H$^-$ - LEBT IN FRANKFURT

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Abstract

A magnetic Low Energy Beam Transport (LEBT, 65kV) line for negatively-charged hydrogen ions is under construction in Frankfurt.
In order to study the space-charge compensation process several conventional beam diagnostic principles were already established. But to prevent compensated ion beams from distortions caused by conventional measurement devices, non-destructive methods are to be developed: Investigations were carried out to determine the emittance of the ion beam based on laser driven photon detachment of the H$^-$-electron using a non-destructive method [1]. Additionally non-destructive diagnostic tools (particle energy analyzer and CCD-camera) are installed to study the temporal development of the compensation process. The functional principles of the measurement devices as well as the whole test bench and planned activities are described.
The investigations to be done at this LEBT system will support the objective of setting up a 150keV H$^-$ injector line for a 150keV proton storage ring. Therefore it is important to study the neutralization cross section of H$^-$ in a gas cell and the stripping cross section of H^0 at different stripping foils. Additionally the transport properties of the H$^-$ - LEBT will be investigated in detail.

1 INTRODUCTION

The LEBT section is designed to fulfill the requirements of the ESS and of the NIS project (>70mA, 35kV, 2.5ms, 50Hz).
Furthermore, protons will be injected and accumulated by a non Liouvillian stacking principle starting from H$^-$ into the future 150keV proton storage ring at Frankfurt. The injector consists of a 150keV, 100mA LEBT with a gas cell to produce neutral H atoms.

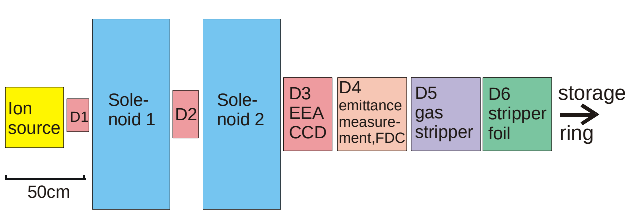

Figure 1: LEBT section with four diagnostic chambers (D1-D4) to investigate the beam transport properties and two diagnostic chambers to investigate the gas cell (D5) and the stripping at a stripper foil (D6).

Due to the magnetic guide field of the proton storage ring, neutral H^0 atoms are injected as negatively charged ions would be deflected out of the ring. Therefore in the injection region of the storage ring the H^0 atoms will be stripped by a stripper foil to produce protons, which will be accumulated in the ring.
Presently a 65keV test bench is set up to study in detail the transport properties of the magnetic H$^-$ - LEBT system using mainly non-destructive measurement devices. Firstly the LEBT will be operated with a cesium free H$^-$ - source of only a few mA. In parallel with the experiments at the LEBT section the 100mA H$^-$ - source will be restarted and improved at another test bench.
After development and test of all components, the 100mA H$^-$ - source and the LEBT will be operated at the future 150kV test bench.

1.1 Investigation of gas cell stripping

Behind the LEBT section a gas cell diagnostic chamber (D5) will be installed to investigate the neutralization cross section of H$^-$ at residual gas (moderate gas pressure, < 10^{-4}hPa) and to study the stripping properties of a stripping cell (high gas pressure, > 10^{-4}hPa). To minimize the gas flow in the LEBT section the gas cell will be terminated on both ends by differential pumping systems. To measure the neutral flux and beam current, a dipole chamber (figure 2) will be installed behind the gas cell to separate the produced neutral atoms from the H$^-$ - beam.

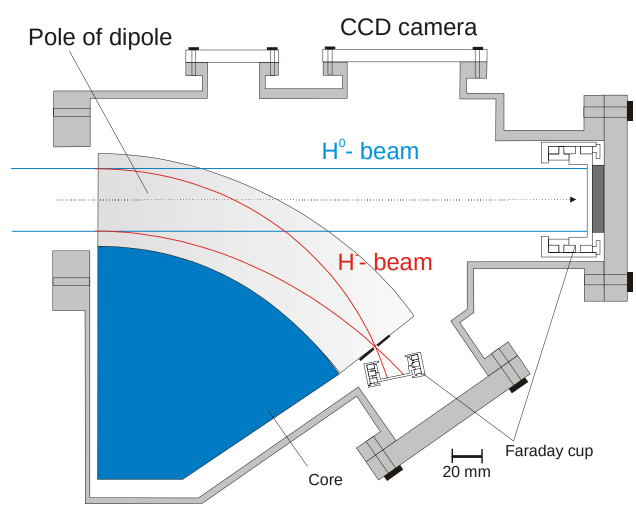

Figure 2: Scheme of the diagnostic chamber and dipole. The separation of neutralized H-atoms from the ion beam is plotted.

This dipole will also be used for the laser driven emittance measurement. In order to optimize the gas cell (gas sort and gas pressure) the influence of the stripping process of the beam in the gas cell will be observed using CCD-cameras. Therefore time resolved beam profile measurements will be performed in front of and behind the gas cell chamber. A further CCD-camera will view the gas cell interior in order to study the influence of the stripping process on the ion beam.

1.2 Investigation of foil stripping

A further diagnostic chamber will be installed to study the stripping process at a stripper foil (D6). To investigate the life time of the stripper foil a CCD-camera will be installed to observe the interaction of the H^0 beam with the foil. In order to investigate the proton to H atom – ratio, current measurements of the separated proton and H-beams will be done. Additionally time resolved beam profile measurements will be performed in front of and behind the stripper foil diagnostic chamber using CCD-cameras in orthogonal arrangement.
To optimize the gas cell stripper and the foil stripper emittance measurements in front of (right behind the LEBT) and behind the gas cell (D5) as well as behind the stripper foil chamber (D6) will be performed.

1.3 Investigation of effects due to beam asymmetries

Due to the magnetic filter field [2] of the H^--source the extracted ion beam will be not cylinder symmetric. Therefore two spectrometers and two CCD-cameras in an orthogonal arrangement (figure 3) will be installed to study effects due to non-symmetric beams [3].

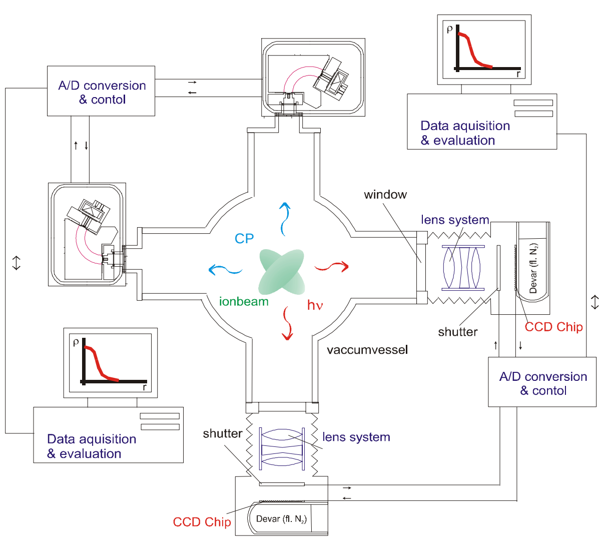

Figure 3: Diagnostic set up of two CCD-cameras and two spectrometers in orthogonal arrangement.

The diagnostic system will be operated by a central control unit to allow time-synchronous measurements. By comparison of time-resolved measurements in both transverse directions effects resulting from a change of the beam particle distribution will be studied.

1.4 Investigation of over compensation

An effect will be investigated, which can only be expected on negative ion beams: Due to the mass of the compensating ions and contrary to the compensation of positive ion beams, a state of overcompensation is expected. In this case, the compensation of positively charged residual gas ions can possibly exceed that of the H^- - beam ions. The dependence on the beam pulse structure will be of special interest. To measure such effects an energy analyzer for electrons and ions will be used (see below).

2 EXPERIMENTAL SETUP

The experimental setup for the first phase of measurements is shown in figure 4. The LEBT section consists of an ion source, an extraction system (triode, 65 kV), a first diagnostic chamber (Faraday cup), two solenoids, and a second diagnostic chamber consisting of a Residual Gas Ion Energy Analyser (RGIEA), a liquid N2-cooled CCD-camera with installed intensifier, a conventional slit – slit emittance measurement device and a Faraday cup.

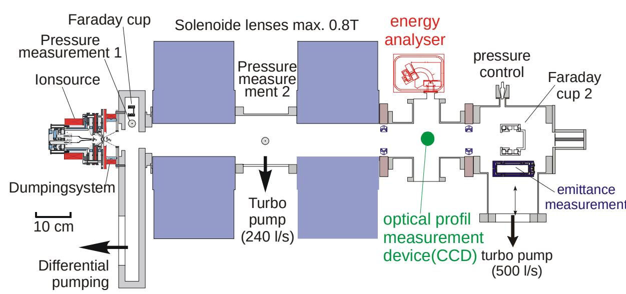

Figure 4: Schematic drawing of the LEBT section with diagnostics in a first testing phase.

Firstly, measurements will be done using proton beams to check the alignment of the LEBT system and of the diagnostics. This proton measurements will serve as reference for the investigations with H^- - beams.
Secondly, the LEBT line will be tested in H^--operation using a low-current cesium-free ion source. For this purpose measurements of the beam potential (using a Electron Energy Analyser EEA), of the beam profile (CCD-camera) and of the emittance (conventional emittance scanner) will be performed.
After testing the transport section the diagnostic chamber behind the second solenoid will be replaced by the laser diagnostic chamber in order to investigate the concept of a laser driven diagnostic and to carry out non-destructive measurements of the beam emittance. After this method has been demonstrated successfully in cw-operation, the laser driven emittance measurement device will be operated in time-resolved mode.

In parallel to the development of the laser driven emittance measurement device the investigations of the stripping processes described above will be performed.

2.1 Non destructive diagnostics

For time resolved measurements an optical device using CCD-cameras for beam profile measurements, a Residual Gas Energy Analyzer, and an Electron Energy Analyzer for beam potential measurements will be installed.

Positively and negatively charged particles are produced by interaction of beam ions with residual gas. Due to the accumulation of compensating particles (positive ions in case of negative ion beams, electrons in case of positive ion beams) the beam potential will decrease. In case of partly compensated beams, the rest gas component with a polarity identical to the beam ions is accelerated radial out by the remaining beam potential.

To study space-charge compensation processes investigations of the beam potential and of the potential distribution are to be carried out. In order to study the time development of the beam potential a 127° Hugh Royanski-type Residual Gas Energy Analyser (RGEA) and an Electron Energy Analyser (EEA) will be used. The diagnostics of the beam potential of positive ion beams using a RGEA are well established. To allow single particle detection, the Energy Analyzer is equipped with a channeltron. Therefore, time resolved measurements of both beam axis and beam edge potential are possible.

As another non-destructive measurement device, a liquid N_2 cooled CCD-camera will be used. The CCD-camera is equipped with an intensifier to allow time-resolved measurements within a minimum gate time of 50 ns.

As a further diagnostic tool for negative ions an online non-destructive emittance measurement system capable of being used for beams of diameters up to 40mm will be developed by C. Gabor [1]. The method is based on H^--neutralization by laser detachment of H^- - electrons [4]. The measurement principles are shown in figure 5.

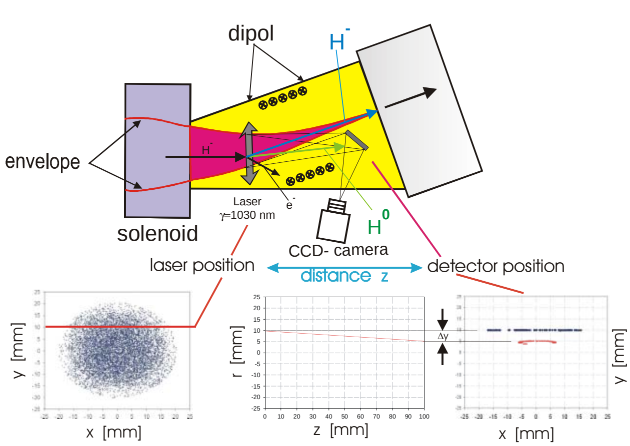

Figure 5: Measurement principle and the diagnostic set up of the laser driven emittance measurement device.

The interaction of laser light and H^--ions produces a small number of neutral atoms and detached electrons. The ion beam is separated magnetically from the neutral beam in a dipole field. The distribution of the photo-neutralized hydrogen atoms is measured using a CCD-camera by observing the light produced by the interaction of laser neutralized H-atoms with a scintillator. The transversal light distribution on the scintillator as a function of the intersection line between the laser and ion beam defines the divergence angle and finally results in the emittance of the ion beam. The spatial resolution is defined by the "virtual slit" of the laser diameter. The angular resolution is given by the drift length (at low gas pressure), the scintillator and the CCD-camera.

3 SUMMARY

A test bench will be set up to investigate the transport properties of a magnetic H^- - LEBT and to study the stripping processes of H^- - ions in a gas cell to produce neutral H atoms as well as the stripping of these atoms by a foil to produce protons.

To study the compensation process at H^--beams and to prevent perturbations of the compensation process and, therefore, of the transport properties of the LEBT section, non-destructive, time-resolved measurement devices (residual gas ion and electron energy analyzer, CCD-camera) were established. Measurements will be performed using particle energy analyzers (RGIEA and EEA) and CCD-cameras in an orthogonal arrangement to study effects on the compensation process and, therefore, on the beam transport due to the non cylinder-symmetry of the ion beam. To develop a non-destructive and time-resolved emittance scanner, the application of a laser driven emittance measurement device will be investigated. It is intended to realize a 150keV storage ring to extend the investigations on space charge compensation as well as to apply non Liouvillian accumulation techniques.

4 REFERENCES

[1] C. Gabor et al. Design of non-destructive emittance measurement device for H^- - beams, Review of Scientific Instruments, Volume 73, Nimber 2, February 2002

[2] M. Bacal, G.W. Hamilton, E. Nicolopoulos and H.J. Doucet. Phys. Lett. 42, p. 1538, J. Phys. (Paris) 38, p 1399 (1977)

[3] A. Jakob et al. „Investigation on temporal development of the Compensation Process of focused ion beams", Proc. 7th European Particle Accelerator Conference (EPAC), Vienna, Austria, June 26-30, 2000 EPC, Austria Academy of Sciences Press, Vienna 2001,ISBN 3-7001-2931-9, OEAW CDR MN2, pp. 1741-1743

[4] R. Connely. P. Cameron, J. Cupolo, D. Gassner, M.Grau, M. Kessemann, S. Peng and R. Sikora, Brookhaven National LabUpton, NY, USA, proceed. of Beam Instrumentation Conference April 2002