

# **Discrimination of neutrons and gamma-rays induced events in Superheated Emulsion Detector**

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# Overview

- Introduction
- Superheated Emulsion Detector (SED)
- SED & Dark Matter (DM) Detection
- Motivation
- Present Experiment
- Result and Discussion
- Conclusion

# What is Superheated State & SED ?

- A liquid is said to be in superheated state if maintains its liquid state above to its boiling point.
- This state is a metastable state and remains stable with respect to small perturbation.
- Large disturbances make it unstable and moves it to more stable (vapour) state.
- SED contains superheated liquid drops which are uniformly distributed inside a gel matrix.
- It was developed as neutron dosimeter but now it is used in many application, e.g. Heavy ion gamma ray and dark matter detection.

# How to Reach Superheated State?

- c is a ordinary vapour state.
- The liquid will be in superheated state if it maintains liquid state at c.
- We can reach c by slowly increasing temperature from liquid state b.
- Or by reducing pressure starting from liquid state d

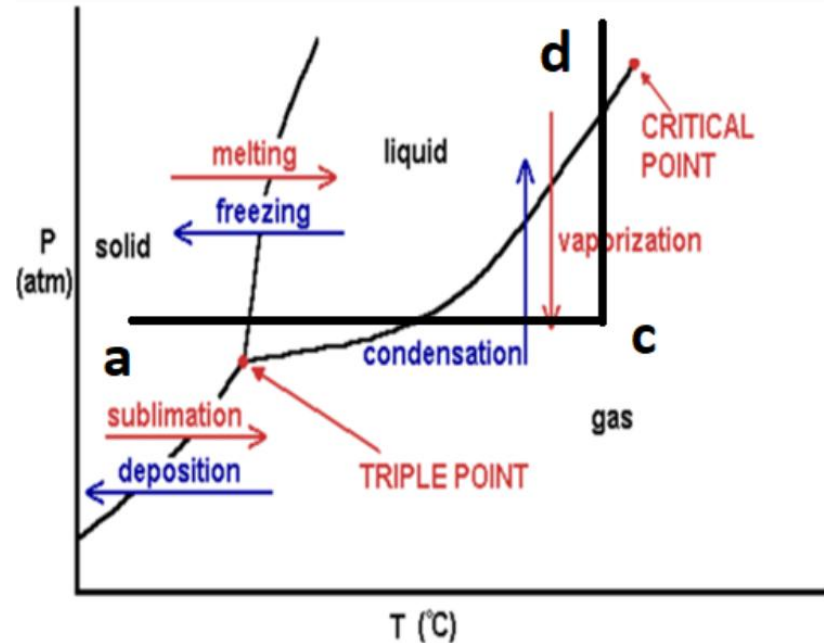
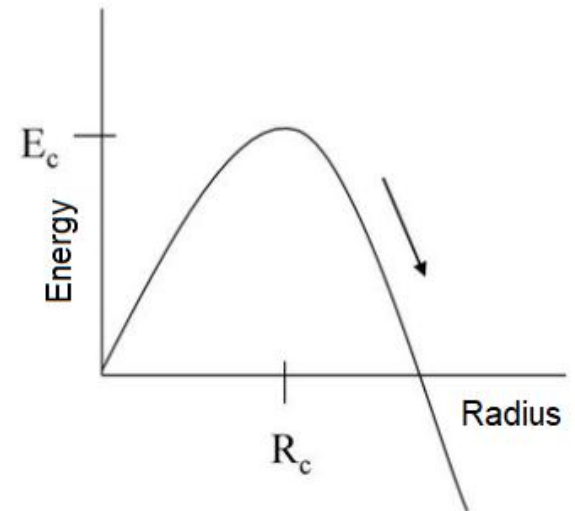
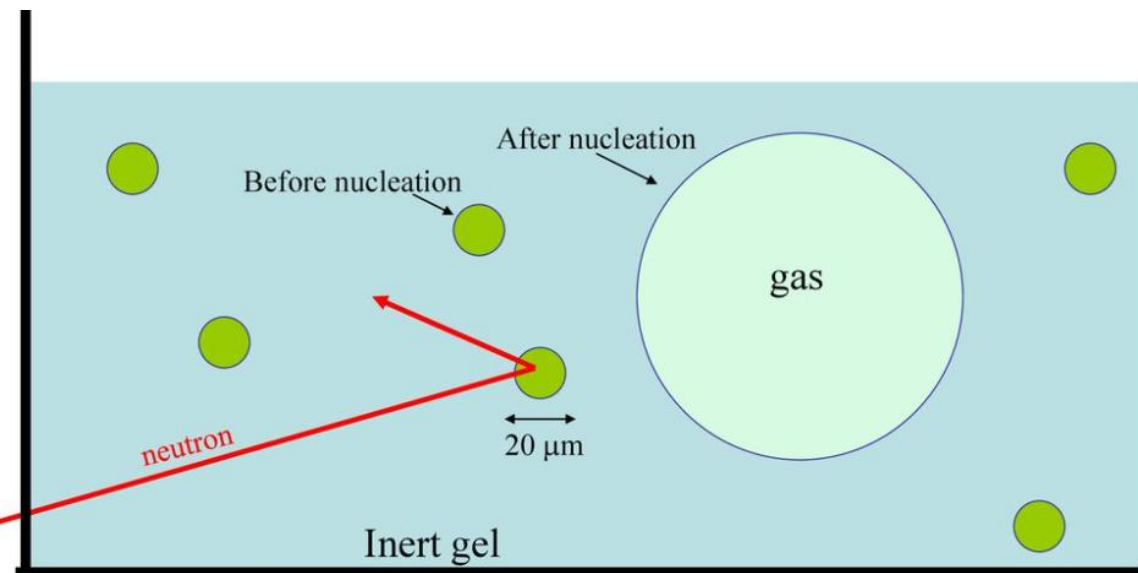


Fig. 1. Typical phase diagram.

# Bubble Nucleation in Superheated Liquid

- An energetic particle deposits energy when it pass through the superheated liquid drops.
- Deposited energy is equal to the critical energy and radius is equal to critical value.
- The bubbles become thermodynamically unstable and grows very fast and vaporised.
- Bubbles smaller bubbles will shrinks and remain in liquid state.



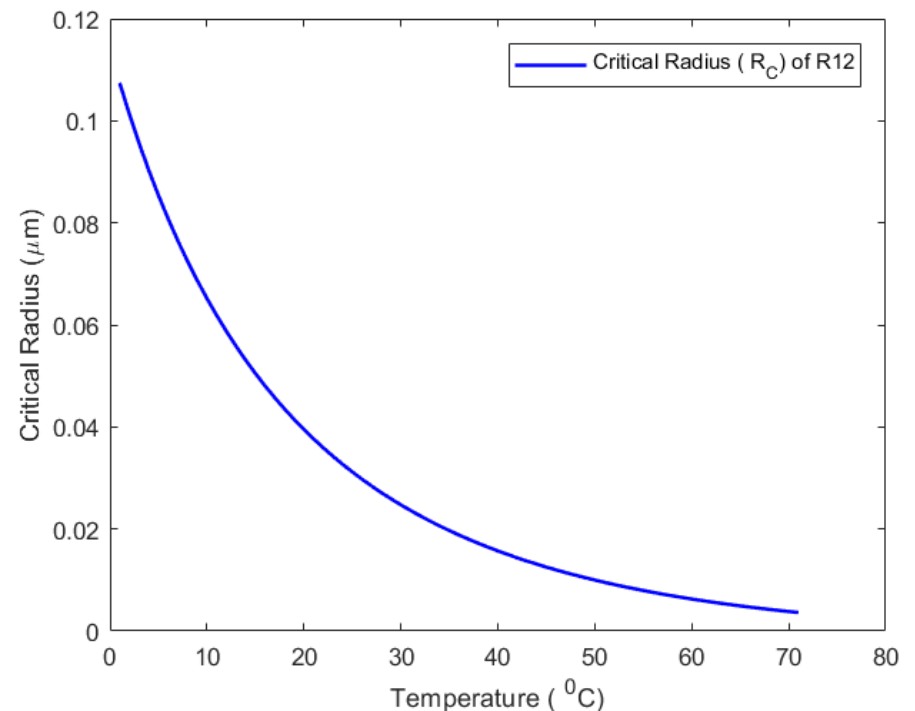
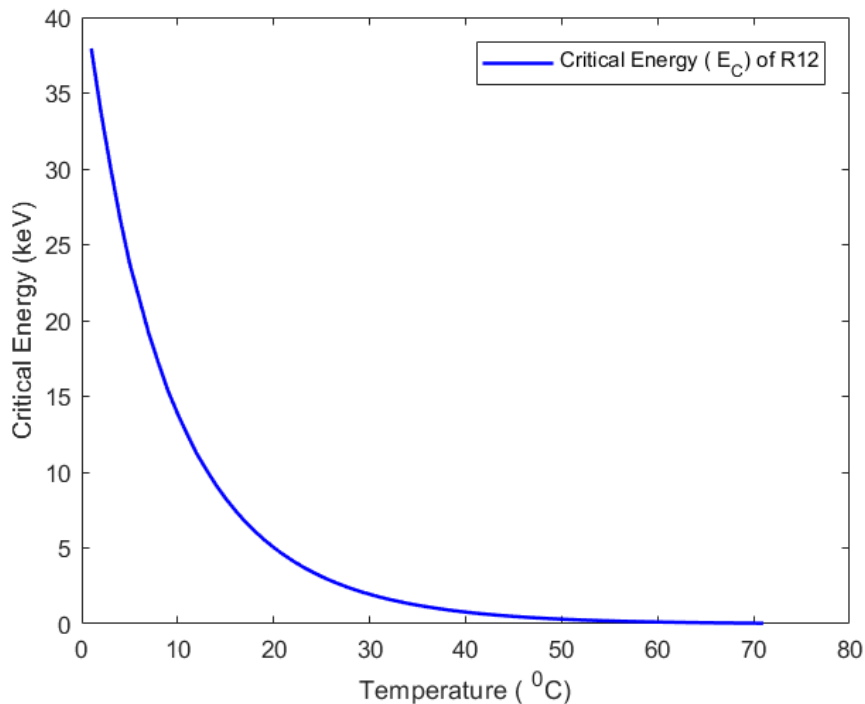
The expression of Critical Energy ( $E_c$ ) and Radius ( $R_c$ ) and its variation with temperature is shown below

$$E_c = 4\pi R_c^2 \left( \sigma - T \frac{\partial \sigma}{\partial T} \right) + \frac{4\pi}{3} R_c^3 \rho_v (h_v - h_l) - \frac{4\pi}{3} R_c^3 (P_v - P_l)$$

$$R_c = 2\sigma(T)/(P_v - P_l)$$

where

- $\sigma$  (T) is the liquid-vapour interfacial tension at temperature T.
- $P_v$  and  $P_l$  are the pressure of the vapour bubble and liquid.
- $\rho_v$  is the vapour density.
- $h_v$  and  $h_l$  are the specific enthalpies of the vapour bubble and liquid respectively



# Few halocarbons used in SED

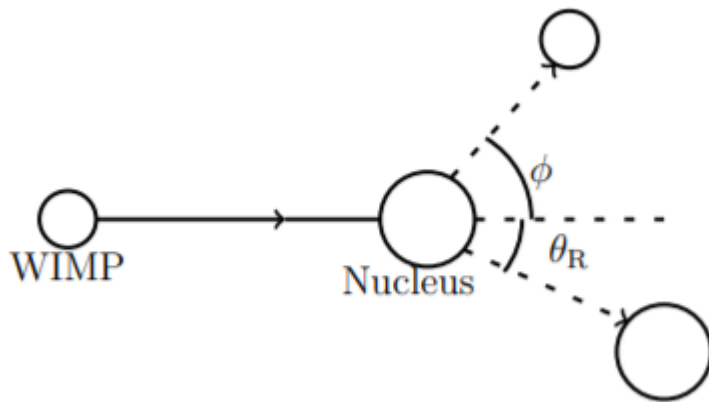
Chemical name	Empirical formula	Boiling point (°C)	Critical point (°C)
1,2-Dichlorotetrafluoroethane	$C_2Cl_2F_4$	3.65	145.7
Octafluorocyclobutane	$C_4F_8$	-6.99	115.22
Dichlorodifluoromethane	$CCl_2F_2$	-29.76	111.8
1,1,2,2-tetrafluoroethane	$C_2H_2F_4$	-26.07	101.2
Hexafluoropropylene	$C_3F_6$	-29.40	85.0
Chloropentafluoroethane	$C_2ClF_5$	-39.17	79.9
Octafluoropropane	$C_3F_8$	-36.65	71.95

At atmospheric pressure – 101 kPa.

Liqui  $CCl_2F_2$  is used in our experiment.

# Direct Detection of DM (WIMPs) by SED

- Detect nuclear recoil produced by scattering of WIMPs.
- Only consider elastic WIMPs-nuclear scattering.
- WIMPs of mass  $M_\chi$  and energy  $E_\chi$  collide with a rest nucleus of mass  $M_A$ .
- Recoil nucleus with energy  $E_R$  deposits energy and nucleate bubble inside SED.



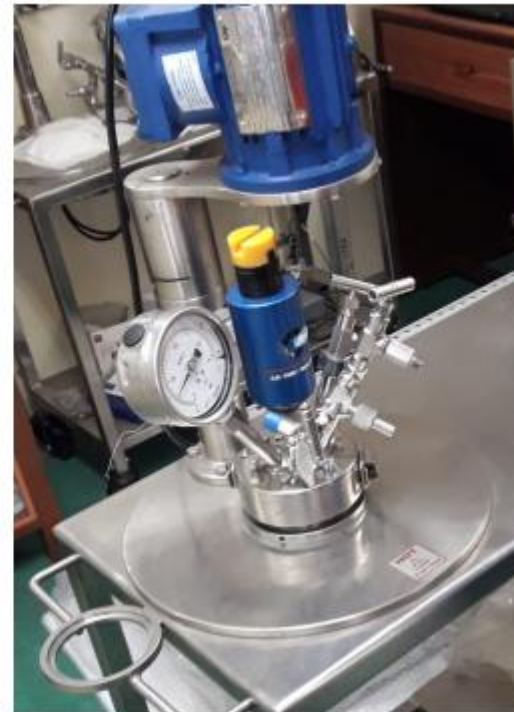
$$E_R = E_\chi \frac{4M_\chi M_A}{(M_\chi + M_A)^2} \cos^2 \theta_R$$

# Motivation

- PICO & SIMPLE are working on the detection of DM (WIMPs) using Superheated liquid.
- They works for the WIMPs of mass greater than  $20 \text{ GeV}/c^2$ , we works below  $20 \text{ GeV}/c^2$ .
- At low low mass region SED become sensitive to many backgrounds especially gamma ray
- There was not good discrimination of backgrounds in precious experiments.
- Neutron and WIMPs induced nucleation are similar.
- We are trying to develop a standard discrimination technique.

# Detector Fabrication

- Aquasonic gel and glycerol were mixed.
- Placed in magnetic stirrer for about 30 minutes.
- Degassed using a vacuum pump.
- Gel matrix was mixed with active liquid ( $\text{CCl}_2\text{F}_2$  (R12)).
- Rotated by stirrer with 1400 rpm for 5 minutes.



# Experimental Set-up

- Signals are collected and stored in excel file by a high frequency acoustic sensor with the help of LabVIEW program.
- $^{137}\text{Cs}$  of activity 5 mCi is used as a gamma rays source.
- $^{241}\text{AmBe}$  of activity 10 mCi is used as a neutron source.

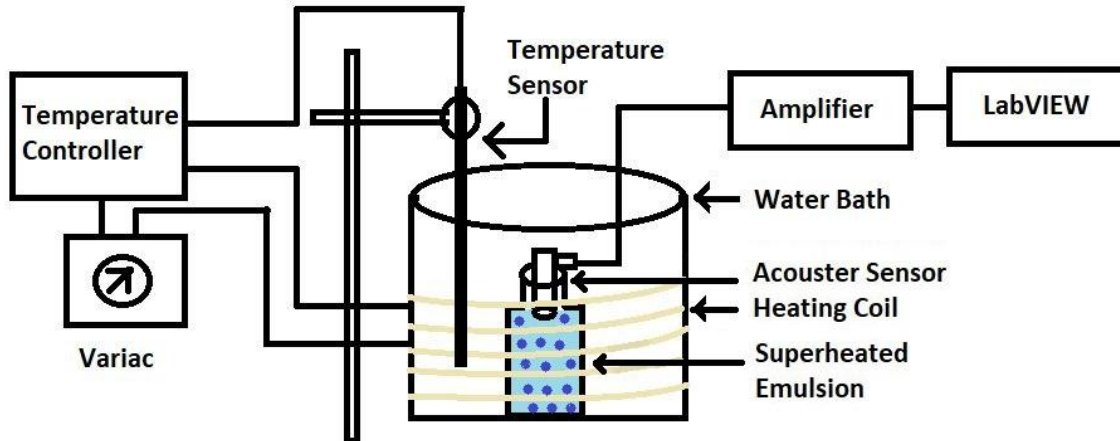
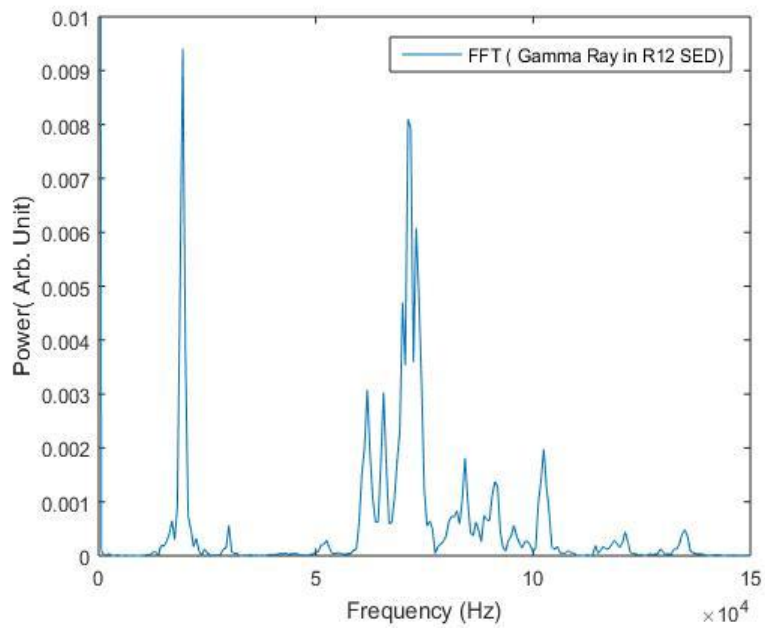
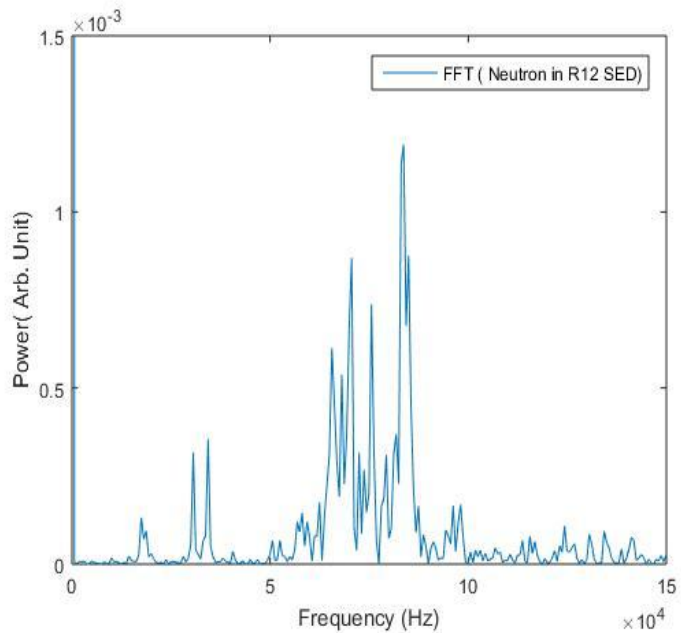
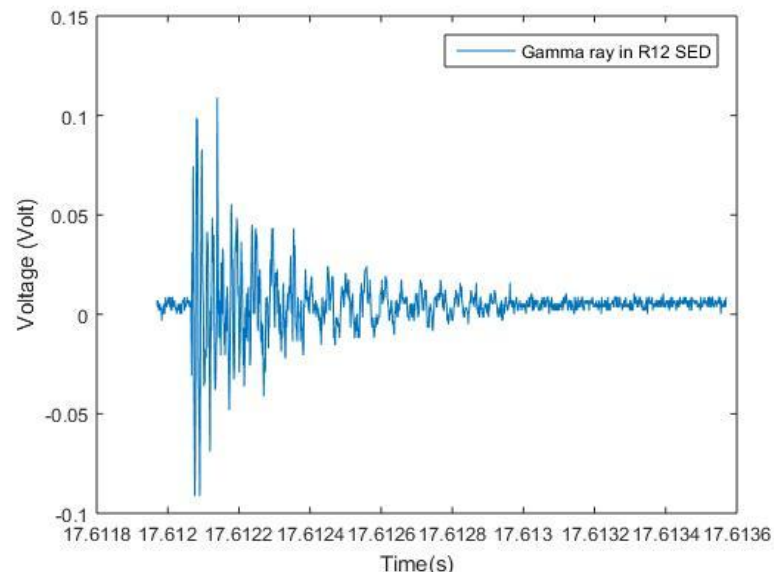
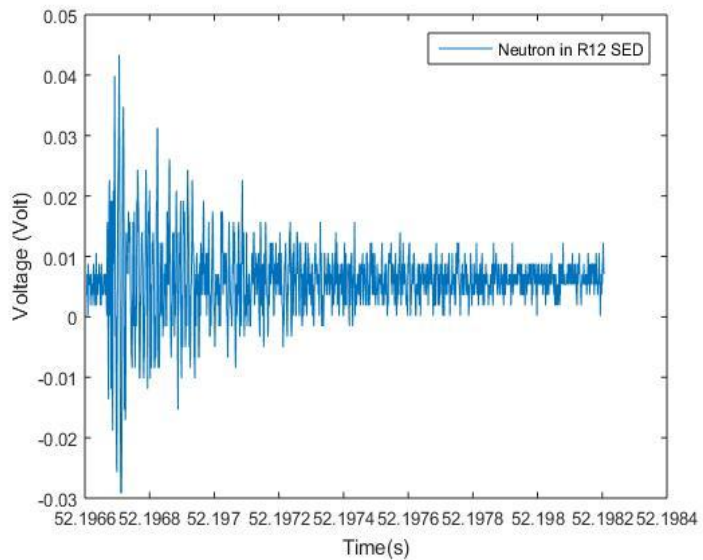


Fig. - A) Experimental set-up.

Fig.- B) Fabricated detector.

# Typical signals and its Fast Fourier Transformation (FFT)



# Result and Discussion

- $\sum V_i$  is considered as Pvar.
- Pvar is proportional to energy released during nucleation.
- Pvar of neutron and gamma rays induced signals mostly overlap with each other

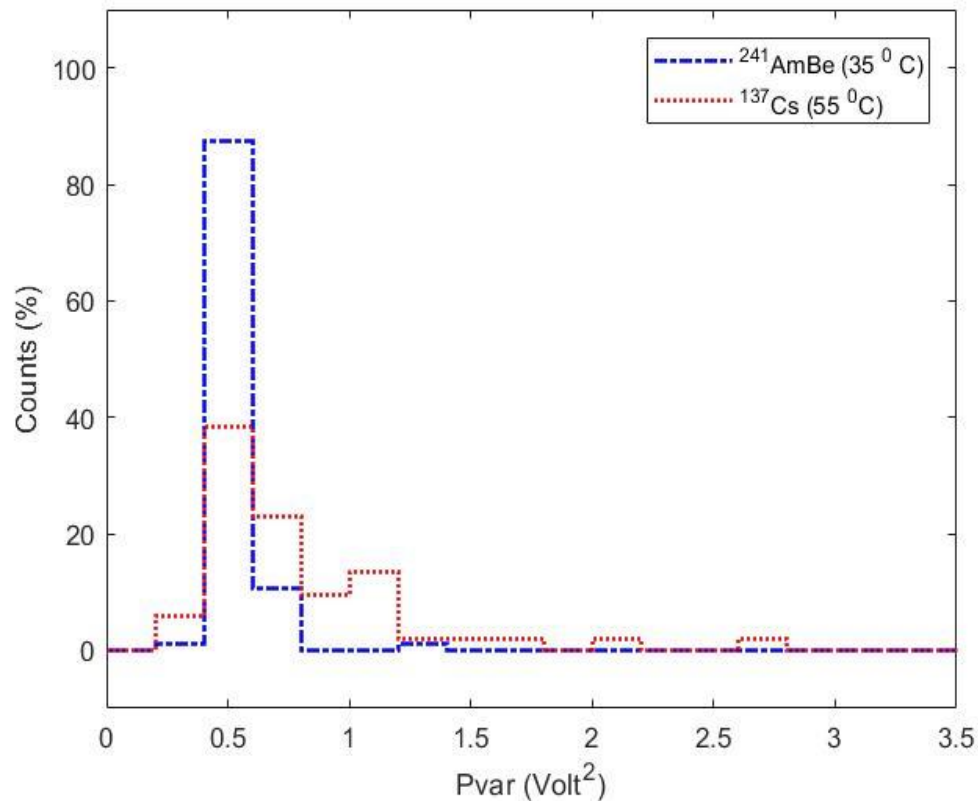


Fig. - The distribution of Pvar of the neutrons and gamma-rays induced events.

# Result and Discussion

- Frequency with maximum power in its FFT plot is considered as Fundamental Frequency (FF).
- FF of gamma rays induced signals lies around 20 kHz.
- FF of neutron induced signals lies within 70 to 90 kHz.

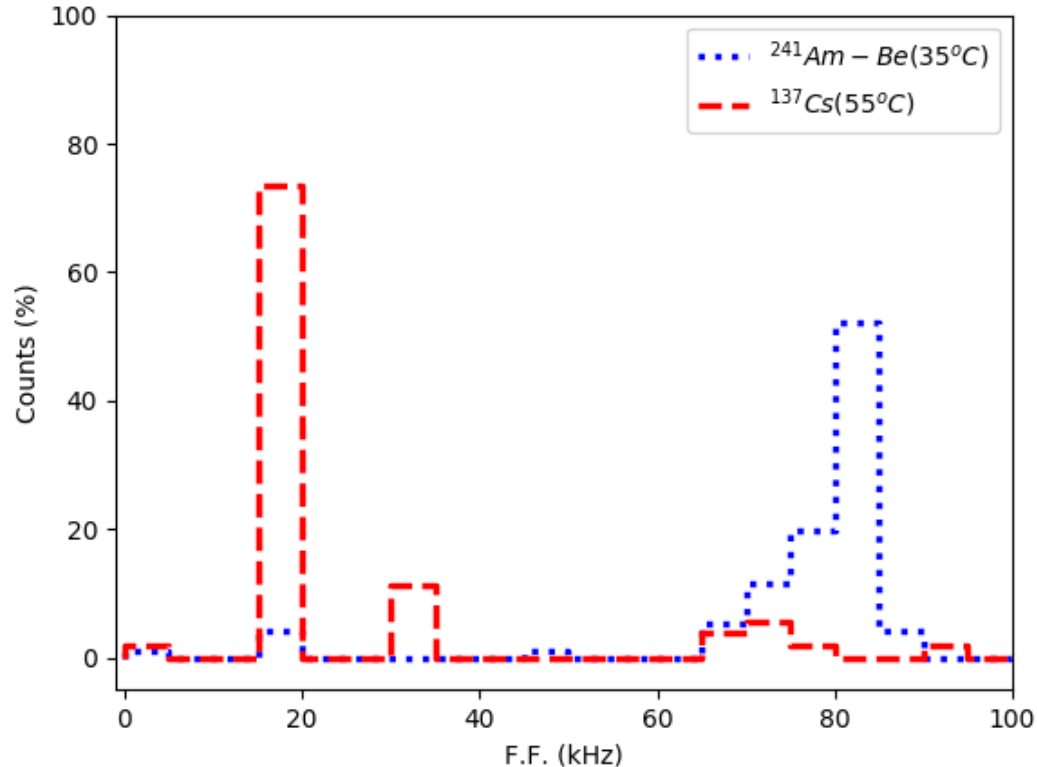


Fig. - The distribution of F.F. of the neutrons and gamma-rays induced events.

# Conclusions

- Range of electrons of energy 662 keV in R134a, produced due to Gamma ray is about 3.5 mm.[1]
- Range of recoil nuclei neutron is of the order of nm.
- Released energy during nucleation is same for both neutron and gamma rays as Pvar of them merged with each other.
- Due to localised energy deposition of recoil nuclei they generate high frequency signal.
- FF variable discriminates about 83.47 % of the neutrons induced events from that of the gamma rays.
- Useful in WIMPs DM search experiment and also in the neutron detection in a background of gamma-rays.

**THANK YOU**