High-resolution magnetic spectrometers: an excellent tool to investigate the properties of nuclear matter
1 $A$ GeV $^{238}$U on proton
1 $A$ GeV $^{238}$U on titanium
measured at the FRAGMENT Separator at GSI

- cold nucleus
- excited liquid nucleus
- liquid-gas coexistence
- hot and compressed nuclear matter

SUPERFLUID FEATURES
FISSION EVAPORATION
MULTI FRAGMENTATION
EXPLOSION OF THE FIREBALL

- final (cold) products ($U+p, U+Ti$)
- slightly excited spectators ($U+p$)
- more excited spectators ($U+Ti$)
- effects from the fireball ($U+Ti$)
Raw experimental data

H and Ti

A/Z

Z

Velocity [cm/ns]

5 10 15 20 25 30 35 40

Ti

Z

Velocity [cm/ns]

5 10 15 20 25 30 35 40
A complex even-odd effect

The structure appears as the result of the condensation process of heated nuclear matter while cooling down in the evaporation process. The results are a manifestation of the passage from the liquid phase to the superfluid phase.

Essential requirement for this investigation: charge and mass resolution

Neutron-rich nuclei

$^{238}\text{U} + \text{Ti}$
In more violent collisions the evaporation starts at lower excitation energies!
Neutron-rich nuclei

Essential requirement for this investigation: 

Z and A resolution

(→ high-resolution magnetic spectrometer)

Mean $N/Z$-ratio + statistical-model code

→ freeze-out temperature (isospin thermometer)

$^{238}\text{U} + p$ Fission

1 A GeV $^{238}\text{U} + p$
All the experimental signatures are consistent with the sequential binary decay of a fully equilibrated compound nucleus.

Clear indications for fast break-up processes seem to be absent.

Essential observables for this investigation: $A$, $Z$, velocity ($\rightarrow$ high-resolution magnetic spectrometer)

Morrissey systematics


Acceleration of spectators

1 A GeV $^{238}\text{U} + \text{Ti}$
Experimental evidence for the response of the spectator to the participant blast

According to some theoretical model, the momentum is selectively sensitive to the momentum dependence of the nuclear force.

The longitudinal momentum is measurable with the required precision with high-resolution magnetic spectrometers.

Conclusion

1 A GeV $^{238}$U on p, Ti

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Acknowledgements

Prof. Dr. Gottfried Münzenberg

Dr. Karl-Heinz Schmidt

Prof. Jose Benlliure