

# Development and commissioning of the 30 ps time resolution MEG II Pixelated Time Detector

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**Abstract:** The experiment MEG II is designed to improve by an order of magnitude the current sensitivity reached by MEG  $4.2 \times 10^{-13}$  on the search for  $\mu^+ \rightarrow e^+ \gamma$  decay. A crucial part of MEG II is a pixelated Timing Counter (pTC) that was developed to measure the positron timing with increased accuracy. The pTC is segmented into 512 small scintillation counters. Since the positron time is measured independently by several counters ( $\sim 9$  on average), the timing resolution improves significantly. We constructed and installed the pTC and performed commissioning runs at piE5 beam line in PSI during 2016 and 2017. The analysis performance is checked by MC and the timing resolution of 38.5 ps is obtained with commissioning run data including some noise contribution.

## Motivation

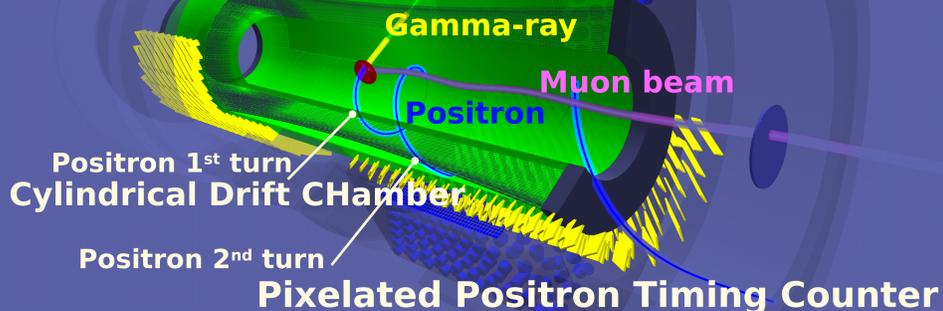
In MEG II experiment we search for the charged lepton flavor violation,  $\mu^+ \rightarrow e^+ \gamma$  decay, which is evidence of BSM physics [1].

Precise measurement of emission angle, energy, and timing of positron and  $\gamma$  is essential.



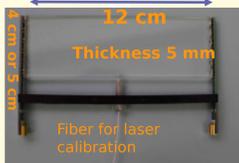
## MEG II Detector

Superconducting Magnet COBRA



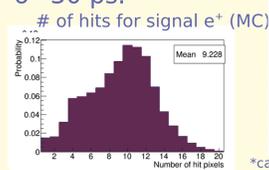
## Pixelated Timing Counter (pTC)

TC consists of 512 plastic scintillator counters readout with 6 SiPMs at both ends.



**Fast Plastic Scintillator**  
 BC422 rise time 0.35 ns  
**6 SiPMs in series**  
 AdvanSiD 3x3 mm<sup>2</sup>  
 50x50um<sup>2</sup> cells

Since positrons hit several counters, the resolution is  $\sigma \sim 30$  ps.



Resolution vs. Number of Hits (Data [3])

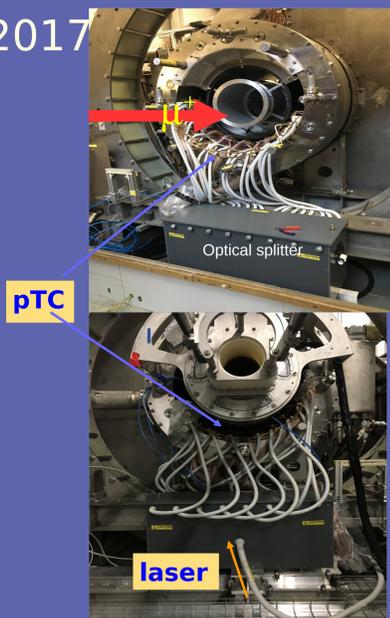
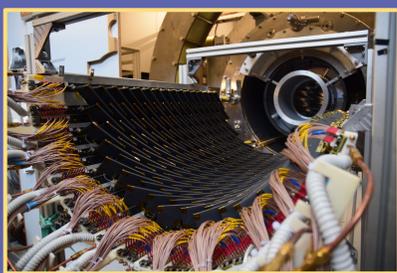


\*calculation includes single counter resolution, inter-counter jitter, and multiple scattering

## Commissioning Run 2017

All counters (512) installed and tested in MEG II site, piE5 beam line at PSI.

- Beam:** DC muon beam. Muons stopped at target ( $\sim 7 \times 10^7 \mu/s$ ), Michel Positrons are measured.
- Installed Detectors:** pTC, magnet, target, frame of drift chamber
- Electronics:** Amplifier (x100), Shaper (PZC), Digitizer (WaveDAQ)
- Trigger:** Single hit, coincidence, Track-like



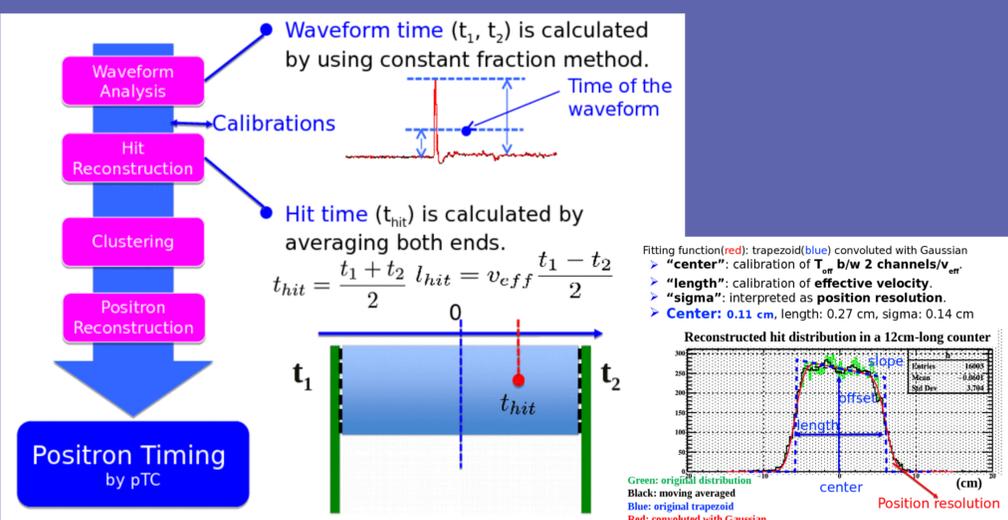
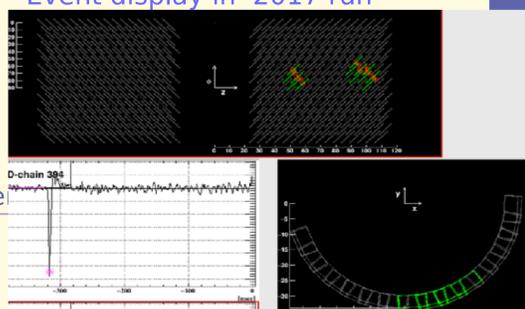
## Clustering

- Many hits from a positron.
- High rate positrons (few MHz in pTC region.)
- Clustering pTC hits is necessary. All hits from the same track and the same turn included in a cluster.

Algorithm

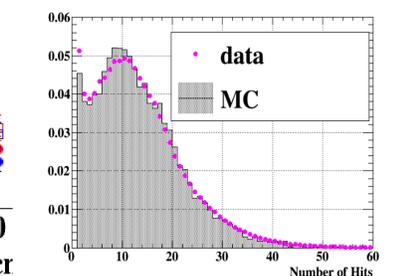
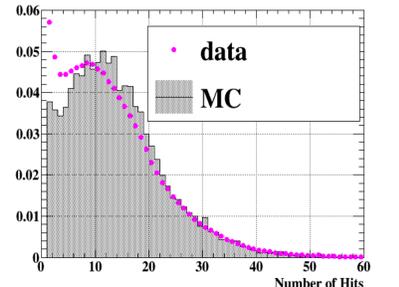
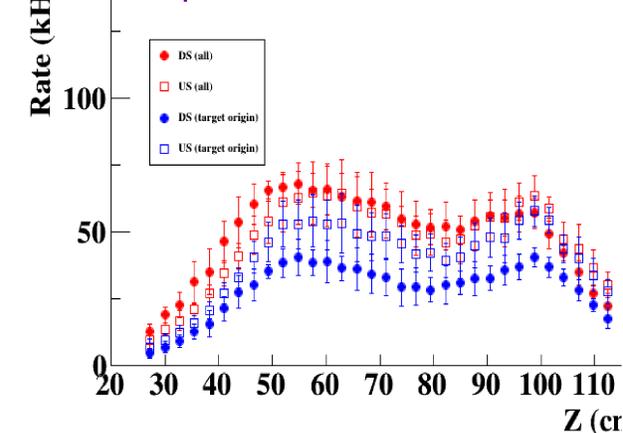
- Project for every hit time with geometrical order dependence.
- Peak Search
- Make clusters in certain region (1 ns) from each peak.

Event display in 2017 run

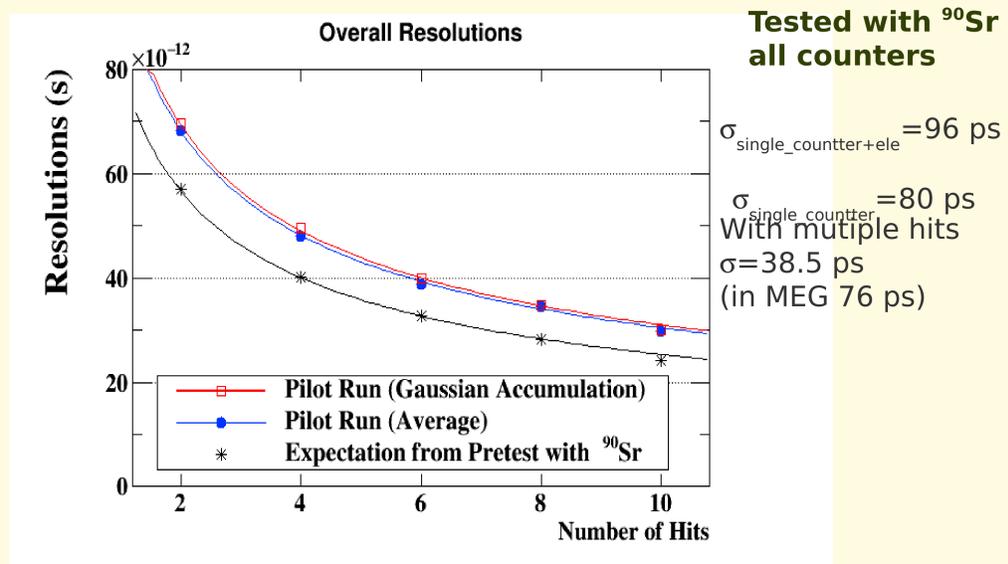


## Comparison hits Data/MC

### Z dependence



## Comparison resolution expectation



Additional contribution  $\sigma = 53$  ps under investigation. After averaging multiple hit only a few ps degradation.

## Summary

- The full pTC was installed and tested in piE5 are at PSI.
- Optimization of clustering algorithm for pTC analysis..
- MC/Data comparison hit rate for all counters.
- Calibration of the algorithm for measuring position:  $v_{eff}$
- Time resolution somehow degraded by noise improved by multiple hits
- Time resolution 38.5 ps improved by a factor of 2 with respect to MEG.

### Reference

- [1] M. Cannoni et al., Phys. Rev. D 88, 075005 (2013).
- [2] P. W. Cattaneo et al., IEEE Trans. Nucl. Sci. 61 (5) 2657-2666. arXiv:1402.1404 (2014).
- [3] M. Nishimura et al, PoS PhotoDet2015 011 (2016).
- [4] S. Ritt et al., NIM-A, 623, pp. 486 - 488, Nov. (2010).

### See posters:

- Design and test of the calibration system of the MEGII Pixelated timing Counter (296)
- Radiation damage effect on time resolution of 6 series connected SiPMs for MEGII positron Counter (82)
- WaveDAQ: an highly integrated trigger and data acquisition system (36)