MEG II実験2021年物理ランに関する報告

-陽電子再構成の現状と課題-

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MEG II Mu - E - Gamma collaboration

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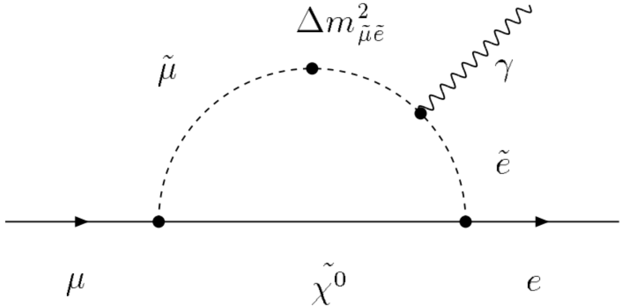
Outline

- MEG II experiment
  - Motivation and principle
  - Overview of event reconstruction
- Positron track reconstruction
  - Tracking detector
  - Reconstruction
  - Momentum resolution
  - Efficiency
- Summary and prospect

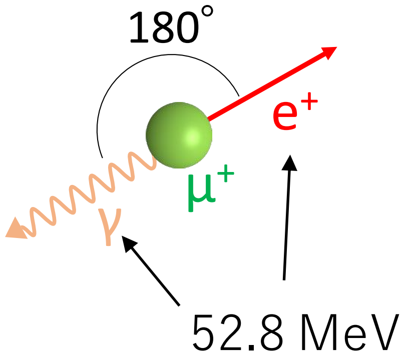
Motivation and principle of MEG II experiment

- $\mu \to e\gamma$ search at MEG II
  - CLFV decay, forbidden in SM
  - Target sensitivity: Br$(\mu \to e\gamma) \sim \mathbf{6 \times 10^{-14}}$ in 3 years
    → Indirect probe of new physics up to O(10 TeV) scale

New physics example:
$\mu \to e\gamma$ from slepton mixing



- Experiment strategy
  - Signal
    - Identified by kinematics
    - Statistics: $N_{sig} \propto R_\mu \cdot T \cdot Br(\mu \to e\gamma) \cdot \epsilon$
  - Main BG
    - Accidental coincidence of BG-e & BG-γ
      - $N_{BG} \propto R_\mu^2 \cdot T$ → DC beam of PSI
    - Identified by kinematics difference from signal
      - $N_{BG} \propto \delta E_e \cdot \delta E_\gamma^2 \cdot \delta\theta^2 \cdot \delta T$
        → **High resolution measurement**

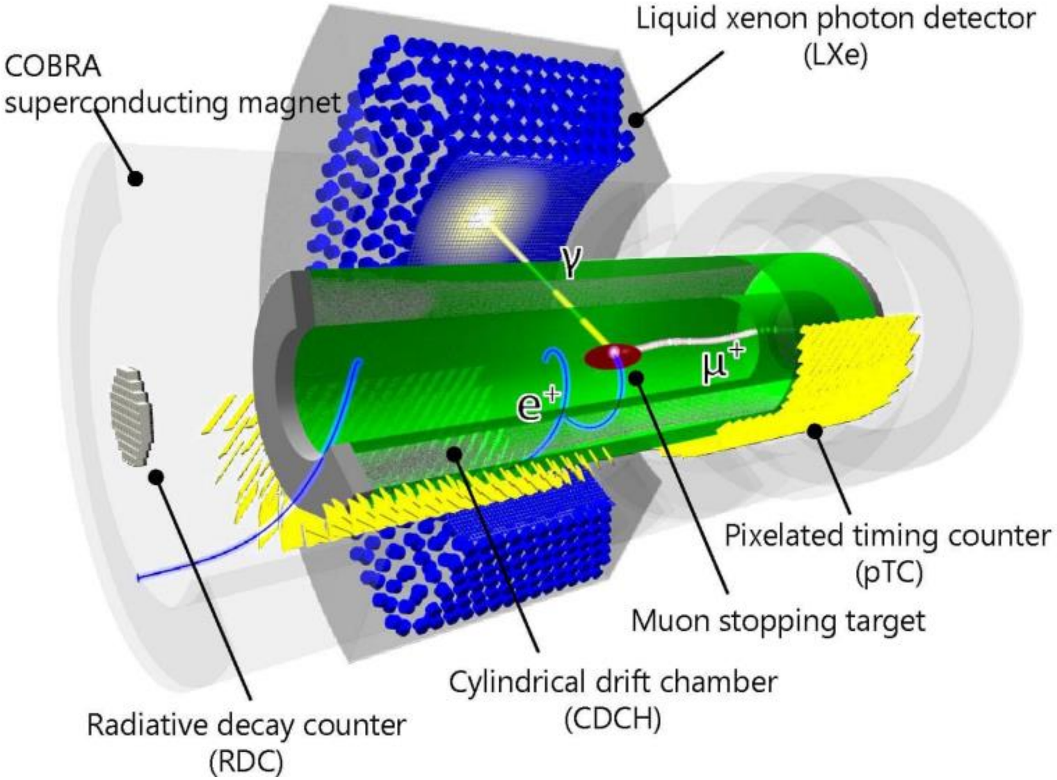


Notation	
R_μ	μ rate
T	Experiment time
ϵ	Efficiency
$\delta E, \delta T, \delta\theta$	Resolution

	Signal	BG
$e\gamma$ time difference	Same time	No correlation
$e\gamma$ direction	Opposite	No correlation
E_e	52.8 MeV	< 52.8 MeV
E_γ	52.8 MeV	< 52.8 MeV

Experimental method of MEG II

- MEG II apparatus
  - Positron detection with spectrometer
    - Bending: COBRA magnet
    - **Tracking: Cylindrical drift chamber (DCH)**
    - Timing: Pixelated timing counters (TC)
  - Gamma detection with LXe detector
  - DAQ: Full waveform acquisition with DRS4



- Event reconstruction
  - Positron measurement
    - t_e measured at TC
    - **Decay vertex, E_e, TOF from target to TC from DCH tracking**
  - LXe detector measurement (15aA562-5)
    - E_γ, γ reaction point, t_γ at reaction point in Lxe
    - t_γ at vertex reconstructed with TOF correction

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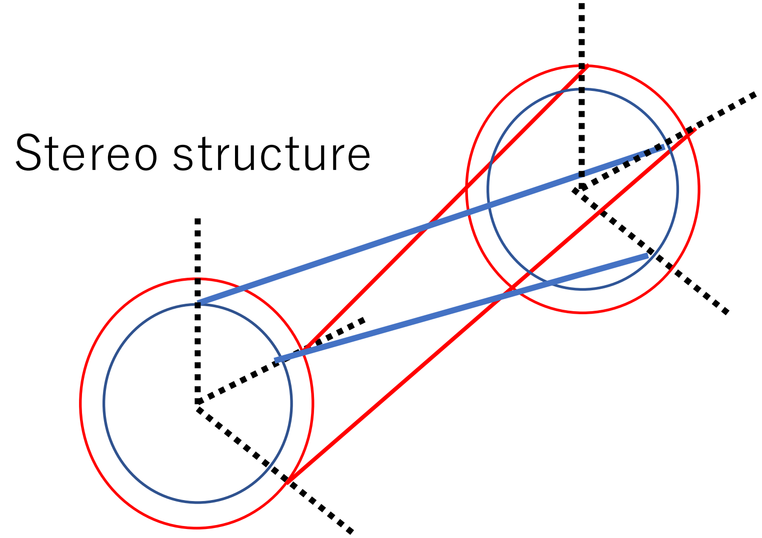
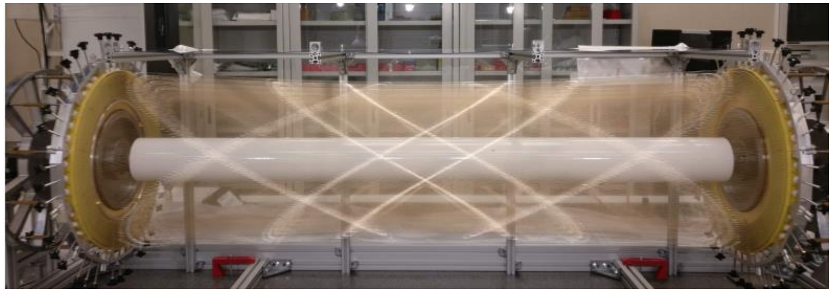
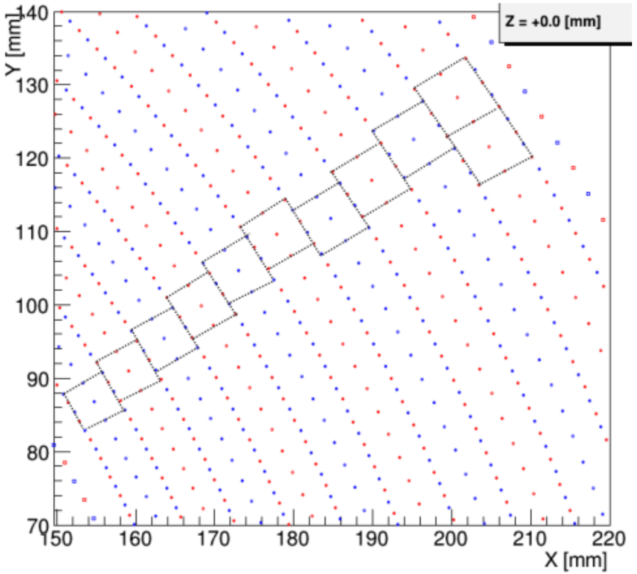
DCH in MEG II

- DCH tracking detector
  - Cylindrical stereo geometry of wires
  - 128 readout cells × 9 layers
  - Gas: He + 10% iso-C_4H_{10} + 0.5% O_2
- Operation in 2021 run
  - Stable operation achieved in muon beam
    - Hit rate of 1 – 2 MHz on each wire
  - Full signal readout for the first time
  - Some bad readout channels found
  - Operated with missing wires





+ stereo drift cells
− stereo drift cells

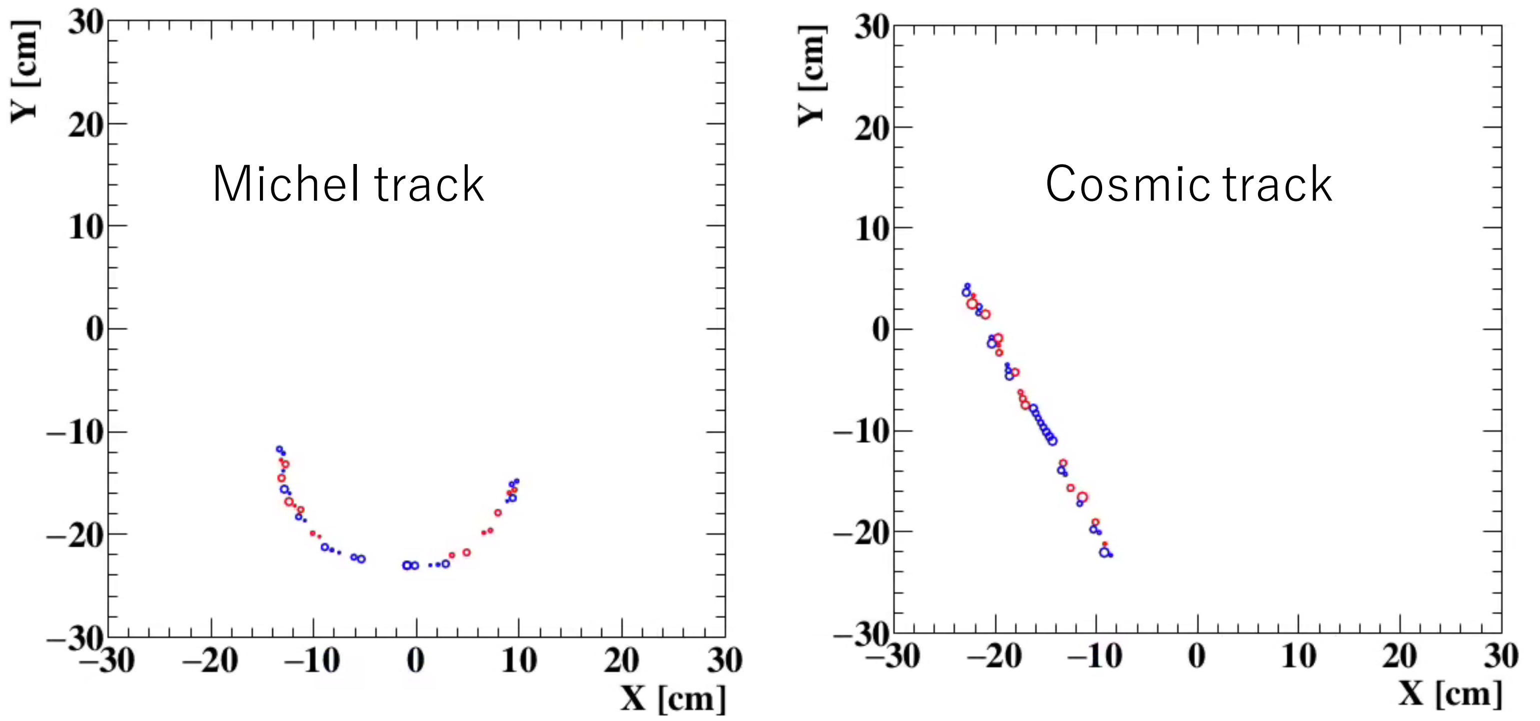


Reconstructed tracks

- Successful tracking demonstrated in 2021 for the first time
  - Michel positron (bended)
  - Cosmic-ray (straight)

- Use of Michel tracks
  - Performance evaluation
  - Calibration
  - Normalization

- Use of cosmic tracks
  - Calibration
  - Detector alignment



Necessary tools are ready for physics analysis

Efficiency estimation

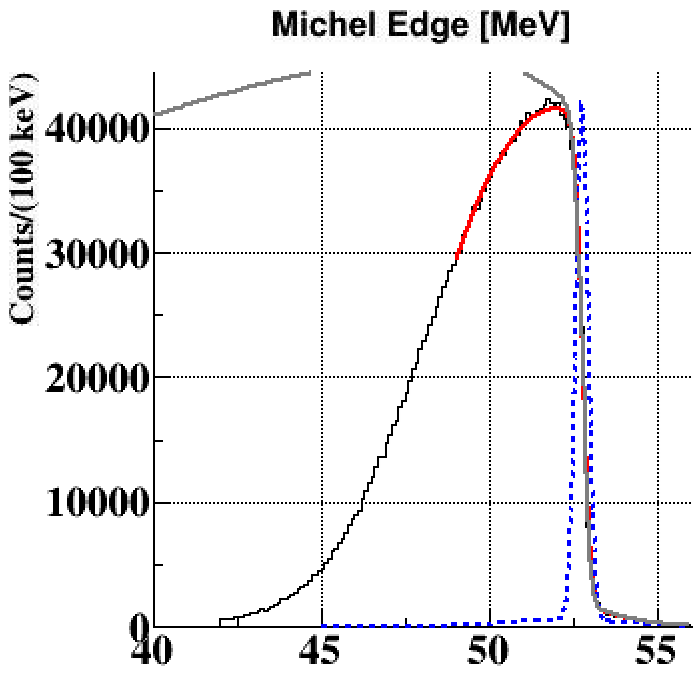
- Definition of efficiency
  - Contribution to MEG II statistics
    - $\frac{\text{Counted number of Michel positron} \times p_e \text{ dependence correction}}{\text{Expected number of Michel positron in acceptance region}}$
    - 52.8 MeV positron efficiency in the acceptance region

- Efficiency evaluation
  - Results at different stopping rate
    - Efficiency uncertainty: $\pm$ 5 % uncertainty
    - Decrease at high rate more significant than MC expected
    - Possible cause of decrease
      - Inefficiency in hit finding due to pileup
      - Inefficiency in track finding

Muon stop/sec	3.5 e7	4.6e7	5.8e7
Estimated efficiency	~60 %	~50 %	~40 %

Momentum resolution

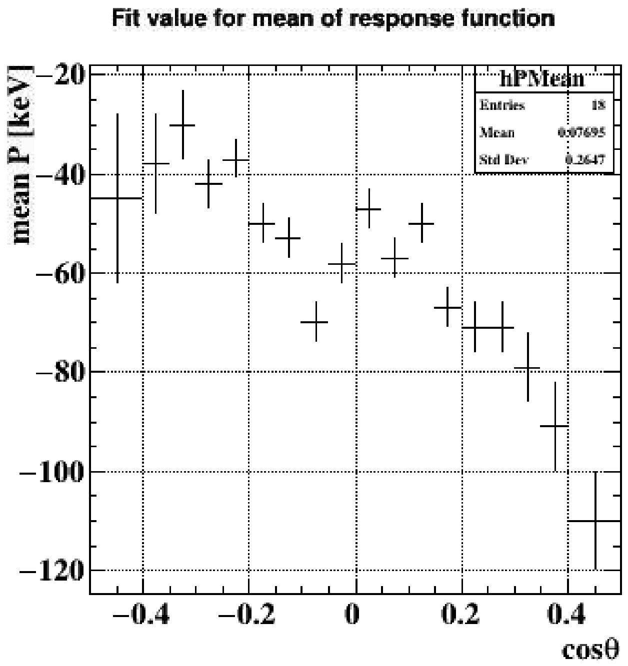
- Michel fitting
  - Fit with $(\textit{theory spectrum} \times \textit{acceptance function}) \otimes \textit{response function}$
    - Acceptance: Parametrize momentum dependence of efficiency with error function
    - Response function: Parametrize detector's response with double gaussian



Fit parameter
- Core resolution: 184 keV
- Acceptance: 48.4 MeV mean, 2.2 MeV sigma

Core resolution: 184 ± 3 keV

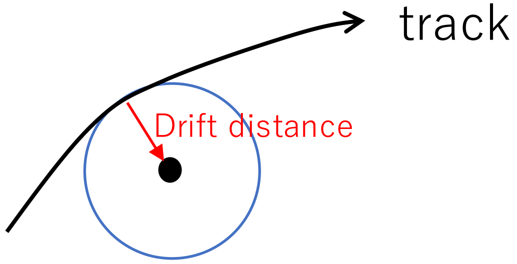
- – 50 keV overall shift of edge
- Emission angle dependence
  → Further improvement expected
  with better alignment

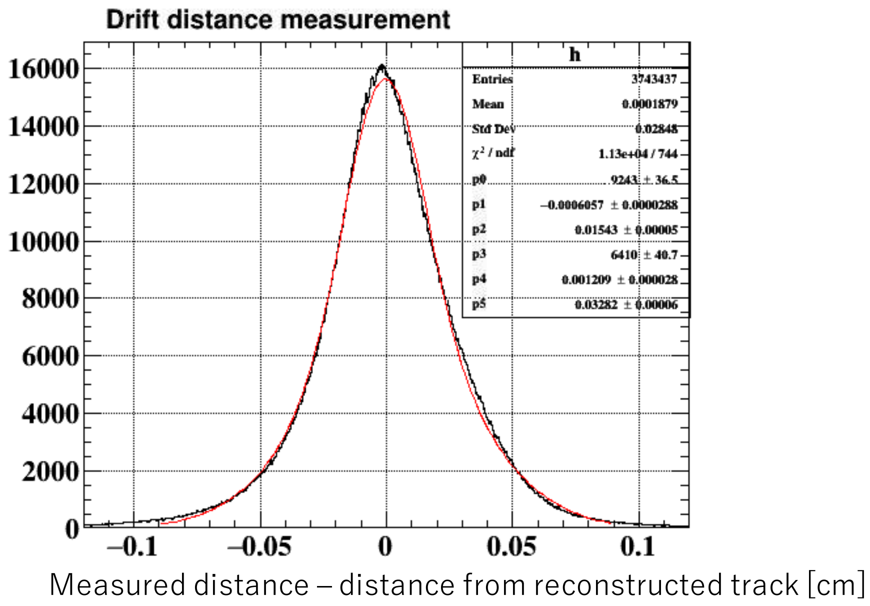


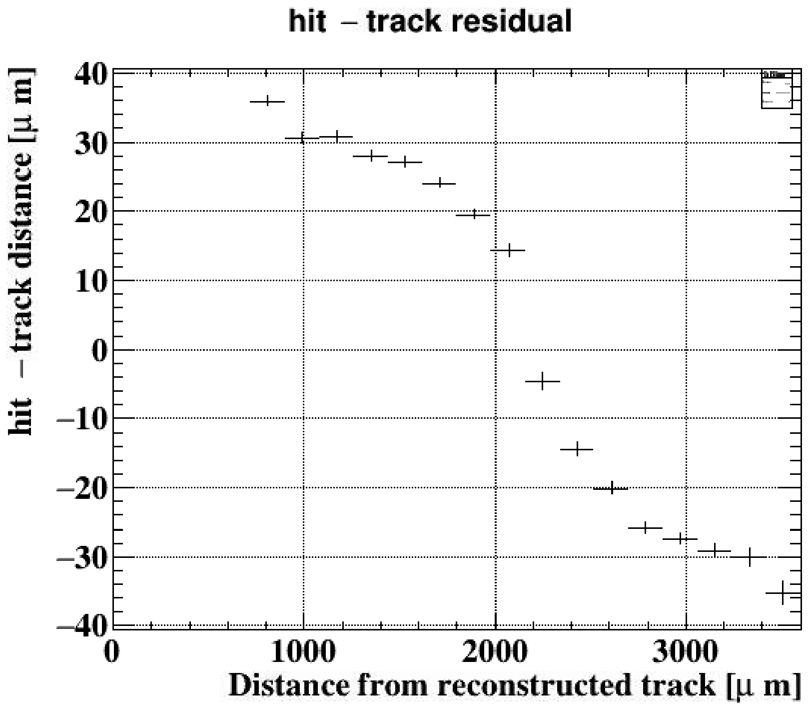
Theory spectrum:
https://journals.aps.org/pr/abstract/10.1103/PhysRev.113.1652

Calibration: Hit resolution

- Distance resolution
  - 0.15 mm resolution
    → × 1.5 worse than MC
  - Calibration in progress
    - Time to distance relation
    - Timing calibration







- Distance measurement is not completely calibrated
  → Further improvement expected
- Aiming < 150 keV momentum resolution after improvement

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Summary

- Successful positron tracking demonstrated in 2021 run
  - 184 keV resolution achieved with a large possibility of improvement
  - 40 – 60 % efficiency depending on the beam rate
  - Already better than the performance in MEG
  - Further improvement still expected

	Momentum resolution	Efficiency
Observed	184 keV → Aiming 150 keV with calibration improvement	60 % @ 3.5e7 stopping rate
MEG value	380 keV	30 % @ 3e7 stopping rate

- Positron reconstruction almost ready for physics analysis

Prospect

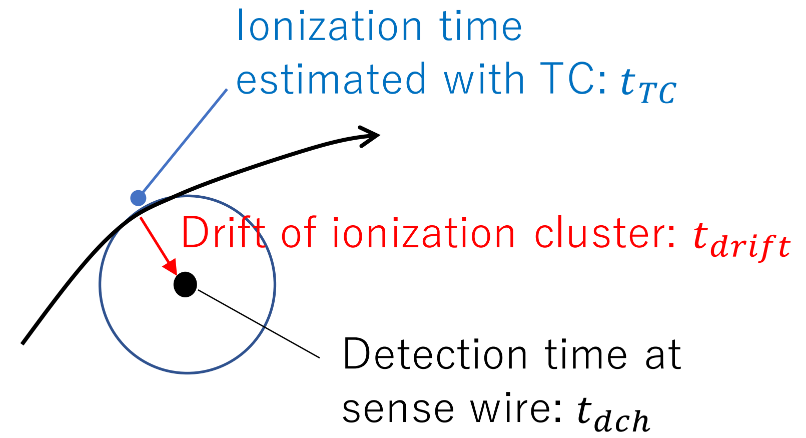
- Expected analysis improvement
  - Calibration

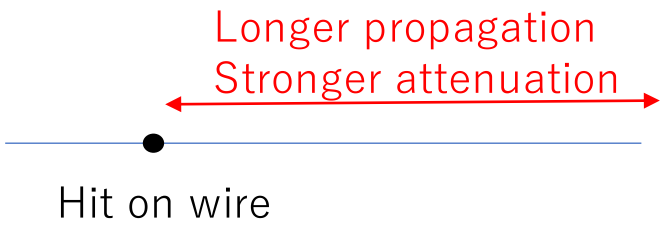
- Planned DCH hardware improvements
  - 2022 run
    - Recovery of dead channels: Suspected to be electronics issues
  - 2023 run and later
    - New DCH project ongoing
    - Missing wire problem will be fixed

Backup

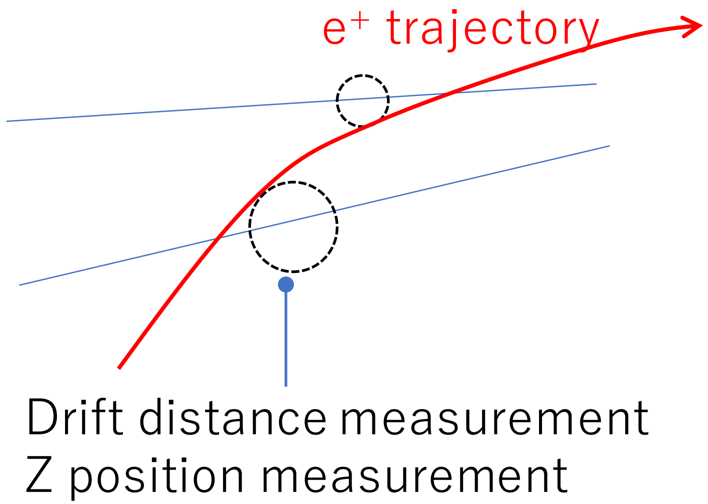
Positron tracking

- Hit reconstruction
  - Drift distance measurement
    - Necessary for both track finding & fitting
    - Drift time (up to 300 ns) + time to distance table
      - Drift time estimated with $t_{drift} = t_{dch} - t_{TC}$
  - Z position measurement
    - Necessary mainly for track finding (Track z reconstruction relies on stereo geometry)
    - Measured with time & charge difference at ends

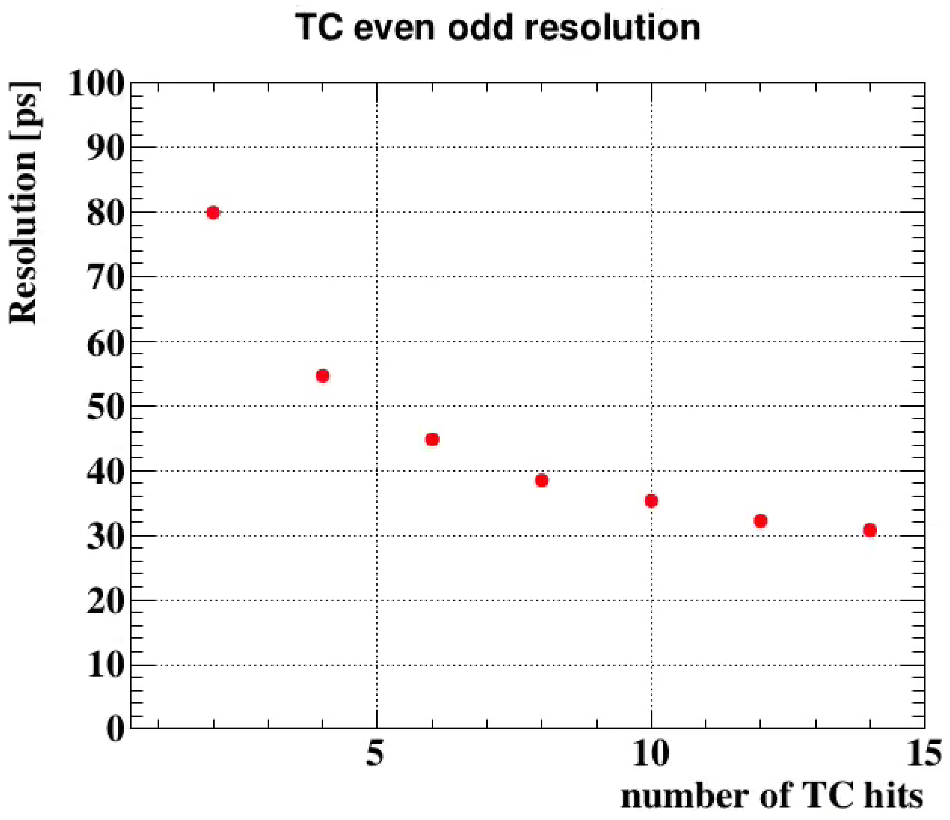


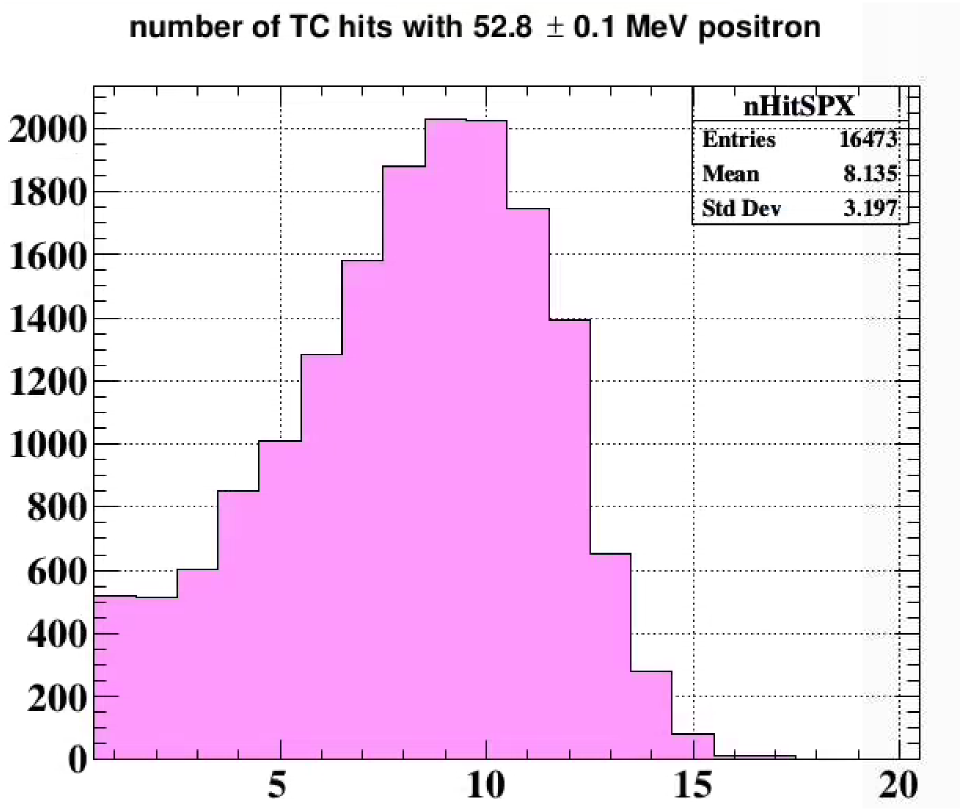


- Track reconstruction
  1. Track finding with local pattern recognition
  2. Track fitting with GENFIT package
  3. Track refinement
     - Add hits missed in track finding
     - TOF correction to $t_{dch} - t_{TC}$ measurement



Time resolution



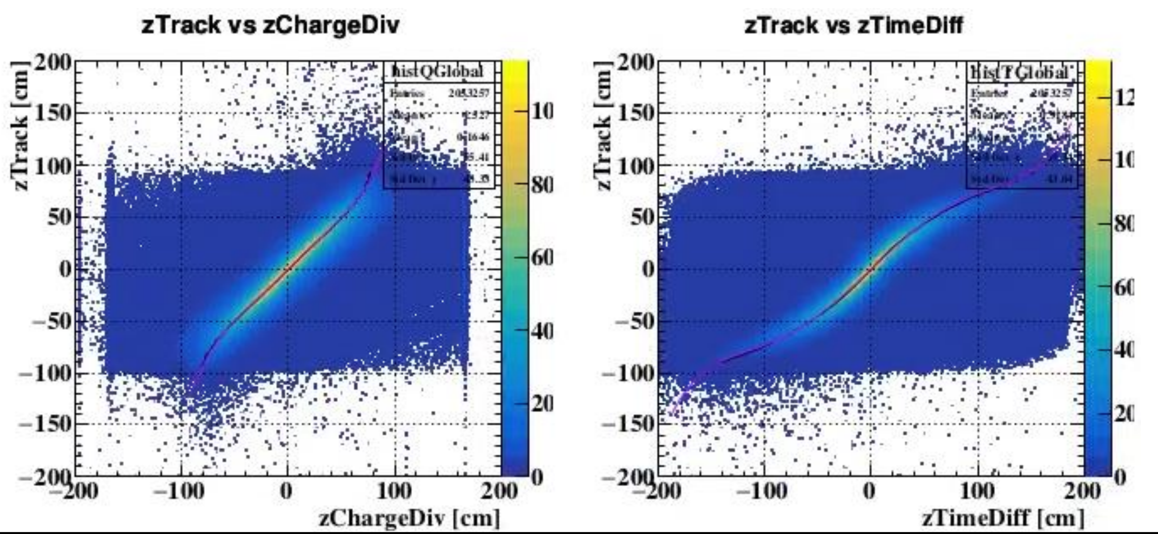


Calibrations

- Parameters to be calibrated
  - Time to distance relation
  - Wire alignment
  - Time difference between each DCH wire/TC counter
  - Z position measurement

  → Calibration in progress. Better performance expected with better calibration

Z measurement calibration with cosmic track



Hit reconstruction

- Z resolution
  - 6 cm core, 17 cm tail
- D resolution
  - 0.15 mm core, 0.3 mm tail