FIRST RESULTS FROM TWO-NUCLEON INTERFEROMETRY EXPERIMENT, E286, AT GANIL*

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Simultaneous measurement of two-nucleon (nn, np, pp) correlations have been performed at GANIL for the reaction ^{40}Ar+^{58}Ni at 77 MeV/u. The aim of the experiment was to find the space-time properties of nucleon emission process in intermediate energy heavy ion collisions and to clarify some related questions. Comparative analysis for protons and neutrons indicates an important role of Coulomb effects. Quantitative analysis is in progress.

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1. Introduction

The mechanisms of heavy-ion collisions at intermediate energies, above the Fermi energy and below 100 MeV/u, are usually considered as consisting of two steps. The first, governed by the reaction dynamics, is relatively fast and gives contribution to the particles emitted at mid-rapidity; the second one, rather slow, is of statistical nature and begins after some "separation time". Particles emitted in this step are located in the region of target and projectile fragmentation.

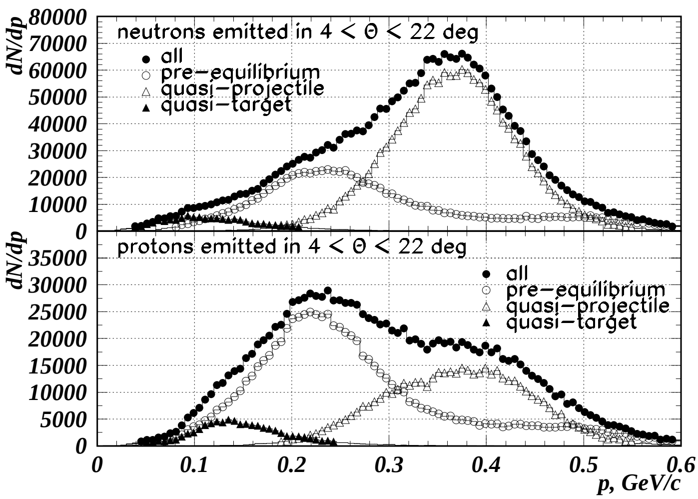

Fig. 1. Momentum distribution of protons and neutrons in the forward direction of the acceptance of E286 experiment, calculated using the event generator "SIMON" [5].

This "classical" picture seems to be well proved by the experimental observations (*e.g.* the flat angular distributions of particles emitted forward in the quasi-projectile reference frame [1,2]). However, it has been argued recently that the convolution of dynamical factors with the effects of Coulomb field coming from the quasi-projectile can lead to almost equal proportion of prompt and delayed component in the quasi-projectile fragmentation region giving flat angular distribution observed experimentally [3]. Some recent analyses of experimental data indicate indeed much less excitation energies of the quasi-projectile [4]. The different components of fast and delayed emission, of dynamical and statistical origin, cannot be distinguished in a simple way.

In order to shed some new light on the question of particle emission in the projectile fragmentation region, to understand the origin of forward emitted particles and to measure space-time properties of their emission, we have registered simultaneously neutrons, protons and light fragments emitted in the forward direction, (4°–22°) in laboratory, in the reaction ^{40}Ar+^{58}Ni at 77MeV/u.

Fig. 1 illustrates the expected relations between different sources of neutrons and protons for the forward direction of our acceptance. One can notice the strong overlapping of protons coming from two different sources in the full interval of their momenta. This effect, related to Coulomb repulsion by the source of quasi-projectile is much weaker in the case of neutrons.

2. Experiment E286 at GANIL

The measurement of two-neutron correlations at small relative momenta is a difficult experimental task due to parasite effects in the detection of neutrons in coincidence. At GANIL the dedicated two-neutron interferometry experiment has been performed for the first time in summer 1998 with the modular neutron detector DEMON [6]. The physical goal of experiment was to find the space-time properties of nucleon emission process in heavy-ion collisions and to clarify some related questions: sequence of particle emission, tree-body Coulomb effects, deuteron formation mechanism *etc.* For the first time the DEMON detector was used not only to detect neutrons but also to register and identify charged particles. Simultaneous measurement of two-nucleon correlations (nn, pp, np), at small relative velocities, was performed.

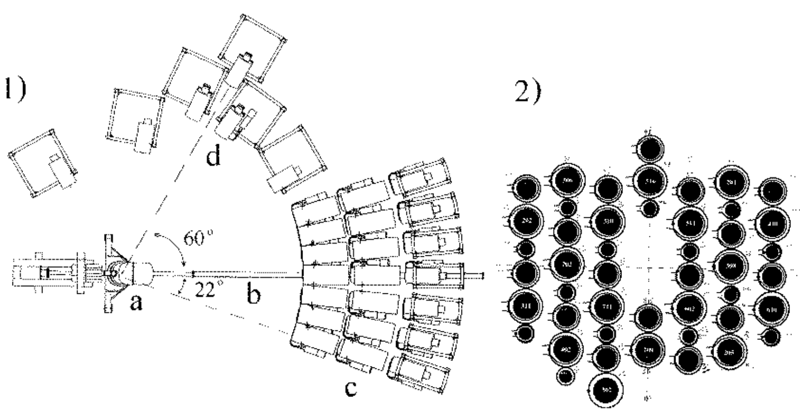

Fig. 2. Geometrical configuration of E286 experiment at GANIL. 1) horizontal projection: a — reaction chamber, b — beam pipe, c — forward block, d — side block. 2) Front view of the forward block; different sizes of detector modules reflect different distances from the target.

The reaction ^{40}Ar+^{58}Ni at 77MeV/u was studied. About 70 million events with the trigger of at least two secondaries registered were collected. Simultaneous measurement of neutral and charged particles in the same reaction, in the overlapping velocity region and with the same experimental technique eliminates essentially most of possible experimental uncertainties. The detector configuration (see Fig. 2) of close geometry was designed in the way allowing to measure the small relative momenta of several MeV/c. A block of 45 detectors was installed in the forward direction (4°–22°) at mean distance 3.2 m from the target. Another block of 15 detectors was placed at a mean angle of 60°.

Detectors in the forward block were equipped with the thin plastic scintillators ("SYREPs") located in front of the face of detectors. The signals from both parts of the module furnish us with the possibility of particle identification and energy measurement, in the exactly same way for neutrons and charged particles. Detectors were arranged in three layers to enable cross-talk elimination [7].

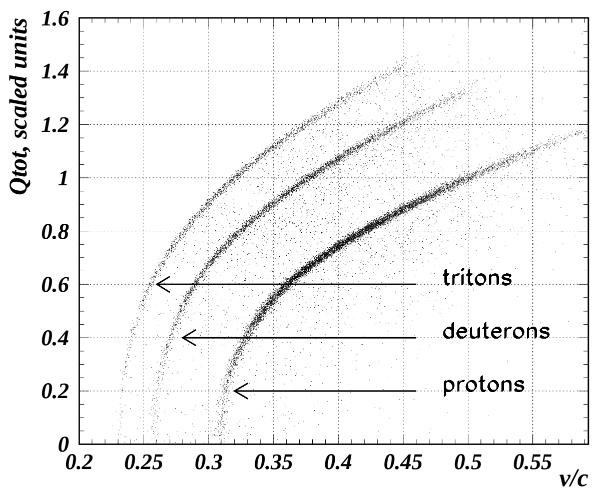

Fig. 3. SYREP identification of protons, deuterons and tritons after separation of neutrons and particles with $Z > 1$.

3. First results

Before starting the correlation studies we have constructed single particle distributions for protons and neutrons in order to make comparative analysis and verify the importance of the Coulomb effects. The differences between neutron and proton emission properties are illustrated in the Fig. 4. Neutron rapidity distributions in the forward direction have an expected maximum slightly below the value corresponding to the projectile rapidity. Different behavior of proton spectra can be attributed to the effect of Coulomb repulsion by the charged quasiprojectile. The effect depends strongly on the emission angle and will be used for the quantitative analysis.

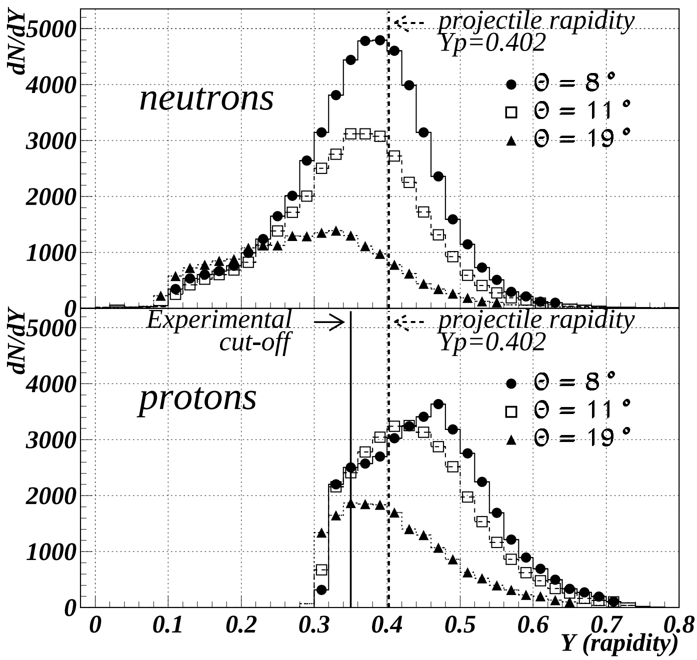

Fig. 4. Rapidity distributions of neutrons and protons for some emission angles indicated in the figure. (The experimental cut-off for protons is due to energy loss in the path from target to detector.)

First examples of correlation functions are presented in the Fig. 5. A lack of Coulomb repulsion in the system of two neutrons results in a positive correlations in the region of small relative momenta due to attractive force of strong interaction. (Note a strong influence of the cross-talk effect and the result of the application of the removing procedure.) Two proton correlation function have a different shape and instead of maximum — the minimum is observed for the smallest momentum differences. In order to make quantitative analysis, the experimental correlation functions will be compared with the theoretical ones coming from different theoretical approaches: static model of three sources, the SIMON model of Durand [5], the model based on the Landau–Vlassov transport equations [8] and the Quantum Molecular Dynamics approach [9].

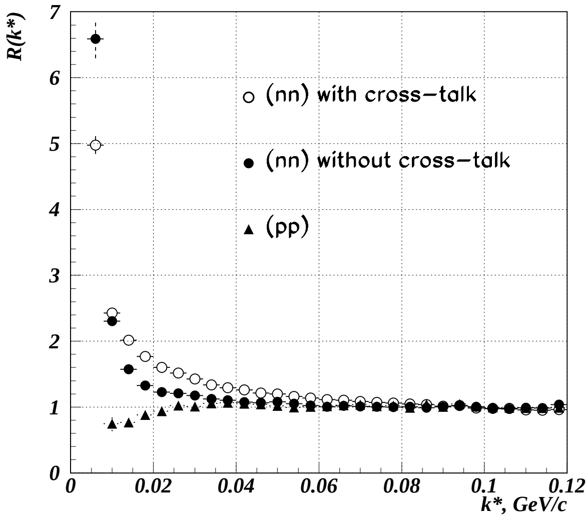

Fig. 5. The two-neutron and two-proton correlation function plotted as a function of the half of relative momenta, $k*$.

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