Dependence from the Isospin of the entrance channel in Projectile-like (PLF) break-up at Fermi energies

The Physics case: dynamical vs. statistical production of Intermediate Mass Fragments (IMF).

The Experiment: The InKilsSy experiment (Inverse Kinematics Isobaric Systems), $^{124}\text{Xe}+^{64}\text{Zn, }^{64}\text{Ni}$ at 35 A.MeV as compared with previous studied reactions $^{124,112}\text{Sn}+^{64,58}\text{Ni}$.

Main Results: the «dynamical» fission of the PLF* is mainly rules by the N/Z content of the projectile and target and not dependent by the sistem «size».

Constrained Molecular Dynamics (CoMD-3) simulations

CHIFAR: CHImera-FARcos: A new experiment to study projectile-like break-up and IMF production at 20 A.MeV with the CHIMERA and FARCOS devices
Physical case: sources of IMFs in semi-peripheral reactions

In the "neck" emission light IMFs (Z ≈ 9) are produced at midrapidity due to the rupture of a piece of nuclear matter a low density ("neck"). This is generally a FAST process (<100 fm/c).

Excitation of a primary Projectile-like PLF* (TLF*) followed by its dynamical (non-equilibrated) splitting (dynamical fission). In this case emission of the lighter IMF is preferentially backwards in the PLF reference system. This process is in competition with statistical (equilibrated) break-up.

Our goal: Study of Isospin influence on PLF dynamical break-up
Previous results: comparison of IMFs cross sections for $^{124}$Sn+$^{64}$Ni and $^{112}$Sn+$^{58}$Ni

Main experimental signature:
Enhanced contribution of dynamical component in binary projectile break-up (dynamical fission) for neutron rich system

- Dynamical component: enhanced for the neutron rich
- Statistical component: almost equal (A ratio: $\sim$1.1 close to the mass ratio between the systems)

Isospin influence on dynamical production of IMFs in the InKilsSy (Inverse Kinematics Isobaric Systems) experiment: $^{124}\text{Xe} + ^{64}\text{Zn}, ^{64}\text{Ni}@35\text{ A.MeV}$

The main goal of the experiment was to disentangle entrance channels Isospin effects from «size» effects by using isobaric systems $M_{\text{proj}}=124 : M_{\text{target}} = 64$.

<table>
<thead>
<tr>
<th>System</th>
<th>N/Z Projectile</th>
<th>N/Z target</th>
<th>N/Z compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{124}\text{Sn} + ^{64}\text{Ni}$</td>
<td>1.48</td>
<td>1.29</td>
<td>1.41</td>
</tr>
<tr>
<td>$^{124}\text{Xe} + ^{64}\text{Ni}$</td>
<td>1.30</td>
<td>1.29</td>
<td>1.29</td>
</tr>
<tr>
<td>$^{124}\text{Xe} + ^{64}\text{Zn}$</td>
<td>1.30</td>
<td>1.13</td>
<td>1.24</td>
</tr>
<tr>
<td>$^{112}\text{Sn} + ^{58}\text{Ni}$</td>
<td>1.24</td>
<td>1.07</td>
<td>1.18</td>
</tr>
</tbody>
</table>

The analysis is done for $M_{\text{IMF}}=1$ events (ternary splitting).

Analysis of the two largest fragments $Z_1 - Z_2$

$$V_{\text{rel}} = V_{\text{PLF}} - V_{\text{IMF}}$$

$$V_{\text{rel}} / V_{\text{viola}} \geq 1.5$$
Analysis of the two largest fragments $Z_1 - Z_2$

We select only data with $V_{rel}/V_{viola} \leq 1.5$ in order to reject IMFs emitted from TLF (see P. Russotto et al., PRC 91, 014610 2015.)
Galileian Invariant cross-sections for the lighter fragment $A_L$ in the reference frame of the PLF source

$^{124}\text{Xe} + ^{64}\text{Ni}$

2.6 $< A_H/A_L < 4.6$

1 $< A_H/A_L < 1.3$
Data analysis method: angular distributions

Disentangling statistical and dynamical emission
Three body analysis of fragments (neck dynamics) in INKIISSY

\[ ^{124}\text{Xe} + ^{64}\text{Ni} @35 \text{ A.MeV} \]

FROM neck emission
TO projectile-like asymmetric break-up

\[ ^{124}\text{Xe} + ^{64}\text{Ni} @35 \text{ A.MeV} \]

We use angular distribution of fragments in order to estimate the probabilities of dynamical vs. statistical emission as a function of IMFs charge.
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This is a different case where the relation between the N/Z of fragments is observed as a function of the break-up angular distributions, related to the time-scale of the process.

A. RODRIGUEZ MANSO et al. • Extract time-scale from rotation

PHYSICAL REVIEW C 95, 044604 (2017)
Main experimental Result: dynamical emission is favored by an increase of projectile and target isospin and is independent by the system size.
Main experimental Result: dynamical emission is favored by an increase of both Projectile and Target Isospin.

Linear Scaling with a weighted N/Z content of projectile and target:

\[ \frac{1*N/Z_{proj} + 2*N/Z_{target}}{3} \]

Dynamical emission is mainly ruled by the N/Z content of both projectile and target.
Constrained Molecular Dynamics simulation (CoMD-3)

✓ $^{124}$Xe + $^{64}$Ni and $^{124}$Sn + $^{64}$Ni @ 35 A.MeV
✓ Preliminary test at 650 fm/c and stiffness parameter on $E_{sym}(\rho)$, $\gamma=1$
✓ Checking for projectile break-up events

Model → see M. Papa, Phys. Rev. C87, 014001 (2013) and refs therein

Selection: data analysis as in the experiment
Simulation with Constrained Molecular Dynamics simulation (CoMD-3)

Filtered

$^{124}$Xe + $^{64}$Ni

$^{124}$Sn + $^{64}$Ni

650 fm/c and stiffness parameter on $E_{sym}(\rho)$, $\gamma=1$ (stiff). Data analysis as for the experimental data.

(work in progress...)

PRELIMINARY
Dynamical processes in projectile break-up and Intermediate Mass Fragments production at 20 A.MeV beam incident energy studied with the CHIMERA and FARCOS devices. **CHIFAR: CHImera-FARcos** (approved LNS-PAC proposal) spokes: E.V. Pagano, E.d.F., P. Russotto

CHIMERA + 10 FARCOS telescopes in a “quasi”-ring configuration

$^{124}$Xe, $^{124}$Sn + $^{64}$Ni, $^{64}$Zn

$^{112}$Sn+$^{58}$Ni @ 20A.MeV

Configuration CAD study for 10 FARCOS telescopes between the sphere and ring 9; Luis Acosta group, Mexico
64 mm, 32 strips, Double-Sided Silicon Strip Detectors produced by Micron Semiconductor.
(300 and 1500 µm / C= 25pF and 5pF )
Capton cable 2x32pin connectors
Minimum PCB frame-area thick, 4 mm,
frame-thick 6.5 mm
\[ \Delta E = 20\text{KeV} \quad (\alpha 5.48 \text{ MeV}) \]
\[ \Delta E/E = 0.2-0.3\% \]
Rise time<20ns

Highly homogeneous CsI(Tl) crystals produced by SCIONIX.
Wrapped with 0.12 mm thick white reflector +50 µm aluminized mylar.
Aluminized mylar window 2 µm thick (0.29 gr/cm²). Read by Photodiode Hamamatsu 300 µm
\[ \Delta E/E = 2-3\% \quad (\alpha 5.48 \text{ MeV}) \]

FARCOS: Femtoscope Array for COrrrelations and Spectroscopy
Technical Design Report (TDR): https://drive.google.com/file/d/0B5CgGWz8LpOOc3pGTWdOcDBoWFE/view
Summary

We have shown results of the InKilSy experiment, $^{124}\text{Xe}+^{64}\text{Zn},^{64}\text{Ni}$ at 35 A.MeV using two systems that are isobaric with the $^{124}\text{Sn}+^{64}\text{Ni}$. All the system have the same size but differ in N/Z isospin.

Results show that in the binary break-up of the quasi-projectile there is an enhancement of the break-up probability for the neutron-rich system with respect to the neutron poor and this is due to the increase of the dynamical emission component, mainly ruled by the N/Z content of the projectile and target.

This effect could be related to the density dependence of symmetry energy but needs calculations that are able to follow the largest possible time-scales of IMF emission. We performed simulations using the CoMD3 model with promising results.

CHIFAR: A new experiment by using CHIMERA and FARCOS devices is programmed in order to study projectile break-up and IMF production and correlations at 20 MeV/A.
Collaboration for the INKIISSY experiment

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