

Loss of Dynamic Aperture due to Random Quadrupole Errors

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BNL

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(1)

Why Should the random a, b , affect Dynamic Aperture?

~~Random b , generates~~

Random a, b , ~~generate~~ generate effects which make the particle go out to larger x and y in the magnets where the particle may see larger field errors due to random and systematic higher multipoles.

Random b , generates $\Delta B_x/B_x$, $\Delta B_y/B_y$ and Δx_p

Random a , generates $\Delta B_1/B_1$, $\Delta B_2/B_2$

(B_1, B_2 are the β -functions of the normal modes)
and Δy_p

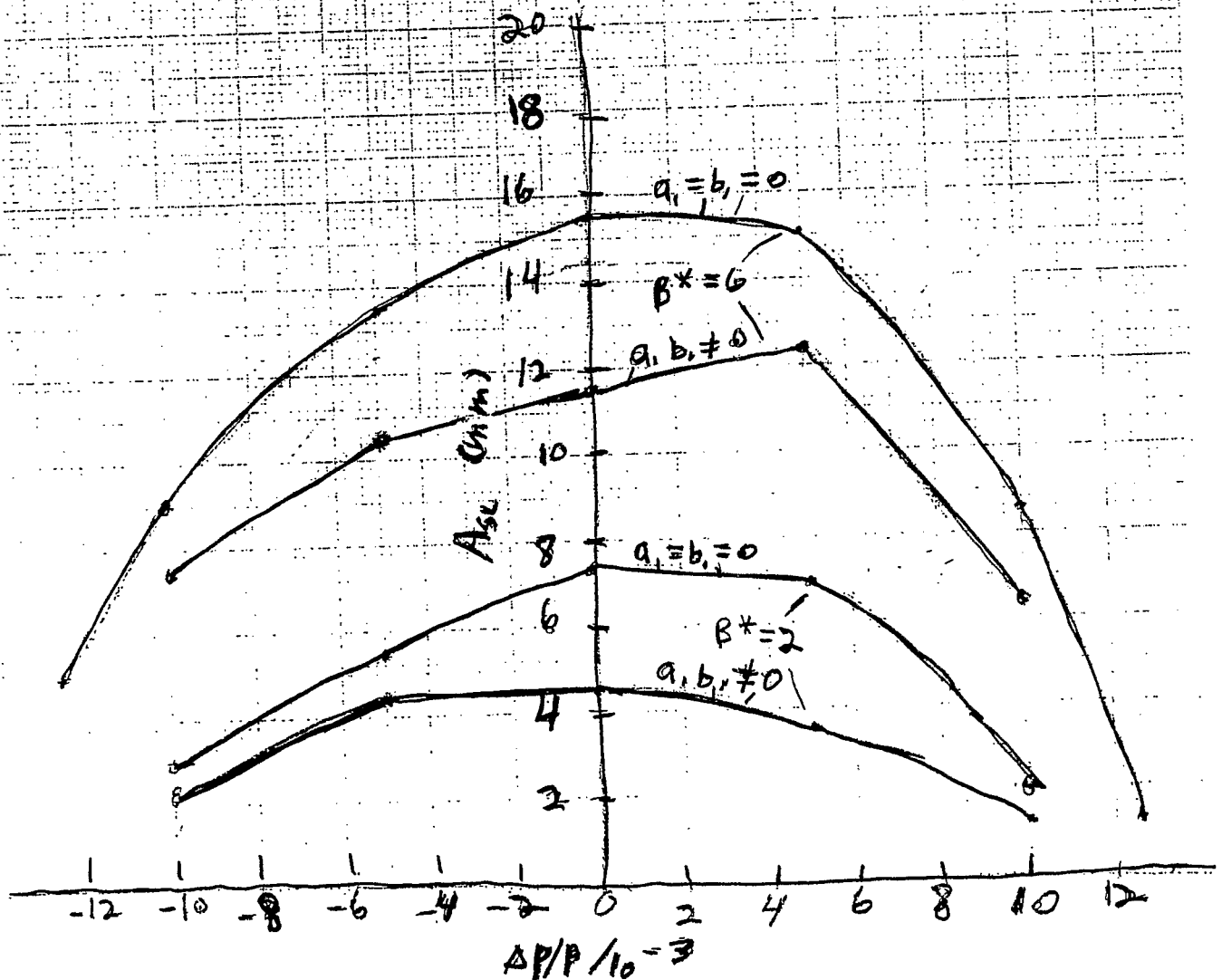
For $\Delta p/p \Rightarrow$, the important effects are

Random b , $\rightarrow \Delta B_x/B_x$, $\Delta B_y/B_y$

Random a , $\rightarrow \Delta B_1/B_1$, $\Delta B_2/B_2$

A_{SL} including a_1, b_1

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A_{SL} definition & Results

Worse case out of 10 machines:

Multipoles present — Random $a, b,$

Random $b_K, K \leq 10$, Systematic $b_K, K \leq 18$.

For $\beta^* = 6$, 2 machines out of 10 have

$A_{SL} = 11.5 \text{ mm}$, a loss of 4 mm at $0.2/p = 0$

For $\beta^* = 2$, 1 machine out of 10 at $0.2/p = 0$

has $A_{SL} = 3.5 \text{ mm}$, a loss of 3 mm

For $\beta^* = 6$ at $0.2/p = 0$, of the 4 mm loss in A_{SL} ,

1 mm appears due to random b ,

3 mm appears due to random a ,

Quads and dipoles appear to cause about equal losses

The source of Asc ~~Loss~~ Loss

The tracking results can be correlated with X_{MXT} , the largest X ~~or~~ ^{or} Y a particle reaches in the run at some particular class of magnets, like the GF and QD, in the high β quadrupoles. The ~~runs~~ ^{random errors} with small Asc, also give the largest X_{MXT} for the same initial X and Y .

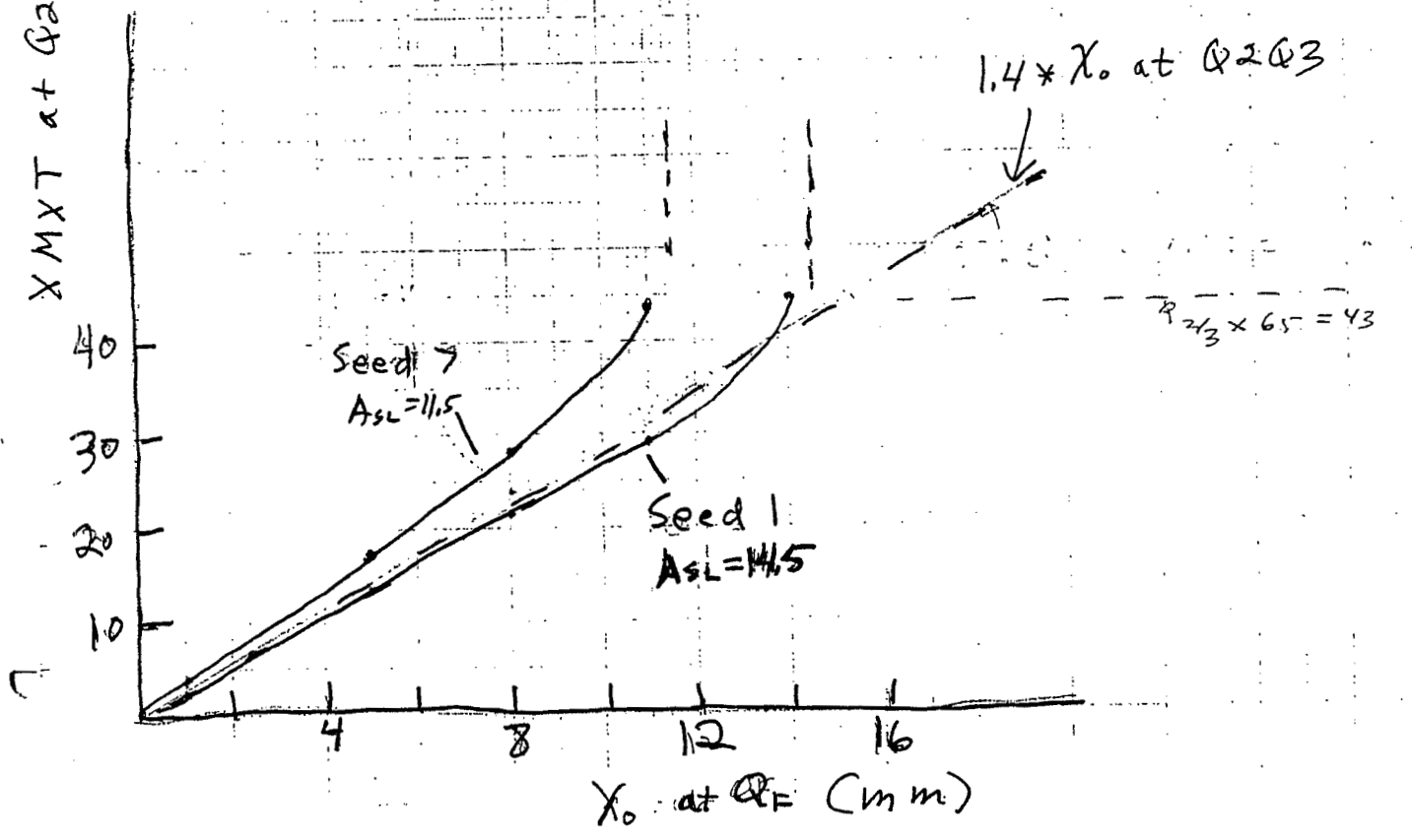
This X_{MXT} is ~~a~~ measure of the distortion ~~in~~ in the β functions due to a , and b .

a, b, present
all bk present

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XMXT versus χ_o

XMXT at Q2Q3 (mm)



The linear increase in X_{MXT} with X_0 is consistent with the source being a β -function distortion. The increase in X_{MXT} for the $N_{seed}=7$ case of about 30% over the $N_{seed}=1$ case indicates β -~~distortion~~ distortion of about 50% primarily due to the random Q_1 .

Correction of the Loss in A_{sc}

Use the Q_1 correctors in the arcs near QD , assuming independent excitation of all correctors. Set correctors so as to reduce X_{MXT} . Compute A_{sc} for case that gives best correction of X_{MXT} .

(6)

Results of Correction

N_{seed}	Reduction in X_{MXT} (mm)	Increase in A_{ASL} (mm)
<u>$B^* = 6$</u>		
7	43 $\rightarrow$ 30	11.5 $\rightarrow$ 15.5
8	41 $\rightarrow$ 34	11.5 $\rightarrow$ 15.5
<u>$B^* = 2$</u>		
7	35 $\rightarrow$ 26	3.5 $\rightarrow$ 6.5

Maximum Correction required $q_1 = 4 \times 10^{-3} / \text{cm}$
over 1M.

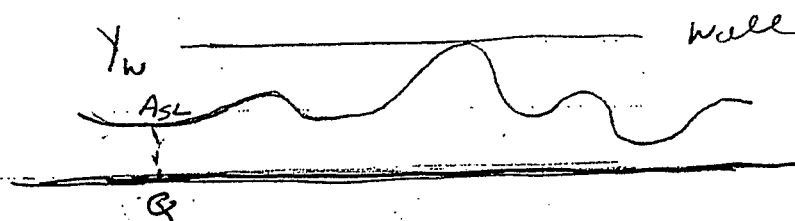
Is the loss in aperture Real?

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Linear Field with wall

Simple example

$$\text{Acceptance} = \frac{\gamma_w^2}{\beta_{\max}}$$



With a perturbation - assume $\Delta \beta / \beta = \pm 20$

$$\text{Acceptance} = \gamma_w^2 / \beta_{\max}, \text{ reduced by } 20\%$$

At observation point Q, A_{SL} depends on $\Delta \beta / \beta$ at Q

If $\frac{\Delta \beta}{\beta} = 0$, A_{SL} reduced by 10%.

$\frac{\Delta \beta}{\beta} = .20$, A_{SL} unchanged

$\frac{\Delta \beta}{\beta} = -.20$, A_{SL} reduced by 20%.

Effective change in A_{SL} not easy to determine.

In our case, since the loss in A_{SL} is correlated with a distortion in the β -functions through an increase in χ_{MXT} of about 30%, a loss in A_{SL} of about 30% may be expected.

possible

Some, Unsolved Problems

How well can one do with
just 4 families of q_1 /s extent?

What measurements can one do
to help set the correctors?

Can one correct the Asc loss
and the residual $|Y_1 - Y_2|$
simultaneously?