MODULAR NEUTRON SPECTROMETER

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1 MOTIVATION

In heavy ion collision studies, it appeared that the neutron information is necessary to study the properties of radiation sources. Neutrons originating from a hot source carry an information on the nuclear temperature. The multiplicity of emitted neutrons grows rapidly with energy of the collision therefore simultaneous registration of many neutrons is required. In order to reach the necessary neutron information, one needs a detector system which gives simultaneous control of the energy spectra, angular distribution and multiplicity. Our detecor MONA (MOdular Neutron Array) allows such neutron measurements with high efficiency in one geometrical setup. MONA was constucted to register neutrons of intermediate energy (0.5 MeV – 30 MeV). The set-up can be used as an autonomic detector or as a part of a greater modular detector.

2 SETUP

Our detection system consists of eight BC–501A scintillation detectors, 8 channel CAMAC system to analyze the pulse shape, and a data acquisition system. Each detector has large scintillator 4" in diameter by 2" thick. The neutron/gamma discrimination was based on charge comparison method which was described in [1]. For this purpose we have used a multi input, dual charge integrating QDC. The experimental setup required only general purpose electronics. The QDC converters are integrating the total charge and that due to slow component of the scintillation pulse. The first integral is proportional to the energy loss of the particle inducing scintillation while the second one depends on the particle type. Appropriate settings are found empirically to maximize the difference between the integrals for neutrons and γ–rays while minimizing the statistical spreads in those integrals.

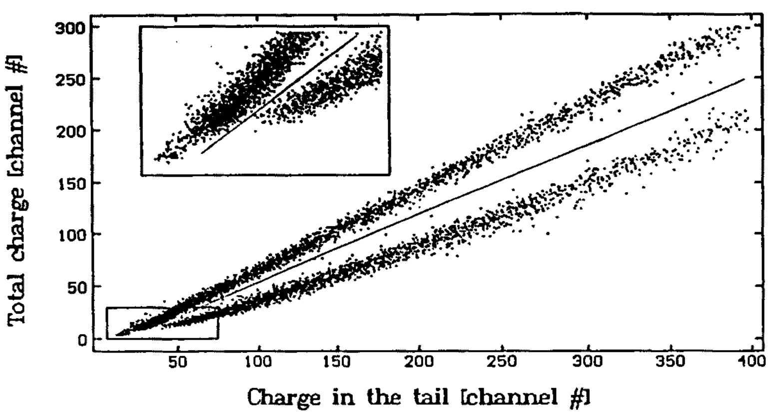

Figure 1: Two dimensional Pu-Be spectrum of total charge vs charge in the tail of the pulse. The solid line shows the separation between neutrons and γ-quanta.

The energy of the neutrons is determined by time-of-flight method. A relation between detector thickness and flight path gives reasonable minimum distance of 70 cm from the target to the detector. The fast trigger could be generated externally by event signal. Stop signals are sent to 8 channels TDC.

We have tested the properties of pulse shape discrimination due to interaction of neutrons and γ-rays in the scintillator. The timing characteristics of the detector were also investigated. The response of that set-up to Pu-Be source is given in Fig.1. The observed separation of neutrons and γ-rays indicates high quality of the scintillation counters.

The counting efficiency of the detectors was established using a calibrated Pu-Be neutron source and additionally calculated by an efficiency code. The detector efficiency is η=0.24 at the neutron energy of 2.5 MeV.

In order to study the timing characteristics of our detectors ^{60}Co source was placed on the axis between two lead colimators 5 cm thick 8 mm in diameter. Amplified anode pulses of both counters were sent to a constant fraction discriminators. For the tested counters threshold was set at 25 keV. This threshold gives limitation in timing with large dynamic energy range. Appropriate setting of walk adjustment was found to be important. One signal was sent to START input while the second one, after delay, to STOP input of the time–to–digital converter. The time difference distribution of coincident γ-rays emitted from ^{60}Co source was measured. Resulting FWHM is 670 ps what corresponds to 470 ps of a single detector.

3 FIRST APPLICATION

Our attention has been attracted by reported neutron bursts emitted from LiD reacting with heavy water [2]. We have investigated [3] quoted neutron emission using four scintillation detectors placed symmetrically around the test tube; the fifth detector was positioned far away to control the background. The distances from the center of the setup were 5 cm for all four detectors and 220 cm for the fifth one.

The reaction of heavy water with LiD crystals was performed in the test tube made of pyrex glass contained 30 ml of D_2O. The LiD crystals were poured every 250 s into the test tube in small portions of about 400 mg each. The temperature of heavy water was measured by a thermocouple embedded in the liquid. The experiment was performed in five separate runs of the "effect" (D_2O + LiD in the test tube), and one run of the "background" (H_2O + LiH). Each run lasted some 70 minutes. Event by event spectra were collected and neutron events were extracted in the off–line analysis.

The average count rate of neutron events in five runs of the "effect" was 92.5 $\pm$ 4.0 events/hour. Long–term neutron background (with pure heavy water in the test tube) was also measured in five long runs of 17 hours each; average value of this background detected by four detectors surrounding the test tube was 97.1 $\pm$ 1.0 per hour. The background level measured during LiH + H_2O reaction (86.4 $\pm$ 8.6 counts/hour) is within statistical error equal to the long term background.

The comparison of neutron counting rates and temperatures measured in one of the runs for the "effect" and "background" experiments is shown in Fig.2; no significant difference is seen. Taking into account the calculated detector efficiency (for neutrons of 2.45 MeV from the D(d,n)^{3}He reaction at a subbarier energy) as well as the solid angle of the system, the resulting flux of neutrons was established to be:

Φ = –1.4$\pm$1.3 neutrons per gram of deuterized matter (LiD + D_2O)

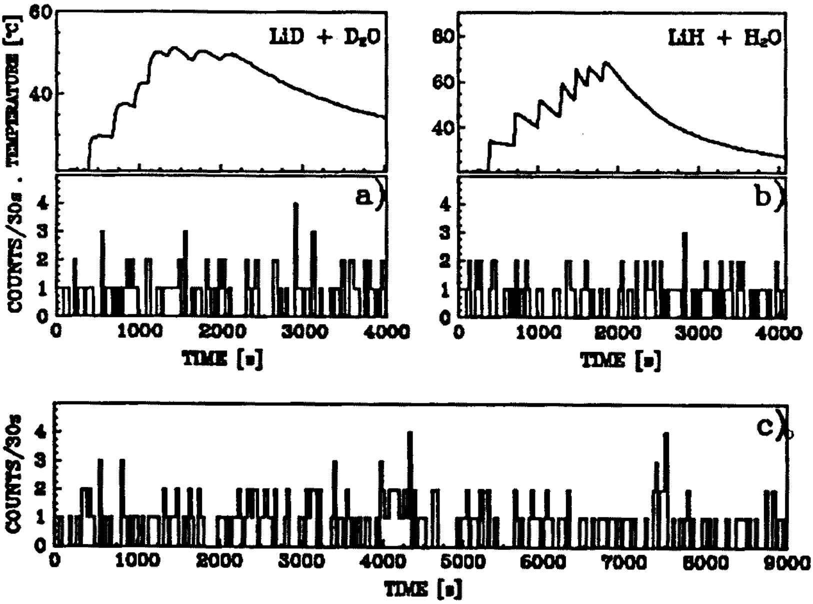

Figure 2: Comparison of neutron counting rates and temperatures for the "effect" (a) (D_2O + LiD in the test tube) and "background" (b) (H_2O + LiH) experiments; an example of long-term background is given (c).

This value is consistent with zero neutron emission within a two sigma limit of 2.5 neutrons per gram of deuterized matter during the chemical reaction, what gives an upper limit 1.2×10^{-26} neutrons/deuterium atom/s. This result is contradictory to the observations made by Arzhannikov and Kezerashvili [2] (few tens of neutrons per gram of deuterized matter). It should be noted that the upper limit obtained in our experiment is more than one order of magnitude lower than the emission rate reported in [2].

The obtained spectra were subjected to a time analysis which made it possible to determine the number of events detected during a definite time interval and to compare it with a corresponding number expected from the Poisson distribution. The comparison confirmed the statistical nature of all observed deviations. The bunched emission of radiation is not observed in any of the time intervals studied.

In final conclusion, within the accuracy of our experiment, no neutrons emitted during the chemical reaction of heavy water with lithium deuteride have been observed. Neither continuous neutron flux nor bunched neutron radiation was registered above the background level.

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