Research Summary

Professor Virendra Singh is internationally renowned for his outstanding contributions to the development of the theory of elementary particles. His contributions extend over a wide range from the deepest conceptual ideas in physics such as his work on the Foundations of Quantum Mechanics to High Energy Phenomenology, Quantum Field Theory and Mathematical Physics. He has published about 200 papers.

Professor Singh has made significant research contributions in the field of Theoretical High Energy Physics, i.e. the theory of elementary particles and quantum field theory. Much of his earlier work is in the area of strong interactions dynamics using approaches based on analyticity, field theory and symmetry. His more recent work explores the unusual phenomena encountered in quantum field theory when either the soliton background field or boundary conditions play an important role.

Regge poles: His exact determination of the analyticity properties of the Coulomb scattering amplitude was quite illuminating as the solution was explicit.

His analysis of high energy pion-nucleus-scattering, using Regge-Pole theory, become the standard way to analyse this process in all later investigations. The importance of the helicity amplitudes, in the Regge-Pole context, was also first pointed out there.

He was also involved in a project (with M. Gell-Mann, M.L. Goldberger, F.E. Low and F. Zaachariasen) to investigate whether elementary particles in the conventional Langrangian field theory could convert themselves into Regge Poles, i.e., Reggeise, as a result of higher order processes. In contrast to the case of spinor electrodynamics the scalar particles in the scalar electrodynamics do not Reggeise.

Symmetry: Assuming that the decay interaction transforms as an octet operator of unitary symmetry SU(3), they decay of the Baryon decuplet into the Baryon and Meson actet was investigated and a number of sum rules obtained. One of these Sum rules connecting various decays into pion, known as Gupta-Singh sum rule, gives a good account of these processes.

The SU(6) symmetry was quite successful in giving the correct spectrum of hadron states. The masses of the hadrons, in this symmetry scheme, received their explanation in the work leading to Bég-Singh SU(6) mass formula. the level spacings in the Baryon resonance decouplet were related to those in the lowest Baryon octet.

Bootstrap and strong coupling theory: Among his large number of investigations on bootstrap theory to understand the particle spectrum and their couplings particularly notable is the one in which he obtained strong interaction coupling constant ratios in a rather elegant manner. Equivalence of the Lie Group of the Strong Coupling Theory to static bootstrap was established. An unusual instance of dynamic symmetry generation was pointed out. The recent work on Skyrmion dynamics and its connection to the Large-N Quantum Chromodynamics again relates to the Strong Coupling Theory.

Current algebra: The discovery of a fixed pole at J=1 in the current algebra amplitudes was made while analysing Fubini Sum Rule.

The classical low-energy theorems such as those giving Thomson Scattering amplitude and, those due to F. Low and Gell-Mann Goldberger give terms up to first order in energy for the Compton scattering amplitude. These are exact to all orders in strong interactions and the lowest order in electromagnetism. A deeper analysis revealed that for certain parts of the amplitude such theorems can be extended to higher order in energy as well. This was a totally unexpected discovery.

High energy theorems: A number of useful and exact restrictions on the high energy behaviour of strong interactions follow from the general principle axiomatic quantum field theory such as unitarity, crossing analyticity and polymonial boundedness. The earlier work on these theorems was due to M. Froissart, A. Martin and others. As noted by Einhorn and Blankenbecler, "The recent revival of interest in the subject is due to the Serpukhov data suggesting a violation of the Pomeramchuk theorem and to the very interesting results by S.M. Roy and V. Singh." Especially important were the results on particle-antiparticle total cross section differences and those giving upper bounds on the elastic scattering amplitudes.

Potential theory: The analytic theory of fractions was applied here to anhoarmonic oscillators, a class of confinement potentials and rotating harmonic oscillators to obtain exact theorems on the coupling constant domain.

The generalisation of high order JWKB expression for energy level, and especially for the wave functions at origin, were obtained and found useful in discussing upsilon resonance decays in electron positron pairs.

All possible solitons in Schrodinger equations, which propagate without change of shape, were found. New generalised coherent states were proposed.

An exact solution of the Schrodinger equation in Aaharanov-Bohm plus Dirac-Monopole potential was obtained.

Proton decay: An effective Baryon-Lepton coupling model for the phenomenological analysis of Baryon number violating decays of a Baryon was proposed. This model allows one to discuss the phenomenology of various decay modes directly in terms of hadrons.

Quantum field theory with solitions and/or boundary conditions: There has been a renaissance in the study of quantum field theory and a number of a new phenomenon have been discovered. These generally arise from a consideration of quantum field in interaction with soliton background field and/or from a considerable or more general boundary conditions. An exact expression for fractional fermion number induced by solitons and boundary conditions, allowed by self adjointness considerations, was obtained.

Even more significant is the discovery of new string theories, obeying different boundary conditions than the usual open and closed strings, which can have Poincare invariance in dimensions less than critical one. Two new classes of string theories arise, namely, quasi open and quasi closed as a result of new boundary conditions allowed by action principle.

Field theory and statistical mechanics: An identification of various O(n) and the q-state Potts models in statistical mechanics in two dimensions with subset of conformally invariant quantum field theories of Belavin, Zamolodochikov and Polyakov type as been proposed. This immediately, leads one to a determination of all critical indices.

Foundations of quantum mechanics: Generalization of Bell's inequalities to provide new tests of hidden variable theories. Formulation and experiments. Tests of signal locality. Violations Einstein locality for large systems. A casual description of one dimensional quantum mechanics treating position and momentum variable symmetrically. New phase space Bell's inequalities have been obtained and used to derive (N+1) marginal theorem for (2N)-dimensional phase space.