HIGH-EFFICIENCY NEUTRON DETECTORS

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During the past year, we compared the performance at the IUCF of a high-density ($\rho = 4.88$ g/cm^3) barium-fluoride (BaF_2) scintillator with a liquid $(CH_2)_n$ scintillator ($\rho = 0.858$ g/cm^3). By comparing the counts observed in the ^{12}N(g.s.) peak from the ^{12}C(p,n) reaction at 135 MeV, the efficiency per unit volume of the BaF_2 (as extracted on-line) appeared to be 3.3 times that of the $(CH_2)_n$ scintillator. Since 86% of the neutrons interact in traversing two mean-free-paths, it appears that a high-efficiency (~86%) neutron detector can be achieved with a BaF_2 thickness of about 40 cm. The observed efficiency ratio of about 3.3 is consistent with that expected on the basis of geometric neutron interaction cross sections. We made a few measurements of the light output of the BaF_2 and $(CH_2)_n$ scintillators in response to proton energy losses from about 40 to 90 MeV. Preliminary results show that light output from BaF_2 is higher than that from NE-102 plastic, whereas the light output from the $(CH_2)_n$ scintillator is lower than that from NE-102 plastic. The overall time resolution for neutrons of about 118 MeV in the ^{12}N(g.s.) peak was broader for the BaF_2 than for the $(CH_2)_n$; however, at this time it is not clear whether this result was caused by degradation of the fast component in the BaF_2 or whether neutrons do not excite the fast component as effectively as photons. Further tests are needed.

USE OF AXIAL GAS-IONIZATION CHAMBERS TO STUDY INTERMEDIATE-MASS-FRAGMENT PRODUCTION IN NUCLEAR REACTIONS

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Two new designs for gas ionization chambers were constructed and tested. They are both based on an axial anode configuration. Figure 1 is a schematic of a multi-anode design. The anodes and electrodes are annular rings. The anode is operated at a high voltage and every other electrode is grounded. Because of the short distance an ionization electron travels to the collecting electrode (anode) in this design, the detector produces very rapid electron collection. Resolution (full-width at half-maximum, FWHM) of an ^{241}Am source (5.48 MeV alpha) was found to be .31 MeV at a gas pressure of 45 Torr (CF_4) and an applied voltage on the anode of 450 volts. In a run with a 200 MeV ^4He beam incident on a ^{nat}Ag target this detector yielded an overall charge resolution of 0.43 Z units, permitting mass identification of ^7Be and ^9Be (see Fig. 2).

A second design included shaping electrodes which produce a more uniform electric field (Fig. 1b). Again, the single anode as well as the shaping electrodes are annular rings. The anode is in the middle and is operated at a high voltage. The entrance window is grounded and a voltage divider using 10 MΩ resistors is arranged so that the voltage of each successive field-shaing electrode is increased until the maximum applied voltage is reached at the anode. The voltage is decreased gradually on the back side of the anode in the same manner. The optimum applied voltage, in volts, was found to be about 10 times the gas pressue in Torr. At 45 Torr results were similar for the applied voltage range of 400 to 500 V. Energy resolution with an ^{241}Am source was similar for the multi-anode design (.31 MeV). However, in on-line experiments this configuration produced significantly improved particle identification, yielding a charge resolution of 0.31 Z units. This improved resolution can be observed by by comparing the ^{7}Be and ^{9}Be spectra shown in Fig. 3 with those in Fig. 2.

An advantage of these detectors is that they are compact and designed to be placed side by side to make up a hodoscope or a large detector array.

These detectors have been used as the ΔE detector to identify IMFs in ΔE/silicon E telescopes in experiments at the Indiana University Cyclotron Facility (IUCF) and the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State

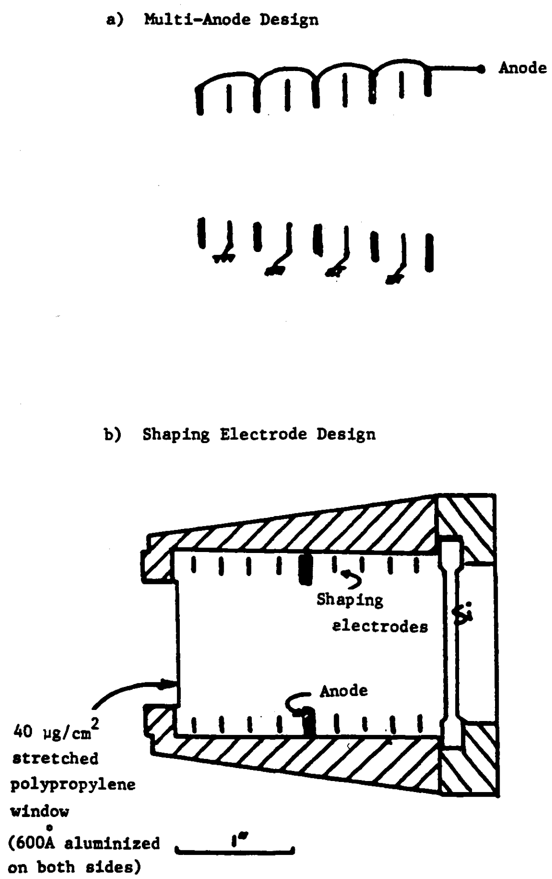

Figure 1. Axial Charge Collection Ionization Chambers.

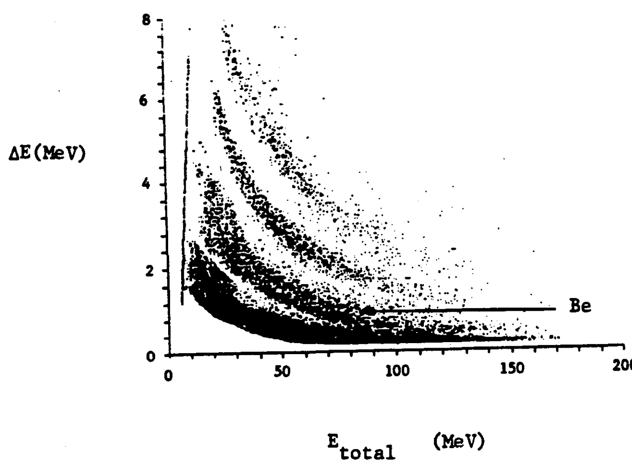

Figure 2. Point plot of ΔE vs E_{total} at 30°. ΔE obtained from multi-anode design ionization chamber.

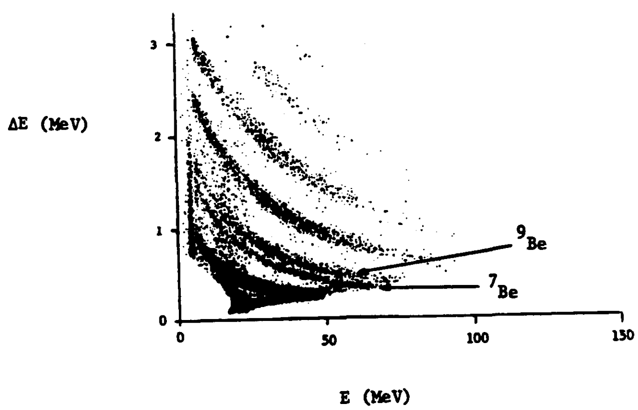

Figure 3. Point plot of ΔE vs E at 30°. ΔE obtained from shaping electrode design ionization chamber. E is a 300 μm Si detector showing Be punch through.

University. In an experiment conducted at NSCL (20-50 MeV/A ^{14}N beam on ^{nat}Ag and Au) in July, 1986, the detector did not exhibit any drift (<1%) in a ΔE-E plot over the course of one week.

CALIBRATION OF PULSE-SHAPE DISCRIMINATING NaI(TL) DETECTORS

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An active area in heavy ion nuclear physics research concerns the evolution of the fusion cross section between 5 and 20 MeV/u. Several groups have measured the centroid velocities of evaporation residues and have found a discrepancy between the experimental value and the value expected on the basis of complete linear momentum transfer. One possibility is that some fraction of the initial linear momentum is carried off by nucleons or clusters, prior to complete fusion equilibrium being attained. We intend to measure correlations between mass- and Z-resolved heavy ion residues and light charged particles in order to disentangle the complete and incomplete fusion processes.

Our previous experiments in this area have used silicon surface barrier detectors for both the heavy residues and the light charged particles. Although such detectors provide unsurpassed energy resolution, they suffer because of small solid angle acceptance and inadequate dynamic range. Therefore, in the past year we have developed a large-volume Bragg Curve Spectrometer and Breskin timing detector system with which we will measure the mass and Z of recoiling heavy particles. For the light particles we have chosen to use a NaI(Tl) particle spectrometer, which resolves masses and charges using pulse-shape discrimination. We currently have available ten of these NaI(Tl) detectors, of which 5 have dimensions 1.9 cm dia. x 3.8 cm deep, and 5 have dimensions 5.0 cm dia. x 3.8 cm deep. These detectors are capale of stopping 100 MeV protons (400 MeV α-particles), and with their extremely thin entrance windows (7.6 μ Havar) they have a lower energy threshold of only 1.2 MeV for protons and 4.8 MeV for α-particles. They also possess relatively good timing resolution (≤0.5 ns), which will aid further in particle discrimination.

Initial testing of the detectors took place at the ATLAS and Notre Dame accelerators, where the pulse-shape discrimination properties were studied for moderate energy particles (< 65 MeV for α-particles, < 50 MeV for protons). We then used the $H(\alpha,p)^4He$, $H(\alpha,\alpha)H$, $D(\alpha,d)^4He$, $D(\alpha,\alpha)D$, and $^{12}C(\alpha,\alpha)^{12}C$ reactions induced by 200, 149, and 81 MeV α-beams from the Indiana Cyclotron to produce α, ^3He, t, d, and p particles over a wide range of energies to obtain energy calibration data for 3 detectors. Unlike silicon surface barrier detectors, the energy response