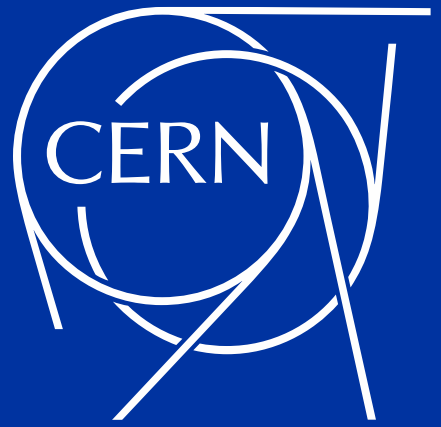


Actinide and molecular beams at CERN-ISOLDE

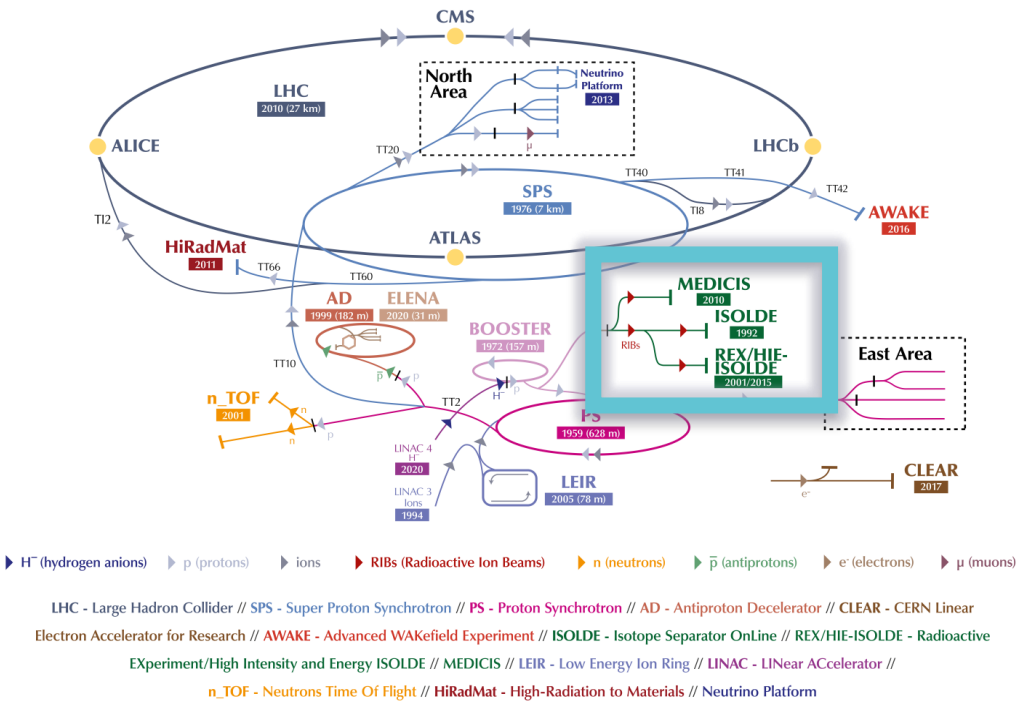
Mia Au

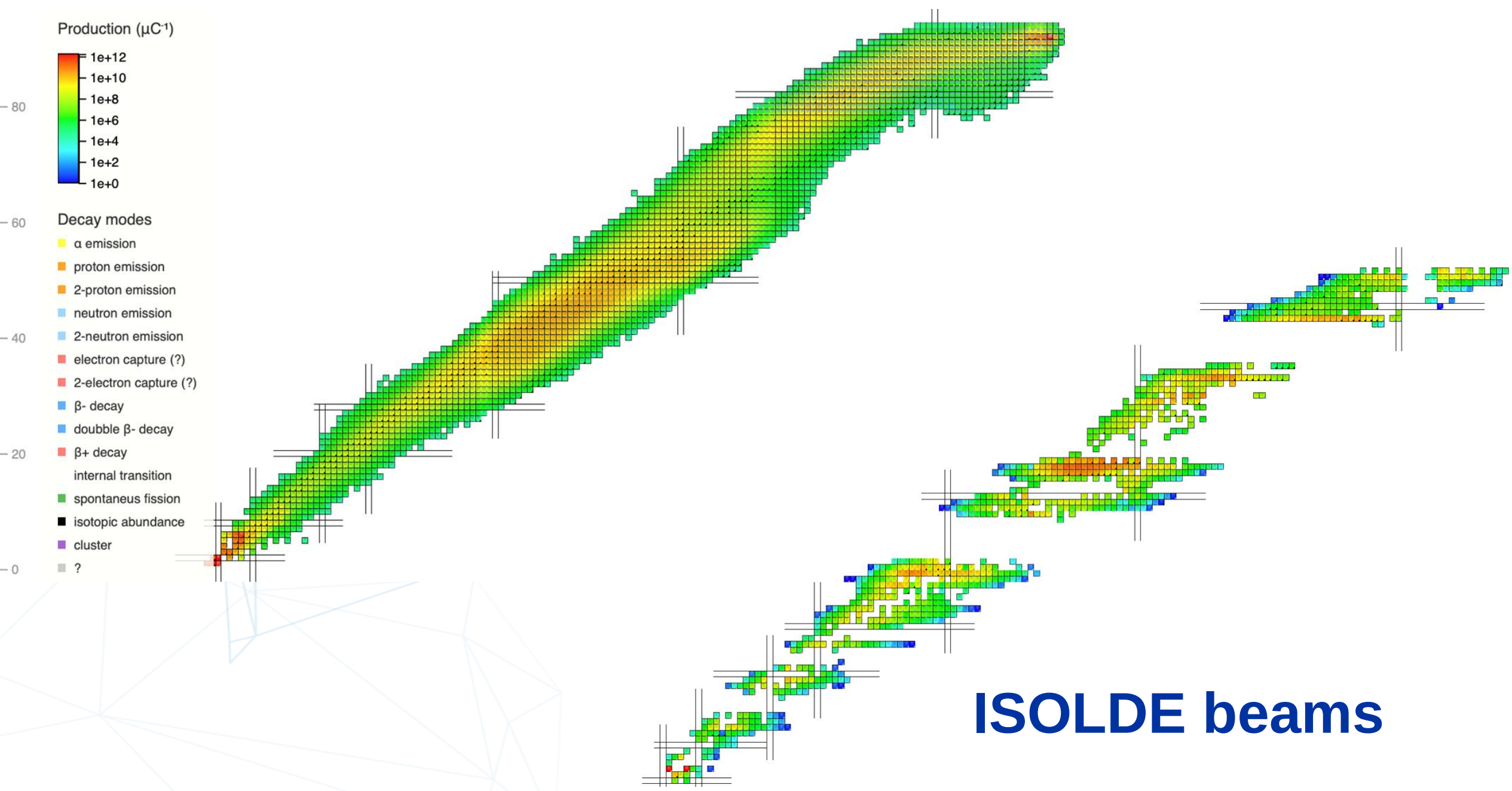
EMIS XIX, Oct 3-7 2022 RAON

LISA
LASER IONISATION AND SPECTROSCOPY OF ACTINIDES

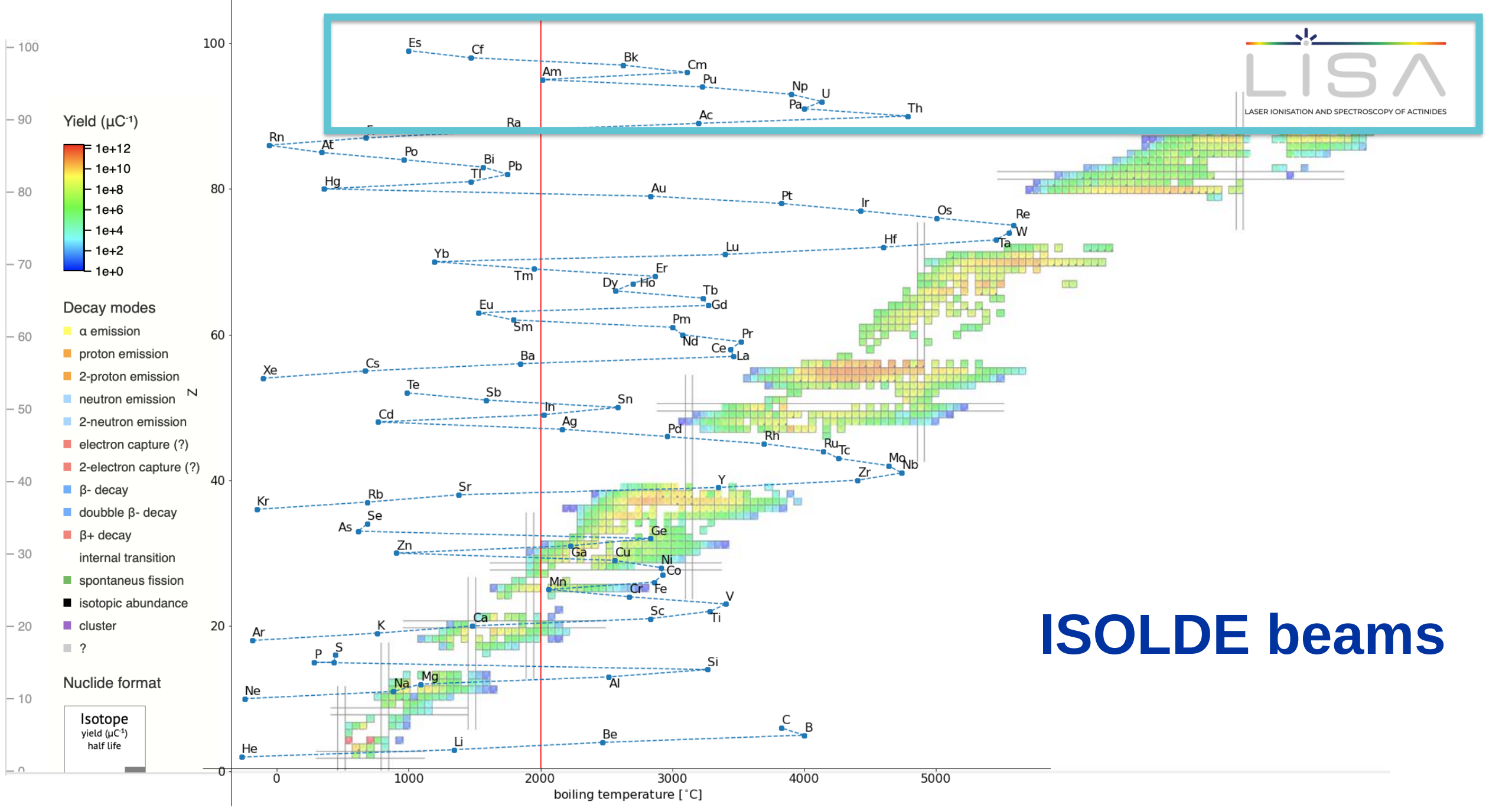
Agenda

1. ISOLDE beams and actinides
2. Actinides at ISOLDE
3. Molecular beams at ISOLDE
4. Actinide molecules
5. Next steps





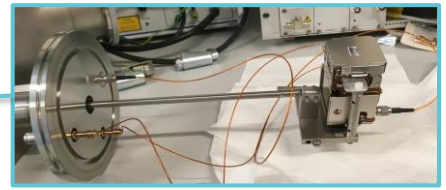
ISOLDE beams



LISA
LASER IONISATION AND SPECTROSCOPY OF ACTINIDES

ISOLDE beams

Actinide atomic beams

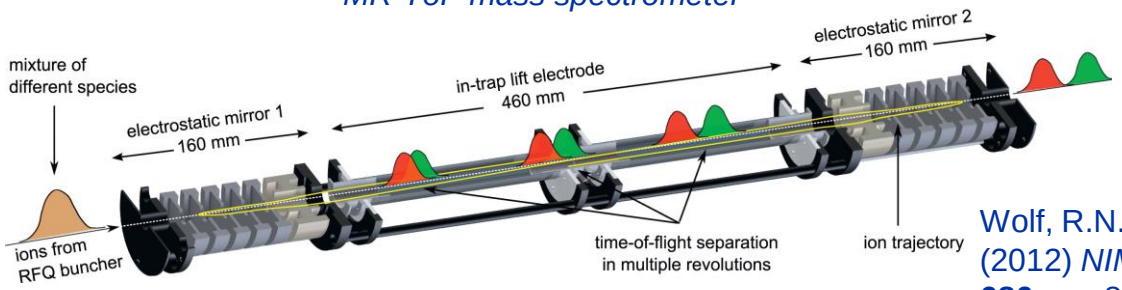


TISD chamber

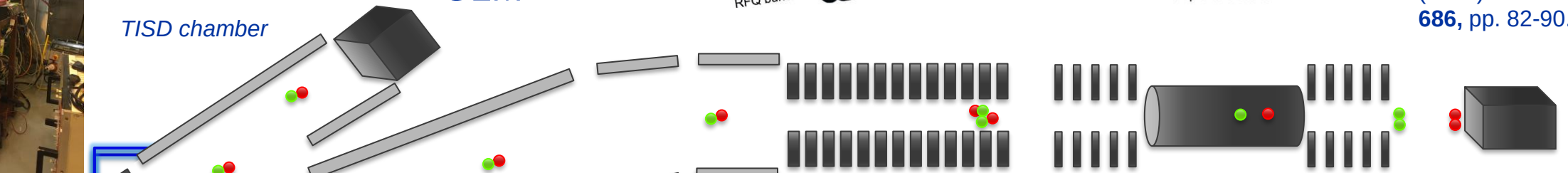
ISOLDE GLM

ISOLTRAP

MR-ToF mass spectrometer

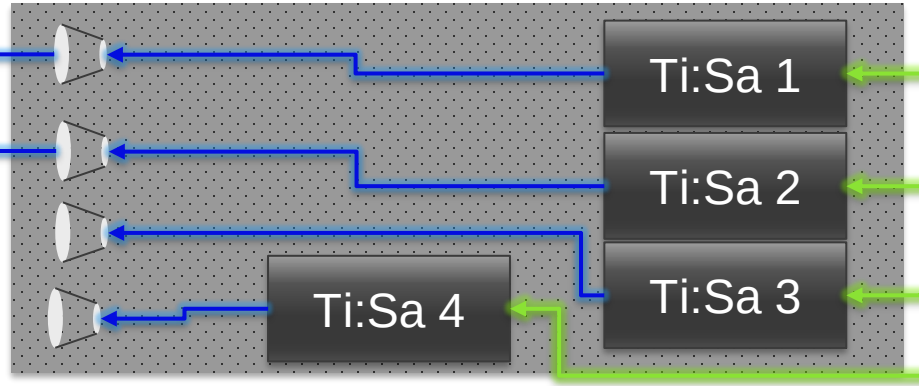


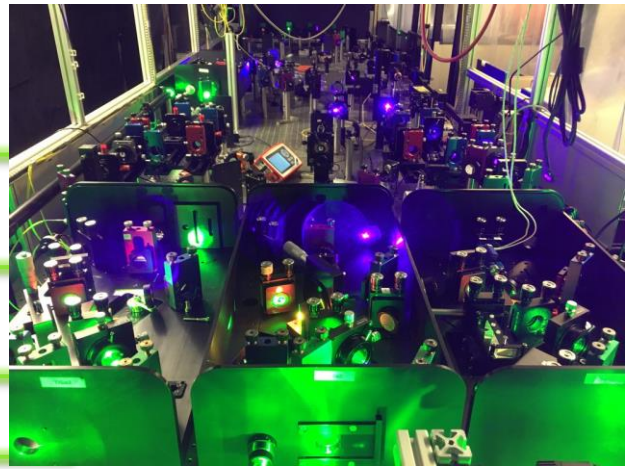
Wolf, R.N. *et al.* (2012) *NIM A* **686,** pp. 82-90.

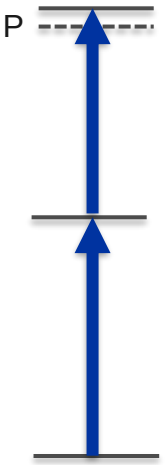


Ac, Pa, U, Np, Pu

RILIS



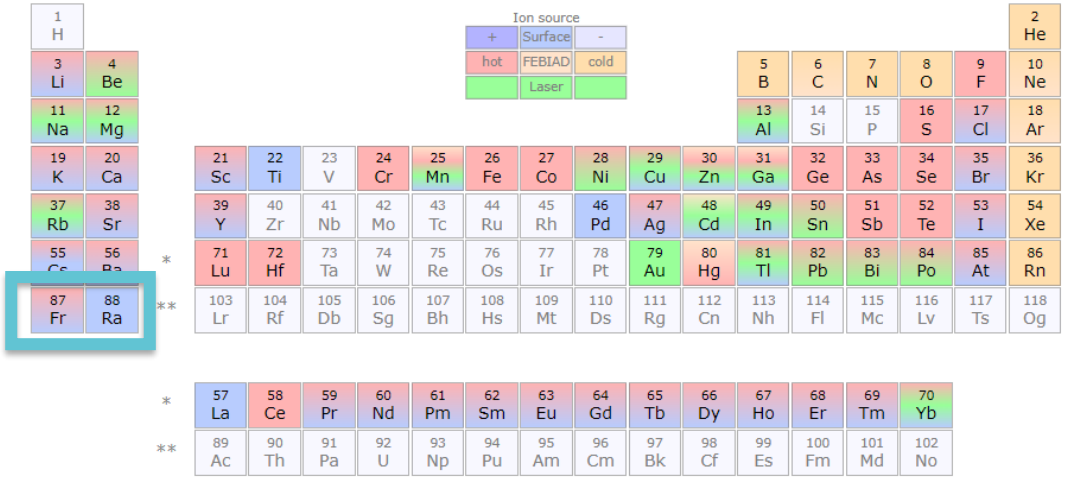




ISOLDE GPS

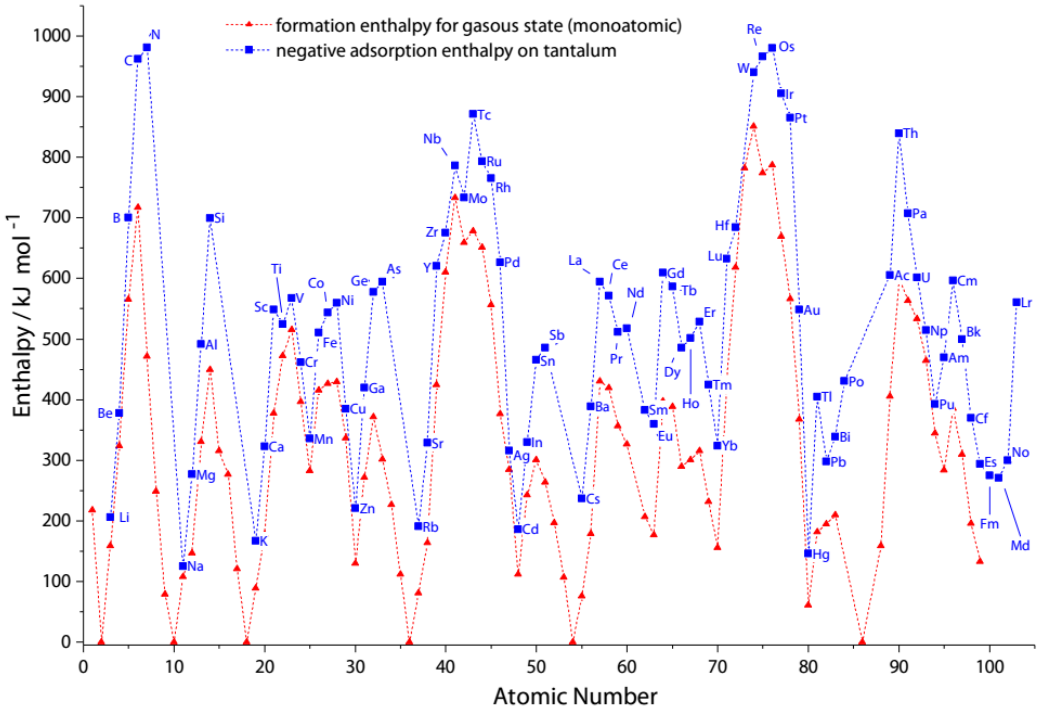
Challenges

Contaminants



cern.ch/isolde-yields

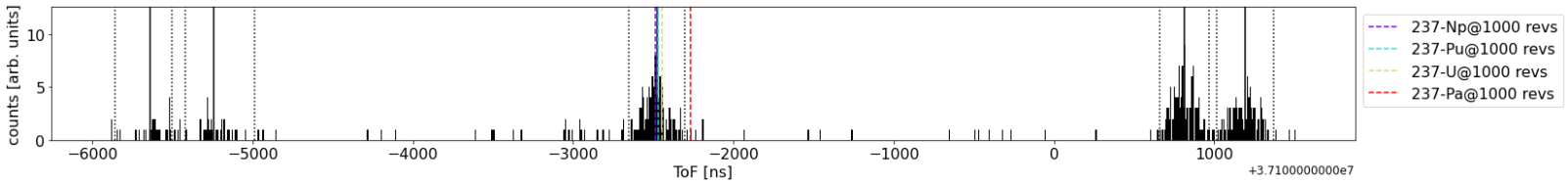
Refractory properties

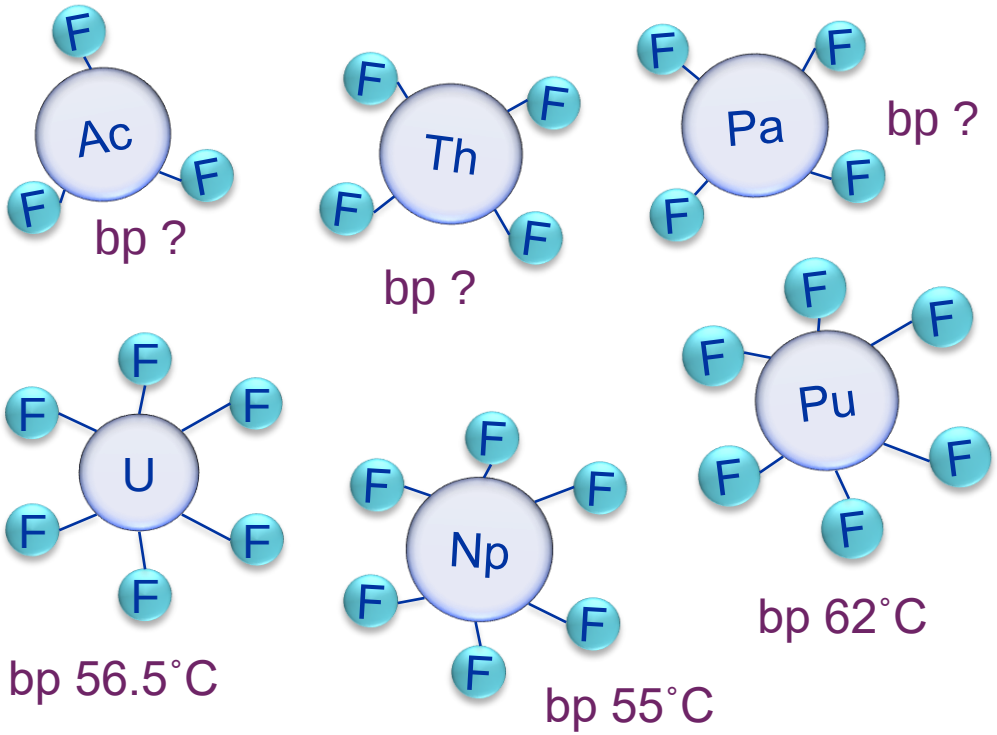


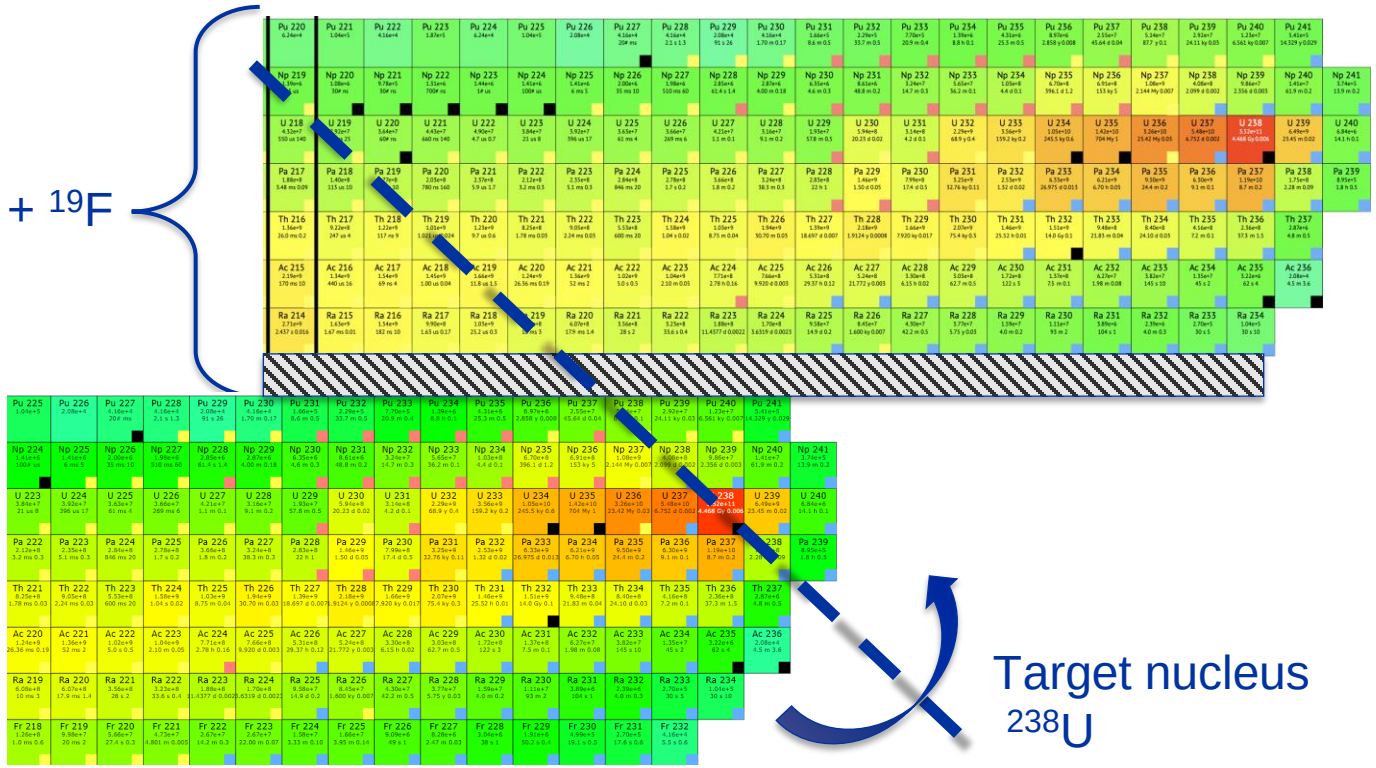
Ballof, J. (2021) Radioactive Molecular Beams at CERN-ISOLDE

Mass resolving power

$$R = \frac{m}{\Delta m} = \frac{t}{2\Delta t}$$

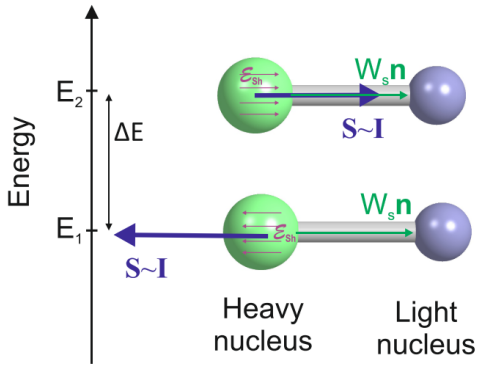




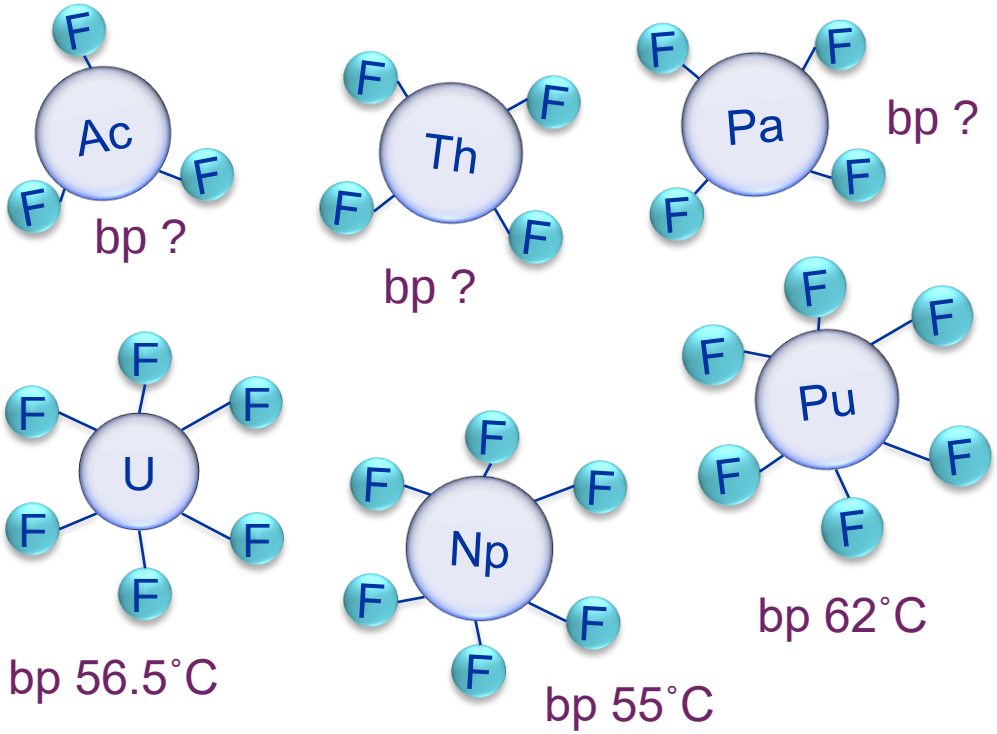


Molecular beams

1. Volatilization
2. Sideband extraction
3. Research opportunities

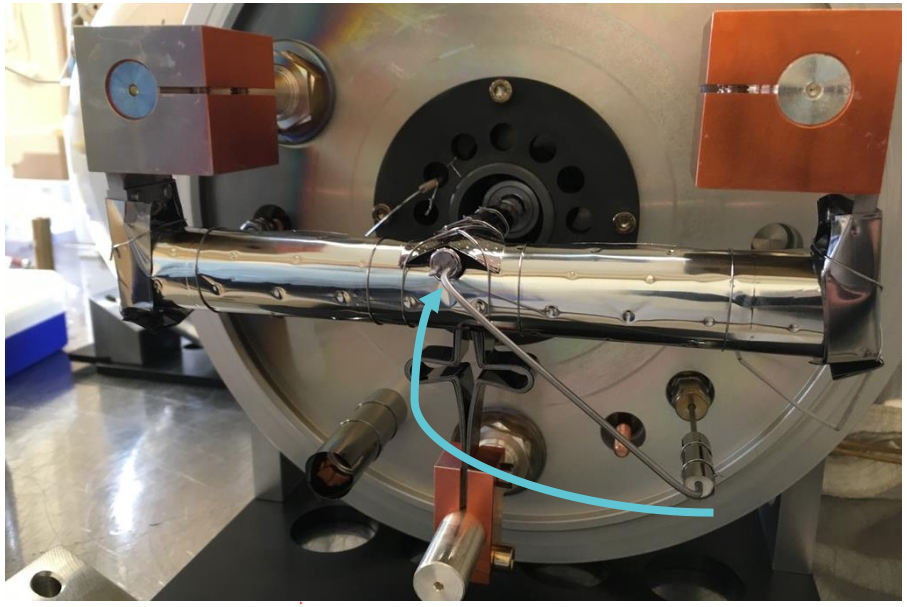


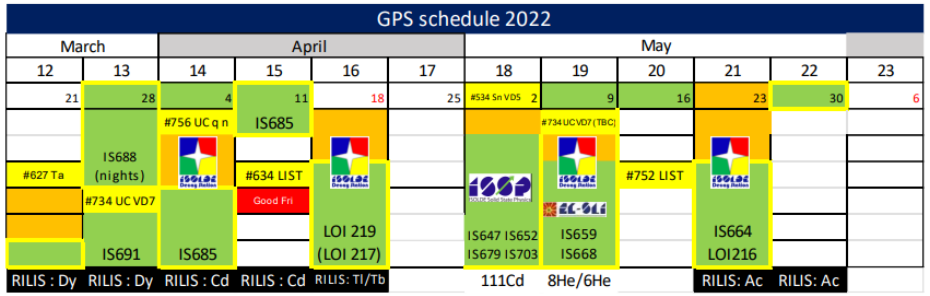
Garcia Ruiz et al. (2020) Nature 581. 396
Safronova, Budker, DeMille et al. (2018) Rev. Mod. Phys. *90. 2,*
Skripnikov et al. (2020) Phys. Chem. Chem. Phys. *22. 33, 18374*

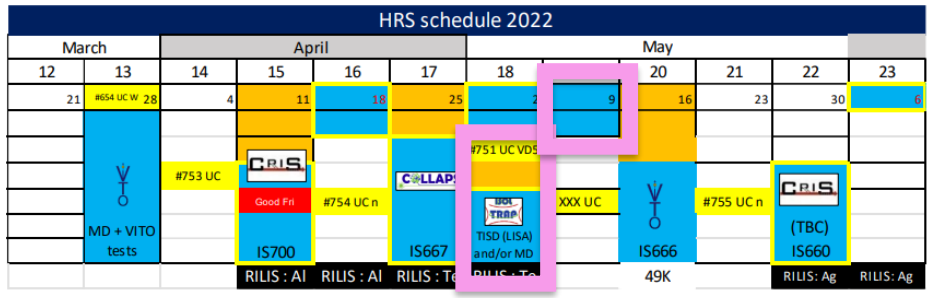


Molecular beams

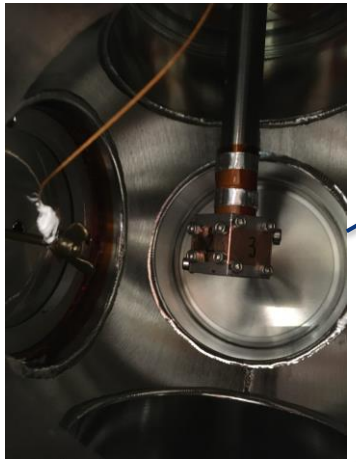
1. Formation
2. Detection
3. Identification







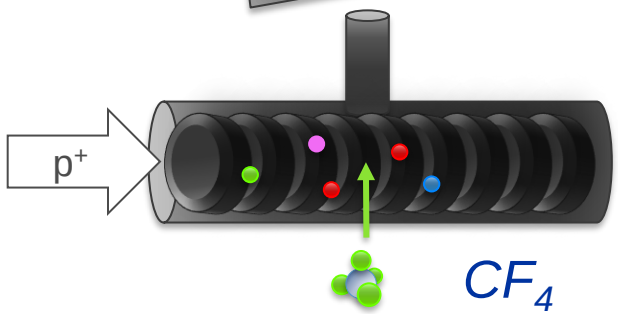
Actinide fluoride ion beams

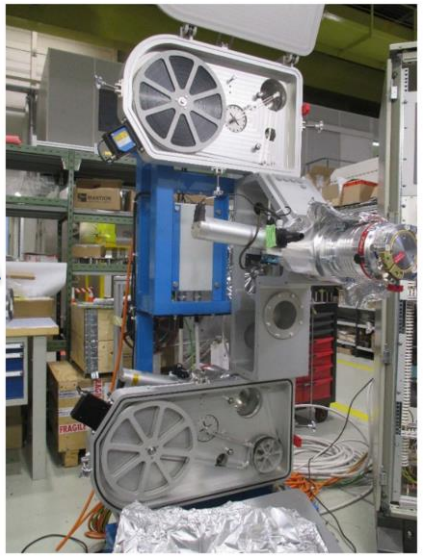


ISOLDE LA1

ISOLDE HRS

ISCOOL



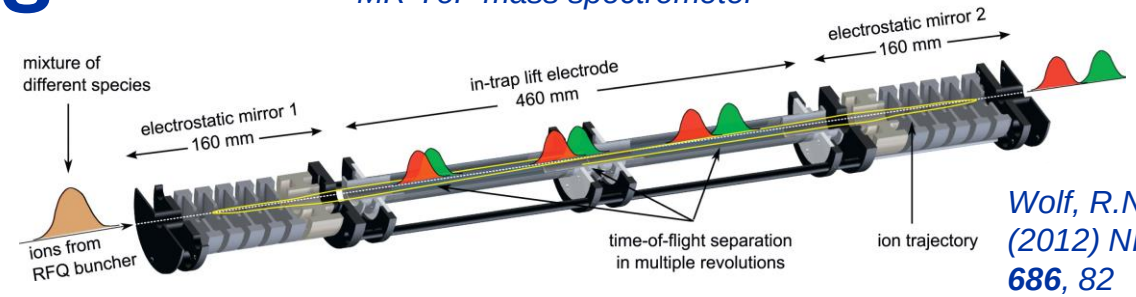


ISOLDE FTS

Catherall, R. et al. (2017) J. Phys. G. **44**, 9

ISOLTRAP

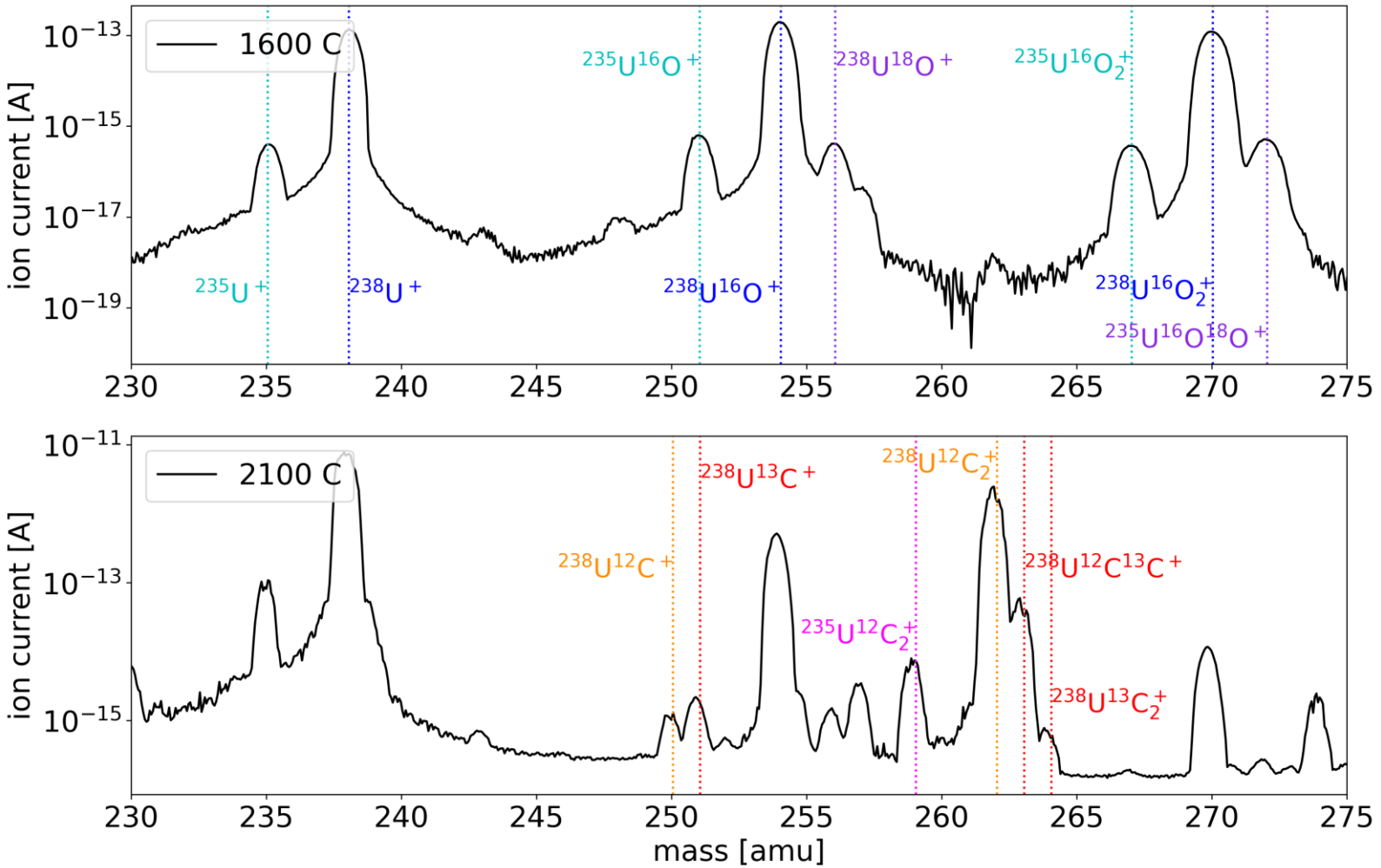
MR-ToF mass spectrometer



Wolf, R.N. et al. (2012) NIM A **686**, 82

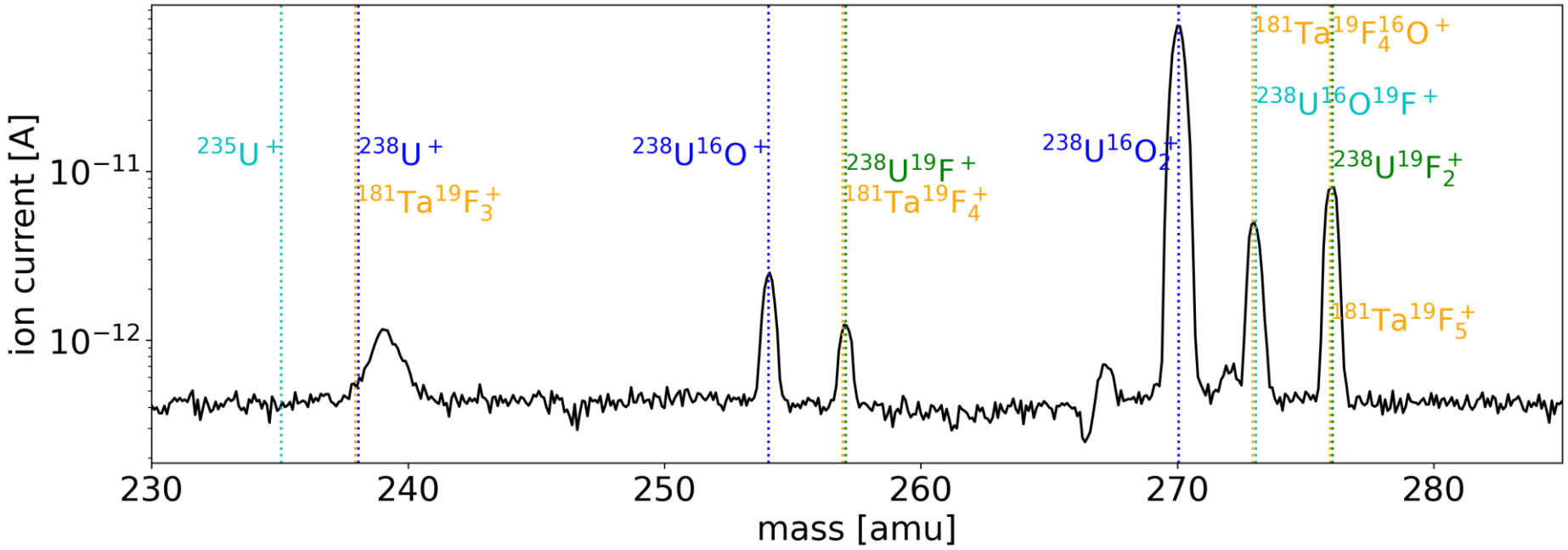
Pre-irradiation

Species	Rate [ions/s]
$^{235}U^{+}$	7E5
$^{238}U^{+}$	3.7E7
$^{238}U^{12}C^{+}$	7.5E3
$^{235}U^{16}O^{+}$	1.3E4
$^{238}U^{16}O^{+}$	4.2E6
$^{238}U^{18}O^{+}$	9E3
$^{235}U^{12}C_2^{+}$	6.5E4
$^{238}U^{12}C_2^{+}$	1.1E7
$^{238}U^{12}C^{13}C^{+}$	4.8E5
$^{238}U^{13}C_2^{+}$	1.65E3
$^{235}U^{16}O_2^{+}$	2E3
$^{238}U^{16}O_2^{+}$	7E5
$^{235}U^{16}O^{18}O^{+}$	2.5E3

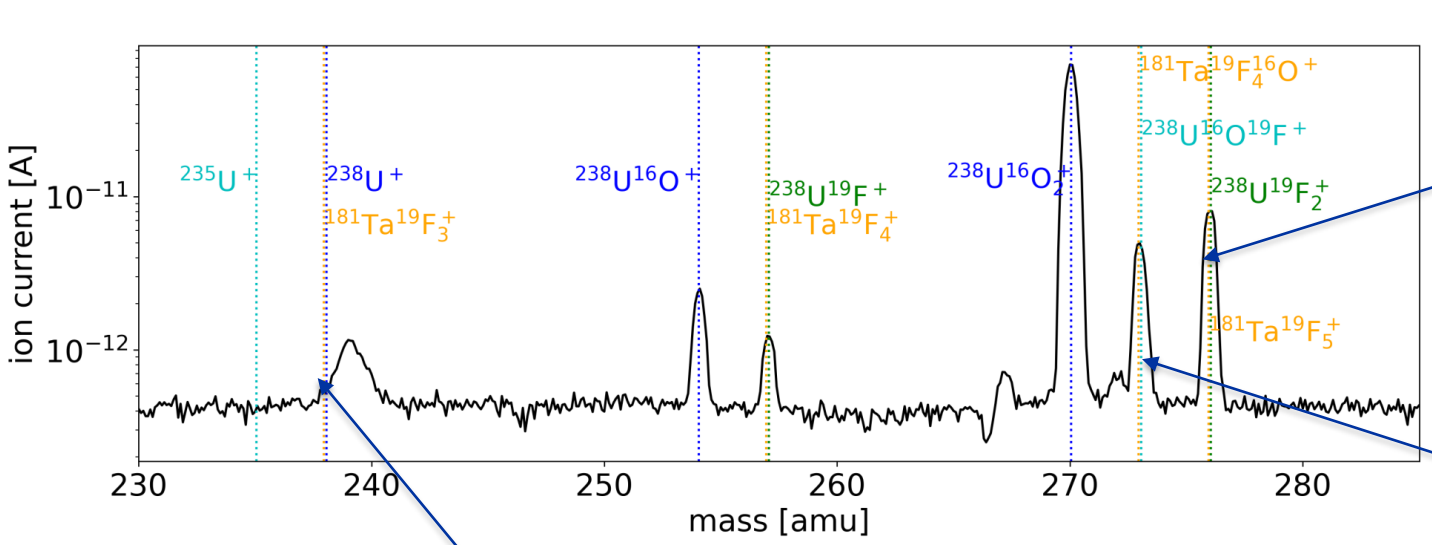


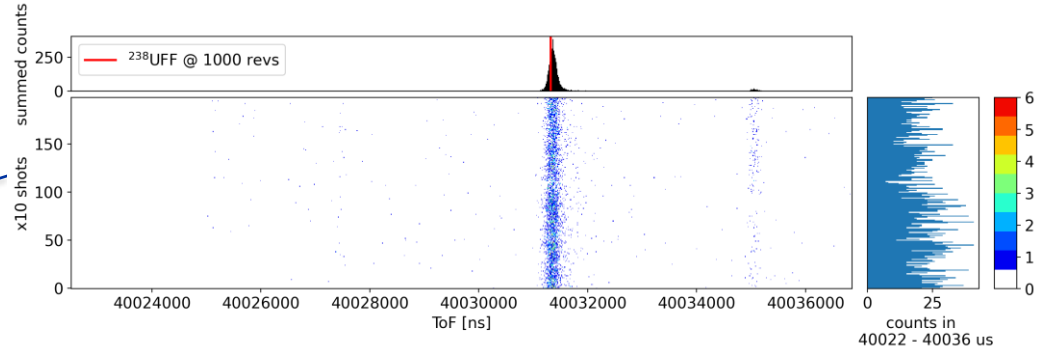
Pre-fluorination

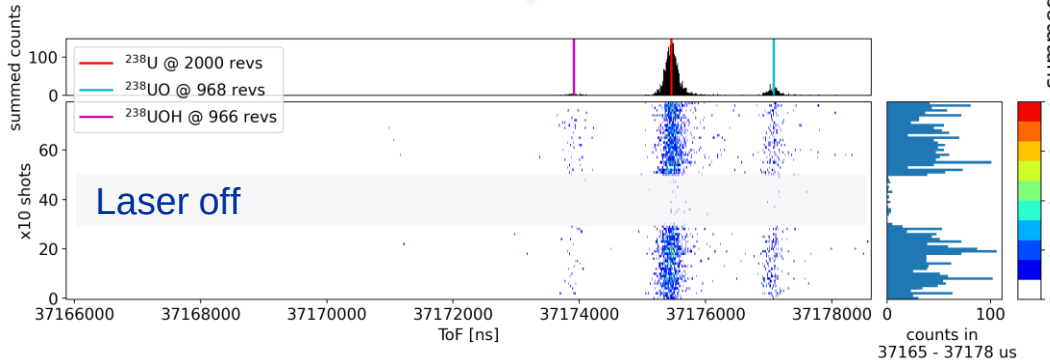
Species	Rate [ions/s]
$^{238}U^{+}$	?
$^{235}U^{16}O^{+}$	1.3E4
$^{238}U^{16}O^{+}$	4.2E6
$^{238}U^{19}F^{+}$	?
$^{181}Ta^{19}F_5^{+}$	?
$^{238}U^{16}O_2^{+}$	7E5
$^{181}Ta^{19}F_4^{16}O^{+}$	?
$^{238}U^{19}F^{16}O^{+}$	?
$^{238}U^{19}F_2^{+}$	?
$^{181}Ta^{19}F_5^{+}$	?

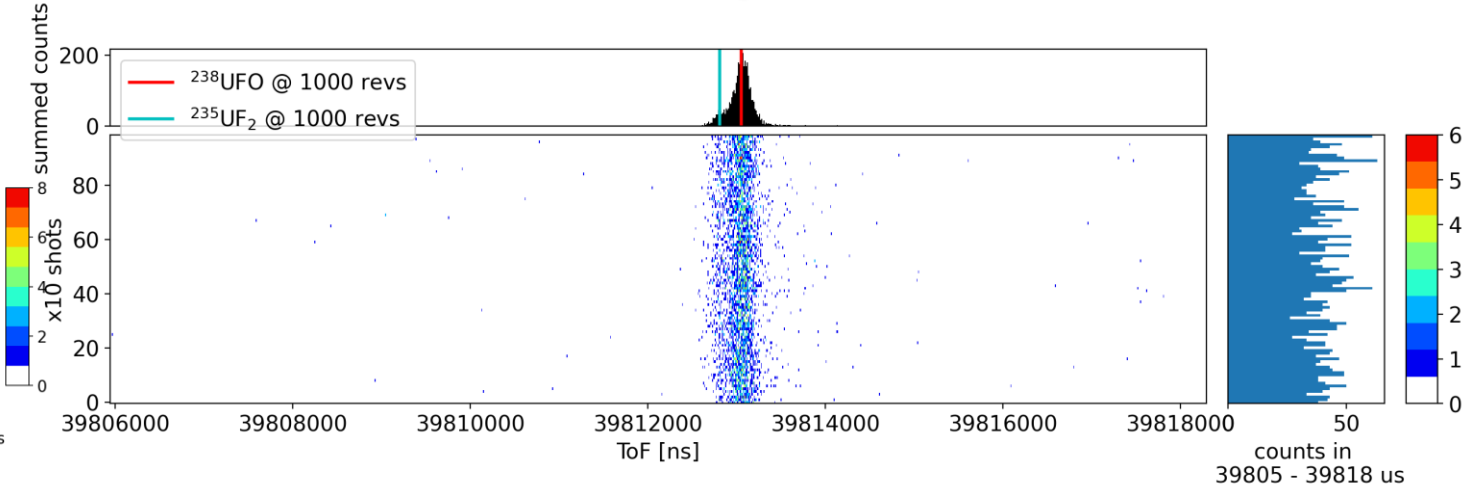


Decomposing mass spectra

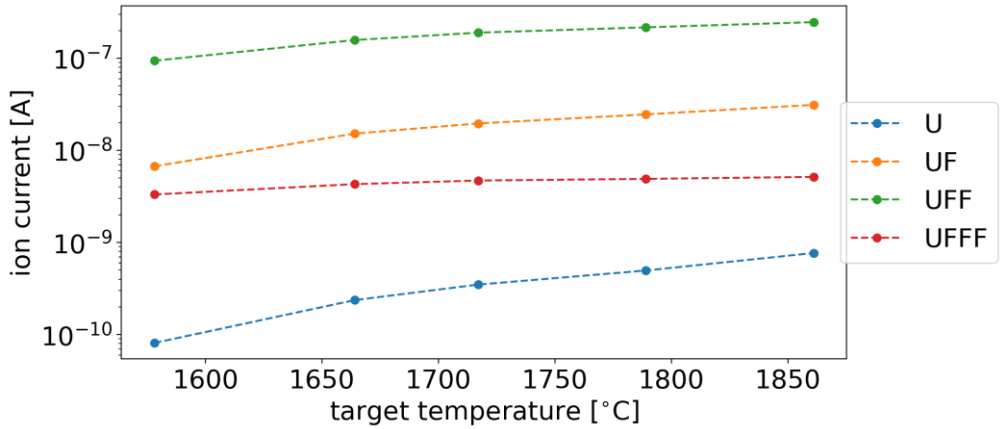


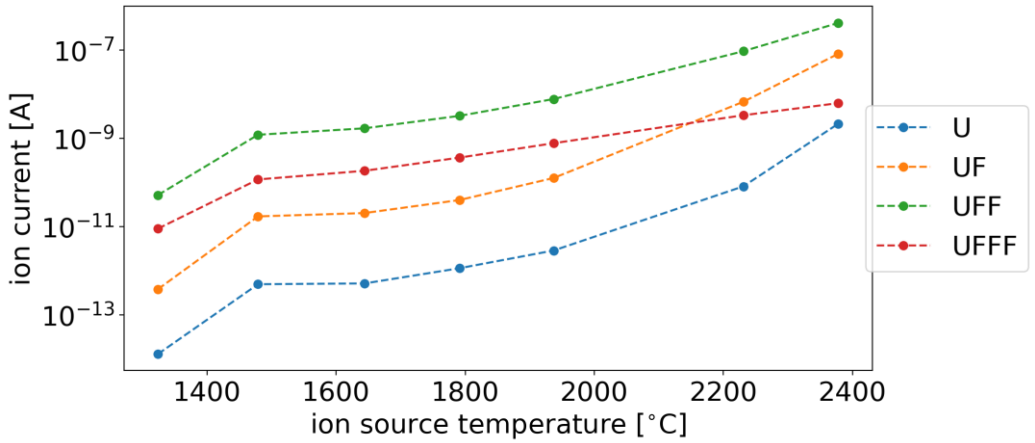


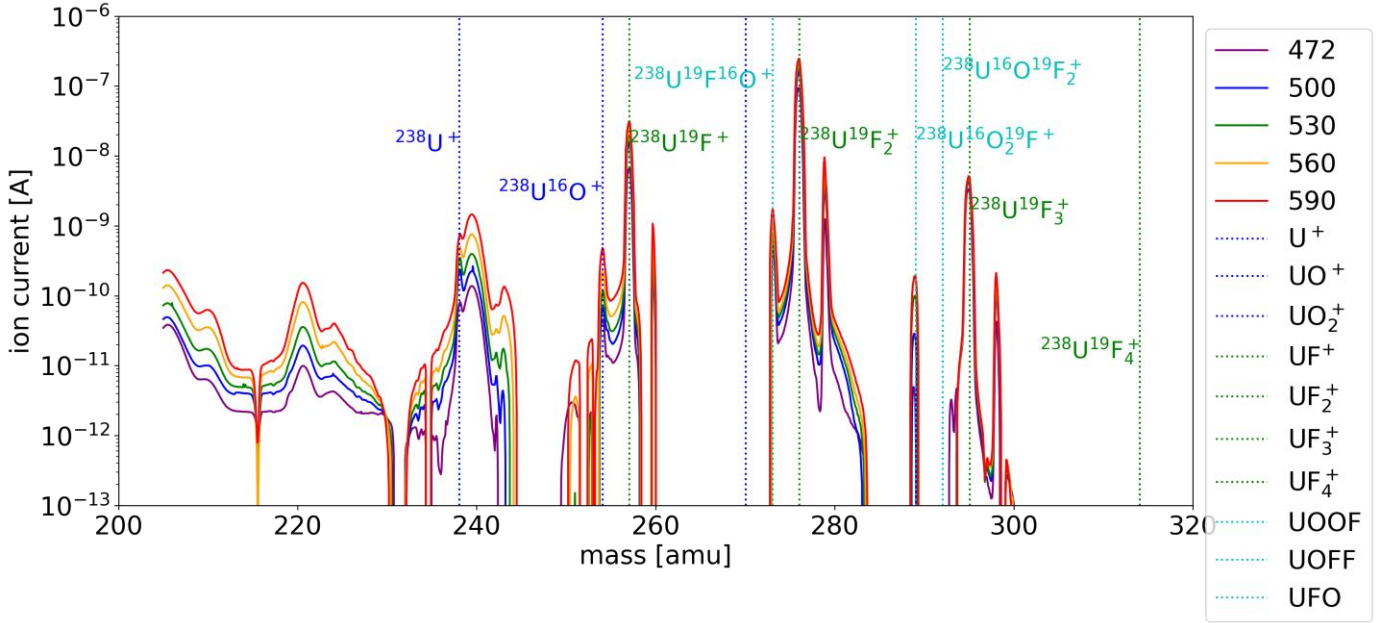


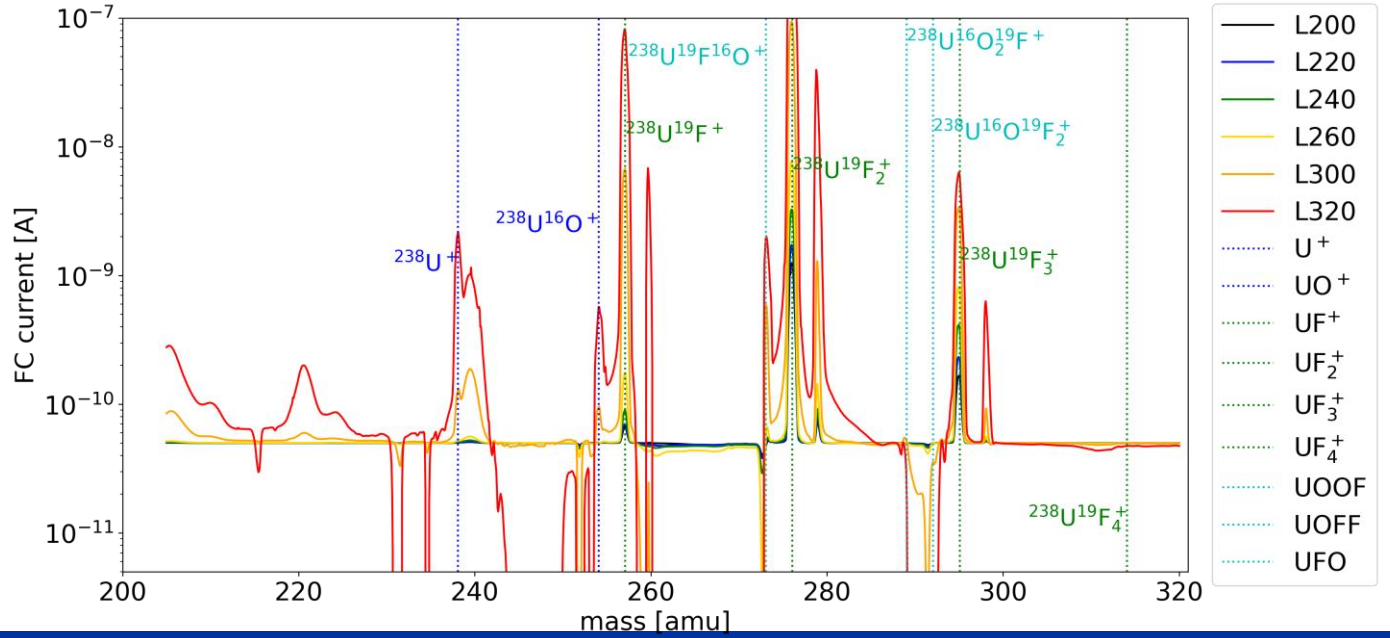


Target and ion source heating









Metastable molecular ions

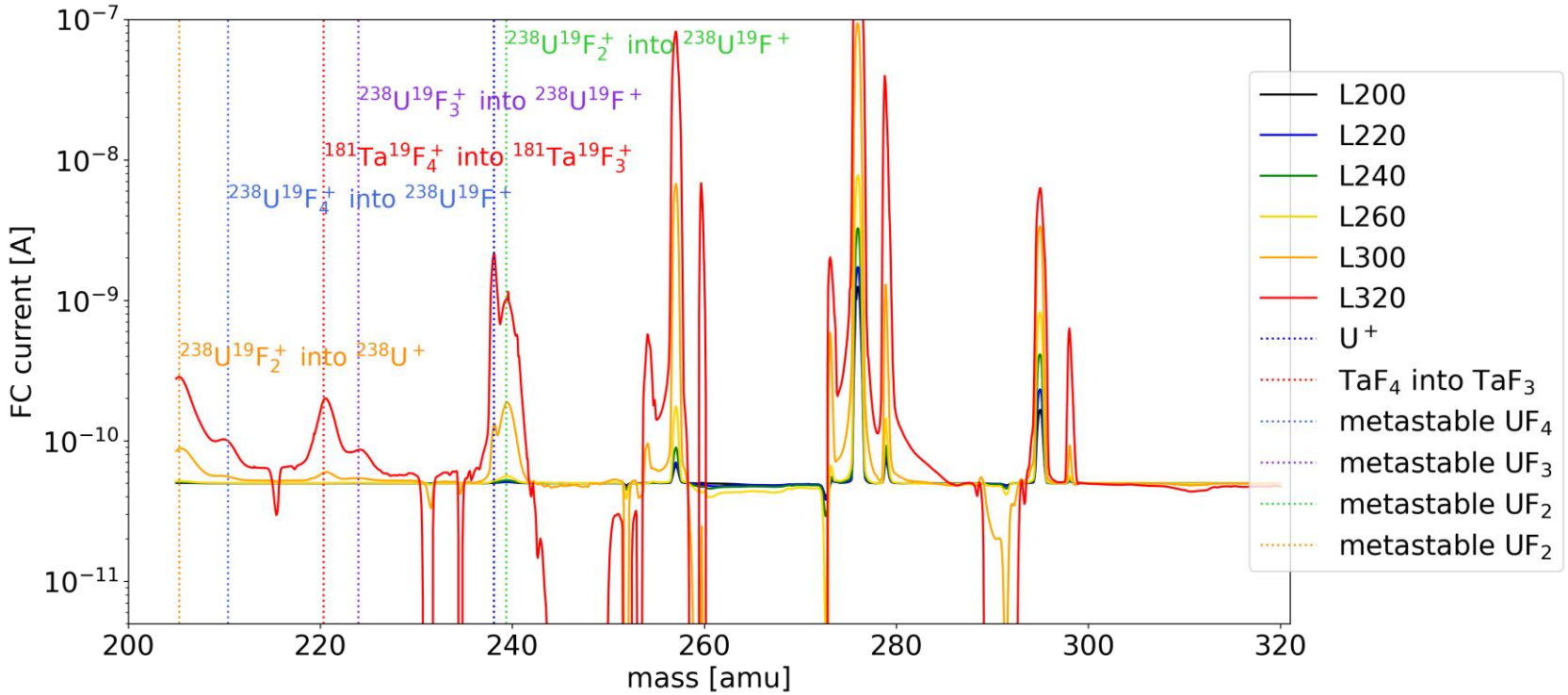
Dissociation **after** acceleration, **before** mass separation.

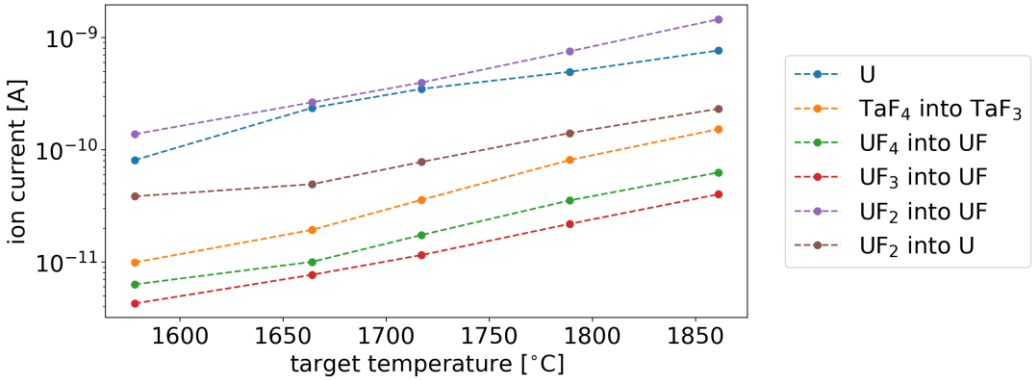
apparent mass: $m^* = \frac{m_f^2}{m_p}$

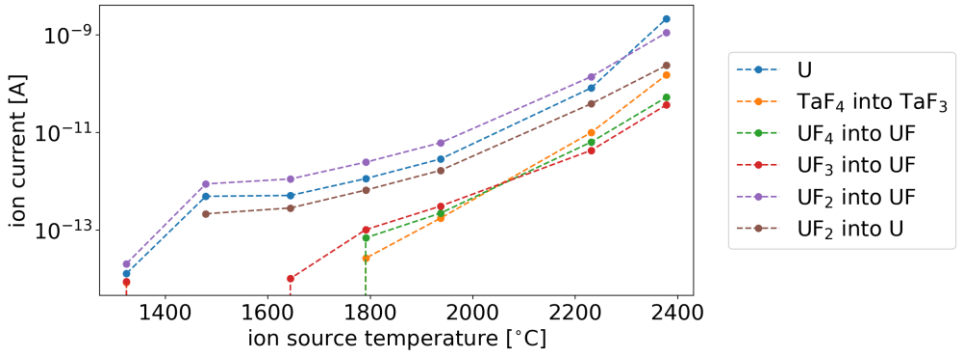
- m_f: mass of fragment ion
- m_p: mass of precursor ion

Ex: UF_2^+ into $UF^+ + F$

$$m^* = \frac{(238+19)^2}{238+2(19)} = 239.31$$

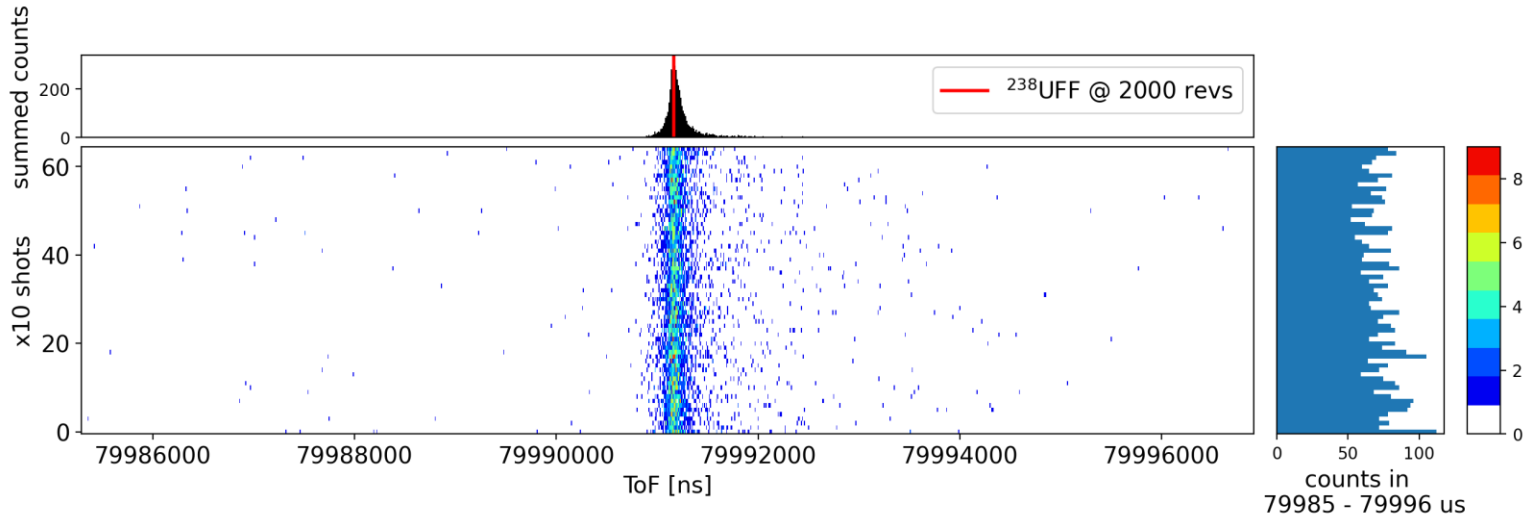


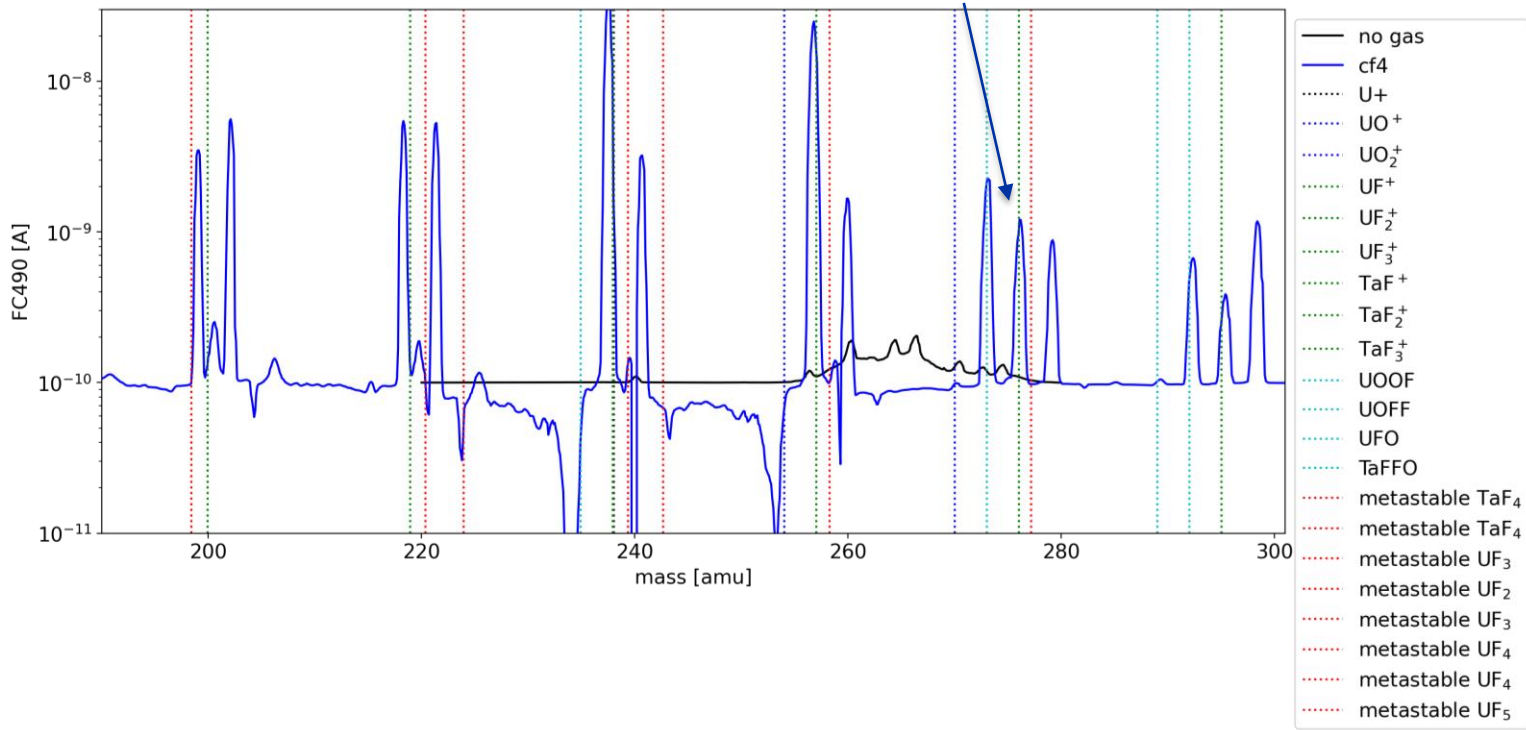




Plasma ionization

- High efficiency
- Low selectivity
- Dissociation

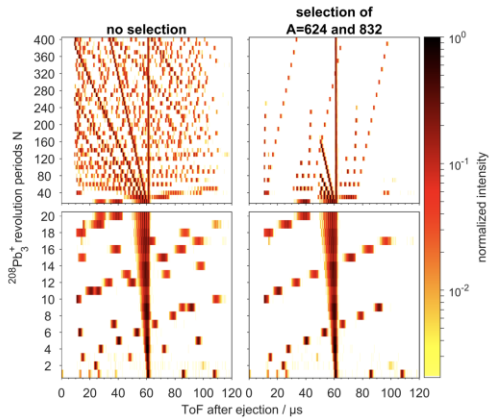




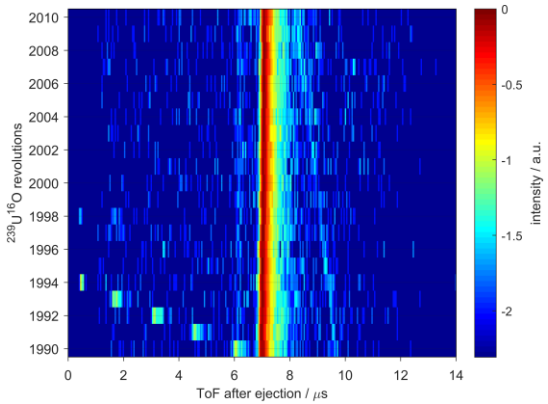
UF_x

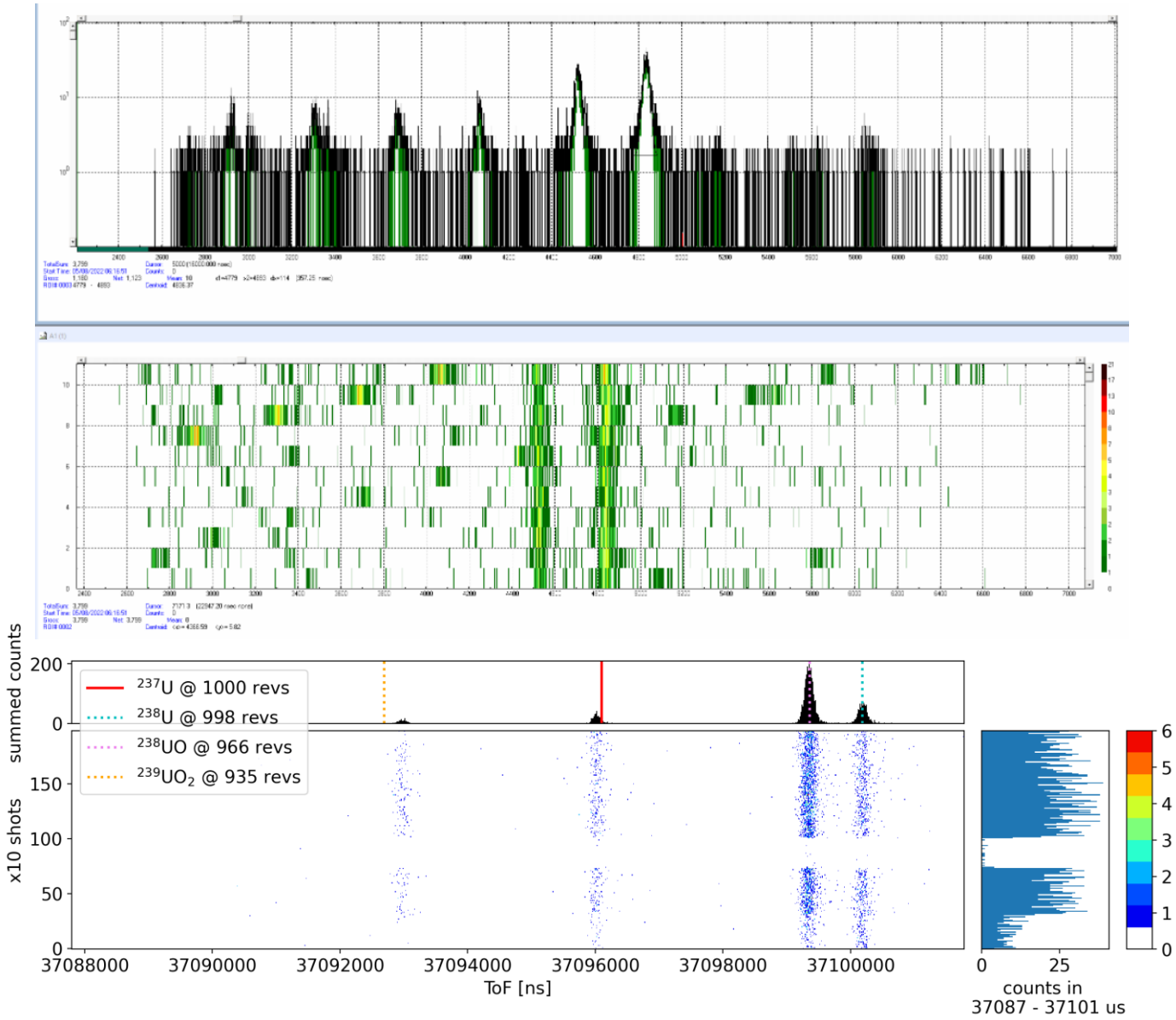
Target material

- ID by ToF and revs vs ToF
- Sideband populations



Fischer, Schweikhard (2020) Rev. Sci. Inst. **91**, 023201, *DOI 10.1063/1.5131582*





AcF_x

Ac

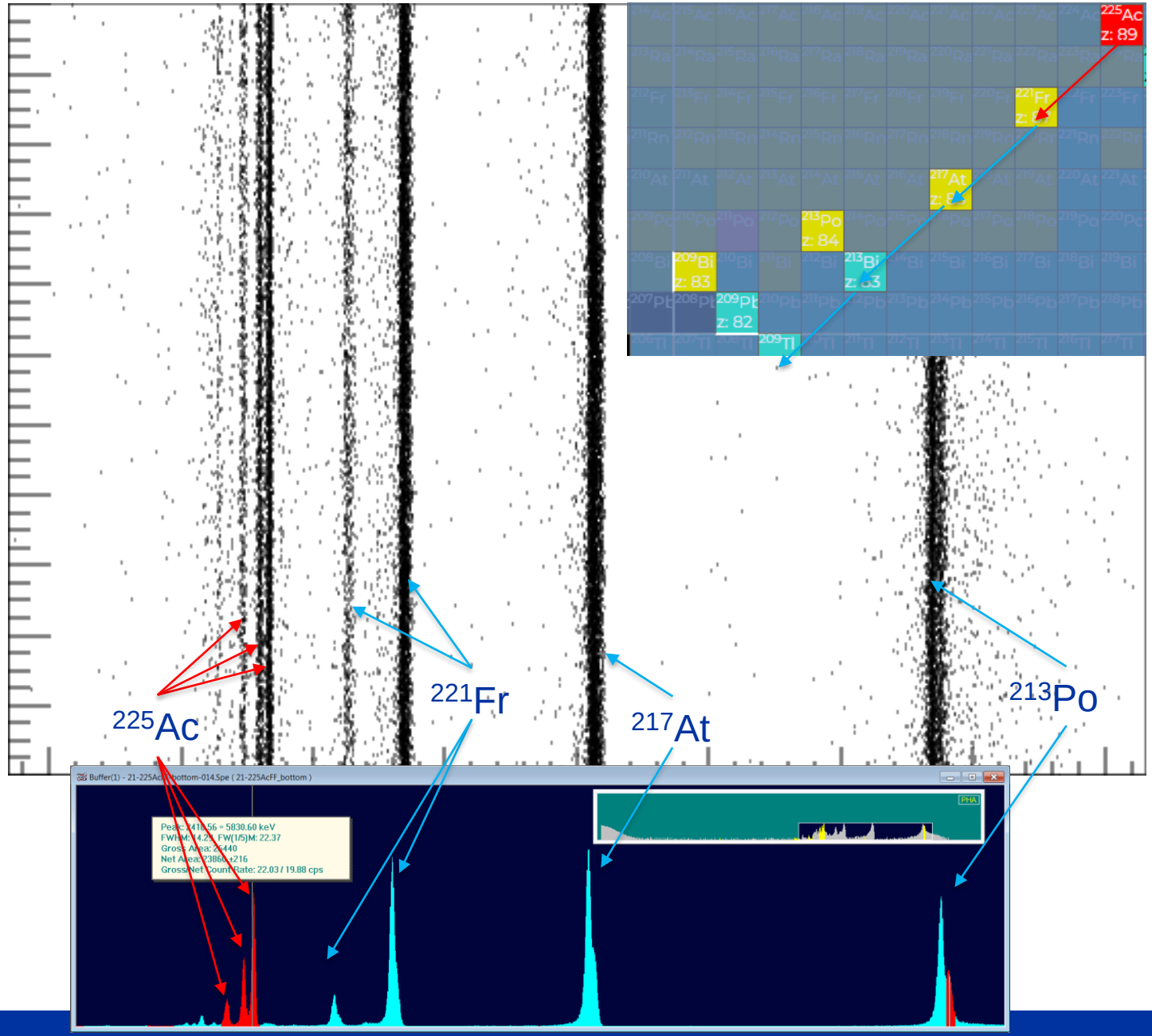
- Enhanced extraction

AcF

- Laser spectroscopy

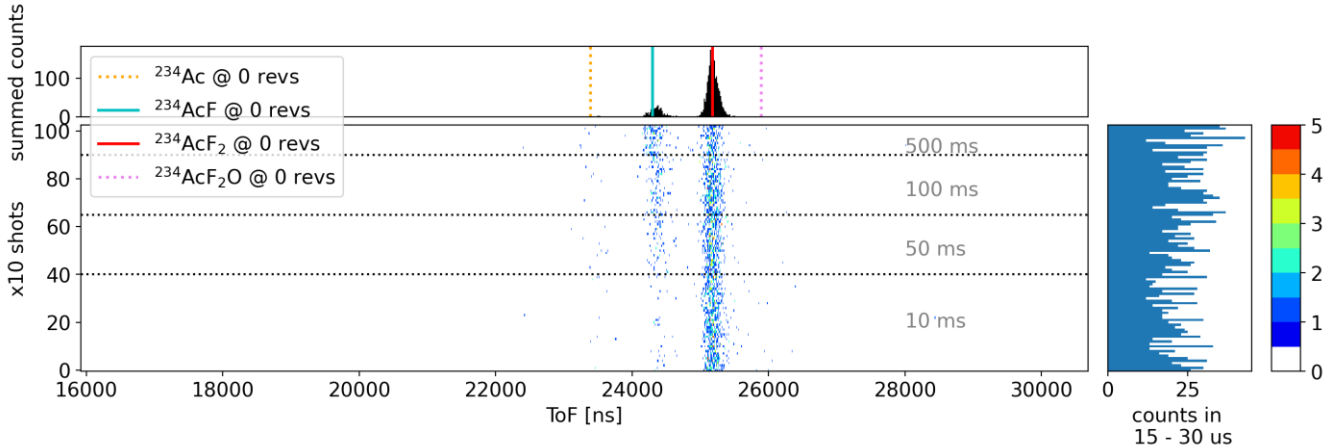
^{225}Ac

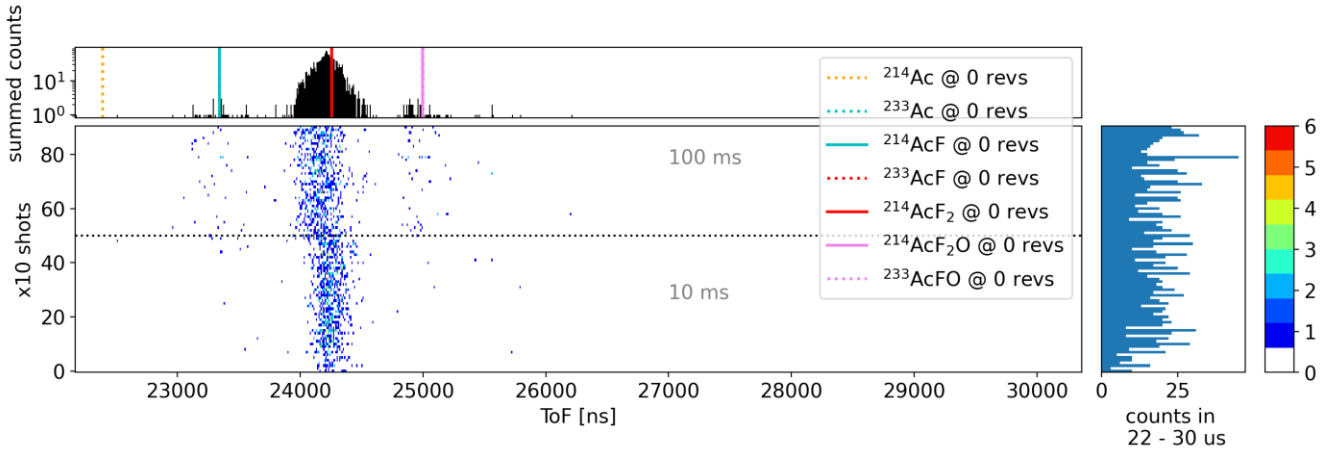
- Radiopharmaceutical “theranostic”
- Optimized production

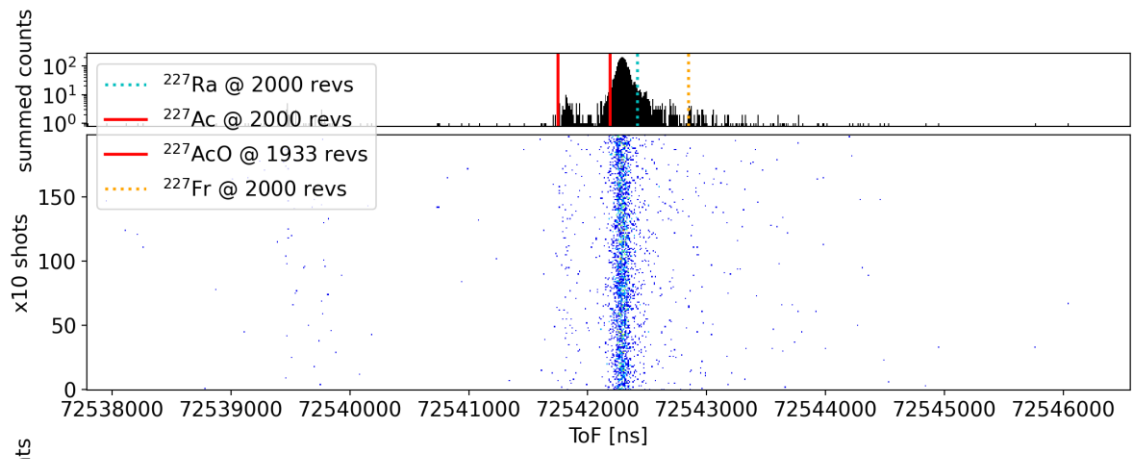


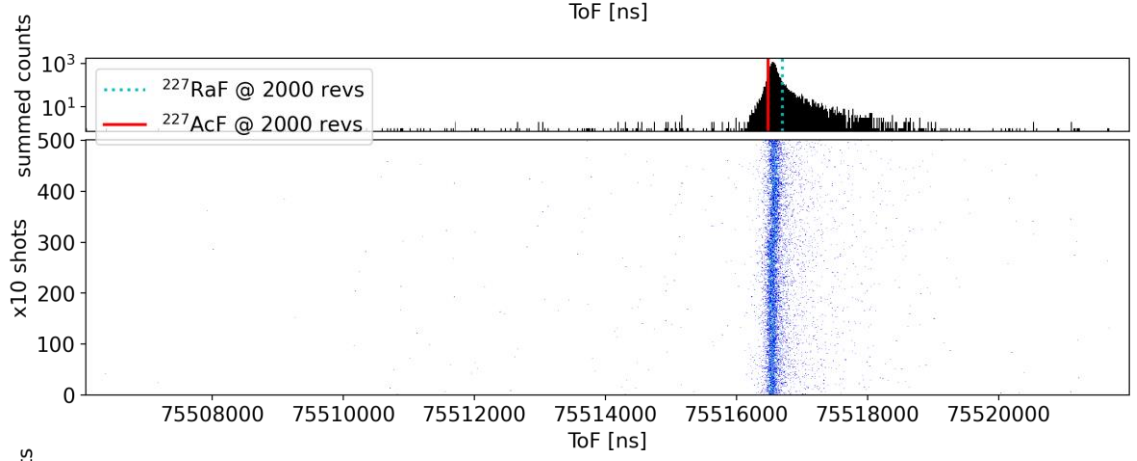
AcF_x

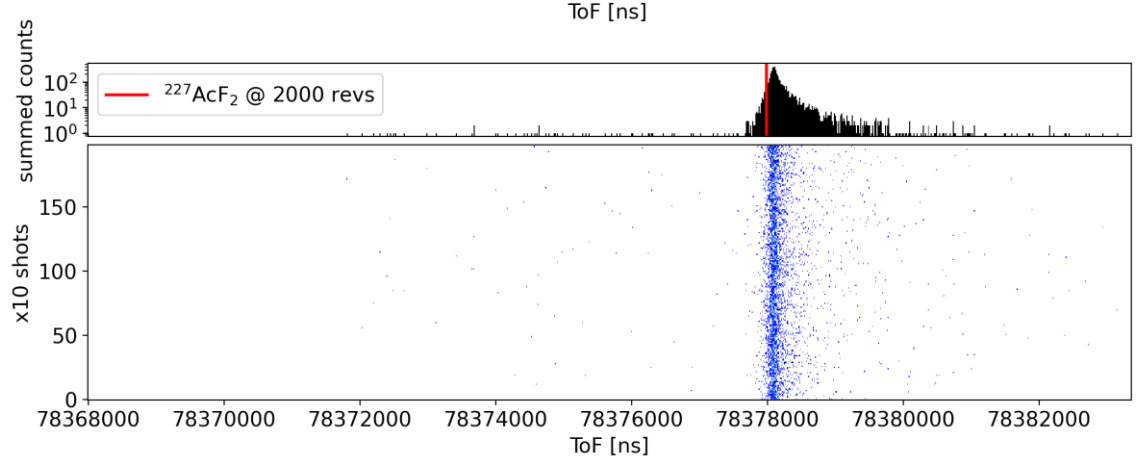
Ac^+, AcF^+, $AcFF^+$, $AcFO^+$











Conclusion

1. Surface ionized beam composition for actinide mass region
2. Metastable ions and dissociation
3. AcF_x production, identification and measurement
4. Outlook: NpF_x, AnF_x

Thank you!

Dinko Atanasov, Michail Athanasakis-Kaklamanakis, Jochen Ballof, Ermanno Barbero, Robert Berger, Mathieu Bovigny, Katerina Chrysalidis, Bernard Crepieux, James Cruikshank, Christoph Düllmann, Sarina Geldhof, Reinhard Heinke, Jake Johnson, Ulli Köster, David Leimbach, Edgars Mamis, Bruce Marsh, Maxime Mougeot, Lukas Nies, Bianca Reich, Jordan Reilly, Edgar Reis, Moritz Schlaich, Christoph Schweiger, Simon Stegemann, Yago Nel Vila Gracia, Julius Wessolek, Frank Wienholtz, Shane Wilkins, Wiktoria Wojtaczka, ISOLDE operations team, ISOLDE targets and ion sources team, Sebastian Rothe

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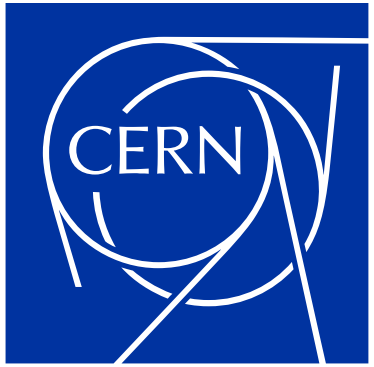

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