On the Track of the Ion Induced Thermal Spike ◊

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If a solid is irradiated by swift heavy ions their energy loss is able to melt the matter along the ion track. This phenomenon is the well known so called thermal spike [1]. Nevertheless, the dynamics of its formation process, however, has never been measured so far. Models describe it as a two step process [2]: (*a*) the energy of the incident ions is transferred to the host electrons, resulting in a high electronic ionization (ionic spike)($\sim$ 10 fs$-$1 ps), (*b*) the lattice melts as a result of strong electron-phonon coupling (thermal spike)($\sim$ 1 ps$-$10 ps).

The thermal spike can cause a latent track of different crystalline phase whose radial extension has been determined by electron microscopy. The ionic spike, in contrast, can only be measured with a time sensitive method of femtosecond resolution.

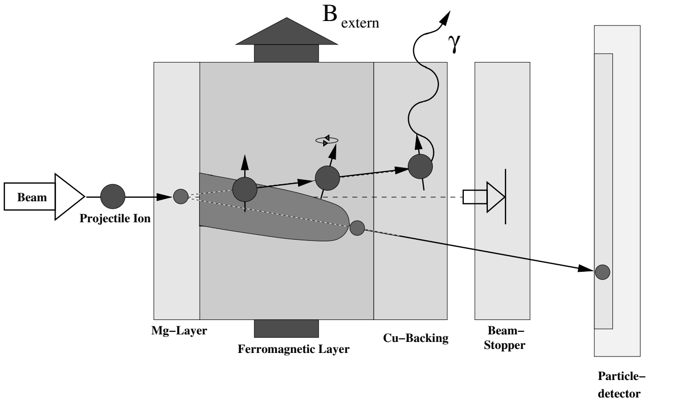

Fig. 1: Experimental scheme: The Coulomb excited projectile follows the target ion through the ferromagnetic layer. The ionic spike induced by the Mg target ion reduces the measured precession angle of the excited projectile due to the local breakdown of magnetization.

The combined technique of projectile Coulomb excitation and transient fields enables measurements in these extreme experimental conditions. The experiment was performed with a 190 MeV ^{80}Se beam at the Tandem accelerator at Munich. Fig. 1 shows the scheme of the ion trajectories in the composite target with the particle detection. The ^{80}Se projectiles are Coulomb excited in collisions with the ^{26}Mg target. As a consequence the ^{26}Mg ions traverse the magnetized Gd-layer and generate ionic spikes. After 0$-$100 fs (depending on the site of excitation) the ^{80}Se ions penetrate the Gd-layer and leave it 100$-$200 fs later. If the electron temperature in the ionic spike reaches the Curie temperature of Gd (294 K) the magnetization will break down. The transient field strength which is linked to the magnetization and experienced by the ^{80}Se ions will change accordingly. If the angle between the directions of the trajectories of the ^{26}Mg and ^{80}Se ions is small the ^{80}Se ions will be affected by the ionic spike resulting in a reduced precession. In the experiment these conditions were verified by restricting the aperture of the particle detector for the ^{26}Mg ions to scattering angles of $\leq 3°$ with respect to the beam axis. The precession of their particle-γ angular correlation was compared to the one simultaniously measured by selecting target ions scattered at large angles (17°-22°) at which the ions are not affected by the ionic spike. The target ions emerging at small scattering angles have a higher energy than the ones scattered at larger angles. Therefore, it was possible to separate both events in the simultaneous measurements. In the 2-dimensional plot of particle energy vs TAC (time difference between particles and γ's detected with four BaF_2 detectors) the events associated with both kinematic conditions are well separated (Fig. 2).

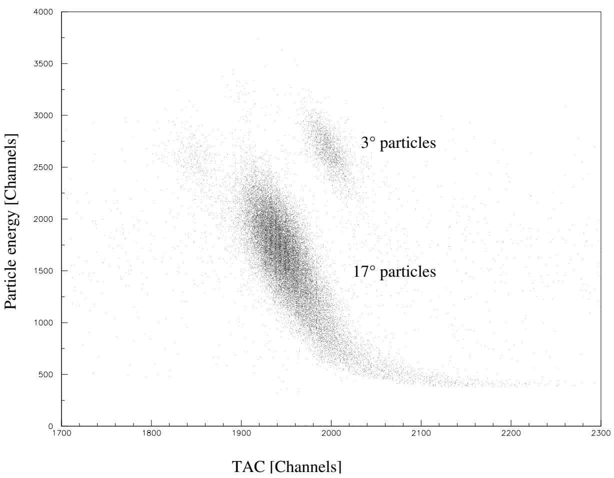

Fig. 2: Particle energy versus TAC. The 3°-particles are well separated from the 17°-particles.

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. These events being sensitive to the ionic spike can be extracted from the data. We expect a reduction of 75 % in the precession compared with the spike-free situation which is consistent with the present preliminary result: $\Phi_{3°}/\Phi_{17°}$=0.70(26). This ratio has to be improved in accuracy. Further experiments with other beams e.g. ^{76}Se, implying a substantially larger Coulomb excitation cross section, are in progress.

References

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

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