Benchmarking of the
$^9$Be EFF-3.0/NMOD=3 evaluation

Dieter Leichtle, Ulrich Fischer
Forschungszentrum Karlsruhe GmbH
Institut für Reaktorsicherheit IRS
Objective

- Benchmarking of the ACE library by MCNP transport calculations of integral experiments
- Assessment of transport characteristics due to partial (n,2n) channels (MT875-890)
- Comments on new ACE format (allowing for tabular representation of angular distributions)
9Be EFF3.03

- Content of ENDF-file (cf. EFF-DOC-689)
  - Neutron emission channels as partial \( (n,2n) \) cross sections (MT875-890)
  - Including energy-angle distributions (subsections of MF6, LAW=7, yield=2) and covariances
  - Redundant \( (n,2n) \)-cross section (MT16 as of EFF3.02) is given as a full consistent sum of the individual channels.
$^9$Be EFF3.03

- ACE library (cf. EFF-DOC 781)
  - Modifications to NJOY99 modules RECONR, ACER
  - Option newfor=1 used, i.e. arbitrary cosine bins
  - Contains all data from the ENDF library
  - Inelastic scattering to second level (MT876) with two separate neutron angular distributions combined to a single one
Datafiles for benchmark calculations

- Full EFF3.03 (including MT875ff, excl. MT16)
- Restricted EFF3.03 (excl. MT875ff, incl. MT16)
- EFF3.02 (processed by FZK in 1998)
- EFF1

- Restricted EFF3.03 and EFF3.02:
  - differ only by lack of MF6 MT107 in EFF3.02
  - ENDF data is pointwise coincident
  - However: ACE libraries differ, mainly due to different angular representations
Integral Beryllium Benchmark Experiments

- Karlsruhe spherical shell experiment KANT
  - Beryllium shell with thickness of 17cm
  - PRS and TOF measurements
Integral Beryllium Benchmark Experiments

- FNS cylindrical slab experiment FNS-TOF
  - Beryllium slab 15.24 cm thick
  - TOF at 0, 12.2, 24.9, 41.8, 66.8 degree
Results for KANT

- Neutron leakage multiplication factors
  - Full EFF3.03: \( M=1.696 \quad C/E=1.001 \)
  - Restricted EFF3.03: \( M=1.684 \quad C/E=0.994 \)
  - EFF3.02: \( M=1.684 \quad C/E=0.994 \)
  - EFF1: \( M=1.696 \quad C/E=1.001 \)
Neutron leakage spectra (KANT)

Neutron leakage \([u^{-1} \cdot sn^{-1}]\)

Neutron energy \([eV]\)

- Full EFF3.03
- EFF3.02
- EFF1
- Exp. (NE-213)
- Exp. (PR H2)
- Exp. (PR CH4)

Neutron energy [eV]

KANT 5/22
Results for KANT

- Neutron leakage spectra
  - General good agreement between 3.03 and 3.02 (+/- 5%)
  - Large positive deviation at 2.7 MeV: major elastic resonance
  - Large positive deviation around 10…11.5 MeV:
    - Probably scattering at 2nd excited level
    - ACE file contains correct distribution!
  - Restricted 3.03 and 3.02 yield identical results
  - Better agreement of 3.03 with experimental data
    - Esp. for the range 10…11.5 MeV, where 3.02 shows crude underestimation
Results for FNS-TOF

- Neutron leakage spectra
  - EFF3.03 gives larger values compared to 3.02 (+10%), except in few MeV range
  - Exceptional positive deviations again at 10…12 MeV, dependent now on detector angle
  - Smoother spectra above 10 MeV
  - Better agreement of 3.03 with experimental data
Neutron leakage spectra (FNS-TOF)

Neutron leakage $[\mu \text{u}^{-1} \text{sn}^{-1}]$

Neutron energy [eV]

FNS TOF 0deg

- full EFF3.03
- EFF3.02
- EFF1
- Experiment

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EFF/EAF meeting, Nov. 2001, NEA-DB
Neutron leakage spectra (FNS-TOF)

Neutron leakage $[\text{u}^{-1}\text{sn}^{-1}]$

Neutron energy [eV]

- full EFF3.03
- EFF3.02
- EFF1
- Experiment

FNS TOF 66.8deg
Results for FNS-TOF

- Neutron flux integrals
  - C/E values improved compared to EFF3.02

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<th>E [MeV]</th>
<th>0 deg</th>
<th>12.2 deg</th>
<th>24.9 deg</th>
<th>41.8 deg</th>
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<td>0.95 1.04</td>
<td>0.88 0.97</td>
<td>0.84 0.92</td>
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</table>
Neutron flux integrals C/E (FNS-TOF)

EFF-3/NMOD=3

0,052-1 MeV
1-5 MeV
5-10 MeV
>10 MeV
>0,052 MeV

Angle [deg.]
Neutron flux integrals $C/E$ (FNS-TOF)

EFF-3

$0.03 - 1.0$ MeV
$1-5$ MeV
$5-10$ MeV
$E > 10.0$ MeV
$E > 0.03$ MeV

Angle [deg.]

C/E

0.0  12.2  24.9  41.8  66.8

0.03  1.0  MeV
1-5  MeV
5-10  MeV
E > 10.0  MeV
E > 0.03  MeV

EFF/EAF meeting, Nov. 2001, NEA-DB

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Conclusions and Comments

- New ACE-format for $^9\text{Be}$ EFF-3.0/NMOD=3 evaluation works with MCNP4C
- Angular distributions are represented as tabular cumulative data, in contrast to 32 equiprobable bins of the old format
- Comparable files of EFF3.02 and EFF3.03 (only MT16) are pointwise identical in ENDF format
  - ACE format files do differ due to angular representations only.
  - In certain cases secondary energy distributions from MCNP calculations also differ (ACE content is identical). Yet unexplained!
Conclusions and Comments

- Although MT16 is supposed to be sum of MT875-890 integral benchmark calculations show differences, which are related to secondary distributions
  - Which is of some benefit to C/E!
  - MF6 MT16 should be constructed anew to coincide with partial distributions

- Todo’s:
  - ENDF library to be completed (missing charged particles, gammas)
  - Sensitivity/uncertainty calculations by MCSEN