

Status of CDF Run II Upgrade

Jack Cranshaw ¹

Texas Tech University, on behalf of the CDF Collaboration

Abstract

For the past several years, the CDF collaboration has been upgrading its detector to accommodate the higher luminosity and beam energy expected during Run II (2001-2006) at the Tevatron $p\bar{p}$ collider. Accelerator improvements include increasing the instantaneous luminosity by an order of magnitude with respect to Run I to $2 \times 10^{32} \text{cm}^{-2} \text{s}^{-1}$ and increasing the center of mass energy from 1.8 TeV to 2.0 TeV. The detector upgrades include replacing the entire tracking volume, extending the muon coverage, adding a time of flight system, and improving the selection capabilities of the trigger. The partially instrumented detector underwent a commissioning run during September/October 2000 in preparation for starting data taking in Spring 2001 with the full detector. Now that Run II has been extended through 2006, we expect to collect an integrated luminosity of 2fb^{-1} during the first two years of running and up to a total of 15fb^{-1} by the end of Run II.

¹cranshaw@fnal.gov

1 Introduction

During the Run I period of collider operations at the Collider Detector at Fermilab, a very rich B physics program was conducted [1]. Many of these measurements and several new measurements would benefit greatly from a variety of detector upgrades and increased statistics. This has led to a set of upgrades of the detector and the beamlines in preparation for Run II at the Tevatron (2001-2006).

2 Accelerator Upgrades

The accelerator has undergone a whole series of upgrades to increase the luminosity delivered to the collider experiments from $1 \times 10^{31} pb^{-1}$ (Run Ib) to $5 \times 10^{31} pb^{-1}$ (Run IIa) and finally to $2 \times 10^{32} pb^{-1}$ (Run IIb)[2]. This involves changing the bunch structure of the Tevatron from 6x6 proton-antiproton bunches respectively to 36x36 and eventually to 140x121 where the latter has a 132ns gap between bunches. The increased number of bunches in the final scenario serves to decrease the average interactions per crossing to between 2-3 from roughly 6 for increased detector performance. The CDF detector upgrades have all been designed to handle this ultimate bunch spacing [3]. The replacement of the Main Ring with the Main injector as the injection source for the Tevatron leads to an increased number of protons per store while also removing a source of background for the detectors. Several upgrades also increase the number of anti-protons per store. The Main Injector's higher intensity beams create anti-protons faster at a higher rate than in Run I. In addition, the plan is to recycle 'unused' antiprotons at the end of a collider store rather than dump them. Finally, the collider center of mass energy has been increased from $\sqrt{s} = 1.80 TeV$ to $\sqrt{s} = 1.96 TeV$.

3 Detector Upgrades

In addition to increased statistics from higher luminosity, the Run II B physics program also benefits from several improvements in the detector. These upgrades were designed to give better tracking (silicon, tracking chamber), increased kinematic coverage (muon, silicon), and improved triggering and tagging capabilities (DAQ, software, time-of-flight). The CDF Run II

detector is shown in figure 1. Many of these upgrades were tested during the Fall 2000 commissioning run. The effect of these upgrades on the CDF Run II physics potential is described in separate talk in these proceedings [4].

3.1 Tracking

Charged particle tracking plays a central role in the CDF B physics program. For Run II the entire central tracking volume has been replaced, although the philosophy of using a silicon tracker surrounded by a gas ionization wire tracker which worked so well for Run I remained. The Run II tracking volume is shown in figure 2. The new silicon system is twice as long for increased forward coverage and has enough layers (5 SVXII + 2 ISL) for stand-alone silicon tracking out to $|\eta| < 2.0$. This design has over 10 times as many channels ($\approx 750,000$) as the Run I detector and a new readout system to accommodate the $132ns$ bunch spacing[3] with a fully pipelined readout. In order to do this it was necessary to mount the readout chips on the silicon itself. This increased the multiple scattering to the point that a final layer of silicon was installed directly on the beam pipe. Figure 3 shows the effect of this final layer called Layer00 on the impact parameter resolution which is very important for the Run II B_s oscillation measurements.

Construction of the Run II silicon is proceeding. The SVXII assembly has been completed and the entire subdetector will be installed in the detector in January 2001. All of the readout electronics have already been installed and tested. For the commissioning run a 60° wedge was available for testing. This included sections of all three components: SVXII, ISL, and Layer00.

The Run I wire tracker was replaced primarily because of aging and its inability to handle the higher luminosity and bunch spacing of Run II. The Run II chamber, the Central Outer Tracker (COT), has 6 times as many wires and a drift time $< 132ns$ to handle the higher occupancy. It also has double the number of stereo layers for resolving hit ambiguities. For ease of construction and to limit the effect of wire breaks, it was constructed in cells of 12 sense wires each for a total of 30240 channels. Each sense wire is read out using a CDF custom designed TDC needed for fast triggering.

The COT was installed inside the detector in the assembly hall in May 2000. Since then all of the preamps have been installed, and the final commissioning has been limited only by TDC delivery. For the commissioning run two 60° sections centered on the vertical were instrumented and read

out.

3.2 Muon

The muon coverage was improved by filling gaps and extending it forward to $|\eta| < 1.5$. The ensemble of several 10-20% improvements results in a doubling of the muon acceptance with respect to Run I. In addition all of the electronics were upgraded to handle the Run II event rate. Approximately half of the muon system was available for the commissioning run due to installation problems and lack of TDC's.

3.3 Trigger

For Run II the entire trigger and data acquisition system was replaced. The trigger still consists of three levels where Level 1 operates synchronously at 40 kHz, Level 2 operates asynchronously at 300 Hz, and Level 3 is a Linux PC farm with an accept rate of 75 Hz.

Two very important components of the upgrade affect the B physics program: the eXtremely Fast Tracker and the Silicon Vertex Tracker. The XFT uses hits in the COT to construct tracks for Level 1. It provides a measurement of track charge, azimuth ($\delta\phi \approx 3mrad$), and p_T ($\frac{\Delta p_T}{p_T} \approx 1\%$) at the rate of once every $132ns$. The SVT uses the information from the XFT to seed a Level 2 trigger based on hits in the silicon. It has improved resolution in azimuth ($\delta\phi \approx 1mrad$), and p_T ($\frac{\Delta p_T}{p_T} \approx 0.3\%$) as well as being able to trigger on displaced vertices using the impact parameter ($\delta d \approx 35\mu m$).

Both of these systems were ready for the commissioning run, but the SVT was expected to play a minor role due to the small amount of silicon present and the requirement that the XFT be tested first.

3.4 Time of Flight System

For Run II CDF is also installing a time of flight system between the COT and the solenoid which will be used for flavor tagging. It consists of scintillator panels which provide both timing and amplitude information. The expected timing resolution is $100ps$. The detector is indicated in figure 1 and covers the central region out to $|\eta| < 1.1$. It gives a 2σ K/π separation

up to a p_T of 1.6 GeV/c. The entire hodoscope along with phototubes has been installed inside the solenoid, but insufficient electronics were available for it to participate in the commissioning run.

4 Conclusion

All of these changes to the accelerator and CDF detector have led to a large increase in the overall physics potential of the Tevatron including B physics. The period September 15, 2000 to November 6, 2000 was spent commissioning the detector in the condition described in the previous sections with collisions. As of the writing of these proceedings the commissioning run has just ended. All of the subsystems performed up to expectations, tracks were reconstructed in both silicon and the COT, all of the subsystems were timed in with respect to the trigger, and the detector was operated at 36x36 with low instantaneous luminosity $\approx 10^{29} pb^{-1}$. With the installation of the final silicon detector in January 2001 and the continued delivery of TDC modules, the CDF detector is expected to be ready for collisions in March 2001.

References

- [1] S. Bailey, “CDF Run I physics overview”, Beauty2000 Proceedings, Kibbutz Ma’agan, Israel (2001).
- [2] Fermilab Beams Division, “The Run II Handbook”, <http://www-bd.fnal.gov/runII/index.html> (1998).
- [3] CDF Collaboration, “The CDF II Detector Technical Design Report”, FERMILAB-Pub-96/390-E (1996)
- [4] M. Tanaka, “CDF Run II Physics Projections”, Beauty2000 Proceedings, Kibbutz Ma’agan, Israel (2001).

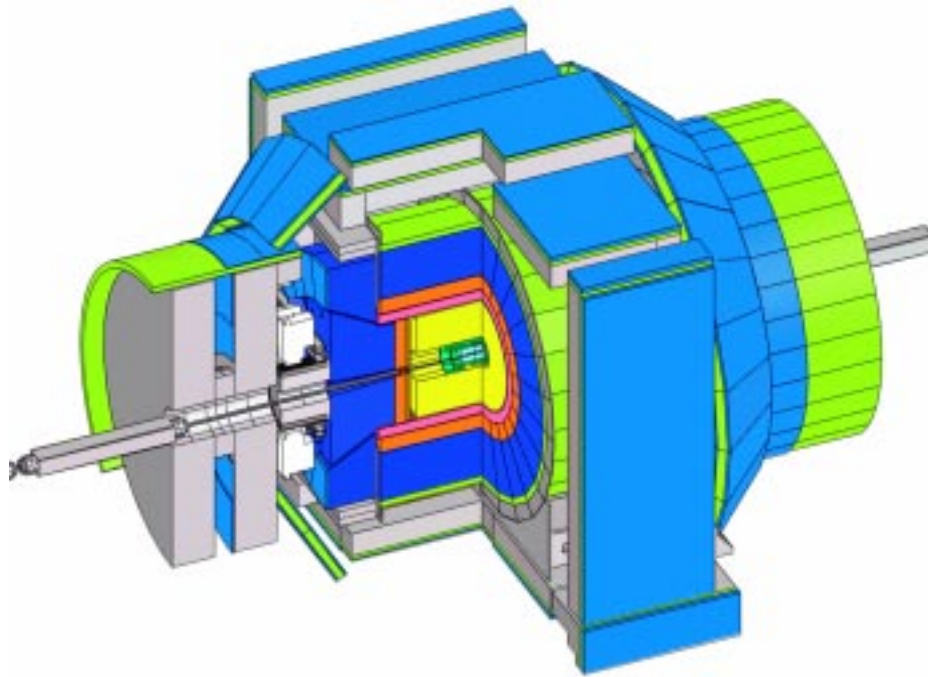


Figure 1: Cut out view of the CDF II Detector. The central region is inside a solenoid and contains a wire chamber and silicon tracking system. Outside of this are the calorimetry and muon systems.

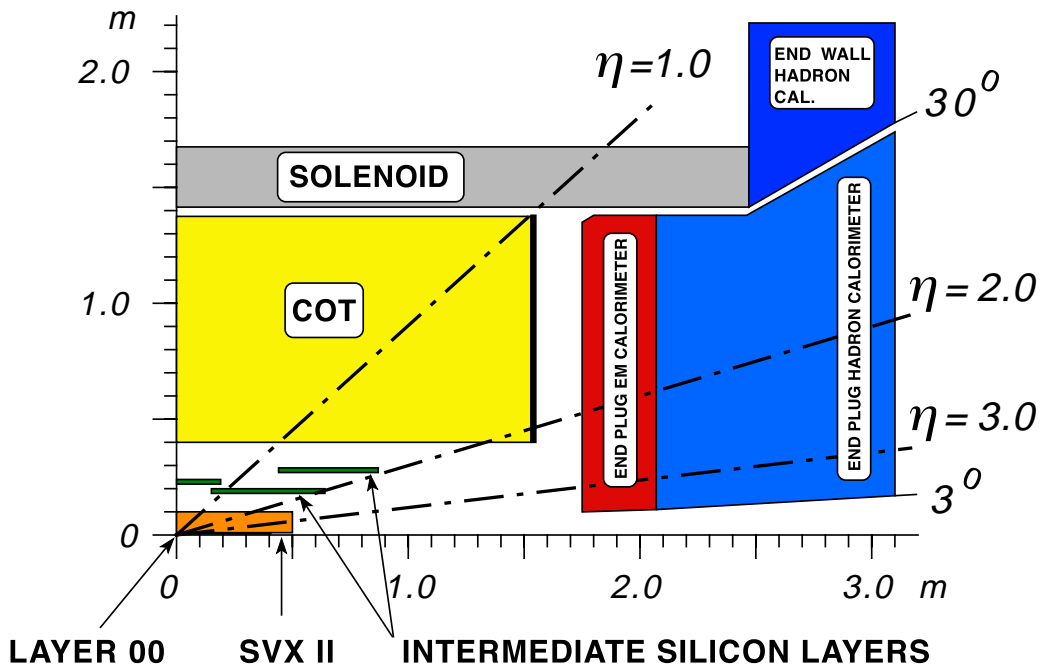


Figure 2: Quadrant of the cross section of the CDF II tracking volume along the beamline. It shows that there is full silicon (SVXII+ISL+Layer00) + wire chamber (COT) tracking out to $|\eta| < 1$. For $1 < |\eta| < 2$ there are enough layers of silicon for standalone silicon tracking. For $|\eta| > 2$ the SVXII can be used for tagging.

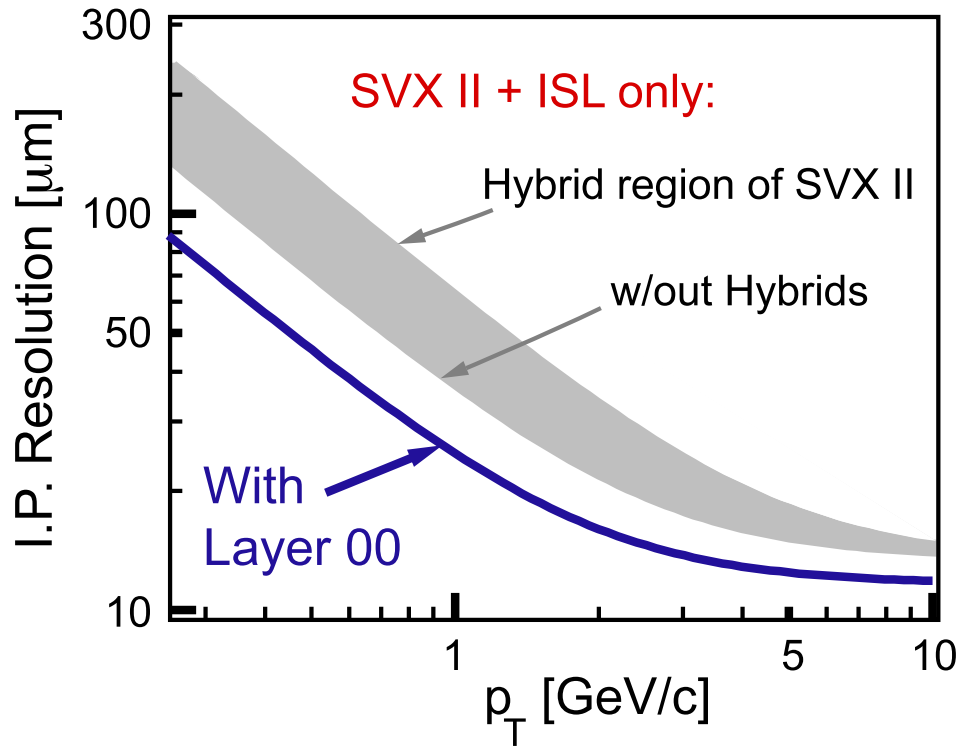


Figure 3: Effect of Layer 00 on impact parameter resolution as a function of p_T . The gray region shows the smearing due to mounting the readout electronics (hybrids) on the SVXII and ISL ladders.