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RF SEPARATED BEAM OF LONG DUTY CYCLE (20-50 GeV/c)

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ABSTRACT

A separated beam of K mesons (20-40 GeV/c momentum) and of antiprotons (20-47 BeV/c) is discussed. This beam, designed for target-area 2, incorporates normally conducting rf separators operating at a frequency of 8 GHz (X-band) at a duty cycle of 33% as required for counter/spark-chamber detectors. Superconducting separators would be preferable but they may not be available in 1972, and a brute-force solution exists for this beam. At a momentum bite of only 0.1% the available K-meson and antiproton intensities are so large that a detector system limited to 10^6 beam particles per second could not handle them unless the separator is employed to remove the π meson or proton background.

The rf separated beam to be described provides 20-40 GeV/c separated K mesons and antiprotons between 20 and 47 BeV/c momentum in Area II with a duty cycle (~33%) appropriate for counter and spark-chamber systems. These momentum pass-bands join onto regions to be investigated at BNL in bubble chambers (up to 20 BeV/c K^-), and they will overlap some of the energies possible at the Russian 70-GeV accelerator. The bands also roughly center on the regions of optimum available K-flux at the 200-GeV accelerator.

The beam emerges at an angle of 15 mrad from a 4-cm long tungsten target of 1×1 mm^2 cross section. The viewing angle widens the target, horizontally, to 1.6 mm maximum, but for purposes of momentum resolution the target width remains 1 mm full width at half maximum.

We assume that the beam will be equipped with a normally conducting rf separator, operating at a frequency of 8 GHz with a 33% duty cycle. The technical feasibility of this approach is demonstrated in a separate note.[1] This assumption is made to demonstrate that a very useful separated beam is feasible at the start of experimental operation in 1972, regardless of the availability of the superconducting device (which would, of course, be much preferred). The separator employs three deflectors (~ 7 meters long each, with a circular beam hole ~ 1.5 cm diameter), which are spaced along a drift length of $L = 115$ meters. It is polarized to separate in the vertical plane. Typical momentum band pass characteristics have been calculated, for instance, in J. Lach's analysis[2] at the Berkeley Summer Study. The choice of drift length L and frequency implies a certain maximum kaon momentum K_{max}. Kaons can be separated between 0.5 K_{max} and K_{max}, antiprotons between 0.5 K_{max} and 1.2 K_{max}. At the lower and upper momentum limits the separator control problems become difficult, and the yields cut off sharply because of decay losses or limits in the separator deflector fields, respectively.

The optical system accepts a solid angle of 5×10^{-6} sterad, a limit which is set by the congestion of beam elements at the upstream end of target-area 2. With the assumed target sizes (1 mm vertically, 1.6 mm horizontally) the beam acceptance is about what can be matched into the optimum acceptance of the deflectors. This optimum match can be accomplished with a target image at the deflector, with horizontal and vertical magnifications $m_k \approx 3$ and $m_v \approx 5$. The dispersion should be cancelled in the deflectors (position and angle) to minimize the beam size. The momentum resolution in this beam is 0.1% for a bending angle of 0.1 radians.

The conceptual design of the beam optics is shown in Fig. 1. Detailed ray tracing has not been done, but the various rf beam designs of the CERN/ECFA groups[3] and the BNL design[4] have served as a model. After momentum analysis and recombination, the beam is matched from one deflector into the next by alternating gradient channels (quadruplets) of simple design. At the beam stopper the angular separation of particles has been converted to a spatial one. The unwanted particles can be intercepted on the beam axis while ~50% of the wanted ones pass above and below the stopper. A high quality momentum analysis section follows to clear out particle debris coming from the stopper.

The beam is 280 m long. In the physical layout standard 10-cm quadrupoles (3-m long, 15-kG pole-tip field) and standard bending magnets (3-m long, 20-kG field) have been assumed. The beam requires two lens triplets (upstream and downstream), two doublets, two quadruplets (between deflectors), and a singlet field lens (at the first momentum-analysis slit). At each of the three bend points we assume 9 m of bending magnet (3 units) to give a bend of 0.1 rad at 50 GeV/c. The lenses are excited so conservatively at 50 GeV/c momentum that many of them need be only half as long. The design could easily incorporate a branch at the last momentum analysis bend, but the beam might then become somewhat longer than 280 m because separation between experiments would have to be ~ 10 m.

Figure 2 shows particle yields at the detector.[5] A stopper loss of 50% is assumed and decay losses are included. Otherwise the estimates do not include flux sacrifices which may become necessary for the sake of beam purity (typically factor of 2). Angular lens aberrations in the AG channels between the deflector have been studied in detail and this part of the transport is actually optimized with respect to chromatic aberrations. With a full momentum bite of 2% the aberrations of the image will be large enough to require a flux sacrifice of 50% to achieve reasonable purity, so one should not run the beam with more than 1% momentum bite.

The yields are limited by the upstream lens apertures at lower momenta and by the separator field at the upper momenta (see Fig. 2). A superconducting separator could improve yields by perhaps a factor of two. It would make the beam more resilient against problems of optical alignment and of beam purity: the deflector could be shorter thus easing the matching tolerances, or it could have a higher deflection and could thus more easily overpower the lens aberrations.

Detector systems limited to 10^6 particles per second would not handle the available kaon flux unless the pion flux is separated out.

We have not specifically included a branch point in the last section to accomodate several experimental setups. It has been suggested that perhaps the initial part of the spill could be deflected toward a bubble chamber of intermediate size for survey experiments. This simultaneous operation looks technically feasible, but one has to keep in mind that a bubble chamber will make much higher demands on the purity of the beam than a counter setup. To attain these purities the beam will have to be more tightly collimated, and this may well require flux sacrifices by a factor of 5, which the counter setups would not normally require. Needless to say, the counter and bubble-chamber experiments would have to be programmed to run at the same momentum. The duty cycle of the counter spill would not be materially affected unless the chamber were pulsing several times per pulse.

REFERENCES

[1] H. Foelsche, A Normal RF Separator With 33% Duty Cycle, National Accelerator Laboratory 1969 Summer Study Report, SS-13, Vol. I.

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[3] Several papers on rf beams: Utilization Studies for a 300-BeV Proton Synchrotron CERN/ECFA 67/16, Vol. II.

[4] H. Foelsche et al., RF Beams at the AGS, Rev. Sci. Instr. 38, 879 (1967).

[5] M. Awschalom and T. O. White, Secondary Particle Production at 200 GeV, National Accelerator Laboratory FN-191, June 9, 1969.

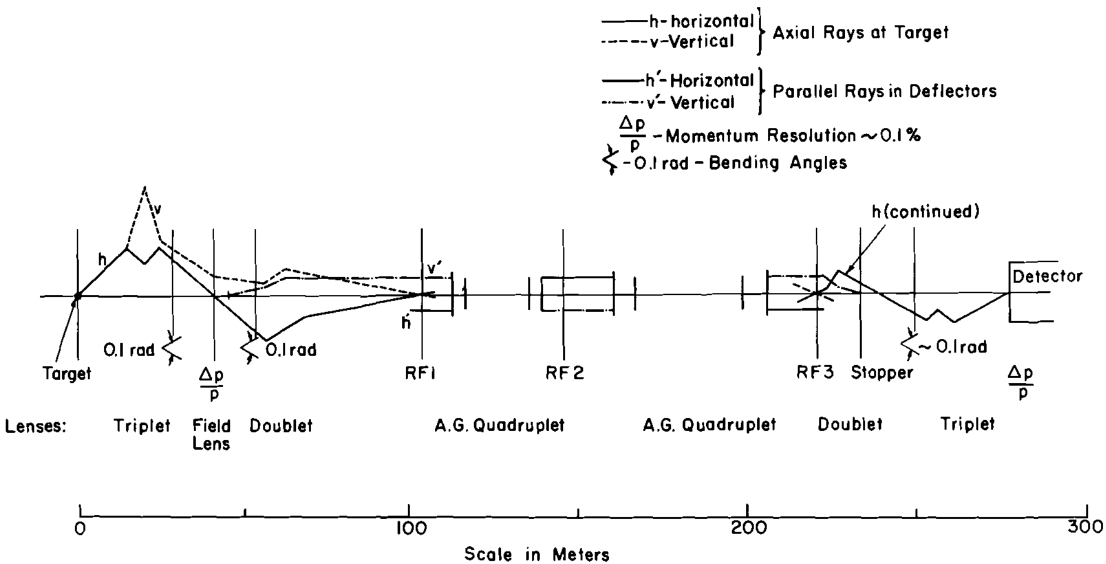

Fig. 1. Optics of the rf-separated beam.

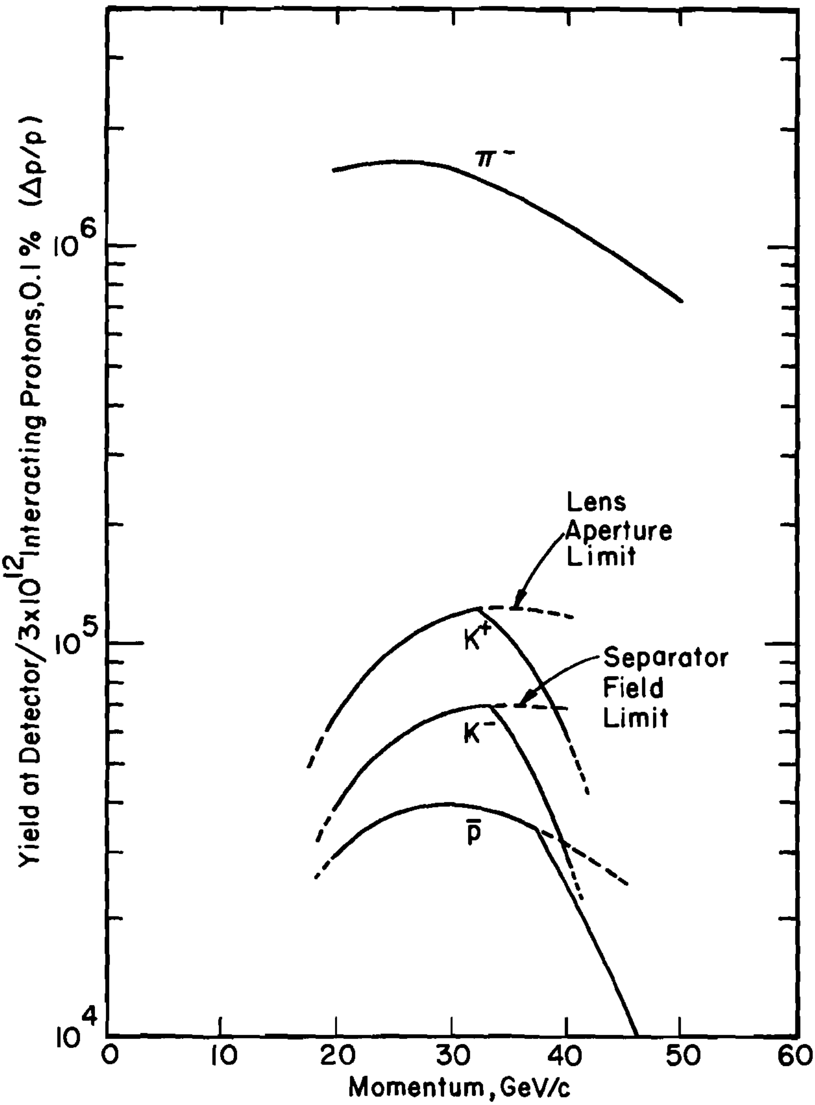

Fig. 2. Particle yields in rf-separated beam.