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STATUS AND PERSPECTIVES OF THE 4 π CHARGED PARTICLES MULTIDETECTOR CHIMERA*

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for CHIMERA Collaboration

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The construction of the multidetector CHIMERA designed to detect and identify charged particles and fragments emitted in heavy ion reactions at intermediate energy is in progress and is coming to an end. The construction of this multidetector is presented in this paper as well as the status of the project.

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1. Introduction

This talk will be devoted to present the new experimental facility that is in progress at LNS Catania and whose construction is coming to an end. This facility is a 4π detector for charged particles named CHIMERA [1].

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At the beginning of the project when we decided to build the new device for heavy ion studies, we first of all, answered the questions why and for what purpose it had to be constructed. Then, we decided how to construct the detector, that means we defined the specific characteristics of the device.

In our case the answer to the first question was to study the reaction mechanisms in the intermediate energy range. In fact, we know that in this energy range several experiments have shown the presence of a complex multifragmentation process of a hot nuclear system formed in the early stage of the collision in several massive clusters (IMF) and light particles (LCP) [2]. Such a mechanism appeared to form a bridge between the evaporation–fission regime and the vaporization or explosion fire ball regime and now, it seems to be deeply related to basic properties of unexplored regions of the nuclear equation of state (EOS) [3–5].

So, the topical aspects of the heavy ion physics in this energy range are: *(i)* multifragmentation, *(ii)* nuclear equation of state, and *(iii)* phase transitions of finite nuclear system.

I shall not discuss the physics underlying the construction of the detector because other speakers at this symposium have done so. I will limit myself to answer to the second question: how did we build the detector for studying the above mentioned topics?

Three innovative aspects of the new device are relevant for multifragmentation studies [6]:

(a) geometrical efficiency;

(b) number of detection cells (granularity);

(c) energy threshold.

In each of them CHIMERA introduced significant improvements with respect to the major 4π detectors presently in use at nuclear physics laboratories.

2. General description

Chimera is the name of a mythological animal which presented itself as a combination of different animals: lion, goat and snake. Today the word *chimera* also means an impossible or idle fancy.

The name for our multidetector is an acronym for “Charged Heavy Ions Mass and Energy Resolving Array” and dates back to 1992, when some researchers from Catania started to design this detection system supported also by external collaborators as R. Bassini (INFN Milan), B. Cahan (CEA Saclay), J. Richard (IPN Orsay), mainly for solving electronic problems. At the end of 1994 we received a grant from INFN and we began the construction of the device. Now, after 5 years, we can assert that CHIMERA has become reality.

CHIMERA is made of about 1200 detection telescopes arranged in 35 rings in a cylindrical geometry around the beam axis. An assonometric view of the mechanical structure supporting the telescopes and a cross section of the multidetector are shown respectively in Fig. 1 and 2.

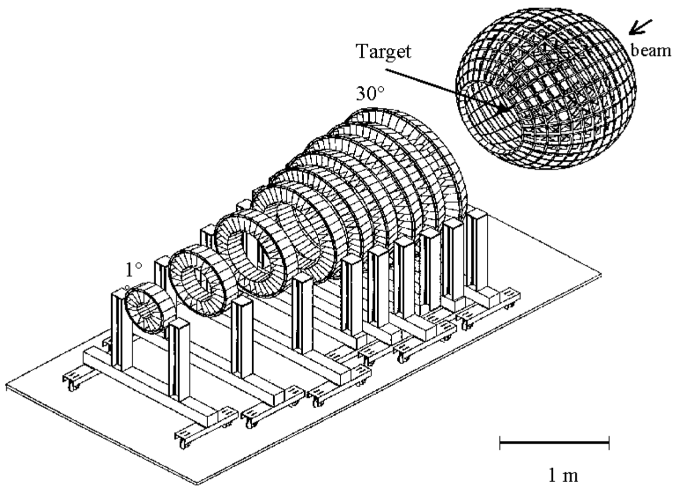

Fig. 1. Assonometric drawing of the CHIMERA multidetector

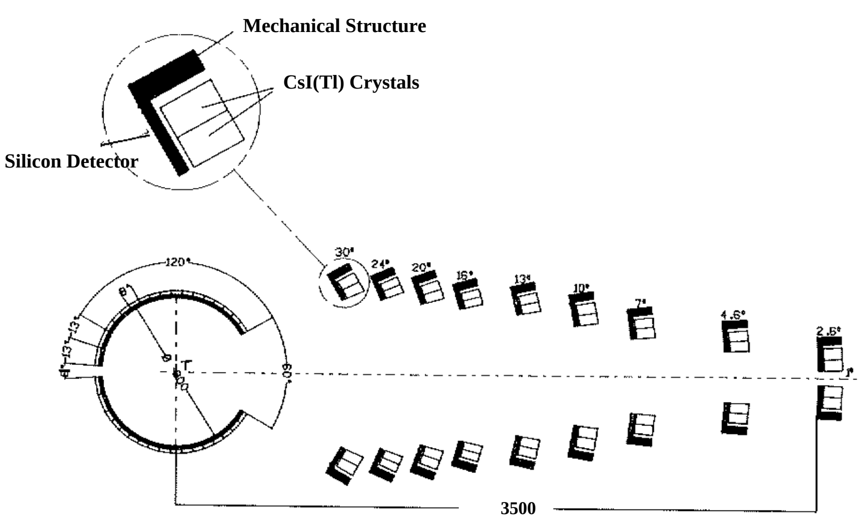

Fig. 2. Cross section drawing of CHIMERA. The number of telescopes placed in 9 wheels between 1° and 30° is 688. The remaining 504 telescopes are placed in a spherical configuration around the target.

The forward 18 rings are paired and are assembled in 9 wheels, placed at distances from the target variable from 350 cm and 100 cm with the increasing polar angle and cover the angular range 1°–30°. The remaining 17 rings are assembled in such a way that they form a sphere 40 cm in radius and cover the angular range 30°–176°.

The shape and dimensions of CHIMERA make it suitable for TOF techniques measurements and enable a mass identification of the detected intermediate mass fragments (IMF).

The detection unit (basic element) is a two stage telescope made of a 300 microns thick silicon detector and a CsI tallium doped crystal whose thickness is varying from 12 to 3 cm and is read by a photodiode.

The primary experimental quantities measured are: energy loss, residual energy and velocity when the range of the fragment is larger than the silicon detector thickness, and the total energy and velocity when the fragment is stopped in the first stage of the telescope. Obviously, the polar and azimuthal angles are also measured with an angular resolution corresponding to a solid angle covered by a single detection cell variable from 0.13 msr at very forward angles to about 27 msr, around 90°.

Great care in the design has been devoted to reduce the dead surface of the telescopes. In particular the wheels trapezoidal silicon detectors (see Fig. 3) are divided into two pads, each corresponding to one CsI crystal and

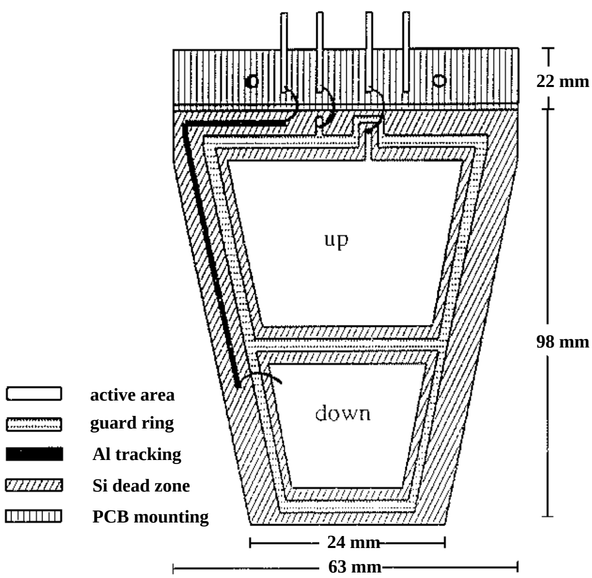

Fig. 3. Silicon detector view. The proportionality of the real dimensions is not respected.

have only one frame along the larger base of the trapezium to connect them to the supporting structure. The sphere the silicon detectors are connected by means of a very thin PVC frame to metallic boxes, whose walls are 0.5 mm thick , which are supported by a spherical structure 60 cm in radius. Along the border of each pad 0.6 mm large, runs a guard ring in order to warrant good uniformity of the electric field.

Considering entrance and exit beam holes and the shadow produced by the target frame an overall solid angle covering of about 94% is obtained. The geometrical features of CHIMERA are summarized in Table 1 of Ref. [1].

3. Detection technique and performances

The high detection efficiency and the low value of the multihit probability, due to the high granularity of the device produce a lever effect on the total reconstruction probability of the collision pattern. In fact, stochastic simulations of the probability for a complete detection of the fragments, assuming isotropical emission, gave a value about ten times higher with respect to the one calculated for the INDRA multidetector operating at present at GANIL, as we can see by looking at Fig. 4.

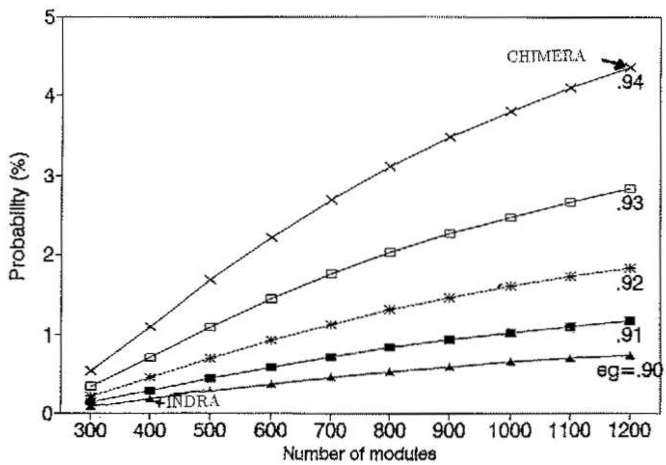

Fig. 4. Total reconstruction probability of the collision pattern *versus* the number of detection cells. Each line corresponds to the geometrical efficiency value of the array.

An illustration of the way CHIMERA works on identifying the fragments detected with a 300 cm path of flight (wheel No 2) is roughly presented in Fig. 5, where energy *versus* mass of fragments is reported and reasonable energy and time resolutions of 1% and 1 nsec, respectively, have been assumed.

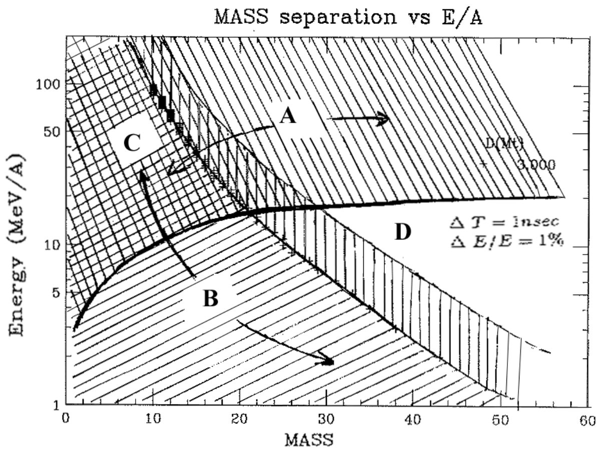

Fig. 5. The way CHIMERA works. Explanation is given in the text.

The growing curve from left to right represents the energy threshold due to the silicon detectors thickness. This means that only fragments falling in the areas A and C can be identified in respect to their charge.

The lower decreasing line represents the limit for which the time of flight technique allows mass identification with a resolution better than 1 a.m.u. ($M/DM > M$): this means that fragments falling in the areas B and C can be fully resolved in respect to their mass.

It is worthwhile to stress that in the area C the fragments are identified both in charge and in mass, and that in this area fall, on average, the intermediate mass fragments emitted in reactions between heavy ions at intermediate energy. Anyway, since we measure the velocity, it is possible to get mass information, by means of careful calibrations, also from larger areas like the D strip, where mass resolution varies between 1 and 2 a.m.u. ($M > M/DM > M/2$).

Many tests had been performed on single CsI crystals [7] and silicon detectors [8, 9] having similar characteristics of the final ones (large area silicon detectors, for instance, giving capacitance values as high as 1000 pF) prior to constructing the device.

Special electronics modules have been designed to define very stringent performances, namely the time and energy resolution for charge and mass identification, and a very low detection threshold assuring at the same time a dynamical range as high as 4000, when coupled with our detectors.

A data acquisition system based on a VME architecture [10–12], and suitable control and triggering methods [13] were specially designed, developed and carefully tested.

The isotopic identification of the high energy light charged particles (LCP) was performed by means of pulse shape technique using a two-gate integration method which takes advantage of the two components of the display light emitted by the CsI(Tl) crystals.

A more complete test involving also the data acquisition system was performed collaborating with GANIL. In order to investigate energy dissipation in binary collisions at intermediate energy the first wheel of CHIMERA was coupled with INDRA detector. Typical matrix giving heavy ion charge and mass identification relative to this experiment are shown in Fig. 6 and 7, respectively.

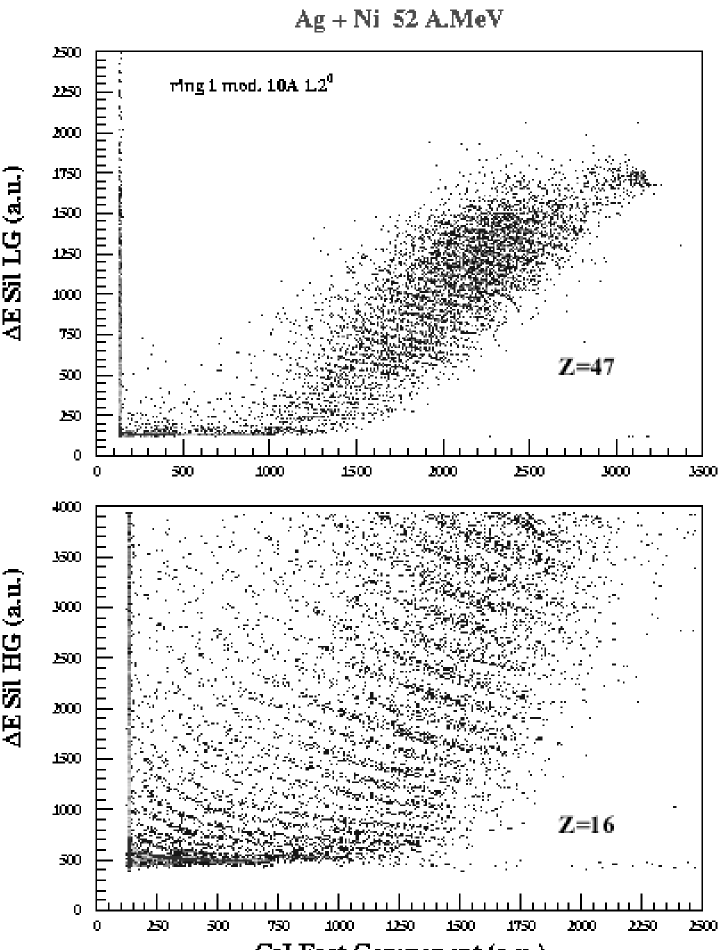

Fig. 6. Charge identification matrix obtained by a CHIMERA telescope in the E273 experiment carried out at GANIL. Upper side: Ampl. X1. Lower side: Ampl. X8.

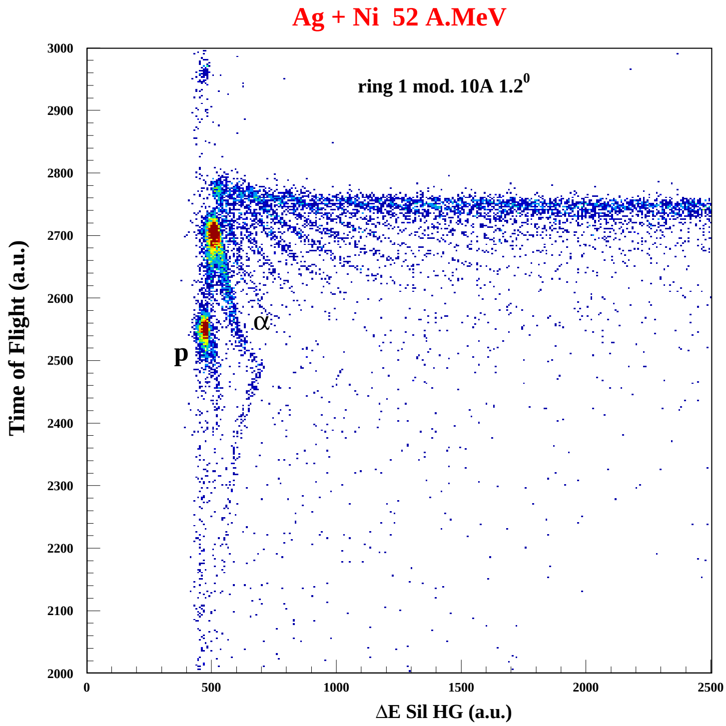

Fig. 7. Mass identification matrix; time *versus* energy loss in the silicon detector (the first stage of a CHIMERA telescope) in the E273 experiment carried out at GANIL.

4. Status and perspective

In 1999 the nine wheels with their 688 telescopes had been assembled in a big multipurpose vacuum chamber and connected to the front end electronics and to the data acquisition system. An internal and external view of the CHIMERA multidetector ready to run is shown in Fig. 8 and 9.

Silicon detectors and CsI(Tl) crystals calibrations had been performed by means of several Tandem and Cyclotron heavy ion beams. Final energy and time resolutions using the RF machine, were measured and, for some typical beams and energies, are shown in Figs. 10, 11 and 12.

Within the REVERSE experiment we scheduled a set of measurements to study multifragmentation and the effects of isospin degree of freedom on this mechanism and the dynamical fission in some heavy ion reactions in reverse kinematics, such as ^{112,124}Sn + ^{58,64}Ni and ^{27}Al at 25 and 35 MeV/A, and ^{238}U + Au and Al, where the particles and fragments produced are focused in the forward direction covered by this part of the multidetector (1°–30°).

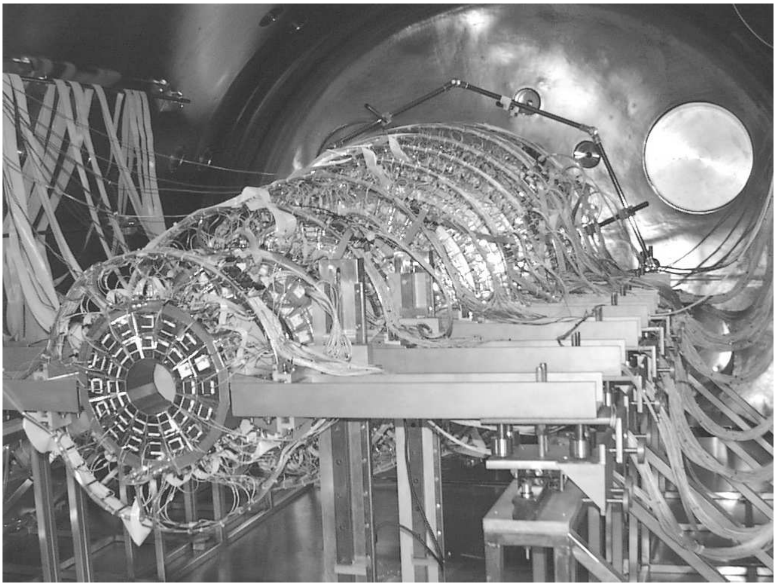

Fig. 8. An external view of the 9 forward wheels of CHIMERA (688 telescopes) assembled and cabled inside the CICLOPE vacuum chamber at LNS.

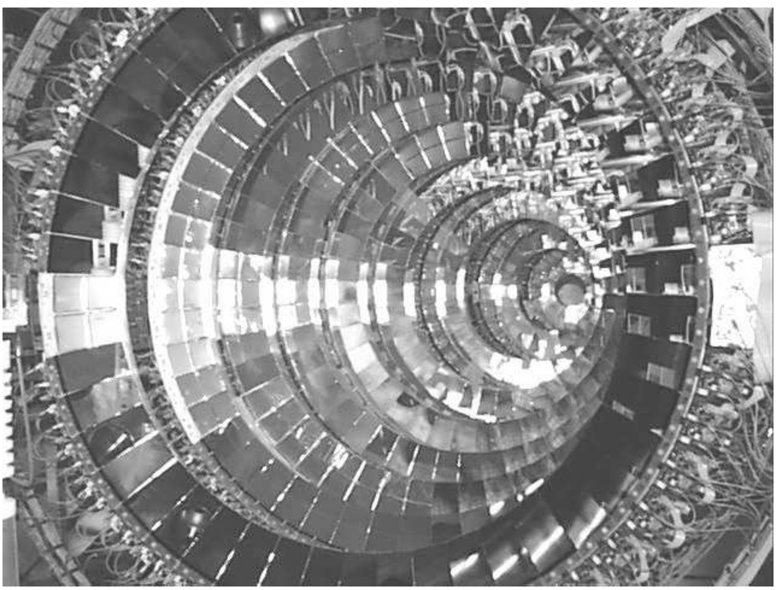

Fig. 9. An internal view of the 9 forward wheels of CHIMERA (688 telescopes) assembled and cabled inside the CICLOPE vacuum chamber at LNS.

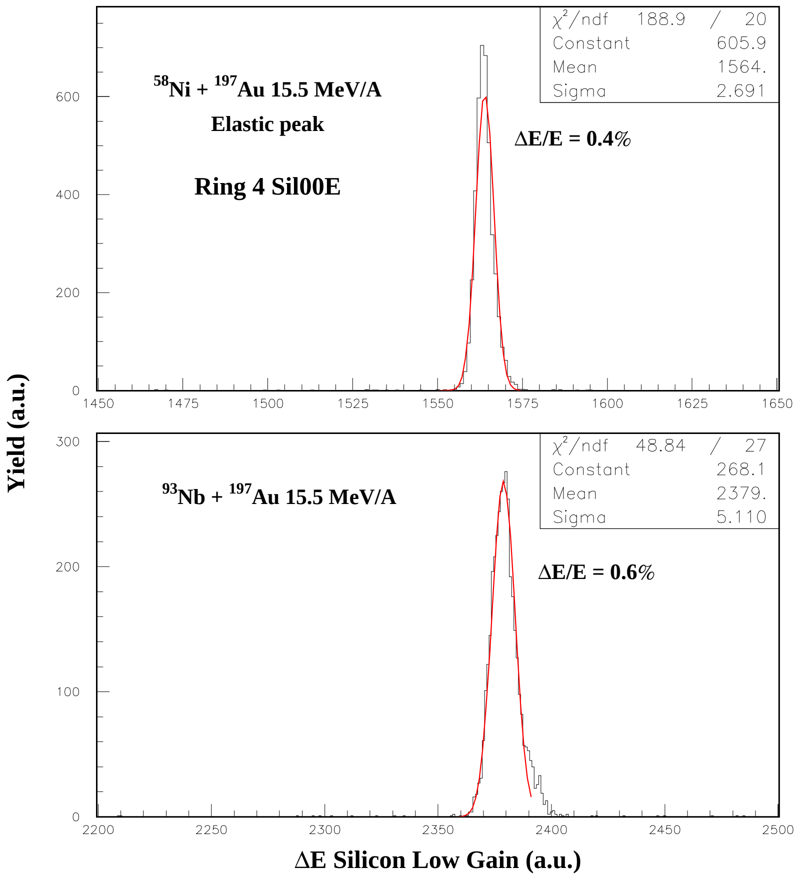

Fig. 10. Silicon detector energy resolution measured for the elastic peak in the ^{58}Ni+^{197}Au and ^{93}Nb+^{197}Au reactions at 15.5 MeV/A.

A few of beam sheets have already been used for the program that should be carried out in the first months of 2000. Some results showing heavy ion charge identification and the LCP isotopic identification are presented in Fig. 13 and 14, respectively.

When the REVERSE experiment will be completed the whole detector will be placed in its own vacuum chamber.

The perspective of CHIMERA is to perform at LNS crucial experiments that will be planned next year in order to better understand the complex phenomena occurring in nuclear reactions at intermediate energies and to contribute to solve important and still open questions in the field of the heavy ion physics.

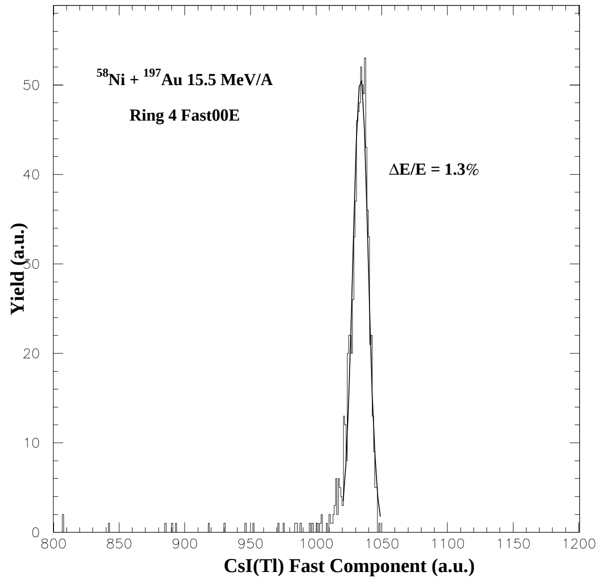

Fig. 11. CsI(Tl) scintillator energy resolution measured for the elastic peak in the reaction ^{93}Nb+^{197}Au at 15.5 MeV/A.

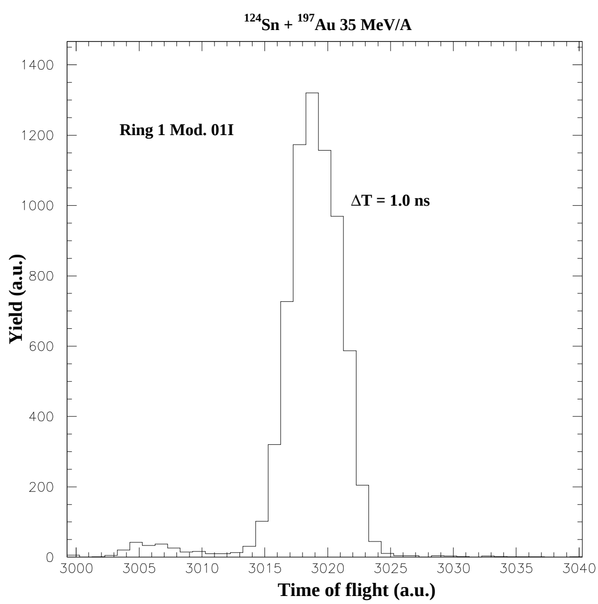

Fig. 12. Elastic peak time resolution measured for the reaction Sn+Au at 35 MeV/A.

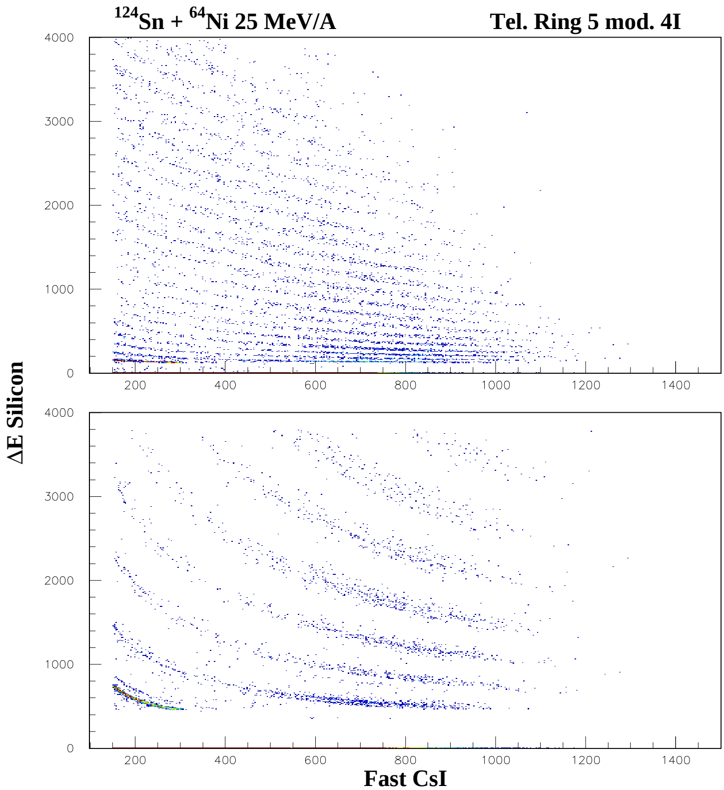

Fig. 13. Charge identification matrix obtained in the first run of REVERSE experiment, ^{124}Sn+^{64}Ni at 25 MeV/A, carried out at LNS. Upper side Ampl. X1, lower side Ampl. X8.

TABLE I

	INDRA	CHIMERA
Experimental Method	$\Delta E - E - E$	$\Delta E - E$ + TOF
Detectors	Gas+Si+CsI Gas+CsI	Si+CsI
$\Delta\Omega$ /Aπ	90%	94%
Identification	Charge ($Z \leq 50$)	Charge ($Z \leq 50$) Mass ≤ 25
Number of modules	400 LCP 180 HI	1200 LCP and HI
Threshold	1 AMeV	0.5 AMeV
Angular range	$2° \div 178°$	$1° \div 176°$

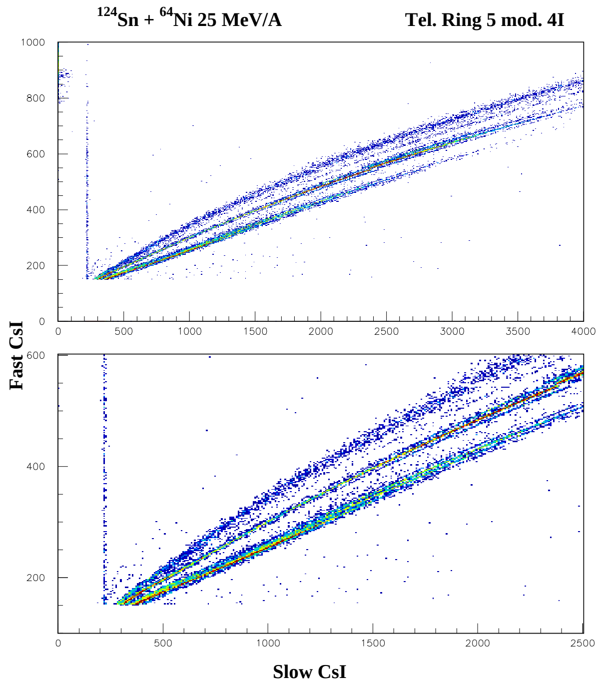

Fig. 14. Isotopic identification of light charged particles (LCP) in the CsI(Tl) detector by using the pulse shape method of the photodiode signal, in the first run of REVERSE experiment, ^{124}Sn+^{64}Ni at 25 MeV/A carried out at LNS. Lower side is a zoom of the upper side.

For such a program, we can reasonably assume that CHIMERA might be fully working at the end of summer 2001.

I finish the presentation of this powerful device by resuming in Table I, its typical features and performances compared with those of INDRA in use for the time being in this field of research.

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