Implementing a 4-way-90° Quadrupole Beam-Deflector into the MLLTRAP System ◇

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MLLTRAP is a double Penning trap system designed for high accuracy mass measurements. Further information on MLLTRAP layout and experimental results can be found in [1,2,3,4]. In the context of ongoing improvements at the MLLTRAP facility, a 4-way-90° electrostatic quadrupole deflector has been installed to the MLLTRAP beam line and successfully commissioned.

In order to compare ions of interest and reference mass ions, it was necessary to install an electrostatic quadrupole beam deflector, allowing to attach a reference ion source perpendicular to the ion injection direction. Therewith, the simultaneous use of either online reaction products from the accelerator together with reference ions from one or two offline ion sources will be possible. The beam deflector consists of four hyperbolic main bending poles, several steering electrodes, two outer baffles on each side and an outside enclosure, see Fig. 1. All electrodes are made of stainless steel. Moreover, the main bending electrodes are electron beam polished. Its outer dimensions are 126x90x90 mm. It is supplied with up to 3 keV via an ISEG power supply module, SHV cables and Kapton-insulated wires.

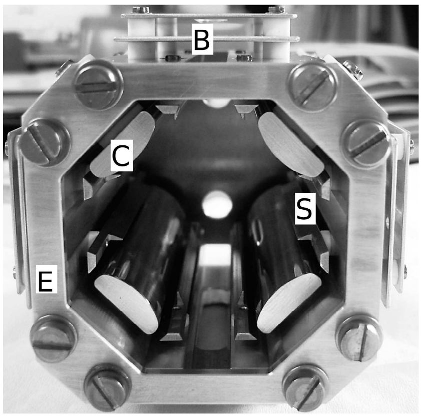

Fig. 1: Quadrupole beam deflector seen from the bottom perpendicular to the beam direction, composed of four inner bending electrodes (C), steering electrodes (S), outer baffles (B) and enclosure (E).

The beam deflector is mounted into a DN100CF double cross attached to the injection line of the MLLTRAP, see Fig. 2. Presently an offline surface ion source providing singly charged ^{85,87}Rb ions is mounted under 90° angle to the main trap axis. By applying adequate negative potentials of typically about 2.6 keV, one can bend the ion beam to the injection line. In order to verify the correct potential settings for optimized transmission, one can compare the current of the non-bent ion beam with the deflected beam via several Faraday cups. One Faraday cup is attached under 0 degrees to the ion source on the opposite flange of the vacuum cross, a second one is positioned behind the first ion optical elements in the injection line and a third one is placed behind the trap system at the end of the beam line. Currently, we reach a transmission efficiency of 60 % comparing the beam current values at the first and second Faraday cups and an efficiency of 16 % by comparing the beam current measured under 0 degrees to the beam current behind the trap. Optimization of these performance is in progress, e.g. by applying additional positive potentials to some of the central bending electrodes. A general outline of the electrode layout can be seen in Fig. 4.

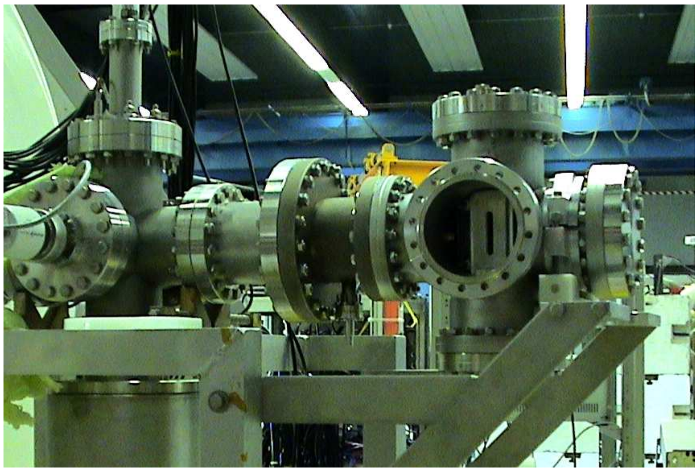

Fig. 2: Injection part of MLLTRAP with the quadrupole deflector mounted in a DN100CF vacuum cross (to be seen behind the flange opening).

In Tab. 1 potential settings for the beam deflector are given. The central electrode 1 is in the corner between the ion source and the injection line, central electrode 2 is located between the injection line and the flange opposite to the ion source, central electrode 3 is positioned in diagonal opposition to electrode 1 and central electrode 4 in diagonal opposition to electrode 2. Steering electrodes are labeled clockwise (viewing direction from above), starting with the ion source side. See also Fig. 3 for orientation.

Electrode	Voltage potential [V]
Central Electrode 1	-3000
Central Electrode 2	+202
Central Electrode 3	0
Central Electrode 4	+202
Steering Electrode 1	-340
Steering Electrode 2	-425
Steering Electrode 3	0
Steering Electrode 4	0
Baffles	-1320
Enclosure	-1320
Extraction Electrode	-900
Einzel Lens Electrode 1	-1560
Einzel lens Electrode 2	-1480
Einzel Lens Electrode 3	-1800

Table 1: Voltage potential settings for the quadrupole beam bender as used during recent test measurements.

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In order to define the required potential settings for the 17 electrodes in the deflector, ion trajectory simulations were performed using SIMION 8.0 [5] and tested at the trap system. For the simulation procedure, a geometry file was set up, matching the beam deflector design as accurately as possible, see Fig. 3. From left to right it shows the ion source with its extraction electrode, the beam deflector and above an Einzel lens as first part of the ion optical system (viewing direction from above). Opposite to the ion source outside the beam deflector the first Faraday cup is located, the second one is installed directly after the Einzel lens (both are not included in this picture).

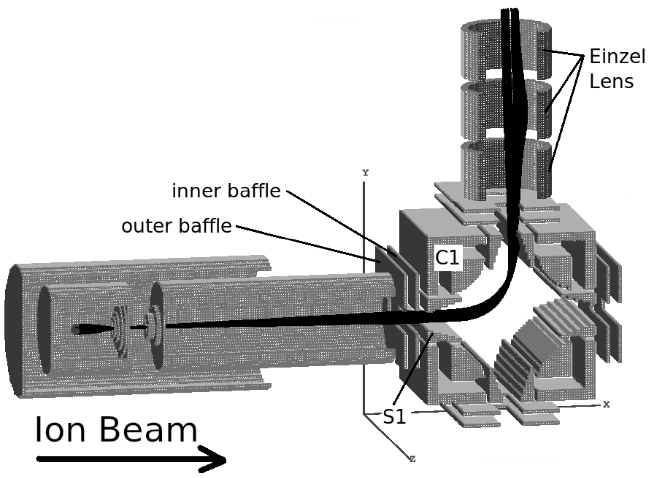

Fig. 3: Result of ion trajectory simulations using the SIMION code, showing the ion source, the beam deflector and a set of Einzel lenses as the first part of the ion optical system of the trap.

The ion trajectories shown in Fig. 3 were generated by converting the outer baffles and the deflector enclosure into a focusing Einzel lens system. At the moment, both outer baffles are operated at the same potential as the enclosure. By design, it is possible to decouple the inner baffle and set it to a different voltage potential. As it turns out, this mode of operation indeed provides an improved beam quality to the trap system. Comparing simulations between different voltage settings is in progress and optimized settings will be further tested experimentally. In addition, the fringe field of the trap magnet has yet to be implemented to the simulation to further improve the description of the realistic experimental scenario.

The beam deflector is also designed to be used as part of a beam separator for beam energies up to 1 keV with q/A ratios from 1/1 up to 1/250. This is essential for first mass measurements at MLLTRAP. It is planned to implement an actinide α-recoil ion source to provide heavy radioactive species which in addition will be highly charged due to conversion processes. A starting point for measurements will be the installation of a ^{244}Pu source leading to ^{240}U via α decay. Thus we aim at a first direct, trap based mass measurement of ^{240}U. Final drawings have already been submitted to the workshop and the source will be implemented upon delivery. Since the α decay will deliver a wide energy range as well as charge distribution for the recoiling ^{240}U nuclei of interest, an (A/q) separation stage has to be installed to facilitate the trapping of a selected high charge state. It is foreseen to install a compact Wien filter (based on permanent magnets) between ion source and quadrupole deflector. The design will fit into a standard DN100CF vacuum cross, matched to the dimensions of the existing ion injection system.

In its final configuration, the quadrupole deflector cross will enable to connect three different ion sources to the MLLTRAP system. Firstly, the just described α ion source for highly charged and heavy ions, secondly the Tandem accelerator beam line for online reaction products (thermalized and pre-separated in the MLL IonCatcher buffer gas stopping cell) and thirdly a reference ion source, the latter most likely in form of a carbon cluster ion source or a surface ion source providing reference ions nuclei such as ^{85}Rb or ^{133}Cs.

References

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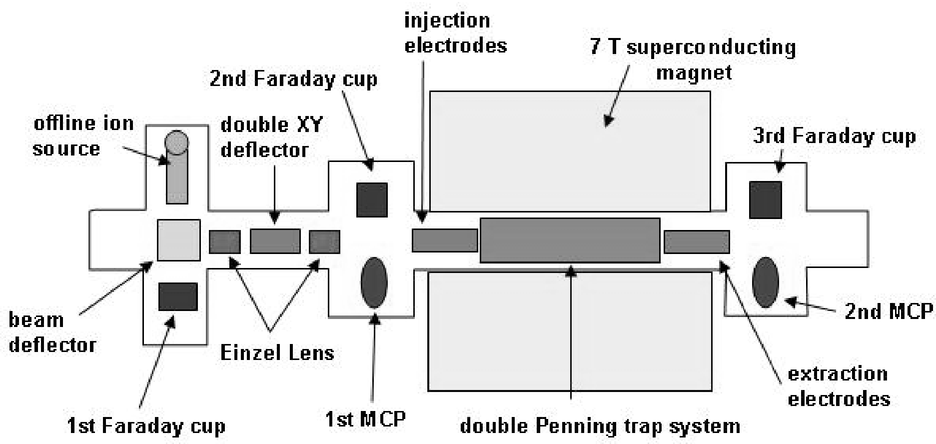

Fig. 4: MLLTRAP layout (viewing direction from above), showing all valuable electrodes and detection devices together with beam deflector position.