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INTERSECTING BEAM ACCELERATOR WITH STORAGE RING

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The idea of an intersecting beam accelerator is attractive for two reasons; first, much higher energies are obtained in the center of mass system than with one beam striking a stationary target, and second, collisions are observed directly in the center of mass system. The principal difficulty is the one of achieving sufficient intensity in the intersecting beams.

The simplest idea to get beams to intersect is to build two machines which accelerate particles in opposite directions. These machines would have a common straight section along which the particles would collide. A perhaps more economical device, however, which achieves the same purpose is a single accelerator and a deflecting mechanism which causes the beam to split into two intersecting orbits. An example of such an accelerator is shown schematically in Fig. 1.

The accelerator is an FFAG machine capable of achieving intensities sufficiently high so that there will be a reasonable number of collisions in the intersecting beams. Pulses of particles are accelerated by an RF oscillator system and stacked at an intermediate orbit in the machine (shown by the dashed line in Fig. 1). This process is continued until all the available phase space is filled as densely as possible. Then this entire bucket of particles is accelerated to the

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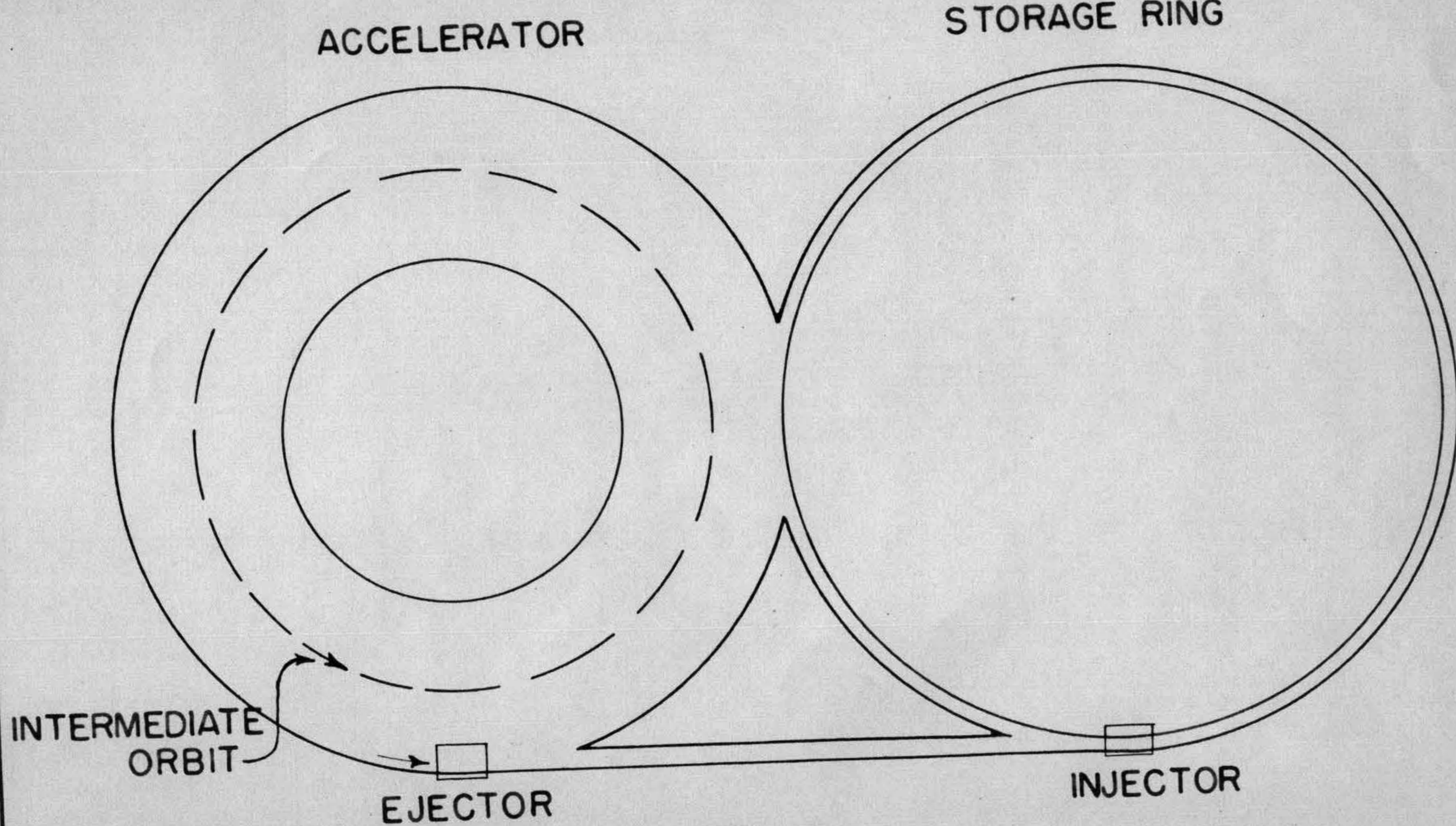

final equilibrium orbit in the accelerator. A calculation in a previous MURA report has shown that there is plenty of phase space available to achieve the desired intensity in the final orbit.

When the beam is in its final orbit in the accelerator, an ejector is turned on which deflects the beam into a straight tube leading to a storage ring. An injector is turned on simultaneously (or with a suitable small delay) which deflects the beam into a storage ring, where it circulates.

In principle, the ejector and injector can be mirror images of each other. This insures that particles can be made to circulate in a stable orbit in the storage ring, since they come from a stable orbit in the accelerator. Of course it may be advantageous to make the injector different from the ejector. Generally the injector should be turned off as rapidly as possible. The ejector is turned off before the next bucket of particles reaches the final orbit in the accelerator so that these particles continue to circulate in their final equilibrium orbit in the accelerator. They collide with the particles in the storage ring in a common straight section.

The principal savings in this scheme are that only one complete RF oscillator system is needed and that much less iron and copper are needed for a storage ring than for a second accelerator.

The additional requirements for a machine of this type are a tube (with appropriate lenses) to transfer the particles from the accelerator to the storage ring and an ejector-injector system. However, even in a conventional accelerator it is desirable to have an ejector in order to be able to obtain an external beam. Another drawback to this device is that the frequency of collisions is somewhat reduced. If the maximum current that can be made to circulate in the accelerator is I, then the current in the storage ring is $\epsilon_1 \epsilon_2 I$, where ϵ_1 and ϵ_2 are the efficiencies of the ejector and injector. Thus, the number of collisions is cut down by the factor $\epsilon_1 \epsilon_2$.* It is therefore important to design very efficient ejector-injector mechanisms.

It should be emphasized that the design shown in Fig. 1 is not the only possible arrangement for an intersecting beam accelerator. Other, more complicated paths for the beams are possible. Furthermore, the ejector and injector may be made to coincide, i.e. the ejector transfers the beam into a new stable orbit which contains the feature that it collides with itself.

We now consider briefly some possible methods of transferring particles from the accelerator to the storage ring. These suggestions have not been carefully evaluated and are only made for illustrative purposes. One possibility is to insert a mechanical lip to reduce the energy of the final beam sufficiently to cause it to pass through a local magnetic field. The magnetic field deflects the beam in the tube between the accelerator and storage ring. This scheme is shown in Fig. 2. The local magnetic field is turned on after the beam has reached its final circulating orbit and before the mechanical lip is

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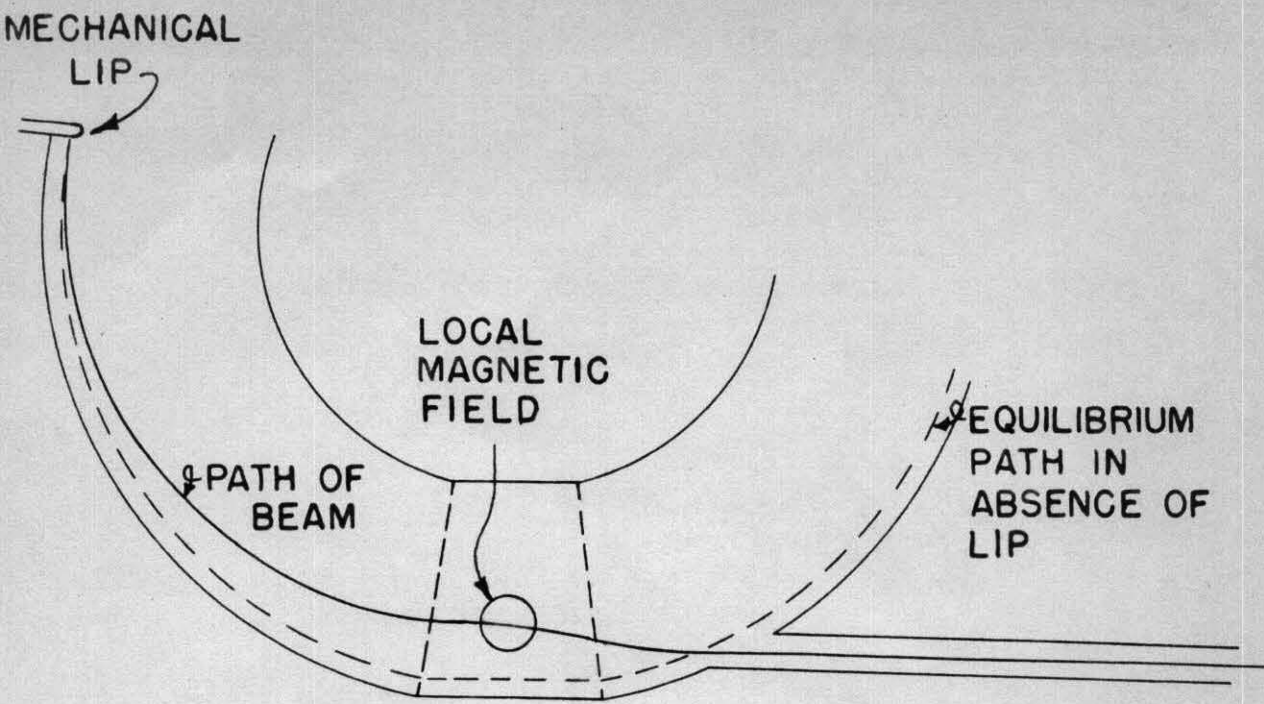
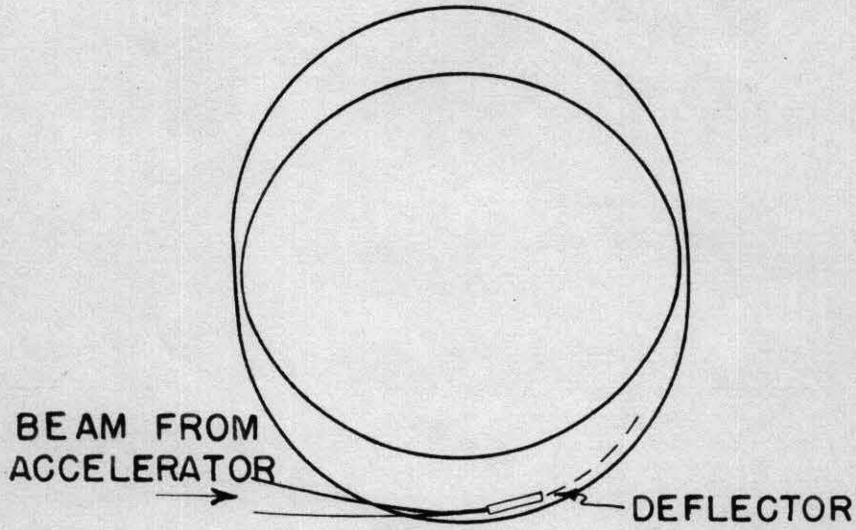
* This is true only if the time required to build up the circulating beam to maximum attainable intensity is small compared to the mean life of the beam, a condition which will probably hold for accelerators now being considered. If this condition does not hold, then the number of collisions is cut down approximately by an additional factor of $\frac{1}{4}$.



A POSSIBLE EJECTION MECHANISM TO TRANSFER BEAM TO TUBE LEADING TO STORAGE RING.



WEAK FOCUSING IN THE REGION OF THE INJECTOR inserted. There is sufficient time to do this, because buckets of particles arrive at the final orbit only once every few seconds. The injector would consist of another local field, lip and a small RF oscillator. This RF is needed to further reduce the energy of the particles in the storage ring so that they do not continually strike the injector lip.

Another possible method is to use a long (a meter or longer) parellel plate capacitor to deflect the beam. If the plates are aligned above and below the beam, they can be installed permanently. Then when the voltage is turned on, the beam is given an upward deflection, passes through a hole in the iron, through the connecting tube, and into another high voltage capacitor which deflects the beam into the storage ring. If the capacitors can be synchronized properly and pulsed quickly enough (perhaps an impossible task), the beam will not see the voltage the second time around in the storage orbit (thus lips are unnecessary). This device will avoid the need for an RF oscillator in the storage ring.

Alternatively, the capacitors can be arranged to give the beam a radial deflection, but then an inner plate may have to be inserted mechanically in the accelerator. The operation of deflecting mechanisms is necessarily more complicated in a strong focusing machine than in conventional synchrotrons where they have been quite successful. In this connection some shaping of fields may make the deflection mechanism practicable. For example, in the storage ring time can be gained for shutting off a vertical field electrical deflector by having the beam defocused in the region of the deflector (e.g. Fig. 3).