A HIGHLY FLEXIBLE LOW ENERGY ION INJECTOR AT KACST

M. El Ghazaly, M. al-Malki, KACST, Riyadh, Saudi Arabia
A. Papash, MPI for Nuclear Physics, Heidelberg Germany and JINR, Russia (on leave)
C.P. Welsch, Cockcroft Institute and University of Liverpool, UK

Abstract

At the National Centre for Mathematics and Physics (NCMP), at the King Abdulaziz City for Science and Technology (KACST), Saudi Arabia, a multi-purpose low-energy experimental platform is presently being developed in collaboration with the QUASAR group. The aim of this project is to enable a multitude of low-energy experiments with most different kinds of ions both in single-pass setups, but also with ions stored in a low-energy electrostatic storage ring. In this contribution, the injector of this complex is presented. It was designed to provide beams with energies of up to 30 kV/q and will allow for switching between different ion sources from e.g. duoplasmatron to electrospray ion sources and to thus provide the users with a wide range of different beams. We present the overall layout of the injector with a focus on its mechanical and ion optical design.

INTRODUCTION

Beams of low-energy ions are highly interesting for a number of different fields, in particular for biophysics, chemistry, nanotechnology, and molecular physics, i.e. life sciences in general. When stored in a storage ring, these beams can be manipulated in various ways and be used for e.g. crossed and merged beam experiments, collision studies, or life time studies of instable ions.

At very low energies, electrostatic storage rings have clear advantages over their magnetic counterparts. In particular the mass-independence of the electric rigidity $E\rho=E_{kin}/q$, where E is the electric field ρ the radius of curvature, E_{kin} the ion's kinetic energy and q its charge state allows for e.g. storing singly charged biomolecules with very high molecular masses in the same field configuration as protons having the same kinetic energy. A fixed-energy electrostatic machine that will store ions up to 30 keV/q has been designed and is presently being constructed at KACST [1,2].

INJECTOR DESIGN

In order to fully exploit the experimental opportunities a low-energy electrostatic ion storage ring offers, a highly flexible beam injector, able to provide different kinds of ions at variable energies up to 30 keV/q, is required. With the aim to closely link the storage ring project with the injector, similar ion optical elements are used throughout, guaranteeing an efficient use of the available design and engineering resources.

To ensure the availability of ions at an early stage of the project and to allow for getting experience in the operation of the different components, the injector will be built up in a staged approach:

The beam envelopes of the initial injector are shown in fig. 1. It will use beam from a small ion source presently being developed at KACST. Over a total length of 3316 mm the beam is extracted from the ion source, before being focused by an Einzellens and finally being shaped and matched to the injection point in the storage ring by two electrostatic quadrupole doublets and several sets of electrostatic steerers (not shown in the figure).

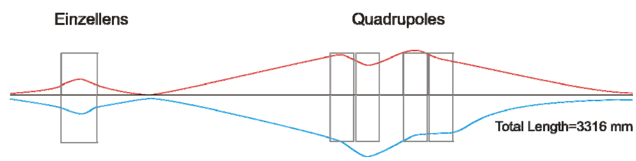

Figure 1: Overview of the injection beam line including the set of four quadrupoles.

In a second step, a 90° analyzing spectrometer magnet with +26.6° pole faces and a high mass resolution will be added to this setup. The magnet will help improving the output beam intensity and quality.

In its final stage of completion, operation of several ion sources in parallel will be possible by using an electrostatic beam switch. A chopper to modify the longitudinal bunch structure before injection into the storage ring will complete the injector.

Beam Extraction

The beam characteristics to be expected from the ion source were estimated through numerical studies with the computer code POISSON [3]. The following Fig. 2 gives an overview of the potential distribution in the extraction region. More detailed information on the potential distribution was extracted from this data and was presented in [4].

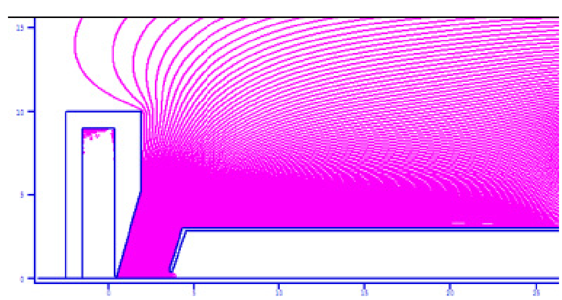

Figure 2: Extraction region behind the ion source with fields computed by POISSON.

Depending on what kind of ions will be extracted at a specific energy from the source, beam extraction will be optimized by a laterally movable electrode (shown on the right in fig. 3) which also forms the first grounded electrode of the Einzellens.

Einzellens

Immediately after the ion source, an electrostatic Einzellens with two grounded electrodes and a central cylindrical electrode at voltage V will be used to radially focus the ion beam.

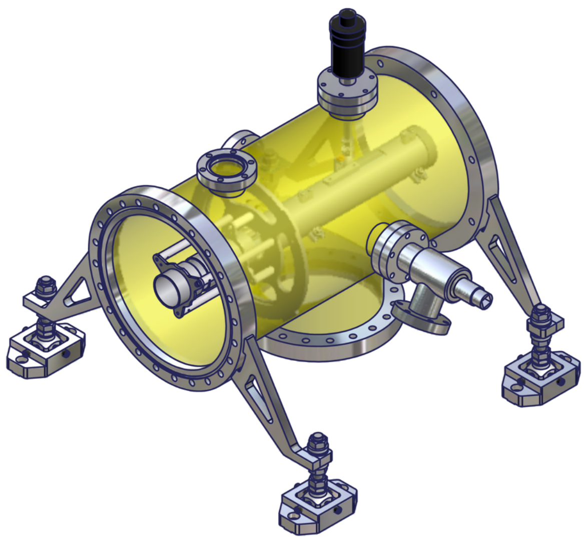

Figure 3: 3D View of the beam extraction (right) and Einzellens (left).

The design parameters of the Einzellens are summarized in the following table 1.

Table 1: Design Parameter of the Einzellens

Parameter	Value
Inner diameter [mm]	40
Length of central electrode [mm]	40
Gaps [mm]	10
Acceptance of Einzellens [π mm mrad]	120
Voltage on central electrode [kV]	16.0

It should be mentioned that one may also apply a negative voltage to the central electrode of the Einzellens. In this case the required amplitude of the negative potential to focus a beam of 30 keV ions would be twice as high as for the case of a positive potential and is thus not a preferable choice.

Electrostatic Quadrupoles

While the electrostatic storage ring presently being built up at KACST and the injector described here form independent research projects, all ion optical elements were developed in parallel. This allows for utilizing similar mechanical designs, power supplies, and control systems for all components, and will thus help reducing the overall construction time.

Beam focusing and shaping is realized by pairs of electrostatic quadrupoles, see Fig. 4 and table 2. Earlier work [5] indicated that extended fringe fields from the individual lenses can give rise to unwanted coupling effects. Therefore grounded shields at the entrance and exit of the lens, as well as in between each pair of quadrupole electrodes were integrated to reduce the effect of fringe fields on the beam to a minimum.

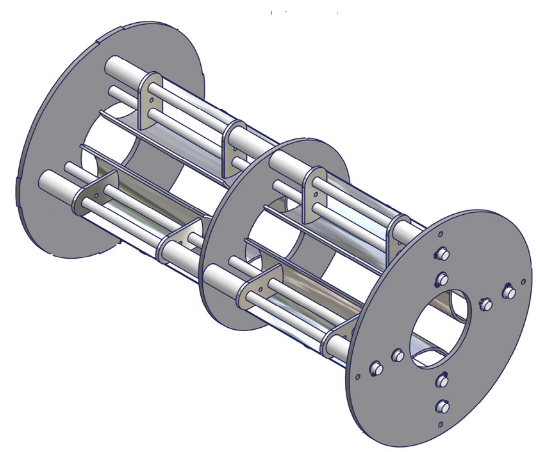

Figure 4: Mechanical design of the electrostatic quadrupole doublet.

The quadrupole electrodes will be manufactured from stainless steel. The ideal hyperbolic shape of the quadrupole surface will be approximated by cylindrical electrodes of radius $r=1.148 \cdot r_{ap}=28.7$ *mm*. They will be supported by Aluminum oxide rods and put in position by Macor spacers. All quadrupoles will be assembled and aligned outside of the vacuum chamber.

Table 2: Design Parameter of a Quadrupole Doublet.

Parameter	Value
Electrode Length [mm]	100
Radius of curvature [mm]	28.7
Aperture radius [mm]	25
Distance electrode-shield [mm]	15
Thickness of shield [mm]	3
Voltage on quadrupoles [kV]	± 5

Beam Steering

The horizontal and vertical position of the beam will be controlled by parallel plate deflectors. A total number of three pairs of deflectors will be initially installed in the injector. One directly behind the Einzellens and one in front of and behind the quadrupole doublets in order control any potential misalignment and to ensure that the beam passes centrally through the quadrupoles. The electrodes will be housed in vacuum chamber with a radius of 150 mm and plates will be positioned at a distance of 50 mm. Each electrode has an area of 100 x 100 mm^2 and a distance of 7 mm to the 3mm thick shields. Electrodes will be again manufactured from stainless steel, supported by Aluminum oxide rods and fine-positioned by Macor spacers.

The combination of two quadrupole doublets with two sets of beam steerers will allow for matching beams from different ion sources efficiently into the electrostatic ring. Both the beam shape and its position can be controlled over a wide parameter range thus allowing for maximizing the experimental output. An overview of the injector is depicted in the following Fig. 5.

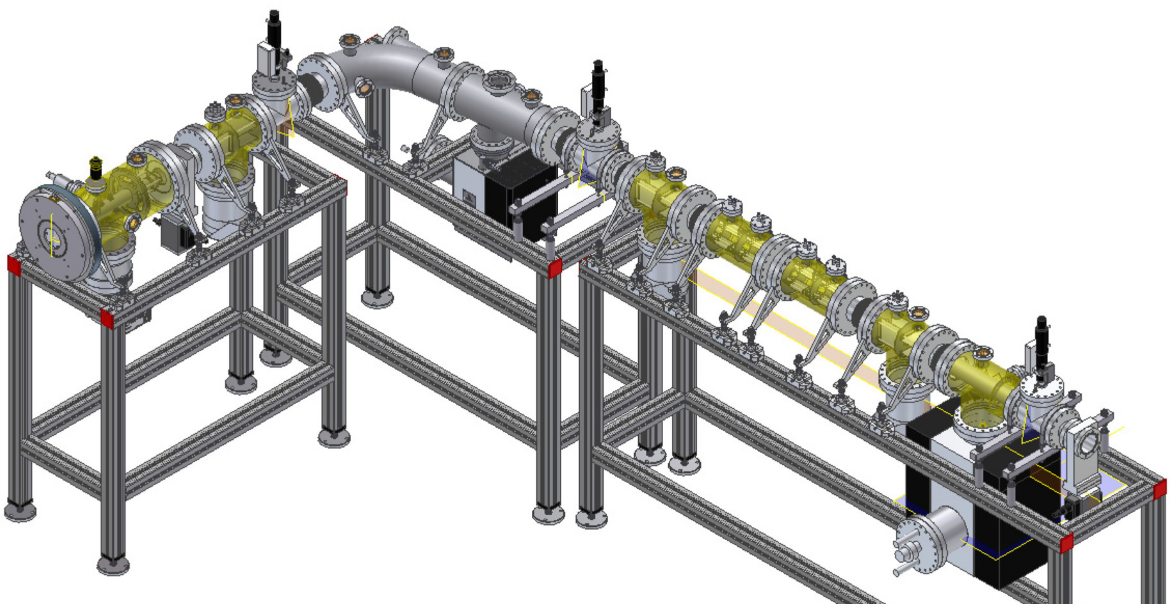

Figure 5: 3D Sketch of the injector.

CONCLUSION AND OUTLOOK

The design of a versatile ion beam injector complex presently under construction at KACST was presented in this contribution. It will allow for a very flexible injection of most different ion species into the Pro-ESR. In a first step the injector will consist of an Einzellens placed right after the ion source and a beam matching section, i.e. a set of four quadrupoles together with a set of electrostatic steerers. This will allow for a quick availability of beam and for getting accustomed to the technologies involved. In a second step, this layout will then be complemented by an analyzing magnet. Finally, a beam switching device will be added which will then make the injector a true multi-purpose facility that can deliver a wide range of ions to different users.

ACKNOWLEDGEMENT

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