Strange-quark suppression in 225-GeV/c π^-Be interactions

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We report here on a new measurement of the strange-quark suppression factor λ, using data on $\omega(783)$ and $\phi(1020)$ mesons observed via the decay to $\mu^+\mu^-$. We find $\lambda = 0.31 \pm 0.05$, compared to a world average of about 0.29.

The relative yields of strange and nonstrange mesons have been found to be in good agreement with simple quark-model predictions, assuming that strange-quark production is suppressed relative to light quarks by some universal factor λ.[1,2] Our data on ω and ϕ production yield a value of λ which compares well with that determined by different methods.[3]

The experiment was performed at Fermilab, using the Chicago Cyclotron Magnet Spectrometer (Fig. 1), and was designed primarily to study charmonium production by hadrons. Negative pions at 225 GeV/c were incident on a 3-in.-thick beryllium target. The event trigger required an interaction in the target in coincidence with hits in diagonally opposed quadrants of a hodoscope situated directly downstream of the 3-m steel absorber. This served to bias the acceptance towards high-mass dimuon pairs, but allowed the recording of some $\omega \rightarrow \mu^+\mu^-$ and $\phi \rightarrow \mu^+\mu^-$ decays. Secondary charged-particle tracks were reconstructed using the 25-plane multiwire-proportional-chamber system and the three drift-chamber planes. The particular data sample used in this analysis corresponds to approximately 300 000 fully reconstructed dimuon events. Most of these result from hadron decay in the 18.5-m space between the target and the steel, rather than prompt dimuons from the target.

Figure 2 shows the dimuon mass spectrum, uncorrected for acceptance, between 500 and 1500 MeV/c^2. Clear peaks at the ω and ϕ masses are visible. Fitting the peaks to Gaussians with polynomial backgrounds, we find 3400 ± 240 and 1700 ± 230 events above background for the ω and ϕ, respectively. The observed full width at half maximum of the ϕ is 30 MeV/c^2, while that of the ω is 39 MeV/c^2, both consistent with our mass resolution. The resolution was good enough to permit separation of the ω from the ρ^0 contribution.

The simple quark-model prediction[1] of the relative yields of meson states assumes that s-quark production is

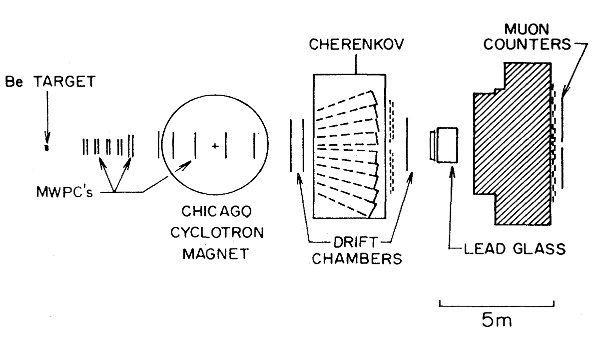

FIG. 1. The apparatus. The Cherenkov counter and lead glass were not used in this analysis.

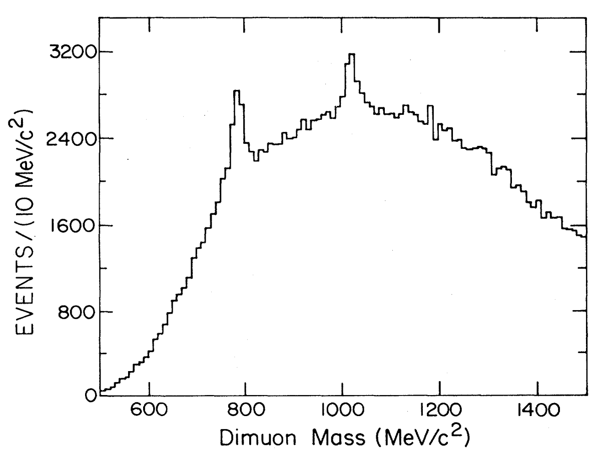

FIG. 2. The low-mass dimuon spectrum.

suppressed relative to u and d quarks by the factor λ, which is independent of the beam and target particles and the total energy of the collision. The ω and ϕ mesons possess identical quantum numbers, and are not very different in mass. They do, however, differ in quark content, as deduced from their principal decay channels. The ϕ is primarily $s\bar{s}$, the ω a mixture of $u\bar{u}$ and $d\bar{d}$. This suggests that the strange-quark suppression factor can be extracted from the production ratio of ϕ to ω.

We consider only ω and ϕ produced in the central region of the collision, that is, mesons with Feynman x (x_F) ≤ 0.25. (Our acceptance in the ω-ϕ mass region is limited to those dimuon pairs with $x_F > 0.10$.) For $x_F > 0.25$ spectator-quark effects are expected to contribute to the relative hadron yields, but the value of λ derived is rather insensitive to the exact x_F used to define the central region. Taking the cut at $x_F \leq 0.5$, for example, does not change our value of λ within the experimental errors. Imposing the $x_F \leq 0.25$ cut, the yields are then 1940 ± 200 ω and 820 ± 170 ϕ events. The background-subtracted central ω and ϕ yields are shown in Fig. 3 with the fit curves superimposed.

Acceptances were calculated for both particles assuming the same decay angular distribution for each particle—either isotropic or $1+\cos^2\theta_{GJ}$. (Here θ_{GJ} is the Gottfried-Jackson angle.[4]) The x_F and $p_\perp$ (transverse-momentum) distributions were generated according to $E\,d^3\sigma/dp^3 \propto (1-x_F)^A e^{-Bp_\perp}$, with $A=0.92$, $B=3.81$ $(\mathrm{GeV}/c)^{-1}$ for the ω, and $A=1.60$, $B=3.51$ $(\mathrm{GeV}/c)^{-1}$ for the ϕ, as parametrized in Ref. 5. The ω/ϕ acceptance ratio was found to be 0.50 ± 0.04, where the error quoted is due mainly to the uncertainties in the angular distributions and in the geometry of the apparatus.

Allowing then for the ω/ϕ acceptance ratio and the branching ratios into the $\mu^+\mu^-$ channel,[6] we find $(\phi/\omega)_{\mathrm{central}} = 0.061 \pm 0.018$.

The strangeness suppression factor λ is determined from[2]

$$(\phi/\omega)_{\mathrm{central}} = \frac{3\lambda^2}{3+(10.6+2.2\lambda)\alpha} \quad . \tag{1}$$

The first term in the denominator reflects the direct ω yield, while the second is the contribution of "feed-down" ω's from decays of more massive resonances. α is a constant determined in Ref. 2 to have the value 0.13 ± 0.03. We have altered slightly the numerical coefficients in (1) to bring them into line with the latest branching-ratio measurements given in Ref. 6. Solving (1), we find $\lambda = 0.31 \pm 0.05$, which agrees well with a published average[3] of 0.29 ± 0.02.

We have not taken into account possible ρ^0-ω interference

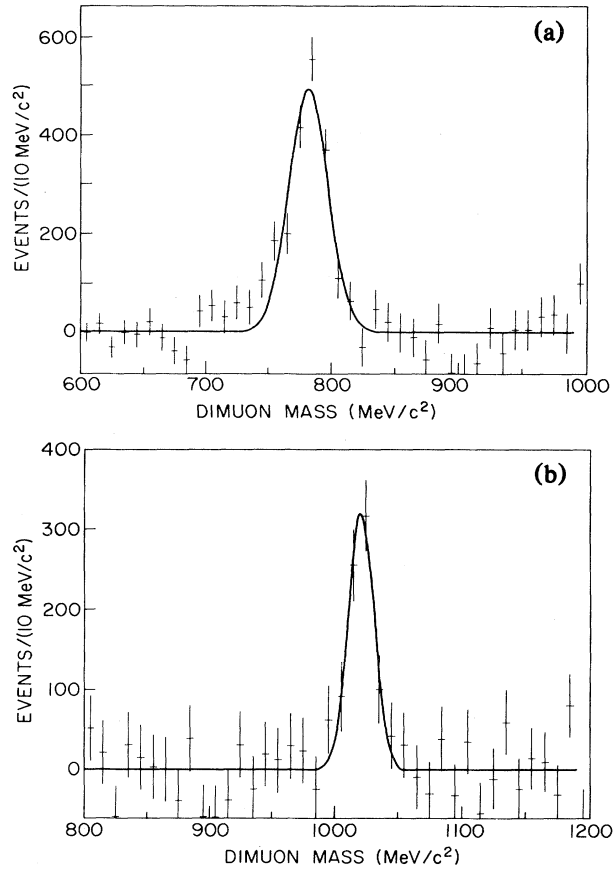

FIG. 3. The background-subtracted central (a) ω and (b) ϕ signals. In each case the curve is a least-squares fit to a Gaussian.

effects in the above analysis. Assuming equal production of ρ^0 and ω, we estimate that the worst-case effect of interference would change λ by about $^{+0.03}_{-0.05}$, i.e., $^{+10\%}_{-16\%}$ of our value.[7]

In conclusion, we have used the relative yields of centrally produced ω and ϕ to determine the strangeness suppression constant. We find that this measurement is in good agreement with measurements from other processes.

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[7]The contribution to the observed ω yield of a ρ^0-ω interference term was estimated by taking the amplitude for $V \to \mu^+\mu^-$ ($V = \rho^0, \omega$) as

$$\sim \frac{(\Gamma^V_{\mu\mu})^{1/2}}{m - m_V - i\Gamma_V/2}$$

with $\Gamma^V_{\mu\mu}$ the partial width into $\mu^+\mu^-$, Γ_V the total width, and m_V the mass of V. The phase was then varied between the ρ^0 and ω amplitudes in the calculated cross section.