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Lipkin H J & Scheck F. Quark model for forward scattering amplitudes. *Phys. Rev. Lett.* **16**:71-5, 1966.
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A model in which nucleons and mesons are bound states of quarks is used to predict relations between forward scattering amplitudes under the 'additive quark model' assumption that the hadron-hadron amplitude is the sum of the scattering amplitudes of the constituent quarks. Relations between total cross sections obtained are found to be in remarkable agreement with experiment, including relations between nucleon-nucleon and meson-nucleon cross sections which are unrelated by any other description. [The *SCI*® indicates that this paper has been cited in over 305 publications since 1966.]

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"By 1965 Gell-Mann[1] and Zweig[2] had proposed that nucleons were made of smaller objects called quarks. Greenberg[3] had shown that the degree of freedom now called 'color' solved the statistics problem, and Nambu had shown that a gauge theory with colored quarks (now called QCD) reproduced the gross features of the hadron spectrum.[4,5] But the particle physics 'establishment' had just barely given up the fight against SU(3) symmetry and the whole quark idea was dismissed as complete nonsense, particularly in America.

"A few European groups took quarks seriously. R.H. Dalitz in England, G. Morpurgo in Italy, W. Thirring in Austria, and several Soviet groups[6,7] (including Andrei Sakharov, then unknown in the West[8]) calculated predictions from the quark model which could be compared with experiment. The Weizmann group had been active in SU(3) symmetry from the beginning and examined the quark model not only as a possible basis for SU(3) but also to look for experimental predictions which went beyond symmetries and really tested the quark model.

"The 'Minerva' program of scientific collaboration and exchange between Israel and the Federal Republic of Germany had recently begun. One of the first postdoctoral fellows at the Weizmann Institute under this program was Florian Scheck, who had a background in nuclear physics and was interested in learning particle physics. Calculating predictions from the quark model was an ideal exercise to start him off. Having been brainwashed by the establishment, I did not expect any dramatic results. The existence of quarks was highly questionable and there was no justification for our basic assumptions not only that mesons and baryons were made out of quarks but also that a two-particle collision could be described as a collision between an 'active' quark in one particle and an 'active' quark in the other, with the remaining 'spectator' quarks just going along for the ride. This model gave new predictions[6,7] relating nucleon-nucleon scattering to meson-nucleon scattering which could not be obtained without the quark picture; e.g., that $\sigma_{tot}(pp) \simeq (3/2)\sigma_{tot}(\pi p)$. We were astounded when the new data showed remarkable agreement with nontrivial predictions of the model.

"We were fortunate in having excellent guides to direct us to the relevant recent experimental data, which was quite meager at that time. Gerson and Sula Goldhaber were then visiting Weizmann, shortly before Sula's unexpected death. During our very productive discussions, she was already complaining about severe headaches.

"This work began a research program on what is now called the 'additive quark model,' but which was initially greeted with extreme skepticism. One of our early papers[9] was accepted for publication only after new experimental results, which were unavailable when the paper was written, confirmed our predictions. It had been bogged down in arguments with referees who insisted that the quarks did not exist and our work was completely wrong.

"During the past 18 years an accumulation of overwhelming experimental evidence has forced the acceptance of the quark model on the reluctant theorists. The new party line is quantum chromodynamics, a theory in which the basic building blocks of matter are quarks. The additive quark model has been accepted, developed in many directions, and is still a major tool in analyses and predictions of experimental results. Many papers have been written which use the additive quark model. Of all these papers, our paper and the one by Levin and Frankfurt[6] are still cited as the first ones that started this ball rolling."

1. **Gell-Mann M.** A schematic model of baryons and mesons. *Phys. Lett.* 8:214-15, 1964. (Cited 815 times.)
2. **Zweig G.** Fractionally charged particles and SU_6. (Zichichi A, ed.) *Symmetries in elementary particle physics.* New York: Academic Press, 1965. p. 192-234.
3. **Greenberg O W.** Spin and unitary-spin independence in a paraquark model of baryons and mesons. *Phys. Rev. Lett.* 13:598-602, 1964. (Cited 365 times.)
4. **Kokkedee J J J.** *The quark model.* New York: Benjamin, 1969. 239 p.
5. **Lipkin H J.** Quarks for pedestrians. *Phys. Rep.—Sect. C Phys. Lett.* 8:173-268, 1973. (Cited 75 times.)
6. **Levin E M & Frankfurt L L.** The quark hypothesis and relations between cross-sections at high energies. *Zh. Eksp. Teor. Fiz. SSSR* 2:105-9, 1965, and *JETP Lett.—Engl. Tr.* 2:65-7, 1965. (Cited 255 times.)
7. **Lipkin H J & Tavkhelidze A.** Magnetic moments of relativistic quark models of elementary particles. *Phys. Lett.* 17:331-2, 1965.
8. **Zel'dovich Y B & Sakharov A D.** The quark structure and masses of strongly interacting particles. *Yad. Fiz.* 4:395-406, 1966, and *Sov. J. Nucl. Phys.—Engl. Tr.* 4:283-90, 1967. (Cited 25 times.)
9. **Alexander G, Lipkin H J & Scheck F.** Neutral-meson production cross sections and mixing angles in a quark model. *Phys. Rev. Lett.* 17:412-16, 1966. (Cited 105 times.)