PERFORMANCE OF LARGE-VOLUME MEAN-TIMED NEUTRON DETECTORS

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This discussion updates the information in last year's report on the performance of our large volume, mean timed, neutron counters. We observed subnanosecond time dispersion for large (13.1 ℓ, 26.2 ℓ, and 52.2 ℓ) NE-102 plastic scintillators with a mean-timing technique described by Evers et al.[1] and Bhowmik et al.[2] A module described by Baldwin and Madey[3] measures the mean time $\bar{t}=(t_1+t_2)/2$, where t_1, t_2 are the photon transit times from the scintillation event to 5 in diameter (Amperex XP2041) photomultiplier tubes (PMTs) coupled to lucite pipes at each end of the 40 in. long scintillator. We measured an upper limit to the intrinsic time dispersion of these detectors with cosmic rays. With one large counter placed directly above another of identical dimensions, we measured coincidences with the cosmic rays passing through the 4 in dimension of each counter. The threshold of each counter was set at 14 MeV equivalent-electron energy (MeV-ee) which is about two-thirds the energy corresponding to the peak in the cosmic-ray pulse-height spectrum. Position identification was used in both counters to eliminate the largest zenith angles in the cosmic ray flux in order to reduce flight-path differences between the detected events in each counter. The observed time resolution of 332 ± 7 picoseconds (fwhm) is shown in Fig. 1 for two 10 in x 40 in x 4 in detectors. From this coincidence time-resolution measurement with cosmic rays, we deduce an upper limit to the intrinsic time dispersion of 235 ± 5 ps (fwhm) for one of our large (10 in x 40 in x 4 in) NE-102 plastic scintillation counters. Similarly, we deduced an upper limit of 155 ± 5 ps (fwhm) for the intrinsic time dispersion of a 5 in x 40 in x 4 in detector. A computer code, which we developed to simulate the mean-timing process in our detectors calculates intrinsic time dispersions of only 15 ps and 25 ps (fwhm) for our 5 in x 40 in x 4 in and 10 in x 40 in x 4 in counters, respectively. We believe that "walk" and time-slewing in the electronics and the residual spread in cosmic-ray zenith angles are the major contributors to the time dispersions measured for these counters.

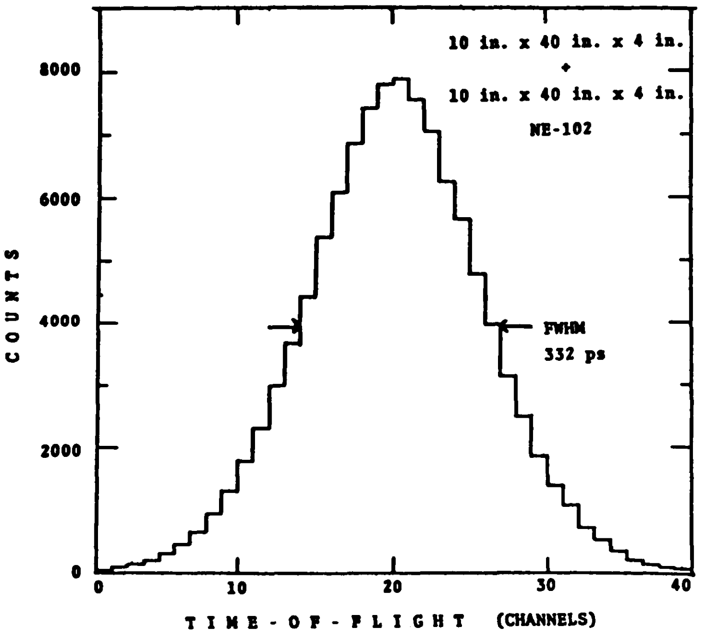

Figure 1. Time-resolution of two 10 in x 40 in x 4 in NE-102 counters for cosmic rays. One was placed on top of the other and both had a threshold set at about two-thirds of the cosmic-ray through-peak (or at about 14 MeV equivalent-electron energy). Position identification was used to eliminate the larger zenith angle in the cosmic-ray flux.

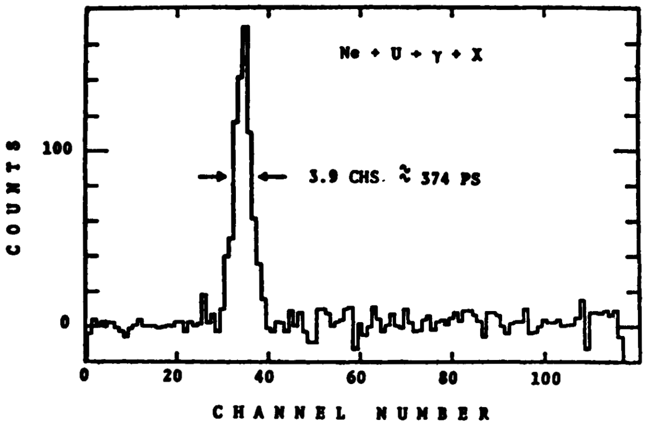

Figure 2. A portion of the time-of-flight spectrum showing the prompt γ-ray peak from 337 MeV/A neon ions on a uranium target. The measurement was made with a 10 in x 40 in x 4 in NE-102 counter with a pulse-height threshold of 8 MeV equivalent-electron energy.

In addition to the cosmic-ray studies of the intrinsic time dispersions of the large-volume neutron detectors, we observed good time resolutions in experiments at the Bevalac and at the IUCF. Figure 2 shows a gamma-flash peak measured by a 10 in x 40 in x 4 in NE-102 counter from Ne+U at 337 MeV/nucleon performed at the Bevalac. The fwhm of 374 picoseconds for the γ peak includes the timing dispersions of the "neutron" counter and the beam telescope folded together. The neutron detector threshold was set at 8 MeV-ee. In a recent experimental run at the IUCF, we obtained a neutron peak with a time resolution of 490 ps for a 10 in high x 40 in x 4 in NE-102 detector. Figure 3 shows a sharp neutron peak corresponding to the 2.52-MeV state in ^{48}Sc from the ^{48}Ca(p,n) reaction at an incident proton energy of 160 MeV; the corresponding energy resolution is 440 keV. Note that the observed resolution includes the finite detector thickness effect and the burst width of the cyclotron proton beam. We measured an upper limit for the burst width of less than 375 ps with a (plastic scintillator) monitor counter positioned close to the target for detecting elastically-scattered protons.

Figure 4 shows a portion of the time-of-flight spectrum of neutrons from the ^{12}C(p,n)^{12}N reaction at 100 MeV proton energy and a laboratory angle of 24.5°. The two peaks are the ^{12}N ground state and 0.96 MeV first excited state. From the observed separation of these peaks we deduce a width of 230 keV fwhm for the ^{12}N(g.s.) peak; these neutrons have an energy of 80 MeV. Note that the 23 mg/cm^2 target contributes 150 keV to the resolution. This spectrum was obtained at a flight path of 76.3 m with our new 20 in x 40 in x

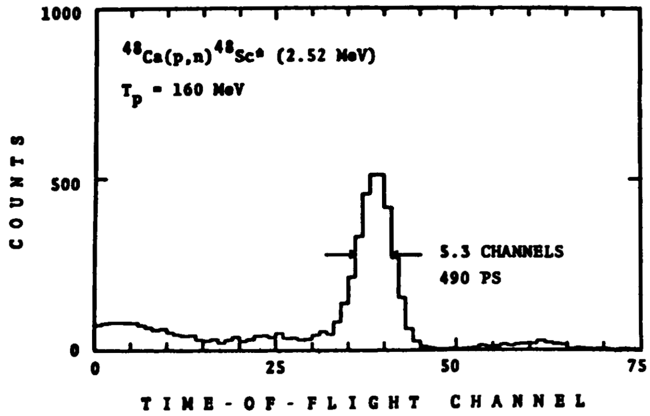

Figure 3. The neutron time-of-flight spectrum at a laboratory angle of 0° from the ^{48}Ca(p,n)^{48}Sc reaction at 160 MeV. The sharp peak is the ^{48}Sc state at 2.52 MeV excitation.

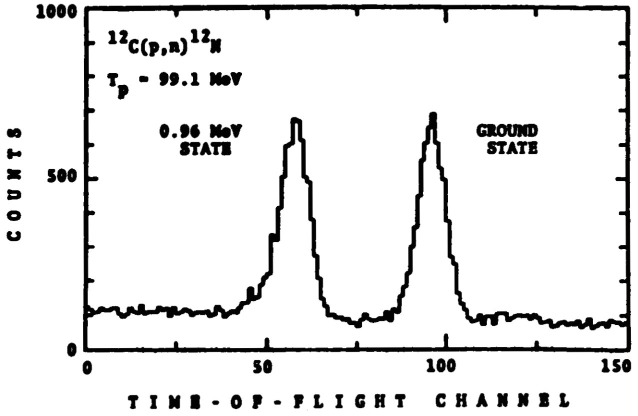

Figure 4. The neutron energy spectrum at a laboratory angle of 24° from the ^{12}C(p,n)^{12}N reaction at 99.1 MeV.

4 in mean-timed neutron counter. This counter was in a two-counter array with one of our 10 in x 40 in x 4 in counters. The overall energy and time resolutions of the two counters were identical. To the best of our knowledge, this is the best energy resolution reported for neutron time-of-flight measurements above 50 MeV. An abstract on the performance of our detectors was submitted to the American Physical Society for presentation at the April 1980 meeting in Washington, D.C.

1) D. Evers et al., Nucl. Instrum. Methods 124, 33 (1975).

2) R.J. Bhowmik et al., Nucl. Instrum. Methods 143, 63 (1977).

3) A.R. Baldwin and R. Madey, Nucl. Instrum. Methods (in press).