

Status of FRENDY

Japan Atomic Energy Agency
Kenichi TADA

This is a collaborative work with JAEA, Global Nuclear Fuel - Japan Co, Ltd., Nagoya University, and Hokkaido University.



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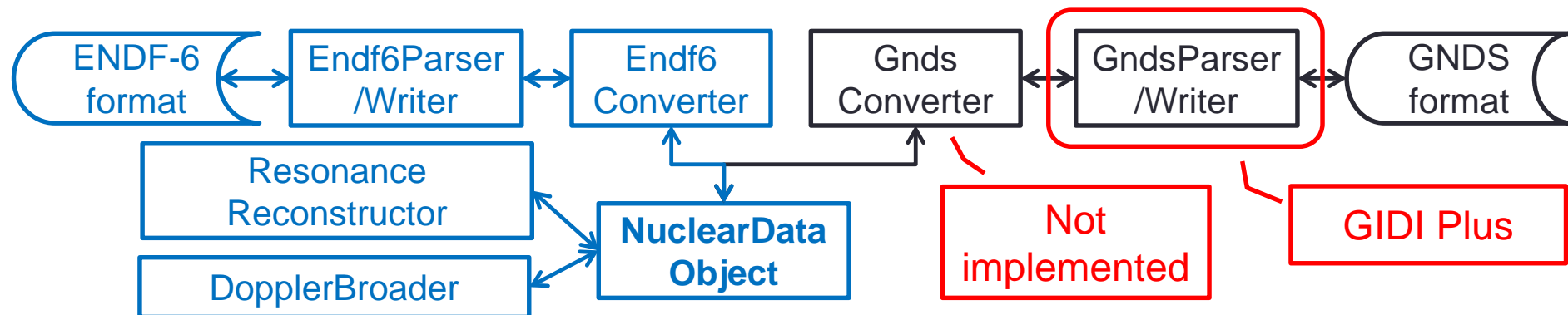
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Outline

- Treatment of GNDS (plan)
- Recent activities
 - Recent improvement of FRENDY
 - Development of multi-group cross section generation module FRENDY/MG
- Concluding remarks

Treatment of GNDS (plan)

- FRENDY will use GIDI plus of LLNL for accessing GNDS.
 - We will implement a converter class to copy the nuclear data from GIDI plus to FRENDY (NuclearDataObject).
- We are now focusing on development multi-group generation and processing covariance data.
 - Treatment of GNDS will be considered after these work is completed.

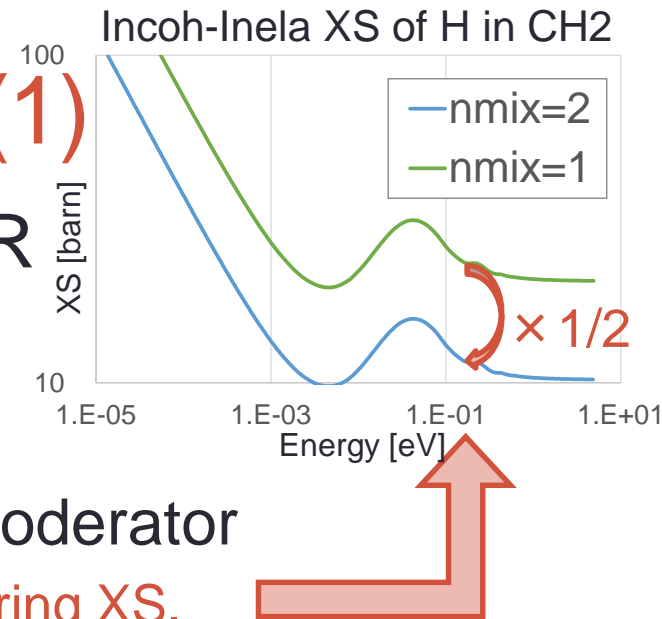


Recent improvement of FRENDY

- Processing of thermal scattering law (TSL) data
 - Improvement of input checker
 - natom of THEMR, nmix of ACER, and ielas of ACER
 - FRENDY checks evaluated nuclear file data and processed results (scattering cross section) to verify these parameters.
 - Termination of MCNP calculation using TSL data
 - MCNP6.1 or previous versions sometimes terminated when iwt of ACER is 2 (tabulated).
 - The cause of this problem is very narrow width of secondary energy grids.
- Others
 - Implementation of particle production cross section calculation function (MT=103-107)
 - Capability of editing ENDF files

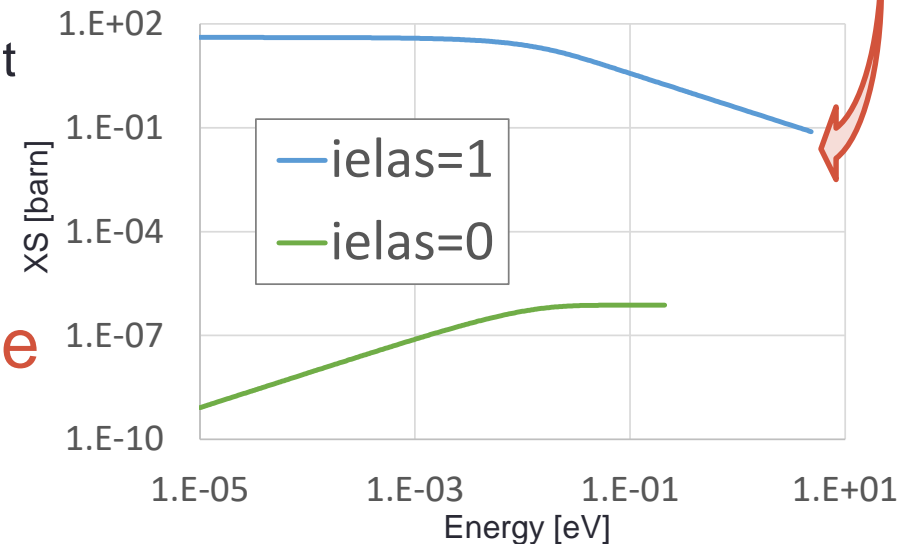
Improvement of input checker (1)

- natom of THEMUR and nmix of ACER affect incoh-inela scattering XS.
 - natom: number of principal atoms
 - nmix: number of atom types in mixed moderator
 - These parameter modifies incoh-inela scattering XS.
- Users have to check XS to verify these parameters
- **FRENDY automatically checks XS**
 - Incoh-inela scattering XS is nearly equal to elastic scattering XS at the upper limit of incident energy.
 - FRENDY compares these XSs at the upper energy.
 - FRENDY outputs warning message if the relative difference is larger than 10%.



Improvement of input checker (2)

- ACER requires elastic scattering type.
 - ielas of ACER : 0=coherent, 1=incoherent
- This parameter has large impact on processing results.
- FRENDY checks elastic scattering type using PENDF file.
 - LCT value of MF=6
 - LCT=7: coherent, LCT=6: incoherent
 - FRENDY outputs warning message if ielas of ACER is different to FRENDY's judgment.
- These checker functions will be helpful to make the correct input file.



Termination of MCNP calculation using TSL data

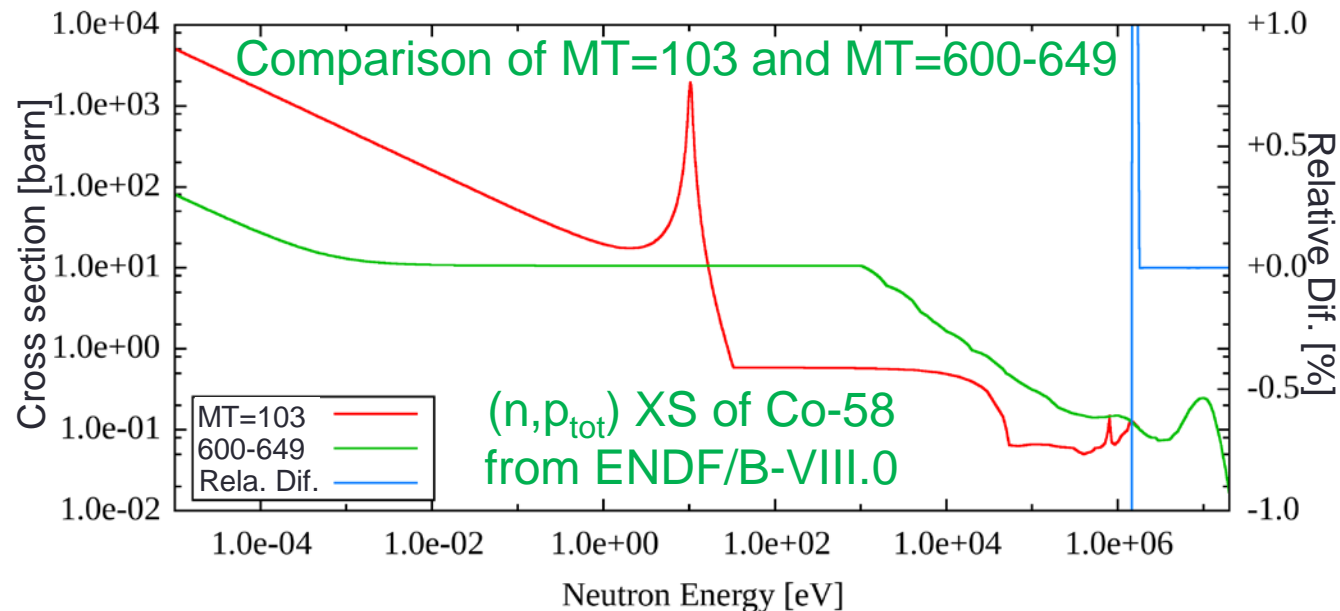
- This modification is for MCNP6.1 or earlier versions.
 - MCNP6.1 sometimes terminated when $iwt=2$ (tabulated).
 - This problem is not occurred in MCNP6.2.
 - We modified TSL data processing for MCNP6.1 or earlier versions.
- The cause of this problem is width of secondary energy grids.
 - The secondary energy grid width becomes very narrow when the secondary energy grid is linearized.
 - The secondary energy grid of THERMR is not so narrow.
 - This problem is found in ACER.

Modification of secondary energy grid linearization of TSL data

- NJOY and old version of FRENDY do not check distance of secondary energy grids.
 - The minimum energy grid distance processed by FRENDY is $1.0\text{E-}11$ eV (H in H_2O from ENDF/B-VIII.0).
 - $1.0\text{E-}11$ eV is converted to $1.0\text{E-}17$ MeV since unit of ACE file is MeV.
 - Such narrow distance must be considered the effect of rounding errors.
- Modified FRENDY does not add new energy grids when the minimum distance is less than $1.0\text{E-}8$ eV.
 - MCNP6.1 or earlier version does not terminate when the modified ACE file is used.

Implementation of particle production XS calculation function (MT=103-107)

- ENDF-6 format allows two types of particle production reaction (p, d, t, He-3, α).
- Total (MT=103-107) / each excited state (MT=600-849)
- Total particle production cross section of some nuclides is not identical to sum of each excited state production cross section.
 - JENDL-4.0: None
 - ENDF-B/VIII.0: Co-58 (MT=103), Gd-154 (MT=107)
 - JEFF-3.3: Rh-103 (MT=103-107), I-127 (MT=103-107), I-129 (MT=103-107), Gd-154 (MT=107)
- Verification of nuclear data file using a processing code is important.



Development of ENDF modification function

- This function removes, adds, exchanges specified MF/MT data.

MF=1
MF=2, MT=151
MF=3, MT=1
MF=3, MT=2
MF=6

remove



MF=1
MF=2, MT=151
MF=3, MT=1
MF=6

add



MF=1
MF=2, MT=151
MF=3, MT=1
MF=3, MT=2
MF=3, MT=102
MF=6

exchange

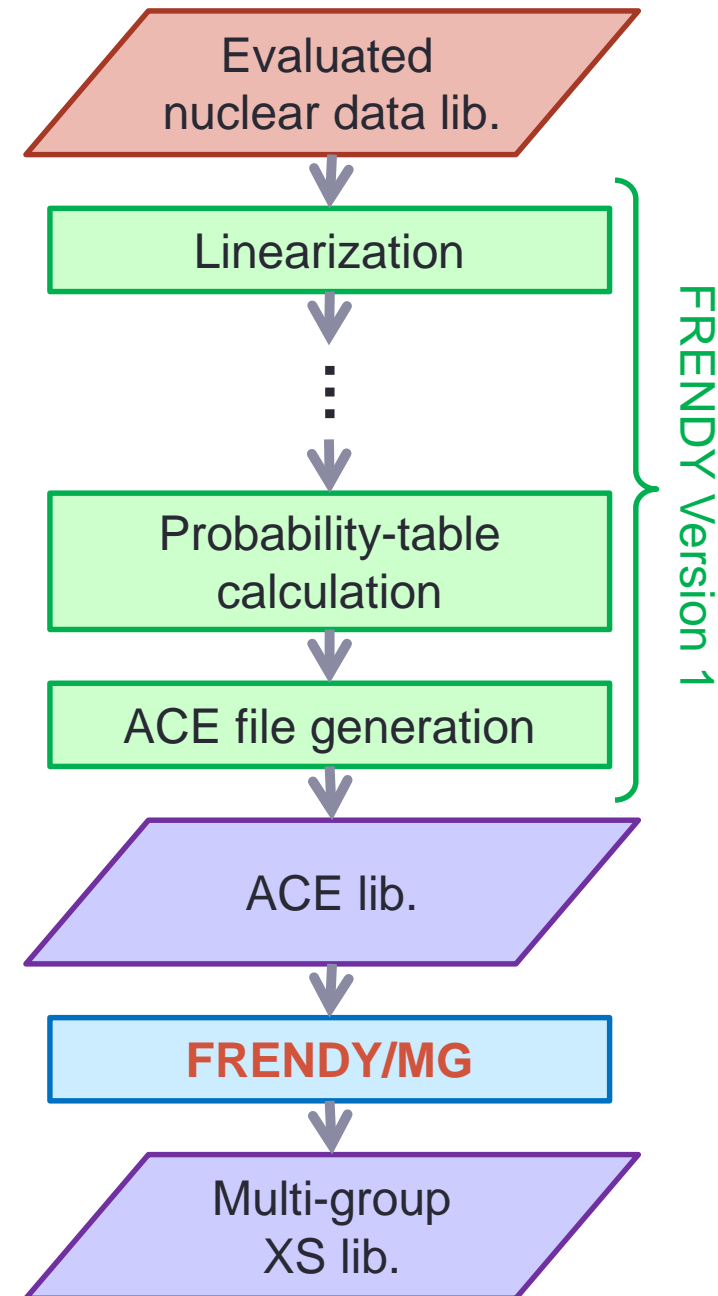


MF=1
MF=2, MT=151
MF=3, MT=1
MF=3, MT=2
MF=6

The modified evaluated nuclear data file **must be checked carefully** since FRENDY does not check the new file.

Development of FRENDY/MG

- FRENDY/MG is a multi-group cross section library generator from ACE file.
 - Multi-group XS library is generated from combination of FRENDY Version 1 and FRENDY/MG.
 - FRENDY/MG can generate multi-group XS library from the existing ACE library.
 - FRENDY/MG will be released as a function of FRENDY Version 2 in the near future.



Major capabilities and features of FRENDY/MG (1/2)

- Focus on neutron cross section generation
 - Can treat fast continuous and thermal scattering law data
- Output format of multi-group cross sections
 - MATXS
 - GENDF (to be implemented)
- Weighting spectrum
 - $1/E$, $\text{Fission}+1/E+\text{Maxwell}$ (arbitral cutoff, temperature), or **User input**
- Ultra-fine group spectrum
 - **Direct slowing down calculation** or **narrow resonance approximation**
 - Automated ultra-fine energy grid refinement using ACE pointwise energy grid
 - **Can treat a material including arbitrary number of isotopes; allows explicit consideration of resonance interference effect**
 - **Arbitrary mass weight of background moderator nuclide for evaluation of IR parameters**

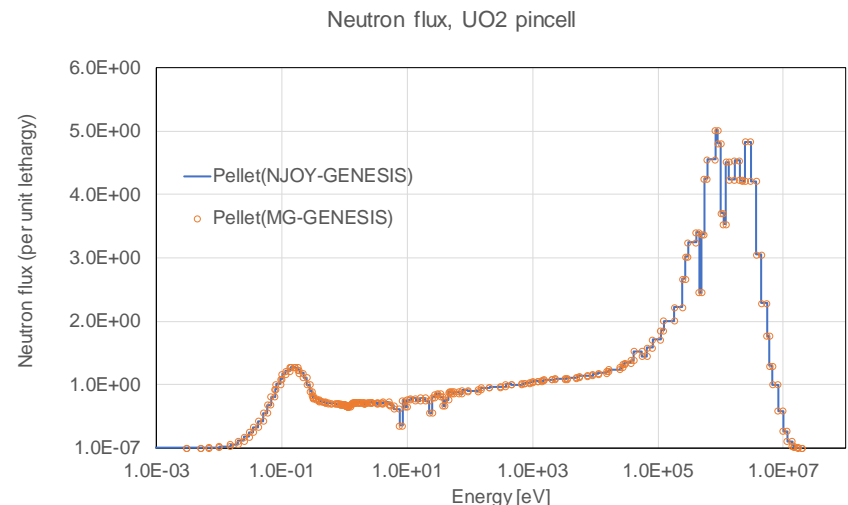
Major capabilities and features of FRENDY/MG (2/2)

- Angular/energy distribution
 - Can treat LAW=3, 4, 7, 9, 11, 44, 61 66 in an ACE file
 - Can treat all nuclides in JENDL-4.0, ENDF/B-VII.1, B-VIII.0, and JEFF-3.3
- Scattering matrices
 - Can treat all reactions including anisotropic scattering
 - $S(\alpha, \beta)$: free gas model, incoherent inelastic, incoherent elastic, coherent elastic
- Self-shielding for unresolved resonance region using probability table
- Fission spectrum, ν values
 - Prompt, Delayed (each group), Prompt + Delayed
- Arbitral multi-group energy structure
- Arbitral thermal cutoff

Verification of FRENDY/MG

- Comparison of all processing results between FRENDY/MG and NJOY
 - All nuclides in JENDL-4.0, ENDF/B-VII.1, B-VIII.0, and JEFF-3.3
 - The processing results shows good agreement.
- Comparison of neutronics calculations
 - PWR pin-cell (5 wt% UO₂, 600 K)
 - MOC (GENESIS code), 172 gr.
 - $S(\alpha, \beta)$: free gas
- K-effective
 - NJOY : 1.4089250
 - FRENDY/MG : 1.4089277

[Comparison of neutron spectrum]



Concluding remarks

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- Recent improvement of FRENDY
 - Improvement of input checker function
 - Modification of secondary energy grid linearization of TSL data
 - Implementation of particle production XS calculation function (MT=103-107)
 - Development of ENDF modification function
- Development of multi-group cross section generation module FRENDY/MG
 - FRENDY/MG is multi-group cross section library generator from existing ACE files.
 - FRENDY/MG will be released as a function of FRENDY Version 2 in the near future.