# Measurement Uncertainty Templates and WPEC SG50

Amanda Lewis[1], Denise Neudecker[2], Arjan Koning[3]

Technical Meeting on the International Network of Nuclear Reaction Data Centres

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[1] Naval Nuclear Laboratory
[2] Los Alamos National Laboratory
[3] International Atomic Energy Agency

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# Templates of Expected Measurement Uncertainties and Covariances

- This effort is led by the CSEWG covariance session, but is an international collaboration of evaluators, experimentalists and EXFOR compilers

- Templates contain typical, “expected” sources of uncertainty for many neutron-induced reaction measurements
  - Where possible, there are recommended uncertainty values or ranges
  - In addition, the metadata helpful for assessing experiments is detailed

- A neutron-induced fission template is already published [1].

- Our current work is on (n,tot), (n,g), (n,xn), (n,cp), PFNS, FY and nu-bar.

[1] D. Neudecker, *et. al*, EPJ Nucl. Sci. Technol. 4 (2018) 21.

# The templates were constructed by both evaluators and experimentalists, and will be submitted to NDS this year

- They summarize the needs of the EXFOR users and the knowledge of those who provide the EXFOR input.
  - *Evaluators* can use them to check or fill in missing/underestimated uncertainties (as a last resort)
  - *Experimentalists* can use them to ensure they are not missing uncertainties or metadata and to provide uncertainties in a **consistent format and language**,
  - *EXFOR Compilers* could use them to ask authors for needed information to make the ERR-ANALYS section more consistent and complete for evaluation purposes.

**Templates of Expected Measurement Uncertainties**

D. Neudecker,[1,*] A.M. Lewis,[2] E.F. Matthews,[3] J. Vanhoy,[4] R.C. Haight,[1] A.D. Carlson,[5] D.L. Smith,[6] S. Croft,[7] B. Pierson,[8] A. Wallner,[9,10] A. Al-Adili,[11] D.P. Barry,[2] L. Bernstein,[3,12] R.C. Block,[13] D. Brown,[14] R. Capote,[15] Y. Danon,[13] M. Devlin,[1] D.L. Duke,[1] S. Finch,[16,17] M. Fleming,[18] B.L. Goldblum,[12] G.M. Hale,[1] S. Halfon,[19] M.W. Herman,[1] K.J. Kelly,[1] A. Koning,[15] H.Y. Lee,[1] P. Lisowski,[1] A.E. Lovell,[1] P. Marini,[20] K. Montoya,[1] R.O. Nelson,[1] G.P.A. Nobre,[14] G. Noguere,[21] S. Okumura,[15] N. Otuka,[15] M. Paris,[1] B. Pritychenko,[14] H. Sjöstrand,[11] L. Snyder,[22] V. Sobes,[23] A. Solders,[11] A. Sonzogni,[14] J. Taieb,[24] P. Talou,[1] I. Thompson,[22] F. Tovesson,[6] and M.C. White[1]

[1] *Los Alamos National Laboratory, Los Alamos, NM 87545, USA*
[2] *Naval Nuclear Laboratory, Schenectady, NY 12301-1072, USA*
[3] *University of California Berkeley, Berkeley, CA 94720, USA*
[4] *U.S. Naval Academy, Annapolis, MD 21402, USA*
[5] *National Institute of Standards and Technology, Gaithersburg, MD 20899-8463, USA*
[6] *Argonne National Laboratory, Argonne, IL 60439-4842, USA*
[7] *Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA (retired)*
[8] *Pacific Northwest National Laboratory, Richland, WA 99352, USA*
[9] *Helmholtz Centre Dresden Rossendorf, 01328 Dresden, Germany*
[10] *The Australian National University, Canberra ACT 0200, Australia*
[11] *Uppsala University, 75120 Uppsala, Sweden*
[12] *Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA*
[13] *Rensselaer Polytechnic Institute, Troy, NY 12180, USA*
[14] *Brookhaven National Laboratory, Upton, NY 11973-5000, USA*
[15] *International Atomic Energy Agency, A-1400 Vienna, Austria*
[16] *Duke University, Durham, NC 27708-0308, USA*
[17] *Triangle Universities Nuclear Laboratory, Durham, NC 27708-0308, USA*
[18] *OECD Nuclear Energy Agency, 92100 Boulogne-Billancourt, France*
[19] *Soreq NRC, Yavne 81800, Israel*
[20] *Univ. Bordeaux, CNRS, CENBG, UMR 5797, F-33170 Gradignan, France*
[21] *CEA, DEN, Cadarache, 13108 Saint-Paul-les-Durance, France*
[22] *Lawrence Livermore National Laboratory, Livermore, CA 94551-0808, USA*
[23] *The University of Tennessee Knoxville, Knoxville, Tennessee 37996, USA*
[24] *CEA DAM Bruyères-le-Châtel, F-91297, Arpajon, France*

# The templates could be used by compilers to ensure consistency of language and provided uncertainties

TABLE I. Uncertainty template for total cross section measurements. The values are relative uncertainties on the parameter, and given in percent. The uncertainties for which the sensitivity must be provided for propagation are in bold. The important uncertainties that cannot be estimated as easily are counting statistics, uncertainty on neutron-energy resolution, uncertainty in the room return correction ($\beta$) and other background neutrons ($\gamma_1$, $\gamma_2$, $\zeta$), the resolution function and on $F_T$.

| Uncertainty Source | TOF | Mono-energetic |
|---|---|---|
| **Background Constant** ($K$) | $> 3$ | – |
| In-scattering Correction ($\Delta T$) | – | 20 |
| Target areal number density ($n$), metal | 0.1–1 | 0.1–1 |
| Target areal number density, ($n$), powder | 2–5 | 2–5 |
| Target areal number density ($n$), liquid | 0.1–1 | 0.1–1 |
| Target areal number density ($n$), diluted liquid | 2–5 | 2–5 |
| Flux normalization ($N_T$) with cycling | $< 1$ | – |
| Flux normalization ($N_T$) without cycling | 4 | – |

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```
ENTRY            14576   20191005   20200218   20200206       1460
SUBENT        14576001   20191005   20200218   20200206       1460
BIB                 12         63
TITLE      Tantalum, titanium, and zirconium neutron total
           cross-section measurements from 0.4 to 25 MeV
AUTHOR     (M.J.Rapp,D.P.Barry,G.Leinweber,R.C.Block,B.E.Epping,
           T.H.Trumbull,Y.Danon)
.....
ERR-ANALYS (DATA-ERR) Total uncertainty determined by
            propagating uncertainties
             - statistical uncertainties in sample and open
                measurement
             - uncertainties in sample and open background
               measurements
             - uncertainties in sample and open monitor counts
....
METHOD     (TOF)
            Repetition rate           400 Hz
            Pulse width               9.8 ns
            Flight path          (99.95+-0.01) m
SAMPLE     Natural Ta metallic sample
            Purity               >99.95 % Ta
            Sample mass          (3041.8+-0.1) g
            Nominal thickness    (39.98+-0.01) mm
            Diameter             (76.24+-0.01) mm
            Temperature           293 K
....
```

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monitor = normalization

cycling?

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```
DATA                 4        6223
EN         EN-RSL     DATA       DATA-ERR
MEV        MEV        B          B
```

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DATA                4       6223
EN        EN-RSL     DATA        DATA-ERR
MEV       MEV        B           B
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monitor = normalization

cycling?

Values are missing for many uncertainties, so the evaluator will have to estimate them to estimate the correlation matrix

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# WPEC SG50: Developing an Automatically Readable, Comprehensive, and Curated Experimental Reaction Database

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# WPEC SG50: Developing an Automatically Readable, Comprehensive, and Curated Experimental Reaction Database

- Our goal is to create a new database for experimental data that will build on EXFOR and will store “subjective” corrections to the data sets made by people other than the authors.
- Approved at the May 2020 WPEC meeting
- 57 members (and counting) from 11 countries and the NEA and IAEA, representing 5 libraries
- Coordinators: A. Lewis (Naval Nuclear Laboratory), D. Neudecker (LANL)
- Monitor: A. Koning (IAEA)

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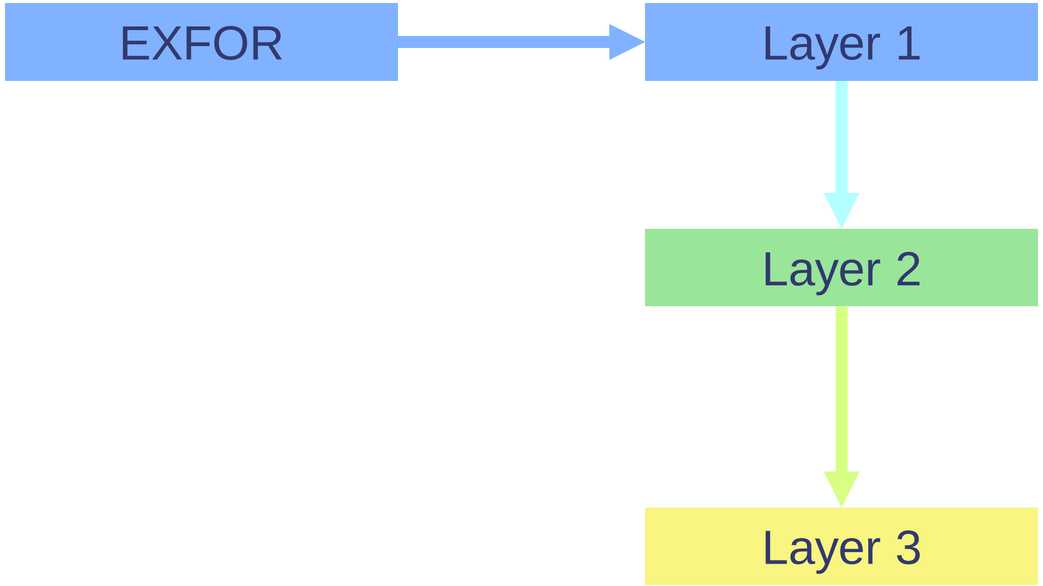
# The subgroup will develop a 3-layer experimental reaction database

- Create a format and structure for the database
- Produce example files for each layer and publish conversion codes




Metadata in an automatically readable format

"Objective" Corrections – updating standards, flagging missing uncertainty sources via templates and identifying outliers, correcting mistakes in the published experimental report

"Subjective" Corrections – including expert judgement, updating uncertainties via templates, expanding on the current correction system

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# So far, we have split up into smaller groups, held 5 meetings, and have started to develop our format

- We have split up into several smaller groups to target specific aspects of this large undertaking:
  - Keywords and metadata
  - NRDC-coordination
  - Codes and database
  - Corrections and quality flags
  - Testing outputs
- We have made progress on a requirements document and the format
  - Details the experimental metadata that we would like to be automatically parsable in the new database – expand on the EXFOR keywords and codes.

```
"incident particles":{
    "facility": {
            "code":"LINAC",
            "description":"Linear accelerator",
            "text":" measurement was conducted at Rensselaer Polytechnic Institute using the electron linear
    "incident source": {
        "code":"PHOTO",
        "description":"Photo-neutron",
        "text":"Neutrons were produced through a (gamma,n) reaction when electrons from the RPI 60-MeV elect
    "beam height":{"constant":{
        "value": 35.6,
        "unit": "cm",
        "type": "average",
        "uncertainty": "unknown",
        "uncertainty unit":"N/A",
        "uncertainty type":"N/A"}},
```

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# We will be developing a stringent format for the database

- We think that some parts of this format might be of interest to the NRDC, and will present the format in this setting to see if it is helpful

- We have not finalized the format yet, but instead have a few examples of the types of format specifics that might be of interest:
  - `INC-SOURCE` and Incident Reaction
  - `STATUS – ALTER`
  - Compiling types of background when given

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# INC-SOURCE and Incident Reaction

```
ENTRY            14576   20191005   20200218   20200206       1460
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...
SUBENT        14576002   20191005   20200218   20200206       1460
BIB                  5         18
REACTION   (73-TA-181(N,TOT),,SIG)
INC-SOURCE (PHOTO)Neutrons were produced through a (gamma,n)
           reaction when electrons from the RPI 60-MeV electron
           linac interact with a tantalum target,
            Nominal beam energy      53 MeV
            Nominal beam power       330 W
            Neutron target       ba
```

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            Nominal beam energy      53 MeV
            Nominal beam power       330 W
            Neutron target       bare bounce target,no moderator
......
```

# STATUS: Altered by Author

```
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...
STATUS     (TABLE) Data sent by author (M.C.R.)
                  --------------SUMMARY---------------------
```

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AUTHOR     (M.J.Rapp,D.P.Barry,G.Leinweber,R.C.Block,B.E.Epping,
           T.H.Trumbull,Y.Danon)
.......
STATUS     (ALTER) Data sent has different bin structure
                   than the plots in the reference
           (TABLE) Data sent by author (M.C.R.)
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NAVAL NUCLEAR LABORATORY

# Compile types of background

```
ENTRY            14576   20191005   20200218   20200206       1460
SUBENT        14576001   20191005   20200218   20200206       1460
BIB                 12         63
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           (TRN) Total cross section was measured using
           transmission method - sample-in data were divided by
           sample-out data collected during each individual
           experiment. All data were corrected for asssociated
           background.
CORRECTION Data were corrected for dead time
MONITOR    (6-C-12(N,TOT),,SIG)
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The background is typically the most difficult parameter to accurately define in a transmission analysis. A constant background and a time-dependent portion are the two components that generally determine the background. The constant background is generated from natural radiation in the environment, such as earthen and building materials and cosmic radiation. This component was determined from the time recorded prior to the generation of neutrons and was consistent with recorded measurements taken without the linac in operation. The time-dependent portion was determined to originate primarily from neutron capture events in the EJ-301 detector volume.[6] As the neutrons enter the volume and interact with the hydrocarbon liquid scintillator and generate the luminescence that is used to detect the presence of the neutron, they also lose energy. When the neutrons slow to thermal energy they can be captured by the hydrogen and release gamma radiation. These gamma rays are then recorded by the system as a background. The spectrum quickly builds while neutrons are impinging on the detector and then exponentially decays in time. To determine this time-dependent portion of the background, simulations were run utilizing the Monte Carlo code MCNP (Ref. 12). The MCNP results were used to obtain the background shape and were then normalized to long TOFs, where essentially no primary neutrons originating from the neutron-producing target are detected. Figure 3 shows an example of the constant background, also known as room background, and the exponentially decaying portion of the neutron data and how the MCNP-simulated background connects the two regions under the peak of the primary neutron collection.

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           neutron capture in the EJ-301 detector volume,
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# Conclusions

- Templates of expected measurement uncertainties will soon be submitted for many neutron-induced observable measurements
  - They could be used by compilers to check if the authors have provided pertinent metadata and uncertainty sources needed for nuclear data evaluations.
  - They could help to render the entries more consistent across EXFOR

- WPEC SG50 is planning to develop a database with a stringent and parsable format that will be able to store “subjective” corrections
  - We are currently developing the requirements document that will list the metadata and numerical values we will have keywords for
  - We will periodically present the format to the NRDC to see if any of the developments are of interest to the community

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