HGS-HIRe for FAIR
Helmholtz Graduate School for Hadron and Ion Research

Lecture Week *"Atomic Physics: Precision experiments with stored highly charged ions"*

Proposals for experiment talks

1 *Title*: **The *g*-factor of the bound electron in hydrogenlike ions**

Task: The *g*-factor has its origin in the magnetic moments associated with the electron's spin (g_S) and orbital angular momentum (g_L). Dirac's theory, which is fully relativistic, states that the g_L-value of the free electron is equal to 1, and that the g_S-value is equal to 2. For an electron bound to the nucleus, *i.e.* a hydrogenlike ion, the situation is somewhat different and such are the *g*-factors. Study the method(s) to determine the *g*-factor in the hydrogenlike ions C^{5+} and O^{7+}, and present an overview of the method(s) and the obtained results.

Literature:
[1] H. Häffner *et al.*, Phys. Rev. Lett. **85**, 5308 (2000).
[2] J. Verdú *et al.*, Phys. Rev. Lett. **92**, 093002 (2004).

2 *Title*: **The ground state hyperfine splitting in heavy highly charged ions**

Task: In an atom or ion, the ground state is, by definition, the lowest bound state. If the nucleus has no spin (I), the electronic state can simply be described by the electron spin (S) and the orbital angular momentum (L). For a one-electron system, the ground state is then simply the 1*s* state (J =1/2). If the nucleus has a spin (*e.g.* I =1/2), the so-called 'hyperfine structure' arises and the 1*s* state splits into two new states (*e.g.* F = 0 and F = 1). Usually, this splitting is much smaller than the fine structure splitting (hence the name 'hyperfine'). In heavy highly charged ions, however, the splitting becomes sizeable and can more easily be measured. Find two different experimental approaches to measure the ground state hyperfine splitting in lithiumlike bismuth ($^{209}Bi^{80+}$) and present your findings and the results in your talk.

Literature:
[1] D.F.A. Winters *et al.*, Can. J. Phys. **85**, 403 (2007).
[2] T. Beier, Phys. Rep. **339**, 79 (2000).

3 *Title*: **The production of highly charged ions**

Task:There are many different types of (commercial) ion sources, each with their own *pro's* and *con's*. Some are small and affordable, others large and expensive. To remove one or two electrons, *i.e.* to produce singly or doubly charged ions, is really easy, but removing (almost) all electrons is a difficult task. Explore the 'market' to see what types of sources or methods for the production of highly charged ions exist. Share your newly gained knowledge with all of us during your presentation.

Literature:
[1] world-wide-web
[2] libraries
[3] ask people

4 *Title*: **Bound-state beta decay of 163Dy**
Task: Half-lives of radioactive nuclei can significantly differ in highly-charged ions compared to neutral atoms. Some decay channels can become disabled, like, e.g., the electron capture decay is impossible in fully-ionized atoms due to the absence of bound electrons, however, also new decay channels can open up. One example of the latter is the bound-state beta decay, which has been predicted to exist about a half of a century ago and was discovered experimentally in the ESR in 1992 on the example of 163Dy. What is so special in the decay of 163Dy? Where this decay can happen in Nature? What can we learn about the environments where this decay proceeds in Nature?

Literature:
[1] J.N. Bahcall, Phys. Rev. **124** (1961) 495.
[2] M. Jung et al., Phys. Rev. Lett. **69** (1992) 2164.
[3] Yu.A. Litvinov and F. Bosch, Rep. Prog. Phys. **74** (2011) 016301.

5 *Title*: **Ultra-precise mass measurements for neutrino physics**
Task: Neutrinos might be the most intriguing particles discovered so far. Until very recently neutrinos were considered to be massless, weakly interacting, left-handed particles with spin 1/2. But the discovery of neutrino oscillations has finally placed neutrinos in the family of massive particles. Unfortunately, the oscillation experiments do not shed light on the rest mass of the neutrino, which has thus to be measured in dedicated experiments. What can we learn about neutrino properties from beta decay? What invaluable information can precision mass measurements contribute to the neutrino physics? What are the present limits on the neutrino masses? Do you know other applications of ultra-precise mass measurements?

Literature:
[1] S. Rahaman et al., Phys. Lett. B **703** (2011) 412.
[2] V. Kolhinen et al., Phys. Lett. B **697** (2011) 116.
[3] S. Eliseev et al., Phys. Rev. Lett. **106** (2011) 052504.

6 *Title*: **Mass measurement of short-lived 65As isotope**
Task: Very recently, mass measurements of short-lived exotic nuclei became possible with a new storage ring facility at the Institute for Modern Physics in Lanzhou in China. The isochronous mass spectrometry technique will be explained in detail during the lectures. What is the main advantage of the isochronous mass spectrometry compared to other direct mass measurement methods? What is special in 65As? What can we learn about nucleosynthesis in stars from the measurements in Lanzhou?

Literature:
[1] X.L. Tu et al., Phys. Rev. Lett. **106** (2011) 112501.
[2] P. Walker, Nature Physics **7** (2011) 281.