**He-3 gas system for experiments with TPC**

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In the last decade, considerable progress has been achieved in implementing the Active Target TPC technique for experiments with rare isotope beams at low energies relevant to nuclear structure and nuclear astrophysics. The versatile TexAT detector has been in operation since 2017. Several successful experiments on resonance elastic and inelastic scattering of protons and □-particles, (□,p) and (p,□)-reactions, nucleon-transfer reactions, such as (d,p), (d,3He), (p,d), (p,t), (□,t) and β- delayed charged particle decay spectroscopy were carried out [1]. The discovery of β- delayed emission of 3□ particle and a proton by 13O [2] has been made with TexAT recently. We are now implementing TexAT upgrade which will allow us to use He-3 gas as an active target volume.

There are several good reasons to use TexAT advantages in experiments with He-3 as an active gas target and rare isotope beams available at CI or other RIB facilities. For instance, a proton transfer reaction (3He,d) is one of the best indirect tools for the evaluation of the reaction rates, which are important for astrophysics [3]. Another important reason for using interactions between He-3 and proton-rich exotic nuclei is a possibility to explore properties of even more proton-rich nuclei through the two-proton stripping reaction of (3He,n), using a capability of recently created neutron TexNeut detector [4].

The challenge of experiments with He-3 target gas is related to the shortage and high price of the rare isotope of 3He and the high demand for the applications in homeland security, science, medicine, and industry [5]. At the moment production, sales and distribution of helium-3 in the United States are managed by the US Department of Energy [6]. The required quantity of He-3 gas for experiments with TexAT is about 40L NTP.

To reduce a loss of expensive He-3 gas in the gas handling system the following requirements were taken into consideration:

- the system must be closed;
- A mixture of several gasses needs to be produced online;
- He-3 needs to be recovered with high efficiency and as little loss as possible.

The He-3 gas is quenched by adding a small amount of carbon dioxide gas (at the level of 2 - 10%, depending on the experiment) to prevent scintillations that substantially suppress electron ionization.

Due to the limited usage of He-3 gas, there are no specific compressors available on the market. Commercial compressors for He-4 are mostly designed to run a large volume of He gas and the compression rate is as high as ~100 bar, which makes it difficult to use them for our applications. Instead of designing a custom compressor, it has been decided to use a possibility of modern dry pumps not only to pump working gas but to compress it in an exhaust line up to ~2 bar [7].

The simplified He-3 vacuum/gas handling system has been designed (shown at Fig.1) and tested with regular He-4 gas. The vacuum part consists of fore-vacuum (Agilent NDP-15) and turbo (Agilent

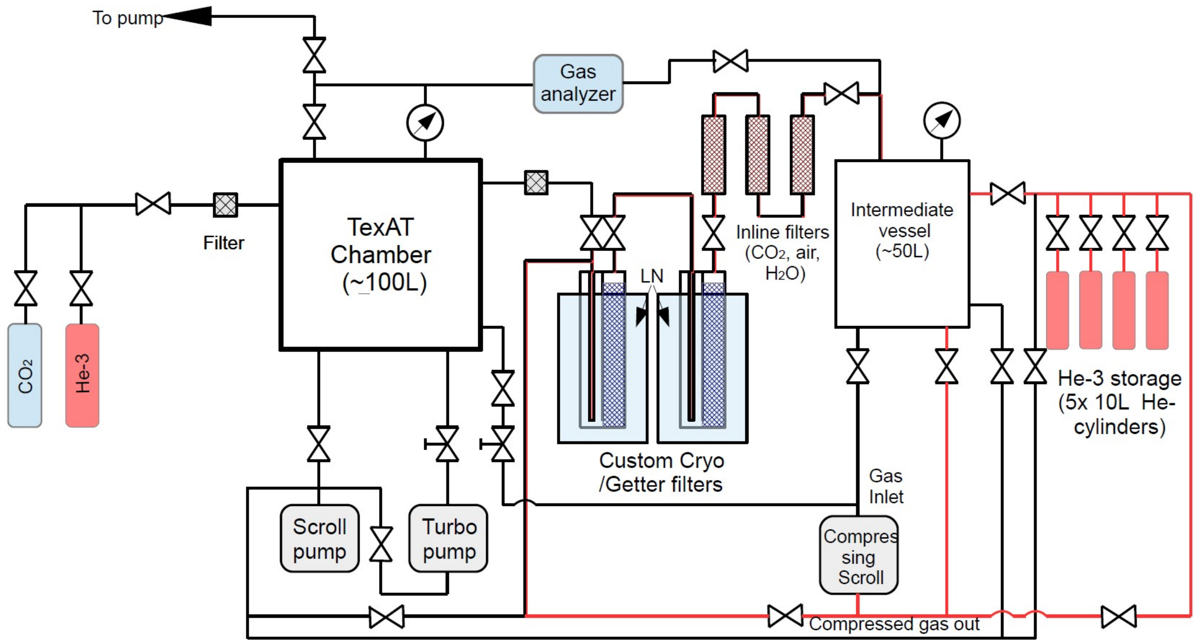


**Fig. 1**. He-3 Vacuum/He-3 Gas handling system. The compressed gas lines are shown in red.

Twistorr 304FS) pumps providing high vacuum (better than 1E-6 Torr) before experiments. Then the TexAT chamber fills up with a calculated mixture of 3He/CO2 gases. The gas composition is maintained and controlled automatically. To prevent the effect of "layering" in the gas system, the fan is installed inside the TexAT chamber. The working gas purity and composition can be checked periodically. According to the tests, the quality of the gas stays satisfactory for up to hours, and then it requires some purification. The main impurities are air (mostly, N2) because of some leaking and Hydrocarbons because of the cables/plastic outgassing.

During purification, the working gas is cleaned from CO2/H2O by two connected in series Cryo/Getter filters, and from other impurities - by a set of specific gases inline filters. The purified gas is stored in the intermediate vessel and then returns back to the experimental chamber after the additional purity check by BGA244HP gas analyzer. The purification procedure takes about 2 hours.

After the experiment gas goes through another purification and compression stage and is stored in the set of He-cylinders at the pressure of ~ 2 bar.

To minimize the gas losses most of vacuum adapters and nipples are SS "Conflat"- type, the high quality VCR-type compression fittings and all metal tubing were used. It was shown that irreversible losses of He gas during a single experiment were at the level of 1 to 1.5%.


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