NUCLEAR EQUATION OF STATE

\[ E(\rho, (N-Z)/A) \]

R. BOUGAULT, INDRA/FAZIA COLLABORATION
NUCLEAR EQUATION OF STATE

The largest uncertainties on the nuclear energy-density functional concern the SYMMETRY potential part.

Even at saturation density!!

A. Dieperink et al. PRC68(2003)064307
WITH THE HELP OF H.I. COLLISIONS
Measure the Density Dependence of the Symmetry Energy
EXOTIC NUCLEI – Data/Models

H.I. collisions
Intermediate energies

Isospin diffusion

132Sn+132Sn, 1.5 AGeV

Adapted from H.Wolter, IWM2007

EXAMPLES OF PROBES
ONE OF A MAJOR PROBLEM IS RELATED TO SECONDARY DECAY EFFECTS

Most isospin observables lose sensitivity to the EOS due to secondary decay.

Solutions:
- Taking ratios amplifies the signals and (partially) cancels secondary evaporation.
- Use very exotic beams.

FAZIA simulation group: P. Napolitani et al, in preparation.
**INDRA@GANIL EXPERIMENT**

\[ {^{136,124}Xe + ^{124,112}Sn} \text{ 32 A.MeV} \]

STUDY OF THE “CHEMISTRY” IN THE FORWARD PART OF c.m
[good detection]
and preliminary results of
STOCHASTIC MEAN FIELD TRANSPORT MODEL (SMF*)

Work in progress, preliminary

IN THE FORWARD PART OF c.m \( \rightarrow \) “QP-side”

\[
^{136,124}_{\text{Xe}} + ^{124,112}_{\text{Sn}} \text{ 32 A.MeV}
\]
INDRA@GANIL EXPERIMENT

136,124Xe + 124,112Sn 32 A.MeV

Light Charged Particles: Transverse Energy (Forward part of c.m)
INDRA@GANIL EXPERIMENT

$^{136,124}$Xe + $^{124,112}$Sn 32 A.MeV

Mean Multiplicities

Total M(charged id.)

$M_{lcp_{p-rich}} > M_{lcp_{p-poor}}$

$M_{frag_{p-rich}} < M_{frag_{p-poor}}$

see MSU. results

MEASURE OF THE IMPACT PARAMETER
**INDRA@GANIL EXPERIMENT**

$^{136,124}_{\text{Xe}} + ^{124,112}_{\text{Sn}}$ 32 A.MeV

$M_{\text{lp p-rich}} > M_{\text{lp p-poor}}$ largely due to $M_{\text{proton}}$

**Proton mean Multiplicities**

Proton Mean Multiplicity

Xe+Sn 32 A.MeV

Forward lcp TRANSVERSE ENERGY (MeV)

MEASURE OF THE IMPACT PARAMETER
INDRA@GANIL EXPERIMENT

$^{136,124}_{\text{Xe}} + ^{124,112}_{\text{Sn}}$ 32 A.MeV

Measuring impact parameter

proton-poor

proton-rich
**INDRA@GANIL EXPERIMENT**

$^{136,124}\text{Xe} + ^{124,112}\text{Sn}$ 32 A.MeV

**MEASURE OF THE IMPACT PARAMETER**

Scale $= (E_{\text{trans}})^{1/2}$

- **proton-poor**
- **proton-rich**
INDRA@GANIL EXPERIMENT

$^{136,124}_{\text{Xe}} + ^{124,112}_{\text{Sn}}$ 32 A.MeV

Measure of the impact parameter

$^{3H}$

Scale: $(E_{\text{trans}})^{1/2}$

10fm 8fm 6fm 4fm

Proton-poor

Proton-rich

$^{124}_{\text{Xe}} + ^{124}_{\text{Sn}} = ^{136}_{\text{Xe}} + ^{112}_{\text{Sn}}$
**INDRA@GANIL EXPERIMENT**

\(^{136,124}\text{Xe} + ^{124,112}\text{Sn} 32 \text{ A.MeV} \)

**Measure of the Impact Parameter**

Scale = \((E_{\text{trans}})^{1/2}\)

10fm, 8fm, 6fm, 4fm

**SMF iso-stiff primary**

QP(N/Z) [PRELIMINARY]

with E. Galichet and M. Colonna
**INDRA@GANIL EXPERIMENT**

$^{136,124}$Xe + $^{124,112}$Sn 32 A.MeV

**Mean Multiplicities**

- Total $M_{\text{charged id.}}$
- $M_{\text{lcp}, \text{p-rich}} > M_{\text{lcp}, \text{p-poor}}$
- $M_{\text{frag}, \text{p-rich}} < M_{\text{frag}, \text{p-poor}}$

See MSU results

Measure of the impact parameter
INDRA@GANIL EXPERIMENT

$^{136,124}$Xe + $^{124,112}$Sn 32 A.MeV

Fragment Multiplicity relative to $^{124}$+124

MEASURE OF THE IMPACT PARAMETER
**INDRA@GANIL EXPERIMENT**

**136,124Xe + 124,112Sn 32 A.MeV**

**Fragment Multiplicity relative to 124+124**

This part is impossible to compare with SMF (neutron) “Et of lcp” for b

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**SMF iso-Stiff primary fragments PRELIMINARY**
Within 2/3 years a demonstrator will be running coupled with existing multi-detectors.
FAZIA collaboration

Identify ions stopped in one silicon detector with low id. thresholds.
FAZIA collaboration

Identify ions stopped in one silicon detector

FAZIA DATA

Ions stopped in ONE silicon

low id. thresholds
FAZIA collaboration

"Channeled"  

"Random"

IMPROVEMENT IN SIGNAL DISPERSION
non-homogeneity in the electric field inside the detector (doping) may have a severe impact over the Pulse Shape Discrimination capabilities:

A typical detector: ~9% non-uniformity

A very good detector: ~1% non-uniformity

IMPROVEMENT IN DOPING UNIFORMITY
FAZIA collaboration

14 bit, 100 MS/s digitizer
1.3 GeV full range

IONS STOPPED IN ONE DETECTOR

Carbon Isotopes

Imax/Efpga

Factor Of Merit

Factor Of Merit

leneindre@lpccaen.in2p3.fr
FAZIA collaboration

ioni 14 bits 100MS/s
6 GeV full scale

IONS STOPPED IN ONE DETECTOR

Apparently no upper limit in Z identification!

Z=36
FAZIA collaboration

USUAL DE/E Id. WITH OUR DETECTOR SELECTION:

Isotopic separation up to $Z \sim 20-25$