FISSION PROPERTIES OF NUCLEI IN THE $^{180}$HG REGION

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OUTLOOK

- Introduction:
  1) Interest to the $^{180}$Hg region and
  2) Theory expectations and some experimental results

- JAEA experiment: fusion-fission of $^{178}$Pt
  1) Experiment
  2) Results (velocities, MED, fission modes)

- Summary & Future work
Region of interest: nuclei with low isospin

Fission properties as a function of isospin??

N/Z ~ 1.3
Bf~Sn ~ 10-12 MeV

Z=82

???

Actinides N/Z ~1.57 : MD : asymmetric

- particle induced
x - e.m. -induced E*~11 MeV

K.-H. Schmidt et al.
Trigger: Mass Distribution from fission of $^{180}$Hg

Andreyev et al. (PRL 105 (2010) 252502):

ASYMMETRIC mass split: $M_H = 100(4)$ & $M_L = 80(4)$

$E_{\text{ff}_1} - E_{\text{ff}_2}$ coincidences $\sim 330$ events

Singles $111\text{ ff}$ $\sim 20\text{ ff/h}$

$Z$ identification: UCD rule $\Rightarrow \text{ } ^{100}\text{Ru} (N=56,Z=44)$ and $^{80}\text{Kr} (N=44,Z=36)$
New Region of Asymmetric Fission: p-rich sub-lead region

FIG. 3. (Color online) Calculated symmetric-yield to peak-yield ratios for 987 fissioning systems. Black squares (open in colored regions, filled outside) indicate β-stable nuclei. We find a new, contiguous region of asymmetric fission separated from the classical location of asymmetric fission in the actinides by an extended area of symmetric fission.

Conclusions: Our self-consistent theory suggests that excitation energy weakly affects the fission pattern of the nuclei considered. The transition from the asymmetric fission in the proton-rich nuclei to a more symmetric fission in the heavier isotopes is governed by the shell structure of pre-scission configurations.
JAEA : Mass Distributions from fission of $^{180,190}$Hg

• $E^* = 34$-$71$ MeV
• 2010-2014: JAEA, Tokai

✓ Robustness with $E_{exc}$:

Asymmetric MD up to $E^* = 70$ MeV

“The mass distributions for both Hg isotopes could be well reproduced with a single asymmetric fission mode”

➢ No symmetric mode?

Best data set in the region!

Fragment-mass, kinetic energy, and angular distributions for $^{234}\text{U}(n, f)$ at incident neutron energies from $E_n = 0.2\text{ MeV}$ to $5.0\text{ MeV}$

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$\overline{TKE}_{\text{symm}} < \overline{TKE}_{\text{asymm}}$

$\sigma^A_{\text{symm}} > \sigma^A_{\text{asymm}}$

FIG. 9. The experimental two-dimensional TKE vs mass data is fitted with three modes. Equation (12) was used to parametrize the data. In total, three fission modes (S1, S2, and SL) were taken into account.
$^{178}\text{Pt Experiment}$: July 2016, JAEA: $^{36}\text{Ar} + ^{142}\text{Nd} \rightarrow ^{178}\text{Pt}$

Target: $\text{C} + \text{NdF}_3$

- $75 \mu g/cm^2$
- $42 \mu g/cm^2$

Diagram: Cross section (mb) vs. $E_{\text{c.m.}}$ (MeV) and $E_{\text{LAB}}$ (MeV) for $^{36}\text{Ar} + ^{42}\text{Nd}$. Key regions for Fusion, Evaporation, and Fission are highlighted.
JAEA Experimental Setup

- **MWPC 1**
- **MWPC 2**
- **MCP 1**
- **MCP 2**
- **ToF 1** ~ 30 cm
- **ToF 2**

- **2 independent TOF arms**
- **44 n/γ detectors** (TOF and PSD)

**Equations:**

\[
A_L \cdot v_L = A_H \cdot v_H
\]

\[
TKE = 0.5 \cdot A_{CN} \cdot v_L \cdot v_H
\]

**DAQ:** digital triggerless
Results: Fission-Fragment Velocities (TOF2)

Expected:
- MDs: predominantly asymmetric
- MDs: must contain the symmetric component

I. Tsekhanovich et al, arXiv: 1804.01832
**Mode position**: Partial Mass Distributions

$$\text{TKE(Viola)} = 135.9 \text{ MeV}$$

Symmetric mode: \( \frac{A_{CN}}{2} \)

Asymmetric mode: \( A_L = 79 \)
\( A_H = 99 \)

I. Tsekhonovich et al, arXiv: 1804.01832
Results: Fission-Fragment Mass Distributions

- MD shapes well reproduced
- Symmetric mode is wider
- Symmetric mode yield ~ 30%

I. Tsekanovich et al, arXiv: 1804.01832
Fission of $^{178}$Pt : PES

Nuclear Density Functional Theory results:

- **Most probable division:** $^{80}$Br + $^{98}$Tc
- **Symmetric division:** in competition

I. Tsekhmanovich et al, arXiv: 1804.01832
Summary for $^{178}$Pt :

- New MED data: apparently insensitive to $E_{\text{exc}}$
- Predominantly asymmetric mass distribution
- Co-existing fission modes
- Fission mode properties as in actinides: insensitivity to isospin

Work to do:

- Need for more experimental data in the new island of asymmetric fission:
  i. To establish systematics on yields
  ii. Fission mode competition, as function of $N$, $Z$ and $E_{\text{exc}}$ of CN

New Challenge:

fission studies at $E_{\text{exc}} \sim Sn$

symmetric fusion reactions:

JAEA tandem:
Zr beams available!!
Who is involved:

CENBG:
- S. Czajkowski
- B. Jurado
- I. Tsekhanovich

JAEA:
- K. Nishio
- K. Hirose
- H. Makii
- R. Orlandi
- M. Vermeulen

York University:
- A. Andreyev

RIKEN:
- K. Morimoto
- T. Tanaka (& Kyushu University)
- K. Morita (& Kyushu University)

Theory:
- W. Nazarewich (MSU/FRIB, USA)
- M. Matheson (MSU/FRIB, USA)
- M. Warda (Lublin, Poland)
- J. Sadhukhan (Kolcata, India)
Thank you for your attention!