Recent updates to the top-level hierarchy, review draft requirements document

David Brown
NNDC, BNL
Requirements for a next generation nuclear data format

OECD/NEA/WPEC SubGroup 38*

(Dated: April 1, 2015)

This document attempts to compile the requirements for the top-levels of a hierarchical arrangement of nuclear data such as is found in the ENDF format. This set of requirements will be used to guide the development of a new set of formats to replace the legacy ENDF format.

CONTENTS

I. Introduction 2
   A. Scope of data to support 3
   B. How to use these requirements 4
   C. Main requirements 4
   D. Hierarchal structures 5
   E. Complications 6
      1. Is it a material property or a reaction property? 6
      2. Different optimal representation in different physical regions 7
      3. Ensuring consistency 7
      4. Legacy data 7
      5. Special cases 8

II. Common motifs 8
    A. Documentation 8
    B. What data are derived from what other data? 11
    C. Product list elements 13

H. Examples of covariance data usage in this hierarchy 48

VII. Required low-level containers 49
    A. The lowest-level 51
    B. General data containers 52
    C. Text 53
    D. Hyperlinks 53

VIII. Special reaction case: Atomic Scattering Data 54
     A. Incoherent Photon Scattering 55
     B. Coherent Photon Scattering 55

IX. Special reaction case: Particle production or Spallation reactions 56

X. Special reaction case: Radiative capture 56

XI. Special reaction case: Fission 57
    A. Introduction 57
    B. Existing ENDF format 57

XII. Special reaction case: Fission Product Yields 59
    A. Introduction 59
    B. Existing ENDF format 59
    C. Detailed FPY format requirements for GND 60
    D. Discussion of possible implementations 61

XIII. Special reaction case: Large Angle Coulomb Scattering (LACS) 62

XIV. Special reaction case: Thermal Scattering Law 64
    A. Theoretical Background 64
    B. Gaussian approximation of the self part of the scattering kernel 66
      1. Coherent Elastic Scattering 67
      2. Incoherent Elastic Scattering 68
      3. Incoherent Inelastic Scattering in the Short Collision Time Approximation 68

XV. Additional derived data elements for applications 68
    A. General Transport Data 69
       1. Product average kinetic energy and forward momentum 69
       2. \(\bar{\mu}_{lab}(E)\) 69
       3. CDF's from PDF's 69
       4. Probability tables in the URR 69
    B. Grouped Transport Data 70
       1. Inverse speed 71
       2. Multiplicity 71
       3. Q-value 71
       4. Projectile kinetic energy and momentum 71
    C. Production data 71
    D. Damage cross sections 72

XVI. Prototyping Functions 72

Acknowledgments 73
Requirements for a next generation nuclear data format

OECD/NEA/WPEC SubGroup 38*

(Dated: April 1, 2015)

This document attempts to compile the requirements for the top-levels of a hierarchical arrangement of nuclear data such as is found in the ENDF format. This set of requirements will be used to guide the development of a new set of formats to replace the legacy ENDF format.

### Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Introduction</td>
<td>2</td>
</tr>
<tr>
<td>A. Scope of data to support</td>
<td>3</td>
</tr>
<tr>
<td>B. How to use these requirements</td>
<td>4</td>
</tr>
<tr>
<td>C. Main requirements</td>
<td>4</td>
</tr>
<tr>
<td>D. Hierarchal structures</td>
<td>5</td>
</tr>
<tr>
<td>E. Complications</td>
<td>6</td>
</tr>
<tr>
<td>1. Is it a material property or a reaction property?</td>
<td>6</td>
</tr>
<tr>
<td>2. Different optimal representation in different physical regions</td>
<td>7</td>
</tr>
<tr>
<td>3. Ensuring consistency</td>
<td>7</td>
</tr>
<tr>
<td>4. Legacy data</td>
<td>7</td>
</tr>
<tr>
<td>5. Special cases</td>
<td>8</td>
</tr>
<tr>
<td>II. Common motifs</td>
<td>8</td>
</tr>
<tr>
<td>A. Documentation</td>
<td>8</td>
</tr>
<tr>
<td>B. What data are derived from what other data?</td>
<td>11</td>
</tr>
<tr>
<td>C. Product list elements</td>
<td>13</td>
</tr>
<tr>
<td>D. General data Containers</td>
<td>52</td>
</tr>
<tr>
<td>E. Text</td>
<td>53</td>
</tr>
<tr>
<td>F. Hyperlinks</td>
<td>53</td>
</tr>
<tr>
<td>VIII. Special reaction case: Atomic Scattering Data</td>
<td>54</td>
</tr>
<tr>
<td>A. Incoherent Photon Scattering</td>
<td>55</td>
</tr>
<tr>
<td>B. Coherent Photon Scattering</td>
<td>55</td>
</tr>
<tr>
<td>IX. Special reaction case: Particle production or Spallation reactions</td>
<td>56</td>
</tr>
<tr>
<td>X. Special reaction case: Radiative capture</td>
<td>56</td>
</tr>
<tr>
<td>XI. Special reaction case: Fission</td>
<td>57</td>
</tr>
<tr>
<td>A. Introduction</td>
<td>57</td>
</tr>
<tr>
<td>B. Existing ENDF format</td>
<td>58</td>
</tr>
<tr>
<td>C. Fission format requirements</td>
<td>58</td>
</tr>
<tr>
<td>XII. Special component case: Fission Product Yields</td>
<td>59</td>
</tr>
<tr>
<td>A. Introduction</td>
<td>59</td>
</tr>
<tr>
<td>B. Existing ENDF format</td>
<td>59</td>
</tr>
<tr>
<td>C. Detailed FPY format requirements for GND</td>
<td>60</td>
</tr>
<tr>
<td>D. Discussion of possible implementations</td>
<td>61</td>
</tr>
<tr>
<td>XIII. Special reaction case: Large Angle Coulomb Scattering (LACS)</td>
<td>62</td>
</tr>
<tr>
<td>XIV. Special reaction case: Thermal Scattering Law</td>
<td>64</td>
</tr>
<tr>
<td>A. Theoretical Background</td>
<td>64</td>
</tr>
<tr>
<td>B. Gaussian approximation of the self part of the scattering kernel</td>
<td>66</td>
</tr>
<tr>
<td>1. Coherent Elastic Scattering</td>
<td>67</td>
</tr>
<tr>
<td>2. Incoherent Elastic Scattering</td>
<td>68</td>
</tr>
<tr>
<td>3. Incoherent Inelastic Scattering in the Short Collision Time Approximation</td>
<td>68</td>
</tr>
<tr>
<td>XV. Additional derived data elements for applications</td>
<td>68</td>
</tr>
<tr>
<td>A. General Transport Data</td>
<td>69</td>
</tr>
<tr>
<td>1. Product average kinetic energy and forward momentum</td>
<td>69</td>
</tr>
<tr>
<td>2. ( \mu_{lab} ) ( E )</td>
<td>69</td>
</tr>
<tr>
<td>3. CDF's from PDF's</td>
<td>69</td>
</tr>
<tr>
<td>4. Probability tables in the URR</td>
<td>69</td>
</tr>
<tr>
<td>B. Grouped Transport Data</td>
<td>70</td>
</tr>
<tr>
<td>1. Inverse speed</td>
<td>71</td>
</tr>
<tr>
<td>2. Multiplicity</td>
<td>71</td>
</tr>
<tr>
<td>3. Q-value</td>
<td>71</td>
</tr>
<tr>
<td>4. Projectile kinetic energy and momentum</td>
<td>71</td>
</tr>
<tr>
<td>C. Production data</td>
<td>71</td>
</tr>
<tr>
<td>D. Damage cross sections</td>
<td>72</td>
</tr>
<tr>
<td>XVI. Prototyping Functions</td>
<td>72</td>
</tr>
</tbody>
</table>

*Edited by D.A. Brown (dbrown@bnl.gov)


Hopefully we’ve captured your input see [https://www.oecd-nea.org/science/wpec/sg38/top_level_hierarchy.pdf](https://www.oecd-nea.org/science/wpec/sg38/top_level_hierarchy.pdf)
Status of requirements coverage

- ENDF/B-VII.1 has 14 sublibraries
  - neutron incident
  - charged particle incident: p, d, t, 3He
  - photonuclear
  - neutron standards
  - thermal neutron scattering
  - photo-atomic, electro-atomic
  - NFY
  - decay,
  - SFY
  - atomic relaxation,

- Other easily envisioned future sub libraries
  - More charged particles: all Z<=6
  - A structure-lite library
  - muons, pi0 (cosmic rays)
  - GFY, PFY, DFY, TFY, HFY, AFY, …
  - heavy-ion projectiles
  - activation
Status of requirements coverage

- ENDF/B-VII.1 has 14 sublibraries
  - neutron incident
  - charged particle incident: p, d, t, 3He
  - photonuclear
  - neutron standards
  - thermal neutron scattering
  - photo-atomic, electro-atomic
  - NFY
  - decay,
  - SFY
  - atomic relaxation,

- Other easily envisioned future sub libraries
  - More charged particles: all Z<=6
  - A structure-lite library
  - muons, pi0 (cosmic rays)
  - GFY, PFY, DFY, TFY, HFY, AFY, …
  - heavy-ion projectiles
  - activation

This is also covered, but by a separate document
We switched to GForge for versioning of requirements after SG38 Tokai Meeting (early 2014)
We switched to GForge for versioning of requirements after SG38 Tokai Meeting (early 2014)

So I guess I have to explain where 45 pages of content came from
Notable meetings (i.e. meetings that resulted in us doing a lot of writing)

- **SG 37 meeting 2013**
  - got lots of good FPY feedback
- **Mar 2014 meeting at NCSU**
  - got lots of TSL feedback
- **SG 38 meeting before Nuclear data week @ BNL**
  - Lots of fixes from meeting
  - Lots of particle property/decay feedback
  - Backlog of fixes from previous meeting(s)
- **ORNL mini-meeting in March**
  - got lots of RR & covariance feedback
- **Work with R. Cullen to learn atomic data**
Major changes

- Move covariance/uncertainty data to be near data
  - A very popular request
- Function prototyping
  - Morgan’s request
- Resonance region fixes
- Expanded derived data discussion
  - Transport data
  - Revisions of placement in hierarchy
- Terminology appendix
  - Need to be precise about definitions
- Library markup
- General cleanup
  - Notation,
  - Figure improvements
  - Typos & wording improvements
Major changes

- **Move covariance/uncertainty data to be near data**
  - A very popular request
- **Function prototyping**
  - Morgan’s request
- **Resonance region fixes**
- **Expanded derived data discussion**
  - Transport data
  - Revisions of placement in hierarchy
- **Terminology appendix**
  - Need to be precise about definitions
- **Library markup**
- **General cleanup**
  - Notation,
  - Figure improvements
  - Typos & wording improvements
Covariance data should go where it is most useful

Self-covariance data and uncertainty data
- Should be as close to the data as possible
- Needs to be built into low-lying data structures

Cross-covariance/correlation data
- Couples many different data
- Should be separate, but linked to all relevant data
Uncertainty/covariance near data

- Most requested feature
- Can read uncertainty rather than grok MT=30-40
- Simplifies finding parts for plotting
- Revise low-level containers

Expanded discussion in “Common motifs” and “Covariance” sections
Cross-covariance data should be collected together, but linked
Cross-covariance data should be collected together, but linked...
Major changes

- **Move covariance/uncertainty data to be near data**
  - A very popular request
- **Function prototyping**
  - Morgan’s request
- **Resonance region fixes**
- **Expanded derived data discussion**
  - Transport data
  - Revisions of placement in hierarchy
- **Terminology appendix**
  - Need to be precise about definitions
- **Library markup**
- **General cleanup**
  - Notation,
  - Figure improvements
  - Typos & wording improvements
We wanted a way to prototype ideas

- Say you have a new parametric form for something…
- You create a format
- You know the parameters in your format have to be plugged into a function
- You’ve implemented it in your own code, but you want to share it
- Eventually, you hope it could be part of the standard format

How can you distribute your ideas to others in the nuclear data community?
Behold, the `<functionDef>`

- Not an implementation but a description of how to implement. Therefore we need
  - inputs
  - output
  - documentation
  - unit tests
  - the actual definition
- Very light weight, meant for simple ideas
-Defs collected in top of evaluation
-Is this what we want?
Things to consider with `<functionDef>`

- What are rules for promoting a `<functionDef>` to part of the formal format?
- How will we handle more complex format changes?
- At left is the *de facto* CSEWG workflow
Major changes

- Move covariance/uncertainty data to be near data
  - A very popular request
- Function prototyping
  - Morgan’s request
- Resonance region fixes
- Expanded derived data discussion
  - Transport data
  - Revisions of placement in hierarchy
- Terminology appendix
  - Need to be precise about definitions
- Library markup
- General cleanup
  - Notation,
  - Figure improvements
  - Typos & wording improvements
FIG. 15 Our proposed resonance data hierarchy.

We then match wave functions on the box boundary. This matching is done in a clever way involving Bloch surface operators on the box boundary and from this we arrive at a Green's function of the projected Bloch-Schrödinger equation, also known as the R matrix. The elements of the R matrix are:

$$R_{cc0} = \sum_{E} c_{c} c_{0} E_{E}, \quad (2)$$

The factor $c_{c}$'s are the reduced widths for channel $c$, $E$ becomes the resonance energy (it is a pole in the Laurent series expansion of the Green's function) and $c_{0}$ is the resonance (pole) index. The channel index $c$ contains all the quantum numbers needed to describe the two-particle state and all of those quantum numbers are described in the $<\text{channel}>$ and $<\text{spinGroup}>$ element markups below. The channel index may refer to an incoming or an outgoing channel.

With the R matrix, it is possible to compute exactly the channel-channel scattering matrix $U_{cc0}$:

$$U_{cc0} = e^{i(\gamma_c + \gamma_{c0})} p_c P_c p_{c0} \times \{ \begin{array}{l} L_{cB} \end{array} \} c_{c0}, \quad (3)$$

where the logarithmic derivative of an outgoing channel function is

$$L_c \alpha_c O_0 c(a) = \frac{r_c}{c} \frac{\partial}{\partial r_c} O_c(a) = \alpha_c L_c,$$

and we write $L_c = S_c + iP_c$.

The penetration factor is $P_c = <L_c$ and the shift factor is $S_c = L_c$. Both take their names from their function.
ENDF’s spinGroup collects channels with same channel JPi

- Denser (more efficient packing) RR parameter tables
- Basically improved version of LRF=7
Leads to obvious change in RRR’s and URR’s hierarchies

FIG. 15 Our proposed resonance data hierarchy.
backgroundReaction used to collect all the extra stuff needed to make transport ready data from RR

- **background crossSection** to add to reconstructed resonance data
- **extra reaction product distributions** (e.g., angular distributions of neutrons)
  - especially useful if don’t trust output from reconstruction of angular distributions or want smoothed version
  - best way to do capture gammas in RR
Major changes

- Move covariance/uncertainty data to be near data
  - A very popular request
- Function prototyping
  - Morgan’s request
- Resonance region fixes
- Expanded derived data discussion
  - Transport data
  - Revisions of placement in hierarchy
- Terminology appendix
  - Need to be precise about definitions
- Library markup
- General cleanup
  - Notation,
  - Figure improvements
  - Typos & wording improvements
Derived data is data that can be derived from other data in an evaluation

- A “virgin” evaluation, created by an evaluator and distributed by a library maintainer usually won’t have any
- Processing codes will insert what is needed for certain applications
  - particle transport vs. activation vs. production
- Some derived data will need to be generated for visualization (e.g. reconstructed cross sections in the resonance range)
- Data placed where it is most needed
FIG. 12 Top level arrangement of an evaluation element. Only the documentation element is required in an evaluation, but reactions, resonances, and covariances are expected in nearly all (neutron induced) reaction evaluations. The styles, particles, and functionDefs elements are used primarily to override or (re)define default behaviors. Finally, the derivedReactions and derivedTransportData elements are nearly exclusively for processed data.

15.7 Require a temperature attribute: for low enough energy projectiles, this is a crucial piece of information. For neutrons, Doppler broadening is important to determine effective reaction rates and to get self-shielding corrections. For astrophysical applications, the temperature of the plasma is needed to handle charge screening properly.

15.8 Require ELow and EHigh attributes to specify the energy range of validity of this evaluation.

15.9 Require an activationFlag attribute to signal whether the data in this evaluation is meant for activation or for particle transport. The two applications have very different completeness requirements that, in the XML variation of a format, can be enforced by checking against an XSD file.

15.10 Require a file-wide <documentation> element.

15.11 Optionally a material database to override defaults with values local to the evaluation (the <particles> element, described in reference (WPEC Subgroup 38, 2015a)).

15.12 Optionally a place for evaluation–wide default style information such as group-structures, fluxes, etc. (see the <styles> element description IV.F).

15.13 Optionally a place for covariance data (see the <covariances> section for more detail VI).

15.14 Optionally a <reactions> element (more on <reactions> in the subsection IV.B).

15.15 Optionally a <resonances> element (more on <resonances> in the subsection IV.H).

15.16 Optionally a <derivedReactions> element (see subsections XV and IV.G).

15.17 Optionally a <derivedTransportData> element to store application specific locations of derived data.
FIG. 12 Top level arrangement of an evaluation element. Only the documentation element is required in an evaluation, but reactions, resonances, and covariances are expected in nearly all (neutron induced) reaction evaluations. The styles, particles and functionDefs elements are used primarily to override or (re)define default behaviors. Finally, the derivedReactions and derivedTransportData elements are nearly exclusively for processed data.

15.7 Require a temperature attribute: for low enough energy projectiles, this is a crucial piece of information. For neutrons, Doppler broadening is important to determine effective reaction rates and to get self-shielding corrections. For astrophysical applications, the temperature of the plasma is needed to handle charge screening properly.

15.8 Require ELow and EHigh attributes to specify the energy range of validity of this evaluation.

15.9 Require an activationFlag attribute to signal whether the data in this evaluation is meant for activation or for particle transport. The two applications have very different completeness requirements that, in the XML variation of a format, can be enforced by checking against an XSD file.

15.10 Require a file-wide <documentation> element.

Optionally a material database to override defaults with values local to the evaluation (the <particles> element, described in reference (WPEC Subgroup 38, 2015a)).

Optionally a place for evaluation–wide default style information such as group-structures, fluxes, etc. (see the <styles> element description IV.F)

Optionally a place for covariance data (see the <covariances> section for more detail VI)

Optionally a <reactions> element (more on <reactions> in the subsection IV.B)

Optionally a <resonances> element (more on <resonances> in the subsection IV.H)

Optionally a <derivedReactions> element (see subsections XV and IV.G)

Optionally a <derivedTransportData> element to store application specific locations of derived data Defaults like group structures, etc. (currently no detail given in requirements)
FIG. 12 Top level arrangement of an evaluation. Only the documentation element is required in an evaluation, but reactions, resonances, and covariances are expected in nearly all (neutron induced) reaction evaluations. The styles, particles and functionDefs elements are used primarily to override or (re)define default behaviors. Finally, the derivedReactions and derivedTransportData elements are nearly exclusively for processed data.

15.7 Require a temperature attribute: for low enough energy projectiles, this is a crucial piece of information. For neutrons, Doppler broadening is important to determine effective reaction rates and to get self-shielding corrections. For astrophysical applications, the temperature of the plasma is needed to handle charge screening properly.

15.8 Require ELow and EHigh attributes to specify the energy range of validity of this evaluation.

15.9 Require an activationFlag attribute to signal whether the data in this evaluation is meant for activation or for particle transport. The two applications have very different completeness requirements that, in the XML variation of a format, can be enforced by checking against an XSD file.

15.10 Require a file-wide <documentation>

15.11 Optionally a material database to override defaults with values local to the evaluation (the <particles> element, described in reference (WPEC Subgroup 38, 2015a))

15.12 Optionally a place for evaluation–wide default style information such as group-structures, fluxes, etc. (see the <styles> element description IV.F)

15.13 Optionally a place for covariance data (see the <covariances> section for more detail VI)

15.14 Optionally a <reactions> element (more on <reactions> in the subsection IV.B)

15.15 Optionally a <resonances> element (more on <resonances> in the subsection IV.H)

15.16 Optionally a <derivedReactions> element (see subsections XV and IV.G)

15.17 Optionally a <derivedTransportData> element to store application specific Locations of derived data Transfer matrices go here
Locations of derived data

Needs further discussion…

FIG. 12 Top level arrangement of an element. Only the documentation element is required in an evaluation, but reactions, resonances, and covariances are expected in nearly all (neutron induced) reaction evaluations. The styles, particles, and functionDefs elements are used primarily to override or (re)define default behaviors. Finally, the derivedReactions and derivedTransportData elements are nearly exclusively for processed data.

Require a temperature attribute: for low enough energy projectiles, this is a crucial piece of information. For neutrons, Doppler broadening is important to determine effective reaction rates and to get self-shielding corrections. For astrophysical applications, the temperature of the plasma is needed to handle charge screening properly.

Require an activationFlag attribute to signal whether the data in this evaluation is meant for activation or for particle transport. The two applications have very different completeness requirements that, in the XML variation of a format, can be enforced by checking against an XSD file.

Require a file-wide <documentation> element.

Optionally a material database to override defaults with values local to the evaluation (the <particles> element, described in reference (WPEC Subgroup 38, 2015a))

Optionally a place for evaluation–wide default style information such as group-structures, fluxes, etc. (see the <styles> element description IV.F)

Optionally a place for covariance data (see the <covariances> section for more detail VI)

Optionally a <reactions> element (more on <reactions> in the subsection IV.B)

Optionally a <resonances> element (more on <resonances> in the subsection IV.H)

Optionally a <derivedReactions> element (see subsections XV and IV.G)

Optionally a <derivedTransportData> element to store application specific Locations of derived data

Needs further discussion…
Derived data can be anywhere

- Dictated by nature of derived data
- Should be linked to original data
- Should be as near to original as possible
Derived data can be anywhere

- KERMA,
- DPA,
- ...

- energy/momentum deposition,
- CDF’s,
- mubar,
  ...

- grouped cross sections,
FIG. 12 Top level arrangement of an evaluation. Only the documentation element is required in an evaluation, but reactions, resonances, and covariances are expected in nearly all (neutron induced) reaction evaluations. The styles, particles, and functionDefs elements are used primarily to override or (re)define default behaviors. Finally, the derivedReactions and derivedTransportData elements are nearly exclusively for processed data.

**Locations of derived data**

Needs further discussion…

**Diagram**

- **evaluation**
  - targetMaterial
  - projectile
  - dataFormat
  - libraryDesignator
  - Elow
  - Ehigh
  - activationFlag
- **documentation**
- **styles**
- **particles**
- **functionDefs**
- **derivedTransportData**
- **derivedReactions**
derivedReactions are like regular reactions

- Things defined by sumrules
  - total
  - absorption
  - ...
- Production data
- Reconstructed data from resonances (URR tables or cross sections)
- Should be able to reconstruct derivedReaction data from rest of evaluation
- Should be linked to original data
Major changes

- Move covariance/uncertainty data to be near data
  - A very popular request
- Function prototyping
  - Morgan’s request
- Resonance region fixes
- Expanded derived data discussion
  - Transport data
  - Revisions of placement in hierarchy

- Terminology appendix
  - Need to be precise about definitions
- Library markup
- General cleanup
  - Notation,
  - Figure improvements
  - Typos & wording improvements
Through our SG38 discussions, it became clear that we don’t all speak the same language

- physicist vs. engineer
- experimentalist vs. theorist vs. computational scientist
- *We need common definitions to avoid confusion*

**Appendix C: Terminology**

**A**: The total number of protons and neutrons in a given nucleus.

**abundance**: For isotopes that occur naturally, the abundance values are proportional to the probability of finding these isotopes and normalized so that the sum of the abundances for all the isotopes of a given chemical element is equal to 100. The source is (Holden, 2004).

**α decay**: The emission of a $^4$He nucleus ($α$ particle).

**α particle**: A $^4$He nucleus, that is, a nucleus made up of 2 neutrons and 2 protons.

**AMPX**: AMPX (Dunn, 2002) is a modular system of computer programs developed at ORNL with primary emphasis on processing neutron and photon evaluations to produce cross-section libraries for nuclear systems analysis.

**β⁻ decay**: The transformation of one neutron inside a nucleus into a proton plus an electron and an antineutrino: $n \rightarrow p + \bar{\nu}_e$.

**β⁺ decay**: The transformation of one proton inside a nucleus into a neutron plus a positron and a neutrino: $p \rightarrow n + \nu_e$.

**β-delayed particle emission**: The emission of a nucleon, nucleons or a nucleus following β-decay. For proton rich nuclei, the emission of a proton following β⁺ decay and electron capture has been observed. For neutron rich nuclei, the release of one or two neutrons following β⁻ decay is possible. The emission of α-particles has been observed for some nuclei in all types of β decay. Also, for a few nu-
The terminology section is unfinished

- I didn’t write some yet (especially variations of cross section)
- Others I need to figure out (multi-band treatment & Bondarenko factors)
- There are many others I didn’t even think to add

I can really use more help here
Major changes

- Move covariance/uncertainty data to be near data
  - A very popular request
- Function prototyping
  - Morgan’s request
- Resonance region fixes
- Expanded derived data discussion
  - Transport data
  - Revisions of placement in hierarchy
- Terminology appendix
  - Need to be precise about definitions
- Library markup
- General cleanup
  - Notation,
  - Figure improvements
  - Typos & wording improvements
Request for scheme to group together evaluations

- Define a (sub) library
- Collect evaluations for batch web retrieval
- Essentially a directory of files/evaluations
- Deliberately light weight
Major changes

- Move covariance/uncertainty data to be near data
  - A very popular request
- Function prototyping
  - Morgan’s request
- Resonance region fixes
- Expanded derived data discussion
  - Transport data
  - Revisions of placement in hierarchy
- Terminology appendix
  - Need to be precise about definitions
- Library markup
- General cleanup
  - Notation,
  - Figure improvements
  - Typos & wording improvements
Notes like these from Caleb and Bret and edits from Morgan were essential. Also, a special thanks to Jeremy for LaTeX help.

Thanks!
What’s left to do

- The occasional FIXME
- Update affiliations
- Update acknowledgements
- Update GND info in appendix
- Integrate responses from review(s)
- Integrate feedback from SG42

What else?