IL NUOVO CIMENTO **39 C** (2016) 413
DOI 10.1393/ncc/i2016-16413-8

Colloquia: IWM-EC 2016

The InKiIsSy experiment at LNS: A study of size vs. isospin effects with ^{124}Xe + ^{64}Zn,^{64}Ni reactions at 35 *A* MeV

S. Norella(1), L. Acosta(2)(3), L. Auditore(1), V. Baran(4), T. Cap(5), G. Cardella (3), M. Colonna(6), E. De Filippo(3), D. Dell'Aquila(7), S. De Luca(1), L. Francalanza(7), B. Gnoffo(3)(8), G. Lanzalone(6)(9), I. Lombardo(7), C. Maiolino(6), N. S. Martorana(6)(8), T. Minniti(10), A. Pagano(3), E. V. Pagano(6)(8), M. Papa(3), E. Piasecki(11), S. Pirrone(3), G. Politi(3)(8), F. Porto(6)(8), L. Quattrocchi(3)(8), F. Rizzo(6)(8), E. Rosato(7)†, P. Russotto(3), K. Siwek-Wilczynska(12), A. Trifirò(1), M. Trimarchi(1), G. Verde(3)(13), M. Vigilante(7) and J. Wilczyński(5)†

(1) *INFN, Gruppo Collegato di Messina and Dip. di Scienze Matematiche ed Informatiche, Scienze Fisiche e Scienze della Terra, Università di Messina - Messina, Italy*
(2) *Instituto de Fisica, Universidad Nacional Autonoma de Mexico - Mexico City, Mexico*
(3) *INFN, Sezione di Catania - Catania, Italy*
(4) *Physics Faculty, University of Bucharest - Bucharest, Romania*
(5) *National Centre for Nuclear Research - Otwock-Swierk, Poland*
(6) *INFN, Laboratori Nazionali del Sud - Catania, Italy*
(7) *INFN, Sezione di Napoli and Dip. Fisica, Università di Napoli - Napoli, Italy*
(8) *Dipartimento di Fisica e Astronomia, Università di Catania - Catania, Italy*
(9) *Università Kore - Enna, Italy*
(10) *CNR-IPCF - Messina, Italy*
(11) *Heavy Ion Laboratory, University of Warsaw - Warsaw, Poland*
(12) *Physics Faculty, University of Warsaw - Warsaw, Poland*
(13) *Institut de Physique Nucléaire, CNRS/IN2P3, Univ. Paris-Sud 11 - Orsay, France*

received 10 January 2017

Summary. — In previous experiments, performed by CHIMERA Collaboration, a strong difference in the cross sections of "dynamical" PLF binary decay between neutron-poor ^{112}Sn(35 *A* MeV)+^{58}Ni and neutron-rich ^{124}Sn(35 *A* MeV)+^{64}Ni colliding systems has been reported. The same effect was not seen in the "statistical" binary decay. The observed difference was related to the different N/Z content between the two systems. However, size effects could not be excluded. In order to disentangle Isospin effects from size ones, the systems ^{124}Xe(35 *A* MeV)+^{64}Zn(^{64}Ni) were studied in the InKiIsSy (Inverse Kinematic Isobaric Systems) experiment, carried out at Laboratori Nazionali del Sud on April 2013, using the multi-detector CHIMERA and 4 prototype-modules of FARCOS array. We will report preliminary results on the binary PLF splitting mechanism.

† Deceased.

1. – Introduction

In semi-peripheral heavy-ion collisions at Fermi energies (20–100 A MeV), the reaction dynamics result mainly in binary products such as excited projectile-like (PLF) and target-like (TLF) fragments, that de-excite following an evaporation path. However also a dynamical IMFs (Intermediate Mass Fragments with $Z \geq 3$) production can take place. In particular, during the REVERSE experiment, performed at the LNS of Catania in order to study ^{124}Sn + ^{64}Ni and ^{112}Sn + ^{58}Ni collision at $E_{lab}(^{124}\mathrm{Sn}, ^{112}\mathrm{Sn}) = 35\,A$ MeV, decay properties of Projectile-Like Fragments in semi-peripheral collisions were analyzed. Specifically PLF, after scattering from TLF, may undergo splitting into two massive fragments, strongly correlated in charge and in velocity space. These two fragments (named as Heavy (H) and Light (L) according to their atomic number) have values of Z such that their sum is close to the charge of the projectile ($Z_{proj} = 50$). The analysis of the two systems, performed as a function of the fission-like fragments $Heavy/Light$ mass asymmetry (A_H/A_L) and kinetic energy loss (E_{2F}) [1, 2], has indicated that the binary break-up of PLF shows features of a mixing between an equilibrated-slow emission and a fast-dynamical one, each characterized by a peculiar angular distribution. In order to estimate the weight of these two components (dynamical and statistical) the $\cos(\theta_{prox})$ distribution was calculated, where θ_{prox} is the "proximity angle", *i.e.* the angle between the direction of the reconstructed PLF*, defined as center of mass velocity of the two selected fragments, and the breakup axis, given by the relative velocity between the two fragments oriented from the light to the heavy one (see fig. 4 of ref. [2]). In particular, in the case of a statistical fission a symmetrical distribution with respect to $\cos(\theta_{prox}) = 0$ is expected. Instead, in the case of dynamical fission the distributions clearly show a peak at $\cos(\theta_{prox}) = +1$. This dynamical component becomes more important with increasing energy dissipation (lower E_{2F}) and-or mass asymmetry (bigger A_H/A_L). Comparing the two systems (^{124}Sn + ^{64}Ni and ^{112}Sn + ^{58}Ni), it has been shown [3,4] that while statistical fission probability is almost the same for the two reactions, the dynamical component is larger for the neutron rich system. This effect could be due to the different N/Z ratio of the two systems. However, some simulations have shown that it could also be related to the different size [5, 6]. In order to disentangle the effects related to the isopin from the ones related to the size of the two interacting systems, a new experiment has been carried out at Laboratori Nazionali del Sud.

2. – The InKiIsSy experiment

The goal of the InKiIsSy experiment was the study of a projectile/target combination, ^{124}Xe + ^{64}Zn, having the same mass of the neutron-rich system (^{124}Sn + ^{64}Ni) and a N/Z ratio close to the value of the neutron-poor one (^{112}Sn + ^{58}Ni), in order to distinguish isospin effects from size ones. During this experiment also the ^{124}Xe + ^{64}Ni reaction was studied, in order to compare two systems with same mass but with different N/Z ratio for the target. In table I the value of Isospin of the four systems studied in the REVERSE and InKiIsSy experiment are reported.

The two systems were studied at 35 A MeV beam energy, using CHIMERA multidetector [7], coupled for the first time with 4 telescopes of FARCOS array [8], placed at 25 cm from the target in a 2×2 configuration. The analysis of the experiment has been completed. Also in this case, the $\cos(\theta_{prox})$ distribution for different mass asymmetry (A_H/A_L) and kinetic energy loss (E_{2F}) (fig. 1) was extracted in order to estimate the weight of the statistical and dynamical contribution. Specifically, comparing the two

TABLE I. – *Isospin values of the systems analyzed during REVERSE* (^{124}Sn + ^{64}Ni *and* ^{112}Sn + ^{58}Ni) *and INKIISSY* (^{124}Xe + ^{64}Zn *and* ^{124}Xe + ^{64}Ni) *experiments.*

System	N/Z projectile	N/Z target	N/Z compound
^{124}Sn + ^{64}Ni	1.48	1.29	1.41
^{124}Xe + ^{64}Ni	1.30	1.29	1.29
^{124}Xe + ^{64}Zn	1.30	1.13	1.24
^{112}Sn + ^{58}Ni	1.24	1.07	1.18

reactions (^{124}Xe + ^{64}Zn and ^{124}Xe + ^{64}Ni), it results that the dynamical component is stronger for the system with the neutron rich target. This result is similar to the one obtained in the REVERSE experiment but in this case the two systems are isobaric, with only different target.

This result indicates that the observed effect has to be related to the different isospin of the systems rather than to the initial size. Moreover, by a first comparison of the four systems studied during REVERSE and InKiIsSy experiments, it can be inferred (not shown here) that dynamical component weight scale with the N/Z ratio of the system. The dynamical probabilities, as a function of mass asymmetry and energy dissipation, are given in table II.

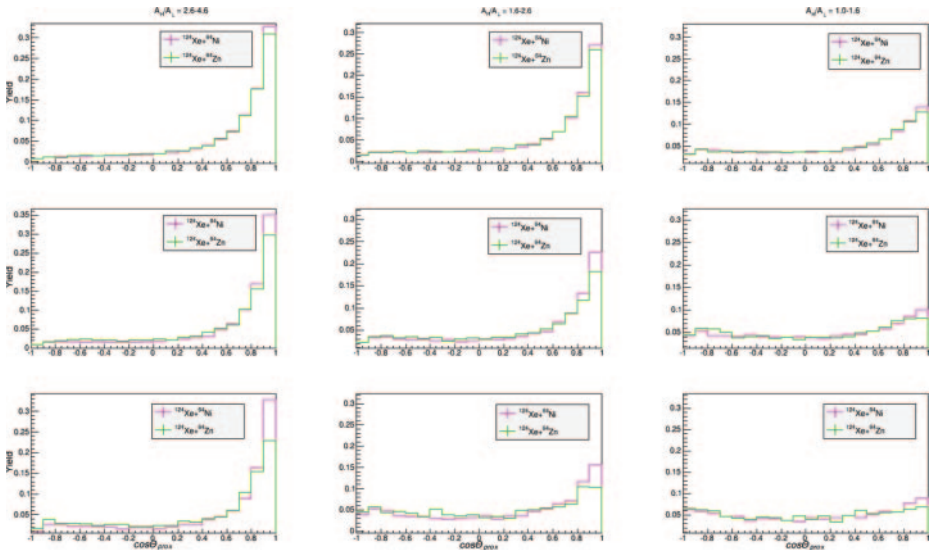

Fig. 1. – (color online) - $\cos(\theta_{prox})$ angular distributions for ^{124}Xe(35 A MeV) + ^{64}Ni (pink line) and ^{124}Xe(35 A MeV) + ^{64}Zn (green line) reactions. These distribution have been evaluated for different ranges of mass asymmetry A_H/A_L (columns) and different ranges of the total kinetic energy $E_{2F} = E_H + E_L$ (rows).

TABLE II. – *Percentage associated to the Dynamical component mechanism for the four systems studied during the REVERSE* (^{124}Sn + ^{64}Ni *and* ^{112}Sn + ^{58}Ni) *and the InKiIsSy* (^{124}Xe + ^{64}Zn *and* ^{124}Xe + ^{64}Zn) *experiments.*

DYN%	^{124}Sn+^{64}Ni; ^{112}Sn+^{58}Ni ^{124}Xe+^{64}Ni; ^{124}Xe+^{64}Zn		
	AH/AL		
E_{2F}(MeV)	2.6-4.6	1.6-2.6	1.6-1.0
2700-3060	73.8 ; 63.1 71 ; 67	56.3 ; 39.3 51 ; 45	21 ; 11.2 18 ;14
3060-3450	68.4 ; 49 63 ; 51	40.9 ; 16.8 31; 20	7.9 ; <5 7.1 ; <5
3450-4000	56.8 ; 36.2 54 ;36	25.4 ; 12.6 13 ; 11	3.8 ; <5 <5 ; <5

3. – Conclusions

The dynamical and the statistical PLF binary decay probability in semiperipheral reactions have been evaluated for the ^{124}Xe(35 A MeV)+^{64}Zn(^{64}Ni) systems. In previous experiments, the systems ^{124}Sn + ^{64}Ni and ^{112}Sn + ^{58}Ni have been studied in inverse (REVERSE) and direct (TIMESCALE) kinematics at 35 A MeV. The analysis of these two reactions has shown that while the statistical binary decay assumes the same cross section for the two systems, the dynamical fission probability is enhanced for the neutron-rich one. This effect can be related to the different N/Z ratio of the two systems but also to the different size of entrance channel. In order to disentangle these two effects, the ^{124}Xe + ^{64}Zn(^{64}Ni) reactions have been analyzed at the same bombarding energy. To separate the statistical from the dynamical contribution, the $\cos(\theta_{prox})$ distributions for different mass asymmetry (A_H/A_L) and kinetic energy loss (E_{2F}) were extracted and it resulted that the observed effect is related to the different isospin of the systems rather than to the size of projectile and target combination.

REFERENCES

[1] DE FILIPPO E. *et al.*, *Phys. Rev. C*, **71** (2005) 064604.
[2] RUSSOTTO P. *et al.*, *J. Phys. C*, **515** (2014) 012020.
[3] RUSSOTTO P. *et al.*, *Phys. Rev. C*, **81** (2010) 064605.
[4] RUSSOTTO P. *et al.*, *Phys. Rev. C*, **91** (2015) 014610.
[5] GIULIANI G., PAPA M. *et al.*, *Isospin degree of freedom and cluster production beyond the mean-field approach*, in *Conference Proceedings*, Vol. **95** (SIF, Bologna) 2008, p. 311.
[6] PAPA M. *et al.*, *Phys. Rev. C*, **75** (2007) 054616.
[7] PAGANO A. *et al.*, *Nucl. Phys. A*, **734** (2004) 504.
[8] PAGANO E. V. *et al.*, *EPJ Web of Conferences*, **117** (2016) 10008.