Measurement of mass-energy distributions of fission fragments using the time-of-flight method

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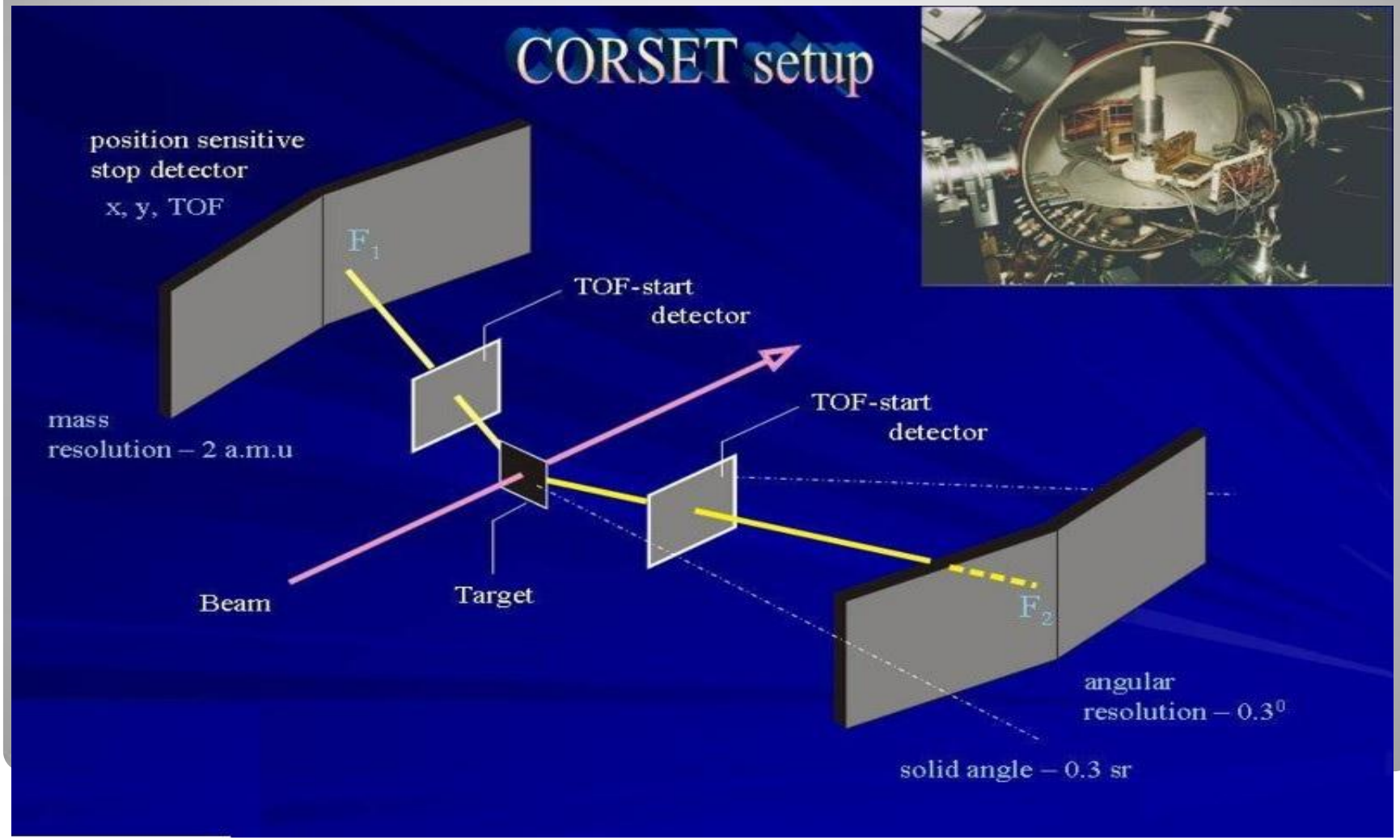
Aim of the project: Study of the properties of induced fission at different energies

Equipment description: CORSET spectrometer

Work/experiment description: Measurements of the quality of the new detectors that will be used in further experiments and data analysis.

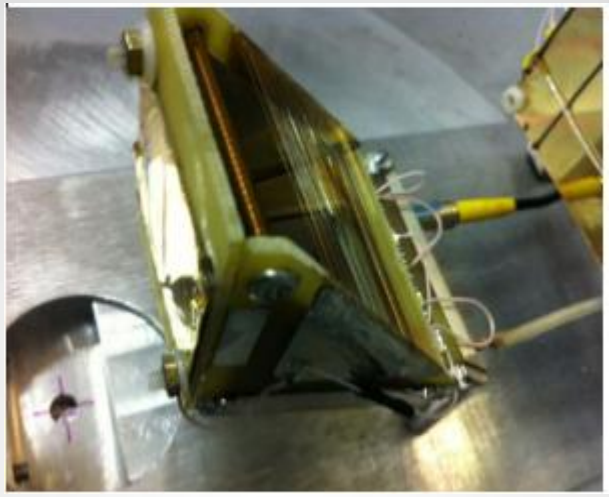
Obtained results: General parameters of the newly produced detectors and conclusions on the fission modes.

Time-of-flight spectrometer

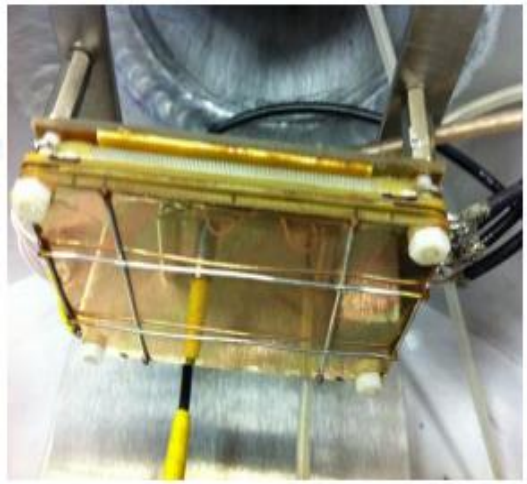


Experimental setup

Reaction chamber



Start detector

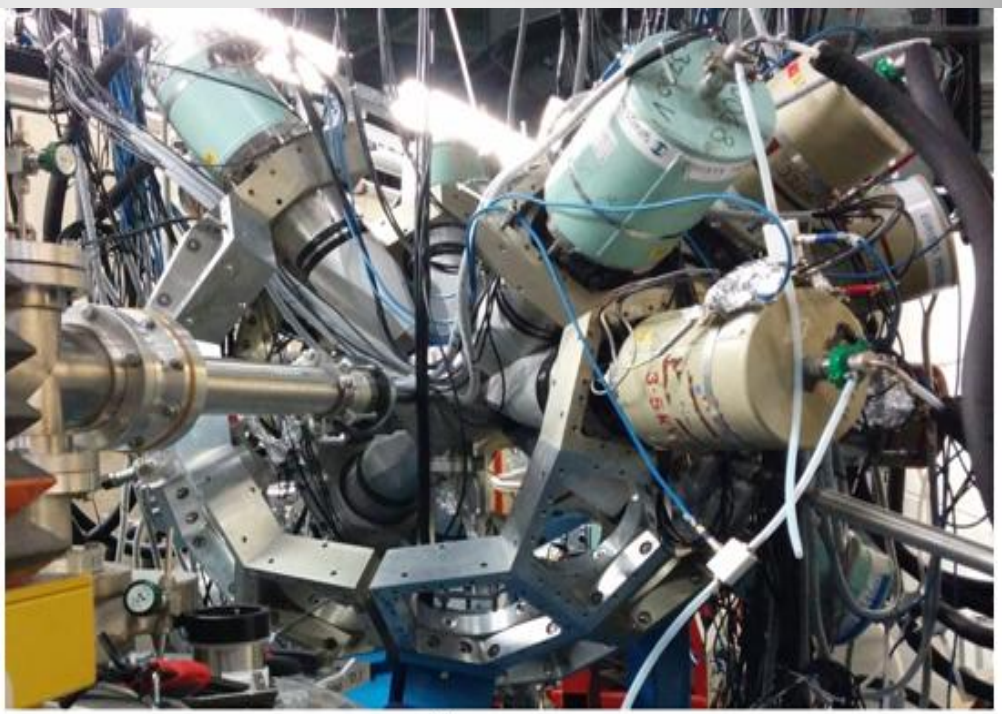


Stop detector

Vacuum system

Data acquisition system

Experimental setup

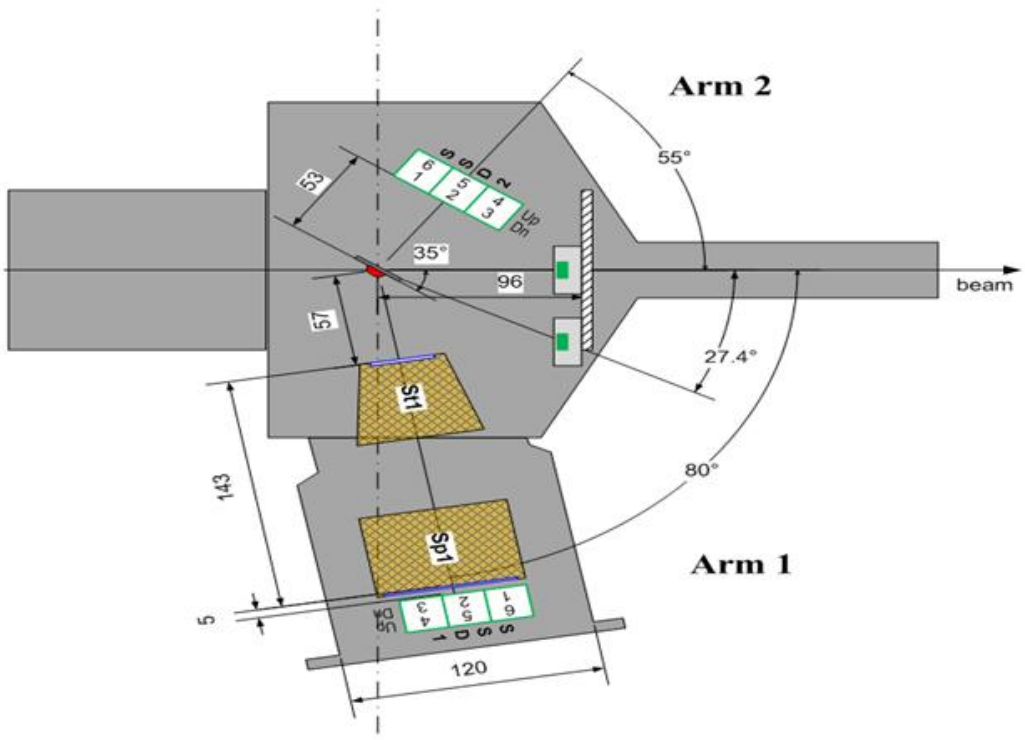


a)

CORSET can be used as a **trigger** in multidetector setups for measuring light charged particles, neutrons, and gamma-rays in coincidence with reaction fragments.

This powerful set-up allows one to measure fission mass and energy spectra in coincidence with **neutrons, light charged particles, and gamma-quanta.**

CORSET @ALTO : ToF, E -E



- CORSET:

Measured parameters:

- ToF, X, Y of each fragment

Extracted parameters :

- Velocity, energy, angles and mass of each fragment
- TKE

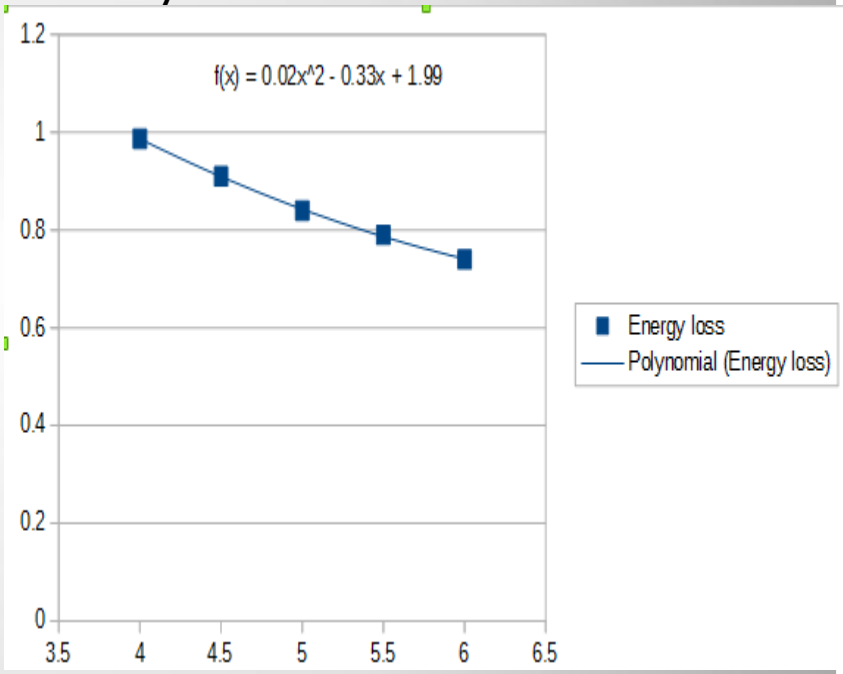
Time resolution	**150-180 ps**
ToF base	10-30 cm
ToF arm rotation range	15°-165°
Solid angle	100 -200 msr
Angular resolution	0.3°
Mass resolution	**2-4 u**
Energy resolution	**1%**

$^{34}S + ^{186}W \rightarrow ^{220}Th^{*}$ (E^{*}~48MeV)

Test Experiment

Measuring the thickness of the foil

- SRIM software is used to obtain the characteristic energy loss per unit length of the incident particle for a given material.
- The material in our experiment was Mylar.
- The procedure starts with the calibration of the device using an alpha source.
- Separate measurements were made for the case where the source directly emits radiation towards the detector and for the other case where the foil is placed between the two.
- The difference in energy, is obtained from the spectra for three separate peaks and the thickness is therefore calculated. The thickness is calculated to be 150±15 mg/cm^2.

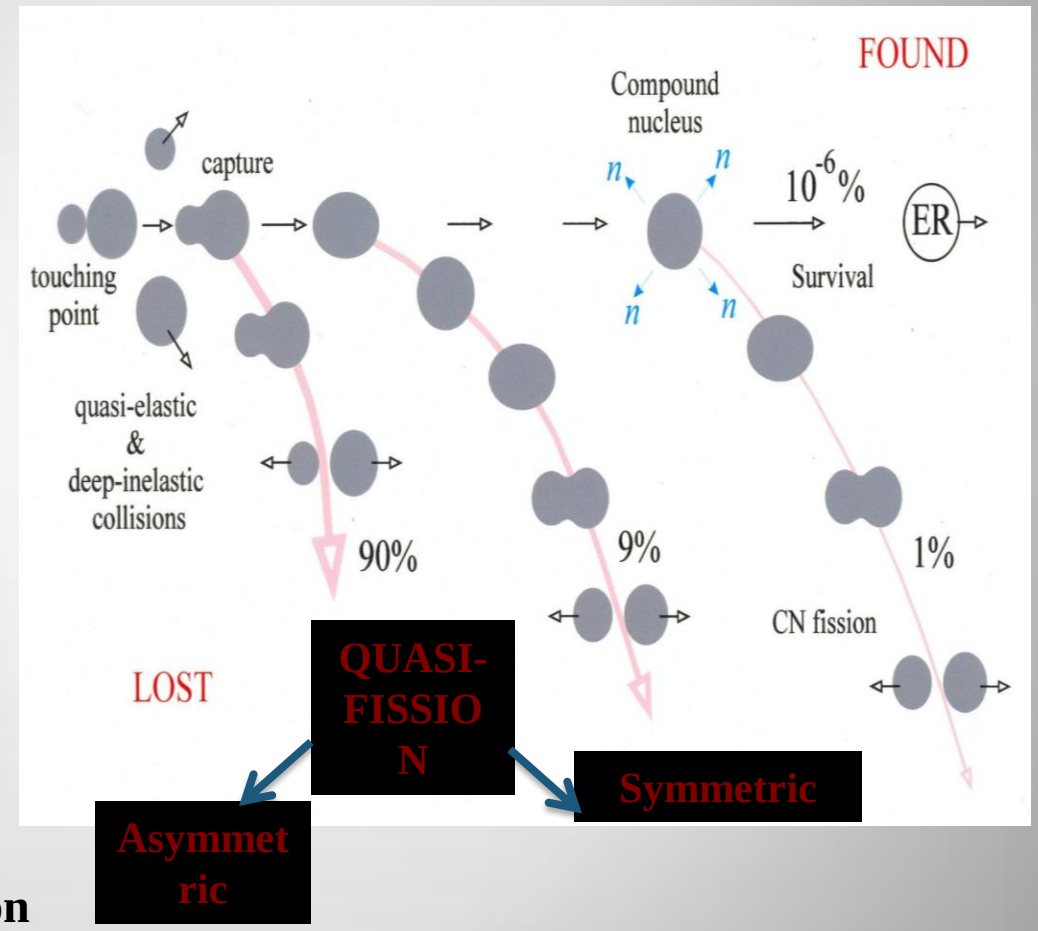


Application of CORSET

- Study of heavy and super heavy elements,their production and the processes that take place during the reactions
- TKE (Total Kinetic Energy), Mass, Total Angular Momentum distribution of fission fragments
- Multi-nucleon transfer reactions: quasi-fission, fusion-fission
- Heavy ion induced reactions
- Nuclear structure and nuclear reactions, mechanisms near Coulomb barrier energies

Shape evolution in heavy ion induced reactions

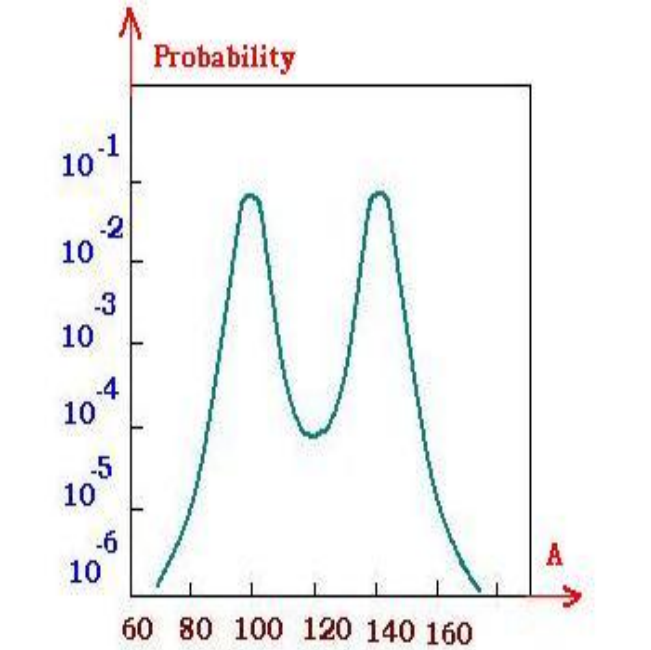
In dependence on the impact parameter and projectile energy:



- **Elastic scattering**
- **Coulomb excitation**
- **Quasi-elastic scattering**
- **Deep-inelastic scattering**
- **Quasi-fission**
- **Fusion → CN → Fission**
- **Fusion → CN → de-excitation (n, γ)→ ER**

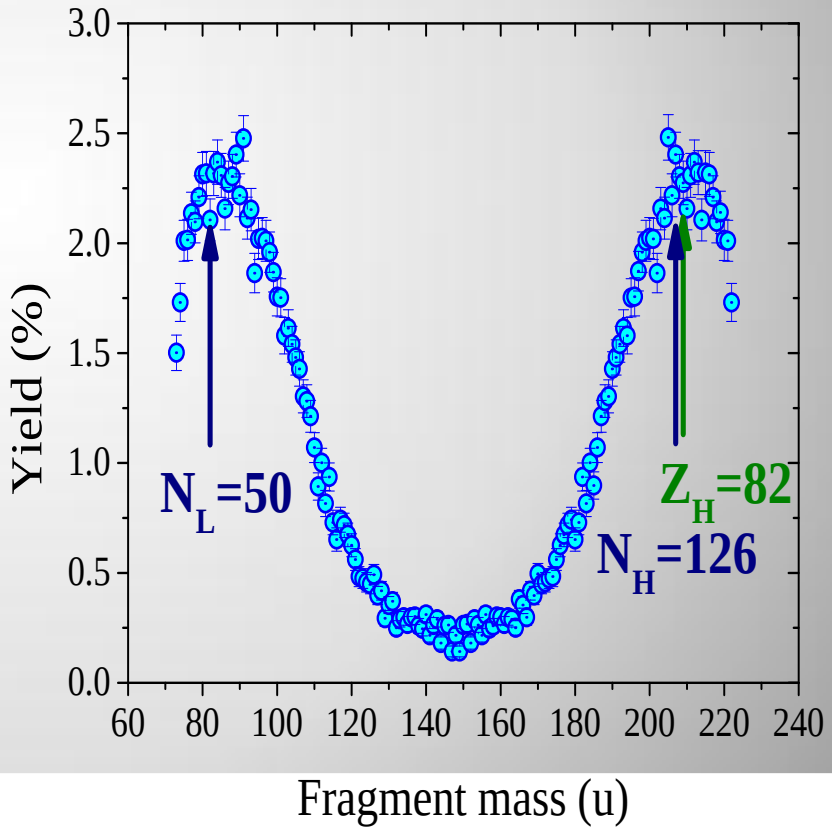
Fragment mass distribution for fission and quasi-fission

- Fission



probability to obtain a nuclide of mass number A with fission of 235-Uranium by thermal neutrons

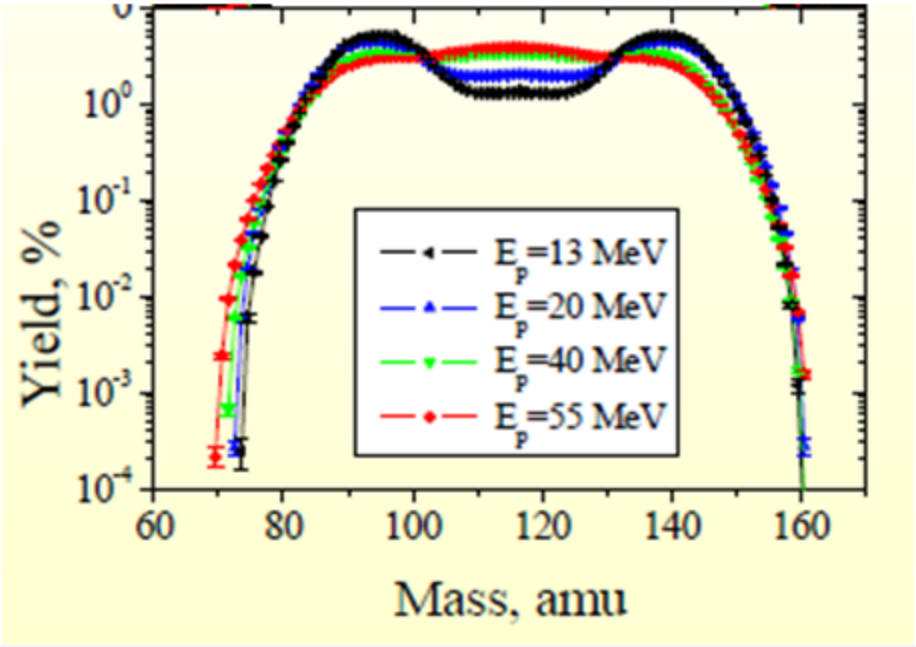
- Quasi-Fission

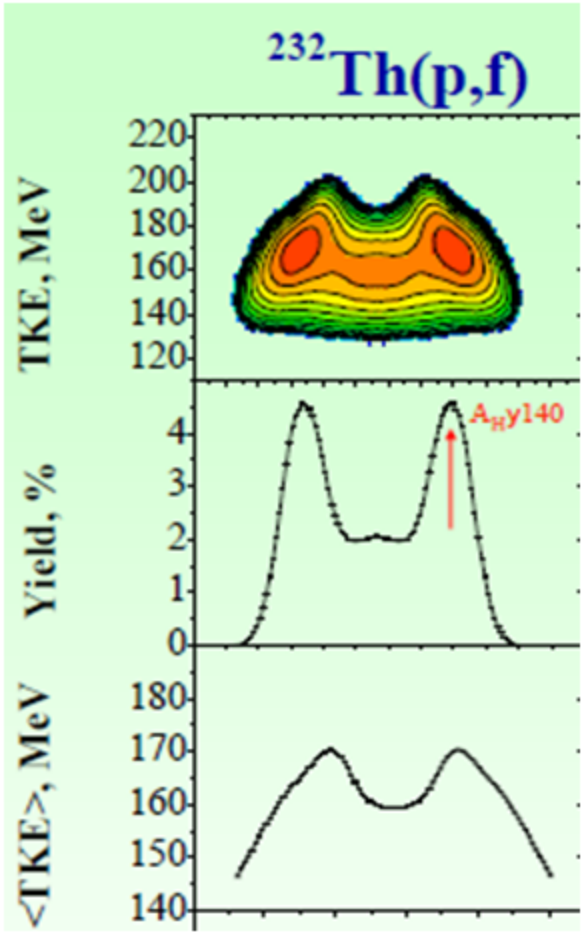


Nucleon induced fission

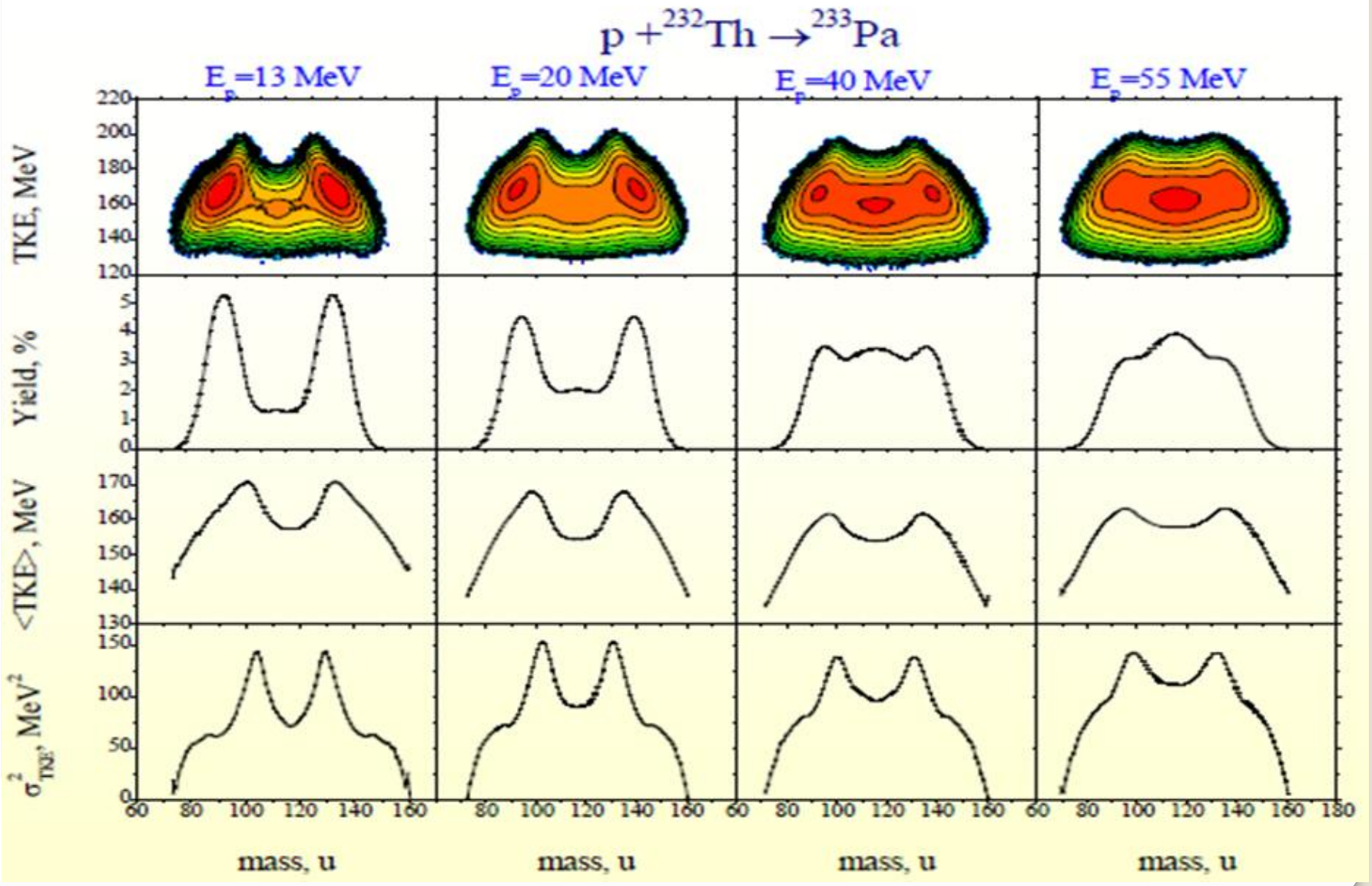
- Th-232(p,f) reactions at intermediate energies.
- Energies of the order of 10 MeV.
- Study of the different modes of fission: symmetric,asymmetric and superasymmetric.
- The dependence of nuclear fission mode on the energy shows a change from asymmetric towards symmetric fission with the increase in energy.
- The multimodal nature of the fission process is considered to be mainly determined by shell model effects.
- Proton shell Z=50 and neutron shell N=82 cause the symmetric mode of the fission process.

- Th-232(p,f) reaction
- The superasymmetric fission mode is caused by the nuclear shells with Z=28 and N=50.
- At beam energy E=13 MeV,a two-humped mass distribution is observed and only a small symmetric peak appears.
- At greater energies,E=55 MeV the data shows that the mass yield is predominantly in the symmetric region but asymmetric products can still be observed.





- Mass and energy distribution



FORMATION AND DECAY OF HEAVY HYPER NUCLEI

- Hypernuclear physics is of great interest because it stands at the intersection of nuclear physics, particle physics as well as astrophysics. Hypernuclear physics has recently received lot of attention as large number of hypernuclei are produced and studied experimentally.

- The hypernucleus is considered as a core of normal nucleus plus the hyperon. Formation and decay of hypernucleus depends on frequency of collision, transmission coefficient, cluster preformation probability, decay constant et.al.

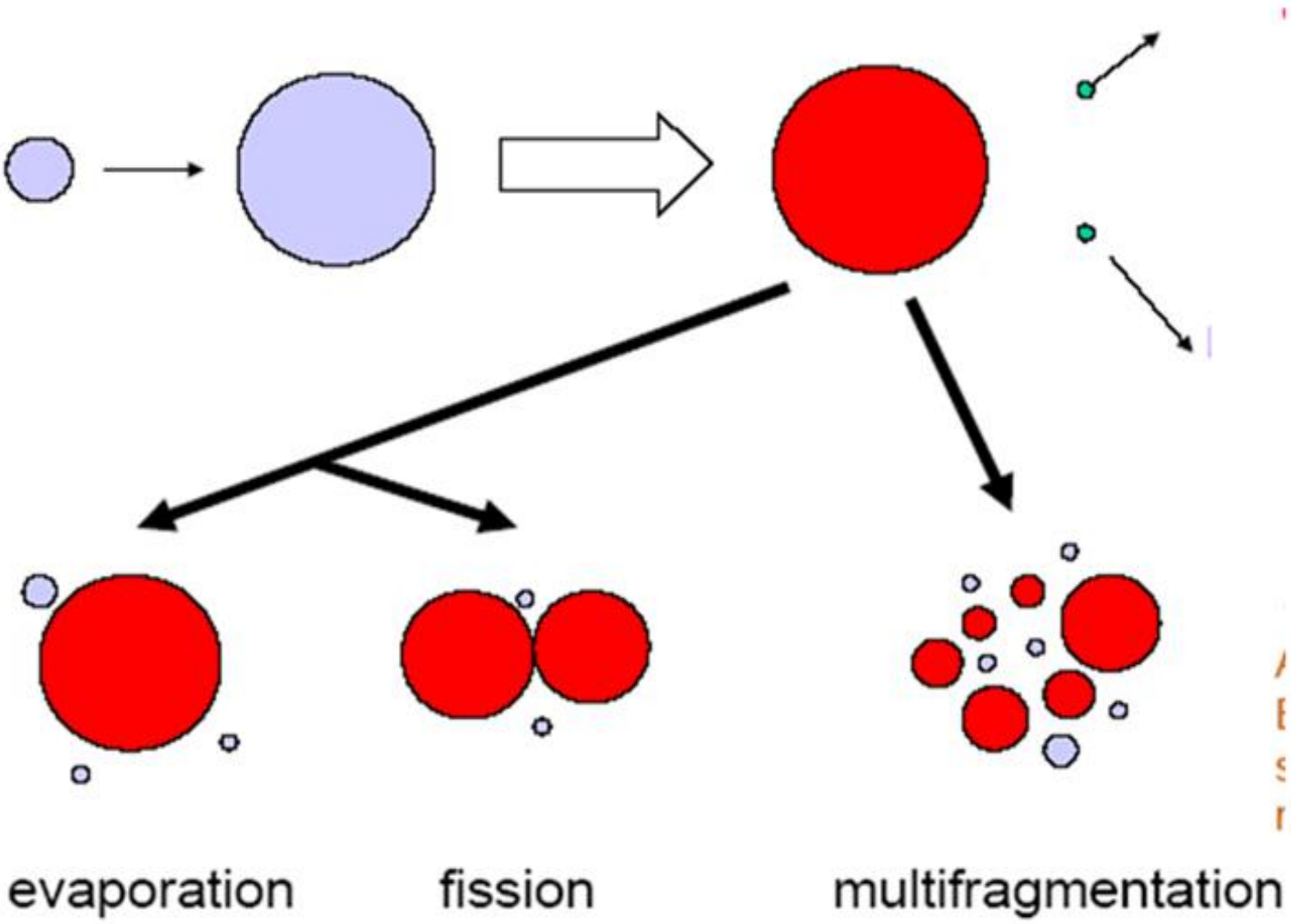


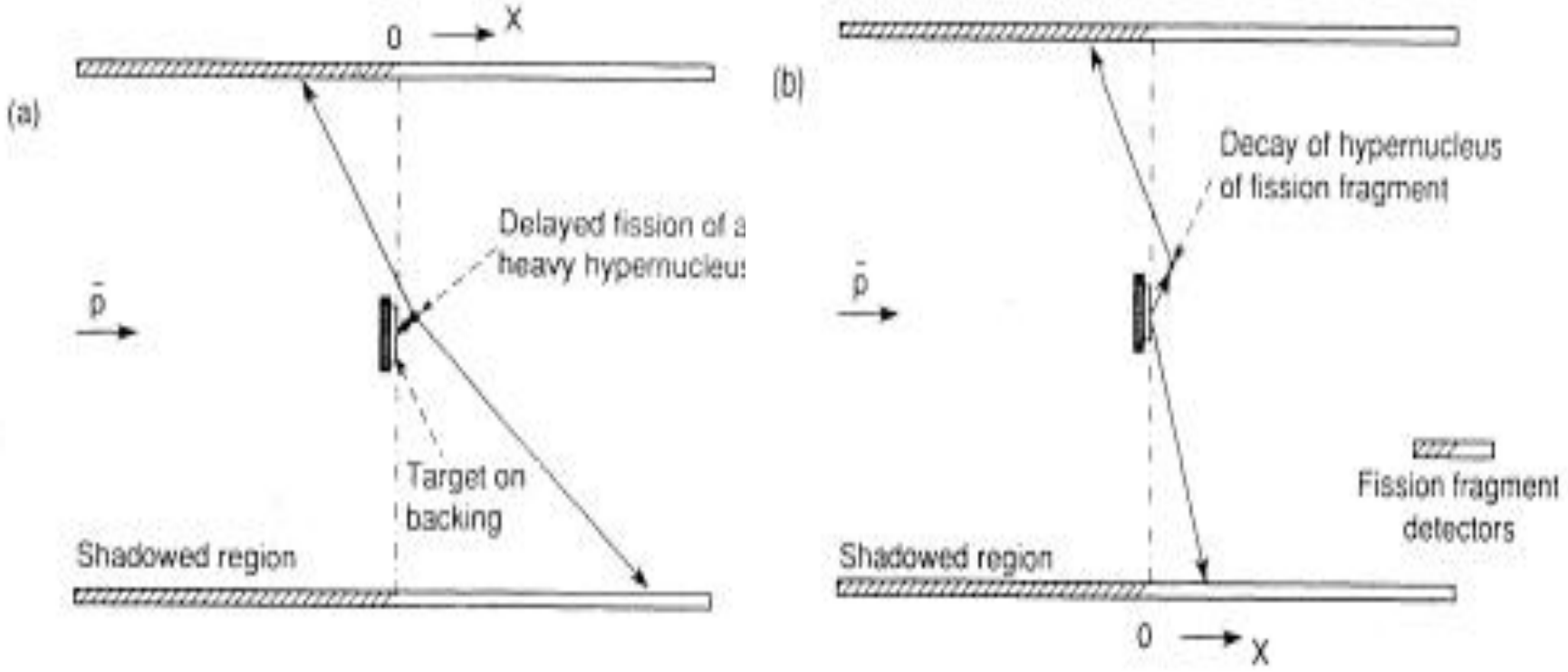
Fig.1 Possible consequence of hypernucleus [N.Buyukcizmeci et.al. Phys.Rev. C (2013) 014611].

Multifragmentation in intermediate and high energy nuclear reactions

Experimentally established:

- few stages of reactions leading to multifragmentation
- short time ~100fm/c for primary fragment production
- freeze-out density is around $0.1\rho_0$
- high degree of equilibration at the freeze-out
- primary fragments are hot

- In the figure there is showed (a) the experimental setup for measurement of delayed fission heavy hypernuclei, and (b) decay of hypernuclei of fission fragments



ACKNOWLEDGMENT

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Thank you for your attention