THEORETICAL PARTICLE PHYSICS

FACULTY

James Daniel Bjorken[†]	Sidney Drell	Michael Peskin
Richard Blankenbecler[†]	Joanne Hewett	Helen Quinn
Stanley Brodsky	Shamit Kachru[††]	Eva Silverstein[††]
Lance Dixon	Pierre Noyes[†]	

[†] Emeritus
[††] Joint Appointment

Theoretical particle physics research at SLAC covers all of the major areas of current interest from MeV energies to the Planck scale and beyond. A unifying theme for the work of our group is the application of quantum field theory and its generalizations to problems of the known fundamental interactions and to possible new interactions at very short distances. We are investigating the properties of the strong interactions as a theory of quarks and gluons ("Quantum Chromodynamics"), the theory of the weak interactions and its precision tests at high-energy colliders, the nature of the Higgs boson and possible alternatives for generating the masses of quarks, leptons, and gauge bosons, the theory of CP violation and the analysis of B-meson decays that probe this theory, and new theoretical structures for unifying the known interactions of particle physics with gravity and possible higher symmetries of Nature.

QUANTUM CHROMODYNAMICS

Much of our knowledge about particle interactions comes from experiments on strongly interacting particles ("hadrons"), which are bound states of quarks and gluons. The binding in these systems is very strong, such that isolated quarks and gluons have never been seen in the laboratory. Nevertheless, there are a variety of phenomena that depend on the quark and gluon structure of hadrons. On one hand, the interactions of hadrons with nuclei and the production of single hadrons at very high energy show remarkable characteristic features that reflect the underlying quark properties. Many of the observables for this study have been invented by our group. On the other hand, the rates for reactions involving large momentum transfer among hadrons or production of heavy electroweak bosons can be computed precisely from the quark-gluon theory, allowing this theory to be tested to high accuracy. Members of our group are leaders in this activity, which has produced some of the most complex calculations performed to date in perturbative QCD. These calculations are also very important for estimating the conventional backgrounds to possible new physics processes at next-generation colliders such as the CERN Large Hadron Collider.

B PHYSICS AND CP VIOLATION

Today, the BABAR experiment at SLAC is studying fundamental asymmetries in Nature between particles and antiparticles by detailed study of the decay of B mesons produced at the PEP-II collider. The question arises again here of how measurements done on hadrons such as B-meson can give precise information about the laws obeyed by the quarks that make up these hadrons. To obtain sharp conclusions about quark-antiquark asymmetries, it is necessary to understand how QCD bridges from the quark to the hadron level, and to choose reactions to study in which that bridge is as simple as possible. Members of our group are studying all aspects of this problem. Particle-antiparticle asymmetry in the fundamental laws is probably the reason that the universe we observe contains more matter than antimatter. We are trying to understand the connection between our laboratory experiments and the large-scale asymmetry of the universe.

WEAK INTERACTIONS AND HIGGS BOSONS

The weak interaction responsible for radiative decay processes is also an important ingredient in the picture of fundamental interactions. During the 1990's, experiments at SLAC and elsewhere made precision tests of the current unified theory of weak and electromagnetic interactions. Members of our group contributed to this work, in thinking about especially powerful observables for this study and in analyzing how precision data would constrain the properties of possible new particles such as the Higgs boson. Accelerators of the next generation, the LHC and the e^+e^- International Linear Collider, will sensitively test the weak interactions of the heaviest known particles, the W boson and the top quark, and will study the Higgs boson directly. We are interested in these experiments as windows to possible new physical interactions.

SUPERSYMMETRY, EXTRA DIMENSIONS, AND THE NEXT NEW FORCE OF NATURE

The recent precision studies of the weak interaction imply with increasing strength that there are new laws of physics that remain to be discovered. It is very likely that the accelerators of the next generation will produce new types of elementary particles. These particles are needed to explain the symmetry-breaking that gives rise to the masses of quarks, leptons, and gauge bosons, and to make up the "dark matter" observed by cosmologists to be associated with galaxies and clusters of galaxies. Members of our group are strongly engaged in building models of possible new physics beyond the known interactions, and in studying how the associated new particles can be studied in future experiments. It is possible that these new particles arise because the universe actually contains more than the observed four dimensions. Members of our group have devised many of the current experimental tests for extra space dimensions in Nature. Another possibility is that the new particles arise from a symmetry called 'supersymmetry' that relates particles of different spin. This theory is connected to superstring theory and new theories of quantum gravity, as will be discussed below. Members of our group are building new models of Nature that incorporate supersymmetry, and are studying how experiments can diagnose the nature and origin of their new particles.

SUPERSTRING THEORY AND QUANTUM THEORY

It is likely not possible to build a quantum theory of gravity on the basis of point particles such as those found in conventional quantum field theory. A candidate for the sort of profound generalization of physical law needed for this step is "string theory", the idea that elementary particles are tiny extended objects with internal degrees of freedom. String theory could be the basis for a unified theory of elementary particle interactions with gravity. It also naturally contains the possibility of supersymmetry and extra dimensions, perhaps at extremely small scales but perhaps in a way that can be directly observed in experiments. Members of our group are engaged in the creation of unified "theories of everything" based on string theory, and in the exploration of how string theory might address the deepest issues of the quantum theory of black holes and cosmology.

SEMINARS, DISCUSSIONS, CONTROVERSY

The best way to make progress in a conceptual field such as theoretical physics is to argue. Within our group, we promote discussion and exchange of ideas. Between SLAC and the Stanford Physics Department, we schedule several seminars per week on particle theory, with speakers from our group and from other universities. We are known as one of the world's toughest audiences. By studying new ideas from the community, analyzing them, and tearing them apart, we can build the new ideas that might solve the difficult problems that Nature poses for us. We invite your participation.