Spacial distribution of events in PICO detector for dark matter search.

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Introduction

Superheated liquid detectors are one of the non-cryogenic detectors currently being used to search for Weakly Interacting Massive Particles (WIMPs), one of the favoured candidates for cold dark matter. PICO 2L experiment uses a bubble chamber of superheated liquid, C_3F_8 (b. p. -36.8° C) (see Fig. 1). This is a new generation experiment uses the techniques of PICASSO [1] and COUPP [2] experiments. The operation began in October, 2013 and approximately 150 kg-days of exposure are used so far, mostly at 3 keV nuclear recoil threshold. Two cameras are used to observe the chamber to detect vapour bubbles from particle interactions. As well as piezo-electric transducers are used to acquire the acoustic signal generated during the nucleation of bubble.

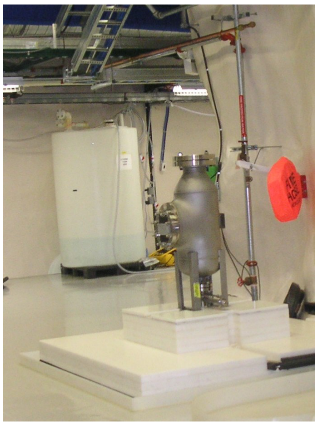

FIG. 1: Setup of PICO experiment.

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The basic principle of operation of bubble chamber [3] based on Seitz's "thermal spike" model [4]. If the energy deposited by a particle within a certain critical length of superheated liquid becomes greater than a certain threshold energy (E_c), the vapour bubble grows, eventually converting the superheated liquid into the vapour phase. If the radius of vapour bubble is less than critical radius (r_c), it collapses back to the liquid state. The threshold energy (E_c) needed to form a vapour bubble of critical radius (r_c) is,

$$E_c = -\frac{4\pi}{3} r_c^3 (p_v - p_0) + \frac{4\pi}{3} r_c^3 \rho_v h_{lv} + 4\pi r_c^2 \left[\sigma - T\frac{d\sigma}{dT}\right] + W_{irr}, \quad (1)$$

where σ(T) is the surface tension of liquid at the temperature T, p_v is the equilibrium vapour pressure of superheated liquid and p_0 is the ambient pressure, ρ_v is the density of the vapour and h_{lv} is the latent heat of evaporation. The first term in Eq. 1 explains the reversible mechanical energy during expansion to a bubble of radius r_c against the pressure of the liquid. The second term represents the energy needed to evaporate the liquid during formation of the bubble of critical radius. The third term describes the work needed initially to create the liquid-vapour interface of vapour embryo while the last term W_{irr}, is the irreversible works which has smaller contribution than other terms. In Fig. 2 E_c for liquid C_3F_8 is plotted as function of temperature at a pressure 30 psi.

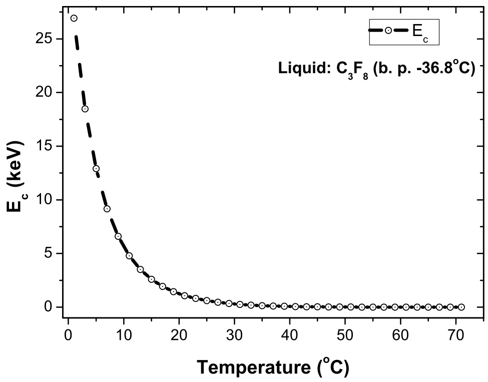

FIG. 2: E_c for liquid C_3F_8 is plotted as function of temperature at a pressure 30 psi.

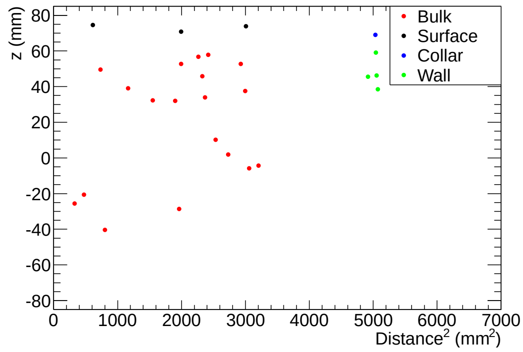

FIG. 3: The bubble nucleation events at different position of the PICO detector.

Present work

The experiment is running in two run modes: One is WIMP run (without presence of any source) and other is calibration run (in presence of poly-energetic AmBe, ^{252}Cf neutron sources). For a particular run, the bubble nucleation events can occur in the entire volume of detector. To study the particle induced nucleation events we focus on the region near the center of bubble chamber because random nucleation events can be caused by the presence of air bubbles or gas pockets trapped at the solid-liquid and liquid-liquid interfaces. Therefore, for a particular run, the bubble nucleation events are identified according to the different regions of the bubble chamber, namely, bulk, surface, collar and wall. The different regions of the detector is defined as

1. Bulk : -5.5 cm $<$ height $<$6.7 cm and radius $\leq$ 7.0 cm,
2. Surface : 7.0 cm $\leq$ height $\leq$7.5 cm and radius $<$ 7.0 cm,
3. Collar : height $\geq$ 6.7 cm and radius $\geq$ 7.0 cm, and
4. Wall : -5.5 cm $<$ height $<$ 6.7 cm and 7.0 cm$<$ radius $\leq$ 7.2 cm.

The z co-ordinate of the position of the occurrence of an event is plotted as a function of (distance)^2 of that event from the center of the detector in Fig. 3. The (distance)^2, is calculated as a sum of the square of x and y co-ordinates of the position of occurrence of an event.

Results and discussions

In Fig. 3 the bubble nucleation events from different regions of the detector are shown for a neutron calibration run operated at threshold energy (E_c) of 5.5 keV in presence of AmBe source kept at a distance 55 cm from the detector. It is observed that for this run most of the nucleation events are present in the bulk region of the PICO detector. The bulk region is the fiducial volume. The nucleation events occur at the surface, collar, wall will be rejected in case of study of particle induced nucleation events.

Acknowledgments

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