Exploring the isospin dependence on decays from compound nucleus and the ISODEC experiment with CHIMERA@LNS

S. Pirrone, INFN Sezione di Catania, Italy
This project fits very well the aims of the LEA COLLIGA agreement

- Italian (5I) and French (5I) teams

- 4π apparata (INDRA@GANIL – CHIMERA@LNS)

- stable beams by GANIL, LNS

- next exotic beams by SPES@LNL, SPIRAL2@GANIL

Experiments

- E475S@GANIL, with INDRA (done)

- ISODEC@LNS, with CHIMERA (approved to be done)

- Loi at SPES and SPIRAL2
• **Context of the experiment**

• **Previous experiment with INDRA@GANIL**

• **Peculiarity of the ISODEC experiment**

• **Suitability of the CHIMERA@LNS**

• **Next experiment**
Context And Physics Case

Heavy ion collisions with stable and exotic beam

Low energy regime $E/A \leq 15$ MeV/A

Fusion reaction mechanism

- The isospin dependence on the emission of complex fragments from CN, to extract information on the N/Z influence on: level density parameter, fission barrier, viscosity, symmetry energy at saturation density.

- The interplay between nuclear structure and reaction mechanism in this emission process, at different excitation energy for medium mass region.

Connected with astrophysics, mass formula, multy-body final states observed in violent dissipative collision (level density parameter, fission barrier, wigner and congruence term, isoscaling).
**E475S**  INDRA @GANIL  **E = 5.5 AMeV**

78, 82 Kr + 40 Ca (1mg/cm²) 118, 122 Ba* (~ 100 MeV)

- 3° ≤ θ ≤ 44°  IC-Si-CsI forward part
- Energy, angular distribution RP
- Charge distribution
- Cross section decay mode

- J.-P. Wieleczko et al., LOI for Lea GANIL-LNL 2007
- J.-P. Wieleczko *et al.*, proceedings of the FUSION08 international conference on New Aspects of Heavy Ion Collisions Near the Coulomb Barrier, sept. 2008, Chicago, USA
- E.Bonnet, Lea Colliga Meeting, LNS 2008
- G.Ademard *et al*, IWM2009, Catania
N/Z effects on $\sigma$ measurement

Bell shape like fission
- $Z \geq 14$
- $6 < Z < 12$
- EvenOdd staggering

CN neutron rich (o)
- 30% less fission
- Less even-odd staggering of IMF
- Even (odd) IMF are less (more) produced

Inclusive data

$\Delta$ even * odd

INDRA@GANIL
The discrepancies with theoretical previsions (Hauser-Feshbach scission-point, transition state, dynamical cluster decay, ..) show the need to include the N/Z dependence on the emission mechanism from CN

(See also G.La Rana N.Le Neindre and C.Rizzo contributions)
Location peaks and slopes give us information on the shape and on the temperature of the emitting system.
Coincidence $\alpha$-ER

Kinetic energy spectra of LCP – Shape evolution

Coincidence: the low energy component becomes less and less important when asymmetry increases: alpha / ER $\rightarrow$ one component

$M_{\text{LCP}} \sim 2-3$

Relative population reflects detection efficiency
Improving and Complementary Experiment: ISODEC

• Higher energy
  Influence on the amplitude of the staggering.
  Influence on the temperature of the emitting system.

• Isotopic separation of IMF
  to investigate the staggering effects looking at the isotopic distribution of IMF.

• Exploration of a larger domain in N/Z of the system (stable beam!)
  to compare with theoretical model and to study the dependence from the N/Z on the mechanism of complex fragment emission from CN

• Exclusive measurements in a large angular range

\[ ^{78,86}\text{Kr} + ^{40,48}\text{Ca} \rightarrow ^{118,134}\text{Ba}^* \]

\[ E_{\text{Lab}} = 10 \text{ AMeV} \quad E^* \approx 250 \text{ MeV} \]
Experimental Observables:

- Isotopic distribution for $3 \leq Z \leq 10$
- Energy spectra and angular distribution of the reaction products
- Absolute cross sections of different decay modes
- Relative velocity analysis and angular correlation
- Coincidence ER-LCP, FF-LCP, IMF-LCP

CHIMERA@LNS
CHIMERA
Charge Heavy Ion Mass and Energy Resolving Array

CsI(Tl)

Granularity: 1192 telescopes
Si (300µm) + CsI(Tl)

Geometry
- RINGS: 688 telescopes 100-350 cm
- SPHERE: 504 telescopes 40 cm

Angular range
- RINGS: 1° < θ < 30°
- SPHERE: 30° < θ < 176° 94% of 4π

Identification method
- ΔE-E
- E-TOF
- PSD in CsI(Tl)
- PSD in Si (upgrade 2008)

Experimental observables and performances
- TOF, δt < 1 ns
- δE/E  LCP (Light Charge Particles) ≈ 2%
- δE/E  HI (Heavy Ions) ≤ 1%
- Energy, Velocity, A, Z, angular distributions

Detection threshold
- ≈ 1 MeV/A for H.I.
- ≈ 2 MeV/A for LCP
Method PSD in Si - (R&D-2008)
Timescale Experiment – Oct 2008 - $^{58}$Ni+$^{112}$Sn  $E = 35$ MeV/A

<table>
<thead>
<tr>
<th>Z</th>
<th>6</th>
<th>8</th>
<th>12</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eth/A</td>
<td>5</td>
<td>5.5</td>
<td>8.5</td>
<td>10</td>
</tr>
</tbody>
</table>
Method (E, TOF)

\[ E \propto A d^2/t^2 \]

Si

CsI(Tl)

HF start

135 ns

HF Cyclotron

Exp TIMESCALE

\(^{58}\text{Ni} + ^{112}\text{Sn} \quad E = 35 \text{ MeV/A}\)

Identification threshold for \(Z=6\) \(E_{th}=5 \text{ MeV/A}\)

Beam time resolution \(\Delta t = 1.250 \text{ ns}\)

\(E.\text{De Filippo et al. Report LNS09}\)
July 8, 2009  ISODEC beam request @ LNS-Pac

$^{78}\text{Kr} + ^{40}\text{Ca}, \quad ^{86}\text{Kr} + ^{48}\text{Ca} \quad E_{\text{Lab}} = 10 \text{ AMeV}$

Spokepersons:
J.-P. Wieleczko GANIL, Caen, France
S.P., INFN-Sezione di Catania, Italy
M.La Commara, Univ. & INFN-Sezione di Napoli, Italy
G.Politi, Univ. & INFN-Sezione di Catania, Italy

LNS-PAC response

*Proposal C123:* **ISODEC**

“The committee considers this experiment as a good scientific case for isospin nuclear physics….”

Assigned 30 BTU experiment + 6BTU beam test (800 ps time resolution /10$^7$pps)

November 26, 2009 Beam Test

**January 12-29, 2010 – Experiment**
• Program to study the isospin dependence on CN decay modes and the N/Z influence on some properties of nuclei (fission barriers, level density parameter, viscosity)

• Obtained results from **E475S** experiment with INDRA@GANIL

• Next improving and complementary **ISODEC** experiment with CHIMERA@LNS

• CHIMERA@LNS is a very suitable device, also in this low energy domain, thanks to recent improvements of PSD on Si.

• Extension of this research program with exotic beams is of course possible and very interesting (SPES@LNL – SPIRAL2-Loi).

“Typical” LEA-Colliga project!
ISODEC participants