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**New Mexico Center for Particle Physics:
Studies of Fundamental Interactions**

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New Mexico Center for Particle Physics: Studies of Fundamental Interactions

Project Summary

The New Mexico Center/UNM group research program includes the CDF experiment at Fermilab and the SDC experiment at the SSC. In both experiments the UNM group research focuses on silicon strip tracking systems. This Progress Report summarizes our research accomplishments from the last year. This document also requests funds for the New Mexico Center/UNM group for the second year of our three year program of research at the world's highest energy colliders.

The New Mexico Center, located in the Physics and Astronomy department at UNM in Albuquerque, facilitates the close collaboration of UNM with Los Alamos National Laboratory (LANL) on high energy physics projects of common interest. The New Mexico Center/UNM group is a university based experimental high energy physics group. To help UNM with the startup costs of the new high energy physics group, 49% of the academic salary of UNM faculty has been provided by LANL for the first two years of the New Mexico Center.

The present research goals of the New Mexico Center/UNM group are to develop and utilize precision silicon tracking to increase significantly the physics reach of the Tevatron, and to make possible the study of high- P_t physics at the SSC. The search for the t-quark in CDF is the primary goal of the upcoming Tevatron runs. The addition of new precision silicon vertex tracking detector(s): SVX, SVX', and SVX II are central to the identification and confirmation of the t-quark by CDF. The New Mexico Center/UNM group plays a major role in the SVX II upgrade and also has a critical role in the SVX' upgrade in CDF.

The silicon tracking system in SDC is essential for the performance of the entire detector; the silicon tracker also provides the most technical challenges. The assembly of the SDC forward silicon disks, and the initial assembly of the entire silicon tracking system will be done at LANL. The New Mexico Center/UNM group will focus on developing the capability to test and verify the electronic functioning of forward silicon disk subassemblies. This is a natural responsibility for UNM based on our proximity to LANL.

The New Mexico Center/UNM group's silicon tracking programs in CDF and SDC are central to the current and next generation of major collider physics experiments, and the similarity of instrumentation for the two experiments allows the group to have a major impact on both projects. Both programs are at the forefront of technology and of high energy physics research.

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1. Introduction

This report summarizes our research activities from the last year and presents our program of proposed research for the coming year. The majority of our research is on the new *SVX* vertex detectors for the CDF experiment and on the *vertex* physics at the world's highest available laboratory energy; the Tevatron $p\bar{p}$ collider at Fermilab. We are also making important contributions to the silicon tracking system for the SDC detector at the SSC laboratory.

The present research goals of the New Mexico Center/UNM group are to develop and utilize precision silicon tracking to increase significantly the physics reach of the Tevatron, and to make possible the study of high- P_t physics at the SSC. The search for the t-quark in CDF is the primary goal of the upcoming Tevatron runs. The addition of new precision vertex tracking detector(s): SVX, SVX', and SVX II are central to the identification and confirmation of the t-quark by CDF. These devices will also further the study of other high- P_t phenomena involving b-quarks and/or the production of prompt leptons, and have the potential for a rich program of b-physics at the Tevatron. The New Mexico Center/UNM group plays a major role in the SVX II upgrade and also has a critical role in the new SVX vertex detector and the SVX' upgrade in CDF.

The SDC experiment relies on a large central tracking system for particle identification, muon momentum measurements, calorimeter calibration, jet studies, etc. The silicon tracking system in SDC is essential for the performance of the entire detector; the silicon tracker also provides the most technical challenges. The assembly of the *forward* silicon disks, and the initial assembly of the entire silicon tracking system will be done at Los Alamos. The New Mexico Center/UNM group will focus on developing the capability to test and verify the electronic functioning of forward silicon disk subassemblies. This is a natural responsibility for UNM based on our proximity to LANL.

The outline of this Progress Report/Proposal is as follows. A short history of the New Mexico Center/UNM group is presented in Section 2. In Section 3 we review our contributions to the present CDF run, to the commissioning and operation of the new SVX vertex detector in CDF, and to the SVX' and SVX II vertex detector upgrades. The major UNM group effort of this last year was on the studies for, and preparation of, the Conceptual Design and Proposal for the SVX II vertex upgrade for CDF. The New Mexico Center/UNM group recent results, and research activities in SDC are summarized in Section 4. A summary of recent talks, technical notes, and papers by group members group is given in Section 5. Section 6 provides our proposed CDF research program for the coming year. The group research facilities are described in Section 7 and the personnel in Section 8. The proposed budget is presented in Section 9. Additional details are provided in several Appendices.

2. History of the New Mexico Center/UNM group

The New Mexico Center/UNM group formed in 1991. The group was initiated in response to the SSC, to the substantial interest at the University of New Mexico to participate in the SSC and in High Energy Physics, and to the growing program in silicon tracking systems for the GEM and SDC experiments at the nearby Los Alamos National Laboratory.

The initial focus of the New Mexico Center program is on precision tracking using silicon detectors. The exploitation of vertex and precision tracking is central to many of the most important physics goals of the Fermilab and SSC collider programs.

The New Mexico Center/UNM group has achieved a *fast start*. This is the result of many positive factors:

1. our collaboration with LANL and thus our special role in the SDC experiment,
2. the hiring of three new high energy faculty by UNM in 1991,
3. the financial support from:
 - *DOE*: Our initial grant with the DOE began July 1, 1992.
 - *LANL*: One half the academic salaries of the 3 new HEP faculty were provided by LANL for the first ~ 2 years of the New Mexico Center to help UNM start up this new group.
 - *TNRLC*: The New Mexico Center received *Infrastructure* grants from the TNRLC in 1991/92 and 1992/93 to help equip our laboratory and computation facilities, and to support our SSC and SDC R&D program.
 - *UNM*: Our initial program in CDF was supported by UNM. The University also supports our research by a partial return on overhead.

The New Mexico Center/UNM group now includes three faculty (Michael Gold, John Matthews, and Sally Seidel), and three research associates: Dr. Nicola Bacchetta (started February 1992), Dr. Mark Frautschi (started April 1992) and Dr. Tim Thomas (to start in December 1992). In addition several students are involved.

Our research program includes the CDF experiment at Fermilab and the SDC experiment at the SSC laboratory. The group joined CDF with responsibilities for the silicon vertex projects and with major responsibilities for the SVX II upgrade.

The group has been a leader in the conceptual design, in the physics and detector simulation studies, in the testing of detector prototypes for SVX II, and in the preparation of the SVX II *Progress Report* that was submitted to the Fermilab PAC in May 1992 and to the SVX II *Technical Proposal* that is about to be submitted. The New Mexico Center/UNM group collaborates closely with the LANL engineers and physicists on the SDC silicon tracking system. The group has been a leader in the study of radiation damage and annealing in cooled silicon detectors, in the evaluation of the impact of the material in the SDC tracking system on the SDC physics capabilities, and in the upcoming beam test of the SDC double sided silicon detectors at KEK.

In June 1992 Sally Seidel, for the UNM group, submitted a proposal to the American Physical Society to host the 1994 DPF meeting at UNM in Albuquerque. The New Mexico Center was reviewed in August as part of the TNRLC review of all *Infrastructure* grants. The group received one of the two *Excellent* reviews. In September 1992 the group joined the Rocky Mountain Consortium for High Energy Physics. With our increasing participation in SDC, the New Mexico Center/UNM group has applied to the SDC collaboration to become an institutional collaborator (distinct from LANL).

3. The CDF Program

3.1 Introduction

High energy physics has evolved to a level of size, complexity and sophistication such that typical experiments take place over a decade or more. Thus, in order to flourish the high energy physics program of today's research university must include both a long range commitment to detector development and an equivalent commitment to a current experiment. An essential part of the program of the New Mexico Center includes a major commitment to the Collider Detector experiment at Fermilab (CDF). The Fermilab Tevatron is currently providing colliding proton-antiproton beams and CDF is presently taking data with the prospect of collecting more than five times the data that was collected during the 1989 run.

CDF provides an opportunity to test the Standard Model and search for new phenomena at the highest available center of mass energies. Thus, the CDF experiment emphasizes the study of high p_t phenomena. The most important goal is to verify the Standard Model prediction of a sixth flavor, the top quark. CDF has placed a limit of $M_t > 91 \text{ GeV}/c^2$ at 95% confidence level based on the analysis of approximately 4 pb^{-1} of data taken in the 1989 run [1]. In addition, CDF has searched for additional gauge bosons (W' , Z'), supersymmetry, and other exotic particles, as well as evidence of substructure for quarks and leptons. The sensitivity of these searches will be increased by the data currently being taken by CDF as a result of both increased statistics and improved detector performance.

To carry out an aggressive program, CDF has implemented a number of detector upgrades in the current run including a silicon microvertex detector (SVX). The SVX will allow for higher efficiency and signal-to-noise for tagging b jets in top events. It will also greatly enhance the study of low p_t b physics. The large ($30 \mu\text{b}$) $b\bar{b}$ cross section at the Tevatron implies an enormous potential for the study of b physics. Already, CDF has obtained a number of important results: a measurement of the total b cross section from inclusive electrons and at low p_t (11.5 GeV) from exclusive reconstruction of $B^\pm \rightarrow \psi K^\pm$; inclusive ψ , ψ' cross sections; a measurement of the rate of $B\bar{B}$ mixing; a search for the Λ_b baryon, and a limit on the rare decay $B^0 \rightarrow \mu^+ \mu^-$. The SVX will provide an enhancement in resolution of more than an order of magnitude. As a result, the SVX will allow a wealth of additional b physics phenomena to be studied.

3.2 Progress Report

3.2.1 SVX Detector, and SVX' Upgrade

The construction of the SVX was completed in August of 1991, with commissioning and installation into the CDF detector by January 1992. Thus, the

1992 run of CDF began with the SVX detector fully functional. A tremendous contribution to the assembly, installation, and commissioning of the SVX was made by Dr. Nicola Bacchetta. Since joining the New Mexico Center/UNM group, Bacchetta has been resident at Fermilab. He led the SVX commissioning effort, during which the completed SVX detector was bench tested with the full data acquisition. The bench tests included pedestal studies and cosmic ray runs. Tests were also performed of the completed detector installed inside the VTX, the CDF inner TPC tracking chamber. Serious electronic cross talk problems were resolved as a result of Bacchetta's efforts. Once fully operational inside the VTX, the commissioning continued inside the full CDF detector. Bacchetta supervised this process on a daily basis. This process included daily operation of the detector (pedestal studies, noise studies, cosmic ray runs) and monitoring of detector safety. As a result of Bacchetta's conscientious monitoring he caught and averted an accident that almost destroyed the SVX.

The SVX is now operating successfully and very nearly at design specifications (see Appendix 1). The signal-to-noise ratio is high (9 to 1), allowing for clean track reconstruction and efficient data sparcification. The occupancy at 99% efficiency is about 4 ~ 6 %, where 2% is due to charged particles. The detector alignment was maintained to 25 μm during construction and installation. With preliminary alignment constants measured *in situ* from the data, the measured resolution is 13.6 μm — very nearly the intrinsic resolution of 12 μm .

Due to the high radiation environment of the Tevatron, the inner layers of the SVX are expected to operate only to an integrated dose (luminosity) of about 10 krad (10 pb^{-1}). Consequently, CDF is planning on rebuilding the SVX with radiation hard electronics. This upgrade, known as SVX', is planned for installation into CDF in the fall of 1993. Bacchetta is taking a leading role in the building and testing of the silicon ladders. He has designed and built a test stand with the full SVX data acquisition capable of testing up to one full wedge. He has also built a separate test stand for directly studying detector response using an infrared light source. This is a critical test of detector bonding for the upgrade which uses AC coupled detectors.

3.2.2 SVX II Upgrade

In order to accommodate the shortened (132 - 395 ns) bunch spacing and high radiation levels of the high luminosity Tevatron upgrade planned for the latter half of this decade, it is necessary to redesign and rebuild the vertex detector completely. This allows CDF the opportunity to design a vertex detector with enhanced performance optimized for high luminosity physics. For the past year, UNM has played a leading role in the CDF vertex upgrade (SVX II) design group, and in writing and editing the SVX II *Conceptual Design Progress Report*, and the SVX II *Simulation Study and Upgrade Proposal* [2,3].

In order to study the physics capabilities of alternative vertex detector designs, a fast, flexible tracking simulation Monte Carlo (SVXSIM) program was written at UNM. The development of this program, led by Professor Michael Gold, allowed Monte Carlo generated events to be simulated in various alternative geometries and with varying detector resolution. Together with Professors John Matthews, and Sally Seidel, and two students (Howard Barnum and Ron Manginell), they compared a number of alternative detector geometries: the SVX barrel design (51 cm), a double length, long barrel geometry (102 cm), a long barrel with forward disks, and an interleaved barrel plus disk geometry as shown in Fig. 1. SVXSIM allowed the only simulation of SVX II detector geometries including forward disks. The UNM development of the SVXSIM simulation package was critical to the CDF collaboration decision to propose a cylinder plus disk geometry for SVX II.

The simulation studies began with a verification of the program SVXSIM by Gold through detailed comparison to existing tracking simulations. Then, as an initial comparison of the alternative geometries, he studied the transverse impact parameter error (σ_D), z impact parameter error (σ_Z), and momentum resolution as a function of rapidity. Due to the elongated interaction region of the Tevatron, the long barrel geometry is necessary to provide high acceptance for central rapidity events. For the less central low p_t b physics, a forward disk system can provide tracking out to large rapidity. However, the multiple Coulomb scattering in the barrel silicon at large rapidity reduces the vertexing capabilities of the forward system. Reconstruction efficiency as a function of rapidity was investigated using a toy track reconstruction model. The position of forward disks was optimized for track reconstruction efficiency. The affect of a potentially degraded CDF central drift chamber efficiency at high luminosity was investigated. Loss or poor performance of the CDF central drift chamber inner layers at high luminosity would be a serious problem for the forward disks. This will have to be addressed in the final forward tracking design.

The SVX II design group studied several physics bench marks with which to evaluate design alternatives: Top decays, B decays, B, mixing, and CP violation in B decays. At the New Mexico Center, we focused on b jet tagging in top decays, vertexing of exclusive B decays, and the prospects for measurement of CP violation. Studies done by Matthews showed that the long barrel geometry provides an increase of 50% in tagging b jets in top decays over the SVX barrel geometry. He showed that the two dimensional readout provides an additional increase of from 10% to 30% depending on top mass. Two dimensional readout is also expected to improve background rejection. For B decays, a large increase in acceptance is achieved by doubling the barrel length, and a further increase of comparable size is achieved by adding the forward disks. For example, another study by Matthews showed that in $B\bar{B} \rightarrow \psi K_s, l^\pm$ events the efficiency for identifying all three leptons from displaced vertices is increased by 50% in the double length barrel geometry, and further increased by 70% with the addition of

forward tracking disks. The double sided detector provides an additional gain of 60% by increasing the vertexing efficiency. Large acceptance for this class of events is necessary to observe the very small contribution to the charge asymmetry in these events expected from weak CP violation. A study of the prospect for measuring CP violation was carried out by Gold working with a student, Howard Barnum (see Appendix 2). The study concludes that a 12% measurement of the CP violating parameter $\sin 2\beta$ from $B \rightarrow \psi K$, is possible with a 1 fb^{-1} data set. Studies of the mass resolution for exclusive B decays have been carried out by Seidel. These studies show that lengthening the barrel (so that tracks of interest are within the SVX II acceptance) and introducing three-dimensional readout improve mass resolution for important CP-violation channels such as $B \rightarrow \psi K^0$ and $B \rightarrow \psi \phi$. The study further shows that the addition of forward tracking improves acceptance for these channels by more than 50%. Seidel is presently incorporating a vertexing package into the simulation and guiding Manginell in exploring the resolution that can be obtained with vertex-constrained mass reconstruction. This latter effort is particularly targeted toward efficient extraction of $B \rightarrow \pi\pi$ decays from high combinatoric background and is part of an effort by Seidel to identify a strategy for observing that challenging CP-violating decay.

The conclusion of the SVX II design group is that the vertex detector upgrade should proceed in two stages. Stage one will be the construction of a long barrel with double sided silicon microstrip detectors. Stage two will augment this barrel detector with forward tracking disks, see Fig. 1. The technology for the forward disks is still under study.

A critical issue for SVX II is the z resolution as a function of track angle of incidence for double sided detectors. In order to fully understand the impact of strip pitch and signal-to-noise on the resolution, Dr. Mark Frautschi carried out a Monte Carlo study of the charge deposition on the microstrips. Building on the work of a previous simulation study [4], Frautschi investigated strip pulse height, charge sharing, strip clustering, and track resolution [5]. Three strip pitches were considered corresponding to 4, 3, and 2-times multiplexing per strip readout; the strip pitches were $73 \mu\text{m}$, $111 \mu\text{m}$, and $166 \mu\text{m}$ respectively. For a signal-to-noise ratio of 12:1, the larger strip width was found to be most robust. With a better signal-to-noise, the intermediate strip width gave acceptable resolution at large angles of incidence. We also considered *alternate strip readout* detectors with strip pitches of $73/2 \mu\text{m}$, $111/2 \mu\text{m}$, and $166/2 \mu\text{m}$ with readout every other strip. The larger strip pitch was found to perform well in detectors with alternate strip readout, see Fig. 2, and should result in a z resolution of $\sim 30 \mu\text{m}$ for track angles < 1 radian. The potential for minimizing the number of read-out channels together with the robustness of the larger strips makes the $166 \mu\text{m}$ strip pitch the leading option. For comparison the resolution in $r - \phi$ is $\sim 15 \mu\text{m}$ for detectors with a strip pitch of $50 \mu\text{m}$.

Seidel has recently broadened the SVX II Group's activities to include the study of prototype double sided silicon strip detectors for the SVX II upgrade. Her responsibilities are two-fold: first, to carry out an extensive program for characterizing AC-coupled double-sided detectors and secondly, to define the specifications for prototype and production detectors and serve as liaison with manufacturers of the devices in order to arrive at a design optimized for the CDF application. Double-sided detector technology is still young, and the use of double metal readout (see below) in a high-radiation environment such as the Tevatron is unprecedented. Consequently the information obtained in these detector studies will benefit not only CDF, but other collider experiments and the evolution of the technology in general.

The double-sided detectors required for use in CDF have very high channel density at the core of the active volume of the experiment. Consequently, these detectors should be designed in a way which allows both sides, with their orthogonal strips, to be read out at the barrel's ends. One proposed method to achieve this is the double-metal technology. A critical design parameter of this technology is the ohmic side capacitance. Working with Bacchetta, Seidel has obtained a preliminary measurement of this capacitance for a subset of channels of a Delphi-style detector. As no predictive calculation of the capacitance for these devices yet exists, an accurate measurement of this parameter is essential for extrapolation to a variety of possible detector geometries.

In order to carry out a program of detector characterization and electronics tests, a test bench has been set up at Fermilab to study the response of a detector (or a complete ladder as shown in Fig. 3) to ionizing radiation. Detectors can be mounted on custom-designed boards for operation with readout chips. The test facility includes a CAMAC based readout for the SVX detectors, the SRS/SDA system, to control the chips and digitize the data. The detectors are exposed to beta-radiation provided by a Sr-90 source. A scintillator provides the trigger, and there is an option for cutting on the beta energy and varying the impact angle of the radiation. Measurements will be made of the front-back charge correlation, n-side interstrip resistance, signal/noise for the p- and n-sides as a function of track angle, and cluster size and pulseheight distributions.

Seidel is preparing to duplicate and extend this system at UNM. Under her direction, Manginell is also equipping a probe station and identifying the necessary method and facilities for rapid quality control of production detectors. Donna Skinner has learned to setup and to operate the wire bonding machine. Under the direction of Matthews and Gold, an undergraduate student, Douglas McDonald, is assembling and learning to operate the precision, motor driven, computer controlled linear stages for use in silicon ladder testing.

3.2.3 CDF Data Run and Analysis

In addition to contributing to the CDF upgrade program, the New Mexico Center/UNM group is involved in the current data taking of the 1992 run. Bacchetta, Frautschi, Gold, Matthews, and Seidel are all participating in the rotating, ten day CDF shifts required to collect the data. Matthews contributed to the 1990/91 CDF test beam effort as well. In the future, Thomas and at least one student (Skinner) will also participate in shifts.

An essential part of the CDF program is the analysis of the data. In order to accomplish this, it is necessary to maintain a local copy of the CDF offline code. Gold has led the effort to port the current "production" version of the CDF offline code to UNM. Together with Frautschi and two of the students (Skinner and Manginell), they have ported the CDF offline to the local Vax cluster operating under VMS. In addition, Skinner has nearly completed the porting of the CDF offline to the Silicon Graphics operating under IRIX. Progress is being made on installing software to provide continuous maintenance and updating of the CDF offline. In addition, various essential analysis software tools have been installed, such as ISAJET, PAW, MN_FIT, and TOPDRAWER.

3.3 References

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- 3.2 *SVX II Conceptual Design Progress Report*, the CDF Collaboration, submitted to the PAC, May, 1992.
- 3.3 *SVX II Simulation Study and Upgrade Proposal*, the CDF Collaboration, to be submitted to the PAC.
- 3.4 *Spatial Resolution of Silicon Detectors. A Monte Carlo Study*, Lüth, Vera G., SLAC Report 1991.
- 3.5 *Resolution of Silicon Microstrip Detectors at Large Angles*, M. Frautschi, CDF/DOC/SEC-VTX/PUBLIC/1842 (October 1992)

Fig. 3.1: Schematic of the SVX II upgrade concepts showing: a) the present SVX with barrel geometry and total length of 51 cm, b) SVX II phase 1 with barrel geometry and total length of 102 cm (still contained within the VTX), and c) SVX II phase 2 as in b) but with the addition of disks for forward tracking.

Fig. 3.2: Simulation of detector z resolution (μm) VS track angle to the silicon detector (radians) for different values of the strip pitch and signal/noise: a) $S/N = 12$ and strip pitch (73, 111, 166) μm denoted ($\circ$, $\triangle$, $\diamond$), and b) $S/N = 18$ and strip pitch (73, 111, 166) μm denoted ($\square$, ∇ , and $+$).

Fig. 3.3: Schematic design of a SVX II silicon ladder

4. The SDC Program

4.1 Introduction

One member of the group, (Matthews), has been involved from the beginning of the SSC Subsystem R&D program, and had a major involvement in the initial design and optimization of the SDC silicon tracker. The New Mexico Center/UNM group has made, and continues to make, significant contributions to:

- R&D program on radiation damage to silicon strip detectors,
- Evaluating the impact of the material in the SDC tracking volume,
- Measuring the resolution of SDC silicon strip detectors at KEK,
- Interfacing the SDC physics requirements with the mechanical engineering group at LANL.

The New Mexico Center/UNM group is presently a member of SDC through Los Alamos National Laboratory. As discussed above, with our increasing involvement in SDC the UNM group has recently applied to join the SDC collaboration as an institutional member distinct from LANL.

4.2 Progress Report

- *Radiation Damage Studies in Silicon Detectors:* The New Mexico Center/UNM group (Matthews and Skinner) participated in a very successful radiation run using the HRS high intensity proton beam at LAMPF in July 1991. Prototype detectors, test structures, and electronics were exposed to a proton flux up to $\sim 10^{14}/\text{cm}^2$. As the silicon strip detectors for the SDC experiment are to be operated at 0°C , some detectors were maintained *cold* $\sim 0^\circ\text{C}$, during and after the run. The New Mexico Center/UNM group were leaders in the study of cooled detectors. The group fabricated the enclosures to keep the detectors cold during the radiation run, and we have been the group studying the annealing of all the *cold* detectors following the radiation run.

The studies of the long term annealing of cooled detectors has been done with three Hamamatsu PIN photodiodes. This type of detector has been used extensively by our collaboration to study radiation damage and annealing. One of these (PD28) is still cold (0°C), one (PD27) was returned to room ($20\text{-}23^\circ\text{C}$) temperature in mid January 1992 and one (PD29) was returned to room temperature in July 1992 and then stored with a bias voltage of 80 V applied.

Our observations are that the cold PIN photodiode(s) exhibit a very much slower change in the depletion voltage with time (long term anti-annealing) than photodiodes that are at room temperature. A comparison of the depletion voltage during the few day irradiation, and during the long term annealing is given in Fig. 1. Annealing is when the depletion voltage decrease with time (toward the initial values before irradiation), and anti-annealing is when the depletion voltage increases with time (following the end of irradiation). Cold photodiodes have a larger change in depletion voltage during the irradiation than warm photodiodes due to the significantly reduced short term annealing effects in the cold detectors. However, over long periods annealing does occur in the cold diodes, while there is little evidence for any anti-annealing. For the warm diodes there is an initial period of annealing but this is followed by long term anti-annealing. We have reported some of these results at conferences [1,2].

A comparison of the (anti-) annealing dependences for 4 photodiodes is summarized in Fig. 2. All these photodiodes had an exposure of $\sim 8 \times 10^{13}$ p/cm². PD20 was exposed warm and stored warm. PD27 and 29 were exposed cold, stored cold initially, and then stored warm, and PD 28 was exposed cold and stored cold. We observe that detectors exposed to the same particle fluence have approximately the same anti-annealing rate once stored at the same warm temperature. However PD29 that was stored warm with a 80 V bias voltage applied was found to anneal at approximately twice the rate of similar detectors that were stored at room temperature without bias. Fig. 1 shows that the depletion voltage following anti-annealing is probably > 60 V for the 170 μ m thick Hamamatsu photodiodes. This corresponds to ~ 200 V for 300 μ m silicon strip detectors. Thus the anti-annealing of the warm detectors results in an unacceptable increase of the detector depletion voltage with time, and it may be essential to keep the detectors cold to extend the overall lifetime of silicon tracking systems at the SSC.

A second successful radiation run was carried out in the HRS high intensity proton beam at LAMPF in September 1992. Five members of our group (Frautschi, Gold, Matthews, Seidel and Skinner) participated in the setup and the data run. We also supplied the online data monitoring system. Photodiodes for studying bulk damage in silicon, prototype silicon strip detectors, and prototype electronics were exposed to proton fluxes between $\sim 1 \times 10^{13}$ /cm² and $\sim 10 \times 10^{13}$ /cm². All detectors were operated at their normal operating bias. Most detectors and electronics were at room temperature, however some detectors were maintained "cold", $\sim 0^\circ\text{C}$, to simulate the operating environment of the SDC silicon tracking system. For this run UNM purchased and irradiated 15 Hamamatsu PIN photodiodes to study the specific question of very long term annealing following radiation

damage. The UNM photodiodes were divided into groups that were exposed to approximately one third, two thirds and to the full $\sim 10^{14}/\text{cm}^2$ flux to confirm our previous measurement of a linear behavior between *detector depletion voltage after long term annealing* and *total proton flux* [2]. These detectors will be annealed at different temperatures, and in particular at temperatures of $\sim 35^\circ\text{C}$ and $\sim 50^\circ\text{C}$ significantly above room temperature. By increasing the temperature, we hope to shorten the time for the detectors to reach a constant depletion voltage following annealing. Several of the detectors were kept cold to test the hypothesis that temperature does not change the level of radiation damage in the bulk silicon. We also need to test the long term annealing of cooled detectors which have a bias voltage applied; this is the operating environment when SDC is running at the SSC. These detectors have been transferred to UNM, and the temperature controlled enclosures are now completed. We anticipate starting the warm annealing any day. These important studies are being done by Frautschi and McDonald.

- *Impact of Material in the SDC Tracking Volume:* The New Mexico Center/UNM group (Matthews) made studies, and edited a report [3] summarizing the impact of the material in the SDC tracking volume on SDC physics performance. This study emphasized the importance to minimize the average material in the silicon tracking system to $\sim 5\%$. In addition the group participated in the preparation of the SDC silicon tracking Conceptual Design Report [4], and the SDC Technical Design Report [5].
- *KEK Beam Test of SDC Double Sided Silicon Detectors:* Prototype Double Sided Silicon Detectors (DSSD) for the SDC experiment have been produced by Hamamatsu. The resolution and overall performance of these detectors will be studied in a program using 2-4 GeV/c pion test beams at KEK.

The New Mexico Center/UNM group (Matthews and Frautschi), in consultation with engineers in the P2 and Me-12 groups at LANL, have designed the support and alignment system for the SDC silicon strip beam test at KEK later this fall and winter. The structure is shown in Fig. 3a and b. The support must be very compact and magnetically inert as it will be positioned in a 1.2 Tesla magnetic field. Additionally, the support must position five silicon strip detectors with a precision of better than ~ 25 microns and be stable in time at the few micron level. Finally, the support needs to provide two linear and two rotational motions to match the range of conditions of the silicon detectors in the barrel section of the SDC silicon tracker.

The construction and operation of the mechanical support is also the responsibility of our group. The construction is almost completed at this

time. The linear and rotation stages for the support and alignment system have been procured, the optical flat used to define the reference surface is also in hand, and the final machining and assembly is well advanced. The full mechanical support system will be delivered by late November 1992 in time for the check-out beam test in December at KEK.

- *SSC Physics*: A fast tracking simulation program has been written by the New Mexico Center/UNM group (Gold, Matthews, Seidel) in a different context, the SVX II upgrade of the silicon vertex detector in CDF discussed in Section 3, to study tracking issues in B and top physics. Adapting this simulation to review the optimization of the SDC silicon tracker for top physics at SSC turn on, i.e. at relatively low luminosities, is straight forward but remains to be done.

4.3 Proposed Program to the TNRLC for 1993

We have submitted a proposal to the TNRLC to develop the capability and the tools for the electronics verification of major sections and subassemblies of the SDC silicon tracking system. These tools are needed not only for the final subassembly verification, but also to carry out a systems test of the operation of many silicon modules as part of the final evaluation of the prototype SDC silicon tracking system electronics, cabling and power supplies.

The assembly of the SDC forward silicon disks, and the initial assembly of the entire silicon tracking system will be done at Los Alamos. We will focus on developing the capability to test and verify the correct electronic functioning of forward silicon disk subassemblies. This is a natural responsibility for UNM based on our proximity to LANL. The full test system will bring together contributions from all members of consortium proposal to the TNRLC. UNM will focus on the evaluation of *conventional* DC cabling and cable connectors, on the development and prototyping of a DC low voltage and high voltage power supply system including monitoring and safe voltage control, and ultimately on building an automated silicon test facility to test major sections and subassemblies of the SDC silicon tracker. A goal of this program is to provide an automated test facility which duplicates, and thus also prototypes, the final power, control and readout, and safety monitoring and interlocks of the silicon tracking system. The timely implementation of the test facility is important to the evaluation of the prototype electronics for the SDC silicon tracking system.

4.4 References

- 4.1 *Tests of the Radiation Hardness of Silicon Strip Detectors Under Neutron, Proton, and Gamma Irradiations*, H.-J. Ziock, et al, Proceedings IEEE Nucl. Sci. Symposium, Santa Fe, NM, (November 2-9, 1991)
- 4.2 *Temperature Effects on Radiation Damage to Silicon Detectors*, E. Barberis, et al, Proceedings of the 6th European Symposium on Semiconductor Detectors, Milan, Italy, UCR/SSC/92-01, (February 24-26 1992)
- 4.3 *Report of the Task Force on Impact of Material in Tracking Volume*, D. Adams, et al, SDC Report, (September, 1991)
- 4.4 *Silicon Tracking Conceptual Design Report*, A.J. Weinstein, et al, SCIPP 92/04, (March 1992)
- 4.5 *SDC Technical Design Report*, G.H. Trilling, et al, SDC Report, SDC-92-201, (April 1992)

Fig. 4.1: A comparison of the depletion voltage of Hamamatsu PIN photodiodes stored *warm* (~ 24-degrees C) or *cold* (~ 1-degrees C) during irradiation, and during *annealing*: a) shows the depletion voltage plotted VS the proton fluence during the irradiation, and b) shows the change in the depletion voltage with time after the end of the irradiation.

Fig. 4.2: A comparison of the long term *annealing* of four Hamamatsu photodiodes stored under different conditions of temperature and voltage.

Fig. 4.3a: Beam's eye view of the mechanical support and alignment structure for the beam test of Hamamatsu double sided silicon detectors at KEK.

Fig. 4.3b: Side view of the mechanical support and alignment structure for the beam test of Hamamatsu double sided silicon detectors at KEK.

5. Recent Talks, Reports, and Publications

5.1 Talks

1. *DAQ Issues*, J. Matthews, Talk, SSC Silicon Subsystem R&D Meeting on Front End Electronics, Cabling, and DAQ, U.C. (Santa Cruz), (April 29, 1991)
2. *Bremsstrahlung Issues*, J. Matthews, Talk, Impact of Tracking Material Task Force Meeting, SSC Laboratory, (June 19, 1991)
3. *Impact of Tracking Material*, J. Matthews, Review Talk, SDC Collaboration Meeting, SSC Laboratory, (June 20, 1991)
4. *Silicon Subsystem Meeting: e Bremsstrahlung Issues and SDC Tracking Material Budget*, J. Matthews, Talk, SSC Silicon Subsystem Meeting, U.C. (Santa Cruz), (August 1, 1991)
5. *e Bremsstrahlung Issues vs # of X_0 in the Tracking System*, J. Matthews, Talk, Impact of Tracking Material Task Force Meeting, LBL, (August 4, 1991)
6. *Impact of Material in Tracking Volume: Task Force Report*, J. Matthews, Review Talk, SDC Collaboration Meeting, LBL, (August 5, 1991)
7. *Measurement of $B_s - \bar{B}_s$ Mixing*, M. Gold, NP2 Colloquium, Las Alamos (December 1991)
8. *New Mexico Center for Particle Physics*, J. Matthews, Talk, Progress report presented to Texas National Research Laboratory Commission, Dallas, Texas, (December 1991)
9. *Mass Resolution in SVX II Geometries*, S. Seidel, Talk, CDF Collaboration meeting, (March 1992)
10. *A FASTBUS based test station for SVX-prime*, N. Bacchetta, Talk, CDF Collaboration meeting, (April 1992)
11. *Radiation Issues: Hot and Cold Data*, J. Matthews, Talk, SDC Silicon Tracking Subsystem Meeting, (April 22, 1992)
12. *SDC Silicon Tracking System*, J. Matthews, Invited Talk, Rocky Mountain Consortium Summer Workshops I, Boulder, CO, (July 14, 1992)
13. *Search for Exotic Particles at CDF*, M. Gold, Invited talk, XXVI International Conference on High Energy Physics, Dallas, Texas, (August 1992)

14. *New Mexico Center for Particle Physics*, J. Matthews, Talk, Infrastructure Review at the Texas National Research Laboratory Commission, Dallas, TX, (August 13, 1992)
15. *Overview of the CDF SVX upgrade*, N. Bacchetta, Invited talk, Yellowstone workshop on front-end electronics for silicon detectors at future high luminosity colliders, (September 1992)
16. *Detector capacitance of various double sided silicon detectors considered for SVXII*, N. Bacchetta, CDF Collaboration meeting, (September 1992)
17. *Resolution of Silicon Microstrip Detectors at Large Angles*, M. Frautschi, CDF Collaboration talk, (September 17, 1992)
18. *The Silicon Vertex Detector for CDF: design and performance*, N. Bacchetta, 78th National Conference of the Italian Physical Society, Pavia Italy, (October 1992)
19. *Specifications for the SVX II Double Sided Detectors*, S. Seidel, Talk, CDF Collaboration meeting, (October 1992)

5.2 Reports

1. *Tracking Task Force Report*, J. Matthews, SDC Report, (April 1991)
2. *Report of the Task Force on Impact of Material in Tracking Volume*, D. Adams, et al, SDC Report, (September, 1991)
3. *Subsystem R&D Progress Report for a Silicon Tracking System FY 1990-1991*, A. J. Weinstein, et al, SCIPP 91/28, (September, 1991)
4. *Silicon Tracking Conceptual Design Report*, A.J. Weinstein, et al, SCIPP 92/04, (March 1992)
5. *SDC Technical Design Report*, G.H. Trilling, et al, SDC Report, SDC-92-201, (April 1992)
6. *Resolution of Silicon Microstrip Detectors at Large Angles*, M. Frautschi, CDF/DOC/SEC-VTX/PUBLIC/1842 (October 1992)

5.3 Publications

1. Proceedings IEEE Nucl. Sci. Symposium, Santa Fe, NM, (November 2-9, 1991):
 - (a) Construction of the CDF Silicon Vertex Detector, B. Barnett, et al;
 - (b) The CDF Silicon Vertex Detector: An Overview and Test Results, W.C. Wester, et al;
 - (c) Tests of the Radiation Hardness of Silicon Strip Detectors Under Neutron, Proton, and Gamma Irradiations, H.-J. Ziock, et al.
2. *Temperature Effects on Radiation Damage to Silicon Detectors*, E. Barberis, et al, Proceedings of the 6th European Symposium on Semiconductor Detectors, Milan, Italy, UCR/SSC/92-01, (February 24-26 1992)
3. *A Measurement of the B Meson and b Quark Cross Section at $\sqrt{s} = 1.8$ TeV Using the Exclusive Decay $B^\pm \rightarrow J/\psi K^\pm$* , F. Abe et al., Phys. Rev. Lett. 68, 3403 (1992)
4. *Measurement of the Isolated Prompt Photon Cross Section Measurement in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV*, F. Abe et al., Phys. Rev. Lett. 68, 2734 (1992)
5. *A Measurement of the Production and Muonic Decay Rate of W and Z Bosons in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV*, F. Abe et al., Phys. Rev. Lett. 69, 28 (1992)
6. *Limit on the Rare Decay $W^\pm \rightarrow \gamma + \pi^\pm$ in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV*, F. Abe et al., Phys. Rev. Lett. 69, 2160 (1992)
7. *Limits on the Production of Massive Stable Charged Particles*, F. Abe et al., FERMILAB-PUB-92/152-E, submitted to Phys. Rev. D, Rapid Communications, (June 2, 1992)
8. *Operation of the CDF Silicon Vertex Detector with Colliding Beams at Fermilab*, F. Bedeschi, et al, FERMILAB-CONF-92/263-E, Proceedings of the XXVI International Conference on High Energy Physics, (August 6-12, 1992)
9. *Search for $\Lambda_b \rightarrow J/\psi \Lambda^0$ in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV*, F. Abe et al., FERMILAB-PUB-92/250-E, submitted to Phys. Rev. Lett. (September 22, 1992)

6. CDF Program Proposal

6.1 Introduction

The New Mexico Center/UNM group has accepted important responsibilities in the SVX' and SVX II projects. In addition the group provides support for the running of the SVX detector, as well as the entire CDF experiment. Following a year devoted mostly to commissioning the SVX, preparing for the construction of SVX', and completing the conceptual design and proposal for the SVX II upgrade, the group will now devote more time to the analysis of the data from the CDF data run. This will be helped by the increase in our *critical mass* at UNM with the arrival of Tim Thomas.

The New Mexico Center/UNM group studies of prototype 2-sided silicon strip detectors for SVX II that began last year will now be expanded to include additional vendors, and to include more complete studies of prototype double sided detectors. Although groups at LEP, Cornell and Fermilab are developing double sided detectors, R&D on the *double metal* readout for the 90° stereo strips in these detectors is still needed. Specifically, the SVX II upgrade requires that we find a solution to the readout of the 90° stereo strips; thus the UNM group has responsibilities for one of the most critical aspects of the SVX II project. Studies will need to be done both on probe stations and with detectors wirebonded to SVX-H readout chips. These studies, begun at Fermilab, will now also be done in our microelectronics measurement laboratory at UNM.

The strip capacitance of microstrip detectors limits the ultimate signal to noise achieved with these detectors. This capacitance may increase when the detectors are irradiated [1]. With the New Mexico Center/UNM group involvement in both the measurement of prototype detector strip capacitance and in the radiation damage program for the SSC, we are ideally suited to lead a study of the effect of radiation on strip capacitance. We will work to include SVX II detector prototypes into our upcoming radiation runs.

6.2 SVX'

The daily operation of the SVX is now becoming routine. Consequently Bacchetta will be free to focus much of his time on the SVX' construction. The SVX' must be completed and tested by mid-1993; this is a daunting challenge. Bacchetta's experience with the construction, installation, and commissioning of the SVX makes his contribution to this upgrade project invaluable. He will continue to lead the program of SVX' ladder testing. In addition, he and time permitting other members of the New Mexico Center/UNM group, will play a leading role in the assembly, installation, and commissioning of the SVX' detector.

6.3 SVX II

Double Sided Silicon Detector Studies

As discussed in Section 3, Seidel has recently broadened the SVX II Group's activities to include the study of the prototype double sided silicon detectors being considered for the SVX II upgrade. The double-sided detectors required for use in SVX II must be designed in a way which allows both sides, with their orthogonal strips, to be read out at the end of the detectors. One proposed method to achieve this is the double-metal technology. A critical design parameter of this technology is the ohmic side capacitance. Seidel, working with Bacchetta, have obtained a preliminary measurement of this capacitance for a subset of channels of a Delphi-style detector.

During 1993 Seidel will continue to refine capacitance measurements and to study other features associated with double metal readout of double-sided detectors produced by the Senter for Industriforskning (SI) of Oslo, Norway. One particular question to be addressed concerns the impact that the method for isolating n-side diffusion strips has on the n-side capacitance. A small number of detectors is being ordered from SI and from Hamamatsu Corporation with both field plate and p-implant isolation structures. Working with Bacchetta, Seidel will design a board to mount and operate these detectors. A dialogue has been established with the major vendors of these detectors, and it is our intention that feedback from these capacitance measurements to the vendors will result in a finalized specification for the production batch to be ordered for SVX II in 1993.

As discussed above, the strip capacitance of microstrip detectors may increase when the detectors are irradiated [1]. It is critical to the SVX II project to measure the actual change in capacitance with radiation. With the New Mexico Center/UNM group involvement in both the measurement of prototype detector strip capacitance and in the radiation damage program for the SSC, we are ideally suited to lead a study of the effect of radiation on strip capacitance. We will work to included SVX II detector prototypes into our upcoming radiation runs.

As part of this program the detector test station that has been set up at Fermilab will be duplicated at UNM to allow more group members to participate in these critical measurements. Substantial progress has already been made at UNM in duplicating the Fermilab facility. One goal for this year is to have both probe station and laser test stands at UNM fully functioning and active in the double sided detector R&D for SVX II. The particular emphasis will be on the measurement of the strip capacitance (before and after irradiation), and the testing of double sided detectors with both beta-radiation and a IR laser pulser. A second goal of these studies will be the effect of radiation damage on noise and pulseheight. The system will use a radioactive source and scintillator trigger to permit measurements of the front-back charge correlation, interstrip resistance,

pulseheight, cluster size, and signal-to-noise for both detector sides as a function of track energy and angle. The characterization of the other detector parameters of prototype double sided silicon detectors is also important and will be part of our program.

SVX II Readout and Detector Studies

One of us (Gold) has proposed building a stand alone (CAMAC or VME based) prototype of the optical data acquisition and control system. This is essential to the SVX II program.

- It will prototype concepts and components of the final data acquisition system. This includes the selection of the read-out protocol as well as an investigation of the *low speed, parallel read-out* versus *high speed port card* options.
- This data acquisition will be needed to verify the electronic functioning of prototype SVX II ladders. This will allow tests of pedestal stability, signal-to-noise, data sparsification and chip data buffering. In addition, this data acquisition system will be used to characterize completed ladders on a laser test stand to discover (and repair) broken wire bonds, identify dead channels, study strip pulse height, etc.

For the low speed, parallel read-out scheme, the reliability of the serial data transmission will be tested. If the port card option is chosen, the engineering and testing of the port card and the testing of chip addressing can be accomplished. Finally, chip analog and digital power supply delivery can be prototyped and tested in a realistic setting to ensure well regulated, low noise power.

Dr. Tim Thomas possess a significant background in electronics engineering and will collaborate in this effort. In addition, a fraction (25%) of an engineer will be needed to complete the design.

A prototype design of the front end read-out chip is essentially complete. Thus, the engineering of the prototype data acquisition can begin immediately. It is anticipated that six months will be needed to build this prototype. This schedule is very well matched to the schedule of the complete SVX II construction which is determined by the fall 1995 installation date for the complete system (Fig. 1). The schedule calls for prototype front end read-out chips in a radiation soft technology as well as prototype detectors to be available in the spring of 1993. With the completion of the proposed prototype data acquisition, this will allow for bench testing of ladder prototypes to begin in the late summer of 1993. The SVX II project schedule calls for the construction of prototype modules for the full data acquisition in the fall of 1993. The completion of the prototype data acquisition allows for experience gained to be incorporated into the full system design. Finally,

it is critical that a beam test of a full wedge prototype be carried out in the fall of 1994. It is likely that the full system data acquisition will not be available and operational in a test beam on that timescale.

Physics Simulation

In order to test fully the Standard Model mechanism for $\bar{C}P$ violation, it is necessary to search for CP violation in all decay channels available that independently constrain the model. The decay $B \rightarrow \pi^+\pi^-$ is interesting because it probes the sum of the V_{td} and V_{ub} phases. During 1993 Seidel and Manginell will continue to simulate and study this decay. Because of the decay's two-prong topology and the large number of primary charged pions produced in a $p - \bar{p}$ collision, $B \rightarrow \pi^+\pi^-$ has a high combinatoric background. Current thoughts are that the signal cannot be extracted without fully three dimensional tracking near the origin. It is anticipated that by the end of the first half of the year the group will have recommendations on an optimized program for topological background rejection and on the features of detector design (particularly in the forward region) which will guarantee the maximum possible acceptance for this signal.

6.4 CDF Data Run

As a member of CDF, the New Mexico Center has the opportunity as well as the obligation to participate in the all aspects of the data taking: hardware maintenance, shifts, data verification, code development, and data analysis. Our contribution to the hardware maintenance has been and will continue to be on the SVX. All three of the senior members of the Center as well as the two post-docs hired this past year will continue to take shifts. In addition, our new post-doc plus at least one of our students will take shifts in the future. During the last year we have been building the necessary computer hardware and software infrastructure for doing CDF data analysis locally. This is an essential part of our overall program, and in the coming year we intend to devote a significant fraction of our person hours to analysis tasks. All members of the group will be involved in this effort.

To insure that the data being taken is of high quality, it is important to inspect the data as rapidly as possible. For this reason, in addition to monitoring the data online the CDF collaboration has instituted "offline shifts" for inspecting the fully reconstructed data as rapidly as possible. At least one of us, Thomas, will be involved in this effort. As part of the SVX group, we will also be involved in the effort to understand the performance of the SVX detector during the course of the run.

Our plans are to focus on physics topics related to b jet tagging. This builds on our experience with heavy flavor studies and simulations for the SVX II upgrade,

and is of great current interest. In addition we will gain invaluable experience with a working silicon microstrip detector. The tagging of b jets in high p_t events is of enormous interest for both top discovery and verification of Standard Model branching ratios. The current limit on the top mass already implies that the detection of a top signal in the single lepton plus jet channel is difficult without b jet tagging. This is because a peak in the lepton plus missing transverse energy transverse mass will no longer distinguish the top signal from the overwhelming background of W plus jets events. The tagging of a b jet in the event will reduce the background by from about 100, for two jet events, to 30, for four jet events [2]. The cleanest top decay channel is the $e + \mu$ mode. Here, the W pair cross section becomes comparable to the top cross section at a top mass of $155 \text{ GeV}/c^2$ [3]. Again, b jet tagging can reduce this background. It is possible that with efficient b jet tagging top events might even be observed in purely hadronic decays [4]. The b tagging efficiency with the SVX detector is estimated to be greater than 30% per top event.

The study of b events produced at the Tevatron collider holds the promise of a wide variety of physics measurements. There is the study of b meson and baryon spectroscopy and lifetimes: B_s , Λ_b , and B_c . There is the measurement of CKM mixing matrix elements, for example through the measurement of the B_s mixing rate. There is the search for new phenomena in rare B decays. Finally, there is the measurement of CP-violation in the neutral B system through decays to CP eigenstates such as ψK_s . Many of these measurements require data sets in excess of 100 pb^{-1} and are beyond the reach of the current run. However, in addition to refining all of the measurements made in the previous run, many important new measurements will be made. We expect a sample of roughly 50,000 inclusive ψ events within the SVX acceptance in the coming run. This will allow for the observation of exclusive reconstructed final states such as $B_s \rightarrow \psi \phi$ and $\Lambda_b \rightarrow \psi \Lambda$ and the measurements of B_s and Λ_b masses. In addition, there will be measurements of production rates, ratios of branching ratios, and exclusive lifetimes.

The New Mexico Center/UNM group expects to carry out an aggressive program of data analysis. We will select a few very closely related topics and focus on them as a group. Our intention is to play a leading role in the publication of physics results. In order to carry out this program, it is essential that we be able to work efficiently. In the past year, in collaboration with the medium energy group in the physics department at UNM, we have built a reasonably powerful local network of workstations. We have installed a baseline version of the CDF analysis code. In addition to this, our program requires both efficient, automatic code maintenance and rapid access to the data. Our major limitation in this regard is network accessibility to the CDF computing facilities. At the present time we communicate to CDF via HEPnet accessed through a VAX node at Los Alamos National Laboratories as a gateway. This has limitations in peak bandwidth and is not

robust. At the present time it is clear that this networking capability is insufficient for our needs and we are investigating the cost effective alternatives. We are fortunate to be located near the UNM telecommunications center which will likely make upgrading our wide area networking capabilities possible with a minimum of new hardware.

6.5 References

- 6.1 H. Ikeda, M. Tanaka, and S. Okuno, N.I.M. A 313, 31 (1992)
- 6.2 F.A. Berends, H. Huijf, B. Tausk, and W.T. Giele, ;
FERMILAB-Pub-90/213-T.
- 6.3 *SVX II Conceptual Design Progress Report*, the CDF Collaboration,
submitted to the PAC, May, 1992.
- 6.4 W. Giele, D. Kosower, H. Kuijf, Nucl. Phys. B, 23B (1991) 22.

Fig. 6.1: Preliminary schedule for the construction of SVX II.

7. Description of Facilities and Resources

7.1 The New Mexico Center

With support from the LANL, TNRLC and UNM, the New Mexico Center has built up effective laboratory facilities in the Department of Physics and Astronomy at UNM. To date these include:

- Micro-electronics measurement facility including cleanroom vertical laminar flow table, probe station, wire bonder, microscopes, Digital (500 MHz) oscilloscope, desiccator storage cabinet, etc for the measurement and characterization of silicon strip detectors.
- Macintosh based laboratory DAQ system with CAMAC and IEEE-488 capability. The IEEE system is used to control the precision capacitance, current, and voltage supply/meter for measuring the radiation damage of silicon detectors. The CAMAC system will be used to run the silicon ladder characterization facility with precision X-Y stages, and laser source.
- Miscellaneous CAMAC crates, oscilloscopes, power supplies, etc for laboratory test setups.
- UNIX and VAXstation workstations for simulation and data analysis including several VAXstation 3100/Model 76, VAXstation 4000/Model 60, and Silicon Graphics workstations, Exabyte 8 mm tapes, and 10 Gbyte disk storage. We will add at least one high speed workstation (R4000 or ALPHA based) in the near future. This is a cooperative venture with an Intermediate Energy DoE group in the Department.

7.2 Department and University Facilities

Machine and electronics shops are available in the Department of Physics and Astronomy. The machine shop is staffed by three full time personnel, and has facilities for light fabrication including: a computer-controlled milling machine, CAD/CAM system, and standard machine tools and equipment. The new electronics shop in the Department is presently staffed by one full time electronics technician and includes a CAD system for circuit layout and design, and standard bench electronics for circuit analysis.

Telecommunications are supported over the New Mexico Technet system that provides high-speed (T1) links between UNM, LANL, and the High Energy Physics Laboratories via the ESNET backbone.

Beyond the Department of Physics and Astronomy there are substantial facilities and expertise in fields of engineering closely related to the New Mexico Center/UNM group's research program. This includes the Center for Micro-Engineered Ceramics, the Center for High Technology Materials.

8. New Mexico Center Physicists

8.1 Physicists and Experiments

a) Faculty:

Dr. Michael Gold, Assistant Professor	CDF, SDC
Dr. John Matthews, Professor	CDF, SDC
Dr. Sally Seidel, Assistant Professor	CDF, SDC

b) Other Senior Scientists:

Dr. Nicola Bacchetta	CDF
Dr. Mark Frautschi	SDC, CDF
Dr. Tim Thomas	CDF, SDC

c) Students:

Howard Barnum, Junior Graduate Student (1992)	CDF
Ron Manginell, Junior Graduate Student	CDF, SDC
Donna Skinner, Junior Graduate Student	CDF, SDC
Douglas McDonald, Undergraduate Student	CDF, SDC

APPENDICES:

A.1 The SVX Detector: Status and Performance

A.2 SVXII: Prospects for CP Violation

A.3 Physicists' Vitae

1. Nicola Bacchetta
2. Mark Frautschi
3. Michael Gold
4. John Matthews
5. Sally Seidel
6. Tim Thomas

A.1 The SVX Detector: Status and Performance

A.1.1 Introduction

The Collider Detector at Fermilab (CDF) is a multi purpose detector with integrated systems for measuring and identifying the products from the $\bar{p}p$ collisions at the center of mass energy of 1.8 TeV of the Fermilab Tevatron Collider. The Silicon Vertex Detector (SVX) constitutes the innermost detecting system in the CDF and has the purpose to identify and reconstruct vertexes from the decay of long-lived particles ($c\tau \sim 300 \mu m$) and in particular of the B mesons produced either directly in the $\bar{p}p$ collisions or from the subsequent decay of a top quark.

The SVX covers 0.5 m along the interaction region and is split into two identical barrels (with 25 cm of active region for each barrel) formed by 4 layers divided in 12 sections (wedges) each subtending a 30° azimuthal angle around the beam line. Each layer within a wedge (ladder) constitutes the basic electrical and mechanical unit of the detector and is formed by three 8.5 cm long single sided DC coupled silicon microstrip detectors serially microbonded with a ceramic readout hybrid circuit board at one end and glued on a lightweight rigid foam support. There are a total of 46,080 channels.

The first proposal for a silicon microstrip vertex detector for CDF was presented in 1985 by a Fermilab-INFN Pisa-Lawrence Berkeley Laboratory collaboration and the project was definitely approved by the Fermilab Project Advisory Committee in 1988. Since then other institutions merged their efforts for the project including in 1991 the University of New Mexico.

In August 1991 the construction of the SVX was completed and the commissioning phase begun through the installation of the detector into CDF in January 1992. The first collision was observed on May 12 1992 with the SVX already fully functional.

A.1.2 Status

dead channels

During the tests prior the installation great attention was given to select detectors with less then 2% of dead strips and less then 3% of noisy (more then 3σ from the average noise) strips. At present there are approximately 600 dead channels (1.3 % of the total) due to bad silicon strips and readout electronics (Fig. 1).

pedestals

This is a measure of the offset that must be subtracted from the readings of each

channel to obtain the true charge released by the particle. It is important that these values do not change very much with time and we found that they are stable over weeks.

noise, differential noise

We measure the noise as the rms of the pedestal distribution and the differential noise as the measure of the rms of the difference in the pedestal distribution of two adjacent channels. With no coherent noise the value of the noise and the differential noise should be equal. We found that the noise is typically around 12.5 counts and the differential noise 13.5 counts showing that we have essentially no coherent noise in the system and that we are able to see the effect of the interstrip capacitance on adjacent strips (Fig. 2).

The charge distribution shown in Fig. 3 has the most probable value of the Landau peaked at 110 counts which gives a Signal/Noise = 9.

threshold

Due to the high number of channels the SVX readout chip was designed in such a way that only the channels that integrate charge above a certain threshold would be read-out (sparse readout). This implies that a stable threshold value must be found as a compromise between the maximum efficiency and the minimum occupancy. Since the number of independent lines to be brought to the chips were also to be minimized we decided to have only 2 calibration lines for each wedge, one for the innermost layer (most likely to be damaged by the radiation and therefore to be adjusted for compensating the increased occupancy) and one for the remaining 3 layers. In Fig. 4 is shown a threshold distribution for a typical wedge. If the variation in the threshold for the channels connected to the same calibration line is less than the noise then it is possible to choose a threshold for which the 99% efficiency point corresponds to about 4 – 6% occupancy. This is the case for most of the wedges (Fig. 5) but for a couple of wedges for the same efficiency point there is an occupancy up to 16%. The contribution of the physics to the occupancy is a flat 2%.

efficiency

Considering all the tracks crossing the SVX in within its boundaries with a P_t greater than 1 GeV, we calculated the hardware efficiency as the ratio between the 3 hits versus the 4 hits tracks for each layer (Table 1).

Since the tracking code recognize a track only if there are at least 3 hits the hardware efficiency corresponds to a tracking efficiency well above 99%.

alignment

In order to reach the intrinsic design resolution of $12\ \mu m$ great care must be taken to measure the position of the detector as accurately as possible. There are two types of alignment:

- *Global alignment*: the alignment of each individual barrel to the external tracking chamber (i.e. the alignment of the SVX relative to the CDF reference frame).
- *Internal alignment*: the alignment of the ladders in within each barrel (i.e. the alignment of the active region of the SVX relative to each other).

The global alignment constants were calculated using the beam line constraints method, where we used the assumption that the external tracking chamber (CTC) and the two SVX barrels must see the same beamline during a given run. In Fig. 6 is shown the beamline as seen by the two barrels after correcting for the position. In this case we are dominated by the beam line dispersion which is of the order of $30\ \mu m$.

In order to minimize the corrections, the SVX was built with a precision better than $25\ \mu m$, and during the construction phase the position of the ladders relative to the bulkhead frames was optically surveyed. This gave immediately a very good residual distribution of $18.5\ \mu m$. The idea here is to minimize the χ^2 of the fitted SVX tracks for each wedge by imposing the beam spot constraint and, keeping the outermost layer fixed in position, adjust the innermost three layers. After this corrections the residual distribution becomes $13.6\ \mu m$ (Fig. 7) and can be still improved by increasing the statistics on the tracks crossing adjacent wedges.

systematics

Now the the first data from the detector is available we are starting to look into the systematics in order to refine the performance of the SVX. We have identified four major sources of systematic errors :

1. *Hall effect*: This is simply due to the presence of the magnetic field (1.5 T) which tends to curve the holes as they drift toward the strips.
2. *readout effect*: comes from the fact that we have a limited amount of time for reading out the detector and this time is not long enough for allowing the analog signal coming from the chip to reach its full value. As a consequence there is a small correlation between subsequent channels in the readout stream where the likelihood of a given channel to reach its full value depends on the value left on the common readout line by the previous strip.
3. *sparse versus latch all*: To determine the value of the pedestal to be subtracted off from the physics data we take a separate calibration run in

which all the channels are readout (latch all mode). It seems like the pedestal calculated in this way are slightly higher than the "true" values that they have during a physics run (which is taken in sparse mode), so that we are underestimating the charge collected.

4. *diffusion*: for a track crossing the silicon with an angle different from 90° the diffusion process would tend to spread the holes coming from the bottom of the silicon more than those released toward the top. This implies that the position of tracks will be shifted by some amount which depend on the angle of the tracks relative to the normal to the strip plane.

So far the only systematic effect for which we are correcting is the Hall effect and we are still studying the implications of the others and how to properly correct them.

radiation issues

As well known since the beginning of the project the radiation environment inside CDF is very harsh for a detector which innermost layer is at only 2.7 cm from the beamline. In Fig. 8 is shown the results of measurements taken during the 1986-1988 run that shows that the expected dose for the innermost layer of the SVX should be 400 rad/pb^{-1} . The radiation hardness of the readout electronics was also measured, showing a loss of 15% in the gain of the chip and an increase of 75% in the noise after a γ dose of 15 krad (Fig. 9). The increase in the leakage current was also measured to be about 4 nA/krad but since the overall noise is largely dominated by the electronic noise, this further contribution is not a concern. The 15 krad corresponds to the upper limit at which the SVX can operate since the overall effect of the gain/noise/leakage degradation would bring the signal to noise ratio down to only 4.5 at which point it would be very hard to use the innermost layer for any practical purpose. The present run (run IA) is scheduled to collect 30 pb^{-1} in a 1 year period which corresponds to a total integrated dose for layer 1 (innermost) of 12 krad therefore very close to the operational limit of the SVX. At present we have integrated about 1.4 pb^{-1} and a total radiation dose of about 1.5 krad (which includes the many collider studies we have experienced at the beginning of the run).

future

The complete success of this detector rely now on our capability of understanding the systematics, to improve the alignment and to make treasure of the experience we have with this detector to better build the new SVX' detector for run IB.

A.1.3 SVX' Upgrade Project

Since the SVX detector cannot survive the high radiation environment in which is

operating we begun last year the design of a new detector (called SVX') meant to last through the 100 pb^{-1} of data foreseen to be collected in the 2 years program of run IB (September 1993 - fall 1995). This new detector will be identical to the SVX in the mechanical aspect of the design, the only difference being the front-end readout electronics that will be the radiation hard version (SVX-H) of the present SVX readout chip (SVX-D) and the silicon detectors themselves that will be AC-coupled to the readout electronics in order to minimize the contribution of the leakage current variations.

The detectors have been ordered at the Micron Semiconductor (England) and all the detectors for the two innermost layers have already been delivered. Once the detectors arrive in Fermilab we test them at a probe station first just inspecting them visually and later using a 100 pins probe card we check for shorts between the metal and the implant on a strip by strip basis measuring also the total leakage current. The results of the measurements highlight the extremely good quality of the detectors we have received so far (Table 2).

In parallel with the detector testing is the testing of the chips prior to be mounted on the hybrid readout boards (called ears). The tests consist of exercising all the functions of the chips and selecting them so that they have the same threshold response in within the same ears. Ears are built at Promex (Santa Clara, California) on a aluminum nitrate substrate for better thermal conductivity and in the same company they also glue and bond the chips on the boards. When the ears are completed they are shipped over to Fermilab where, after been tested, they are glued together with three silicon detectors on a rohacell-foam structure to for a ladder. The ladders are then microbonded using a K&S automatic bonding machine now available in our clean room in Fermilab.

The University of New Mexico took the responsibility for all the electrical tests of the ears/ladders.

The test station in Fermilab consists of an exact replica of the data acquisition system developed for the SVX and implemented in a smaller scale capable of testing up to one full wedge. In addition to the usual electrical tests (pedestal, gain, noise, threshold) we also built a separate station for testing directly the silicon response to infrared light in order to study the uniformity of the charge distribution collected by the strips.

This is expecially useful for SVX' because the new detectors are AC-coupled to the input of the charge sensitive preamplifiers, and it was no longer possible to measure the integrated leakage current to establish whether or not a given strip is truly connected to the readout electronics.

The infrared light is provided by pulsing a IR-silicon diode with a wavelength of 900 nm ($\sigma_\lambda = 50$ nm), a light spot of about 30 μm and an intensity equivalent to about 4 fC of charge released in the silicon. The ladder is mounted on a 60 by 60 cm X-Y table which moves with a precision of few microns (the strip pitch is 60 μm) by means of stepping motors under the control of a small computer. This system is synchronized to the data acquisition electronics so that is possible to quickly test the response uniformity of the silicon ladders on a strip by strip basis.

future

For this project we are now entering the production and assembling phase of the silicon ladders which requires a lot of testing work. Once the detector has been completed, we would like to play a major role in the commissioning and early data taking to understand the different systematics and to make sure that the knowledge gained with the SVX will be properly transfer to his new detector.

Table 1: SVX hardware efficiency by layer

<i>layer</i>	<i>hardware efficiency</i>
0	98.0%
1	98.4%
2	98.4%
3	98.8%

Table 2: Summary of the results of the SVX' detector probing tests

	<i>layer 1</i> <i>128 strips</i>	<i>layer 2</i> <i>256 strips</i>
number of detectors delivered	100	100
number of detectors tested	59	59
average depletion voltage per detector (V)	29.4	30.0
average number of shorts per detector	0.86	1.18
average number of opens per detector	0.05	0.13
average leakage current per strip (nA)	1.3	1.3
number of detector rejected	3	4

Fig. 1: Quality control in ladder production: dead and noise channels distribution

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Fig. 2: SVX: typical pedestal and noise distribution (wedge 18)

Fig. 3: SVX: Landau distribution normalized for incident angle

Fig. 4: SVX: typical threshold distribution (wedge 18)

Fig. 5: SVX: occupancy distribution by wedge

Fig. 6: SVX: distribution of vertexes along the beam line (after alignment correction)

Fig. 7: SVX: distribution of residuals before and after alignment correction

Fig. 8: CDF: expected radiation level inside CDF as a function of the distance from the beam line (the position of the 4 SVX layers is indicated by arrows)

Fig. 9: SVX: gain and noise for the SVXD chip as a function of the dose (^{60}Co measurements)

A.2 SVXII: Prospects for CP Violation

A.2.1 Measuring CP violation

Measurement of CP violation in the B system would be a strong test of the standard model. At the Tevatron, CP violation in neutral B decays results in a net, time integrated asymmetry in the rate for B decays to CP eigenstates. Consequently, the measurement requires only the counting of the rates for B vs $\bar{B}$ decays. Even so, the measurement of such asymmetries presents an enormous experimental challenge. This is due to the statistics required, the small branching ratios involved, and the low p_t of the events. A key aspect of this challenge is the performance of the tracking detector, so it is important to examine the implications of our vertex detector design in this context.

The cleanest signal at a collider will likely be in the decay $B \rightarrow \psi k_s$, where the leptonic decay of the ψ provides a clear trigger. We wish to determine our sensitivity to CP violation as a function of luminosity. The analysis of the asymmetry is discussed in many references [1]. The statistical error on the CP violating parameter $\sin 2\beta$ is given by [2],

$$[\delta(\sin 2\beta)]^{-2} = \mathcal{L} 2\sigma \frac{x_d}{1 + x_d^2} (1 - 2\bar{\chi})^2 \frac{S}{S + B} \epsilon_{trig} \epsilon_{rec} \epsilon_{tag} (1 - 2w)^2$$

where

$\mathcal{L}$	is the integrated luminosity
σ	is the total $b\bar{b}$ cross section
x_d	is the B_d mixing rate
$\bar{\chi}$	is the averaged B mixing probability
S, B	are the signal and background
ϵ_{trig}	is the trigger efficiency
ϵ_{rec}	is the ψk_s reconstruction efficiency
ϵ_{tag}	is the tagging efficiency for the second b
w	is the probability of mis-tagging the second b

The B_d mixing rate has been well measured at the $\Upsilon(4S)$ with the result, $x_d = 0.72 \pm 0.15$ [3]. We have measured the average B mixing probability at CDF with the result $\bar{\chi} = 0.176 \pm .045$. These numbers are very precisely known for the purpose of this measurement. Below, we (Howard Barnum and Michael Gold) estimate the b cross section and then investigate the remaining parameters which are dependent upon detector performance.

A.2.2 Cross Sections

CDF has measured the inclusive b cross section down to $p_t=10.5$ GeV from reconstructed B decays and, at higher p_t 's from inclusive electrons [4]. Based on these measurements we extrapolate the total b cross section to lower p_t and calculate the cross section for the exclusive ψk_s decay mode.

We use ISAJET (version 6.43) to generate b events. The ISAJET calculation includes leading order diagrams (order α_s^2 – “pair production”) as well as approximate higher order effects through initial and final state gluon bremsstrahlung. However, there are large contributions from diagrams that are formally of order α_s^3 but may be comparable to the leading order processes. We have compared the ISAJET cross sections as a function of quark p_t and pseudo-rapidity (η) to the complete order α_s^3 calculation of Nason, Dawson, and Ellis (NDE) [5]. Fig. 1 shows that the ISAJET P_t distribution agrees well with the NDE calculation, down to p_t 's as low as 6 GeV. This is sufficiently low for calculating the cross section at the lowest achievable thresholds for a ψ trigger. However, there remains potentially large uncertainty at low p_t due to poor knowledge of the low x behavior of the gluon distribution function. Fig. 1 also shows a direct comparison of ISAJET and NDE to the CDF data. The agreement in shape is good, but the low p_t behavior of the cross section is poorly constrained. We use an ISAJET normalization factor of 4.4 derived from this comparison to the CDF data in the following calculations. The ISAJET cross section as a function of η is compared to NDE in Fig. 2. ISAJET compares well to the higher order calculation except at large pseudorapidity ($\eta=3$) where it differs by as much as a factor of 1.75. Finally, it should be noted that the distribution of the b jets in the azimuthal angle (ϕ) is considerably different in ISAJET than in the more complete calculation. In ISAJET the b jets are produced in opposite directions with a ϕ separation of greater than 90° . Higher order calculations indicate that this will be the case less than 69% of the time [6]. However, it is not necessarily true that events with b jets not well separated in ϕ will be more difficult to analyze.

We have used ISAJET to calculate the cross section for the process $b \rightarrow B \rightarrow \psi k_s \rightarrow \mu\mu\pi\pi$. The cross section (σ) per b for various acceptances is tabulated in Table 1. The muons were required to have $p_t > 2$ GeV and the pions $p_2 > 1$ GeV, corresponding to realizable trigger thresholds. The cross sections include fragmentation and branching ratios. We see that the expected event rates in a high luminosity data set of the order 1 fb^{-1} are quite high. In addition, it is clear that high η tracking will significantly improve the statistics of the measurement, even given the possible over estimate of the cross section at high rapidity.

Table 1: ψk_s cross section as function of η

$ \eta_\mu $	$ \eta_\pi $	σ pb
3.0	3.0	12.8
3.0	2.0	10.1
3.0	1.5	8.0
2.0	2.0	9.1
2.0	1.5	7.8
1.5	1.5	6.6

A.2.3 Tagging

The flavor (b quantum number) of the B that decays to ψk_s , can be determined by the flavor of the other b in the event. We have considered two types of tags: the sign of the leading (highest p_t) muon and the sign of the leading (highest p_t) kaon. We calculated the tag efficiency and mistag probability using a sample of ISAJET generated events where the trigger B jet contains two muons with $p_t > 2$ GeV and two pions with $p_t > 1$ and acceptance to an $\eta = 3.0$. Fig. 3 shows the p_t distribution produced trigger B hadron and of the accompanying tag B hadron. We note that the trigger requirements yield a relatively high p_t B tag jet. An additional background to sequential decays for the muon tag is pion/kaon decays in flight. We model this background in a simple way: we calculate the probability of decay inside of our tracking volume and consider this fraction to be detected as muons. We account for the kinematics of the decay simply by multiplying by an average momentum degradation of 80 %. No attempt is made to model the effects of the decay in flight on the track fitting. Since one might expect some reduction of decay in flight background using tracking information, this is a conservative background estimate.

Table 2 shows the results of the calculation for various values of the leading muon tag p_t (see Fig. 3). We have calculated the combined effect of tag efficiency (ϵ_{tag}) and mistag probability (w) as the dilution factor $\epsilon_{tag}(1 - 2w)^2$. This is the factor that maximizes the statistical power of the measurement. In Fig. 3 we see that the p_t distribution of the decay muon is very soft. Consequently, we expect that it has very little effect on the tagging: eliminating the decays in flight changes the w by 1 % and the dilution by 0.3 %. Below a p_t of 2 GeV muon identification becomes difficult due to rangeout preceeding the muon chambers. We have not included a muon identification efficiency which is expected to be $\approx 90\%$.

Although the statistics are poor, we can conclude that the maximum dilution will be at a reasonably high lepton p_t , near 3 GeV. Consequently, we expect that an electron tag will roughly about equal in power to the muon tag. Efficient, low p_t electron identification can be achieved by effective use of the high electromagnetic

Table 2: Flavor tagging with leading particle.

Tag	p_t GeV	ϵ_{tag}	w	Dilution
μ	4	$.05 \pm .01$	$.20 \pm .08$	$.02 \pm .01$
μ	3	$.09 \pm .01$	$.18 \pm .08$	$.04 \pm .02$
μ	2	$.13 \pm .01$	$.26 \pm .06$	$.03 \pm .02$
k	3	$.09 \pm .01$	$.15 \pm .06$	$.04 \pm .02$
k	2	$.19 \pm .02$	$.15 \pm .04$	$.09 \pm .02$
k	1	$.39 \pm .02$	$.19 \pm .03$	$.14 \pm .03$
k	0.5	$.52 \pm .03$	$.19 \pm .03$	$.20 \pm .04$

shower position resolution of the CDF calorimetry combined with tracking information. In addition, it is expected that precision tracking information from the vertex detector will help distinguish prompt electrons from B decays from backgrounds such as conversions.

We consider a leading kaon tag to gauge the potential of particle identification. These numbers are also tabulated in Table 2. Here as well no identification efficiency has been included— the generated particle id is used to select the highest p_t kaon in the event opposite the trigger B jet. In Fig. 3 we see that the p_t spectrum of the tag kaon is very soft. Studies are under way to investigate the potential of π, k separation by dE/dx and high resolution time-of-flight measurements. It is hoped that a combination of vertexing tracks from the B jet together with some particle identification will lead to a powerful flavor tag to compliment the lepton tags.

A.2.4 Sensitivity

We now combine the above results to yield an estimate of the error on the CP violating parameter ($\delta(\sin 2\beta)$). The two remaining parameters we estimate from the CDF measurement of the exclusive reconstruction of $B \rightarrow \psi k^\pm$ [4]. We take $S/(S+B) \approx 0.75$ and the efficiency to reconstruct the trigger B (including trigger efficiency) $\epsilon_{rec} = 0.25$. Then we find for a combined lepton tag (muon and electron) with $p_t=3$ GeV,

$$\delta(\sin 2\beta) = 0.12 \text{ for } \mathcal{L} = 1 \text{ fb}^{-1}.$$

We believe this estimate to be conservative, in that it does not reflect expected improvements in muon identification, reconstruction efficiency, and trigger efficiency. A kaon tag would obviously further improve the measurement.

A.2.5 $B \rightarrow \pi\pi$ Mode

In order to fully test the standard model mechanism for CP violation, it is desirable to search for CP violation in other decay modes that independently constrain the model. Another such mode is the flavor changing neutral current decay $B \rightarrow \pi\pi$ whose branching ratio is expected to be about 1.2×10^{-5} . It should be noted that this branching ratio is comparable to the product of branching ratios in $B \rightarrow \psi k_s \rightarrow \mu\mu\pi\pi$ which is 1.57×10^{-5} . Consequently, an equally powerful measurement is conceivable.

Here, the one of the principal challenges is triggering. Fig. 4 shows the cross section for $b \rightarrow \pi\pi$ as a function of the dipion p_t threshold including the branching ratio. Studies have shown that a dipion trigger with threshold of 2 GeV can be built with a trigger efficiency of $\approx 6\%$. We see that the cross section is not too steeply falling and one expects the statistics to be enhanced as the trigger efficiency improves with higher p_t . If we assume conservatively a trigger efficiency of 6% we estimate 36,000 $B \rightarrow \pi\pi$ events in a 1 fb $^{-1}$ data set. For comparison, Fig. 5 shows the cross section for a lepton tag. Compensating for the branching ratio of $B \rightarrow \pi\pi$ and the lepton tagging efficiency, we see that a comparable statistics sample requires a lepton trigger of 5 GeV p_t .

In addition to the previous challenges of flavor tagging, here the separation of signal from combinatoric and πk background in identifying the trigger B is expected to be difficult. Studies are underway to determine the role of the vertex detector and especially the utility of high resolution Z information.

A.2 References:

1. See, for example, *b Physics at CDF*, June 4, 1991; M. Gold, C. Haber, P. Tipton, *b Physics with existing Colliders*, Physics at Existing Colliders, D. Green and H. Lubatti, editors, World Scientific, New Jersey, 1990.
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Fig. 1: Comparison of the b cross section as a function of quark p_T between ISAJET, NDE, and CDF data. The theoretical calculations have been normalized to fit the data.

Fig. 2: Comparison of the b cross section as a function of quark p_t between ISAJET (crosses) and NDE (line) for $\eta = 1, 2$, and 3. The error bars indicate the size of the theoretical error.

Fig. 3: Starting with top left: ψ k , trigger p_t with μ and π kinematic cuts, tag B p_t showing trigger bias: μ and k tag p_t ; and the μ pt from k/π decays in flight.

Fig. 4: Cross section of $b \rightarrow \pi\pi$ as a function of the dipion p_T threshold. A branching ratio of 1.2×10^{-5} is included. Since the $\bar{b}$ can also decay to $\pi\pi$, a factor of 2 should be used to obtain the total number of $\pi\pi$ events per unit luminosity. A smooth curve has been drawn through the calculated points.

Fig. 5: Cross section of $b \rightarrow \mu$ as a function of the muon p_T threshold, where the μ is required to be from the b quark decay. The branching fractions are as generated by ISAJET. A factor of 2 should be used to obtain the total number of B or $\bar{B}$ events per unit luminosity. A smooth curve has been drawn through the calculated points.

Nicola Bacchetta**Biographical Sketch**

I have been educated at the University of Padua (Italy). For my thesis I worked on Experiment PS179 at LEAR (CERN) where I participated in the construction of an automatic system for analyzing tracks recorded on film from the self-shunted streamer chamber. In this system film frames from the two spatial views were digitized. Events were then reconstructed using pattern recognition and noise suppression algorithms. The two views of the event were then put together and a full spatial reconstruction was performed.

On September 1987 I came to SLAC with an INFN (Italy) Fellowship and worked on the Warm Iron Calorimeter subsystem for the SLD detector. Our group was led by Dr. Marcello Piccolo of INFN-Frascati and Professor Wit Busza of MIT. At SLAC I worked mainly on the development of data acquisition electronics for the WIC calorimeter which consisted of 100,000 channels of streamer tubes instrumented both with projective pad towers and longitudinal strips. As a part of the strip readout system I had responsibility for the design and engineering of the Splitter Board, a multipurpose module which served as an interface between the front-end electronics and the FASTBUS readout system as well as providing trigger logic for the calorimeter. I also worked on the commissioning of the detector and on the cosmic ray run in April 1990. As a consequence of this work I have considerable experience in FASTBUS and CAMAC electronics and online data acquisition software.

In June 1990 I joined the CDF collaboration at Lawrence Berkeley Laboratory. At LBL I undertook a detailed study of radiation effects on the SVX readout chip for the CDF Silicon Vertex Detector. I made measurements on the rad-soft Rev.D version as well as the new rad-hard ReV.H version. I also studied fundamental damage effects on individual transistor test structures in order to understand the overall damage effects seen on the full readout chips. As part of this work I developed an automatic testing system for characterizing irradiated devices under computer control. At LBL I worked primarily with Professor Robert Ely and Dr. Carl Haber.

In May of 1991 I came to Fermilab as a Visiting Scientist where I joined the group undertaking the installation of the SVX detector for the 1992 run. At Fermilab I have had a primary responsibility for the testing, characterization, and commissioning of the front end and readout electronics for the SVX. This has involved understanding many issues such as noise and stability in a new system of 50,000 channels of silicon microstrips.

Based on this experience I begun to work on the upgrade of the SVX, called SVX-prime, which will be installed in CDF during the shut-down of the accelerator foreseen for the spring 1993. This new detector will collect 100 pb^{-1} of data in a period of 2 years. For this project I am responsible of all the electrical tests necessary to ensure the quality of the electronics/silicon to be assembled in the detector.

Sample Publications Relevant to Proposed Research

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4. Radiation Damage measurements on the SVX readout chip, to be published on NIMA (1992)

Vitae

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Professional Societies and Activities

1. Member, Italian Physical Society

Invited Talks at Major Conferences

1. The Silicon Vertex Detector for CDF: design and performance
78th National Conference of the Italian Physical Society, Pavia Italy 1992

Recent Publications

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Phys. Rev. D **46** (1992) 1889
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Biographical Sketch

Mark Frautschi took his B.Sc. (with honors) from the University of North Carolina at Chapel Hill in 1983. He Received a M.Sc in elementary particle physics in 1987 from The Ohio State University and his Ph.D in 1992 for the study of vector and pseudoscalar mesons (D^{*+} and K_s^0) in the TRISTAN energy region with the AMY collaboration at the KEK laboratory in Tsukuba-shi, Japan.

In March 1992 Dr. Frautschi accepted a Research Associate staff III position with the Physics and Astronomy at the University of New Mexico. He joined the CDF and SDC collaborations shortly thereafter.

Sample Publications Relevant to Proposed Research

1. *Resolution of Silicon Microstrip Detectors at Large Angles.* Frautschi, M. CDFnote CDF/DOC/SEC_VTX/PUBLIC/1842, 1 Oct 1992.
2. *The AMY Inner Tracking Chamber.* Frautschi, M. et al. , *Nucl. Instrum. Meth.* **A307**, 52-62 (1991).

Vitae

PERSONAL DATA

Born: Northampton Massachusetts, US 20 March 1957

EDUCATION

1992 Ph.D. Elementary Particle Physics, The Ohio State University

1987 M.Sc. Elementary Particle Physics, The Ohio State University

1983 B.Sc. Physics (honors), The University of North Carolina at Chapel Hill

PROFESSIONAL EXPERIENCE

1992–Present Research Associate Staff III,
New Mexico Center for Particle Physics,
University of New Mexico/Los Alamos National Laboratory

1987–1992 Graduate Research Associate, The Ohio State University

1983–1987 Graduate Teaching Associate, The Ohio State University

Professional Societies and Activities

1. Member, American Physical Society
2. Member, $\Sigma\Pi\Sigma$

Recent Publications

1. *Evidence for Hard Scattering of Hadronic Constituents of Photons in Photon Photon Collisions at TRISTAN.* By AMY Collaboration (R. Tanaka, *et al.*), KEK-preprint-91-14, Apr 1991. 16pp. Published in *Phys. Rev. Lett.* **B277**: 215-220 (1992).
2. *The AMY Inner Tracking Chamber.* Frautschi, M. *et al.*, *Nucl. Instrum. Meth.* **A307**, 52-62 (1991).
3. *Measurements of Heavy Quark Fragmentation at TRISTAN.* By AMY Collaboration (S.S. Myung, *et al.*), KEK-preprint-90-66-MC (microfiche), Jul 1990. 19pp. Submitted to Int. Conf. on High Energy Physics, Singapore, Aug 2-8, 1990. Published in Madrid EPS HEP 1989: ROHRER-NO (QCD161: 148: 1989)
4. *Comparison of the Next to Leading Logarithm QCD Approximation with TRISTAN Data and a Determination of $\Lambda_{\overline{MS}}$.* By AMY Collaboration (H. Sagawa, *et al.*), KEK-preprint-90-67, Aug 1990. 28pp. Submitted to Int. Conf. on High Energy Physics, Singapore, Aug 2-8, 1990.
5. *A Search for Charged Higgs Bosons in e^+e^- Annihilation using the AMY Detector at $\sqrt{s} = 50 \text{ GeV} - 61.4 \text{ GeV}$.* By AMY Collaboration (J. Vinson, *et al.*), KEK-preprint-90-80, Aug 1990. 13pp. Submitted to Int. Conf. on High Energy Physics, Singapore, Aug 2-8, 1990.
6. *Comparison of Quark and Gluon Jets using Three Jet Events from e^+e^- Annihilation at TRISTAN.* By AMY Collaboration (Y.K. Kim, *et al.*), KEK-preprint-90-79, Aug 1990. 27pp. Submitted to Int. Conf. on High Energy Physics, Singapore, Aug 2-8, 1990.
7. *A Measurement of the Photon Structure Function F_2 .* By AMY Collaboration (T. Sasaki, *et al.*), KEK-preprint-90-95, Sep 1990. 26pp. Published in *Phys. Lett.* **B252**: 491-498, 1990.
8. *Measurement of the Polarization of Tau Leptons from e^+e^- at $\sqrt{s} = 57 \text{ GeV}$.* By AMY Collaboration (M.H. Lee, *et al.*), KEK-preprint-90-70, Aug 1990. 15pp. Submitted to Int. Conf. on High Energy Physics, Singapore, Aug 2-8, 1990.
9. *Search for Charged Heavy Leptons with Arbitrary Neutrino Masses in e^+e^- Annihilations at $\sqrt{s} = 50 \text{ GeV} - 60.8 \text{ GeV}$.* By AMY Collaboration (G.N. Kim, *et al.*), KEK-preprint-90-55, Jun 1990. 47pp. Published in *Int. J. Mod. Phys.* **A6**: 2583-2610, 1991.

10. *Bose-Einstein Correlations in Pion Production at TRISTAN*. By AMY Collaboration (R. Walker, *et al.*), KEK-preprint-90-60, Jul 1990. 14pp. Submitted to Int. Conf. on High Energy Physics, Singapore, Aug 2-8, 1990.
11. *Measurement of the $e^+e^- \rightarrow B \bar{B}$ Cross Section and Forward - Backward Charge Asymmetry at a Center-of-mass Energy of 57.2 GeV*. By AMY Collaboration (J. Lim, *et al.*), KEK-preprint-90-61-MC (microfiche), Jul 1990. 20pp. Submitted to Int. Conf. on High Energy Physics, Singapore, Aug 2-8, 1990.
12. *Mass Limits of Charged Higgs at Large Tan (Beta) from e^+e^- Annihilations at $\sqrt{s} = 50 \text{ GeV} - 60.8 \text{ GeV}$* . By AMY Collaboration (J.R. Smith, *et al.*), KEK-preprint-90-3, Apr 1990. 6pp. Published in *Phys. Rev. D* **42**: 949-951, 1990.
13. *Charged Hadron Multiplicities in e^+e^- Annihilations at $\sqrt{s} = 50 \text{ GeV} - 61.4 \text{ GeV}$* . By AMY Collaboration (H.W. Zheng, *et al.*), KEK-preprint-90-5, Apr 1990. 36pp. Published in *Phys. Rev. D* **42**: 737-747, 1990.
14. *Observation of Anomalous Production of Muon Pairs in e^+e^- Annihilation Into Four Lepton Final States*. By AMY Collaboration (Y.H. Ho, *et al.*), KEK-preprint-89-195, Mar 1990. 20pp. Published in *Phys. Lett. B* **244**: 573-579, 1990.
15. *Measurements of R for e^+e^- Annihilation at TRISTAN*. By AMY Collaboration (T. Kunita, *et al.*), KEK-preprint-89-188, Feb 1990. 39pp. Published in *Phys. Rev. D* **42**: 1339-49, 1990.
16. *A Search for Leptoquark and Colored Lepton Pair Production in e^+e^- Annihilations at TRISTAN*. By AMY Collaboration (G.N. Kim, *et al.*), KEK-preprint-89-177, Dec 1989. 15pp. Published in *Phys. Lett. B* **240**: 243, 1990.
17. *Multi - Hadron Event Properties in e^+e^- Annihilation at $\sqrt{s} = 52 \text{ GeV} \text{ to } 57 \text{ GeV}$* . By AMY Collaboration (Y.K. Li, *et al.*), KEK-preprint-89-149, Nov 1989. 45pp. Published in *Phys. Rev. D* **41**: 2675, 1990.
18. *Forward - Backward Charge Asymmetry in $e^+e^- \rightarrow \text{Hadron Jets}$* . By AMY Collaboration (D. Stuart, *et al.*), KEK-preprint-89-127, Oct 1989. 11pp. Submitted to Int. Symp. on Lepton and Photon Interactions, Stanford, CA, Aug 7-12, 1989. Published in *Phys. Rev. Lett.* **64**: 983, 1990.
19. *A Search for SUSY Particles in e^+e^- Annihilations at $\sqrt{s} = 50 \text{ GeV} - 60.8 \text{ GeV}$* . By AMY Collaboration (Y. Sakai, *et al.*), KEK-preprint-89-134, Oct 1989. 17pp. Published in *Phys. Lett. B* **234**: 534, 1990.
20. *A Measurement of the Photon Structure Function F_2 at an Average Q^2 of $67 \text{ GeV}/c^2$* . By AMY Collaboration (T. Sasaki, *et al.*), KEK-preprint-89-56,

- Aug 1989. 25pp. Submitted to Int. Symp. on Lepton Photon Interactions, Stanford, CA, Aug 7-16, 1989.
21. *A Study of e^+e^- Annihilation into four Lepton Final States.* By AMY Collaboration (Y. Kurihara, *et al.*), KEK-preprint-89-64, Aug 1989. 20pp. Submitted to Int. Symp. on Lepton Photon Interactions, Stanford, CA, Aug 7-16, 1989.
 22. *Determination of the QCD Renormalization Scale and $\Lambda_{\overline{MS}}$ from Multi - Jet Events Produced in Electron - Positron Collisions.* By AMY Collaboration (I.H. Park, *et al.*), KEK-preprint-89-53, Aug 1989. 15pp. Submitted to Int. Symp. on Lepton and Photon Interactions, Stanford, CA, Aug 7-12, 1989.
 23. *Measurements of the Cross Section for $e^+e^- \rightarrow \gamma \gamma$ at TRISTAN.* By AMY Collaboration (H.J. Kim, *et al.*), KEK-preprint-89-52, Aug 1989. 15pp. Submitted to Int. Symp. on Lepton and Photon Interactions, Stanford, CA, Aug 7-12, 1989.
 24. *Measurements of R for e^+e^- Annihilation at TRISTAN.* By AMY Collaboration (T. Kumita, *et al.*), KEK-preprint-89-48, Jul 1989. 14pp. Submitted to Int. Symp. on Lepton and Photon Interactions, Stanford, CA, Aug 7-12, 1989.
 25. *Search for Nonminimal Higgs Production in e^+e^- Annihilations at $\sqrt{s}$ Approximately = 56 GeV.* By AMY Collaboration (E.H. Low, *et al.*), KEK-preprint-89-47, Jul 1989. 15pp. Published in *Phys. Lett. B228*: 548, 1989.
 26. *Search for a fourth Generation Charge $-\frac{1}{3}$ Quark.* By AMY Collaboration (S. Eno, *et al.*), KEK-preprint-89-46, Jul 1989. 12pp. Submitted to Int. Symp. Lepton and Photon Interactions, Stanford, CA, Aug 7-12, 1989. Published in *Phys. Rev. Lett. 63*: 1910, 1989.
 27. *A Comparison of Quark and Gluon Jets Produced in High Energy e^+e^- Annihilations.* By AMY Collaboration (Y.K. Kim, *et al.*), KEK-preprint-89-44, Jul 1989. 12pp. Published in *Rev. Lett. 63*: 1772, 1989.
 28. *A Search for Heavy Leptons and New Particles Beyond the Standard Model in e^+e^- Annihilations at $\sqrt{s} = 50$ GeV to 60.8 GeV.* By AMY Collaboration (Y. Sakai, *et al.*), KEK-preprint-89-42, Jul 1989. 42pp. Submitted to Int. Symp. on Lepton and Photon interactions, Stanford, CA, Aug 7-12, 1989.
 29. *A Search for Unstable Heavy Neutral Leptons in e^+e^- Annihilations at $\sqrt{s}$ from 50 GeV to 60.8 GeV.* By AMY Collaboration (N.M. Shaw, *et al.*), KEK-preprint-89-41, Jul 1989. 11pp. Published in *Rev. Lett. 63*: 1342, 1989.
 30. *A Measurement of $e^+e^- \rightarrow B \bar{B}$ Forward - Backward Charge Asymmetry Between $\sqrt{s} = 52$ GeV and 57 GeV.* By AMY Collaboration (H. Sagawa,

et al.), KEK-preprint-89-38, Jul 1989. 15pp. Published in *Phys. Rev. Lett.* **63**: 2341,1989.

31. *Multi - Hadronic Event Properties in e^+e^- Annihilation at $\sqrt{s} = 52$ GeV to 57 GeV.* By AMY Collaboration (Y.K. Li, *et al.*), KEK-preprint-89-34, Jul 1989. 33pp. Submitted to Int. Symp. on Lepton and Photon Interactions, Stanford, CA, Aug 7-12, 1989. *Rev. D***41** (1990) 2675-2688 and Tsukuba-shi KEK - KEK-Prepr.-89-034 (89, rec. Sep.) 33 p.
32. *Measurements of Cross Sections and Charge Asymmetry for $e^+e^- \rightarrow \tau^+ \tau^-$ and $e^+e^- \rightarrow \mu^+ \mu^-$ for $\sqrt{s} = 52$ GeV, 55 GeV and 56 GeV.* AMY Collaboration (A. Bacala, *et al.*), Tsukuba-shi KEK - KEK-preprint.-88-044 (88,REC.OCT.) 15p.
33. *Search for the Substructure of Leptons in High Energy QED Processes at TRISTAN.* By AMY Collaboration (S.K. Kim, *et al.*), KEK-preprint-88-125, Feb 1989. 25pp. Published in *Phys. Lett.* **B223**: 476,1989.
34. *Measurements of the e^+e^- Total Hadronic Cross Section and a Determination of m_Z and $\Lambda_{\overline{MS}}$.* By AMY Collaboration (T. Mori, *et al.*), KEK-preprint-88-109, Jan 1989. 26pp. Published in *Phys. Lett.* **B218**: 499,1989.
35. *Experimental Evidence for the Nonabelian Nature of QCD.* By AMY Collaboration (I.H. Park, *et al.*), KEK-preprint-88-113, Jan 1989. 14pp. Published in *Phys. Rev. Lett.* **62**: 1713,1989.
36. *Measurements of Cross Sections and Charge Asymmetries for $e^+e^- \rightarrow \tau^+ \tau^-$ and $e^+e^- \rightarrow \mu^+ \mu^-$ for $\sqrt{s}$ from 52 GeV to 57 GeV.* By AMY Collaboration (A. Bacala, *et al.*), KEK-preprint-88-81, Nov 1988. 18pp. Published in *Phys. Lett.* **B218**: 112,1989.
37. *A Study of QED Processes in the Electron - Positron Interactions and Search for Excited Leptons at $\sqrt{s} = 50$ GeV to 56 GeV.* By AMY Collaboration (S.K. Kim, *et al.*), KEK-preprint-88-49, Sep 1988. 29pp. Contributed to Int. Conf. on High Energy Physics, Munich, Germany, Aug 4-10, 1988.
38. *Hadron Production in Gamma Gamma Collisions at Large Q^2 at AMY.* By AMY Collaboration (T. Sasaki, *et al.*), KEK-preprint-88-48, Sep 1988. 16pp. Submitted to Int. Conf. on High Energy Physics, Munich, Germany, Aug 4-10, 1988.
39. *The Physics of Jets Produced in Electron - Positron Collisions at Center of Mass Energies from 50 GeV to 56 GeV.* By AMY Collaboration (I.H. Park, *et al.*), KEK-preprint-88-45, Sep 1988. 37pp. Submitted to Int. Conf. on High Energy Physics, Munich, Germany, Aug 4-10,1988.

40. *Measurement of Cross Sections and Charge Asymmetry for $e^+e^- \rightarrow \tau^+ \tau^-$ and $e^+e^- \rightarrow \mu^+ \mu^-$ for $\sqrt{s} = 52 \text{ GeV}$, 55 GeV and 56 GeV .* By AMY Collaboration (A. Bacala, *et al.*), KEK-preprint-88-44, Sep 1988. 15pp. Contributed to Int. Conf. on High Energy Physics, Munich, Germany. Aug 4-10, 1988.
41. *Measurements of R and a Search for Heavy Quark Production in e^+e^- Annihilation for $\sqrt{s}$ from 50 GeV to 56 GeV .* By AMY Collaboration (T. Mori, *et al.*), KEK-preprint-88-43, Sep 1988. 26pp. Submitted to Int. Conf. on High Energy Physics, Munich, Germany, Aug 4-10, 1988.
42. *A Search for Charged and Neutral Heavy Leptons in e^+e^- Annihilations at $\sqrt{s} = 56 \text{ GeV}$.* By AMY Collaboration (G.N. Kim, *et al.*), KEK-preprint-88-42, Sep 1988. 27pp. Contributed to Int. Conf. on High Energy Physics, Munich, Germany, Aug 4-10, 1988.
43. *A Search for New Heavy Quarks using Hadronic Events Containing Leptons.* By AMY Collaboration (S. Eno, *et al.*), KEK-preprint-88-47, Sep 1988. 11pp. Contributed to Int. Conf. on High Energy Physics, Munich, Germany, Aug 4-10, 1988.
44. *a Search for MARK-J Events at TRISTAN.* By AMY Collaboration (S.S. Myung, *et al.*), KEK-preprint-88-46, Sep 1988. 15pp. Contributed to Int. Conf. on High Energy Physics, Munich, Germany, Aug 4-10, 1988.
45. *Experimental Mass Limit for a Fourth Generation Sequential Lepton from e^+e^- Annihilations at $\sqrt{s} = 56 \text{ GeV}$.* By AMY Collaboration (G.N. Kim, *et al.*), KEK-preprint-88-8, May 1988. 14pp. Published in *Phys. Rev. Lett.* 61: 911, 1988.
46. *Search for Isolated Leptons in Low Thrust e^+e^- Annihilation Events at $\sqrt{s} = 50 \text{ GeV}$ and 52 GeV .* By AMY Collaboration (S. Igarashi, *et al.*), KEK-preprint-87-142, Dec 1987. 13pp. Published in *Phys. Rev. Lett.* 60: 2359, 1988.
47. *Measurements of R and a Search for Heavy Quark Production in e^+e^- Annihilation at $\sqrt{s} = 50 \text{ GeV}$ and 52 GeV .* By AMY Collaboration (H. Sagawa, *et al.*), KEK-preprint-87-84, Sep 1987. 14pp. Published in *Phys. Rev. Lett.* 60: 93, 1988.

Michael S. Gold

Biographical Sketch

Michael Gold graduated *Magna Cum Laude* with a B.A. from Wesleyan University (Middletown, CT) in 1979. He was elected *Phi Beta Kappa* and received Wesleyan University High Honors in Physics for his senior thesis on nonrelativistic quantum scattering theory. He received a Ph.D. in elementary particle physics in 1986 for the study of hard photon processes in e^+e^- annihilation with the Mark II detector at PEP.

From 1987 through the summer of 1991 Dr. Gold was a Research Associate at Lawrence Berkeley Laboratory. As a CDF collaborator, his major responsibility to the experimental operation was to develop techniques and procedures for the calibration of the CDF gas calorimeter systems. This included a leading role in the 1987/1988 CDF test beam as well as responsibility for the design and implementation of a system for online gas calorimeter calibration and monitoring for the 1989/1990 data run. Dr. Gold's analysis of data taken during that run has focused on inclusive dielectrons. He developed a technique for identification of photon conversions that has become the CDF standard. He searched for top decays in the dielectron decay mode and obtained preliminary limits for the top mass. He played a major role in the analysis of isolated electron pair events: Drell-Yan, σ_Z , and a search for high mass pairs. Final results include limits on an additional neutral vector boson (Z') mass and on the mass scale parameterizing electron-quark compositeness. Recently, these limits have been extended to include a search for high mass muon pairs. During the summer of 1990, Dr. Gold joined the silicon vertex detector project for CDF. He played a leading role in the assembly, testing, and read out of a complete four layer barrel segment of the SVX in the 1990 test beam. He has also developed techniques for the simulation of tracking and vertex reconstruction.

In the fall of 1991 Dr. Gold joined the faculty of the University of New Mexico. Dr. Gold's current research interest continues to be hadron collider physics, and in particular the study of beauty mesons. His current focus is the design and development of precision silicon tracking devices for high luminosity hadron colliders. He is a member of the CDF and SDC collaborations.

Publications Relevant to Proposed Research

1. "Search for $\Lambda_b \rightarrow J/\psi \Lambda^0$ in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., The CDF Collaboration, submitted to Phys. Rev. Lett. September 22, 1992. FERMILAB-PUB-92/250-E.
2. "A Lower Limit on the Top Quark Mass from Events with Two Leptons in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., The CDF Collaboration, Phys. Rev. Lett. 68, 447 (1992).
3. "A Measurement of the B Meson and b Quark Cross Section at $\sqrt{s} = 1.8$ TeV Using the Exclusive Decay $B^\pm \rightarrow J/\psi K^\pm$," F. Abe et al., The CDF Collaboration, Phys. Rev. Lett. 68, 3403 (1992). FERMILAB-PUB-92/21-E.
4. "Measurement of $B^0 \bar{B}^0$ Mixing at the Fermilab Tevatron Collider," F. Abe et al., The CDF Collaboration, Phys. Rev. Lett. 67, 3351 (1991). Fermilab PUB-91/201-E.
5. "Operation of the CDF Silicon Vertex Detector with Colliding Beams at Fermilab", F. Bedeschi *et al*, FERMILAB-CONF-92/263-E, Proceedings of the XXVth International Conference on High Energy Physics, Dallas, TX, August 6, 1992.
6. "Construction of the CDF Silicon Vertex Detector", J. Skarha *et al*, published in Proc. of the 1991 IEEE Nuclear Science Symposium, Santa Fe, New Mexico, May, 1992.
7. "The CDF Silicon Vertex Detector: An Overview and Test Results", W.C. Carithers *et al*, published in Proc. of the 1991 IEEE Nuclear Science Symposium, Santa Fe, New Mexico, May, 1992.
8. "Progress in the Construction of the CDF Silicon Vertex Detector", A. Barnett *et al*, Proc. of the 5th Pisa Meeting on Advanced Detectors, Isola d'Elba, Italy, 1991, and Nucl. Inst. and Meth., A315, 125 (1992).
9. "b Physics with Existing Collider Detectors ", (M. Gold, C. Haber, P. Tipton). Physics at Fermilab in the 1990's, D. Gran and H. Lubatti, editors, Breckenridge, Colorado.
10. "Results of the SVX 1990 Test Beam", F. Bedeschi *et. al.*, CDF-1423.
11. "New Particle Searches at an Upgraded Tevatron Collider", H. Baer, M. Cummings, H. E. Fisk, J. Freeman, M. Gold, J. Green, S. Inoue, K. Kondo, S. Kuhlmann, S. Kunori, A. Lassanen, X. Yata, A. White, J. Woodside, CDF-1169.

Vitae

PERSONAL DATA

Born: May 5, 1957
Glen Ridge, New Jersey

EDUCATION

1986 Ph.D. Physics, University of California, Berkeley

1979 B.A. Physics, Wesleyan University, Middletown, CT
Magna Cum Laude with High Honors in Physics

PROFESSIONAL EXPERIENCE

1991–Present Assistant Professor, University of New Mexico
/Los Alamos National Laboratory

1987–1991 Research Associate, Lawrence Berkeley Laboratory

Recent Talks

1992

1. "Search for Exotic Particles at CDF", XXVI International Conference on High Energy Physics, Dallas, Texas, August 1992.
2. "Measurement of $B_s - \bar{B}_s$ Mixing", NP2 Colloquium, Los Alamos December 1991.

1991

1. "Direct Production of High P_t leptons and Search for Extra Heavy Bosons at 1.8 TeV", Joint International Lepton-Photon Symposium and Europhysics Conference on High Energy Physics, Geneva, Switzerland, July, 1991.
2. "Direct Production of High P_t Leptons at CDF", Fermilab, March 1991.

1990

1. "Search for High Mass Electron Pairs Produced in $\bar{p}p$ Collisions at 1.8 TeV", Lawrence Berkeley Laboratory, May 1990.
2. "Drell-Yan, Weak Boson Production in $\bar{p}p$ Collisions at 1.8 TeV", Aspen Winter Conference, January 1990.

Publications: 1991-1992

- 1992 "Limits on the Production of Massive Stable Charged Particles," F. Abe et al., The CDF Collaboration, submitted to Phys. Rev. D, Rapid Communications, June 2, 1992. FERMILAB-PUB-92/152-E.
- 1992 "Limit on the Rare Decay $W^\pm \rightarrow \gamma + \pi^\pm$ in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., The CDF Collaboration, Phys. Rev. Lett. 69, 2160 (1992). FERMILAB-PUB-92/157-E.
- 1992 "A Measurement of the Production and Muonic Decay Rate of W and Z Bosons in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., The CDF Collaboration, Phys. Rev. Lett. 69, 28 (1992). FERMILAB-PUB-92/69-E.
- 1992 "Measurement of the Isolated Prompt Photon Cross Section Measurement in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., The CDF Collaboration, Phys. Rev. Lett. 68, 2734 (1992). FERMILAB-PUB-92/31-E.
- 1992 "A Limit on the Top Quark Mass from Proton-Antiproton Collisions at $\sqrt{s} = 1800$ GeV," F. Abe et al., the CDF Collaboration, Phys. Rev. D. 45, 3921 (1992). FERMILAB-PUB-91/352-E.
- 1992 "A Search for New Gauge Bosons in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., the CDF Collaboration, Phys. Rev. Lett. 68, 1463 (1992). FERMILAB-PUB-91/327-E.
- 1992 "Properties of Events with Large Total Transverse Energy Produced in Proton-Antiproton Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., The CDF Collaboration, Phys. Rev. D. 45, 2249 (1992). FERMILAB-PUB-91/283-E.
- 1992 "Search for Squarks and Gluinos from $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., The CDF Collaboration, submitted to Phys. Rev. Lett., August 13, 1992. FERMILAB-PUB-92/221-E.
- 1992 "Measurement of the Ratio $\sigma B(W \rightarrow \tau\nu)/\sigma B(W \rightarrow e\nu)$ in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV, as a Test of Lepton Universality," F. Abe et al., The CDF Collaboration, Phys. Rev. Lett. 68, 3398 (1992). FERMILAB-PUB-91/356-E.
- 1992 "Inclusive Jet Cross Section in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., The CDF Collaboration, Phys. Rev. Lett. 68, 1104 (1992). Fermilab-PUB-91/231-E.
- 1992 "Topology of Three Jet Events in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., The CDF Collaboration, Phys. Rev. D 45, 1448 (1992). Fermilab-PUB-91/181-E.
- 1992 "Lepton Asymmetry in W Decays from $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., the CDF Collaboration, Phys. Rev. Lett. 68, 1458 (1992). FERMILAB-PUB-91/263-E.
- 1991 "Search for $W' \rightarrow e\nu$ and $W' \rightarrow \mu\nu$ in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., The CDF Collaboration, Phys. Rev. Lett. 67, 2609 (1991). Fermilab PUB-91/208-E.

- 1991 "The Topology of Three Jet Events in $\bar{p}p$ Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., The CDF Collaboration, Phys. Rev. D 45, 1448 (1992). Fermilab-PUB-91/181-E.
- 1991 "Lepton Asymmetry in W Decays from $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., the CDF Collaboration, Phys. Rev. Lett. 68, 1458 (1992). FERMILAB-PUB-91/263-E.
- 1991 "Measurement of the e^+e^- Invariant Mass Distribution in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., the CDF Collaboration, Phys. Rev. Lett. 67, 2418 (1991). Fermilab PUB-91/169-E.
- 1991 "Measurement of the Z p_t Distribution in $\bar{p}p$ Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., The CDF Collaboration, Phys. Rev. Lett. 67, 2937 (1991). Fermilab PUB-91/199-E.
- 1991 "Measurement of the W p_t Distribution in $\bar{p}p$ Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., Phys. Rev. Lett. 66, 2951 (1991). Fermilab-PUB-91/33-E.
- 1991 "A Measurement of $\sigma(W \rightarrow e\nu)$ and $\sigma(Z^0 \rightarrow e^+e^-)$ in $\bar{p}p$ Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., Phys. Rev. D 44, 29 (1991). Fermilab-PUB-90/229-E.
- 1991 "A Determination of $\sin^2 \theta_W$ from the Forward-Backward Asymmetry in $p\bar{p} \rightarrow ee$ Interactions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., submitted to Phys. Rev. Lett., May 13, 1991. Fermilab-PUB-91/135-E.
- 1991 "Measurement of QCD Jet Broadening in $\bar{p}p$ Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., Phys. Rev. D 44, 601 (1991). Fermilab PUB-91/23-E.
- 1991 "Top Quark Search in the Electron + Jets Channel in Proton-Antiproton Collisions at $\sqrt{s} = 1.8$ TeV," F. Abe et al., Phys. Rev. D. 43, 664 (1991).
- 1991 "A Measurement of the W Boson Mass in 1.8 TeV $\bar{p}p$ Collisions," F. Abe et al., Phys. Rev. D. 43, 2070 (1991).

John A. J. Matthews**Biographical Sketch**

John Matthews received the Governors General's Medal on graduation with a B.Sc. (honors) from the University of Victoria (Canada) in 1966. He Received a Ph.D. in elementary particle physics in 1971 from the University of Toronto for the study of ρ , $f^0(1270)$, $g(1690)$, $\omega^0(783)$, $A_2(1320)$, and $\omega^0(1670)$ meson production in quasi two-body interactions.

During the period of 1971 to 1974 Dr. Matthews was a Research Associate at SLAC. He studied *two body* scattering in a number of K_L^0 proton scattering experiments, and in particle and anti-particle precision diffractive and elastic scattering experiments. Spectroscopic results from these experiments determined the spin-parities of the $\kappa(1350)$ and $k^*(1780)$ meson resonances, and presented the first evidence for two unnatural spin-parity resonances in the Q meson mass region.

In 1974 Dr. Matthews joined the faculty of Michigan State University as an Assistant Professor. Between 1974 and 1976 he was active in n-p charge exchange and charm search experiments at Fermilab.

Dr. Matthews was appointed Assistant Professor on the Johns Hopkins faculty in the summer of 1976, Associate Professor in July 1978, and was promoted to full Professor in July 1983. His research has included experiment E95 at Fermilab, the PEP4-TPC experiment at the PEP storage ring and the Mark II experiment at the SLC collider at SLAC, and the CDF experiment at the Tevatron collider at FermiLab. In experiment E95 Dr. Matthews' work centered on one of the first measurements of the production of prompt photons at large transverse momentum in hadron collisions. In the PEP4-TPC experiment his work focused on the study of the production and decay of heavy (c and b) quarks. In 1982 he was the Deputy Spokesman of the PEP4-TPC experiment. In the Mark II experiment, his work included machine physics: the design of the SLC *final focus*, and the suppression of detector backgrounds, as well as work on the determination of the Z mass, width, and the number of generations of light neutrinos.

In 1986, Dr. Matthews joined the silicon vertex detector upgrade project for the Mark II. This work led subsequently to the participation in the silicon vertex detector upgrade for the CDF detector at the Tevatron collider at FermiLab.

In 1991, Dr. Matthews joined the faculty at the University of New Mexico as Professor and Director of the New Mexico Center for Particle Physics. The New Mexico Center is a joint program between the University of New Mexico and Los Alamos National Laboratory. Dr. Matthews current research emphasizes the development of precision silicon tracking for use at high luminosity hadron colliders. He is a member of CDF and SDC collaborations.

Sample Publications Relevant to Proposed Research

1. Silicon Tracking Conceptual Design Report, with A.J. Weinstein, et al, SCIPP 92/04, March 1992
2. The Mark II Silicon Strip Vertex Detector, with C. Adolphsen, et al, Nucl. Instr. and Meth. **A313**, 63 (1992)
3. Temperature Effects on Radiation Damage to Silicon Detectors, with E. Barberis, et al, 6th European Symposium on Semiconductor Detectors, Milan, Italy, February 24-26 1992, UCR/SSC/92-01 (1992)
4. Proceedings IEEE Nucl. Sci. Symposium, Santa Fe, NM, November 2-9, 1991:
 - (a) Construction of the CDF Silicon Vertex Detector, with B. Barnett, et al;
 - (b) The CDF Silicon Vertex Detector: An Overview and Test Results, with W.C. Wester, et al;
 - (c) Tests of the Radiation Hardness of Silicon Strip Detectors Under Neutron, Proton, and Gamma Irradiations, with H.-J. Ziock, et al.
5. Subsystem R&D Proposal to Develop a Silicon Tracking System, with A.J. Weinstein, et al, SCIPP REPORT (1990); Subsystem R&D Progress Report for a Silicon Tracking System: FY 1990-91, with A.J. Weinstein, et al, SCIPP REPORT 91/28 (1991)
6. Silicon Tracker for the Superconducting Supercollider, with J. Hylen et al, 2nd London Conf. on Position Sensitive Detectors, London, England Sept 4-7, 1990, Nucl. Instr. and Meth. **A310**, 497 (1991)
7. The CDF SVX: a Silicon Vertex Detector for a Hadron Collider, with W.C. Carithers et al, Nucl. Instr. Meth. **A289**, 388 (1990)
8. An Alignment Method for the Mark II Silicon Strip Vertex Detector Using an X-Ray Beam, with C. Adolphsen, et al, Proceedings of the European Symposium on Semi-Conductor Detectors, Munich, February 21-23, 1989, Nucl. Instr. Meth. **A288**, 257 (1990)
9. Prospects for Top at the Tevatron Collider in the 1990's, with S. Abachi et al, Proceedings of Physics at Fermilab in the 1990's, Breckenridge, Colorado 1989.
10. Initial Measurements of the Z Boson Resonance Parameters in e^+e^- Annihilation, with Mark II Collaboration, G. S. Abrams et al, Phys. Rev. Lett. **63**, 724 (1989);
Measurements of Z Boson Resonance Parameters in e^+e^- Annihilation, with Mark II Collaboration, G. S. Abrams et al, Phys. Rev. Lett. **63**, 2173 (1989)

Vitae

PERSONAL DATA

Born: May 11, 1945
Canada

EDUCATION

- 1971 Ph.D. Elementary Particle Physics, Univ. of Toronto (Canada)
- 1967 M.Sc. Nuclear Physics, Univ. of Toronto (Canada)
- 1966 B.Sc. Physics (honors), Univ. of Victoria (Canada)

PROFESSIONAL EXPERIENCE

- 1991–Present Professor and Director,
New Mexico Center for Particle Physics,
University of New Mexico/Los Alamos National Laboratory
- 1983–1990 Professor, Johns Hopkins University
- 1978–1983 Associate Professor, Johns Hopkins University
- 1976–1978 Assistant Professor, Johns Hopkins University
- 1974–1976 Assistant Professor, Michigan State University
- 1971–1974 Research Associate, Stanford Linear Accelerator Center

Professional Societies and Activities

1. Member, American Physical Society
2. Member, Canadian Association of Physicists
3. Invited to/participated 1975 *PEP Summer Study*, Lawrence Berkeley Laboratory
4. Coordinator: Group Studying "Data Handling for a Lepton Detector" 1978 *ISABELLE Summer Study*, Brookhaven National Laboratory
5. Secretary/Treasurer of the SLAC Users Organization, 1980
6. Co-Chairman of "Interaction Region Group" for the SLAC *Linear Collider Workshop*, 1981
7. Deputy Spokesman for experiment PEP4-TPC at SLAC, 1982
8. Coordinator of Committees of the SLAC Users Organization, 1984/85
9. Member of Organizing Committee of "Workshop on e^+e^- Physics at High Luminosities", Nov 30-Dec 1, 1984 at SLAC
10. President of the SLAC Users Organization, 1985/86
11. Coordinator of Dipole Detector Subgroup, Workshop on Experiments, Detectors and Experimental Areas for the SSC., Berkeley, July 1987.
12. Provocateur, *SLAC Summer Institute*, August 1987
13. Member of SLAC Scientific Policy Committee, 1988-1992
14. Fellow of the American Physical Society
15. Member of the "SLAC Beam Line" Editorial Advisory Board, 1989-
16. Invited to/participated in *TRIUMF Workshop on Tracking Systems for the SSC*, Vancouver, Canada, July 24-28, 1989
17. Invited to/participated in *Physics at Fermilab in the 1990's*, Breckenridge, Colorado, August 15-24, 1989
18. Coordinator of Tracking Subgroup, *Workshop on Physics and Detector Simulation for SSC Experiments*, January 9-19, 1990
19. Invited to/participated in *Workshop on Major SSC Detectors*, Tucson, Arizona, February 19-23, 1990
20. Invited to/participated in *L* Tracking Workshop*, Santa Fe, NM, April, 1990
21. Invited to/participated in *1990 Summer Study on High Energy Physics - Research Directions for the Decade*, Snowmass, Colorado, July 2-7, 1990
22. Member, Institute of Electrical and Electronics Engineers

Invited Talks at Major Conferences

1. Regge Absorption Model Analyses of ρ^0 and K^* Production Data, Rochester Meeting of the DPF, Rochester, September 1971
2. Direct Channel Effects in Non-Diffractive Scattering, Pion-pion Scattering Conference, Tallahassee, March 1973
3. Inelastic Scattering Amplitudes, Berkeley Meeting of the DPF, Aug. 1973
4. Future Directions in Baryon Spectroscopy, Symposium on Production of Heavy Excited Hadrons, Argonne National Laboratory, March 1974
5. Search for Narrow High Mass States at Fermilab, Conference on Particle Searches and Discoveries, Vanderbilt, 1976
6. Particle Search Results from Fermilab, 1976 CAP-APS-SMF Joint Congress, Quebec City, 1976
7. Interaction Region Group Report, SLAC/SLUO Users' Meeting on the SLAC Linear Collider, Dec. 1981
8. Heavy Quark Semi-Leptonic Decays and Tau Lepton Branching Fractions, XXII International Conference on High Energy Physics, Leipzig, July 1984
9. Countdown to Z^0 Physics at the Stanford Linear Collider, 1987 CAP Congress, Toronto, June 1987
10. The First Hadronic Z^0 Decays, 10th and Final Workshop on Grand Unification, Chapel Hill, NC, April 20-22, 1989
11. SSC Tracking: Demands and Choices, 1st US/Latin American Symposium on Physics, Technology, and Experiments at the SSC, Guanajuato, Mexico, December 1990

Publications: 1991-1992

1. The Mark II Silicon Strip Vertex Detector and Performance of a Silicon Detector Telescope in the Mark II Detector at the SLC, with L. Labarga, C. Adolphsen, G. Gratta, A. Litke, M. Turala, C. Zaccardelli, A. Breakstone, S. Parker, B. Barnett, P. Dauncey, D. Drewer, R. Jacobsen, and V. Luth, SLAC-PUB-5158, Proceedings of the 1989 IEEE Nucl. Sci. Symposium, San Francisco, January 15-19, 1990: IEEE Trans. Nucl. Sci. **38**, 25 (1991)
2. A Search for Elastic Non-Diagonal Lepton Pair Production in e^+e^- Annihilation at $\sqrt{s} = 29$ GeV, with Mark II Collaboration, J.J. Gomez-Cadenas et al, Phys. Rev. Lett. **66**, 1007 (1991)
3. Measurement of the Total Hadronic Cross Section in e^+e^- Annihilation at 29 GeV, with Mark II Collaboration, C. Van Zanthier, et al, Phys. Rev. **D43**, 34 (1991)
4. Silicon Tracker for the SSC, with J. Hylen et al, 2nd London Conf. on Position Sensitive Detectors, London, England Sept 4-7, 1990, Nucl. Instr. and Meth. **A310**, 497 (1991)
5. Measurement of the $B\bar{B}$ Fraction in Hadronic Z Decays with Precision Vertex Detectors, with Mark II Collaboration, R. Jacobsen et al, SLAC-PUB-5603, submitted to Phys. Rev. Lett. (1991)
6. Subsystem R&D Proposal to Develop a Silicon Tracking System, with A.J. Weinstein, et al, SCIPP REPORT (1990); Subsystem R&D Progress Report for a Silicon Tracking System: FY 1990-91, with A.J. Weinstein, et al, SCIPP REPORT 91/28 (1991)
7. Proceedings IEEE Nucl. Sci. Symposium, Santa Fe, NM, November 2-9, 1991:
 - (a) Construction of the CDF Silicon Vertex Detector, with B. Barnett, et al;
 - (b) The CDF Silicon Vertex Detector: An Overview and Test Results, with W.C. Wester, et al;
 - (c) Tests of the Radiation Hardness of Silicon Strip Detectors Under Neutron, Proton, and Gamma Irradiations, with H.-J. Ziock, et al.
8. The Mark II Silicon Strip Vertex Detector, with C. Adolphsen, et al, Nucl. Instr. and Meth. **A313**, 63 (1992)

9. Temperature Effects on Radiation Damage to Silicon Detectors, with E. Barberis, et al, 6th European Symposium on Semiconductor Detectors, Milan, Italy, February 24-26 1992, UCR/SSC/92-01 (1992)
10. A Luminosity Monitor for the Mark II Detector at the SLC, with J. Hylen, et al, Nucl. Instr. and Meth. A317, 453 (1992)
11. Silicon Tracking Conceptual Design Report, with A.J. Weinstein, et al, SCIPP 92/04, March 1992
12. SDC Technical Design Report, with G.H. Trilling, et al, SDC Report, SDC-92-201, April 1992

Sally Carol Seidel

Biographical Sketch

Sally Seidel received her Bachelor of Science degree in physics from Yale University in 1980. In 1983 she obtained a Master of Science degree at the University of Michigan, and in 1987 the same institution awarded to her the Ph. D. in Physics. The subject of her dissertation was "A Search for Nucleon Decay Employing Particle Identification, Invariant Masses, and Complete Track Reconstruction With a Water Cherenkov Detector."

From 1987 to 1991, Dr. Seidel worked as a research associate with the ARGUS experiment at the University of Toronto. She participated in the design and construction of a unique vertex chamber optimized for B physics. She also conducted an extensive study of charmed baryon decay.

Dr. Seidel joined the University of New Mexico faculty as assistant professor in 1991. A member of the CDF and SDC collaborations, she is presently involved in the development of a precision silicon tracking detector.

Publications Relevant to Proposed Research

1. The ARGUS Micro Vertex Drift Chamber, E. Michel, W. Schmidt-Parzefall, R.D. Appuhn, J. Buchmuller, H. Kolanooski, B. Kreimeier, A. Lange, K.W. Edwards, R.C. Fernholz, H. Kapitza, D.B. MacFarlane, M. O'Neill, J.A. Parsons, J.D. Prentice, S.C. Seidel, G. Tsipolitis, S. Ball, A. Babaev, M. Danilov, and I. Tichomirov; *Nucl. Instr. and Meth. A*, Vol. 283, 544 (1989).
2. A Measurement of $\tau(B^+)/\tau(B^0)$ from Lepton and Dilepton Rates in $\Upsilon(4S)$ Decays, H. Albrecht et al., ARGUS Collaboration; DESY Preprint 91-056, submitted to *Z. Phys.*
3. Search for $B \rightarrow sX^+X^-$ in Exclusive Decays of B Mesons, H. Albrecht et al., ARGUS Collaboration, *Phys. Lett. B*, Vol. 262, 148 (1991).
4. Search for $b \rightarrow s$ Gluons in B Meson Decays, H. Albrecht et al., ARGUS Collaboration, *Phys. Lett. B*, Vol. 254, 288 (1991).
5. Study of Inclusive Semileptonic B Meson Decays, H. Albrecht et al., ARGUS Collaboration, *Phys. Lett. B*, Vol. 249, 359 (1990).
6. Exclusive Hadronic Decays of B Mesons, H. Albrecht et al., ARGUS Collaboration, *Z. Phys. C*, Vol. 48, 543 (1990).
7. Reconstruction of Semileptonic $b \rightarrow u$ Decays, H. Albrecht et al., ARGUS Collaboration, *Phys. Lett. B*, Vol. 255, 297 (1990).
8. Search for Hadronic $b \rightarrow u$ Decays, H. Albrecht et al., ARGUS Collaboration; *Phys. Lett. B*, Vol. 241, 278 (1990).
9. Observation of Semileptonic Charmless B Meson Decays, H. Albrecht et al., ARGUS Collaboration; *Phys. Lett. B*, Vol. 234, 409 (1989).
10. Measurement of the Lifetime Ratio $\tau(B^+)/\tau(B^-)$, H. Albrecht et al., ARGUS Collaboration; *Phys. Lett. B*, Vol. 232, 554 (1989).

Vitae

PERSONAL DATA

Born: January 8, 1958

EDUCATION

1987 Ph.D., Physics, University of Michigan

1983 M.S., Physics, University of Michigan

1980 B.S., Physics, Yale University

PROFESSIONAL EXPERIENCE

1991-Present Assistant Professor, University of New Mexico

1991-Present Staff Member, Los Alamos National Laboratory

1987-1991 Research Associate, University of Toronto

Professional Societies and Activities

1. Member, American Physical Society
2. Member, Fermilab Users Executive Committee
3. Member, American Association of Physics Teachers
4. Member, The Institute of Particle Physics, 1987-1991
5. Member, The American Astronomical Society, 1987-1988
6. Invited to *Eighth Workshop on Grand Unification*, Syracuse, 1987
7. Participated in *1986 Summer Study on High Energy Physics*, Snowmass, Colorado, July 1986
8. Invited to *1985 SLAC Topical Conference on Particle Physics*, SLAC, 1985

Invited Talks at Major Conferences

1. New Results From IMB, SLAC Topical Conference in Particle Physics, 1985
2. Searching for Nucleon Decay with Invariant Mass Techniques, Meeting of the American Physical Society Division of Particles and Fields, Salt Lake City, 1987
3. Recent Results From the IMB Nucleon Decay Experiment, The Eighth Workshop on Grand Unification, Syracuse, 1987
4. Recent Results in Heavy Hadron Spectroscopy, XXIV International Conference in High Energy Physics, Munich, 1988
5. Results in B and D Physics From ARGUS, Meeting of the American Physical Society Division of Particles and Fields, Houston, 1990
6. The ARGUS Micro-Vertex Drift Chamber, Meeting of the American Physical Society Division of Particles and Fields, Vancouver, 1991

Recent Talks, Seminars, Colloquia

1. Meeting of the American Physical Society Division of Particles and Fields, Vancouver, 1991
2. Los Alamos National Laboratory, seminar, 1991
3. Superconducting Supercollider Laboratory, seminar, 1991
4. University of Illinois, seminar, 1991
5. University of Chicago, seminar, 1991
6. University of New Mexico, colloquium, 1991
7. Haverford College, colloquium, 1991
8. Union College, colloquium, 1991
9. Southern Methodist University, seminar, 1991
10. Meeting of the American Physical Society Division of Particles and Fields, Houston, 1990
11. Queen's University, colloquium, 1990
12. The XXIV International Conference in High Energy Physics, Munich, Germany, 1988
13. The Eighth Workshop on Grand Unification, 1987
14. Meeting of the American Physical Society Division of Particles and Fields, Salt Lake City, 1987
15. University of Toronto, seminar, 1987
16. DESY, colloquium, 1987
17. University of Michigan, seminar, 1987
18. Fermi National Accelerator Laboratory, seminar, 1987
19. Columbia University, seminar, 1987
20. University of Chicago, seminar, 1987
21. State University of New York at Stony Brook, seminar, 1987

Publications: 1991-1992

1. New Results on D^0 Decays, H. Albrecht et al., ARGUS Collaboration; DESY Preprint 92-077, submitted to *Phys. Lett.*
2. Measurement of Inclusive Baryon Production in B Meson Decays, H. Albrecht et al., ARGUS Collaboration; DESY Preprint 92-074, submitted to *Phys. Lett.*
3. A Search for $D^0 \rightarrow K^+ \pi^-$, H. Albrecht et al., ARGUS Collaboration; DESY Preprint 92-056, submitted to *Phys. Lett.*
4. Evidence for the Production of the Charmed Doubly Strange Baryon Ω_c in e^+e^- Annihilation, H. Albrecht et al., ARGUS Collaboration; *Phys. Lett. B*, Vol. 288, 367 (1992).
5. A New Determination of the $B^0 - \bar{B}^0$ Oscillation Strength, H. Albrecht et al., ARGUS Collaboration, DESY Preprint 92-050, submitted to *Phys. Lett.*
6. Exclusive Semileptonic Decays of B Mesons to D Mesons, H. Albrecht et al., ARGUS Collaboration, DESY Preprint 92-029, submitted to *Phys. Lett.*
7. Search for Neutrinoless τ Decays, H. Albrecht et al., ARGUS Collaboration, DESY Preprint 92-013, submitted to *Phys. Lett.*
8. Search for Charm Production in Direct Decays of the $\Upsilon(1S)$ Resonance, H. Albrecht et al., ARGUS Collaboration, *Z. Phys. C*, Vol. 55, 25 (1992).
9. Production of D_s^+ Mesons in B Decays and Determination of $f(D_s)$, H. Albrecht et al., ARGUS Collaboration, *Z. Phys. C*, Vol. 54, 1 (1992).
10. Measurement of the Decay $B^- \rightarrow D^{*0} \ell^- \bar{\nu}$, H. Albrecht, ARGUS Collaboration, *Phys. Lett. B*, Vol. 275, 195 (1992).
11. A Measurement of the Inclusive Semileptonic Decay Fraction of Charmed Hadrons, H. Albrecht et al., ARGUS Collaboration, *Phys. Lett. B*, Vol. 278, 202 (1992).
12. A Measurement of the Asymmetry in the Decay $\Lambda_c^+ \rightarrow \Lambda \pi^+$, H. Albrecht et al., ARGUS Collaboration, *Phys. Lett. B*, Vol. 274, 239 (1992).

13. Measurement of R and Determination of the Charged Particle Multiplicity in e^+e^- Annihilation at $\sqrt{s}$ Around 10 GeV, H. Albrecht et al., ARGUS Collaboration, *Z. Phys. C*, Vol. 54, 13 (1992).
14. Measurement of Exclusive One-Prong and Inclusive Three-Prong Branching Ratios of the τ Lepton, H. Albrecht et al., ARGUS Collaboration, *Z. Phys. C*, Vol. 53, 367 (1992).
15. First Evidence for χ_c Production in B Meson Decays, H. Albrecht et al., ARGUS Collaboration, *Phys. Lett. B*, Vol. 277, 209 (1992).
16. The Measurement of D_s^+ and D^+ Meson Decays into $K^{*+}\bar{K}^{*0}$, H. Albrecht et al., ARGUS Collaboration; *Z. Phys. C*, Vol. 53, 361 (1992).
17. Inclusive Production of D^0 , D^+ , and $D^{*}(2010)^+$ Mesons in B Decays and Nonresonant e^+e^- Annihilation at 10.6 GeV, H. Albrecht et al., ARGUS Collaboration; *Z. Phys. C*, Vol. 52, 353 (1992).
18. Observation of Λ_c^+ Semileptonic Decay, H. Albrecht et al., ARGUS Collaboration; *Phys. Lett. B*, Vol. 269, 234 (1991).
19. A Measurement of $\tau(B^+)/\tau(B^0)$ from Lepton and Dilepton Rates in $\Upsilon(4S)$ Decays, H. Albrecht et al., ARGUS Collaboration; DESY Preprint 91-056, submitted to *Z. Phys.*
20. Observation of the Decay $D_s^- \rightarrow \phi e^- \bar{\nu}$ and $D^- \rightarrow K^{*0} e^- \bar{\nu}$, H. Albrecht et al., ARGUS Collaboration; *Phys. Lett. B*, Vol. 255, 634 (1991).
21. A Spin-Parity Analysis of $\gamma\gamma \rightarrow \rho^+ \rho^-$, H. Albrecht et al., ARGUS Collaboration, *Phys. Lett. B*, Vol. 267, 535 (1991).
22. Observation of the Decay $\tau \rightarrow \rho \pi \pi \nu_\tau$, H. Albrecht et al., ARGUS Collaboration, *Phys. Lett. B*, Vol. 260, 259 (1991).
23. Observation of Spin Parity 2^+ Dominance in the Reaction $\gamma\gamma \rightarrow \rho^0 \rho^0$ Near Threshold, H. Albrecht et al., ARGUS Collaboration; *Z. Phys. C*, Vol. 50, 1 (1991).
24. Study of pp and $\Lambda\Lambda$ Production in e^+e^- Annihilation at 10 GeV Center of Mass Energy, H. Albrecht et al., ARGUS Collaboration; *Z. Phys. C*, Vol. 49, 349 (1991).

25. Search for $B \rightarrow sX^+X^-$ in Exclusive Decays of B Mesons, H. Albrecht et al., ARGUS Collaboration, *Phys. Lett. B*, Vol. 262, 148 (1991).
26. Search for $b \rightarrow s$ Gluons in B Meson Decays, H. Albrecht et al., ARGUS Collaboration, *Phys. Lett. B*, Vol. 254, 288 (1991).

Timothy L. Thomas

Biographical Sketch

Timothy L. Thomas graduated from Clarkson College of Technology (now Clarkson University) in Potsdam, New York in 1984 with a bachelor of science cum laud in computer science. He remained at Clarkson an extra year to complete work on a second bachelor degree in physics, with a minor in mathematics.

During the three years prior to his departure from Potsdam, Tim worked on a variety of projects: at the E.R.C. Computing Center, he created a centralized microcomputer networking system and a CAI applications subroutine library and also acted as a software consultant to students and faculty; as a research assistant to physics professor Herb Helbig, he worked on elastic ion scattering spectroscopy; and with professors Tassos Bountis (mathematics) and David Kaup (physics) he performed a series of numerical studies of non-linear beam-beam interaction models and soliton solutions of the non-linear Schoedinger equation, respectively.

In the fall of 1985, he entered the University of Minnesota to pursue a Ph.D. in elementary particle experimentation. While completing required coursework, he taught freshman physics labs, modern physics recitation sections and labs, and a senior project lab for physics majors and worked as a research assistant on several projects including software maintenance for the Soudan I Proton Decay Detector, electronics and chamber repair for Fermilab Experiment-756 (a precision measurement of the Ω^- magnetic moment), and design and construction of trigger electronics for the muon detector sub-system of the D0 experiment, spending the summer of 1987 at Fermilab.

In June of 1988, he went to the Japanese National High Energy Physics Laboratory (KEK) to work on the AMY experiment under the aegis of professor Ronald Poling. During his first year in Japan, Tim worked primarily on the construction, operation, and analysis of a xenon-based X-ray detector, designed to tag electrons based on detection of the synchrotron photons emitted during their curved flight through AMY's 3 Tesla solenoidal B-field. Subsequent to this, he began work on the analysis of high- P_t inclusive leptons as a tag for quark flavor and charge. This work evolved into his thesis topic, a measurement of the electroweak interference-induced forward-backward asymmetry of b-quark pairs produced in e^+e^- annihilations.

He is recently married, and his long-neglected hobbies include reading (esp. philosophy, history, and current/world events), music, ballroom dancing, roller skating, bicycling, and hiking.

Sample Publications Relevant to Proposed Research

1. An X-ray Detector as a Detector for Electron Identification, Y. Fujii, K. Abe, S. Eno, D.H. Han, H. Harada, Y. Higashi, Y. Ishi, T. Ishizuka, H. Miyata, K. Ohta, D.R. Perticone, R. Poling, N.M. Shaw, H. Takei, T. Thomas, E.H. Thorndike, H. Yokota (KEK, Tsukuba, Rochester U., Kyungpook National U., Niigata U., Saitama U., Minnesota U., Tokyo Inst. Tech.), Nucl. Instr. Meth. **A283**, 655 (1989)

Vitae

PERSONAL DATA

Born: July 10, 1962
Albany, New York

EDUCATION

- 1992 Ph.D. Elementary Particle Physics, University of Minnesota, Minneapolis
- 1985 B.S. Physics/mathematics, Clarkson University, Potsdam, New York
- 1984 B.S. cum laude, Computer Science, Clarkson University

PROFESSIONAL EXPERIENCE

Jun 1986 – Present	Research Assistant,
School of Physics and Astronomy,
University of Minnesota, Minneapolis
(Jun 1988 – Sep 1990	Resident at KEK National High Energy Physics Lab
Tsukuba, Japan – in connection with R.A. position)
(May 1987 – Sep 1987	Resident at Fermi National Accelerator Laboratory,
Batavia, Illinois – in connection with R.A. position)
Sep – May, 1985, 1986, 1987	Teaching Assistant
School of Physics and Astronomy,
University of Minnesota, Minneapolis
Jan 1981 – Aug 1985	Student Systems Programmer,
E.R.C. Computing Center,
Clarkson University, Potsdam, NY
Mar 1978 - Aug 1982	Junior Programmer/Analyst,
Vision Data Corporation,
Albany, New York

Professional Societies and Activities

1. Member, American Physical Society
3. Member, Minnesota chapter, Japan-American Friendship Association
2. Travelled to Washington D.C. in support of the SSC (July 1992)

Selected Recent Publications

1. Evidence for Hard Scattering of Hadronic Constituents of Photons in Photon-Photon Collisions at TRISTAN. The AMY Collaboration (R. Tanaka, et al.), Phys. Lett. **B277**, 215 (1992).
2. A Measurement of the Photon Structure Function F_2 , The AMY Collaboration (T. Sasaki, et al.), Phys. Lett. **B252**, 491 (1990).
3. Measurements of R for e^+e^- Annihilation at TRISTAN, The AMY Collaboration (T. Kumita, et al.), Phys. Rev. **D42**, 1339 (1990).
4. Multi-Hadron Event Properties in e^+e^- Annihilation at $\sqrt{s} = 52$ to 57 GeV. The AMY Collaboration (Y.K. Li, et al.), Phys. Rev. **D41**, 2675 (1990).
5. Forward-Backward Charge Asymmetry in $e^+e^- \rightarrow$ Hadron Jets, The AMY Collaboration (D. Stuart, et al.), Phys. Rev. Lett. **64**, 983 (1990).
6. A Comparison of Quark and Gluon Jets Produced in High-Energy e^+e^- Annihilations, The AMY Collaboration (Y.K. Kim, et al.), Phys. Rev. Lett. **63**, 1772 (1989).
7. A Measurement of $e^+e^- \rightarrow b\bar{b}$ Forward-Backward Charge Asymmetry Between $\sqrt{s} = 52$ and 57 GeV. The AMY Collaboration (H. Sagawa, et al.), Phys. Rev. Lett. **63**, 2341 (1989).

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