PHOSWICH DETECTOR AS AN ONLINE POLARIMETER

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In the upcoming (p,2p) quasi-free knockout experiment (E336, E337), kinematic coincident p+d elastic scattering will be used to define a proton "beam" to monitor the gain variation of the large solid angle NaI array. p+d elastic scattering is known for its large analyzing power over a large range of incident proton energies.[1] It is very sensible that we could obtain a measurement of the beam polarization as an extra benefit from the same reaction. Space limitations imposed by the E336 apparatus require a compact design for the polarimeter and consequently a novel design for the detectors. A set of BGO/plastic scintillator phoswich detectors have been developed for this purpose.

The phoswich detector consists of two different scintillators which are optically coupled to a single photomultiplier(PM) and are used as ΔE-E detectors. The two scintillators must have different decay constants. Usually one is on the order of a few ns and the other a few hundred ns. When a charged particle passes through the two scintillators, the signal which is delivered by the PM has two components. Two charge integrations of the PM pulse using different width gates allow us to measure the two light outputs to get the value of ΔE and E. The ΔE vs. E correlation will provide clean particle identification very effectively.

At a lab angle of 51°, the outgoing protons and corresponding deuterons are scattered through the same angle left-right (or up-down) of the beam for 200 MeV incident protons. Thus, only a single pair of phoswich detectors is needed to measure the normal (or side ways) component of beam polarization. The deuteron energies at this angle are around 70 MeV and the proton energies are 130 MeV. To separate the p+d elastic events of interest from the ^{12}C(p,2p) quasifree knockout process also present from the CD$_2$ target, we concentrated on the deuteron events. The thickness of BGO is chosen to be 1.0 cm so that the deuterons will stop in the BGO crystal and the full energy of deuterons will be detected. The protons on the other hand deposit only 27 MeV of energy in the crystal.

The primary purpose of using phoswich detectors is to get a clear distinction between deuterons and protons. If deuterons are not cleanly identified a substantial background of ^{12}C(p,2p) will dilute the asymmetry measurement. Variation of the C:D ratio in the CD$_2$ target will make this dilution time dependent. We found that the thickness of plastic scintillator is crucial for separating deuterons from protons. At first we used 0.15 cm thick plastic scintillator which did not produce sufficient light output. The proton/deuteron separation for deuteron energies of interest was marginal. By increasing the plastic thickness to 0.3 cm we obtained a significant improvement in the p/d separation.

Our final design of the phoswich detector is as follows (Fig. 1). A $0.5 \times 1.5 \times 0.3$ cm^3 fast plastic scintillator (NE102) is glued in front of a $1.0 \times 2.0 \times 1.0$ cm^3 BGO crystal. Together they are coupled to a 1.9 cm diameter and 14 cm long Hamamatsu photomultiplier tube/base assembly (H3167). The distance from the front face of a detector to the target is 9.4 cm, resulting in deuteron angular acceptances $\Delta\theta = 3.0°$, $\Delta\phi = 9.1°$ and a deuteron lab solid angle of 6.64 msr, defined by the plastic scintillator. Detector collimation is

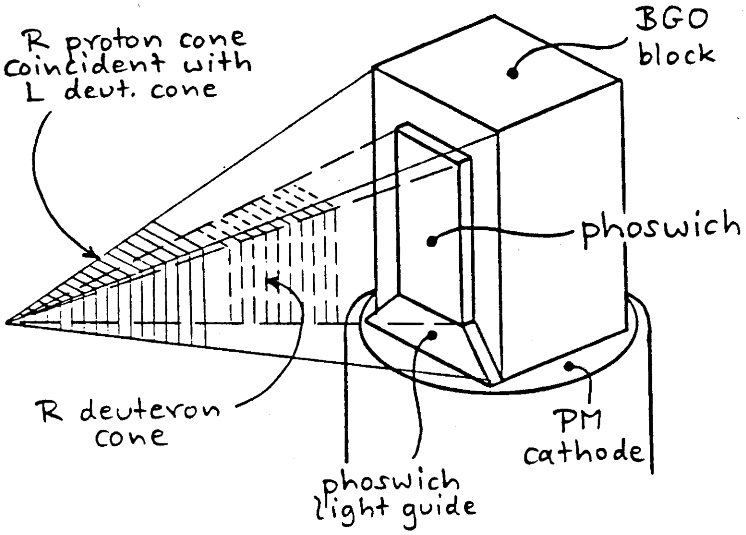

Figure 1. Schematic view of a phoswish detector.

unnecessary for solid angle definition thus saving considerable space. The smaller plastic scintillator is centered on the BGO front surface such that it leaves 0.25 cm wide border on the BGO face required by the larger solid angle for coincident protons. To be considered as good events for polarization evaluation deuterons must pass through both plastic and BGO.

An intrinsic problem of kinematic coincident detection is the sensitivity to geometrical errors produced by beam motion. These errors provide a source of potential instrumental asymmetries undesirable for a polarimeter. To minimize these errors we decided to use 0.2 cm wide strip targets. To avoid the right detector interfering with other apparatus due to the space limitation and blocking part of the proton flux from the target intended for monitoring the gain of NaI detectors, two small target chambers were used. One chamber has a vertical strip target for L/R detectors and the other chamber has a horizontal strip target for U/D detectors (Fig. 2).

We have developed two schemes for electronic readout and data analysis which provide reliable determination of the L/R (U/D) p+d scattering asymmetry. In the first scheme, event data including "narrow gate" (30 ns) and "wide gate" (500 ns) ADC charge integrals and relative timing are readout for coincident triggers. The "narrow gate" timing is critical to achieve good p/d separation. A 2 ns timing shift causes a 15% change in the "narrow gate" integral. Since good particle identification is necessary on the deuteron locus it is required to have the deuteron define the ADC gate timing. This is accomplished by having the gate be the OR of the overlap between a high threshold constant-fraction discriminator (CFD) ("deuteron") and a low threshold leading-edge discriminator (LED) ("proton"). A software window on the "narrow gate" vs. "wide gate" ADC correlation defines a deuteron

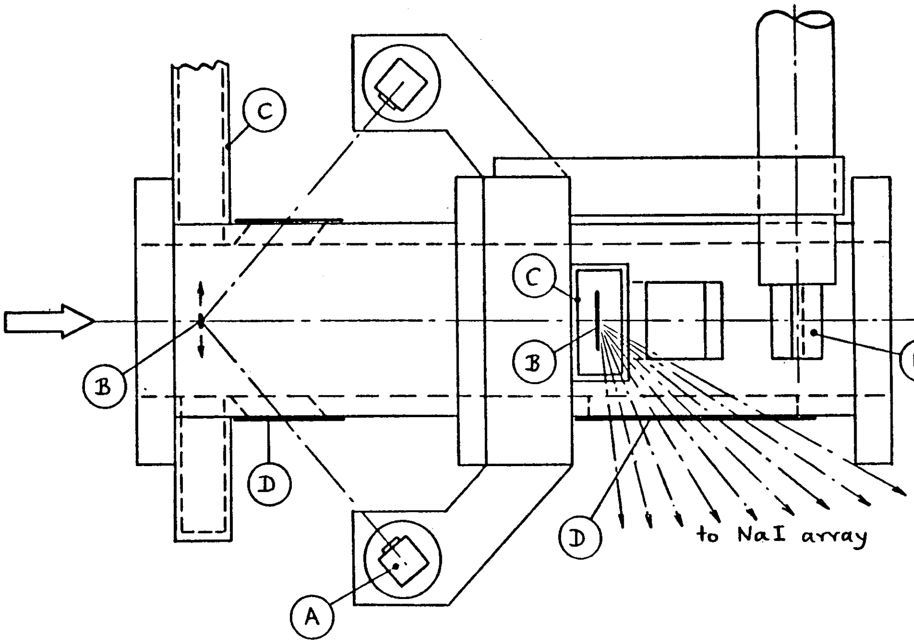

Figure 2. Top view of polarimeter assembly. A: L/R detectors. B: CD_2 strip targets. C: target ladder guides. D: 5 mil Kapton window. E: U/D detectors.

on one side (Fig. 3). The opposite side "wide gate" ADC spectrum is then sorted with this condition (Fig. 4).

The second readout scheme involves approximating the deuteron-defining software window by hardware discriminator thresholds. The high-threshold CFD cut is essentially a ΔE threshold (Fig. 3, dashed curve). An E threshold (Fig. 3, solid curve) can be generated by integrating the anode pulse height with a timing filter amplifier (50 ns integration time constant). A three fold coincidence of the ΔE and E thresholds from one arm ("deuteron") and a low threshold from the opposite arm provides excellent hardware definition of p+d free scattering coincidence. The possibility of using scalers to determine the L/R (U/D) scattering asymmetry is being investigated. This scheme eliminates software analysis and limits dead time in the (already overburdened) data acquisition computer. The stability of the photomultiplier and amplifier gains as well as discriminator thresholds can be monitored by a sampled readout of the event data.

Finally, we calibrated our online polarimeter and obtained the analyzing power of the p+d reaction for 186 MeV and 200 MeV incident protons at 51°. The beam polarization

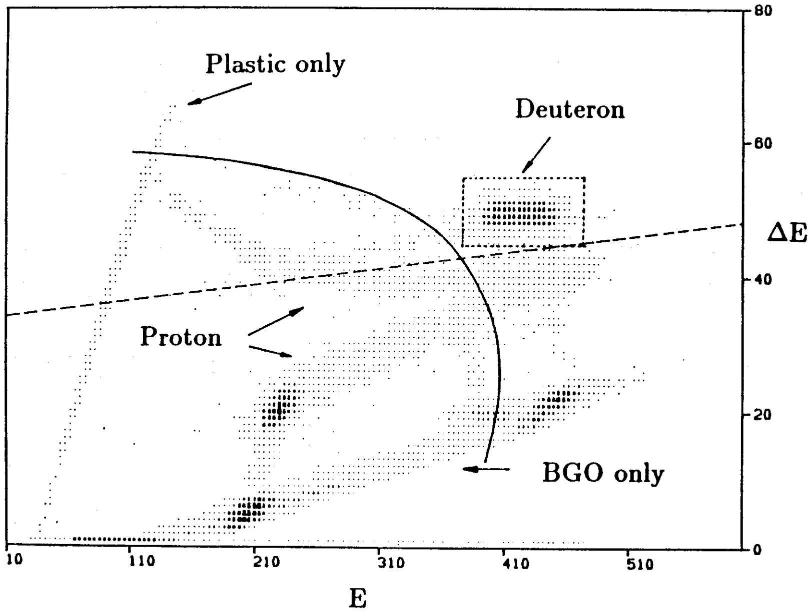

Figure 3. Particle identification with a phoswich detector composed of 0.5 cm wide and 0.3 cm thick plastic glued on 1.0 cm wide and 1.0 cm thick BGO crystal. ΔE and E are the charge integrations within the time intervals of 30 ns and 500 ns. A software cut window, high CFD threshold cut (dashed curve) and high threshold cut after integrating the input pulse by TFA (solid curve) are also indicated.

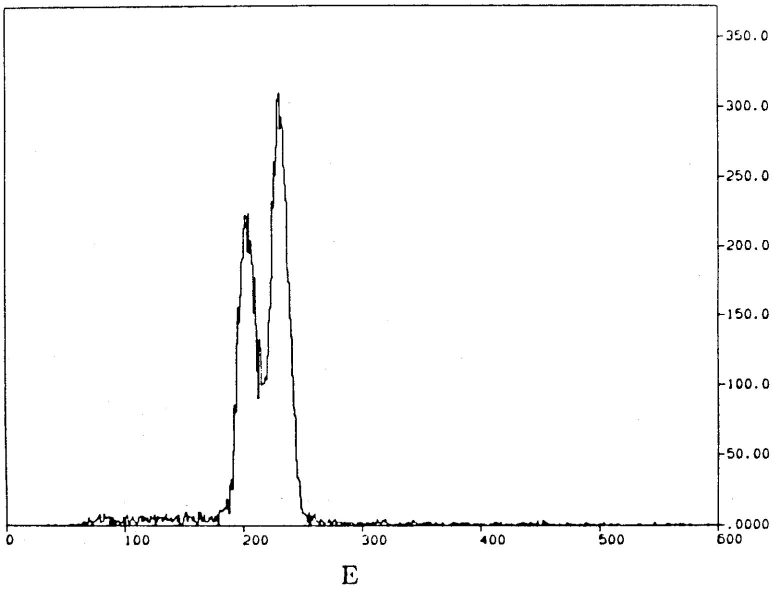

Figure 4. E spectrum gated by deuterons in the opposite arm. The two peaks correspond to the valid protons passing through BGO crystal only and passing through plastic and BGO both.

was measured simultaneously using p+^{12}C elastic scattering at angles where the analyzing power is very nearly unity.[2] Since only the normally polarized beam was available, the U/D polarimeter was rotated 90° into a L/R polarimeter for calibration. The measured analyzing powers of the phoswich online polarimeter are 0.433 ± 0.006 for 200 MeV incident protons and 0.399 ± 0.007 for 186 MeV protons. The reals:accidentals ratio for 10 nA of beam incident on a 1.7 mg/cm^2 CD$_2$ target is at least 100:1. The rate capability of this polarimeter is also significant. Tests have been performed up to a beam current of 80 nA. The current polarimeter will be used in E336 and E337 production runs this fall.

1. J. Arvieux and J.M. Cameron, Adv. Nucl. Phys., **18**, 107 (1989).
2. E. Stephenson, *et al.*, (private communication).

ISiS: A 4π DETECTOR SYSTEM FOR COMPLEX FRAGMENTS

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The investigation of hot nuclear matter formed in central collisions between intermediate-energy projectiles and heavy target nuclei demands a highly versatile detector system. This condition is imposed by the complex spectrum of fragments produced in such collisions—which span a broad range in mass, charge and kinetic energy. At the same time, the multibody nature of these events is such that determination of fragment multiplicities and spatial relationships on an event-by-event basis is essential for understanding the salient reaction mechanisms. Thus, full solid-angle coverage with good granularity is a prerequisite for such studies.

ISiS is a 4π detector currently under construction that will be employed in such studies at IUCF and other high-energy light-ion accelerators.

The detector (Fig. 1) will consist of 162 detector telescopes arranged in a honeycomb network that will surround a target. It will cover about 86% of the total surface of a sphere around the target. Each detector telescope will have three elements: (1) A gas-ionization chamber for low velocity fragments; (2) a 500 μ-thick ion-implanted passivated silicon detector for intermediate-velocity fragments, and (3) a 28 mm CsI scintillator with photodiode readout for energetic light ions. Each telescope will be able to measure fragments with energies between 0.5 to 90 MeV per nucleon (e.g., $\approx$ 2 to 360 MeV for ^{4}He