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A multiple sampling ionization chamber for the External Target Facility

X.H. Zhang [a,*], S.W. Tang [a], P. Ma [a], C.G. Lu [a], H.R. Yang [a], S.T. Wang [a], Y.H. Yu [a], K. Yue [a], F. Fang [a], D. Yan [a,c], Y. Zhou [a,c], Z.M. Wang [a,c], Y. Sun [a,c], Z.Y. Sun [a], L.M. Duan [a], B.H. Sun [b]

[a] Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China
[b] School of Physics and Nuclear Energy Engineering, Beihang University, Beijing 100191, China
[c] University of Chinese Academy of Sciences, Beijing 100049, China

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ABSTRACT

A multiple sampling ionization chamber used as a particle identification device for high energy heavy ions has been developed for the External Target Facility. The performance of this detector was tested with a ^{239}Pu α source and RI beams. A Z resolution (FWHM) of 0.4–0.6 was achieved for nuclear fragments of ^{18}O at 400 AMeV.

1. Introduction

An experimental setup, the External Target Facility (ETF), has been constructed at the Heavy Ion Research Facility in Lanzhou (HIRFL) [1]. It is an universal experimental setup for kinematically complete measurements and consists of several different sub-detector systems [2]. Using this facility, research on the reaction studies with radioactive isotope (RI) beams around several hundred AMeV as well as the structure of exotic nuclei can be carried out.

Like the FRagment Separator (FRS), which delivers RI beams to the ALADIN-LAND setup at GSI [3,4], the first half of the second Radioactive Ion Beam Line in Lanzhou (RIBLL2) can be used to produce and separate the RI beams of interest to the ETF. The RI beams can be identified by combining the time-of-flight (TOF), the energy loss ΔE, and the magnetic rigidity $B\rho$, which is widely used by all projectile fragmentation type separators. A suitable ΔE detector needs to have good energy resolution, high counting rate capability and robustness against beam irradiation. As a candidate, the gas ionization chambers are extremely stable under beam bombardment. They have good energy resolution. Also, the energy resolution can be further improved using the multiple sampling ionization chamber (MUSIC) detector according to Ref. [5]. The MUSIC can provide energy resolution which is as good as that of semiconductor detectors. Large-scale MUSIC detectors are easy to be fabricated. Considering these outstanding features, a MUSIC detector for ΔE measurements was proposed for the ETF.

In this paper, the construction and operation of the MUSIC detector will be described together with the tests of this detector with a standard alpha source and RI beams.

2. Construction and operation

The MUSIC design is summarized in Fig. 1. The cathode and anode, which are made of 2 mm thick printed circuit board coppered on one side, are placed parallel at a distance of 100 mm. The active length of the chamber is 380 mm and is divided into 8 equal anode segments (100 mm wide $\times$ 45 mm long with 2 mm spacing between segments). A Frisch grid which consists of parallel wires is located 10 mm above the anode. Between the Frisch grid and the cathode, two side panels, which are made from 1.5 mm thick printed circuit boards etched to provide 2 mm width aluminium strips in 4 mm steps, are installed. A resistor chain is used to connect the aluminium strips, the cathode, and the Frisch grid for the field homogenization. All the electrodes are fixed with epoxy fiberglass for insulating supports. The whole assembly of the electrodes is housed in an aluminum vessel for electromagnetic shielding. Two mayler sheets with a thickness of 25 μm are attached to the entrance and exit windows with an active area of 85 $\times$ 85 mm^2.

An ideal grid would shield the moving electrons in the cathode-grid region perfectly from inducing a signal on the anode.

* Corresponding author.
E-mail address: zhxh@impcas.ac.cn (X.H. Zhang).

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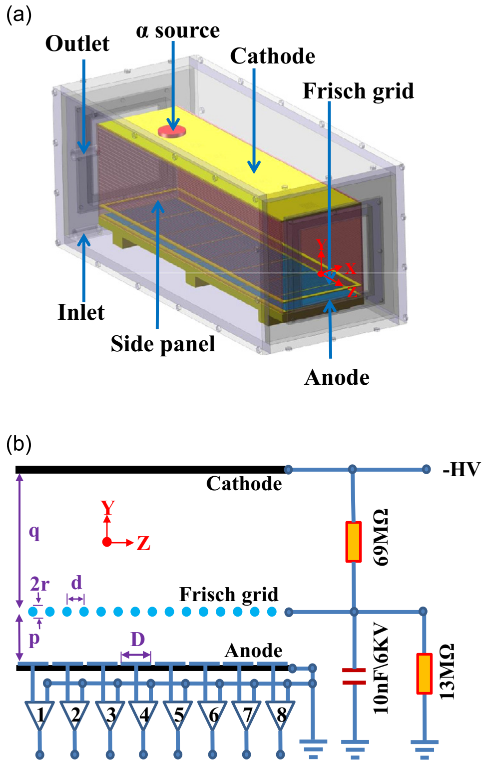

Fig. 1. (a) 3D perspective of the MUSIC. (b) Schematic view of the MUSIC. The eight anode signals are fed into the charge sensitive preamplifiers. A voltage divider circuit is used for the high voltage supply. The cathode-grid distance q and grid-anode distance p are 90 and 10 mm. The segment length D is 45 mm. The grid wire radius r and the distance between grid wires d are 0.05 and 2 mm, respectively.

However, this cannot be realized in real experimental conditions. The time dependence of the signals for this MUSIC have been simulated with Garfield [6] shown in Fig. 2(a). In the simulation, the Frisch grid consisted of 0.1 mm diameter wires with 2 mm wire spacing, and the field strength in the anode-grid region was kept 1.7 times higher than the one in the cathode-grid region. Two thousand electrons with an uniform distribution in a length of 4 cm were drifted from the cathode to the anode. The simulated results for electron emission angles close to $\theta = 0^\circ$ and 90°, relative to the Z-axis in the Y–Z plane, are plotted in Fig. 2(a). Here we focus on the anode signals. From T_C the electrons started to drift away from the cathode, and at T_G the first electron arrived at the grid. During this time, the anode signal already exhibited a linear rise due to the so-called Grid Inefficiency (GI). As long as the electrons drift in the cathode-grid region the following relation is valid [7]:

$$Q_A(t) = -\sigma Q_C(t). \quad (1)$$

Here $Q_A(t)$ and $Q_C(t)$ mean the anode and cathode charge pulses as a function of time, respectively, and σ is the GI factor. Following this relation, the GI factor can be obtained experimentally by the ratio of the anode and cathode signal slopes. After the time of T_G, the electrons started passing through the grid, and the anode signal quickly increased in amplitude until the time of T_A. The maximum corresponds to the time when the collection of electrons is over.

The maximum of the anode signal is affected by the GI. The anode and cathode signals have been simulated for different d, and the σ determined from Eq. (1) and the maximum of the anode signal is plotted as a function of the d in Fig. 2(b) and (c), respectively. The theoretical values of σ based on Ref. [8] are also plotted with solid line in Fig. 2(b). They are almost coincident with the simulated results. Obviously, the σ decreases with the decrease

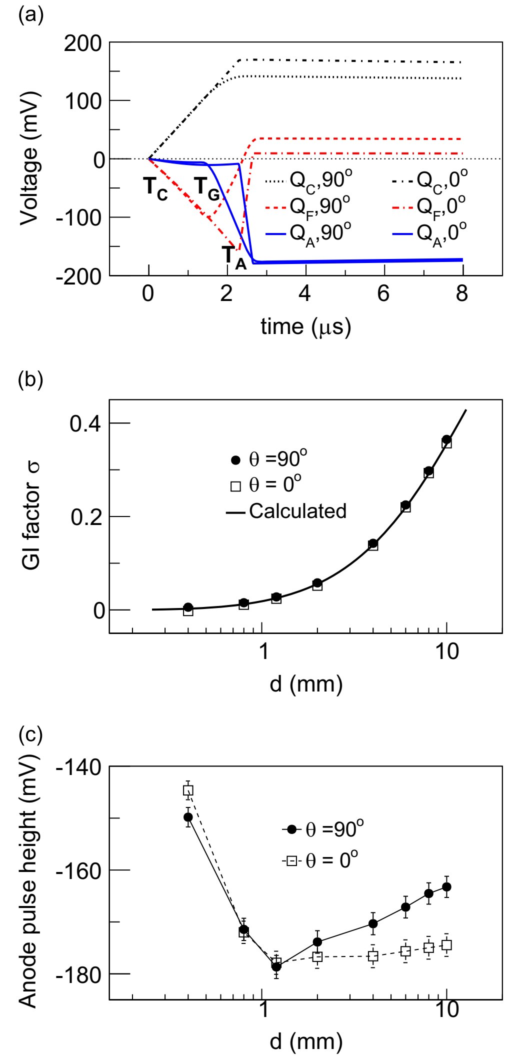

Fig. 2. Simulated results with Garfield. (a) Simulated voltage output from the preamplifier as a function of time (8 ns/channel). (b) The GI distributions for different spacing widths and emission angles as determined from Eq. (1). The solid line represents the theoretically calculated values based on Ref. [8]. (c) The maximum of the anode signals for $\theta = 0^\circ$ and 90° are plotted as a function of d.

of d, and a larger σ leads to a lower anode pulse height. When the values of d are smaller than 1.2 mm, the anode pulse heights start to decline although σ still decreases. That is because the fraction of field lines are intercepted by the grids. Bunemann [8] proposed a condition on the field strength ratio between the anode-grid and cathode-grid regions

$$\frac{E_A}{E_C} \geq \frac{1+2\pi r/d}{1-2\pi r/d}, \quad (2)$$

where E_A and E_C denote the field strength in the anode-grid and cathode-grid regions, respectively. In order to ensure minimum electron losses on the grids, a large value of E_A/E_C is required for a small d.

As a consequence of the GI, the anode signal height is slightly angle dependent, as shown in Fig. 2(c). When a charged particle is emitted parallel to the grid ($\theta = 0^\circ$), the effect of the GI on the anode signal height is smaller than the case of the particle emitted perpendicular to the grid ($\theta = 90^\circ$). This is beneficial for the beam experiments because the directions of the incident particles are almost parallel to the grid.

According to the simulated results, the Frisch grid with 0.1 mm diameter Cu–Be wires and 2 mm wire spacing are used for the