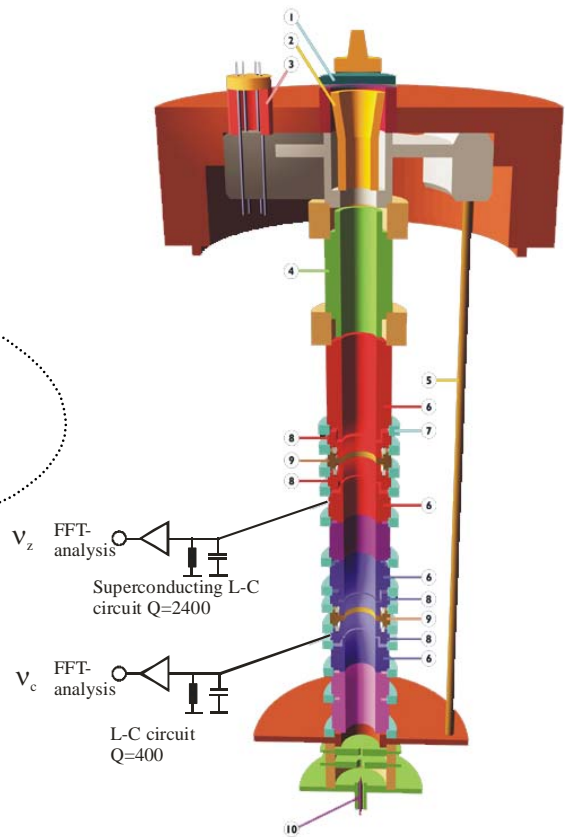
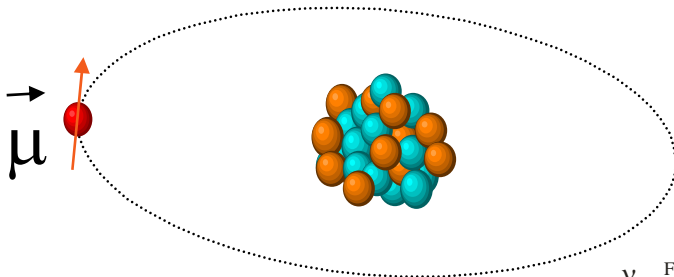
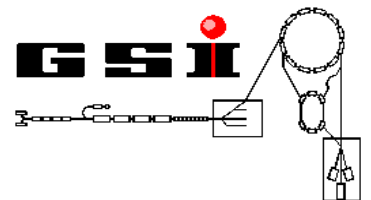


Towards g-factor measurements in medium-heavy and heavy ions

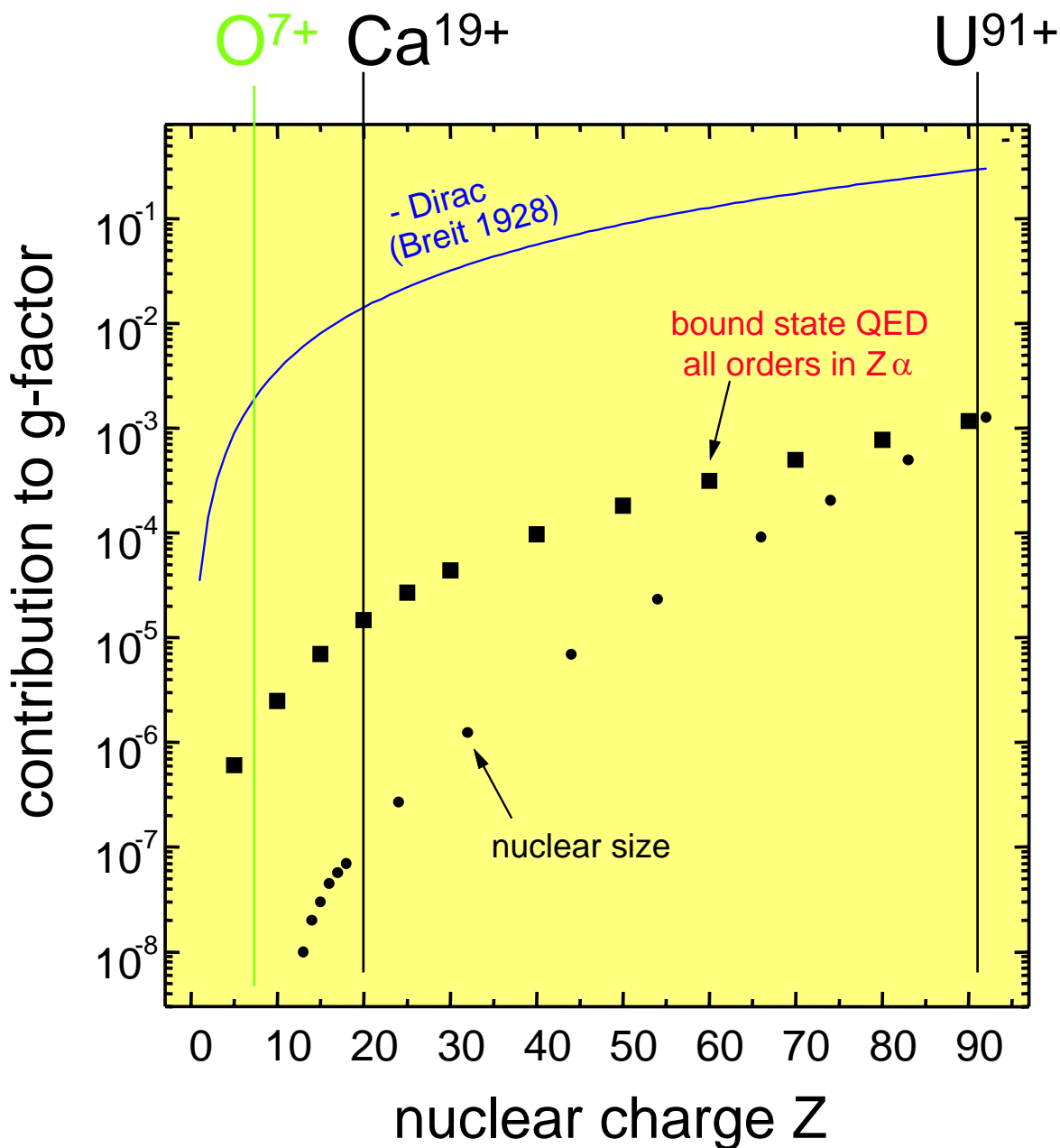


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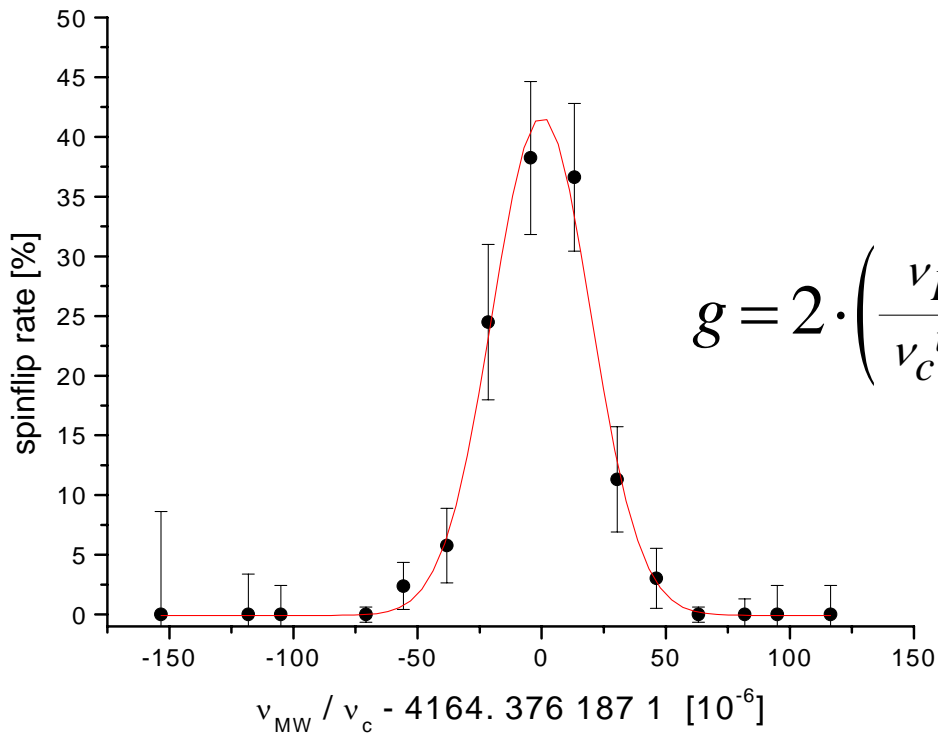
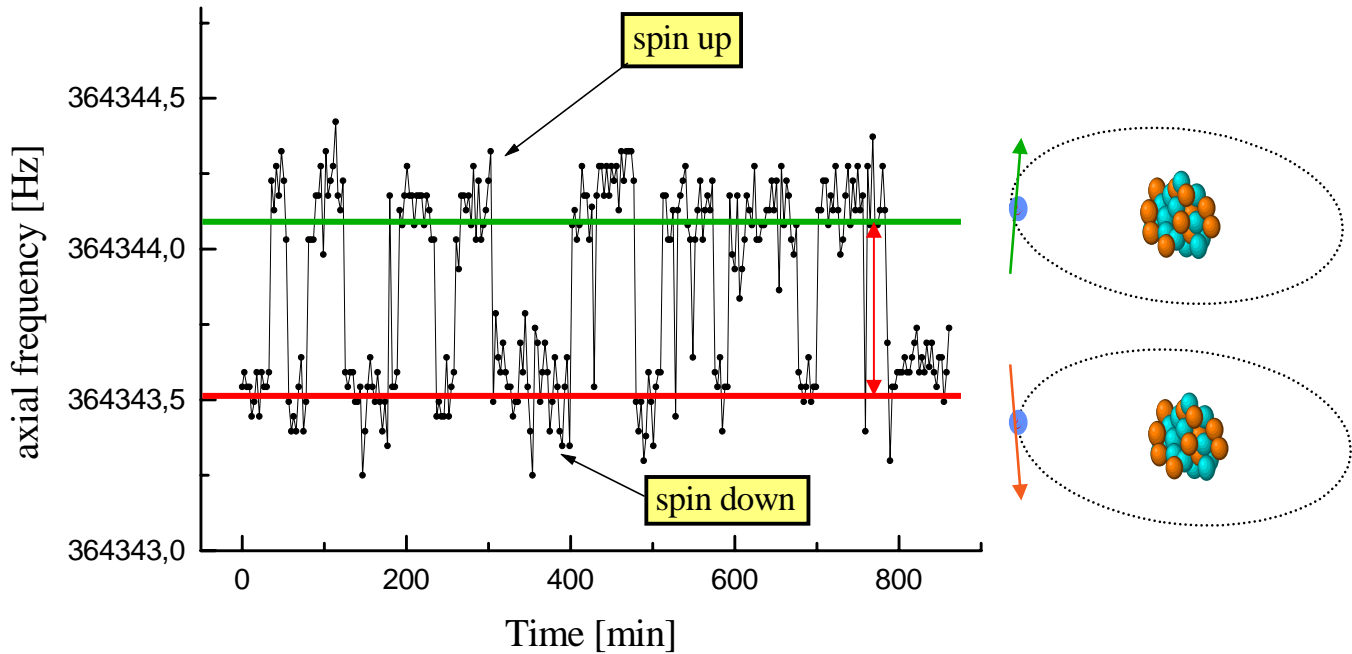


g-factors as benchmark for QED calculations

$$g_{\text{bound}}/g_{\text{free}} \approx 1 - \underbrace{(Z\alpha)^2/3}_{\text{Dirac theory}} + \underbrace{\alpha(Z\alpha)^2/4\pi + \dots}_{\text{bound-state QED}}$$



Measurement of g-factor



Achievements so far

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

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

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

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

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

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

Resulting electron mass

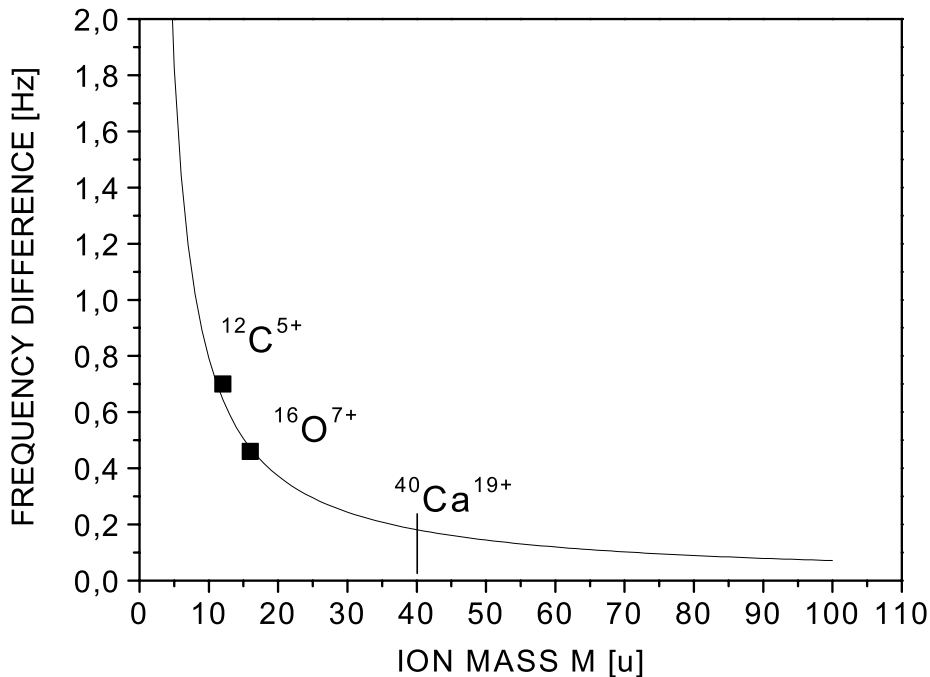
$$m = 0.000\,548\,579\,909\,3\,(3) \text{ u} \quad \text{T. Beier et al, PRL 88 (2002) 011603}$$

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

How to proceed to Ca¹⁹⁺

Problems:

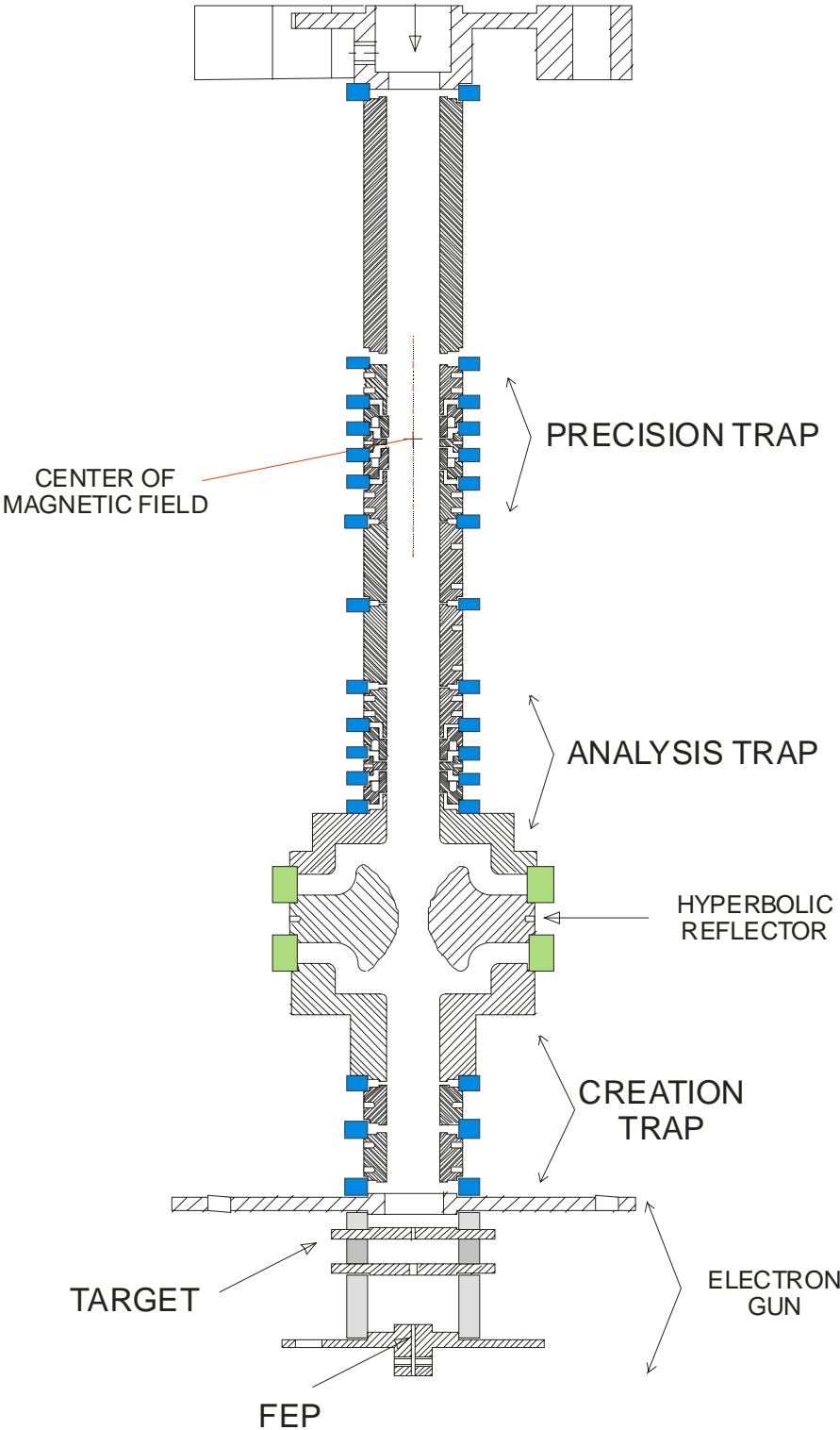
- 1.) creation: 19+ instead of 7+, IP 5 times higher
- 2.) detection: frequency difference due to spin flip small



...and how we plan to address them:

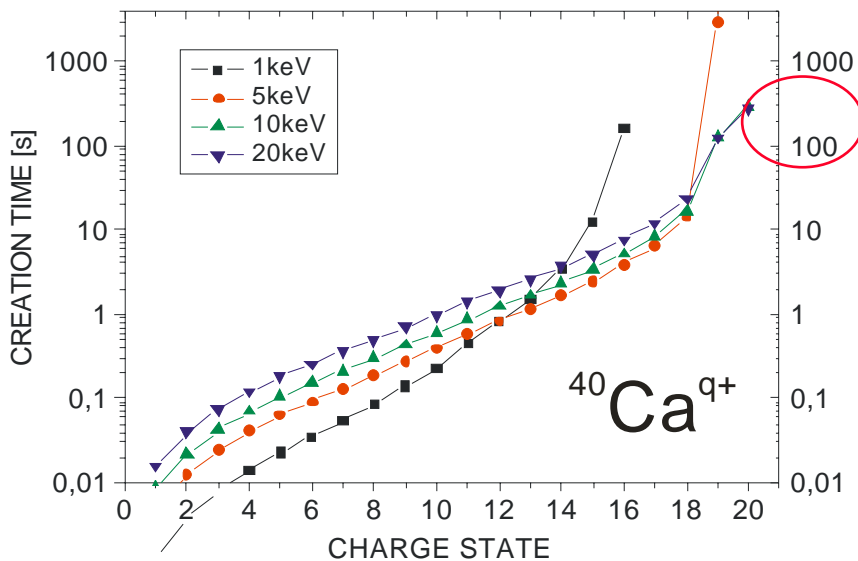
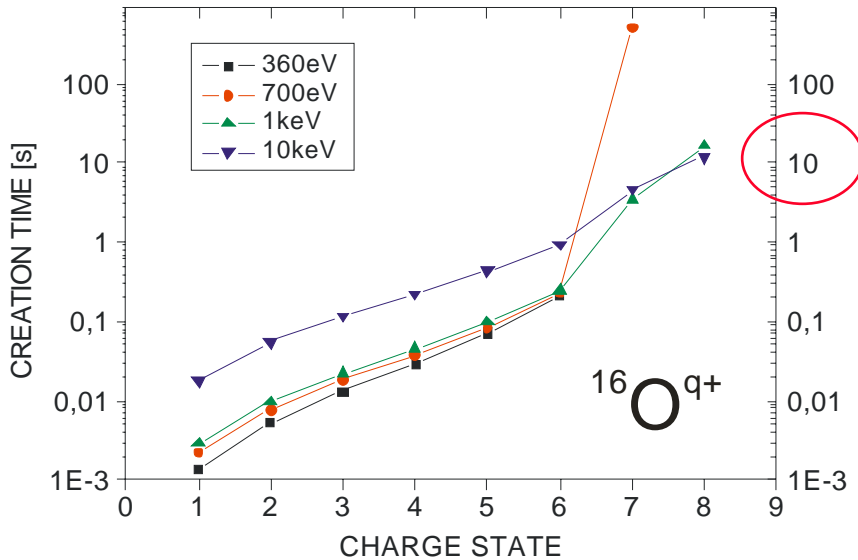
- ad 1.) „mini-EBIS“ with beam energy up to 10keV,
real-time FTICR mass spectrometry during
creation process (controlled charge breeding)
- ad 2.) novel detection electronics and techniques...

Novel triple trap setup



Breeding time

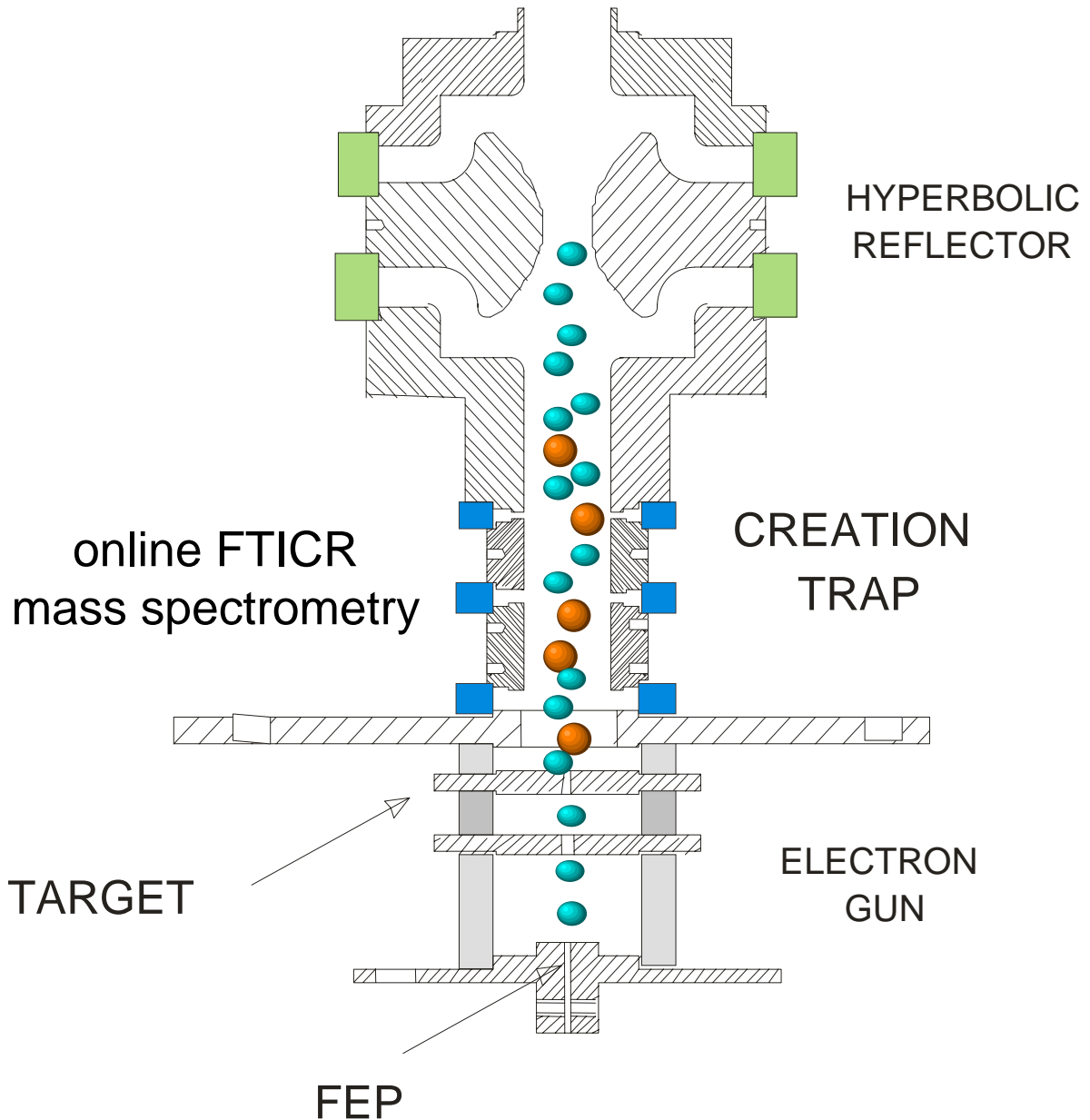
rather detailed simulations give:



one order of magnitude higher beam energy AND breeding time

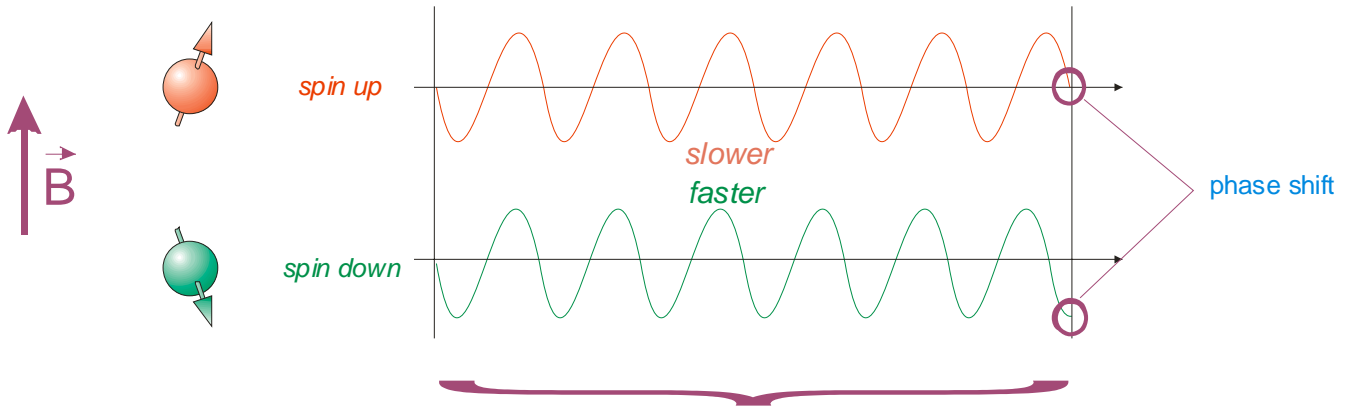
Controlled charge breeding

„mini-EBIS“



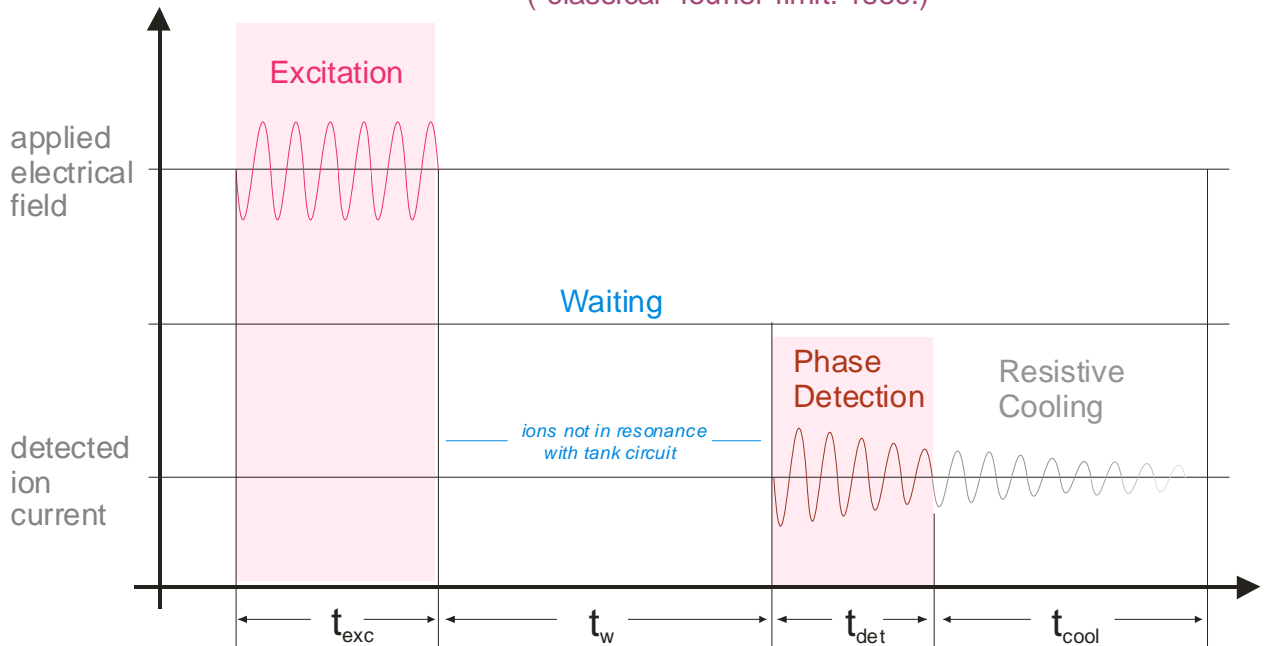
Novel detection scheme

phase-sensitive frequency difference measurement

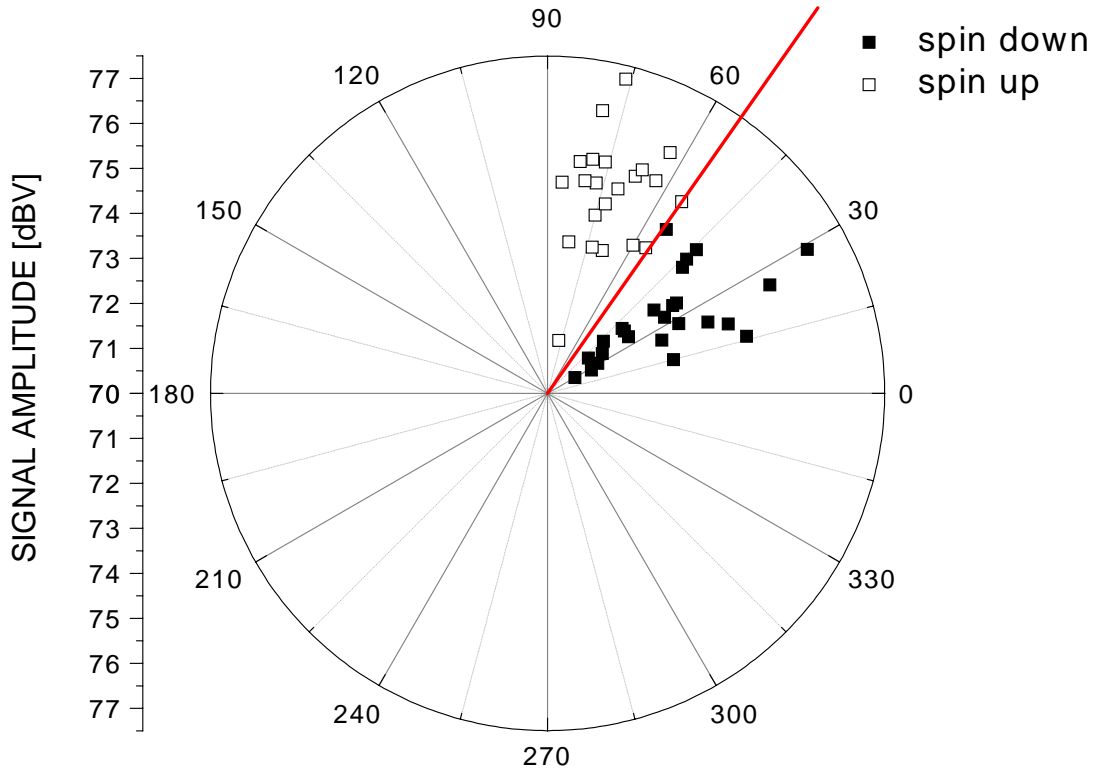


measurement time required to measure
1Hz frequency difference: only $\frac{1}{4}$ sec.

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



First test results



Ca¹⁹⁺ 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 $^{40}\text{Ca}^{19+}$ and $^{40}\text{Ca}^{17+}$, and also of other ions of interest, e.g. $^{24}\text{Mg}^{11+}$ with an uncertainty of roughly 5ppb, allowing bound-state QED tests well below the 0.1%-level.

The team

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V. Shabaev (theory)

V.A. Yerokhin (theory)