Fission Product Yield Measurements at TUNL

Dr. Matthew E. Gooden

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OUTLINE

• MOTIVATION
• ‘LONG’-LIVED YIELDS
• ‘SHORT’-LIVED YIELDS
• RABITTS
MOTIVATION

• Majority of fission yield measurements have been performed with reactors (thermal) and with critical assemblies (fission)
• 14 MeV neutron sources from DT fusion are also common and numerous measurements exist for this energy

If we consider the fission product $^{147}\text{Nd}$ from $^{239}\text{Pu}(n,f)$ what do we see?
• An energy dependent trend with increasing neutron energy
• But .. Is this an artifact or real physics?
Denis source
FN TANDEM 10MV

$^2$H gas

Dual fission chamber n-detector

$^2$H gas
From accelerator

$^3$H(p,n)$^3$He; Monoenergetic neutrons: 0.5 – 7.7 MeV
$^2$H(d,n)$^3$He; Monoenergetic neutrons: 4.0 – 7.7 MeV
$^3$H(d,n)$^4$He; Monoenergetic neutrons: 14.8 – 20.5 MeV
Fission Chambers

To measure the fission yield, we need to know how many fissions happened — *Fission Chambers*

- 3 Chambers were constructed: 1 for each target isotope
  - \(^{235}\text{U}\): \(\sim 100 \mu\text{g/cm}^2\) ref. / 200 mg/cm\(^2\) target
  - \(^{238}\text{U}\): \(\sim 100 \mu\text{g/cm}^2\) ref. / 400 mg/cm\(^2\) target
  - \(^{239}\text{Pu}\): \(\sim 10 \mu\text{g/cm}^2\) ref. / 200 mg/cm\(^2\) target

The number of fissions in the target is determined by scaling

\[ \text{Total Fissions} = \text{Counts} \times \frac{M_T}{M_R} \]

- No fission cross section needed!
Experiment Summary:

- The experiments have been broken down into 3 time scales and 11 Energies:
- Energies: 0.5, 1.4, 2.4, 3.6, 4.6, 5.5, 6.5, 7.5, 9, 11 and 14 MeV
  - **Long**: cumulative yields of long lived (days-months) fission products; i.e. near stability
    - Requires irradiations of a few days to a week+
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- **Long**: cumulative yields of long lived (days-months) fission products; i.e. near stability
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- **Short**: cumulative yields of short(er) lived fission products (10’s of minutes to hours)
  - Irradiations for 1-2 hours
  - Analog sample transfer system -> LLNL Colleague runs sample to counters
    - So called *Jack Rabbit* measurements

**Experiment Summary:**
Experiment Summary:

RABITTS: RApid Belt-driven Irradiated Target Transfer System

Irradiation & Counting Cycles

<table>
<thead>
<tr>
<th>Time</th>
<th>Counting Cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 s</td>
<td>20 s</td>
</tr>
<tr>
<td>10 s</td>
<td>60 s</td>
</tr>
<tr>
<td>60 s</td>
<td>300 s</td>
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Target Position Reproducibility: 42 µm

Transit Time: 1 s
RESULTS
For $^{147}$Nd, we have demonstrated a positive energy dependence to its cumulative fission yield, in agreement with data from other sources.

- **TUNL**: 5.8%/MeV
  
  \[ 1.950 + 0.113E \]

- **Chadwick**: 4.7%/MeV
  
  \[ 1.950 + 0.091E \]
We have addressed the question of energy dependence in the low-energy region, added data between 2-14 MeV and have helped address the discrepant data near 14 MeV.
From whole foil gamma counting we have found yields for ~15 fission products
- Small sample of all yields
- No valley products
- Reasonably good agreement with England & Rider
  - E&R for some yields can have very large uncertainty: >50%
  - New data will help to reduce this
Short Activations (JR):

$E_n = 9.0$ MeV

Cumulative Yield %

$E_n = 4.6$ MeV

Cumulative Yield %

Fission Product

Los Alamos National Laboratory
Summary: Our Coverage on the Nuclear Chart

Completed: Long Irradiation
16 FPYs @ 11 energies

Measured: jackRabbit
46 FPYs @ 6 energies

Measured: RABITTS
60 FPYs @ 5 energies
Collaboration

Joint collaboration between LANL, LLNL and TUNL:

**LANL**
Matthew E. Gooden
Todd A. Bredeweg
Evelyn Bond
David Vieira
Jerry Wilhelmy
Vanessa Linero

**LLNL**
Ron Malone
Anthony Ramirez
Jack Silano
Mark Stoyer
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THANK YOU