Nuclear Instruments and Methods in Physics Research A 745 (2014) 106–113

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Detector system for the study of low energy heavy ion reactions using kinematic coincidence technique

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ARTICLE INFO

Article history:
Received 11 June 2013
Received in revised form
16 December 2013
Accepted 16 December 2013
Available online 6 February 2014

Keywords:
Multiwire proportional counter
Ionization chamber
Fast timing
Charge sensitive preamplifier

ABSTRACT

The characteristics and performance of a new detector system developed for the study of low energy heavy ion binary reactions using the kinematic coincidence technique are presented. The detector system has been developed to carry out experiments such as multi-nucleon transfer reactions using the General Purpose Scattering Chamber (GPSC) facility at IUAC [1,2]. The detector system consists of a pair of two-dimensional position sensitive multi wire proportional counter (MWPC) and a $\Delta E - E$ gas ionization chamber. Both MWPC have an active area of 5×5 cm^2, and provide position signals in horizontal (X) and vertical (Y) plane, and timing signal for time of flight measurements. The main design feature of MWPC is the reduced wire pitch of 0.025 in. (0.635 mm) in all electrodes, giving uniform field and faster charge collection, and usage of 10 μm diameter in anode frame which gives higher gains. The position resolution of the detectors was determined to be 0.45 mm FWHM and time resolution was estimated to be 400 ps FWHM. The detector could handle heavy ion count rates exceeding 100 kHz without any break down. The timing and position signals of the detectors are used for kinematic coincidence measurements and subsequent extraction of their mass and angular distributions. The ionization chamber has a conventional transverse field geometry with segmented anode providing multiple ΔE signals for nuclear charge (Z) identification. This article describes systematic study of these detectors in terms of efficiency, count rate handling capability, time, position and energy resolution.

1. Introduction

The study of heavy ion binary reactions such as multi-nucleon transfer reactions [3] around Coulomb barrier is an intriguing subject and important to investigate the nucleon correlation effects on the nucleus and its subsequent effect on the reaction mechanisms. Such reactions require identification of reaction products in terms of their mass (A), nuclear charge (Z), energy and spatial information. In the past several years, variety of apparatus have been used to study these reactions for the cross-section/angular distribution measurements as well as for gamma spectroscopy/structure studies. These include magnetic/electromagnetic separators such as PISOLO [4], PRISMA [5], VAMOS [6], and HIRA [7,8]. On the other hand use of detector telescopes, time of flight systems and kinematic coincidence techniques [9,10] using large scattering chambers have also been widely used to study such binary reactions ranging from elastic, quasi-elastic, deep inelastic or multi-nucleon transfer reactions. Kinematic coincidence technique requires simultaneous detection of the two reaction products by charged particle detectors placed at kinematically coincident angles. This technique can be very efficiently utilized for measurements at not too forward angles, specially above Coulomb barrier where grazing angles are small ($\sim 50^\circ$). This technique can yield resolutions comparable to that of magnetic spectrometers provided that experimental conditions are optimum in terms of good detection system, good targets and equally good beam from the accelerators in terms of minimum energy spread, spot size and narrow pulse width (if pulse beam is used). Moreover one can collect all charge states in contrast to a magnetic spectrometer where the transport efficiency is limited by different charge states of the reaction products.

We have developed a detector system based on position sensitive gas proportional counters and ionization chamber for investigating binary reactions using kinematic coincidence technique. The primary motive behind the development of these detectors is the study of multi-nucleon transfer reactions in the

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http://dx.doi.org/10.1016/j.nima.2013.12.039
0168-9002

energy domain near the Coulomb barrier using the 1.5 m diameter General Purpose Scattering Chamber (GPSC) facility at the Inter University Accelerator Centre (formerly Nuclear Science Centre). Gas counters offer a very efficient and flexible solution for the detection of heavy ions. In general, apart from being inexpensive, they provide good timing, energy and position resolutions, are insensitive to radiation damage, have high count rate handling capability, and can be fabricated with ease in various sizes (large as well as small) and geometry to make them compatible with the given experimental requirements. Moreover the operating parameters such as gas pressures and voltages on electrodes can be adjusted for detection of different kind of ions (light or heavy) at different energies. The detectors have been thoroughly tested off-line with radioactive sources and have been used in experiment using beam from the IUAC tandem accelerator. This article describes the above detector system in detail.

2. Detector system

Detector system described in this paper has been developed to carry out multi-nucleon transfer reactions and their angular distributions. The detector system consists of a pair of transmission type two dimensional position sensitive MWPC which are placed at kinematically coincident angles. One of the MWPC is followed by a transverse field ionization chamber. The MWPC provides the position and timing of the incoming particles. They also provide differential energy loss signal which is sufficient to discriminate between projectile like ($A \leq 40$) and target like particles ($A \geq 70$). The ionization chamber with segmented anode provides nuclear charge (Z) identification and total energy of projectile like particles. The entire detector system was installed on the movable arms of the GPSC, as schematically shown in Fig. 1.

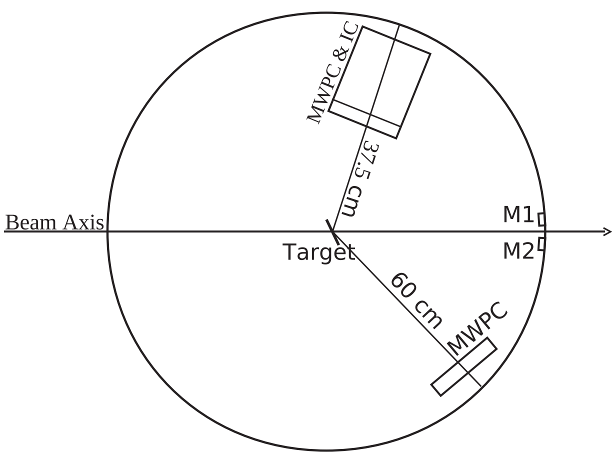

Fig. 1. Schematic picture of the experimental setup for kinematic coincidence. M1 and M2 are Silicon detectors used as monitors.

2.1. Multi wire proportional counter (MWPC)

A schematic cross-section of the MWPC is shown in Fig. 2. It was designed to fulfill the following requirements: (1) It must provide good timing resolution < 500 ps. (2) It should be position sensitive to provide both horizontal and vertical position information with ~ 0.5 mm resolution. (3) It should provide differential energy loss information for the incident particles in the active volume. (4) It should be insensitive to radiation damage. (5) It should have a high count rate handling capability (100 kHz).

The core of the MWPC consists of four wire frames [11] each with an active area of 5 cm $\times$ 5 cm. The wire frames are a cathode, a position wire frame to measure horizontal (X) position, a central anode frame, and position frame for measuring vertical (Y) position. The distance between adjacent wire frames is 1.6 mm. Cathode and position wire frames are made from gold plated tungsten wires (diameter 20 μm), stretched with a tension of ~ 75 cN/wire, on a 1.6 mm thick printed circuit board. The central anode wire frame is made from 10 μm gold plated tungsten wire to provide higher gains and fast decay times for better timings. The 10 μm wire is stretched with a tension of ~ 30 cN/wire. All wire frames have 80 wires each having a separation of 0.025 in. (0.635 mm) [12] between adjacent wires. Position information in both X and Y plane is extracted using commercially available Rhombus delay line integrated chips (Model TZB12-5). Each chip has 10 taps with a delay of 2 ns per tap and a characteristic impedance of 50Ω. In position electrodes, wires are shorted in pair and connected to one tap of delay chip. End to end delay in both X and Y positions is 80 ns. The position frames are kept at ground potential by terminating both ends of delay lines through 150 kΩ resistors. The electrode assembly is mounted inside a metal housing milled out from a solid aluminum block. Gas detector is

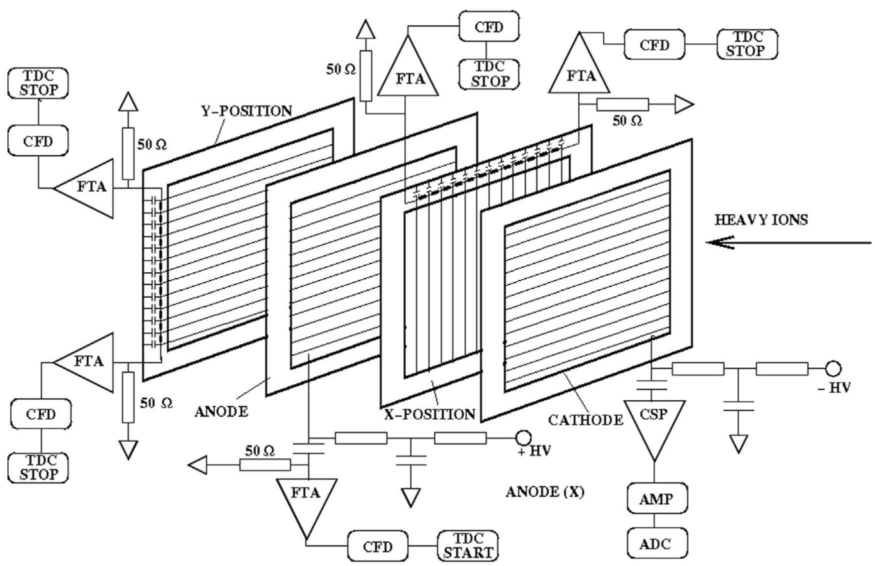

Fig. 2. Schematic of MWPC with front-end electronics.