SYSTEM FOR INJECTION STUDY OF THE NAL MAIN ACCELERATOR

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Introduction

This paper describes instruments for injection and preliminary studies of a 1 GeV proton beam injected into the main accelerator ring of the NAL 500 GeV Synchrotron. After six hours of tuning a relatively unattenuated beam was observed at a point some 1200 feet into the first superperiod (Superperiod A) of the accelerator. Further studies were not possible at this time because of fluctuation in beam quality.

General Description

The layout of Superperiod A is shown in Fig. 1. Remaining superperiods will be essentially identical. A superperiod consists of sixteen cells; one Long Straight section (LS), one Medium Straight section (MS), and fourteen Normal Cells (NC). The superperiod is divided into four sections of roughly the same length, each of which is governed by a service building as shown in Fig. 1. Remote control of correction magnets and monitoring of various beam sensors are accomplished via a computer-controlled multiplex system. The current of the main bending and quadrupole magnets was controlled by another computer.

In Superperiod A, thirty-eight dipole correction magnets (eighteen horizontal and twenty vertical), thirty-six pick-up electrode beam detectors, five ferrite beam detectors, thirty-four radiation loss monitors, and three TV-monitored internal scintillation targets were installed for use in the injection study.

Figure 2 shows a picture of the beam detected by a pick-up electrode in the long straight section. Beam signals were monitored by oscilloscopes at the service buildings and viewed via a closed circuit television in the main control room.

Dipole Correction Magnets

Dipole correction magnets are used to steer the beam horizontally and vertically in order to maintain the beam orbit near the center of the vacuum chamber during injection.

Large radial deviations of the beam can be caused by horizontal misalignment of the main quadrupole magnets or variation of the effective field of the main bending magnets due to their remanent field.

Similarly, vertical deviations can be caused by vertical misalignment of the main quadrupole magnets and tilt of the main bending magnets. These effects are particularly important during injection when the betatron oscillation amplitudes are largest.

The average remanent field in the B-1 magnets is 45.9 G and in the B-2 magnets 12.3 G (as determined by field measurement). The rms deviation in remanent field per magnet is 1 G. The current in the horizontal correction dipoles required to correct for the remanent field variation have been calculated, using the actual magnet location assignments. The maximum current needed in Superperiod A is 0.6 Amp. Effects due to misalignment of the main quadrupole magnets and small tilt of the main bending magnets are estimated to be much smaller.

As shown in Fig. 1, in the normal cell horizontal dipole correction magnets (HD) have been placed immediately following QF magnets and vertical correction dipole magnets (VD) after QD magnets. A pair of horizontal and vertical dipole correction magnets have also been placed at the downstream end of the long straight section, at the medium straight section, and at the beginning and middle of the long straight section (near the end of Superperiod A).

The important parameters of the dipole correction magnets are given in Table I.

<table>
<thead>
<tr>
<th>Types of Magnets</th>
<th>Horizontal</th>
<th>Vertical</th>
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<tbody>
<tr>
<td>Effective magnetic length</td>
<td>10.0 in.</td>
<td>9.1 in.</td>
</tr>
<tr>
<td>Aperture (height and width)</td>
<td>4.9 x 5.4 in.</td>
<td>2.4 x 4.2 in.</td>
</tr>
<tr>
<td>Maximum field (± 5A current)</td>
<td>± 680 G</td>
<td>± 430 G</td>
</tr>
<tr>
<td>Maximum bending angle (8 GeV)</td>
<td>± 0.58 mrad</td>
<td>± 0.34 mrad</td>
</tr>
<tr>
<td>Maximum deviation at the 2nd QF (or QD) (200 ft. downstream) (8 GeV)</td>
<td>± 2.2 in.</td>
<td>± 1.3 in.</td>
</tr>
</tbody>
</table>
Fig. 1. Layout of Superperiod A.

Fig. 2. Beam detected by a pick-up electrode at the first long straight section. 20 mV/div. and 2 μs/div.

Fig. 3. Cutout view of horizontal beam sensor.
Each dipole correction magnet can be independently current-controlled by the computer in the main control room. Current settings for all correction magnets are checked periodically by analog-to-digital converters which read back the power supply currents. The currents can be set digitally to 1%. About one ampere gives one-half of the full aperture deflection for a 1 GeV injected beam.

Beam Detectors

Two types of beam detectors have been built. The first detector uses pick-up electrodes and measures relative beam intensity and horizontal or vertical beam position. To avoid problems created by radiation damage, this detector does not employ electronic circuitry located in the main accelerator tunnel.

Figure 3 shows a schematic drawing of a horizontal detector. The vertical electrode configuration is essentially the same. The detector measures variation of the beam current inside the electrode. Signal depends upon detailed structures of RF bunching of the beam. With a 750Ω termination at both ends of the cable, a 3 mV signal will be seen for 1 mA beam of current at 53 MHz for moderate bunching. Each detector has two outputs corresponding to two electrodes facing each other. Beam intensity is computed in the control computer by taking the sum of two output signals, and its position by taking the difference of them and normalizing by the beam intensity. Typically, a vertical deviation of 0.25 in. corresponds to about ±20% change in output signal amplitude.

Horizontal detectors are installed after QF magnets and vertical detectors after QD magnets (see Fig. 1). Each service building at Superperiod A has a relay multiplex to permit remote addressing of up to twelve detectors from the computer. Outputs from an addressed detector are RF-amplified, converted to DC signals in a balanced demodulator and integrated over a fixed time interval. The integrator outputs are scanned by a twelve-bit analog-to-digital converter. Because of the relay multiplexing, only one detector at each service building can measure beam intensity at any given time during the beam pulse. Since each service building has up to ten detectors, ten beam cycles are required to record beam signals from all detectors in Superperiod A.

During the injection study an FET "head amplifier" was used for some detectors. This signal is a voltage-induced one in a capacitance between an electrode and a housing, while the beam current flows inside the electrode. Since the time constant of this circuit is very long (∼0.5 msec.), output voltage shape follows the beam intensity through the detector. The sensitivity is 5 mV/mA. We could clearly see beam signals with an oscilloscope for beam intensities less than 1 mA.

Commercial wideband amplifiers with a gain of 16 were used inside the tunnel for the first six detectors to further improve the signal-to-noise ratio for beam intensities of less than 1 mA.

The second type of detector uses ferrite core current transformers, which will be used for absolute calibration of the beam intensity with a sensitivity of 40 mV/mA. Five ferrite detectors were used in Superperiod A for the injection study.

References