム
	直径	15 μm
	本数	144/136
	張力	41 g
ポテンシャルワイヤー	物質	金メッキタングステン
	直径	50 μm
	本数	145/137
	張力	80 g
ワイヤー間距離 (アノード・ポテンシャル)		0.7 mm / 0.75 mm
x 軸方向読み出しカソードストリップ	物質	アルミマイラー
	幅	3.0 mm
	本数	80
y 軸方向読み出しカソードストリップ	物質	アルミマイラー
	幅	15 mm
	本数	16
カソード面-ワイヤー面間距離		3.0 mm

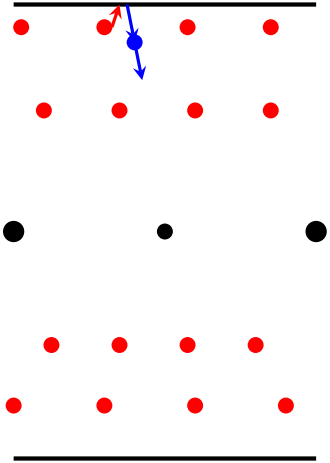
遅延ヒットメカニズム



HV スイッチが ON になるまでに
電子はワイヤーに吸収される。

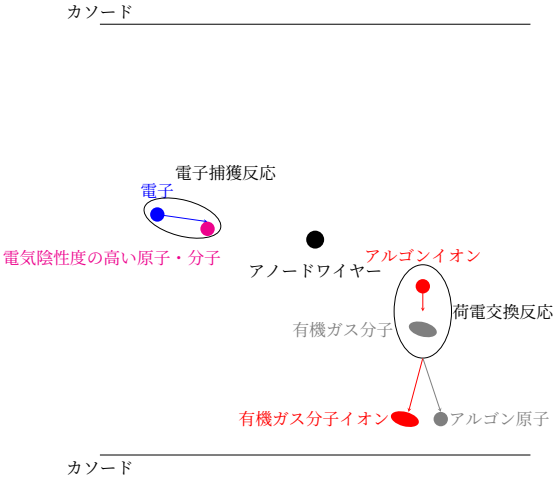


HV スイッチが ON の間にカソードや
PW から電子が放出される。



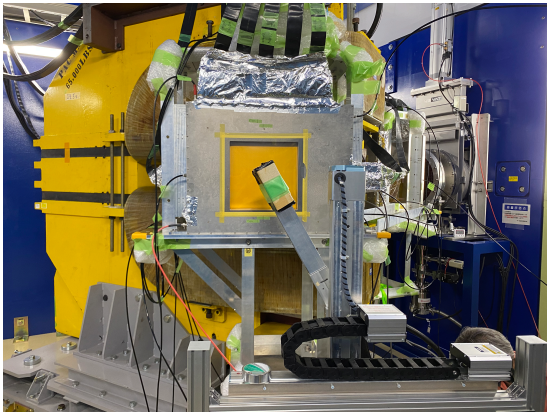
遅延ヒットの削減

- 電子捕獲反応
  - 電気陰性度の高い原子・分子が電子と結合し陰イオンを形成
  - 放出された電子がアノードに到達するのを阻止
- 荷電交換反応
  - アルゴンイオンと有機ガス分子が電荷を交換
  - アルゴンイオンがカソードに到達するのを阻止

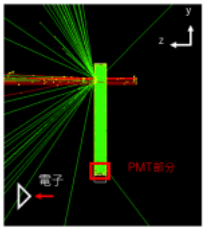


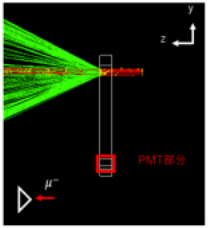
ビームプロファイルスキャン装置

- 2 軸ロボットとチェレンコフカウンターの組み合わせ



- 105 MeV/c の電子とミュオンを分別





- ビームプロファイルの一例