CDFは走ってます！[1]

筑波大学　物理学系　　受川 史彦 [2]

概 要

The CDF experiment, after a long hiatus, has resumed its physics run (Run II) with an upgraded detector. The Tevatron accelerator complex has also been upgraded, including newly constructed Main Injector replacing the old Main Ring. In this talk we present the current status of the accelerator and the CDF detector and physics prospects in Run II.

1 Machine and Detector Status

The Collider Detector at Fermilab (CDF) is one of the two large collider experiments operational at the Tevatron proton-antiproton collider at Fermilab in Batavia, Illinois, USA. The previous physics run, called Run I, ended in February 1996. CDF collected about 110 pb^{-1} of data from 1992 to 1996, in which the top quark has been observed. Since then both the accelerator and the CDF detector have undergone vast upgrades. CDF resumed its physics run (Run II) in summer 2001, and has been running since then. The accelerator is now operational with 36 bunches of protons and antiprotons, with an increased center-of-mass energy of nearly 2 TeV. The newly constructed Main Injector has replaced the old Main Ring, and provides higher $\bar{p}$ production rates and higher particle intensity into Tevatron, resulting in higher collider luminosity. The best instantaneous luminosity has exceeded $3.5 \times 10^{31}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$, and a weekly integrated luminosity of about 6 pb^{-1} (Figure 1). We expect to collect about 100 pb^{-1} of physics quality data by the end of this year 2002, a few hundred pb^{-1} in 2003, and a total of 2 fb^{-1} in Run-IIa period (end of 2004?).

The CDF detector has been upgraded [1] to cope with the machine changes, namely shorter beam crossing time (400 ns) and a higher luminosity up to a few $\times 10^{32}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$, while keeping the strengths of the previous CDF detector [2], high resolution charged particle tracking and excellent lepton identification capabilities.

The tracking detectors occupy the region inside the 1.4-T CDF solenoid, 3 m in diameter and 5 m long. The main tracking chamber is the central outer tracker (COT), replacing CTC. It is a large cylindrical drift chamber with 30 k sense wires and small drift cells. Its momentum resolution is $\sigma(p_T)/p_T = 0.0008\,p_T$ for tracks in $|\eta| < 1$ where p_T is the track momentum (in GeV/c) in the plane transverse to the beam (and magnetic field) axis. It also provides limited dE/dx particle identification information. Inside the COT are layers of silicon micro-strip detectors. The silicon system consists of three sub-detectors, Layer 00 (L00), SVX-II and the Intermediate Silicon Layers (ISL), from inside out. The L00 detector sits on beam pipe (radius 1.5 cm) and uses single-sided sensors, while the latter two systems use double-sided sensors for three-dimensional measurements. The total number of channels is 700 k. They together provide a maximum of 15 precision spatial measurements per track and are essential for detection and measurements of long-lived particles such as B hadrons. The new endplug calorimeter based

[1] 研究会「実験・観測にもとづく素粒子統一描像の構築–21 世紀の情報発信基地としての日本–」，京都大学基礎物理学研究所，2002 年 8 月 21 - 23 日.

[2] E-mail: ukegawa@hep.px.tsukuba.ac.jp

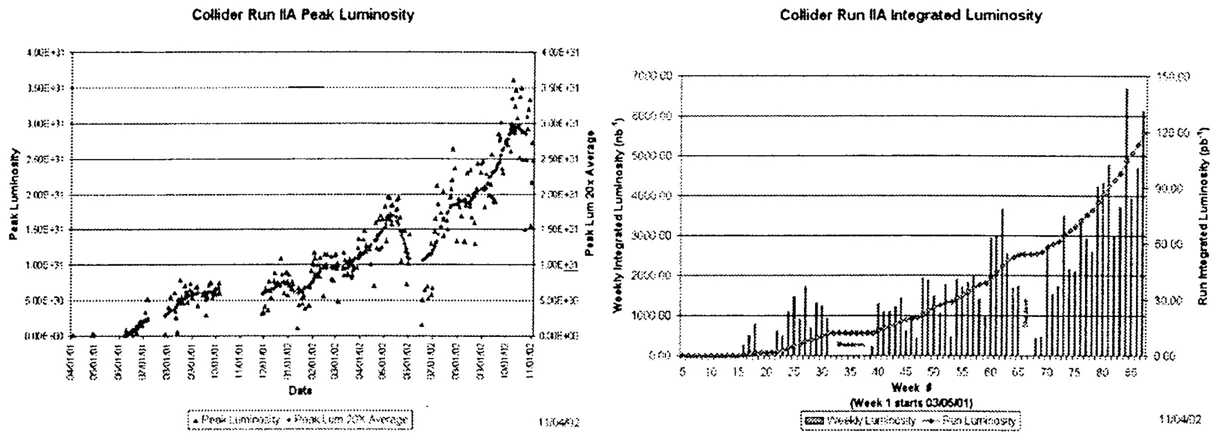

図 1: Tevatron Run-II luminosity. Instantaneous (left) and integrated (right).

on scintillator tiles with wavelength-shifting fibers has been constructed and has replaced the old gas-chamber calorimeter. Time-of-flight counters have been installed in the central region between COT and the solenoid, and provides > 2-σ $K^{\pm}/\pi^{\pm}$ separation up to 1.5 GeV/c, to be used mainly for B flavor tagging. The muon coverage is also extended. The front-end electronics and the data acquisition system are also brand-new.

2 Run-II Physics Prospects

A wide variety of physics results are expected from CDF Run-II data. Here we mention only some of them.

2.1 Top quark physics

The top quark was discovered by the CDF experiment in 1995. With an expected 20-fold increase in integrated luminosity and a 30% increase in the production cross section (1.8 TeV to 2.0 TeV), we expect to collect $\sim$ 1k top decay events, with which more detailed studies of its properties will become possible. The top quark mass will be measured to about 3 GeV/c^2. The production cross section, p_T distribution, and $t\bar{t}$ mass distribution will be measured, and decays to e.g. non-Wb final states will be searched for. Also, production of single top quarks could be observed, leading to a direct determination of $|V_{tb}|$ to 20%.

2.2 Electroweak physics

The $W^{\pm}$ boson mass will be measured with $\sim$ 40 MeV/c^2 precision. Coupled with the top quark mass measurement, it will provide an indirect information on the Higgs boson mass, which enters the loops in the W and top propagators. The Higgs mass information will be obtained with a precision of $\sigma(m_h)/m_h \sim 0.3$ (Figure 3 (Left)).

Also, detailed studies of gauge boson self couplings will be performed, including production of vector boson pairs and radiation amplitude zero in $W^{\pm}\gamma$ events.

2.3 *B* physics

The high B-hadron yield at the Tevatron provides CDF an opportunity to perform interesting B-physics measurements, provided that we can trigger on and collect their decays. Traditionally CDF relied on leptons as B triggers, collecting leptons produced in semileptonic decays and $B \to J/\psi X$. The $J/\psi \to \mu^+\mu^-$ trigger remains the channel for a measurement of $\sin 2\beta$ with

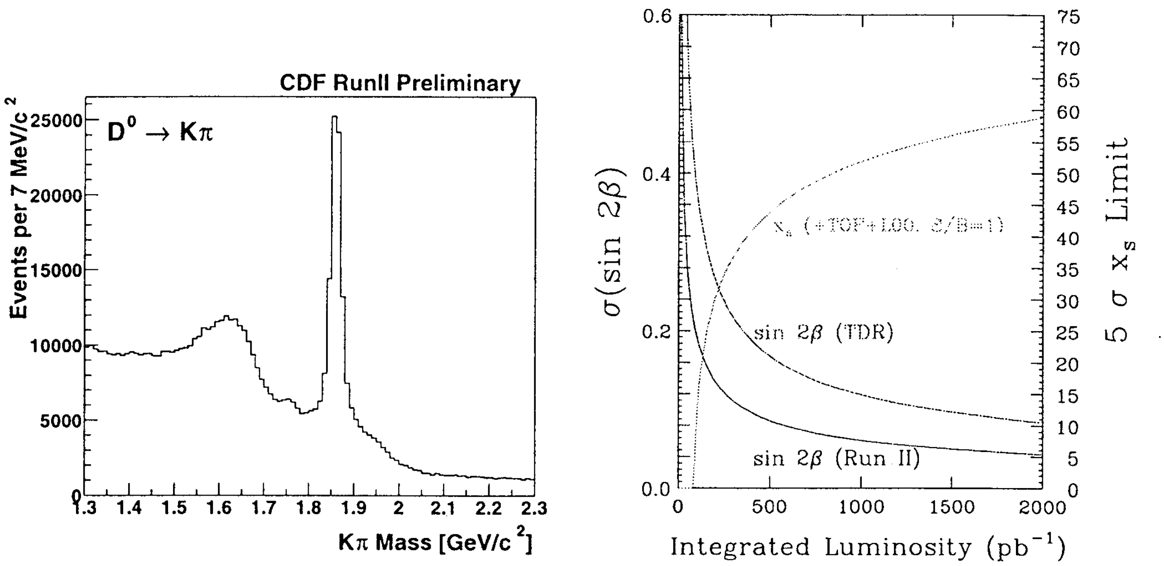

図 2: Left: Run-II $D^0 \to K^-\pi^+$ signal collected using SVT. Right: Expected precision in $\sin 2\beta$ measurement (left axis) and $B_s^0\overline{B}_s^0$ mixing reach (right axis), as a function of accumulated amount of data.

$B^0/\bar{B}^0 \to J/\psi K_S^0$. We expect to determine $\sin 2\beta$ with a precision of $\pm 0.04 - 0.08$ with 2 fb^{-1} of data [3].

In Run II, CDF has introduced a device called SVT (silicon vertex trigger), which uses silicon information at the second level of the trigger and measures the impact parameter of the tracks with about 50 μm resolution for $p_T > 2$ GeV/c. This enables us to trigger on tracks with large impact parameters (e.g. $> 100\ \mu$m) with respect to the primary vertex (beam spot). These tracks can arise from decays of long-lived particles such as charm and B hadrons. Huge $D^0/D^+/D_s^+$ meson signals have already been seen (Figure 2 (Left)). With SVT, we can trigger on B decays with the final states consisting of only hadrons, such as $B^0/\bar{B}^0 \to h^+h^-$ and $\bar{B}_s^0 \to D_s^+\pi^-$. The latter is our main mode for $B_s^0\bar{B}_s^0$ oscillations. We should be able to observe oscillations with the frequency Δm_s up to 40 ps^{-1}. Once the oscillations are established, the frequency Δm_s will be measured to a few per cent. It is essential for a precise determination of the length of one side of the CKM unitarity triangle, $|V_{td}/V_{ts}|$. These two quantities will determine precisely the parameters $\bar{\rho}$ and $\bar{\eta}$ of the triangle. Another interesting measurement might emerge from CDF, which is a determination of the angle γ (phase of V_{ub}) using $B^0/\bar{B}^0 \to \pi^+\pi^-$ and $B_s^0/\bar{B}_s^0 \to K^+K^-$ simultaneously. A measurement of γ will be the first meaningful test of the consistency of the triangle.

2.4 Quantum chromodynamics

A wide variety of measurements will be performed at a new center-of-mass energy of 2 TeV [4]. Also, increased statistics allow measurements in a wider range of spectra, e.g. highest E_T jets, photons and other objects with less statistical uncertainties. For example, a few jets of E_T of up to 550 GeV will be observed in 2 fb^{-1}. One of the surprises in QCD measurements in Run I was an anomalously high rate for direct J/ψ production. The rate exceeded the color-singlet model prediction by a factor of 50 [5]. This obviously calls for the existence of another production mechanism, e.g. color-octed model, but CDF polarization measurement [6] seems not to favor the model. New data should provide a better measurement of polarization as well as the production cross sections.

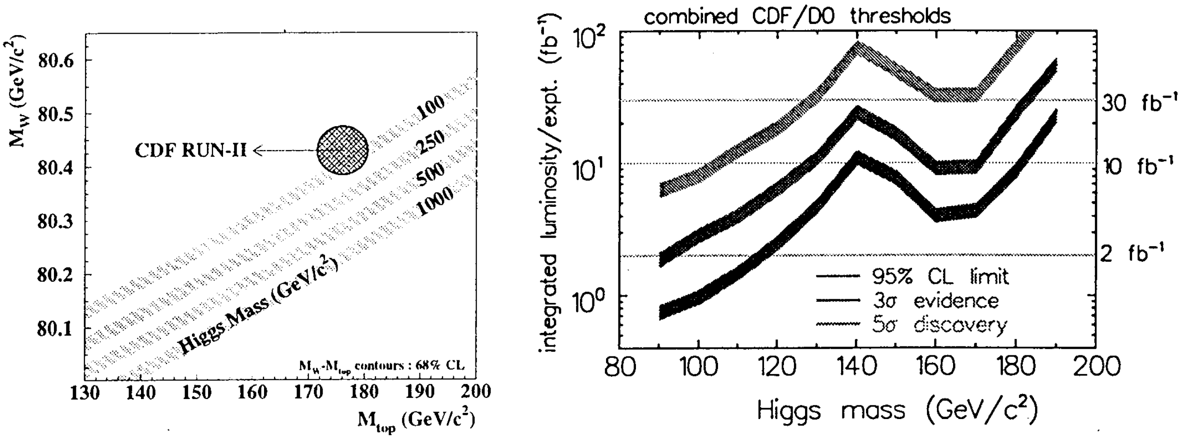

図 3: Left: Expected precision in $W^{\pm}$ boson mass and the top quark mass measurements in Run II and possible constraints on the Higgs mass. Right: Tevatron reach for the standard model Higgs boson. Three bands show, as a function of the Higgs mass, the amount of data that are necessary (a) to exclude at 95% CL if the Higgs does not exist at that mass (bottom band), (b) to provide 3σ evidence for existence (middle), and (c) to discover with 5σ significance (top).

2.5 New particle searches

Searches for the Higgs boson, supersymmetric particles, extra gauge bosons, and other new particles arising from models such as technicolor, topcolor and compositeness will be performed. The standard model Higgs boson can be searched for in a mass range up to 120 GeV/c^2 with 2 fb^{-1} of data [7]. The mass range up to 160 GeV/c^2 can be covered if we collect 15 fb^{-1}. This is shown in Figure 3 (Right).

3 Summary

CDF *has* been running. Maybe not as fast as we wanted to be, but the detector is working very well and the machine luminosity is improving rapidly in recent weeks. We expect a lot of exciting physics results to come out from the new data. Watch out!

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