Calibration of Superheated Liquid Detector system for Dark Matter Search experiment

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Introduction

The superheated liquid detector (SLD) is known to detect neutrons since its development as Superheated drop detector (SDD) and bubble detector (BD). The advanced form of this detector is being used in rare event search such as for WIMPs (Weakly Interacting Massive Particles). The WIMPs are the most favoured candidates of dark matter (DM) and the dark matter is considered to be about 27% of the total mass energy budget of the Universe. The superheated liquid in the form of Bubble chamber is currently using in the PICO, SBC, MOSCAB dark matter direct search experiments. In the present work, superheated droplet detectors with $C_2H_2F_4$ as active liquid have been fabricated and characterized with the high frequency (~10kHz-MHZ) acoustic sensor by optimizing the sensor position and FPGA based data acquisition system. The $C_2H_2F_4$ is shown to have the potential of probing the low mass DM (less than 10 GeV/c^2) which is an interesting region to explore [1]. The calibrated detector and the DAQ system is being using at the DM search experiment initiated at the 555m deep underground, Jaduguda Underground Science Laboratory (JUSL), UCIL, Jaduguda.

Experiment

The superheated droplet detector has been fabricated by suspending the droplets of $C_2H_2F_4$ liquid (b.p. -26.3^{o}C) in a degassed gel matrix at high pressure and the droplets became superheated by lowering the pressure. The emulsion containing the droplets was taken in the glass container of 100ml for the calibration run and of 500ml for the WIMP run. The acoustic sensor was coupled at two different positions of the detector container to find out the optimum position of the sensor. One position was at the bottom of the container and the other was at the top surface of the container touching the emulsion as shown in Fig.1. The signals from the sensor were amplified and stored in the FPGA based data acquisition system [2].

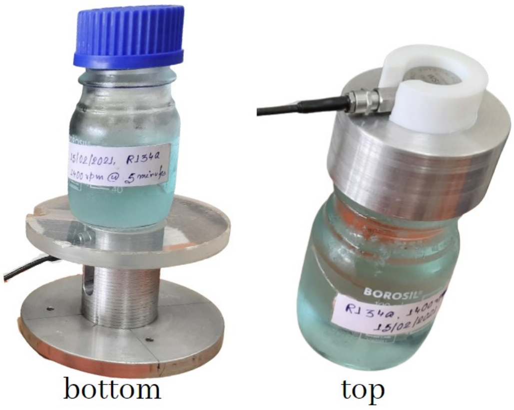

Fig .1. The two positions of the sensor

The fabricated detector was calibrated with ^{241}Am-Be (10mCi) and ^{137}Cs (5mCi) sources at the surface lab (SINP) at the room temperature and also at higher operating temperatures.

Results and Discussion

The observed variation of the two parameters, P_{var} and FF for two different positions of the sensors are shown in Fig.2 and in Fig.3 while the detector at room temperature is irradiated with Am-Be source. It is found that the parameter, P_{var} which is proportional to the energy released during the bubble formation process is higher in case of sensor at bottom position than the sensor at top position.

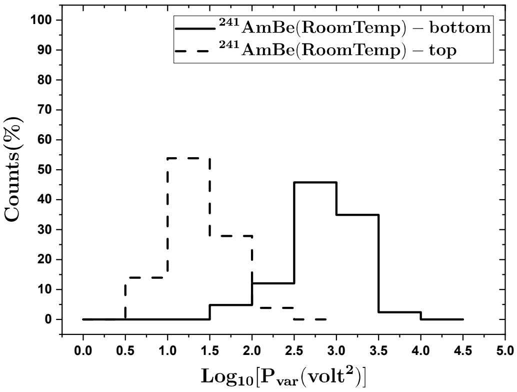

Fig.2. The P_{var} distribution for the different positions of the sensor

The fundamental frequency (FF) distribution is almost similar for both the cases only few additional higher frequencies are present for the sensor at top position.

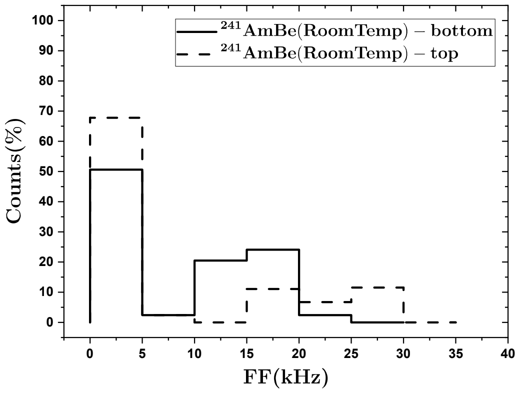

Fig.3. The FF distribution for the different positions of the sensor

Although the signals are louder for the sensor in bottom position, a significant amount of noise pick up was observed in this case than that of the sensor in top position. Therefore, the sensor in top position has been carried forward for the measurements at JUSL. The calibrated detectors with Am-Be and ^{137}Cs were run for the background at different operating temperatures starting from the room temperature. The results from two such measurements are shown in Fig.4 and in Fig.5 for the operating temperatures of 45°C and 50°C.

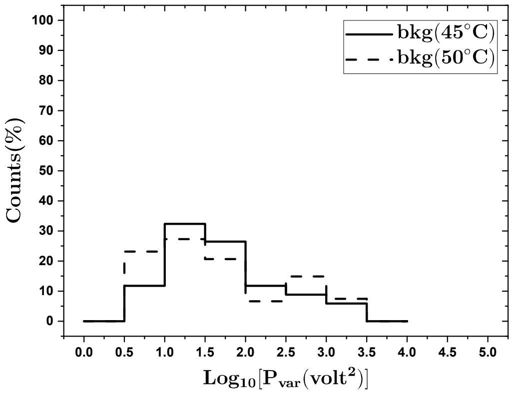

Fig.4. The P_{var} distribution for the background events

The distributions of the P_{var} and FF parameters for the background run were found to be in the observed parameter ranges of neutron and gamma-ray induced bubble nucleation events.

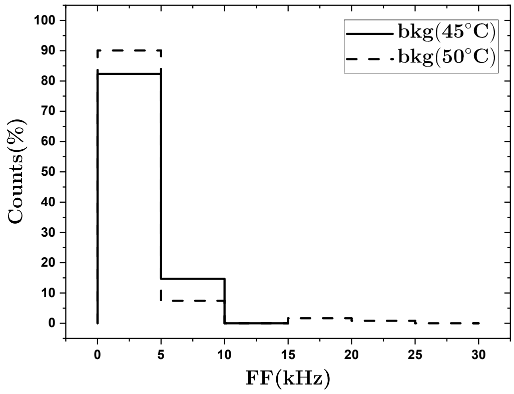

Fig.5. The FF distribution for the background events

The calibrated $C_2H_2F_4$ in a 500ml detector along with the sensor at top position and the FPGA based data acquisition system has been installed recently at JUSL for the preliminary WIMP run at the room temperature. The expected WIMP mass, sensitive to the room temperature, is below $10GeV/c^2$ and this detector is expected to be sensitive to the MeV/c^2 range of DM at higher operating temperatures.

References

[1] Phy. Rev. D **101**, 103005 (2020).

[2] Nucl. Instrum. Meths.A **1009**, 165457 (2021).