EXPERIMENTAL EVIDENCE OF COLD NUCLEAR FUSION IN A MEASUREMENT UNDER THE GRAN SASSO MASSIF


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ABSTRACT

We have observed the emission of 2.45 MeV neutrons following the electrolytic infusion of deuterons into titanium electrodes. The present results were obtained by n-\gamma discriminating proton-recoil detectors at the Gran Sasso Laboratory. The observed neutron emission rate is comparable in size to the one recently reported by Jones and coll.

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1. Introduction

In a recent experiment, Jones et al. detected the neutrons emitted following the electrolytic infusion of deuterons into Ti (and Pd) electrodes. The 2.45 MeV neutron energy, which was measured by a sensitive spectrometer, is characteristic of the nuclear fusion reaction

\[ d + d \rightarrow ^3\text{He} + n + 3.3 \text{ MeV} \]  \hspace{1cm} (1)

The observation was then attributed to the catalysis of such a process, occurring when deuterons (and metal salts from the electrolyte) are deposited at (and into) the metal electrodes.

We report here the preliminary results of a new measurement of the neutrons released following the electrolytic infusion of deuterons into Ti electrodes. Our first objective was to observe the effect found by Jones et al. under privileged neutron-background conditions and with a different apparatus. Having this in mind, we have planned an experiment based on the following points:

i) to perform the measurements at the INFN Gran Sasso Laboratory, which provides an exceptional natural screen (4000 m water thickness equivalent) with respect to cosmic radiation;

ii) to use proton-recoil liquid scintillators as neutron detectors, which allow to distinguish effectively neutrons from gamma-rays through a well established pulse-shape discrimination technique.

iii) to perform simultaneous measurements in two equal detectors: counter A (where the neutron emission was to be observed) and counter B (which was set in a remote position
from A, and monitored the background counts).

The electrolytic solution of $\text{D}_2\text{O}$ and metal salts (0.2 g in 20 cm$^3$ of $\text{D}_2\text{O}$) was the same as the one used in the previous work$^{11}$.

The results reported here were obtained by a preliminary set-up, in which the neutron counters were operating with minor additional shieldings within the Gran Sasso Laboratory hall.

2. **Apparatus and measurements**

The electrolytic cells were 6 cm high, 4 cm in diameter glass containers. Gold foils, having a thickness smaller than 250 $\mu$m, were used as positive electrodes. The negative ones were made of fused titanium pellets, about 1 g in weight. The DC power supply provided 6-10 V with currents of 40-60 mA across each cell. Typically three cells were operated simultaneously.

The scintillator of the neutron counters was NE-213 liquid, contained in cylindrical glass cells, 5 cm thick and 12.5 cm in diameter. The n-$\gamma$ discrimination was obtained by the method of gating separately the fast (E) and slow (T) component of the same scintillation pulse$^{22}$. Neutrons and gamma-rays distribute then on different regions in a two-dimensional display of the (E,T) signals from the same detector pulse (n-$\gamma$ plot). The same counters were effectively used to detect 2.45 MeV neutrons coming from process (1) occurring in muon-catalyzed fusion of $d+\mu$-d molecular ions.$^{33}$

The n-$\gamma$ discrimination figures were first established by means of an $\text{Am-Be}$ source. The energy calibrations were obtained by $^{22}\text{Na}$ and $^{137}\text{Cs}$ sources, providing 0.511, 1.275 and 0.66 MeV gamma-ray peaks, respectively. These measure-
ments, which were frequently repeated during the runs, were used to determine the neutron-energy scale, on the basis of measured electron-to-proton energy response curves. They also provided the energy resolution of our counters, which turned out to be about 28% at 0.77 MeV (electron equivalent energy).

Previous background measurements showed that the γ-ray discrimination effectuated by our counters was better than $1/10^4$ at the lowest cut operated in the ($E, l$) plot on the neutron region identified by the Am-Be source.

In the Gran Sasso Laboratory, the same cut provided a counting rate in the neutron region which was consistent with the $1/10^4$ γ-rejection efficiency, and with a very low neutron background (of the order expected on the basis of previous measurements). Under these conditions, a neutron emission rate of the order of the one reported by Jones et al. was expected to be clearly detectable.

The cells were kept in front of counter A. Counter B was kept about 8 meters apart from A. Background measurements were performed before and after operating the cells.

The n-γ discrimination threshold was set at a level fixed by the previous calibrations for the on-line analysis. The measurements were carried out in subsequent runs of about one hour each. After about one hour following the connection of the cells to the power supply, the counting rate of neutrons defined in this way markedly increased, went through a maximum, and eventually dropped (in about three hours) at the level of the background counts.

This behaviour was observed in two subsequent sets of measurements. The neutron counting rate in detector A fell at the background level when the cells were removed while the rate of signals was close to its maximum. Counter B, to which the cells were then approached, recorded a significant
signal increase.

3. Analysis and results

The data were successively processed in the off-line analysis, where the final n-γ discrimination threshold was established run by run by looking directly at the (E, T) plot of the collected events. Minor adjustments had then to be introduced, to account for small variations of the centroid of the T-signals distributions. This readjustment did not significantly affect the overall results. In particular, the number of neutrons detected at the most severe T-signal cuts turned out to be practically unaffected by the analysis.

Fig. 1 shows the behaviour described for the two detectors during one cycle of runs, as obtained off-line after subtraction of the background. Runs 14 and 21 were performed before and after operating the cells. Runs 17 to 19 correspond to the time interval during which detector A recorded a significant signal-to-noise increase, which disappeared during run 20 (while the cells were still under operation).

From the upper part of the Figure, it is seen that, when the n-γ cut (T-cut) is low (530), and a significant contamination of gamma-rays is included within the accepted events, the signal is compatible with zero. In this case, no difference is recorded between the background runs 14 and 21, on the one hand, and runs 17-19, on the other. When the cut on the T-pulses is set sufficiently high (540), instead, a significant signal is present during runs 17-19 in counter A. Such a signal obviously reduces when the T-cut is increased further.

In the lower part of the Figure, the corresponding behaviour of detector B is shown for T-cuts operated with the same criterium as above. It is seen that no comparable signal corresponding to runs 17-19 is present in the remote
detector B. Furthermore, this counter does not show any particular fluctuation of the background counting rates during the runs in which the cells were operating.

This behaviour was confirmed during the second set of experiments. The total number of collected neutrons, for a lower-energy cut of 0.3 MeV (electron equivalent energy) was (350±51).

As a second step, we analyzed the energy spectrum of these neutrons by looking at the distribution of the relevant amplitude (E) signals. The results obtained are presented in Fig. 2, where they are compared to the Monte Carlo-calculated amplitude spectrum for 2 MeV neutrons impinging on our detector. The calculation took into account the geometry of the detector, its observed energy resolution and the quoted energy response curve of the NE-213 liquid to electrons and protons. We conclude that the observed energy spectrum within experimental errors corresponds to 2.45 MeV neutrons.

We interpret these results as the evidence of the emission of 2.45 MeV neutrons by the cells during their operation.

4. Discussions and conclusions

On the basis of the Monte-Carlo calculation, and of the calibrations performed, the overall efficiency of counter A turned out to be (4 ± 0.6)×10⁻² for 2.45 MeV neutrons, when a low-energy cut is operated at about 0.3 MeV (electron equivalent energy). This number includes a solid angle of about 25×10⁻², with which the cells were viewed by the detector.

Keeping into account that the neutrons collected (see Fig. 2) were obtained during a total cell operation period
of about 10 hours, this would correspond to an observed neutron emission of about \( (875 \pm 183) \) neutrons/hour.

In order to compare it to the one (about 1500 neutrons/hour) reported by Jones et al.\(^{13}\), the following points of difference should be recorded between the present and the previous\(^{11}\) experiment:

i) Typically four cells, having characteristics similar to ours, were used in the past (to be compared to three in the present work). Scaled up for a \( 4/3 \) factor, our observed neutron emission becomes about 1200 neutrons/hour.

ii) We used for the present measurements an almost double proportion of the metal salt mixture with respect to the previous work.

iii) The measuring time interval during which we observed a detectable effect in connection to the operation of a set of cells is smaller by a factor of about \( 5/8 \) with respect to the corresponding time which was evidenced out by Jones et al.\(^{13}\).

Keeping in mind these differences (point ii) and iii) may be connected to each other), we should like to formulate the following conclusions:

i) the present results confirm the emission of 2.45 MeV neutrons following the electrolytic infusion of deuterons into Ti electrodes.

At the present status of knowledge, the only reasonable explanation we see for this fact is that reaction (1) is actually catalyzed when deuterons are made to diffuse up to Ti electrodes. We consider then the present results as further evidence of the occurrence of cold nuclear fusion in metals.

ii) The rate of observed neutrons is of the order of the one
previously observed by Jones et al.12 Under this respect, their experiment is confirmed by the present measurements, with a statistics which is more than twice and an entirely different detection system.

iii) It is confirmed that electrochemistry plays in this type of measurements a quite significant and critical role.

iv) The present results also point out that the apparatus can be optimized, both as far as regards the type of electrolyte, and by further reducing the gamma-background component by suitable shielding procedures. The fact that the neutron emission effect was detected by using directly n-pulse shape discrimination detectors, without any further significant background-rejecting technique, underlines the essential role of the Gran Sasso Laboratory in providing an extremely effective tool for looking at small radiation effects.

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FIGURE CAPTIONS

Fig. 1 - Background - subtracted neutron counting rates observed in counter A and B during one set of measurements. Runs 14 and 21 correspond to background measurements performed before and after operating the cells. Runs 17 to 20 were taken while the cells were set under DC voltage. Runs 14 and 21 were consistent with other background measurements performed in the Gran Sasso Laboratory. However, the subtracted background level in the Figure is the average between the ones detected in Runs 14 and 21. A lower-energy cut at 0.3 MeV (electron equivalent energy) was operated on the selected events. The n-γ cuts on the (E-T) plots were
performed with the same criteria for the two detectors; the units reported are only average reference numbers.

Fig. 2 - Background-subtracted energy distribution of the (350±51) neutrons detected in the present measurements.
Abscissae: upper scale, electron-equivalent energy; lower scale, proton-equivalent energy.
The continuous curve represents the Monte Carlo calculated energy distribution for the neutron detector.