PERFORMANCE OF LARGE-VOLUME MEAN-TIMED NEUTRON DETECTORS

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This discussion updates information in the 1981 Annual Report[1] on the performance of our large-volume, mean-timed detectors. During the past year, we continued our program of testing the performance of our large-volume, mean-timed neutron detectors; in particular, we developed an improved way of measuring their position resolution.

Because two timing signals--one from each PMT--are obtained from each detector, two pieces of information can be derived from each event. Let t_1 and t_2 be the time signals derived from the two PMT's. The mean time $t = (t_1+t_2)/2$ is largely independent of the position of an event along the length of the detector, and the time difference Δt resolution, hence the position resolution, for cosmic rays passing through the 4 in. dimension of a given detector. The energy loss of "minimum ionizing" cosmic rays is about 20 MeV through 4 in. of scintillator.

We "collimated" the cosmic-ray flux with two small scintillators (1 in. × 4 in. and 5 in. thick), one placed below the large-volume detector. A triple-coincidence between time signals from these two small counters and the t_1 signal restricts the cosmic-ray measurements to a small (1 in. wide) strip across the large detector. Figure 1 shows our measurements for five different locations along the axis of a 20 in. × 40 in. × 4 in. detector. From these data we deduce a position resolution of 1.8 in. (FWHM), independent of position along the axis. Figure 2 shows off-axis measurements for this same detector. These

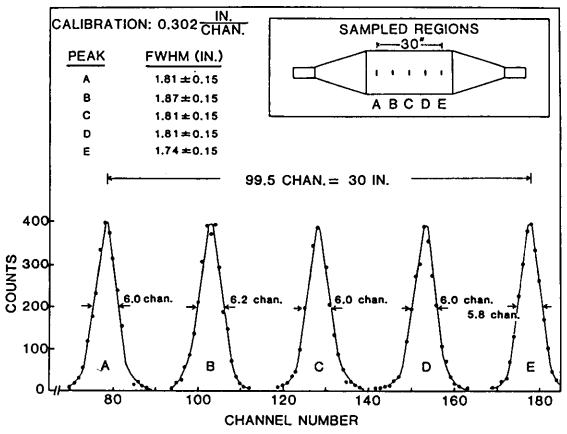

Figure 1. Position resolution for a 20 in. × 40 in. × 4 in. detector. Cosmic rays passing through the indicated areas, A, B, C, D, and E, were selected by small coincidence detectors above and below the large detector. The measured quantity is Δt, the time difference between the pulses from the photomultiplier tubes at the two ends of the large detector.

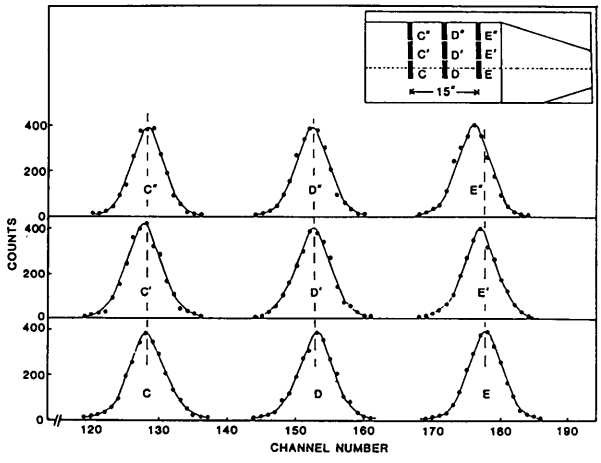

Figure 2. Off-axis position resolution for one quadrant of a 20 in. × 40 in. × 4 in. detector. The data labeled C, D, and E are the same as in Fig. 1. Note the maximum position slewing is only ~ 0.5 in. for the corner.

data indicate a maximum slewing of the deduced position of only 0.5 in. for off-axis points, and then only for the extreme corners of the detector. Table I summarizes the position resolution along with the intrinsic time dispersion for several different sizes of mean-timed detectors. The techniques for measuring intrinsic time dispersions were discussed in the 1979 IUCF Annual Report.[2]

Table I. Position resolution and intrinsic time dispersion of mean-timed detectors.

Scintillator Dimensions (in.)	Light Pipe Length (in.)	FWHM Position Resolution[a] (in.)	FWHM Intrinsic Time Dispersion (ps)
5 x 40 x 4	6	< 1.0	155 ± 5
10 x 40 x 4	12	1.65 ± 0.10	235 ± 5
10 x 80 x 4	12	1.80 ± 0.15	--
20 x 40 x 4	24	1.81 ± 0.15[b]	300 ± 7
40 x 40 x 4	24	--	410 ± 13
30 x 60 x 4	31	--	350 ± 20

a) Measured on the central axis.
b) Maximum position slewing of ~ 0.5 in. for the corners.

1) IUCF Scientific and Technical Report, 1981, p. 111. 2) IUCF Scientific and Technical Report, 1979, p. 128.

A NEUTRON FACILITY FOR NEUTRON-INDUCED CHARGED-PARTICLE REACTION STUDIES

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A study of the feasibility of conducting (n,p) experiments at intermediate neutron energies using the IUCF facilities was approved by the Directors at IUCF after it was reviewed by the Program Advisory Committee (PAC). Six shifts were allocated and the experiment was run 13-15 August 1982.

Neutrons were produced via the reaction $^{7}Li(p,n)^{7}Be$ using 120 MeV protons. For a 1.5 MeV thick ^{7}Li target, the estimated neutron production at $\theta = 0°$ is approximately 6 x 10^{9} n/μA-sr. An evacuated 1" × 2" collimator embedded in a temporary concrete wall separated the neutron source from the target 3.3 m away. A magnet was used to deflect particles emitted from the target at 0° into a ΔE-E telescope consisting of 3 HP Ge detectors shielded from the incident neutron flux. An x-y position sensitive multiwire proportional chamber (MWPC)[1] was used to define the path of the charged particles emitted from the target. The

distance between target and Ge detectors (3/4" diameter collimator) was about 20".

A beam current of at least 1 μA of 120 MeV protons was expected; however, a large beam-dependent background observed in the Ge detectors limited the tolerable beam current to 0.15 μA. Under those conditions the total number of neutrons on the sample was approximately 9000 n/cm^2-sec.

Two CH_2 targets (1.5 MeV thick to 120 MeV protons) were used. One was about 2" × 2" and another 3/4" in diameter. The latter one had the same dimensions as an enriched ^{13}C target, also 1.5 MeV thick. Only the last few hours were left to try the smaller targets and we present some of the on-line results. Analysis of this work is still in progress.

Figure 1 is a proton background-subtracted spectrum obtained after monitor normalization. Neutrons were produced using a thick ^7Li target (~ 4.2 MeV) and the radiator was a thick CH_2 (~ 4 MeV) target. This set-up provided an order-of-magnitude larger count rate than in the previous set-up and clearly indicates the feasibility of these type of experiments. The data were obtained in about 15 minutes.

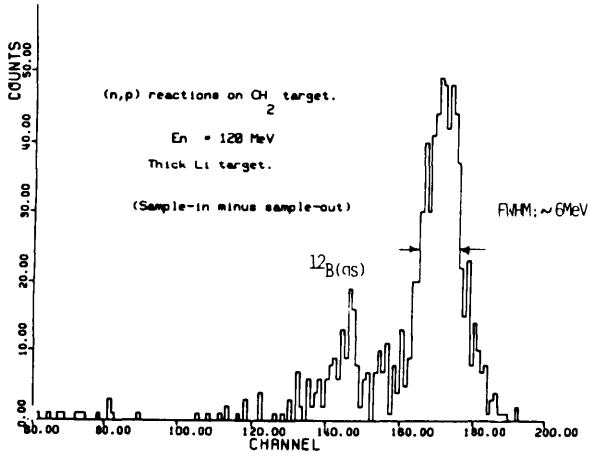

Figure 1. Proton spectrum obtained from the CH_2 (n,p) reaction using 120 MeV neutrons ($\theta \sim 0°$).

The scientific motivation for this type of work is many-fold. The importance of the (p,n) studies at intermediate energies has been clearly demonstrated. The interpretation of the "missing" GT strength in terms of the coupling of nucleon-hole and delta-hole states may be considered one of the highlights of this research.

The sum rule for GT strength is written as $S_{\beta-} - S_{\beta+} = 3(N-Z)$ where $S_{\beta-}$ corresponds to the GT strength observed in (p,n) reactions. The corresponding strength $S_{\beta+}$ that may be observed in (n,p) reactions has not yet been empirically obtained. This quantity is important not only for nuclear structure information but is also of extreme importance in the calculation of astrophysical processes that eventually lead to neutron stars.

The (n,p) reaction is also a unique and selective tool that excites only $\Delta T = \Delta T_Z = +1$ transitions. The states in the final nucleus are $(T_0 + 1)$ analogs of the T_0 (if $T_0 \neq 0$) states in the target nucleus. Thus with the (n,p) reaction it is possible to study the excitation of analogs of isovector giant resonances. The energy dependence of spin-flip excitations observed in the (p,n) reaction[2] may be used in these studies to distinguish $\Delta S = 0$ and $\Delta S = 1$ resonances. These type of studies should provide unequivocal empirical evidence for excitation of isovector monopole ($\Delta L = 0$, $\Delta S = 0$) resonances, for which there has been a large theoretical interest. Evidence for excitation of the isovector monopole in the $^{209}Bi(n,p)^{209}Pb$ reaction at $E_n = 60$ MeV has been recently presented. The excitation of spin-flip resonances should be enhanced with increasing neutron energy, thus allowing the

excitation of states with $\Delta L = 0$ and $\Delta S = 1$.

The study of $\Delta L = 1$ resonances in (n,p) reactions should provide empirical evidence for $\Delta S=0$ transfer (isovector dipole resonance) as well as $\Delta S = 1$ transfers which will lead to final states with $J^{\pi} = 0^-$, 1^- and 2^-.

1) G.A. Needham, Ph.D. Thesis, U.C. Davis (unpublished); F.P. Brady et al., Phys. Rev. Lett. 48, 860 (1962).

2) T.N. Taddeucci et al., Phys. Rev. C 25, 1094 (1982).