The FERMI Apparatus and a Measurement of Tritium Production in an Electrolytic Experiment

B. STELLA, M. ALESSIO, M. CORRADI, F. CROCE, F. FERRAROTTO, S. IMPROTA, N. IUCCI, V. MILONE, G. VILLORESI
INFN Roma and Dipart. di Fisica e Chimica,
Universita' "La Sapienza", P. A. Moro 2, 00185 Roma
F. CELANI, A. SPALLONE - INFN Frascati (Roma) -ITALY

ABSTRACT

FERMI is a 7 BF_3, 2 ^3He apparatus with high detection efficiency for moderated neutrons,pulse shape acquisition and good sensitivity to neutron bursts; it also performs a good statistical reconstruction of the average neutron energy. Gamma rays are detected by a complementary low background NaI detector. The total neutron background measured by the apparatus in the Gran Sasso INFN underground laboratory amounts to 0.09 Hz.

A few different experiments have been performed with the same detector (see also the following contribution)..

A D_2O-LiOD electrolysis with Pd cathode has been realized with emphasis on the cleanliness of all components. D_2 and O_2 produced gases were recombined using a room temperature catalyzator and the resulting water was monitored twice a day for tritium content; the same was done for samples of the electrolytical solution.

Loading the Pd with variable currents, an elongation of 130 μm (with much larger radial broadening)was observed in the first few days accompanied by a 60-100 % tritium excess detected in the recombined water. The measured neutron rate in the same period was consistent with the background.

1. Introduction. The apparatus.

Unambiguous detection of nuclear ashes is fundamental in cold fusion studies. Neutrons,protons,tritium and gamma rays can be individually detected in principle,with larger difficulties for protons. We have set up an apparatus to detect neutrons,gammas and tritium. The name FERMI means (in italian) "Electrochemical Fusion with Interdisciplinary dedicated Research" and refers to the collaboration of specialists in different branches.

A cross section of the apparatus is shown in fig.1. In a big structure of poliethylene moderator seven large BF_3 (2 m long) proportional counters are imbedded. In an inner gap two ^3He are aside of a longitudinal bogie allowing to extract the samples. A big NaI crystal equipped with a spe-

FRONTIERS OF COLD FUSION

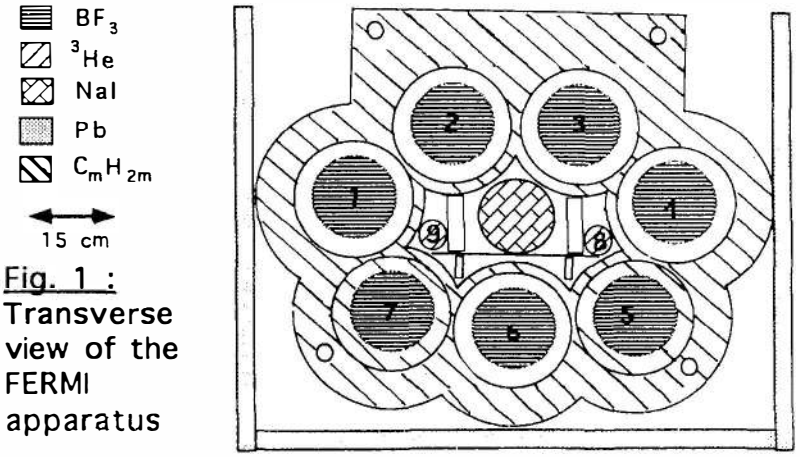

Fig. 1 : Transverse view of the FERMI apparatus

cial low noise photomultiplier, closes the gap axially.

The electronics provides per each counter 1) 100 MHz counting, 2) pulse height analysis, 3) full pulse shape acquisition within 500 μsec (for high multiplicity events). This redundancy allows internal cross checks, discrimination of neutrons from other particles, oscillations and discharges and time resolution from a few μsecs (same counter) to zero (different counters). A full automatic acquisition is performed, including timing for every event.

The detector has been fully simulated by Monte Carlo method (MCNP code), including the moderation and interaction of neutrons. Comparison with various experimental data has been used to improve the reliability of the simulation, which then has been used to compute the efficiency and to optimize various parameters. The thickness of poliethylene in front of every neutron detector (including grains in the cylindrical gap of counters 5 and 7) has been optimized to obtain the maximal efficiency and energy dependence of it (fig.2). This way the 9 rates provide a statistical reconstruction of the average energy of the neutrons by a likelihood algorithm. The final resolution is $\sigma_E/E=(16\pm2)/\sqrt{N}$ (N=total number of detected neutrons).

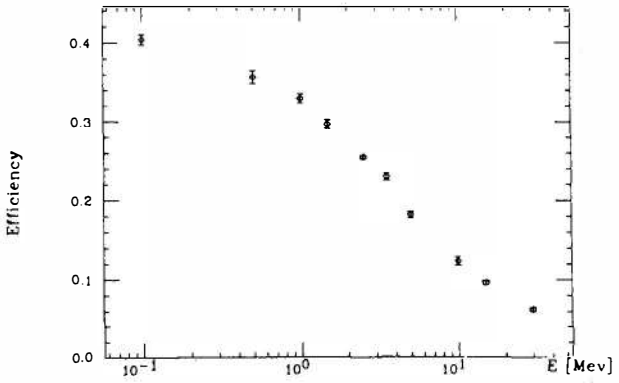

Fig. 2: Total neutron counters efficiency vs energy

To summarize, FERMI's "virtues" are: 1) high neutron efficiencies in a wide range; 2) good energy resolution;

3) low background (0.09 n/sec in the Gran Sasso tunnel); 4) good time resolution and sensitivity to bursts; 5) gammas and tritium detection; 6) multihit feature (we have observed events with up to 16 neutrons); 7) redundancy; 8) automatic acquisition (including pulse shape); 9) slow controls acquisition (temperature, pressure, voltages); 10) full MC simulation (tested).

2. The electrochemical experiment.

We have designed the cells for electrolysis with special care of the cleanliness from impurities, the minimization of systematic errors and the possibility to measure tritium content both in the solution and in the gas. A sketch of the cells is shown in fig.3. The cells body is

1) Pd cathode
2) Teflon cell
3) Entrance D_2O
4) Reference electrode
5) Thermical sensor
6) Mechanical comparator
7) Pt electrode (fine net)
8) Condensation spiral
9) Hole for D_2O pickups
10) Cathalyzator
11) Exit for recombined solution
12) Exit for pickups
13) Mechanical structure
14) Pd mechanical blocking

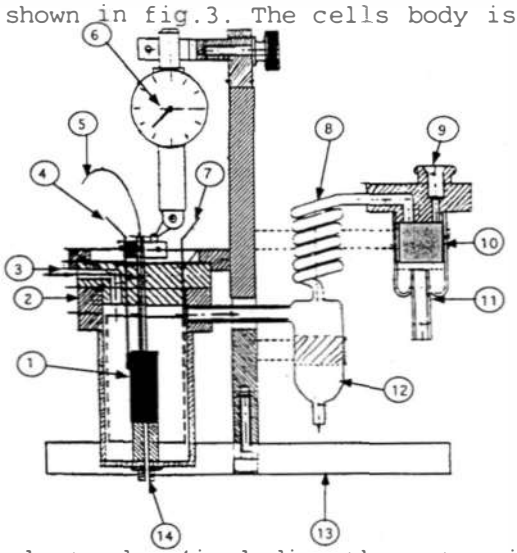

Fig. 3

made of teflon and the electrodes (including the extremities of the Pd cathode) are made of Platinum, to avoid contamination of the Pd sample. The samples (three cylinders 2.5 cm high and 4 mm diameter) were degassed in vacuum (~10^{-5} Torr) at 650 °C. The Pd temperature is measured by a thermocouple directly on the electrode.

The solution is D_2O-LiOD 0.1M and is continously provided by a peristaltic pump. The level is kept constant by the hole at right: the excess solution drops in a small container and the gases flow through a serpentine to a vessel where a room temperature catalyzator recombines D_2 and O_2 with 100% efficiency. The recombined water drops in a temporary container. Both excess solution and recombined water are sampled twice a day for tritium measurements.

The loading of Pd during the electrolysis has been monitored for cell D only, by measuring the elongation of the electrode by a micrometer.

Three cells were individually supplied with current densities up to 300 mA/cm^2. The cells were inserted in FERMI's longitudinal gap and all relevant variables were automatically acquired by computer. The electrolysis lasted about one month, using different current densities.

3. Results

After an initial loading, giving 130±5 μm elongation (together with a much larger radial broadening at center) the length of the monitored electrode came back almost to the original value (see bottom of fig.4). At top of fig.4 we report the measured activity of the samples: the letters indicate the three cells, capital for recombined water, small for solution. We find, as expected due to the isotopic effect in the ion mobility, approximate double activity for the solution respect to the recombined water, but for the four measurements in coincidence with the elongation (loading). Here we find an excess of 60% for D and 100% for A (C was not yet measured, unfortunately).

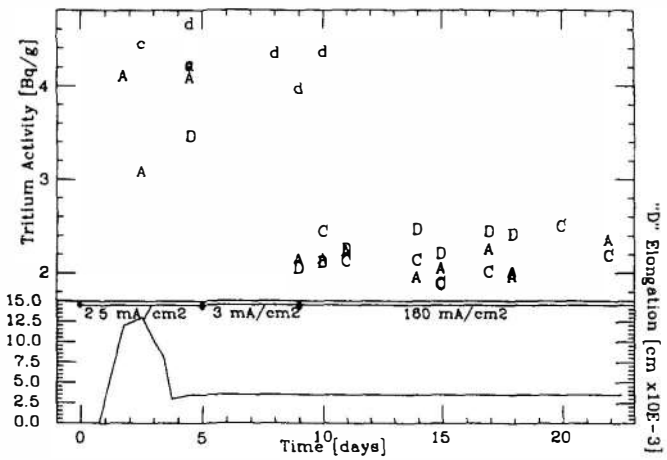

Fig. 4: upper part: specific tritium activity in the solution (lower case letters) and in the recombined gas (upper case) vs time; lower part: electrode D elongation vs time ; used current densities are indicated.

In order to check that the tritium was not accumulated originally in the catalyzer itself, we measured its activity separately. The result has been negative, with upper limit .050 Bq/cm^2 at 5σ level. Other sources of tritium are very unlikely.

The neutron rate measured during all the experiment was consistent with background. The ratio of produced neutrons over the excess tritium atoms is lower than approximately 10^{-7}, in agreement with other results [1].

4. Conclusions

We have observed a clear tritium excess in recombined water from two samples of degassed Pd. The excess happened in coincidence with a clear elongation and enlargement of the monitored sample. The effect is not due to previous enrichment of the catalyzer.

We are analyzing the data of the temperature of the samples and of the gamma rays detected in the same period.

Reference

1) Storms, E.,1991, Fusion Technology 20, 433.