Development of the He-filling system for the SAMURAI spectrometer

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In the upcoming Light-Ion experiments SAMURAI 12/13 and in the HI-Proton experiments SAMURAI 24/25/28/29, the SAMURAI gap will be filled by He at 1 atm pressure, as required by the use of large-sized windows at the entrance and exit ends of the spectrometer to maximize its angular acceptance.

A test window was constructed with the total area of 1200×3340 mm^2, which can replace the existing window for outgoing charged particles. The chosen material for the He-window was the 100-μm PET film KEL86W.

To validate the design of the He-window and the air-replacement method, a He filling test was performed using a test chamber with volume $V \approx 1.4$ m^3. The PET film was superposed onto a 2-mm rubber frame and both were attached to the chamber's flange by a segmented metal frame to provide sufficient gas tightness. He was injected into the chamber and the air-He mixture was ejected to the atmosphere through the outlet port on the opposite side of the chamber. Time-dependence of the absolute O_2 concentration, $C^{O_2}(t)$, in the chamber was monitored by the O_2 sensors with a precision of 0.1%. The sensors were placed at three different heights: 2 cm (bottom), 27.5 cm (middle), and 55 cm (top) in the center of the chamber to control the homogeneity of the He-air mixture. The O_2 sensors were controlled via an external PC and their data were read out every 5 seconds.

The air concentration, $C^{air}(t)$, at every moment of time t was determined as follows:

$$C^{air}(t) = \frac{C^{O_2}(t)}{20.9\%} \times 100\%, \qquad (1)$$

where 20.9% is the C^{O_2} in the air at normal conditions. Hence, the He concentration is determined as:

$$C^{He}(t) = 100\% - C^{air}(t). \qquad (2)$$

The results of the gas-replacement test are summarized in Fig. 1. The total time of gas ventilation required to reach $C^{He} \approx 95\%$ (or $C^{O_2} \approx 1\%$) was around 3 h and 35 min with an average input He-flow $F_{in} \approx 20$ L/min.

The air replacement as a function of time t is described by the basic room-purge equation:

$$C^{air}(t) = C^{air}(t_0)\exp(-\frac{F_{in}}{V}(t-t_0)), \qquad (3)$$

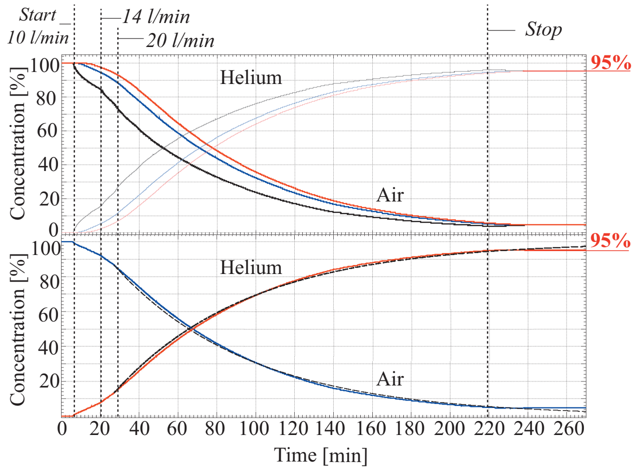

Fig. 1. Top figure: time-dependence of the air (bold lines) and He (faint lines) concentrations, derived from the data of the bottom (red line), middle (blue line) and top (black line) O_2 sensors. Bottom figure: same as the top figure, but the concentrations (He - red line, air - blue line) are averaged between the three sensors. The dashed curves in the bottom figure are calculated using equation 3. The vertical dashed lines indicate the start and the end of He injection as well as the time points when the injected He-flow changed to the indicated values.

where V is the volume of the chamber and t_0 is the start time of the ventilation. This function is plotted in the bottom graph of Fig.1 (dashed curves) and is in good agreement with the data. Based on this, one can estimate for the SAMURAI gap with $V \approx 10$ m^3 and input He-flow $F_{in} \approx 20$ L/min, the necessary time to reach C^{He}=95% is about 25 h with a consumption of about 30 m^3 of He-gas (at 1 atm).

No He leak was found after stopping the ventilation and sealing the chamber. C^{He} and C^{O_2} remained constant for at least 4 consecutive days. Moreover, no significant change in pressure (< 1mbar) was observed during and after the ventilation.

In conclusion, good performance of the He-window design and the feasibility of the applied gas-filling method, which is in agreement with theoretical expectations, have been confirmed. In future, a large exit window (5340×1000 mm^2) will be constructed and tested with the SAMURAI gap under experimental conditions.

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