

<<统一理论和超对称>>

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前言

The new millennium has brought new hope and vigor to particle physics. The menacing clouds of despair and discontent that enveloped the field following the collapse of SSC have all but vanished. The discovery of neutrino mass has brought the first light of new physics beyond the standard model. The LEP-SLC data has given strong hints of a light Higgs boson, which is widely hoped, will be discovered soon either at the Tevatron or LHC. LEP may quite possibly have missed it by a hair. Many neutrino experiments are either underway or are in the planning stages, and a rough outline of neutrino mixing is appearing on the horizon. There are discussions of pulling resources internationally to build a linear collider after the LHC. Many major breakthroughs in the sister discipline of cosmology have lightened up the sky. Even the job situation in the field is showing signs of improvement after a long plateau. All this hope and optimism about a bright future for the field seem to be resting on two ideas: unification and supersymmetry. The first is based on the amazing success of the standard model, giving credence to the possibility that the final theory of particle physics could come from gauge theories and string theory, from which the gauge symmetries follow. The belief in supersymmetry arises not only from its beauty and elegance and its ability to truly unify matter and forces but also from the way it embraces gravity into the fold of particle physics. Its hold on the field is almost as pervasive as that of gauge theories. Even though there are many other competing ideas vying for the attention of theorists, the general direction seems to be largely set towards supersymmetry, supergravity, and superstrings.

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内容概要

本书是作者依据其为马里兰大学高年级研究生授课时所用的讲义编著而成，详细介绍了人们尝试建立一个能够描述自然界中各种基本相互作用的大统一理论的最新进展。

本书包罗甚广，涉及到粒子物理学中的大统一理论和超对称理论中的许多议题，例如自发对称破缺，大统一理论，超对称性和超引力等。

作者在简要回顾了基本粒子理论之后，详细介绍了复合夸克，轻子，希格斯玻色子和CP破坏等论题，最后讨论超对称的大统一方案。

这是本书的第三版，进一步修订了书中内容，添入该领域的最新进展，特别是近年来实验方面的诸多进展。

对这些新进展的集中介绍很有意义，使得本书成为该领域中连接传统理论与研究前沿的有益桥梁。

无论对该领域的研究生还是对研究人员来讲，本书都是一部很有价值的教科书和参考文献。

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章节摘录

插图：three-quark bound states, whereas meson spectroscopy arises from nonrelativistic quark-antiquark bound states. Accepting quarks as the constituents of hadrons, we have to search for a field theory that provides the binding force between the quarks. In trying to understand the Fermi statistics for baryons (such as Λ), it became clear that if they are S-wave bound states, then the space part of their wave function is totally symmetric; since a particle such as Λ consists of three strange quarks, and has spin $3/2$, the spin part of its wave function is symmetric. If there were no other degree of freedom, this would be in disagreement with the required Fermi statistics. A simple way to resolve this problem is to introduce [11] a threefold degree of freedom for quarks, called color (quarks being color triplets) and assume that all known baryons are singlet under this new $SU(3)_c$. Since an $SU(3)_c$ singlet constructed out of three triplets is antisymmetric in the interchange of indices (quarks), the total baryon wave function is antisymmetric in the interchange of any two constituents as required by Fermi statistics. It is now tempting to introduce strong forces by making $SU(3)_c$ into a local symmetry. In fact, if this is done, we can show that exchange of the associated gauge bosons provides a force for which the $SU(3)_c$ color singlet is the lowest-lying state; and triplet, sextet, and octet states all have higher mass. By choosing this mass gap large, we can understand why excited states corresponding to the color degree of freedom have not been found. While this argument in favor of an $SU(3)_c$ gauge theory of strong interaction was attractive, it was not conclusive. The most convincing argument in favor of $SU(3)_c$ gauge theory came from the experimental studies of deep inelastic neutrino and electron scattering off nucleons. These experiments involved the scattering of very-high-energy (E) electrons and neutrinos with the exchange of very high momentum transfers (i.e., q^2 large). It was found that the structure functions, which are analogs of form factors for large q^2 and E , instead of falling with q^2 , became scale-invariant functions depending only on the ratio $q^2/2mE$. This was known as the phenomenon of scaling [12]. Two different theoretical approaches were developed to understand this problem. The first was an intuitive picture called the parton model suggested by Feynman [13] and developed by Bjorken and Paschos [14], where it was assumed that, at very high energies, the nucleon can be thought of as consisting of free pointlike constituents. The experimental results also showed that these pointlike constituents were spin- $1/2$ objects, like quarks, and the scaling function was simply the momentum distribution function for the partons inside the nucleon. These partons could be identified with quarks, thus providing a unified description of the nucleon as consisting of quarks at low, as well as at high, energies. The main distinction between these two energy regimes uncovered by deep inelastic scattering experiments is that at low energies the forces between the quarks are strong, whereas at high energies the forces vanish letting the quarks float freely inside the nucleons.

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