production of mesons by a cascade process. All the tracks appear to be of the same age. The tracks in Group 1 have originated outside the chamber; the other two groups have originated within the chamber. The left-hand track of group 2 is absorbed in the lead plate (2.2 cm), and its energy is $<4\times10^7$ ev. The four tracks in group 3 appear to start as a pair which is doubled again. These tracks are not appreciably scattered during their traversal through the lead plate, but they have produced knock-on electrons.

BURST PRODUCTION

One of us (M.S.)[7] has recently published a photograph of a burst originating in the gaseous volume of a Wilson chamber. It appears to start as a number of ionization strands, diverging from a small region, which subsequently broaden and merge into a dense volume of ionization. A possible interpretation of the burst according to I is as follows: A high energy proton has by a process of nuclear collision given rise to a cascade production of fast vector mesons. The latter have within a short length disintegrated into high energy electrons, from which several cascade showers have started.

The above theory enables us to correlate and interpret many findings on penetrating particles obtained from Wilson chamber photographs and from tracks on photographic plates. A detailed comparison between the predictions of the theory and our findings will be given elsewhere.

[7] M. Sinha, Phys. Rev. **64**, 248 (1943).

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Letter to the Editor

PROMPT publication of brief reports of important discoveries in physics may be secured by addressing them to this department. The closing date for this department is the third of the month. Because of the late closing date for the section no proof can be shown to authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents. Communications should not in general exceed 600 words in length.

On the Maximal Energy Attainable in a Betatron

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BY means of a recently constructed induction accelerator-betatron, Kerst succeeded in obtaining electrons up to 20 Mev.[1] The principle of operation of the betatron is the acceleration of electrons by a tangential electric field produced by a changing magnetic flux, which is connected with the magnetic field keeping electrons on the orbit by a simple relation. In contrast to a cyclotron, whose applicability is essentially limited to the non-relativistic region on the ground of defocusing of orbits due to the change of mass at high energies, there is no such limitation for the betatron.

We may point out, however, that quite another circumstance would lead as well to the existence of a limitation for maximal energy attainable in a betatron. This is the radiation of electrons in the magnetic field. Indeed, electrons moving in a magnetic field will be accelerated and must radiate in accordance with the classical electrodynamics. One can easily see that quantum effects do not play here any important role as the dimension of the orbit is very great. As was shown by one of us[2] an electron moving in a magnetic field $\mathbf{H}$ radiates per unit of path the energy

$$-(dE/dX)=2/3(e^2/mc^2)^2(E/mc^2)^2[(\mathbf{V}/c)\mathbf{H}]^2 \qquad (1)$$

where e is the charge, m the mass, $\mathbf{V}$ the velocity, and E the energy of the electron; E is assumed much greater than mc^2.

In the betatron $\mathbf{V}$ is normal to H and practically for the whole path equal to c. Then we have

$$-(dE/dX)=2/3(e^2/mc^2)^2(EH/mc^2)^2. \qquad (2)$$

The limiting value of energy E_0 is to be determined from the condition that the radiated energy (2) will be equal to energy gained by the electron in the electric field produced by magnetic flux per unit of path:[3]

$$\frac{2}{3}r_0^2\left(\frac{E_0H}{mc^2}\right)^2=\frac{e|d\phi/dt|}{2\pi R_0c}=\frac{e}{c}R_0|\dot{H}| \qquad (3)$$

$$\dot{H}=dH/dt \qquad r_0=e^2/mc^2.$$

Here R_0 is the radius of the orbit, ϕ is the induction flux.[1] Hence:

$$\frac{E_0}{mc^2}=\left(\frac{3eR_0}{2r_0^2c}\frac{\dot{H}}{H^2}\right)^{\frac{1}{2}}. \qquad (4)$$

Taking for H and E the values now being in use we get $E_0\approx5\times10^8$ ev, which is only five times as great as the energy which one expects to obtain in the betatron now under construction. From (4) one sees that E_0 is inversely proportional to the magnetic field applied and proportional to the square root of energy gained in the rotation electric field per unit of path. All this requires the using of smaller H or of higher frequencies with the purpose of getting higher limiting values of E_0.

The radiative dissipation of energy of electrons moving in a magnetic field must be also of importance for the discussion of the focusing of the electronic beam, as the energy of particles being accelerated will grow more slowly with the growth of H if the radiation is taken into account. This latter question may deserve a separate discussion.

[1] D. W. Kerst, Phys. Rev. **61**, 93 (1942).
[2] I. Pomeranchuk, J. Phys. **2**, 65 (1940).
[3] D. W. Kerst and R. Serber, Phys. Rev. **60**, 53 (1941).