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INCLUSIVE PRODUCTION OF VECTOR MESONS IN e^+e^- ANNIHILATION AT 29 GeV*

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ABSTRACT

We report a measurement of the inclusive production rates for ρ^0, K^{*0} and $K^{*\pm}$ mesons in e^+e^- annihilation with the Mark II detector at PEP. These rates can be interpreted in terms of a suppression factor of $0.52 \pm 0.12 \pm 0.16$ for strange relative to non-strange vector meson production in jet fragmentation.

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In this letter we present a measurement of ρ^0, K^{*0} and $K^{*\pm}$ inclusive production rates in e^+e^- annihilation at $\sqrt{s} = 29$ GeV. The ratio of K^{*0} to ρ^0 is a measure of the suppression of strange relative to non-strange vector mesons in the quark fragmentation process. As the masses are similar, this measure should be relatively free of phase space effects. In addition, if one assumes that pseudo-scalar and vector mesons dominate in hadronic events at 29 GeV, most vector mesons produced are primary particles while most pseudo-scalar mesons are decay products of heavier particles. Vector mesons should thus directly reflect the underlying dynamics.

The data sample used in this measurement was accumulated by the Mark II detector at PEP from 1980 to 1984 and corresponds to an integrated luminosity of 220 pb^{-1}. The detector has been described in detail elsewhere.[1,2] The analysis presented here relies on the reconstruction of charged tracks in two concentric cylindrical drift chambers. These chambers, immersed in a 2.3 kG magnetic field, provide a momentum measurement with uncertainty $(\sigma_p/p)^2 = (.02)^2 + (.01p)^2$, where p is in GeV/c.

Only hadronic events with at least 5 well-reconstructed charged tracks whose total energy is greater than one quarter of the center of mass energy are included in this sample. In addition the sphericity axis defined by the charged tracks is required to have $|\cos\theta| < 0.65$ with respect to the beam, or z, axis. A well-reconstructed track is defined as one with $|z| < 10$ cm, $r < 2$ cm (at the point of closest approach to the beam interaction point), momentum perpendicular to the beam axis, $p_\perp >$ 100 MeV/c and $|\cos\theta| < 0.85$. For tracks with momenta below 1 GeV/c the cut on r is loosened to $r \cdot p < 2$ cm GeV/c to avoid losses due to multiple scattering. After these cuts the contamination of the hadron sample of 59,498 events due to beam gas, two-photon processes and $e^+e^- \to \tau^+\tau^-$ is less than 4%.[3]

ρ^0 and K^{*0} are detected via the decays $\rho^0 \to \pi^+\pi^-$ and $K^{*0} \to K^+\pi^-$. Tracks used in the search for ρ^0 and K^{*0} are required to pass the more stringent cuts, $p_\perp >$

200 MeV/c, $|\cos\theta| < 0.75$, and $r < 0.5$ cm. Invariant masses of oppositely charged tracks are calculated for all hypotheses $\pi^+\pi^-$, $K^+\pi^-$, $K^-\pi^+$ as no attempt at K-π identification is made. Figures 1a and 1b show the $\pi\pi$ and $K\pi$ invariant mass spectra. These distributions are fit to extract the numbers of ρ^0 and K^{*0} in the sample.

The fit includes contributions from $\rho^0 \to \pi^+\pi^-$, $K^{*0} \to K^+\pi^-$, $\omega \to \pi^+\pi^-\pi^0$ and $K_S \to \pi^+\pi^-$. The remaining backgrounds are approximated by quartic polynomials. The shapes of both $\pi\pi$ and $K\pi$ mass distributions expected from each of the four resonance decays are found with a Monte Carlo simulation which includes the detector resolution and geometry.

The $\pi\pi$ and $K\pi$ mass spectra for pair momenta, $p \geq 1$ GeV/c are then fit simultaneously over the ranges 0.44 GeV/c^2 $< m_{\pi\pi} <$ 1.40 GeV/c^2 and 0.70 GeV/c^2 $< m_{K\pi} <$ 1.40 GeV/c^2. The numbers of ρ^0, K^{*0}, K_S and the parameters of the polynomials are allowed to vary. As the ω is similar in mass and quark content to the ρ^0, the number of ω is set equal to the number of ρ^0. The fit yields 10465 ± 1062 ρ^0 and 6377 ± 700 K^{*0} and $\overline{K}^{*0}$ decays into charged particles. The χ^2 per degree of freedom is 66/72 with negligible correlation between the K^{*0} and ρ^0 rates. The solid lines in Figures 1a and 1b show the results of the fit.

As a check of the fitting procedure, an identical fit has been made to a Monte Carlo[4] sample with comparable statistics. The numbers of ρ^0 and K^{*0} found in this fit are $10 \pm 9\%$ and $9 \pm 12\%$ higher respectively than the known numbers for which both decay tracks pass the cuts. Fits to Monte Carlo samples with resonant $\pi\pi$ and $K\pi$ combinations removed indicate that slight residual structure in the background produces the small excess in the fit.

The efficiency for detecting ρ^0 and K^{*0} is found by comparing the numbers of ρ^0 and K^{*0} found in the fit to the Monte Carlo sample with the numbers produced. This method of calculating the efficiency automatically corrects for the over-estimate noted above. We also correct the efficiency for measured variations in track reconstruction efficiency over the running period. The efficiency corrected numbers are then normalized to the hadronic event sample to yield the production rates per event. Radiative corrections are applied to the results.[5]

The $\pi\pi$ mass distribution is also separately fit for each of five momentum bins with the ρ^0 to K^{*0} ratio fixed at the value determined in the global fit. The $K^{*\pm}$ rates described in the next section confirm that the momentum dependence is, in fact, similar for K^* and ρ^0. The results are insensitive to reasonable variations in the K^{*0} to ρ^0 ratio. Figure 2 shows the $z \equiv E/E_{beam}$ dependence of the ρ^0 production rate. The sizeable background under the K^{*0} signal prevents a similar study of K^{*0} production as a function of momentum.

To estimate the effects of ω rate uncertainties, we varied the ratio of ω to ρ^0 to .5 and 1.5; the ρ^0 rate changes by -6% and $+4\%$ and the K^{*0} rate by -11% to $+11\%$ respectively. The best fit value of the ω/ρ^0 ratio is 1.6 ± 0.4 with a χ^2 of 63.8.

The hadron normalization, tracking efficiency and uncertainties in the radiative corrections and production model contribute another 8% error. If the estimated errors from the ω rate, the statistical error on the efficiency correction and the normalization are added in quadrature the total systematic errors on the ρ^0 and K^{*0} production rates are $\pm 13\%$ and $\pm 18\%$ respectively. As there is correlation between the errors, the estimated error on the K^*/ρ^0 ratio is only 17%. The production rates per hadronic event for ρ^0 and $K^{*0} + \overline{K}^{*0}$ with $p > 1$ GeV/c are thus $0.436 \pm 0.043 \pm 0.057$ and $0.416 \pm 0.045 \pm 0.075$ respectively.[6] The ratio of $K^{*0} + \overline{K}^{*0}$ to ρ^0 is $0.96 \pm 0.14 \pm 0.17$. The same analysis for the region $p > 2$ GeV/c yields $0.254 \pm 0.030 \pm 0.033$ ρ^0 and $0.243 \pm 0.029 \pm 0.044$ $K^{*0} + \overline{K}^{*0}$. The ρ^0 measurement is consistent with an earlier measurement by the TASSO collaboration[7] at 34 GeV and lower than a recent result from the JADE collaboration[8] at 34 GeV. The TPC collaboration[9] has measured a $K^{*0} + \overline{K}^{*0}$ rate at 29 GeV consistent with the rate from this experiment.

We find $K^{*\pm}$ by fitting the $K_S\pi^\pm$ mass spectrum. The K_S are found by combining pairs of tracks which have impact parameters relative to the beam center greater than 1 mm. These tracks are not required to pass the reconstruction cuts described earlier. The track pairs are constrained to meet at a single point in space. This decay point must correspond to a proper decay length, $c\tau$, of more than 5 mm and the line of flight of the K_S candidate is required to trace back to within 5 mm of the beam interaction point. Only K_S candidates with masses within 30 MeV/c^2 of the nominal mass are kept and constrained to that mass. The $\pi^\pm$ used in $K_S\pi$ combinations are required to pass the same cuts as those used in the ρ^0 analysis. The $K_S\pi^\pm$ mass spectrum for $K\pi$ momenta greater than 2 GeV/c is then fit with a quartic polynomial plus a $K^{*\pm}$ line-shape determined from the Monte Carlo. Figure 1c shows the fit in which 724 ± 128 $K^{*\pm}$ decays are found with a χ^2 of 37 for 31 degrees of freedom.

We determine the efficiency by running the same analysis on a Monte Carlo sample. The efficiency, which has a 15% statistical error and a 13% estimated error due to possible uncertainties in the tracking efficiency has been corrected for measured variations in the K_S and $\pi^\pm$ efficiency within the data sample. The normalization procedure and radiative corrections are the same as for the ρ^0 and K^{*0}. The resulting number of $K^{*\pm}$ with $p > 2$ GeV/c is $0.260 \pm 0.047 \pm 0.055$ per event. This result is consistent with the $K^{*0} + \overline{K}^{*0}$ rate from this experiment but lower than a recent measurement by the JADE collaboration[8] at 34 GeV. The z dependences of the invariant production rates for ρ^0 and $K^{*\pm}$ are shown in Figure 2.

To extract and compare the pure fragmentation contributions to ρ^0 and K^{*0} production, we subtract out the smaller contributions from leading quarks and from charm and bottom decay.

The initial $e^+e^- \rightarrow q\overline{q}$ vertex produces 4 times as many u and c quarks as d, s or b due to the differing quark charges. As u quarks cannot contribute to K^{*0} and s quarks cannot contribute to ρ^0 production, the relative rates are correspondingly affected. We estimate the contributions of these 'leading' u and s quarks to be 0.10 ± 0.04 ρ^0 and 0.04 ± 0.02 $K^{*0} + \overline{K}^{*0}$ per event. These calculations assume that 30-70% of leading mesons are vector mesons and also include the decay products from b decay, $b \rightarrow cd\overline{u}$, as if they were leading.

From known D meson branching fractions we estimate that the charm quark branching fraction into K^{*0} is between 3 and 15% and that the branching fraction into ρ^0 is between 3 and 10%. We estimate that these charm decays contribute $0.03 - 0.09$ ρ^0 and $0.03 - 0.14$ $K^{*0} + \overline{K}^{*0}$ per event. Monte Carlo studies indicate that 85% of ρ^0 and K^{*0} from the leading u, d and s quarks have $p > 1$ GeV/c and that 80% of the vector mesons from charm decay have $p > 1$ GeV/c. These values are reasonably insensitive to the Monte Carlo model chosen and have little effect on the result.

A simple calculation then yields a corrected ratio of $K^{*0} + \overline{K}^{*0}$ to ρ^0 from fragmentation alone of $1.05 \pm 0.24 \pm 0.32$ where the first error is statistical and the second the 20% uncertainty from the charm and leading quark subtraction and the systematic error from the measurement added in quadrature. We have assumed that the contribution of η' decays to the ρ^0 cross section is negligible. A 10% contribution would raise the ratio by 10%.

In the limit of flavor SU(3) symmetry all vector mesons, ρ^0, ω, K^{*0} and $\overline{K}^{*0}$, would be produced equally. The measured value thus indicates that the production of strange vector mesons in the fragmentation process is suppressed relative to that of non-strange vector mesons by a factor of $0.52 \pm 0.12 \pm 0.16$. This can be interpreted as the suppression of strange *quark* production only if the fraction of vector mesons is the same for strange and non-strange mesons. Other estimates of strange quark suppression in e^+e^- annihilation have used inclusive K^0 or $K^\pm$ rates. Such measurements generally find values of the strangeness suppression of 0.30.[10] The measurement reported here is marginally consistent with that value but suggests that the relative fraction of vector mesons is higher for strange than for non-strange mesons.

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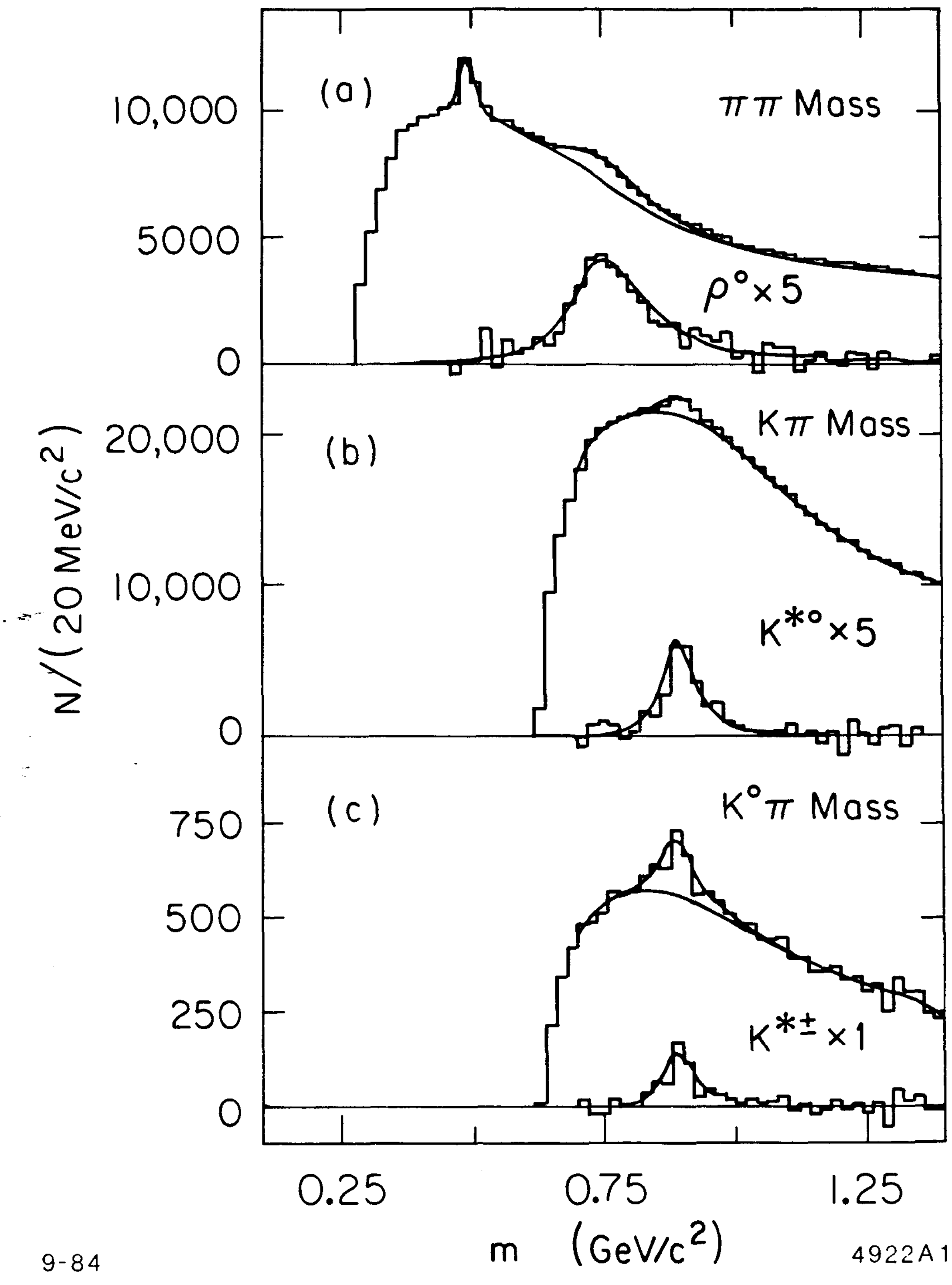
FIGURE CAPTIONS

Figure 1: Fits to mass spectra. 1a and b show the results of the simultaneous fit to the $\pi\pi$ and $K\pi$ spectra. 1c shows the separate fit to $K_S\pi$. The background subtracted ρ^0 and K^{*0} peaks are also shown with $\times 5$ magnification.

Figure 2: The invariant rate for ρ^0 and $K^{*\pm}$. The errors are statistical only.



(a)
ππ Mass
ρ°×5
(b)
Kπ Mass
K*°×5
(c)
K°π Mass
K*±×1
10,000
5000
0
20,000
10,000
0
750
500
250
0
N/(20 MeV/c²)
0.25
0.75
1.25
m (GeV/c²)
9-84
4922A1

Fig. 1

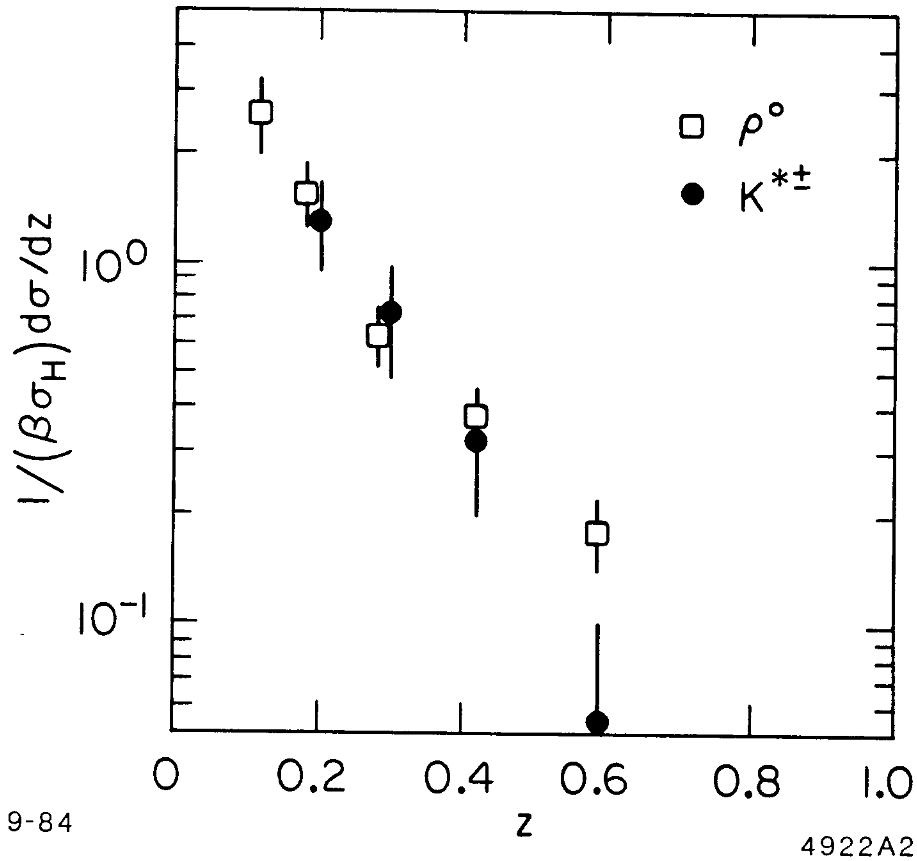


Fig. 2