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HIGH-ENERGY SCRAPER SYSTEM FOR THE S-DALINAC EXTRACTION BEAM LINE – COMMISSIONING RUN*

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Abstract

The S-DALINAC is a thrice recirculating, superconducting linear electron accelerator at TU Darmstadt. It delivers electron beams in cw-mode with energies up to 130 MeV. The high-energy scraper system has been installed in its extraction beam line to reduce the energy spread and improve the energy stability of the beam for the experiments operated downstream. It comprises three scraper slits within a dispersion-conserving chicane consisting of four dipole magnets and eight quadrupole magnets. The primary scraper, located in a dispersive section, allows to improve and stabilize the energy spread. In addition energy fluctuations can be detected. Scraping of x- and y-halo is implemented in two positions enclosing the position of the primary scraper. We will present technical details and results of the first commissioning run of the recently installed system at the S-DALINAC. Besides improving on the energy spread, it proved to be a valuable device to observe energy spread and energy fluctuations as well as to reduce background count rates next to the experimental areas.

INTRODUCTION

Since 1987 the S-DALINAC serves nuclear- and astrophysical experiments at the Technical University of Darmstadt [1]. It is fed by either a thermionic or a photoemission gun which delivers a spin-polarized beam [2]. After pre-acceleration by the injector module the electron beam can either be used for experiments at the NRF-setup [3] or it is guided through a 180°-arc to enter the main linac. By passing the linac up to four times the maximum energy of about 130 MeV can be reached. The beam current can be adjusted from several pA up to 20 μA. The layout of the S-DALINAC is given in Fig. 1.

The high-energy beam of the S-DALINAC is used for nuclear physics experiments with a need for high energy resolution and low noise next to the experimental area. The recently installed scraper system [4] is placed between the accelerator hall and the experimental hall and provides beam-cleaning and –monitoring features. The energy spread can be reduced by sending the dispersive beam through a narrow slit which determines the energy and the energy range that continues towards the experimental areas. Blocked parts of that beam deposit their charge onto the high- and the low-energy side of that slit which allows for an online monitoring of energy fluctuations during long beam times.

If not optimized, γ-ray background from bremsstrahlung processes can prevent sensitive detection of photons from searched-for nuclear reactions. The background is produced by beam losses resulting from collisions of beam halo with beam line components. In order to remove beam halo the installed scraper system also contains halo scrapers that work in horizontal as well as in vertical direction.

CONSTRUCTION

The presented high energy scraper system resembles a chicane which consists of four dipole magnets, eight quadrupole magnets, four vertical steerers and the three scraper chambers themselves. The system is depicted in Fig. 2. Beam scraping will be done in three different positions. This is necessary because beam dynamics have to be adjusted individually for halo scraping and for the energy defining scraper (see section *Beam Dynamics*). The system consists of three spherical vacuum chambers, each measuring 9” in diameter. The two chambers for halo scraping contain guided, water cooled copper blocks which are positioned using a stepping motor outside the vacuum. In this set-up a positioning accuracy better than 0.01 mm is possible. Downstream of the halo scrapers, BeO-screens can be inserted to check for beam position and shape. The amount of beam current, which is stopped during halo-scraping, is in the order of 1% of the total beam intensity. The energy defining scraper is however outlaid to deal with the full beam power. Additionally to the extensive cooling water system, both scraper brackets are mounted electrically isolated from the beam pipe. By measuring the current, one gains information about the amount of beam current which is stopped on each bracket. This helps to find the optimal position of the slit and in addition identify energy fluctuations of the beam. Monitoring this quantity will also help to detect and cure irregularities of the rf-system to further decrease the potential of failure.

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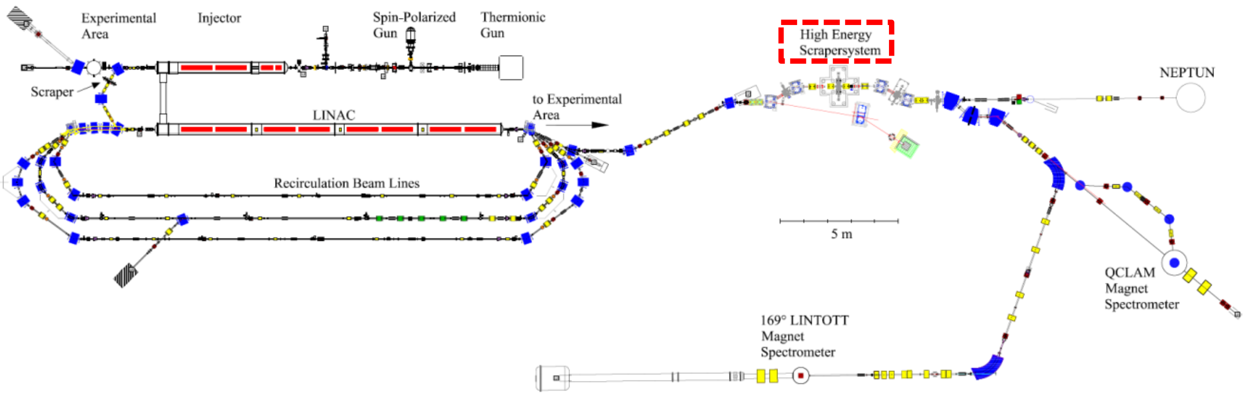

Figure 1: The S-DALINAC floor plan including accelerator hall, extraction beam lines and experimental areas. The scraper system is highlighted in red.

BEAM DYNAMICS

The new system replaces a straight part of the former extraction beam line and therefore has to conserve dispersion and allow beam tuning independently for the rest of the beam line. The chicane had to be built within a space of 8 m x 2 m which set the limits for beam line design. The final results of the beam dynamics calculations using the *XBEAM* [5] code are shown in Fig. 3. Dipole positions and dipole chamfer angles, quadrupole positions and their gradients were outlaid to build a fully symmetric system with high transverse dispersion and small horizontal beam size at the position of the energy defining scraper. The width of the slit together with the dispersion at this position, determine the energy spread which can pass the scraper. A horizontal beam focus in this point allows using a narrow slit without losing too much beam current. The halo scrapers are positioned where dispersion and beam width are small.

INSTALLATION

The high energy scraper system was built up in the extraction beam line of the S-DALINAC within the installation period for the third recirculation path [6]. Due to radiation shielding for the neighbouring experimental areas, the former extraction beam line has been placed inside a tunnel of concrete blocks which had to be opened and slightly changed to gain space for the chicane. After the removal of the old beam line, the chicane including dipole and quadrupole magnets were positioned. For the optimal performance of the system it is of great importance to meet the calculated drift lengths and magnet positions. In a first step the positions of the stands were marked using a laser tracker system. The beam axis has been marked in close collaboration with our partners from the geodetic groups of the Frankfurt University of Applied Sciences and Technische Universität Darmstadt [7].

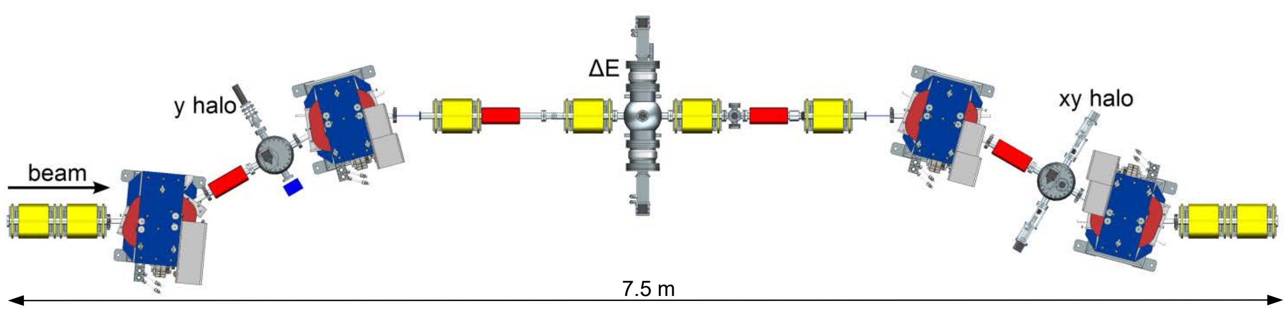

Figure 2: The high energy scraper system: from left to right the chambers for y halo-, energy defining- and xy halo-scraper can be seen, dipole magnets in blue, quadrupole magnets in yellow, steerers in red.

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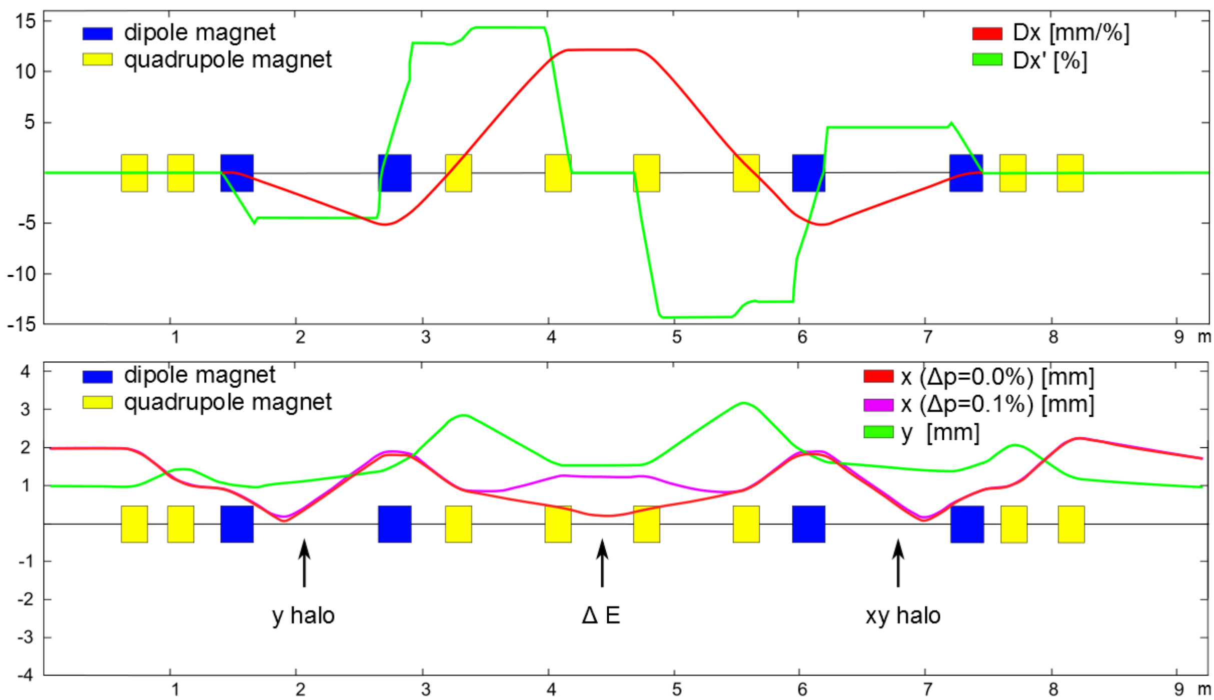

Figure 3: Beam dynamics calculation: The upper graphic shows the dispersion and its derivative along the new beam line. The beam envelope (1σ radius) for Δp = 0 % and Δp = 0.1 % is plotted below. The locations of the energy defining scraper (ΔE) and the halo scrapers are indicated by small arrows.

COMMISSIONING RUN

During the experimental beam time in October and November 2017 the scraper system went into operation. Its impact on the energy spread was measured at beam energies of 42.5 MeV and 22.5 MeV while the latter will be presented here. Figure 4 shows the measured energy spread after the scraper system for a variation of the energy scraper's gap width. It can be seen that the energy spread could be reduced starting from 25 keV down to 5 keV. By measuring the deposited beam current on each of the energy scraper brackets we gained information on energy fluctuations. Decreasing error bars indicate an efficient reduction of energy fluctuations for small gap width. Further tests at a beam energy of 42.5 MeV showed a reduction of the energy spread to 8 keV.

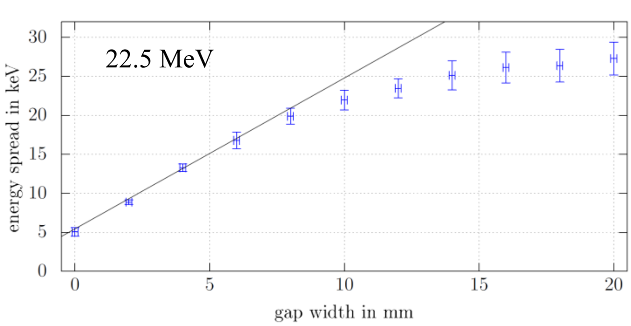

Figure 4: Measured energy spread for several gap widths of the energy scraper at a beam energy of 22.5 MeV.

Additionally several photon-sensitive detectors had been placed next to our experimental setup that showed an efficient reduction of the γ-ray background by closing the energy scraper slit (the count rate dropped below 10% of its initial value). Further reduction could be reached by using the halo scrapers. Their commissioning is scheduled within the next months.

CONCLUSION

The new high-energy scraper system at the S-DALINAC and its first commissioning run have been presented in this contribution. The system will help to improve beam quality by halo and energy scraping of the beam after acceleration. The energy defining scraper performed well and therefore has already been used for experimental beam times. Using this new feature, future experiments with high resolution and low noise can be approached.

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