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A NEW ELECTRON COOLER FOR THE CERN ANTIPROTON DECELERATOR (AD)

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Abstract

The current electron cooler at the Antiproton Decelerator (AD) at CERN was built in the second half of the 1970s and is thus well over 40 years old. It was built for the Initial Cooling Experiment (ICE) where stochastic and electron cooling were tested to ascertain the feasibility of using these techniques to generate high intensity antiproton beams for the SPpS. The ICE electron cooler was subsequently upgraded and installed in LEAR (Low Energy Antiproton Ring) to help generate intense beams of antiprotons at low energies. After the stop of the anti-proton physics at LEAR in 1996 and two years of studies of electron cooling of Pb ions, the electron cooler was moved to the AD where it has been in use ever since.

With the new ELENA ring becoming operational, a major consolidation project has been launched to extend the lifetime of the AD and as a part of this a new electron cooler for the AD is being built. In this paper, we describe some of the design considerations and challenges of this project as well as the expected gains in terms of cooling performance.

INTRODUCTION

Since the completion of the LEAR physics program a simplified scheme using a modified AC (antiproton collector) as a decelerator (AD) was implemented at CERN to deliver antiprotons to experiments at an energy of 5.3 MeV. The scheme relies on stochastic and electron cooling to efficiently decelerate and extract high brightness beams to the experimental zones. With the recent addition of the ELENA ring to the CERN antimatter complex and an electron cooler with more than 40 years of operation [1], it was decided that a new cooler should be built to ensure reliable operations for the next 20 years.

Table 1: Main Parameters of the new Electron Cooler

	Value	Comment
E_e	68 keV	Cooling at 500 MeV/c
B_{gun}	2400 G	Expansion factor 2
Ie@68keV	3.5 A	
Ie@3keV	0.45 A	Factor 4 more current

The new device (Fig. 1) has been designed to cool antiprotons at a considerably higher energy than what is presently possible. Cooling at a higher energy will limit the adiabatic blow-up of the emittance of the circulating beam by a factor of three making the cooling of this “hot” beam more efficient. The cooler will also have an electron beam expansion system to obtain an electron beam with a reduced transverse energy for efficient and faster cooling of the circulating beam. It will be installed horizontally allowing easier access to the device for maintenance and repairs. Some of the main parameters and the potential gains of the new cooler are given in Table 1.

ELECTRON GUN

A high perveance electron gun capable of operating up to 80 kV is presently under design (Fig. 2). It is based on a study of various gun optics (Fig. 3) performed some years ago [2] and incorporates some ideas inspired by the decelerating tube of the Gbar experiment at CERN [3]. With a four times higher perveance, the gun will be able to deliver up to 450 mA of electron current for cooling at the lowest energy plateau of 5.3 MeV. At the top energy for electron cooling, the current will be limited to 3.5A.

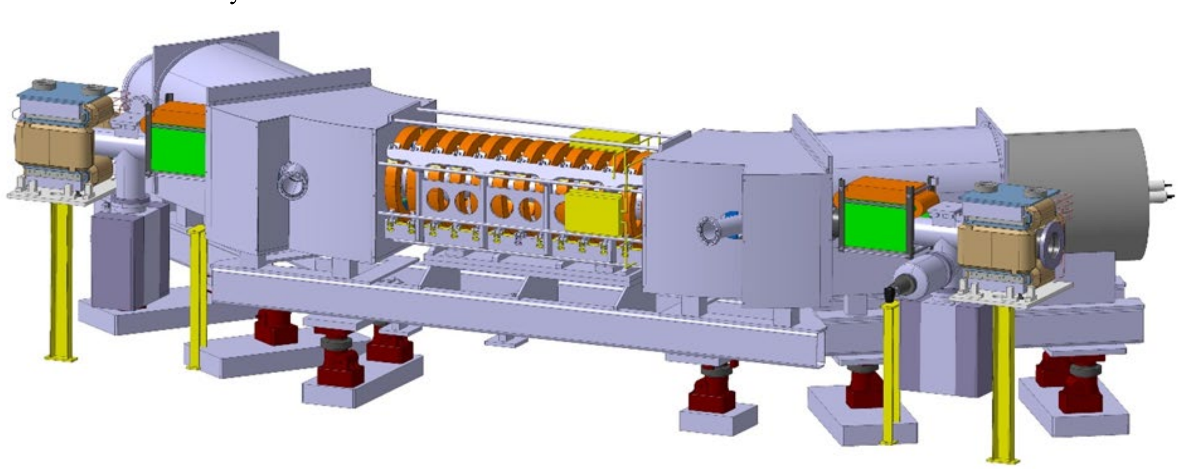

Figure 1: Mechanical design of the new AD electron cooler.

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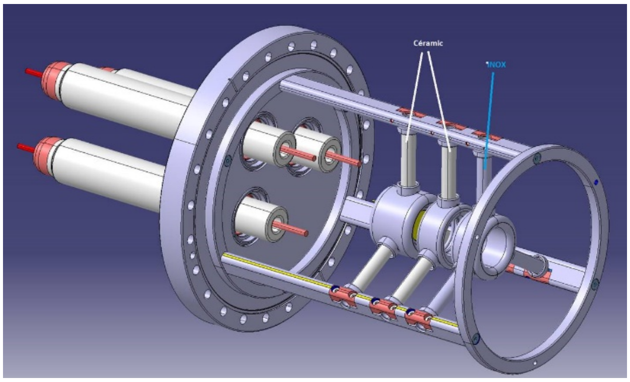

Figure 2: The new electron gun design.

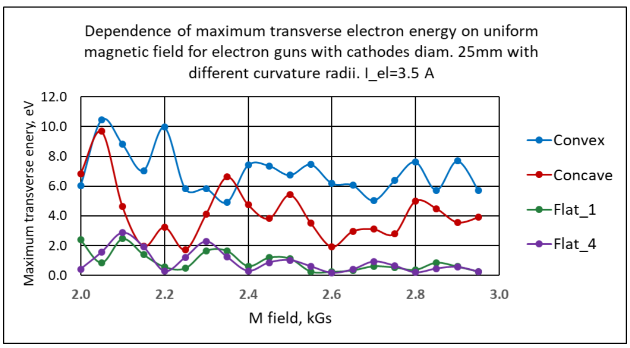

Figure 3: Maximum electron beam transverse temperature for different cathode configurations.

MAGNETIC SYSTEM

Apart from the expansion solenoid and the two transition solenoids, the magnetic system of the new cooler will be constructed using short "pancake" coils (Fig. 4). This has the advantage that the local field errors can be easily corrected by the adjustment of the individual coils [4]. The return flux of the field is insured by a set of iron rods running alongside the coil assembly. Magnetic field calculations with Opera [5] have shown that there is no substantial difference in the magnetic field quality between the rods or a full shield (Fig. 5). In the final design additional shielding will be installed around the toroids and gun/collector solenoids to avoid any external magnetic fields perturbing the electron beam in these regions.

The magnetic field of the current AD electron cooler was measured twice, the first time in 1984 and again in 1997 and those measurements show that the transverse field in the drift region is only at the level 2×10^{-3} compared to the longitudinal field. The new cooler has been designed to have a transverse magnetic field that is much better than this with a specification value of better than 5×10^{-4} . This could potentially shorten the cooling time and result in a lower final temperature of the antiproton beam.

The new cooler will also feature compact orbit correctors similar to what was built for the ELENA electron cooler, this saves space and, by being as close as possible to toroid regions of the cooler, will help minimize the orbit excursions of the circulating beam of antiprotons.

We have also decided to combine the installation of the new electron cooler with moving some of the magnets close to the electron cooler section in the current AD set-up. At the moment on each side of the electron cooler there is a quadrupole triplet in between the electron cooler and the compensation solenoids. With active optics elements in between the drift region solenoidal field and the compensation solenoids, the compensation cannot be complete and the result is increased coupling in whole of the AD.

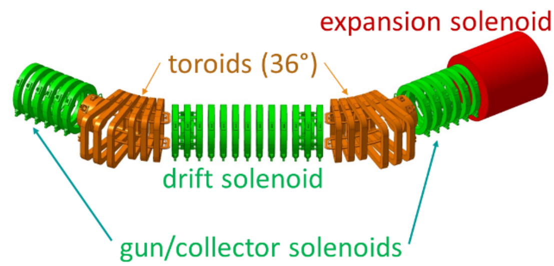

Figure 4: The magnetic system of the new cooler.

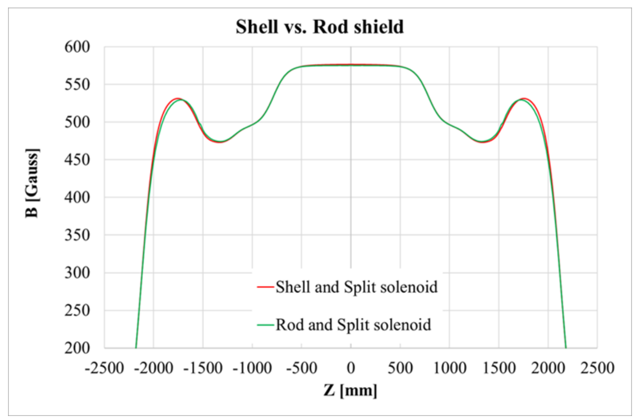

Figure 5: Comparison of the magnetic field for "pancake" coils with iron bars or full shield for the return flux.

COLLECTOR

Recent failures on the current AD electron beam collector has meant that the design and construction of the new collector needed to be mechanically compatible with the present setup. This is to make sure we have a spare collector available should the current collector run into problems before the installation of the new electron cooler. The current design of this new collector (Fig. 6) has suffered some HV breakdowns and the design is under review to better understand the exact causes of these breakdowns and hence mitigate them.

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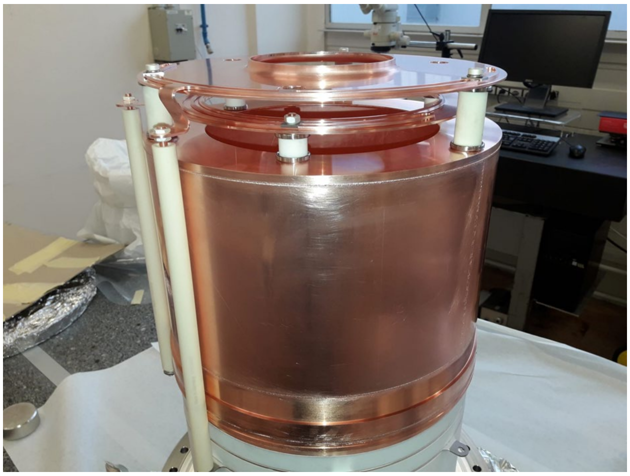

Figure 6: Electron beam collector.

VACUUM SYSTEM

The vacuum is fully designed and is shown on Fig. 7. All the elements will be made from vacuum fired 316LN stainless steel and be fully bakeable up to 350°C. In order to reach the desired vacuum level below 10^{-11} mbar, both toroid chambers, central drift vacuum chamber and pick-up bodies will be NEG coated [6] and additional NEG strips [7] will be placed at the gun exit and the collector entrance. Two vacuum ports are foreseen on the toroid chambers for vacuum instrumentation and additional pumping.

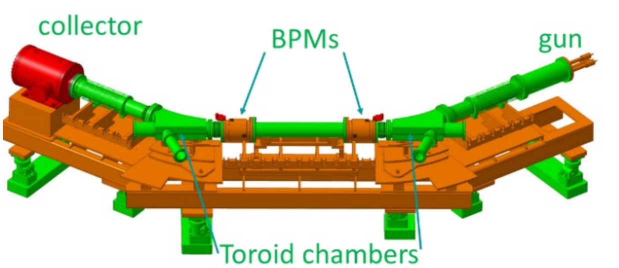

Figure 7: The vacuum envelope and support system.

SCHEDULING

The design of the new AD electron cooler is well advanced. The vacuum and support structures will go into production early in the new year.

The magnetic system is expected to go for tender in the first half of 2022. All parts are expected to be ready for assembly by the end of 2023. The assembly, testing and full validation of the new AD electron cooler is expected to take place in our test area during 2024. The cooler will be installed in the AD ring during CERNs next Long Shutdown (LS3) which is currently scheduled for 2025.

CONCLUSION

CERN Antiproton Decelerator is undergoing a big consolidation to make it fit to run for another 20 years. As part of this effort it has been decided to build a new electron cooler for the AD. The current electron cooler, which has been in use with great success for almost 45 years, will be retired, . It has served as an operational electron cooler on both ICE, LEAR and the last more than 20 years at the AD.

The new electron cooler will feature a range of what has been learned in the field over the last 50 years. Thus, it will make use of an expansion coil around the e-gun to reduce the transverse temperature of the electron beam. It will also feature a substantially better magnetic field in the drift region, better diagnostics, compact orbit correctors and much better vacuum. It is difficult to predict any improvements that might come from this, but perhaps it will be possible to reduce the time needed on each of the two electron cooler plateaus at the AD, thus perhaps reducing the AD cycle time, as well as possibly reaching a lower final temperature of the antiproton beam. The magnet reshuffling in the vicinity of the new electron cooler, to be done at the same time as the installation of the new electron cooler, should make the AD optically simpler by reducing coupling in the whole ring.

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