TASK TTMN-002

VALIDATION OF FENDL-2.1 and JEFF-3.1 LIBRARIES FOR FUSION APPLICATIONS

Paola Batistoni, Luigi Petrizzi
ENEA Fusion Department – Frascati

JEFF/EFF Meeting, Aix-en-Provence, 4-5 June 2007

- **Bulk shield experiment** (inboard shield, stainless steel & water)
- **Streaming experiment** (shield with streaming channel, stainless steel & water)
- **Silicon Carbide (SiC) block**
- **Tungsten block**
- **Breeder blanket (Be / Li₂CO₃) experiment**
  ➔ now also JEFF-3.1 analysis
## Main elements in benchmark experiments

<table>
<thead>
<tr>
<th>Materials</th>
<th>EFF-3.0/3.1</th>
<th>J EFF-3.1</th>
<th>FENDL-1.0</th>
<th>FENDL-2.0</th>
<th>FENDL-2.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe-56</td>
<td>EFF-3.1</td>
<td>EFF-3.1</td>
<td>ENDF/B-VI.1</td>
<td>EFF-3.0</td>
<td>EFF-3.1</td>
</tr>
<tr>
<td>Cr-52</td>
<td>EFF-3.0</td>
<td>EFF-3.1</td>
<td>ENDF/B-VI</td>
<td>ENDF/B-VI</td>
<td>ENDF/B-VI.8</td>
</tr>
<tr>
<td>Ni-58</td>
<td>EFF-3.1</td>
<td>EFF-3.1</td>
<td>ENDF/B-VI.1</td>
<td>ENDF/B-VI.8</td>
<td>EFF-3.1</td>
</tr>
<tr>
<td>Ni-60</td>
<td>EFF-3.0</td>
<td>EFF-3.1</td>
<td>ENDF/B-VI</td>
<td>ENDF/B-VI.8</td>
<td>ENDF/B-VI.8</td>
</tr>
<tr>
<td>W-182,3,4,6</td>
<td>EFF-3.1</td>
<td>J ENDL-3.3</td>
<td>ENDF/B-VI</td>
<td>J ENDL-FF (W-nat)</td>
<td>ENDF/B-VI.8</td>
</tr>
<tr>
<td>Li-6</td>
<td>ENDF/B-VI.3</td>
<td>EFF-2.4</td>
<td>ENDF/B-VI.1</td>
<td>ENDF/B-VI</td>
<td>ENDF/B-VI.8</td>
</tr>
<tr>
<td>Li-7</td>
<td>EFF-3.0</td>
<td>EFF-3.1</td>
<td>ENDF/B-VI (C-nat)</td>
<td>J ENDL-FF</td>
<td>J ENDL-FF</td>
</tr>
<tr>
<td>Be-9</td>
<td>EFF-3.1</td>
<td>ENDF/B-VI (C-nat)</td>
<td>J ENDL-FF</td>
<td>J ENDL-FF</td>
<td>J ENDL-FF</td>
</tr>
<tr>
<td>C-12</td>
<td>ENDF/B-VI</td>
<td>ENDF/B-VI.1 (C-nat)</td>
<td>J ENDL-FF</td>
<td>J ENDL-FF</td>
<td>J ENDL-FF</td>
</tr>
<tr>
<td>O-16</td>
<td>ENDF/B-VI</td>
<td>ENDF/B-VI</td>
<td>J ENDL-FF</td>
<td>ENDF/B-VI.8</td>
<td>ENDF/B-VI.8</td>
</tr>
<tr>
<td>Si-28</td>
<td>EFF-3.0</td>
<td>J ENDL-3.3</td>
<td>BROND-2</td>
<td>ENDF/B-VI.8</td>
<td>ENDF/B-VI.8</td>
</tr>
</tbody>
</table>
Mock-up of the ITER inboard first wall/shielding blanket/vacuum vessel/toroidal magnet

- Measurements of the neutron flux as a function of depth by activation foils
Validation of FENDL-2.1 & JEFF-3.1

Bulk Shield Experiment

$E > 10 \text{ MeV}$

Ni-$58(n,2n)$

Nb-$93(n,2n)$
Validation of FENDL-2.1 & JEFF-3.1

Bulk Shield Experiment

E > 3 MeV

Al-27(n,a)

Fe-56(n,p)
Validation of FENDL-2.1 & JEFF-3.1

Bulk Shield Experiment

E > 0.8 MeV

Ni-58(n,p)

In-115(n,n')

Graphs showing the ratio C/E for Ni-58(n,p) and In-115(n,n') as a function of depth (cm) for different models (FENDL-1, EFF-3.0, EFF-3.1, FENDL-2, FEN-2.1, JEFF-3.1).
Validation of FENDL-2.1 & JEFF-3.1

Bulk Shield Experiment

\[ E \approx \text{eV} \]

Mn-55(n,g)

Au-197(n,g)
Validation of FENDL-2.1 & JEFF-3.1

**Bulk Shield Experiment**

Nuclear Heating in stainless steel and copper
Validation of FENDL-2.1 & JEFF-3.1

SiC Experiment

Silicon Carbide block (SiC, advanced low-activation structural material)

- Measurements of the neutron flux in four positions at different depths by activation foils
Validation of FENDL-2.1 & JEFF-3.1

SiC Experiment

Graphs showing the comparison of C/E values for different materials (Nb, Al, Ni, Au) across varying depths (cm). Each graph plots C/E against depth, with different materials represented by distinct line colors and markers.
Validation of FENDL-2.1 & JEFF-3.1

Tungsten Experiment

DENSIMET-176 (93.2%w W, 2.6%w Fe, 4.2%w Ni, 17.70 g/cm³).
DENSIMET-180 (95.0%w W, 1.6%w Fe, 3.4%w Ni, 18.075 g/cm³)

- Measurements of the neutron flux in four positions at different depths by activation foils
Validation of FENDL-2.1 & JEFF-3.1

Tungsten Experiment

E > 10 MeV

Zr-90(n,2n)

Nb-93(n,2n)

Ni-58(n,2n)
Validation of FENDL-2.1 & JEFF-3.1

**Tungsten Experiment**

- \( E > 3 \text{ MeV} \quad \text{Fe-56(n,p)} \)
- \( E > 1 \text{ MeV} \quad \text{Ni-58(n,p)} \)
- \( E > 3 \text{ MeV} \quad \text{Al-27(n,a)} \)
- \( E \sim \text{eV} \quad \text{Au-197(n,g)} \)
Validation of FENDL-2.1 & JEFF-3.1

Tungsten Experiment

Gamma Heating in tungsten
Validation of FENDL-2.1 & JEFF-3.1

Breeder blanket experiment

Mock-up of the EU breeder blanket Helium Cooled Pebble Bed (HCPB)

Measurements of tritium production in 4 positions P.2 – P.8 by Li$_2$CO$_3$ pellets (nat. Li) (12 pellet/position) and of the neutron flux in the central Be layer by activation foils.
Validation of FENDL-2.1 & JEFF-3.1

Breeder blanket experiment

Analysis of tritium production in Li$_2$CO$_3$ pellets

case b) Be from EFF 3/JEFF 3.1

case c) Be from FENDL 2.0

case e) all nuclides from JEFF-3.1

case e) all nuclides from FENDL 2.1
Validation of FENDL-2.1 & JEFF-3.1

TBM - HCPB breeder blanket

Analysis of activation measurements

- **case b) EFF2.4/Be-9 from EFF3.0**
  - Depth (cm): 0, 5, 10, 15, 20, 25
  - CE: 0.80, 0.90, 1.00, 1.10, 1.20, 1.30, 1.40
  - Diagram showing comparisons for Au(n,g), Nb(n,2n), Al(n,a), Ni(n,p)

- **case d) JEFF-3.1**
  - Depth (cm): 0, 5, 10, 15, 20, 25
  - CE: 0.80, 0.90, 1.00, 1.10, 1.20, 1.30, 1.40
  - Diagram showing comparisons for Au(n,g), Nb(n,2n), Al(n,a), Ni(n,p)

- **case c) EFF2.4/Be-9 from FENDL2.0**
  - Depth (cm): 0, 5, 10, 15, 20, 25
  - CE: 0.80, 0.90, 1.00, 1.10, 1.20, 1.30, 1.40
  - Diagram showing comparisons for Au(n,g), Nb(n,2n), Al(n,a), Ni(n,p)

- **case e) FENDL-2.1**
  - Depth (cm): 0, 5, 10, 15, 20, 25
  - CE: 0.80, 0.90, 1.00, 1.10, 1.20, 1.30
  - Diagram showing comparisons for Au(n,g), Nb(n,2n), Al(n,a), Ni(n,p)
Conclusions on FENDL-2.1 validation

• All libraries give the same predictions for steel/water assemblies
  - Underestimation of fast neutron flux
  - Improvement in the nuclear heating calculation
  - Convergence for steel

• Significant underestimation of the fast neutron flux is found in SiC block with FENDL-2.1~2.0, better results with EFF-3/JEFF3.1

• Significant improvement of the calculation of fast neutron flux from FENDL-2.0 to FENDL-2.1 in tungsten block, better results with EFF-3/JEFF3.1. Underestimation of gamma heating both with JEFF and FENDL

• Very good prediction of neutron flux in breeder blanket mock-up (Be/Li$_2$CO$_3$) – Tritium production underestimated by 10-15%. FENDL-2.1~2.0 ~JFF-3.1