THE STRONG ROLE OF N/Z DEGREE OF FREEDOM IN Ca+Ca REACTIONS AT 25 MeV/NUCLEON*

I. Lombardo[a,f], C. Agodi[a], F. Amorini[a], A. Anzalone[a]
L. Auditore[d], I. Berceanu[h], G. Cardella[b], S. Cavallaro[a,c]
E. DeFilippo[b], G. Giuliani[c], E. Geraci[b,c], L. Grassi[b,c], J. Han[a]
E. LaGuidara[b,e], G. Lanzalone[a,f], D. Loria[d], C. Maiolino[a]
A. Pagano[b], M. Papa[b], S. Pirrone[b], G. Politi[b,c], F. Porto[a,c]
F. Rizzo[a,c], P. Russotto[a,c], A. Trifirò[d], M. Trimarchi[d]
G. Verde[b], M. Vigilante[g]

[a]INFN Laboratori Nazionali del Sud, Catania, Italy
[b]INFN, Sezione di Catania, Catania, Italy
[c]Dipartimento di Fisica e Astronomia, Università di Catania, Catania, Italy
[d]Dipartimento di Fisica, Università di Messina, Messina, Italy
[e]Centro Siciliano di Fisica Nucleare e Struttura della Materia, Catania, Italy
[f]Università Kore di Enna, Enna, Italy
[g]Dipartimento di Fisica, Università Federico II, Napoli, Italy
[h]NIPNE, Bucarest, Romania

(Received January 20, 2011)

Isospin effects on dynamics of semi-central collisions involving ^{40}Ca+^{40}Ca, ^{40}Ca+^{48}Ca and ^{48}Ca+^{48}Ca reactions at 25 MeV/nucleon have been investigated. For the selected class of events, the balance between the emission of evaporation residues and the presence of binary-like phenomena seems to be influenced by the neutron to proton ratio (N/Z) of entrance channels. In particular, for neutron-rich systems, evaporation residue emission is enhanced. Experimental observations confirm the key role played by the N/Z degree of freedom on nuclear dynamics at 25 MeV/nucleon.

DOI:10.5506/APhysPolB.42.701
PACS numbers: 25.70.Mn, 25.70.Lm

1. Introduction

One of the most intriguing topics in nuclear physics concerns the influence of N/Z degree of freedom on different aspects of nuclear dynamics. In the bombarding energy regime around 20 MeV/nucleon, reactions involving medium mass nuclei (as calcium isotopes) can lead to incomplete fusion

* Presented at the Zakopane Conference on Nuclear Physics "Extremes of the Nuclear Landscape", August 30–September 5, 2010, Zakopane, Poland.

phenomena [1, 2]. Moreover, evaporation residue emission and binary-like phenomena can be simultaneously present at semi-central impact parameters [3]. Since a long time ago it was supposed that neutron richness of intermediate system formed in the first phases of the collision could play a key-role in the evolution of reaction dynamics [4]. To investigate the role of N/Z degree of freedom in the dynamics of semi-central reaction involving medium mass nuclei, we performed the reactions ^{40}Ca+^{40}Ca, ^{40}Ca+^{48}Ca and ^{48}Ca+^{48}Ca at 25 MeV/nucleon; reaction products were detected by means of the 4π detector CHIMERA. We analyzed semi-central events and we found that the balance between production of evaporation residues and binary-like mechanisms is strongly regulated by the N/Z degree of freedom. In particular, nuclear reactions characterized by a high N/Z value of entrance channels show a larger probability of producing evaporation residues. These findings open the way for further investigations with exotic beams in the region of calcium.

2. Experimental apparatus

The experiment was performed at INFN-Laboratori Nazionali del Sud Super-Conducting Cyclotron facility. Beams of ^{40}Ca accelerated at 25 MeV/nucleon impinged on self-supporting targets of ^{40}Ca (1.24 mg/cm^2 thick) and isotopically enriched ^{48}Ca ($\simeq$ 2.7 mg/cm^2 thick). Preliminary results concerning the reaction ^{48}Ca+^{48}Ca at 25 MeV/nucleon will be also discussed (thickness of ^{48}Ca target: $\simeq$ 2.7 mg/cm^2). Reaction products were detected by using the 4π multi-detector CHIMERA. It is constituted by 1192 Si-CsI(Tl) telescopes, covering $\simeq$ 94% of the whole solid angle. Si detectors are 300 μm thick, while CsI(Tl) thicknesses vary as a function of the polar angle. Details about the array and its detection and identification capabilities are described in Refs. [5, 6, 7, 8, 9]. The obtained mass resolution is around 5% for nuclei having masses $A \approx 50$, that are typical of evaporation residues detected in this type of reactions because of the partial momentum transfer, characterizing incomplete fusion mechanisms, and of the abundant evaporation of light particles [10]. We selected events where the total detected charge was between 80% and 100% of the total charge, and with total parallel momentum larger than 70% of the entrance momentum. Quasi-elastic reactions were removed during the experiment by the chosen electronics trigger condition, requiring the detection of at least 3 charged particles.

3. Mass distributions in incomplete fusion events

Semi-central events have been selected by using constraints on charged particle multiplicity ($m_{\rm cp}$) [11, 12, 13]. The global behavior of $m_{\rm cp}$ distributions is similar for the three studied reactions, even if for the neutron-

rich systems the $m_{\rm cp}$ distributions are slightly shifted towards lower values. This effect could be attributed to the larger probability of emitting neutrons (that are undetected) in neutron-rich systems. For this reason, to analyze events belonging to similar windows of impact parameters, we selected events having $m_{\rm cp} \geq 6$ for ^{40}Ca+^{40}Ca reaction and $m_{\rm cp} \geq 5$ for ^{40}Ca+^{48}Ca and ^{48}Ca+^{48}Ca reactions. Emitted fragments are sorted accordingly to their masses. We selected the class of events where the second or the third fragment in the mass rank has velocity $v > 1.3 \times v_{\rm cm}$ ($v_{\rm cm}$ is the center of mass velocity), in order to look for the presence of a quasi-projectile in the event. For this class of events, we show in Figure 1 mass distributions (m_1) of the largest fragment emitted for the three studied systems.

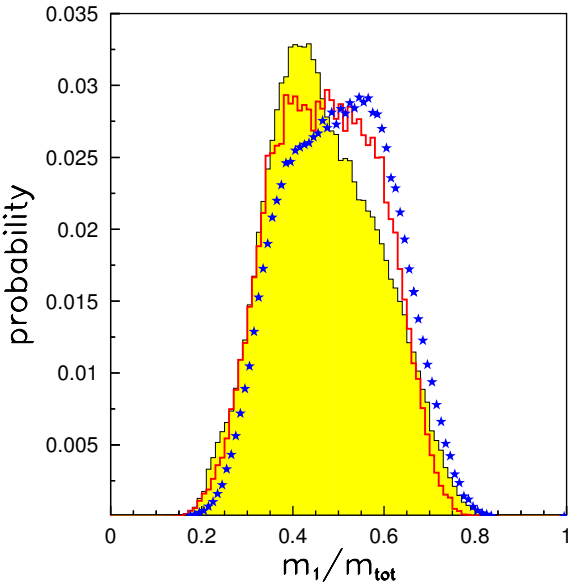

Fig. 1. $m_1/m_{\rm tot}$ spectra for semi-central events of ^{40}Ca+^{40}Ca (filled histogram), ^{40}Ca+^{48}Ca (red solid histogram) and ^{48}Ca+^{48}Ca (blue stars) reactions. Spectra have been normalized to the total number of selected semi-central events: 1.45×10^5 for ^{40}Ca+^{40}Ca, 6.7×10^4 for ^{40}Ca+^{48}Ca and 5.63×10^5 for ^{48}Ca+^{48}Ca system. The selected semi-central events are approximately 1/3 of the total number of well reconstructed events.

A cut on the velocity of the largest fragment (v_1) is used to discard contaminations due to quasi-projectile and quasi-target emission ($0.04 < \frac{v_1}{c} < 0.15$). Effects due to the different masses of entrance channels can be reduced by normalizing m_1 to the total mass of the systems $m_{\rm tot}$ [11]. A quite different behavior is observed. Evaporation residues ($m_1/m_{\rm tot} \approx 0.6$) are emitted with larger probability in the neutron rich system ^{48}Ca+^{48}Ca ($N/Z = 1.4$),

while binary-like events ($m_1/m_{\rm tot} \approx 0.4$) prevail in the $N/Z = 1$ system ^{40}Ca+^{40}Ca. ^{40}Ca+^{48}Ca system, having an intermediate value of neutron to proton ratio ($N/Z = 1.2$), shows an intermediate behavior. We verified that the observed effect is not due to the different selection criteria applied on $m_{\rm cp}$. Comparisons with CoMD-II model calculations [11, 14], including also the ^{48}Ca+^{48}Ca case, show that this effect can be attributed to the behavior of the symmetry potential in the nuclear equation of state. Calculations show that a parameterization of the density dependent part of the symmetry potential $(\frac{\rho}{\rho_0})^\gamma$ with $\gamma = 1.0 \pm 0.15$ [11, 14] must be used in order to reproduce successfully the experimental mass distributions.

4. Conclusions and perspectives

The fate of hot nuclear systems populated in semi-central events of reaction involving Ca isotopes at 25 MeV/nucleon was investigated. The balance between emission of evaporation residues and binary-like events is strongly regulated by the N/Z of entrance channels. For neutron rich systems, an enhancement of evaporation residue emission is seen. These findings open the way to perform studies with radioactive beams at $\approx$ 20 MeV/nucleon, in order to enlarge the N/Z range of the available entrance channels.

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