Probing LGPT in asymmetric nuclear matter with HIC

1. Some generally accepted theoretical predictions
2. Some considerations about experimental measurements

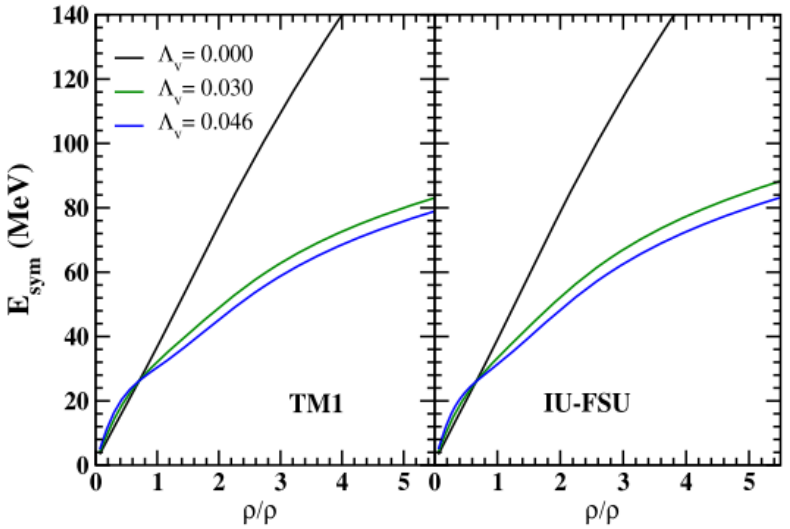
[and, of course, no summary or conclusions 🙂]

LGPT in asymmetric nuclear matter

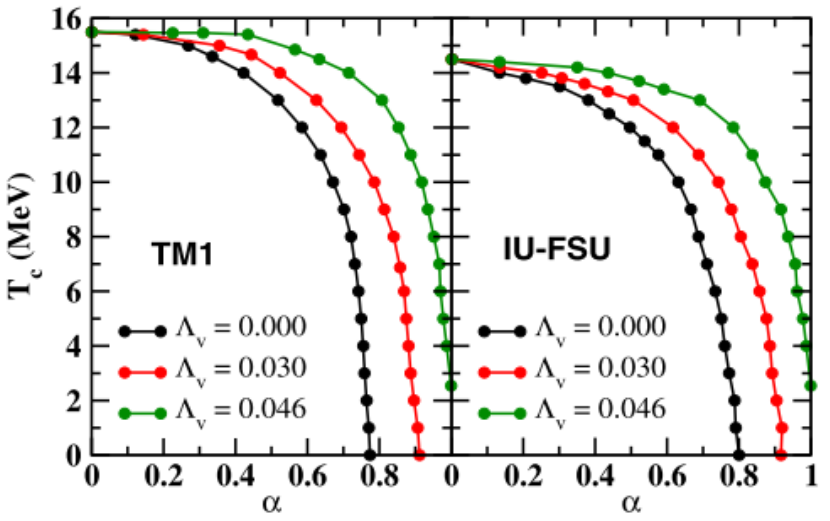
- critical temperature decrease with increasing asymmetry

Example: RMF calculations

B.K. Sharma et al. / Nuclear Physics A 1002 (2020) 121974



B.K. Sharma et al. / Nuclear Physics A 1002 (2020) 121974



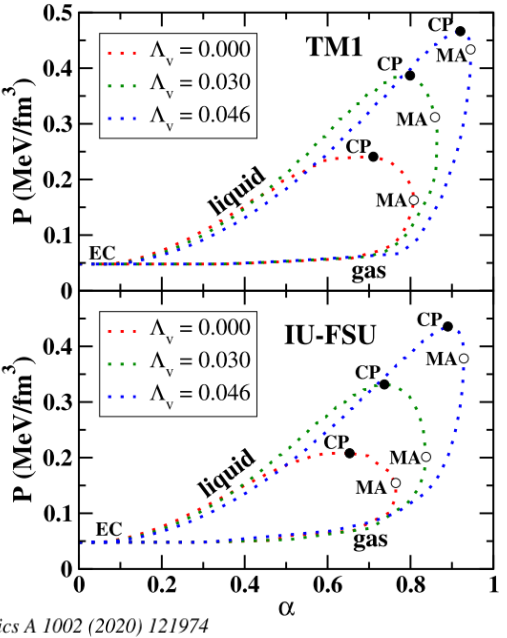
$$\alpha = \frac{\rho_n - \rho_p}{\rho} \sim \frac{N - Z}{A}$$

LGPT in asymmetric nuclear matter

- critical temperature decrease with increasing asymmetry
- reduced spinodal/coexistence zone

0 and 0.046 at fixed temperature T = 10 MeV.

RMF calc



B.K. Sharma et al. / Nuclear Physics A 1002 (2020) 121974

$$\alpha = \frac{\rho_n - \rho_p}{\rho} \sim \frac{N - Z}{A}$$

Mean field (Skyrme)

V. Baran et al. / Physics Reports 410 (2005) 335–466

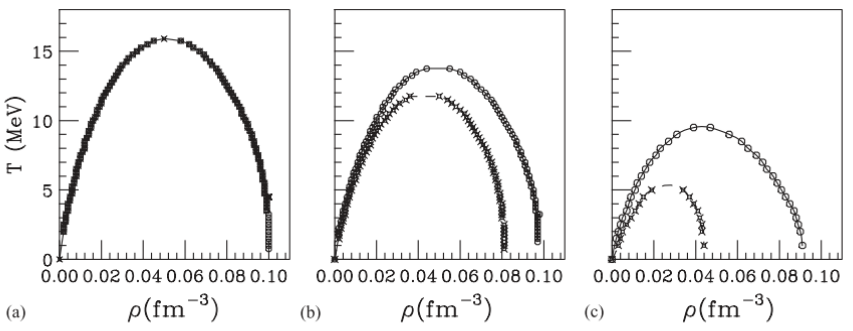
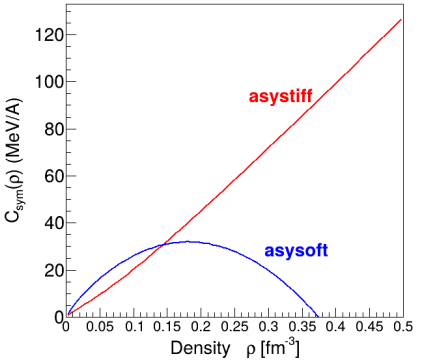


Fig. 3-1. Spinodal line corresponding to isoscalar-like instability of asymmetric nuclear matter (circles) and mechanical instability (crosses) for three proton fractions: $y = 0.5$ (a), $y = 0.25$ (b), $y = 0.1$ (c).

LGPT in asymmetric nuclear matter

- critical temperature decrease with increasing asymmetry
- reduced spinodal/coexistence zone
- isospin distillation: *n*-rich gas, + symmetric liquid



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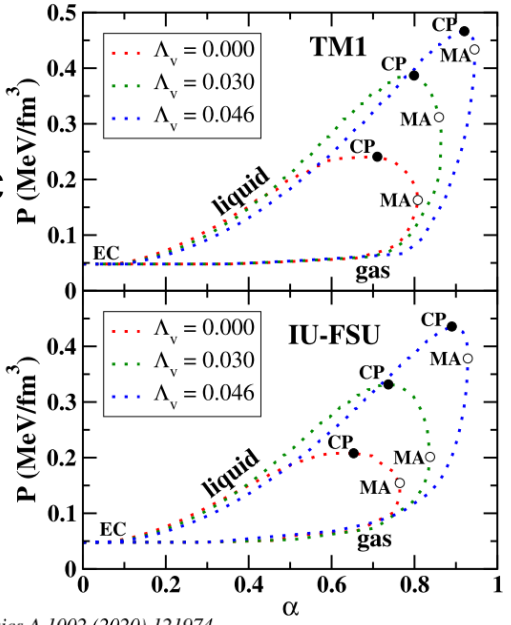
RMF calc



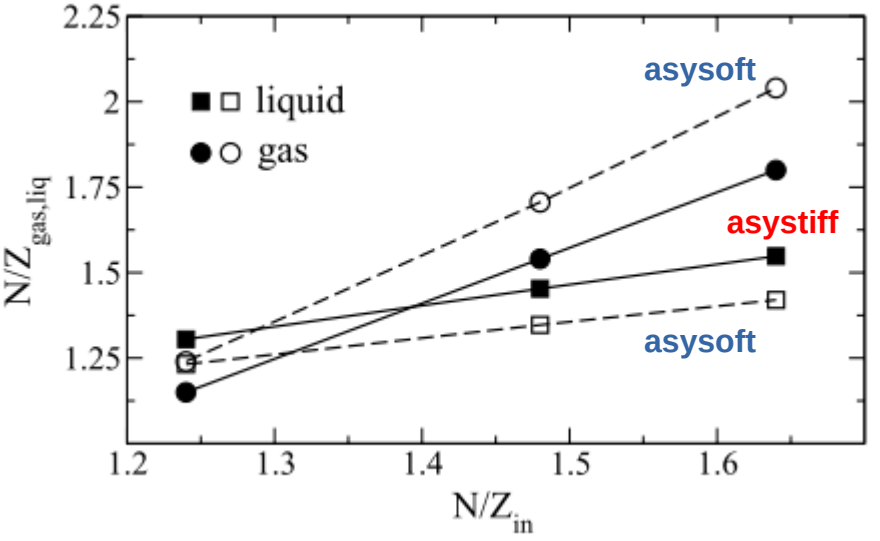
B.K. Sharma et al. / Nuclear Physics A 1002 (2020) 121974

$$\alpha = \frac{\rho_n - \rho_p}{\rho} \sim \frac{N - Z}{A}$$

Mean field (SMF)

M. COLONNA, V. BARAN, M. DI TORO, AND H. H. WOLTER

PHYSICAL REVIEW C **78**, 064618 (2008)

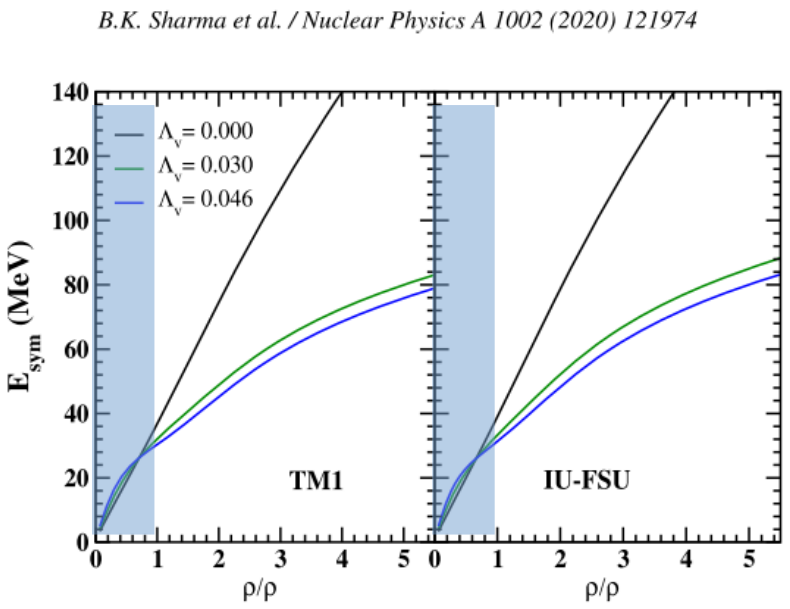


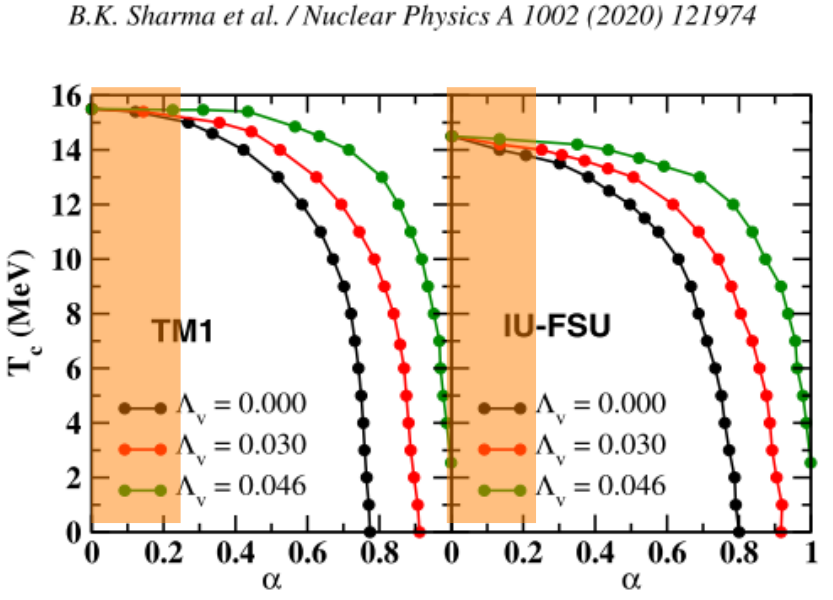
α= 0.09 0.13 0.17 0.2 0.23

^{84}Kr ^{48}Ca ^{136}Xe ^{238}U

LGPT in asymmetric nuclear matter

- WARNING: LGPT in HIC should not probe the most sensitive parts of the EoS!





LGPT densities

HIC asymmetries

$$\alpha = \frac{\rho_n - \rho_p}{\rho} \sim \frac{N - Z}{A}$$

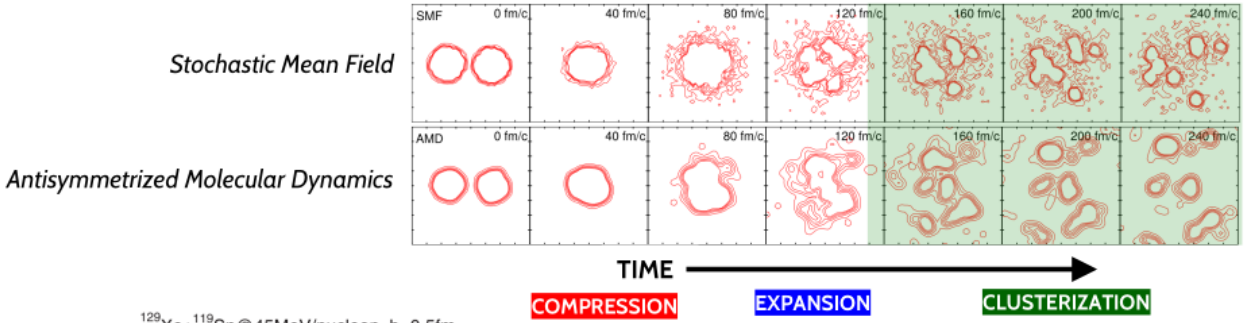
Probing LGPT in asymmetric nuclear matter with HIC

- 2 ways to go (reaction mechanisms)

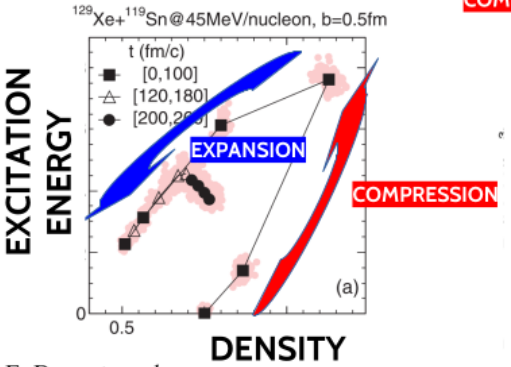
Probing LGPT in asymmetric nuclear matter with HIC

- 2 ways to go (reaction mechanisms)
  * quasi-fusion (QF)/single-source (“central” collisions 30~60 AMeV)

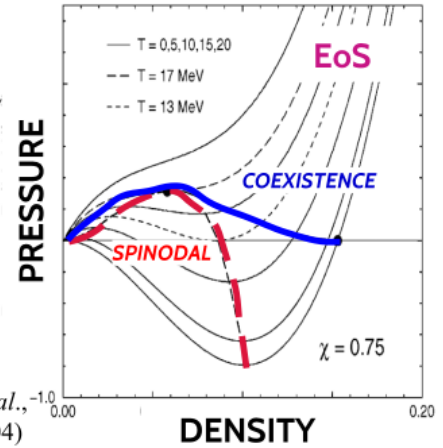
Multifragmentation in central collisions



$^{112}Sn+^{112}Sn$ E/A=50MeV b=0.5fm



E. Bonnet *et al.*, PRC89 (2014)



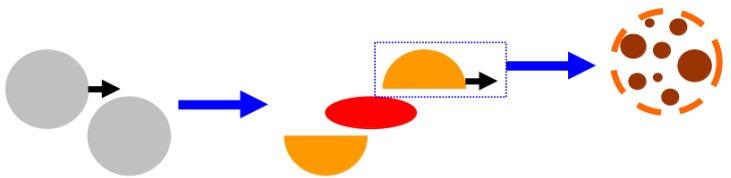
Chomaz *et al.*, PR389 (2004)

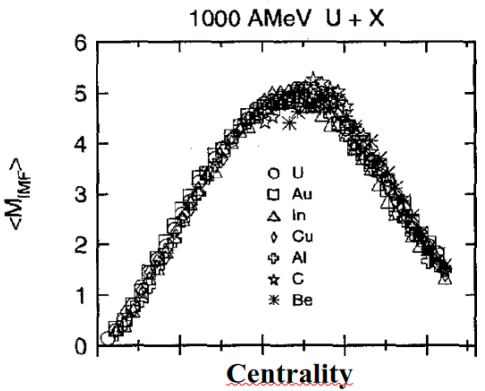
- Different models, different interactions, same story
- Multifragmentation in 3 stages
- Subsaturation density nuclear matter unstable to clusterization
- Infinite matter EoS, “liquid-gas”-type phase transition

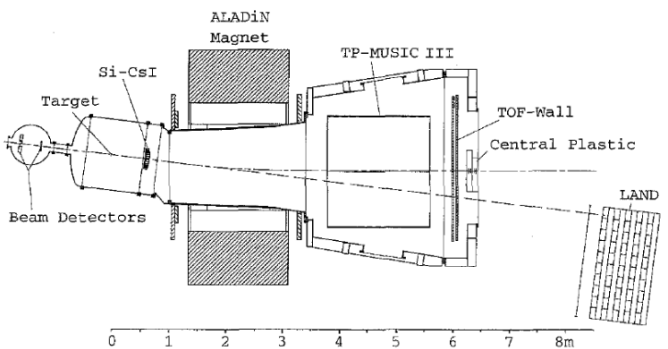
Probing LGPT in asymmetric nuclear matter with HIC

- 2 ways to go (reaction mechanisms)
  * quasi-fusion (QF)/single-source (“central” collisions 30~60 AMeV)
  * quasi-projectile (E/A < ~100) / spectator decay (E/A > ~100 MeV) (“non-central”)

- Multifragmentation in spectator decay @ E>100 MeV/u







Universality of spectator fragmentation

↓

statistical equilibrium

A. Schüttthauf et al, Nucl. Phys. A607, 457 (1996)

Probing LGPT in asymmetric nuclear matter with HIC

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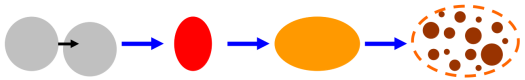
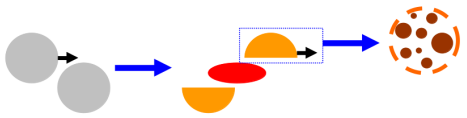


- low cross-sections
- ~fixed available/excitation energy
- careful selection with ~full reconstruction
  → large area (~4π) detection array
  [or inverse kinematics…]
- isotopic identification required up to large angles [or inverse kinematics...]



+ large cross-section
+ wide range of excitation energies
+ isotopic identification required at forward angles

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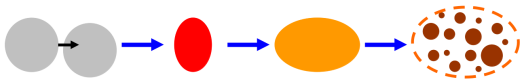

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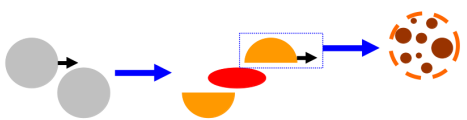
→ **INDRAFAZIA@GANIL ?**



+ large cross-section
+ wide range of excitation energies
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→ **FAZIA@FRIB (E/A<100AMeV) ?**

Probing LGPT in asymmetric nuclear matter with HIC

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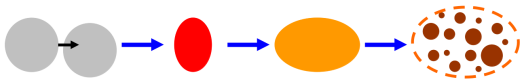

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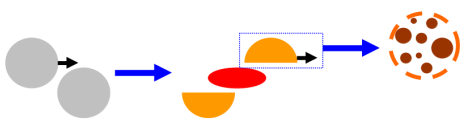
→ **INDRAFAZIA@GANIL ?** *But:* limited range of *n*-rich beams



+ large cross-section
+ wide range of excitation energies
+ isotopic identification required at forward angles

→ **FAZIA@FRIB (E/A<100AMeV) ?** *But:* intensity/quality of decelerated beams?

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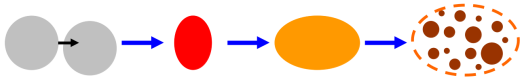

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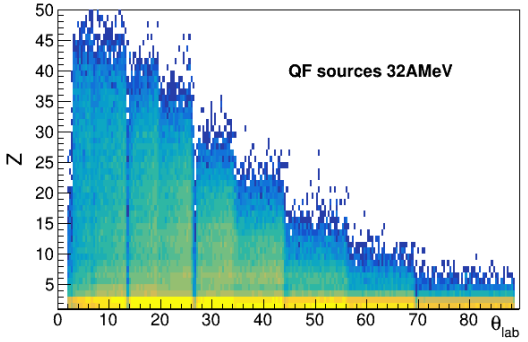
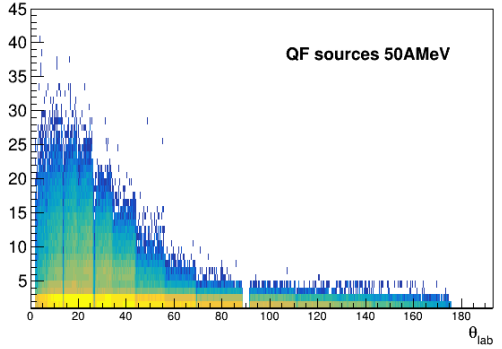
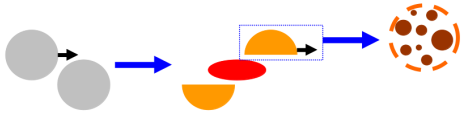




Xe+Sn
data (INDRA)

→ **INDRAFAZIA@GANIL ?**



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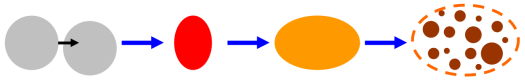

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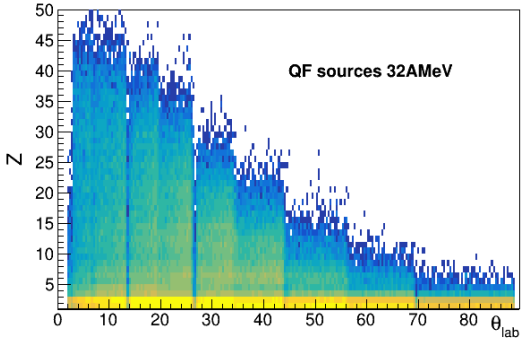

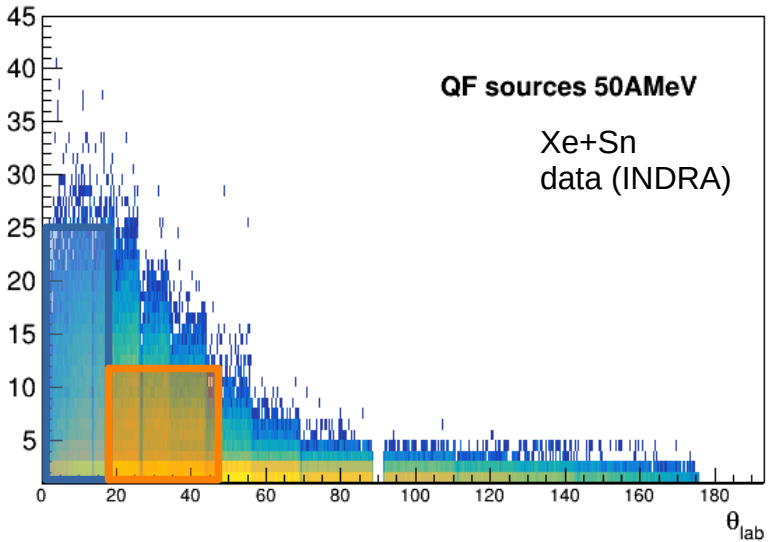

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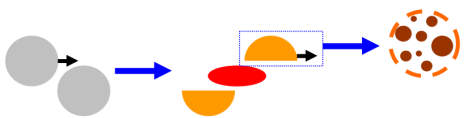

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→ **FAZIA@FRIB (E/A<100AMeV) ?**

FAZIA Z&A

INDRA Z&A

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  * quasi-fusion (QF)/single-source (“central” collisions 30~60 AMeV)
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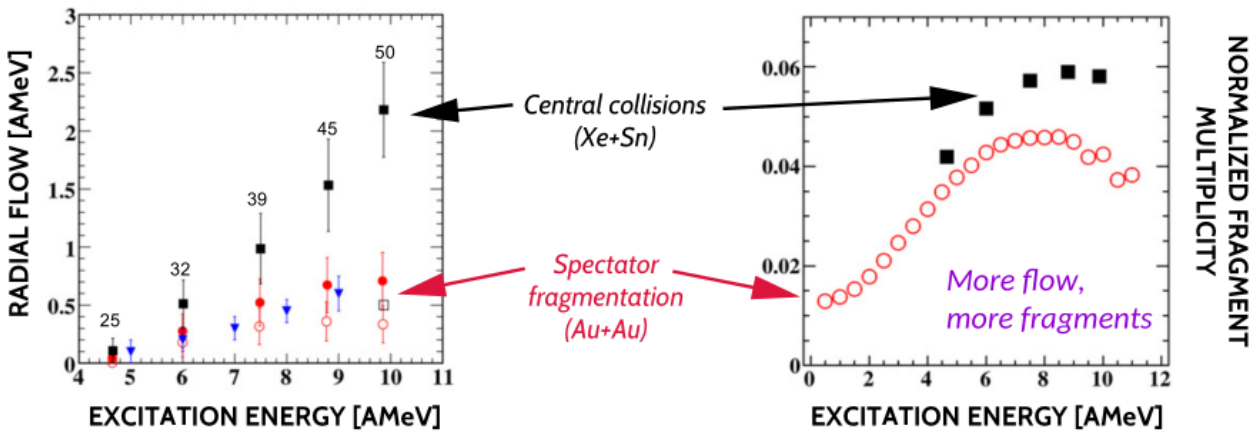
- 1 last difference between “central” vs. “peripheral:”

Same system size,
same E*/A,
radial flow
→ number of fragments

Onset and increase
of radial flow

Bonnet *et al.*
(INDRA/ALADIN)
NPA816(2009)



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Summary

I think that Alberto’s next/last presentation may be very interesting...