Title
REGGE POLE DAUGHTERS AND REACTIONS INVOLVING UNEQUAL-MASS PARTICLES

Author
Chew, Geoffrey F.

Publication Date
1966-08-30

UCRL-17099

University of California

Ernest O. Lawrence Radiation Laboratory

REGGE POLE DAUGHTERS AND REACTIONS INVOLVING UNEQUAL-MASS PARTICLES

Comments on Nuclear and Particle Physics

UCRL-17099

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
University of California
Berkeley, California

AEC Contract No. W-7405-eng-48

REGGE POLE DAUGHTERS AND REACTIONS INVOLVING UNEQUAL-MASS PARTICLES

Geoffrey F. Chew

August 30, 1966

UCRL-17099

REGGE POLE DAUGHTERS AND REACTIONS INVOLVING UNEQUAL-MASS PARTICLES*

Geoffrey F. Chew

Physics Department and Lawrence Radiation Laboratory
University of California, Berkeley, California

August 30, 1966

During the past year sufficient experimental support has accumulated in favor of Regge behavior for hadron reaction amplitudes at high energy to cause a new wave of theoretical activity on the subject. One important practical question surrounded by confusion for half a decade has recently been clarified, and the resolution turns out to have startling dynamical implications.

The issue in question centers on the region of an unequal-mass particle reaction where the energy of one of the "crossed reactions" passes through zero. Such a region occurs, for example, in high-energy elastic pion-nucleon scattering near the backward direction. It has been commonly asserted that Regge behavior can hold only where the absolute value of the cosine z_c of the crossed-reaction angle is large compared with unity, while kinematical requirements force $|z_c|$ to be $\lesssim 1$ in the region in question, no matter how large the (direct-reaction) energy. The conclusion has often been reached, therefore, that this interval must be excluded when applying Regge analysis, but at the same time general analyticity considerations preclude singularities that could distinguish the interval where $|z_c| \lesssim 1$ from neighboring regions. The necessity for resolving this theoretical paradox became urgent during the past months, when the first accurate experimental measurements of backward πN scattering began to appear.

What now appears to be the appropriate modification of the Regge recipe was conjectured independently by many theorists:[1] Instead of an expansion involving powers of z_c, one should use corresponding powers of E_d, the direct-reaction energy, with coefficients that depend analytically on the crossed-reaction energy E_c near $E_c = 0$. Such a representation had been introduced by Khuri in the equal-mass case, where it is convenient but not essential. With unequal masses, the functional relationship between the three quantities E_c, E_d, and z_c is singular at $E_c = 0$, so the proper choice of variable is critical. The above conjecture is suggested rather directly by the Mandelstam representation, but its justification as elucidated by Freedman and Wang,[2] following a suggestion by Mandelstam, has turned out to involve a surprise.

Consistency between analyticity requirements and the leading power of the Khuri expansion is achieved merely by requiring that the reduced residue of the leading Regge pole have an analytic dependence on E_c near $E_c = 0$.[1] Such behavior of the residue, however, does not in itself lead to analytic behavior for secondary terms in the expansions, which involve powers less than the leading power by 1, 2, 3, ··· units. The difficulty here led to two different conjectures. Goldberger and Jones[3] suggested that if the leading power is $\alpha(E_c)$, then a series of fixed powers, $\alpha(0) - 1$, $\alpha(0) - 2$, ··· would occur in the reaction amplitude in order to restore compatibility with analyticity requirements near the point $E_c = 0$. This conjecture abandoned the attractive idea that all asymptotic powers vary with the crossed energy. Mandelstam, on the other hand, conjectured that for every Regge trajectory there would necessarily exist an infinite sequence of "daughter" trajectories that at $E_c = 0$ would pass through the points $\alpha(0) - 1$, $\alpha(0) - 2$, etc. The residues of the various members of the sequence would be correlated so as to preserve analyticity of the full amplitude.

The Mandelstam conjecture at first sight seemed implausible because the spacing between Regge trajectories and the relation between residues is a dynamical issue usually depending on the details of the forces acting. Freedman and Wang, however, realized that a certain well-known model of strong interactions ought to exhibit the Mandelstam mechanism because this model was known not to contain fixed powers. They then set out to discover what property of this model, the so-called Bethe-Salpeter equation, could lead to the apparent miracle conjectured by Mandelstam. They found that the required property was a special symmetry of the Bethe-Salpeter equation at zero total energy--a symmetry that had been recognized by previous workers but whose relation to the issue here had not been appreciated. Freedman and Wang showed that the special symmetry guaranteed not only the integer spacing of trajectories but also the required relation between residues.

Within pure S-matrix models it has not yet been possible to identify a special symmetry at $E_c = 0$ corresponding to that of the Bethe-Salpeter equation, but where Regge behavior has been established, as in the strip model, it appears that the Mandelstam sequence of daughter trajectories is bound to follow. Since the daughters can be expected to produce particles at their points of physical angular momentum, a new dimension has been added to the already abundant spectrum of hadrons. Not only do we have the finite multiplets associated with internal symmetries such as SU_2 and SU_3 and the infinite Regge sequences of increasing angular momentum, but, also, if the daughter trajectories remain even roughly parallel to the primary, we can now anticipate increasing-mass sequences within which all other quantum numbers remain the same.

A further point of interest emphasized by Freedman and Wang is that the Mandelstam daughters alternate in signature, so that odd members of the sequence have an "anomalous" charge conjugation. For example, the first daughter of the ρ trajectory is physical at $J = 0, 2, 4, \cdots$ (with even parity) even though it has $I = 1$ and even G parity. Such a trajectory cannot communicate with particle-antiparticle pairs and could easily have been overlooked by most experiments to date. If the slope of primary and daughter trajectories is similar, the integer spacing continuing to hold roughly even away from zero energy; one thus expects an octet of 0^+ mesons of the same internal quantum numbers (including odd charge conjugation) and roughly the same mass as the octet of 1^- mesons. Analogous predictions can of course be made in connection with all known particles.

REFERENCES

[*] This work was performed under the auspices of the U. S. Atomic Energy Commission.

1. See, for example, J. Stack, Phys. Rev. Letters 16, 286 (1966).
2. D. Z. Freedman and J-M. Wang, Phys. Rev. Letters 17, (September 5, 1966).
3. M. L. Goldberger and C. E. Jones, Phys. Rev. Letters 17, 105 (1966).