The Top Quark

Sean Ericson

UO

History (prediction)

1973: Makoto Kobayashi and Toshihide Maskawa propose expanding the then known quark quartet to a 6-plet to explain CP-violating weak interactions

Next we consider a 6-plet model, another interesting model of CP-violation. Suppose that 6-plet with charges $(Q, Q, Q, Q-1, Q-1, Q-1)$ is decomposed into $SU_{\text{weak}}(2)$ multiplets as $2+2+2$ and $1+1+1+1+1+1$ for left and right components, respectively. Just as the case of (A, C), we have a similar expression for the charged weak current with a 3×3 instead of 2×2 unitary matrix in Eq. (5). As was pointed out, in this case we cannot absorb all phases of matrix elements into the phase convention and can take, for example, the following expression:

$$\begin{pmatrix} \cos\theta_1 & -\sin\theta_1\cos\theta_3 & -\sin\theta_1\sin\theta_3 \\ \sin\theta_1\cos\theta_2 & \cos\theta_1\cos\theta_2\cos\theta_3-\sin\theta_2\sin\theta_3 e^{i\delta} & \cos\theta_1\cos\theta_2\sin\theta_3+\sin\theta_2\cos\theta_3 e^{i\delta} \\ \sin\theta_1\sin\theta_2 & \cos\theta_1\sin\theta_2\cos\theta_3+\cos\theta_2\sin\theta_3 e^{i\delta} & \cos\theta_1\sin\theta_2\sin\theta_3-\cos\theta_2\sin\theta_3 e^{i\delta} \end{pmatrix}. \tag{13}$$

Then, we have CP-violating effects through the interference among these different current components. An interesting feature of this model is that the CP-violating effects of lowest order appear only in $\Delta S\neq 0$ non-leptonic processes and in the semi-leptonic decay of neutral strange mesons (we are not concerned with higher states with the new quantum number) and not in the other semi-leptonic, $\Delta S=0$ non-leptonic and pure-leptonic processes.

So far we have considered only the straightforward extensions of the original Weinberg's model. However, other schemes of underlying gauge groups and/or scalar fields are possible. Georgi and Glashow's model[4)] is one of them. We can easily see that CP-violation is incorporated into their model without introducing any other fields than (many) new fields which they have introduced already.

History (prediction)

1975: Haim Harari proposes the names "Top" and "Bottom" for the additional quarks.

ABSTRACT

We propose a new quark model for the hadron spectrum. It consists of six quarks — the usual triplet and a new antitriplet of Heavy quarks, with electric charges $+2/3$, $+2/3$, $-1/3$. The ψ particles are bound states of Heavy $q\bar{q}$ pairs. Among many other predictions we find that $R = 5$ in e^+e^- scattering and $\Gamma(\psi \to e^+e^-) : \Gamma(\psi' \to e^+e^-) = 2:1$. The model naturally forbids neutral $|\Delta S| = 1$ weak currents and predicts a spectrum of Heavy mesons and baryons.

History (discovery)

1995: Nearly 20 years later, the Top is discoverd at Fermilab by the CDF and D0 collaborations.

Observation of Top Quark Production in $\bar{p}p$ Collisions

Abstract

We establish the existence of the top quark using a 67 pb^{-1} data sample of $\bar{p}p$ collisions at $\sqrt{s} = 1.8$ TeV collected with the Collider Detector at Fermilab (CDF). Employing techniques similar to those we previously published, we observe a signal consistent with $t\bar{t}$ decay to $WWb\bar{b}$, but inconsistent with the background prediction by 4.8σ. Additional evidence for the top quark is provided by a peak in the reconstructed mass distribution. We measure the top quark mass to be $176 \pm 8(\mathrm{stat.}) \pm 10(\mathrm{sys.})$ GeV/c^2, and the $t\bar{t}$ production cross section to be $6.8^{+3.6}_{-2.4}$ pb.

Abstract

The DØ collaboration reports on a search for the Standard Model top quark in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV at the Fermilab Tevatron, with an integrated luminosity of approximately 50 pb^{-1}. We have searched for $t\bar{t}$ production in the dilepton and single-lepton decay channels, with and without tagging of b-quark jets. We observed 17 events with an expected background of 3.8 ± 0.6 events. The probability for an upward fluctuation of the background to produce the observed signal is 2×10^{-6} (equivalent to 4.6 standard deviations). The kinematic properties of the excess events are consistent with top quark decay. We conclude that we have observed the top quark and measure its mass to be 199^{+19}_{-21} (stat.) ± 22 (syst.) GeV/c^2 and its production cross section to be 6.4 ± 2.2 pb.

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2012: The higgs boson

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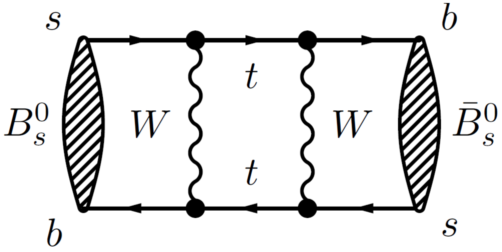

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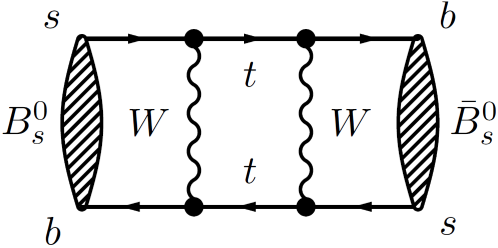

Beyond Standard Model theories also constrain the mass of the top quark.

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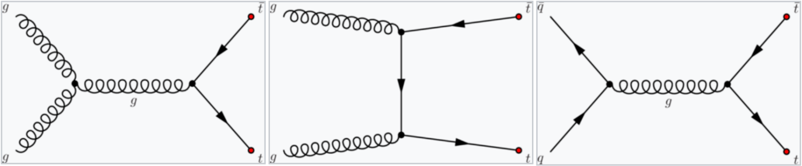

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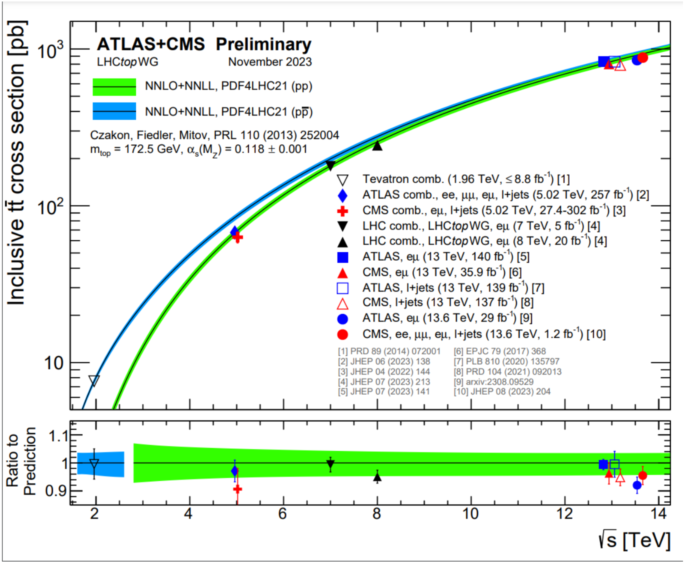

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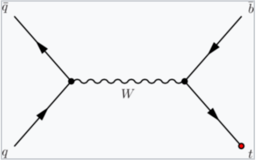

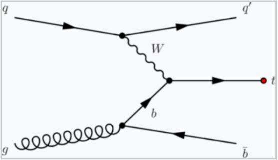

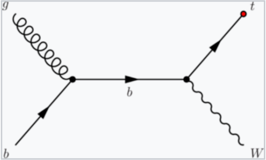

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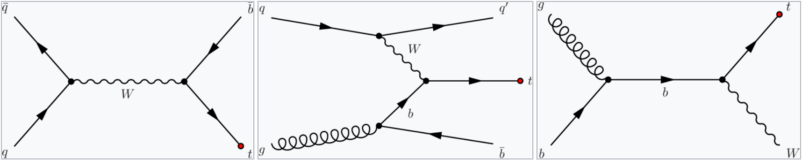

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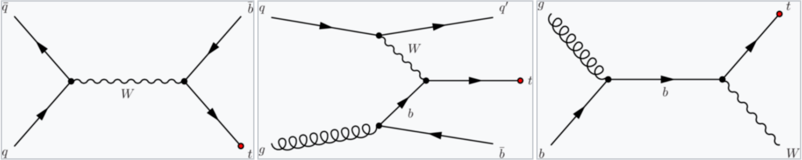

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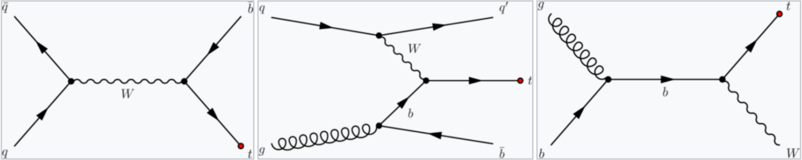

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In the limit $|V_{tb}| \gg |V_{td}|, |V_{ts}|$ single top production cross sections are proportional to $|V_{tb}|^2$

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Exotic decay modes involving the production of a Z boson and a charm or up quark are theoretically possible, but have never been observed.

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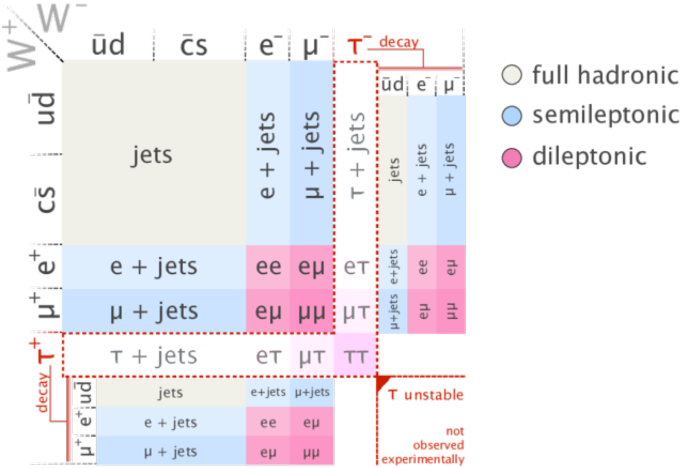
W+
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τ unstable
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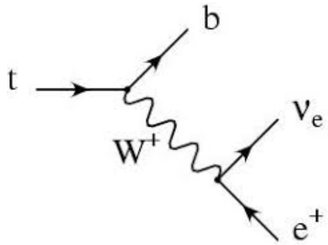

Higgs Production