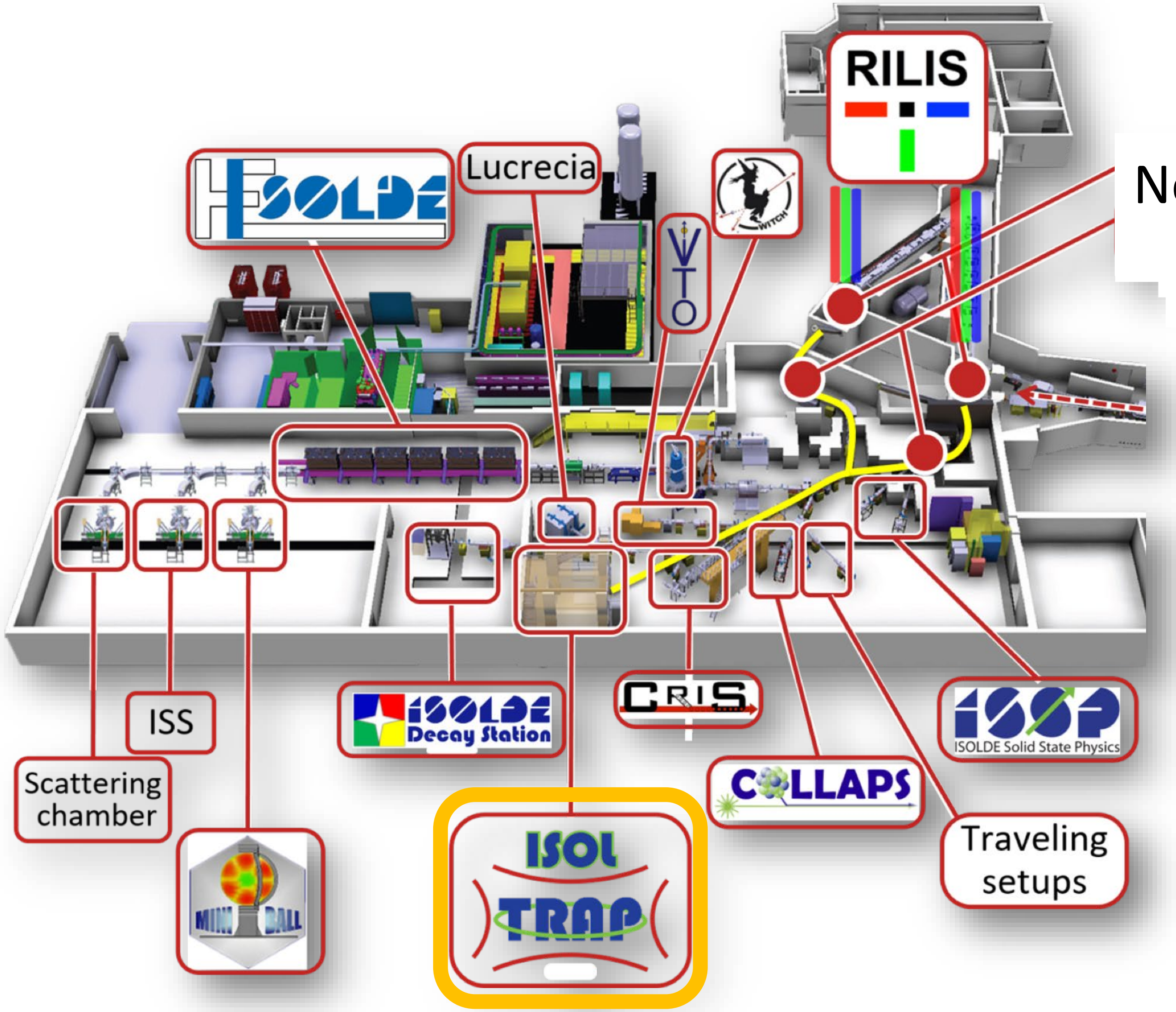
Combining mass spectrometry with laser spectroscopy at ISOLDE

David Lunney (CNRS, France)

with the ISOLTRAP, RILIS and WINDMILL/IDS collaborations

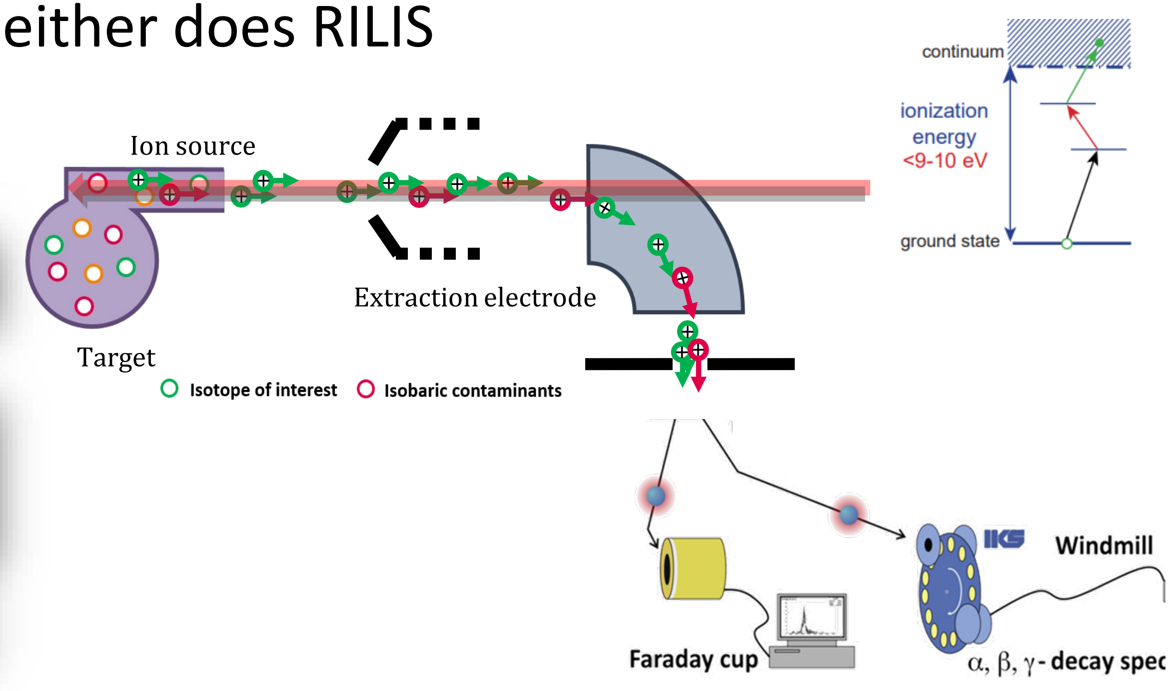
CNRS NUCLÉAIRE & PARTICULES | ISOLTRAP | RILIS | ISOLDE Decay Station | IKS | ISOLDE

ISOLDE – needs no introduction!



- F. Scheerer et al., Rev. Sci. Instrum. (1992)
- A.E. Barzakh et al. Phys. Rev. C (2000)
- V.N. Fedosseev et al. *NIM B* (2003)

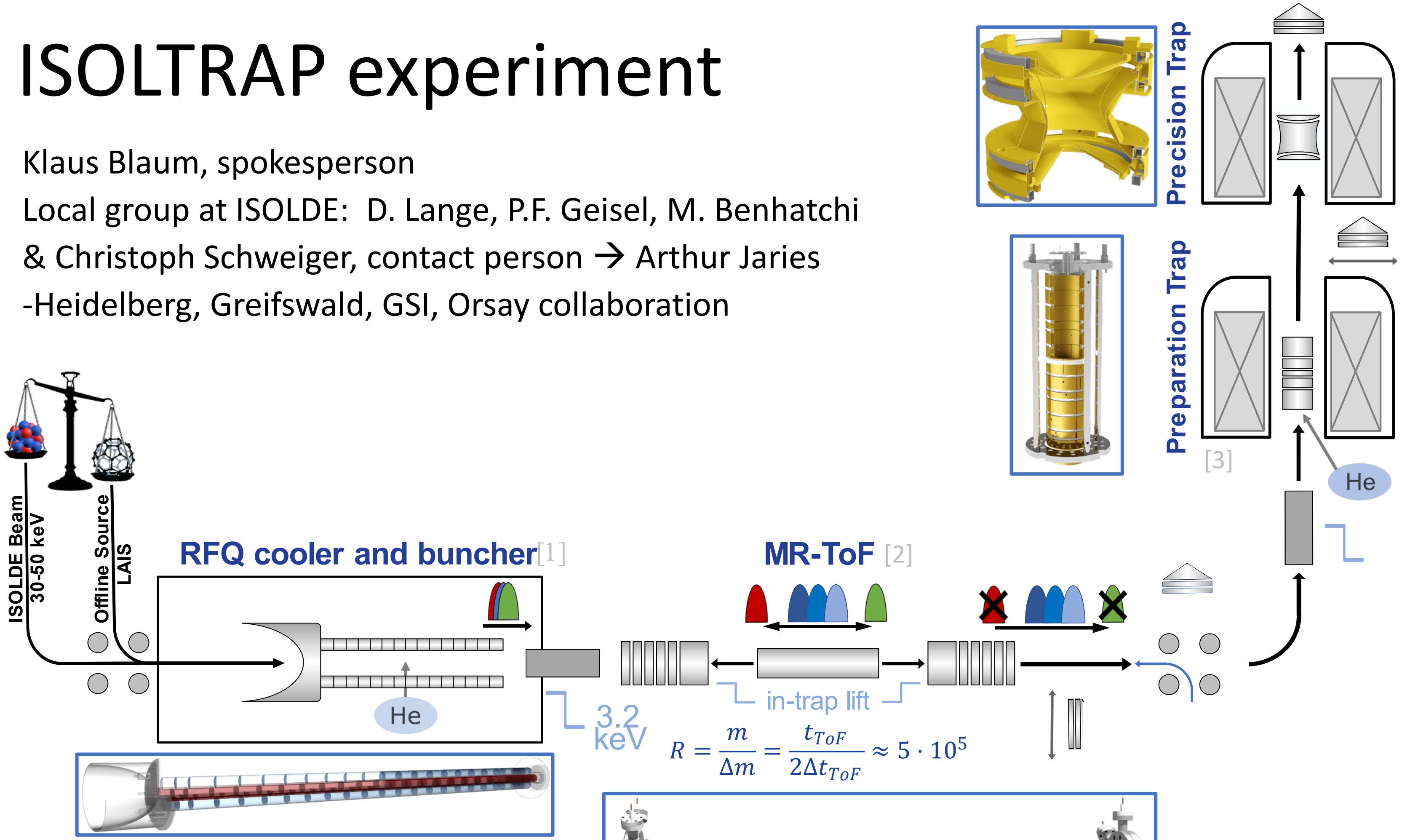
Neither does RILIS

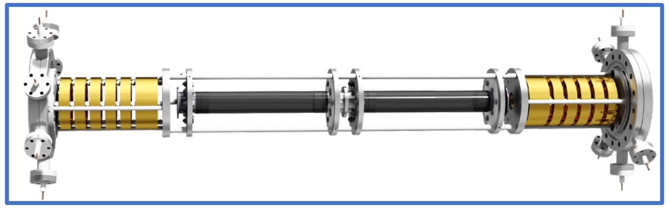


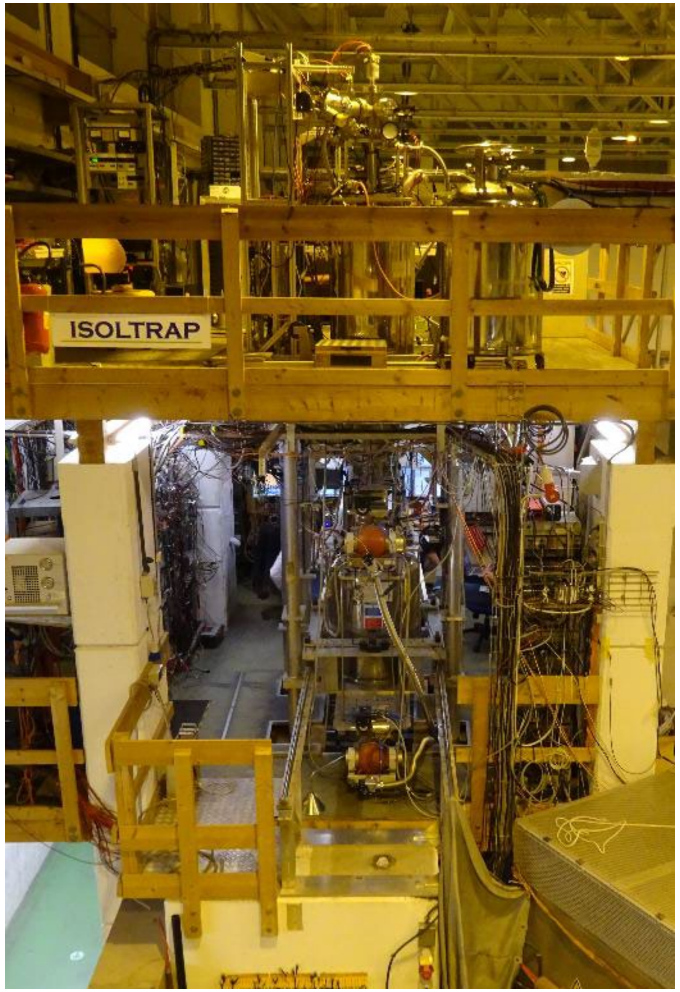
- H. De Witte et al., *Phys. Rev. Lett.* (2007)
- T.E. Cocolios et al. *Phys. Rev. Lett.* (2011)
- …

ISOLTRAP experiment

Klaus Blaum, spokesperson
Local group at ISOLDE: D. Lange, P.F. Geisel, M. Benhatchi
& Christoph Schweiger, contact person → Arthur Jaries
-Heidelberg, Greifswald, GSI, Orsay collaboration

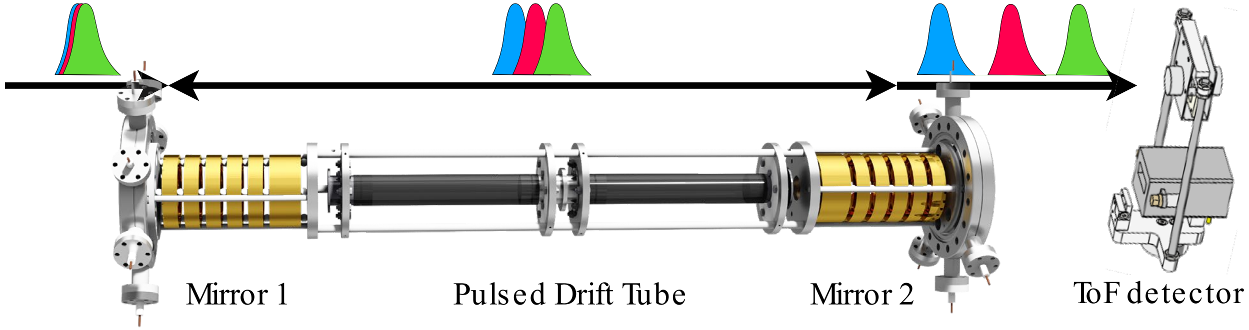


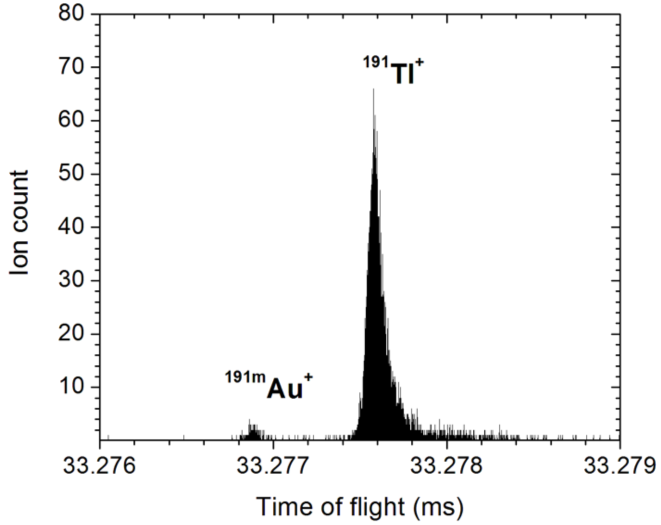


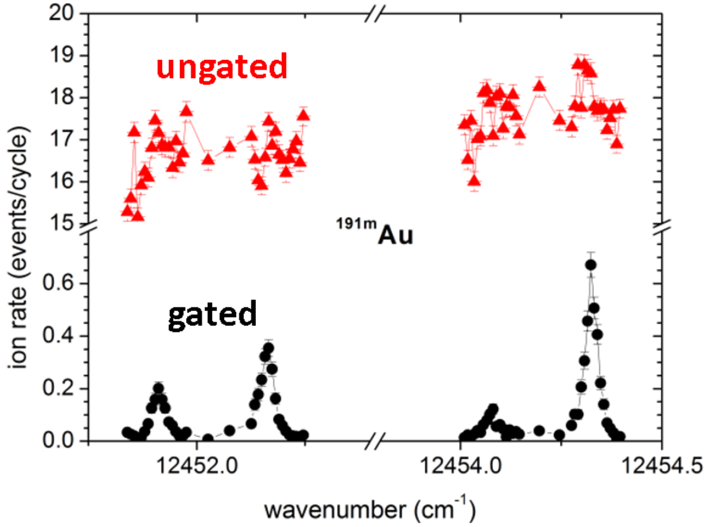


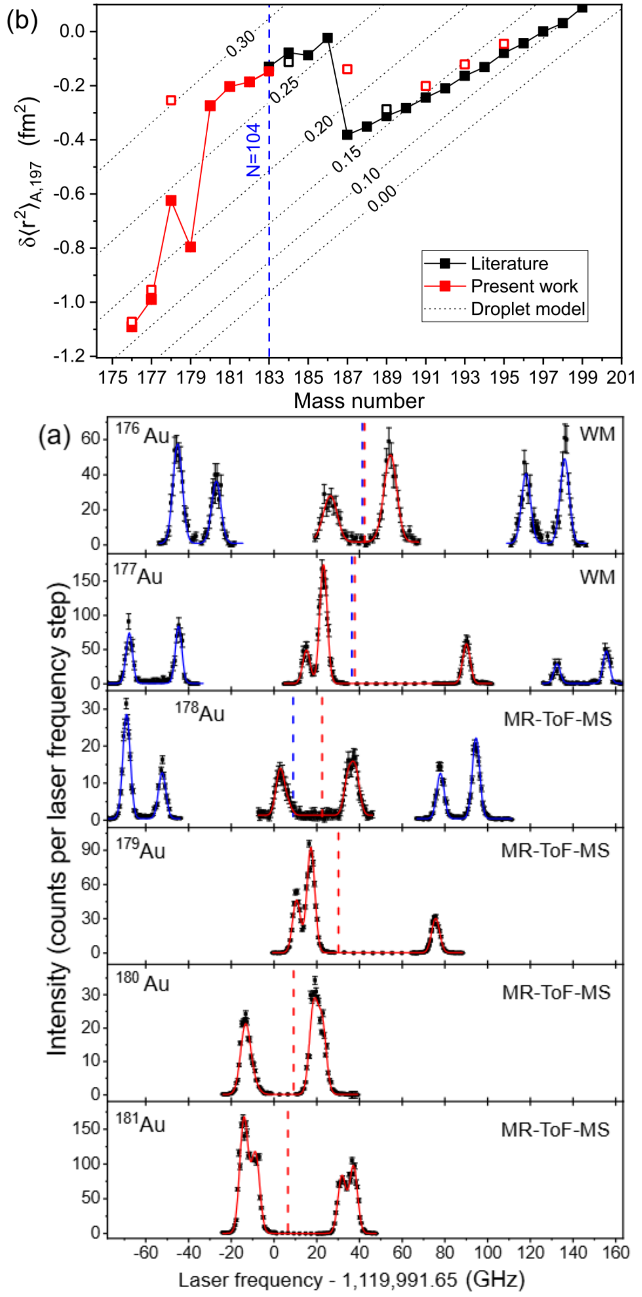
[1] Herfurth, F. et al., NIM A469, 254 (2001)
[2] Wolf, R.N. et al., Int. J. Mass. Spectrom. 349, 123 (2013)
[3] Savard, G. et al., Phys. Lett. A158, 247 (1991)
[4] König, M. et al., Int. J. Mass. Spectrom. 142, 95 (1995)
[5] Lunney, D., J. Phys. G 44, 064008 (2017)

Multi-Reflection Time-of-Flight MS









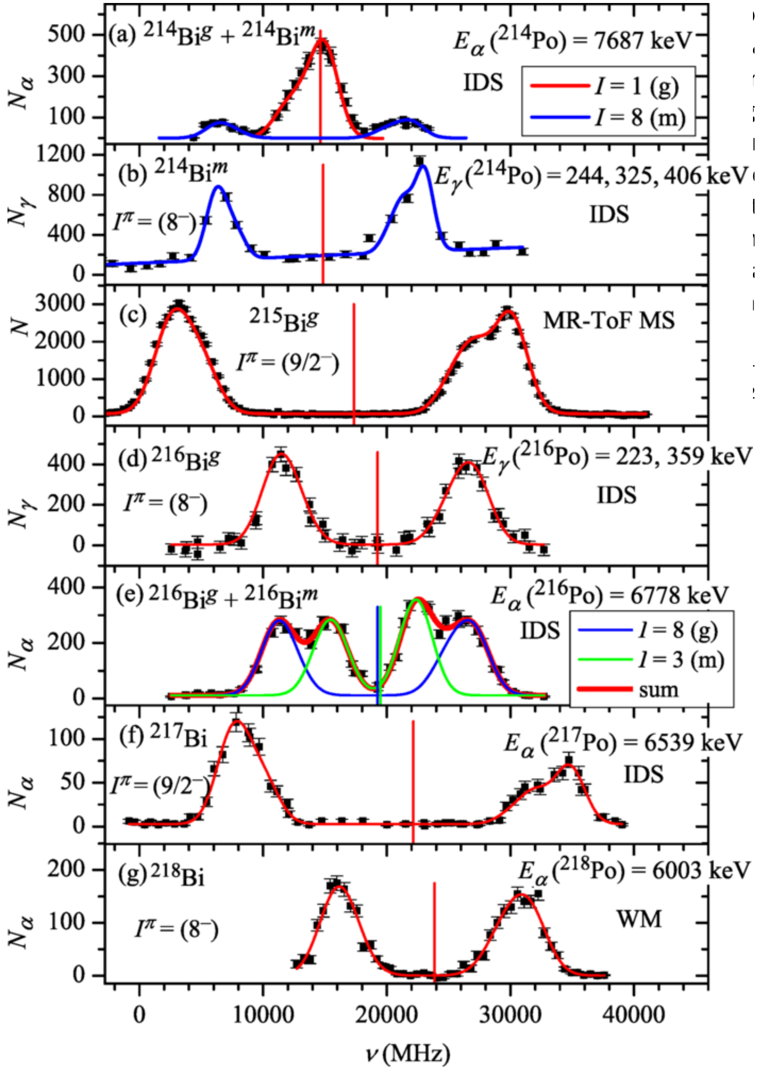
Deformation versus Sphericity in the Ground States Lightest Gold Isotopes

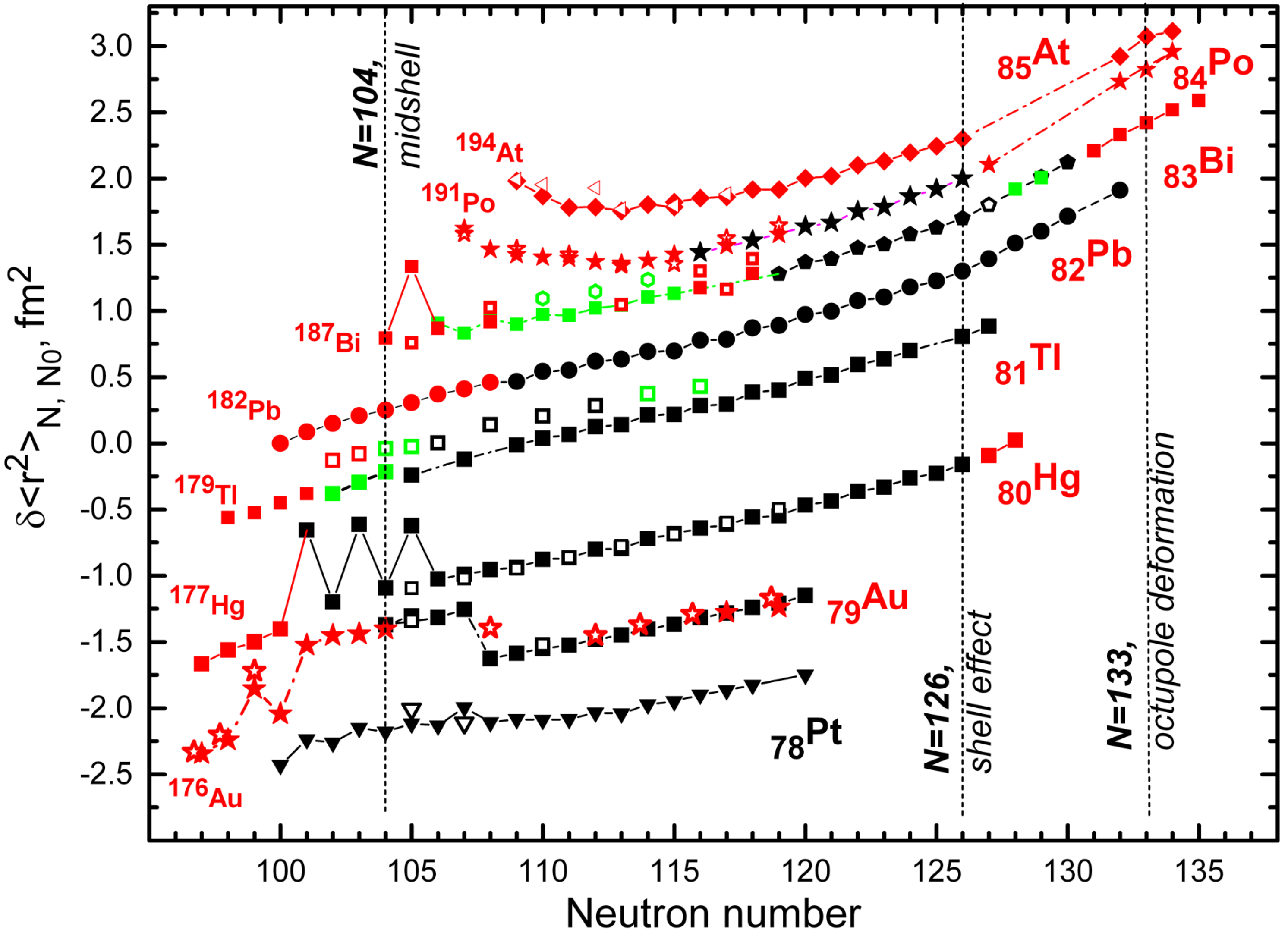
J. G. Cubiss *et al.*

Phys. Rev. Lett. **131**, 202501 (2023) – Published 14 November 2023

Bibliography of the WINDMILL/IDS + RILIS + ISOLTRAP results (so far!)

• A. Barzakh et al. "Charge radii and moments of $^{214-218}$Bi: Exploring the "southern" border of the $Z > 82$ octupole-deformation region," *Physical Review C* 112, 034304 (2025)

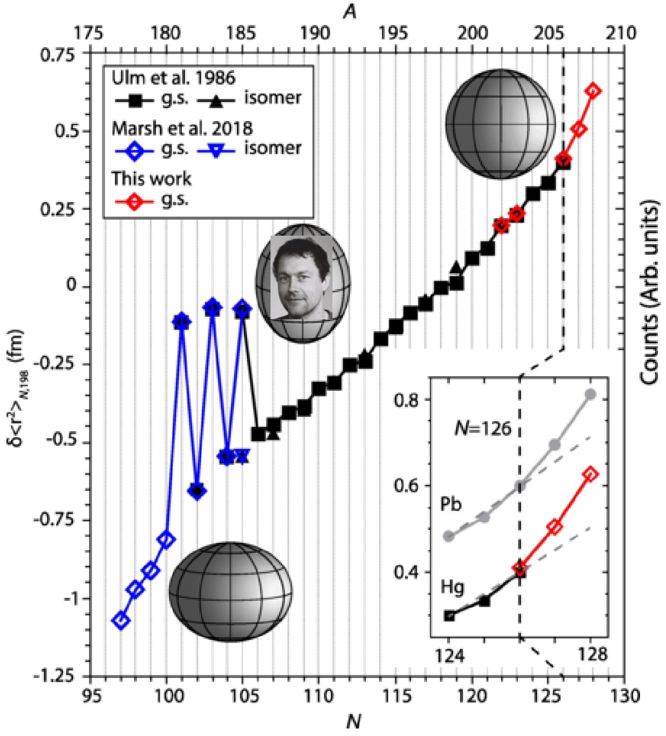


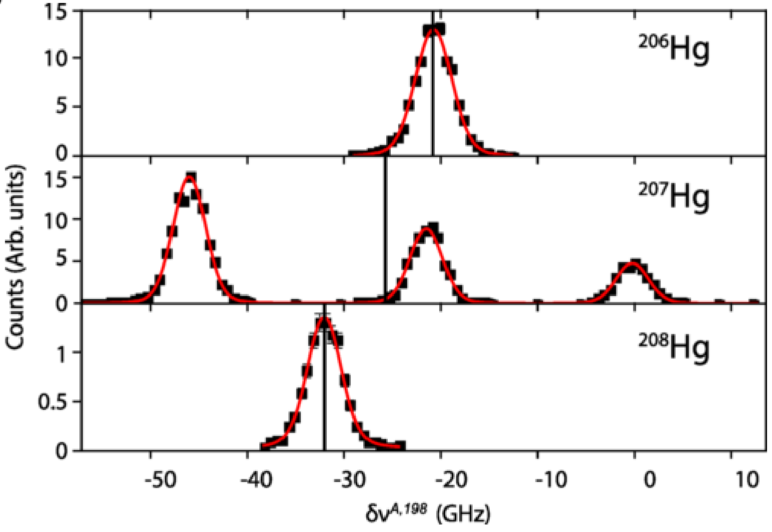


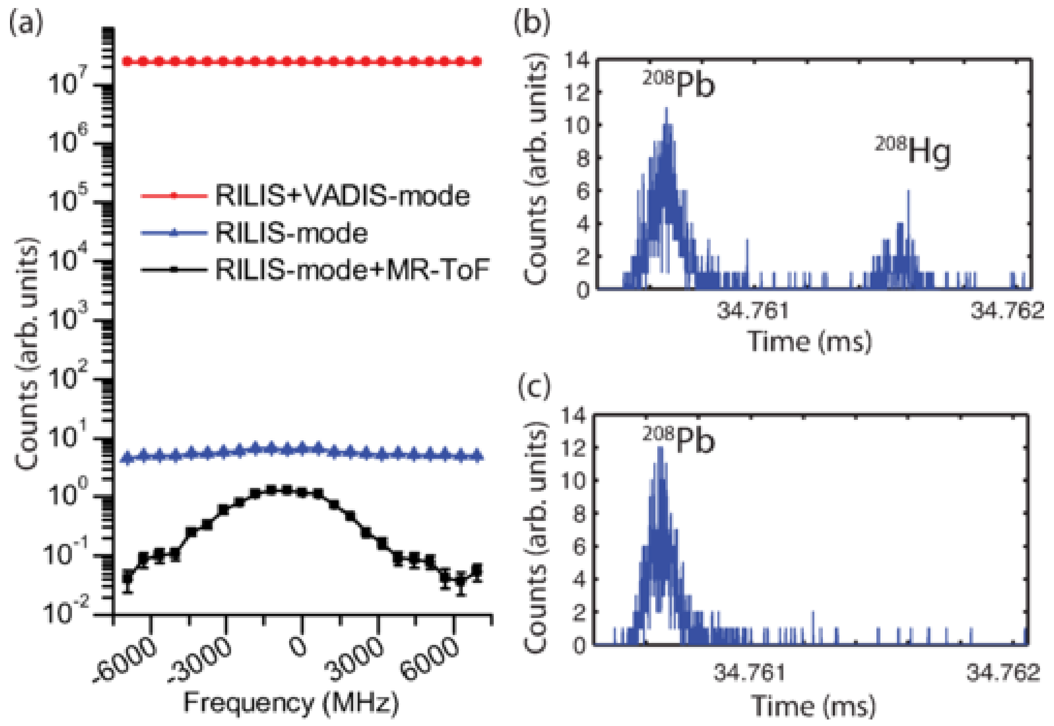
Red data = our data from ISOLDE campaign; Green points = Gatchina; Black points = literature

Bibliography of the WINDMILL/IDS + RILIS + ISOLTRAP results (so far!)

- **A. Barzakh et al. “Charge radii and moments of $^{214–218}$Bi: Exploring the “southern” border of the Z > 82 octupole-deformation region,” *Physical Review C* 112, 034304 (2025)**
- J. Cubiss et al. “Deformation versus sphericity in the ground states of the lightest gold isotopes,” *Physical Review Letters* 131, 202501 (2023)
- A.E. Barzakh et al. “Producing gold at ISOLDE,” *Nuclear Instruments & Methods in Physics Research B* 513, 26 (2022)
- **T. Day Goodacre et al “Charge radii, moments and masses of mercury isotopes across the N = 126 shell closure,” *Physical Review C* 104, 054322 (2021)**
- **T. Day Goodacre et al. “Laser Spectroscopy of Neutron-Rich ^{207,208}Hg Isotopes: Illuminating the Kink and Odd-Even Staggering across the N = 126 Shell Closure,” *Physics Review Letters* 126, 032502 (2021)**
- J. Cubiss et al. “Laser-assisted decay spectroscopy and mass spectrometry of ^{178}Au,” *Physics Review C* 102, 044332 (2020)
- R.D. Harding et al. “Laser-assisted decay spectroscopy for the ground states of ^{180,192}Au,” Physical Review C, 102, 024312 (2020)
- A.E. Barzakh et al. “Shape coexistence in ^{187}Au studied by laser spectroscopy,” *Physics Review C* 101, 064321 (2020)
- A.E. Barzakh et al. “Hyperfine anomaly in gold and magnetic moments of $11/2^-$ gold isomers,” *Physics Review C* 101, 034308 (2020)
- A.E. Barzakh et al., “Inverse odd-even staggering in nuclear charge radii and possible octupole collectivity in ^{217,218,219}At revealed by in-source laser spectroscopy,” *Physical Review C* 99, 054317 (2019)
- S. Sels et al. “Shape staggering of mid-shell mercury isotopes compared with EDF and MCSM calculations,” *Physical Review C* 99, 044306 (2019) – **Editor’s Suggestion**
- **B.A. Marsh et al. “Characterization of the shape-staggering effect in mercury nuclei,” *Nature Physics* 14, 1163 (2018)**
- J.G. Cubiss et al. “Change in structure between the I = 1/2 states in ^{181}Tl and ^{177,179}Au,” *Physics Letters B* 786, 355 (2018)
- J.G. Cubiss et al. “Charge radii and electromagnetic moments of $^{195-211}$At isotopes,” Physical Review C 97, 054327 (2018)







INTC-I-244 to develop Hg beams
→ CERN-INTC-2024-019; INTC-P-698

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

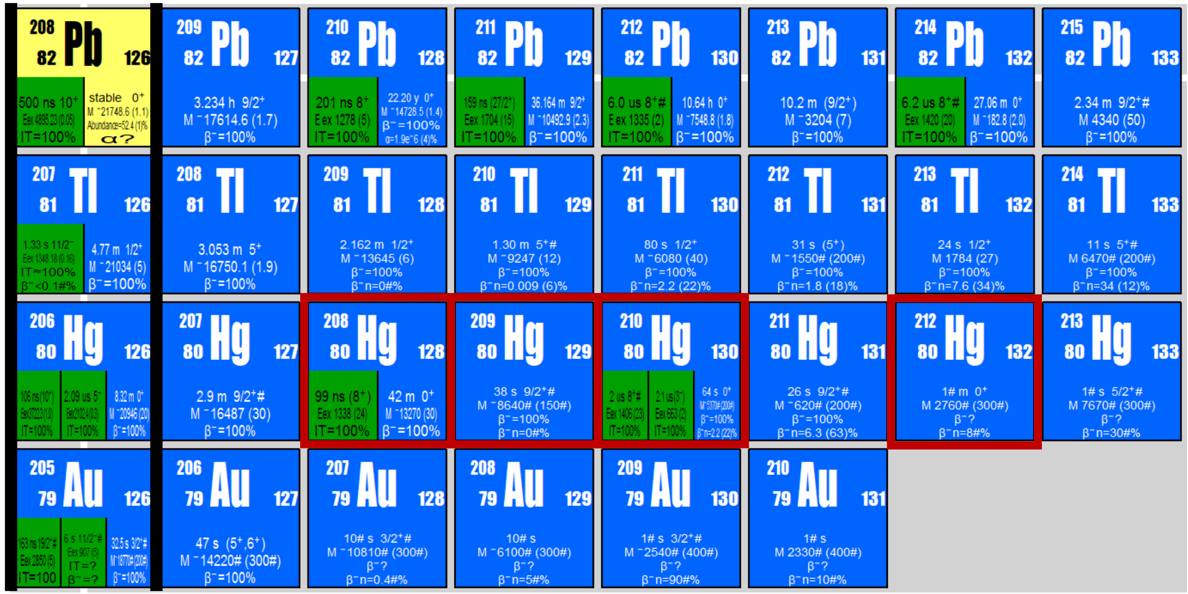
Proposal to the ISOLDE and Neutron Time-of-Flight Committee

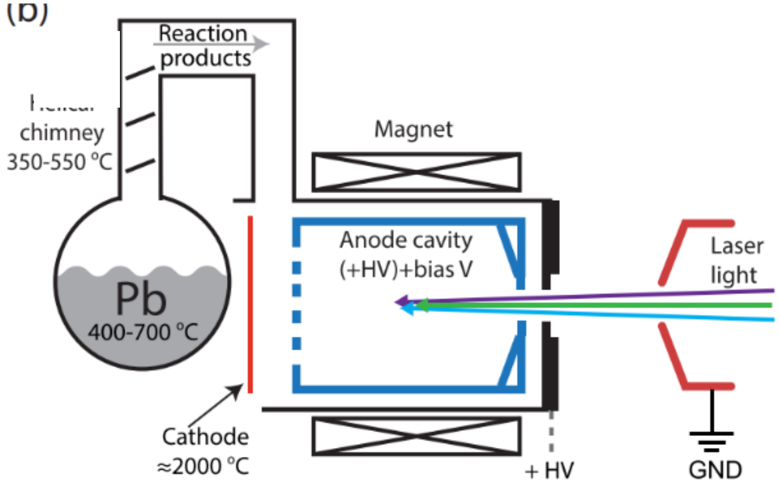
Laser & decay spectroscopy and mass spectrometry of neutron-rich mercury isotopes south-east of ^{208}Pb

10th January 2024

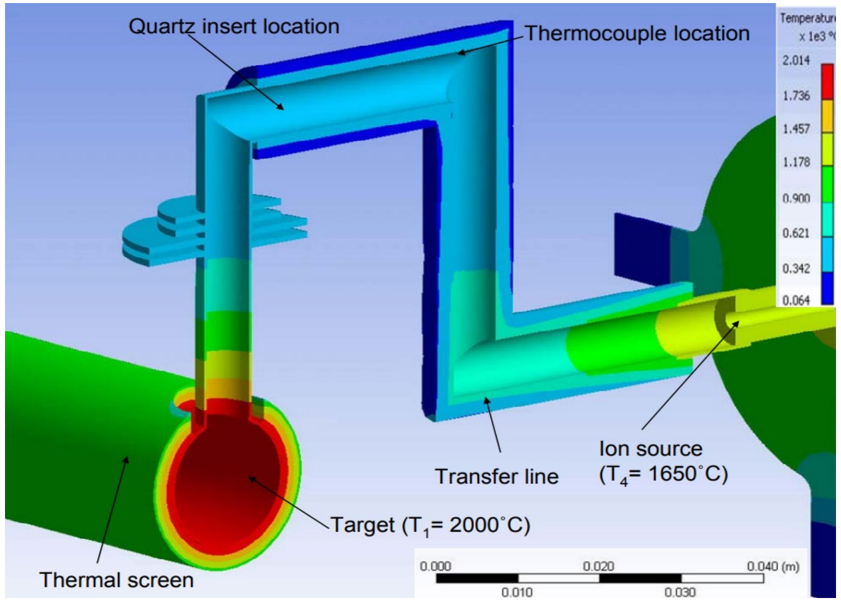
A. Algora[1], B. Andel[2], A. N. Andreyev[3], S. Antalic[2], D. Balabanski[4] M. Benhatchi[5], J. Benito[6], C. Bernerd[7], K. Blaum[8], J. A. Briz[6], R. B. Cakirli[9], K. Chrysalidis[7], T. Cocolios[10], J. G. Cubiss[3], T. Day Goodacre[11], V. N. Fedosseev[7], L. M. Fraile[6], L. P. Gaffney[12], G. Georgiev[5], P. F. Giesel[13], K. Gladnishki[14], R. Heinke[7], Y. Hirayama[15], A. Illana[6], D. Kocheva[14], U. Köster[16], D. Lange[8], R. Lica[17], Yu. A. Litvinov[18], D. Lunney[5], B. A. Marsh[7], A. McFarlane[3], J. Mišt[2], A. Morales[1], M. Mukai[19], S. Naimi[5], L. Nies[7], T. Niwase[15], J. Ojala[12], B. Olaizola[20], C. Page[3], R. D. Page[12], J. Pakarinen[21], Z. Podolyak[22], G. Rainovski[14], M. Rosenbusch[15], S. Rothe[7], P. Schury[15], Ch. Schweiger[8], L. Schweikhard[13], S. Sharma[23], A. Sitarčík[2], P. Srivastava[23], K. Stoychev[7], M. Stryjczyk[21], P. Van Duppen[10], Y. Watanabe[15], J. Wilson[3], Z. Yue[3,7] + IDS collaboration

Spokesperson: J. G. Cubiss [james.cubiss@york.ac.uk], D. Lange [daniel.lange@cern.ch], A. N. Andreyev [andrei.andreyev@york.ac.uk], U. Köster [koester@ill.fr]
Contact person: Ch. Schweiger [christoph.schweiger@cern.ch], Z. Yue [zixuan.yue@york.ac.uk]



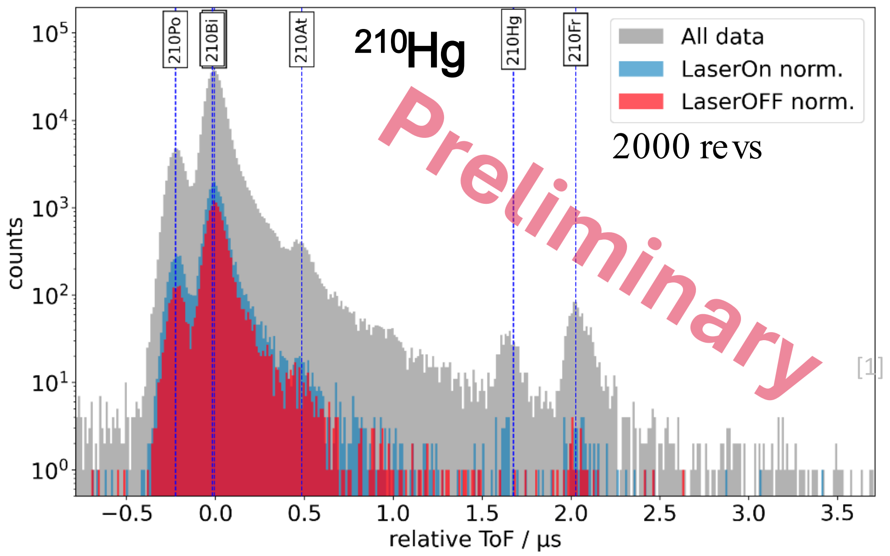


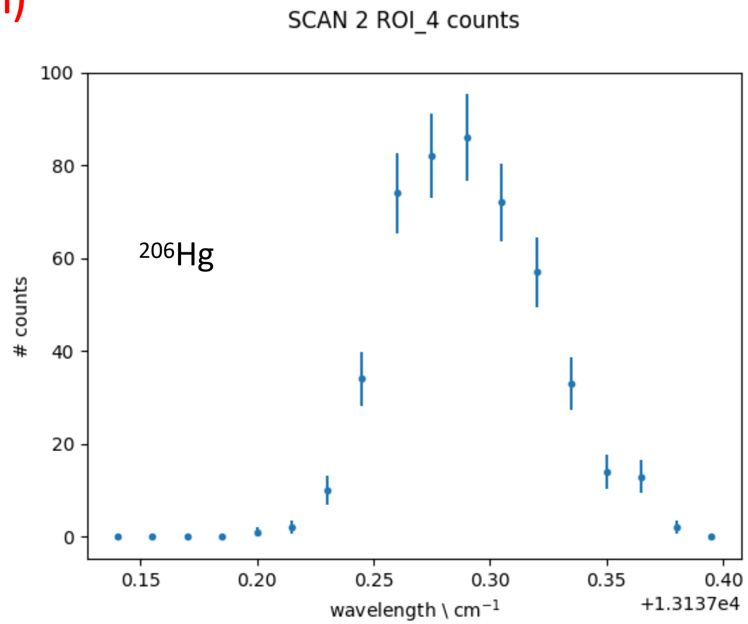
Uranium carbide
(dreaded francium…)



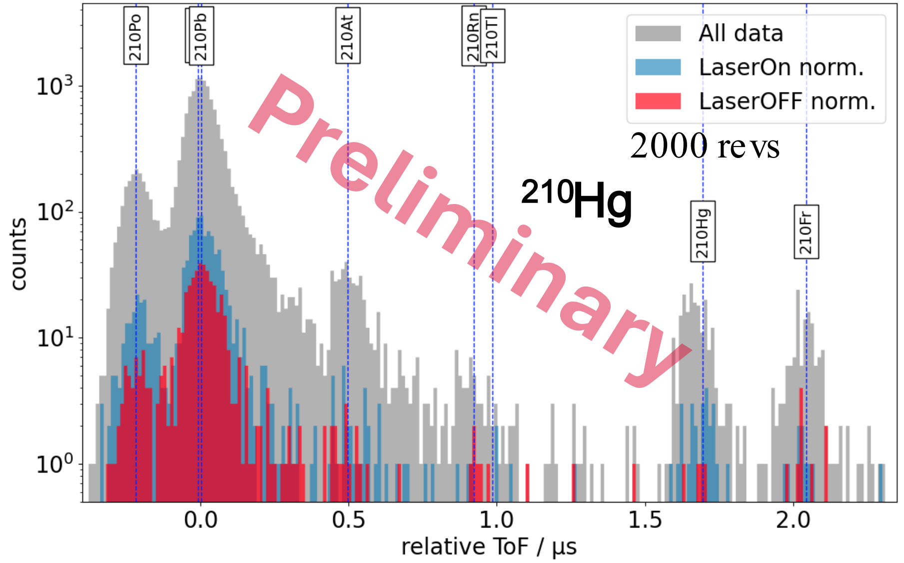
Quartz transfer line:
Lower negative adsorption enthalpy of Hg vs. Fr ! ☺

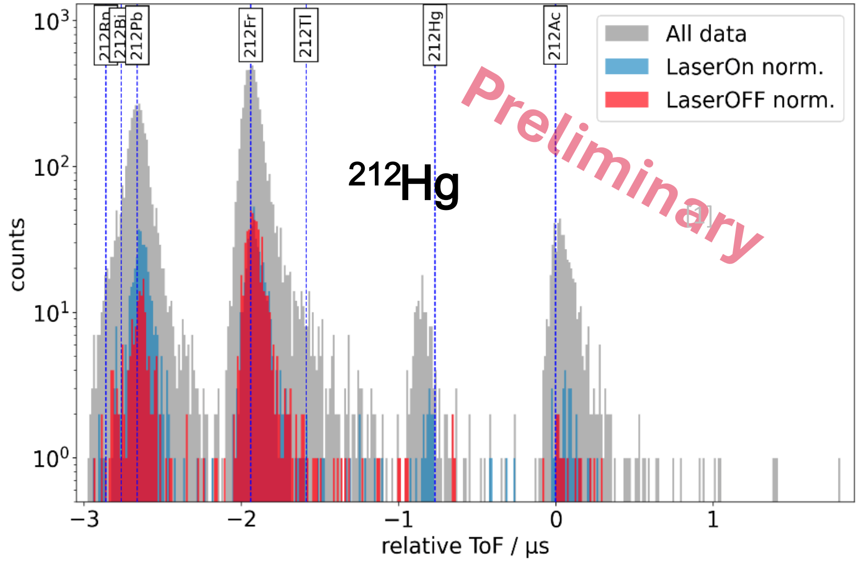
New Hg masses (D. Lange, in preparation)





Reduction of target and line heating

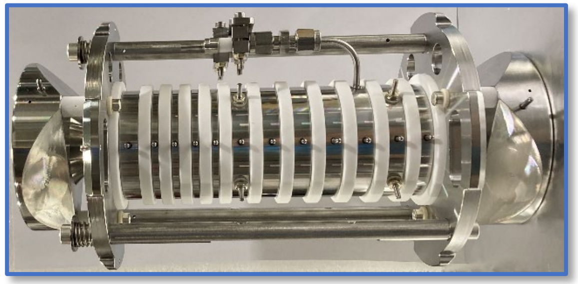




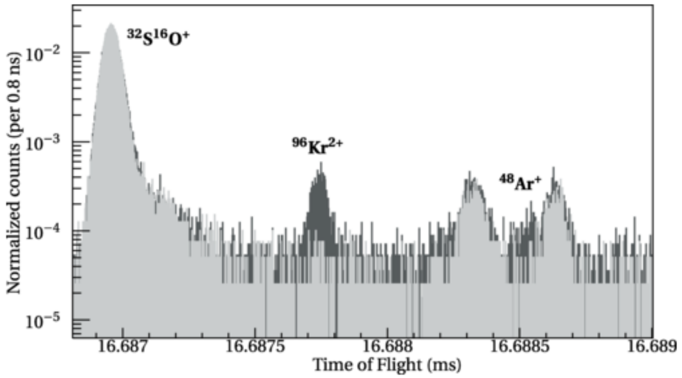
MiniRFQ: Mass-selective re-trapping [1]

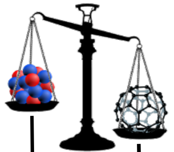
(part of the PhD work of **Daniel Lange**, U. Heidelberg)

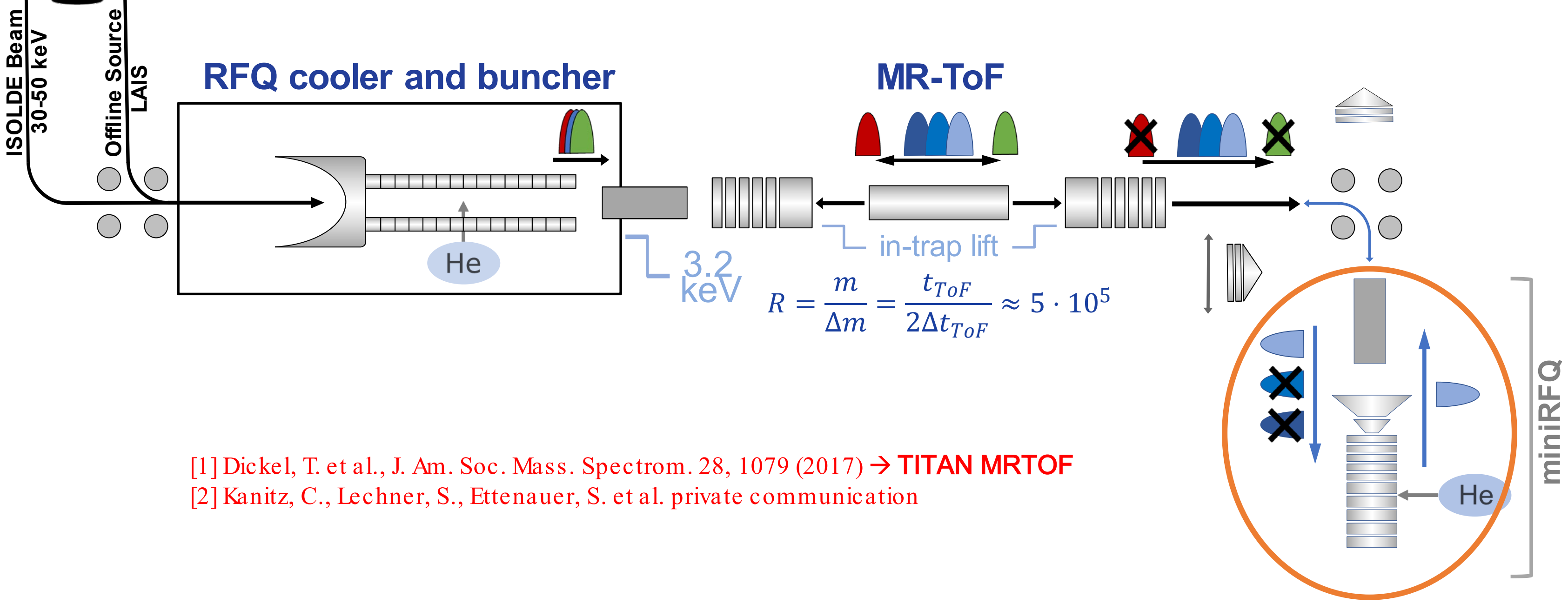
- Low production cross section combined with isobaric and molecular contamination
- miniRFQ design from the MIRACLS experiment [2]

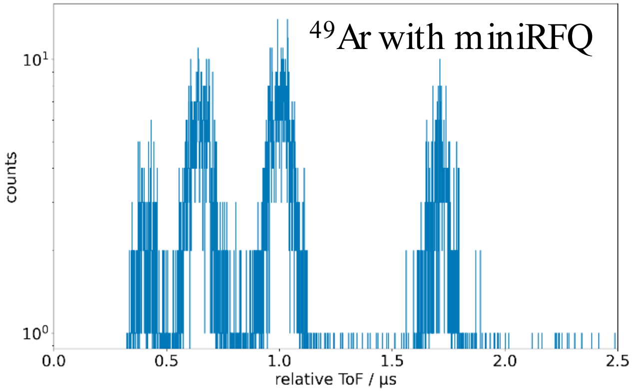


M. Mougeot et al., Phys. Rev. C (2020)





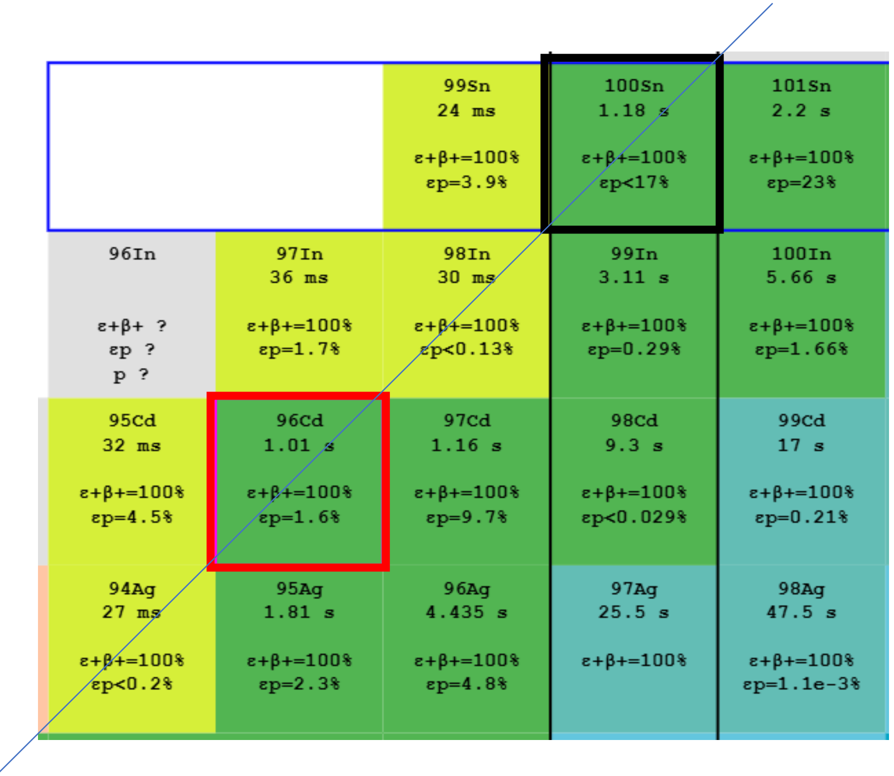


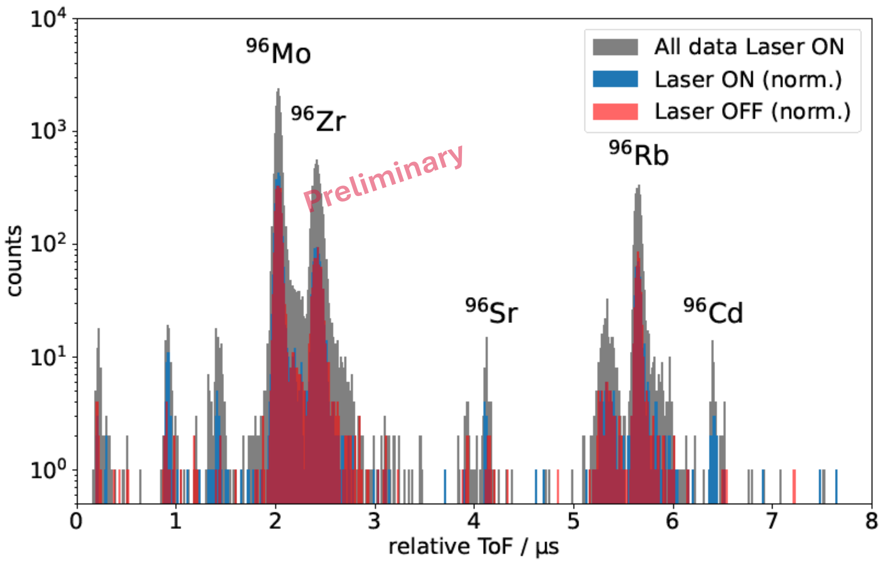


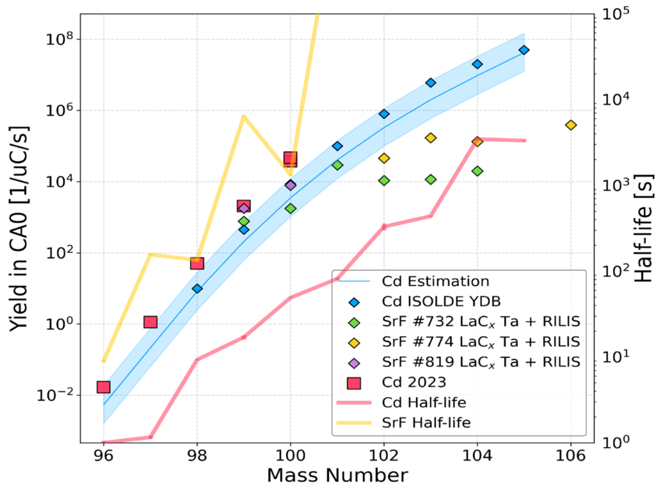
D. Lange et al., under analysis

[1] Dickel, T. et al., J. Am. Soc. Mass. Spectrom. 28, 1079 (2017) → TITAN MRTOF
[2] Kanitz, C., Lechner, S., Ettenauer, S. et al. private communication

Other measurements (not related to charge radii)



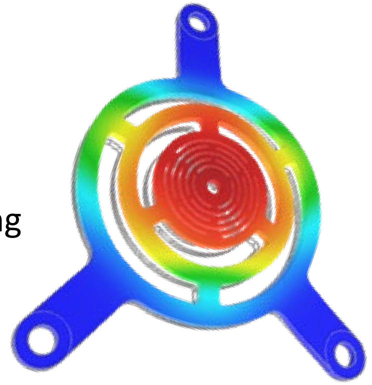


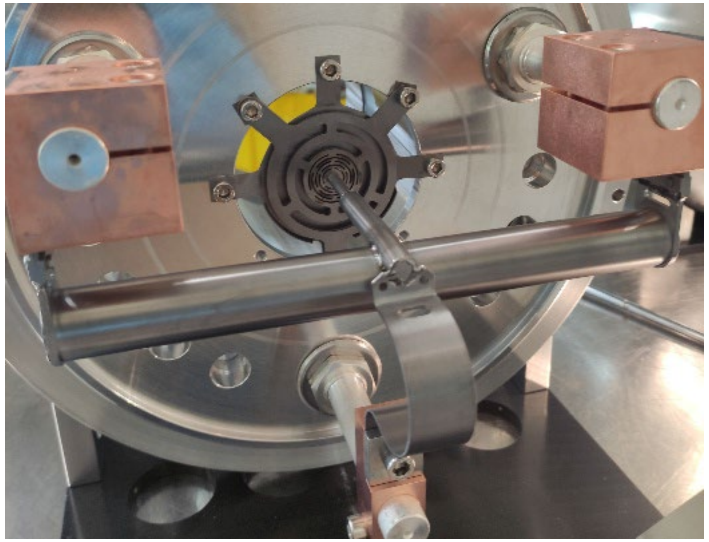


M. Benhatchi (IJCLab, Orsay) and D. Lange (MPIK), under analysis

Prototype LaC_x target
(A. Koliatos, ISOLDE)

- Improved heat shielding
- Spider-web ion source





Developments at ISOLTRAP

PicoDAQ [part of PhD work of M. Benhatchi]

Current DAQ - MCS6A :

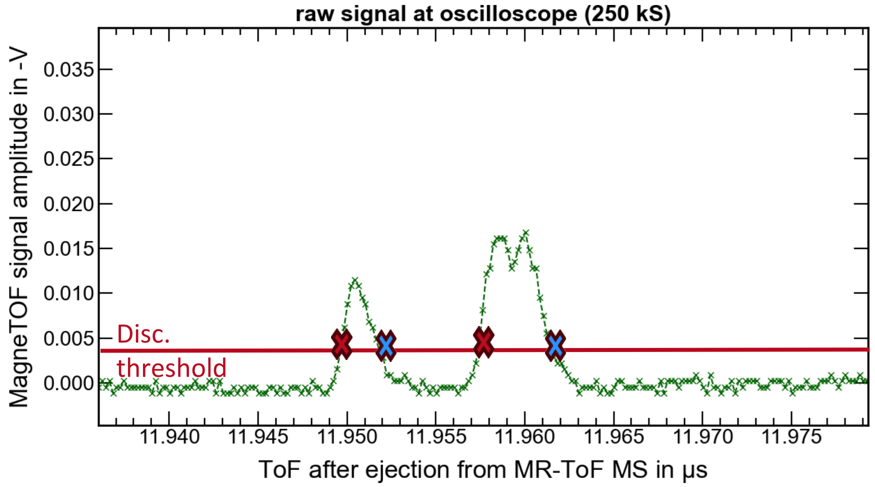
Scaler TDC type that converts raw data into histogram

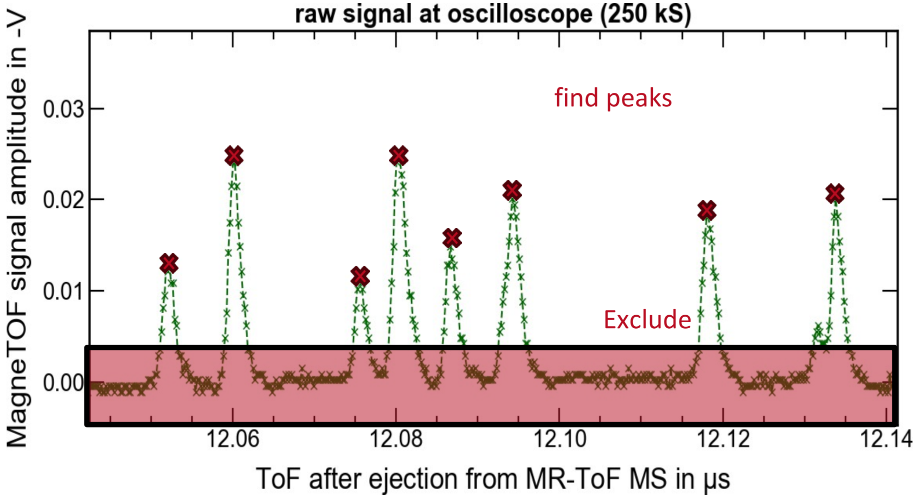
- good for low intensity beams
- amount of data is reduced
- but all raw data is lost → bias

New DAQ - Picoscope 6428A :

Oscilloscope + python codes

- raw data ⇒one spectrum saved for each shot
- python to control scope and conversion





Acknowledgements:

D. Antanasov, M. Benhatchi,
K. Blaum, R. B. Cakirli,
P. F. Giesel, P. Fischer,
D. Lange, Yu. Litvinov,
D. Lunney, V. Manea,
S. Naimi, L. Nies,
Ch. Schweiger, L. Schweikhard,
F. Wienholtz, *et al*.
for the ISOLTRAP collaboration

WINDMILL/IDS Collaboration,
ISOLDE OPERATIONS TEAM,
RILIS TEAM, TARGET TEAM,
& the ISOLDE Collaboration

Slides from: Ch. Schweiger, D. Lange, M. Benhatchi, J. Cubiss
A. Andreyev and A.E. Barzakh

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