estimation of these corrections will be provided in a later report.

In conclusion, our results are consistent with the $\Delta I=\frac{1}{2}$ rule, the linear-matrix-element approximation, and the pion pole model for K (η) $\rightarrow 3\pi$ decays. However, they raise doubts concerning the validity of the Brown and Singer model of τ, τ', and η decay.

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EXPERIMENTAL STUDY OF THE DECAY MODE $K^+\rightarrow\pi^+ +\pi^0+\gamma$†

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The decay mode

$$K^+\rightarrow\pi^+ +\pi^0+\gamma \tag{1}$$

is connected with an interesting problem. The largest known violation of the $|\Delta T|=\frac{1}{2}$ rule occurs for the decay

$$K^+\rightarrow\pi^+ +\pi^0; \tag{2}$$

if electromagnetic effects are responsible for the observed violation, then the amplitude for direct emissions of the photon from the decay vertex in Reaction (1) might be expected to compete favorably with the amplitude for inner bremsstrahlung.[1,2] Several calculations of the rate and π^+ spectrum for Reaction (1) have been reported[2-5]; in particular, Cabibbo and Gatto have assumed a specific model for the direct emission process and find that the total amplitude for Reaction (1) may be slightly larger or several times larger than the amplitude for pure inner bremsstrahlung depending on whether the two amplitudes interfere constructively or destructively.[3]

Previously three events that have been interpreted as the decay mode (1) have been reported.[6] An analysis of the existing data leads to the speculation that a large direct emission term is required. The branching ratio for Reaction (1) to all K^+ decays, for π^+ kinetic energies between 55 and 80 MeV, was given as 8×10^{-4}.

We have searched for the decay mode (1) in film from a recent Berkeley stopping K^+ run in the heavy liquid bubble chamber filled with freon (C_3F_8). A sample of 18 events has been found in film containing 165 000 stopped K^+'s. Film with another 500 000 stopped K^+'s has been scanned for this decay mode, but the analysis has not yet been completed.

The events were found by scanning for K^+ decays where the decay particle was a π^+, as indicated by the presence of the π-μ-e chain at the end of the track, and where the length of the π^+ was incompatible with that available from either decay at rest or in flight of mode (2) or from the decay mode

$$K^+\rightarrow\pi^+ +\pi^0+\pi^0. \tag{3}$$

The latter criterion essentially restricts the region of π^+ spectrum that can be investigated to that lying between 55- and 90-MeV kinetic energy. A few events were found with one or two converted photons, but in general, the pair conversion probability was too low to be useful in finding events, and events were identified completely by the range of the π^+. The K^+ was required to appear stopped, and angular cutoffs were imposed on the direction between the K^+ and the π^+ to remove any background from modes (2) and (3) for K^+'s that were actually in flight but appeared stopped. This essentially eliminated all background from Reaction (3). Each π^+ track was examined to determine whether an inelastic scatter could have occurred along the track. In general, such scatters were quite readily visible because of a change in curvature or because of a proton knock-on. The vertex of each event was carefully looked at to determine if an elastic or inelastic scatter could have occurred there. It is estimated that, at most, two events in the sample could have come from the mode (2) where an undetected π^+ scatter occurred at the origin. In an independent scan the detection efficiency for the π-μ-e chain was estimated to be 80%. The initial energy of each π^+ was measured by using the range. Each event was corrected for the solid angle available due to angular cutoffs, the chamber geometrical corrections, and the over-all detection efficiency, including scanning efficiency.

Figure 1 shows the spectrum found based on these events. Also shown is the theoretical prediction of Cabibbo and Gatto for both constructive and destructive interference,[3] and the spectrum expected for pure inner bremsstrahlung.[2] The estimated branching ratio with respect to all K^+ decays for the π^+ kinetic-energy interval 55-80 MeV is $(2.2\pm0.7)\times10^{-4}$ which is consistent with 1.6×10^{-4} predicted for pure inner bremsstrahlung. At present the data do not warrant any large direct emission amplitude that interferes constructively with the inner bremsstrahlung amplitude. In view of the fit to the inner bremsstrahlung spectrum, it does not seem necessary to invoke a large direct emission amplitude with destructive interference, although the results of this experiment are consistent with such a hypothesis. Finally it should be pointed out that a larger direct emission amplitude than that predicted by Cabibbo and Gatto that also interferes destructively with the inner bremsstrahlung amplitude could be present and the π^+ spectrum would be very similar to that expected for pure

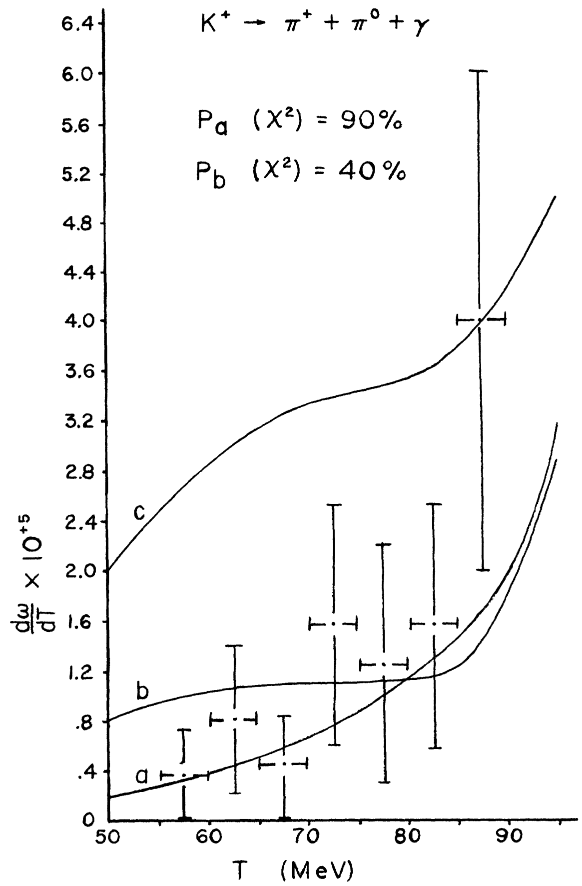

FIG. 1. Charged-pion kinetic-energy spectrum in the decay $K^+\to\pi^++\pi^0+\gamma$. The errors are statistical. Curve *a* is the theoretical spectrum for pure inner bremsstrahlung. Curves *b* and *c* are, respectively, theoretical predictions for a direct amplitude that interferes constructively and destructively with the inner bremsstrahlung amplitude.[3] P_a and P_b are the χ^2 probabilities that the data in the kinetic-energy region 55-85 MeV fit curves *a* and *b*, respectively.

inner bremsstrahlung.[2] In this case a measurement of the angular correlation between the π^+ and the photon would be needed to detect the direct process.

We would like to thank Dr. Wilson Powell and his group for helping us obtain this exposure in his chamber and for loaning us the film. We would also like to thank Dr. B. Sakita and Dr. J. Gaidos for useful discussions on this subject and Mr. R. Hantman for the geometrical correction program. We appreciate the diligent work of Mr. B. McGee in scanning the film.

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STRUCTURE IN FORWARD-DIRECTION π^--p CHARGE-EXCHANGE SCATTERING IN THE 3 GeV/c REGION*

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A survey of the forward-direction elastic charge-exchange scattering reaction $\pi^- + p \rightarrow \pi^0 + n$ has been made over the range $p_{\pi^-} = 2.4$ GeV/c through 18 GeV/c at the BNL AGS. We report here that strong energy dependence is evident in the lower part of that energy range.

On the assumption of charge independence, the amplitude for charge-exchange scattering (hereafter referred to as CEX) is proportional to the difference between the $I=\frac{3}{2}$ and $I=\frac{1}{2}$ amplitudes. Combined with the optical theorem, this yields the relationship

$$\frac{d\sigma}{d\Omega}(0^0)_{\text{CEX}} = \tfrac{1}{2}(D^- - D^+)^2 + \tfrac{1}{2}\left(\frac{k}{4\pi}\right)^2(\sigma^- - \sigma^+)^2$$

for the forward direction cross section, where D^- and D^+ are real parts of the forward-scattering amplitudes for π^--p and π^+-p, respectively, and σ^- and σ^+ are the total cross sections. Since above 2.4 GeV/c the difference between σ^- and σ^+ is much smaller than the magnitude of each, the forward CEX cross section should reflect resonances in this energy region with a much more favorable signal-to-noise ratio than would a total cross-section measurement, barring accidental cancellation by the variation of the term in the real parts. An $I=\frac{1}{2}$ resonance increases σ^- and not σ^+, and since σ^- is already larger than σ^+, $(d\sigma/d\Omega)(0^0)_{\text{CEX}}$ increases also. By contrast, an $I=\frac{3}{2}$ resonance increases σ^+ more than σ^- and results in a decrease in $(d\sigma/d\Omega)(0^0)_{\text{CEX}}$.

The data described here, from the low-energy part of the survey, were obtained with the apparatus shown in Fig. 1. A liquid hydrogen target was placed in a 2.4- to 6.0-GeV/c momentum-analyzed (±0.8 %) beam of unseparated negative particles. The target was surrounded by alternate layers of scintillating plastic and lead in order to veto both charged particles and gammas produced in all but the downstream direction. A square opening in the downstream direction, subtending approximately $12° \times 12°$, was covered only by a $\frac{1}{2}$-in. thick scintillator which vetoed only charged particles. Gammas passed through this scintillator and converted in a 14-plate brass spark chamber, 5 radiation lengths thick. The detection of one or more charged particles in a large scintillation counter directly downstream from the spark chamber completed the trigger. The spark chamber had an additional three plates of thin aluminum foil on the upstream side to provide a visual veto of any charged particles which escaped our veto system. Loss of events due to low-energy recoil neutrons triggering the veto counters have been estimated to be small compared with the counting errors.

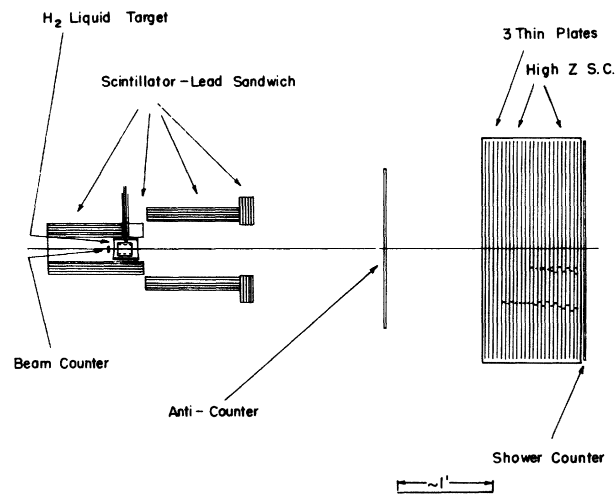

FIG. 1. Experimental apparatus. The π^- beam enters from the left.

There were typically less than 6×10^{-5} trigger per incident particle with the target empty, and