THE TEVATRON ORBIT PROGRAM

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Abstract

The new application program which is used to control the closed orbit in the Tevatron is described. Unique features include the ability to acquire closed orbits at all energies on one ramp and provide dipole settings which smooth the orbit and are continuous as a function of energy. The program is also used to correct for the orbit distortions caused by the placement errors of the low β quadrupoles as the transition is made from the injection optics to the low β optics.

I. INTRODUCTION

The Tevatron upgrade program includes new features which require a more sophisticated program to control the closed orbit [1]. Electrostatic separators are used to provide separate orbits for the proton and antiproton beams and two new low beta insertions replace the single simple one. In addition, each of the new insertions has more quadrupoles which generate closed orbit distortions as the insertion is changed from the injection to the low beta optics. The two insertions may be energized individually or together, leading to a large number of possible intermediate steps and corresponding lattice solutions.

Past experience has also shown that the older programs[2] need to be made more flexible and able to do required manipulations with a minimum of dedicated control room activity. Experience has also shown that most problems with an orbit control program occur due to hardware problems. After a maintenance and development period, it is not uncommon to find beam position monitor polarities reversed due to cable interchanges. Other problems have included function generator and power supply failures. It has been convenient, even necessary, to include features in the Tevatron Orbit Program (TOP) to allow easy verification of the correction dipoles and the beam position monitor system.

At the same time, a new generation of control consoles has made more complex programs much easier to create [3]. The older method of generating lattice functions by using TEVLAT or SYNCH offline to provide many files of possible lattice configurations has been made obsolete.

II. OBTAINING A SMOOTHED ORBIT

TOP can calculate closed orbit corrections using either a standard three bump algorithm or a matrix inversion algorithm (χ^2 algorithm). Momentum corrections are optional in the calculation. One can smooth around the entire ring or do an individual three bump or four bump locally. The desired positions which TOP smooths to have three control bits per location which are used in the orbit correction algorithms. A position can be specified to be fixed, or a bad detector or corrector can be masked from the closed orbit smoothing. The energy levels and the tune values are also be specified by the user.

III. ONE RAMP SMOOTHING CAPABILITY

A main advantage of TOP is that it is capable of calculating a closed orbit at all energies from a single acceleration ramp and providing smoothed orbit corrections to the ramp tables of the magnetic correction elements for the next ramp. Orbit profile data for 108 beam position monitors, BPM's, located around the ring are read at nine energy levels up the ramp. A closed orbit correction is calculated at each energy level. A program display of an orbit in a Tevatron collider store is shown in Fig. 1. After calculating new settings for the correction Dipole Function Generators, DFG's, the predicted orbit after a TOP smoothing is shown in Fig. 2. The fact that these corrections can be applied simultaneously gives TOP the capability of placing continuity requirements on individual DFG settings as a function of energy. Discontinuities can cause tracking problems if steps between adjacent energy slots exceed the slew rate capabilities of the correctors. By maintaining continuity of the DFG settings during acceleration, orbit distortions due to large DFG current changes

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beyond the slew rate limitations of the power supplies are eliminated.

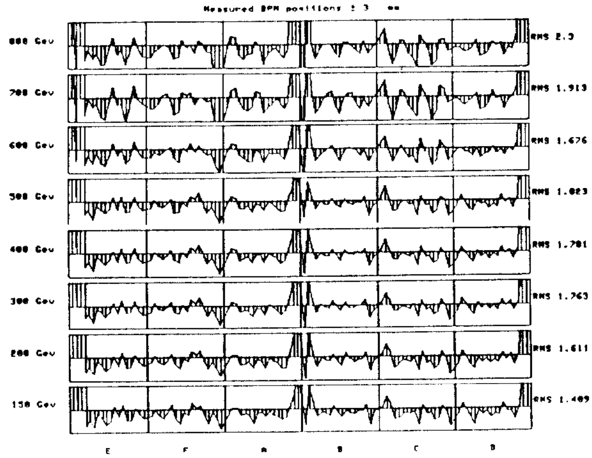

Fig. 1

Orbits in the horizontal plane for eight energy levels as the beam is accelerated in the Tevatron. The horizontal axis is the azimuthal position starting at E0. The rms position for the orbits is listed at the right. The scale of the plots is +/- 3mm.

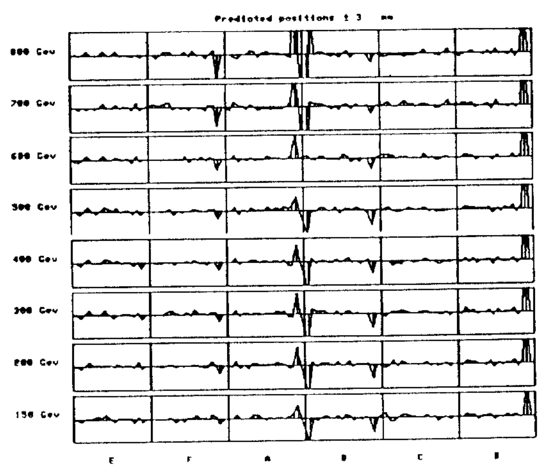

Fig. 2

The predicted positions after a smooth up the ramp of the orbits shown in Fig. 1. The horizontal axis is the azimuthal position starting at E0. The scale of the plots is +/- 3mm.

IV. Lattice Function Retrieval

The two low beta lattice insertions of the Tevatron present a problem to TOP in that it must be able to calculate closed orbits under multiple lattice configurations. The low beta squeeze, for example, occurs over seventeen steps, or seventeen different low beta quad lattice configurations. One may want to smooth the orbit at each of these steps during a low beta parsing session [5]. TOP is now capable of smoothing these orbits by obtaining lattice parameters in an interactive environment using a package, TEVCONFIG, which has recently been added to the Tevatron software library. TOP has the flexibility of obtaining any existing lattice configuration on a real-time basis or reading a stored lattice file using TEVCONFIG.

The ability to obtain various lattice configurations is especially useful for the orbit play capabilities of TOP. The orbit play option allows DFG settings, lattice parameters, orbit positions and tune values to be varied and the resultant changes displayed. Orbits which are on file or the present orbit can be used as input data. This feature allows one to view effects without affecting accelerator operation.

IV. Orbit Display Features

The user interface of TOP is made up of a set of hierarchical menus. A menu of options is displayed corresponding to the previous menu selection. This aids in maintaining a standard smoothing procedure which is very useful in a control room environment.

Predicted and measured values are displayed through a standardized graphics package. The compare capabilities of TOP allow differences in orbits, DFG settings or DFG corrections to be plotted. A single device feature allows one to look at DFG and BPM settings for all energy levels before and after a smooth at a specific location in the ring. A plot of a typical single device display is shown in Fig. 3. This allows the user to easily view the evolution of parameters through the accelerator cycle.

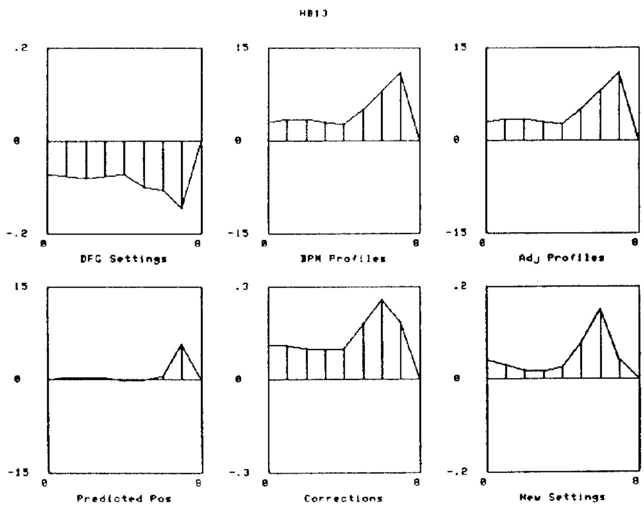

Fig. 3

A single device display feature of TOP. DFG settings, BPM profiles, adjusted BPM profiles, predicted positions, DFG corrections and new DFG settings, all shown at a specific location in the ring, can be plotted.

DIAGNOSTIC TESTS

One particularly useful test after a shutdown is to change the current in one dipole, causing an orbit distortion which can be compared to a predicted change. A BPM with incorrect polarity or an incorrect calibration can easily be seen. To check all BPMs in one plane, another DFG with 90 degrees betatron phase advance from the first must be varied. Thus it suffices to change four dipoles, one at a time, taking an orbit and comparing it to the predicted orbit to do a rather good check on all the BPMs. This along with a measurement of the dipole response without beam, setting all function generators to some preset value and comparing the measured currents in the correction dipole magnets, is necessary before using TOP to correct the orbit.

CONCLUSIONS

TOP is a powerful new program, consistent with the capabilities of a modern control system and required by the complexities of the Tevatron Collider. By making it easy for an operator to bring the orbit to the desired positions, TOP helps to make the Tevatron a reproducible and understandable machine.

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