1. MEG II Experiment & Positron Detectors

**MEG II Experiment**: The world’s most sensitive $\mu^+ \rightarrow e^+ \gamma$ search with the most intense $\mu^+$ beam ($7 \times 10^7 \mu^+/s$) 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

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

<table>
<thead>
<tr>
<th>Positron Resolution / Efficiency</th>
<th>MEG II</th>
<th>MEG II Design (CDCH 10 layer)</th>
<th>Expected from MC (CDCH 9 layer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theta (mrad)</td>
<td>9.4</td>
<td>5.3</td>
<td>5.9</td>
</tr>
<tr>
<td>Phi (mrad)</td>
<td>8.7</td>
<td>3.7</td>
<td>5.3 (5.5)</td>
</tr>
<tr>
<td>Momentum (keV)</td>
<td>360</td>
<td>130</td>
<td>83</td>
</tr>
<tr>
<td>Vertex Z (mm)</td>
<td>2.4</td>
<td>1.6</td>
<td>1.3</td>
</tr>
<tr>
<td>Vertex Y (mm)</td>
<td>1.2</td>
<td>0.7</td>
<td>0.72</td>
</tr>
<tr>
<td>Position time (ps)</td>
<td>108</td>
<td>46</td>
<td>49 (56)</td>
</tr>
<tr>
<td>Efficiency (%)</td>
<td>30</td>
<td>70</td>
<td>68</td>
</tr>
</tbody>
</table>

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

4. pTC Self Tracking: Algorithm

1. Obtain / Estimate initial position & momentum information in a counter (r (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 Algorithm

1. Seed
2. Extrapolate
3. Search
4. Update
5. Repeat

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
  - TOF correction, outlier rejection based on DAF weight can be applied
  - 36.1 ps on average (4 – 10 hits) with 2018 data was confirmed.

5. Application

Application to Positron Analysis (MC)
- MEG II Experiment & Positron Detectors
- pTC Self tracking and its first application prospect with CDCH pattern recognition
- Work In Progress!

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