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Loss of Dynamic Aperture due to Random Quadrupole Errors

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Why Should the random a_1, b_1 affect Dynamic Aperture?

~~Random b_1 generates~~

Random a_1, b_1 generate effects which make the particle go out to larger x any in the magnets where the particle may see larger field errors due to random and systematic higher multipoles.

Random b_1 generates $\Delta\beta_x/\beta_x$, $\Delta\beta_y/\beta_y$ and Δx_p

Random a_1 generates $\Delta\beta_1/\beta_1$, $\Delta\beta_2/\beta_2$

(β_1, β_2 are the β-functions of the normal modes)

and Δy_p

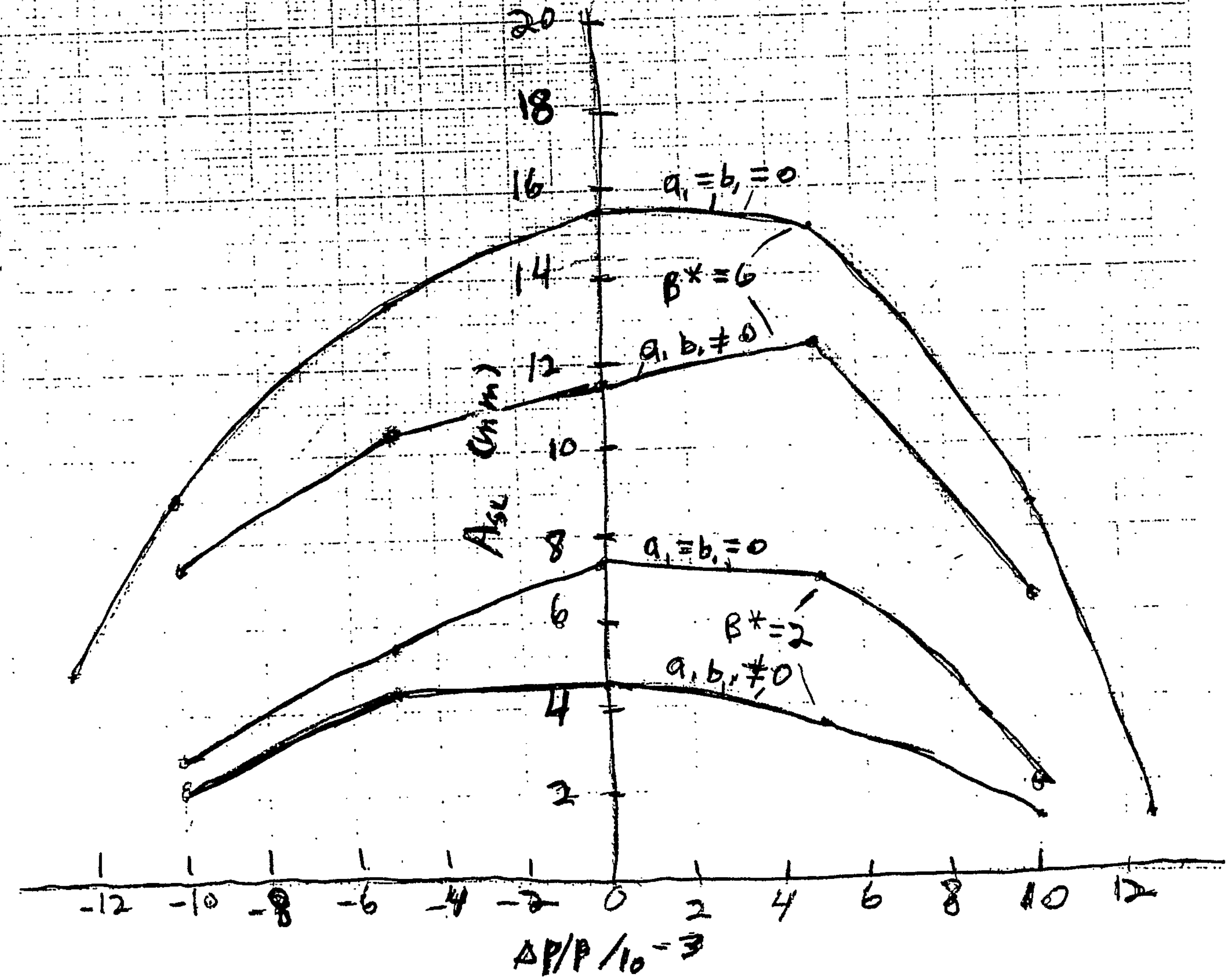
For $\Delta p/p = 0$, the important effects are

Random $b_1 \longrightarrow \Delta\beta_x/\beta_x$, $\Delta\beta_y/\beta_y$

Random $a_1 \longrightarrow \Delta\beta_1/\beta_1$, $\Delta\beta_2/\beta_2$

A_{SL} including a_1, b_1

G. Parzen



A_{SL} definition & Results

Worse case out of 10 machines.

Multipoles present — random a_1, b_1,

random b_K, $K \leq 10$, systematic b_K, $K \leq 18$.

For $\beta^* = 6$, 2 machines out of 10 have
$A_{SL} = 11.5$ mm, a loss of 4 mm at $\Delta p/p = 0$

For $\beta^* = 2$, 1 machine out of 10 at $\Delta p/p = 0$
has $A_{SL} = 3.5$ mm, a loss of 3 mm

For $\beta^* = 6$ at $\Delta p/p = 0$, of the 4 mm loss in A_{SL},
1 mm appears due to random b_1
3 mm appears due to random a_1

Quads and dipoles appear to cause about equal losses

The source of Asc ~~Beam~~ Loss

The tracking results can be correlated with XMXT, the largest x ~~or~~ or y a particle reaches in the run at some particular class of magnets, like the QF and QD, or the high β quads. The ~~runs~~ random errors with small Asc, also give the largest XMXT for the same initial x and y.

This XMXT is ~~a~~ measure ~~of~~ the distortion in the β functions due ~~to~~ a_i and b_i

a, b, present
all bk present

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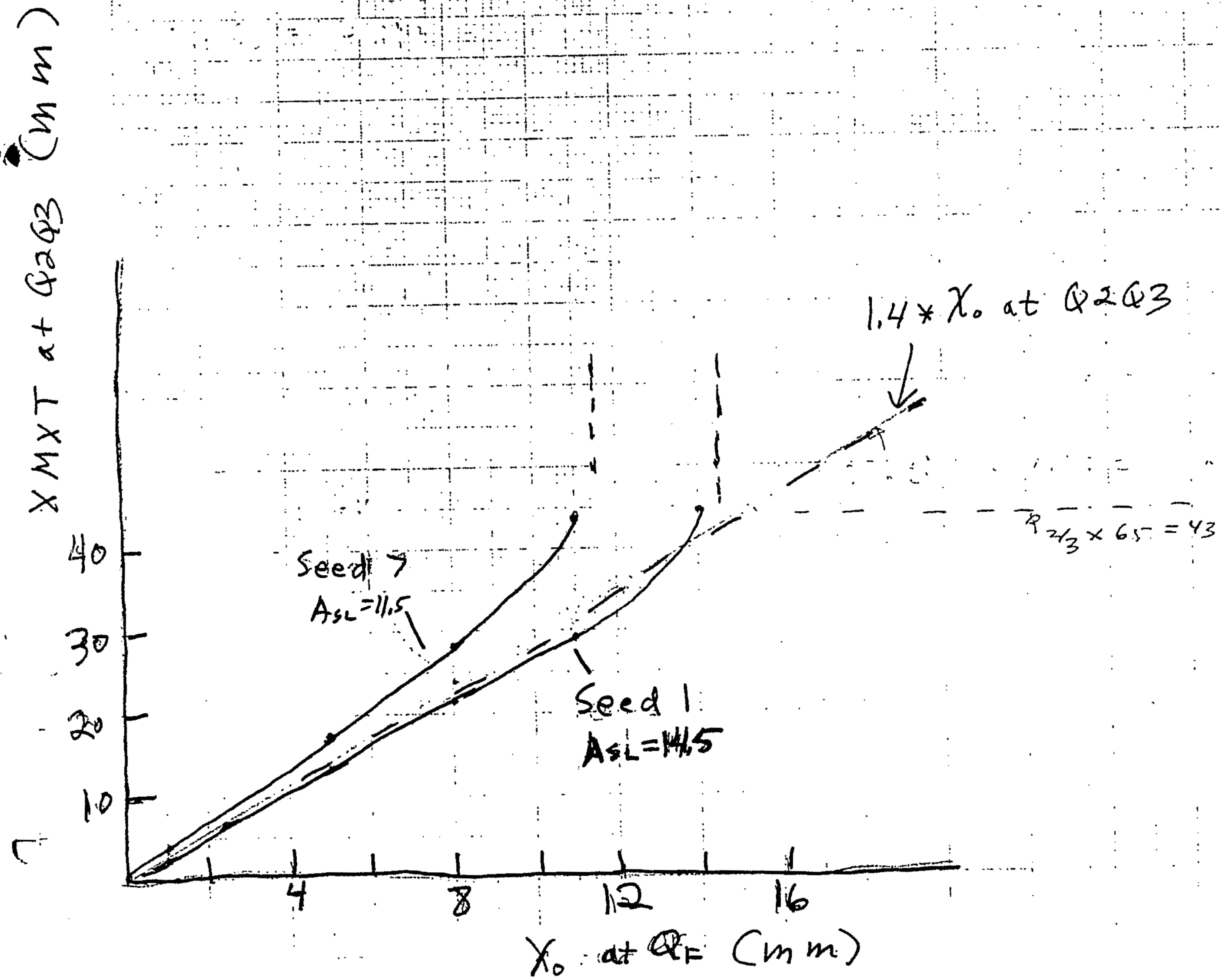
XMXT versus X_o



The linear increase in XMXT with X_0 is consistent with the source being a β-function distortion. The increase in XMXT for the $N_{seed}=7$ case of about 30% over the $N_{seed}=1$ case indicates β-~~distion~~ distortion of about 50% primarily due to the random a_1.

Correction of the Loss in Asc

Use the a_1 correctors in the arcs near QD, assuming independent excitation of all correctors. Set correctors so as to reduce XMXT. Compute Asc for case that gives best correction of XMXT.

Results of Correction

N_{seed}	Reduction in XMAXT (mm)	Increase in ASL (mm)
$B^* = 6$		
7	43 → 30	11.5 → 15.5
8	41 → 34	11.5 → 15.5
$B^* = 2$		
7	35 → 26	3.5 → 6.5

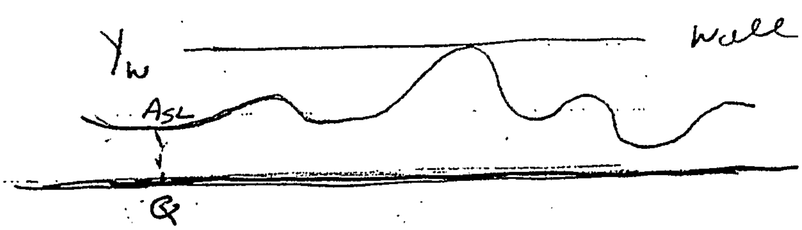
Maximum Correction required $q_1 = 4 \times 10^{-3}$/cm over 1 m.

Is the loss in aperture Real?

Linear Field with Wall

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

Simple example



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

$\text{Acceptance} = Y_w^2/\beta_{max}$, 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 XMXT of about 30%, a loss in A_{SL} of about 30% may be expected.

Some possible Unsolved Problems

How well can one do with just 4 families of a_1 / sextent?

What measurements can one do to help set the Correctors?

Can one correc the Asc loss and the residual $|\nu_1 - \nu_2|$ simultaneously?