

Lifetime measurements of the ground state hyperfine transitions in H-like and Li-like bismuth*

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The goal of the LIBELLE experiment is to determine the energies of the ground state HFS transitions in H-like and Li-like bismuth via laser spectroscopy. If both values are known with sufficient precision, this enables a test of bound state QED in extreme electric and magnetic fields via the calculation of the so-called specific difference of the transitions (see Shabaev et al. [1]). Nuclear structure effects, like the distribution of the magnetic moments, that otherwise mask the QED contribution, are largely canceled out in the specific difference.

Both transitions were successfully measured with the LIBELLE experiment in 2011 [2]. The accuracy was limited, however, by the determination of the ion velocity which is needed for transformation to the rest frame. Besides the investigation of the transition energies the lifetime of the Li-like state was measured as well. With an improved determination of the ion velocity and a high performance data acquisition (DAQ) the beam-time was repeated in March 2014 [3]. The new DAQ was capable to record timestamps for each detected photon which are set in relation to a reference point. For $^{209}\text{Bi}^{82+}$ this reference point is given by the laser shot itself leading to a measurement interval of 30 ms. This is long enough since the lifetime of $^{209}\text{Bi}^{82+}$ is about 400 μs . For $^{209}\text{Bi}^{80+}$ a shutter has been introduced into the laser beam line to extend the decay interval to ~ 1 s, since the expected lifetime is about 80 ms. During measurement cycles the upper HFS state is populated for about 0.5 s, than the shutter is closed and the ions can de-excite for about 1 s.

The ions are compressed into two bunches, one is excited by the laser, the other is treated as reference. The timestamp can be synchronized to the ions revolution period in the ESR to obtain fig. 1 and distinguish between signal and reference peak. For H-like ions the most accurate re-

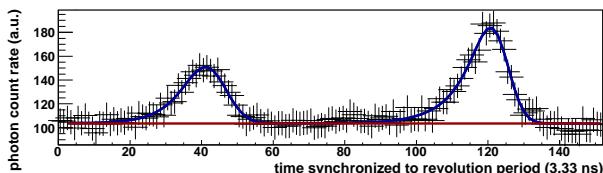


Figure 1: Photon count rate versus photon incident time convoluted with revolution time in 3.33 ns bins.

sult is obtained by simply counting all events in the signal peak region as a function of time after laser excitation (see

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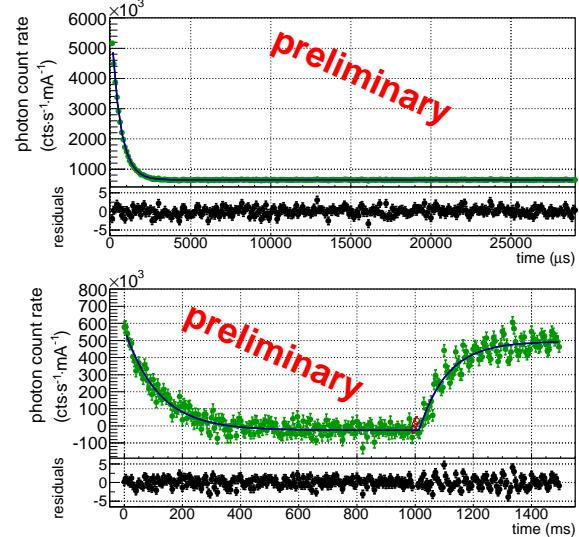


Figure 2: Photon count rate versus decay time for H- and Li-like bismuth together with fit.

Table 1: Preliminary lifetime results transformed in the ions rest frame, compared to other experimental work and theoretical prediction.

	H-like ($\tau/\mu\text{s}$):	Li-like (τ/ms):
this work	(399.15 ± 1.64)	(82.15 ± 2.93)
exp. [4]	(351.0 ± 16.0)	-
exp. [5]	(397.50 ± 1.50)	-
theo. [6],[7]	(399.01 ± 0.19)	(82.0 ± 1.4)

fig. 2, upper plot). For Li-like data a background correction is mandatory, therefore the signal and reference peaks of fig. 1 are fitted via two exponentially modified Gaussians and a constant offset with the difference area as fit parameter. The obtained lifetime curves (fig. 2) can be fitted via an exponential decay model. In case of $^{209}\text{Bi}^{80+}$ the model can be extended taking into account stimulated emission and absorption, to also fit the rising branch of the data during laser excitation. Preliminary lifetimes transformed into the rest frame are given in tab. 1.

References

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