The Ion Source for the Commissioning of ELENA Ring

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Abstract.
The commissioning and first results of the ion source to test the Extremely Low ENergy Antiproton ring ELENA are presented. ELENA is a compact ring for cooling and further deceleration of 5.3 MeV antiproton delivered by CERN Antiproton Decelerator (AD) down to 100 keV. Because of the long AD cycle of 100 s, one ion source for protons and H^- with a kinetic energy of 100 keV has been installed for commissioning and start-up. The complete device is described including the control and power subsystems. The beam profiles and the emittance for protons and H^- were measured with a wire scanner and a pepper-pot diagnostic. The current was also measured by means of a current transformer. The ion source meets the parameters required by the ELENA testing program in order to tune the decelerator ring before starting with the antiproton beam.

INTRODUCTION

The Antiproton Decelerator (AD)[1] at CERN produces antiproton beams and sends them to different experiments. The AD stores, cools and decelerates the antiprotons before injecting them into the experiments injection line with an energy of 5.3 MeV. The AD physics program is focused on trapping antiprotons in Penning traps where antihydrogen is formed after recombination with positrons. The experiments of this program require antiprotons to have lower energy so they use a series of degrading foils for further deceleration of antiprotons from 5.3 MeV down to 3-5 KeV. This process anhilates most of the antiprotons (99.9 %) and the number of particles that can finally be trapped in an experiment is as low as 0.03% of the AD beam. The Extremely Low ENergy Antiproton ring ELENA[2] was conceived to cool and decelerate the antiprotons to 100 keV. Degrading foils will be still needed but they could be much thinner, leading to an increase in the effciency of the antiproton facility.

The AD cycle is quite long (100 s) and to do the commissioning of ELENA with antiprotons would require a long shut down for the experiments. For this reason, an ion source with dual polarity has been installed for commissioning and start-ups. This ion source produces protons and H^- at 100 keV. Here we present the commissioning of the source, its main subsystems and the first measurements of beam intensity and emittance.

ELENA RING OVERVIEW

Figure 1 (a) shows a diagram of the AD Hall layout where ELENA is installed. An injection line introduces the 5.3 MeV particles coming from the AD into ELENA ring. Two extraction lines are installed to guide the 100 keV antiprotons to the experiments. The H^+/H^- ion source is installed on the space between the injection line and the first extraction line.

The H^- ions and antiprotons, having the same charge, circulate in the same direction inside ELENA with the same polarity of the ring. However, protons, having positive charge should circulate in the opposite direction, thus, being injected through the first extraction line unless the polarity of the ring is changed. To change the direction of the beams coming from the source and inject them in the appropriate direction in ELENA an Ion Switch was installed at the confluence of the injection, extraction and ion source lines. The ion switch is an electrostatic device consisting of three sets of parallel plates. It deflects the H^- ions to ELENA's injection line and the H^+ to the extraction line.

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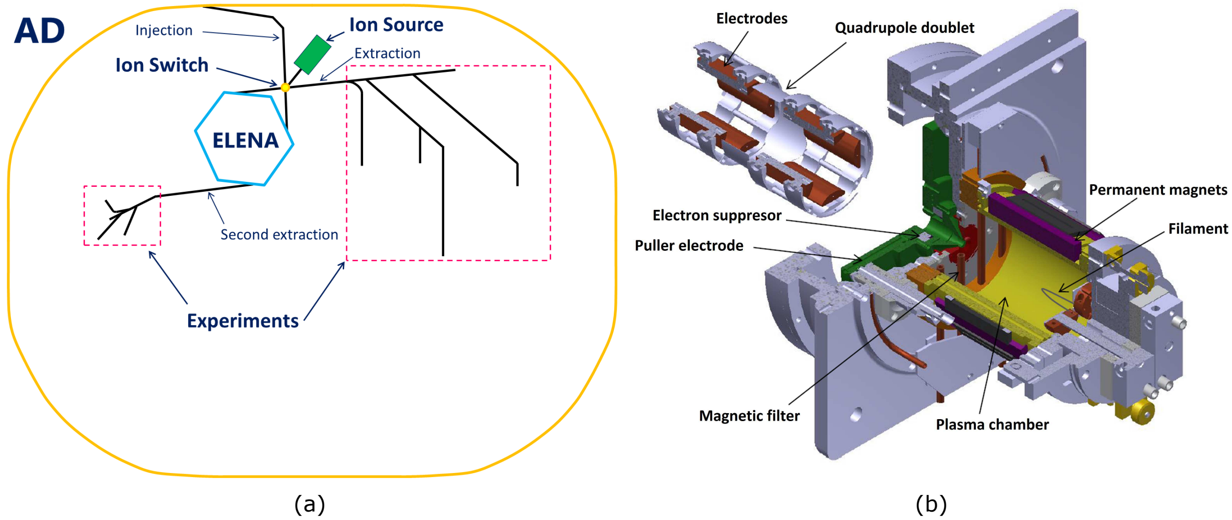

FIGURE 1. *(a) AD Hall Layout. The yellow outer lines marks the AD path. Inside it the ion source, ELENA ring and the main experimental lines are shown. (b) Ion Source section view*

THE ION SOURCE

The Ion Source for the commissioning of the ELENA ring was developed and tested at the Nuclear Physics Institute (IKP) in Jülich Forschungszentrum (Germany)[3] and recently installed at CERN in April 2015[4]. It can produce both H^- and protons without any mechanical modification, just by reversing the polarity of the source and the extraction.

Figure 1 (b) shows a section of the main components of the source and the first part of the beam transport line. Hydrogen plasma is produced in an arc discharge chamber where electrons coming from a tungsten filament tend to reach the plasma chamber walls that are positively biased with respect to the filament. On their way towards the plasma chamber wall, the electrons collide with the hydrogen atoms ionizing them and, thus, igniting the plasma. To keep the electrons and ions far from the plasma chamber walls and to increase the confinement time, ten permanent magnets are arranged around the plasma chamber producing a magnetic cusp field. A filter field divides the plasma chamber in two regions preventing the high energetic electrons from reaching the extraction area. The plasma is allowed to run continuously in order to get the maximum stability while the extraction is pulsed. When protons are extracted the extraction pulse is negative (few kilovolts) with respect to the source voltage and its base level is positive (few hundred volts) to prevent the extraction of a negative particle beam between pulses. Polarities are inverted to work with H^-. After the extraction structure a quadrupole doublet with eight independent electrostatic electrodes gives the possibility of steering and focusing the beam.

Due to the limited space for the installation of the source, the high voltage cabinet for the different power supplies and the source itself are separated by more than 3 m. This represents a challenge for the integration of the source due to the high voltage (100 kV). The high voltage cabinet is stored inside a Faraday cage for safety reasons and three coaxial hollow high voltage cables connect it with the source. The empty inner part of the high voltage cables is used to carry the power voltage for the Hydrogen flow controller and the extraction voltage. All devices floating on high voltage had been modified to work with electrical supply of 220V/400Hz. This reduces the size of the isolating transformer and avoids the use of an oil transformer.

Two PLCs (Programmable Logic Controllers) are used to control all subsystems. One of them is grounded while the second one is floating on high voltage inside of the high voltage cabinet and it is connected by fiber optics to the computer. For the timing and synchronization of the beam extraction with other events in ELENA a delay generator receives the main trigger and fires a TTL (Transistor-Transistor Logic) pulse. This TTL pulse is transferred by fiber optics to the high voltage cabinet where the puller pulse is produced.

Prior to the connection of the source to the injection line a set of diagnostics were installed in order to characterize the behavior of the source under different working conditions. This set of diagnostics consists of a current transformer (CT), a pepper-pot, two wire scanner (vertical and horizontal), a screen and a CCD camera.

RESULTS

Beam Current Measurements

The current provided by the ion source was measured for both polarities. It is important to keep in mind that when the source is operated on positive polarity not only protons are extracted but also H_2^+ and H_3^+ molecules. To fit the requirements for ELENA the source must provide beams of less than 100 μA of H^- and less than 150 μA of H^+ with an rms normalized emittance of less than 1.2 mm mrad [4]. Hydrogen flow and filament current were observed to be the parameters with the highest influence on the source performance and stability. The source shows a very stable behaviour for filament currents between 70 and 74 A and Hydrogen rates between 0.3 and 1.2 sccm. As expected, the beam current increases both with the hydrogen flow and the filament current. The measured current ranges from 20 to 100 μA of H^- and from 20 to 200 μA of protons.

Beam Profile Measurements

The beam profile was measured by means of two wire scanners: one horizontal and one vertical. Two metallic rings upstream and downstream of the wire scanner are polarized to repel the secondary particles emitted by the wires avoiding false current measurements.The beam passes through the pepper-pot plate before interacting with the wire scanner this allows us to use the wire scanner profiles to determine the emittance of the beam. The pepper pot plate has 0.1 mm diameter holes distributed in rows and columns separated 3 mm. The beam profile is determined by a Gaussian fit of the maximum value of each peak. The average sigma in the explored working range was 9 mm for H^- and 7 mm for the H^+.

Beam Emittance Measurements

The emittance of the beam can be measured using the wire scanner data. Knowing the distribution of the pepper-pot holes and the distance between the pepper-pot and the wire scanners (138 mm for the vertical scan and 139 mm for the horizontal one) it is possible to calculate the angular deviation of each beamlet. In the studied working parameter range, the values of the rms normalized emittance are always below 1.2 π *mm mrad* for both H^+ and H^-.

CONCLUSIONS

A dual polarity ion source to produce H^+ and H^- ion beams has been installed in the the AD at CERN (European Organization for Nuclear Research). The source is used for the commissioning fo ELENA ring. Different beam diagnostics have been used to characterize the source. Measurements of beam profiles, currents and emittances show that the source meets the requirements for ELENA commissioning. During November 2016 the first H^- was injected in ELENA and observed during some microseconds. Currently, the source provides beams to commission ELENA allowing the normal functioning of the experiments connected to the AD for a longer period of time.

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