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Construction of a fast ionization chamber for high-rate particle identification

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ABSTRACT

A new gas-filled ionization chamber for high count rate particle identification has been constructed and commissioned at the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL). To enhance the response time of the ionization chamber, a design utilizing a tilted entrance window and tilted electrodes was adopted, which is modified from an original design by Kimura et al. [1]. A maximum counting rate of $\sim 700,000$ particles per second has been achieved. The detector has been used for several radioactive beam measurements performed at the HRIBF.

1. Introduction

The detection of beam and beam-like heavy recoils at far forward angles is often critical for radioactive beam measurements in inverse kinematics for nuclear astrophysics and nuclear structure studies [2,3]. A detection system for the beam and beam-like heavy recoils should exhibit a detection efficiency close to 100%. In many cases, the radioactive heavy ion beams are highly contaminated by other elements having similar energies and masses. Therefore, the detection system should provide information to distinguish the beam particles from unwanted constituents. In some cases, it is important to design a detector that avoids unnecessary energy straggling and angular dispersion. A crucial feature is a fast response time so that the device does not limit the intensity of the beam in the experiment. Gas-filled ionization chambers are well suited for these applications, since they have moderately good energy resolution and can withstand prolonged exposure to high beam intensities without damage, in contrast to fragile semiconductor detectors. At the Holifield Radioactive Ion Beam Facility (HRIBF), a conventional ionization chamber using a Frisch grid [4] was used for many scientifically important reaction measurements including Refs. [5–9]. The Frisch grid removes the dependence of the anode pulse amplitude on the transverse position of interaction. A schematic diagram of the ionization chamber is shown in Fig. 1. The chamber is divided into two sections by the Frisch grid, and the interactions occur in the section between the cathode and the grid. The cathode consists of one long plate and the anode is segmented into 5 cm, 5 cm, and 20 cm-long plates to enable particle identification via differential energy loss. The count rate of the ionization chamber is limited to $\sim 10^4$ particles per second (pps), however, as the electrons generated along the particle trajectory must travel relatively long distances perpendicular to the ion optical axis to reach the anode planes.

For many experiments, however, higher counting rates are needed. There are a number of techniques to obtain this. When ionized electrons are generated by a charged particle entering the chamber, the anode potential continuously drops until all the electrons reach the anode. Finer segmentation of the anode will therefore improve response time, but perhaps at most by a factor of ~ 3 (for 10 anode segments instead of 3). Reducing the electron drift length to the anode will also improve the response time. With the design shown in Fig. 1, however, this improvement will be at

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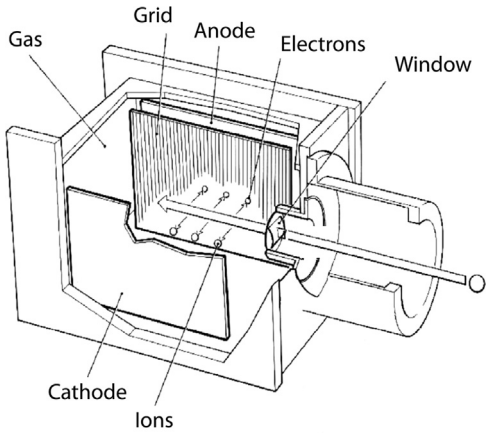

Fig. 1. A schematic diagram of the conventional ionization chamber is shown. The chamber uses a Frisch grid which causes slow response times of the detector. The figure is taken from Ref. [10].

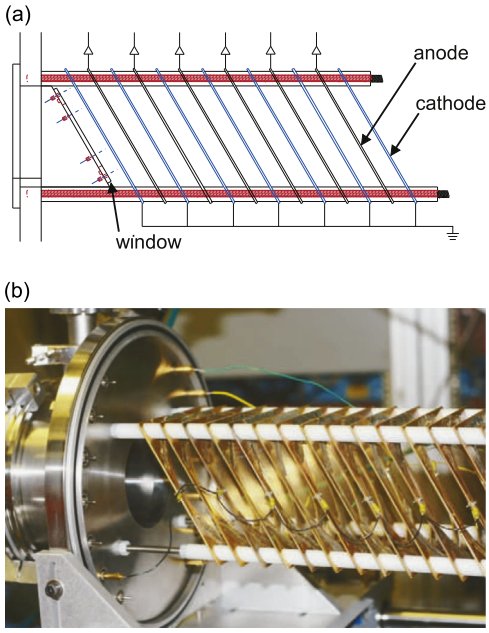

Fig. 2. (a) The cross-sectional diagram of the fast ionization chamber, and (b) a photo of the electrodes assembled in the chamber is shown.

most a factor of ~ 2, since the detector needs to be wide enough to fully accept the incident particle flux. As the distance between the ion trajectory and the anode plane increases, so does the response time of the ionization chamber. To reduce the response time, a fast ionization chamber based on an original design by Kimura et al. [1] using tilted electrodes was developed and commissioned at Oak Ridge National Laboratory (ORNL)'s Holifield Radioactive Ion Beam Facility (HRIBF).

2. Tilted electrode ionization chamber

The design of our new ionization chamber was adopted and modified from that of the Tilted Electrode Gas Ionization Chamber (TEGIC, [1]) which was originally developed to identify the atomic number and the mass number of individual particles of the secondary radioactive isotope beams at facilities such as RIKEN and GSI. Fig. 2(a) shows a cross-sectional diagram of our fast ionization chamber, and Fig. 2(b) a photo of the electrodes assembled in the chamber. The electrodes (anodes and cathodes)

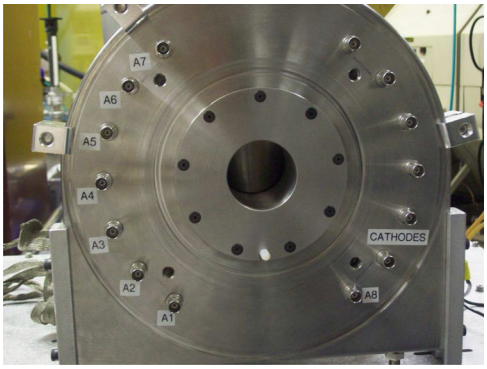

Fig. 3. The front flange of the ionization chamber is shown. Each anode is connected to a BNC feedthrough labeled A1–A8 in the picture. All cathodes are combined internally and connected to a single BNC feedthrough to be grounded.

are made of 5.38 in. × 5.38 in. copper frames. The frames have 4.62 in. diameter circular openings and thin (0.0007 in. diameter) gold coated tungsten wires (CFW-101021 manufactured by California Fine Wire) soldered to the frames with 1 mm spacings. The grids are supported by four steel rods that are shielded by thin Kapton sheets and Teflon tape for electric insulation. The electrodes are tilted 30° from perpendicular beam line as shown in Fig. 2 so that the electric field generated by electrodes is not parallel to the beam axis. By tilting the electrodes in this way, the electrons and positive ions liberated in the gas drift away from the beam axis, which helps to avoid recombination. A total of 17 electrodes (8 anodes and 9 cathodes) were installed, separated by 0.72 in. long polyoxymethylene spacers visible as white cylinders in Fig. 2(b). The capacitance between adjacent electrodes was measured to be 0.065 nF independent of the gas pressure of the chamber. The alternating arrangement of anodes and cathodes results in short drift distances (times) for liberated electrons and positive ions before capture by an anode and a cathode, respectively. Each anode plane is connected to a separate BNC feedthrough, whereas all the cathode planes are combined together electrically inside the chamber and connected to a single BNC feedthrough. Fig. 3 shows the front flange of the ionization chamber. BNC feedthroughs connected to anodes are labeled as A1–A8, where A1 (Anode 1) refers to the first anode plane from the entrance window. The combined cathode signal is grounded outside the chamber. In this configuration, any section between two adjacent cathodes provides an energy loss *dE* measurement, and the *dE* signals from each anode can be easily manipulated outside the chamber as needed.

The entrance window was made of 5.08 μm thick Mylar $(C_{10}H_8O_4)_n$ polyester film (gauge 20C). This film is easy to handle and robust against pressure differentials across the window. The Mylar film is glued to the window frame using epoxy, which is in turn mounted on a window block shown in Fig. 4. The window is aluminized (~ 10 nm−thick) on the upstream side (vacuum side) in order to dissipate the heat deposited from the incident particles.

One difference from the TEGIC detector was the implementation of a window tilted at 30° from perpendicular beam line to keep the distance between the window and the first electrode (cathode) constant. This implementation was especially important for the detection of low-energy particles, which can lose significant amounts of energy before reaching the first anode. The window block can be easily removed from the ion counter without affecting any electric connections to the electrodes. The robustness of the entrance window against the gas pressure has been examined extensively. The gauge 20C Mylar window which covered the 2.5 in. ∅ hole on the window frame can hold more than 450 Torr of gas without breaking. Any pressure of gas in the chamber will cause stretching of the Mylar polyester film to some