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SEPARATED K^- BEAMS (10 GeV and ABOVE)*

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INTRODUCTION

Proton intensities now available at the AGS are considerably higher than just a few years ago and there are steps planned which should increase the accelerated intensities by a factor of four or more by 1988/89. Longer term plans would introduce a stretcher ring to allow for rapid pulsing of the AGS with a continuous spill. The LAMPF II proposal, if approved, would offer still more protons. Separated kaon beams with intensity similar to our present pion beams are, in fact, possible to build now, with the potential of even high kaon flux in the future.

It is particularly attractive to work with a K^- beam due to the large number of final state combinations which would be available, due to the strange quark. Pion beams, being made of the same quarks as targets, are not so enticing. And yet our spectroscopy has so far been dominated by the pion results; kaon experiments have been more difficult with a factor of 50 to 100 lower intensity, and separated beams have only been possible up to about 6 GeV/c. The exception here is the rf-separated beam at CERN (and earlier rf-separated beams to bubble chambers at CERN and BNL).

In the AGS-II Task Force Report, Cason and Donoghue[1] showed that a kaon beam combined with a complete spectrometer capable of observing both neutral and charged particles would increase the available states for spectroscopy for masses from 1 to 3 GeV by a factor of 10. They urged a complete mapping of states, using a sky survey as an analogy. Our present capability is similar to scans of the sky made only in the optical range. They also point out that the specific subject of confinement--whether there can be combinations of quarks and gluons not yet seen--is an exciting topic which is beginning to get theoretical guidance from QCD calculations on a lattice. This confluence of technical advance (intensity) and physics interest (confinement) makes a separated kaon beam particularly compelling.

RF SEPARATION

Static electric fields separate particles with different mass according to the velocity difference of the particles, which is proportional to $\Delta m^2/p^2$. The separation angle $\Delta\theta = \Delta p_\perp/p$ is proportional to $1/p^3$. In the medium energy separated beam at Brookhaven, with 20 meters of separator, this angle is .1 mrad for separating kaons from pions at 6 GeV/c. This is about the limit of static electric field

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separation for kaons. To separate particles at higher momenta, Panofsky suggested (29 years ago) using time-varying fields.[2]

The rf-separation scheme is based on the time-of-flight difference between particle types between separator cavities. Both cavities are run to give a transverse deflection. The relative phase of the power for the second cavity is adjusted to cancel the deflection from the first cavity for unwanted particles (pions). The wanted particles (kaons) receive a second kick there. A central beam stopper then removes the particles which remain on the central axis. Roughly half of the kaons are not deflected by either rf-cavity and are lost in the stopper along with all the pions. The distance required between cavities is proportional to the rf wavelength and the square of the particle momentum:

$$L = \frac{\lambda(pc)^2}{\Delta m^2} \quad . \qquad (1)$$

The deflection between particle types for momenta near the design momentum p_0 is a function of $1/p$. Thus, this method has considerable advantages at higher energy.[3]

The first rf-separated beams built (20 years ago) were based on pulsed rf (~ 10 μsec) and were used for bubble chambers.[4] Techniques have been suggested using room temperature cavities to obtain c.w. operation for counter experiments, but the most promising technique and the one used at the CERN SPS uses superconducting cavities.[5]

At CERN the cavities were run at 1 MV/meter (design was 2 MV/meter, but breakdown occurred at 1.2) giving a transverse momentum kick of 2.7 MeV/c for a 2.74 meter-long cavity. The operating frequency was 2866 MHz, $\lambda = 10.5$ cm. The aperture diameter was 4 cm. The beam length was 83 meters between cavities so the design momentum for kaons was 14 GeV/c. Their momentum acceptance was ± 2% and angular acceptance was 16 x 4 mrad^2 for an incident beam momentum of 200 GeV/c. They achieved a π^-/K^- ratio of 2/1 at 16 GeV/c, and an enrichment factor of 31. The deflection was .3 mrad. Measured fluxes were typically a factor of 2 lower than predictions, with 10^5 at 12 GeV/c and ~ 5 x 10^5 at 18.5 GeV/c per 10^{12} 200 GeV protons on target.

At BNL a beam line was proposed in 1971 with three deflectors over a 48 meter intracavity distance, operating at the same frequency as at CERN for a 10 GeV/c design momentum for kaons.[6] The design assumed 2 MV/meter, twice the field subsequently reached at CERN. The beam line was 110 meters long, somewhat shorter than the present A1 line at the AGS which feeds the MPS. The product of solid angle and momentum bite was 760 μsr % $\Delta p/p$, which is similar to the present A1 line. The calculated kaon flux was 1/3 x 10^5 at 10 GeV/c per 10^{12} 28.5 GeV protons on target.

There are several parameters which can be optimized to get a higher yield, especially if the beam is designed to separate K^- only. A factor of two gain would result from the scheme discussed in the next section. The point is that high intensity separated K^- beams can be built now with a yield near 10^6 at 10 GeV/c for 10^{13} protons on target.

SOME WRINKLES

Rf separation requires only 1 cavity station if the beam has an inherent time structure. In this case the intracavity distance (L in equation (1)) becomes the distance between the production target and the cavity. This time structure can come from the acceleration rf, except that typical acceleration frequencies are far too slow ($\lambda = 220$ feet in the AGS). Maschke suggested (years ago)[7] that a cavity could be used to deflect the primary proton beam off and on the production target, giving the produced particles a time structure. The cavity in the secondary beam then could be phased to deflect the pions into a stopper, with kaons (all of them) proceeding to the experiment.

A variation of this idea would be to use a cavity to scan the primary beam across an existing electrostatic beam splitter, which is used to divide the extracted beam into two branches. Beam on one side of the splitter wires would be transported, modulated, to the production target. Beam on the other side would be used elsewhere (the modulation of 1/3 nanosecond would not be too noticeable). There seem to be many advantages of this scheme. All the primary beam is then used efficiently; one obtains twice the flux of kaons per proton-on-target compared with the "conventional" separator scheme; the separation is at least a factor of 2 better (the number of pions produced per proton is unchanged, while the accepted kaon rate approximately doubles); a slit might be more efficient than a central beam stopper; the beam line can be considerably shorter; and more than one primary beam line can be time-modulated so that an additional separated beam line might be built with only one new cavity. In addition, it may be possible to use the alternating polarity of the rf pulse to alternately kick pions up and kaons down to further enhance the separation. Such a technique might also be useful for the time separated beam proposed by Kalogeropoulos.[8]

POLITICS AND STRATEGY

A proposal to build an rf-separated beam line to the Multiparticle Spectrometer Facility at the AGS was turned down in 1971 as a result of a user task force study which determined that the physics was not worth the cost.[9] The cost estimate was $3M. The physics considered was small angle scattering and high precision comparisons between π^- and π^+-induced reactions.

Clearly, the context has changed with the introduction of QCD confinement questions and with the availability of considerably higher intensities. What to do? To quote B.W. Montague from an excellent review article[3] on the subject that he wrote 19 years ago:

> "At the time when serious study of radio-frequency separation began, there was no obvious and immediate need to be fulfilled. D.c. separators were satisfying most of the current requirements, and high-energy physicists had to be prodded somewhat to specify their future needs."

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