Effects of shell closure of target on neutron multiplicity for the $^{28}Si+^{204,206,208}Pb$

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Introduction

Pre-scission neutrons are the most commonly used probe to understand the heavy ion induced fusion-fission reaction. Experimentally measured pre-scission neutron multiplicities show significant deviations from predictions of the standard Bohr–Wheeler theory of compound-nucleus fission. It is well established now that measured pre-scission neutron multiplicities are substantially higher than the standard statistical model predictions. This experiment has been performed, to explore the effect of shell closure of $^{204,206,208}Pb$ with a deformed ^{28}Si beam [1] on the neutron multiplicity near and above the coulomb barrier .

Experimental Arrangement:

The experiment was carried out at Inter University Accelerator centre (IUAC), New Delhi, using pulsed beam of ^{28}Si (Energy range is from 159 to 186 MeV) having a repetition rate of 250ns from the 15UD Pelletron followed by two modules of super-conducting linear accelerator (LINAC). The compound nucleus was populated at the excitation energies 46-70 MeV at step size of 8 MeV. This experiment was performed at National Array of Neutron Detectors (**NAND**). The isotopically enriched $^{204,206,208}Pb$ targets were used. The thickness of ^{204}Pb was around 0.5 mg/cm^2 which was sandwiched between carbon foils and $^{206,208}Pb$ was around 1.5 mg/cm^2 which were self-supporting prepared at the target lab. of IUAC. These targets were placed at the center of a spherical chamber having a diameter of 60 cm.

Fission fragments were detected in coincidence with a pair of Multiwire proportional counter (5”x3”) placed at the folding angles (30^0 & 124.5^0) and at a distance of 21 cm from the center . Two silicon surface barrier detectors were also placed at an angle of $\pm16^0$ with respect to beam direction for monitoring the incident projectile.

Twenty four liquid scintillator detectors (BC501) were placed outside the scattering chamber for the detection of neutrons, out of which 16 (5”x5”) were placed in reaction plane and 8 (5”x3”) were placed at $\pm15^o$ with respect to the reaction plane. Out of the 16 detectors which were placed in reaction plane, 8 were at a distance of 1m from the center and remaining 8 at a distance of 2m. The threshold of pulse shape discrimination module [2] was set at 0.5 MeV by calibrating it with a standard γ source (^{137}Cs). The neutrons were detected in coincidence with fission fragments. The trigger of the data acquisition was generated by setting up a coincidence between RF of the beam pulse and any one of the of cathode signals of the two Multiwire proportional counters(MWPC).

To reduce gamma background beam dump was extended 4m downstream from target and beam line was shielded with paraffin and lead bricks. The time width of the beam was continuously monitored using a BaF_2 detector placed near to the beam dump. The beam width was found out to be between 0.60ns to 1.0ns at different beam energies.

Results

The neutron energies were determined from the observed time of flight spectra. Since neutron detectors are sensitive to both gamma and neutrons, so the separation was achieved by pulse shape discrimination (PSD) based on zero cross and the time of flight technique(Fig.1). Prompt gamma peak in TOF spectrum was used for time reference and neutron TOF spectra was converted to neutron energy (Fig2) using the following relation,

$$En = (½)\, m\, l^2/t^2.$$

where m is the mass of neutron, l is the flight path and t is the time of flight. The efficiency correction for neutron detector was performed using statistical model code MODEFF[3].

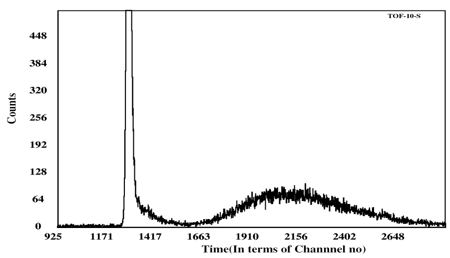

Fig.1 TOF spectrum for n-γ separation for $^{28}Si+^{204}Pb$ at 177 MeV

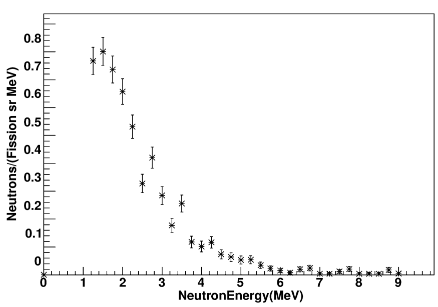

Fig.2 Neutron Energy spectrum (derived from TOF of neutrons) for $^{28}Si+^{204}Pb$ at 177MeV.

A typical 2-Dimensional spectrum, of the time correlation between the two Multiwire proportional counters for the system $^{28}Si+^{204}Pb$ at 177 MeV is shown in fig.3 The coincidence condition between the two TOF signals from the two detectors helps in removal of all elastic events.

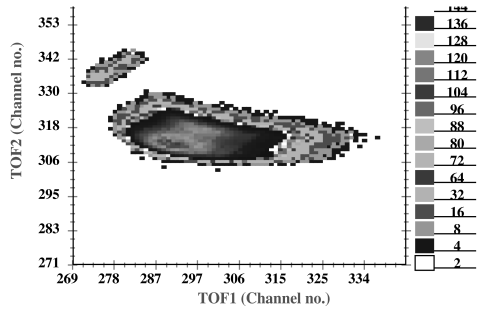

Fig.3 Timing correlation between the two MWPCs for the reaction $^{28}Si+^{204}Pb$ at 177 MeV.

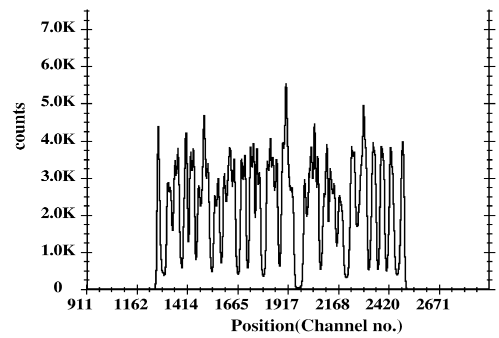

Fig4. Position spectrum for $^{28}Si+^{204}Pb$ at 177MeV

Fig4 shows one dimensional Y position from one of the MWPCs taken from $^{28}Si+^{204}Pb$ reaction at 177 MeV. Further analysis is in process.

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