Fission properties of N=100 isotones ^{176}Os, ^{177}Ir and ^{179}Au

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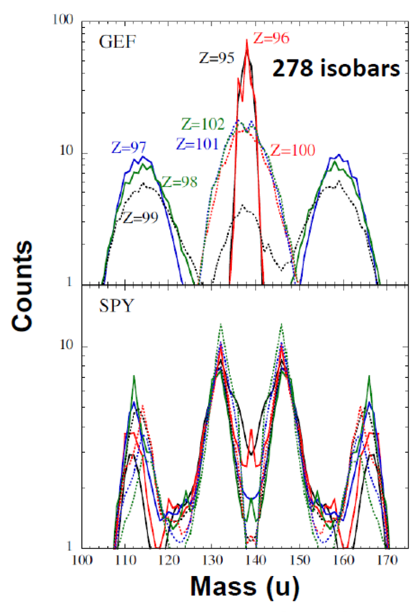
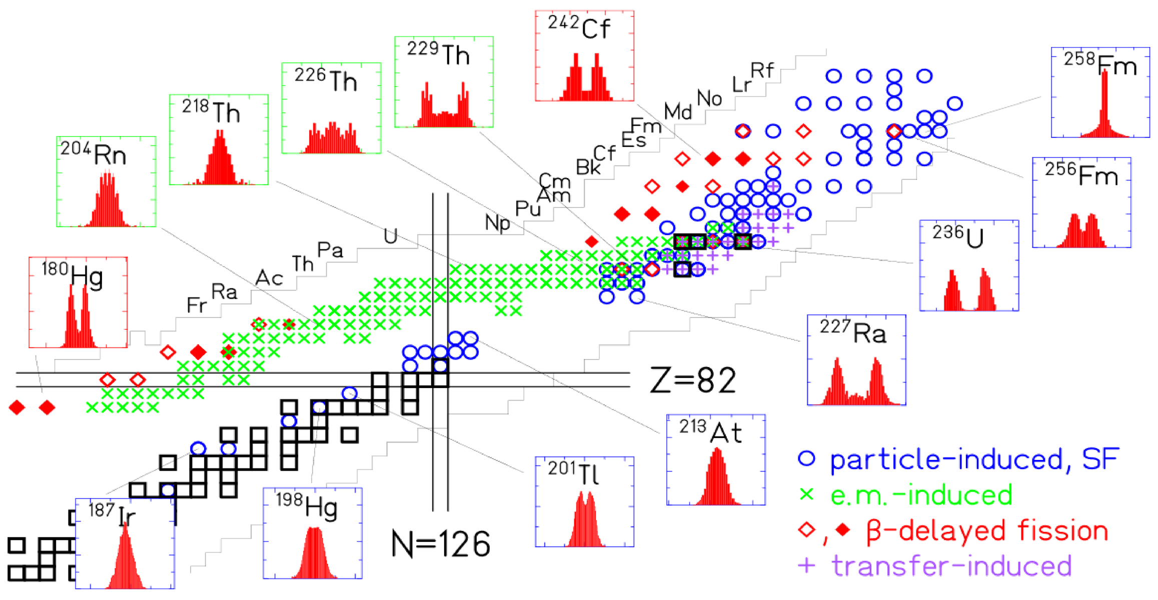
Introduction

Nuclear fission is a complex process where a single nucleus splits into two or more heavy nuclei, releasing a large amount of energy but also offering a rich laboratory for research on nuclear properties. Driven by its variety of applications, fission studies are traditionally made in the actinide region, i.e., in the isospin range $N/Z \sim 1.48$–1.58. The structure and composition of the **fission fragment mass distribution** and its dependence on **isospin** is crucial in accounting for the creation of $110 \leq A \leq 170$ in neutron star mergers.



FFMDs predicted by GEF and SPY models [1].



Typical fission fragment mass distributions in the actinide and ^{180}Hg region [2].

Problem: Projection of fission properties to nuclei matter at high isospin values.

Solution: Investigation of fission properties of nuclear matter with **low** isospin values, as function of Z and N.

Discovery of the **asymmetric fission of ^{180}Hg** [3] in 2010 has opened a new region for fission studies, drawing worldwide attention from both theory [4] and experiment. This is because nuclei in the ^{180}Hg region :

- are ***very neutron-deficient*** → good candidates to address the isospin issue;
- have an ***asymmetric FFMD***, which is ***not linked to shell effects in final fragments***.

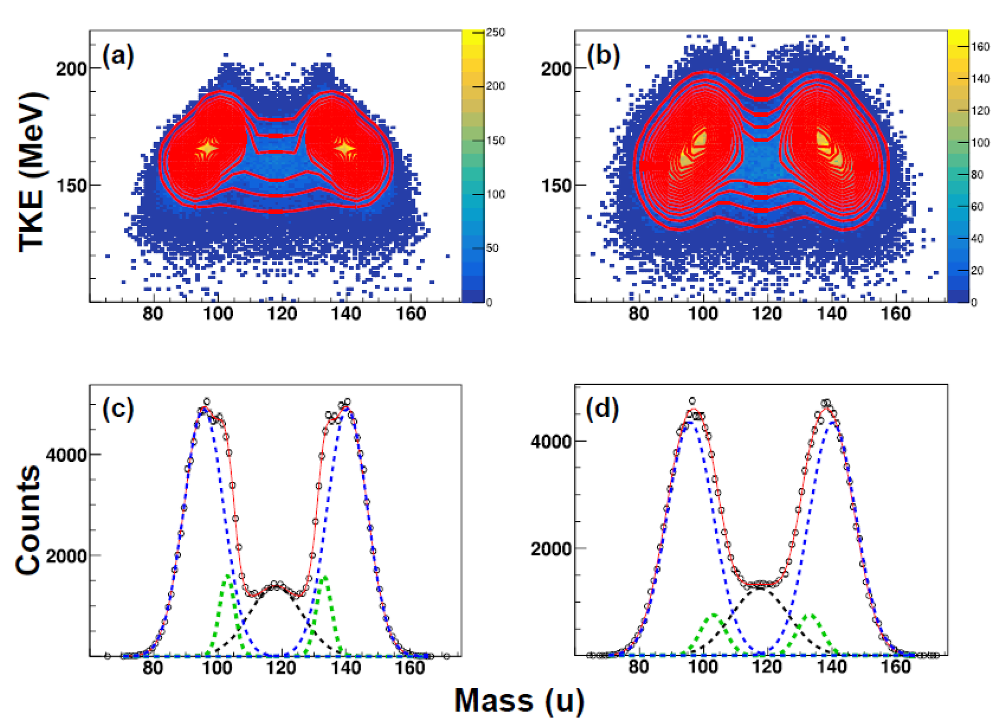
QUEST FOR EXTENSIVE SET OF EXPERIMENTAL DATA ON FISSION OBSERVABLES

Possible experimental techniques	Advantages	Disadvantages
Beta-delayed fission (βDF) :	Cold fission	Very limited range of nuclei
Complete fusion-fission reactions :	Wide range of nuclei	Excitation energy > 15 MeV

Present Study : *Fusion-fission reactions*

Reaction	Beam Energy	Excitation Energy
^{35}Cl + ^{141}Pr → ^{176}Os*	187 MeV	E* = 76 MeV
^{35}Cl + ^{142}Nd → ^{177}Ir*	173 MeV	
^{35}Cl + ^{144}Sm → ^{179}Au*	159 MeV	
	148 MeV	E* = 41 MeV

Simulation / With Resolution

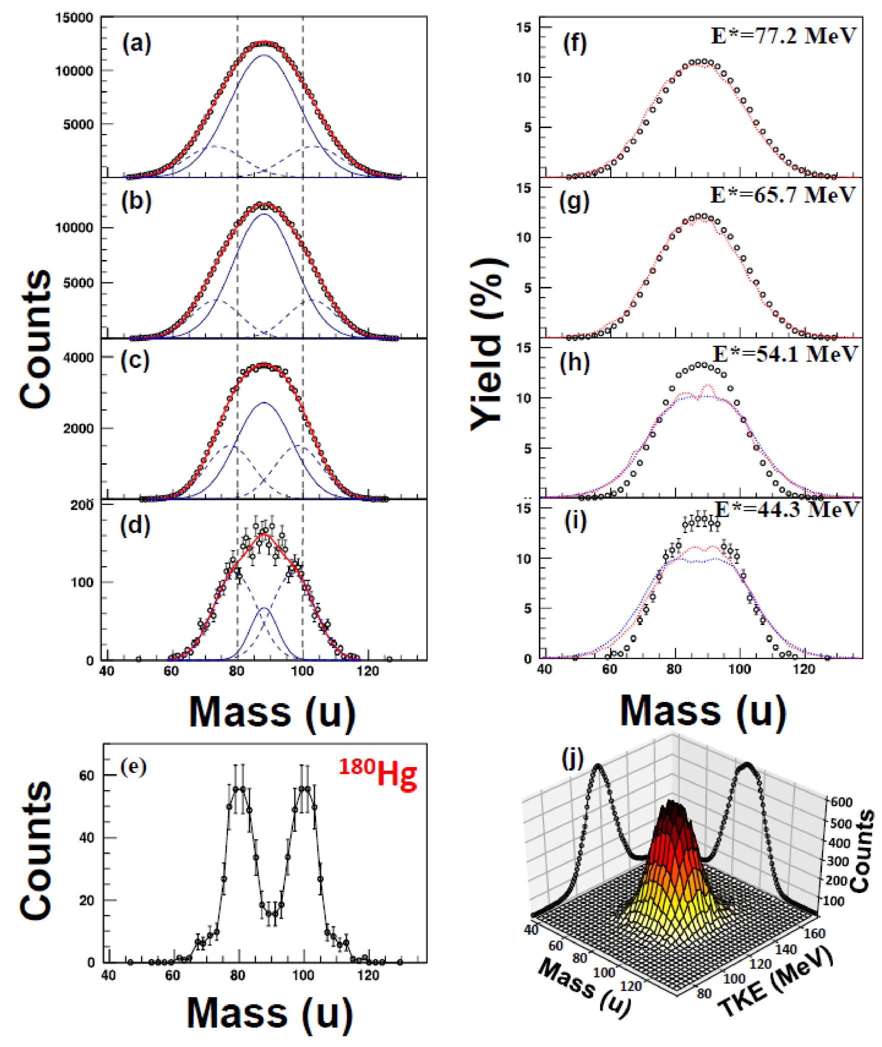


Assessing effect of experimental resolution:

- GEF simulation [5].
- ^{236}U at E*=20MeV , L = 20ħ.
- 3 main fission modes (1S, 2A)

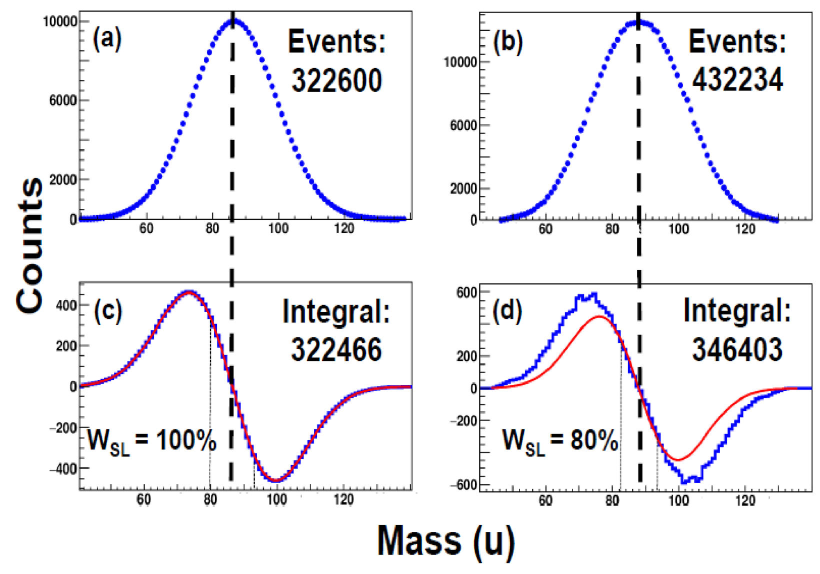
Selected Results

Fission mode identification in ^{176}Os



(a-d): ^{176}Os FFMD obtained at different E.*
(f-i): FFMDs from (a-d), normalized to 200%, in comparison with two Langevin calculations:[6,7]

Novel method for symmetric mode extraction : Derivative Method



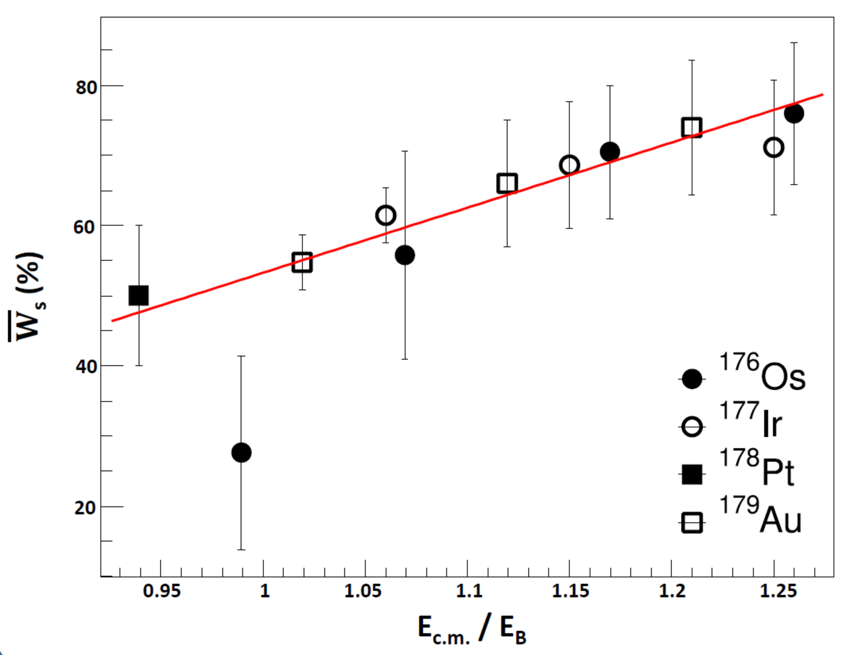
Upper row: *(a) Theoretical Gaussian function and (b) Experimental FFMD of ^{176}Os for E*=77.2 MeV.* ***Lower row:*** *figures depict the derivative curves obtained from the data in the upper panel.*

$$f'(x) = -f(x) * \frac{x-\mu}{\sigma^2},$$

$$f(x) = H * exp\left(\frac{-(x-\mu)^2}{2\sigma^2}\right).$$

Main Results

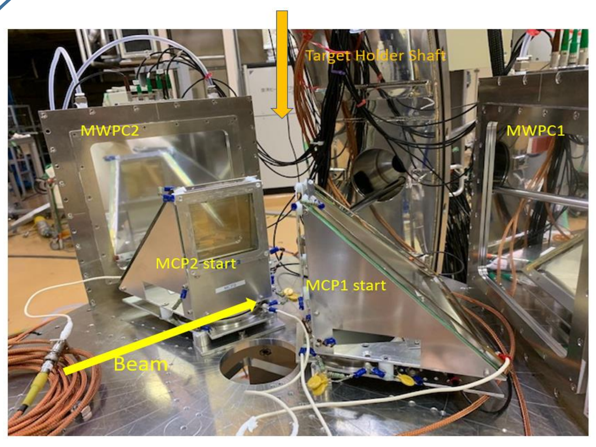
- ✓ High statistics data as f(E*)
- ✓ **Dependence of symmetric mode on excitation energy**

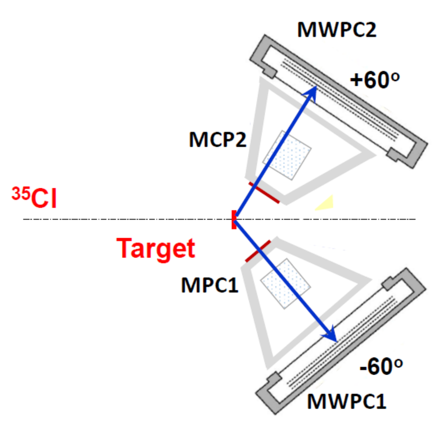


Average S-mode weight as a function of E_{cm}/E_b for the studied reactions. The point E_{cm}/E_b=0.94 is from [8].

- ✓ Good agreement with Langevin theoretical calculation.
- ✓ Fission mode extraction:
  - 2 main fission modes (1S, 1A)
  - Asymmetric mode drift-resolving power and E*.
- ✓ Non Gaussian FFMD's : mixture of symmetric and asymmetric fission.
- ✓ Fission mode : Similar average TKE *Consequence*: Similar fission configuration (unlike actinides)
- ✓ Origin of asymmetric mode: $A_L \approx 80$, $A_H \approx A_{CN}-80$ ^{80}Se (Z=34, N= 46) **octupolly deformed…**

Experimental Setup





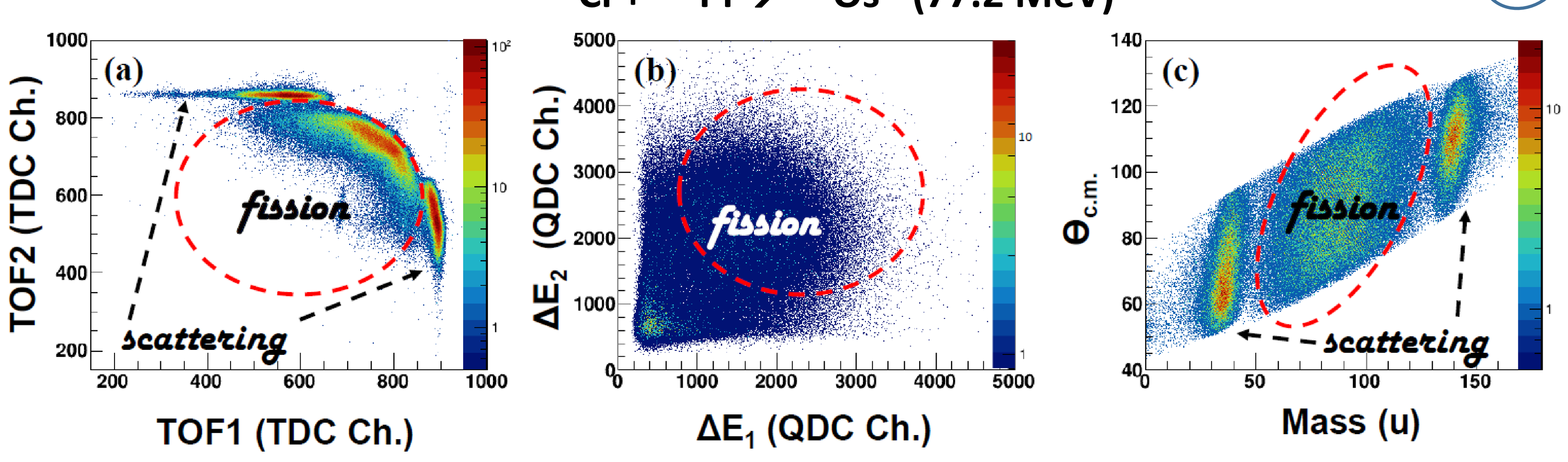
Fission chamber with mounted pairs of MCP-MWPC detectors.

Time-of-flight Difference Method (Two Body Kinematics) → **Mass, TKE Fission angles**

- ✓ Two independent TOF arms (MCP + position-sensitive MWPC detectors) :
  - **Correlated TKE-A data**
- ✓ High-efficient array of n/γ detectors (discrimination by PSD and TOF) :
  - **n/γ multiplicities and spectra**
- ✓ Advanced digital DAQ and electronics :
  - **Better BG suppression**

Fission event selection

^{35}Cl + ^{141}Pr→ ^{176}Os* (77.2 MeV)



Correlated raw data for (a) TOF signals between two pairs of MCP and MWPC detectors, (b) electric charges E2 and E1 from anodes of the MWPC detectors. (c) Mass-angle distribution (MAD).

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