Accelerator Division
Alternating Gradient Synchrotron Department
BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York 11973

Accelerator Division
Technical Note

No. 266

A THOUGHT ON VERY LOW ENERGY ANTI-PROTONS

October 17, 1986

Y.Y. Lee

A THOUGHT ON VERY LOW ENERGY ANTI-PROTON

Y. Y. LEE

INTRODUCTION

It has been proposed to use the AGS Booster[1] as a time stretcher purifier for the anti-protons of momentum .65 to 5.2 GeV/c.[2] In this note, we would like to extend the idea to very low energy of tens of KeV anti-protons.

A brief description of the system is as followes. In each AGS cycle the booster field is set to accept anti-protons of momentum 3.5 GeV/c, where one expects maximum production of anti-protons, after injecting protons into the AGS. The AGS extracts three rf bucket of protons from either H10 or I10 to strike an anti-proton production target. The anti-protons will be collected by an appropriate lens system (eg. lithium lens) and transported to the booster area and injected into the booster through the channel identical to its extraction channel. Since anti-proton is the anti-particle of the proton, injection of the anti-proton is identical to the extraction of the protons. Once the anti-protons are injected and captured in the booster, one can either accelerate or decelerate them in the booster. After deceleration to 200 MeV kinetic energy, they can be further decelerated through the linac and an RFQ preinjector down to ion source energy.

ANTI-PROTONS WITHOUT COOLING

Assuming standard production rate at AGS energies of

10^{-6} anti-protons/m-str/%/interacting protons

anti-protons at 3.5 GeV/c, one can estimate the number of anti-protons which can be accumulated in the booster acceptance of 50 mm-mr and 2% momentum bite. Realistically the AGS proton beam at 30 GeV/c can be focussed down to 1mm spot size, and therefore the angular acceptance one can expect in each dimension would be

50 mm-mr/0.5 mm = 100 mr

And the solid angle subtended would be 0.04 steradians.

Because of the finite length of the target, the collection efficiency would be reduced further. For a 10 cm long target, particle production studies show that only one third of the particles fall into the useable phase space, and thus the effective solid angle becomes

.04/3 str = 13.3 mstr

The anti-proton production rate is therefore

$$N_{\bar{p}} = 10^{-6} \times 13.3 \times 2(\%) \times Np/3$$
$$= 8.89 \times 10^{-6}\ Np$$

where Np is number of incident protons and the factor 3 is to correct for interacting versus incident protons.

The post booster AGS will accelerate .5 x 10^{13} protons/bucket and if one uses three of those buckets for the production per cycle,

$$N_{\bar{p}} = 8.89 \times 10^{-6} \times 1.5 \times 10^{13} = 1.33 \times 10^{8}\ \text{anti-protons/pulse}$$

at 3.5 GeV/c.

If one decelerates the collected anti-protons, assuming rf system has enough debunching to take care of the anti-proton beam energy spread(i.e. while making the bunch longer, reduce the energy spread), then the betatron phase space decreases by the factor $1/P^2$. The normalized emmitance of the collected beam at 3.5 GeV/c is 186.5 mm-mr and this emmitance will be trimmed through the deceleration process. The normalized acceptance of the booster at 200 MeV linac energy is 34.3 mm-mr. Figure 1 shows the resultant anti-proton intensity as a function of final decelerated energy in the booster.

DECELERATION THROUGH THE LINAC

The decelerated anti-protons can be extracted near the booster injection channel, and transported through either injection transport system with its dipoles reversed or separate transport system to the 200 MeV linac. The beam can be decelerated through the linac to a kinetic energy of 750 KeV at the "entrance" of linac tank 1. The acceptance of the system is dominated by the normalized admittance[3] at the 750 KeV point of 10 mm-mr. Thus one will lose beam intensity through the 200 MeV linac by a factor of

$$(10/34.3)^2 = .085$$

and in addition by an additional factor of two due to beam bunching efficiencies. As a result

$$1.9 \times 10^5 \text{ anti-protons}$$

will survive to 750 KeV. The anti-protons can be further decelerated through the RFQ pre-injector to energies of 20 KeV.

EFFECT OF COOLING

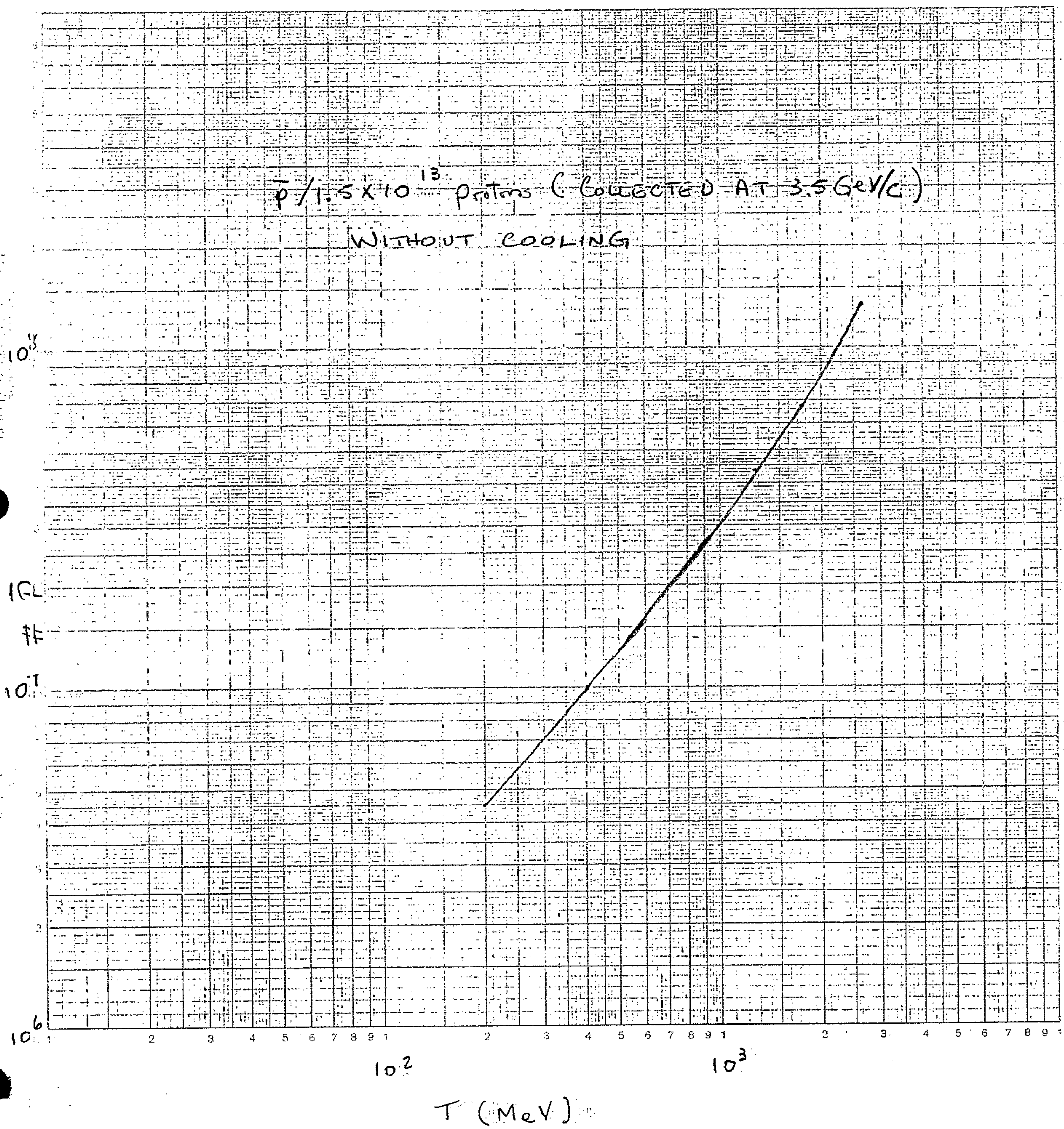
If one cools the anti-protons in the booster to less than 10 mm-mr normalized or 14.6 mm-mr at 200 MeV energy, theoretically half of the 1.33 x 10^8 anti-protons collected at 3.5 GeV/c could be decelerated to 750 KeV and then to 20 KeV.

REFERNCES

1) AGS booster conceptual design report, BNL 34989 R, 1985

2) A. S. Carroll, Y. Y. Lee, D. C. Peaslee, and L. S. Pinsky, to be published

3) G. W. Wheeler et al. Particle Accelerators Vol. 9 No. 1/2, 1979



$\bar{p}$/1.5 X 10^{13} protons (COLLECTED AT 3.5 GeV/c)
WITHOUT COOLING
10^8
10^7
10^6
10^2
10^3
T (MeV)