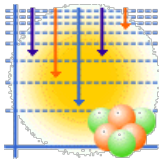
Argonne NATIONAL LABORATORY

Member of the US Nuclear Data Program

The Atomic Mass Evaluation & NUBASE: Status and Perspectives



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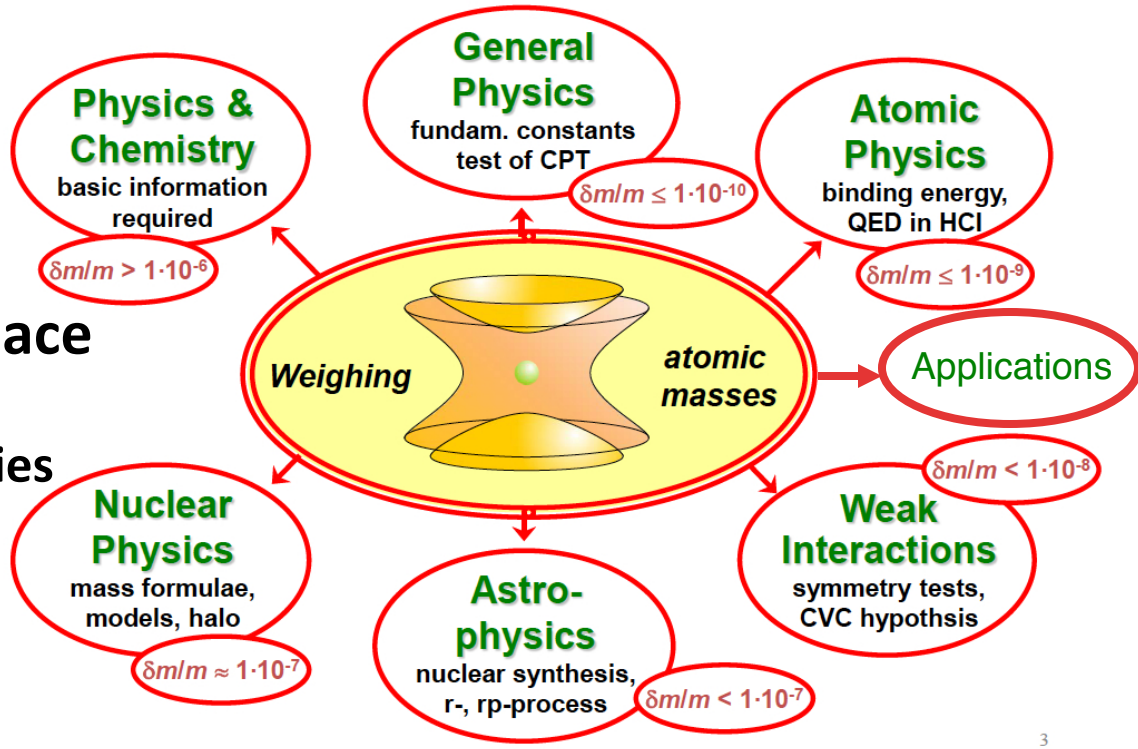
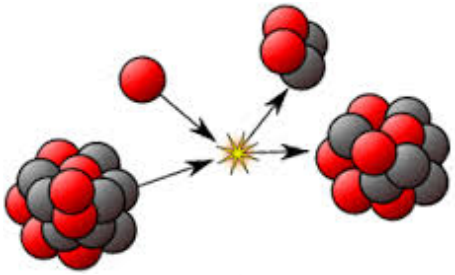
Introduction

- **Binding energies**
  - ✓ mass models
  - ✓ shell structure
- **Correlations**
  - ✓ pairing
  - ✓ p-n
- **Reaction & decay phase space**
  - ✓ Q values
  - ✓ decay & reaction probabilities
- **The limits of existence**
  - ✓ drip lines
  - ✓ specific configurations and topologies

$E=mc^2$

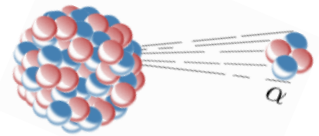


Experimental Data



Indirect methods:

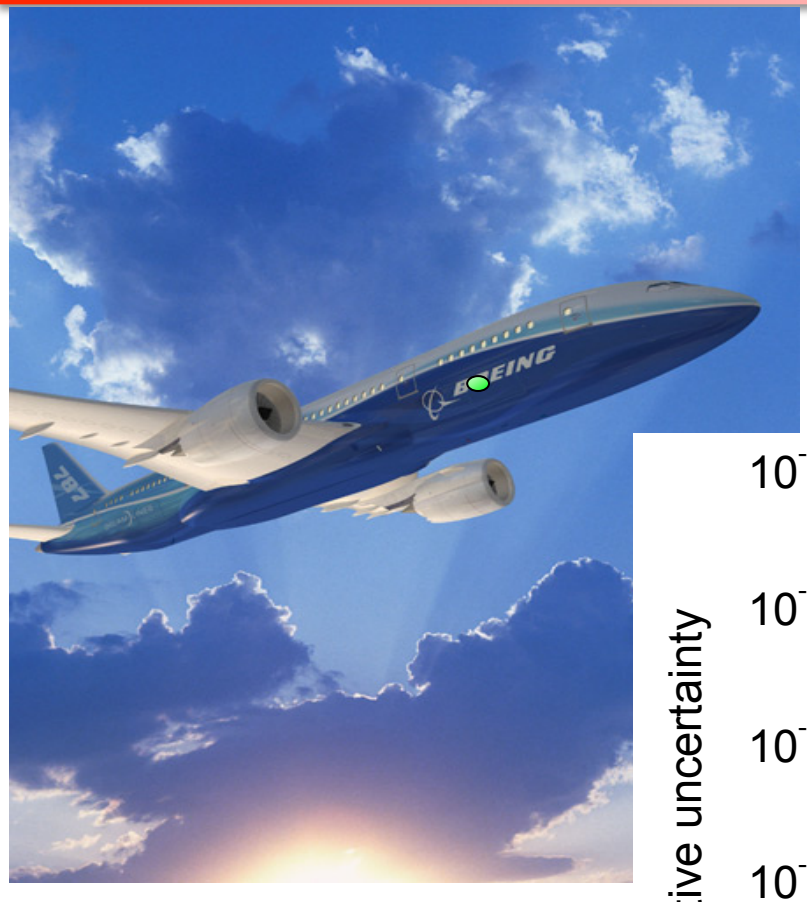
- ✓ Reaction Energies – A(a,b)B: $Q_r = M_A + M_a - M_b - M_B$
  - (n,γ) and (p,γ) are the backbone
  - self-calibrated - A(a,b)B vs. C(a,b)D
  - close to stability
- ✓ Decay Energies in β−, α and p decays
  - far from stability – α and p (proton-rich) & $Q_{\beta-}$ neutron-rich



Direct methods:

- ✓ various mass spectrometry techniques using TOF, Penning Traps, Storage Rings spectrometers, etc.
  - far from stability
  - high precision

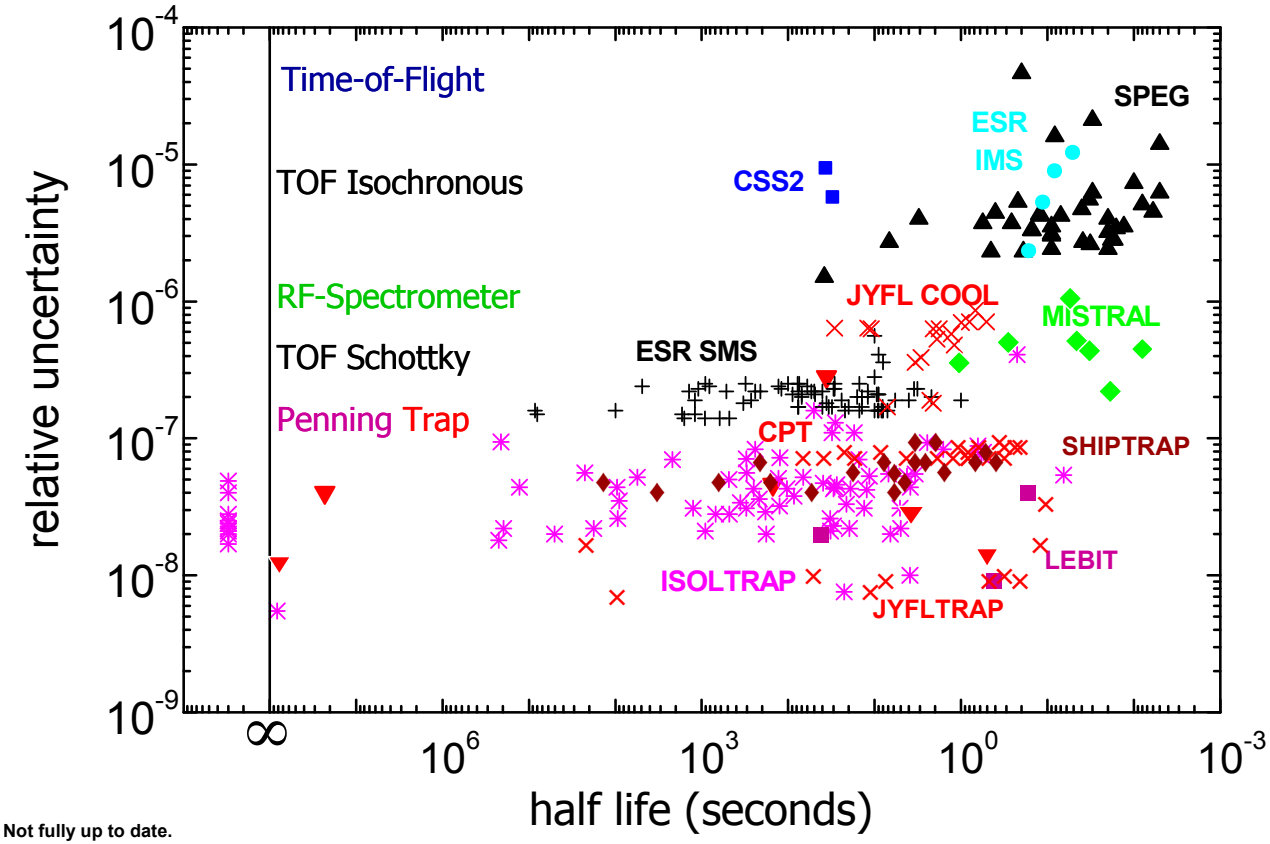
Experimental Data – cont.



M ~ 500 t = 5×10^8 g
(Dreamliner)

m ~ 1 g (bean seed)

m/M=1 g / 5×10^8 g = 5×10^{-9}



Not fully up to date.

Atomic Mass Evaluation

- combining the experimental results from different techniques and those from different laboratories (using similar techniques) -> using the least-square method (developed by A.H. Wapstra)
  - ✓ recommended (best) values for the atomic masses and their uncertainties
  - ✓ extrapolation to the extremes using the smoothness of the mass surface

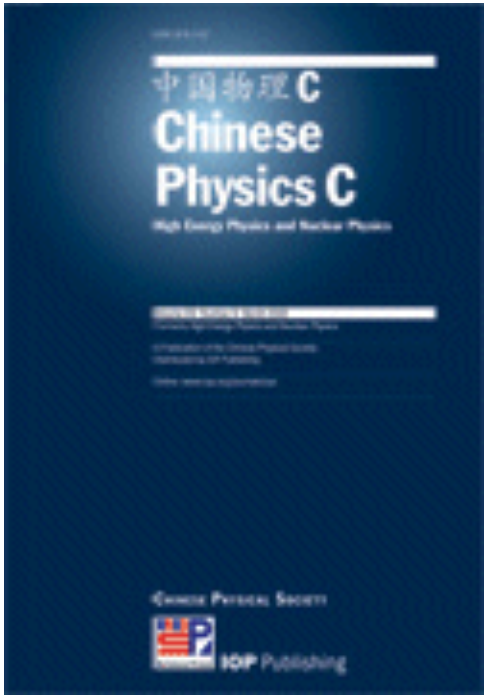
Ame1955, Ame1961, Ame1964, Ame1971, Ame1977
Ame1983, Ame1993, Ame2003 -> A.H. Wapstra & G. Audi

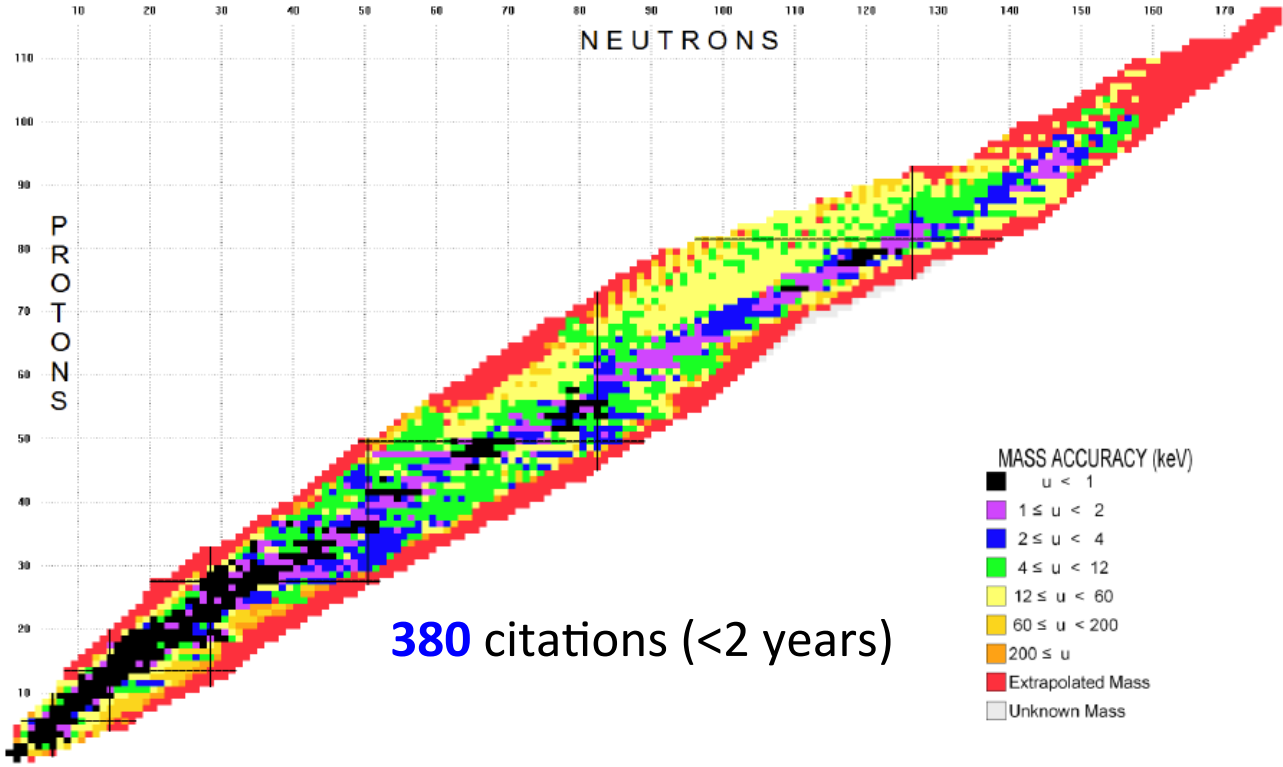
Ame2012

G. Audi* M. MacCormick M. Wang & X. Xu B. Pfeiffer F.G. Kondev

AME2012

December 2012 issue of Chinese Physics **C** (IOP Science)





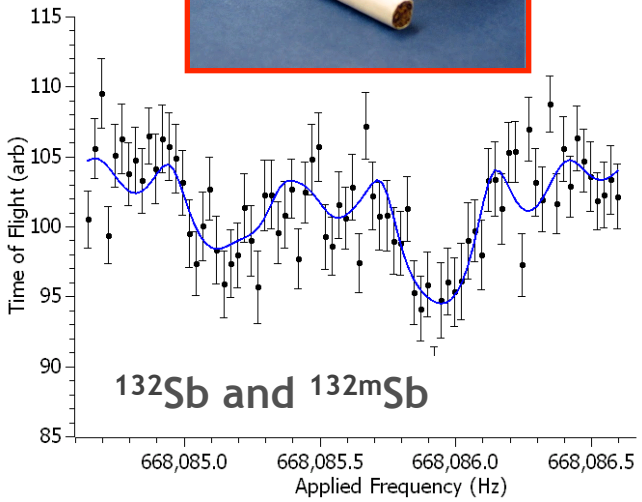
380 citations (<2 years)

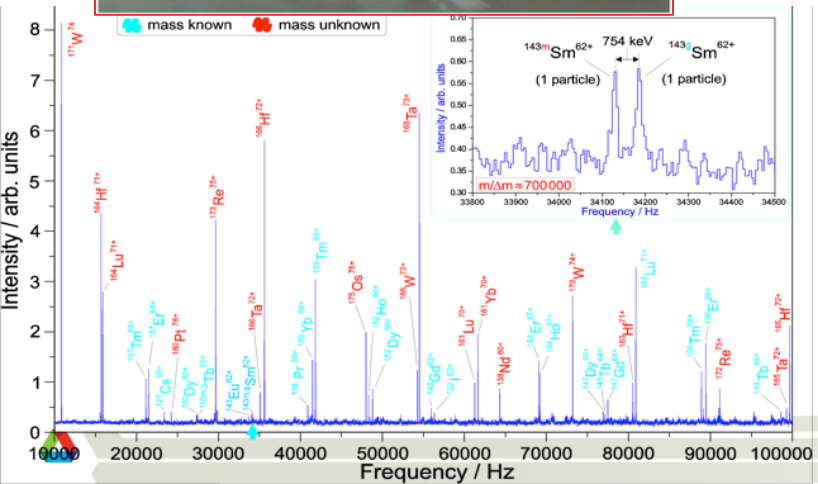
3711 Masses
- **2416** known ground state
- **232** known isomers
- **1063** extrapolated

- significant improvement compared to AME2003
  - ✓ more nuclei (more than 150)
  - ✓ better precision – availability of Penning trap and storage rings mass measurements

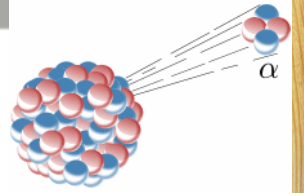
AME2012 – cont.

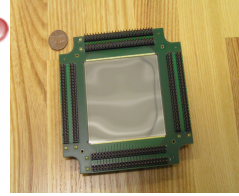
13809 input equations in **AME12**
5275 mass spectrometry
8534 reactions & decays

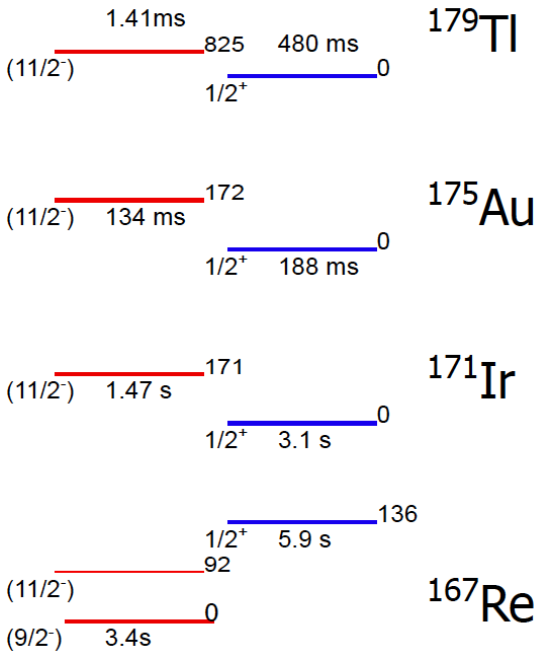




J. Van Schelt et al., PRL111 (2013) 061102







F.G. Kondev et al., EPJ (2013)

Beware of … Isomers

Do we have the right relation?

- ✓ Excitation energy
- ✓ Lifetime
- ✓ Decay mode

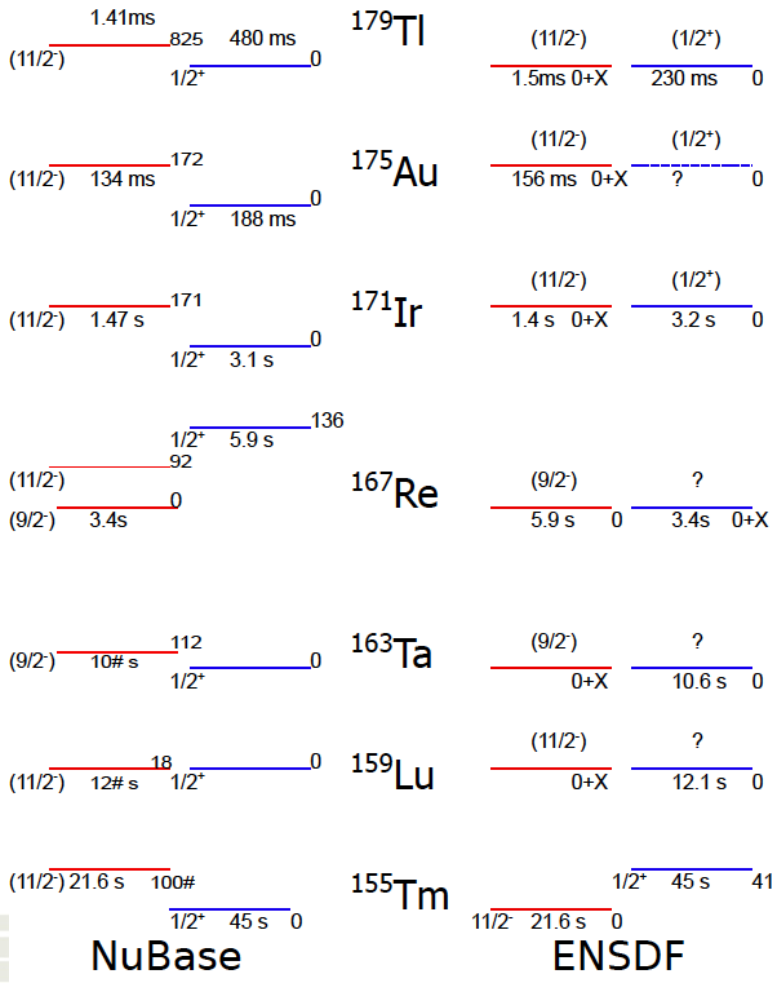
NUBASE2012 – cont.

CPC(HEP & NP), 2012, **36**(12): 1157–1286 **Chinese Physics C** Vol. 36, No. 12, Dec., 2012

The NUBASE2012 evaluation of nuclear properties*

G. Audi[1,§], F.G. Kondev[2], M. Wang[1,3,4], B. Pfeiffer[5,‡], X. Sun[1], J. Blachot[1], and M. MacCormick[6]

- Ex, J^{π}, $T_{1/2}$ & decay modes
- both ground state & Isomers ($T_{1/2}$>100ns)
- independently evaluated data
  - ✓ complete
  - ✓ up-to-date
  - ✓ credible & reliable
  - ✓ properly referenced



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Ex,
J^{π},
$T_{1/2}$,
decay modes:
β−n, β−2n,
ECp, EC2p,…

nuclear structure &
astrophysics

NUBASE12	ground state	isomers
# of cases	3316	1827
stable	286	1
with Jπ	3043 (92%)	1681 (92%)
with $T_{1/2}$	3288 (99%)	1787 (98%)
with $T_{1/2}$ (exp)	2892 (87%)	1680 (92%)
β−	1343	205
β−n	583	20
EC+β+	1404	355
ECp	132	28
α	852	195

Future Perspective

Change in coordination:

G. Audi officially retired from CNSNM-Orsay (October 13)

- ✓ retain emeritus scientist status
- ✓ continue contributing for the next release (and foreseen future)

W. Meng, IMP, Lanzhou

AMDC Atomic Mass Data Center

IMP 中国科学院近代物理研究所 Institute of Modern Physics, Chinese Academy of Sciences

http://ribll.impcas.ac.cn/ame/

Change in collaboration:

CSNSM

IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

IMP

Argonne NATIONAL LABORATORY

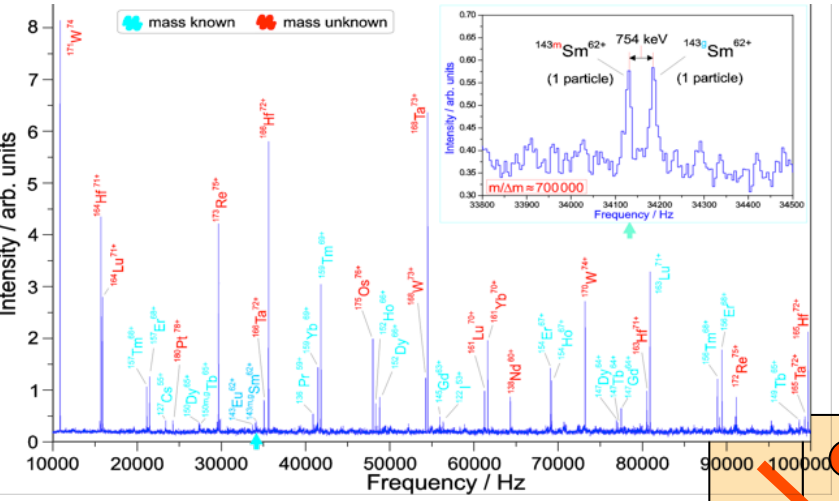
RIKEN NISHINA CENTER

G. Audi | M. MacCormick | **M. Wang*** | F.G. Kondev | S. Naimi ?

Future Perspective

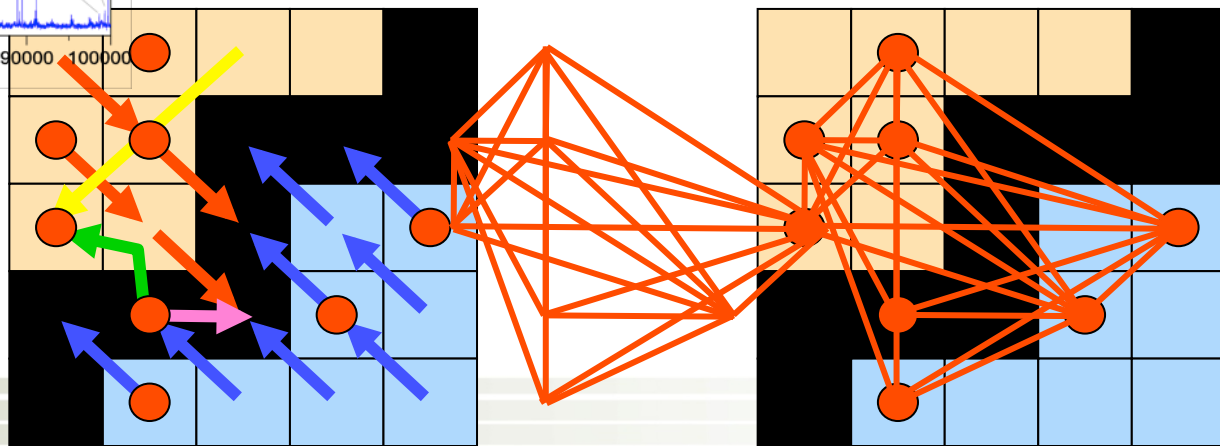
Next Tables are foreseen for rlease in 2016:

- ✓ envisioned to be an electronic update only
- ✓ correlations (new challenges): storage ring mass measurements
- ✓ extension of NuBase – isomers, moments, directly measured J^{π}…



AME12

FRS-ESR data



Conclusions

- The new AME12 & NuBase12 evaluations have been completed and released – significant improvement compare to the previous AME03 and NuBase03 evaluations – more nuclei & better precision

- Rising of the wings – Q_β's often underestimated – r-process path less far from stability

- Individual files are available for download (ascii):

  http://ribll.impcas.ac.cn/ame/

  - ✓ mass.mass12
  - ✓ nubase.mass12

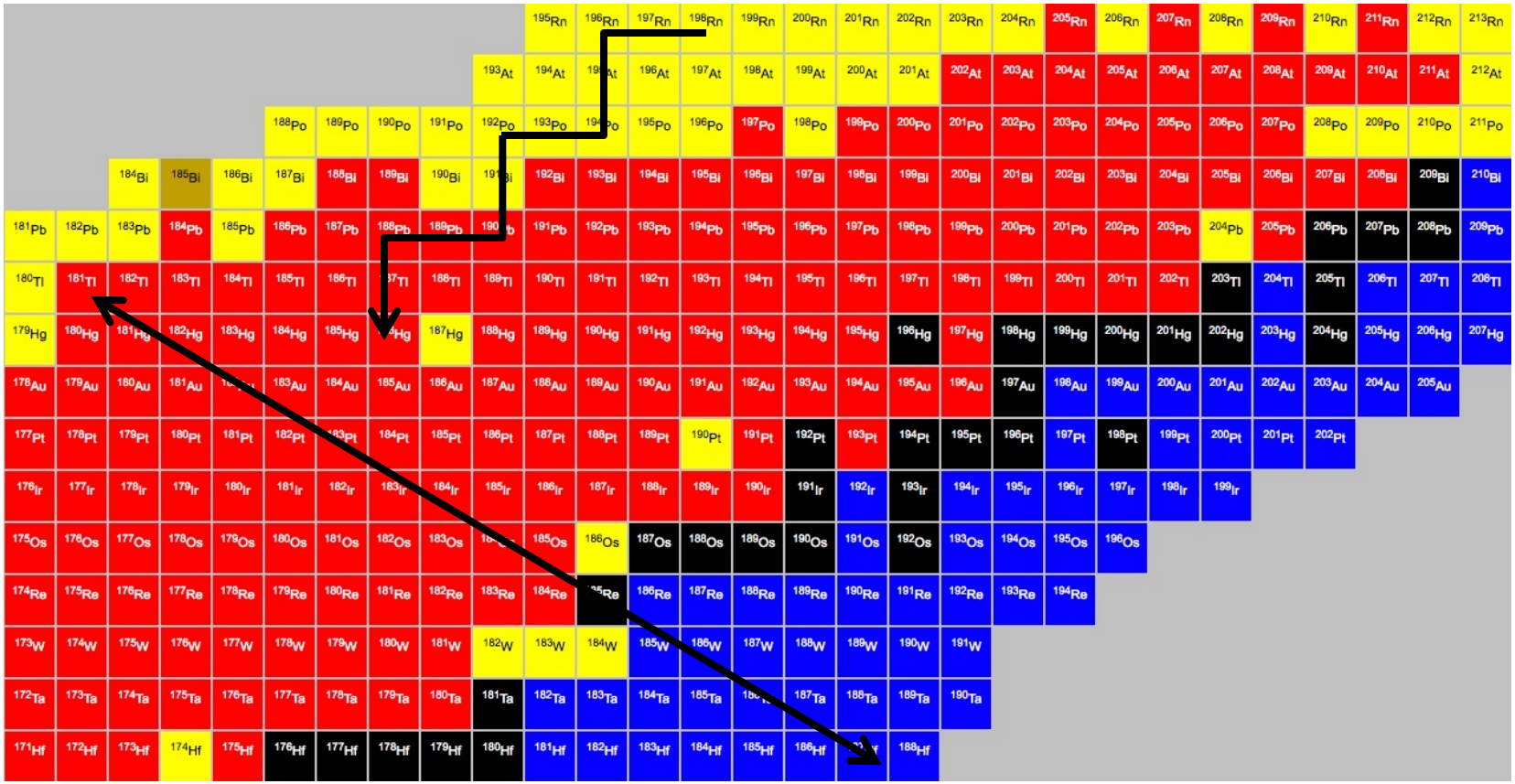
  If you need a hard copy – please contact me: kondev@anl.gov

- Next tables are foreseen in 2016 (electronic publication only)

- The AMDC coordination at IMP-Lanzhou (Mang Weng)

Implications for ENSDF

- A-chain (β^-Chain) vs α−Chain



- synchronization of Q record in ENSDF