Simulation of the response of superheated droplet detector to high energy heavy ion

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Introduction

A superheated droplet detector (SDD) consists of a large number of drops of superheated liquid suspended in another immiscible liquid like gel or polymer matrix. During passage of a particle through a drop, if the energy deposited within a certain critical length is larger than a certain critical energy, the superheated liquid undergoes a phase transition to vapour phase, *i.e.* a nucleation event occurs. Acoustic pulse generated in this process constitutes the signal, which is recorded by acoustic sensor. SDD is traditionally used in detection of neutron and gamma rays, and is also being used in cold dark matter search [1, 2]. Some studies have also been done for the detection of charged particles [3].

In present work, the response of SDD with active liquid R-114 ($C_2Cl_2F_4$; b.p. 3.77° C) to high energy heavy ions, ^{12}C (180 MeV/u) and ^{28}Si (350 MeV/u), is studied using GEANT3.21 simulation toolkit [4] and compared with experimental data. The variation of nucleation parameter ($\boldsymbol{k}$), one of the important parameters [1] for SDD, is also studied for different ions.

Present work

The details of the experiment for which the simulation is carried out is described in the literature [3]. The SDD used in the experiment was about 80 mm long and 15 mm in diameter, containing 5000 drops of R-114 liquid suspended in a firm polymer matrix. The main component of the polymer was glycerine and there was a distribution in diameter of drop with peak at 20 μm. Before entering into the detector, the ions passed through 6 m of air, 1 mm Al holder and 1 mm of glass vial. In the experiment, the particle flux (I_B) was 1000 particles/sec/cm^2.

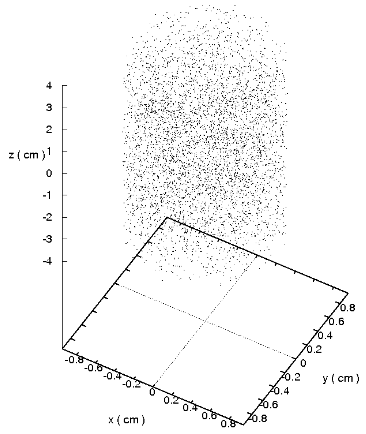

FIG. 1: Distribution of center of drops of R-114

There are two parts in the simulation : geometry and tracking. In the geometry part, the detector with height 80 mm and diameter 15 mm is created. It consists of a total of 5000 (N_0) uniformly and randomly distributed non-overlapping drops of R-114 in glycerine of density 1.24 gm/cc (shown in Fig. 1). The diameter of each drop is taken as 20 μm. The detector is placed within 1 mm thick hollow glass cylinder, which is enclosed with a 1 mm thick hollow Al cylinder.

The second part of the simulation is tracking of particles through the geometry described above. The energy deposition by the ions during the passage through 6 m of air

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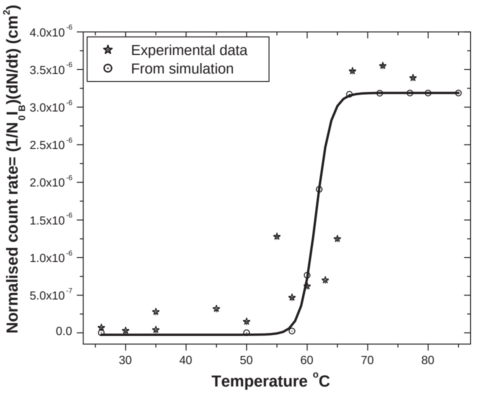

FIG. 2: Simulation result for ^{12}C (180 MeV/u) ion.

is obtained using the SRIM code [5]. As the simulation is done for an experiment of 100 sec time duration, a total of $\sim$ 2.6 million particles coming from negative x-direction fall randomly on the outer surface of Al cylinder perpendicular to long axis of detector. The distribution of the drop centers and incident points are generated outside the GEANT code, using the 'SRAND' random number generator.

The Linear Energy Transfer (dE/dx) within a drop is obtained from the GEANT code. A true bubble nucleation event is asuumed to occur if dE/dx is greater than the critical energy deposition ($\frac{W}{kr_c}$) required for nucleation. Thus, the condition of nucleation is [1],

$$\frac{W}{kr_c}(T,P) = \frac{dE}{dx}, \quad (1)$$

where, W is the critical energy (at temperature T and pressure P) required to form vapour bubble of critical radius r_c, and $\boldsymbol{k}$ is nucleation parameter. Extra events due to more than one nucleation for same drop are rejected. The normalised count, $\frac{1}{N_0 . I_B}(\frac{dN}{dt})$ in unit of cm^2, is calculated and plotted as a function of operating temperature.

Results

The result of the simulation for ^{12}C (180 MeV/u) is shown in Fig. 2. It shows that response obtained from simulation matches with experimental result for $\boldsymbol{k} = 0.23$. Simulation result is fitted to Boltzmann function (solid line in Fig. 2)

$$y(x) = \frac{(A_1 - A_2)}{(1 + e^{\frac{(x-x_o)}{dx}})} + A_2$$

where, A_1 = base line, A_2 = plateau value.

Simulation has also been carried out for a heavier ion, ^{28}Si (350 MeV/u), with the similar detector geometry and experimental condition. The threshold temperature obtained from simulation, for $\boldsymbol{k} = 0.23$ is found to be at lower temperature than that from experiment. Experimentally the response above 5×10^{-7} cm^2 was taken as true response for the ions with a specific energy. Using this condition, $\boldsymbol{k}$ obtained for ^{28}Si (350 MeV/u) is 0.07.

Discussions

In the present work, geometry of the superheated droplet detector with random distribution of drops in the detector medium is constructed. It is seen from the result that $\boldsymbol{k}$ of ^{12}C (180 MeV/u) is higher than that for ^{28}Si (350 MeV/u). As LET for the latter case (80.28 MeV/mm) is greater than that of former one (22.51 MeV/mm), fraction of energy required for nucleation *i.e.* thermodynamic efficiency [6] is less for ^{28}Si than ^{12}C. Simulation provides an important observation that the nucleation parameter ($\boldsymbol{k}$) depends on mass number of ions.

References

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