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A new approach to a pure antiproton beam at GeV-energies

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ABSTRACT

In this note we want to re-iterate the possibilities for the installation of a GeV antiproton beam of high intensity and purity at the AGS. At present there exists no separated antiproton beam of several GeV of this kind, although a variety of interesting experiments in this energy domain are waiting to be carried out. There exists a unique possibility at the AGS for the installation of such a beam with limited effort and cost. It will be suggested here to use the existing tunnel for the planned beam transfer line from the AGS to the CBA to transport antiprotons from the U-line to a CBA experimental area.
The antiproton transport line would be identical with the foreseen transfer line for heavy ions; it would just be operated at lower field values. No additional elements would be needed nor any extra installations other than those required anyhow for the heavy ion transfer.
Undoutedly there is a rich physics programme to be accomplished with such a facility.

INTRODUCTION

The idea for the installation of a time separated or time purified antiproton beam was put forward long time ago by T. Kalogeropoulos [1] and credit has to be given to his contineous intercession. In a recent proposal [2] by him and his collaborators a detailed study of such a new facility was presented and the possible physics programme was outlined. That proposal asked for the installation of a completely new beam line. In contrast to that we want to emphasize here that such a beam could be realized with limited manpower, effort and costs when use is made of the existing and planned infra-structure for the heavy ion colliding beam programme [3]. The following is suggested. Protons of 28 GeV are ejected from the AGS to the U-line and transported to the neutrino area as it is done right now. Some tens of meters upstream of the neutrino target region a removable antiproton production target will be installed. The production spectrum of antiprotons is rather well known for high antiproton energies. It peaks at roughly 3.5 GeV for 26 GeV primary protons and falls off rapidly towards low and less dramatically towards high energies. Antiprotons will be extracted from the target and transported to an experimental area situated in the CBA tunnel. The planned beam transfer line for the transport of heavy ions from the AGS to the CBA will be used. This line was designed to transport beams of about 30 GeV/c. The possibility to operate it at momenta between, say, 3 GeV and 10 GeV will be discussed later. In one of the experimental halls of the CBA tunnel or next to it one or more zones for experiments with that antiproton beam could be installed. In the following we discuss briefly the implications of such an installation.

PROTON BEAM EXTRACTION

At present the 26 GeV proton beam is injected into the U-line by single turn extraction. The beam structure consists of 12 bunches 40 nsec long and separated by 220 nsec [4]. This extraction mode is of limited use for the production of a good duty cycle secondary antiproton beam. For this purpose one would rather like to have a slowly extracted proton beam as it is for example, delivered to the C-line (spill length 800 ms, repetition rate 2-3 sec). It is useful for antiproton beams not relying on a defined time structure. Measurements have shown in a previous experiment [5] that the slowly extracted beam can be delivered in small pulse of 4 ns separated by 220 ns if the RF-system is kept on during the slow extraction. Such an extracted proton beam would be extremely interesting for the production of a time separated antiproton beam as pointed out earlier [1]. The implications of an slowly extracted antiproton beam for the U-line has to be studied and the consequences have to be worked out. However there seems to be no major obstacle.

PRODUCTION TARGET

At present the U-line transports the proton beam to the neutrino area where the full beam is dumped on a target for neutrino production. It is planned to use it later for the transfer of heavy ion beams to the CBA (Fig. 1).
A suitable position for an antiproton production target (Fig. 2) would be at the first 10 degree bend. One would use a standard heavy metal production target (e.g. W) which can be removed from the beam whenever the U-Line is needed for neutrino or heavy ion physics. The target should withstand high proton intensities, a requirement which does not go beyond standard techniques. The target area could be constructed in a similar way as for the neutrino area. There should be not major shiedling problems.

ANTIPROTON BEAM TRANSPORT

The antiproton beam (3-10 GeV/c) may be transported to the CBA by making use of the planned AGS-CBA transfer beam line for the heavy ions. This transfer line (Fig. 2) was designed for 30 GeV/c equivalent proton momentum [6-8] .

It consists of four combined function FODO patterns between B and D providing a dispersion free transport, to D and six separated function FOFDOD between E and F. Six quadrupoles are used to carry the beam from D to the switching magnet E. The 10 degree dipoles are supposed to be operated at about 1.2 T and the dipoles between E and F at 1.3 T. The quads between B and E would run at 1.2 T/m and between E and F around 3.7 T/m. Finally a matching section of three separate function FODO cells are used to match the transfer line to the CBA lattice. The dipoles (quads) here operate at 1.6 T (15 T/m).
The whole line was designed to take a beam of 2 mm mrad transverse emittance and 0.3% momentum spread from the AGS to the switching magnet E. The momentum acceptance from E to the CBA is 1% [7].
These acceptances are rather small. However, since the antiproton beam is to be transported at relatively low energy there should be enough quadrupole strength available to achieve a low beta value at the target. For instance with a beta of 1 m one could capture antiprotons into a solid angle of 12 µstrd. The beta function never exceeds 100 m which means such a beam would remain well inside the aperture (about 28 mm vertical and 70 mm horizontal). For this optimistic case (and 1% momentum acceptance) one would sample $2 \cdot 10^5$ antiprotons per 10^{13} protons interacting in the target.
Taking the above given magnetic field strengths it should be possible to run the transfer line as low as 3 GeV/c, which means a factor of ten lower field. Since some of the existing elements have been optimized for high transport momentum their performance at lower values has to be re-checked. However, there should be in principle no problem.

EXPERIMENTAL AREA

There are several possibilities for the installation of an experimental area.

The simplest one would be to install it directly in the CBA tunnel at the point where the heavy ion beam is later to be injected in the storage ring. This leaves little space for the experimental set-up and would also perturb the installation of the collider ring.
Another possiblity would be to transport the antiproton beam further counter clockwise in the CBA to the OPEN AREA (Fig. 1) where plenty of space would be available. For this transport, again, at least initially, the CBA ring magnets could be used.
It may even be conceivable at a later stage to transport the antiprotons from the switching magnet (position E) through the other injection line into the CBA and circulating them clockwise to the NARROW ANGLE HALL (Fig. 1). This would provide an extremely long flight path for the antiproton beam and would clean it from other particles even at high energies.
Finally there is the possibility to pass the antiproton beam from point E directly without any further bend to the WIDE ANGLE HALL. This requires however civil-engineering work for a tunnel from E onwards.

FLIGHT PATH

The flight path from the production target to the switching magnet (E) amounts to about 200 m. Adding another 200 m from point E to point G gives a total path length of 400 m. Antiprotons (pions) of 3 GeV/c would need 2096 (2002) ns to cover this distance. The corresponding value at 10 GeV/c is 2009 ns. This flight path corresponds to 3.6 (1.1) decay length for pions of 3 (10) GeV/c.

At least at low energies antiprotons could therefore be well separated by time-of-flight measurements from pions. With an experimental zone in the OPEN AREA one is even better off. The various methods of tagging the antiprotons were discussed in Ref. 1 and 2 and are also applicable here.
In contrast to the earlier proposal, however, the suggestion here has the further advantage that the beam transport line analyses automatically the antiproton momentum.

ANTINEUTRON BEAM

It should be noted that a time separated antineutron beam could be set-up if the production target was installed in position D and a pulsed slowly extracted beam was directed to the target. The forward produced antineutrons would run down the antiproton beam line to point E. Provided there is a vacuum tube from there to the WIDE ANGLE HALL they could be used in this zone.
The total flight path would be about 200 m. Making use of the time structure of the slowly extracted proton beam (pulse of 4 ns) one could get a 7% momentum resolution for a antineutron beam of 3 GeV/c.

SUMMARY AND CONCLUSON

We pointed out the possibility of installing a long antiproton beam in the AGS-CBA transfer tunnel with the aim of providing a cleaned-up or even time separated beam of 3 GeV to 10 GeV antiprotons. Emphasis was put on the fact that virtually no new beam elements would be needed if the heavy ion transfer line could be used. Moreover a great part of the infra-structure is already existing or will be available whenever heavy ions are transported to the CBA. In principle this solution can be made compatible with heavy ion and neutrino physics operation of the U-line. A broad field of physics, currently hardly explored, would be opened up by such a facility. At present and certainly still for some time, nowhere can such a high quality beam be found. Apart from that, the described scheme seems to be appealing as it makes use of existing and so far unused installations and may even be helpful for setting up the heavy ion operation of the CBA. In contrast to earlier proposals this solution provides an intrinsic momentum analysis of the antiproton beam. Furthermore, it might also be possible to combine this facility with the installation of an antineutron beam. In order to realize such a antiproton beam only little effort, cost and manpower is needed.
This note is not meant to be a proposal, it is rather intended to trigger further thinking along the lines sketched here. Amongst other aspects, certainly the following ones have to be worked out in more detail.

- Slowly extracted beam feeding the U-line
- Pulsed slowly extracted beam
- Beam optics of transfer line in view of beam spot size at the target
- Target position and shielding
- Beam optics of transfer line for antiproton transport
- Experimental area in the CBA or next to it
- Intensity and beam quality estimate
- cost and work estimate

ACKNOWLEDGEMENT

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FIGURE CAPTIONS

Fig. 1: AGS-CBA configuration (Ref. 3)

Fig. 2: Schematic layout of the beam transfer line from the AGS to CBA (Ref. 3)

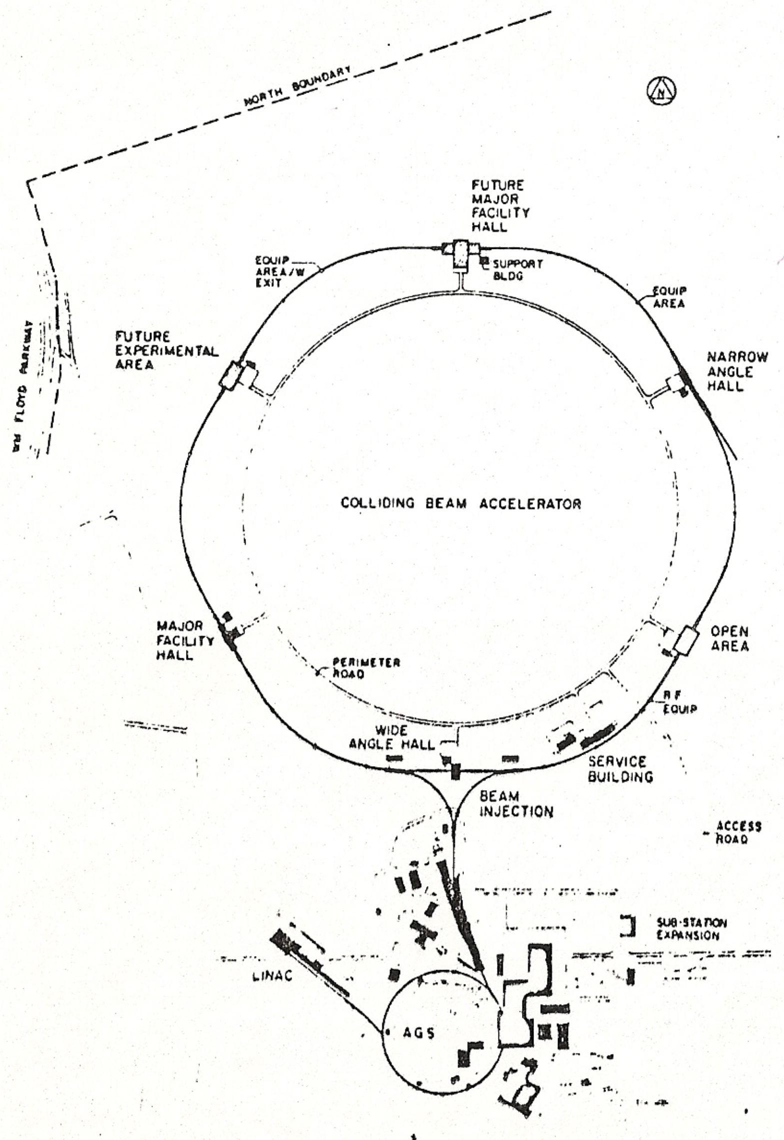

Figure I

CBA

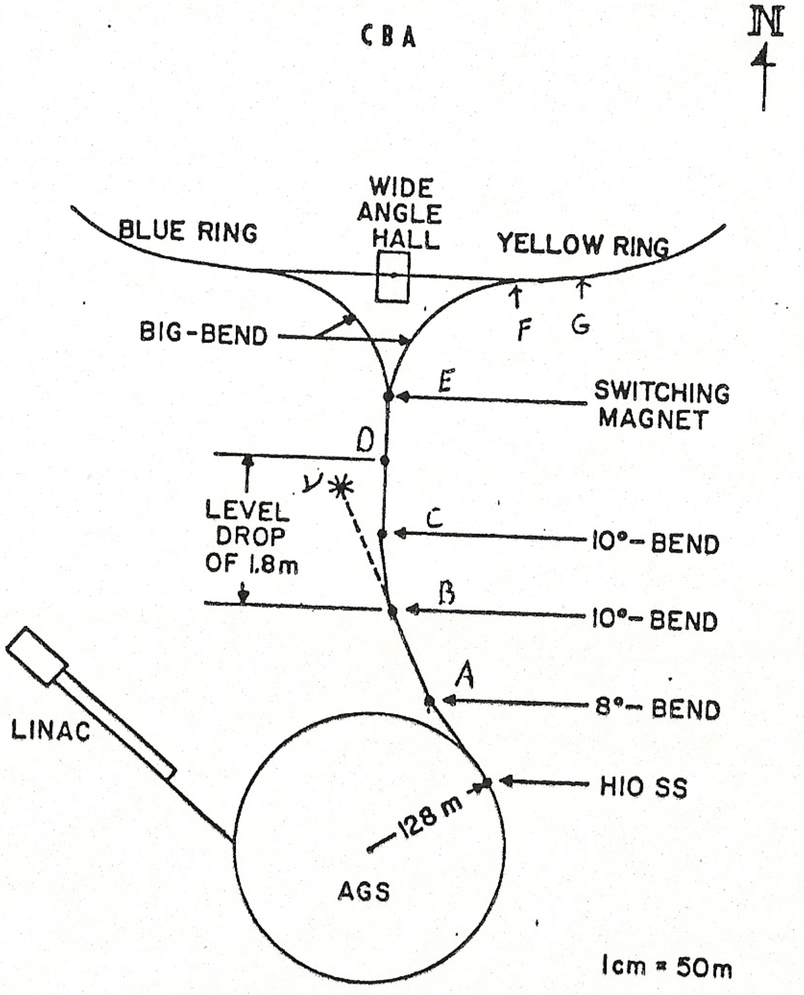

Figure II