MI-Note 0040
Main Ring Remnant Configuration

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The Main Ring remnant, between F0 and A0, will be used by the Main Injector for four functions:

i. 120 GeV/c protons to switchyard
ii. 120 GeV/c protons to F17 and the antiproton production target
iii. 8.9 GeV/c protons to the Accumulator for shot setup (F0-F17)
iv. 8.9 GeV/c antiprotons from the Accumulator (F17-F0)

There be two distinct power circuits, one from F0 to F17, and a second from F17 to A0. Each section will track the Main Injector ramp, as required according to MI reset, to conserve power and to provide maximum flexibility of operation. While the general attitude has been that only slow spill (2.867 sec cycle) is run to switchyard, the case of fast cycling (1.467 sec cycle) is also discussed. The current for 120 GeV operation is 1356 A (bends and quads).

Magnet Loads

The power calculations are based on the following load parameters. The resistance is calculated based upon the magnet resistance plus an allowance for bus and power supplies. The inductance includes the magnets plus 1 mH per power supply. Details are given in Appendix A.

F0-F17: The F0-F17 magnet string will consist of 24 B2 bend magnets (for maximum aperture) plus one 0.9 m and three full length B2s added upstream of F11. There will be ten quads (seven 7-ft quads and three 4-ft quads). Allowing for buswork and filters, etc., the resistance is 205 mΩ (60 mΩ) for the bends (quads); the inductance is 217 mH (12.5 mH) for the bends (quads).

F17-A0: F17 to A0 will consist of 107 bend magnets, including two that must be added at A0, 54 B1s and 53 B2s, and 30 quads (27 7-ft and three 4-ft). The resistance will be 753 mΩ (156 mΩ) for the bends (quads). The inductance will be 774 mH (38 mH) for the bends (quads). An option for this section is to change the B2 magnets to B1 magnets to take advantage of the lower resistance of the B1 magnets (R → .692 Ω, L → .696 H). Since this beam line is only used for 120 GeV beam, it does not need the large aperture of the B2s. The cost savings in power would be about 10% with a dollar savings per year of operation running 100% slow spill of $40,000. The labor costs will be about $30,000 for this change, (NOT part of the Main Injector project.) The change to B1s could be done slowly, as the schedule permits.

Power Supplies

The sections are powered as duiscussed below. The peak voltages are those required to track the Main Injector ramp given in MI Note 0027.

i. The F0-F17 bend bus will use one existing Main Ring power supply, running at 750 V peak out of 835 V available. The supply will be LF1 (an arbitrary choice).

ii. The F0-F17 quad bus will use one new 110 V power supply, QF1. The two quadrupole (F&D) busses will run in series.

iii. The F17-A0 section will use four existing Main Ring power supplies for the bend bus, designated as LF2, UF2, LF4 and UF4. The maximum voltage is 3018 V for the dipole supplies.

iv. The F17-A0 section will use one existing Main Ring power supply configured to 420 V, QF3, for the quadrupoles. The two quadrupole busses will run in series. The maximum voltage is 285 V.

As now configured, the dipoles in the F17-A0 section are not evenly spaced between the supplies, leading to voltage to ground distributions much higher than can be attained through some modest buswork. The feed-points for the LF4 and UF4 power supplies must move upstream by one cell, or alternatively, one feed, e.g. UF4, could be moved upstream by one cell, and four dipoles within that cell moved from the lower to the upper bus. The latter method avoids extra bus work, which may be a problem due to space-constraints. The bus configuration is shown in the attached figure.

Extraction/injection at F17 are discussed in a later section.

Power and Feeder Implications

The following summarizes the power requirements of the two sections under the two different ramps envisioned. The power and feeder currents from the dipole bus are given without brackets; the contributions from the quad bus are shown in paranthesis.

i. F0-F17 fast cycling: The power required will be 106 kW (31 kW) to track the Main Injector; if this section were to be run at 120 GeV DC, the power would more than triple to 377 kW (110 kW). The contributions to rms feeder currents from this section are 28 A (4 A).

ii. F0-F17 slow spill: The power required will be 186 kW (54 kW) to track the Main Injector. The contributions to rms feeder currents from this section are 38 A (5 A).

iii. F17-A0 dipoles fast cycling: The power required will be 390 kW (81 kW) tracking the Main Injector; if this section were run at 120 GeV DC, the power would be 1.4 MW (287 kW). Using all four supplies with no bypass control, the reactive power is 2.6 MVA (.34 MVA) average, 5.1 MVA (.64 MVA) peak. The rms feeder current is 110 A (14 A).

iii. F17-A0 dipoles slow spill: The power required will be 683 kW (141 kW) tracking the Main Injector. The power with bypass control with 1, 2 or 4 supplies turning on, as required by the voltage demand, is 2.3 MVA (.45 MVA) average, and 5.1 MVA (.64 MVA) peak. The rms feeder current is 95 A (19 A).

Power Supply Control

Ramping control for the F0-F17 section will consist of a C468 type reference card and either a relocated main ring overpass regulation and control system or a low beta quad type current regulation system for each loop. Due to the tight regulation constraints during the 8 Gev transfers a smaller D.C. supply may be needed to be switched in instead of the main supply. This is presently done with the lambertson magnet now and the same type of circuit could be constructed for this loop, or a better filter for the main supply could be considered.

The F17-A0 section will require five C468 type cards and the same type of main current regulation system as above. This section will also require the reconfiguration of the existing voltage to ground monitors, fast trip, safety system (MASS package) and the design of a new bypass controller for the SCR unit interface chassis. The new bypass controller will be needed to conserve reactive power in this section due to the need for -2500 volts out of the power supplies in invert to track the Main Injector. This controller will be like the new bypass loop controller for the Main Ring which will be relocated to the Main Injector.

Water Cooling
The cooling system in the remnant section will still need to supply 7 kW of cooling per magnet and the same amount of cooling now used for the supplies.

Extraction/Injection at F17
The present extraction at F17 occurs as follows: the beam is displaced from the center of the beam pipe by 1.653 inches (42 mm) by the E17 kicker. There is a residual 1 mrad angle which is removed by rolling the first lambertson magnet by 6.4°. The two lambertsons and two C-magnets result in a vertical angle of 32.7 mrad (1.875°), with a deflection of 9.7 inches at the end of the C-magnets, in order to clear the Main Ring magnet at F17-4/5 (a double strength magnet). The beam is bent horizontally to leave the Main Ring tunnel at a position 7.741 inches (= 9.394 - 1.653 inches) outside of a line parallel to the circulating Main Ring at the lambertson, and with an angle of 33 mrad (1.893°). The last two EPB magnets are rolled by about 45°, reducing the vertical angle to 19.04 mrad (1.091°); vertically, the beam is positioned up 30.235 inches at the exit of the last EPB magnet. Thus, the beam exits the last EPB with positions and angles, relative to a line through the first lambertson:

x = 7.741 inches
x' = 1.893°
y = 30.235 inches
y' = 1.091°

Proposed Solution: The F17 lambertsons and C-magnets can be replaced by a single B3, running at 17.25 kG. It should be powered from the F1 building, using a new 100 V power supply. The B3 will be excited only for 120 GeV extraction to the AP1 line; it must be turned off for 120 GeV slow spill. The time for turn-off should be less than .25 seconds. Some of this time will be required for longitudinal preparation of the bunches for slow spill, following the bunch narrowing for antiproton production in the mixed mode in which both are done on the same cycle. The bend of the B3 will have to be greater than the 19.04 mrad at which the beam leaves the EPBs, in order to get the position correct. Use of two B3s is not possible because the excursion at the downstream end is too large for the beam pipe. Thus, the excitation given above is required. (One of the new half-length B3s may be an option to reduce the strength; i.e. use one full length plus one half-length, reducing the excitation to ~11.5 kG. This should be looked at more closely.) By using a "switched" B3, the extracted 120 GeV protons, and the injected 8 GeV antiprotons, can remain in the center of the beam pipe, and the F14 kicker can be eliminated. Also, the aperture restriction imposed by the lambertsons and C-magnets is removed.

The following describes the layout; some further work needs to be done to refine the geometry. The B3 is rolled by about 4° to provide a horizontal displacement, equivalent to the E17 kicker effect, at the entrance to the EPB dipoles. This is required because the bend centers of the EPBs cannot be shifted sufficiently to maintain the same angular kick while reducing the horizontal displacement. The vertical angle is 26.098 mrad (1.495°) out of the B3 which has a bend center 196.175 inches downstream of the quadrupole. Only the last EPB is rolled, again by about 45°, to put the vertical orbit back at 1.091°. The four EPB dipoles all run in series at a current slightly below their present settings.

Appendix A

Assumptions:
(Sources: TM-424, TM-632; N.B. the two sources have some discrepancies)

	Resistance	Inductance
B1	5.78 mΩ	6.47 mH
B2	6.93 mΩ	7.95 mH
3Q52	3.37 mΩ	0.8 mH
3Q84	4.76 mΩ	1.3 mH
Main Ring Bus	10.7 μΩ/ft	0 mH
Power Supply	2 mΩ	1 mH

F0-F17:

	Quantity	Resistance	Inductance
B1	0	0 mΩ	0 mH
B2	27.15	188 mΩ	216 mH
Tunnel Bus	1200 ft	13 mΩ	0 mH
P.S. Bus	200 ft	2 mΩ	0 mH
Bend P.S.	1	2 mΩ	1 mH
Bend Bus Total		205 mΩ	217 mH
3Q52	3	10 mΩ	2.4 mH
3Q84	7	33 mΩ	9.1 mH
Tunnel Bus	1200 ft	13 mΩ	0 mH
P.S. Bus	200 ft	2 mΩ	0 mH
Quad P.S.	1	2 mΩ	1 mH
Quad Bus Total		60 mΩ	12.5 mH

F17-A0:

	Quantity	Resistance	Inductance
B1	54	312 mΩ	349 mH
B2	53	367 mΩ	421 mH
Tunnel Bus	5300 ft	57 mΩ	0 mH
P.S. Bus	800 ft	9 mΩ	0 mH
Bend P.S.	4	8 mΩ	4 mH
Bend Bus Total		753 mΩ	774 mH

<u>OR</u> (All B1 option):

	Quantity	Resistance	Inductance
B1	107	618 mΩ	692 mH
B2	0	0 mΩ	0 mH
Tunnel Bus	5300 ft	57 mΩ	0 mH
P.S. Bus	800 ft	9 mΩ	0 mH
Bend P.S.	4	8 mΩ	4 mH
Bend Bus Total		692 mΩ	696 mH
3Q52	3	10 mΩ	2.4 mH
3Q84	27	129 mΩ	35 mH
Tunnel Bus	5300 ft	13 mΩ	0 mH
P.S. Bus	200 ft	2 mΩ	0 mH
Quad P.S.	1	2 mΩ	1 mH
Quad Bus Total		156 mΩ	38 mH

Appendix B

Power and Feeder Currents

	120 GeV Fast	120 GeV Slow	
Cycle Time	1.4667	2.8667	sec
F0-F17 DIPOLES + QUADS			
Peak Current	1356	1356	A
RMS Current	720	953	A
Power	.1	.2	MW
RMS Feeder Current	32	43	A
Peak Feeder Volt-Amps	1.5	1.5	MVA
Average Feeder Volt-Amps	.8	1.0	MVA
F17-A0 DIPOLES + QUADS			
Peak Current	1356	1356	A
RMS Current	720	953	A
Power	.4	.8	MW
RMS Feeder Current	124	114	A
Peak Feeder Volt-Amps	5.8	5.7	MVA
Average Feeder Volt-Amps	2.9	2.7	MVA