Single Tquark Events at CDF

Frank D. (Tony) Smith, Jr. - Nov 2006

CDF has recently released two different analyses of its search for single Tquark events:

- Likelihood Function method (LF), which is based on data near the Tquark mass peak around 175 GeV, found no events, thus disagreeing with the Standard Model; and
- Matrix Element method (ME), which did find events, but many of those events were for Tquark mass below 150 GeV.

My explanation for the apparent discrepancy is based on a model of the Tquark - Higgs - Vacuum system in which the T-quark is regarded, not as a simple quark with mass about 175 GeV, but as a system in which the Tquark has three mass states:

> CDF and D0 observed 3 peaks in their T-quark data (see FERMILAB-PUB-94/097-E from CDF and hep-ex/9703008 from D0):
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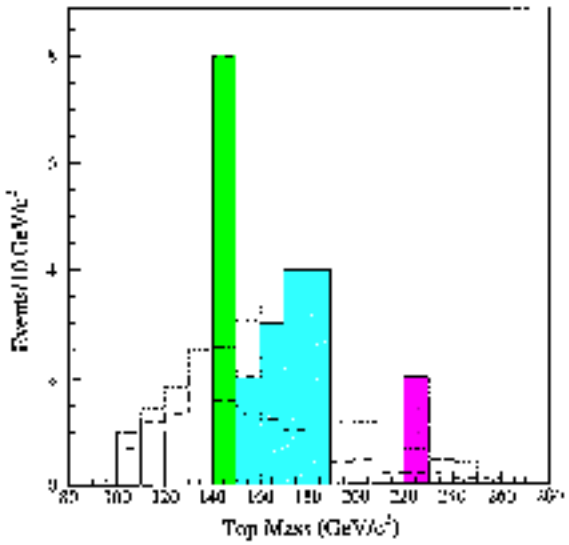
> 
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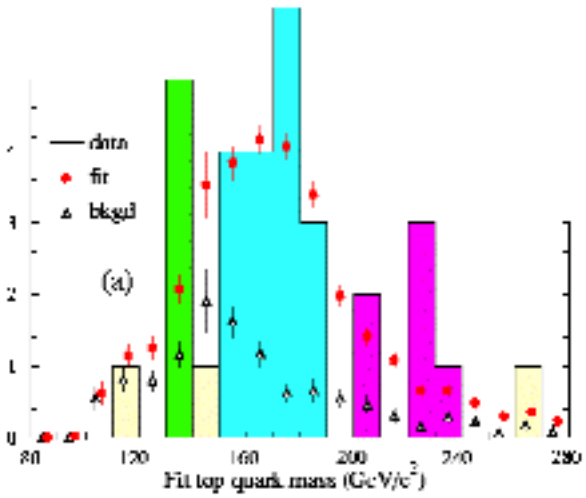
> 
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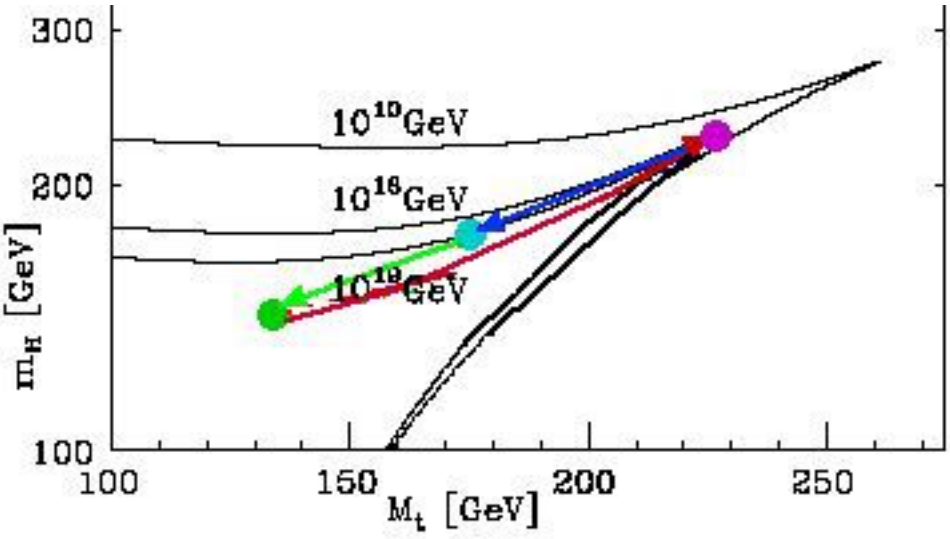
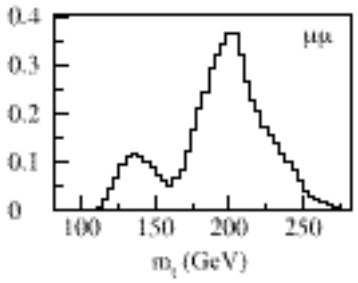
>
> The middle (cyan) peak (around 175 GeV) is the one they initially identified as the T-quark.
>
> The low peak (green) around 130-150 Ge V and the high peak (magenta) around 225 GeV

can be understood in terms of Froggatt's paper hep-ph/0307138 in terms of a 3-part system of the T-quark, the Higgs, and the Triviality Bound, with a high-energy cut-off that goes all the way to the Planck energy 10^19 GeV (the graph below also shows curves for cut-offs at 10^16 and 10^10 GeV and it can be seen that a GUT-level cut-off around 10^16 GeV gives similar results).



For one example of the high and low peaks, look at the D0 event Run 84395, Event 15530 (mu mu) described in the 1997 UC Berkeley PhD thesis of Erich Ward Varnes and in hep-ex/9808029



analyzed using the matrix-element weighting algorithm that, according to hep-ex/9808029, "... is an extension of the weight proposed in [R.H. Dalitz and G.R. Goldstein, Phys. Rev. D45, 1531 (1992)] ...". Further examples of events related to the three peakcan be found at http://www.valdostamuseum.org/hamsmith/TQ3mHFII1vNFadd97.pdf

Further details can be found in:

- the paper by Koichi Yamawaki at hep-ph/9603293 describing Tquark condensate Higgs models (NJL and BHL) that seem to be related to the low and high T-quark peaks; and
- the paper by Michio Hashimoto, Masaharu Tanabashi, and Koichi Yamawaki at

> hep-ph/0311165 describing a Tquark condensate models in 8-dimensional spacetime (with 4 compact dimensions) that seem to be related to the middle T-quark peak.

In that 3-peak model:

- the peak around 175 GeV is on the curve of vacuum stability and is therefore closely related to the Higgs and T-Tbar condensates, and hence to T-Tbar events, while
- the peak around 130-150 GeV is in the stable region far from the triviality and vacuum stability bounding curves and is therefore closely related to other quarks in the stable region and therefore to single-Tquark events involving such things as T-Bbar events,

so it is natural that

the LF method which only looks at events near Tquark mass 175 GeV would miss single-Tquark events, while

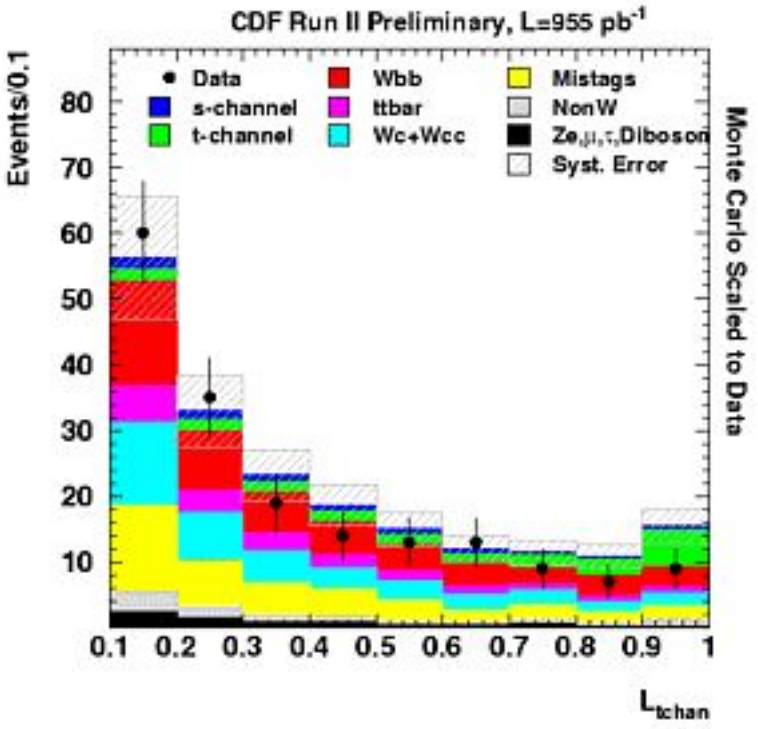
the ME method would see single-Tquark events, which would be seen at Tquark mass below 150 GeV.

Likelihood Function (LF) Method

Tommaso Dorigo in his Nobember 2006 blog entry at http://dorigo.wordpress.com/2006/11/07/the-elusive-single-top/ said, about search for single-Tquark events at CDF by the Likelihood Function (LF) method:

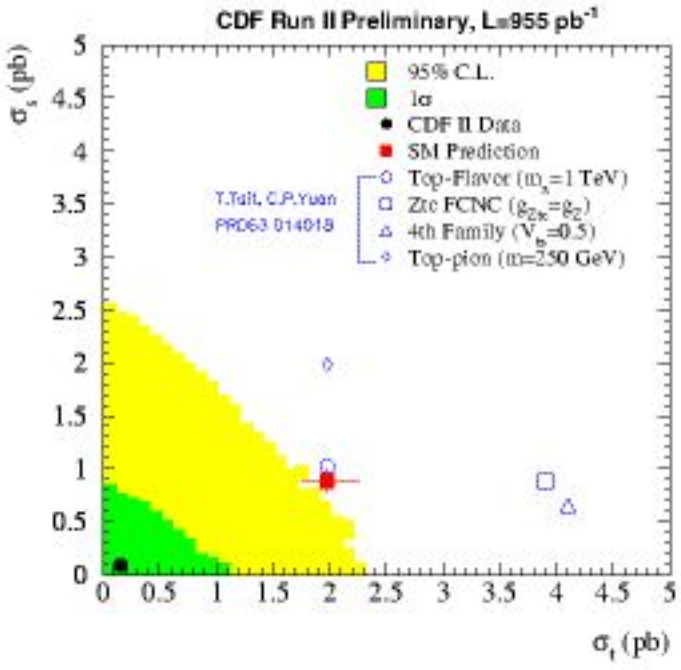
> "... CDF has recently blessed two new results on the search for the process called "single top production" ... All searches for the elusive single top quark production have been [u] nsuccessful so far. ... We thought that one inverse femtobarn of available CDF data would do the trick. ... Not yet.
>
> In a careful analysis of "W+2jet events" ... ones containing a lepton, missing energy originated by a neutrino, and two jets, at least one of which originated from b-quark hadronization, CDF can not measure the production of single top yet, and actually is in the awkward position of excluding its production according to the predictions of the Standard Model. ...
>
> Nobody really believes that single top production is not there: it must be. It probably is

just a unlucky downward fluctuation of our data. But still, it starts to be embarassing! Here you can see a plot of the event likelihood, constructed with all available kinematic information, for the set of events where the search has been conducted.



... the single top production processes (actually mostly the t-channel one in this particular plot ...) should contribute sizeably (green and blue histograms), but they do not, and in fact we observe a deficit of events with respect to all concurrent background processes.

... the most probable value of the cross section for single top production via "s-channel" and "t-channel" processes (two different mechanisms that should both yield a single top signal, which have been searched independently in the data) is very close to zero,



and that the standard model prediction (the red point on the right) is actually excluded! ...".

Matrix-Element (ME) Method

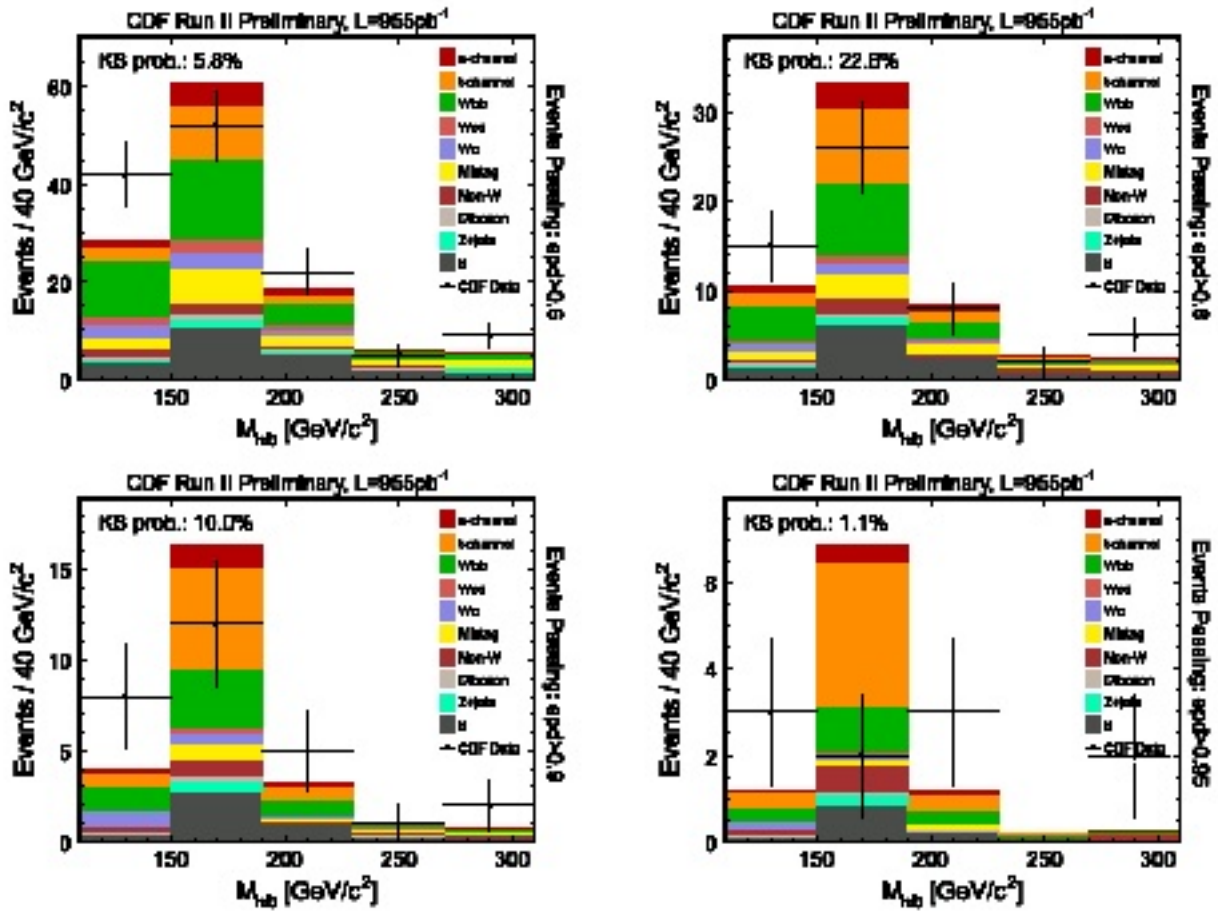
In a comment to the Tommaso Dorigo blog entry mentioned above, Andrea Giammanco said:

> "... Thanks to the CDF analysis webpages (discussed in this site a few days ago) I see that there is an inconsistency between this result and one, yet to be pubished, with a competing method:
>
> http://www-cdf.fnal.gov/physics/new/top/2006/SingleTop/ME_1FB/index.html
>
> http://www-cdf.fnal.gov/physics/new/top/2006/SingleTop/COMP_MELF_1FB/compat.html
>
> That's thrilling! ...".

The description of the "competing method" of Matrix-Element (ME) analysis in the paper "Search for Electroweak Single Top Quark Production using the Matrix Element Method with L=955 pb-1" by

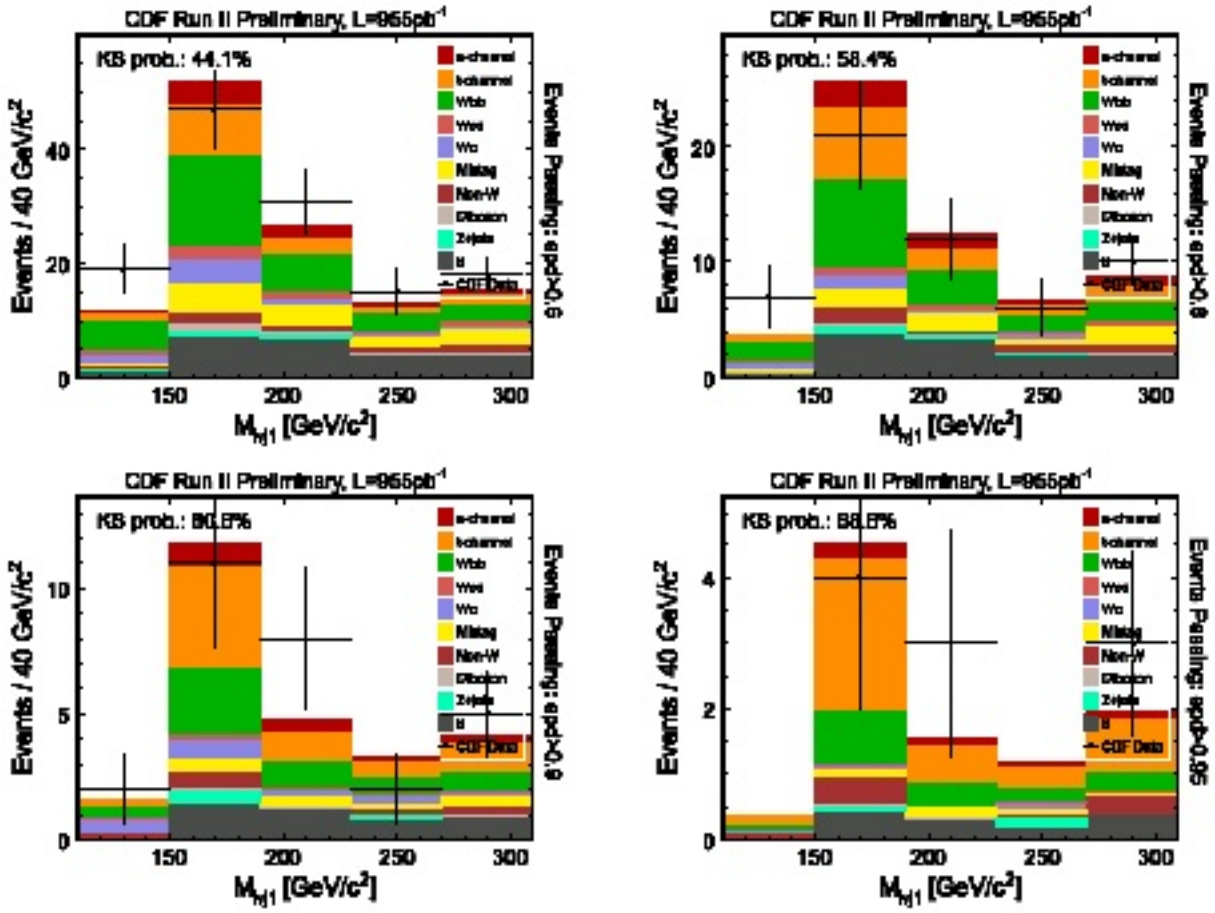
Florencia Canelli (FNAL), Peter Dong (UCLA), Bernd Stelzer (UCLA), and Rainer Wallny (UCLA) that is at at http://www-cdf.fnal.gov/physics/new/top/2006/SingleTop/ME_1FB/index.html said:

> "... We performed the first search for single top using a Matrix-Element based analysis. We apply our method to 955 pb-1 of data taken by the CDF experiment. We include rate and shape systematic uncertainties in our method. We measure a single top cross-section &sigmasingle top =2.7+1.5-1.3pb. ...
>
> More cross-checks ... We look at variables which are sensitive to single top production. As we make increasing cuts on our event probability discriminant (EPD), we can observe the increasing sensitivity of these variables and the behavior of the data. ...



Increasing cuts on the EPD for the invariant mass of the lepton, neutrino, and b-jet.

...



Increasing cuts on the EPD for the invariant mass of the lepton, neutrino, and leading jet.

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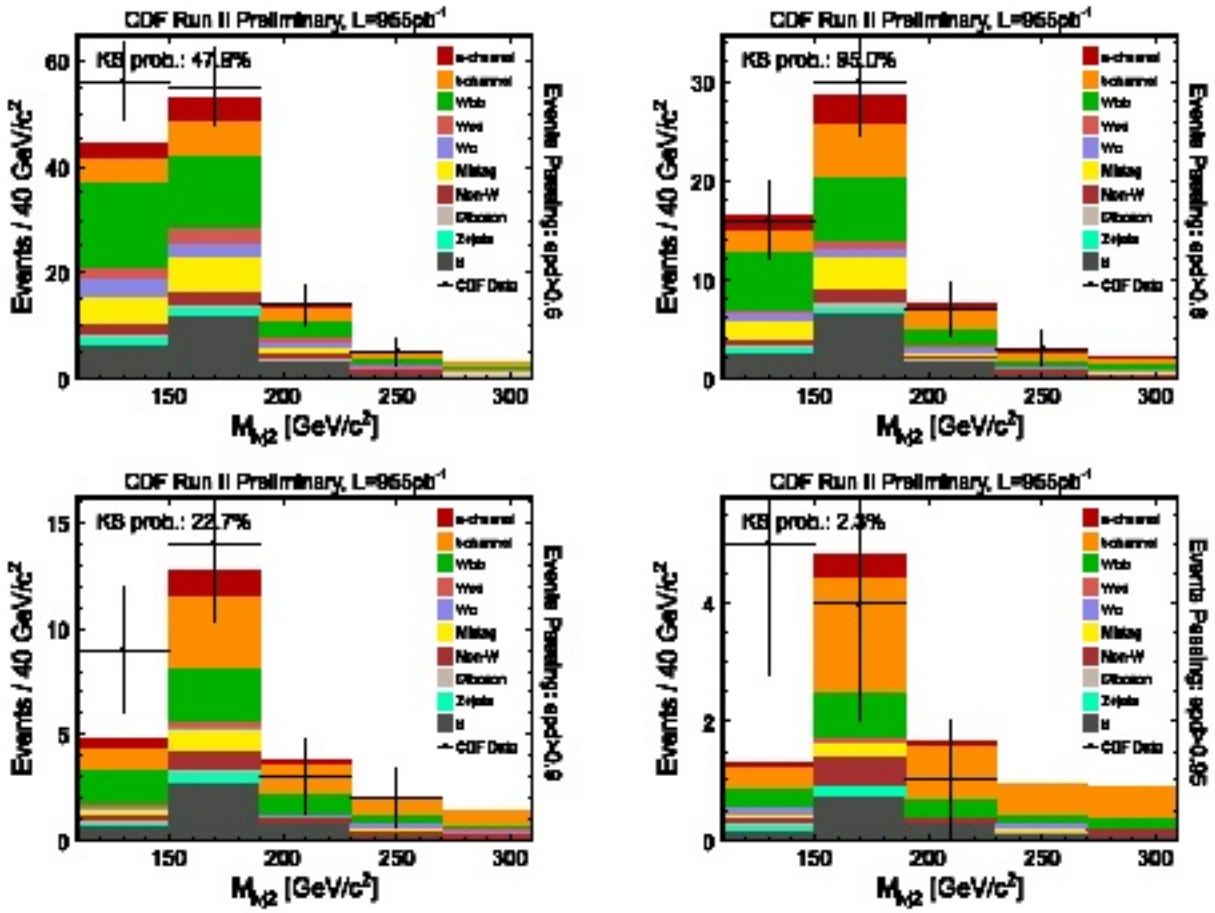

Increasing cuts on the EPD for the invariant mass of the lepton, neutrino, and second jet. ...".

It seems to me that the invariant mass cross-check data shown above indicate that much of the excess of events over background is in the bin for 0 to 150 GeV.

The main deviations that I see from that seem to be in the third and fourth histograms for "leading jets" (in which many excess events seem to be in the 200 to 250 GeV bin) and in the second histogram for "second jet" in which there is not much excess at all, just a little in the 150 to 200 GeV bin.

So, overall, it seems to me that the ME method does in fact see single-Tquark events, but that they are mostly seen in events with Tquark mass below 150 GeV.

Discussion

Tommaso Dorigo, in a 19 November 2006 e-mail message to me, said:

> "Hi Tony,
>
> indeed, part of the excess in the matrix element analysis is at low invariant mass... Some of the KS probabilities are smallish, although of course many variables are tested and if one plays the game of going for the fluke in one out of many distributions one is sure to find it.
>
> In your case though, you have a reason for looking specifically for those one or two distributions (low three-object masses) and I agree that you score a point there.
>
> As for the other analysis, the likelihood of course selects "top-like" stuff, intended at 172 GeV of mass or so, and so a top quark with low mass would not contribute to the signal region too much.
>
> Therefore yes, I agree that as far as present data is concerned, a single top quark of mass below 150 GeV could still be present in our data without us realizing it with the used means.
>
> I think one more year -two times the data we have analyzed so far- will give you a more clear answer. If you have theoretical input to submit to our experimenters working at new physics searches, I suggest you talk to our exotics physics conveners (their e-mail is in the web page of exotics analyses).
>
> Cheers,
>
> T. ".

I expect to send an e-mail message to the exotics physics conveners as suggested by Tommaso Dorigo.

Tommaso Dorigo has put up an entry about this on his blog at

http://dorigo.wordpress.com/2006/11/20/a-low-mass-top-in-single-top-events/

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19 Feb 2007 Update for CDF SingleT results:

Tommaso Dorigo, on February 19, 2007, posted a blog entry (along with comments by him and others) entitled

Compatibility of CDF single top results

saying:

"... The CDF experiment has been looking for single top production for quite a while now, and the latest results, based on larger statistics and more refined analysis methods than ever before, have been puzzling.

Single top production occurs at the Tevatron proton-antiproton collisions mainly through two electroweak processes, which have a combined cross section of about 2.9 picobarns - that is to say, they happen once every 20 billion collisions, or twice per hour at the highest Tevatron luminosity. The process is quite hard to distinguish from background processes, and sophisticated analysis techniques have to be devised to see a signal.

A priori calculations show that the data collected in Run II is by now enough to show single top production, and indeed our cousins at the competitor D0 experiment claimed to see a nice signal of single top production a couple of months ago, but CDF struggled, hard-pressed to explain why its three analyses (now four) show conflicting results: while one analysis sees a signal compatible with expectations, the others see nothing at all, at the point of being close to ruling out the existence of the process!

The mesmerizing paradox spurred a deep investigation of the correlation of the four analyses, performed with pseudo-experiments: you simulate all known processes contributing to your data samples in large amounts with Monte Carlo generators, and then fish randomly from the simulated samples respecting the proportions of the various processes, creating a large number of sets of events ("pseudo-data") each of which represent the possible outcome of your data selection process.

Once you have pseudo-data sets, you can forget about their origin, and concentrate on the search for single top with your four methods in each of the sets, coming up with four independent measurements of single top production cross section for each pseudo-experiment. The sets of results allows you to see how likely it was to see such a poor compatibility in the four cross section measurements as the one you saw in the real data.

CDF finds that they have been unlucky, although not overly so: the probability of the puzzling result in the data is 0.65%. That is to say, you should expect to get such poor agreement between the four analyses only twice in three hundred trials.

I am not sure what is the plan now. I suppose we will collect more data, planning on a measurement with 2 inverse femtobarns, which should allow to come up with a measurement after all.

Comments»

1. island - February 19, 2007 Tommaso, could this have any effect on the recalculated expectation for the Higgs mass, or is this strictly a CDF related problem?

2. Tony Smith - February 19, 2007 Tommaso said: "… the data collected in Run II is by now enough to show single top production … CDF … three analyses (now four) … one analysis sees a signal … the others see nothing …". In earlier posts, Tommaso described CDF using a Likelihood Function (LF) method and a Matrix Element (ME) method, and D0 using a Decision Tree (DT) method.

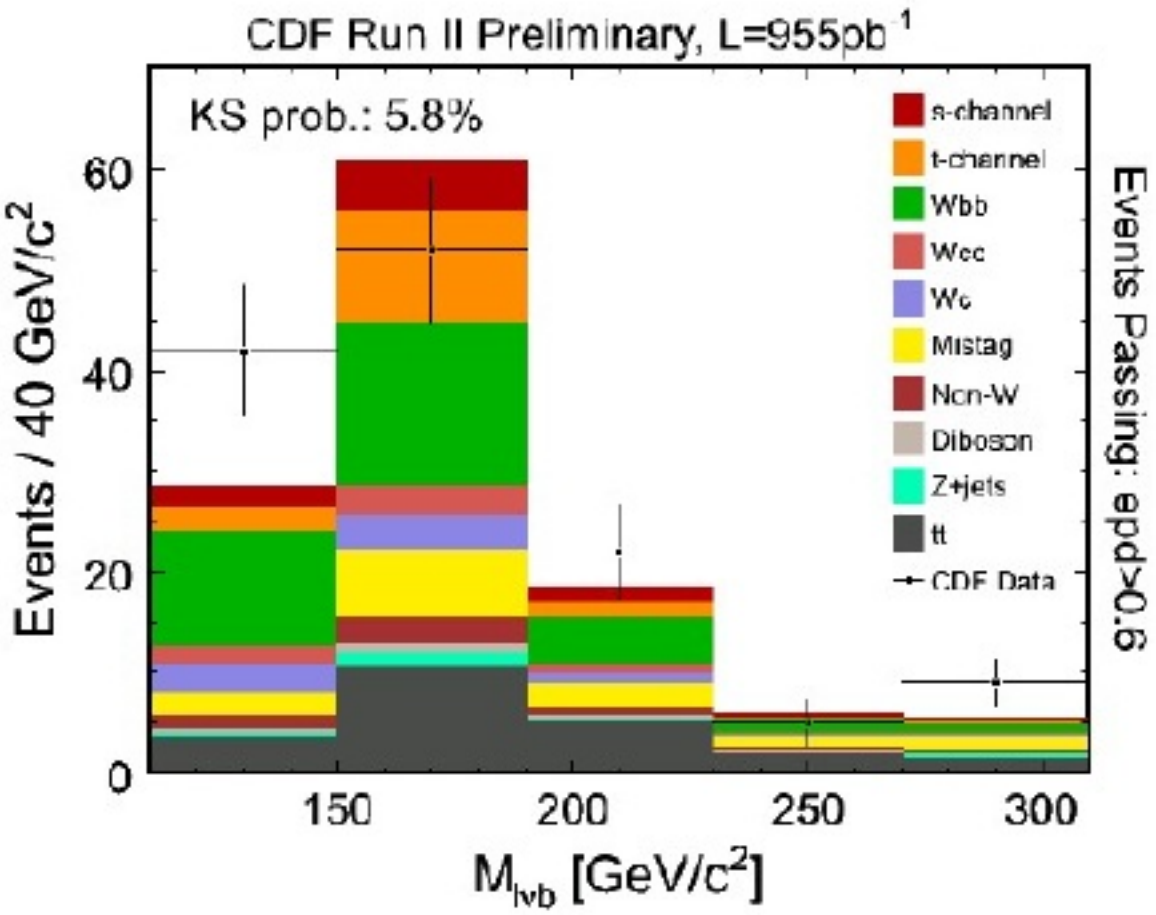
- Were those the three methods of analysis first used by CDF?
- What was the fourth method of analysis used by CDF?
- Which analysis showed the signal?
- Were the methods of analysis that see nothing primarily looking for a single-T near 175 GeV?
- Was the method of analysis that saw a signal looking over a wider range of T-quark masses? ...

3. dorigo - February 19, 2007 Hi Island, well, I believe this indeed is just a statistical fluke. Not a fault of CDF - once you do many analyses, sometimes you are bound to find inconsistencies of this kind. If, anyway, one were to doggedly try and associate any significance to the discrepancy among the analyses, one would be hard-pressed to fit it in whatever model. Tony has reminded us of his model a while ago, and **indeed, one of the CDF analyses -the one not using much of a mass information, thus not assuming 172 GeV for Mt - is more in line with expectations**. Your question, though, is more focused on the Higgs. Well, I believe that if Tony were right - i.e., a single top of 145 GeV of mass present in the data - then the indirect Higgs limit would change quite significantly! But the whole SM would be shaken, so I doubt one could conclude that the predictions on the Higgs mass would still decrease (as you know, dMh/dMt>0, dMh/dMw

4. dorigo - February 19, 2007 Hi Tony, wow, you force me to do quite a bit of homework today! I am still struggling with the KM post - which I think I will put out tomorrow - and there you go with yet another question that deserves a full answer. My problem is that I have not seen the latest blessed results of single top searches in CDF out yet. I only saw this 0.56% number today. I will have to dig into our public web pages. Let me do that. In the meantime, what I can say is that **CDF has a matrix element, a global likelihood, and a one- and two-dimensional Neural Network analysis**. **The one finding a signal is the ME one**. But I will be more precise later. Right now I have to go upstairs to put the telescope out - Saturn observation in order tonight, and the mirror needs some cooling! ...

5. dorigo - February 19, 2007 Ok, t**he matrix element analysis indeed is the one which sees a signal, and measures sigma(t) = 2.7 +1.5 -1.3 pb (theory predicts 2.9 pb)**. The measurement assumes Mt=175 GeV to estimate the selection efficiency. You already saw the mass plot in http://dorigo.wordpress.com/2006/11/20/a-low-mass-top-in-single-top-events/

…[here is that mass plot along with description by Tommaso on that blog page: "...



With a single top event, one cannot really run a kinematical fitter very effectively to extract the most probable top quark mass. So one usually looks at things such as the mass of lepton,neutrino, and b-tagged jet, which has a sizable probability of being the triplet of objects emitted in top decay. If one looks at the distribution shown below, one does observe an excess of candidates with respect to non-single-top processes, but indeed part of the excess clusters at low mass (if the legend does not read well, orange and red are the contributions from t-channel and s-channel single top production in the selected sample). ...".]...

The other analyses are the 1-dim and 2-dim Neural Network searches, who find a cross section compatible with zero (the first determines sigma(t)

6. Tony Smit[h] - February 19, 2007 Tommaso said: "… if Tony were right - i.e., a single top of 145 GeV of mass present in the data - then the indirect Higgs limit would change quite significantly! …". I

am not sure about that, because in my modelthe single-T mass state around 145 GeV is mostly coupled to other quarks (such as the B-quark) and is not the T-quark mass state that forms the Higgs through T-Tbar condensate while the Higgs is primarily a T-Tbar condensate of T-quarks in a mass state around 175 GeV. My model is speculative and may be wrong, but it may not be very non-standard with respect to the conventional standard model predictions involving the Higgs and the 175 GeV T-quark state of the T-Tbar condensate that gives the Higgs. ... PS - Happy Saturn viewing. A nice planet to see on Mardi Gras. ...".

So:

It seems to me that the invariant mass cross-check data shown above indicate that much of the excess of events over background is in the bin for 0 to 150 GeV. So, overall, it seems to me that the ME method does in fact see single-Tquark events, but that they are mostly seen in events with Tquark mass below 150 GeV.

Further, since no single-T events are seen by the 3 other methods of analysis (LE and two Neural Nets) which DO substantially look only for Tquark mass states around 172 GeV,

I feel that the Fermilab results support at least 2 of the 3 Tquark mass states in my physics model with 3 Tquark mass states.

...