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TITLE: Modification of the code BEAMCORR, and some simulation results of the magnet and achromat misalignments for the SLC South Arc

1.0 INTRODUCTION

This note supplements the previous note **CN-252**. Since the publication of **CN-252** an important decision has been made regarding the correction scheme for the arcs leading to the adoption of the so called scheme I. In this scheme the beam position data are collected from *single-plane* x and y BPMs, which are placed in the drift spaces adjacent to the downstream D- and F- magnets correspondingly. Similarly, *single-plane* x and y correctors are used for moving the upstream end of the corresponding magnets. In the present simulation this scheme is used exclusively.

The first order calculations performed by means of **TRANSPORT** appear to be unsatisfactory from the point of view of the beam spotsize at the interaction point (IP). In this note we describe the modification to our program **BEAMCORR** which employs second order calculations by means of the program **TURTLE**. We also present the results of the following simulations:

a) study of the effects of two different levels of magnet misalignment on the beam spotsize at IP, and comparison of the results with those obtained by means of the program **DINGBAT**
b) study of disjoints between achromats (both the displacement of the adjacent ends and angular discontinuity between achromats).

2.0 BEAMCORR2

The flow chart of the program is presented in **Fig.** 1. The input for the program is essentially the same as the input for the old version:

a) the **TRANSPORT** input for the arc
b) MMID table which specifies which magnets should be misaligned
c) rms values and cutoff factors for the misalignments of dipoles, quads, sextupoles, and BPMs.

As in the original version of **BEAMCORR**, the initial step involves creating a **TURTLE** input file in which each misaligned magnet is sandwiched between two **"7."** cards representing displacements and tilts in horizontal and vertical planes. In addition, if radiation loss is required to be simulated, then the sixth parameter on each of the **"7."** cards represents half of the energy loss in a given magnet. The energy loss is restored to zero once per achromat, thus representing the tapering of the bending fields. To simulate achromat misalignment, each achromat as a

whole is sandwiched by two additional "7." cards containing the corresponding Δx, $\Delta x'$, Δy and $\Delta y'$. Prior to correcting the orbit, the whole arc (excluding the Final Focus System) is divided into several segments which are then corrected consecutively. The flow chart for correction of an individual segment is presented in **Fig. 2**. The input file to the orbit correction step contains a list of the segments along with the position of correctors and monitors for each segment. Provisions have also been made to optionally permit correction of dispersion function at the end of each segment. **Fig. 3** illustrates the flow chart for the dispersion correction algorithm.

The arc correction is followed by a seperate 5–step orbit correction in FFS. The reasons for special treatment of FFS are the placement of BPMs inside the strong sextupole magnets and the lower misalignment tolerances in comparison with those for the arcs.

The final correction step takes place at IP where both the centroids and the dispersion functions are reduced to zero.

At the completion of the above correction steps the program **TURTLE** is used to trace one thousand rays through the whole system and collect the set of two dimensional histograms which represents the cross section of 6-*dimensional* phase space occupied by the particle trajectories at the IP.

A typical simulation of the South Arc, including the above corrections and the final ray tracing requires approximately 13 minutes of IBM 3081 CPU time. This time might however be decreased by proper segmenting of the arc. A reduction in the number of monitors and correctors per segment increases the number of steps, and hence the time required, linearly while decreasing the computation time for the individual steps quadratically.

3.0 SIMULATIONS

This section summarizes the results of correction scheme I as applied to the SLC South Arc with various errors and misalignments. All simulations were performed under the following conditions:

- All errors and misalignments have gaussian distributions and are truncated at $\pm 2.0\sigma$.
- 1000 rays were traced to obtain beam soptsize at IP.
- $\Delta p/p_0$ is truncated at $\pm 1.0\sigma$.
- There is no monitor misalignment at IP.

The following cases were investigated:

a. Ideal machine: no synchrotron radiation(SR), errors or misalignments
(Table 1)

b. SR; no errors or misalignments.
(Table 2)

c. SR; magnet misalignment (100 μm)
(Table 3)

d. SR; magnet & monitor misalignment (100 μm)
Fig. 4 presents a comparison of the results with those obtained from **DINGBAT.**
(Table 4)

e. SR; magnet & monitor misalignment (200 μm)
(Table 5)

f. SR; magnet & monitor misalignment (100 μm)
Achromat misalignment (100 μm)
(Table 6)

g. SR; magnet & monitor misalignment (200 μm)
Achromat misalignment (200 μm)
(Table 7)

Table 1: Ideal Machine

- No errors, misalignments, or energy loss.

Run#	Seed	η corr. before FFS	σ_x μm	σ_y μm	$\frac{1}{\sigma_x \sigma_y}$ μm^{-2}
748	9876543	no	1.273	1.334	0.589

Table 2: Synchrotron Radiation

- Radiation energy loss
- No monitor or magnet misalignments

Run#	Seed	η corr. before FFS	σ_x μm	σ_y μm	$\frac{1}{\sigma_x \sigma_y}$ μm^{-2}
747	9876543	no	1.274	1.304	0.602

Table 3: SR, Magnet Misalignment

- Radiation Energy Loss
- Magnet Misalignment 100.0 μm
- Quad Misalignment 70.0 μm
- Quad Tilt Angle 60.0 μrad
- No Monitor Misalignment
- No Achromat Misalignment

Run#	Seed	η corr. before FFS	σ_x μm	σ_y μm	$\frac{1}{\sigma_x \sigma_y}$ μm^{-2}
736	9234567	no	1.453	1.447	0.476
737	8234567	no	1.267	1.291	0.611
738	7234567	no	1.358	1.440	0.511
739	6234567	no	1.490	1.434	0.468
740	5234567	no	1.371	1.494	0.488
741	4234567	no	1.358	1.517	0.485
742	3234567	no	1.503	1.344	0.467
743	2234567	no	1.529	1.478	0.443
744	1234567	no	1.516	1.414	0.466
745	9876543	no	1.421	1.293	0.544

Table 4: SR; monitor and Magnet Misalignment ($100\mu m$)

- Radiation Energy Loss
- Magnet Misalignment 100.0 μm
- Quad Misalignment 70.0 μm
- Quad Tilt Angle 60.0 μrad
- Monitor Misalignment 100.0 μm
- Monitor Mis. in FFS 25.0 μm
- No Achromat Misalignment

Run#	Seed	η corr. before FFS	σ_x μm	σ_y μm	$\frac{1}{\sigma_x \sigma_y}$ μm^{-2}	$\sum n^2$
850	9234567	no	1.501	1.650	0.404	4886
851	8234567	no	1.533	1.221	0.534	5610
852	7234567	no	2.213	2.207	0.205	2756
853	6234567	no	1.365	1.446	0.507	5445
854	5234567	no	1.487	1.436	0.468	5503
855	4234567	no	1.568	1.882	0.339	4019
856	3234567	no	1.984	1.817	0.283	4222
859	2234567	no	1.581	1.483	0.427	4584
858	1234567	no	1.916	1.908	0.274	4162

Table 5: SR; monitor and Magnet Misalignment ($200\mu m$)

- Radiation Energy Loss
- Magnet Misalignment 200.0 μm
- Quad Misalignment 140.0 μm
- Quad Tilt Angle 120.0 μrad
- Monitor Misalignment 200.0 μm
- Monitor Mis. in FFS 50.0 μm
- No Achromat Misalignment

Run#	Seed	η corr. before FFS	σ_x μm	σ_y μm	$\frac{1}{\sigma_x \sigma_y}$ μm^{-2}	$\sum n^2$
789	3234567	yes	3.022	2.632	0.126	2783
790	4234567	yes	2.855	3.077	0.114	1843
784	5234567	yes	1.915	1.620	0.322	3956
793	6234567	yes	2.164	1.943	0.238	2978
792	7234567	yes	4.416	3.255	0.070	1258
782	8234567	yes	2.997	3.692	0.090	2560
783	9234567	yes	1.569	3.207	0.199	3105

- Monitor Mis. in FFS 20.0 μm

817	3234567	yes	3.062	2.018	0.162	3074
818	4234567	yes	2.792	2.715	0.132	2455
809	5234567	yes	1.693	1.532	0.386	4444
819	5234567	no	1.477	1.696	0.399	5075
814	6234567	yes	2.082	1.758	0.273	3302
813	7234567	yes	3.854	2.372	0.109	2140
815	8234567	yes	3.076	3.582	0.091	2802
816	9234567	yes	1.493	3.083	0.217	3318

Table 6: Achromat Misalignment ($100\mu m$)

- Radiation Energy Loss
- Magnet Misalignment 100.0 μm
- Quad Misalignment 70.0 μm
- Quad Tilt Angle 60.0 μrad
- Monitor Misalignment 100.0 μm
- Monitor Mis. in FFS 25.0 μm
- Disjoints Between Achromats 100.0 μm
- Tilts Between Achromats 100.0 μm

Run#	Seed	η corr. before FFS	σ_x μm	σ_y μm	$\frac{1}{\sigma_x\sigma_y}$ μm^{-2}	$\sum n^2$
833	9234567	no	1.422	1.607	0.438	5004
834	8234567	no	1.694	1.260	0.469	5043
835	7234567	no	2.000	2.125	0.235	3246
836	6234567	no	1.392	1.543	0.466	5301
837	5234567	no	1.651	1.486	0.408	5118
838	4234567	no	1.652	1.851	0.327	3770
839	3234567	no	2.157	1.691	0.274	4085
840	2234567	no	1.683	1.319	0.450	5121

Table 7: Achromat Misalignment ($200\mu m$)

- Radiation Energy Loss
- Magnet Misalignment 100.0 μm
- Quad Misalignment 70.0 μm
- Quad Tilt Angle 60.0 μrad
- Monitor Misalignment 100.0 μm
- Monitor Mis. in FFS 25.0 μm
- Disjoints Between Achromats 200.0 μm
- Tilts Between Achromats 200.0 μm

Run#	Seed	η corr. before FFS	σ_x μm	σ_y μm	$\frac{1}{\sigma_x\sigma_y}$ μm^{-2}	$\sum n^2$
849	9234567	no	2.029	2.101	0.235	3408
848	8234567	no	1.566	1.369	0.466	5531
846	6234567	no	2.184	2.386	0.192	3530
845	5234567	no	1.866	1.811	0.296	3875
844	4234567	no	1.984	2.006	0.254	3587
843	3234567	no	2.109	1.501	0.316	4272
841	2234567	no	1.790	1.289	0.433	5011

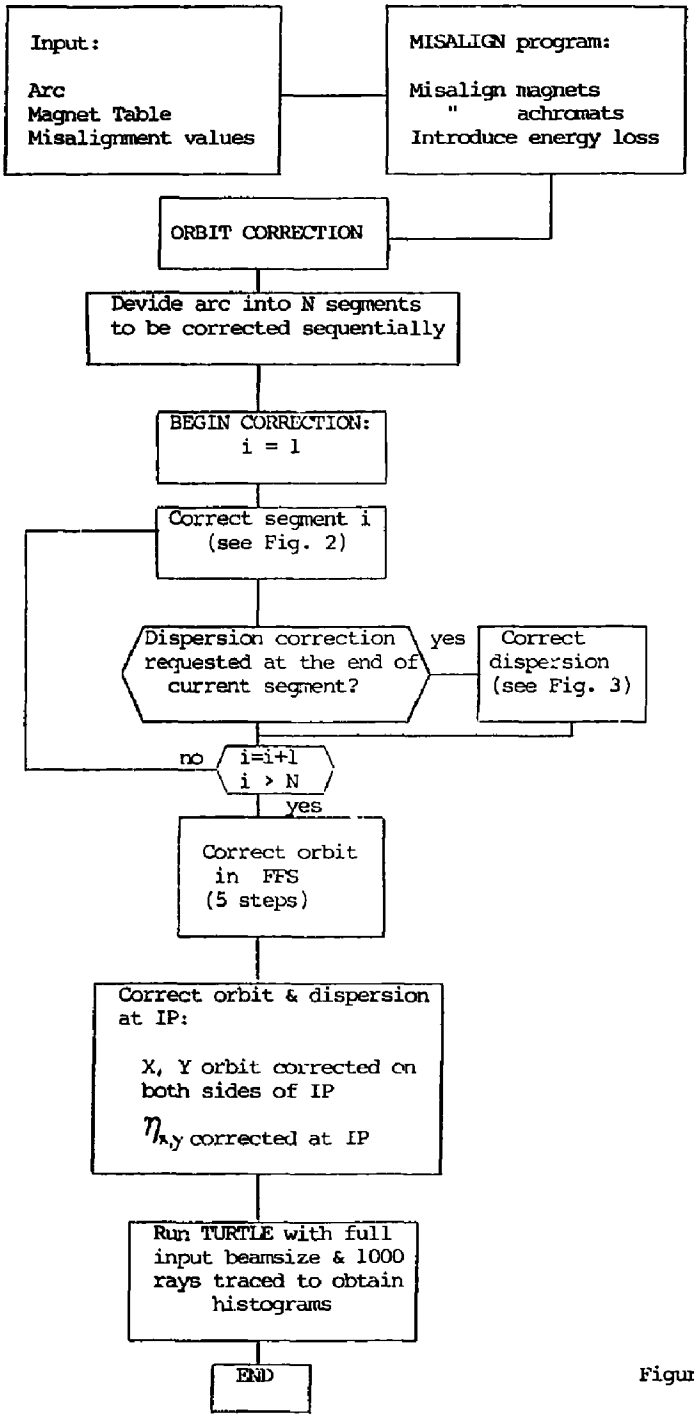

Input:
Arc
Magnet Table
Misaligmment values
MISALIGN program:
Misalign magnets
" achromats
Introduce energy loss
ORBIT CORRECTION
Devide arc into N segments
to be corrected sequentially
BEGIN CORRECTION:
i = 1
Correct segment i
(see Fig. 2)
Dispersion correction
requested at the end of
current segment?
yes
Correct
dispersion
(see Fig. 3)
no
i=i+1
i > N
yes
Correct orbit
in FFS
(5 steps)
Correct orbit & dispersion
at IP:
X, Y orbit corrected on
both sides of IP
$\eta_{x,y}$ corrected at IP
Run TURTLE with full
input beamsize & 1000
rays traced to obtain
histograms
END

Figure 1

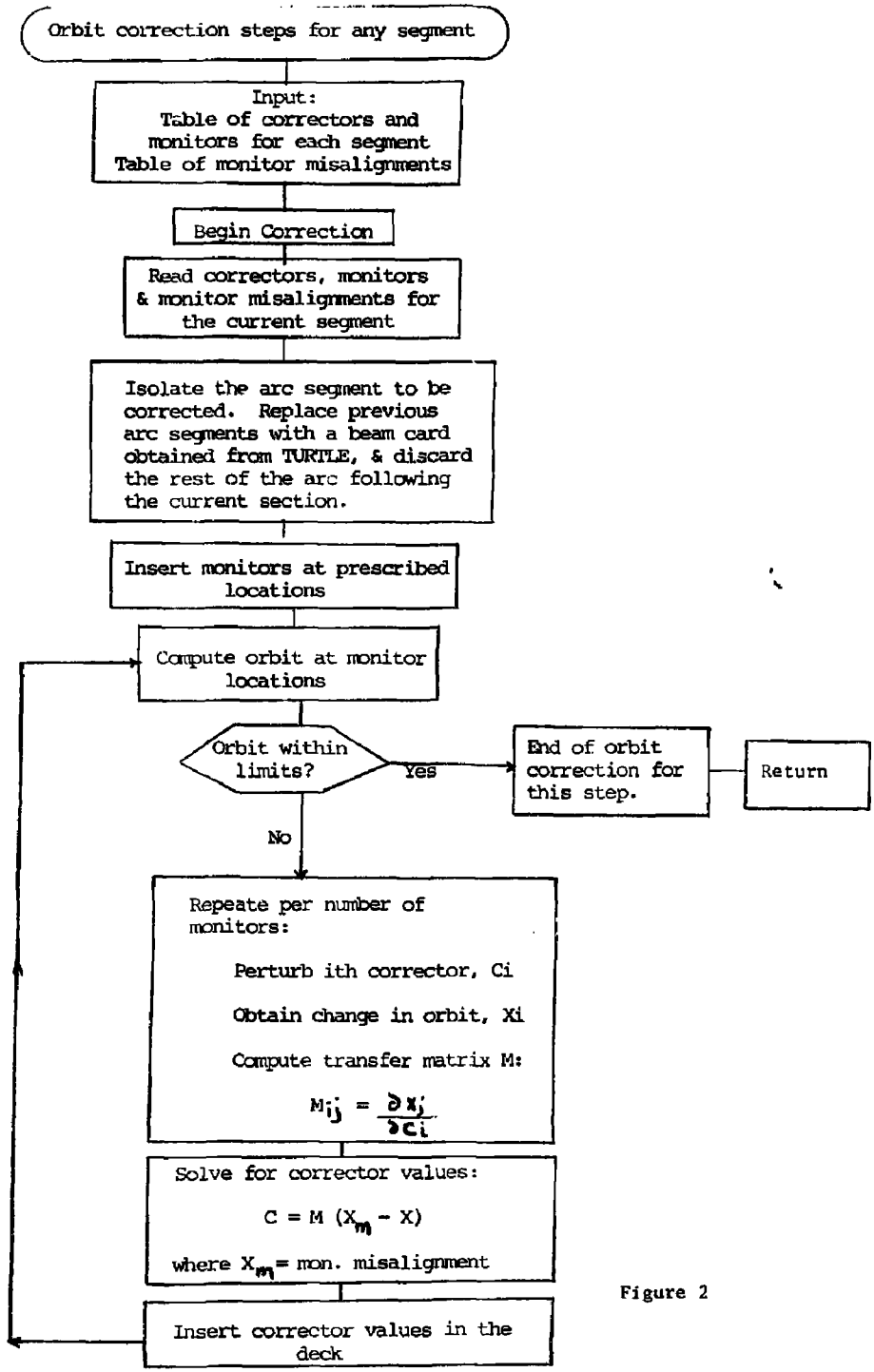

Orbit correction steps for any segment
Input:
Table of correctors and monitors for each segment
Table of monitor misalignments
Begin Correction
Read correctors, monitors & monitor misalignments for the current segment
Isolate the arc segment to be corrected. Replace previous arc segments with a beam card obtained from TURTLE, & discard the rest of the arc following the current section.
Insert monitors at prescribed locations
Compute orbit at monitor locations
Orbit within limits?
Yes
End of orbit correction for this step.
Return
No
Repeate per number of monitors:
Perturb ith corrector, Ci
Obtain change in orbit, Xi
Compute transfer matrix M:
$M_{ij} = \frac{\partial x_j}{\partial c_i}$
Solve for corrector values:
$C = M (X_m - X)$
where X_m = mon. misalignment
Insert corrector values in the deck

Figure 2

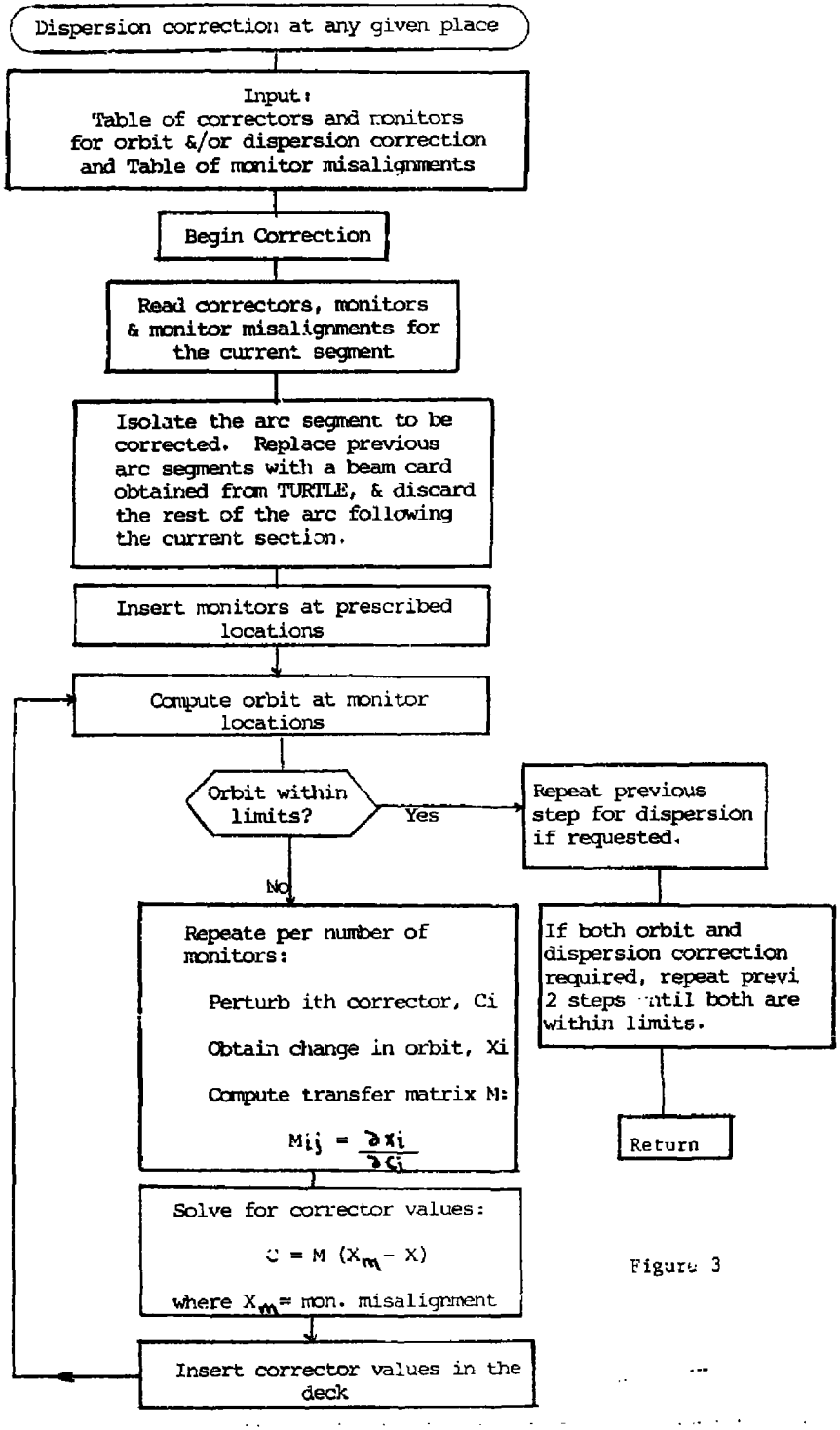
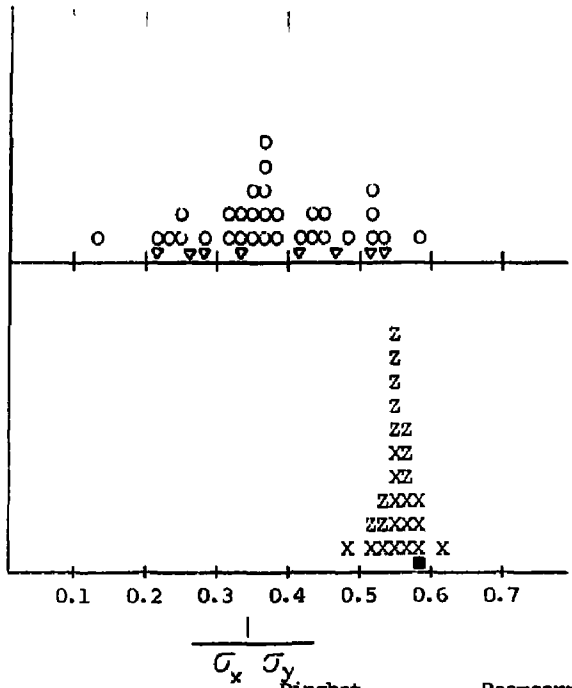

Dispersion correction at any given place
Input:
Table of correctors and monitors
for orbit &/or dispersion correction
and Table of monitor misalignments
Begin Correction
Read correctors, monitors
& monitor misalignments for
the current segment
Isolate the arc segment to be
corrected. Replace previous
arc segments with a beam card
obtained from TURTLE, & discard
the rest of the arc following
the current section.
Insert monitors at prescribed
locations
Compute orbit at monitor
locations
Orbit within
limits?
Yes
No
Repeat previous
step for dispersion
if requested.
If both orbit and
dispersion correction
required, repeat previ
2 steps until both are
within limits.
Return
Repeate per number of
monitors:
Perturb ith corrector, Ci
Obtain change in orbit, Xi
Compute transfer matrix M:
Mij = ∂xi / ∂Ci
Solve for corrector values:
C = M (Xm - X)
where Xm = mon. misalignment
Insert corrector values in the
deck

Figure 3

South Arc Simulation
with Dingbat & Beamcorr



	Dingbat	Beamcorr
Ideal South Arc (500)	X	
" " " (1000)	Z	■
Synch. Rad. Monitor Mis 100 mic	O	
Magnet Mis 100 "		▽

Figure 4

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