UPGRADE OF THE FERMI APPARATUS WITH DETECTION AND IDENTIFICATION OF PROTONS IN THE 3 MeV ENERGY REGION.

F.F. Kayumov, B.N. Lomonosov, G.I. Merzon,
D.I. Minasyan, V.A. Tsarev
P.N. Lebedev Physical Institute, Russian Academy of Science,
Leninsky Prospekt 53, Moscow - Russia; Dipart. di Fisica Università di Roma III
at Univers. "La Sapienza", Roma; INFN Roma 1 - Italy

A. Asmone, M. Corradi, F. Ferrarotto,
B. Stella
INFN Roma 1 and Dipart. di Fisica Univ. Roma III,
Università "La Sapienza," P.A. Moro 2, 00185 Roma - Italy

F. Celani, A. Spallone, P. Tripodi
Lab. Naz. INFN - Via E. Fermi 40-00044 Frascati (Roma) - Italy

ABSTRACT

The FERMI apparatus is mainly a neutron moderator-detector developed for cold fusion research, situated in the Gran Sasso INFN underground laboratory. It has 40%-8% detection efficiency for neutrons in the range 1 keV-20 MeV (25% at 2.5 MeV), low background, pulse shape acquisition and good time resolution for neutron bursts; it also allows us to perform a good reconstruction of the average original neutron energy. Gamma rays are revealed mostly by a complementary low background NaI detector with a 26% solid angle coverage. The performances are controlled by a full MC simulation, experimentally tested.

The samples are put in the central axial gap. Aside, close to the sample (a specially designed electrolyzer with a thin Pd cathode/wall), two MWPC's and a CsI scintillator provide charged particles detection, dE/dx and E measurement, with identification of protons (hadrons) in the region of 3 MeV. The performances are tested with α particles, giving ~10% FWHM for each of two MWPC and 20% for the scintillation counter (25% and 15% respectively are expected for protons). A three-fold coincidence with very low background drives the data acquisition for charged hadrons.

INTRODUCTION

The FERMI apparatus is described elsewhere [1] and has been summarized in the abstract of this paper. Previous research activities of the FERMI collaboration are listed in [2]. Here we will only describe the upgrading with a multiple detector specially designed for protons of the dd→pT fusion reaction.

THE PROTON SYSTEM

The charged particles detectors (Fig. 1) consist of two multiwire proportional chambers (MWPC), filled by 95% He + 5% CH_4, and a CsI scintillating counter. Protons (or other hadrons) coming from a palladium foil, through a cellular brass collimator of 5 mm thickness (cells diameter being 2.7 mm drilled with 3 mm steps), pass through MWPC's (each being 9 mm thick) and stop in the CsI crystal (1 mm thick). In this way the pulse height of the two MWPC give the dE/dx of the particles and the CsI photomultiplyer provides their residual energy.

A permanent calibration of the system is provided by a ^{241}Am α particle source (of ≈ 10^{-1} per minute intensity) placed outside the detector. Alpha particles pass into detector through 7 μm mylar window (or 4-6 μm aluminum) in the same plane of the Pd foil, and through a collimating hole (3 mm diameter, 14 mm length) drilled in the Al body of the MWPC with declination angle of 45 degrees.

Threefold coincidence trigger (WC1*WC2*CsI) reduces the proton-like background records down to <0.04 per hour (no protons for 24 hours observation).

A typical plot of energy losses in MWPCs versus energies measured in CsI for alpha particles is shown in Fig. 2 (in arbitrary units). For 5.5 MeV initial energy of α's, they are expected to have ≈2.2 MeV at the entrance of CsI.

A calibration (with a slightly different gas) was performed by use of alpha particles from a ^{238}Pu source of ≈ 10^{-2} per second intensity. In this way the resolution was found to be ≈ 10% FWHM for each of two MWPC and 20% for scintillation counter (25% and 15% respectively are expected for protons in the same energy region). In addition to alpha particles from source, we have observed with the present gas the weak proton flow of 1 per hour intensity when alpha particles pass through mylar window (Fig. 3). This proton flow is to be referred mainly to elastic scattering of alpha particles on hydrogen in mylar ($C_5H_4O_2$), as we have demonstrated by doubling the thickness of the mylar window. It provides a handy proton source for calibration, with approximately the same end energy of the spectrum as one expected from cold fusion, but for obvious background reasons it cannot be used for permanent calibration when searching for cold fusion protons. We will use an aluminum window instead, available at the same time in another hole of the detector.

In the last conditions the proton background is found to be ≈ 1/day, if we exclude background contributions (the few points in the corner of Fig. 3 are due to noise from pulse generator and have been subtracted off line). Without an alpha source the α particle background is found to be ≈ 1/hour in the outside laboratory.

The special electrolyzer is made of teflon (Fig. 4). Outside surface of Pd sample (of 100 μm thickness or less) is covered by silver (of 1-5 μm thickness) to prevent deuterium leakage from the sample. Electrolyzer and proton detector are coupled so that emitted protons leave the sample and immediately pass into detector without crossing any material excluding silver coating.

MWPC occurs to be very sensitive to hydrogen leakage: its signal amplitude sharply depends on the fractional hydrogen content in the gas mixture. Several coatings were investigated to find the appropriate one (surface coated by mercury amalgama, poisoned by iodine, coated by vacuum evaporation of 800 Angstrom gold and others).

Time dependencies of mean MWPC signal amplitude from alpha particle source are shown in Fig. 5 for three samples: a) the one covered by ≈5 μm silver; b) pure palladium sample; c) the one covered by palladium oxide.

Deuterium loading of the palladium sample is performed by use of current pulse generator analogous to the one presented in this book by Celani et al. Electrolyte used is 0.3 M LiOD solution in heavy water. Current pulse amplitude goes from 15 A up to 100 A on 5 KHz frequency.

Electrolyte level is controlled by capacity sensor and peristaltic pump. Capacity sensor consists of two teflon wires, immersed into electrolyzer, the electric capacity depending on electrolyte level. The electrolyte level control (computerized) is available with ±1 mm accuracy and automatically drives the peristaltic pump.

CONCLUSIONS

The proton system is still being developed. A first experiment will be running at the time of the conference. Once assembled together with the existing detector, the full FERMI system will have the possibility to detect multiple correlations of neutrons, gammas, protons, alpha particles, tritium, thermal effects and deuterium loading. Search for ^{4}He could be possible in the future.

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