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#4-172 Development of a Time-of-Flight Spectrometer for Characterizing a 30-MeV Cyclotron-based Quasi-monoenergetic Neutron Beam

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We report the results of time-of-flight (TOF) measurements used to characterize the spectrum of a neutron beam generated by a proton cyclotron at the National Atomic Research Institute in Taiwan. The quasi-monoenergetic neutron beam is produced through the interaction of 30-MeV protons with a 1-mm-thick beryllium target via the $^9Be(p,n)^9B$ nuclear reaction. To effectively discriminate between neutron and gamma-ray signals emitted from the target, the time-of-flight spectrometer was constructed using two EJ-309 liquid organic scintillators. The first trigger detector, a 2-inch EJ-309 used to measure gamma rays and initiate the TOF measurement, was positioned 20 cm from the beam port at an angle of 45 degrees relative to the beam axis. Meanwhile, a 3-inch EJ-309 record detector was placed 294 cm away from the beam port to measure the output neutrons. The time differences between gamma rays and neutrons detected by the trigger and record detectors, respectively, were analyzed as "gamma-neutron coincidence events" to evaluate neutron flight times and determine the energies of neutrons based on the known flight distance. Since the 30-MeV cyclotron operates at a radio frequency of 73.13 MHz to produce proton bunches with a period of 13.67 ns, the TOF measurements were triggered by gamma-ray bursts that were synchronously emitted from the target with the proton bunches. Consequently, repetitive distributions for the gamma ray-gamma ray and gamma ray-neutron coincidences were obtained in the measured TOF results, limiting the analyzable time window to between 39.44 ns and 53.11 ns (39.44 + 13.67 ns), which corresponds to neutron energies ranging from 30 MeV to 16.19 MeV. In this manner, neutrons with energies below 16.19 MeV contributed to chance coincidences in the measurements, forming a DC background in the TOF spectrum. By eliminating these chance coincidences, the measured neutron spectrum exhibits a quasi-monoenergetic distribution peaked at 25 MeV, showing remarkable agreement with the spectrum simulated by the Monte Carlo model MCNP. Our TOF method has been highly successful in characterizing the spectrum of fast neutrons from a cyclotron-based neutron source. The results provide reliable spectral properties of neutrons and facilitate quality assurance of the neutron beam for downstream applications.

Primary author: Mr LIN, Tzu-Hsiang (Institute of Nuclear Engineering and Science, National Tsing Hua University)

Co-authors: Dr LEE, How-Ming (Department of Physics, National Atomic Research Institute); Mr CHU, Kuo-Yuan (Department of Isotopes, National Atomic Research Institute); Dr DUH, Ting-Shien (Department of Isotopes, National Atomic Research Institute); Prof. TSAI, Hui-Yu (Institute of Nuclear Engineering and Science, National Tsing Hua University); Prof. LIN, Ming-Wei (Institute of Nuclear Engineering and Science, National Tsing Hua University)

Presenter: Mr LIN, Tzu-Hsiang (Institute of Nuclear Engineering and Science, National Tsing Hua University)

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