Fermilab

$\bar{p}$ Note #340

Main Ring Overpasses: WD6 at DØ,
TCB21 or TCB16 at BØ

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I.

Since $\bar{p}$ Note #334 on the same subject was issued in mid-August, it has been decided that we shall install a DØ overpass (called "Wildman's Dream" in $\bar{p}$ Note #334) in '84 to see the general effects of an overpass on the main ring operation. This overpass requires practically no tunnel modification but it will require eight new dipoles. As for the overpass at BØ, the choice of overall height is either 21' (the original value) or 16'4", the former strongly prefered by the experimenters and the latter desired by the construction people. As for the members of Accelerator Division, there seems to be no consensus but it is not deniable that the higher value is (resignedly and grudgingly, to be sure) getting accepted by many. This report is a summary of the expected optical characteristics of the main ring with 1) DØ overpass "WD6" alone or 2) "WD6" plus either 21' "TCB21" or 16' "TCB16" at BØ. The precise geometry of these overpasses is fully described in my memo to Tim Toohig (Sept. 14, 1983). New dipoles required have been designed by Stan Snowdon ("Overpass Dipoles-II", a memo to Tim Toohig, June 23, 1983). In this report, the following symbols will be used for new dipoles:

H* : horizontal bend, slot length 251", bend angle = $4\pi/774$, 2" gap × 4" aperture.

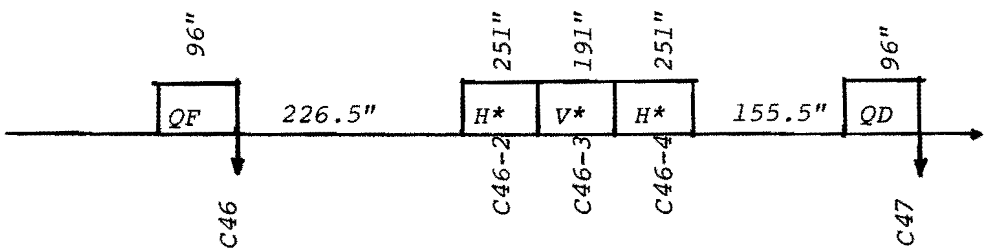
V* : vertical bend, slot length 191", bend angle = $(4\pi/774)\times(179/239)$, 3" gap and 3" aperture.

V**: same as V* but the slot length is 251" and the bend angle is $4\pi/774$.

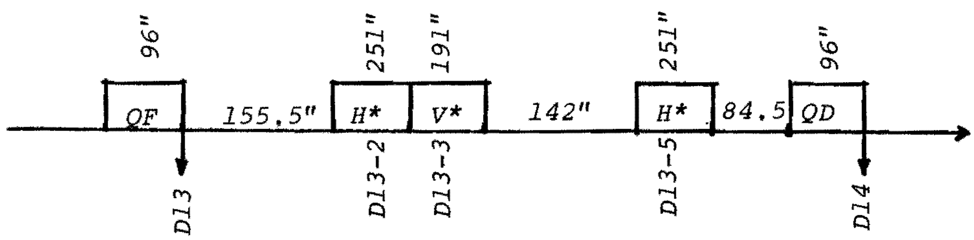
All these new dipoles will be connected to one new power supply which must be programmed to give the design bend angle at all beam momenta from 8.9 GeV/c to 150 GeV/c. The total required are:

WD6	4 H*	and	4 V*,	(1984)
TCB16	8 H*	and	8 V*,	(1985)
TCB21	8 H*	and	8 V**.	(1985)

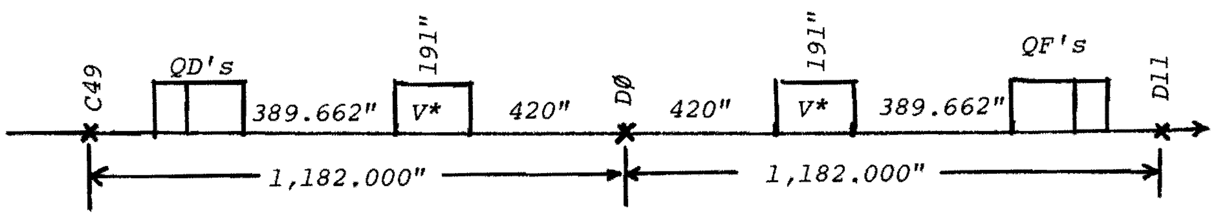
A. WD6 No attempt has been made to localize the vertical dispersion. As a consequence, the vertical dispersion outside the overpass is rather large (∿1.5m at β_V = 100m) in spite of the small up-and-down angle of 11.88mr. The overpass starts at C46 and ends at D14. It should be noted that C48 kicker is inside the overpass. The clearance at DØ along the beamline for the DØ detector is ±35'.



a) C46-5 missing; b) C46-3 roll angle 214mr (wall-side up)



a) D13-4 missing; b) D13-3 roll angle 214.14mr (wall-side up)



roll angle: upstream V* 214mr, downstream V* 215.05mr.

beam height at DØ: 43.59" + 25.50" = <u>69.09"</u>

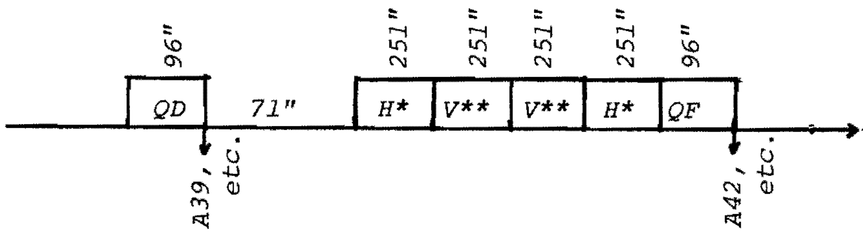
C48 kicker hight: (21.5"∿24.5")+25.5" = 47"∿50"

up-and-down angle = 11.88 mr.

B. TCB21 This is Tom's original design.

beam height at BØ = 226.66" + 25.50" = 252.16"

vertical bends at A39-3&4, A47-3&4, B12-3&4, B18-3&4



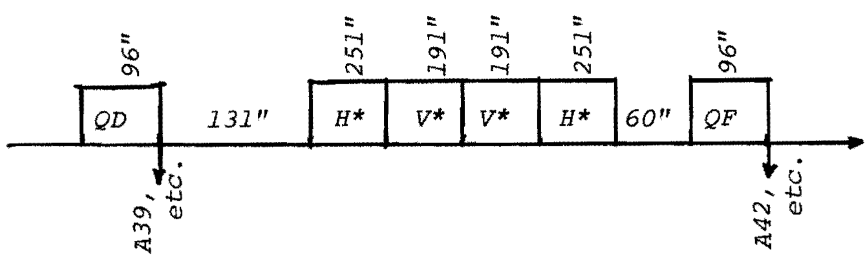
up-and-down angle = 32.27 mr

roll angles: A39-3&4 109.62mr, A47-3&4 112.58mr,
B12-3&4 113.03mr, B18-3&4 109.97mr. always wall-side up.

ATTENTION! Quadrupole A43-1 has the Edward-Stiening roll of 10.5mr, wall-side down.

C. TCB16 Scaled-down version of TCB21. Vertical bends at the same locations.

beam height at BØ = 170.23" + 25.50" = 195.73"



up-and-down angle = 24.23 mr.

roll angles: A39-3&4 82.10mr, A47-3&4 82.10mr,
B12-3&4 88.84mr, B18-3&4 84.29mr.

ATTENTION! Quadrupole A43-1, see above.

II.

With overpasses, the main ring lattice has a small but non-vanishing coupling of horizontal-vertical motions. This coupling makes it necessary to use procedures that are somewhat different from the standard ones in calculating linear parameters such as beta's and alpha's. The procedures adopted are described in $\bar{p}$ Note #318, "Calculation of Lattice Parameters for the Main Ring with BØ Overpass".

A. WD6 Stand-alone mode.

two tunes for the eigenmodes: 19.4003 and 19.4007

transition gamma : 18.7255 (including the effect of vertical dispersion)

change in the horizontal dispersion

stations		#17	#28	#42
present MR		5.65m	5.85m	5.67m
with WD6:	"A"	5.99	6.36	6.28
	"B"	5.14	5.51	5.54
	"C"	5.20	5.27	5.03
	"D"	5.02	5.32	5.29
	"E"	5.43	5.44	5.11
	"F"	6.23	6.30	5.92

vertical dispersion

Peak values of Y_p are shown here.

A12	-1.40m	C12	1.37m	E12	1.36m
A18	1.26	C18	-1.34	E16	-1.19
A23	-1.31	C23	1.20	E23	1.37
A29	1.38	C29	-1.37	E29	-1.33
A37	-1.23	C37	1.33	E35	1.22
A43	1.33	C43	-1.23	E43	-1.38
A49	-1.44			E49	1.30
		D14	1.20		
B14	1.20	D21	-1.25	F14	-1.30
B21	-1.33	D25	1.24	F21	1.32
B27	1.25	D33	-1.34	F27	-1.12
B33	-1.23	D39	1.22	F33	1.31
B39	1.33	D45	-1.27	F39	-1.31
B47	-1.23			F45	1.14

In particular, the vertical dispersion is very small at the C48 kicker so that there is no need to enlarge its gap. The dispersion is less than 15 cm. At F17-18, another location of interest, it is less than 50cm.

beam size

Since vertical dispersions are everywhere less than $\sim$1.5m, 2" gap should be adequate even with the most demanding beam size at the transition,

$$\text{emittance } (95\%) = 1.3\pi \text{ mm-mr}, \quad (\Delta p/p)_{95\%} = \pm 0.5\%.$$

For the vertical dipoles V* with 3" gap (in the horizontal direction), the relevant parameters are the horizontal dispersion and β_H:

	C46-3	LSUE	LSDE	D13-3
X_p	2.73m	2.28	3.12	1.92
β_H	57.4m	59.4	100.0	61.1
beam size	1.67"	1.53"	1.92"	1.43"

The beam size(horizontal) given above is computed by adding quadratically contributions from 1.3π mm-mr and ±0.5% together with an extra ±5mm to take care of the orbit distortion.

B. WD6 & TCB21

For TeV I mode of operation, the tunes are probably near 19.6 instead of the standard value of 19.40. However, the difference in the lattice parameters are negligible for the present consideration. TCB21 has a rather well-localized vertical dispersion and it does not affect the dispersion outside. WD6, on the other hand, changes the dispersion outside. The phase relation is such that the large dispersion near A49 created by TCB21 is reduced by the maximum possible amount by WD6 (almost perfect out-of-phase relation). One might then conclude that the existence of WD6 makes the situation better compared to the case of TCB21 alone. This of course is only partially true. WD6 creates vertical dispersions of the order $\sim$1m everywhere and, as will be shown below, it reduces the luminosity by as much as 20%.

change in the horizontal dispersion

As far as horizontal bending is concerned, TCB21 has very little perturbation so that the horizontal dispersion is practically unchanged from the stand-alone mode of WD6. See the table on p. 4 for values at stations #17, #28 and #42 where it takes the maximum value.

vertical dispersion

Although TCB21 does not produce large vertical dispersions outside, that is, from B19 to A39 (proceeding in the direction of the beam), a small perturbation is still noticeable. Peak values of Y_p outside the overpass are (compare to those shown on p. 4 for WD6 stand-alone mode):

A12	-1.01m	C12	1.58m	E37	0.98m
A18	1.04	C18	-1.36	E43	-0.97
A25	-0.90	C23	1.55	E49	1.13
A29	1.02	C29	-1.56	F21	1.00
A37	-1.03	C35	1.33	F27	-0.98
B21	-1.48	C43	-1.56	F39	-1.01
B25	1.36	D21	-1.01	F47	0.97
B33	-1.53	D39	1.01		
B39	1.45	E12	1.05		
B45	-1.39	E29	-1.05		

Note that the vertical dispersion is rather small within the overpass WD6; the largest $|Y_p|$ is 81cm at D14. The out-of-phase relation between two overpasses can be seen better by comparing the vertical dispersion inside the BØ overpass TCB21 with and without the DØ overpass WD6.

	WD6 alone	TCB21 alone	WD6+TCB21
A43	1.33m	-2.36m	-1.03m
A45	.84	-1.89	-1.05
A49	-1.22	4.28	3.06
QD(7')	-1.44	5.17	3.74
B11	-.46	2.84	2.38
B12	-.09	2.28	2.20
B16	.99	-2.51	-1.52

At C48 kicker, $|Y_p|$ <34cm; at F17-18, $|Y_p|$ <21cm.

beam size

The requirement for the gap and aperture at the transition, which is given on p. 5, is admittedly a rather generous one. Nevertheless, the following locations can be regarded as a potential bottleneck:

vertical dipoles (3" horizontal gap)	A39-3 =2.40", A39-4 =2.72"
horizontal dipoles (2" vertical gap)	A48-4&5 =1.7" B11-2 to 5 =1.7"

C. WD6 & TCB16

The only significant difference from the combination WD6 & TCB21 is that the vertical dispersion is less than 1.3m anywhere in the entire ring, including the BØ overpass itself. Within the BØ overpass, the largest value of $|Y_p|$ is 1.22m at B12 which should be compared with 3.74m near A49 when TCB21 is used at BØ. As a consequence, this combination is the best (even better than WD6 stand-alone mode) as far as the vertical dispersion is concerned. Unlike WD6 & TCB21, we should not have any bottleneck. Before one jumps into the conclusion that this should be our choice, one must examine the possible reduction in the luminosity arising from the mismatch in the vertical dispersion at the EØ beam transfer.

III.

The reduction in the luminosity arising from the mismatch in the vertical dispersion has been discussed in the previous report, $\bar{p}$ Note #334 (pp. 11 - 13, figure on p. 15). In trying to compare different cases from the table given below, it is important to remember that there is an uncertainty of (my guess) 0.2m or so in the estimate of "normalized magnitude of dispersion mismatch" coming from our ignorance of the vertical dispersion in the superconducting ring. When the vertical dispersion Y_p and its derivative Y_p' are properly transformed through two pairs of Lambertsons and one horizontally-focussing trim quadrupole to the upstream end of N99Ø5f, the first quadrupole in the s.c. ring, the normalized magnitude of dispersion mismatch is defined as

$\sqrt{100}\,\sqrt{\xi^2 + \eta^2}$ where 100 comes from the normalizing β_v = 100m,

$$\xi = (Y_p - \hat{Y}_p)/\sqrt{\beta_v}$$

$$\eta = \sqrt{\beta_v}\ \{(Y'_p - \hat{Y}'_p) + (\alpha_v/\beta_v)(Y_p - \hat{Y}_p)\}$$

where (Y_p, Y'_p) = dispersion transformed from the main ring to s.c. ring,

$(\hat{Y}_p, \hat{Y}'_p)$ = dispersion in the s.c. ring, at the upstream end of N99Ø5f; these quantities are unknown.

β_v, α_v = lattice parameters in the s.c. ring, at the upstream end of N99Ø5f; these are known.

From the figure on p. 5 of $\bar{p}$ Note #334, we find the luminosity relative to the one without overpasses as a function of the normalized dispersion mismatch.

	normalized disp. mismatch	case (1)	case (2)
TCB21, ν=19.4	0.54m	98.5%	98%
WD6 & TCB21			
ν=19.4	1.89m	84%	80%
ν=19.6	2.01	83%	78%
WD6 & TCB16			
ν=19.4	1.67m	87%	83.5%
ν=19.6	1.39	90.5%	88%

<u>Note</u> case (1) bunch area (longitudinal) 2.5 eV-s, V_{rf} = 0.75MV
case (2) 3.0 eV-s, = 1.0 MV

It seems clear that the reduction of ten to twenty percent caused by the DØ overpass WD6 is a real one. On the other hand, the difference between two tune values and between TCB21 and TCB16 may not be significant. Although I have not thought about much on this point, it might be possible to make up the difference of ten percent or less by some sort of tuning.