

RUN II HANDBOOK

TABLE OF CONTENTS

| | |
|---------------------------------------------------------------------|-------------|
| 1. INTRODUCTION AND SUMMARY..... | 1.1 |
| 1.1 Tevatron Performance in Run Ib..... | 1.3 |
| 1.2 Run II Performance Goals | 1.6 |
| 1.2.1 Protons | 1.6 |
| 1.2.2 Antiprotons | 1.7 |
| 1.2.3 Luminosity Lifetime and Stacking Rate | 1.8 |
| 1.3 Subsystem Performance Requirements..... | 1.10 |
| 1.3.1 Linac/Booster..... | 1.10 |
| 1.3.2 Antiproton Source..... | 1.10 |
| 1.3.3 Recycler..... | 1.10 |
| 1.3.4 Main Injector..... | 1.11 |
| 1.3.5 Tevatron/Switchyard..... | 1.11 |
| 1.4 Accelerator Improvement Plan..... | 1.12 |
| 2. BOOSTER PERFORMANCE AND PROJECTIONS..... | 2.1 |
| 2.1 Transverse Emittance vs. Intensity..... | 2.1 |
| 2.2 Longitudinal Emittance vs. Intensity..... | 2.2 |
| 2.3 Aperture | 2.3 |
| 2.4 Damper Requirements | 2.4 |
| 2.5 Booster Extraction to the Main Injector..... | 2.5 |
| 2.6 Booster Losses..... | 2.5 |
| 2.7 Booster Shielding..... | 2.6 |
| 3. ANTIPROTON SOURCE PERFORMANCE AND PROJECTIONS..... | 3.1 |
| 3.1 Current Performance and Required Improvements..... | 3.1 |
| 3.1.1 Antiproton Source Performance..... | 3.2 |
| 3.1.2 Antiproton Source Limitations and Required Improvements | 3.5 |
| 3.2 Target Station Upgrades..... | 3.6 |
| 3.2.1 Beam Sweeping System..... | 3.6 |
| 3.2.2 Lithium Lens for Proton Beam..... | 3.8 |
| 3.2.3 Pre-Target SEM | 3.8 |
| 3.2.4 Lithium Collection Lens..... | 3.8 |
| 3.2.5 Single-Turn Pulsed Magnet..... | 3.10 |
| 3.2.6 Beam Dump..... | 3.10 |
| 3.2.7 Radiation Safety Issues..... | 3.10 |
| 3.2.8 Injection Line Transverse Aperture Increase..... | 3.10 |
| 3.3 Debuncher Stochastic Cooling..... | 3.11 |
| 3.3.1 Performance of the existing 2-4 GHz system..... | 3.11 |
| 3.3.2 Overview of the new 4-8 GHz cooling systems..... | 3.13 |
| 3.4 Stack-Tail System Upgrade | 3.14 |
| 3.4.1 Overview..... | 3.14 |
| 3.4.2 Lattice Modifications..... | 3.15 |
| 3.4.3 Stack Tail Cooling System..... | 3.22 |
| 3.4.4 Core cooling systems..... | 3.29 |
| 3.5 Unstacking Scenario..... | 3.36 |
| 4. Recycler (see TM-1991) | |

| | |
|-----------------------------------------------------------------------|-------------|
| 5. MAIN INJECTOR PERFORMANCE GOALS | 5.1 |
| 5.1 Project Overview..... | 5.1 |
| 5.1.1 Role In The Fermilab III Program | 5.2 |
| 5.1.2 Performance | 5.3 |
| 5.1.3 Operational Modes | 5.5 |
| 5.2 Lattice and Performance Simulations..... | 5.7 |
| 5.2.1 Sources of errors..... | 5.9 |
| 5.2.2 Closed orbit and betatron function errors | 5.11 |
| 5.2.3 Tune versus amplitude and dynamic aperture results | 5.13 |
| 5.3 Aperture | 5.15 |
| 5.4 Transverse Emittance..... | 5.15 |
| 5.5 Longitudinal Considerations and Emittance Projections..... | 5.16 |
| 5.5.1 Proton Acceleration and Coalescing | 5.16 |
| 5.5.2 Antiproton Acceleration | 5.16 |
| 5.5.3 Antiproton Deceleration | 5.16 |
| 5.5.4 Transition Crossing..... | 5.17 |
| 5.6 Impedance and instabilities | 5.23 |
| 5.6.1 Impedance budget and the microwave instability..... | 5.23 |
| 5.6.2 Chromaticity and slow head-tail instability..... | 5.24 |
| 5.6.3 Resistive wall instability..... | 5.25 |
| 5.6.4 Coupled bunch instabilities | 5.25 |
| 5.6.5 Transient beam loading..... | 5.25 |
| 5.7 Damper requirements | 5.26 |
| 5.7.1 Transverse dampers..... | 5.26 |
| 5.7.2 Longitudinal dampers..... | 5.28 |
| 5.8 RF Systems and Beam Loading Compensation..... | 5.28 |
| 5.9 Intensity and Transmission Efficiency..... | 5.30 |
| 5.10 Resonant Extraction..... | 5.32 |
| 5.10.1 Half-Integer Resonant Extraction..... | 5.32 |
| 5.10.2 Extraction Elements | 5.33 |
| 5.10.3 Spill Regulation Elements | 5.34 |
| | |
| 6. Tevatron Performance and Projections..... | 6.1 |
| 6.1 Performance During Run Ib and Run II Goals | 6.6 |
| 6.1.1 Comparison of Parameters for Run I and Run II..... | 6.6 |
| 6.1.2 Transverse emittance..... | 6.7 |
| 6.1.3 Longitudinal Emittance | 6.9 |
| 6.2 Luminosity Leveling..... | 6.9 |
| 6.3 Integrated Luminosity and Store Lifetime | 6.11 |
| 6.3.1 Experience in Run Ib | 6.11 |
| 6.3.2 Predictions for Run II | 6.15 |
| 6.3.3 Intrabeam Scattering | 6.18 |
| 6.4 Collider Fill Steps (Shot Setup)..... | 6.20 |
| 6.4.1 Tevatron at 150 GeV and Proton Injection..... | 6.20 |
| 6.4.2 Antiproton Injection..... | 6.21 |
| 6.4.3 Acceleration..... | 6.22 |
| 6.4.4 Low Beta Squeeze | 6.22 |
| 6.4.5 Beam Halo Scraping | 6.23 |
| 6.4.6 Proton Removal | 6.23 |
| 6.4.7 Low Beta Unsqueeze | 6.23 |
| 6.4.8 Antiproton Deceleration | 6.23 |
| 6.4.9 Antiproton Extraction..... | 6.24 |
| 6.5 Run II Tevatron Lattice Issues..... | 6.24 |
| 6.5.1 Dispersionless Interaction Region..... | 6.24 |
| 6.5.2 Individually Powering the Tune Quads in E and F sectors..... | 6.27 |

| | |
|---------------------------------------------------------------------|--------------|
| 6.5.3 Roman Pots at D0..... | 6.27 |
| 6.5.4 Interaction Point Orbit Control | 6.28 |
| 6.5.5 Differential Coupling Feed-down Circuit | 6.29 |
| 6.6 Injection of 36 proton and antiproton bunches..... | 6.35 |
| 6.6.1 Injection at F0 | 6.35 |
| 6.6.2 Injection Sequence | 6.37 |
| 6.6.3 Tevatron Injection Kickers..... | 6.39 |
| 6.6.4 Short Batch Proton Injection Kicker..... | 6.40 |
| 6.6.5 Injection Bumper Magnet | 6.45 |
| 6.7 Energy of 1 TeV | 6.46 |
| 6.8 Collective Effects and Damper Requirements..... | 6.48 |
| 6.8.1 Potential well distortion | 6.48 |
| 6.8.2 Landau damping..... | 6.48 |
| 6.8.3 Single bunch instabilities..... | 6.49 |
| 6.8.4 Single beam, multi-bunch instabilities..... | 6.50 |
| 6.8.5 Longitudinal Coupled-Bunch Instabilities..... | 6.50 |
| 6.8.6 Tevatron Dampers..... | 6.51 |
| 6.9 Beam-beam tune shift for 36×36 operations..... | 6.53 |
| 6.10 Beam Halo Scraping..... | 6.61 |
| 6.11 Antiproton Recycling from the Tevatron | 6.65 |
| 6.11.1 Proton Removal..... | 6.65 |
| 6.11.2 Antiproton Deceleration..... | 6.67 |
| 6.12 Instrumentation..... | 6.68 |
| 6.12.1 Initial Run II 36×36 | 6.69 |
| 6.12.2 Instrumentation for 132 ns Bunch Spacing..... | 6.72 |
| 6.13 Warm Straight Section Allocation..... | 6.73 |
| 6.13.1 List of devices by functionality | 6.73 |
| 6.13.2 List of devices by straight sections | 6.74 |
| 6.14 Operational Concerns | 6.80 |
| 6.15 132 nsec Bunch Spacing..... | 6.83 |
| 6.15.1 Kicker Considerations | 6.83 |
| 6.15.2 Beam-Beam Considerations..... | 6.84 |
| 6.16 High Temperature Superconducting Power Leads..... | 6.100 |
| 6.17 Tev Spare Magnet Requirements..... | 6.101 |
| 6.17.1 Tevatron Dipoles..... | 6.102 |
| 6.17.2 Standard Tevatron Quadrupoles | 6.106 |
| 6.17.3 Tevatron Spool Pieces | 6.106 |
| 6.17.4 Low Beta Quadrupoles..... | 6.107 |
| 6.18 C0 Collision Hall..... | 6.107 |
| 6.19 Superconducting RF..... | 6.111 |
| 6.19.1 Use of a Higher Frequency, higher voltage rf System..... | 6.111 |
| 6.19.2 Effect of Crossing Angle and Bunch Length on Luminosity..... | 6.111 |
| 6.19.3 Choice of Frequency and Voltage | 6.112 |
| 6.19.4 Cavity Groups | 6.112 |
| 6.19.5 Cryogenic Requirements..... | 6.112 |
| 6.19.6 Power Amplifier | 6.112 |
| 6.19.7 Steady State Beam Loading | 6.113 |
| 6.19.8 Transient Beam Loading: Injection | 6.114 |
| 6.19.9 Transient Beam Loading: Collisions | 6.114 |
| 6.19.10 Effect of Higher Frequency rf on Intrabeam Scattering | 6.115 |
| 6.19.11 Power Loss in the Beam Pipe | 6.116 |
| 6.19.12 Summary of Cavity Specifications..... | 6.116 |
| 6.20 Speculative Ideas..... | 6.117 |
| 6.20.1 Electron Compression of Beam Beam Tune Shifts..... | 6.117 |
| 6.20.2 Optical Stochastic Cooling..... | 6.118 |
| 6.20.3 Electron Cooling in the Tevatron | 6.118 |

| | |
|-----------------------------------------------------------------------------------|-------------|
| 7. OPERATING SCENARIOS..... | 7.1 |
| 7.1 36 x 36 Collider Operations..... | 7.1 |
| 7.1.1 Shot Setup | 7.1 |
| 7.1.2 Accumulator to RR Antiproton Transfers | 7.3 |
| 7.2 Beam Transfers and Synchronization | 7.3 |
| 7.2.1 Proton transfers from Tevatron to MI | 7.4 |
| 7.2.2 Antiproton deceleration..... | 7.4 |
| 7.2.3 NUMI operation..... | 7.4 |
| 7.2.4 120 GeV Fixed Target operation | 7.4 |
| 7.2.5 Inject decelerated antiprotons from the MI via the MI-22 transfer line..... | 7.4 |
| 7.2.6 Inject antiprotons from Accumulator via AP5 line | 7.4 |
| 7.2.7 Inject protons from MI via MI-32 line..... | 7.4 |
| 7.2.8 Extract protons to MI via MI-22 line..... | 7.5 |
| 7.2.9 Extract antiprotons to MI via MI-32 line | 7.5 |
| 7.2.10 Extract protons to the Accumulator via the AP5 line | 7.5 |
| 7.2.11 Extract protons via MI-40 (dump)..... | 7.5 |
| 7.2.12 Transfer Synchronization..... | 7.5 |
| 7.3 Transverse and Longitudinal Emittance Budget | 7.6 |
| 7.3.1 Antiprotons - Transverse..... | 7.6 |
| 7.3.2 Protons - Transverse..... | 7.7 |
| 7.3.3 Antiprotons - Longitudinal..... | 7.7 |
| 7.3.4 Protons - Longitudinal..... | 7.8 |
| 7.4 Instrumentation and Controls Requirements..... | 7.8 |
| 7.4.1 Software..... | 7.8 |
| 7.4.2 Controls Upgrades..... | 7.11 |
| 7.5 Main Injector Fixed-Target Operations..... | 7.12 |