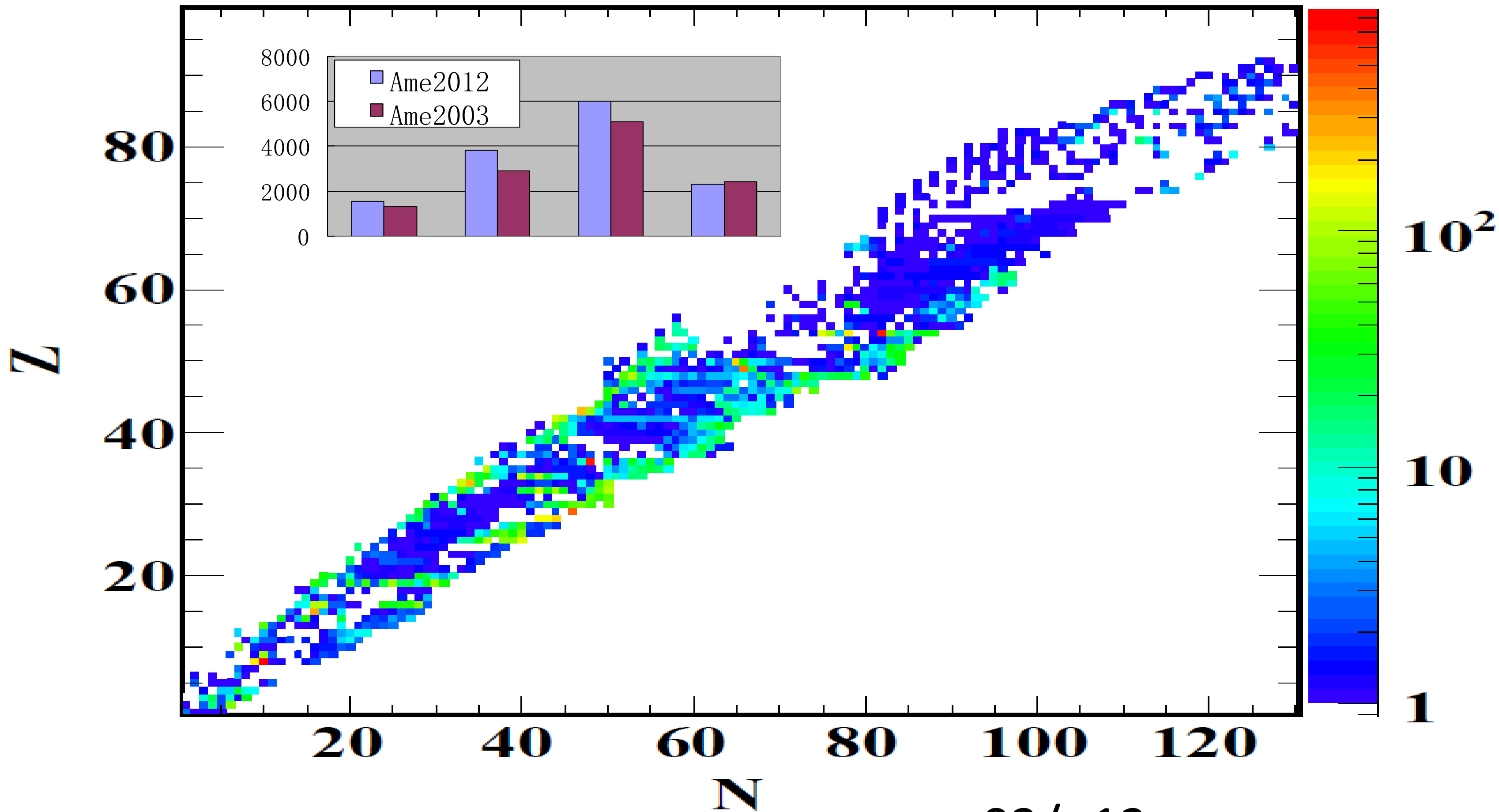
April 2015, NSDD

Atomic Mass Evaluation and NUBASE

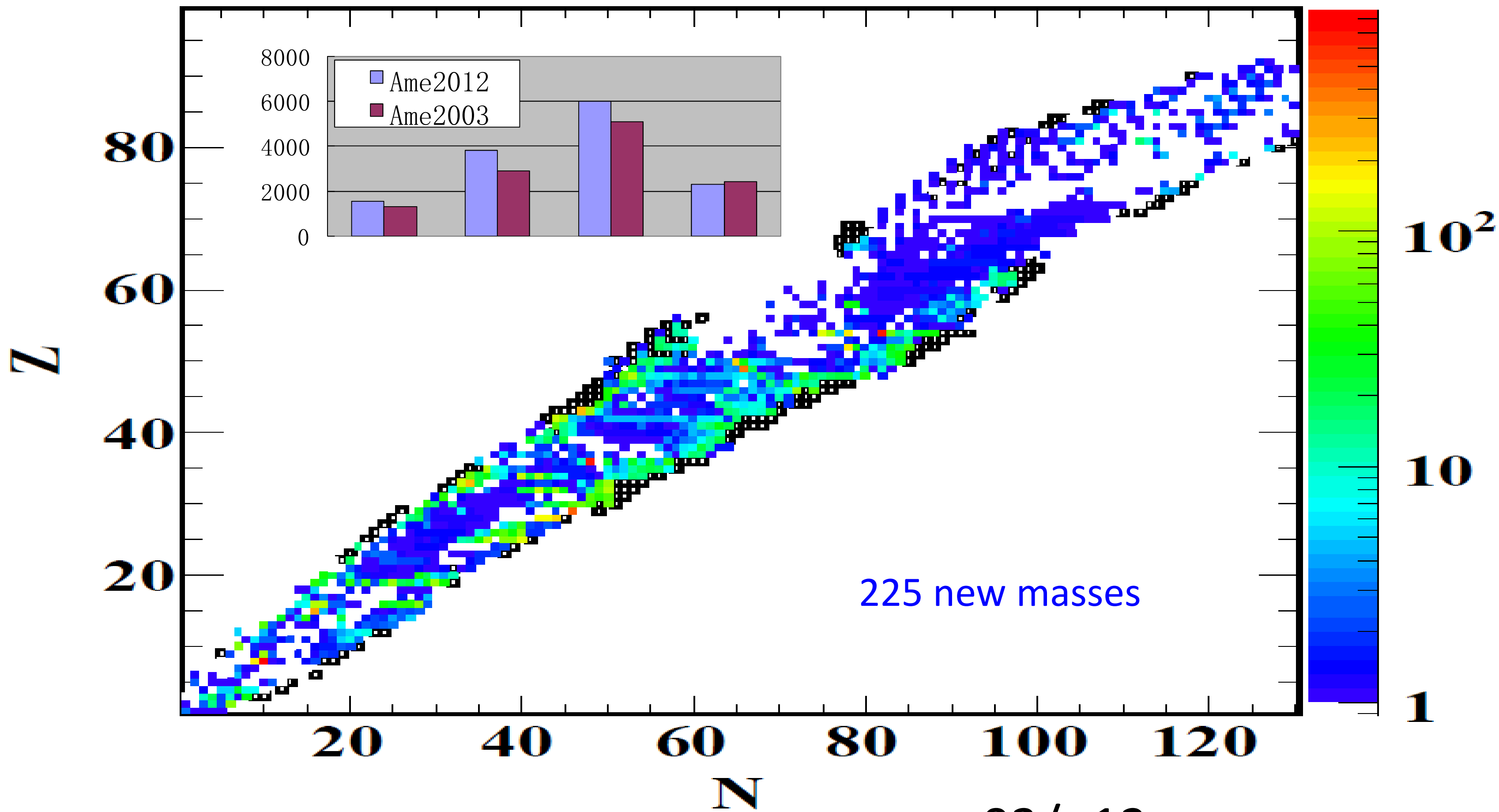
AME collaboration

Comparison of uncertainties



σ03/σ12

Comparison of uncertainties



σ03/σ12

Fashions of mass measurements:

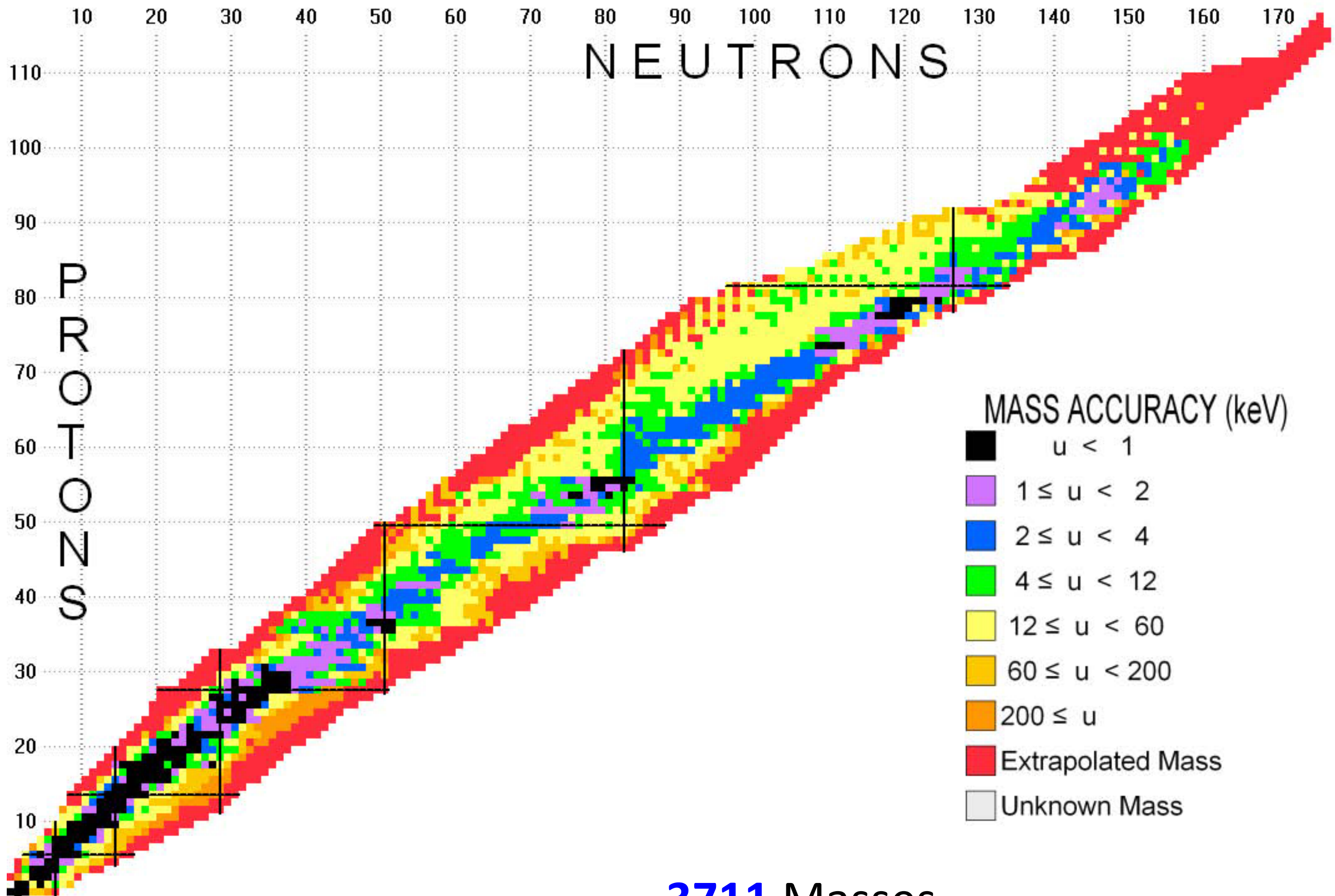
Publications in Nature/Science

1. **An Ion Balance for Ultra-High-Precision Atomic Mass Measurements,** S.Rainville, J.K.Thompson, D.E.Pritchard, *Science* 303, 334 (2004)
2. **Cyclotron frequency shifts arising from polarization forces**, J.K.Thompson, S.Rainville, D.E.Pritchard, *Nature(London)* 430, 58 (2004)
3. **A direct test of $E=mc^2$**, S.Rainville, et al., *Nature(London)* 438, 1096 (2005)

4. **Direct mass measurements above uranium bridge the gap to the island of stability,** M.Block et al., *Nature(London)* 463, 785 (2010)
5. **Direct mapping of nuclear shell effects in the heaviest elements,** E. Minaya Ramirez et al., *Science* 337 (6099), 1207-1210 (2012).
6. **Masses of exotic calcium isotopes pin down nuclear forces,** F.Wienholtz et al., *Nature(London)* 498, 346 (2013)

Two frontiers：accuracy, exoticism

Accuracy of mass values



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

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

Atomic Mass 3H and 3He—Using HD$^+$ as a mass reference

PRL **114,** 013003 (2015) PHYSICAL REVIEW LETTERS week ending 9 JANUARY 2015

Atomic Masses of Tritium and Helium-3

E. G. Myers, A. Wagner, H. Kracke, and B. A. Wesson
Department of Physics, Florida State University, Tallahassee, Florida 32306-4350, USA

(Received 11 September 2014; published 7 January 2015)

By measuring the cyclotron frequency ratios of $^3He^+$ to HD^+ and T^+ to HD^+, and using HD^+ as a mass reference, we obtain new atomic masses for ^3He and T. Our results are $M[^3\mathrm{He}] = 3.016\,029\,322\,43(19)$ u and $M[\mathrm{T}] = 3.016\,049\,281\,78(19)$ u, where the uncertainty includes an uncertainty of 0.12 nu in the mass reference. Allowing for cancellation of common systematic errors, we find the Q value for tritium β decay to be $(M[\mathrm{T}] - M[^3\mathrm{He}])c^2 = 18\,592.01(7)$ eV. This allows an improved test of systematics in measurements of tritium β decay that set limits on neutrino mass.

Unc.= 0.2 eV

Detailed calculation for mass HD

Atomic masses and the mass difference between tritium and helium-3.—Using the 2010 CODATA values for the masses of the electron, proton, and deuteron [9] combined with the ground-state energy of HD^+ relative to its separated constituents [25], we predict the atomic mass of the HD^+ ion to be 3.021 378 241 97(12) u, where the uncertainty is due to the uncertainty in the masses of the

Ame2012	1H	1 007 825 032.23	(09)	(0.093nu)
	2H	2 014 101 778.12	(12)	(0.122nu)
H+D	=	3 021 926 810.35	(14)	(0.136nu)
BEmol	-	4.85		
HD molec.	=	3 021 926 805.50		
me	-	548 579.91		
BEe(+)	+	16.58		
HD+	=	3 021 378 242.17	(14)	
compared to				
2015Myers		3 021 378 241.97	(12)	
The difference is		0.20	(14)	1.4 sigma

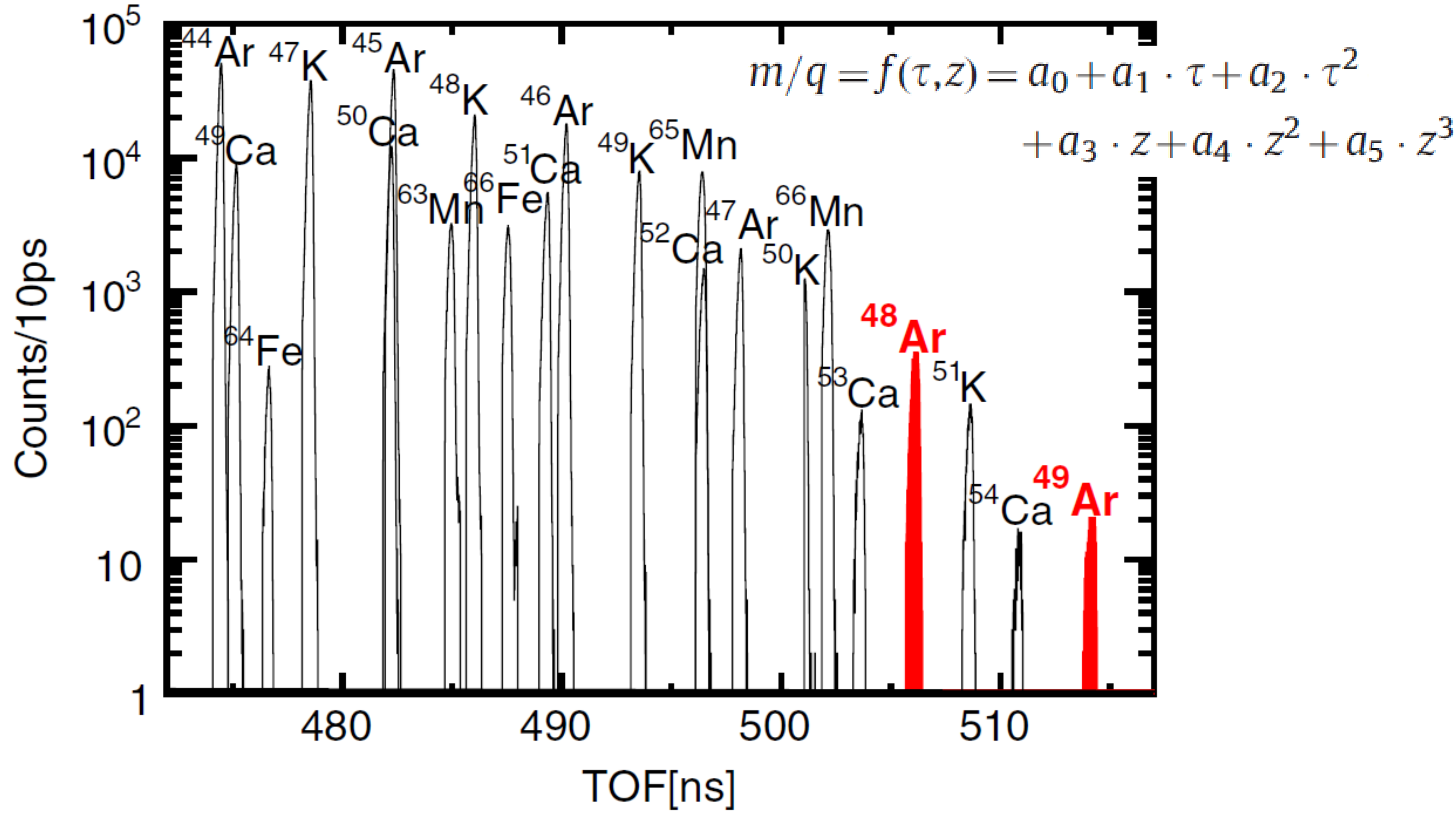
Strategy to treat Molecule

- Molecule binding energy calculated from the standard heat of formation of the species.
- $D^o(A_n B_k C_i) = n\Delta H f_0^o(A) + k\Delta H f_0^o(B) + i\Delta H f_0^o(C) - \Delta H f_0^o(A_n B_k C_i)$
- Where $\Delta H f_0^o$ is the standard-state heat of formation, extracted from *http://webbook.nist.gov/chemistry/*
- Molecule ionization energy extracted from *http://physics.nist.gov/PhysRefData/ASD/ionEnergy.html*

Exotic nuclides

PRL **114,** 022501 (2015) PHYSICAL REVIEW LETTERS week ending 16 JANUARY 2015

Mass Measurements Demonstrate a Strong $N = 28$ Shell Gap in Argon



New nuclides

Z.Y. Xu et al., PRL 113, 032505 (2014)

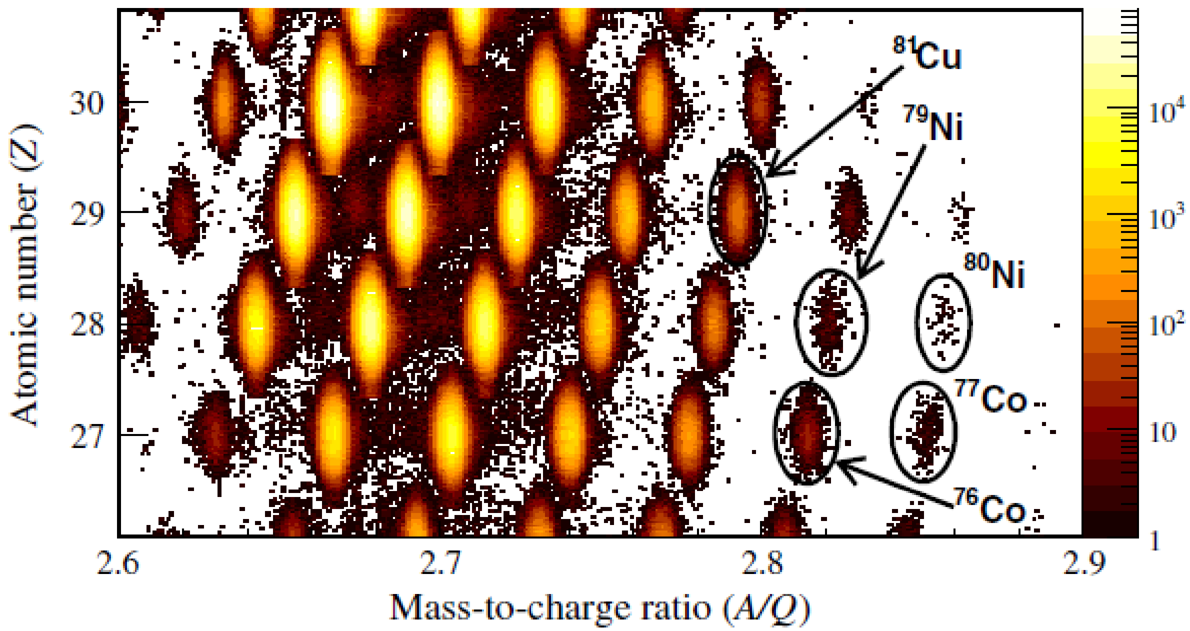
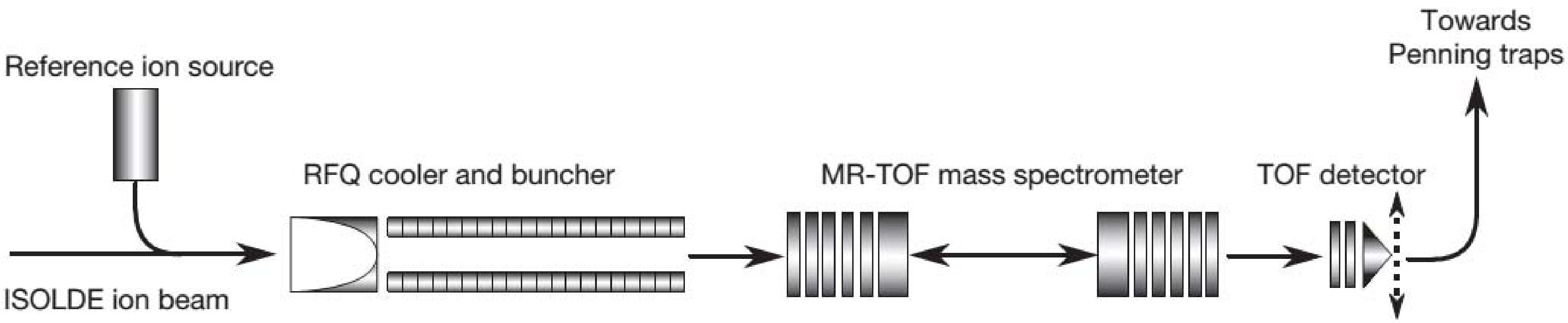


FIG. 1 (color online). PID plot of the experiment. The nuclei with new half-lives determined in this work are highlighted by black circles. The identification of the new isotopes ^{77}Co and ^{80}Ni is reported in Ref. [28].

Multi-reflection time-of-flight mass spectrometer/separator(MR-TOF MS)



2013Wienholtz et

Time of flight $t=\alpha(\frac{m}{q})^{1/2}+\beta$

$$m^{1/2} = C_{TOF}\Delta_{Ref} + \frac{1}{2}\Sigma_{Ref}$$
$$C_{TOF} = (2t - t_1 - t_2)/2(t_1 - t_2)$$
$$\Delta_{Ref} = m_1^{1/2} - m_2^{1/2}$$
$$\Sigma_{Ref} = m_1^{1/2} + m_2^{1/2}$$

```
39K      +1    -36293.5136  ..   0.0049   (-33807.1902 0.0046 a0znoged 18dec2014)
52Cr     +1    -59493.770   ..   0.631     -55418.089  0.588  a0znoged
52Ca     +1    501632.110        0.785            2013Wienholtz06    21nov2014
  NEW
39K      +1    -36293.5136  ..   0.0049
53Cr     +1    -59351.852   ..   0.620     -55285.895  0.578  a0znoged
53Ca     +1    501847.61         3.09
  NEW
39K      +1    -36293.5136  ..   0.0049
54Cr     +1    -61120.843   ..   0.611     -56933.698  0.570  a0znoged
54Ca     +1    502106.48         3.23
```

Ctof Program

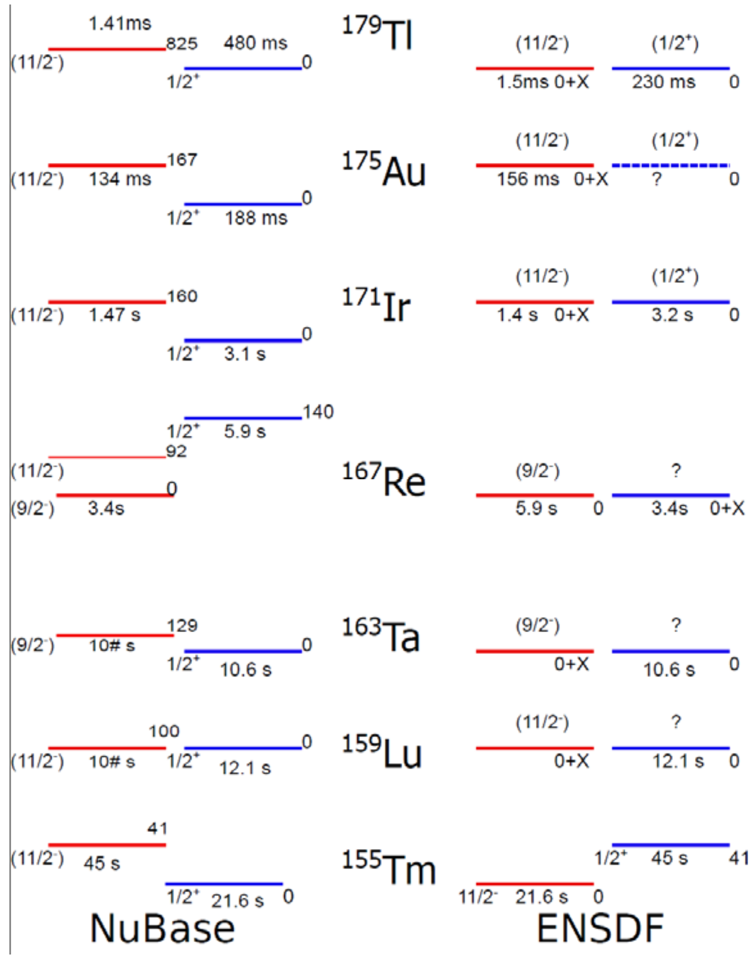
NUBASE2012

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



Ex from mass determination

L. Chen et al., PRL 110, 122501 (2013)

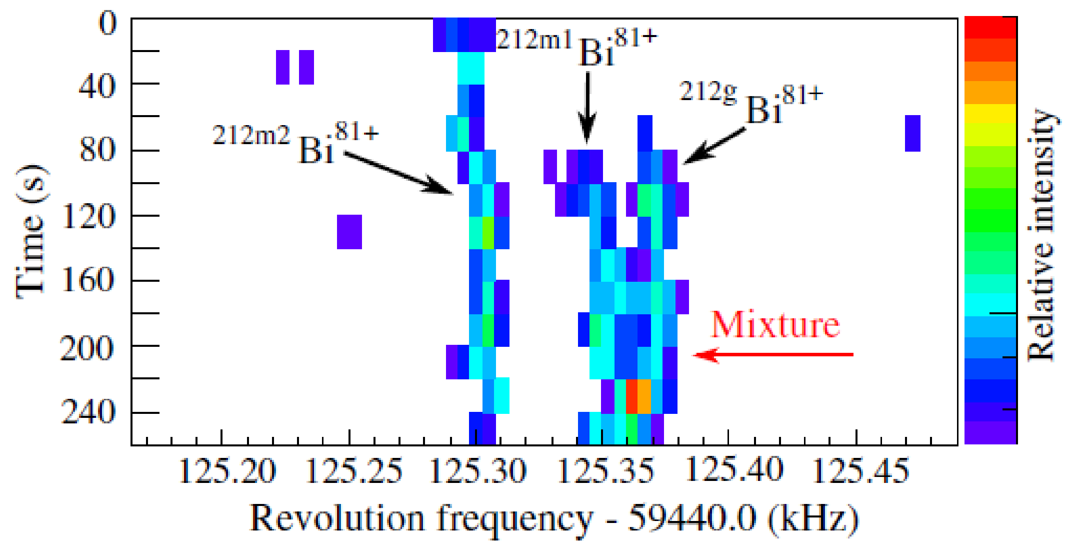


FIG. 1 (color online). ^{212}Bi data, illustrating the ground and two isomeric states as a function of time. The revolution frequency is inversely proportional to the mass-to-charge ratio. During the second half of the observation period, the ground-state and first-isomer ions merge (see text).

NUBASE2012 Evaluation of Nuclear Properties, Nuclear Data Sheets 120 (2014) 6–7

Thank you for your attention!

AME collaboration:

M. Wang, G. Audi, F.G. Kondev, M. MacCormick, X. Xu, W.J. Huang, S. Naimi …

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

Argonne NATIONAL LABORATORY

CSNSM

IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

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