Argonne NATIONAL LABORATORY

Member of the US Nuclear Data Program

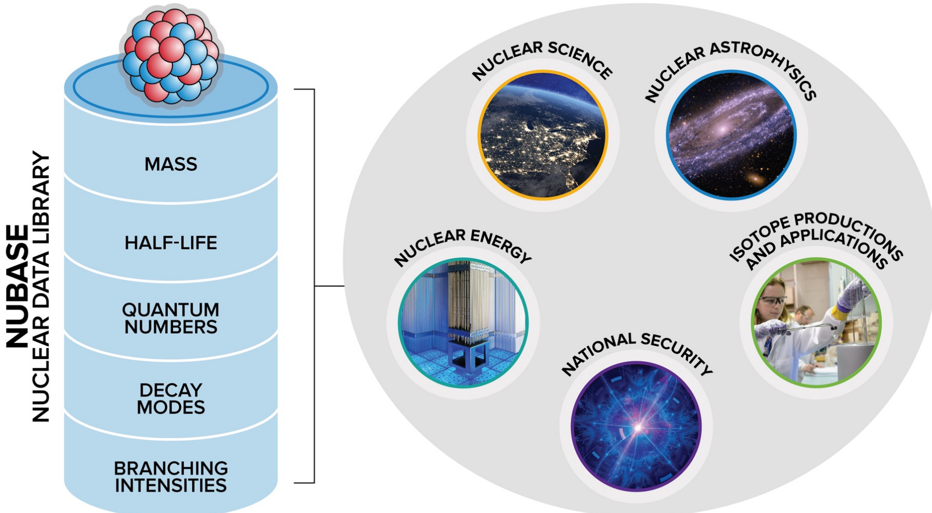
Status of AME & NUBASE

F.G. Kondev & R. Chakma
Physics Division, Argonne National Laboratory

U.S. DEPARTMENT OF ENERGY | Office of Science

Nuclear Physics

AME & NUBASE



⇒ provide the recommended values for atomic masses, various decay and reaction Q values & other basic nuclear properties ($T_{1/2}$, $J\pi$, decay modes and BR) for all known nuclei in their ground and isomeric ($T_{1/2}$ >100 ns) states

- impact on the fundamental sciences (not only NP) and applied programs
- one of the most cited articles in LE Nuclear Physics

⇒ ANL-NDP contributes since 2005 – involved in the 2012, 2016 & 2020 editions

⇒ latest libraries were published in March 2021: AME2020 & NUBASE2020

- coordinated by M. Wang (IMP) & F.G. Kondev (ANL)
- recommended data for 3558 ground states and 1983 isomers

AME: What Data Are Considered

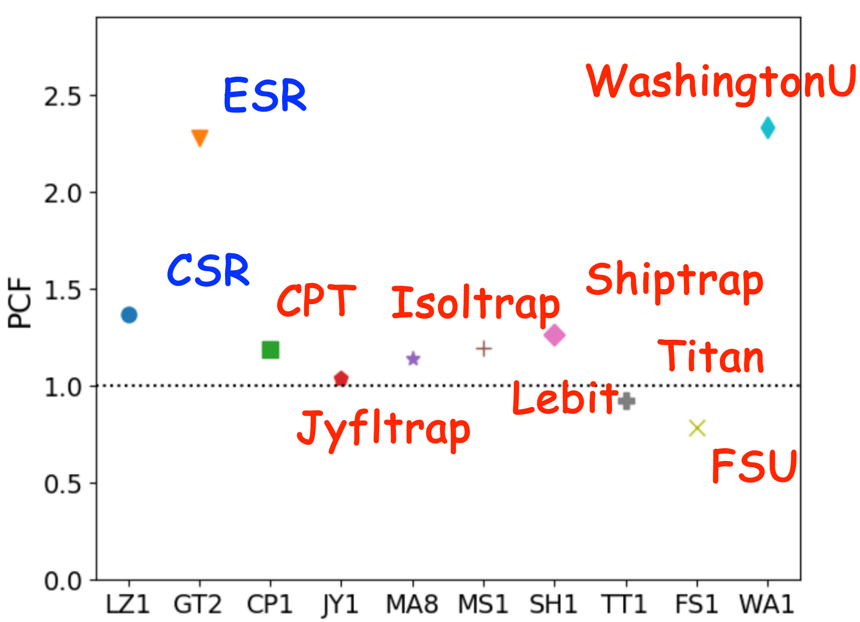
⇒ Direct (mass spectrometry) and Indirect (reactions and decays) Data worldwide

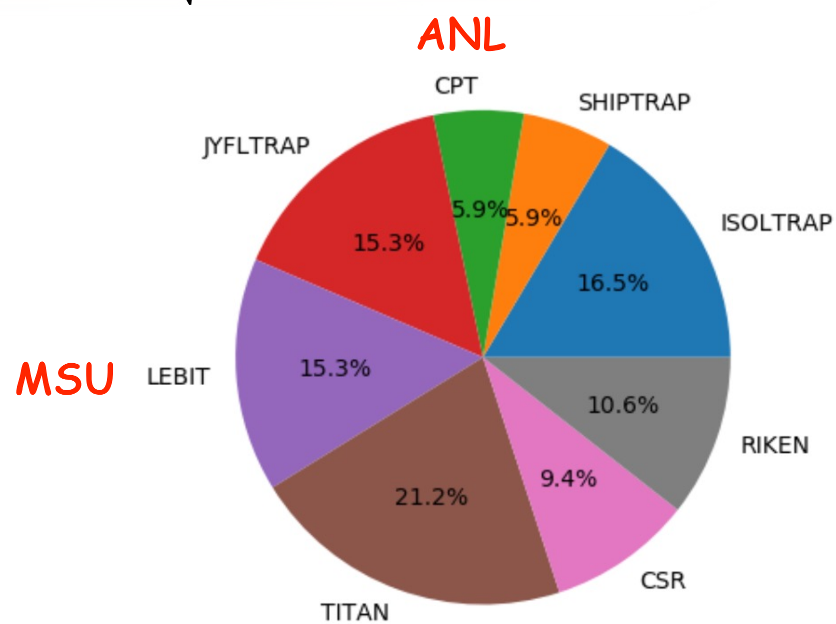
- TOF & MR-TOF, Storage Rings & Penning Traps - DIRECT
- Reaction Energies – (n,γ), (p,γ) and (a,b) – close to stability
- Decay Energies - β^-, β^+, α and p decays – far from stability

} INDIRECT

⇒ **experimental data** are critically evaluated & the recommended values and their uncertainties (covariances) are determined using least-squares fit approach

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





published direct mass data since AME2016

Value of Evaluation – example $^{69,69m}Co$

PHYSICAL REVIEW C **101**, 041304(R) (2020)

Rapid Communications

1

Precision mass measurements of ^{67}Fe and ^{69,70}Co: Nuclear structure toward $N = 40$ and impact on r-process reaction rates

Nuclide	$T_{1/2}$ (ms)	I^{π}	r	Δ_{JYFL} (keV)	Δ_{lit} (keV)	Difference (keV)
^{67}Fe	394(9)	$(1/2^-)$	0.797874190(8)	−45709.1(3.8)	−45610(270)	−99(270)
^{69}Co	180(20)	$7/2^-$#	0.821649141(428)[a]	−50383(44)	−50280(140)	−103(147)
^{69}Co^m	750(250)	$1/2^-$#	0.821651504(291)[a]	−50207(36)	−49780(240)#	−430(240)#
^{70}Co[b]	508(7) [50]	$(1^+, 2^+)$ [50]	0.833615937(21)	−46525(11)	−46430(360)#	−95(360)#

...publication

$$R = \frac{f_r}{f} = \frac{M - D - m_e\, q + B}{M_r - D_r - m_e\, q_r + B_r}\,\frac{q_r}{q}$$

erratum ...

PHYSICAL REVIEW C **103**, 029902(E) (2021)

Erratum: Precision mass measurements of ^{67}Fe and ^{69,70}Co: Nuclear structure toward $N = 40$ and impact on r-process reaction rates [Phys. Rev. C 101, 041304(R) (2020)]

Nuclide	$T_{1/2}$ (ms)	I^{π}	r	Δ_{JYFL} (keV)	Δ_{lit} (keV)	Difference (keV)
^{67}Fe	394(9)	$(1/2^-)$	0.797874191(49)	−45709.1(3.8)	−45610(270)	−99(270)
^{69}Co	180(20)	$7/2^-$#	0.82164916(110)[a]	−50385(86)	−50280(140)	−105(170)
^{69}Co^m	750(250)	$1/2^-$#	0.82165149(64)[a]	−50203(50)	−49780(240)#	−423(250)#
^{70}Co[b]	508(7) [16]	$(1^+, 2^+)$ [16]	0.83361594(15)	−46525(11)	−46430(360)#	−95(360)#

2

PHYSICAL REVIEW C **97**, 014309 (2018)

Precision mass measurements of neutron-rich Co isotopes beyond $N = 40$

Ion	Reference	Frequency ratio	Mass (u)	ME (keV)	AME2016 (keV)	ΔME (keV)
^{68}Co^{2+}	^{16}O^{18}O$^+$	1.000 641 552(70)	67.944 559 2(48)	−51 642.8(4.4)	−51 930(190)	290(190)
	^{34}S$^+$	0.999 870 11(12)	67.944 559 3(82)	−51 642.6(7.6)		290(190)
^{69}Co^{2+}	^{39}K$^+$	1.130 267 90(24)	68.946 093(15)	−50 214(14)	−50 280(140)	66(140)

claimed to be ^{69}Co, but it is actually ^{69m}Co

- ^{69}Co – 100% influence from 1
- ^{69m}Co – 93% influence from 2 and 7% influence from 1

NUBASE - Ground states & Isomers

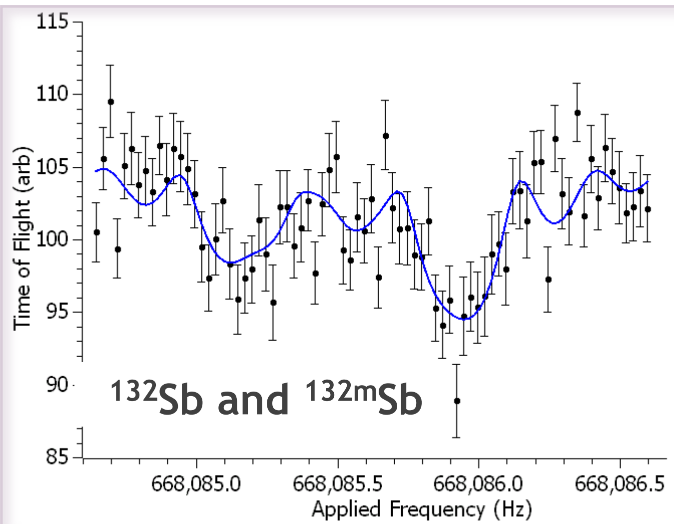
- beware of isomers - do we have the right relations?

DIRECT

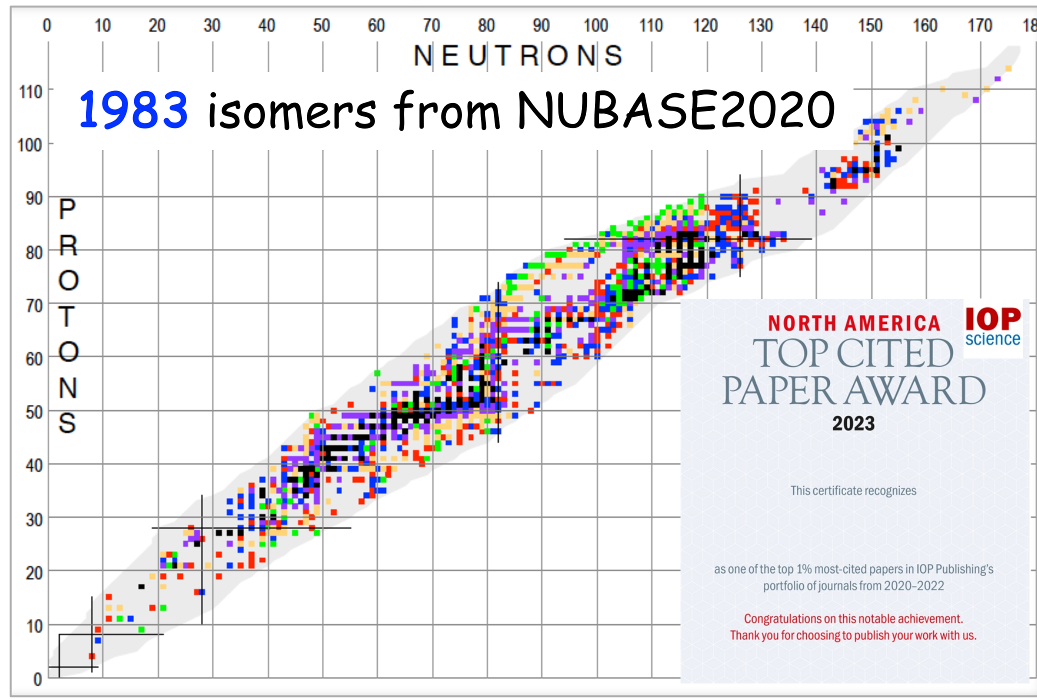
18Ha19	107678.2	1.6	162Eu-84Kr1.929
20Vi04	52124.0	6.0	162Eu-133Cs1.218
18Ha19	107850.1	2.0	162Eum-84Kr1.929
20Vi04	52286.4	2.4	162Eum-133Cs1.218
20Vi04	52292.4	8.1	162Eum-133Cs1.218

INDIRECT

20Ma27	9725.2	30.6	220Pa(a)216Ac
21Ma66	9725.2	30.6	220Pa(a)216Ac
18Hu13	9730.3	20.4	220Pam(a)216Ac
21Ma66	9843.3	40.7	220Pam(a)216Ac
21Ma66,*	9843.3	40.7	220Pan(a)216Ac



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

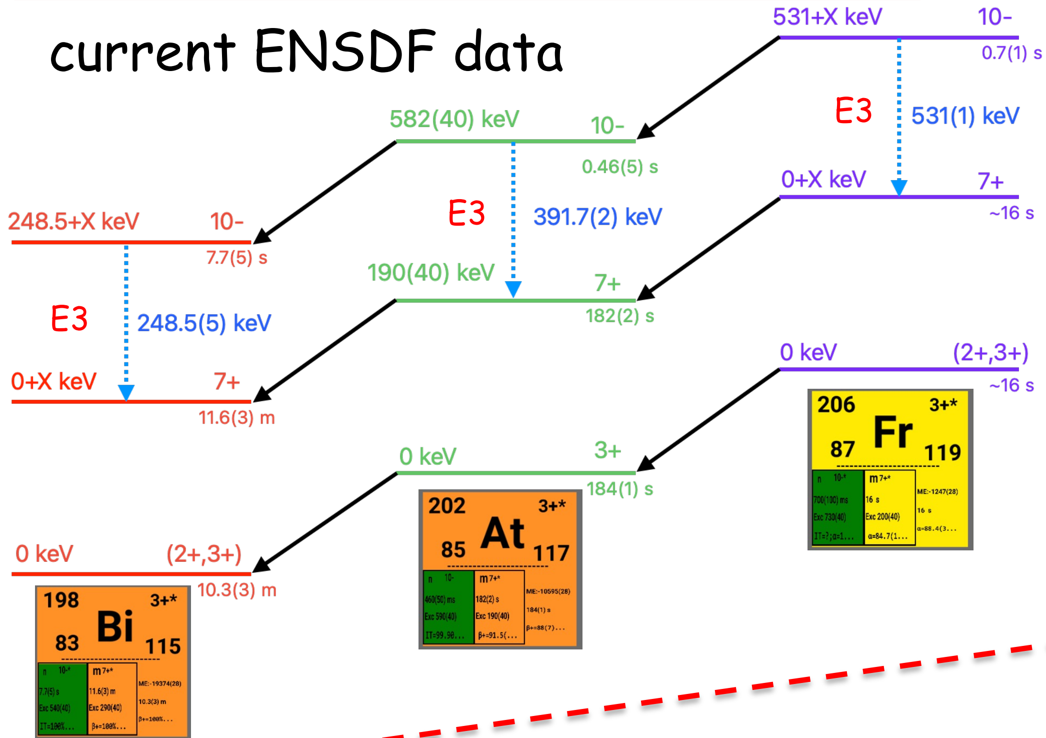
Value to ENSDF

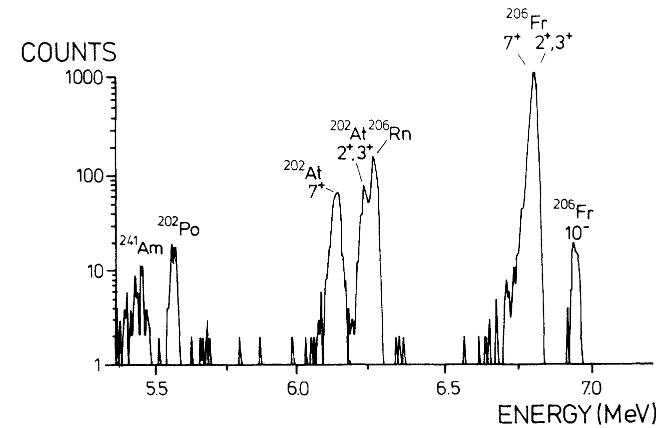
PHYSICAL REVIEW C VOLUME 46, NUMBER 4 OCTOBER 1992

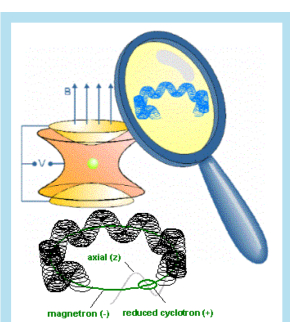
Isomers in three doubly odd Fr-At-Bi α-decay chains

M. Huyse, P. Decrock, P. Dendooven, G. Reusen, P. Van Duppen, and J. Wauters
LISOL, Instituut voor Kern-en Stralingsfysica, K. U. Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium
(Received 28 May 1992)

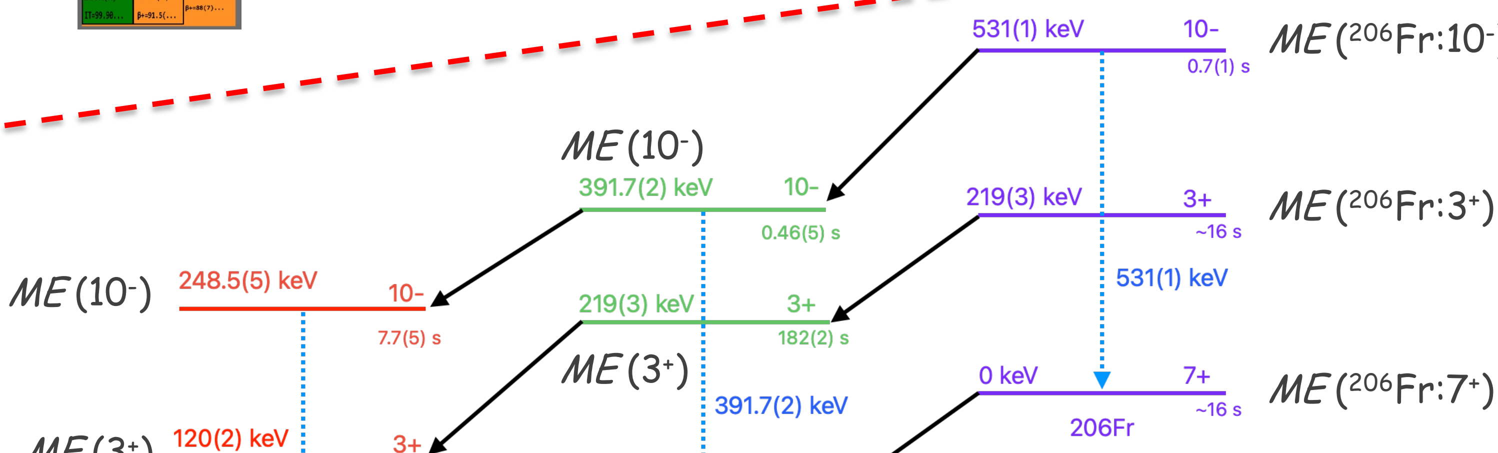
current ENSDF data







SHIPTRAP data
E. Morin (2022)



$E(Iso)=ME(g.s) - ME(Iso)$

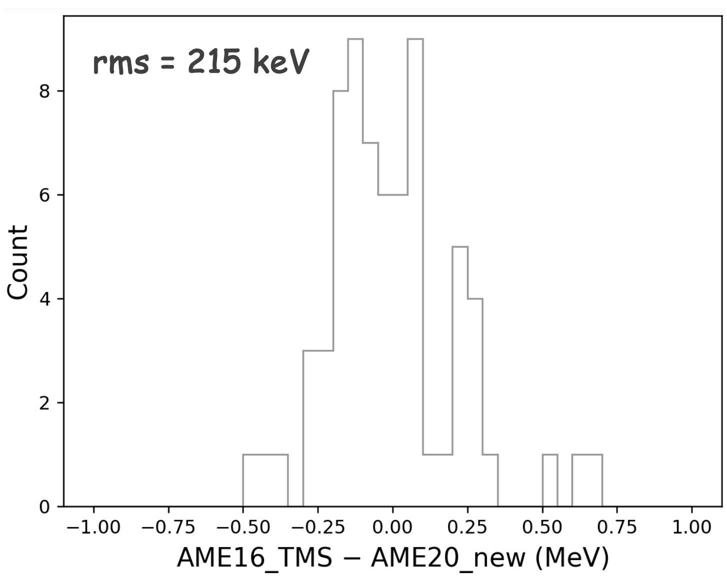
$Q(\alpha)=ME(p) - ME(d) - ME(\alpha)$

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

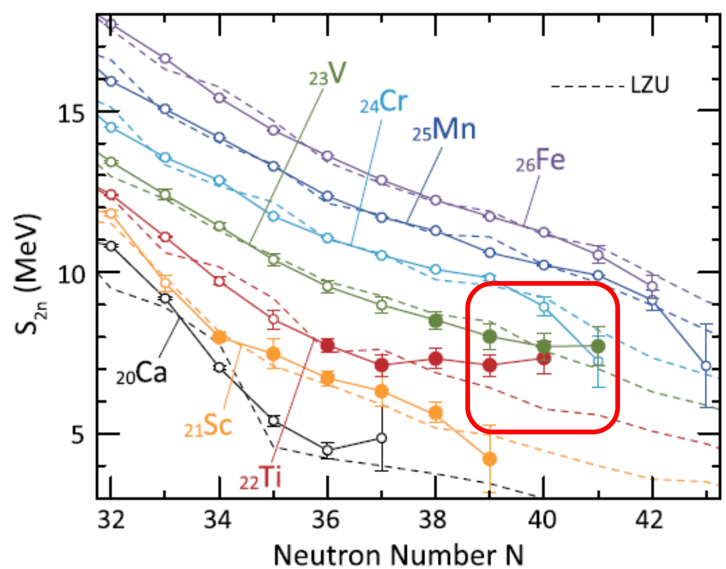
accuracy of the AME extrapolation



TMS in AME2016, BUT exp in AME2020

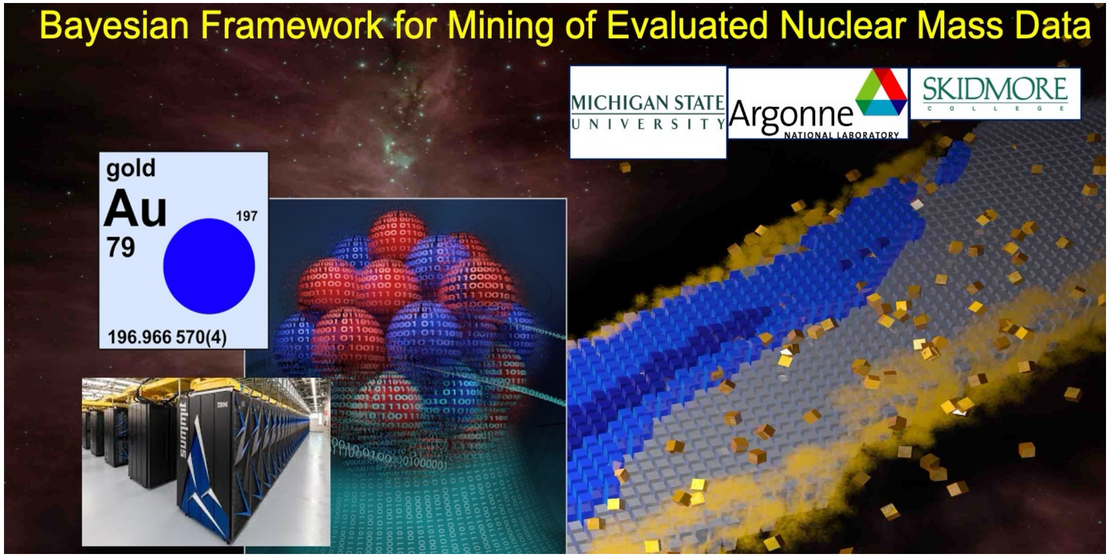
not always justified … new physics?

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**

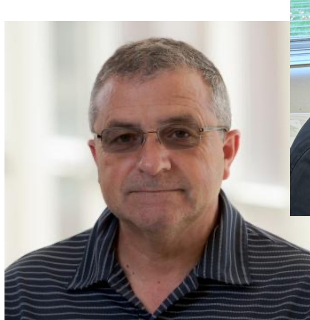
- quantify nuclear binding in regions where no experimental data are available by employing global nuclear models, current Nuclear Data and Bayesian ML- implications for nuclear astrophysics

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

MICHIGAN STATE UNIVERSITY

Witek Nazarewicz (PI)

Argonne NATIONAL LABORATORY



Filip Kondev (Co PI)

Rikel Chakma
post-doc

SKIDMORE COLLEGE

Vojtech Kejzlar

MICHIGAN STATE UNIVERSITY

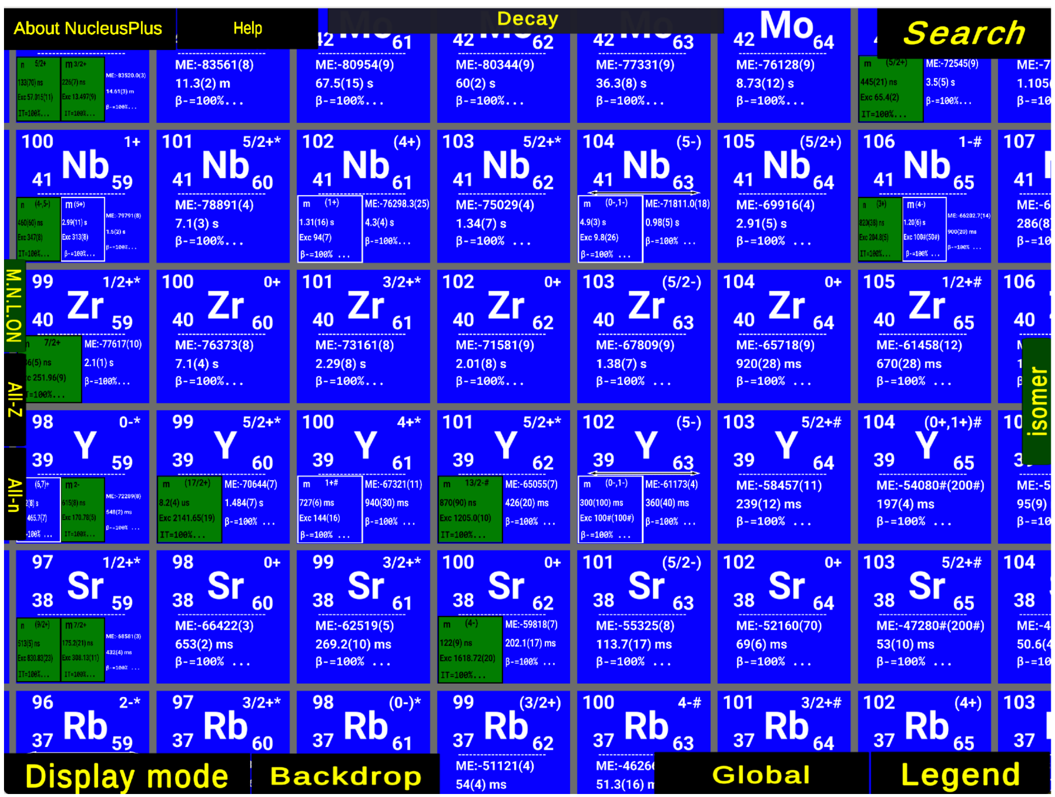
Hendrik Schatz (Co PI)

New dissemination platforms

pdf & ascii
covariances

https://www.anl.gov/phy/atomic-mass-data-resources (ANL)
https://amdc.impcas.ac.cn/web/nubcleus%202_en.html (IMP)
https://www-nds.iaea.org/amdc/ (IAEA)

Nucleus++: Data Analysis Tool



Desktop Applications

macOS

Windows

Mobile Applications

iPhone & iPad

Android

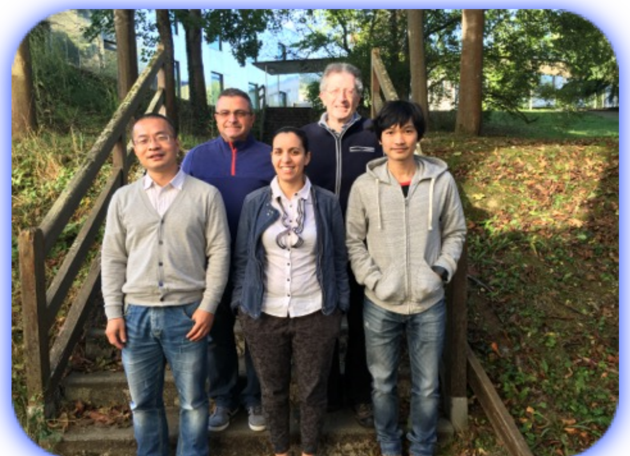
Next AME & NUBASE Libraries

IMP

IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis

Argonne NATIONAL LABORATORY

2016



2023

2024

- **initially** planed for 2024 -> currently aiming for 2026

⇒ limited workforce – positive development Rikel Chakma (ANL)

⇒ collaboration is more challenging – mostly via ZOOM …