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THE SISWICH, A DETECTOR TELESCOPE WITH INTRINSIC CALIBRATION

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ABSTRACT

Phoswich counters have gained widespread popularity as detectors for medium energy charged particles. They provide adequate energy resolution and particle identification up to atomic numbers $Z \approx 20$. However, the question of calibration has not been resolved satisfactorily. To overcome this difficulty we have built a Silicon-Scintillator Sandwich (SISWICH). This detector consists of a silicon PIN photo diode glued to the front of a CsI (Tl) scintillator crystal. The signal coming from the PIN diode contains the energy loss of the particle in the silicon, which is fast (nuclear counter effect), and the light output of the scintillator which is slow.

The component coming from the nuclear counter effect can be calibrated with a pulser. Therefore, since the energy loss of a particle with known Z has been measured, its energy is known, and this can be used to calibrate the signal from the scintillator. Results will be shown.

INTRODUCTION

Phoswich counters (1) - i.e. two scintillators with different light output decay times sandwiched together and viewed by one photo multiplier tube - have found widespread use as detectors for medium energy particles (2) (3) (4) (5). They provide moderate energy resolution and particle identification up to atomic numbers $Z = 20$. The detectors described in the references (2) to (5) use plastic scintillators with relatively low light output. In order to identify particles the detectors consist of a thin " ΔE " layer and thick "E" layer. To obtain good identification photo multipliers with high gains and attendant stability problems have to be used. More recently CsI (Tl) has been used as the E layer (6) (7) because of its high light output and stopping power. A recent description of a very ambitious 4π detector setup (Dwarf Ball) using Phoswiches has been published by D. Stracener, et al (7). However, the question of calibration has not been resolved satisfactorily. In general the response of scintillators to different particles is nonlinear, and depends on the atomic number Z . The CsI (Tl) used in modern

detectors has a significant temperature dependence of the light output (7). An additional complication is the gain instability and limited dynamic range of photo multiplier tubes. Also, light pulser calibration is of limited utility, as it does not test the energy loss to light conversion in the scintillator (2) (7).

A group of the Max Planck Institute München has addressed and resolved the stability problem by using silicon photo diodes (8) (9). G. Blamar, et al (8) note in their paper, that they suffer from the "nuclear counter effect", where particles deposit their energy in the photo diode, generating large signals.

THE SISWICH

To overcome the calibration, stability and dynamic range problems, we have built a Silicon-Scintillator Sandwich (The name was coined in analogy to the PHOSWICH in (1)). This detector consists of a silicon photo diode glued to the front of a CsI (Tl) scintillator crystal. The photo diode measures the energy loss of a traversing charged particle as well as the light output coming from the energy deposited in the scintillator. See Fig. 1.

Fig. 1. The SISWICH

The signal delivered by the photo diode contains two contributions. A fast component of the measured current pulse lasts for only 10ns and corresponds to the electronic charge produced directly in the silicon by the traversing particle (nuclear counter effect (8)). The second component is considerably slower, $\tau \approx 1 \mu\text{s}$, and comes from the scintillation light decay corresponding to the energy loss in the CsI (Tl). Both components can be separated by shaping the output signal coming from a charge sensitive preamplifier with a short peaking time ($\sim 1 \mu\text{s}$) and with a long peaking time ($\sim 10 \mu\text{s}$). In a first order approximation the pulse heights are given by

$$E_{\text{short}} = A_1 \Delta E + B_1 E$$

$$E_{\text{long}} = A_2 \Delta E + B_2 E$$

with $A_1 = A_2$ and $B_1 < B_2 < A_1, A_2$.

Therefore ΔE and E can be calculated from E_{short} and E_{long} . The energy loss signal can be calibrated, as the nuclear counter effect generates a signal $U = 44\text{mV} \times (1\text{pF/C}) \times (E/1 \text{ MeV})(10)$. Thus a detector calibration can be easily provided by feeding known voltage steps through a calibrated capacitance into the input of the detector preamplifier system. Since the energy loss of a particle in silicon of a given thickness is well known and only weakly energy dependent for particles of medium energy ($E > 100 \text{ MeV/nucleon}$), one can use the calibrated fast signal for particle identification and thus fix the energy itself. The slow E signal must then correspond to that energy. This provides an easy calibration of the CsI (Tl) light output including the optical coupling.

This arrangement has several other advantages. The intrinsic electronic energy loss "gain" is more than five times that of the rest energy (11), assuming good light collection. This is very useful for high energy particles where the energy loss is small compared to the total energy. Furthermore only one signal line is needed per telescope. The detector bias is uncritical ($\sim 100\text{V}$). The photo diode is intrinsically linear ($< 10^{-4}$), insensitive to magnetic field, and has a high dynamic range ($> 10^8$) (8).

However, these SISWICH telescopes are of limited use for low energy particles due to the minimum thickness of $d = 200 \mu\text{m}$ for commercially available photo diodes and the poor light output of the CsI (Tl) at these energies.

EXPERIMENTAL RESULTS

We have used a SISWICH, consisting of a $220 \mu\text{m}$ thick photo diode (FD109D, Siemens) and a $1 \times 1 \times 1 \text{ cm}^3$ CsI (Tl) crystal (Bicron). The signal was read out with a commercial preamplifier (Canberra Mod 2003) and two spectroscopy amplifiers (Canberra Mod 2021) with peaking times of $1 \mu\text{s}$ and $10 \mu\text{s}$, Fig. 2. A SISWICH detector was tested in a beamtime at the SIS-FRS accelerator facility of GSI, Darmstadt (Germany). Reaction products from $80 \text{ A} \times \text{MeV}$ ^{56}Ni ions impinging on a titanium foil were observed under very forward angles. The radioactive ^{56}Ni projectiles were produced by fragmentation of $200 \text{ A} \times \text{MeV}$ ^{58}Ni ions on a thick beryllium target and separated by the fragment separator (FRS), a momentum loss achromat for relativistic heavy ions (15).

Fig. 2. SISWICH Electronics

Fig. 3. Eshort vs Elong unprocessed

Fig. 3 shows a two dimensional display of the fast versus the slow signal. Fig. 4 shows the energy loss (ΔE) versus the total energy (E_{tot}) calculated from these data. Fig. 5 shows an atomic number (Z) spectrum generated from the data in Fig. 4 by linearization in analogy to the methods of (7).

Fig. 4. ΔE vs E_{tot} processed from Fig. 3

Fig. 5. Atomic Number (Z) Spectrum

CONCLUSIONS

We have shown that the SISWICH is a compact, rugged particle detector for identifying particles with $>5\text{MeV/nucleon}$. This detector will be used in further experiments at SIS. In a separate contribution to this conference, we present a simple inexpensive shaping circuit for silicon detectors, which can also be used to process signals from a SISWICH (12). This work grew out of a masters thesis, while one of us (MRM) worked at NSCL MSU (13) (14).

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Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Department of Energy to the exclusion of others that may be suitable.

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