M. Berz, K. Makino

I. INVESTIGATION OF THE "PURE" IR LATTICE PROPERTIES

→ **WHAT NONLINER TERMS ARE DOMINANT**

As observed in F. Zimmerman's work also, multiturn collisions show significant DISTORTION OF THE IP SPOT.

a 1-turn map of the 10TeV / 4TeV IR was produced to very high order with and without CHROMATIC CORRECTION showing

$p_x^2 \delta \sim 10^{-3}$ $\qquad$ $p_x^3, p_y^3 \sim 10^{-3} - 10^{-4}$

these terms will require independent, as yet undesigned, high order correction ⊕ lattice inserts

Detailed INVESTIGATION OF QUADRUPOLE FRINGE-field effects on the dynamics

Shape of the fringe fields are known from spectrography

⊕

They compare well with a detailed modeling of the fringe-fields measured/calculated in the LHC high-β quads

LHC study produced tune changes $\sim 10^{-3}$; insignificant

Severe in all muon machines

not only the COLLIDERS, the neutrino factories as well.

LARGE APERTURE ⊗ LARGE EMITTANCE

SOLUTIONS?

one hopes different poletip end designs will mitigate this effect and/or local correction schemes

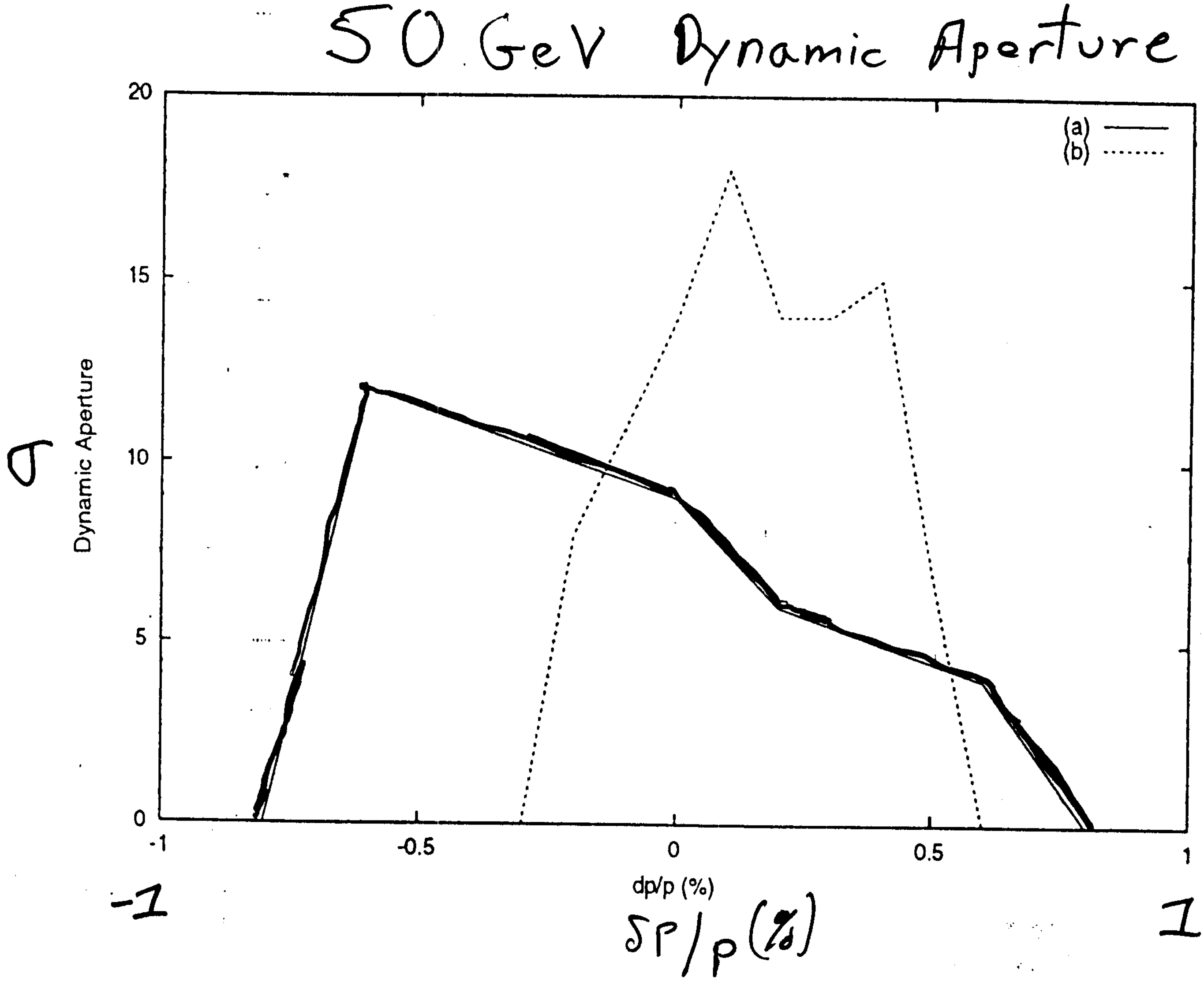
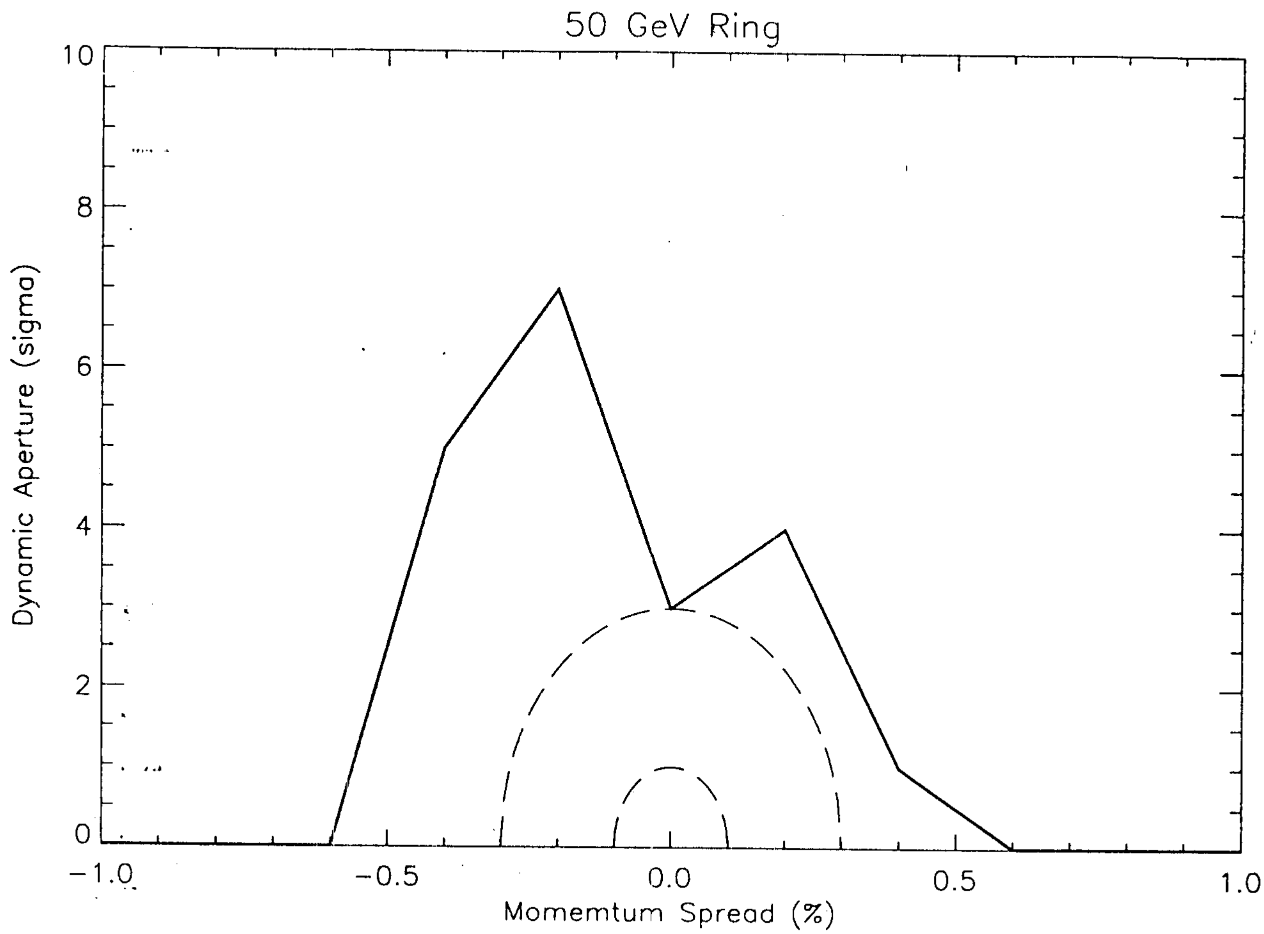


Figure 4: A preliminary dynamic aperture for the 4 cm β^* mode where σ (rms) = $82\mu m$ (solid line) and the 14 cm β^* mode where σ (rms) = $281\mu m$ (dashed line).

WAN, Johnstone



Effect of Large-Aperture IR quad end fields on Dynamic Aperture

Challenges:

- limited quadrupole strength & high beam energy

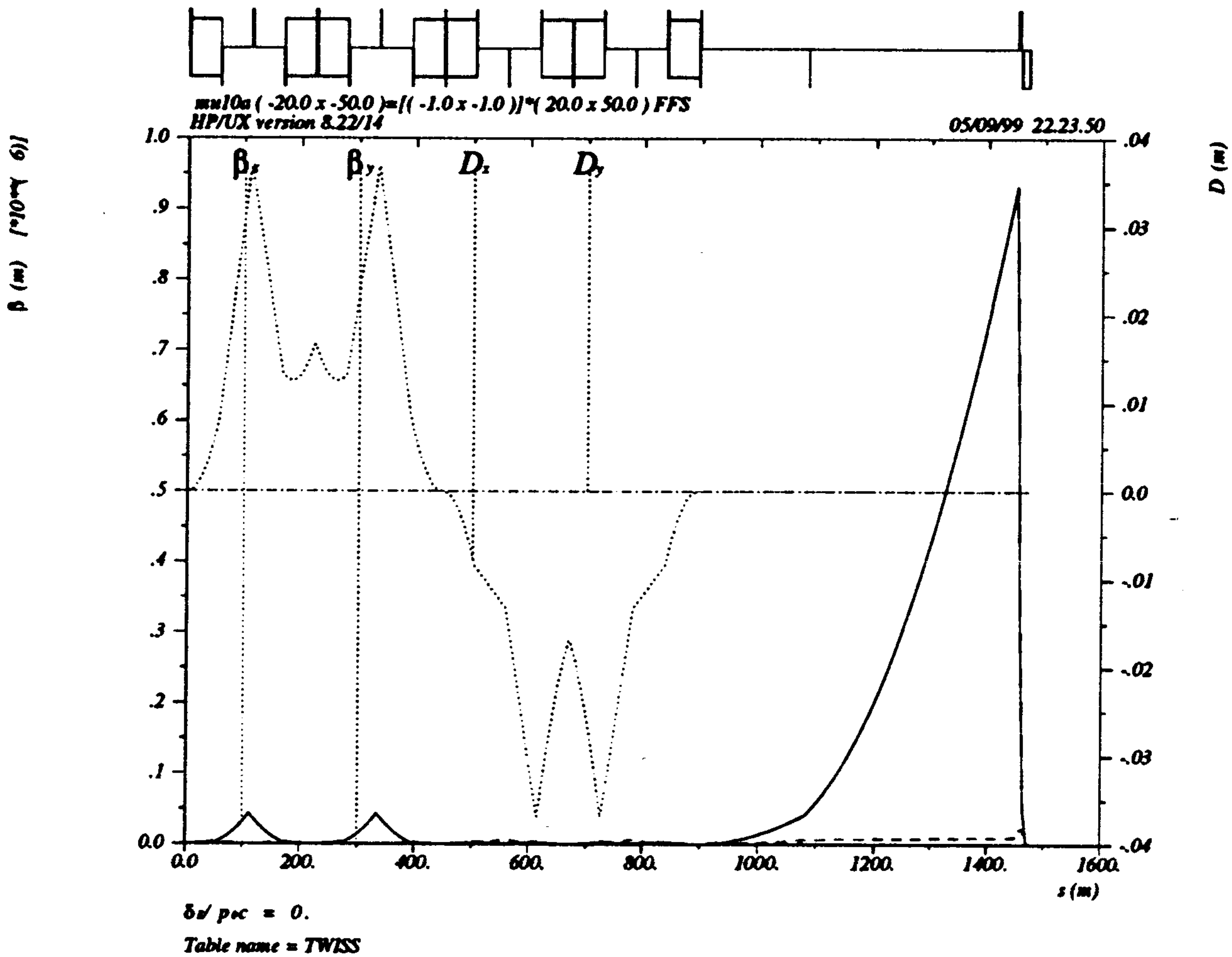
  SLC triplet: 100 T/m $\rightarrow$ 500 T/m ?

  but energy increases factor 100 or 1000!

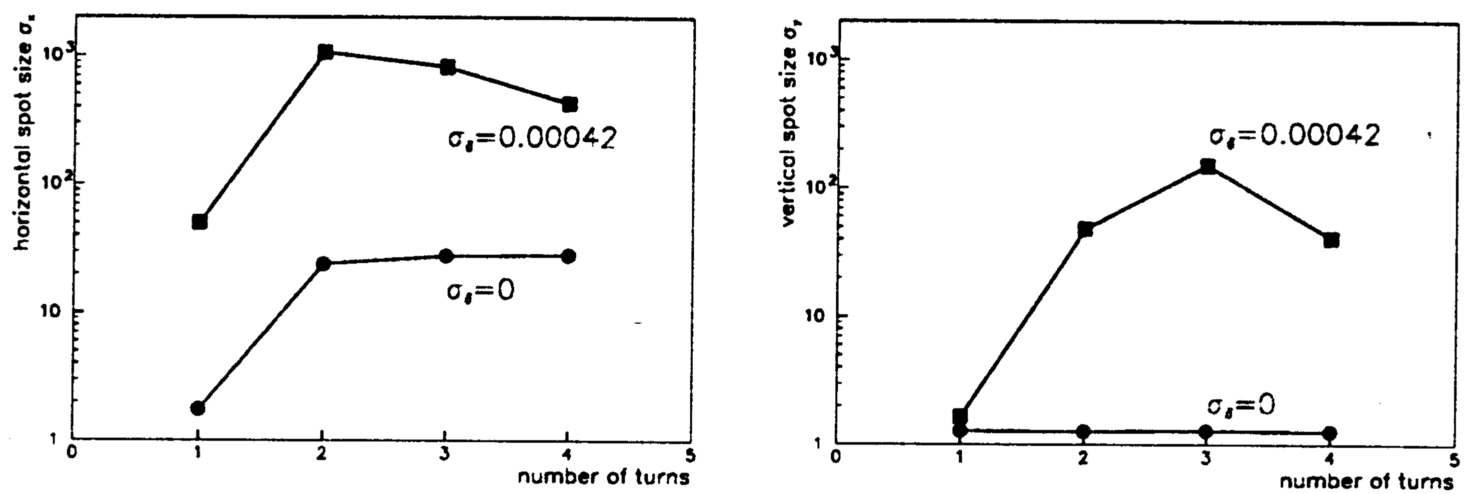
- large geometrical emittances

- high bunch charge: 20–75x SLC, 200–750x CLIC

- multiple passages



Twiss functions for a 10-TeV final focus ('10-TeV a') with a maximum quadrupole gradient of 320 T/m.



Spot size on first few turns, for optics '1-TeV c'. Blow-up for $\delta_{\rm rms} = 0$ possibly caused by imperfections of the $-I$ or of the phase advance between the sextupoles and the final doublet, and/or by a tiny mismatch between turns? Huge spot-size increase with $\delta_{\rm rms} \neq 0$, due to higher-order chromaticity?

Single-Pass Collider Option

The design of a muon ring collider at multi-TeV energies faces severe, perhaps insurmountable problems:

- neutrino radiation could limit the ring collider to energies below a few TeV;
- beam has to survive hundreds of passes through a final-focus system more challenging than that of the SLC, retaining the same constant emittance. Non-trivial!

Similarily, several difficulties lie in the way of electron-positron linear colliders at multi-TeV energies: beamstrahlung, coherent pair creation at high Υ, and associated degradation of the luminosity spectrum and large background.

single pass parameters

10 TeV

$N_b = 3 \times 10^{12}$

$f_{rep} = 27$ Hz

$\mathcal{L} = 10^{36}$ cm^{-2} s^{-1}

needs $\sigma_{x,y} = 44$ nm

e.g. $\beta^*_{x,y} = 25\ \mu m$, $\sigma_z \lesssim 25\ \mu m$

$\gamma \varepsilon_{x,y} = 3.8\ \mu m$

100 TeV

$N_b = 8 \times 10^{11}$

$f_{rep} = 7.9$ Hz

$\mathcal{L} = 10^{36}$ cm^{-2} s^{-1}

needs $\sigma_{x,y} = 6.3$ nm

e.g. $\beta^*_{x,y} = 25\ \mu m$, $\sigma_z \leq 25\ \mu m$

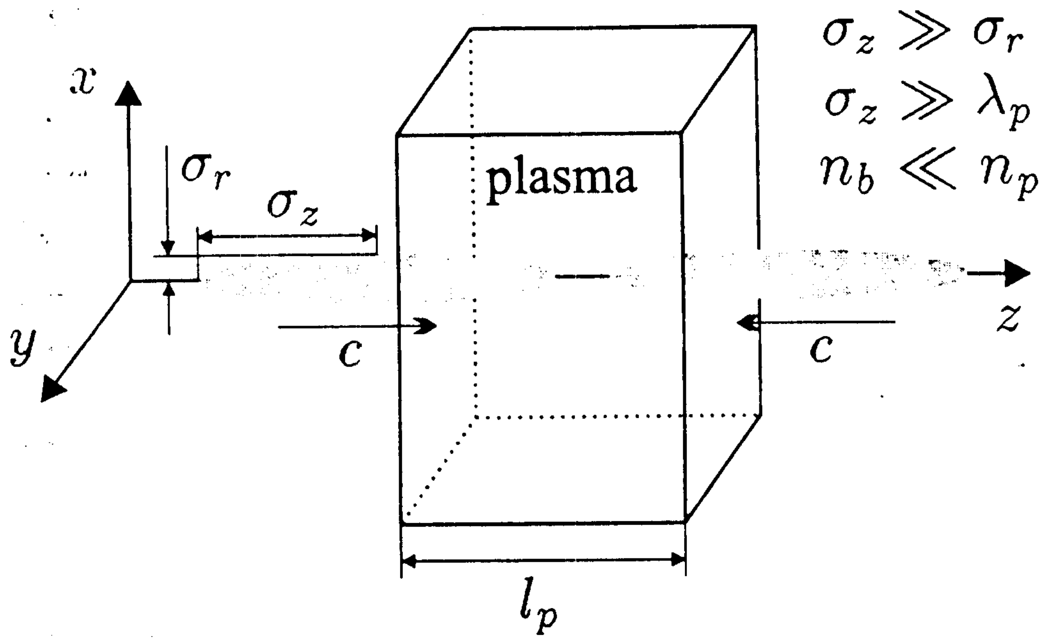
$\gamma \varepsilon_{x,y} = 0.9\ \mu m$

Conclusions

- 1-turn final-focus optics not trivial due to limited quadrupole strength and large emittances; possible cures: plasma lenses, dynamic focusing, advances in high-field magnets...? cooling
- multiple passages imply many additional challenges concerning spot-size stability, tolerances, tuning,...
- single-pass collider à la CLIC is one option which avoids these last (and other) problems and could achieve a high luminosity

What is plasma compensation

The beams induce charges and currents in plasma, which locally compensates the charge and current of the beams:



"Bad" features of the plasma are possibly not so bad for a muon collider:

! no reduction of beam lifetime (short-lived μ),

! beam density $\ll$ electron density in solids (lithium jet),

? background.

Conclusion: further steps for theorists

+ Various models of plasma response are developed.

+ First notion of plasma capabilities is obtained.

? Background.

? Transverse beam stability.

? Interplay of beam-plasma and beam-beam instabilities.

? Multiple lithium ionization.

? Ion dynamics.

? 2d and 3d simulations.

V. Telnov

On problems in plasma suppression of beam-beam interactions at $\mu\mu$ colliders

Conclusions:

1. Background from photonuclear reactions is very (too) large.

2. In consideration of plasma suppression a transverse growth of „return" current due to scattering (finit conductivity) should be taken into account.

   Preliminary estimations show that this effect put very serious limitations on possibilities of the plasma suppression of b.-b. interaction (works only for rather large σ_x)

Initial Stage: Linac

- Large longitudinal emittance
  - Large relative energy spread at low energies
  - Arcs difficult
- Large losses at low energies: don't waste time in arcs
- Linac relatively short
- Design based on matching beam to RF bucket in adiabatic approximation
  - Bucket area determined by emittance: adjust phase to fill bucket
  - Switch frequency to get higher gradient
    - ⋆ Higher frequency, larger gradient
    - ⋆ Higher frequency, further off crest
  - Adiabatic approximation wrong with these gradients: probably good initial guess

Recirculating Linacs

- Go through same linac several times
- Increase efficiency (average power): more turns better
- Muons can be bent
- Size determined by largest energy
  - Minimize decays: smaller recirculator for lower energies
  - Lower energies, low frequency RF required: switch to allow higher RF frequency
    - ⋆ Better gradients
    - ⋆ Easier to get RF power
    - ⋆ Better efficiency
- Different types of arcs

- FFAG
  - Fixed-field magnets
  - Accept large range of energies in one arc
    - ⋆ As much as factor of 4 or more
    - ⋆ Large fraction of quadrupoles
    - ⋆ Arc length longer: average bend field smaller
  - Only one arc
    - ⋆ Can't control map turn-by-turn
      - ➢ Can't synchronize with RF phase
      - ➢ Longitudinal dynamics different for each pass
      - ➢ Only matched into straight for one energy
      - ➢ Chromaticity uncorrected
      - ➢ Potentially fix with ramped NC magnets: high energy only
  - Accepts large energy spread in beam for free
    - ⋆ In multiple arc scheme, some low energy arcs require this type for only one turn
  - Potentially combine with fast ramping scheme: get extra degree of freedom from ability to ramp?

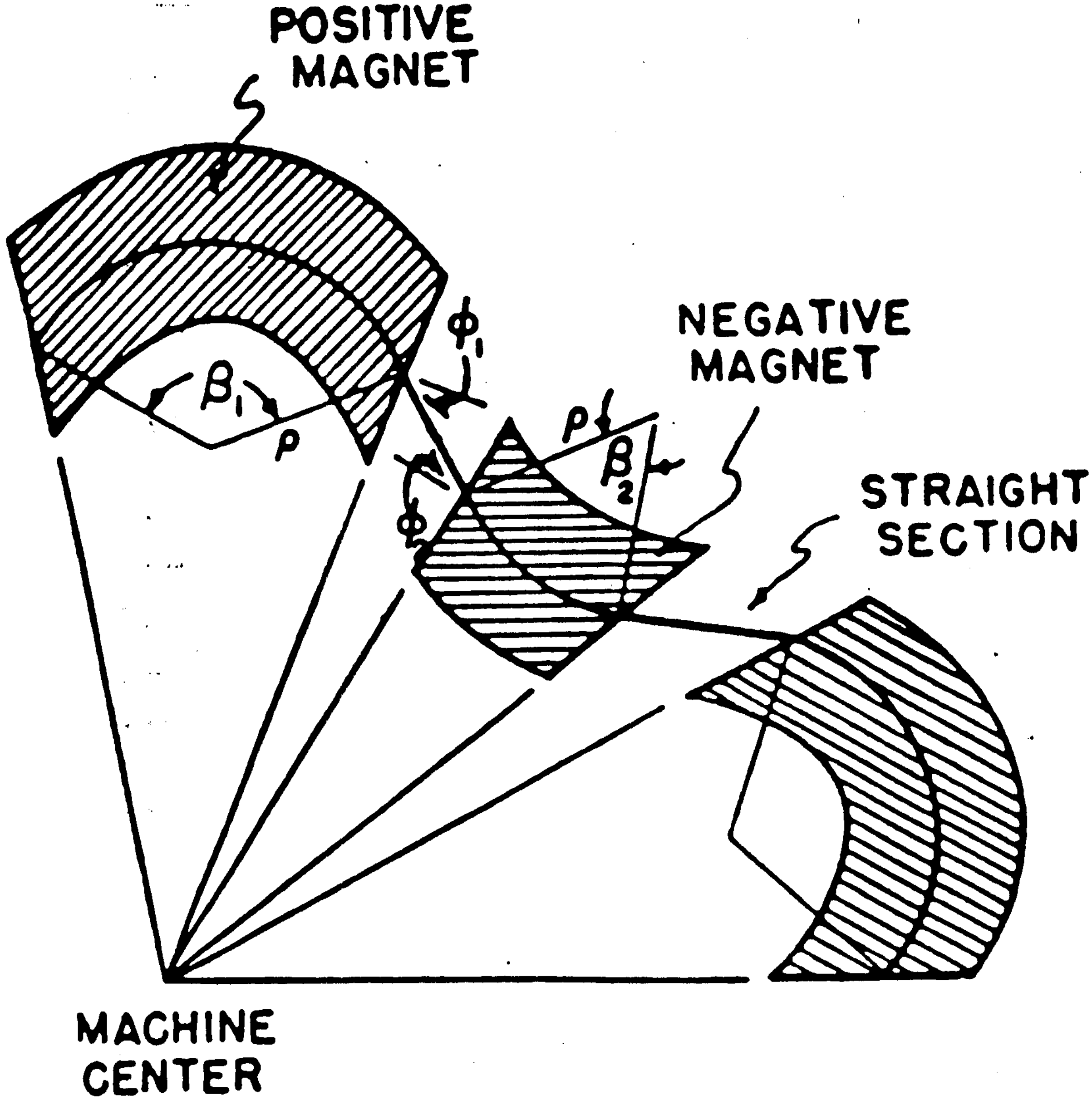
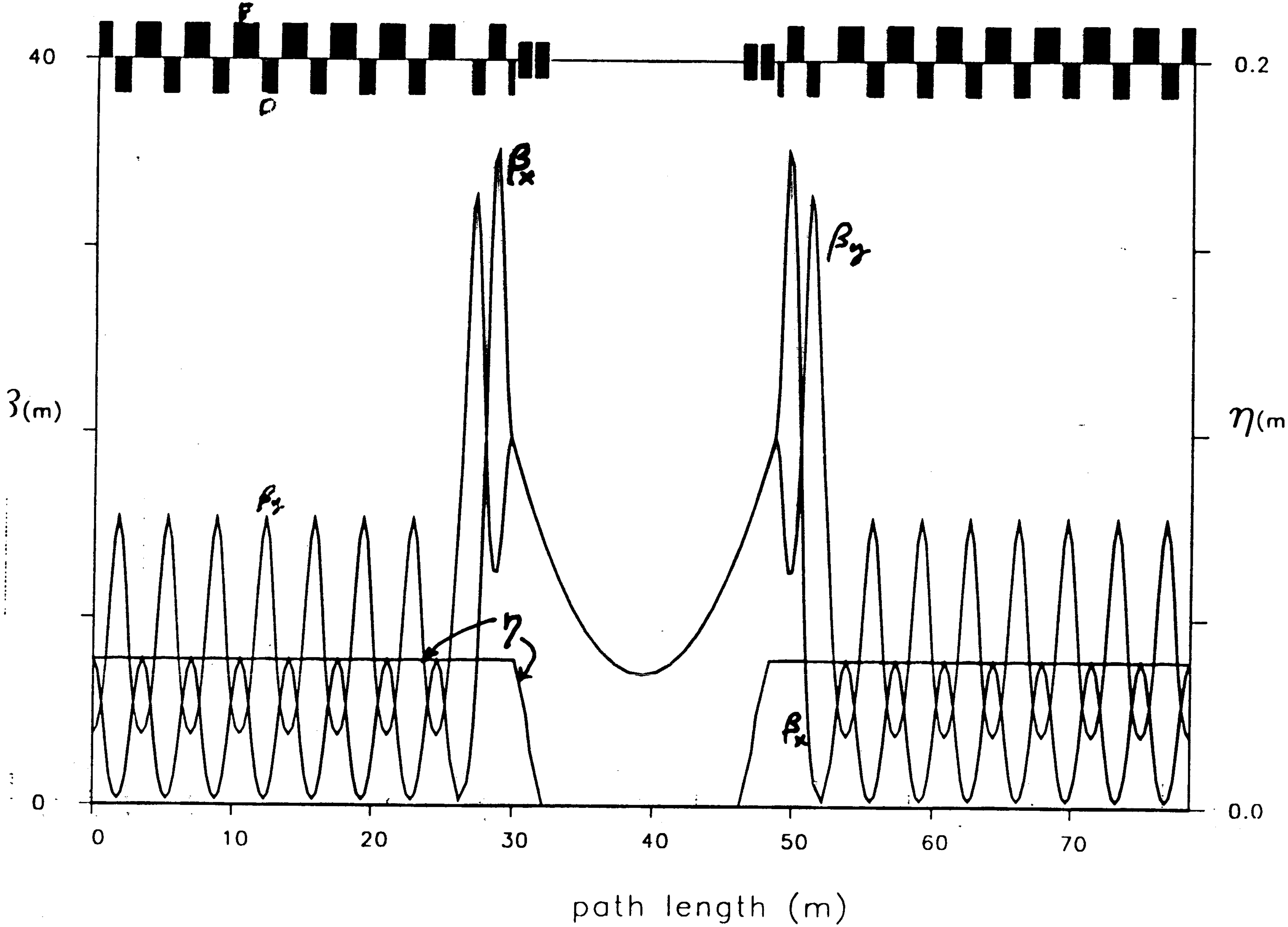


FIG. 7. Equilibrium orbit notation for radial sectors with straight sections.

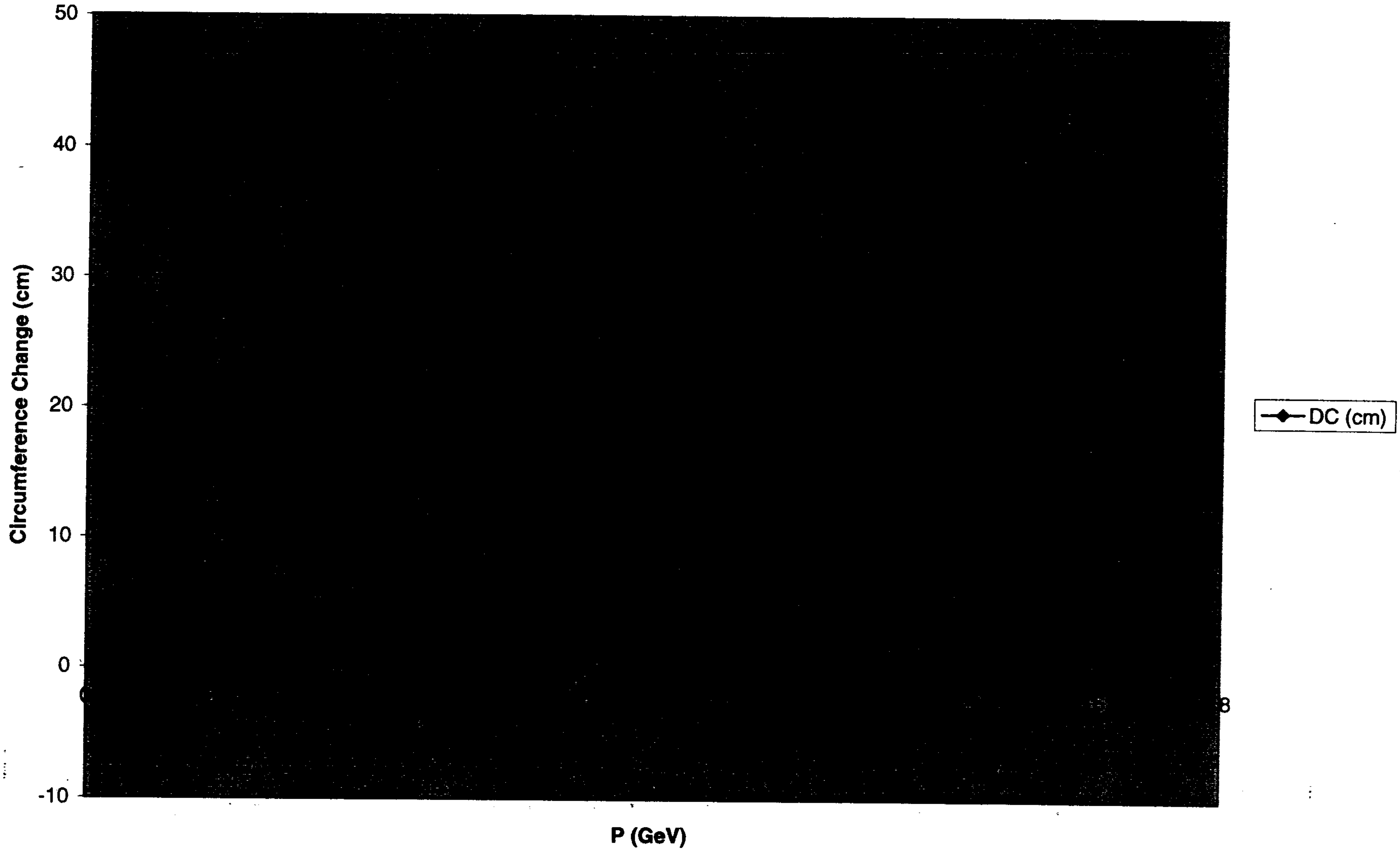
SECTOR (1/16 OF RING) WITH FODO CELLS
AND STRAIGHT SECTION INSERTION



Performance Parameters

Injection energy	Ei	16	GeV
Central energy	Eo	40	GeV
Extraction energy	Ef	64	GeV
Radial displacements	xi	-3.6	cm
	xo	0.0	
	xf	1.8	cm
Radial spread in straights	dxs	0.8	cm

Circumference Variation vs P in 4-16 GeV FFAG



Momentum Compaction vs P for 4-16 GeV FFAG