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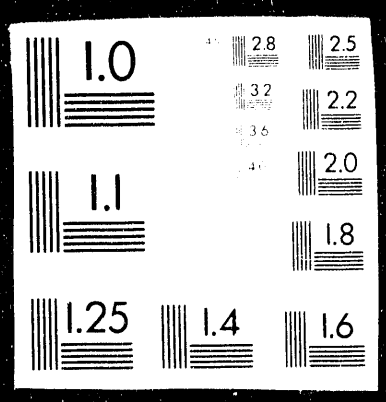

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Highlights from CDF

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Highlights from CDF

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ABSTRACT

After a hiatus of 3 years, CDF is again taking data. Many of the upgrades made to the detector during this period are described here, along with some preliminary indications of their performance. A brief survey of the new data is presented. Prospects for the current run are discussed.

1. Introduction

The CDF detector has begun to collect data again starting in the summer of 1992, after a shutdown of 3 years. The current run is proceeding well, and will be briefly discussed in section 2. During the 3 years since the last run (1988-9), there have been a large number of upgrades, which enhance the performance of the detector in acceptance, triggering, and event information. We describe in section 3 the important upgrades, as well as some preliminary indication of their performances from data collected in this run. We show in section 4 preliminary physics results from this current run, and compare some of them with results from last run. In addition, we include a few new results from more thorough analysis of the data from the 88-89 run. Finally, we give some indications of the prospects for various physics goals that might be achievable in this run.

2. Operations

The Fermilab Tevatron collider resumed operation on May 12, 1992, when it started delivering $p\bar{p}$ collisions to the CDF detector, as well as the new D0 detector. The time period berween May 12 and August 26 1992 was taken to comission the CDF detector, including those components of the detector that were added for the 1992 run.

The performances of the Tevatron collider and CDF had sufficiently matured by August 26 1992 that good quality data begun to be recorded. As of this date (November 1992), the Fermilab Tevatron achieved a peak luminosity of $4.5 \cdot 10^{30}$, three times higher than the peak luminosity of the last run. In the period August 26, 1992 to November 12, 1992, the Tevatron has delivered an integrated luminosity of 3.2 pb^{-1} , with CDF recording 2.3 pb^{-1} on tape, more than 1/2 of the data sample from the last run; this was achieved with an average initial luminosity of around $2 \cdot 10^{30}$; thus, the recent factor of 3 increase in initial luminosity bodes well for the

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future. Figure 1 shows the delivered and recorded integrated luminosity versus time.

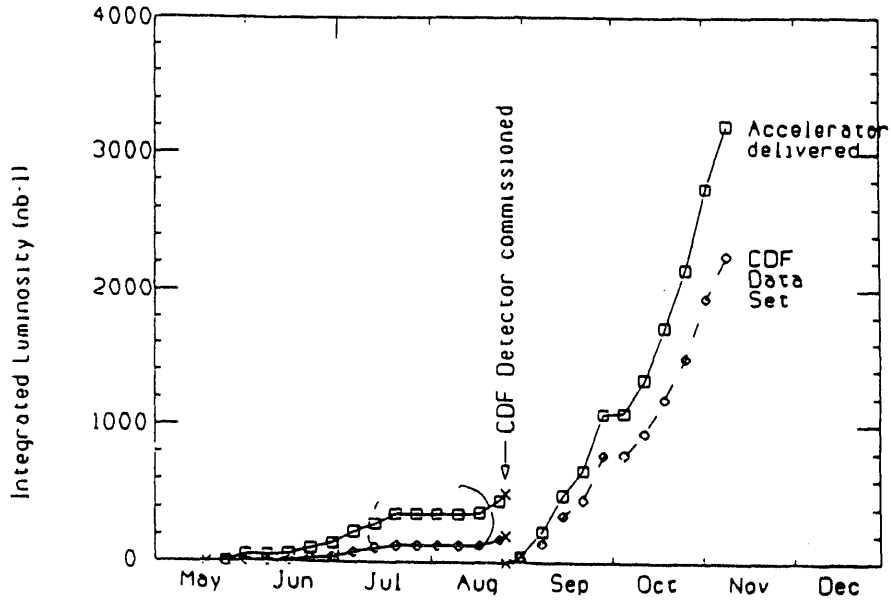

Figure 1: The integrated luminosity (pb^{-1}) versus time. The boxes are delivered luminosity, and the diamonds are the luminosity CDF wrote to tape.

3. Upgrades

3.1 Central Muon Upgrade (CMP)

The original CDF Central Muon detector (CMU), which covers the pseudorapidity region $|\eta| < 0.6$, has been complemented by the addition of four layers of drift tubes behind 2 feet of steel. As a result, hadronic punch-through backgrounds to the muon signal have been considerably reduced. This is illustrated in Figure 2 where we compare the energy deposited in the calorimeter by muon candidates with and without a requirement of hits in the CMP system. The minimum ionizing component is greatly enhanced. The addition of the CMP improves the muon identification capabilities of CDF.

3.2 Central Muon Extension (CMX)

We have also added layers of drift tubes outside the calorimeter in the pseudorapidity region of $0.6 < |\eta| < 1.0$. This increases the muon coverage in CDF by 50%. Figure 3 illustrates the increased acceptance to $J/\psi \rightarrow \mu^+\mu^-$ events using the CMX system.

3.3 Central PreRadiator (CPR)

The Central PreRadiator (CPR) system consists of a set of MWPCs mounted between the solenoid's coil (≈ 1.1 radiation lengths) and the central Electro-Magnetic

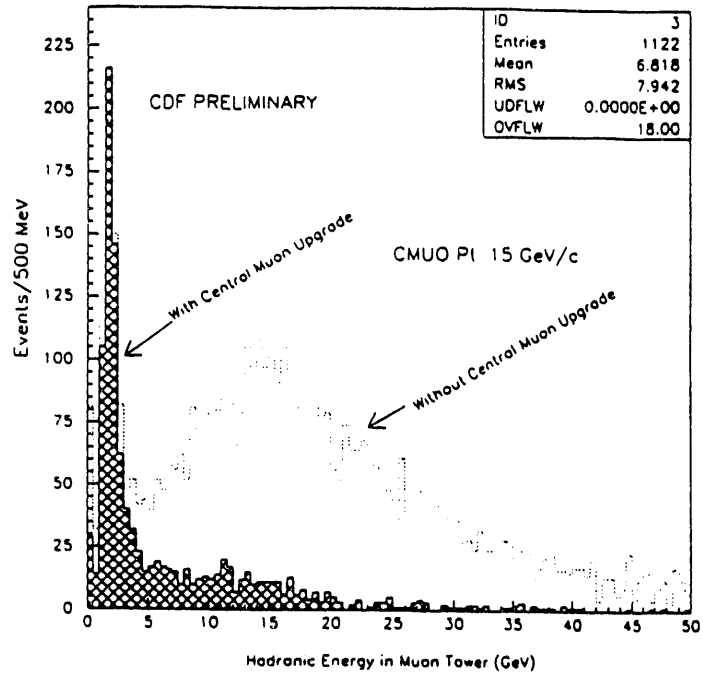

Figure 2: Hadronic Energy deposited in the muon tower: open histogram is for tracks with a stub in the Central Muon system (CMU), and the shaded area is that for tracks that have a stub in the Central Muon Upgrade (CMP)

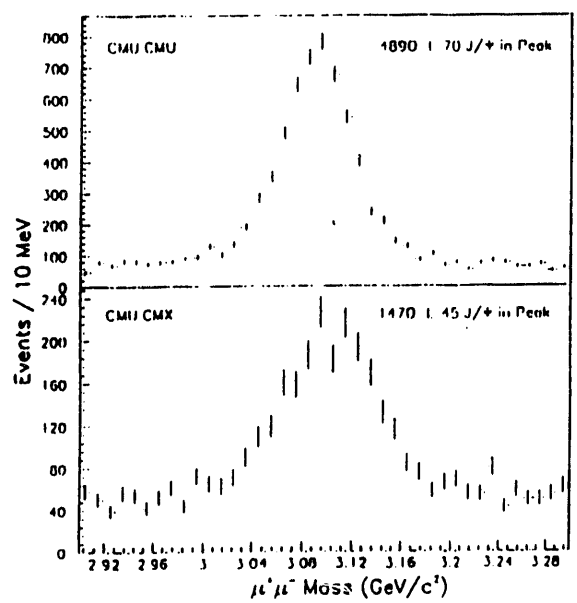

Figure 3: $M(\mu^+\mu^-)$in the J/ψ region; shown are dimuon combinations of CMU-CMU (both muons in the Central Muon) and CMU-CMX (one muon in the Central Muon Extension)

calorimeter. The CPR gives an additional factor of 2-3 in pion-electron separation. It will also reduce the systematic uncertainties in the prompt-photon cross section measurement by a factor of 5 due to the enhanced γ/π^0 separation. The performance of the CPR is illustrated in Figure 4.

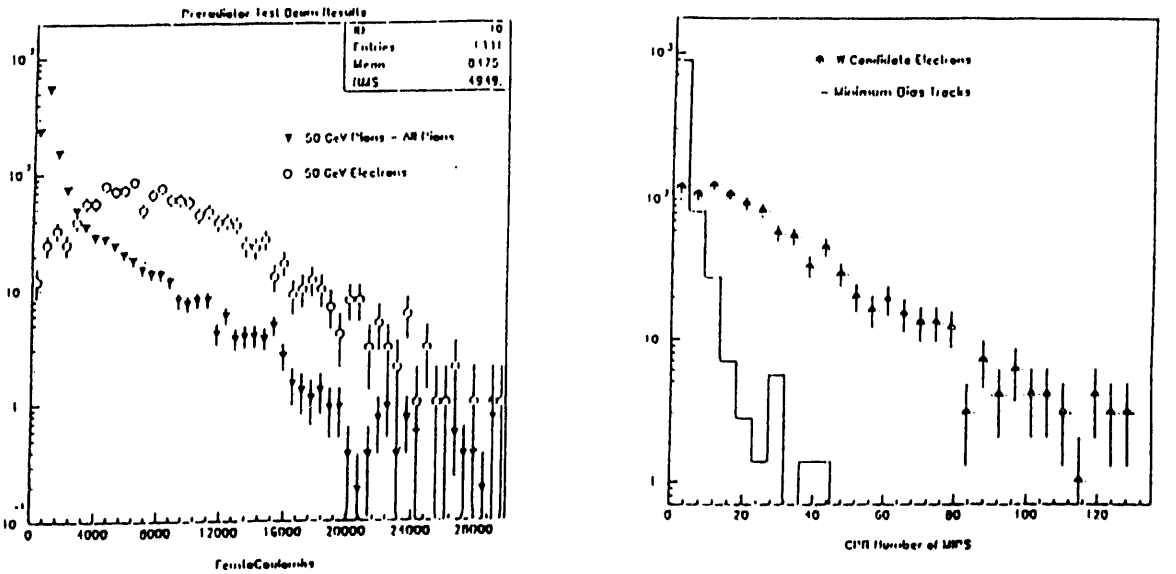

Figure 4: A comparison of the observed charge in the Central PreRadiator between electrons and pions is shown for: a) Testbeam and b) collider data.

3.4 Silicon Vertex Detector (SVX)

Four layers of DC coupled, single sided, silicon detectors with $R-\phi$ readout and $\approx 60\mu$ pitch have been added around the beam-pipe. The SVX covers the region of $|z| < 26$ cm around the interaction point (the luminous region has a width of ≈ 30 cm). The impact parameter resolution is better than 40μ (15μ) for tracks with $P_T > 1$ GeV/c ($P_T > 10$ GeV/c). Despite the large number of channels (46K), the readout is fast due to the sparsification performed on the readout chips. For tracks within the SVX fiducial volume the reconstruction efficiency is > 92%. The performance of the device is illustrated in Figure 5.

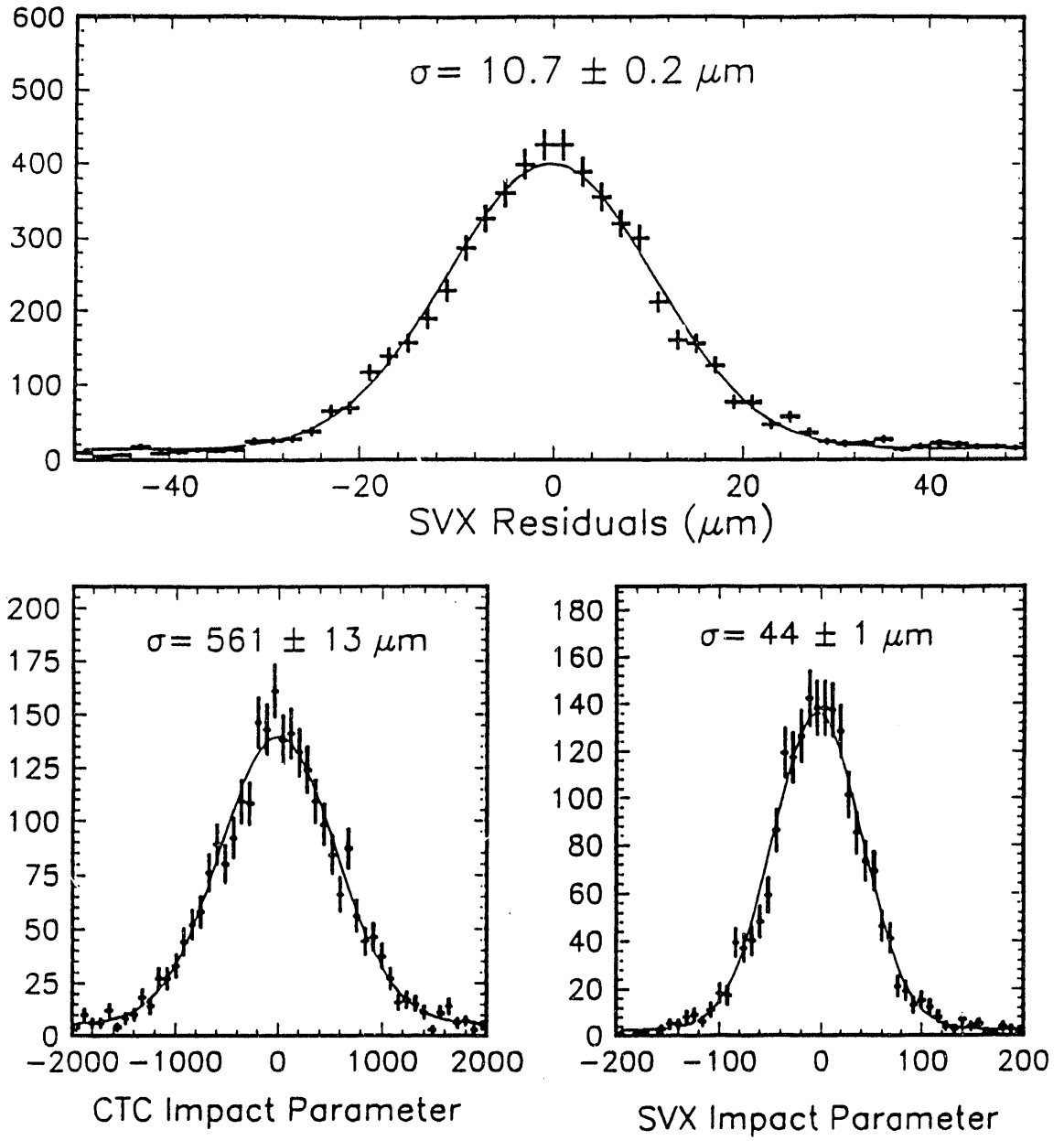

Figure 5: The Silicon Vertex performance is illustrated by: a). SVX track residual distribution (the observed resolution corresponds to spatial resolution of $\approx 13\mu$. b). Comparison of Impact Parameter as measured by the Central Tracker (CTC), and the CTC+SVX.

3.5 dE/dx in the Central Tracker

The outermost 54 (out of 84) layers of the Central Tracking Chamber (CTC) have been instrumented to measure charge deposition on the wires. The goals of the dE/dx system are to improve the e/π separation for $P_T < 4$ GeV/c and to assist in identifying kaons below 700 MeV/c. The expected resolution in the dE/dx measurement is $\approx$ 10%; calibration of this system is still underway, and a 13-15% resolution has already been achieved (see Figure 6).

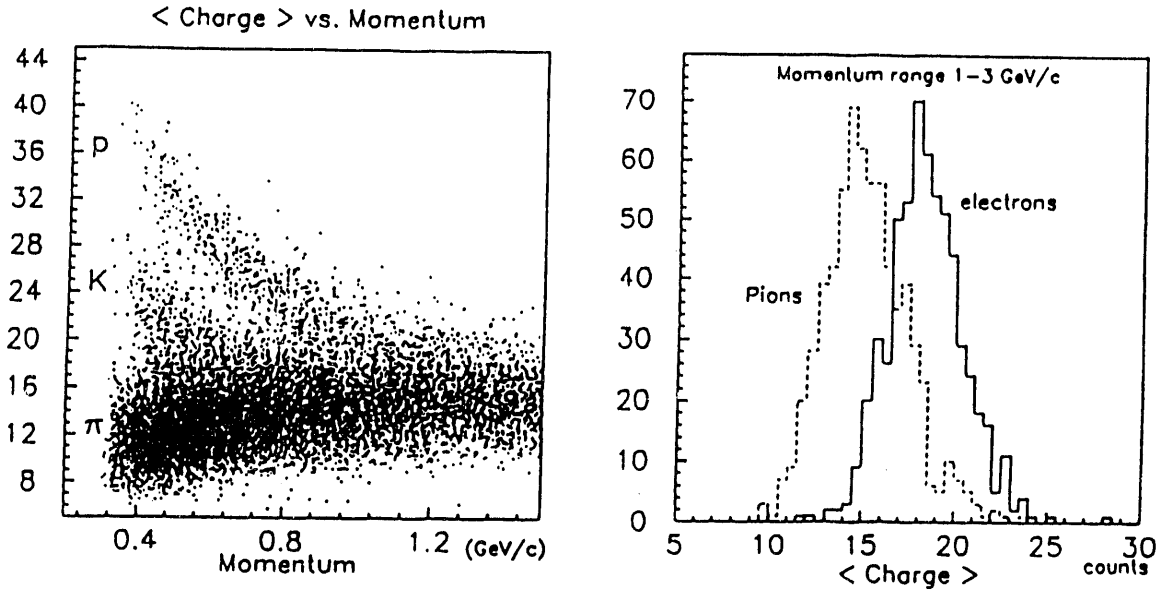

Figure 6: a).Mean charge Vs. momentum of CTC tracks. b). Electron/pion mean charge distribution ($1 < P_T < 3$ GeV/c).

3.6 Trigger

A number of changes to the trigger were implemented for the 1992 run, resulting in improved purity of the data written to tape and lower trigger thresholds for electrons and muons (see Figure 7). Hardware improvements included new triggers for the CMP and CMX systems, a better plug electromagnetic trigger, addition of a second processor to reduce the L2 decision time, a neural net (NN) based isolated photon trigger, as well as a NN electron trigger. In addition, a completely new software level 3 system using SiG computers replaced the old ACP based system.

3.7 Offilne

Between 1989 and 1992, all of CDF's reconstruction code was ported to UNIX (both SiG and IBM), enabling us to run the offline code as part of the level 3 trigger.

Large fraction of the 1992 code is new (for new detectors: VTX, SVX, CPR, CMP and CMX). Many changes to the reconstruction code for existing detectors

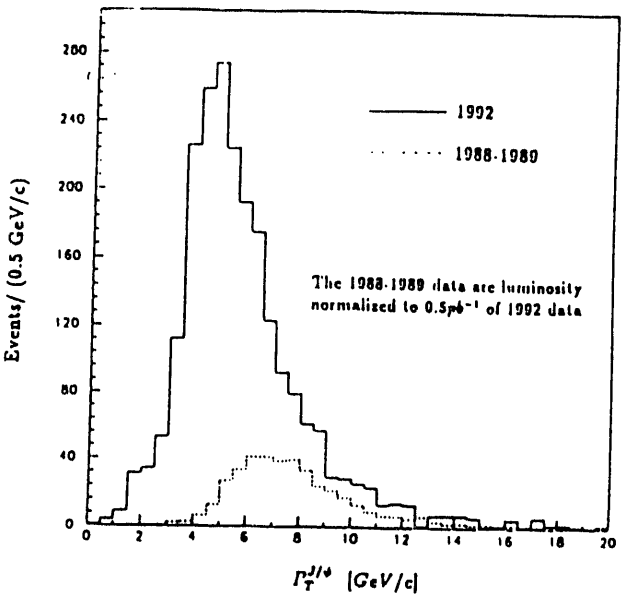

Figure 7: Comparison of J/ψ P_T spectrum using 88/89 data and 92 data - luminosity normalized.

were made based on the data collected in the 88/89 run. A new data compression scheme is being used, to accomodate the expected large size of the data set.

Full reconstruction of all CDF data is complete within two days of data taking, using 1000 MIPS from a SiG farm, while approximatley 5-10% of the data, including the most interesting events, are reconstructed and available within a few hours of data taking.

Utilities have been developed to distribute and maintain code across three hardware platforms (SiG, IBM and VAX) as well as computer systems at remote institutions.

4. Data

We will now turn to a discussion of the physics capabilities of CDF, as well as a brief review of selected results from the 1988/89 run.

4.1 QCD

In the past five years we have performed several tests of QCD using CDF data. The main goals for the 1992 run are to exploit the increase in statistics to improve the sensitivity to quark compositness and to combine our data on direct photons, Drell-Yan and jets in order to better constrain the understanding of parton distribution functions. In addition, the new CPR (see section 3.3) in conjunction with a lower photon-trigger threshold will allow us to greatly improve on our previous measurement of the direct photon cross section. In Figures 8 and 9, we show comparisons of 1992 and 1988/89 jet data. Figure 10 provides a demonstration of the capabilities of the CDF detector in photon physics.

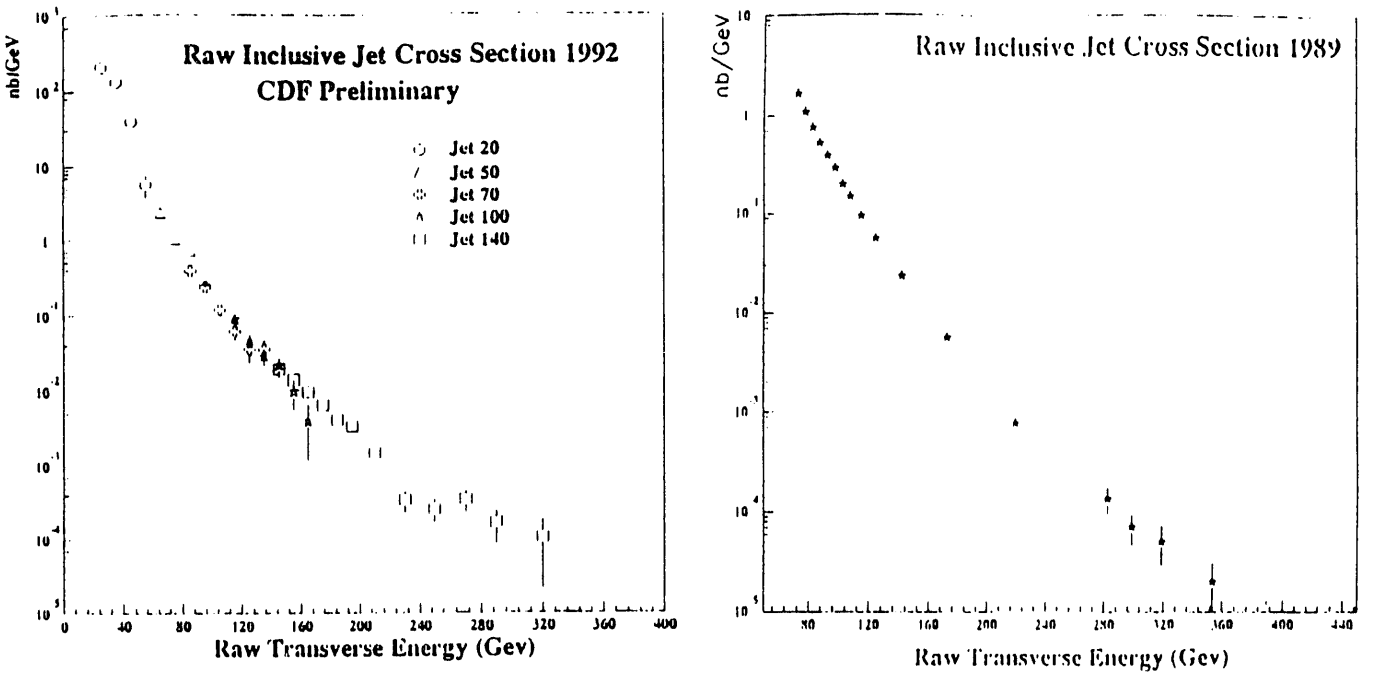

Figure 8: Comparison of RAW jet cross section for the 88/89 and 1992 data.

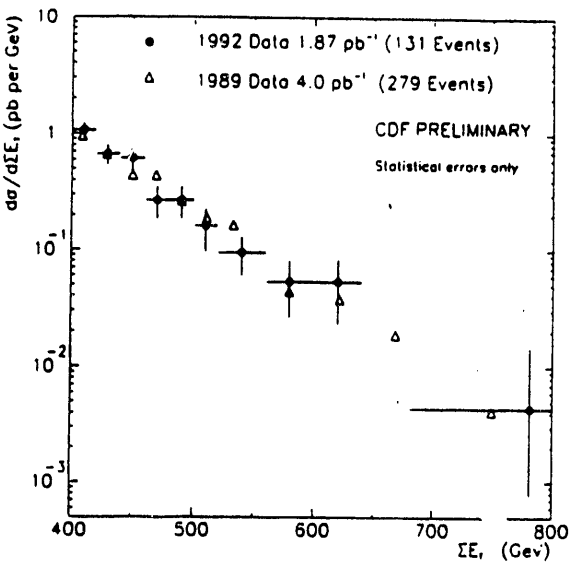

Figure 9: Comparison of the Total Transverse Energy (ΣE_T) cross section, for the 88/89 and 1992 data.

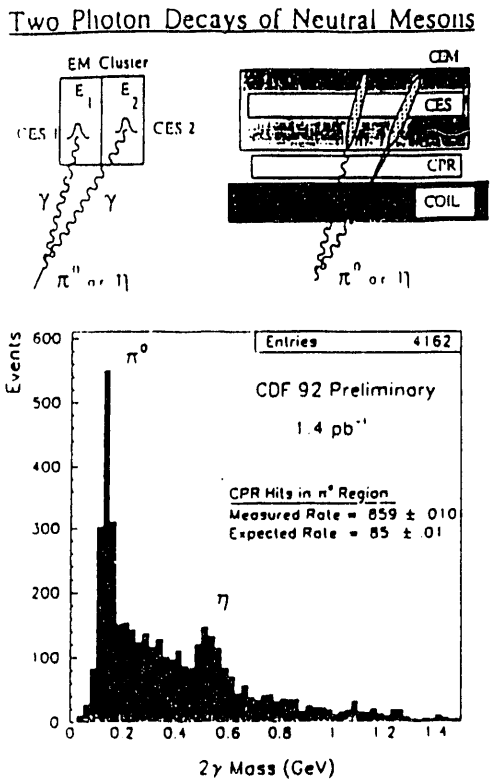

Figure 10: 2γ mass spectrum

4.2 Exotic Physics

Since the Tevatron collider provide antiproton-proton collisions with an unprecedented high center-of-mass energy of 1.8 TeV, it has open up a new mass window where exotic physics beyond the Minimal Standard Model could manifest themselves. With every substantial increase in integrated luminosity, additional regions of the mass windows are reached. Thus, one of the most important goals of CDF is to search for new physics, perhaps even in those topologies that theorists have not mentioned.

In previous runs, CDF have searched for Squarks and Gluinos, as well as for heavy stable charged particles. Results from a search for a 1st generation Lepto-Quark is close to publication. Many other topics are under study, including the search for τ's from the decay of charged Higgs, which itself could come from the decay of a top quark.

4.3 Electro-Weak Physics

In the field of Electro-Weak physics, the main goal of CDF is to increase the accuracy of the W mass measurement. This is a very important topic since within the framework of the standard model there is a well defined relationship between the masses of the W, the top quark and the Higgs boson. In addition, we plan to improve our previous measurements of W/Z production cross sections, W/Z transverse momenta, W asymmetry and Drell-Yan. We will also be searching for diboson production ($W\gamma, Z\gamma, WW, WZ, ZZ$) as well as new heavy intermediate vector

and $W \rightarrow \mu\nu$ candidates and the invariant mass of Z candidates using 1.43 pb^{-1} of 1992 data.

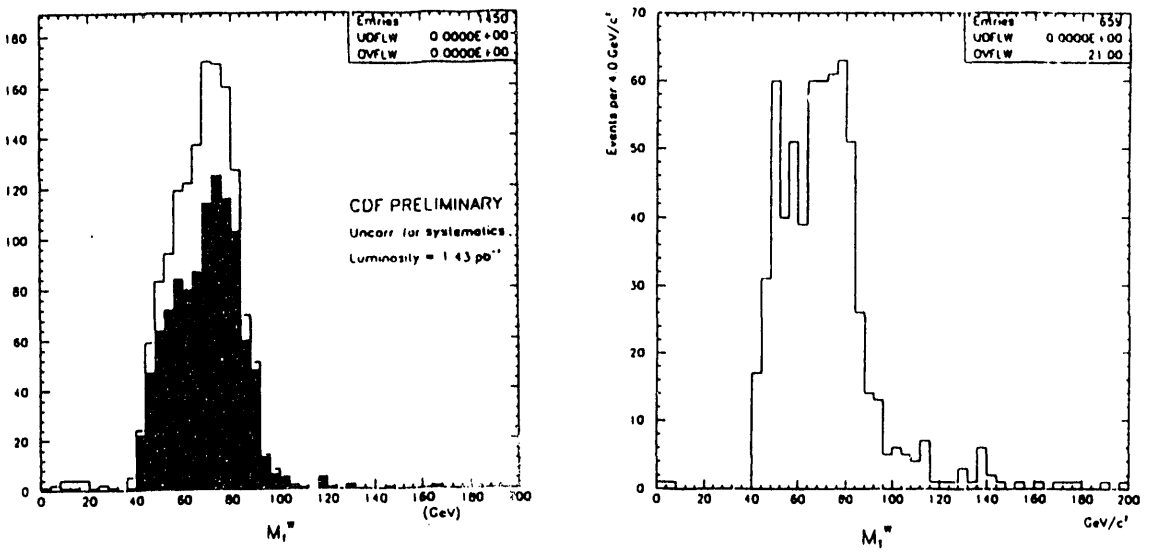

Figure 11: W Transverse Mass: a). $W \rightarrow e\nu$, the shaded area is central electrons and the open represents the histogram is contribution of plug electrons. b). $W \rightarrow \mu\nu$

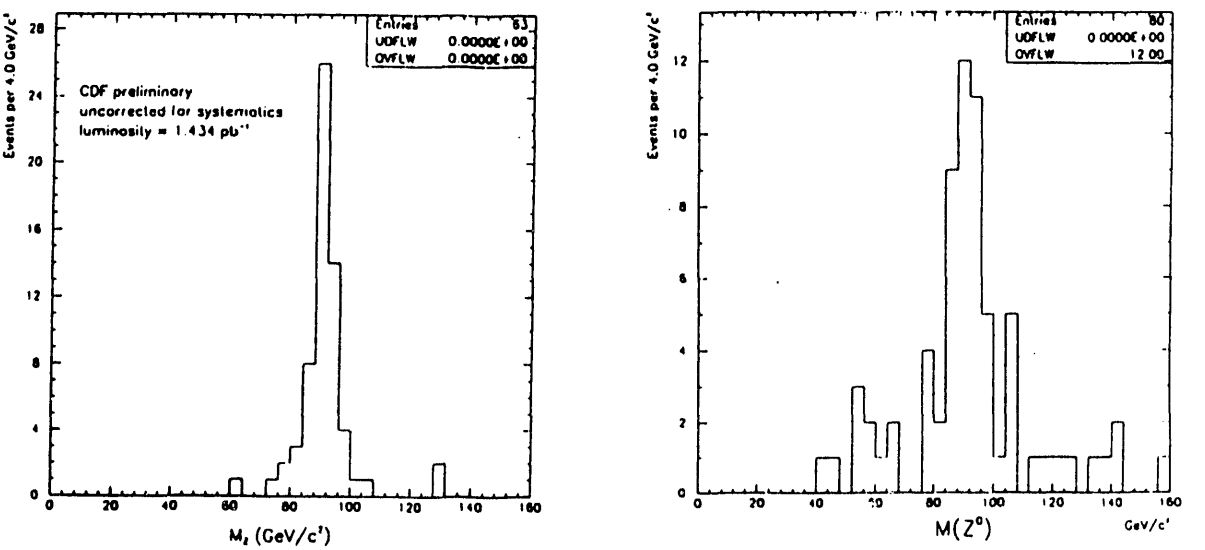

Figure 12: Z^0 Invariant Mass: a). $Z \rightarrow ee$ b). $W \rightarrow \mu\mu$

4.4 B Physics

b-quarks are copiously produced in $p\bar{p}$ collisions. Over the last few years, much interest has emerged within the HEP community at the prospect of exploiting this large cross section to study b production and decay at the Tevatron.

Using the data from the 1988/89 run, we have measured the b-quark production cross section with electron, muon and J/ψ data (see Figure 13). We have also reconstructed exclusive final states ($B \to \psi K, \psi K^*$), and have mesured $B\bar{B}$ mixing.

With the addition of the SVX, the b-physics capabilities of CDF will be greatly enhanced. We expect to search for, and measure the mass of the B_s, Λ_b and possibly B_c. We will also measure the lifetime for inclusive b-hadrons from electron, muon and J/ψ data, as well as the individual lifetimes of B_u, B_d and B_s. We plan to improve our measurement of the mixing parameter, to search for rare B decays, to study $b\bar{b}$ correlations, and to perform engineering studies aimed at an eventual CP violation experiment.

In Figure 14, we show the improvement in mass resolution achieved with the usage of the SVX information. In Figure 15 we demonstrate the power of the SVX in reducing combinatorial backgrounds in a spectroscopy-type analysis, and in Figure 16 we illustrate the cleanliness of a b-lifetime measurement from inclusive $J/\psi \to \mu^+\mu^-$.

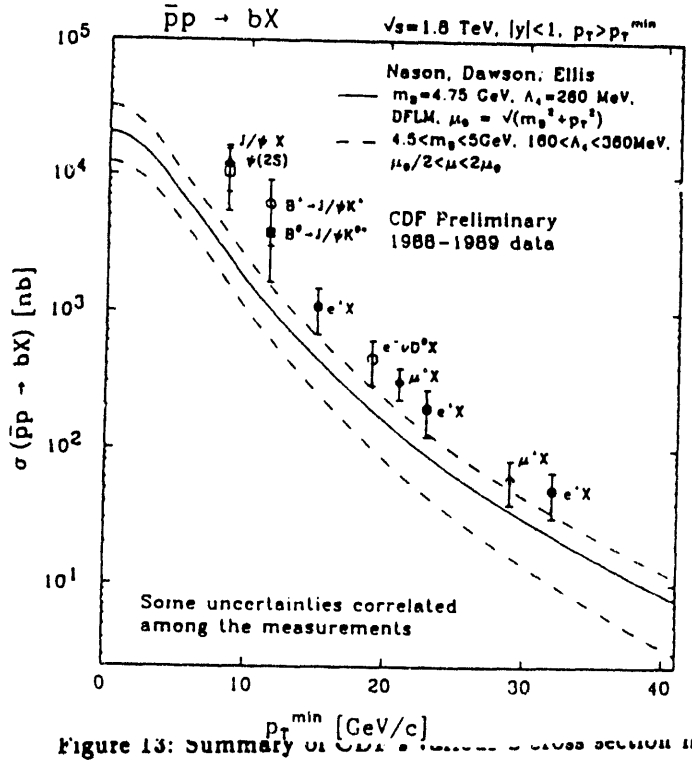

Figure 13: Summary of CDF's [illegible] cross section measurements.

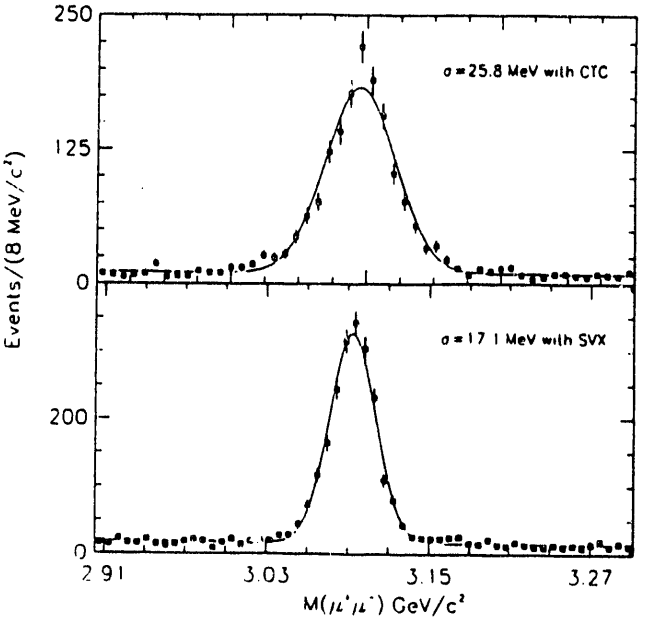

Figure 14: Improvement in Mass Resolution due to the SVX: $M(\mu^+\mu^-)$compared for CTC only and CTC+SVX tracking.

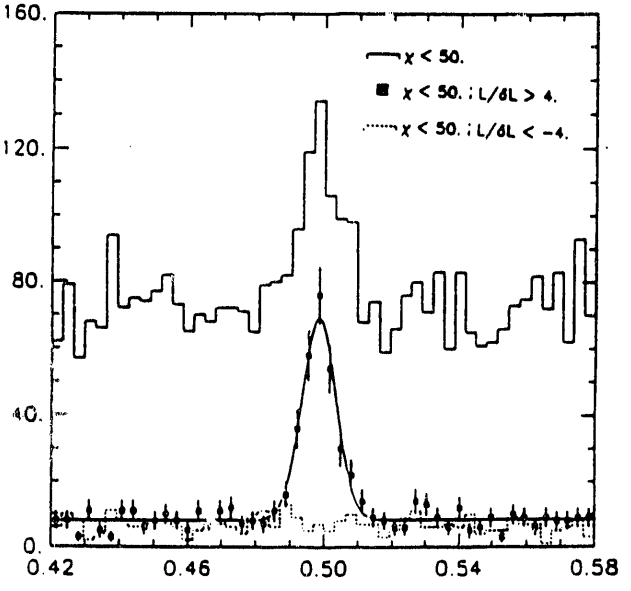

Figure 15: Reduction of combinatorial background due to the SVX: $M(\pi^+\pi^-)$, with no displaced vertex cut and a 4σ cut on the decay length.

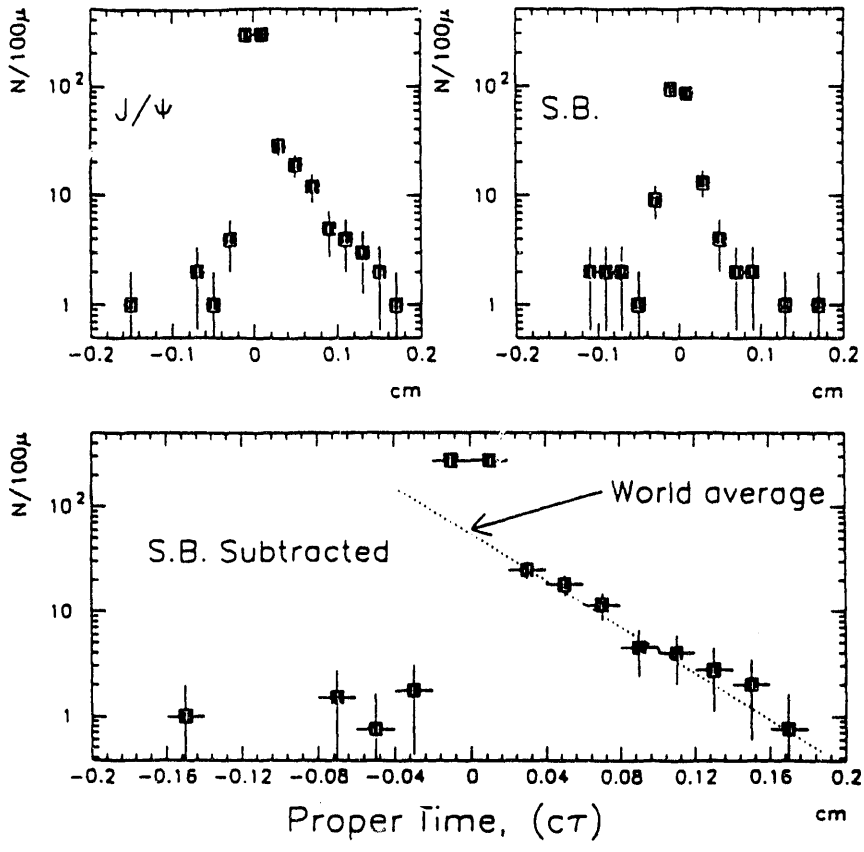

Figure 16: The proper time, $c\tau$, is shown for a). J/ψ mass region, b). J/ψ side band, and c). background subtracted J/ψ .

4.5 Top Search

At Tevatron energies, Standard Model top quarks are expected to be pair produced, through quark annihilation and gluon fusion. The decay of a Standard Model top quark is expected to proceed via $t \rightarrow W + b$. The W can then decay into quarks or lepton-neutrino. Decay modes with no leptons have the highest branching ratio, but are very hard to distinguish from multi-jet QCD backgrounds. Final states with one W decaying into lepton-neutrino and the other W decaying into quarks also have a large branching ratio, and have to be separated from the $p\bar{p} \rightarrow W + jets$ background by tagging the b-quarks in top events. This can be achieved either by using the SVX to reconstruct a displaced vertex or by searching for an additional (soft) lepton (e or μ) from semileptonic b-decays (see figures 17 and 18).

The cleanest $t\bar{t}$ events, with the least amount of backgrounds but the smallest branching ratio, are those with both W's decaying into electons or muons. The (small) backgrounds in this channel arise from the decay of $Z \rightarrow \tau\tau$, as well as WZ and WW production. Once again, b-tagging can provide the required background rejection.

With a 25 pb^{-1} data set, we expect to be able to claim a top discovery up to $M_{Top} \leq 130\ GeV/c^2$.

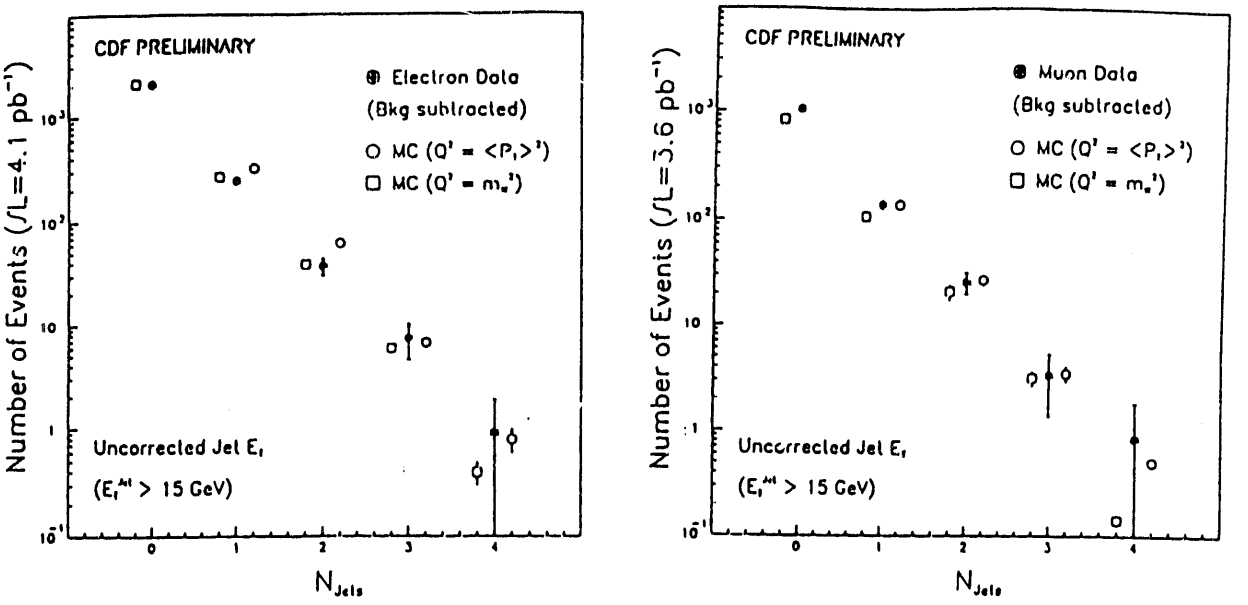

Figure 17: Jet multiplicity in W+Jet events: a). Electrons, and b). Muons. compared with VECBOS calculation.

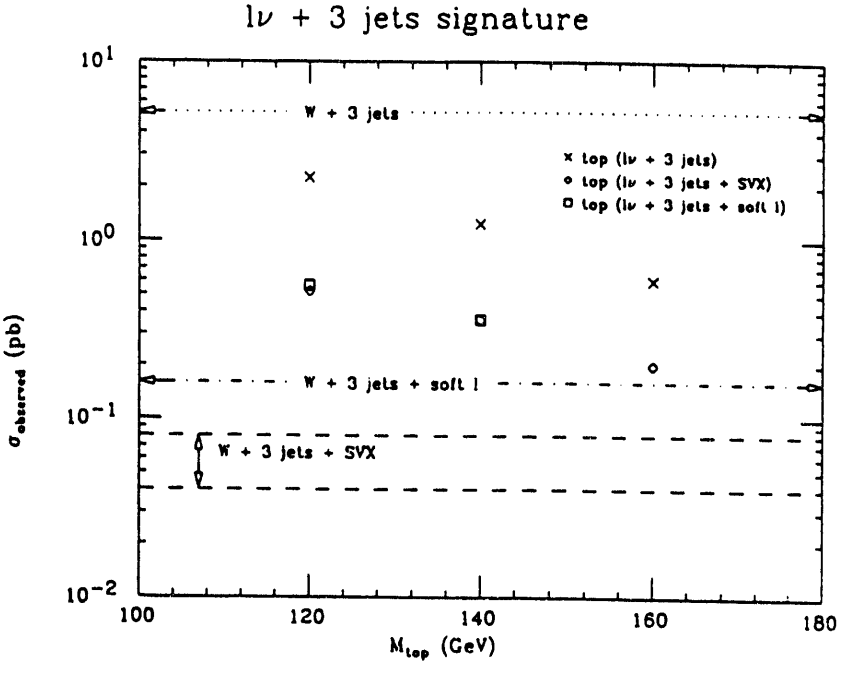

Figure 18: Expected cross sections for $t\bar{t}$ and W+jets using the high P_T lepton+3 Jets signature. The crosses are for $t\bar{t}$, before b tagging. The diamonds represent the $t\bar{t}$ rate after an SVX tag is added. The area bounded by the dotted lines shows the rate for W+jets+SVX. The squares are for $t\bar{t}$ using the soft lepton tag. The dot-dashed line show the W+jets rate for this tagging technique.

5. Conclusion and Prospects

CDF is begining to accumulate a large sample of data. During the last 2-1/2 months, we have already accumulated data which corresponds to more than 1/2 of the data sample of the last run. With the recent improvement in Tevatron luminosity, the Tevatron's goal of delivering 25 pb-1 appears likely to be met.

Based on a first look at the data, the performance of the CDF detector and its various upgrades appears to be very good. The agreement of the preliminary physics results from the new data with those from the 1988/89 run is encouraging. While many further studies need to be carried out, the indications are that CDF is able to study a variety of important physics goals with improved acceptance, more information on the event properties (such as the ability to provide secondary vertex tagging for b jets), and other improvements in triggering, event selection and data handling.

We are optimistic that with the data sample that we expect to accumulate, CDF will be able to address some of the most critical issues in High Energy physics. Along with the possibility of the discovery of top, we would be able to make much progress in understanding B-mesons and hadrons, precisely measuring the W mass, searching for exotic physics, and many other areas.

6. Acknowledgements

I would like to thank the many people who have assisted me in the preparation of this talk, particularly C. Campagnari, J. Yoh, Y.K. Kim and K. Maeshima.

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