
Brookhaven
National Laboratory
U.S. DEPARTMENT OF
ENERGY
Nuclear Data Evaluations
Elizabeth McCutchan
@BrookhavenLab

National Nuclear Data Center

U.S. DEPARTMENT OF ENERGY | Office of Science

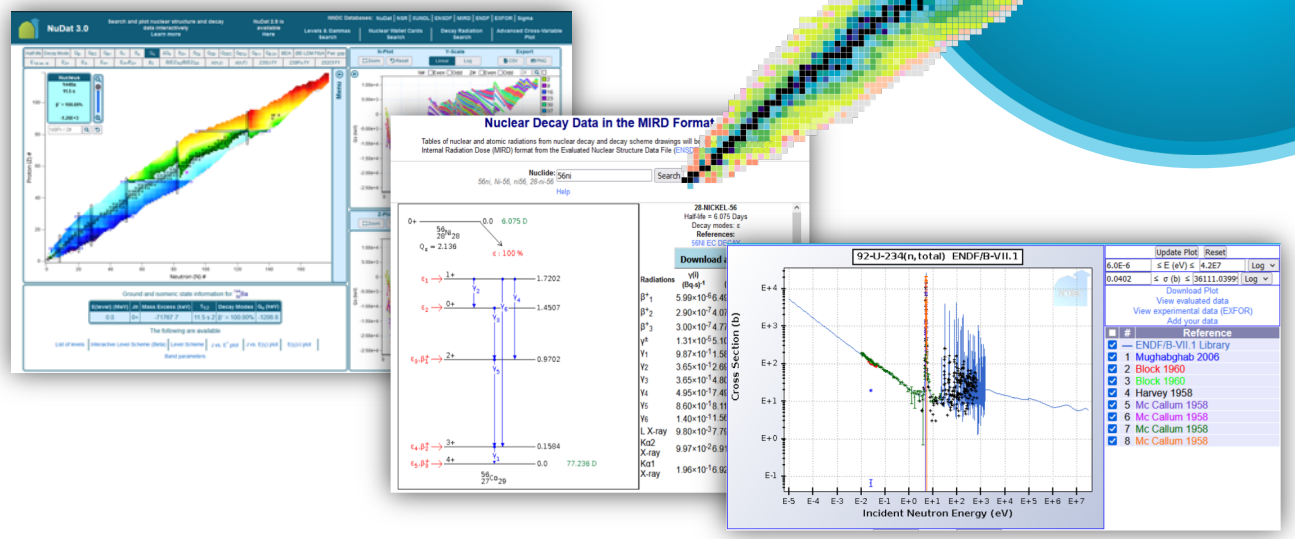
Maintaining and improving nuclear data for world-wide use

Mission

To provide current, accurate, authoritative data for workers in pure and applied areas of nuclear science and engineering

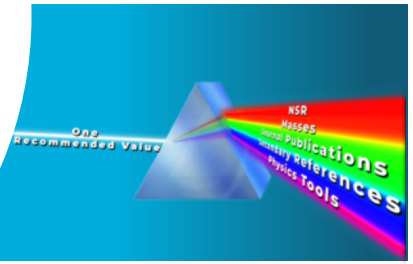
Services

Disseminate nuclear data through feature-rich web applications



Databases

PuRe Data Resources



Nuclear Structure & Decay:

- ENSDF
- XUNDL

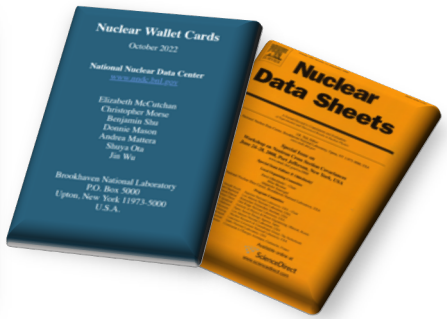
Nuclear Reaction:

- ENDF
- EXFOR

Bibliographic:

- NSR

Publications



Nuclear Data Sheets:
World leading journal on nuclear data evaluations and research

Nuclear Wallet Cards:
Ground and isomeric state nuclear properties of all-known nuclei

ENSDF : the ONLY comprehensive resource for

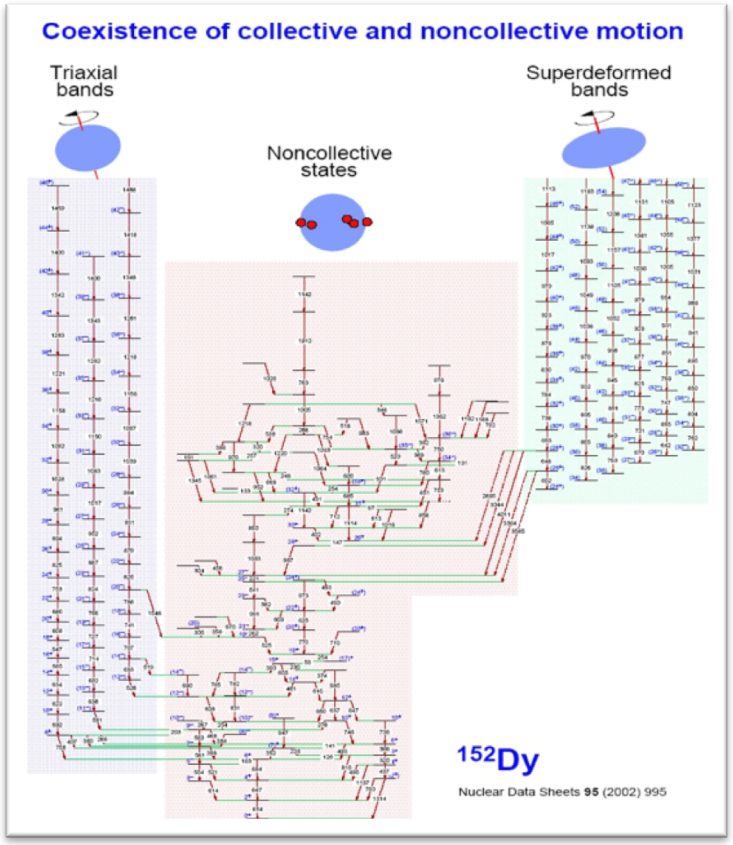
Nuclear Structure

Discrete Quantized States

- Excitation Energy
- Half-life
- Angular Momentum
- Magnetic Moment
- Configuration
- …

Emitted Radiation

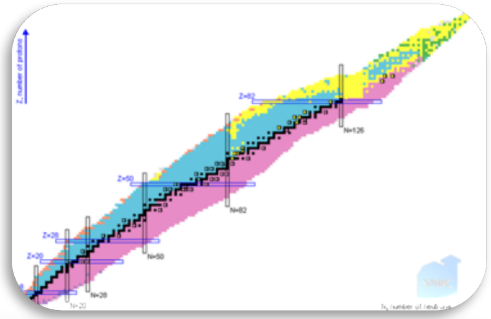
- Energy
- Intensity
- Dipole, Quadrupole, …
- Mixing ratio
- Conversion coefficient

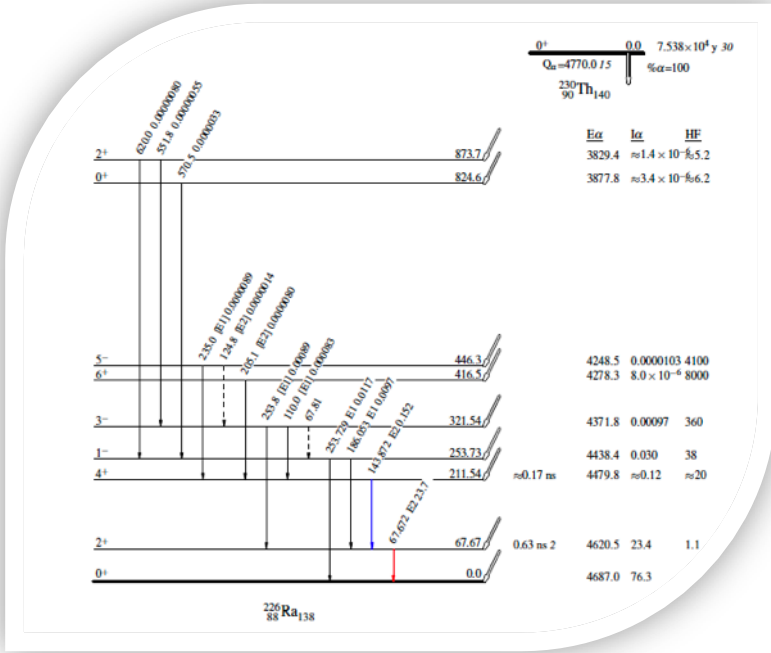


Nuclear Decay Data

For each decay type:

- Half-life
- Branching ratio
- Energy
- Intensity
- Coincidences
- …





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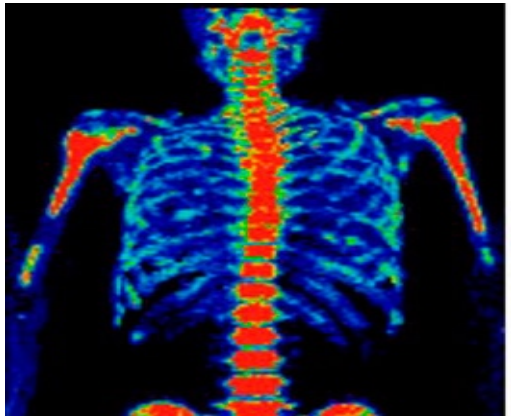
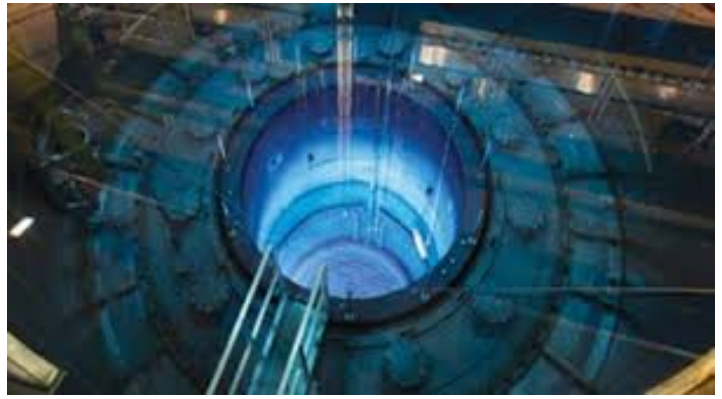
Users of ENSDF

FRIB RIKEN NISHINA CENTER FAIR TRIUMF GANIL SPIRAL2 laboratoire commun CEA/DRF CNRS/IN2P3

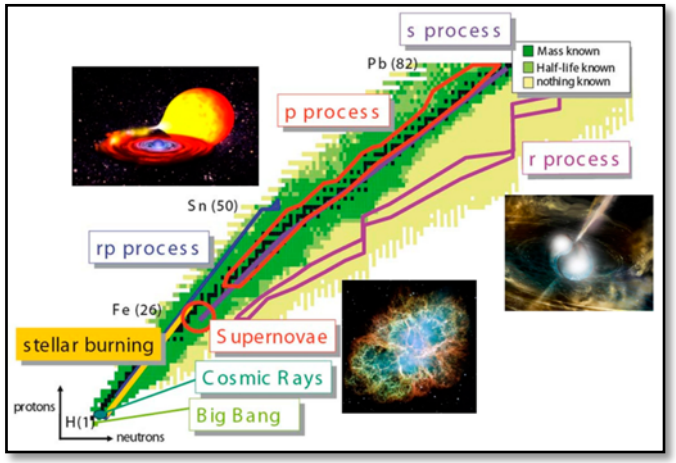
Fundamental Nuclear Science



Nuclear Medicine



Nuclear Power



Astrophysics

Homeland Security

Stockpile Stewardship

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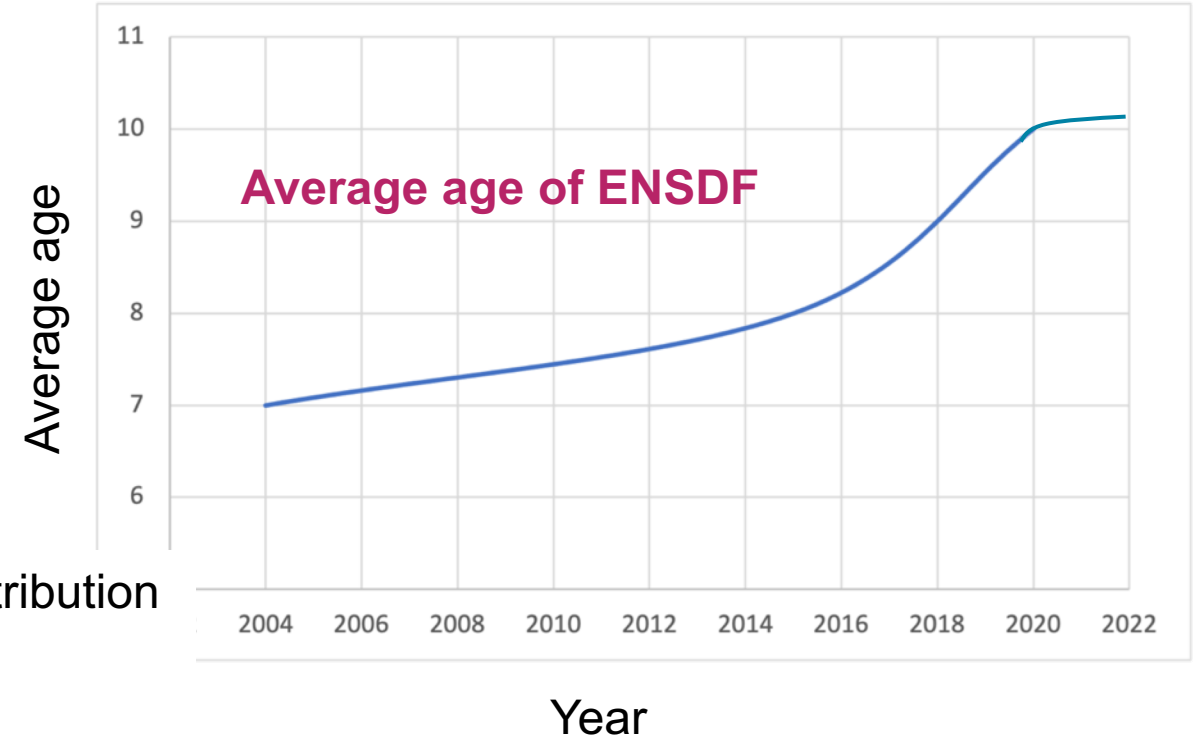
ENSDF - Organization & Management

INTERNATIONAL NETWORK OF NUCLEAR STRUCTURE AND DECAY DATA EVALUATORS (NSDD)

- NSDD network established in 1974 under the auspices of IAEA
- Meetings coordinated by IAEA nuclear data section
- Database management and storage by the National Nuclear Data Center

Currently

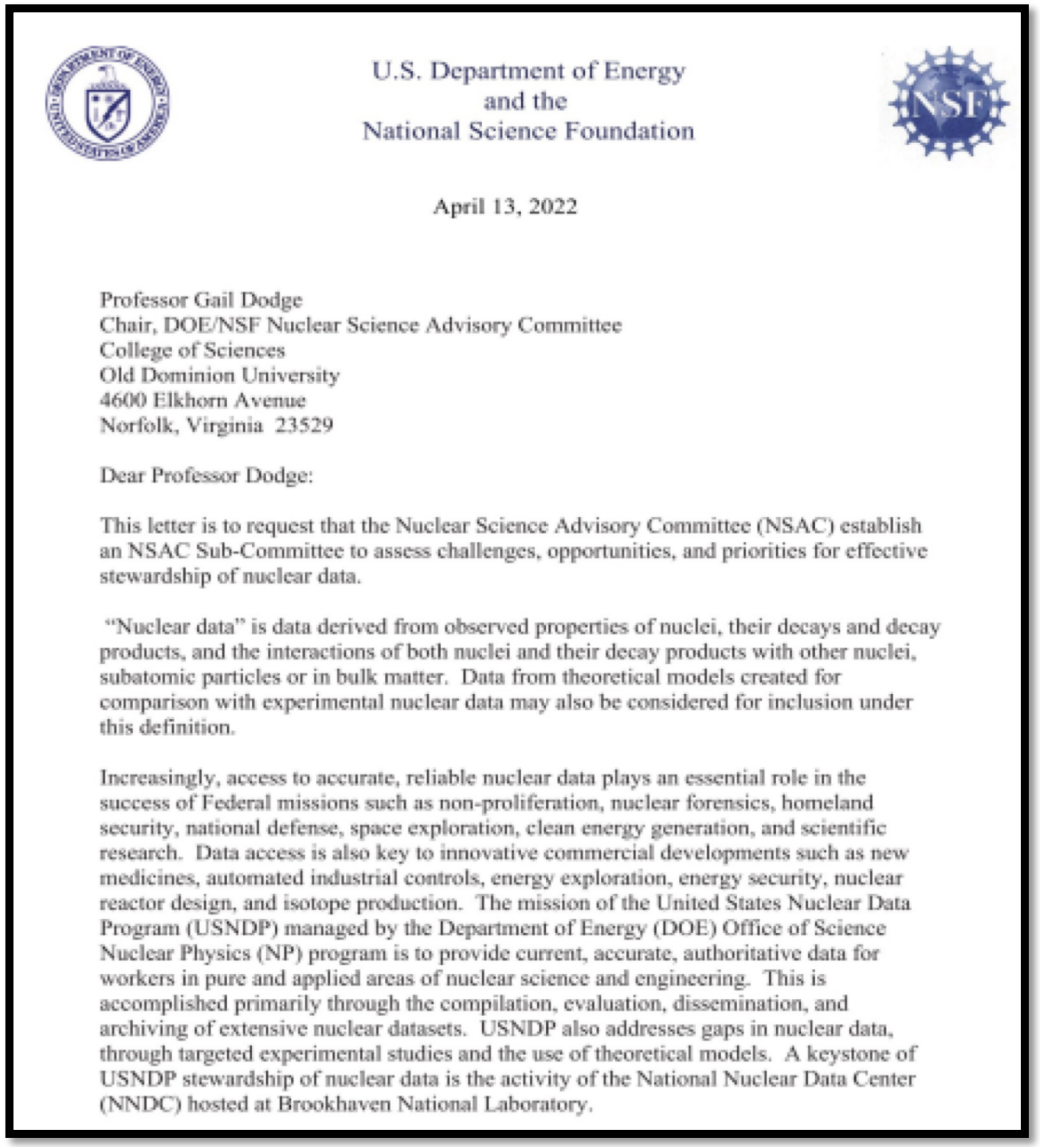
- 8 US Centers - all funded through DOE
  - ANL, BNL, LBNL, McMaster, MSU, ORNL, TAMU, TUNL
- 9 International Centers
  - PNPI/Russia, CIAE/China, Julin/China, JAEA/Japan, ANU/Australia, IFIN/Romania, Sofia/Bulgaria, Atomki/Hungary, VECC/Kolkata



2019 : Evaluated **187** nuclides, **13** international – **7%** contribution
2020 : Evaluated **144** nuclides, **0** international
2021 : Evaluated **263** nuclides, **0** international
2022 : Evaluated **225** nuclides, **0** international

Nuclear Data is coming into the spotlight

- NSAC charge to
  - Assess challenges, opportunities and priorities for effective stewardship of ND
  - Two reports have been produced
- US is currently going through long range planning process
- Nuclear data specific resolutions have emerged from all 3 town halls



U.S. Department of Energy
and the
National Science Foundation

April 13, 2022

Professor Gail Dodge
Chair, DOE/NSF Nuclear Science Advisory Committee
College of Sciences
Old Dominion University
4600 Elkhorn Avenue
Norfolk, Virginia 23529

Dear Professor Dodge:

This letter is to request that the Nuclear Science Advisory Committee (NSAC) establish an NSAC Sub-Committee to assess challenges, opportunities, and priorities for effective stewardship of nuclear data.

"Nuclear data" is data derived from observed properties of nuclei, their decays and decay products, and the interactions of both nuclei and their decay products with other nuclei, subatomic particles or in bulk matter. Data from theoretical models created for comparison with experimental nuclear data may also be considered for inclusion under this definition.

Increasingly, access to accurate, reliable nuclear data plays an essential role in the success of Federal missions such as non-proliferation, nuclear forensics, homeland security, national defense, space exploration, clean energy generation, and scientific research. Data access is also key to innovative commercial developments such as new medicines, automated industrial controls, energy exploration, energy security, nuclear reactor design, and isotope production. The mission of the United States Nuclear Data Program (USNDP) managed by the Department of Energy (DOE) Office of Science Nuclear Physics (NP) program is to provide current, accurate, authoritative data for workers in pure and applied areas of nuclear science and engineering. This is accomplished primarily through the compilation, evaluation, dissemination, and archiving of extensive nuclear datasets. USNDP also addresses gaps in nuclear data, through targeted experimental studies and the use of theoretical models. A keystone of USNDP stewardship of nuclear data is the activity of the National Nuclear Data Center (NNDC) hosted at Brookhaven National Laboratory.

From Nuclear Structure, Reactions and Astrophysics Town Hall

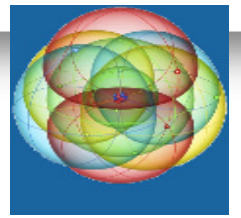
Resolution 5

Nuclear data play an essential role in all facets of nuclear science. Access to reliable, complete and up-to-date nuclear structure and reaction data is crucial for the fundamental nuclear physics research enterprise, as well as for the successes of applied missions in the areas of defense and security, nuclear energy, space exploration, isotope production, and medical applications. It is thus imperative to maintain an effective US role in the stewardship of nuclear data.

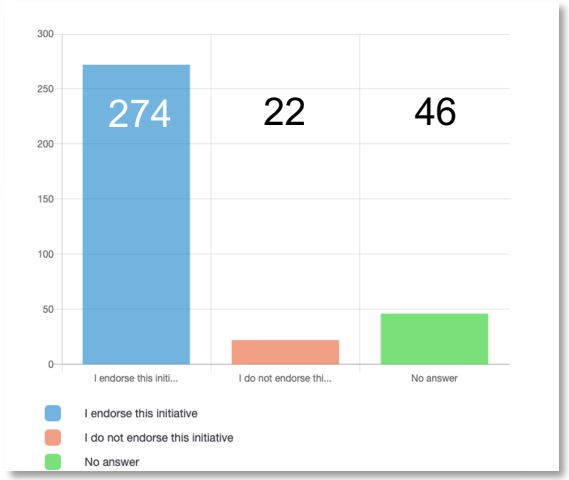
- We endorse support for the compilation, evaluation, dissemination and preservation of nuclear data and efforts to build a diverse, equitable and inclusive workforce that maintains reliable and up-to-date nuclear databases through national and international partnerships.
- We recommend prioritizing opportunities that enhance the prompt availability and quality of nuclear data and its utility for propelling scientific progress in nuclear structure, reactions and astrophysics and other fundamental physics research programs.
- We endorse identifying interagency-supported crosscutting opportunities for nuclear data with other programs, that enrich the utility of nuclear data in both science and society.

Similar Nuclear Data Resolutions endorsed by:

- **Nuclear Structure, Reactions and Astrophysics,**
- **Hot & Cold QCD and**
- **Fundamental Symmetries town hall meetings**



2022 Low Energy Town Hall



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Opportunities in Europe - Nuclear Physics Expert Collaboration Committee (NuPECC) Long Range Plan 2024

ENSDF contribution status in Europe

- 3 Data Centers (Bulgaria, Hungary, Romania)
- total declared contribution amounts to 12% of total effort
- Fragmented effort – effectively amounts to < 1% (past 5 years)
- Limited funding obtained from a EURATOM project (SANDA – ends 2023)

NuPECC Long Range Plan 2024

- IAEA presentation at NuPECC Meeting, 2 Dec. 2022, Vienna
- Nuclear data and evaluation more prominent in the LPR 2024:
  Workpackage 9: Open Science and Data
  Subsection 9.5: Nuclear data(databases) and evaluation (IAEA contr.)
- Proposal for an IAEA meeting to discuss European strategy for nuclear data [done: see next slide]

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Slide from P. Dimitriou - IAEA

IAEA Consultant's Meeting on Needs for a Comprehensive European Plan to acquire and curate nuclear data, April 2023, IAEA, Vienna

Participants: NuPECC, EURATOM, CEA, ChETEC-INFRA, SANDA, DoE USNDP Manager

Recommendations: To ensure the timely incorporation of experimental data measured at European facilities in the nuclear databases and maintain expertise and autonomy in nuclear data compilation, evaluation and dissemination, the European nuclear physics community needs to

- Establish priorities for nuclear data measurements and evaluations that will be addressed by a comprehensive European nuclear data programme
- Establish a sustainable source of funding of measurements and data evaluation, including support of well-defined career paths in nuclear data that will involve national funding agencies and the European Commission (EC) (EURATOM and all other relevant EU work programmes)
- Reinforce cooperation with international organizations to attract and train the next generation of evaluators

Actions:

- Organize side event on nuclear data at IAEA General Conference 2023 (led by JRC Geel) with contributions from US, Europe, Japan, China [in progress] – to reach out to nuclear stakeholders of IAEA member states
- Meeting of stakeholders (national and EU funding agencies and programs), industry partners, representatives of nuclear physics research and nuclear data communities, international organizations
- Reach out (separate meetings) to national and EU funding agencies
- Organize workshops,summer schools, and webinars to raise awareness of the importance of nuclear data and to enhance capacity building in nuclear data evaluation methods, validation, and dissemination.

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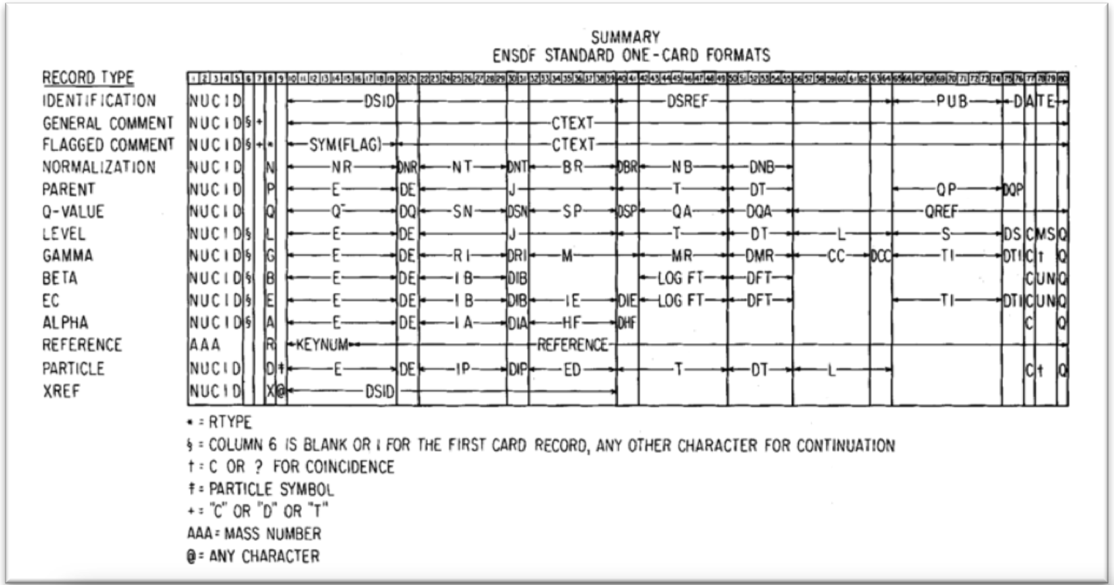
Slide from P. Dimitriou - IAEA

Major modernization efforts underway

Under the hood of ENSDF

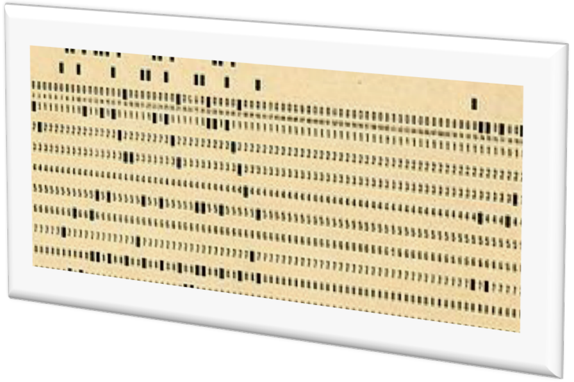


SUMMARY
ENSDF STANDARD ONE-CARD FORMATS

RECORD TYPE	Fields
IDENTIFICATION	NUCID, DSID, DSREF, PUB, DATE
GENERAL COMMENT	NUCID, §, +, CTEXT
FLAGGED COMMENT	NUCID, §, +, *, SYM(FLAG), CTEXT
NORMALIZATION	NUCID, N, NR, DNR, NT, DNT, BR, DBR, NB, DNB
PARENT	NUCID, P, E, DE, J, T, DT, QP, DQP
Q-VALUE	NUCID, Q, Q⁻, DQ, SN, DSN, SP, DSP, QA, DQA, QREF
LEVEL	NUCID, §, L, E, DE, J, T, DT, L, S, DS, C, MS, Q
GAMMA	NUCID, §, G, E, DE, RI, DRI, M, MR, DMR, CC, DCC, TI, DTI, C, †, Q
BETA	NUCID, §, B, E, DE, IB, DIB, LOG FT, DFT, C, UN, Q
EC	NUCID, §, E, E, DE, IB, DIB, IE, DIE, LOG FT, DFT, TI, DTI, C, UN, Q
ALPHA	NUCID, §, A, E, DE, IA, DIA, HF, DHF, C, Q
REFERENCE	AAA, R, KEYNUM, REFERENCE
PARTICLE	NUCID, D, ǂ, E, DE, IP, DIP, ED, T, DT, L, C, †, Q
XREF	NUCID, X, @, DSID

* = RTYPE
§ = COLUMN 6 IS BLANK OR 1 FOR THE FIRST CARD RECORD, ANY OTHER CHARACTER FOR CONTINUATION
† = C OR ? FOR COINCIDENCE
ǂ = PARTICLE SYMBOL
+ = "C" OR "D" OR "T"
AAA = MASS NUMBER
@ = ANY CHARACTER

80 Column ASCII format



```
137CS PN                                                                     6
137CS  L 0.0          7/2+                 30.08 Y   9                      A
137CSX L XREF=ACDEFGH
137CS2 L %B-=100$MOMM1=+2.8413 1 (1989Ra17)$MOME2=+0.051 1 (1989Ra17)
137CS cL T$Deduced by evaluators using the Limitation of Relative Statistical
137CS2cL Weights (LRSW) method for analyzing the following set of
137CS3cL discrepant (|h{+2}/|n=18.6) experimental values: 10970 d {I20}
137CS4cL (2004Sc04); 11018 d {I10} (2002Un02); 10941 d {I7} (1992Go24);
137CS5cL 10968 d {I5} (1990Ma15); 11009 d {I11} (1980Ho17); 10906 d {I33}
137CS6cL (1978Gr08); 11034 d {I29} (1973Co39); 11021 d {I5} (1973Di01); 11023 d
137CS7cL {I37} (1972Em01); 10921 d {I17} (1970Wa19); 1
137CS8cL 11286 d {I256}, 10921 d {I183} (1965Fl01); 11
```

80 column fields

"Continuation record"

A LOT of data stored in comments
Non-standardized entry

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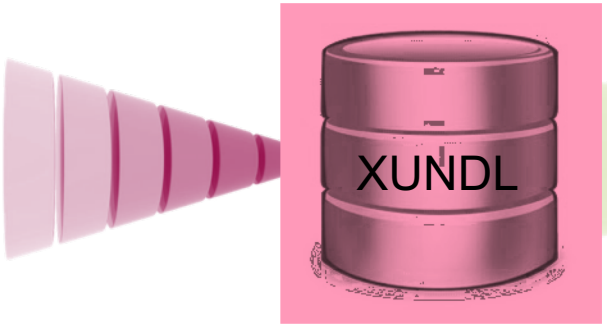
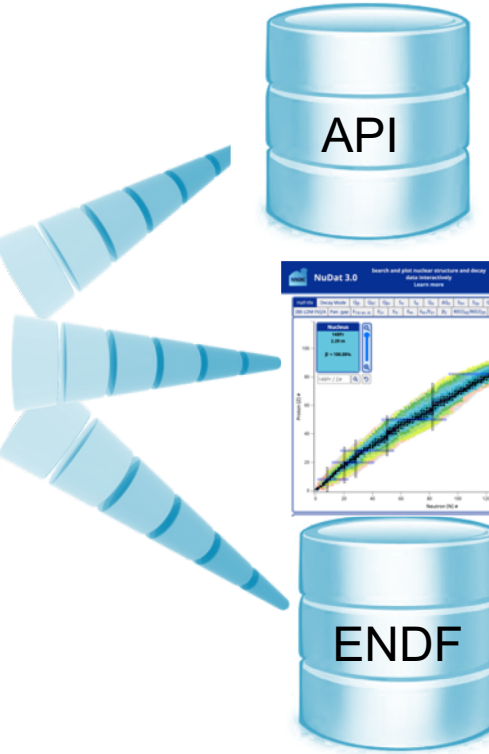
ENSDF Modernization

DOE has made significant investment to modernize and improve ENSDF
3 year project involving 3 DOE national laboratories – BNL – ANL - LLNL



ML for improved tabular recognition
Lead – BNL-CSI

New Object-Oriented Database - couchDB



Compatibility and increased flexibility for end users

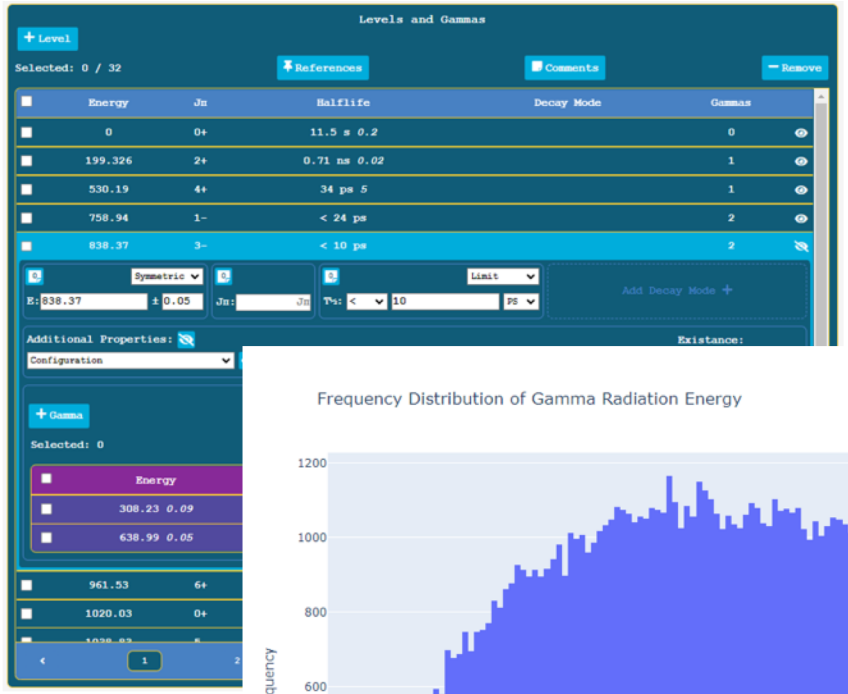
A new object-oriented database for ENSDF

We've migrated from 80 column ASCII to JSON based schema

```
137CS PN                                                              6
137CS  L 0.0         7/2+              30.08 Y   9                    A
137CSX L XREF=ACDEFGH
137CS2 L %B-=100$MOMM1=+2.8413 1 (1989Ra17)$MOME2=+0.051 1 (1989Ra17)
137CS cL T$Deduced by evaluators using the Limitation of Relative Statistical
137CS2cL Weights (LRSW) method for analyzing the following set of
137CS3cL discrepant (|h{+2}/|n=18.6) experimental values: 10970 d {I20}
137CS4cL (2004Sc04); 11018 d {I10} (2002Un02); 10941 d {I7} (1992Go24);
137CS5cL 10968 d {I5} (1990Ma15); 11009 d {I11} (1980Ho17); 10906 d {I33}
137CS6cL (1978Gr08); 11034 d {I29} (1973Co39); 11021 d {I5} (1973Di01); 11023 d
137CS7cL {I37} (1972Em01); 10921 d {I17} (1970Wa19); 11191 d {I157} (1970Ha32);
137CS8cL 11286 d {I256}, 10921 d {I183} (1965Fl01); 11220 d {I47} (1965Le25);
```

```
{
    "spinParityValues": [
        {
            "spin": 2,
            "isTentativeSpin": true,
            "isTentativeParity": true,
            "parity": "+",
            "parityNumber":1
        },
        {
            "spin": 3,
            "isTentativeSpin": true,
            "isTentativeParity": true,
            "parity": "-",
            "parityNumber":-1
        }
    ],
    "comments": [
        "Assignments are based on..."
    ]
}
```

Developed a new Editor for ENSDF evaluators



And (for the first time!) designed an API for ENSDF

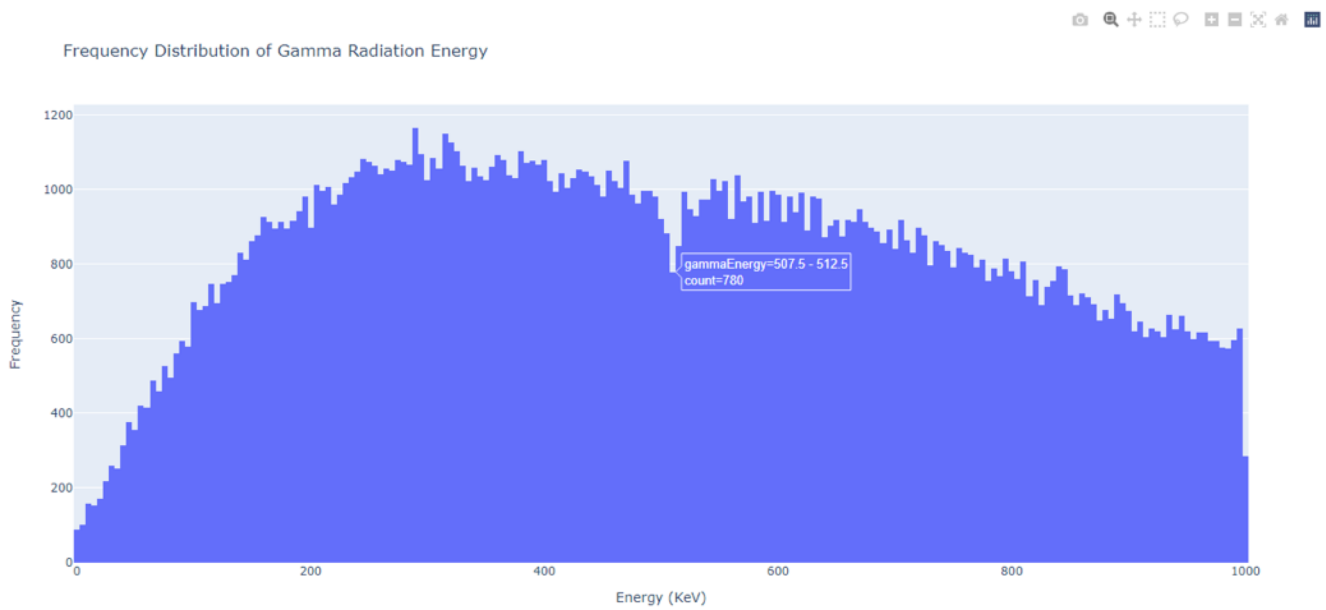
```
# Initialize API
api = ensdfAPI(ipAddress="127.0.0.1", port=5001)

# Get all gammas 0-1000 keV
values_dict=api.filterByGammas(0,1000)
dataframe = plot.createViewDataFrame(values_dict)

# Label plot
plot.configuration.setAxisTitle("x", "Energy (KeV)")
plot.configuration.setAxisTitle("y", "Frequency")
plot.configuration.setTitle("Frequency Distribution of Gamma Radiation Energy")

# Plot as a histogram
figure=plot.createHistogram(dataframe, "gammaEnergy")

plot.showFigure(figure)
```



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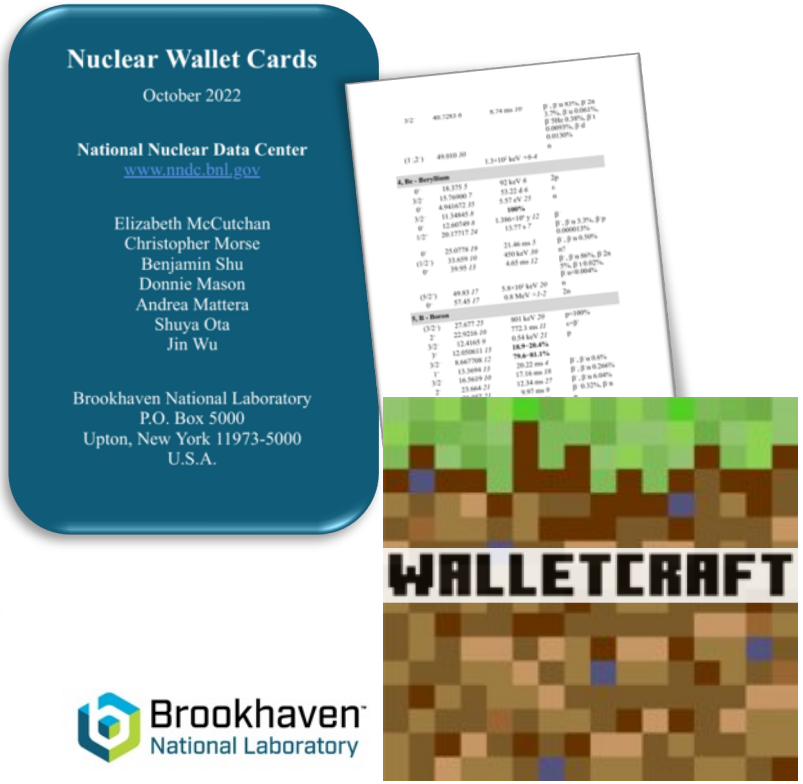
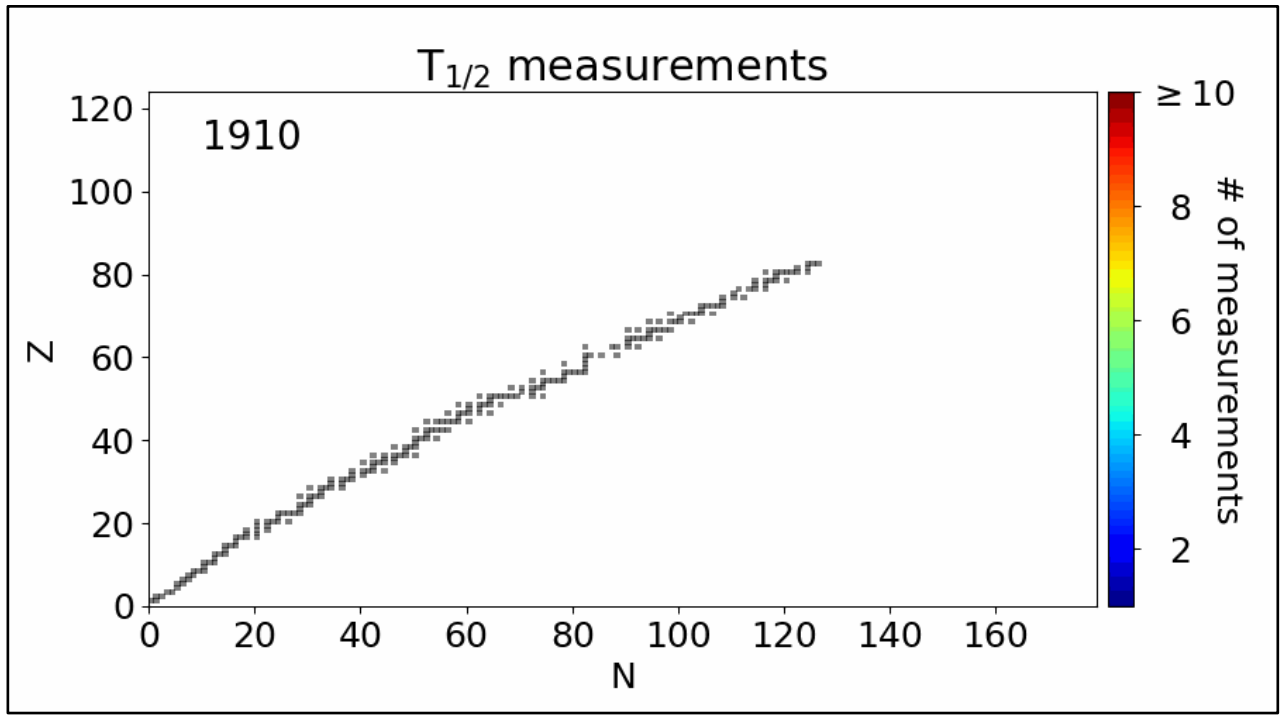
WalletCraft: a new evaluation of properties of ground-state and long-lived isomers for all known nuclei

Evaluation for g.s. and isomers ($T_{1/2}$>100ms) of:
- Spin/Parity
- Mass Excess – from AME2020
- Half-life, Width or Abundance
- Decay Mode(s)



Major changes *under the hood*:
- New JSON-based OODB
- We store experimental measurements (building block of the evaluation)

Advantages:
- Transparent documentation of evaluation history
- Format can be easily read in modern codes and data plotted/analyzed
- Allows for much shorter versioning (from 5-10 yr to ~1yr)



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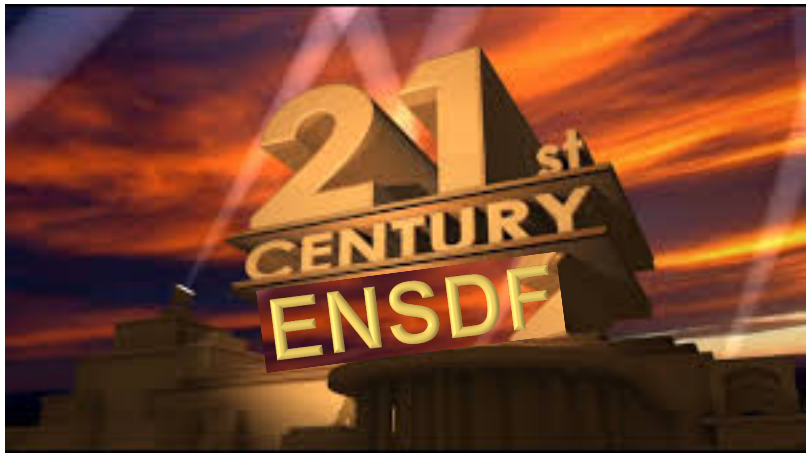
The future looks bright



- ENSDF has grown into definitive source for Nuclear Structure and Decay data
- Tools for accessing database, print and web, likewise have evolved
- In process of completely modernizing format and tools

BUT …. we need help

- Return to the original model of ENSDF with broad international contributions
- Dedicated funding at the level of 50% or more
- Long term commitments to learning and maintaining ENSDF evaluation expertise