BNL Report # BNL-209790-2018-INRE

Minutes of the 2018 Cross Section Evaluation Working Group Annual Meeting

Evaluation Committee

- *Dr. Alejandro Sonzogni et al.* **BNL welcome and feedback received on B-VIII.0**
  - Welcome
  - Memoriam for Said Mughabghab
  - 6th Edition of Atlas of Resonances was published in Spring 2018
  - David Brown will be new Atlas POC
  - 50th CSEWG Annual Meeting
- *Dr. Mark Chadwick.* **Goals of evaluation session and feedback received on B-VIII.0**
  - Work differently, each lab summarizing what they will do in future rather than what did before.
  - Each lab summarizes what they are doing, identify gaps and deficiencies, and the team that will address the issues. Teams general made of multiple labs, so want to encourage collaboration and use this meeting as a chance to start setting up communications.
  - Each speaker for given nuclide comes from lab that took lead role in previous evaluation.
  - Obviously workplan is premature, but this is the beginning of outlining scope of workplan.
  - Developing new tools including new optimization tools based on machine learning, exploiting new formats that are more expressive (GNDS), possibly new collaboration/revision system, and discuss how we will use integral and differential data appropriately.
  - Should we consider plain vs. adjusted libraries?
  - Overall good agreement with integral benchmarks, but are areas to improve. Problem areas known and discussed in paper(s).

- *Dr. Andrej Trkov et al.* **^{235}U, ^{238}U, Fe, Si, Ni**
    - International Nuclear Data Evaluation Network (INDEN), follow up to the CIELO pilot project organize by the OECD/NEA
    - ^{238}U –
        - Neutron transmission: PFNS 5-8 MeV needs improvement, to account for opening up of second chance fission. This is included in JENDL. Chi-Nu experiment in process
        - Planned improvements:
            - New RRR evaluation in process, expect minor changes (JRC EC Geel)
            - (n,n'γ) will get upgraded to improve scattering
            - FPY, decay data and PFGS would benefit from improvements
    - ^{235}U –
        - No new validation surprises
        - Planned improvements:
            - Chi-Nu experiment in process. Two-fragment model doesn't include scission neutrons (about 2% of them) which contribute to low energy tail of PFNS. This is above thermal because thermal fixed by standards.
            - Fluctuations in nubar confirmed, but need higher resolution data to do better
            - Need improvements to URR fission cross section. This likely won't affect criticality, but is clear inconsistency between URR evaluation and current data.
            - RPI quasi-integral data will help with validation
            - Spectrum Averaged Cross Section (SACS) from Rez, Czech. Republic, we do well so far
        - **COMMENT: From B. Rearden: we need to include reaction rates in validation. Westinghouse indicates may be problem, but we need details. This comment seemed to relate to uranium fuel systems.**

    - Fe –
        - Neutron transmission underpredictions already known before release (but after was too late to change anything)
        - Planned Improvements:
            - Elastic too low and therefore inelastic too high
            - (n,tot) minimum poorly described around 27 keV, an update from ORNL is planned.
            - Firestone advocates a 10% reduction of (n,γ) at thermal
            - (n, nonel) to be reduced above 40 MeV (TIARA)
            - Minor isotopes also need improvement in RRR
            - Some of validation problems stem from Cr (esp. 53Cr)
            - Have test file that addresses Elastic/Inelastic corrections

            - Pb reflected benchmark also impacting Fe validation
  - Ni –
    - Criticality problems identified by S. van der Marck
    - ^{58}Ni(n,p), ^{58}Ni(n,2n) activation reactions
    - Planned Improvements
      - JAEA planning improvements, BNL may help (but is currently lower priority)
      - IAEA seeks to adopt TENDL approach, but focusing on specific case of Ni. Chance to examine in detail data and figure out approach for fluctuations, in an automated way.
      - A chance to exercise the **EXFOR correction system.** This allows us to accept/reject data, apply normalizations or corrections and assign uncertainties. Allow evaluators to share corrections, etc. and to not to have to start from scratch each time an evaluation is done.
      - **ACTION: IAEA to provide connection information for the EXFOR correction system:**
        - Access to the corrections is available from the EXFOR page after the "Data Selection" has been made by ticking the "Apply" box and expanding the "Data re-normalisation…" link. Examples are provided, as well as a "Help" button. As an example, the list of corrections for a dosimetry evaluation by K. Zolotarev is also available there under the "[ZK]" button.
        - Description of the correction system is available on https://www-nds.iaea.org/exfor/x4guide/x4corrections/x4corrections.pdf

- *Dr. Mark Chadwick et al.* **Pu isotopes, minor U isotopes, Am, Ir, Y, F**
  - ^{239}Pu –
    - No new issues, but there is obviously ongoing work
    - Planned Improvements:
      - Fission TPC and Chi-Nu data coming and will impact evaluation
      - Elastic and inelastic, there are large differences between different evaluations and has large impact on leakage. RPI semi-integral data can help here – experimental work at LANSCE has begun.
      - Thermal fission not consistent with Nuclear Data Standards evaluation. IAEA thermal PFNS suggests softer spectrum. However current PFNS agrees well with Chi-Nu
      - Updated RR planned. Current set based on SG42, merging 3 RRR sets to keep covariance small. CIELO did not update. URR same as ENDF/B-VI. Include (n,f)+(n,γf)
      - (n,2n), (n,γ) will be reviewed by LANL/LLNL

            - FPY, DN, decay energy and PFGS would benefit from upgrades
        - Team to include LANL, ORNL, LLNL, IAEA
    - Other Pu –
        - Is patchwork of JENDL, new & old ENDF
        - Planned improvements
            - Develop consistent suite of Pu evaluation with global parameter optimization
            - New capture data from Mosby, fission TPC
            - New NA-22 FPY project
            - Will ORNL be able to help with Pu RRR?
            - Revisit Lo-Fi estimates, including eigenvalue decomposition for representing covariances
        - LANL to lead, but with help from LLNL and others
    - ^{241}Am –
        - NEA subgroup closing, providing recommendations for changes. ^{241}Am thermal capture will need increasing to ~ 710b, per the subgroup findings.
    - ^{19}F –
        - Total looks good, but (n,n') follows total sort of, and it seems it should have followed Broder (1969) data (as JENDL has). Broder (1969) has low-resolution, washed out, resonances. Likely problem with RRR. LRF=7 format not used in final file even though was intermediate format during the evaluation.
        - Angular distributions taken from optical model, not RRR.
        - Was mistake in previous LRF=7 RRR evaluation so it had to be removed.
        - (α,n) used in NDA, so some work was done at ORNL
    - ^{89}Y –
        - (n,2n) good. There is new data, but they confirm existing evaluation so we don't have to do anything
    - ^{191}Ir –
        - (n,2n)m2 & (n,p) are dosimetry reactions. Excellent agreement here
        - However, (n,2n)m1 are about 300 mb higher than Filatenkov's experiment, so we have serious error.
    - ^{193}Ir –
        - (n,p) seems fine
- *Dr. Marco Pigni.* **Cl, Ca, Cu, Ce, Gd, Dy, W, V, La, Ta, ^{233}U, and α reactions**
    - ^{233}U –
        - Continued poor performance in benchmarks
        - Precise ORELA measured (n,f) and (n,tot), but only shape data for (n,f) used in 2001 ORNL evaluation. nToF (PRC 80, 044604 (2009)) confirmed ORELA (n,f) measurements.
        - Old evaluation only given to 300 eV, but evaluation actually extended to 600 eV. Is gap in covariance that is not understood in unused file.
    - ^{28,29,30}Si –

    - ORNL/TM-2001/271, ORNL did evaluation including direct component in ENDF/B-VII.1. Somehow lost.
    - Evaluation thermal cross sections matched to Mughabghab, including direct capture contribution. Original code (TEDCA) made unphysical shape at high energy. CUPIDO behaving better. Must adjust bound levels so don't double count direct capture.
    - Want to investigate inclusion of complex channel radii to account for direct capture.
  - n+^{35}Cl –
    - (n,p) is very messed up from 100 keV -- 1.2 MeV, is giant jump and widths based off average proton width, not detailed data. Working to remeasure the (n,p) cross section at nTOF so can refit.
    - Use Bc=-l basis, include direct capture
  - α+^{17,18}O –
    - Ready to submit, product of NA-22 funding
  - ^{140,142}Ce –
    - Chris Chapman evaluation (PD@ORNL)
    - Seems to be typo in copying RRR parameters from Atlas to ENDF
  - ^{62,65}Cu –
    - Full evaluation not included in final library
    - New capture data evaluated
    - Benchmark performance poor, want to revisit with current set of other evaluations to see if poor performance was in fact Cu or something else
    - High energy part to be revisited by BNL and is part of INDEN
  - ^{40}Ca –
    - (n,α) and (n,p) included in fit, but added as background rather than explicit channels in evaluation. Want bring back as official channels in evaluation. No data to base fit on however.
  - Gd, Dy, W, Vi, La, Ta, …
    - Ran out of time!!! Please see talk
- *Dr. Gustavo Nobre et al.* **Cr, Zr, Pb, Kr**
  - Cr –
    - Minor constituent in steel, but several benchmarks are very sensitive to various isotopes
    - ^{52}Cr planned work:
      - Evaluation not touched in long time
      - Elastic SAD not great, is elemental SAD, copied into each isotope
      - Cr_2O_3 targets are used in two highest precision datasets (Argrawal & Carlton) at ORELA, requires detailed understanding
      - (n,inel) did not have fluctuations built in, clear in new Geel (n,n'γ) data
      - Inelastic SAD in current ENDF is terrible
      - Need correct OMP
    - ^{53}Cr planned work:

                - RRR needs correction, impacts several benchmarks
                - Seems Cr has capture window, like Fe, and some benchmarks very sensitive to tail of cluster of resonances near 20 keV (Pronyaev slides). Data from ORELA (Guber) not properly included in evaluation (despite what documentation of evaluation says)
            - ^{50,54}Cr planned work:
                - Issue with RRR compared to Stieglitz (RPI)
            - BNL does fast, IAEA help with validation, ORNL help with RRR
    - Zr –
        - Lots of benchmarks that are systematically deficient (Snoj et al.)
        - Zr Oktavian spheres
        - ^{90}Zr planned work:
            - Unused (n,n'γ) data
            - Lots of new data
            - Angular distributions inconsistent with cross sections
        - ^{91}Zr planned work:
            - Ditto for ^{90}Zr
        - ^{94}Zr planned work:
            - Lots of new data
        - ^{96}Zr planned work:
            - New capture data
        - BNL fast, ORNL resonances, BNL can do validation of ICSBEP, but will need help with Oktavian spheres. NNL can help with testing, but on classified benchmarks
    - Pb –
        - Long term issues with validation, esp. LCT's
        - Pb pulsed spheres
        - ^{206}Pb
            - SAD not great
            - New (n,n'γ) data not used
        - ^{207}Pb
            - SAD not great
            - New (n,n'γ) data not used
        - BNL lead, RPI
    - ^{86}K –
        - Niche evaluation, no testing
        - Planned improvements
            - Missing fluctuations from Carlton
            - (n,2n) & (n,γ) off from Bhike
        - Work with LBNL
    - ^{238}U(n,n'γ) covered in IAEA talk above
- *Dr. Mark Paris.* **^{16}O, Be, Li, N α+^{6}Li, d+d,t,^{3}He, p+^{6,7}Li, t, ^{3}He, t+t,^{6}Li**

- R-matrix approach, did many nuclei, but is completely data-driven. Therefore there are gaps.
- LLNL stepped into and did some recent evaluations, addressing gaps in target-projectiles, gaps in energy
- Need to establish review criteria for CP evaluations
- Overview of all evaluations in process, see presentation
- ^{16}O work continues
  - LANL
  - ORNL, different normalization choice
  - JAEA
  - We will need to keep an eye on the $^{16}O(n,\alpha)$ evaluation – ORNL does not concur with the changes adopted for CIELO and ENDFB-VIII.0. LANSCE/LENZ measurements will be finalized in the coming year.
- Hydrogen standard file > 20 MeV needs to be sent to Carlson
- Work going on to get EDA open sourced, elements of resonance reconstruction being added to NJOY.
- Requested to release at least reduced widths for ^{16}O

- *Dr. Erich Ormand et al.* **d+^{4}He, p+^{7}Li, and d+^{7}Li + comments on other CP reactions LLNL added in VIII.0**
  - Review of previous LLNL contributions
    - Covering gaps
    - Many older evaluations from LLNL, franken-evaluations by Navratil & Brown and are not so great. They were meant to be temporary.
    - d+α
      - elastic SAD OK
      - 2-step breakup reactions are bad
    - α+^{6}Li
      - elastic SAD OK at forward angles, bad at back
    - Many evaluations, I lost track
      - Generally "plausible" evaluations, but missing resonances (as were not proper evaluations) so generally bad fits
      - A few cases are "point Coulomb" and really not good
  - Plan to work with LANL to improve evaluations
    - n+d needs work, ENDF/B-VIII.0 was stopgap. Faddeev approach may work, but which 3 body force? We need to obtain more clarity from Chalk River as to their view of the performance of this evaluation in heavy water reactor validation testing.
- *Prof. Ayman Hawari et al.* **TSLs: H(in heavy paraffinic oil), F Li Be (in FLiBe), Al O (in Al_2O_3), H(UH_3), and H(PuH_2).**
  - NNL working on hydride fuels: UH_3, PuH_2
    - Both using ab initio lattice dynamics
    - PuH_{2+x} eventually
    - Large separation of mass means clear separation of modes in phonon spectrum

                - VASP+PHONON
        - NCSU looking at heavy paraffinic oil, FLiBe, Al_2O_3
            - For liquids use classical molecular dynamics (amorphous structure means big supercells)
                - Accounted for viscosity in heavy paraffinic oil evaluation
                - FLiBe (Li_2BeF_4)
            - Sapphire (Al_2O_3) filter in moderator, modeled single crystal, used VASP+PHONON, ignores MT=2 section in TSL file
- *Dr. Jesse Holmes.* **NNL Special-Purpose (α, n) Evaluations**
    - Use α's from actinide decay
    - Uses AmBe or PuBe sources, NDA, safeguards, shielding
    - Modified JENDL/AN-2005 evaluations
    - O(α,n) –
        - Major issues compared to $^{nat}UO_2(\alpha,n)$ data, using MC-21 & JENDL data. SOURCES4C compares well, but has built-in hardwired cross sections
        - Kalbach-Mann used in $^{17,18}O$ and there is a disconnect between cross sections and outgoing distributions (used MF6, not MF4). Non-conservation of energy/momentum. By using MF4 instead for (α,n) MT=51-90, is much better.
    - $^9Be(\alpha,n)$ –
        - Generally consistent except at low energy.
        - Missing ^9Be breakup reaction physics
        - $^9Be(\alpha,\alpha')^9Be^*$, $^9Be^* \rightarrow n + {}^8Be$, $^8Be \rightarrow 2\alpha$, so just adjusted breakup reaction cross section
    - **QUESTION: No other errors that were found in JENDL files, should we add them? Should we report back fixes to JAEA?**

Executive Committee

- Minutes not taken

Validation Committee

- *Dr. David Brown.* **Status of ADVANCE and GForge**
    - CSEWG has need for GForge-like functionality.
    - Need to have review-on-commit capability.
    - Future of GForge: Buy new server is an option, but expensive. Open GitHub not viable. Closed GitHub is.
    - Advance2 server is improved capability.
    - ENDF QA Phase testing.
    - Advance is for Phase 1 testing (Comparisons to microscopic testing).
    - **COMMENT by Morgan White: Data in EXFOR is not necessarily what is actually used – it is fit/adjusted. So, how does Advance judge XS "reasonableness" with access to this information?**

- How do we make sure files can be processed by all user codes? NJOY, SCALE, etc. Who do we satisfy?
- Changes to Advance: Upgrading to Python3.7 from Python2, changes to build report, etc.
- Resonance QA: What to check? Long/Short-range behavior: Examples are nearest neighbor spacing, average spacing vs. E, cumulative level distribution, correlations in widths, etc.
- How do we assess fraction of missing resonances?
- Issues w/ Advance: Examples are sublibraries need more plots vs. data, are reports organized in a usable way, turn-around time is unacceptable. So, what in Phase 2 testing can be automated?
- For ENDF/B-VIII.1, bring back formal reviews!
- Tie subversion to review process.
- Brett Beck volunteered to assist with Advance and ENDF QA.
- What exactly do we check for in a review? Should we have an ENDF QA document? Sounds like a big YES
- **ACTION: Dave to set up ENDF QA document project on GForge. Aim is to have standards fleshed out in 1-2 years so is ready for main library release in ~5-6 years.**

- *Dr. Ibrahim Attieh.* **Validation of ENDF/B-VIII.0 Neutron Cross-Sections Library for CANDU Applications for criticality and burnup calculations**
  - 228 benchmarks done, but CANDU want to review…. Will distribute results when get OK.
  - Predicted k_{eff} for water reflected Pu nitrate solutions much worse than ENDF/B-VII.1
  - ENDF/B-VIII.0 systematically gives lower k_{eff} than ENDF/B-VII.1
  - Test calculation: 1000K fuel, 500K D_2O moderator, cylinder. Significant changes in average nu, k_{inf}
  - Overall, ENDF/B-VIII.0 lower, but average k_{eff} then agrees with benchmarks better
- *Dr. Danila Roubtsov et al.* **Nuclear Data testing & Evaluating at CNL and CAB**
  - Light and heavy water evaluations
    - Light water
      - Coverage in energy-temperature plane of data in EXFOR skimpy
      - Some high temp (Dritsa), some ice, new data from Marquez Damien in progress
      - For T<100C, ENDF/B-VIII.0 agrees with data
      - Only Dritsa data above, is 200C, ENDF/B-VIII.0 agrees. Uncertainty on Dritsa data needs to be increased (Dritsa says is only good to 6%, so translation to EXFOR may be messed up). We need new data!
      - Modest number of new EXFOR data, not helpful though
      - Light water saga continues…
      - Will be discussion of V&V at ND2019

            - Heavy water
                - Similar story to light water
                - Zaitsev data needs corrections, has some light water inside and are normalization problems due to messed up EXFOR coding. Other questions about data, doesn't seem to match at all
                - **ACTION: pass corrections onto Boris!**
                - Good agreement with Dritsa data for 200C
                - Will be discussion of V&V at ND2019
    - Experience ND libraries for MCNP/SERPENT
        - ENDF80Sab.pdf (2018) from LANL about ACE files
        - Discussion of picking good cut-off E for TSL-neutron sublibrary transition
    - ZED-2
        - 1^{st} critical in 1960
        - Tank type reactor
        - 2521 cores built, trying to get collection of benchmarks freed so can be used for validation
- *Dr. Marie-Anne Descalle.* **Testing of ENDF/B-VIII.0 in the GNDS format: update**
    - Translator for GNDS → ACE finished over the summer
    - Can translate GNDS <→ ENDL and ENDF too
    - Can process transport libraries
    - APIs: GIDI, MCGIDI soon to be released under BSD
    - To do (still): URR, TSL
    - When neither URR nor TSL needed, find excellent agreement between
        - FUDGE+MCNP6.2 and NJOY+MCNP6.2 ACE file performance
        - ARDRA+GNDS, Mercury+GNDS, MCNP – need final TSL, URR! Otherwise good
        - Comparisons for Fe, Cu, Pb reflected crits
        - Reaction rates: Mercury & MCNP mostly agree, but U233 reaction rates imperfect
    - Angle biasing just added so can start running LLNL pulsed sphere validation. There are differences between E8 in GNDS and legacy ENDL2009.3
- *Dr. Denise Neudecker.* **Validating ENDF/B-VIII.0 with LLNL pulsed spheres spanning materials from light water to plutonium**
    - 75 spheres
    - 14 MeV source that downscatters to 2 MeV
    - Decks are from Stephanie Frankle's suite for ENDF/B-VI.8, LA-UR-05-5879 (2005)
    - Just cover ones where data doesn't do well or have big changes to VIII.0
        - ^{6}Li, minimal change in E8, still bad
        - 12C: in carbon, polyethylene, Teflon and Fe
            - Suspect problem in C
            - C impacts Fe validation
        - ^{16}O: O_2, concrete, light & heavy water
            - Systematic problems, is there still a problem with oxygen?
        - Mg, nothing changed in E8, still bad

        - ^{27}Al, nothing changed in E8, still bad
        - Ti, nothing changed in E8, still bad
        - Pb:
            - not very good,
            - why change, in E8 not much changed
        - Si in concrete, suspect oxygen though
        - F in Teflon, suspect carbon but could be F
        - performing well in describing pulsed spheres: ^{1}H, ^{2}H, ^{7}Li, ^{9}Be, ^{14}N, ^{235,238}U, ^{239}Pu
- *Dr. Andrej Trkov.* **Post-ENDF/B-VIII improvements to the ^{56}Fe nuclear data evaluation**
    - Several deficiencies were noted with Fe after evaluation finished but before paper and library released. Biggest is thick Fe shell leakage spectra from ^{252}Cf and d-t source data from Simakov. Shown in NDS article for Fe.
    - Problem traced to elastic/non-elastic cross sections – need elastic to increase at expense of inelastic
        - New data from JRC Geel (Pirovano) support higher elastic.
        - Nelson correction suggests (n,inel) should be lower
        - Beyer et al. EPJ WoC 146 (2017) 02017 show SAD for inel (nElbe), we can safely go lower
        - Brings into better agreement with Negret data
        - Is pragmatic solution
    - Decreased thermal capture 10%
    - Also cut out high energy part of fit to Kinney/Perey SAD data (this is part that required undocumented corrections). Helps with leakage from reflectors. Both P_1 and P_2
    - Additional benchmarks: IPPE broomsticks, IPPE thick sphere leakage, ASPIS, LLNL pulsed spheres, Oktavian spheres, FNS slab, TIARA
    - Less useful benchmarks: NIST leakage spectra (coarser binning than IPPE), Illinois Fe leakage spectra (too coarse), EURACOS-Fe (poor source definition), LSD-RPI (poor statistics)
    - Potentially useful: KfK leakage from thick shells, NRI & Skoda leakage spectra from ^{252}Cf source, ORNL broomstick, Ohio U. benchmarks, RPI quasi-differential
    - IPPE ^{252}Cf sphere results: 1-6 MeV systematic underprediction resolved
    - ASPIS-Fe-88 benchmark:
        - B. Kos from JSI developed model
        - Agreement generally good
        - Question about ^{27}Al(n,α), is Na contamination?
    - IPPE d-t sphere:
        - A. Milocco developed good MCNP decks
        - Improvement, gets better with thicker spheres
    - LLNL pulsed spheres: no significant improvement of ENDF/B-VIII.0 with think spheres, but better with thicker sphere
    - Performance in IPPE Fe sphere is worse, particularly for neutron transmission experiments. An updated file is in preparation that removes these deficiencies.

- Oktavian sphere had worse statistics so was less useful, but suggests improvement at 300 keV
- FNS-Fe leakage: agreement good, at some angles can see big improvement
- TIARA: 40 & 65 MeV source
  - All evaluation OK for thick spheres
  - New evaluation does better with thicker spheres
  - Weird oscillations in datasets at 70 cm.
  - New evaluation as good as JENDL
  - For thickest sphere with 65 MeV have bad agreement but again a lot of unexplained structure in benchmark. May also be statistics issues in MCNP runs.
- RPI-LSD needs more statistics
- Critical assemblies:
  - Improvements overall
  - ^{53}Cr seems to be problem, or is it ^{50}Cr?
  - Pb seems to be a problem
  - Add HMF96 to suite? HEU rods in Fe matrix, no Cr, added Sep. 2016 so is new
    - Done for HMF096, no surprises.
    - As suggested by J. Bess, the DIMPLE benchmarks were also looked at. The LCT048 computational model for MCNP for Case-1 was obtained from Wu Haicheng (CNDC) and expanded to the other cases by A. Trkov, using Case-1 as a template. Something similar can be done for LCT055, but not completed yet. The predicted reactivities for LCT048 are on the high side (possibly because of the reduced thermal capture of ^{56}Fe), but within the uncertainty interval.
- New iron files available on INDEN meeting website for friendly testing, noting that this is "work in progress" and requires a more thorough approach, especially in the resonance region. The Meeting web page is https://www-nds.iaea.org/index-meeting-crp/CM-INDEN-III-2018/

- *Dr. John Bess.* **Status of the ICSBEP and IRPhEP 2018 Handbooks**
  - ICSBEP & IRPhEP big collaboration
  - "Oct. 2018 edition" available by ~Dec.
  - Calcs. based on ENDF/B-VII.1 because ENDF/B-VIII.0 wasn't ready yet
  - Noteworthy ICSBEP revisions:
    - HST-048, uncertainty doubled, reduced # acceptable configurations by factor of 2
    - LCT-072, updated sample calculations
    - LCT-079, updated pitch array
  - New ICSBEP:
    - LCT-98, from Westinghouse
    - LCT-100, UO_2 in poly-something block

        - LST-012, TRACY (JAEA), 10% UN solution, 1 critical and 1 supercritical, 3$
        - IMF-024, FCA IX-7, is ZPR-like, for minor actinides
    - New IRPhEP:
        - LR(0)-VVER-RESR-003, Czech, molten salt & FHR
        - DUKE-PWR-POWER-001, depletion reactivity measurement
        - VENUS-PWR-EXP-006, MOX fuel
        - EBR2-LMFR-RESR-001, safety heat removal test
        - IPEN(MB-01)-LWR-RESR-019, Brazil, reaction rates
        - ORCEF-FUND-EXP-001, radial fission reaction rates, UO_2F_2 sphere
        - PROTEUS-GCFR-RESR-002, MOX with ThO_2 fuel, reaction rates
        - PROTEUS-GCFR-RESR-003, MOX with Th metal, reaction rates
        - RB-FUND-EXP-009, Serbia RB reactor (HERBE)
        - TREAT-FUND-RESR-001, sensitive to fuel impurities, very sensitive to graphite Sab data
    - Guides to properly cite handbooks
    - IRPhEP uncertainty guide
    - Working on how to add proprietary data
    - Don't use input decks blindly
    - Is ongoing work to go back through books and fix older evaluations
    - Other related projects:
        - SINBAD -- shielding
        - SFCOMPO – spent fuel
        - EGMPEBV -- multiphysics
- *Dr. Dave Brown.* **Feedback from RPSD-2018**
    - Big discussion about EPICS. Keep it? If so, who to own it? Lose it? SNL major obvious users in US, mainly for space applications
    - Topic for WANDA?
    - Dosimetry reactions to fix (see talk)
    - **ACTION: Add Trackers!**
- *Dr. Boris Pritychenko.* **Assessment of ENDF/B-VIII.0 and TENDL-2015 Evaluated Nuclear Data Libraries Using Stellar Nucleosynthesis Modeling**
    - Stellar nucleosynthesis
    - ^{56}Fe occupies special place since has highest binding energy
    - R-process on millisec timescales
    - S-process, takes about 1 year for neutron to get captured
        - Neutron closed shells are bottlenecks since small capture cross section
        - In-between bottlenecks, abundances in equilibrium
        - Branching points where s-process competes with beta-decay rate
    - ENDF materials closely match s-process pathway, so modeled s-process with ENDF!
    - S-process takes less than 1% of star lifetime, about one million years
    - Kadonis not as good as ENDF or TENDL, major revision from Kadonis now closer to ENDF
    - If subtract modeled s-process from abundances, see r-process abundances

        - Good agreement with Arnould et al. 2007 (state of art)
    - GW170817! Renewed interest in nucleosynthesis
    - Deficiencies:
        - ^{209}Bi, ^{208}Pb deficient, had to be removed from network
        - ^{76}Se(n,γ) not showing in EXFOR webapp
        - ^{88}Sr, ^{138}Ba, ^{140}Ce give negative r-process abundance: either wrong cross section, wrong abundance or too much production of s-process of ^{138}Ba, ^{88}Sr
        - TENDL has similar problem for ^{127}I, ^{202}Hg, ^{203}Tl
        - Need ^{198}Au in ENDF
        - Need to fill gap between Po and Ra in ENDF
    - **ACTION: Add trackers!**

Covariance Committee

- *Dr. Denise Neudecker.* **Feedback from users who could not attend**
    - Pino Palmiotti Feedback
        - Missing covariance for
            - P_1 for ^{56}Fe, ^{235}U, ^{238}U
            - Answer: there are ^{235,238}U P_n value covariances, but they cannot be processed. No ^{56}Fe P_n covariances.
            - Cross correlations for ^{56}Fe reactions that were in COMMARA2.0
        - Unacceptable values (corr > 1)
            - ^{235}U cross corr: Inelastic/(capture and fission), fission/capture
            - ^{238}U cross corr: elastic/inelastic, Inelastic/(capture and fission)
            - ^{238}U fission spectrum (very low energy)
            - **Question: Could be an issue that occurs when processing the covariances from the evaluators grid to the processed energy grid. Could Pino send the processing input deck?**
        - Strange values (>>>>>>> 100%) for ^{16}O P_1 values
        - Answer: Mark Paris looked into the file and does not see an issue in the covariances. Could this happen during processing? Could Pino send the processing input deck?
        - Some difficulties in processing MF35
        - Answer: yes, agreed. This is painful.
        - Big problem for the P_n covariance files of ^{56}Fe, ^{235}U, ^{238}U has new way for NJOY2016, resulting in null matrix
        - Answer: 56Fe seems to concern JEFF-3.3 (Wim Haeck did not find any P_n covariances in the file) while the uranium files do concern ENDF/B-VIII.0. A fix for the 56Fe JEFF-3.3 problem was proposed for NJOY but that does not solve the problem. Wim will take a look if he can fix it quickly. If not, this might be a longer discussion.
        - Large changes from VII.1 → VIII.0
            - ^{56}Fe: elastic, inelastic, capture

        - ^{235}U: fission, PFNS
        - **ANSWER: PFNS was re-evaluated and new covariances were given based on this new evaluation. The (n,f) cross-section uncertainties were increased by the Neutron Data standards committee to account for underestimated uncertainties (see talk of Denise Neudecker in the covariance session.)**
        - ^{238}U: elastic, inelastic, capture, fission, nubar, PFNS
        - **ANSWER: PFNS was re-evaluated and new covariances were given based on this new evaluation. The (n,f) cross-section uncertainties were increased by the Neutron Data standards committee to account for underestimated uncertainties (see talk of Denise Neudecker in the covariance session.) Elastic, inelastic and capture were re-evaluated and new covariances were given.**
        - ^{239}Pu: capture, fission. The (n,f) cross-section uncertainties were increased by the Neutron Data standards committee to account for underestimated uncertainties (see talk of Denise Neudecker in the covariance session.) Capture were re-evaluated and new covariances were given.
      - Did adjustment exercise. Bigger than 1-sigma adjustment needed for:
        - ^{56}Fe (n,inel) 800 keV-10 MeV, (n,γ) 60-800 keV
        - ^{238}U (n,inel) 800 keV-1.3 MeV
        - ^{239}Pu (n,γ) 2-15 keV, (n,2n) 6-10 MeV
  - Roberto Capote
    - Make uncertainty budget for all experiments used
  - Patrick Griffin
    - Please provide untweaked files
    - Issue with compliance with standards if files are pre-adjusted by hand
  - Annual discussion about adjustment vs not adjustment
    - CSEWG has unofficially tweaked data to get better mean
      - Is not clear how this is different from a computer doing it, other than the documentation of the adjustment
      - Equivalent to a "lucky draw"
    - Many users need unadjusted data and complete traceability
    - Other users need adjusted data for their application (or at least good behavior, consistent with previous library release)
    - Must document ALL user requirements and bring them into accord
    - Must document current CSEWG procedures and perhaps what they should be
    - Without understanding both what we are doing and are capable of doing can we figure out how to tailor processes to user needs
    - All tweaks should be clearly documented in the MF=1 files. This requirement should go into the Q&A document.
- *Dr. Dorothea Wiarda.* **ENDF/B-VIII.0 covariance testing in ORNL**
  - Using covariances as is, comparing to VII.1

- ENDF/B-VIII.0 to be part of SCALE 6.3 beta release
- Corrections applied to SCALE (COGNAC) covariance libraries automatically
  - Redundant covariances removed
  - Illegal correlations repaired
  - Relative uncertainties larger than 100% set to 100% as these are usually threshold effects for very small cross-sections.
  - ^{235}U –
    - Non-zero values in groups that should be zero
    - This makes illegal correlations
  - ^{7}Li –
    - Given as relative uncertainty
    - So, small cross section with big uncertainty makes for badness
  - Thermal moderator uncertainties
    - Take high energy evaluations, assume free-gas (for ^{1}H) and then apply covariance to TSL data for H_2O, ZrH, …
    - Ditto for graphite, but use ^{12,13}C. They have not yet split Carbon in its isotopes (sensitivity profiles still for ENDF/B-VII.1 where it was an element), so take with a salt of grain.
  - All covariance data taken from VIII.0, Chi covariance taken from JENDL-4.0 for several minor actinides, how some in ENDF are actually from JENDL?
  - SCALE-6.1 data (mainly lo-fi) retained for ~215 missing nuclides
- Big changes
  - ^{1}H –
    - Major changes in elastic and capture high energy shape
    - Thermal values changed a lot and don't match standards
    - Gerry Hale has provided explanation, yet change does cause concern
  - ^{235}U, ^{239}Pu –
    - Fission cross section and nubar changed substantially
    - We think new uncertainties more realistic, but they are bigger
    - Big change is concerning
  - ^{238}U –
    - Inelastic
- Covariance testing with VALID
  - Uncertainty in k_{eff}
    - LCT-001-001, MCT-008-002, others validation
  - c_k (similarity) of a reference set of experiments with reference applications
    - which systems are similar has changed since VII.1, is a bit of surprise
- Suggestions for GNDS, in "same file"
  - As evaluated

        - Adjusted
- *Dr. Vladimir Sobes.* **Augmented ENDF/B-VIII.0 covariance matrix**
    - Nuclear data dominates several aspects of nuclear reactor simulations
    - Uncertainties still bigger than difference between mean value and answers
    - JEFF community just lowered their uncertainties while ENDF/B-VIII.0 increased
    - Adjustment process
        - Lowers uncertainty down to C/E level differences
        - There is something like a "lower bound" on what is physically reasonable uncertainty given evaluation input (see Denise WPEC-SG44 presentation), adjustment doesn't respect this bound
    - Hand-wavy engineering ad-hoc solution, but at least it will be documented and reproduceable
        - Philosophy
            - 20/80 rule, start with only the "20%" most impactful cross correlations
            - Augment matrix, not adjust
            - Estimate bulk correlation coefficients
            - Do not change variances
        - Used GLLS TSURFER, extract posterior cross correlations, ignoring posterior variance, show that build cross correlations are only weakly dependent on the choice of integral system
        - Approach made impact on fast assemblies, but not solution assemblies. It helped LCT too
- *Dr. Denise Neudecker.* **Updating the experimental ^{239}Pu(n,f) cross-section uncertainties in the Neutron Data Standards database**
    - Uncertainties got bigger in standards evaluation, accounts for "unknown unknowns". Increased k_{eff} uncertainties of nearly 3x (GODIVA, JEZEBEL) following CIELO paper.
    - What's missing
        - Missing unrecognized uncertainties across many data sets due to using the same methods of measurement/ analysis.
        - Missing cross correlations between uncertainties of different experiments.
        - Missing uncertainty sources for single experiments.
    - Establish template:
        - which uncertainties should be given in an experiment
        - typical values in the event the experimenter didn't provide the values or if they maybe underestimated it
        - correlations
    - Resulted in increases nearly across the board in GMA database (some looked wacky, but are artifact due to steep slope of cross-section leading to large energy uncertainties relative to the cross-section). Only one set in the example had an uncertainty decrease (they double-counted an uncertainty source!)

- This then forces re-fit in GMA database and changes mean values and uncertainties.

- *Dr. Caleb Mattoon*. **One slide (plus or minus two)**
  - d(n,2n) mean value nails experimental data so 5-10% probably realistic, but ENDF uncertainty is 200%
  - Need covariances for ^{14}N, it is everywhere!
  - ^{54}Fe, ^{58}Ni, and ^{60}Ni have covariances with no cross section data
    - ^{54}Fe has fix in its tracker
  - Some uncertainties >> 100%
  - Some uncertainties way way too small ^{23}Na(n,el), ^{239}Pu nubar
  - **ACTION: Add trackers!**
- *Ms Amanda Lewis*. **Uncertainty and Covariance Analysis for Fast-Neutron Induced Cross Section Partial Gamma Measurements**
  - Need to deal with discrepant data, uncertainties underestimated
  - Set up template…
    - Identify all sources of uncertainty
    - Estimate "default" values
  - Look at class of experiments where characteristic discrete gammas were measured
    - Divide by gamma type: prompt vs. isomer vs. decay
    - Divide by using a direct neutron beam determination or one via a reaction monitor
    - In beam or out of beam in counting room
  - Found not only expected values for holes in template, but also a "PDF" based on what is distribution of uncertainty values for one particular uncertainty source found in selection of EXFOR experiments. Not perfect, but does give estimate of reliability of template default values. Also highlights whether an uncertainty value given for an experiment is unusually large or small. This might trigger giving a second look why they are unusually small or large (e.g., could be a compilation mistake or justified.)
  - Documented in report that is currently under review
  - How to back out reaction cross section from partial gamma cross section… need experiment (yes) but even more need theory since experiment is not complete
    - Applied to Fotiades $^{238}U(n,n'\gamma)$, just $4^+ \rightarrow 2^+$, and applying template
    - Compared to CoH calculations
    - Also looked at $6^+ \rightarrow 4^+$ and two others, got lower bound with realistic uncertainties, including cross gamma correlations
  - This template idea is resonating! Helps in many ways, can be a checklist for evaluator to review an experiment but also for experimentalists to provide all information that is needed for nuclear data evaluations.
- *Dr. Pavel Grechanuk et al.* **Applying machine learning techniques to ICSBEP benchmark validation**
  - Pavel is student of Mike Rising at LANL from Oregon State U.

- First attempt at using machine learning for predicting bias in benchmark experiments
- ENDF/B-VII.0 used in this exercise
- Use Whisper-1.1
  - Covariance data for cross sections
  - Catalog of 1100+ ICSBEP benchmarks, with per isotope sensitivities in 40 groups.
- Using only sensitivity profiles, for an unknown application, want to see
  - Predict bias? (regression)
  - Find similar cases (clustering)
  - Adjustment?
- Use ^{233}U solution assemblies for test study
- Bias prediction (C-E)
  - Regression trees. Splits in tree are decided by minimizing a cost function
  - Random forest: ensemble of regression trees
  - Adaboost, Random Forest biases comparable to direct calculation of bias
  - SHapley Additive exPlanation (SHAP) metric
    - Estimate addition of each feature to overall "bias budget"
    - ^{19}F seems to be problem child in ^{233}U solution benchmarks (but apparently ^{233}U is fine? No, but changing ^{233}U would change all benchmarks at the same time and does not help to align only a group with the experimental values while does with good agreement stay the same. ^{235}U and ^{19}F help here more because differing content of these materials is included.)
- Clustering
  - Segregated based on materials and spectrum
- Adjustment
  - Could do with GLS, instead use random forest and genetic algorithm
  - k_{eff} change estimated by perturbation
  - Top 100 reactions figured out
  - Cost=$\sum(k_{eff\_pert} - k_{eff\_real})^2$
  - Found ^{19}F and ^{27}Al elastic need to be changed a lot, but at counter-intuitive energies
  - Found ^{235}U nubar needed to be adjusted in area that actually was adjusted in VII.0 → VIII.0 transition
- Machine learning used here does not obey unitarity and did not know about angular distributions, so unphysical results are obtained for adjusting ^{19}F given that these data should obey multiple constraints (sum-rule, cross-correlations from modeling) while ^{235}U nu-bar (less physical constraints to start with) is more realistic.

- *Dr. Arjan Koning.* **Bayesian Monte Carlo applied to Ni isotopes**
  - Goodness of fit estimator
    - χ^2 per point
    - RMS deviation per point

- RMS asymmetry per point $\exp(N^{-1} * \sum_i(\ln R_i))$
- $R_i=\sigma_{tot}/(\sigma_{exp} +/- d\, \sigma_{exp})$

- Global predictive power of TALYS
  - Compute how far away on average from experiment
  - Can set global estimates of uncertainty
  - Only for (n,X) reactions, where X in {n,p,d,t,^{3}He,α,γ} (multiparticle emission is still trouble…)
- Bayesian Monte Carlo, including χ^2, but also account for model defect and prior estimates from global assessment above
- Applied to Ni
  - If data, it dominates uncertainty determination
  - If no data, global assessment dominates
  - Looked reasonable…, but also badly underestimates uncertainty when cross section fluctuating. However, if you know that cross section is fluctuating, you must have measured it, so you wouldn't use the global assessment, would you?
- TALYS-2.0 coming in the 2018-2019 timeframe, will include fitting and formatting codes
  - Will include tutorials & helping videos, maybe even a course

- *Dr. Andrej Trkov et al.* **Reduction of uncertainty in general purpose libraries without using integral data**
  - Similar in spirit to Vlad's talk
  - Error on C/E from nuclear data very big, but C/E eerily close to 1
  - Proposed solution is adjusted library. Small uncertainties, but will impose bias. Generally unsafe.
  - Toy problem: 1 group 0-D transport
    - k_{eff}=nubar*$\sum_f/(\sum_f + \sum_c + \sum_{other}$ +Leakage)
    - From this, derived universal (anti)correlations
    - Using fast & solution k_{eff}, get mostly same correlations even though use different cross sections, nubar in different energy ranges
    - Generic correlations that are not present in the differential data (e.g. nu-bar and fission) can be obtained from such simple model and added to the evaluated data files for criticality studies, without changing other covariances. This would greatly reduce the uncertainties in the predicted reactivities to values acceptable in applications.

Formats & Processing Committee

- *Dr. Mike Dunn.* **Format Issues and Proposals**
  - Implementation in transport simulation of angular distribution of nucleon emission from breakup reaction – A. Koning
    - Extend Kalbach formalism to take deuteron breakup into account
    - Kalbach provided modified parameterization for breakup reactions, but it was never included in ENDF

        - Need to add 2nd set of Kalbach parameters, one for regular distribution and other for breakup. Specifically, need to be able to describe what happens to the residual nuclei.
        - Need extra parameter (r_{BU}) to switch between two components
        - Propose to add LANG=3 option for Kalbach, so use spot for "a" (which is rarely used) to store r_{BU}
        - NJOY patch for this formalism exists, but may need updates
        - MCNP would need to be extended
        - LANL has not been included in the development and implementation for NJOY and MCNP
        - The Formats & Processing Committee recommended that the proposal be tabled for now until the above tasks are completed.
        - **ACTION: M. Dunn to make format proposal trackers**
        - **ACTION: D. Brown to add Kalbach paper to tracker**
        - **ACTION: P. Sauvan and A. Koning to generate ENDF manual suggested text. We need usage details captured in ENDF manual (breakup part only applies to n or p since that's what the deuteron breaks up into)**
    - Covariance and uncertainty on fission yields: propagation to decay heat – L. Fiorito
        - Several efforts to create FPY evaluations with covariance
        - Proposed format/file – adding MF38
            - We need a lot of detail and this talk doesn't provide any details other than a screenshot
            - Current file 8 provides uncertainty already, so how would this new format interact with file 8? Do not want to duplicate content. Just store correlation matrix?
            - What about energy-energy correlations? Or just yield-yield correlations?
        - We are standing up a new FPY evaluation committee and such a proposal needs to be vetted through the FPY evaluation committee.
    - Need clarification in manual as to what frame RRR parameters are in.
        - **ACTION: Marco Pigni and Ian Thompson will either prepare a new proposal for a format change to include the Brune parameters or provide an ENDF manual update to explicitly define the frame of reference for the resonance parameters.**
    - ENDF Constants discussion
        - CODATA 2018 coming out soon
        - Why not just link to them?
        - Is common agreed upon constant for all of CSEWG
        - Also includes masses, etc.
        - Serves archive role for ENDF
        - Changes are not every very big (and not even visible at floating point precision)

        - The consensus among the Formats & Processing Committee is to keep the constants documented in the ENDF manual and not link to a website that is easily changed.
        - **ACTION: if and when new CODATA values published, Jeremy will produce mini-format proposal**
- Dr. Jeremy Conlin. **NJOY Status**
    - Wim Haeck implemented several changes to NJOY2016, two reports describe the changes
    - New formats implemented
        - Tabulated energy release
            - Required changes to HEATR for KERMA calculation
            - Impacts how KERMA done for fission
        - Sub-actinide fission cross sections
        - P(nu), nu = number of neutrons
    - Other changes made
        - ACE file plotter in ACER
        - Formatting TSL data in ACER
        - Covariance processing in ERRORR
        - TSL generation in LEAPR
        - PURR fixes
        - TSL processing in THERMR
        - Integration of the IAEA NJOY2012 update file
    - Please use GitHub! Makes issue tracking much easier. Can even have conversation
    - Making changes to how number of atoms specified in response to goofs in TSL file preparation for ENDF/B-VIII.0
    - **Big News: NJOY2016 is deprecated**
        - **Only bug fixes to be made, ~next 5 years**
        - **All production should move to NJOY21**
        - **All development work shifting to NJOY21**
    - NJOY21
        - www.njoy21.io
        - Usage:
            - Has command line options (like -h for help)
            - Can run like before with redirects
        - NJOY21 does input verification. Can even do this:
            - njoy21 --verify-only
        - NJOY21 uses NJOY2016 input format
        - Versioning
            - njoy21 --version (doesn't change often)
            - njoy21 --signature (so can understand all the components)
                - make JSON file with hashes of all major components
                - this lets you change parts and define uniquely that mix of parts

        - the hashes are computed by git, not NJOY
        - CMake knows about this too
        - Given signature maps to particular release
        - List of signatures stored at https://github.com/njoy/signatures
        - Major concern that this does not conform to SQA standard
- *Dr. Dorothea Wiarda.* **AMPX Status**
    - Processing ENDF/B-VIII.0
        - In order to process B8, need patch which is available (just send email), will be available in next SCALE beta
        - New moderator data will be available in next SCALE as well
        - No easy way to automate TSL SCALE ID ↔ ENDF MAT assignments, this is SCALE "Standard composition library"
        - Verify data with VALID suite
    - AMPS and GNDS
        - "Onion principle", many layers
            - File access layer
            - General data containers
            - GNDS structure
            - AMPX and SAMMY in-memory structures
        - Comparisons between ENDF vs. GNDS formatted data
            - Pointwise reconstructed cross sections (Polident)
            - Multigroup data (X10)
            - Pointwise URR (Prude)
            - Covariance data (Puff_iv)
        - Working with LLNL to ensure consistency between AMPX and FUDGE
    - Future plans to share with SAMMY
        - Same people develop
        - There is shared code that will pull from common repository
        - ENDF I/O in C++ from AMPX is first things to share
        - Resonance processing in AMPX is another thing to share
            - Includes SAMRML for derivatives
            - Want all of this done using SAMMY routines, not AMPX routines
        - Doppler broadening is another thing to share, have NRC funding for AMPX modernization
            - Solbrig kernel broadening
            - Leal-Hwang
- *Dr. Bret Beck et al.* **FUDGE Status**
    - GNDS:
        - XML, HDF5
        - hybrid XML/HDF5 is in development
        - Hierarchical
    - FUDGE

        - Started in 2002, probably Python 2.2
        - Now works 2.7, should work with 3.6+
        - Can translate all sublibraries to/from ENDF
        - New fission formats not yet implemented
        - Can process for transport n,p,d,t,^{3}He,α,γ,x sublibraries
        - Missing features: URR PT, TSL data
        - URR PT
            - Create realization of resonances from URR data (fully GOE, with Porter-Thomas widths)
            - Reconstruct σ(E) around E of interest
            - Convert single σ(E) into P(σ) in vicinity of E
            - Repeat, then average P(σ)'s as PDF
            - Same approach as FRENDY, SESH
    - API for GNDS in C++
        - PoPs, API in C++ called PoPsCpp
        - GIDI, C++
            - API for main part of GNDS
            - On-the-fly multi-group collapse
            - Calculates multi-group energy depositions
        - MCGIDI, C++
            - For sampling stuff read by GIDI
        - All API's to be released soon at LLNL
        - GIDI/MCGIDI implemented in Mercury & Ardra
    - Testing discussed by Marie Anne Descalle
    - xsdir-like "map file" lets you glue stuff togethers
    - LLNL job posting for FUDGE or APIs going up soon, other positions at LLNL
- *Dr. Dave Brown.* **EG-GNDS Report**
    - GNDS is in production now – showed processing and transport status results
    - Documentation
    - Problem in GNDS with workers being spread too thin
        - We have four different authoritative sources of the main format structure
        - Specifications
        - Requirements
        - XML schema
        - XML files themselves
    - Each one provides an incomplete representation of GNDS – need to bring together
        - Idea/solution is to automate the documentation generation
    - Develop a data structure that represents the format (projectile, target, reference frame, evaluation, etc.).
    - Dave has created a JSON file format to describe the GNDS format that can then generate LaTeX (a little weird but it is a process that can work).
    - So, why would do such a strange thing?

    - We have a data hierarchy
    - Can use a “tree walker” on the schema and figured out all the formats in use
    - Produced the JSON file
    - Then converted to LaTeX
  - Plan (currently at step 4 below)
    1. Initialize the database
    2. Crawl representative sample of XML files
    3. Serialize output to JSON (or equivalent)
    4. Update descriptions by hand
    5. Serialize to LaTeX files
    6. Frame file be used to organizer
    7. Then develop a back translator
  - There are problems that remain
    - Corrections in resonance formats
    - Corrections in covariance data formats
    - Other inconsistencies in tree walking
    - TSL data
    - FPY data – probably need to revisit with new subgroup
  - Reviewed plan for completing specifications for next WPEC meeting, GNDS 2.0
  - Collaboration platform discussion
    - Continue investigating Git-hub-like options
    - A non-nation specific solution
    - In-progress work must be accessible without some level of password protection
    - Need money
    - NEA/OECD has set up GitLab that we can use
- *Dr. Jeremy Conlin.* **SG-43 Report**
  - Mandate is to
    - Define interface for I/O for GNDS
    - Define physics checks for validate new evaluation
  - Stretch goals too
  - API status
    - LLNL “complete”
    - ORNL very far along
    - CEA, LANL starting
  - GNDS format not stabilized
  - Physics checks work not really begun
  - Are we defining one API or one API specification?
  - Interface vs. interface implementation?
- *Dr. Dave Brown.* **ENDF-102 Update**
  - ENDF-102 released officially in tandem with the library
  - No substantive changes since November 2017 CSEWG
  - Fixed subscript for the photo-atomic coherent scattering cross-section

- *Dr. Goran Arbanas.* **SAMMY Modernization and Advances in Nuclear Data Evaluation Methods**
    - SAMMY history
        - Nancy Larson, developed since 1970's
        - SAMMY + 25 auxiliary codes
        - F77
        - 185 test cases, tutorials
        - Capabilities
            - R matrix
            - Build in resolution functions for ORELA, RPI, GELINA, nTOF
            - Doppler broadening
            - Multiple scattering
            - FITX to do URR fitting (from Froehner)
            - SAMINT (from Vlad)
        - Part of SCALE SQA system
    - SAMMY modernization
        - Wrap with C++, slowly replace modules in F77 with those in C++
        - Coulomb WF is case in point
            - Use that from N. Michel from CPC [CPC 176, 232-249 (2007)]
            - SAMMY used 3 different variants
            - Negotiated license for use ORNL-wide
            - Will share with AMPX and SCALE
            - Required rebaselining test cases
            - Analytical derivatives now for Coulomb WF things
        - Get rid of COMMON block in favor of F90 modules
            - ~100 common blocks
            - Took about a week, sounds like they had fun
        - Things they want to do
            - Simultaneous evaluation of thermal and RRR
                - Sab done separately from RRR
                - Covariance between two is missing
                - C. Chapman Ph.D. thesis
                - Recognized that scattering lengths for Sab related to those from RRR
                - Needs complex scattering length
                - DOPUSHx computes crystal lattice effects (Naberejnev (1999))
            - Direct capture
                - Motivated by simple direct capture form
                - Can be parameterized by complex channel length too
                - Unitarity still enforced
                - Raman & Lynn direct capture papers trying to get at thermal capture compound contribution

        - Bayesian optimization of defective models
            - Introduce model defect in fits,
                - generalize cost function
                - G. Schnabel Ph.D. thesis
            - Scaling of chi2,
                - account for missing covariance data in experimental data
                - without it, uncertainty too small
                - also needed when doing MC since weights can be exponentially small
        - Generalized Reich-Moore approximation
            - Reported in ND2016
            - Enables Brune transform for capture channels
    - SAMMY 8.2 anticipated features, early 2019
        - Coulomb WF
        - Closed channels
        - Bug fixes
        - Reich-Moore for Brune transform
        - Documentation
        - Open source
    - Asked about imaginary channel radius, does it work?
        - Seems elegant and simple
        - Is there an evaluation that uses it for something?
        - Noguerre has tried it?
        - Would require format change

Measurements Committee

- *Dr. Matthew Devlin.* **^{235}U and ^{239}Pu prompt fission neutron spectra measurements from Chi-Nu at LANSCE**
    - Update by Chi-Nu project: Chi-Nu is a long-term project to measure neutron-induced PFNS.
    - Chi-Nu has two arrays: Li-glass array for low energies, Liquid scintillator array for high energy PFNS.
    - they measure implicitly: first, second etc. chance fission prompt fission + pre-equilibrium neutrons.
    - Preliminary ^{235}U PFNS is shown for outgoing neutron energies from 10 keV to 10 MeV and incident neutron energies from 1 to 14 MeV. They see multiple chance fission and pre-equilibrium structures as predicted by ENDF/B-VIII.0 and not seen before in other measurements.
    - ^{235}U PFNS mean energies from 1.5 to 20 MeV incident neutron energy is shown. The outgoing neutron energy range is again 10 keV to 10 MeV. They see fairly good agreement between Chi-Nu mean energies and ENDF/B-VIII.0.

- Preliminary ^{239}Pu PFNS: is shown for 10 keV to 10 MeV outgoing neutron energy and 1-14 MeV incident neutron energy. They see a harder PFNS than Lestone et al. at high outgoing neutron energies. They see also second chance fission spectra and pre-equilibrium structures in the PFNS which is also predicted by ENDF/B-VIII.0
  - ^{239}Pu PFNS mean energies: ENDF/B-VIII.0 agrees well until 12 MeV but then the Chi-Nu data don't see that strong a third chance fission behavior as ENDF/B-VIII.0.
  - ^{235}U and ^{239}Pu PFNS comparison: There is a difference in the behavior of third chance fission. In ^{235}U PFNS mean energy, the third chance fission structure is distinctly stronger than in ^{239}Pu PFNS mean energy.
  - They clearly see that PFNS becomes more forward-focused with increasing incident neutron energy which is expected from physics point of view. However, it has a larger cone of angles than expected (up to 100 degree).
  - **Discussion: Question was whether the PFNS should be given angle-dependent (MF=6) rather than MF=5 because of angle-dependent effects. It was mentioned that the angular distribution goes to the inelastic channel and PFNS, for inelastic channel it is considered but not in PFNS.**
- *Dr. Hye Young Lee.* **Status update on NZ reaction studies at LANSCE**
  - 3 different chambers: LENZ, ALSOLENZ and miniLENZ allow to study several nuclear reactions.
  - LENZ ^{16}O(n,α): 2017 set-up with 3 silicon detectors, tantalum blank runs and ^{16}O runs using Ta backing. They have charged particles coming down from the accelerator. They simulated the charged particle background from the beam with an MCNP program. Most of it should be swept away by magnets. The neutron flux was monitored using fission counter using a ^{238}U foil and simulated it with MCNPX. Reasonable agreement between 1-20 MeV.
  - LENZ campaign to study structural materials like Cr, Mn, Fe, Co, Ni, Neutron scattering is a problem in these measurements. They are able to resolve (n,α_0) reactions. They need for their detector simulations: nuclear data of angular distribution of (n,p) and (n,α) reactions of structural materials (target frame, target holder, etc.). Relevant nuclear data used from ENDF/B-VIII.0 are Al, Zr, Cl, Fe, Mn. CoH3 was used to calculated Cr, Ni, etc. data which were needed for simulations. ^{56}Fe(n,p) flat angular distributions in ENDF/B-VIII.0, CoH3 is predicting a different shape. They cannot measure all angles, just a limited range.
  - They developed an MCNP6 model of LENZ chamber and universities are developing GEANT4 model.
  - Showed measured charged particle energy vs TOF for ^{nat}Ni versus MCNP simulated ^{58}Ni results.
  - ^{56}Ni: of interest for heavy ion production via neutron-proton process in explosive supernovae. Direct measurements are very limited because of short half-life (6 days). Use isotope-production at LANSCE (from ^{59}Co). Separation is difficult from

chemical point of view because of separation from other isotopes. It is electro-plated. Radioactivity might be problematic.
  - This run-cycle: ^{58,59,60}Ni, ^{54,56}Fe, ^{35}Cl.
  - Discussion: There is a mistake in processing leading to double-counting of files in gas-production. NJOY2016.42 has a fix. ACE data currently on the internet still has this problem.
  - Cross-section of ^{16}O(n,α) is coming this fiscal year.
- *Dr. Klaus Guber.* **ORNL neutron cross section measurements for the US Nuclear Criticality Safety Program**
  - talking about total and capture cross-section measurements.
  - measured data for thermal resonance, URR and fast energy cross-section data. In answer to NCSP nuclear data needs following a NCSP 5-year plan.
  - The measurements are performed at the TOF facility GELINA providing a pulsed white neutron source, 10 meV to 20 MeV with 1 ns pulse width with a good time-resolution to resolve resonance.
  - Used natural La sample with 99.91% ^{139}La using a metallic samples. No oxygen contamination as they have a metallic sample. They have two sample thickness. Samples are sealed in an Al-can to avoid oxidation. They have an Aluminum blank. They determine the background with black resonance filter combinations.
  - total cross-section: Li-glass detector for low energies and H(n,n) plastic scintillator for high energies.
  - La-transmission measurements: sample in and sample-out measurements, above 19 keV ENDF/B-VIII.0 does not have any resonances, but experimentally they still can be resolved. Deficiencies in ENDF/B-VIII.0 to capture resonance.
  - La capture measurement: flux is measured with ^{10}B(n,α) at low energies with α-chamber and with ^{235}U(n,f) fission chamber at higher energies. They could also resolve resonances well.
  - Next: ^{142}Ce sample problems resolved and will start measurement in fall. Zr capture and transmission measurements.
  - Discussion: ^{16}O(n,α) data coming this FY.
- *Prof. Yaron Danon.* **Nuclear Data Measurements and Analysis at RPI**
  - they plan to do major upgrades to neutron source in 2020.
  - This year completed measurement: focusing on capture of Ta measurement (NCSP funded) (10 eV-100keV MeV), transmission of Hf (0.5-20 MeV) and Cu scattering (0.5-20 MeV).
  - Resonance Region Measurements: 3 detectors at different TOF lengths. Ta-results agree better with JEFF-3.2/ JENDL-4.0. Focus was unresolved resonance region. URR ENDF/B-VIII.0 for Ta clearly has issues for total Ta cross-section. Capture cross-section: JEFF-3.3 a bit lower.
  - Benchmark of self-shielding: transmission of very thick sample. ENDF/B-VIII.0 has a problem simulating the experiment.
  - ^{235}U and ^{239}Pu quasi-differential measurement at LANL: used part of the Chi-Nu array for a semi-integral measurement (all neutrons out measured, scattered, PFNS, etc.). Graphite, ^{235}U and ^{239}Pu were simulated with ENDF/B-VIII.0 and

measured. Graphite does look ok. For ^{239}Pu, they are seeing big differences around 3 MeV and up but they are investigating whether some measurement corrections are missing. For ^{235}U, they see a difference in one specific energy range but otherwise good agreement.
    - Thermal scattering: Light water, polyethylene, concrete, Teflon, quartz, etc. They try to use these measurements through DFT code to inform the evaluations. They completed evaluations of H and C in polyethylene, H, C and I in C in Lucite, etc. Problems at lowest energies for the total cross-sections compared to ENDF/B-VIII.0. With the updated evaluation using these experiments, criticality benchmarks using Lucite improved.
    - Discussion: They do not look at correlation information between gammas and neutrons yet for the scattering experiments but they might in the future.
- *Dr. Devin Barry.* **NNL Nuclear Data Measurements and Analysis at RPI**
    - RPI measurements at LINAC: Copper scattering with 3 cm natural copper for 2 weeks of experiments for 26-155 degrees (laboratory angle). They ran a graphite reference sample. Have a lot of information on graphite from past which they can cross-compare and, thus, validate Cu-measurement. Measured by array of 8 EJ-301 detector. ENDF/B-VIII.0 at 52 degrees agreeing very well with graphite measurement. For Cu, ENDF/B-VIII.0 is predicting high energies imperfectly. At 107 degrees, Graphite is well-described but all libraries are doing badly compared to the Cu-measurements. At 154 degrees, Graphite works, but ENDF/B-VIII.0 is doing not great in describing Cu while JEFF-3.3 agrees well with the experiment.
    - natural Hf high energy transmission: HiE detector. They did an MCNP calculation of beam profile. They can stack the samples to get a thick sample (9 cm and 7 cm thick samples). They used a C reference sample. Below 4 MeV, ENDF/B-VIII.0 is not predicting measured data very well. The experimental data around 8 MeV are higher than all nuclear data. They think that it is not a background effect as they checked for that.
    - Comment from audience: Cu Zeus benchmark experiments are not well described and validators think it might be the angular distribution. For Carbon, the ENDF/B-VIII.0 angular distribution improved compared to measurements.
- *Dr. Elizabeth McCutchan.* **Decay Data Measurements for Applications**
    - Measurements to improve ENSDF database.
    - ENSDF: complete as it covers all nuclear and radiation properties that have been measured for more than 3000 nuclides. ENSDF can be accessed through NNDC. It is updated on a monthly basis. On average the evaluated data is 8 year old. NuDat gives you the data without comment. They provide decay sub-library.
    - Decay data in ENSDF is used for nuclear medicine, forensics, reactor decay heat and anti-neutrons, non-destructive assay.
    - ENSDF might be complete but not perfect. Some data sets are more than 30 years old. Gamma ray spectroscopy used usually 1-2 small detector, today larger arrays are used. Compton suppression helps today in reducing background. Also, gamma-gamma coincidence can be used. Many measurements with 100 HPGE

detectors at Argonne with gamma-gamma coincidence and Compton suppression. They work with USNDP to target deficient data. Started with ^{82}Rb (Cardiac PET). Was measured in 80s with two detectors. They re-measured it and found new and moved decay scheme and some were removed. Nuclear medicine moves toward non-conventional PET agents. One example is ^{86}Y. In the 1970, they measured it last. With the Gamma-sphere, they see many more lines. 11-keV intensity increases by 20%.

  - High-precision gamma ray spectroscopy for fission measurements: they are interested in reactor anti-neutrons. They see discrepancies between measured anti-neutrino spectrum and predicted one (4th class of neutrinos??). If they want to model the antineutrino spectrum well they need good decay data. ^{92}Rb is needed for that. They measured at CARIBU at ANL. They found 52 new levels. This will help pin down the calculations of anti-neutrino spectrum in a reactor.
  - They need help in identifying which experiments are needed for applications.
  - **Comment: Analyzed data can go within a few months into XUNDL. It takes maybe 1 year from XUNDL to an ENSDF data file. They use RADWARE for spectrum analysis of coincidence spectrum.**

- *Dr. Anthony Paul Ramirez.* **Neutron Cross Sections at UKAL: C, Si, Li, F**
  - UKAL Van de Graaff accelerator accelerating p, d, ^{3}He and α-beams.
  - they extract level life-times and level schemes as well as elastic and inelastic cross-section measurement.
  - they do measurements with one or two detectors. ^{3}H(p,n) for $E_n < 5$ MeV and ^{2}H(d,n) 5-8 MeV. They have massive copper shielding. Flux is measured by a long-counter. They measure both neutrons (TOF) and gamma-ray (TOF to gate gamma rays).
  - Measured the differential elastic cross-section for ^{12}C. They used it as a secondary target to validate angular distribution. Very good agreement between ENDF/B-VIII.0 and experiment. Integrated measured data to give angle-integrated elastic cross-section. Agrees with measured and nuclear data. Verification of ENDF/B-VIII.0 and JENDL-4.0.
  - Measured the ^{12}C(n,n$_1$) as there is a discrepancy among evaluated libraries. Measured it from 5.6-7 MeV incident neutron energy. Measured data agree with ENDF/B-VIII.0 and Perey's data.
  - They suspect that Perey data are in CM frame and are mis-labeled.
  - Photon angular distribution for C-12 at E_{lev} = 4.439 MeV. Consistently lower values than those obtained by Steve Wender.
  - Differential elastic cross-section of n+^{nat}Si: reasonable agreement between existing data and ENDF/B-VIII.0.
  - differential cross-section for ^{28}Si(n,n1): some discrepancies with previous data. Good agreement with ENDF/B-VIII.0.
  - gamma ray production cross-section for ^{28}Si also given
  - preliminary n+19F measurements: inelastic for 0.8-4.5 MeV. Background gamma-rays overlap with peaks of interest. Gamma ray production cross-section. Very few comparable data sets in EXFOR. The inelastic cross-section

follows JENDL in magnitude but not in shape. Follows in shape ENDF/B-VIII.0 but not in normalization.
    - ^{nat}Li contained in carbon and hydrogen. ^{7}Li(n,n$_1$) was measured. In the future, they will do additional measurements of Li.
- *Jonathan Morrell.* **Nuclear Data Measurements from LBNL and UC-Berkeley**
    - high-flux neutron generator (d,d)-neutron generator with 2.8 MeV spectrum: they measure ^{35}Cl(n,p) and ^{35}Cl(n,α) for fast reactor studies (poison), ^{58}Ni(n,p) fast neutron monitor, ^{39}K(n,p) geochronology.
    - Cyclotron at LBNL: ^{139}La(p,n) PET-isotope, ^{64}Zn(n,p) therapeutic isotopes. ^{235}U(d,n), etc.
    - high neutron flux: use most of neutrons they produce, use energy-angle correlation with respect to incident beam. Activation and gamma counting is done for cross-section analysis.
    - ^{35}Cl(n,α): ok with data libraries and data agree with ENDF/B-VIII.0, ^{35}Cl(n,p): differences between libraries and measured data is significantly lower than ENDF/B-VIII.0.
    - ^{58}Ni(n,p) cross-section shows some structures between 2.2 and 2.8 agreeing with data that have been measured in the past.
    - LBNL-measurement: ^{139}La(p,n): used stacked target activation. Two monitor foils are used with each of the La-foils. Activation measurement using gamma-counting. Significant deviation from TALYS and EMPRIE calculation from the measured cross-section. This has some implications for pre-equilibrium modeling. They model in MCNP and SRIM the stopping power, SRIM does well, MCNP was 20% off.
    - ^{225}Ac production from ^{226}Ra(n,2n): they are going to measure this cross-section through activation with a coincidence clover HPGE array in a close mounting location.
    - Discussion: SRIM and MCNP stopping power has not been vetted carefully, take them with a grain of salt (10%). Uncertainties are both statistics and systematics (10-12%). MCNP model includes scattering around the massive shielding. They benchmarked the MCNP model. Hungarian measurement group provided La measurement and they agree with TENDL while they see in their presentation a factor 10 difference with TALYS calculations. There could be a problem in how the level densities are assumed for their calculations.
- *Dr. Boris Pritychenko.* **EXFOR status report**
    - Compilation and dissemination of experimental data for nuclear data evaluation. Two contractors help the NNDC and do great work.
    - They compiled 130 new entries and corrected 211 experiments this year.
    - They migrated the database from MySQL to MariaDB.
    - They improved zoom and cursor functions.
    - Missing data: EXFOR scope evolved over years beginning with neutron cross-sections only adding the FY, PFNS, etc., later. Some experiments were missed because of that and also because some data are only published as plots in journal articles. Today they use tools to recover these data using OCR technology

and read them from plots. They will travel to research labs to recover data that is not archived in EXFOR if need be.

  - Fission yields: they made a search of science nuclear data base (simple NSR retrieval) and EXFOR to make sure that they have all fission yields measurement. Potentially, they missed 40 measurements in EXFOR. W. Mills database also included in this study. All references found have been analyzed. They will be available in the EXFOR database.
  - Pilot FY compilation project: compiled 15 new experiments to see how long it takes. SF5+IND is redundant.
  - EXFOR-NNDC team needs more contact to research labs to get the newest and best data there.
  - Discussion: Templates of experimental uncertainties should be taken into account for future compilation such that evaluators have all needed uncertainty information. Differential measurement templates are available.

- *Dr. Allan Carlson.* **Recent work on neutron cross section standards**
  - ^{1}H-standard: ongoing measurements at Ohio at 10 and 14.9 MeV detecting the proton-recoil. Neutron and proton counting agree well with each other and the ENDF/B-VIII.0 evaluation. Yang et al. had an effort to increase accuracy from 90 keV to 1.8 MeV, but Kovash withdrew the data because of quality of data.
  - ^{6}Li(n,t): NIST measured the ^{6}Li(n,t) cross-section. Deposit is a problem. Due to change of mass, the cross-section is 1% lower than the ENDF/B-VIII.0 which A. Carlson doubts. It is very hard to get the mass of the sample. Another measurement at IRMM by Josh Hambsch and Kai Jansson. They have a big gamma-flash problem. They see big differences to ENDF/B-VII.0 above 0.5 MeV. They want to extend the energy of the standard to 2-3 MeV.
  - ^{10}B(n,a): Bevilaqua et al. in collaboration with Hambsch. Not sure about the status of measurement given Hambsch's retirement. Big difference between ENDF/B-VIII.0/ JENDL-4.0 and measurements.
  - C(n,n): Yang et al. data was withdrawn because of quality of data. Gritzay et al. data still preliminary.
  - Au(n,γ): recommended standard data between 10-100 keV disagrees with Ratynski-Kaeppeler evaluation in KADONIS (5-7% near 30 keV). New work was done to understand the 30 keV MACS problem with gold capture. They think that the effect of copper backing in the experiment of Ratynski and Kaeppler was not properly taken into account.
  - ^{238}U(n,f)/^{235}U(n,f): NIFFTE TPC, overall good agreement with current standard evaluation. The data were included soon after publication. NIFFTE data are slightly lower but in very good with agreement Shcherbakov data, Tovesson and Lisowski data are slightly higher.
  - ^{235}U(n,f) cross-section measurement planned at NIST using the same setup as for the ^{6}Li(n,t) cross-section.
  - they want to improve NBS-I source. It has been calibrated by MnSO4 Bath.
  - Discussion: no time

- *Dr. Ninel Nica.* **Internal Conversion Coefficients Precision Measurements**

- they measure 39.752 keV E3 transition in ^{103m}Rh as the experimental data available where insufficient to validate models.
- Texas A&M-Cyclotron Institute including a momentum achromatic recoil separator. The target can be pressured hydrogen. Can get very advanced purity of the beam.
- They measure with HPGe detector, gas detectors and plastic scintillator detector.
- selected 100 cases of E2, M3, E3, M4, EF ICC values with precision of 0.5-6%.
- They added 8 new measurement and had 3 for comparison with existing data.
- ^{103m}Rh 39.748 keV, E3 transition: not enough for comparison to theory right now. They analyze versus KX to gamma-ray method. Very precise detection efficiency (0.4%). Use ^{60}Co source from PTB to calibrate detector, measured relative efficiency with 9 detector and had a ^{109}Cd efficiency calibration point.
- they made impurity analysis to 0.01% level analysis using decay-curve analysis. They do a correction for coincidences.
- 3 sources were prepared for the experiment: ^{103}Ru (2 sources) and ^{103m}Pd sources over several months total. One Ru-source has a big Gd contamination.
- They got seven experimental points with 1.6% and 0.9% and a consistency check. Calculations look good for frozen orbital but disagreement with theory ignoring the vacancy. Good agreement with theory including the vacancy.
- Discussion: the detector is in principle available to use for other groups. How do we get these data in Red Cullen's Atomic database? These data are complimentary to Red Cullen's work and they are both produced from the same HF-theory.

Fission Product Yields and Any Other Business

- *Bruce Pierson.* **Fission Yields**
  - Short lived fission yields
    - Collaboration PNNL-WSU-UM: Measured yields of many isotopes at UofM Neutron Science Lab
    - PNNL-LLNL-LANL at NSERC: Godiva radiation field
    - Methodology:
      - Measure gamma ray spectra
      - Irradiate under controlled conditions with witness foil
      - Time series gamma count
      - Analyze self-shielding using FP and unirradiated material data
      - Analyze fluence
      - Analyze FY using Bateman
    - J. Burke LLNL-TR-657064
  - Long live fission yields
    - PNNL+NCERC+AWE
    - Independent yields + short lived
    - Stack of activation foils
    - D-t source DU foil

        - Improve yields for ^{91}Y, ^{115m}Cd, ^{136}Cs, indicate shortcomings in ENDF
    - ENDF format/library complaints
        - Only 3 energies
        - No covariance
        - Painful format
        - Covariances on cross section data not always available e.g. Ho
    - EXFOR webapp comments
        - Dead links
        - Usability, hard to navigate web
        - Element abbreviation non-standard
        - Very dated look-n-field
- *Toshihiko Kawano.* **Fission Yields**
    - HF^3D Hauser-Feshbach Fission Fragment Decay [S. Okumura et al. J. Nucl. Sci. Tech. 55, 1009 (2018)]
        - Start with:
            - primary fission fragment yields
            - energy sharing between fragments (related to TKE(A))
            - spin distribution
            - studied by Stetcu & Talou in CGMF
        - Then follow HF "decay"
            - Is deterministic (CGMF is Monte Carlo)
            - Have to discretize excitation of each fragment, do decay in fragment rest frame, then boost product distribution back to lab
            - Extra boosting adds computational cost
        - Follows total independent mass yield data quite well
            - Because is deterministic, it can do very small yields
            - Detailed yields good but imperfect
        - Obviously can do PFNS too
            - Has trouble with high energy part of PFNS, issue not understood
        - Cumulative yields
            - Charged distribution before and after beta decays pretty good
            - Detailed distributions (Rudstam) not bad
        - Decay heat good
        - Prompt and delayed nubars as function of energy is not bad
    - Micro/Macro approach to primary fission fragment yield
        - Part of FIRE collaboration
    - Toward new FPY data library
        - Construction of experimental database in progress
            - A lot needs to be added to EXFOR, Boris is working on it
            - Personal databases (England, Mills and Katakura)
            - Also want TKE, mass yield, etc.
        - Workshop on Fission Product Yield Experimental Data
            - Aug. 20-23 (2018)

            - IAEA CM on Fission Product Yield Experimental Database
                - Plan is May 2019 in Tokyo
            - IAEA FPY CRP
    - Ternary fission? Is currently neglected but could be added
- *Paraskevi Dimitriou.* **Fission Yields CRP**
    - New CRP on Updating Fission Yield Data for Applications
    - Previous CRPs on 2007 (for ADS) and 1997 (lead to ENDF FPY)
    - CRP on beta-delayed neutrons
        - Compilation of $T_{1/2}$ and P_n
        - Over 600 nuclides
        - On-line
        - New systematics
        - Benchmark against integral data (nubars, <T>, group constants), these benchmarks ended up being very sensitive to FPY
    - New CRP on FPY recommended, proposal submitted to INDC in 2016, endorsed and confirmed by INDC in 2018
        - Objective: provide updated fission yield data with associated uncertainties for applications for $^{235,238}U$; $^{239,241}Pu$; ^{252}Cf
        - Duration 4-5 years: 2019-2023/24
        - Output: new data files, online database, technical report (+publications, conference presentations etc.)
    - Aim for first Research Coordination Meeting in 2019
    - Participation
        - 10-15 participants
        - ~10 countries
        - Research contracts (12-16K euros) to Central/East Europe, China, Russian, Asia, S. America
        - Research agreements (no funding) to N. America, N/W Europe, Japan Australia
- *Elizabeth McCutchan.* **Nuclear Data Sheets**
    - Started in 1966, currently published by Elsevier
    - NNDC editor and management
        - Editor: E.A. McCutchan (NNDC)
        - Special Issue Editor: P. Oblozinsky (under contract)
    - Original mission and main work to publish ENSDF evaluations and recent references
        - Recent references handled by NSR, not part of journal any more
        - Starting in 2006, one issue per year dedicated to nuclear reaction related articles
        - 20-25 manuscripts per year
    - This year: 10 articles, > 400 pages, thanks to LANL is 9/10 articles Open Access
    - Very highly referenced
        - ENDF/B-VII.0: 1147 citations
        - ENDF/B-VII.1: 791 citations

    - Some mass chains also highly cited (~60-70 citations)
    - Relatively high impact factor
    - Interest in "Special Articles" has increased
    - Seeking articles relevant to Nuclear Data and Evaluations that might not have a place in a traditional journal
    - Discussion of originality requirements, is a requirement stated by Elsevier, on its website. Although we don't enforce it with on-line submission system as our submission is handled rather informally. We cannot accept previously published material!
- *Dr. Alejandro Sonzogni.* **Some of the Latest Developments on Nuclear Reactor Antineutrinos**
    - There is a deficit of e- antineutrinos, ~5%, emitted by reactors at short distances, ~ 100 m
        - 3+1 model including fourth sterile neutrino was proposed with the electron survival probability computable
        - Also, there is a bump in measured spectra with respect to the Huber-Mueller model
    - Triggered many new experiments.
        - Neutrino-4, see clear evidence of oscillation. Also they see the bump.
        - PROSPECT at ORNL does not agree with Russian group and don't see a bump
        - Also Yoshida, et al. suggest is trouble with ^{239}Pu and ^{241}Pu FPY
        - Daya Bay thinks is ^{235}U
        - RENO 2018 blames ^{235}U and they see a bump
        - Now ~20 active experiments
    - We are using nuclear databases to find signature of individual nuclei and rule out 3+1 model
        - Summation method
        - Cumulative FPY (using JEFF-3.1.1)
        - ENDF/B-VIII.0 decay data
        - Sum of roughly 800 contributions, can see sharp cut-offs from each isotope. The cut-offs survive smoothing. Structure seen in Daya Bay data and not in Huber-Mueller model.
        - Bump caused by four isotopes with nearly same end-point energy (^{95}Y, ^{98}Nb, ^{101}Nb, ^{102}Tc). See additional impact from ^{92}Rb, ^{96}Y from recent ILL measurement
    - JUNO detector project ~53 km baseline. Attempt to discern mass ordering of neutrinos, pin down oscillation parameters, hunt for extra species
    - NEOS data also shows fine-structure & Bugey-3 too. Both match Daya Bay after corrections. 3+1 model doesn't compare as well. In fact, appears ruled out.
    - Need uncertainties and correlations in FPY to do proper UQ
- *Tony Hill.* **Versatile Test Reactor (VTR) Overview**

- Mission: to provide leading edge capability for accelerated testing and qualification of advanced fuels and materials enabling the U.S. to regain and sustain technology leadership in the area of advanced reactor systems.
- Goal: Enable a fast spectrum Versatile Test Reactor that can begin operations by 2026.
- At CD-0, aim for CD-1 in 2020, and 1st critical in 2026
    - Need fast neutrons for testing, esp. materials that can sustain significant radiation damage (~400 dpa)
    - Be capable of running different coolants, give fast flux ~4e15 n/cm^2/s, big load factor, large number of experiments simultaneously
    - Test height < 1 m
    - Metallic fuel
    - Pool-type sodium reactor
- To maximize experimental outcomes…
    - Broad array of experimental capabilities
    - All data to be openly available
    - Science-based Engineering Learning Layer
    - Separate from licensing codes and instrumentation which are frozen
- Given huge radiation field, will kill power monitoring. Antineutrinos seem like a way to work around issue
- Funded trade-study to investigate inverse beta detector, must be done before final design since will be buried underneath
- Significant ^{239}Pu content which is stable over 100 day run cycle
- Ideas:
    - Maybe add neutrino hall underneath
    - Neutrino line shapes
    - FPY with rabbit system
    - Electron emission from fission (replace ILL)
- Studied needs for sterile neutrino research, looks very promising
- What else will we want?
    - Beamlines? Rabbits? On-site capabilities (e.g. hot cells)
- Cannot poke through core, but may be options to get in close
- Have begun drafting whitepaper ASAP, by end of CY, since must act fast
- Entire mini-fuel cycle built around this facility. All will be instrumented. Is test bed for all sorts of safeguards approaches.
- Other cooling options tested with looping system
- Lots of fuel options/reactivity change possibility