APPENDIX F – Analysis of Scintillator Spectra in the *Science* 2002 Publication

The IqC has been presented with a large number of allegations of research misconduct directed at Professor Rusi P. Taleyarkhan by both anonymous and identified sources. In the course of evaluation of these allegations, we have made a close examination of the publications of Professor Taleyarkhan and collaborators in *Physical Review Letters, Physical Review, Science* and other journals. We have also considered the response of Professor Taleyarkhan to questions put to him by the committee concerning these publications, his presentation of July 23, 2007 to the committee, and documents submitted to the IqC by Professor Taleyarkhan and others.

We have identified many instances of questionable analysis and interpretation of data to support conclusions beyond which the data can be said to justify. Similar sentiments can be found from the very start of the sonofusion work.[89]

We acknowledge that many of the publications in question have been subjected to the process of peer review. Indeed, a large portion of our time was spent acting as an impartial reviewer, evaluating material as a conscientious referee might and should do. We also must acknowledge up front that some portion of our examination may itself be in error. However, we offer the following analysis as an example of the scientific process – something not well implemented in much of the material we have received.

The first publication on sonofusion research by Taleyarkhan et al. is *Science* **295**, 1868 (2002). In this experiment they use two detectors, a 5 cm ϕ by 2.5 cm plastic scintillator and a 5 cm $\phi \times$ 5 cm liquid scintillators.[90] For the liquid scintillator, pulse shape discrimination was accomplished with the Ortec model 552 pulse shape analyzer.[91] The energy scale for the liquid scintillator was calibrated with ^{137}Cs[92] and ^{60}Co sources. Spectra from a PuBe[93] source and from the pulsed neutron generator[94] are also shown in *Science* 295. The threshold and energy scale of this detector are a critical issue for understanding the data of *Science* **295**. This issue was raised by Shapira and Saltmarsh,[95] and by Galonsky.[96]

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[89] As an example, in an email dated 20 February 2003 from Wm. Bugg to R. Taleyarkhan, Bugg, though generally supportive of sonofusion, encourages Taleyarkhan "to reverse this situation a really compelling paper is needed with the loose ends tied up." A copy of this email was attached to the letter from L. Selander to W. Kealey dated July 20, 2007.

[90] See, Taleyarkhan et al., *Science* **295**, footnote 22.

[91] See, Taleyarkhan et al., *Science* **295**, supplement #1, Figure 1, for a block diagram of the electronics.

[92] See, Taleyarkhan et al., *Science* **295**, supplement #1, Figure 2.3b.

[93] See, Taleyarkhan et al., *Science* **295**, supplement #1, Figure 2.3a.

[94] See, Taleyarkhan et al., *Science* **295**, supplement #1, Figure 2.4a,b.

[95] D. Shapira and M. J. Saltmarsh, "Comments on the possible observation of d-d fusion in sonoluminescence," March 1, 2002. This report is reference 32 in Taleyarkhan et al. *Science* **295**. It is available at http://www.rpi.edu/~laheyr/SciencePaper.pdf., the website of Science 295 co-author, Dr.

Figure 1 shows the pulse height spectrum of the liquid scintillator with the pulse shape discriminator gated on neutrons. The source is the 14.1 MeV neutrons from the PNG.

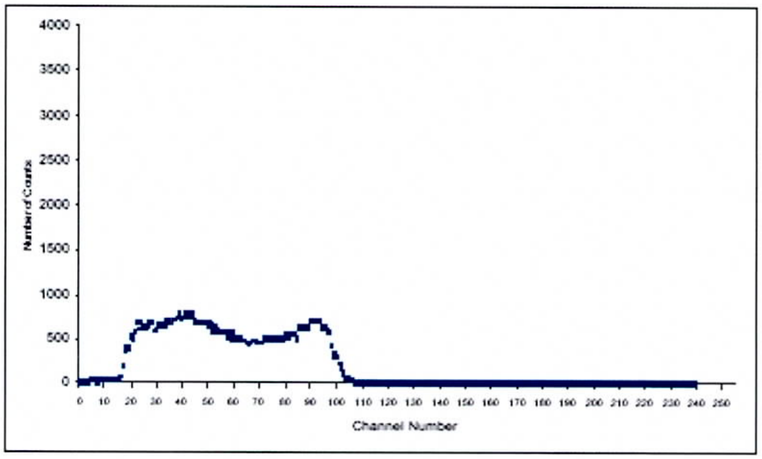

Figure 1 14.1 MeV neutron pulse height spectrum

The maximum energy recoil proton is 14 MeV so the end point of the spectrum, channel ~100, represents 14 MeV proton energy. The light output in a liquid scintillator for protons is a non-linear function of energy. Figure 2 shows a parametrization of the light output due to Cecil et al.[97] This parameterization is a fit to data of Verbinski et al.[98]

Richard T. Lahey. A February 20, 2002 version of this comment had been available an the ORNL website. Their comment became D. Shapira and M. J. Saltmarsh, Phys. Rev. Lett. **89**, 10430 (2002).

[96] A. Galonsky, *Science* **297**, 1645 (2002), followed by a reply from Taleyarkhan et al.

[97] R. A. Cecil, B. D. Anderson and R. Madey, Nucl. Instr. Meth. **161,** 439 (1979).

[98] V. V. Verbinski, W. R. Burrus, T. A. Love, W. Zobel, and N. W. Hill, Nucl. Instr. Meth. **65**, 8 (1968).

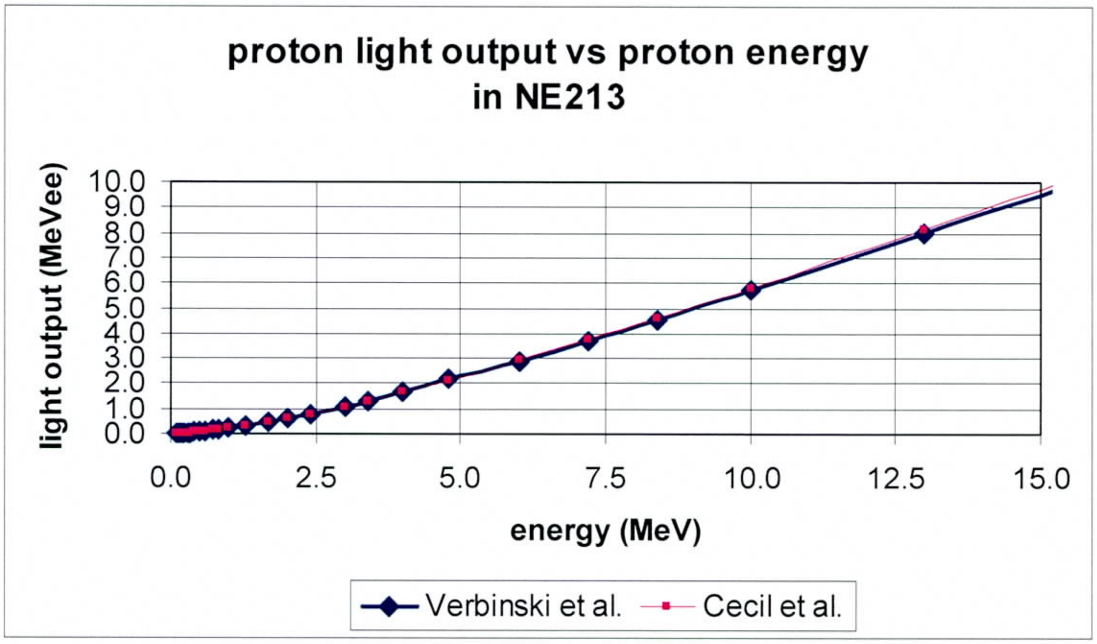

Figure 2 Proton light output in NE-213.[99]

The light output is given in units of MeVee. The "ee" stands for electron equivalent. The light output in scintillator from electrons is linear. The scintillator is exposed to a gamma-ray source. The Compton edge of the source represents an electron of a well-defined energy. So it is straightforward to establish the energy scale for electrons. Reading from the graph, the light output for 14 MeV protons is 8.95 MeVee and for 2.45 MeV neutrons is 0.800 MeVee. Since Figure 1 shows that 14 MeV is in channel ~100, 2.45 MeV will be in channel (100) × (0.800 / 8.95) = 9. Footnote 26 in *Science* **295** states:

"The 2.5-MeV proton recoil edge was determined by using cobalt-60 and cesium-137 monoenergetic gamma ray sources(24). For a 255-channel energy scale, the 2.5-MeV threshold was found to lie around channel 40, and the 14-MeV shoulder around channel 110."

The spectrum in Figure 1 has a cut off at channel 15. Other spectra shown in the *Science* **295** supplement have a different cut off. Figure 3 shows the spectrum from ^{137}Cs. The cut off in this spectrum is channel 8 and the Compton edge is in channel 25. Figure 4 shows the spectrum with the pulse shape discriminator gated on neutrons from the PuBe source. The PuBe source produces a continuum of neutron energies. The average energy is approximately 4.2 MeV. The cut off in this spectrum is channel 15.

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[99] NE-213 is an organic liquid scintillator detector commonly used by nuclear and particle physicists.

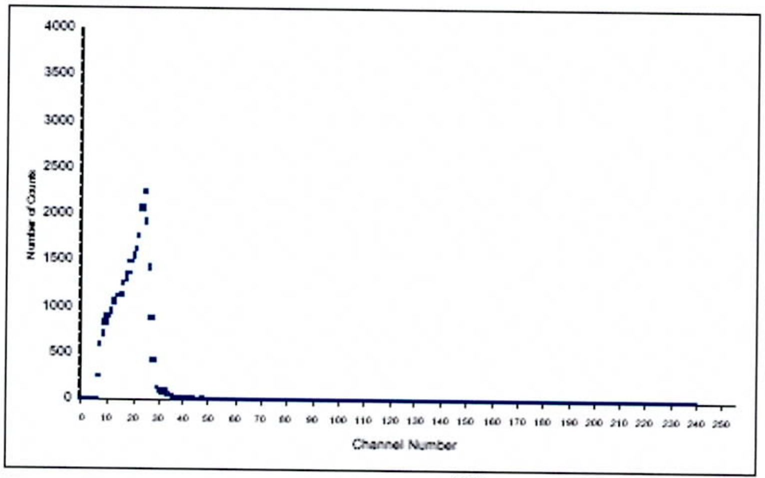

Figure 3 pulse height spectrum from ^{137}Cs

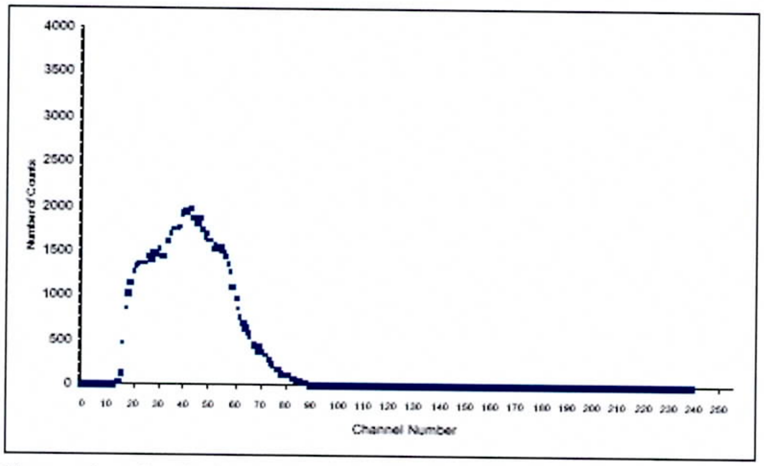

Figure 4 pulse height spectrum from PuBe source.

Science **295** does not show the spectrum from the ^{60}Co source.[100] Since the cut off moves around in these calibration spectra, we could wonder where it is in the sonofusion data.

We also could wonder about the energy scale. The Compton edge from the ^{137}Cs gamma ray is 0.48 MeV. If channel 100, the 14 MeV proton recoil edge, is 8.95 MeVee, then the ^{137}Cs Compton edge should be at channel 54. These inconsistencies were noted by Galonsky. What does Galonsky write?

> "If the response of the scintillators was linear, the maximum output from 2.5-MeV neutrons would be in channel (2.5 / 14) × (100) = channel 18. Two points

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[100] ^{60}Co emits a 1.173 MeV and a 1.332 MeV gamma ray with equal intensity. The Compton edge of the former is 0.964 MeV and the latter is 1.118 MeV. The average of these two energies is 1.040 MeV.

> must be recognized, however: (i) A neutron of energy *E* is detected when it strikes a proton of the scintillator, and that recoiling proton, of maximum *E* in a head-on collision, excites scintillator molecules; and (ii) only a fraction of the proton's energy makes light, and, in an organic scintillator, that fraction becomes ever smaller as the proton energy gets smaller; i.e., the response is not linear. In particular, it disfavors 2.5-MeV protons versus 14-MeV protons… From the well-known data given by Knoll,[101] the maximum pulse height from 2.5-MeV neutrons would be in channel 9 rather than 18."

This criticism is serious, since several spectra show a cut off at channel 15. How does Taleyarkhan et al. respond? The first part of their response is general.

> "We thank Galonsky for pointing out the difficulties arising from interpretation of the threshold for detecting 2.5-MeV neutrons. We concur that the response of the scintillator should be close to linear (but not precisely so)."

Actually, Galonsky states that the response is **not** linear. The importance of the non-linearity is shown in Figure 5 where a straight line from 15 MeV to 7.5 MeV is extrapolated back to zero light output.

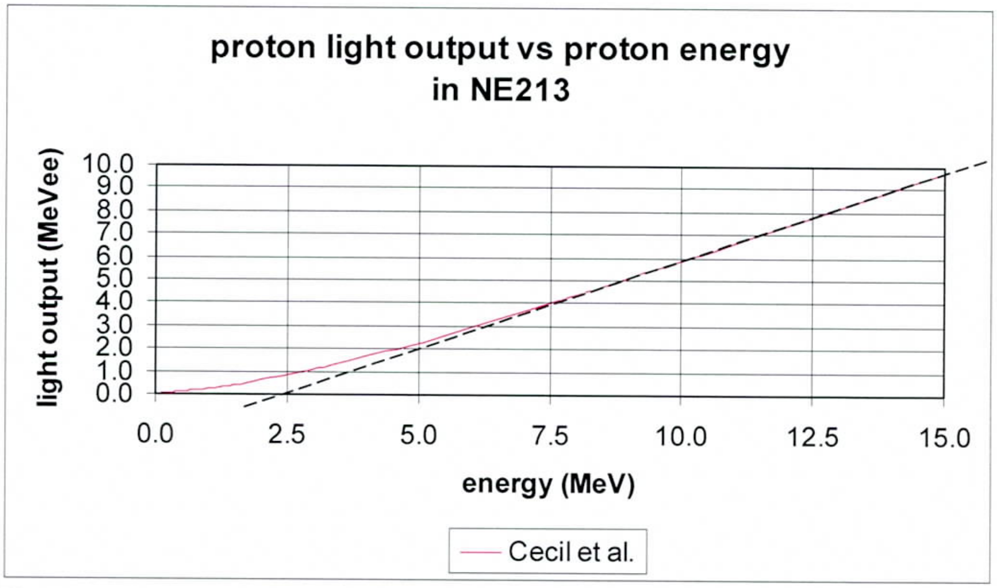

Figure 5 proton light output from Cecil et al. and straight line extrapolation.

How do Taleyarkhan et al. explain the energy scale?

> "We also note that our NE-213 detector was calibrated with both Cs-137 and Co-60 sources, and we equated the intercept of the Compton edge with the x-axis to

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[101] G. F. Knoll, Radiation Detection and Measurement, Wiley, 1989, cited in footnote 22 of *Science* **295**

> the energy of the forward scattered electron, namely, 478 keV for the 662-keV Cs-137 γ-ray and 1.12 MeV for the 1.33-MeV Co-60 γ -ray. These two edges appeared approximately in channel numbers 29 and 40, respectively. A 2.5-MeV proton emits the same light as a 0.881-MeV electron (1), which corresponds approximately to channel 34. Thus, counts from 2.5-MeV neutrons can only appear below channel ~34. It is important to recognize that we had a ~21-channel offset in the multichannel analyzer (MCA) channel corresponding to zero pulse height. Thus, ~21 channels need to be subtracted from our pulse-height data."

Taleyarkhan et al. say that the Compton edge of the ^{137}Cs gamma ray (0.478 MeVee) is in channel 29 and the Compton edge of the 1.33 MeV ^{60}Co gamma ray (1.12 MeVee) is in channel 40. With these two points, (478 keVee, channel 29) and (1120 keVee, channel 40) the detector calibration is $E[keVee] = 58.4 \times (\text{channel number})\text{-}1215$. This energy scale is strange. With this calibration zero energy is channel 21. Figures 1, 3, and 4 show counts below channel 21.

The claim of the 21 channel offset allows Taleyarkhan et al. to claim that their threshold is below the 2.5 MeV proton recoil edge. Recall that the proton recoil edge for 14 MeV protons is in channel 100, see figure 1. (In their response to Galonsky, Taleyarkhan et al. use channel 110.) Their footnote 26 states that the 2.5 MeV proton recoil edge is channel 40. (In the response to Galonsky, they use channel 34.) With the offset the ratio of the light output for 14 MeV to 2.5 MeV protons is (110 – 21) / (34 - 21) = (89 / 13) = 7. The data in figure 2 from Cecil et al. gives a ratio of 11. Taleyarkhan et al. claim that "the estimated value of R ~ 7 from our calibration is reasonably close to the published values and within the range of variations reported by other researchers in the literature." Many works have noted differences in proton light output functions and thus an uncertainty in the neutron response. These differences in the response of various detectors of similar or even identical geometry are an experimental fact, and the implication is that for accurate work the relative light output scale for protons and electrons for each detector must be determined. This point is mentioned in Hawkes et al.,[102] and cited by Taleyarkhan et al. Without the 21 channel offset the ratio of the proton recoil edges is (110) / (34) = 3. The 21 channel offset appears inconsistent, however, with the spectra shown in the *Science* **295** supplement.

What is the threshold in *Science* **295**? The spectra in Figures 1, 3, and 4 show cut offs between channels 8 and 15. With a 21 channel offset we do not know how to interpret these cut offs. The low efficiency found by Taleyarkhan et al. is some evidence that the threshold is high. The efficiency for PuBe neutrons with source at the face of the detector "was determined to be ~5×10^{-3} for a 2×10^{6} neutrons / s source." With the source at the face of the detector the detector subtends 30 – 50% of 4π. The intrinsic efficiency is then 1.0 – 1.7 %. At 5 to 7 cm from the cavitation region, footnote 26 states that the efficiency is estimated to be ~$1 - 2 \times 10^{-4}$. This value includes the solid angle. At 5 to 7 cm from a point source the detector subtends 0.66 sr to 0.37 sr, or 5.3% to 2.9%

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[102] N.P. Hawkes, Nucl. Instr. Meth. **A476**, 190 (2002).

of 4π. Then efficiency is 0.19% to 0.69%, say 0.44 ± 0.25 %. The efficiency of a very similar detector is given by Verbinski et al. as a function of threshold. This efficiency is shown in Figure 6.

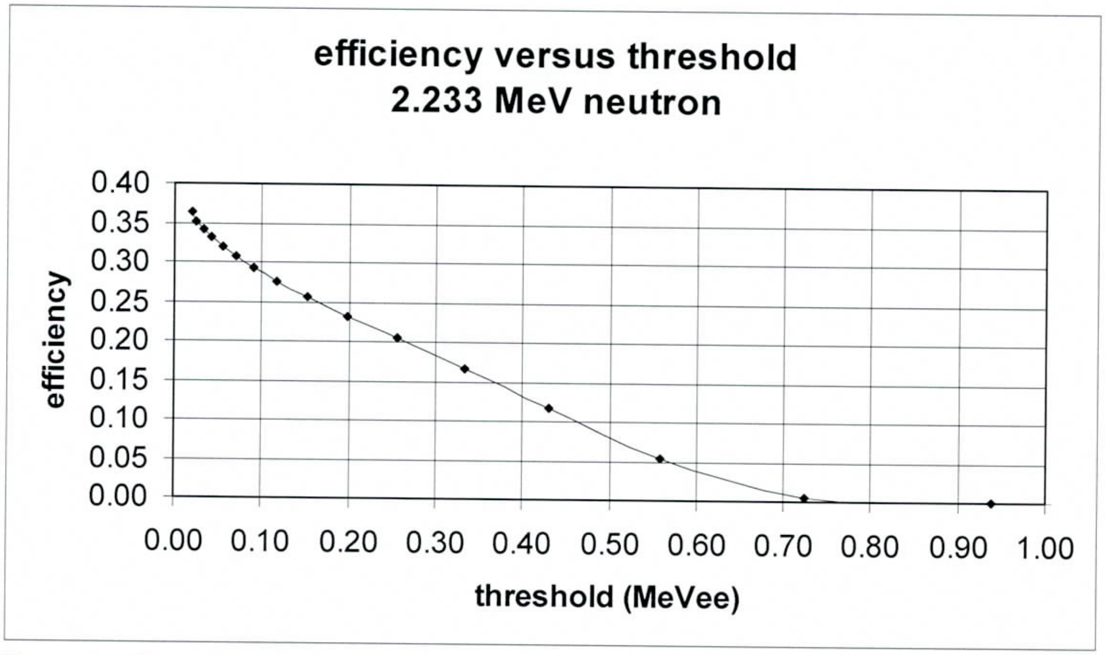

Figure 6 Efficiency versus threshold for 2.233 MeV neutrons as reported by Verbinski et al.

Granted that the energy scale is not well determined, an efficiency of 0.5% implies a threshold of at least 0.7 MeVee, which is the proton recoil edge 2.2 MeV neutron. Shapira and Saltmarsh come to the same conclusion.

It is very troubling that the important matter of the energy scale, the threshold, and the detection efficiency are so poorly determined in *Science* **295**.

Appendix G - Analysis of Physical Review Letters 2006 Publication

The Inquiry Committee has been presented with a large number of allegations of research misconduct directed at Professor Rusi P. Taleyarkhan by both anonymous and identified sources. In the course of evaluation of these allegations, we have made a close examination of the publications of Professor Taleyarkhan and collaborators in *Physical Review Letters, Physical Review, Science* and other journals. We have also considered the response of Professor Taleyarkhan to questions put to him by the committee concerning these publications, his presentation of July 23, 2007 to the committee, and documents submitted to the committee by Professor Taleyarkhan and others.

We have identified many instances of questionable analysis and interpretation of data to support conclusions beyond which the data can be said to justify. Similar sentiments can be found from the very start of the sonofusion work.[103]

We acknowledge that many of the publications in question have been subjected to the process of peer review. Indeed, a large portion of our time was spent acting as an impartial reviewer, evaluating material as a conscientious referee might and should do.

We were compelled to delve into the details of the results reported in the Physical Review Letters **96** publication precisely because it was apparent to us that sufficient care was not taken by either the authors or by the referees. The analysis presented here shows the extent to which this publication falls short of acceptable scientific standards. We also must acknowledge up front that some portion of our examination may itself be in error. However, we offer the following analysis as an example of the scientific process – something not well implemented in much of the material we have received.

The paper, "Nuclear Emissions During Self-Nucleated Acoustic Cavitation" by R. P. Taleyarkhan, C. D. West, R. T. Lahey, Jr., R. I. Nigmatulin, R. C. Block, and Y. Xu, which was published on January 27, 2006 in Physical Review Letters, reports on work done in total at Purdue University. The work described in this paper follows the methodology of earlier published work: the experiment is designed to detect nuclear emissions from a liquid sample in which multi-bubble sonoluminescence is excited. The presence of nuclear emissions is measured for both normal and deuterated hydrocarbons and with cavitation "ON" and with cavitation "OFF". In the PRL **96** work, bubble

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[103] As an example, in an email dated 20 February 2003 from Wm. Bugg to R. Taleyarkhan, Bugg, though generally supportive of sonofusion, encourages Taleyarkhan "to reverse this situation a really compelling paper is needed with the loose ends tied up." A copy of this email was attached to the letter from L. Selander to W. Kealey dated July 20, 2007.

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nucleation is induced by the alpha particle emission of dissolved uranyl nitrate.[104] In earlier work bubble nucleation is induced by an external neutron source, either a radioisotope or a neutron generator. A schematic of the experimental arrangement is reproduced from Figure 1 in the PRL **96** publication.

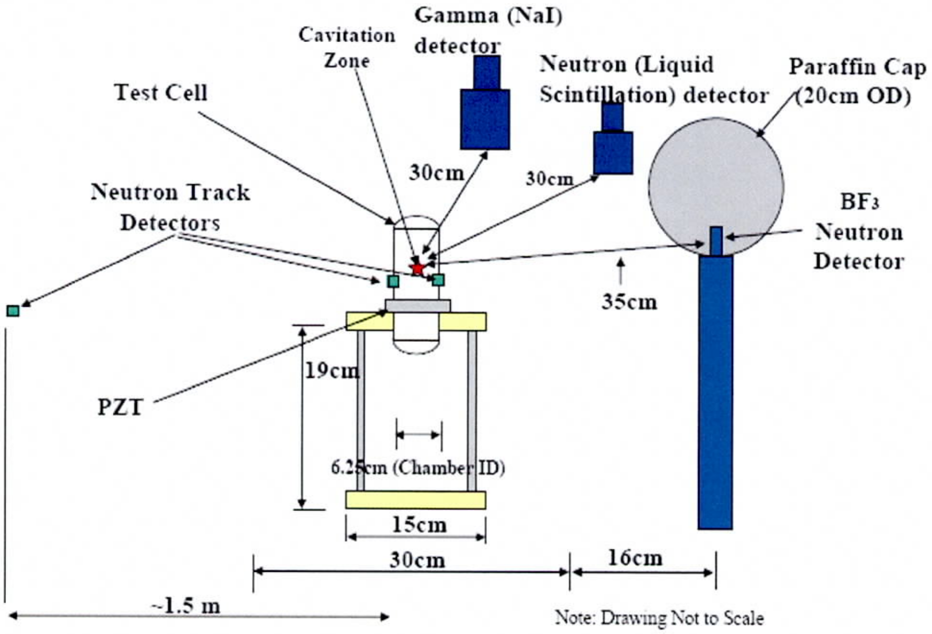

Figure 1: Experimental setup of Taleyarkhan et al. Phys. Rev. Lett. 96, 034301 (2006). The figure is from the supplement to PRL 96.

What is not shown in the figure is thermal shielding surrounding the cell, and thus between the cell and the BF_3 neutron detector,[105] the liquid scintillator neutron detector,[106] and the NaI gamma detector.[107] Also not shown in the figure is extensive

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[104] The 7 g of uranyl nitrate produces approximately 8×10^4 alpha particles per second. Taleyarkhan et al. estimate that only one bubble per second is formed. The bubble formation rate in earlier work was estimated to be 30 per second.

[105] In PRL **96** the active element of the thermal neutron detector (TND) is erroneously identified as a BF_3 proportional counter. The identification error is corrected in the errata to PRL 96, but no change in the data analysis is made. The detector is a Model 42-5 neutron ball cart from Ludlum Industries, Sweetwater, TX. The active element of the detector is a 4 mm in diameter by 4 mm in length LiI(Eu) scintillator. The passive spherical moderator is polyethylene. The TND of PRL **96** is identical to the detector described in Bramblett et al., Nucl. Instr. Meth. **9,** 1 (1960). The detector is known as a Bonner sphere, after the third author of the paper. It is used widely in neutron dosimetry because of its insensitivity to gamma radiation.

[106] The liquid scintillator is 5 cm in diameter by 5 cm in length cylindrical cell of NE-213 equivalent, EJ-301, from Eljen Technology, Sweetwater, TX. See Taleyarkhan et al. Phys. Rev. **E69**, 036109 (2004).

[107] The gamma detector is a 5 cm in diameter by 13 cm in length cylindrical NaI crystal from Harshaw Chemical Company. Harshaw scintillation products are now available from Saint-Gobain Crystals, Newbury, OH.

shielding surrounding all of the detectors. Two of the track detectors[108] are fixed to the cell and are within the thermal shield.

Including the shielding materials would be relevant to any simulation of emissions from the cell, since absorption and scattering of emissions from the cell can occur in the sample liquid, the cell, the thermal shielding and the external shielding. The figure shows no collimation for any of the detectors, and thus the detectors are exposed to radiation from the entire environment. As viewed from the center of the cell, each detector subtends a certain solid angle.

Each detector has its own energy-dependent efficiency for the detection of nuclear radiations. In the present case gamma rays and neutrons are the relevant radiations. The experiment records 256 channel digitized pulse height spectra for the TND (Thermal Neutron Detector), the LS (Liquid Scintillator), and the NaI (Sodium Iodide) detectors. The track detectors are exposed and processed off-line.

The experiment seeks to produce conditions for fusion of deuterium nuclei through the elevated pressures and temperatures of the collapsing bubbles. The nuclear reactions,

$^2H + ^2H \text{->} ^3H + n$ and $^2H + ^2H \text{->} ^3He + p$ (See footnote)[109],

have positive Q-values. At threshold 2.45 MeV neutrons are produced. The electrically neutral neutrons can leave the cell. The electrically charged ^3H, ^3He and protons stop in the cell. The presences of ^3H can be detected through its beta decay. This measurement was done in earlier work of Taleyarkhan et al., but not in PRL **96**. Although the fusion reaction does not produce gamma rays directly, this radiation can be produced through other processes, notably for the present experiment, by neutron absorption. No nuclear emissions are expected from the non-deuterated hydrocarbons.

Although a 2.45 MeV neutron is produced in the fusion reaction, nuclear scattering from the liquid, the cell, or the shielding materials will reduce the neutron energy. The experiment provides no direct measurement of the energy distribution of neutrons incident on the various detectors. Indeed, neutron spectrometry is difficult. Very simple considerations[110] show that some fraction of the neutrons will scatter, and, since the efficiency of the detectors is energy dependent, the unknown neutron energy distribution

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[108] CR-39, allyl diglycol carbonate, is a trademark of PPG. The detectors are obtained from Landauer, Inc., Glenwood, IL. Landauer, Inc. provides dosimetry services worldwide.

[109] Also, d + d -> t + n and d + d -> h + p (less commonly).

[110] The neutron scattering cross sections for the various components of the sample, ^1H, ^2H, C, N, O, Cl, and U are available online from the National Nuclear Data Center at Brookhaven National Laboratory. The total cross section for neutrons of 2 MeV is typical 1-3 b. From these cross sections, the cell dimensions, and the sample composition, a simple calculation shows that the probability for a neutron interaction in the cell is approximately 50%. In PRL **96** Taleyarkhan et al. account for this effect by multiplying the measured neutron detection rates for the various detectors by a factor of two.

makes a quantitative determination of the neutron flux uncertain.[111] The experiment does attempt to determine the detector efficiencies with radioactive sources of known strength,[112] so the efficiencies of the detectors for this neutron field are available.

In PRL **96** the calibration and data of each detector is presented and discussed, and from these data the neutron emission rate is calculated. PRL **96** reports that neutron emission is found for each detector only for the deuterated sample with cavitation on. The space limitation of a Physical Review Letter is four pages, and because of this limitation much of the data is published in a supplement. The supplementary material is sent to reviewers at the same time as the primary manuscript. Lipson[113] and Naranjo[114] commented on PRL **96**, and Taleyarkhan et al. replied to their comments.[115]

We will now review the data and analysis from each detector.

Thermal Neutron Detector

Following the order in PRL **96**, the first detector is the TND. Since the neutron is not electrically charged, neutron detection requires a nuclear interaction. The (n,α) reaction has a positive Q-value and a large cross section at thermal energies for some nuclei, and the TND operation is based on these properties. Neutrons that enter the polyethylene sphere scatter on the hydrogen, their energy is reduced, and some reach the central detector. For a BF_3 detector, the reaction is on ^{10}B. BF_3 is a gas, and ionization in the gas from the alpha particle is detected by a proportional counter. In general, a proportional counter, due to its low mass, has very poor gamma-ray detection efficiency.

Taleyarkhan et al. believed incorrectly that the central detector was a BF_3 proportional counter. Evidently, the detector was loaned to Professor Taleyarkhan, and the lender provided incorrect information.[116] The central detector in the TND was actually a

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[111] This uncertainty should be expressed in terms of a systematic uncertainty. In general, systematic uncertainties receive little, if any, explicit consideration in this work and earlier works of Taleyarkhan et al.

[112] Two isotopic neutron sources are used in PRL 96. In response to an inquiry, Dr. J. Schweitzer, Director, Radiological and Environmental Management Division, Purdue University, provided a description of the two sources. One source is a 1 Ci plutonium-beryllium (PuBe) source from Mound Laboratory obtained in December 1960 with a nominal neutron emission rate of 2 x 10^6 neutrons per second. The activity of this source is unchanged. The second source is a 0.5mCi ^{252}Cf source obtained from Isotope Produces Laboratory on June 1, 2002. The activity of this source must be corrected for the 2.645 year ^{252}Cf half-life. During the work for PRL **96**, the activity was approximately 1 x 10^6 neutrons per second. Both PuBe and ^{252}Cf sources are well characterized. See, for example, M. E. Anderson and R. A. Neff, Nucl. Instr. Meth. **99**, 231 (1972) for the PuBe source, and J.W. Boldeman, in IAEA-TECDOC-410, 180 (1987) for the ^{252}Cf source.

[113] A. Lipson, Phys. Rev. Lett. **97**, 149401 (2006).

[114] B. Naranjo, Phys. Rev. Lett. **97**, 149403 (2006) with supplement E-PRLTAO-97-071640. Naranjo's comment is continued in arXiv:physics/0702009v1, 1 Feb 2007.

[115] R. P. Taleyarkhan et. al., Phys. Rev. Lett. **97**, 149402 (2006), and Phys. Rev. Lett. **97**, 149404 (2006) with supplement E-PRLTAO-97-080640.

[116] In the errata to PRL **96** Taleyarkhan et al. state that "This clarification does not affect the data, analyses, nor the conclusions…" In PRL **96** Taleyarkhan et al. consider both the counts in the gamma ray region and in the neutron region of the TND response as part of the sonofusion signal. Even allowing this

LiI(Eu) crystal. The reaction is on ^{6}Li, and the alpha particle causes scintillations in the crystal.

In general, such crystals have good efficiency for gamma ray detection, but the gamma-ray detection efficiency is minimized by the small volume of the crystal. The operation of the TND is conveniently verified by exposure to the PuBe source. The pulse height spectrum from the TND is shown in Figure 2.

The peak at channel 40 is due to scintillations from the alpha particle. There are counts below this peak largely due to gamma rays. The detection efficiency of the TND can be determined from the data in figure 2.[117] Note that Taleyarkhan et al. detect 1,197 neutrons in 100 seconds from their PuBe source when the detector to source distance is 50 cm.

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questionable procedure, at the very least a different efficiency should be applied to counts in the gamma ray and neutron regions, and at the very least the efficiency should be different for a BF_3 proportional counter and a LiI(Eu) scintillation crystal. That no change would be made to the analysis after the discovery that the central detector was not as assumed is a surprise.

[117] From figure 2a of the supplement in an exposure of 100 s to a PuBe source of an intensity of 2×10^{6} n / s, 22,203 neutrons are detected at 10 cm, 3,554 at 30 cm, and 1,197 at 50 cm. At 10 cm, the BF_3 subtends a solid angle of 56 msr, or 4.5×10^{-3} of 4π. The efficiency is then $(22{,}203) / (4.5 \times 10^{-3} \times 2 \times 10^{8}) = 2.5$ %. At 30 cm the BF_3 subtends a solid angle of 6.2 msr, or 5.0×10^{-4} of 4π. The efficiency is then $(3{,}554) / (5.0 \times 10^{-4} \times 2 \times 10^{8}) = 3.6$ %. At 50 cm the BF_3 subtends a solid angle of 2.2 msr, or 1.8×10^{-4} of 4π. The efficiency is then $(1{,}197) / (1.8 \times 10^{-4} \times 2 \times 10^{8}) = 3.3$ %. Thus the efficiency at each distance is approximately 3 %, in agreement with the statement of Taleyarkhan et al. in PRL **96**. Although the central detector is incorrectly identified, the detection efficiency is not in error, since the detector is calibrated against a source of known strength.

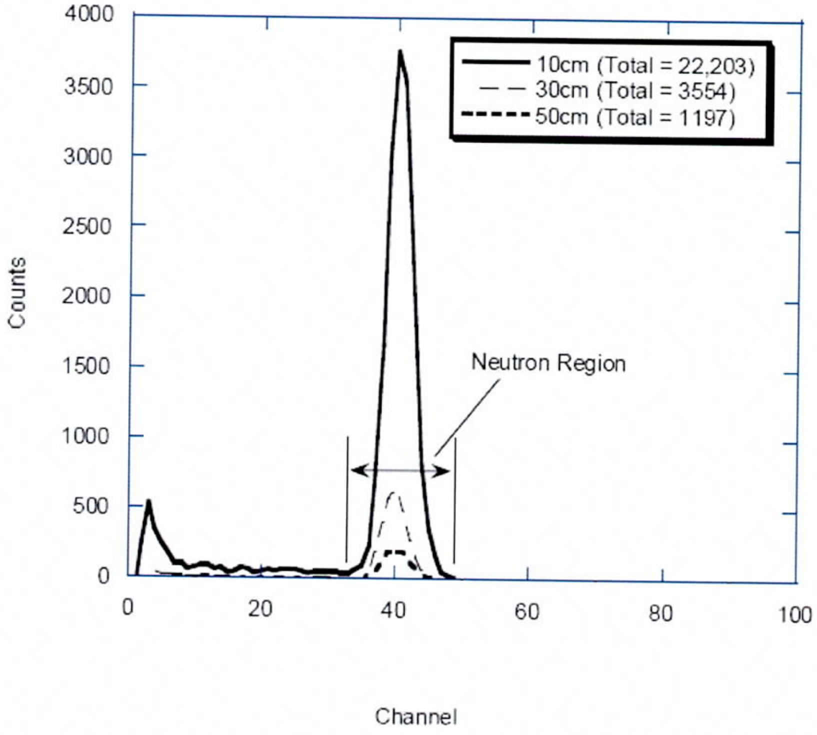

Figure 2. Pulse height spectrum of TND. The figure is from the supplement to PRL 96.

At 40 cm they would then have 1,870 neutrons according to the inverse square law. In 100 s their source emits 2×10^8 neutrons. For a sonofusion source emission of 1×10^6 neutrons, Taleyarkhan et al. would therefore expect to detect $(1{,}870 / 2 \times 10^8)\ 1 \times 10^6 =$ 9.4 neutrons. The average neutron energy from a PuBe source is 4.2 MeV, and at 4.2 MeV figure 6 of Bramblett et al. shows that 9.5 neutrons would be detected. Thus the calibration data of Taleyarkhan et al. are in good agreement with Bramblett et al. when the neutron signal is identified with the counts in the neutron region.

The TND pulse height spectrum from the deuterated sample is shown in Figure 3 and for the normal sample in Figure 4.

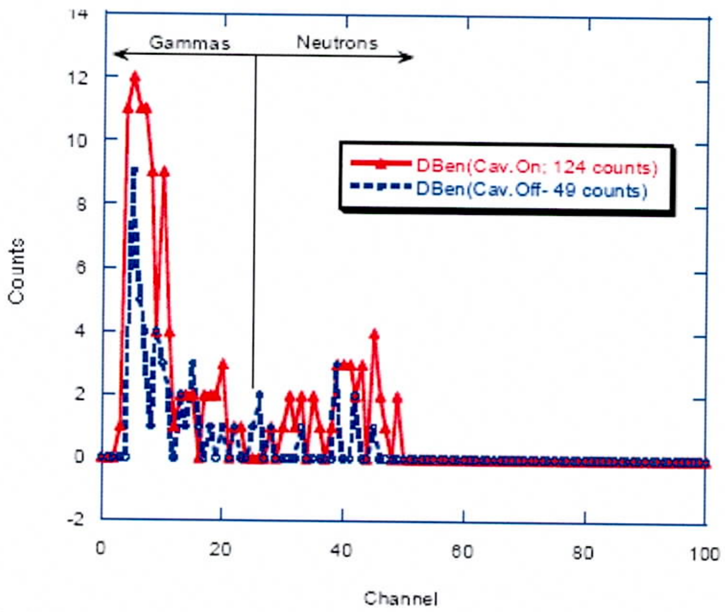

Figure 3 TND pulse height spectrum from sonofusion experiment with deuterated sample. Figure 3 is taken from Figure 4a of PRL 96 supplement.

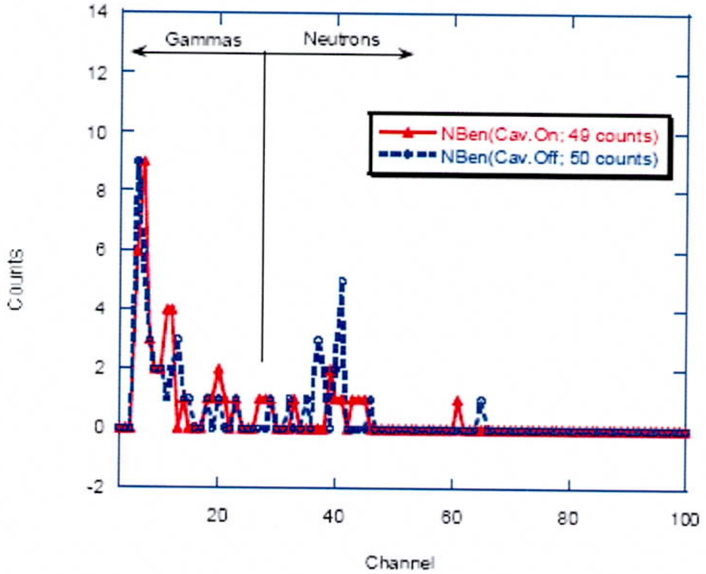

Figure 4 TND pulse height spectrum from sonofusion experiment with the normal sample. Figure 4 is taken from Figure 3a of PRL 96 supplement.

The counts listed in the legend box in Figures 3 and 4 are the sum of the counts in the gamma and the neutron region. Often the next step in the analysis is to subtract the cavitation off spectrum from the cavitation on spectrum. This difference spectrum is shown in Figure 5.

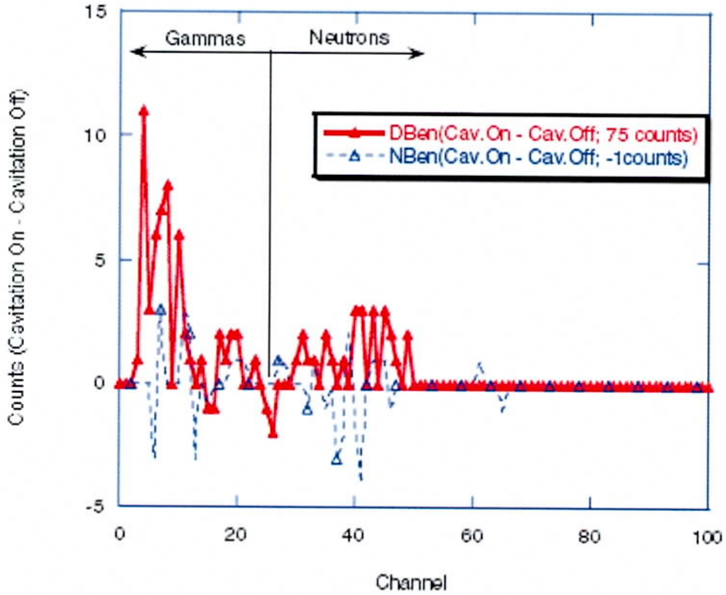

Figure 5 TND pulse height difference spectrum, cavitation on minus cavitation off, from sonofusion experiment with the deuterated and the normal sample. Figure 5 is taken from Figure 2 of PRL 96.

With cavitation on there are 34 neutrons and 90 gammas detected with d-benzene and 10 neutrons and 39 gammas with n-benzene. With cavitation off there are 10 neutrons and 39 gammas detected for d-benzene and 18 neutrons and 32 gamma detected for n-benzene.[118] Thus cavitation on minus cavitation off gives 75 counts for d-benzene and -1 counts for n-benzene.

In PRL **96** Taleyarkhan et al. find "a significant increase (~400%) in neutron counts and ~100% increase of gamma counts" between cavitation on and off. Reproducing this arithmetic, we find for the neutrons an increase from 10 to 34 counts so that the increase is (34 - 10) = (24 ± 6.6) counts, or, expressed as a percentage increase over the cavitation off counts, (240 ± 28)%, not 400%. For the gammas an increase from 39 to 90 is (90 - 39) = (51 ± 11.4) or as percentage increase over the cavitation off counts, (130 ± 22)%. The increase in neutron counts is overstated. [Note: We have used standard propagation of error theory: z = x – y; error(z) = square root((error(x)) + (error(y))^2). For counting experiments, this reduces to: error(z) = square root(x+y).

If cavitation on minus cavitation off is the signal, then in the neutron region there are 24 counts and in the gamma region there are 51 counts. Taleyarkhan et al. add the counts in the two regions to obtain 75 counts. With 75 counts they claim an emission rate of "~5-7 x 10^3 n / s." Using the detector efficiency of 3%, the solid angle ($\Delta\Omega$ / 4π = 3.6 x 10^{-4})[119], and cavitation on time (3,600 s) obtain an emission rate of (75) / (0.03 x 3.6 x 10^{-4} x 3,600 s) = 1.9 x 10^3 n / s, lower by a factor of 2-4 from Taleyarkhan's number.

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[118] The counts in the plots have been used to obtain these numbers.

[119] The BF$_3$ detector is assumed to be a 1.25 cm diameter by 4.5 cm long cylinder, 35 cm from center of cell. The solid angle efficiency product is correct even though the detector had been misidentified.

Perhaps, Taleyarkhan et al. have included a factor of 2-4 to account for neutron loss due to scattering. Some such factor could be justified; however, why should the counts in the gamma region be added to the counts in the neutron region? Note that by adding the counts from the gamma region to the neutron region the rate is increased by a significant factor, (51 + 24) / (24) = 3.1. Just from the counts in the neutron region the emission rate would be 620 n / s.

Taleyarkhan et al. offer an argument for adding the counts in the gamma region to the counts in the neutron region in their reply to Lipson.[120]

> The Erratum [5] clarifies that our thermal neutron detector (TND) was Li based and produced pulses proportional [6] to the energy of the charged particle. A PuBe source emits neutrons and monoenergetic 4.4 MeV γ rays [6] but the ^{6}Li(n,α)^{3}H reaction also has a "Q" of ~4.78 MeV from which the 4.4 MeV γ rays from the PuBe source are detected [3] in the same peak region as the ^{6}Li(n,α)^{3}H reaction products accompanied with a continuum of voltage pulses in lower channel numbers. The pulse-height dependence with incoming γ ray energy has been quantified [see Figs. 2(b) and 2(c) of Ref. [3]].

The argument in this paragraph is very difficult to follow. First, how well has the "pulse-height dependence with incoming γ ray energy" been quantified? Figure 6 shows the two gamma ray spectra obtained with the TND.

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[120] Lipson also looks carefully at the TND data. He finds a neutron emission rate of 496 ± 150 n / s, and he also argues against adding the gamma counts to the neutron counts.

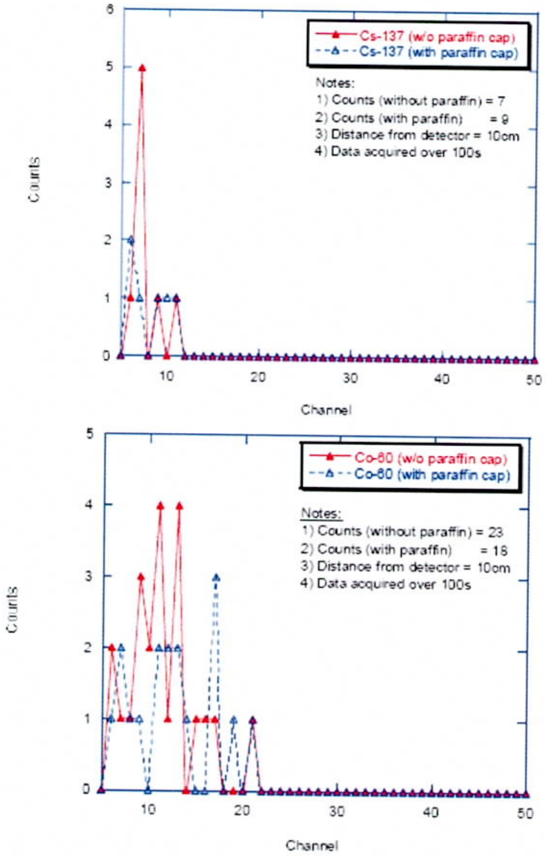

Figure 6 Pulse height spectra from the TND obtain with gamma-ray sources. Figure 6 is taken from figures 2b,c of PRL 96 supplement.

Each spectrum has a **very** small number of counts, and for no good reason. These spectra cannot be said to determine with any accuracy the centroid for either the 0.66 MeV ^{137}Cs or the 1.13 and 1.32 MeV ^{60}Co gamma rays. From these data extrapolation to a 4.4 MeV gamma ray is extremely problematic.

Secondly, recall that Taleyarkhan et al. analyze the data in PRL **96** with the belief that the central detector is a BF_3 proportional counter. In this counter a gamma ray would interact dominantly by the Compton effect. The Compton electron would ionize the gas and produce a signal. The energy loss of an electron, however, in a few centimeters of gas must be small.[121] Even with the knowledge that the central detector is, in fact, a LiI(Eu) crystal, it is thus quite difficult to understand how Taleyarkhan et al. can claim that a 4.4

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[121] Perhaps this point should not be belabored, but it suggests what appears to be an extremely cavalier treatment of data. The signal in a proportional counter is due to the ionization, and the ionization is the result of the energy loss of the passing particle. The properties of the BF_3 counter are unknown to Taleyarkhan et al., but, typically, the counter has a gas load of 60% Ar and 40% BF_3 for a density of ~ 3 mg / cm^3. The Compton electrons will be minimally ionizing, ~2 MeV / g / cm^2, so that the energy loss in a few centimeters of gas can only be ~20 keV. In contrast, ~4 MeV alpha particles can stop in the counter.

MeV gamma ray gives the same signal as the alpha particle from the ^{6}Li(n,α)^{3}H reaction. Due to the small volume of the crystal, the photopeak would be greatly suppressed.

Thirdly, Figure 6 of Bramblett et al. gives the efficiency of the TND for neutrons. The calibration data in Figure 2 of the PRL **96** supplement agree with Bramblett et al. for the counts in the neutron region. Therefore, the counts in the neutron region are due solely to neutrons, and not to the neutrons and gamma rays emitted by the PuBe source. It appears that Taleyarkhan et al. have a poor understanding of this detector. Adding the counts in the gamma region to the neutron region is not justified. The emission rate reported from this detector is likely to be incorrect.

Data are also obtained with the TND at a greater distance from the cell, 65 cm versus 35 cm. Radiation due to the cell should be inversely proportional to the square of the distance between the cell and the detector. These data are shown in Figure 7.

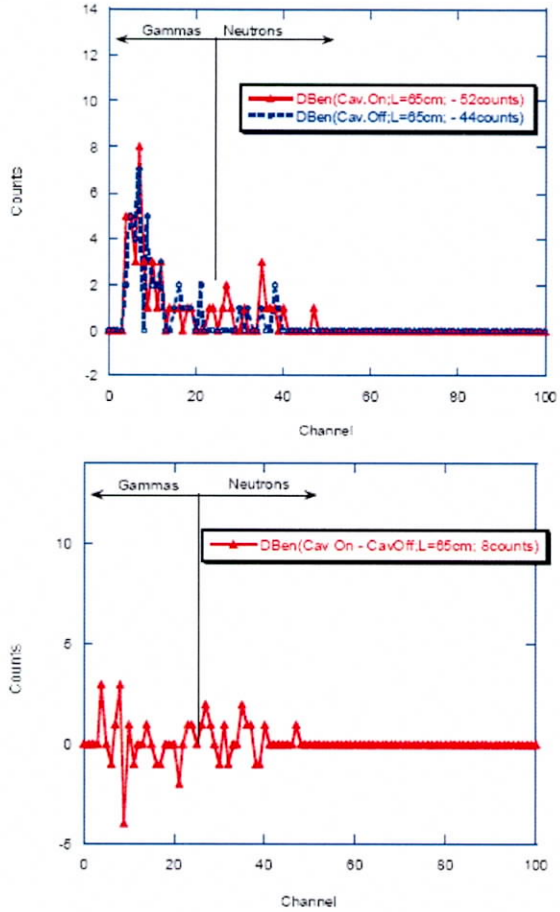

Figure 7 TND pulse height spectra and difference spectrum from sonofusion experiment with deuterated sample with cell to detector separation of 65 cm from PRL 96 supplement Figures 5a, b.

Figure 7 shows in the difference spectrum 8 ± 10 for the total, 3 ± 9 in the gamma region, and 5 ± 4 counts in the neutron region. Statistics are very poor, and no conclusion should be made concerning these data.

Even so, Taleyarkhan et al. state in PRL **96,** "The measured neutron emissions … obeyed the well-known and expected inverse law dependence with distance." No data are reported from the other detectors with more than one cell to detector difference. This statement does not appear to be justified.

It should noted that Taleyarkhan et al. also analyze data from the normal sample, and from a comparison of D_2O to H_2O they report that no signal is found for any of these cases. See Table I of PRL **96**. Table I reports results in terms of the signal: cavitation on minus cavitation off. When gamma and neutron counts are added, the signal is 75 ± 13 counts, for a mean divided by standard deviation of 5.7. If only neutron counts are considered, the signal is 25 ± 7 counts, for a mean divided by standard deviation of 3.6. Scientists rarely make claims of significance for a particular process based on less than a 5 standard deviation effect.

Liquid Scintillator Detector

Continuing with the order in PRL **96**, the second detector is the liquid scintillator (LS). The liquid scintillator is a hydrocarbon, and the scintillation is produced from n + p elastic scattering. Neutron-carbon interactions do not produce detectable scintillations at the neutron energies under consideration, although neutron-carbon must be considered in a calculation of the detector efficiency. At the neutron energies under consideration n + p elastic scattering is isotropic in the center-of-mass system, and the energy distribution of the scattered proton is uniform from zero energy to the incident neutron energy. The scintillation light output for protons is highly non-linear, and thus one of the requirements for neutron spectroscopy is the determination of the energy scale.

Isotopic neutron sources, PuBe and ^{252}Cf in particular, produce a continuum of neutron energies, and, as such, cannot be used straightforwardly to determine the energy scale. Monoenergetic neutrons can be obtained by a number of techniques. For example, the fusion reaction, $d + d \rightarrow n + {}^3He$ produces 2.45 MeV neutrons at threshold; the reaction $d + t \rightarrow n + {}^4He$ produces 14.1 MeV neutrons at threshold.[122] Many other nuclear reactions can produce monoenergetic neutrons, but, in general, a particle accelerator is needed.

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[122] Taleyarkhan et al. had used a commercial pulse neutron generator (PNG), Model N-550 from Activation Technology Co., Colorado Springs, CO, in earlier work to obtain 14.1 MeV neutrons. See Taleyarkhan et al., Phys. Rev. **E69**, 036109 (2004) and Science **295**, 1868 (2002). In the March 1, 2006 DARPA demonstration meeting, Professor Taleyarkhan reported that the PNG had become unreliable, and, apparently, its use at Purdue was abandoned. Activation Technology reports that this PNG could also produce 2.45 MeV neutrons with a different neutron tube. Since the experimental program of Taleyarkhan et al. seeks to detector 2.45 MeV neutrons, a generator of 2.45 MeV neutrons would have been invaluable. In PRE **69** Taleyarkhan et al. report that "In addition, the LS detector was carefully calibrated with monoenergetic neutrons at the RPI LINAC..." In his July 23, 2007 interview with the Inquiry Committee, Professor Taleyarkhan stated that there were no such data. The importance of understanding the signal from a 2.45 MeV neutron in the liquid scintillator detector cannot be overstated.

The response of a detector of very similar geometry to the one of PRL **96** is described by Verbinski et al.[123] This paper is especially useful as it makes available in tabular form pulse height spectra and efficiency determinations for a broad range of neutron energies and detection.

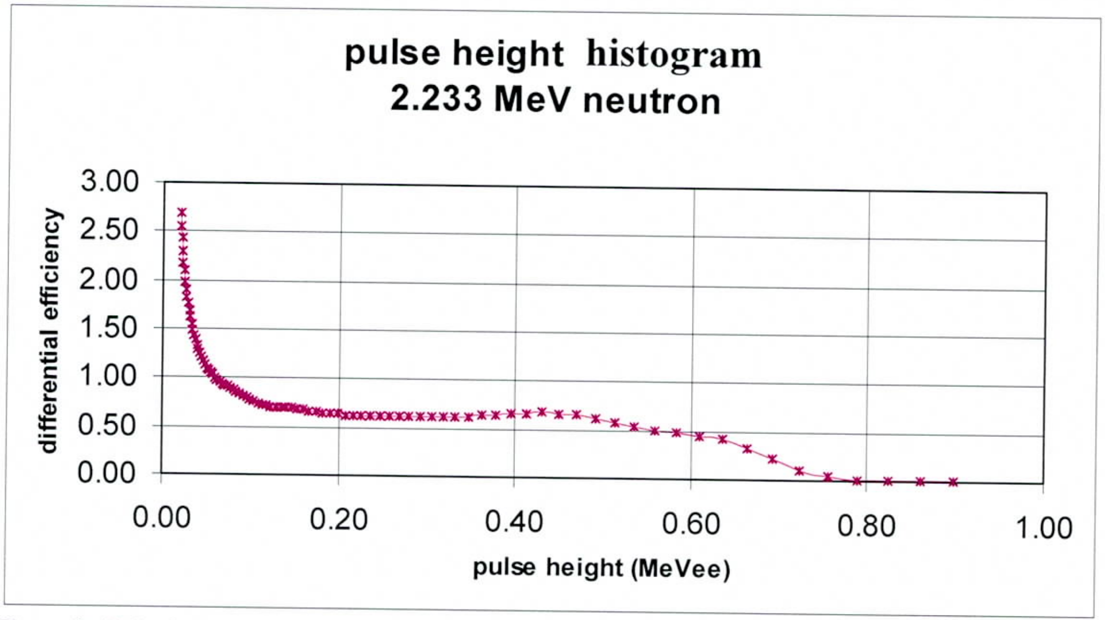

Figure 8. Pulse height distribution of a 2.233 MeV neutron as reported by Verbinski et al. thresholds.

Figure 8 is the pulse height distribution of a 2.233 MeV neutron in the 4.6 cm in diameter by 4.6 cm in length liquid scintillator of Verbinski et al. Since a number of monoenergetic gamma ray sources are available, the energy scale is in units of the light output of an electron of an equivalent energy, hence the MeVee. The procedure for calibration of the energy scale of a liquid scintillator with gamma ray sources is described in Verbinski et al. and in many other sources. The light output of a recoil proton of a given energy in electron equivalent energy units is show in Figure 9. Figure 8 uses a parameterization by Cecil et al. of the data in Verbinski et al.

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[123] Verbinski et al., Nucl. Instr. Meth. **65**, 8 (1968).

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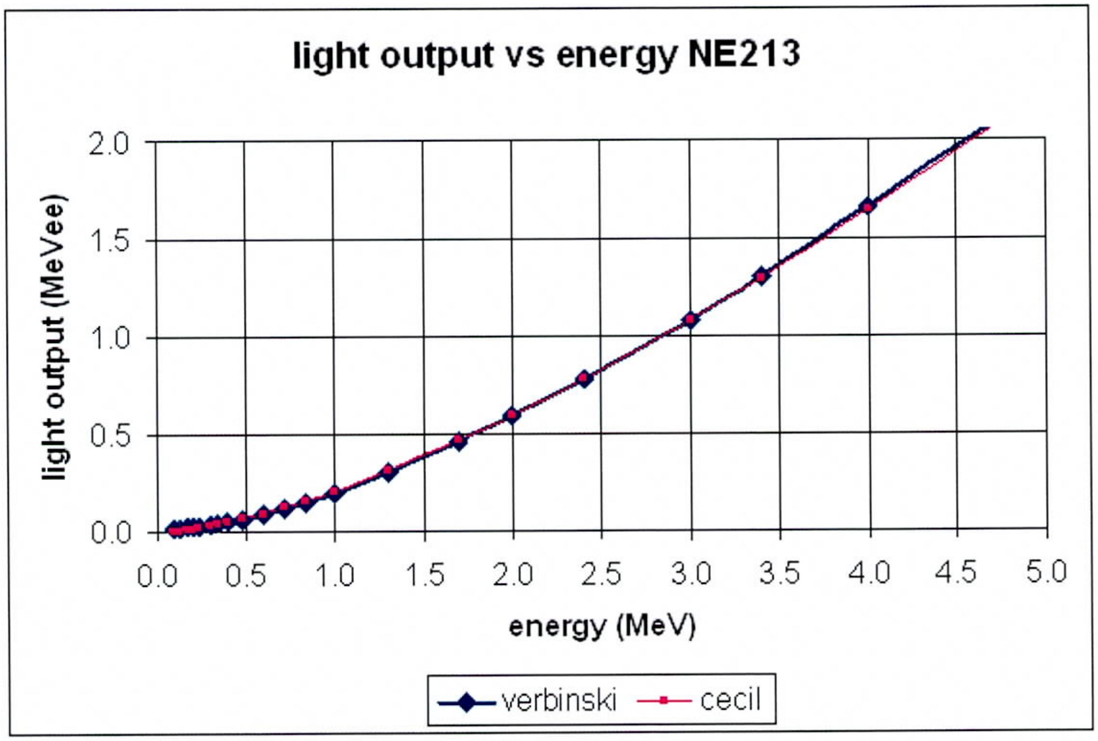

Figure 9 Proton light output in electron equivalent energy units.

Note the strongly non-linear energy dependence of the light output for low energy protons. The maximum proton recoil energy of from the scattering of a 2.45 MeV neutron is 2.45 MeV. The light output of a 2.45 MeV proton is 0.800 MeVee. The maximum light output of a 2.00, 1.50, 1.00, and 0.50 MeV neutron from its recoil proton is 0.590, 0.385, 0.205, and 0.068 MeVee.

A pulse height spectrum from PRL **96** with an energy scale in MeVee is shown in Figure 10. The data are from PRL **96** supplement Figure 9b. An energy scale in MeVee is substituted for the axis in channel number. The vertical height is adjusted to be approximately the same as Figure 8, although the data in Figure 10 go off scale at low pulse heights. The purpose of this version of the data is to show that the spectrum reported in PRL **96** is different quantitatively and qualitatively from the spectrum of a 2.45 MeV neutron. This statement should be obvious.

Such a difference can easily be attributed to scattering in the sample, the cell, the thermal shield, and the external shielding. The spectrum from PRL **96** is not unique. Very similar spectra are reported in Xu and Butt,[124] and in PRE **69**.[125] None of these works present an attempt to account quantitatively for the shape of the spectrum. The first

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[124] Yiban Xu and Adam Butt, Nucl. Eng. Design **235**, 1317 (2005).

[125] This spectrum is not reported in *Science* **295**. *Science* **295** does report gamma and neutron calibration spectra.

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attempt to account for the shape of the spectrum is due to Naranjo.[126] Although a speculation, one might believe that Taleyarkhan et al. neglected to consider the shape of the spectrum because they focused on the difference spectrum of cavitation on minus cavitation off, the sonofusion signal.

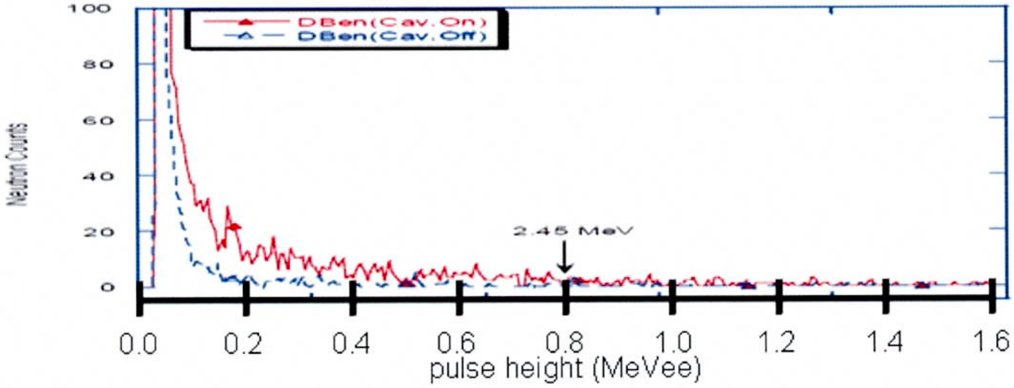

Figure 10 LS pulse height spectrum for cavitation on and off with deuterated sample, adapted from PRL 96 supplement figure 9b.

The difference spectrum is shown in Figure 11. This difference spectrum is also not unique. Very similar difference spectra are reported in Xu and Butt, and in PRE **69**.

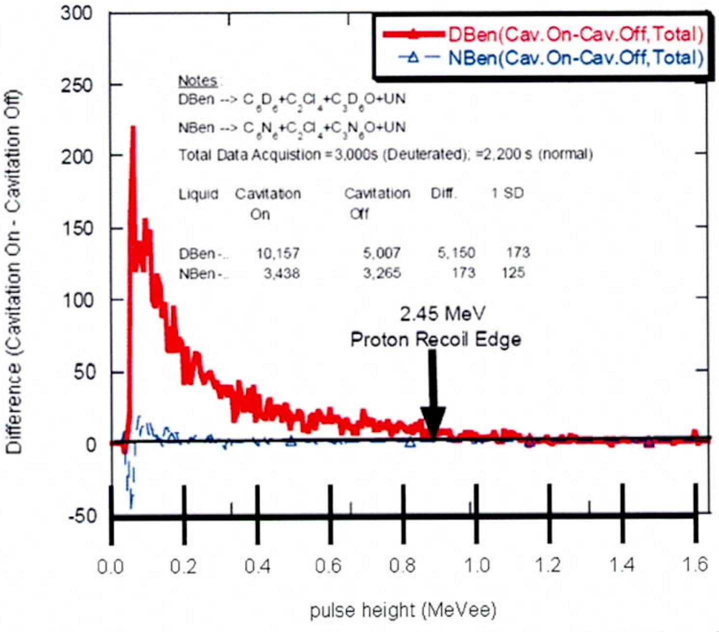

Figure 11 LS pulse height difference spectrum for cavitation on minus cavitation off with deuterated sample, adapted from PRL 96 supplement Figure 12. Figure 4 of PRL 96 is similar.

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[126] B. Naranjo, Phys. Rev. Lett. **97**, 149403 (2006) and supplement E-PRLTAO-97-071640.

The difference spectrum for the deuterated sample shows a significant signal. Perhaps half of the signal is at pulse heights below 0.2 MeVee. Neither Figure 10 nor Figure 11 should be used quantitatively. The figures are constructed only from pictures of the plots in PRL **96**, not from the data themselves. Figures 10 and 11 are sufficiently accurate to demonstrate the shape of the pulse height spectrum and its energy scale.[127]

These spectra strongly suggest that there is a distribution of neutron energies that reach the detector. Since the neutron detection efficiency is strongly energy and threshold dependent, the uncertainty in this energy distribution will produce an uncertainty in the determination of the neutron emission rate. This point is not addressed in PRL **96** or in earlier works. The detection efficiency for neutrons is derived from the calibrated PuBe and ^{252}Cf sources. In fact, the neutron emission rate from the LS is not reported in PRL **96** and its supplement. In the reply to Lipson, Taleyarkhan et al. report that the 996 counts[128] in the difference spectrum, PRL **96** Figure 4, represent a neutron emission rate of $\sim 4 \times 10^4$ n / s. Assuming that 996 counts are detected in 300 s, we calculate a rate of 3.22 ± 0.18 cps. At 30 cm the LS subtends a solid angle of 0.174% of 4π. At the threshold shown in figure 11, ~50 keVee, Verbinski et al. report an efficiency of ~0.3. Correcting for solid angle and efficiency, the neutron emission rate is $(6.2 \pm 0.3) \times 10^3$ n / s. The difference between this calculation and that of Taleyarkhan et al. (a factor of 6) is in the assumed neutron detection efficiency.

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[127] The position of the proton edge indicator in the difference spectrum, Figure 11, is different from the position of the proton edge indicator in Figure 10. In his July 23, 2007 interview with the Inquiry Committee, Professor Taleyarkhan stated that these differences were due solely to inaccurate placement of the indicator arrows.

[128] Table I of PRL **96** gives 966 counts as the difference of 2,015 and 1,055. Figure 4 gives 966 as the difference of 2,051 and 1,055. The arithmetic is in error in both cases. We use 996 as the number of counts in the difference spectrum.

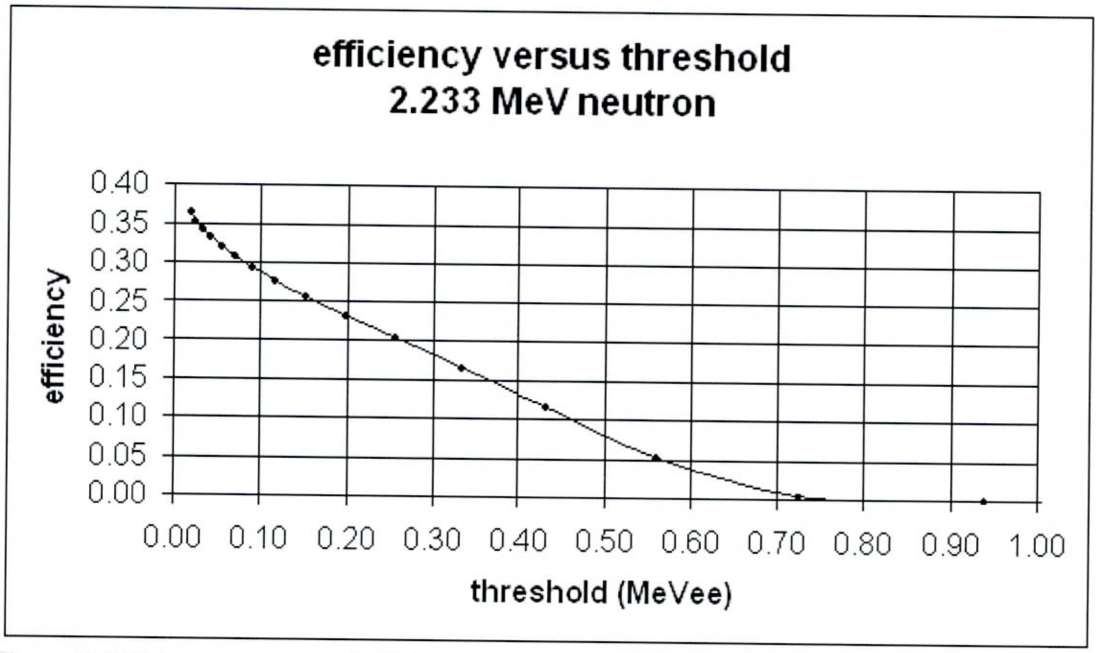

Figure 12 Efficiency versus threshold for 2.233 MeV neutrons as reported by Verbinski et al.

When we remove the solid angle factor, we find that the efficiency reported by Taleyarkhan et al. from their measurement with the PuBe source in their reply to Lipson is 4.2%. For the threshold shown in their data this efficiency appears low. Figure 12 shows efficiency data from Verbinski et al. There is a discrepancy here that needs to be resolved before a neutron emission rate from the LS can be determined.

Although the calibration of a LS with gamma ray sources is a standard, accurate, and straightforward procedure, the LS response to neutrons has an additional uncertainty. Many works have noted a difference in proton light output functions and thus an uncertainty in the neutron response. These differences in the response of various detectors of similar or even identical geometry are an experimental fact, and the implication is that for accurate work the relative light output scale for protons and electrons for each detector must be determined. This point is mentioned in Hawkes et al.,[129] a paper in which the light output of several NE213 cells is measured. Hawkes et al. also examine the algorithm by which the Compton edge is determined and find that the algorithm cited by Verbinski et al. is valid. The measured proton light output and the light output functions from various groups are often not in good agreement. For example, at 2.45 MeV Verbinski et al. find a light output of 0.800 MeVee and Hawkes et al. find a light output of 0.730 MeVee. Hawkes et al. cite Dickens[130] in reference to these differences. These differences suggest that the extrapolation from measured Compton

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[129] N.P. Hawkes, Nucl. Instr. Meth. **A476**, 190 (2002).

[130] J.K. Dickens, Proceedings of the Specialists' Meeting on Neutron Cross Section Standards for the Energy Region above 20 MeV, Uppsala, Sweden, 21–23 May 1991, NEANDC-305 'U', pp. 142–153.

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edge to proton edge has an uncertainty of ± 5 %, if the difference between Hawkes et al. and Verbinski et al. is interpreted as the typical deviation.

In their March 26, 2006 letter to the editors of Physical Review Letters (this letter is in response to the comment submitted by Naranjo), Taleyarkhan et al. argue the proton recoil edge has an uncertainty of ~20%, citing Hawkes et al. Is the uncertainty ± 20 % or ± 10 %? The letter is not clear. An uncertainty of ± 20 % is very pessimistic and for an interpolation not what is found by Hawkes et al. An uncertainty of ± 10 % is still pessimistic. An uncertainty of ± 5 % should be possible with the sources and detectors available to Taleyarkhan et al.

Whether the position of the proton edge is known to ± 5 % (± 5 channels) or to ± 10 % (± 10 channels) is not a crucial issue to PRL **96**.[131] None of the data show an obvious proton edge, and there are certainly counts beyond the proton edge, regardless of the uncertainty in its position. The presence of counts beyond the proton edge and the LS pulse height spectrum in general is discussed in the comment by Naranjo and the reply by Taleyarkhan et al. We will return to this matter.

CR-39 Track Detectors

PRL **96** also reports data from CR-39 track detectors. The CR-39 foils from Landauer, Inc. are 1 cm by 2 cm by 1 mm. These detectors are widely used for personal dosimetry, but they also are used for scientific applications. J. A. Frenje et al.[132] report on their use in fusion research. Proton recoils from neutron interactions cause radiation damage in the foil. Etching in a caustic bath produces a pit at the point of the damage, and the pits are counted. The pits are easily seen under a microscope, and the counting could be by hand or automated. Taleyarkhan et al. count the pits by hand. Pre-existing tracks must be accounted for, and the pit development depends on processing conditions. Taleyarkhan et al. expose some track detectors to the PuBe source to calibrate their processing procedure. They obtain an efficiency for track formation of 6 x 10^{-5}; this value is in good agreement with Frenje et al.

The data from the track detectors is reported in Table 2 of the PRL **96** supplement. Taleyarkhan et al. report that "On the aggregate, the production of neutron tracks for the deuterated liquid amounted to a ~14 SD change, whereas, for the control liquid the changes were within 0.5 SD. Doing the arithmetic for ourselves, the track detectors come from two batches, which had 13 ± 2 and 19 ± 2 pre-existing tracks. For batch 1 with cavitation on for two hours 22, 25, 23, and 27 tracks are found in four track detectors. For batch 2 with cavitation on for two hours 32, 27, and 27 tracks are found in three track detectors. For batch 1 then we find 11.5 ± 3.0 net counts so mean / sigma = 3.8, and for batch 2 we find 10.3 ± 4.0 net counts so mean / sigma = 2.6. It is not clear how Taleyarkhan et al. obtain a "~14 SD change."

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[131] The position of the proton edge is a crucial matter to *Science* 295 as noted by its many critics.

[132] J. A. Frenje et al., Rev. Sci. Instr. **73**, 2597 (2002).

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Sodium Iodide Detector

PRL **96** also reports data from a NaI crystal, a gamma ray detector. In PRL **96** Taleyarkhan et al. report a difference in the NaI spectrum between the deuterated and normal sample, and they interpret this difference as evidence of sonofusion. These data are not of high quality, but, since they appear in the reply to the comment of Naranjo, they deserve mention. Figure 13 shows the ^{60}Co calibration spectrum of the NaI detector. For no good reason the gain of the detector and electronics is set at approximately 100 keV per channel. Full scale then is of the order of 20 MeV. This gain makes it very difficult to identify the energy of a gamma ray. The four spectra, deuterated and normal with cavitation on and cavitation off, are shown in figure 13. The signal found in these data and reported in PRL **96** is the 16,176 – 15,844 = 332 ± 179 count difference between the cavitation on and cavitation off spectra for the deuterated sample. Taleyarkhan et al. suggest in the PRL **96** supplement that "The ~1 MeV region's accumulation of counts may be attributed to gamma emissions when neutrons get absorbed in the chlorine atoms of the test liquid (which has a large cross-section of about 33 barns)." This statement is, of course, a speculation.

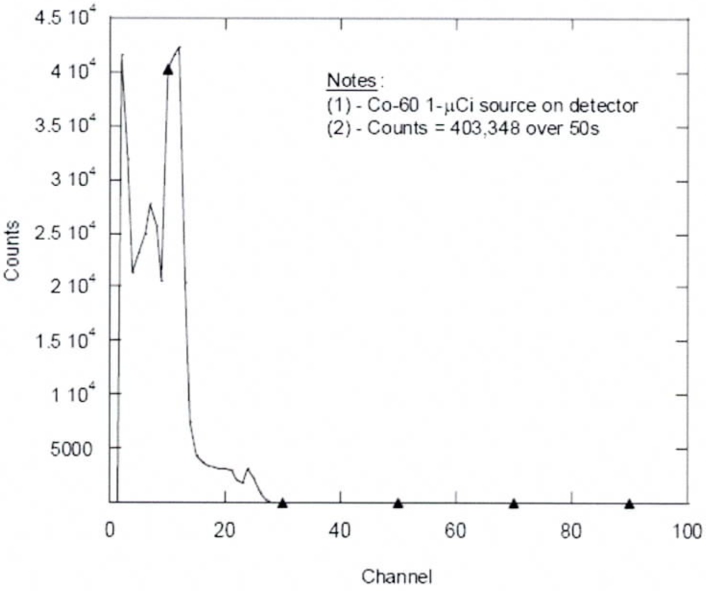

Figure 13 NaI calibration spectrum from PRL 96 supplement Figure 14.

It is surprising that there is no comment about the peak in channel 14 of all four gamma-ray spectra, a feature much more prominent than any increase in counts around channel 10. If there is neutron production, one could wonder why there is no increase in the number of counts around channel 25. The shielding has a large amount of hydrogen and neutron capture would produce 2.2 MeV gamma rays. We believe that any gamma ray data would be difficult to interpret and that these poor quality gamma ray data carry little information.

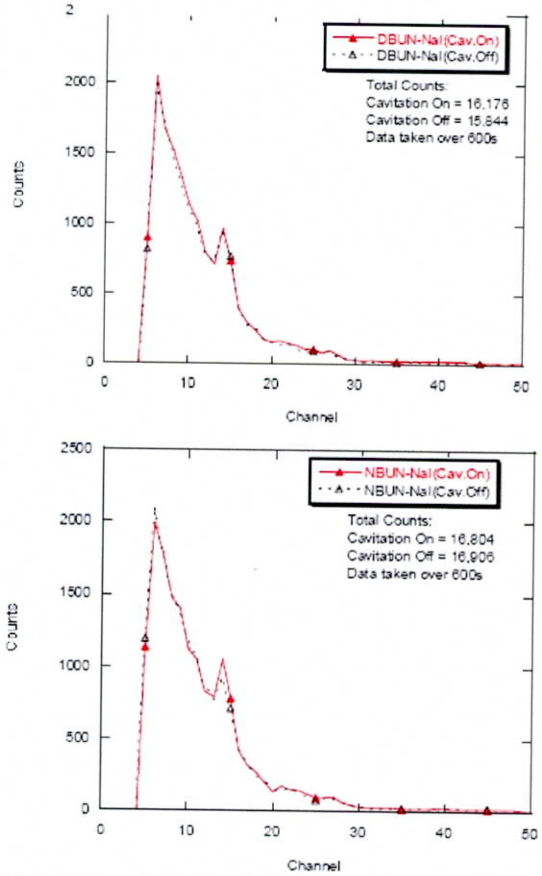

Figure 14 NaI spectra for deuterated and normal samples with cavitation on and cavitation off from PRL 96 supplement figure 15a, b.

PRL **96** concludes with the statement that "statistically significant emissions of 2.45 MeV neutrons were measured with multiple independent detectors during self-induced cavitation experiments in deuterated benzene-acetone mixtures…" PRL **96** is claimed to support the earlier work in PRE **69** and *Science* **295**. The elimination of an external neutron source is new to the work of PRL **96**. The data presented in PRL **96** do appear to show a signal from the deuterated sample with cavitation on, and the emission of 2.45 MeV neutrons would be a possible explanation of this signal.

However, this conclusion is suspect since the work of PRL **96** has arithmetic errors, errors in detector efficiency, and errors in detector calibrations. All of these errors appear to enhance the signal, and the number of errors is worrisome. Further investigation could determine that these errors do represent "practices that seriously deviate from those that are commonly accepted within the scientific and academic community."

Comment by Naranjo and Reply by Taleyarkhan

We return to the comment by Naranjo and the reply by Taleyarkhan et al. concerning the LS pulse height spectrum. We noted that this spectrum is quantitatively and qualitatively different from the spectrum that would be produced by a 2.45 MeV neutron. We noted that the deviation could be due to scattering in the sample, the cell, the thermal shielding, and the external shielding. Naranjo has made a Monte Carlo simulation of these effects, but he is unable to account for the spectrum. The geometry of Naranjo's simulation is shown in Figure 15.

Naranjo uses the GEANT4 simulation package. The simulation allows for interactions in the sample, the cell, and the shielding. The simulation produces some distortion of the spectrum, but not enough distortion to account for the data of Taleyarkhan et al. How should this discrepancy be understood? Does the simulation have a sufficiently realistic description of the cell, the detector and their environment? Naranjo makes reference to his successful simulation of the LS spectrum of another fusion experiment.[133] A close examination of that comparison shows that Naranjo's data and simulation shown in Figure 16 is limited to energies above 300 keVee. The greatest discrepancy between Naranjo's simulation and data of Taleyarkhan et al. is at low pulse heights. This observation is only put forward to encourage caution when evaluating Naranjo's comparison. Monte Carlo simulation is a well-established and important technique, but only with extreme confidence in the model would one argue that it could give a unique explanation of a data set.

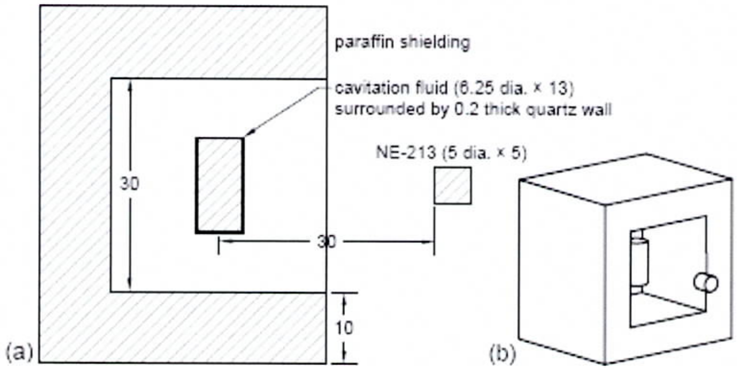

Figure 15. Monte Carlo geometry of Naranjo's simulation from supplement to his comment.

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[133] B. Naranjo, J. K. Gimzewski, and S. Putterman, Nature **434**, 1115 (2005) and supplements.

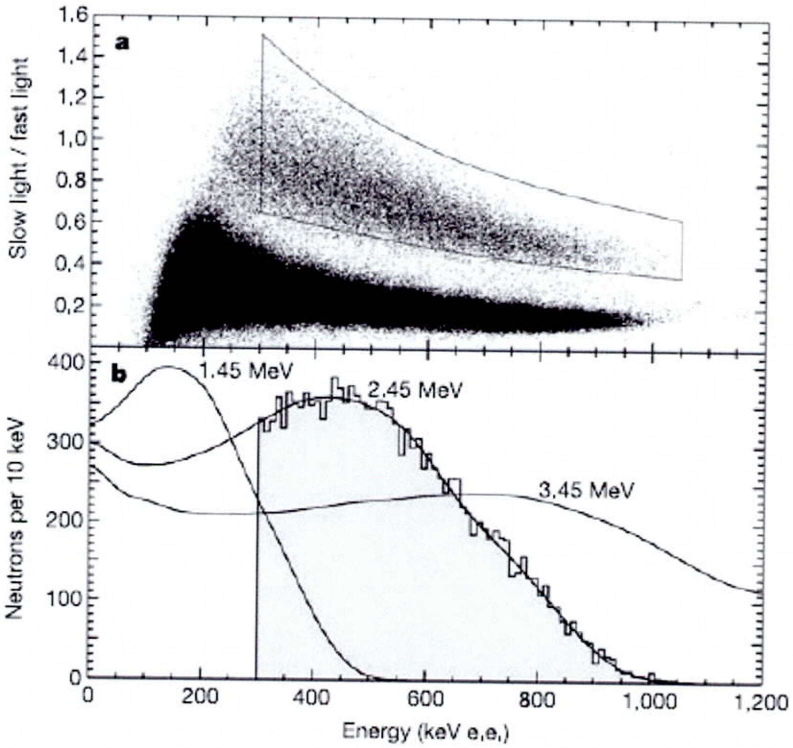

Figure 16 Data and simulation of neutron interactions from Naranjo et al. Nature 434, 1115 (2005).

In his comment, Naranjo also produces a simulation of the pulse height spectrum from cosmic rays, a PuBe source, and a ^{252}Cf source. He finds that the spectrum of Taleyarkhan et al. is consistent with his simulation using the ^{252}Cf source. Some very unguarded statements have been made about the similarity of the simulation using the ^{252}Cf source and the data of Taleyarkhan et al. The unguarded implication is that Taleyarkhan et al. used a ^{252}Cf to produce the spectrum.

The deviation between the simulated 2.45 MeV neutron spectrum and the data of Taleyarkhan et al. occur in two ways: i) the data have too many counts at low energy, and ii) the data extend beyond the proton recoil edge. We note that the spectrum of PRL **96** is similar to the spectrum in Xu and Butt and the spectrum in PRE **69**. Naranjo uses some data from Xu and Butt, but he does not note the similarity between the spectrum in Xu and Butt and the spectrum in PRL **96**. In the supplement of their reply Taleyarkhan et al. show the LS and NaI spectra from a ^{252}Cf, see Figure 17.

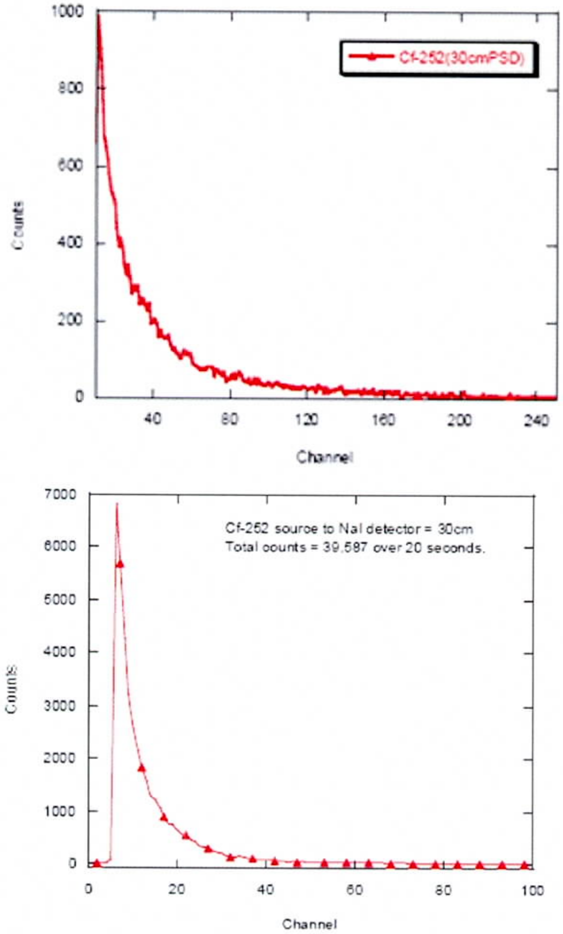

Figure 17 LS (top) and NaI (bottom) pulse height spectra from the supplement of Taleyarkhan et al. reply to Naranjo.

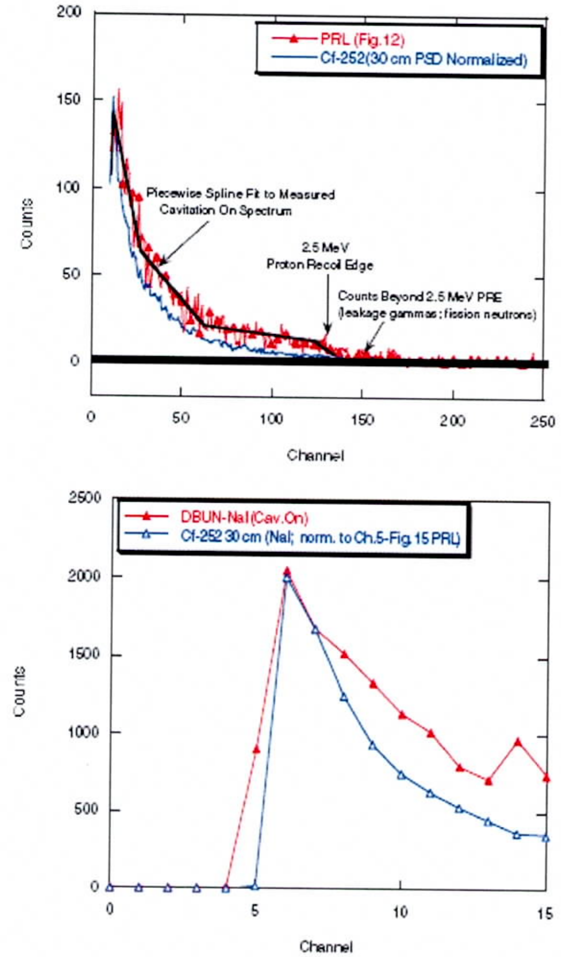

Figure 18 PRL 96 LS (top) and NaI (bottom) pulse height spectra from compared to ^{252}Cf source spectra from Taleyarkhan et al. reply to Naranjo.

They show the NaI spectrum because they argue that if the LS spectrum were due to a ^{252}Cf source, then the NaI spectrum would also be that of a ^{252}Cf source, and, in their opinion, their NaI spectrum is different from a ^{252}Cf source spectrum. In the reply itself they compare the spectra of PRL **96** to the spectra from the ^{252}Cf source. This comparison is shown in Figure 18. The NaI spectra in Figure 18 (bottom) is not plotted above channel 15 so it is impossible to make a good comparison. The normalization of the spectra tries to emphasize the difference, namely, the peak at channel 14. In any case, the NaI spectra and the LS spectra should be understood individually.

In Figure 18 (top) the presentation tries to show a difference between the PRL **96** spectrum and the ^{252}Cf source spectrum. The thick black line obscures the counts beyond channel ~120, and the spline fit introduces a proton recoil edge at channel ~120. Neither of these embellishments is useful, and both obscure the similarity of the PRL **96** spectrum and the ^{252}Cf source spectrum. To be absolutely clear, the similarity between the two spectra does not demonstrate that the PRL **96** spectrum is a ^{252}Cf source spectrum. With a different normalization the blue ^{252}Cf source spectrum would sit on top of the red PRL **96** spectrum.

Taleyarkhan et al. argue that the counts beyond channel ~120 could be due to neutron-induced fission in the cell on the ^{235}U and ^{238}U of the uranyl nitrate. Naranjo has supplied an email from an anonymous reviewer of his comment to the Inquiry Committee.

> On p. 5 of Taleyarkhan's March 24 rebuttal, he estimates the contribution of neutrons from induced fission of uranium. For the U-238 contribution he assumes all the neutrons to have an energy of 2.5 MeV, well above the fission threshold. For neutrons of 2.5 MeV the fission cross section of ^{235}U is only twice the U-238 cross section. To balance the tiny ^{235}U abundance of 0.7%, Taleyarkhan gets an enhancement by a factor of 2,000 for the ^{235}U contribution by assuming all neutrons are thermal, with a fission cross section of 1,000 barns; it's actually 580 barns. Fast neutrons when its suits the ends, thermal neutrons when that suits the ends.

The reviewer clearly has no patience for self-serving arguments, and the reviewer recommends publication of Naranjo's comment. Naranjo has supplied to the Inquiry Committee the correspondence among the editors of *Physical Review Letters*, Taleyarkhan, and Naranjo. The claim of Taleyarkhan et al. that the spectrum of PRL **96** and the spectrum from a ^{252}Cf source are "quite different" is unconvincing. The claim that there is a proton recoil edge at 2.45 MeV is unconvincing. The claim that there are counts beyond channel ~120 is also unconvincing.