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# This Week's Citation Classic

**Jacob M & Wick G C.** On the general theory of collisions for particles with spin. *Ann. Phys.* 7:404-28, 1959. [Brookhaven National Laboratory, Upton, NY]

The general analysis of reactions involving particles with arbitrary spin was reformulated so that it applied equally well to relativistic particles. The formalism proposed was both simpler and more powerful than the one so far in use. The discovery of a large number of fundamental particles of often high spin quickly imposed this new formalism as the standard for treatment of spin effects. [The *SCI*® indicates that this paper has been cited over 890 times since 1961.]

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"Fundamental particles have spin and this internal degree of freedom plays an important role in their interactions. If a detailed theory is still lacking, one may discuss spin effects at a general level making use explicitly of the invariance principles which constitute the framework of the quantum mechanical description of particle interactions. The purpose of this article, which we wrote in 1959, was to provide such a general formalism which would be suitable for the description of particle interactions among particles of arbitrary spin and which would apply equally well in the relativistic case. This could be achieved using the longitudinal spin component or the *helicity* of the interacting particles at all steps in the development of the formalism.

"Prior to that, theoretical techniques were available to deal with particles of arbitrary spin, but applications became cumbersome when considering the relativistic case. This was nevertheless suitable for nuclear physics uses. Nuclei may have rather high spins. Yet, usual kinetic energies remained very low as compared to mass energies.

Whenever relativistic particles had to be considered, as already the rule in particle physics, they were in practice low spin particles (spin $^{1/2}$ baryons and leptons, spin zero Ð mesons, spin 1 photons). They also could be described in terms of specific wave equations (i.e., the Dirac equation for electrons), which could be used to incorporate all spin effects. Our paper offered a more general and, as a matter of fact, far simpler approach for the treatment of spin than all formalisms so far available. Our treatment was fully relativistic and did not rely on the knowledge of any specific wave equation. However, it came at a time when there was not yet any urgent practical need for it. This may be why this research proceeded over several months before its results were published in a unique and detailed article, which is now both an original publication and a reference paper.

"Within a very short while it had an important impact on particle physics. This is due to two main reasons. First, was the rapid discovery of a very large number of particles of often large spins, (spin 1,2 ... mesons; spin 3/2, 5/2 ... baryons) which are actually just as fundamental as the ð mesons and the nucleons of particle physics in the 1950s. The phenomenology of the production and decay of such particles soon made great use of the helicity formalism. Second, was the impressive development of the S-Matrix approach to particle interactions which occurred in the early 1960s. It relies strongly on the explicit use of general invariance principles as a first step in the theoretical analysis of relativistic interactions. Spin effects were readily phrased in terms of helicity amplitudes.

"This paper had a particular importance in my career as a physicist since it was among the very first articles that I published in theoretical physics. It was part of my thesis work. I would like to use this note to express once more all the gratitude which I owe to Gian Carlo Wick whose influence on me has been so lasting and profound."