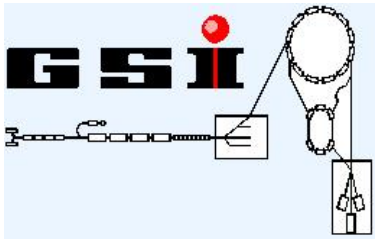
The Ramsey technique in high-precision mass spectrometry

Outline

S. George for the ISOLTRAP collaboration

University of Mainz, GSI Darmstadt

- Ramsey technique
- Step-size optimization
- FT-ICR detection technique



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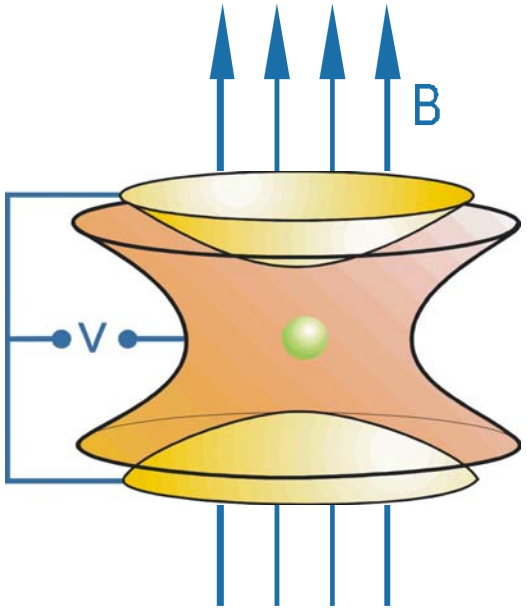
Ion motion in a Penning trap

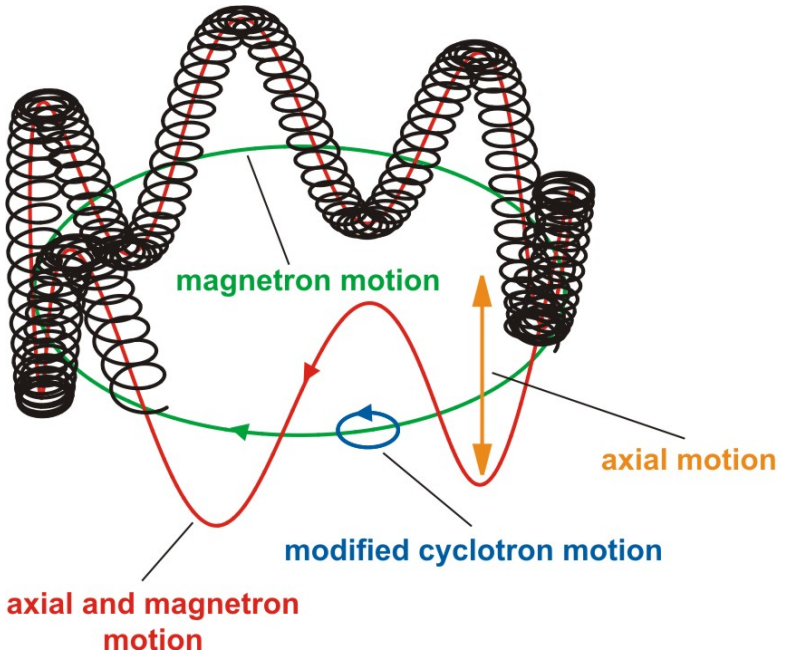


three characteristic harmonic motions:

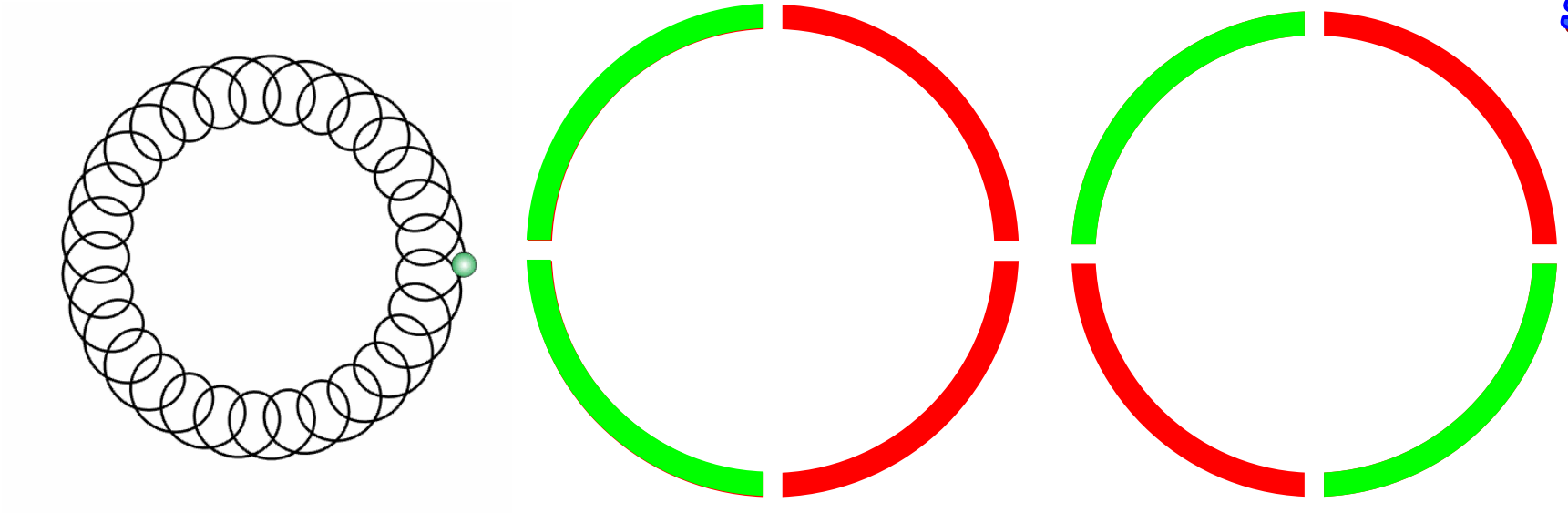
- modified cyclotron motion (frequency f_+)
- axial motion (frequency f_z)
- magnetron motion (frequency f_-)

$$f_c = \frac{1}{2\pi} \cdot \frac{q}{m} \cdot B$$

Typical frequencies
q = e, m = 100 u,
B = 6 T
$\Rightarrow$ $f_- \approx 1$ kHz
$f_+ \approx 1$ MHz

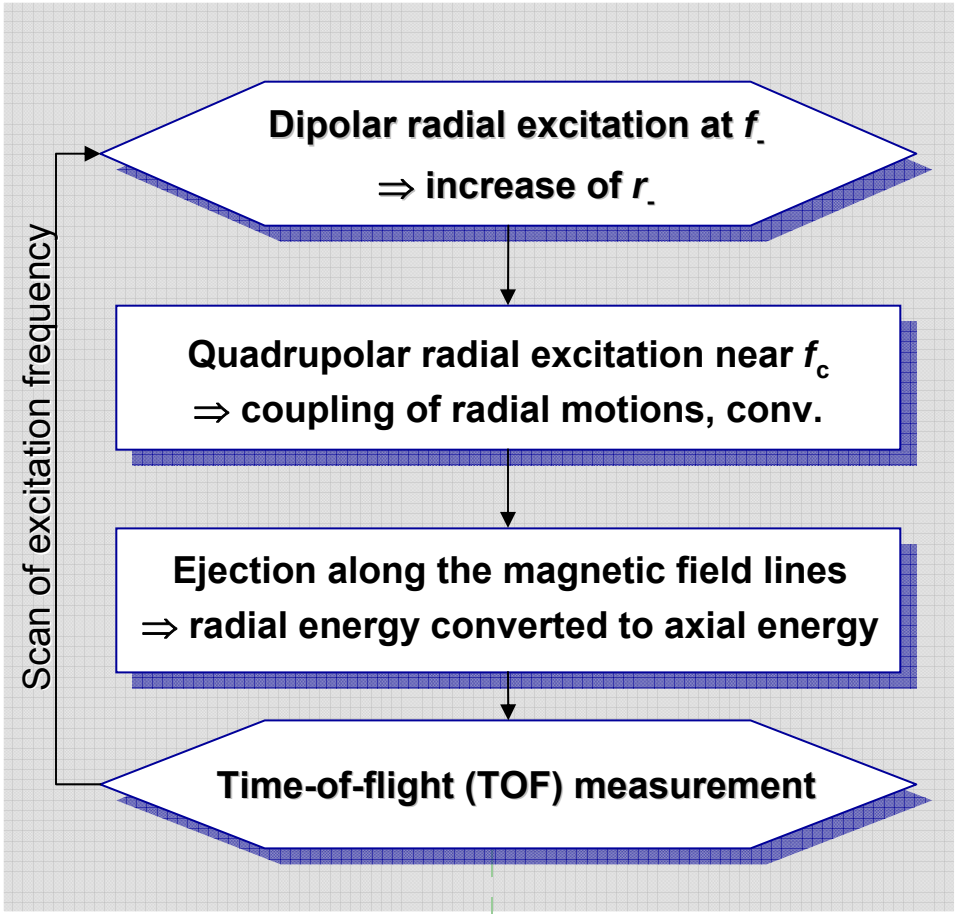


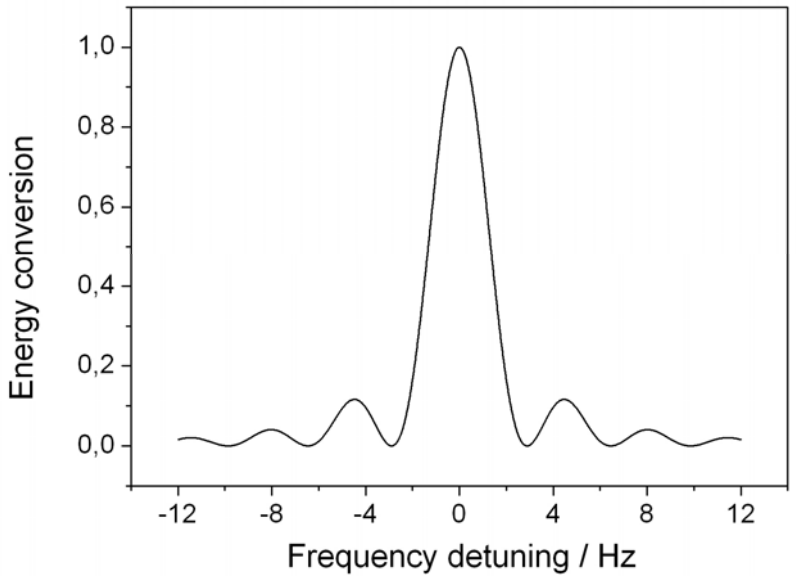
Excitation of radial ion motions

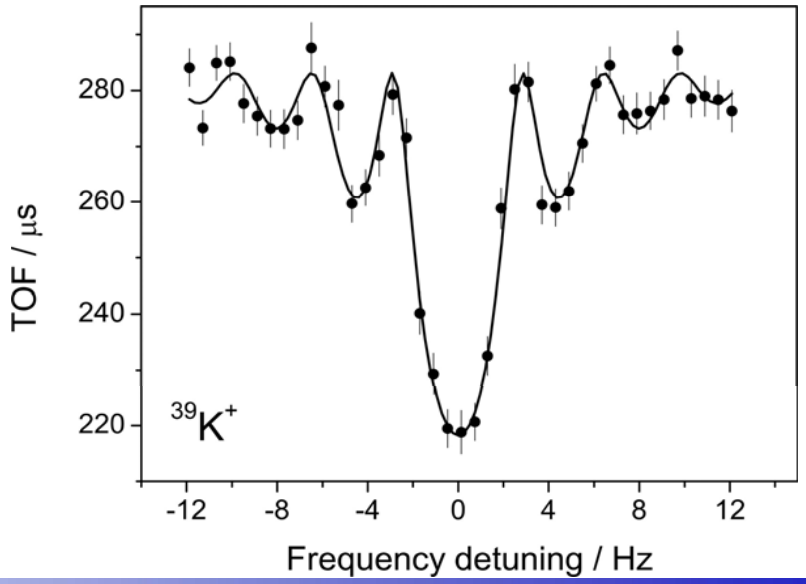


- Ring electrode (four segments)
- Dipolar excitation at f_-: increase of the magnetron radius
- Quadrupolar excitation at f_c: conversion from magnetron into reduced cyclotron motion
- Coupling of the radial motions: $f_c = f_+ + f_-$

Frequency determination

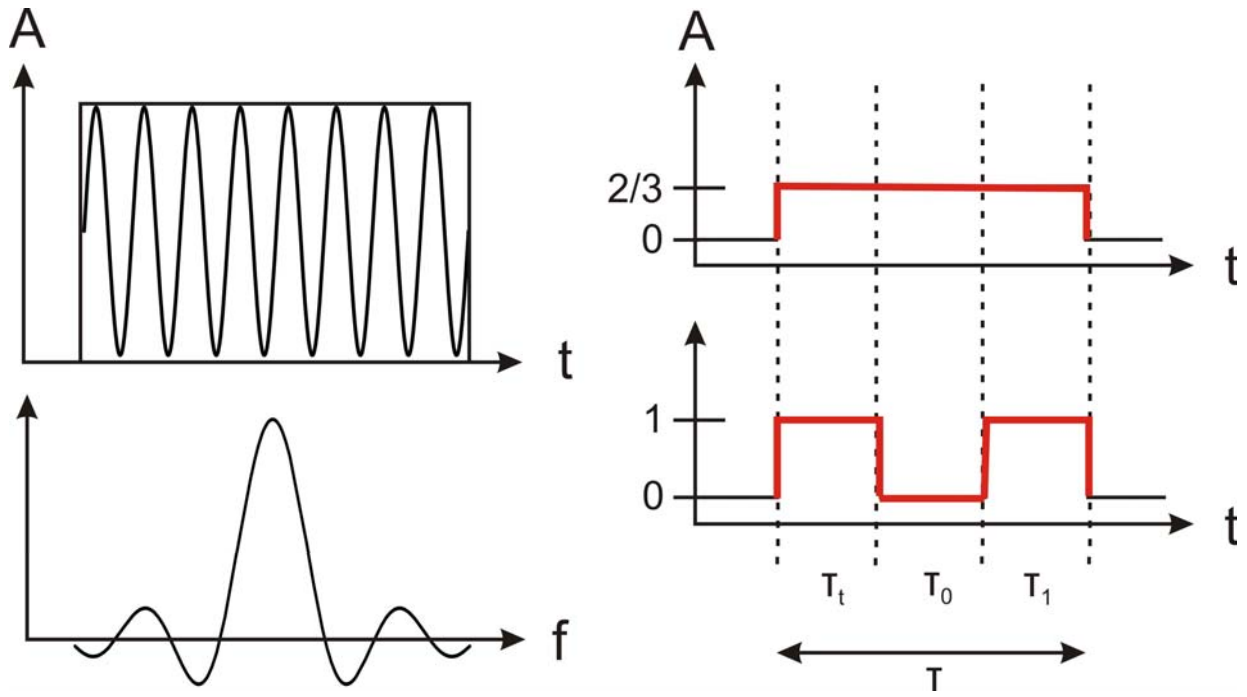






$$F_1 = \frac{4g^2}{\omega_R^2}[\sin(\frac{\omega_R \tau_1}{2})]^2$$

Ramsey excitation in a Penning trap



Lineshape as a function of detuning δ of the driving field:

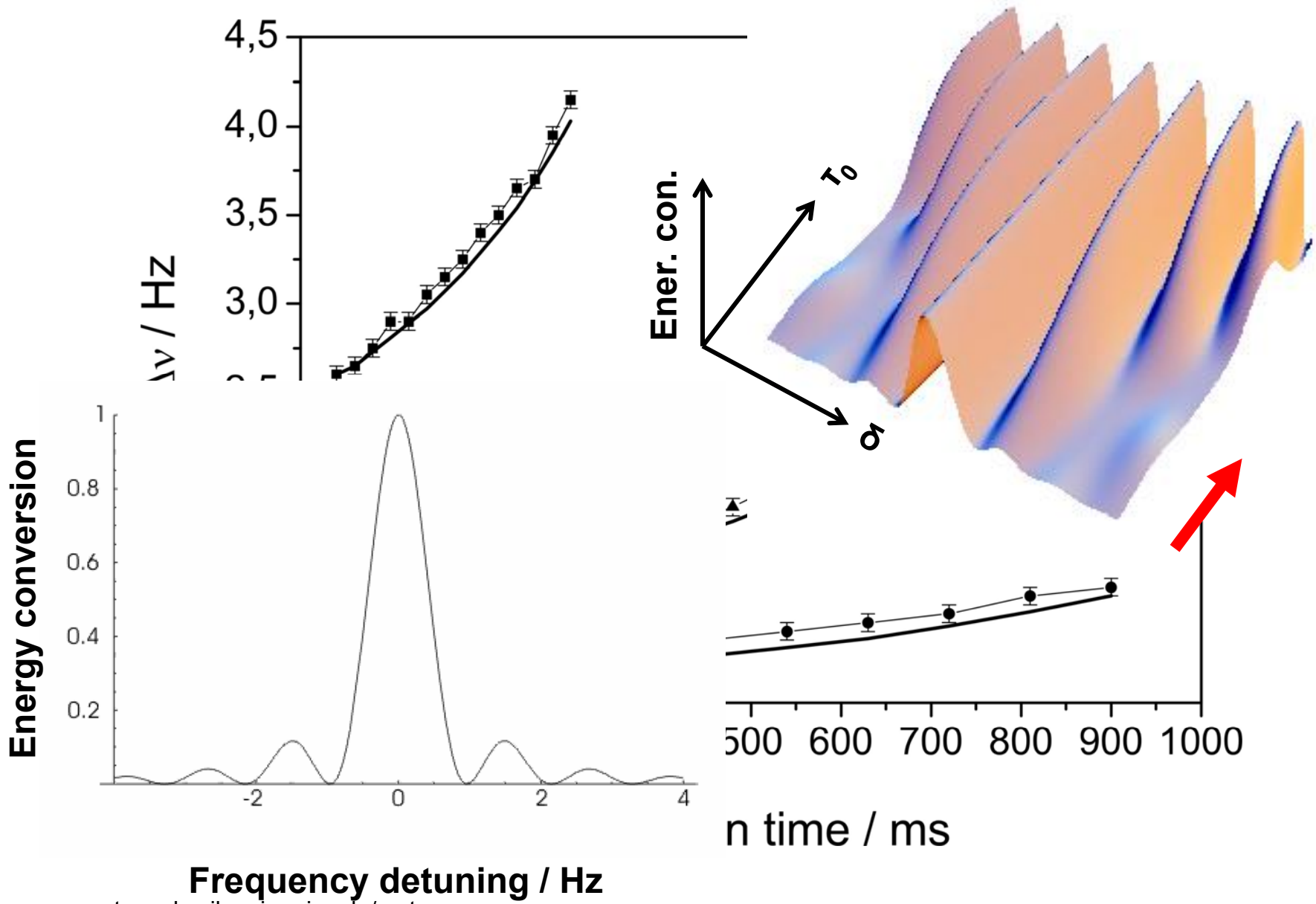
$$F_2 = \frac{4g^2}{\omega_R^2}\left[\cos\left(\frac{\delta\tau_0}{2}\right)\sin(\omega_R\tau_1) + \frac{\delta}{\omega_R}\sin\left(\frac{\delta\tau_0}{2}\right)(\cos(\omega_R\tau_1)-1)\right]^2$$

$$\omega_R = \sqrt{4g^2+\delta^2}$$

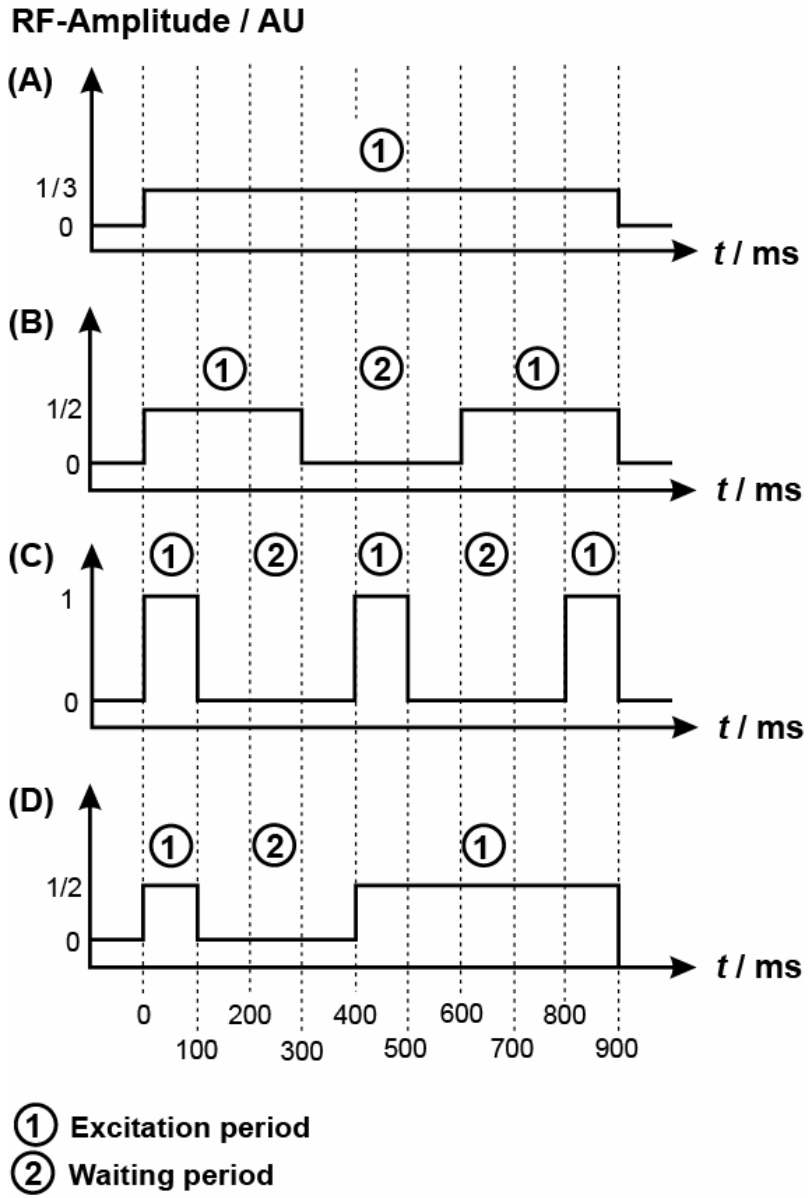
g: strength of coupling

δ: frequency detuning

Two-fringe excitation

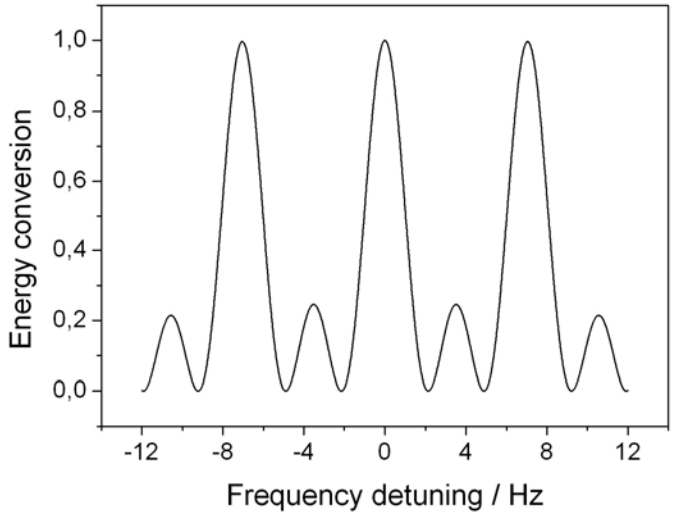


Different excitation schemes

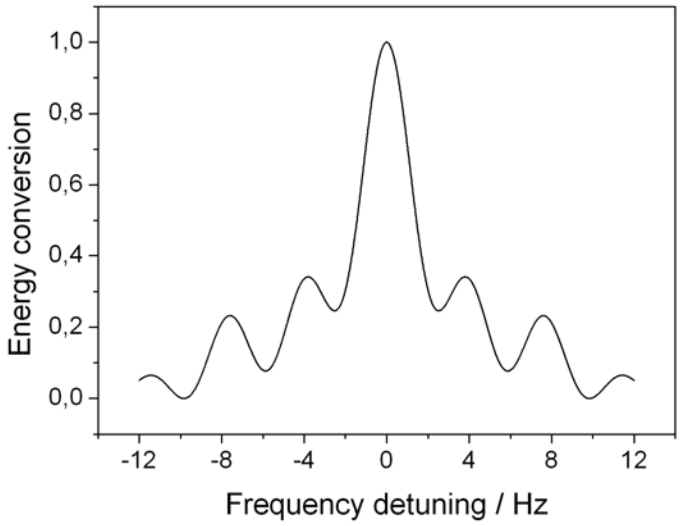


① Excitation period
② Waiting period

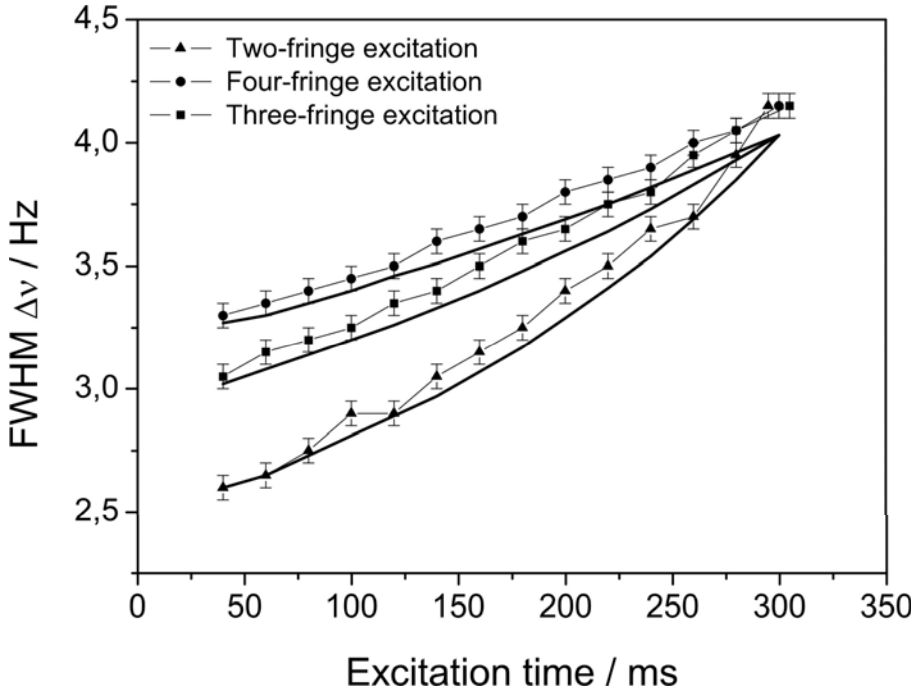
3-fringes:



2-fringes (unequal):



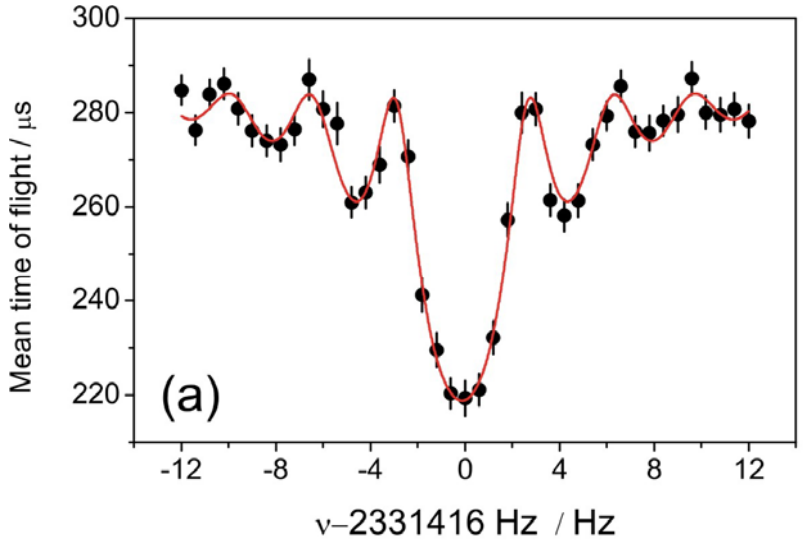
Line width

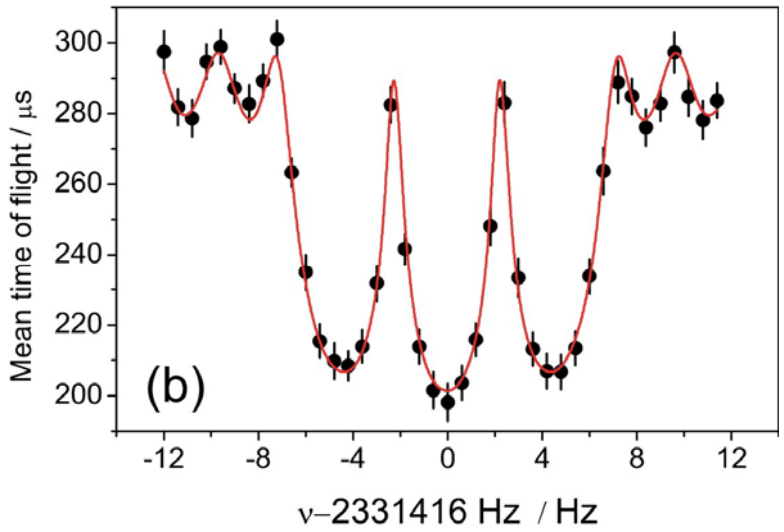


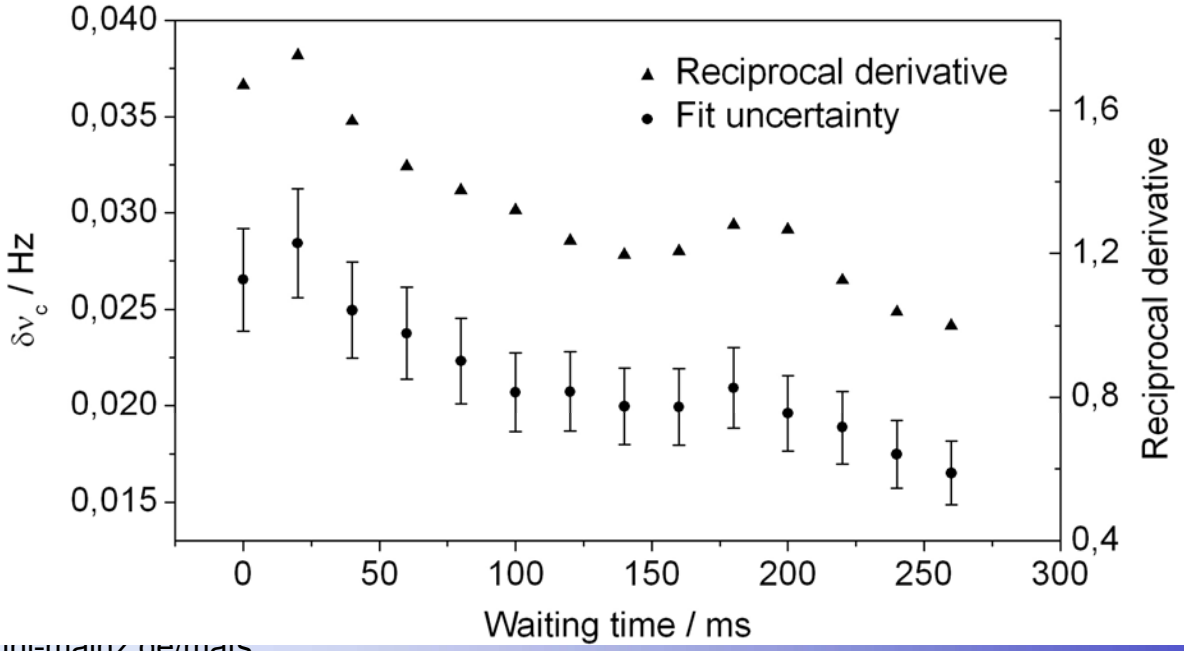
number of fringes	cycle time	max. FWHM / Hz	min. FWHM / Hz	reduction gain / %
2	300	4.1	2.6	**37.3 (2.0)**

number of fringes	cycle time	max. uncertainty / Hz	min. uncertainty / Hz	Improvement factor
2	300	0.025	0.007	**3.6 (0.4)**

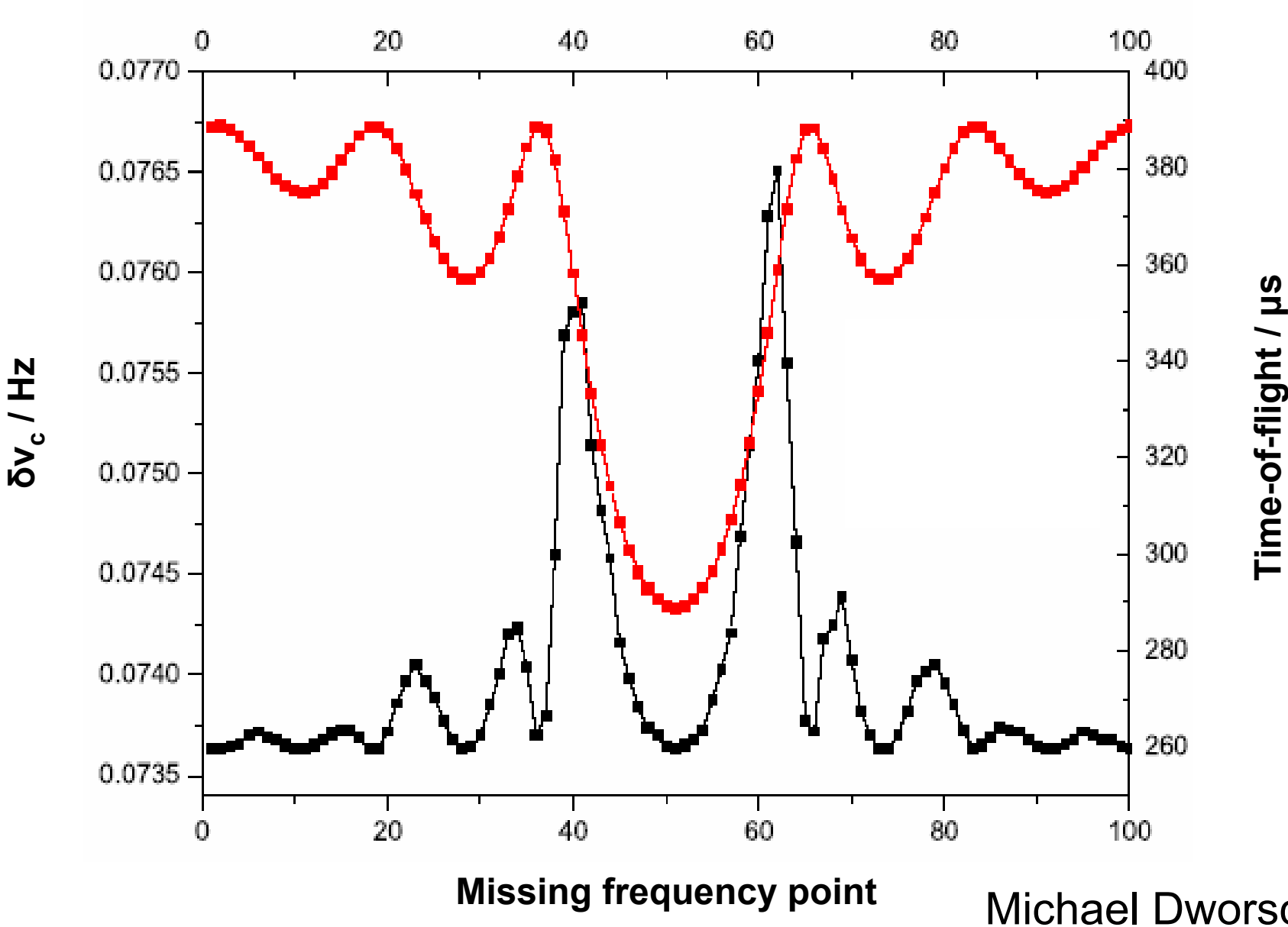
Uncertainty of frequency determination





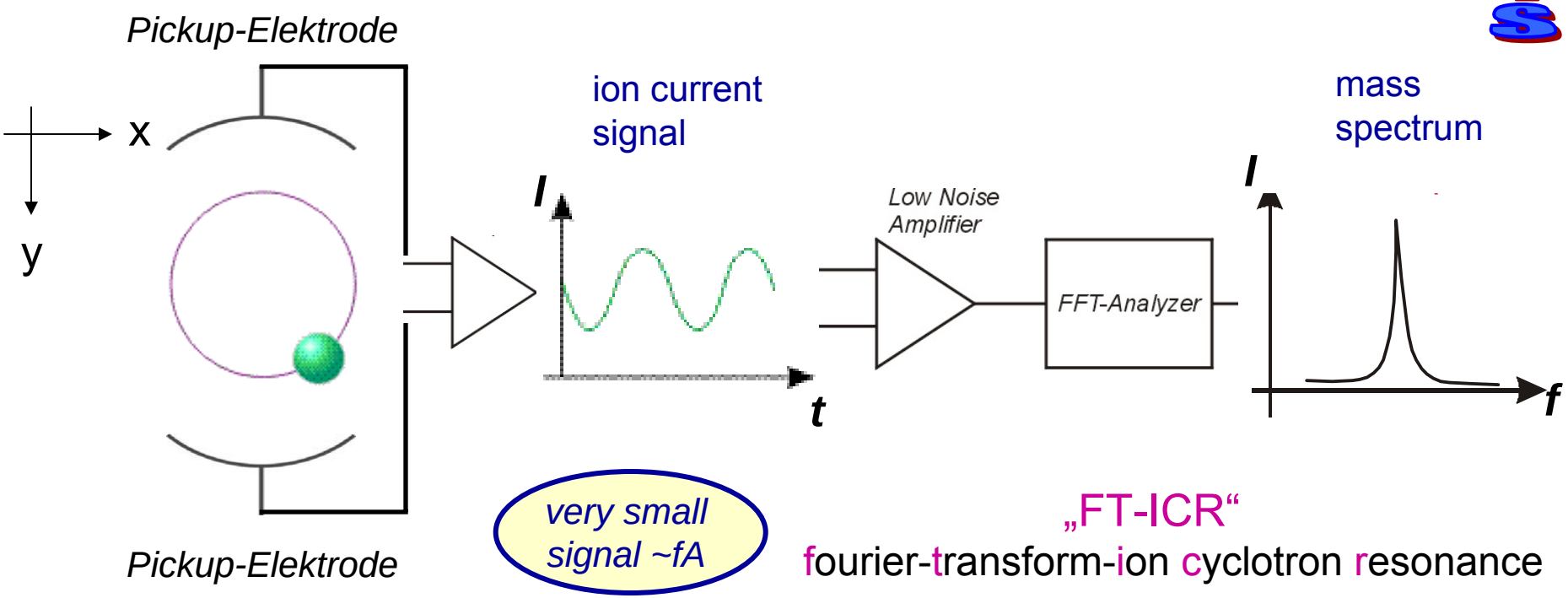


Step-size optimization: Experimental approach



Michael Dworschak

Non-destructive single ion FT-ICR detection



„FT-ICR“
fourier-transform-ion cyclotron resonance

Development of **cryogenic** traps for resonant detection.

Applications

- Mass measurements on superheavy rare elements
- High-accuracy mass measurements on longer-lived and stable ions
- Fast identification and effective use of stored ions

Christine Weber, Rafael Ferrer

C. Weber *et al.*, Eur. Phys. J A 25, 65 (2005)

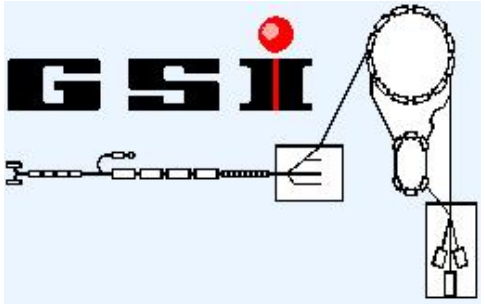
THE END

Thanks a lot to

K. Blaum, M. Dworschak, R. Ferrer, C. Guénaut, A. Herlert, F. Herfurth, A. Kellerbauer, H.-J. Kluge, D. Lunney, L. Schweikhard, S. Stahl, C. Weber, C. Yazidjian, and the ISOLTRAP and MATS collaboration

Thanks for funding and support:

GSI, BMBF, CERN, ISOLDE, **HGF**
EU networks EUROTRAPS, EXOTRAPS, and NIPNET,
QUANTUM working group (I. Bloch)



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