FIRST RUN II RESULTS FROM CDF

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In this paper we report on the first run II results from the CDF experiment. A brief description of the Tevatron collider and CDF detector upgrades and performance achieved in the first part of run II is followed by the CDF expectations in the fields of beauty, top, electroweak and Higgs physics.

1 Run II collider upgrades

Major upgrades have been made to the Tevatron collider for run II. The energy of the beams has been increased from 900 GeV to 980 GeV. A new 150 GeV synchrotron (“main injector”) was built in a new tunnel. The main injector is much faster than the old “main ring” in producing antiprotons to be stored in the debuncher-accumulator-recycler complex. The 8 GeV permanent magnet recycler ring, housed in the same tunnel as the main injector, is also new. At the end of a store the antiprotons rather than being aborted are decelerated in the Tevatron and in the main ring and rescued in the recycler. In run I the luminosity reached $1.5 \times 10^{31} \text{ cm}^{-2} \text{ sec}^{-1}$ and was obtained with 6 on 6 proton-antiproton bunches in the collider with an interbunch time of 3.5 $\mu s$. The luminosity ultimately planned for run II with the new injector/antiproton source is $2 \times 10^{32} \text{ cm}^{-2} \text{ sec}^{-1}$ and will be obtained with 36 on 36 bunches with an interbunch time of 396 ns. At $2 \times 10^{32} \text{ cm}^{-2} \text{ sec}^{-1}$ with these beams the average number of interactions per bunch crossing would be about 5. In order to limit this number below 2 as in run I the plan is to increase the number of bunches in the antiproton beam to 108 with 140 bunches in the proton beam and reduce the interbunch time to 132 nanoseconds.
2 Run II detector upgrades

While the central calorimeter, the solenoid and part of the muon system have been inherited from run I, the other CDF subdetectors are completely new. CDF has a new tracking system made of three independent silicon detectors (L00, SVXII and ISL) and a drift chamber (COT). There is a new time of flight system (TOF) for particle identification and a new plug calorimeter. All the front end electronics, the DAQ and the trigger have been completely redesigned to cope with the new time constraints imposed by the shorter interbunch time.1

The new 7 layer (8 layer in the forward region) silicon system has a barrel geometry and extends from a minimum radius of 1.6 cm (L00) to a maximum radius of 28 cm (layer 7 of ISL) 2. The layer closest to the beamline is a radiation hard single-sided detector which employs recent LHC designs for sensors supporting high bias voltage. This enables good signal-to-noise performance even after extreme radiation doses. The remaining seven layers are radiation hard double-sided detectors. The measurement of seven points on the silicon matched to the COT information provides a robust tracking in the central region (|η| < 1). In the forward region (1 < |η| < 2) where the COT acceptance rapidly decreases, silicon-only tracking is performed. The new drift chamber reproduces the excellent performance of the run I chamber in terms of efficiency and transverse momentum resolution (σ_{pT}/p_T < 0.1 %), but this is achieved in the much more difficult run II environment. By using a faster gas mixture (50:35:15 Ar:Et:CF_4) the maximum drift time has been reduced to 100 ns (it was 800 ns in run I). The COT has also more robust 3D pattern recognition capability and it provides dE/dx information. The time of flight detector is made of one layer of scintillator bars (4 x 4 cm^2 cross section, 2.8 m long) placed in the space between the COT and the solenoid and read by photomultipliers on both ends. The TOF resolution of 100 ps allows a 2σ π/K separation for transverse momentum up to 1.6 GeV/c.

Finally all the front end and DAQ electronics has been changed and made able to work with a 132 ns crossing period. At level 1 (within 5 µs) a new online processor which reconstructs COT tracks has been implemented. At level 2 (within 20 µs) the Online Silicon Vertex Tracker3 (SVT) links level 1 COT tracks to the silicon hits and reconstructs offline-quality tracks (~40 µm impact parameter resolution 4). SVT is the first such device installed in hadron collider detectors and CDF relies upon it to collect large samples of hadronic b-decays which are crucial for B_0^s mixing (like B_0^s → D_7^- π^+ and B_0^s → D_7^- π^+ π^-) and CP violation (like B_d^- → π^+ π^-, B_s^- → D_7^- K^- and B^± → D^0 K^±).

3 Run II physics highlights

3.1 Beauty and charm physics

A precision measurement of the B_0^s flavor oscillations is very important for testing the unitarity of the CKM mixing matrix. The Standard Model favored value of x_s is in the range 22.55 < x_s < 34.11 at 95 % C.L.5 CDF plans to use fully reconstructed hadronic B_0^s decays (B_0^s → D_7^- π^+ and B_0^s → D_7^- π^+ π^-π^+) with D_7^- reconstructed as φπ^-, K^0_0 K^- and K^0_2 K^-). These signals will come from the data taken with the triggers based on SVT tracks. CDF expects 75,000 reconstructed B_0^s decays in 2 fb^{-1} (expected run IIa integrated luminosity) using the above decay modes with an estimated signal-to-background ratio in the range 1:2 to 2:1. The proper time resolution is expected to be in the range 45-60 fs and the flavor tag effectiveness (εD^2) 11.3 %. This value for εD^2 includes the same-side tagging, the soft-lepton tagging and the opposite-side jet tagging, as well as the kaon tagging, which is now made possible by the particle identification provided by the time of flight detector. The resulting 5σ sensitivity on x_s reaches values close to 60 which is well beyond the Standard Model expectation for this parameter.6 Figure 1 shows the D_s and D^± signals reconstructed in the φπ^+ decay mode in the first run II SVT data (1.05 pb^{-1}). The expectation is to reconstruct clean B_0^s signals as the integrated luminosity increases.
transverse momentum and compatible measurements in the field of mixing and CP violation.

Assuming BR(D^0 -> K^+K^-) = 10^-6, CDF expects from 0 to 1000 fully reconstructed D^0 -> K^+K^- decays.

The trigger selection based on SVT and designed to collect hadronic B decays is expected to provide also large charm samples. In Figure 1, preliminary but clean signals of D^0 and D^0 -> K^+K^- are reconstructed in about 1 pb^-1 of data collected in run I.

Within the Standard Model the time dependent CP asymmetry in the decay mode B^0 -> J/psi K^+K^- is the most popular mode for the measurement of the angle sin(2phi). Using the run I sample of about 500 events, with the possible addition of approximately 100 events from run II, CDF has measured sin(2phi) = 0.05 +/- 0.01 MeV/c^2. Studies performed in run I data have shown that the QCD background separation for tracks with dE/dx > 2 GeV is negligible.

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CDF plans to measure the CP asymmetry in the charmless hadronic decay B^0 -> D^0 -> K^+K^- and in the modes B^0 -> pi^+pi^- and K^+K^-.

Figure 1: Preliminary signals from D^0 and D^0 -> K^+K^- decays reconstructed in the charmless hadronic decay B^0 -> D^0 and in the modes B^0 -> pi^+pi^- and K^+K^-.
3.2 Top physics

With 2 fb$^{-1}$ CDF will have a sample of top events 30 times larger than in run I due to the top cross section increase by nearly 40 % and better detector performance, in addition to the increase in integrated luminosity. The top mass measurement will be improved to a level of 2-3 GeV/c$^2$. In addition the goal for run II is to search for $t\bar{t}$ resonances, rare decays and deviations from the expected patterns of top decays. From run II data CDF expects also to perform a measurement of the W mass at the level of 20-30 MeV/c$^2$.

3.3 Higgs potential

Standard Model Higgs is produced single or in conjunction with a W or a Z at the Tevatron with a cross section in the range 0.1-1.0 pb. The cross section is largest for single Higgs production from gluon fusion, with the WH and ZH modes lower by nearly one order of magnitude. Nevertheless the sensitivity is greater for the WH and ZH modes since for single H production the background from dijets is too large. The searches for Higgs divide into the Higgs mass below and above about 135 GeV/c$^2$, the mass at which the dominant Higgs decay modes change over from $b\bar{b}$ to WW. At lower masses the decay mode of the accompanying W or Z determines the final state ($W\rightarrow q\bar{q}$ is the largest, followed respectively by $W\rightarrow b\nu$, $Z\rightarrow l^+l^-$ and $Z\rightarrow \nu\bar{\nu}$). For Higgs masses above about 135 GeV/c$^2$ the decay mode $H\rightarrow WW$ dominates and provides a means for a potential observation. The main problem in this case is the roughly 10 pb cross section for vector boson pair production; the rates for Higgs are 10-100 times smaller (interesting final states: like-sign lepton pairs with jets, dileptons with missing transverse energy, and triplets). Simulations show that for a Higgs in the region indicated by LEP 2 ($\sim 115$ GeV/c$^2$) CDF+D0 will reach a 95 % exclusion power with an integrated luminosity per experiment of 2 fb$^{-1}$ (run IIa). For the same mass there will be a $3\sigma$ evidence after $\sim 5$ fb$^{-1}$ and a $5\sigma$ evidence after $\sim 15$ fb$^{-1}$ (run IIa+run IIb). For significantly larger masses 10-15 fb$^{-1}$ are necessary even for a 95 % exclusion.

Conclusions

In this paper the preliminary results concerning the CDF performance in the early phase of run II have been reported. The commissioning of the accelerator and of the CDF detector is advanced and the expectation is to have preliminary physics results for the summer 2002 conferences.

References