Developments of time-of-flight detectors for Rare-RI Ring

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Construction of the Rare-RI Ring, which will be used to measure masses of short-lived rare-RI with a relative precision of 10^{-6}, is underway at RIBF.[1,2]

We are developing three types of time-of-flight (TOF) detectors for installation in the Rare-RI Ring; two of the three are placed at the entrance (start detector) of the ring and the third is placed inside the ring as the circulative ion detector (CD). The start detector provides the start signal of the TOF system for the mass measurement. The CD provides a signal corresponding to each circulation. The CD is indispensable for monitoring the motion of the particle inside the ring at the beginning of the storage.

The required specifications for the start detector are i) a good timing resolution less than 100 ps because the total TOF is about 0.7 ms, ii) a large effective area (100 mm × 50 mm) to cover the large beam size, iii) small energy loss and energy straggling so as to not affect the mass resolution of mass measurement in the ring, and iv) no change in the charge state of the nuclei, achieved by passing them through a detector to avoid reduction of the transmission efficiency in the ring. On the other hand, the required specifications for the CD are i) small energy loss to maintain the momentum of the nuclei within the momentum acceptance during 100 circulations, ii) a high detection efficiency, iii) a large effective area (100 mm × 50 mm) to match the large beam size, and iv) a good timing resolution to separate each circulation (the typical time for one revolution is about 350 ns.) Furthermore, the CD should be maintained in ultra high vacuum.

To mount the detector in a limited narrow space, we developed a "T-shaped" TOF detector, as shown in Fig. 1(a). The left part of the detector consists of two 1" photomultipliers (R4998) coupled to the top and bottom parts of a 100 μm-thickness scintillator, while the right part contains one 2" photomultiplier (H2431-50) coupled directly to the right side of the scintillator. It is noted that, in the "T-shaped" TOF detector, we can obtain the horizontal position information, which may be used to improve the timing resolution. In the case of heavy nuclei and changes in the charge state, the 100-μm-thickness of the scintillator is no sufficiently thin. We thus consider introducing a micro channel plate (MCP) detector, as has been used at ESR[3] and CSRe[4], which has a sufficiently thin carbon foil. To cover the larger beam size at the entrance of Rare-RI Ring, we are developing the detector with a lager sensitive area.[5]

As the CD, we developed a similar MCP-type detector, used at the Gas filled Recoil Ion Separator (GARIS). [6] When the beam passes through the thin carbon foil (60 μg/cm^2), secondary electrons are generated in the foil. The generated electrons are transported to the MCP by only the electric field. A schematic view of the detector is shown in Fig. 1(b). A mirror electric field and an acceleration electric field are how they are created using wires. Wires (W+Au) with a 40-μm diameter are set at distance of 8.0 mm from carbon foil with a 1.0-mm pitch, and wires (W+Au) for the triangular part are set with a 3.0-mm pitch.

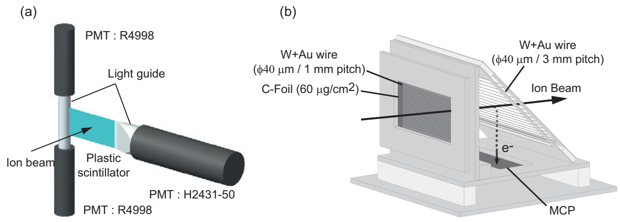

Fig. 1. Schematic view of the (a) "T-shaped" TOF detector and (b) circulative ion detector (CD).

The experiment to check the performance of the TOF detectors was carried out at the secondary beam line, SB2 course,[7] at HIMAC at the National Institute of Radiological Sciences (NIRS). A primary beam of ^{84}Kr was accelerated up to 200 A MeV and delivered to the SB2 course. For the "T-shaped" TOF detector, a timing resolution of $\sigma \approx 60$ ps is obtained. The position resolution in the horizontal axis is around $\sigma \approx$ 2 mm. For the CD, a timing resolution of $\sigma \approx 130$ ps is obtained. The detection efficiency was about 72%. This value is comparable with the efficiency for the isochronous mass measurement at ESR.[8]

We will install these TOF detectors in the Rare-RI Ring in the next fiscal year.

References

1) Y. Yamaguchi, et al.: Nucl. Instr. and Meth. B 317 (2013) 629.
2) A. Ozawa, et al.: Prog. Theor. Exp. Phys. (2012) 03C009.
3) M. Hausmann, et al.: Nucl. Instr. and Meth. A 446 (2000) 569.
4) B. Mei, et al.: Nucl. Instr. and Meth. A 624 (2010) 109.
5) D. Nagae, et al.: Nucl. Instr. and Meth. B 317 (2013) 640.
6) K. Morimoto et al.: RIKEN Accel. Prog. Rep. 46 (2013) 191.
7) M. Kanazawa, et al.: Nucl. Phys. A 746 (2004) 393.
8) N. Kuzminchuk: PhD thesis, Justus-Liebig Universität Gießen, (2011).

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