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Operational results with the pixelated Time Detector of MEG II experiment during the first year of physics data taking

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ABSTRACT

The MEG II experiment was designed to improve by an order of magnitude the sensitivity of 4.2×10^{-13} reached by MEG on the branching ratio of the $\mu^+ \to e^+\gamma$ decay. The resolution of the positron timing is improved by using a segmented pixelated Timing Counter (pTC) where each counter is read independently. The pTC was commissioned in several engineering runs as well as in the first year of physics run (2021) at the πE5 beam line at PSI. Degradation of time resolution performance is observed and a program of partial upgrading the pTC is ongoing.

1. Introduction

The experiment MEG II [1] is designed to improve by about an order of magnitude the sensitivity reached by MEG, 4.2×10^{-13} on the branching ratio of the decay $\mu^+ \to e^+\gamma$ [2]. A subdetector of MEG II is the pixelated Timing Counter (pTC) which has the role to precisely measure the positron timing to reduce the combinatorial background [3]. The time resolution is improved compared to ~ 75 ps achieved in MEG [4] by reducing the size of counters and by relying on each counter crossed by the positron for an independent measurement of the positron time. Hence the pTC is segmented into 512 scintillation tiles readout separately. The pTC was constructed and commissioned at the πE5 beam line at PSI during pre-engineering runs in the period 2015–2020. During the physics run in 2021 the pTC reached an average resolution of 43 ps on positron time which is 11% worse than the value reported [5] due to the degradation of the performance discussed later in this paper. An upgrade program is underway to substitute the lesser performant counters.

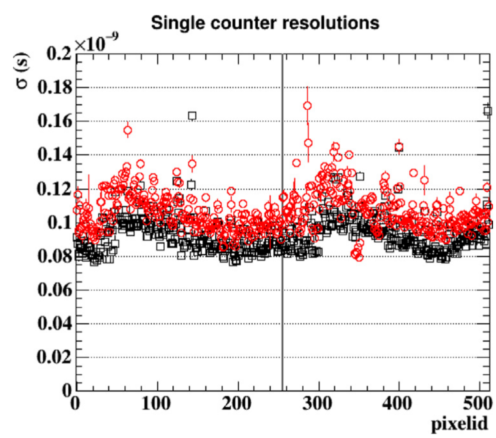

Fig. 1. Single counter resolutions in 2017 (black) and in 2021 (red). The bumps in resolution around counter number (pixelid) equal 50 and 300 are due to presence of 5 cm wide pixels.

2. Operating pTC in physics run

During 2021, we installed the full MEGII detector into the spectrometer magnet at PSI. The pTC consists of two separate sectors (upstream and downstream of the target region), each consisting of 256 counters with sizes of $L \times W \times T = 120 \times (40 \text{ or } 50) \times 5$ mm^3. Each counter

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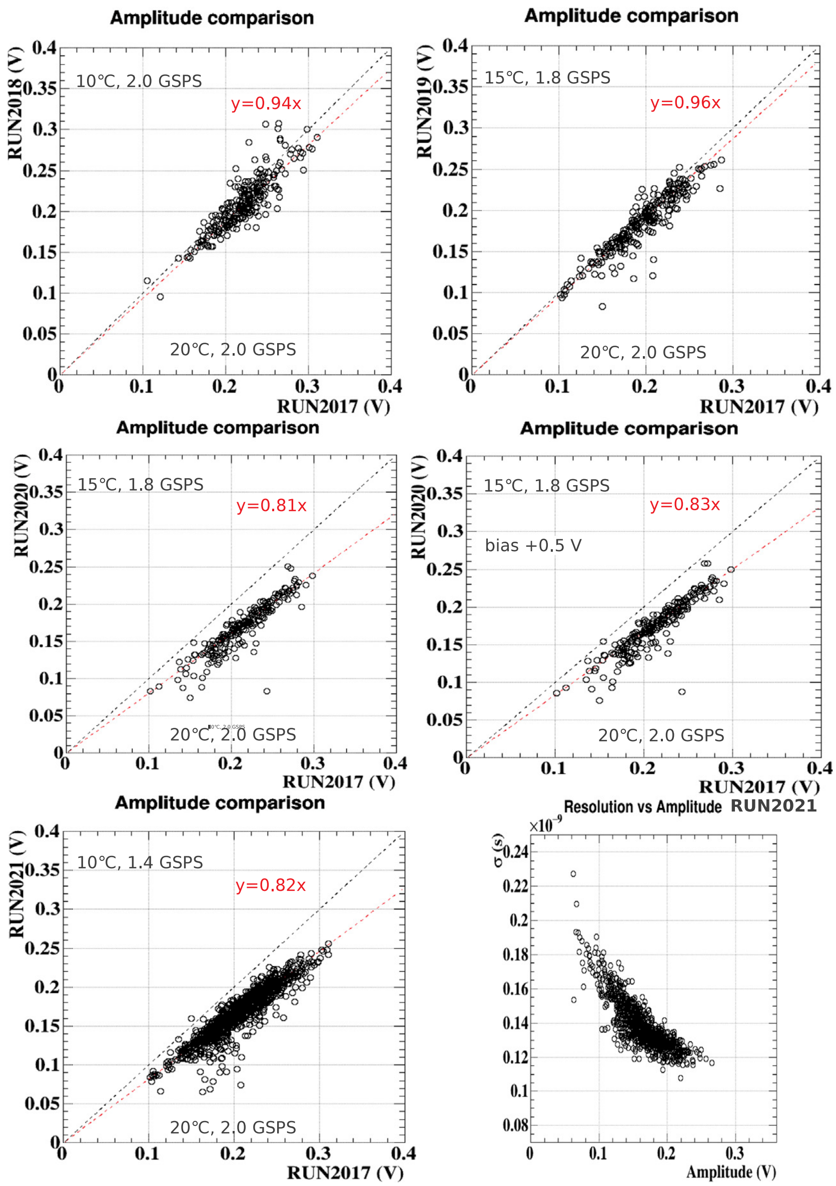

Fig. 2. Upper two rows and third row left: amplitudes in different runs versus average amplitudes in 2017; the red dashed lines are the results of linear fits. Third row right: relation between single channel time resolutions and amplitudes in 2021.

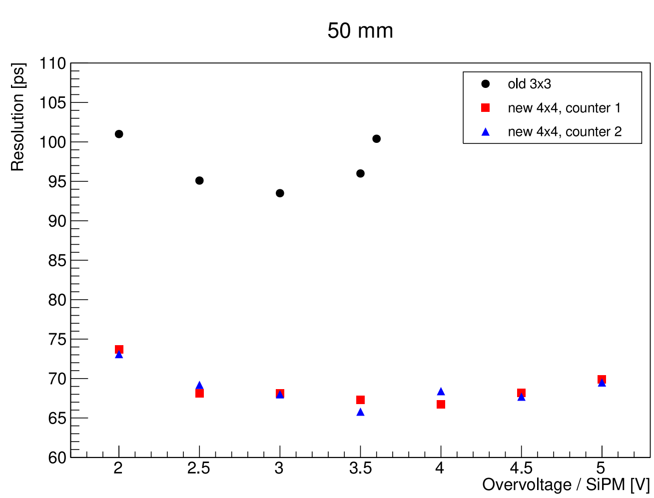

Fig. 3. Time resolution versus over voltage of a single $120 \times 50 \times 5$ mm^3 counter read out on each side by 6 SiPMs of area 4×4 mm^2 compared with the resolution of the same counter read out with SiPMs of area 3×3 mm^2.

is a scintillator tile (Saint-Gobain BC-422) readout by two sets of 6 3×3 mm^2 silicon photo-multipliers (ASD-NUV3S-P-High-Gain from AdvanSiD) glued on opposite sides connected in series. Each counter is readout by an amplifier with gain 100, followed by a shaper with pole-zero cancellation and a high frequency digitizer (WaveDream) operating at 1.4 GSPS [6]. The beam rate on target was up to 5×10^7 μ^+/s, the value to be used in MEG II. The detector temperature was controlled at 10 °C to mitigate the dark counts of SiPMs.

2.1. Resolution degradation

From the first commissioning runs the counter signal amplitudes for Michel positrons and the corresponding time resolutions have gradually degraded as shown in Fig. 1 for the time resolutions and in Fig. 2 for signal amplitudes. That is partially due to a lower sampling frequency required by the trigger, partially to other causes (noise, detachment, scintillator aging, SiPM radiation damage) still under study. SiPM detachment consists in loosening of the adhesion between SiPM and the scintillator resulting in an air gap in between. The cause is likely to be mechanical stress on SiPM boards and poor adhesion on a too smooth surface. Those counters can be repaired at the end of each run adding additional glue and scratching the scintillator surface to enhance adhesion.

2.2. Upgrade

On the basis of the degradation of performances of a fraction of the counters, that required the construction of a few tens of new counters as spare, we opted for an upgrade of the pTC striving to improve its time resolution. We studied the time resolution of counters equipped with 4×4 mm^2 SiPMs instead of 3×3 mm^2. The time resolutions of the same tile equipped with different size SiPMs in Fig. 3 show an improvement consistent with or better than the expectation based on the root square of area ratio $4/3$. The plan is to equip 100 counters[1] with 4×4 mm^2 SiPMs and replace the installed counters with lowest time resolution retaining them as spares. The new counters will be positioned to optimize the physics performance of MEGII.

References

[1] A.M. Baldini, et al., Eur. Phys. J. C 78 (380) (2018) 1.
[2] A.M. Baldini, et al., Eur. Phys. J. C 76 (8) (2016) 1.
[3] P.W. Cattaneo, et al., IEEE Trans. Nucl. Sci. 61 (5) (2014) 2657.
[4] J. Adam, et al., Eur. Phys. J. C 73 (4) (2013) 2365.
[5] M. Nishimura, et al., Nucl. Instrum. Methods A 958 (2020) 162785.
[6] S. Ritt, et al., Nucl. Instrum. Methods A 623 (2010) 486.

[1] Determined by availability of scintillator plates and budget constraint.