Nuclear level density and gamma-ray strength function of $^{240}\text{Pu}$ and $^{243}\text{Pu}$ (Part I)

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Motivation

- Fundamental nuclear structure
- Enables Cross Sections calculations via Hauser–Feshbach formalism ➔ advanced nuclear reactors
  ➔ waste management
  ➔ nuclear security
Previous work with actinides

PHYSICAL I

Constant-temperature level density

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G. M. Tve

PRL 109, 162503 (2012) PHYSICAL

Observation of Large Scis

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T. Renstrøm,1 S. Siem

PHYSICAL RE

Level density and γ-ray strengt

T. G. Torny,1,2,* M. Guttormsen,1 T. K. Eriksen,1 A
A. C. Larsen,1 T. Renstrøm,1

Diagram:

- Present experiment, 233Th
- Photo-nuclear reaction, 232Th
- f(E1) from (n,γ)
- f(M1) from (n,γ)

Radiative strength function (MeV⁻³)

Γ-ray energy Eγ (MeV)
Experimental Setup

- Beam time: June 2014
- 12 MeV deuteron beam on $^{239}$Pu and $^{242}$Pu targets (0.400 mg/cm$^2$ on 1.8 mg/cm$^2$ Be backing)
- p, $\gamma$ coincidence with SiRi
- Fission, $\gamma$ coincidence with NIFF

Tornyi et al. NIM A 738 (2014)
Experimental Setup

Siri 8x8 ΔE–E particle telescope
At 126° to 140° with respect to the beam

Cactus: 28 5”x5” NaI γ detectors
Experimental Setup

- NIFF: low pressure gas filled PPACs
  ➔ insensitive to light ions

Allows veto of fission events

Tornyi et al. NIM A 738 (2014)
SiRi calibration

\(^{239}\text{Pu}\) target

\(^{242}\text{Pu}\) target
SiRi Calibration

Second calibration point needed

239Pu (d,d) on gs
SiRi Calibration

Where is the $^{239}$Pu(d,p) to the ground state?
Heavy or light?

Different strips correspond to different angle of the detector in respect to the incident beam

Light nuclei are more sensitive than heavy nuclei

Moving peak believed to be for Al

experiment with just the Al frame
Low Z contaminant from target fabrication process

Low Z($^{37}$Cl)

$^{239}$Pu gs

contaminant
Particle-$\gamma$ coincidence matrix
Particle-$\gamma$ coincidence matrix

$^{239}\text{Pu}(d,p\gamma)^{240}\text{Pu}$

$^{242}\text{Pu}(d,p\gamma)^{243}\text{Pu}$
Unfolding procedure

Unfolding: Correct $\gamma$ spectra with known detector response
See: M. Guttorsen et al., NIM A 374, 371 (1996)

Huge $^{17}$O contamination peak at 870 keV
First generation extraction

First generation: Extract primary $\gamma$ from the total $\gamma$ spectra
See: M. Guttorsen et al., NIM A 255, 518 (1987)
Partial conclusion

Important contamination with light (O, Be) and heavy nuclei causing some pile-up

For first generation matrix extraction, we had to remove an O peak (only important peak in the excitation energy range of interest)

Following in Fabio’s talk: Nuclear level density, $\gamma$–ray strength function and cross section calculation with Talys
Many thanks

- Oslo Cyclotron Laboratory
## Target contamination

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Number of atoms</th>
<th>% error</th>
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</thead>
<tbody>
<tr>
<td>U237</td>
<td>2.2E6</td>
<td>14.1</td>
</tr>
<tr>
<td>Pu238</td>
<td>3.5E13</td>
<td>9.5</td>
</tr>
<tr>
<td>Pu241</td>
<td>6.9E13</td>
<td>32.7</td>
</tr>
<tr>
<td>Pu242</td>
<td>1.5E18</td>
<td>2.7</td>
</tr>
<tr>
<td>Am241</td>
<td>1.5E11</td>
<td>6.5</td>
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</table>
## Other possible contamination

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Qvalue (MeV)</th>
<th>T1/2</th>
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</thead>
<tbody>
<tr>
<td>Pu239</td>
<td>4.3</td>
<td></td>
</tr>
<tr>
<td>Pu237</td>
<td>4.8</td>
<td>46 d</td>
</tr>
<tr>
<td>Np234</td>
<td>4.8</td>
<td>4 d</td>
</tr>
<tr>
<td>U233</td>
<td>4.6</td>
<td>1.6E5 y</td>
</tr>
<tr>
<td>Am239</td>
<td>4.9</td>
<td>11.9 h</td>
</tr>
</tbody>
</table>
Fission following $^{239}\text{Pu}(d, p)$

#fission events per Eex

<table>
<thead>
<tr>
<th>m_fiss_ex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entries</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>RMS</td>
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</tbody>
</table>

Eex
Fission following $^{242}\text{Pu}(d,p)$

#fission events per Eex

<table>
<thead>
<tr>
<th>m_fiss_ex</th>
<th>Entries</th>
<th>Mean</th>
<th>RMS</th>
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<tr>
<td></td>
<td>2493494</td>
<td>6479</td>
<td>1165</td>
</tr>
</tbody>
</table>
Particle group: 
$E_x = 835 \pm 10$ keV

Magne Guttormsen,
Private communication