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NUCLEAR PHYSICS B
PROCEEDINGS
SUPPLEMENTS

The cavitation chamber

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1. THE PRINCIPLE

The spinner [1,2,3] is a bubble chamber operated at negative pressure, therefore named cavitation chamber. As shown in fig. 1 it is a glass container with returning arms and filled with the desired target liquid. By rotating, an underpressure develops by centrifugal forces. The radial underpressure profile is independent of the shape of the glass container and is

$$\Delta p = \frac{\rho}{2}\,\omega^2\left[R^2 - r^2\right]$$

where ρ = liquid density, ω = rotation frequency and R = distance from the rotation axes to the free liquid surface in the arms. By local energy deposition, e.g. by nuclear recoils within a subcritical volume, a supercritical cavity, which grows to visible size can be created. After photographing the rotation is halted, the pushed up liquid returns by gravity and the cycle can be restarted.

2. SENSITIVITY OF THE CHAMBER

The cavitation chamber has for a given underpressure an energy threshold sensitivity with sharp onset.

Fig. 2 represents a threshold sensitivity curve for the liquid C_5F_{12} at 25^0C. The minimum energy loss inside a critical cavity is plotted versus the required underpressure.

For fission fragments a tiny amount of spontaneously fissioning ^{252}Pu was dissolved in the liquid. The Bragg maximum of F-recoils corresponds to the onset of the cosmic ray background curve which is mainly due to neutrons. F-recoils with a maximum of 2 MeV kinetic energy were produced by a Pu-Be neutron source. Recoils from α-decay could be observed from the initial ^{222}Rn content in the liquid which disappeared according to its lifetime. The sensitivity to α-particles relative to the Bragg maximum was obtained from the residual α-activity of the glass container, the α-particles penetrating into the liquid. The sensitivity to minimum ionizing particles was determined by exposing a rotating capillary tube to a 30 MeV electron beam.

The calibration points can be approximated by the relation, energy loss (ΔE) versus underpressure (Δp) as

$$\Delta E \simeq \frac{450}{\left[\Delta p(atm)\right]^2}\; KeV$$

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3. VISUALIZING OF THE EVENTS

The cavitation chamber is continuously sensitive and can be photographed immediately at the occurance of an event, provided there is an event trigger. Since each cavitation process produces a sharp clicking noise it can be picked up by a microphone, whose signal in turn can trigger a μsec-flash for photographing with a monoshot video camera. The delay between cavity creation and flash signal is approximately 200 μsec, in which time the cavity has grown to several mm in radius. Two views at a stereo angle of 90(0) are obtained by using a mirror.

4. OPERATING CONDITIONS

The cavitation chamber operates most conveniently at room temperature. The desired sensitivity to a minimum of recoil energy can be adjusted by the rotation frequency. There is a large choice for the target liquid from light to heavy elements. The most important parameter for high sensitivity is the surface tension of the liquid, which should be as small as possible. So far only "normal" liquids with boiling points above room temperature have been tried, e.g. C_5F_{12}, $C_2Cl_3F_3$, CBr_2F_2, CH_3I. Temperature is controlled by cooling and heating to an accuracy of $\pm$ 0.5^{0}C.

The highest sensitivity with a normal liquid has been reached so far with 640 gr. of C_5F_{12} at an underpressure of 9 atm., corresponding to a recoil energy threshold of approximately 5 KeV. An event with a cavity radius of 3 mm is shown in fig. 3.

The chamber is periodically calibrated on its threshold sensitivity by a Pu-Be neutron source.

5. THE CRITICAL CAVITY SIZE

A parameter of decisive importance for discriminating against radioactive background is the critical size r_c of the cavity.

$$r_c = \frac{2\sigma}{\Delta p}$$

where σ = surface tension and Δp = underpressure.

Table 1 gives for different sensitivity thresholds the necessary underpressure and the critical radius.

Table 1

Δp *atm*	r_c Å	*energy deposition by*
0.1	20000	*fission fragments*
1	2000	$2\ MeV\ F-recoils$
4	500	$\alpha - decay\ recoils$
9	220	$5\ KeV\ F-recoils$

For 2r$_c$ = 440 Åat 5 KeV F-recoil sensitivity the average energy loss for minimum ionizing particles is only $\sim$ 10 eV, but δ-rays in rare occasions can deposit as much as several 100 eV.

This means that the cavitation chamber can discriminate sharply between nuclear recoils and β- and γ-radioactivity, a background of major concern for low level counting with scintillators, semiconductor and cryogenic detectors.

The uniform liquid of the cavitation chamber behaves as if it would have a superfine granularity. There is in fact an agglomeration of approximately 10^{19} independent microcalorimeters per kg. of liquid. The range of nuclear recoils with energy below 30 KeV is smaller than the cavity diameter.

There remains background induced by cosmic ray neutrons, by α-particles and by α-recoils. Neutron shielding and avoiding contaminations of α-active nuclei is necessary. Radon induced background dies out since the cavitation chamber is sealed off.

6. CONCLUSIONS

The cavitation chamber is a promising apparatus to search for cold dark matter, specially when operated deep underground where neutrons from μ-induced nuclear spallation are very rare.

REFERENCES

1. B. Hahn, Il Nuovo Cimento 22, (1961), 650.

2. B. Hahn and A. Spadavecchia, Il Nuovo Cimento 54B, (1968), 101.

3. A. Spadavecchia and B. Hahn, Helvetica Physica Acta 40, (1967), 1063.

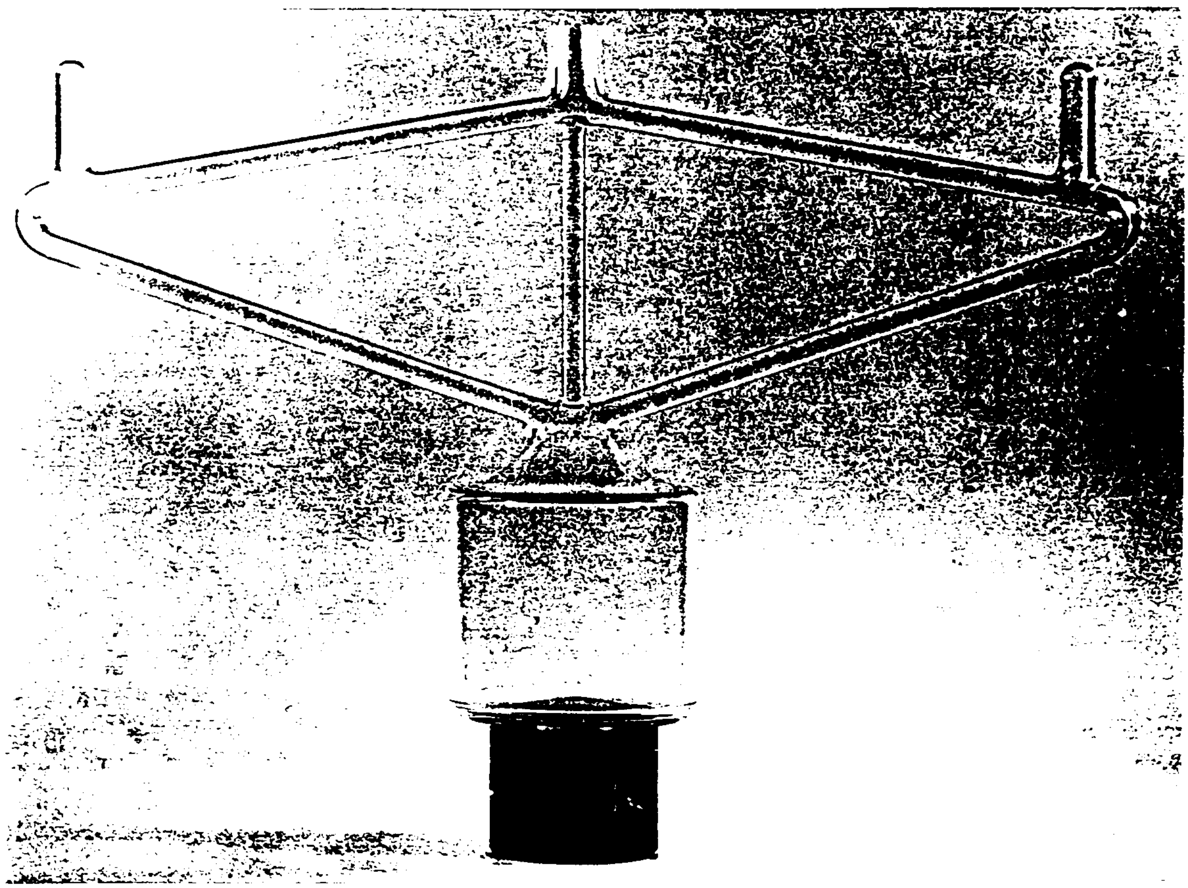

Figure 1. A 0.4 liter cavitation chamber.

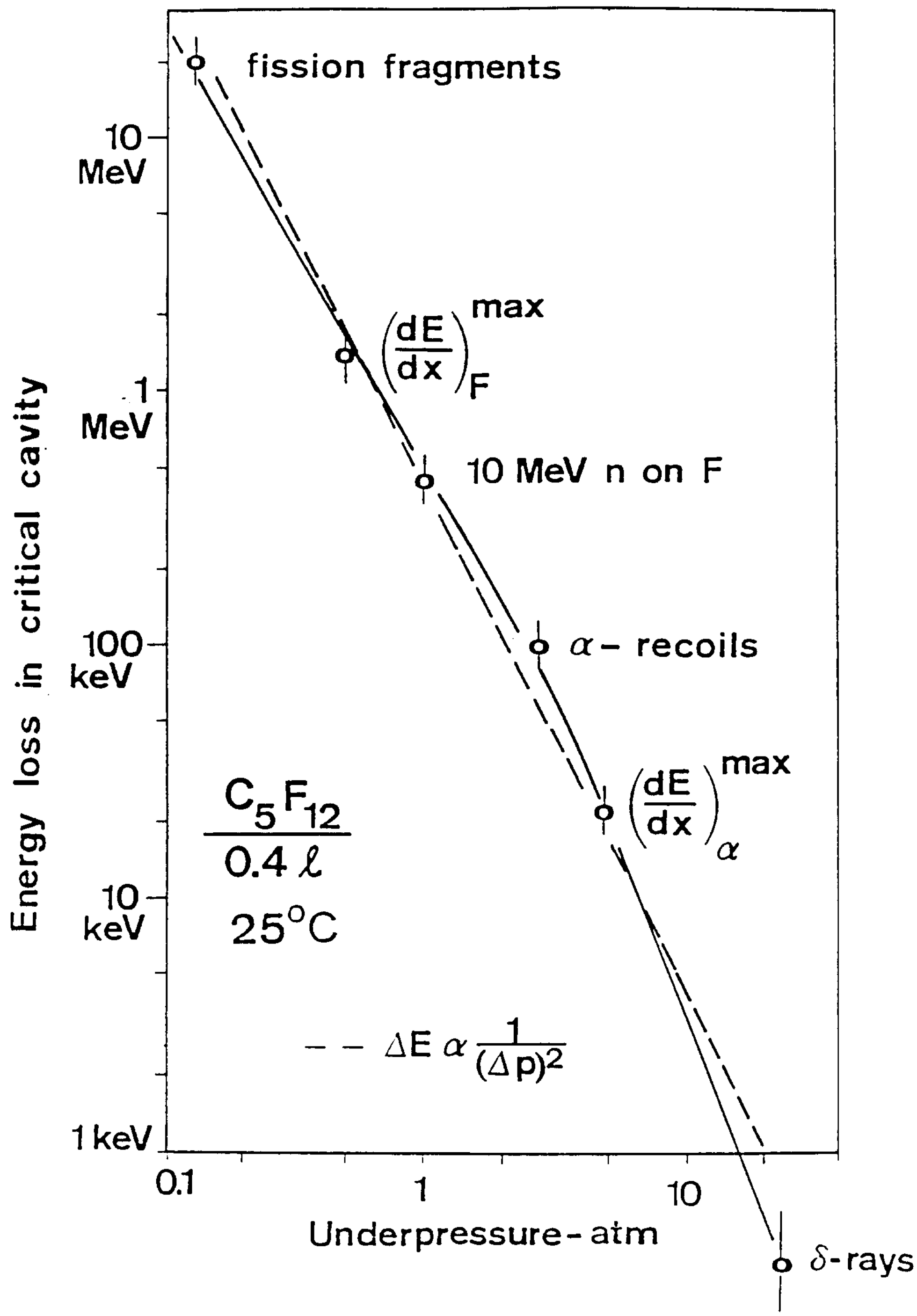

Figure 2. Sensitivity threshold curve for C_5F_{12}. Energy deposition inside a critical cavity versus the required underpressure.

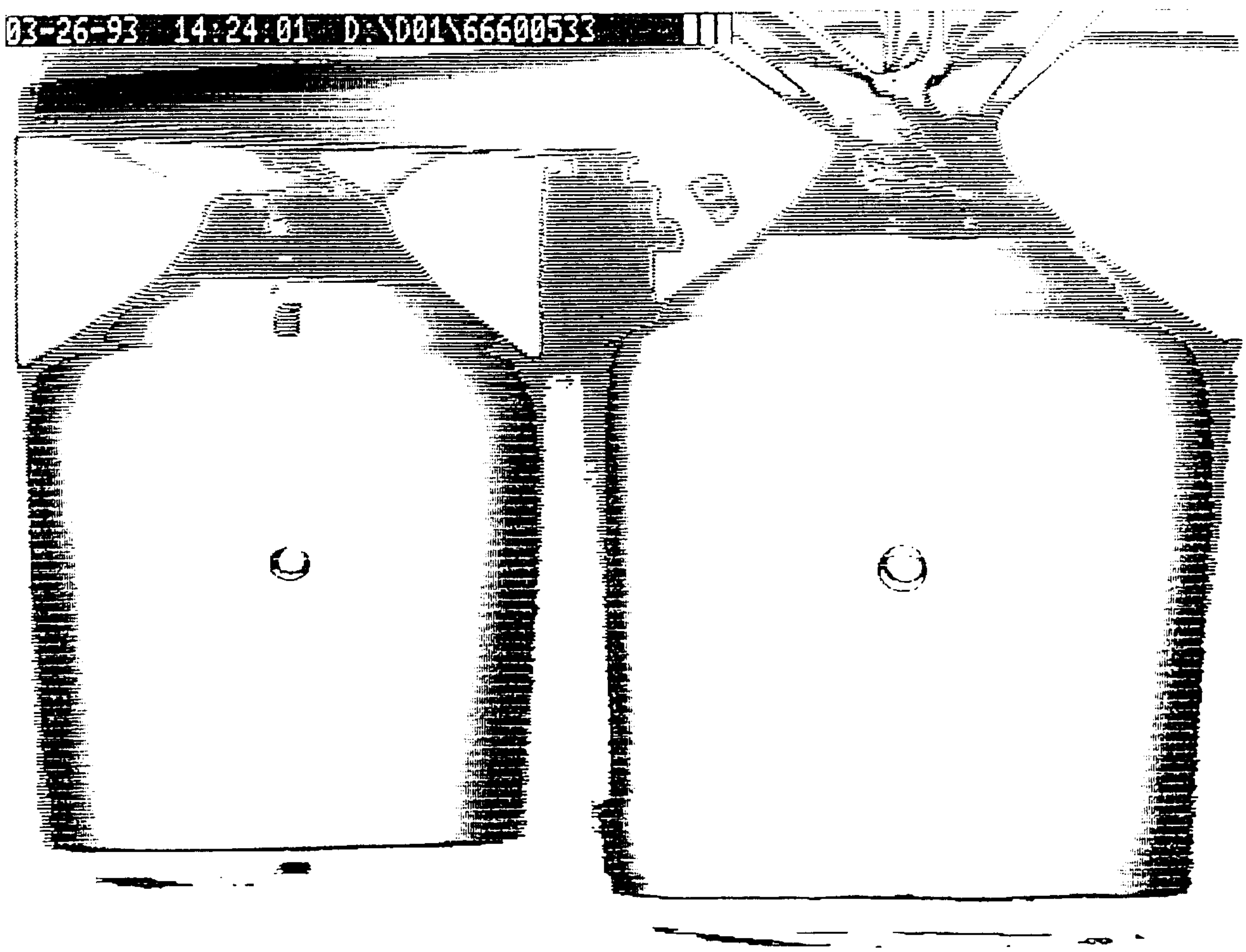

Figure 3. Cavity seen in 2 stereo views produced at an underpressure of 9 atm. in 640 gr. of C_5F_{12}, corresponding to a threshold sensitivity of 5 KeV F-recoil. The cavity radius is 3 mm.