Ion Optical Design Studies and Simulations of the Super-FRS Energy Buncher

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The extension of the present accelerator complex Gesellschaft für Schwerionenforschung (GSI) in Darmstadt, Germany to a "Facility for Antiproton and Ion Research" (FAIR) is one of the most challenging but at the same time most rewarding physics projects in Europe [1]. The new superconducting fragment separator (Super-FRS) will be a major installation of the FAIR facility [2]. High intensities of secondary beams exceeding those presently available at GSI by a factor of 10^5 will provide ideal conditions for experiments using nuclei far off the valley of stability (see e.g. [3]). After production and in-flight separation in the pre- and main stages of the Super-FRS, the secondary beam can be distributed to either of three experimental areas: a high-energy cave, a storage ring complex and a dedicated low-energy branch (LEB).
In the LEB the exotic species can be slowed-down to ion energies ranging from a few hundred MeV/u down to rest. The LEB will be equipped with an energy-bunching stage in order to reduce the energy spread of the secondary ions originating from the fragment production process and from straggling in the target and the degraders. The novel technique of energy and range focussing proposed for the LEB (see [4] and references therein) opens the door for new kinds of nuclear physics studies with short-lived species that require an efficient slowing-down and/or a well defined or minimal stopping range in matter (see e.g. documents and references in [3]).
The experiments can be classified into two different categories according to the hybrid character of the LEB: Firstly, measurements that directly deploy the low energy exotic beam, e.g. detector systems like AGATA, HYDE, charged particle arrays, magnetic spectrometers and implantation or decay set-ups (HIgh resolution in-flight SPECtroscopy, HISPEC, and DEcay SPECtrscopy with implanted beams, DESPEC). Secondly, the ions can be stopped in a gas-cell and subsequently be extracted, thus allowing for experiments like LASer SPECtroscopy (LASPEC), X-ray spectroscopy in an EBIT or precision mass measurements in ion traps (MATS). More detailed information about the individual research programs can be found on the web pages of the NUSTAR collaboration [3].
The diversity of installations requires some flexibility in the ion optical layout in order to provide optimal conditions for the individual set-ups: For the first class of experiments, in many cases the detector geometry puts some constraints on the maximal emittance of the beam, i.e. its size and divergence. For the latter class, a quasi-monoenergetic low-energy beam is a prerequisite for an efficient stopping of the ions in the gas-filled stopping cell. The necessary maximum energy separation in the last dispersive stage of the energy-buncher can typically only be obtained at the expense of an increased transversal emittance of the beam.
In this contribution, ion optical design studies of the LEB, the energy-buncher stage and the beamline to the experimental set-ups will be presented. Different scenarios will be discussed according to the individual experimental requirements. The ion optical calculations will be supplemented using Monte-Carlo simulations of the performance of the buncher and the beam properties at the experiments.

[1] Facility for Antiproton an Ion Research (FAIR),http://www.gsi.de/fair/index_e.html.
[2] H. Geissel, H. Weick, M. Winkler, et al., Nucl. Instr. Meth. in Phys. Res. B 2004 (2003) 71.
[3] Nuclear Structure and Astrophysics and Reactions (NUSTAR) collaboration, http://www.gsi.de/nustar.
[4] C. Scheidenberger, H. Geissel, M. Maier, et al., Nucl. Instr. Meth. in Phys. Res. B 2004 (2003) 119.