STACKTAIL MOMENTUM COOLING IN THE FERMILAB ANTIPROTON SOURCE

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Introduction

The stacktail momentum cooling system is one of eight cooling systems in the Fermilab Anti-proton source. (Figure 1) The use of cryogenic pickups, preamps, and superconducting notch filters make it the most complex in terms of hardware and operation. This paper will attempt to describe some of the hardware and its operation along with the latest performance results of the present pbar running period.

Hardware Description

System parameters and schematic graphic control[1] of the stacktail system are shown in figures 2 and 3 respectively. The pickups and kickers used throughout the cooling systems were designed and built through a collaboration of Lawrence Berkeley Lab, Argonne National Lab, and Fermilab.[2] They are a loop coupler design that incorporates from eight to thirty-two loops per array depending operation as a pickup or kicker. Pickup arrays are cryogenically cooled with liquid nitrogen to 80 degree Kelvin to keep the thermal noise contribution of the back terminating resistor at a minimum. Initial thoughts of using helium to cool the pickups were abandoned due to the small noise improvement to cost ratio.

As in all low signal to noise ratio systems, excellent preamp performance is imperative. Liquid nitrogen cooled preamps with effective noise temperatures of 20 degrees Kelvin were designed and built at Lawrence Berkeley Laboratory.[3] The combination of cooled pickups and preamps sets the effective noise temperature of the stochastic cooling system front end to 100 degrees Kelvin.

The superconducting notch filters provide two very important functions in momentum cooling: 1) gain shaping for high gain at the edge of the tail to move particles quickly and minimal gain at the core revolution orbit to reduce core heating 2) the core particles' signal is a noise source to the stack hence the notch improves system signal to noise ratio. Thirty DB notch depths and ten part per million notch stability have been achieved.[4]

The remaining amplifiers, attenuators, phase shifters, and traveling wave tubes were all very carefully specified and measured for gain flatness and phase linearity. The performance of the cooling system depends totally on the ability of the cooling electronics to produce a linear negative feedback gain transfer function. A typical system transfer function is shown in figure 4. Note that this an open loop measurement with the particle beam as the feedback element. The slope in the phase is due to the fact that the beam revolution frequency is not at the synchronous frequency of the feedback system. Gain bandbass characteristics are caused mainly by the pickup, kicker, and TWT amplitude response. Plans for improvement of the gain and phase flatness by means of equalizing filters is being considered for future operation.

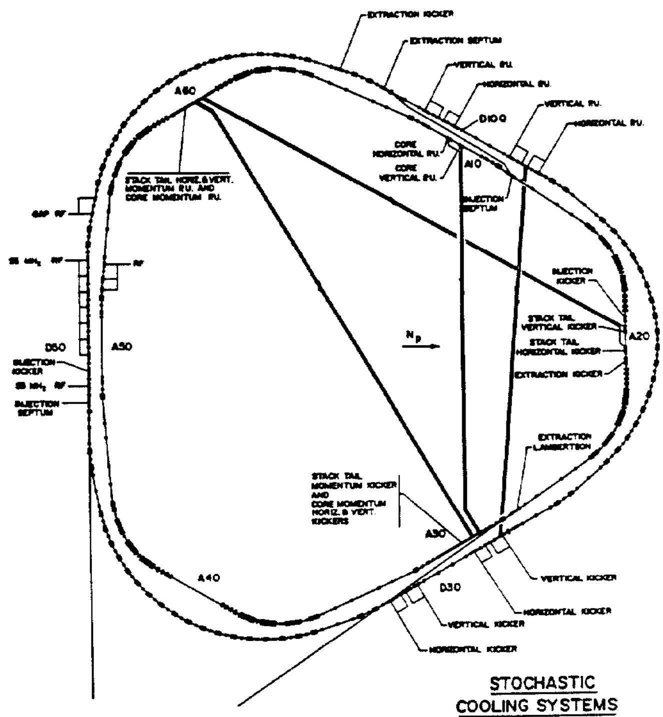

Figure 1.

System Parameters

Frequency	1-2 GHz
Number of pickup loop pairs	162
Pickup characteristic impedance	109 ohms
Pickup sensitivity.	.85
Back termination thermal noise temp	80 deg K
Preamplifier noise temperature	20 deg K
Net system gain	150 Db
Number superconducting filters	3
Number of TWT's	40
Total system power	1600 watts
Number of kicker loop pairs	160
Design stacking rate	1×10^{11} /hour
Design cycle time	2 seconds

Figure 2

*Operated by Universities Research Association Inc., under contract with the U.S. Department of Energy.

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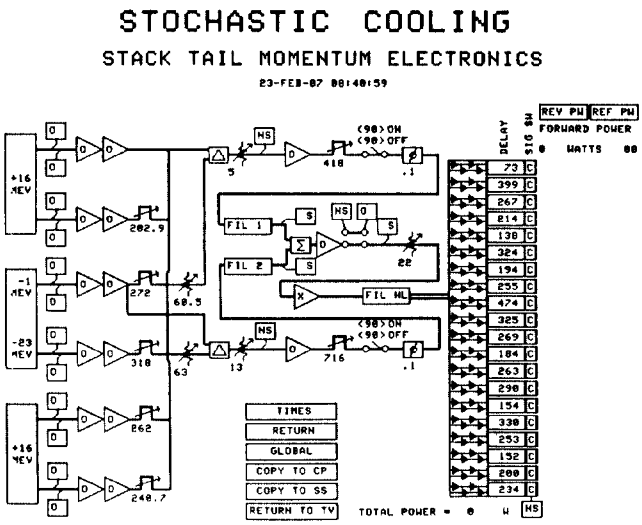

Figure 3. Interactive Graphic Control Schematic

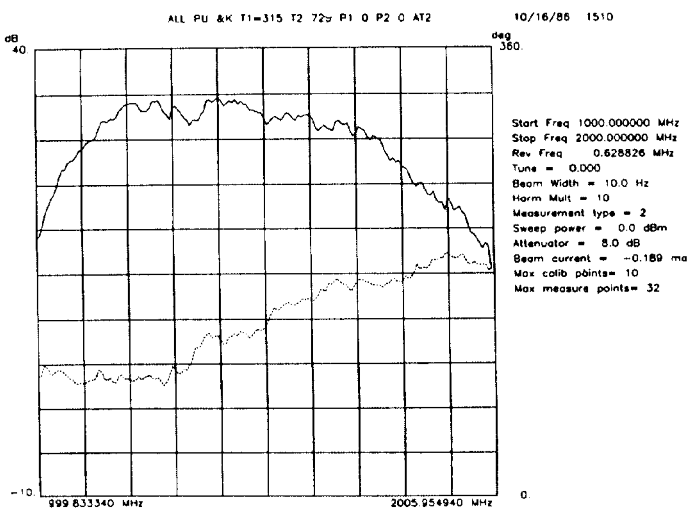

Figure 4. Stacktail Momentum Transfer Function

System Measurements

Beam transfer function measurements are performed with a Hewlett Packard 8409C automatic network analyzer and the Fermilab control network. The automatic network analyzer allows for remote calibration of devices under test by mathematically manipulating measured parameters. This technique avoids misinterpretation of data due to excessive cable loss and dispersion. A transfer coaxial switch which is placed in the middle of the electronic feedback path allows a signal to be injected to modulate the particle beam via the kickers and simultaneously monitor the beam feedback response via the pickups. All electronic and beam related characteristics are contained in this vector measurement which totally represents the transfer function for the open loop at this revolution frequency of the beam. A series of measurements are made at different revolution periods of the beam hence rendering a complete transfer characteristic as a function of beam energy. Additional software within the control system calculates the appropriate phase/group delay to adjust the variable coax trombone line within the system for negative feedback.

Performance Results

The best stacking performance with antiprotons achieved to date is 9.0×10^9 per hour. The major missing factors from the design stacking rate are due mostly to low number of incident protons on target, poor antiproton transport to the debuncher, and inefficient bunch rotation within the debuncher ring resulting in a wider momentum spread than the accumulator can accept. Figure 5 shows an actual antiproton stack profile taken from the accumulator diagnostic Schottky pickup. The inset depicts the design book profile. (Note that the energy and frequency horizontal scales are flipped.)

Before switching magnet polarity for antiproton running, it was possible to run proton stacking for a period of ten hours. The booster accelerator provided the protons directly to the accumulator at a rate of 4.5×10^7 every 4 seconds. The resulting stacking rate, shown in figure 6, is 3.75×10^{10} protons per hour for a stacking efficiency of 93%. After core densities of 2×10^{11} particles, the system starts showing some signs of saturation. This may be caused in part by insufficient core cooling and excessive core heating via the stacktail system.

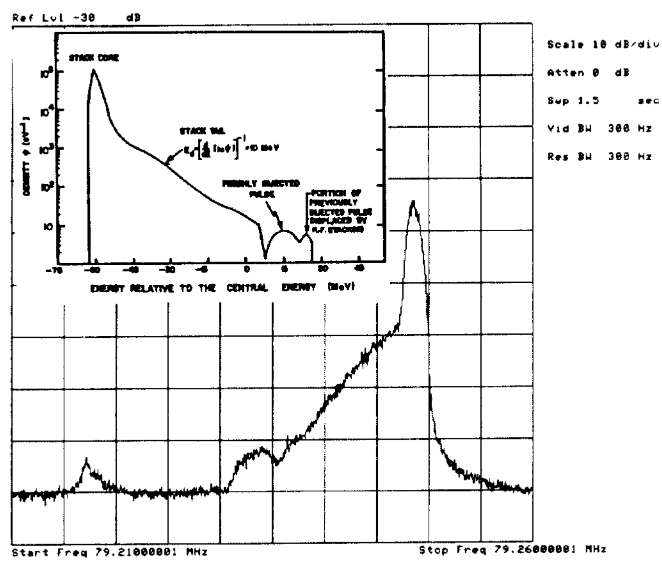

Figure 5. Stacktail Momentum Profile with Design Book Spec (inset)

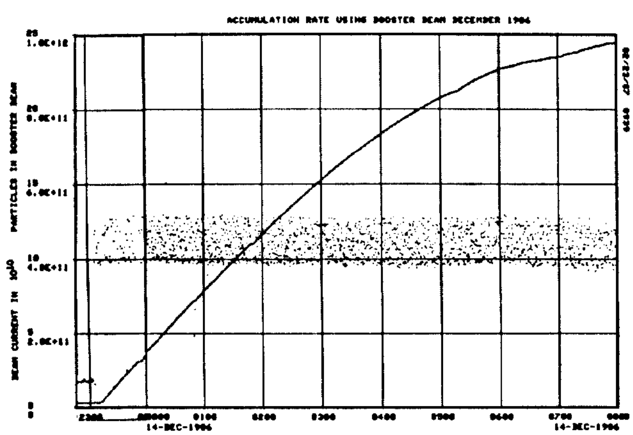

Figure 6. Stacking Rate with Booster Protons

Conclusions

Anti-proton production at Fermilab is presently proceeding at approximately 10% of design book specifications. The top priority for the spring 1987 run is reliable production of anti-protons for colliding beam physics. A number of studies have been made indicating room for improvement in the accelerator systems. As the proton studies indicate, stacking has already been run to near 40% of design. Future study time will be required to study the performance of stacking at 10^{11} per hour and higher.

Acknowledgements

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