Preliminary Results of a 2V-2E Fission Fragment Spectrometer

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In collaboration with
The SPIDER group
Los Alamos National Laboratories
Outline

• Motivation/Introduction
• Detector Overview & Equations
• Time of Flight Detector
• Ionization Chamber
• Preliminary Results
• Conclusions & Future Work
  – Active Cathode
SPectrometer for Ion DEtection in fission Research (SPIDER)

• Motivation
  – More information for fission fragment inventories
    • Current data limited to ~thermal & 14MeV (DT)
    • Waste, reactors, nonproliferation, stockpile stewardship
    • Verification of simulation and theory regarding fundamental fission processes
  – Goal: less than or equal to 1 amu mass resolution
Fission Fragments

An example of one of the many reactions in the uranium-235 fission process.

\[ n + ^{235}_{92}U \rightarrow ^{236}_{92}U \]

\[ ^{236}_{92}U \rightarrow ^{144}_{56}Ba + ^{89}_{36}Kr + 3n + 177\text{MeV} \]

Fission yields fragments of intermediate mass, an average of 2.4 neutrons and average energy about 215 MeV.

Neutrons can initiate a chain reaction.
Fission Fragments: Nuclear Peanuts
Fission Fragments

Diagram showing the fission process of U-235, producing elements like Ba-141, Kr-92, Cs-144, Xe-142, Sr-91, and Rb-90.
Spectrometer Overview

- **2V-2E**

\[ KE_f = \frac{1}{2} m_f v_f^2 = \frac{1}{2} m_f \left( \frac{l}{t} \right)^2 \]

\[ m_f = \frac{2KE_f}{v_f^2} = \frac{2KE_f}{\left( \frac{l}{t} \right)^2} \]

\[ \delta m^2 = \left( \frac{dm}{dE} \right)^2 + \left( \frac{dm}{dl} \right)^2 + \left( \frac{dm}{dt} \right)^2 \]
1-Arm SPIDER

MCP #2

MCP #1

Fission Source

Ionization Chamber
Time of Flight

A: Source
B: Timing signal #1
C: Timing signal #2
Time of Flight

MCPs:
- Fast timing signal
- Similar to proportional counters

Pu-239 Alpha Source:

<table>
<thead>
<tr>
<th>TOF</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Entries</td>
<td>2236</td>
</tr>
<tr>
<td>Mean</td>
<td>6.388e+04</td>
</tr>
<tr>
<td>RMS</td>
<td>839.9</td>
</tr>
<tr>
<td>$\chi^2$ / ndf</td>
<td>60.39 / 30</td>
</tr>
<tr>
<td>Constant</td>
<td>58.25 ± 2.67</td>
</tr>
<tr>
<td>Mean</td>
<td>6.39e+04 ± 5.61e+00</td>
</tr>
<tr>
<td>Sigma</td>
<td>156.2 ± 5.4</td>
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</tbody>
</table>
Limits of the Mylar Window

Results of SRIM/TRIM Data

- % (std/ave) vs. Thickness (μm)
- Standard Deviation (MeV) vs. Thickness (μm)
- Average (MeV) vs. Thickness (μm)

Graphs showing the relationship between thickness and various parameters for different energies.
Ionization Chamber
Basic DAQ

Ionization Chamber

Pre-Amp

Amplifier

MCA

Power Supply

Pulse Height [V]

Time [μs]
Ionization Chamber Basics

- IC's operate in the saturation region
Guard Rings

Numerical analysis of electric field within the ionization chamber using SIMION
Alpha Spectroscopy

Tri-nuclide data:
Pu-239, Am-241, Cm-244

Figure 7. Alpha mixed source spectrum recorded with CERN diode at room temperature and -60 V.
Preliminary Results

Timing histogram

Energy histogram

235-U(n\text{\_th}, f)X

Ten hour data run, uncorrelated data
Conclusions & Future Work

- Preliminary results were collected at the LANSCE Lujan Center
  - TOF w/ 0.5% resolution
  - IC w/ 1.5% resolution for alphas @ 600Torr
  - IC resolution @ 200Torr w/ fission fragments still under analysis (about 8% initial tests)

- Future work
  - Second Arm
  - Active Cathode design
  - Efficiency improvements
  - Window improvements
Active Cathode Design (Sanami, et. al.)

MCA energy data

MCA timing data
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UNM SPIDER team

Interested in a graduate degree in nuclear engineering?
Contact Dr. Adam Hecht: hecht@unm.edu
References


