Direct high-precision determination of the electron capture Q-value in ^{163}Ho

Christoph Schweiger/Loredana Gastaldo
Max-Planck-Institute for Nuclear Physics/Kirchhoff Institute for Physics, Heidelberg

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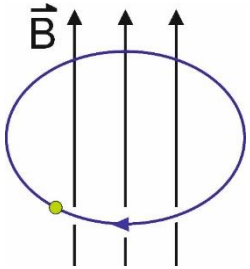
MAX-PLANCK-GESELLSCHAFT

INTERNATIONAL MAX PLANCK RESEARCH SCHOOL

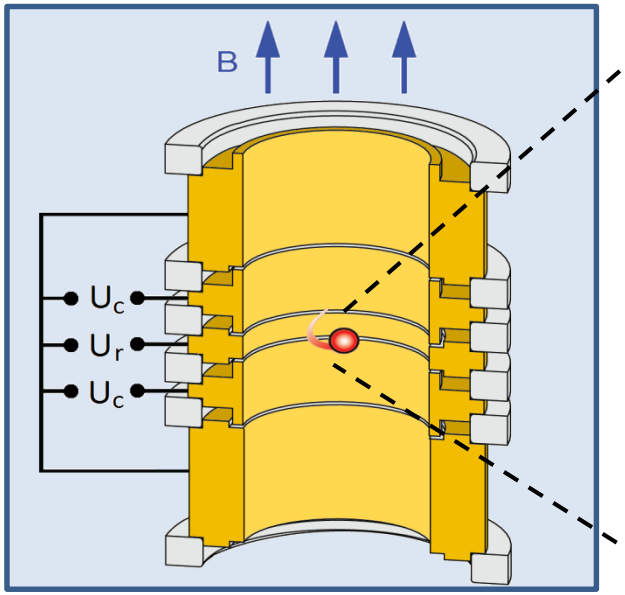
PT FS FOR PRECISION TESTS OF FUNDAMENTAL SYMMETRIES

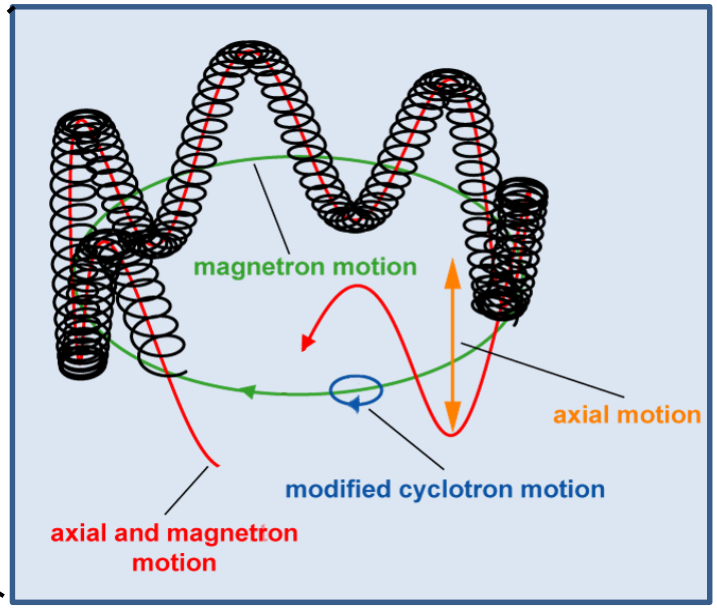
MAX-PLANCK-INSTITUT FÜR KERNPHYSIK

Penning-trap mass spectrometry (PTMS)



Free-space **cyclotron frequency**





$$\omega_c = \frac{q}{m} B$$

Invariance theorem:

$$\omega_c^2 = \omega_+^2 + \omega_z^2 + \omega_-^2$$

Three independent eigenmotions:

Modified cyclotron motion (ω_+)

Axial motion (ω_z)

Magnetron motion (ω_-)

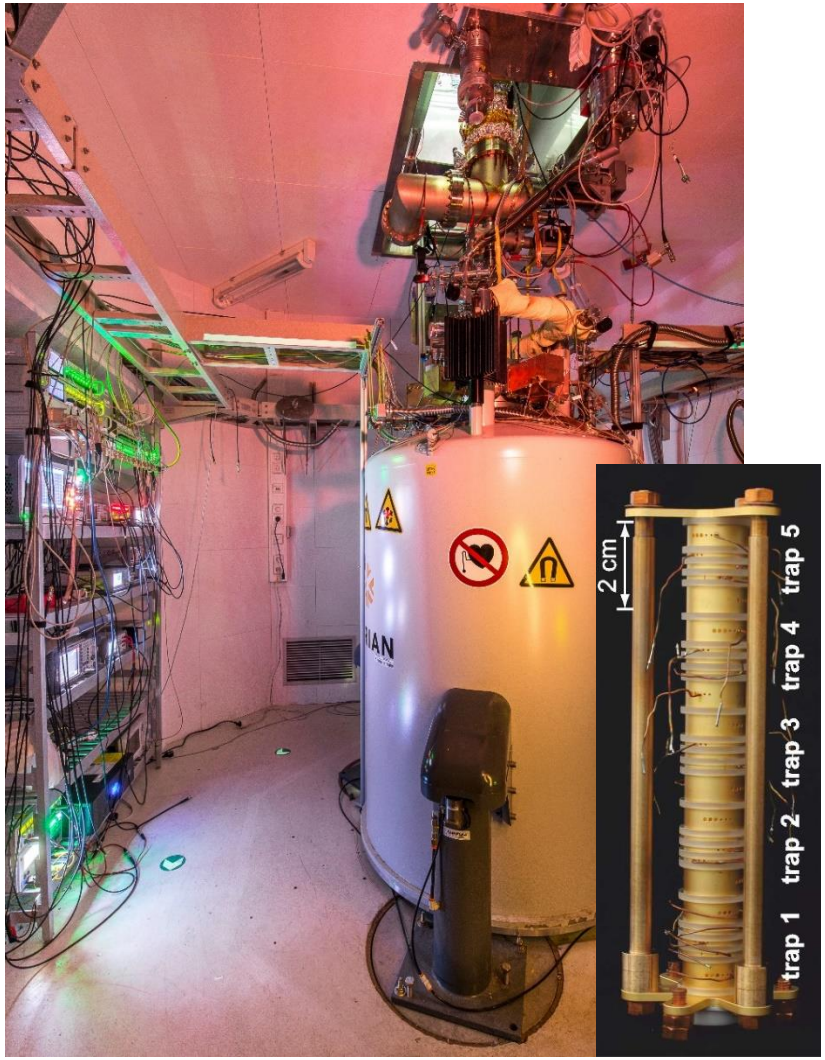
Brown, L. et al., Rev. Mod. Phys. 58, 233 (1986)

Features of the PENTATRAP experiment

Mass-ratio measurements of stable and long-lived highly charged ions with a **fractional uncertainty below 10^{-11}**

Unique features

- Trap tower consisting of 5 cylindrical Penning traps
- Strong magnetic field (7 T)
- Pressure and level stabilization for the superconducting magnet
- Temperature stabilized lab (<0.05K/30 min)
- Non-destructive image-current detection and phase sensitive measurements
- Ultra stable voltage source StaReP
  Future: Josephson Junction voltage supply
- **Use of highly charged ions**



Highly charged ions of ^{163}Ho

Challenge: ^{163}Ho is a synthetic radioisotope with a half life of ~4600 y

- Production by neutron irradiation of ^{162}Er and chemical separation
- Only small quantities available: 10^{16} atoms corresponding to 2.7 µg

Dorrer, H. et al., Radiochim. Acta 106, 535 (2018)

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- Production by neutron irradiation of ^{162}Er and chemical separation
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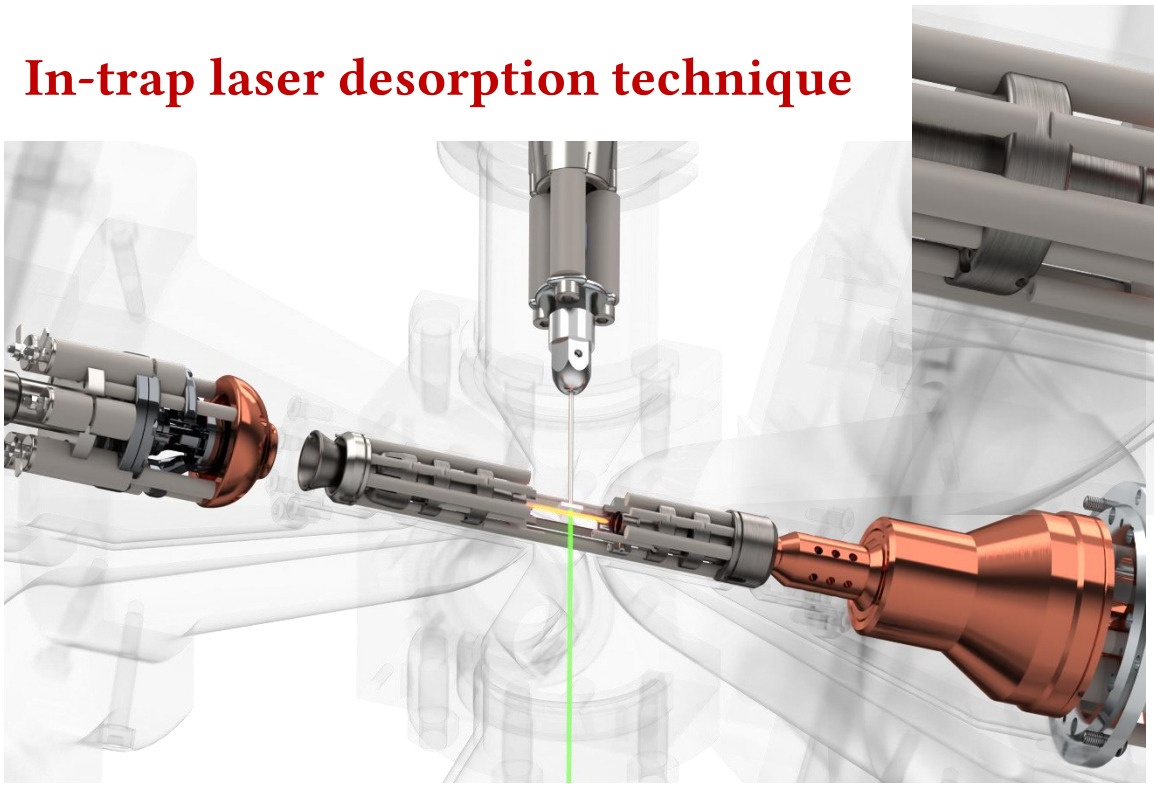
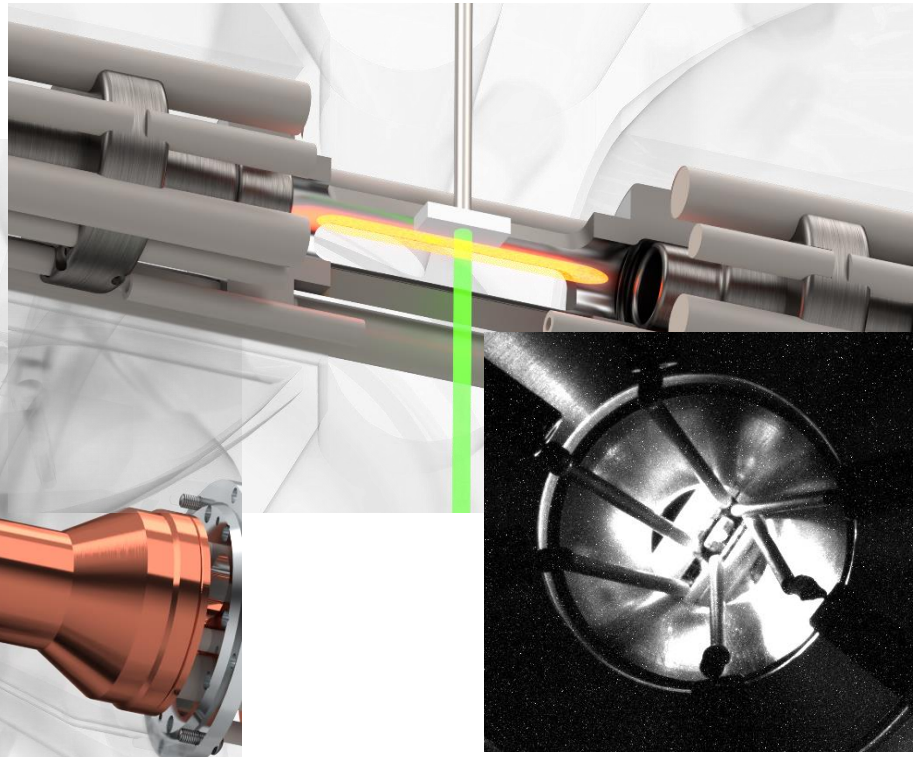
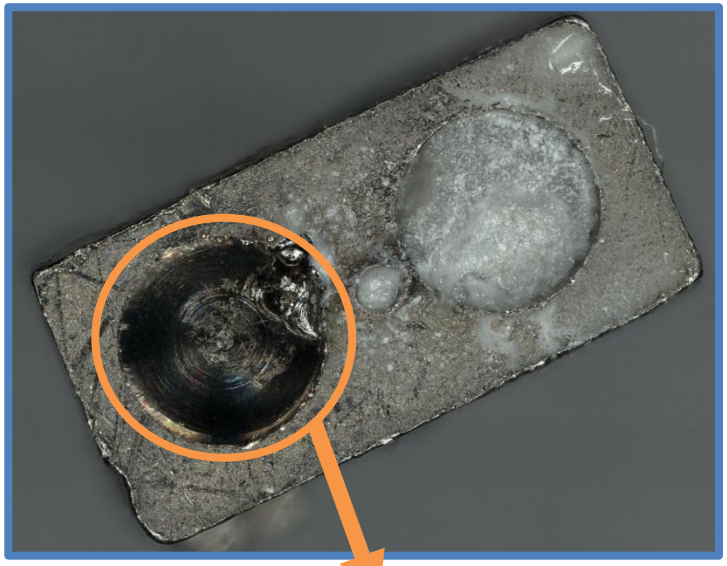
In-trap laser desorption technique

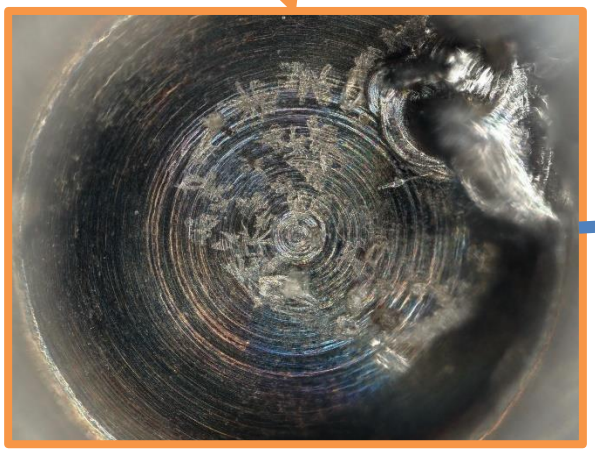




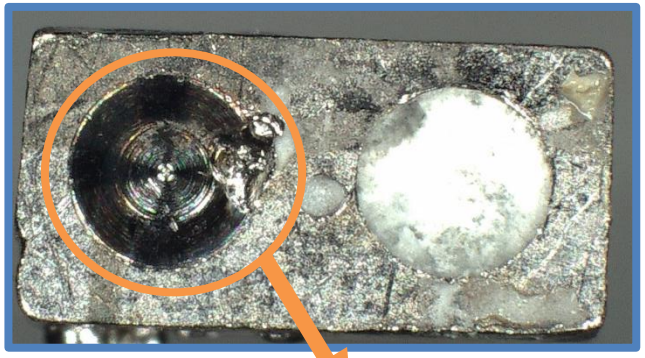
Dorrer, H. et al., Radiochim. Acta 106, 535 (2018)
Schweiger, Ch. et al., RSI 90, 123201 (2019)

^{163}Ho/^{163}Dy targets

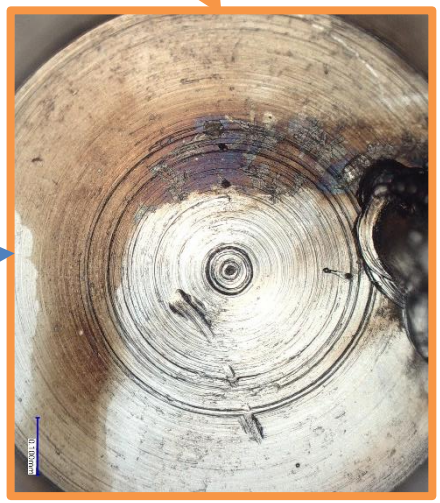




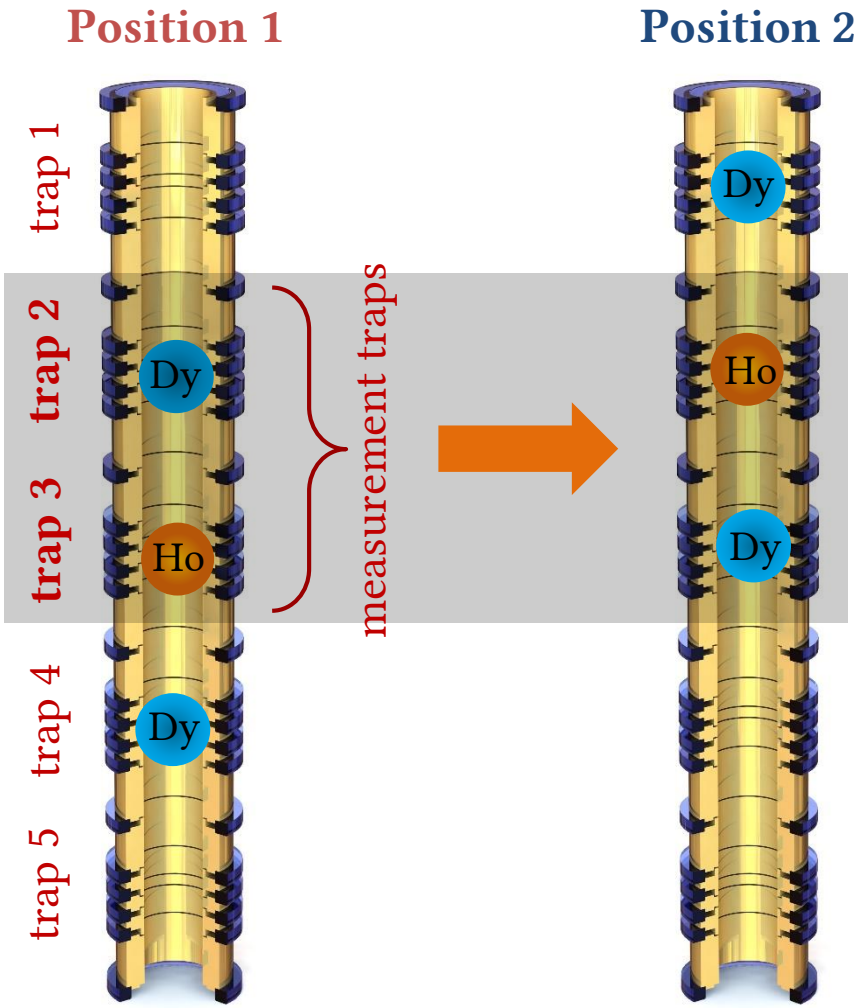
Target with 10^{14} atoms of ^{163}Ho corresponding to 27 ng/481 Bq



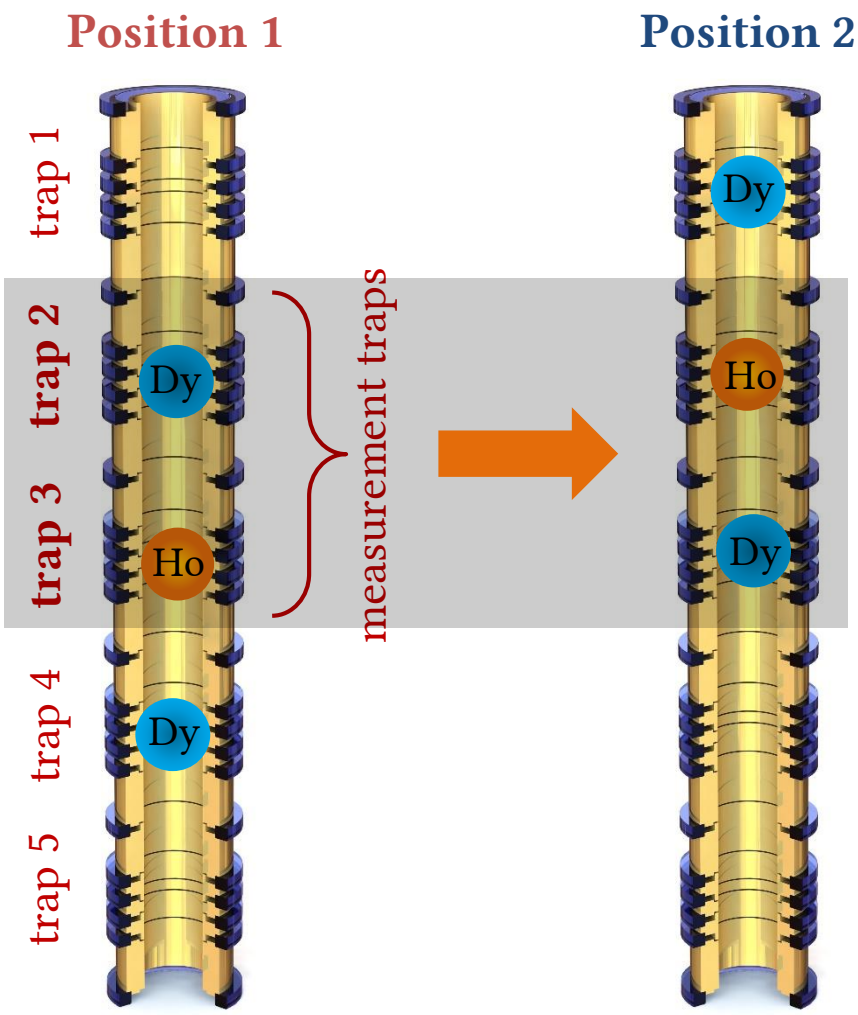
Laser desorption

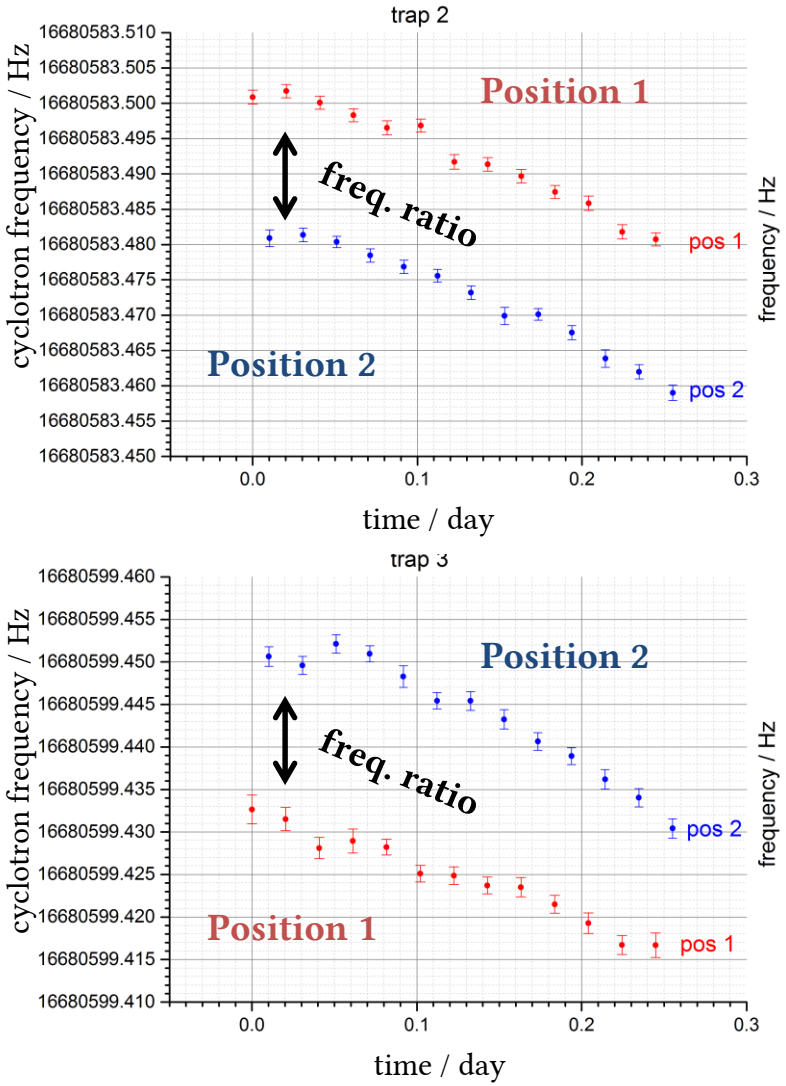


Measurement preparation and sequence

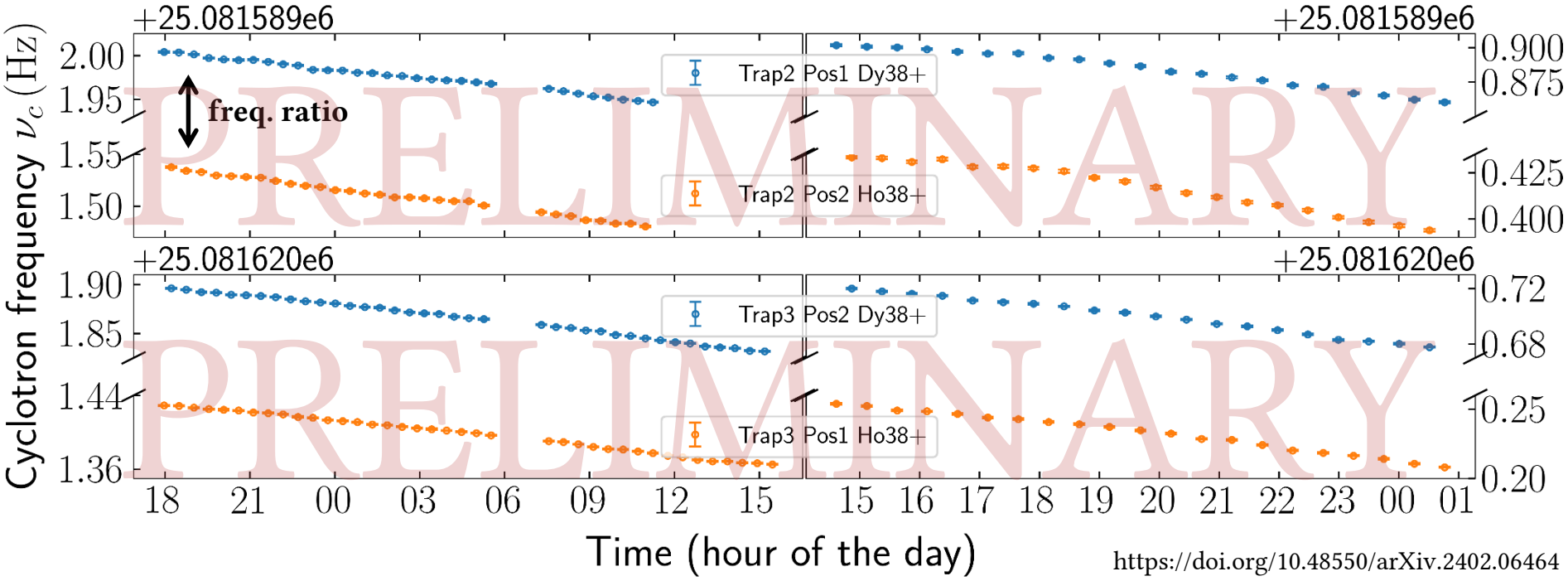


Measurement preparation and procedure





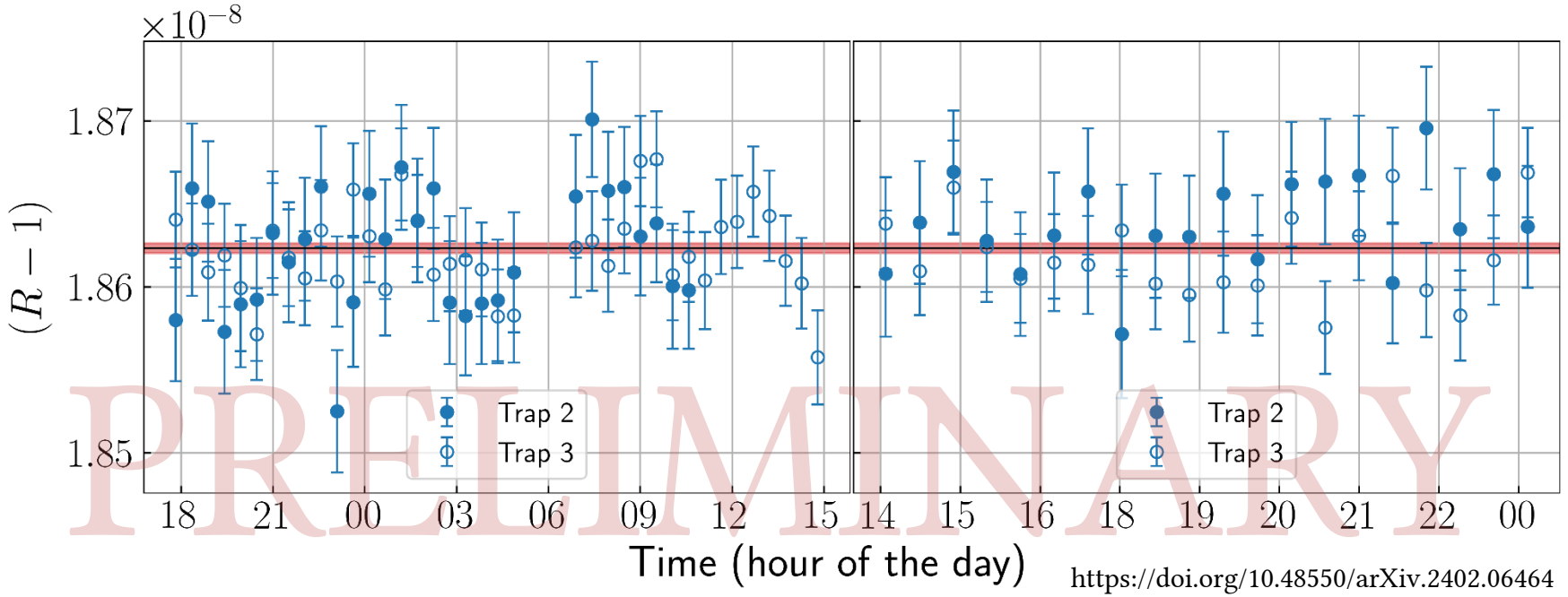
Measurement of charge state q=38+



https://doi.org/10.48550/arXiv.2402.06464

q	R	dR
38	1.0000000186232842	3.0254163376677894e-12
39	1.0000000113074665	4.079252483056971e-12
40	1.0000000115156475	3.4868062799341045e-12

Measurement of charge state q=38+



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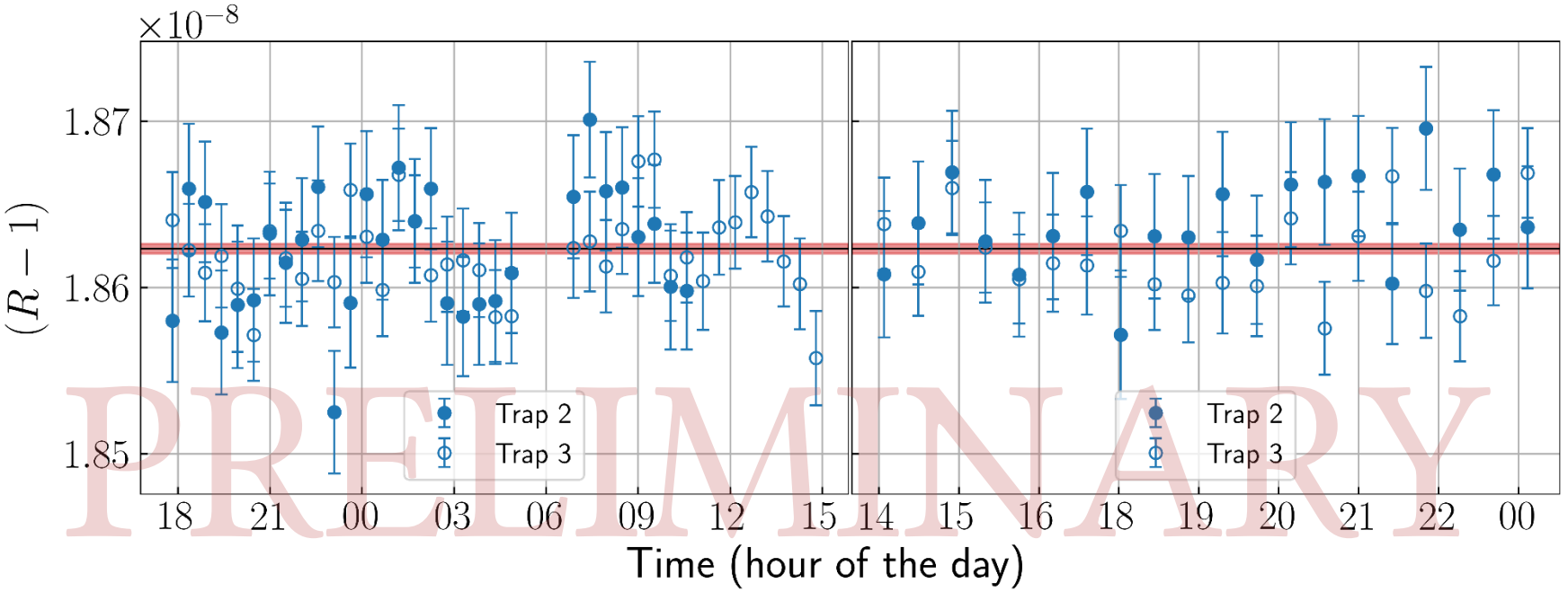
$$Q = m_{\mathrm{Dy}}^{q+}\left(R^{q+} - 1\right) + \Delta E_{\mathrm{B}}^{q+}$$

Calculated from AME, electron mass (CODATA) and binding energies (NIST)

Z. Harman, M. Haverkort and P. Indelicato

Measurement of charge state q=38+



q	R	dR	Eb	dEb	Q	dQ	dR/R
38	1.0000000186232842	3.0254163376677894e-12	37.4	1.4	**2863.4**	**1.5**	3,0E-12
39	1.0000000113074665	4.079252483056971e-12	1147.3	0.7	**2863.2**	**0.9**	4,1E-12
40	1.0000000115156475	3.4868062799341045e-12	1115.7	0.7	**2863.2**	**0.9**	3,5E-12

$$Q = 2863.2\ (0.6)\ \mathrm{eV/c^2}$$

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PT FS FOR PRECISION TESTS OF FUNDAMENTAL SYMMETRIES

Menno Door, Sergey Eliseev, Pavel Filianin, Jost Herkenhoff, Felix Herzog, Kathrin Kromer, Daniel Lange, Yuri N. Novikov, Alexander Rischka, Christoph Schweiger and Klaus Blaum

Thank you for your attention!