Report of the UK groups in the CDF collaboration to the PPESP committee

Introduction

In 1996 the first period of Tevatron data-taking, distinguished by the discovery of the top quark, ended. Since then, both the Tevatron and CDF have been upgraded and improved in order to extend their physics reach. Run II started in March 2001, after a brief commissioning run in October 2000, and will deliver $2fb^{-1}$ of integrated luminosity over the next two years at an energy of 2 TeV. This represents a 10% increase in energy over Run I and a factor of 20 increase in luminosity. The Tevatron is the highest energy collider in the world, and will remain so until the advent of the LHC.

The last two years have seen the completion of the CDF detector, the commissioning of the Tevatron, physics quality data-taking and the observation of the first physics signals. Despite a UK involvement in CDF which commenced just three years ago in 1998, the four UK institutions have played a major role in detector building, commission ing, data-taking and physics analysis.

This report is organised as follows. After a brief description of the operation of the Tevatron collider, an overview of the status of the CDF experiment is presented. The status of the UK funded items is described indicating their performance and their contributions to physics results. Plans for the future are outlined, including our ongoing commitments analysis efforts in addition to a possible upgrade of the detector with which we may wish to be involved.

Tevatron Operations

The Commissioning Run

A seven-week preparatory test run of the Tevatron began in September 2000. The first colliding beams, operating in a 1x8 bunch mode, were established and proton-anti-proton collisions were recorded by CDF on October 8th. Seven fills took place between then and 4th November. A maximum luminosity of $4x10^{29}$ cm^2/s was obtained running with a 36x36 bunch mode, and a total integrated luminosity of 57.6 nb^{-1} was delivered over a period of 160 hours.

Run II

The first store of Run II circulated on 3rd April 2001 in a 1x8 bunch mode. By the end of the month the 36x36 mode was established. A record luminosity of $7.9x10^{30}$ cm^2/s was obtained on August 16th 2001 and as of September 12th, an integrated luminosity of $7.2pb^{-1}$ has been delivered. Run II is currently scheduled to continue until early 2004 and expects to deliver an integrated luminosity of $2fb^{-1}$.

Run IIb

Although the current programme of research provides a significant improvement in physics output compared to Run I, current studies indicate that certain discovery channels (in particular the Higgs) will require greater luminosities. An extension to the current run, (called Run IIb), has been proposed and Fermilab has issued a memorandum stating a goal of providing a total integrated luminosity of $15fb^{-1}$ per experiment by 2007. This would necessitate a shutdown of 6 months for modifications to the Tevatron, during which time upgrades to the detectors could be installed.

CDF Operations

The CDF Run II detector has been considerably upgraded and improved since the end of Run I four years previously. The entire tracking system has been replaced. The Central Tracking Chamber now has 30,000 wires compared to 6,000 before, while the Silicon Detectors are composed of 8 layers of silicon with a length of 150cm, compared to 4 layers and a length of 100cm. The muon chambers have been extended and all the electronics replaced. New electromagnetic and hadronic calorimeters have been built in the forward region. The trigger and data acquisition system have been completely redesigned.

On September 9^{th}, 2000, the CDF detector was rolled into the Tevatron beamline to begin a "commissioning run" for testing the detector. All sub detectors were installed with the exception of the silicon system where a prototype wedge constituting 6% of the full detector coverage was used. All three levels of the trigger were exercised and the full data acquisition system operated successfully. UK institutes had a major involvement in the commissioning run, were responsible for the Level 3 trigger, ensured the successful operation of the database, and reconstructed the first silicon tracks and the beamspot profile.

After the commissioning run, CDF was returned to the assembly hall where the silicon detectors were installed on January 6^{th} before the detector was closed up and rolled back into the beamline on February 20^{th} , ready for the start of Run II on March 1^{st}. Since then, the detector has performed impressively. W and Z boson signals have been observed and the data currently being taken is usable for physics analyses. It is intended that data taken up until the November shutdown will be used as the basis for analyses presented at next summer's conferences.

Most time is currently spent understanding the responses of the various sub-components, both detectors and triggers. All detectors must be calibrated in order to be able to make reliable physics measurements. In anticipation of the high trigger rates which will accompany the increased luminosity, much time is being spent understanding the trigger and trigger rates. Unlike an e+e- collider where essentially all data is written to tape, most is discarded at a hadron collider. An extra delay is therefore built into obtaining

physics results since the detector and trigger must be fully commissioned before knowing that the data of interest has been recorded.

With the exception of some miscellaneous pieces of instrumentation, the readout electronics for the TOF, and the beam shower counters, the CDF detector is now complete and ready for the increase in luminosity which the Tevatron should provide after the November shutdown.

UK participation in CDF

Our preparations for and involvement in data-taking has been in three broad areas: firstly with the silicon systems; secondly with the Level 3 triggering; and thirdly with databases. We have also made a significant contribution to the computing infrastructure of CDF.

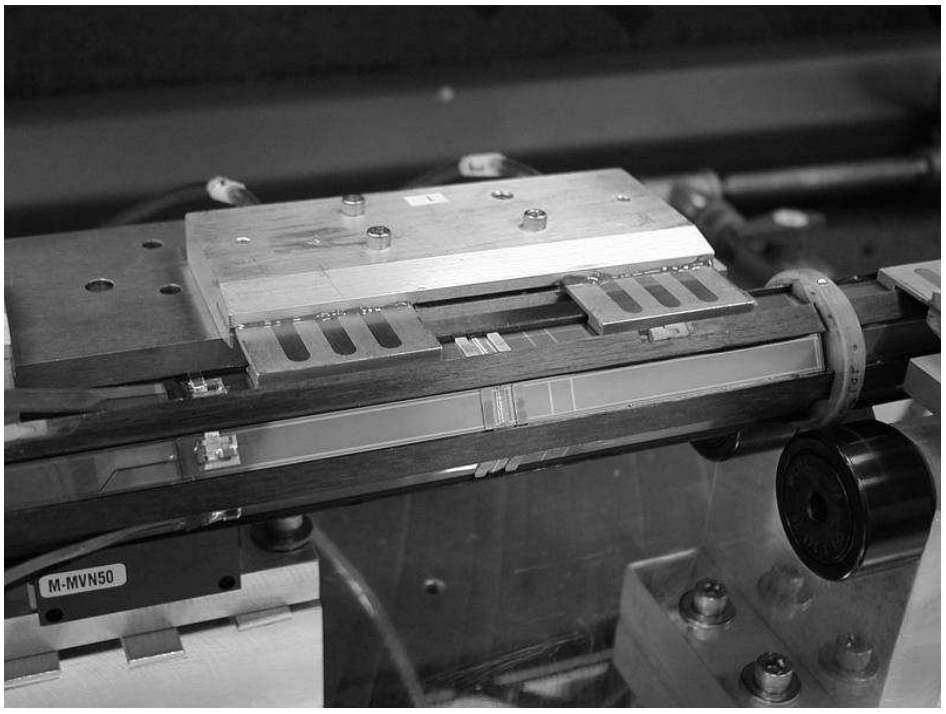
The Layer00 Detector

The Layer00 Detector is a high precision silicon microstrip detector mounted directly on the beam-pipe, at a radius of 1.6cm. Layer00 is specifically designed to optimise the ability of the experiment to reconstruct short-lived particles produced with low transverse momenta.

UK physicists have played a leading role in designing both the geometric layout of the detector and the silicon sensors, and in fabricating the carbon fibre support structure. The 12-fold symmetry of the detector was proposed by us in order to minimise the crossing angles of tracks and maximise the spatial precision of the detector, while taking account of the very limited space available. We designed the layout of the silicon sensors in the UK, using in-house CAD tools, and purchased the sensors from Hamamatsu, delivering them to CDF on time and to specifications. We also irradiated the read -out cables in a test-beam at CERN and showed them to be operational at voltage and irradiation dosages in excess of those foreseen at CDF.
The design and manufacture of the support structure for Layer00 was provided by UK physicists and engineers using special carbon-fibre materials, (purchased from YLA, a UK based supplier), which had the required stringent mechanical and thermal properties. The support structure had to be a single stable cylinder of radius 1.6cm and length 100cm, sufficiently stable to support the silicon, hybrids and read-out cables, yet with as little material as possible in order to minimise the amount of multiple scattering. In addition it had to incorporate cooling pipes within its structure and be thermally designed to keep the silicon at a temperature of less than 5C in order to minimise the radiation damage. An end-on view of the UK-designed support structure is shown in the picture below: cooling channels are visible as well as a castellated structure onto which the silicon sensors are placed.

Two halves of the Layer00 support structure encircle the beampipe, represented here by a US quarter coin.

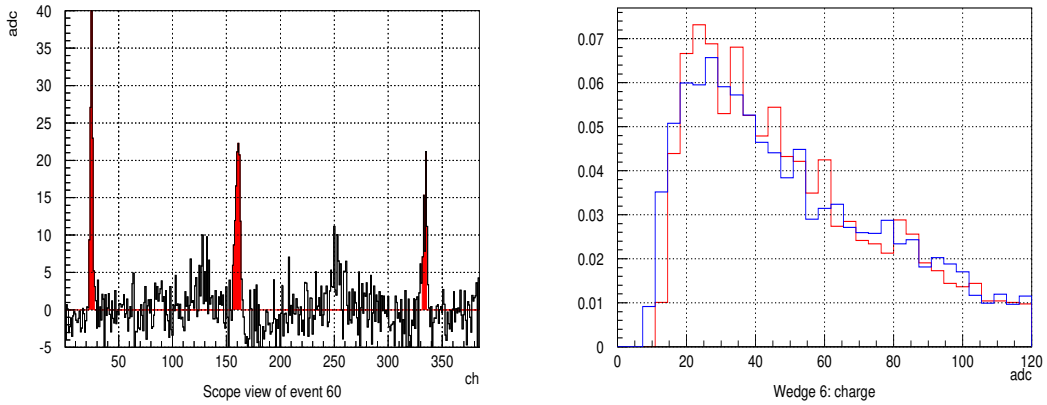
During Autumn 2000, the silicon sensors, cables and hybrids were mounted onto the two halves of the carbon fibre support structure. The figure below shows the assembly jig with half the detector already mounted on the support structure. The two halves were then locked around the beam-pipe and inserted into the rest of the silicon system comprising of the SVX and ISL detectors.



The assembly jig for Layer00. Half the sensors have already been mounted in the narrow wells of the castellation. The hybrids and kapton readout cables are also visible.

Since the collider started running in March 2001, one sixth of Layer00 has been biased and taking data. The remainder of the detector is not taking data due to a delay in the delivery of the CAEN power supplies. An analysis of the performance of the two wedges

of silicon currently operational has been undertaken by UK physicists, and shows the detector to be performing as expected. The figure on the left below shows the pedestal corrected ADC counts in one of the wedges for one event; it is clear that three tracks traversed the silicon. Superimposing many such deposits leads to the observation of a Landau distribution as shown on the right. The peak occurs at 25 ADC counts which implies a signal to noise ratio of ten to one, in agreement with the design expectation.



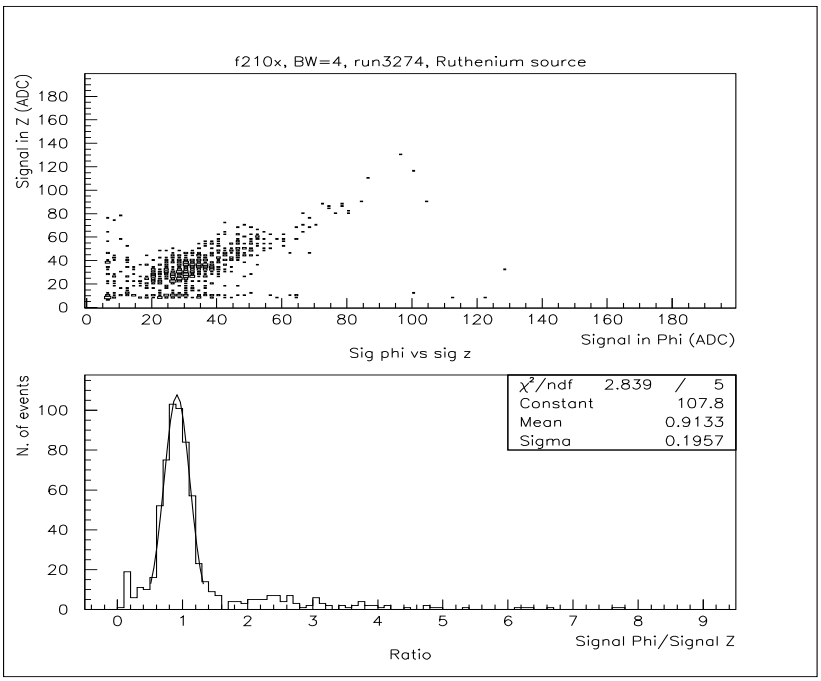
Left: Pedestal corrected ADC counts in one wedge of Layer00
Right: Distribution of signal counts.

The SVX Detector

The SVX detector is a 5-layer silicon detector located between radii of 2.5cm and 10.5cm. UK physicists worked on a variety of aspects in its construction: we established anti-electrostatic damage procedures; validated power supplies; defined testing procedures for detectors; tested irradiated ladders; solved grounding problems; constructed and set up a prototype wedge of detectors; set up the test stations for assembly of the silicon ladders into barrels; graded and debugged full ladders during final assembly; and provided sensors for radiation monitoring.

In order to debug the electronics used in the silicon readout, UK physicists designed and produced printed circuit boards which were used extensively in the testing of 1500 devices. We set up test-stands both in the UK and at Fermilab and provided expert support as well as personnel in the testing of the silicon data-acquisition. We designed and built a portable SVX wedge with solid state cooling, which was used to validate the DAQ and power chain for each portion of the final system in the collision hall.

We tested the charge collection response of the silicon sensors using a ruthenium source. The figure below shows the correlation between the charge collected on either side of the SVX double-sided detectors. In addition, we designed and built a cosmic ray test stand which allowed an evaluation of the detection of minimum ionising particles by the silicon wafers before installation in CDF.

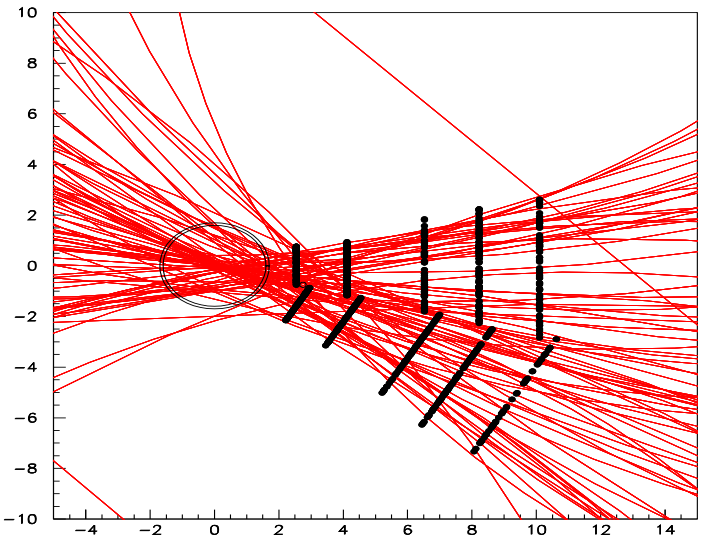


The upper plot shows the correlation between the charge collected on the p- and n-sides of the silicon wafer.

The lower plot is a projection along the diagonal, showing a relative charge collection efficiency of one.

Silicon Commissioning

The UK has been leading an effort towards understanding the performance of the silicon. During the commissioning run, studies of the signal-to-noise and cluster characteristics were undertaken. UK physicists were the first to reconstruct tracks in the silicon detectors and to observe the beam profile. The figure below shows a superposition of many reconstructed tracks with transverse momenta greater than 0.5GeV. The fact that they appear to originate from a common point is proof of the successful operation of the silicon detectors, alignment, and tracking algorithms.

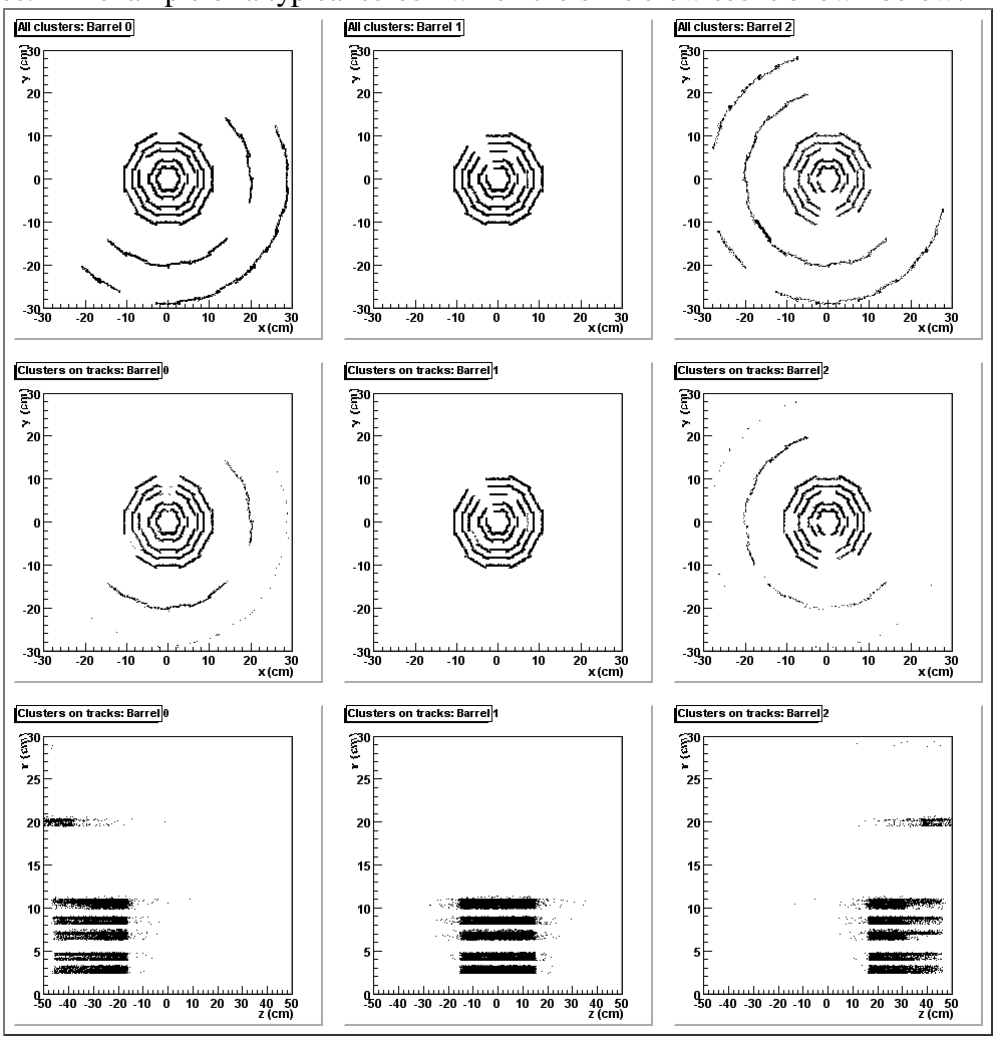


Superposition of many tracks reconstructed in the silicon during the commissioning run. Note that the reconstructed beamspot is offset from the centre of the detectors.

Silicon Monitoring

Leading on from this success, UK physicists have been charged by the collaboration with the task of monitoring the integrity and quality of the silicon data. We responded by firstly, defining which quantities would be of greatest use in monitoring the silicon performance, secondly, writing code which produces 3175 histograms, and thirdly, creating an intuitive interface for the user (often a non-expert) to tell if a problem exists with the silicon system.

The monitoring programme runs both online and offline. It runs continually during data-taking and outputs simple summary histograms to the shift crew, who compare these to references and contact silicon experts if deviations exist. In this way, we have a rapid reaction to any problems discovered in the silicon. Running the same programme offline with greater statistics allows more subtle effects to be noted as well as providing a continuous record of the silicon performance for future consultation during physics analyses. An example of a typical screen which the shift crew see is shown below.



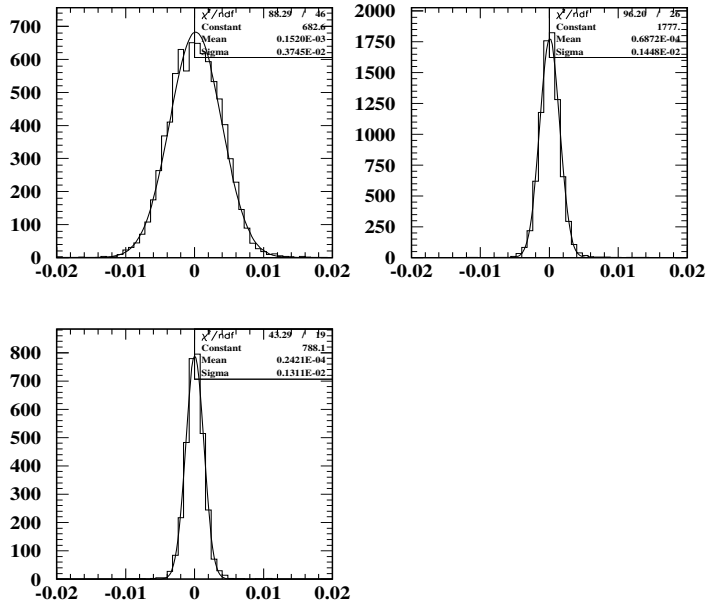
Hitmap of silicon clustersin each of the three barre ls as presented to the shift crew

Because of the large number of silicon wafers (1752) and the even greater number of readout channels (722,432), we have designed a graphical user interface which allows for a simple and intuitive navigation through the numerous histograms which summarise the silicon performance.

Silicon Alignment

The UK is playing a pivotal role in providing the software alignment of the silicon system. This is a crucial activity if the silicon system is to be used in searches and to measure B lifetimes, oscillations, or CP violation. The very act of triggering on, or tagging B mesons and hadrons depends on aligning the silicon system to micron precision.

After the mechanical survey, the positions of the silicon modules in both SVX and ISL are known to about 20μm. We have developed a procedure which will take the global precision to a few microns, and the local precision to the sub-micron level. This procedure has been tested on simulated data. The figure below shows the impact parameter (IP) distribution for tracks with a transverse momentum above 2GeV. Before alignment, a resolution of 40μm is obtained , while after our procedure we observe a resolution of 15μm, which is just one micron larger than the resolution with a perfect detector.



Top Left: IP resolution for unaligned detector. Top Right: IP resolution after alignment. Bottom Left: IP resolution for perfect alignment. Units on the x-axis are in cm.

Level 3

The third level trigger is a software trigger and uses a fast version of the CDF reconstruction software on a farm of over 100 commodity PCs. It reduces the level-2 trigger output rate of several hundred Hertz by approximately a factor of 10, providing a rejection power that will be crucial in the high luminosity environment of Run II.

The Level 3 trigger was successfully implemented during the Commissioning Run, and has continually operated as part of the trigger. The Level 3 trigger is coordinated by a UK physicist with UK physicists providing 24 hour support.

The UK has responsibility for the generation and validation of the Level 3 trigger code. This has led us to develop an automated system which guarantees the reproducibility of executables, taking into account specifications in the trigger database as well as detector calibration constants which are exported from the database in real-time.

Progress has been made on the Level 3 electron/photon triggers. Many physics groups have made requests for new functionality in the electron filters and they have all been included. We have reduced the default thresholds for electron identification to 2GeV to enable low energy electrons to be used for B physics and SUSY studies. In addition, this filter is used to select high pT electrons/photons for the Express stream. It will soon be included in a J/ψ->ee trigger as well as W->ev, several exotics, electroweak and B group triggers.

We have designes and delivered a regional tracking system, which allows full offline tracking algorithms to be run in selected detector regions as Level 3. This enables many more track-based triggers to be run in Level 3 than would otherwise be possible, which is of particular importance to high rate B-physics and forward-lepton triggers. The regional tracking software has been extensively tested and benchmarked in CDF Monte Carlo studies, demonstrating its ability to find tracks in far shorter times than required by running the same algorithms globally.

The CDF Database

Part of the conditions of entry to the collaboration was that we assume the leadership of and the responsibility for delivering the CDF database, both online and offline. This required defining the structure and providing the software to acquire, store, and provide information about the data and the conditions under which they were taken. Online, thousands of parameters must be written to and from the database in real time by hardware, run control, trigger, monitoring and calibration, while offline, these must be propagated to the reconstruction programmes for data and physics analysis. This task required coordination of analysts and consultants who provide the operation, support and maintenance; schema designers who lay out the structure of the databases; computer system experts who configure the hardware; and users who access the database. One UK person leads and coordinates the database project.

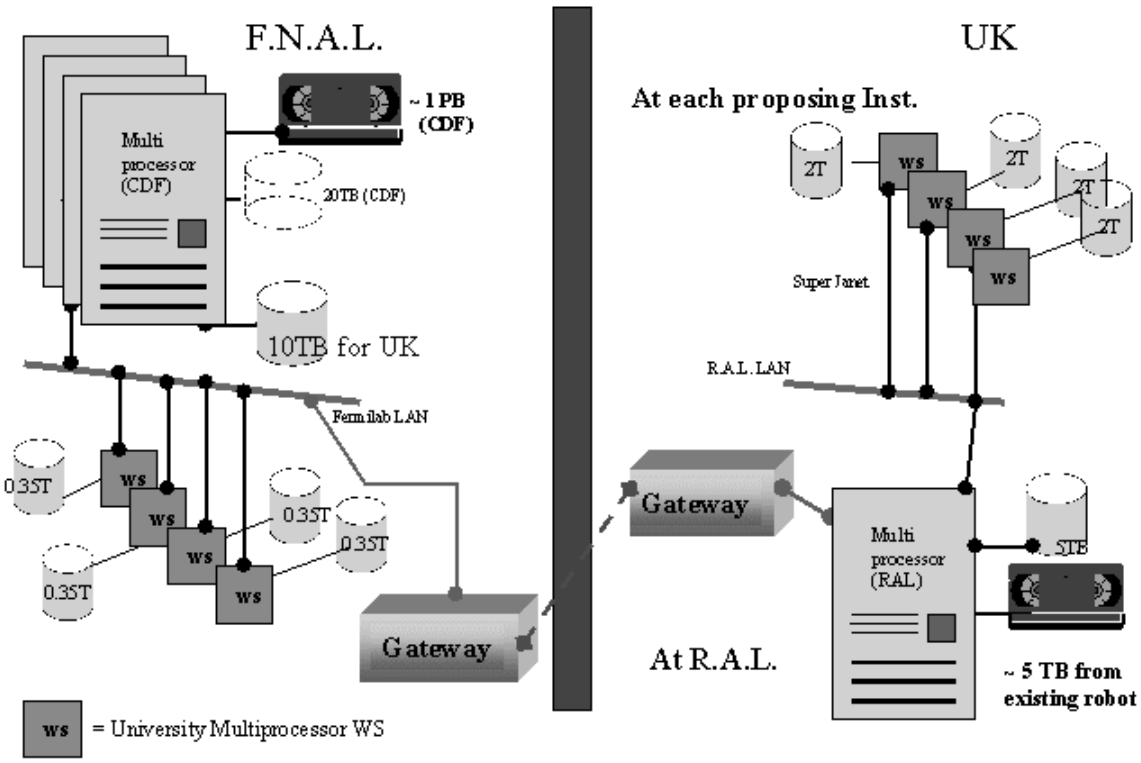
When we assumed the responsibility for this project, there were deficiencies in the structure and organisation, which did not anticipate either the size required or usage

which would be experienced. We first polled each subdetector and each physics analysis group to determine which information they would require. We then implemented a management structure for the databases. At the top, Database Administrators oversee the implementation of Oracle. Next, physicists skilled in C++ and database language integrate the information from each of the detector subcomponents. Below them are the application programmers who provide the information for, or take information from, the database. We also provided simple tools which allow the average user to access the information in the database without requiring sophisticated knowledge of either C++ or Oracle. The installation and commissioning of the database machines was also overseen by the UK. The success of this project can be judged from the fact that during both the commissioning run and the current Run II, this 8GB database has successfully handled 50,000 accesses per day and has experienced an uptime of 99.8%.

We are very aware that the success of many analyses depends on the rapid reprocessing of data using the latest calibrations. In light of the substantial computing resources we possess in the UK (see the next section), the export of the database to remote institutes is of great importance to us. We have therefore designed and implemented a prototype database export system in the UK and this has been recommended by a CDF review committee as the solution for CDF physicists to transfer constants to institutes outside Fermilab for analysis.

Computing, Networking and Contributions to Offline Hardware

CDF is expected to obtain over 1 Petabyte of data stored to tape in RunII. The UK CDF institutions have been awarded a £1.65m grant from the Joint Infrastructure Fund (JIF) for computing equipment located in the UK and at the experimental site. About 4/5 of this award will be spent on high-speed high-volume disk storage with high bandwidth access to local CPUs while the remainder is allocated to lease a dedicated network link to Fermilab to improve interactive access to computing resources at the experiment and to provide internet video conferencing capabilities. A schematic of the infrastructure request is shown below.



Schematic overview of the Computing and Data Storage provided by the JIF award.

To date, a 10TB RAID has been provided to CDF and is being used to hold the all-important Stream A data. Stream A data has triggers designed primarily for SUSY searches, W, Z and B events with high pT leptons as well as J/ψ events and are key to the UK science programme on CDF. This provision of disk space amounts to an in-kind contribution to CDF from the UK groups this year of £140,000 funded external to PPARC. A similar sized contribution will be made to the experiment next year.

The JIF grant has also supplied each UK institution with an IBM 8-way SMP server connected via a Fibre Channel link to its own 1TB RAID. A similar system, twice as large, has also been provided to RAL for use by all the UK groups. Next year, the remainder of the grant will be used to approximately double the computing and storage capacity. This award will have a direct impact on the speed and ability of UK institutes to analyse the large data samples which CDF produces.

Transporting data to and managing these systems was to be done locally when we initially envisioned our JIF proposal. However, since then it has become clear that CDF in general, and the UK institutes in particular, can and should take advantage of the new Grid infrastructure that is being developed in Europe and the US. We intend to place the JIF computing and data-storage facilities on the Grid so that the CDF data and our combined computing power is seamlessly available, initially to all the UK groups, and

subsequently to the whole collaboration. A further goal is to make our disk storage and CPU available to the whole particle physics community so that the prototype opportunity which CDF presents grows into, forms, and becomes part of the Grid for Particle Physics. The initial stages of this programme have already started and further resources are being sought from the GridPP project.

Accelerator Work

The Fermilab Beams Division made a request for assistance from physicists in improving the performance of the Tevatron. We have developed a software package to optimise the design of the lithium lens, which acts as the primary collection element for the antiprotons before they are debunched, cooled and accelerated. To maximise the anti-proton yield, the parameters of the lens must be optimised. We have modelled the antiproton production and propagation as a function of the lens parameters and presented the results so that Beam Division members can rapidly assess the effects that their modifications are making.

Physics Analyses

In parallel to the work which has taken place preparing for physics and understanding the first data, simulation studies and analyses of Run I data, have been performed in order to ensure that we are ready to make some of the first physics measurements with Run II data. UK groups are currently interested in three broad areas: firstly B physics; secondly electroweak physics; and thirdly searches.

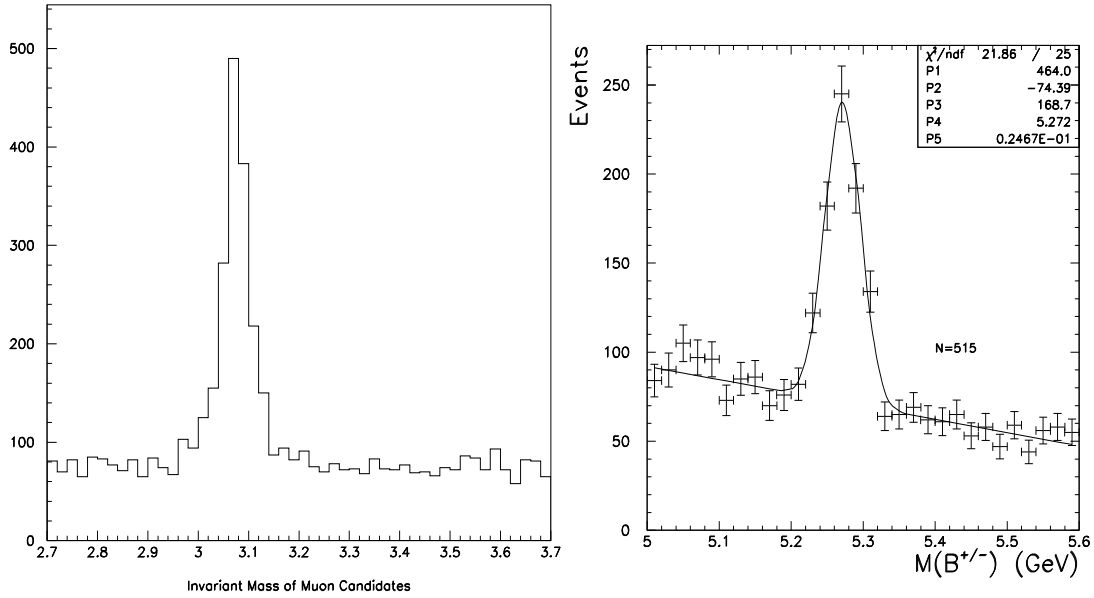
B physics: B meson lifetimes and Λb lifetime

In the 7.2pb^{-1} of data already delivered by the Tevatron, over 1 million B mesons will have passed inside the silicon acceptance of CDF. However, only a small percentage will have been written to tape since triggering to date has depended on the presence of high pT leptons, though the eventual goal is to trigger on the presence of displaced vertices.

The first measurements which will be made in the B sector are the B lifetimes, and these will serve a number of purposes. Initially, a comparison of these measurements to the world averages will be test the silicon alignment and tracking precision. Later, some of these measurements will become comparable to the world averages and some will become the single best measurement in the world. Furthermore, understanding the lifetime distributions is a necessary step towards measuring B oscillations.

In the spectator model of b quark decay, the B^+ B^0 B_s^0 and Λ_b all have the same lifetimes. Heavy quark effective theory, which takes non-spectator effects into account, can be used to obtain precise predictions for a lifetime hierarchy: $\tau(B^+)/\tau(B^0)=1.05$; $\tau(B_s^0)/\tau(B^0)=1.00$; $\tau(\Lambda_b)/\tau(B^0)=0.9$ to 1.0**[1]**. The current world average experimental value for $\tau(\Lambda_b)/\tau(B^0)$ is 0.78+-.04 **[2]** a deviation of three sigma with the theoretical value, and is statistically limited. CDF, with its large sample of Λ_b should soon be able to supercede this value and test the predictions precisely.

We have studied the acceptance for triggering and reconstructing the above species in exclusive modes with J/ψs in the final state. We have isolated a sample of events where two tracks have been identified as muons and both tracks having hits in the vertex detector. The invariant mass of the tracks is shown in below (left), and the presence of the J/ψ is clearly indicated. More statistics are necessary before we can isolate the prompt production of J/ψ from those due to the decays of B mesons or baryons. However, we have already tested our reconstruction algorithms using Run I data. The figure below (right) shows the B^+ meson mass measured in the exclusive decay mode $B^+ \rightarrow J/\psi\ K^+$.



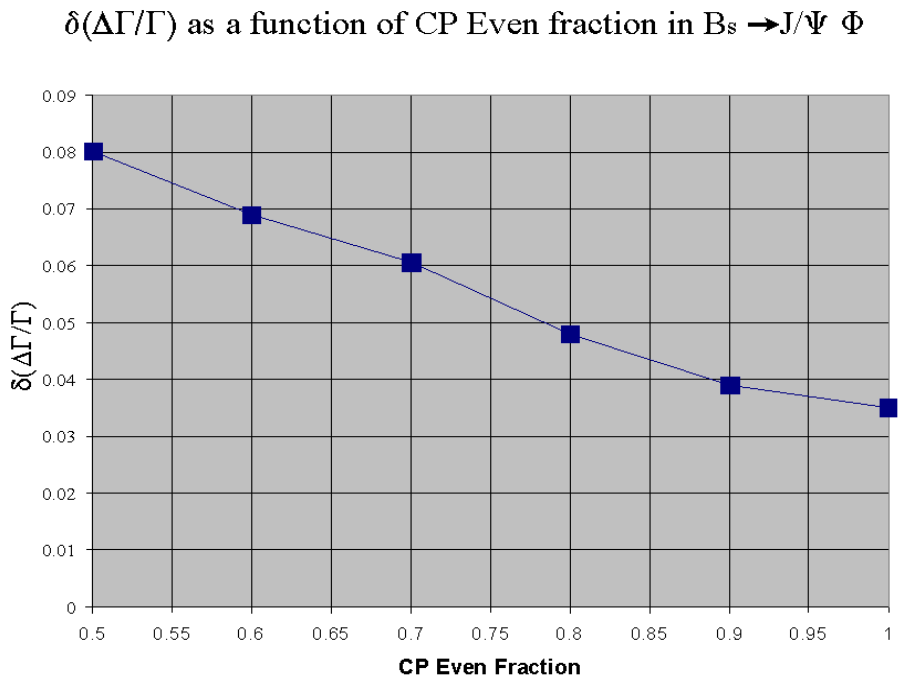
Left: Invariant mass distribution for pairs of muon tracks taken at Run II.
Right: The B^+ mass measured from the decay $B^+ \rightarrow J/\psi\ K^+$ at Run I.

B physics: Bs oscillations

The ability of CDF to make measurements in the B_s system is unique since the production of B_s mesons is beyond the reach of all current B factories. Although the B factories will make definitive measurements of the mixing parameter x_d, they can not measure x_s. The 'standard' method of measuring x_s is to observe the oscillation from B_s to B_s(bar) meson through the modulation of the normal exponential decay distribution. We have studied a different and complimentary technique.

The mass difference between the CP even and odd B_s states is related to the width difference **[3]** which in turn implies a lifetime difference. If either of the two eigenstates can be separated, a measurement of its lifetime compared to the average lifetime gives the width difference and thus the mass difference and x_s. Theoretical predictions suggest that the lifetime of either eigenstate could be 20% different from the average, currently measured to be 1.49+-.06 ps.**[2]**

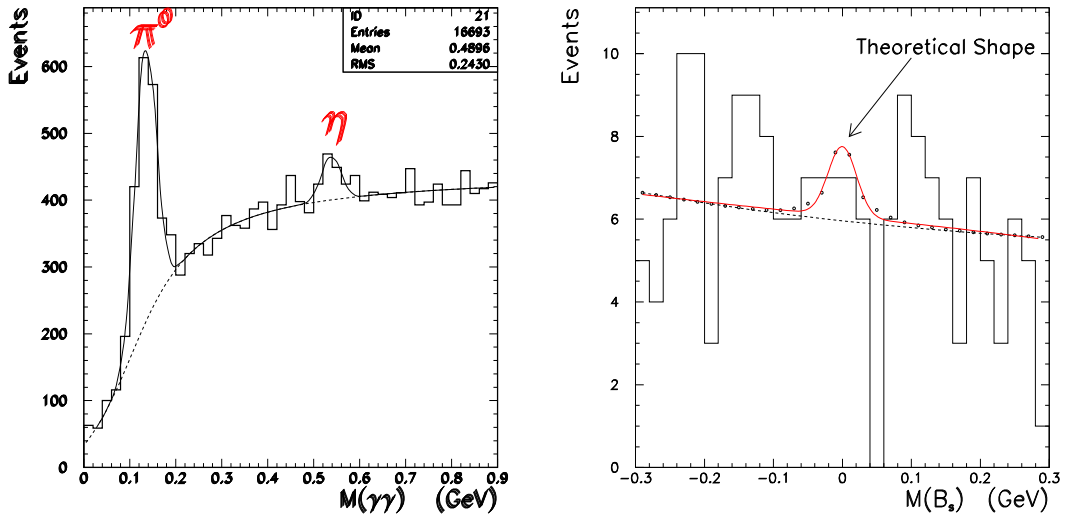
We have studied the feasibility of this method utilising the decay $B_s \rightarrow J/\psi\,\phi$. This mode was observed for the first time in Run I at CDF using a dimuon trigger based on the decay $J/\psi \rightarrow \mu^+\mu^-$. We expect 6000 $B_s \rightarrow J/\psi\,\phi$ events in Run II. We have shown that the angular variables can be used to separate the CP even and odd components of the decay and have developed a simultaneous fit to the admixture and the mixing, whose results, summarised in the figure below, show an expected precision on $\Delta\Gamma/\Gamma$ of between 0.03 and 0.08.



The error on $(\Delta\Gamma/\Gamma)$ as a function of the CP even fraction in the decay $B_s \rightarrow J/\psi\,\phi$

We are also studying the feasibility of this method utili sing the decay $B_s \rightarrow D_s + D_s$, where the final state is a pure CP even state. The difficulty with this channel is in triggering on the decay. We will utilise the Level 2 silicon vertex trigger to select hadronic B decays and combine this with invariant mass cuts at Level 3. Studies of the efficiency and purity which can be obtained are ongoing. We have also studied the mode $B_s \rightarrow D_s\pi$ using the silicon vertex trigger and a thesis describing this method is in preparation.

Another channel which results in a pure CP final state is $B_s \rightarrow J/\psi\,\eta$; however it has not yet been observed. Consequently, we have made a search for this decay using Run I data. The results of this search are described in a forthcoming thesis. On the left in the figure below is shown the invariant mass of two photons in events with an identified J/ ψ; a pi0 peak is clearly evident, though only a slight indication of a η peak is present. The invariant mass for the combination of J/ψ and η is shown on the right for events around the expected B_s peak. No signal is observed from which we obtain a preliminary 90% confidence limit on the branching ratio $Br(B_s \rightarrow J/\psi\,\eta) < 8.75 \times 10^{-4}$.



Left: Photon-photon invariant mass spectrum from selected J/ψ data.
Right: Invariant mass distribution for combining J/ψ and η candidates to make B_s.

Electroweak Physics

We have been involved in preparations for electroweak measurements at CDF in Run II, with particular emphasis on the measurement of the W boson mass. A new W production Monte Carlo that incorporates the latest calculations of electroweak radiative calculations has been introduced into the CDF software framework, and work on the corresponding Z production Monte Carlo program is underway. This new program was used to estimate the likely contribution to the systematic uncertainty on the W mass measurement from higher order electroweak effects in Run II. This study formed part of an extensive investigation into precision measurements in Run II that has concluded, amongst other things, than a measurement of the W mass at the 30 MeV/c^2 level is possible with 2 fb^{-1} collected by the CDF experiment. This is similar to, or better, than the final expected precision from LEP II measurements. A direct measurement of the width of the W boson can also be made from a study of the high transverse lepton-neutrino mass spectrum. The expected precision for 2 fb^{-1} is 40 MeV/c^2 when electron and muon channels are combined.

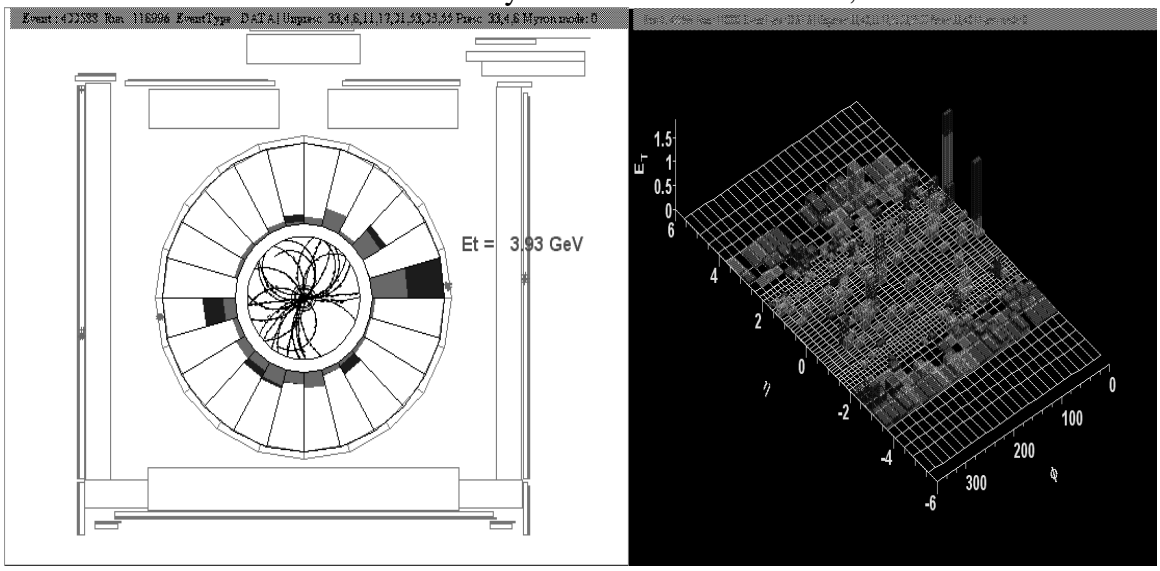
Electroweak physics will be a very rich area of investigation in Run II. In addition to the W mass measurement, we have an interest in di-boson production. So far, preliminary work has been undertaken to compare next-to-leading order estimates of the rates and distributions of di-boson production with estimates from leading order programs such as PYTHIA. Eventually these measurements will be a crucial part of the search for a relatively high mass Higgs at the Tevatron.

The data collected and studied for the determination of the W boson mass and the Drell-Yan final states can also be used to look for, or set limits on physics beyond the SM. New

W' bosons can be searched for using the transverse lepton-neutrino mass spectrum and new Z' bosons using di-muon and di-electron channels. The effects of large extra dimensions, and of modifications to the Standard Model due to string theory, are also expected in these distributions for certain classes of string models. The large q-qbar collision energies and the large luminosity available in Run II are vital ingredients in these searches. The higher energy regime available at the Tevatron compared to LEP will considerably increase the scales at which new physics which can be probed.

Searches: SUSY

We are studying events with leptons in the final state for evidence of SUSY production and are investigating the effect of several different SUSY models on the lepton transverse momentum ($p_{T)}$ spectrum. We have started a simulation effort using so called "Snowmass slopes" as a baseline for our analysis. These are lines in SUSY parameter space, devised at this year's Snowmass workshop, intended as guidance for researchers around the world to focus their analyses and simulations of SUSY. This analysis requires an extensive understanding of how one identifies electrons and muons in the CDF detector and we are heavily involved in the validation and definition of these objects in CDF. In fact, UK physicists, as part of their studies of muon identification, were the first to observe the decay of the Z to two muons at Run II. An event display of one of the events found which were shown at this year's summer conferences, is shown below.



Left: Transverse view of an event with tracks in the COT, deposits in the calorimeters and hits in the muon chambers. The invariant mass of the muons is consistent with the Z.
Right: Calorimeter energy in the η–ϕ view showing the deposits of the muon candidates.

We are also making a specific search for charginos which decay to three leptons and missing energy via the decay channel χ+-> χ^0_2 lν; χ^0_2->χ^0_1 1l. In certain regions of

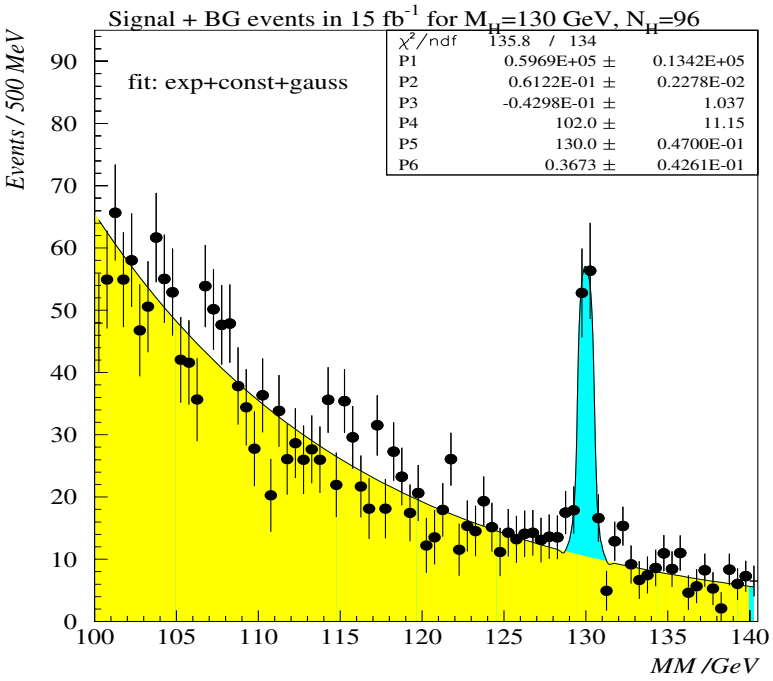
parameter space, the favoured decays are into tau leptons which will result in a softer lepton spectrum than is normally assumed. We are currently working to define trigger conditions for muons and electrons which are of general use to the collaboration as well as of specific use for the above search.

Searches: Higgs

The search for the Higgs boson has generated enormous interest recently. Combining many different decay modes and using results from both CDF and D0, it appears that the Tevatron may be able to exclude (at the 95% confidence level) Higgs masses up to 160 GeV before the LHC starts**[4]**. However, none of the modes give a clear signal and furthermore a discovery at the 5σ level looks unlikely anywhere in the mass region.

An interesting idea was recently proposed to look for the Higgs by diffractive production. If the Higgs is produced with a large enough cross section in the exclusive reaction $p^+p^- \rightarrow p^+ + H + p^-$, it will give rise to a peak at the Higgs mass in the missing mass spectrum, measured from the proton and antiproton. The resolution on m_H could be 250MeV, independent of m_H from 100GeV to 200GeV, and is an order of magnitude better than could be obtained by reconstructing the Higgs from its decay products. The measurement depends on a precise measurement of the momentum of the outgoing proton and antiproton. A new detector called the Very Forward Tracking Detector (VFTD) has been proposed to accomplish this, and would be composed of several planes of silicon wafers in Roman Pots, close to the beamline, 50 metres on either side of the interaction region. UK institutes are currently assisting with the simulation studies and examining the experimental and theoretical aspects of the proposal with a view to assisting in the construction of this detector.

Large theoretical uncertainties exist in estimating the exclusive cross section. We have performed a number of simulations using various theoretical predictions, propagating the proton and antiproton through the magnetic field and detecting them in the silicon. One of the more optimistic models**[5]** suggests that after 2 years of data-taking, a Higgs signal as shown in the figure below would be observable. However, other models predict no signal events. In an effort to reach a theoretical consensus and discuss the experimental detail, the IPPP have organised a workshop in Durham where theorists from the UK and abroad as well as experimentalists from both CDF and D0 will meet. We hope this workshop will resolve some of the issues and point the way to the future.



Simulation of the signal in the VFTD for a Higgs of 130GeV after 15pb-1 of data, using the theoretical predictions of ***[5]****.*

Conclusions

The UK institutes have been members of CDF for just three years and have a relatively small number of physicists working full time on the experiment. Despite this, we have played a major role in the activities of CDF and are responsible for several key aspects of the experiment. We have designed, purchased and manufactured various parts of the Layer00 detector. We are in charge of the Level 3 trigger and the CDF database. We are responsible for silicon monitoring and alignment. We have also focused on physics and performed simulations and studies in anticipation of data. Now that Run II has started, we are actively involved in understanding the data, and committed to achieving physics results as rapidly as possible.

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Appendix A: CDF journal publications since 1999

Conference Proceedings

- R.D St. Denis, "Heavy Flavours in Collider Experiments", J. Phys. G26 (2000) 541.
- B.C. Allanach et al., "Report of the Beyond the Standard Model Working Group of the 1999 UK Phenomology Workshop on Collider Physics (Durham)", J. Phys. G26 (2000) 551.
- M. Lancaster et al., "W Mass Measurements at LEP and the Tevatron", J. Phys. G26 (2000) 616.
- M. Lancaster, D. Waters, "Vector Boson P(T) Measurements", J. Phys. G26 (2000) 646.
- T. Huffman et al., "Heavy Flavour Working Group", J.Phys. G26 (2000) 721.
- F. Azfar, T. Huffman, L. Lyons, A. Reichold, D. Waters, "Measuring CP violation and Bs mixing using Bs->J/psi phi, with phi->KK, J/psi->mumu", J.Phys.G.26(2000) 741.
- R. McNulty "bb Rapidity Correlations in pp Collisions", Proc. EPS-HEP 99, Tampere ,eds. K. Huitu, H. Kurki-Suonio, J.Maalampi, IOP publishing, 411.

CDF papers

- CDF Collaboration, "Production of chi/c1 and chi/c2 in p anti-p collisions at s**(1/2) = 1.8-TeV", *Phys.Rev.Lett.*, **86**,(2001)3963.
- CDF Collaboration, "Measurement of the inclusive jet cross-section in anti-p p collisions at s**(1/2) = 1.8-TeV", *Phys.Rev.* **D64**,(2001).
- CDF Collaboration, "Measurement of the t anti-t production cross-section in p anti-p collisions at s**(1/2) = 1.8-TeV", *Phys.Rev.* **D64**, (2001).
- CDF Collaboration, "First measurement of the ratio B(t ---> W b) / B(t ---> W q) and associated limit on the CKM element |V(tb)|", *Phys.Rev.Lett.*, **86**, (2001) 3233.
- CDF Collaboration, "Measurement of the two jet differential cross-section in proton anti-proton collisions at s**(1/2) = 1800-GeV", *Phys.Rev.*, **D64**,(2001)
- CDF Collaboration, "Measurement of the top quark p(T) distribution", *Phys.Rev.Lett.* **87**,(2001).
- CDF Collaboration, "Search for the supersymmetric partner of the top quark in p anti-p collisions at s**(1/2) = 1.8-TeV" *Phys.Rev.* **D63**,(2001) 91101.
- CDF Collaboration, "Search for neutral supersymmetric Higgs bosons in p anti-p collisions at s**(1/2) = 1.8-TeV" *Phys.Rev.Lett.* **86** (2001)4472.
- CDF Collaboration, "Test of enhanced leading order QCD in W boson plus jets events from 1.8-TeV anti-p p collisions", *Phys.Rev.* **D63**,(2001) 72003.

- CDF Collaboration, "Measurement of the W boson mass with the collider detector at Fermilab" *Phys.Rev.* **D64,**(2001).
- CDF Collaboration, "Measurement of the decay amplitudes of B0 ---> J / psi K* and B0(S) ---> J / psi phi decays", *Phys.Rev.Lett.***85,**(2001)4668.
- CDF Collaboration, "Measurement of the top quark mass with the Collider Detector at Fermilab" *Phys.Rev.* **D63,**(2001)
- CDF Collaboration, "Measurement of d sigma / d y for high mass Drell-Yan e+ e- pairs from p anti-p collisions at S**(1/2) = 1.8-TeV", *Phys.Rev.* **D63,**(2001)
- CDF Collaboration, "Dijet production by double pomeron exchange at the Fermilab Tevatron", *Phys.Rev.Lett.* **85** (2000)4215.
- CDF Collaboration, "Measurement of J / psi and psi(2S) polarization in p anti-p collisions at S**(1/2) = 1.8-TeV", *Phys.Rev.Lett.* **85** (2000) 2886.
- CDF Collaboration, "Search for color singlet technicolor particles in p anti-p collisions at s**(1/2) = 1.8-TeV", *Phys.Rev.Lett.* **84,**(2000)1110.
- CDF Collaboration, "Direct measurement of the W boson width in p anti-p collisions at S**(1/2) = 1.8-TeV", *Phys.Rev.Lett.* **85,** (2000) 3347.
- CDF Collaboration, "Search for second and third generation leptoquarks including production via technicolor interactions in p anti-p collisions at s**(1/2) = 1.8 TeV", *Phys.Rev.Lett.* **85,** (2000) 2056.
- CDF Collaboration, "Limits on gravitino production and new processes with large missing transverse energy in p anti-p collisions at S**(1/2) = 1.8-TeV", *Phys.Rev.Lett.* **85,** (2000) 1378.
- CDF Collaboration, "Diffractive dijets with a leading anti-proton in anti-p p collisions at S**(1/2) = 1800-GeV", *Phys.Rev.Lett.* **84,** (2000) 5043.
- CDF Collaboration, "Search for new particles decaying to top - anti-top in proton - anti-proton collisions at S**(1/2) = 1.8-TeV", *Phys.Rev.Lett.* **85,** (2000) 2062.
- CDF Collaboration, "Vector boson p(T) measurements", *J.Phys.G.* **26,** (2000) 646.
- CDF Collaboration, "A Measurement of the differential dijet mass cross-section in p anti-p collisions at S**(1/2) = 1.8-TeV", *Phys.Rev.* **D61,** (2000).
- CDF Collaboration, "Search for scalar top quark production in anti-p p collisions at S**(1/2) = 1.8-TeV", *Phys.Rev.Lett.* **84,** (2000) 5273.
- CDF Collaboration, "Observation of orbitally excited B mesons in p anti-p collisions at S**(1/2) = 1.8-TeV", *Phys.Rev.* **D64,** (2001).
- CDF Collaboration, "Search for the charged Higgs boson in the decays of top quark pairs in the e tau and muon tau channels at S**(1/2) = 1.8-TeV", *Phys.Rev.* **D62,** (2000).
- CDF Collaboration, "Search for scalar top and scalar bottom quarks in p anti-p collisions at S**(1/2) = 1.8-TeV", *Phys.Rev.Lett.* **84,** (2000) 5704.

- CDF Collaboration, "Production of upsilon(1S) mesons from chi(b) decays in p anti-p collisions at S**(1/2) = 1.8-TeV", *Phys.Rev.Lett.* **84**, (2000) 2094.
- CDF Collaboration, "Search for a W-prime boson via the decay mode W-prime ---> muon muon-neutrino in 1.8-TeV p - anti-p collisions", *Phys.Rev.Lett.* **84**, (2000) 5716.
- CDF Collaboration, "Search for a fourth generation quark more massive than the Z0 boson in p anti-p collisions at S**(1/2) = 1.8-TeV", *Phys.Rev.Lett.* **84**, (2000) 835.
- CDF Collaboration, "Measurement of b quark fragmentation fractions in the production of strange and light B mesons in p anti-p collisions at S**(1/2)=1.8-TeV", *Phys.Rev.* **D60**, (1999).
- CDF Collaboration, "Measurement of the B0(D) anti-B0(D) oscillation frequency using dimuon data in p anti-p collisions at S**(1/2) = 1.8-TeV", *Phys.Rev.* **D60**, (1999).
- CDF Collaboration, "Measurement of B0 - anti-B0 flavor oscillations using jet charge and lepton flavor tagging in p anti-p collisions at S**(1/2) = 1.8-TeV", *Phys.Rev.* **D60**, (1999).
- CDF Collaboration, "Measurement of the associated gamma + muon +- production cross-section in p anti-p collisions at S**(1/2) = 1.8 TeV", *Phys.Rev.* **D60**, (1999).

Appendix B: Talks at International Conferences since 1999

- F. Azfar, "CP violation in B decays at CDF: Results and Prospects", Durham Workshop on CP Violation (2000).
- M. Martin, "CDF Run II prospects for Bs mixing", APS, DPF 2000, Columbus, Ohio.
- R. McNulty, "bb Rapidity Correlation in pp Collisions", EPS-HEP 99 Tampere.
- D. Waters, "The High Energy Frontier: Physics at Hera and The Tevatron", IOP Particle Physics Annual Conference, Bristol, April 4th 2001.

Appendix C: People currently working on CDF

University of Glasgow	
Saverio d'Auria	Research Assistant
William Bell	Student
Peter Bussey	Academic
Sinead Farrington	Student
Rick St. Denis	Academic
Stan Thompson	Physicist Programmer
Brian Ward	Student
Simon Waschke	Student
Tatiana Unverhau	Student
University of Liverpool	
Paul Booth	Academic
Beate Heinemann	PPARC Fellow
Mike Houlden	Academic
Barry King	Physicist Programmer
Ronan McNulty	Advanced Fellow
Salvador Marti	Physicist Programmer
Tara Shears	Royal Society Fellow
Anyes Taffard	Research Assistant
Martin Turner	Student
University of Oxford	
Farrukh Azfar	Research Assistant
Todd Huffman	Academic
Jim Loken	Physicist Programmer
Louis Lyons	Academic
Guilia Manca	Student
Matt Martin	Student
Thilo Pauli	Student
Jonas Rademacker	PPARC Fellow
Armin Reichold	Academic
Peter Renton	Academic
Dave Waters	Research Assistant
University College London	
Lucio Cerruti	Student
Paul Crosby	Student
Mark Lancaster	Academic
Dustin McGivern	Student
Rob Snihur	Research Assistant

Appendix D: Staff years per category and institute

	Full Time Equivalents			
	01/02	02/03	03/04	04/05
University of Glasgow				
HEFCE Academic	1.0	0.9	0.8	0.8
PPARC Rolling Grant	1.6	1.6	1.1	1.1
University of Liverpool				
HEFCE Academic	1.1	1.1	1.1	2.0
PPARC Rolling Grant	2.0	2.0	2.0	2.0
PPARC Fellows	2.0	2.0	2.0	1.0
R.S. Fellows	0.8	0.8	0.8	0.5
University of Oxford				
HEFCE Academic	2.2	2.6	2.9	2.9
PPARC Rolling Grant	1.5	1.5	1.5	1.5
PPARC Fellows	1.0	1.0	1.0	1.0
University College London				
HEFCE Academic	0.6	0.6	1.0	1.0
PPARC Rolling Grant	1.0	1.0	1.0	1.0
R.S. Fellows	0.5	1.0	1.0	1.0

Appendix E: M&O and Travel for this and the next five years

Resources Required from RAL 2001/02 - 2006/7

	Estimates	Forward Look				
	2001/02	2002/2003	2003/04	2004/05	2005/06	2006/07
FUNDS (£K)						
Maint. & Running Costs	**44**	**44**	**44**	**40**	**25**	**7**
New Equipment	**0**	**0**	**0**	**0**	**0**	**0**
Travel - Long Term	**197**	**150**	**130**	**65**	**30**	**0**
Travel - Short Term	**100**	**80**	**80**	**80**	**60**	**40**
TOTAL	**341**	**274**	**254**	**185**	**115**	**47**
RAL EFFORT (SY)	**1.0**	**1.0**	**0.5**	**0.5**	**0.5**	**0**
Eng. Div. (PAG)	**0**	**0**	**0**	**0**	**0**	**0**
Instrumentation Division (formerly Tech/Electronics)	**0**	**0**	**0**	**0**	**0**	**0**
Other (IT support)	**1.0**	**1.0**	**0.5**	**0.5**	**0.5**	**0**

Appendix F: Computing Resources

CDF does not require CPU or disk storage on the central computing facilities outside that which it has bought as part of the JIF award.

CDF is in receipt of a JIF award which has supplied each UK institution with an IBM 8-way SMP server connected via a Fibre Channel link to its own 1TB RAID. A similar system, twice as large, has also been provided to RAL for use by all the UK groups. Next year, the remainder of the grant will be used to approximately double the computing and storage capacity. The JIF award has also bought 10TB of disk space currently at Fermilab, and will fund an additional 10TB next year.

We are currently leasing a 622Mbps peering point to ESnet, the DOE network in the US that connects the national labs to the internet. The current peering point has an extra routing hop and allows only 85Mbps for all UK research. This new peering will be available to all UK researchers sending or receiving packets to or from Esnet.

We estimate the peak bandwidth requirements of CDF to be 30Mbps within Britain and 15Mbps from the US to the UK.