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## Loss of Dynamic Aperture due to Random Quadrupole Errors

G. Parzen

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Collider Accelerator Department  
**Brookhaven National Laboratory**

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*G. Parzen*

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(1)

## Why Should the random $a_i, b_i$ affect Dynamic Aperture?

### Random $b_i$ , generates

Random  $a_i, b_i$ , ~~not~~ generate effects which make the particle go out to larger  $\chi$  and  $\gamma$  in the magnets where the particle may see larger field errors due to random and systematic higher multipoles.

Random  $b_i$ , generates  $\Delta B_x/B_x$ ,  $\Delta B_y/B_y$  and  $\Delta \gamma_p$

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

( $B_1, B_2$  are the  $\beta$ -functions of the normal modes) and  $\Delta \gamma_p$

In  $\Delta P/P \Rightarrow$ , the important effects are

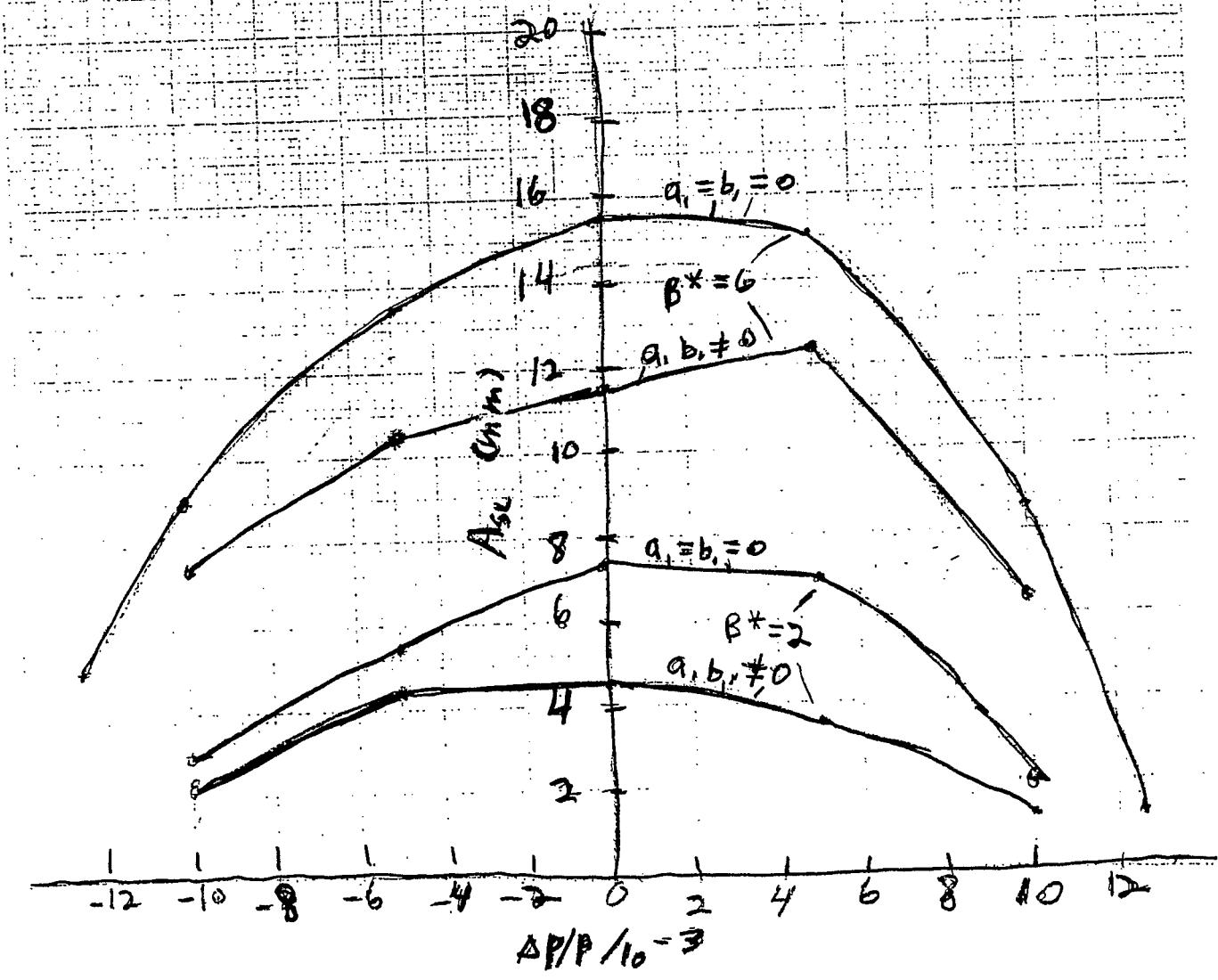
Random  $b_i \rightarrow \Delta B_x/B_x$ ,  $\Delta B_y/B_y$

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

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$A_{SL}$  including  $a_i, b_i$

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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

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

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

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

For  $\beta^* = 6$  at  $\delta p/p = 0$ , 2 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

The tracking results can be correlated with  $X_{\text{MXT}}$ , the largest  $\Delta x$  <sup>in</sup> a particle reaches in the run at some particular class of magnets, like the QF and QD, in the high  $\beta$  quads. The ~~cells~~ with small  $A_{\text{SL}}$ , also give the largest  $X_{\text{MXT}}$  for the same initial  $x$  and  $y$ .

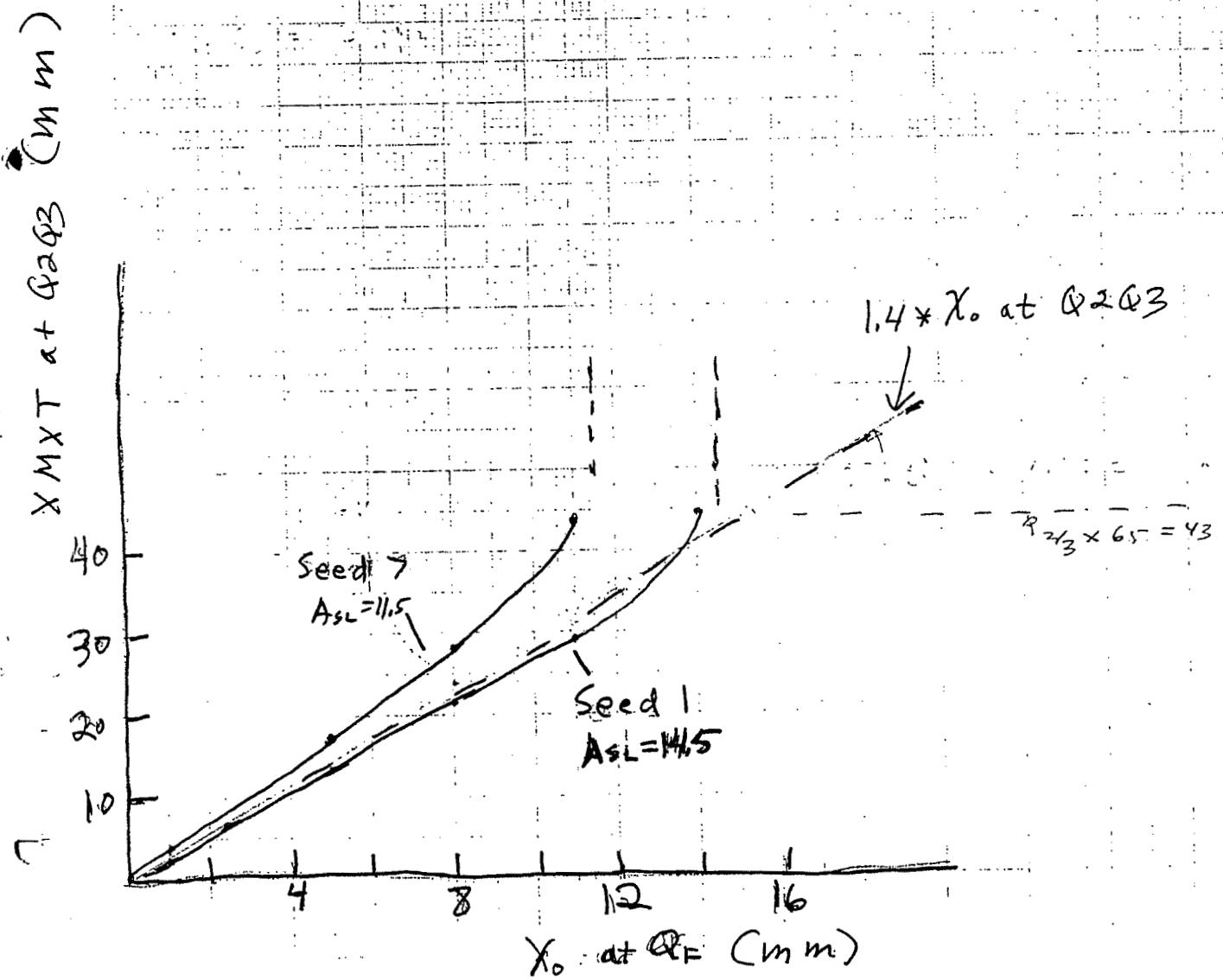
This  $X_{\text{MXT}}$  is ~~a~~ measure of the distortion ~~in~~ in the  $\beta$  functions due to  $a$ , and  $b$ .

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a, b, present  
all bk present

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$\chi_{MXT}$  versus  $\chi_0$



The linear increase in  $\chi_{MXT}$  with  $x_0$  is consistent with the source being a  $\beta$ -function distortion. The increase in  $\chi_{MXT}$  for the  $N_{seed}=7$  case of about 30% over the  $N_{seed}=1$  case indicates  $\beta$ -~~distortion~~ distortion of about 50% primarily due to the random  $a_1$ .

### Correction of the Loss in $A_{SL}$

Use the  $a_1$  correctors in the arcs near QD, assuming independent excitation of all correctors. Set correctors so as to reduce  $\chi_{MXT}$ . Compute  $A_{SL}$  for case that gives best correction of  $\chi_{MXT}$ .

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## Results of Correction

N <sub>seed</sub>	Reduction in $\Delta MXT$ (mm)	Increase in A <sub>ISL</sub> (dm m)
<u>B* = 6</u>		
7	43 → 30	11.5 → 15.5
8	41 → 34	11.5 → 15.5
<u>B* = 2</u>		
7	35 → 26	3.5 → 6.5

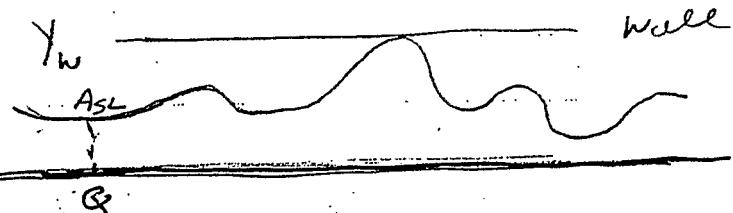
Maximum Correction Required  $Q_1 = 4 \times 10^{-3} / \text{cm}$   
over 1m.

Is the loss in aperture Real?

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Linear Field with Wall

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



Simple example

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

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

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

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

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

$\frac{\Delta B}{B} = -.20$ ,  $A_{SL}$  reduced by 2.7%

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  $\beta$ -functions through an increase in  $\chi_{MXT}$  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  $\alpha_1$  / sextant?

What measurements can one do  
to help set the correctors?

Can one correct the  $A_{SC}$  loss  
and the residual  $(Y_1 - Y_2)$   
simultaneously?