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MC-MICAP-MS: A New Era of Stable Isotope Mass Spectrometry

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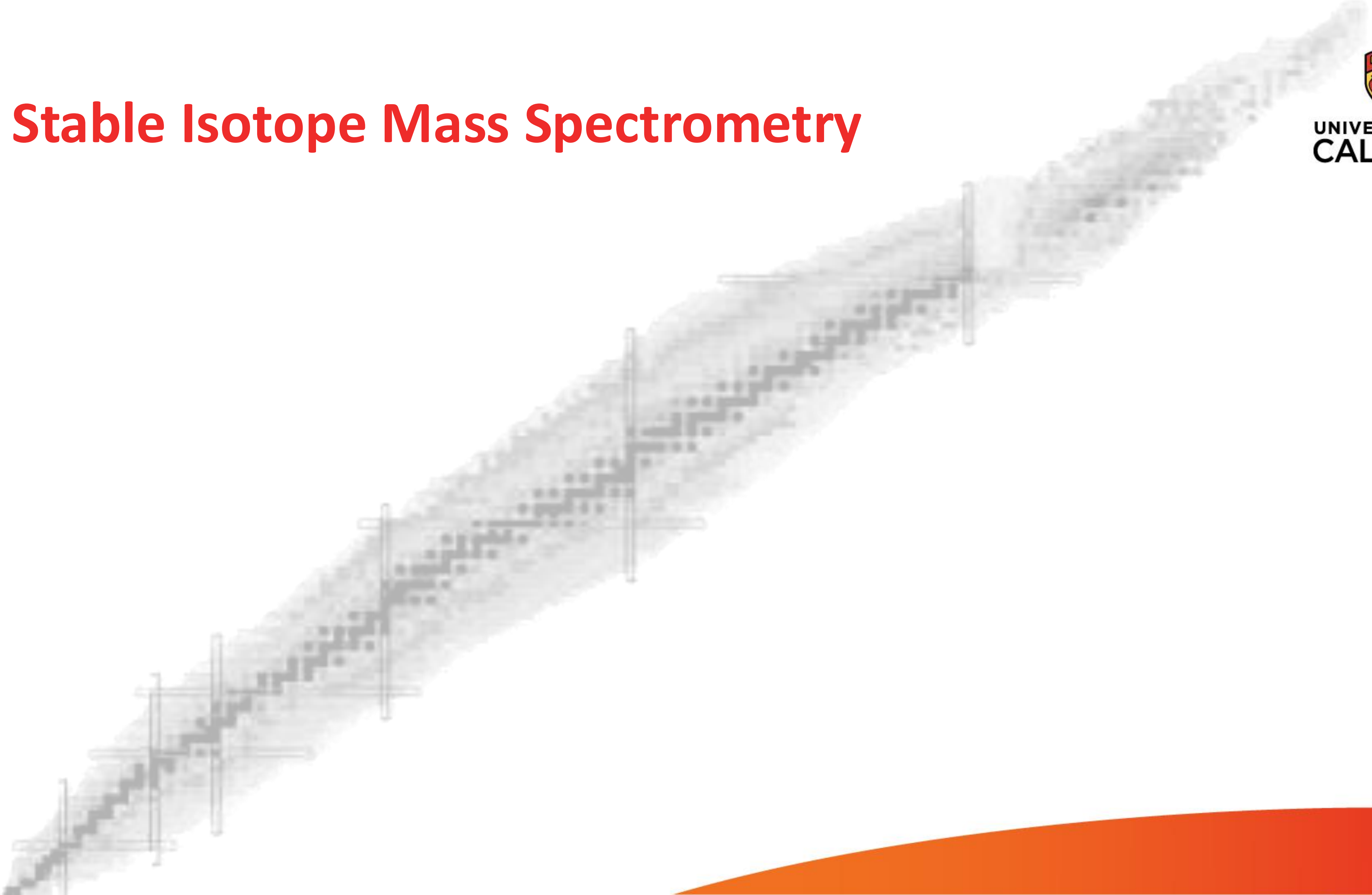
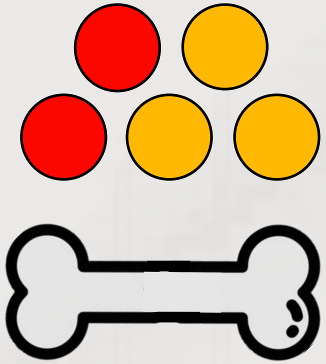
Stable Isotope Mass Spectrometry



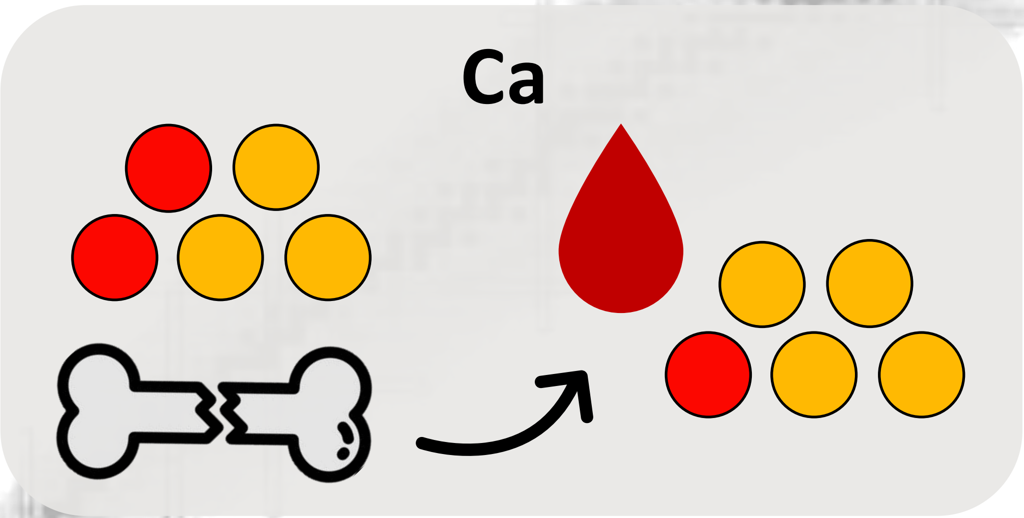
Stable Isotope Mass Spectrometry

Stable Isotope Mass Spectrometry

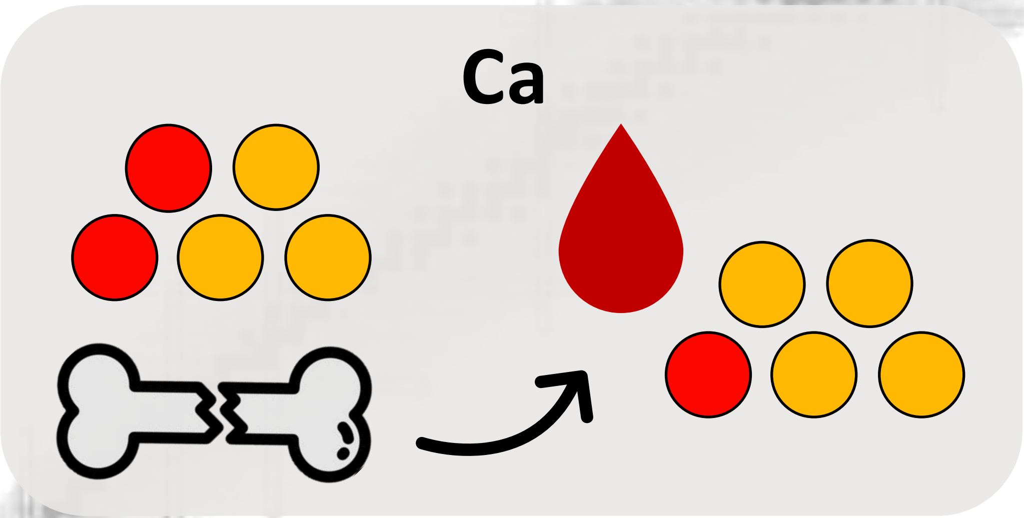
Ca

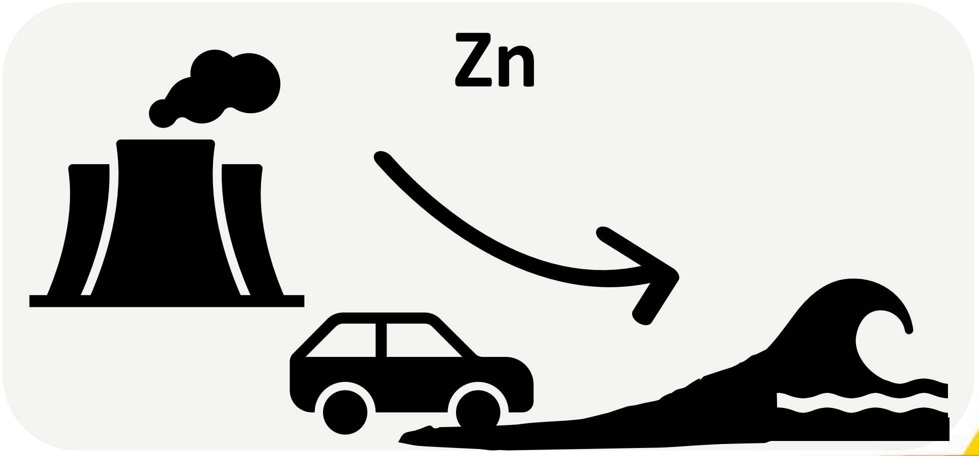


Stable Isotope Mass Spectrometry



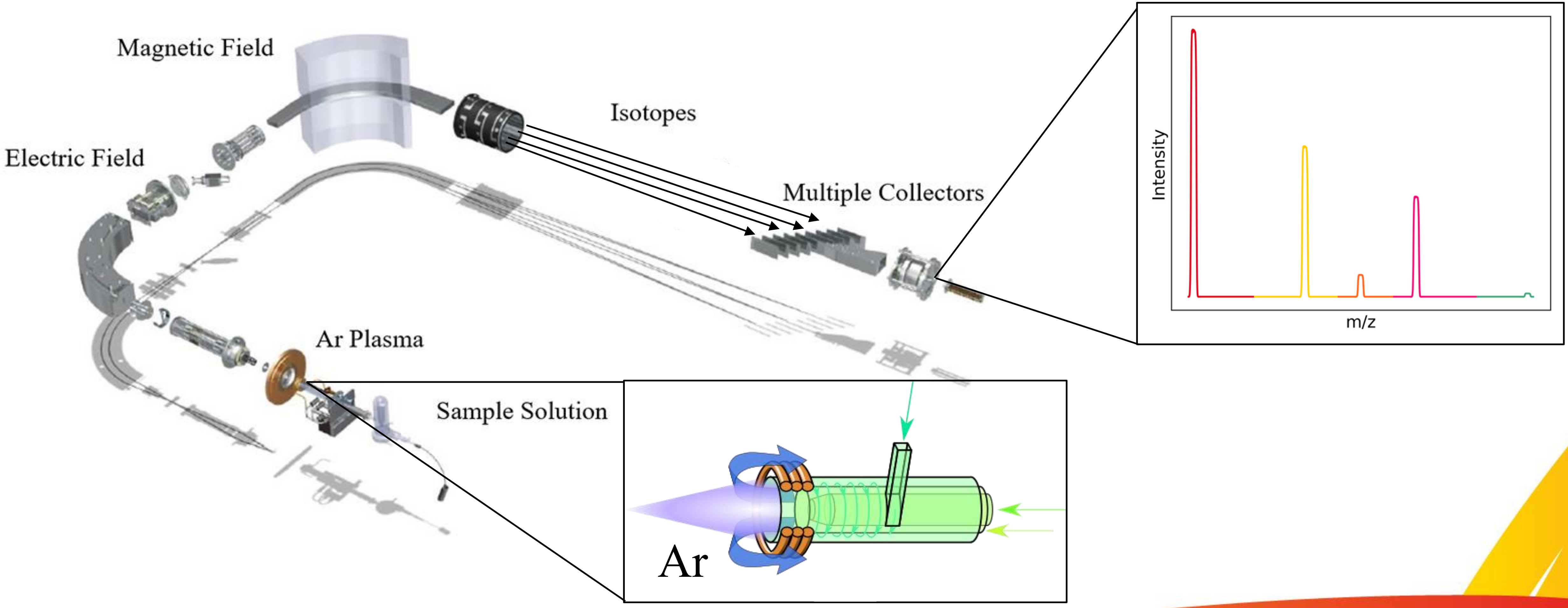
Stable Isotope Mass Spectrometry





Conventional Measurements: MC-ICP-MS

Multiple collector inductively coupled plasma mass spectrometry



MC-ICP-MS Limitations

Isotopes measured with MC-ICP-MS

H																	He
Li	Be											**B**	**C**	N	**O**	F	Ne
Na	**Mg**											Al	**Si**	P	**S**	**Cl**	Ar
K	**Ca**	Sc	**Ti**	**V**	**Cr**	Mn	**Fe**	Co	**Ni**	**Cu**	**Zn**	**Ga**	**Ge**	As	**Se**	**Br**	Kr
Rb	**Sr**	Y	**Zr**	Nb	**Mo**	Tc	**Ru**	Rh	**Pd**	**Ag**	**Cd**	**In**	**Sn**	**Sb**	**Te**	**I**	Xe
Cs	**Ba**		**Hf**	**Ta**	**W**	**Re**	**Os**	**Ir**	**Pt**	Au	**Hg**	**Tl**	**Pb**	Bi	Po	At	Rn
Fr	**Ra**		Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og
		La	**Ce**	Pr	**Nd**	Pm	**Sm**	**Eu**	**Gd**	Tb	**Dy**	Ho	**Er**	Tm	**Yb**	**Lu**	
		Ac	**Th**	Pa	**U**	Np	**Pu**	**Am**	**Cm**	Bk	**Cf**	Es	Fm	Md	No	Lr	

MC-ICP-MS Limitations

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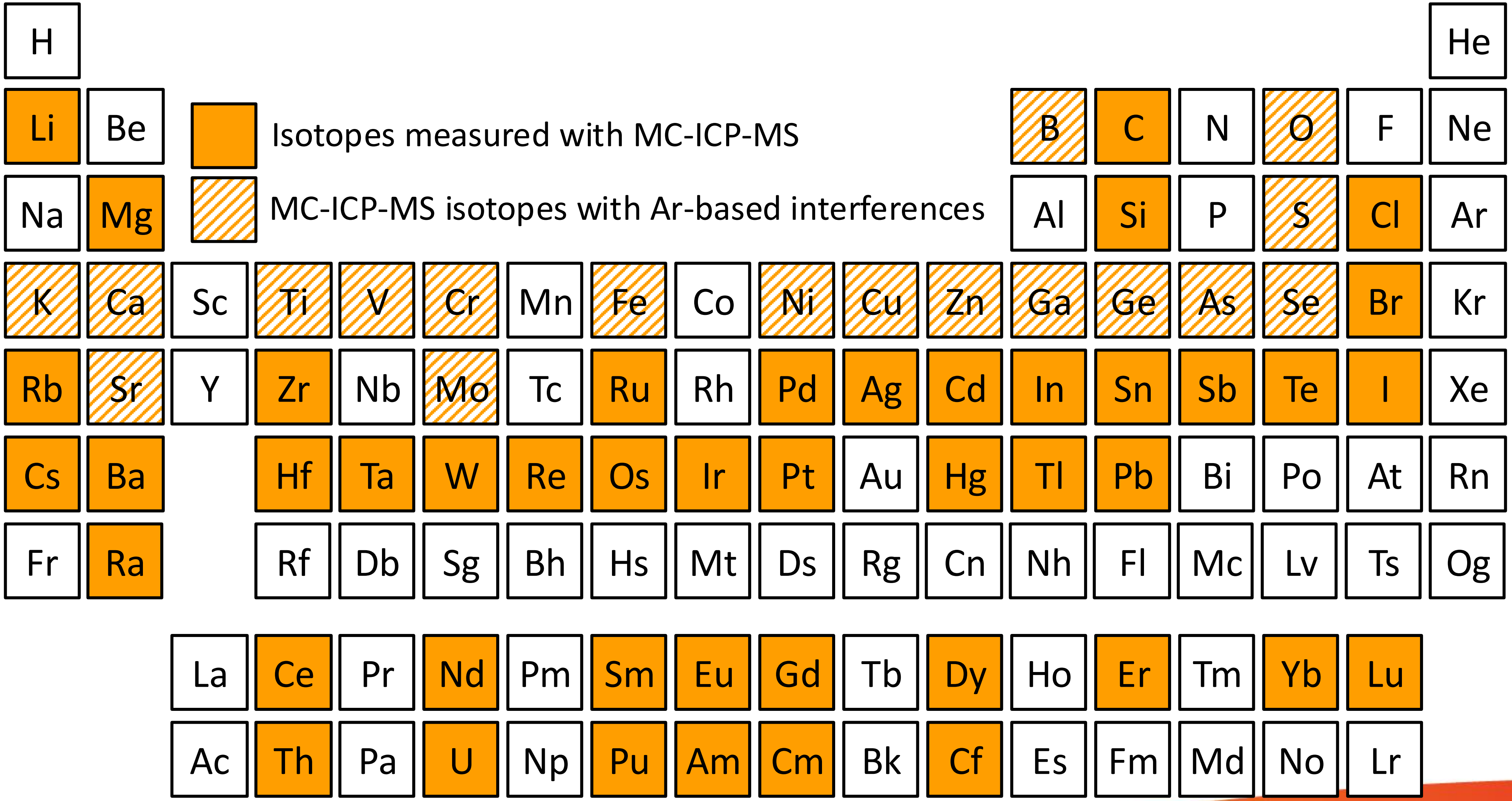
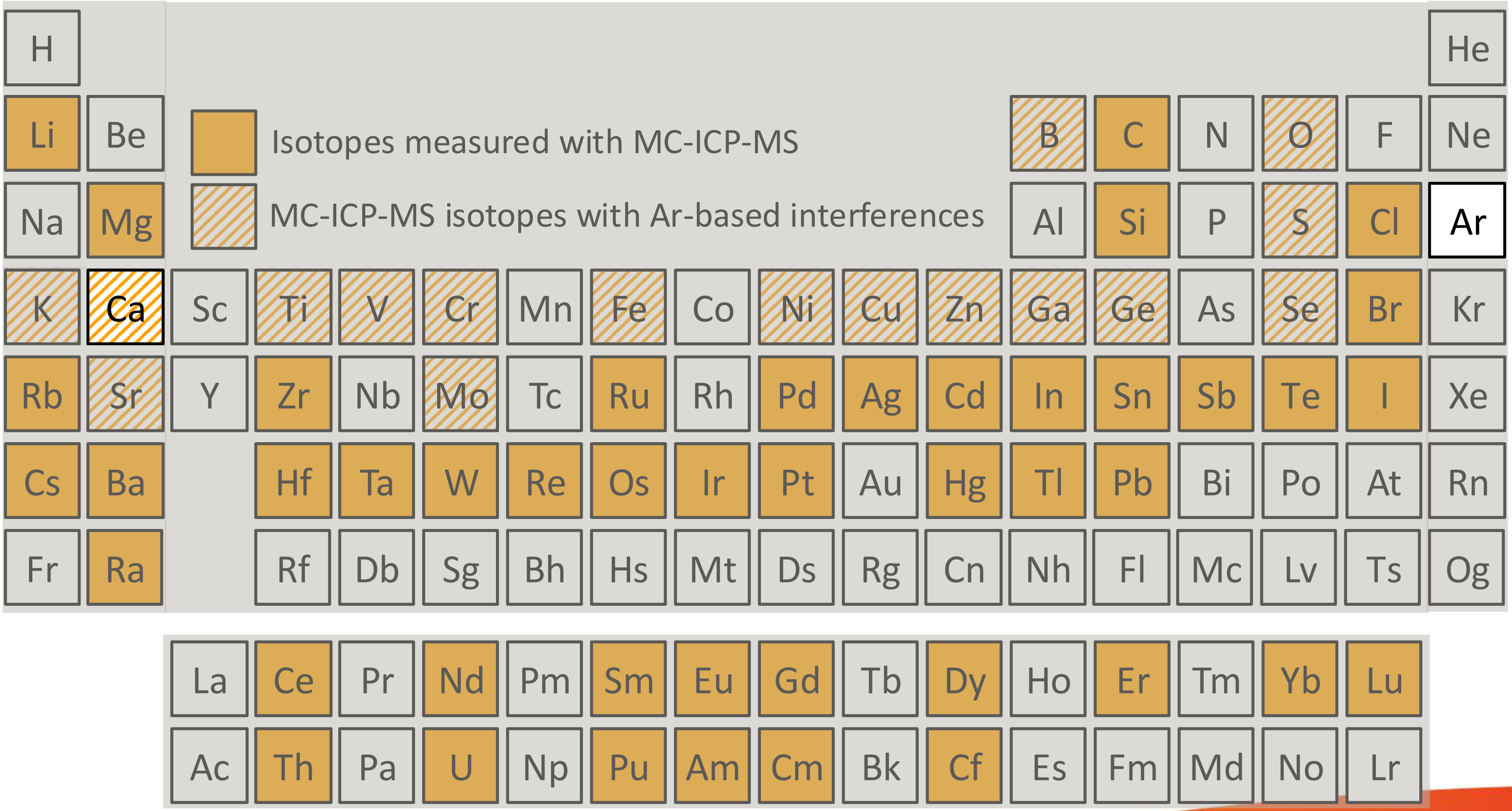
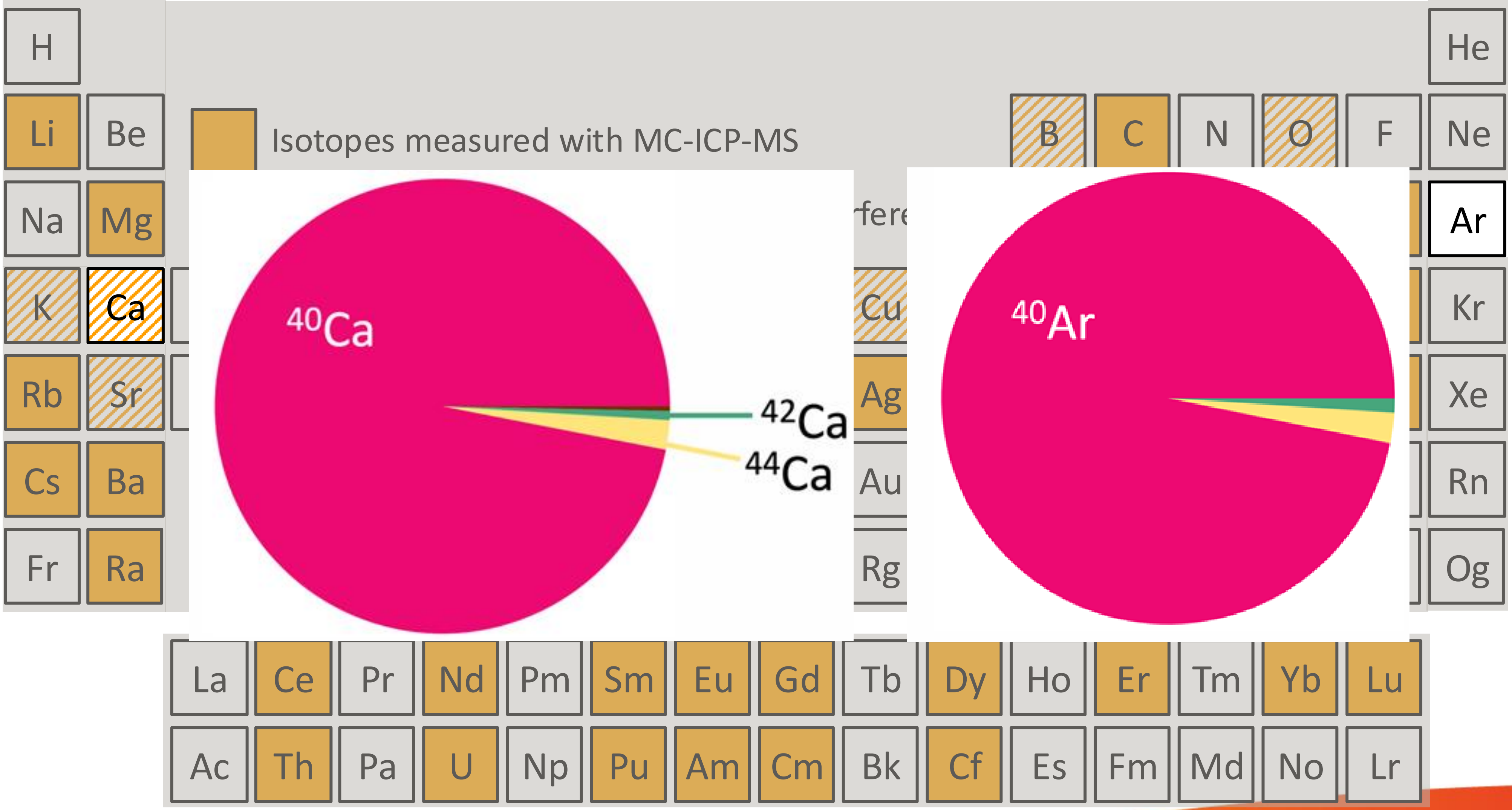


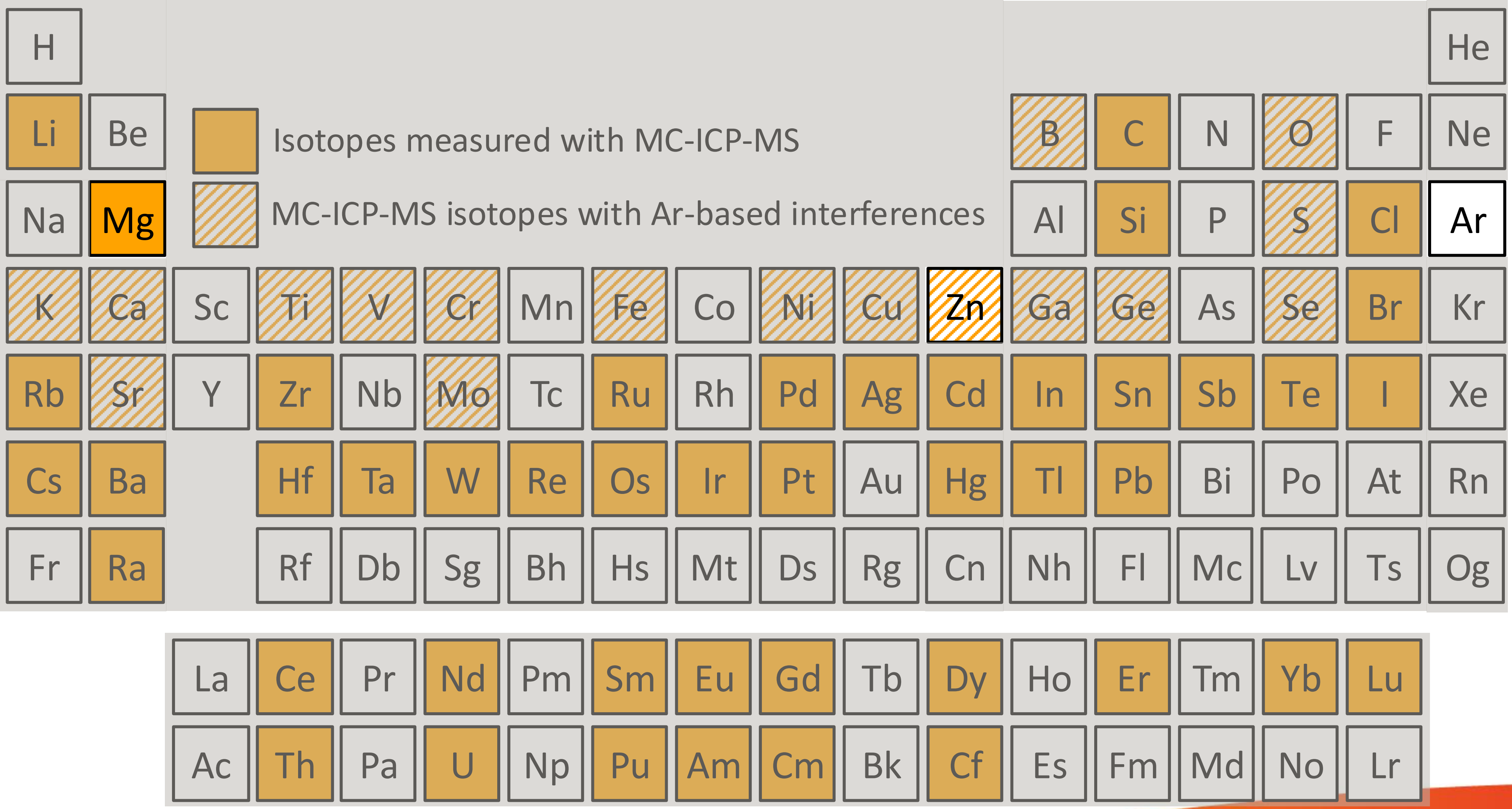
MC-ICP-MS Limitations



MC-ICP-MS Limitations

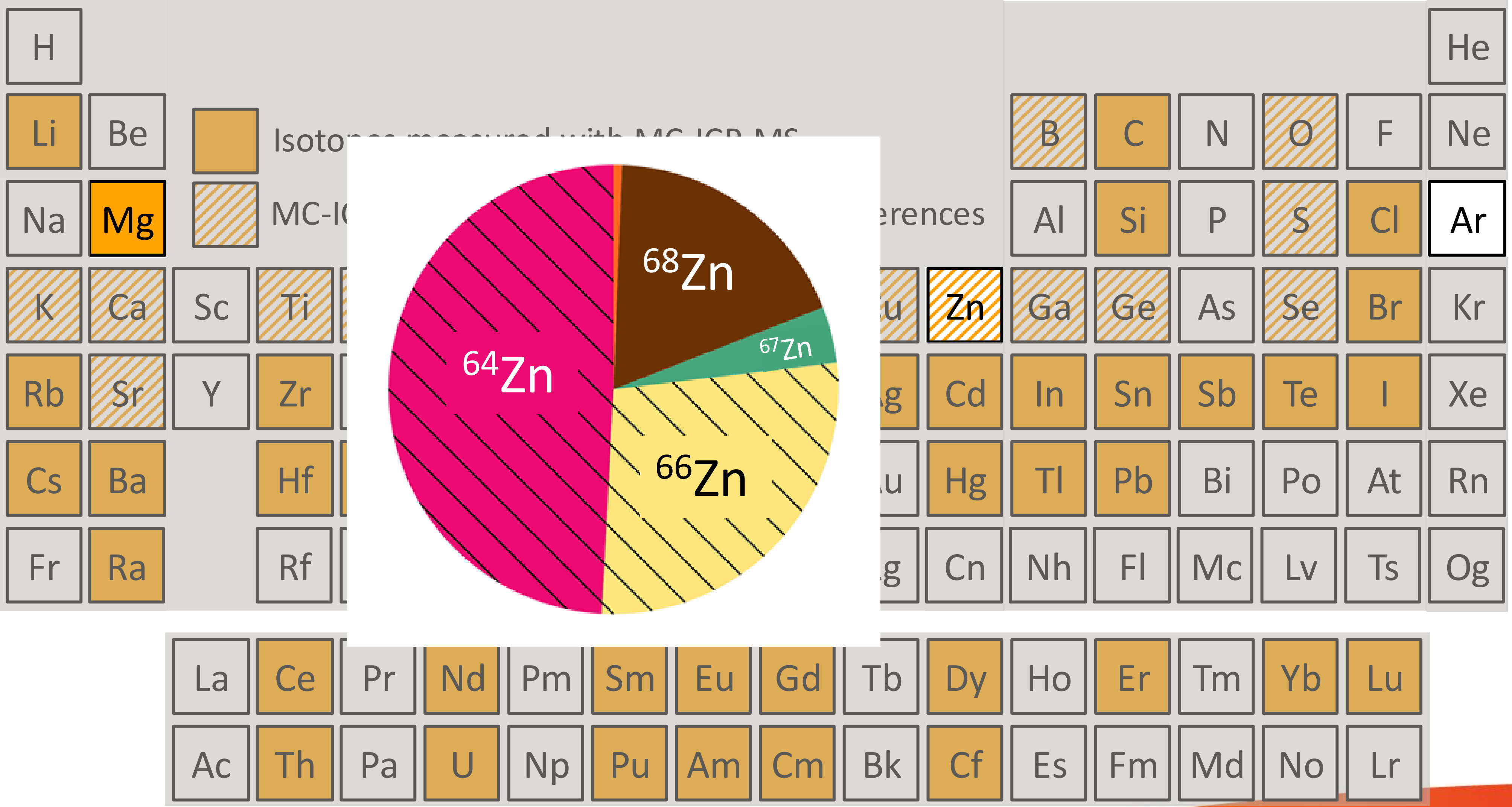


MC-ICP-MS Limitations



ArMg⁺ interference

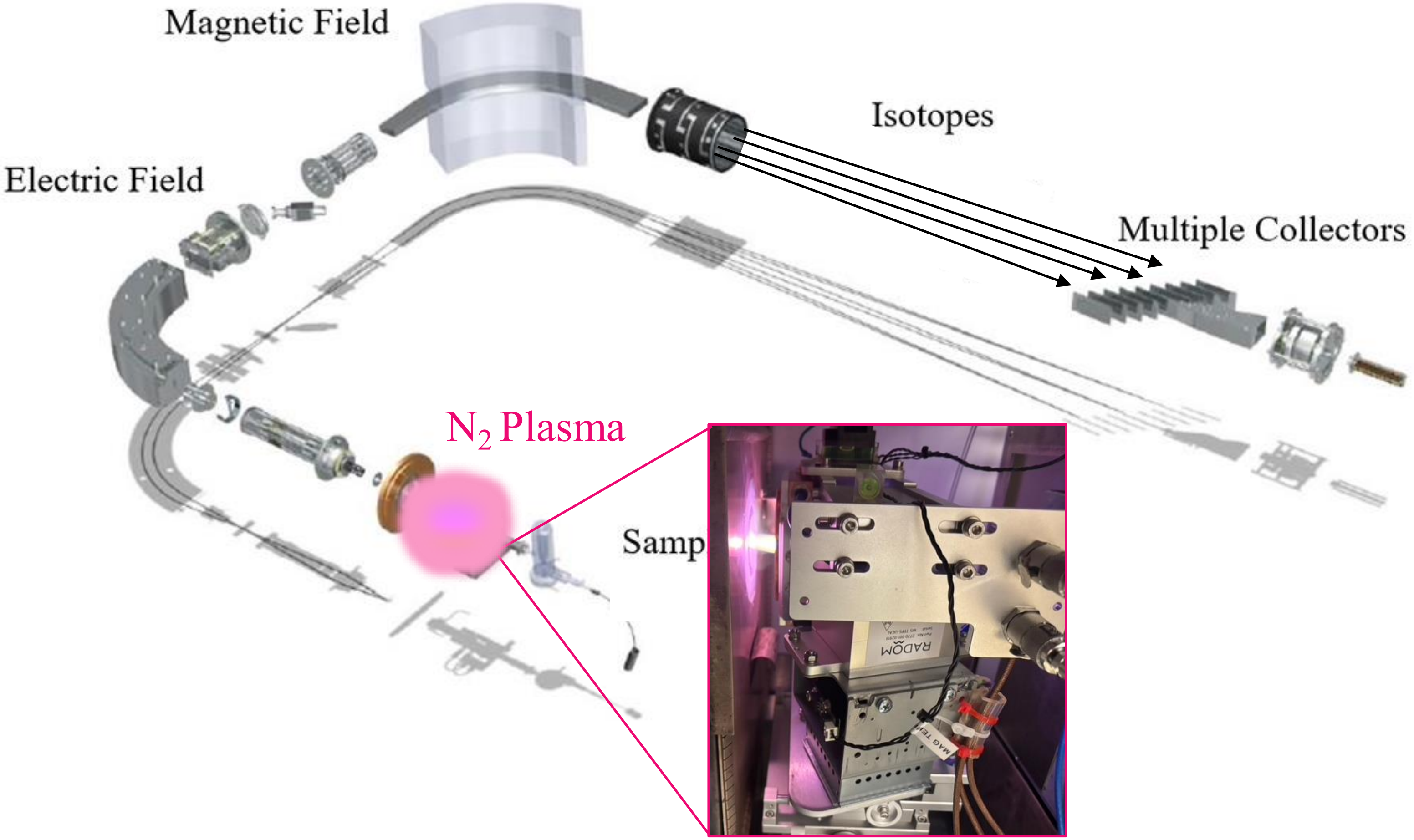
MC-ICP-MS Limitations



ArMg$^+$ interference

MC-MICAP-MS

Multiple collector microwave inductively coupled atmospheric plasma mass spectrometry

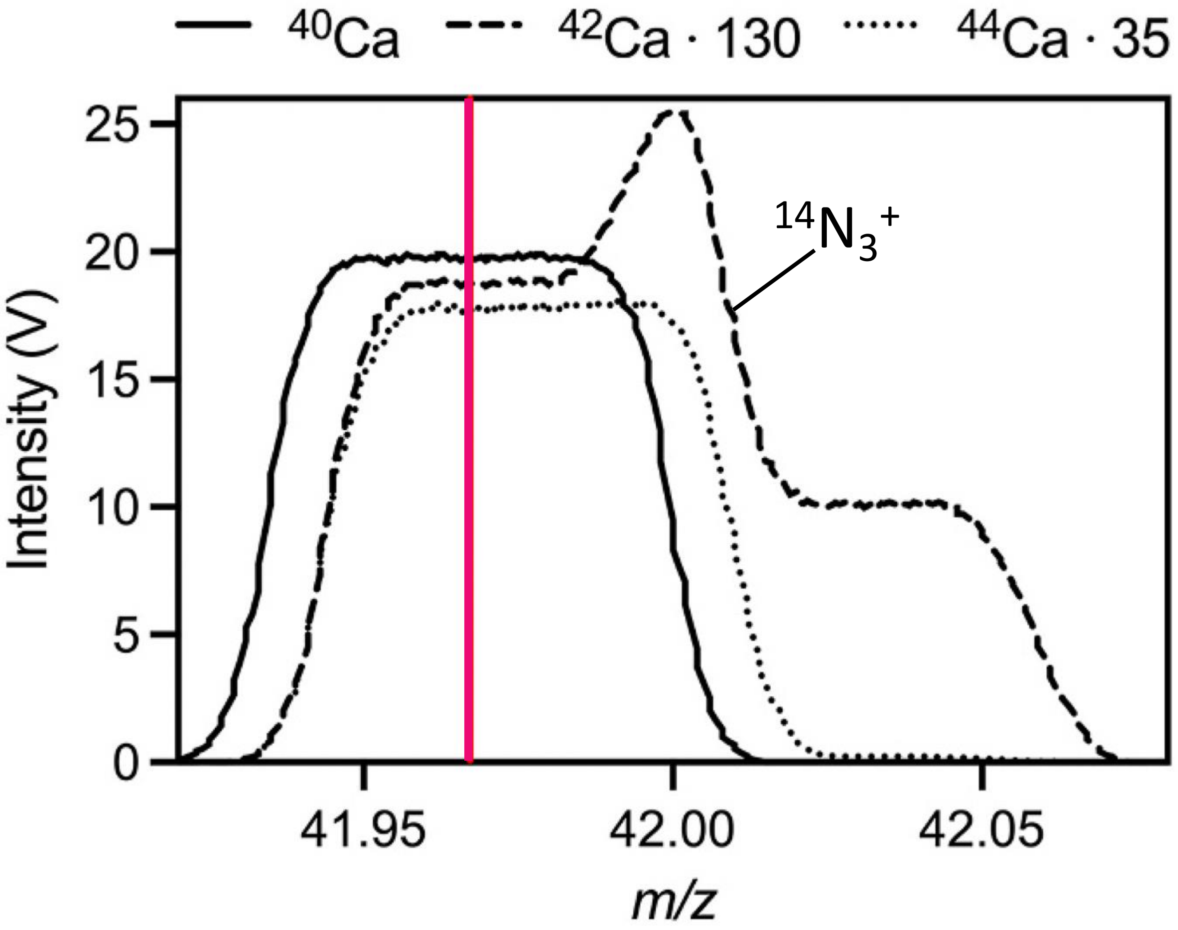


MICAP
Microwave Inductively Coupled Atmospheric Plasma

Retzmann, A., Menon, A. & Wieser, M. E. Introducing MC-MICAP-MS: using a N2-based plasma ion source for Sr isotope abundance ratio measurements. *Journal of Analytical Atomic Spectrometry* **40**, 2803–2815 (2025).

MC-MICAP-MS: Ca Measurements

Work of Anika Retzmann



MC-ICP-MS
≤0.20 ‰

$\delta^{44/42}$ Ca, 2SD

MC-MICAP-MS
≤0.10 ‰

$\delta^{44/40}$ Ca, 2SD

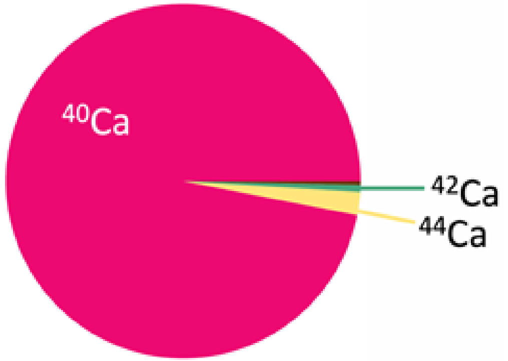
$$\delta^{a/b}\mathrm{Ca}[‰] = \left(\frac{r^{a/b\ \mathrm{Ca}}_{\mathrm{sample}}}{r^{a/b\ \mathrm{Ca}}_{\mathrm{standard,\ avg}}} - 1\right)1000$$

Retzmann, A. & Wieser, M. E. Advancing Ca isotopic analysis: Direct measurement of 44Ca/40Ca isotopic composition by MC-MICAP-MS with nitrogen plasma. *Analytica Chimica Acta* 344865 (2025).

MC-MICAP-MS: Ca Next Steps

Ca analysis of biological samples

$\delta^{44/42}$Ca, ICP	$\delta^{44/40}$Ca, MICAP
• Human blood, urine, and feces Ca composition • Yet-to-be disentangled confounding factors	• Human toenail Ca composition • Higher abundance isotope and larger mass difference • **Potential as early and non-invasive bone turnover monitor**



MC-ICP-MS vs MC-MICAP-MS

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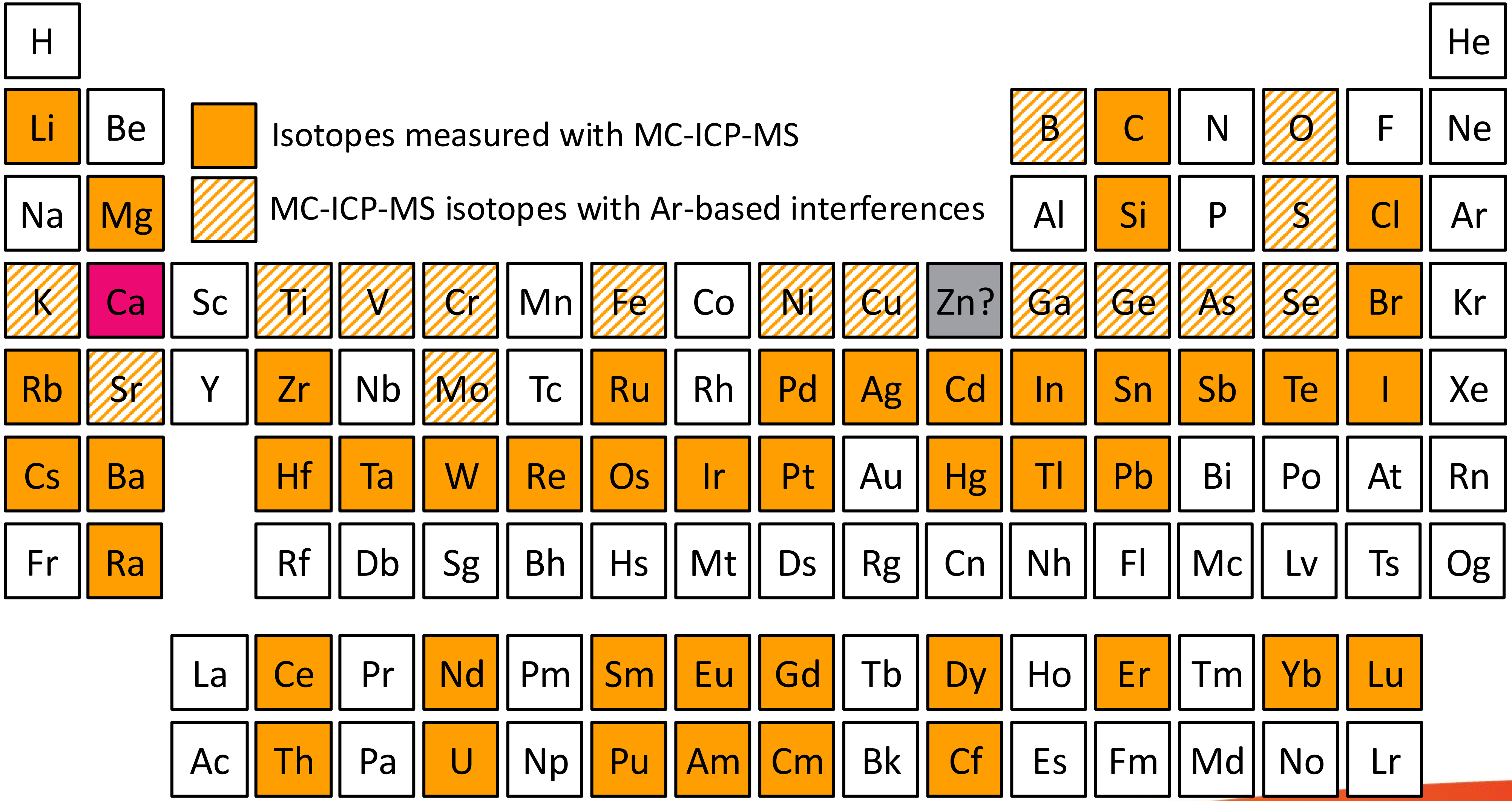
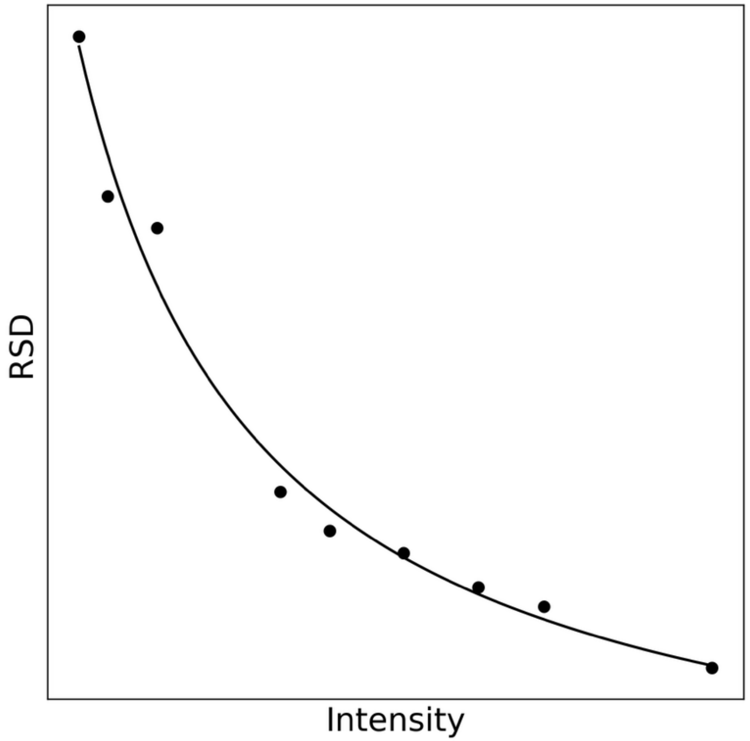


MC-MICAP-MS: Zn Measurements

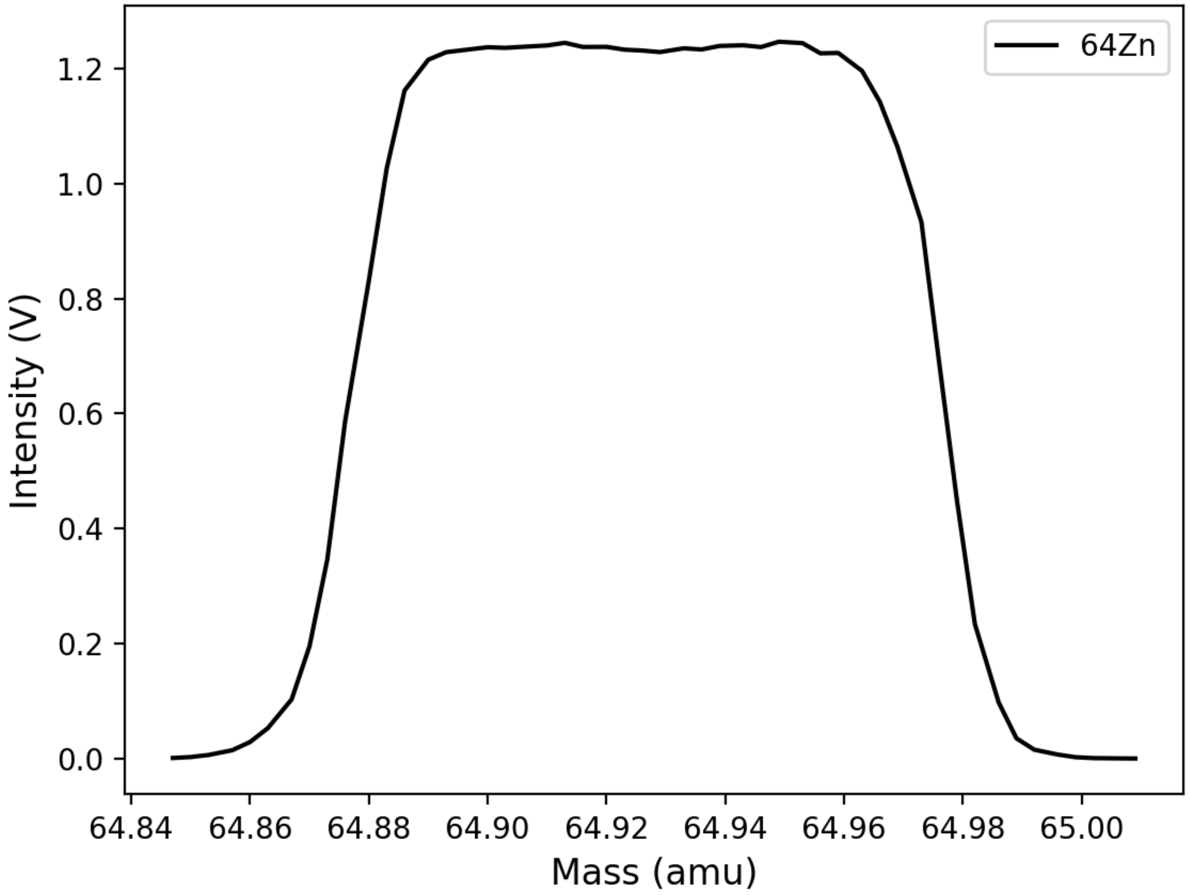
Challenge: high first ionization energy

Ca 6.113 eV	Zn 9.394 eV	NO 9.264 eV



MICAP: lower plasma temperature

MC-MICAP-MS: Zn Measurements



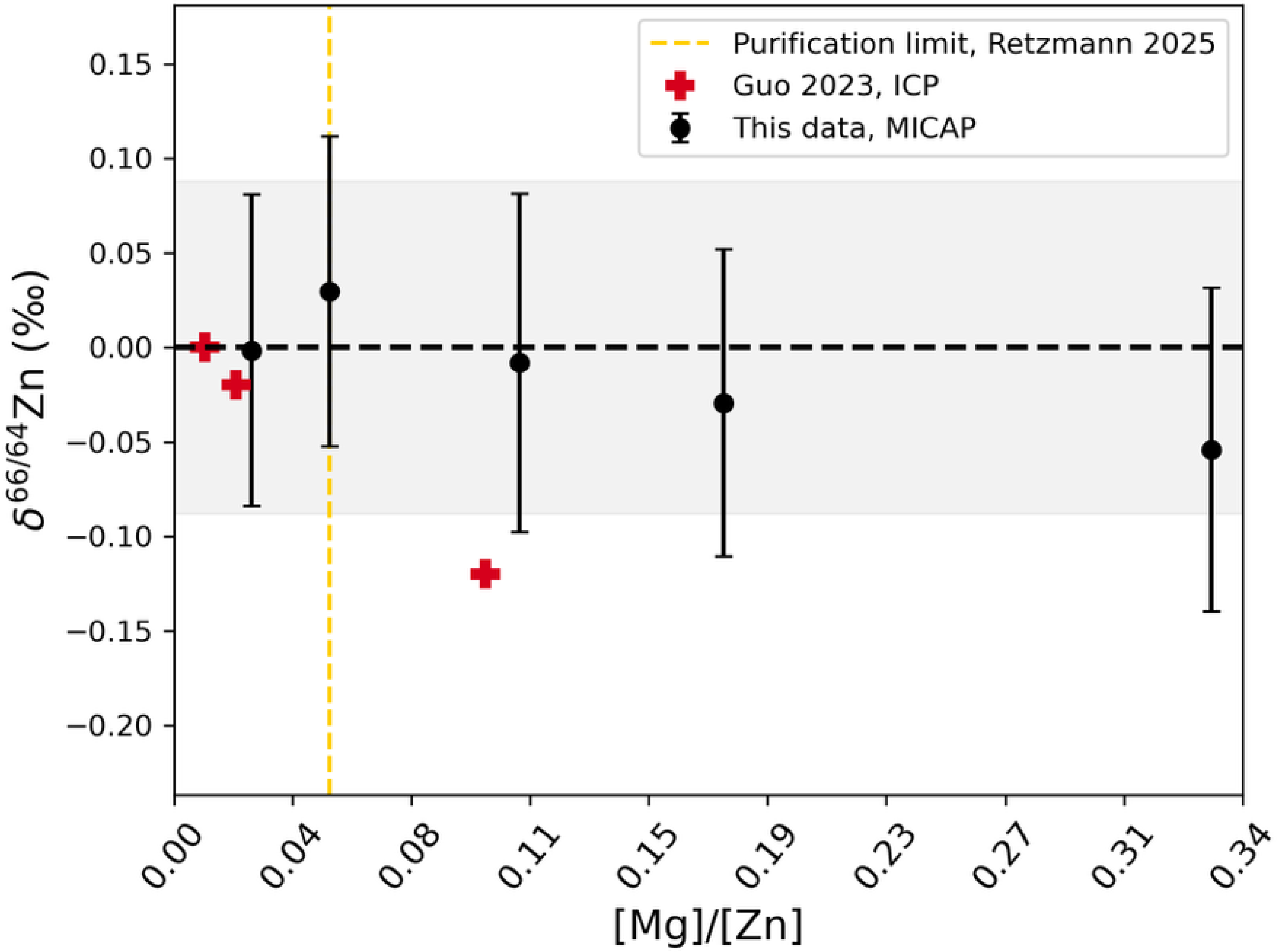
High stability

Factor of 3-5 **intensity reduction** compared to ICP source

MC-ICP-MS	MC-MICAP-MS
0.04 – 0.07 ‰	0.09 ‰

$\delta^{66/64}$ Zn, 2SD

MC-MICAP-MS: Zn Measurements



No Mg impact on Zn isotope ratio determination

$$\delta^{a/b}\mathrm{Zn}[‰] = \left(\frac{r^{a/b\,\mathrm{Zn}}_{\mathrm{sample}}}{r^{a/b\,\mathrm{Zn}}_{\mathrm{standard,\,avg}}} - 1 \right) 1000$$

Summary

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- Precision stable isotope mass spectrometry can provide **insight into subtleties of biological and physical processes**

- MC-MICAP-MS **enhances opportunities for applications of Ca isotope abundance ratio analysis** in medicine by enabling the observation of magnified fractionation effects

- MC-MICAP-MS is **ideal for high-Mg Zn isotope abundance measurements** and produces comparable quality Zn measurements of purified solutions to MC-ICP-MS

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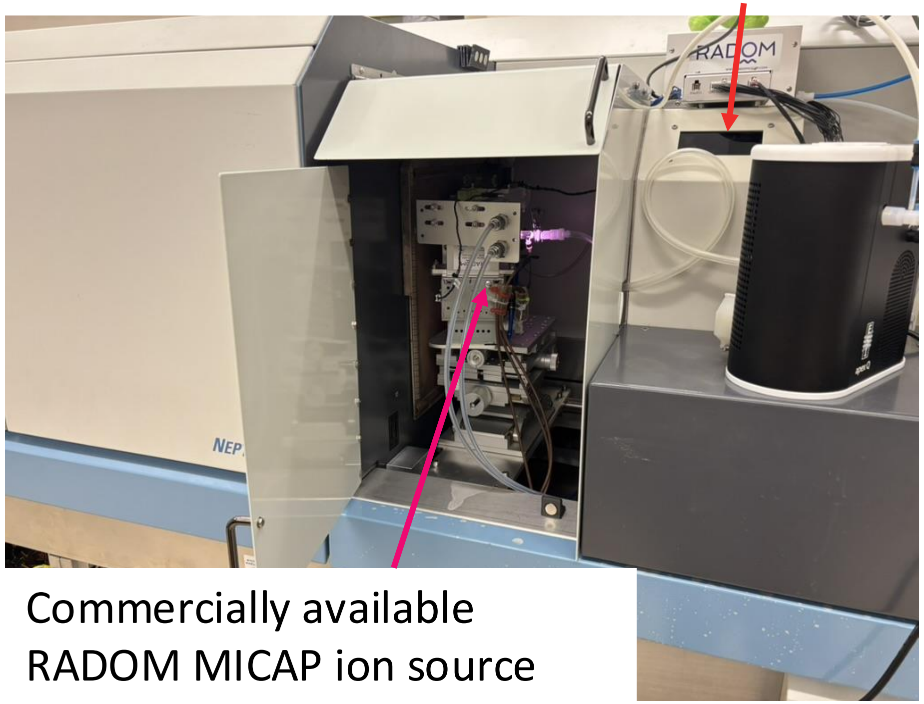
Lauréats KILLAM Laureates
NSERC CRSNG
EYES HIGH

Backup

Instrument Modification

Commercially available ThermoFisher Neptune MS base

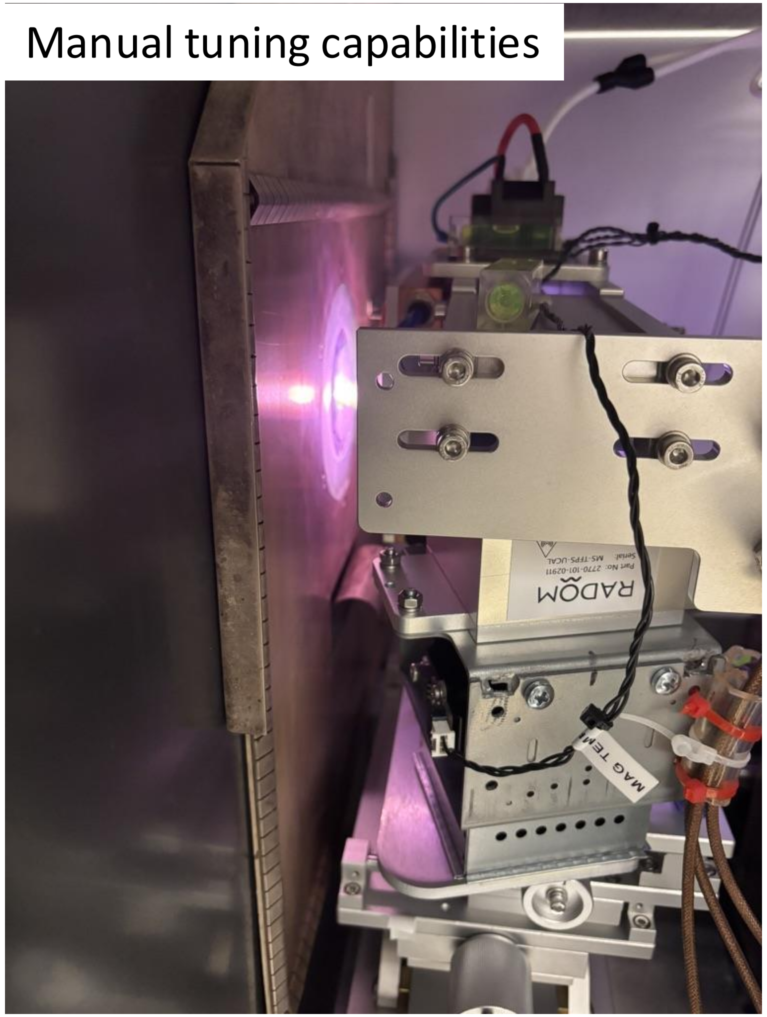
Stock ICP ion source



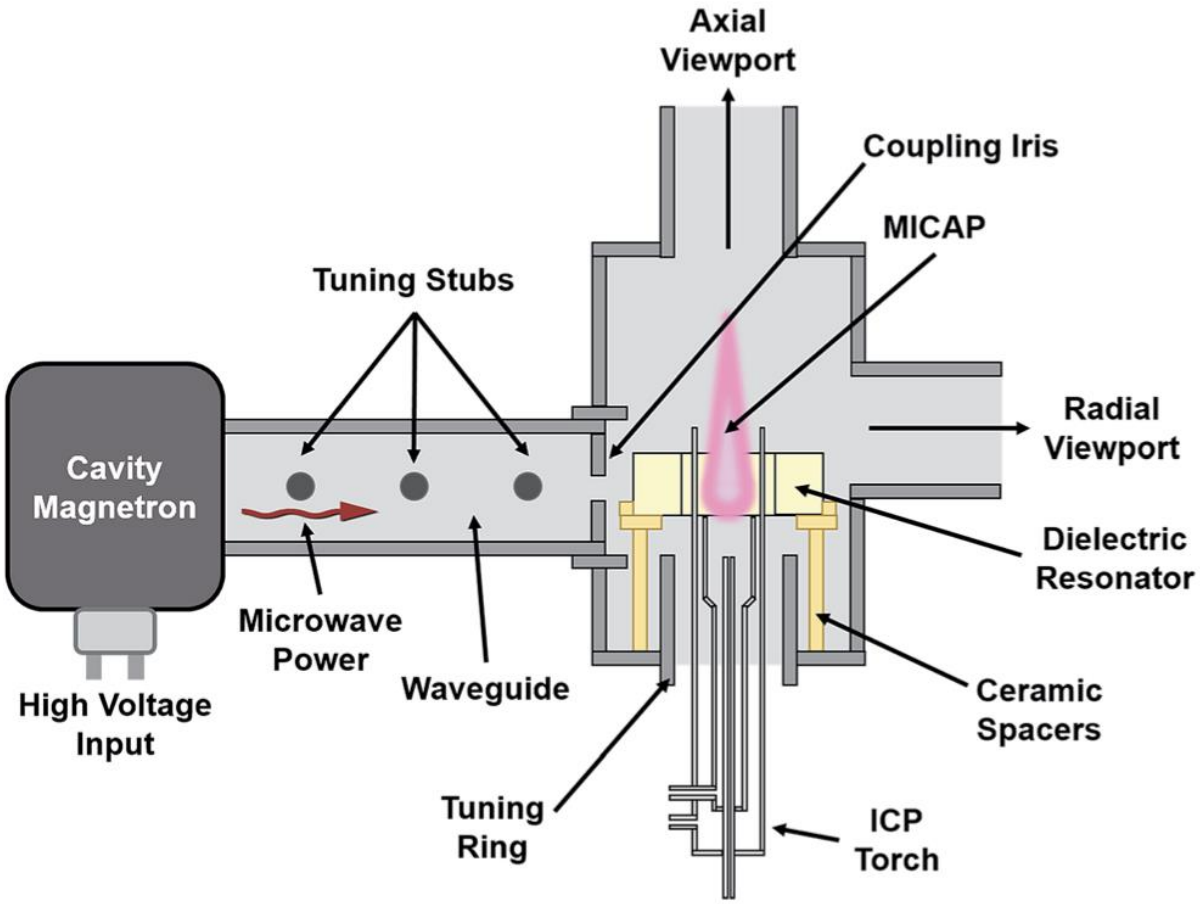
Commercially available
RADOM MICAP ion source

Instrument Modification


Full maintenance access


Manual tuning capabilities

MICAP Operation



1. Microwave directed down waveguide
2. Dielectric resonator couples with magnetic field of iris
   1. Induces polarization currents in dielectric
3. Oscillating magnetic field around torch generates electric field
4. Argon gas sent through torch for plasma ignition
5. Send sparks through gas line to ignite plasma
   1. Produce a cascade of free electrons and ions
6. Send nitrogen gas through source to sustain plasma

Schwartz, A. J. et al. *JAAS.* **31**, 440–449 (2016).