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CONCENTRIC AND ECCENTRIC COLLIDING BEAMS GEOMETRIES

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Recent interest in alternate colliding beams methods[1] suggests that the following geometry, originally discussed last year, be given wider circulation. Not that this is the best possible way of using colliding beams, but it is hoped that discussion of the virtues and drawbacks of this system may lead to broader examination of the entire problem.

The radial sector type of fixed field alternating gradient accelerator can be designed with either positive or negative momentum compaction, that is, with the maximum energy orbits on either the outside or the inside of the magnet radial aperture. Two radial sector F.F.A.G. machines, one of positive and one of negative momentum compaction, could be constructed concentric to each other, and special magnets in straight sections devised for bringing beams into

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[1] Lichtenberg, Newton, and Ross MURA-DBL/RGN/MHR-1.

collision. Beams in the two machines would be accelerated in opposite directions. With the same number of sectors in each machine, the magnets could be made as a single unit for both machines, as shown in figure 1.

A difficulty with this system is that either two R.F. systems would be needed, or that a single R.F. system would have to compromise the different R.F. programs of the different machines (almost identical at low energy, but not at higher energy).

One solution is suggested by the old Mark IV proposal[2] in which high-and low-energy orbits criss-crossed as they progressed around the machine. The difficulty with this proposal was that adequate focusing was hard to achieve. However, one might revive this concept of crossing orbits if each "magnet" consists of a sequence of F.F.A.G. sectors. A machine might be made of radial sector positive momentum compaction F.F.A.G. sectors for half a revolution, then of radial sector negative momentum compaction sectors for the other half. The design of magnets to cross the beam over between halves should not be difficult. This machine would in general have no transition energy - the circumference of all orbits would be almost the same, hence the frequency

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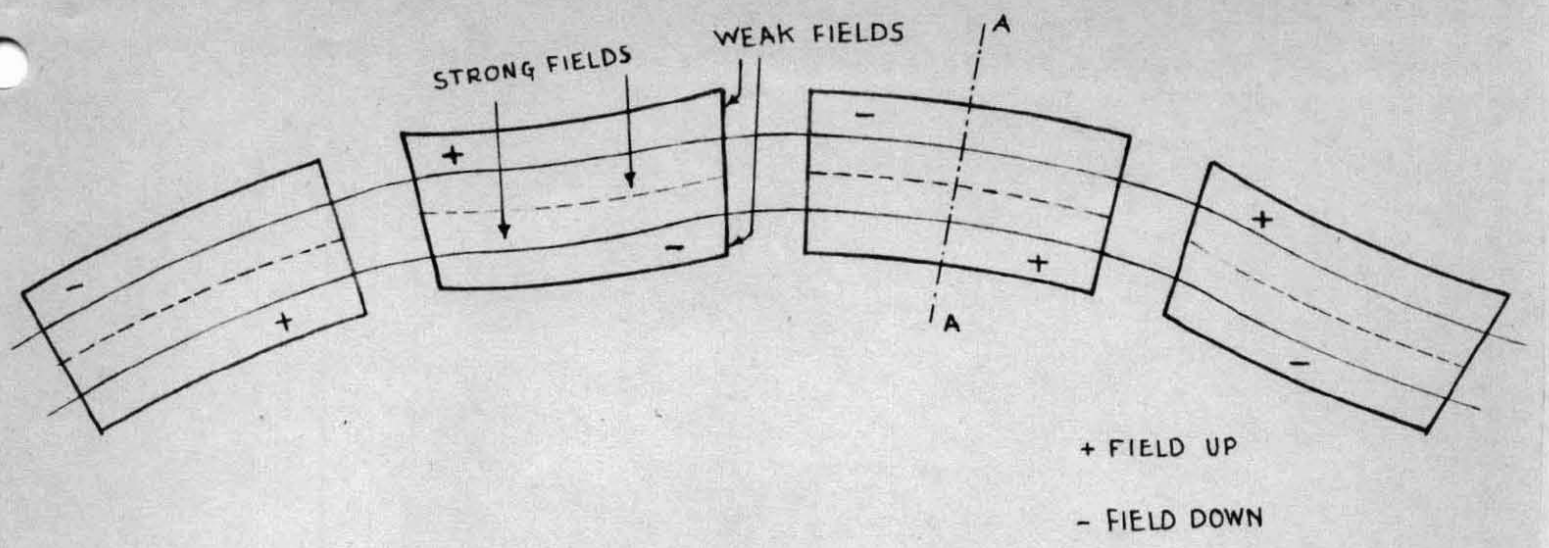
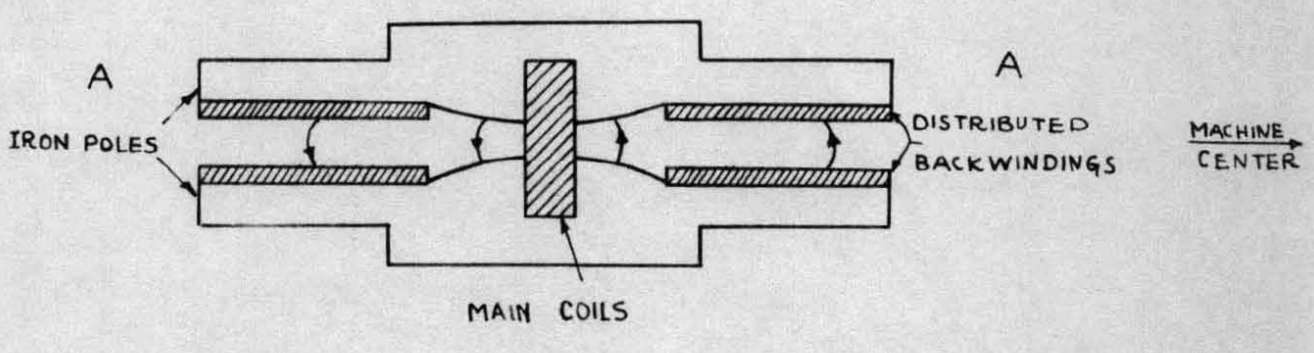
2 Michigan Working Group Notes November 3, 1954. Also discussed independently by Ohkawa.



SECTION OF CONCENTRIC MACHINES SHOWING MAGNET DESIGN



MAGNET CROSS-SECTION

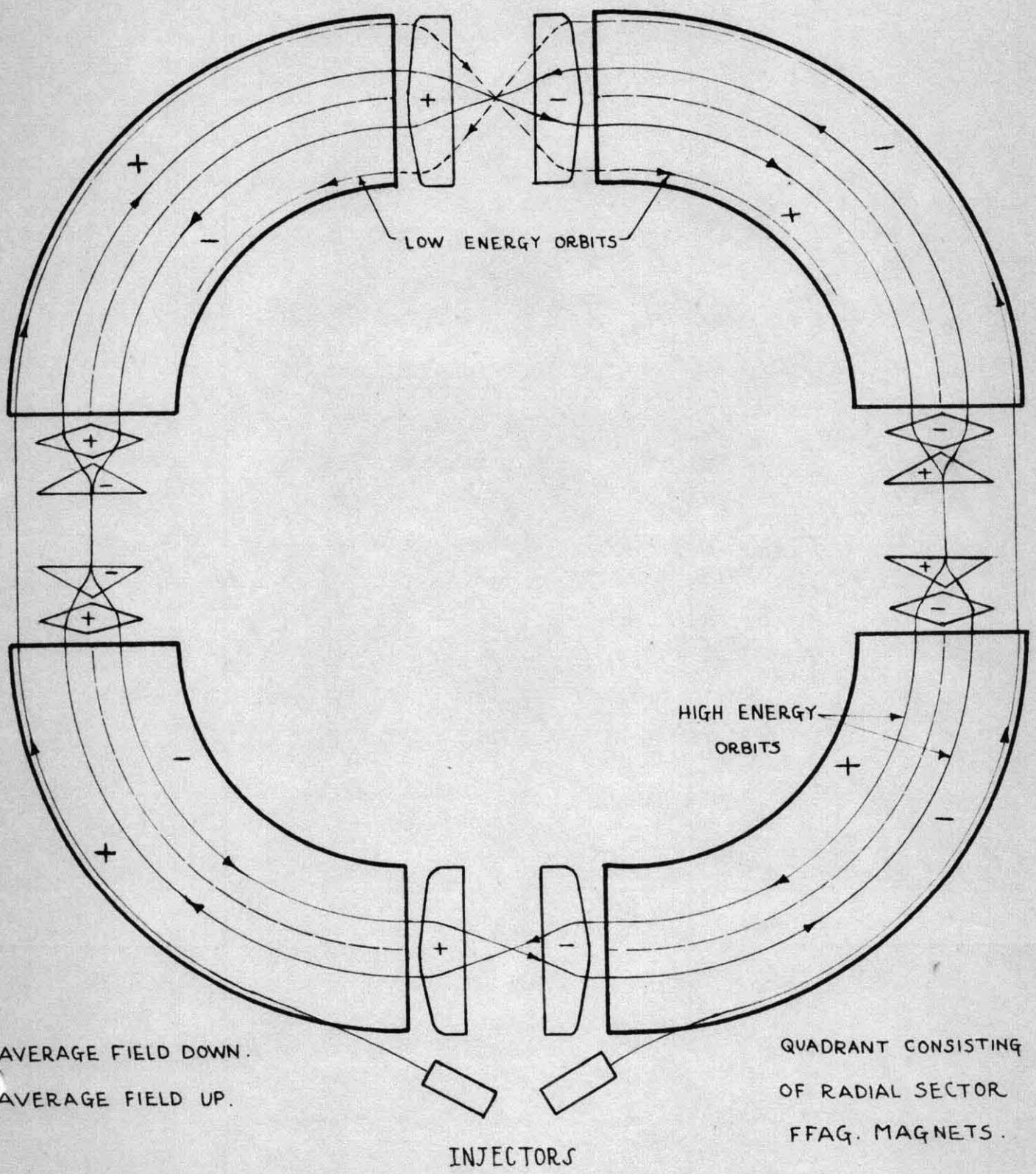
FIGURE - 1

would be almost entirely determined by the velocity of the particles. (Actually the only difference in orbit circumference would be due to different path lengths in the cross-over region.) The obvious application of this idea to a colliding beams geometry is to have two such machines "overlapping" or eccentric. Again, as with concentric machines, the magnets of both machines would be combined to single units, and the high energy orbits made to overlap in other special straight sections. Such a machine is represented very schematically in figure 2.

Here both machines, or both components of the single machine, have identical R.F. requirements. Furthermore, all orbits or both components cross in a region of relatively small radial aperture.

This makes possible a single R.F. cavity for both accelerators which need have an aperture only determined by the amplitudes of injection oscillation (about 30 x 30 cm) rather than the radial aperture of the machine (3 to 5 meters). Of course the beams could be made to cross the recross many times, (instead of just twice as illustrated) each crossing point providing space for R.F. cavities or for colliding beams experiments. Since the beam would be attenuated almost entirely by collisions with gas molecules

FIG.2 - COLLIDING BEAM GEOMETRY USING OVERLAPPED RADIAL SECTOR FFAG.



- AVERAGE FIELD DOWN.
+ AVERAGE FIELD UP.

QUADRANT CONSISTING OF RADIAL SECTOR FFAG. MAGNETS.

rather than in flying collisions, ten or twenty intersecting beams experimental stations could be set up around the machine with no sacrifice of interaction rate at any one station.

The most obvious fault of the concentric or eccentric geometries discussed above is that they must both use radial sector-type magnets with the attendant large circumference factor. Although this is a serious disadvantage, the following numbers are given to indicate that such a device is not implausible.

The 10 Bev radial sector synchrotron proposed a year ago had the following characteristics:

number of sectors N = 64

Circumference factor C = 5.35

radius R = 100 meters

radial aperture $\triangle R$ = 2.3 meters

iron = 10,000 tons

magnet power = 5 megawats

peak field B = 20,000 gausses.

A concentric or eccentric geometry of two 10 Bev machines might have all of the above characteristics except that the magnet power would be doubled.

To scale these figures to 15 Bev, one would have for the double machine:

Radius	R = 150 meters
Radial aperture	ΔR = 3.5 meters
iron	34,000 tons
power	34 megawatts

These figures may be contrasted with the "octatron" (figure 8) geometry of spiral sector 15 Bev machines proposed by the Illinois group. The possible advantages of the radial sector eccentric geometry might be enumerated. They are:

Savings in buildings, foundations, shielding, real estate, vacuum system, and control system.

Single, simpler R.F. system for both accelerators.

Many experimental areas (2 to 20 or more) available for colliding beams.

Simpler, radial sector magnets with fewer orbit non-linearities. No transition energy.

Obvious strong disadvantages of this system are:

Poor circumference factor with corresponding attrocious magnet weights and powers.

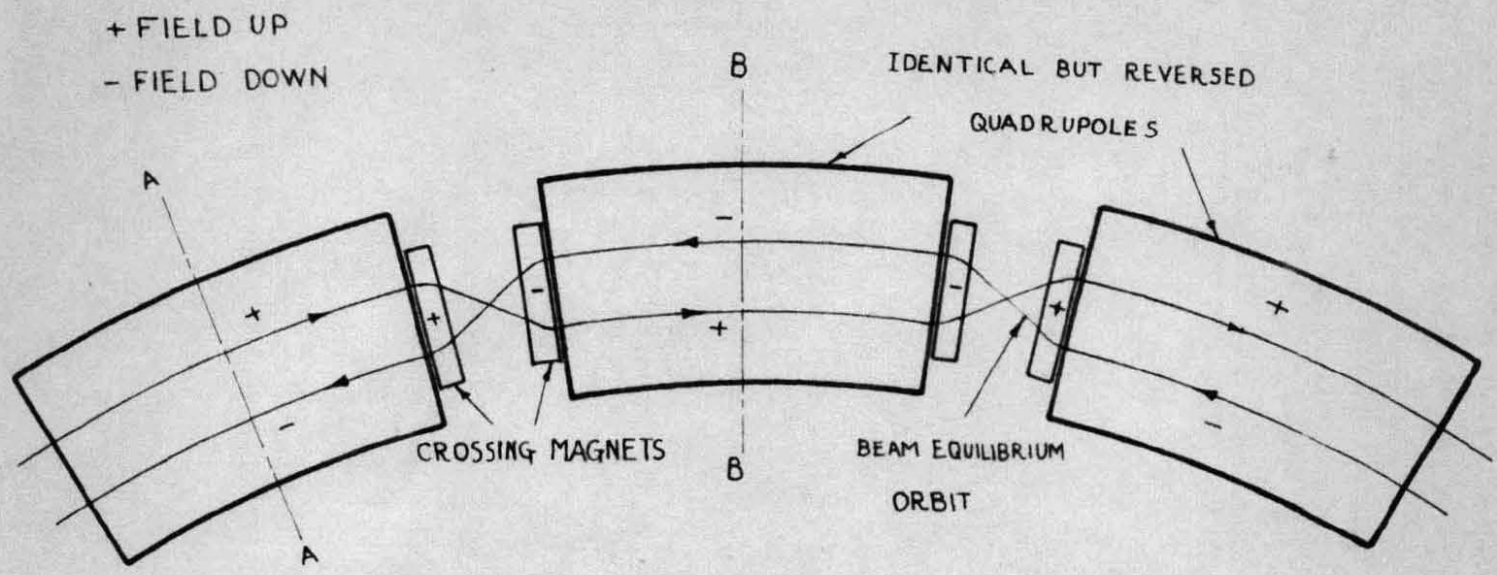
Inflexibility of the system.

Difficulty of using or extracting the beam of one machine.

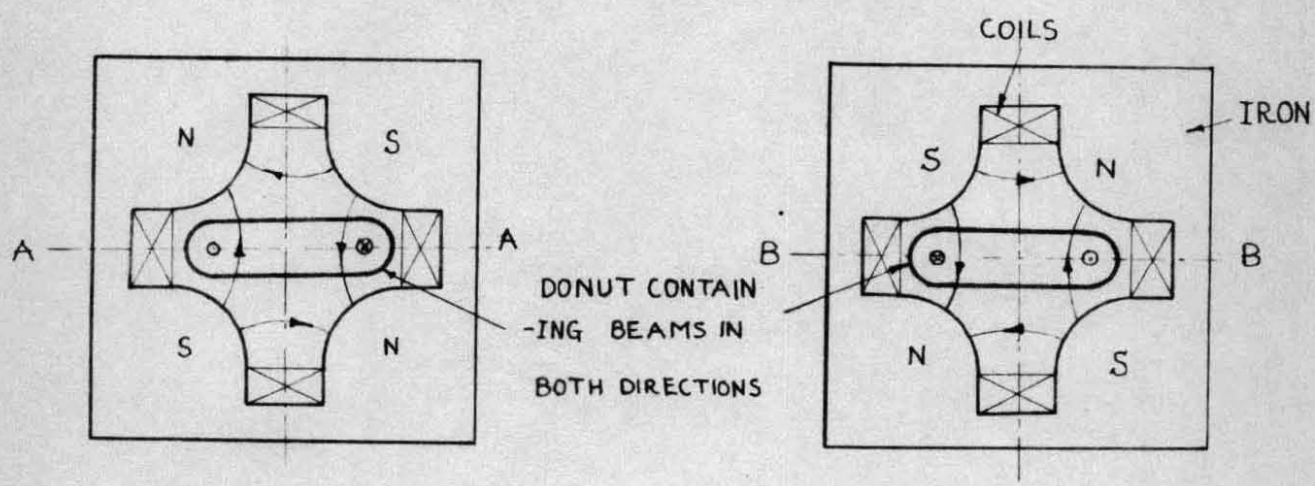
Stability problems associated with additional periodicities.

There seems with this geometry considerable incentive to try to find spiral sector smaller circumference factor designs which have negative momentum compaction.

For those whose interest is in pulsed field accelerators, if the intensity problem did not exist, there is easy application of this criss-crossing beams concept. A simple quadrupole lens might carry a beam in one direction through its gap on one side, and in the opposite direction but bending about the same center of curvature in the other gap. The next magnet around the machine could be an identical quadrupole but with its currents reversed. For the beams to still bend about the same center of curvature, beam-crossing magnets would be needed in every straight section. The beam crossing magnets could be very simple, and could be pulsed with the main quadrupoles. In order to realize the greatest duty factor for colliding beams of peak energy, the magnets could be pulsed to full energy, then switched to a D.C. source for a time comparable to the coasting beam's lifetime. Figure 3 illustrates a section of such a machine.



SECTION OF CRISS-CROSSING COLLIDING BEAMS PULSED ACCELERATOR



MAGNET CROSS-SECTION

FIGURE 3