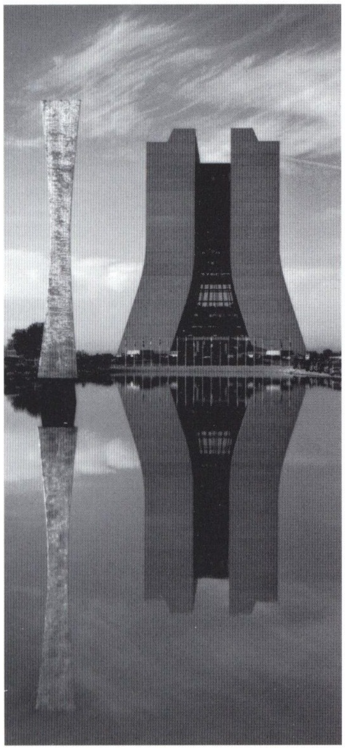
Fermilab Report

January February March 1993

Fermilab is developing the data acquisition system for a new telescope that will probe the large-scale structure in the universe.



Fermilab

Fermi National Accelerator Laboratory, popularly known as Fermilab, is one of the world's foremost laboratories dedicated to research in high-energy physics. The Laboratory is operated by Universities Research Association, Inc. under a contract with the U. S. Department of Energy.

Since its founding in 1967, Fermilab's mission has remained unchanged: to understand the fundamental particles of matter and the forces acting between them. The principal scientific tool at Fermilab is the Tevatron—the world's first superconducting accelerator and currently the highest energy collider in the world. Protons and antiprotons travel at nearly the speed of light in the Tevatron's tunnel which is four miles in circumference.

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Modern astrophysics is concerned with understanding the structure in the observed distribution of matter on all scales, requiring not only understanding the influence of gravity, but also gas dynamics and energy input from compact sources.

The Sloan Digital Sky Survey

by Richard Kron

Motivation

A guiding tenet of cosmology is that the universe is uniform on large scales. If we look far enough away, and measure large enough volumes, the granularity we see on the relatively small scales of galaxies and clusters of galaxies should smooth out. Indeed, it is a challenge to understand why matter appears to have condensed so efficiently from originally diffused gas into galaxies of stars. It is imagined that gravity has been working over large distances and long times to amplify small "seed" perturbations. But, gravity alone works slowly, and it is likely that other processes—perhaps explosions from an early generation of super-massive stars, or jets of matter and radiation from accreting black holes—have also influenced the distribution of matter. The edge-on view of our flattened Milky Way galaxy is the most easily accessible example of structure in the night-time sky. It is the result of inelastic dissipation of kinetic energy by collisions of gas clouds before the formation of stars. Modern astrophysics is concerned with understanding the structure in the observed distribution of matter on all scales, requiring not only understanding the influence of gravity, but also gas dynamics and energy input from compact sources.

Another puzzle is the nature and distribution of dark matter: material we know to be present because of its gravitational influence, but which cannot be directly identified in the form of stars or gas. How the dark matter is distributed—whether it is in the haloes of galaxies, or distributed throughout clusters of galaxies—may be an important clue to its identity. The distribution of mass in gravitationally bound systems can be deduced from Doppler measurements of the visible galaxies, but even after decades of effort, we are still discovering new facets of the velocity field of galaxies on larger and larger scales.

An especially intriguing problem is the mapping of the largest seemingly coherent structures as seen in the distribution of distant galaxies (or quasars, or intervening clouds of gas). Current studies have detected structure ("walls" of galaxies, giant voids, long filaments) on scales comparable to the volumes that have been surveyed. We still do not know at what scale the anticipated "smoothing out" actually takes place, yet this feature is central to making the connection between physical processes in the early (high-energy) universe, and tracing the subsequent development of the imprinted structure at later cosmic epochs.

There are various ways to quantify the observation of structure in the observed distribution of galaxies. "Smoothing out" means that the amplitude of clustering is expected to decrease as the length scale increases, which means that very large-scale structure—that which is most likely to be primordial in origin—is the hardest to detect. What is needed to make substantial progress is a survey of galaxies that is both very large in number of galaxies and in the volume sampled, and very well controlled so that selection biases in the studied galaxies can be accurately calibrated. Moreover, any new survey should include spectroscopic redshift measurements—equivalent to distance measurements—to yield a 3-D view.

Everything that we know about the distribution of galaxies has come from co-opting existing telescopes, using whatever observing time can be wheedled from time-assignment committees. Often, the instrumentation used was developed for some other purpose, and often the target list of galaxies was not as well controlled as is now possible. With a deliberate effort to map the distribution of galaxies in space, it should be possible to take advantage of new technology to yield orders-of-magnitude improvement in the speed at which such surveys can be done: this is the key idea behind the Sloan Digital Sky Survey.

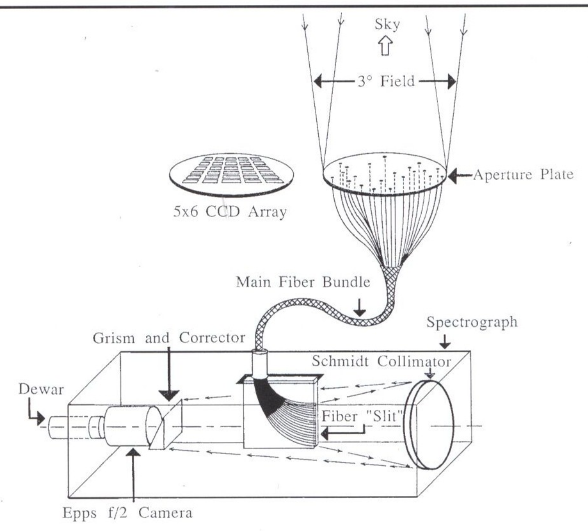


***Figure 1:* Schematic view of how the optical fibers feed light from the focal plane to the spectrograph. The aperture plate can be exchanged with the CCD array as indicated.**

Figure 2: Engineering prototype of the aperture plate. The prototype was developed to study the cost effectiveness of people inserting the optical fibers by hand into the aperture plate as opposed to developing a robot to complete the task. The results of the test showed that a person can manually plug a hole every three second. This level of human-efficiency was sufficient to eliminate the need to build a robot.

A new observatory

The plan is to build a new telescope that is optimized for surveys, specifically for studies of large-scale structure. The new telescope will be dedicated to this task, as opposed to being a multi-use facility (making a departure from traditional astronomical programs). There are to be two instruments that are swapped in and out of the focal plane: a large camera with an array of charge-coupled devices (CCDs), and a pair of spectrographs. The camera works by scanning a thin strip of sky at the rate of 160 square degrees per night. Four distinct filters provide a way to evaluate the spectral-energy distributions (i.e., the colors) of detected objects, covering altogether more than an octave in observed-frame frequency. From the digital map, the positions of galaxies and quasars will be determined, and from this list a refined sample of objects will be selected for subsequent spectroscopy. The spectrograph is capable of obtaining about 600 redshifts for galaxies and quasars per exposure. This is accomplished by coupling the spectrograph detectors to images of galaxies and quasars using optical fibers that are precisely located in the focal plane. Up to about eight spectroscopic fields can be surveyed

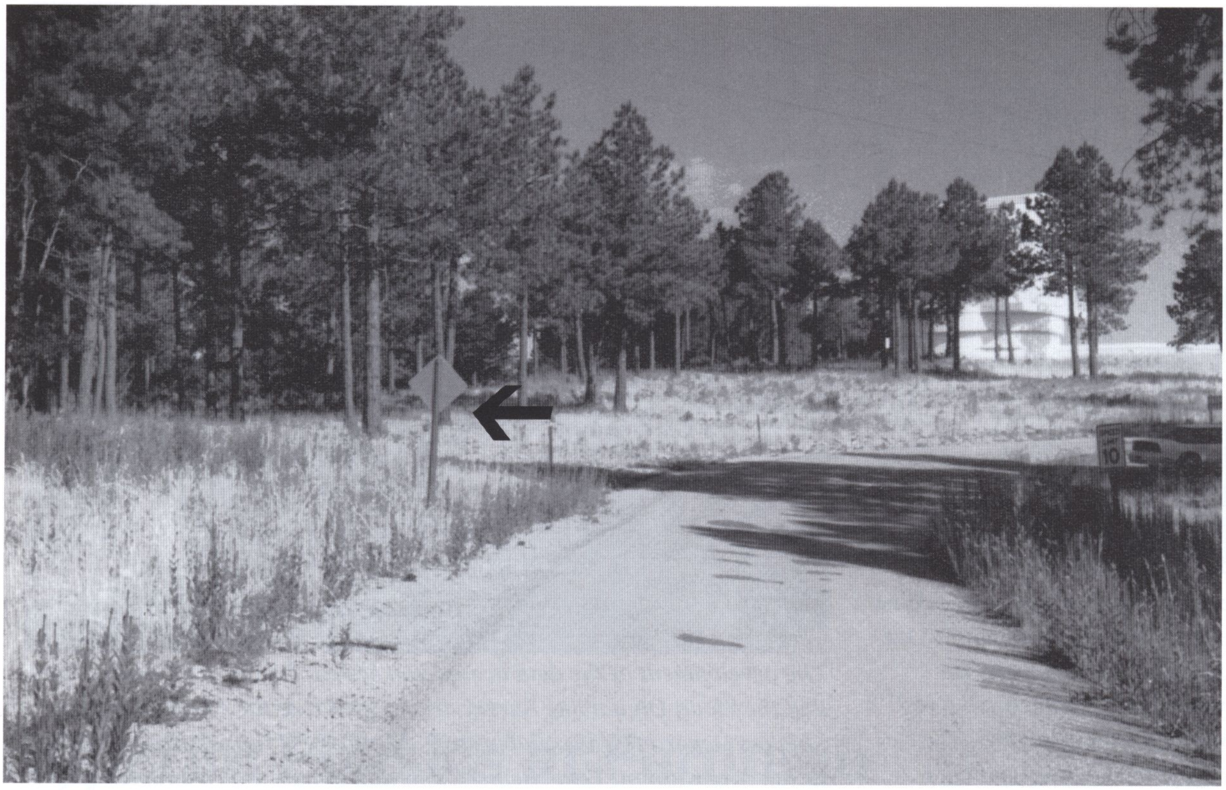


Photo courtesy of Jim Fowler, ARC member.

Apache Point Observatory is owned and operated by the Astrophysical Research Consortium and is located in the Lincoln National Forest. Consisting of four buildings with a 3.5M mirror (seen through the trees on the right), it occupies approximately six acres situated on the rim of the Sacramento Mountains. Staffed by technicians, it offers remote observing capabilities to consortium members. The arrow marks the site of the new telescope. Construction is planned to begin in late spring.

per night. In only two or three nights of observing, the new telescope will match the size of the largest current redshift surveys.

The telescope and the on-site data system are to be at Apache Point, near the National Solar Observatory in the Sacramento Mountains of southern New Mexico. This site is already being developed by a consortium of universities that include partners in the sky survey project: The University of Chicago, Princeton University, the Johns Hopkins University and the Institute for Advanced Study. Also serving as a collaborator is the Japanese Promotion Group. In addition, mechanical and optical engineering is being done by engineers at the University of Washington, the same group responsible for the existing 3.5 meter telescope at Apache Point.

Fermilab's role

Fermilab's principal technical contribution to the project is the design and construction of the data system, beginning with the logging of raw data from the instruments, through the reduction of the images to select spectroscopic targets, and up to the production of a scientifically useful data archive. The data volume and rate is higher than in most other astronomical experiments: up to 30 terabytes of (uncompressed) data by the completion of the survey, acquired at up to 130 gigabytes per night. To handle the data, the expertise in the Computing Division Online Support Group is being tapped to design and implement both the hardware and the software. The needed scientific infrastructure at Fermilab is in the Research Division Theoretical Astrophysics Group, which has longstanding research interests in the study of large-scale structure as a cosmological tool, and in the new Computing Division Experimental Astrophysics Group, which is working closely with the Online Support Group. The two astrophysics groups also help link the scientists at the other participating institutions into the work going on at Fermilab.

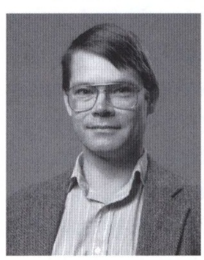
A number of other tasks in support of the sky survey are being undertaken at Fermilab. These include tests relating to the mechanical precision with which the optical fibers can be positioned, the near-term development of a prototype CCD camera, electronics design for the CCD controllers and coordinating the scientific software development that is being undertaken at all of the partner institutions.

Current status

We are currently working on a time line that calls for "first light" at the end of 1994 and one year of commissioning before the survey proper begins in late 1995. The duration of the survey has been scoped at about 5 years (there is no commitment to operate the telescope beyond what it takes to achieve the primary scientific goals). Funding has come from a variety of sources: the participating institutions have contributed cash and other resources, and a major grant was made by the Sloan Foundation in late 1991. Progress has been made in the acquisition of the optics for the telescope (the primary mirror is a light-weighted glass structure, 2.5 meters in diameter) and in the acquisition of the detectors (30 large CCDs for the camera and four for the spectrographs). Fermilab's specification and design of the data acquisition system are complete, and we hope to acquire the hardware soon for assembly and integration, prior to deployment to New Mexico. Much attention is currently being focused at Fermilab on the design of the data processing pipeline. The buildings at the Apache Point site, including a smaller "monitor" telescope for tracking the absorption due to the Earth's atmosphere, have been bid out, and construction of these is expected to be largely complete by the end of 1993. ■

The development of the data acquisition system for the drift scan camera and the Sloan Digital Sky Survey are projects that the Fermilab Online Support Department is collaborating. Members of the department include: Bryan MacKinnon, Tom Nicinski, Eileen Berman, Don Petravick (assoc. head), Jim Franzen, Ruth Pordes (head), John Anderson, Gary Sergey, David Berg, Lourdu Udumula, Jonathan Streets, Jim Meadows, Margaret Votava, Ron Rechenmacher, Laura Appleton, Penelope Constanta-Fanourakis, Brian Strode (co-op), Neal Wilcer, Carmenita Moore, Margherita Vittone and Dave Slimmer. Not pictured are Bob Forster, Gene Oleynik and Simon Kent.

The contributor



Richard Kron joined the Fermilab staff in April 1991. He is also a professor at the University of Chicago and director of that institutions Yerkes Observatory. Kron has a B.S. in physics from the University of Arizona and a Ph.D. in astronomy from the University of California, Berkeley. Kron has served as the chairperson of both the Space Telescope Working Group on Deep Surveys and the Scientific Advisory Committee of the Columbus Telescope Project. He is the recipient of the 1975 Dorothea Klumpke-Roberts Prize, the 1981 Astronomical Society of the Pacific Robert J. Trumpler Award and the 1985 American Astronomical Society Newton Lacy Pierce Prize.

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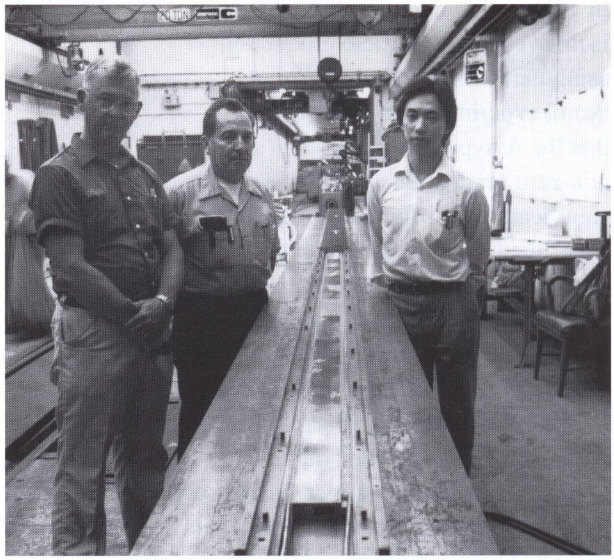


Hyperon Physics at Fermilab

The results of two decades of experiments from E8 to E800

by Gina Rameika

Since the mid 1970s Fermilab has supported a continuously evolving program of experiments to study the production and decays of hyperons. Beginning with the measurements of the neutral hyperon production cross sections through the most recent experiment to polarize the Ω^-, this series of experiments has lead to precision measurements of fundamental quantities such as magnetic moments, asymmetry parameters and lifetimes (Table 1). Fermilab has been an ideal place to explore the hyperon sector. Typically the hyperons are produced by protons incident on nuclear targets such as beryllium or copper, though the diversity of beams and targets available at Fermilab has allowed experiments to be done with pion and kaon beams and using targets ranging from hydrogen to lead. The high energy available at Fermilab makes hyperon production copious, and decay lengths are on the order of meters.

Table 1: Fermilab hyperon experiments

1974-76	E8	300 GeV	cross-sections elastic scattering $P_\Lambda;\mu_\Lambda;\mu_{\Xi^0}$
1977	E440	400 GeV	$P_\Lambda;\mu_\Lambda$
1977	E441	400 GeV	$P_\Lambda;\mu_\Lambda;\mu_{\Xi^0}$
1978	E495	400 GeV	P_Λ from H_2 target
1979	E361	400 GeV	Λ_β decay
1979	E620	400 GeV	$P_{\Xi^-,\Sigma^-,\Sigma^+} \rightarrow \mu_{\Xi^-},\mu_{\Sigma^-},\mu_{\Sigma^+}$
1980	E497	400 GeV	$P_{\Xi^-,\Sigma^-,\Sigma^+} \rightarrow \mu_{\Xi^-},\mu_{\Sigma^-},\mu_{\Sigma^+}$
1982	E555	400 GeV	P_Λ at high p_t
1982	E619	400 GeV	$\mu_{\Sigma^0\rightarrow\Lambda}$
1984	E715	400 GeV	$\Sigma^-\beta$ – decay
1987	E756	800 GeV	$P_{\Xi^-}P_{\Omega^-(?)} \rightarrow \mu_{\Xi^-},\mu_{\Omega^-}$
1990	E761	800 GeV	$\Sigma^+ \rightarrow p\,\gamma$ asymmetry
1991	E800	800 GeV	$P_{\Omega^-} \rightarrow \mu_{\Omega^-}$

In 1976, in the midst of studying inclusive strange particle production using the Fermilab 300 GeV proton beam, experiment E8 discovered that the Λ hyperons produced at a non-zero production angle had a significant polarization. Subsequent experiments both at Fermilab and at other accelerators confirmed this discovery and throughout the next decade, measurements of the polarization as a function of energy, transverse momentum, (p_t) and Feynmann x (x_f) revealed that the Λ polarization had remarkably simple behavior, and other hyperons exhibited polarization as well. Despite the fact that a convincing theoretical explanation for the origin of the polarization would remain a challange throughout the next decade, this discovery would be the cornerstone of the hyperon program.[1]

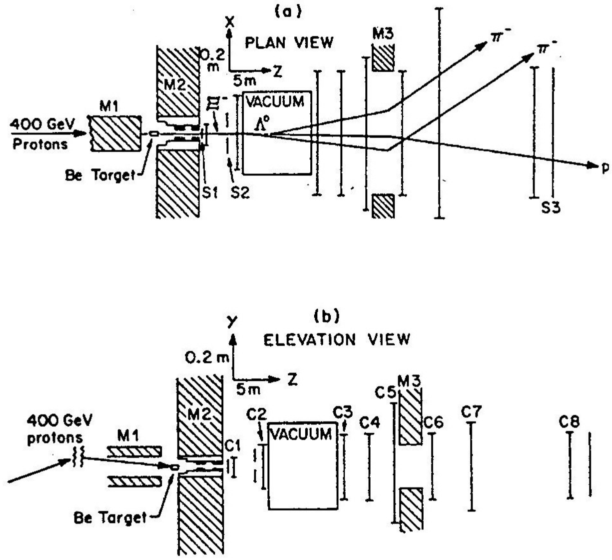


Figure 1: Plan and elevation views of a typical hyperon experiment.

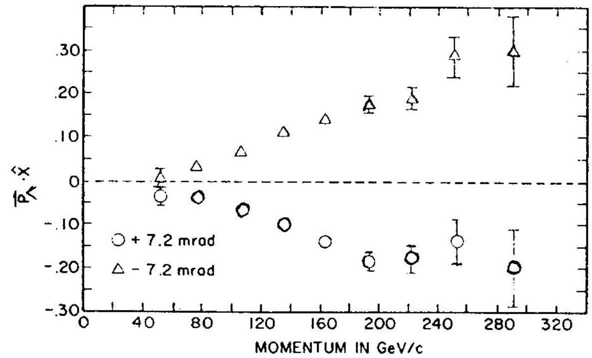
Most hyperon experiments focus on inclusive production in a closed geometry so the typical triggered event contains only the hyperon of interest. In this very "clean" environment, the hyperons' simple decay topologies are easy to reconstruct. The key feature in designing this type of experiment is the use of a brass or tungsten collimator imbedded in a high-field sweeping magnet. The combination of an incoming production angle and the sweeping field is used to move the incident proton beam away from a defining aperture which creates the hyperon beam. The sweeping field which removes the low-energy particles from the hyperon beam is also used to momentum select charged hyperons. A typical layout for the beam and experiment is shown in Figure 1.

Parity conservation in the strong interaction requires that the polarization vector at production be perpendicular to the production plane. In the laboratory, the polarization of a hyperon can be measured by analyzing the parity violating decay of the parent into a baryon and a meson. For a spin 1/2 hyperon such as a Λ , which decays to a proton and a π^-, the decay distribution of the daughter protons is given by:

$$dN / d(\cos\Theta) = 1 + \alpha P \cos\Theta$$

where Θ is the angle between the proton and the polarization direction in the rest frame of the Λ. The observable decay parameter, α, describes the magnitude of the weak asymmetry in the decay, and P is the magnitude of the Λ polarization. In the case where all decay protons are detected and measured, this distribution is simply a straight line which has a slope αP. In practice, experiments have less than full acceptance due to the apparatus geometry and reconstruction inefficiencies. An experimental technique has been used which, to first order, eliminates the problem of acceptance induced asymmetries. The data sample is prepared such that if a real polarization asymmetry exists, what will be measured in the cos Θ distribution will be a "sum" of the real polarization and a bias. However, since the real polarization must be normal to the production plane, by reversing the angle of the incident proton beam, the normal, and hence the polarization, is reversed. Geometrical acceptance and apparatus and software biases are unchanged by this reversal. Thus the bias can be cancelled by subtracting the asymmetries measured at opposite production angles, while the sum leads to a direct measure of the bias. The benefit and beauty of this technique can be seen particularly well in high-statistics experiments. Asymmetries measured at opposite production angles for Λ's produced by 400 GeV protons in experiment E440 are shown in Figure 2.[2]

A beneficial complication to



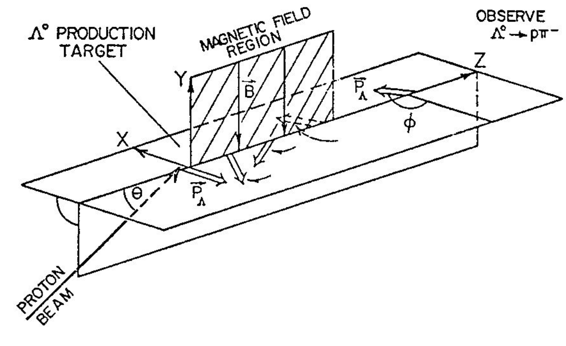


Figure 2: Asymmetry measurements taken at opposite production angles. This data is for Λ^0's from E440 (1977).

Figure 3: The precession of the production polarization in the sweeping magnetic field.

the measurement of hyperon polarization is illustrated in Figure 3. Since the polarization at production is normal to the production plane, if the sweeping field is also perpendicular to the polarization, the polarization will precess due to the particle's magnetic moment. In the typical experiment, the proton beam is incident on the target in the y-z plane which then requires that the polarization vector lie along +/-x. The magnetic field which is usually along the y direction will then cause the polarization vector to precess in the x-z plane. The relationship between the angle and the magnetic moment can be derived from the classical equation of motion for the angular momentum vector interacting with an external magnetic field,

$$d\vec{S} / dt = \vec{\mu} \times \vec{B},$$

where S is the particle's intrinsic spin and $\vec{\mu}$ is the particle's intrinsic magnetic moment, defined by $\vec{\mu}=g/2q/mc\vec{S}$. For a charged particle of mass m_B passing through a field of strength $\int Bdl$, the precession angle in the laboratory is given by

$$\phi = (g/2 - 1)\, m_p/m_B\, (18.3°/\text{T-m}) \int Bdl$$

The precession angle is determined from the ratio of the polarization in the z and x directions :

$$\phi = \tan^{-1}(P_z/P_x)+n\pi$$

Once the precession angle has been determined, the magnetic moment follows directly. The error on the magnetic moment is directly proportional to the error in the precession angle, $\Delta\phi$ and inversely proportional to the strength of the field, where $\Delta\phi$ is given by:

$$\Delta\phi = \frac{P_x^2\, \Delta P_z^2 + P_z^2\, \Delta P_x^2}{|P|}$$

Hence, there are three key ingredients to making precision magnetic moment measurements. These are:

1) making ΔP as small as possible (requires 10^5-10^6 events)

2) making the polarization P as large as possible (10 to 30%) and

3) making the precession field as large as possible (10-25 Tesla-meters).

Throughout the course of the Fermilab hyperon program, success in optimizing each of these ingredients has lead to precision measurements of the Λ (E440), Ξ^0 (E495), Σ^- (E620, E497, E715), Σ^+ (E620, E497, E761) and Ξ^- (E620, E497, E756) magnetic moments.[3-7]

In E756 data was taken at five different values of the precession field. The magnetic moment of the Ξ^- determined from the angles plotted in Figure 4 is Ξ^- = - 0.6505 +/- 0.0025.

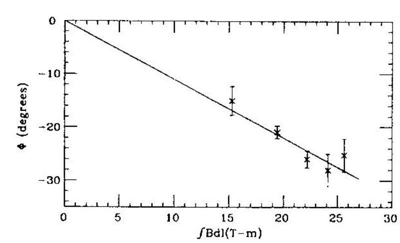


Figure 4: The precession angle plotted as a function of the field integral. This data is for Ξ^-'s from E756 (1987).

High-statistics experiments such as this one allow determination of magnetic moments at the few percent

Table 2: Precession angle ϕ *and* μ_Ξ for each of the five values of $\int Bdl$ for M1

$\int Bdl$(Tm)	Φ(deg)	μ_Ξ (nuclear magnetons)	Number of Events
15.30±0.15	-15.0±2.7	-0.656±0.010	745 x 10^3
19.43±0.19	-20.9±1.2	-0.651±0.004	1971 x 10^3
22.18±0.22	-26.0±1.6	-0.646±0.005	1034 x 10^3
24.11±0.24	-28.1±3.0	-0.647±0.007	301 x 10^3
25.62±0.26	-25.2±3.1	-0.656±0.007	314 x 10^3

level. However, equally important to statistical precision is the understanding of the systematic errors in the measurements. Ultimately, the consistency of a number like the magnetic moment as a function of momentum is also an important check. Table 2 and Figure 5 show the Ξ^- moment as a function of momentum for the full data sample.

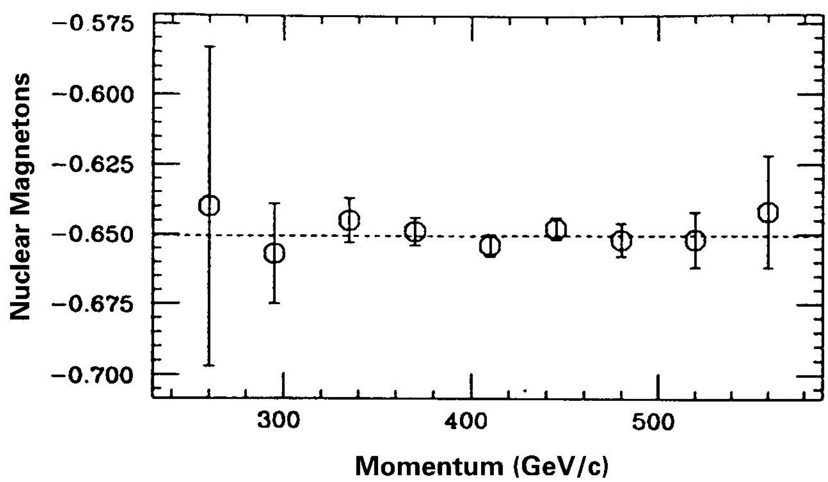


Figure 5: The Ξ^- magnetic moment plotted as a function of momentum. This is the data listed in Table 2.

From 1978 through 1984 the evolution of the Fermilab hyperon program produced many successful measurements of magnetic moments and other properties. However one hyperon remained elusive—the Ω^-. For the most part, this is because the Ω^- is the rarest of the hyperons, being produced only at the rate of about 1/100 of the Ξ^-. Yet the Ω^- is an ideal particle to study since it is an extremely simple system—three strange quarks with aligned spins. In the simple quark model both μ_Ω and μ_Λ provide direct measures of the strange quark moment. In 1979, Fermilab Experiment 620 collected a sample of 2000 Ω^-, which were analyzed but statistically below the threshold for a significant measurement of the polarization.[8] Coupled with the difficulty in obtaining events, it was worried that producing polarized Ω^-'s might not be trivial. Though polarization seemed to be a general feature of hyperon production, the anti-Λ, which, like the Ω^-, contains no quarks in common with the incident proton beam, was unpolarized up to a p_t of 2 GeV/c.[9] With the general lack of understanding of the polarization mechanism, whether or not the Ω^- could be produced polarized remained an open question.

In 1987, E756 answered that question. As suspected, when the Ω^- was produced by the 800 GeV proton beam, the polarization was insignificant. This is particularly obvious when the "polarization" is plotted in comparison to the Ξ^- and the anti-Λ, as shown in Figure 6.[10] Not to be daunted by the mysteries of nature, the E756 group modified the Ω^- production method to produce the Ω^-'s using a neutral beam, composed of neutrons, Λ's and Ξ^0's. In this way, the Ω's which were produced from the incident neutral hyperons, now did have quarks in common with the incident beam. Additionally, the neutral beam was produced at a 2 mrad production angle such that the Λ's and Ξ^0's were polarized along the x direction. The experiment collected 22,000 Ω^- in this mode which was called "spin-transfer" because of the expectation that some fraction of the neutral hyperons' polarization would transfer to the Ω^-. Though the statistics were not compelling, a magnetic moment could be calculated from the asymmetry measured in the Λ decay indicating that the

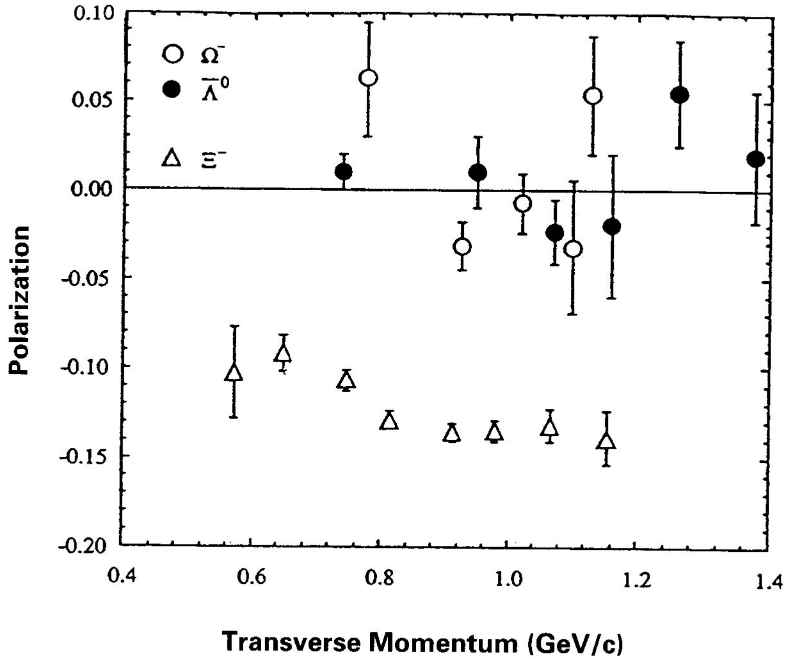


Figure 6: The "polarization" for Ω^- produced directly by 800 GeV protons is compared with the polarization of Ξ^- and anti-Λ.

parent Ω^- was indeed polarized. If the polarization was assumed real, the resulting moment was $\mu_\Omega = -2.02 \pm 0.16$.[11]

A follow-on experiment to E756, called E800, completed data taking in January 1992. This experiment collected a total of 400,000 Ω^-, 200,000 of which were potentially polarized. Approximately 50,000 were taken in the spin-transfer mode, and 150,000 were produced in an inclusive production mode where the neutral beam was produced at a zero mrad production angle so that the neutral hyperons were unpolarized, but were however incident on the Ω^- production target at a non-zero production angle. Though the analysis of this data is preliminary, both neutral beam production methods give both polarization and magnetic moments consistent with the E756 result.[12] The final answer is expected within the year.

The main reason one measures the hyperon magnetic moments is to be able to compare the measurements with theoretical predictions which are derived from assumptions about the way quarks combine to form baryons. Table 3 shows formulas for the baryon moments in terms of the magnetic moments of the up, down and strange quarks. These relations are based on a simple quark model (SQM) where hyperons are described by SU(6) wave functions. The numerical predictions can be compared with experimental measurements if the measured values of the proton, neutron and Λ moments are used as

Table 3: Baryon magnetic moment measurements

Baryon	Measurement in nuclear magnetons	Quark contribution	SQM nm
p	2.793	$\mu_p = (4/3)\,\mu_u - (1/3)\,\mu_d$	input
n	-1.913	$\mu_n = (4/3)\,\mu_d - (1/3)\,\mu_u$	input
Λ	-0.613±0.004	$\mu_\Lambda = \mu_s$	input
Σ^+	2.419±0.022	$\mu_{\Sigma^+} = (4/3)\,\mu_u - (1/3)\,\mu_s$	2.74
Σ^-	-1.156±0.014	$\mu_{\Sigma^-} = (4/3)\,\mu_u - (1/3)\,\mu_s$	-1.21
Σ^0 - Λ	-1.61±0.08	$\mu_{\Sigma^0 - \Lambda} = \frac{1}{\sqrt{3}}(\mu_u + \mu_d)$	-1.63
Ξ^0	-1.23±0.14	$\mu_{\Xi^0} = (4/3)\,\mu_s - (1/3)\,\mu_u$	-1.46
Ξ^-	-0.6505±0.0025	$\mu_{\Xi^-} = (4/3)\,\mu_s - (1/3)\,\mu_u$	-0.52
Ω^-	-2.02±0.16	$\mu_\Omega = 3\,\mu_s$	-1.83

input. On a coarse scale the agreement is quite good, though on the finer scale one can see that the agreement is particularly poor with the Ξ hyperons. Attempts to refine the SQM yield little improvement or insight to the problem.

Similarly, at this time, our understanding of what causes particles to be produced polarized is more uncertain than ever. What we thought was predictable behavior is certainly questionable. An interesting twist to the hyperon polarization picture was uncovered when E756 collected a sample of 70,000 anti-Ξ^-'s. While the folklore and anti-Λ's indicated that the anti-hyperons would be unpolarized, as were the Ω^-'s, it was discovered that the anti-Ξ^- had a significant polarization.[13] The anti-Ξ^- polarization is plotted in Figure 7 as a function of p_t, along with the polarization of Ξ^-'s produced at 400 and 800 GeV. The agreement is striking. Indeed, another Fermilab hyperon experiment, E761, is analyzing a large sample of anti-Σ^- results, and has preliminary indications that this anti-hyperon also has a non-zero polarization signal.[14] Excluding the anti-hyperon puzzle, some simple theoretical "rules" have evolved in attempts to predict the experimental data. One model of DeGrand and Miettinen is based on the quark model of the hyperon, where the valence quarks are those of the hyperon which are in common with the incident beam projectile, and the others are from the sea. "Sea" quarks are required to speed up to form the hyperon and are negatively polarized. "Projectile" quarks slow down to form the hyperon and are positively polarized. The polarization has the same strength in both

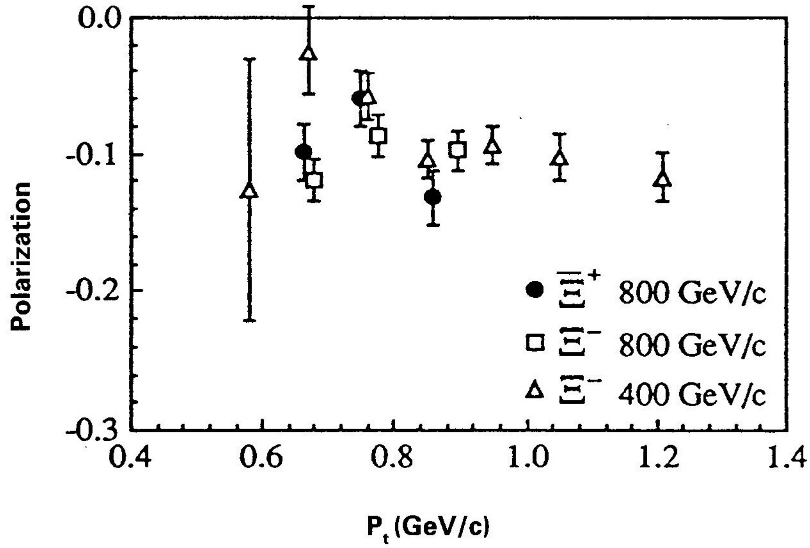


Figure 7: The anti-Ξ^- polarization is compared with the polarization of the Ξ^- for both 400 and 800 GeV production.

cases, and results totally from the quark combination process.[15] The problem with this and most of the models, in addition to the fact that they have little real theoretical motivation, is that although they have some success in predicting the direction and magnitude of the overall polarization, they are not able to address the kinematic behavior of the effect. Some recent work by J. Soffer and N. Tornqvist have attempted to address this, though the model is limited to the Λ.[16]

Experimentally, particularly for the Λ, it has been determined that the kinematic behavior is consistent with being energy independent, there is a transverse momentum plateau, such that the polarization increases with p_t up to about 1 GeV/c and then saturates, and finally, is strongly dependent on x_f. Collecting large samples of data for hyperons other than the Λ in order to see if these were general features of hyperon production was not possible until the Fermilab energy increase from 400 to 800 GeV. The E756 Ξ^- data finally offered enough statistical power to begin to explore the kinematic dependence of the polarization in another particle. For better or worse, it was found that the simple Λ rules did not hold for the Ξ^-. The striking difference between the Λ and the Ξ^- is seen in Figure 8.[17]

At this time, the Fermilab Hyperon program is complete. Though the origin of the polarization remains unexplained, it has provided the mechanism for completing the magnetic moment measurements. Perhaps in the future, a new program could be initiated to further explore the mysteries of hyperon spin effects, though it is likely that this will have to wait for some theoretical advances to motivate the experimental program. ■

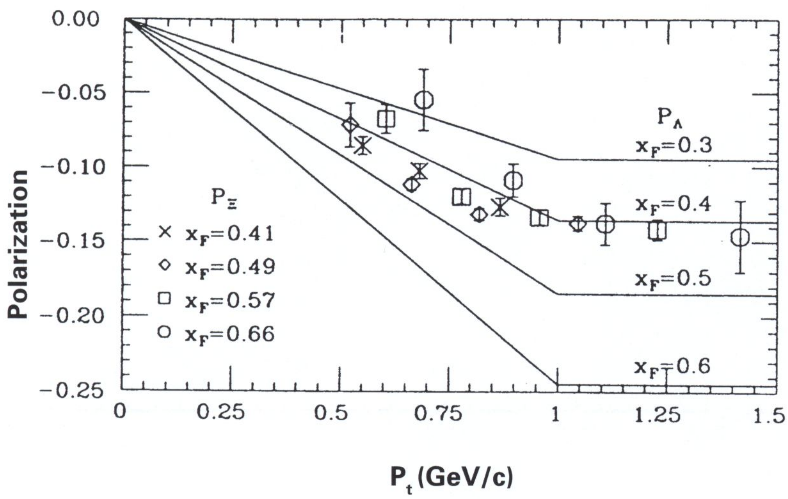


Figure 8: The polarization of the Ξ^- from E756 is compared with the parameterization of the Λ polarization. The Λ curves are based on data from E440, E441 and E555.

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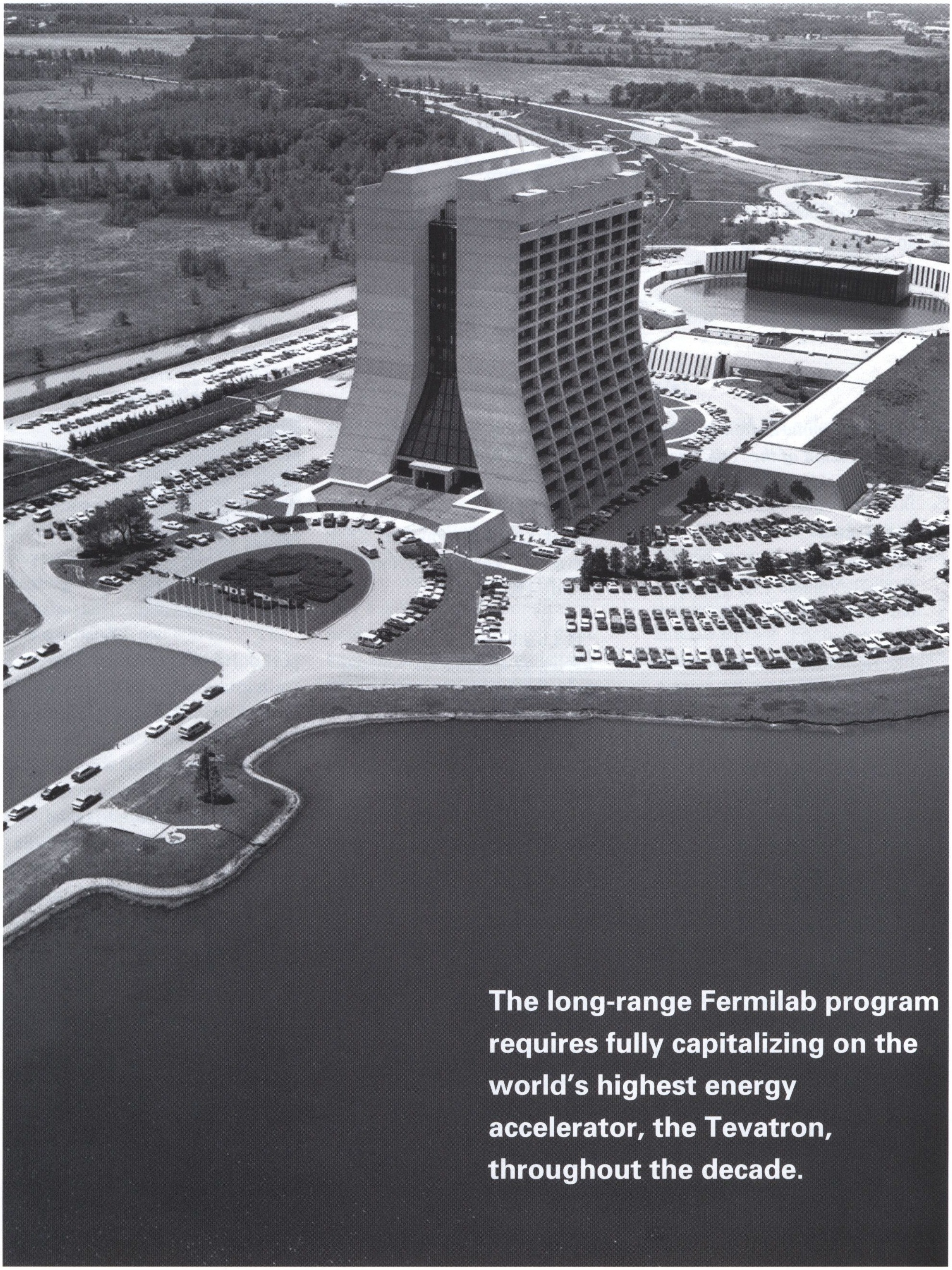
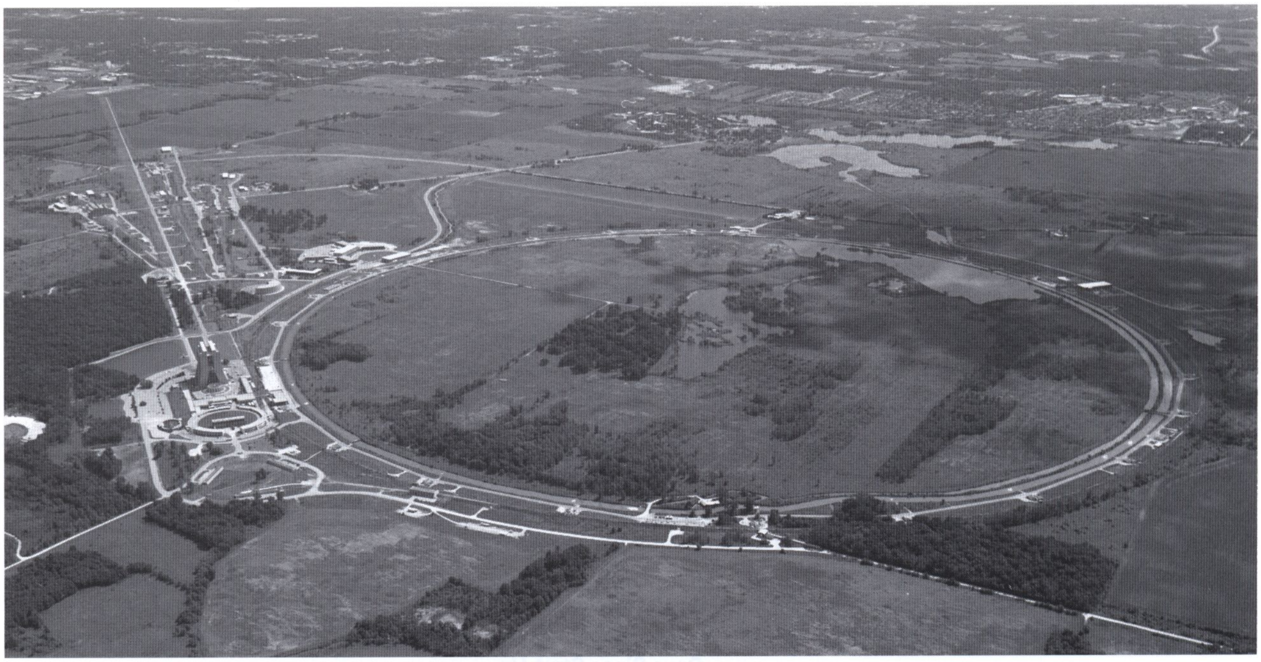
The contributor

Regina Rameika has a Ph.D. in physics from Rutgers University. As a graduate student and later as a post-doctoral research associate, she participated in Fermilab experiments E495, E361, E620, E555 and E619. From 1982-1985, Rameika worked at Fermilab as a post-doctoral research associate. During this time she participated in the design, set-up and first run of E705 and helped prepare the proposal to measure the magnetic moment of the Ω^-, which was approved as E756. Rameika joined the Fermilab staff in 1985. Since then she has served as the associate department head for the Research Division Operations Group and assumed responsibility as co-spokesperson for E800. Experiment 800 has completed taking data and analysis is in progress. Rameika is currently deputy head of the Fermilab Research Division.



The long-range Fermilab program requires fully capitalizing on the world's highest energy accelerator, the Tevatron, throughout the decade.



Fermilab Accelerator Setting Record Run

1992-1993 Collider Run Report

by James Holt

The long-range Fermilab program requires fully capitalizing on the world's highest energy accelerator, the Tevatron, throughout the decade of the 90s. The program calls for increasing the collider luminosity with each successive run until peak luminosities of $>5 \times 10^{31} cm^{-2} s^{-1}$ and integrated luminosities of in excess of 100 pb^{-1} per run are achieved, effectively doubling the mass range accessible for discovery. If, as appears likely, the top quark lies at the upper range of the mass reach of the Tevatron, then increasing the energy of the collider operation could prove to be a crucial factor in the future program as well. In order to achieve these goals, we present a highly challenging upgrade of the present accelerator complex, called Fermilab III. During the 1989 collider run the maximum luminosity attained was slightly in excess of the design goal of the Tevatron I project which was set at $10^{30} cm^{-2} s^{-1}$. In order to increase this performance level by a factor of 50, many changes are needed. Such a plan, of necessity, has modifications in almost all areas of the accelerator as the present system is reasonably optimized.

Fermilab III places emphasis on collider operation since productively searching new physics domains requires a continual increase in integrated luminosity. Fixed-target-physics intensity improvements are also part of the overall considerations. The increased proton intensities needed for both collisions and antiproton production will also substantially benefit the fixed-target program.

During phase I of the upgrade, there have been major modifications to the Tevatron. These modifications were commissioned at the start of this collider run and include the installation of electrostatic separators to separate the orbits and new low-beta insertions at both experiment interaction regions. These modifications have already enabled the Tevatron to achieve a record peak luminosity of $7.45 \times 10^{30} cm^{-2} sec^{-1}$ and a record weekly integrated luminosity of $1.477 pb^{-1}$.

Figure 1 shows a comparison of the first four hundred days between this collider run and the last collider run of the initial luminosity as a ten times running average. Figure 2 is a comparison of the weekly luminosity and total luminosity.

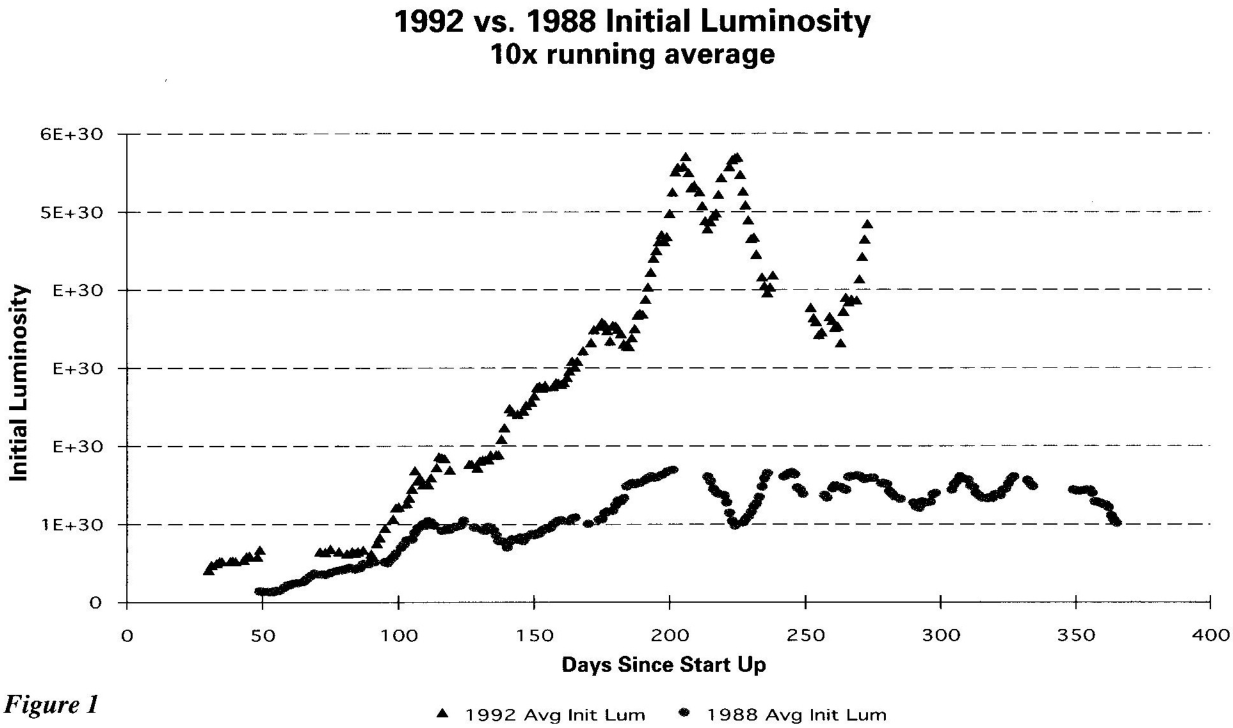


Figure 1

The goal for the present run is $5x10^{30}cm^{-2}sec^{-1}$. In the 1989 collider run the record peak luminosity was $2.07x10^{30}cm^{-2}sec^{-1}$. The Tevatron was operated with six bunches colliding head-on in all locations (twelve collision points). One of the luminosity-limiting factors was a maximum sustainable tune shift of .025 due to the beam-beam interaction. A similar value has also been achieved at CERN with a different working point in the tune diagram and with different bunch parameters. In addition to a tune shift, the beam-beam interaction causes a tune spread across the beam and enhances the strength of various destructive, nonlinear resonances. In the Tevatron, resonances up to twelfth order must be avoided. An orbit separation scheme was developed to eliminate the unnecessary collision points (there are only two experiments) as well as total separation during injection, acceleration and low-beta squeeze. The beams are brought into collision at only two points when low beta is reached.

In contrast to LEP and Cornell, the Tevatron uses separators in both the horizontal and vertical planes to produce a helical orbit. A helical orbit is accomplished by creating a betatron oscillation in the horizontal and vertical plane such that the phase between the two oscillations is n times π over 2 where n in an odd integer. The location of the separators in the Tevatron is shown in Figure 3. Helical orbits were chosen to keep the beams separated everywhere in the ring so that when the position of the bunches was cogged from the injection location to the collision location the beams remain separated.

The design goals were a minimum separation of 5σ and a maximum separation of 15mm (beam-beam center to center). This goal has been met. During operation we have run with separators as small as 3σ with no problems. The separators have been very reliable. There has been only one separator spark during operations to date (4000+ hours). The observed spark did not appreciably affect the store in progress.

During injection, acceleration and the low-beta squeeze, separation is achieved using the horizontal separators at B17 and vertical separators at C17. During the injection process, the horizontal separator at B11 is used to adjust the phase of the helix through the injection Lambertson. Finally, the beams are brought into collision at B0 and D0 and kept apart everywhere else with local electrostatic three bumps in each plane. One pair of bumps creates a helical orbit from B11 to C49. The other pair of bumps keeps the beam apart from D11 to A49. This results in 6.5

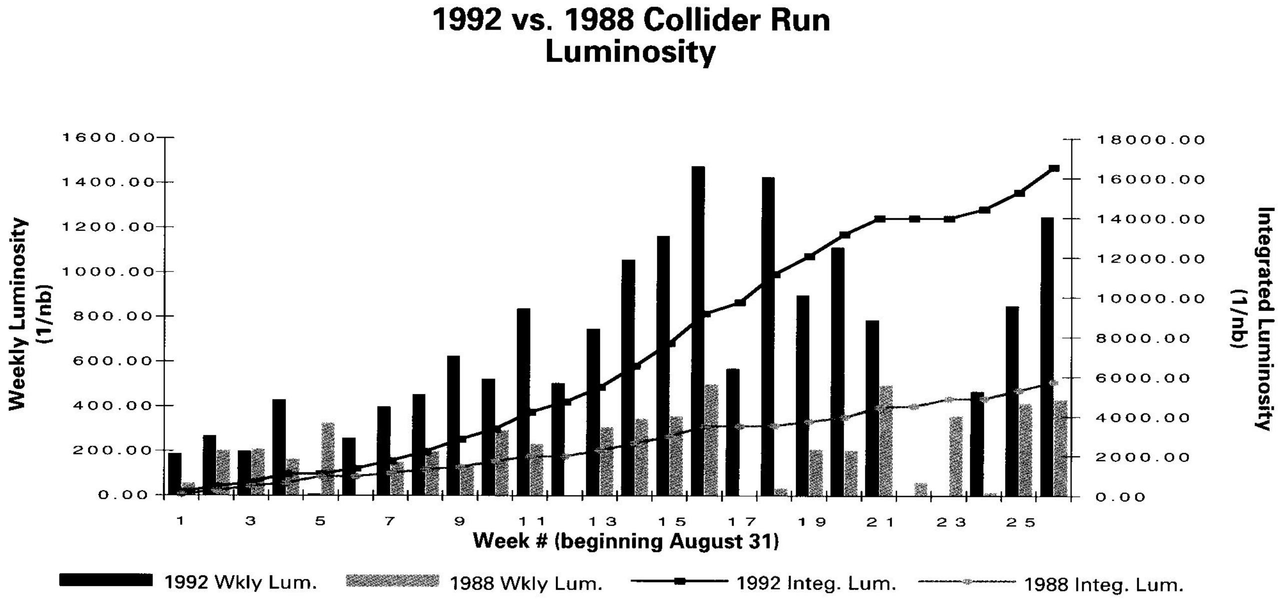


Figure 2

betatron oscillations in the third of the ring between B0 and D0 and 13 betatron oscillations in the remaining two-thirds of the ring. Since the number of betatron oscillations in these bumps is only approximately an integer or half-integer, the local bumps require three elements. The location of the middle element of the three bumps in the vertical plane is C17 and A17. The location in the horizontal plane is B17 and F17.

Since the protons and antiprotons are traveling on different orbits they experience different nonlinear fields and therefore have different tunes, coupling and chromaticities. These differential effects were measured and it was found that the differential tune and coupling that were produced could be explained by persistent currents in the main bending dipoles (b2) and the chromaticity sextupoles. However, no differential chromatic effects were observed. A correction scheme was designed to correct these differential effects using existing sextupoles in the secondary correction spool packages in the Tevatron. The idea is to create three circuits, two for adjusting the tunes and one to correct coupling. The correction scheme consists of 46 sextupoles distributed around the ring, 16 normal sextupoles and 30 skew sextupoles. The tune-adjusting sextupoles are connected in pairs causing their chromatic effects to cancel. The three correction circuits are configured by controls software. It is necessary to reconfigure the 23 hardware circuits into three software circuits whenever the lattice changes; i.e. at each step in the squeeze. The system (46 sextupoles) has more than enough strength to correct any differential effect for intensities through the Main Injector era. In fact, the system was designed to also compensate for the beam-beam tune shift created by the head-on collisions at B0 and D0. It was designed to compensate beam-beam tune shifts up to 0.020. However, it is not known if such strong sextupole fields will cause problems related to dynamic aperture effects. Part of the system has been tested and shown that a field strength can be achieved which allows correction of beam-beam tune shifts of 0.010. The partial system is currently being used to control the antiproton tunes at energies up to 500 GeV.

The construction of a colliding beam facility at the D0 long, straight section of the Tevatron, coupled with the presence of the CDF detector at the B0 straight section, has produced the need for a low-beta insertion that, unlike the old system, permits the simultaneous and essentially independent operation of more than one interaction region. The new low-beta insertion enables simultaneous operation of a multiple of such systems by matching each

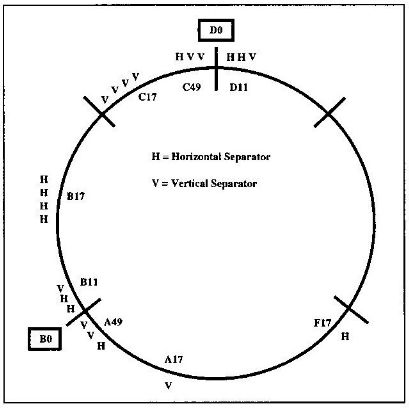


Figure 3

insertion to the arcs of the machine in betatron and momentum space. Matched insertions in collider mode are independent except for the need to maintain a constant tune with distributed tune-correction quadrupoles in the rest of the accelerator. The addition of each low-beta insertion to the accelerator lattice raises the tune of the accelerator approximately one-half unit unless compensated. The operating point of the collider has vertical and horizontal tunes with two collision regions of 20.576 and 20.585 respectively. By comparison, the lattice used for fixed target has no low-beta inserts and has a tune of 19.4.

The insertions at both experimental regions are optically identical. The original low-beta region at B0 was deliberately unmatched and produced a large beta and dispersion wave in the rest of the accelerator and was replaced. Each new low-beta insertion is composed of 18 high-gradient quadrupoles that are physically located symmetrically around the straight section region and in the arcs. The magnetic gradients are antisymmetric relative to the center. A field free region, 15.24m long, is available for each detector between the final quadrupoles. The lattice design is a relatively conventional one; the low-gradient quadrupoles are used to provide the matching into the arcs, the high gradient ones provide the strong focusing close to the interaction point to give the small beam size. Twelve independent circuits are used to vary the insertion optics. The inclusion of extra circuits beyond the minimum of eight results in a more efficient insert by allowing some of the quads to run at less than their maximum values. The β^* at injection is 170cm. Currently the β^* at the end of the squeeze is 50cm. The magnets are capable of going to a β^* of 25cm.

Both the separators and the low-beta insertions were commisioned at the beginning of the current collider run which started in May of 1992. Both systems have performed reliably. Further upgrades to the Fermilab accelerator complex include upgrading the Linac to 400 MeV from 200 MeV, improvements to the antiproton source and construction of the Main Injector which will replace the Main Ring. These improvements are expected to yield another factor of ten improvement in the luminosity which can be delivered by the Tevatron collider.

Antiproton source performs well

The Antiproton Source has been performing exceptionally well in the collider run. Figure 4 shows a comparison between this collider run and the last run of the weekly pbar production and the integrated pbar total for the first 21 weeks. The record antiproton stacking rate now stands at 3.83 mA/hour, just short of the goal of 4 mA/hour for Collider Run Ia. The stacking record previous to the 1992 collider run was 2.5 mA/hour. This improvement is primarily due to increased delivered Main Ring intensity due to improvements in the Booster on antiproton production cycles and major upgrades to all the stochastic cooling systems in the Antiproton Source. This includes the core-cooling system (upgraded from 2-4GHz bandwidth to 4-8GHz bandwidth since the last collider run), the stacktail-cooling system (improved pickup arrays, plus many other modifications), the stacktail-betatron system (newly commissioned), and the Debuncher cooling systems (increased power capability). With several more planned modifications and some fine tuning, we anticipate that we will exceed this run's goal of 4 mA/hour stacking rate.

The efficiency of transferring antiprotons from the Accumulator Ring to the Tevatron has increased dramatically, from 25% to over 60%, during the course of the present collider run. This is a complicated process involving beam manipulations in the Accumulator, Main Ring and Tevatron. In November the ion-clearing system in the Accumulator Ring was upgraded from 100V to 600V, eliminating the trapped ions which are a source of beam instability to the antiproton stack. This has had three beneficial effects. First, transverse beam emittances can be made smaller, greatly improving the antiproton transfer efficiency through the limited aperture of the Main Ring to the Tevatron. Second, transfers can be made from larger stacks (we now routinely transfer from 80+ mA stacks). Third, the 4-8Ghz core-

1992 vs. 1988 Collider run
Pbar Stacking

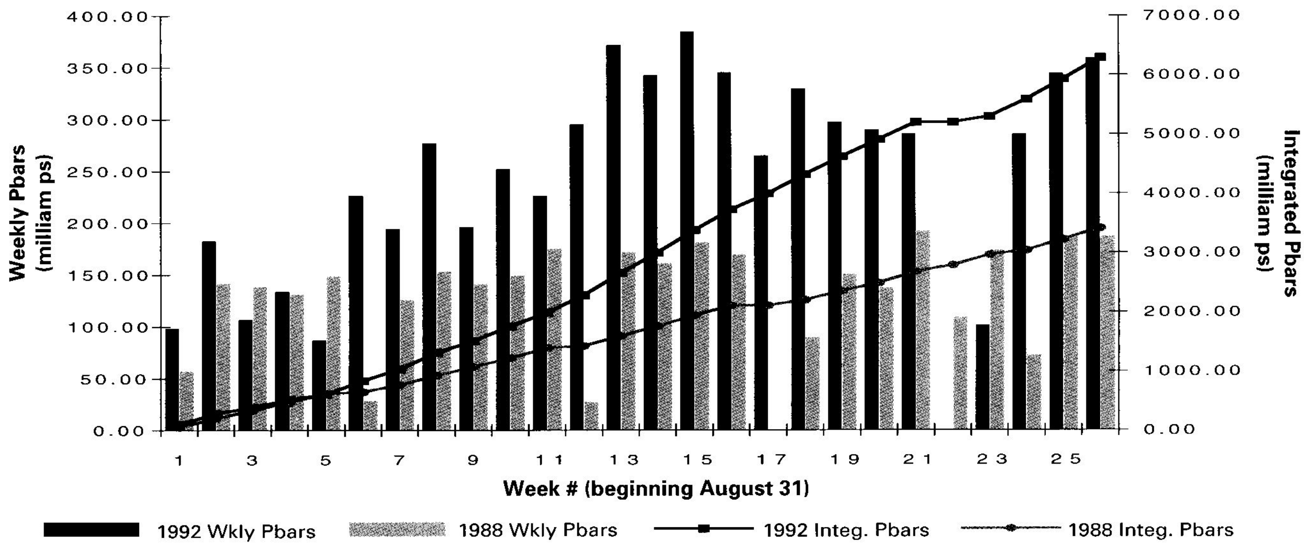


Figure 4

momentum stochastic-cooling system can now be used during transfers, reducing the beam momentum width and thereby further increasing the fraction of antiprotons transferred to the Tevatron. These numbers are expected to continue to increase as the collider run progresses.

FMI project progresses

The Fermilab Main Injector project is the centerpiece of Fermilab's program for the 1990s, Fermilab III. It is designed to support a luminosity of at least $5x10^{31}cm^{2}sec^{-1}$ in the Tevatron collider while providing the potential for development of new capabilities at Fermilab in the realm of rare neutral K decays and neutrino oscillations. The Fermilab Main Injector is an 8-150 GeV synchrotron designed to replace the Main Ring. The existing Fermilab Main Ring represents, with the changes required to accomodate the demands of the Tevatron era, a serious limitation in the beam intensities that can be provided to the Tevatron and onto the antiproton production target. The proposed Main Injector will overcome these limitations. The FMI project has passed several significant milestones over the past several months and is now proceeding rapidly towards the initiation of physical construction. The project received a $11.65M appropriation in FY92 and $15M for the current fiscal year. Through the Energy Systems Acquisition Advisory Board process the Department of Energy has authorized the application of funds to construction of the underground enclosure and service building at the point of tangency between the Main Injector and the Tevatron (MI-60), and to the preparation of bid packages for all remaining project construction.

Earlier this past summer, on July 24, wetland mitigation work was initiated. The construction of the FMI requires the filling of approximately six acres of wetlands. Permission to do this has been granted by the U.S. Army Corps of Engineers contingent upon the creation of nine acres of new wetlands in close proximity to those destroyed. The wetland mitigation project includes the immediate filling of approximately four acres of wetland and creation of the full nine acre mitigation area. Earth moving is now completed, with only spring plantings and five years of monitoring remaining to complete the mitigation.

The accelerator will be constructed of 344 new conventional dipole magnets, but will use quadrupoles, accelerating rf cavities and instrumentation from the Main Ring. The lattice features two types of cells: normal (34.6m) cells in the arcs and straight sections and dispersion-suppressor (25.9m) cells adjacent to the straight sections to reduce the dispersion to zero in the straight. The tighter focusing and smaller dispersion result in physically smaller beams than in the Main Ring, and an acceptance over three times larger. The standard cell consists of a FODO lattice containing two dipoles in each half-cell; the dipole length is 6m. The straight-section cells are the same length as the normal cells. The dispersion-suppressor cells require special length quadrupoles and dipoles; again, the lattice is a simple FODO array with two, 4m dipoles between quadrupoles.

The dipole magnet has been designed and two prototypes have been constructed and measured. Both magnets exhibit field quality well described by computer models and within the performance specification. The magnets have four turns per pole of conductor with dimensions 2.54cm x 10.16cm, with a peak current of 9375 A, and a peak power of 75kW. The poletip gap is 5cm, and the good-field region ($\Delta B/B<1 \times 10^{-4}$) exceeds ±4.4cm at injection. At the peak field (1.72 T) there is significant saturation producing a sextupole field which determines the required strength of the chromaticity-controlling sextupole magnets. Twelve production prototype dipoles will be built in 1993 with magnet production starting late in the year.

Four new beamlines are required to connect the FMI to the Fermilab accelerator complex: a 760m 8 GeV line to connect to the Booster, two 260m beamlines to connect to the Tevatron (one for protons and one for antiprotons) and a beamline to allow transport of 120 GeV protons to the antiproton production target or to the experimental areas. This latter beamline utilizes the Main Ring remnant that will remain in F-sector of the Tevatron enclosure. Designs exist for all of these beamlines. The 8 GeV line has been designed with a lattice strongly resembling the Main Injector lattice, except for the matching section at the Booster end of the line. The beamline utilizes existing Main Ring dipoles for most of the bending elements. The two 150 GeV lines are almost mirror images of one another. They transfer beams to the Tevatron at a point 13m downstream (in the proton direction) of the center of the F0 straight section with common Lambertson magnets to place the beam onto the Tevatron vertical closed orbit. These beamlines utilize Main Ring magnets for all of the dipoles and quadrupoles. Beam transfers to the Main Ring remnant utilize the same beamline as for proton transfers to the Tevatron. The Lambertson magnets at the Tevatron are turned off, allowing the beam to continue upwards to the Main Ring elevation.

Tracking studies underway

Extensive tracking studies are underway. To date, the most complete studies have been done at the injection energy of 8 GeV. These studies include the measured multipoles from the prototype Main Injector dipoles and from the Main Ring quadrupoles. Random errors have been included with distributions based on the more extensive data from Main Ring dipoles. Misalignment errors have been included, with rms position errors of .25mm assumed in both x and y for dipoles and quadrupoles and rms roll angles of .5 mrad for the dipoles. The tracking studies include chromaticity-correcting sextupole magnets which correct the chromaticites to -5 in both planes (+5 for tracking at energies above transition). The rf voltage is turned on at the nominal injection value, and synchrotron oscillations corresponding to the maximum expected momentum offset are included. The tracking studies reveal an uncorrected closed orbit error of 4 to 8mm, varying with the seed of the random distribution, and survival for the full 35,000 turns (the nominal injection dwell time for injecting six Booster batches) for particles with initial amplitudes of less than 20mm. This corresponds to an admittance of almost 60π mm-mrad, a full factor of two larger than the largest (95%) beam emittances anticipated. It appears that the admittance at 8 GeV is limited by the amplitude-dependent tune shift from the octupole component on the Main Ring quadrupoles. The inclusion of octupole correction elements (which can be recovered from the Main Ring) increases the admittance even further. Limited tracking studies have been done at transition, 120 GeV and 150 GeV. While the work done so far has yielded no surprises, much more work remains, particularly with regards to the resonant extraction of the beam at 120 GeV.

R&D work advances

R&D work in support of the project is also well advanced. In addition to the dipole effort discussed earlier, R&D on the

1000V/10,000A power supply required to power the dipoles has also been initiated. Twelve such supplies are required in the accelerator. The first prototype will be assembled next spring in the area which was most recently home to the SSC string test. Finally, significant progress has been made on the 200 kW rf power amplifier required for the project. Eighteen units will be required ultimately. Work will continue through 1993 on this critical component.

Construction of the Main Injector is being coordinated by the Fermilab Accelerator Division with significant contributions expected from all divisions of the Laboratory. Much work has been accomplished in technical design, in project management and in permit applications. Fermilab was awarded a grant from the State of Illinois, with which the architect/engineering firm Fluor-Daniel was contracted to provide advance conceptual design work for the civil construction and site mitigation required for the project. The state money was also used to prepare an Environmental Assessment which recommended a Finding of No Significant Impact (FONSI) for the project. Following the determination by DOE that this document was acceptable, the FONSI was published in the Federal Register on July 6, allowing the mitigation work to proceed. All other construction permits have been secured and it is expected that construction of the MI-60 underground enclosure will start in early January 1993.

Linac upgrade nears completion

An important parameter throughout the accelerator chain is ε, the transverse invariant beam emittance, a measure of beam brightness. The initial value of ε is established in the Linac and its pre-injector. At each step in the acceleration process, ε can only become larger through dilution processes. The first place where this occurs is in transferring the protons into the Booster. The most straightforward way in which to preserve the small emittance of the Linac is to raise the energy at which the Linac beam is injected into the Booster.

The Linac currently provides 0.7×10^{10} H^-/bunch/turn into the Booster with $\varepsilon = 7$ to 8π mm-mrad (95% normalised). Theoretical calculations and experimental measurements have established that the tune-spread caused by space-charge, $\Delta\nu$, degrades transverse emittance of the proton beam at injection into the Booster at intensities corresponding to two turns or greater injected from the Linac. It has been shown that the degradation of the transverse beam emittance is determined by a space-charge tune-shift limit of $\Delta\nu=0.37$ in the Booster at the start of acceleration after the beam has been bunched. As the space-charge tune-shift is inversely proportional to a relativistic factor $\beta\gamma^2$, and proportional to N/ε, it should be possible to reduce the emittance in the space charge dominated intensity regime by increasing the injection energy from 200 MeV to 400 MeV, a change in $\beta\gamma^2$ of 1.75. Normalized emittances of 10π for bunch intensities of 3.5×10^{10} particles out of the Booster could be expected instead of the presently measured 18π numbers. Conversely, transmitted intensities in the Booster and Main Ring, which are limited by the transverse emittance growth, could be expected to increase by approximately the same 1.75 factor for the emittance which is presently utilized.

Most of construction for the 400 MeV Linac upgrade has been completed. Beam commissioning plans have been started in preparation for the Laboratory shutdown in the summer of 1993. All of the new Linac is in the temporary position adjacent to the operating drift tube Linac inside the present Linac enclosure. The seven new side-coupled accelerator modules are under power without beam to verify overall system reliability. All rf power systems in the Linac gallery now operate twenty-four hours a day with little intervention. All major components for the 400 MeV transfer line to the Booster are complete. Only the four orbit-bump magnets for the Booster injection girder are still in fabrication, and these should be complete by March 1993.

Tevatron operates at lower temperatures

The operating energy of the Tevatron is defined by the ability of the superconducting cable to carry the necessary current density in the presence of high magnetic fields; the so-called cable short sample limit. The 1000 magnets in the ring form an ensemble with a distribution of quench currents with a full width of ±60 GeV; the machine operating energy is determined by the lowest quench current of any magnet in the ring. There are two possible methods of increasing the machine energy: identifying and replacing the weak magnets with higher quench current elements, or lowering the temperature of the magnets which increases the critical current. Since the quench current of each magnet was measured prior to installation in the ring, we can estimate with good accuracy that ~40% of the magnets would need replacement to reach 1000 GeV at the present cryogenic temperature. Since weak magnets can only be identified and replaced serially this option is not viable, independent of financial considerations. We have therefore decided to implement lower-temperature operation. For the Tevatron magnets, the enhanced current-carrying capability amounts to about 15% per degree Kelvin.

The present operating threshold of the Tevatron is 935 GeV with a peak coil temperature of 4.9K. A coil temperature reduction of 1.0K is expected with the new system. Assuming that no mechanical limits are reached in the magnets, this will result in an energy of 1075 GeV. In reality, mechanical limits and weak splices will be encountered between 935 GeV and 1075 GeV which will require a small number of magnet changes. The 1075 GeV energy level represents the operational limit of several major subsystems of the Tevatron: the cryogenic system capacity, power supply and power lead current, and magnet-collar strength.

Lower temperature will be achieved by pumping on the magnet two-phase helium circuit with cold-vapor compressors. A subcooling dewar will be located between the refrigerator and the magnet strings to buffer oscillations. The dewar is sized to help minimize the transients caused by the AC losses during ramp turn on/off in fixed-target physics.

Control of the system will be achieved by replacing the ten-year-old multibus I, Z80-based refrigerator control system. This system is currently at the limit of input channels, controlled devices and control software. A new Multibus II and Intel 80386-based system will handle the additional hardware and software necessary and allow for expansion to more elaborate system control and tuning.

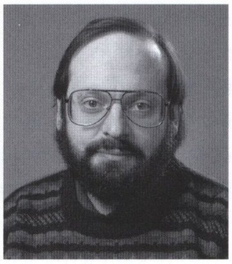
Cryogenic system upgrades

The Fermilab satellite refrigeration system and the Central Helium Liquefier provide cooling for approximately 1000 superconducting magnets and assorted cryogenic components that make up the Tevatron. The current system is capable of maintaining magnet temperatures at about 4.9K, allowing the Tevatron to operate reliably at a beam energy of 900 GeV. The cryogenic system upgrade requires that the cold compressors, with an accompanying phase separator return dewar, be fitted into existing refrigerator building piping. The phase separator dewar protects the cold compressor from possible damage due to liquid surges and provides a source of stored refrigeration available from the liquid in the dewar.

This fall, Fermilab took delivery of twenty-seven centrifugal cold compressors. A centrifugal-type cold compressor was small enough to fit into the existing system, requiring no further floor space in an already crowded satellite refrigerator building. Seven of the twenty-five replacement satellite valve boxes have been delivered. Continued shipment is expected early in 1993. Nearly all subassemblies have been completed.

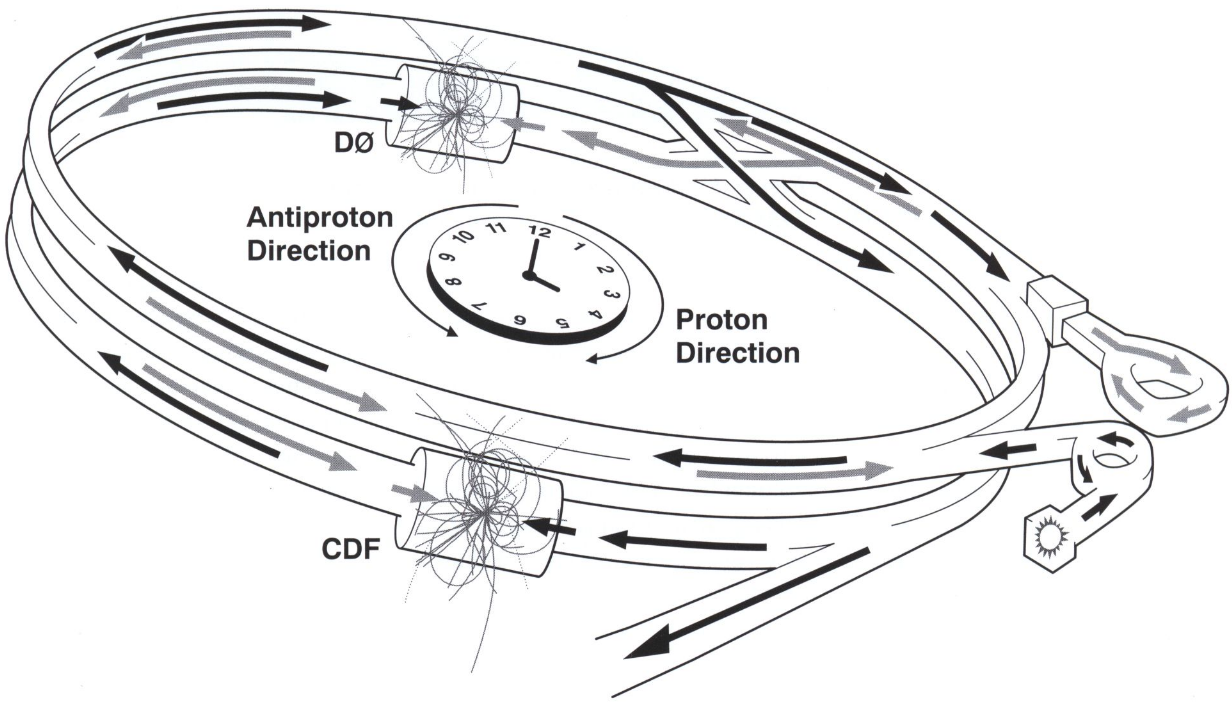
The satellite refrigerator controls are being upgraded to accommodate the added requirements of the low-temperature upgrade as well as to allow for future expansion. A prototype system has been operational in an auxiliary satellite refrigerator since June. Installation is currently underway in one of the eight satellite compressor buildings during collider operations. It is planned to install the new controls system in as many compressor buildings as possible prior to the next shutdown. ■

The contributor



James Holt received his Ph.D. in physics from Texas A&M University. He was a staff member at the National Laboratory of High Energy Physics (KEK), Japan, where he worked on the polarized proton beam project at the proton synchrotron. In 1991 he joined the Fermilab Accelerator Division Physics Department where he has been heavily involved in all phases of Tevatron Collider commissioning including control software, machine startup, machine studies, low-beta insert and separator commissioning. In addition, he is working on the analysis and simulation of various Tevatron acclerator physics issues as well as future upgrades. He is also the division *CERN Courier* representative.

Colliding Beam Experiments at Fermilab



Reports from CDF and DØ →

New CDF Data Surpasses Last Run

by John Cooper

At 4:30 on December 9, 1992, the CDF Collaboration reported that events from a total integrated luminosity of 4.69 pb^{-1} had been written to tape during the 1992 Collider Run at Fermilab. This equals the data sample collected in the 1988-89 run and signals a solid new beginning to Fermilab collider operations.

The upgraded CDF detector was rolled into the B0 Collision Hall at the end of March 1992, and first collisions were seen in May. Studies with the Tevatron and detector continued until August 26 when CDF declared the detector commisioned and the data quality sufficient to begin the top search. The new CDF data set was collected from August through December from a delivered integrated luminosity of 6.6 pb^{-1}. Data which took 272 days to accumulate in 1988-89 took only 106 days in 1992 (Figure 1) due to the increased Tevatron luminosity and to increased efficiency at CDF.

The upgrades of CDF since 1989 are extensive: A new 0.020 inch wall beryllium beam pipe with diameter 1.5 inches was installed to replace the 2.0 inch diameter pipe used in 1989; a new 4-layer, 46,000 channel Silicon microstrip Vertex Detector was installed around the beampipe to detect secondary vertices; a new set of Vertex Time Projection Chambers with 4cm drift spaces and 8,600 wires replaced the old 15cm drift space devices; new low-noise preamplifiers were added to these Vertex TPCs; new higher gain preamplifiers were installed on the inner layers of the Central Drift

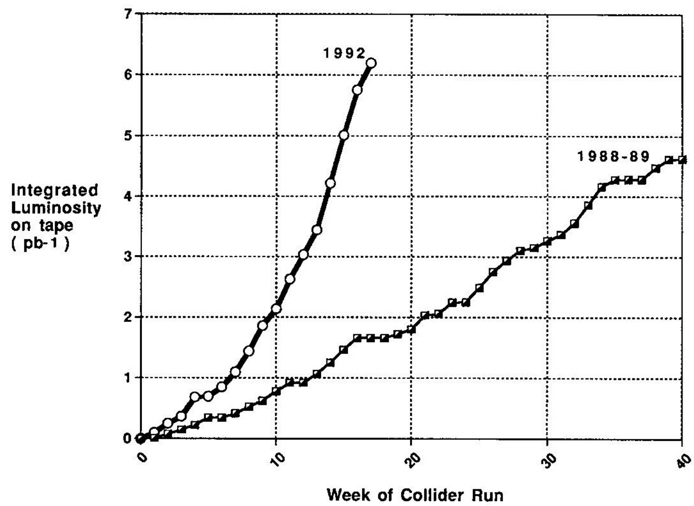


Figure 1: Integrated luminosity on tape at CDF versus week for both the 1988-89 and the 1992-93 Collider Runs.

Chamber and the high voltage was reduced to increase the lifetime of the device; new amplifiers were installed on the outer layers of the Central Drift Chamber to give dE/dx information from 54 layers; a vacuum leak in the solenoid cryostat was repaired; 50 square meters of new wire chambers were added just behind the 1.1 radiation length solenoid as preradiator detectors; 630 tons of steel was added to beef up the central muon detection; 856 new chambers were added behind the steel walls and above/below the return yoke steel of the magnet to detect muons with rapidity less than 0.5; an additional 1632 muon chambers and scintillators were added to extend the central muon coverage from rapidity of 0.5 to 1.0; the forward (rapidity greater than 2.0) muon chambers and scintillators interspersed in the forward magnetic toroids were removed, refurbished with finer phi segmentation and reinstalled; and the gas calorimeter chamber gains were lowered to ease operation at 10 times the original design luminosity.

Improvements to the data acquisition and trigger are also numerous: 24,000 channels of new front-end electronics were installed on the gas calorimeters to compensate the gain change mentioned above, to shorten the integration times and to reduce noise to the trigger system; high-voltage feedback was installed on the gas calorimeters to keep the gain stable with changing temperature and atmospheric pressure; the existing multiplexed Analog to Digital Converter cards were replaced with faster versions to reduce the front-end readout time from 18 to 3 milliseconds; new luminosity monitors were installed; dual Fastbus Event Builders were installed to increase the data acquisition rate by a factor of 4 to about 25Hertz (= events per second); the data acquisiton system rate

The CDF collaboration now has 399 members and offers a training ground for 126 graduate students.

to 8mm magnetic tape was increased from 1.2 to 8Hertz; the Level Two trigger processors were speeded up from 40 μsec to 20 μsec processing time per event; a new Neural Net Level Two trigger was installed to make possible an isolation requirement on photon and electron triggers; and the computing power in the Level Three trigger farm was increased by a factor of 25 using UNIX-based processors.

Offline computing capability is also increased: the offline code (and identical Level Three trigger code) was ported to UNIX, 1000 Mips of offline computing was installed in offline farms, and a robotic tape silo with 1.2 Terabytes of storage was installed for fast access to the data. The new data set has already been fully reconstructed.

The CDF Collaboration has increased dramatically in size since 1989. Sixteen new universities and National Laboratories have joined to double the number of collaborating institutions to 33. A total of 399 physicists are now members, up from "only" 187 in 1989. Of these 399, 126 are graduate students, 77 hold post-doctoral positions and 196 are permanent staff. Part of the commisioning has included understanding sociological interactions at a new scale! The shift crews are composed of a Scientific Coordinator (dubbed the "SciCo"), an "Ace" who is an expert on the data acquisition system (usually a graduate student) and two "consumer operators" who monitor the data quality with many online programs which "consume" events. All members of the collaboration participate in the shift work and serve for 10 day rotations. The physicist crew is supplemented by Fermilab personnel responsible for the cryogenic solenoid, the gas systems and the safety systems. Rotating "Operations Managers" coordinate detector operations around the clock and are liaisons to the Accelerator Division. A Trigger Working Group meets every week and keeps the total trigger cross sections under control as the luminosity of the Tevatron increases. The collaboration assembles every other week at Fermilab in a series of meetings to coordinate the physics analysis. Co-Conveners steer this analysis in four working groups concentrating on QCD, Electroweak, Heavy Flavor and Exotic physics topics.

As reported at the Division of Particles and Fields meeting held at Fermilab in November, the detector is functioning well. Only 2% of the 46,000 Silcon detector channels are non-functional and the device is surviving the Tevatron Collider radiation thanks to close and fruitful interaction between CDF and the Accelerator Division. Less than 1% of the channels in the rest of the detector have problems. The operational uptime of the detector is about 80% (still short of the collaboration's goal of 90%). The trigger plus readout live time is 90% at luminosities of $5x10^{30}$ as planned. The W and Z production rates in the older detector systems are comparable to 1989, and additional Ws and Zs are seen in the newly upgraded muon systems and in the gas calorimeters with rapidity >1.0 (Figure 2). Detector thresholds have been lowered to give nearly 5 times the rate of $J/\psi \rightarrow \mu^+\mu^-$ detected per pb^{-1} of luminosity recorded (Figure 3). Secondary vertices have been seen with the new Silicon detector and it is clear the device will allow a measurement of the b-quark lifetime (Figure 4). Even a new e μ candidate has emerged to match the single such event seen in 1989.

By the end of calendar 1992, more than 6.2 pb^{-1} of integrated luminosity had been collected on tape at CDF. More data is eagerly awaited as the run continues into 1993. ■

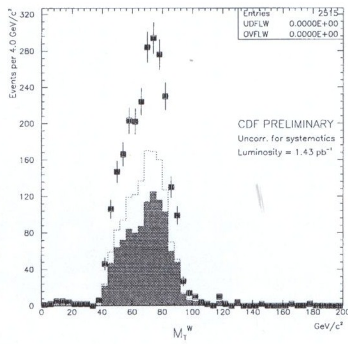


Figure 2: Preliminary CDF W transverse mass from 1.43 pb^{-1} of 1992 data. The shaded area is for $W \rightarrow \mu + \upsilon$ electrons in the central detector (rapidity less than 1.0), the dotted histogram is for electrons in the plug calorimeters (rapidity between 1.0 and 2.5), and the solid points are for $W \rightarrow \mu + \upsilon$. All three contributions have been added in this figure.

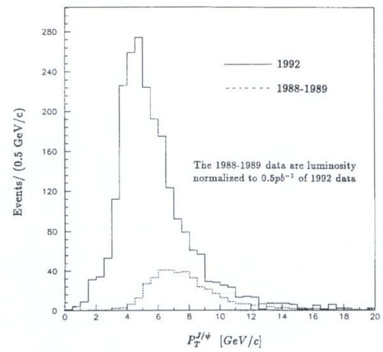


Figure 3: Preliminary CDF J/ψ transverse momentum spectrum using 0.5 pb^{-1} of 1992 data (solid histogram). The 1988-89 CDF data (dotted histogram) is shown normalized to the same total integrated luminosity. More data at lower transverse momentum is being collected in 1992 because the muon trigger has been lowered.

The contributor

John Cooper is the CDF department head. He has a Ph.D. in physics from the University of Michigan. His thesis work was done at Brookhaven using the 80-inch bubble chamber. He also worked on two Fermilab 30-inch bubble chamber experiments. As a post-doc at the University of Illinois and later as a visiting research assistant professor, Cooper worked on Fermilab E369 and E610. As an assistant professor at the University of Pennsylvania, he continued his Fermilab connection by serving as spokesperson for E673. In 1982, Cooper joined the CDF collaboration. Since that time, he has worked on the Central Calorimeter Cesium source calibration system, helped coordinated the CDF testbeam effort, and served as operations manager, CDF deputy head and assistant Research Division head for strategic planning. He is also a Fermilab representative for the *CERN Courier.*

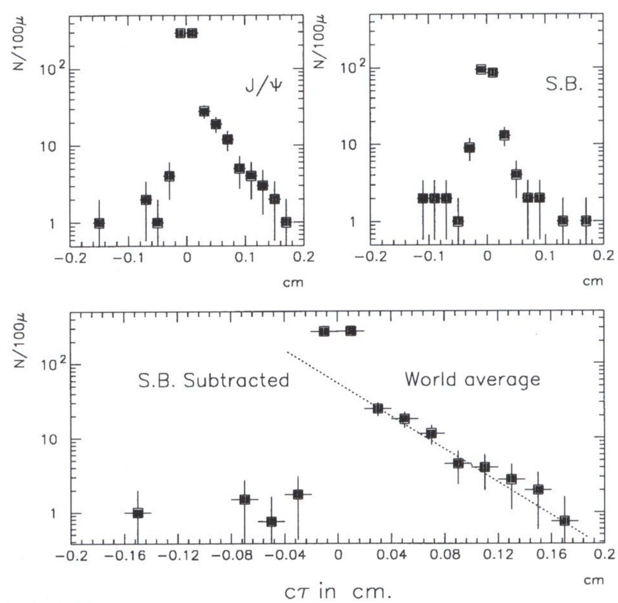


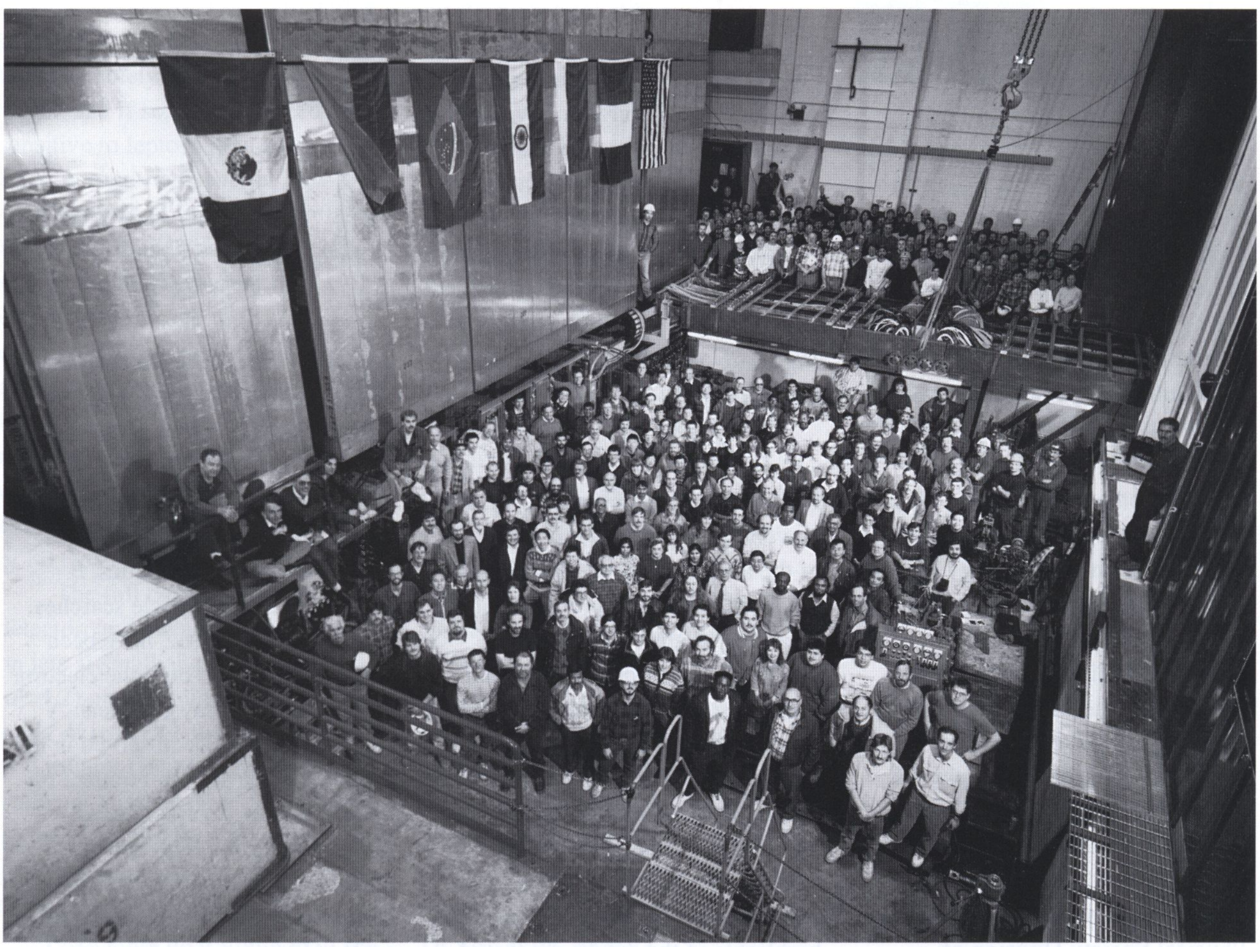
Figure 4: Preliminary CDF distribution of proper length (relativistically corrected flight distance) measured by the Silicon Vertex detector for the inclusive $J/\psi \rightarrow \mu^+\mu^-$ sample. The upper left distribution is for the J/ψ mass region, the upper right distribution is for a side-band m^+m^- mass bin adjacent to the J/ψ and the lower figure shows the background subtracted with the world average b-lifetime measurement superimposed (dotted line).

DØ Announces First Physic Results

by Mike Tuts

The excitement of observing the first collision in the DØ detector (Figure 1 on page 26), on May 12, 1992, was the payoff for more than eight years of hard work by a large and dedicated group of physicists, students, engineers, technicians and other support staff. The DØ detector had completed the journey from design (1983-1984) to final construction and subsequent rolling in to the collision hall in February 1992. The international collaboration (see photo below) of about 370 physicists (including some 65 graduate students) from 36 institutions could now begin the new phase of commissioning the DØ detector, readying it for its first physics run. The commissioning of the detector with beam took place from May 1992 until August 1992.

The commissioning of the DØ detector went very well. The collaboration was able to demonstrate that the detector was well on the way to achieving the design goals that include the ability to make precision measurements of leptons (electrons and muons) and photons, quark and gluon jets, and to be sensitive to missing transverse energy that signals the presence of non-interacting particles such as neutrinos. The design emphasis on the precision measurement of these simple objects produced in hadronic collisions allows us to carry out the study of high-mass, large-transverse-momentum phenomena produced at the Fermilab collider. (Details of the DØ detector elements have been presented in earlier issues of *Fermilab Report*, and are not presented here.) The fruits of this



The DØ collaboration has 370 members of which 65 are graduate students.

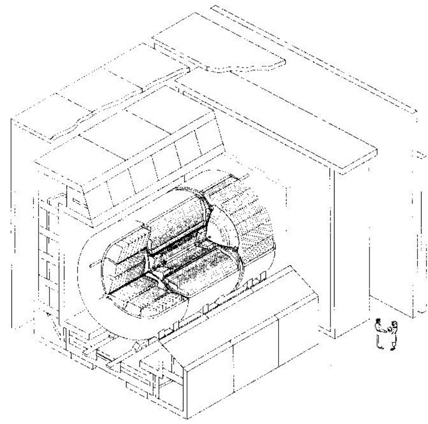


Figure 1: DØ detector.

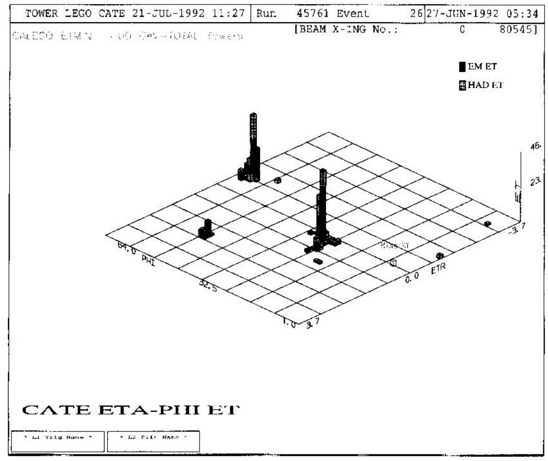


Figure 2: Lego plot of E_T of three jet event.

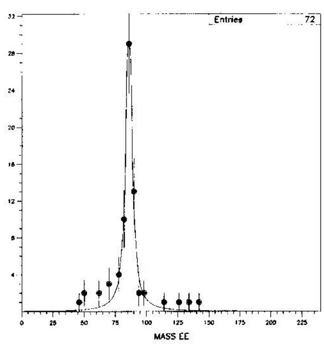


Figure 3: Z peak in di-electron invariant mass peak (preliminary).

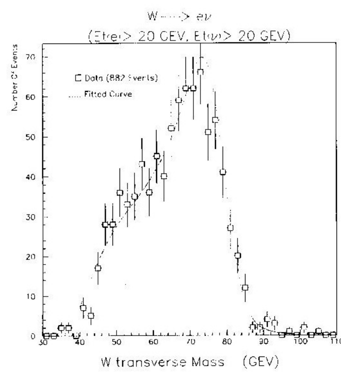


Figure 4: The W transverse mass (preliminary).

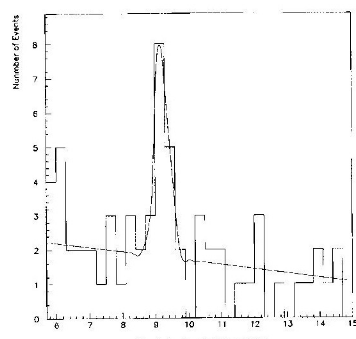


Figure 5: Upsilon signal observed in di-electron invariant mass (preliminary).

detector commissioning run were first presented at the International Conference on High Energy Physics in Dallas in August 1992, where the collaboration presented eight papers, including the first events seen in the detector. A typical three jet event can be seen in Figure 2.

With the start of the physics run in August 1992, the collaboration turned its attention to extracting the first physics results from the detector in time for the American Physical Society Division of Particles and Fields meeting held in November at Fermilab. A measure of the analysis activity was the large number of abstracts presented at the meeting (18 abstracts and one parallel session presentation) and the high quality of the results that were produced on a very short time scale. By the end of October 1992, DØ had accumulated data on tape from an integrated luminosity of 1.1 pb^{-1}, from which the results presented at the DPF meeting were obtained. The highlights of the results presented include preliminary results on electroweak physics, top physics, Quantum Chromodynamics, *B* physics and new particle searches.

The *W* and the *Z* have been observed in DØ in both the electron and the muon decay channels. A clean Z→*ee* peak is observed in the data, as can be seen in Figure 3 of the di-electron invariant mass distribution from 72 events for electrons with transverse energy greater than 20 GeV. The energy scale calibration is under study, but the peak position at 86 GeV is consistent with the present energy scale calibration from the test beam. The *W* boson production and decay into *e*ν can be seen in the plot of the number of events versus the transverse mass constructed from the measured electron and the neutrino inferred from the missing transverse momentum in the event. The sharp edge in the distribution from 882 events at about 80 GeV is the evidence that *W*s are being produced with a mass of about 80 GeV (Figure 4). The exact mass determination must wait for a better understanding of the energy scale.

The top quark has proved to be rather elusive; however the strengths of the DØ detector will provide a powerful tool with which to search for it. One expects the top to decay solely to a *W* boson and a *b* quark, and if so, one will need to be sensitive to leptons, jets and missing transverse energy, or combinations of them. The collaboration has already begun to search for the top in the di-electron, electron+muon and the electron+jets channels. No events are seen in any of these channels for the first 1.1 pb^{-1} and rather stringent requirements, where one would expect to observe 0.9, 0.6 and 2.6 events for a top quark with a mass of 80 GeV.

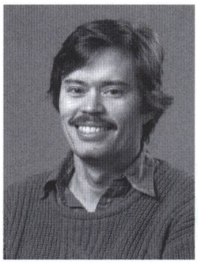
The full coverage of the detector, and the ability to trigger on jets at small angles (up to $|\eta|=3.2$) makes it well suited to the study of jets. DØ already has preliminary results (within energy scale uncertainties) on the inclusive jet cross section. In addition, the fine segmentation and good energy resolution of the detector have allowed a good measurement of the direct photon cross section to be made, and thus offer a unique probe of the gluon content of hadrons. The jet multiplicity distribution in *W*+jet events offers the opportunity to both test QCD predictions and ultimately measure the strong coupling constant α_s.

The large muon coverage as well as DØ's compactness and thickness offer the potential of studying *B* physics. Measurements of the p_T spectrum for inclusive single muon production have been made, as well as dimuon production with jets, where the ratio of same sign to opposite sign events is consistent with previous measurements of *B* mixing. The *b* system can also be accessed via the electron channel, where a clear $\Upsilon \rightarrow ee$ signal can be seen in the invariant di-electron mass distribution shown in Figure 5.

Part of the emphasis on high-quality measurements of leptons, photons, jets and missing transverse energy is that those are the measurements that will point the way to new physics. Thus DØ has searched for signs of new particles. The collaboration has looked for supersymmetric particles (squarks and gluinos) using a small sample of the collected data (140 nb^{-1}). Unfortunately, no candidate events were found from which one can clearly rule out a squark and gluino with masses both equal to 100 GeV/c^2, for which one would have expected to see 6.9±2.2 events. Similar null results are obtained for a scalar leptoquark search from data obtained from a 0.8 pb^{-1} sample, which if it were to always decay into an electron and a quark would lead to a lower mass limit of 74 GeV/c^2 at the 95% CL.

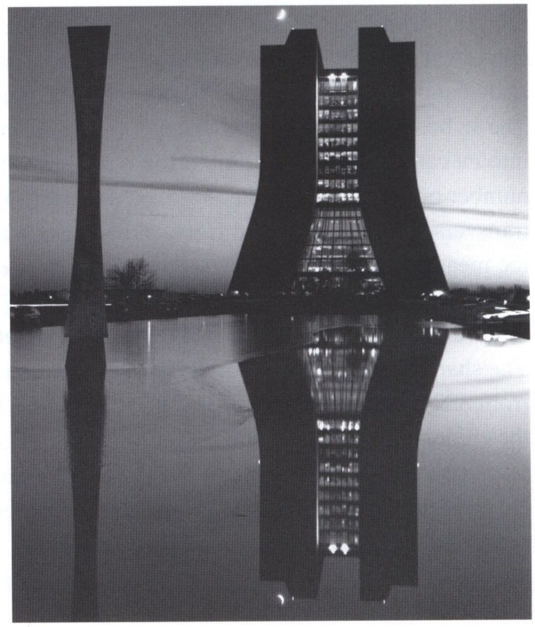
As 1993 begins, the DØ collaboration finds itself in the middle of its exciting first physics run having already accumulated five times the data sample it used to extract the first physics results for the DPF meeting. The collaboration anticipates that 25pb^{-1} will have been delivered by the time this run ends in the spring, and that it will be in the position to make the first of many significant contributions in the 1990s. ■

The contributor



Mike Tuts is co-coordinator of the DØ upgrade and has been involved in DØ calorimeter electronics since the start of the experiment. He has a Ph.D. in physics from SUNY at Stony Brook and is currently an associate professor at Columbia University. Tuts has also worked on Fermilab Experiment 321 pp inelastic scattering at C0, $\mu \rightarrow e\gamma$ search at Nevis Cyclotron and Υ spectroscopy with the CUSB experiment at the Cornell Electron Storage Ring.

The architecture at Fermilab is deeply rooted in aesthetics and function.



Physics in Beauty: An Architectural Vision

by Jean L. Kidd

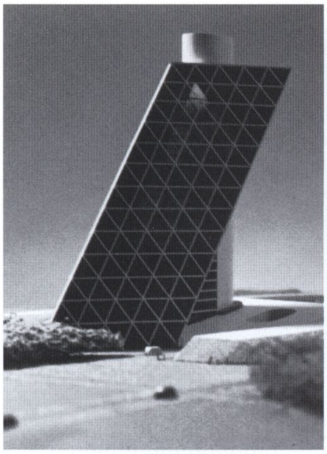
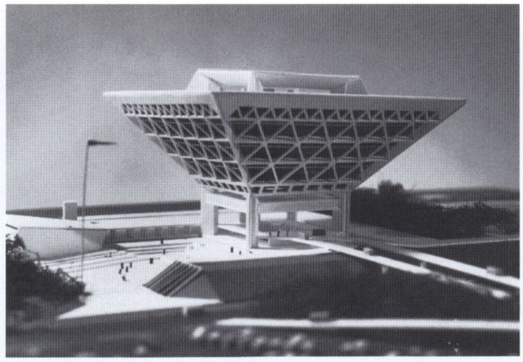
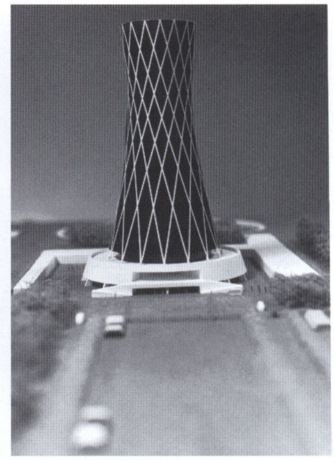
Since its inception, Fermilab has been not only a scientific endeavor, but also an architectural endeavor. From the beginning, the architecture of the Laboratory was greatly influenced by the visions of Robert R. Wilson, Fermilab's first director and artist and sculptor of renown. Wilson wanted to create a laboratory that was both scientifically sound and aesthetically pleasing. He felt a research laboratory should be an attractive cultural center in the community and the nation. To that end, he saw that each building and structure on site, no matter how small or how large, was architecturally valuable.

Robert R. Wilson Hall

The central laboratory building, which now bears Wilson's name, was dedicated in May 1974. Wilson worked closely with the consortium of architectural and engineering firms hired to help design the Laboratory. The consortium of Daniel, Urbahn, Seeleye and Fuller accepted a challenge from Wilson to create a building with the ambiance of the Ford Foundation Building in New York City, which has a large, plant-filled atrium. The challenge was to design a similar building, but one that was much less expensive. The designs that members of the consortium presented included a leaning building with triangular cross sections inspired after the Leaning Tower of Pisa, a building in the shape of a Prell shampoo bottle and an inverted pyramid-shaped structure.

The eventual winner was a building designed by George Adams. Adams' design captured Wilson's interest in cathedrals and his desire to have an atrium in the new central laboratory building. However, the principal design work for the central laboratory building was not done by Adams, but rather by Allen Ryder of the DUSAF consortium.

Wilson's interest in cathedrals began several years earlier while on a visit to France in 1954. While there, he became intrigued by Chartres Cathedral outside of Paris. Wilson said that it was the cathedral's striking height (as viewed in the context of when it was built) that caught his attention and influenced his desire to replicate its effect in the Laboratory's central building. Ultimately however, it was

Models of proposed designs for the Central Laboratory Building. The Leaning Tower of Pisa was the inspiration for the building on the left, while the clean lines of a Prell shampoo bottle influenced the design on the right. The inverted pyramid design of the middle proposal was submitted by Max Urbahn and Associates.

not Chartres but Beauvais Cathedral with its twin towers and crossovers connecting the towers that had a closer resemblance to Wilson Hall.

Fixed-target experimental areas

In overseeing the design of the Laboratory, Wilson worked with the goal in mind of creating buildings that were economical in construction, but with unique architectural significance. The three structures that identify each fixed-target experimental area typify that objective.

The Meson Laboratory Building is one of the most easily recognizable buildings on site with its large scalloped roof. It was constructed of inverted half-sections of steel culvert which created the scalloped effect. The culvert sections, which are approximately the same size as the concrete sections forming the tunnel of the Tevatron, are painted blue on one side and orange on the other.

This use of bold colors is a theme throughout the Laboratory and can be seen on many utility buildings and other structures on site. Wilson said that he and Angela Gonzalez, Fermilab's artist, wanted the metal utility buildings on site to make an architectural statement as a whole on the basis of color.[1]

One of the more unique buildings constructed at the Laboratory is the Neutrino Assembly Building. The top of the building, a modified geodesic dome, was constructed of a series of 10-foot triangles. Each triangle is a "sandwich" of two triangular pieces of colored reinforced fiberglass stacked over aluminum beverage cans. Over 120,000 cans were donated by the public for use in the dome. Originally, the building resembled a dome of stained glass and honeycombs. Today, copper sheathing covers the outside of the triangles.

The third fixed-target area, the Proton Area, is identified by the Proton Pagoda. One of many interesting structures on site, the pagoda sits upon legs 26-feet tall. A spiral staircase in the shape of the double helix strand of the DNA molecule leads from the ground to the second level.

Landmarks

Wandering the site, it is easy to understand what Wilson meant when he said he "hoped that the chain of accelerators, the experiments and the utilities would all be strongly but simply expressed as objects of intrinsic beauty."[2]

Evidence of this effort can be seen everywhere at the Laboratory and even in things not often thought of as beautiful, such as a pumping station and a series of high-voltage power lines.

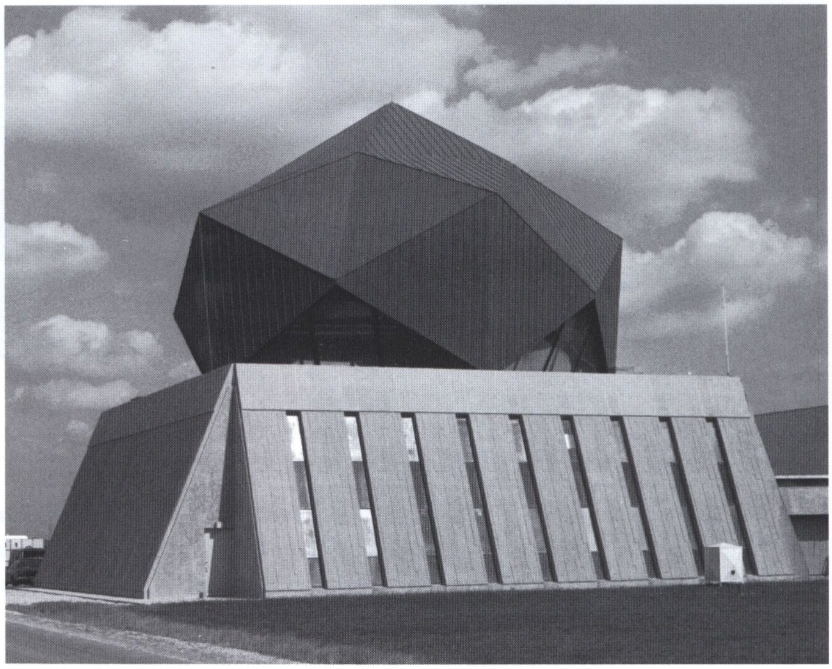
At Casey's Pond, for example, the walls of the pumping station were shaped like a concrete Archimedes Spiral to add to its appearance. The power lines that run through part of the site, in addition, were designed with more than just support as a criterion. Wilson said he felt the power poles that were originally designed by the engineers were not very attractive, so he submitted his own design.[3]

The result was a distinctive series of high voltage lines which resemble the Greek letter pi (Π).

Wilson's pursuit for a beautiful and structurally sound laboratory did not stop with the buildings on site, but extended to the surrounding landscape as well. When deciding on where to locate Pine Street, for instance, Wilson did not plot the road the conventional way using a land survey, but chose rather to walk through the woods, marking the path of the new road. "I didn't want to chop any trees down," Wilson said. "I went out and walked through the woods and essentially put down stakes so that we didn't have to cut down any of the big old oaks. We cut down some little ones. ...my road was a very curvaceous road. It was impossible to travel it fast. I guess I was imposing a value of mine on everybody who was going to come down that road thereafter. They were going to have to take it slow and enjoy the woods."[4]

Wilson wanted people to enjoy the Laboratory and have it be an attractive cultural center for the community and for the employees. With that as an objective, Wilson designed and built several sculptures on site that are now as much a part of the Laboratory as the Tevatron. *Broken Symmetry* is one of Wilson's largest sculptures he designed. Built by the Machine Shop, it stands at the Pine Street entrance. Straddling the road, the three-span arch appears symmetric when viewed directly from below, but has carefully calculated asymmetry from its other views.

Tractricious, conceived by Wilson and designed and constructed by members of the Technical Support Section, is an example of Wilson's use of economy. The structure, which sits in front of the Industrial Complex, is comprised of 16 stainless steel tubes made from scrap cryostat tubes from Tevatron magnets and 16 inner pipes from old well casings. Although each tube is free standing, the sculpture is designed to withstand winds up to 80 m.p.h.



The modified geodesic dome atop the Neutrino Laboratory.

Other sculptures at the Laboratory designed by Wilson include the *Topological II (Mobius Strip)* and *Hyperbolic Obelisk*. The *Mobius Strip* is mounted on the roof of Ramsey Auditorium. It is built of 3" x 5" pieces of stainless steel which Wilson welded on a tubular form eight feet in diameter. *Hyperbolic Obelisk* stands at the foot of the reflecting pond in front of Wilson Hall. It is 32 feet high, fabricated of three stainless steel plates each 1/4" thick. Each plate is made up of 23 smaller plates which were edge-welded by Wilson.

The newest structures

The newest structures to be built on site include the Feynman Computing Center, dedicated in December 1988 and the Leon Lederman Science Education Center, dedicated in September 1992. Ed Crumpley of the Facilities Engineering Services Section was the primary architect of the Feynman Center. The Science Education Center was largely designed by Crumpley along with Wayne Nestander of Facilities Engineering. These buildings, just like the many built before them, were designed with two criteria in mind: economy and significance. For example, the Science Education Center, Wilson said, has a completely different architectural style than other buildings at Fermilab, with its Prairie-style architecture. Wilson said that although the

Southern view of the recently completed Leon Lederman Science Education Center.

architecture of the Center "just grew," the building design was kept as "economical as possible"[5] through the efforts of Crumply and Nestander.

The Feynman Computing Center is yet another display of significant architecture. The three-story semi-circular structure is similar to Ramsey Auditorium with its circular design, vertical lines and concrete forms. The 74,000 square foot building houses the Laboratory's central computing facilities.

The architecture at Fermilab is deeply rooted in aesthetics and function. As Wilson once said, "It seem(s) to me that the conditions of (Fermilab) being a beautiful laboratory were the same conditions as its being a successful laboratory."[6] Wilson and countless others worked hard to create this "utopia on the prairie," as Raymond Sokolov of the *Wall Street Journal* called Fermilab, and rightly deserve such praise.

Perhaps Fermilab's architecture can be summed up by what V.F. Weisskopf said at the 1979 International Symposium in Honor of Wilson. "Just look around here...to see what Bob has created: Beauty in physics and physics in beauty."[7]

References

[1]Personal interview with Robert R. Wilson, July 1992.

[2]*1987 Annual Report of the Fermi National Accelerator Laboratory*, p. 178.

[3]"An Interview with Robert Wilson," by Linda Dackman, *Arts & Architecture*, vol. 3, no. 1, 1984, p. 75.

[4]*Arts & Architecture,* p. 75.

[5]Personal interview with Robert R. Wilson, July 1992.

[6]*Arts & Architecture*, p. 75.

[7]*Aesthetics and Science*, Proceedings of the International Symposium in Honor of Robert R. Wilson, April 27, 1979, p.99.

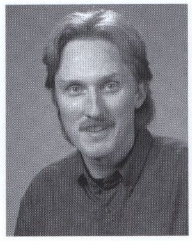
The contributor

Jean L. Kidd is an editor in the Fermilab Publications Office. She has a B.A. in history from Millikin University and a masters degree in journalism from Roosevelt University. Prior to joining the Publications Office, Kidd worked in the Fermilab Business Services Section and the Facilities Engineering Section.

Photo page 28: Wilson Hall at nightfall. Wilson's Hyperbolic Obelisk rises from the reflecting pond.

Lab notes

Scientific appointments



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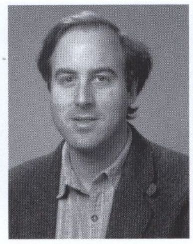
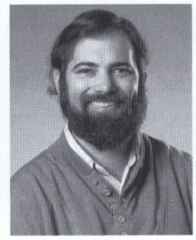
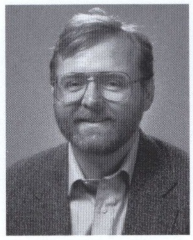


J. Frieman



A. Hahn

S. Kent



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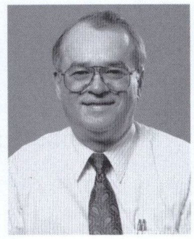
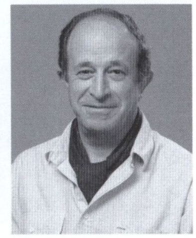


J. Venard

R. Carrigan



C. Hojvat

At its recent meeting, the Fermilab Board of Overseers approved promotions from associate scientist to scientist I for Michael Crisler, Joshua Frieman, Alan Hahn, Stephen Kent and Michael Lamm. These promotions followed recommendations from Director John Peoples and the Fermilab Committee on Scientific Appointments.

Mike Crisler is a member of the Projects Group in the Research Division's Research Facilities Department where he worked on the conceptual designs for the KAMI (Kaons at the Main Injector) project and for the KTeV (Kaons at the Tevatron) project. He recently accepted the position of technical manager of the KTeV project. Crisler joined the Laboratory in November 1983 as a research associate in the Physics Section. He worked on the E711 experiment, a study of large invariant mass hadron pair production. In 1986, Crisler received a Robert R. Wilson fellowship. As a Wilson Fellow, he served as spokesperson for E774, a search for short-lived neutral particles produced in an electron beam dump, which completed data taking in 1990.

Josh Frieman joined the Laboratory in October 1988. He is a member of the Research Division's Theoretical Astrophysics Group. According to John Peoples, this promotion recognizes Frieman's "important contribution to the new field of particle cosmology."

Alan Hahn is the head of the Accelerator Division Instrumentation Department and the current collider run coordinator. He joined the Laboratory in March 1989. He has recently been involved in beam diagnostics activities that included the construction of a synchrotron light telescope. Hahn was commended by the director for his contributions to the E670 charmonium formation experiment and the flying wire system and the synchrotron radiation monitor.

Stephen Kent is in the Experimental Astrophysics Group in the Computing Division. He joined the Laboratory in September 1991. Since that time his major activity has been working on the Sloan Digital Sky Survey, a collaborative project between Fermilab, the University of Chicago, Princeton University, the Institute for Advanced Study and the Johns Hopkins University. As part of this project he is working with the the Computing Division Online Support Group to build a CCD camera known as the Drift Scan Camera. It will be used on a 3.5 meter telescope at Apache Point Observatory.

Mike Lamm joined Fermilab in 1983 as a Physics Department postdoctoral research associate. He worked with a team of physicists and technical staff to develop and construct a large area drift chamber for the CCFR neutrino detector in Lab E. Lamm participated in the running and analysis of E744 and E770 that used the CCFR detector to study neutrino charged current interactions. In 1987 he joined the Technical Support Section as an associate scientist. For the last four years, he has been the director of the Advanced Magnet R&D Test Facility (Lab 2), where quadrupole magnets for the Fermilab low-beta insertion and one-meter model dipoles for the SSC have been evaluated. He is a member of the E815 collaboration. E815 is an experiment designed to make precision measurements of neutrino neutral current interactions. Lamm also serves as the coordinator of the SDC test-beam operations at the Laboratory. ■

Appointments

John Venard named head of ORTA

Director John Peoples appointed John Venard head of the Office of Research and Technology Applications (ORTA) and coordinator for the Fermilab Industrial Affiliates.

Venard is replacing Richard Carrigan Jr., who left his post in October for a one-year assignment to the High Energy Physics Division of Energy Research at the Department of Energy in Washington, D.C.

Carrigan led the technology transfer effort at Fermilab for nearly ten years. During his tenure, he established the Office of Research and Technology Applications, created an intellectual property licensing office and set up the Fermilab Applications Assessment system, a technology appraisal system. That system now has information on more than 680 Fermilab technologies. Carrigan was responsible for adapting Leon Lederman's concept of an Industrial Affiliates organization to the Fermilab environment. The Fermilab Industrial Affiliates is now one of the oldest and healthiest technology transfer efforts within DOE and often a model for other laboratories.

Prior to his role in ORTA, Carrigan served as the director of Personnel Services and assistant head of the Research Division. He was also actively involved in the Fermilab research program.

As the new head of ORTA, John Venard will assume Carrigan's duties as the Laboratory's patent officer and of facilitating the transfer of technology developed at Fermilab out to wider use.

Venard had been licensing officer for ORTA since November 1988. In that position, he was responsible for various technology-transfer activities, including the licensing out of patented or copyrighted innovations. Before coming to the Laboratory, Venard served as the technology utilization representative and as head of the Technology Transfer Office at Argonne National Laboratory. Prior to his position with Argonne, Venard was a research metallurgist at Oak Ridge National Laboratory.

Venard holds an M.S. degree from the University of Tennessee in metallurgical engineering and an M.B.A. from the University of Chicago.

Carlos Hojvat appointed to Directorate

Deputy Director Ken Stanfield recently appointed Carlos Hojvat to the position of program planning assistant. The appointment is for an initial period of two years and became effective October 1, 1992. Within the Directorate, Hojvat will be a member of the Program Planning Group with the responsibility for assisting in the preparation of experiment planning documents including Memoranda of Understanding and working closely with experiment spokespersons to make sure they clearly understand the Laboratory's requirements for each document. He will also facilitate negotiations and discussions between the Directorate and the divisions, sections and spokespersons to reach final approval by the director of experiment planning documents.

In his new position, Hojvat will continue to assist Taiji Yamanouchi in coordinating and scheduling test beam activities as he has done previously as a member of the Research Division. "Planning for the use of Fermilab test beams will continue to play a very important role in view of upcoming demands from SSC detectors as well as CDF and DØ," said Ken Stanfield.

Dr. Hojvat has a Ph.D. in experimental nuclear physics from the University of British Columbia, Canada. From 1969-1972, while associated with the University of London, Hojvat collaborated on two experiments at CERN involving the antiproton-proton production of pion and kaon pairs. Later, as a member of a McGill University experimental group, he worked on E177, one of the first experiments in the Proton West Area at Fermilab. In 1977, Hojvat joined the Fermilab staff as a member of the Accelerator Division. Since joining the Laboratory, Hojvat has served as project leader for the conversion of the Booster accelerator. During the construction of the Tevatron, he was involved in understanding the instability of the orientation of the Tevatron Superconducting dipole's magnetic field under thermal cycling. He then joined the Antiproton Source Group and was responsible for the production of antiprotons. During the Tevatron I Project, he served as head of the Antiproton Production Group. Shortly before the successful commissioning of the Antiproton Source, Hojvat left for the Physics Department where he worked on E735, a quark-gluon plasma search. In 1989 Hojvat joined the Research Division. Along with his new duties within the Directorate, Hojvat is presently associate head of the Research Facilities Department and is responsible for the Technical Support Group. He also serves as the Fermilab coordinator of test beams.

Tom Groves to head Conduct of Operations Office

Deputy Director Ken Stanfield named Tom Groves to serve as the Fermilab Conduct of Operations Officer for a period of two years beginning October 1, 1992. Groves will remain a member of the Accelerator Division and carry out his new duties as a half-time assignment. In this role, he will help the Directorate organize the Laboratory's Conduct of Operations program. Working with the deputy director, Groves will develop laboratory policy that when implemented will establish an appropriate level of formality in Conduct of Operations documents and procedures. He will also assist in managing tasks related to conduct of operations in the Corrective Action Plan for the Department of Energy Tiger Team Assessment, other external assessments and self-assessment. As COO officer, Groves will work with the deputy director to initiate, organize and conduct as an ongoing activity a thorough review of operational hazards, working environment, functional activities and ES&H performance goals. He will also draft responses to DOE on matters related to conduct of operations.

Groves has a Ph.D. in particle physics from the University of Wisconsin. Prior to joining the Fermilab staff, he served as an assistant professor at both Purdue University and the University of Notre Dame. From 1968 until 1974, Groves was on staff at Argonne National Laboratory in the High Energy Physics Division. In 1974, Groves came to Fermilab to serve as the Laboratory's assistant director. He has also served as secretary of the Physics Advisory Committee and head of the Program Planning Office. Groves is currently a physicist in the Accelerator Controls Group.

Keith Ellis named head of the Theoretical Physics Department

Director John Peoples appointed Keith Ellis head of the Theoretical Physics Department. Ellis replaces William Bardeen who is leaving the Laboratory to head the newly forming Theoretical Physics Department at the SSC Laboratory. Bardeen served as head of the Fermilab Theory Department for five years. "Bill has been a superb head of the theory group here and it will certainly be a challenge to do the job as well as he has done," said Ellis.

A native of Aberdeen, Scotland, Ellis joined the Laboratory in 1984. He has a Ph.D. in physics from the University of Oxford. Prior to joining the Fermilab staff, Ellis served on the research staff at Instituto di Fisica in Italy and as a research fellow at CERN, CALTECH, MIT and Imperial College, London.

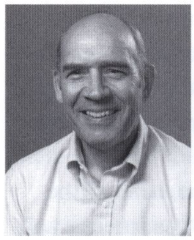
Chris Quigg, a member of the department who served as its head from 1977 until 1987, is excited about Ellis's recent appointment. "I am quite delighted that Keith has agreed to do this. He is a first-rate scientist and one of the most important people in the world for the study of the strong interactions—really the acknowledged expert. He is a person with very high standards and a lot of energy. He will have new ideas and a new vision that will really be very good for us."

The theory program has existed at Fermilab since the beginning of the Laboratory and became a permanent part of the Laboratory in the early 1970s. Ben Lee, a Stony Brook theorist served as the first head of the Fermilab Theory Department. According to Quigg, Lee set out to build a strong theoretical physics department—not just one that concentrated on day-to-day, routine types of problems, but one from which ideas would come. "Since Fermilab was to be the most important Laboratory in the U.S. in particle physics, it was our goal to have a theoretical physics department that was matched to that," said Quigg.

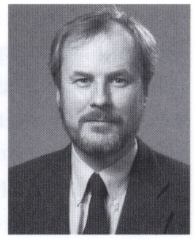
From its inception, the Theory Department has served as one of the centers of the intellectual life at the Laboratory. A very early contribution made by the department to the scientific community was the introduction of the wine and cheese seminars in the fall of 1972. This Joint Theoretical Experimental Seminar, designed for the informal exchange of ideas, has now grown from a small gathering of around 20 people to an "almost national" seminar that often bursts the confines of Curia II.

Over the years, theorists have helped steer the agenda of the high-energy physics program by looking ahead and making suggestions for future measurements or machines. One such example was a now famous paper, written by Estia Eichten, Fermilab; I. Hinchliffe, Lawrence Berkley Laboratory; K. Lane, Boston University; and Chris Quigg, Fermilab, that formed the scientific case for the SSC. "By no means does this mean that all the important developments have begun at Fermilab, but certainly a fair share of the most influential work has been done here," said Quigg.

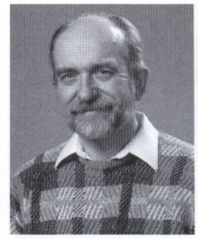
As the head of a department with a distinguished past, Ellis is very optimistic about the future at Fermilab and the challenges ahead. "We are very excited that the top quark may be discovered here within the next few years. We had many people in our group who worked very actively on estimating backgrounds for the top."



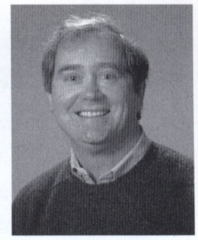
T. Groves



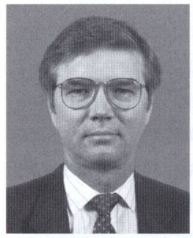
K. Ellis



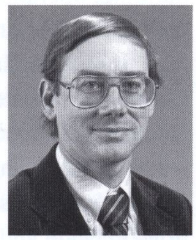
R. Stefanski



C. Quigg



K. Stanfield



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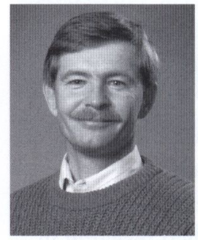


J. Cumalat

M. Shapiro

Ray Stefanski joins Directorate

Director John Peoples appointed Ray Stefanski as a Fermilab assistant director. Stefanski's appointment became effective January 1, 1993 and marks his return to the Laboratory following two years of work at the SSC Laboratory. Stefanski's duties as an assistant director will be to provide assistance to Dennis Theriot, associate director for technology.

In his new position, Stefanski will be involved in managing the Quality Assurance Office, until a head of the QA Office is selected, and developing and managing a maintenance plan in accordance with DOE Order 4330.4A. Stefanski will also be overseeing the Facilities Engineering Section. Under Theriot's direction, Stefanski will be responsible for the maintenance of Fermilab Technical Site Information documents and the management of DOE correspondence on QA, Maintenance and Real Property. He will also provide Directrorate oversight of Research Divison construction projects and serve as secretary of ESHPAC.

Before returning to the Laboratory as a member of the Directorate in June 1992, Stefanski served as department head for Detector Engineering Resources at the SSC Laboratory from August 1991 to May 1992. From January 1990 to July 1991, he was the SSC's department head for Experimental Facilities Support.

Stefanski began his Fermilab career in August 1969 as a member of the Experimental Areas Department. There he carried out beam optics calculations for several types of beams, ultimately concentrating on neutrino beams. During the 1970s, Stefanski was a member of the Neutrino Area serving as leader of the Beams Group, group leader of the Electrical Support Group and associate department head for operations. In 1981 he became head of the Neutrino Area, which he served until June 1982 when he was appointed head of the Construction and Planning Group in the Experimental Areas Department. From 1983 to 1986, Stefanski held the position of deputy project manager for Tevatron II. In this position, he contributed to several phases of the Tevatron II project, including design, coordination and budget management. In 1986 he became associate head for construction in the Research Division and also served as head of the Research Facilities Department in the Resarch Division.

Stefanski received a Ph.D. in Physics from Yale University in 1968 and an M.B.A. from Keller Graduate School of Management in Chicago in 1983.

Besides his duties as an assistant director, Stefanski is also a member of E853, which is a study of crystal extraction techniques at the Tevatron. ■

Chris Quigg elected to AAAS Fellowship

The American Association for the Advancement of Science recently announced the election of Chris Quigg, member of the Fermilab Theoretical Physics Department, to the rank of Fellow. The only AAAS members eligible to attain this rank are those whose efforts on behalf of the advancement of science or its applications are scientifically or socially distinguished.

Quigg was elected to fellowship "for distinguished research in high-energy physics and theory of the fundamental interactions of the elementary particles." He will be honored at the next AAAS annual meeting to be held in Boston on February 14, 1993. At this meeting, each newly-elected Fellow will be presented with an official certificate and rosette pin.

Founded in 1848, AAAS is the world's largest general science organization and has more than 134,000 members worldwide. The Association publishes the weekly journal *Science* and the electronic journal *Current Clinical Trials.* ■

APS Fellows named

The American Physical Society announced the election of Ken Stanfield, Robert Kephart, John Cumalat, Marjorie Shapiro and James Prentice to the rank of fellow. Election to fellowship is limited to no more than one half of one percent of the membership in each APS division. They are all members of the Division of Particles and Fields.

Ken Stanfield, Deputy Director of Fermilab, was elected to fellowship "for contributions to the success of the U.S. High-Energy Physics Program as an experimental physicist and as a leader and manager of the Fermilab research program for 15 years."

Robert Kephart, head of the Collider Detector Department, was selected "for his leading role in the building, operation and physics of the CDF Detector."

John Cumalat, University of Colorado at Boulder, E687, was elected "for contributions to the study of the production and decay of charmed particles and for innovations in beam and detector design."

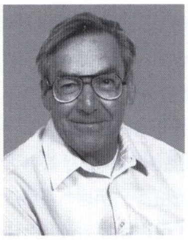
Marjorie Shapiro, Lawrence Berkeley Laboratory, CDF, was cited "for contributions to the study of high transverse momentum phenomena in proton-antiproton collisions."

James Prentice, University of Toronto, Canada, SDC, obtained this honor "for experimental studies of the spectroscopy of hadrons."

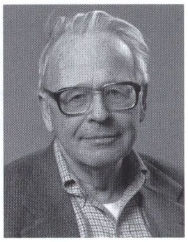
They will be honored at the next APS Division of Particles and Fields business meeting to be held in Washington, D.C. in April 1993. At this meeting, each newly-elected fellow will be presented with a fellowship certificate. Their election to fellow will also be noted in the March 1993 *APS News.*

Three Fermilab pioneers were elected to the rank of fellow in the American Physical Society Physics of Beams Division. Frank Cole, Don Edwards and Jim Griffin will be honored at the Physics of Beams Meeting to be held in May 1993 in Washington D.C.

Frank Cole, who joined the Laboratory in 1967 was elected "for contributions to accelerator theory in areas including nonlinear dynamics and space-charge phenomena, and



F. Cole



D. Edwards

D. Jovanovic

A. Lennox

for contributions to the design of accelerators for use in particle physics and in medicine."

Don Edwards who came to Fermilab in 1969 was cited "for his many contributions to accelerator science, and the key role he played on the design and commissioning of the Tevatron."

Jim Griffin was honored "for conception and development of numerous techniques for manipulation of particles in longitudinal phase space leading to successful operations of the Fermilab Proton-Antiproton Colliding Beam Program." Griffin joined the Laboratory staff in 1969.

Cole and Griffin are now retired from the Laboratory. Edwards left Fermilab in 1988 to work at the SSC Laboratory. He returned to Fermilab in 1992. ■

DPB elects executive committee

The election for the American Physical Society Division of Physics of Beam Executive Committee was held November 6.

Thirty-eight percent of the membership cast votes in the election. Offices up for election this year were vice-chair, secretary-treasurer and members-at-large. Each office is for a three-year term. Elected were Robert Siemann, vice-chair, Melvin Month, secretary-treasurer and Stephen Holmes and Robert Pollock members-at-large.

With the election completed, the members of the 1993 DPB Executive Committee will be: Helen Edwards, chairperson; John Rees, chair-elect; Robert Siemann, vice-chair; John Peoples, divisional councillor; Melvin Month, secretary-treasurer; Hermann Grunder, past chair and William Herrmannsfeldt, Paul Reardon, Gerald Dugan, Christroph Leemann, Stephen Holmes and Robert Pollock, members-at-large. ■

Jovanovic and Lennox named to APS Forum

Drasko Jovanovic has been elected chairperson of the American Physical Society's Forum of Education. Jovanovic was elected to the post in October and will officially assume his role when the forum begins its operations in January 1993.

Arlene Lennox was elected to the forum as an American Physical Society-American Association of Physics Teachers member-at-large. She will serve a two-year term on the Executive Committee to help ensure coordination between forum and AAPT activities.

The forum is a newly formed subcommittee of the American Physical Society, a 45,000 member society dedicated to the advancement of science. The forum, Jovanovic said, is a 2,500 member group "that reads like a who's who in education, who are all doing their best to help educate children in physics."

The forum was created to provide a mechanism for all interested APS members to become involved with education. One important goal of the forum is engaging more professional research physicists to collaborate in educational efforts with high school teachers in their area. As chair of the forum, Jovanovic will organize sessions that address these issues. ■

DPF meeting draws capacity crowd

More than 1000 physicists gathered at Fermilab for the 7th Meeting of the American Physical Society's Division of Particles and Fields. According to Co-chairpersons Rajendran Raja and John Yoh, the five-day conference is a forum for international physicists to share results from high-energy physics research.

This conference outdrew its previous versions by almost a factor of two in attendance and by more than a factor of two in contributed papers. This far exceeded the expectations of the organizing committee. Despite the record crowds, the level of organization was such that the Laboratory was able to cope with all contingencies and things flowed smoothly from start to finish.

The main topic of interest was the search for the top quark. In the opening sessions, the latest results from CDF, DØ, HERA and LEP were presented as well as talks on

J. Yoh and R. Raja

astrophysics, accelerators and detector development. Late Tuesday morning conference attendees flocked to Ramsey Auditorium to hear a presentation by Nobel Prize Laureate Sam Ting, a talk that was rumored to contain some startling results. Ting met with an enthusiastic response when he concluded his presentation by stating that "Fermilab will discover the top" and asked for continued support for the Tevatron.

On the evening of November 10, conference organizers presented a panel discussion and town meeting designed to address the challenges and issues facing high-energy physics as it looks to the future. For the meeting William Happer, Director of the Office of Energy Research at the Department of Energy, joined laboratory directors John Peoples, Burton Richter (SLAC), Roy Schwitters (SSCL) and director designate Bjorn Wiik (DESY) and physicists Melvyn Shochett (University of Chicago) and Michael Witherell (University of California, Santa Barbara) to discuss the future of international collaboration in building the next generation of accelerators, the evolution of large collaborations and the current economic climate. DPF Chairperson Gary Feldman moderated the meeting.

The panelists agreed that international collaboration will have to be the wave of the future. "I don't think any nation can go it alone, cowboy style," said John Peoples.

In light of the current budget problems being experienced by Fermilab and other laboratories, William Happer did not see a quick fix. "Cuts are being made across the board, not just in Energy Research. We are all going to have to work harder to sell basic research, unless it has an obvious connection to profit," Happer said.

Reacting to Happer's comments on funding, Roy Schwitters stressed the importance of communication. "We have to get involved, tell people what we do." He also said we must continue to "do really good and exciting science so we are not accused of being a WPA project for physicists."

Following the plenary sessions and the town meeting, there were three days of parallel sessions held at the Pheasant Run Resort Center. "The meetings are intended to give up-and-coming physicists an opportunity to present their results, consequently there are a large number of parallel sessions," said Rajendra Raja. "We had to run eight sessions a day plus one on the opening day to satisfy the abstract demands," said Raja. More than 600 abstracts were submitted to the conference by physicists from 20 countries, according to John Yoh. There were 475 parallel session talks in all.

The final day of the meeting was a plenary session at Fermilab that contained talks summarizing the parallel sessions on QCD, electroweak physics, charm, bottom and tau physics as well as theoretical physics. Director Emeritus Leon Lederman concluded the conference. In his closing remarks, he stressed the importance of elevating the general public's perception of science and scientists. "Pessimism is running rampant in Washington," said Lederman. His answer to this problem is to educate those who elect our officials. According to Lederman, it will take a "grass roots effort" on the part of the scientific societies to accomplish this goal.

The American Physical Society is the leading society of physicists in the United States, with major influence internationally. The Society is a not-for-profit scientific organization founded in 1899. Its purpose is the advancement and diffusion of the knowledge of physics. The Society accomplishes its purpose principally through the publication of scientific journals and the organization and management of meetings for the exchange of scientific ideas and results. Within the Society are Divisions serving research specialities. The Division of Particles and Fields is one of these. The DPF meetings began in Santa Fe. They are held every 18 months. The last two meetings were held at Rice University in Texas and in Vancouver, Canada. Fermilab was selected for this year's meeting after submitting a proposal to the Executive Committee of the DPF in Dallas, Texas in late January 1992. ■

B physics workshop held at Fermilab

The concluding session of a series of workshops dedicated to *B* physics was held at Fermilab November 16 and 17. Following immediately after the DPF meeting, the workshop drew over 90 participants.

"This particular workshop benefited tremendously from the initial experience of DØ and the ongoing experiments at CDF because it is the only place anyone is currently doing *B* physics in a hadron collider," said Jeff Appel, chairperson of the workshop's local organizing committee.

The study of *b* quark production and decay, an important field of research now in its infancy, will likely grow through the 1990s and beyond. As a major goal, this research will test whether the three generations of quarks lead to a unitary Cabibbo-Kobayshi-Maskawa matrix. The measurement of the production cross section of *b* quarks will provide additional insights into perturbative quantum chromodynamics, and the observation of a large number of *B* decays could provide additional tests of the standard electroweak-weak interaction.

The *B* physics program at Fermilab builds on the experience gained in detecting charm particles. Charm physics has proved a particularly fruitful area of research at Fermilab; initially experimenters made precise measurements of charm particle lifetimes, and, in the near future, the results will lead to a detailed picture of the hadronic form factor that governs the semi-leptonic decays. Perturbative QCD predicts the production of heavy quarks, and the agreement for charm is very encouraging, considering the relatively light mass of the charm quark. Physicists expect to find these calculations for *B* meson production much more reliable. The first measurements from both a fixed-target experiment, E653, and CDF at the collider, suggest a cross section slightly higher than present theoretical expectations.

Both fixed-target and collider experiments have very large cross sections compared to e^+-e^- production. The challenge of isolating the *b* decays from the much larger background presents the main problem encountered in hadron experiments. The results so far have relied on identifying *b* decays inclusively, through measurement of high P_t leptons, or exclusively, either in J/ψ decay modes (CDF) or by identifying the *b* decay vertices for modes involving charm mesons (E653). CDF and DØ in the collider, and E789 and E771 in the fixed-target program, as well as the proposed P829, will push to higher luminosities and will further develop the use of vertex detectors to extend the sample size and the precision of the measurements.

Observation of B_s mixing and CP violation will require very large data sets. Achieving the high data rates and background rejection of such experiments will require an extensive R&D effort in detectors and data-acquisition systems, and in off-line handling techniques.

The November workshop was the fourth in a preliminary series that focused on using hadron detectors to study the physics of the *b* quark and was jointly sponsored by Fermilab and the SSC Laboratory. All four sessions were preparatory to a two week conference which will be held June 21-July 2, 1993 in Snowmass, Colorado. The expected outcome of the conference will be a better understanding of the best avenues for pursuing the study of CP violation in the bottom quark system. "It is part of the future that we are still defining," said Appel.

Several Fermilab employees and users served on the workshop's local organizing committee. The committee included Alvin Tollestrup, Ron Lipton, Dan Green, John Butler, Tom Diehl, Bruce Hoeneisen, Ken Johns, Paul Tipton, Jeff Spalding, Fritz DeJongh, John Skarha, Mike Gold, Ping Hu, Shekhar Mishra, Simon Kwan, Isi Dunietz and Cynthia Sazama. ■

Education Center formally opens doors

A dedication ceremony held September 25 formally opened the doors of the Fermilab Science Education Center to the public. Named in honor of Fermilab's second director, Leon M. Lederman, the 8,200 square foot building houses the staff and facilities for Fermilab's education programs that yearly attract thousands of teachers and students from around the country.

Secretary of Energy James D. Watkins and his wife traveled to the Laboratory to take part in the opening ceremony along with Director John Peoples, Leon Lederman and Marjorie Bardeen, program manager of the Fermilab Education Office. Admiral Watkins noted that the Leon M. Lederman Science Education Center exemplifies the department's commitment to use vast scientific resources to improve math and science education in the nation.

R. Wilson, S. Jovanovic, J. Peoples, L. Lederman, J. Watkins and M. Bardeen participated in the dedication of the Lederman Science Education Center.

Important elements of the new center are a science laboratory that accommodates 60 students and a computer and technology classroom for 24 students. In addition, an array of interactive teaching stations, environmental field stations and audio-visual materials invite exploration and experimentation. The interactive displays focus on four areas particularly appropriate to the research conducted at Fermilab: accelerators, detectors, scattering experiments and powers of ten, which presents the very large and the very small in nature.

The Fermilab Education Office currently offers a variety of institutes and workshops for teachers and research appointments for students and teachers from all over the United States. Local teachers bring their students to the Center for a variety of stimulating and innovative classes, for field experiences in the reconstructed prairie and for creative investigations in physics. The Teacher Resource Center, a clearing-house for ideas, materials and resources, provides an educational hub that enriches the teaching of mathematics and science in the surrounding community.

The Lederman Center is open to the public Monday through Friday between 8:30 a.m. and 5 p.m.

Fermilab's education initiatives are one element of DOE's nationwide strategy for improving mathematics and science education in America. In May 1990, Admiral Watkins issued a Secretarial Notice that vastly expanded the department's education mission. In 1991, more than one million students, teachers and parents participated in over 800 DOE-funded education programs. ■

Japanese university is newest URA member

Waseda University in Japan was recently elected as a member institution in the Universities Research Association, Inc. Waseda was formally accepted at URA's annual meeting of the council of presidents on January 28, 1993 in Washington, D.C.

According to URA's vice president Ezra Heitowit, Waseda's acceptance is a "milestone" for URA and marks the first time a university outside of North America has been accepted into membership.

Waseda is a private Japanese university with a strong high-energy physics program, Heitowit said. Several of its staff and students have participated in electron and proton emulsion experiments at Fermilab, including E340, E423 and E499.

Heitowit added that Waseda's inclusion in URA may foster future Japanese collaboration with the U.S. and with Fermilab and the SSC.

Fermilab and the SSC Laboratory are operated by URA. URA is a consortium of 80 universities and institutions. ■

URA executes license agreement with Loma Linda

On September 23, Universities Research Association executed a nonexclusive patent site agreement with the Loma Linda University Medical Center. The agreement will allow LLUMC to use the technology from a high-voltage DC power supply, a patented invention created by Fermilab employee Tom Droege.

LLUMC will have the right to have made and use at their place of business power supplies that are similar to those created by Droege and currently supplied to DØ by Benchmark Electronics, a Texas-based firm.

The power supply is used to provide a selectable, precise current and voltage to drift chambers. Drift chambers are used for detecting and tracking particles during colliding beams or fixed-target interactions. Several hundred power supplies are needed for the drift chambers in the collider detectors at CDF and DØ. Because drift chambers are usually located in inaccessible areas, a great improvement over an earlier design allows the power supplies to be remotely monitored and controlled by a computer. Each power supply is very compact, about the size of a 35mm camera, so it can be closely mounted, eight across, onto a common-size printed circuit board. The board with eight units attached is packaged as a module that plugs into a standard electronics crate of the type extensively used at Fermilab.

John Venard of the Office of Research and Technology Applications, said this is a significant technology transfer. "We feel it may prove to be the key to getting this technology into the marketplace," Venard said. "The license also represents the most recent chapter in the ongoing relationship between Fermilab and LLUMC during which the first proton accelerator built specifically for medical applications was designed and commissioned."

Fermilab's contribution to the proton accelerator began in 1986 when a small group of physicists, led by Phil Livdahl and Frank Cole, began designing and developing the proton accelerator that would be used at LLUMC for radiation therapy in the treatment of cancer. The accelerator was completed in 1989 and after much testing and operational checkout late in that year, the accelerator was shipped to LLUMC.

The accelerator, a synchrotron, is approximately 20 feet in diameter and provides proton beams up to 250 MeV of energy. It is housed at the Loma Linda Medical Center in a new facility specially designed and built to house the accelerator and the clinical facilities required for the treatment of patients. In the treatment rooms, gantries bring the proton beam to the disease site from any desired angle.

The original proposal for a proton accelerator was made by Fermilab's first director Robert R. Wilson. He pointed out in 1946 that protons have significant advantage in localizing the radiation dose to the disease site, sparing healthy tissue and reducing side effects. Since this original proposal, proton therapy has been carried out in Sweden, Switzerland, Japan and Russia with good results.

Although synchrotrons have been used to accelerate particles and provide protons for cancer therapy, there had never been an accelerator built specifically for this application. The effort to design and build this proton therapy accelerator marked the first time that any group had worked to provide feasible, economical solutions to the many problems of this new application. The design, construction, commissioning and now the routine use of the Loma Linda proton-therapy accelerator has provided mankind with a significant new weapon in the battle against cancer. "It is also an example of very successful collaboration involving a government-funded laboratory, a hospital and private industry, in which a large amount of technology transfer has been achieved," said Venard. ■

Fermilab honors inventors

The Laboratory honored the achievements of 23 Fermilab inventors who received patent, copyright or license agreements in 1991 at a reception held September 3 in Wilson Hall.

During the ceremony, each innovator received a framed certificate in recognition of his valuable technology contribution at Fermilab. Honored at the reception were:

Venkata Areti, Robert Atac, Joe Biel, Mark Fischler, Irwin Gaines, Robert Hance, Don Husby and Tom Nash for their work on Interprocessor Bus Switching System for Simultaneous Communication in Plural Bus Parallel Processing that resulted in the issuance of a patent. This system facilitates high-speed parallel processing in several configurations and allows calculations much faster, more conveniently and much less expensively than previously possible.

David Anderson was honored for his patent on Divalent Flouride Doped Cerium Flouride Scintillator. According to Anderson, the use of cerium floride shows considerable promise for improvements in medical imaging devices. Its use as the scintillator in a positron emission tomography camera will greatly enhance the ability to image the living heart and thus better predict and prevent heart disease. Its principal application will be for medical imaging and the study if metabolic processes.

Honored for his invention of Planar Slot Coupled Microwave Hybrid was Jeff Petter. He received his patent in December 1991. This invention can be used to design a whole new class of higher-performance broadband microwave hybrids, such as Magic Tees, 180 Hybrids and Wilkinson-type power splitters.

Ralph Niemann, John Gonczy, Tom Nichol, Finley Markley and Bill McCaw were honored for the patent they received for their invention, Cryogenic Support Member, and for their patent application for Apparatus for Measuring Tensile and Compressive Properties of Solid materials at Cryogenic Temperatures. The Cryogenic Support Member is a joint that serves in cryogenic load-bearing applications, and is good in tension, compression, flexure and torsion. The technique can be applied to a wide range of tube diameters and across a broad range of service temperatures. Such a support system could be used for low-heat leak cryostats for over-the-road-transports, MRI cryostats, medical accelerators that utilize superconducting magnets and similar applications.

The Apparatus for Measuring Tensile and Compressive Properties of Solid Materials at Cryogenic Temperatures is a system for the study of material properties at cryogenic temperatures. Its features include: material samples in operating (cryogenic) environment, controlled application of compressive and/or tensile loads, measurement of forces and displacement and low-heat input to cryogenic environment.

George Hockney, Paul McKenzie and Mark Fischler were recognized for their receipt of a copyright for the creation of CANOPY software. This software is written for the ACPMAPS multi-array processor and is highly portable and available to run on Ultrix vaxes, Sun workstations, IBMPCs and ACP farms of AT&T 32100 nodes. CANOPY is framework which facilitates the development and coding of a certain set of algorithms. The types of problems helped by CANOPY are those which can be thought of as existing on a collection of "sites" on a grid. For these problems, the software framework provides an easy-to-use and hardware-independent way of eliminating the complexities of paralleling tasks and communicating between sites.

Also honored at the ceremony were Charles Briegel and Kevin Cahill. They were recognized for the copyright they received on FIRUS-88 software. This software is a new embodiment of FIRUS, Fermilab's fire, utility, security and power-consumption monitoring system. FIRUS-88 runs from an IBM-AT console and uses a commercial database to provide an intuitive windowing user interface that enables simultaneous alarm reporting, device monitoring, plotting, parameter pages and data logging via a variety of displays.

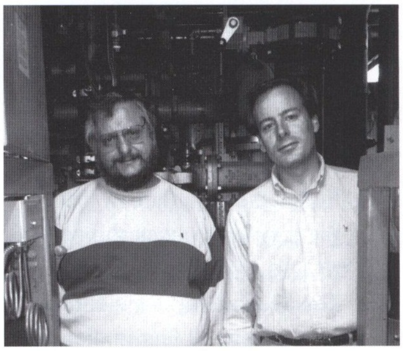
Mark Fischler was also honored for his copyright on the Second Generation ACP MIPS Multiprocessor User's Manual and Joe Biel, Mark Edel, Mike Isley and Mariano Miranda were honored for the copyright for the Second Generation ACP MIPS Multiprocessor Software. This software was developed to support Second Generation ACP MIPS system hardware and is based on the MIPS very high-speed board-oriented micro processor. The software complements the improved performance and flexibility of the hardware while reducing programming complexity for the user.

Honored for his copyright of IBM 3812 Printer Utility Software was Mike Lazarski. This software is a set of programs which provides an on-line, menu driven facility to print line-printer type documents on the IBM 3812-series laser printer and is culmination of an effort to simplify the usage of these printers. It is designed to allow non-technical end users a simple method of producing high-quality output using these advance function printers. In addition, it has been written to allow its inclusion into existing systems by a site's programming staff to provide a standard method of access to these printers. ■

Energy retrofit increases CDF chiller efficiency

Field testing of a recent energy retrofit to three chillers at CDF has indicated significant energy reduction, and may lead to further energy savings in the future for the Laboratory.

Working with Johnson Controls and HY-Save Corp., Steve Krstulovich, Al Schmitt and Venkat Kumar of FESS/Engineering & Planning modified the refrigeration cycle of the chillers at CDF. This retrofit caused the power consumption of the chillers to be cut dramatically at optimal conditions during the field tests.



Steve Krstulovich (l) and Al Schmitt review the operation of the CDF chillers.

The retrofit included the installation of a liquid pressure amplification pump (LPA) and liquid injection superheat suppression line (LI). The installation of these two devices into the chillers now allows the chiller head pressure to decrease and the condenser to transfer heat more efficiently. It also lessens the wear and tear on the chiller compressors. The combined effect of the two devices means increased efficiency and capacity in the chillers and an overall reduction in energy consumption.

The increased capacity of the chillers is particularly important as new refrigerants with zero ozone depletion potential, such as R134a, are introduced. While R134a is more environmentally safe then chlorofluorocarbons (CFCs), it is not as efficient. However, if the new technology being applied at Fermilab can also be applied to systems using R134a, the lost capacity and efficiency can be made up by the LPA and LI systems.

CDF was an ideal application for this technology due to its year-long steady electrical load. Because of the successful field tests, FESS/ Engineering & Planning and HY-Save are planning further installations on site where this technology could be more widely investigated. At this time, coordination is being sought with other divisions and sections to setup and run tests using this technology. The intent is to test the application of the LPA and LI systems at different locations, on different equipment configurations, and for a variety of operating conditions, said Krstulovich. At each location, one unit will be retrofitted with the LPA and LI system and a second unit will be monitored along with the retrofitted unit to provide a control. To account for cyclical weather conditions, the monitoring will be done for a full year. This will allow the development of guidelines for correct and verifiable energy-saving application of the technology, and possibly, improvements to the system itself.

As a Department of Energy site, Fermilab is committed to DOE guidelines to foster emerging energy technologies and to using energy efficiently and economically, promoting ways to meet the requirements of the Fermilab In-House Energy Management Plan, Krstulovich added. To do this, Fermilab and HY-Save are investigating a Cooperative Research & Development Agreement or CRADA. The CRADA would allow Fermilab and HY-Save to define and address various issues pertaining to the application of this technology and to monitor the success of the technology on various sizes and types of installations on site. The test guidelines would be prepared in conjunction with recommendations from the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).

This technology and its application may have a useful role in enhancing non-ozone depleting technologies, said Krstulovich. "If we can recover both capacity and efficiency, I think nationally and globally, we are really doing a service." ■

Dates to remember

- March 2, 1993 Deadline for the receipt of reservations for summer on-site housing. Housing assignments will be made in April and responses should be mailed by April 15, 1993. The starting date for summer occupancy is June 1, 1993. For further information, contact the Housing Office at 708-840-3777, E-mail: FNAL::HOUSING or FAX 708-840-2823

- March 22, 1993 Deadline for receipt of materials to be considered at the April PAC meeting

- April 23-25, 1993 Physics Advisory Committee Meeting

- May 19, 1993 Deadline for receipt of materials to be considered at the June PAC meeting

- May 27-28, 1993 13th Annual Fermilab Industrial Affiliates Meeting and Industry Briefing. For further information contact John Venard, Fermilab Office of Research and Technology Application (ORTA), P.O. Box 500, MS 200, Batavia, Illinois 60510-0500, 708-840-3333 or E-mail: VENARD@FNAL

- June 11, 1993 Fermilab Users Annual Meeting, for information contact Joy Miletic, Users Office, 708-840-3111 or E-mail: USERSOFFICE@FNAL

- June 19-25, 1993 Physics Advisory Committee Meeting

- June 21-July 2, 1993 Summer Workshop on B Physics at Hadron Accelerators, Snowmass, Colorado, for further information contact Connie Gorman, SSC, E-mail: BPHYSICS@SSCVX1

- June 21-July 2, 1993 US Particle Accelerator School at Harvard University, Cambridge, MA. Application deadline is March 31, 1993. For applications and information, contact the USPAS Office at Fermilab, MS 125, P.O. Box 500, Batavia, IL 60510-0500, FAX 708-840-8500 or E-mail USPAS@FNAL

- July 25-August 1993 Summer School on QCD Analysis and Phenomenology, organized by the CTEQ Collaboration (Coordinated Theoretical/ Experimental Project on Quantitative QCD Phenomenology and Tests of the Standard Model), Lake Monroe, Indiana, Jorge Morfin, Fermilab, Chairman. Contact Cynthia M. Sazama, Fermilab, MS 122, P.O. Box 500, Batavia, IL 60510 or
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Back Cover photograph: (l to r) Members of the Computing Division Experimental Astrophysics Group Chris Stoughton, Jonathan Loveday, Rich Kron, Tim McKay, Heidi Newberg and Steve Kent with the cryogenic housing for the drift scan camera.

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