Probing fission fragments of $^{182,183}\text{Hg}$ nuclei at energies around coulomb barrier

- Mercury mass-asymmetry
- Deformed mercury isotopes $^{182,183}\text{Hg}$
- Experimental set-up
- Results and comparison
- Summary and outlook

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Asymmetry region in Nuclear Chart

Figure. Calculated symmetric-yield to peak-yield ratios for 987 fissioning systems. Black squares (open in colored regions, filled outside) indicate $\beta$-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.

Asymmetric fission in Sub-Lead region

Calculations: courtesy P. Moller (LANL) and J. Randrup (LBNL)
Probability of asymmetric fission for deformed nuclei is higher compared to spherical nuclei.

- $^{182}\text{Hg}$ - Prolate $\delta \langle r^2 \rangle$ (-0.7)
- $^{183}\text{Hg}$ - Oblate $\delta \langle r^2 \rangle$ (-0.1).

Mean-square charge radii calculated with respect to $A=N+Z=198$.

Experimental details

- Experiment was conducted in FLNR CORSET setup, $^{40}$Ca beam extracted from U-400 cyclotron
- Energy - 172, 192, 212 and 244 MeV
- Energy resolution - 2%
- Target thickness:
  - $^{142}$Nd - 225 $\mu$g/cm$^2$
  - $^{143}$Nd - 196 $\mu$g/cm$^2$
- Carbon backing - 30 $\mu$g/cm$^2$
- Beam Intensity - 80-100 nA
Experimental setup & Procedure

- Double-arm TOF (time-of-flight) CORSET spectrometer which functions on the basis of 2V method was used.
- Time resolution - 150 ps
- Angular resolution - 0.3°
- Position sensitive MCP’s are used to detect the particle in the stop detector.
- To analyse and process the data we use standard two-body kinematics.
- Energy losses due to start detector foil and target backing are taken into account during the data analysis.
Results for $^{182}$Hg
Results for $^{183}\text{Hg}$
Mass distribution

- For $^{182}$Hg and $^{183}$Hg asymmetric peaks are observed at 81 and 101 ($\pm 1$).
- Asymmetric component contribution diminishes with increase in energy.
- No additional difference observed for $^{183}$Hg.
TKE distribution

**VIOLA**
- 143.2 MeV - $^{182}$Hg
- 143 MeV - $^{183}$Hg
Comparison of $^{182}\text{Hg}$ and $^{183}\text{Hg}$ fission mass distribution

- Largest deviation in yield is found for lab energy 212 MeV.
- We find appreciable agreement for lab energies 172 and 192 MeV.
Comparison with theory and previous experiment

\[ {}^{40}\text{Ca} + {}^{142}\text{Nd} \rightarrow {}^{182}\text{Hg} \]

- Prasad et al. 33.6 MeV
- Moller et al. 20 MeV
- Moller et al. 40 MeV
- Current data 37 MeV
Summary & Outlook

- **Mass-TKE distributions** as we measured have been measured within 37-96 MeV excitation energy for $^{182,183}\text{Hg}$, populated using $^{40}\text{Ar}+^{142,143}\text{Nd}$ respectively.

- Our study indicates unique fission behavior, where prolate deformed nuclei shows identical result with oblately deformed nuclei and the result contradicts the previous observation of fission of deformed nuclei.

- Analysis was made using Rotational Liquid Drop and Double Gaussian model.

- At lab energy 244 MeV, where mass distribution is very wide, we are expecting fast-fission since the asymmetric contribution is low.

- Comparative analysis showed that only at lab energy 212 MeV the difference in the yield is higher compared to the rest of the energies yield difference.

- The presence and effect of deformation on the fission fragment mass distribution in higher excited energy needs to be investigated.

*Thank you.*
Collaboration

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## Comparison

<table>
<thead>
<tr>
<th>Reaction</th>
<th>$E_{\text{lab}}, \text{MeV}$</th>
<th>$E_{\text{cm}}/E_B$</th>
<th>$E^*, \text{MeV}$</th>
<th>$\langle l \rangle$ ($\hbar$)</th>
<th>$\sigma_M$ (amu)</th>
<th>$\sigma_E$ (amu)</th>
<th>$L_{cr}$, $\hbar$</th>
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<tbody>
<tr>
<td>$^{40}\text{Ca} + ^{142}\text{Nd} \rightarrow ^{182}\text{Hg}$ ($L(B_f=0) = 69 , \hbar$) $TKE_{\text{Viola}} = 143.2 \text{ MeV}$</td>
<td>172</td>
<td>0.97</td>
<td>37</td>
<td>9</td>
<td>9</td>
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<td></td>
<td>192</td>
<td>1.08</td>
<td>52</td>
<td>30</td>
<td>10.2</td>
<td>10.1</td>
<td>49±6</td>
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<td>1.19</td>
<td>68</td>
<td>46</td>
<td>11.2</td>
<td>11.4</td>
<td>67±7</td>
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<tr>
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<td>244</td>
<td>1.37</td>
<td>93</td>
<td>62</td>
<td>15.4</td>
<td>12.9</td>
<td>87±10</td>
</tr>
<tr>
<td>$^{40}\text{Ca} + ^{143}\text{Nd} \rightarrow ^{183}\text{Hg}$ ($L(B_f=0) = 70 , \hbar$) $TKE_{\text{Viola}} = 143 \text{ MeV}$</td>
<td>172</td>
<td>0.97</td>
<td>39</td>
<td>10</td>
<td>9.6</td>
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<td>68±8</td>
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<td>244</td>
<td>1.37</td>
<td>96</td>
<td>66</td>
<td>15.6</td>
<td>13.6</td>
<td>88±10</td>
</tr>
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Asymmetric fission in Mercury

Asymmetric mass distribution was observed in spite of a mass symmetric split that could lead to two $^{90}\text{Zr}$ fragments, with magic $N=50$ & semimagic $Z=40$.

$^{180}_{80}\text{Hg}_{100} \rightarrow ^{90}_{40}\text{Zr}_{50} + ^{90}_{40}\text{Zr}_{50}$?
