fermilab report

July/August 1990

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On the cover: Wilson Hall as viewed from the proposed site of the Main Injector ring.
Photograph by Fred Ullrich, Fermilab Visual Media Services.

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REPORT AND RECOMMENDATIONS FROM THE 1990 ASPEN MEETING OF THE FERMILAB PHYSICS ADVISORY COMMITTEE

The Fermilab Physics Advisory Committee (PAC) met in Aspen from June 15 through June 22, 1990. As has been its custom since 1976, it made a number of recommendations of a general nature to the Laboratory Director. The text of the General Recommendations follows:

The Committee congratulates the Laboratory on the smooth startup of the 1990-91 Fixed Target run including the efficient operation of the accelerator and the beam lines. The current program is both diverse and strong, consisting of 17 experiments. These will probe the electroweak sector, including CP violation and weak decays, the production and decay of heavy quarks, the dynamics of strong interactions and the structure of hadrons.

We anticipate a fruitful run, allowing successful completion of much of the current program, and look forward to a continuing strong physics program.

In the view of the Committee, an essential element of the continuing program is the construction of the new Main Injector. The increase in luminosity (to > $5 \times 10^{31}/cm^2 sec$) for the Collider mode made possible by this upgrade greatly enhances the reach of the searches for new physics, especially the top quark, at both CDF and DØ. The Fixed Target program will also reap substantial benefits from the increase in luminosity. Fixed Target experiments using the Main Injector will be able to run simultaneously with the Collider program.

While the details of the current Fixed Target run were not treated as an issue for discussion, the preparations for the 1991 Collider run are of central interest to the Committee. The status of the CDF and DØ detectors was reviewed for the Committee. We congratulate the CDF Collaboration on the remarkable rapidity with which physics results have been published. We also note the effort made by the Laboratory to provide CDF with the computing facilities that helped make this achievement possible. The Committee continues to endorse the Laboratory's plan to keep the relative priority high for a roll-in of

the CDF and DØ detectors in summer of 1991. The Committee is concerned about the apparent delays for both DØ (e.g., the endcap cryostat) and CDF (e.g., the SVX silicon). The Laboratory is strongly encouraged to present a detailed schedule review of both DØ and CDF at the next PAC meeting.

The primary consideration of the Committee at this meeting focused on the question of what would constitute the optimum physics program for study at Fermilab in the 1992-1994 time frame (i.e., after the current Fixed Target run) and beyond (i.e., presumably after the construction of the new Main Injector). Several funding scenarios for the former period were presented and discussed. The Committee strongly endorses those scenarios that include **both** Fixed Target and Collider runs in the 1992-1994 period (approximate dates).

As the highest energy particle physics machine in the world, the primary physics goal at Fermilab remains the exploration of interactions at the highest possible energy. The targets include not only the discovery of the anticipated top quark but also the discovery of *unexpected* physics. To deal with the issue of the remaining physics goals, the Committee discussed them in terms of five sub-areas characterized by the elementary particle of greatest interest involved in the process. The five areas are I) ν physics; II) u and d quarks and gluons; III) s quarks; IV) c quarks; and V) b quarks. This basis choice is clearly neither orthogonal (there is overlap between topics and between Collider and Fixed Target physics), nor normalized (the different topics are not of equal weight), nor complete (due to the topics noted above). However, it did supply a framework for the discussion and the conclusions. It is worth noting that the question of how to make the largest possible contribution to the evolution of our understanding of b quark physics is probably the most challenging planning issue facing the Laboratory and the PAC.

I) ν Physics

Neutrino physics is very important, and Fermilab still has a unique role as the highest energy Fixed Target machine. With the Main Injector, it will also become the most powerful source of high energy neutrinos.

The questions of mass and mixing in the three light neutrino generations are

fundamental. There are important ranges of the parameter that can best be studied at Fermilab. Also the weak mixing angle, $\sin^2\theta w$, can be measured to precisions comparable to other methods, and the comparison provides a strong test of the Standard Model. Finally, the measurements of structure functions in deep inelastic scattering have unique aspects and are complementary to those that will be obtained at HERA.

After the Main Injector is built, there will be important opportunities in ν physics due to the higher available intensity. The Laboratory should continue to encourage detailed feasibility studies of the various options.

With the new Main Injector facility, it seems possible to collect a data sample more than an order of magnitude greater than past experiments. An acceptable proposal for deep inelastic neutrino measurements must demonstrate how to provide a precise determination of $\sin^2\theta w$ to 1% and of ρ to a 1/4% level. It should also indicate how information on structure functions can be obtained.

We consider the search for $\nu_\mu \rightarrow \nu_\tau$ mixing with sensitivities at the level $\sin^2 2\alpha \gtrsim 10^{-4}$ and $\Delta m^2 > (10\ \mathrm{eV})^2$ to be important. One needs detailed costed designs of the beam options. An acceptable proposal must demonstrate that the direct ν_τ background is not a problem and that evidence for a ν_τ signal can be identified above background.

Given the magnitude and importance of a long-baseline neutrino oscillation experiment, a careful study should be undertaken to decide exactly the detector and beamline requirements necessary to accomplish the goals of a search for $\nu_\mu \rightarrow \nu_\tau$ and $\nu_\mu \rightarrow \nu_e$ oscillations with a sensitivity of $\sin^2 2\alpha \sim 0.01$ and $\Delta m^2 \sim 0.001\ \mathrm{eV}^2$.

These experiments are very large efforts. If they are to be done, they must be done incisively and with adequate manpower. Consequently, they require great resources and commitment from the Laboratory and the physicists. The Committee encourages the Laboratory to pursue further efforts in defining these goals and their costs.

II) Up, Down and Gluon Physics

The field of QCD tests has matured. It is no longer necessary to establish that quarks and gluons are the relevant degrees of freedom in hard hadronic interactions. It is the recommendation of this Committee that further experiments in this vein must significantly improve the determination of QCD parameters and hadron structure functions. The Committee believes that most such measurements of hard QCD processes are best done in collider experiments. The production of jets, direct photons, lepton pairs (Drell-Yan) and the ψ and the Υ are examples. Such data will test QCD calculations, constrain structure functions, and build confidence in our ability to see the deviations from QCD that are indicative of new physics such as compositeness.

We draw attention to the fact that W and Z production in a wide rapidity range have the potential to constrain parton distribution function parameters in the proton. Jet data help constrain the gluon distribution function and may help in the measurement of both the gluon and quark fragmentation functions. Analysis of the remainder of the event associated with hard processes (e.g., the "pedestal" effect and mini-jet production) will also likely yield interesting, if less easily interpretable results. There is also intrinsic interest in partons at very small x.

Issues that can still fruitfully be studied in the Fixed Target program include structure function measurements in neutrino and muon scattering and in measurement of the Drell-Yan process. However, such work will be useful only if the measurements yield significant improvements over existing data. The kinematic reach at Fermilab is complementary to the region to be explored by HERA.

Primary polarized beams offer the possibility of performing spin measurements in the hard kinematic regime ($P_t \gtrsim 10$ GeV) where the theoretical issues are clear. The Committee recommends that potential users be encouraged to study the problems of preserving the polarization of protons throughout the entire accelerator chain in the framework of the new Main Injector. The value of spin asymmetry experiments using secondary or tertiary beams, which must be done at much lower P_t, is much less obvious.

III) S Quark Physics

The Committee believes that the most important objective in kaon physics continues to be an accurate measurement of ε'/ε. It would be very valuable if one could achieve a measurement of this quantity to the accuracy of $\pm 1\text{-}2 \times 10^{-4}$ before the advent of the Main Injector. In addition, the exploration of rare decay processes in the kaon system remains a physics goal well worth pursuing.

The Main Injector facility could significantly enhance the capabilities for pursuing further the kaon physics program at Fermilab by virtue of the high intensity kaon beams that could be derived from the 120 GeV Main Injector beam. In an experiment at the Main Injector, one could push the precision of the measurement of ε'/ε to the level of 5×10^{-5}. Rare K decay physics could also be pursued with studies of the CP violating decays $K_L \rightarrow \pi^0 l \bar{l}$, where $l = e, \mu$ or ν (provided that backgrounds can be adequately understood and controlled) and searches for flavor changing decays such as $K_L \rightarrow \mu e$ at sensitivities approaching 10^{-13}. These are all valuable physics goals, but it is still too early for the Committee to ascertain what are the best experimental objectives or facilities for the program. The Committee encourages the Laboratory to pursue further efforts in defining these goals and their costs.

IV) C Quark Physics

For the foreseeable future, the study of charm at Fermilab will continue as a rich, world-class program. For the next two Fixed Target runs, an achievable goal is 1×10^6 reconstructed charm events. The Laboratory should carefully consider the importance and physics payoff of a charm program continued beyond that level and investigate how to accomplish the new steps that would be necessary.

In the 1990-91 run, two experiments (E-687 and E-791) each expect to reconstruct of order 1×10^5 charm events. E-760 is beginning its exploration of excited charmonium states.

In the next two Fixed Target runs, one high-rate photoproduction experiment could reconstruct 1×10^6 charm events. This very attractive possibility can be realized only if appropriate steps are taken by the Laboratory, including

strengthening of the experimental group(s) that might be involved. Also, E-781 will open a possible new front emphasizing charmed baryons produced at large x in a hyperon beam. Important questions concerning this production mechanism are expected to be answered soon by experiment WA89 at CERN.

We are confident that a charm program similar to the one we describe would give the Laboratory one excellent component of a balanced heavy flavor program in 1992-94.

V) B Quark Physics

The Committee heard well prepared summaries of b physics progress and plans in the Fixed Target program and at CDF. The Fixed Target experiments that could reconstruct tens of b events include E-791 (an open geometry detector) and E-789 (a restricted geometry detector). E-771 has been approved to perform similar measurements. The techniques of all three experiments are quite distinct and so could offer considerable diversity to this program. Evidence for a strong b quark signal in CDF's inclusive electron trigger was presented. The CDF collaboration appears to be making rapid and very interesting progress in this part of its program.

The Committee generated a list of b physics topics it considers important and relevant to the 1992-94 period. The list, not prioritized, includes (i) hadronic cross sections for B, B_s, Λ_b, etc.; (ii) lifetimes for $B^{\pm}$ and B^0 mesons; (iii) discovery of B_s and B_c (including measurements of cross section, mass, and lifetimes); (iv) measurement of B_s-$\bar{B}_s$ mixing; and (v) branching ratios into selected modes.

The Fixed Target experiments with an open geometry could observe B mesons in the 1993 Fixed Target run. If they can operate at the desired rates, limited but significant physics results could be obtained. These include hadroproduction cross-sections, separate lifetimes of B^+ and B^0 and possible observations on B_s. There could also be some information on relative branching ratios. With the exception of hadroproduction cross-sections, however, these physics

results may be obtained earlier by competitive experiments such as SLD, CDF, CLEO and experiments at LEP. E-789, with a more restricted geometry, could observe the charmless decay $B^0 \rightarrow \pi^+\pi^-$ and provide the first evidence of "Penguin" diagrams by observing $B^0 \rightarrow K^+\pi^-$.

Even though the Committee believes that both CDF and DØ should maintain as their top priority the search for new phenomena at high energy, both collaborations should continue to explore seriously the possibility of doing b physics with their detectors. The Committee is impressed by the potential for doing b physics that is offered by the Collider as indicated by the results from CDF and urges the Laboratory to encourage efforts to exploit this physics opportunity with the CDF and DØ detectors. The Laboratory should also give due consideration to new initiatives dedicated to doing b physics. Whether or not a significant b physics program can be carried through at the Collider may be better judged after one sees the results obtained with the SVX in the next run of CDF.

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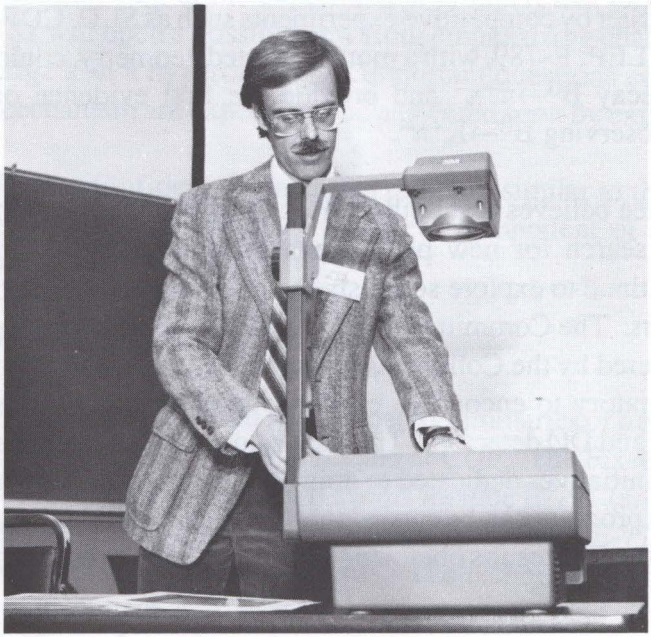
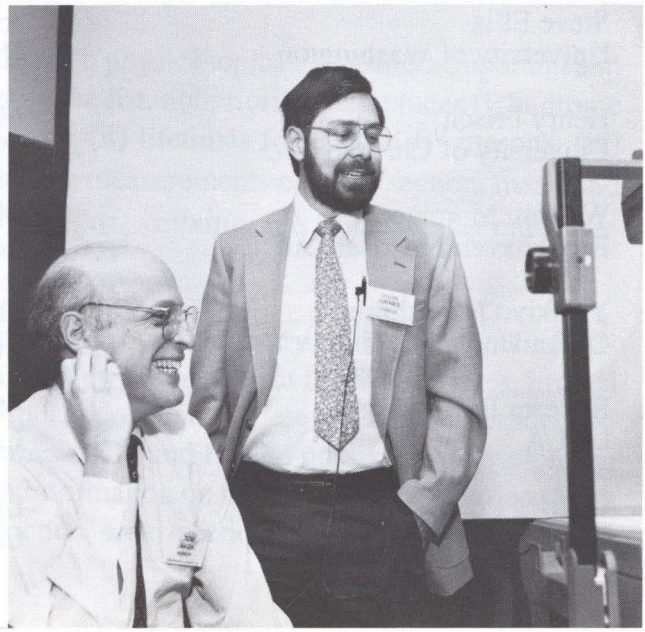


Stephen Holmes briefs industrial representatives on the Main Injector proposal.

Tom Nash, Head of the Computing Division and colleague Irwin Gaines participate in a debate on the issue of "Big Boxes vs Little Boxes."



FERMILAB III TECHNOLOGY COMES OF AGE
A Report on the Fermilab Industrial Affiliates Spring Meeting

By *Richard Carrigan, Jr.*

The tenth anniversary meeting of the Fermilab Industrial Affiliates was held May 31-June1, 1990. The Fermilab Industrial Affiliates are a group of about thirty-five companies interested in the technology developed at Fermilab. The annual Affiliates meeting is used as a forum for Fermilab to interact with industry and to brief industrial representatives on new programs at the Laboratory.

This year the program featured two areas at the Laboratory with the potential for important new technology: Fermilab III with the Main Injector Project now on the table, and the activities of the new Computing Division.

The Main Injector Project

Steve Holmes gave the industrial representatives a complete briefing on the Main Injector proposal. The Main Injector will replace the existing Main Ring (the original Fermilab accelerator still in use as an injector for the Tevatron). The replacement will result in a five-fold luminosity improvement for the Tevatron. (See *The Main Injector* page 15 of this issue for details of this project). Holmes placed heavy emphasis on the new equipment and technology needed for the project. The Main Injector will require 650 new magnets containing 7,500 tons of good magnet steel and 800 tons of copper. Holmes stressed the importance of getting steel with a very low coercive force, less than one oersted. Twelve new ten megawatt power supplies are needed along with many smaller ones and RF power amplifiers.

Some components will be recycled from the present Main Ring including several hundred magnets, the ion pumps in the vacuum system and the RF cavities. A 19,000 square feet industrial building is planned to handle magnet construction. The new accelerator will be housed in 15,000 feet of tunnel enclosures.

Professor Brig Williams of the University of Pennsylvania reported on the detector requirements for Fermilab III. Williams stressed the need for new, advanced electronic technology. He noted that much of the technology needed for Fermilab III is similar to the far more demanding performance specification developments that are required for the SSC. The requirements for the new systems are mind-boggling: up to a million channels of electronics feeding data in on a system approaching the scope of the Midwest telephone network; computing power needs of ten to one hundred thousand VAX-780 equivalents; and image processing at a rate on the order of 10 megahertz.

In addition to the new electronics and computing requirements, there are calls for sophisticated new electronic devices. These include adaptations of the pixel-based infrared detectors used in other applications at slower rates; and devices called solid state photomultipliers.

Computing Projects and Challenges

The second program highlight was the focus on the need for ever more powerful computing resources at Fermilab. In the last several years, the data collection and data analysis problems at Fermilab have approached the point where all of the existing conventional super computers in the world would have a hard time keeping up with the data analysis. The advent of Fermilab III will magnify the problem by at least another factor of ten. A second challenge is data storage. With the old nine track tape storage technology used at the Laboratory, we were approaching the point where tapes would have driven both man and computer out of the newly constructed Feynman Computing Center.

Fermilab has made several noteworthy assaults on its computing problem in the last several years. The Laboratory has led in developing microprocessor farms to handle large quantities of experimental data with ganged arrays of hundreds of processors. This capability enabled the computing forces at the Laboratory to untangle the enormous amounts of data generated in the last Collider run where the integrated luminosity outstripped the anticipated amount by a factor of five. Another important development has been technology to employ 8 mm video tapes as a data storage medium for experimental

data. Finally in the last year we have brought a powerful central processor on line in a new 74,000 square feet building, the Feynman Computing Center.

For years, the Fermilab computing problem has been viewed as an arcane novelty by much of the rest of the computing world. The last year has seen a major sea change. The requirements of data visualization and the new power of RISC technology has uncovered many other users interested in the very problems Fermilab has been attacking.

The Fermilab assault on its own computing problem has resulted in two major initiatives: the use of video tape technology for data storage; and farms of hundreds of microprocessors loosely coupled together to process data. In addition, the availability of powerful inexpensive workstations has intrigued many researchers. These workstations are sometimes referred to as "little boxes." On the other hand, Fermilab has also recently acquired a very powerful Amdahl central computing system housed in the new Feynman Center, a "big box" so-to-speak. The features and powers of these two apparently disparate approaches formed the framework for the computing portion of the program.

Dr. Irving Wladawsky-Berger of IBM was the banquet speaker. Wladawsky-Berger, one of the developers of RISC systems at IBM, described some of the new initiatives underway to address the large-scale computing problem. Fermilab is no longer alone. Berger cited the computing "Grand Challenges" outlined by the Office of Science and Technology Policy. These include such diverse areas as fluid dynamics for hypersonic flight, data analysis for the NASA great observatories, understanding the human genome and forecasting the weather. Berger emphasized that in many cases extremely large general purpose computers are necessary. The software for these systems can be very challenging. Even the "little box" workstations are increasingly linked together to share complex software and enormous data bases. Often these big nets of hundreds of workstations require a large central computer for system management. This software management can become a problem in itself.

Grant Saviers, Vice President for Storage and Information Management at Digital Equipment Corporation, discussed another phase of the Fermilab

computing challenge, the requirement for more and more storage capacity. Fermilab is also not alone in wanting more memory storage. Users now anticipate requirements for hundreds of petabytes of storage (a petabyte is a million-billion bytes of information). For example, a planned earth orbiting satellite will generate a mere two trillion bytes of data a day over a thirty year period. Information users on the ground will need access to all the data.

Fortunately, available memory is becoming more economical. The costs are dropping twenty to thirty percent per year. In looking into the future, Saviers saw a number of trends. There is a real information explosion underway. Computers want more and more access to extremely large global data bases. Managing such large information systems remains a challenge for many companies.

Saviers expects that economies of scale in memories will continue. He also saw no appreciable change from reliance on magnetic media for the middle-range future. Storage devices will become ever more intelligent and the trend toward hierarchical arrangements will continue. Above all, software is the key to the future for storage management.

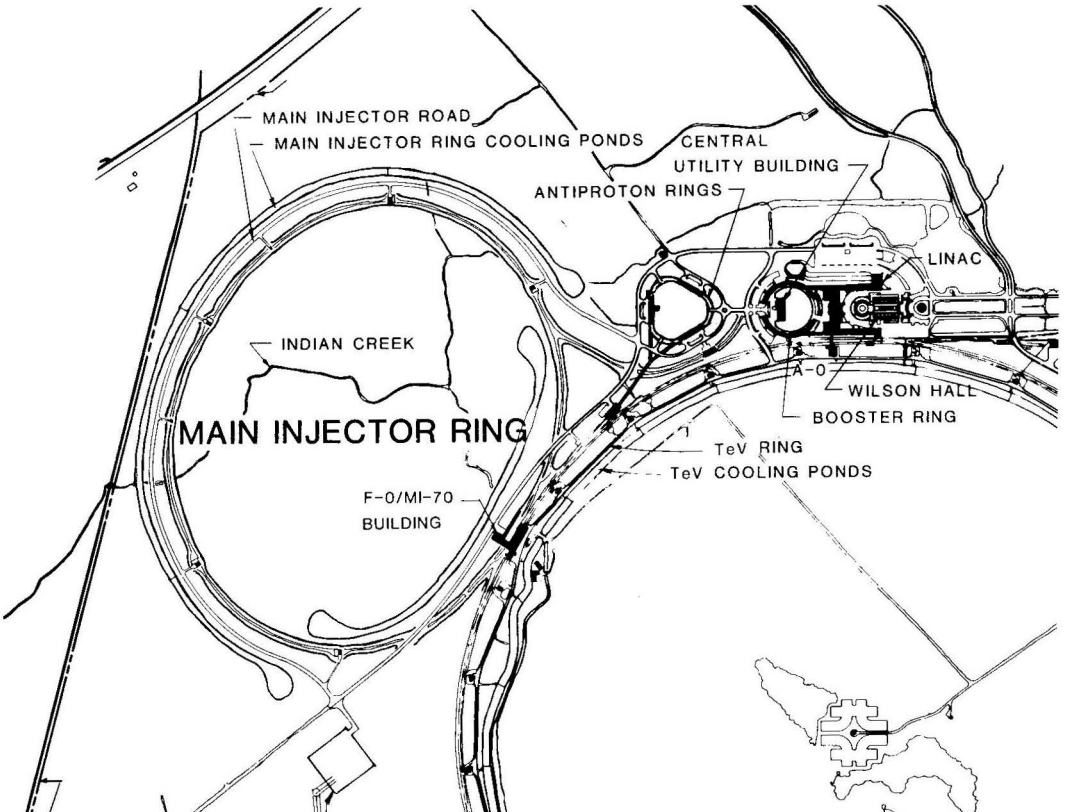
Big Boxes Versus Little Boxes

A highlight of the computing presentations was the "Great Computer Debate-Big Boxes versus Little Boxes." For many years, much of the high energy physics computing load has been handled using gigantic central computing facilities ("Big Boxes" in the debate). These provide relatively large-scale computing resources in a disciplined environment. The advent of reduced instruction set technology has brought approximately the same power to the desktop workstation, often at a substantial cost savings. In the last several years Fermilab has developed a home-brew solution to its own computing problem which exploits this technology in tandem with a loosely parallel computing approach. That is an outgrowth of the award-winning Fermilab Advanced Computing Project (ACP). Meanwhile commercial workstations have also been harnessed into the problem. It was a combination of those two technologies that solved the challenging computing load that developed because of the enormously successful CDF run. These devices represent the "Little Boxes" of the debate.

Like the "Little Engine that Could" the little boxes were the sentimental favorite in the debate. The two debate teams were formed by four key members of the new Computing Division: Joel Butler, Irwin Gaines, Tom Nash and Jack Pfister. Tom Nash, the Head of the Division, served as moderator. With experience as a member of the Harvard Debating Team, Irwin Gaines laid out the rules. They were simple. Two people took each side of the debate for the first half. For the second half, they switched over to the other side. The debate became a mirror of real life; the debaters often found they were arguing with themselves.

It soon became clear that although the little boxes had developed enormous power there were also important features that the central computing environment contributed. The small boxes often operate in a UNIX environment, an operating system that engenders fierce devotion but also many criticisms. There are also incompatibility problems and, in some cases, a lack of system support. File management is often desultory at best. On the other hand, nearly everyone is impressed by the cost performance and user friendliness of many small systems.

The details of the high energy computing and data collection challenge will be assembled into a publication. This should be available for the interested reader in several months. Some details on memory demands and possibilities for the nineties are already available from the Laboratory.



The location of the proposed Main Injector ring showing interconnections to the Booster, antiproton source and the Tevatron.

THE FERMILAB MAIN INJECTOR

By *Stephen D. Holmes*

The Fermilab Main Injector is the centerpiece of a series of improvements to the Fermilab accelerator complex known as Fermilab III. Specifically, this new accelerator is designed to support a luminosity in excess of $5 \times 10^{31} cm^{-2}$ sec in the Tevatron $\bar{p}$-p Collider. The concept of the Main Injector has been developed over the last two years. A Conceptual Design Report has been prepared and submitted to the U.S. Department of Energy accompanied by a request for a Fiscal Year 1992 construction start. The total project cost is estimated at $194 million. Fermilab has proposed to complete the project over a 38 month period starting on October 1, 1991. Construction will require a seven month disruption to the Fermilab High Energy Physics program starting on April 1, 1994. Development work on a new dipole magnet required for the Main Injector was initiated on October 1, 1989. The first full scale prototype will be delivered to the Magnet Facility on September 28, 1990.

Role in Fermilab III

The Fermilab Tevatron is the highest energy particle collider in the world today. It will remain in this preeminent position until the advent of either the SSC in the United States or of the LHC in Europe. The Tevatron collider was operated at a center-of-mass energy of 1800 GeV, with a total delivered luminosity of 10 pb^{-1}, during the June 1988 - June 1989 collider run. The data accumulated by the CDF detector during this period have been used for precision measurements of the Z^o mass and Z^o-W mass difference, to set a lower limit of 90 GeV on the top quark mass, and to set lower limits of a few hundred GeV on the production of several types of particles which represent potential extensions to the Standard Model.

The Fermilab III program is designed to create the capability for the production and observation of a top quark in the mass range 90-200 GeV, as required by our current understanding of the Standard Model, and for the observation of possible extensions to the Standard Model characterized by several hundred GeV mass scales. Fermilab III consists of the implementation of electrostatic

separators in the Tevatron, a series of Antiproton Source improvements, doubling the Linac energy, raising the collider center-of-mass energy to 2000 GeV, and replacement of the Main Ring with the Main Injector. It is expected that over the course of Fermilab III the luminosity delivered from the Tevatron collider will rise by a factor of five following the implementation of separators and the Linac Upgrade, and another factor of five to six following construction of the Main Injector.

The Main Injector is specifically designed to carry out in a much more efficient manner the support functions currently being provided by the Main Ring—the original 400 GeV Fermilab accelerator. Through the 1970s, the Main Ring was the primary High Energy Physics producing accelerator at Fermilab. However, with the construction of the Tevatron superconducting accelerator during the early 1980s, the Main Ring was reconfigured in order to provide support for the Tevatron based $\bar{p}$-p collider and fixed target programs. This reconfiguration included the addition of (vertical) overpasses around the BØ and DØ interaction regions, and the addition of several new extraction areas required for operations with antiprotons. These modifications had the affect of reducing the available aperture in the Main Ring to the extent that today the Main Ring represents the primary bottleneck in the delivery of high intensity proton and antiproton beams to the Tevatron, and in the delivery of protons onto the $\bar{p}$-production target. Construction of the Main Injector is designed to remove this bottleneck once and for all.

The Main Injector will be constructed tangent to the Tevatron in a separate tunnel on the southwest corner of the Fermilab site. The Main Injector is roughly half the size of the existing Main Ring yet will boast greatly improved performance. The Main Injector will allow the production of about seven times as many antiprotons per hour (1.5×10^{11}/hour) as are currently possible using the Main Ring and will have a capability for the delivery of five times as many protons to the Tevatron (at least 3×10^{11} protons/bunch for collider operations). The Main Injector is anticipated to support a luminosity of at least 5×10^{31} $cm^{-2}sec^{-1}$ in the collider, a factor of 30 larger than the current operation.

In addition to furthering the search for the top quark and potential high-mass extensions to the Standard Model, construction of the Main Injector will simplify and enhance operations of the Fermilab complex. By removing the Main Ring from the vicinity of the Tevatron, interferences with the experimental detectors studying $\bar{p}$-p interactions will be eliminated. The Main Injector will support the delivery of very intense proton beams (3×10^{13} protons every 2.9 seconds with a 33% duty factor) to existing experimental areas where they can be used for state-of-the-art studies of CP violation and rare Kaon decays, and for experiments designed to search for transmutation between different neutrino generations. Low intensity proton beams emanating from the Main Injector will support test and calibration beams required for the development of new experimental detection devices which will be required both at Fermilab and at the SSC. In contrast to the present situation at Fermilab simultaneous antiproton production and Main Injector slow spill operation will be possible under normal circumstances, i.e., when the antiproton stack has not recently been lost. Delivery of beam from the Main Injector to all experimental areas is compatiblewith Tevatron Collider running,while delivery of beam to a dedicate K/v line is compatible with Tevatron Collider and Fixed Target operations.

Performance

The Main Injector is designed to perform all duties currently required of the Main Ring. Following commissioning of the Main Injector, operation of the Main Ring will cease. In fact, many Main Ring components, including the RF, quadrupole magnet/power supply and the correction element systems, will be recycled into the Main Injector.

The Main Injector parameter list is given in the accompanying table. The Main Injector will perform at a significantly higher level than the existing Main Ring as measured either in terms of protons delivered per cycle, protons delivered per second, or transmission efficiency. For the most part, expected improvements in performance are directly related to optics of the ring. The MI ring lies in a plane with stronger focussing per unit length than the Main Ring. This means that the maximum betas are half as big and the maximum (horizontal) dispersion a third as big as in the Main Ring, while vertical dispersion is

nonexistent. As a result, physical beam sizes associated with given transverse and longitudinal emittances are significantly reduced compared to the Main Ring. The elimination of dispersion in the RF regions, raising the level of the injection field, elimination of sagitta, and improved field quality in the dipoles will all have a beneficial impact on beam dynamics. The construction of new, mechanically simpler magnets is expected to yield a highly reliable machine.

The Main Injector is seven times the circumference of the Booster and slightly more than half the circumference of the existing Main Ring and Tevatron. Six Booster cycles will be required to fill the Main Injector and two Main Injector cycles to fill the Tevatron. The Main Injector is designed to have a transverse aperture of 40π mm-mr (both planes, normalized at 8.9 GeV/c). This is 30% larger than the expected Booster aperture following the 400 MeV Linac upgrade, and a factor of three to four larger than that of the existing Main Ring. A single Booster batch will be accelerated for antiproton production while six such batches are required to fill the Main Injector. Yields out of the Main Injector for a full ring are expected to lie in the range $3\text{-}4\times10^{13}$ protons ($6\text{-}8\times10^{13}$ delivered to the Tevatron.) By way of contrast the existing Main Ring is capable of accelerating 1.8×10^{13} protons in twelve batches for delivery to the Tevatron.

The power supply and magnet system is designed to allow a significant increase in the number of 120 GeV acceleration cycles which can be run each hour for antiproton production, as well as to allow a 120 GeV slow spill with a 35% duty factor. The cycle time at 120 GeV can be as low as 1.5 seconds. This is believed to represent the maximum rate at which the Antiproton Source might ultimately stack antiprotons and is to be compared to the current Main Ring capability of 2.6 seconds.

Main Injector Parameter List

Circumference	3319.419 meters
Injection Momentum	8.9 GeV/c
Peak Momentum	150 GeV/c
Minimum Cycle Time (@120 GeV)	1.5 sec
Number of Protons	3×10^{13}
Harmonic Number (@53 MHz)	588
Horizontal Tune	22.42
Vertical Tune	22.43
Transition Gamma	20.4
Natural Chromaticity (H)	-27.5
Natural Chromaticity (V)	-28.5
Number of Bunches	498
Protons/bunch	6×10^{10}
Transverse Emittance (Normalized)	20π mm-mr
Longitudinal Emittance	0.4 eV-sec
Transverse Admittance (at 8.9 GeV)	40π mm-mr
Longitudinal Admittance	0.5 eV-sec
b_{max} (Arcs)	57 meters
b_{max} (Straight Sections)	80 meters
Maximum Dispersion	2.2 meters
Number of Straight Sections	8
Length of Standard Cell	34.3 meters
Phase Advance per Cell	90 degrees
RF Frequency (Injection)	52.8 MHz
RF Frequency (Extraction)	53.1 MHz
RF Voltage	4 MV
Number of Dipoles	300
Dipole Length	6.1 meters
Dipole Field (@150 GeV)	17.3 kGauss
Dipole Field (@8.9 GeV)	1.0 kGauss
Number of Quadrupoles	202
Quadrupole Gradient	196 kG/m
Number of Quadrupole Types	3
Number of Quadrupole Busses	2

Research Division personnel, Dave Ifversen, Dan Johnson (group leader) and Tara Vraniak, operate the newly installed control system for the Fixed Target area.

THE 1990 FIXED TARGET RUN

By *Regina Rameika and Bruce Baller*

When the Fixed Target run ended on Februrary 15, 1988, both Fermilab users and the Research Division staff entered the shutdown with long lists of projects to complete during the subsequent months. It was expected that the shutdown would be at least one and a half years long, where Fermilab's major goal during that time would be a Collider physics run and a major maintenence period for the accelerator. For the Fixed Target program the shutdown would be used to install EPICURE, a new beamline and cryogenics control system, and to prepare for a full program of new experiments and test beam calibration efforts.

During 1988 and 1989, the Fermilab Directorate faced the difficult task of maintaining the running Collider program as well as getting ready for the heavily committed Fixed Target program under severe budget constraints. By April 1989 it was realized that the Fixed Target run was not likely to begin until January 1990. It was also realized that because of the large number of experiments, most of which were running for the first time, the length of the run needed to be considerably longer than the initially planned seven months. The new schedule allocated a six month run followed by a six week shutdown for power conservation and then three additional months of running. Along with this scenario went a set of priorities for commissioning the beamlines and experiments based on beamline commitments and budget considerations. The PB, PC and MP beamlines were to be commissioned first in order to provide the maximum running time for experiments E-687, E-761 and E-704, each of which would be turning over their beamlines later in the run to a new experiment. High priority was also given to E-760, a charmonium production experiment, which is located in the $\bar{p}$ Accumulator ring and collects data during Fixed Target running periods. Lower priority was given to the experiments which would not be under such severe time constraints such as the returning E-665 and E-706, and to the new installations of E-690 and E-782. Finally, three new experiments, E-771, E-789 and E-791, each of which required major new electronics or detector acquisitions, would have their startups significantly

delayed. Throughout the summer and fall, following these priorities, the Research Division prepared the beamlines for the startup.

As the year came to a close, an even more difficult budget scenario unfolded. This forced the Directorate to consider several different scheduling scenarios which might enable the Laboratory to meet its commitments to both the Fixed Target as well as the Collider programs while also staying within the constraints of the budget. A special users meeting, followed by a meeting of the PAC, led the Directorate to propose a staggered Fixed Target startup which would allow the heavily committed beamlines to begin running first, followed by the remainder of the program as it became ready and the budget would allow.

At the end of December, the Director's Office announced that the accelerator startup would begin in January and that the 1990 Fixed Target run would officially begin on Februray 12, 1990, with beam being delivered to the three top priority experiments.The new schedule allocated six to seven months of running and a two to three month "summer/fall" shutdown. Five additional months of running would then complete the 1990-91 Fixed Target run.

On January 24, the Accelerator Division successfully circulated beam in the Tevatron and was ready to try extracting beam into the switchyard. This opportunity was used by both the Switchyard and Research Division groups to get an early shot at delivering beam to the Fixed Target areas. By the evening of January 26, beam had been extracted and successfully transported to the Proton, Meson and Neutrino Muon areas. On January 27, the Accelerator Division began a two week studies period, while the Research Division and the Fixed Target experimenters continued getting their beamlines and experiments ready for the run. On February 10, the Tevatron startup began and by mid-day Februrary 11 beam was being transported to the PB, PC and MP experiments. Though much beamline tuning would follow in order to optimize the running conditions, all the Accelerator and Research Division personnel involved in the startup were happy to have met the goal of having beam to the three highest priority experiments by February 12.

The PB beamline provides a beam of photons ranging in energy from 200 to 500 GeV to experiment E-687, which is studying photoproduction of charm. The same beamline is simultaneously used by E-774, which is doing an electron beam dump particle search. The PC beamline transports 800 GeV primary protons to E-761 which is studying the rare radiative decays of the Σ^+ and Ξ^- hyperons. The MP beamline provides a 200 GeV polarized proton beam to E-704, which is carrying out a multifaceted program in spin measurements.

Along with the three top priority lines, tuning of the NM line was also started by February 12. The NM primary line was used by the Accelerator tuners as a place to send excess beam as they attempted to raise the machine's intensity. The NM secondary line transports a pion/muon beam to E-665, which studies muon scattering in nuclear targets.

In the days that followed the startup, the Operations Group's attention turned to the commissioning of the beams in the NW and MW lines. The NW beamline provides 10 - 150 GeV electrons and pions for use as a test beam for the D0 collaboration. In the early weeks of the run the test beam was used for testing the D0 muon drift chambers. Later in the run a testing program for modules of the liquid argon/uranium calorimeter began. The MW beamline transports a 500 GeV pion beam to two experiments which run simultaneously in the MW9 experimental hall. E-706, a direct photon experiment, is followed by E-672 which is an open geometry di-muon experiment.

The MW primary beam is also the primary beam for the MT line which is produced by a transmission target placed in the primary beam. On February 25, the MT line began providing an electron/pion beam to the CDF collaboration for the calibration of the central calorimeter wedges. In addition to CDF, the MT line is also used as a test beam by E-795, which is testing a tetramethyl pentane (TMP) sampling calorimeter, and by E-784, the BCD collaboration, which has begun a test beam R & D effort.

By the end of February, beam was routinely being delivered to the PB, PC, NW, MP, MW and MT beamlines. As the experimenters in these beams made progress towards data taking, the Research Division next turned its attention

towards commissioning the remaining Neutrino area beams, NE, NT and NK. NE is a primary proton beam which is split to provide an attenuated proton beam to E-690, a charm and beauty production experiment; and to provide a secondary pion beam which is transported to either the NT or the NK line. In NT, E-790 is calibrating depleted uranium/scintillator calorimeter modules for the HERA/ZEUS detector. At the termination of the NK line, E-782 is using the Tohoku Bubble Chamber to study the interactions produced by the muons resulting from the decay of the beam pions. In mid-March, the NT and NK experimenters began working out a schedule for when the NT/NK changeovers would occur. Over the next five months, eight such changes would take place, culminating with the completion of E-782 on July 19.

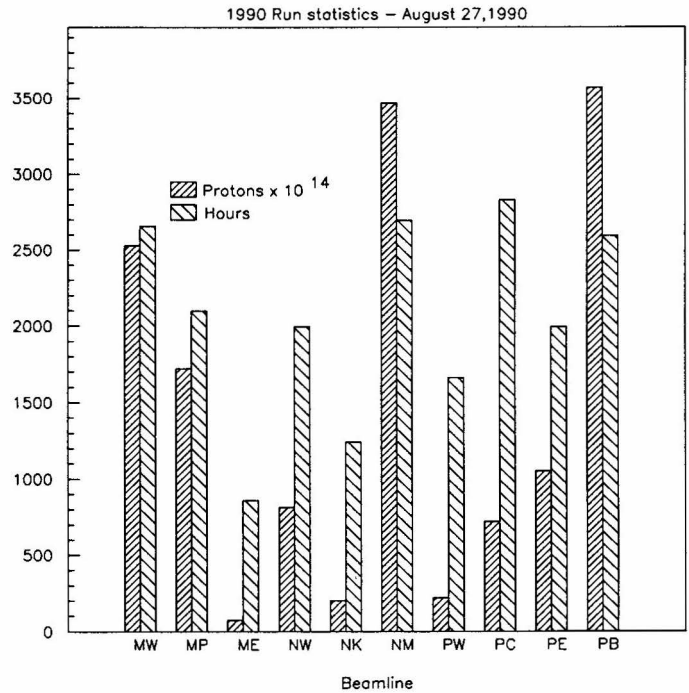
On March 2, beam commissioning began for the PE secondary beamline. For the early part of the run (March and April), PE was to be used as a 10 - 100 GeV electron/pion test beam for three independent efforts, E-797, E-798 and T-807 which would time share the use of the beam. Both E-797 and E-798 were supported by SSC R&D funding for detector development. E-797 tested a fine grained electromagnetic calorimeter using fast proportional tubes and E-798 tested a lead/scintillating fiber synchrotron radiation detector. The purpose of T807 was to investigate the use of warm, short radiation length liquid as a radiator for use in calorimetry. By May 3, the test beam users had achieved their goals and the beamline was turned over to E-791, a charm and beauty hadroproduction experiment. Beam commissioning for the other two late-start experiments, E-771 and E-789 began in early and late April, respectively. Both experiments use primary proton beams to study beauty production, albeit in different decay modes.

Since the Fixed Target startup on February 12, a total of 3,500 hours of accelerator running time have been logged and $1.9*10^{18}$ protons have been accelerated and extracted to the Fixed Target beamlines. The total number of operating hours and protons delivered to each of the major beamlines for the 1990 Fixed Target run are shown in the figure on page 25. Unlike previous Fixed Target runs, where weekly or bi-weekly maintenance and development (M&D) periods were scheduled, the accelerator has operated almost con-

tinuously. Two accelerator studies periods were scheduled and took place from March 5-9 and from April 4 -10. Only one Tevatron magnet failure and three days of construction work for the Linac Upgrade have caused a continuous downtime of longer than 24 hours.

The first part of the 1990-91 Fixed Target run is scheduled to end in late August, at which time E-761 and E-704 as well as E-782 will be completed. During the three month shutdown E-800, which will measure the magnetic moment of the Ω^- will be installed in the PC line. The MP line will be decommissioned and the MC line will be made operational. During the second part of the run the MC users will measure the phase difference between η_{00} and η_{+-} in E-773 and then change over to E-799, which is a search for the rare decay $K_L \rightarrow \pi^0 e^+ e^-$. When the run resumes on December 1, control of the PB line will go to E-683, which is studying photoproduction of high p_t jets.

The second part of the run is expected to be five months long.



The Panda Development Team. Front row: Gary Sergey, Dave Slimmer, Neal Wilcer, Margaret Haire, Lordu Udumula. Second row: Tom Nicinski, Margaret Votava, Jim Meadows, Ruth Pordes, Vicky White, Eileen Berman. Third row: Bryan MacKinnon, Gene Oleynik, Dave Berg, Carmenita Moore, Jonathan Streets. Fourth row: Don Petravick, Ron Rechenmacher, Rich Knowles, John Anderson, Simon Kent. Members of the team not pictured are Penelope Constanta-Fanourakis and Jim Franzen.

THE PAN-DA DATA ACQUISITION SYSTEM

By *Phil Stebbings*

The first implementation of the PAN-DA data acquisition system has recently been installed at the fixed target, photoproduction experiment E-687. PAN-DA, or PANDA, is the overall name given to a new generation of data acquisition (DA) systems developed at Fermilab by the Online Support Department headed by Ruth Pordes.

"The system is modular and flexible, like VAXONLINE, but has a higher throughput, since it is FASTBUS and VME based," says Pordes.

Peter Kasper, E-687 experimenter, concurs. "We've already collected three times the data we collected during the last fixed target run. Using PANDA, we've been able to collect up to 10,000 events per spill. It's faster, more reliable and much easier to use than the DA we had for the last run. We were able to collect 2 million events during our last shift alone."

While PAN-DA is based on existing hardware, much effort has been devoted to ensuring that all of the components work together as a system. Before the first system was brought into production, teams of both hardware and software experts identified and corrected potential problems in the Struck General Purpose Master (GPM), which serves as the FASTBUS event builder module, as well as problems in the tape drives, and the tape and Ethernet controllers. "We have spent the time to deliver a reliable system," Pordes says, "We took advantage of tools like logic analyzers to find system hardware problems as well as understand the throughput of the system."

An Integrated Multiprocessor Environment

PAN-DA has many of the features experiments will need in the 90s. It supports farms of processors in VME, distribution of events to UNIX workstations, and is capable of supporting multiple event building or data source crates, thus allowing lower dead time at the front end.

Both the Fermilab ACP 68020 and ACP R3000 boards have been incorporated into PAN-DA. Other commercially produced processor boards can also easily be incorporated. Experiment specific subroutines for data compression, event filtering, monitoring and analysis can run on farms of these processor boards embedded in a PAN-DA system.

Each VME crate in a PANDA system has an Ethernet controller, which provides a standard network protocol (TCP/IP) for DA control and event distribution. Experimenters may monitor their DA system by receiving events on any number of UNIX or VAX/VMS workstations.

The PANDA VME Processor farm is only loosely coupled to the data acquisition front end. E-687, like many existing experiments, has all data from the front ends flowing through a single FASTBUS crate. In this mode, the system can sustain data rates of 4 MB per second. For experiments that require even higher data rates, PAN-DA can support new event building techniques. Data from the front end may be delivered at even higher speeds to several VME crates.

A Modular, Portable System

Both existing and new experiments at Fermilab can make use of parts or all of the PAN-DA system. The software allows for collection, logging and distribution of events, control and monitoring of data taking and access to each subsystem. The system provides a flexible DA framework in which users are given a wide latitude in tailoring the DA to their own needs.

Experimenters can tailor the PAN-DA data acquisition control to synchronize the start up of their data taking and the sequencing of their shut down procedures. Any interested program may access over Ethernet a centralized database of state information and statistics about the overall DA system.

At each stage in the data pipeline well defined interfaces and frameworks are provided for the experimenters to include their own specific software and hardware. PAN-DA has built in user hooks in event building, processing and analysis that allow for the addition of experiment specific subroutines. Event

concatenation utilities place user supplied sub-event headers where requested and mark data into tape blocks for logging to 9-track and/or 8 mm tape drives.

Planned extensions to PAN-DA include enhancements in many of its functional areas: incorporation of new event builders in the FASTBUS host crate, implementation of event building and data recording from multiple VME crates, evaluation of commercial processors such as the Silicon Graphics and Motorola 88000 processor boards, and using UNIX workstations as the system integration and control host as well as the recipients of distributed events.

Lab news

URA Named Illinois Technology Challenge Grant Recipient

By Barbara Lach

Universities Research Association, Inc. (URA) is the recipient of an Illinois Technology Challenge Grant totalling $200,000 for FY90 and $2,000,000 for FY91. The monies will be utilized at Fermilab for preconstruction design and environmental assessment for the Main Injector slated to be built on the southwest corner of the existing site. The Main Injector is the centerpiece of **Fermilab III**, a set of major improvements which will significantly extend the scientific reach of Fermilab's Tevatron.

The April 16 announcement of the grant award preceded by only a few days the strong endorsement **Fermilab III** received from the High Energy Physics Advisory Panel, a group charged with making priority recommendations for the field through the 1990s.

The funds allocated for FY90 are to be spent in three major areas: wetland mitigation plans, site characterization studies and endangered species reports. In addition, Fermilab has retained Sidley and Austin, a firm specializing in environmental law, to review the documentation prepared. In making its award for the Main Injector, it was noted that the environmental data collected for the Illinois SSC proposal should be valuable to the new project.

Because current plans for the Main Injector call for seven acres of wetlands to be filled, a section 404 permit must be filed jointly with the U.S. Army Corps of Engineers, the Illinois Environmental Protection Agency and the Illinois Division of Water Resources. Current legislation requires that theLaboratory create one and a half times the amount of wetlands which it intends to fill. Using Challenge Grant funds, the Laboratory has hired Envirodyne Engineers, Inc. of Chicago to carry out the necessary in-the-field wetland delineations. Envirodyne has formulated a mitigation plan which incorporates recommendations as to how to recreate the requisite area of wetlands. Since the

construction of the Main Injector impacts the drainage basin of Indian Creek, a flood plain mitigation plan must also be developed. This will insure that there is no net change in drainage patterns due to the new construction.

A second important component of environmental assessment is the site characterization. Another Illinois company, Soil Testing Service Consultants, is providing the extensive core drilling and analysis required.

Challenge Grant monies have also been utilized to hire consultants to review the proposed Main Injector site for its impact on endangered species on both the federal and the state lists. The Laboratory will utilize special investigators to determine the status of bird, insect, amphibian and reptile, mammal and plant populations in the effected area.

The 1989 Illinois Technology Advancement and Development Act authorized the Technology Challenge Grant Program which is administered by the Department of Commerce and Community Affairs (DCCA). The Challenge Fund is designed to accelerate the process of state economic growth through investment in science and technology research and development. The purpose of the program is to identify, develop and commercialize technology which will permit Illinois to successfully compete in today's global marketplace.

This year, the first for the Challenge Grants, 47 grants totalling $19 million were awarded to Illinois institutions. These came from an initial pool of 128 proposals totalling $165 million in requests. Businesses, universities, community colleges, research laboratories such as Fermilab and Argonne, and various consortiums responded to the call for proposals. The topics of successful proposals ranged from aerospace education to printing technology to food safety to mobile radio systems to medical imaging techniques.

According to the legislation, the Governor's Science Advisory Committee (GSAC), chaired by Leon M. Lederman, the Governor's Science Advisor, and The Illinois Coalition, chaired by former Jewel Companies Chairman Donald S. Perkins, were charged with the responsibility of evaluating grant proposals. GSAC and The Coalition established nine panels to review and make rec-

ommendations on the proposals received. Assignment of proposals to panels was made on the basis of the subject matter of the work proposed.

The Physics/Optics/Electronics panel handled the URA/Fermilab proposal and gave it the highest ranking, "Highly Recommended." In its recommendation to the Illinois Department of Commerce and Community Affairs (DCCA), the panel wrote, "(it) wishes to send a strong message of State support to the U.S. Congress and the U.S. Department of Energy with respect to the viability of Fermilab's mission and its extension into the late 90s." The panel also noted that, "This proposal presents the State of Illinois with an opportunity to significantly increase the probability of eventual approval and construction of the Fermilab Main Injector project."

Workshop on B-Physics

By *Jeff Spalding*

A workshop on B-physics was held at the Leningrad Nuclear Physics Institute, May 21-27. The bottom or beauty quark was discovered at Fermilab in 1977. Since then, experiments at e+e- machines have studied the gross properties of B-decays, but relatively little is known in detail about the production and decay of these particles containing the b quark. Experiments to study these processes are planned at many laboratories, including Fermilab, and will form a major field of research through this decade and beyond. In particular, a detailed study of the decays of B-particles will lead to a rigorous test of the standard model.

The workshop was organized by Professor A. A. Vorobyov, the Director of the Leningrad Institute, and the spokesperson for Fermilab experiment E-761. The Leningrad group is also involved in the preparations for E-781 at Fermilab, a study of the hyperon production of charm, and they plan a follow-up experiment studying charm and beauty at UNK.

The workshop was attended by physicists from several countries, with participants from several Soviet institutions, Fermilab, Carnegie Mellon, LBL, Lund (Sweden) and CERN. The sessions included discussion on the theory of B-physics, detector development (especially vertex detectors and triggering techniques), and the status and plans for experiments at the hadron accelerators at Fermilab, CERN, UNK and the SSC, and e+e- accelerators at DESY, Cornell, CERN and a proposed machine at Novosibirsk.

The purpose of the workshop was to understand the plans and prospects for different experimental approaches and to further cooperation between the different groups. Each of the approaches (hadron collider and fixed-target, symmetric and asymmetric electron collider) has its own strength in vertex resolution, luminosity or simplicity of the events.

The B-physics program at Fermilab includes CDF (soon to be joined by DØ), and several fixed target experiments, with detector R&D in test beams. This program will grow in scale and complexity. The prospects were discussed for higher energy fixed-target experiments (3TeV at UNK, 20TeV at the SSC) and for collider experiments (3TeV on 3TeV at UNK) and the possibility of asymmetric hadronic collisions (3TeV on 400GeV at UNK). Such asymmetric collisions combine the advantages of a high cross-section with a relatively simple, fixed-target-like geometry.

In addition to an intensive schedule of physics reviews and discussion, there was time to view some of the splendors of Czarist St. Petersberg. The workshop provided both a physics and a cultural exchange, enhancing the close collaboration between Soviet and western research groups.

Workshop on QA in Basic Research and R&D Environments

By *Mark Bodnarczuk*

Lawrence Livermore National Laboratory was the site of the first annual Workshop on QA in Basic Research and R&D Environments. The January 12 meeting was attended by representative from Ames Laboratory, Argonne National Laboratory, Brookhaven National Laboratory, Continuous Electron Beam Accelerator Facility, Fermi National Accelerator Laboratory, Lawrence Berkeley Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, Princeton Plasma Physics Laboratory, Sandia National Laboratory, Solar Energy Research Institute, Stanford Linear Accelerator Center and Stanford Synchrotron Radiation Laboratory. The proceedings of the workshop were published in May 1990 and distributed nation-wide.

Basic research and research and development (R&D) activities have been ongoing at U.S. Department of Energy (DOE) sponsored laboratories for many years. While some laboratories involved in nuclear related work have instituted formal quality assurance (QA) programs, the vast majority of national laboratories (especially non-nuclear basic research laboratories like Fermilab) have developed a variety of informal QA systems to assure quality and programmatic success. Practices such as planning, peer review, recording of data and ideas in notebooks, personnel selection, calibration of data gathering devices and reports to sponsors have helped to assure quality but were often not adequately documented or applied with consistency. Today, many QA professionals believe that these practices can provide a sound basis for meeting current requirements for QA programs in basic research and R&D when they are adequately documented on an institutional scale.

The issuance of DOE Order 5700.6 required the development of formally documented QA programs throughout the DOE structure and opened a new era in the application of QA requirements to basic research and R&D at DOE-funded laboratories. DOE Order 5700.6 states that ANSI/ASME NQA-1 is the preferred QA standard in the nuclear area. NQA-1 is a National Consensus standard which was developed to guide the siting, design, construction, operation and decommissioning of nuclear reactors. The task that laboratory personnel have faced in attempting to comply with DOE Order 5700.6 and NQA-1 has stimulated much thought in this area, but many QA professionals who attended the workshop believed that it may have produced more questions than answers. The proceedings of the workshop describe some of the ways in which a number of DOE-funded laboratories have applied the principles of more formal QA within basic research and R&D environments and represent an on-going dialogue between QA professionals and laboratories about these matters. In a sense, learning how to implement more "orthodox" QA programs at places like Fermilab is like doing R&D on QA in basic research. In addition to the workshop, these attempts at "tailoring" QA for basic research have resulted in the publication of many papers at professional quality conferences like those sponsored by the National Energy Division of the American Society for Quality Control (ASQC).

The workshop was an open forum where QA professional from around the nation gave descriptions of their respective QA programs, policies and methodologies. The purpose of the published proceedings is to provide encyclopedic information about existing QA programs in basic research and R&D environments. Topics covered by each laboratory in the workshop proceedings include: 1) the overall goal and mission of the laboratory, 2) the QA model used at the laboratory, 3) a description of the architecture of the QA program, i.e. what standard it was based upon, etc., and 4) any pertinent QA issues that the laboratory considered to be of substance.

A major portion of the discussion at the workshop was devoted to identifying significant laboratory issues in regard to the implementation of QA. Some of the issues discussed were: 1) There is no uniformly agreed upon interpretation of the meaning of "independent verification" in regard to laboratory activities.

2) There is no uniform understanding of the actual role of DOE's "oversight" function, especially in regard to things like Technical Safety Appraisals and Tiger Teams. 3) In regard to funding for quality, some laboratories were concerned about the degree to which QA organizations were financially supported by their laboratories. 4) Some laboratories were concerned about the resistance of middle and top level laboratory management to support or incorporate the principles of QA into their laboratory culture. 5) There was concern about the apparent incompatibility of a) using the lowest bidder and b) insisting on the appropriate level of quality in products or services. 6) There was concern about consistency within DOE in that some levels of the DOE structure demand verbatim compliance to NQA-1 in areas that are clearly beyond the scope of the standard, while other levels of DOE espoused more reasonable interpretations.

The consensus of workshop attendees was that the workshop should be held annually to discuss pertinent issues in QA. It is hoped that by sharing common experiences with a wide cross-section of laboratories, that solutions to common problems may be possible.

Publications

Experimental Physics Results

Experiment 537
Tzamarias, S. et al. "Ψ Production in $\bar{p}$ N and π^-N Interactions at 125 GeV/c and a Determination of the Gluon Structure Functions of the $\bar{p}$ and the π^-." (FERMILAB-Pub-90/63-E) Submitted to *Phys. Rev. D.*

Experiment 557
Stewart, C. et al. "Production of High-p_t Jets in Hadron-Nucleus Collisions." (FERMILAB-Pub-90/22-E) Submitted to *Phys. Rev. D.*

Experiment 621
Thorne, K. A. "Precision Measurement of the Lifetime and Decay Asymmetry of the Cascade-Zero Baryon." Ph.D Thesis, University of Minnesota, Minneapolis, Minnesota, April 1990.

Experiment 632
Naon, R. et al. "A System for Viewing Holograms." (FERMILAB-Pub-90/41-E) Published in *Nucl. Instrum. Methods A.*

Experiment #665
Aïd, S. "Preliminary Results from E665 on Cross-Section Ratios at Low x_{bj} Using H_2, D_2 and Xe Targets." (FERMILAB-Conf-90/125-E) Presented at the Workshop on Hadron Structure Functions and Parton Distributions, Batavia, Illinois, April 26-28, 1990.

Magill, S. R. "Xe/D_2 Cross-Section Ratio at Low x_{Bj} from Muon Scattering at 490 GeV/c." (FERMILAB-Conf-90/127-E) Presented at the 15th APS Division of Particles and Fields General Meeting (DPF '90), Houston, Texas, January 3-6, 1990.

Schmitt, M. "Muon Interactions at 490 GeV." (FERMILAB-Conf-90/126-E) Presented at the XXVth Rencontres de Moriond: High Energy Hadronic Interactions, Les Arcs, Savoie, France, March 11-17, 1990.

Experiment #687
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Experiment #691
Anjos, J. C. et al. "Experimental Results on the Decays $D \rightarrow K4\pi$." (FERMILAB-Pub-90/106-E) Submitted to *Phys. Rev. Lett.*

Anjos, J. C. et al. "Study of $D_S^+ \rightarrow \phi e^+ \nu_e$ and the Absolute $D_S^+ \rightarrow \phi\pi^+$ Branching Fraction." (FERMILAB-Pub-90/82-E) Submitted to *Phys. Rev. Lett.*

Anjos, J. C. et al. "Measurement of the Form Factors in the Decay $D^+ \rightarrow \bar{K}^{*0} e^+\nu_e$." (FERMILAB-Pub-90/124-E) Briefer version submitted to *Phys. Rev. Lett.*

Experiment #706
Ballocchi, G. "A New Measurement of π^0 Production at Low Transverse Momentum." Ph.D. Thesis, University of Rochester, Rochester, New York, 1989.

Lanaro, A. "π^0 Production with K^- and π^+ Beams at 530 GeV/c." Ph.D. Thesis, University of Rochester, Rochester, New York, 1989.

Experiment #710
Amos, N. A. et al. "Antiproton-Proton Elastic Scattering at $\sqrt{s}$=1.8 TeV from $|t| = 0.034$ to 0.65 $(GeV/c)^2$." (FERMILAB-Pub-90/96-E) Submitted to *Phys. Lett. B.*

Experiment #731
Yamanaka, T. "A New Measurement of CP Violation Parameter ε'/ε." (FERMILAB-Conf-90/14-E) Talk presented at the International Europhysics Conference on High Energy Physics, Madrid, Spain, September 6-13, 1989.

Experiment #741/CDF
Abe, F. et al. "Jet Fragmentation Properties of $\bar{p}p$ Collisions at $\sqrt{s}$=1.8 TeV." (FERMILAB-Pub-90/71-E) Submitted to *Phys. Rev. Lett.*

Abe, F. et al. "Search for a Light Higgs Boson at the Tevatron Proton-Antiproton Collider." (FERMILAB-Pub-89/250-E) Submitted to *Phys. Rev. D.*

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Contreras, M. "Search for the Top Quark in Electron-Muon Events in the Collider Detector at Fermilab." Ph.D. diss., Bradeis University, Waltham, Massachusetts, April 1990.

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Andrews, C. et al. "Providing a Computing Environment for a High Energy Physics Workshop." (TM-1636) Summary of computing activities from Physics at Fermilab in the 1990s, Breckenridge, Colorado, August 15-24, 1989.

Barsotti, E. et al. "A Scalable Parallel Open Architecture Data Acquisition System for Low to High Rate Experiments, Test Beams & All SSC Detectors." (FERMILAB-Pub-89/260) To be published in *IEEE Trans. Nucl. Sci.*

Barsotti, E., Booth, A. and Bowden, M. "Effects of Various Event Building Techniques on Data Acquisition System Architectures." (FERMILAB-Conf-90/61) Presented at the 1990 Conference on Computing in High Energy Physics, Santa Fe, New Mexico, April 9-13, 1990.

Biel, J. R. "Use of UNIX in Large Online Processor Farms." (FERMILAB-Conf-90/88) Presented at the 1990 Conference on Computing in High Energy Physics, Santa Fe, New Mexico, April 9-13, 1990.

Cooper, P. S. "Computing and Data Handling Recent Experiences at Fermilab and SLAC." (FERMILAB-Conf-90/79) Talk presented at the 1990 Conference on Computing in High Energy Physics, Santa Fe, New Mexico, April 9-13, 1990.

Denby, B. "Neural Network Tutorial for High Energy Physicists." (FERMILAB-Conf-90/94) Presented at the International Workshop of Software Engineering, Artificial Intelligence and Expert Systems for High Energy and Nuclear Physics, Lyon, France, March 19-24, 1990.

Denby, B. et al. "Neural Networks for Triggering." (FERMILAB-Conf-90/20) Invited talk presented by B. Denby at the 1989 IEEE Nuclear Science Symposium, San Francisco, California, January 15-19, 1990.

Denby, B. and Linn, S. L. "Status of HEP Neural NET Research in the U.S.A." (FERMILAB-Conf-90/21) Talk presented by B. Denby at the 1989 Conference on Computing in High Energy Physics, Oxford, England, April 10-14, 1989.

Denby B., Lessner, E. and Lindsey, C. S. "Tests of Track Segment and Vertex Finding with Neural Networks." (FERMILAB-Conf-90/68) Talk presented by C. S. Lindsey at the 1990 Conference on Computing in High Energy Physics, Santa Fe, New Mexico, April 9-13, 1990.

Kaliher, C. "Cooperative Processes Software (CPS)." (FERMILAB-Conf-90/87) Presented at the 1990 Conference on Computing in High Energy Physics, Santa Fe, New Mexico, April 9-13, 1990.

Michelotti, L. "MXYZPTLK: A Practical, User-Friendly C++ Implementation of Differential Algebra: User's Guide." (FN-535).

Napier, A. "A Fast Online Event Display for a High Intensity Fixed-Target Spectrometer." (TM-1666) Presented at the 1990 Conference on Computing in High Energy Physics, Santa Fe, New Mexico, April 9-13, 1990.

Nash, T. "Human-Computer Systems in the Military Context." (FN-528).

Pfister, J. "Recent Experiences and Future Expectations in Data Storage Technology." (FERMILAB-Conf-90/70) Talk presented at the 1990 Conference on Computing in High Energy Physics, Santa Fe, New Mexico, April 9-13, 1990.

Pordes, R. et al. "Portable Software for Distributed Readout Controllers and Event Builders in FASTBUS and VME." (FERMILAB-Conf-89/259) Submitted to the 1989 IEEE Nuclear Science Symposium, San Francisco, California, January 15-19, 1990.

Cryogenics

Carson, J. A. and Bossert, R. "A Technique for Epoxy Free Winding and Assembly of COS θ Coils for Accelerator Magnets." (TM-1658) Published in the proceedings of the 1986 Applied Superconductivity Conference, Baltimore, Maryland, September 29 - October 3, 1986.

Carson, J. A. et al. "A Device for Precision Dimensional Measurement of Superconducting Cable." (TM-1659) Published in the proceedings of the ICFA Workshop on Superconducting Magnets and Cryogenics, Upton, New York, May 12-16, 1986.

Markley, F. W. and Kerby, J. S. "Investigation of the Mechanical Properties of Superconducting Coils." (TM-1660) Submitted to the 1990 International Industrial Symposium on the Super Collider (IISSC), Miami Beach, Florida, March 14-16, 1990.

Other

Bodnarczuk, M. "Assuring Both Quality and Creativity in Basic Research." (FERMILAB-Conf-90/65) To be presented at the 17th Annual Conference of the American Society for Quality Control–Energy Division, Tucson, Arizona, Sept. 9-12, 1990.

Garrett, P. and Ritchie, D. "Fermilab Library Directions." (TM-1668) Submitted to the First Inter-Laboratory Workshop on Preprint Database Management, Geneva, Switzerland, May 14-16, 1990.

Garrett, P. and Ritchie, D. "Fermilab Library Projects." (TM-1667) Submitted to the First Inter-Laboratory Workshop on Preprint Database Management, Geneva, Switzerland, May 14-16, 1990.

Requests for Publications

The publications listed in this issue of *Fermilab Report* were prepared or presented from January 1, 1990 to July 31, 1990.

Copies of Fermilab TMs, FNs and preprints (exclusive of Theoretical and Theoretical Astrophysics preprints) can be obtained from the Fermilab Publications Office, WH6NW or by sending your request to (DECnet) FNAL::TECHPUBS or (BITnet) TECHPUBS@FNAL.

For copies of Theoretical and Theoretical Astrophysics preprints, contact those departments directly.

For papers with no Fermilab catalogue number, contact the author directly.

The Publications Office prints a monthly listing of new Fermilab technical publications. If you would like to be placed on the mailing list for this monthly publications listing, please send your request to: Fermilab Publications Office, P.O. Box 500, MS 107, Batavia, Illinois 60510 U.S.A.

Seminars

by Fermilab staff, at Fermilab, January - July 1990, unless otherwise noted.

January 4
D. Trbojevic. "Designing a High Energy Accelerator Without a Transition Energy."

D. Salopek. "Stochastic Inflation and Nonlinear Inhomogeneous Gravity." University of Alberta, Edmonton, Canada.

January 5
D. Petravick and R. Pordes. "Introducing PAN DA - a Distributed Data Acquisition System from the DA Support Department."

January 6
E. W. Kolb. "The SSC and Cosmology." Houston, Texas.

January 9
A. Olinto. "Strange Stars and Neutron Stars." Adler Planatarium, Chicago, Illinois.

January 16
J. MacLachlan. "RF Systems and Particle Dynamics in Longitudinal Phase Space."

January 18
K. Ng. "Longitudinal Impedance Due to Ring Curvature."

January 19
M. Turner. "Dark Matter." Aspen Winter Conference, Aspen, Colorado.

January 22
D. Green. "Gravity for the Masses."

January 23
E. W. Kolb. "Extended Inflation." Harvard University, Cambridge, Massachusetts.

January 25
B. Hanna and G. Annala. "Maintenance Required on a Superconducting Accelerator."

E.W. Kolb. "Cosmological Phase Transition." Harvard University, Cambridge, Massachusetts.

M. Turner. "The Cosmic Microwave Background Radiation." Aspen Winter Physics Conference, Aspen, Colorado.

January 26
J. Friedman. "A New Probe of the Homogenity and Large-Scale Structure of the Universe." Aspen Winter Physics Conference, Aspen, Colorado.

February 1
A. Olinto. "SN87A as a Laboratory for High Density Matter." University of Florida, Gainsville, Florida.

D. Trbojevic. "Glow Discharge Cleaning of a Vacuum System."

February 5
M. Johnson. "Practical Electronics for Experimenters."

February 8
S. Holmes. "Main Injector Progress Report."

February 10
E. W. Kolb. "The Big Bang." Adler Planatarium.. Chicago, Illinois.

February 15
E. W. Kolb. "Neutrino Cosmology." International Workshop on Neutrino Telescopes, Venice, Italy.

February 16
E. Paschos. "Status of CP Violation."

L. Lueking. "Characteristics of Hadroproduced Charm from E-769."

March 1
G. Jackson. "A New Collider Interaction Region Design Using Crossing Angles."

A. Mukherjee. "Electroweak Results from CDF."

March 8
J. Ostiguy and F. Harfoush. "3-D Electromagnetic Field Calculations."

S. Cihangir. "High-Pressure, Ionization Chambers for Calorimetry."

March 12
R. Johnson. "Around the Fermilab Accelerators in Eight Days."

March 15
F. Mills. "Low Energy Antiproton Rings at Fermilab."

March 19
J. Frieman. "New Models for Large-Scale Structure Formation." Tokyo University, Tokyo, Japan.

March 20
J. Griffin. "Buckets, RF, Beam Loading and All That."

March 21
J. Elias. "The Proposed Lab 6 Fiber/Scintillator Facility."

March 22
N. Gelfand. "Luminosity Calculation for the Last Collider Run."

March 23
R. Plunkett. "CDF Results on QCD."

March 27
M. Fischler. "The CANOPY Software Paradigm for Problems on a Grid."

March 28
R. Kephart. "Magnet R&D."

March 29
K. Ng. "Calculation of Transverse Wakefields in a Dielectric Accelerator."

April 4
A. Para. "Detector Simulation Tools."

April 5
H. Jostlein. "Electronic Alignment Sensors and Systems."

M. Turner. "Dark Matter in the Universe." Lab Colloquium, Naval Research Laboratory,Washington, District of Columbia.

April 11
S. Hansen. "Front-End R&D."

April 12
L, Michelotti. "C++ and Differential Algebra in the Workplace."

April 18
B. Foster. "Trigger R&D."

April 24
P. Mantsch. "SSC Dipole Magnet Status."

C. Hill. "Minimal Dynamical Symmetry Breaking of the EWK Sector and M_{top}."

C. O'Reilly and U. Pabrai. "X-Terminal Evaluation."

April 25
D. Wildman. "Beam Loading and High Intensity Bunches in the Main Ring."

April 30
M. Turner. "Windows on the Axion." Yale University, Cambridge, Massachusetts.

May 1
S. Shukla .'The E-710 Measurement of the Total p-bar Cross Section.'

May 2
D. Green. "KEK."

May 3
C. Bhat. "Energy Deposition in the Antiproton Target."

May 4
D Ryu. "Analytic Treatment of the Correlation Function in a Bubble Universe." Workshop on the Legacy of Zel'dovich for Astrophysics and Cosmology, Lawrence, Kansas.

May 5
M. Turner. "Testing the Inflationary Paradign." Carnegie-Mellon University, Pittsburgh, Pennsylvania.

May 7
E. W. Kolb. "Before the Big Bang." University of Chicago, Chicago, Illinois.

May 8
J. Peoples. "Main Injector Proposal: Status Report and Plans."

May 9
B. Denby. "Neural Nets for SSC."

T. Murphy. "External Beamline Design: From Freshman Optics to the Second-Order Achromat."

May 10
G. Jackson. "Preliminary Impedance Measurement Results."

D. Anderson. "Compensation in Hadronic Calorimeters - a Review."

May 11
D. Salopek. "Nonlinear Long Wavelength Gravitational Radiation and the Choice of Time." Quantum Cosmology Workshop, Vancouver, British Columbia, Canada.

May 14
J. Friedman. "Cosmological Implications of a Late Phase Transition." Workshop on Inflation and Exotic Stucture Formation, Vancouver, British Columbia, Canada.

E. W. Kolb. "The Inflaton Sector of Extended Inflation." Workshop on "Inflation and Exotic Stucture Formation," Vancouver, British Columbia, Canada.

D. Salopek. "Inflation and Exotic Structure Formation Scenarios." Workshop on Inflation and Exotic Stucture Formation, Vancouver, British Columbia, Canada.

May 15
J. Mack. "Amdahl Tape Staging and the STK Automated Cartridge System."

May 16
T. Nash. "Computing R&D Issues."

May 17
W. Miller. "How to Tune a Multicavity Structure."

J. Freeman. "A Calorimetry Technique Using Scintillator Plates and Wavelength Shifter Fibers."

May 22
U. Pabrai. "Methodology for Network Security Design."

May 23
E. Barsotti. "Data Acquisition R&D."

M. Kaletka. "Networks: Future Costs vs Capability."

May 24
V. Visnjic. "Study of Dynamic Aperture of Low Beta Lattices in the Tevatron Collider."

J. Butler, A. Thomas and J. Nicholls. "Support Implications of Options."

May 29
G. Goderre and S. Saritepe. "Results of the Separated Orbit Studies."

A. Bross. "Scintillator Issues."

May 31
J. Rosenzweig. "A Residual Gas Emittance Monitor for the Booster."

June 6
M. Atac. "Scintillating Fiber Tracking with SSPM Readout."

J. R. Orr. "Introduction to the Tevatron."

June 7
D. McGinnis. "Bunched Beam Stochastic Cooling Performance in the Accumulator."

T. Nash. "Preliminary FY91 Plan."

June 19
U. Pabrai. "UNIX and Security."

June 20
K. Leininger. "Data Acquisition and Data Analysis for High Energy Physics Experiments."

June 21
M. Golden. "Radiative Corrections to Electroweak Parameters for Technicolor Theories."

June 25
D. Jovanovic. "The Standard Model."

July 3
A. McInturff. "Ternary Superconducting Cable for High Field He II Operations."

July 11
G. P. Yeh. "Looking for the Top Quark."

July 17
A. Para. "Scintillating Fiber Calorimetry."

July 25
G. Jackson. "Particle Accelerators."

July 27
A. Yagil. "Summary of Physics from CDF."

Dates

October 8, 1990
Deadline for receipt of material to be considered at the November Physics Advisory Committee Meeting.

November 7-14, 1990
1990 Joint US-CERN School on Particle Accelerators: Frontiers of Particle Beams—Intensity Limitations, Hilton Head Island, South Carolina. For information or application, contact the Accelerator School Office, Fermilab, MS 125, P.O. Box 500, Batavia, IL 60510, (708) 840-3896 or BITNET [USPAS@FNAL].

November 9-10, 1990
Physics Advisory Committee Meeting (Proposal Presentations).

February 1-2, 1991
Physics Advisory Committee Meeting.

May 6-9, 1991
Particle Accelerator Conference, Sheraton Palace Hotel, San Francisco, California. For further information contact Rene Donaldson, SLAC, (415) 926-2585 or BITNET [RENED@SLACVM].

June 22-28, 1991
Physics Advisory Committee Meeting.