Cryogenic Study of the LXe TPC at KEK

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In order to characterize the LXe TPC system at KEK, we analyzed data taken between November the 18th and the 30th.

The data include a first phase of system pre-cooling and Xenon liquefaction, as well as a second stable recirculation phase consisting of several deliveries during different periods.

The gas injection was stopped when ~120 mm of LXe have been filled into the cryostat.

By studying the first phase, we estimated that the time needed to increase the liquid Xenon level of ~100 mm is ~12h. The same amount of time is needed to reach the internal temperature stability of the cryostat (164 K) as well as to cool down the cold head of the PTR to 164 K.

Once the stability has been reached, we measured the relevant parameters of the different parts of the experimental setup: inlet and outlet temperatures of the thermal exchanger in the pre-cooling system, internal and external temperatures and pressures of the cryostat, pressures before and after the gas pump circulation. For most of such parameters we observed a constant behavior within ~2%. Indeed, we noticed a slight increase of the pressure and temperature in the chamber with time: we verified that the ratio between them stays constant with time.

During the re-circulation and purification processes, the detector was operating at different flow rates from 4.2 l/min to a maximum value of 11.0 l/min that allow us to estimate the performance of the system as a function of the gas flow rate. We observed an improved performance in terms of time to reach the steady state as well as a better stability of pressures and temperatures, for higher values of delivery.

The power supplied to the heater was measured for each of the different flow rates. Slide 35 shows the required cooling power as a function of the flow rate. The cooling power is computed as the available cooling power of the PTR to achieve a specific temperature of the cold head, minus the heater power needed to maintain constant the temperature inside the chamber. A required heater power of the PTR of 29 W was measured by KEK to achieve a temperature of 164 K. As we can see, a gradual increase of the cooling power is observed as the flow rate increases. Since the recirculation rate is measured but not controlled, we have observed that the flow rate is not constant during the data-taking period but drift towards equilibrium slowly, together with a slightly increase of temperature and pressure.

We have also estimated the efficiency of the heat transfer process as a function of the flow rate. To measure the performances of the heat exchanger, we have calculated inlet and outlet pressures and temperatures of the heat exchanger as well as the pressure inside the cryostat. The temperature differences at the warm and cold parts of the heat exchanger are presented in slide 36. The temperature at the cold part of the heat exchanger is quite stable with the flow rate, which implies that even for a small flow rate there is heat exchange between the LXe and the GXe. However, high temperature differences are measured in the warm part of the heat exchanger ($\Delta T \sim 57$ K). We observed that the gas exits the heat exchanger with a different temperature, far from the room temperature, with respect to that it re-enters. This high temperature difference may imply an important heat conduction between the bottom and top parts of the heat exchanger. The amount of heat to be transferred between the inlet and outlet of the heat exchanger can be calculated from this temperature difference. The heat capacitance of Xenon is $C_p \sim 0.34$ $\mathrm{Jg^{-1}\ K^{-1}}$ at 1 bar and the latent heat is $L_p \sim 96.26$ $\mathrm{Jg^{-1}}$. The efficiency of heat exchanger as a function of recirculation rate is presented in slide 37. We estimate that the efficiency of the heat exchanger is 86 %. A drop pressure between the cryostat and the inlet of the heat exchanger of around 300 mbar has been estimated. At such pressure difference, we can assume that the Xenon returns to the cryostat in a liquid state. The result of pressure drop is shown in slide 38.

The cooling power has to compensate for all the thermal losses in the connecting tubes despite the insulation. Outside the vacuum enclosure, the tubes are surrounded by an insulation based on an AEROFLEX tube with k ~ 0.038 W/mK at 24 ºC. A considerable thermal loss of 2.5 W has been estimated in the tube that connects the second cryocooler outlet and the cryostat inlet. Also a thermal loss of 1.8 W for an insulation of 40 mm thickness (1.6 W for 60 mm insulation thickness) has been calculated in the tube that connects the cryostat outlet and the heat exchanger inlet. With such a thermal loss in the connecting tubes, part of the liquid xenon that re-enters into the cryostat may evaporate. The losses of the second cryocooler are estimated to be small since an almost constant temperature has been measured at the inlet and outlet of the cryocooler, and not additional heat power on the Stiring Cooler Twinbird is needed to maintain the temperature.