its gain in the energy sector. Since electricity can be generated via an extraordinary diversity of sources, it is a convenient, high-quality common mode for delivering energy. Its high quality partly accounts for its steady growth compared with other fuel cycles. That high quality also accounts for the fact that advances in technology constantly increase the efficiency of electricity use. But Hurwitz's implication that higher efficiency creates a booby trap (by holding down demand growth) does not hold water. Indeed, even the historical trends are somewhat misleading. The ratio of electricity use of GNP has been relatively constant since the mid-1970s, while the ratio of energy use overall to GNP has fallen considerably since the 1970s. Nonetheless, the constant electricity–GNP ratio trend disguises the fact that dramatic improvements in efficiency (which, alone, would cut demand) were offset by new uses, increased market shares and substitution of electricity for other energy forms. As more efficient technologies using electricity are developed, electricity can compete more directly with alternative energy supplies and its market expands. In other words, higher efficiency, while it may momentarily delay the growth of demand for electricity, ultimately will drive demand growth.

As external costs of energy supplies become more widely recognized and are incorporated into price, the alternative ways to generate electricity will sort themselves out. However, this may take an additional push from regulators to foster greater competition in generation, fuller incorporation of external (particularly environmental) costs into the price of electricity, and utility investment decisions made on a "least total cost" basis.

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11/91

Why Quarks Remain Questionable

The news report on the 1990 Nobel Physics Prize (January 1991, page 17) gives the impression that the existence of quark–partons is confirmed in inelastic electron–nucleon scattering. That implication is premature at best and in complete error at worst.

Quarks and gluons are not directly observable. Their existence can be confirmed only if quantum chromodynamics can make sweeping predictions to explain the majority of hadron scattering phenomena beyond a reasonable doubt. The major sector of QCD seeks to explain the permanent confinement of quarks and gluons, the hadron spectra and "soft hadronic scattering processes." This sector of QCD has not been solved, so it can yield no definitive predictions. In the asymptotically free sector of QCD perturbative methods can be applied because of the weak coupling at short distances. But the transition from confinement to asymptotic freedom is not proven.

The parton model[1] postulates point-like constituents inside a hadron. The naive parton model is not viable since its prediction of exact scaling is not supported by experiment. The modern parton model is the marriage of the original parton conjecture with the asymptotically free sector of QCD. The parton conjecture is also not derivable from QCD. The modern parton model relates the momentum-transfer dependence of deep-inelastic-scattering structure functions to Λ, a parameter that determines the variation of the perturbative QCD coupling constants with the momentum transfer Q. When the relation is applied at moderate Q, Λ is[2] approximately 500 MeV/c. When it is applied at larger Q, Λ is[3] approximately 85 MeV/c.

This inconsistency in Λ casts doubt on the applicability of the parton model at moderate Q, because the relation is best in the limit of infinite momentum transfer. Recent analysis reveals that in the moderate-Q region the cross section has significant Q-dependent structure that can be explained by soft hadronic processes but not by the parton model. At larger Q, the applicability of the parton model is still an open question whose answer must await the next generation of experiments. A recent analysis suggests that deep inelastic scattering is much more violent than envisioned by the parton model. The data seem to require hadrons to have hard cores, whereas in the parton model a hadron is just a bag of parton gas. QCD does not favor one picture over the other because it is not solvable and thus has failed to offer definitive predictions.

The inclusive cross sections of soft hadronic processes display similar scaling violation, as does e^+e^- annihilation into hadrons.[4] Actually so many aspects of e^+e^- annihilation into hadrons are similar to soft hadronic processes that strong suspicions have persisted as to whether annihilation is really different enough to warrant use of the parton model. Multijets are produced in

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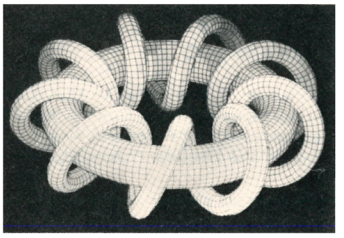

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both processes. Three-jet analysis of e^+e^- annihilation, which is claimed to confirm the parton model, assumes arbitrarily that the multijet background from soft hadronic processes is minimal. Some phenomenologists have reported that the rate of four-jet events in high-energy e^+e^- annihilation is much larger than can be explained by the parton model. Profuse production of four or more jets at higher energies is characteristic of soft hadronic processes, but not of the parton model. Unfortunately, those who claim to have confirmed the parton model failed to report this crucial excessive rate of four-jet events in e^+e^- annihilation.

In spite of a few noteworthy successes in explaining cross-section ratios, there are many serious objections to the hasty application of the parton model. Any claim of the confirmation of the existence of quarks or gluons is as unfounded as the claims of confirmation of the modern parton model on which it is based.

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Editional Information on a Particle Text

In his review of Otto Nachtmann's book *Elementary Particle Physics: Concepts and Phenomena* (April 1991, page 101), our colleague Francis Halzen compares it with our own *Gauge Theories in Particle Physics* as well as with texts by Donald Perkins and by Alan Martin and himself. We were surprised that Halzen referred to our first edition (published in 1982) rather than to our completely revised, enlarged and updated second edition (Adam Hilger, 1989; distributed in North America by AIP). In two particular respects, Halzen's remarks—while perfectly fair as regards our first edition—are definitely inapplicable to the second.

First, Halzen contrasts the field theoretic approach followed by Nachtmann with "the very phenomenological paths traveled" in the three other texts. We believe that our second edition offers precisely a novel and appealing "middle way" between the intuitive but (at crucial points) *ad hoc* procedures of the phenomenological approach and the rather daunting formalism of the full field theory treatment. In our low-level introduction to quantum field theory, we have judiciously controlled the spread of the formalism, using the field theory ideas to buttress the formerly weak points of the phenomenological approach. In our experience, this kind of treatment is very popular with beginning graduate students and with our experimental colleagues.

Second, Halzen refers to "the older texts, which were written before the weak intermediate bosons were discovered." A vital component of our 1989 edition is the *confrontation* between the predictions of the standard model and the dramatic experimental discoveries of the early 1980s, which so remarkably confirmed the theory. This goes for both weak interactions and quantum chromodynamics, the latter of which we treat in a wholly new chapter.

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HALZEN REPLIES: I read and was indeed referring to the first edition. I apologize and stand corrected.

FRANCIS HALZEN
12/91 *University of Wisconsin, Madison*

Photo Flip Remark

There was no reason to invert the photo in Leo Kadanoff's Reference Frame column (March 1991, page 9) so that it could serve as a crude representation of a thermal plume. If the picture had been run right-side up, it could have been labeled a downwelling structure in a front between two eddies. Such structures are actually fairly common in all major oceanic current systems. The same technical points could have been made in the column with an accurate label and by using the mixed layer above the thermocline as the "boundary layer" discussed in the text.

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