FAST IN-MEDIUM FRAGMENTATION OF PROJECTILE NUCLEI IN ASYMMETRIC CENTRAL COLLISIONS

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The framework

✓ **HEAVY ION COLLISIONS**

Investigation of nuclei structure and nuclear dynamics.

Study of the Equation Of State of nuclear matter.

Several ingredients: system size, isospin, impact parameter, incident energy…

✓ **INTERMEDIATE ENERGY**

Between 10 and 100 AMeV.

Onset of fragments (clusters of nucleons) production: 3-body → Multifragmentaion

Interplay between mean field and n-n interactions..

Large devices: 4π multidetector.

✓ **CENTRAL COLLISIONS**

Violent, most dissipative collisions.

Competition of several reaction mechanisms.

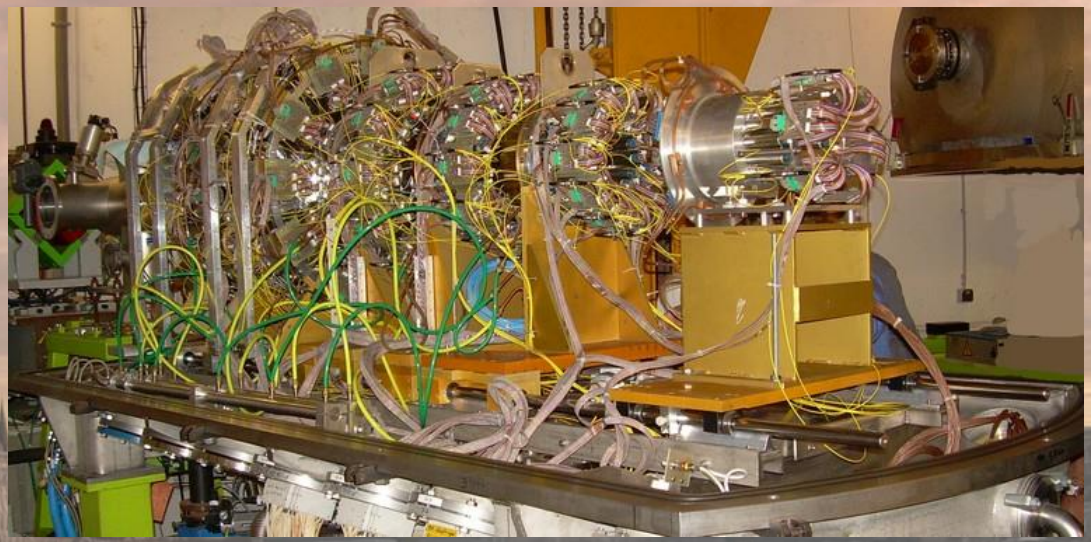
Extreme conditions of temperature and density.

Exploration of the low-right region of the nuclear matter phase diagram.

The experiment

$^{36}Ar + ^{58}Ni$ @ 32, 40, 52, 63, 74, 84, 95 *AMeV*

Grand Accelerateur National d'Ions Lourds (GANIL) – INDRA 4π detector



Wide angular coverage: ~90% of 4Pi

High granularity

High dynamic range in energy,

with small detection thresholds of ~1 MeV/A

High charge resolution, of up to Z ~ 50

Isotopic identification of light charged particles

No ionization chambers were installed on rings 12–17.

Therefore, only fragments with charge up to Z = 4 are identified above 90°

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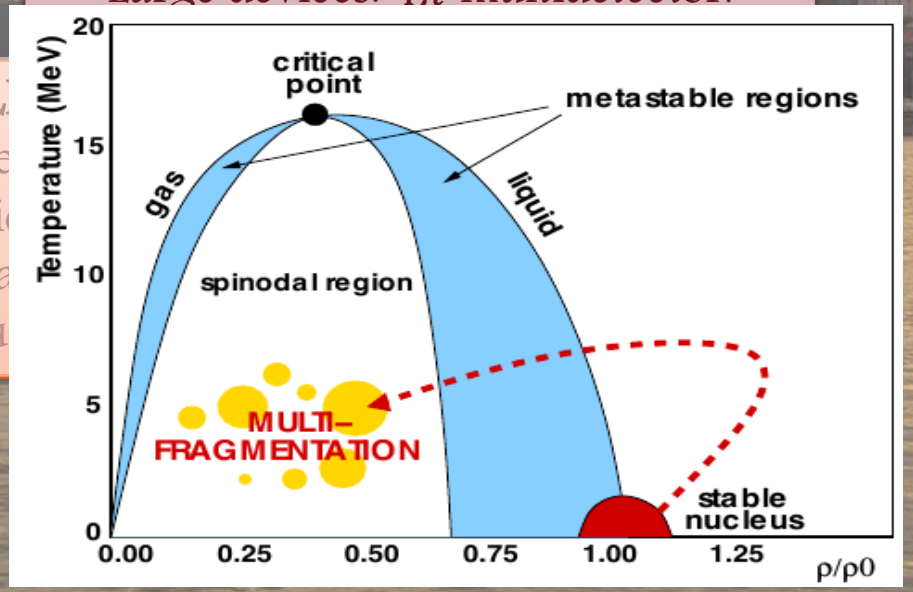
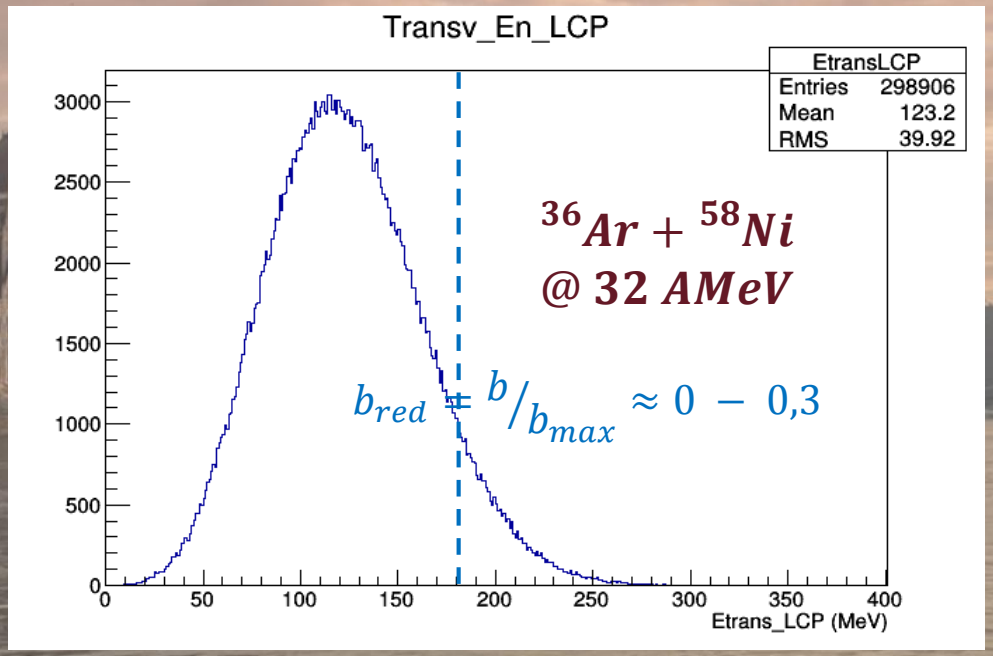


Centrality

$^{36}Ar + {}^{58}Ni$ @ 32, 40, 52, 63, 74, 84, 95 AMeV

Multiplicity of charged Particles (MCP); Total Kinetic Energy (TKE); Flow angle or similar Shape Variables; Total transverse Energy (Etr) …

E_{tr12}

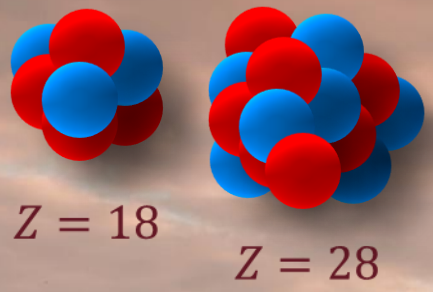


E_{inc} (AMeV)	E_{tr12} (MeV)
32	183
40	221
52	285
63	352
74	421
84	479
95	550

Cavata Method : $\frac{b}{b_{tot}} = \left(\frac{1}{N} \int_{E_{t12MAX}}^{E*_{t12}} Y(E_{t12}) dE_{t12} \right)^{1/2}$

Asymmetric Central Collisions

$^{36}Ar + {}^{58}Ni$



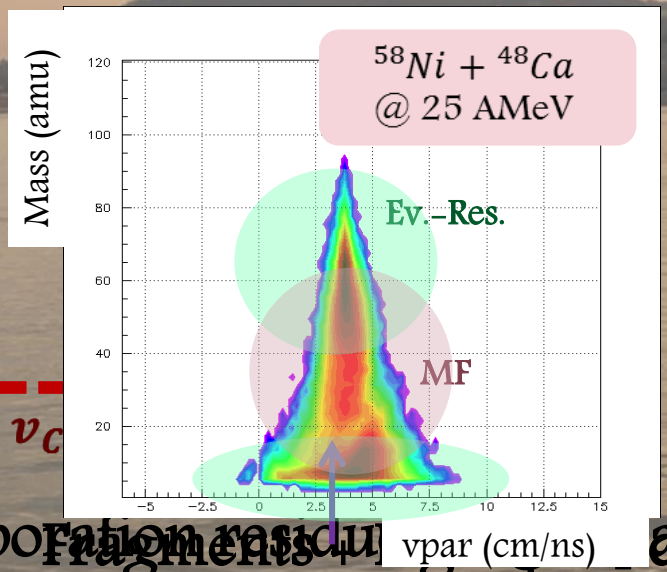
OVERLAP region
Projectile + Target nucleons

$$b_{red} = {}^{b}/_{b_{max}} \cong 0{,}3$$

Different scenarios from literature

FULL STOPPING case

$v = v_c$



MULTIFRAGMENTATION MECHANISM

vpar

beam

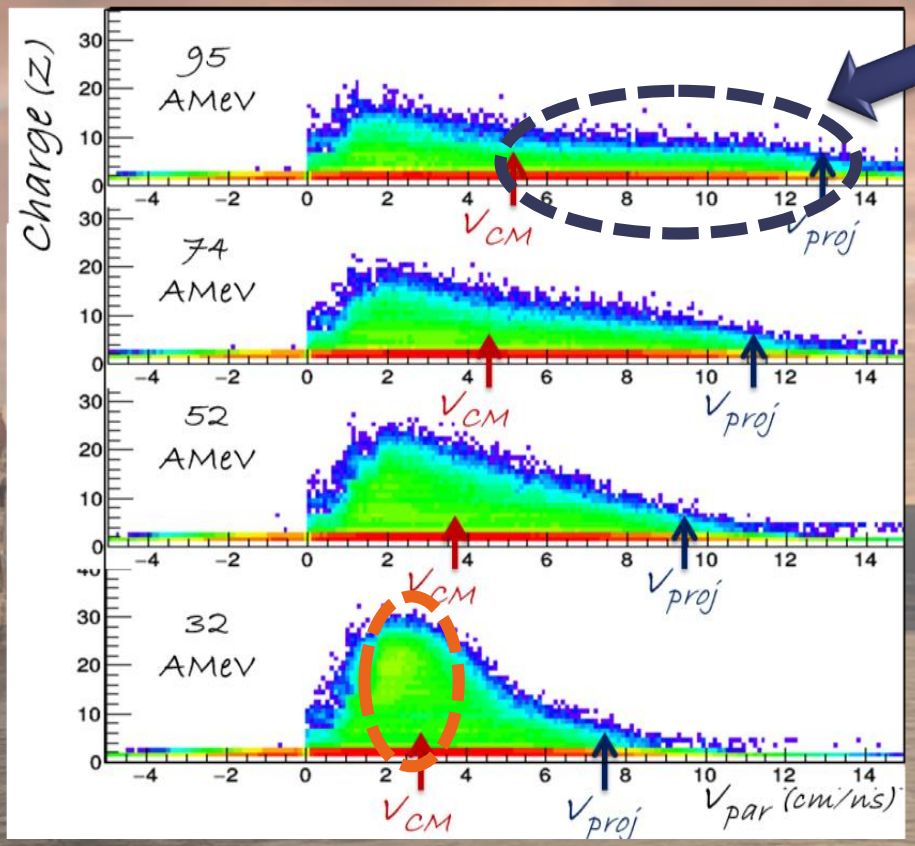
Evaporation residu[illegible] articles

Fragments + [illegible]

L. Francalanza, NCC (2012)

Central events

$^{36}Ar + {}^{58}Ni$ @ 32, 40, 52, 63, 74, 84, 95 *AMeV*



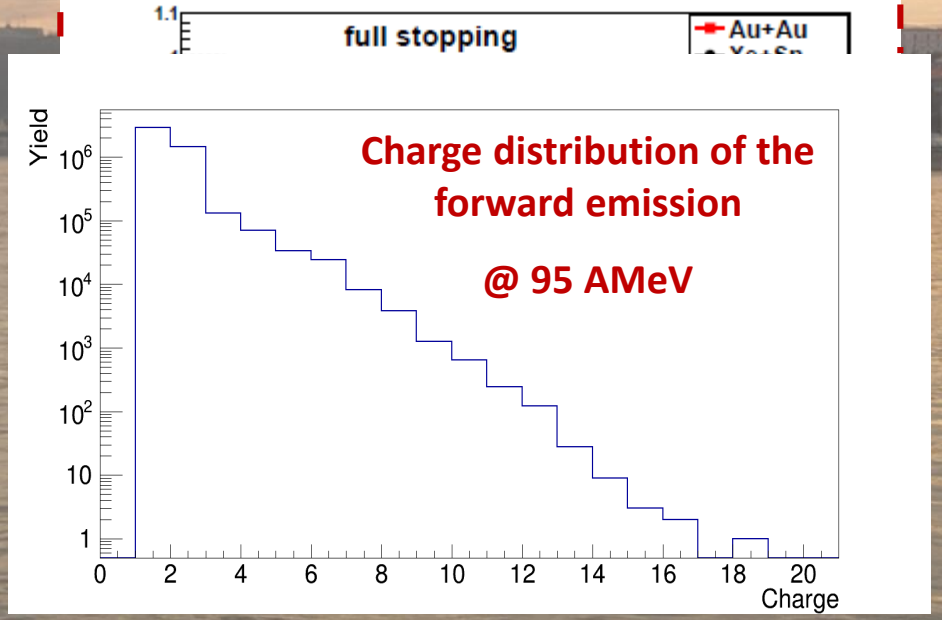
Charge–velocity correlation in central events.

PROJECTILE IN-MEDIUM "CRUMBLE"

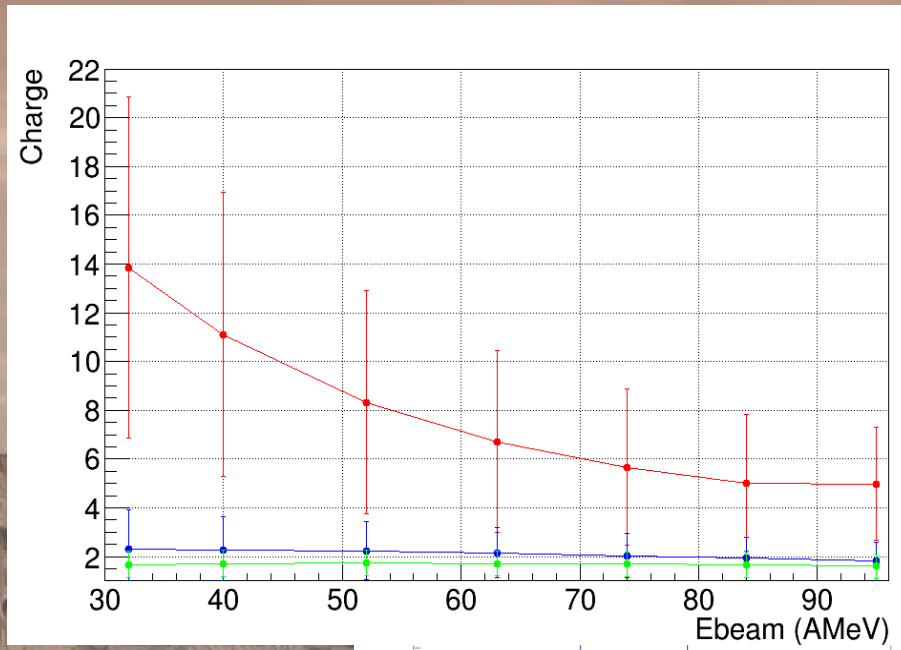
(transparency-like behavior of nuclear medium)

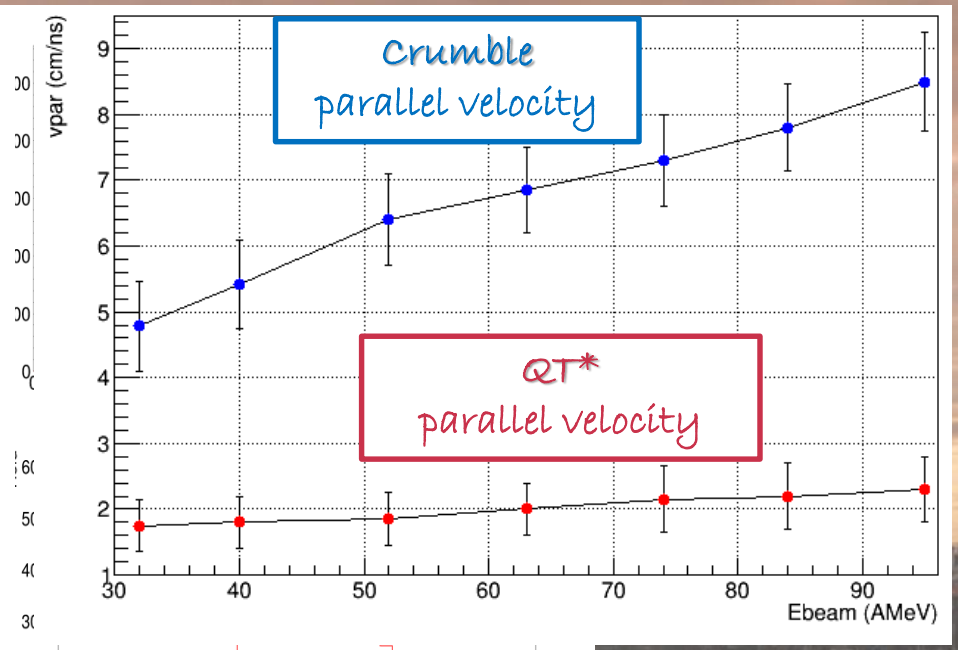
- ✓ Projectile undergoes a multiple breakup into fragments from Z=1 to about Z=10–15.
- ✓ Products spread along the vpar axis.

central collisions:



Reconstruction and characterization of QT source and projectile crumble





QT* **increasing dissipation degree**: gradual transition from an asymmetric to a more symmetric charge splitting.

The **QT* is dragged** along the beam direction by the crumbling projectile's fragments.

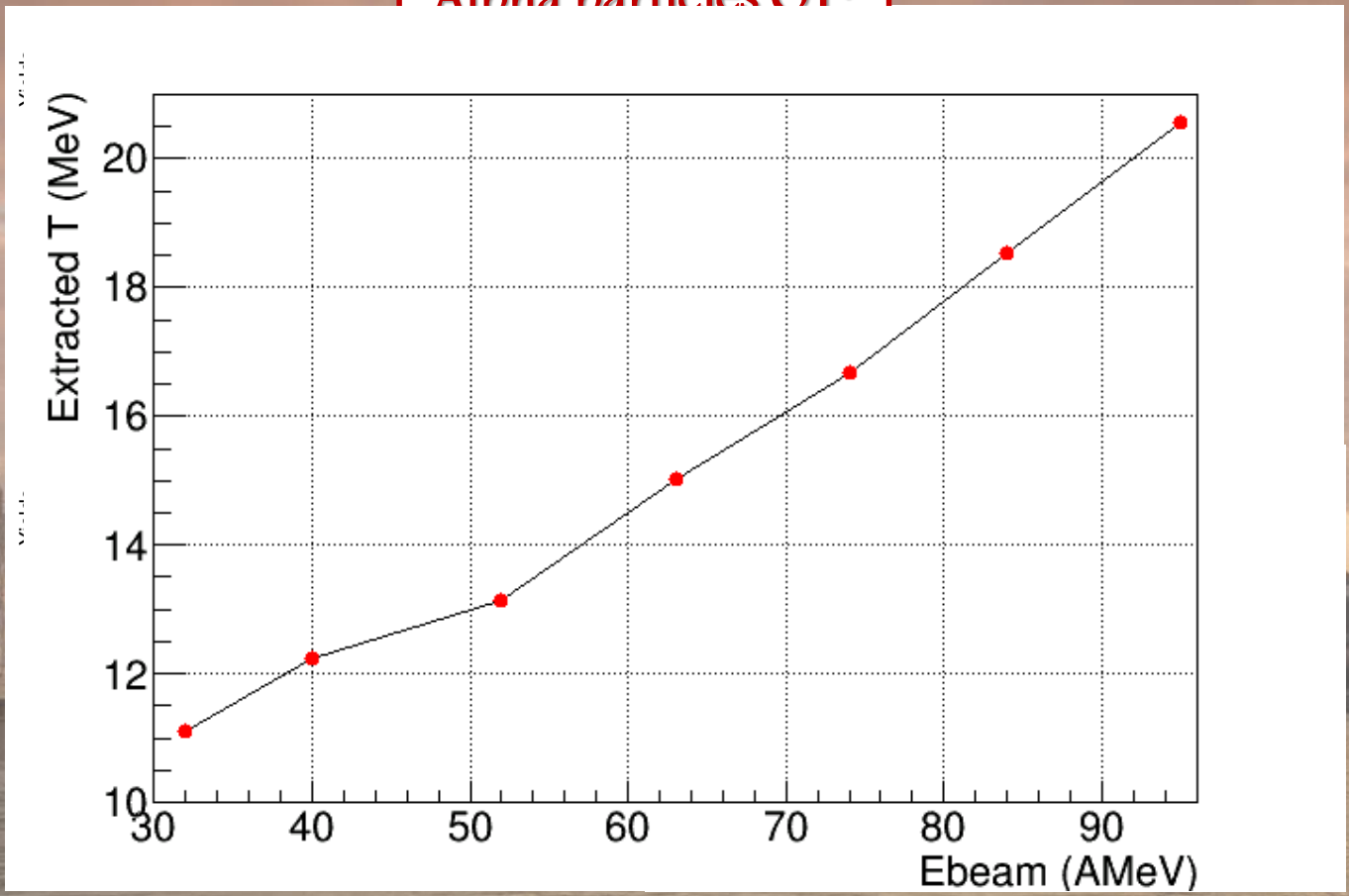
…duct…

than the c.m. velocity:

$$Z_{QT,QP} = \sum_{\substack{v<v_{CM} \\ v\geq v_{CM}}} Z_v$$

De-excitation of the QT*

Alpha particles QT*



TEMPERATURES extracted from maxwellian fits have values ranging from 11 to about 22 MeV for incident energies from 32 to 95 AMeV.

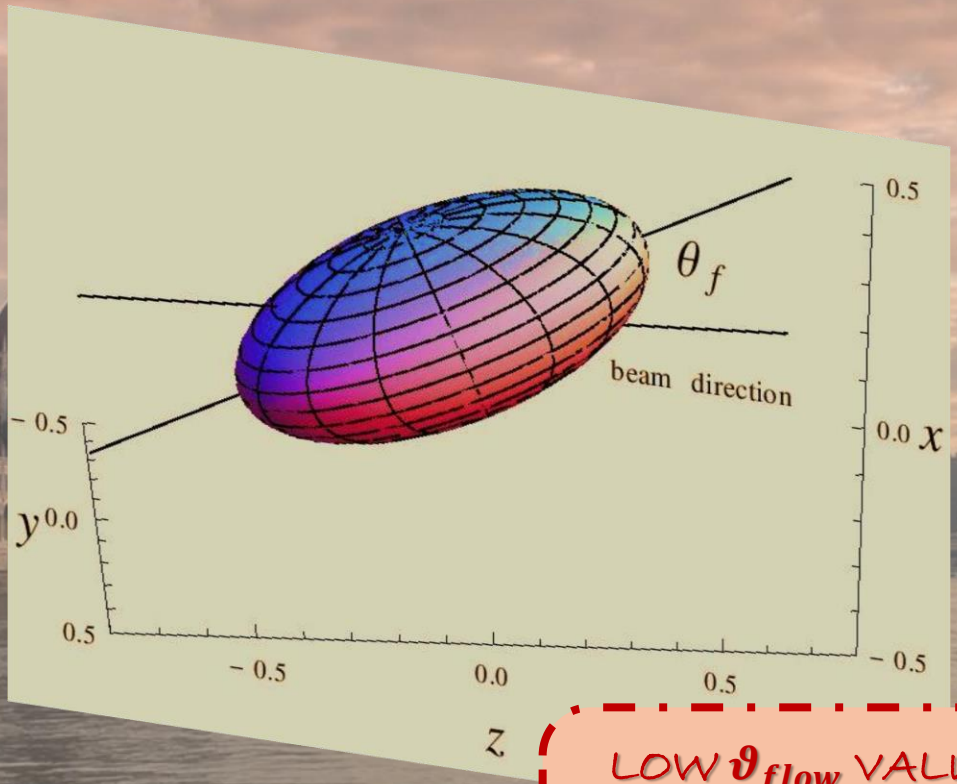
projectile alphas.

Shape Analysis

$$F_{ij} = \sum_n \frac{p_i p_j}{2m_n}$$

$$\lambda_1 + \lambda_2 + \lambda_3 = 1$$

$$\lambda_1 \geq \lambda_2 \geq \lambda_3 \geq 0$$



Flow angle: $\cos(\vartheta_{flow}) = \boldsymbol{e_1} \cdot \boldsymbol{z}$

E_{inc} AMeV	$\langle\vartheta_{flow}\rangle$ degrees
32	50,85
40	35,14
52	26,57
63	25,43
74	23,5
84	23,3
95	23,5

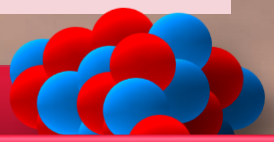
LOW ϑ_{flow} VALUES

Fast emission along the beam direction; out of equilibrium process

CONCLUSIONS & PERSPECTIVES

$^{36}Ar + {}^{58}Ni$ @ 32, 40, 52, 63, 74, 84, 95 *AMeV*

CENTRALITY → complete overlap of projectile and target nuclei

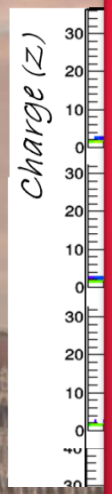


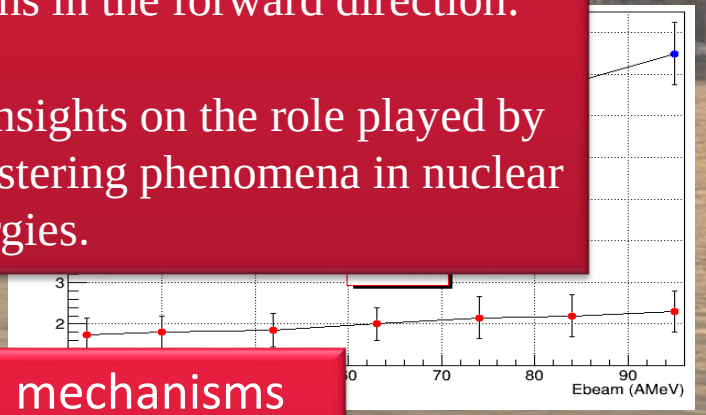
What parameters may favor the projectile crumble? total mass of the system and its charge, isospin asymmetry ...

Investigations on system with the same mass but different N/Z ratio, or systems with a different mass asymmetry are in progress.

Possible effects induced by the structure of alpha-conjugate ^{36}Ar projectile nuclei may be also investigated by multi-particle correlations in the forward direction.

These further investigations may provide important insights on the role played by the isospin degree of freedom or by the in-medium clustering phenomena in nuclear dynamics at intermediate energies.





Cohexistence of two different fragment emission mechanisms **"in medium crumbling"** of the projectile - decay of the **excited and forward dragged quasi-target.**

Thank you all

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