

Physicists 'See' Single Top Quarks at the Tevatron

August 22 2008, By Laura Mgrdichian

(PhysOrg.com) -- Scientists at the world's largest fully operating particle accelerator, the Tevatron at Fermi National Accelerator Laboratory (Fermilab) in Illinois, have discovered convincing evidence suggesting the existence of top quarks that are not coupled to their antiparticle, the antitop. These "single" top quarks have been hunted since Fermilab scientists first discovered top-antitop pairs in 1995.

The results, published in a recent edition of *Physical Review D*, affirm and improve upon preliminary data published last year in *Physical Review Letters*, which pointed to the production of single top quarks but were not precise enough to claim true discovery.

Fermilab physicists hope that the techniques they used to find the single top quark could help them in their search for the proposed Higgs boson, a particle that exists so far only in theory but if actually found would have a huge impact on physics. The Higgs is expected to reveal such basic information as why nature assigned certain masses to certain particles—the origin of mass, essentially.

The results are the product of a long period of analysis by Fermilab's D0 ("D-Zero") collaboration, an international group of physicists from 90 institutions. The group studies data from particle collisions that occur within the D0 particle detector; in this case, data generated by collisions between a beam of protons and a beam of antiprotons. D0 is a building-sized cylindrical device that surrounds the collision site, measuring and recording the energies and trajectories of the many, many particles

produced when the beams are smashed together.

Isolating one signal of interest out of the massive amounts of data collected by the D0 detector, the "signature" of a certain particle or event, is an extremely difficult task.

"I would say that the single top is the most subtle signal that we have been able to successfully extract from our data," said D0 co-spokesperson Darien Wood, of Northeastern University, to *PhysOrg.com*. "In the end, the signal is based on only a few events, but it is not particular events that you can point to. Instead, it is a subtle statistical difference in the population of events that tells you that the single top is in the mix."

He clarified, "For example, I could say that the population of Danes is on average slightly taller than the population of Norwegians. But I cannot say that if I randomly pick one Dane and one Norwegian, the Dane will be taller. Nor can I look at someone's height and determine whether that person is Danish or Norwegian.

"If, however, I had a sample with an unknown mix of Danes and Norwegians, I could estimate the fraction of Danes knowing only their heights."

Using this premise, and some very sophisticated analysis techniques, D0 physicists first narrowed down a million billion proton-antiproton collisions worth of data to about 1,400 events that may have produced a single top quark. From there, they determined that 60 of these were single-top events.

The co-leader of the team who performed the analysis, Ann Heinson from the University of California, Riverside, told *PhysOrg.com*, "These 60 events differed only in the tiniest details from the rest of the sample

of 1,400 events. We had to use three independent methods to combine multiple measurements of different properties of the events to be able to distinguish the signal events from the background ones. We then combined the three results for maximum sensitivity.

"These three discrimination methods had not been used in a search before. The graduate students and postdocs who did the analyses really broke a lot of new ground."

Single top quarks, as well as the Higgs, are predicted by the "Standard Model" of particle physics, the broad theory that describes elementary particles, three fundamental physics forces—strong, weak, and electromagnetic—and the relationships between them.

At very high energies, like those produced in accelerators, the weak and electromagnetic forces are often thought of as two aspects of the same force, and are therefore sometimes collectively referred to as the electroweak interaction. The Standard Model states that the electroweak interaction can produce a top quark together with either a "down" antiquark, a "strange" antiquark, or (the vast majority of the time) a "bottom" antiquark.

This is unlike strong-force interactions, in which the top quark is always produced with a top antiquark. It was from these interactions that physicists from both of Fermilab's main experiments, D0 and CDF, were able to first discover the top quark in top-antitop pairs.

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