NAL-THY-41
1971

OMEGA UNIVERSALITY REVISITED*

H. J. Lipkin

Argonne National Laboratory, Argonne, Illinois 60439

and

National Accelerator Laboratory, Batavia, Illinois 60510

The ω universality relation is shown to agree with experiment also at Serpukhov energies up to 50 GeV/c, even though other regularities found at lower energies do not persist and a simple pole interpretation of the data would require different intercepts for the ρ and ω trajectories. Applications of the ω universality relation to inclusive reactions are suggested.

The ω universality relation[1] has been shown to be in remarkable agreement with experimental total cross sections[1, 2] over the momentum range up to 18 GeV/c. The purpose of this note is to point out that this remarkable agreement is still found in the new higher energy data[3] (up to 50 GeV/c) from Serpukhov, even though many of the other experimental regularities found in the lower energy region have been shown to break down in the energy range between 20 and 50 GeV.[4]

The ω universality relation, which was first obtained from a quark model, is equivalent in a Regge picture to the assumption that the ω trajectory is coupled three times as strongly to nucleons as to kaons and dominates the isoscalar odd-signature exchange amplitude. The factor 3 comes from the assumption that the ω trajectory is coupled universally to the number of nonstrange quarks in any hadron. From these assumptions it follows[1] that the relation between kaon-deuteron and nucleon-deuteron total cross sections is

$$\sigma(\bar{p}d) - \sigma(pd) = 3[\sigma(K^-d) - \sigma(K^+d)]. \tag{1}$$

The use of the deuteron target selects the contribution from isoscalar exchange.

An equivalent relation can be obtained for scattering data on proton targets if an additional universality assumption is made.

The isovector exchange which carries the quantum numbers of the ρ trajectory is assumed to be universally coupled to the isospin current. The ρ couplings to kaons and nucleons are thus equal, and the coupling to pions is twice as strong as either. The combination of ω universality and ρ universality leads to the relation

$$\sigma(\bar{p}p) - \sigma(pp) = 3[\sigma(K^-p) - \sigma(K^+p)] - [\sigma(\pi^-p) - \sigma(\pi^+p)]. \tag{2}$$

The left-hand side of this relation contains contributions from both ω and ρ exchange to nucleon-nucleon scattering. The kaon-nucleon terms on the right-hand side of Eq. (2) are predicted to have an ω exchange contribution equal to that on the left-hand side. However, the ρ contribution is too large, since the ρ couplings to the kaon and nucleon are equal—not different by a factor of 3. The additional correction term involving pion-nucleon cross sections is pure ρ exchange and compensates for the excessive ρ contribution in the kaon-nucleon cross sections.

Figure 1 shows the experimental data for the three total-cross-section differences appearing in Eq. (2). To this figure has been added a dashed line giving the value of $3[\sigma(K^-p) - \sigma(K^+p)]$ obtained by multiplying the straight-line fit to the data by 3. This line is seen to be somewhat higher than the experimental data for $\sigma(\bar{p}p) - \sigma(pp)$, as expected from Eq. (2). The difference is compensated exactly by subtracting

$\sigma(\pi^- p) - \sigma(\pi^+ p)$, as shown by the two crosses in Fig. 1. These give the $\sigma(\bar{p}p) - \sigma(pp)$ predictions obtained when the straight-line fits to the kaon-nucleon and pion-nucleon data of Fig. 1 are substituted in Eq. (2) at two energies.

In addition to the remarkable quantitative agreement of these data with the prediction (2), there is one particularly interesting qualitative feature. The difference between the pion-nucleon cross sections is seen to drop off much more slowly with energy than the kaon-nucleon or nucleon-nucleon differences. In simple pole models in which only ρ and ω exchanges contribute, this implies that ρ exchange drops off much more slowly with energy than ω exchange. This difference appears not only in the slower dropoff of the pion-nucleon difference, which is pure ρ exchange, but also in the difference between the dashed line in Fig. 1 and the experimental nucleon-nucleon difference. This difference drops off more slowly with energy than either line does individually. Thus on a logarithmic plot the two lines appear to diverge with increasing energy.

In models in which these cross sections are described only by ρ and ω poles, the ρ and ω trajectories must depart considerably from exchange degeneracy. They must have different intercepts. However, the universality relations between the meson and baryon couplings in the odd-signature amplitudes seem to hold up individually much better than exchange degeneracy.

Some models begin with exchange-degenerate trajectories to give the observed regularity in the energy range up to 20 GeV and attempt to introduce cuts and other phenomena to explain the deviations at higher energies. In these models it is very mysterious that the additional dynamical mechanisms should conspire to preserve the ω universality relation. [The ρ universality relation is not tested to great precision by relation (2) because the ρ contribution is small—only 15—20%.]

The ω universality relation is particularly puzzling when the total cross sections are considered as sums of cross sections into all channels, rather than as the imaginary part of the forward amplitude. An appreciable part of the difference $\sigma(\bar{p}p)$ - $\sigma(pp)$ is due to contributions from annihilation channels. Thus Eqs. (1) and (2) relate these annihilation processes to meson-baryon processes which have no annihilation contribution. It has been suggested that annihilation contributions should be subtracted before quark-model relations are used.[5] This procedure would spoil the agreement between these relations and experiment.

Further tests of ω and ρ universality are of interest. One possibility is to apply them to inclusive reactions by using the approach of Bialas and Czyzewski,[6] which is based on the Mueller analysis.[7] Consider the process

$$A + B \rightarrow C + \text{anything}. \tag{3}$$

By analogy with Bialas *et al.*, but using the ω-ρ universality relation (2) instead of the relations used there, we obtain

$$f(\bar{p}B \rightarrow C) - f(pB \rightarrow C) = 3[f(K^{-}B \rightarrow C) - f(K^{+}B \rightarrow C)]$$

$$- [f(\pi^{-}B \rightarrow C) - f(\pi^{+}B \rightarrow C)], \tag{4a}$$

where $f(AB \rightarrow C)$ is the Lorentz-invariant cross section for process (3),

$$f(AB \rightarrow C) = E_c d^3\sigma/dp_c{}^3, \tag{4b}$$

and E_c and p_c are the energy and momentum of particle C.

The relation (4a) should hold in any kinematic region in which the Mueller six-point function is described by the exchange of a conventional Regge trajectory between particle A and the $B\bar{C}$ complex—e.g., the fragmentation region of particle B.

Relation (4a) is simplified if both B and C have isospin zero, by analogy with Eq. (1). For example,

$$f(\bar{p}d \to \omega) - f(pd \to \omega) = 3\left[f(K^-d \to \omega) - f(K^+d \to \omega)\right], \tag{5a}$$

$$f(\bar{p}d \to \eta) - f(pd \to \eta) = 3\left[f(K^-d \to \eta) - f(K^+d \to \eta)\right]. \tag{5b}$$

It would be interesting to see whether the agreement with experiment for relations (4) and (5) is comparable to that for relations (1) and (2).

Footnotes and References

*Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] C. A. Levinson, N. S. Wall, and H. J. Lipkin, Phys. Rev. Lett. 21, 1122 (1966).

[2] V. Barger and D. Cline, Phys. Lett. 26B, 591 (1968).

[3] S. P. Denisov, S. V. Donskov, Yu. P. Gorin, A. I. Petrukhin, Yu. D. Prokoshkin, D. A. Stoyanova, J. V. Allaby, and G. Giacomelli, Phys. Lett. 36B, 415 (1971).

[4] A very striking example of the breakdown of these regularities is the change in behavior of $\sigma_{tot}(K^+p)$ and $\sigma_{tot}(pp)$. Below 20 GeV/c, $\sigma_{tot}(K^+p)$ is constant and $\sigma_{tot}(pp)$ is slowly decreasing. Above 20 GeV/c, $\sigma_{tot}(pp)$ becomes constant and $\sigma_{tot}(K^+p)$ increases. The difference between the two regions is clearly exhibited on a plot of $\sigma_{tot}(K^+p)$ vs $\sigma_{tot}(pp)$, as suggested by H. J. Lipkin and V. Rabl, Nucl. Phys. B27, 464 (1971). A curve through the data changes abruptly from a horizontal line $\sigma_{tot}(K^+p)$ = const. to a vertical line $\sigma_{tot}(pp)$ = const.

[5] J. J. J. Kokkedee and L. Van Hove, Nucl. Phys. B1, 169 (1967).

[6] A. Bialas and O. Czyzewski, Phys. Lett. 35B, 576 (1971).

[7] A. H. Mueller, Phys. Rev. D2, 2963 (1970).

Figure Caption

Fig. 1. Experimental test of the ω-ρ universality relation (2). The data and the straight-line fits to the data are from Ref. 3. The solid lines and points are for $\Delta\sigma(\pi^{\pm}p) = \sigma_{tot}(\pi^{-}p) - \sigma_{tot}(\pi^{+}p)$, $\Delta\sigma(p^{\pm}p) = \sigma_{tot}(\bar{p}p) - \sigma_{tot}(pp)$, and $\Delta\sigma(K^{\pm}p) = \sigma_{tot}(K^{-}p) - \sigma_{tot}(K^{+}p)$. The dashed line represents $3[\sigma_{tot}(K^{-}p) - \sigma_{tot}(K^{+}p)]$. Crosses (x) give $\Delta\sigma(p^{\pm}p)$ as predicted from Eq. (2).

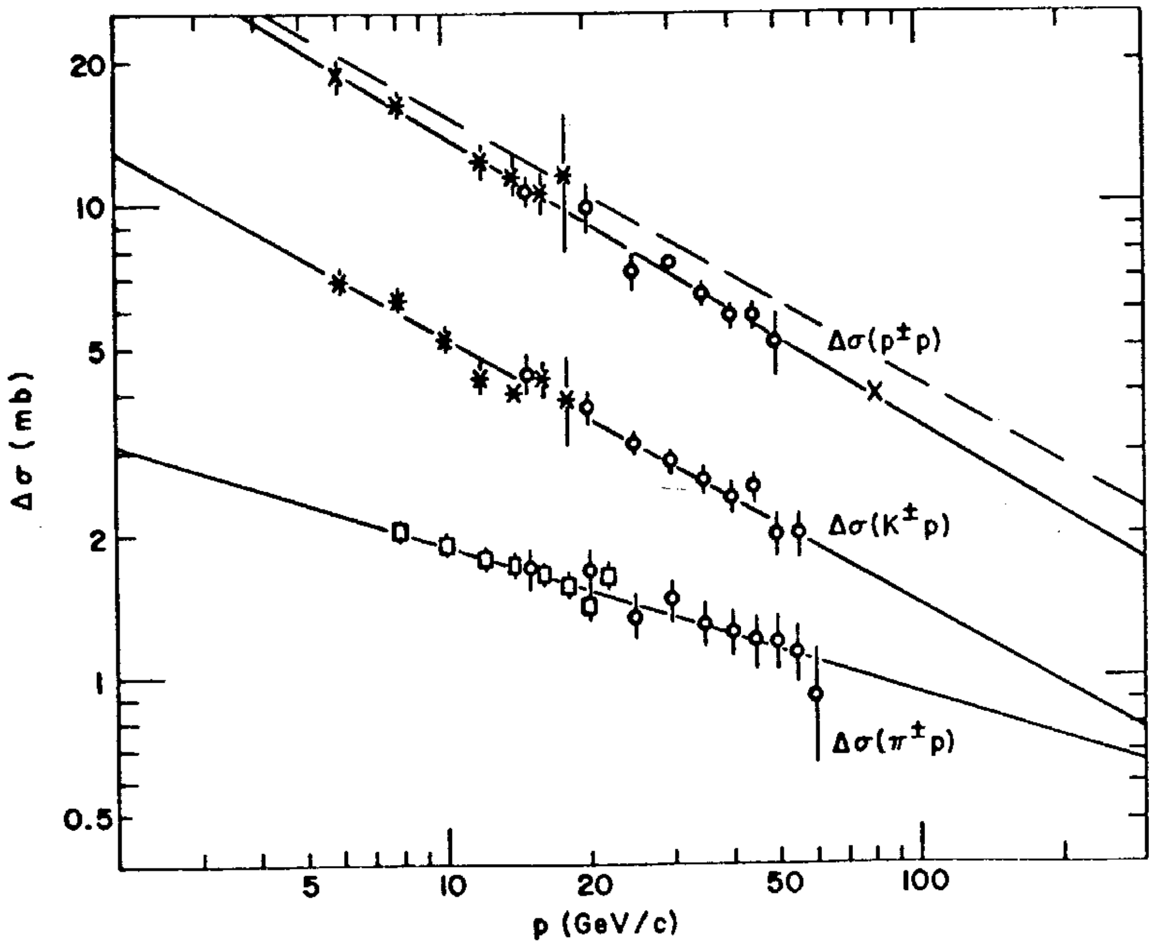

Fig. 1. (Neg. No. 209-1868); Phg. 10,604)