The measurement of $^{80}\text{Se}(n,\gamma)$

and

Commissioning of the i-TED Demonstrator (i-TED2)

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the n_TOF local team (CERN)

and the n_TOF Collaboration

PROPOSAL TO BE SUBMITTED TO THE NEXT INTC-PAC, by January 10th, 2018

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Outline

• Motivation & Introduction: The branching around $^{79}\text{Se}(n,\gamma)$
• Need for a new $^{80}\text{Se}(n,\gamma)$ measurement
• Need to develop high-selectivity (n,g) techniques: i-TED
• i-TED Commissioning
• Summary & Outlook
Motivation and Introduction: MSs & Temperature evolution

Currents, rotation, mixing
Temperature: a key ingredient in stellar structure and evolution

N. Nishimura, et al. 2017 MNRAS
The massive-star nuclear-thermometer
The massive-star nuclear-thermometer

Objective of HYMNS-ERC Project (LoI, CERN INTC 2014)
- Improvements in the detection system: i-TED
- Accurate (n,g) CSs of neighbouring nuclei
The massive-star nuclear-thermometer

M. Heil et al. PRC2008 → Unc.(79Br) = 5.5%
Unc.(81Br) = 3%

Objective of HYMNS-ERC Project (LoI, CERN INTC 2014)

Improvements in the detection system: i-TED

Accurate (n,g) CSs of neighbouring nuclei

C. Lederer, A. Murphy et al. (n_TOF Col.), 2017 → CS Uncertainty 4-5%
$^{80}\text{Se}(n,\gamma)$ Status of the data

![Graph showing the status of data for $^{80}\text{Se}(n,\gamma)$ reactions with various elements and their abundances over time.](image-url)
$^{80}$Se$(n, \gamma)$ Status of the data


- Low energy cut-off at 3 keV
- Limited En-resolution
- (Probably with strong n-sensitivity bias)
$^{80}$Se$(n,\gamma)$ Status of the data

$^{80}$Se$(n,\gamma)$ at n_TOF EAR1

Simulation for n_TOF EAR1
185 m
4xC$_6$D$_6$
$2 \times 10^{18}$p
### $^{80}\text{Se}(n,\gamma)$ Status of the data

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<tr>
<th>Sample</th>
<th>Objective(s)</th>
<th>Protons</th>
<th>Area</th>
<th>Set-up</th>
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<tr>
<td>$^{80}\text{Se}$</td>
<td>$^{80}\text{Se}(n,g)$ via C6D6 Benchmark i-TED2 performance</td>
<td>$2\times10^{18}$</td>
<td>EAR1</td>
<td>4xC$_6$D$_6$ i-TED2</td>
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<td>Dummy</td>
<td>Background for $^{80}\text{Se}(n,g)$</td>
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<td>EAR1</td>
<td>4xC$_6$D$_6$ i-TED2</td>
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<tr>
<td>Au, Pb, C</td>
<td>Normalization $^{80}\text{Se}(n,g)$, Beam-induced background in (n,g) Data to develop i-TED bkg. rejection algorithms.</td>
<td>$1\times10^{18}$</td>
<td>EAR1</td>
<td>4xC$_6$D$_6$ i-TED2</td>
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<td>Au,Pb,C</td>
<td>i-TED Detector response function.</td>
<td>$5\times10^{17}$</td>
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<td>$^{80}\text{Se}$</td>
<td>S-wave at 2keV in $^{80}\text{Se}$, 1 g sample n-sensitivity (no i-TED)</td>
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</table>

**Total protons requested:** $4.5\times10^{18}$
Need of new developments: illustrated @ $^{93}\text{Zr}(n,\gamma)$

- HERMES observations of Nb and Zr in S-type stars
- Determination of the s-process temperature directly in evolved low-mass GSs, using Zr and Nb abundances, independent of stellar evolution models.
- $^{93}\text{Zr}/^{93}\text{Nb}$ provides chronometric information on the time elapsed since the start of the s-process (one-three million years).

The i-TED project

High E-resolution → Better selectivity

60Co measurement with LaCl3 (i-TED)

γ-Imaging → Better sensitivity

204Tl(60Co) measurement with C6D6

\[ 204Tl(n,\gamma) = 60Co \]
Radioactive sample

Small (n,g) vs. (n,n)

- 99.3% $^{78}\text{Se}$ [Cortecnet]
- 99.1% $^{208}\text{Pb}$ [ORNL]

6g $^{208}\text{Pb}$
2.5g $^{78}\text{Se}$

- 0.01% $^{74}\text{Se} \rightarrow$ GBq of $^{75}\text{Se}$
- 0.01% of $^{60}\text{Co} \rightarrow$ 2.6 MBq $^{60}\text{Co}$ (10 months after EOI)
Radioactive sample $\rightarrow$ Enhance selectivity via high $E_g$-resolution

Small (n,g) vs. (n,n)

60Co measurement with LaCl$_3$ (i-TED)

204Tl(60Co) measurement with C6D6

Energy resolution (spectroscopy resol.) means higher selectivity
Radioactive sample $\rightarrow$ Enhance selectivity via high $E_g$-resolution

Small ($n,g$) vs. ($n,n$) $\rightarrow$ Enhance ($n,\gamma$) sensitivity via imaging techniques
The concept of Total-Energy Detector with $\gamma$-imaging: i-TED

- **True Capture Event**
  - $E_1, r_1$
  - $E_2, r_2$
  - $\theta$
  - Sample

- **Background Event**
  - $E_1, r_1$
  - $E_2, r_2$
  - $\theta$

Capture sample

Absorber PSD

Scatter PSD

Neutron beam

$\cos \theta = 1 - \frac{E_1 m_0 c^2}{E_\gamma (E_\gamma - E_1)}$
i-TED: imaging-Total Energy Detector

Technical commissioning i-TED Prototype (OK)

Performance commissioning needed → i-TED2

- Technical validation of the detectors
- Technical validation of readout electronics
- PS-Trigger signal correctly implemented
- Efficiency
  - Estimate from tech. Comm.
  - Enhancement due to improved detector design and larger A
Objectives for the i-TED Commissioning

- Proof-of-concept demonstration via a true / realistic (n,g) measurement (in the low energy range where CS is larger)

- Check for the long-term stability of the full i-TED2

- Evaluate the intrinsic neutron sensitivity of i-TED, via the C-sample measurement

- Explore the i-TED performance in EAR2
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| $^{80}\text{Se}$ | $^{80}\text{Se}(n,g)$ via C6D6  
Benchmark i-TED2 (n,g) performance                                      | $2 \cdot 10^{18}$ | EAR1     | 4xC$_6$D$_6$ i-TED2 |
| Dummy   | Background for $^{80}\text{Se}(n,g)$                                         | $5 \cdot 10^{17}$ | EAR1     | 4xC$_6$D$_6$ i-TED2 |
| Au, Pb, C | Normalization $^{80}\text{Se}(n,g)$, Beam-induced background in (n,g)  
Data to develop i-TED bkg. rejection algorithms.                      | $1 \cdot 10^{18}$ | EAR1     | 4xC$_6$D$_6$ i-TED2 |
| Au,Pb,C | Detector response function.                                                   | $5 \cdot 10^{17}$ | EAR2     | i-TED2     |
| $^{80}\text{Se}$ | S-wave at 2keV in $^{80}\text{Se}$, sample  
n-sensitivity                   | 1 g      |          |            |

**Total protons requested:** $4.5 \times 10^{18}$
• Effect of sample-detector distance, how close we can come with i-TED (its S-detector) to the sample → Efficiency / high En

• Possibility to use a veto time-gate in our readout electronics to go higher in neutron energy, for the case that the detector is affected by the gamma-flash

• Combined capture & gamma-source measurement to develop sample-activity rejection algorithms

• Effect of the LiH moderator for reducing intrinsic neutron sensitivity

• i-TED response tests at EAR2