Development of MCP timing detector for low-energy heavy ions

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A prototype microchannel plate (MCP) timing detector was developed for correlated measurement of time of flight and decay properties by coupling with a multi-reflection time-of-flight mass spectrograph. The detector consists of a silicon PIN photodiode S3590-19 and an MCP F2223-21SH, as shown in Fig. 1. We investigated the performance of the detector using five types of beams: 2, 3 and 9 MeV ^{197}Au and 0.6 and 3 MeV ^{4}He at the Pelletron accelerator. Three degrader settings were available to reduce the beam intensity and provide various beam energies. The beam was collimated by a 0.2-millimeter-wide hole, degraded by a 2-micrometer-thick mylar foil, or stopped by a 0.5-millimeter-thick aluminum sheet, as shown in Fig. 1.

Energy calibration of a silicon detector for ^{197}Au was conducted by evaluating its dead layer thickness and pulse height defect using the Stopping and Range of Ions in Matter (SRIM) code[1] and assuming the charge state assignment for the multi-peak 9 MeV Au^{5+} spectrum in Fig. 2. From the SRIM results, the entrance window effect and the nuclear collision effect account for 7% and 48%, respectively, of 9 MeV Au. By considering both effects, the calculated dead layer thickness of the silicon detector was 0.266 μm and the energy-response function was obtained.

Based on coincidence of the MCP and silicon detector signals, the detection efficiency of the MCP was evaluated. The MCP efficiency for detecting Au is over 90% down to 2 MeV, as shown in Fig. 3. Pulse height analysis was performed to determine the energy response of the MCP using the offline data produced by a digitizer. The pulse height of the MCP fast amplifier signal was calculated by subtracting the baseline from the maximum of the pulse. The response was sensitive and increased with the beam energy linearly, as shown in Fig. 4. We confirmed that the MCP timing detector could be a complementary option for a timing detector instead of MagneTOF and α-TOF.[2]

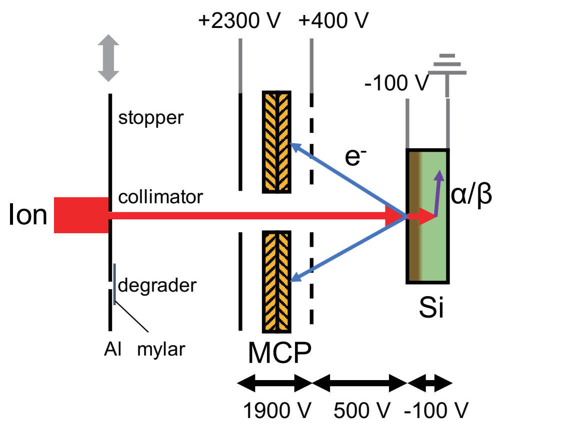

Fig. 1. Schematic of experimental setup, including degrader and MCP timing detector, with voltage settings. Position of aluminum plate is adjustable. Ion beam, secondary electrons, and decay particle are shown. Decay is not in scope of this experiment.

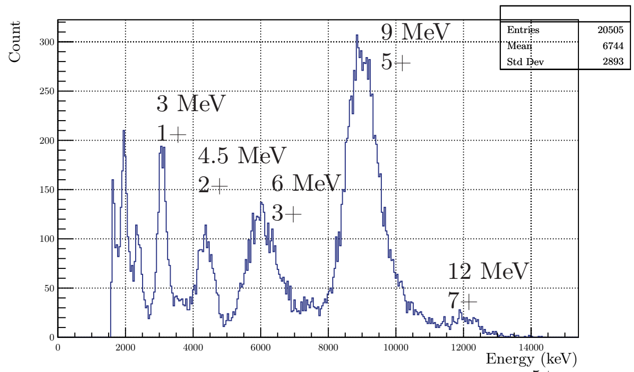

Fig. 2. Calibrated energy spectrum for 9 MeV Au^{5+} beam with labelled energy and charge state.

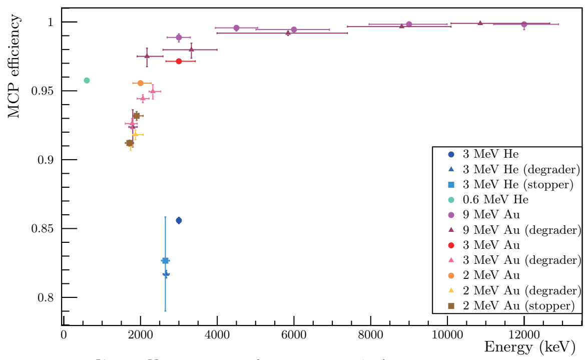

Fig. 3. MCP efficiencies for He and Au against ion energy.

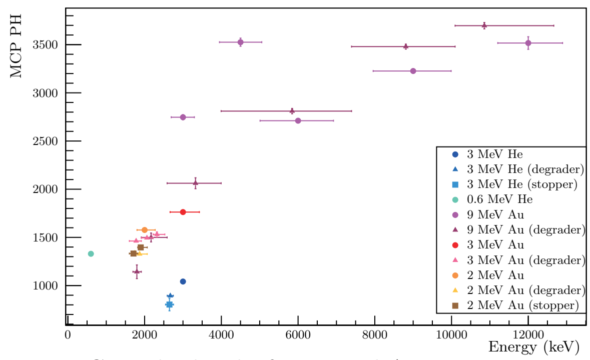

Fig. 4. MCP pulse height for He and Au against ion energy.

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References

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