Development of ion detectors for the 1–10 MeV/u energy range*

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Physics case

Within the universe, matter is commonly found in the state of ionized plasma, where collisions between ions occur regularly. The interaction cross sections of the involved charge-exchange processes are largest in the so-called *intermediate regime*, where the electron and relative target–projectile speed are comparable. For a proton colliding with a hydrogen atom, this regime corresponds to an energy of about $10\,\mathrm{keV}$; heavier ions require some $10\,\mathrm{MeV}$. Unfortunately, it is difficult to calculate the relevant cross sections theoretically, as the rigorous electronic treatment of the system amounts to an N-body problem. On the other hand, experimental investigations are hampered by the fact that the probabilities of a variety of interaction mechanisms attain similar magnitudes, which causes "interference effects". Therefore the intermediate collision regime, despite its undeniable importance, is only barely investigated, with experimental data lacking for all but the lightest systems.

The Franco-German *Fit-FISIC* cooperation ("**Fi**rst steps **t**owards atomic physics of **F**ast **I**on–**S**low **I**on **C**ollisions") constitutes a novel attempt to better understand these ion–ion interactions. Using intense high-quality ion beams that are available at French and German accelerator facilities such as SPIRAL2 and FAIR (currently under construction at Caen and Darmstadt, respectively), collisions of multi-charged ions will be realized under well-controlled conditions [1]. The planned setup is outlined in Figure 1.

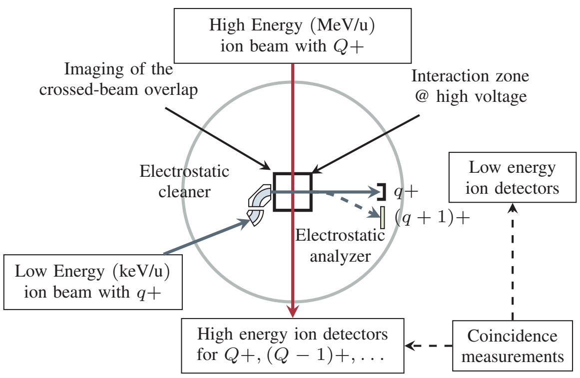

Figure 1: Planned setup for the Fit-FISIC project. Coincidence measurements of the low- and high-energy branches will be used to detect charge-exchange reactions. Figure reproduced from [1]

Ion detector development

As a collaborative effort of both GSI and FSU, a detection system for the high-energy branch of the project is currently being developed. This detector will have to cope with MHz count rates of ions having energies between sub-$\mathrm{MeV/u}$ and $15\,\mathrm{MeV/u}$, while remaining windowless so as to not stop impinging ions before they reach the actual sensor material. A movable stage will position the detector relative to the beam of charge-exchanged ions. Since the projected energy and ion range are only scarcely investigated with respect to suitable detector models, extensive research into possible sensor configurations is necessary.

Above all else, radiation hardness is a critical demand: charged particles deposit their energy locally, evident in the so-called *Bragg peak* of the energy loss curve, leading to conventional semiconductor and plastic scintillator detectors being virtually "scorched" by the incident ion flux, which renders them unusable almost immediately.

A favorable material choice for these conditions is artificial diamond, one of the most resilient materials around. CVD diamond also offers a desirably high charge carrier mobility [2], although it is somewhat diminished by grain boundaries present in polycrystalline substrates. Its behavior under prolonged ion bombardment, most notably the long-term signal stability, will be studied in 2015 at tandem accelerators capable of delivering the required ion species and energies.

In parallel, alternative detector models are being considered. Among these, scintillator crystals such as cerium-doped yttrium aluminum perovskite (YAP:Ce) appear particularly promising. The material has been successfully employed to detect ions in earlier experiments, where it exhibited a surprising level of radiation hardness [3]. A test setup to investigate the feasibility of these alternative approaches is currently being assembled at Helmholtz Institute Jena, and will be used for initial measurements in 2015.

References

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