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PROPOSED RADIOFREQUENCY SEPARATOR

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ABSTRACT

A radiofrequency separation is discussed.

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Present particle separation schemes usually make use of crossed electric and magnetic fields to selectively deflect particles of the same momentum but different velocities. In these devices the difference in the transverse momentum Δp_t per unit length imparted to the particles is given by

$$c\Delta p_t \quad 1.5 \times 10^{-2}\, B \frac{m_2^2c^2 - m_1^2c^2}{p^2} \; ; \; (1-\beta \ll 1), \qquad (1)$$

where m_1 and m_2 are the masses of the two particles and p is their momentum; Δp_t is in units of Mev/c per meter of separator and B is in gauss. One can see that these devices decrease in effectiveness rapidly with increasing momentum.

On the other hand, an r-f separator, combined with a beam that is bunched at the production target into pulses whose length is short compared to the r-f wavelength in the separator, can be adjusted to give a Δp_t that is independent of the particle momentum ($\beta \approx 1$).

Suppose we wish to separate K- and π-mesons of the same momentum. We also suppose that the unseparated beam is pulsed at some high frequency. If we use an r-f separator, the drift space between the production target and the separator should be long enough to allow the two particle bunches to separate by a quarter of the wavelength of the separator r-f. For π's and K's this drift space D is given by

$$D = \frac{\lambda}{2}\left(\frac{p^2}{m_K^2c^2 - m_\pi^2c^2}\right) \; ; \qquad (1-\beta \ll 1), \qquad (2)$$

where λ is the r-f wavelength, m_K and m_π are the particle rest masses, and p is their common momentum. For a 3000-Mc r-f system and 10-Bev/c particles,

$$D \approx 20 \text{ meters.} \tag{3}$$

The decay length for charged K-mesons at this energy is about 60 meters.

An r-f beam deflector which can give a transverse momentum of 1 Mev/c to particles with $\beta \approx 1$ has been built at Stanford.[1,2] The device is a standing-wave cavity operating in a transverse magnetic mode at 3000 Mc. The cavity requires 1 Mw of r-f power, is 2-in. long, and has a beam aperture of about 1 x 1.5 in.[2] Table I describes the properties of this device. If we duplicate this gadget enough times, we have a beam separator.

If we want to give our 10-Bev/c π's and K's an angular separation of 4×10^{-3} radian (this number is chosen arbitarily), we need 40 cavities. The length of the separator is then 80 in. The total power required is 40 Mw, which is prohibitive for a beam with a very large duty cycle but is not too difficult for very short beam pulse. For example, the klystrons that power the Stanford linear accelerator deliver 20 Mw each for a pulse a few microseconds long. Two such klystrons could power the separator described above, but only for a short pulse.

This deflection method can also be used to produce the required pulsed unseparated beam. If the external proton beam of an accelerator was passed through such a device, it could then be deflected on and off a small target at the r-f frequency of the deflector. This entails some loss in intensity since the target does not intercept the whole primary beam. As before, this system is useful, with presently available r-f power sources, only for a beam pulse of the order of a few microseconds duration.

TABLE I. Parameters of TM_{012} cavity

Frequency	2856 Mc/s
Q	30,000
Peak Power	1.3 Mw
$E_{max}P^{-1/2}$	5.6×10^7 volt-meter^{-1} -megawatt$^{-1/2}$
$B_{max}P^{-1/2}$	2.1×10^3 gauss-megawatt$^{-1/2}$
Transverse impluse to relativistic electron:	
Theoretical	2 Mev/c(Mw)$^{1/2}$
Experimental	0.9Mev/c(Mw)$^{1/2}$
Aperture	2.5 x 3.7 cm
Length	5 cm
Pulse length	10 μsec
Repetition rate	60 pulses / sec

The complete scheme would, then, require two deflectors with miscellaneous bending magnets and quadrupoles strewn about. The solid angle available through the separator would be of the order of the separator aperture divided by its length squared, or about 10^{-4} steradian. The pulsed power required is very large, but power sources are available to supply it for the short pulses used by bubble chambers.

No attempt has been made here to optimize the parameters for the most efficient separator. The device described uses components which have been built and are working now. This merely serves to show that the high-frequency separator with its short drift space is a practical device, at least for use with bubble chambers. For this type of device to be much use with counters, power sources are needed that can stand longer pulse lengths than present ones.

REFERENCES

1. W.K.H. Panofsky, "A mass-sensitive deflector for high-energy particles," High-Energy Physics Laboratory internal memerandum HEPL-82, May, 1956(unpublished); W.K.H. Panofsky and W.A. Wenzel, Rev. Sci. Instr. 27, 967 (1956).

2. P.R. PHILLIPS, "Interim report on microwave deflection techniques," High-Energy Physics Laboratory internal memorandum HEPL-171, June, 1959 (unpublished).