Part X

ENDF/HE-VI

Incident Neutron Sublibrary (NSUB=10)

Evaluation: **^{12}C ENDF/HE-VI Incident Neutron Sublibrary, Release 2 (MAT 625)**
Energy Range: 1.0×10^{-5} eV to 10 GeV
Files: 1, 2, 3, 4, 6
Evaluators: S. Pearlstein (BNL)

In general, the ENDF/B-VI data [1] was used below 32 MeV. The nuclear model codes ALICE-P [2][1], and LAHET [4][2] were extensively used as well as systematics [2,5,6]. Extensive comparisons were made with experimental data for total, elastic scattering, nonelastic cross sections; residual nuclide production yields, elastic scattering angular distributions, and double-differential neutron emission. The evaluation is partially documented in Ref. [7].

RESONANCE PARAMETERS (File 2)

Resonance range to 100 keV; taken from ENDF/B-VI.

SMOOTH CROSS SECTIONS (File 3)

Total (MT=1), elastic (MT=2), nonelastic (MT=3) cross sections are taken from systematics [2].

Product yields (MT=5) below 25 MeV, used ALICE-P, above 25 MeV LAHET; these were normalized to data where available. Consistency with ENDF/B-VI below 32 MeV is not assured.

Neutron production (MT=201) used ENDF/B-VI to 32 MeV, LAHET to 10 GeV.

γ, p, d, t, ^{3}He, α production (MT=202-207) used ALICE-P to 25 MeV, LAHET to 10 GeV.

$\pi^{+,}\ \pi^0$, π^- production (MT=208-210) used LAHET to 10 GeV.

ANGULAR DISTRIBUTIONS (File 4)

Elastic (MT=2) taken from systematics [5].

PRODUCT ENERGY-ANGLE DISTRIBUTIONS (File 6)

Product yields (MT=5) below 25 MeV, used ALICE-P [2], above 25 MeV LAHET [4]. Normalized to data where available. Consistency with ENDF/B-VI below 32 MeVis not assured. Data given for ^{5,6}He,m ^{6,7,8}Li, ^{7,8,9,10,11}Be, ^{8,10,11,12}B, and ^{10,11}C.

Neutron production (MT=201) used ENDF/B-VI to 32 MeV, systematics to 10 GeV.

γ, p, d, t, ^{3}He, α production (MT=202-207) used ALICE-P to 25 MeV, LAHET to 10 GeV.

$\pi^{+,}\ \pi^0$, π^- production (MT=208-210) used LAHET to 10 GeV.

REFERENCES

1. C. Fu, ***Nucl. Sci. Eng.*** **106**, 494 (1990)
2. S. Pearlstein, ***Astrophys J.*****, 346**, 1049 (1989)
3. M. Blann, **UCID 20169** (1984) Lawrence Livermore National Laboratory, and updates
4. R. Prael, et al., **LA-UR-89-3014** (1989) Los Alamos National Laboratory

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[1] A modification of ALICE89 [3].

[2] The LANL upgrade of HETC.

5. S. Pearlstein, ***Nucl. Sci. Eng.*, 49**, 162 (1972)
6. S. Pearlstein, ***Nucl. Sci. Eng.*, 95**, 116 (1987)
7. S. Pearlstein, **Nuclear Data Evaluation Methodology**, Conference, Brookhaven National Laboratory, 12-16 October 1992 (World Sci. Singapore, 1993) p. 471

Evaluation: **^{56}Fe ENDF/HE-VI Incident Neutron Sublibrary, Release 2 (MAT 2631)**
Energy Range: 1.0×10^{-5} eV to 1 GeV
Files: 1, 2, 3, 4, 6
Evaluators: S. Pearlstein (BNL)

In general, the ENDF/B-VI data was used below 20 MeV. The nuclear model code ALICE-P [2][1] employed extensively, uses parameters in a Woods-Saxon potential to fit neutron total and particle reaction cross sections from data and systematics [1,14].

RESONANCE PARAMETERS (File 2)

Resonance range to 100 keV; taken from ENDF/B-VI.

SMOOTH CROSS SECTIONS (File 3)

Total cross section (MT=1) empirical fits [6] similar to the method for proton nonelastic [1].

Elastic cross section (MT=2) set equal to total - nonelastic; Rutherford-nuclear interference is ignored.

Nonelastic (MT=3) calculated by ALICE-P. Neutron and proton nonelastic cross-section similar at high energies.

ANGULAR DISTRIBUTIONS (File 4)

Elastic scattering based on the diffraction model [3] amended for relativistic effects and empirical fits to high energy data.

PRODUCT ENERGY-ANGLE DISTRIBUTIONS (File 6)

Spallation product yields (MT=5) Calculated using ALICE-P. Data compares fairly well with experimental data [10-13].

Neutron production (MT=201) calculated by ALICE-P. Below 20 MeV, equal to sum of ENDF/B-VI MT's 4, 2*16, 22, and 28; above 250 MeV, based on systematics [4] and is consistent with data [7,8].

Gamma production (MT=202) calculated by ALICE-P and MODS [9].

Particle production cross sections above 20 MeV calculated by ALICE-P. Proton production (MT=203) below 20 MeV, equal to sum of ENDF/B-VI MTs 28 and 103; d, t, ^{3}He production (MT=204,205,206) below 20 MeV, equal to ENDF/B-VI MTs 104, 105, 106, respectively; α production (MT=207) below 20 MeV, equal to ENDF/B-VI MTs 22 and 107.

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1. J.R. Letaw, et al., ***Astrophys. J. Suppl. ser.*** **51**, 271 (1983)
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5. M. Blann, et al., ***Phys. Rev.*** **C28** (1983) 1648, and **UCID 20169** (1984) Lawrence Livermore National Laboratory, and updates
6. S. Pearlstein, ***Astrophys J.*****, 346**, 1049 (1989).

7. M. M. Meier, **Nucl. Data for Basic and Applied Sci.**, Conference, Santa Fe, NM, 13-17 May 1995, Volume 2 (Gordon and Breach, 1986) p. 1415
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9. M. Blann, et al., ***Nucl. Inst. Meth.*** **A265**, 490 (1988)
10. B. K. Gupta, et al., ***Nucl. Phys. A 170***, 49 (1970)
11. R. Silberberg, et al., **NRL 7593** (1973) Naval Research Laboratory
12. C. J. Orth, et al., ***J. Inorg. Nucl. Chem.*** **38**, 13 (1976)
13. R. Michel, et al., ***Nucl. Instr. Meth. B*** **16**, 61 (1986)
14. L. Townsend, et al., ***Rad. Res.*** **106**, 283 (1986)

Evaluation: **^{208}Pb ENDF/HE-VI Incident Neutron Sublibrary, Release 2 (MAT 8237)**
Energy Range: 1.0×10^{-5} eV to 1 GeV
Files: 1, 2, 3, 4, 6
Evaluators: T. Fukahori, S. Pearlstein (BNL)

Below 20 MeV the ENDF/B-VI data is used [1]. The nuclear model code ALICE-P[1], used extensively, uses parameters in a Woods-Saxon potential to fit neutron total and particle reaction cross-sections from data and systematics [4,5]. Tritium and ^{3}He emission is added.

RESONANCE PARAMETERS (File 2)

Resonance range to 100 keV; taken from ENDF/B-VI.

SMOOTH CROSS SECTIONS (File 3)

Total cross section (MT=1) empirical fits [2] similar to the method for proton nonelastic [4].

Elastic cross section (MT=2) set equal to total - nonelastic; Rutherford-nuclear interference is ignored.

Nonelastic (MT=3) calculated by ALICE-P. Neutron and proton nonelastic cross-section similar at high energies.

Spallation product yields (MT=5) Calculated using ALICE-P. Data compares fairly well with experimental data [7].

Fission (MT=18) based on systematics [8].

Neutron production (MT=201) calculated by ALICE-P. Below 20 MeV, equal to sum of MT's 4, 2*16, 22, and 28 [1].

Gamma production (MT=202) calculated by ALICE-P and MODS [10].

Particle production cross sections above 20 MeV calculated by ALICE-P. Proton production (MT=203) below 20 MeV, equal to sum of ENDF/B-VI MTs 28 and 103; d, t, ^{3}He production (MT=204,205,206) below 20 MeV, equal to ENDF/B-VI MTs 104, 105, 106, respectively; α production (MT=207) below 20 MeV, equal to ENDF/B-VI MTs 22 and 107.

ANGULAR DISTRIBUTIONS (File 4)

Elastic scattering Based on the diffraction model [6] amended for relativistic effects and empirical fits to high energy data.

PRODUCT ENERGY-ANGLE DISTRIBUTIONS (File 6)

Spallation product yields (MT=5) Calculated using ALICE-P. Data compares fairly well with experimental data [7].

Neutron production (MT=201) Calculated by ALICE-P. Double-differential data based on systematics [9]. Below 20 MeV, equal to sum of ENDF/B-VI MTs 4, 2*16, 22, and 28.

Gamma production (MT=202) Calculated by ALICE-P and MODS [10].

Particle production cross sections above 20 MeV calculated by ALICE-P. Proton production (MT=203) below 20 MeV, equal to sum of ENDF/B-VI MTs 28 and 103; d, t, ^{3}He production (MT=204,205,206) below 20 MeV, equal to ENDF/B-VI MTs 104, 105, 106, respectively; α production (MT=207) below 20 MeV, equal to ENDF/B-VI MTs 22 and 107.

REFERENCES

1. C.Y. Fu, et al., ***Atomic Data and Nucl. Data Tables*** **16**, 409 (1975)
2. S. Pearlstein, ***Astrophys J.*****,** **346**, 1049 (1989).
3. M. Blann, et al., ***Phys. Rev.*** **C28** (1983) 1648, and **UCID 20169** (1984) Lawrence Livermore National Laboratory, and updates
4. J.R. Letaw, et al., ***Astrophys. J. Suppl. ser.*** **51**, 271 (1983)
5. L. Townsend, et al., ***Rad. Res.*** **106**, 283 (1986)
6. S. Pearlstein, ***Nucl. Sci. Eng.*****,** **49**, 162 (1972)
7. P. Welch, et al., ***Bull. Am. Phys. Soc.*** **26**, 708 (1981)
8. T. Fukahori, internal memorandum (unpublished)
9. S. Pearlstein, ***Nucl. Sci. Eng.*****,** **95**, 116 (1987)
10. M. Blann, et al., ***Nucl. Inst. Meth.*** **A265**, 490 (1988)

Evaluation: ^{209}**Bi ENDF/HE-VI Incident Neutron Sublibrary, Release 2 (MAT 8325)**
Energy Range: 1.0×10^{-5} eV to 1 GeV
Files: 1, 2, 3, 4, 6
Evaluators: T. Fukahori, S. Pearlstein (BNL)

Below 20 MeV the ENDF/B-VI data are used [1]. The nuclear model code ALICE-P[1], employed extensively, uses parameters in a Woods-Saxon potential to fit neutron total and particle reaction cross-sections from data and systematics [4,5]. Tritium and ^{3}He emission is added.

RESONANCE PARAMETERS (File 2)

Resonance range to 100 keV; taken from ENDF/B-VI.

SMOOTH CROSS SECTIONS (File 3)

Total cross section (MT=1) empirical fits are made[2] similar to the method for proton nonelastic [4].

Elastic cross section (MT=2) Rutherford-nuclear interference is ignored; cross section set equal to total - nonelastic.

Nonelastic (MT=3) calculated by ALICE-P. Neutron and proton nonelastic cross-section similar at high energies.

Spallation product yields (MT=5) Calculated using ALICE-P. Data compares fairly well with experimental data [7].

Fission (MT=18) based on systematics [8].

Neutron production (MT=201) calculated by ALICE-P. Below 20 MeV, equal to sum of MT's 4, 2*16, 22, and 28 [1].

Gamma production (MT=202) calculated by ALICE-P and MODS [10].

Particle production cross sections above 20 MeV calculated by ALICE-P. Proton production (MT=203) below 20 MeV, equal to sum of ENDF/B-VI MTs 28 and 103; d, t, ^{3}He production (MT=204,205,206) below 20 MeV, equal to ENDF/B-VI MTs 104, 105, 106, respectively; α production (MT=207) below 20 MeV, equal to ENDF/B-VI MTs 22 and 107.

ANGULAR DISTRIBUTIONS (File 4)

Elastic scattering based on the diffraction model [6] amended for relativistic effects and empirical fits to high energy data.

PRODUCT ENERGY-ANGLE DISTRIBUTIONS (File 6)

Spallation product yields (MT=5) calculated using ALICE-P. Data compares fairly well with experimental data [7].

Neutron production (MT=201) calculated by ALICE-P. Double-differential data based on systematics [9]. Below 20 MeV, equal to sum of ENDF/B-VI MTs 4, 2*16, 22, and 28.

Gamma production (MT=202) calculated by ALICE-P and MODS [10].

Particle production cross sections above 20 MeV calculated by ALICE-P. Proton production (MT=203) below 20 MeV, equal to sum of ENDF/B-VI MTs 28 and 103; d, t, ^{3}He production (MT=204,205,206) below 20 MeV, equal to ENDF/B-VI MTs 104, 105, 106, respectively; α

production (MT=207) below 20 MeV, equal to ENDF/B-VI MTs 22 and 107.

REFERENCES

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2. S. Pearlstein, ***Astrophys J.*, 346**, 1049 (1989)
3. M. Blann, et al., ***Phys. Rev.* C28** (1983) 1648, and **UCID 20169** (1984) Lawrence Livermore National Laboratory, and updates
4. J.R. Letaw, et al., ***Astrophys. J. Suppl. ser.* 51**, 271 (1983)
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6. S. Pearlstein, ***Nucl. Sci. Eng.*, 49**, 162 (1972)
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11. M. Blann, et al., ***Nucl. Inst. Meth.* A265**, 490 (1988)

Part XI

ENDF/HE-VI

Incident Proton Sublibrary (NSUB=10010)

Evaluation: ^{12}**C ENDF/HE-VI Incident Proton Sublibrary, Release 2 (MAT 625)**
Energy Range: 1.0×10^{-5} eV to 10 GeV
Files: 1, 3, 6
Evaluators: S. Pearlstein (BNL)

ENDF/HE-VI MOD 2 REVISION 1 (V. McLane, NNDC, December 1996)
Comments updated.

ENDF/HE-VI MOD 2 EVALUATION (S. Pearlstein, NNDC, September 1992)
The nuclear model codes ALICE-P [1][1], and LAHET [3][2] were used extensively as well as systematics [1,4,5]. Extensive comparisons were made with experimental data for nonelastic cross sections; residual nuclide production yields, and double-differential neutron emission. The evaluation is partially documented in Ref. [6].

SMOOTH CROSS SECTIONS (File 3)
Elastic (MT=2), nonelastic (MT=3) cross sections are taken from systematics [1].
Product yields (MT=5) below 25 MeV, used ALICE-P, above 25 MeV LAHET; these were normalized to data where available.
Neutron production (MT=201) used LAHET to 10 GeV.
γ, p, d, t, ^{3}He, α production (MT=202-207) used ALICE-P to 25 MeV, LAHET to 10 GeV.
$\pi^{+,}$ π^{0}, π^{-} production (MT=208-210) used LAHET to 10 GeV.

PRODUCT ENERGY-ANGLE DISTRIBUTIONS (File 6)
Product yields (MT=5) below 25 MeV, used ALICE-P, above 25 MeV LAHET. Normalized to data where available. Data given for ^{6}He, ^{6,7,9}Li, ^{7,8,9,10}Be, ^{10,11}B, and ^{10,11}C.
Neutron emission spectra taken from systematics [4].
Same as File 3 for MT = 201-210.

REFERENCES

1. S. Pearlstein, ***Astrophys. J.*, 346**, 1049 (1989)
2. M. Blann, **UCID 20169** (1984) Lawrence Livermore National Laboratory, and updates
3. R. Prael, et al., **LA-UR-89-3014** (1989) Los Alamos National Laboratory
4. S. Pearlstein, ***Nucl. Sci. Eng.*, 49**, 162 (1972)
5. S. Pearlstein, ***Nucl. Sci. Eng.*, 95**, 116 (1987)
6. S. Pearlstein, **Nuclear Data Evaluation Methodology**, Conference, Brookhaven National Laboratory, 12-16 October 1992 (World Sci. Singapore, 1993) p. 471

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[1] A modification of ALICE89 [3].

[2] The LANL upgrade of HETC.

Evaluation: **^{56}Fe ENDF/HE-VI Incident Proton Sublibrary, Release 2 (MAT 2631)**
Energy Range: 1.0×10^{-5} eV to 1 GeV
Files: 1, 3, 6
Evaluators: S. Pearlstein (BNL)

ENDF/HE-VI MOD 2 REVISION 1 (V. McLane, NNDC, December 1996)
Comments updated.

ENDF/HE-VI MOD 2 EVALUATION (S. Pearlstein, NNDC, June 1988)
The nuclear model code ALICE-P [2][1] employed extensively, uses parameters in a Woods-Saxon potential to fit neutron total and particle reaction cross sections from data and systematics [1,14].

SMOOTH CROSS SECTIONS (File 3)
Total cross section (MT=1) empirical fits [6] similar to the method for proton nonelastic [1].
Elastic cross section (MT=2) set equal to total - nonelastic; Rutherford-nuclear interference is ignored.
Nonelastic (MT=3) calculated by ALICE-P. Neutron and proton nonelastic cross-section similar at high energies.
Spallation product yields (MT=5) Calculated using ALICE-P. Data compares fairly well with experimental data [10-13].
Neutron production (MT=201) calculated by ALICE-P. Above 250 MeV, based on systematics [4] and is consistent with data [7,8].
Gamma production (MT=202) calculated by ALICE-P and MODS [9].
p, d, t, ^{3}He production cross sections (MT=203-207) calculated by ALICE-P.

PRODUCT ENERGY-ANGLE DISTRIBUTIONS (File 6)
Same as File for for MT = 5, and 201-207.

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2. I. Angeli, et al., ***Nucl. Phys. A*** **170**, 577 (1971)
3. S. Pearlstein, ***Nucl. Sci. Eng.*****, 49**, 162 (1972)
4. S. Pearlstein, ***Nucl. Sci. Eng.*****, 95**, 116 (1987)
5. M. Blann, et al., ***Phys. Rev.*** **C28** (1983) 1648, and **UCID 20169** (1984) Lawrence Livermore National Laboratory, and updates
6. S. Pearlstein, ***Astrophys J.*****, 346**, 1049 (1989)
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9. M. Blann, et al., ***Nucl. Inst. Meth.*** **A265**, 490 (1988)
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11. R. Silberberg, et al., **NRL 7593** (1973) Naval Research Laboratory

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14. L. Townsend, et al., ***Rad. Res.*** **106**, 283 (1986)

Evaluation: ^{208}**Pb ENDF/HE-VI Incident Proton Sublibrary, Release 2 (MAT 8237)**
Energy Range: 1.0×10^{-5} eV to 1 GeV
Files: 1, 3, 6
Evaluators: T. Fukahori, S. Pearlstein (BNL)

ENDF/HE-VI MOD 2 REVISION 1 (V. McLane, NNDC, December 1996)
Comments updated.

ENDF/HE-VI MOD 2 EVALUATION (T. Fukahori and S. Pearlstein, NNDC, June 1990)
The nuclear model code ALICE-P [1][1], employed extensively, uses parameters in a Woods-Saxon potential to fit neutron total and particle reaction cross-sections from data and systematics [4,5]. Tritium and ^{3}He emission is added.

SMOOTH CROSS SECTIONS (File 3)
Total cross section (MT=1) Empirical fits are made [1] similar to the method for nonelastic [3].
Elastic cross section (MT=2) Rutherford-nuclear interference is ignored; set equal to total - nonelastic.
Nonelastic (MT=3) Calculated by ALICE-P. Neutron and proton nonelastic cross-section similar at high energies.
Spallation product yields (MT=5) Calculated using ALICE-P. Data compares fairly well with experimental data [6,7].
Fission (MT=18) Based on systematics [8].
Neutron production (MT=201) Calculated by ALICE-P.
Gamma production (MT=202) Calculated by ALICE-P and MODS [10].
p, d, t, ^{3}He, α production (MT=203) Calculated by ALICE-P.

ANGULAR DISTRIBUTIONS (File 4)
Elastic scattering Based on the diffraction model [6] amended for relativistic effects and empirical fits to high energy data.

PRODUCT ENERGY-ANGLE DISTRIBUTIONS (File 6)
Same as File for for MT = 5, and 201-207.

REFERENCES

1. S. Pearlstein, ***Astrophys J.*, 346**, 1049 (1989).
2. M. Blann, et al., ***Phys. Rev.*** **C28** (1983) 1648, and **UCID 20169** (1984) Lawrence Livermore National Laboratory, and updates
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4. L. Townsend, et al., ***Rad. Res.*** **106**, 283 (1986)
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16. M. Blann, et al., ***Nucl. Inst. Meth.*** **A265**, 490 (1988)

Evaluation: ^{209}**Bi ENDF/HE-VI Incident Proton Sublibrary, Release 2 (MAT 8325)**
Energy Range: 1.0×10^{-5} eV to 1 GeV
Files: 1, 3, 6
Evaluators: T. Fukahori, S. Pearlstein (BNL)

ENDF/HE-VI MOD 2 REVISION 1 (V. McLane, NNDC, December 1996)
Comments updated.

ENDF/HE-VI MOD 2 EVALUATION (T. Fukahori and S. Pearlstein, NNDC, June 1990)
The nuclear model code ALICE-P[1], employed extensively, uses parameters in a Woods-Saxon potential to fit neutron total and particle reaction cross-sections from data and systematics [4,5]. Tritium and ^{3}He emission is added.

SMOOTH CROSS SECTIONS (File 3)
Total cross section (MT=1) Empirical fits are made [1] similar to the method for nonelastic [3].
Elastic cross section (MT=2) Rutherford-nuclear interference is ignored; cross section set equal to total - nonelastic.
Nonelastic (MT=3) Calculated by ALICE-P. Neutron and proton nonelastic cross-section similar at high energies.
Spallation product yields (MT=5) Calculated using ALICE-P. Data compares fairly well with experimental data [6-18].
Fission (MT=18) Based on systematics [19].
Neutron production (MT=201) Calculated by ALICE-P.
Gamma production (MT=202) Calculated by ALICE-P and MODS [22].
p, d, t, ^{3}He, α production (MT=203) Calculated by ALICE-P.

PRODUCT ENERGY-ANGLE DISTRIBUTIONS (File 6)
Same as File for for MT = 5, and 201-207.

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1. S. Pearlstein, ***Astrophys J.*, 346**, 1049 (1989).
2. M. Blann, et al., ***Phys. Rev.* C28** (1983) 1648, and **UCID 20169** (1984) Lawrence Livermore National Laboratory, and updates
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22. M. Blann, et al., ***Nucl. Inst. Meth.*** **A265**, 490 (1988)