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Studies of anomalously long-delayed afterpulses in vacuum photomultipliers

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We report a systematic study of afterpulses with anomalously long delays in photomultiplier tubes (PMTs) with photocathode diameters ranging from 0.75 inch (Philips/HZC XP1911) to 20 inch (Hamamatsu R12860 and NNVT N6205). Our studies reveal a clear dependence of the afterpulse delay on the PMT geometry, specifically on the distance between the photocathode and the first dynode; for the Hamamatsu R12860, for instance, this delay reaches 260 μ s. These measurements are motivated by large-scale neutrino detectors, where delayed afterpulses can mimic genuine neutron-capture signals and produce accidental coincidences with preceding positron events, thereby degrading sensitivity to neutrinos.

The amplitudes of such afterpulses remain at the single-photoelectron level, and their probability is below 0.1% per photoelectron. The observed delay times and the absence of dependence on the operating voltage indicate that these afterpulses cannot be satisfactorily explained within the standard ion-feedback model. Their characterization is essential for reliable background suppression and event reconstruction in large neutrino telescopes, and further studies are needed to clarify their origin.

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