Trip Report - Visit to CERN - July 5th to August 5th 1984

Carlos Hojvat

September 13, 1985
Introduction

The present visit to CERN was as a result of an invitation from Dr. Colin Johnson of the Antiproton Accumulator (AA) group. Two activities were planned for this visit. First, the second beam test of one of the original Fermilab lithium lenses (serial No.2). Second, the installation and beam tests for a new Fermilab lens of improved design (serial No.5).

It should be mentioned here that CERN, after realizing the possible gains to be obtained, has started a considerable development effort in short focal length lenses. Presently they have 3 operational lithium lenses, transformers and power supplies for tests. They are in the process of constructing 3 other transformers and designing lenses of 4 cm diameter (twice the present Fermilab lenses). Fermilab should devote some added effort in the field to maintain the initiative.

The first beam test of lens No.2 was performed during the summer of 1983, when the lens was used as an antiproton collecting lens. For this test the original lens was used as a strong focusing element in the 26 GeV proton beam in conjunction with a current carrying target. Preliminary tests for this geometry were conducted during 1984, when the lens was exposed to over 2E6 pulses at 320kAmps and 1.3E13 protons per pulse.

Lens No.5 was installed as an antiproton collecting lens, immediately following the AA production target, in a geometry similar to the one designed for the Tevatron 1 project at Fermilab. Targets of a different design than the one used normally at CERN were also required. After completion of the antiproton yield measurements and optimization the lens was left in the beam during regular operation for antiproton accumulation.
During antiproton accumulation for the Lear accelerator new records were achieved on the accumulation yield and accumulation rate of antiprotons for the AA machine.

CERN activities in the development of a Plasma Lens, as an alternative to the lithium ones, and new broadband pick-ups for stochastic cooling were observed as they are of great interest to Fermilab.

1-CERN Collaboration

The AA group at CERN and the Antiproton Production Group of the Tevatron I project have been collaborating for some years on the general subject of antiproton production and collection. In particular the development of lithium lenses of large aperture has been the subject of many exchanges. The planned upgrade of the CERN AA, ACOL project, is presently based on the Fermilab designed lithium lens, although a plasma lens alternative is being developed. At the moment two lenses (serial No.2 and No.5) and three transformers have been in location at CERN for beam and/or power tests. The Fermilab design uses water cooling to remove the energy deposited in the lens by the electrical pulse.

A CERN SPS group (under the direction of Peter Sievers) based on the experience gained at Fermilab has developed a new design that could be adapted to gas cooling. Two prototypes have been constructed. The first one has already survived more than 2 million pulses at 320 kAmps on the bench and without beam exposure. This unit is operated with water cooling. The second prototype failed during the lithium filling operation.

Another area of collaboration is in the development of conducting targets, where an electrical current through the target itself focuses the secondary particles. Two new prototypes were beam tested during this visit.

The third area of close interaction between the Fermilab and CERN groups is in the study of the antiproton yields obtained at the AA ring. Further measurements were carried out for comparison with the predictions of the Fermilab computer program.

2-Conducting Targets Beam Tests
For these tests, the lens was utilized as a strong short focal distance lens for the 26 GeV proton beam. This is an important test in connection with possible future upgrades utilizing conducting targets. The lens was followed by a conducting target and the AA regular horn was used as an antiproton collector. Use of a lithium lens following the conducting target, a better set-up, was not possible due to the limited space available upstream of the lithium lens for the conducting target connections.

The lens was located in the proton beam, approximately 1 meter upstream of the conducting target. The focussing of the proton beam (focal distance 1 meter) matches the incoming beam in order to compensate for the strong defocussing produced by the target current (for focussing negative particles). If the divergency of the proton beam at the upstream face of the target matches that expected from defocussing, then a symmetric beta function can be obtained around the centre of the target. This is an important consideration to preserve the possible gains due to the focussing of negative secondary particles by the electrical current within the target. The larger the target current the more the focussing lens with a short focal distance becomes a necessity. Otherwise, the strong defocussing current would cause a large increase in proton beam size through the target length such that not all the beam will interact in it.

The first conducting target tested consisted of a 3 mm diameter low carbon steel rod, 126 mm long. After optimization a yield of 7.3*E-7 antiprotons per incident proton was obtained for a current of the order of 100 kAmps. This is to be compared with a normal yield of 6.0*E-7 obtained immediately previous to the geometry change. The machine acceptance was measured to be 95 pi mm*mrad in the horizontal plane and 79 pi mm*mrad vertically. The yield optimization was limited by the fact that varying the horn current also varies the target current, although three different ratios of currents were available.

The second conducting target tested was labelled a "separate function" target. It consisted of a 25 mm long 3mm diameter tungsten rod (no current), followed by a conducting 126 mm long 4mm diameter aluminium and terminated by a 10mm long 3 mm diameter tungsten rod (no current). A maximum yield of 5.3*E-7 antiprotons per proton was obtained at approximately 120 kAmps.

3-Lithium Lens Beam Tests
Following the conducting target tests, lens No. 2 was removed from the beam on its movable platform. Lens No. 5 was then installed downstream of the target.

A new target snout, that attaches to the normal target container, was designed to position the target as close to the lithium lens as possible. This target will permit exploring high lithium lens currents (very short focal distances). This geometry required a severe reduction on the amount of cooling that can be provided to the target, resulting in some target failures. The target itself was a 3mm diameter rhenium rod of lengths between 55 and 60 mm, surrounded by graphite, and mounted within the target snout. The snout material, being the beam window on the downstream end, was made first of steel and later from a titanium alloy.

Antiproton yields of 7.2*E-7 were obtained soon after start of operation, for an order of 306 kAmps in the lithium lens. The yield shows a strong dependence with current, increasing by 1.5% per 1% increase in current. The peak current was kept below 430 kAmps as the test of a similar lens at 620 kAmps at Fermilab was just getting underway. The yield appears to keep increasing with the same slope at this maximum current, putting the focus of the lens downstream of the calculated optimum. A maximum yield of 7.74*E-7 was obtained at the maximum current and at a time into the pulse of 460*E-6 seconds, some 50*E-6 seconds later than the calculated optimum.

During the next few days when optimization of the AA ring was taking place, yields as high as 8.61*E-7 were recorded, or an increase of 43% over normal yields.

The data collected has for the most part not been analysed yet.

4-Accumulation Operation for LEAR

After 6 days of machine studies related to the conducting targets and the lithium lens, on July 20th, the AA was switched to the antiproton accumulation mode. The machine studies were scheduled just in advance of a period of physics in the LEAR machine. The lithium lens was left in place as an antiproton collector to benefit from the larger yields obtained. This first operational test of the Fermilab lens was planned for LEAR as a possible failure during a SpS collider run would have been more disrupting for the CERN program.
Three parameters are used to describe the performance of the AA machine during antiproton accumulation. The first one is the "Accumulation Yield" (AY). This is the number of antiprotons added to the stack per pulse and per accelerated proton (in the P.S.). It is a 100 pulse average updated every pulse. As such it is to be distinguished from the "Antiproton Yield", quoted above, as it also includes the effect of moving the particles from the injection orbit into the cooling systems and its addition to the stack. The interpretation of improvements in this quantity is more complex as it is affected by the performance of many systems in the AA machine, and by the details of the distribution of antiprotons in phase space.

The highest AY previously recorded was of 4.05*E-7 during March 1985. A new record of 4.77*E-7 was established during this run for a gain of 18%.

The second quantity is the "Normalized Accumulation Rate" (NAR) in antiprotons per hour. This 100 pulse average, is the rate of antiproton accumulation normalized to every P.S. cycle being a production cycle. As the number of cycles per supercycle varies frequently, the NAR provides an easy way of comparing rates measured at different times.

For comparison with the AA design report the NAR is further normalized to 1.0*E13 protons accelerated per pulse and used to divide an expected accumulation rate of 2.5*E10 antiprotons per hour (obtained from the design figure of 6.0*E11 every 24hrs found in CERN/PS/AA 78-31, 1978). In this way the "Missing Factor" (MF) is obtained, the expected performance over the actual performance.

The best recorded NAR during operation is of the order of 7.3*E09 (March 1985) for an MF of 4.4.

During operation with the Lithium Lens new records were established, NAR = 8.3*E9 and MF = 3.49, for gains of 14% and 26% respectively.