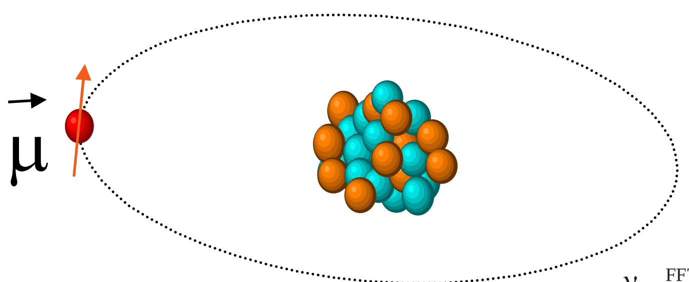
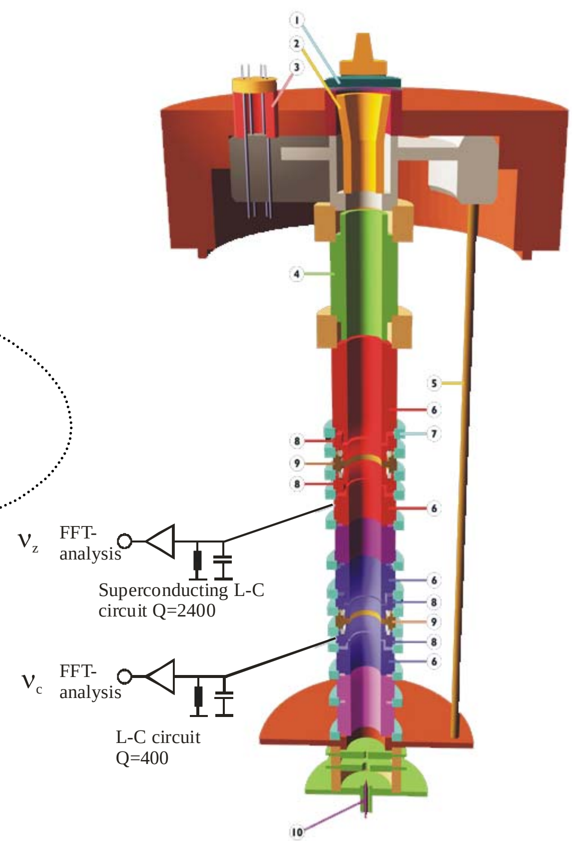
Towards g-factor measurements in medium-heavy and heavy ions



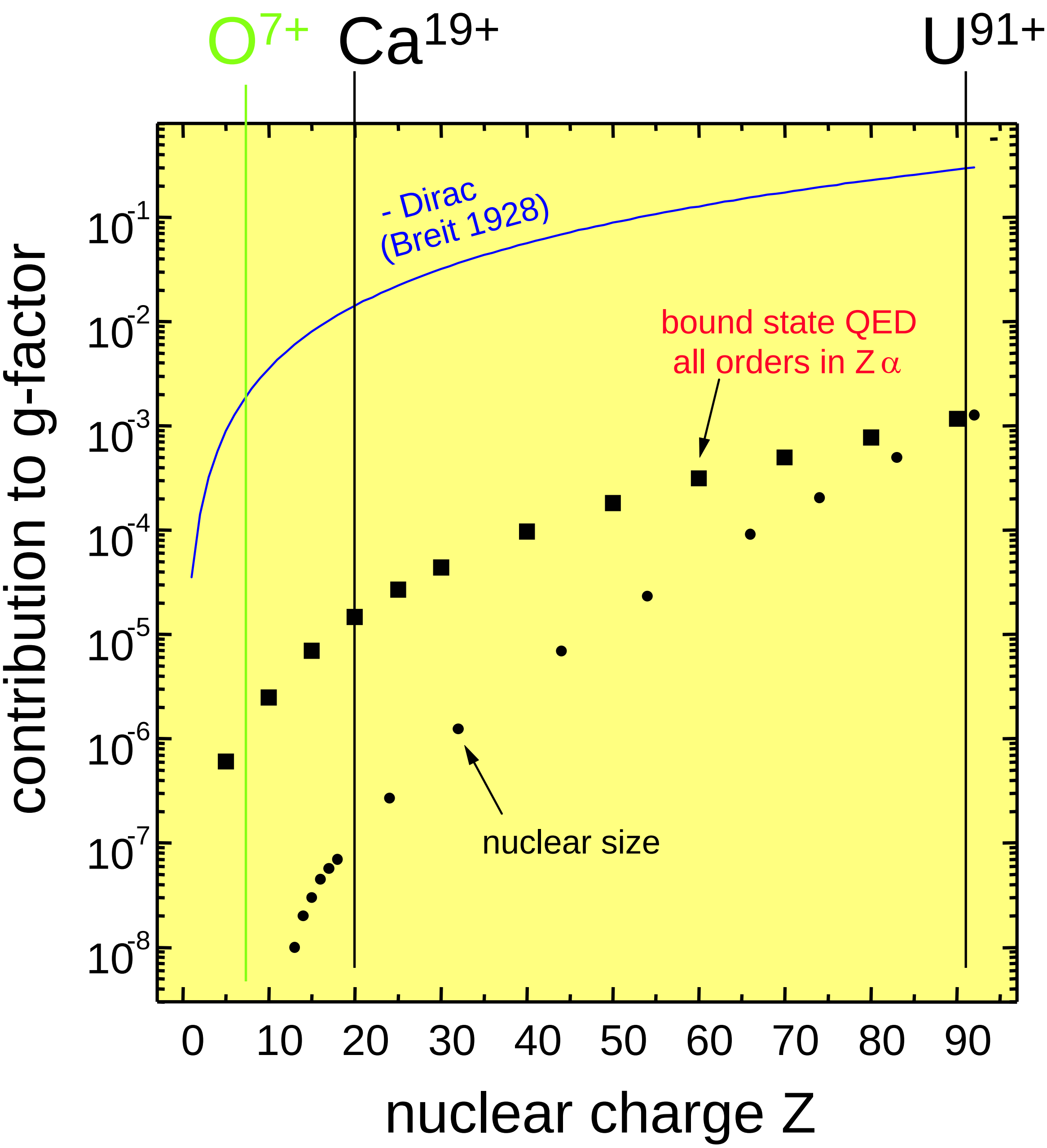


Joseba Alonso
University of Mainz

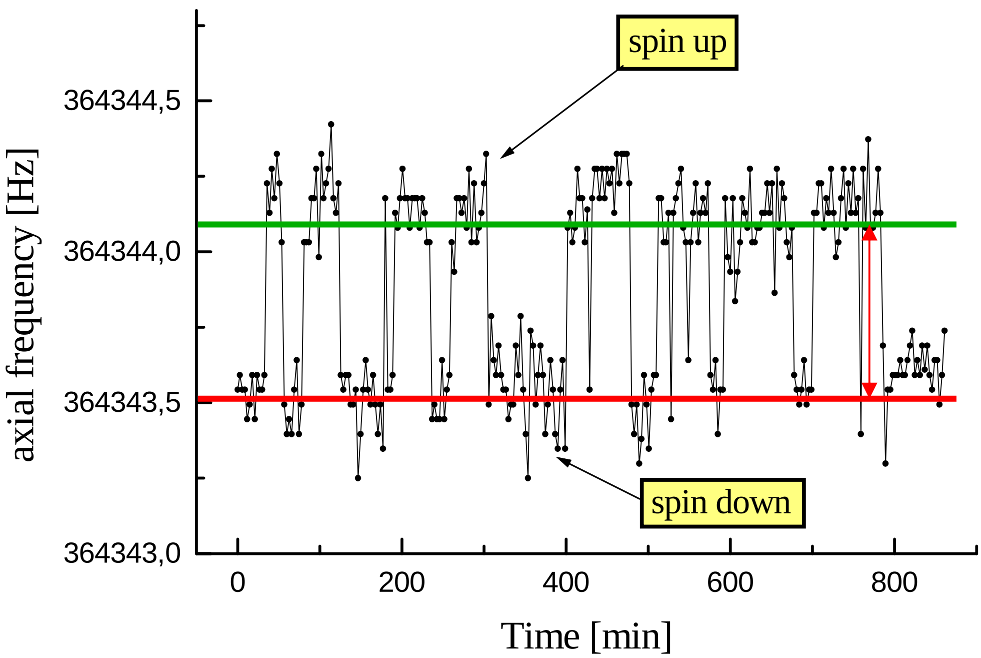
g-factors as benchmark for QED calculations

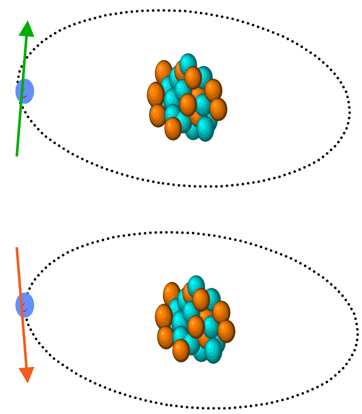
$$g_{bound}/g_{free} \approx 1 - (Z\alpha)^2/3 + \alpha(Z\alpha)^2/4\pi + \ldots$$

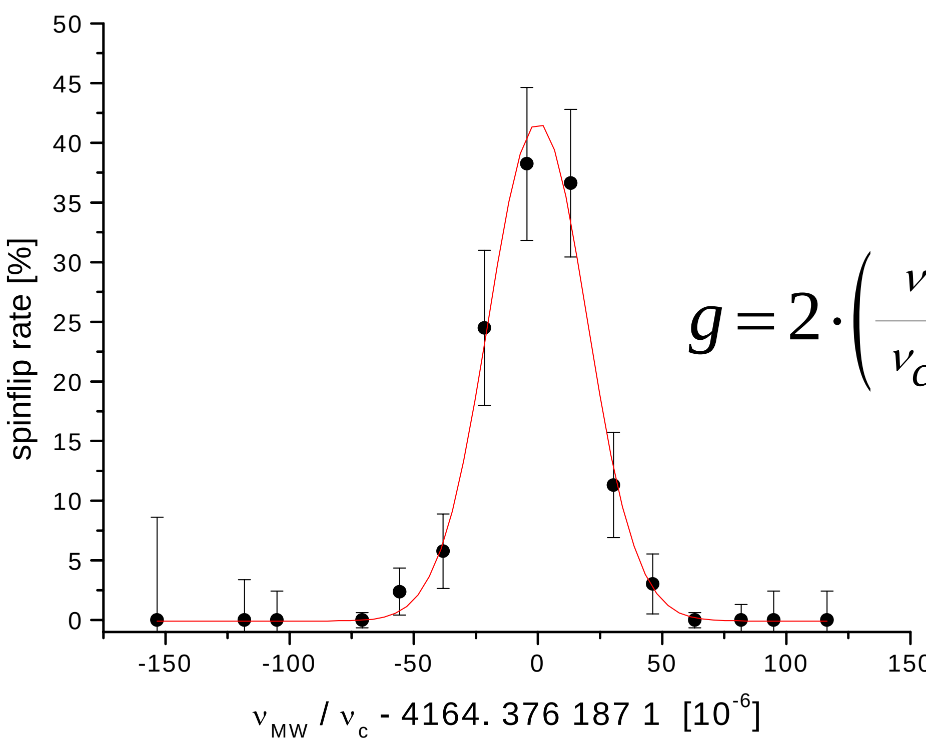
Dirac theory   bound-state QED



Measurement of g-factor







$$g = 2 \cdot \left(\frac{\nu_L}{\nu_c^{\,ion}} \right) \cdot \frac{\left({}^{m}\!/\!{}_{e} \right)^{e}}{\left({}^{M}\!/\!{}_{q} \right)^{ion}}$$

Achievements so far

$^{12}C^{5+}$

g_{expt}=2.001 041 596 3 (10)(44) H.Häffner et al. PRL 85 (2000) 5308

g_{theo}=2.001 041 590 1 (3) V.A. Yerokhin et al. PRL 89 (2002) 143001

$^{16}O^{7+}$

g_{expt}=2.001 047 026 0 (15)(44) J. Verdu et al. PRL 92 (2003) 093002

g_{theo}=2.001 047 020 2 (6) V.A. Yerokhin et al. PRL 89 (2002) 143001

Resulting electron mass

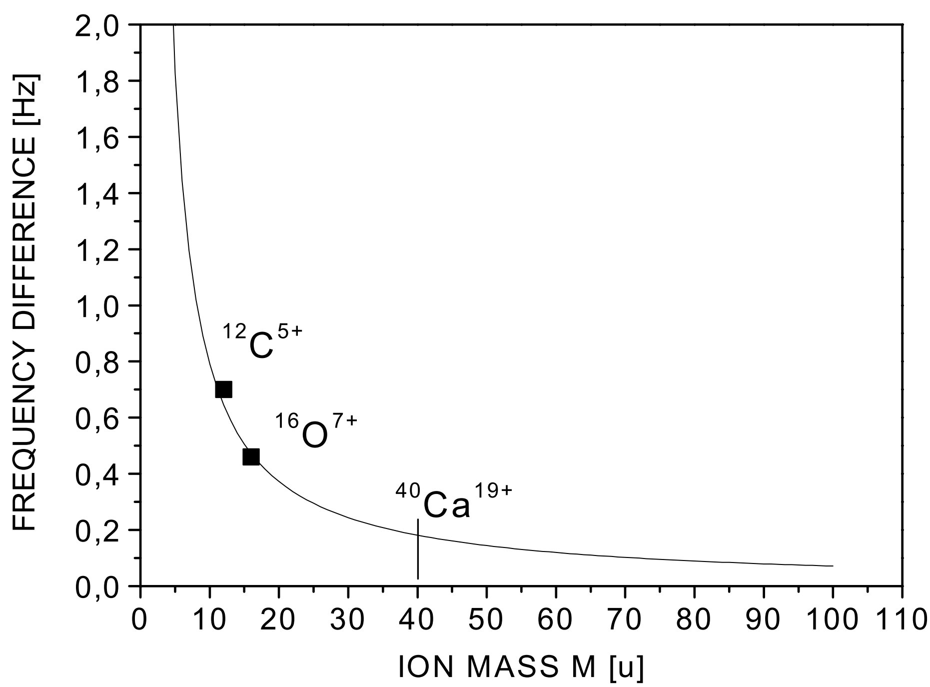
m=0.000 548 579 909 3 (3) u T. Beier et al, PRL 88 (2002) 011603

(which is the main contribution to the currently accepted CODATA value)

How to proceed to Ca^{19+}

Problems:

1.) creation: 19+ instead of 7+, IP 5 times higher
2.) detection: frequency difference due to spin flip small

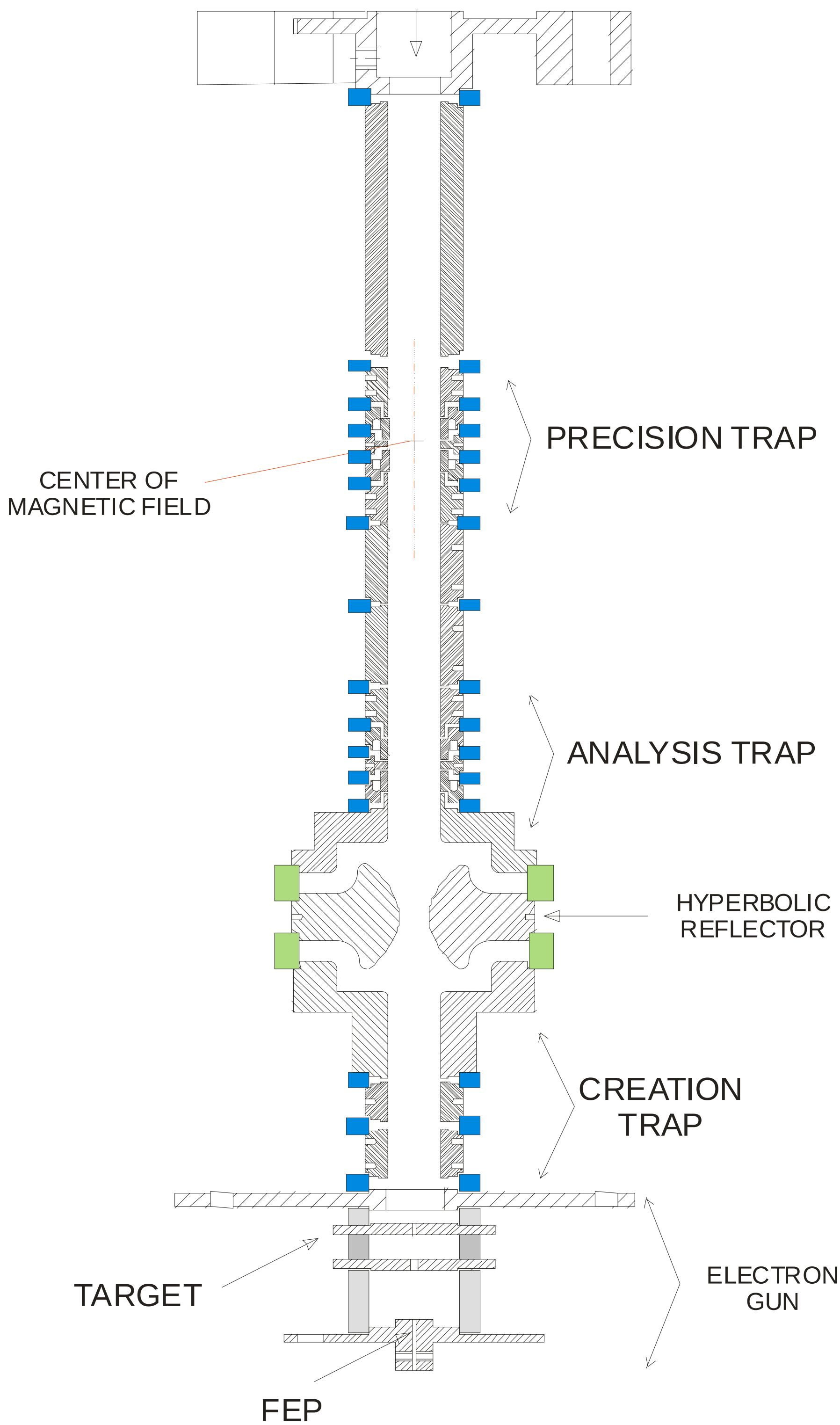


…and how we plan to address them:

ad 1.) „mini-EBIS“ with beam energy up to 10keV,
real-time FTICR mass spectrometry during
creation process (controlled charge breeding)

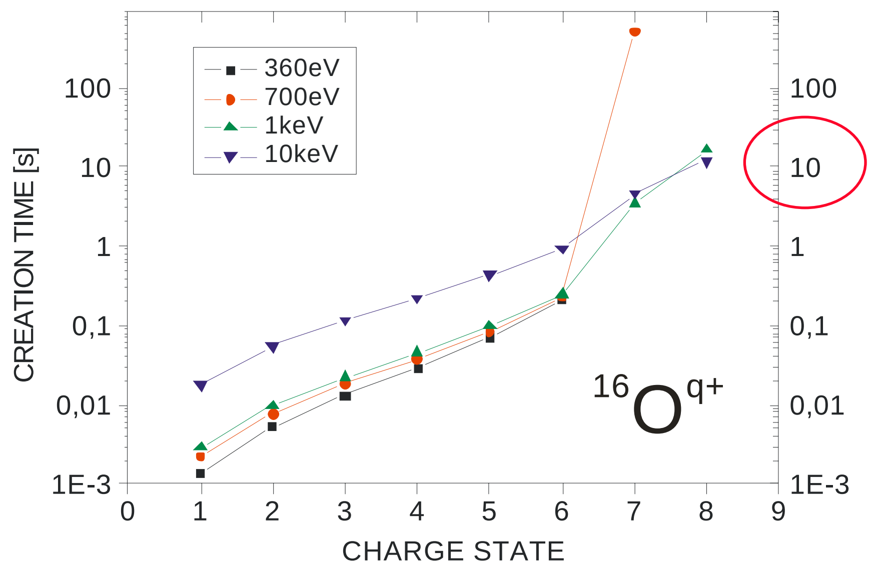
ad 2.) novel detection electronics and techniques…

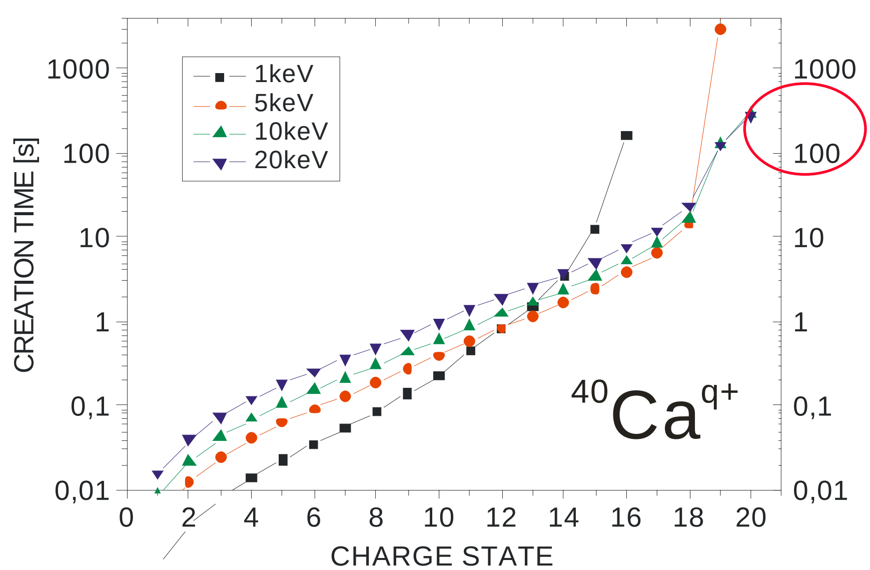
Novel triple trap setup



Breeding time

rather detailed simulations give:

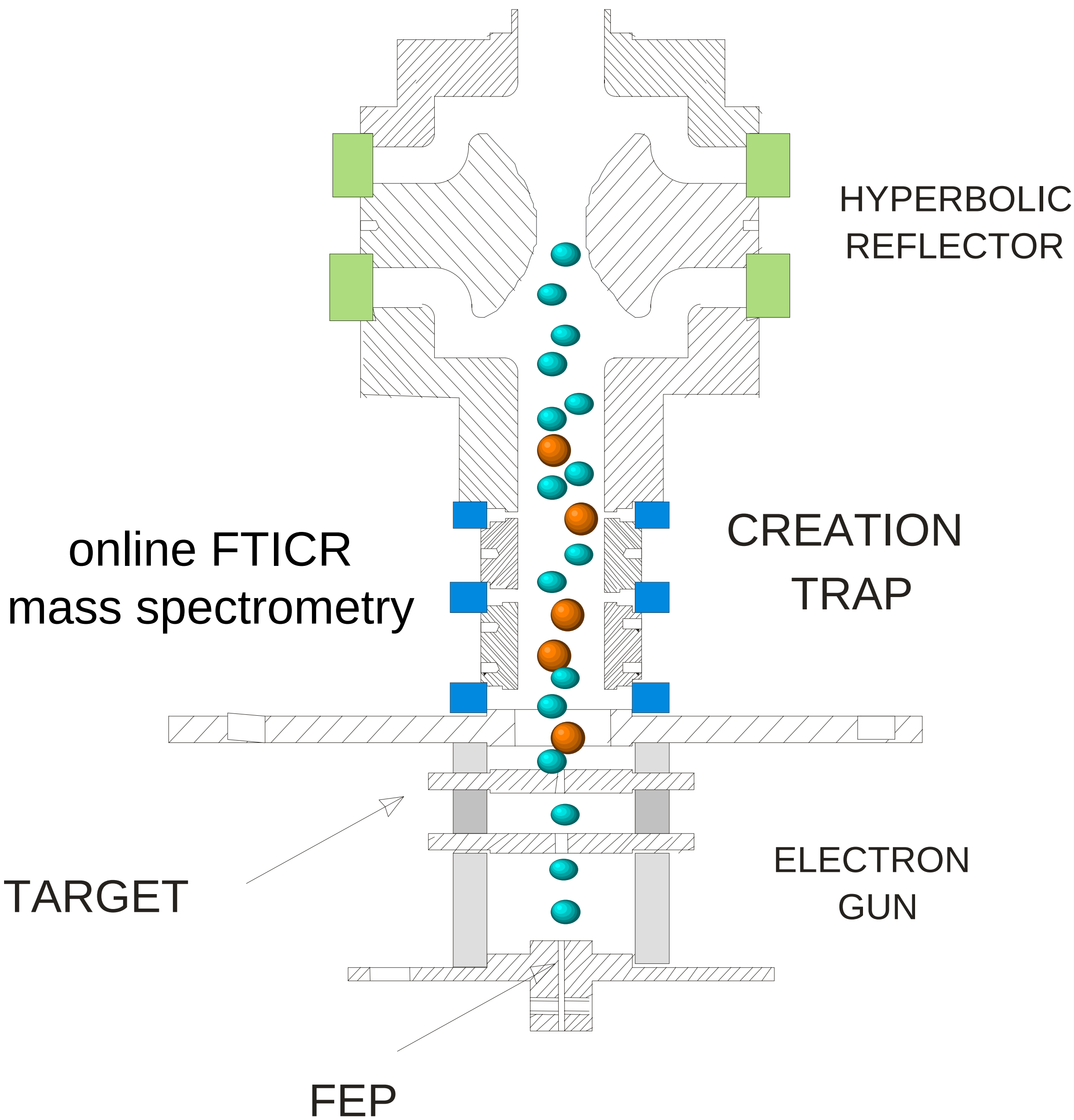




one order of magnitude higher beam energy AND breeding time

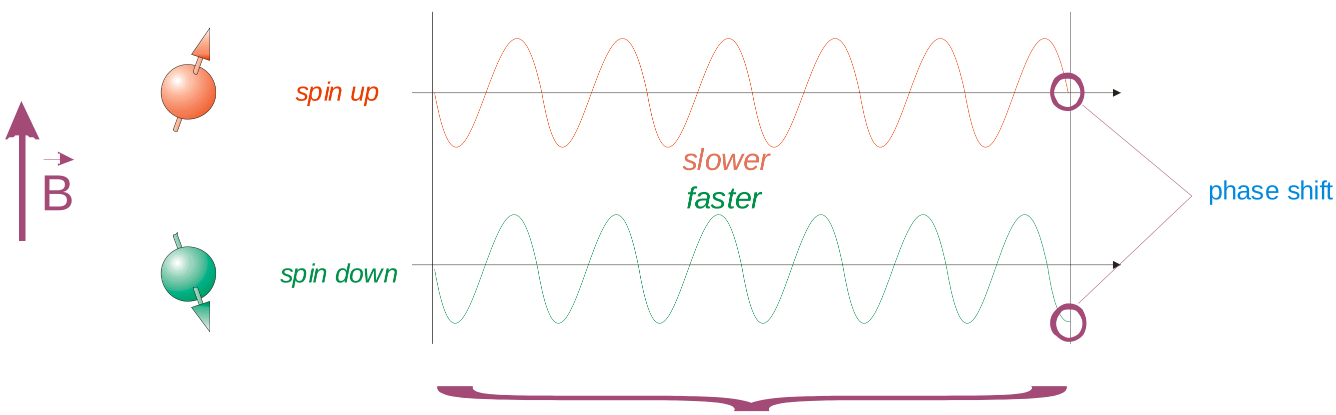
Controlled charge breeding

„mini-EBIS“



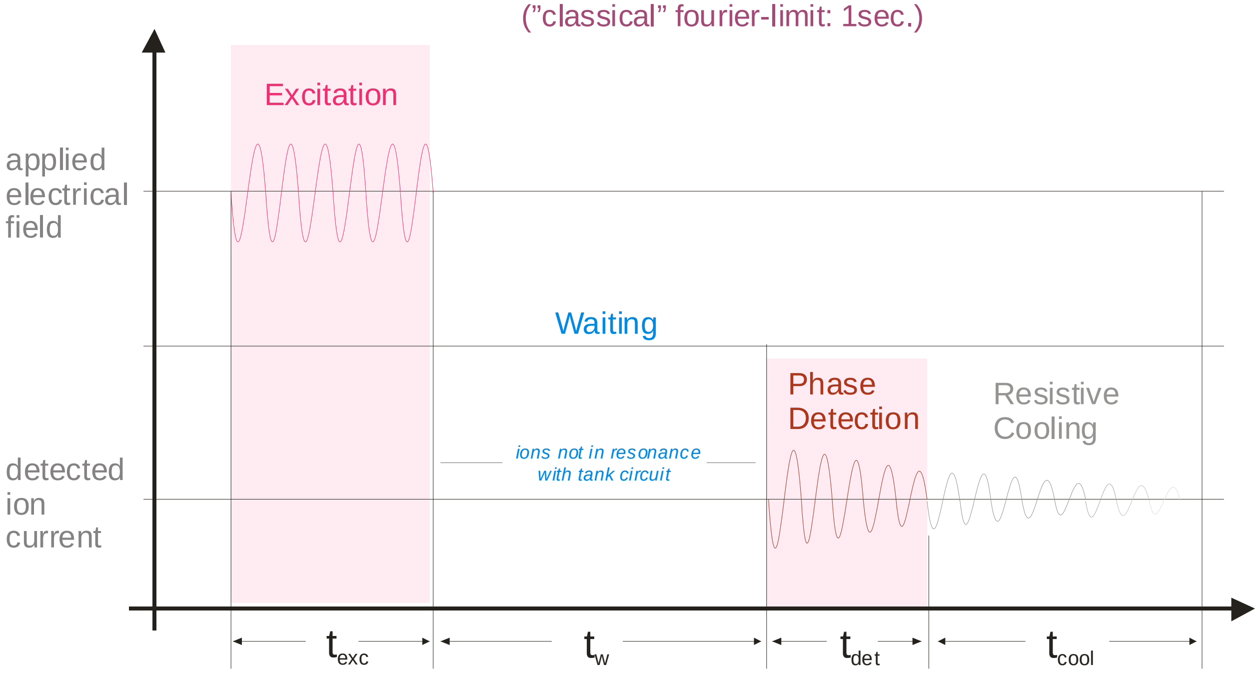
Novel detection scheme

phase-sensitive frequency difference measurement

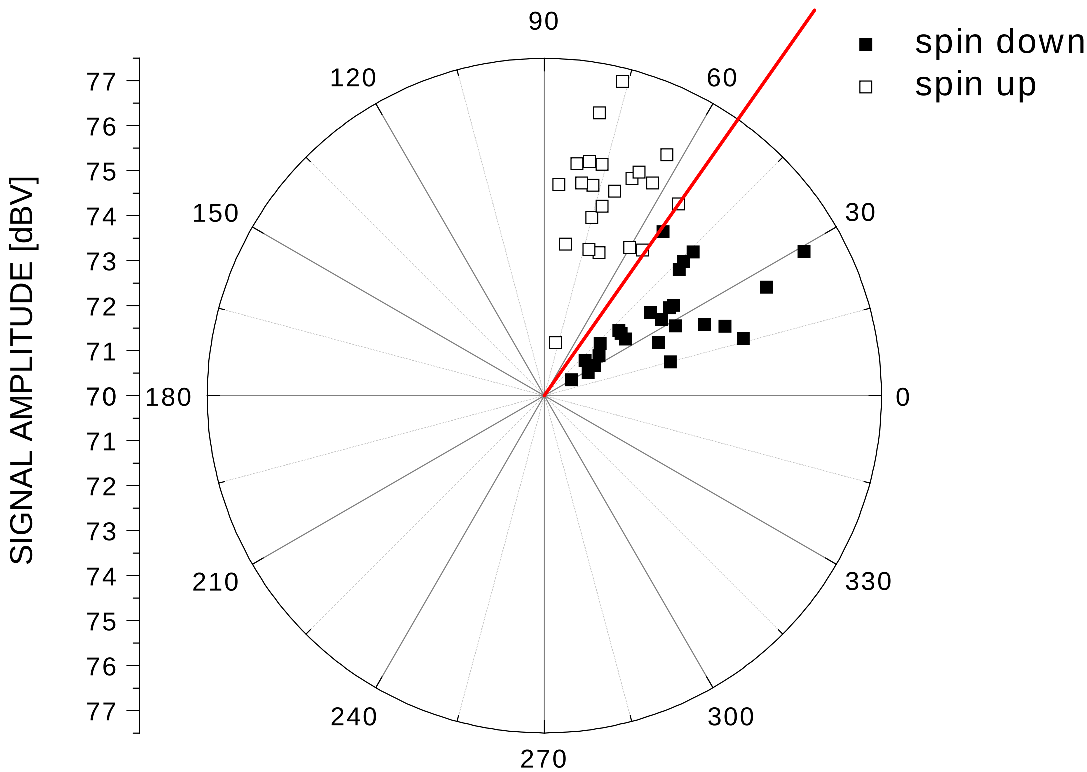


measurement time required to measure
1Hz frequency difference: only ¼ sec.

("classical" fourier-limit: 1sec.)



First test results



Ca^{19+} phase difference can be clearly resolved in only ¼ of the traditional measurement time

Conclusion:

We have tools for in-trap production of highly charged ions up to 10keV IP

Frequency differences down to roughly 50 mHz can be distinguished (order of magnitude higher sensitivity). Sufficient also for U^{91+}

Improved measurement techniques should shorten the traditional measurement time by a factor of about 4

We should be able to measure the g-factor of $^{40}Ca^{19+}$ and $^{40}Ca^{17+}$, and also of other ions of interest, e.g. $^{24}Mg^{11+}$ with an uncertainty of roughly 5ppb, allowing bound-state QED tests well below the 0.1%-level.

The team

Mainz

J. Alonso

S. Djekic

P. Fernández

F. Galve

S. Stahl

T. Valenzuela

J. Verdú

M. Vogel

G. Werth

GSI

T. Beier (theory)

H.-J. Kluge

W. Quint

Others

S. Karshenboim (theory)

V. Shabaev (theory)

V.A. Yerokhin (theory)