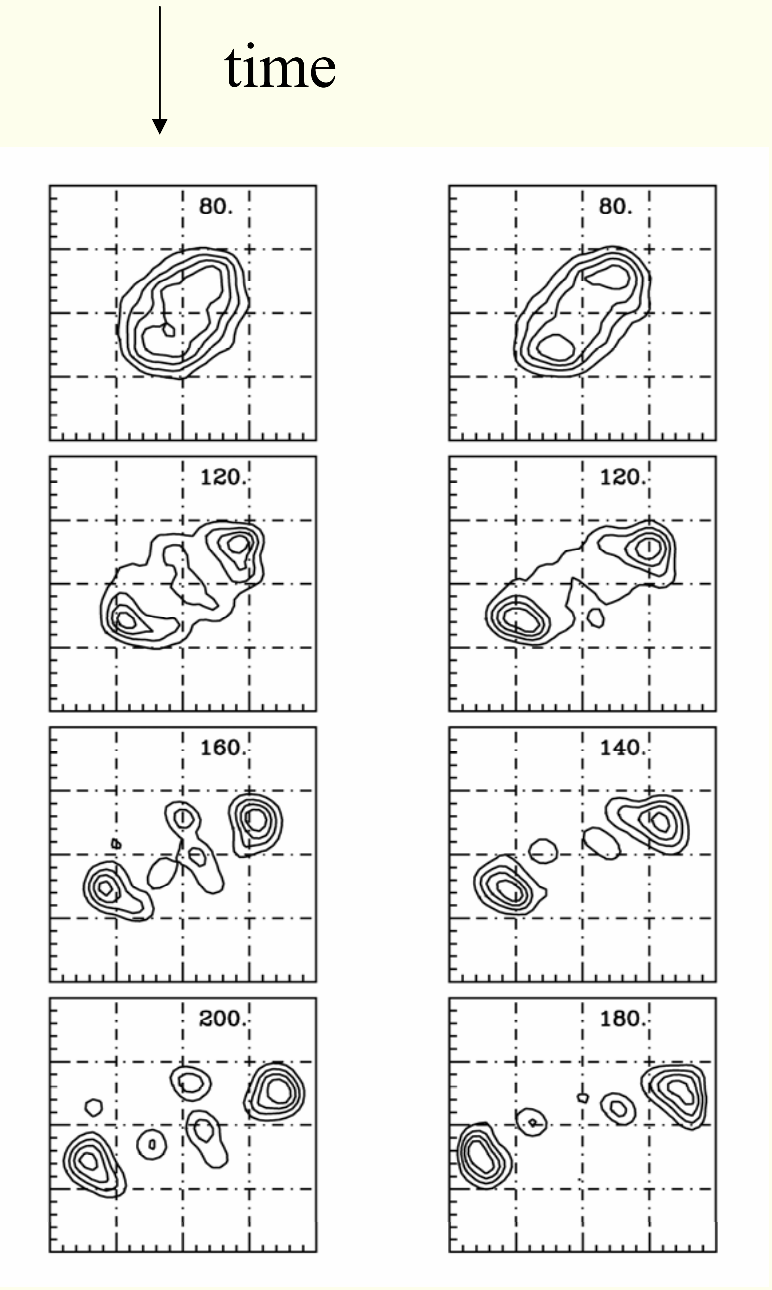
Neck fragmentation

Semi-peripheral reactions:
Fragmentation in a smaller region, but with larger cross section !

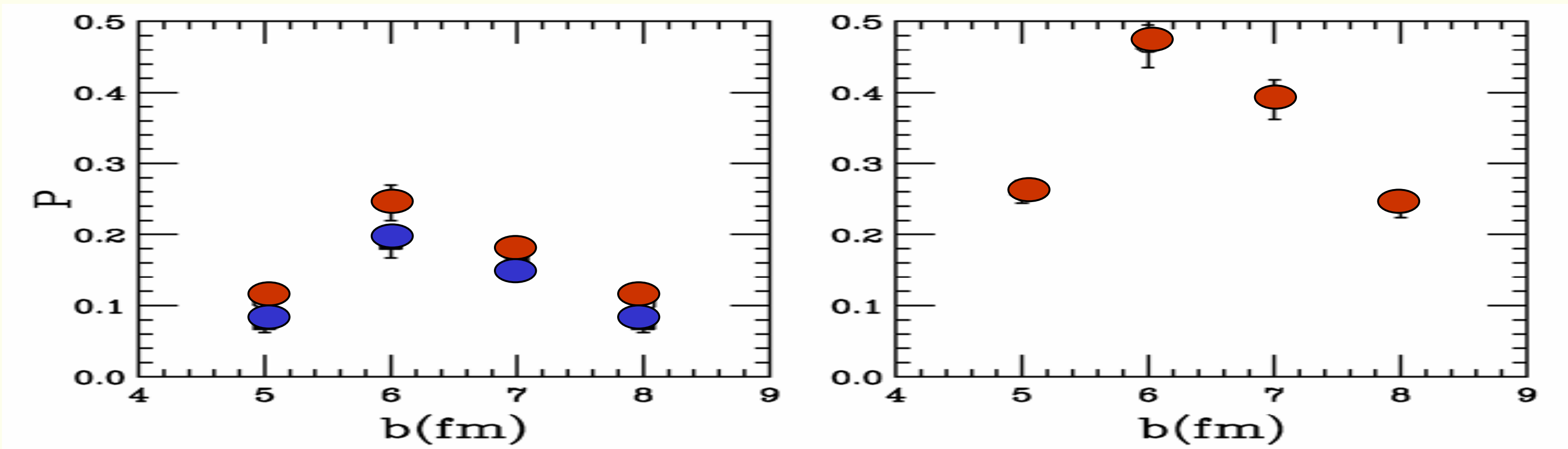
Possibility to better disantangle and/or correlate kinematical and thermodynamical features



Impact parameter dependence

E/A = 35 AMeV; b=6 fm

free cross sections half free cross sections

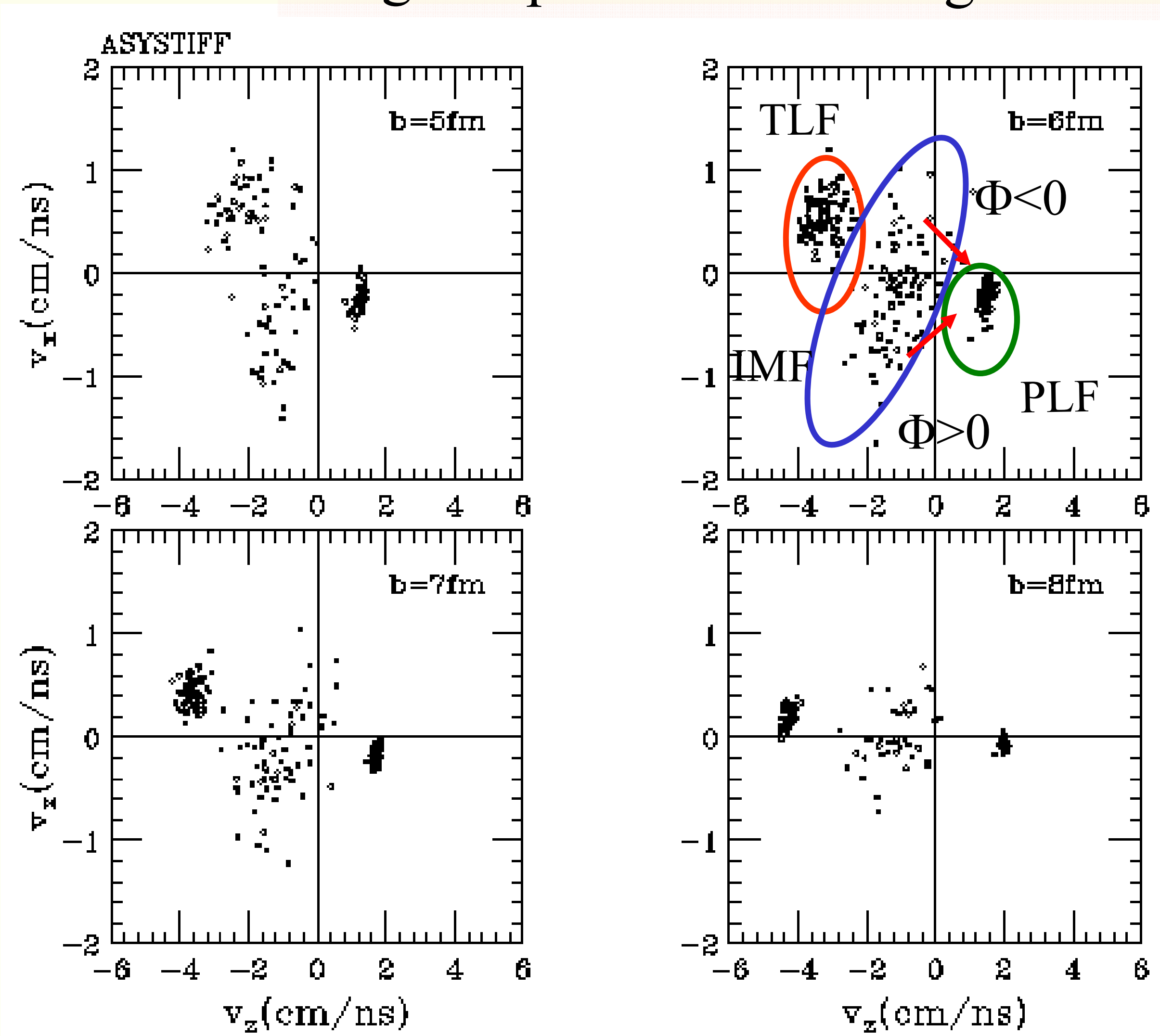


$P=N_{ternary}/N_{total}$

$^{124}Sn+^{64}Ni$ **$^{112}Sn+^{58}Ni$**

NECK FRAGMENTATION: CM V_z-V_x CORRELATIONS

Large dispersion also along transversal, x, direction



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

Alignement +
Centroid at $\Phi_{plane} > 0$

$\Downarrow$

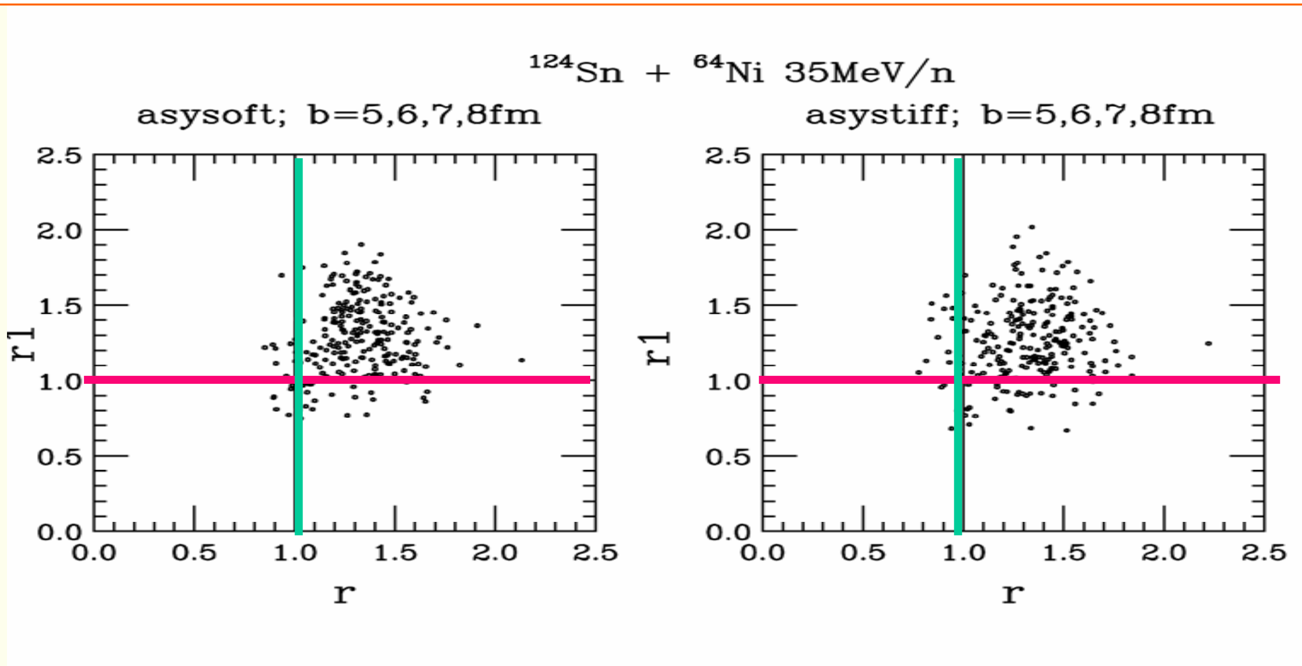
Clear Dynamical
Signatures !

DEVIATIONS FROM VIOLA SYSTEMATICS

r - ratio of the observed PLF-IMF relative velocity to the corresponding Coulomb velocity;

r1- the same ratio for the pair TLF-IMF

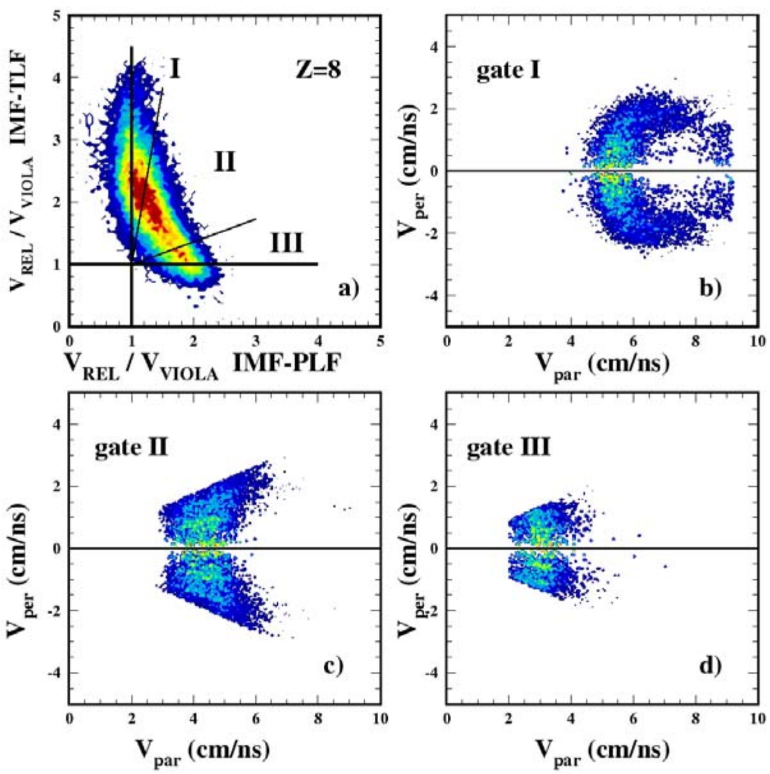
The Neck-IMF is weakly correlated with both PLF and TLF

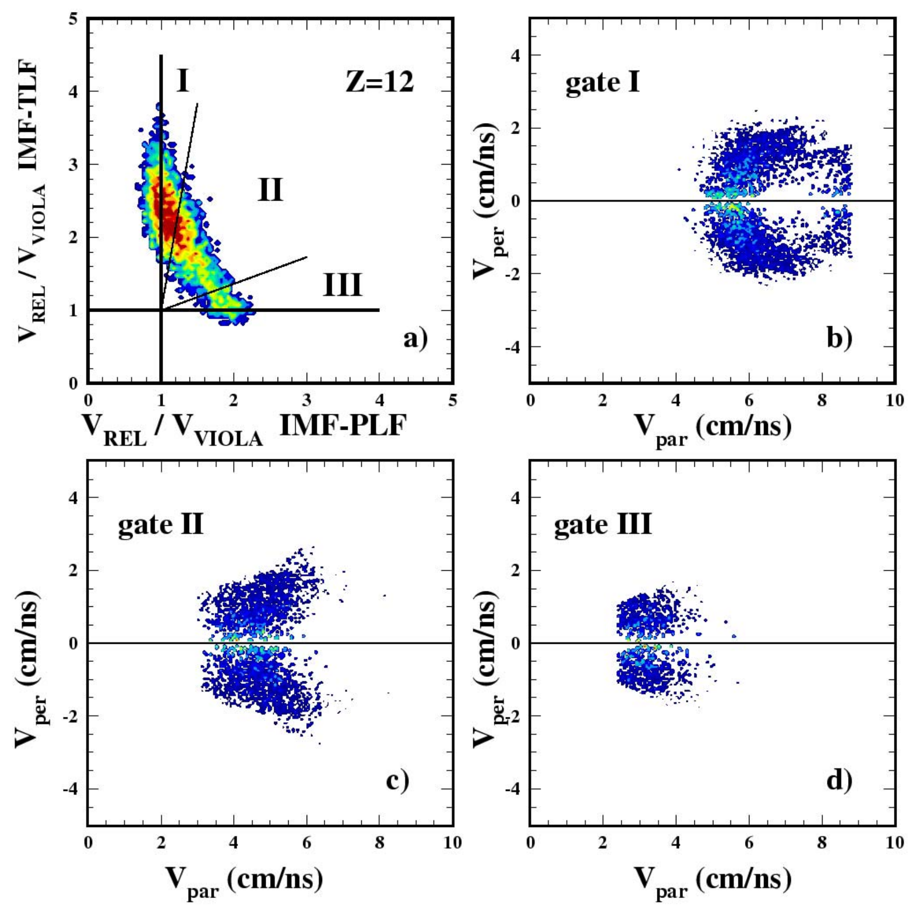


V.Baran, M.Colonna, M.Di Toro NPA 730 (2004)

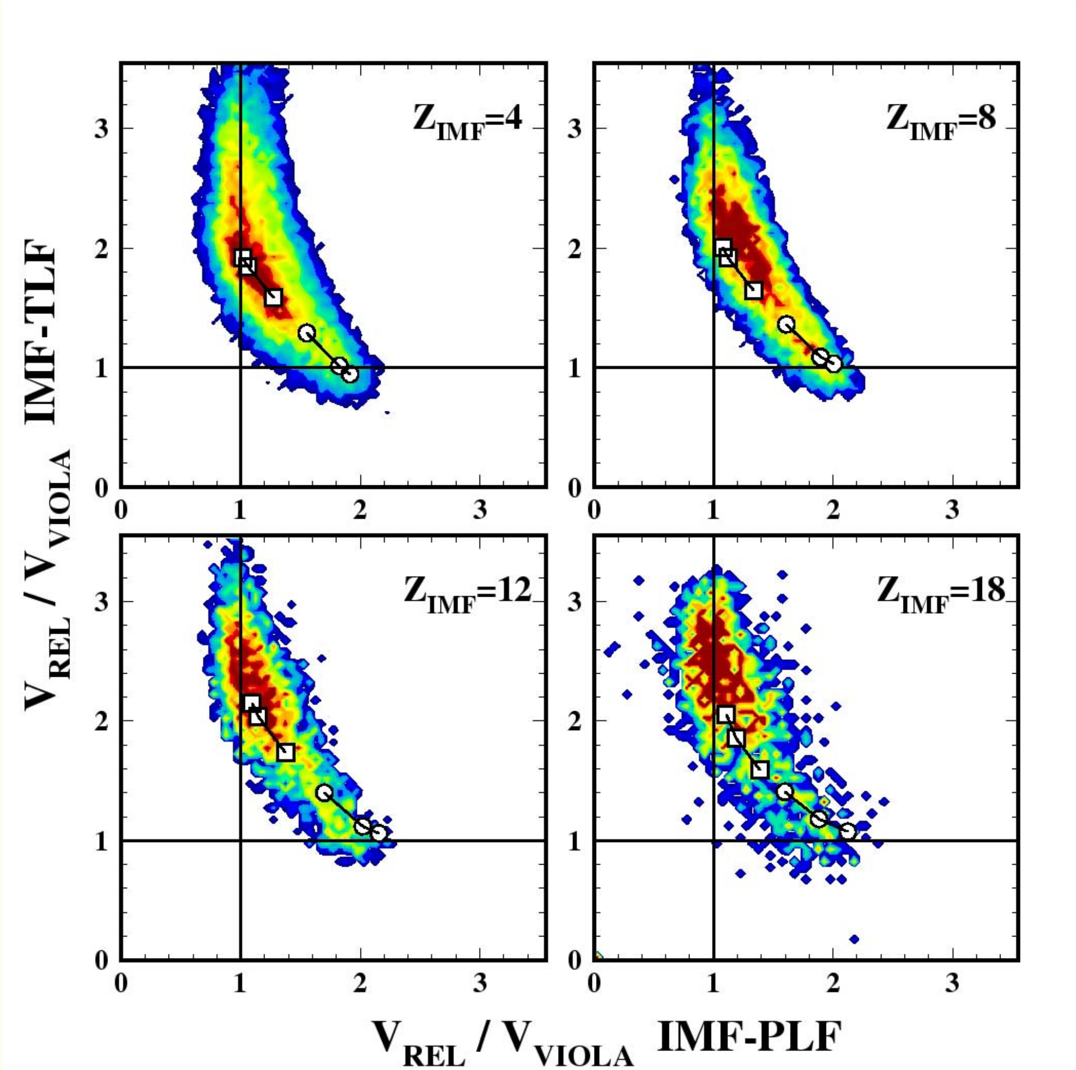
Gating the reduced plot for light IMFs:

(exp. data)





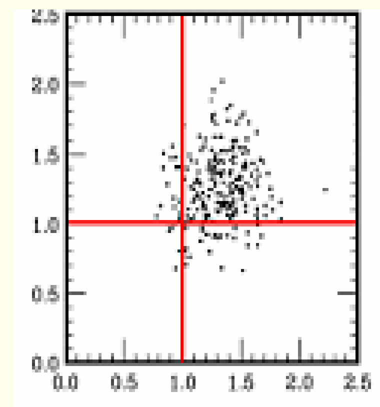
REDUCED VELOCITY PLOTS:



(exp. data)

Note: BNV model accounts only for the "prompt" component of IMF's

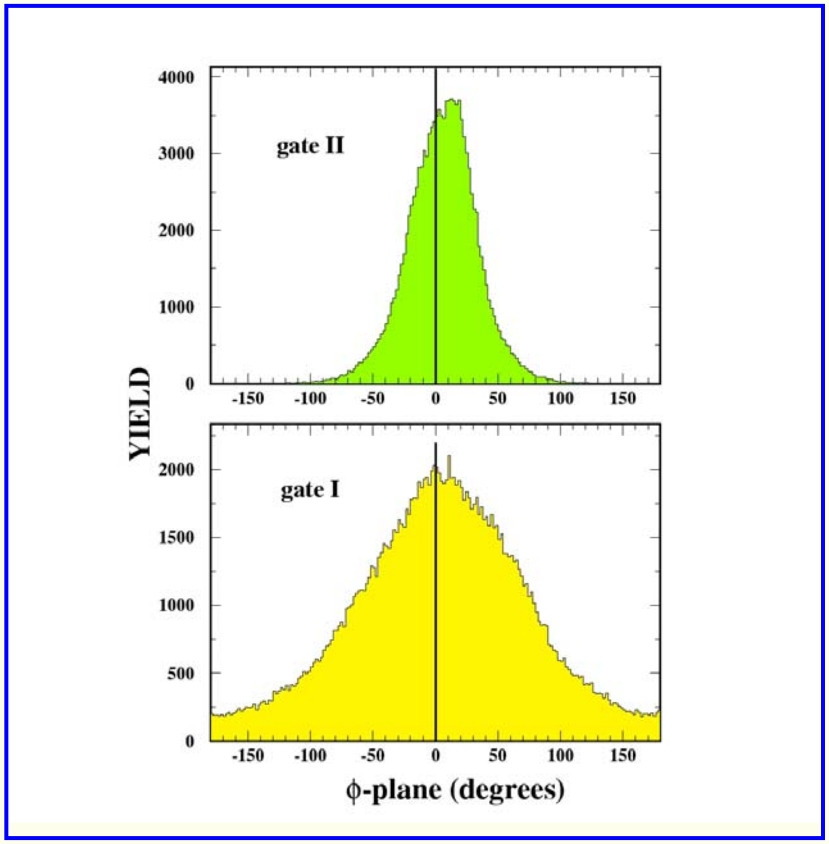
BNV



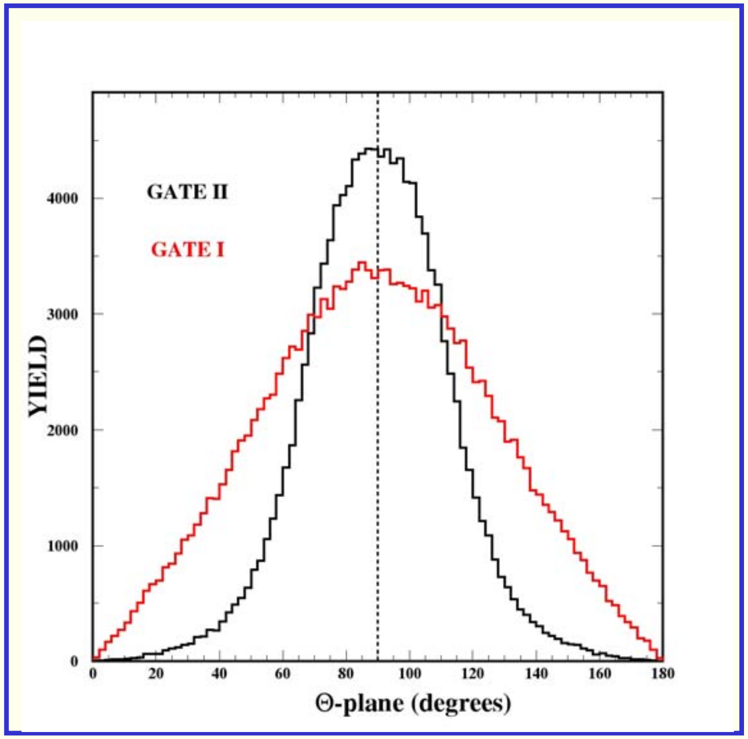
V. Baran et al. Nucl. Phys A730 (2004) 329

Chimera 124Sn+64Ni 35AMeV data, same E_loss selections

Angular distributions: alignment characteristics



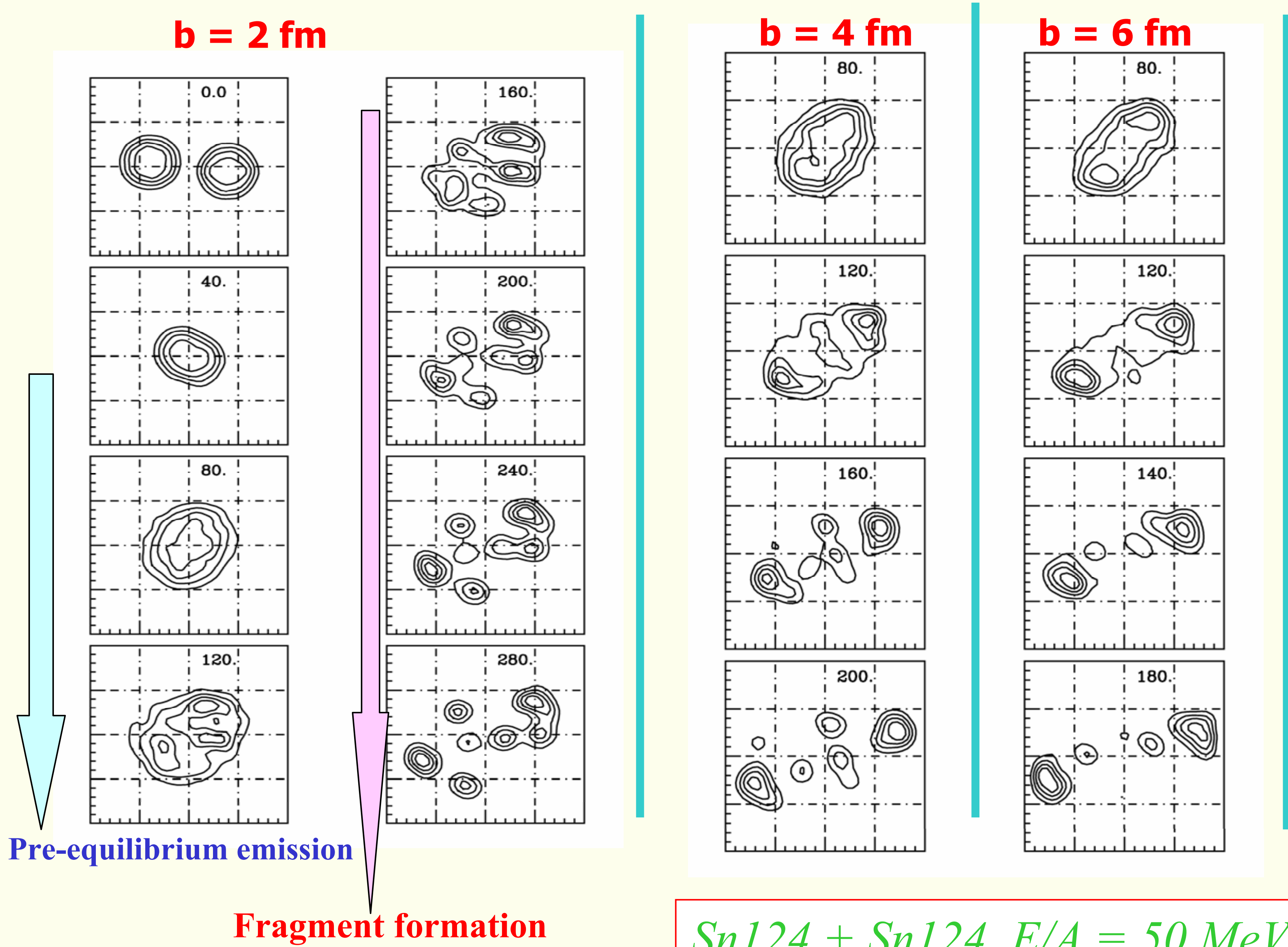
Out-of-plane angular distributions for the “dynamical” (gate 2) and “statistical” (gate 1) components: these last are more concentrated in the reaction plane.



Φ_{plane} is the angle, projected into the reaction plane, between the direction defined by the relative velocity of the CM of the system PLF-IMF to TLF and the direction defined by the relative velocity of PLF to IMF

(Chimera data)

Stochastic mean field (SMF) calculations



Sn124 + Sn124, E/A = 50 MeV/A

Frammentazione in sistemi ricchi di neutroni

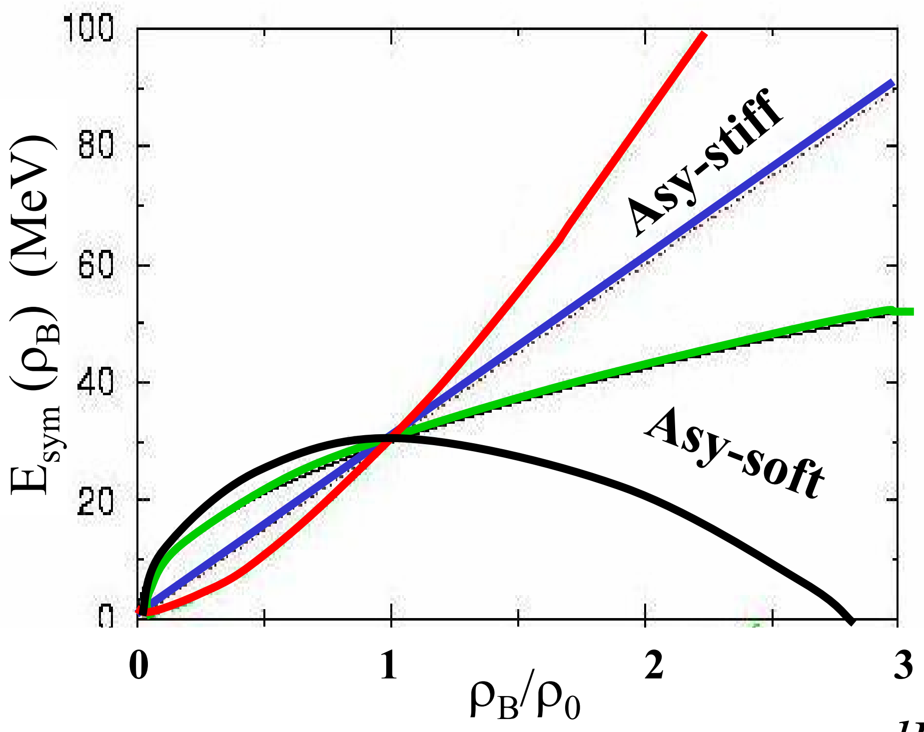
- **Convalidare il meccanismo di frammentazione.**
Nuovi aspetti legati a transizioni di fase in sistemi asimmetrici

- **Dedurre informazioni sul comportamento dell'energia di simmetria in condizioni di densita' diverse da quelle normali (bassa densita')**

Symmetry Energy

$$E(\rho_B,\alpha) = E(\rho_B) + E_{sym}(\rho_B) I^2 + O(I^4) + \ldots$$

$$I = \frac{\rho_n - \rho_p}{\rho_n + \rho_p} \qquad E_{sym} = \frac{1}{2}\frac{\partial^2 E}{\partial I^2}\bigg|_{I=0}$$



Expansion around ρ_0

$$E_{sym} = a_4 + \frac{L}{3}\left(\frac{\rho_B - \rho_0}{\rho_0}\right) + \frac{K_{sym}}{18}\left(\frac{\rho_B - \rho_0}{\rho_0}\right)^2$$

Pressure & compressibility

$$L = 3\rho_0 \frac{\partial E_{sym}}{\partial \rho_B}\bigg|_{\rho_B=\rho_0} = \frac{3}{\rho_0} P_{sym}$$

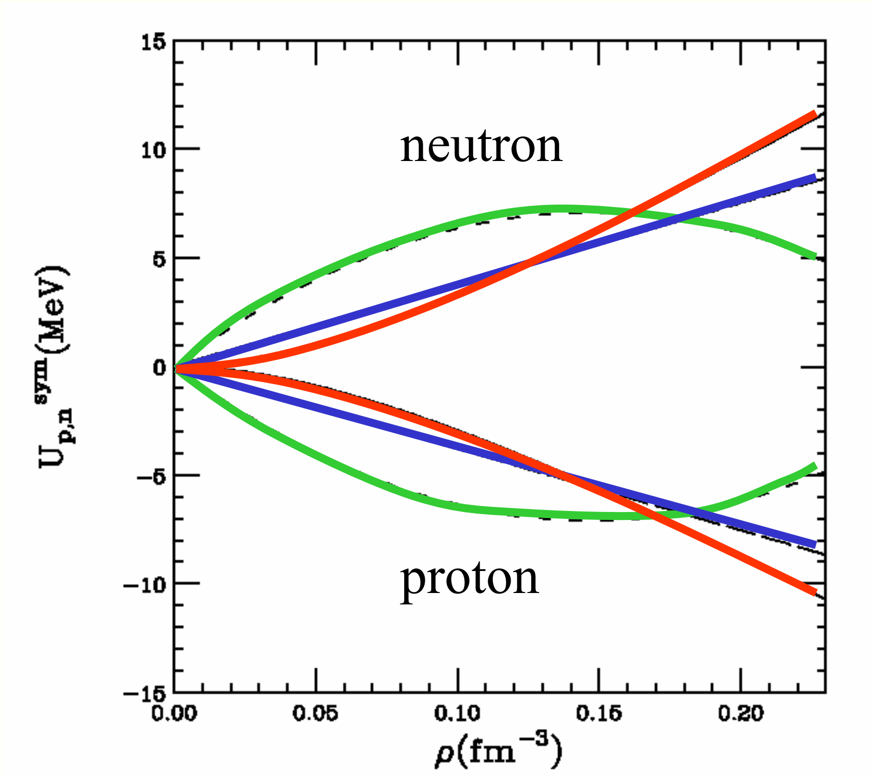
$$K_{sym} = 9\rho_0^2 \frac{\partial^2 E_{sym}}{\partial \rho_B^2}\bigg|_{\rho_B=\rho_0}$$

Pressure gradient

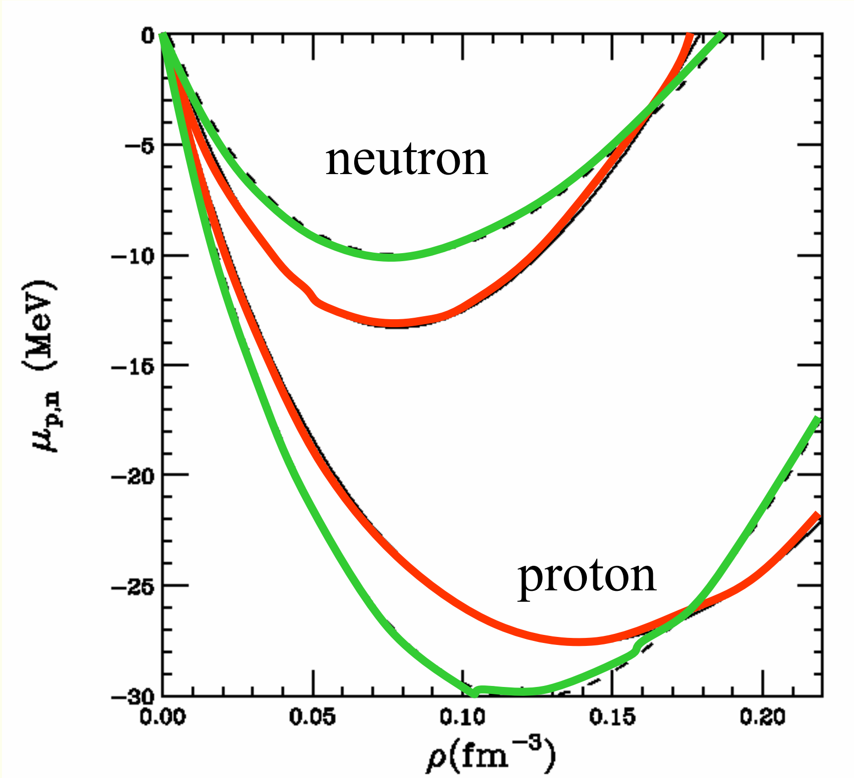
$$\frac{dP_{sym}}{d\rho} = \frac{2}{3}L + \frac{1}{9}K_{sym}$$

Mean Field & Chemical Potentials

symmetry part of the mean field



neutron-proton chemical potentials

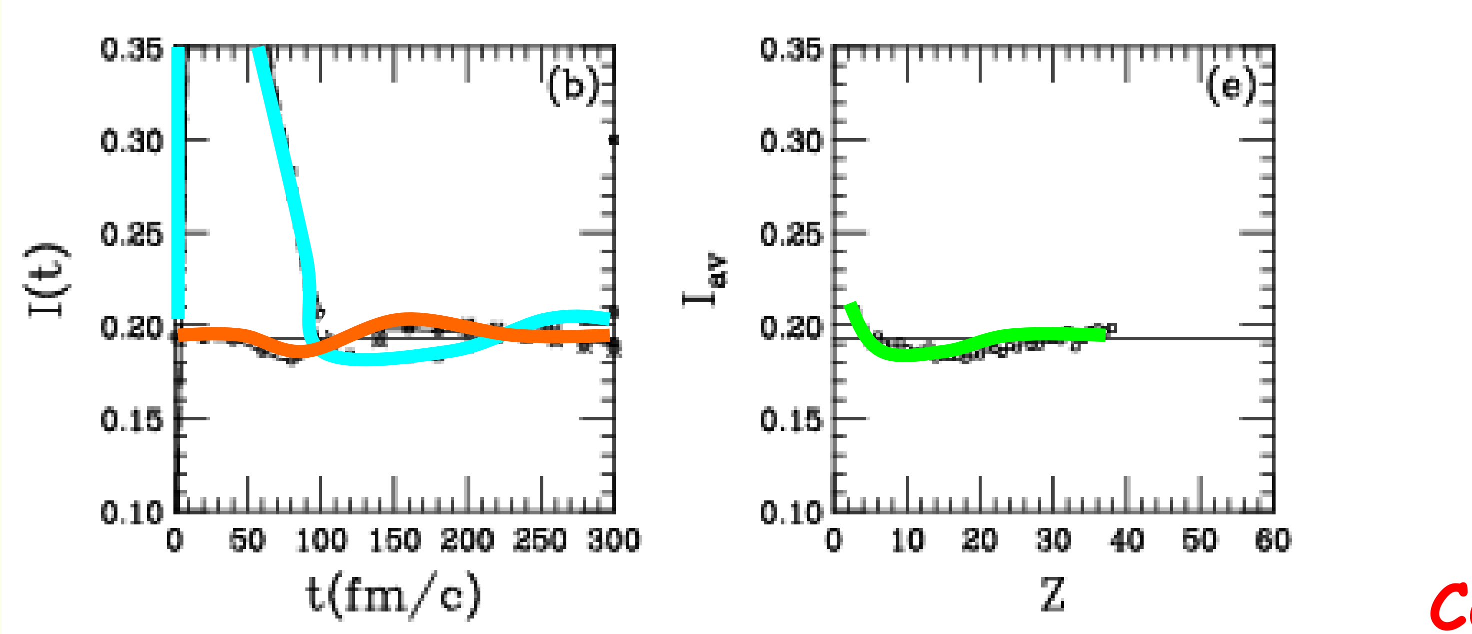


stiff

soft

^{124}Sn "asymmetry" I = 0.2

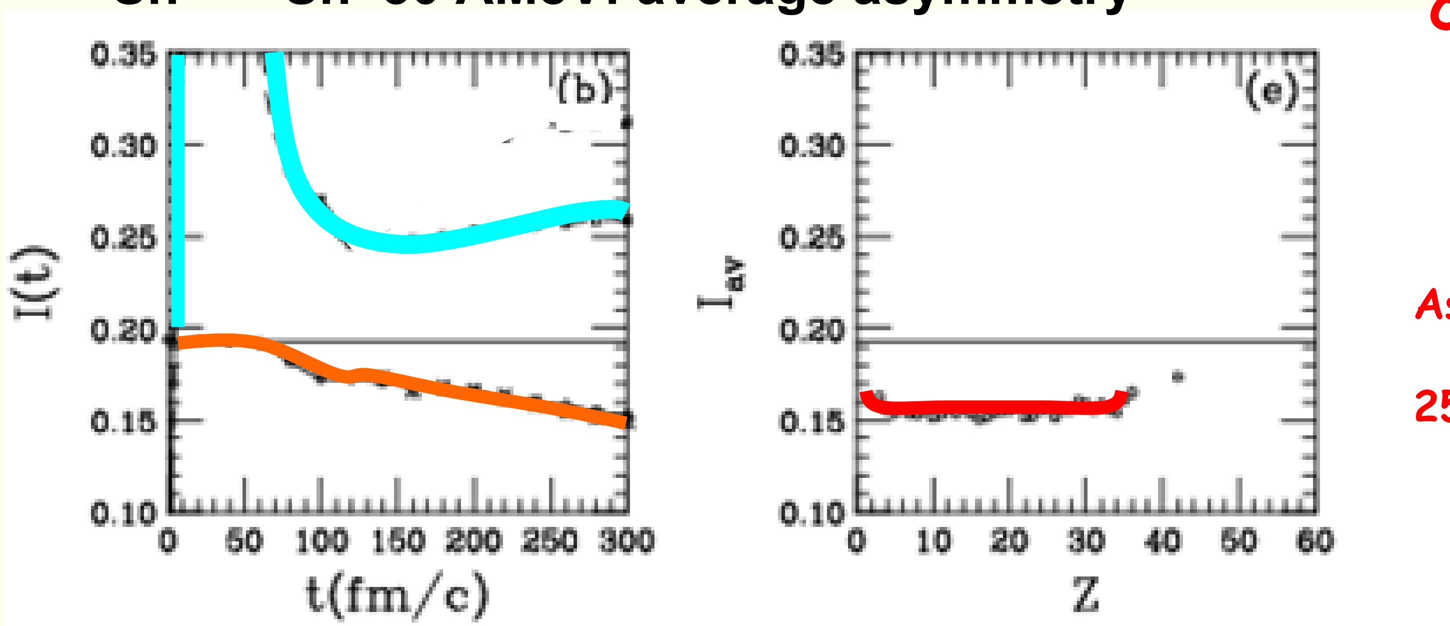
Fragment isospin properties: the iso-distillation



Asy-stiff

^{124}Sn+ ^{124}Sn 50 AMeV: average asymmetry

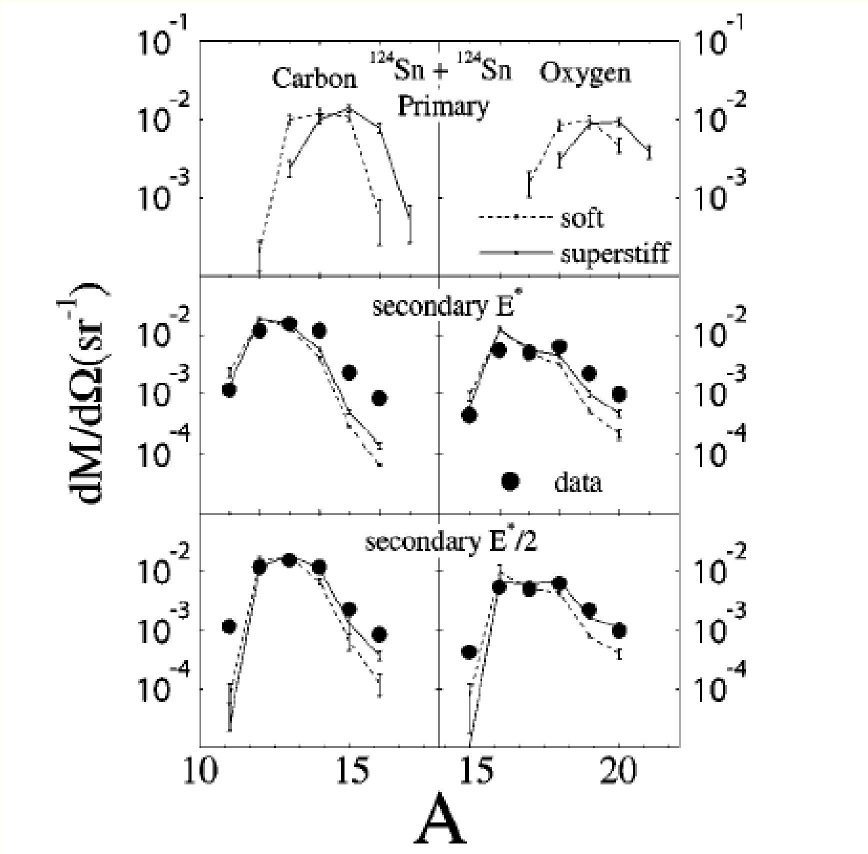
Central collisions



Asy-soft

25 % reduction

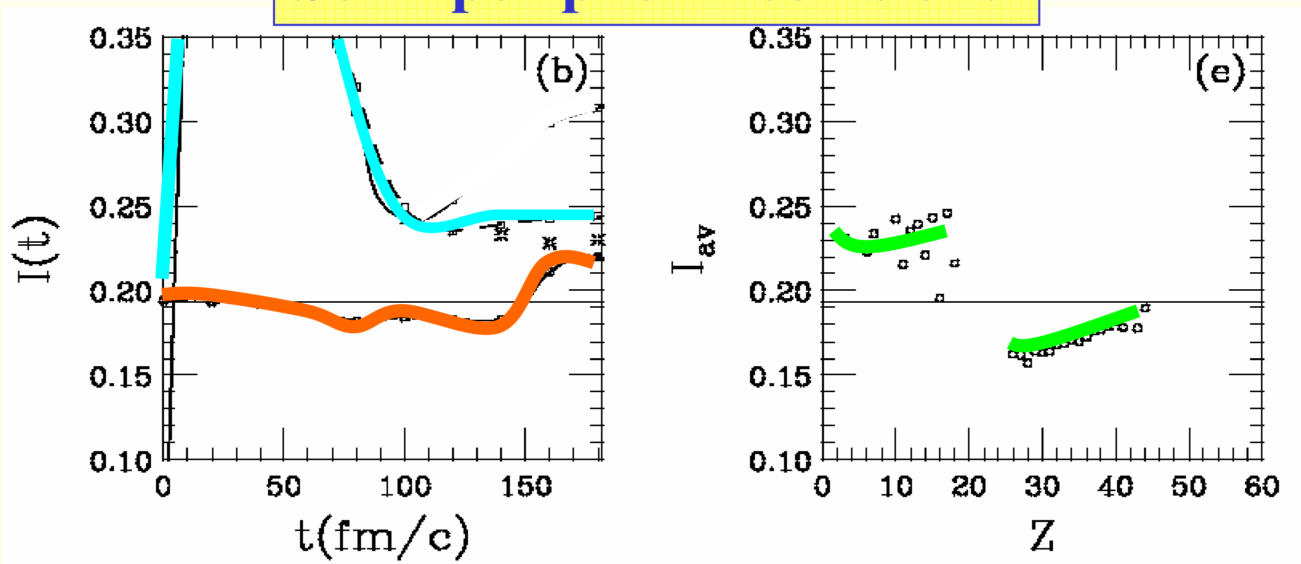
Comparison of isotopic distributions with data

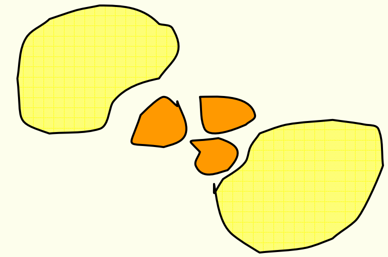


Stochastic BNV calculations
T.X.Liu et al., PRC69(2004)

^{124}Sn+ ^{124}Sn 50 AMeV: central collisions

Semi-peripheral collisions

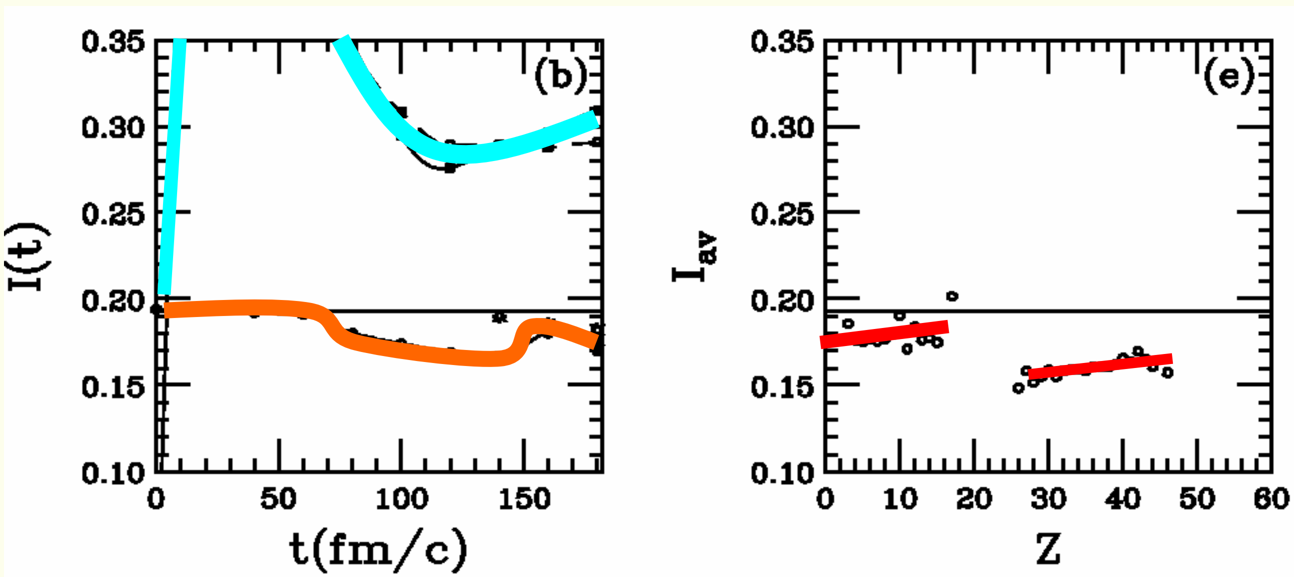




Asy-stiff: neutron enrichment of light IMFs

$^{124}Sn + ^{124}Sn$ 50 AMeV: average asymmetry

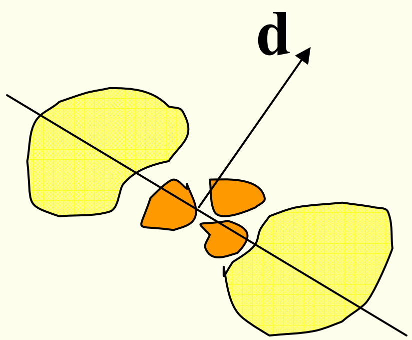
Isospin migration

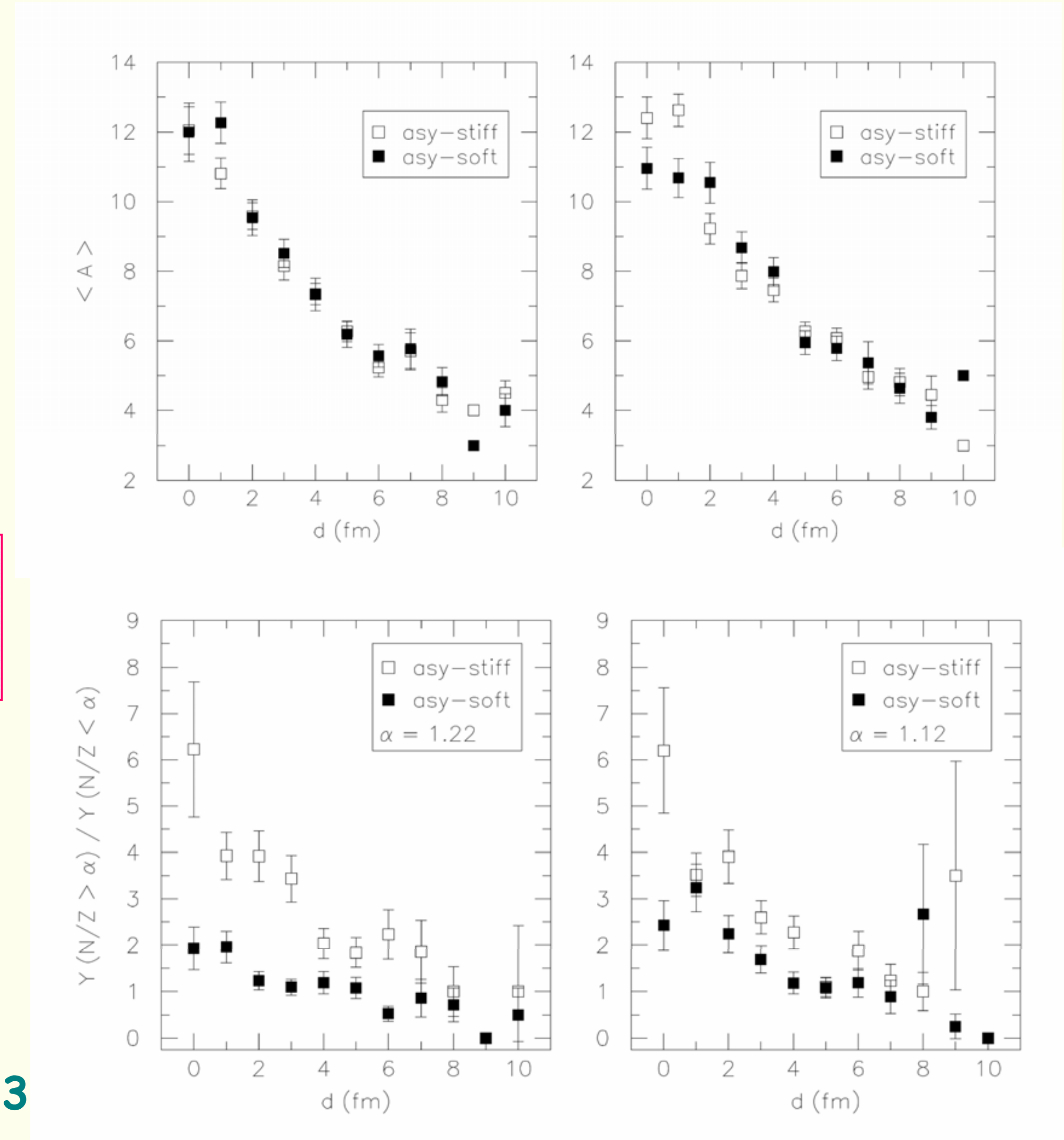


Asy-soft

V.Baran et al.,
NPA703(2002)603
NPA730(2004)329

Fe + Fe @ 47 AMeV   Ni + Ni, @ 47 AMeV

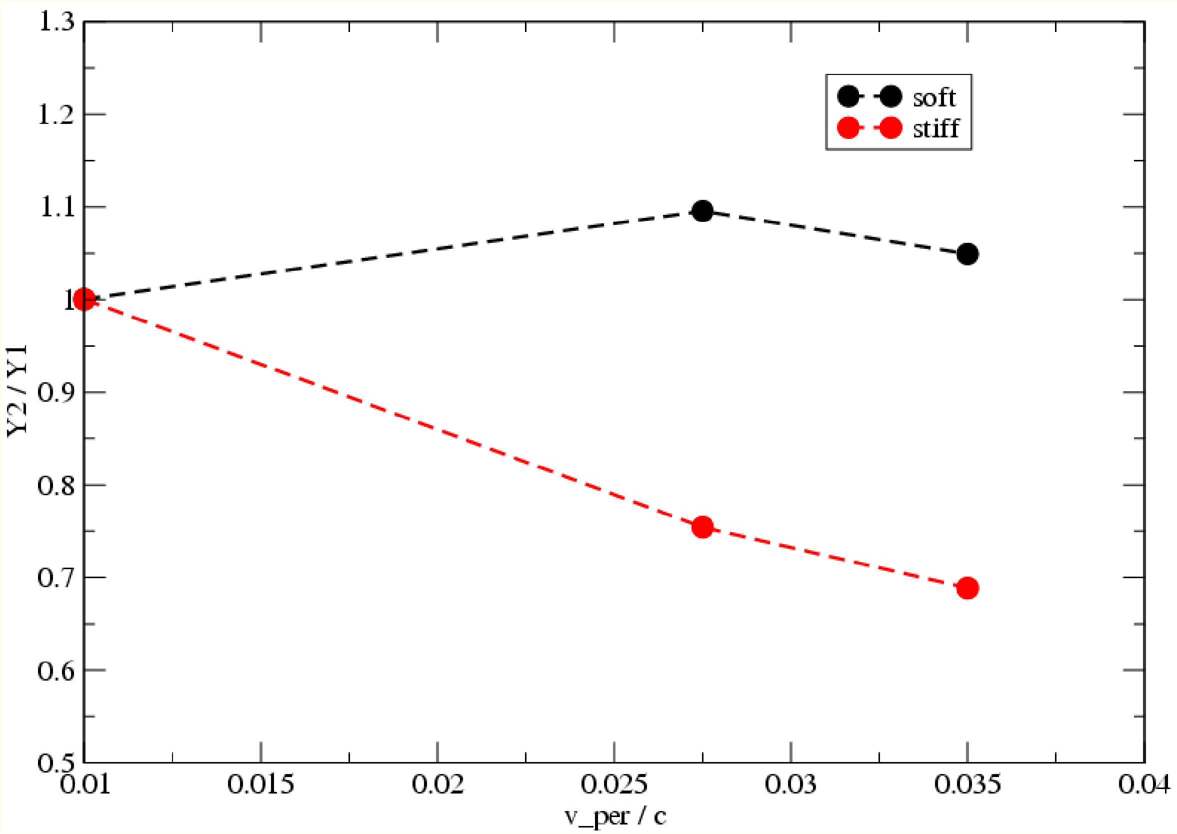




IMF's properties vs. alignement

R.Lionti et al.,
PLB 625 (2005) 33

Transverse velocity dependence of fragment asymmetry



asy-soft

asy-stiff

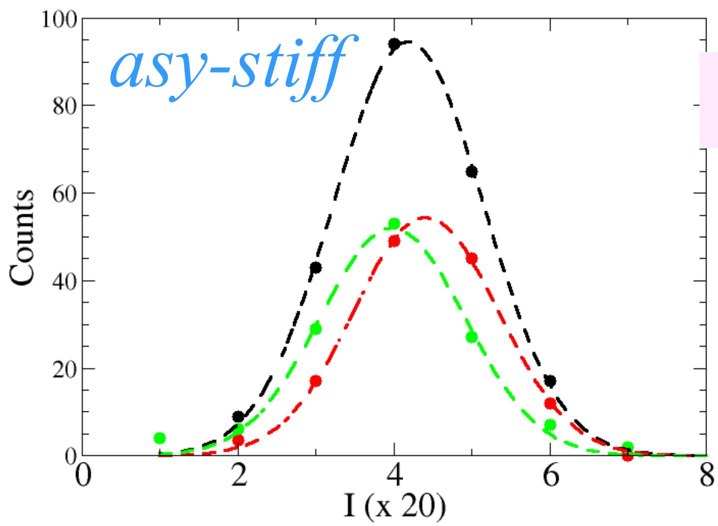
n-rich / n-poor ratio

Sn124 + Sn124,
E/A = 50 MeV/A
b = 6 fm

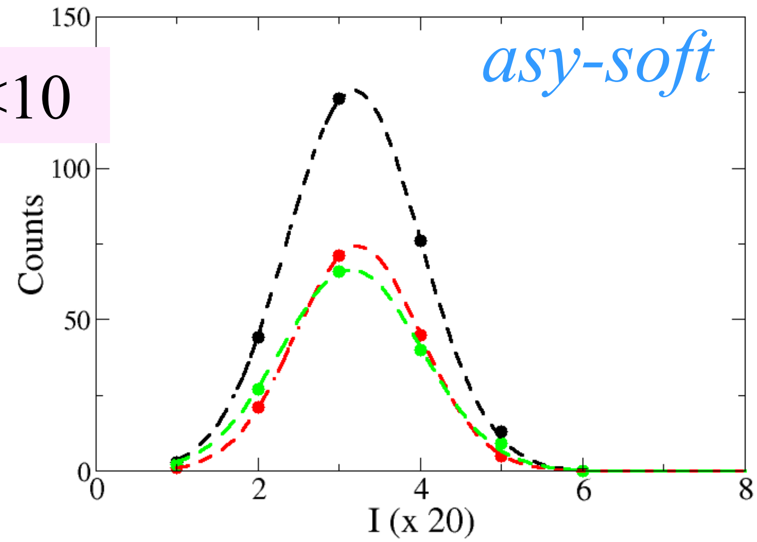
Asymmetry distributions in velocity bins

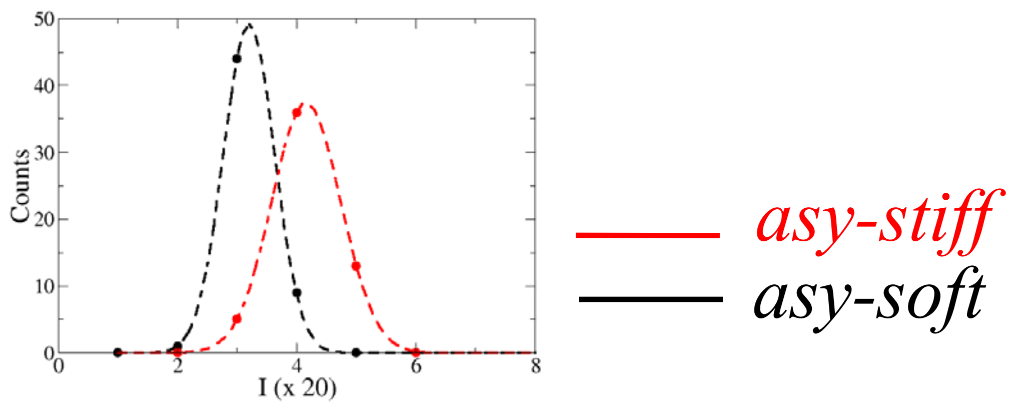
0 < v_tra /c < 0.02

v_tra /c > 0.02



0<A<10





Fragment isotopic distributions

$P(\delta\rho_n - \delta\rho_p) \sim \exp - [(\delta\rho_n - \delta\rho_p)^2 / (f(\rho,T)\ \rho/V)]$

$P(N,Z) \sim \exp -\{ [(N-Z)-(N^o-Z^o)]^2 / (\rho V\ f(\rho,T)) \} =$

$\exp -\{ a(N-Z)^2 - bN - cZ\}$

$b = (4(Z^o/ A^o)^2 - 1) / \sigma$; $c = (4(N^o/ A^o)^2 - 1) / \sigma$

✓ Isoscaling analysis $(Y_2(N,Z)/Y_1(N,Z))$:

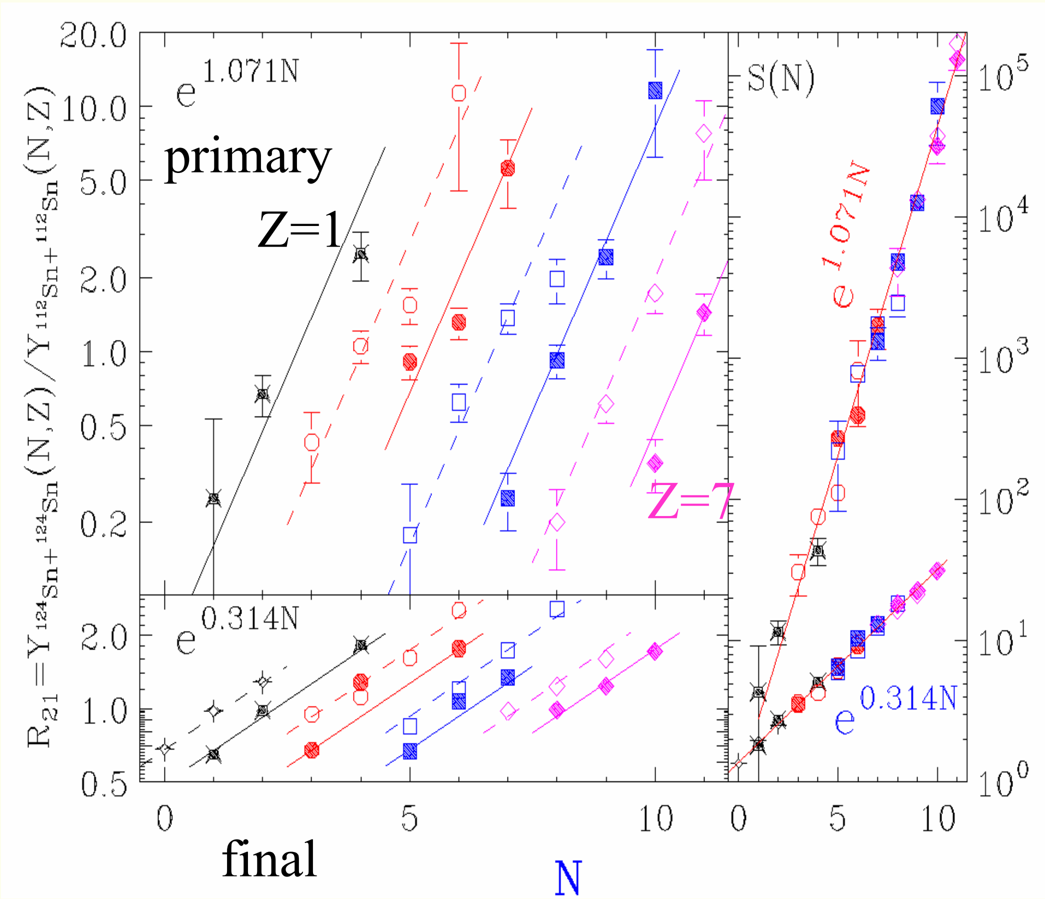
$\exp(\alpha N + \beta Z)$

$\alpha = 4 [(Z^o/ A^o)^2_1 - (Z^o/ A^o)^2_2] / \sigma$ $\boxed{\sigma = f(\rho,T)\ (\rho V)/A^o}$

$f(\rho,T) \sim T / E_{sym}(\rho)$ $(\rho V)/A^o < 1$

ρ is the density of the initial low density (unstable) system

Isoscaling: a way to analyze isotopic distributions



$$\frac{^{124}Sn}{^{112}Sn} \quad light \quad ion \quad yield$$

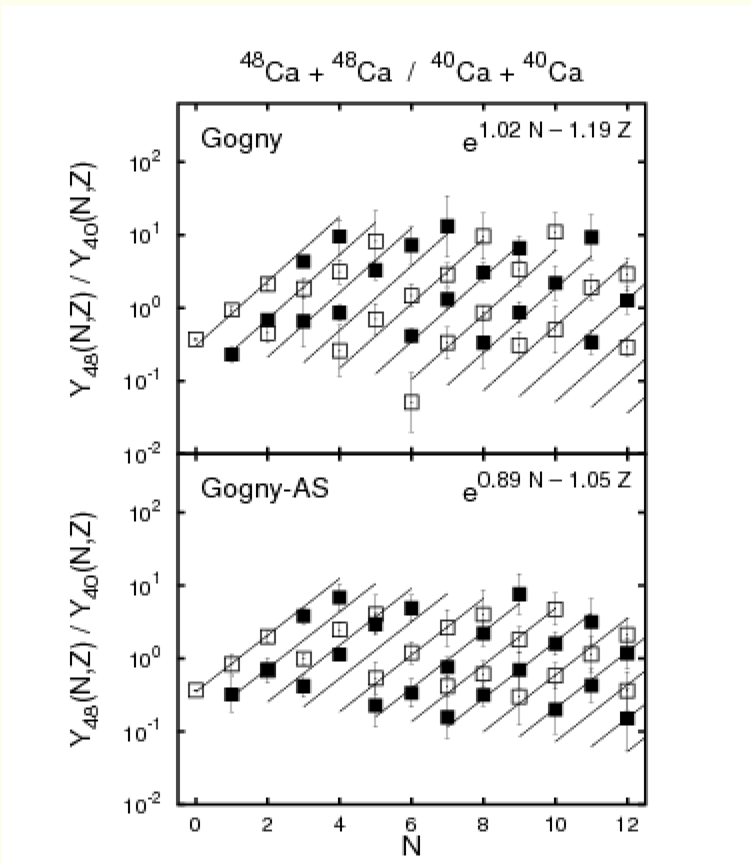
Central collisions

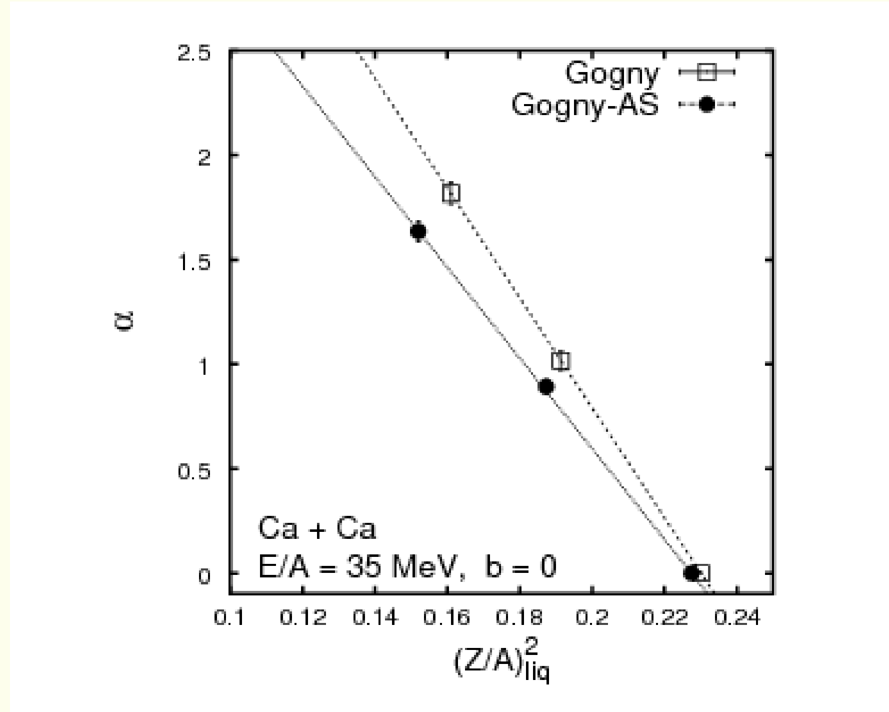
$\alpha = 4\,[\,(Z^o/A^o)^2{}_1 - (Z^o/A^o)^2{}_2\,]/\sigma^2$

α exp = 0.35

T.X.Liu et al., PRC2004

Extraction of Esym from isoscaling analysis





$\alpha = 4\ [\ (Z^o/\ A^o)^2 1\ \ -\ (Z^o/\ A^o)^2 2\ ]\ /\ \sigma$

$\sigma \sim\ f(\rho,T)$

$f(\rho,T) \sim T\ /\ Csym(\rho)$

Isoscaling in AMD (anti-symmetrized molecular dynamics) calculations **A.Ono et al.**

In conclusione ….

Segnali che indicano transizione di fase liquido-gas:

- Espansione radiale (bassa densita') + bassa temperatura
- Curva calorica
- Bimodalita'
- Calore specifico negativo
- Distillazione di isospin

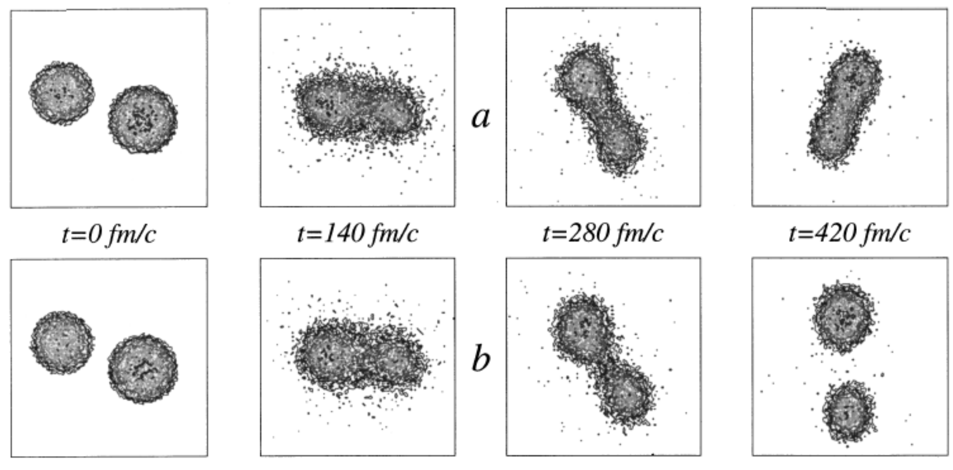
Segnali che supportano il meccanismo spinodale:

✓Tempi di frammentazione (100 fm/c)

✓Formazione di frammenti di taglia tipica (segnale che sopravvive solo in alcuni eventi)

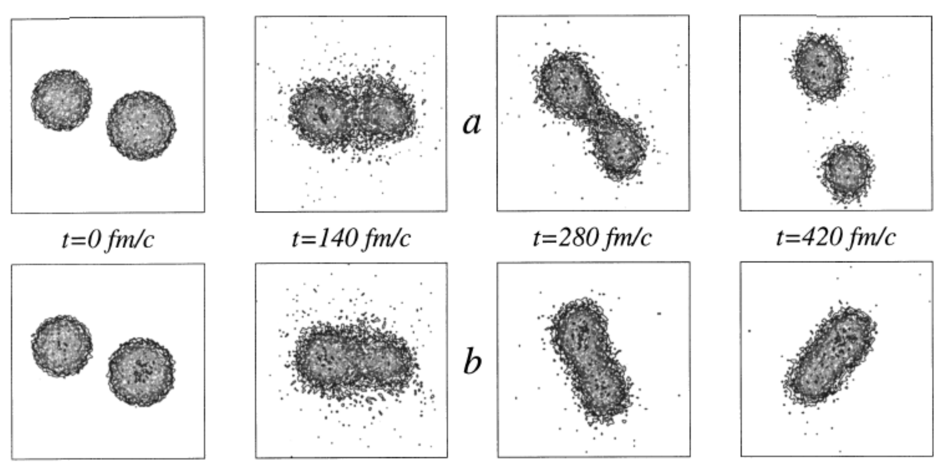
✓Buona corrispondenza fra le osservabili cinematiche dei frammenti e proprieta' legate a massa e N/Z $\longrightarrow$ descrizione corretta della dinamica di frammentazione

Competition between reaction mechanisms: fusion vs deep-inelastic



$^{46}Ar + ^{64}Ni$

E_{lab} = 30 Mev/A, b = 4 fm



$^{46}V + ^{64}Ge$

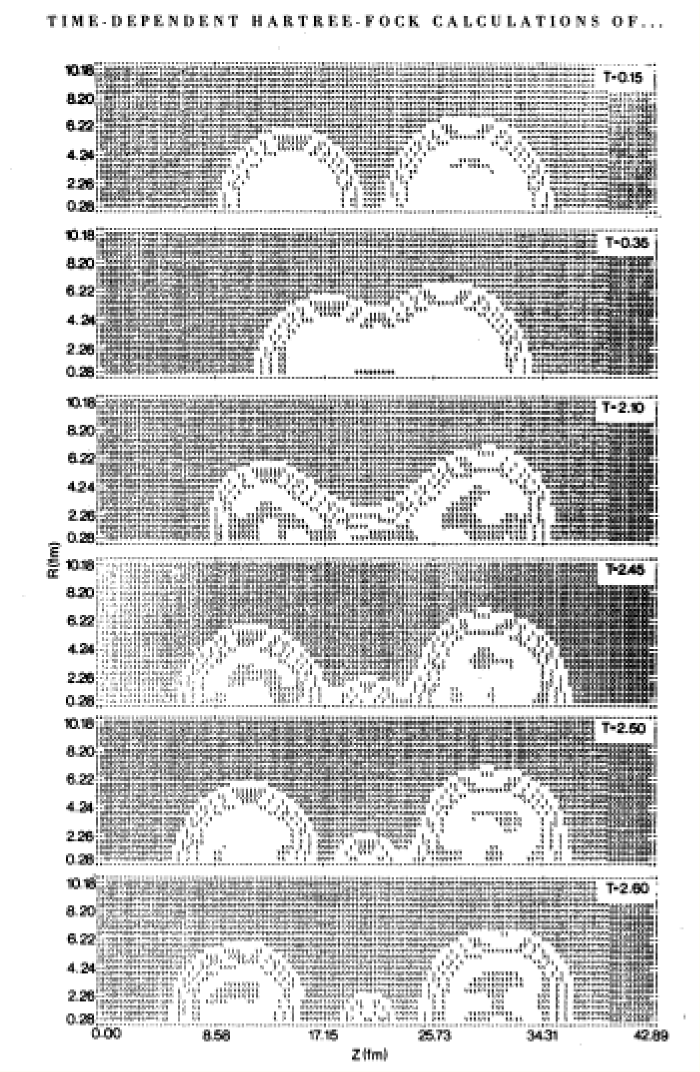
a) -- soft
b) -- stiff

neutron-rich

proton-rich

M.Colonna et al., PRC57(1998)1410

Binary vs ternary reactions (neck emission)

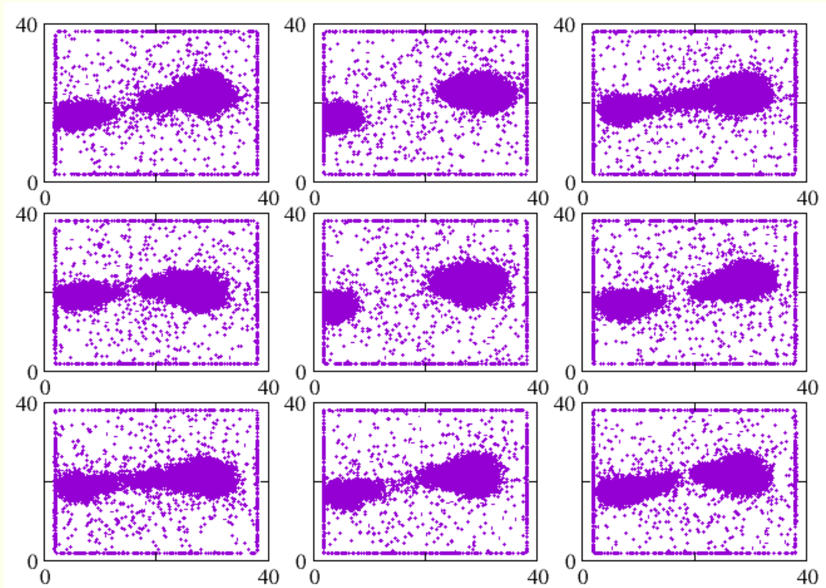


Reactions at low energy:
E_{lab} < 10 MeV/A (SPIRAL2)

TDHF calculations:
Davies et al, PRC20(1979)1372

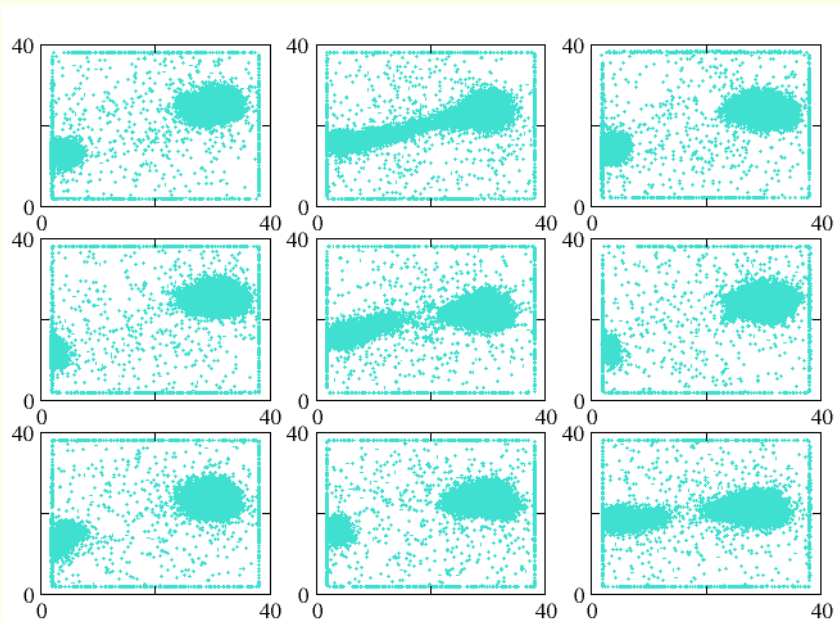
$^{86}Kr + ^{139}La$, l=100 E_{lab} = 710 MeV

Dynamical emission of small clusters at mid-rapidity



asy-stiff

More dissipative neck dynamics with asy-stiff !



$^{132}Sn + ^{64}Ni$ E_{lab} = 10 MeV/A
b = 7 fm, t = 500 fm/c

asy-soft