Development of a cryogenic radon distillation column for next generation liquid xenon experiments

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Radon emanation from detector materials is a dominant background source in liquid xenon (LXe) detectors used for rare event searches including dark matter and neutrinoless double beta decay. Being a noble gas radon can not be removed from xenon in the same way as other impurities and while its alpha decay is easily identified, the following beta decays in its decay chain contribute heavily to the low energy background relevant for DM and neutrino searches. The removal of radon is achieved by cryogenic distillation, which uses the lower vapor pressure of radon compared to xenon at -100 Â°C. By constantly liquefying and evaporating xenon inside a distillation column the radon is trapped inside the LXe at the bottom of the column until it decays. Because of the continuous emanation of radon from radioactive impurities inside the detector material, it is necessary to purify the xenon faster than the radon decay time of 3.8 days. For the large detector masses of next generation LXe experiments (e.g. XLZD) this requirement corresponds to a total xenon flow of up to 2.4 t/h, which is more than an order of magnitude higher than those achieved by current systems of about 80 kg/h.

In the scope of the LowRAD project a cryogenic distillation setup is developed for reducing the concentration of radon to unprecedented levels. To investigate the scalability of the system to next generation capacity, the required heating and cooling power is provided by a cryogenic xenon heat pump. As a radon removal system for a next generation LXe system of $\mathcal{O}$(60-80 tons) requires $\mathcal{O}$(60 kW) heating and cooling power respectively, a conventional cooling with liquid nitrogen is no longer feasible and using a heat pump system the cooling power can be provided using electrical power. The usage of xenon as working gas inside a heat pump has been studied in the form of a demonstrator setup, which achieved a cooling and heating power of 120 W utilizing the phase change of xenon. This talk will present the design and commissioning of the radon distillation column, with a particular emphasis on the integrated radon-decay detector enabling continuous online monitoring of radon concentrations.