Development of 1.5-mm thick liquid hydrogen target

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We report on the development of a thin liquid hydrogen target using the CRYPTA system.[1)] We aim to perform missing mass experiments on proton-rich nuclei with high statistics and reasonable resolution via one and two neutron transfer ((p,d) and (p,t), respectively) reactions with 50 MeV/nucleon radioactive beams, which generate deuterons and tritons ranging between 10 and 30 MeV/nucleon. Consequently we obtained a 1.5 mm thick liquid hydrogen target.

The system was placed in a vacuum chamber. A target cell was connected to a refrigerator with a copper bar and cooled down below the boiling point. To monitor the temperatures, a thermometer labeled 'A' was attached to the connecting end of the cell and 'B' was attached to the surface of the window frame, as shown in Fig. 1 (a). A gas pipe was connected to the inside of the cell. The pipe was also connected to a reserver tank placed outside the vacuum chamber, which was filled with hydrogen gas. Hydrogen was introduced from the tank to the cell. The hydrogen gas was liquefied near thermometer A and dropped into the cell. A heater was placed near thermometer A to maintain the temperature above the melting point.

The target cell consisted of one body frame and two window frames, all made of aluminum, as shown in Fig. 1 (b). Each window frame had a hole with a diameter of 20-mm at the center. The window frame of the downstream side was tapered to detect recoil particles at large angles. The side view of the constructed target cell is shown in Fig. 1 (a). The volume was defined by a pair of 6.47-μm-thick HAVER foils glued to the window frames. The designed distance between the foils was 0.5 mm. The liquid hydrogen volume thus defined expanded toward the outside by 0.5 mm at the center of each side due to the 0.8-atm gas pressure. The shape of the expansion was measured with a laser displacement sensor. The total thickness was found to be 1.5 mm at the center. We had no experience of liquefaction of hydrogen in such narrow volume and tested to determine the design of the window frames. Finally, we placed a 7-mm thick volume outside the foils to fully fill the target cell, as shown in Fig. 1 (a).

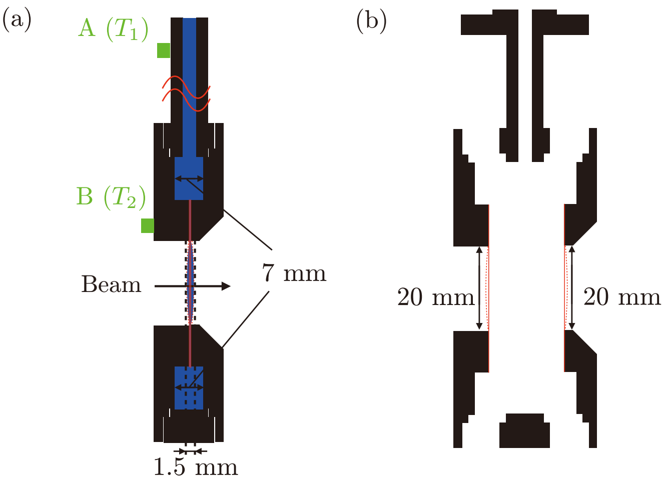

Fig. 1. (a) Side view of the cross-section of target cell. Blue area is filled with liquid hydrogen. Green squares indicate the thermometers. (b) Side view of the cross-section of target cell components.

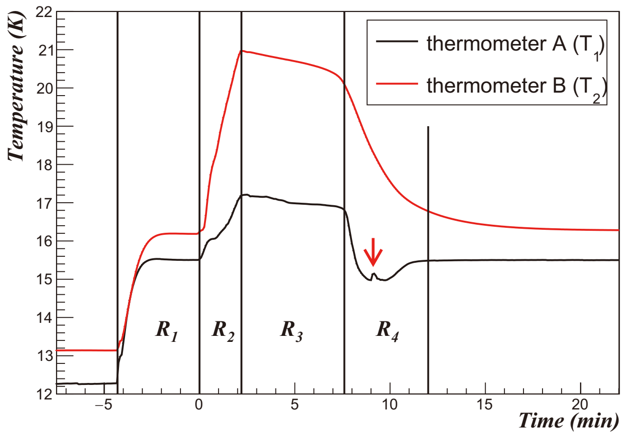

Fig. 2. Variation of temperatures during liquefaction.

We performed a test at our test-bench at the RIBF. To visually confirm that the target cell was fully filled with liquid hydrogen, one of the foils was replaced with a 125-μm-thick Kapton foil. Figure 2 shows the variations in the temperature of thermometer A (T_1) and thermometer B (T_2) during liquefaction. Before introducing the hydrogen gas, the target system was maintained at temperatures above the melting point by the heater (R_1). When hydrogen gas was gradually introduced, the temperature of the target became higher because hydrogen gas was cooled (R_2). Liquefaction gradually occurred while the temperature was almost constant (R_3). During this step, it was observed from outside that only the lower part of the 20-mm diameter hole was filled. While the cell was filled only partially, the full 7-mm thick volume was likely filled at this point. Then, the temperature started to decrease (R_4). When T_1 became lower than 15.5 K, the heater turned on and the rate of decrease reduced. T_1 suddenly increased at $t = 9.5$ min, as indicated by the red arrow. At this point the target was fully filled. This behavior of temperature was observed using HAVAR foils at both sides. Therefore, we consider the target was also fully filled in this condition.

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Reference

1) H. Ryuto *et al.*, Nucl. Instrum. Methods Phys. Res. A **555**, 1 (2005).