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INDRA@GSI A STUDY OF THE REACTION MECHANISMS OF COLLIDING NUCLEI FOR A WIDE RANGE OF ENERGY AND MASS *

Ketel Turzó

Gesellschaft für Schwerionenforschung mbH
Planckstr. 1, D-64291 Darmstadt, Germany

for the ALADIN and INDRA collaborations
Institutions: DAPNIA Saclay, GANIL Caen, GSI Darmstadt, INFN Catania, IPN Lyon, IPN Orsay, LPC Caen, SINS Warsaw, Univ. Frankfurt

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The 4π-multidetector INDRA was installed in GSI for one and a half years, including three experimental periods between June 1998 and March 1999. The goal of the experiments was to extend the study of the multifragmentation, of the liquid-gas phase transition of nuclear matter and of the production and decay modes of highly excited nuclei to energies beyond those previously studied at GANIL. This experimental campaign proceeded smoothly and the analysis of the data is in progress.

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1. Introduction

The 4π-multidetector INDRA was developped at the GANIL (Caen, France) by a collaboration of French laboratories. This detector offers optimum capabilities for the simultaneous detection of the numerous light charged particles and nuclear fragments that are emitted from heavy-ion collisions. A total of 640 individual detectors (ionization chambers, Si detectors and CsI crystals) cover 95% of the 4π solid angle (figure 1) [1].

Three campaigns of INDRA at GANIL have been devoted to the study of the production and decay modes of excited nuclei produced with intermediate-energy heavy-ion beams. The continuation of these measurements and their extension to higher beam energies has been one of the motivations

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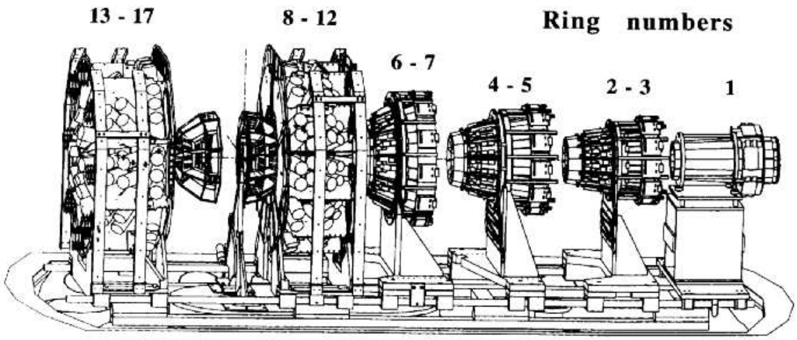

Fig. 1. INDRA: a detector assembly consisting of 96 ionization chambers, 192 silicon detectors and 336 crystals of cesium iodide.

for the recent campaign at GSI (Darmstadt, Germany). Moreover, previous experiments performed at GSI with the ALADIN spectrometer show interesting evidences of a phase transition of nuclear matter for mid-peripheral reactions. It is the hope that experimental signals for this phase transition can be obtained from multifragmentation data. The highly excited nuclear systems required for these studies can be produced in heavy-ion reactions within the energy range accessible with the heavy-ion synchrotron SIS at the GSI.

2. First preliminary results

Several systems over a wide range of energies were studied during this experiment, Au+Au between 40 and 150 AMeV in June 1998, Xe+Sn between 20 and 200 AMeV in September 1998, and finally, in February 1999, C+Au and C+Sn between 95 and 1800 AMeV. Enriched targets of ^{112,124}Sn were used in order to study isotopic effects.

At the present stage of the analysis, only preliminary data from the CsI array alone are available. These detectors permit particle identification with the technique of pulse shape analysis [1]. In particular, charged particles and fragments can be distinguished from the neutrons and gamma rays with a low threshold. Charged-particle multiplicities obtained in this way from the CsI array should be a good approximation to the total multiplicities because of the low multiplicity of slow fragments that do not reach the CsI detectors. They are shown in Fig. 2 for all four systems that were studied in the present experiments. All multiplicity distributions have very similar shapes with rather large cross sections for small multiplicities corresponding to the more peripheral collisions and with wide distributions extending to rather large multiplicities for the most central collisions. The highest multiplicities of up to about 80 are observed for the Au+Au system at 100 and 150 AMeV. With a total of 158 charges in the collision system, they correspond to an average charge of $\langle Z \rangle = 2$ and indicate that a nearly total vaporization has been achieved. In the Xe+Sn system with multiplicities of up to about 60 the average charge in these most violent collisions is even smaller. We further observe, at this rather qualitative level, that the maximum multiplicities for central collisions evolve more rapidly for Au+Au between 40 and 80 AMeV and, in particular, for C+Au between 95 and 300 MeV while, for the Xe+Sn system, a saturation seems to be reached already at the lower bombarding energies covered by the present study. These observations should fit well into the systematics obtained from earlier studies of these and comparable systems [2, 3].

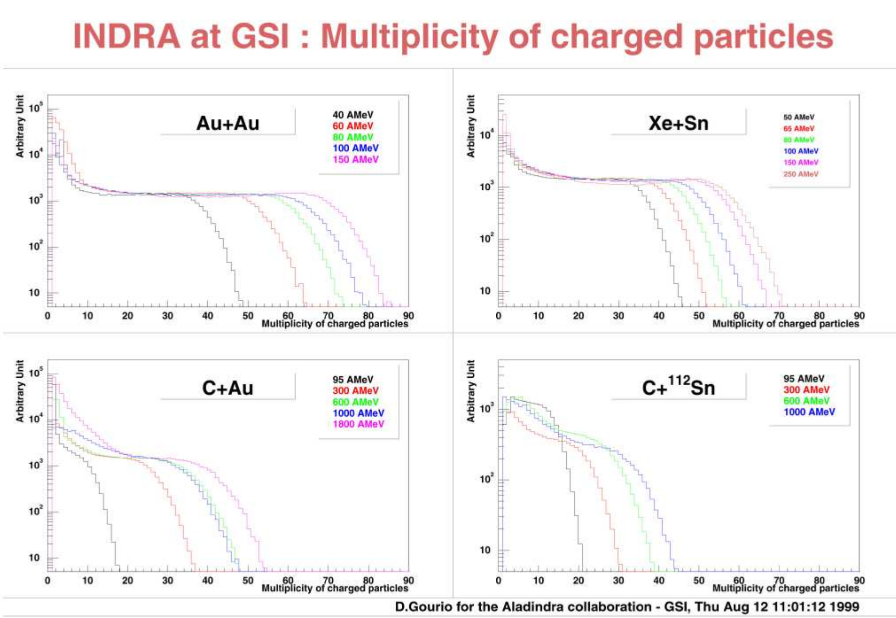

Fig. 2. Measured multiplicities for various systems and energies.

The elemental and isotopic identification of the detected particles and fragments is based on the energy losses measured with the ionization chambers and Si detectors ($\theta_{\rm lab} \leq 45°$) and on the pulse shape analysis of the CsI signals. Figure 3 illustrates the quality of the isotopic resolution obtained with the technique of pulse-shape analysis of the scintillation signals provided by the CsI detectors. Isotopes are resolved for elements up to $Z = 4$. Boron and carbon ions are resolved in some cases. Heavier elements will have to be resolved with the $\Delta E - E$ technique by using the signals from the ionization chambers and, for $\theta_{\rm lab} \leq 45°$, from the Si detectors. For most systems, the abundance of heavier fragments decreases rapidly with angle, and mostly hydrogen and helium fragments are detected in the backward hemisphere. identification for the first eight rings shows all isotopes from protons to ^{13}C. This number of detected isotopes decreases in inverse function of the angle: in the backward rings, only light particles until ^{4}He are visible.

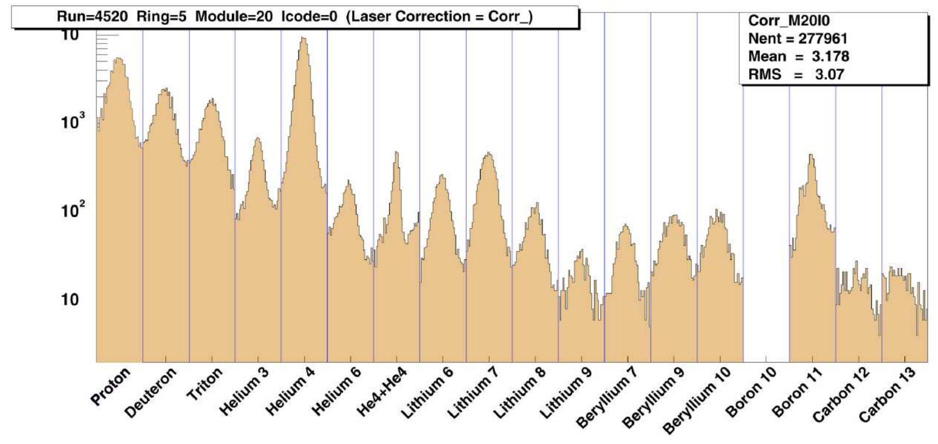

Fig. 3. Light particle isotopic identification with a crystal of Cesium Iodide at $\theta_{\rm lab} = 10^{\circ}$ ranging from protons to ^{13}C (^{10}B and ^{11}B were not resolved).

3. Outlook

With the calibration and particle identification near completion, it may be expected that first physics results from the analysis of this comprehensive set of data will appear at the beginning of the year 2000. It should be possible to address a variety of questions of high current interest. Among those are the onset and evolution of collective radial flow with bombarding energy for the symmetric Au+Au and Xe+Sn systems [4], the invariance properties of the spectator decay over a wide range of bombarding energies for the C+Au system [5] [6], and the question of transparency versus full stopping in central collisions of Xe+Sn at 100 AMeV where techniques similar to those reported in [7] may be applied.

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