FFAG tolerance: Orbit correction with multipole errors

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Mixed multipole assignment

One assignment = Each FFAG magnet is assigned with a 16-vector

$$\frac{b_n}{lim\_b_n} \quad \frac{a_n}{lim\_a_n}$$

Each $\frac{b_n}{lim\_b_n}$ comes from normal distr.

A number u is chosen uniformly in [0,1] for each magnet, and the 2-norm is scaled to "u^(1/16)" (to uniformly fill the 16-D ellipsoid)

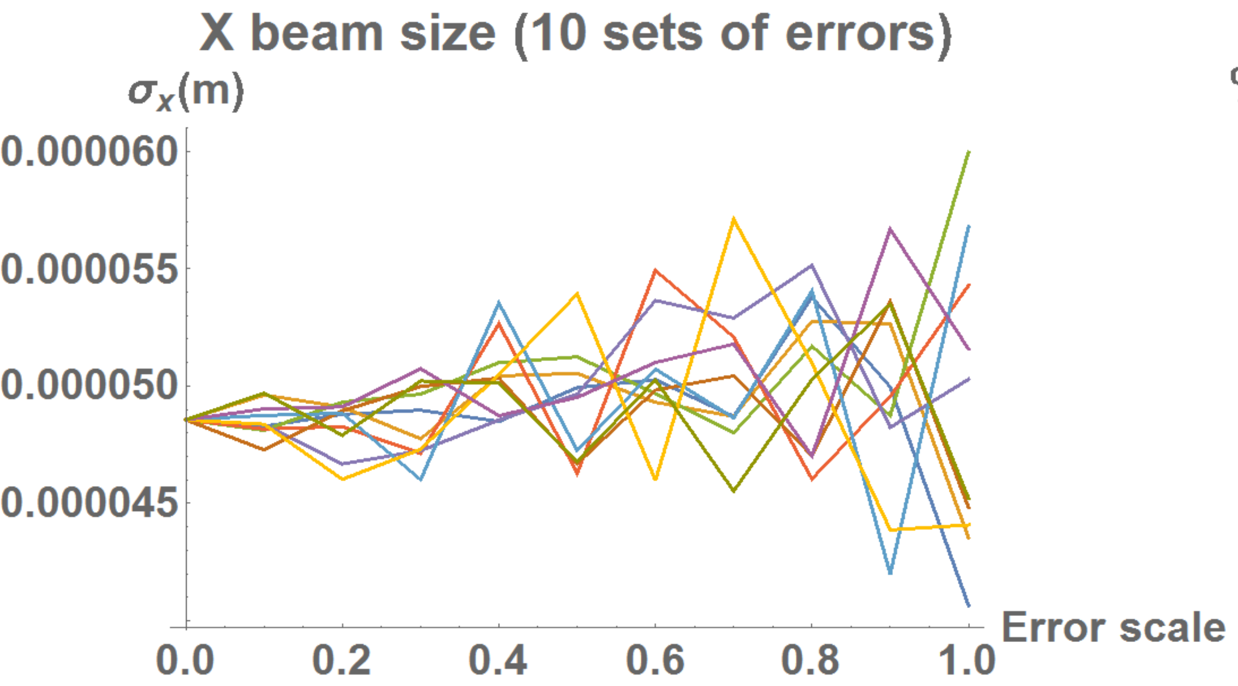
The 2-norm is $\sqrt{\Sigma_n (\frac{b_n}{lim\_b_n})^2 + (\frac{a_n}{lim\_a_n})^2}$

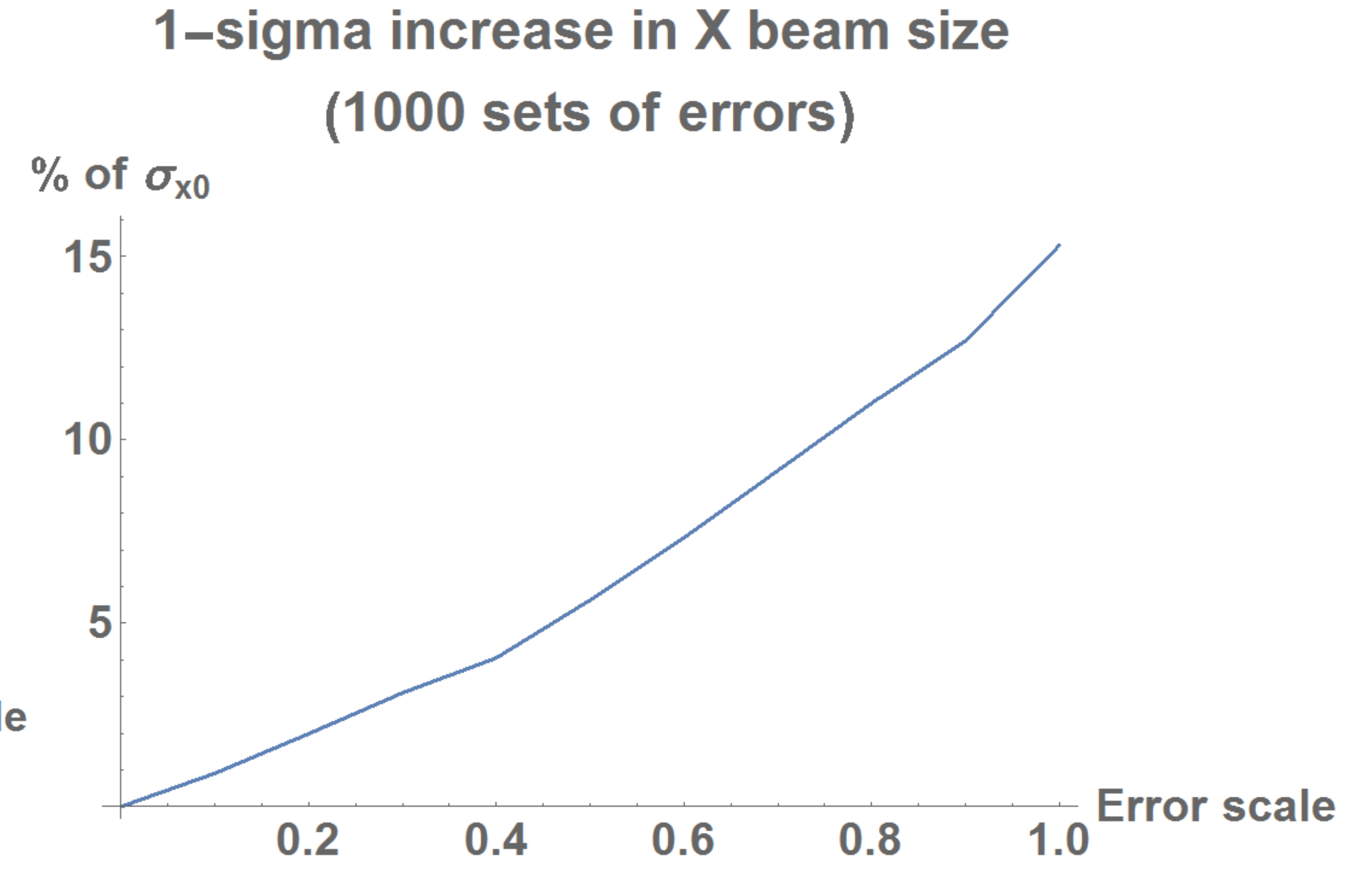
Individual limit (u): 10 % increase

in either X/Y emittance/beam size

	lim_b_n		lim_a_n
b2	37	a2	140
b3	30	a3	90
b4	26	a4	80
b5	21	a5	65
b6	21	a6	63
b7	19	a7	58
b8	21	a8	56
b9	18	a9	53

X beam-size



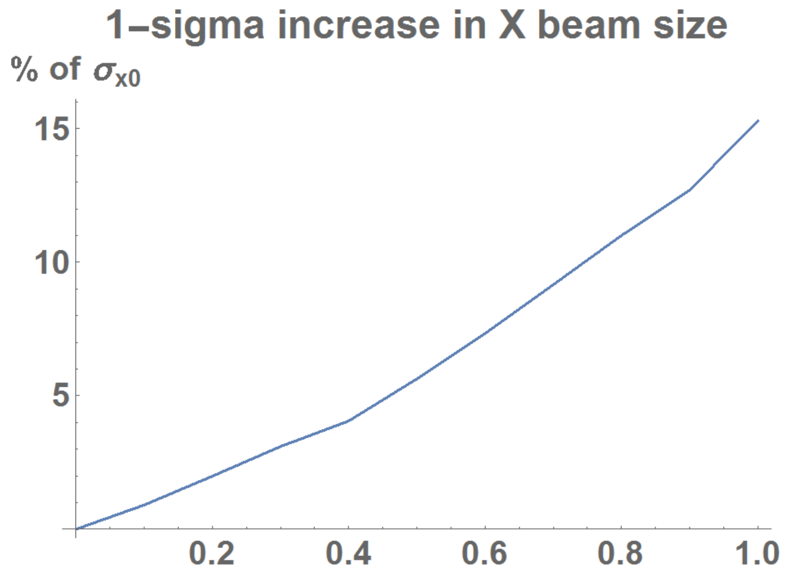


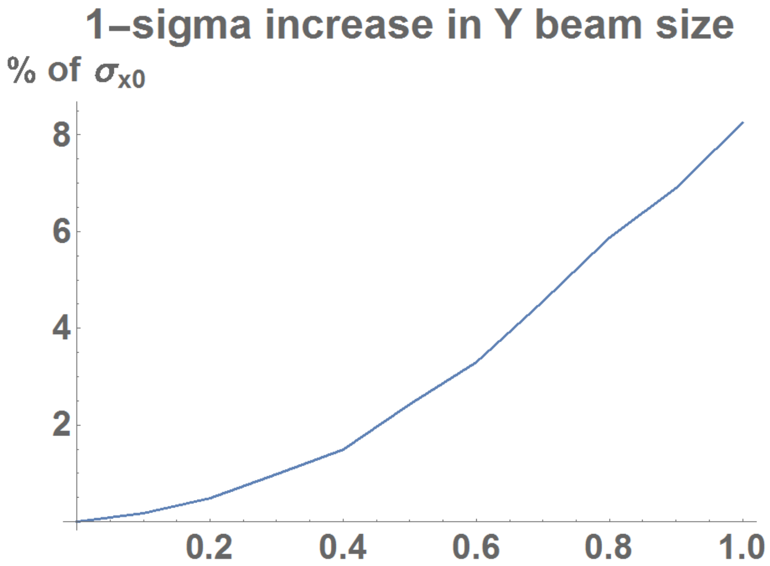
Horizontal axis “error scale” = 1 means the assignment is original.

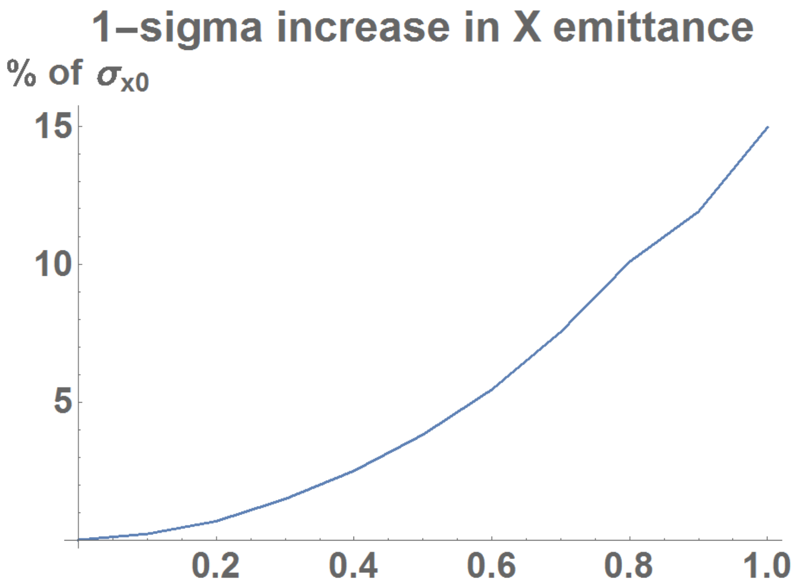
Each assignment is scaled down from 1 to 0 at a step of 0.1.

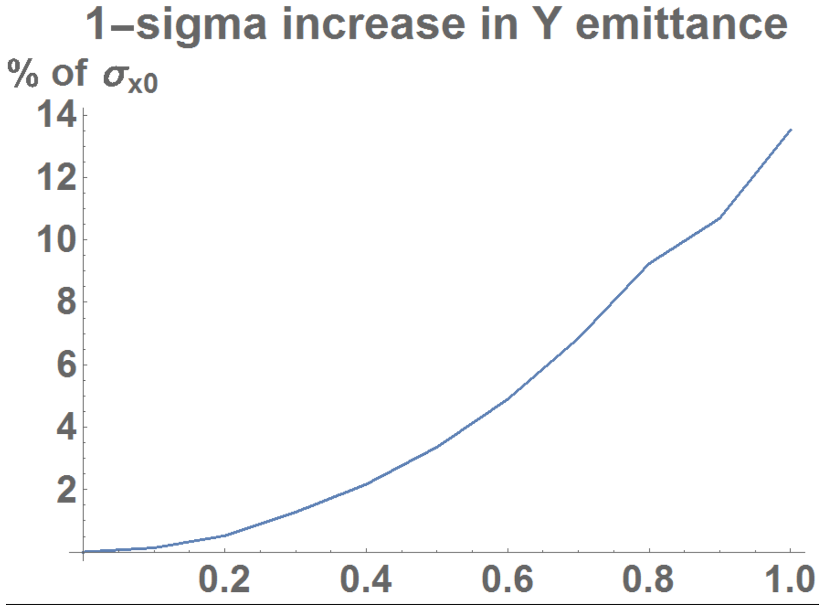
For example, at scale = 0.2, all multipole errors assigned to all magnets are 20% of the original assigned strength.

Results with 1000 assignments
(each scaled down from 1 to 0 at step of 0.1)

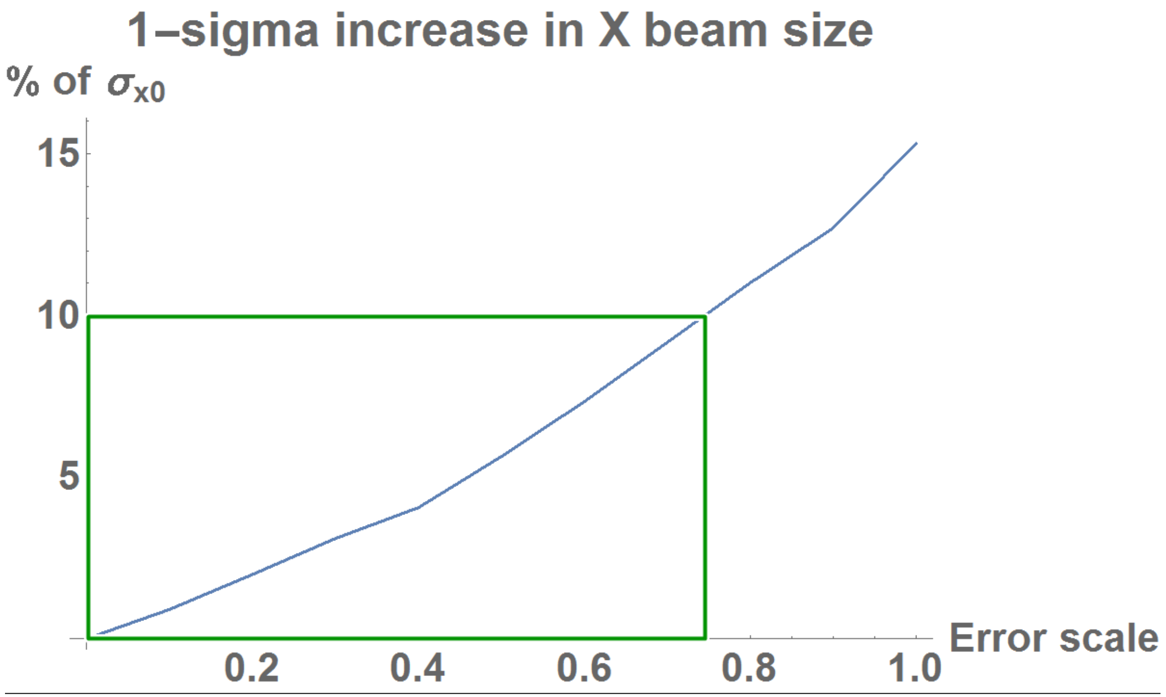








X_beam_size is doing the worst.



X_beam_size is doing the worst.

1-sigma x_beam_size increases by 10% when all multipoles are 75% of the original strength

The requirement for less than 10% increase is

$$\sqrt{\Sigma_n(\frac{b_n}{lim\_b_n})^2 + (\frac{a_n}{lim\_a_n})^2} < 0.75$$

Summary

To keep increase in either X/Y emit/beam_size to be < 10%

Individual limits

b2	37	a2	140
b3	30	a3	90
b4	26	a4	80
b5	21	a5	65
b6	21	a6	63
b7	19	a7	58
b8	21	a8	56
b9	18	a9	53

$$B_x + iB_y = \frac{b_n + ia_n}{L}(x+iy)^n \qquad b_n = \left[10^{-4}\frac{GL}{r_0^{n-1}}\right]u_0$$

Multipole limits

$$\sqrt{\Sigma_n(\frac{b_n}{lim\_b_n})^2 + (\frac{a_n}{lim\_a_n})^2} < 0.75$$