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# STATUS OF THE CDF II EXPERIMENT

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Abstract

The status of the CDF II experiment is described. Since operations start-up for run II data taking in March 2001, the CDF detector has been commissioned using about 20 $\text{pb}^{-1}$ of data provided by the Tevatron ( utilized about 4-8). Most detector components are ready for physics quality data. The goal is to present the first physics results by summer-fall 2002.

# 1 Run II collider and detector upgrades

## 1.1 TeVatron upgrades

The run I data taking period at the TeVatron ended in February 1996. Since then the collider and both the detectors ( CDF and D0) underwent substantial upgrades.

The energy of the beams has been increased from 900 GeV to 980 GeV. A new syncrothron (" main injector") has been built in a new tunnel. The main injector together with a debuncher-accumulator-recycler complex allows for faster production of antiprotons and the possibility of reusing them after they are rescued in the recycler. In run I the luminosity reached $1.5\times10^{31}\text{cm}^{-2}\text{sec}^{-1}$ and was obtained with a 6 on 6 proton-antiproton bunches in the collider with an interbunch time of $3.5\mu$sec. The luminosity ultimately planned for run II is $2.0\times10^{32}\text{cm}^{-2}\text{sec}^{-1}$ and it will be obtained with 36 on 36 proton-antiproton bunches with interbunch time of 396 ns. Eventually, in order to decrease the number of average interactions per bunch crossing below 2, the number of bunches in the antiproton beam will be increased to 108 with 140 bunches in the proton beam and a reduced interbunch time of 132 ns.

## 1.2 CDF Detector upgrades

Many components of the CDF detector have been replaced or improved with respect to Run I [1]. Only the central calorimeter, the solenoid and part of the muon system have been retained, although in general the electronics has been upgraded to cope with the new interaction time. Going from the inside to the outside of the detector, CDF has a new tracking system, composed of one silicon detector ( L00, SVXII and ISL) and a drift chamber. The silicon detectors are double sided microstrips devices ( except for the inner most detector that is single sided) able to provide $r-\phi$ and $r-z$ information. The inner most layer, called L00, is at $r = 2.5$ cm from the beam pipe while the SVXII is composed of 5 layers at $3 < r < 10$ cm. The Intermediate Silicon Layer detector sits at $10 < r < 20$ cm. Coverage in $\eta$ extends up to 2, while the $z$ coverage has increased to cover the full luminous region. 3-D track reconstruction is possible with impact parameter resolution $\sigma_{phi} < 30$ $\mu$m and $\sigma_z <$ $60\mu$m.

A completely new open cell drift chamber (Central Outer Tracker ) with maximum drift time of 100 ns ( $<$ 132 nsec bunch spacing) allows for better stereo capabilities in tracking reconstruction in respect to Run I($\Delta p_T/p_T < 0.001$). It also provides $dE/dx$ information.

Between the COT and the solenoid a new Time Of Flight detector has been installed. It is composed of one layer of scintillators bars ( $4\times$ 4 $cm^2$ cross section, 2.8 m long) read by photomultipliers on both ends. The TOF resolution of order 100 ps allows for $2\sigma$ $K\pi$ separation for transverse momentum up to 1.6 GeV.

The calorimeter has been retained from Run I in the central part, while a new scintillator based plug calorimeter is replacing the old gaseus calorimeter in the large $\eta$ region. It extends to $\eta$ up to 3.6 and maintains as much as possible the same $\eta\phi$ segmentation of the central calorimeter.

Finally, the muon system has been partially upgraded: the old Run I central muon detectors has been retained but equipped with new readout electronics, while a new extension and intermediate muon chambers will guarantee the muon trigger coverage from $|\eta| = 0.6$ to 1.0.

In figure 1 photon conversion e+e- pairs reconstructed with COT are shown. This provides a nice X-ray image of the CDF detector with all the compone-nents in view up to the COT inner cylinder. In figure 2 we show the reconstructed $J/\psi$ and $\Psi(2s)$ using the muon trigger.

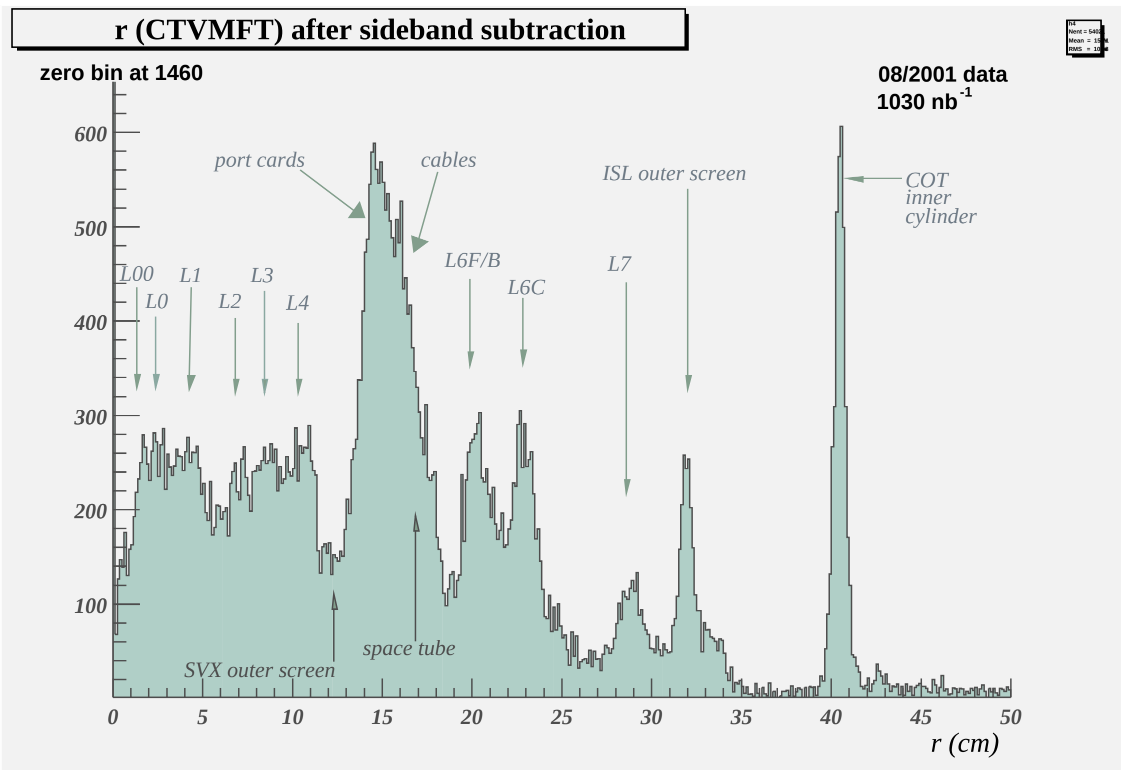


Figure 1: *Photon e+e- pairs reconstructed with COT*

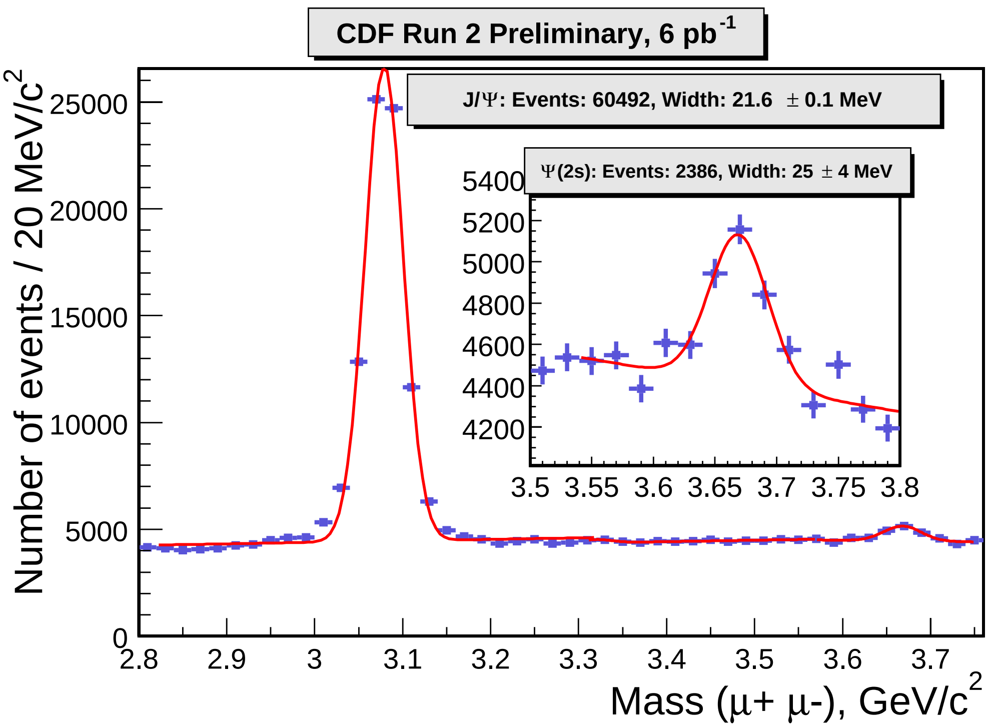


Figure 2: *Reconstructed $J/\psi$ and $\Psi(2s)$ using the muon trigger*

All the front end and DAQ electronics have been changed and made able to work with a 132 ns crossing period. At Level 1(within 5$\mu$s) a new online processor reconstructing COT tracks has been implemented (eXtremly Fast Tracker) and at Level 2 (within 20 $\mu$s) a Silicon Vertex Trigger (SVT) links the Level 1 COT tracks to the silicon hits and reconstructs offline-quality tracks ( with about 40 $\mu$m impact parameter resolution). This is the first time such a device has been installed in a hadron collider detector and CDF relies upon it to collect large samples of hadronic $b$ decays crucial for $B_s^0$ mixing and CP violation studies. On the other hand the device is going to be very powerful for high $p_t$ physics, where for example it will allow to select samples enriched in heavy flavors already at the trigger level, that can subsequently be used in b-tagging based analysis.

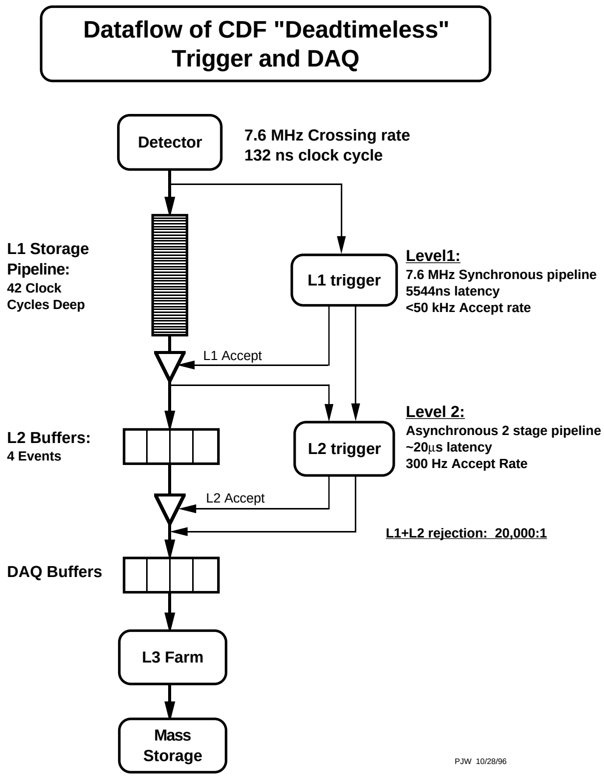


Figure 3: *The CDF II trigger system and data flow.*

# 2 Run II physics higlights

## 2.1 Charm and beauty physics

A precision measurement of the $B_s^0$ flavor oscillations is very important for testing the unitarity of the CKM matrix [2]. The Standard Model favors a value of the parameter $x_s$ between 22.55 and 34.11 at 95% C.L. CDF plans to use the fully reconstructed hadronic $B_s^0$ decays ( $B_s^0 \to D_s^- \pi^+ \pi^- \pi^+$ with $D_s^-$ reconstructed as $\phi\pi^-$, $K^{0*}, K^-$ and $K_s^-, K^-$). These signals will come from data taken with the triggers based on SVT tracks. CDF expects 75000 reconstructed $B_s^0$ decays in 2fb$^-$1 and using the above decay modes an estimated signal-to-background ratio in the range 1:2 to 2:1. In figure 3 the expectations for the next few months ( expected integrated luminosity of order 50pb$^{-1}$) are shown.

The proper time resolution is expected to be in the range 45-60 fs and the flavor tag effectiveness ($\epsilon D^2$) around 11%. This value includes same-side tagging, soft lepton tagging and opposite-side jet tagging, as well as kaon tagging now made possible by the use of the TOF detector. Even in the more traditional semileptonic decay there is already a factor 2 gain in acceptance ( for example for $B \to eD$). Using the lepton + SVT trigger gives a yeald of about 45 evts/pb).

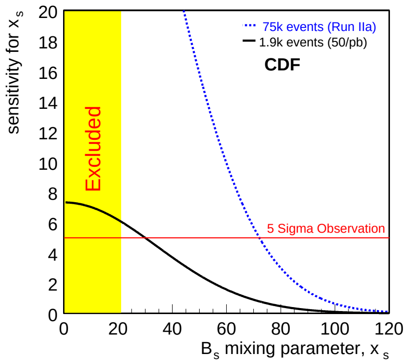


Figure 4: $x_s$ reaches as function of number of events expected in run IIa and in the next several months

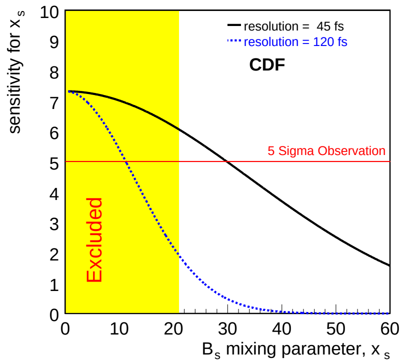


Figure 5: $x_s$ reaches as function of time resolution

The trigger selection based on SVT and designed to collect hadronic B decays is also expected to provide a large charm sample. In figure 6 a preliminary but clean signal for $D^0 \to \pi\pi$ is reconstructed using just about 1 pb$^{-1}$ of data, using online information from the SVT for the track impact parameter.

Signal extraction relies only on mass separation, but further improvements in signal purity are expected from the use of particle identification. Preliminary estimates show that with 50-100 $pb^{-1}$ CDF could collect a fully reconstructed charm sample of magnitude similar to those used for the best published measurements. Although the CDF particle id capabilities are somehow more limited than specialized experiments and the trigger bias and contamination from secondary charm needs to be properly evaluated, CDF can provide a unique charm cross section measurement at low transverse momentum and competitive measurements in the field of $D^0$ mixing and CP violation in charm decays.

### 2.2 Top and Electroweak physics

For top physics an extra 30-35% in the cross section is gained ( 1.8 to 2TeV). There will also be a gain from acceptance and efficiency: 100$pb^{-1}$ in Run II is equivalent to 150-300pb$^{-1}$ in run I). At this time work is still ongoing to finalize b-tagging software algorithms and the complete understanding of associated background. Top

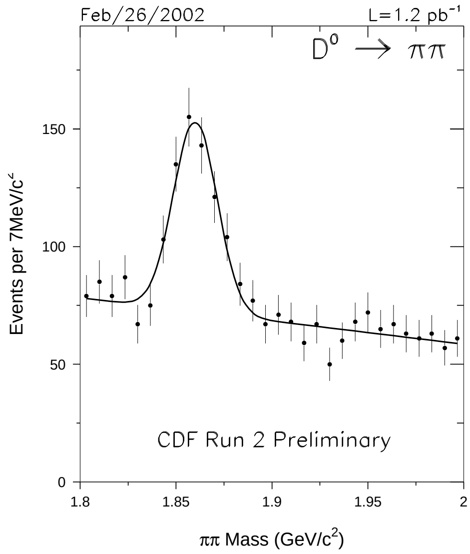


Figure 6: *Reconstructed $D^0 \rightarrow \pi\pi$ using $SVT$ tracks*

mass and W mass measurements will be updated from run I results in winter 2003. The precision expected on the W mass is of order 20-30 MeV/$c^2$. The top mass measurement will be improved to a level of 2-3 GeV/$c^2$. Indirect constraints on the Higgs mass will be of course derived. In addition one of the goals of Run II is to search for $t\bar{t}$ resonances, rare decays and deviations from the expected patterns of top decays. The decay mode where both the W's from top decay decay leptonically will be the first to be looked at: in fact a moderate excess of events in run I, especially at large missing energy is driving the investigation with an eye to signal for new physics [3].

### 2.3 SM Higgs prospects at the TeVatron

At the TeVatron run II the $gg \rightarrow H$ production mode dominates over all mass ranges, but the huge irreducible QCD background makes it impossible to use this production channel for a measurement. So, for low mass Higgs ($M_H < 130$ GeV/c$^2$) the $H \rightarrow b\bar{b}$ associated production with a vector boson mode is the most promising, with an estimated cross section production of order 0.1pb. The double b-tagging of the 2 jets coming from the Higgs decay, together with the signature of the additional boson helps to discriminate from the background. From the trigger point of view, channels with one high $P_T$ lepton coming from the vector boson decay are not a

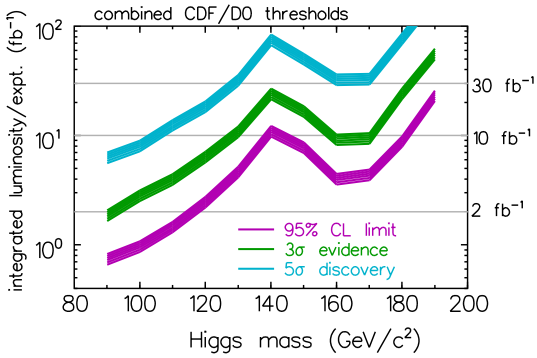


Figure 7: Projected discovery/exclusion regions for SM Higgs as function of luminosity at RunII

concern, since the rate can be easily controlled. On the other hand the channels where the vector boson decays into quarks ( W/Z) or neutrinos ( Z) have a higher branching ratios and trigger strategies need to be devised to control data taking rates. It has been shown in preliminary studies [4] that a trigger strategy based on the use of SVT tracks is crucial in selecting a sample enriched in heavy flavors, keeping the rate at a reasonable level. Improved offline b-tagging efficiency ( a factor 1.3 is already achieved only due to the increased geometrical coverage of the silicon detector) will then help in discriminating signal from background.

In figure 7 the expected discovery reach in Run 2 for the Standard Model Higgs boson from the study carried out during the run II workshop at Fermilab [5] is shown. Based on a simple detector simulation, the integrated luminosity necessary to discover the SM Higgs in the mass range 100-190 GeV was estimated. The first phase of the Run 2 Higgs search, with a total integrated luminosity of 2 $fb^{-1}$ per detector, will provide a 95% C.L. exclusion sensitivity comparable to that expected at the end of the LEP2 run. With 10 $fb^{-1}$ per detector, this exclusion will extend up to Higgs masses of 180 GeV, and a tantalizing 3 sigma effect will be visible if the Higgs mass lies below 125 GeV. With 25 $fb^{-1}$ of integrated luminosity per detector, evidence for SM Higgs production at the 3 sigma level is possible for Higgs masses up to 180 GeV. However, the discovery reach is much less impressive for achieving a 5 sigma Higgs boson signal. Even with 30 $fb^{-1}$ per detector, only Higgs bosons with masses up to about 130 GeV can be detected with 5 sigma significance.

## 3 Physics beyond the SM

The expected total integrated luminosity for Run II will allow to search more efficiently for physics beyond the Standard Model. CDF will search for SuperSymmetric particles in first place. Assuming that SUSY breaking results in universal soft breaking parameters at the grand unification scale, and that the lightest supersymmetric particle is stable and neutral, with 30 $\mathrm{fb}^{-1}$ luminosity and one detector, charginos and neutralinos, as well as third generation squarks, can be seen if their masses are not larger than 200-250 GeV, while first and second generation squarks and gluinos can be discovered if their masses do not significantly exceed 400 GeV [6].

Models where SUSY is broken at low scale as those including gauge-mediated supersymmetry breaking are generally distinguished by the presence of a nearly massless Goldstino as the lightest supersymmetric particle. The next-lightest supersymmetric particle(s) (NLSP) decays to its partner and the Goldstino. Depending on the supersymmetry breaking scale, these decays can occur promptly or on a scale comparable to or larger than the size of a detector. A systematic analysis based on a classification in terms of the identity of the NLSP and its decay length has been presented for example in [7]. The various scenarios have been discussed in terms of signatures and possible event selection criteria. Analysis are starting in CDF with the aim of understanding our datasets in terms of background contribution and possible deviation from it as a sign of new physics. Signatures involving photons are of particular interest to look for deviations from the SM predictions in the context of GMSB models. CDF is also using photon signatures as a first follow-up and check of strange events seen in Run I: in figure 8 the spectra of single photons candidate is reported using approximately 8$\mathrm{pb}^{-1}$ of Run II data.

### 3.1 Conclusions

In this paper we have reported on the status of the CDF II experiment. While commissioning of the detector is still ongoing, the physics program at CDF is getting in place. The first 200 $pb^{-1}$ of data expected to be delivered by the end of 2002 will help establish a basic physics program and understand the detector performance. Major physics results will include: $B_s$ mixing; CP violation studies in the B system; charm cross section and updated results on top and W physics. CDF will of course follow up Run 1 anomalies and try to improve our limits in major areas of physics beyond the Standard Model.

An increase in the integrated luminosity to $> 2$ $\mathrm{fb}^{-1}$ by 2004 will allow precision studies of top and W physics, with stringent tests of the SM and interesting

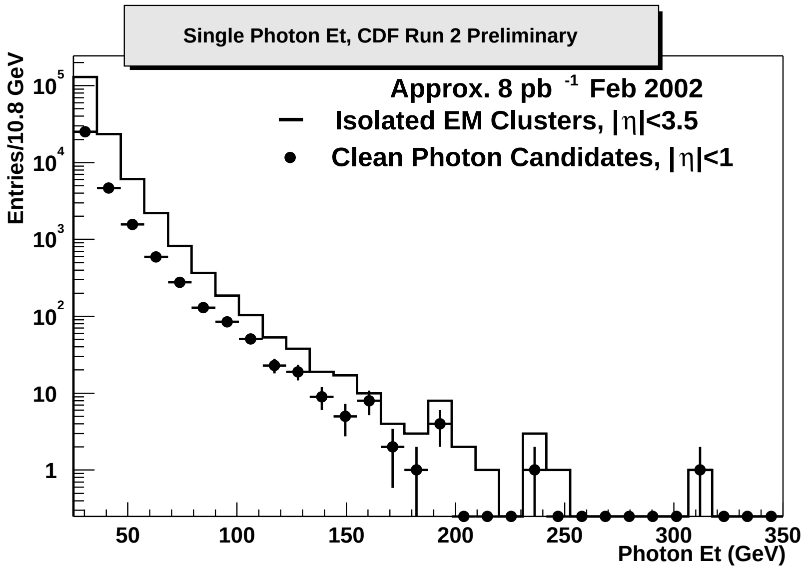


Figure 8: *First photon candidate events from CDF Run II.*

indirect constraints on the Higgs mass. Finally a precision B physics program will produce results comparable to b factories and the searches for SUSY and other new physics will be carried on on wider parameters space regions. Finally, the TeVatron will proceed to highest attainable luminosity ($> 15\ fb^{-1}$) by 2007. We will push our high precision B, W and top studies to the limit. Hopefully we will be able to follow up previous discoveries or hints. A complete search for low mass Higgs will be carried on.

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