Status Report of CENDL Project

GE Zhigang

China Nuclear Data Center (CNDC)
China Committee of Nuclear Data (CCND)
China Institute of Atomic Energy (CIAE)
P.O.Box 275-41, Beijing 102413, P.R.China
E-Mail: gezg@ciae.ac.cn
I. General Information of CNDC

CNDC
China Nuclear Data Center (CNDC) was established in 1975 and joined the nuclear data activities of IAEA as the national nuclear data center of China since 1984.

The main tasks of CNDC:
• The nuclear data evaluations, libraries and relevant technique researches.
• The exchange of nuclear data activities with IAEA, foreign nuclear data centers and agencies.
• The management of domestic nuclear data activities.
• The services for domestic and foreign nuclear data users.

Mainly tasks of CNDC in 2017/2018:
• New evaluations and re-evaluations for neutron data file for CENDL-3.2β0.
• Nuclear structure and decay data evaluations.
• Update photonuclear data modeling and evaluations.
• Methodological studies of nuclear data evaluation.
• The compilations for EXFOR.
• The regular update and maintenance of IAEA/NDS mirror-site in China.
• Nuclear data services is providing to all the nuclear data users.
• ND2019 preparation.
Staff and Organization of CNDC

组长：黄小龙 博士
- 实验核数据的编纂和评价工作
- 实验数据评价方法研究
- 建立实验核数据库（EXFOR）

副主任：钱晶 博士
- 核数据的核反应理论基础研究。
- 中子/带电粒子核反应程序研制。
- 核数据模型计算任务。

主任：葛智刚 博士
- 对外合作

副主任：吴海成 博士
- 办公

评价组 Evaluation Unit
Head: Dr. Huang Xiaolong
- Exp. data evaluations
- Methodological studies of exp. data eval.
- EXFOR compilation

理论组 Theory Unit
Head: Dr. Xu Ruirui
- Nucl. data model study
- Development of nucl. data code.
- Nucl. data calculation compilation

2018/8/23
30th meeting of the WPEC Working Party on International Nuclear Data Evaluation Co-operation
17-18 May 2018 OECD Headquarters Paris, France

组长: 舒能川 博士
- 数据评价方法研究
- 评价核数据库群常数加工制作
- 群常数制作和宏观检验方法研究
- 建立计算机化中国评价核数据库
- 计算机网络系统/用户服务

数据评价方法研究
- 评价核数据库群常数加工制作
- 评价核数据基准检验
- 群常数制作和宏观检验方法研究
- 建立计算机化中国评价核数据库
- 计算机网络系统/用户服务

<table>
<thead>
<tr>
<th>部门</th>
<th>部门负责人</th>
<th>官员数</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation Unit</td>
<td>Head: Dr. Huang Xiaolong</td>
<td>3 official staff</td>
</tr>
<tr>
<td>Theory Unit</td>
<td>Head: Dr. Xu Ruirui</td>
<td>6 official staff</td>
</tr>
<tr>
<td>Macroscopic Data Unit</td>
<td>Head: Dr. Liu Ping</td>
<td>5 official staff</td>
</tr>
<tr>
<td>Data Library Unit</td>
<td>Head: Dr. Shu Nengchuan</td>
<td>4 official staff</td>
</tr>
<tr>
<td>Secretary Office</td>
<td></td>
<td>1 official staff</td>
</tr>
</tbody>
</table>

- 19 official staff + 6 students (Master 2, Ph.D 4).
- Planning to increase the official staff up to 25 in recently years.
II. CENDL-3.2β0 and Methodology Study

2.1 CENDL-3.2 β0 evaluations

CENDL-3.2β0 will be the updated library as the main fruit of the CENDL project recent years.

Various kinds of nuclear data are involved in CENDL library, which mainly include the complete set of neutron data, activation data, decay data, fission yield data files.

Therefore, the massive activities are carried out and going on to develop our methodologies of nuclear data evaluation to fulfill the mission, including microscopic nuclear model, covariance evaluation scheme, theory of fission product… …

1. The total materials of CENDL3.2β0 is 250 (240 in CENDL3.1);
   - 56 nuclides are newly evaluated and updated in CENDL3.2 β0;
   - 14 nuclides are new members in CENDL3.2 β0;
   - 42 nuclides are revised based on CENDL3.1;
   - Covariance for 16 nuclides (²³H, ³He, ¹⁹F, ⁴⁰Ca, ⁴⁸Ti, ⁵⁵Mn, ⁶³,⁶⁵,⁷⁰Cu, ⁹⁰,⁹¹,⁹²,⁹³,⁹⁴,⁹⁵,⁹⁶Zr, ¹⁸⁰,¹⁸²,¹⁸³,¹⁸⁴,¹⁸⁶W, ²³³,²³⁵U) with high fidelity based on CENDL3.1

2. The incident neutron energy $E_n \leq 20\text{MeV}$;
3. $MF = 1, 3, 4, 5, 6, 12, 14, 15, 33$. 
### Content of nuclei in CENDL-3.2β0 (250)

<table>
<thead>
<tr>
<th>Nucl.</th>
<th>1-3H, 3,4He, 6,7Li, 9Be, 10,11B, 12C, 14N, 16O, 19F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Elements(14)</td>
<td>23Na, 24-26Mg, 27Al, 28-30Si, 31P, 32,33,34,36S, 58Fe, 59Co, 60-62,64Ni, 0,63,65Cu, 0,77Zn, 0,79Ge, 80-90Zr, 0,92,94,96Mo, 0,107,109Ag, 0Cd, 0Sn, 141-170Hf, 181Ta, 180,182,183,184,186W</td>
</tr>
<tr>
<td>Structural Materials</td>
<td>69,71Ga, 70-78Ge, 75,77,79As, 83,84,85,86,87Kr, 85,87Rb, 88-90Sr, 89,91Y, 93,95Zr, 93,95Nb, 99Tc, 99-105Ru, 103,105Rh, 105,108Pd, 113Cd, 113,115In, 112,114-120,122,124Sn, 121,123,125Sb, 127,129,131,133,134-136Xe, 133-135,137Cs, 130,132,134-138Ba, 139La, 136,138,140-142,144Ce, 141Pr, 142-148,150Nd, 147,148,148m,149Pm, 144,147-152,154Sm, 151,153-155Eu, 152,153,154-158,160Gd, 164Dy</td>
</tr>
<tr>
<td>Fission Products &amp; Medium Elements</td>
<td>232Th, 232-240,241U, 236-239Np, 236-246Pu, 240-244,242mAm, 249Bk, 249Cf</td>
</tr>
<tr>
<td>Actinides</td>
<td>232Th, 232-240,241U, 236-239Np, 236-246Pu, 240-244,242mAm, 249Bk, 249Cf</td>
</tr>
</tbody>
</table>

### New evaluated and updated nuclei in CENDL-3.2β0 (57)

<table>
<thead>
<tr>
<th>Nucl.</th>
<th>1H, 6,7Li</th>
<th>23Na, 32,33,34,36S, 27Al, 40Ca, 56Fe, 58Ni, 181Ta, 180,182,183,184,186W</th>
<th>87,88Kr, 93Nb, 125Sb, 123,124,129,131,133,134,135Xe, 140,141,142Ce, 152,153,154,155,156,157,158,160Gd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Elements</td>
<td>3</td>
<td>15</td>
<td>22</td>
</tr>
<tr>
<td>Structural Materials</td>
<td>15</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Fission Products</td>
<td></td>
<td></td>
<td>22</td>
</tr>
<tr>
<td>Actinides</td>
<td>15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

2018/8/23

---

30th meeting of the WPEC Working Party on International Nuclear Data Evaluation Co-operation
17-18 May 2018 OECD Headquarters Paris, France
Re-evaluation of $^{56}\text{Fe}(n,\text{inl})$ cross section

- The latest evaluations of $^{56}\text{Fe}$ were tested with the IPPE iron shielding benchmark (ALARM-CF-Fe-001) which measured neutron leakage flux from 7 iron sphere with different thickness.
- The results from a 34cm-thick iron sphere show that the B8b4 and C32b1 for $^{56}\text{Fe}$, which are outcome of SG40/CIELO, cause $10 \sim 40\%$ underestimation of neutron leakage flux above 0.8MeV.
  - The (n,inl) XSs of the B8b4 and C32b1 are both based on the CNDC’s evaluation of available experiment data.

![Graph showing neutron spectrum and cross section for $^{56}\text{Fe}(n,\text{inl})$]
Re-evaluation of $^{56}\text{Fe}(n,\text{inl})$ cross section

- Sensitivity analysis of the iron benchmark done by the INL shows that the XS of $(n,\text{inl})$ is the main source of calculation bias.
- Re-evaluation of $^{56}\text{Fe}(n,\text{inl})$ XS have been done according the integral testing result of the benchmark Cf-Fe-001_7 and the Geel’s measurement. Both XSs of first discrete level and continuum were adjusted. The $(n,\text{el})$ XSs were calculated from $(n,\text{tot})$ - $(n,\text{inl})$. 

![Comparison of $^{56}\text{Fe}(n,\text{inl})$]
Re-evaluation of $^{56}$Fe(n,\textit{inl}) cross section

- With adjusted XS of (n,\textit{inl}), the prediction of the neutron leakage flux between 0.8 to 16MeV has been remarkable improved.
  - C32b2m4 and m5 are two different trail version.
Re-evaluation of $^{56}$Fe(n,inl) cross section

- The trail version data have been tested with the fast and inter-medium spectra criticality benchmarks which are sensitive to iron.
  - C32b2m4 show better prediction ability than the others in criticality testing, but under prediction of $k_{eff}$ about 500pcm for some MF benchmarks which has an EALF value larger than 0.8MeV.
- Future work need to be done to improve the prediction of criticality benchmarks.
$^2$H(D) reaction

D(n,tot)

D(n,2n)

D(n,el)
Li-7

Comparison between Exp. and Eval. of $^7\text{Li}(n, nt)\alpha$ reaction

- JENDL-4.0
- CENDL-3.1
- PRESENT
- R.G. Thomas (1954)
- M.E. Wyman (1958)
- K.M. Mikhailina (1961)
- L. Rosen (1962)
- F. Brown (1963)
- J.C. Hopkins (1968)
- M.T. Swinhoe (1980)
- Qi Buija (1980)
- D.L. Smith (1981)
- E. Goldberg (1985)
- M.T. Swinhoe (1985)
- S. Chiba (1985)
- J.W. Meadows (1987)
- S.M. Qaim (1987)
$^6\text{Li}$

- **(n,tot)**: Cross sections as a function of $E_n$ (MeV) for the $(n,tot)$ reaction.
- **(n,el)**: Cross sections as a function of $E_n$ (MeV) for the $(n,el)$ reaction.
- **(n,t)**: Cross sections as a function of $E_n$ (MeV) for the $(n,t)$ reaction.
- **(n,p)**: Cross sections as a function of $E_n$ (MeV) for the $(n,p)$ reaction.

The graphs show data from various sources, with a focus on the $(n,tot)$ reaction.
30th meeting of the WPEC Working Party on International Nuclear Data Evaluation Co-operation
17-18 May 2018 OECD Headquarters Paris, France

27Al(n, p)

Cross Section (b)

27Al(n, xn)

$E_n = 14.1$ MeV

$E_n' (MeV)$

$E_{v} = 0.9847$ MeV

27Al(n, pγ)

$E_n = 14.1$ MeV

$E_{v} = 0.9847$ MeV

Cross Section (b)

2018/8/23

2018/8/23
Cross sections (b) vs. En (MeV)

- **32S(n,tot)**
  - This work (evaluation)
  - This work (calculation)
  - JENDL3.3
  - Abfalterer00
  - Cierjacks68(S-0)

- **32S(n,p)**
  - This work (evaluation)
  - JENDL3.3
  - Allen Jr 57
  - Kleine48
  - Ricano 51
  - Khurana65

- **34S(n,p)**
  - This work
  - JENDL3.3
  - Paul 53
  - Prasad 66
  - Gupta 85
  - Bormann 66
  - Ngoc 80
  - Kasugai 60
  - Schantl 70

- **Cross sections (b)** vs. En (MeV)

2018/8/23

En (MeV)
30th meeting of the WPEC Working Party on International Nuclear Data Evaluation Co-operation
17-18 May 2018 OECD Headquarters Paris, France

\[ 58^{\text{Ni}}(n, \text{tot}) \]

\[ 58^{\text{Ni}}(n, \gamma) \]

\[ 58^{\text{Ni}}(n, p) \]

\[ 58^{\text{Ni}}(n, \alpha) \]
$^{58}$Ni(n, xn) $E_n = 14.1$ MeV

Exp: S. Matsuyama+ (1992)
For evaluation of the fission nuclei with scarce of experimental data

Recommended data for $^{236}$U(n,2n)

Fig:2n-txt-EB
Recommended data for $^{237}$U(n,2n)

Fig:2n3n-recom

Cross Section/b

$E_n/\text{eV}$

$10^{6}$ $10^{7}$ $10^{8}$ $10^{9}$ $10^{10}$

$0.0$ $0.2$ $0.4$ $0.6$ $0.8$ $1.0$ $1.2$ $1.4$ $1.6$ $1.8$ $2.0$

This work,(n,2n)
This work,(n,3n)
ENDF/B7,(n,2n)
ENDF/B7,(n,3n)
JENDL-4,(n,2n)
JENDL-4,(n,3n)
CENDL-3.1,(n,2n)
CENDL-3.1,(n,3n)
2.2 CENDL-3.2 β₀ Benchmarking

In order to assess the performance of $^{232}$Th、$^{233}$U、$^{6,7}$Li on reactor criticality, benchmarks testing of these data were done with M-C code MCNP5, and the calculated results were compared with other evaluated data libraries. Criticality benchmarks were taken from the ICSBEP.

$^{232}$Th cases

The 15B series of HCT021 was used to test the $^{232}$Th.

- $k_{eff}$ are over-estimated with all libraries.
- Improvements are obtained with CENDL-3.2b.
- The results show the resonance parameters of $^{232}$Th need to be improved.
$^{233}$U cases

U233-MET-FAST, U233-COM-THERM, U233-SOL-THERM, U233-SOL-INTER systems were used to test $^{233}$U.

- Under estimation of $k_{\text{eff}}$ from CENDL-3.1 may be caused by the lower $^{233}$U(n, inl) XS.
- Improvements are obtained with CENDL-3.2b.

C/E of $k_{\text{eff}}$ for UMF system
Over estimation of $k_{eff}$ from CENDL-3.1 may be caused by the resolved resonance parameter of $^{233}\text{U}$.

Improvements are obtained with CENDL-3.2b.
233U cases

U233-SOL-INTER system

Under prediction of $k_{\text{eff}}$ with all libraries

$C/E$ of $k_{\text{eff}}$ for USI system

2018/8/23
**Benchmarking of $^{6,7}$Li**

Benchmarks with Lithium reflector

The results of CENDL-3.1 are closed to those of ENDF/B-VII.1
2.3 Validation of CENDL-NP-1.2 and ENDF/B-VIII.b4

- CENDL-NP-1.2 and ENDF/B-VIII.beta4 libraries have been tested with the criticality and shielding benchmarks in the ENDITS-1.0.

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Form</th>
<th>Spectra</th>
<th>ICSBEP 2006</th>
<th>ENDITS S-1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEU</td>
<td>MET</td>
<td>FAST</td>
<td>304</td>
<td>147</td>
</tr>
<tr>
<td></td>
<td>INTER</td>
<td>14</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>THERM</td>
<td>127</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MIXED</td>
<td>32</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SOL</td>
<td>INTER</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>THERM</td>
<td>463</td>
<td>118</td>
<td></td>
</tr>
<tr>
<td>COMP</td>
<td>FAST</td>
<td>8</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INTER</td>
<td>14</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>THERM</td>
<td>216</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MIXED</td>
<td>45</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>MISC</td>
<td>THERM</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IEU</td>
<td>MET</td>
<td>FAST</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>SOL</td>
<td>THERM</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>COMP</td>
<td>FAST</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>INTER</td>
<td>14</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>THERM</td>
<td>41</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MIXED</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LEU</td>
<td>MET</td>
<td>THERM</td>
<td>65</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>SOL</td>
<td>THERM</td>
<td>104</td>
<td>58</td>
</tr>
<tr>
<td>COMP</td>
<td>THERM</td>
<td>1066</td>
<td>122</td>
<td></td>
</tr>
<tr>
<td>MISC</td>
<td>THERM</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total**

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Form</th>
<th>Spectra</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3956</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1261</td>
</tr>
</tbody>
</table>

CENDL-NP-1.2 and ENDF/B-VIII.beta4 libraries have been tested with the criticality and shielding benchmarks in the ENDITS-1.0.
2.3 Validation of CENDL-NP-1.2 and ENDF/B-VIII.b4

- Shielding benchmarks

Ni, Cu

Arrange diagram of OKTAVIAN pulse sphere benchmark

Fe

Benchmark model of IPPE Iron shielding benchmark (ALARM-CF-FE-001)
2.3 Validation of CENDL-NP-1.2 and ENDF/B-VIII.b4

- Generating of ACE libraries
  - NJOY99.396c10.
- MCNP5 simulation
  - criticality: 10000 particles * 1000
  - Shielding: NPS=10^8
- Analysis
  - Trend analysis.
  - $\chi^2$.

$$\chi^2 = \frac{1}{n} \sum_{i=1}^{n} \left( \frac{C_i - E_i}{\delta E_i} \right)^2$$
U-235: HMF system

- Compared to B71, the prediction of $k_{\text{eff}}$ values for the HMF system have been improved. $\chi^2$ get smaller.

### HMF system

![Graph showing comparison of $k_{\text{eff}}$ values for different models.]

### Table: Comparison of $k_{\text{eff}}$ values

<table>
<thead>
<tr>
<th>Type</th>
<th>Cores</th>
<th>Quantity</th>
<th>CENDL-NP-1.2</th>
<th>ENDF/B-VIII.b4</th>
<th>ENDF/B-VII.1</th>
<th>CENDL-3.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMF</td>
<td>151</td>
<td>Average</td>
<td>114</td>
<td>42</td>
<td>150</td>
<td>176</td>
</tr>
<tr>
<td></td>
<td></td>
<td>STDEV</td>
<td>467</td>
<td>442</td>
<td>470</td>
<td>546</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K2</td>
<td><strong>472.72</strong></td>
<td><strong>472.41</strong></td>
<td><strong>498.36</strong></td>
<td><strong>538.62</strong></td>
</tr>
</tbody>
</table>
U-235: NU or DU reflected HMF benchmarks

- For the cores with the EALF values between 0.8 and 0.85, the predictions of the $k_{\text{eff}}$ have been improved when the B8b4 used.
  - Reaction ratios of $^{235}\text{U}$ and $^{238}\text{U}$ in the fast region for the B8b4 have been improved.
  - The combination of $^{235}\text{U}$ from C32b1 and $^{238}\text{U}$ from B71 in the CENDL-NP-1.2 makes the prediction worse than B71.
U-235,238: IMF system

- Compared with the B71, the results for the B8b4 have been improved slightly and $\chi^2$ decreased.
- For NP-1.2, a local $k_{\text{eff}}$ bias related to spectra index was observed.

<table>
<thead>
<tr>
<th>Type</th>
<th>Cores</th>
<th>Quantity</th>
<th>CENDL-NP-1.2</th>
<th>ENDF/B-VIII.b4</th>
<th>ENDF/B-VII.1</th>
<th>CENDL-3.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMF</td>
<td>17</td>
<td>Average</td>
<td>108</td>
<td>67</td>
<td>198</td>
<td>445</td>
</tr>
<tr>
<td></td>
<td></td>
<td>STDEV</td>
<td>369</td>
<td>302</td>
<td>311</td>
<td>594</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K2</td>
<td>3.95</td>
<td>1.67</td>
<td>3.39</td>
<td>10.69</td>
</tr>
</tbody>
</table>
U-235&O-16, H-1: HST system

- Compared with the B71, the results for the B8b4 and NP-1.2 get worse slightly. The balance among $^{235}\text{U}$, $^{16}\text{O}$, and $^1\text{H}$ was not as good as B71.

### HST system

<table>
<thead>
<tr>
<th>Type</th>
<th>Cores</th>
<th>Quantity</th>
<th>CENDL-NP-1.2</th>
<th>ENDF/B-VIII.b4</th>
<th>ENDF/B-VII.1</th>
<th>CENDL-3.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>HST</td>
<td>118</td>
<td>Average</td>
<td>-241</td>
<td>-146</td>
<td>-130</td>
<td>178</td>
</tr>
<tr>
<td></td>
<td></td>
<td>STDEV</td>
<td>772</td>
<td>847</td>
<td>781</td>
<td>793</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K2</td>
<td>3.22</td>
<td>3.02</td>
<td>2.66</td>
<td>2.89</td>
</tr>
</tbody>
</table>
U-235,238&O-16, H-1: LCT system

- $\chi^2$ improved slightly
  - For cores without Fe and Gd, most of the C/E values fall into the uncertainty margin of benchmarks.
  - However, the slope of the C/E values still not zero.

<table>
<thead>
<tr>
<th>Type</th>
<th>Cores</th>
<th>Quantity</th>
<th>CENDL-NP-1.2</th>
<th>ENDF/B-VIII.b4</th>
<th>ENDF/B-VII.1</th>
<th>CENDL-3.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCT</td>
<td>122</td>
<td>Average</td>
<td>-416</td>
<td>-318</td>
<td>-382</td>
<td>-385</td>
</tr>
<tr>
<td></td>
<td></td>
<td>STDEV</td>
<td>653</td>
<td>679</td>
<td>696</td>
<td>758</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K2</td>
<td>4.34</td>
<td>3.90</td>
<td>4.46</td>
<td>5.12</td>
</tr>
</tbody>
</table>
U-235,238&H-1, O-16, Fe-56: LST system

- The $\chi^2$ improved slightly when using the NP-1.2, but $k_{\text{eff}}$ bias related to energy spectra still not removed.
  - Analysis shows that bias correlated to the Fe-56 data.

<table>
<thead>
<tr>
<th>Type</th>
<th>Cores</th>
<th>Quantity</th>
<th>CENDL-NP-1.2</th>
<th>ENDF/B-VIII.b4</th>
<th>ENDF/B-VII.1</th>
<th>CENDL-3.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>LST</td>
<td>58</td>
<td>Average</td>
<td>-79</td>
<td>141</td>
<td>163</td>
<td>262</td>
</tr>
<tr>
<td></td>
<td></td>
<td>STDEV</td>
<td>296</td>
<td>321</td>
<td>311</td>
<td>283</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K2</td>
<td><strong>2.25</strong></td>
<td>4.50</td>
<td>4.66</td>
<td><strong>7.09</strong></td>
</tr>
</tbody>
</table>
Pu-239: PMF system

- No significant improvement was observed.
- The slope of the NP-1.2 looks better than the other.

<table>
<thead>
<tr>
<th>Type</th>
<th>Cores</th>
<th>Quantity</th>
<th>CENDL-NP-1.2</th>
<th>ENDF/B-VIII.beta4</th>
<th>ENDF/B-VII.1</th>
<th>CENDL-3.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMF</td>
<td>80</td>
<td>Average</td>
<td>-32</td>
<td>145</td>
<td>154</td>
<td>-170</td>
</tr>
<tr>
<td></td>
<td></td>
<td>STDEV</td>
<td>489</td>
<td>525</td>
<td>523</td>
<td>528</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$K^2$</td>
<td>3.29</td>
<td>3.04</td>
<td>3.13</td>
<td>3.75</td>
</tr>
</tbody>
</table>
Pu-239: PST system

- Based on the reevaluated the RPs, the performance of B8b4 and NP-1.2 have been significantly improved comparing with B71 and C31.
Fe-56: Fast and intermedium spectra benchmarks sensitive to iron

- For the B8b4, the calculated $k_{\text{eff}}$ results of the benchmark sensitive to iron have been improved based on the fruit of CIELO.
  - But the result for the PMI2 are still out of the benchmark uncertainty margin.
Fe-56: IPPE shielding benchmark
(34cm-thick, about~7mfp for 2MeV neutron)

- In the test result below, “improving” and “retrograding” show at the same time.
  - Between 0.1 and 0.8MeV, where $k_{\text{eff}}$ of fast benchmarks are sensitive to, the results are getting closer to the experiment data.
  - But above 0.8 MeV, the predictions turn worse than the B71.
Ni: criticality and shielding

- For the cores with relative harder spectra in fig., the results of the B8b4 have been improved, but not for the cores with softer spectrum;
- The result of shielding benchmark shows that the data for the (n,inl) reaction may not properly evaluated.
  - CENDL-3.1 gives better agreement with the EXP. where (n,inl) reaction contributes.
Cu: criticality and shielding

• The slope of the HMI benchmarks which sensitive to Cu data get smaller when using B8b4, but bias still there.

NP1.2(C31) gives better agreement in the OKTAVIAN shielding benchmark, because of the data of (n,\text{inl}).
Overall performance for criticality benchmarks

- The overall performance of the CENDL-NP-1.2 and ENDF/B-VIII.beta4 libraries are close. Improved significantly compared with the old versions.

<table>
<thead>
<tr>
<th>Type</th>
<th>Cores</th>
<th>Quantity</th>
<th>CENDL-NP-1.2</th>
<th>ENDF/B-VIII.b4</th>
<th>ENDF/B-VII.1</th>
<th>CENDL-3.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-235</td>
<td>698</td>
<td>Average</td>
<td>-85</td>
<td>-5</td>
<td>23</td>
<td>186</td>
</tr>
<tr>
<td></td>
<td></td>
<td>STDEV</td>
<td>830</td>
<td>857</td>
<td>875</td>
<td>915</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K2</td>
<td><strong>116.64</strong></td>
<td><strong>119.97</strong></td>
<td><strong>128.59</strong></td>
<td><strong>145.97</strong></td>
</tr>
<tr>
<td>U-Pu</td>
<td>7</td>
<td>Average</td>
<td>-64</td>
<td>-94</td>
<td>-14</td>
<td>-36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>STDEV</td>
<td>202</td>
<td>226</td>
<td>171</td>
<td>285</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K2</td>
<td>6.40</td>
<td>4.51</td>
<td>4.49</td>
<td>11.89</td>
</tr>
<tr>
<td>Pu</td>
<td>388</td>
<td>Average</td>
<td>-46</td>
<td>97</td>
<td>475</td>
<td>729</td>
</tr>
<tr>
<td></td>
<td></td>
<td>STDEV</td>
<td>512</td>
<td>486</td>
<td>523</td>
<td>788</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K2</td>
<td>3.03</td>
<td><strong>2.25</strong></td>
<td>4.17</td>
<td>8.90</td>
</tr>
<tr>
<td>U-233</td>
<td>165</td>
<td>Average</td>
<td>-610</td>
<td>-544</td>
<td>-353</td>
<td>-36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>STDEV</td>
<td>1248</td>
<td>1124</td>
<td>1091</td>
<td>1196</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K2</td>
<td>6.08</td>
<td>4.79</td>
<td><strong>4.25</strong></td>
<td>6.52</td>
</tr>
<tr>
<td>All</td>
<td>1261</td>
<td>Average</td>
<td>-143</td>
<td>-46</td>
<td>111</td>
<td>321</td>
</tr>
<tr>
<td></td>
<td></td>
<td>STDEV</td>
<td>836</td>
<td>827</td>
<td>859</td>
<td>960</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K2</td>
<td><strong>66.33</strong></td>
<td><strong>67.76</strong></td>
<td><strong>73.05</strong></td>
<td><strong>84.46</strong></td>
</tr>
</tbody>
</table>
Overall performance for criticality benchmarks

- Still have $k_{\text{eff}}$ bias larger than 3% for several cores.

### Cases of which the bias of the C/E values is larger than 3%

<table>
<thead>
<tr>
<th>ID</th>
<th>C/E of $k_{\text{eff}}$</th>
<th>Sensitive Nuclides</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NP-1.2</td>
<td>B8b4</td>
</tr>
<tr>
<td>HCI5.2</td>
<td>1.0398</td>
<td>1.0361 U-235, Fe-56, Ni-58, Cr-52</td>
</tr>
<tr>
<td>HCI5.4</td>
<td>1.1023</td>
<td>1.1126 U-235, Cr-52, Cr-53, Cr-50</td>
</tr>
<tr>
<td>HCI5.5</td>
<td>0.9365</td>
<td>0.9699 U-235, Zr-90, Zr-91, Zr-92</td>
</tr>
<tr>
<td>HST39.1</td>
<td>1.0341</td>
<td>1.0353 H-1, U-235, F-19, O-16</td>
</tr>
<tr>
<td>PMI2.1</td>
<td>1.0412</td>
<td>1.0292 Pu-239, Fe-56, Ni-58, Mn-55</td>
</tr>
<tr>
<td>USI1.6</td>
<td>0.9628</td>
<td>0.9669 U-233, H-1, Be-9, O-16</td>
</tr>
<tr>
<td>USI1.11</td>
<td>0.9668</td>
<td>0.9705 U-233, H-1, Be-9, O-16</td>
</tr>
<tr>
<td>USI1.21</td>
<td>0.9687</td>
<td>0.9710 U-233, H-1, Be-9, O-16</td>
</tr>
<tr>
<td>UST15.8</td>
<td>0.9700</td>
<td>0.9706 U-233, H-1, Be-9, O-16</td>
</tr>
<tr>
<td>UST15.9</td>
<td>0.9657</td>
<td>0.9668 U-233, H-1, O-16, Be-9</td>
</tr>
</tbody>
</table>
Summary of Validation

- The data for $^{235,238}\text{U}$ and $^{239}\text{Pu}$ have been improved, which makes better predictions of $k_{\text{eff}}$ for the HMF, IMF, LCT, PST, $^{235}\text{U}$ and Pu systems than before.
- Fe-56
  - The calculated benchmark results for the fast and inter-medium spectra benchmarks sensitive to iron have been improved.
  - Validation with the shield benchmarks shows that the prediction of the neutron leakage flux between 0.8~12MeV get worse than B71. Re-evaluation is necessary.
- The $k_{\text{eff}}$ bias in the LST system has not been improved yet.
- The results for the HST system get a little worse than B71, which means the relative cross sections among $^{235}\text{U}$, $^{1}\text{H}$ and $^{16}\text{O}$ get worse.

- For shielding benchmarks of Ni and Cu, NP-1.2 gives better prediction of neutron leakage flux than B8b4.
  - The data for the (n,inl) reaction of Cu and Ni were not evaluated properly in the B8b4.
- The evaluated data file for Fe, Cr, Ni, Zr, $^{19}\text{F}$ and $^{233}\text{U}$ need to be improved at the first stage.
- Compared with B71, the overall performance of NP-1.2 and B8b4 have been improved significantly.
2.4 Methodology Study

The evaluation scheme for resonance at CNDC

Analysis Scheme at CNDC

SUMMY8.0
### The concerned experimental data for $^{241}$Pu (n,tot), (n,γ), (n,fission)

<table>
<thead>
<tr>
<th>Energy Region (eV)</th>
<th>Exp. data used for evaluation</th>
</tr>
</thead>
</table>
| 0.001-0.5         | **TOT**: Schwartz, Simpson, Craig, Young, Smith  
|                   | **FIS**: Adamchuk, Richmond, Seppi, Raffle, Watanabe(1964,1966), James, Wagemans(1975,1991), Weston, Tovesson  
|                   | **CAP**: Weston |
| 0.5-20            | **TOT**: Harvey, Kolar, Pattenden, Simpson, Craig  
|                   | **FIS**: Adamchuk, Richmond, Moore, Watanabe(1964), James, Migneco, Blons, Wagemans(1976,1991), Weston, Tovesson  
|                   | **CAP**: Weston |
| 20-45             | **TOT**: Harvey, Kolar, Pattenden, Craig  
|                   | **FIS**: Moore, Watanabe(1964), James, Simpson, Migneco, Blons, Wagemans(1976), Weston, Tovesson  
|                   | **CAP**: Weston |
| 45-100            | **TOT**: Harvey, Kolar, Pattenden, Craig  
|                   | **FIS**: Moore, Watanabe(1964), James, Simpson, Migneco, Blons, Weston, Tovesson |
| 100-200           | **TOT**: Harvey, Kolar, Pattenden, Craig  
| 200-300           | **FIS**: Watanabe(1964), James, Simpson, Migneco, Blons, Weston, Tovesson |
1. The total cross section, the fission cross section and the capture reaction are considered simultaneously in our work to achieve more consistent results;

2. The experimental data reported by L. W. Weston et al in 1978 are adopted after our evaluation;

3. In the resolved resonance region ($E_n<300\text{eV}$), 274 RPs are adopted in our final evaluation, including 4 minus RPs and 5 RPs beyond 300eV;

4. The current evaluation contains additional 29 RPs in total than that in ENDF/B-VIII.beta5.
### 2.5 The covariance evaluation of CENDL

---

#### Priority of Cova. Evaluation for CENDL-3.2b

<table>
<thead>
<tr>
<th>PRI 1</th>
<th>PRI 2</th>
<th>PRI 3</th>
<th>PRI 4</th>
<th>PRI 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{235}\text{U}$</td>
<td>$^9\text{Be}$</td>
<td>$^1\text{H}$</td>
<td>$^{19}\text{F}$</td>
<td>$^3\text{H}$</td>
</tr>
<tr>
<td>$^{238}\text{U}$</td>
<td>$^{12}\text{C}$</td>
<td>$^2\text{H}$</td>
<td>$^{24,25,26}\text{Mg}$</td>
<td>$^{3,4}\text{He}$</td>
</tr>
<tr>
<td>$^{239}\text{Pu}$</td>
<td>$^{55}\text{Mn}$</td>
<td>$^6\text{Li}$</td>
<td>$^{28,29,30}\text{Si}$</td>
<td>$^{14}\text{N}$</td>
</tr>
<tr>
<td>$^{240}\text{Pu}$</td>
<td>$^{63}\text{Cu}$</td>
<td>$^7\text{Li}$</td>
<td>$^{92,94,96}\text{Mo}$</td>
<td>$^{15}\text{N}$</td>
</tr>
<tr>
<td>$^{241}\text{Pu}$</td>
<td>$^{65}\text{Cu}$</td>
<td>$^{11}\text{B}$</td>
<td>$^{95,97,98,100}\text{Mo}$</td>
<td>$^{93,95}\text{Zr}$</td>
</tr>
<tr>
<td>$^{56}\text{Fe}$</td>
<td>$^{27}\text{Al}$</td>
<td>$^{50}\text{Cr}$</td>
<td>$^{131,132,134}\text{Xe}$</td>
<td>$^{99}\text{Tc}$</td>
</tr>
<tr>
<td>$^{52}\text{Cr}$</td>
<td>$^{208}\text{Pb}$</td>
<td>$^{53}\text{Cr}$</td>
<td>$^{155,156,157,158,160}\text{Gd}$</td>
<td>$^{101,102,103,104}\text{Ru}$</td>
</tr>
<tr>
<td>$^{58}\text{Ni}$</td>
<td>$^{209}\text{Bi}$</td>
<td>$^{54}\text{Fe}$</td>
<td>$^{149,151,152}\text{Sm}$</td>
<td>$^{106}\text{Ru}$</td>
</tr>
<tr>
<td>$^{23}\text{Na}$</td>
<td>$^{59}\text{Co}$</td>
<td>$^{57}\text{Fe}$</td>
<td></td>
<td>$^{103}\text{Rh}$</td>
</tr>
<tr>
<td>$^{10}\text{B}$</td>
<td>$^{83}\text{Nb}$</td>
<td>$^{60}\text{Ni}$</td>
<td></td>
<td>$^{105,108}\text{Pd}$</td>
</tr>
<tr>
<td>$^{16}\text{O}$</td>
<td>$^{232}\text{Th}$</td>
<td></td>
<td>$^{90,91,92,94,96}\text{Zr}$</td>
<td>$^{106,107}\text{Pd}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$^{109}\text{Ag}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$^{127}\text{I}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$^{129}\text{I}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$^{133}\text{Cs}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$^{135}\text{Cs}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$^{139}\text{La}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$^{141}\text{Ce}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$^{141}\text{Pr}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$^{148}\text{Nd}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$^{143,145,146,148}\text{Nd}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$^{147}\text{Pm}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$^{153,155}\text{Eu}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$^{166,167,168,170}\text{Er}$</td>
</tr>
</tbody>
</table>

---

Since 2015

Cov. evaluations based on abundant experimental data analysis

- **green**: newly finished (11)
- **pink**: CENDL3.1(6)

---

2018/8/23
Non-model dependent evaluation
Analysis of Experimental Source Uncertainty (ASEU)

Physics quantity $y$ is derived based on $N$ sets of experimental observables $X$ following function $F$:

$$y = f(x_1, x_2, \ldots, x_N)$$

Taylor expansion around $\langle X \rangle$, and the high order items are ignored:

$$y = f(\langle x \rangle) + \sum_{i=1}^{N} \left( \frac{\partial f}{\partial x_i} \right)_{x = \langle \rangle} \times (x_i - \langle x_i \rangle) + \frac{1}{2!} \sum_{i,j=1}^{N} \left( \frac{\partial^2 f}{\partial x_i \partial x_j} \right)_{x = \langle \rangle} \times (x_i - \langle x_i \rangle) (x_j - \langle x_j \rangle) + \cdots,$$

$$y = f(\langle x \rangle) + \sum_{i=1}^{N} \left( \frac{\partial f}{\partial x_i} \right)_{x = \langle \rangle} \times (x_i - \langle x_i \rangle)$$

Covariance is derived based on the uncertainties of diversified experimental observables $X$, which the experimental uncertainty sources.

$$\sigma^2(y) = \sum_{i=1}^{N} \left( \frac{\partial f}{\partial x_i} \right)^2 \sigma_i^2 + \sum_{i,j=1}^{N} \left( \frac{\partial f}{\partial x_i} \frac{\partial f}{\partial x_j} \right)_{x = \langle \rangle} \text{Cov}(x_i, x_j)$$

$$\text{Cov}(y_i, y_j) = \langle \sum_{i=1}^{N} \frac{\partial f}{\partial x_i} | \Delta x_i, \langle \rangle \rangle \langle \sum_{i=1}^{N} \frac{\partial f}{\partial x_i} | \Delta x_i, \langle \rangle \rangle \rangle$$

$$= \sum_{i,k=1}^{N} \left( \frac{\partial f}{\partial x_i} \right)_{j} \left( \frac{\partial f}{\partial x_k} \right)_{j} \Delta x_i \Delta x_k \rho_{y^i \mu^i} \sigma_{\mu^i} \sigma_{\beta^i}$$

$$= \sum_{i,k=1}^{N} \rho_{y^i \mu^i} \left( \sigma_{\mu^i} \sigma_{\beta^i} \right) \left( \frac{\partial f}{\partial x_i} \right)_{j} \left( \frac{\partial f}{\partial x_k} \right)_{j} \Delta y_{ik} \Delta y_{kj}$$

$$= \sum_{i,k=1}^{N} \rho_{y^i \mu^i} \Delta y_{ik} \Delta y_{kj}$$
Model dependent evaluation

Bayesian probability statistics:

\[ p(p|D) = \frac{L(D|p)p_a(p)}{\int L(D|p')p_a(p')dp'} \]

The covariance of parameters:

\[ (V_p)_{kq} = \langle (p_k-<p_k>)(p_q-<p_q>) \rangle \]

\[ = \int (p_k-<p_k>)(p_q-<p_q>) p(p'|D)dp' \]

after introducing the assumption of normal distribution and maximum likelihood, function, then the formula becomes the following cases based on different prior distributions,

\[ p(p|D) = C \exp\{ (-1/2)(y-f(p))^T V_y^{-1} [y-f(p)] \} \]

\[ p(p|D) = C \exp\{ (-1/2)[y-f(p)]^T V_y^{-1} [y-f(p)] \} p_a(p) \]

\[ p_a(p) = 1 \quad \text{(等概率假设)} \]

\[ [y-f(p)]^T V_y^{-1} [y-f(p)] = \text{minimum} \]

\[ p(p|D) = \exp\{ (-1/2)[y-f(p)]^T V_y^{-1} [y-f(p)] \}
+ (-1/2)(p-p_a)^T V_a^{-1}(p-p_a) \} \cdot \]

\[ [y-f(p)]^T V_y^{-1} [y-f(p)] + (p-p_a)^T V_a^{-1}(p-p_a) = \text{minimum} \]

\[ \Delta \hat{C} = (F^T V^{-1} F)^{-1} F^T V^{-1} (Y-Y_0) \]

\[ \hat{V}_C = (F^T V^{-1} F)^{-1} \]

\[ \hat{Y} = F \Delta \hat{C} + Y_0 \]

\[ \hat{V}_{\hat{p}} = F V_C F^T \]
Deterministic approach: Data recommendation together with COV

Correlations among single (or multiple) set(s) of experimental data are vital elements to get an 'honest' covariance. But it is almost inaccessible in the real evaluation.
The contribution from collaboration network (CN) of nuclear data

The covariance evaluation from CNDC and the Chinese nuclear data collaborated network

<table>
<thead>
<tr>
<th>Index</th>
<th>Nucl.</th>
<th>Reaction</th>
<th>Method</th>
<th>Comp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$^{48}$Ti</td>
<td>$(n,\text{tot}), (n,p),(n,\alpha)$</td>
<td>实验数据评价+SPCC+模型依赖</td>
<td>CNDC</td>
</tr>
<tr>
<td>2</td>
<td>$^{40}$Ca</td>
<td>$(n,\text{tot}), (n,\alpha)$</td>
<td>实验数据评价+SPCC+ASEU</td>
<td>CNDC</td>
</tr>
<tr>
<td>3</td>
<td>$^{54}$Fe</td>
<td>$(n,2n)$</td>
<td>实验数据评价+SPCC</td>
<td>CNDC</td>
</tr>
<tr>
<td>4</td>
<td>$^{90}$Zr</td>
<td>$(n,2n),(n,\text{incl})$</td>
<td>ASEU + 模型依赖</td>
<td>CNDC</td>
</tr>
<tr>
<td>5</td>
<td>$^{58}$Ni*</td>
<td>多反应道</td>
<td>实验数据评价+SPCC</td>
<td>CN</td>
</tr>
<tr>
<td>6</td>
<td>$^{63,65}$Cu</td>
<td>多反应道</td>
<td>实验数据评价+SPCC</td>
<td>CN</td>
</tr>
<tr>
<td>7</td>
<td>$^{93,95}$Nb</td>
<td>多反应道</td>
<td>实验数据评价+ASEU</td>
<td>CN</td>
</tr>
<tr>
<td>8</td>
<td>Isotopes of W</td>
<td>多反应道</td>
<td>实验数据评价+ASEU</td>
<td>CN</td>
</tr>
<tr>
<td>9</td>
<td>$^{209}$Bi*</td>
<td>多反应道</td>
<td>实验数据评价+ASEU</td>
<td>CN</td>
</tr>
<tr>
<td>10</td>
<td>$^{233}$U</td>
<td>$(n,\text{tot}),(n,f)$</td>
<td>实验数据评价+SPCC</td>
<td>CNDC</td>
</tr>
</tbody>
</table>
Samples - Ca40

现状
- 实验数据: $^{40}\text{Ca}(n, \text{tot})$ 11 家, $^{\text{nat}}\text{Ca}(n, \text{tot})$ 43 家,来自EXFOR库。
- 评价数据: JENDL-4.0, JEFF-3.2 (同JEFF-3.1, ENDF/B-VII.1), CENDL-3.1, etc. 无协方差。

评价难点:
- 结构区: 多家数据分歧,不同能量分辨,能量漂移问题
- 平滑区: 相对一致,误差及关联情况复杂

处理方法:
- 根据实验测量条件,如实验目的、飞行距离、中子源、探测器、样品定量、样品厚度、本底扣除、散射影响等因素进行评价。
- 结构区推荐单家实验数据,平滑区采用拟合数据。
- 重新评价误差及关联。

绝对协方差矩阵

<table>
<thead>
<tr>
<th>误差源项</th>
<th>值(%)</th>
<th>关联</th>
</tr>
</thead>
<tbody>
<tr>
<td>统计</td>
<td>1.5</td>
<td>无</td>
</tr>
<tr>
<td>本底修正</td>
<td>0.6</td>
<td>中程</td>
</tr>
<tr>
<td>内散射修正</td>
<td>0.5</td>
<td>中程</td>
</tr>
<tr>
<td>死时间修正</td>
<td>0.6</td>
<td>中程</td>
</tr>
<tr>
<td>几何因素</td>
<td>0.2</td>
<td>长程</td>
</tr>
<tr>
<td>样品定量</td>
<td>0.3</td>
<td>长程</td>
</tr>
</tbody>
</table>
Samples — Fe56

Exp. Data evaluation

\[ ^{54}\text{Fe}(n,2n)^{53}\text{Fe} \]

Correlation coefficient

### Samples — W182

**recommended data with uncertainties**

![Graph showing Cross Section vs. Energy](image)

**182W(n, tot)**

<table>
<thead>
<tr>
<th>Uncertainty source - &gt;</th>
<th>statistic</th>
<th>background</th>
<th>inscattering correction</th>
<th>deadtime correction</th>
<th>Energy drift</th>
<th>geometry</th>
<th>sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>correlation-&gt;</td>
<td>no</td>
<td>middle-range</td>
<td>middle-range</td>
<td>middle-range</td>
<td>middle-range</td>
<td>long-range</td>
<td>long-range</td>
</tr>
<tr>
<td>Section I [0.1, 0.5]</td>
<td>valua</td>
<td>original</td>
<td>0.006</td>
<td>0.006</td>
<td>0.005</td>
<td>0.003</td>
<td>0.008</td>
</tr>
<tr>
<td>Coefficient factor</td>
<td>0</td>
<td>0.2</td>
<td>0.3</td>
<td>0.3</td>
<td>0.1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Section II [0.5, 5.45]</td>
<td>valua</td>
<td>original</td>
<td>0.005</td>
<td>0.005</td>
<td>0.0045</td>
<td>0.005</td>
<td>0.002</td>
</tr>
<tr>
<td>Coefficient factor</td>
<td>0</td>
<td>0.2</td>
<td>0.3</td>
<td>0.3</td>
<td>0.1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Section III [5.45, 20]</td>
<td>valua</td>
<td>original</td>
<td>0.003</td>
<td>0.004</td>
<td>0.003</td>
<td>0</td>
<td>0.002</td>
</tr>
<tr>
<td>Coefficient factor</td>
<td>0</td>
<td>0.2</td>
<td>0.3</td>
<td>0.3</td>
<td>0.1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Discussion for the correlated Samples**

- W182

![Correlation Coefficient Matrix](image)
The covariance evaluation from CNDC and the cooperative network

$^{209}$Bi(n, 2n)

$^{93}$Nb(n, α)
The covariance evaluation from CNDC and the cooperative network
2.6 The evaluation for photonuclear data at CNDC

Methods during 1996-1999,
B. S. Yu, J. S. Zhang, Y. L. Han

What is new in the current technique from 2016 to now?

1. New codes for more light nuclei besides $^9$Be, and middle-heavy nuclei:
   - MEND-G for middle-heavy nuclei up to 200 MeV
   - GLUNF for $^6,^7$Li, $^9$Be, $^{10,11}$B, $^{12}$C up to 150 MeV

2. Combine 7 kinds of approaches in PSF calculation, adjust new parameters for each isotopes;

3. Discussion of the theoretical calculated transitional multiplicity function $F_i$

4. This work is building on more: latest experimental data
   latest evaluation data
   latest concentration in ENDF format
The evaluation for photonuclear data — W isotopes

The experimental data of $\gamma + \text{W}$

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Author/Ref.</th>
<th>Reaction Type</th>
<th>Energy (MeV)</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{182}\text{W}$</td>
<td>G.M.Gurevich+</td>
<td>$(\gamma, \text{abs})$</td>
<td>8.53 - 20.7</td>
<td>1981</td>
</tr>
<tr>
<td></td>
<td>A.M.Goryachev+</td>
<td>$(\gamma, \text{n})$</td>
<td>8.02 - 20.8</td>
<td>1978</td>
</tr>
<tr>
<td>$^{184}\text{W}$</td>
<td>G.M.Gurevich+</td>
<td>$(\gamma, \text{abs})$</td>
<td>8.53 - 20.7</td>
<td>1981</td>
</tr>
<tr>
<td></td>
<td>A.M.Goryachev+</td>
<td>$(\gamma, \text{x})$</td>
<td>9.0 - 19.4</td>
<td>1973</td>
</tr>
<tr>
<td></td>
<td>A.M.Goryachev+</td>
<td>$(\gamma, \text{n})$</td>
<td>8.02 - 20.8</td>
<td>1978</td>
</tr>
<tr>
<td></td>
<td>Berman+</td>
<td>$(\gamma, \text{x})$</td>
<td>9.1 - 28.5</td>
<td>1969</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$(\gamma, \text{n})$</td>
<td>9.1 - 28.5</td>
<td>1969</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$(\gamma, \text{np})$</td>
<td>9.1 - 28.5</td>
<td>1969</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$(\gamma, \text{2n})$</td>
<td>9.1 - 28.5</td>
<td>1969</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$(\gamma, \text{3n})$</td>
<td>9.1 - 28.5</td>
<td>1969</td>
</tr>
<tr>
<td>$^{186}\text{W}$</td>
<td>A.M.Goryachev+</td>
<td>$(\gamma, \text{n})$</td>
<td>9.0 - 19.4</td>
<td>1973</td>
</tr>
<tr>
<td></td>
<td>A.M.Goryachev+</td>
<td>$(\gamma, \text{x})$</td>
<td>9.0 - 19.4</td>
<td>1973</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$(\gamma, \text{unw.})$</td>
<td>9.0 - 19.4</td>
<td>1973</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$(\gamma, \text{deriv.})$</td>
<td>8.02 - 20.8</td>
<td>1978</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$(\gamma, \text{n})$</td>
<td>8.67 - 19.7</td>
<td>1981</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$(\gamma, \text{n})$</td>
<td>7.26 - 10.9</td>
<td>2004</td>
</tr>
</tbody>
</table>

Experimental data for $\gamma + \text{W}$ isotopes are measured mainly for $^{186}\text{W}$ below 30MeV.

- The evaluated $(\gamma, \text{abs})$ with SMLO are based on the data by Berman and Varlamov's;
- The competing photonuclear reactions are calculated with MEND-G, and separate photon-neutron cross sections and physics criteria $F_i$ are estimated.
The sub-library of CENDL for the photonuclear data is under study:

1. Near to 270 nucleus will be obtained;
2. The global estimation based on various Lorentzian model for all elements is performed;
3. The calculation for the competing photonuclear data is performed based on MEND-G and GUNF codes for light nuclei.
III. Nuclear Data Service and Other

3.1 Nuclear data service

CNDC provides the nuclear data service in China for different institutes, schools or other requirements. CNDC joined the developing of Chinese basic database and established a “The Database of Nuclear Physics” Website including experimental data (EXFOR), evaluated data, nuclear structure and decay data, astrophysical data and nuclear data for medical applications.
3.2 EXFOR activities at CNDC during 2017/2018

- Since 2010, CNDC has compiled 185 EXFOR entries, which included 84 neutron and 101 charged particle entries, feedback & correction performed for more than 40 entries.
- From NRDC-2017 to now, 33 entries have been finalized and 11 entries have been updated, more than 35 articles under compiling and more than 5 entries under checking.

The number of the finalized EXFOR entries
3.3 Other

Major Program of National Natural Science Foundation of China (NSFC)

Research on key scientific problems in nuclear fission data of actinide

RMB ¥20 million (USA $3 million) from 2018.01 to 2022.12. Five institutions play as the major roles and more than 10 institutions will join the project.

The project contained the following fields:

- This project is planned to establish experimental techniques for capture and fission CS measurement based on China Spallation Neutron Source and independent fission yields measurement.
- On the other hand, phenomenological method, macroscopic-microscopic model and microscopic theory will be used to study multidimensional potential energy surface, fission dynamics and post fission observables.
**Task1: Experimental study on neutron capture and fission cross sections for actinide**
To develop measurement methods for neutron capture and fission cross section of actinide nuclei, based on the China Spallation Neutron Source.

**Task2: The measurement technology research for primary fission products mass and charge distribution**
To establish the experimental method for identification of primary fission products, the E-V correlation technology design to measure fission mass distribution and prompt gamma spectrum method to identify isobaric relative amount distribution of fission primary product.

**Task3: Research on the fission yield with phenomenological method and benchmark testing**
To adopt the phenomenological method, focus on the fission yield charge distribution, mass distribution, try to resolve the key problem of conversion between the pre- and post- mass distribution. And more, the application research of yield data will be performed, including benchmark testing, uncertainty and sensitivity calculation.

**Task4: Calculations of multi-dimensional potential energy surfaces within a macroscopic-microscopic model and the study of fission dynamic processes**
The potential energy surfaces for heavy nuclei will be calculated in a five-dimensional (5D) space for different shapes within the framework of macroscopic-microscopic model. The advanced search algorithms will be developed and used in searching for the optimal fission path, fission saddles and other structure information on a multidimensional surface.

**Task5: The studies on the mechanism of nuclear fission in Actinide nuclei with microscopic theories**
To study of the multi-dimensional potential energy surface and the scission dynamics of nuclear fission based on the effective nuclear energy density functional.
Thank you for your attention!
Comments and suggestion welcome!
May. 20~24, 2019, Beijing China

First Circular
of the 2019 International Conference on Nuclear Data for Science and Technology (ND2019)
(http://www.nd2019.org)

Background

The China Nuclear Data Center (CNDC) is organizing the 2019 International Conference on Nuclear Data for Science and Technology (ND2019), which will be held on May 19~24, 2019, at China National Convention Center in Beijing, China.

Co-sponsored by the OECD NEA and supported by the IAEA. ND2019 is the fourteenth event of the ND conference series held every three years shifting between America, Europe and Asia. After the success in Harwell (1978) and the following Antwerp (1982), Santa Fe (1985), Mito (1988), Julich (1991), Gatlinburg (1994), Trawka (1997), Tsukuba (2001), Santa Fe (2004), Nice (2007), Jeju Island (2010), New York (2012) and Bruges (2016), ND conference series have become a major event in not only the nuclear data community but also in all related fields of nuclear science and technology.

The aim of such a conference is to create a forum for all scientists and engineers interested in one of the following topics to present their achievements, share their insights and facilitate potential cooperation.

Topics

Nuclear data is a comprehensive investigational field connecting fundamental physics and nuclear applications, which has been an essence in the development of peaceful use of nuclear. Given the increasingly paramount role of nuclear data in diverse fields of research and application, ND2019 will address many active scientific and technical fields, including fundamental nuclear physics, astrophysics, nuclear data measurements, nuclear power and energy, nuclear medicine, nuclear non-proliferation, nuclear safety, nuclear materials and public acceptance, and so on.

Local Organizing Team of ND2019

Mail list:
Foreign: 500+
Domestic: 500+

http://www.nd2019.org
When and Where?

Importance points

- **Registration Open:** May 01, 2018
- **Abstract Sub. Deadline:** Nov. 01, 2018
- **Author Notification:** Dec. 31, 2018
- **On-line Reg. Deadline:** Apr. 19, 2019
- **On-site Reg:** May. 19, 2019
- **ND2019:** May. 20~24, 2019

Vendor

- **China National Convention Center**
Progressing Status

**Finished**

1. The organizational structure of ND2019
2. Committees nomination and Topics
3. Logo & Main visual design
4. Registration & Abstracts collection system
5. Distribution of the 1st Circular: Call for Abs.

**On the way**

1. On-line payment solution and system
2. Committee member confirmation
3. Paper publication solution
4. Extended visual design
5. 2nd Circular: About the Fees and Payment
Accommodation:

<2Km more than 30 hotels
<2Km more than 70 restaurants

To Airport about 30 Km

Tax: About RMB 120 (USD $20 including toll).
30th meeting of the WPEC Working Party on International Nuclear Data Evaluation Co-operation

17-18 May 2018 OECD Headquarters
Paris, France

See you in Beijing 2019!