ISTITUTO NAZIONALE DI FISICA NUCLEARE

Sezione di Catania

INFN/BE-90/05
20 Marzo 1990

S. Aiello, E. De Filippo, G. Lanzanò, S. Lo Nigro and A. Pagano:

NUCLEAR FUSION EXPERIMENT IN Pd CHARGED BY DEUTERIUM GAS

Servizio Documentazione
dei Laboratori Nazionali di Frascati

INFN - Istituto Nazionale di Fisica Nucleare
Sezione di Catania

INFN/BE-90/05
20 Marzo 1990

Nuclear fusion experiment in Pd charged by deuterium gas

S.Aiello, E. De Filippo, G.Lanzanó, S. Lo Nigro and A. Pagano

Dipartimento di Fisica dell'Università di Catania
Istituto Nazionale di Fisica Nucleare, Sezione di Catania
Corso Italia,57 - I 95129 Catania (Italy)

ABSTRACT

A Pd-D system subject to different experimental thermodynamic conditions was studied in order to look for low-temperature d-d fusion reactions. Neutrons, light charged particles and energetic γ *rays were detected. No significant effects were observed in the neutron and* γ *ray measurements. From the analysis of the light charged particles a fusion rate* $\lambda_f \approx 10^{-23} events/(D_2 \times sec)$ *was deduced.*

1. INTRODUCTION

It has been suggested recently$^{1,2)}$ that deuterium in hydrideforming metals (i.e. palladium and titanium) can undergo nuclear reaction at room temperature.

Such a fascinating supposition has stimulated a variety of both experimental and theoretical investigation in the scientific community. But, up to now, the experimental information is quite incomplete and a clear signature of the phenomenon does not yet exist.

Furthemore, if we consider the matter from the experimental point of view , the actual controversy seems to be related to arguments concerning fundamental questions as the reproducibility of the observations and the adopted experimental procedure.[3)]

In our case the metal-deuterium system was obtained by a gas absorption method similar to the one employed by De Ninno et al.[4)]. However, we investigated different dynamic conditions by changing temperature and pressure of a Pd-D system. In fact, an enhancement in d-d fusion process rate is expected in hydrogenated metals during gas absorption in non equilibrium states, as suggested by Cassandro et al.[5)]

Assuming that d-d nuclear fusions could occur during phase transitions, we focused the attention to study the nuclear products of the following reactions:

$$d + d \rightarrow ^3He + n \qquad (1)$$

$$d + d \rightarrow ^3H + p \qquad (2)$$

$$d + d \rightarrow ^4He + \gamma \qquad (3)$$

2. EXPERIMENTAL APPARATUS AND PROCEDURE

2.1 Palladium-deuterium system

A schematic drawing of the experimental apparatus is shown in fig.1. A thick sample of Pd (99,8%) in the shape of a rectangular sheet, 1×1 cm^2 of surface and 1mm of thickness, was put inside a stainless steel cell of about 15 cm of diameter. The cell was connected to a deuterium-gas cylinder through a valve and a pressure regulator. The mechanical arrangement was tested for vacuum and high pressure both at room temperature and liquid nitrogen temperature.

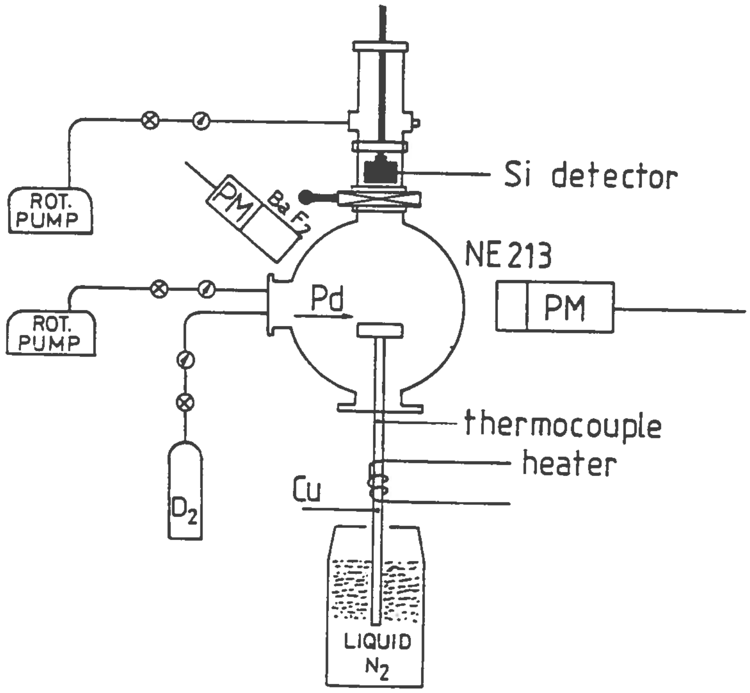


FIG.1-*Schematic drawing of the experimental apparatus*

The Pd sample was attached to a proper copper support in order to ensure a good thermal contact during the change of the temperature of the system.

The copper support was surrounded by a special dewar during the phase of cooling up to the liquid nitrogen temperature and by an electric heater during the phase of heating up to about 300°C.

An auxiliary line allowed us to evacuate the cell up to 10^{-1}torr. Both the pressure inside the cell and the temperature of the copper support were continuously monitored.

The Pd-D system was prepared in the following way:

1) The Pd sample was kept at 77°K under D_2 pressure of 10 bar for ≈ 15hours.

2) Successively the system was subject to dynamical transitions for ≈ 22hours, as shown in fig. 2. During this period the Pd-D system is expected to change the stechiometry from $Pd\text{-}D_{0.3}$ to $Pd\text{-}D_{0.7}$ and then to pure Pd. The compositions were tested on various Pd targets prepared by the same way and measured by Nuclear Reaction Analysis (NRA) [6].

3) Finally the system was left at room temperature under vacuum for ≈ 9hours.

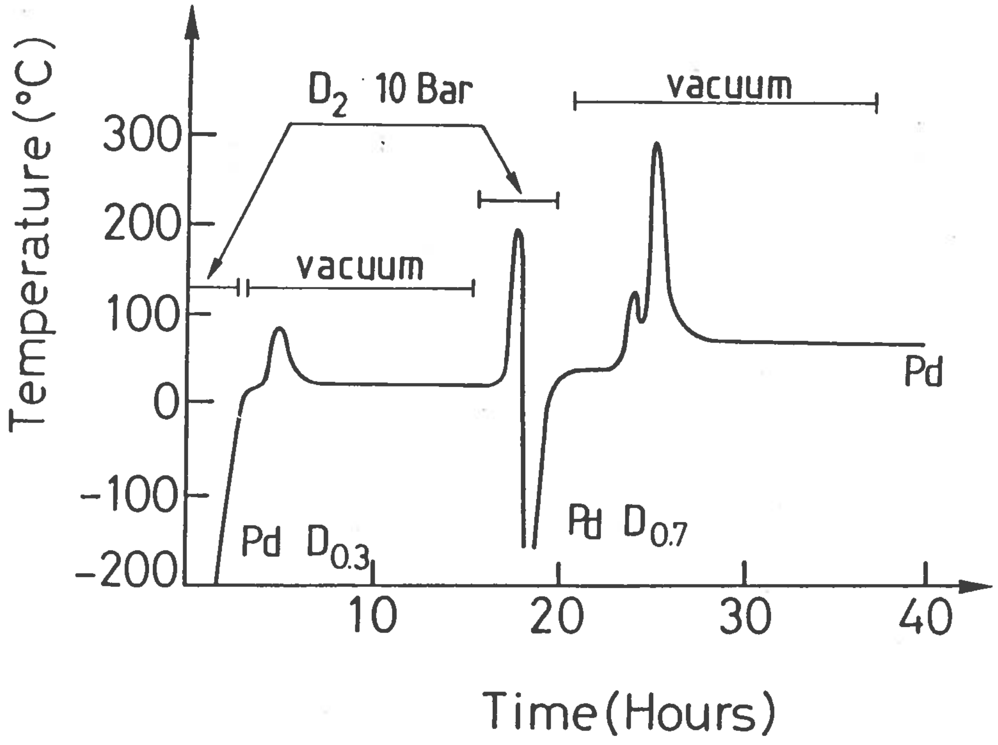


FIG.2- *The temperature of the Pd-D system versus the elapsed time. The stechiometry of the Pd-D sample and the pressure of deuterium gas are also indicated*

2.2 Detectors

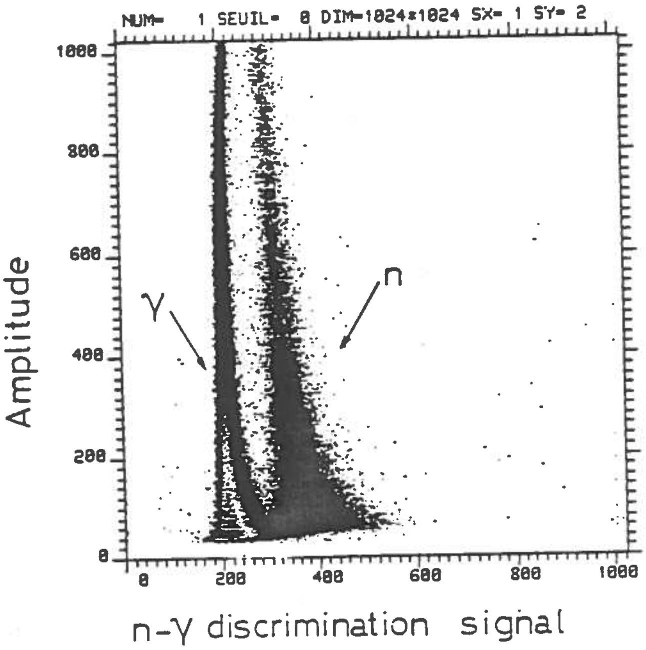
We used three different kinds of detectors.

The neutrons counting rate was monitored by a liquid NE213 scintillator (2in.×2in.) placed outside the cell. The scintillator was optically coupled with a photomultiplier. In order to identify neutron counts, the shape of the anodic signal was properly analysed. A typical bidimensional matrix of the n-γ dicrimination established by means of a standard ^{252}Cf source is shown in fig. 3. The bidimensional matrix was obtained at room temperature both at the beginning and at the end of the experiment. In addition, the matrix was verified both at low and high temperatures of the cell.

The overall detection efficiency of the neutron counter (including the geometric efficiency) was estimated to be $\approx 3.10^{-4}$.

The γ-rays with energy higher than 10 MeV were monitored by a BaF_2 (5cm diameter $\times$ 10cm long)scintillator crystal placed quite close and externally to the cell.

FIG.3- *The obtained neutron-γ discrimination using a standard ^{252}Cf source. The bidimensional array shows the anodic pulse versus the neutron-γ discrimination signal*



Finally, the charged particles were measured by means of a large area (450mm^2) silicon surface barrier detector(SSB) . In order to prevent damages to the SSB detector, during the change of pressure and/or temperature in the Pd-D sample, the detector was located into a separate vacuum chamber connected with the cell by a valve. The detector was placed in front of the Pd sheet, at ≈20mm of distance, only when the pressure in the cell was less than 10^{-1}torr.

In order to have a rough identification of the detected particles, the SSB detector was covered by an Al absorber thick enough ($\approx 35\ \mu m$) to stop protons of about 1 MeV kinetic energy.

During the experiment both the external temperature and the electronic threshold of the detectors were continuously monitored.

A connection of the detection apparatus with a personal computer acquisition system allowed us to store the experimental data in an event by event mode.

3. RESULTS AND DISCUSSION

The response of the BaF_2 scintillator for a total time of seven days is reported in fig.4. The γ ray counts were obtained by integrating the spectrum from 10MeV to 30MeV at intervals of 20 minutes.

No change in the counting rate was observed during the "fusion experiment" indicated as a) in fig. 4. Within the experimental sensitivity of the used detector the contribution of the reaction (3) was not evidenced.

The SSB detector spectrum (energy calibrated) was obtained by summing the counts of four runs for a total exposure time of 16hours. The spectra of the different runs showed similar shapes within the statistical errors. In particular we noted the presence of an exponential decreasing tail in the energy region between 330KeV (the electronic SSB threshold) and 650KeV. This component of the spectrum was present also during various "background" runs performed by putting the SSB detector in a $\approx 10^{-1}$torr atmosphere of hydrogen at room temperature.

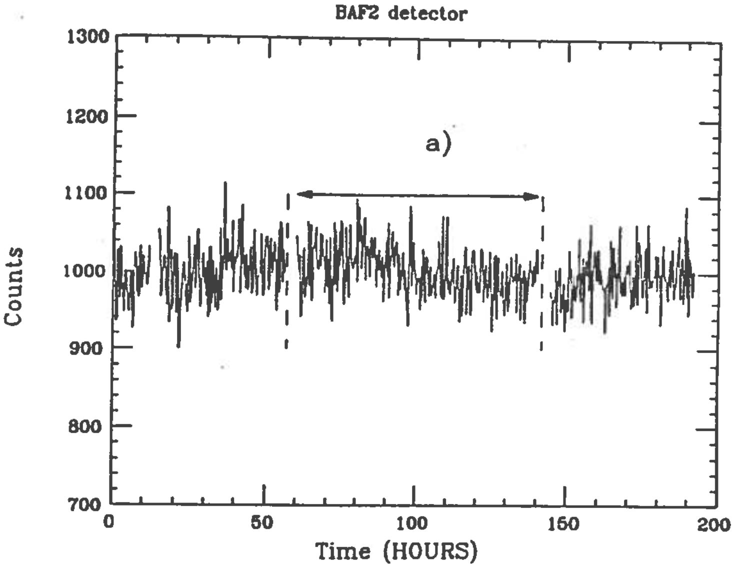


FIG.4- *Time evolution of the counting rates of the BaF_2 scintillator. The region a) indicates the results obtained during the fusion experiment.*

Fig. 5 shows the SSB spectrum where the low energy noise contribution was subtracted. It can be observed in the spectrum a broad component peaked at about 1.8 MeV with 106 total counts. Taking into account both the electronic threshold and the energy loss in the Al absorber covering the SSB detector, that bump is consistent with the detection of 3 MeV protons coming from the reaction (2), being excluded the detection of tritons (1.01 MeV).

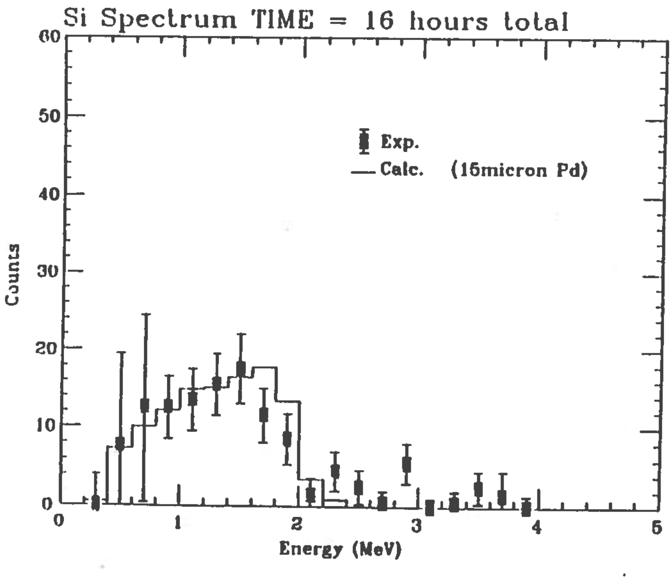


FIG.5- *Energy spectrum of the Silicon surface barrier detector. The background contribution to the spectrum was subtracted*

In order to test this hypothesis a simple Montecarlo calculation was performed. We assumed that protons of 3MeV energy were emitted isotropically from an internal point of the Pd sample and that, after the particles crossed both the Pd layer and the Al absorber (where energy loss was properly calculated by using tabulated energy loss in the materials), they were detected into the SSB. We estimated also the effective solid angle efficiency taking into account the effects of the actual geometry. In the calculation the deuterium was assumed uniformly distributed in a fixed layer of the Pd lattice. In fig. 5 the calculated spectrum obtained for a layer of $15\mu m$ of palladium and $35\mu m$ of Al absorber is shown. We can note that the experimental and calculated spectra are in a good agreement. However in the frame of this calculations we observed that Pd layers greater than 15μm were also compatible with the data. In fact, the increase of the Pd layer strongly modifies only the shape of spectrum with an energy less than $\approx$ 400KeV ,near to the SSB electronic threshold. So we can estimate only a lower limit of the effective Pd layer. By assuming a D/Pd ratio equal to 1 we could give an estimation for the fusion rate of $\approx 10^{-23} events/(D_2 \times sec)$, that agrees with the value claimed by Jones1) and by ref.7)

The results on the neutron emission are reported in Fig.6 and Fig.7. The counting rate of neutrons, as deduced from the n-γ discrimination matrix during the background measurements and the fusion experiment, are shown as a function of time in fig. 6 and fig. 7 respectively. Each value represents the counts integrated over a period of 30 minutes.

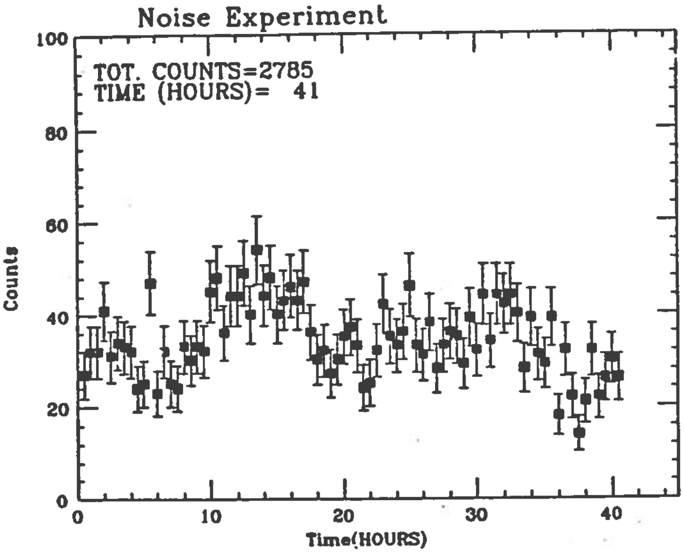


Fig.6-*Neutron counts obtained during the background measurements*

Background measurements (fig.6)were performed for 41 hours and 2785 total neutron counts were collected. The mean value and the variance resulted $< m >= 34.4\pm0.2$ and $\sigma= 8.0$ (counts/30minutes) respectively. This variance could be imputed in part to the method used in order to extract the neutron counts from the n-γ discrimination matrix and in part to the background day by day changes.

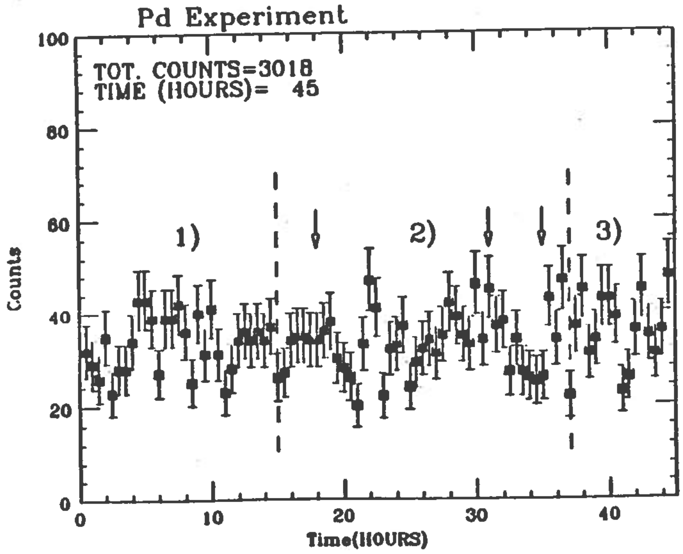


FIG.7-*Neutron counts obtained during the fusion experiment. The three different regions: 1),2) and 3) are described in the text. The arrows correspond to the three phase transitions of Pd-D system.*

The fusion experiment was performed for 45 hours where 3018 total neutron counts were collected (fig.7). The mean value and the variance were $< m >= 33.9\pm0.1$ and $\sigma=$ 6.6 (counts/30minutes) respectively.

The three phases of the "cold fusion" experiment, as described in the text and shown in fig.2, are indicated with the numbers 1), 2) and 3) respectively. In the region 2) the arrows show the time interval where phase transitions of the Pd-D system are expected.

The neutron counts obtained during the evolution of the Pd system do not show any significant differences from the background measurements . However, in the hypothesis that the fusion rate deduced from the light charged particle results is the same for the reactions (1), one can estimate the number of the neutrons expected. By knowing the detector efficiency and by assuming an emission from the whole of the Pd sample, we calculated that the excess of the number of neutrons coming from the fusion d-d reaction over the one from the background could be equal to ≈ 12 counts for 40 hours. This counting rate obviously remains hidden in our background signal.

In conclusion, the fusion rate per deuterium pair λ_f obtained is in good agreement with the upper limit values reported in ref.[1,7,8]) but it is four order of magnitude smaller than that deduced from ref.[4]). Our experimental apparatus is insensitive to the values of λ_f quoted in ref.[9])

The results presented stress the importance to perform measurements by improving both the light charged particle identification system and the sensitivity of the neutron detection [10]) with respect to background in order to obtain more definitive conclusions on the existence of the investigated processes.

The authors wish to express their warmest thanks to S.Leotta, N.Marino, O.Parasole, V.Parasole, S.Reito, A.Trovato and S.Urso for their skilful thecnical assistance and F. Arriva for careful drawings.

They are grateful to U.Campisano, P.Baeri and L.Torrisi for helpful discussions and suggestions during the experiment and for their help in preparing the Pd-D sample.

Finally the authors express their gratitude to G.V.Russo and R. Fonte for their help in operating the acquisition system.

REFERENCES

1) S.E. Jones, E.P. Palmer, J.B. Czirr, D.L. Decker, G.L. Jansen, J.M. Thorne, S.F. Taylor, and J.Refelski, Nature **338**, 737 (1989)
2) M. Fleischmann, S. Pons, M.J. Hawkins, Electroanalyt. Chem. **261**, 301 (1989)
3) Proceedings of the Workshop on " Understanding of cold fusion Phenomena" held in Varenna (Italy), 15-16 September 1989 (in press)
4) A. De Ninno, A. Frattolino, G. Lollobattista, L. Mertinis, M. Martone, L. Mori, S. Podda, and F. Scaramuzzi, Europhysics Letters **9**,221 (1989)
5) M. Cassandro, G. Cavallotti, and G. Jona-Lasinio, Preprint Dipartimento di Fisica, Università di Roma (Italy)
6) A. Turos, and O. Meyer, Nucl. Inst. Methods **B4**,92 (1984) and references therein
7) K.E. Rehm, W. Kutschera and G.J. Perlow, Phy. Rev. C **41** (1), 45 (1989)
8) L. Bruschi, M.Santini, G. Torzo and G. Nardelli, Europhys. lett., **10** (4), 303 (1989)
9) M. Gai, S.L. Rugari, R.H. France, B.J. Lund, Z. Zhao, A.J. Davemport, H.S. Isaacs, and G.K. Lynn, Nature **340**,29(1989)
10) A. Bertin, M.Bruschi, M. Capponi, S. DeCastro, U. Marconi, C. Moroni, M. Piccinini, N. Semprini-Cesari, A. Trombini, A. Vitale, A. Zoccoli, S.E. Jones, J.B. Czirr, G.L. Jensen, and E.P. Palmer, Nuovo Cimento **101A**,997 (1989)