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Coincident signals on multiple counters in a neutron monitor: Sparse vs. dense atmospheric secondary particles from cosmic ray showers

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Neutron monitors were designed to measure atmospheric secondary neutrons from cosmic ray showers in order to track the cosmic ray flux vs. time. Furthermore, at the Princess Sirindhorn Neutron Monitor (PSNM), an 18-counter NM64 detector at 2560-m altitude at Doi Inthanon, Thailand, the leader fraction (inverse multiplicity) inferred from time delay distribution between successive neutron events in the same counter has been used to track spectral variations. More recent measurements of time delays between neutron events in different counters, as a function of counter separation, have confirmed that 1) the product neutrons from the interaction of a single atmospheric secondary neutron can spread among neighboring counters, with a cross-counter leader fraction that depends on whether the first counter is an end or middle counter, and 2) coincident counts between distant counters can be produced by multiple atmospheric secondary neutrons from the same primary cosmic ray, with a leader fraction that depends on whether the second counter is an end or middle counter. Here we report on measurements of neutron signals in amplifier outputs at PSNM using a 4-channel oscilloscope, in order to further investigate these phenomena. For a pair of neighboring counters located at the edge of the counter array, we find roughly equal event rates in either neighbor following a neutron trigger in one of them, implying that the difference in leader fraction relates to the base count rate of the first counter and is therefore lower if that is an end counter. In addition, an FPGA-based readout system was developed for more efficient collection of neutron events on two distant counters (Tubes 2 and 18) that were coincident within a 250-microsecond time window, while also monitoring Tube 10 in between. The time distributions and neutron multiplicities indicate that a small fraction of the cosmic ray events that triggered both Tubes 2 and 18 also led to neutron events on Tube 10 with an enhanced rate of high multiplicity, indicating a few air shower events that densely "carpeted" the neutron monitor, while the majority of such coincidences apparently involved a sparse distribution of isolated secondary particles near Tube 2 and near Tube 18 and not near the intermediate Tube 10, which is consistent with a cross-counter leader fraction dependence on the count rate of the second counter. This research was supported by the

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