Some ideas on PHYSICS for next PAC

FaziaDays 2023 Villa Galileo in Arcetri

Some ideas on PHYSICS for next PAC

- Idea 1: Zn+X with X=C,Zn,Pb
- context: QP break-up following dissipative collision
- Subject: isospin equilibration and n-p exchange vs. neutron reservoir in the target

See Caterina

References (beyond our group)
A. Rodriguez Manso Phys. Rev. C 100, 044612
K.Brown et al. PRC 87 061601 (2013)

Some ideas on PHYSICS for next PAC

See Alberto

- Idea 2: S+C at 25,50 AMeV
- context: clustering and fragmentation between equilibrium and dynamics
- Related point: how much can we brittle excited light nuclei?

Some ideas on PHYSICS for next PAC

• Idea 3: Sn+Fe or others

Reference: Mechanism of ternary breakup in the reaction Au+Au at 15 A MeV or other systems

Papers

1 Junlong Tian Phys. Rev. C 82, 054608 – 2010 Au+Au
2 J Tian Universe, https://doi.org/10.3390/universe8110555
3 Yanjing Li et al NPA 2013 https://doi.org/10.1016/j.nuclphysa.2013.02.015
4 K. R. Vijayaraghavan Proceedings of the DAE Symp. on Nucl. Phys. 56 (2011) 298X114 SHE

Theoretical studies with **IQMD model to compare with exp data**

Within the IQMD model, the mechanism of ternary breakup reactions is studied with several symmetrical colliding systems. The result shows that the nearly symmetrical ternary breakup occurs in central and semiperipheral reactions and experiences an extremely and sufficiently inelastic collision with intense nucleon exchanges. The dynamical effects and n-n-correlations play very important roles for determining the reaction.

Ternary BU scenarios

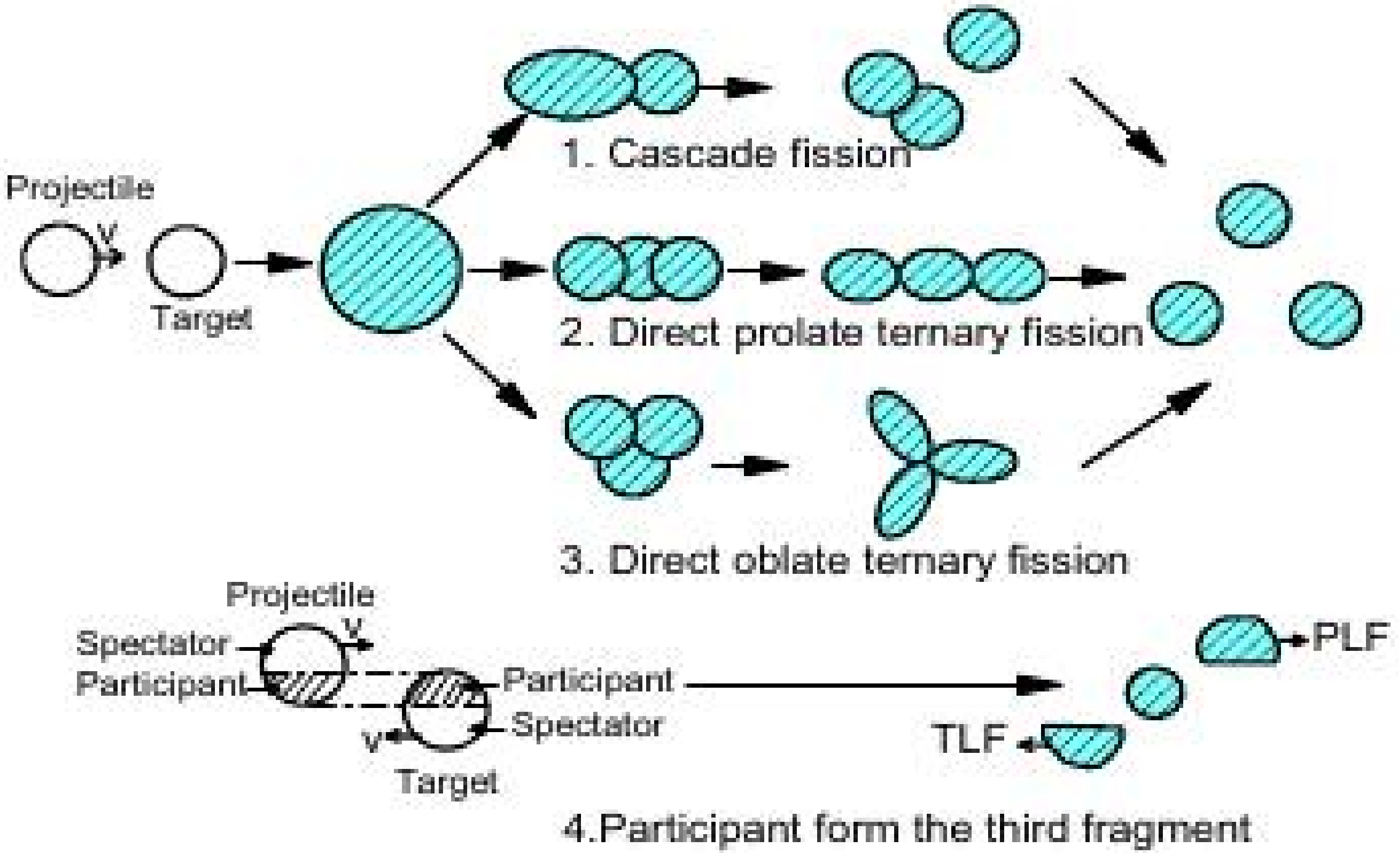


Figure 7. Possible modes of ternary breakup reactions.

Some ideas on PHYSICS for next PAC

What does ImQMD indicate?

197 Au+ 197 Au at the energy range of 5–30 A MeV have been studied within the **improved quantum molecular dynamics (ImQMD)** model.

It is found that the largest probability of ternary breakup is located at the energy around 24 A MeV for the system 197 Au+ 197 Au

The features in ternary breakup events, three mass-comparable fragments, and the **very fast, nearly collinear breakup, account for the two-preformed-neck shape of the composite system**.
The mean free path of nucleons in the system is studied; the shorter mean free path is responsible for the ternary breakup with three mass comparable fragments, in which the two-body dissipation mechanism plays a dominant role.

IQMD results (vs. exp data) AuAu15MeV/u: TOPOLOGY

The direct prolate ternary mode is responsible for those events having the features found in the experiments (Chimera group Swiyra-Chalot). These events are at relatively small impact parameter (not at peripheral reactions); the configuration of the composite system has a two-preformed neck shape. The ternary breakup reaction at peripheral reactions belongs to the mode of the participant from the third fragment or binary breakup with a neck emission.

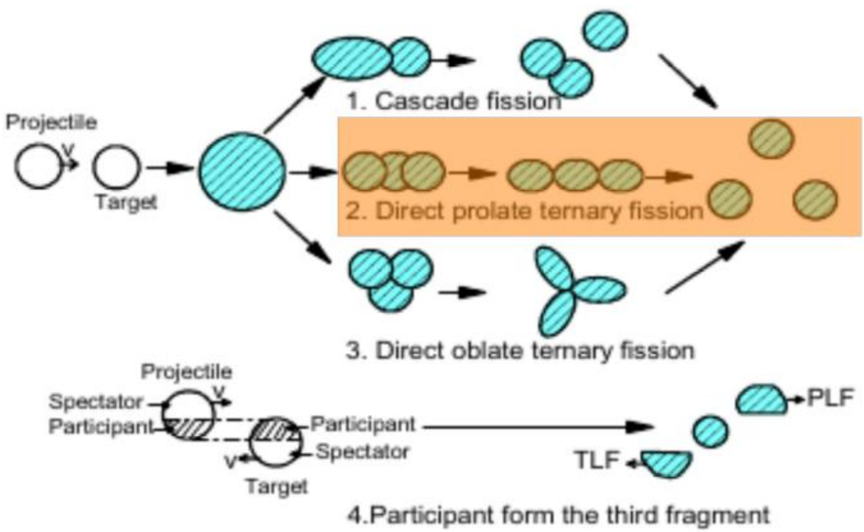
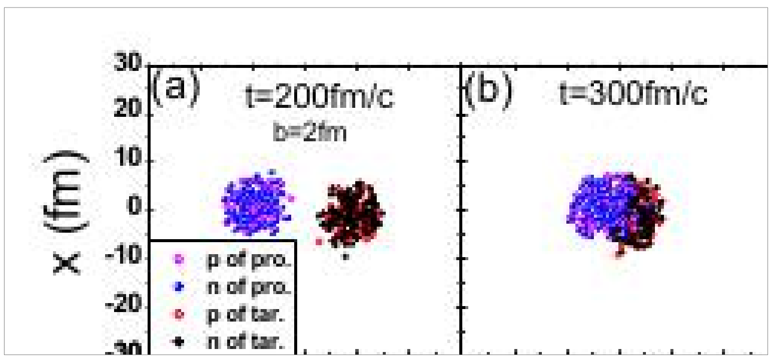


Figure 7. Possible modes of ternary breakup reactions.

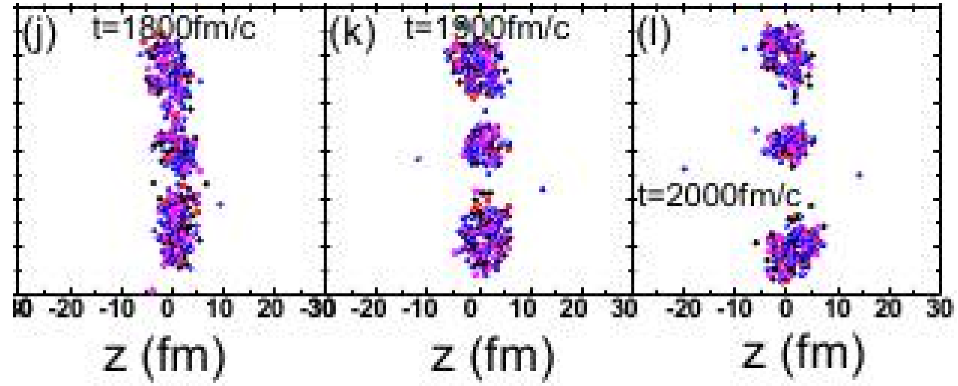
Peripheral coll.; ‘classical’ fast fission with only one neck rupture

Compatible with CHIMERA data, Central coll.

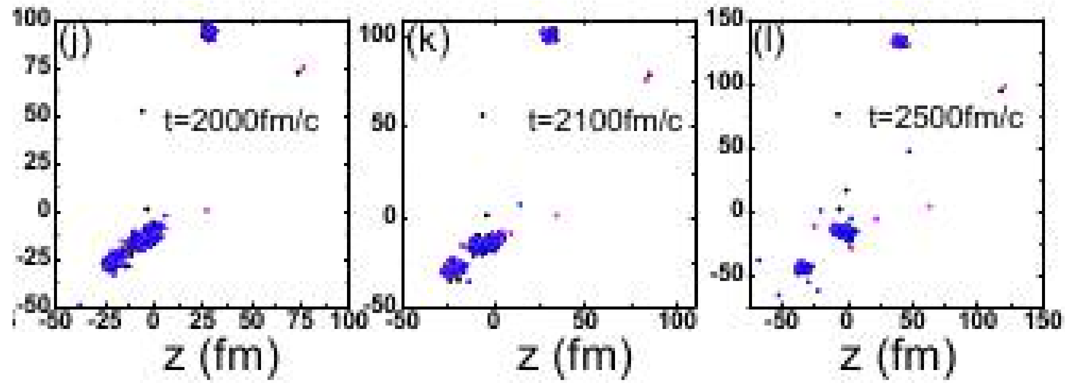
IQMD results (vs. exp data) AuAu15MeV/u: TOPOLOGY



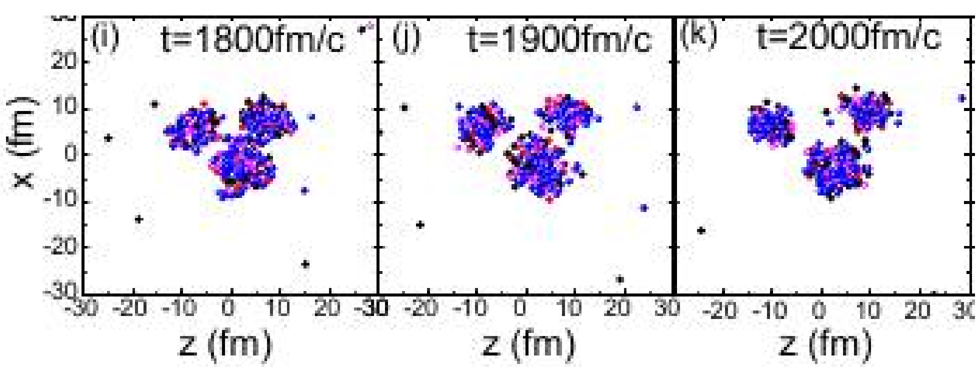
prolate
Direct BU



Sequential
with /w.o.
neck



oblate
Direct BU



INDRA FAZIA

IQMD results (vs. exp data) AuAu15MeV/u: TIMESCALES

In direct prolate ternary events, two necks are preformed and rupture almost simultaneously; the three fragment centers are almost aligned. The direct oblate ternary breakup is a very rare event, in which three necks are formed and rupture simultaneously, forming equally sized three fragments along space-symmetric directions in the reaction plane.

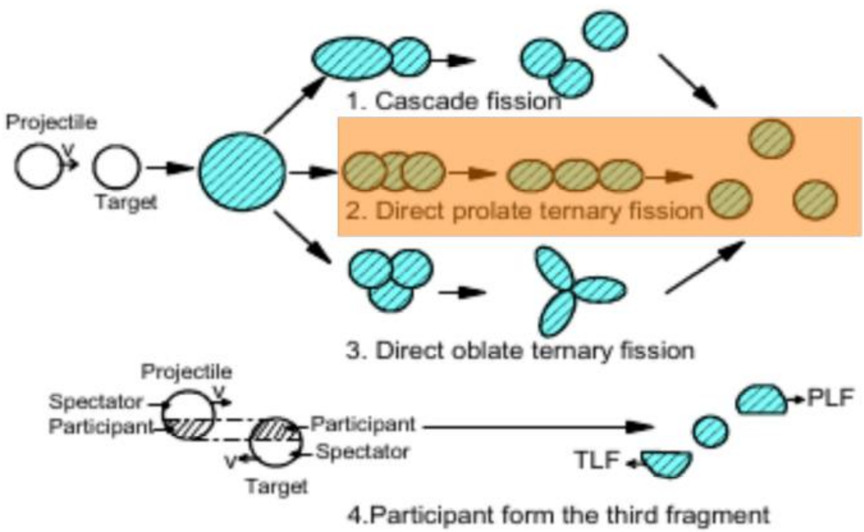


Figure 7. Possible modes of ternary breakup reactions.

Peripheral coll.; ‘classical’ fast fission with only one neck rupture

Two preformed necks rupture almost at the same time

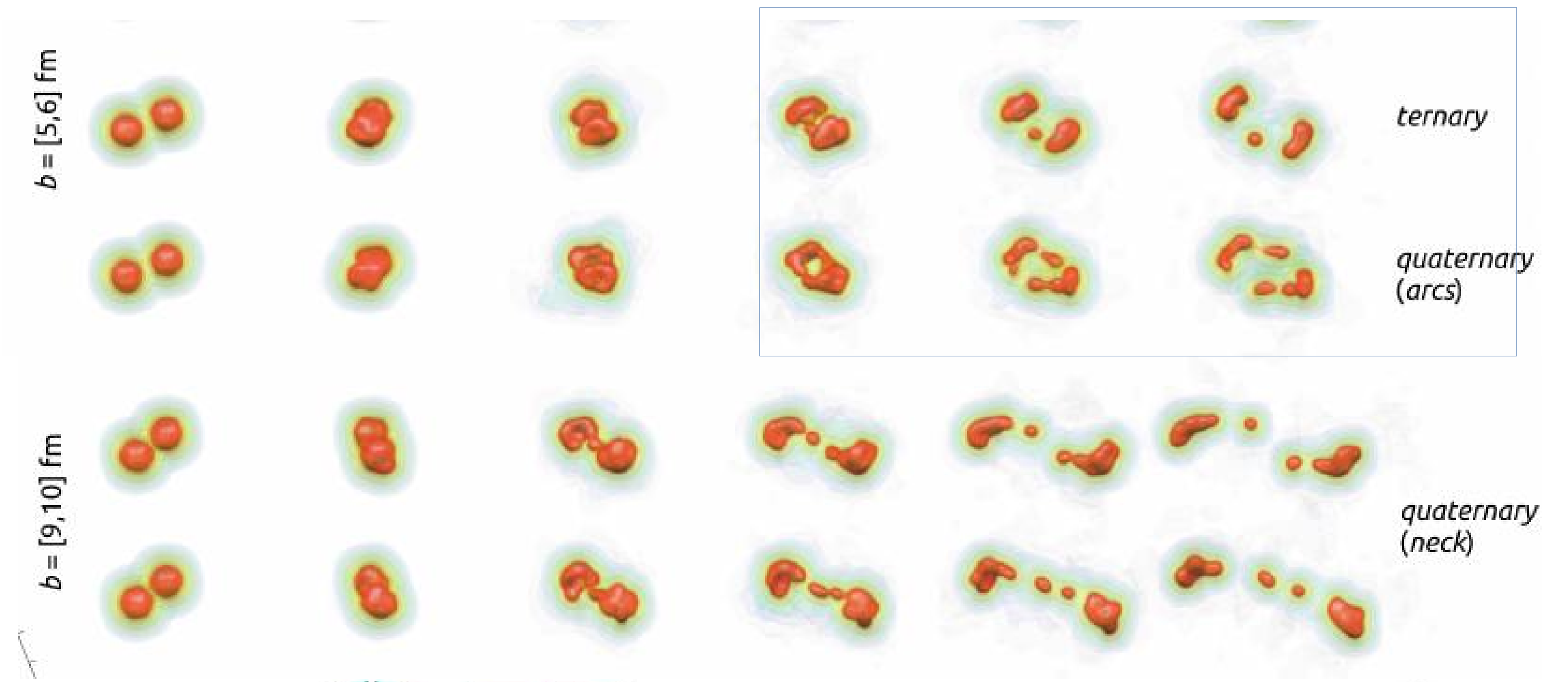
Very rare, almost negligible.

BLOB results (vs. exp data) AuAu15MeV/u

Dynamic description of ternary and quaternary splits of heavy nuclear systems in the deep-inelastic regime

P. Napolitani, A. Sainte-Marie, and M. Colonna Phys. Rev. C 100, 054614 – Published 19 November 2019

At variance with the Fermi-energy domain, where multiple-fragment modes are frequent, in the deep-inelastic regime instabilities are not associated with expansion effects but they rather characterise highly deformed and elongated configurations. In such conditions, the BLOB approach of Eq. (2) provides a thorough description of shape fluctuations leading to fragment formation. A



Semi-central to Central? Ask BLOB!

PERIPHERAL
Our beloved neck...

Condensing ideas into a proposal...

- **COMMENTS**
- Is it a sufficient physics point? Is an “existing detectable” channel? Model predictions?
- Three fragments of almost same size, each Z(max) around 23 (FAZIA top limit A-ident); evaporation helps (i.e. secondary fragments are lighter!)
- Ebeam close to the maximum foreseen by IQMD, a little more to help FAZIA and GANIL
- Not symmetric to favour A-Z indentification at CM
- Not too asymmetric reactions to favour larger spin values and fluctuations

124Sn+56Fe at 25 or 30MeV/u

ZTOT=76 N/Z_SYS=1.37
Ztot/3=25
Ztot/3 with evaporation (crude est. c.col)=19

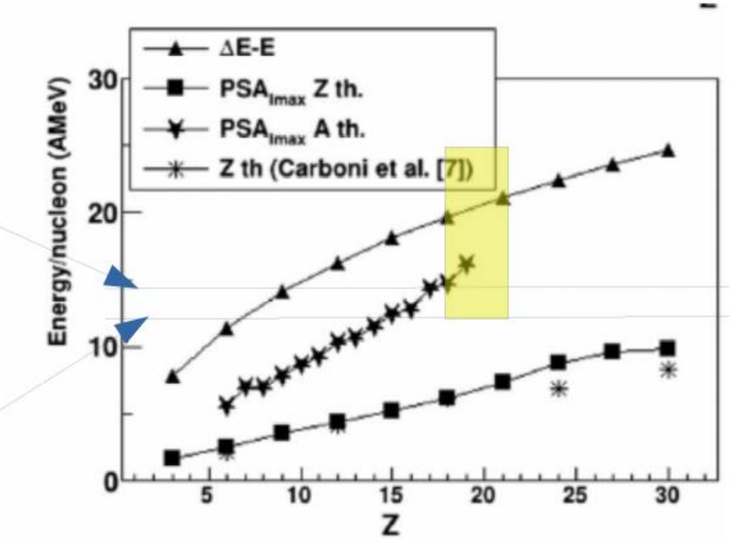
- **OBSERVABLES and MODELS**
- 3 fragments $Z\approx15$ measured at forw angles compatible with ternary BU
- Select most c.c.
- Evaluate yield and abs Xsect
- FAZIA exclusive: access A,Z of the three bodies (equilibrium values?)
- Demonstrate topology: i.e. stretched config vs. oblate
- Ask chinese authors, some calc?
- Ask Paolo specific BLOB calc?

Matching physics with FAZIA-INDRA

vcb== 150.535095 ecm== 1157.33337
b grazing= 11.5987206
proj and targ graz.lab angle= 2.48 86.0113373
proj and targ graz.cm angle= 7.97732830 172.022675
ellegrazing= 536.725281 R12= 12.4356384
vcm,massa ridotta= 5.24637032 38.5777779
EkinCNLAB (0deg)=, E/A_CN= 2562.66699 14.23
Static Fissility X for full CN= 0.659069240
Ecm/Atot= 6.42962980
Xfusall/Xtot(Eudes)= 8.28%
XfusCF/Xtot(Eudes)= 0.3%

124Sn+56Fe 30MeV/u

Grazing angles



vcb== 150.535095 ecm== 964.444458
b grazing= 11.4239817
proj and targ graz.lab angle= 3.02 85.1441879
proj and targ graz.cm angle= 9.71162987 170.288376
ellegrazing= 482.579498 R12= 12.4356384
vcm,massa ridotta= 4.78925896 38.5777779
EkinCNLAB (0deg)=, E/A_CN= 2135.55566 11.86
Static Fissility X for full CN= 0.659069240
Ecm/Atot= 5.35802460
Xfusall/Xtot(Eudes)= 11.3%
XfusCF/Xtot(Eudes)= 4%

124Sn+56Fe 25MeV/u

INDRA FAZIA

.variations on the theme

- 124Sn N/Z=1.48 56Fe N/Z=1.15
- Coulomb Field help fragmentation: better 112Sn instead of 124Sn (N/Z=1.24)?
- In this respect better 58Fe(0.28%natural) N/Z=1.24. Isospin symmetric. No diffusion. Better?
- A bit less asymmetric, worse focusing, slower CM

112Sn+58Fe at 25 or 30MeV/u

ZTOT=76   N/Z_SYS=1.24
Ztot/3=25
Ztot/3 with evaporation (crude est. c.col)=19

- 152Sm N/Z=1.45 28Si N/Z=1.00
- More asymmetric, better focusing, faster CM
- Perhaps less fluctuations, less elongation… qualitative feeling.
- Feasible at GANIL?

152Sm+28Si at 25 or 30MeV/u

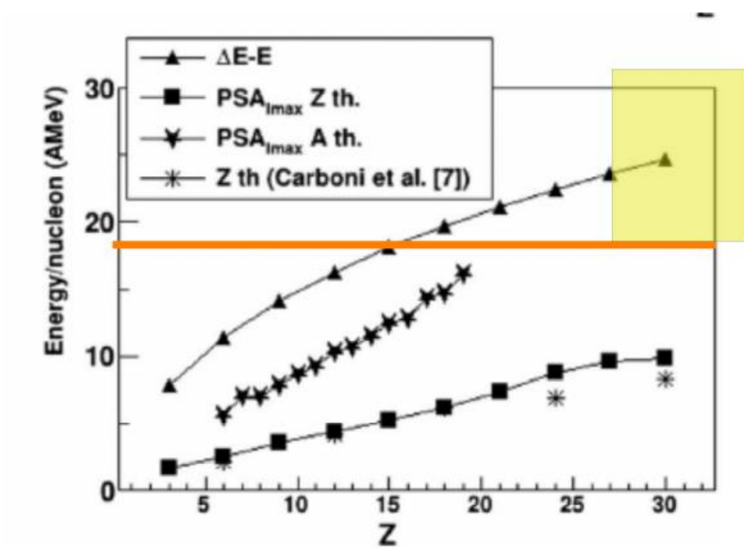
ZTOT=76   N/Z_SYS=1.37
Ztot/3=25
Ztot/3 with evaporation (crude est. c.col)=19

.variations on the theme

- Going heavier
- Peraphs more fluctuations and elongation (closer to the AuAu reference system)
- Models: stronger signals of direct BU? BLOB, IQMD?

197Au+58Fe at 30MeV/u

ZTOT=105 N/Z_SYS=1.41
Ztot/3=35
Ztot/3 with evaporation (crude est. c.col)=25-26



We are the limits (DE300micron-E)

150micron thickness would
Help!

No way for A-separation, anyhow