# New liquid hydrogen target for in-beam $\gamma$-ray spectroscopy

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We report the development and experimental results of a 35 mm thick liquid hydrogen target based on the CRYPTA system.[1,2] The target is designed for in-beam $\gamma$-ray spectroscopy to study bound excited states following proton-induced knock-out reactions. This system has been used in the $^{100}$Sn experiment with DALI2$^+$ array[3] at F8, and showed good stability.

Figure 1 presents the cross-sectional view of the target. The system is constructed using a two-stage 4 K cryocooler system (SHI RDE-418D4 with a compressor unit F-50L), with the target section attached to the second stage (1.8 W@4.2 K) and the aluminum thermal shields mounted on the first stage (42 W@50 K). The system is designed in an L-shape to fit the structure of the DALI2$^+$ array. The target cell is approximately 40 cm away from the buffer tank and supported by two copper rods. The target cell and buffer tank are linked by two flexible pipes, which serve as the inlet and outlet for hydrogen circulation. The target cell is 30 mm thick, with two windows of 50 mm in diameter. These windows are enclosed by 10-$\mu$m Havar foils, which deform by approximately 2 mm under a pressure of 1.1 atm. Three temperature sensors and one heater are installed on the target. Sensor and heater denoted by K1 and J in Fig. 1 form a closed PID loop for target temperature control via a LakeShore 336 Model, operated by a python-based graphical interface. The other two sensors monitor the temperature of the buffer tank (K2) and the target cell (K3).

Figure 2 shows temperature and pressure profiles of the target during different stages. It takes approximately 4 hours for the target to cool from room temperature to below 20 K. After the target is cooled down, the system is connected to an 800 liter hydrogen gas tank at 150 kPa. It takes about 2 hours for the liquefied hydrogen to completely fill the buffer tank and the target cell, and the gas pressure stabilizes at 108 kPa. During the 10-day experiment, the temperatures and pressure remained very stable. After the experiment, we gradually heated up the target to vaporize the liquid hydrogen, and it took about 1 hour for the target to be completely emptied.

In summary, we developed a new liquid hydrogen target system based on CRYPTA. The system was successfully used in the experiment and demonstrated good stability during its operation. Based on the current design, it is highly desirable to develop a more compact, flexible, and multi-purpose target system capable for both in-beam $\gamma$-ray spectroscopy at F8 and invariant mass spectrometry at SAMURAI.

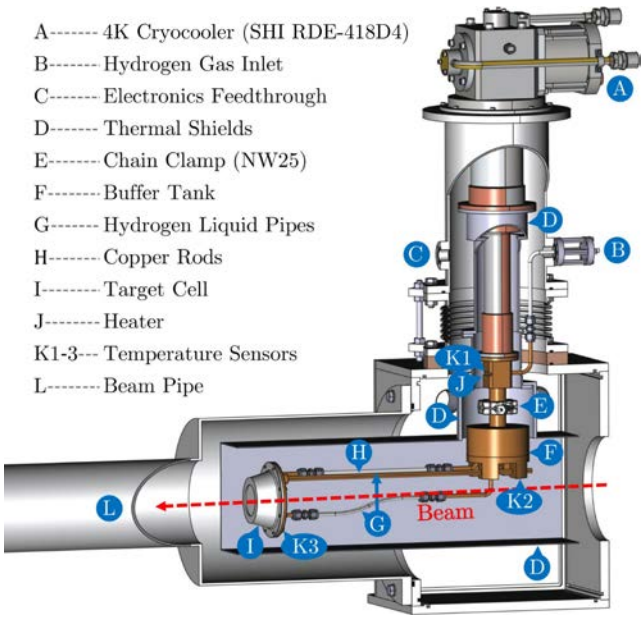


Fig. 1. Cross-sectional view of the liquid hydrogen target.

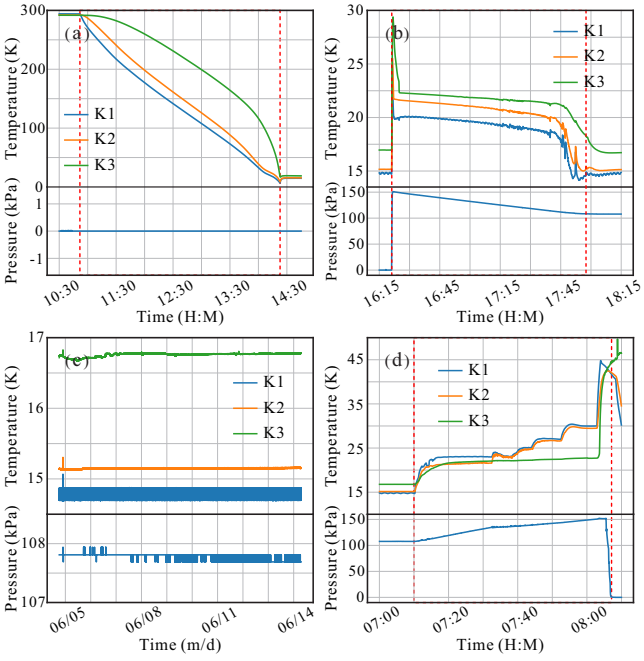


Fig. 2. Temperature and pressure profiles of the target during different stages: (a) target cooling, (b) target filling, (c) operation, and (d) target emptying.

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