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A CONCEPTUAL DESIGN FOR A VERY LOW ENERGY ANTIPROTON SOURCE

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A CONCEPTUAL DESIGN FOR A VERY LOW ENERGY ANTIPROTON SOURCE

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In a previous note[1] we raised the possibility of obtaining very low energy antiprotons of the order of 20 keV kinetic energy from the AGS. In this note we would like to outline the requirements for such a facility (or experiment) to accomplish the very low energy antiproton source.

The basic magnetic cycle of the AGS and the Booster is given in Figure 1. After injecting 1.5 GeV protons into the AGS, the magnetic field of the Booster is ramped up to 8.5 kG in order to receive 3.5 GeV/c antiprotons produced by the AGS. The antiprotons are decelerated by the Booster and then extracted to the 200 MeV linac while the AGS delivers the rest of the available protons for other experiments. The antiprotons are then decelerated in the linac to 750 keV and then to 20 keV in the RFQ linac. Figure 2 is a description of the accelerator complex.

THREE BUNCH EXTRACTION FROM THE AGS

At the end of the AGS acceleration cycle, the AGS rf voltage is raised to shorten the bunch length to a few nanoseconds before extracting three of the twelve bunches through the I10 extraction channel. This will increase the proton beam momentum spread and provide for a short antiproton bunch. The extraction channel and the beam transport should be able to accommodate the proton momentum spread. The additional equipment needed for the extraction is a ferrite kicker and power supply similar to the ones installed at H5 or E5, an extraction septum and power supply similar to the one at H10, and an AGS orbit bump and power supply.

PROTON TRANSPORT AND THE TARGET STATION

The beam transport consists of six quadrupoles, a triplet in the AGS tunnel for beam shaping and another triplet upstream of the target for focusing the beam on to the target. A special target station similar to the ones at the CERN and Fermilab antiproton facilities must be constructed because of the high intensity beams involved. A focusing element such as a lithium lens is required in order to focus the produced antiprotons into the apertures of the transport quadrupoles.

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1. Y.Y. Lee, A Thought on Very Low Energy Antiprotons, BNL Acc. Div. Tech. Note No. 266 (1986).

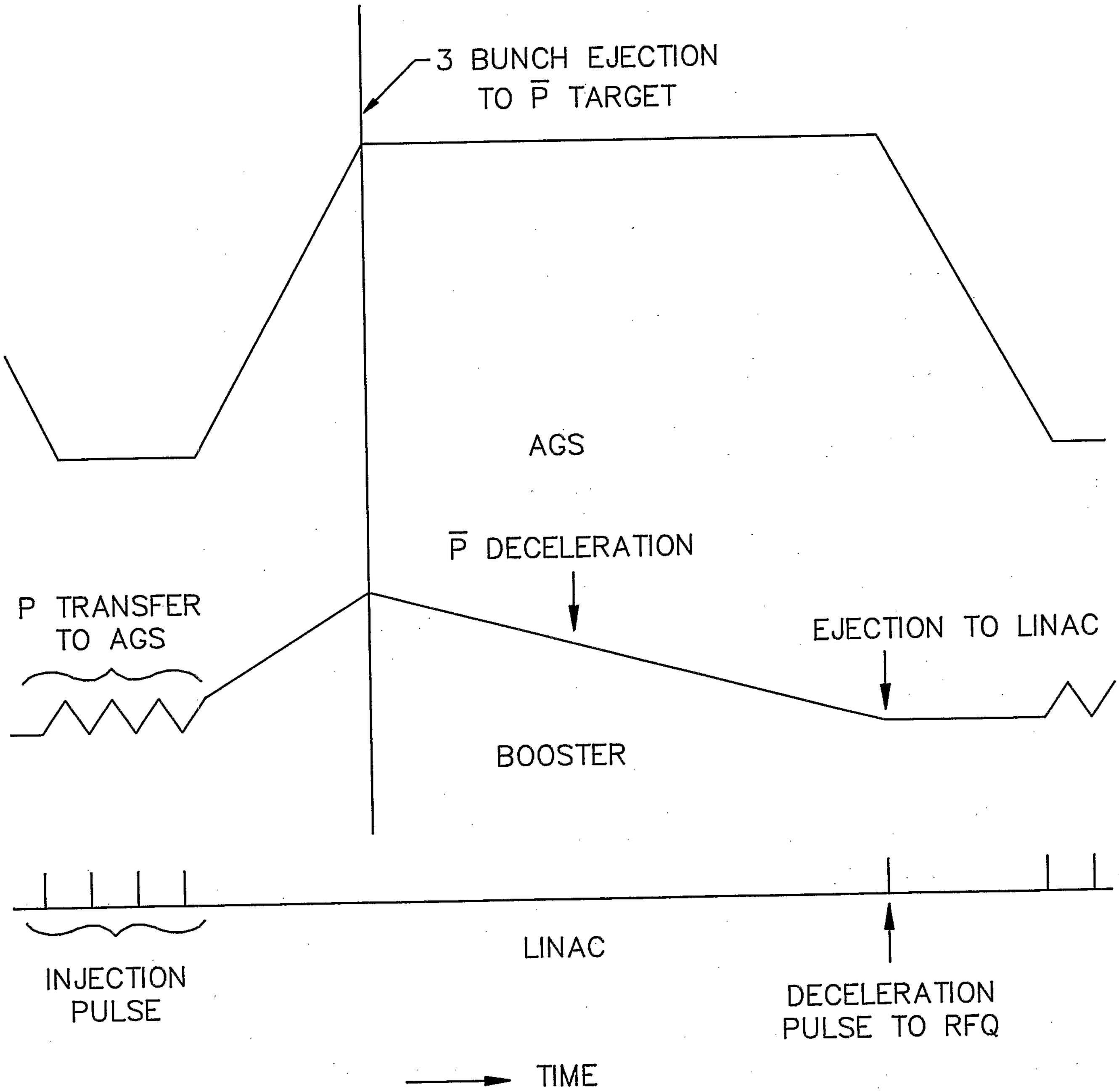
3 BUNCH EJECTION TO $\bar{P}$ TARGET
AGS
$\bar{P}$ DECELERATION
P TRANSFER TO AGS
EJECTION TO LINAC
BOOSTER
LINAC
INJECTION PULSE
DECELERATION PULSE TO RFQ
TIME

Figure 1

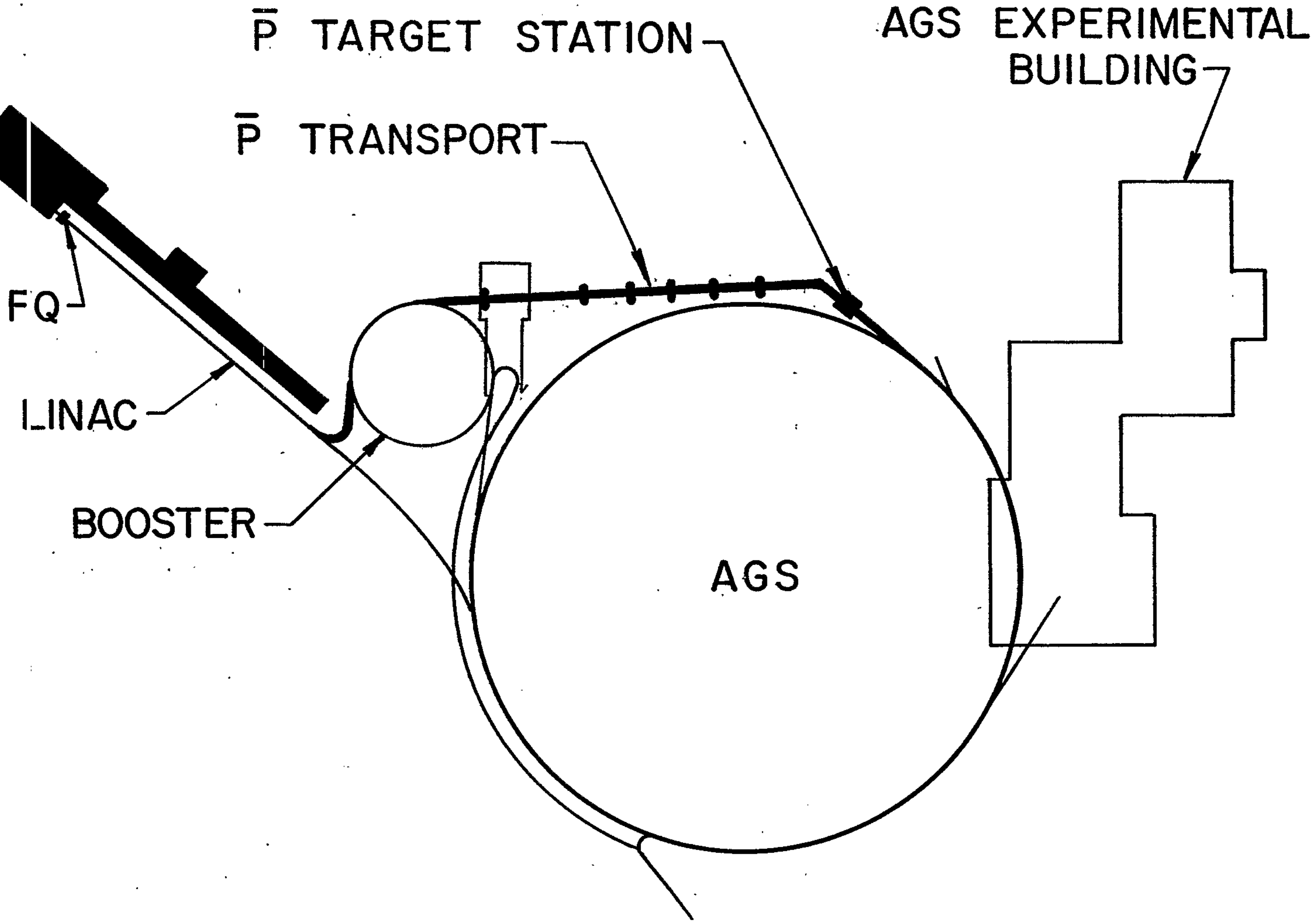
P̄ TARGET STATION
AGS EXPERIMENTAL BUILDING
P̄ TRANSPORT
FQ
LINAC
BOOSTER
AGS

Figure 2

ANTIPROTON TRANSPORT AND INJECTION INTO THE BOOSTER

Produced antiprotons will be transported to the Booster. The length of the line is approximately 150 meters and requires about 30 degrees of total bend. It requires the order of 10 quadrupoles and six 5 degree bending magnets.

Injection into the booster is accomplished by duplicating the Booster extraction septum and kickers.

DECELERATION IN THE BOOSTER

The antiprotons transported to the Booster will have the 50 pi-mm-mr emittance in both planes and a momentum bite of 2%. The length of the antiproton bunch is the same as the AGS proton bunch which was tailored to a few nanoseconds. By allowing the bunch to rotate in logitudinal phase space one can lengthen it to 50 nanoseconds and the antiproton momentum spread can then be reduced to a few tenths of a percent. No special equipment is needed to decelerate the beam to 200 MeV kinetic energy. One may have to install special instrumentation to detect the low intensity beam.

BOOSTER EXTRACTION AND TRANSPORT TO LINAC

Decelerated antiprotons can be extracted at the Booster straight section C6. A fast ferrite kicker of strength 6 kG-meter can extract 200 MeV antiprotons from the Booster. A transport system identical to the injection line but of opposite polarity can transport the antiprotons to the HEBT line of the linac. A fast kicker can inject the beam into the upstream end of the linac.

DECELERATION THROUGH LINAC-LEBT-RFQ-EXPERIMENT

At present we do not foresee any additional equipment required to decelerate the antiprotons through the linac and RFQ except increased sophistication in phase and amplitude controls. At the exit of the RFQ a kicker is required to deflect the decelerated antiprotons away from the regular proton channel and direct it to the detector region.

CONTROLS MODIFICATION

Additional sophistication is needed in the control system of the AGS, Booster and linac. Pulse-to-pulse modulation of the system is required, not only for the magnetic cycle of the machines, but also to all other systems such as rf and extraction systems.

COMMENTS ON THE BOOSTER POWER SUPPLY AND RF SYSTEM

At present there are two modes of Booster operation, namely fast cycling proton operation and slower cycling heavy ion operation. The proton operation needs higher voltage and lower current while heavy ion operation needs lower voltage but higher current. Power supply modules are rearranged for each of the operations. For the proposed antiproton option, the range of antiproton deceleration current requirements forces one to use the arrangement of the heavy ion option which results in the Booster cycle period to be lengthened by a factor of two. If faster cycling of the Booster is important, one would add a set of modules to the present power supply to increase the repetition rate.

It is inefficient to bunch and decelerate in the linac unless the antiproton beam is prebunched to the linac frequency. One would add a 200 MHz rf cavity to bunch the antiprotons in the Booster. This will bring the efficiency to about 80% compared to 50% for decelerating through the linac and RFQ.

COMMENTS ON COOLING THE ANTIPROTONS

It has been demonstrated that one can reduce the six dimensional emittance of the beam in a synchrotron either by stochastic or electron cooling. As a proof of principle experiment the option of cooling is not compelling. In the previous note we show a factor of 350 decrease in the available antiproton flux at 200 MeV without cooling versus with cooling. We have not estimated the additional costs of introducing stochastic cooling but refer the reader to the copious literature from both CERN and Fermilab.

APPROXIMATE COST

We estimate the order of magnitude costs to carry out a test of the scheme. The estimate is scaled from either existing AGS equipment costs or scaled from the Booster proposal. We used a rule of thumb number of about $150/kilowatt for the power supply estimates. We summarize them in Table I.

TABLE I
(cost in thousands)

I. EXTRACTION FROM AGS		360.
FERRITE KICKER	50.	
POWER SUPPLY	50.	
EXTRACTION SEPTUM	100.	
POWER SUPPLY	100.	
ORBIT BUMP	10.	
POWER SUPPLY	50.	
II. TARGET STATION AND PROTON TRANSPORT		1070.
QUADRUPOLES (6)	240.	
POWER SUPPLIES	180.	
TARGET STATION AND LI LENS	650.	

TABLE I - continued

III. P-BAR TRANSPORT AND BOOSTER INJECTION		1750.
TRANSPORT TUNNEL(450 FT)	450.	
QUADRUPOLES (10)	400.	
POWER SUPPLIES	300.	
DIPOLES (5)	200.	
POWER SUPPLIES	100.	
INJECTION SEPTUM	100.	
POWER SUPPLY	100.	
FAST KICKER	50.	
POWER SUPPLY	50.	
IV. BOOSTER EXTRACTION AND TRANSPORT TO LINAC		1010.
EXTRACTION KICKER	100.	
POWER SUPPLY	100.	
QUADRUPOLES (15)	150.	
POWER SUPPLIES	250.	
DIPOLES (8)	160.	
POWER SUPPLY	150.	
KICKER	50.	
POWER SUPPLY	50.	
V. INSTRUMENTATION AND CONTROLS		500.
VI. CHANGES IN BOOSTER TUNNEL AND BUILDING 914		100.
VII. BOOSTER POWER SUPPLY ADDITION		1000.
VIII. 200 MHz CAVITY SYSTEM		450.
SUBTOTAL		6240.
EDIA(@15%)		940.
CONTINGENCY(@20%)		1440.
TOTAL		8620.