THE VERTICAL ALIGNMENT OF THE DO OVERPASS IN THE FERMILAB MAIN RING*

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Abstract

The DO overpass was recently reconfigured in order to reduce the vertical dispersion in the Main Ring[1]. The relationship between the global arrangement of the Main Ring Quadrupoles and the placement of the quads in the overpass is described.

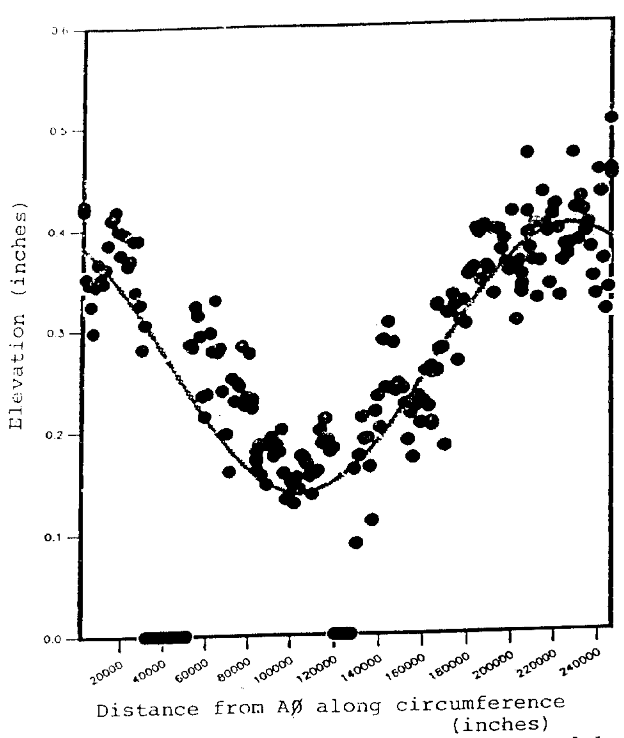
Introduction

In order to accomodate large detectors for pbar p physics at the Tevatron, the Main Ring has been modified to be non-planar in the sense of installing overpasses which create large vertical displacements of the beam orbit. The detailed placement of magnetic elements follows the "screw" geometry proposed by Tom Collins[2] and implemented in a Fortran coded program ,DSCREWF, by Sho Ohnuma.

This program calculated the deviation of the new overpass from an assumed flat, perfectly aligned Main Ring. This paper describes the reality of working with the Main Ring as it was and fitting the new overpass into the overall pattern of the Main Ring.

Global Pattern of the Main Ring

The sea level elevation of the Main Ring Quadrupoles (modulo 720' 65.8") is shown in figure 1.



Distance from AØ along circumference (inches)

Fig. 1 Main Ring quad elevations modulo 720' 65.8".

The marks on the horizontal axis refer to the overpass locations. One observes that the magnets do not have a constant elevation, however, ignoring the jitter, they do appear to follow the curve in the figure. The Main Ring tunnel settled in the region around DO and a great deal of effort was spent in placing the quads in a tilted cartesian plane. The curve in figure 1 is derived as indicated in figure 2, i.e. a circle in one plane has a varying distance from another plane which is titlted with respect to the first plane.

$$d = R \sin \theta \, [1 - \cos (S/R)]$$

S = distance along circle

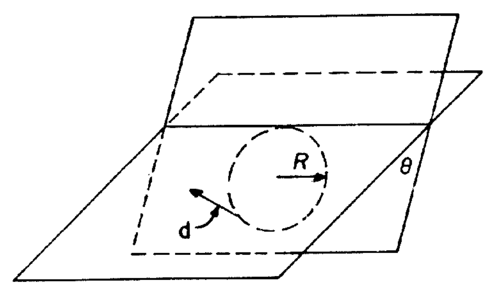


Fig. 2 The varying distance of a circle in one plane from a tilted plane.

If there were no straight sections in the ring, then our anlaysis would be complete(a plane that is perpendicular to a radius vector of a sphere intersects the sphere in a circle). However, the Main Ring has straight sections and figure 3 indicates the contour of the Ring while table 1 shows that the radial deviation[3] ,from the circle whose circumference equals the circumference of the ring ,can exceed 20'.

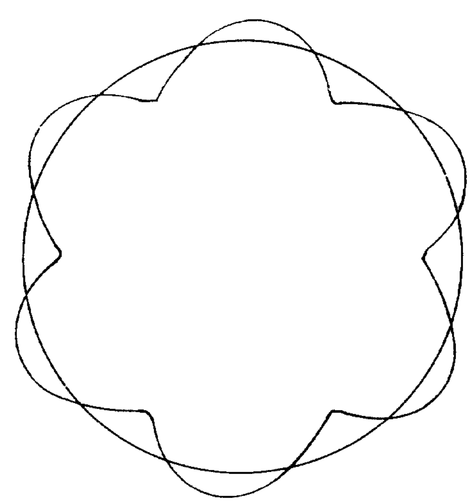


Fig. 3 Schematic of the deviation of the beam orbit from a circle of the same circumference.

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For the moment let us consider the ring to be in a plane perpendicular to a radius vector of an assumed spherical Earth. Portions of the accelerator will lie inside the average radius and portions will lie outside, both situations are depicted in figure 4.

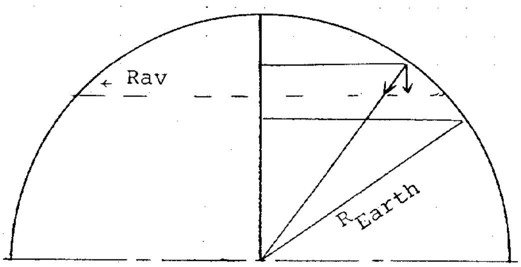


Fig. 4 Elevation differences for circles of different radii.

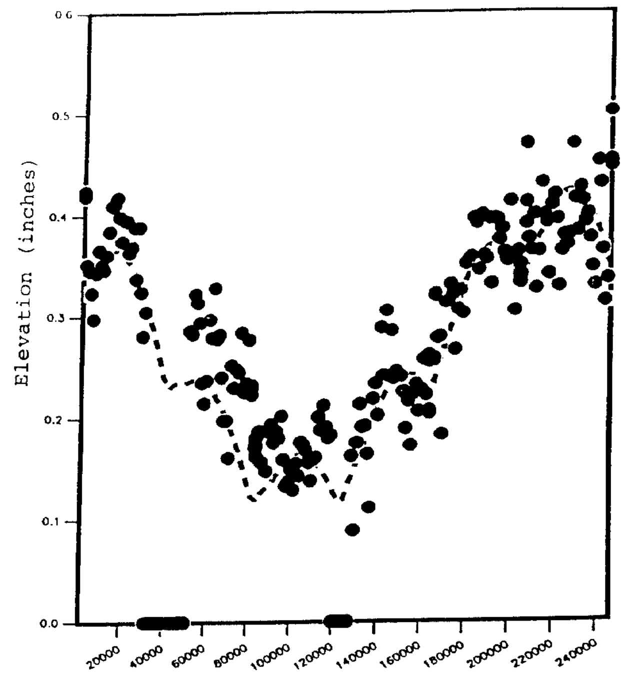
Two points that have the same elevation are at the same distance from the center of the Earth and are on the same spherical surface. From the figure it is immediately obvious what the sign of the correction is to go to the plane which contains the average radius; for a smaller radius one must have a smaller elevation than the average circle.

Table 1
Deviation[3] of the Beam Orbit with respect to a Circle of Radius 3289.840 feet and with the Corresponding Elevation Correction

Main Ring Station Label	Difference in Radius (feet)	Elevation Correction (inches)
0	-21.528	-.040
11	-20.252	-.038
12	-16.779	-.032
13	-14.058	-.026
14	-11.591	-.022
15	-9.382	-.018
16	-7.430	-.014
17	-5.739	-.011
18	-3.162	-.006
19	-0.413	-.001
21	2.069	.004
22	4.281	.008
23	6.224	.012
24	7.894	.015
25	9.291	.018
26	10.413	.020
27	11.260	.021
28	11.930	.022
29	12.124	.023
32	12.141	.023
33	11.881	.022
34	11.344	.021
35	10.531	.020
36	9.443	.018
37	8.079	.015
38	6.442	.012
39	4.533	.009
42	2.353	.004
43	-0.096	.000
44	-2.812	-.005
45	-5.793	-.011
46	-9.037	-.017
47	-12.540	-.024
48	-16.300	-.031
49	-19.828	-.037

A very good approximation to the change in elevation can be simply obtained by asking for the intersection of a circle $x^2 + y^2 = R^2 = (R_{av}+dR)^2$, and a sphere $x^2 + y^2 + z^2 = R^2 + z^2 = R^2_{Earth}$, and then solving for $dz = dz(dR)$. This procedure has been independently checked[4] in a totally different fashion. These elevation corrections are given for Main Ring Station locations in table 1.

Applying this analysis to the elevation distribution of the Main Ring quadrupoles yields the curve shown in figure 5. The origin of the tilt, the elevation of the origin, and the elevation of the point on the ring 180 degrees opposite from the origin are varied to minimize the RMS deviation of the quad elevations from the plane.



Distance from AØ along circumference.
Fig. 5 Main Ring Quad elevations modulo 720' 65.8" with a representation of the best fit plane.

Application to DO

Finally we come to the reason for this analysis, the installation of the "shoulder" at DO. A blowup of the region around DO is shown in figure 6, with dots on the bottom representing the quadrupoles in the previous overpass.

There are various options that one can adopt in dealing with the observed pattern: one could keep the pattern (and the closed orbit) the same while moving the quadrupoles several feet, one could smooth the distribution, or one could move the quads as though they had been on the global plane. The decision was made to choose the last option and to attempt to fix the closed orbit by moving quadrupoles outside the overpass. These corrections were applied using a modified version of DSCREWF so that the surveyors were given elevation numbers which had already been corrected.The reason that one had the confidence to proceed in this fashion is that the effect of these 'moves' could be modeled using a conventional quadrupole move program. The modeling answered two questions positively: at startup would there be a high field closed orbit inside the beam pipe, and would a small number of quadrupole moves outside the overpass regions yield a high field closed orbit that was satisfactory in terms of pbar production targeting, proton transfer to the Tevatron, pbar transfer to the Tevatron, proton aborts,and losses at B0,C0,D0, and E0. Experience has shown that the modeling predictions were correct, and in fact the vertical closed orbit now has a smaller RMS than before this shoulder overpass was installed.

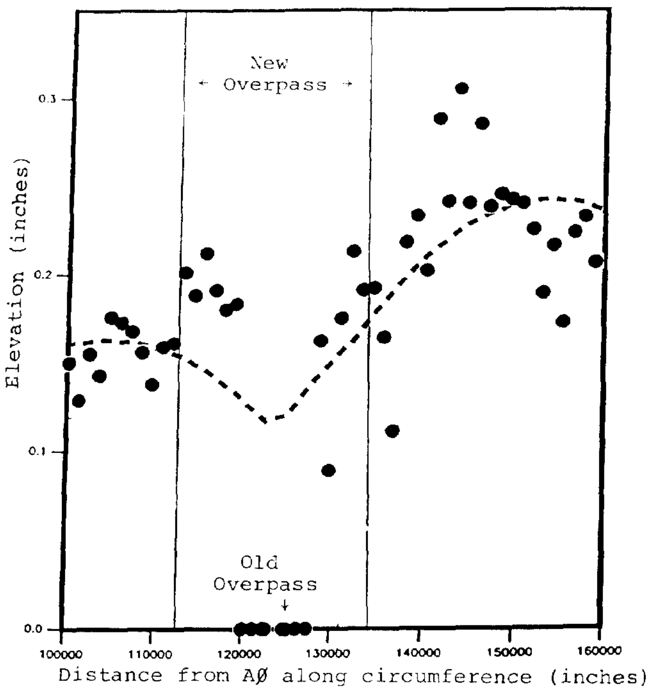


Fig. 6 Main RIng quad elevations around DØ

References

1. R. Gerig, D. Trbojevic,"Design and commissioning of the D0 Vertical Non-Dispersive Overpass in the Fermilab Main Ring.", this proceedings.
2. T. Collins,"A By-Pass for the Main Ring Around B0 (or D0) After Doubler Operation",Fermilab internal note.
3. T. Collins,"Stations of the Main Ring",TS-2, Fermilab internal note.
4. L. Ketcham,private communication.