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Towards electron-impact dissociation dynamics of biologically relevant molecules in a reaction microscope

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Synopsis We present a new design of an advanced reaction microscope (REMI) for electron collisions with biologically relevant molecules. It will combine advancements which have been implemented for (e, 2e)-experiments, such as multi-hit detectors with a high detection efficiency, as well as new features for target creation and increased fragment acceptance.

Investigation of the ionization dynamics of simple atoms and molecules in electron collision experiments has provided significant background to enable the study of more complex targets, such as biologically relevant molecules(e.g. [1, 2, 3]). Our aim is to provide highly differential ionization cross sections and insight into fragmentation dynamics, especially of DNA constituents. Data of this nature – with special emphasis on low collision energies – has a high importance in the modeling of radiation damage to biological tissue [4] and in cancer treatment.

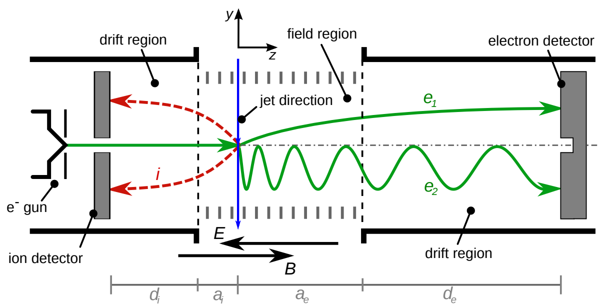

Figure 1. Schematic view of a REMI.

The experiment is based on an advanced reaction microscope (REMI) which was modified for electron impact studies [5]. Its general working principle can be seen in Figure 1. Briefly, a collimated molecular target beam is crossed with a monoenergetic, pulsed electron beam. All charged particles which emerge from a reaction are detected and their momentum vectors are reconstructed. Hence, highly detailed electronic information in form of e.g. triple-differential cross sections can be obtained. Furthermore, information on molecular fragmentation processes like kinetic energy release and molecular orientations are extracted by detecting the ionic fragments in coincidence with the electrons.

With respect to the conventional REMI technique several constrains had to be overcome. Since molecular dissociation can result in large fragment momenta, a short detector distance and/or a pulsed high-voltage extraction is required. Our studies show that the type of ramp applied makes a significant difference in the ion resolution and allows the operation of the spectrometer in two modes: a mass spectrometer mode and a momentum spectrometer mode. Additionally, the REMI measurement relies on the target species to be present in gaseous form. While some volatile DNA constituents or surrogates can be provided in seeded supersonic jet or by evaporation in an oven, less volatile molecules can be brought into vacuum by laser-induced acoustic desorption from a foil. Consequently, the new apparatus has the possibility to incorporate several methods of target creation.

Finally, since good energy resolution is paramount, projectile beam creation requires special attention. A specially designed electron gun with minimal dimensions was built, which can be inserted close to the interaction volume.

A detailed overview of the project and the employed methods and their performance will be presented.

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