$^{9}Be(p,p')^{9}Be(n)^{8}Be$ COINCIDENCE MEASUREMENTS WITH DEUTERATED NEUTRON DETECTORS

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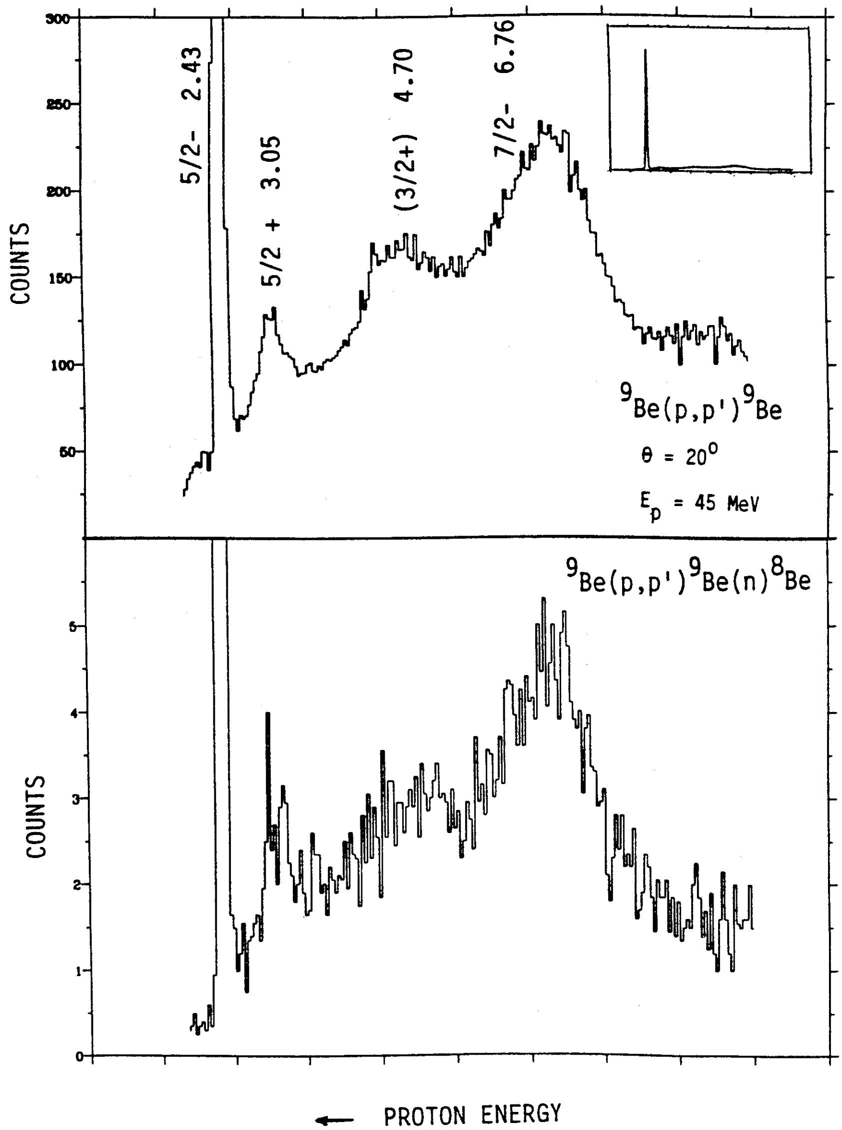
Experiments with 45-MeV protons were made to test the performance of fully deuterated NE230 scintillation neutron detectors in coincidence with charged reaction products. The reaction $^{9}Be(p,p')^{9}Be$ was chosen to produce charged particles in the focal plane of the K600 magnetic spectrograph. All excited states in ^{9}Be are neutron unstable, and they therefore lead to the emission of low-energy neutrons. This is important, as the future use of these detectors will include the detection of low-energy evaporation neutrons from the decay of giant resonances. Calculated evaporation spectra (code CASCADE) for such decays show that the strength is strongly concentrated at energies on the order of 1 MeV. A new geometry was used with four (and in the future more) 2-inch scintillation detectors mounted at backward angles of 135° with respect to the beam outside the scattering chamber at distances of only 10 cm from the target. Improvements in electronics, electric shielding, and geometry made it possible to set the lower threshold at 30 keV (electron equivalent). The pulse height spectrum covers a neutron energy range from about 0.5 to 3.5 MeV. The neutron detection efficiency for the four small detectors is significantly higher than that given by conventional time-of-flight geometries. The upper part of Fig. 1 displays a proton singles spectrum obtained at $\theta_p = 20°$ and E(p) = 45 MeV. The strong transition to the $5/2^-$ state at 2429 keV in ^{9}Be (see also inset) is very prominent, and several broad resonances are seen. The lower part of Fig. 1 shows a proton spectrum measured in coincidence with neutrons of energies between 0.5 and 3.5 MeV. This spectrum is gated on neutrons using pulse-shape-discrimination, and only true (prompt minus random) coincidences are recorded. The $5/2^-$ state emits neutrons of only 0.7 MeV, and the low threshold for neutron detection is clearly established. This can be seen directly from Fig. 2 which displays a two-dimensional plot of the pulse height of the neutron detector versus proton energy (position in the focal plane) gated on prompt neutrons. Background from random events is present, but these events are removed for all projected one-dimensional spectra. Decays into the 0^+ ground state of ^{8}Be and the broad 2^+ state at 2.9 MeV can already be distinguished due to the special characteristics of the NE230 scintillator. Neutron/γ discrimation, see Fig. 3, was successfully employed, and the time-of-flight spectra allow the separation of prompt and random events which were measured simultaneously. Time of flight also provides energy information for slow neutrons where the pulse shape discrimination is slightly reduced. Detection with high efficiency of low-energy neutrons in coincidence with charged-particle focal plane events has thus been successfully demonstrated.

Figure 1. Proton energy spectra from $^9Be(p,p')^9Be$ at $\theta_p = 20°$ and E(p) = 45 MeV. The upper part shows the spectrum obtained in singles mode, whereas the lower part shows the spectrum obtained in coincidence with decay neutrons in the energy range 0.5 to 3.5 MeV.



These preliminary results also suggest that it will become possible to unfold neutron pulse height spectra and to extract low-resolution neutron spectra without the need for time-of-flight information. Calibration measurements with a ^{252}Cf fission source confirm that the detector response function for NE230 scintillators (unlike NE213) increases at the maximum pulse height.

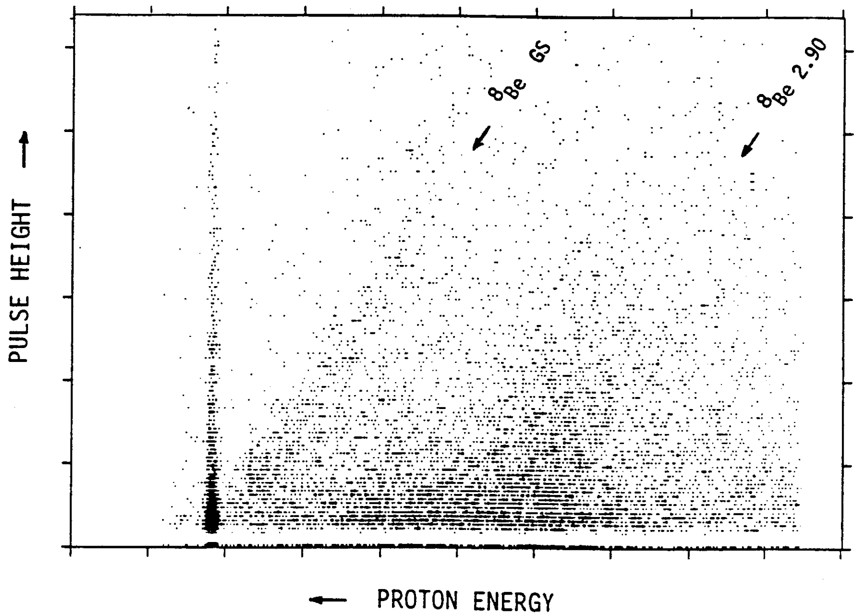


Figure 2. Two-dimensional display of neutron detector pulse height versus proton energy for prompt events gated on neutrons.

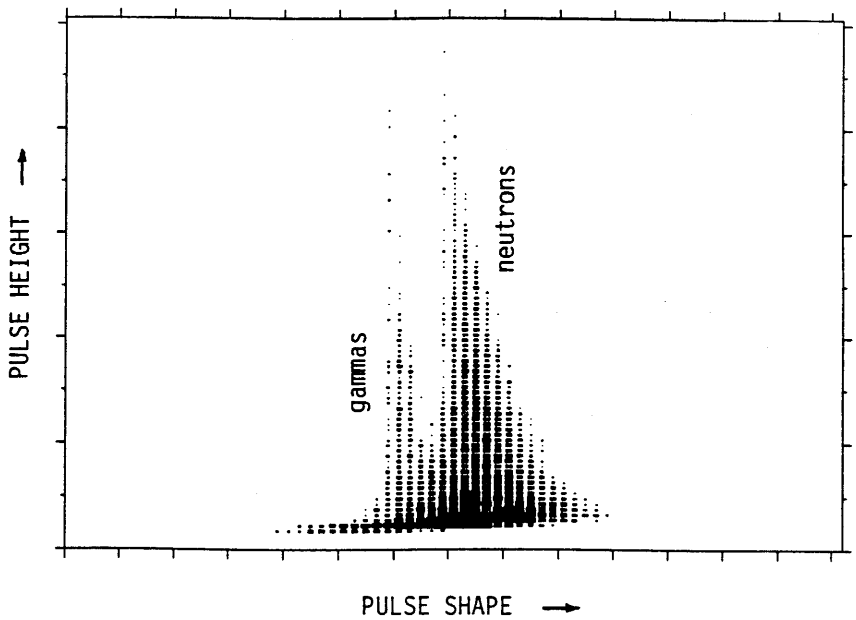


Figure 3. Typical pulse-shape discrimination spectrum. The threshold is 30 keV (electron equivalent) and the corresponding range in neutron energies is 0.5 to 3.5 MeV