A LOGARITHMIC, LARGE-SOLID-ANGLE DETECTOR TELESCOPE FOR NUCLEAR FRAGMENTATION

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We discuss the features of a particle identification telescope based upon passivated silicon photodiode technology that has been developed for use in a multielement detector system for the study of fragmentation reactions at intermediate energies.

The detector has been designed to measure the spectra of light charged particles (LCP = H and He) up to energies of $\approx$ 70 MeV/nucleon and intermediate-mass fragments (IMF: $3 \leq Z \leq 15$) emitted in central collisions at intermediate bombarding energies. Reported here are the properties of a detector telescope with an active area of 25 cm^2 which consists of the following elements: (1) a gas-ionization counter, (2) two passivated silicon detectors, and (3) two CsI(Tl) scintillator crystals operated with photodiodes. A cross-sectional diagram of the detector is shown in Fig. 1.

The gas-ionization counter (GIC) element is of the axial field design and is operated at 15–20 Torr of CF_4 gas. In order to minimize the electron collection time, the anode

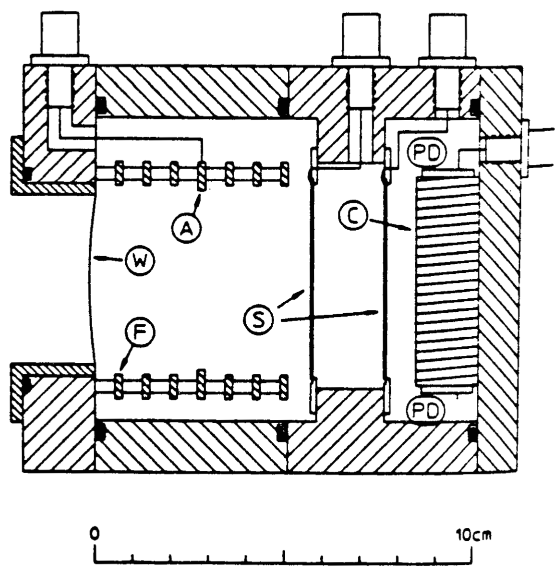

Figure 1. Schematic diagram of large-solid-angle, logarithm complex-fragment/light-charged particle detector telescope. Legend: A - anode: W - 1.5 μm thick alumized Mylar window; F - field shaping electrode; S - silicon detectors; C - CsI(Tl) scintillator, and PD- photodiodes.

plane is positioned in the middle of the active length of the ion chamber. The anode consists of a square brass frame with 12 parallel, gold-plated tungsten wires of 50 μm diameter strung across the frame. Each wire spacing is 3.8 mm. To ensure the uniformity of the electric field, three field-shaping electrodes are placed on each side of the collector electrode. This detector provides energy-loss (ΔE) information for charge identification of Z$\geq$3 fragments with good charge resolution. The pair of 5 cm $\times$ 5 cm silicon detectors, with thicknesses of 220 μm and 500 μm respectively, serve several functions. The 200 μm element provides energy information for $\Delta E - E$ charge identification of low-energy and/or massive fragments. When combined with an appropriate fast start signal, e.g. a beam rf signal, the detector also provides a fast-timing stop signal for time-of-flight (TOF) mass determinations of all fragments stopped in the detector. By removing gas from the GIC, the front silicon detector can also be used for recoil or fission fragment TOF mass identification. The high degree of uniformity of the 220 μm and 500 μm silicon elements permits charge and mass identification of fragments up to oxygen, which stop in the 500 μm detector.

The scintillation detector consists of a pair of 1.7 cm thick $\times$ 2.8 cm $\times$ 5.6 cm (front-face area) CsI(Tl) crystals operated side-by-side, with a pair of 2 cm $\times$ 1 cm photodiodes glued to the top and the bottom of each crystal. The two photodiodes are connected in parallel to a Canberra 2004 preamplifier. These elements are capable of stopping up to $\sim$ 70 MeV/nucleon hydrogen and helium ions with good isotopic resolution. An added advantage of the operation of CsI(Tl) crystals in conjunction with silicon detectors is relative ease and reliability of calibrating the scintillator light output based upon the known energy response of silicon semiconductors.

Test of this device have been performed at the Argonne National Laboratory ATLAS accelerator with 160 MeV ^{16}O ions incident on a ^{nat}Ag target. Figs. 2a, b and c show the respective charge identification spectra for fragments observed at 20° in the laboratory system for each successive pair of detector $\Delta E/E$ elements (i.e. GIC/220 μm Si, 220 μm Si/500 μm Si, and 500 μm Si,/17 mm CsI(Tl)). Fig. 2d displays a time-of-flight versus energy spectrum for TOF derived from the 220 μm detector and the ATLAS linac booster rf signal ($\sim$200 ps timing resolution). A rise time of $\tau_R \approx 10.5$ ns was obtained with a fast time pickoff unit and 40% overbias on the detector, providing a timing resolution of 300 ps (excluding the beam contribution) for elastic ^{16}O ions. The charge and mass resolution are about 0.3$-$0.4 units each.

Detectors of this design have subsequently been used for studies of $E/A = 60 - 100$ MeV ^{14}N-induced reactions at the National Superconducting Cyclotron Laboratory at Michigan State University and with 0.9$-$6 GeV ^{3}He beams at the Laboratoire National Saturne in Saclay and at the LBL Bevalac. Thus far, they have shown excellent long-term stability and lifetime when placed in vacuum and exposed to reaction products produced by such beams for periods of over one week.

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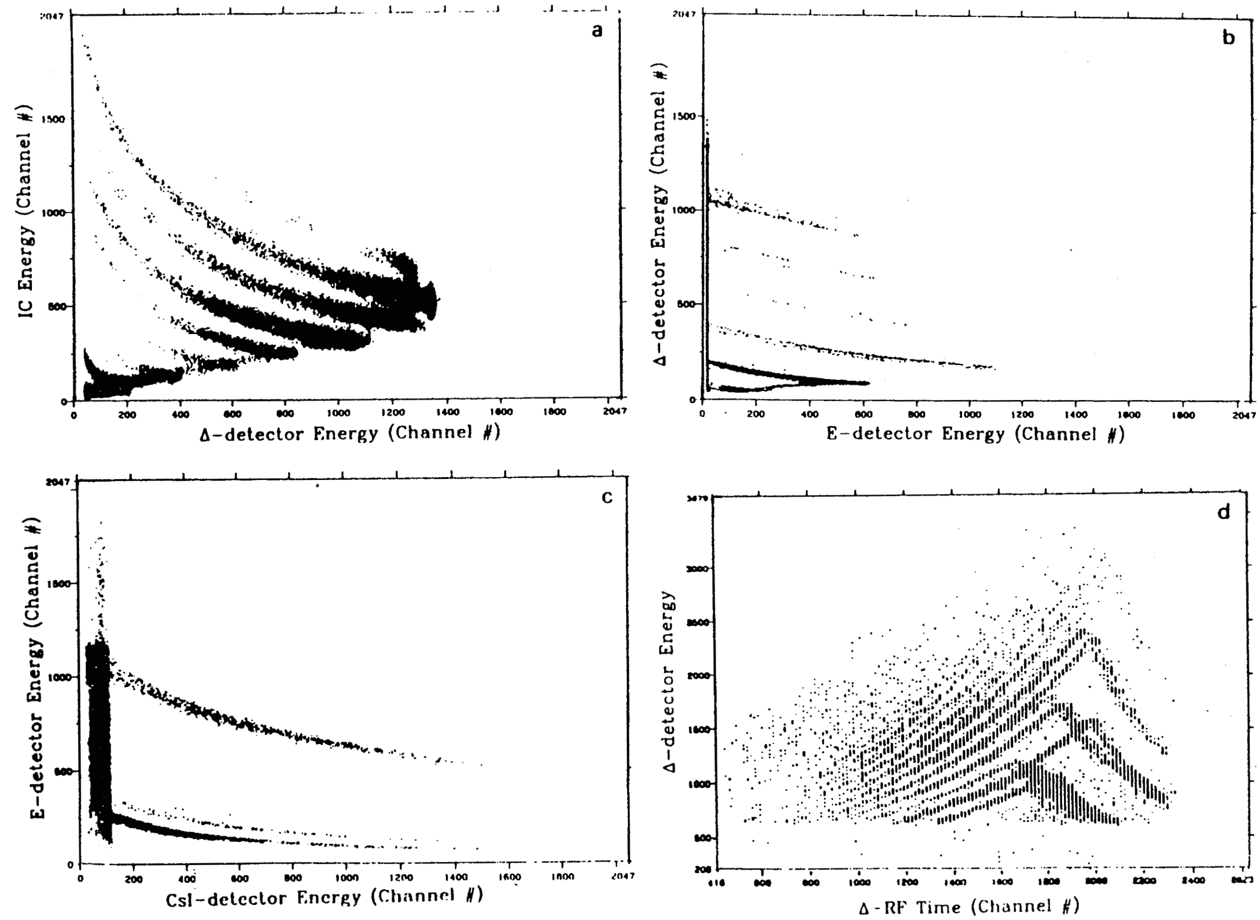

Figure 2. (a) Particle identification spectrum for gas-ion chamber vs. 220 μm silicon detector; (b) same for 220 μm silicon vs. 500 μm silicon detector; (c) same for 500 μm vs. CsI detector with two photodiodes readout, and (d) time-of-flight relative to beam rf vs. fragment energy.