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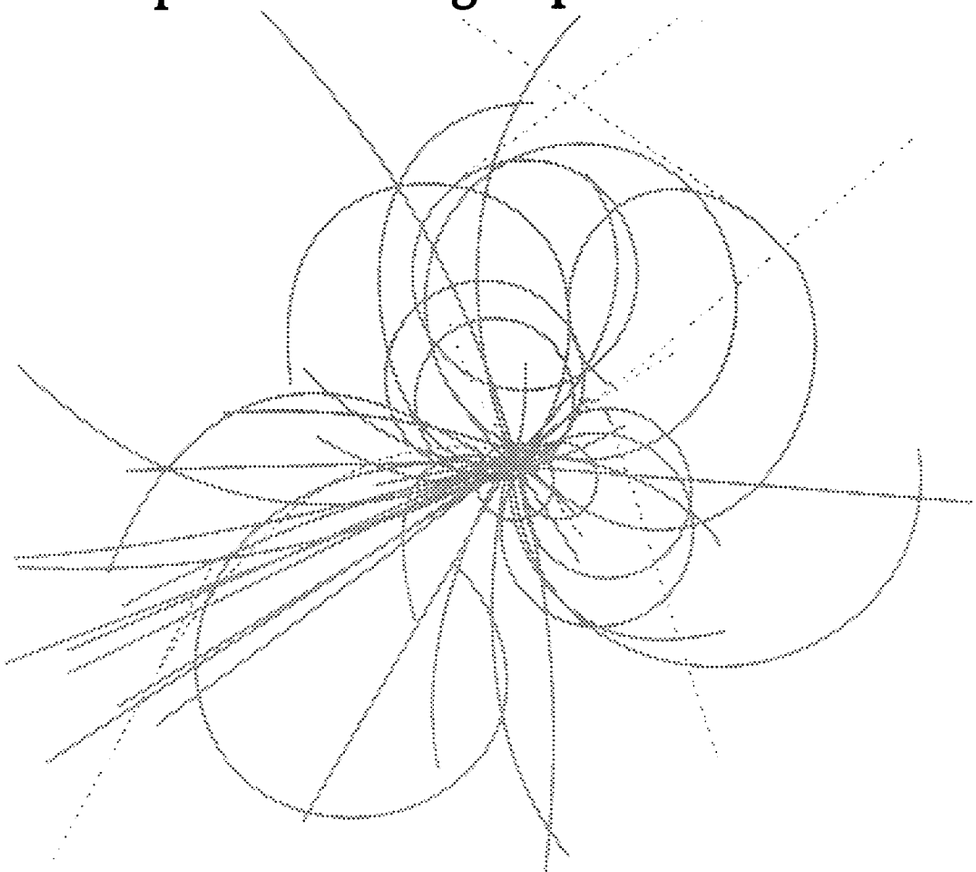

Aperture Task Force Interim Report
Aperture Criterion Group

D. Edwards

April 1985

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APERTURE TASK FORCE INTERIM REPORT - APERTURE CRITERION GROUP

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1 INTRODUCTION

The purpose of this interim report is to present a short, and, it is to be hoped, intelligible magnet aperture/field quality criterion. The first part is on the conceptual as opposed to the numerical content of the criterion. In the second part, we comment on the values that may be assigned to the various "blanks" in the criterion.

The two-part division is made to indicate the distinction between the main issues. Does the criterion reflect an appropriate distillation of the host of accelerator physics considerations that are related to aperture and field quality? Do the numerical values suggested in the second part represent reasonable starting values for a costing cycle?

The decision that this aperture/field criterion is supposed to assist relates to the magnets in the long bending arcs. The dynamical questions that are of immediate concern center around the tolerable multipole content of the main superconducting magnets. The criterion has been formulated in this context.

2 AN APERTURE CRITERION

All statements pertain to rings with closed orbit and other corrections turned on. The notion of what constitutes a reasonable (taking into account considerations of cost, operation, etc.) correction system will doubtless evolve, so it is assumed that decisions are based on the correction system and procedures as specified as of that date. Similarly, when a word such as "stable" is used, it means that the motion is stable according to the most credible means available at the time of decision.

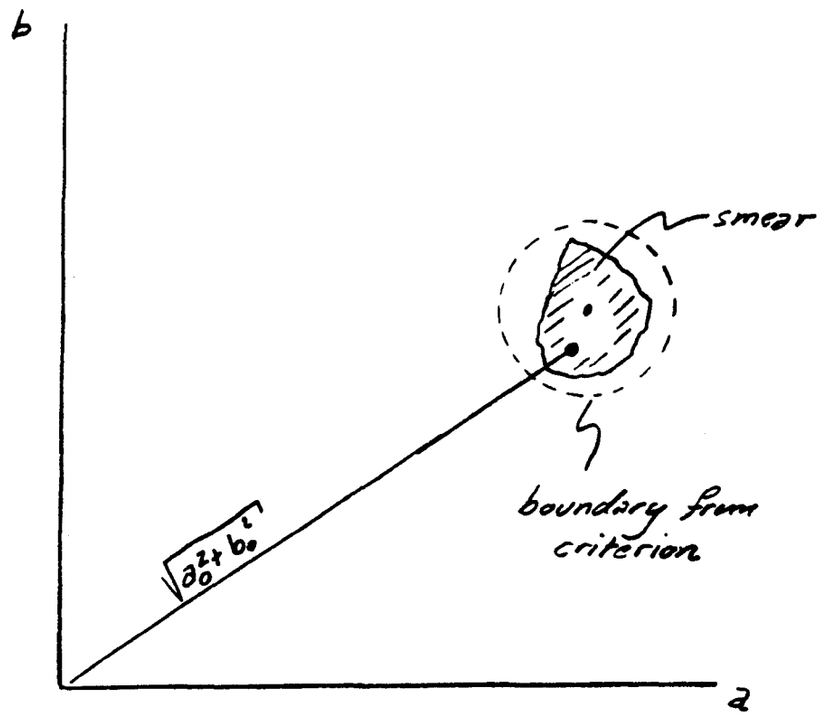
The primary emphasis in the criterion is placed on limiting the deviation from linear behavior. Commissioning, diagnosis of accelerator pathologies, and routine operation all demand rational, interpretable dynamical performance; with present controls and instrumentation, "interpretable" and "linear" are virtually synonymous. The two characteristics of linearity which are used here are a narrow tune spread and a restricted excursion of the transverse amplitudes.

The amplitude excursions can conviently be exhibited on a plot. Suppose one measures the transverse position of the beam centroid at two monitors that are sufficiently close to one another that intervening nonlinear fields are unimportant. Then from the linear optics between the monitors one may obtain a point in the four dimensional phase space for the beam centroid. If the two transverse axes are called x and y, then the quantities

$$a = \left[x^2 + (\beta x' + \alpha x)^2 \right]^{1/2}$$

$$b = \left[y^2 + (\beta y' + \alpha y)^2 \right]^{1/2}$$

would be invariant amplitudes for the linear, uncoupled motion with which the Courant-Snyder parameters are associated. The "smear" of the a,b plot due to uncorrected field imperfections will be used as a measure of the degradation of interpretable behavior.



Statement of Criterion

1. For initial amplitudes up to sqrt(a*a+b*b) = [_#1_] at betamax in the arcs, the smear of the a,b plot must be confined within an area of linear dimension less than [#2_]% of the initial amplitude for particles at the central momentum. The tune variation must be less than [#3_].

2. At a fractional momentum deviation of plus/minus [#4_]% from the central trajectory, the Condition 1 applies, but with amplitudes reduced to [#5_]% of the above.

3. Initial amplitudes a factor of [#6_] larger than those in Conditions 1 and 2 must be stable and not strike the physical aperture boundary.

3 PROPOSED VALUES FOR THE BLANKS

There are a total of six blanks in the three statements above. Here we propose some values to be inserted. The maximum value of the amplitude function in the standard arc cell is typically between 300 and 350 meters in the high field designs. For this value of betamax, the standard deviation of a Gaussian beam for one transverse degree of freedom is in the range 0.6 to 1.2 mm at injection depending on the choice of emittance; this first figure corresponds to the emittance used in the Reference Design Study, and the second follows from the present Fermilab nominal emittance. Because amplitudes rather than admittances are used in the criterion, appropriate scaling should be applied for other values of betamax.

The fractional momentum spread in the beam will have a standard deviation of about 1.E-4 according to the RDS. The maximum dispersion in the standard cell is about 2.5 m, so the mortgage on the aperture due to the momentum spread of the beam is somewhat less than a millimeter.

Blank 1. Suggest 7 mm. That is, the initial displacements in both x and y can be 5 mm. This figure reflects recommended operational tolerances, particularly at injection energy, rather than any subtle characteristics of the collision process.

Blank 2. Suggest 10%. This level of "smear" is consistent with both measurements and calculations on the Tevatron.

Blank 3. Suggest 0.005. This figure is small enough to make low-order resonance avoidance relatively easy when developing a, b plots, and the tune spread within the beam itself will be safely small insofar as measurements are concerned. It is possible that too many considerations are being fed into this one number. Experience may show that a somewhat more complicated statement is needed.

Blank 4. Suggest 0.1%. This is considered an adequate operational allowance.

Blank 5. Suggest 70%. The linearity of behavior will normally deteriorate somewhat as the beam moves off of the central momentum; this factor represents an allowance.

Blank 6. Suggest 40%. One would expect the dynamic aperture to be larger than the linear aperture as defined here, though the factor may be greater than 1.4.