Isospin equilibration in theoretical calculations

K. Mazurek, S. Piantelli, G. Casini, D. Gruyer, J. Frankland, A. Kelic-Heil, D. Lacroix .....

September 9, 2019

Outline

- Entrance channel description: ABRABLA, HIPSE
- Isospin equilibration in ^{70}Zn(35AMeV)+^{70}Zn
- Predictions for Ni+Ni and Ca+Ca

A. RODRIGUEZ MANSO *et al.* PHYSICAL REVIEW C **95**, 044604 (2017)

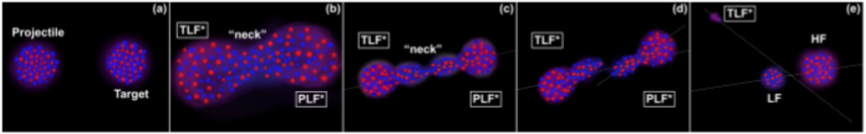


FIG. 1. Representation of dynamical deformation and decay. Panel (a) shows a projectile approaching the target. In panel (b), the projectile has rotated around the target, forming a low-density "neck" region. In panel (c), the excited PLF* and TLF* have moved further away from each other and stretched into a "string of pearls" with the smallest fragments forming out of the neck region. Panel (d) represents the breaking of the nuclear system with the PLF* separating from the TLF*. Panel (e) shows the subsequent separation of the PLF* into HF and LF. (Figures from Ref. [9].)

Isospin equilibration - ^{70}Zn(35AMeV)+^{70}Zn

A. Jedele, A. B. McIntosh et al PRL 118, 062501 (2017)

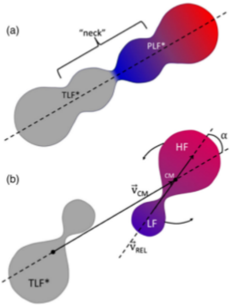


FIG. 1. Illustration of dynamical deformation and decay. Panel (a) shows the deformed PLF* and TLF* system before rupture of the neck. Panel (b) shows a later time after the PLF* and TLF* system has separated. The PLF* has rotated relative to the TLF* separation axis ($\vec{v}_{CM}$) and is itself about to break up into two fragments (**HF** and **LF**). The time the PLF* lives before breaking up is measured by the angle α. The color denotes the composition with blue indicating neutron richness and red indicating relative neutron deficiency.

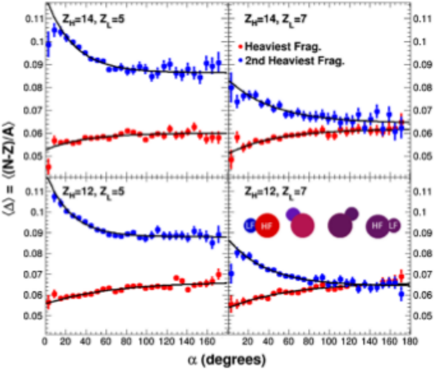
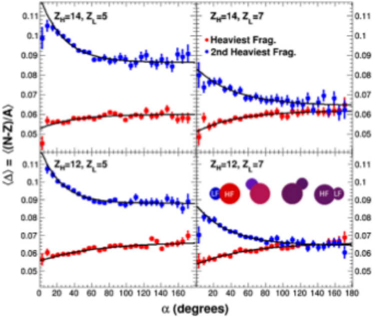


FIG. 3. Composition as a function of decay alignment showing equilibration. As the angle of rotation increases (α increases from 0° to 180°), the $\langle N - Z/A \rangle$ initially decreases rapidly for Z_L and increases for Z_H before plateauing. The majority of equilibration occurs between 0° and 80°.

Isospin equilibration - ^{70}Zn(35AMeV)+^{70}Zn

A. Jedele, A. B. McIntosh et al PRL 118, 062501 (2017)



- Sensitivity of n-p equilibration to the form of the density dependence of the symmetry energy
- Equilibration depends on the contact time, the potential driving equilibration, and relative n-p asymmetry of the reaction partners
- Large mass asymmetries lead to strongly aligned configurations, with the lighter partner emitted towards the QuasiTarget (QT), while small mass asymmetries produce more isotropic distributions.
- The α angle as a clock for the QP fission process: small α - bigger isospin - shorter time

HIPSE dynamical model

Heavy-Ion-Space Exploration (HIPSE) is a phenomenological model dedicated to heavy-ion reactions around Fermi energy. It can be used as an event generator and gives access to partitions before and after statistical decay. D. Lacroix et al. Phys. Rev. C69,054604 (2004)

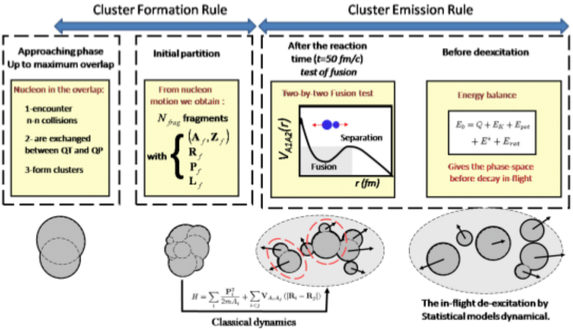


FIG. 38: *Illustration of the different steps to describe nuclear collisions. From left to right are shown: (i) the definition of the participant region after the approaching phase. (ii) the cluster formation. Properties of clusters are directly deduced from properties of nucleons issued from the Thomas-Fermi sampling and eventually distorted by the nucleon-nucleon direct collisions. (iii) Once clusters are formed and after some expansion, a test is made to check if they escape from the attraction of surrounding clusters. If not, the two attracting clusters fuse. (iv) Once the chemical freeze-out is reached, a global energy balance is made to check that the partition is energetically accessible. Then the excitation energy deduced from the energy balance is shared between clusters (v) The in-flight decay is performed. Calculation is stopped once all fragments are cold.*

HIPSE - Results

LACROIX, VAN LAUWE, AND DURAND

PHYSICAL REVIEW C 69, 054604 (2004)

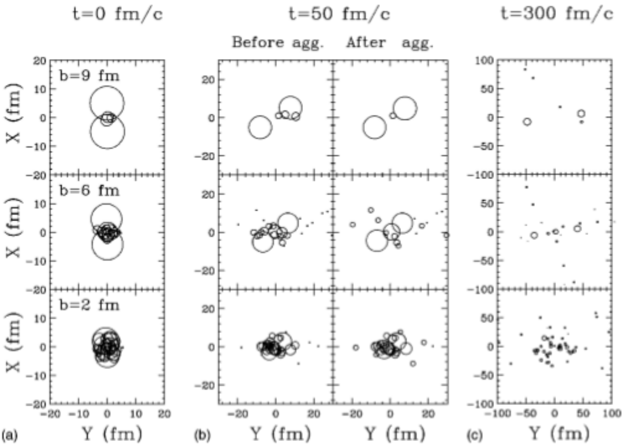


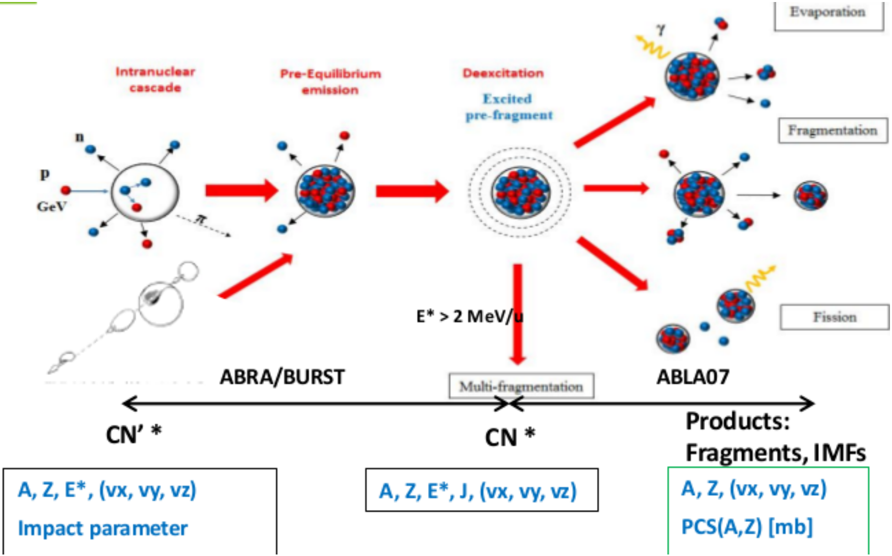
FIG. 2. Example of nuclear dynamics obtained for the reaction $^{129}Xe+^{120}Sn$ at $E=50$ MeV/nucleon. From top to bottom, the initial impact parameters $b=9$ fm, $b=6$ fm, and $b=2$ fm are presented. In each case, from left to right figures correspond to the initial cluster configuration ($t=0$ fm/c), the configuration before and after the reaggregation ($t=50$ fm/c), and during the deexcitation ($t=300$ fm/c).

ABRABLA model

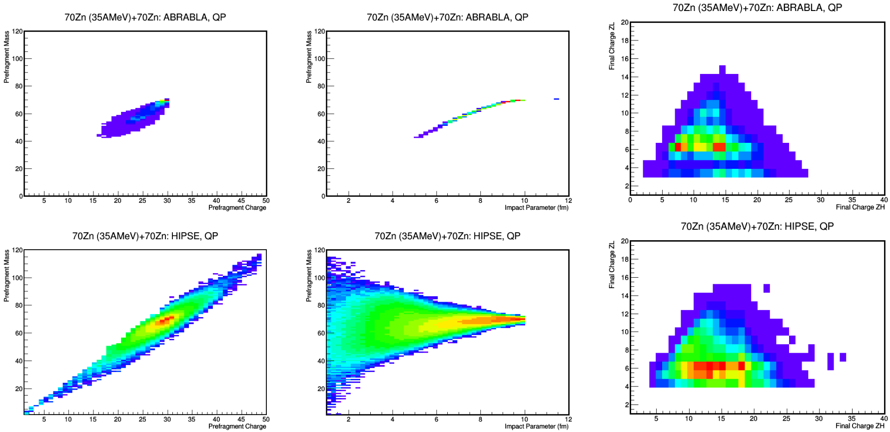
Abrasion-Ablation code

- Monte-Carlo code allows to calculate production cross section (PCS) and velocities of residues produced in relativistic heavy-ion collisions
- peripheral and mid-peripheral collisions
- ABRABLA code =
  ABRA + ABLA (Nucleus-Nucleus)
  BURST + ABLA (nucleon-Nucleus)
- Codes ABRA/BURST are valid at E$>$ 100 AMeV
- Parameterization based on the data measured at FRS GSI using the beams 56Fe, 136Xe, 197Au, 208Pb, 238U + 1H @ 1 GeV

ABRABLA model

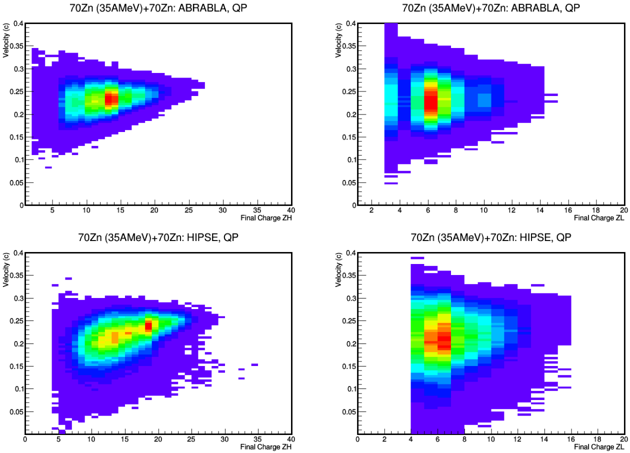


ABRABLA/HIPSE model (Preliminary)



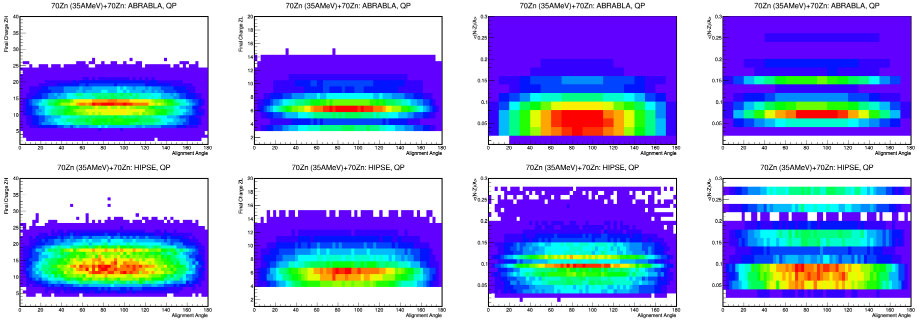
The prefragment mass/charge distribution, prefragment mass/impact parameter; final charges for ^{70}Zn(35AMeV)+^{70}Zn reactions with ABRABLA (top) and HIPSE (bottom).

ABRABLA/HIPSE model (Preliminary)

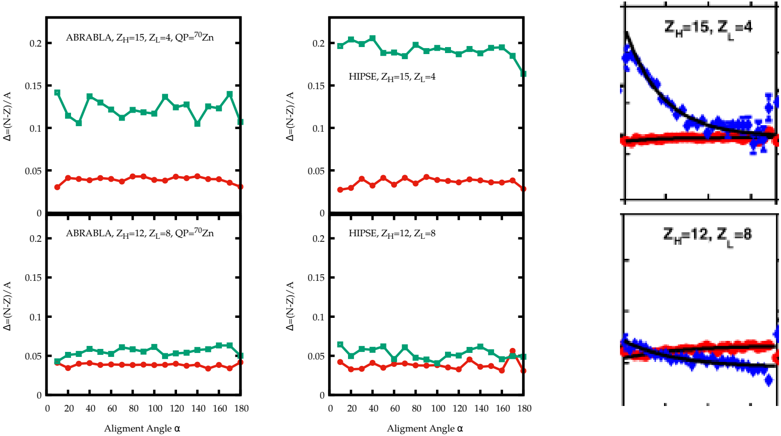


The final charge and its velocity in beam direction for ^{70}Zn(35AMeV)+^{70}Zn reactions with ABRABLA (top) and HIPSE (bottom).

ISOSPIN EQUILIBRATION (Preliminary)



The final charge for light (ZL) and heavy (ZH) fragments/alignment angle distribution; average composition $\langle \Delta \rangle = (N - Z)/A$ and alignment angle distribution for ^{70}Zn(35AMeV)+^{70}Zn reactions with ABRABLA (top) and HIPSE (bottom).

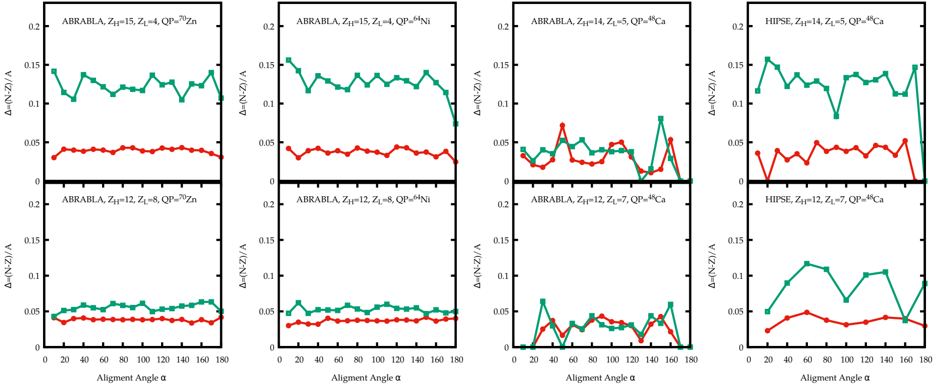


The final charge for light (ZL) and heavy (ZH) fragments/alignment angle distribution; average composition $\langle \Delta \rangle = (N - Z)/A$ and alignment angle distribution for ^{70}Zn(35AMeV)+^{70}Zn reactions with ABRABLA (top) and HIPSE (bottom).
Exp. A. Rodriguez Manso et al,PRC 95, 044604 (2017)

Isospin Equilibration (Preliminary)

ABRABLA — ^{70}Zn+^{70}Zn, ^{64}Ni+^{64}Ni, ^{48}Ca+^{48}Ca

HIPSE — ^{48}Ca+^{48}Ca

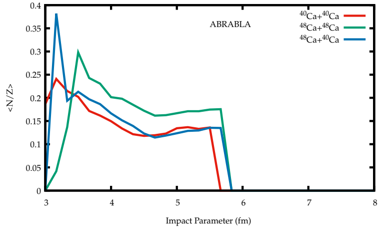


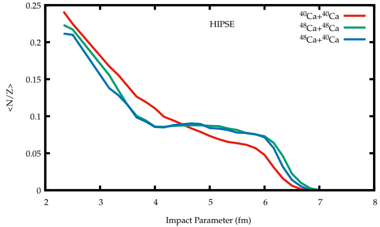
The average composition $\langle\Delta\rangle = (N-Z)/A$ and alignment angle distribution for ^{70}Zn(35AMeV)+^{70}Zn, ^{64}Ni(35AMeV)+^{64}Ni,^{48}Ca(35AMeV)+^{48}Ca, reactions with ABRABLA for asymmetric (top) and more symmetric (bottom) pairs of fragments.

Imbalance Ratio in ^{40,48}Ca(35AMeV)+^{40,48}Ca (Preliminary)

M. B. Tsang et al PRL 92,062701

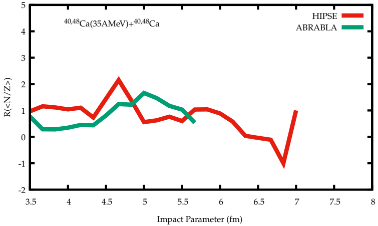
$\langle N/Z \rangle$ of the heavy fragment ZH





Imbalance ratio

$$R(\langle N/Z \rangle)_{Ca} = \frac{2I_{40,48} - I_{48,48} - I_{40,40}}{I_{48,48} - I_{40,40}}$$



Summary

- The isotopic equilibration process gives the knowledge about quasiprojectile fission time and contact time between QT i QP.
- The ABRABLA and HIPSE models gives many information about time-space evolution participants of the moderate energy reaction.
- The preliminary estimations of the mass/charge distributions of the asymmetric fragments coming from QP fission don't show any equilibration with increasing alignment angle.
- The imbalance ratio of $< N/Z >$ obtained from ABRABLA and HIPSE shows similar behavior with centrality for the reactions: more central - higher imbalance ratio.
- Plans: applying the experimental filters and compare with the data.