

# Nuclear Data 101 & The Nuclear Data Pipeline (Part I)

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National Nuclear Data Center

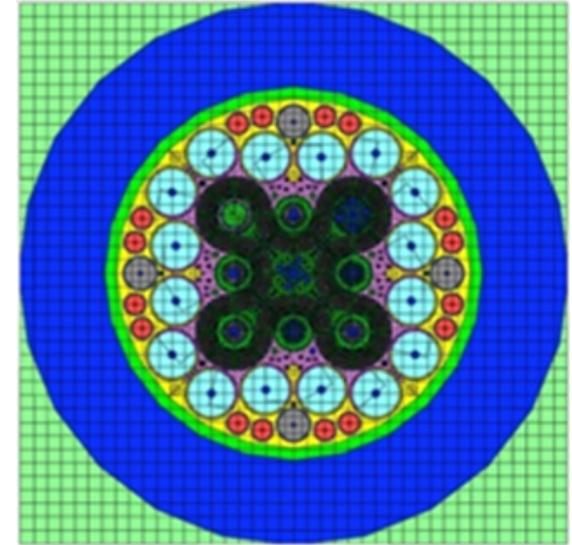
Brookhaven National Laboratory

**BROOKHAVEN**  
NATIONAL LABORATORY

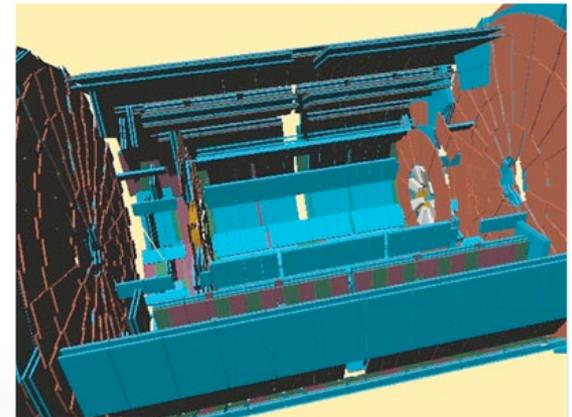
 U.S. DEPARTMENT OF  
**ENERGY**

# Nuclear data underpins many different codes

- **MCNP6, SCALE, & GEANT4 particle transport codes**
  - used for simulating nuclear energy generation
  - shielding and health physics calculations
- **ORIGEN & CINDER for isotope burn-up**
  - nuclear waste management
  - radiochemical applications
- **All have modules that use ENDF/ENSDF data**
- **Codes switch between models and data tables based on:**
  - speed
  - fidelity to physics
- **Other code systems also use covariance data in uncertainty quantification (e.g. SCALE's TSUNAMI)**

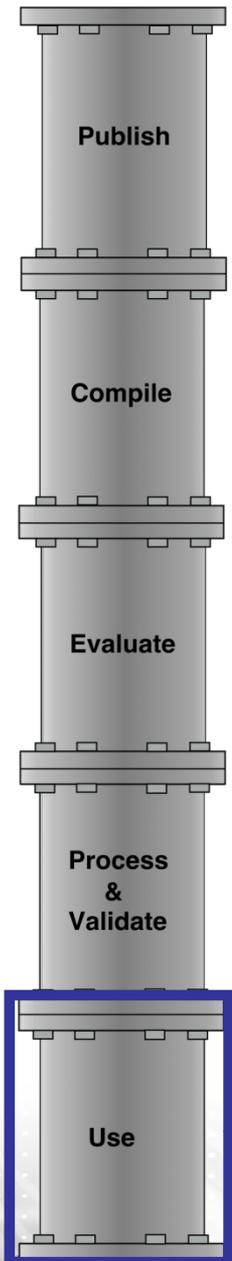


SCALE model of INL Advanced Test Reactor



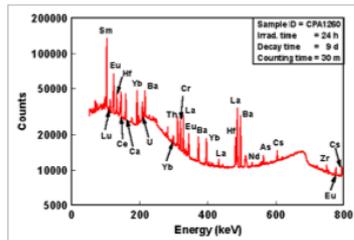
ATLAS detector muon system, simulated in GEANT4

# The Nuclear Data Pipeline



Our goal is to get the highest quality data to users

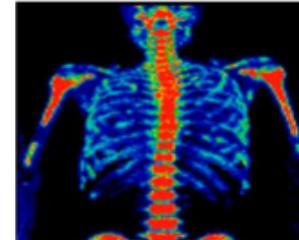
security



science



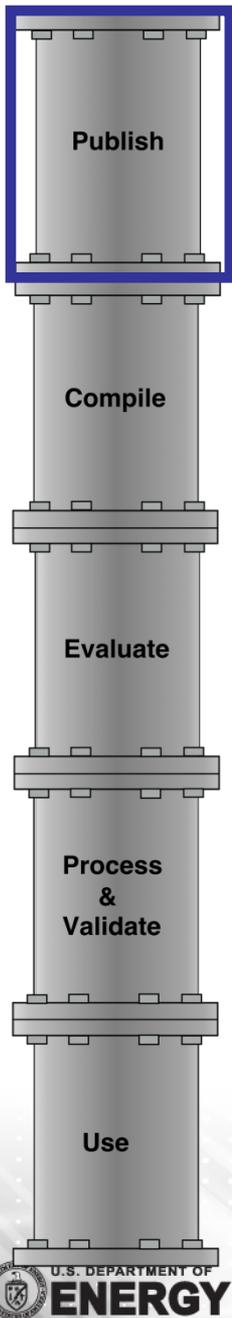
isotopes



energy



# The Nuclear Data Pipeline

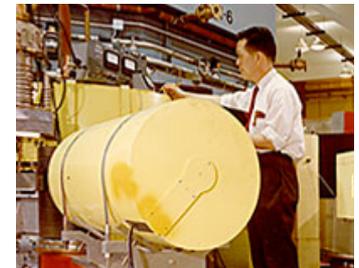
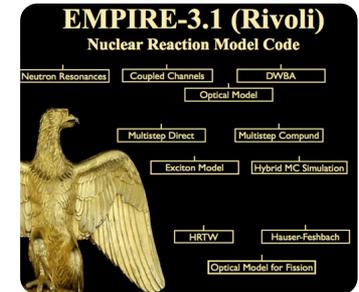


**Our work begins when data is (or should be) published**

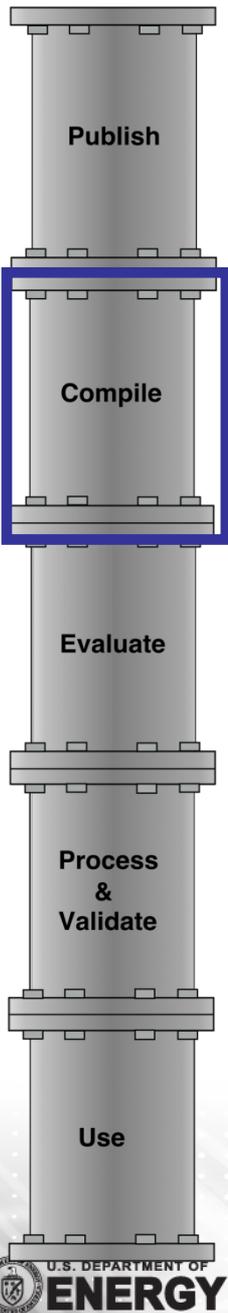
**Code development:** Actively develop codes that support our work

**Archive:** Seek “abandoned” data and archive it before it is lost

**Address gaps:** Perform targeted experiments to address gaps in databases



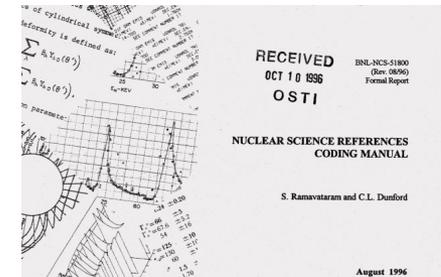
# The Nuclear Data Pipeline



## Data is compiled into databases

### Nuclear Science References (NSR):

229,594 nuclear physics articles indexed according to content. 3,714 articles added in FY18 from 80 journals.



**EXFOR:** Compiled nuclear reaction data, originally only for neutron-induced. Data from 130 articles added in FY18.

**XUNDL:** Compiled nuclear structure and decay data. Data from 325 articles added in FY17.

# EXFOR and NSR Compilation is On-going

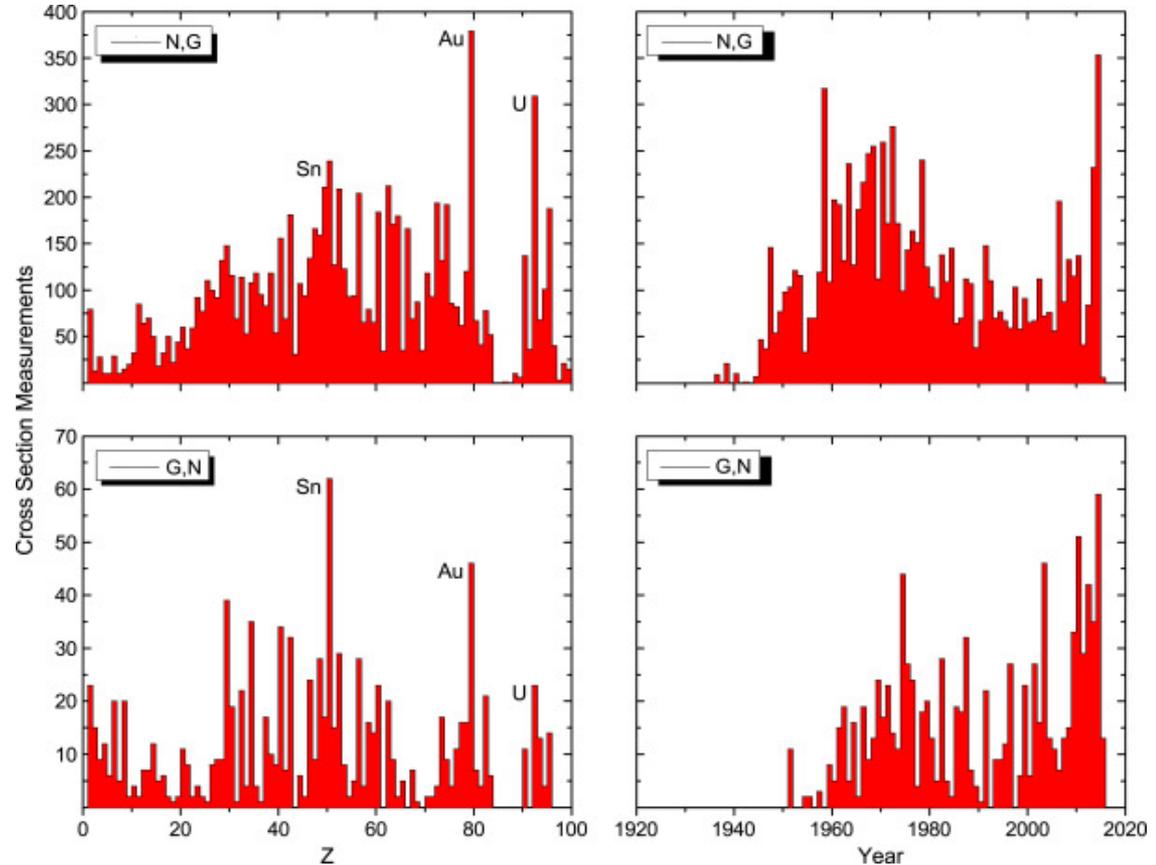
- **BNL (Pritychenko POC)**

- Responsible for EXFOR compilations for Americas
- BNL is sole compiler for NSR
- Team of contractors
- (~5) + 1 BNL staff

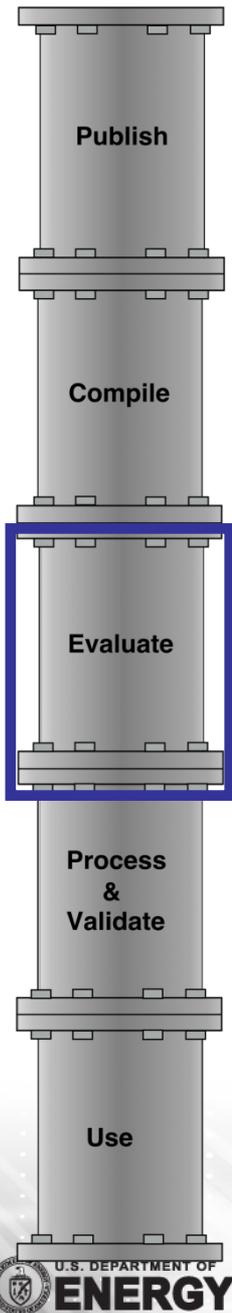
- **NSR updated 2-3 times a week, is up to date with current literature**

- **All searchable on BNL and IAEA sites**

- Recent focus of EXFOR compilation is ensuring completeness in compilations of FPY data



# The Nuclear Data Pipeline

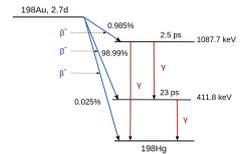


## Evaluate data by combining all information into recommended values

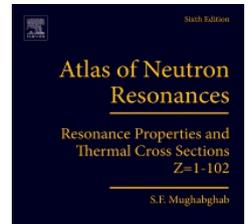
**ENSDF:** Recommended nuclear structure and decay data for all 3,325 known nuclides.

**ENDF:** Recommended particle transport and decay data, with a strong emphasis on neutron-induced reaction data

**Atlas of Neutron Resonances:** 6<sup>th</sup> edition of the famed successor to BNL-325, contains neutron resonance parameters, thermal cross sections and average resonance parameters.



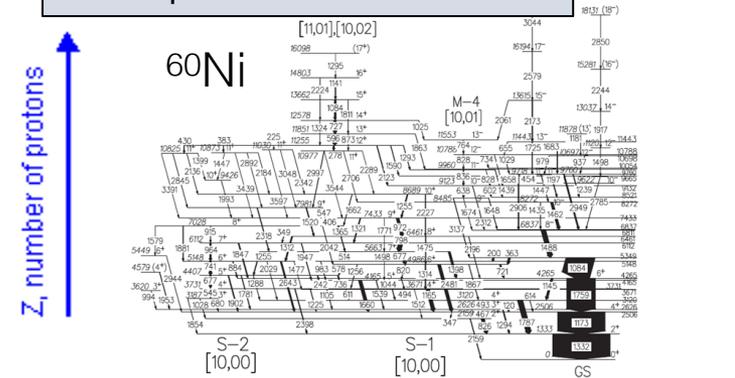
**ENDF**  
B-VIII.0



# Evaluated Nuclear Structure Data

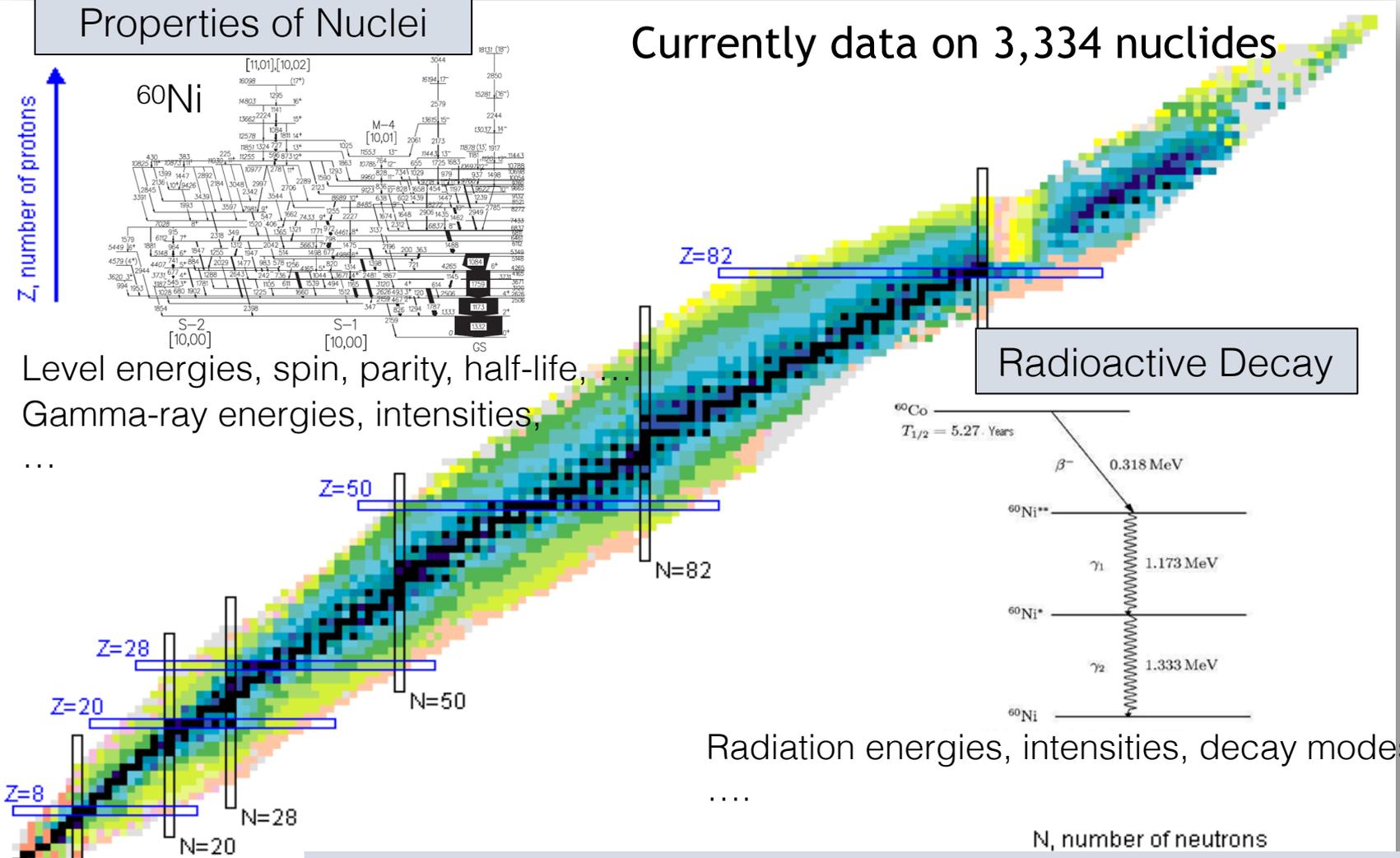
## Properties of Nuclei

Z, number of protons



Level energies, spin, parity, half-life, ...  
Gamma-ray energies, intensities, ...

Currently data on 3,334 nuclides



## Radioactive Decay

Radiation energies, intensities, decay modes  
....

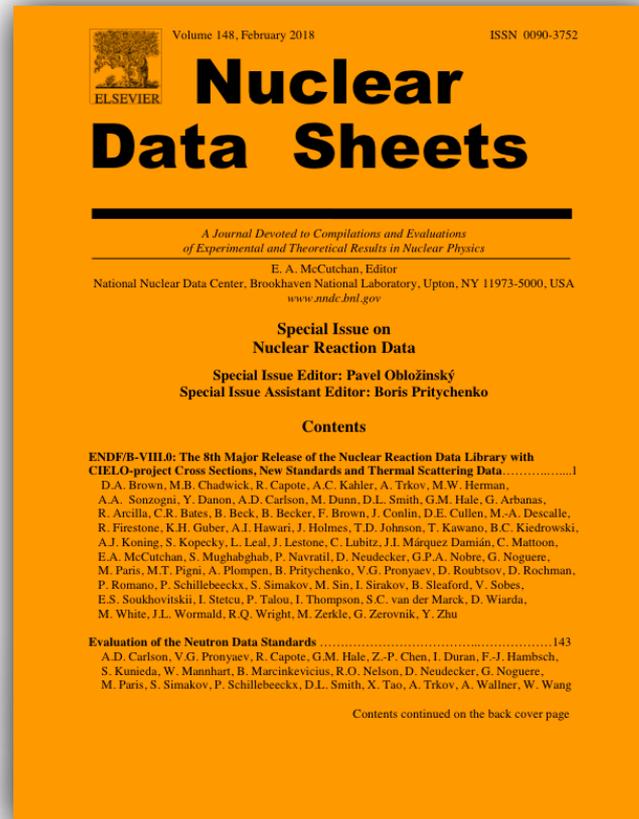
N, number of neutrons

It is Unique: Only Nuclear Database of this kind in the world  
It is Complete: All nuclei and all level and radiation properties  
It is Versatile: Feeds back into both basic and applied sciences

# ENDF/B-VIII.0 was released on 2 Feb. 2018 by the Cross Section Evaluation Working Group (CSEWG)

# ENDF B-VIII.0

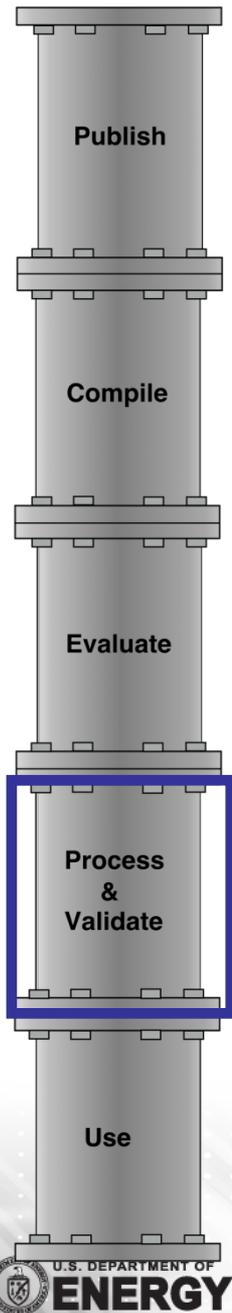
Library and evaluations detailed in Nuclear Data Sheets vol. 148 (2018)



Happy  
50<sup>th</sup>  
Anniversary!

\* ENDF/B-I was released in June 1968

# The Nuclear Data Pipeline

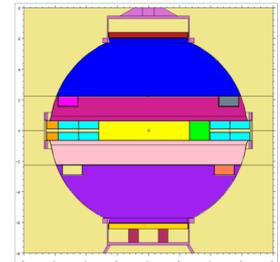
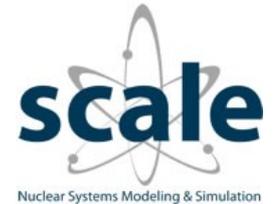


**Collaborate with nuclear data community to get data ready for users**

**Processing:** Prepare data for use in application codes.

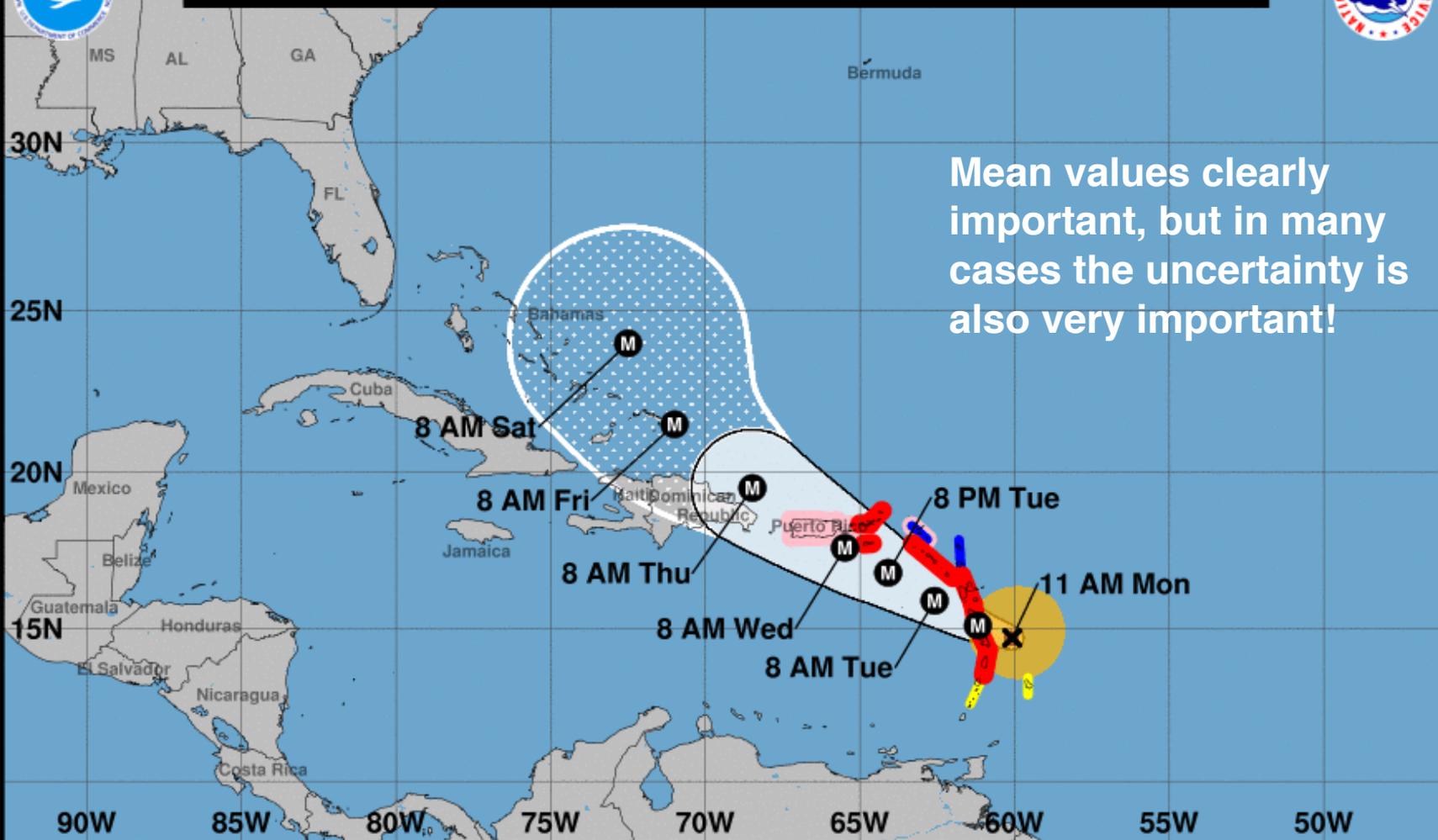
**Validation:** Test data in simulations of non-trivial, but well understood, nuclear systems.

**Quality Assurance:** The NNDC's ADVANCE nuclear data continuous integration system ensures the quality of data by automatically testing each ENDF evaluation as soon as it is changed.





Note: The cone contains the probable path of the storm center but does not show the size of the storm. Hazardous conditions can occur outside of the cone.

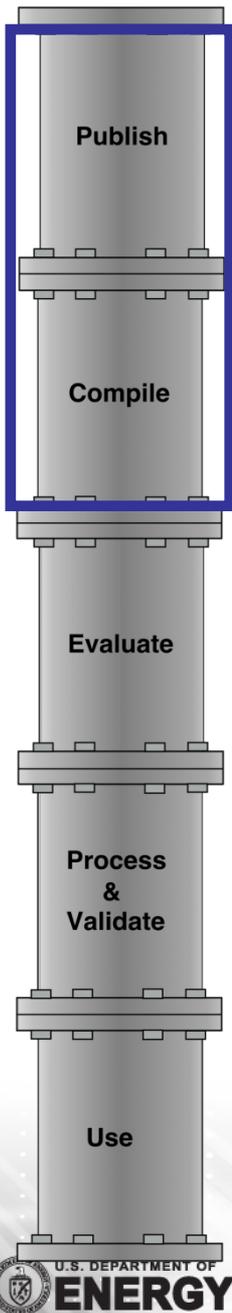


Mean values clearly important, but in many cases the uncertainty is also very important!

<p><b>Hurricane Maria</b>          Monday September 18, 2017          11 AM AST Advisory 9          NWS National Hurricane Center</p>	<p><b>Current information: x</b>          Center location 14.7 N 60.1 W          Maximum sustained wind 120 mph          Movement WNW at 10 mph</p>	<p><b>Forecast positions:</b>          ● Tropical Cyclone   ○ Post/Potential TC          Sustained winds:   D &lt; 39 mph                                    S 39-73 mph   H 74-110 mph   M &gt; 110 mph</p>
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<p><b>Potential track area:</b>   Day 1-3    Day 4-5</p>	<p><b>Watches:</b>   Hurricane    Trop Stm</p>	<p><b>Warnings:</b>   Hurricane    Trop Stm</p>	<p><b>Current wind extent:</b>   Hurricane    Trop Stm</p>
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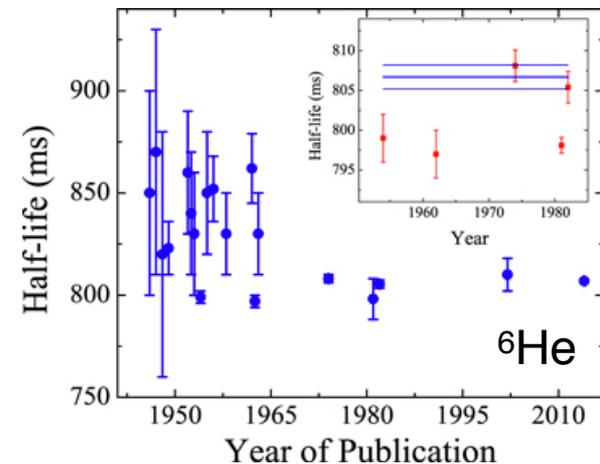
# Uncertainty data in the Nuclear Data Pipeline



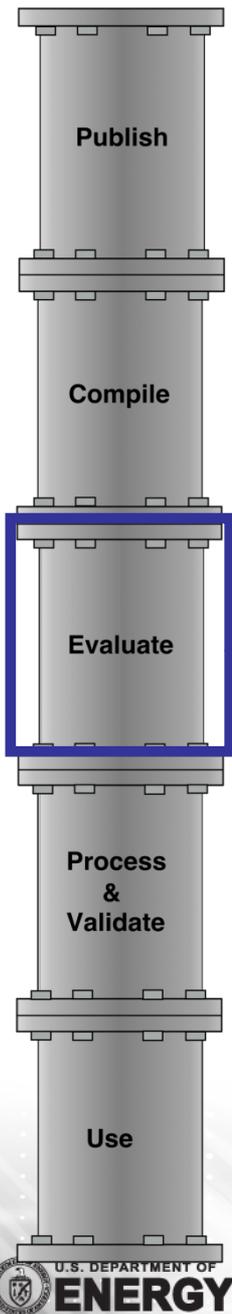
## Essential to compile complete and correct uncertainty data

**Experimenter:** Best estimates of uncertainties for all sources of error in all measured quantities. Essential for understanding correlations between data.

**Compilation:** EXFOR and XUNDL compilers log this data for use in evaluation process



# Uncertainty data in the Nuclear Data Pipeline

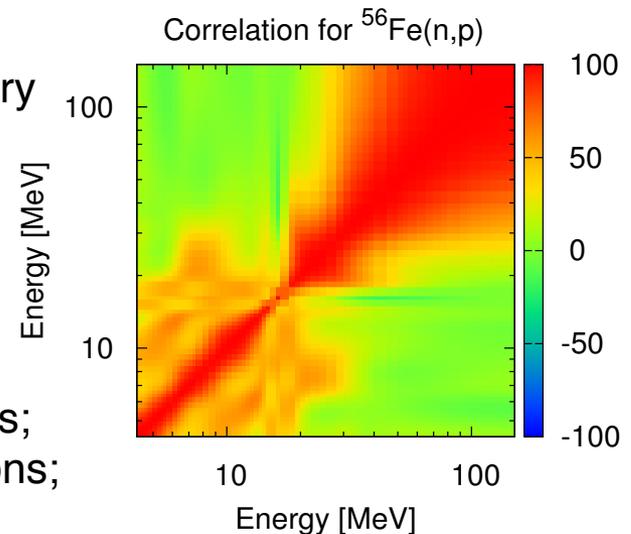


**Evaluators combine best theory with measurements to recommend values & uncertainties**

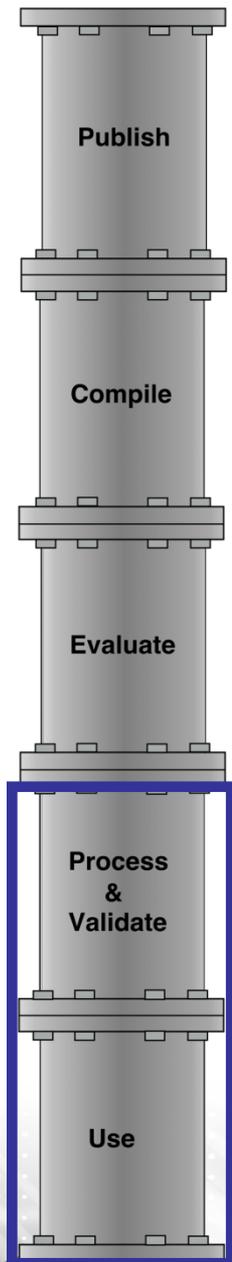
**Structure (ENSDF):** Combine experimental values compiled in XUNDL database to provide best values.

**Reaction (ENDF):** Combine experimental values with best theory to create coherent and complete recommended values for applications.

**Common Issues:** Incomplete experimental information; Experimental correlations; Mistakes; Theoretical constraints & correlations; Model mis-fit; Non-Gaussian-ness



# Uncertainty data in the Nuclear Data Pipeline

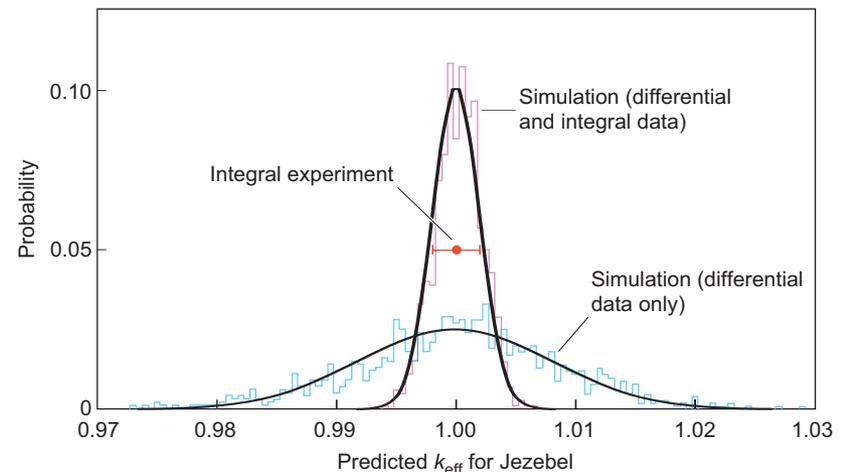


**Collaborate with nuclear data community to get data ready for users**

**Processing:** Formats must be available for the covariances and the processing codes must be able to handle them.

**Validation:** Test data in simulations of non-trivial, but well understood, nuclear systems.

**User codes:** Must have capability to actually use the reported covariances



# Missing or extremely limiting covariance data format

- Thermal Scattering Law data

- **Nothing!**

- Fission Product Yield data

- $Y \pm \Delta Y$  only

- Decay data

- Discrete energies,

- $Q$ ,

- $T_{1/2}$ ,

- Branching ratios,

- ICC

- Atomic data

- **Nothing!**

} criticality, reactors

} spent fuel,  
decay heat, etc.

} radiotherapy

# Full format, but (basically) no data

- protons
- deuterons
- tritons
- helions ( $^3\text{He}$ )
- alphas
- photonuclear

} fusion

non-proliferation, assay

# Neutron sub library contains nearly all the covariance data in ENDF/B

- 30: any parameters
  - 31: nubar
  - 32: resonance
  - 33:  $\sigma(E)$
  - 34:  $P(\mu|E)$
  - 35:  $P(E'|E)$
  - 40:  $Y(E)$
  - energy release in fission
- unused
- widespread use
- limited use
- Big 3 only

# Happy 50 $\pm$ 1 Anniversary!\*

\* CSEWG formed in 1966  
ENDF/B-I released in 1968