In Search of the Ionic Spike with a ^{76}Se Beam ◇

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The energy loss of swift heavy ions traversing a solid is able to melt the matter along the ion track. Models describe the formation of this so called thermal spike [1] as a two step process [2]. First the energy of the incident ions is transferred to the host electrons, resulting in a high electronic ionization. This so called ionic spike exists just (10−1000) fs after the passage of the heavy ion. Then the thermal spike rises as a result of strong electron-phonon coupling (∼(1−10) ps).

In contrast to the thermal spike, which is able to cause a latent track of different crystalline phase, the ionic spike has never been measured so far because of its short lifetime.

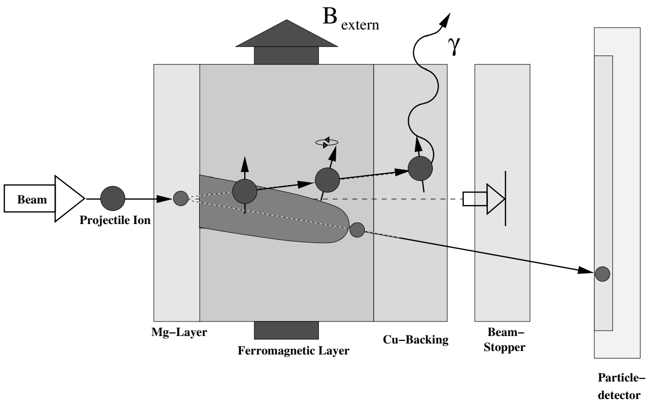

Fig. 1: Experimental scheme: The Coulomb excited projectile follows the target ion through the ferromagnetic layer. The ionic spike induced by the Mg target ion reduces the measured precession angle of the excited projectile due to the local breakdown of magnetization.

The combined technique of projectile Coulomb excitation and transient fields primarily developed for g-factor measurements of short lived nuclear states is highly sensitive on this fs timescale. The experiment was performed with a 190 MeV ^{76}Se beam from the MP tandem accelerator at Munich. A multilayered target consisting of 0.24 mg/cm^2 ^{26}Mg, 1.0 mg/cm^2 Gd, 1 mg/cm^2 Ta, 6.5 mg/cm^2 Cu was used. As seen in Fig. 1 the ^{76}Se projectiles are Coulomb excited to the 2_1^+ state in the Mg layer. After the collision the Mg ions traverse the magnetic Gd layer and generate ionic spikes before they are detected in a Si detector in forward direction. The transient field in the Gd layer causes a spin precession of the following excited ^{76}Se nuclei. If the electron temperature in the ionic spike reaches the Curie temperature of Gd (294 K) the magnetization and thereby the transient field breaks down. If the angle between the directions of the trajectories of the ^{26}Mg and ^{76}Se ions is small the Se ions will be affected by the ionic spike resulting in a reduced precession. To select these events the aperture of the Si detector was restricted to scattering angles of $\leq 3°$ with respect to the beam axis. Simultaniously ^{26}Mg ions scattered to larger angles between 17° and 22° where detected at which the associated Se ions are not affected by the ionic spike. In both situations the precessions of the particle-γ angular correlations have been measured. The two different scattering directions were defined by a diaphragma placed in front of the Si detector.

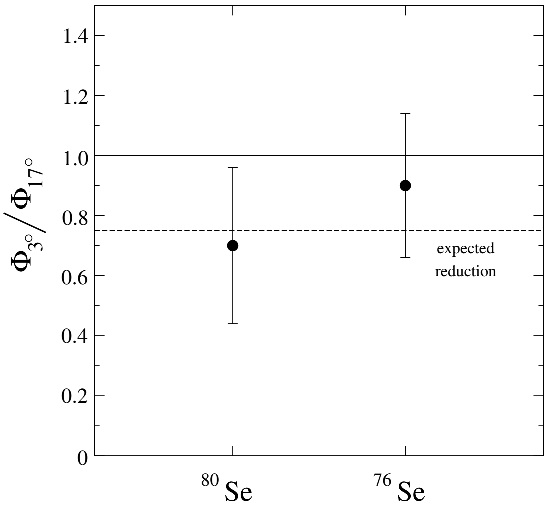

Fig. 2: The measured ratio of the precession angles $\Phi_{3°}/\Phi_{17°}$ for a ^{80}Se and a ^{76}Se beam. Dashed line represents the expected value.

In contrast to a former measurement using a ^{80}Se beam now a ^{76}Se beam was preferred because of its larger cross section for Coulomb excitation. The calculated electron temperature [2], predicts a strong rise of the ionic spike radius induced by the ^{26}Mg from $\sim$ 50 nm at 50 fs to 70 nm after (100-200) fs which is in this experiment the difference in the time of flight between the Mg- and Se-ions. A reduction of 75 % in the precession compared with the spike-free situation is expected from these data. Fig. 2 shows the ratio $\Phi_{3°}/\Phi_{17°}$ for both Se beams. The accuracy is still too low for clearly establishing an effect. Further experiments are in progress.

References

[1] G. Bonfiglioli *et al.*, J. Appl. Phys. **32** (1961) 2499
[2] Z.G. Wang *et al.*, J. Phys.:Condensed Matter **6** (1994) 6733

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