Status of AME & NUBASE

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U.S. DEPARTMENT OF ENERGY | Office of Science

Nuclear Physics

Atomic Masses & Nuclear Physics

⇒ Binding energy
- mass models
- shell structure

⇒ Correlations
- pairing
- p-n

⇒ The limits of existence
- drip lines

⇒ Nuclear astrophysics
- nucleosynthesis pathways & scenarios

- essential to Nuclear Structure research & Data Evaluation
  ⇒ widely used in other areas of physics, chemistry, metrology and applications …

Atomic Masses & Nuclear Structure

PHYSICAL REVIEW C **109**, 044311 (2024)

Nucleonic shells and nuclear masses

Landon Buskirk,[1,2] Kyle Godbey,[1] Witold Nazarewicz,[1,2] and Wojciech Satuła[3]
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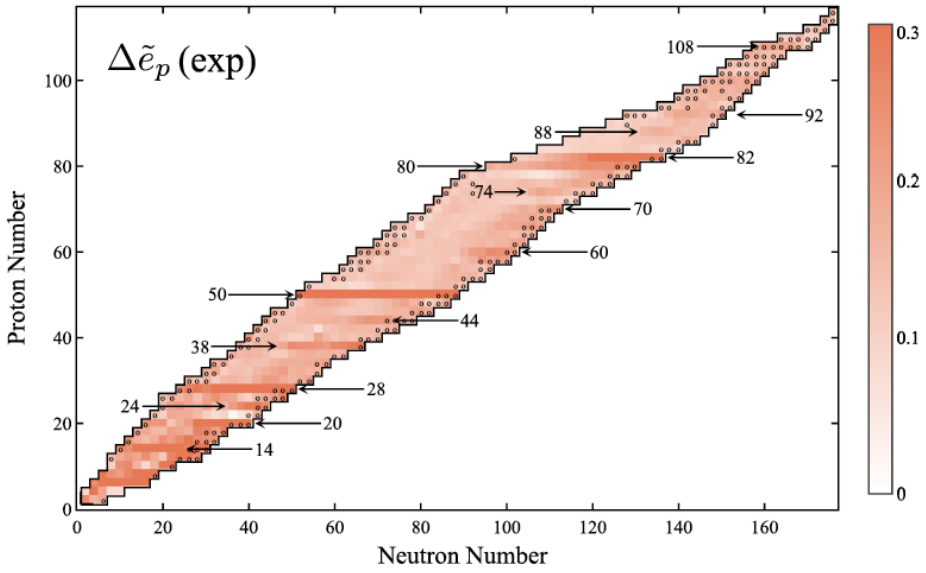
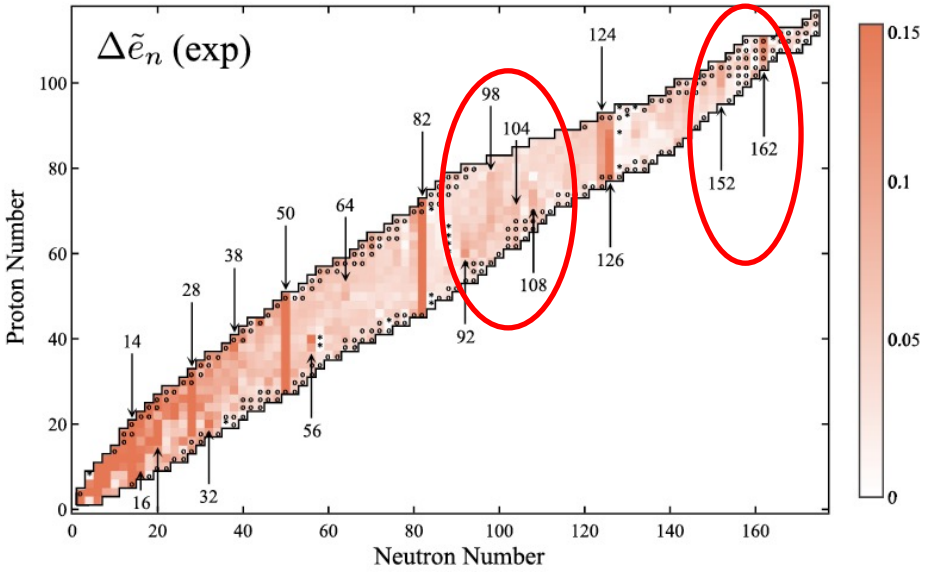
[3]*Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, PL-02093 Warsaw, Poland*

⇒ sensitivity to single-particle energies near the Fermi level





AME & NUBASE

- **AME & NUBASE** provide the recommended values for atomic masses, various decay and reaction Q values & other basic properties for all known nuclei

⇒ input to **ENSDF, ENDF, RIPL** …
⇒ applications of nuclear science **MCNP, GEANT4, OpenMC** …

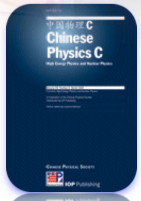
- historically contributed by A. Wapstra & G. Audi
- since 2008 – collaboration between experts from China, Europe, Japan & US

latest tables were published in March 2021
*** AME2020 & NUBASE2020 ***
coordinated by M. Wang & F.G. Kondev

The AME2020 atomic mass evaluation **

The NUBASE2020 evaluation of nuclear physics properties**

F.G. Kondev [1,*], M. Wang (王猛)[2,3,*], W.J. Huang (黄文嘉)[2,4,5,6], S. Naimi[7], G. Audi (欧乔治)[6]



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F.G. Kondev, M. Wang (王猛), W.J. Huang (黄文嘉), S. Naimi and G. Audi (欧乔治)

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The NUBASE2020 evaluation of nuclear physics properties *

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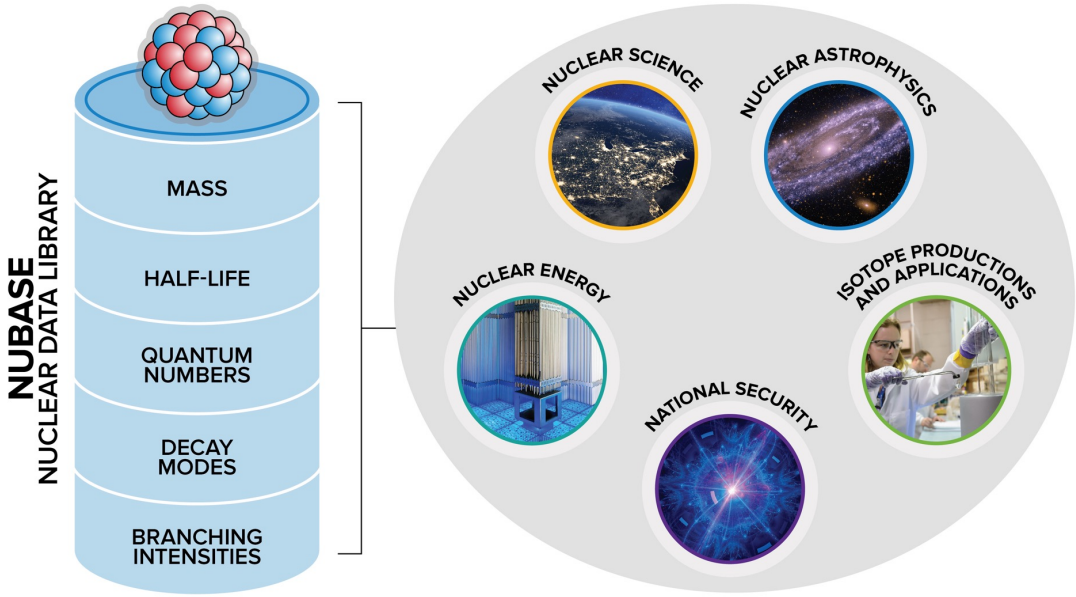
The current NUBASE nuclear data library contains recommended values and uncertainties for nuclear physics characteristics of all nuclei in their ground and excited isomeric states.



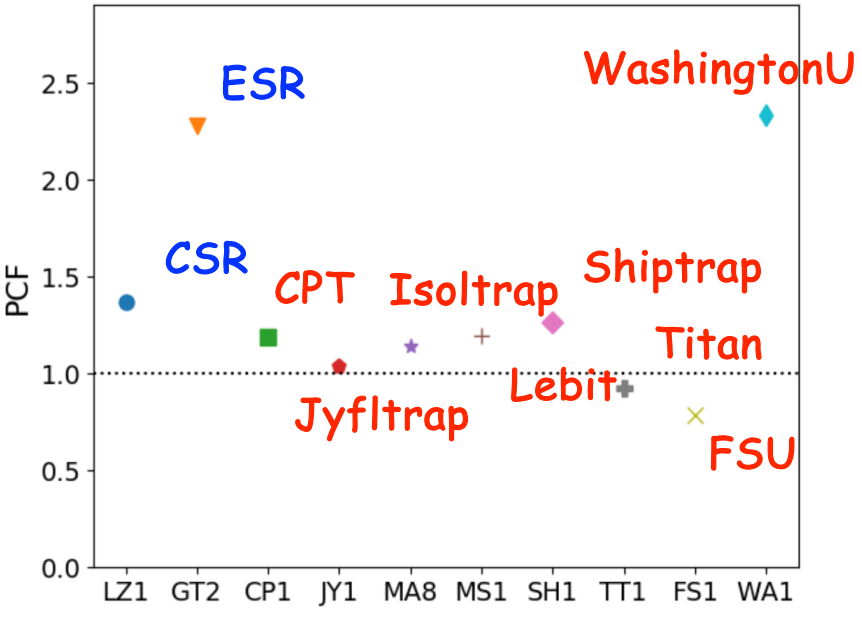
Which Data Are Considered

⇒ Direct (mass spectrometry) and Indirect (reactions and decays) Data produced worldwide

- TOF & MR-TOF, Storage Rings & Penning Traps
- Decay Energies in β^-, β^+, α and p decays – far from stability

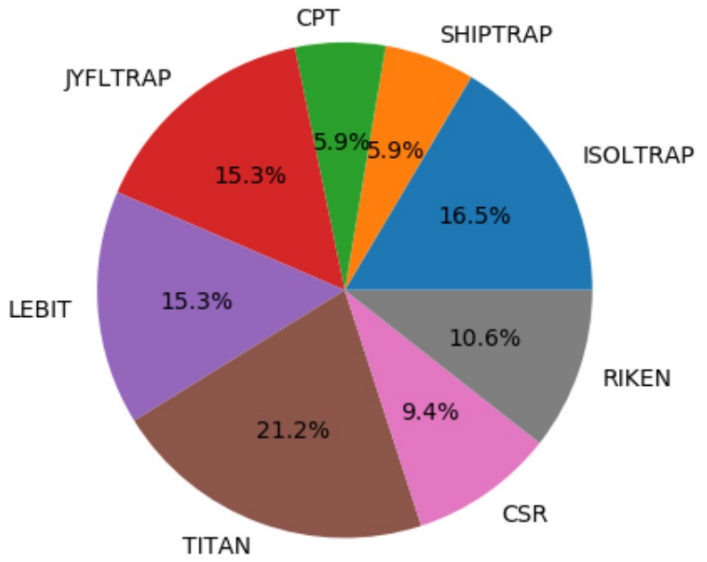
⇒ critically evaluate all experimental data & combine the accepted values using the least-squares fit approach -> mass values & covariances for all known nuclei

Partial Consistency Factor (PCF): $\chi^p = \sqrt{\frac{Q}{Q-M}\frac{1}{p}\sum_{i=1}^{p}\frac{(q_i-\bar{q})^2}{\sigma_i^2}}$



ANL

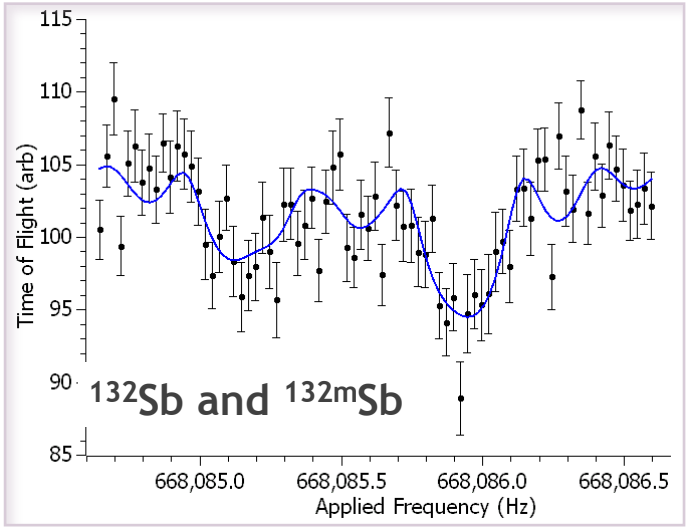
MSU



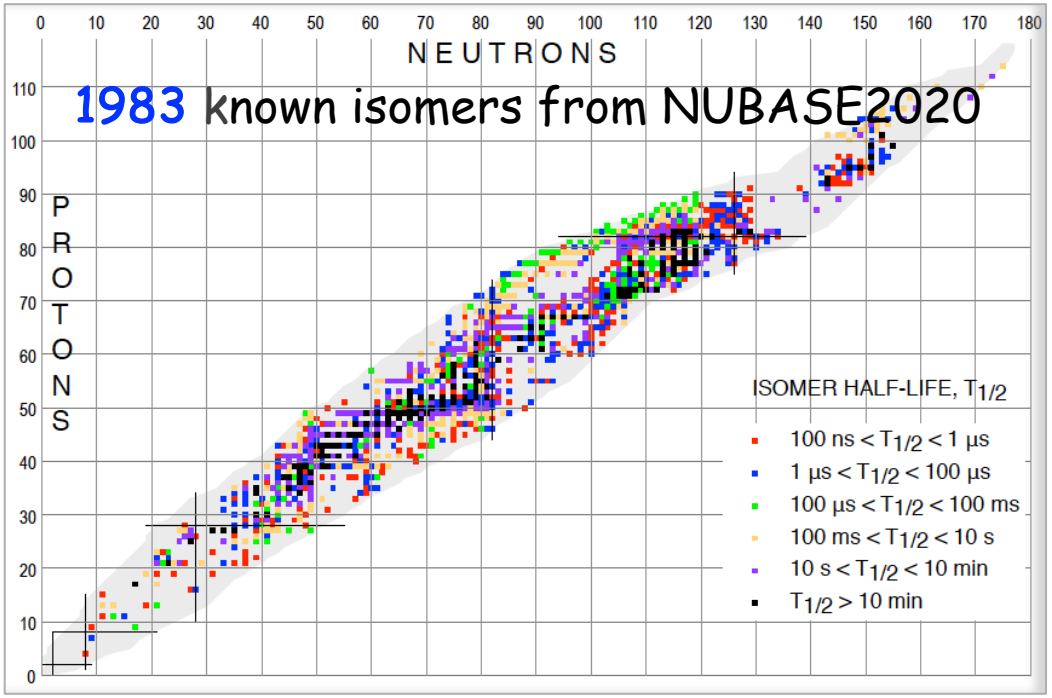
published direct mass data since AME2016

Connection to Nuclear Structure

- Beware of isomers – do we have the right relations?



J. Van Schelt et al., PRL111 (2013) 061102



F.G. Kondev et al., *CPC* 45 (2021) 030001

NUBASE evaluation of basic nuclear properties

⇒ masses (Ex) for isomers and their method of deduction – integral part of **AME**

⇒ $T_{1/2}$, Jπ, decay modes and BR for both ground states (3558) and isomers (1983)

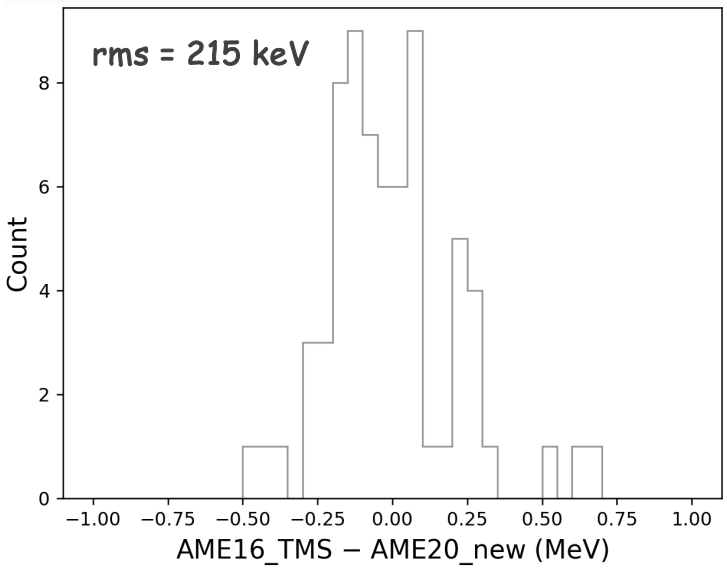
⇒ properties of 205 Isobar Analog States

AME extrapolations

⇒ using an empirical approach by assuming that the Trend of the Mass Surface (TMS) is smooth

- TMS extrapolated mass values for a limited number of unknown nuclei
- replace "irregular" experimental masses by TMS extrapolated values – 77 cases in AME2020

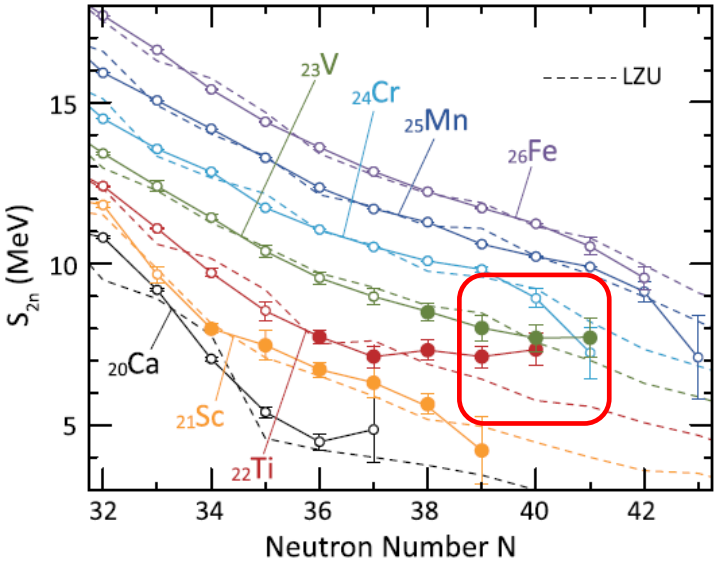
accuracy of the AME extrapolation



TMS in AME2016, BUT exp in AME2020

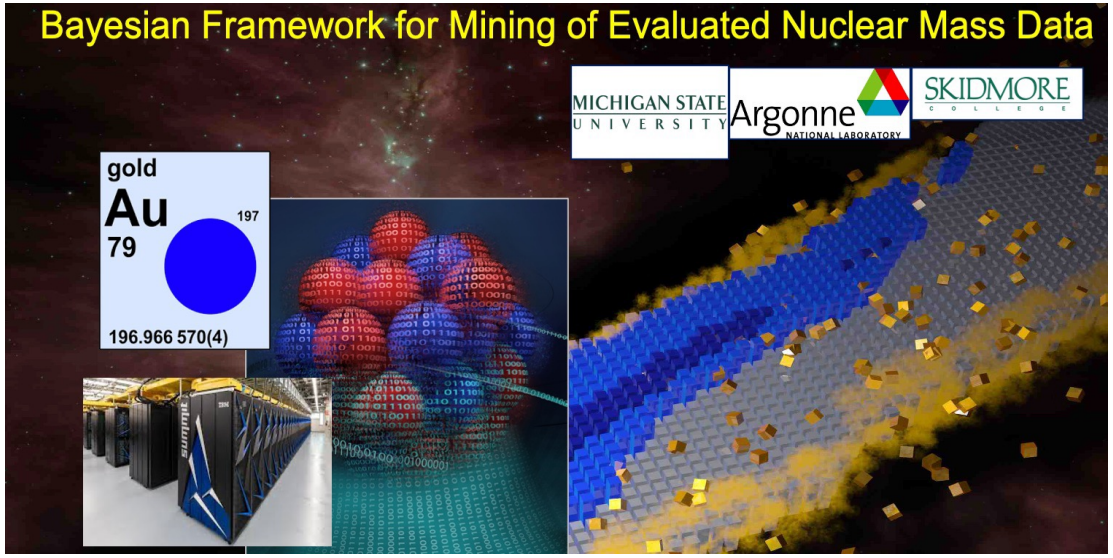
not always justified … new physics?

S. Michimasa et al., PRL125 (2020) 122501



build up of deformation around N=40

AME extrapolations – cont.



Collaborative DOE/SC/NP FOA funded project between MSU, ANL and SKIDMORE

⇒ quantify nuclear binding in regions where no experimental data are available by employing **global nuclear models, current Nuclear Data and Bayesian ML**- implications for nuclear astrophysics

experts in nuclear theory, nuclear data, nuclear astrophysics & statistics

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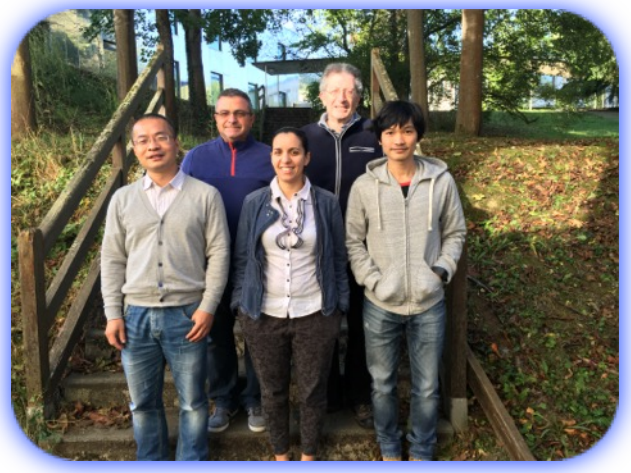
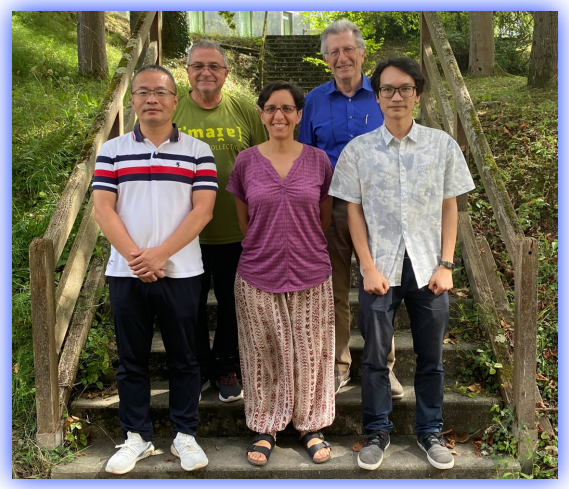
Next AME & NUBASE Tables

2016



2023



- AME & NUBASE collaboration meeting – Sept. 2023, Orsay

- next tables were planed for 2024 but will be delayed -> aiming at 2026