# PERSPECTIVES FOR A HIGH ENERGY ELECTRON COOLING AT LEAR AN EXPERIMENTAL TEST

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## Abstract

The feasibility of a high energy electron cooling device, has been studied through tests on a prototype of the electron device. The apparatus consists of a pulsed (20÷60 KeV, 2 μs) electron gun, a drift region 1 m long and a depressed collector to recover the electron energy. Tests on beam optics and energy recovery have been performed, a high efficiency for energy recovery has been obtained. The high energy device project is in progress.

## Introduction

The increasing demand for high intensity and small momentum spread proton/antiproton beams has emphasized the necessity of very efficient p/$\bar{p}$ cooling devices.

Electron cooling, compared to the well tested stochastic cooling[1], offers much shorter cooling times, but his feasibility has been demonstrated only at low energies[2].

A prototype for electron cooling with characteristics suitable to be scaled at higher energies has been built in Frascati.

## Demands for electron cooling

Up to now at least two projects in Europe are asking for a strong cooling system: the operating Low Energy Antiproton Ring LEAR[3] at CERN and the proposed proton-antiproton storage ring Super LEAR[4].

The proposed use of LEAR as mini p$\bar{p}$ collider in the momentum range 0.6÷2 GeV/c involves high luminosity requirements (from the foreseen value of $1.4 \times 10^{29}$ cm$^{-2}$s$^{-1}$ up to $10^{30}$ cm$^{-2}$s$^{-1}$). Moreover the envisaged operation with an internal gas target for very low energy experiments requires very short cooling times: in fact Coulomb scattering in the target strongly limits the beam lifetime.

In Table I are summarized the principal electron beam requirements for this options. Fig.1 shows the proposed device layout,and Fig.2 the LEAR layout (1/2 of machine) with the drift region where it would be installed.

Table I. LEAR Electron Beam Parameters

| | |
|---|---|
| Beam energy | 0.3 ÷ 1.1 MeV |
| Electron current | 3.5 A |
| Beam diameter | 3 cm |
| $\Delta p/p$ | $<10^{-3}$ |
| Beam temperature | <1 eV |
| Vacuum in drift tube | $10^{-12}$ Torr |
| Magnetic guide field | <3 kG |

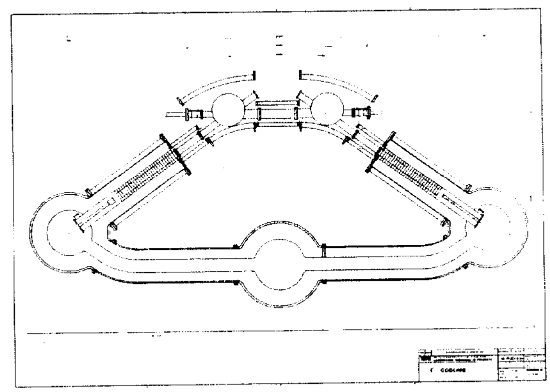

FIG. 1 - LEAR Electron Cooling Device Project.

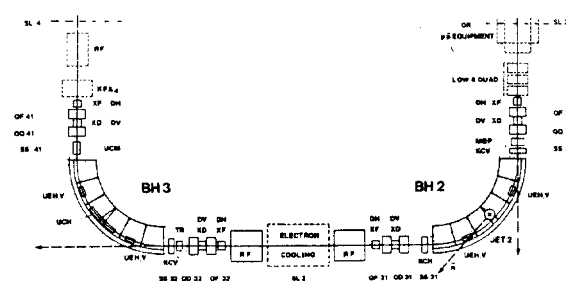


FIG. 2 - LEAR layout (1/2 of machine).

Super LEAR is a proposed proton-antiproton storage ring featuring strong phase-space cooling. The momentum range (3.5 ÷ 7 GeV/c) has been chosen to work with an internal target for charmonium spectroscopy and with colliding beams for bottomonium spectroscopy. In both cases an efficient electron cooling, that will allow operation with high luminosity and a much smaller momentum spread, is needed.

To study charmonium and bottomonium spectroscopy via p$\bar{p}$ collisions, provided cooling is operating, is interesting to detect excited levels not accessible via $e^+e^-$ interactions, neither directly nor via radiative decay. The small momentum spread achievable ( $\Delta p/p \simeq 10^{-4} \div 10^{-5}$) will allow high counting rates for narrow resonances and to measure directly the total width of not extremely narrow (~ 1 ÷ 10 MeV) resonances.

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Although the machine lattice has not yet been fixed, the achievable luminosity cannot exceed $3\times10^{30}$ $cm^{-2}s^{-1}$ (assuming a compact small ring, 120 m long, for $p\bar{p}$ collisions with $10^{12}$ circulating particles and a beam-beam tune shift $\Delta Q \simeq .005$ ). This value does not meet the experimentalists requirements. To increase the luminosity, reducing the interaction area, and to decrease the momentum spread, a high energy electron cooling has been proposed.

Table II summarizes the electron beam characteristics for this option.

Table II. Super LEAR Electron Beam Parameters

| | |
|---|---|
| Beam energy | 1.9 ÷ 3.3 MeV |
| Electron current | 2 A |
| Beam diameter | 1.5 cm |
| $\Delta p/p$ | $10^{-3}$ |
| Beam temperature | 5 eV |

Prototype performances

The apparatus[5] consists of a pulsed (20÷60 KeV, 2μs) electron gun, a 1 m long drift region and a depressed collector to recover the electron energy.

Fig. 3 is a picture of the whole apparatus.

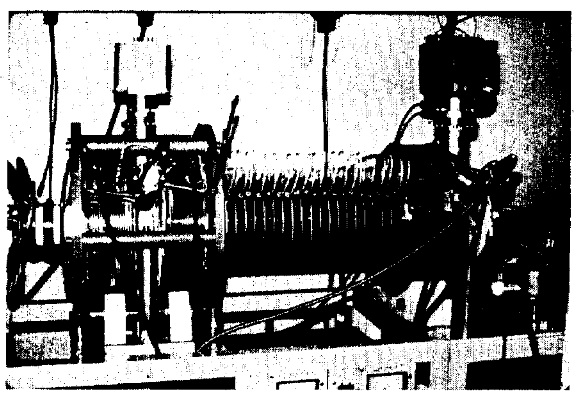

FIG. 3 - The Prototype.

The electron gun has been designed with a classic immersed flow Pierce geometry. The beam is guided by a uniform magnetic field (1 kG max) to overcome space charge effects. The coils have different diameters: 50 cm in the gun and collector regions, 20 cm in the drift region. In the matching region the field relative non-uniformity is less than $10^{-3}$. To improve the collection efficiency a correcting coil in the collector region has been added.

The device parameters are summarized in Table III.

Table III. Prototype Electron Beam Parameters

| | |
|---|---|
| Beam energy | 20 ÷ 60 KeV |
| Electron current | 5 A @ 60 KeV |
| Beam diameter | 3 cm |
| Pulse length | 2 μs |
| Magnetic guide field | <1 kG |

The electrons are emitted from a thoriated tungsten cathode heated at 1500°C. The source is shown in Fig. 4.

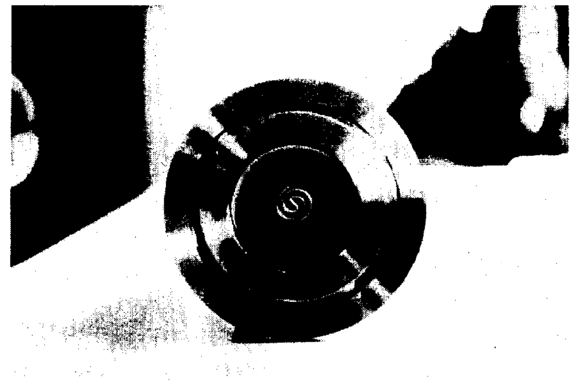

FIG. 4 - The Prototype Electron Cooling Source.

The gun region has been conceived according to the "resonant optics" requirements, to achieve a low final transverse temperature.

Setting different voltages on the gun anode it is possible to operate the device in a continuous energy range.

Fig. 5 shows the single-plate collector. Here the electrons are decelerated by a tapered magnetic field before the collection. A spike is added to deflect the axial electrons to the collector walls. The collector can operate beetwen 0 and 3 KeV.

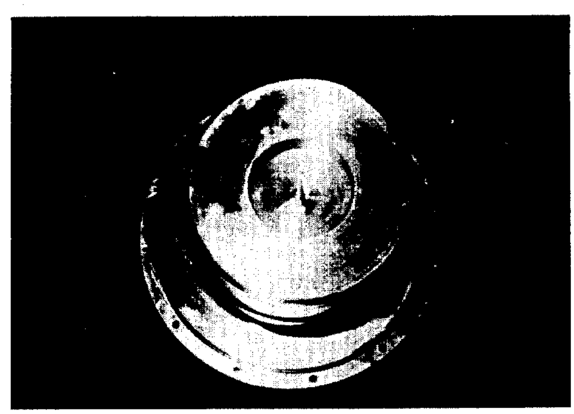

FIG. 5 - The Prototype Collector.

The main problem to maximize the energy recovery is the secondary emission from the collector surface. For stainless-steel collector this rate is about 1% of primary electrons.

Tests have been performed in two steps.

Firstly beam performances have been studied with temperature limited current, by reducing cathode temperature. The beam energies were ranging from 20 to 55 KeV, the currents from 0.2 to 0.4 A. The total emitted electron collection has been studied with the collector connected to ground potential, and then with a depression of 3 kV to perform the energy recovery. Current losses of the order of a few mA, consistent with the estimate rate of secondary electrons in the collector, have been measured.

Finally the space charge limited operation has been performed.

Fig. 6 shows the final emitted electron current at different energies; the Child's law behaviour is well verified. In Fig. 7 the measured fraction of current loss ($I_L$) during the recovery process at different beam energies, with collector potential set at 3 KV, is plotted.

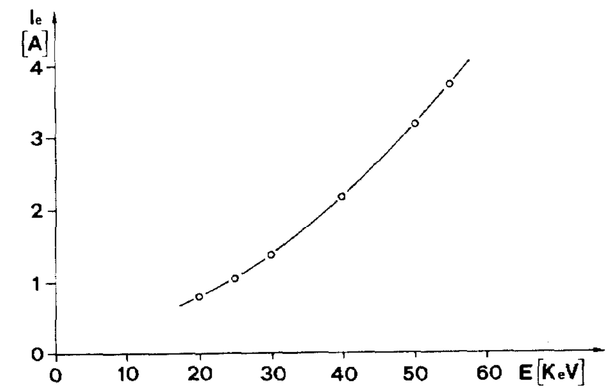


FIG. 6 - Emitted electron current vs. beam energy.

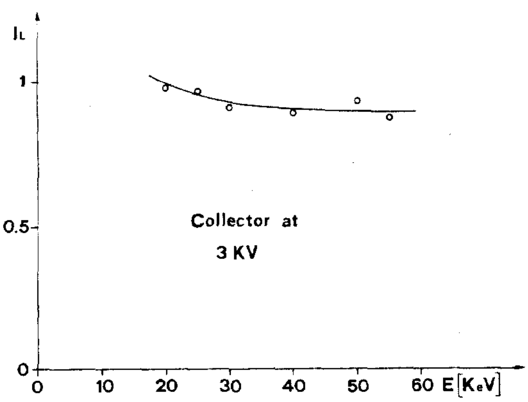


FIG. 7 - Current loss vs. beam energy.

The power loss, $V_C I_C$, where $V_C$ is the collector potential with respect to the cathode and $I_C$ is the collected current, is supplied by the collector power supply. This loss is in general dissipated as heat in the collector causing degassing and desorption of residual gas molecules. For this reason it would be preferable to collect the beam at the lowest possible potential. Fig. 8 shows the minimum collector voltage needed to obtain the total beam recovery as a function of beam energy.

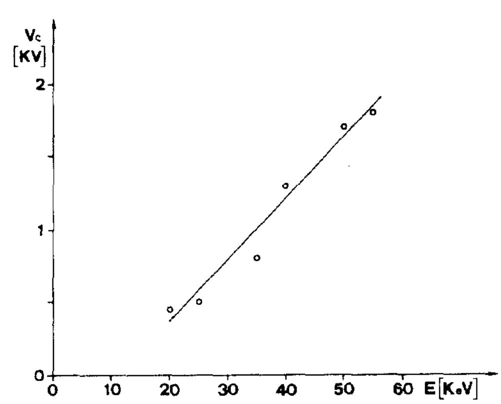


FIG.8 - Minimum collector voltage vs. beam energy.

Although no particular attention has been devoted to achieve high recovery efficiency, about 98% of the involved power has been collected.

Using materials with a low secondary emission coefficient like titanium and platinum, much better results will be possible in the proposed high energy electron cooling device. This project is still in progress. Computer simulations of the electron trajectories in the Pierce and accelerating regions (see Fig. 9) show a possible configuration with final electron energy of 400 KeV, guiding magnetic field of 2.7 kG and transverse temperature lower than 1 eV. An ultra high static vacuum of $10^{-12}$ Torr, required for the performance of the device, has been furthermore obtained in a vacuum pipe prototype.

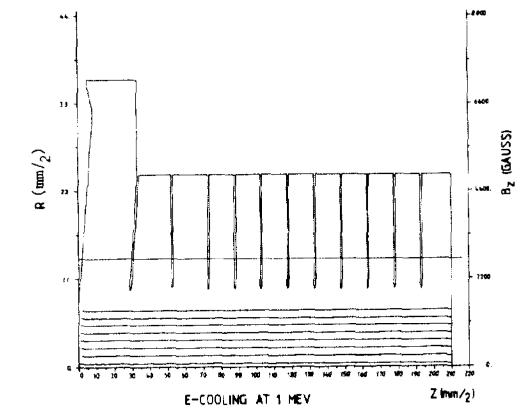


FIG. 9 - Computed Electron Trajectories for the High Energy Device.

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