The last piece of the Tevatron top quark asymmetry story

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Comparison of the combined inclusive forward-backward asymmetry for Tevatron measurements and NNLO calculations, where the asymmetry is measured in percent.

With the Run II data collected at the Tevatron over a period of 10 years, the CDF collaboration was able not only to confirm the prediction of the existence and the properties of the top quark, but also to constrain and refine the predictions. A perfect example is the measurement of the “forward-backward asymmetry” of top quarks produced in pairs.

A top quark-antiquark pair was produced about every hour from proton-antiproton collisions at the Tevatron. Some of the top quarks follow the direction of the proton, the forward direction, while others go the other way, in the backward direction. A small preference for the forward direction was predicted many years ago and is quantified as the forward-backward asymmetry. With the data collected by the CDF detector, we were able to measure this asymmetry and compare it to predictions from the Standard Model.

The first experiments, begun in 2008, by both CDF and DZero to measure this result showed an interesting hint of a larger asymmetry than the 4-5 percent prediction (next-to-leading order) at that time, but had large statistical uncertainties. Later experimental results from both the CDF and DZero collaborations also saw this trend toward a larger asymmetry with better precision.

This intriguing excess triggered a lot of discussion and a worldwide chase for new physics. The theory community worked on improving the predictions from the Standard Model and postulated novel scenarios with new particles that could explain this excess.

On the experimental side, the CDF and DZero collaborations worked on better measurements taking into consideration the improved simulations, and a lot more results were released.

The primary analysts for this measurement are Ziqing Hong (top, Texas A&M University, now at Northwestern University), Dave Toback (bottom left, TAMU) and Jon Wilson (TAMU).

CDF has just completed its last measurement of this asymmetry, using the full Tevatron Run II data set, in the scenario where both the top quark and antiquark decay leptonically (see the above figure). The result yields a total asymmetry of 0.12 ± 0.13. After combining with the previous CDF measurement, the final CDF measurement comes to 0.160 ± 0.045, which is consistent with the current best Standard Model calculation (next-to-next-to-leading order) of 0.095 ± 0.007.

While this measurement may be the last word from proton-antiproton production for many years, the legacy of these Tevatron results should not be underestimated. The top quark continues to be a fascinating probe, and the push from leading-order calculations, which are now clearly insufficient to understand top quark production, has moved us to the point where we need next-to-leading order and next-to-next-to-leading order and beyond if we are to understand nature's heaviest fundamental particle and use it to discover new physics beyond the Standard Model.

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