Positron Reconstruction Algorithms for MEG II Pixelated Timing Counter

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Summary : This poster shows a novel algorithm in MEG II positron reconstruction : pTC self tracking and its first application prospect with CDCH pattern recognition

1. MEG II Experiment & Positron Detectors

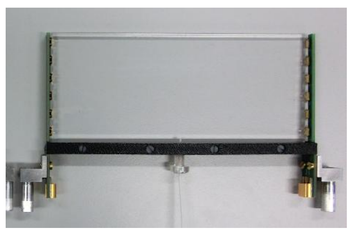
MEG II Experiment: The world's most sensitive $\mu^+ \to e^+ \gamma$ search with the most intense μ^+ beam ($7\times10^7 \mu^+/s$) in PSI [1] : precise measurement & reconstruction of positron is the key for success

Pixelated Timing Counter (pTC) :

- Composed of 512 scintillation counters
- One positron will cross the multiple (~8) counters
- Measure the positron's **crossing timing** with O(30 ps) resolution

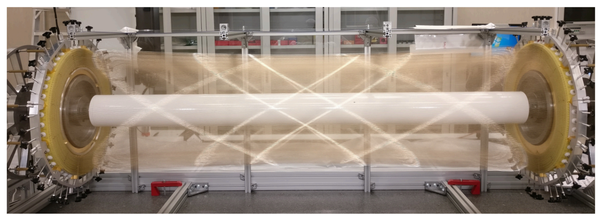
Cylindrical Drift Chamber (CDCH) :

- Ultra-low mass (90 % helium based gas mixture + 10 % isobutene)
- 192 cells per layer (9 layer)
- Higher occupancy at inner layer (35-22% in 250 ns)
- Reconstruct the positron **track** from continuous hits



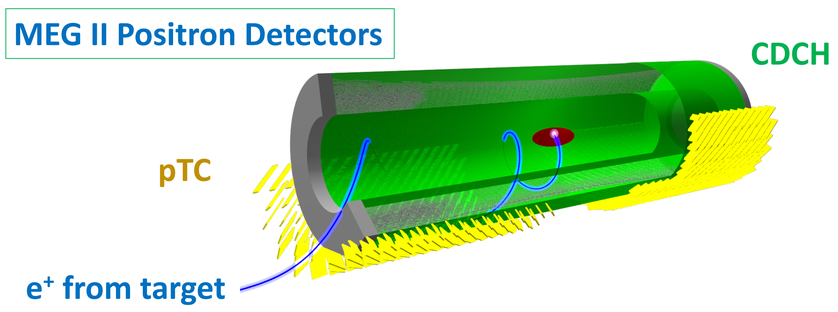
x 512

pTC : 4 or 5 [cm] x 12 [cm] x 0.5 [cm] counter
Series connected SiPMs readout at both side



CDCH: 9 layer **stereo wire** configuration
~7mm x 7mm square drift cells

MEG II Positron Detectors



e^+ trajectory: bended by gradient magnetic field
(Low momentum e^+ does not enter pTC region)

2. Expected Performance

Positron reconstruction efficiency is lower than expected

- Inefficiency comes from tail events of tracking
  - Hit reconstruction becomes difficult under high hit rate environment

Improving the tracking quality is the key to achieve the target sensitivity

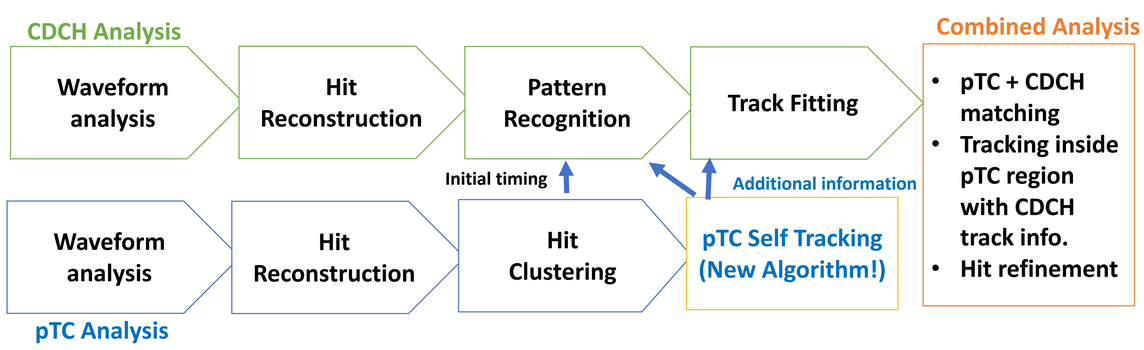
Positron Resolution / Efficiency	MEG	MEG II Design (CDCH 10 layer)	Expected from MC (CDCH 9 layer)
Theta (mrad)	9.4	5.3	5.9
Phi (mrad)	8.7	3.7	5.3 ※A
Momentum (keV)	380	130	83
Vertex Z (mm)	2.4	1.6	1.3
Vertex Y (mm)	1.2	0.7	0.72
Positron time (ps)	108	46	49 ※B
Efficiency (%)	30	70	60

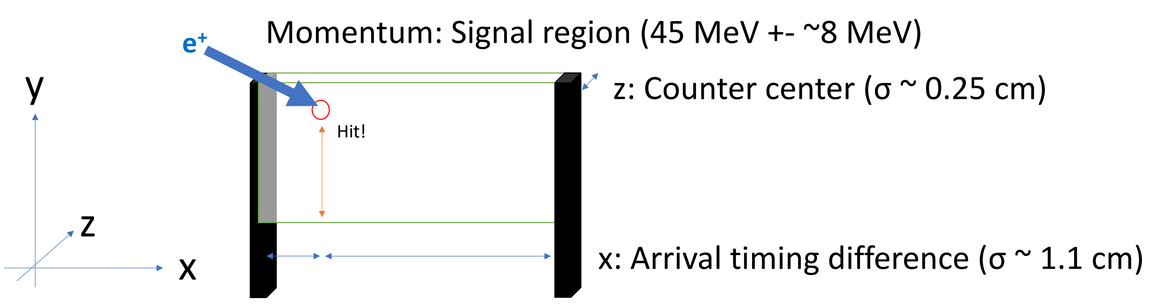
MEG & MEG II values from [1].
※A. Correction based on theta and phi correlation is not applied, though design value include it.
※B. 1 year radiation damage effect is roughly simulated, w/o cooling condition. $\sigma(T_{calib})$ ~10 ps, $\sigma(T_{WDB\_sync})$ ~25 ps is added [1].

3 . pTC Self Tracking: Idea

New idea: **Partial tracking inside pTC w/o CDCH information**

- Additional information for CDCH track finding to improve the track quality
  Initial timing, position, **direction**, trigger information etc ...
- Application to commissioning data in 2017 – 2019
  Partial readout electronics, no tracking info. from CDCH
  pTC track may help to try the detector response study
- Difficulty: no 3D information from pTC hits only -> **Estimation** needed

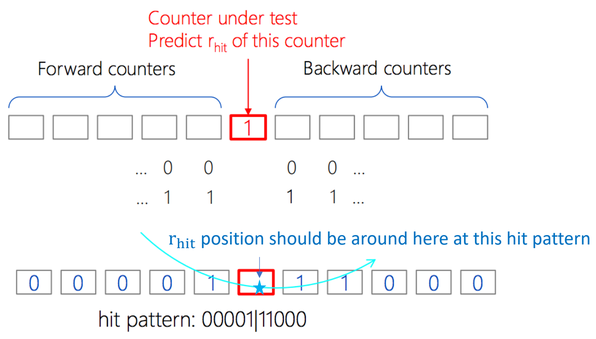


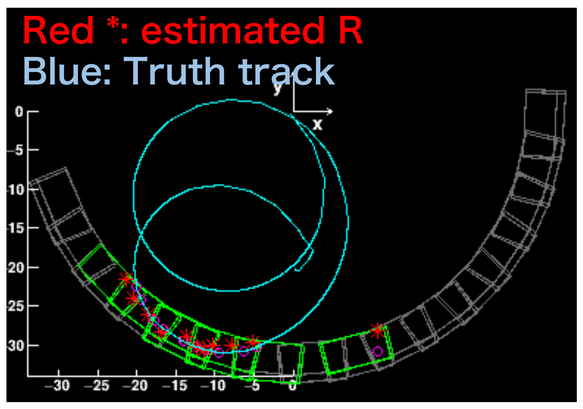


No y-position (radius) information from hits!

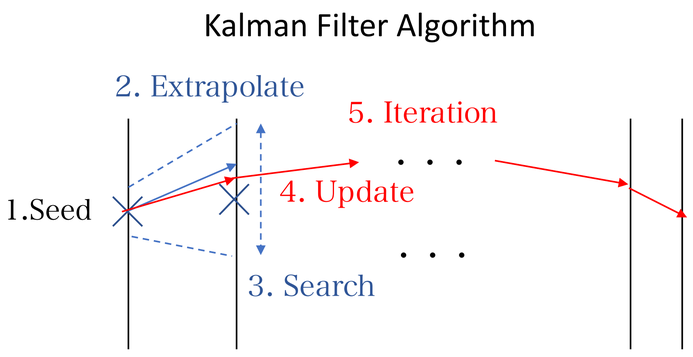
4. pTC Self Tracking: Algorithm

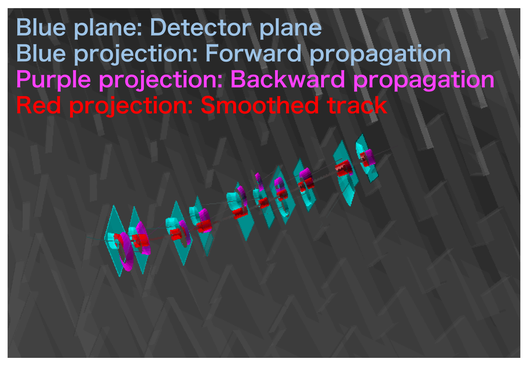
1. Obtain / Estimate initial position & momentum information in a counter
   y (r) -position: **Estimate** from hit pattern in a cluster (σ ~ 0.8 cm)
   We list up the possible patterns of hits in advance, use the mean value of R





2. Fitting with **Kalman Filter technique**
   Efficient recursive algorithm to estimate the state and its covariance including the previous states information





※Kalman Filter implementation and visualization are from **GENFIT** package: A generic toolkit for track reconstruction for experiments in particle and nuclear physics. See [2] on GENFIT.
※Practically Deterministic Annealing Filter (DAF, extension of Kalman Filter algorithm) in GENFIT is used.

Expected Performance (MC)

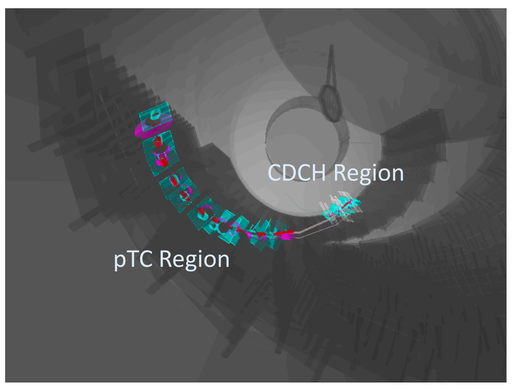
- Efficiency (When requiring a cluster has > 4 hits) > 90%
- R position resolution on a counter: 5mm
- Momentum resolution: 5 MeV
- Angle (θ) resolution: 100 mrad
- TOF b/w adjacent counters: 5 ps

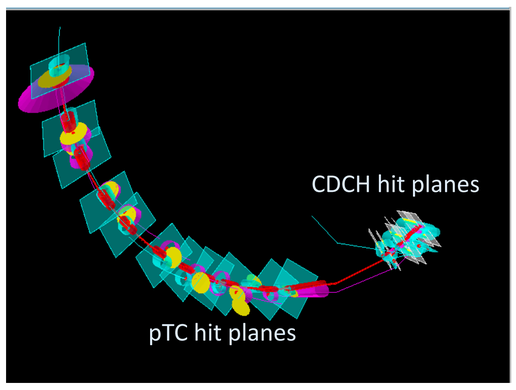
5. Application

Work In Progress !

Application to Positron Analysis (MC)

- **First attempt of pTC + CDCH combined tracking**
  CDCH hit finding and fitting from pTC partial track





Application to pTC Analysis

- Track based time offset calibration:
  preciseness improved from **19.6 ps ->13.5 ps** (MC)
- pTC's timing resolution evaluation with commissioning data:
  W/o tracking we have to fix the combination of cluster
  W/ tracking we do not have to fix the combination
  TOF correction, outlier rejection based on **DAF** weight can be applied
  36.1 ps on average (4—10 hits) with 2018 data was confirmed.

6 . Summary & Prospect

We established **a novel positron reconstruction algorithm: pTC self tracking**
We plan to ...

- **Improve the tracking quality** (reconstruction efficiency, resolution)
  First attempt of CDCH + pTC combined tracking is shown
- **Apply to commissioning data** to understand detector response
  pTC timing analysis, CDCH hit response, time offset calibration etc...

References

[1] A.M. Baldini et al. "The design of the MEG II experiment", Eur. Phys. J. C (2018) 78: 380.
[2] C. Höppner et al. "A novel generic framework for track fitting in complex detector systems", Nuclear Instruments and Methods in Physics Research A 620 (2010) 518–525