Non-evaporable getter-based differential pumping system for SRILAC

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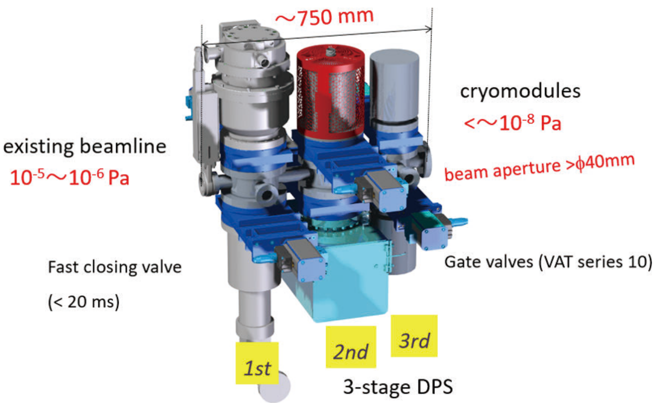
Upgrades of the RIKEN heavy-ion linac (RILAC) involving a new superconducting linac (SRILAC[1]) are in progress. High-vacuum ($<10^{-8}$ Pa) and particulate-free conditions are strictly necessary for keeping the performance of the superconductive radio frequency (SRF) cavities of SRILAC. It is crucially important to develop neighboring warm sections to mitigate the large difference in the vacuum and clean conditions with respect to the existing old RILAC and beamlines built almost four decades ago. In the present study, a non-evaporable getter (NEG)-based differential pumping system (DPS) has been developed.

The three-stage DPS (Fig. 1) was designed to achieve a pressure reduction from the existing beamline vacuum (10^{-5}–10^{-6} Pa) to an ultra-high vacuum of less than 10^{-8} Pa in the SRF cavities within a very limited length of only 75 cm, ensuring a beam aperture greater than 40 mm. The properties of pumps we used for the DPS are summarized in Fig. 1. Optimizations of the design were performed with Molflow+[2]. We measured the pressures of three stages in a prototype DPS when we leaked N_2 and H_2 with three different leak rates, respectively. The observed pressures are in good agreement with the calculated ones (Fig. 2). The DPS also has fast closing gate valve (Series 75.2; VAT Group AG) responses within 10 ms after receiving the signal of the pressure rise of three distributed cold-cathode gauges to protect the SRF systems from unexpected vacuum breaks. Compact electrostatic particle suppressors (EPSs) were equipped at the inside of the first-stage chambers of the DPSs to suppress the scattering of particles and reduce possibilities to transport particles to the SRF cavities. The EPS consists of two electrodes, each of which consists of 6 stainless-steel bars, as shown in Fig. 3. Some particle tests with the EPS in air and vacuum were performed with a vacuum particle sensor (VACUUM PARTICLE SENSOR; Wexx Co., Ltd). Ceramic and metal particles were artificially generated by scraping blocks. The counts were significantly reduced when we applied a high voltage on the electrodes. The vacuum in the beamlines becomes an ionizing environment due to the energetic heavy ions passing during the operation. We expect that the EPS can suppress particle transport to the SRF cavities.



	Type	Model	Vendor	Nominal pumping speed [L/s]
1st. Stage	Turbo Mol. Pump	HiPace700	Pfeiffer	685 (N_2), 555 (H_2)
~5×10^{-7} Pa	Roots Pump	NeoDry60E	Kashiyama	500 L/min (N_2)
	Cryo Pump	ULVAC-U6H	ULVAC	750 (N_2), 1100 (H_2), 2100 (H_2O)
2nd. Stage	High Vacuum NEG	Capacitorr HV1600	SAES	1400 (H_2), 300 (N_2)
~5×10^{-8} Pa	Ion Pump	Valcon Plus 200	Agilent	180 (N_2), 63 (Ar), ~100 (CH_4)
3rd. Stage	NEG	Capacitorr Z400	SAES	500 (H_2), 125 (N_2), 210 (CO)
$<10^{-8}$ Pa				

Fig. 1. Design of three-stages DPS and pump properties.

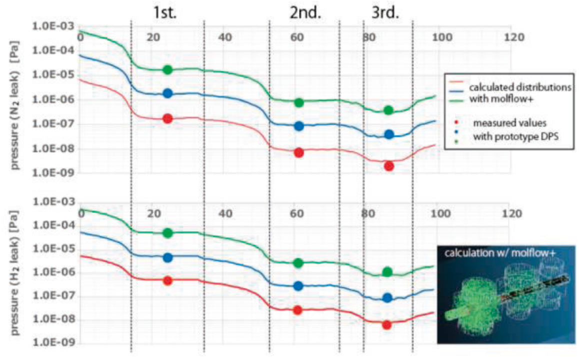


Fig. 2. Pressure distributions for N_2 and H_2 leakage.

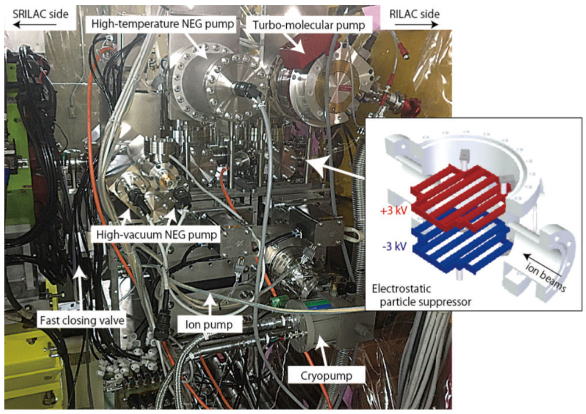


Fig. 3. Photograph of the DPS and the EPS.

All components (chambers, pumps, valves, vacuum gauges, etc.) were cleaned and assembled in a clean room of ISO class 1. The installation of the pair DPSs was completed in December 2019. Some pumps are equipped in the horizontal direction to prevent particle falls (Fig. 3). We already confirmed that the desired pressure reductions were successfully achieved, and actual operations will start soon.

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References
1) N. Sakamoto *et al.*, Proc. LINAC'18, Beijing, WE2A03 (2017).
2) Molflow+, http://molflow.web.cern.ch/.