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CDF Experiment

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The CDF experiment is currently in a transition stage. The upgrade of the detector and preparation for the collider Run II, scheduled to begin in early 2001, proceed in full swing. Before the physics run, CDF will have a Commissioning Run for two months from August 2000, where $p\bar{p}$ collision data for detector calibration will be taken with the full CDF detector excluding silicon vertex trackers. On the other hand, important physics results continue to come out from analyses of the data sample collected during the Run I period.

1 Physics Analysis of Proton-Antiproton Collision Data

The collider Run I ended in February 1996, yielding 110 pb^{-1} of data recorded by the CDF detector. Analyses of the data continued in the fiscal year 1999, and have led to publication of several important results.

1.1 Top quark physics

Since its discovery in 1994 [1] the CDF experiment has concentrated on precision measurements of the mass and the production and decay properties of the top quark. In 1999 CDF published a combined result of the top quark mass measurements using all of the dilepton, lepton+jets, and all-hadronic channels [2]. The top quark mass was measured to be 176.0 ± 6.5 GeV/c^2 at CDF.

T. Kikuchi (Tsukuba) has searched for single top quark production and set an upper limit of its cross section [3]. Two subprocesses are considered, one being "Wg fusion" process that leads to a $tq\bar{b}$ final state (estimated cross section of 1.7 pb), the other being a virtual W boson production called "s-channel W^*" process followed by its decay to a $t\bar{b}$ pair (cross section of 0.7 pb) as shown in Figure 1. These processes are of interest because the cross

section is proportional to the partial width $\Gamma(t \to Wb)$, which depends on the CKM matrix element $|V_{tb}|$. The candidates events of single top quark production have the distributions of the reconstructed top quark mass and the jet pseudorapidity times lepton charge which were consistent with those for the expected backgrounds as shown in Figure 2. As a result, the search has produced upper limits on the production cross section of 13.5 pb for "Wg fusion" process and 12.9 pb for s-channel W^* process at 95% confidence level. The combined cross section of single top quark production through both processes was measured to be $5.2\ ^{+5.1}_{-3.7}$ pb resulting in the upper limit of 18.6 pb at 95% confidence level.

1.2 Bottom quark physics

CDF continues to produce rich physics results in the area of B physics, and the year 1999 is no exception.

One of the most important B physics analyses from CDF is the search for CP violation in the decay of the neutral B meson $B^0/\overline{B}^0 \to J/\psi K^0_S$. The Kobayashi-Maskawa picture of CP violation predicts a large asymmetry in the decay rates to the $J/\psi K^0_S$ final state between the B^0 meson and its anti-particle $\overline{B}^0$. The asymmetry can be cleanly related to the angle β of the unitarity triangle. CDF has reconstructed about 200 such decays and applied a flavor tagging method called "same-side tagging" [4], yielding $\sin 2\beta = 1.8 \pm 1.1$ [5]. CDF has extended this analysis to include the B^0 candidates where the muons from the J/ψ are not reconstructed in the SVX detector. These events have less precise lifetime information, but they are still useful because, unlike the $\Upsilon(4S)$ experiments, the asymmetry in the decay rates would not vanish even if it is integrated over decay time. The inclusion of these events roughly doubles the sample size to about 400 signal events. In addition to the same-side tagging, lepton and jet-charge flavor tagging methods [6] are applied to the sample, and CDF finds $\sin 2\beta = 0.79\ ^{+0.40}_{-0.44}$ [7]. Figure 3 shows the observed decay asymmetry. These results, although statistically not significant yet, firmly establish the methods that will lead to precise CP violation measurements in Run II.

Other B physics results published this year include precise measurements of $B^0\overline{B}^0$ oscillation frequency Δm_d [4, 6, 8, 9]. The measurement using $\ell^- D^{*+}$ pairs and lepton flavor tags is a work by T. Kuwabara (Tsukuba) and F. Ukegawa (Tsukuba). The average of all CDF results on Δm_d is (0.495 ± 0.035) ps^{-1}. The precision is comparable to that from the LEP experiments.

M. Tanaka (Tsukuba) has searched for radiative b decay using conversion photon. An upper limit at 90% CL on the branching ratio $B_s \to \phi\gamma$ was obtained to be 2.4×10^{-4}. This is the best limit in the world.

1.3 Electroweak physics

CDF has completed the measurement of the W boson mass using the electron channel. Combined with the measurement using the muon channel, it gives a CDF W mass value of $M_W = 80.433 \pm 0.079$ GeV/c^2 [10]. The W boson mass measured at CDF, D0 and LEPII and the top quark mass measured at CDF and D0 are related to the Higgs mass as shown in Figure 4. These M_W, M_{top} and other electroweak results at LEP and SLC give the Higgs mass of $M_H = 77^{+69}_{-39}$ GeV/c^2 and its upper limit of 215 GeV/c^2 at 95% confidence level [11].

Other electroweak studies in progress by Japanese collaborators include a measurement of the strength of the tau lepton coupling to the W boson relative to the electron coupling.

1.4 QCD physics

A few studies are in progress in the area of diffractive physics. K. Terashi (Tsukuba) has investigated the dijet production by double pomeron exchange in diffractive events [12]. The diffractive double pomeron exchange is identified with the existence of two rapidity gaps both in the forward and backward regions and a leading antiproton track in the very backward tracker. The fraction of the double pomeron exchange dijet events among the diffractive dijet events is measured to be $0.12 \pm 0.03 \pm 0.05\%$. It is inconsistent with theoretical predictions.

Other diffractive analyses under way by Japanese collaborators include studies of pomeron structure function using diffractive two-jet events.

1.5 Searches for new phenomena

The analyses on new phenomena searches are under way by Japanese collaborators include searches for R-parity violating supersymmetric particles, and a search for new particles using multi-jet events.

2 Detector Upgrade for Run II

2.1 Plug upgrade calorimeter

The analysis of test beam data using the test module is complete; performance characteristics such as energy resolution, response linearity, and response uniformity along the surface of the calorimeter are studied. The test beam module has performed according to design specifications. These data will be used to establish methods for electron and photon identification.

The construction of the production modules and the assembly into the plug calorimeter are now complete. Both east and west plug calorimeters were installed to the CDF detector after they have undergone pre-installation tests using cosmic rays, including gain adjustments of photomultiplier tubes, measurements of response to cosmic ray muons, and calibration

using radioactive wire source. Then the west plug calorimeter is currently outside of the CDF detector to install the trackers inside of the solenoid magnet.

In August 2000, the production, test and installation of readout electronics will be complete and the plug calorimeter as a whole will be ready for the Commissioning Run.

Y. Seiya, T. Asakawa, R. Oishi from Tsukuba have contributed to the plug calorimeter efforts. Y. Seiya is a co-leader for the plug calorimeter project.

2.2 Silicon vertex detector (SVX II)

The production of double-sided silicon micro-strip sensors were completed at Hamamatsu Photonics. They have been tested for quality and performance, including total and individual channel leakage current, $I - V$ characteristics, and dead channel fraction.

At the same time, preparation for assembly of the sensors into unit ladders is complete and the delivery of ceramic hybrids and readout chips is awaited. The production of ladders will start soon.

T. Ohsugi, Y. Iwata from Hiroshima, I. Nakano from Okayama and R. Takashima from the Kyoto University of Education have been working on the SVX II project.

2.3 Intermediate silicon layers (ISL)

K. Hara and M. Shimojima from Tsukuba have worked on the silicon sensors of the ISL detector. The production of double-sided silicon micro-strip sensors was completed at Hamamatsu. Sampling probing tests were performed to assure quality, including $I - V$ characteristics, leakage current, and dead channel fraction.

T. Okusawa, T. Yoshida (Osaka City) and Y. Kato (Kinki) have been working on the data acquisition system to be used for testing hybrids.

2.4 Data acquisition system (DAQ)

M. Shimojima (Tsukuba) has responsibility for the data logger, which, as a part of the online data acquisition system, receives events from the level-3 trigger and sends to disk and tape storage as well as to online monitoring programs. A prototype of the data logger was constructed and evaluated for performance.

2.5 Time-of-flight detector (TOF)

F. Ukegawa (Tsukuba) is a co-leader of the time-of-flight counter project, which was approved in 1999 as a beyond-the-baseline project. The Tsukuba group is in charge of quality control of photomultiplier tube production. About 70% of whole photomultipliers have been produced, tested in KEK 1.5-Tesla Ushiwaka magnet and sent to Fermilab. The TOF counter is now being installed into the CDF detector as shown in Figure 5.

References

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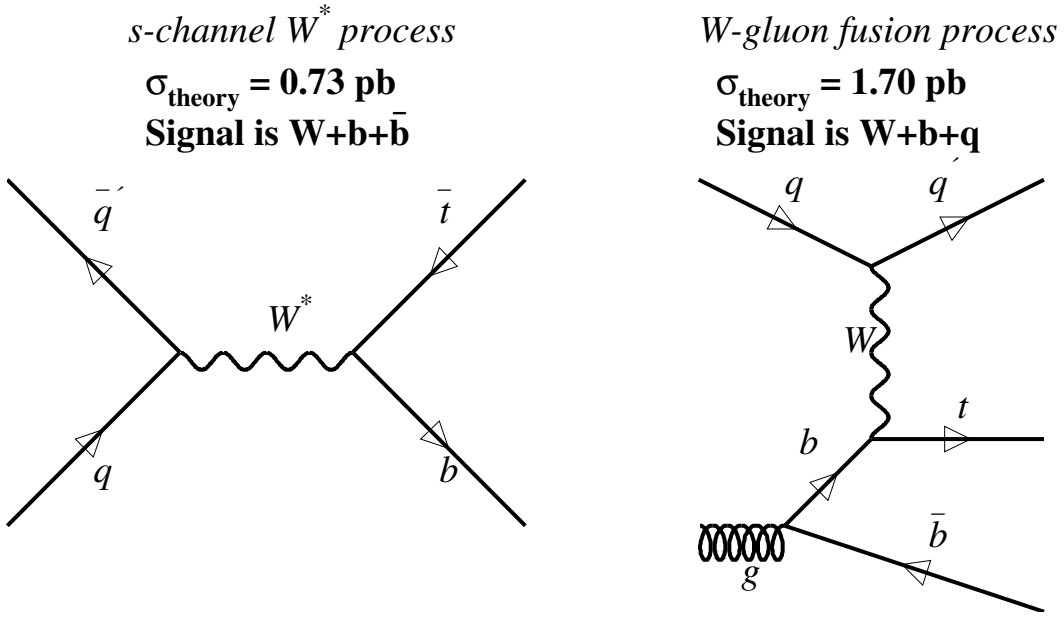

Figure 1: Two diagrams for single top quark production. Left: s-channel W^* process. Right: W gluon fusion process.

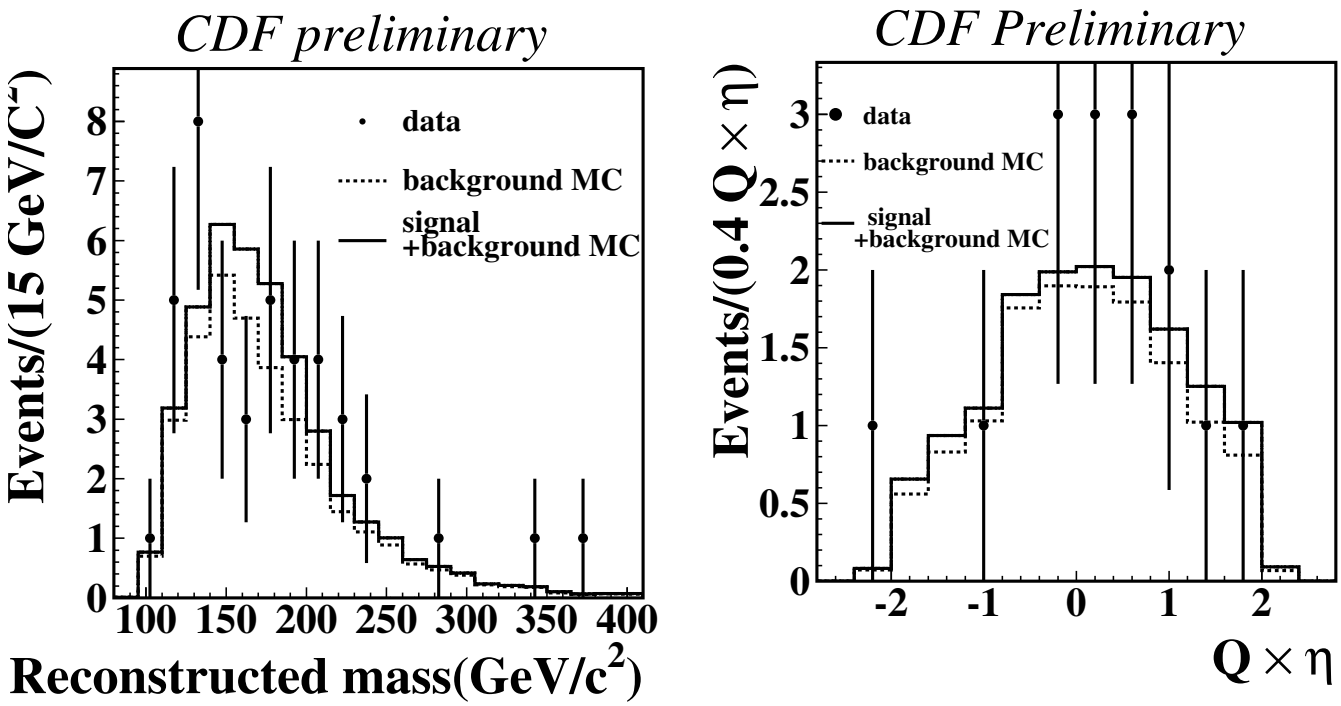

Figure 2: Left: Reconstructed top mass distribution for single top candidates events through s-channel W^* process. Right: Distribution of the untagged jet pseudorapidity times lepton charge for single top candidates events through W gluon fusion process.

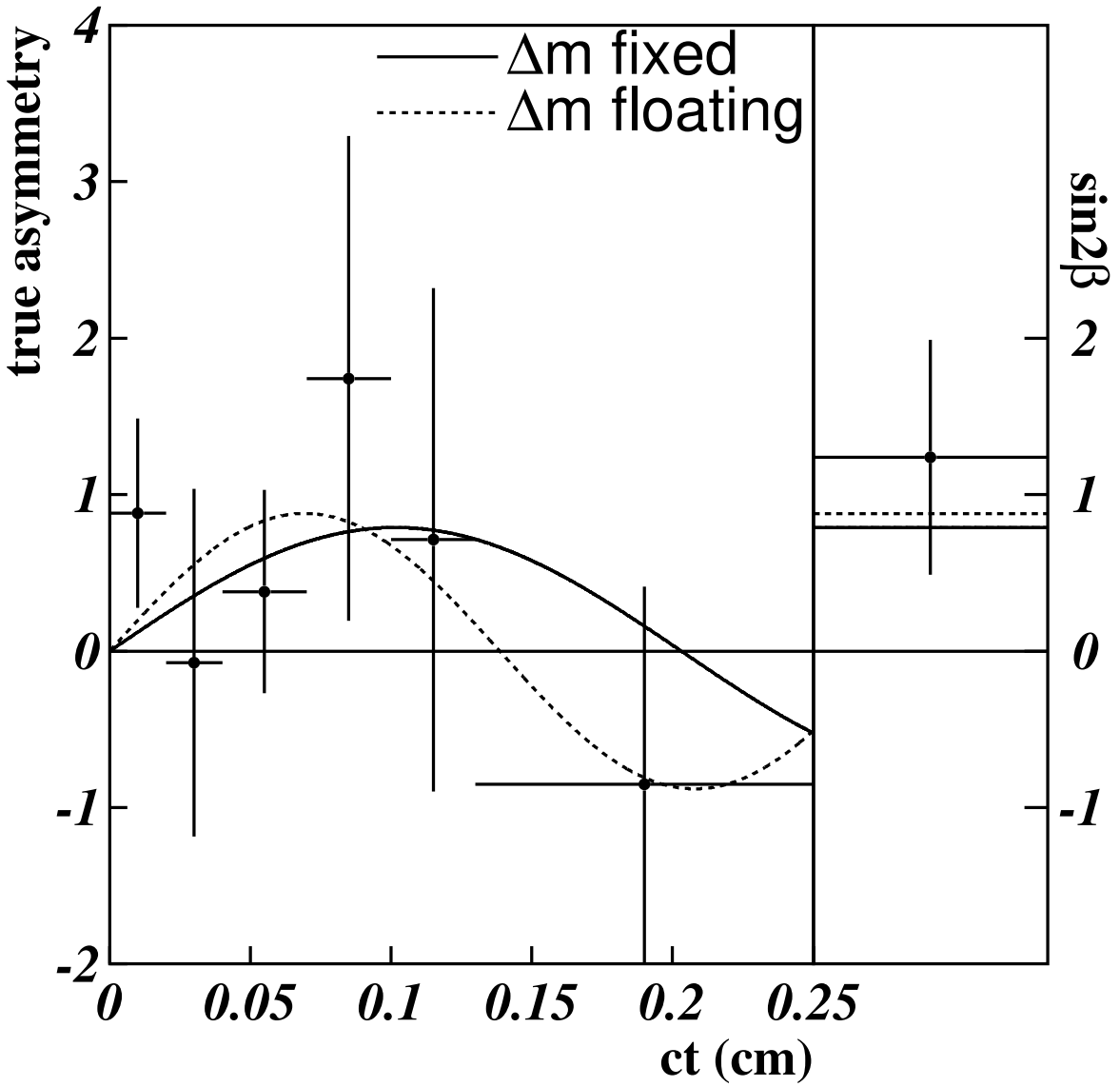

Figure 3: Left: Asymmetry in the $\overline{B}^0$ and B^0 decay rates to the $J/\psi K_S^0$ final state as a function of the proper decay time for events with precise decay time information. Right: Asymmetry in the decay rates integrated over decay time (converted to $\sin 2\beta$) for events with less precise decay time information.

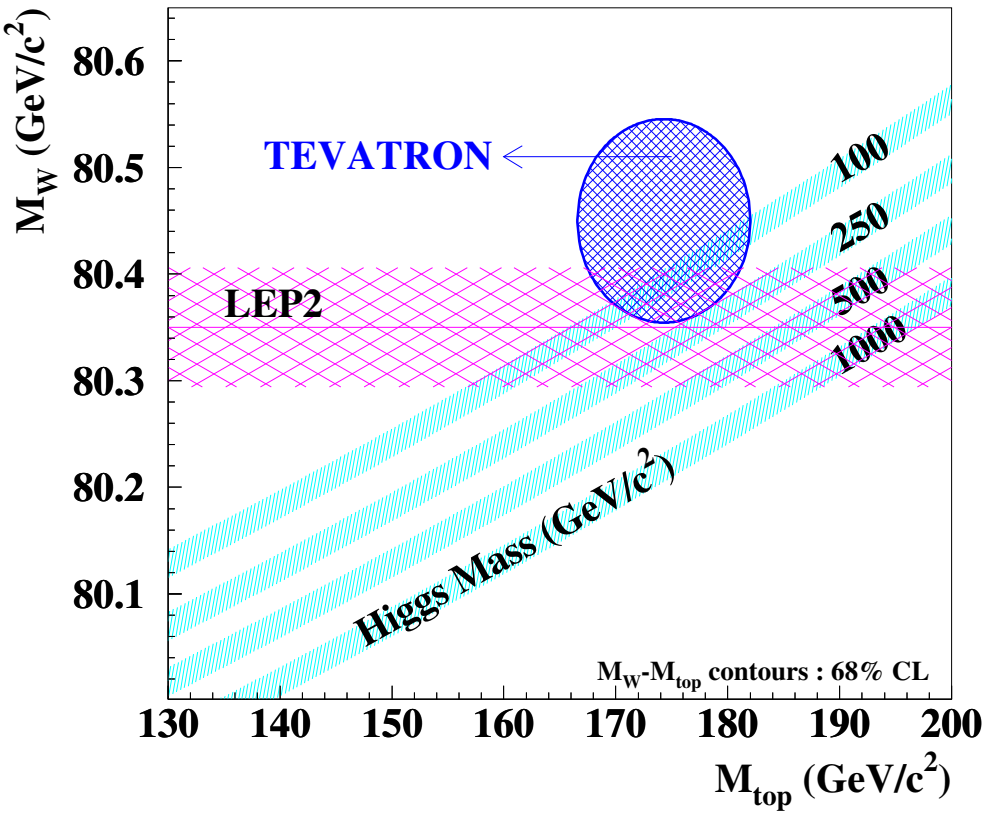

Figure 4: A plot of the W boson mass M_W versus the top quark mass M_{top}. M_W and M_{top} measured at Tevatron are shown by a shaded contour at 68% CL. M_W measured at LEPII is shown by a cross-hatched band at 68% CL. Theoretical constraints on M_W-M_{top} relation are also shown by bands at fixed Higgs masses of 100, 250, 500 and 1000 GeV/c^2.

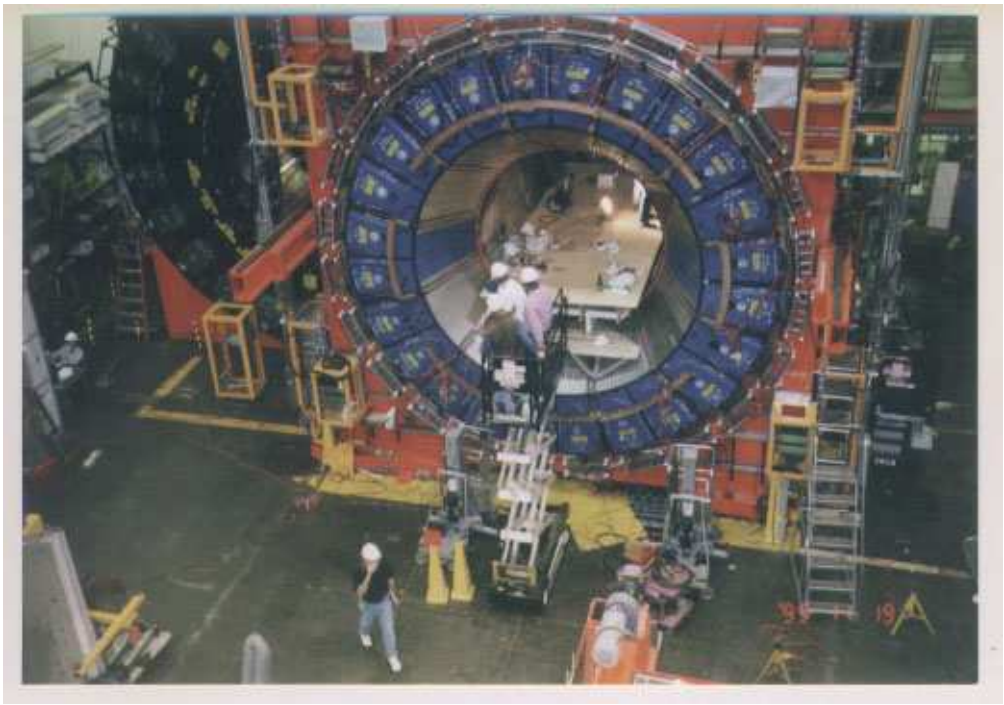

Figure 5: The TOF counters are being installed to the CDF detector.