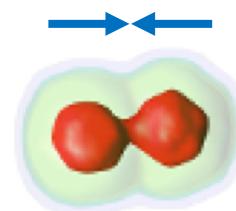
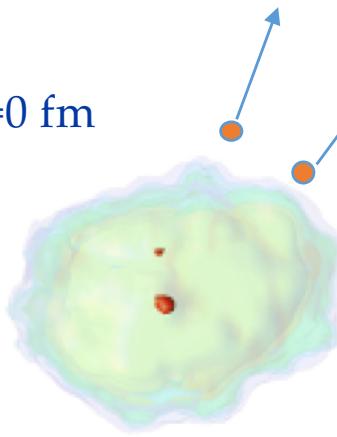


Dynamics and particle correlations at intermediate energies: status and perspectives

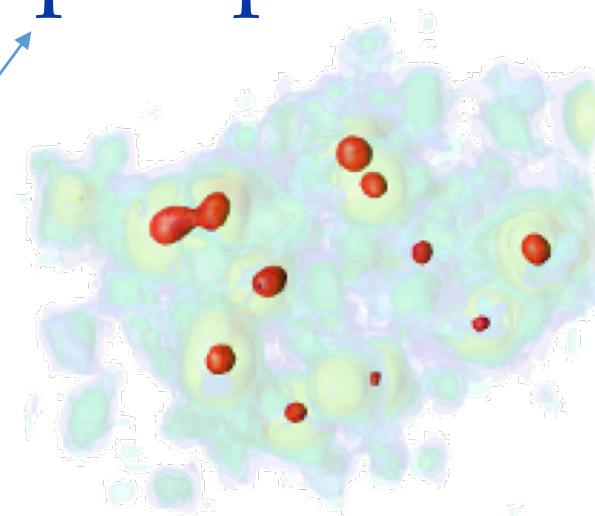
Central Xe+Sn
E/A=56 MeV, b=0 fm



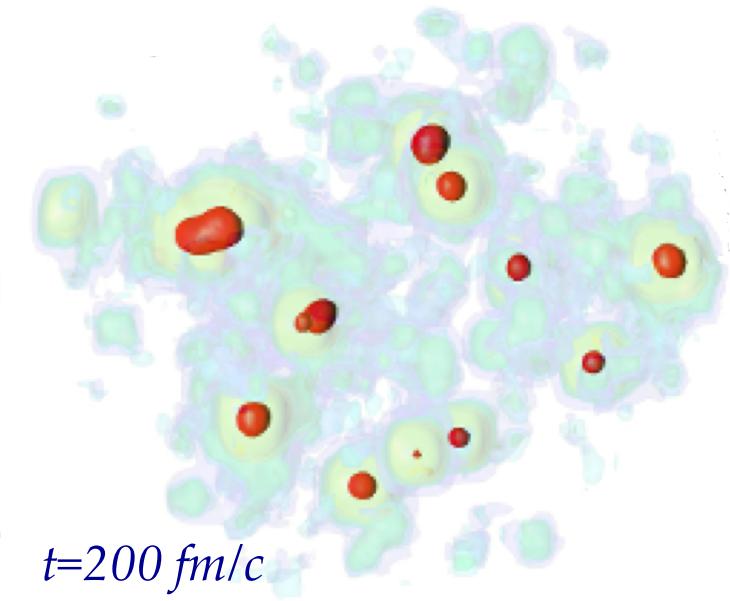
$t=10 \text{ fm}/c$



$t=50 \text{ fm}/c$



$t=100 \text{ fm}/c$



$t=200 \text{ fm}/c$

BLOB, M. Colonna, P. Napolitani

G. Verde, INFN Catania & GANIL

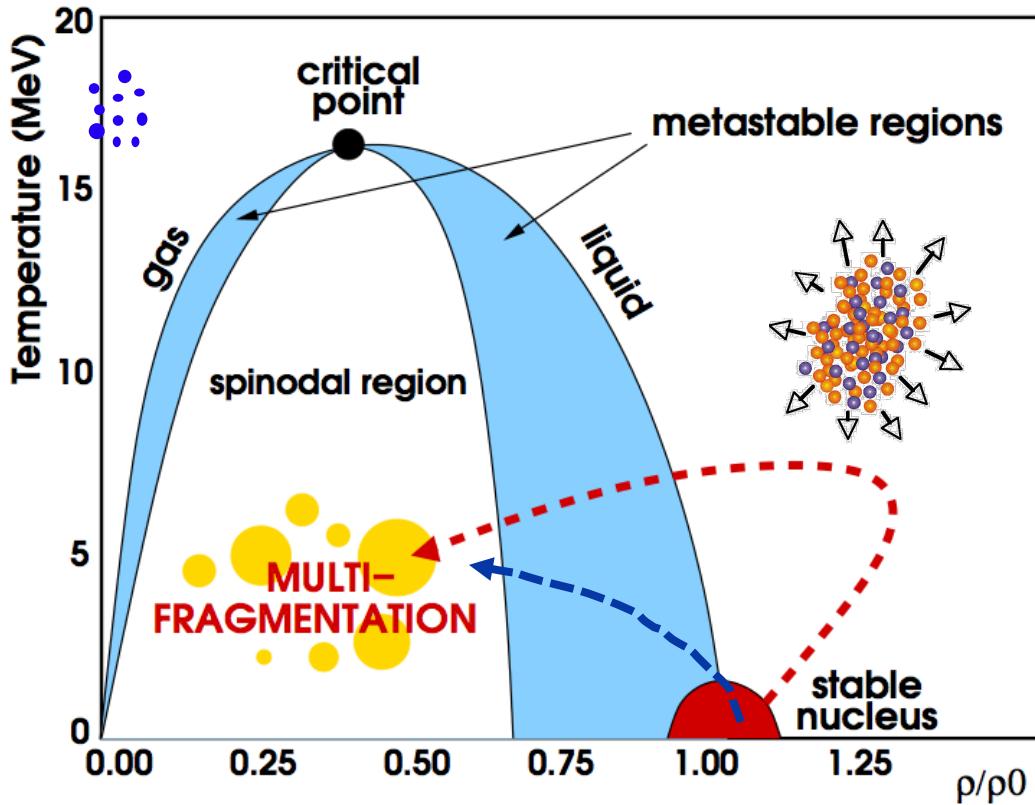
FAZIA & INDRA collaborations

Special acknowledgements:

D. Dell'Aquila (NSCL-MSU)

D. Gruyer (LPC Caen)

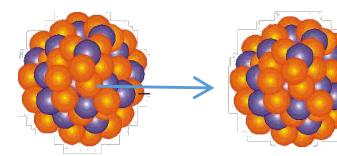
EoS: paths with HIC



Open many-body quantum nuclear systems

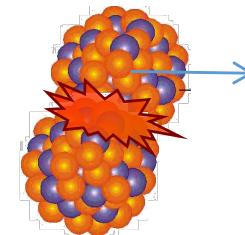
From low densities to clusters

- Central collisions:
excitation controlled by beam energy



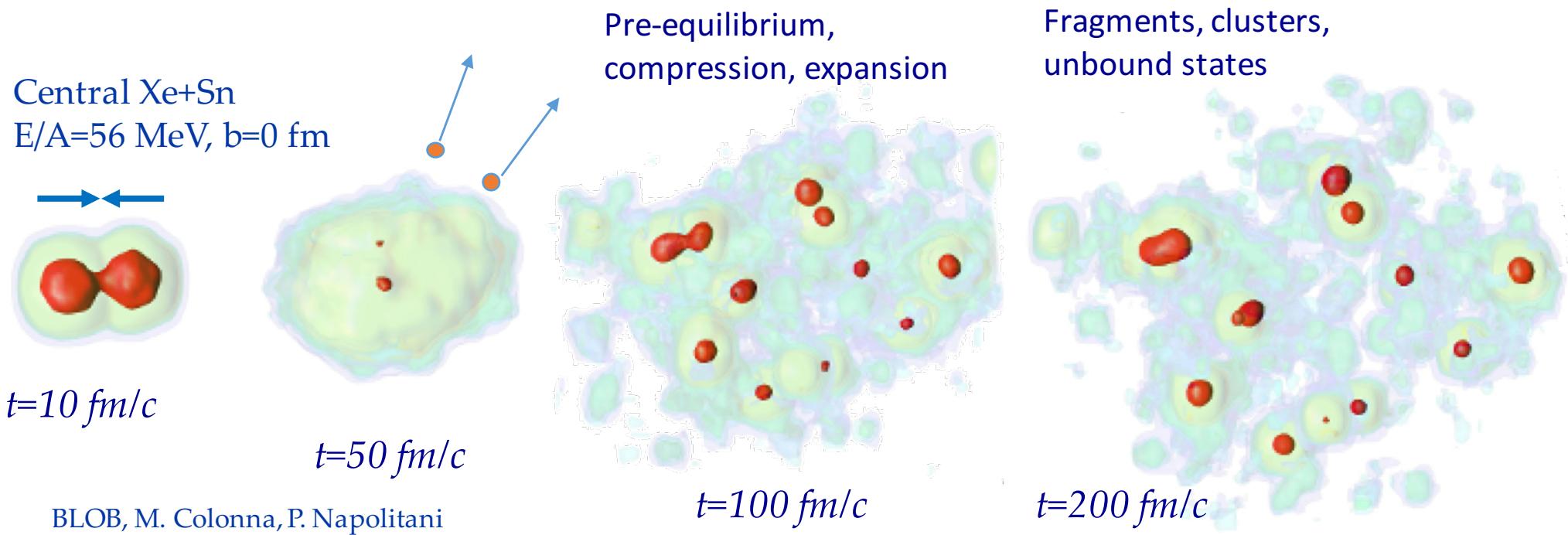
Decay of dense and hot central source
Thermal and collective motion important
Low densities $\rho=0.001-0.3$

- Peripheral collisions:
excitation controlled by impact parameter



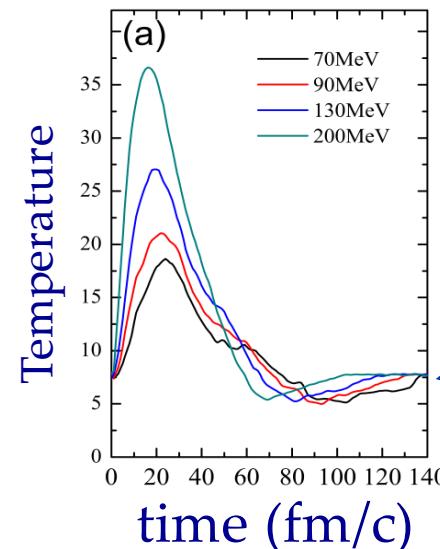
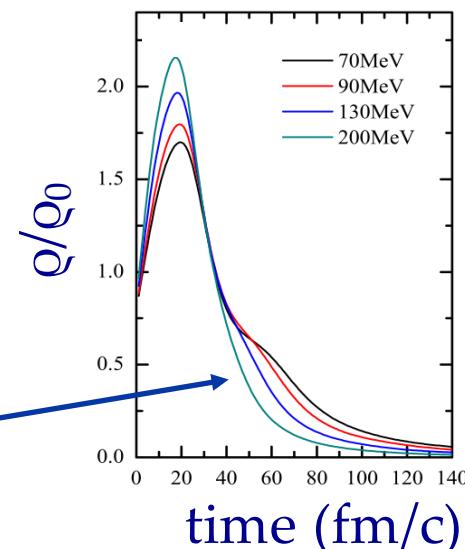
Decay of Quasi-Projectile Size
decreases with excitation
~saturation $\rho \sim 0.8-1$

Do we probe dilute and warm matter?



Au+Au
Central collisions

Sub-saturation
densities



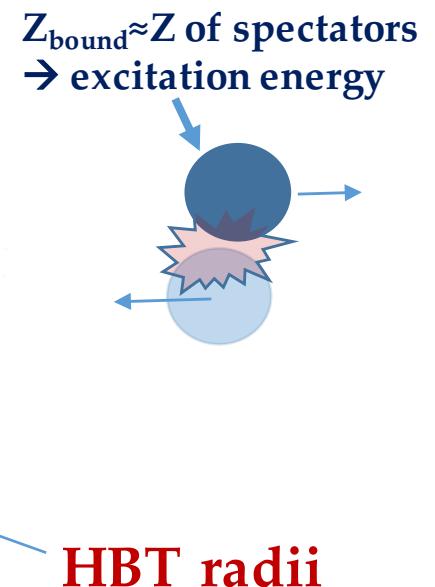
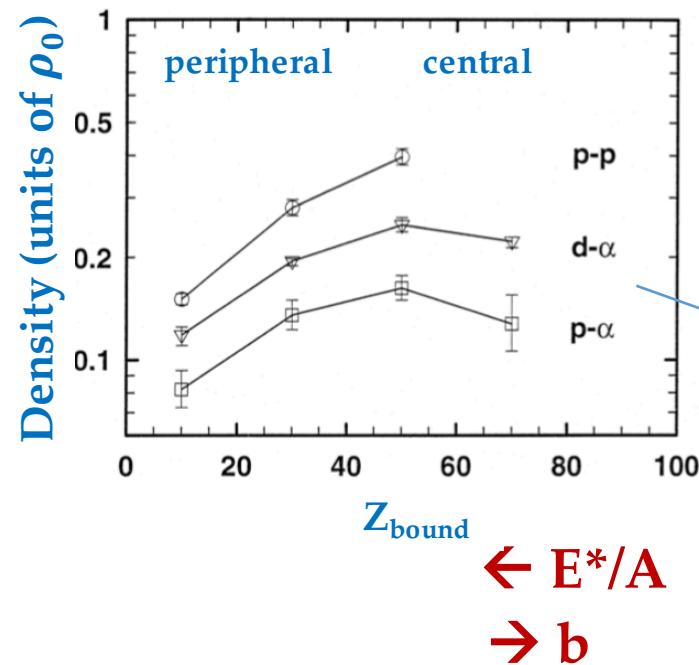
Transport model
simulations

Finite temperatures

Densities vs Temperatures

Target and Proj spectators in Au+Au E/A=1 GeV

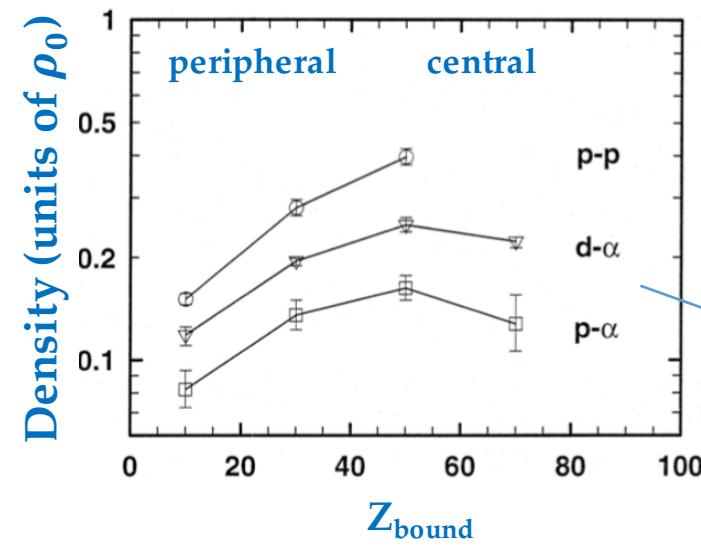
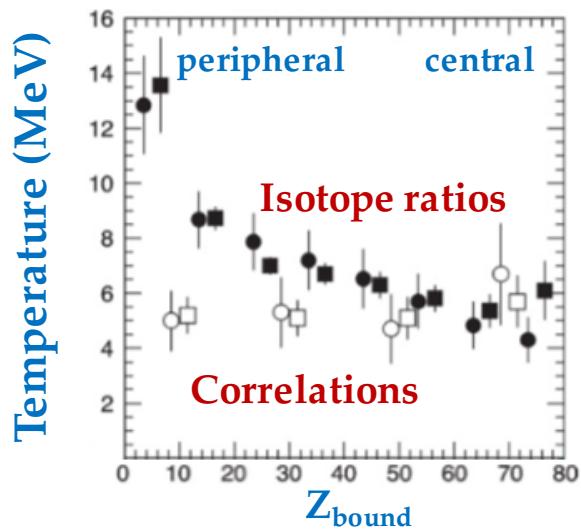
HBT (femtoscopy) and correlations
G. Verde et al., Eur. Phys. J. A30, 81 (2006)



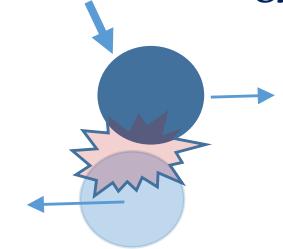
Densities vs Temperatures

Target and Proj spectators in Au+Au E/A=1 GeV

HBT (femtoscopy) and correlations
G. Verde et al., Eur. Phys. J. A30, 81 (2006)



$Z_{\text{bound}} \approx Z$ of spectators
→ excitation energy



HBT radii

← E^*/A
→ b

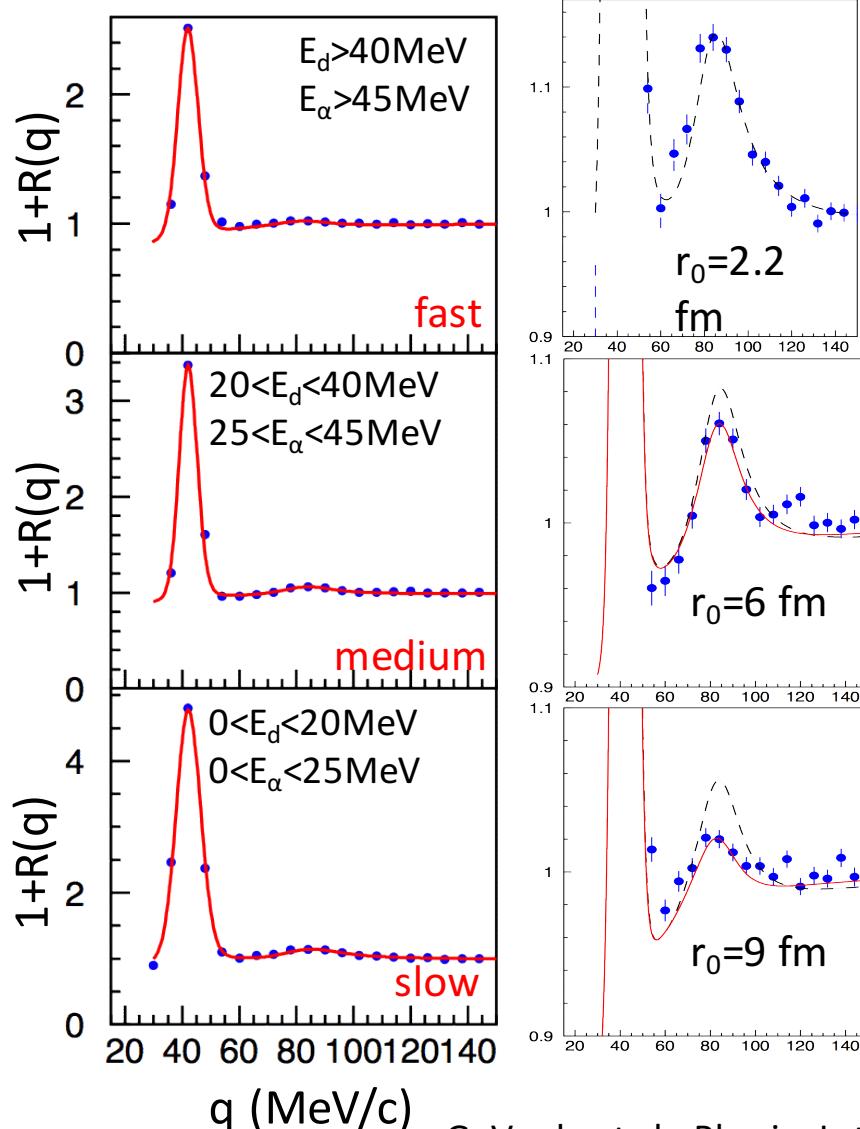
Densities at intermediate energies

Xe+Au E/A=50 MeV $b_{\text{red}} < 0.3$

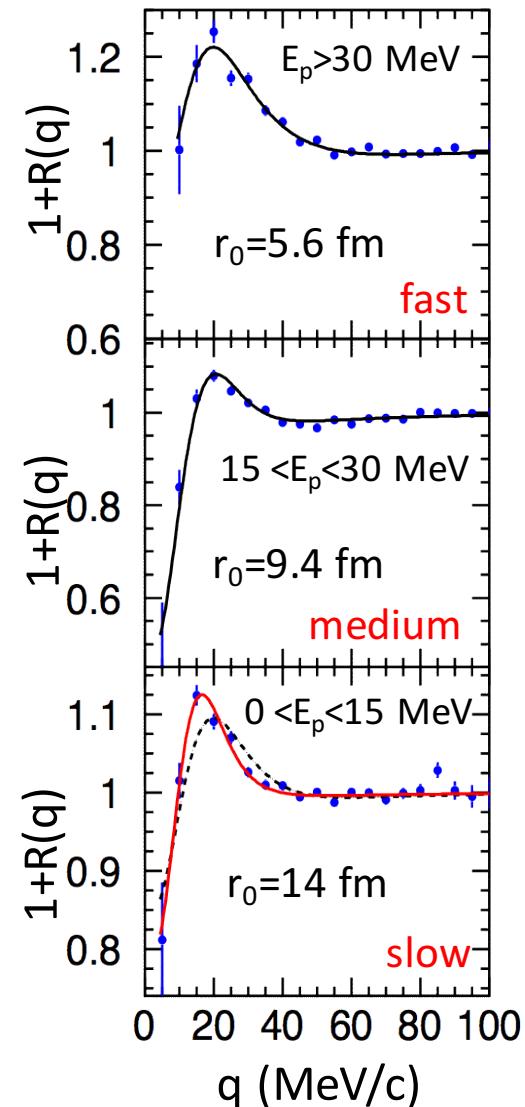
LASSA Data @ MSU

HBT radii

Deuteron-Alpha



Proton-Proton

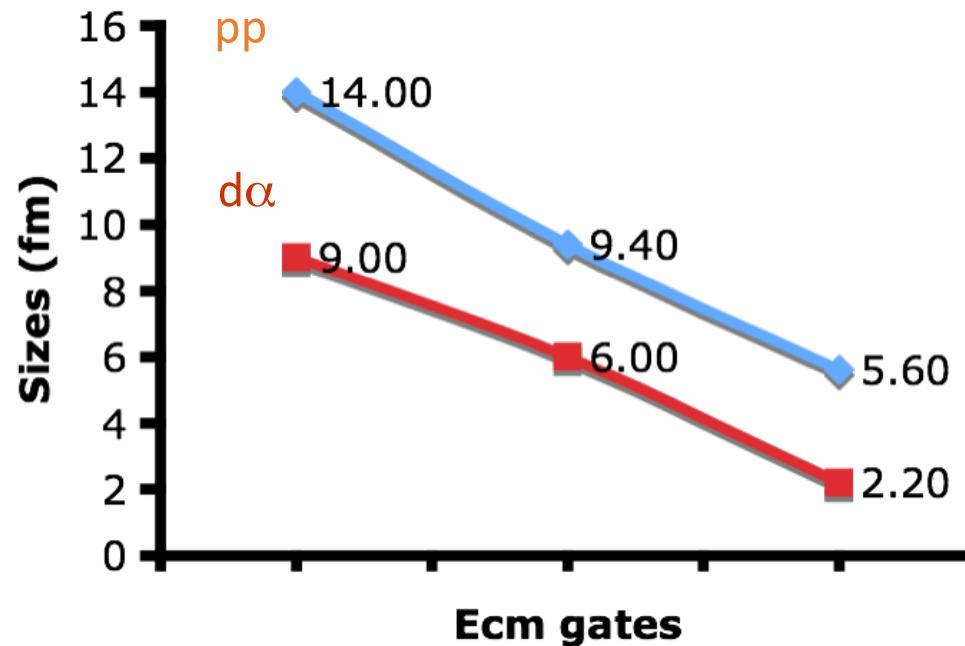


Densities at intermediate energies

Xe+Au E/A=50 MeV $b_{\text{red}} < 0.3$

LASSA Data @ MSU

HBT radii



G. Verde et al., Physics Letters B653, 12 (2008)

HBT Volumes/Densities as seen by different particles

- Very large volumes
- Different particles probe different medium properties?
- Boson Vs. Fermion behavior?

Complex N-body quantum systems

LASSA @ NSCL-MSU

EoS of asymmetric nuclear matter

$$E(\rho, \delta) = E(\rho, \delta = 0) + \boxed{E_{\text{sym}}(\rho) \cdot \delta^2} + O(\delta^4)$$

Asymmetry term

$$\delta = \frac{\rho_n - \rho_p}{\rho_n + \rho_p}$$

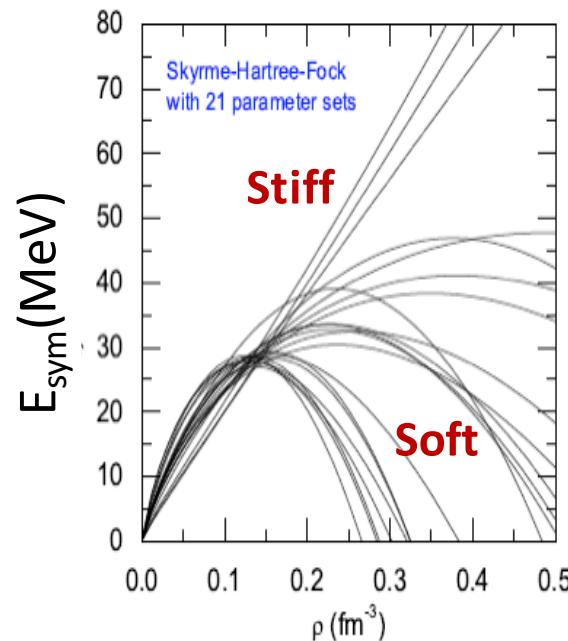
$$\rho = \rho_n + \rho_p$$

B.A. Li et al., Phys. Rep. 464, 113 (2008)

Many approaches... large uncertainties....

...Especially at high densities
(three-body forces)

ZH Li, U. Lombardo, PRC74 047304 (2006)

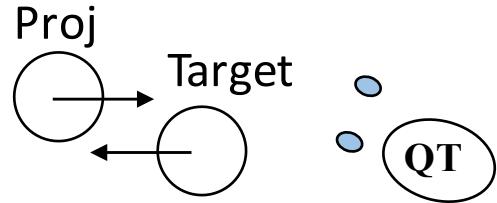


E_{sym} enhanced in reactions with large N/Z asymmetries (due to δ^2)

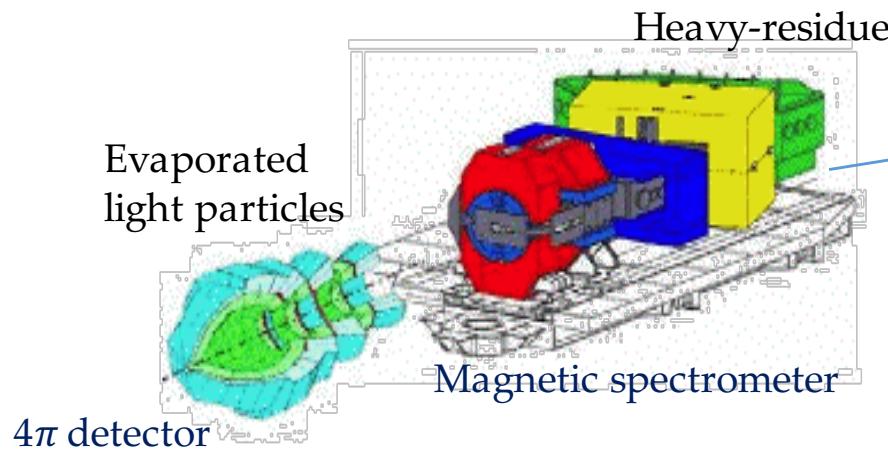
Brown, Phys. Rev. Lett. 85, 5296 (2001)

Fuchs and Wolter, EPJA 30, 5 (2006)

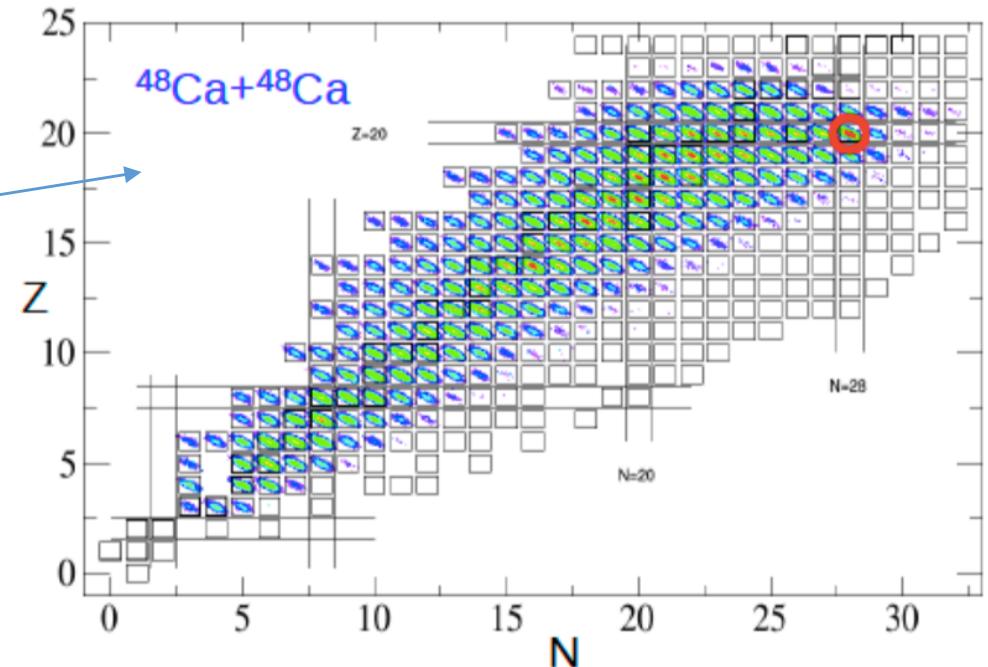
Densities of bosons and fermions



INDRA-VAMOS experiment
 $^{40,48}\text{Ca} + ^{40,48}\text{Ca}$ @ E/A = 35 MeV
Decay of excited quasi-projectile

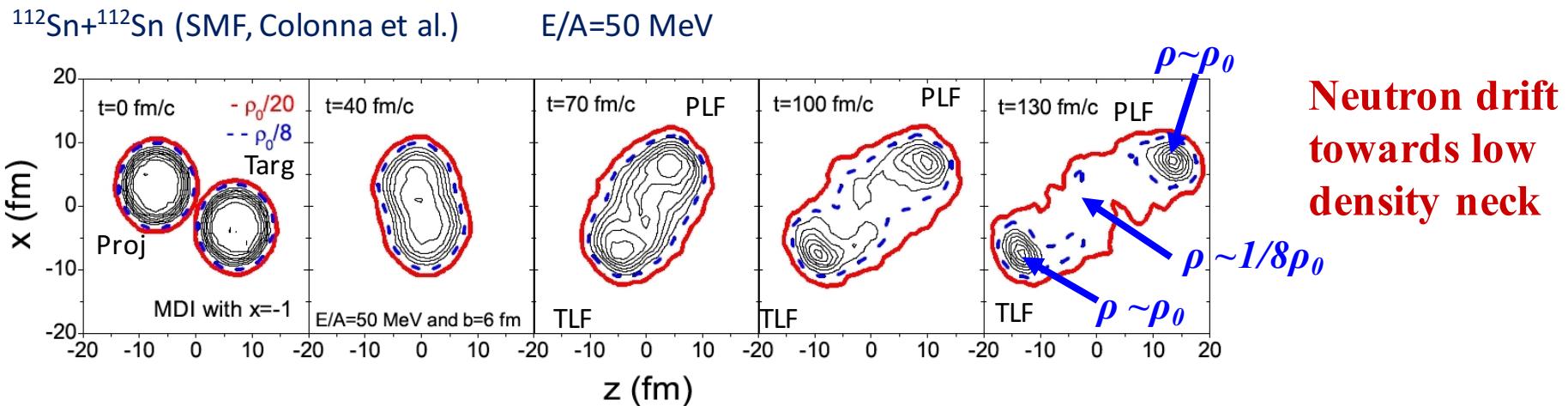


INDRA-VAMOS



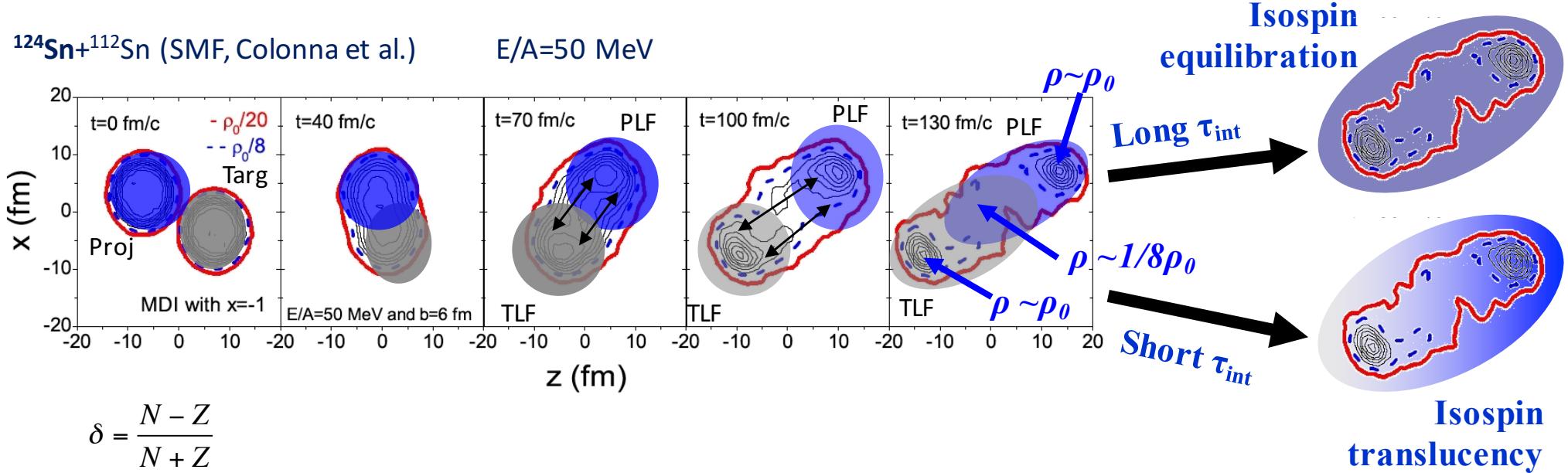
P. Marini, H. Zheng, M. Boisjoli, G. Verde, A. Chbihi et al.
Phys. Lett. B 756, 194 (2016)

Isospin drift and diffusion



Isospin drift

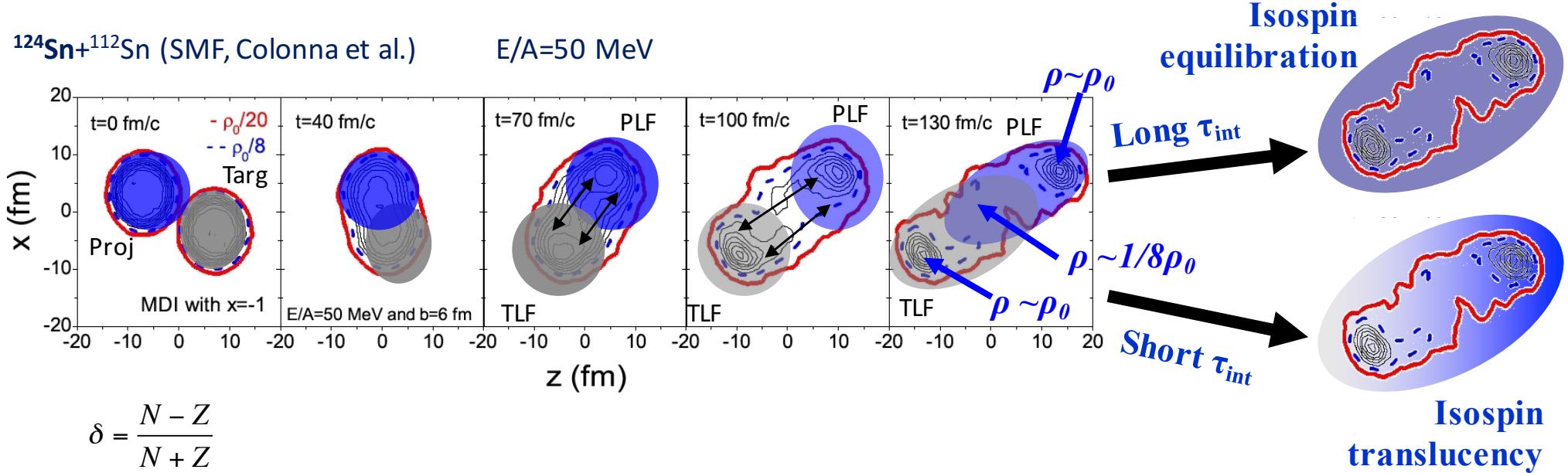
Isospin drift and diffusion



Isospin drift

Isospin diffusion

Isospin drift and diffusion



Isospin drift

$$\mathbf{j}_n - \mathbf{j}_p = (D_n^\rho - D_p^\rho) \nabla \rho - (D_n^\delta - D_p^\delta) \nabla \delta$$

$$\propto \frac{\partial E_{sym}}{\partial \rho}$$

Isospin diffusion

$$\propto E_{sym}$$

Probing $E_{sym}(\rho)$

Isospin diffusion and imbalance ratios



PP



MIX



MIX

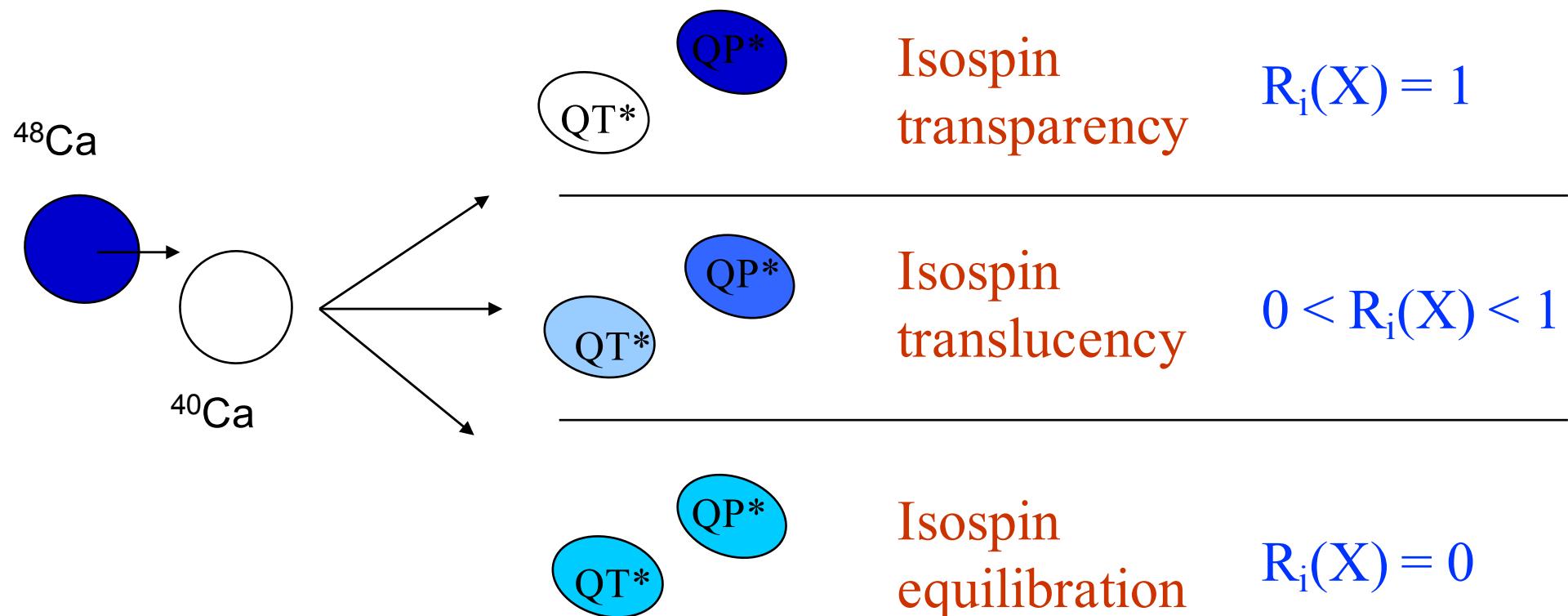


NN

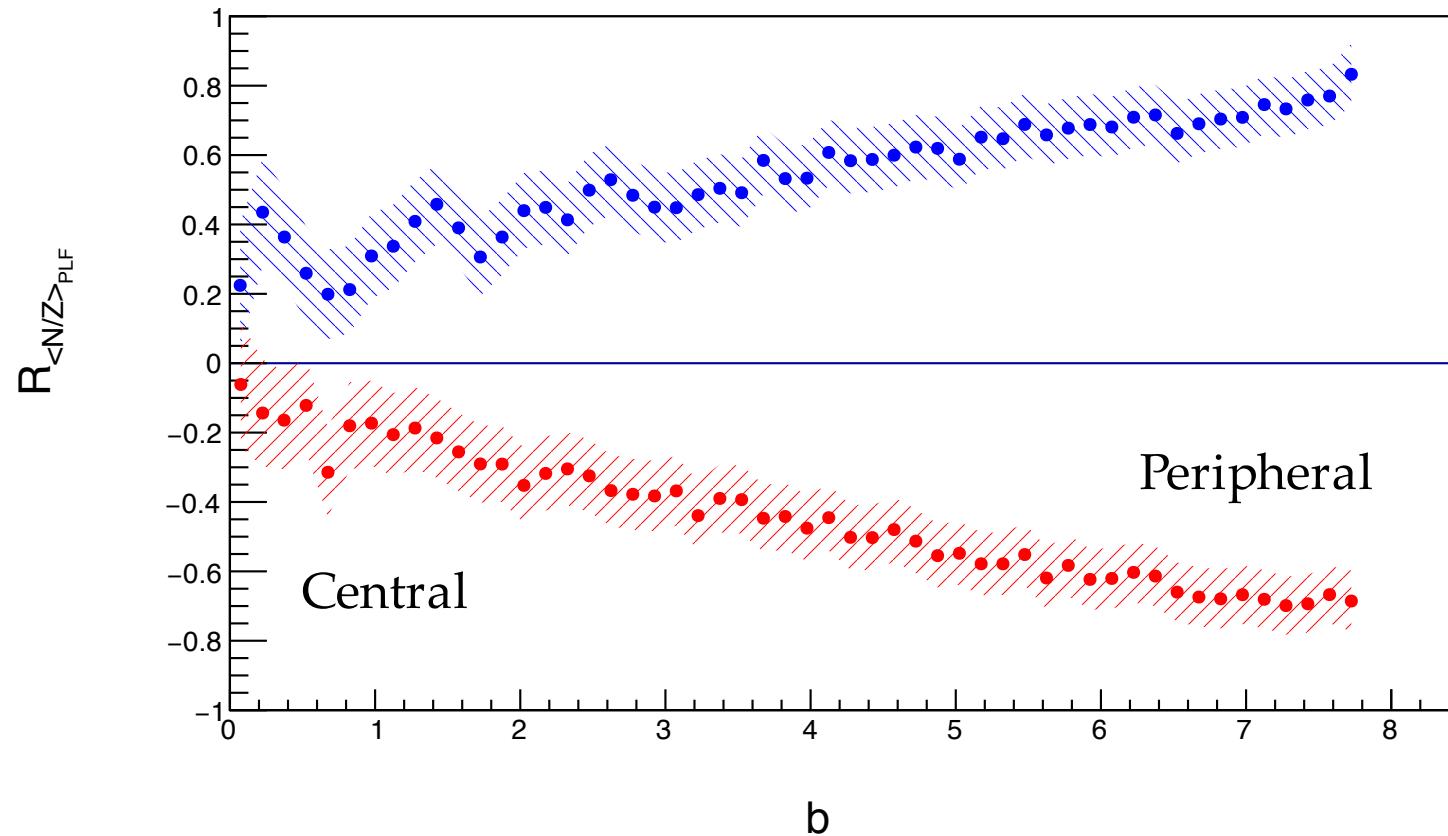
X=Sensitive to N/Z of emitter



$$R_i(X) = \frac{2X - X^{NN} - X^{PP}}{X^{NN} - X^{PP}}$$



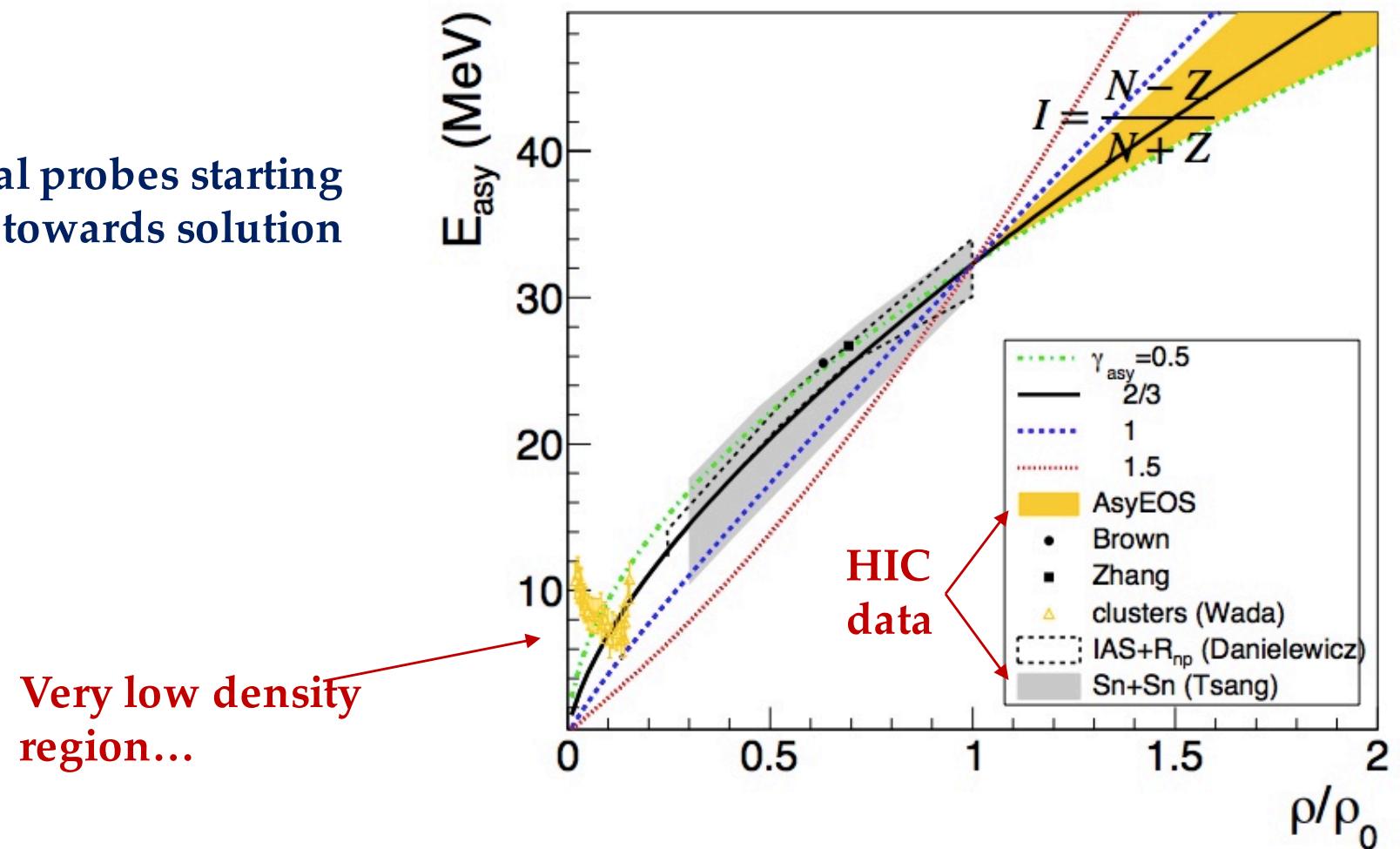
Isospin diffusion data



Towards equilibration

Density dependence of symmetry energy

Experimental probes starting to converge towards solution



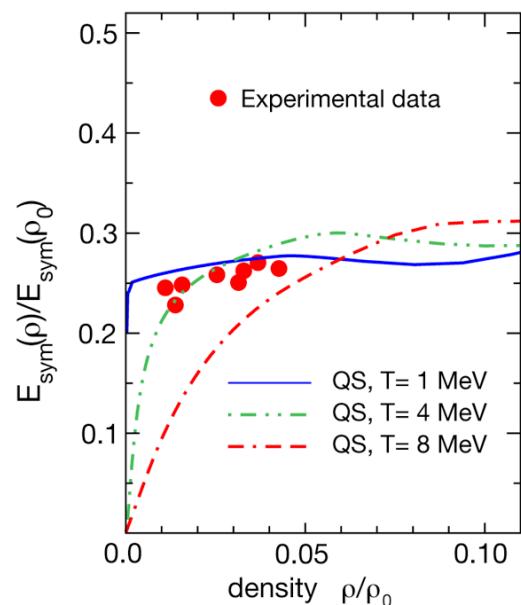
EoS of asymmetric nuclear matter

$$E(\rho, \delta) = E(\rho, \delta = 0) + \boxed{E_{\text{sym}}(\rho) \cdot \delta^2} + O(\delta^4)$$

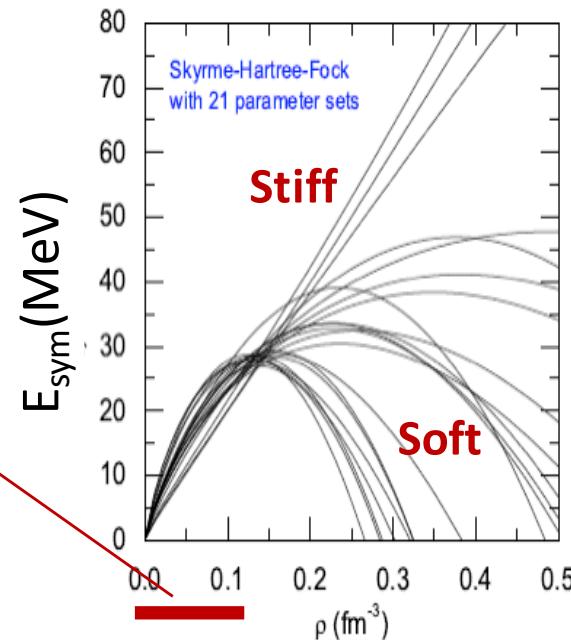
Asymmetry term

$$\delta = \frac{\rho_n - \rho_p}{\rho_n + \rho_p}$$

$$\rho = \rho_n + \rho_p$$



B.A. Li et al., Phys. Rep. 464, 113 (2008)



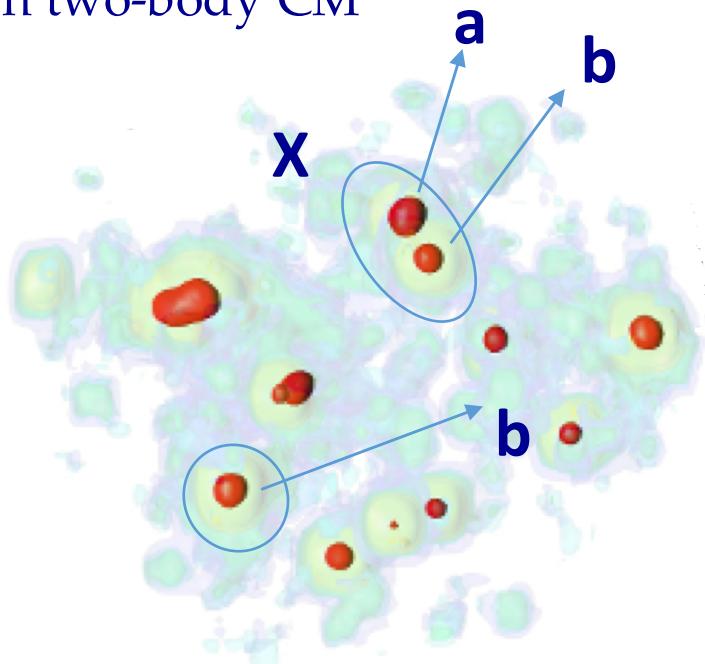
- Alpha clusters at low densities modify EoS prescriptions
- In-medium modified nuclear properties

E_{sym} enhanced in reactions with large N/Z asymmetries (due to δ^2)

In-medium cluster decays: thermal model

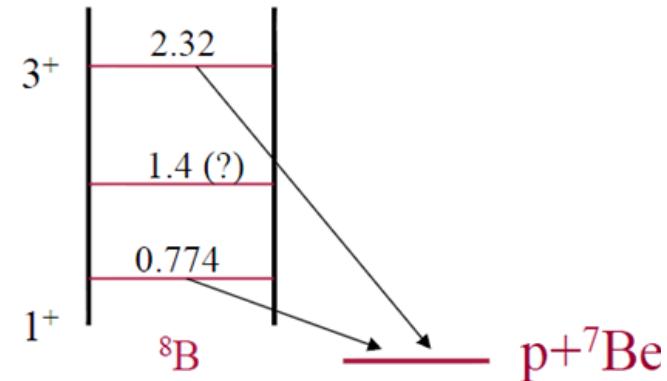
Thermal approach

\vec{v}_a, \vec{v}_b velocity vectors
in two-body CM



Particle emitting sources
extended in phase-space

States of ${}^8\text{B} \rightarrow \text{p}+{}^7\text{Be}$



$Y_{coinc}(E^*)$

$$\propto \frac{N}{\pi} e^{-E^*/T} \sum_i (2J_i + 1) \left[\frac{\Gamma_i/2}{(E^* - E_i)^2 + \Gamma_i^2/4} \right]$$

In-medium
temperature

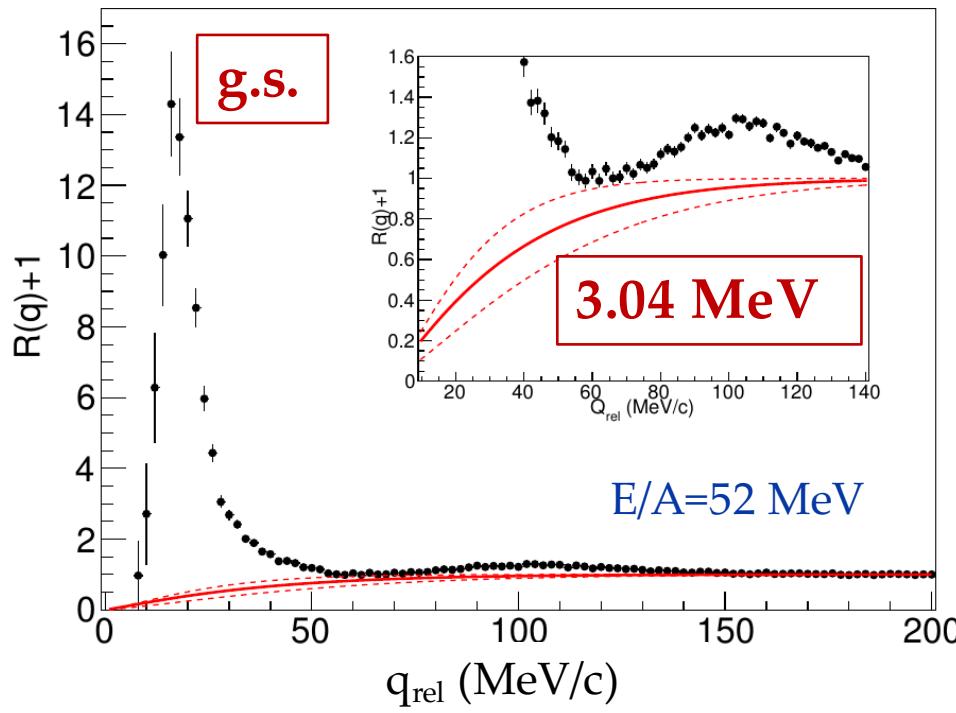
Nuclear structure:
spin, branching ratios,
resonance position

^{8}Be resonances decays

Ar+Ni, E/A=32-95 MeV – central $\rightarrow {}^8\text{Be} \rightarrow \alpha + \alpha$

INDRA @ GANIL

$$1 + R(q_{rel}) = \frac{Y_{coinc}(\alpha, \alpha)}{Y_{evt\,mixing}(\alpha, \alpha)}$$



$$1 + R(q_{rel}) = \frac{Y_{coinc}(\alpha, \alpha)}{Y_{evt\,mixing}(\alpha, \alpha)}$$

$$Y_{nucl}(E^*) =$$

$$= \frac{N}{\pi} e^{-E^*/T} \sum_i (2J_i + 1) \left[\frac{\Gamma_i/2}{(E^* - E_i)^2 + \Gamma_i^2/4} \right]$$

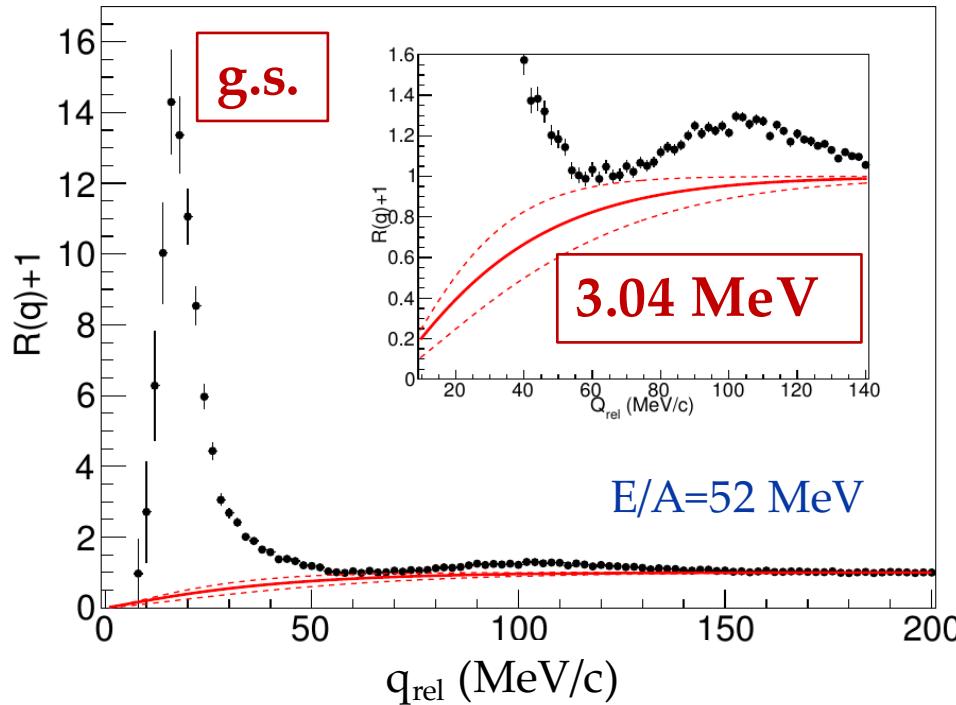
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Nuclear structure:
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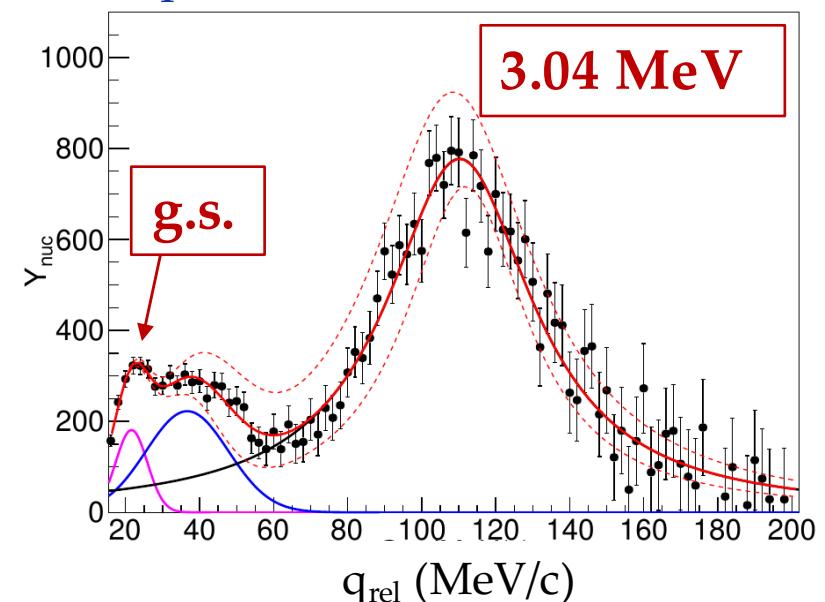
Ar+Ni, E/A=32-95 MeV – central
INDRA @ GANIL

$$1 + R(q_{rel}) = \frac{Y_{coinc}(\alpha, \alpha)}{Y_{evt\ mixing}(\alpha, \alpha)}$$



$$= \frac{N}{\pi} e^{-E^*/T} \sum_i (2J_i + 1) \left[\frac{\Gamma_i/2}{(E^* - E_i)^2 + \Gamma_i^2/4} \right]$$

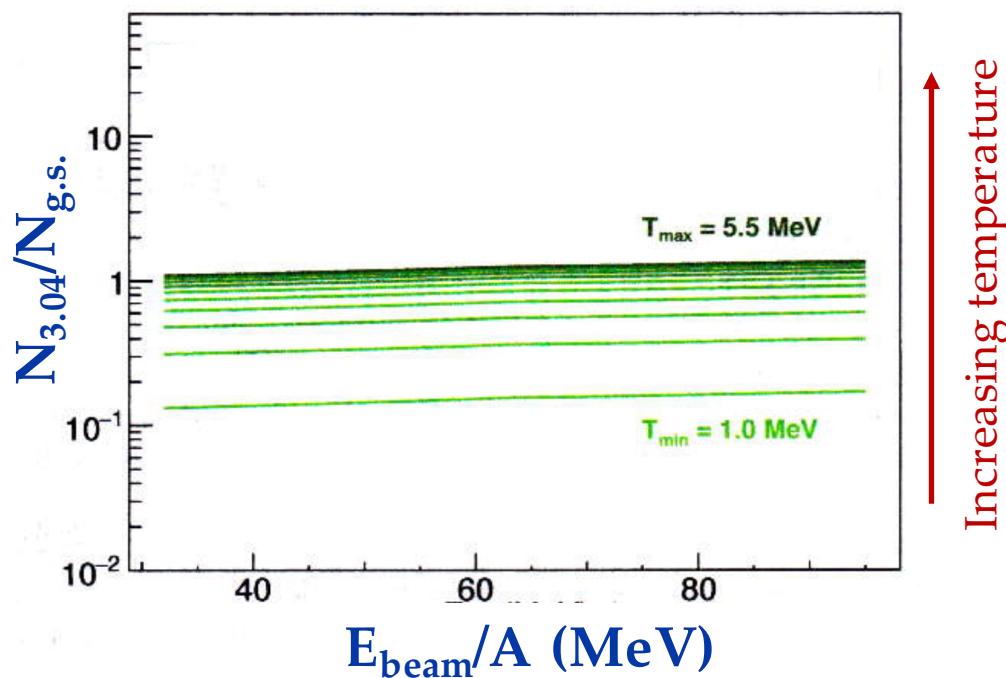
Experimental Y_{nucl}



^{8}Be resonance decays

Ar+Ni, E/A=32-95 MeV – central $\rightarrow {}^8\text{Be} \rightarrow \alpha + \alpha$

INDRA@ GANIL

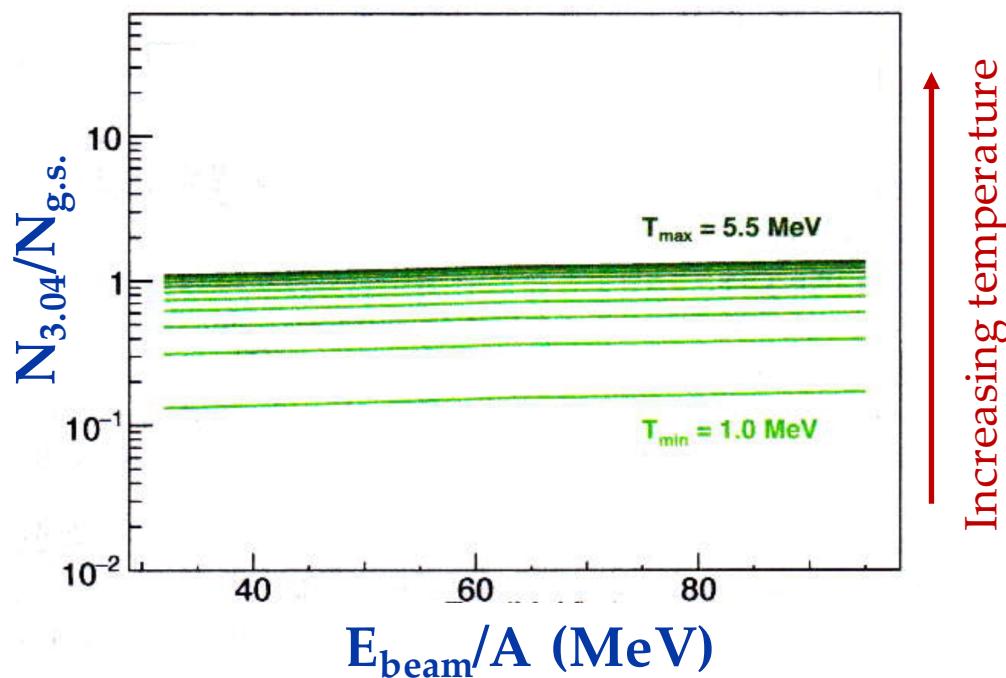


$$Y_{nucl}(E^*) =$$

$$= \frac{N}{\pi} e^{-E^*/T} \sum_i (2J_i + 1) \left[\frac{\Gamma_i/2}{(E^* - E_i)^2 + \Gamma_i^2/4} \right]$$

^{8}Be resonance decays

Ar+Ni, E/A=32-95 MeV – central $\rightarrow {}^8\text{Be} \rightarrow \alpha + \alpha$
INDRA@ GANIL



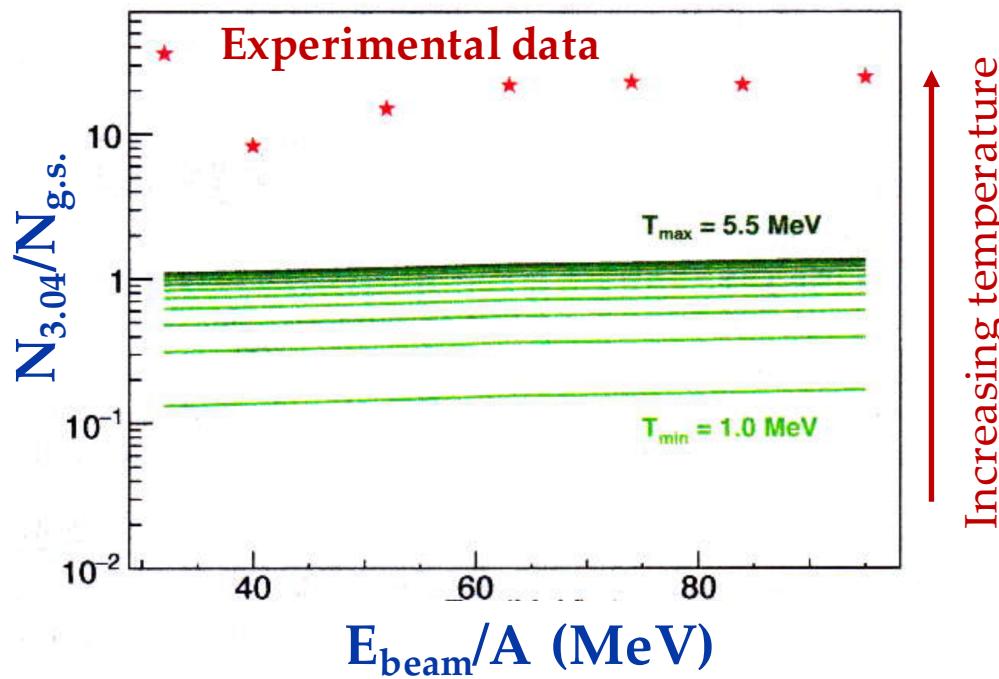
$$Y_{nucl}(E^*) =$$

$$= \frac{N}{\pi} e^{-E^*/T} \sum_i (2J_i + 1) \left[\frac{\Gamma_i/2}{(E^* - E_i)^2 + \Gamma_i^2/4} \right]$$

Which temperature T is
consistent with a measured
relative population of state?

^{8}Be resonance decays

Ar+Ni, E/A=32-95 MeV – central $\rightarrow {}^8\text{Be} \rightarrow \alpha + \alpha$
INDRA@ GANIL



Thermal mechanism fails

$$Y_{nucl}(E^*) =$$

$$= \frac{N}{\pi} e^{-E^*/T} \sum_i (2J_i + 1) \left[\frac{\Gamma_i/2}{(E^* - E_i)^2 + \Gamma_i^2/4} \right]$$

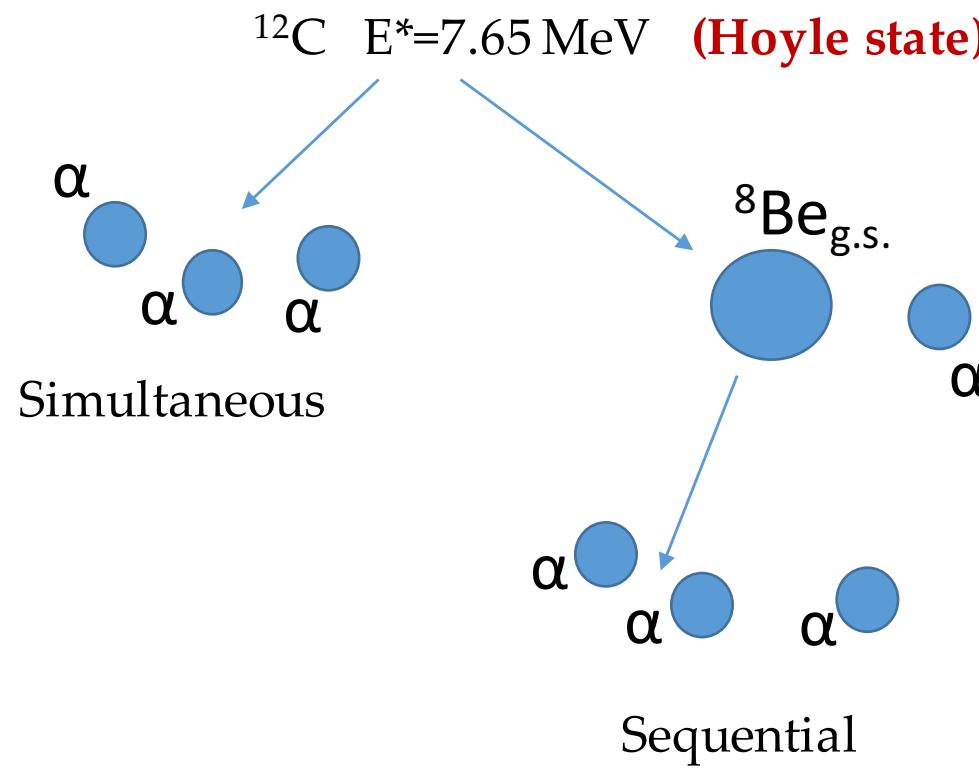
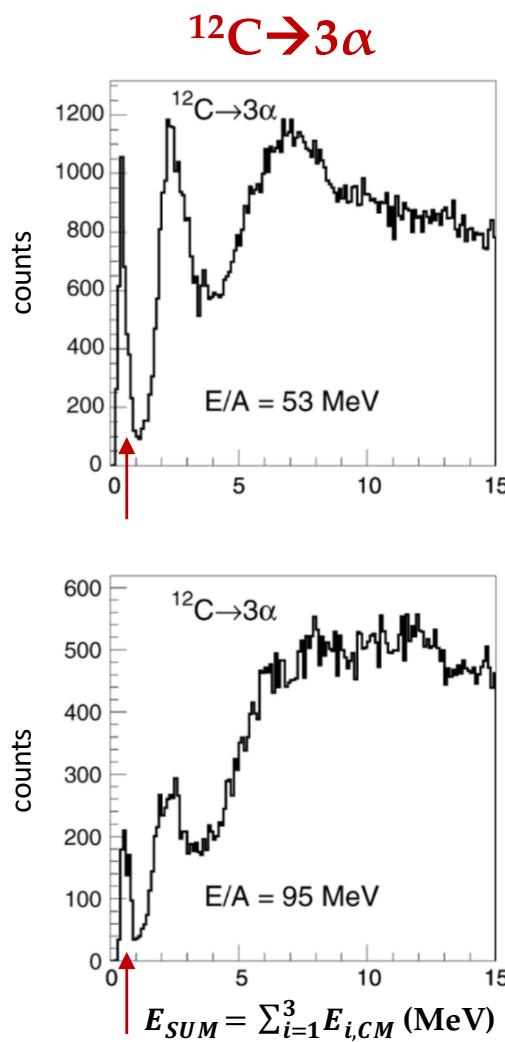
Which temperature T is consistent with a measured relative population of state?

None
overpopulation of excited states

**Lifetime effect?
Nuclear structure effects?**

Higher order correlations: $3\alpha \rightarrow ^{12}\text{C}$ states

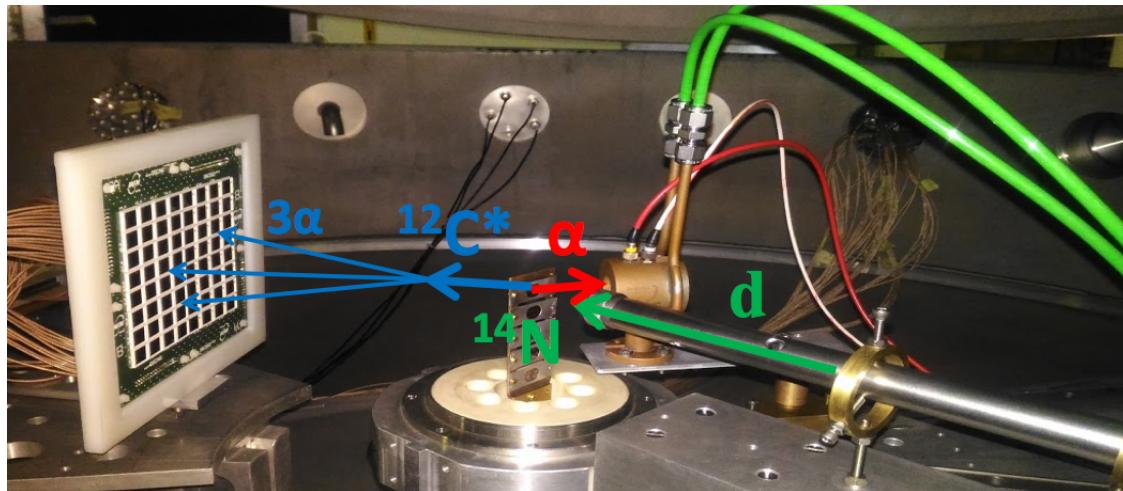
$^{12}\text{C} + ^{24}\text{Mg}$ E/A=53 and 95 MeV
INDRA data



Astrophysics relevance: Which stars do host the Hoyle process?

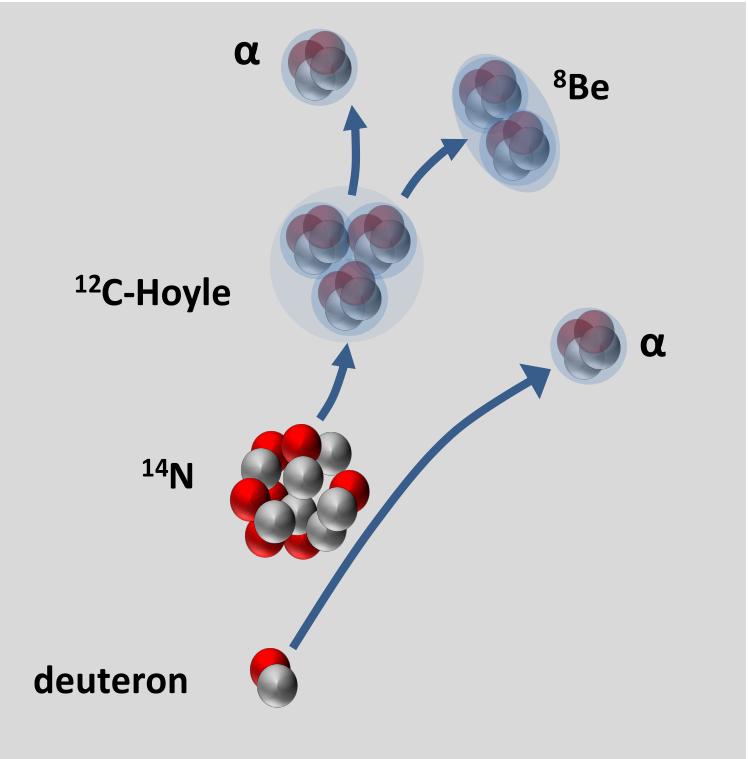
In-vacuum measurements

OSCAR data @ LNS



D. Dell'Aquila, I. Lombardo, G. Verde et al.,
Physical Review Letters 119, 132501 (2017)

$^{14}\text{N}(\text{d},\alpha)^{12}\text{C}^*$



Direct decay < 0.043% (95% C.L.)

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Viewpoint: Watching the Hoyle State Fall Apart

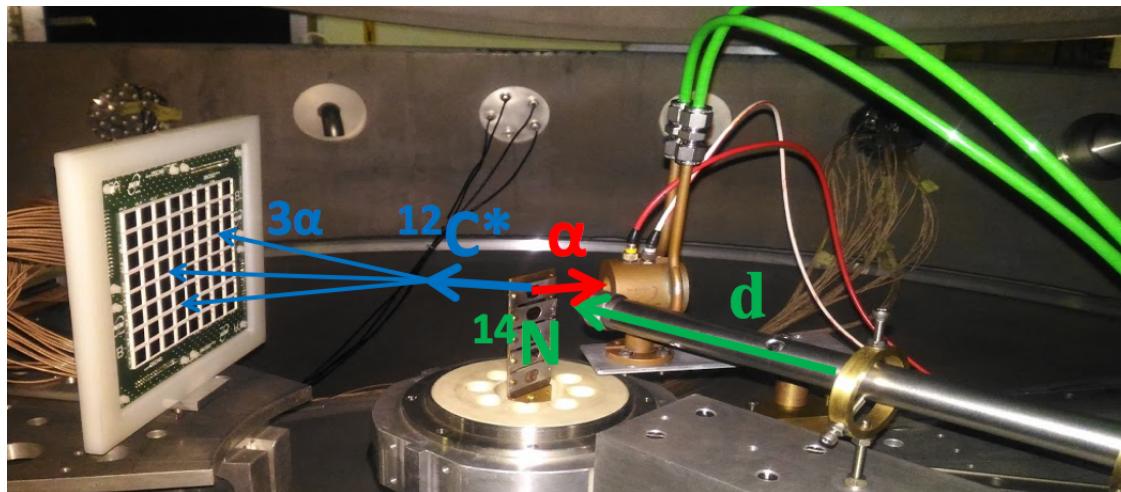
Oliver Kirsebom, Department of Physics and Astronomy, Aarhus University, Ny Munkegade 120, Aarhus C Denmark, 8000

September 25, 2017 • Physics 10, 103

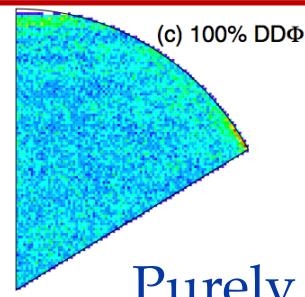
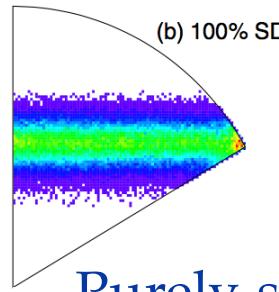
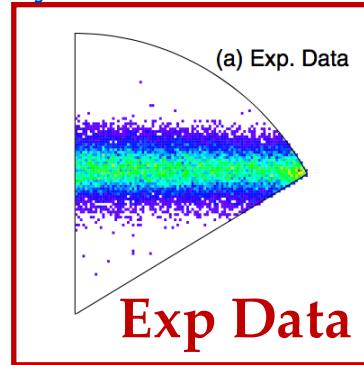
Two experiments provide the most precise picture to date of how an excited state of carbon decays into three helium nuclei.

In-vacuum measurements

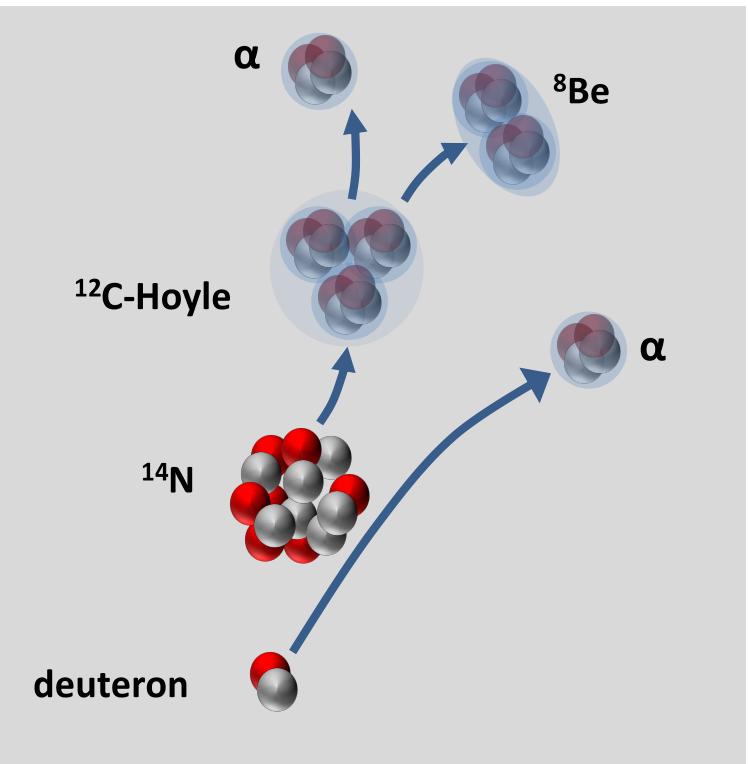
OSCAR data @ LNS



D. Dell'Aquila, I. Lombardo, G. Verde et al.,
Physical Review Letters 119, 132501 (2017)



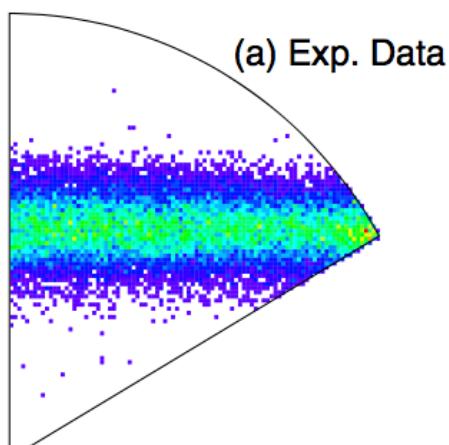
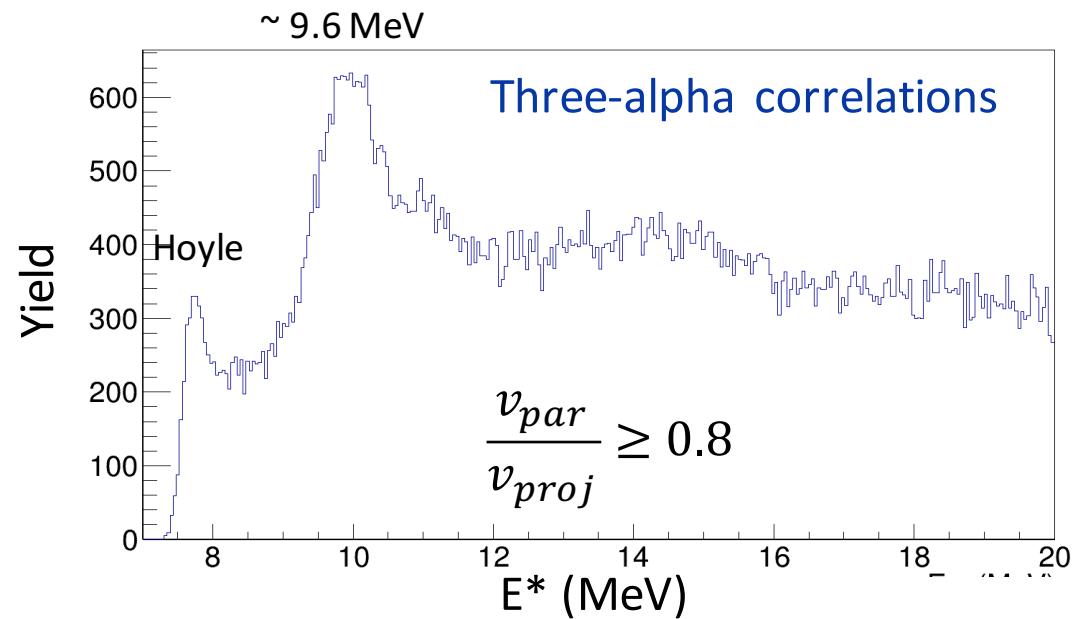
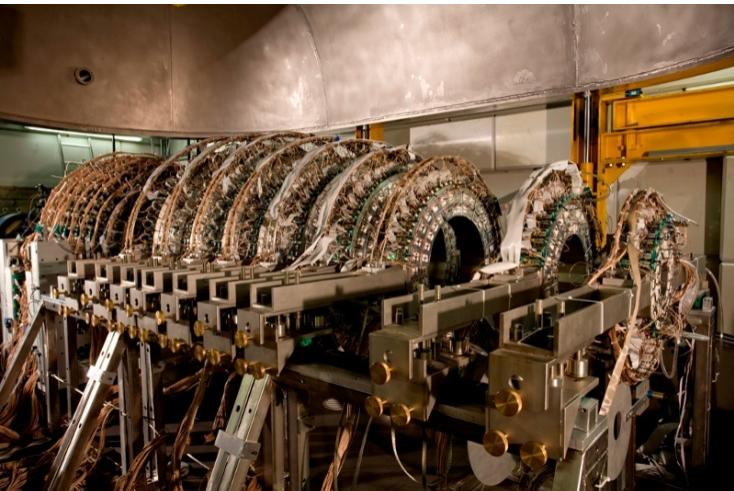
$^{14}\text{N}(\text{d},\alpha)^{12}\text{C}^*$



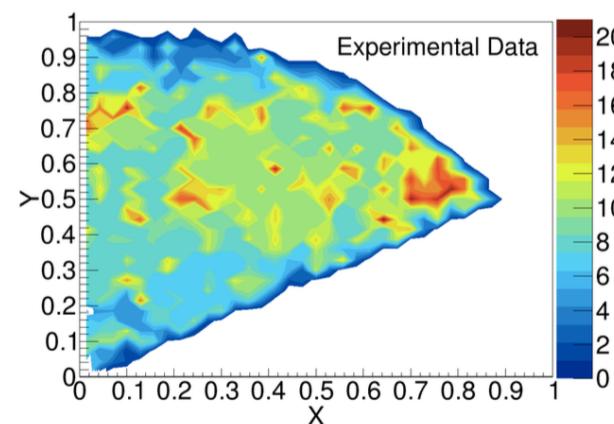
No direct decay
DD < 0.043% (95% C.L.)

Dedicated in-medium studies

CHIMERA $^{12}\text{C} + ^{24}\text{Mg}$ @ 35 AMeV



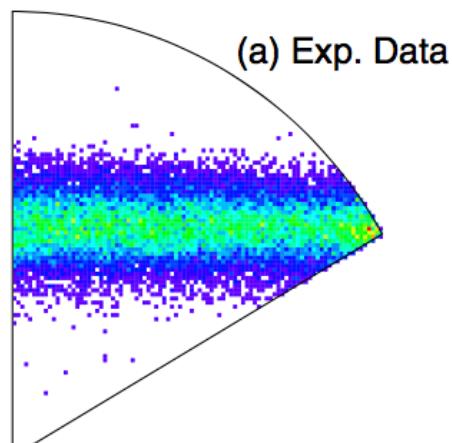
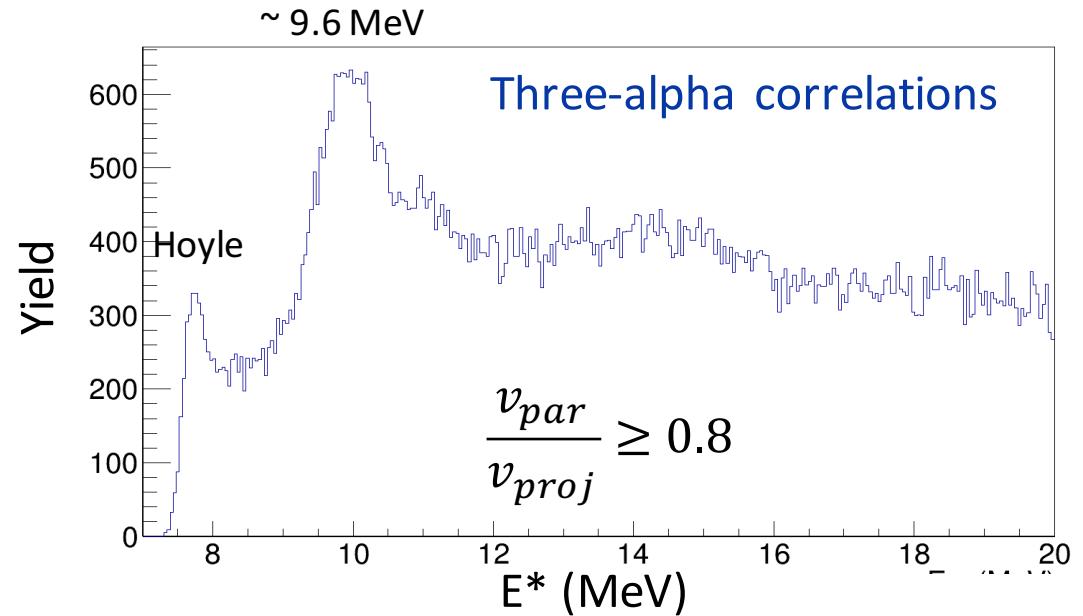
In-vacuum: No direct decay



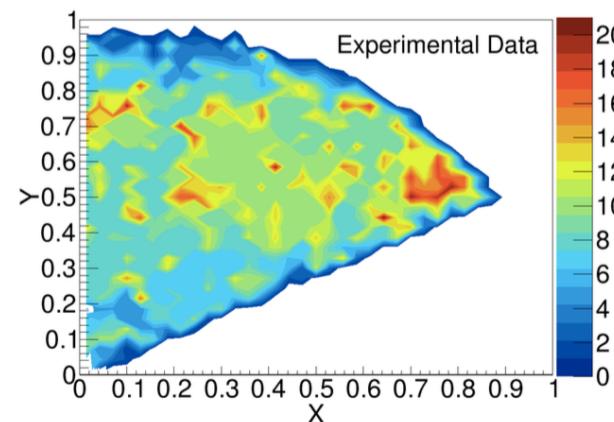
In-medium:
Strong
contribution
from direct
decay (> 20%)

Dedicated in-medium studies

- In-medium modification of nuclear structure properties?
- Probing complexity of N-body quantum clusterized systems?



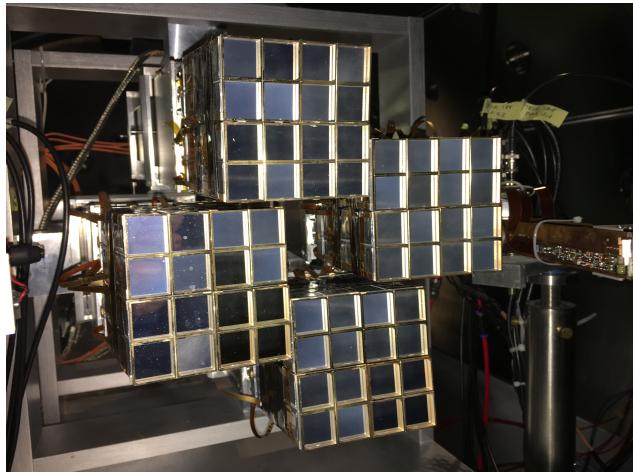
In-vacuum: No direct decay



In-medium:
Strong
contribution
from direct
decay (> 20%)

Dedicated in-medium studies

FAZIA (Four-pi A- and Z-Identification Array)

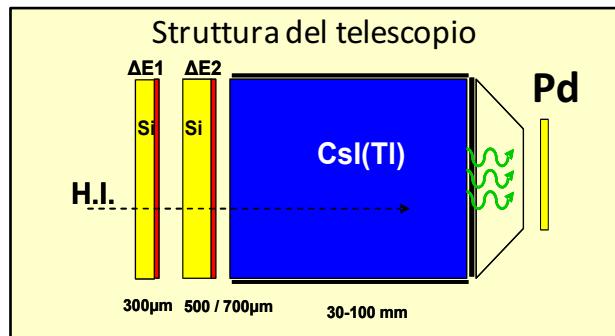


FAZIACOR @ LNS

G. Verde, D. Gruyer, FAZIA Collaboration

$^{32}\text{S} + ^{12}\text{C}$ E/A=25, 50 MeV

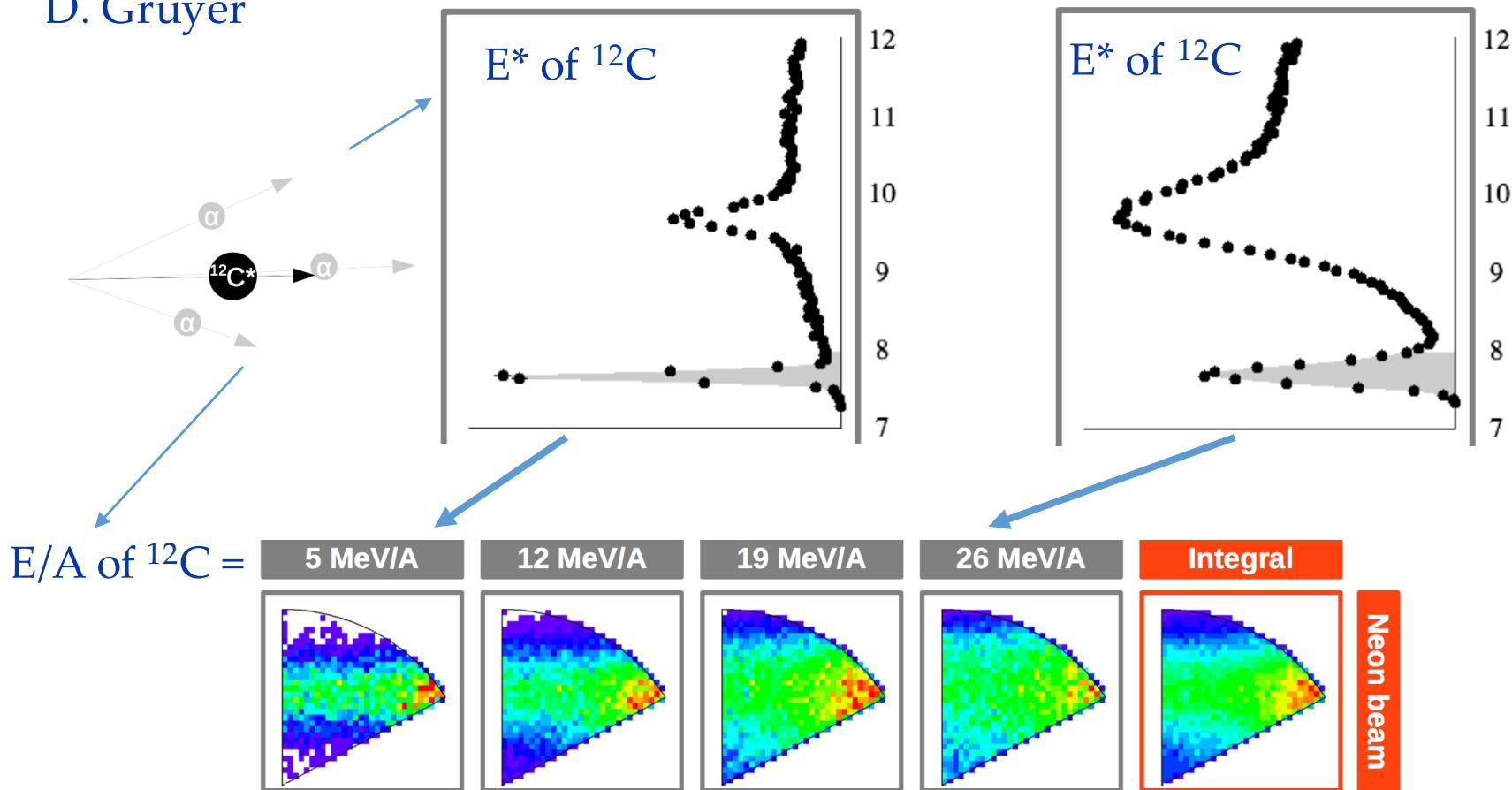
$^{36}\text{S} + ^{12}\text{C}$ E/A=25, 50 MeV ... → $^{20}\text{Ne} + ^{12}\text{C}$



Fully digital electronics: particle identification directly from digitalization of Si and CsI(Tl) signals
→ almost online available
→ Wide dynamic range (100 keV- GeV)

Preliminary data on the Hoyle state

D. Gruyer



Slow ^{12}C

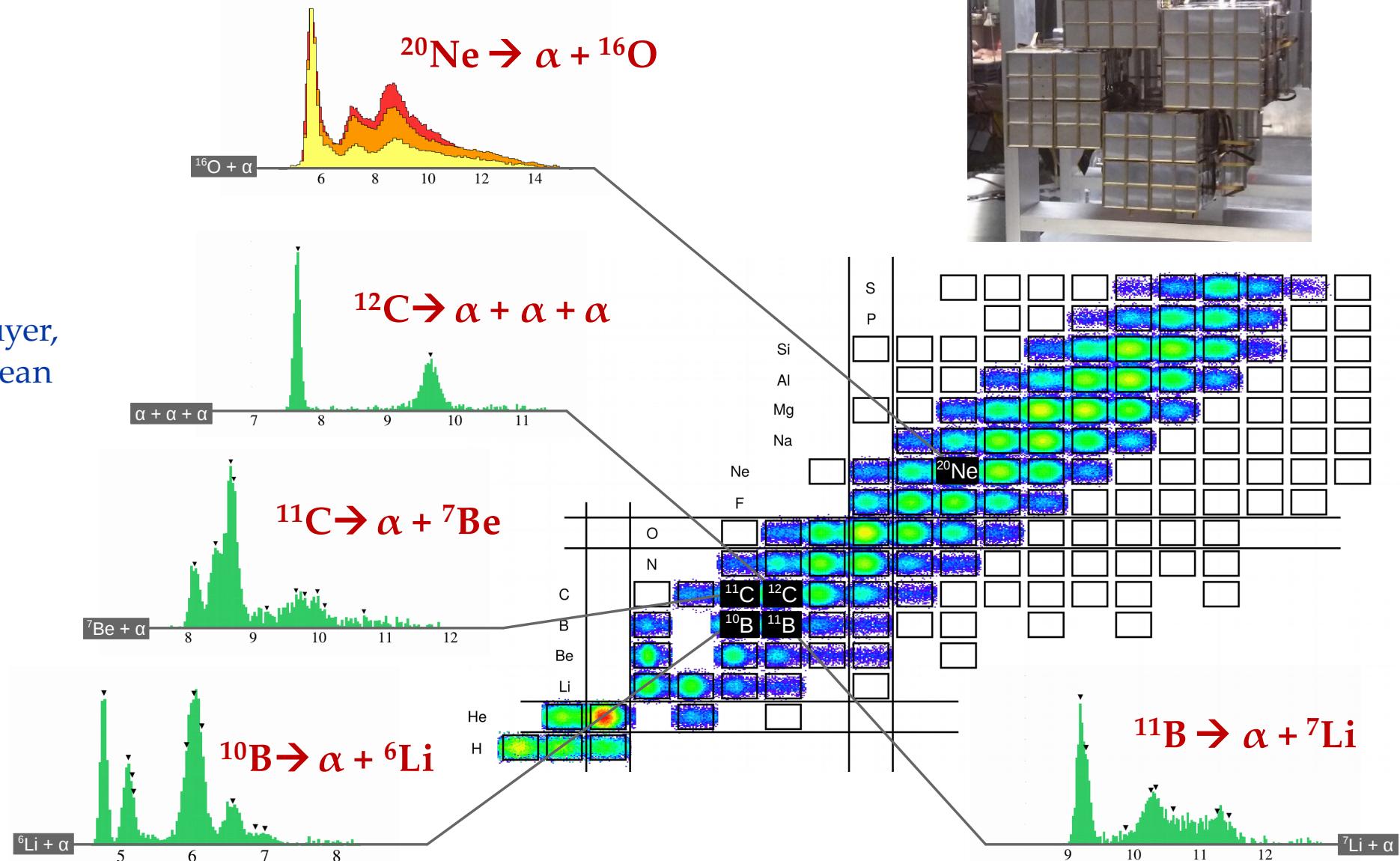
- Only direct decay
- Negligible background
- Agreement with out-of-medium results

Fast ^{12}C

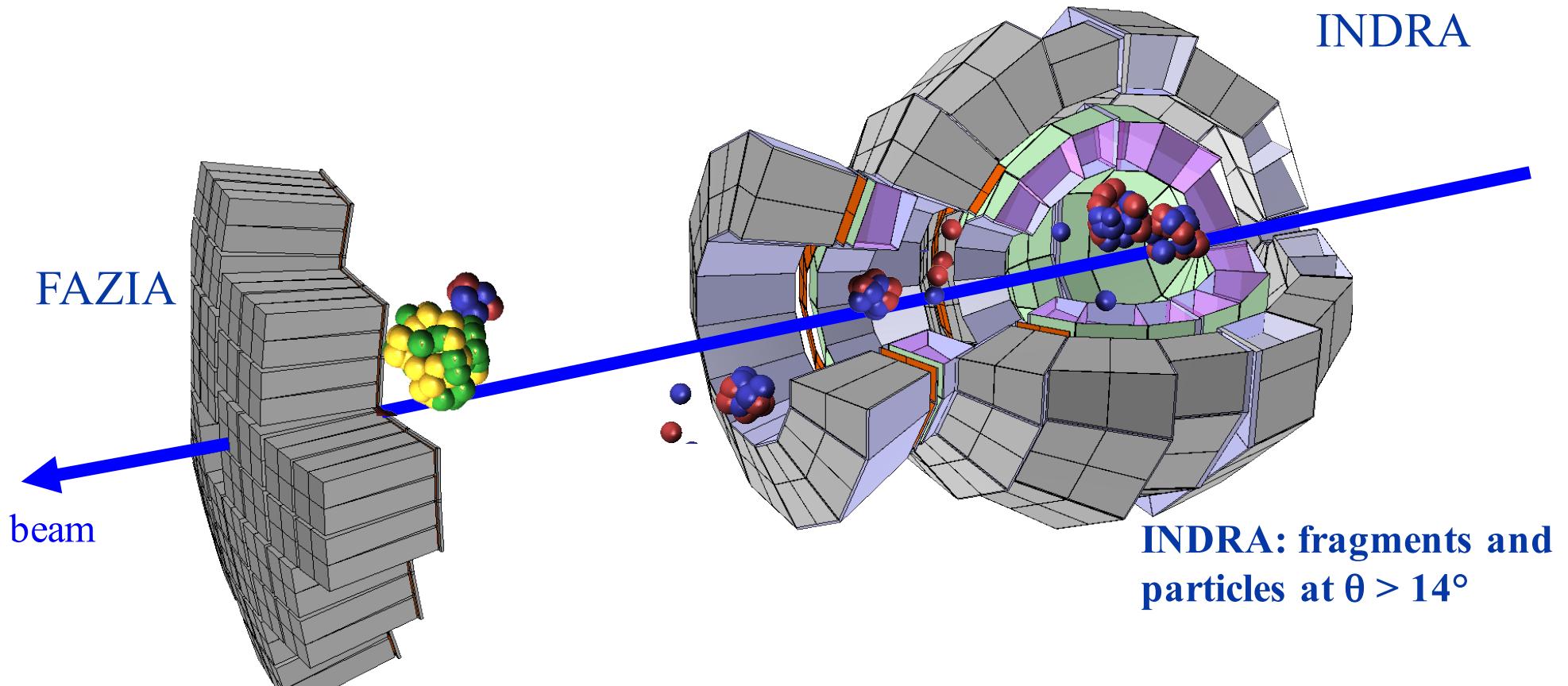
- direct decay: Effects of medium on nuclear structure? Links to alpha density estimates... BES?

Some preliminary $\text{Na}\alpha$ -X correlations

D. Gruyer,
LPC Cean



FAZIA-INDRA @ GANIL (2019-2020)



- **12 Blocks (192 telescopes)**
- **full Z & A identification of $1 \leq Z < 25$ at $\theta < 14^\circ$**

$^{58,64}\text{Ni} + ^{58,64}\text{Ni}$ $E/A = 30\text{-}90\text{ MeV}$

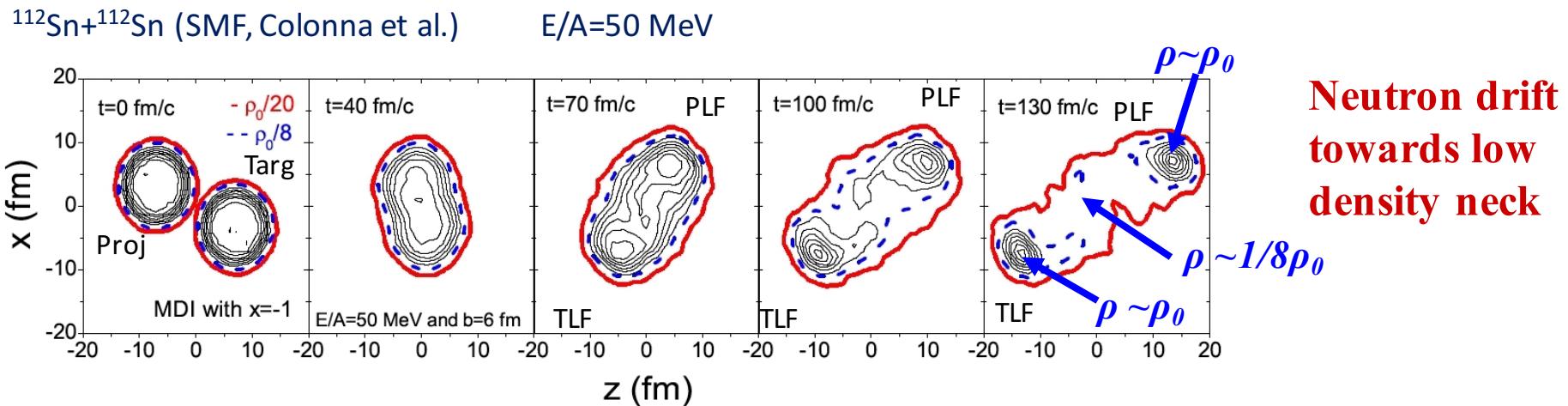
In-medium investigations

- HIC: warm and dilute medium with plenty of unbound states
 - Femtoscopic probes to characterize medium → EoS, symmetry energy (astrophysical implications)
 - Study structure properties in thermal medium: resonance decays → beyond thermodynamics picture
- Modification of structure properties in resonance decays?
 - Future perspectives: INDRA-FAZIA campaigns at GANIL
Welcome to collaborate (experiment, analysis techniques, theory)

Backup slides

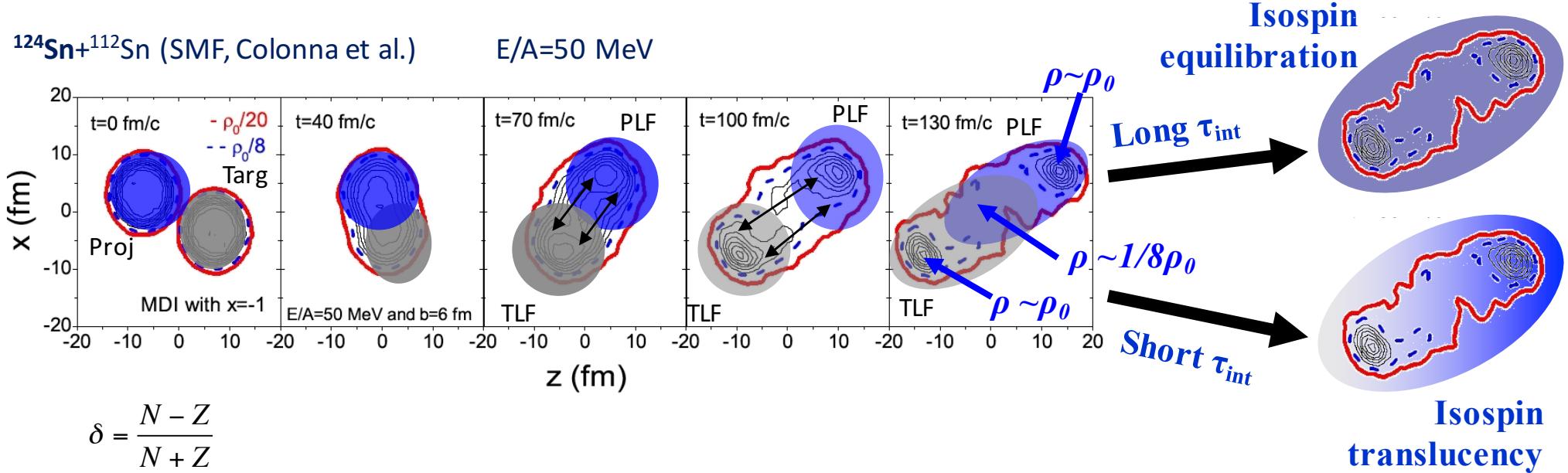
INDRA-VAMOS stuff

Isospin drift and diffusion



Isospin drift

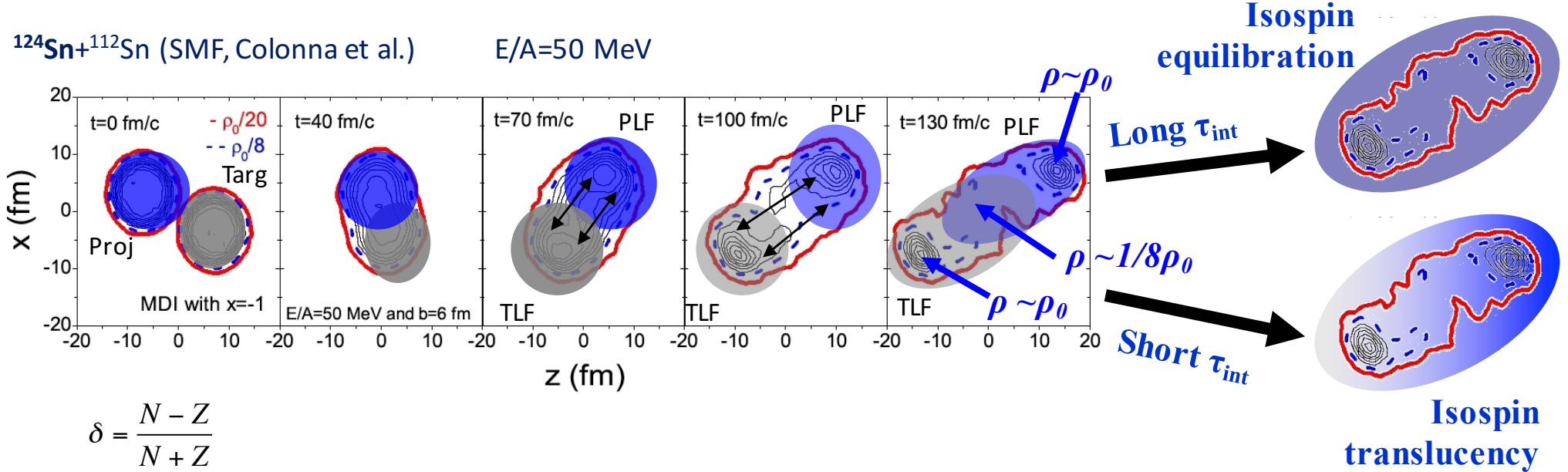
Isospin drift and diffusion



Isospin drift

Isospin diffusion

Isospin drift and diffusion



Isospin drift

$$\mathbf{j}_n - \mathbf{j}_p = (D_n^\rho - D_p^\rho) \nabla \rho - (D_n^\delta - D_p^\delta) \nabla \delta$$

$$\propto \frac{\partial E_{sym}}{\partial \rho}$$

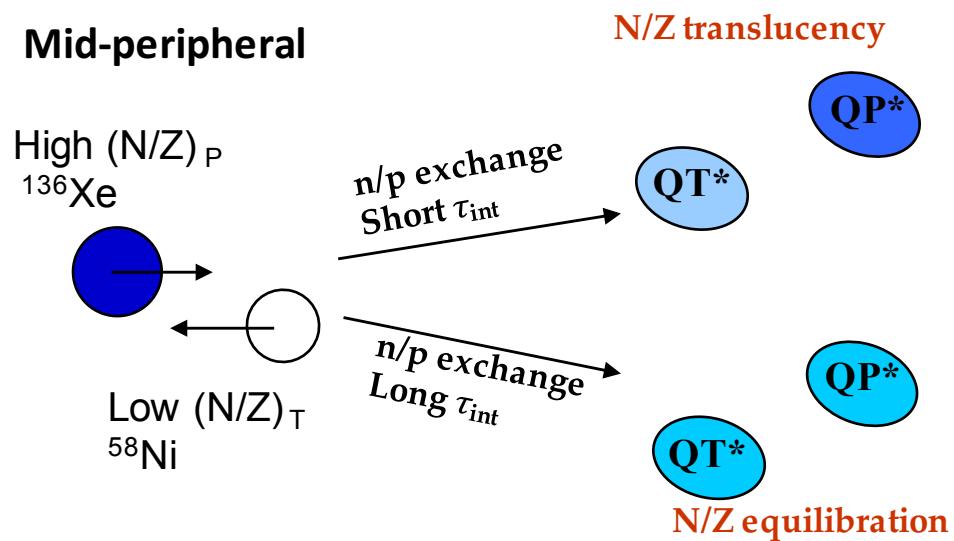
Isospin diffusion

$$\propto E_{sym}$$

Probing $E_{sym}(\rho)$

Isospin diffusion/drift @ INDRA-FAZIA

Mid-peripheral

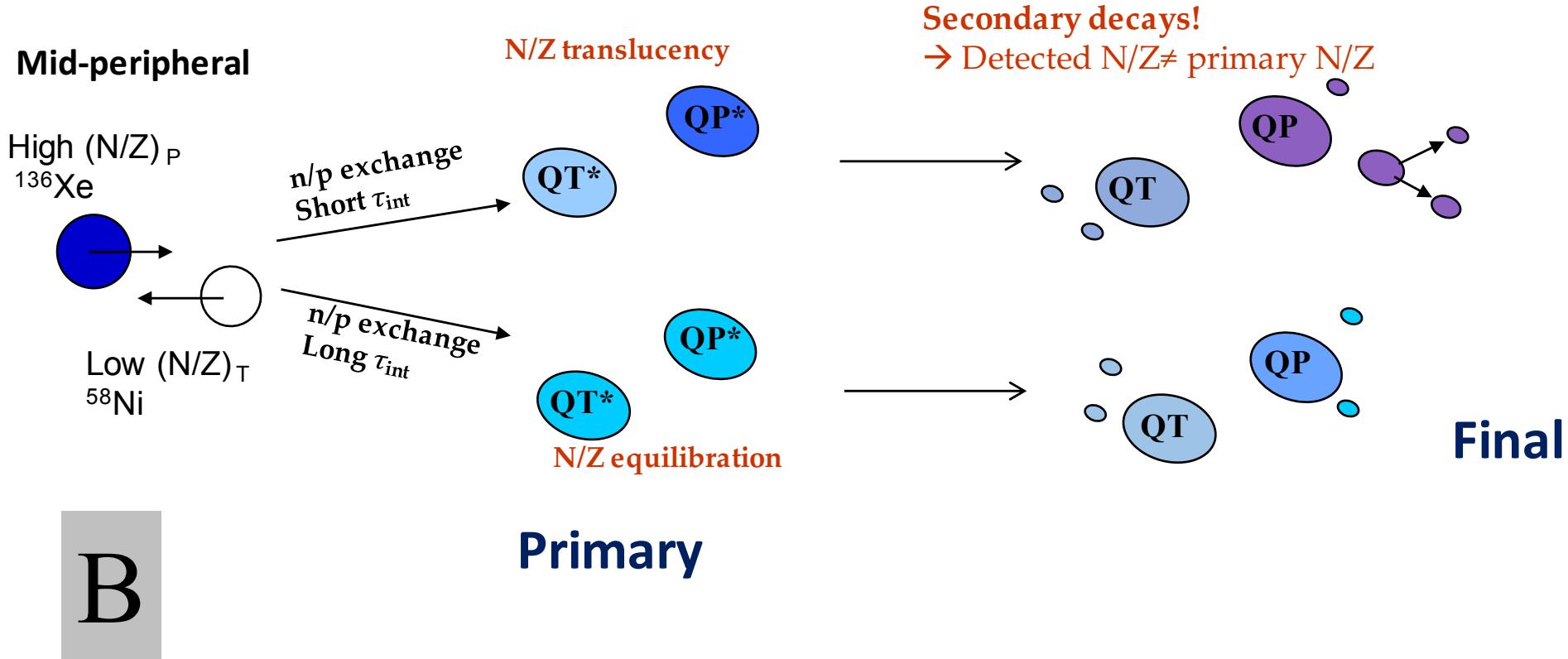


Primary

B

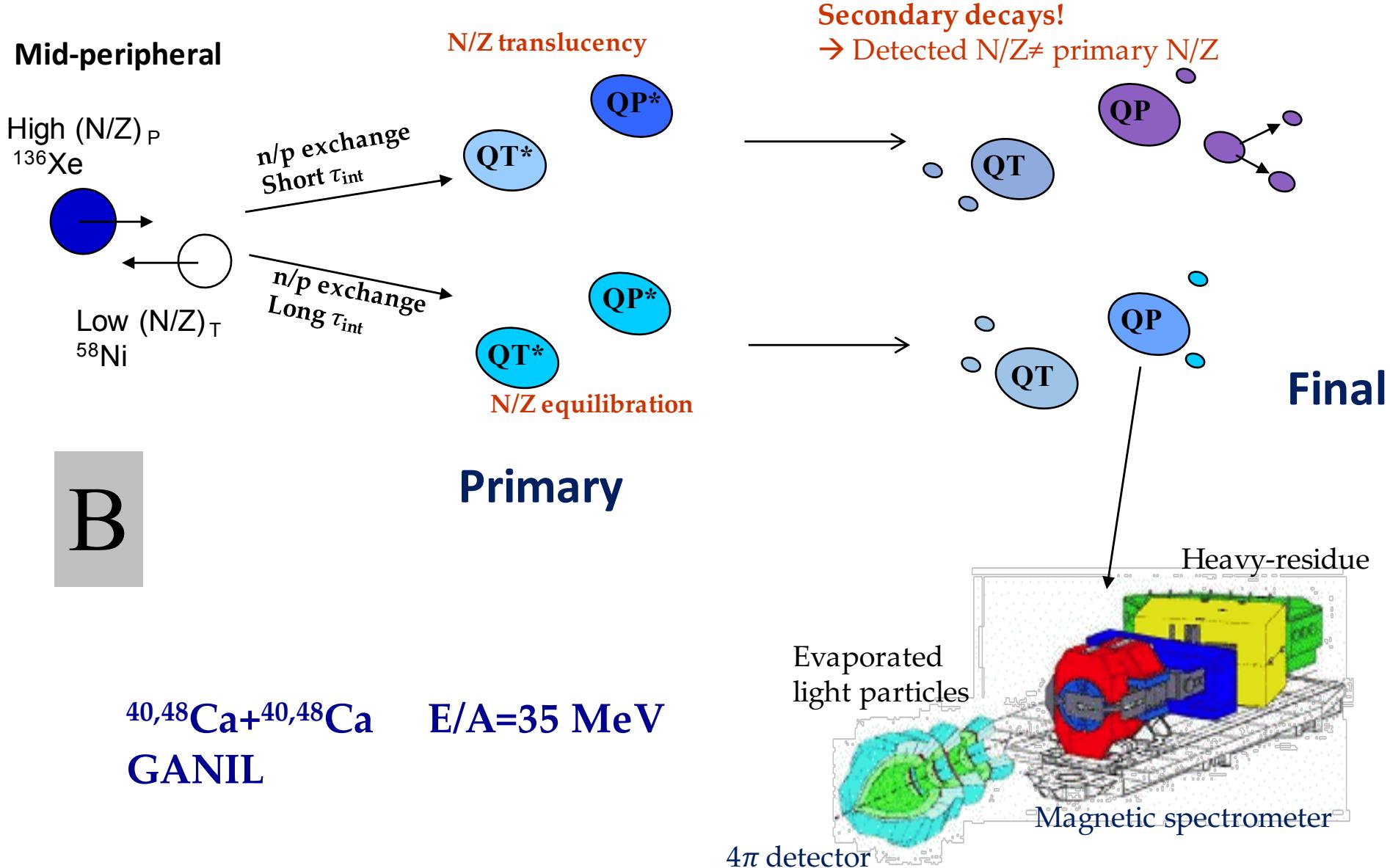
E. Galichet et al. PRC79, 064614 (2009)
G. Verde et al., EPJA 30, 81 (2006)

Isospin diffusion/drift @ INDRA-FAZIA



E. Galichet et al. PRC79, 064614 (2009)
G. Verde et al., EPJA 30, 81 (2006)

Isospin diffusion/drift @ INDRA-FAZIA

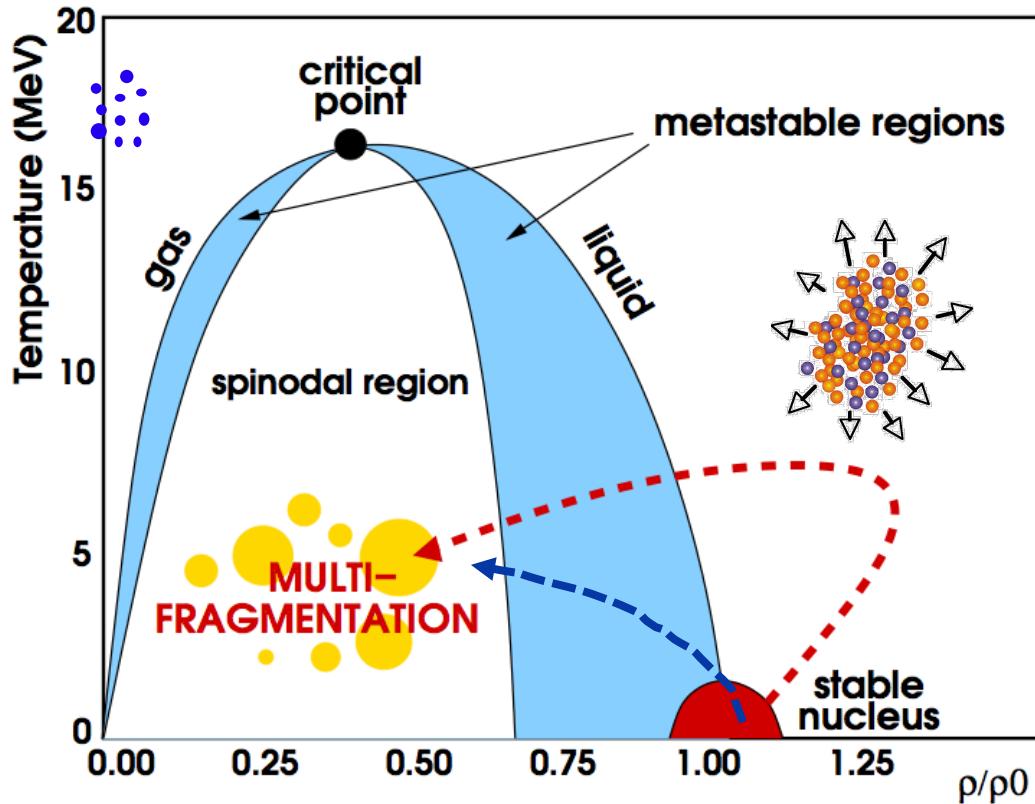


INDRA-VAMOS

Results from INDRA-VAMOS

Other stuff

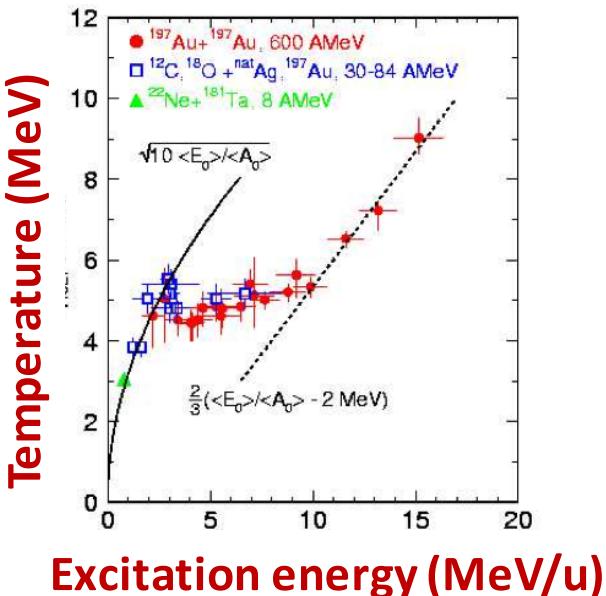
EoS: paths with HIC



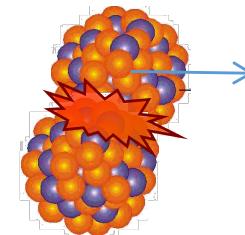
Open many-body quantum nuclear systems

From low densities to clusters

Caloric Curves

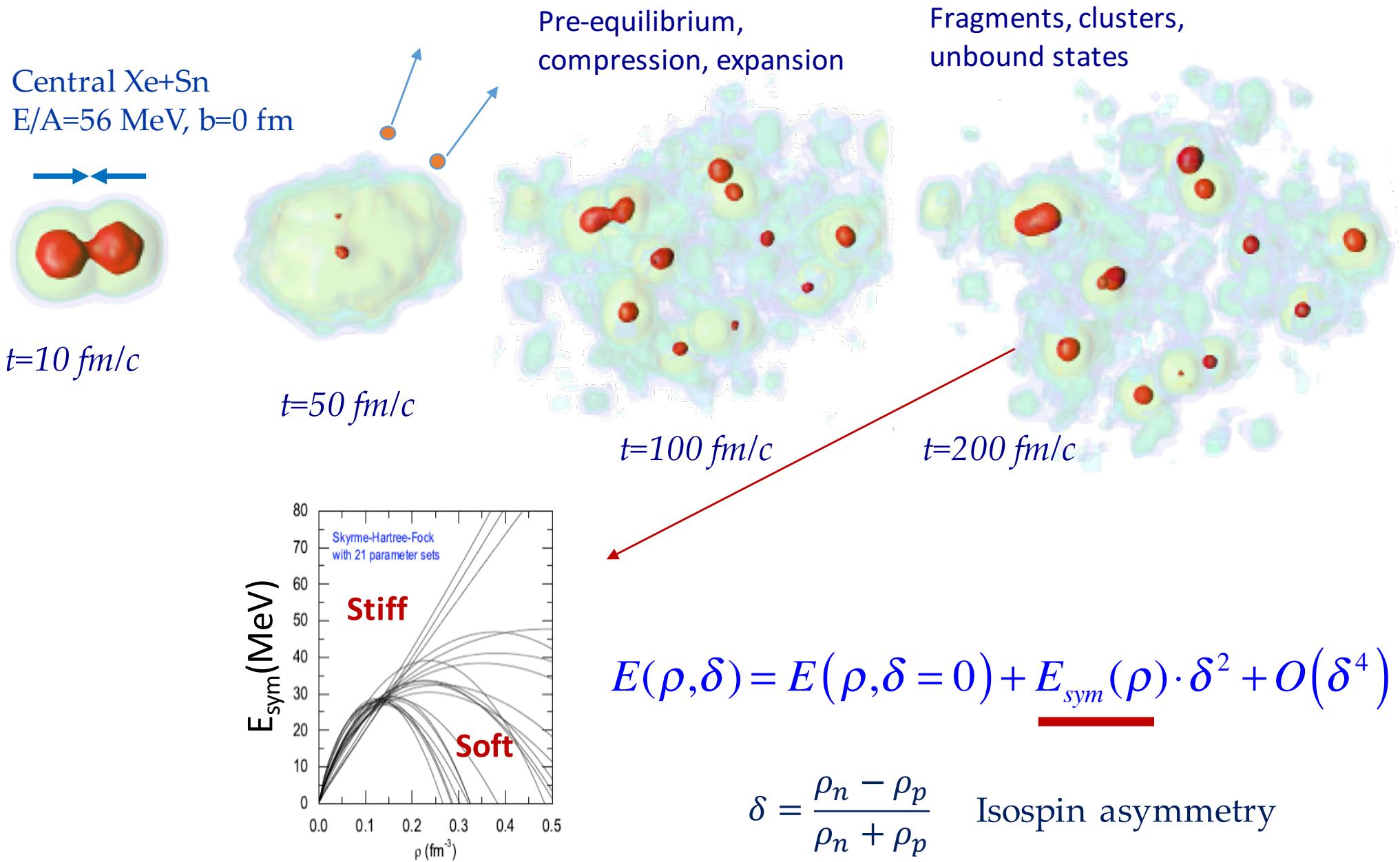


- Peripheral collisions:
excitation controlled by impact parameter

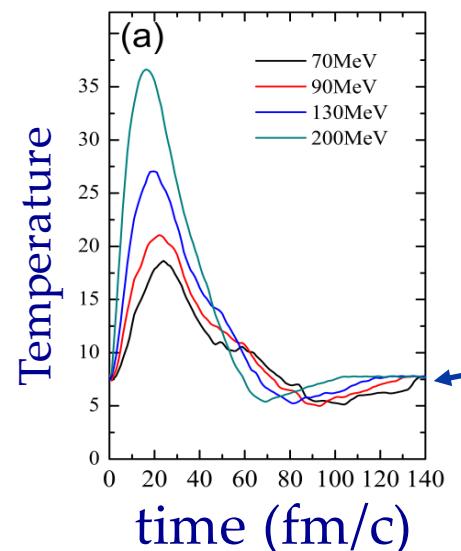
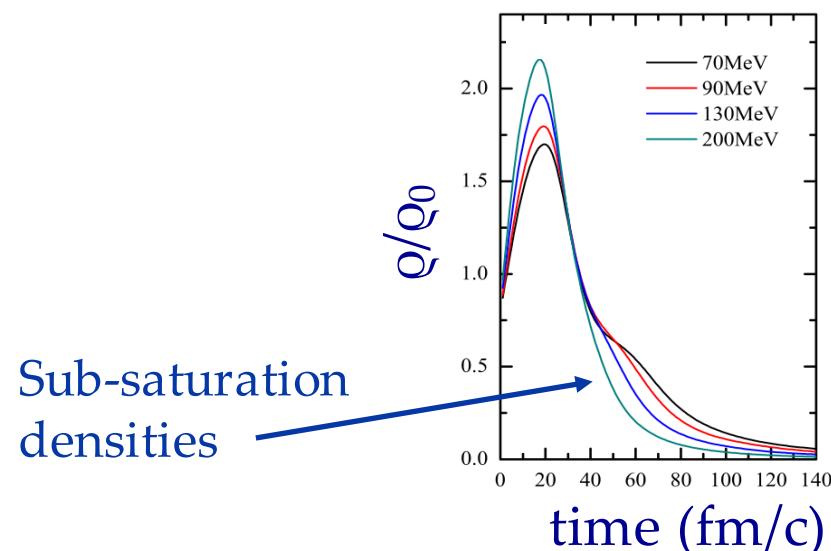
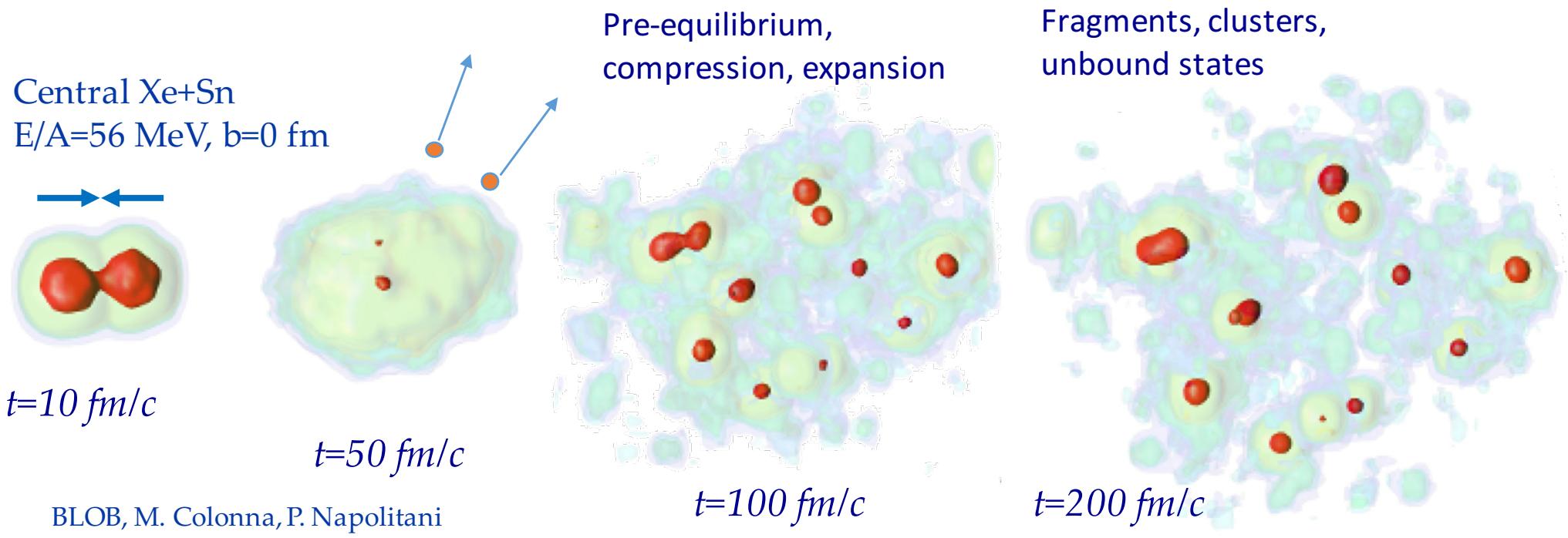


Decay of Quasi-Projectile Size
decreases with excitation
~saturation $\rho \sim 0.8-1$

Intermediate energy dynamics



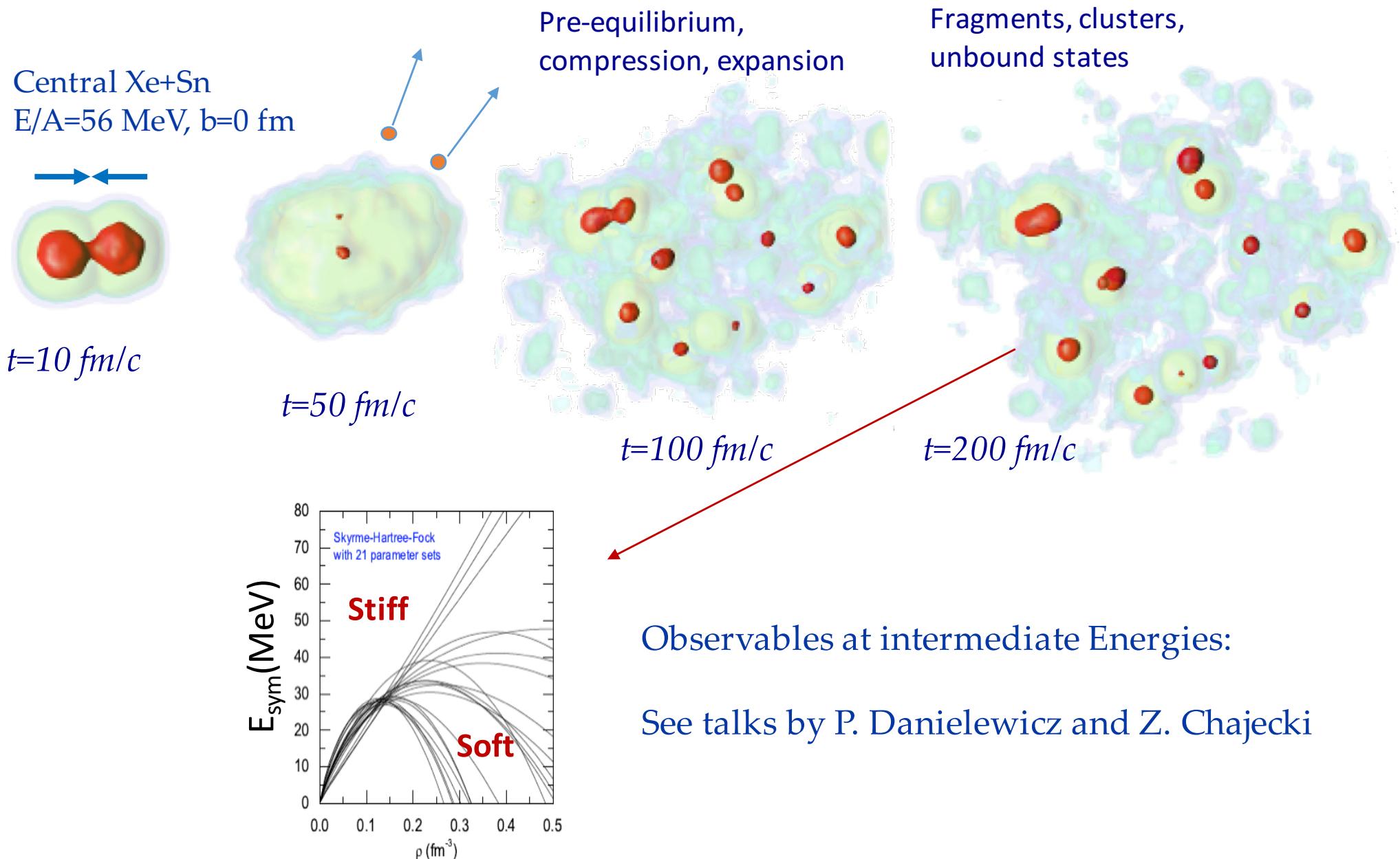
Intermediate energy dynamics



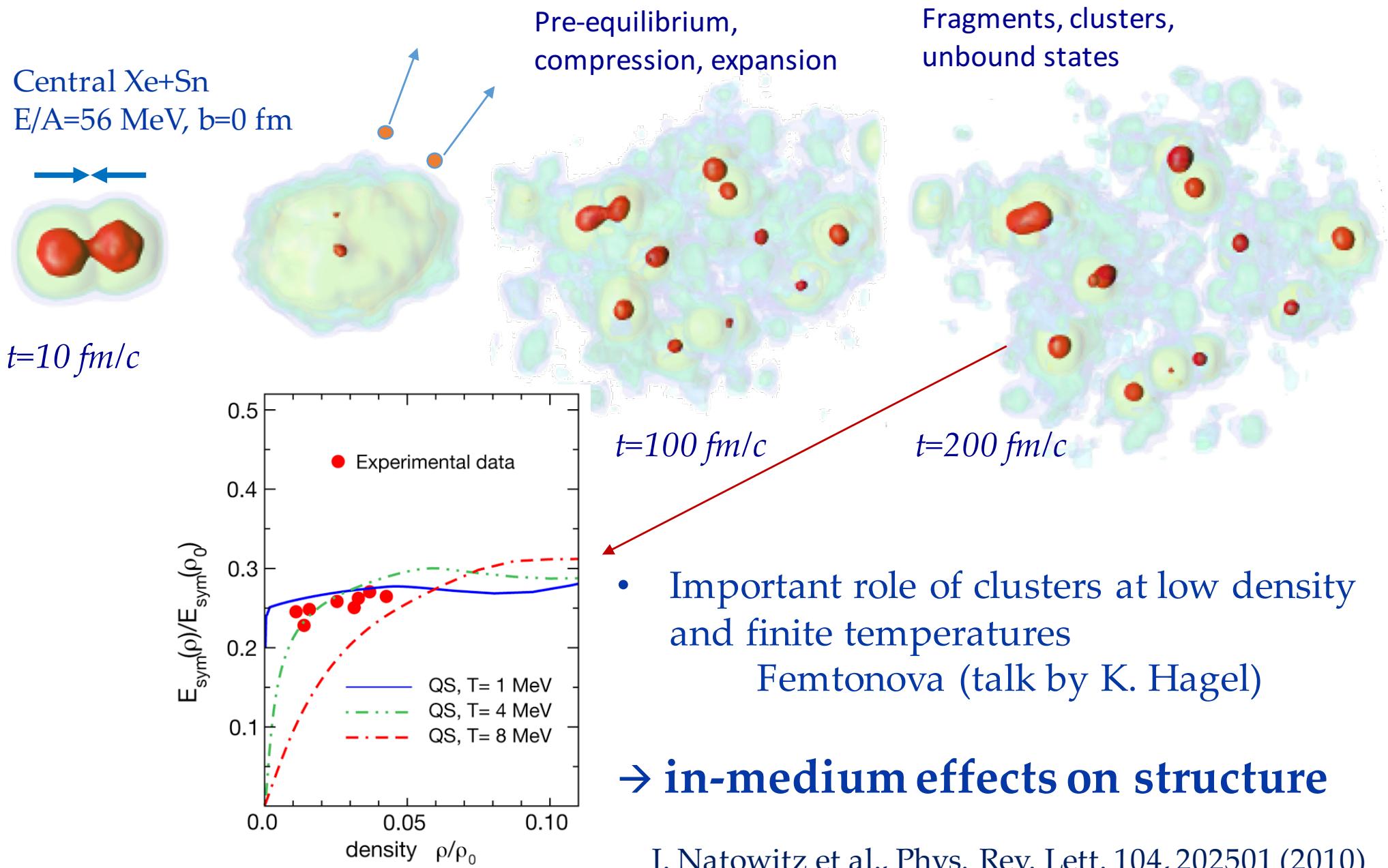
Transport model
simulations

Finite temperatures

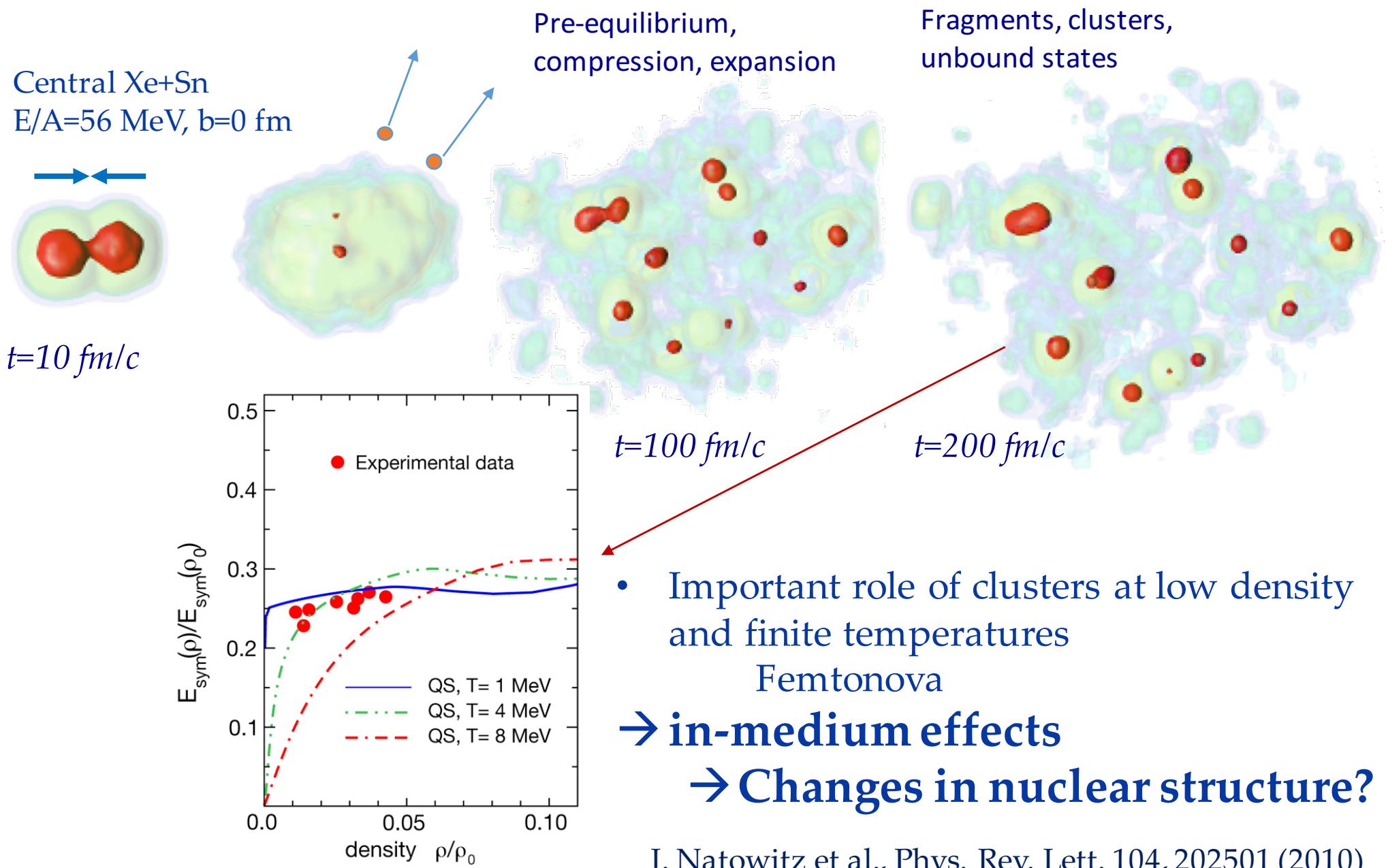
Intermediate energy dynamics



Interplays dynamics \leftrightarrow structure

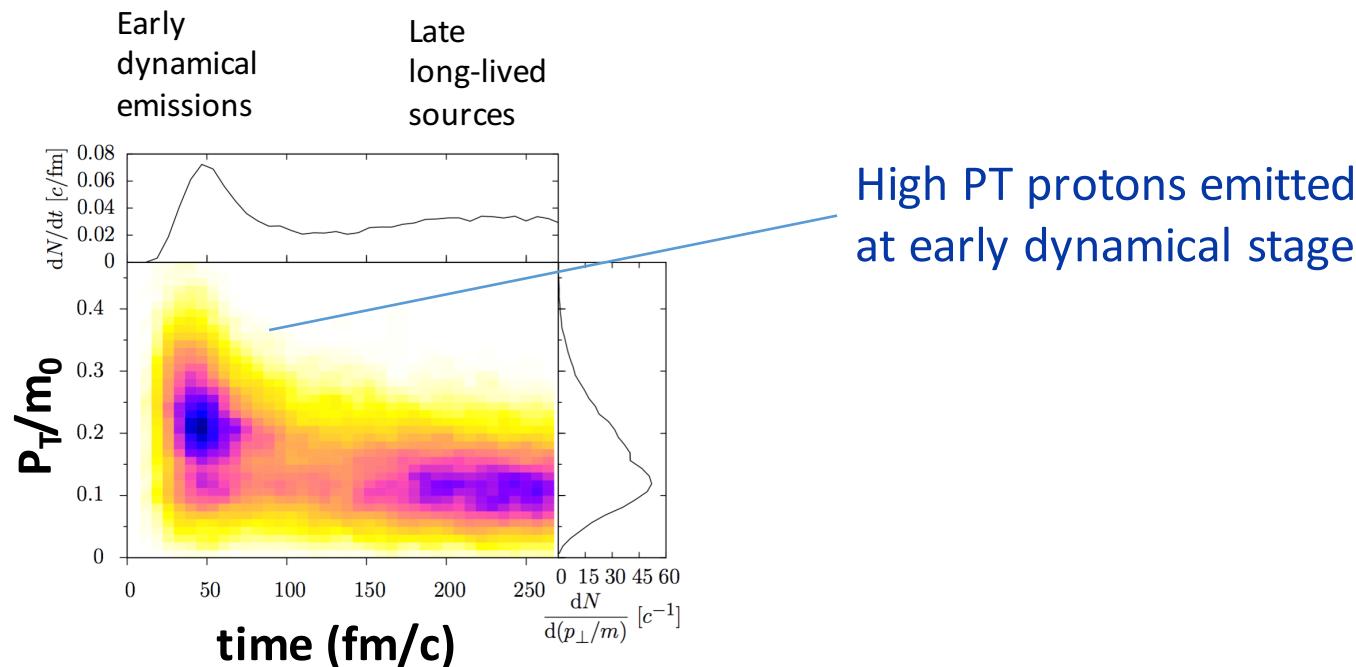


Clusterized matter \neq Uniform matter



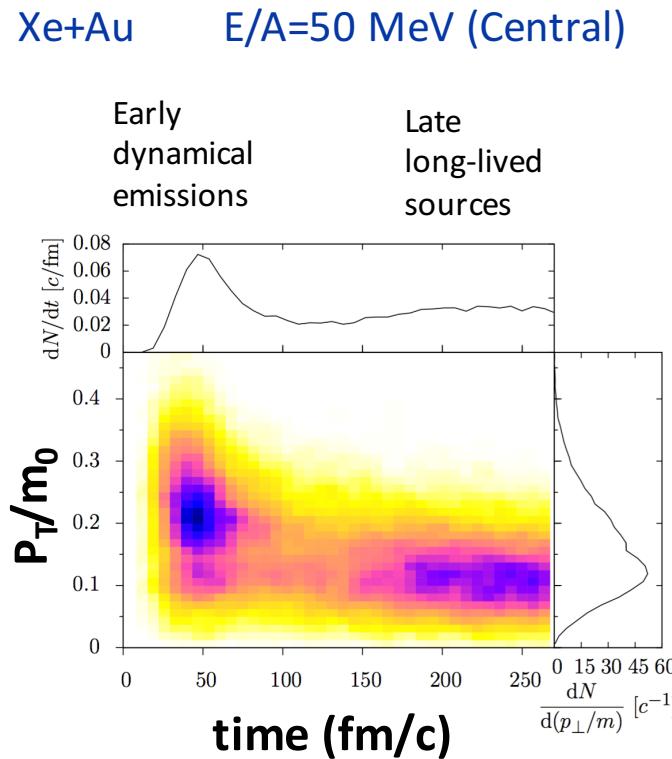
Imaging sources at different emission stages

Xe+Au E/A=50 MeV (Central)

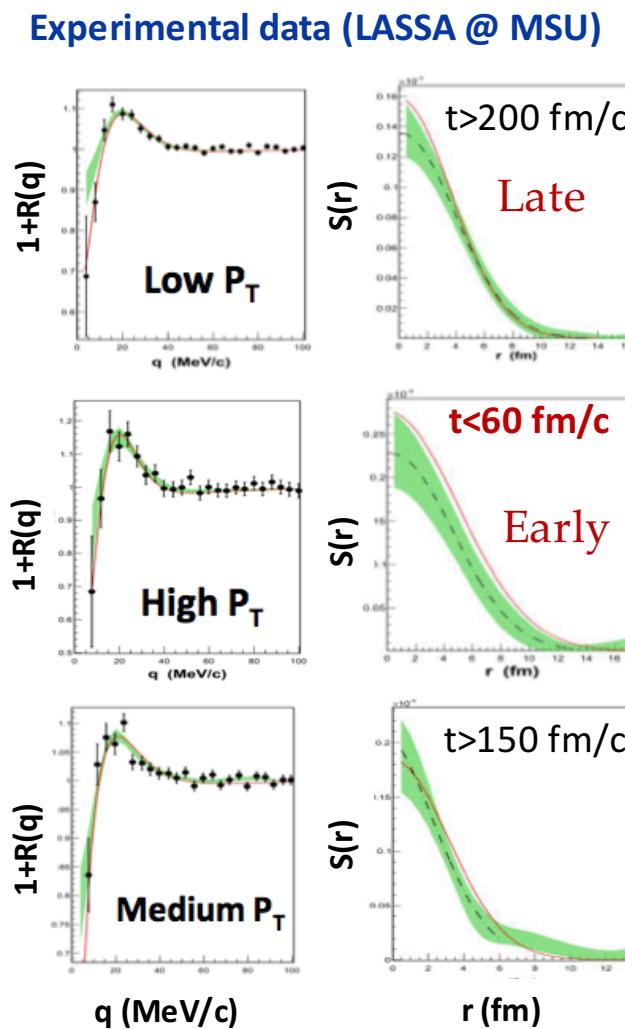


BUU simulations

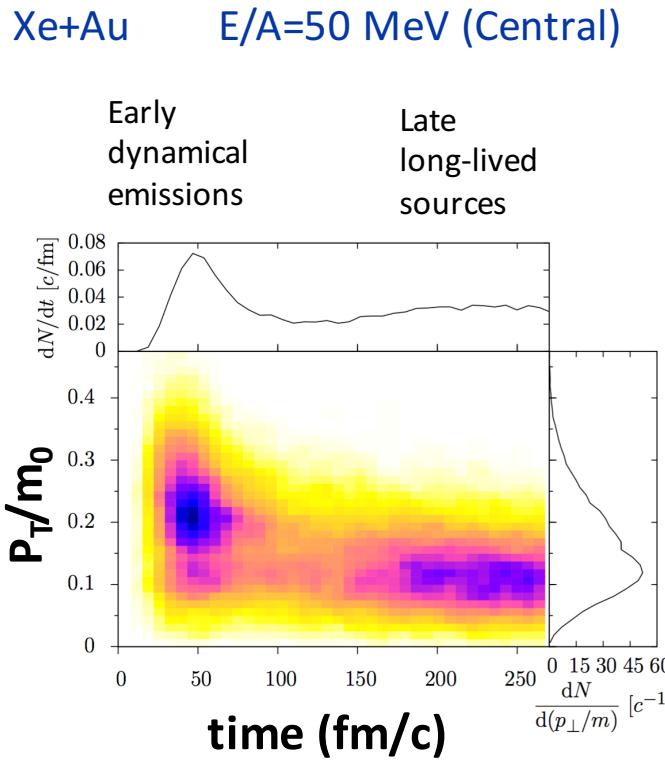
Imaging sources at different emission stages



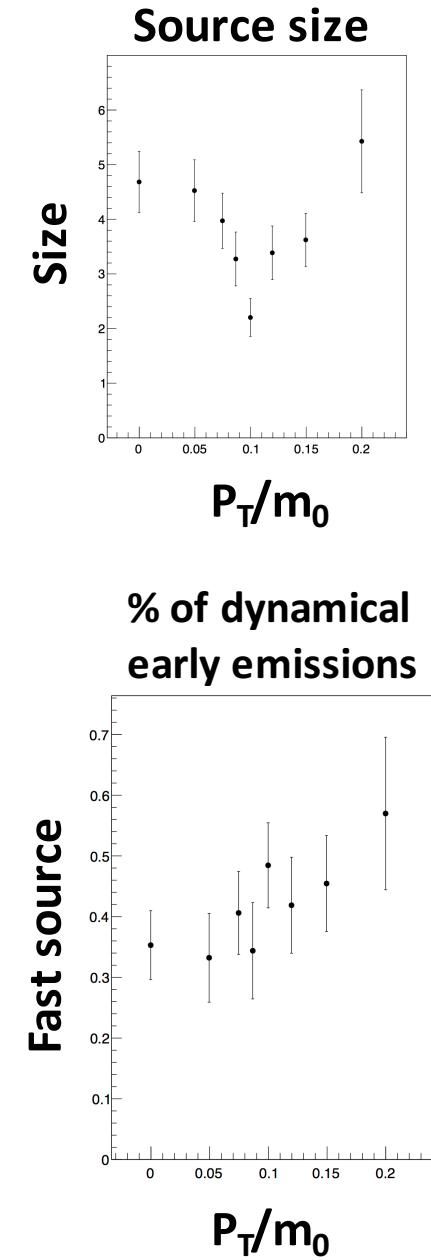
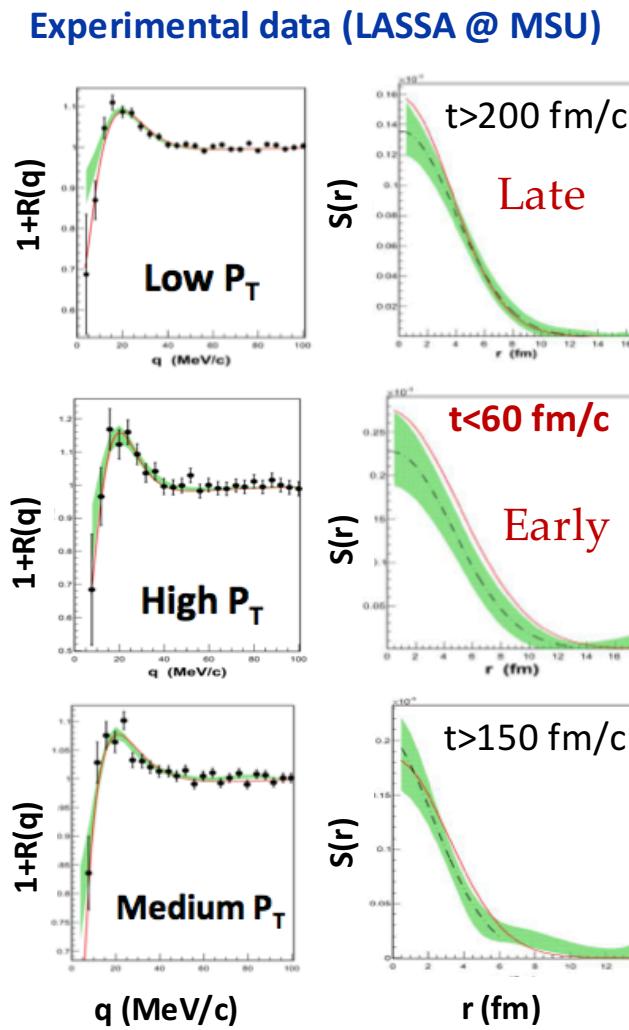
BUU simulations



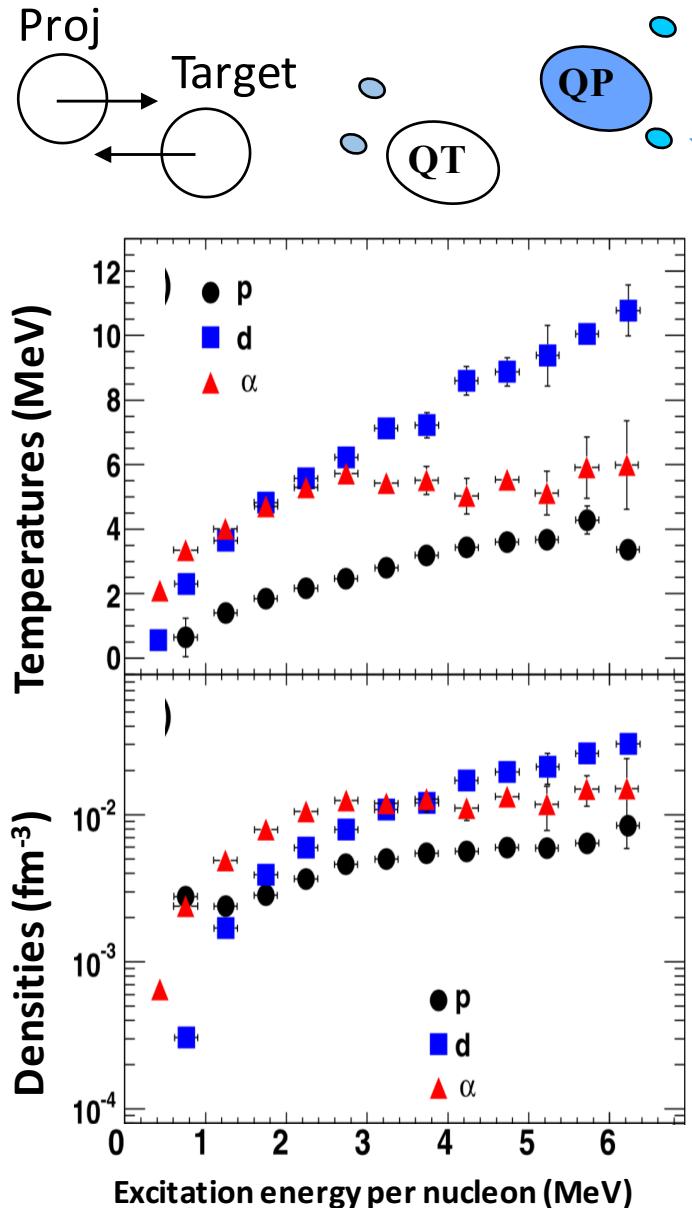
Imaging sources at different emission stages



BUU simulations



Densities “as seen” by bosons and fermions



INDRA-VAMOS experiment
 $^{40}\text{Ca} + ^{40}\text{Ca}$ @ $E/A = 35$ MeV
Decay of excited quasi-projectile

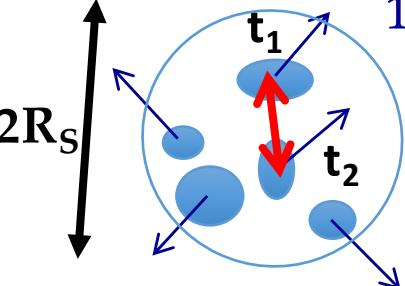
- Different particle species probe different densities and temperatures
- Mixtures of bosonic and fermionic hot matter at sub-saturation density

P. Marini, H. Zheng, M. Boisjoli, G. Verde, A. Chbihi et al.
Phys. Lett. B 756, 194 (2016)

Fragment emission time-scales

IMF-IMF Correlation Functions

IMF: Z>2

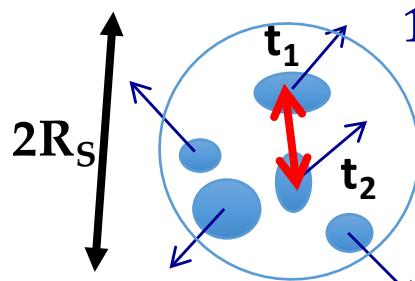

$$1 + R(v_{red}) = \frac{Y_{coinc}(v_{red})}{Y_{evt\ mixing}(v_{red})}$$
$$v_{red} = \frac{|\vec{v}_1 - \vec{v}_2|}{\sqrt{Z_1 + Z_2}}$$

Compact thermal
source (T, β_{coll}, \dots)

Fragment emission time-scales

IMF-IMF Correlation Functions

IMF: $Z > 2$



$$1 + R(v_{red}) = \frac{Y_{coinc}(v_{red})}{Y_{evt\ mixing}(v_{red})}$$

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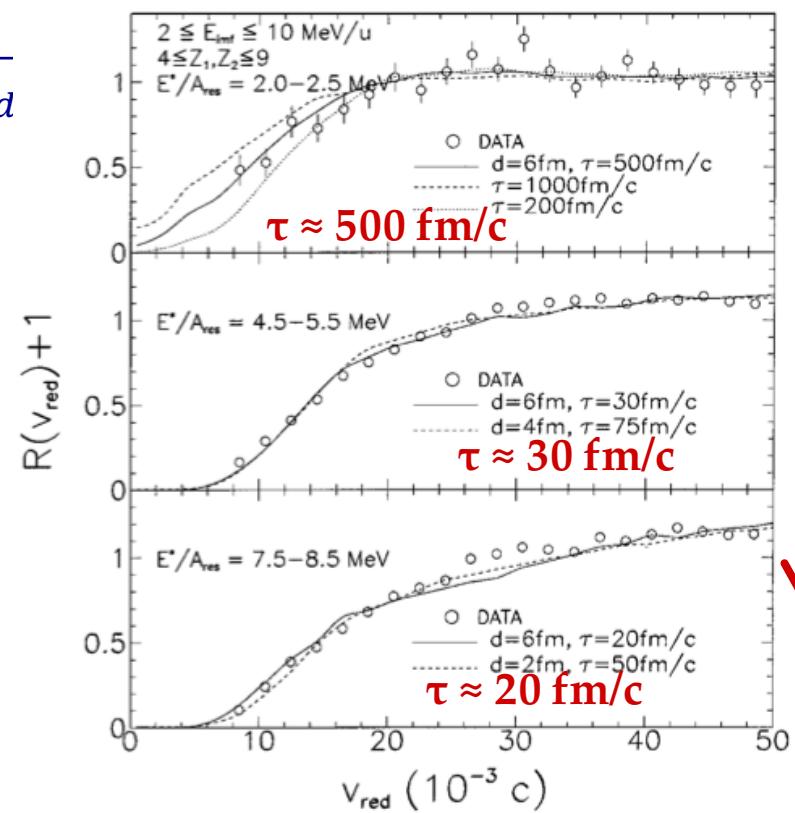
Compact thermal
source (T, β_{coll}, \dots)

N-body Coulomb trajectories

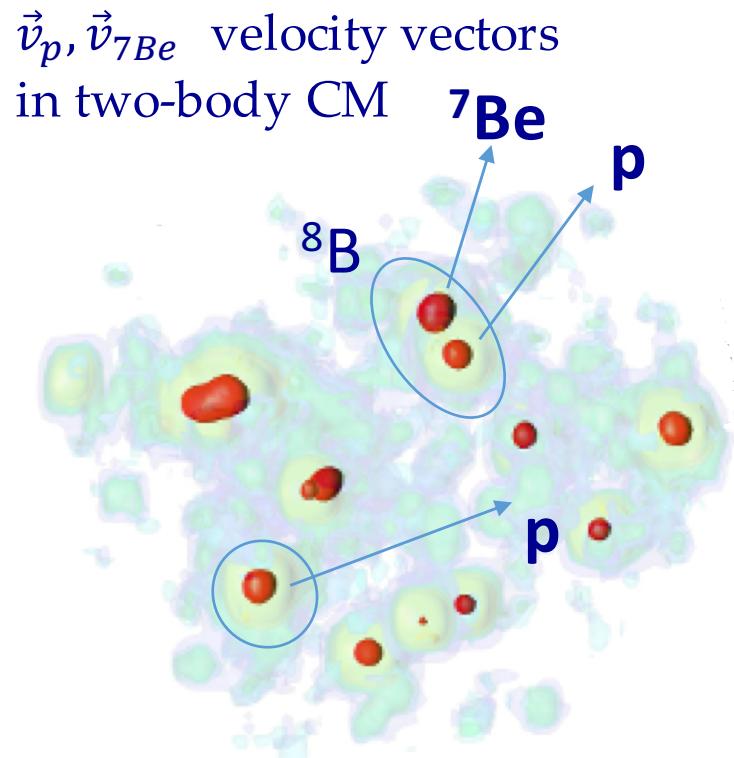
Source radius and emission times:

$$R_s, P(t) = (1/\tau) \cdot \exp(-t/\tau) \rightarrow \tau$$

$\pi^-, p + Au \quad 8.0, 8.2, 9.2, 10.2 \text{ GeV}/c$



Two-particle correlations: resonances in dilute nuclear medium



Particle emitting sources
extended in phase-space

$$Q_{decay} = M_{8B} \cdot c^2 - (M_p \cdot c^2 + M_{7Be} \cdot c^2)$$

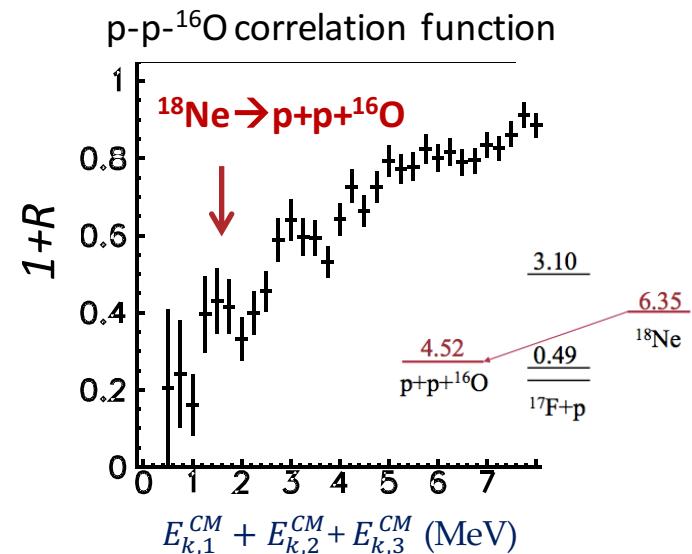
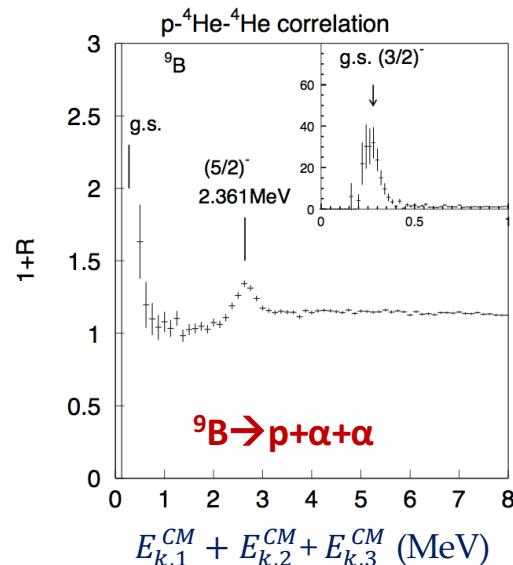
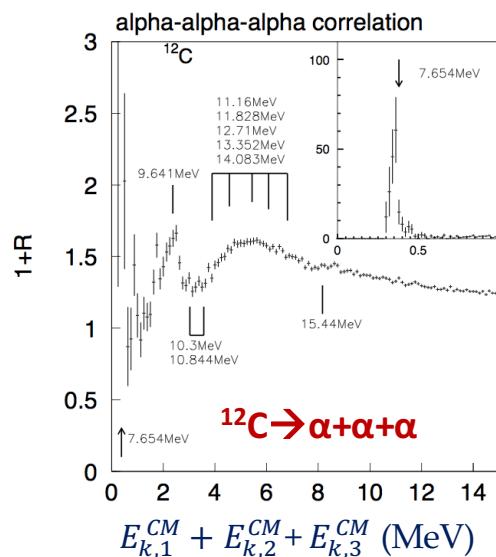
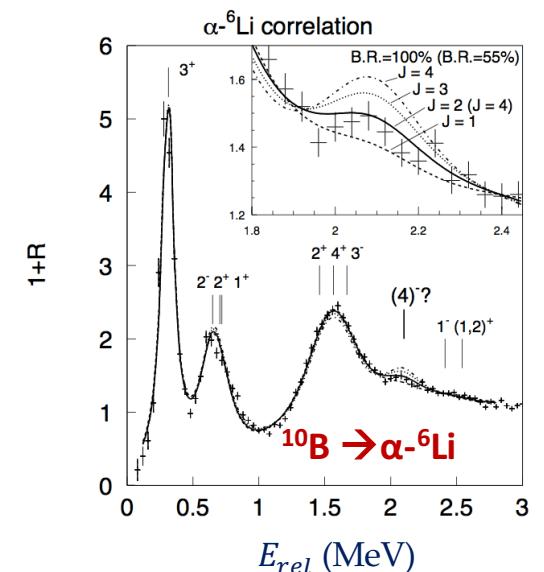
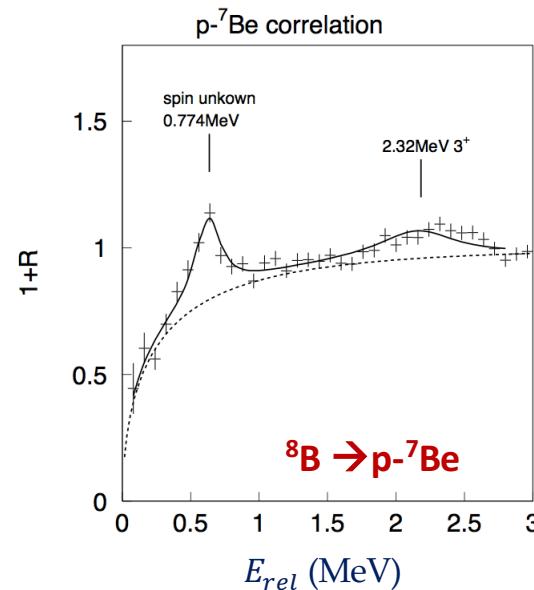
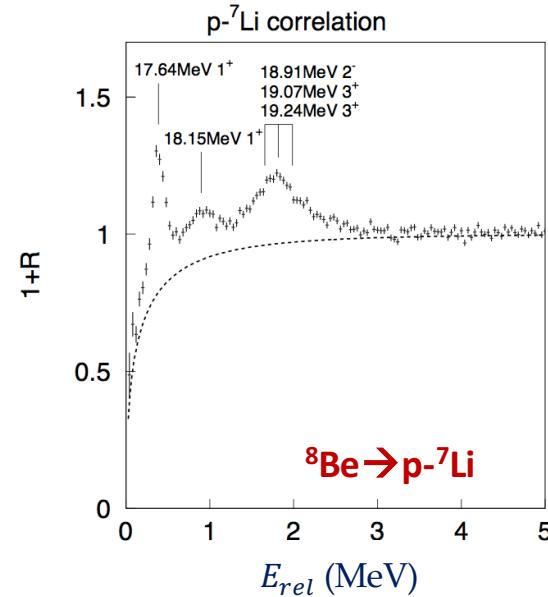
$$\begin{aligned} E^*({}^8B) &= -Q_{decay} + \frac{1}{2} M_p v_p^2 + \frac{1}{2} M_{7Be} \\ &= -Q_{decay} + \frac{1}{2} \cdot \mu v_{rel}^2 = -Q_{decay} + E_{rel} \end{aligned}$$

Correlation function:

$$1 + R(E_{rel}) = \frac{Y_{coinc}({}^7\text{Be}, p)}{Y_{evt\,mixing}({}^7\text{Be}, p)}$$

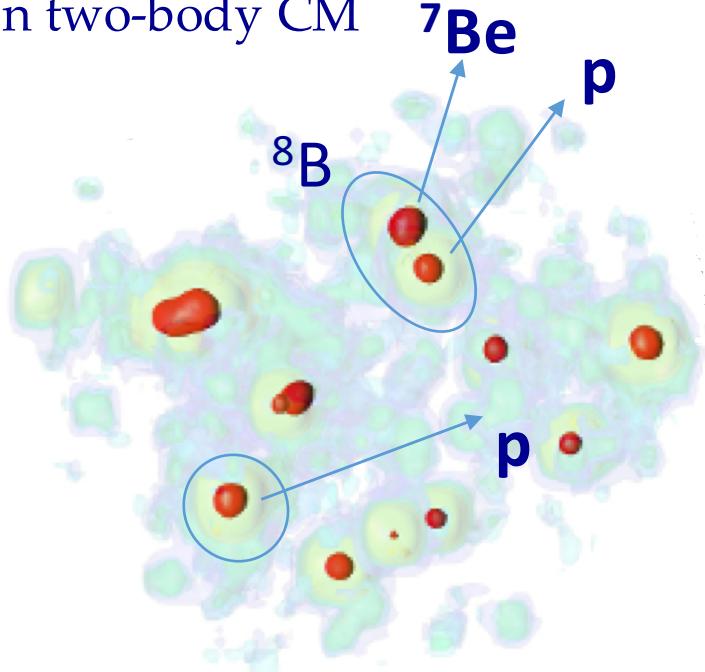
Resonance decays in dilute and warm nuclear medium

$^{112}\text{Sn} + ^{112}\text{Sn}$ E/A=50 MeV



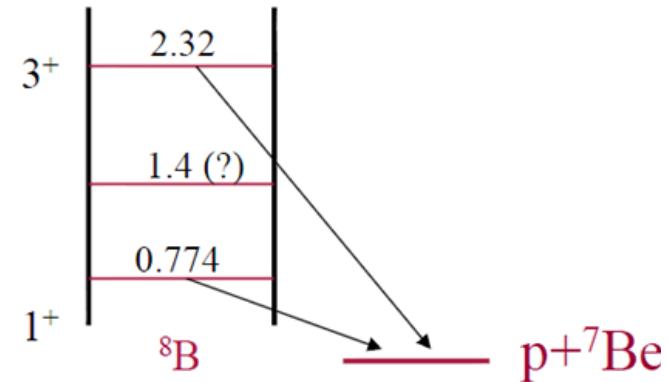
Thermal model of in-medium resonance decays

$\vec{v}_p, \vec{v}_{^7Be}$ velocity vectors
in two-body CM



Particle emitting sources
extended in phase-space

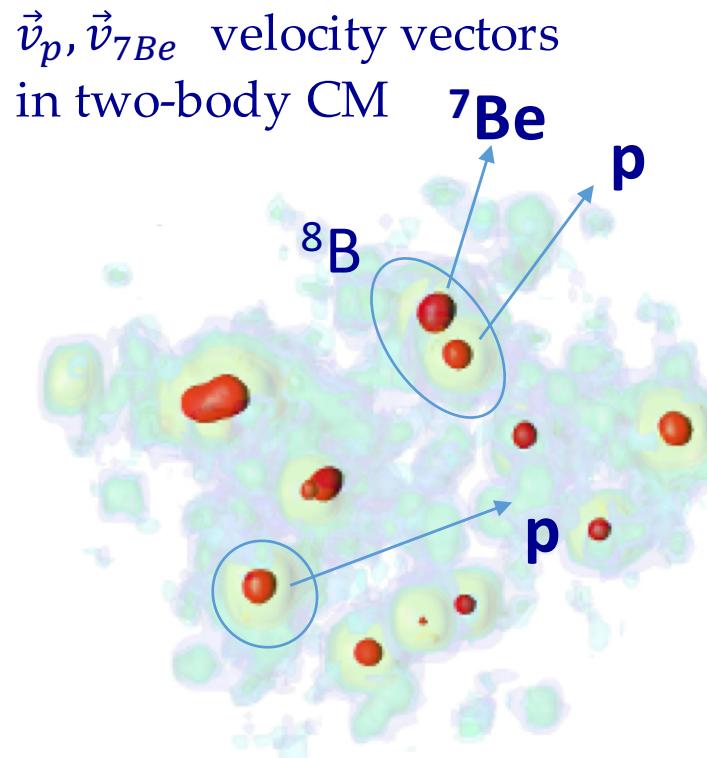
States of ${}^8B \rightarrow p + {}^7Be$



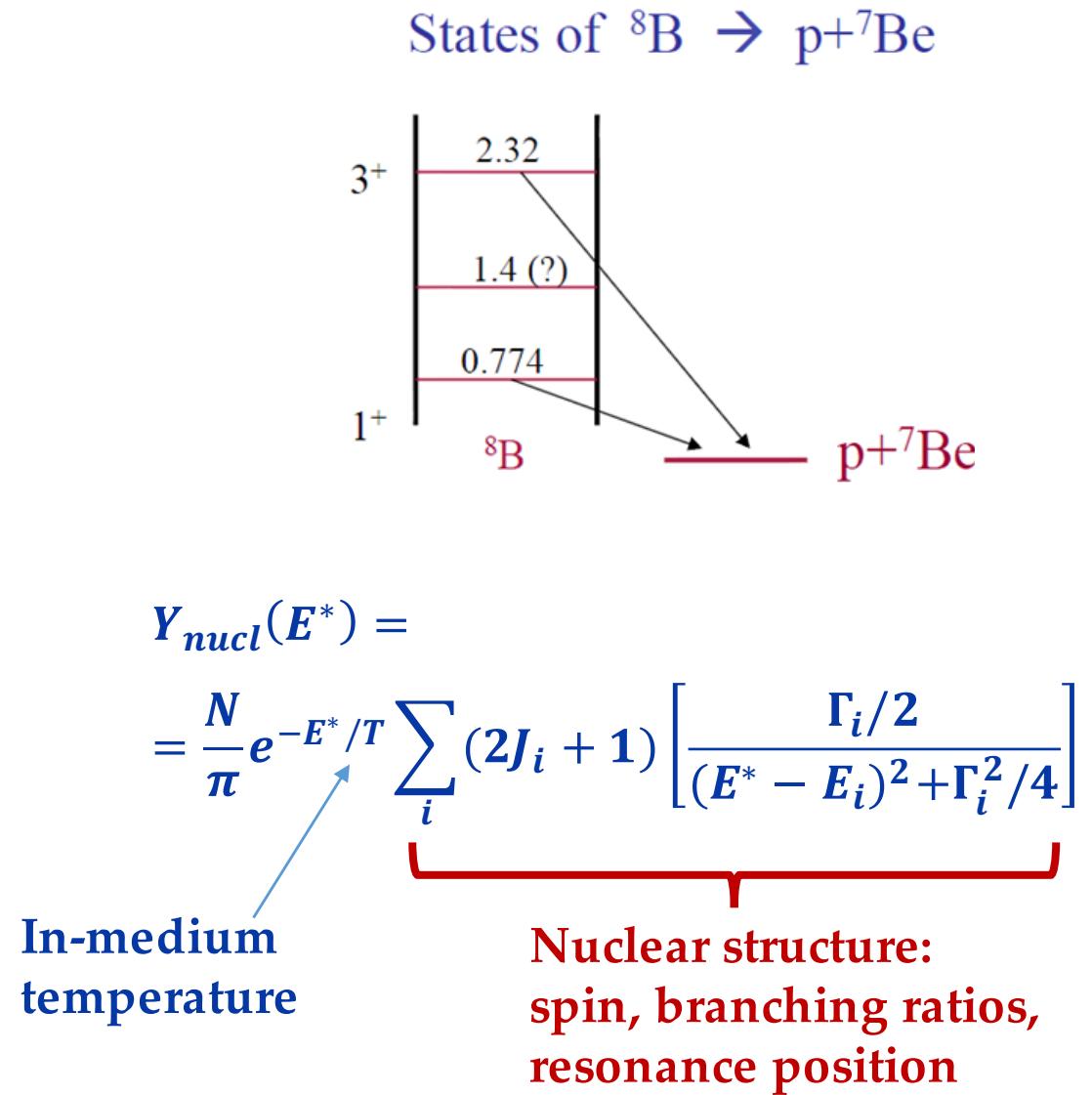
Correlation function:

$$1 + R(E_{rel}) = \frac{Y_{coinc}({}^7Be, p)}{Y_{evt\,mixing}({}^7Be, p)}$$

Thermal model of in-medium resonance decays



Particle emitting sources
extended in phase-space

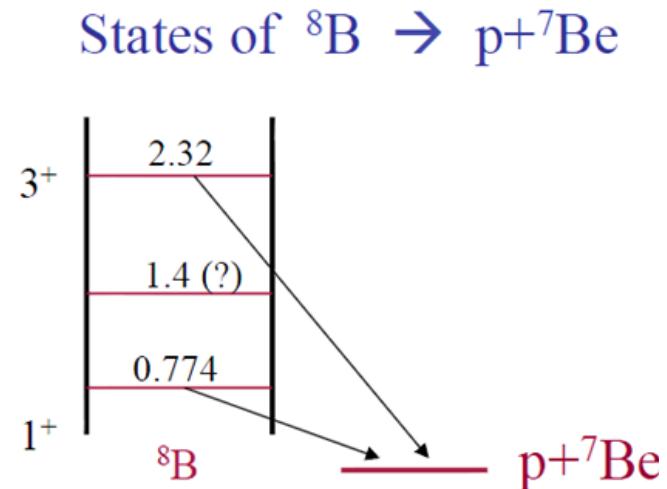
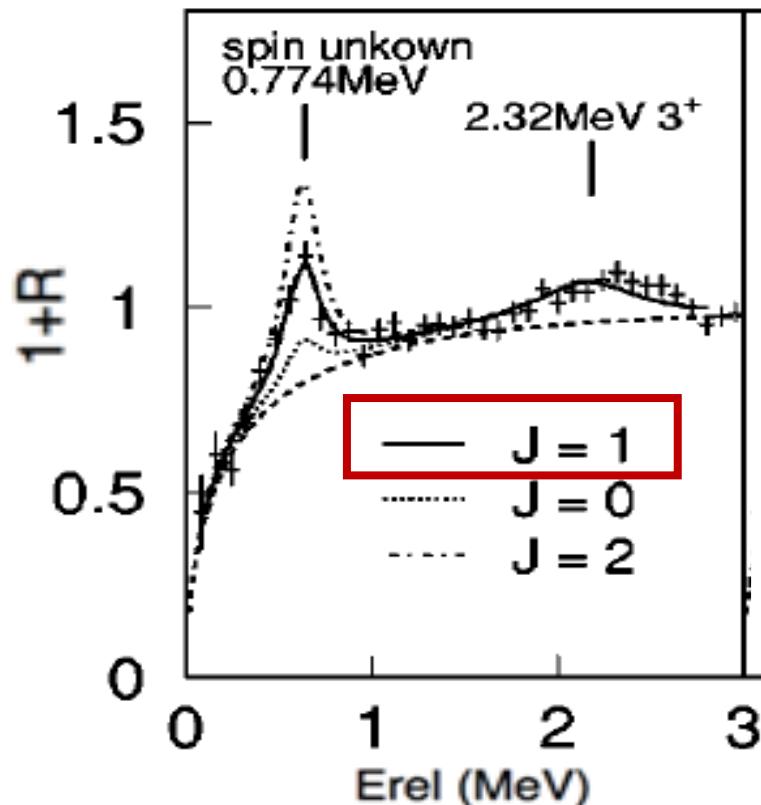


In-medium structure: spin

$p+^7\text{Be}$ correlation function

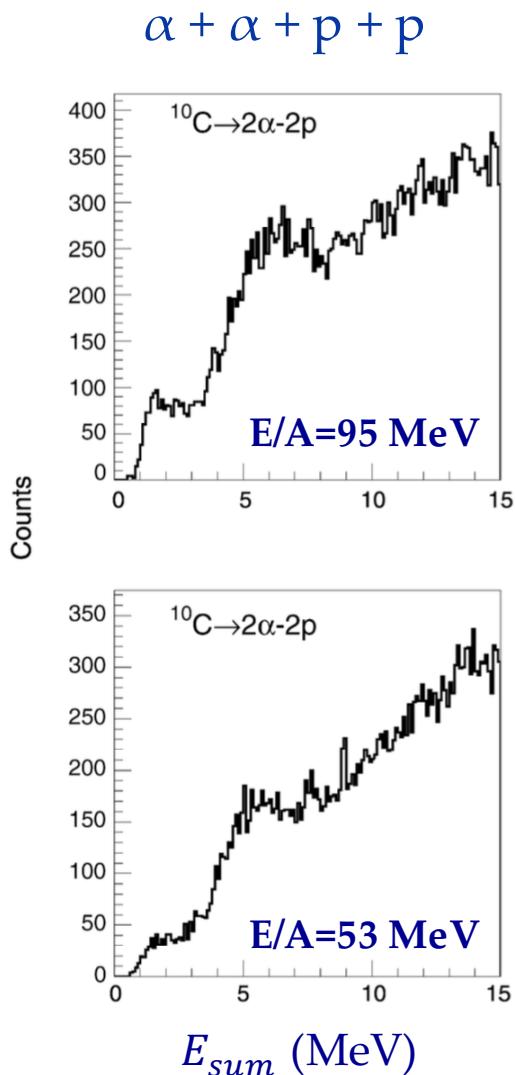
$$1 + R(E_{rel}) = \frac{Y_{coinc}(^7\text{Be}, p)}{Y_{evt\ mixing}(^7\text{Be}, p)} \propto \sum_i (2J_i + 1) \left[\frac{\Gamma_i/2}{(E^* - E_i)^2 + \Gamma_i^2/4} \right]$$

↑



Xe+Au E/A=50 MeV central collisions
(LASSA data)

Other cluster correlations: N>2



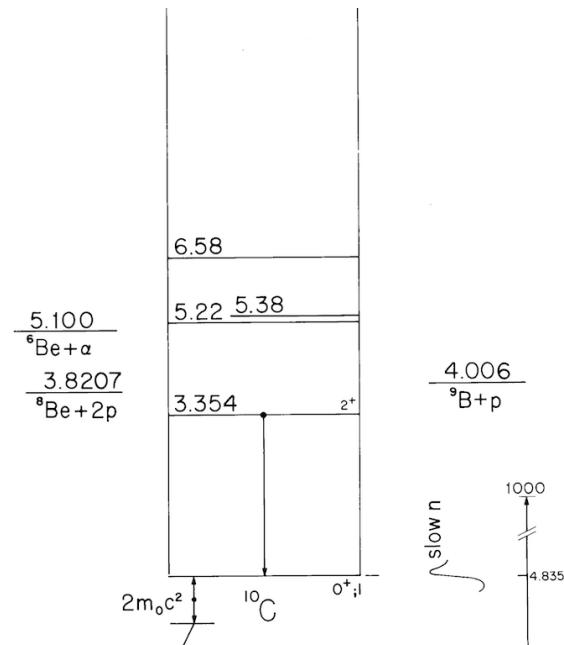
$^{12}\text{C} + ^{24}\text{Mg}$ E/A=53 and 95 MeV

INDRA Data

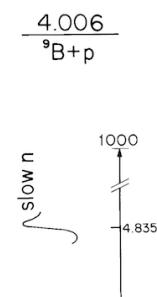
^{10}C

$$Q_{decay} = -3.7 \text{ MeV}$$

$$E_{sum} = \sum_{i=1}^4 E_{k,i} \text{ (MeV)}$$

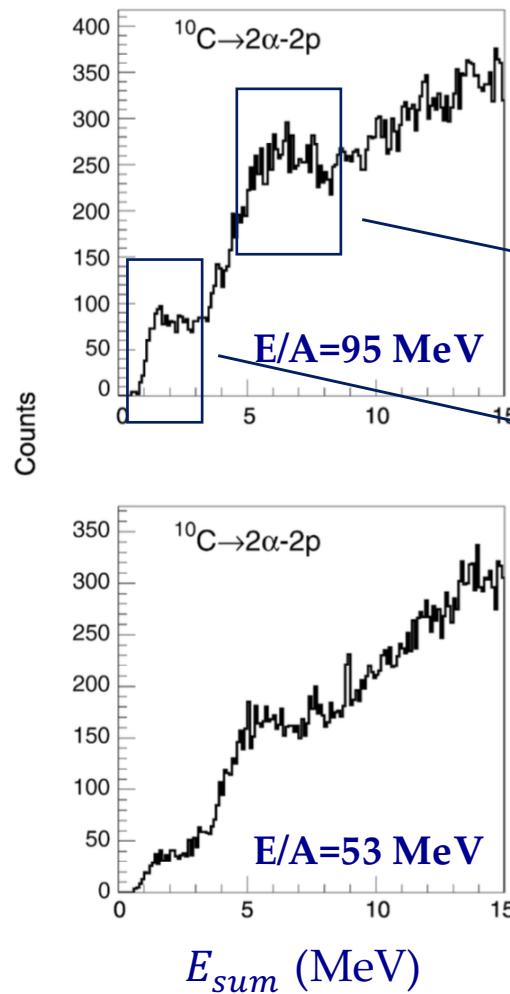


Doubly Borromean
(Brunnian) nuclear system



Other cluster correlations: N>2

$\alpha + \alpha + p + p$



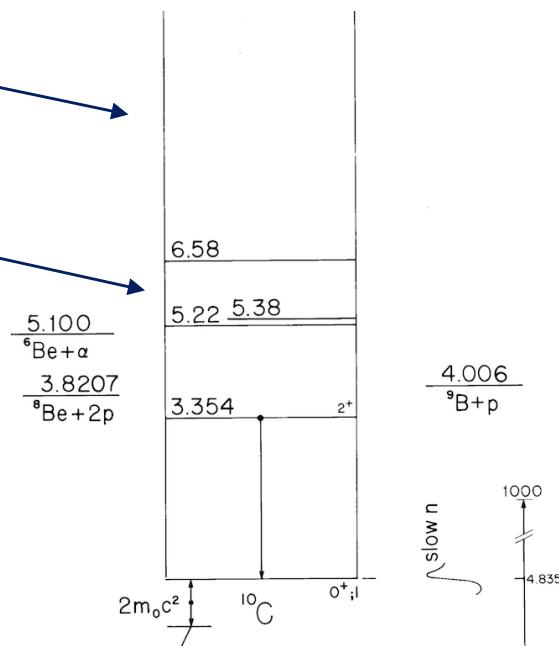
$^{12}\text{C} + ^{24}\text{Mg}$ E/A=53 and 95 MeV

INDRA Data

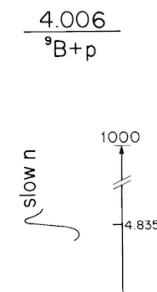
$$Q_{decay} = -3.7 \text{ MeV}$$

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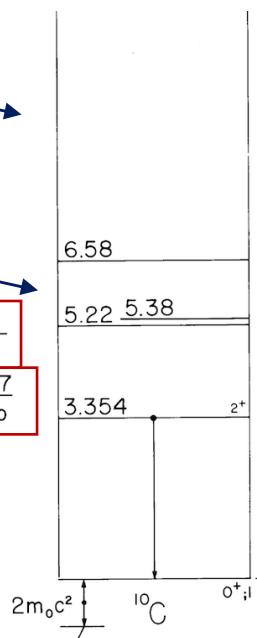
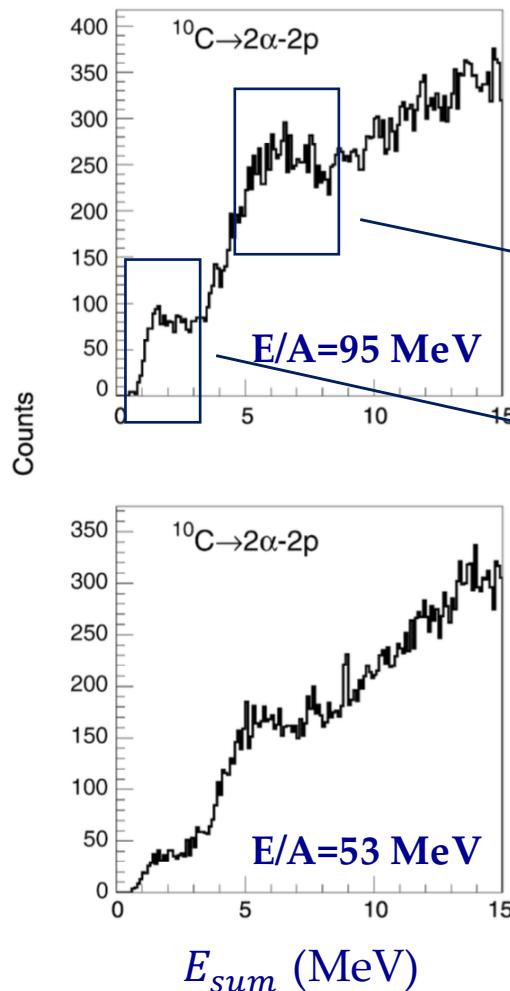
^{10}C



Doubly Borromean
(Brunnian) nuclear system



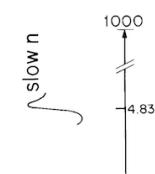
In-medium structure: branching ratios



$$Q_{decay} = -3.7 \text{ MeV}$$

$$E_{sum} = \sum_{i=1}^4 E_{k,i} \text{ (MeV)}$$

Doubly Borromean
(Brunnian) nuclear system



Sequential

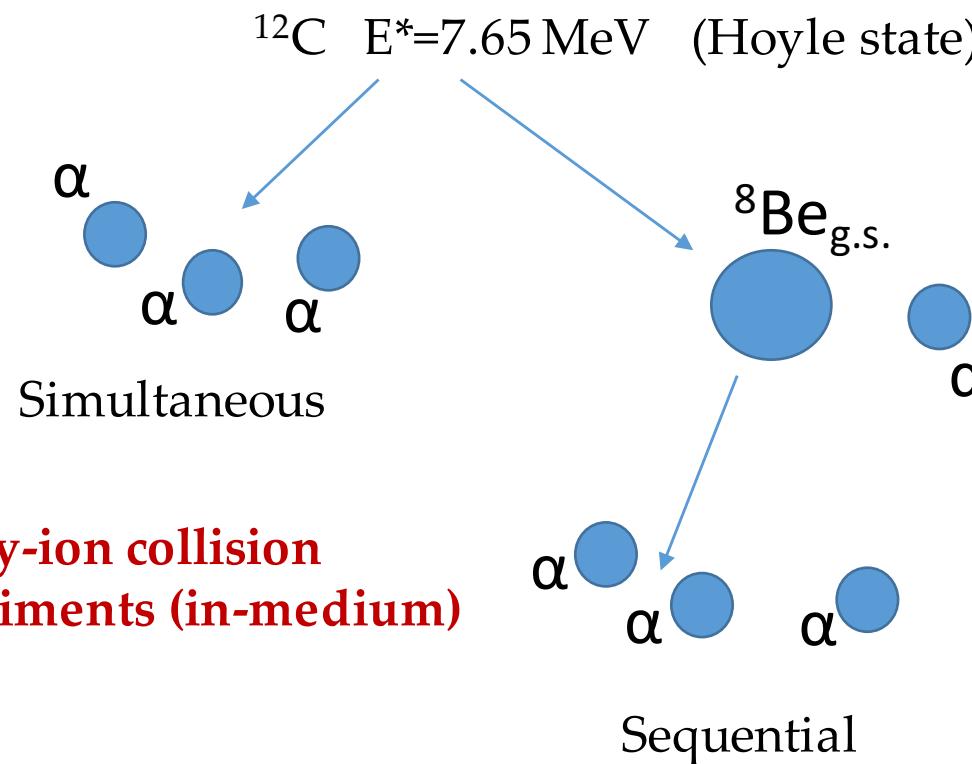
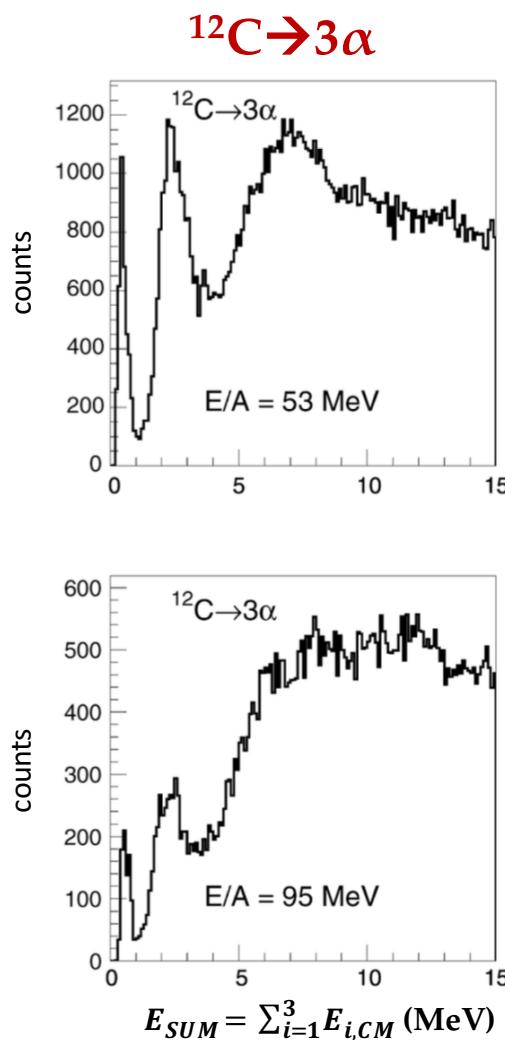


Direct



In-medium vs out-of-medium?

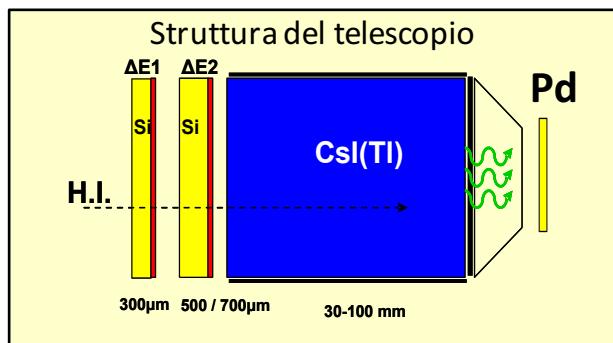
$^{12}\text{C} + ^{24}\text{Mg}$ E/A=53 and 95 MeV
INDRA data



Heavy-ion collision experiments (in-medium)
Direct transfer reaction experiments (out-of-medium, "vacuum")

In-medium resonance decays in HIC

FAZIA (Four-pi A- and Z-Identification Array)

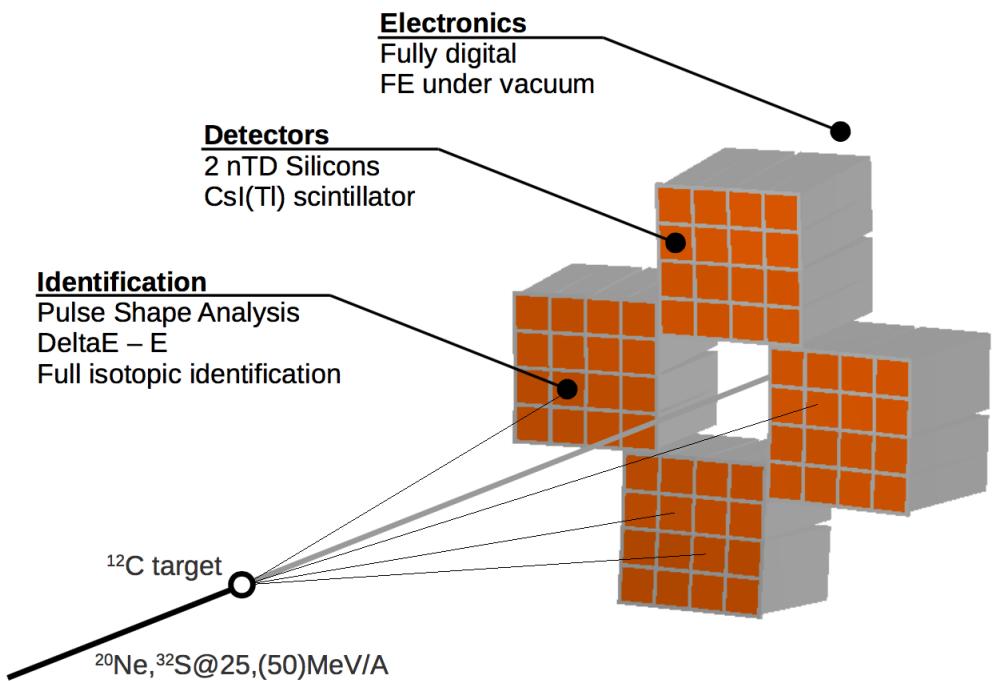


Fully digital electronics: particle identification directly from digitalization of Si and CsI(Tl) signals
→ almost online available
→ Wide dynamic range (100 keV- GeV)

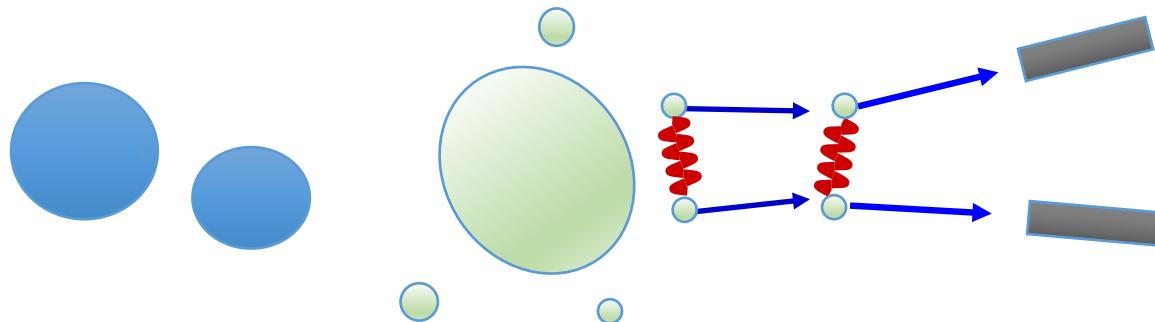
FAZIACOR experiment (March 2017)

G. Verde, D. Gruyer, FAZIA Coll.

^{20}Ne , ^{32}S + ^{12}C
E/A=25 and 50 MeV



What densities? femtoscopy

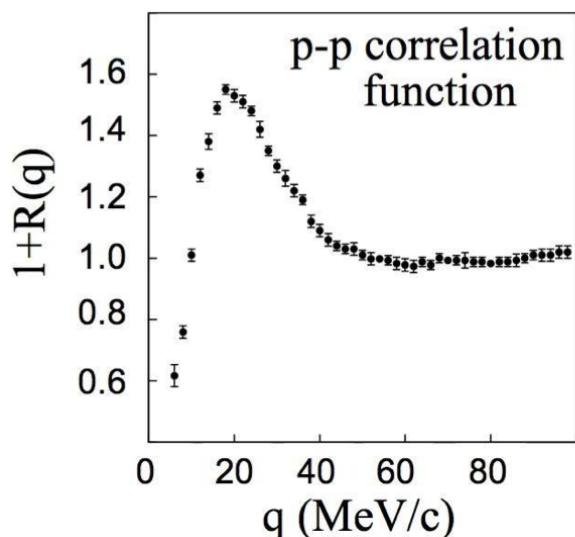


Physical correlations

- Final State Interactions: Coulomb + Nuclear
- Quantum statistics (if identical)
- Phase-space, ...

Intensity interferometry / Femtoscopy

q = mom. of relative motion

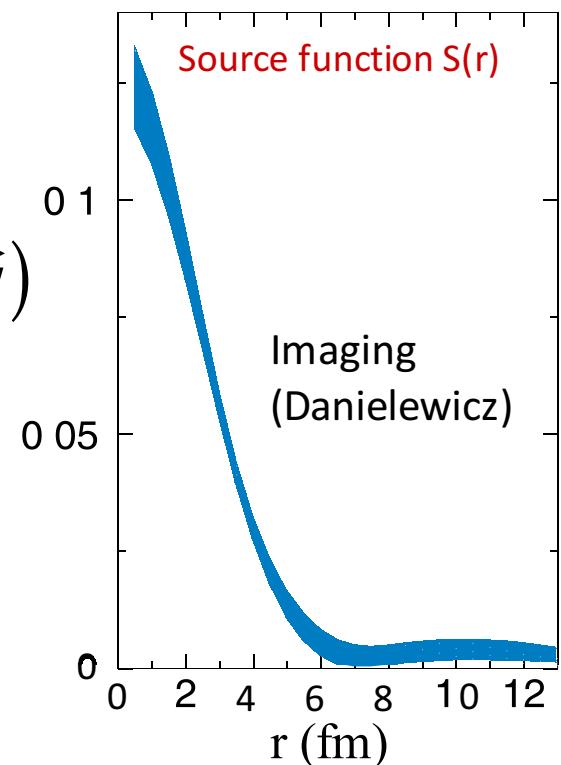


Koonin-Pratt

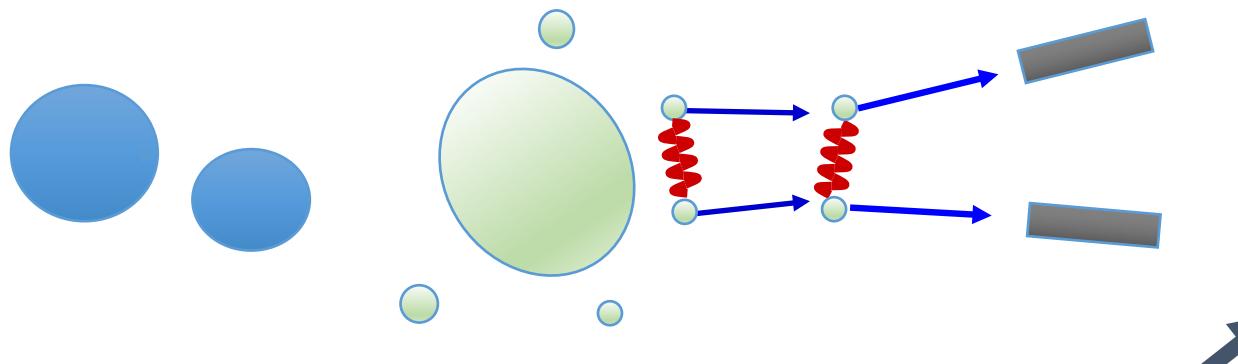
$$R(\vec{q}) = \int d\vec{r} \cdot S(\vec{r}) \cdot K(\vec{r}, \vec{q})$$

- Space-time image and size of early dynamical source

$$1+R(q) = k \cdot \frac{Y_{coinc}(q)}{Y_{evt.\,mixing}(q)}$$

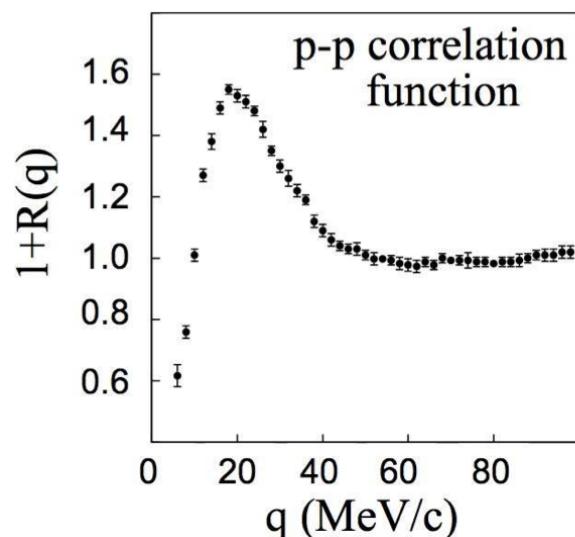


What densities? femtoscopy



Intensity interferometry / Femtoscopy

q = mom. of relative motion



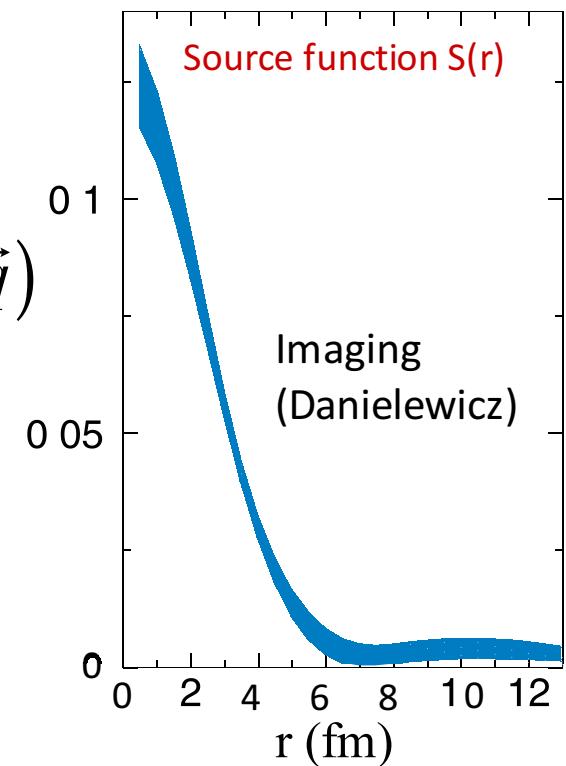
Koonin-Pratt

$$R(\vec{q}) = \int d\vec{r} \cdot S(\vec{r}) \cdot K(\vec{r}, \vec{q})$$

- Space-time image and size
of early dynamical source

$$1 + R(q) = k \cdot \frac{Y_{coinc}(q)}{Y_{evt.\,mixing}(q)}$$

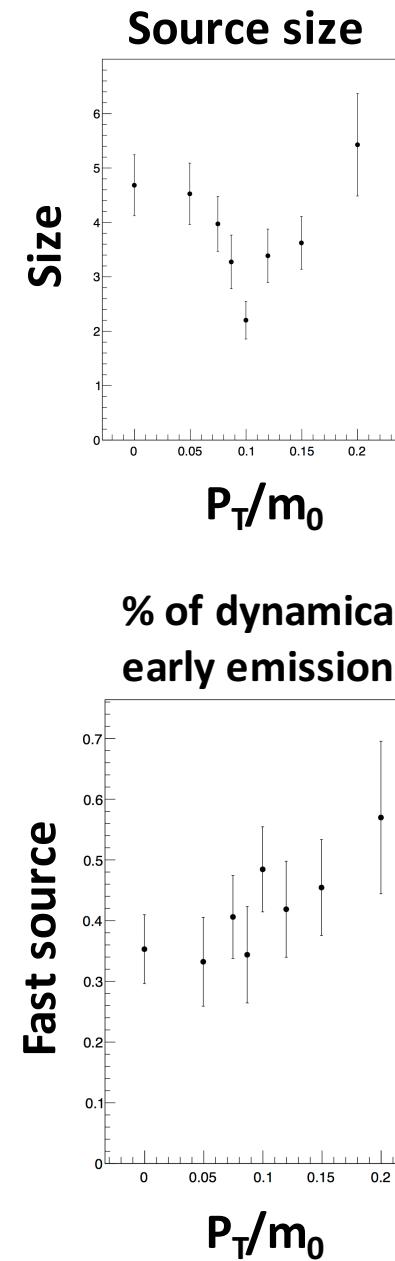
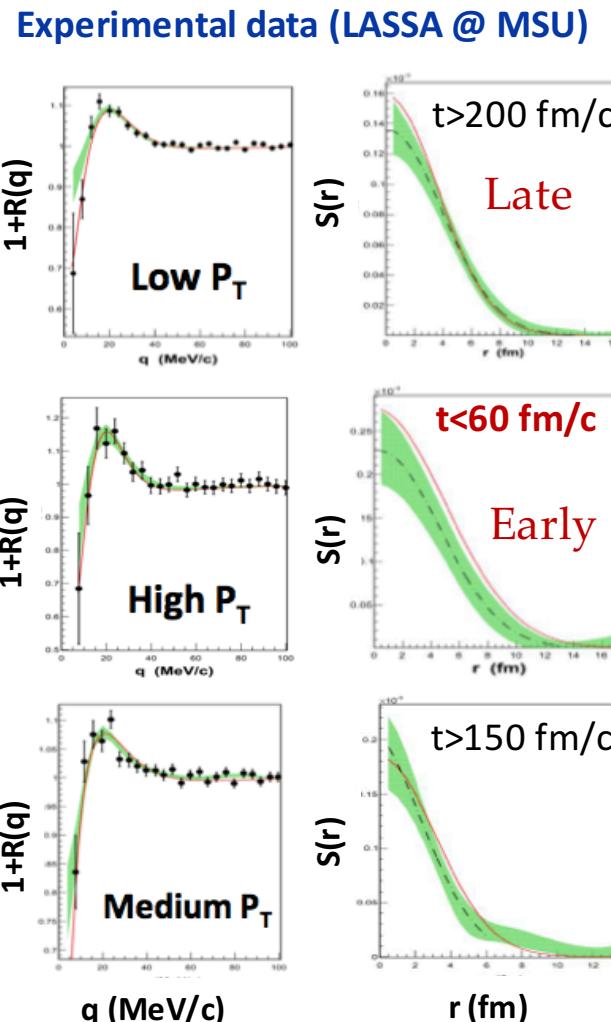
- Radii, λ values, etc.
- Directional studies, shapes, elongations,
- ...



Imaging
(Danielewicz)

Source radii and λ Vs. p_T

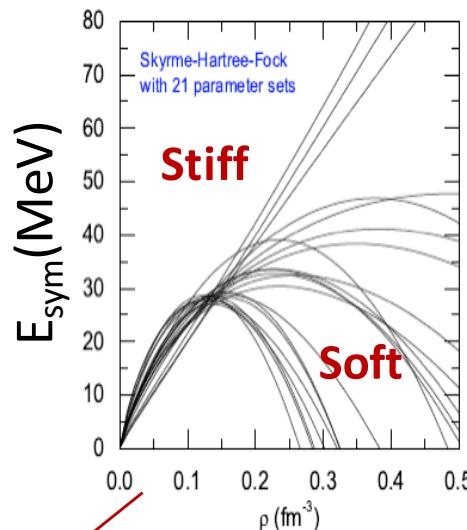
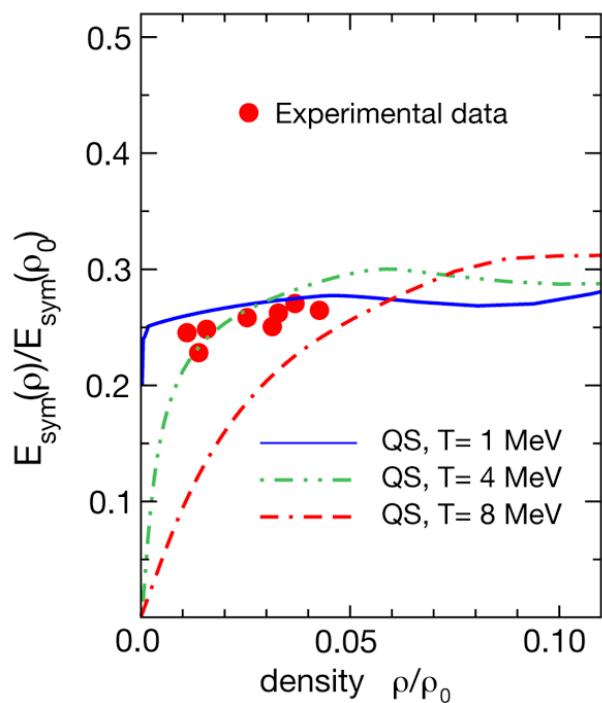
Xe+Au E/A=50 MeV (Central)



Clusterized matter \neq Uniform matter

$$E(\rho, \delta) = E(\rho, \delta=0) + E_{sym}(\rho) \cdot \delta^2 + O(\delta^4)$$

$$\delta = \frac{\rho_n - \rho_p}{\rho_n + \rho_p} \quad \text{Isospin asymmetry}$$



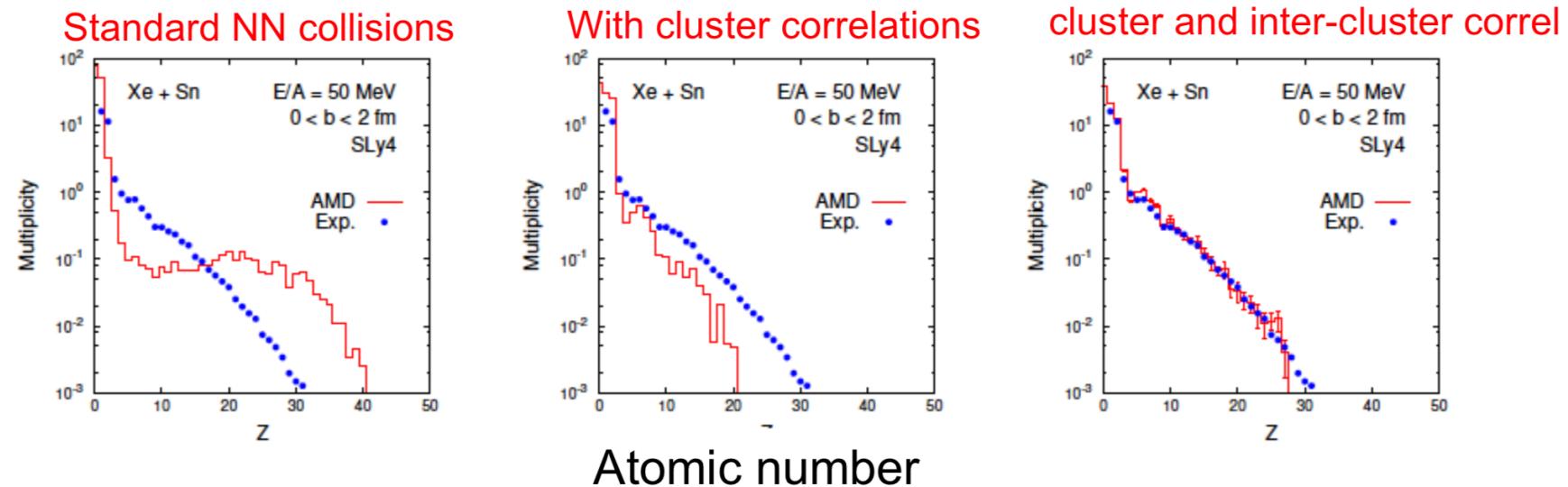
→ Alpha clusters at low densities modify EoS prescriptions

→ EoS of dilute matter modifies nuclear structure properties?

Comparisons to models: relevance of α clusters

Xe+Sn E/A=50 MeV – Central. Vs. AMD transport model simulations

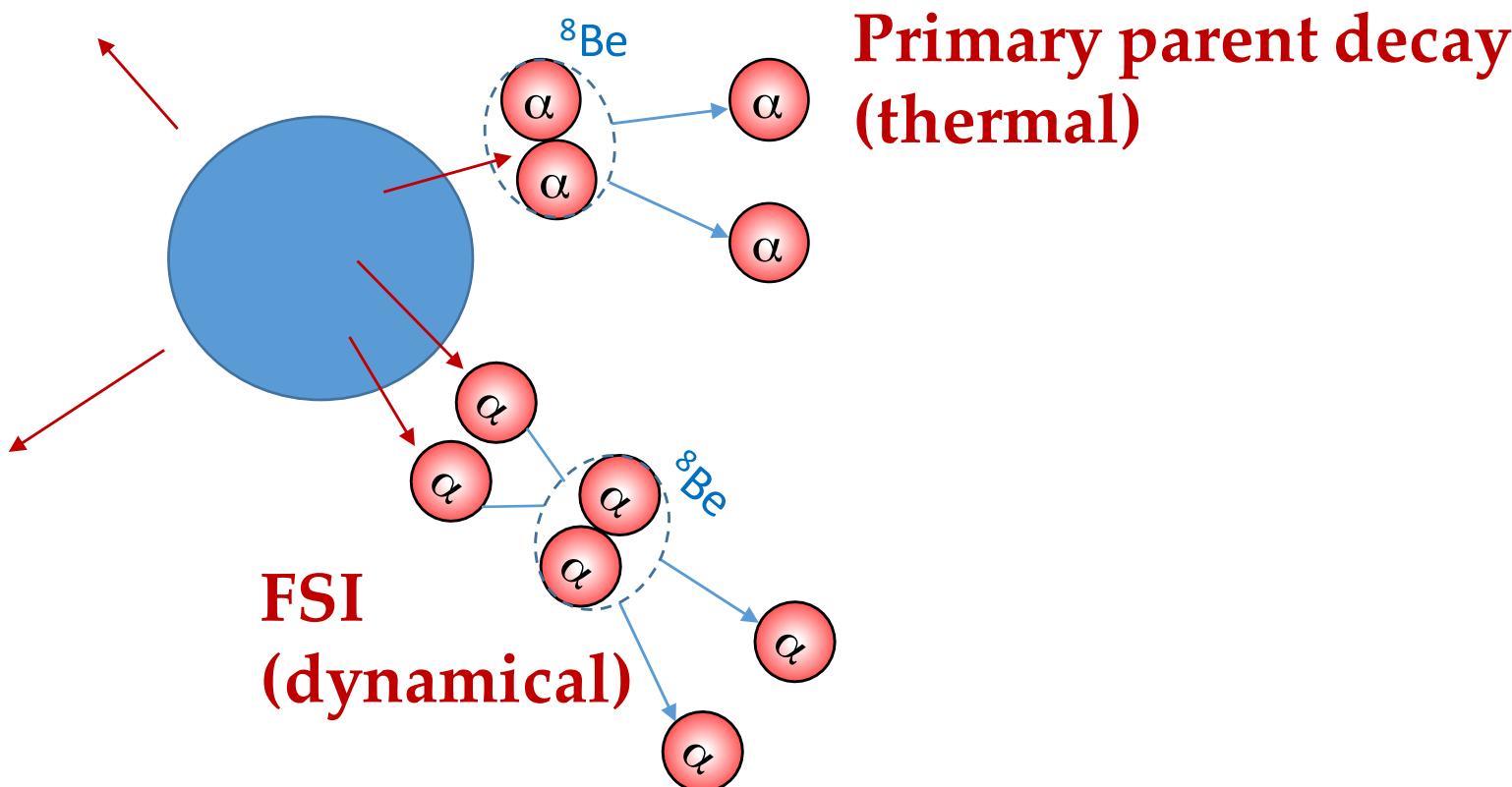
A. Ono, Journal of Physics: Conference Series **420** (2013) 012103



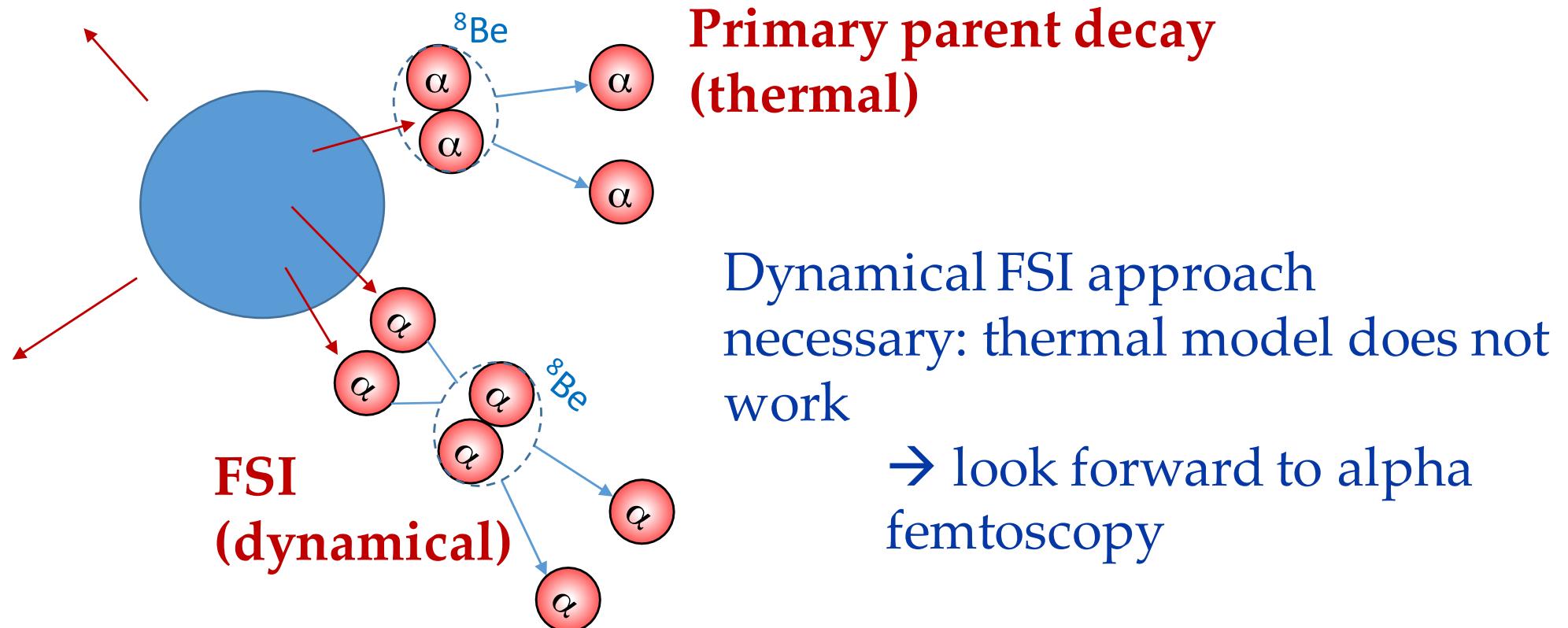
- Data can be described only if cluster formation and cluster-cluster interactions are included in AMD

Lifetime effects?

Parent decay and resonance generation by Final State Interactions

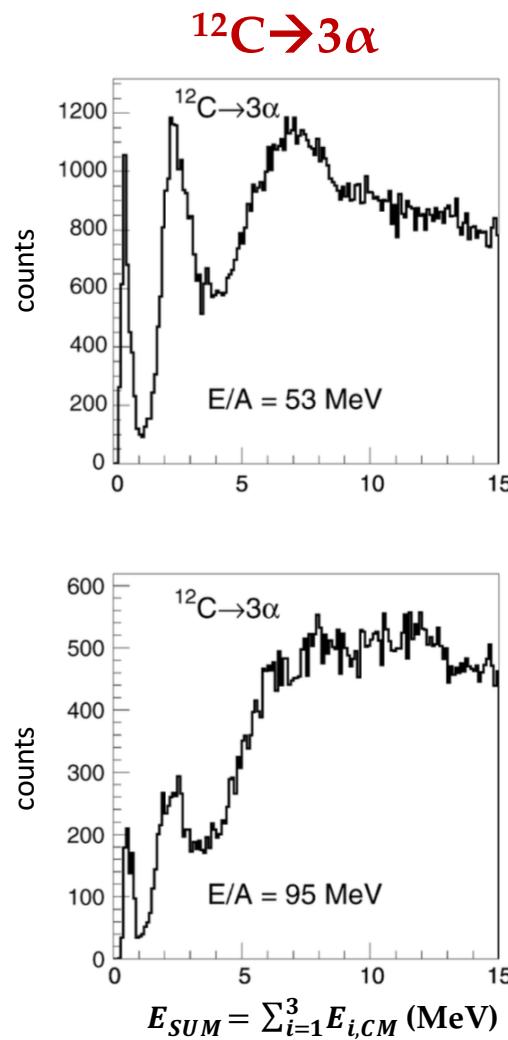


Parent decay and resonance generation by Final State Interactions



In-medium heavy-ion collision experiments

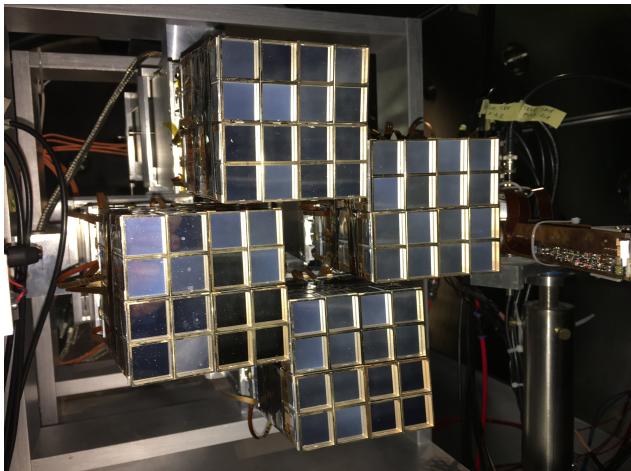
$^{12}\text{C} + ^{24}\text{Mg}$ E/A=53 and 95 MeV
INDRA data



**Strong contributions from
3 α direct decay mode?
....17% in Phys. Lett. B 705, 65 (2011)!**

Dedicated in-medium studies

FAZIA



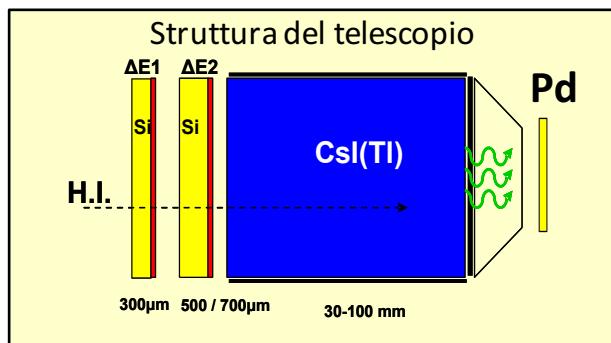
FAZIACOR @ LNS

G. Verde, D. Gruyer, FAZIA Collaboration



In-medium resonance decays in HIC

FAZIA (Four-pi A- and Z-Identification Array)



Fully digital electronics: particle identification directly from digitalization of Si and CsI(Tl) signals
→ almost online available
→ Wide dynamic range (100 keV- GeV)

FAZIACOR experiment (March 2017)

G. Verde, D. Gruyer, FAZIA Coll.

^{20}Ne , ^{32}S + ^{12}C
E/A=25 and 50 MeV

