The Collider Detector at Fermilab (CDF) experiment is studying the world's highest energy proton-antiproton ($p\overline{p}$) collisions. The CDF collaboration consists of scientists from eleven different countries, including a group of 20 Canadian particle physicists affiliated with the Institute of Particle Physics (IPP). The IPP group joined CDF in 1991 and is now participating in the Tevatron Run II programme. For Run II, the CDF detector and the Tevatron collider underwent major upgrades and we anticipate a factor of 50-100 increase in the statistics of specific final states by the end of 2008.

Our group has made major contributions to CDF Run-II data analyses by providing massive off-site computing resources and the human resources necessary to coordinate this effort. This involvement along with our long-standing contributions to CDF software has allowed Canadian physicists to make key contributions to the first physics results of Run II.

The Tevatron and the CDF detector are performing very well with data taking efficiencies close to 90% and peak luminosities of 1.5 cm^{-2}s^{-1}. This has allowed us to collect over 1 fb^{-1} of data and we anticipate doubling the current dataset between now and the end of next year. The fully realized physics programme of Run II requires the analysis of inverse femtobarns of collision data. This integrated luminosity will allow us to search for new particles and forces, and measure key parameters of the Standard Model of particle physics to unprecedented precision.

This proposal requests funding for the next 3 years in order for the IPP group to fully capitalise on NSERC's significant investment in the CDF II experiment and its physics. This will allow our graduate students, research associates, and faculty to continue their service contributions to CDF and to complete their ongoing physics analyses at the exciting time when the scientific output of the experiment reaches its peak.

CDF commissioning run	First operation of Inchworm positioning system	Sep 00	Dec 00
Tracker Alignment	Analysis of construction survey/first tracks	Oct 00	Jul 01
CDF-II data-taking		Mar 01	Mar 07
CDF-II Physics Analysis		Jul 01	Jan 08

A. TITLE

The CDF-II Experiment at the Fermilab Tevatron

B. INVESTIGATORS

(i) Applicants

J. Pinfold	Alberta	Professor	30%
P. Savard	Toronto	Professor	100%
P. K. Sinervo	Toronto	Professor	70%
W. Trischuk	Toronto	Professor	80%
A. Warburton	McGill	Professor	100%

(ii) Collaborators

B. Burris	Alberta	Computing Professional	50%
P.H. Beauchemin	Toronto	Research Associate	100%
B. Caron	Alberta	Computing Physicist	20%
S. Carron	Toronto	Research Associate	100%
R. Snihur	McGill	Research Associate	100%
A. Buzutu	McGill	Graduate Student	100%
S. Lai	Toronto	Graduate Student	100%
J. Krishna-Prasad	Toronto	Graduate Student	100%
D. MacQueen	Toronto	Graduate Student	100%
S. Pashapour	Toronto	Graduate Student	100%
J.P. Roy	McGill	Graduate Student	100%
S. Sabik	Toronto	Graduate Student	100%
T. Spreitzer	Toronto	Graduate Student	100%
G. Williams	McGill	Graduate Student	100%
I. Vollrath	Toronto	Graduate Student	100%

Other Collaborators: physicists from Academica Sinica, Argonne National Laboratory, Istituto Nazionale di Fisica Nucleare, University of Bologna, Brandeis University, University of California at Davis, University of California at Los Angeles, University of California at Santa Barbara, University of Cantabria, Carnegie Mellon University, University of Chicago, JINR-Dubna, Duke University, Fermi National Accelerator Laboratory, University of Florida, Laboratori Nazionali di Frascati, University of Geneva, University of Glasgow, Harvard University, University of Helsinki, Hiroshima University, University of Illinois, Johns Hopkins University, Universität Karlsruhe, KEK, LBL, Liverpool University, University College London, Massachusetts Institute of Technology, University of Michigan, Michigan State University, ITEP Moscow, University of New Mexico, Northwestern University, Ohio State University, Okayama University, Osaka City

University, Oxford University, Universita di Padova, University of Pennsylvania, University and Scuola Normale Superiore of Pisa, University of Pittsburgh, Purdue University, University of Rochester, Rockefeller University, University of Roma, Rutgers University, University of San Diego, Texas A & M University, Texas Tech University, INFN-Trieste, University of Tsukuba, Tufts University, Waseda University, University of Wisconsin, and Yale University.

A. Executive Summary

The CDF-II experiment is studying 2.0 TeV proton-antiproton ($p\overline{p}$) collisions produced by the Fermilab Tevatron Collider, currently the highest energy collider in the world. The collider data taking period known as Run II started in 2002 and as of September 2005, the accelerator has delivered over 1 fb^{-1} with an additional 3 fb^{-1} expected by the end of 2007. The analysis of these integrated luminosities represent an unprecedented scientific opportunity to explore the high energy frontier. The IPP-Canada group requests funding for the next 3 years to take advantage of this outstanding opportunity.

IPP scientists have been supported by NSERC to participate in the CDF project since 1991, when the experiment was in preparation for a data-taking period known as Run I. In anticipation of the large increase in luminosity we completed a major overhaul of the CDF sub-detectors and associated readout electronics, creating the new detector facility known as CDF-II. The Canadian hardware contribution to the CDF-II detector, funded through an NSERC equipment grant, focused one the silicon vertex detector support mechanics. We have also made significant contributions to the Offline Project by developing most of the calorimetry reconstruction and simulation software. More recently, we committed the resources necessary to make our CFI-funded Beowulf cluster (450 2.4 GHz Xeon processors with approximately 30 TB of disk) the main Monte Carlo production facility for the CDF collaboration.

These NSERC and CFI-sponsored efforts have allowed us to play a very important role in the experiment as is evidenced by the scientific productivity of our group and the leadership roles of our faculty and research associates. We have published and submitted more papers than other groups of our size, including the first high-pt physics paper of Run II, the best single measurement of the top mass to date, and the first measurement of the W boson mass in Run II. The leadership roles assumed by members of the group include Calorimetry group leader, Simulation Group leader, Head of Offline Operations, Silicon Detector Project leader, Offline Analysis leader, and Top and Electroweak Physics Group convener. Another important contribution of our group involves the training of graduate students and research associates in hadron collider physics. The Tevatron remains the ideal training ground for the next generation of physicists that will work at the Large Hadron Collider.

We intend to continue our effort on CDF in order to capitalise scientifically on the Canadian contributions to CDF-II. The scientific programme for the next three years showcases outstanding opportunities that include measurement of Bs mixing, a first single top cross section measurement, precision electroweak measurements (W mass, top mass, etc.), precision measurements of top quark properties, and searches for new phenomena. Many of these measurements (e.g. Bs, single top, new phenomena like SUSY trileptons) will probably require integrated luminosities beyond 2 fb^{-1} with additional time required to thoroughly understand the data.

This proposal requests funding for the next 3 years in order for the IPP group to fully capitalise on NSERC's significant investment in the CDF II experiment and its physics. This will allow our graduate students, research associates, and faculty to continue their service contributions to CDF and to complete their ongoing physics analyses at the exciting time when the scientific output of the experiment reaches its peak.

B. The Canadian CDF-II Physics Program

The multi-purpose CDF detector makes possible the pursuit of a very broad physics program that is progressing on several principal fronts: high-precision inquiry into electroweak physics observables of top quarks and intermediate vector bosons; exploration of both perturbative and nonperturbative QCD, including measurements of heavy-quark hadroproduction; and energy-frontier searches for physics beyond the Standard Model, a description of Nature that is generally reasoned to be incomplete.

Canada's CDF group is engaging in physics analyses that span this breadth. Below, we summarise the significant Canadian efforts underway using the early Run-II data; we follow this with a discussion of the Tevatron luminosity program and its projected physics reach.

(i) Top Quark Physics Studies

Since the discovery of the top quark during Run I of the Fermilab Tevatron, emphasis has turned to the precise characterization of its properties. Given the relatively small samples collected in Run I, much remains to be discovered about this unusually massive and highly short-lived fermion. The current Run II dataset represents an order of magnitude increase in statistics over the world's previous top quark sample and, together with new analysis approaches and improved detector functionality, is enabling precision measurements of this exotic particle. The CDF Run II upgrades have enhanced the top quark yield per unit of time-integrated luminosity by both extending and improving the lepton identification systems, and by significantly improving the bottom quark tagging capability. Combined with the additional time-integrated luminosity and the higher cross section afforded by the increase in centre-of-mass energy from 1.8 to 2.0 TeV, we are now able to study samples of top-quark candidates of order 10^3 in number.

(a) Top Mass

The top quark's great mass is arguably its most striking feature, one that figures prominently in radiative corrections to Standard Model descriptions of electroweak observables. A precise understanding of the top mass is therefore crucial to providing constraints on the Higgs boson mass and consistency checks of the Standard Model, both with much sensitivity to new physics.

The Canadian top-mass effort (Arguin, Sabik, Savard, and Sinervo) is focussing on the lepton + jets and dilepton channels of $t\bar{t}$ production and decay, whereby both top quarks decay into b-quark jets and W bosons. In the dilepton channel, both W bosons decay leptonically whereas in the lepton + jets channel, on W boson decays leptonically and the other hadronically. The resultant topologies consists of one or two charged leptons, missing transverse energy due to the neutrino, and two to four jets. A major challenge to measuring the top mass is the complicated reconstruction of the final state required. In the case of the dilepton channel, the two neutrinos are not measured which requires solving a kinematically underconstrained problem. For the l +jets case, CDF's b-jet-tagging capabilities are employed, with efficiencies of approximately 40%, to reduce these combinatorics significantly. A second major challenge is overcoming the largest systematic uncertainty, namely that due to the jet energy scale. Uncertainties in the jet energy scale arise from model dependence in our descriptions of fragmentation and the particle

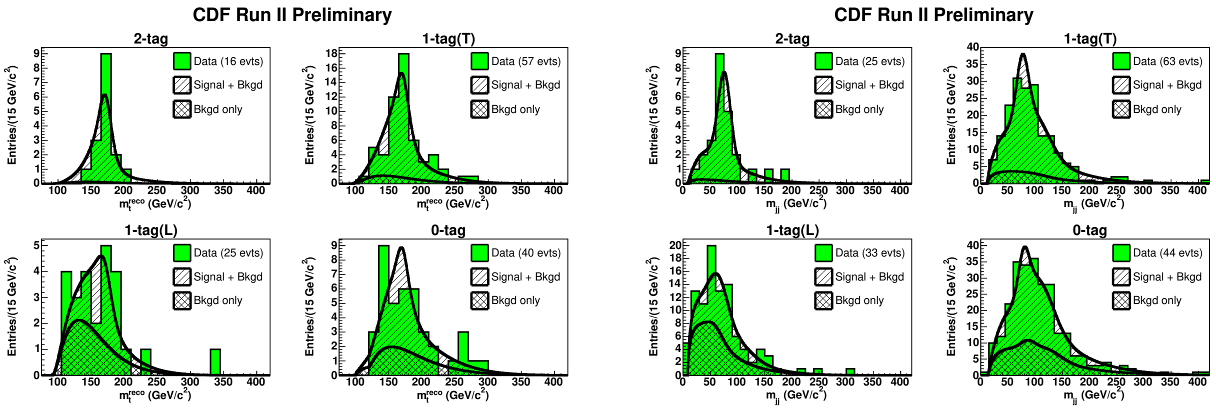

Figure 1: The reconstructed **[left]** top-quark and **[right]** W-boson mass distributions fit for simultaneously and plotted with the expected distributions from the Monte Carlo signal template at the fit mass and the background template. The m_t and m_W distributions are shown for different categories of b-jet tags, namely number of b tags and tight (T) or loose (L) requirememnts.

responses attributed to jet behaviour in our detector. A major component of the top mass analyses, contributed by our group, is a set of top-specific jet-energy corrections, corrections that account for fragmentation differences between light-quark and b-quark jets, that are tuned to the non-flat p_T spectrum of jets from $t\bar{t}$ decay, and that supply the mass reconstruction fitting machinery with top-specific jet-energy resolutions. Nevertheless, with recent increases in time-integrated luminosity, the systematic uncertainty associated with the jet energy scale has alone become comparable to the statistical uncertainty.

Our Canadian group has been prominent in pioneering a novel means to reduce the jet energy scale (JES) uncertainty in a statistically scalable way by introducing the *in situ* reconstruction of hadronic W boson candidates embedded in $t\bar{t}$ candidate final states. In the conventional template analysis, top mass candidates are reconstructed kinematically for each selected event and compared with a sequence of Monte Carlo top-mass templates to extract the best-fit mass. In the new extended approach, templates of both top-quark and W-boson mass are used to fit for the top-quark mass and jet energy scale simultaneously. Refer to Fig. 1. This approach has resulted in the world's single best measurement of the top quark mass, $(173.5\,^{+2.7}_{-2.6}[\mathrm{stat}] \pm 2.5[\mathrm{JES}] \pm 1.3[\mathrm{syst}])$ GeV/c^2, which is alone more precise than the previous world average value.

(b) $t\bar{t}$ Production Cross Section

The top quark production cross section at the Tevatron is predicted within the Standard Model with an uncertainty of approximately $< 15\%$, and is expected to increase by $\sim 30\%$ due to the increase in centre-of-mass energy from 1.8 to 1.96 TeV. The experimental measurement of the cross section using a particular final-state topology is potentially sensitive to new physics governing the production aspect, *e.g.*, a heavy resonance decaying to $t\bar{t}$ pairs; similarly, a marked departure from the Standard Model prediction could also signal the presence of a novel mechanism for the decay aspect, *e.g.*, supersymmetric particles in the final state.

CDF has been pursuing several measurements of the top-pair production cross section in the dilepton, lepton + jets, and all-hadronic channels. Using the dilepton mode, $p\bar{p} \rightarrow t\bar{t} \rightarrow b\ell^{+}\nu_{\ell}\bar{b}\ell'^{-}\bar{\nu}_{\ell'}$, Canadians Savard, Spreitzer, and Tafirout have developed techniques to measure the $t\bar{t}$ production cross section with greater acceptance using a sample with tight cuts on one lepton candidate and generic isolated-track criteria on the other track. Although it results in some increase in the background contribution, this method brings a gain in the overall acceptance as well as an ability to accept hadronic decays of the τ lepton. This analysis was the first top physics paper published by the Tevatron experiments. An updated measurement was recently obtained using $\sim$360 pb^{-1} giving $\sigma_{t\bar{t}} = 9.9^{+2.2}_{-2.0}[\text{stat}]^{+1.3}_{-1.3}[\text{syst}] \pm 0.6[\text{lumi}])$ pb, assuming $\mathcal{B}(W \rightarrow \ell\nu) = 10.8\%$.

In the context of CDF $t\bar{t}$ production cross-section measurements, Buzatu and Warburton are assessing algorithms used to select primary vertices with respect to the high-p_T leptons in candidate $t\bar{t}$ events. The efficient selection of the correct primary vertex is important for the many analyses that employ secondary-vertex b-tagging, and is anticipated to undergo refinement as the instantaneous luminosity increases, with an attendant increase in event pile-up.

(c) Single-Top Production

Whereas the discovery of the top quark was made possible by observing $t\bar{t}$ pairs produced via the strong interaction, single top quarks can also be produced at the Tevatron by electroweak processes. The cross section of a virtual W^* propagator decaying into a top and bottom quark is proportional to the CKM matrix element $|V_{tb}|^2$ and has sensitivity to non-standard couplings of the top quark, making it an ideal observable in our search to uncover new physics. Canadian researchers Savard, B. Stelzer, and Trischuk have conducted an initial search for single-top production, setting a limit $\sigma < 17.8$ pb at 95% C.L. in the combined s and t channels using 162 pb^{-1}, the first limit obtained using Run II of the Tevatron. Refer to Fig. 2. The significant additional luminosity expected from Run II along with new analysis techniques developed by our group portends the exciting prospect for the first observation of electroweak top prodcution.

(d) $t\bar{t}$ Production Mechanisms

A highly challenging analysis is seeking to study $t\bar{t}$ production characteristics, specifically the ratio of $t\bar{t}$ cross section due to gluon-gluon fusion to that due to quark-antiquark annihilation. Pashapour and Sinervo are investigating techniques and variables to discriminate between the two production mechanisms by examining initial-state gluon radiation properties while minimizing model dependence. In particular, track and forward-jet multiplicity observables are showing promise in providing separation between gluon- and quark-enriched events. Refer to Fig. 3. The study aims to measure the ratio $\sigma(gg \rightarrow t\bar{t})/\sigma(q\bar{q} \rightarrow t\bar{t})$ with a precision of $5-10\%$.

(ii) W Boson Physics Studies

A precise mass measurement of the W boson, by virtue of the fact that its mass and that of the top quark are connected to the Higgs boson mass through radiative corrections, can help to provide both constraints on the Higgs mass and a valuable consistency check of the Standard Model. The W mass is also sensitive to new physics from exotic particles populating loops in the W propagator.

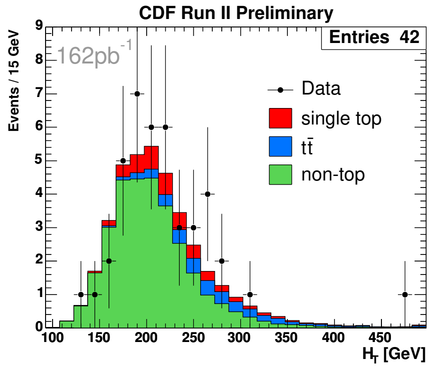

Figure 2: The H_T (or scalar ΣE_T over all jets, lepton, and $\not{E}_T$ in the event) distribution for 162 pb^{-1} of Run-II data, with Monte Carlo templates representing calculated contributions for single-top signal and backgrounds. The H_T variable is used because both the s-channel and t-channel single-top processes, which are combined in the figure, exhibit similar distributions in this quantity.

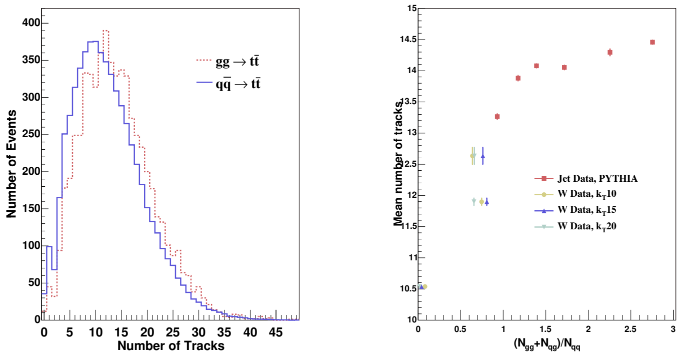

Figure 3: a) **[left]** Track multiplicity distributions from Monte Carlo simulations of $t\bar{t}$ production due to gg and $q\bar{q}$ production processes. A similar trend is observed in jet multiplicity. b) **[right]** Mean low-p_T track multiplicities versus the fraction of gluon-rich events to $q\bar{q}$ events for (from left to right) $W+0$, $W+1$, and $W+2$ jet samples, followed by inclusive jet samples with leading E_T thresholds increasing by 20 GeV from 100 GeV to 200+ GeV.

Canadian CDF members Stelzer-Chilton, Trischuk, and Vollrath are conducting a measurement of the W-boson mass using candidates in the $W \to \mu\nu_\mu$ channel both in terms of transverse mass (m_T) and transverse momentum (p_T). For this analysis the determination of the muon momentum scale is critical. We have been heavily involved in understanding the tracker alignment and calibrating the momentum scale using J/ψ and Υ control samples. Further, the m_T distribution cannot be predicted analytically, necessitating the use of Monte Carlo line shape predictions. Currently, no NLO QCD Monte Carlo calculation includes $O(\alpha)$ electroweak corrections. Our group has developed techniques to merge the output from the RESBOS QCD generator numerically with that from the WGRAD/ZGRAD QED generator providing improved understanding of one of the

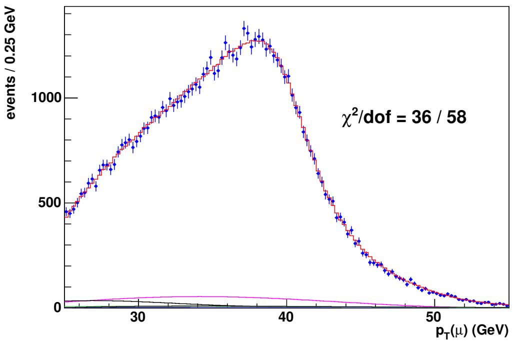

Figure 4: The muon transverse momentum distribution for $W \to \mu\nu_\mu$ candidates.

few W mass systematics that is not naturally reduced by having larger statistics control samples.

The technique of instead using the p_T distribution has an advantage over the traditional m_T approach in that it is less sensitive to detector related effects such as calorimeter response and resolution. In the past the charged lepton p_T measurement was used as a cross check; however, now due to better QCD Monte Carlo generators we are able to model the $p_T(W)$ spectrum (which the $p_T(\mu)$ measurement is sensitive to) more reliably and we observe that the p_T measurement has slightly lower systematic uncertainties than the transverse mass. This work will be very useful for future W mass measurements at hadron colliders since the transverse mass measurement will continue to degrade in higher luminosity environments due to pileup and the p_T measurement will be the primary method for measuring the W mass.

(iii) Exotics, QCD, and Higgs Physics Studies

(a) Searches for Exotic Particles

Supersymmetry (SUSY) is one of the most popular candidates for physics beyond the Standard Model. In one range of SUSY theories, those for which R-parity is conserved, pair-produced squarks and gluinos decay, producing energetic hadronic jets and weakly interacting stable neutralinos. The neutralinos would escape detection by the CDF calorimeter, thus leaving missing transverse energy.

The IPP group (MacQueen and Orr) is exploring signatures for SUSY in searches for R-parity conserving supersymmetry signals using jet $+\not{E}_T$ signatures. In this search, a signal region with high missing transverse momentum and three or more energetic jets is defined. Refer to Fig. 5. The signal region is treated as a "blind box", and will not be examined until the backgrounds to the signal are fully understood in nearby control regions and the cuts on the data are optimized. Using the significantly increased data sample available from Run II, either existing limits on squark and gluino masses will be significantly extended in a model-independent way, or evidence for SUSY will be seen.

Beauchemin and Savard have also been working on the development of generic signature-based searches involving significant missing transverse energy, which figures prominently in the signals

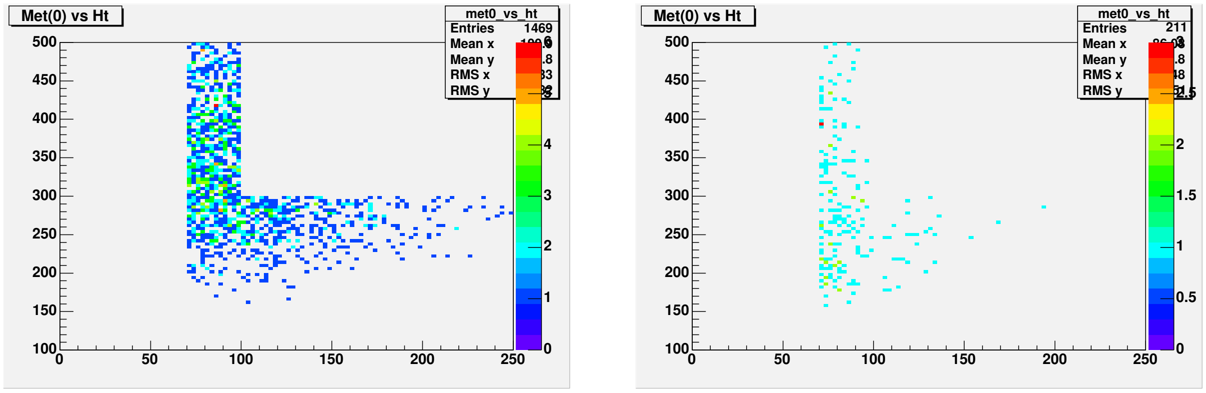

Figure 5: Plots of missing transverse energy versus H_T (defined in Fig. 2) in GeV for events with three or more jets in a) **[left]** a Monte Carlo calculation for gluino-squark production using mSUGRA parameters m(up squark) = 375 GeV and m(gluino) = 300 GeV and b) **[right]** a data sample of $\sim$320 pb^{-1} in which the upper-right corner is blanked due to the blinded region.

for many exotica, including large extra dimensions, SUSY-associated or other dark matter, and escaping gravitons (in models with TeV-scale gravity). Initial studies, which have involved low numbers of jets, have extended existing limits of models with Large Extra Dimensions. With the help of Krishna-Prasad, these studies are being extended to include higher jet multiplicities and to make use of the expected larger future Tevatron data samples that will enhance the discovery reach of this approach.

(b) QCD and Higgs Studies

The exciting possibility of detecting a light Higgs boson has been the focus of much attention. Double diffractive collisions, in which the final state contains only intact protons that escape the central detectors, could allow a precise measurement of the Higgs mass near 200 GeV using the missing mass method on protons tagged with Roman pot detectors, far downstream of the interaction region. While this method, which applies only to exclusive Higgs production, is expected to have a rate too low to be observable at the Tevatron, the inclusive process has recently been estimated to be detectable. Hamilton and Pinfold are investigating the use of the doubly diffractive channel as a clean Higgs production environment, work that is expected to inform similar searches in diffractive production at the LHC. In Fig. 6, a peak representing an absence of particle multiplicity in both opposing forward directions is suggestive of pomeron exchange; the ridges along the axes represent single diffraction candidates, and the remaining events are deemed to be non-diffractive.

Intimately linked to searches for the Higgs boson in the low-mass region, where the $H \to b\bar{b}$ mode dominates, is a deeper understanding of QCD jets, in particular high-momentum b-quark jets. Pairs of b quarks can also be produced through purely QCD interactions at rates orders of magnitude greater than those from Standard Model Higgs decays; this underscores a need for well understood b-quark production cross sections and QCD jet properties. By demanding the presence of an associated W boson, the QCD background can be markedly reduced, and indeed the $Wb\bar{b}$

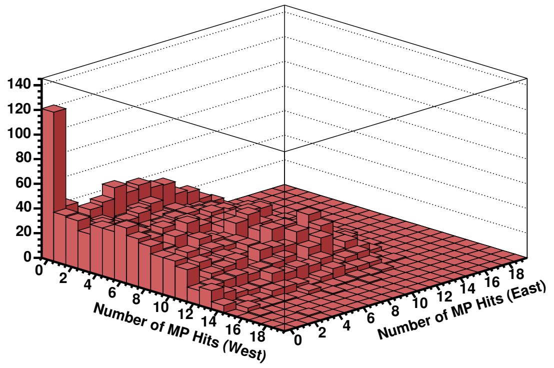

Figure 6: Particle multiplicity in the east miniplug (MP) versus the west miniplug for events containing two loose photon candidates. The peak near (0,0) is suggestive of double-pomeron exchange candidates.

Figure 7: A preliminary normalized b-jet cross-section distribution using a sample of $\sim$340 pb^{-1} of CDF Run-II data.

cross section is a promising avenue to setting the world's best lower limit on the Higgs mass with CDF.[1] As a component of this larger study, Snihur, Williams, and Warburton are analysing the inclusive b-jet production cross section at high transverse momenta using a jet-probability b-tagging method. A preliminary result is presented in Fig. 7. Work is going into understanding the trigger efficiencies and prescales, as well as using jet-probability tagging information to provide separation between different quark-jet flavours.

Of particular relevance to energy-frontier electroweak and QCD studies is the development of a deeper understanding of the production of an intermediate vector boson in association with n QCD jets. Mazini is examining the production of $Z(W)+n$ jets processes to test higher order QCD corrections to electroweak effects; these processes pose a background to top, Higgs, and SUSY signatures. Although the $Z+n$ jets process may be favourable given the cleaner signal (no missing energy, good kinematical reference), it is statistically limited and will therefore benefit from the envisaged enlarged Tevatron data samples.

Another enticing low-mass Higgs signature observable, under study by Lai and Sinervo, is the $p\bar{p} \to t\bar{t}H$ final state. Although the cross section for a Higgs mass of 120 GeV is predicted to be only $\sim$4.8 fb, this mode's distinctive topology (which requires the efficient identification of leptons and b-quark jets), data from additional Run II Tevatron operation, and our pioneering work on a new high-efficiency "combined tagger" will enable us to achieve increased signal-to-background ratios and better characterise the backgrounds in this channel. Fig. 8 describes our acceptance as a function of Higgs boson mass. This measurement will be pursued further by the LHC experiments.

[1] Note that this topology is complementary to that for the single-top production described in Section (i), where the $W^* \to t\bar{b}$ channel mimics the associated WH Higgs production final state.

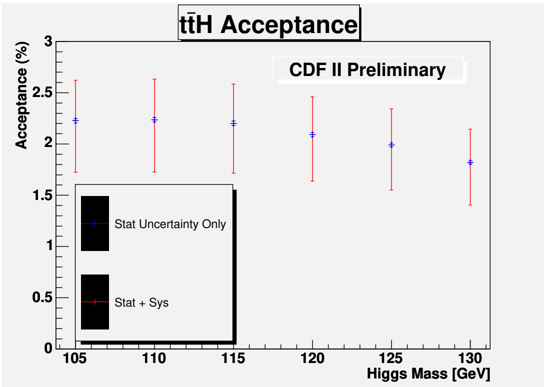

Figure 8: Calculated CDF II acceptance for the $t\bar{t}H$ channel as a function of the Higgs boson mass.

C. Tevatron Luminosity Program and Projected Physics Reach

The early Run-II results that are currently entering publications are primarily based on data samples having time-integrated luminosities of 0.2 – 0.4 fb^{-1}. The recorded time-integrated luminosity for Run II is presently in excess of 1 fb^{-1} and, at the time of this writing, the Tevatron peak instantaneous luminosity record recently exceeded 1.5×10^{32} cm^{-2}s^{-1}.

At present datataking efficiencies of 85−90%, and under the current Tevatron accelerator performance, a minimum of 2 fb^{-1} are expected by the end of 2006 and 6 fb^{-1} by the end of 2008, at least two doublings over the next four years. When considered beside both the data already collected and these conservative luminosity projections, the data that have been analysed to date represent less than one tenth of the Tevatron program's baseline reach. Factoring in planned upgrades to the Tevatron accelerator complex, including electron cooling, three integrated luminosity doublings are expected, *i.e.*, 4 fb^{-1} by 2007 and 8 fb^{-1} by 2009. The following discusses selected physics projections for Run II of the Tevatron.

In the broad range of B physics measurements possible at, and unique to, the Tevatron, the study of B_s mixing will contribute unique testing of the flavour sector in the Standard Model. When taking into account improvements in existing analysis procedures, including kaon tagging, additional channels, trigger adjustments, and a 20% improvement in vertex resolution, the Tevatron is expected to extend sensitivity from a 95% C.L. exclusion with 2 fb^{-1}, to 3σ evidence with 4 fb^{-1}, to 5σ discovery with 8 fb^{-1}. Refer to Fig. 9. The absence of a discovery of B_s mixing in 8 fb^{-1} would represent a striking contravention of the Standard Model, *i.e.*, new physics.

In the intense international search for the Standard Model Higgs boson, the Tevatron is anticipated to play a vital role. With samples of 4 fb^{-1}, potentially attainable before the end of the period of LHC commissioning, 3σ evidence for Higgs masses greater than the LEP limit (114.4 GeV at 95% C.L.) will be possible. With 8 fb^{-1}, the 3σ evidence could be extended to Higgs masses as high as 130 GeV. This mass region, favoured by electroweak data and supersymmetry, represents a particular challenge to the LHC experiments, which, to explore it, would need ideal and well understood detector performance, more than 10 fb^{-1} of data per experiment, and effective rejection of high backgrounds. If the SM Higgs boson were to lie in this favoured region, these challenges, in addition to the fact that the Tevatron and LHC are sensitive to different Higgs decay

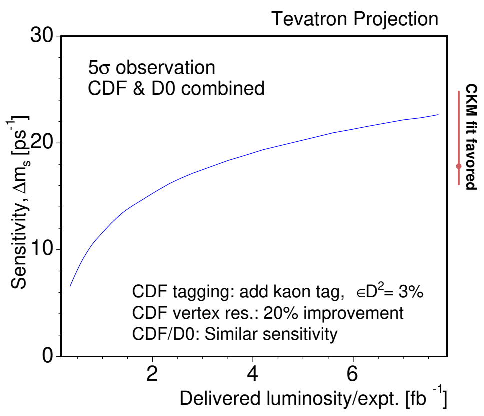

Figure 9: The Tevatron B_s mixing 5σ discovery projection, as a function of delivered luminosity per experiment.

modes, underscore the critical importance of the development of a multi-fb^{-1} CDF-II physics programme. The shortened time-to-discovery that such a complementarity between the LHC and Tevatron programmes will promote will also serve to inform urgent planning for the International Linear Collider.

Supersymmetric mass scales could be accessible to the Tevatron if SUSY is the mechanism for maintaining radiative stability at both the electroweak and GUT energy scales. Using the most straightforward model-independent signature of jets and missing transverse energy, the mass discovery reach for gluinos and squarks increases by over 20 GeV for an increase in time-integrated luminosity from 2 fb^{-1} to 8 fb^{-1}. In the case of gaugino-partner (chargino and neutralino) production with the distinctive decay signature of no jets, three charged leptons, and missing transverse energy, the gain from luminosity is even greater: 30 GeV for chargino masses when increasing from 2 fb^{-1} to 4 fb^{-1}, and an additional 30 GeV from 4 fb^{-1} to 8 fb^{-1}. It has been noted that these gains in reach exceed those that were achievable by the energy increase throughout the LEP2 program.

Run II has already been able to exclude part of the light-mass regions of MSSM Higgs boson predictions. There exists the exciting prospect, however, of a discovery by the Tevatron of MSSM Higgs bosons in the large $\tan\beta$ region. For $\tan\beta = 60$, the 3σ reach is expected to range up to masses of 180 GeV for 1 fb^{-1} and 240 GeV for 8 fb^{-1}.

Profound constraints placed on descriptions of electroweak symmetry breaking are driven by the experimentally challenging reduction of measurement uncertainties on the masses of the top quark and W boson. As the integrated luminosity increases from 2 fb^{-1} to 4 fb^{-1}, for example, the anticipated uncertainties on the masses are expected to improve by $\sim 20\%$; refer to Fig. 10. Once direct evidence for a Higgs or similar mechanism begins to be revealed, these precision measurements will be key to decisive tests of the theory.

Clearly, some measurements made using the anticipated Tevatron Run II data will later be repeated at the LHC with enhanced statistics. We note, however, that in some cases the two accelerators probe different regions of initial-state dynamics, by virtue of the different beam

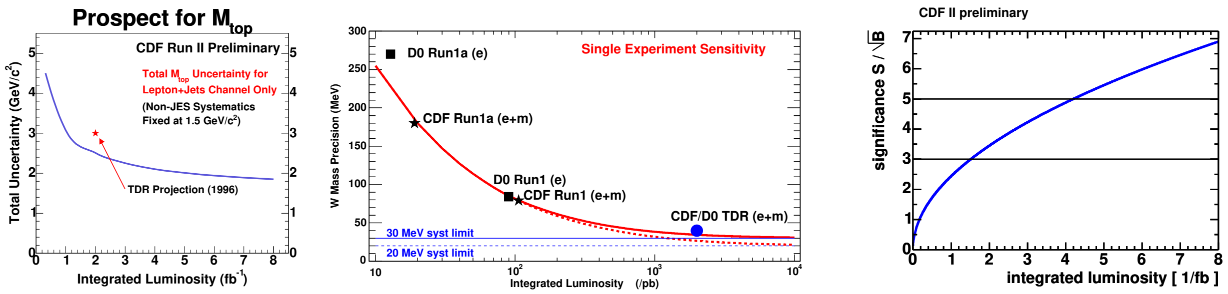

Figure 10: **[left]** Total uncertainty on m_{top} for CDF in the lepton-plus-jets channel alone; the reduction with luminosity is driven by the statistical nature of the jet-energy-scale (JES) uncertainty. **[centre]** Extrapolation of the scaling of the m_W uncertainty with increasing luminosity. **[right]** Projected sensitivity for single-top production for the s and t channels combined, not taking into account systematic uncertainties.

energies and particles. In addition to the complementary low-mass Higgs reaches mentioned above, electroweak single-top production at the two accelerators is expected to have differing contributions to the s and t channels, each of which have different sensitivities to new physics processes. Single-top production may first be observed (5σ) at the Tevatron using a time-integrated luminosity of $5-7$ fb^{-1}; refer to the projection depicted in Fig. 10. In a similar spirit, and to enhance the chances of discovering physics beyond the SM, efforts to understand the relative strengths of different $b\bar{b}$ and $t\bar{t}$ QCD hadroproduction mechanisms at the Tevatron are needed for comparisons with similar measurements to be made at the LHC, where the same production mechanisms are anticipated to contribute with markedly different weights.

The CDF physics program has begun productively in both an energy-frontier and precision capacity, following a significant investment of scientific, technical, and financial resources. Following through on this investment, the multi-fb^{-1} Tevatron Run II plan will cover an exciting period at the discovery and sensitivity frontiers in a manner that is both unique and complementary to LHC turn-on and commissioning.

D. The Canadian Responsibilities in CDF-II

The CDF detector was rolled onto the Tevatron beamline in March 2001 and commissioned int he following 18 months. Between October 2002 and July 2004 we recorded 400 pb^{-1} of data that is now being used to produce physics. We surpassed the 1 fb^{-1} mark in August of 2005 and are on track to record 1.5 fb^{-1} of data prior to the next scheduled shutdown in March 2006. Over the next three years the Fermilab plan calls for a further doubling of our dataset by Spring 2007 and yet another doubling by the end of 2008 – at which point we should have in excess of 6 fb^{-1} of data for physics studies. This represents a factor of fifteen more data than is currently under available and will give us access to a wealth of new measurements.

In order to achieve this goal we must continue to operate CDF efficiently over the next three years and preserve the detector and trigger performance in the face of instantaneous luminosities that will more than double during that period. The IPP group is contributing to CDF-II in four ways: First, our CFI computing infrastructure has allowed us to continue take responsibility for the generation of the bulk of CDF-II's Monte Carlo simulation samples for physics analyses. Second, we play a growing role in the development of tools to facilitate off-site computing and maintain the calorimeter reconstruction software we developed for Run II. Third, we remain involved in the silicon vertex detector performance studies. Each of these contributions will be described in more detail in the sections that follow. Finally, we provide personnel to staff 20 one week-long shifts at Fermilab each year – our share of this aspect of CDF operations.

(i) Monte Carlo Production

Over the last two years the IPP-CDF group has lead the coordination and the production of large-scale physics simulation datasets for the CDF collaboration. Since 2004 Warburton has been the co-convener of the Monte Carlo simulation project taking on the additional responsibility for the quality of the CDF detector simulation software. The Canadian commitment is detailed in a memorandum of understanding, that specifies our responsibilities of coordinating all large-scale Monte Carlo production and providing the equivalent of one million $t\bar{t}$ simulated events per day.

While Warburton has taken on the role leader of the CDF Simulation Group, Mazini and Snihur have shared the responsibility for leading the Monte Carlo dataset production group. While this started out as a body responsible for identifying collaboration-wide simulation sample priorities, producing the simulation sets required and ensuring that standard techniques and validation procedures were uniformly employed, it has grown over the last two years to include the organization and prioritisation of large sample requests made to all off-site CDF computing farms around the world. In addition Snihur has developed new tools that allow these datasets to be efficiently cataloged at FNAL thereby making them accessible to users throughout the collaboration. Close contacts with the CDF physics groups (bottom, electroweak, exotics, QCD, and top) have been successfully maintained through liaison physics-group representatives who are members of the Monte Carlo Production Group. The collaboration continues to rely on the service work contributions of Snihur developing CDF simulation infrastructure and Mazini and Beauchemin executing the Monte Carlo production tasks, including day-to-day operations of the Canadian clusters.

(a) Computing Facilities

The Alberta, McGill, and Toronto groups have committed a minimum equivalent of 250 1 GHz CPUs to the CDF off-site Monte Carlo computing effort. The Toronto cluster consists of 224 dual-Pentium-4 nodes, each with two 2.4 GHz processors (a 1.1 THz cluster) and 2 GB of RAM; 14 dual-Pentium fileservers, each with 2 TB (raw) of SCSI RAID disk; Gigabit Ethernet interconnectivity; and 1 Gb/s optical connectivity to CA*net 4. In order to make optimal use of this computing facility the CDF-IPP group has added a 4 TB disk server that allows us to store the datasets necessary for analyses undertaken by the Canadian group members. While this computing facility has been crucial to our analyses so far, it is coming under increasing pressure from the ATLAS Canada collaboration as they approach data-taking. The lack of disk storage space will become a serious concern as we tackle datasets that are an order of magnitude larger than what we have analysed so far. The Toronto HEP group has submitted a seprate RTI grant to address this concern.

The Alberta Thor multiprocessor facility consists of 170 2 GHz processors with 4 TB of disk connected via an optical 1 Gb/s link to CA*net 4. Approximately 50 processors from the Thor facility are being used for CDF Monte Carlo sample generation. *I know the following is no longer the best information about HEP computing at McGill, but don't know enough about the new CFI computing that Andreas, Brigitte and Steve got at McGill. Andreas should work on this last couple of sentences...* The McGill theoretical condensed matter CFI cluster has 350 Athlon dual-processor nodes, $\sim$2 GHz per CPU and $\sim$2 GB of RAM per node, a GHz Black Diamond telecom switch, $\sim$12.6 TB of disk distributed across the nodes, and a 100 Mb/s connection to the campus backbone; up to 20% of this cluster's resources have been used for CDF-II computing.

(b) Performance

Between December 2004 and August 2005, 225 million Monte Carlo events were produced on Canadian farms for official large-scale samples. This consumed more than 10,000 CPU days on our machines (described above) or about 30% of the processing power of the Toronto cluster. These events populated *yyy* data sets[2] and used 19 TB, all of which was network transferred to Fermilab by Mazini and Caron. For the summer 2005 conference season, zz% of all official CDF Monte Carlo events were produced using Canadian resources, both in the form of computing equipment and personnel.

(ii) Calorimeter Energy Reconstruction

The IPP group is a strong participant in the understanding and utilisation of the CDF calorimeter systems. This work fits well with our previous experience on CDF-I and ZEUS, and meshes with our activities on the ATLAS calorimeter. In terms of physics aims, our work has two main themes: understanding the jet energy scale in order to make a precision measurement of the top mass, and understanding the $\not\!E_{\mathrm{T}}$ performance in order to study non-Standard-Model signatures involving neutral penetrating particles.

The understanding of the jet-energy scale and resolution has been the most important factor in the initial measurements of the top-quark mass in Run II of the Tevatron. Our group has been involved in many areas related to jets. Spreitzer is responsible for the jet reconstruction software development and maintenance. A recently graduated student (Arguin) and Sinervo have developed the jet-energy corrections for the underlying event and multiple interactions per bunch crossing. We have also developed a technique to study the response of low-p_T jets using photon-jet balancing, a method in which the photon undergoes conversion and is detectable by the tracking system. Finally they have applied this to the measurement of the top quark massing, constraining the energies of the two light quark jets in top decay to the W boson mass, to produce the single most precise measurement of the top quark mass as of September 2005. In related work, Sabik and

[2]The number of data sets produced provides a measure of the HQP processing costs involved in such large-scale production; each sample has overhead related to prioritisation, set up, submission, logging, validation, transferring to Fermilab, and bookkeeping.

Savard have studied the tracking efficiency in the core of jets, an essential part of the understanding of the absolute energy scale, another key ingredient to top quark mass measurements.

A typical search for non-Standard-Model physics involving missing energy is the search for evidence of superpartner production. The most critical aspect of such a search is a reliable understanding of both the resolution functions and systematic uncertainties of the hadron calorimeter system. MacQueen worked full time on these issues for two years, with Orr providing supervision, as part of his service work. More recently Spreitzer, with supervision from Savard, has taken over these efforts as part of their interest in searches for new physics in high $\not\!\!E_T$ events. Currently, we are working on filter code to clean up $\not\!\!E_T$ data samples. This is mainly pattern recognition studies to remove spurious $\not\!\!E_T$ due to beam halo from upstream machine components. Snihur, who has considerable experience in CDF data validation in general and jet reconstruction in particular, continues to provide oversight in the area of calorimeter data validation.

(iii) Silicon Tracker Alignment and Operations

The Canadian group made two hardware contributions to the CDF-II silicon tracker. These consisted of a set of precisely positionable feet for the three SVX-II barrels, allowing them to be aligned parallel to one another to better than 40 μrad, and a set of remote controlled positioning motors that enables us to re-orient the whole silicon tracker with a precision of better than 10 μrad. Both of these are necessary to ensure optimal operation of our silicon track trigger, which reconstructs track impact parameters in the plane perpendicular to the detector axis. These hardware contributions led naturally to our playing major roles in assembly and installation of the silicon tracker. We have also led interventions on two occasions, since then, to re-orient the silicon tracker when the beam has drifted more than 100 μrad from the silicon tracker axis, the most recent of these dates back to 2003. We no longer foresee having to re-orient the silicon detector, although we continue to monitor the orientation of the tracker with respect to the beamline. Our experience in silicon position monitoring was extended by Vollrath, with supervision from Savard, to monitor the position of the end-plug calorimeters. After openings to service the tracker, or (infrequent) quenches of the CDF solenoid, these detectors can move by several millimeters. Prototype optical position monitors were installed on the end-plug calorimeters in late 2004 and their effectiveness is being evaluated.

Our involvement in the silicon tracker has led naturally to two sets of detector performance studies. Lai and Sabik have led the effort to understand the shape of the interaction region in CDF with supervision from Trischuk. Over the last year, our interaction region shape measurements have been scrutinized by Tevatron machine experts searching for clues to couplings between the horizontal and vertical machine tunes that could explain the 10% differences in instantaneous luminosity seen between CDF and D0. We have also become heavily involved in the alignment of the silicon tracker. Since late 2002, one of us (Trischuk) has led the silicon detector performance study group (that has about a dozen active studies). Two of our students who recently graduated focused their service work on the effort to understand the intrinsic resolution of our novel innermost “layer 00” silicon ladders. This device is mounted directly on the beampipe at radii between 1.5 and 1.7 cm from the beam line. As a result of their work layer 00 is now an integral part of our physics studies and will be a key to improving the incisiveness of CDF’s measurement of the B_s^0 oscillation rate.

As a result of his work in the silicon studies group, Trischuk took on the added responsibility of overall silicon project co-leader in 2003-04 There he led a group of graduate students, postdocs, and other researchers/faculty members (about 20 FTE from ten institutions) in the collaboration and was responsible for all aspects of the silicon detector's operation, maintenance, and exploitation. One of the main emphasis of his time a silicon project leader was the streamlining of silicon operations that was becoming more and more critical as the emphasis of the collaboration shifted to data analysis, or hardware projects that were not part of the CDF programme.

We will continue our detector performance studies of the silicon tracker, as performance needs fed back from physics studies dictate and as student effort is available. Although we are very close to the design resolutions of all elements of the detector the issues will focus more on maintaining this performance as occupancies increase – with higher luminosities – as well as monitoring detector performance as the sensors begin to approach their radiation dose lifetime. This experience will be invaluable as similar fates await the silicon trackers in ATLAS where will be headed next. This work provides the basis for service work contributions to the collaboration of at least one faculty member and one or more students.

(iv) Offsite Computing

In order to fully exploit the computing facilities available in Canada to generate MC sets (see above) or perform physics analyses we need to simplify offsite operation of the CDF simulation and reconstruction programs. As our team grew with the addition of physicists and programmers from Alberta group we have undertaken additional service tasks designed to facilitate offsite computing. These activities are outlined in this section.

(a) Service Activities in the CDF Database Group

Hamilton's service work involved upgrading the tools used to monitor offline database usage and develop software tools to assist in offsite database monitoring. The goal of this monitoring effort is to ensure the CDF offline database meets the heavy demands of the collaboration without interruption due to an overload failure. The bulk of the work is determining which users are putting the highest demands on the database and then determining if that demand can be reduced without sacrificing the user's physics goals. This work has been crucial to CDF's ability to harness off-site computing resources as we move into the era of Grid computing.

(b) Activity on SAM

At present, prototype installations of the CDF CAF (Central Analysis Facility) and SAM (Sequential Access to Metadata) Grid servers are installed at Alberta and are integrated with the THOR Linux cluster. Both systems are fully kerberized to comply with Fermilab computing security policies. Once both the remote CAF and SAM stations have been fully tested, the JIM (Job and Information Management) system of the CDF Grid installation will be added to the Alberta infrastructure.

In addition to the CDF SAM Grid installation, Caron is contributing to performance monitoring software for the central CDF CAF system. Performance information is collected using the Ganglia distributed monitoring and execution system, allowing for the eventual display of information from the federations of clusters and Grids that are part of the CDF SAM Grid.

E. Summary

The IPP group on CDF now has six faculty, four research associates and ten graduate students working on the project. In the past we have filled a number of leadership roles in the collaboration including: reconstruction software project leader (Sinervo, 1993-1995), calorimetry reconstruction leader (Savard, 1998-2000), speakers committee chair (Trischuk, 1999-2001), top physics convener (Savard 2000-2002), physics software project leader (Savard, 2002-2003), silicon tracker project leader (Trischuk, 2003-2004). We currently have responsibility for the offline production manager (Savard 2004-) and Monte Carlo simulation convener (Warburton, 2003-). In addition members of our group have served on a number of internal committees, ranging from those reviewing physics prior to publication, reviews of detector upgrade proposals and most recently an evaluation of the current silicon detector lifetime. The table below summarises the operational responsibilities and physics activities of all members of the group that have been described in more detail in our proposal.

Name	Position	Joined	Service Work	Physics Interest
R.S. Orr	Faculty	2000	Calorimeter software	Supersymmetry searches
J. Pinfold	Faculty	2001	Database access offsite	Diffractive Higgs production
P. Savard	Faculty	1998	Head Offline Operations	Top physics, exotic searches
P.K. Sinervo	Faculty	1991	Calorimetry software	Top mass
W. Trischuk	Faculty	1996	Silicon offline reconstruction software	W mass
A. Warburton	Faculty	2002	MC dataset coordination	Heavy quark production
H. Beauchemin	Research Assoc.	2004	MC dataset production	Di-lepton searches
B. Caron	Computing phys.	2002	MC dataset production	
S. Carron	Research Assoc.	2005	Calorimeter software?	Top Physics
R. Mazini	Research Assoc.	2003	MC dataset production	Di-Boson MC generators
R. Snihur	Research Assoc.	2003	MC production tools	QCD physics
A. Buzatu	PhD Student	2004	Monte Carlo Production	Top Physics
A. Hamilton	PhD Student	2002	Monitoring offsite database usage	Diffractive Higgs production
S. Lai	PhD Student	2000	Beamline measurement	Search for $t\bar{t}H$ production
D. MacQueen	PhD Student	2000	Missing energy algorithms	Search for Supersymmetry
S. Pashapour	PhD Student	2000	Calorimeter simulation validation	Top production mechanisms
P. Roy	MSc Student	2005	Monte Carlo Validation	
S. Sabik	PhD Student	2001	Silicon support upgrades	Top mass measurement
T. Spreitzer	PhD Student	2004	Calorimeter Reconstruction software	Top mass measurement
I. Vollrath	PhD Student	2001	Detector position monitoring	Measurement of the W mass
G. Williams	PhD Student	2003	MC event generator librarian	B meson production
L. Zhang	PhD Student	2005	MC dataset production	Diffractive production

Several students have recently graduated from the CDF-II project in Canada over the last year. Bernd Stelzer was awarded a Humboldt Fellowship and is now a research associate with the UCLA group on CDF. Jean-Francois Arguin won a Chamberlain Fellowship at the Lawrence Berkeley National Laboratory where he is shifting his research focus to the ATLAS experiment at CERN. Oliver Stelzer-Chilton has won one of the first Marie Curie Fellowships for postdoctoral research from the European Union. He will use it to continue his study of the W boson mass with the Oxford group on CDF.

We have also had several research associates move on to other positions from the CDF-II project over the last few years. Dr. Michael Riveline is now a senior research associate at the Weizmann Institute in Israel where he is working on the ZEUS experiment. Dr. Kostas Kordas has taken a staff scientist position at the INFN lab in Frascati where he is working on the ATLAS experiment. Dr. Reda Tafirout has recently taken a permanent staff scientist position at TRIUMF where he is responsible for the ATLAS-Canada LHC Tier 1 computing centre.

Members of our group are currently producing physics measurements from 300 to 500 pb^{-1} of data collected through the spring of 2004. We recently recorded our first full 1 fb^{-1} data sample in August 2005 and expect to accumulate a total of 1.5 fb^{-1} before the spring 2006 shutdown. Two further doublings , first to surpass the original Run II physics goal of 2 fb^{-1}, and then to an excess of 4 fb^{-1} are planned, by early 2007 and late 2008, respectively. CDF will remain the pre-eminent collider experiment until the start of LHC data-taking and the CDF/IPP group is well positioned to continue to lead key physics analyses over that period.

F. Explanation of Budget Details and Justification

In 2004-05 the IPP CDF-II group received \$540k in operating support from a NSERC Project grant awarded in 2003. These funds have been augmented by approximately \$30k per annum in operating support from the University of Toronto plus \$15 from FQRNT per year with an additional \$12.5 one-time equipment grant. The \$30k per annum of University support will be reduced to \$20k in the next three years and the FQRNT funds have now been exhausted. The group also relies on 0.5 FTE of technical and computing support provided by Major Facilities Access grants held by the University of Toronto group.

This funding has provided the minimum resources to support approximately 3.5 research associates (RA), 15 graduate students and the six faculty members involved in the project. We note that with the two new faculty members joining the IPP-Canada group, the number of students incresed to 14 over the course of the last grant.

The group's finances have benefited in the past from three students holding NSERC PGS scholarships. Two of those students have now graduated and the third student's scholarship has expired. We only intend to take on one new M.Sc student in 2006 and therefore we do not anticipate such external support again in the future.

(i) Operating Support

We have estimated the operating support requirements for the CDF-II project from our 15-year-long experience on the experiment, our operational commitments and the level of effort required to extract physics results from the CDF-II data set.

The primary budget "drivers" are the personnel commitments for RAs and graduate students. In section **D** of our proposal we have justified half of the time of the personnel for which we are requesting funds. The other half of their time is devoted to physics analyses (outlined in section **B**). This is summarised in the table in section **E**. A reduction in this effort would require us to renegotiate our role in the CDF-II experiment and reduce our physics analysis effort at a time when the most exciting results are at hand.

We are requesting funding for the 3 research associates currently working with us in 06-07, with a ramp-down to one RA in the last year of this grant. This is to be compared to the 3.5 research associate we currently support. The three research associates will work full time on CDF and will do physics analyses at a critical time when datasets in the inverse femtobarn range are available. We want to emphasize the fact that we have analysed only 30% of the data that is now available and only 10% of the data that will have been collected in 2007. Given NSERC's signficant investment in the CDF II experiment and its physics programme, it is easy to justify supporting these research asscoiates at a time when the physics output of the experiment reaches its maximum.

Our request for student support is consistent with our commitments to the current students in our groups and reflects significant support provided to the students by the host universities. At this point in the experiment, the financial resources necessary to adequately support our students and their analysis needs are well understood. We anticipate that we will take one additonal M.Sc. student in the next 3 years.

Our travel costs are based on our recent experience, anticipated numbers of field trips to Fermilab, the need to support 2 people at Fermilab to take shifts over 4 month periods per year, and to support one research associate living in Chicago (the latter two are listed as cost of living adjustments (COLA) in the budget tables. We make extensive use of extisting videoconference equipment at all three of our institutions. These reduce our overall travel requirements by providing us with connections to over 10 hours of meetings per week. When working in smaller analysis groups, we supplement video conferencing with phone conferences and the electronic exchange of documents. Without these additional capabilities we would attend less than half of these meetings at twice the cost. The video facilities have allowed us to integrate new members of the group into CDF physics discussions at an early stage, before their presence at Fermilab would be necessitated to discuss analyses of their own. Taking this into account, we find that senior graduate students need to travel to Fermilab on average 5 times per year while junior students will typically go twice. These trips normally include a Collaboration meeting. These field trips to Fermilab has allowed our students to make significant contributions in supporting the experiment and has allowed them to play central roles in large analysis groups (e.g. top quark and W boson mass).

(ii) CDF-II Common Fund

A change in funding of the Fermilab CDF operations budget in 1999 required that all non-US collaborators contribute to a "Common Fund," which has been set at \$5k US per Ph.D. physicist per annum based on the average annual materials and supplies budget of the CDF experiment. This commitment, which is being met by most foreign collaborators (including us), represents a minimum additional burden on our group of \$20k US per year. The \$5k US per physicist level of support is reviewed annually by the International Finance Committee of CDF. Although there has been some discussion of offsetting cash contributions to the common fund on the basis of off-site computing resources made available to the collaboration – offsetting resources that would have otherwise been provided by Fermilab – no agreement has yet been reached. We have contributed to the common fund in the form of equipment purchased for the CDF control room, data analysis cluster and video conferencing and projection systems for meeting rooms. This equipment remains the property of Canadian based researchers but is on indefinite loan to CDF. Over the last three years these items have been purchased with funds from our NSERC project grant.

(iii) Anticipated Expenditure Trends

With these considerations in mind, we include copies of our proposed budget at each of the three institutions over the next three years, taking into account recent experience in cost trends. During this time we have planned for a reduction of the current group as the current cohort of students graduates and the faculty members increase their committement to the ATLAS experiment.

Research associate salaries are about 5% higher now than they were two years ago and we still find it difficult to compete on the open market with US institutions for postdocs at the salaries we are able to pay.

Student support represents the single largest item in our request for NSERC funding. Our request for NSERC student support reflects approximately $10k per year of support that is provided to our students by our physics departments in the form of scholarships and teaching assistanceships.

Our proposed travel costs are affected by the US-CDN exchange rate, which we have assumed to be $1.2 CDN = $1 US and increases in airfare due to higher oil prices.

Dissertations and Theses from the CDF/IPP group

G. Sganos, "b Quark Production Cross Section Measurements at $\overline{p}\ p$ Colliders," M.Sc. report, University of Toronto (September 1991).

R. Grindley, "Collider Triggering: The Art of the Cut," M.Sc. report, University of Toronto (September 1991).

A. Warburton, "Exclusive Nonleptonic Weak Decays of Beauty Mesons and their Detection at the CDF," M.Sc. report, University of Toronto (August 1992).

Y. Ye, "Search for the decay $B^{\pm} \to \chi_c K^{\pm}$ at CDF," M.Sc. thesis, McGill University (April 1993).

K. Kordas, "Comparison of CDF Electron Response between Test Beam and Simulation," M.Sc. thesis, McGill University (July 1993).

W. Taylor, "$B^{\circ} - \overline{B}^{\circ}$ Mixing," M.Sc. report, University of Toronto (August 1993).

P. Musgrave, "An error reporting system for the upgraded CDF data acquisition system", M.Sc. thesis, McGill University (November 1993).

G. Sganos, "A Study of B Meson Decays Involving a J/ψ Meson," Ph.D., University of Toronto (June 1996).

R. Cropp, “Quarkonium Production in High Energy Hadron Colliders,” M.Sc. thesis, University of Toronto (August 1997).

A. Robinson, “New Strong Interactions and Top Quark Properties,” M.Sc. thesis, University of Toronto (August 1997).

A. Warburton, “A Study of Exclusive Nonleptonic Decays of B mesons into Final States of Strange Mesons and 1S or 2S Charmonia,” Ph.D., University of Toronto (December 1997).

B. Hinrichsen, “A Measurement of the Dijet Mass Differential Cross Section in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV,” Ph.D., University of Toronto (January 1999).

W. Taylor, “A Measurement of b-quark Fragmentation Fractions in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV,” Ph.D., University of Toronto (January 1999).

H. S. Kim, “Search for W' Bosons at CDF,” Ph.D., University of Toronto (June 1999).

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R. Cropp, “A Measurment of the Polarisation of J/ψ Mesons Produced in High-Energy Proton-Antiproton Collisions,” Ph.D., University of Toronto (August 2000).

S. Lai, “A Search for Higgs Production associated with $t\bar{t}$ Candiates at CDF-II,” M.Sc., University of Toronto (August 2001).

S. Pashapour, “Top Production at CDF-II,” M.Sc., University of Toronto (September 2001).

I. Vollrath, “The Forward Backward Asymmetry in $W^{\pm}$ Production at CDF-II,” M.Sc., University of Toronto (August 2002).