Application of Calorimetric Low-Temperature Detectors for the Investigations of Z-Yields Distributions of Fission Fragments

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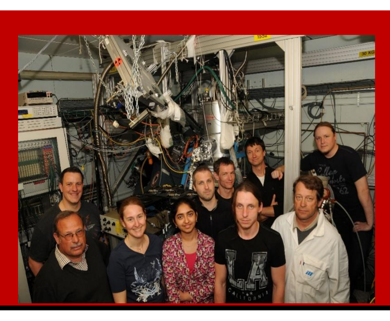
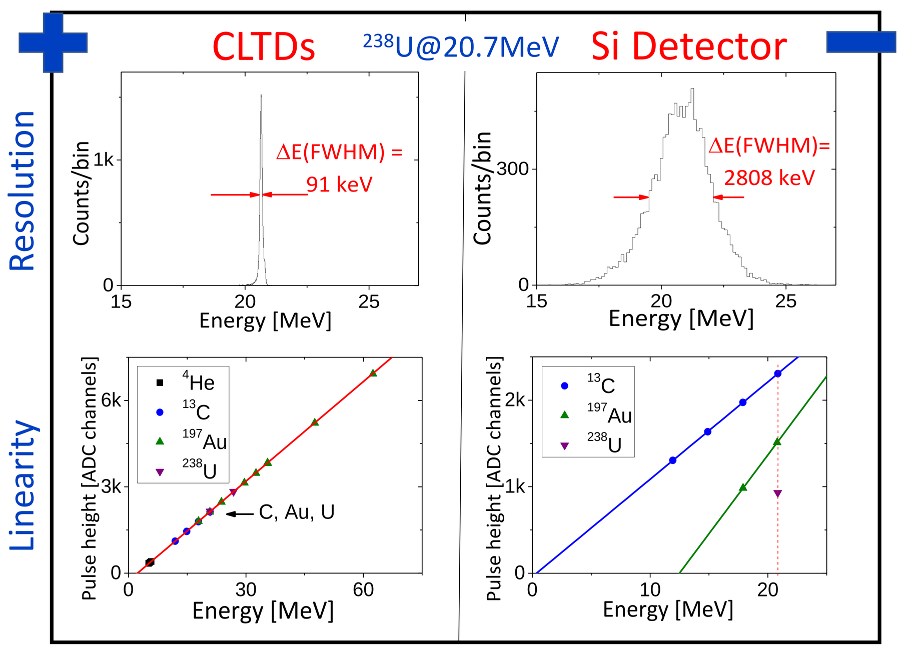


Introduction

Advantages of Calorimetric Low Temperature Detectors (CLTD`s) over conventional detectors with respect to basic detector properties: E.g. energy resolution, energy linearity, detection threshold and radiation hardness results in its wide range of applications in heavy ion research.

Recent Application – investigation of Z-yields distributions of fission fragments, from thermal neutron induced fission at ILL, Grenoble for better understanding of the nuclear fission processes.



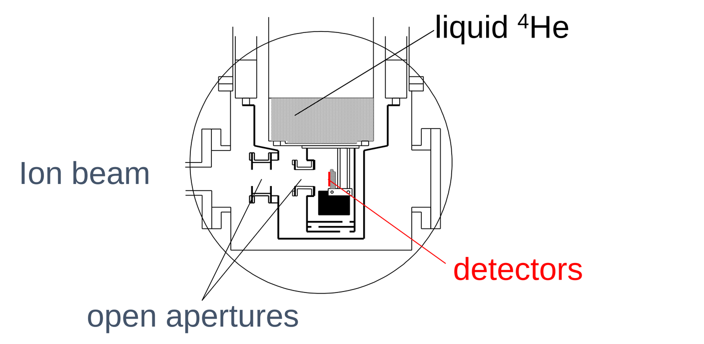
Plots from: Kraft-Bermuth et al., Rev. Sci. Instrum. 80, 103304 (2009)

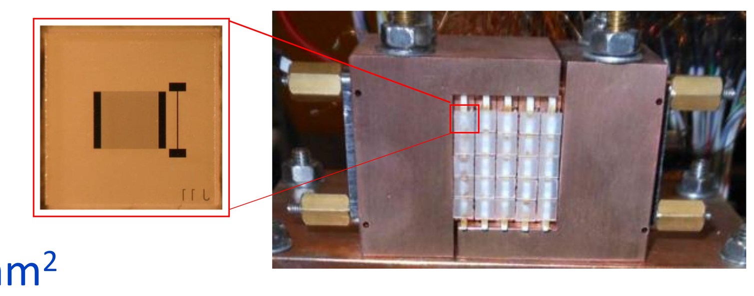
Detector Design

Incident energies: 1 MeV – few hundred MeV

Direct coupling of cryostat to beam line: $T_A \geq 1$ K

- Absorber: Sapphire
  - high Debye temperature
  - high resistivity against radiation damage
- Thermometer: superconducting Al film
  - Film thickness 10 nm: $T_C \sim 1.4$ K
  - individual temperature stabilization for each detector pixel
- Active area of the array with 25 pixels: 15×15 mm²





Experimental Set-up

Nuclear Reactor

- Produces fission fragments from ^{235}U, ^{239}Pu, ^{241}Pu(n_{th}, f) with different atomic masses A, kinetic energies E, ionic charges Q and nuclear charges Z.

LOHENGRIN

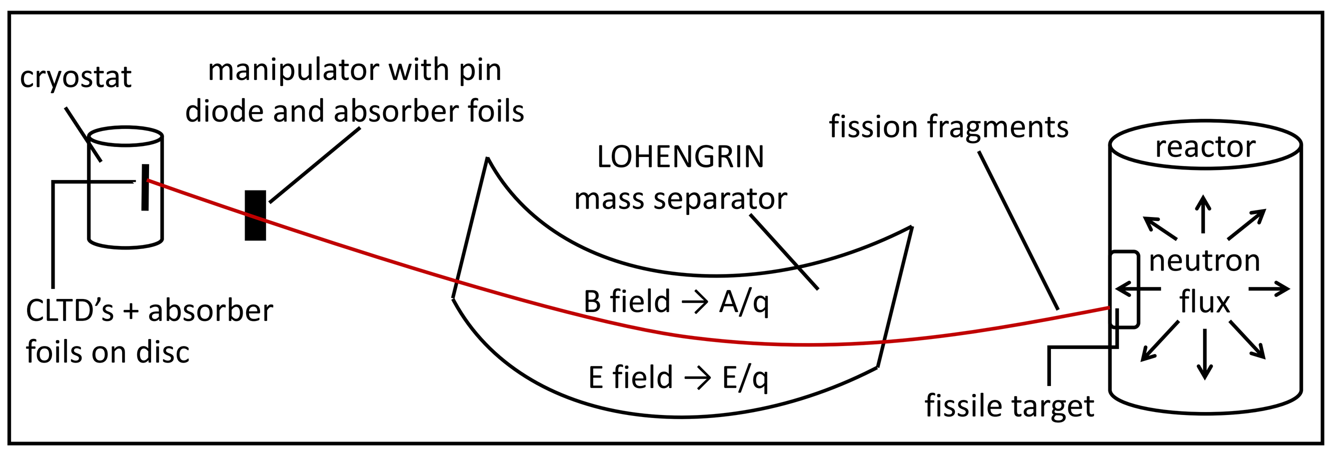
- Filters a specific A, E and Q but not Z.
- The spectrometer combines horizontal magnetic deflection (A/q) with subsequent vertical electrostatic deflection (E/q).

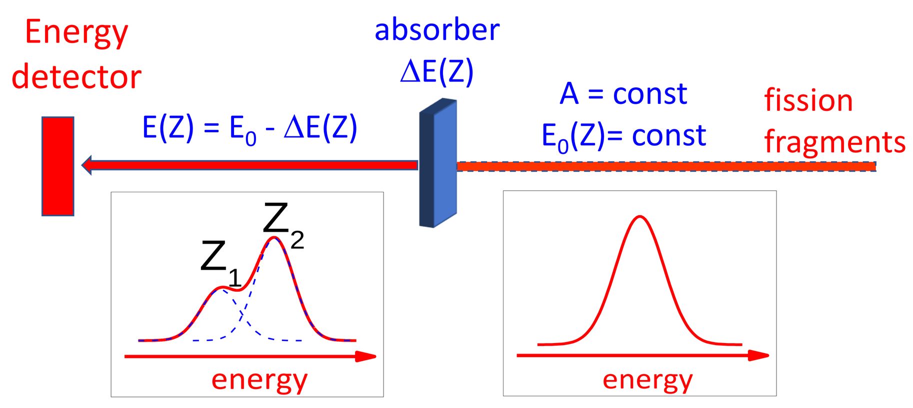
Absorber Foils

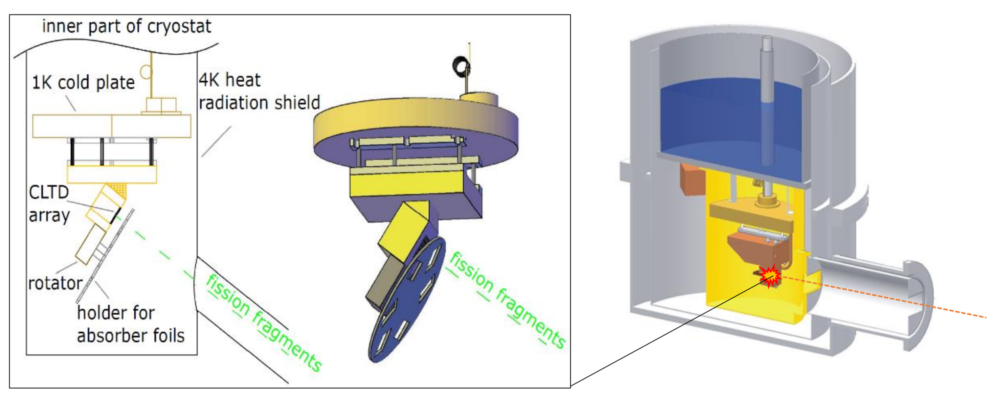
- Passive absorber method provides the Z-separation.
- Test at Munich tandem accelerator suggested Si_3N_4 foils to be a better choice compared to previously used Parylene C w.r.t homogeneity & energy loss straggling in the foils.

CLTDs in Cryostat

- CLTD's offer high energy resolution and negligible pulse height defect providing substantial advantage to observe the Z-separation for heavier ions.



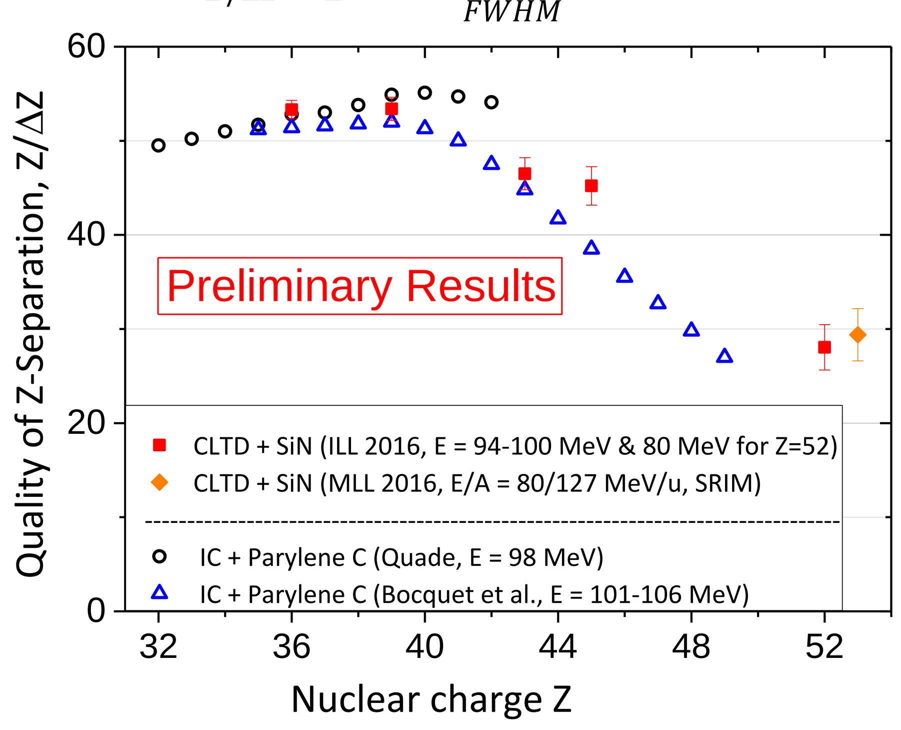




Preliminary Results

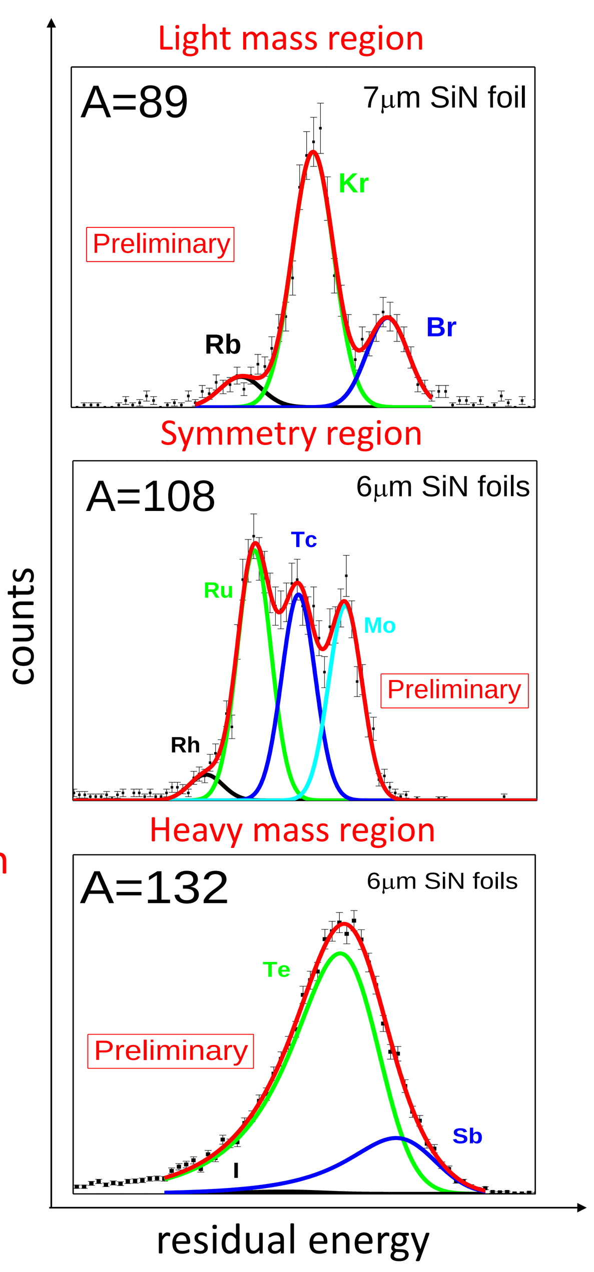
- Successful application of CLTDs for Z-yield measurements.
- For light masses results comparable to previously achieved best separation.
- With CLTD + SiN: Possibility to measure in symmetry and heavy mass region.
  → to study odd-even staggering
- Systematic study of Z-resolving power (Z/ΔZ).

$$Z/\Delta Z := Z \times \frac{\delta E(Z) - \delta E(Z-1)}{FWHM}$$



CLTD+SiN: good resolution & linearity

→Possibility to measure in symmetry & heavy mass region



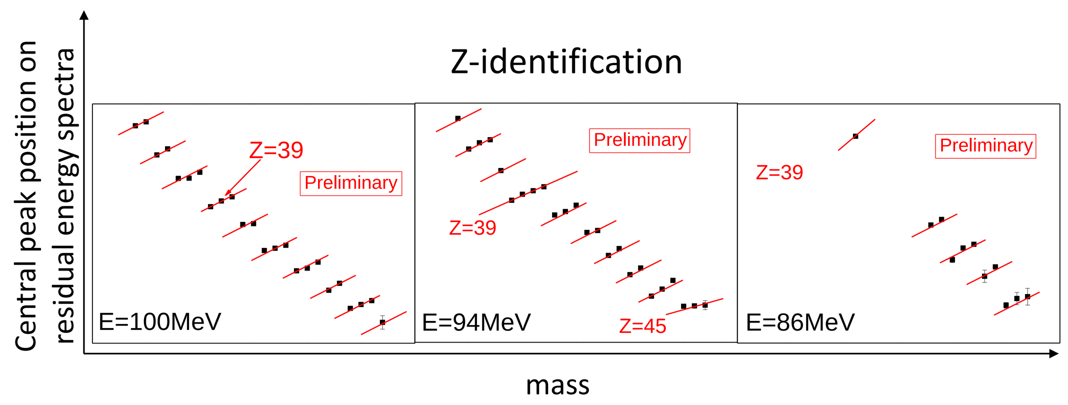
List of measured masses for different fissile nuclei

	^{235}U	^{239}Pu	^{241}Pu
Light mass region	92, 96	92	89-109
Symmetry region	104-110	109-113	110-112
Heavy mass region	132, 140	128-137, 139	x

- Extended data sets were cumulated to determine ^{92}Rb & ^{96}Y yield from ^{235}U, ^{239}Pu, ^{241}Pu(n_{th},f).

Important for **neutrino oscillations** and the **reactor antineutrino anomaly** studies

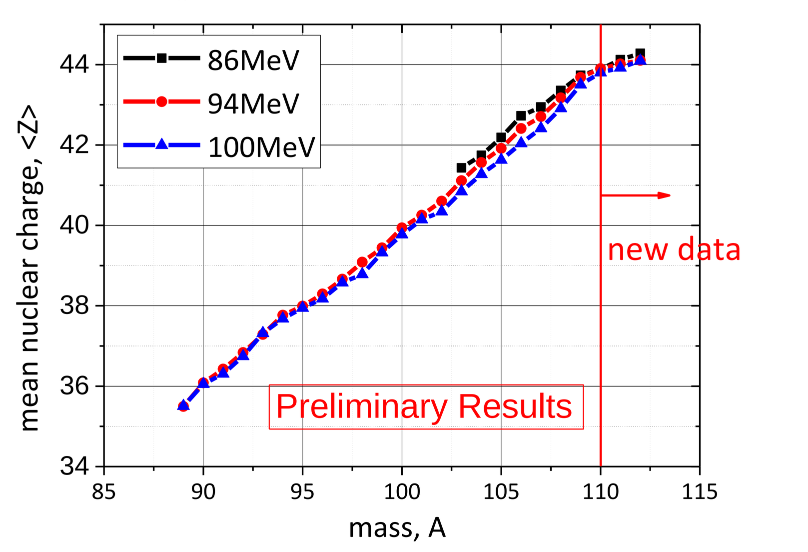
- Present result for cumulative yield of ^{92}Rb is in good agreement with the JAEA and JEFF databases whereas its in disagreement with the values reported by Tipnis *et al.*, Phys. Rev. C 58, 905 (1998).

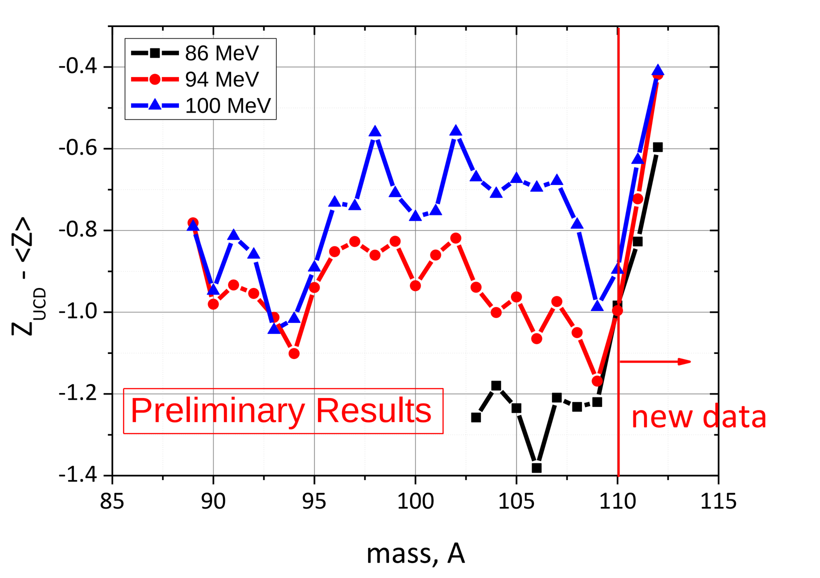


PRELIMNARY RESULTS
Analysis ongoing..

- Towards mass symmetry, new Z-yield measurements were made in the range A = 110 to 112 for ^{241}Pu, and A = 111 to 113 for ^{239}Pu.
- We gained first Lohengrin data on the isotopic yields in the light-mass group of ^{241}Pu fission.
- An attempt to extend isotopic yield measurements to the heavy-mass region was made.

Range of measurements for ^{241}Pu





Future Perspective

- Development of calorimetric ΔE (transmission) detectors facilitating ΔE -E measurements simultaneously would bring huge improvements in the quality of Z-separation crucial for these measurements.

References

- Cryogenic Particle Detection,Topics in Applied Physics 99 (2005)
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