Fermi National Accelerator Laboratory

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Prospects for Top at CDF

The CDF Collaboration
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ABSTRACT

During the next two years, the Fermilab Tevatron is expected to deliver approximately 100 pb^{-1} of integrated luminosity. We describe improvements to the CDF detector since the 1988–89 collider run and discuss the prospects for the discovery of the top quark during the 1992–93 collider runs.

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1. INTRODUCTION

The top quark is required to complete the fermion content of the Standard Model. Along with the Higgs, it represents the last missing piece of this outstandingly successful theory, and for many years now its discovery has been eagerly anticipated. With the advent of precision measurements of the W mass at hadron colliders[1], and of other electroweak parameters at LEP[2], the discovery of the top quark takes on additional significance, since the direct measurement of the top mass would permit many more precision tests of the Standard Model, and possibly point the way to new physics.

During the 1988–89 Tevatron collider run, CDF collected 4.1 pb^{-1} of data, and established a lower limit on m_{top} of 91 GeV at the 95% confidence level, assuming Standard Model charged current decays[3]. Upper limits of approximately 200 GeV are inferred by demanding consistency with the measured W and Z masses[4], with weak neutral current data, and with precision measurements of charge asymmetries in Z decays[5]. Thus, if the Standard Model is correct, the top quark lies between 91 and 200 GeV, a mass window accessible in the next few years only at the Fermilab Tevatron. With an integrated luminosity of 100 pb^{-1} expected in 1992–93, and as much as 1 fb^{-1} following the commissioning of the Main Injector around 1997, the prospects are bright not only for closing the top mass window but for carrying out a broad range of top physics studies.

2. CDF DETECTOR UPGRADES

The CDF detector in its 1988–89 configuration has been described in detail elsewhere[6]. Since the 1988–89 run CDF has added a number of improvements aimed both at handling the higher luminosities of the Tevatron and at enhancing the physics capabilities of the experiment. Those with the most relevance to the top search include expanded and improved muon identification, improved low-P_T electron identification using a central preradiator, and a silicon vertex detector (SVX) that will permit the tagging of secondary vertices from the b quarks produced in top decay.

The SVX[7] will add a new dimension to the top search. The impact parameter resolution of this device is approximately 50 microns for a 1 GeV track and 12 microns for tracks with $P_T > 10$ GeV. These numbers should be compared to the typical impact parameter of 350 microns for a b-quark from heavy top decay. Monte Carlo studies of various b-tagging algorithms indicate an efficiency of about 30% per $t\bar{t}$ event[8].

3. TOP SEARCH STRATEGIES

Because of the large number of possible final states, the top search is expected to proceed in several different channels. The cleanest signal is found in events in which both W's decay to either an electron or a muon. Backgrounds are particularly suppressed in the e-μ channel, although the branching ratio for this process, 2/81, is small. The presence of opposite-sign e-μ events is likely to provide the first direct evidence for top. However, because of the low rate and the presence of two neutrinos, this channel may be less useful for the arguably more interesting task of measuring the top mass. The rate is higher in the channel where one of the W's decays hadronically and the other W decays to an electron or muon. The branching ratio for this process is 12/81, but there are significant backgrounds from QCD W + multijet production. The best hope for separating the signal from background lies in tagging the b's, either by identifying soft leptons from their semileptonic decays, or from the presence of a secondary vertex. Other channels (such as those involving τ's) and techniques (for example, likelihood fits involving kinematic constraints) may hold longer-range prospects, presumably in conjunction with a b-tag or other "smoking gun."

4. SCHEDULE AND PROSPECTS

At the time of this writing, the 1992 collider run was just underway. The current run—the so-called Run IA—is expected to continue through early 1993 and provide approximately 25 pb^{-1}. A six-month shutdown, during which the Linac upgrade will be completed, will be followed by Run IB with a projected 75 pb^{-1}. Anyone familiar with Fermilab schedules is aware that all such numbers and dates come with large error bars. Nonetheless, let us speculate on the discovery range for top under this scenario. In the 1988–89 run, CDF was sensitive to about 1% of the total $t\bar{t}$ cross section. Under the not unreasonable assumption that this number can be raised to 1.5% with the improvements described above, the top quark can be discovered in Run IA if $m_{top} < 130$ GeV. Run IB would be sensitive to a top quark with a mass up to 150–160 GeV. CDF for the first time faces local competition from the D0 experiment, whose detector, with its emphasis on calorimetry and muon identification, is in many ways complementary to CDF, with its emphasis on central tracking and precision vertexing. The competition can only be good for physics, and the next few years promise to be very exciting indeed.

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