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A timing detector with pulsed high-voltage power supply for mass measurements at CSRe

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ABSTRACT

Accuracy of nuclear mass measurements in storage rings depends critically on the accuracy with which the revolution times of stored ions can be obtained. In such experiments, micro-channel plates (MCP) are used as timing detectors. Due to large phase space of injected secondary beams, a large number of ions cannot be stored in the ring and is lost within the first few revolutions. However, these ions interact with the detector and can saturate the MCP and thus deteriorate its performance. In order to eliminate such effects, a fast, pulsed high-voltage power supply (PHVPS) has been employed which keeps the detector switched-off during the first few revolutions. The new detector setup was taken into operation at the Experimental Cooler-Storage-Ring CSRe in Lanzhou and resulted in a significant improvement of the detector amplitude and efficiency characteristics.

1. Introduction

The mass is a fundamental property of atomic nuclei [1]. For mass measurements of short-lived nuclei, the isochronous mass spectrometry (IMS) at storage rings has proven to be a very efficient technique [2,3]. Since few years, IMS experiments have been successfully conducted at the Institute of Modern Physics, Chinese Academy of Sciences in Lanzhou, China [4–10]. The radioactive-ion beam facility, consisting of the heavy ions synchrotron CSRm, the in-flight fragment separator RIBLL2, and the experimental cooler-storage ring CSRe, is employed for this purpose [11]. Here, the nuclides of interest are produced by fragmenting relativistic primary beams provided by CSRm, separated in-flight with RIBLL2, and then injected and stored in the CSRe. If the storage ring is tuned into the so-called isochronous ion-optical mode, then the revolution times of the stored ions depend, in first order, only on their mass-of-charge ratios and are independent of their velocities. Therefore the masses of exotic nuclei can be determined by measuring their revolution times. The details on the IMS technique and recent experiments can be found in Refs. [12–14].

In present IMS experiments, the revolution times are measured by using dedicated timing detectors. Each detector consists of a carbon foil and a Micro-Channel Plate (MCP) [7]. At the CSRe, we use a carbon foil of 19 μg/cm^2 in thickness and 40 mm in diameter (see Fig. 1). The foil is positioned in the circulation path of the stored ions. Ions passing through the foil result in secondary electrons released from its surface. The electrons emitted in the forward direction are then guided isochronously to the MCP with the help of perpendicularly arranged electric and magnetic fields. The signals from the MCP are digitized and stored by a commercial fast oscilloscope for off-line analysis. In our experiments we employed Tektronix DPO 71254 [15]. The data acquisition is triggered by the CSRe injection kicker. Usually, the sampling rate is set to be 50 GHz and the recording time is 200 μs for each injection corresponding to ∼300 revolutions of the stored ions.

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Due to the nuclear reaction process, the secondary beam has a relatively large emittance, which is much larger than the acceptance of the CSRe. Therefore, only a part of the injected ions is stored and used for revolution time determinations, while most of the ions can, however, survive only a few revolutions before they hit the boundaries of the CSRe vacuum pipe. Dependent on the particular experiment, the number of such "un-stored" ions can be significant and they can result in a huge number of secondary electrons released from the carbon foil. In such cases the electrons hitting the MCP will discharge many MCP channels. Since the recovery time of each channel of a few tens of milliseconds is much longer than the overall measurement time of merely 200 μs, considerable saturation effects can occur affecting the detection efficiency and signal amplitudes. A typical signal sequence for one injection is presented in Fig. 2(a) with Fig. 2(b) showing the zoomed part of the first few revolutions right after beam injection and Fig. 2(c) showing the zoomed part at the same number of revolutions taken at 80 μs The discharging of many channels of the MCP detector at the first few turns can clearly be seen in Fig. 2(b). The saturation effect can be seen in the slow reduction of the signal amplitudes vs. time. Since the primary beam intensities are expected to increase by several orders of magnitude in the planned facilities such as FAIR [16] and HIAF [17], this effect could become dramatic in future experiments.

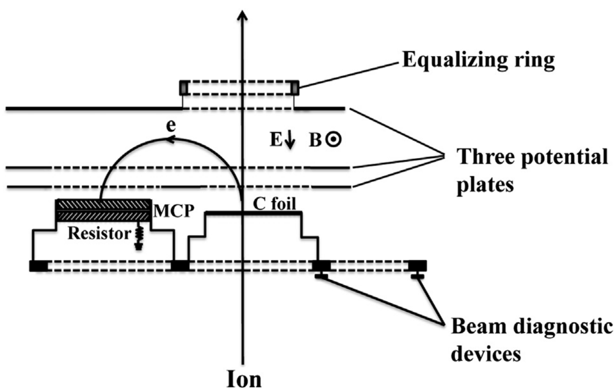

Fig. 1. Schematic view of the time-of-flight detector with the perpendicularly arranged electric and magnetic fields.

In order to avoid discharging of many channels during the first few revolutions, the detector can be disabled and then switched-on after the first several revolutions, when most of the ions lying outside the storage acceptance are lost from the CSRe. This idea has been proposed previously, but, to our knowledge, was not implemented and tested in a real experiment [18]. A pulsed high-voltage power supply (PHVPS) has been implemented for the timing detector used in mass measurements at the CSRe. The structure of this dedicated PHVPS, its off-line test and online application are described in this work.

2. Design and test of PHVPS

2.1. Design considerations

The detector (Fig. 1) is described in detail in Refs. [6,7]. In routine uses, the electrons emitted from the carbon foil are guided

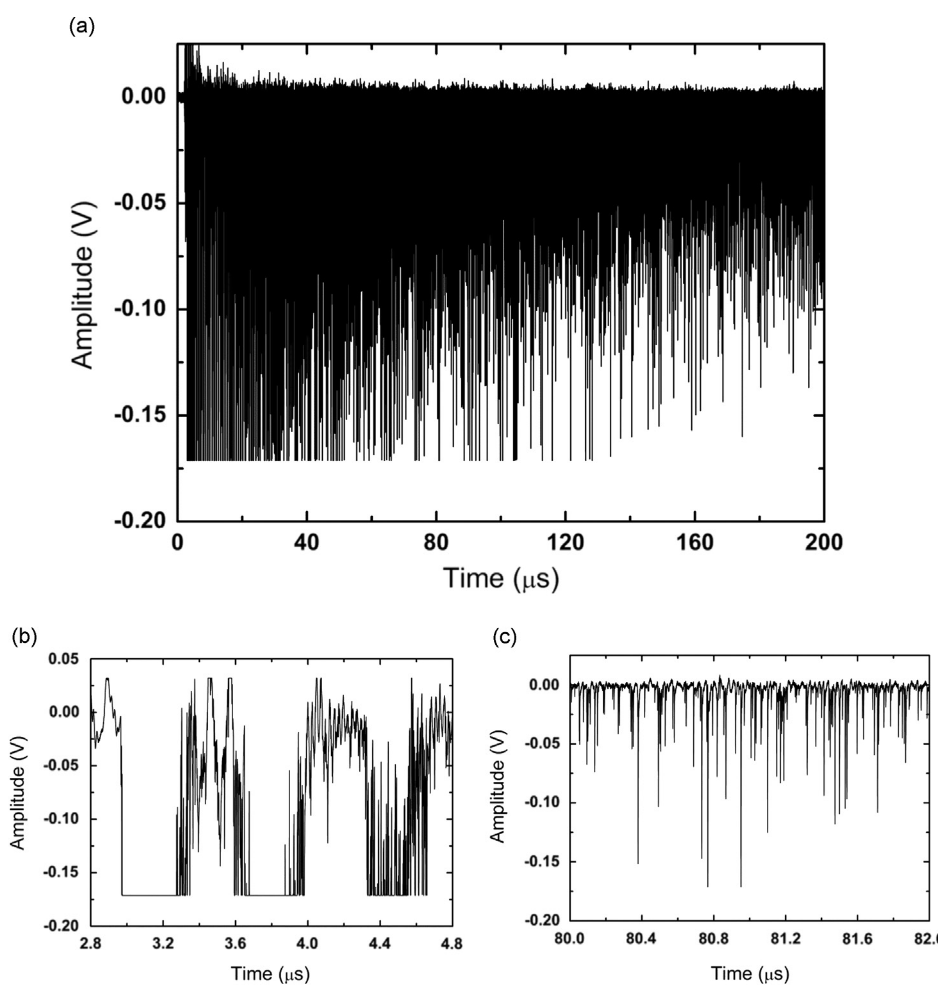

Fig. 2. An example of timing signals from the MCP detector recorded by the oscilloscope. The entire measurement of 200 μs is illustrated (a). The zoomed parts of the spectrum at the first turns (b) and at around 80 μs (c).