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D to A Line Tuning

Introduction

Although in the past the D to A line was well tuned, through the course of years of operations it has not kept up with changes in the Debuncher and Accumulator. The beam is now steered well off center in SEM's 806 and 807, and is possibly scraping in TQ5. In addition, there is some evidence that the beta functions are not matched, causing emmitance blowup of the beam. As the cycle time of the main ring has decreased these limitations have become a significant limitation to the stacking rate.

The TRANSPORT Model

To study the D to A line I used TRANSPORT. Extensive modifications of an older TRANSPORT deck were required to persuade the program to put the magnets in the locations determined by the surveyors. Using what I interpret to be the design values for the kickers and septa I have verified that most magnets are in the intended positions to within 10 mils. Debuncher magnet settings were taken from a SYNCH output in my area, D to A quad settings are close to what we now use, and the Accumulator magnet settings are from the SYNCH output in the design report. Beam is transported from the center of D6Q10 to the end of the 014P drift section in order to study the sextapole corrections.

The version of TRANSPORT that I used has several bugs that I learned to get around. These are important in the Accumulator, where the beam is injected off momentum. 1) It was necessary to increase the magnetic field of the dipoles to get the right bend angle in the floor coordinates. The extra bend in each dipole was then taken out. 2) The fitting package had difficulty fitting the Accumulator section, even with one constraint and one degree of freedom, so for the steering fits I divided the problem into two sections and matched them by hand. In addition, the transition from the beamline of the rings to the D to A beamline is rather awkward to keep track of. At the exit of the Debuncher, for instance, one must: a) change the angle of the beam to rotate it into the new beamline, b) rotate the floor coordinate system by the same amount, c) shift the beam centroid to the center of the beamline, d) shift the floor coordinates to compensate for the centroid shift above, e) shift the beam centroid again to make D6Q6 off center, f) pass the beam through D6Q6, g) take out the offset introduced in e). Finally, the angle of the floor coordinates is not printed with sufficient resolution in the TRANSPORT printout, so it is necessary to calculate the angle from the floor coordinates.

Steering in the D to A Line.

There are five devices that are normally used to steer beam in the D to A line, the two extraction kickers, the two septa, and the hard bend. The trim in the D to A line was allowed to vary in my simulation, but was not often used by used by TRANSPORT to meet the tuning requirements because it is in the center of a straight line of quads. Only two of the above devices are necessary to zero the Turn by Turn injection oscillations, that leaves three free parameters. In practice the beam can be approximately centered by varying fewer elements. This gives a wide range of solutions.

Because of the increased acceptance of the Debuncher relative to the original design, there is a need for a larger displacement at the extraction septum than was originally provided for. We currently run with a 9.3 mm bump at the DTOA septum, and with the extraction kicker set to it's maximum value. TRANSPORT was able to find a reasonable tune that centered the beam on all three SEM's in the injection channel with this DTOA septum bump and D:EKIK set as we currently have them. The solution is D:EKIK +8.3% of design value, D:ESEP -1.2%, D:H807 +.5% A:ISEP -0.3%, and A:IKIK -4.4%. These settings are very close to where we run, and therefore do not explain why the beam is off center in SEM's 806 and 807. I expect that the most likely explanation is that septa magnetic fields are mis-calibrated.

Using this model I calculated several bumps that move the beam at the SEM's without causing turn by turn injection oscillations. These bumps are listed in Table I. To move the position at SEM802 it is necessary to change the extraction kicker voltage. The other two SEM positions can be moved without such a change. It is also possible to trade kicker voltages for septum voltages without causing significant steering changes. Those bumps are listed in Table II. The bumps in Tables I and II appear to be consistent with our experimental knowledge of the D to A injection oscillations summarized in Figures 1 and 2.

At present the SEM profiles show that the beam is 34 mm off at SEM806 and 12 mm at SEM807. We can center the beam by making the following changes: E:ESEP +44 Volts, D:H807 +25 Amps, A:ISEP +39 Volts, and A:IKIK -6 KV. An alternative solution that will work almost as well is E:ESEP +43 Volts, D:H807 +20.4 Amps, A:ISEP +33 Volts. Both these solutions involve considerably higher septa voltages than have been run in the past. Some of this increase in the septa voltages can be compensated by raising the kicker voltages as shown in Table II, but the kickers are already running near their maximum. Both solutions correct a 52 mm offset in the horizontal position at the center of TQ5, which also has the maximum horizontal beta function. A 10 pi beam has a diameter of 66 mm at TQ5, so it is likely that the beam is scraping at this location. That may be why this magnet alone has a Class 2 radiation sticker on it.

Beam Steering Study Plan

1) Check to see if the septa and/or kickers can be run at higher voltage. This can be done now.

2) Using reverse protons set D:EKIK and A:IKIK to 3.5 KV lower than their stacking value, then minimize the turn by turn oscillations in the normal way.

3) Verify that the bumps in Tables I and II do what they say without causing turn by turn oscillations. They might need a little bit of tuning to get them to work well.

4) Use the bumps to center the beam in the DTOA line. Verify that the beam is centered by turning the quads on and off and looking for displacement.

5) Measure any residual quad steering of the bumps so that the beta function matching can proceed during stacking.

6) Setup the kicker voltage ramps so that the stacking value of the kicker voltages are 3.5 KV higher.

7) While stacking adjust the DTOA septum bump in Table I while measuring the transfer efficiency, A:FFTTOT/D:FFTTOT, and Debuncher acceptance, D:FFTTOT/M:TOR109.

8) While stacking change the DRF1 adiabatic program to leave beam bunched until transfer and try to use the Accumulator BPM system to measure turn by turn oscillations.

Beta Function Matching

If the quad steering is eliminated by the above procedure, or well known, the beta function matching can be studied while stacking. An interface program was written that enabled me to use the MINUIT fitter with TRANSPORT. With this program I was able to impose the instrumentation constraints. It proved difficult to obtain a good fit with 7 free variables, so I set QS802 and QS804 to zero, and allowed QS803 to run to twice it's usual current limit. In addition, Q807 was reversed to have the same sign as Q806. In this manner I obtained an exact match of the beta functions using the fields shown in Table III. This solution has a beam size that is about 20% larger at TQ5, but should still be well within the aperture at this location.

Bumps that change either the beam size or the relevant r matrix parameters while leaving the other parameters constant are listed in the Table IV. The bump that changes betax may require switching the leads on Q807. The others should have adequate range.

Table I
Bumps that change only one SEM

D:EKIK*-2.376 D:ESEP*2.751 D:H807*1.422 A:ISEP*.6482 A:IKIK*-.3349	Moves beam on SEM802 by +.39 mm/KV on D:EKIK
D:ESEP*-1.3049 D:H807*-1.22 A:ISEP*-1.821 A:IKIK*1.093	Moves beam on SEM806 by +.66 mm/Volt on D:ESEP Moves beam on SEM802 by +.23 mm/Volt
D:H807*1.3975 A:ISEP*2.011 A:IKIK*-2.476	Moves beam on SEM807 by +.68 mm/Amp on D:H807
D:ESEP*4.437 D:H807*2.473 A:ISEP*3.946 A:IKIK*-.646	Moves beam on SEM806 by +.77 mm/volt on D:ESEP Moves beam on SEM807 by +.28 mm/volt Moves beam on SEM802 by +.10 mm/volt
D:ESEP*4.307 D:H807*2.036 A:ISEP*3.308	Moves beam on SEM806 by +.77 mm/volt on D:ESEP Moves beam on SEM807 by +.34 mm/volt Moves beam on SEM802 by +.09 mm/volt
D:BS608*-4.5 D:H606*-2.09 D:H604*3.204 D:ESEP*-.6996 D:H807*-1.324 A:ISEP*-.703 A:IKIK*.4576	Moves closed orbit in debuncher nearer to septum while keeping beam roughly centered in D to A channel, and TBT oscillations zero. Sensitivity .41 mm/amp on D:BS608.

Table II
Bumps that don't change beam steering much

D:EKIK*-.58 D:ESEP*.704 D:H807*.3133 A:ISEP*.1532	Use this to trade reduced D:EKIK voltage for increased septa voltage. Changes SEM802 by a little.
A:IKIK*-.3258 A:ISEP*.2988 D:H807*.1876	Use this to trade reduced A:IKIK voltage for increased septa voltage.

Table III
Beta Function matching solution

NOMINAL MATCHING	Field	Current	
Q801	10.733	262.71378	amps
QS803	1.1555	28.2834	amps
Q804	7.2833	178.2748	amps
QS806	0.39833	9.75	amps
Q807	-1.7974	43.995	amps

Table IV
Bumps to change Beta Function matching

Beam Size in X (1 mm = 8 amps on Q801)

Q801	-.327
QS803	-.27908
Q804	+.1315
QS806	+.06552
Q807	-1.3667

ALPHA X (10% in r(2,1) = 2.52 amps on Q801)

Q801	-.103
QS803	+.1128
Q804	+.3814
QS806	+.35942
Q807	+.3768

Beam size in Y (4 mm = 7.8 amps on Q801)

Q801	-.319
QS803	-.26412
Q804	+.6544
QS806	+.08886
Q807	-.1492

ALPHA Y (10% in r(4,3) = 7.35 amps on Q801)

Q801	-.300
QS803	-.36393
Q804	-.0051
QS806	-.06096
Q807	-.7865

Figure 4

(HORIZONTAL STEERING)

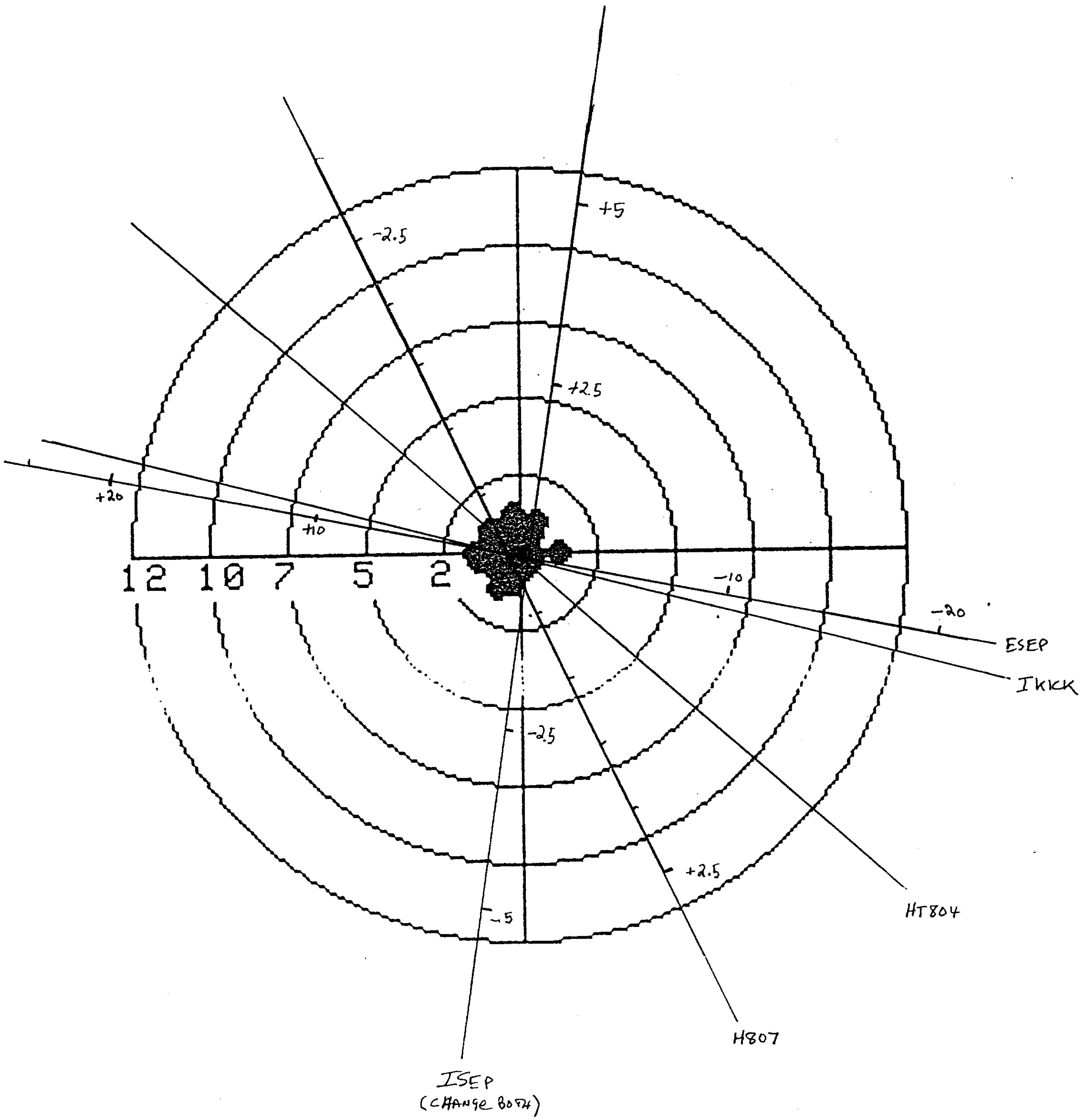
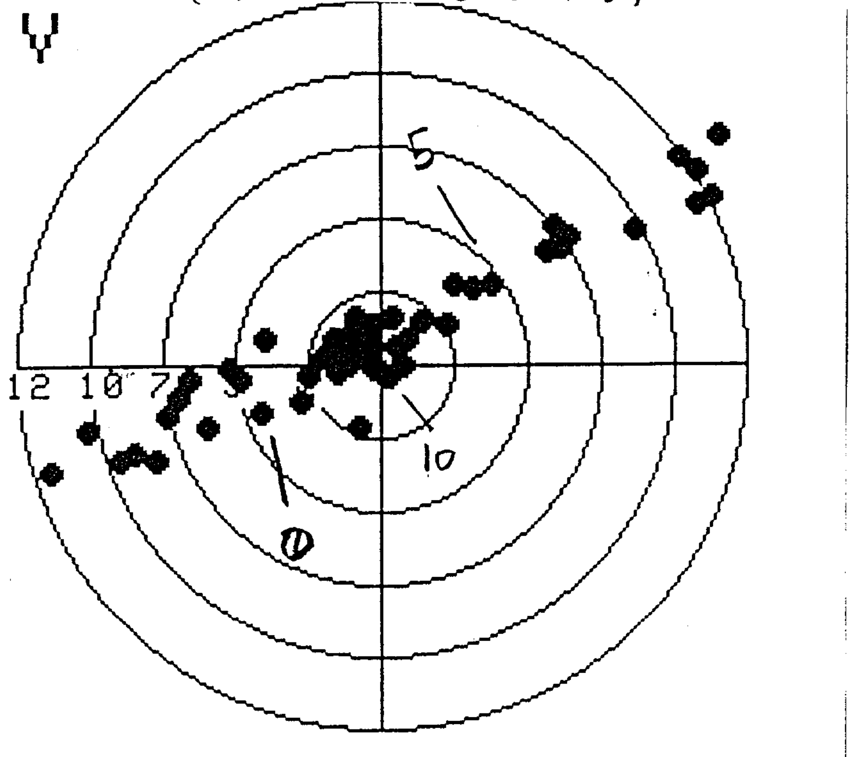
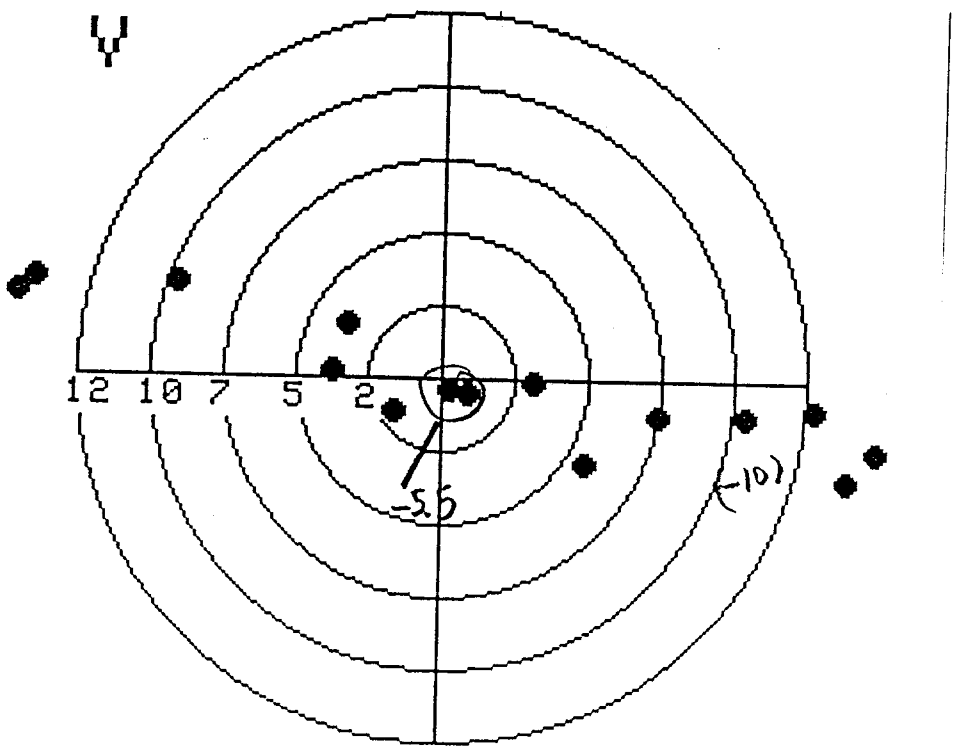


Figure 2
(Vertical Steering)



.ED

VT801



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VT806