A Phase Trombone for the Recycler Ring

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A phase trombone has been designed that could operate in the Bypass Straight Section (BSS) of the Recycler Ring. This design is based on the current design of that straight section by David Johnson, Figure 1. That insertion design has lengthened dispersion suppressors to make the bypass displacement and four FODO cells made up of equal-gradient quadrupoles in the straight section itself. These non-bending cells have the same length as those of the arcs.

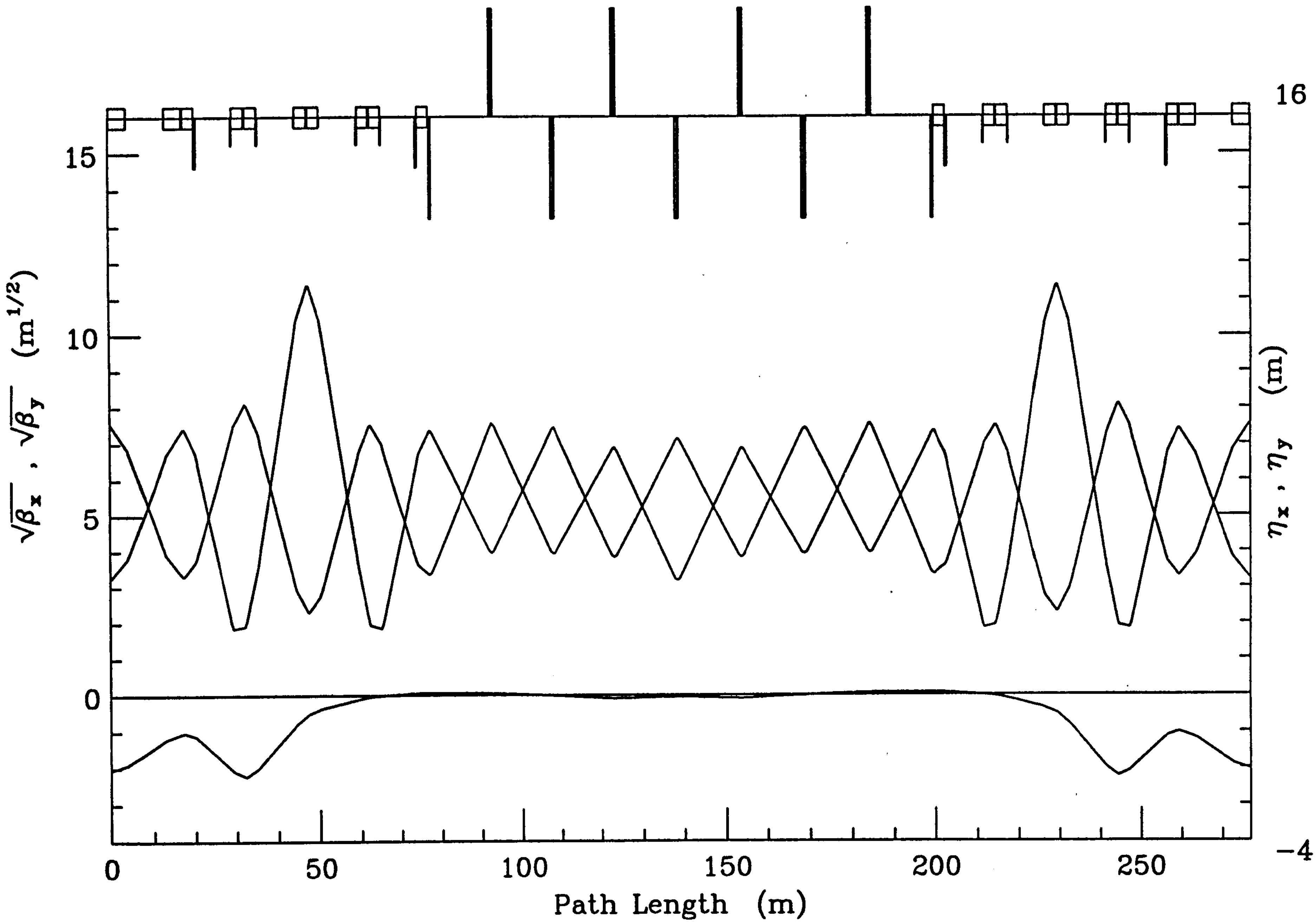
The first step of the design was to improve the matching from the dispersion suppressors (DS). To do this we began by fitting the empty straight section cells (CO) to 90^o phase advance in each plane. We then varied the eight quadrupoles that Johnson had put in the DS and constained the orbit functions starting from the last normal arc quadrupole, through the DS, to the beginning of the BSS to have the lattice function values of the CO cells at that point. This imposes six constraints. Two more were added: maximum values of betax and betay through the DS. The result is shown in Figure 2, which shows the upstream half of the insertion and half of an arc cell at the beginning (the downstream half insertion is the reflection of the upstream one). The matching is shown by the zero dispersion through the BSS and the periodicity of betax and betay there. These eight different quadrupole strengths are **not** altered when the trombone is set to different tune-shift values.

The next step was to make the nine BSS quadrupoles variable, but with reflection symmetry about the center, which makes five families. These were adjusted by tracking betax, betay from the beginning of the BSS, using the values of the CO cell, to the center of the BSS where four strong and two weak constaints were applied: alphax=alphay=0 (reflection symmetry constraints); mux, muy set to specified values to obtain desired tune shifts; and maximum values of betax and betay applied through the trombone. Figure 2 shows the trombone in its 'rest state', where the quadrupoles are set for 90^o phase advance per cell, in each plane.

The results are summarized in Figure 3 and Table 1. The nine points in the tune diagram of Figure 3 represent tune shifts obtained with the trombone, and the attached numbers show the maximum beta values in the trombone corresponding to each point. Table 1 gives the gradients of the five quadrupole families for each of the nine tune points calculated, which cover a tune spread of +- 1/2.

Thus it looks quite feasible to control the tune working point with a phase trombone located in the bypass straight section.

Fig. 1 - Bypass Insertion Reference Design - D. Johnson



FILEs: rrv4.lat : bp_fit.prc

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Fig. 2a - ... INSERTION WITH TROMBONE IN REST STATE (HALF)

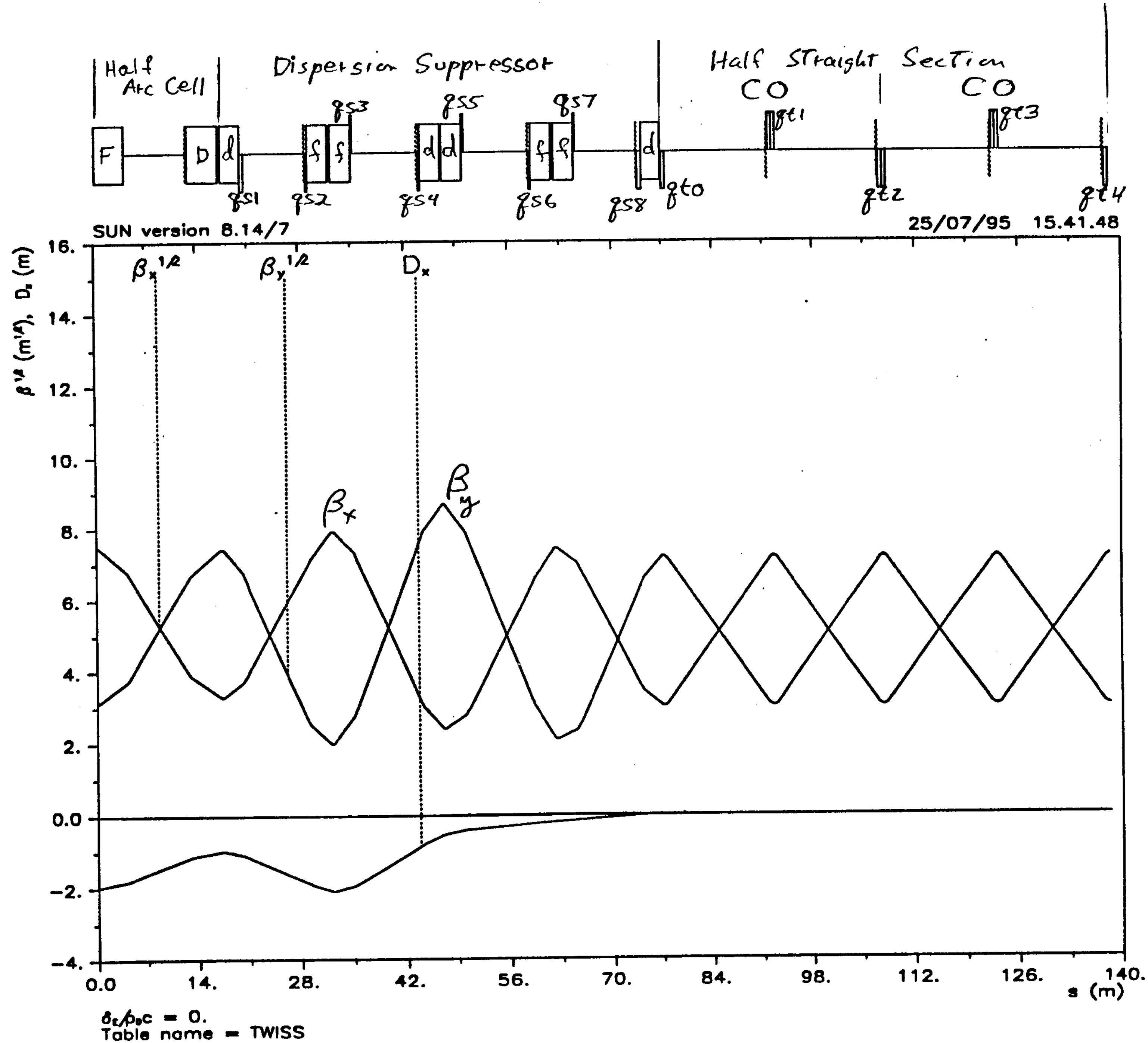


Fig ab: $\Delta\nu_x = \Delta\nu_y = 0.25$

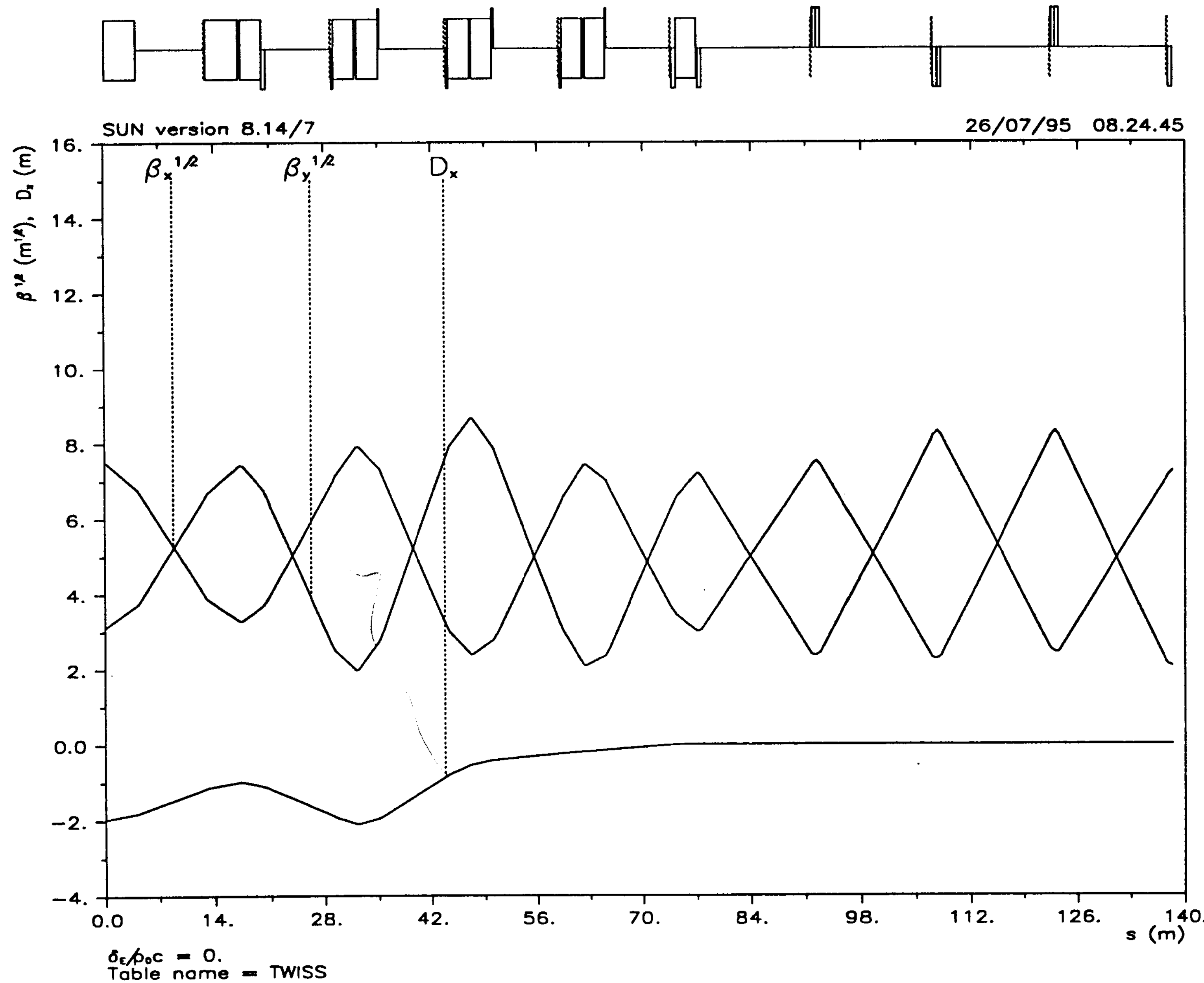
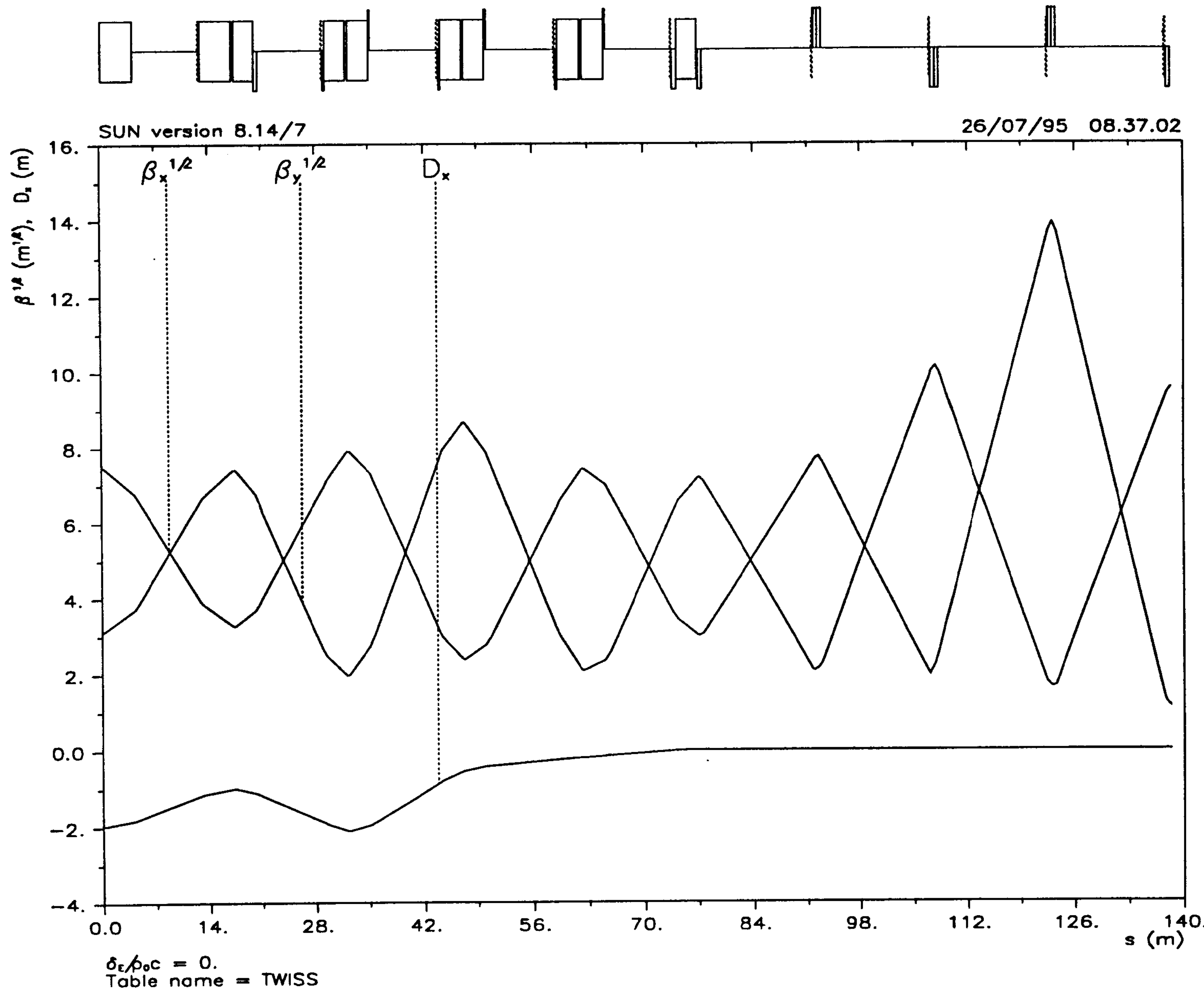


Fig. 2C:

$\nu_x = \nu_y = 0.5$



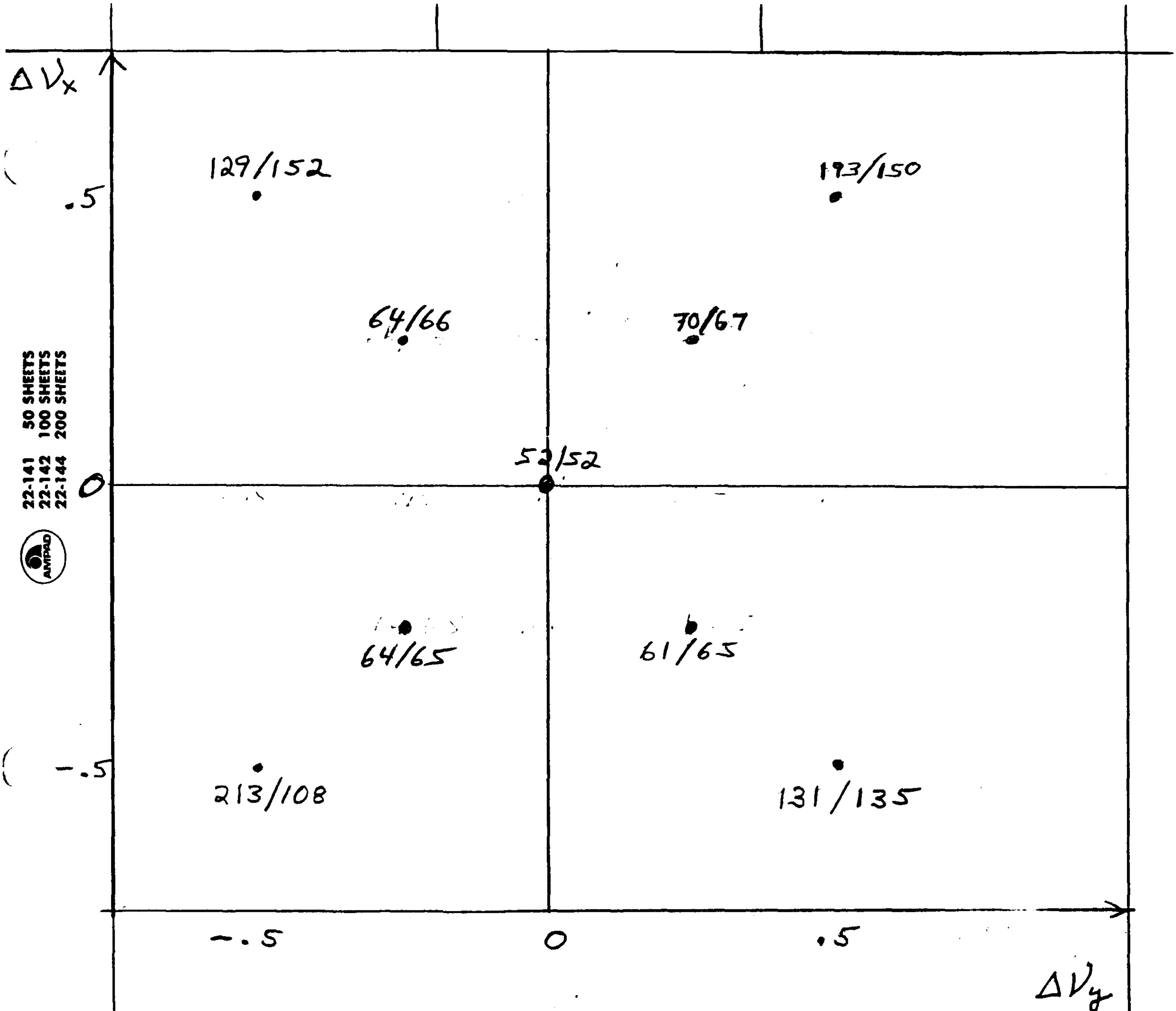


Fig. 3 Phase Trombone in Bypass Straight Section.
$\hat{\beta}_x / \hat{\beta}_y$ are maximum β-values in Trombone

$\Delta\nu_x$	$\Delta\nu_y$	k_0	k_1	k_2	k_3	k_4
0	0	-.0946	.0946	-.0946	.0946	-.0946
.25	.25	-.1130	.1057	-.1097	.1160	-.1126
-.25	.25	-.1170	.0870	-.1054	.0787	-.1046
-.25	-.25	-.0671	.0814	-.0775	.0689	-.0764
.25	-.25	-.0807	.1032	-.0839	.1125	-.0823
.5	.5	-.1431	.1238	-.1127	.1237	-.1431
-.5	.5	-.1530	.0756	-.1056	.0756	-.1530
-.5	-.5	-.0242	.0464	-.0634	.0464	-.0242
.5	-.5	-.0587	.1208	-.0838	.1208	-.0587

Table 1
Phase Trombone Quadrupole Strengths $k = B'/B\rho$ (m^{-2})
$l_q = 0.5$m (half length)