# System for Continuous Chemical and Isotopic Purification of Hydrogen for the MuCap Experiment

A.A. Vasilyev[a], I.A. Alekseev[a], O.A. Fedorchenko[a], V.A. Ganzha[a], M. Hildebrandt[b], P. Kammel[c], P.A. Kravtsov[a], C. Petitjean[b], G.G. Semenchuk[a], G.N. Shapkin[a], V.A. Trofimov[a] and M.E. Vznuzdaev[a]

[a]*Petersburg Nuclear Physics Institute, Russia*
[b]*Paul Scherrer Institute, Switzerland*
[c]*University of Illinois at Urbana-Champaign, US*

The MuCap experiment at PSI is a high-precision measurement of the rate of nuclear muon capture by proton, $\mu+p\rightarrow n+\nu$, the basic electroweak process. One of the main requirements of this experiment is extremely high purity of hydrogen – better than $1\cdot10^{-8}$ for all impurities, such a nitrogen, oxygen, water. Additionally very low ($< 10^{-6}$) deuterium contamination of the protium gas is required to avoid muon transfer to dμ-atoms which has a large diffusion length. The gas with such parameters was filled in the Time Projection Chamber (TPC), operating as an active target and detector of charge products from capture reactions. It was found that the TPC internal elements have the permanent outgasing of the atmospheric components.

A Circulating Hydrogen Ultra-High Purification System (CHUPS) was designed to purify hydrogen by removing high-Z impurities. The system is based on an adsorption cryopump to stimulate the hydrogen flow and on cold adsorbent for the hydrogen purification. It was installed at PSI in 2004 and performed reliably during three experimental runs. The system can maintain the purity of the hydrogen in the detector over a several months long running period on the level of 20 ppb for moisture, which is the main contaminant and less than 7 ppb and 5 ppb for the nitrogen and oxygen correspondingly. The pressure inside the TPC was stabilized at the required level of 10 bar with 2.4 mbar instability at 3 slpm average hydrogen flow.

This system was appended by a Deuterium Removal Unit (DRU) – device for producing ultra pure protium from hydrogen obtained by electrolysis of previously "depleted" water or even from natural hydrogen. The principle of hydrogen cryogenic distillation was used as basis for the unit design. This method uses the difference in saturation vapor pressure of separating species above the surface of the mixture. It can be considered as a multi-step distillation with the use of a column (1.5 m effective height and 22 mm diameter) filled with special material for increasing the phase contact surface. The height equivalent to a theoretical plate (HETP) for the column is 2.2 cm and almost constant in a wide range of vapour flow rate. It is one of the best ever obtained results for columns of low and medium cryogenic power. Deuterium depleted hydrogen with a deuterium content less than 0.1 ppm was produced in the required quantity.

Ortho-para hydrogen analysis by gas chromatography was used for the column performance evaluation because of the inefficacy of low deuterium content hydrogen analysis. During these tests the DRU demonstrates a possibility to produce ortho- or para- hydrogen in a continuous mode with the particular form domination of more than 98%.