Comments on the possible observation of d-d fusion in sonoluminescence

(Reference-31 in Taleyarkhan et al. [2002][1])

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Abstract

We have repeated the experiment of Taleyarkhan et al.[1] in an attempt to detect the emission of neutrons from d-d fusion during bubble collapse in deuterated acetone. Using the same apparatus, a more sophisticated data acquisition system, and a larger scintillator detector, we find no evidence for 2.5-MeV neutron emission correlated with sonoluminescence from the collapsing bubbles. Any neutron emission that might occur is many orders of magnitude smaller than that necessary to explain the tritium production reported in Ref. 1 as being due to d-d fusion. We demonstrate that proper allowance for random coincidence rates in such experiments requires the simultaneous measurement of the complex time-varying singles rates.

Introduction

In a recent paper Taleyarkhan et al.[1] reported the possible observation of d-d fusion events occurring in collapsing bubbles formed by cavitation in deuterated acetone. The bubbles were seeded by pulses of neutrons from a 14-MeV pulsed-neutron generator (PNG). This note summarizes the results of an attempt to reproduce some of these experimental results with the help of some of the original authors. We repeated their original experiment using all of the same equipment, with the exception of the neutron detector, for which we substituted a much larger one based on NE213 and thus capable of n-γ discrimination, and a significantly more sophisticated data acquisition system.

The coincidences we observed were totally explained by random events, any excess neutrons in the singles data, if significant, did not correlate with sonoluminescence signals, and the reported level of tritium production should have been accompanied by a substantial neutron emission which we did not observe.

Scope of the repeat experiment

Our experiment focused on the detection of “penetrating radiation” from the sonoluminescent bubbles. No attempt was made to verify the reported tritium production. We note that these levels of tritium – if due to d-d fusion – would have been accompanied by easily detectable levels (10^6/s) of neutron emission. This is the same strength as the 14-MeV neutron generator used.

The published experiment used fast sampling oscilloscopes to count coincidences between pulses from a phototube designed to detect light (SL) emission from sonoluminescent bubbles, and a plastic scintillator/phototube combination for detecting neutrons.

Setup for the repeat experiment

The physical setup for our experiment, shown in Fig. 1, was essentially identical to the original experiments, except that the large n-γ detector was used and located as shown. However, the data acquisition system was very different, involving conventional particle-counting systems rather than sampling scopes.

The discriminator threshold for the sonoluminescence was set up as specified by the authors of Ref. 1, i.e., at about the same triggering level used on their sampling scope. There was no defined threshold for their neutron detector as the raw signals were merely displayed on an oscilloscope. Our detector threshold, set by a fast discriminator, was calibrated by comparison with gammas from a Pu-Be source available during the experiment. The relative response to a Pu-Be source and a Co^{60} source was checked prior to the experiment and agreed with the scintillator output curves published by Harvey et al.[2] Using these curves, we estimate our threshold to have been at an equivalent proton energy of 1.4 MeV, thus below the threshold for 2.5-MeV neutron detection.

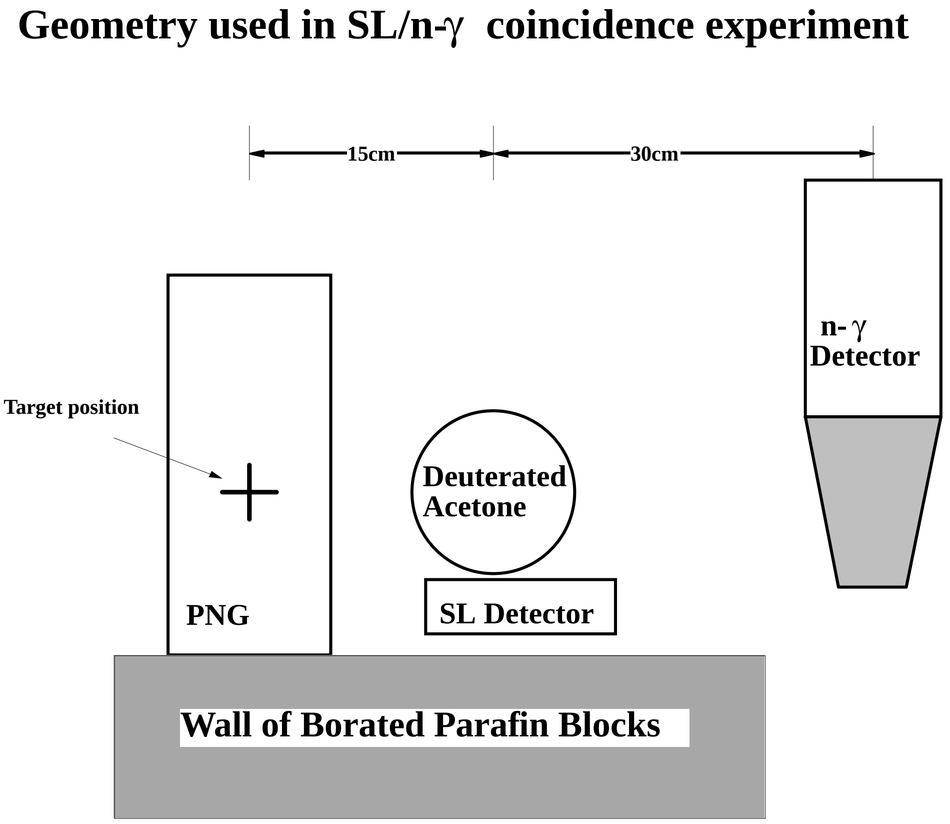

Fig. 1. A rough outline of the detector and shielding arrangement used in the experiment.

The cavitation apparatus was operated by the original authors of Ref. 1. The trigger pulse for the PNG was phased to the acoustic-wave-driving signal with the frequency divided by a factor of 100 to produce 193 firings/second, i.e., a period of about 5.2 ms.

We measured both the SL/n-γ coincidences and the time dependence of the singles rates in both detectors during the 5-ms period between successive neutron pulses from the PNG. The time of any event (singles or coincidence) was measured relative to the start of each PNG firing using a 1-MHz clock. The time resolution was 1 μs. A coincidence window of ± 10 μs was set to record SL/n-γ events, and a TAC was used to measure the time separation of the SL and n-γ signals within this 20-μs window with a resolution of about 10 ns.

The pulse width from the PNG was measured as ~12 μs. The data rates seen by the electronics during the PNG pulse were extremely high (> 10^6/sec) and resulted in unacceptable counting losses in the period immediately after the start of the neutron pulse. To avoid this, a blocking signal was used to veto all counts from the n-γ detector for 20 μsec after the onset of the PNG trigger pulse. In addition, the event rate from n-γ singles (i.e., with no SL coincidence) was reduced by looking only at every eighth pulse, thereby reducing the deadtime for the data acquisition systems to <5% in the worst case. The division by 8 was not applied to the pulses used to identify the coincidences. The n-γ discrimination output was recorded so that a suitable cut could be made after the fact. All the results here refer to the total counts (no n-γ discrimination) in order to correspond to the coincidence setup in the published data.

Experimental results

In a 65-minute run with cavitation, 51 coincidences between pulses from the SL detector and the n-γ detector were observed, a number consistent with the expected random rates. Figures 2 and 3 show the time distribution of singles and coincidences relative to the start of the PNG trigger pulse. Note that the coincidence event timing is defined by the neutron signal. The SL events occur in four distinct regions

A. During the PNG neutron pulse (0-19 μs).

B. In a 30-μsec burst immediately after the PNG pulse (20-61 μs).

C. In a zone of high n-γ background between 62 and 539 μs.

D. In a series of short (5-μsec fwhm) bursts spaced every 52 μsec (the acoustic wave period).

The observed singles count rates in the n-γ detector within these four regions are quite different, as can be seen by the time spectra shown in Figs. 2 and 3. These rates must be measured to calculate the expected random coincidence rates within the 20-μsec-coincidence window. Table 1 shows the results of such calculations. Note that the n-γ events in region A were almost entirely eliminated by the 20-μs blocking pulse. In the absence of this blocking pulse essentially 100% of the SL signals in region A would be in coincidence with an n-γ count, increasing the predicted random coincidence events by about 409. These coincidences would also exhibit a peaked time structure defined by the shape of the PNG pulse, unlike the others that are scattered randomly throughout the 20-μs-coincidence window.

Table 1.

Region	n-γ (c/s)	Probability of random coincidence	SL events	SL/ng coinc (random)	SL/ng coinc (observed)
A	89	0.0018	409	0.72 ± .04	1
B	3915	0.0783	424	33.20 ± 1.61	29
C	953	0.0191	47	0.89 ± .13	1
D	153	0.0031	6983	21.37 ± .26	20
TOTALS				56.2 ± 1.6	51 ± 7

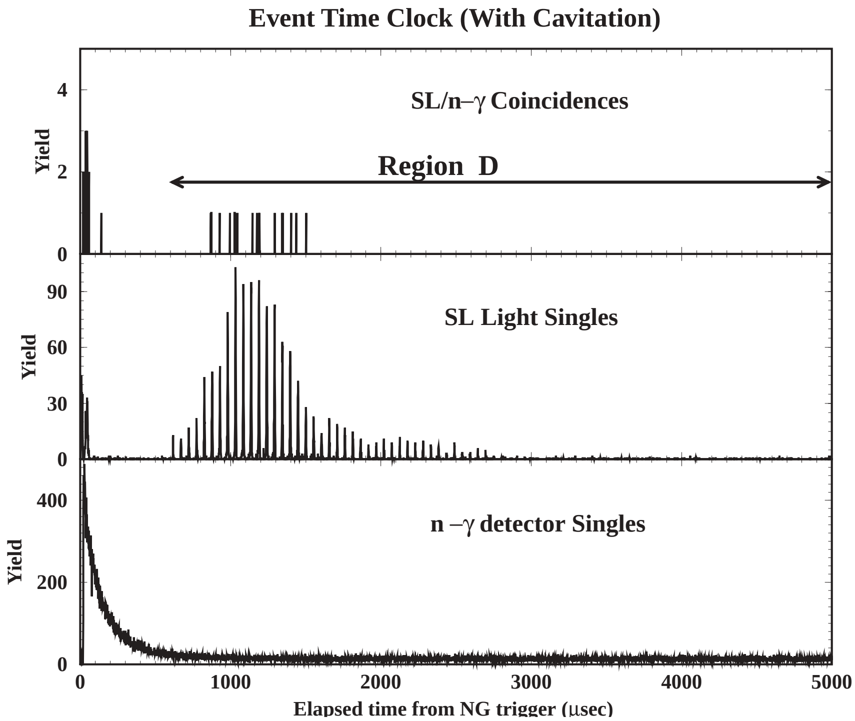

Fig. 2. Event occurrence time relative to PNG trigger time for n/γ singles, SL light emission singles, and the SL/n-γ coincidences.

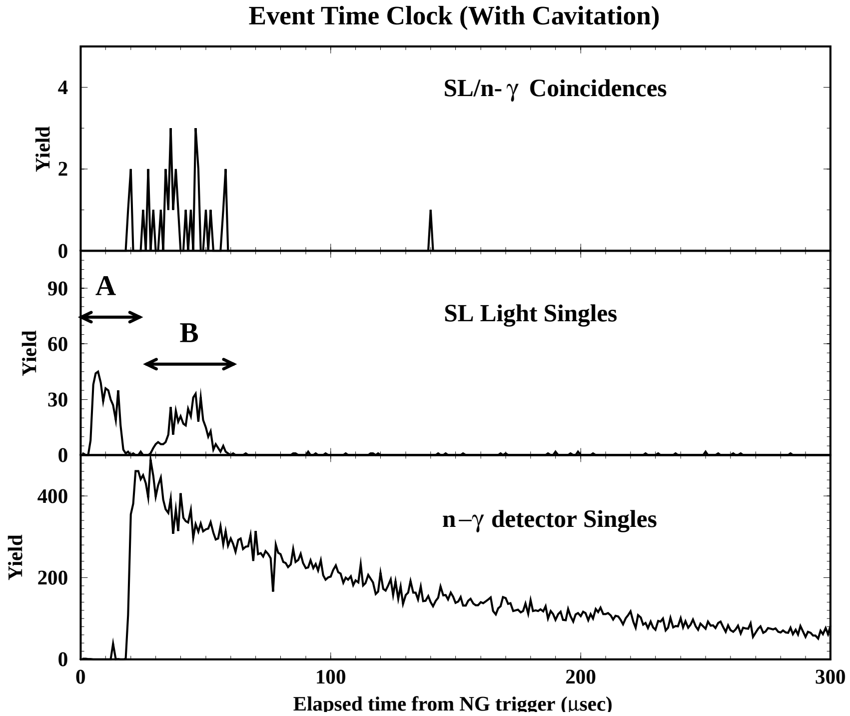

Fig. 3. Event occurrence time relative to PNG trigger time for n/γ singles, SL light emission singles, and the SL/n-γ coincidences shown with an expanded time scale.

The number and time distribution of the coincidence events (see Figs. 2 and 3) agree with the calculated random rates.

The experiment was repeated without cavitation. In a 58-minute run, only 4 coincidences were observed, consistent with the expected random rate.

Taleyarkhan et al.[1] report seeing more neutrons in their singles data during runs with cavitation as compared to those without. We have re-analyzed our data to check for this and note a statistically significant difference ~1000 counts (~1% of the total) in the period immediately after the PNG pulse in our n-γ singles rate. Our data do not show the time distribution of this excess to be correlated with the observed SL emissions.

Making a rough estimate of our detector efficiency for 2.5-MeV neutrons (~10 – 25%) and applying the solid angle factor appropriate for the detector geometry (3×10^{-2}), we estimate the net efficiency for detection of 2.5-MeV neutrons emitted from the acetone flask to be $3\text{–}8 \times 10^{-3}$. Thus, we would have detected an excess of $\sim 10^6$ (about 1000%) counts in the singles spectrum shown in Fig. 2 if d-d fusion at the rate of 10^6 events /sec were occurring, as reported in Ref. 1.

Conclusions

We conclude that there is no evidence of any real coincidences in this experiment. Furthermore, there is a substantial random coincidence rate, which must be properly allowed for in any attempt to measure coincidences. As the background rates seen by both detectors are very time dependent, it is essential that these time dependencies be measured at the same time as the coincidences in order to properly evaluate the background rates.

Any excess neutron production was at least 3 orders of magnitude less than that required to explain the tritium production rate reported in Ref. 1 as being due to d-d fusion.

The time dependence seen in the SL singles is fascinating, and is worth further study.

Acknowledgements

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[1] R. P. Taleyarkhan, C. D. West, J. S. Cho, R. T. Lahey, Jr. and R. I. Nigmatulin, R. C. Block, *Science*, **295**, 1868 (2002).

[2] J. A. Harvey and N. W. Hill, *Nucl. Instrum. Methods* **162,** 507 (1979).