THE VACUUM SYSTEM OF THE EXTRA-LOW ENERGY ANTIPROTON DECELERATOR ELENA AT CERN

R. Kersevan, CERN, Geneva, Switzerland

Abstract

The Extra Low Energy Antiproton ring (ELENA) is a CERN project aiming at constructing a 30 m circumference synchrotron which will take antiprotons extracted at 5.3 MeV from the Antiproton Decelerator (AD), and further decelerate them down to 100 keV [1].

The ring will be equipped with two electrostatic (ES) pulsed extraction deflectors which will allow to deliver the low-energy, cooled antiproton beams to a number of experimental beamlines [2]. The total length of these transfer lines, equipped with ES optical elements is of the order of 100 m. From the vacuum point of view, machine physics issues related to rest-gas scattering and intra-beam scattering mandate a very low average pressure limit, calculated to be 4.0E-12 mbar [3,4]. The very compact ring and the beam-instrumentation installed on it, with many components placed inside of the vacuum system, and lack of space to install lumped pumps, has pushed us to design a pumping system based primarily on non-evaporable getter (NEG) coatings, and few lumped integrated NEG-ion pumps.

The vacuum requirements for the transfer lines are a bit more relaxed, in the 1.0E-10 mbar range, but still require state-of-the-art solutions in order to reduce the potentially large outgassing of the many electrodes, insulators, metal connections used for the ES components installed inside the vacuum system. NEG-coating and integrated NEG-ion pumps will therefore be used here too.

The entire vacuum system of ELENA, with the exception of a short, initial part of the injection line coming from the AD machine, has been specified to be bakeable at 250 ºC.

MACHINE PHYSICS ISSUES AND VACUUM REQUIREMENTS

The low-energy of the antiproton beams, and the length of the deceleration and cooling cycles, mandate a very low average pressure along the ring, 4.0E-12 mbar [1,3-4]. This is not an unprecedented vacuum requirement at CERN, since the LEIR ring has, in the past, required the design of a vacuum system capable of reaching similar performances [5].

OVERVIEW OF THE MACHINE AND TRANSFER LINES

In the following, the naming conventions adopted for the ELENA project will be used, for brevity:

- LNI: injection line from AD;
- LNR: ELENA ring;
- LNExx: transfer lines (total of 9 sections/segments);
- LNS: H\(^+\)/H\(^-\) commissioning source

Figure 1 shows a bird’s eye view of LNI, LNR, LNExx, and LNS. Figure 2 shows a busy intersection of vacuum lines, LNI, LNE, and LNS.

VACUUM CHAMBER MATERIALS AND FLANGES

Materials

The very low energy of the antiproton beam after the deceleration and cooling cycles mandate the choice of a very low magnetic permeability material. The choice has fallen on austenitic stainless steel, 316 LN grade, 3D-forged for all parts machined from blocks, and for flanges.

Flanges

The already mentioned lack of space longitudinally along the ring has pushed us to choose a conical ConFlat flange design, with collars instead of the usual holes. This is a solution which is already employed and validated at CERN on several machines since a long time, both for un-
baked and baked cases. LNExx will be equipped with standard CF flanges.

Bellows

In order to allow proper chemical cleaning and NEG-coating of all vacuum surfaces, we have decided to adopt hydro-formed bellows everywhere possible. At the few locations where this is not allowed by space restrictions, welded-cup design will be adopted.

THERMAL TREATMENTS, NON-EVAPORABLE GETTER THIN-FILM DEPOSITION, BAKE-OUT AND CONTROLS

NEG-coating

The Low-Energy Ion-Ring (LEIR) machine at CERN is working reliably since many years. It has been designed for massive NEG-coating implementation, due to very stringent requirements on its vacuum pressure limits [5]. CERN has also an extensive experience on NEG-coated vacuum chambers installed along the > 6 km of room-temperature Long Straight Sections of the LHC. We are therefore confident that this is a reliable and stable solution for reducing the outgassing load and efficiently pumping all gettable species all at once.

Dedicated prototype mock-up chambers have been fabricated in-house for practicing and optimizing the NEG-coating procedure for the six 60-degree LNR dipole chambers, which have a challenging cross-section.

Surface Treatments

Vacuum firing at 950 °C for 2 h or 600 °C for 24 h will be carried out on almost all vacuum chamber components, in our facility at CERN. Well known and tested procedures for cleaning and preparation of the surfaces to be NEG-coated will also be applied.

Bake-out

For a number of reasons, it has been decided not to equip the vacuum chambers with dedicated insulating jackets. All chambers will be heated up using ribbon heaters wound around the chamber (either before sub-assembly into the magnets in the magnets' lab, or in-situ), and then thermally isolated using aluminium foils and kapton films, especially near the temperature-sensitive low-field dipole magnets [6].

Vacuum and Bake-out Controls

All gauges and pumps will be cabled to dedicated crates which have already been partially populated with controllers and power supplies. Bake-out will be carried out sector-by-sector, using removable controllers shared with other CERN machines.
custom-designed differential pumping system (LNS-DPS), depicted in figure 5. Under the LNS-DPS girder 3 ACP turbo backing pumps are visible. Total length (without IS and source) is 2,503 mm.

Figure 5: LNS vacuum components; right to left: H⁺/H⁻ source; turbo pump for stand-alone source operation (mounted vertically); sector GV with side-port gauges; LNS-DPS (3x 1,200 l/s turbo pumps (dark grey) and 1x 1,400 l/s ZAO-NEG pump (not visible); see-through micro-wire BPM (in-kind contribution) with NEXTorr D1000 pump; see-through ES FODO element (2 quadrupoles, 1 combined HxV corrector; second sector GV with gauges; IS vacuum chamber with NEXTorr D1000 pump on top flange.

Figure 6 shows a Molflow+ screen-shot showing the 3D model created for the LNS-DPS.

Figure 6: 3D Molflow+ model of the LNS-DPS: the source’s flange is on the top-right corner; the facets highlighted in red indicate the pumping surfaces (NEXTorr D1000 pumps on the 3 micro-wire BPMs, and the IS. ZAO-NEG pump on the DPS. The red circles simulate the entrance flange of the 4 large-capacity turbo pumps; the curves on the inset show the pressure profiles along several segments of the beam path (red: source to IS; blue: IS in; green: IS: out; black: IS to ring). The lower left end of the model is attached to the exit of the ES deflector taking the beam out of LNR. The transmission probability from source to ring has been computed to be equal to 0.00024.

**ELECTRON COOLER [9,10]**

The vacuum system for the EC is presently under advanced design in collaboration with CERN/BE-BI. It will be 100% NEG-coated, and will have two NEXTorr-D500 pumps at the two extremities, and a custom-made differential pumping system in front of the electron gun filament, based on St707 NEG strips, similar to what is reliably working since many years on the AD EC.

**PRESENT STATUS AND LOOK AHEAD**

The ELENA area in the AD hall is practically ready for start of installation of the machine’s components.

Fabrication of the vacuum chambers for the ring has started; while the design of the transfer lines is being completed, fabrication has also started.

The first vacuum components to be tested are parts of the line used for the commissioning H⁺/H⁻ source (IS chamber), which is provided as in-kind contribution by a laboratory member of the ELENA collaboration. This is expected to take place in mid 2015. Installation of the ring’s vacuum system in the AD hall is scheduled to take place between the second half of 2015 and first half on 2016, with finalization of the transfer line in early 2017.

**ACKNOWLEDGMENTS**

Too many colleagues from different CERN departments and groups, as well as several others from research institution collaborating to the ELENA Project should be mentioned here. I am particularly indebted to my colleagues in the Surfaces, Chemistry and Coatings section (VSC-SCC); to L. Dassa and C. Eymin (CERN/EN-MME-EDM) for the amount and quality of the work done for us, most notably the drawings of the vacuum chambers and the collaboration in writing several technical specifications, and for providing many of the figures used in this presentation; to G. Pigny (CERN/VSC-ICM) for controls. The recent addition of G. Riddone and M. Gallilee on the ELENA Vacuum team is particularly acknowledged. Also, the fruitful collaboration with other ELENA Project Work Package holders and the project leader C. Carli is greatly appreciated.

To all of the above my sincere gratitude for a so far very efficient collaboration and information exchange. This paper is written on behalf of all of them.

**REFERENCES**


