Tutorials of Klaus Blaum and Stefan Ulmer

Questions:

1. What is the minimum magnetic field required to balance the radial component of the applied electric field in a Penning trap?

2. In high-precision mass spectrometry with ion traps only Penning traps are in use. Why?

3. What is the mathematical reason for the side-bands in the destructive time-of-flight cyclotron resonance detection?

4. Draw the Feynman-diagrams of self-energy and vacuum polarization for the free electron.

5. Describe typical trap errors and their typical contribution in precision Penning trap measurements?

6. In high precision g-factor measurements a frequency ratio is measured to cancel the magnetic field. What are the ultimate limitations in such Penning trap experiments?

7. Derive the shift of the axial frequency induced by a spin quantum jump in a magnetic bottle. Compare the spin quantum jump of different systems, e.g. an electron, a proton and an electron bound to a hydrogen-like ion. Why are proton magnetic moment measurements specifically difficult?

8. Two charged particles are trapped close to each other and interact by Coulomb interaction. Assume the particles are tuned to the same resonance frequency, what is the Rabi frequency for the energy exchange?

9. What are the amplitudes and typical quantum numbers of a particle at 4K with a certain q/m ratio which is trapped in a magnetic field of 5T, at an axial frequency of 1MHz?

Exercise: Separation of isomers

Fig. 1 shows the separation of the ground and an isomeric state of ^{68}Cu, measured at ISOLTRAP.

1. Which of the curves shown in Fig. 1(b) and (c) belong to the ground state and which to the excited state?
2. What mass resolution was achieved?
3. What quadrupole excitation time was chosen to achieve the observed line width?
4. $^{85}Rb^{+}$ was chosen as reference ion for these measurements. The measured frequency ratio for the ground state is 0.800000818(20) and 0.800009879(19)

for the isomeric state, respectively. Calculate the mass excesses (what is it?) $D = m - A \cdot u$ in keV.

5. What is the excitation energy of the isomeric state?
6. What would be the advantage of using highly charged ions (e.g. He-like ions) for these measurements under the same conditions, i.e. excitation time and isotope?

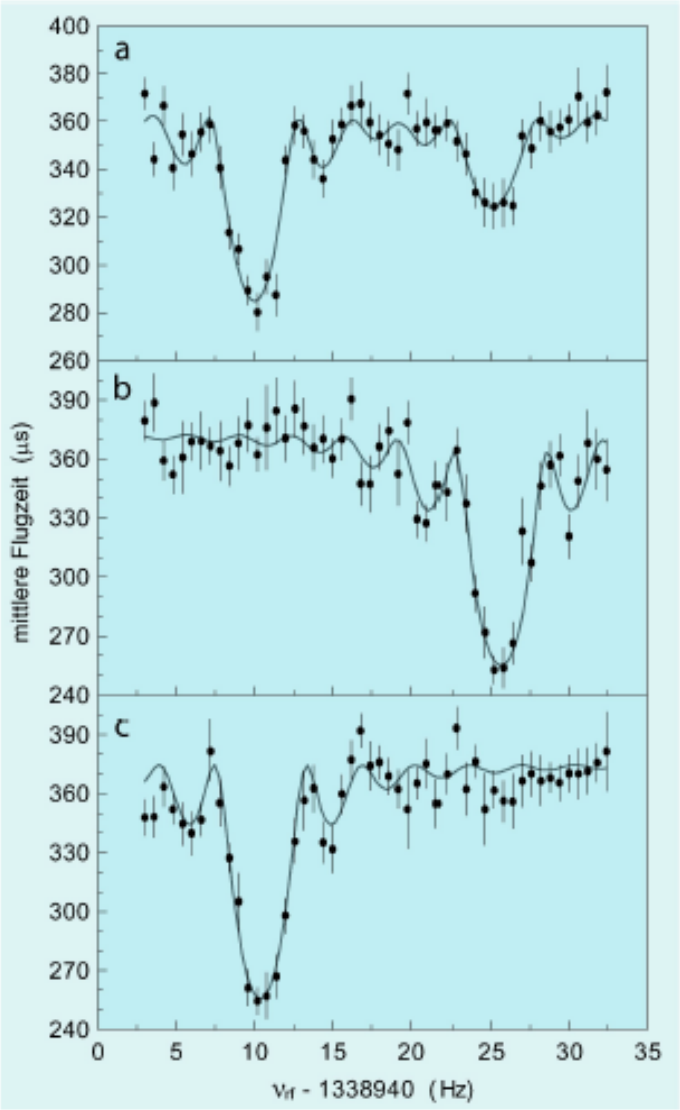

Figure 1: Separation of ground and isomeric state of ^{68}Cu, measured at ISOLTRAP. (a) is a mixture of both states, whereas (b) and (c) are the isolated states. The solid lines are the curves fitted to the data points to extract the resonance frequencies.