PROGRESS IN ELENA DESIGN

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Abstract

The Extra Low Energy Antiproton ring (ELENA) is a small ring at CERN which will be built to increase substantially the number of usable (or trappable) antiprotons delivered to experiments for studies with antihydrogen and antiprotonic nuclei. The report shows the progress in the ELENA design. The choice of optics and ring layout inside the AD hall is given. The main limitations for beam parameters at extraction like intra beam scattering and tune shift due to space charge are discussed. The electron cooler plays a key role in ELENA both for efficient deceleration as well as for preparing extracted beam with parameters defined by the experiments. The other important systems like beam vacuum, beam instrumentations and others are reviewed as well.

INTRODUCTION

At present, antiproton beams are transferred from the Antiproton Decelerator (AD) with a kinetic energy of 5.3 MeV to the experiments mainly capturing them in traps (see Fig. 1). ELENA [1,2] will further decelerate these antiprotons to 100 keV to i) increase the number of captured antiprotons by one to two orders of magnitude and ii) allowing for new experiments. An essential ingredient of ELENA is an electron cooler reducing the emittances and energy spread at an intermediate energy of about 650 keV and the final energy to reduce the required ELENA acceptance and to improve the beam quality for the experiments. The main ELENA parameters are given in Tab. 1.

AD HALL AND NEW BUILDING

The ELENA machine will be fitted in the already crowded CERN building 193, where the AD machine and related experiments have been operated for the past 14 years. The insertion of this new machine (see Fig. 1), together with related infrastructure (shielding, access structures, ion source, transfer lines, power supplies, controls, safety systems etc.) and the new experiments (Gbar plus undoubtedly others) will necessitate to modify the layout of the AD environment in several steps.

The first stage of the modifications is already in progress. It comprises:

- Modification of transfer line 7000 from AD to existing experiments to allow later the transfer line to ELENA machine to be fitted.
- Relocation of existing experiments control rooms in a specifically dedicated adjacent building (bldg. 93).
- Construction of a new multipurpose annex building (bldg.. 393) to be delivered mid 2014.

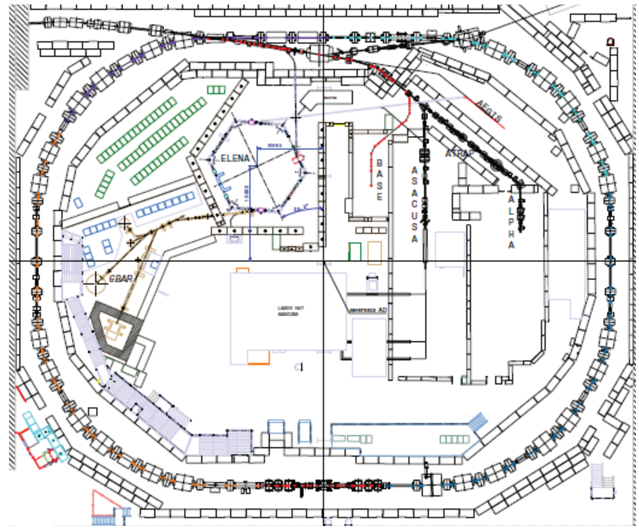

Figure 1: AD hall layout with ELENA and experimental areas.

Table 1: ELENA Machine and Beam Parameters

Momentum range, MeV/c	100 – 13.7
Kinetic Energy range, MeV	5.3 – 0.1
Circumference, m	30.4
Injected beam population	$3 \cdot 10^{7}$
Ejected beam population (total of all bunches)	$1.8 \cdot 10^{7}$
Number of extracted bunches	$4^{*)}$
Δp/p of extracted bunches, [95%]	$2.5 \cdot 10^{-3}$
Bunch length at extraction, m /ns	1.3 / 300
Emittance (h/v) at extraction, π mm·mrad, [95%]	6/4
Required (dynamic) vacuum, Torr	$3 \cdot 10^{-12}$
Machine tunes h/v	2.3/1.3

*) A smaller number of extracted bunches is an option leading to slightly larger emittances and momentum spreads

- Modification of the AD crane to allow an easy transfer of equipment between the two adjacent buildings.
- Preparation of space for a new small experimental area, possibly used by ATRAP (if approved by CERN).
- Installation of a large metallic structure to make space for additional racks in view of ELENA needs.

The second stage of the AD environment modifications between end 2014 and end 2016 will include:

- Relocation of existing cleaning rooms, experiments workshop and stored equipment in building 393.

ISBN 978-3-95450-122-9

- Removal of AD kicker generators to building 393, also incorporating new generators for ELENA.
- Installation of ELENA concrete shielding and main components for commissioning with the ion source.
- Installation of the GBar experiment infrastructure.

The third stage of the infrastructure installation will start after the AD run of 2016, and will include:

- Modification of the AD shielding to allow installation of transfer lines from ELENA to existing experiments.
- Installation of transfer lines to all experiments so that the whole new system can be operated before CERN facilities Long Shutdown 2 (LS2) presently planned for 2018.

AD TO ELENA TRANSFER

The first part of the AD extraction line will be re-used for the beam transfer to ELENA. It will be modified significantly in order to make space for the installation of two 40° bending magnets deflecting the beam towards ELENA as far upstream as possible (see Fig. 2). The rest of the line up to the injection septum will be equipped with four more quadrupoles, instrumentation and vacuum equipment. The Twiss parameters along the AD to ELENA transfer line are shown in Fig. 3.

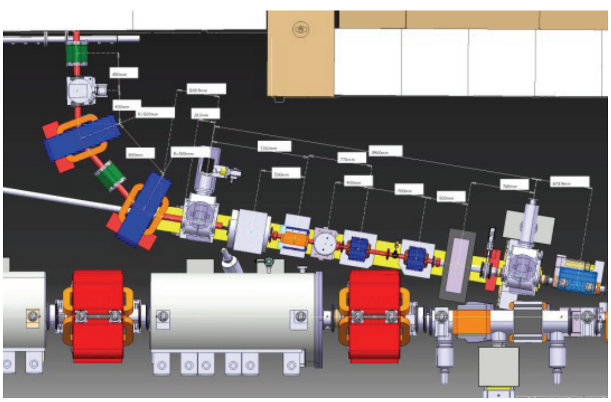

Figure 2: Initial part of the ELENA injection line.

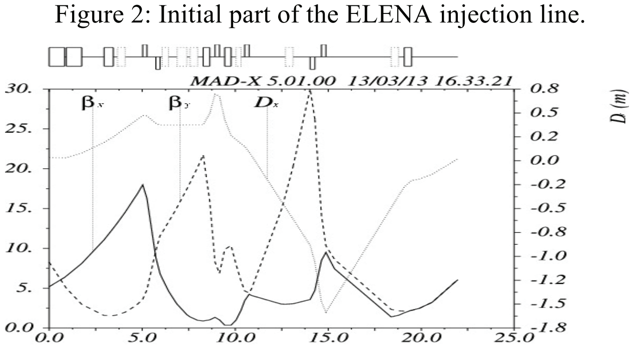

Figure 3: Twiss parameters along the AD to ELENA transfer line.

RING LATTICE, MACHINE PARAMETERS AND ISSUES

The ELENA layout and optics is determined by several constraints. The ring together with the injection line and two extractions serving two experimental areas has to fit into the foreseen space and it must be compatible with the geometry of the AD and the experiments. A long straight section with appropriate beta functions and dispersion values is required for the electron cooler.

A hexagonal layout with a circumference of 1/6 of the AD ring was chosen to provide enough space for equipment and fulfil all requirements. Three quadrupole families and 18° pole-face rotations of the 60° bending magnets are used to control tunes (Qh=2.3, Qv=1.3) and to some extent beta function values in the electron cooler. The lattice functions are shown in Fig. 4.

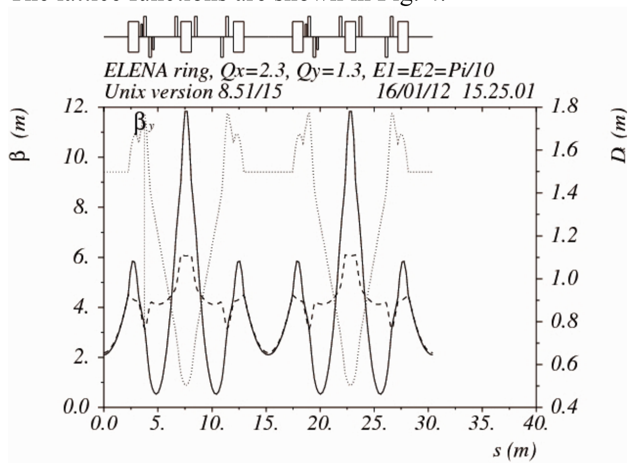

Figure 4: ELENA ring lattice functions.

Bunches with a maximum length of 300 ns can be captured by the experiments. The number of four extracted bunches per cycle has been adjusted such that, with the expected emittances, the direct space charge tune shift is -0.1. Recent simulations with the BETACOOL program [5] showed that the expected transverse emittances can be reached, but higher than the initially expected momentum spread at equilibrium between electron cooling and Intra Beam Scattering (IBS) has been found for coasting beams. Further studies [3] showed that bunched beam cooling allows reducing the momentum spread of the extracted bunches to values compatible with the design of the transfer line and acceptable for most experiments. Thus, bunched beam cooling before extraction is considered now the baseline scenario for ELENA operation.

With the design pressure of 3 10^{-12} Torr, residual gas effects lead to acceptable emittance blow-up and loss rates mainly due to scattering.

Transverse emittance blow-up due to intra beam scattering along the two deceleration steps lasting 5 s and 3 s has been found acceptable.

VACUUM SYSTEM

During the past 12 months the vacuum system has evolved towards a configuration compatible with its integration with other sub-systems, mainly magnets and beam diagnostics. The main parameter, which has been changed, is the dipole magnet gap, decreased from the initial 100 mm to 76 mm. This has forced a re-consideration of the geometry of the pumping taper placed on the external side of the dipole chamber. The conductance of this taper has been reduced with respect to the initial geometry, because of the interference with the magnet coils, which do not allow now an enlargement of the pumping taper vertically. Also, the position and number of pumping ports along the 6 straight sections had to be reviewed, due to the interference with the lattice elements, namely solenoids. Detailed test-particle Monte Carlo simulations have confirmed the necessity to apply NEG-coating to all vacuum surfaces, the most important ones being the quadrupole BPM chambers, with their "nested" coaxial tube-shields-electrodes geometry which multiplies by a factor of about 4 the outgassing area and gas load with respect to a tube of the same length. The simulations show that we can still meet the pressure limit of 3.0E-12 Torr. Lumped integrated NEG-ion pumps (NEXTorr family, from SAES Getters) have been chosen.

The vacuum layout for the transfer lines (TL) has also advanced. We plan to apply the NEG-coating as much as possible, and to employ NEXTorr pumps as well. The number and exact location of these pumps has not been finalized yet, it will depend on the exact sectorization and magnetic lattice layout of the TL.

ELECTRON COOLING

The cooler will be based on the device that was built for the S-LSR ring [4] in Japan and will incorporate adiabatic expansion to reduce the electron beam temperature as well as electrostatic bending plates for efficient collection of the electron beam. Work is on-going to optimize the gun design and cooling simulations using Betacool [5] will help to fine-tune the final parameters of the cooler.

BEAM INSTRUMENTATION

The closed orbit will be measured during the whole cycle with 10 electrostatic beam position monitors installed inside some of the ring quadrupoles and correctors and with a resolution of 0.1 mm and an accuracy of 0.3 to 0.5 mm.

As in the AD, it is planned to use a high sensitivity longitudinal pick-up to measure the beam intensity by Schottky diagnostics of coasting beams and observing the bunch shape for bunched beams. Discussions are on going whether the signal from a high sensitivity magnetic pick-up as in the AD or from all electric position pick-ups or from both will be used.

Additional beam diagnostics devices are TV stations to observe the beam in the injection channel, a tune measurement system based on the BBQ system [6] and using one of the position pick-ups, a (destructive) scraper to determine transverse emittances.

EJECTION FROM ELENA

At 100 keV, a single fast electrostatic separator will be used to extract all bunches at once with subsequent switching into the different transfer lines [7]. One extraction will serve the four existing experimental lines with an additional line going to the BASE experiment, which will be installed in the near future. The second extraction directs to a new experimental zone in the AD hall housing the GBAR experiment and a line for a future experiment.

All beam lines from ELENA to the experiments and the transfer line from the source to ELENA will use electrostatic steering and focussing elements as described in detail in [8].

CONCLUSIONS AND OUTLOOK

The basic conception of the ELENA ring and transfer lines is almost completed and the design and integration of components is on going. A technical design report is expected by the end of the summer. First installation work to modify the first part of the AD extraction line, which will be re-used, will take place during the present long accelerator shutdown.

The place inside the AD hall, where ELENA will be installed, will only be made available during the first part of 2015, when kicker equipments can be moved to a new building. After installation in 2015, ELENA ring commissioning is planned in 2016 in parallel to AD operation mainly with the help of a dedicated source delivering 100 keV protons or H^- ions. During the first part of 2017, the existing magnetic transfer lines from the AD to the experiments will be dismantled and the new electrostatic lines from ELENA installed. After commissioning of the new lines, first physics beams are expected in the second half of 2017.

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