Fermi National Accelerator Laboratory
FERMILAB-CONF-94/225-T

Top Quark Matters

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Abstract

The top quark's properties test electroweak theory and influence parameters of the everyday world.

The exotic concerns of particle physics—quarks and gluons and Higgs bosons—help us to understand nature on the human scale. We have known since the 1920s that to explain why a table is solid, or why a metal gleams, we must understand the atomic structure of matter, which is ruled not by the customs of everyday life, but by the laws of quantum mechanics. The evidence for the top quark presented in Glasgow makes us think anew about how the microworld influences our surroundings.

It is popular to say that top quarks were created in great numbers in the early moments after the big bang, disintegrated in a fraction of a second, and vanished from the scene until physicists learned to create them in accelerators. That would be reason enough to be interested in top: to learn how it helped sow the seeds for the primordial universe that has evolved into the world of diversity and change we live in. But it is not the whole story; it invests the top quark with a remoteness that hides the immediacy of particle physics. The real wonder is that here and now, every minute of every day, the top quark affects the world around us.

A few numbers determine the dimensions and character of the everyday world, from the size of atoms to the energy output of the sun. Only a generation ago, these parameters of the quotidian—the mass of the proton, the mass of the electron, and the strengths of the fundamental interactions—seemed givens, beyond the reach of science. Today, we have begun to discern links among them. We see how each of them might be understood in principle, or even computed.

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† Operated by Universities Research Association under contract DE-AC02-76CHO300 with the US Department of Energy.

Once top is established, the next crucial test of the electroweak theory will come from precise measurements of the top and W masses. If they stand in the predicted relation, we will have new confidence that we understand the weak and electromagnetic interactions—and understand how the top quark influences our world.

A short speculative leap leads to a dramatic example of top's influence on the mundane. In a unified theory, the strengths of the strong, weak, and electromagnetic interactions all are equal at some very high energy. The different strengths we observe arise because the interactions evolve differently with energy. How they evolve depends on the character of the forces themselves and on the spectrum of particles from very high energies down to the energy scale of common experience. Because top stands apart as very much heavier than the other quarks, it has a special influence on running couplings. The mass of the top quark is encoded in the strengths of the forces that rule the everyday world.

But that is not all. The proton is made of up and down quarks bound together by gluons. In a sense we can make reasonably precise in lattice gauge theory, the proton's mass is governed by the QCD scale parameter Λ_{QCD}, which is influenced by the top mass. The top quark is not a constituent of the proton, but if top weighed ten times more or less, the proton mass would shift up or down by about twenty percent. This world—our world—would have a very different character.

While we await definitive news of the top quark, we can savor the realization that to understand one of the most decisive parameters in the everyday world—the proton's mass—we need to know the top's properties. Top matters!

To appear in the Proceedings of the 1994 International Conference on High Energy Physics, Glasgow.

Operated by Universities Research Association Inc. under contract with the United States Department of Energy