

INFORMATION SHEET
(January – July 2003)

Experiment at	TANDEM []	CYCLOTRON [x]
<i>Technical test</i> []	<i>New experiment</i> [x]	<i>Continuation of approved experiment</i> []

Title of the experiment	Thermodynamical coordinates of excited nuclear systems
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Participant	Institution
NUCL-EX collaboration	(see included proposal)
ISOSPIN - Collaboration	

Beam	Energy (A MeV)	Intensity (pnA)	Beam line	BTU	Excluded dates
58Ni	25	0.02 pnA	Ciclope	6	
58Ni	35	0.02 pnA	Ciclope	6	
64Ni	25	0.02 pnA	Ciclope	6	
64Ni	35	0.02 pnA	Ciclope	6	

Special requirements (targets, sources, electronics, vacuum, beam timing,)	Timing < 1 ns
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Thermodynamical coordinates of excited nuclear systems

NUCL-EX collaboration

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Abstract

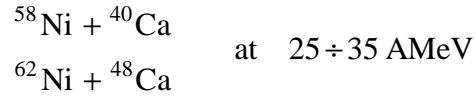
The measurement of thermodynamical coordinates (T - ρ , N/Z) of excited sources formed in $^{58,62}\text{Ni}+^{40,48}\text{Ca}$ at 25, 35 A MeV incident energies are proposed. This detailed experimental information on the nuclear phase diagram allows a deeper understanding of finite nuclear systems at the phase transition.

The existence of different phases for finite nuclear matter, predicted by theoretical calculations from the 60's, has been deduced from several experimental signals which give a **circumstantial evidence** of this occurrence [1].

The signals for the phase coexistence and phase transition [2] have been extracted from experimental data through long and cumbersome procedures which backtrace the asymptotic data to the initial stage information. However, to better clarify this picture, many new and more precise measurements are needed.

The measurements we would like to perform with the Chimera apparatus are in the framework of a systematic study of the coexistence region planned by the NUCL-EX collaboration, starting from the liquid side, up to some A MeV of available energy. Indeed, from first measurements performed at the ALPI accelerator (LNL) with the Garfield apparatus at relatively low excitation energies (~ 3 A MeV) it resulted that nuclear systems of $A \approx 100$, formed in central collisions, already manifest a critical behavior, with the opening of the multifragmentation channel [3].

We propose to deeper investigate the multifragmentation, by performing the measurements:



These reactions are expected to give rise to a fused system with $Z \approx 40$, $N/Z \approx 1.02$ and 1.28 and excitation energies about 5 and about 7 AMeV, respectively. The expected cross section for this process is estimated of the order of 100-200 mb.

Due to the different N/Z values, the limiting temperature, i.e. the maximal temperature for a nucleus in a liquid phase at normal density [4], results 6.5 MeV and 8.4 MeV for the neutron-poor and for neutron-rich system [5], respectively. Different temperatures correspond to different liquid drop level density parameters (8 and 12, respectively) and this should give less *liquid (asymmetric)* partitions for the decay of the neutron-poor system with respect to the neutron-rich one at the phase coexistence. Also multifragmentation statistical models [6] predict microcanonical temperatures for the neutron-poor systems lower than those of neutron-rich over a wide range of excitation energies.

These theoretical predictions can be experimentally checked by measuring, together with the charge partition of the systems, also the isotopic composition of the emitted products.

The isotope double ratio temperatures can be calculated from data and the corrections to extract the microcanonical temperature of the system can be deduced not only via model comparisons, but also by estimating the excitation energy of primary fragments from the correlation functions between asymptotically detected fragments and light particles.

By evaluating the average volume of the system from Coulomb trajectory calculations and its isospin from the N/Z ratio of the decay products, the thermodynamical coordinates ($T - \rho$ and isospin) of the finite and equilibrated source at the phase coexistence can provide experimental information to the nuclear phase diagram.

Another interesting aspect, which has to be experimentally studied, is related to the preequilibrium stage. A considerable emission of nucleons, light particles and even larger mass fragments can occur before producing thermally equilibrated nuclear systems. These emissions not only reduce the excitation energy provided to the equilibrated sources, but may also change the isotopic composition of the intermediate system created when the projectile and the target nucleus overlap. Another important feature is that nuclei produced at the end of the pre-equilibrium phase have a distribution in A , Z and E ; thus *fluctuations* of the quantities which characterize the equilibrated nuclei are expected.

To estimate the extent and the importance of these fluctuations is a significant aim of present experiment. This may be done by correctly estimating the multiplicity and the spectra of

particles emitted during the pre-equilibrium phase with methods which provide not only information about average observables, but also on high order correlations. An approach, based on the Boltzmann Master Equation theory [7] resulted very suitable, for a wide range of projectile – target combinations at many incident energies, to reproduce accurately the double differential spectra of nucleons [8,9], light particles [10], and intermediate mass fragments [11] emitted in the first stage of the reaction.

We estimate that the beam time, needed to collect at least $5 \cdot 10^5$ complete central events, with a cross section of 100 mb, a beam intensity of 0.02 pA and a thickness of the target about $500 \mu\text{g}/\text{cm}^2$ is 6 BTU for each combination of projectile/target/energy.

Beam time for the settings is not included since we would like to perform these measurements close to the ones proposed by G. Cardella and M. Papa and therefore collaborate to the settings included in their measurements.

Due to the high accuracy required for the analysis of isotope-fragment correlations, we require additional beams for CsI energy calibrations. The detailed plan of required beams, energies and the BTU needed for calibration purposes, will be performed in agreement with the requirements of other proposed experiments.

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