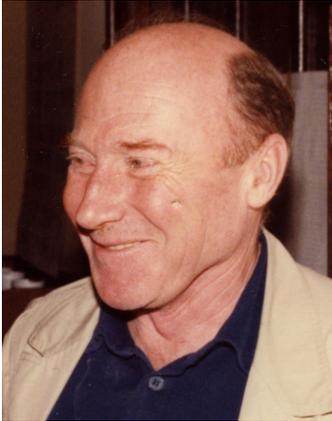# Obituary

Rudolf Haag

Rudolf Haag, german mathematical physicist, born August 17, 1922, passed away on January 5, 2016 at the age of 95 years.

Rudolf Haag's legacy is his seminal way of conceptual thinking about quantum field theory. His first groundbreaking contribution to the structural understanding of quantum field is known as Haag's Theorem (1955): While the canonical commutation relations are universal, they require an inequivalent representation - of which a system with continuous degrees of freedom possesses infinitely many - for every parameter set of a model (masses, coupling constants). As a consequence, the „interaction picture", despite its success as an approximative scheme, can be valid in an interacting theory only when there is a cutoff. In this respect, quantum field theory proves to be markedly distinct from quantum mechanics.

Following postdoctoral positions in Munich (where he got his PhD with Fritz Bopp in 1951), Copenhagen and Göttingen, Rudolf Haag was a guest professor in Marseille and in Princeton (1957-1959), and professor in Urbana-Champaign (1960-1966). During this period, he laid the foundations to an algebraic approach to quantum field theory that is complementary to Wightman's axiomatic setting.

His reformulation of scattering theory (1956/57, further elaborated by D. Ruelle, K. Hepp, and H. Araki) was the mathematical counterpart of the fact that the physical interpretation of scattering processes, in terms of particle species and their interactions, only relies on the localization of measuring results and their correlations („particle tracks"), without the need of a detailed specification of what has been measured.

This insight, detaching the analysis of quantum field theory from the use of fields and equations of motion, led him to the formulation of the new general framework (1964, with D. Kastler). It emphasizes the primary role of algebraic relations, the most prominent being Einstein causality referring to the localization of observables, while different physical states may and will require different representations of the same algebra. This is brilliantly exhibited in his book „Local Quantum Physics" (1992).

Haag's approach bore enormous fruit. Soon after he became professor in Hamburg (1966-1987), the analysis of the general concept of charge (with S. Doplicher and J.E. Roberts) revealed fundamental connections between charge, spin, and statistics, and eventually led to the proof that the charge structure of a quantum field theory uniquely determines its internal symmetries. While the converse is a familiar fact, no version of this result is known

in any other approach to quantum field theory.

Rudolf Haag had a strong intuition for the mathematics appropriate for the subtle issues of quantum physics, and he took the messages seriously that it has in store for physics. In order to illustrate the broad scope of his thinking about quantum field theory, a few further seminal contributions should be mentioned: his analysis of the BCS model of superconductivity (1962), the relevance of phase-space properties for the existence of particle states of a quantum field theory (1965, with J.A. Swieca), and the first classification of supersymmetries as symmetries of the scattering matrix (1975, with J. Łopuszański and M. Sohnius).

Jointly with N. Hugenholtz and M. Winnink, Haag strived to understand thermal equilibrium of infinite quantum systems independent of an approximation by Gibbs states in finite volume (1967). They could completely characterize such states by the so-called KMS condition, and they discovered a hidden structure that was unveiled at the same time by mathematicians M. Tomita and M. Takesaki for a large class of states on von Neumann algebras. It was found later to be also related to space-time symmetries (Lorentz boosts and CPT) and to the Unruh effect. For Rudolf Haag, this conjunction was an indication of a „pre-established harmony" between physics and mathematics.

Haag also took up the challenge from general relativity in articles with H. Narnhofer and U. Stein (1984) on the stability of quantum field theory in curved space-time, and with K. Fredenhagen (1990) on the Hawking radiation of a star collapsing into a black hole.

After his retirement in 1987, Rudolf Haag's focus of his interest turned on the concept of an „event" in quantum theory as the transition between a statistical possibility and a fact. In spite of his bad health and almost complete blindness, he kept attending conferences and continued to contribute to the scientific discussions until the end.

Rudolf Haag was the founder (jointly with R. Jost) and first editor-in-chief (1965-1973) of the *Communications in Mathematical Physics*, that became the leading journal for the mathematical study of quantum field theory and many related issues. Among other honors, he was awarded the Henri Poincaré Prize of the International Association of Mathematical Physics (1997), and the Max Planck medal of the German Physical Society (1990). Among his students are Huzihiro Araki, Detlev Buchholz, Volker Enss, Klaus Fredenhagen, and Bert Schroer.

By fortune, Rudolf Haag had been visiting his sister in England in the fall of 1939, so that he was detained as „enemy alien" and had to spend the wartime in a camp in Canada. He made the best of it by teaching himself physics from books. He was married twice and has three sons and a daughter from his first marriage.

Rudolf Haag leaves a great legacy to the mathematical physics community. He will be missed.

Arthur Jaffe, Harvard University
Karl-Henning Rehren, Göttingen University