GNDS status and development

CSEWG Formats/Processing session

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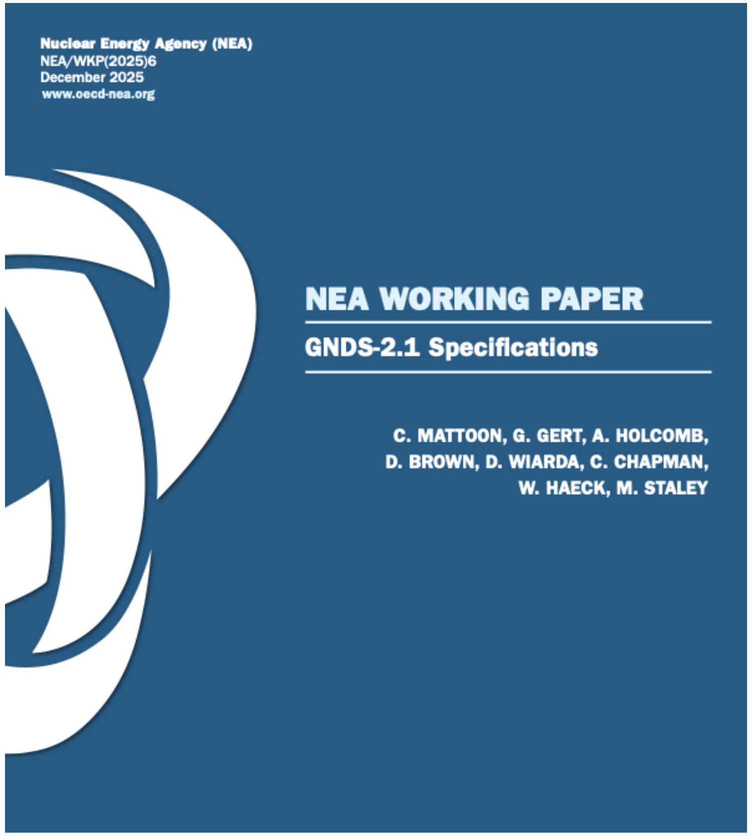
Generalised Nuclear Database Structure (GNDS)

- Adopted in 2018 as a new international standard for storing evaluated and processed nuclear reaction and decay data
  - GNDS-1.9 was the first official version
- GNDS specifications version 2.0 published in September 2023
  - Biggest impact was on the organization of TNSL data
- GNDS 2.1 published December 2025
  - Minor additions to support TNSL target stoichiometry
  - Fixes broken links, fixes typos and clarifies language in the specification document, converts some data types into enumerated lists


Nuclear Energy Agency (NEA)
NEA/WKP(2025)6
December 2025
www.oecd-nea.org

NEA WORKING PAPER

GNDS-2.1 Specifications

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GNDS-2.1 introduced the <targetInfo> section for TNSL evaluations

- Stores isotopic abundance for thermal neutron scattering data

```
<targetInfo>
  <isotopicAbundances>
    <chemicalElements>
      <chemicalElement symbol="O">
        <nuclides>
          <nuclide pid="O16" atomFraction="0.99762"/>
          <nuclide pid="O17" atomFraction="0.00038"/>
          <nuclide pid="O18" atomFraction="0.002"/></nuclides>
    </chemicalElement></chemicalElements>
</isotopicAbundances></targetInfo>
```

- Other changes:
  - Fixed broken links in pdf
  - Resolved circular dependencies
  - Fixed other inconsistencies between specs and published GNDS files

Code support for GNDS is expanding. Status as of June 2025 (WPEC EG-GNDS):

- NJOY: the **dryad** interface is a format-agnostic layer for interacting with data. Complete for electro-atomic and photo-atomic interactions, making progress on neutrons / CPs / photo-nuclear.

- AMPX: demonstrated ability to process recent ENDF library releases from either ENDF-6 or GNDS. Now doing extensive comparison of processed results to identify differences.

- NECP-Atlas: able to generate ACE files from both ENDF-6 and GNDS, shared results of various criticality benchmarks using both versions.

Code support for GNDS is expanding. Status as of June 2025 (WPEC EG-GNDS), continued:

- NDEX: supports reading from both ENDF-6 and GNDS, with comparison operators to help check for consistency. GNDS support is not high priority yet since libraries continue to be published primarily in ENDF-6.
    - Suggestion: do a ‘soft transition’ where the main download link for a library points to GNDS files, but ENDF-6 and ACE versions are still available?
- FRENDY: interested in supporting GNDS but little progress yet
- GALILLÉE: little progress as of June 2025, but extensive progress since then

CEA recently expanded GNDS support and pointed out several issues in translated GNDS files

- Galillée-1 (CEA Saclay) is being updated to support GNDS. They report differences in reconstructed resonances
- Mea culpa: in several cases FUDGE mixed up the channel radius and the hard sphere radius! Some issues are simple translation errors, but others require GNDS clarifications.
  - GNDS-2.1 doesn't allow energy-dependent hard sphere radius, but several older evaluations rely on one
  - GNDS doesn't support the 'calculateChannelRadius' property for the unresolved region
  - Need a way to differentiate NLS and NLSC

ENDF-6 energy-dependent AP is translated to *scatteringRadius*, should be *hardSphereRadius*

```xml
<resonances>
  <scatteringRadius>
    <constant1d label="eval" value="0" domainMin="1e-5" domainMax="1e3">
      <axes>
        <axis index="1" label="energy_in" unit="eV"/>
        <axis index="0" label="radius" unit="fm"/></axes></constant1d></scatteringRadius>
  <resolved domainMin="1e-5" domainMax="1e3" domainUnit="eV">
    <BreitWigner label="eval" approximation="MultiLevel" calculateChannelRadius="true">
      <hardSphereRadius>
        <XYs1d>
          <axes>
            <axis index="1" label="energy_in" unit="eV"/>
            <axis index="0" label="radius" unit="fm"/></axes>
          <values>1e-5 3.288 2e3 3.277 5e3 3.255 7e3 3.244 1e4 3.23 2e4 3.197 5e4 3.138 7e4
      <resonanceParameters>
        <table rows="4" columns="6">
          <columnHeaders>
            <column index="0" name="energy" unit="eV"/>
            <column index="1" name="L" unit=""/>
            <column index="2" name="J" unit=""/>
            <column index="3" name="totalWidth" unit="eV"/>
            <column index="4" name="neutronWidth" unit="eV"/>
            <column index="5" name="captureWidth" unit="eV"/></columnHeaders>
          <data>
           <!--   energy | L | J | totalWidth | neutronWidth | captureWidth  -->
               -14626.47    0    3      2.098772       0.9487723            1.15
               -4875.475    0    3      2.098772       0.9487723            1.15
                4875.525    0    3      2.098772       0.9487723            1.15
                14626.53    0    3      2.098772       0.9487723            1.15</data></table>
```

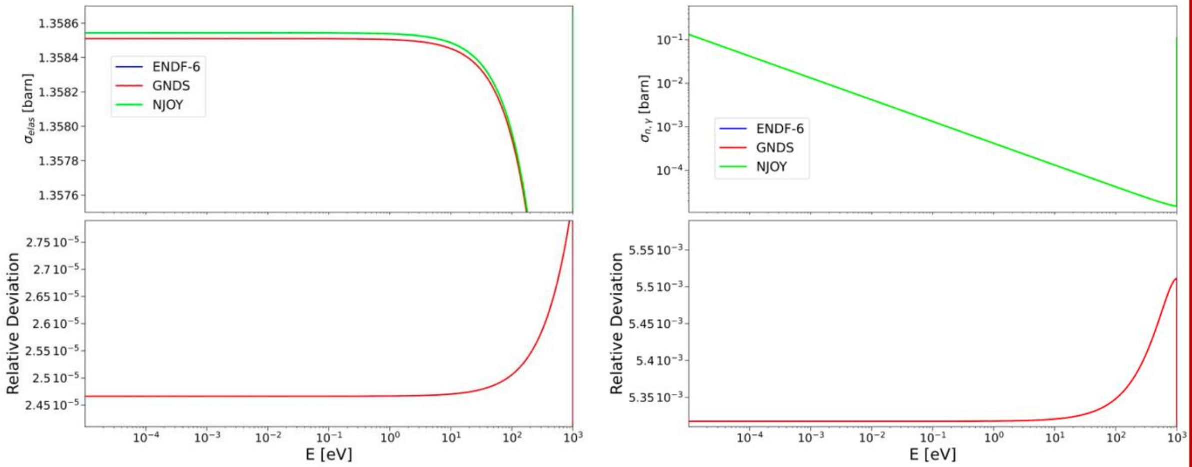
hardSphereRadius only impacts the phase shift, not penetrability or shift function.
Treating it as scatteringRadius leads to ~0.5% error on some (n,γ) cross sections

GNDS must allow either <constant1d> or <XYs1d> inside the hardSphereRadius

Impact (slide courtesy of CEA Saclay):

Conflict in channel radius definition: ~50 nuclei (3)

Example: ENDF/B-VIII.1 Ar39 in RRR



Before modification

RRR between 10^{-5} eV and 1000 eV

Before modification

MT	Maximum relative deviation
2	2.83 E-05
102	5.51 E-03

After modification

MT	Maximum relative deviation
2	1.81 E-15
102	7.03 E-12

2^{nd} issue: unresolved region needs to support the ‘calculateChannelRadius’ attribute

- ENDF-6 ‘NRO’ and ‘NAPS’ flags are repeated for each resolved / unresolved energy region. NAPS=0 indicates that the radius for penetrability / shift factor can be computed

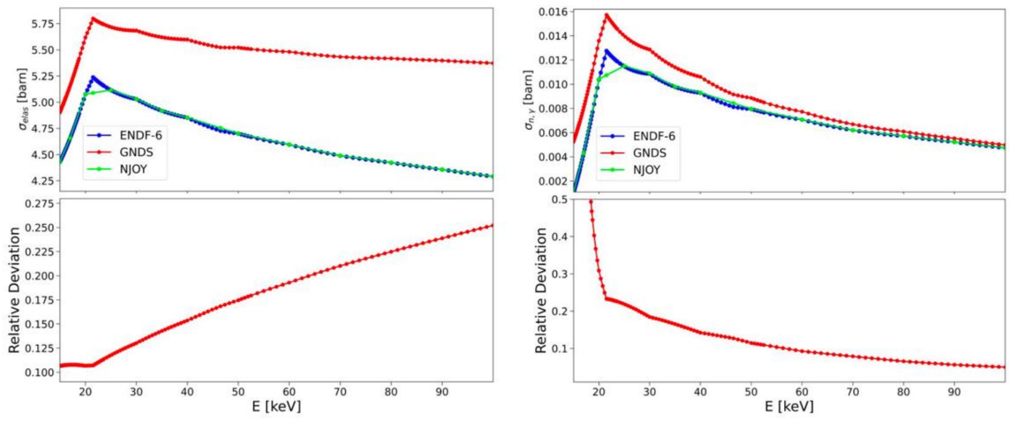
$$a = 0.123 \times \mathrm{AWRI}^{1/3} + 0.08 \qquad \text{(D.14)}$$

- GNDS *calculateChannelRadius* attribute has the same meaning, but it’s only currently allowed for resolved resonances
  - ENDF manual says to *always* calculate the channel radius for URR, but better to be explicit

Impact (slide courtesy of CEA Saclay):

No “calculated a” in URR: ~350 nuclei (3)

Example: ENDF/B-VIII.1 Na22 in URR



Before modification

URR between 1.5 10^4 eV and 10^5 eV

Before modification of a for ℓ = 1

MT	Maximum relative deviation
2	2.52 E-01
102	4,22

After modification: of a for ℓ = 1

MT	Maximum relative deviation
2	1.81 E-11
102	1.06 E-10

GNDS has no equivalent of the ENDF-6 ‘NLSC’ flag (L-values needed for reconstructing angular dist.)

NLSC Number of l-values which must be used to converge the calculation with respect to the incident l-value in order to obtain accurate elastic angular distributions. See Sections D.1.5 and D.1.6 ($NLSC \geq NLS$).

- ENDF->GNDS translator was adding empty spin groups up to NLSC, but that leads to too much potential scattering when computing cross sections.
- Better option: only add empty spin groups up to NLS, add a new attribute if NLSC > NLS

How to address ENDF-6 / GNDS processing differences?

- CEA report indicates that GNDS fixes are necessary to support faithfully representing data in some existing evaluations.
- Suggested path forward: work towards a GNDS-2.2 update to address these and potential other issues uncovered during processing inter-comparison.
  - Use GNDS-2.2 release candidate files for processing code intercomparison

Status of primary gammas in MT=102

- Use MT=900-998 for capture followed by primary gamma emission to the first 99 discrete states
- Use MT=999 as continuum channel
- Subsequent gamma cascade can be validated against evaluations in ENSDF Adopted Levels and Gammas.
- No change needed for GNDS 2.1, but open format proposal for ENDF-6 is still under consideration

What’s beyond GNDS-2.2?

- Several new proposals for expanding the types of evaluated data in GNDS are already under development:
  - Expand PoPs to better support decay data from ENSDF.
  - GRIN project: need new ways of storing photon distributions to support better photon decay cascades, including continuum-to-continuum and continuum-to-discrete transitions.
  - Expand MT=504 incoherent photon scattering (in photo-atomic libraries) into multiple reactions to support scattering off specific electron subshells. Requires adding the Compton profile for each subshell, then outgoing photon and electron distributions can be obtained from the Compton profile.
    - Thanks to summer student Jordan Northrop for implementing this option in FUDGE and GIDIplus!
  - Support thick target Bremsstrahlung, also thanks to Jordan

What's next for GNDS development?

- Add more containers for storing derived / processed data, moving them from the 'applicationData' section into the main GNDS hierarchy
  - URR probability tables (and potentially full conditional cross-section pdfs)
    - Including support for CALENDF-style PTs
  - Pre-summed multigroup data (e.g. transfer matrices summed over all reactions)
- Next EG-GNDS meeting will be held during WPEC, May 26 – 29 2026. Please participate if you are interested in contributing to GNDS development!

Why is switching to GNDS worth the effort?

- GNDS takes advantage of off-the-shelf software: XML libraries, schema checking, xPath queries, XSLT for web visualization.
- Search within a GNDS file either with an API like FUDGE or using standard tools like grep / text editors
- For now, *evaluated* data in GNDS is backwards-compatible with ENDF-6 so institutions can continue to write back and use an ENDF-based workflow. We encourage you to try using GNDS to better understand nuclear data libraries!