LARGE-VOLUME NEUTRON COUNTERS WITH SUBNANOSECOND TIME DISPERSIONS

R. Madey,* B. Anderson,* A. Baldwin,* J. Knudson,* and T. Witten*†

In order to achieve an energy resolution of the order of a few hundred keV for neutrons of about 100 MeV, we expect to utilize flight paths of 100 m and possibly longer. The longer flight paths require larger-volume neutron counters with subnanosecond time dispersions in order to achieve the better energy resolution without significant loss of counting rate.

In a measurement of a neutron flight time t, the fractional energy resolution $\Delta T/T$ is

$$\frac{\Delta T}{T} = \frac{(T + M)(T + 2M)}{M^2} \left[\frac{\Delta x}{x}^2 + \frac{\Delta t_b}{t}^2 + \frac{\Delta t_c}{t}^2 \right]^{\frac{1}{2}} \quad (1)$$

Here M is the neutron rest mass, x is the uncertainty in the neutron flight path x arising from the finite dimensions of the counter, t_b is the Gaussian-quadrature combination of the beam burst-width and the beam phase-drift, and t_c is the intrinsic time dispersion of the counter. Equation (1) can be re-expressed as

$$\frac{\Delta T}{T} = \frac{(T + M)(T + 2M)}{M^2} \left(\frac{v}{x}\right) \left[\frac{\Delta x}{v}^2 + (\Delta t_b)^2 + (\Delta t_c)^2 \right]^{\frac{1}{2}} \quad (2)$$

where v is the speed of the neutron. In Eq. (2), the square-root factor corresponds to the observed time-width of a peak in a time-of-flight spectrum. For a fixed overall time resolution, the energy resolution improves linearly with an increase in the flight path; for example, doubling the flight path cuts the energy resolution in half. Larger counters are needed to compensate for the loss in solid angle as the flight path is increased.

We report here progress in the construction and texting of successively larger NE-102 plastic scintillation counters with subnanosecond time dispersions. In Table 1, we list for each counter the dimensions of the NE-102 plastic scintillator and the length of the tapered acrylic-plastic light-pipe which is attached to each end of the long dimension of the scintillator. An Amperex XP2041 5 in. diam. photomultiplier tube is coupled to each light pipe.

The mean-timing technique[1,2] is used to achieve subnanosecond time dispersions with these large-volume counters. The anode signal from each photomultiplier feeds a constant-fraction timing discriminator. The discriminator outputs serve as inputs to a mean-timer module which was designed and constructed in our laboratory. The mean-timer generates an output pulse at a time equal to the mean time of arrival of the two input pulses plus a constant propagation time through the network. The mean time of arrival of the input trigger signals is related to the average of the photon transit times from the scintillation event to the photomultipliers at each end of the long scintillator. The mean detection time is independent of the position of the scintillation event across the long dimension of the scintillator.

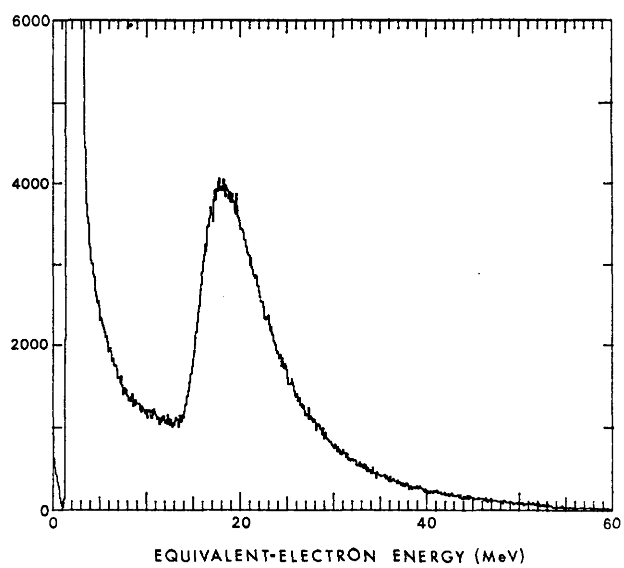

Figure 1. Cosmic-ray pulse-height spectrum in a 10 in. x 40 in. x 4 in. NE-102 counter in coincidence with another identical counter placed on top. The 4 in. dimension is in the vertical direction.

We deduced the intrinsic time dispersion of each of these counters from measurements with cosmic rays. With one counter placed directly above another, we measured coincidences with cosmic rays passing through the 4 in. dimension of each scintillator. The threshold of each counter was 6 MeV equivalent-electron energy, which is about one-third the energy corresponding to the peak in the cosmic-ray pulse-height spectrum. Figure 1 is a typical pulse-height spectrum from cosmic rays. The peak corresponds to the most probable energy deposited in 4 inches of scintillator by energetic muons.[3] With two 10 in. x 40 in. x 4 in. counters in coincidence, we measured a time resolution of 435 ± 10 ps (fwhm) and unfolded an intrinsic resolution of 308 ± 7 ps (fwhm) for each 10 in. x 40 in. x 4 in. counter. With a 10 in. x 40 in. x 4 in. counter in coincidence with a 5 in. x 40 in. x 4 in. counter, we measured a time resolution of 456 ± 8 ps (fwhm) and unfolded an intrinsic time resolution of 334 ± 13 ps (fwhm) for a 5 in. x 40 in. x 4 in. counter. The third column in Table 1 lists the time dispersion observed with each counter in coincidence with a 10 in. x 40 in. x 4 in. control counter. We deduced the intrinsic dispersion of each test counter by quadrature unfolding the assumed contribution of the 10 in. x 40 in. x 4 in. control counter from the observed dispersion. The results are listed in the fourth column of Table 1.

Acknowledgement

This work was supported in part by the National Science Foundation under NSF grant PHY 75-02870-A01 and the Department of Energy under DOE contract EY-76-S-02-2231.

*Kent State University

†Current Address: Sperry Univac, Dahlgren, Virginia

1) D. Evers, E. Spindler, P. Kourade, K. Rudolph, N. Assman, and P. Sperr, Nucl. Instr. and Meth. 124, 33 (1975).

2) R.J. Bhowmik, R.R. Doering, S.M. Austin, A. Galonsky, and S.E. Sherry, Nucl. Instr. and Meth. 143, 63 (1977).

3) J.M. Paul, Nucl. Instr. and Meth. 96, 51 (1971).

Table 1

Scintillator Dimensions, Light-Pipe Length, and Intrinsic Time Dispersion of Large-Volume Neutron Counters

Scintillator Dimensions (inches)	Length of Light Pipe (inches)	Observed Dispersion with a 10 in. x 40 in. x 4 in. Control Counter (picoseconds)	Intrinsic (fwhm) Dispersion (picoseconds)
5 x 40 x 4	6	456 ± 8	334 ± 13
10 x 40 x 4	12	435 ± 10	308 ± 7
20 x 40 x 4	30	520 ± 9	417 ± 12
10 x 80 x 4	12	473 ± 7	357 ± 11