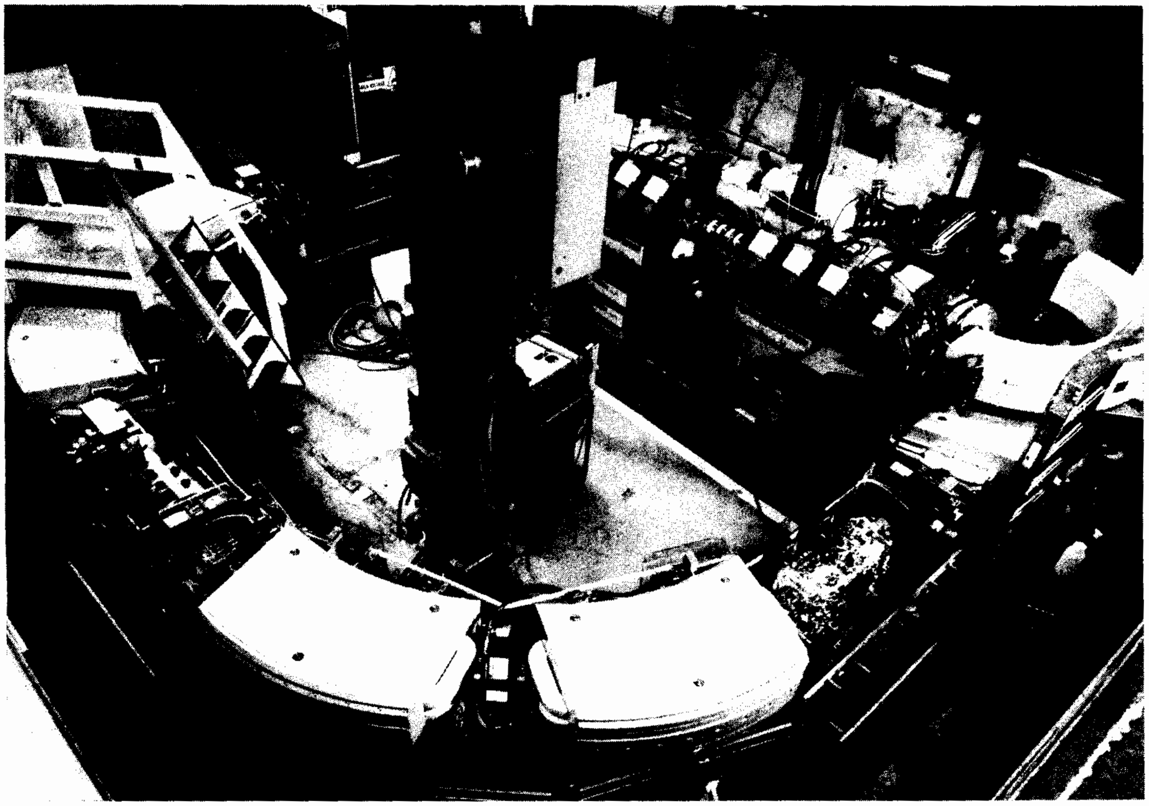
fermilab report

Fermi National Accelerator Laboratory Monthly Report

November/
December
1988



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88/11 **Fermi National Accelerator Laboratory**

On the cover: *The Loma Linda proton therapy accelerator, designed and built at Fermilab for Loma Linda University Medical Center, Loma Linda, California, achieved its first successful operation in January 1989 at Fermilab's Industrial Complex. Commissioning of the synchrotron is being accomplished by a group headed by Rich Orr and Jack McCarthy.*

This first operation is an important step in the agreement the Medical Center and Fermilab signed in 1986 to develop and build the accelerator. Under the agreement, the accelerator will be disassembled and moved to Loma Linda during the summer of 1989 - when clinical facilities for the first treatment of patients are ready.

This accelerator is the first synchrotron designed specifically for therapy. It is approximately 20 feet in diameter - the world's smallest proton synchrotron - and will deliver a variable energy of 70 to 250 MeV. The accelerator has several features, such as precise energy control and long beam spill, that are included to make therapy easier and more efficient.

The facility at Loma Linda will have four treatment rooms, three with gantries to bring the beam to the disease site from any desired angle and one specialized room for treatment of the head and neck. *(Fermilab photograph 89-5-4)*

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Accelerator Division Accomplishments in 1988

by John L. Crawford and David Finley

The year 1988 began with the Accelerator in the final phase of a fixed-target run which had commenced on June 15, 1987; before the run ended on February 15, the seventh and last TEVATRON dipole failure occurred on February 4. Despite the unfortunate spate of magnet failures, the run exceeded all expectations, with some 2.2 x 10^{18} protons delivered in nearly 2900 hours of operation. The peak extracted intensity for the run was 1.80 x 10^{13} ppp, not quite up to the 2.0 x 10^{13} we had hoped for, but the TEVATRON ran for extended periods at greater than 1.6 x 10^{13} ppp with excellent stability and reliability. Figures 1 and 2 summarize the 35-week fixed-target run.

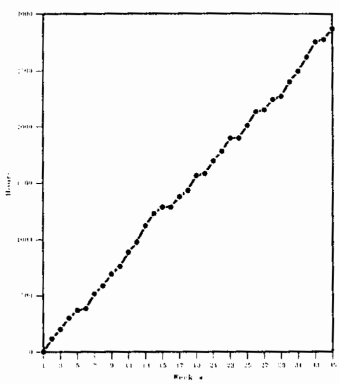


Fig. 1. *TEVATRON fixed-target operation, integrated HEP hours at 800 GeV*

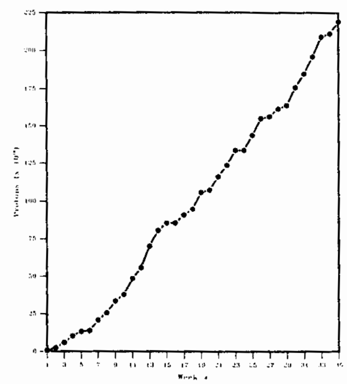


Fig. 2. *TEVATRON fixed-target operation, integrated intensity at 800 GeV*

Near the end of the fixed-target run, the Switchyard Beam Position Monitor system and associated application software was used as a position servo to maintain beam position through the Meson beamline. Once this system is made fully operational, it promises much improved position stability throughout the Switchyard.

On the Pbar Source front, an E-760 installation and study period was scheduled during which the gas jet target and detector were installed in the A50 pit;

This article is excerpted from the Fermilab 1988 Annual Report, *which will be available from the Fermilab Publications Office in April 1989.*

the jet was made operational and the detector saw $\bar{p}$-p collisions. Protons were decelerated in the Accumulator from 8900 MeV/c to 3500 MeV/c (through transition) via a γ t jump.

Following a two-week period of SSC-related studies, the Accelerator was shut down for three months of maintenance and development work. The Division's primary mission during this period was to inspect and repair as many TEVATRON dipoles as possible; inspection consisted of visually examining the magnet lead areas using a borescope and utilizing two industrial gamma-ray sources to take "x-ray" pictures of the magnet ends. The magnets were examined to see if the leads were properly tied down (to prevent flexing and strand breakage), if the G10 lead-clamping blocks were intact and were sufficiently far away from the end of the single-phase can, and whether the beam tube insulation was tied down. All magnets in A Sector, B1, and E1 were examined, with 138 out of 200 magnets undergoing some degree of repair. Seven magnets were found to have broken lead strands and so were replaced.

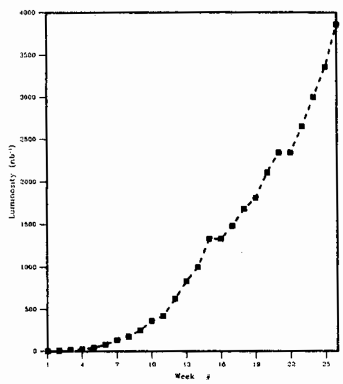


Fig. 3. TEVATRON Collider operation, integrated luminosity at 900 GeV.

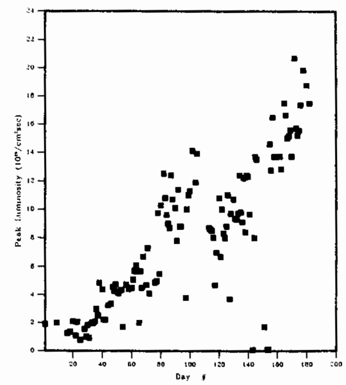


Fig. 4. TEVATRON Collider operation, peak luminosity/day.

A second major undertaking during these three months was the installation of a redesigned Main Ring overpass in the D0 interaction region. The original D0 overpass was installed in 1984 and was intended to be more of a "proof-of-concept" test bed than a permanent operational feature. A known shortcoming of the original design was an undesirable increase in the vertical dispersion function around the Main Ring and a dispersion mismatch between the Main Ring and the TEVATRON (leading to emittance growth in the TEVATRON). The new design lengthened the overpass by some 700 feet (although the height remained the same) and incorporated a near clone of the B0 "double dogleg" vertical bending system.

A 900-GeV ramp was established on May 26, 150-GeV circulating beam on May 27, and by May 29 the orbit was smoothed all the way to 900 GeV. Antiprotons were injected into the TEVATRON on June 6, and by June 12 we had our first 1.8-TeV 6 x 6 store with an initial luminosity of 4 x 10^{28} cm^{-2} sec^{-1}. (6 x 6 is shorthand for 6 proton bunches colliding with 6 antiproton bunches; all of the 1987 Collider run was 3 x 3.)

Collider operation was sporadic for the first four weeks, but by week six it had surpassed the integrated luminosity of the entire 1987 run. Since then the performance of the TEVATRON Collider has been nothing short of phenomenal - we reached 3 x 10^{29} cm^{-2} sec^{-1} (our "operational goal") on July 28, the design peak luminosity of 1.0 x 10^{30} cm^{-2} sec^{-1} was reached on September 7, an integrated luminosity of 1000 nb^{-1} (1 inverse picobarn) was delivered by September 24, 2000 nb^{-1} by November 5, and 3000 nb^{-1} by December 4. As this report goes to press, the integrated luminosity is nearing 4.0 pb^{-1}, the peak luminosity has exceeded 2.0 x10^{30}, and store duration is averaging 13.8 hours. Figure 3 shows the integrated luminosity through December 18, while Fig. 4 shows the progression of the peak initial luminosity. Figures 5 and 6 detail the weekly performance of the Collider.

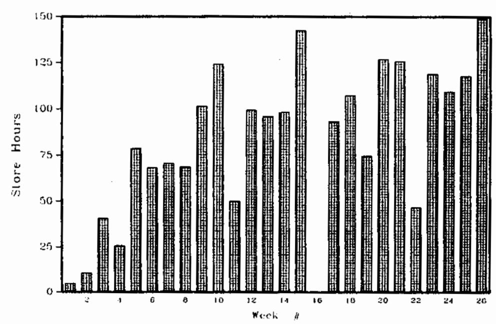


Fig. 5. TEVATRON Collider operation, integrated store hours/week.

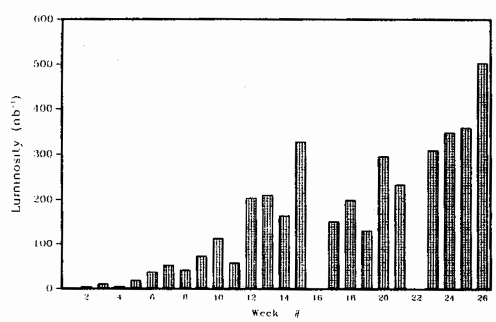


Fig. 6. TEVATRON Collider operation, integrated luminosity/week.

Meanwhile, the Pbar Source has not been resting on its laurels; its performance has also astounded accelerator aficionados. The peak stack achieved exceeds 81 x 10^{10} pbars, the number of pbars stacked in one week has reached 175.5 x10^{10}, the stacking rate per hour has been as high as 1.898 x 10^{10}, and as of this writing the Source has operated for 39 days without interruption. (As an aside, on November 9 a glitch on the commercial power grid caused the 81-milliamp pbar stack to be lost - some have suggested that this was the largest number of antiprotons annihilated in one fell swoop since the Big Bang.)

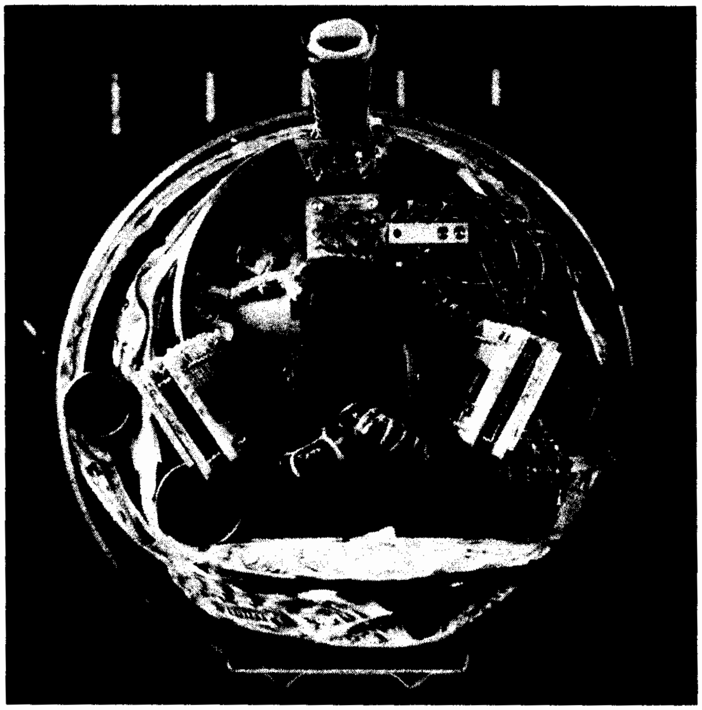
Why is the Collider performing so well? The present run is delivering integrated luminosity at a rate which is about 20 times greater than that delivered during the first Collider run. This spectacular difference is not (entirely) the result of luck. Indeed, by the time the first run ended in May 1987, the inter-meshing of improvements which were needed among all the accelerators had been clearly identified. During the intervening fixed-target run, the process of improvements for the second Collider run had already begun.

There are more antiprotons available this run. Main Ring and Accumulator improvements have resulted in a very much improved stacking rate. For instance, Main Ring intensity has averaged about 1.7 x 10^{12} ppp on stacking cycles, compared to 1.2 x 10^{12} last run; in the Pbar Source, the Accumulator aperture was increased to the design value and the horizontal dispersion in the low-dispersion straights was corrected, core cooling was improved due to the introduction of microwave mode dampers, and Debuncher betatron cooling times were reduced by the addition of optical notch filters. These improvements, coupled with improved TEVATRON reliability, have resulted in larger stacks. The larger stacks have made it profitable to extract bunches six times instead of only three times from the Accumulator. Once the bunches have been extracted, the improved Main Ring transmission and coalescing have resulted in higher intensity single bunches at 150 GeV. These improvements have resulted in an overall gain factor of about seven.

Getting the particles into a single high-intensity bunch in the Main Ring at 150 GeV is only part of what is required for large integrated luminosity. In the first run, one of the major problems was not being able to obtain sufficiently small beam sizes in the TEVATRON and, even if they had been small enough, not being able to keep them small during a store. The transverse emittances of the beams in the TEVATRON during the present run are half as large as in the last run. This is because the vertical dispersion match between the Main Ring and the TEVATRON was improved by the re-configuration of the D0 overpass, and because the compensation of the time-dependent higher order multipole fields in the TEVATRON magnets has been greatly improved. The abort kicker power supplies were identified as the primary source of the anomalous transverse emittance growth during the last run; modifications to these supplies have resulted in an improvement in the luminosity lifetime by a factor of 2 to 3. Once these kickers were fixed, the full advantage of the "100% mini-beta" squeeze could be implemented and this reduced the beam size at the Collider Detector at Fermilab (CDF) even further. Without these improvements, the present Collider run's integrated luminosity would be disturbingly smaller by another factor of three.

There have also been operational improvements which are necessarily invisible if they are successful. These invisible improvements are nonetheless very important to the integrated luminosity. One of these items is the policy of relentless pursuit of things which kill stores. The improved diagnostics, controls, and applications software needed to accomplish this for each killed store involves the continuing efforts of many individuals. Without question, it is their constant effort which keeps the Collider functioning as well as it does.

Can a similar improvement factor be expected for the next Collider run? The answer is a resounding "no" - not without an upgrade program. Even now, the stacking rate drops steadily as the stack size grows, so that without improvements in the Pbar Source, peak stacks will probably be limited to less than 100 mA. (The pbar transfer efficiency also decreases as the stack size grows.) Creating more intense bunches or a greater number of less intense bunches is foiled by an effect called "beam-beam interaction"; the cure for this is separated beams - but all this sounds like a subject for Michael Harrison's article on the TEVATRON upgrade in the *Fermilab 1988 Annual Report.*



(Fermilab photograph 88-102-6)

End view of a Superconducting Super Collider (SSC) dipole on a test stand at the Fermilab Technical Support Magnet Test Facility. Two TEVATRON test stands have now been converted to accommodate full-length SSC dipoles. The second stand has an improved design, allowing the magnets to be operated at superfluid helium temperatures (1.8 K).

Since June of 1986, a series of eight coil assemblies has been delivered to Fermilab from Brookhaven National Laboratory. In the interim, an increasing number of diagnostic instruments, including strain gauges, voltage taps, temperature sensors, and deflection gauges, has been added in order to better understand magnet quench behavior. Additionally, full-length tooling, based on the proven design used for the TEVATRON, is under construction. The new tooling consists of full-length curing and collaring presses and a full-length press for applying the yoke and helium-containment skin. This tooling will provide high-precision coil sizing and uniformity for better magnet performance and reliability.

Magnetic Moments of the Hyperons - A Short Experimental Review

by Joseph Lach

The advent of high-energy hyperon beams, the discovery that hyperons produced by the interaction of high-energy protons are polarized, and the realization that this polarization vector can be readily precessed to yield their magnetic moments, has allowed us to test quark models of the baryons to an astonishing level of sophistication. This has all happened in the last dozen years. Let me review where these measurements are now and what the future directions might be.

Overview

Figure 1 shows the baryon octet and decouplet. Intrinsic to each of these particles is an associated magnetic moment. Many of these particles have allowed strong decay modes, making their lifetimes so short that their magnetic moments will be widened similar to their mass broadening. Measurement of these magnetic moments are far beyond our present experimental reach.

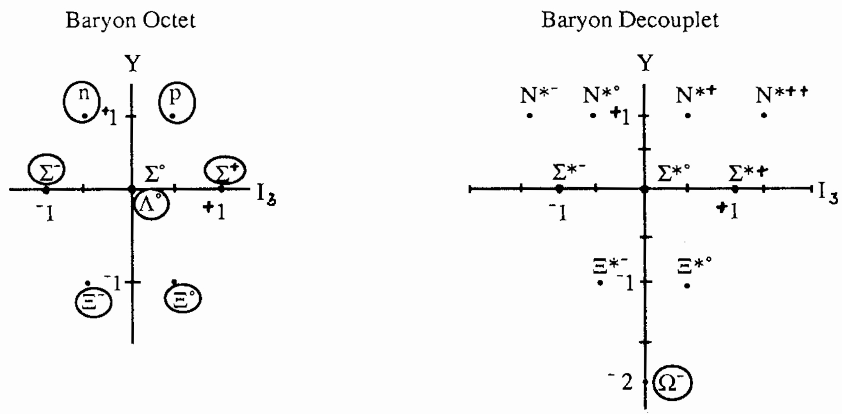


Fig. 1. The baryon octet and decouplet

The Σ^0 decay is electromagnetically dominated, resulting in a short (but still well defined) lifetime of 5 x 10^{-20} seconds. This magnetic moment is also well

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This article is based on an invited talk given by the author at the 8th International Symposium on High Energy Spin Physics, Minneapolis, Minnesota, September 12-17, 1988, and will appear in the proceedings of that symposium and as Fermilab preprint Conf-89/19.

beyond our reach. That is the discouraging news. The good news is that all of those baryon states forbidden to decay via the strong or electromagnetic forces have now had their magnetic moments measured. This includes a new measurement of the Ω^- moment, the first and probably only member of the decouplet that can be expected to have its magnetic moment measured in the foreseeable future. I have circled those that have been measured in Fig. 1. Except for refinements, we have gone about as far as we can with the ground state baryons containing only u, d, and s quarks. However, the states which include heavier quarks are untouched and many have lifetimes that, at least in principle, make them accessible to measurement.

The electromagnetic decay, $\Sigma^0 \rightarrow \Lambda^0 \gamma$, is a magnetic dipole transition and has associated with it a transition magnetic moment. This transition moment is described by the same formalism as the static magnetic moments and amenable to the same quark model predictions. It has been measured by the Primakoff method. The Primakoff technique can also be used to investigate electromagnetic transitions involving excited baryon states, thus gaining insight into their quark structure. The measurement of the transition rate $\Sigma^+ (1385) \rightarrow \Sigma^+\gamma$ is of particular interest since it is forbidden in SU_3 but allowed in SU_6. With present-day hyperon beams, a measurement of this rate is feasible and was proposed as part of an abandoned Fermilab proposal, P-734.

Measurement Techniques

Most hyperons produced at $P_t \approx 1$ GeV/c by high-energy unpolarized protons have polarizations of 10-25%. This has become the standard mechanism to produce polarized hyperons whose polarization directions have then been rotated by a magnetic field. The direction of the polarization vector is determined through the parity violating asymmetries of the subsequent weak decay. The sensitivity of this measurement is limited by the product αP of the intrinsic weak decay asymmetry α and the hyperon polarization P. If either of these parameters is small, the more challenging becomes the measurement. As they approach zero, the measurement becomes impossible.

The only other method that has been used to measure hyperon magnetic moments is through the formation of an "exotic" atom containing a negative hyperon captured near rest by a nucleus. X-rays from the exotic atom transitions are detected with high-resolution solid-state detectors, and from the hyperfine splitting, the hyperon magnetic moment can be inferred. So far this technique has only been applied to the measurement of the Σ^- magnetic moment. Complications occur because the captures are usually done in heavy elements, there are significant atomic physics corrections, and one is not able to resolve all the transition lines.

New Results

The first attempt to measure the Ω^- magnetic moment using 400-GeV incident protons found a value of P = 0.12±0.08. Taking this at face value led to a Ω^- magnetic moment of -2.1±1.0 μ_N. A recent further analysis of the same data led the experimenters to conclude that the polarization was not sufficiently different from zero to place a significant constraint on the Ω^- magnetic moment.

A new measurement of the Ω^- magnetic moment was presented at this meeting by the Fermilab E-756 group. This group attempted to measure the Ω^- polarization and magnetic moment as was done by Luk et al. (but with 800-GeV incident protons), and found, with higher statistics, that the polarization was consistent with zero. However, they were able to modify the apparatus to first produce a neutral beam containing polarized Λ^0 and Ξ^0 and then targeted them to produce Ω^-. They were able to determine that the produced Ω^- had significant polarization. This spin transfer technique has allowed them to obtain a measurement of the Ω^- magnetic moment of -2.0±0.2 μ_N. This value is preliminary and does not contain systematic errors. This was an important demonstration of the strength of the spin transfer technique. Further measurements of spin transfer using a variety of projectiles and targets over various kinematic regions should be extremely useful to probe the mechanisms of the spin process.

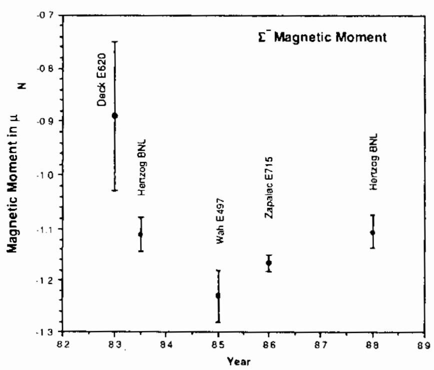

Fig. 2. Σ^- *magnetic moment*

Figure 2 shows the recent history of measurements of the Σ^- magnetic moment. I have tabulated the magnetic moment values starting with the initial operation of the Fermilab hyperon beams and apologize to the authors of earlier works, but the data is really dominated by results from the start of this period. Since the last spin conference the only new result is from the group working at Brookhaven National Laboratory using the exotic atom technique. Note that in Fig. 2, two values are given. The later value comes from the same data sample but from a more mature analysis and differs only slightly from the earlier version. The other points on Fig. 2 come from three Fermilab hyperon-beam experiments. The one with the highest precision represents a combination of measurements at two momenta and two final states ($\Sigma^- \rightarrow n\pi^-$ and $\Sigma^- \rightarrow ne^-\nu$). The final value from the exotic atom measurement differs from it by 1.7σ, the agreement being reasonable. The weighted mean of these measurements yields a Σ^- magnetic moment of -1.156±0.014 μ_N. No new measurements are under way or planned to improve on this number.

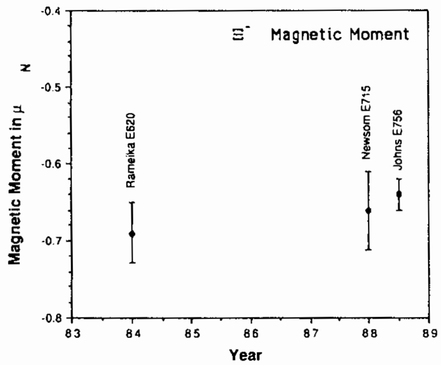

Fig. 3. *Ξ^- magnetic moment*

Two new measurements of the Ξ^- magnetic moment have been presented at this meeting. Their measured values are -0.661±0.036 μ_N and -0.64±0.01 μ_N and they are from Fermilab experiments 715 and 756 respectively. Both are preliminary and the stated errors are statistical only. They are both plotted on Fig. 3 with their errors increased to include a systematic error estimated to be the same as the statistical error. They are both in excellent agreement with the earlier dominant hyperon-beam measurement. The E-715 measurement represents the complete data sample from that experiment. However, the E-756 result is only part of a considerably larger sample and this is the experiment which is expected to eventually provide the most precise measurement. The weighted mean of these three measurements is -0.651±0.017 μ_N for the Ξ^- magnetic moment.

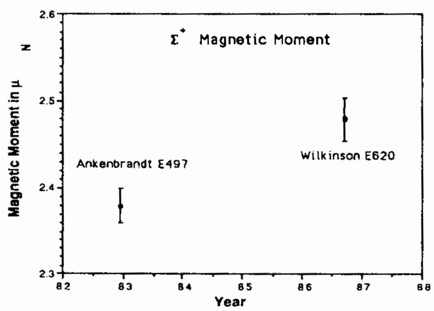

Fig. 4. *Σ^+ magnetic moment*

Old Result, Old Problem

The satisfactory status of the Σ^- and Ξ^- measurements is contrasted with the unsatisfactory state of the two most precise Σ^+ measurements. They are from Fermilab experiments 497 and 620 respectively and are shown in Fig. 4. These two nominally 1% measurements differ by 3.1σ, indicating one or both of them probably has errors larger than the stated ones. This is a well known problem and it has been handled by increasing the error so that the mean is 2.419±0.022 μ_N. Although this discrepancy is not crucial for the confrontation of existing models, it may be important in the future. Certainly it is a loose end which should be tidied up.

Summary

There are no new results on neutral hyperon magnetic moments or on the $\Sigma^0 \rightarrow \Lambda^0\gamma$ decay since the last review in this conference series. Table 1 summarizes the current status of the baryon magnetic moments. Also tabulated are the customary predictions from the simple quark model where we assume as input the p, n, and Λ^0 moments. The sign of the $\Sigma^0 \rightarrow \Lambda^0$ transition moment is taken from the quark model. The Ω^- moment is taken as three times the Λ^0 moment.

The quark model predictions reproduce all the signs correctly. In magnitude the worst disagreement is about 0.25 μ_N. This agreement makes you feel you are on the right track. However, this is far from the complete story as a glance at the column showing the deviations in σ, or the % difference, will attest. The Ξ^-, with a ≈30% deviation, is striking. The quality of the hyperon magnetic moment measurements has steadily improved and they will continue to be an important constraint on model builders.

Table 1

Baryon	Magnetic Moment μ_N	Quark Model μ_N	Difference μ_N	σ	% Dif
p	2.7928444 ± 0.0000011	input			
n	-1.91304308 ± 0.00000054	input			
Λ^0	-0.613 ± 0.004	input			
Σ^+	2.419 ± 0.022	2.67	-0.251 ± 0.022	11.41	-9.40
Σ^-	-1.156 ± 0.014	-1.09	-0.066 ± 0.014	4.71	6.06
$\Sigma^0 \rightarrow \Lambda^0$	-1.61 ± 0.08	-1.63	0.02 ± 0.08	0.25	-1.23
Ξ^0	-1.253 ± 0.014	-1.43	0.177 ± 0.014	12.64	-12.38
Ξ^-	-0.651 ± 0.017	-0.49	-0.161 ± 0.017	9.47	32.86
Ω^-	-2.0 ± 0.2	-1.84	-0.16 ± 0.20	0.80	8.70

Figure 5 is a plot of the differences. Here the error on the Λ^0 moment is plotted to illustrate the precision of the Λ^0 compared to the others. The larger errors on the $\Sigma^0 \rightarrow \Lambda^0$ transition moment and Ω^- moment distinguish them from the rest.

Future Prospects

In the near future, before the next spin conference, we should expect to see final results from E-756 on the Ω^- moment and from E-715 on the Ξ^- moment, although they are not expected to change in any major way from the results presented at this meeting. The completion of the E-756 Ξ^- moment analysis using their full data sample should make that a definitive measurement.

In the more distant future, we might expect to see new data on the Σ^+ magnetic moment from Fermilab E-761. This experiment will measure hyperon radiative decays ($\Sigma^+ \rightarrow p\gamma$ and $\Xi^- \rightarrow \Sigma^-\gamma$) in the next Fermilab fixed-target running period. They also expect to collect a large sample of $\Sigma^+ \rightarrow p\pi^0$ decays from which they will be able to extract a measurement of the Σ^+ magnetic moment. Hopefully, they will be able to resolve the two present conflicting measurements of the Σ^+ magnetic moment.

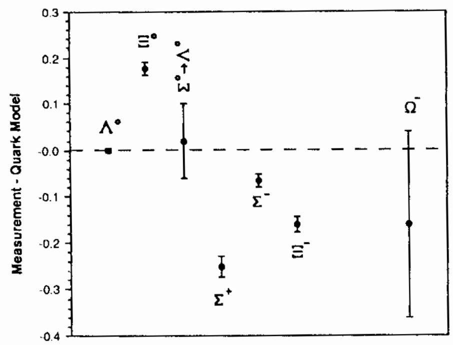

Fig. 5. Comparison with quark model

This same experiment will also attempt to see the rotation of the Σ^+ polarization by channeling Σ^+ with a bent crystal. The use of such crystals for the deflection of a 800-GeV beam has recently been demonstrated. This technique has been suggested as a possible way of measuring the magnetic moment of short-lived baryons containing heavy quarks.

Members of the Fermilab E-756 group (renamed E-800) plan to run again to improve the statistics (perhaps by as much as a factor of 5-10) of their Ω^- moment measurement. The time for this run has not yet been scheduled.

Approved programs exist at CERN, Fermilab, and UNK for significant new hyperon-beam programs. These are mainly aimed at studying the production of heavy quark baryonic states. It is these long-range programs that will continue to make the field exciting.

"Lattice 88"

by Paul Mackenzie

The ability to understand the properties of the strongly interacting particles from first principles is a 40-year-old dream which is now approaching reality. Following the development of quantum chromodynamics (QCD) in the early 1970s, honest calculations of the masses and other properties of hadrons were made possible by Ken Wilson's inventions of lattice gauge theory and renormalization group methods. Lattice gauge theory became a major industry around 1980, when Monte Carlo methods were introduced, and the first prototype calculations of the hadron spectrum yielded qualitatively reasonable results. This past year has seen the most powerful attacks yet on the theory of the strong interactions and the richest variety of physics results.

(Fermilab photograph 88-961-9)

Peter Hasenfratz discusses the bounding of the mass of the Higgs.

(Fermilab photograph 88-962-22)

A. A. Migdal shown here "putting strings on the lattice."

From small workshops first held at CERN, lattice meetings have evolved into annual international conferences. For the last few years they have been alternating between Europe and the United States, and have been increasing in size every year. At the 1988 Symposium on Lattice Field Theory, "Lattice 88," which was held at Fermilab on September 22-25, 1988, over 200 physicists from around the world heard reviewers report major progress not only in attacking QCD, but in understanding all components of the Standard Model.

Peter Hasenfratz of Bern summarized recent lattice work on placing bounds on the mass of the Higgs particle in the Standard Model. It has been known for a long time that a sensible weak coupling theory of Higgs scalars does not exist if the mass of the Higgs is greater than about 1 TeV. If the Higgs is very massive, however, its self-coupling is large, and until recently it has been an open question whether large Higgs self-coupling effects might affect this bound. A variety of recent nonperturbative lattice calculations have strengthened the bound and made it more precise: It has been impossible to obtain a sensible one-doublet elementary Higgs theory in which the Higgs weighs more around 600 - 700 GeV. According to these calculations, if a Higgs is not found with a mass less than around 700 GeV, it is a definite sign of physics beyond the Standard Model.

Julius Kuti of the University of California, San Diego, outlined further applications of lattice methods in the electroweak sector of the Standard Model, including bounds on the mass of the top quark and investigations of the viability of Abbott and Farhi's proposed strongly coupled Standard Model. Tantalizing indications of a new strongly coupled phase of quantum electrodynamics were discussed by John Kogut of the University of Illinois.

The calculation of the masses of hadrons is one of the most important and immediate goals of lattice gauge theory. At the present time, the inclusion of the effects of sea quarks is the most difficult part of the calculation. The quenched, or valence, approximation ignores these effects and is an important intermediate goal of the analysis. While it is not expected that this approximation will yield exactly the correct hadron spectrum, it is important to ascertain the precise degree of deviation from experiment while preparing to tackle the full calculation. Progress in this area was described by Enzo Marinari of the University of Rome. High-statistics calculations of a special purpose computer built by the APE collaboration, using improved calculational methods, have provided the clearest evidence yet that the proton/rho mass ratio in this approximation is between 1.4 and 1.5, as opposed to the physical answer of 1.22 which is expected in the full theory. While it is too early to be sure that this is the final prediction of the quenched approximation, it appears that we may be rapidly closing in on this result.

Massive improvement in the power of algorithms for producing sample QCD gauge field configurations was reviewed by Don Weingarten of IBM, Yorktown Heights, and Stephen Adler of the Institute for Advanced Study. Progress has been most spectacular in methods for including the effects of sea quarks. The hybrid Monte Carlo algorithms which are just beginning to be applied are around 10,000 times faster than the seven-year-old algorithms from which they descend.

A comparable improvement has been achieved in the hardware used for lattice calculations. The special purpose QCD machines now under construction at various institutions around the world are roughly 10,000 times more powerful than the VAXes on which the original hadron spectrum calculations were done seven years ago. Norman Christ of Columbia University described machines now existing or under construction at Columbia, IBM, Rome, Fermilab, Caltech, and Tsukuba. He also described related commercial machines, some of which have begun to borrow ideas from the approach pioneered by the Columbia group and are now in universal use in machines constructed especially for lattice gauge theory: fast floating point chips on a massively parallel array of nodes.

The greatly improved understanding of the glueball spectrum in SU(3) gauge theory without quarks was described by Andreas Kronfeld of Fermilab. Two years ago, confusion reigned in this area and there was no unanimity on even such an apparently simple question as whether the 0++ glueball state was heavier or lighter than the 2++. Improved methods of calculating glueball masses have helped to clarify the situation, producing a consensus, based on the work of several different groups, that the 2++ glueball is 1.5 ±.1 times as heavy as the 0++. Pierre van Baal of CERN summarized recent analytic work on the spectrum of the pure glue theory at small and intermediate volumes. In addition to being very beautiful, this work has been accurately verified by Monte Carlo methods, providing added confidence in the performance of the numerical methods.

The physics of QCD at high temperatures and densities has interesting applications in heavy-ion physics, astrophysics, and cosmology. A few years ago, this area of lattice theory produced the first apparently accurate, reliable result of Monte Carlo methods for nonabelian gauge theory: the temperature of the deconfining transition in pure gauge theory. Masataka Fukagita of Kyoto concluded that this calculation is still in good shape. The phase transition seems to be much weaker than originally thought, and an interesting controversy has developed between the Columbia group, who find a weak first order transition, and the APE collaboration whose data are consistent with a second-order phase transition. Of analogous calculations in full QCD, Fukugita echoed Marinari's summary of hadron massed in full QCD: *hic sunt leones* (here there be lions). Preliminary calculations of the deconfining phase transition in full QCD indicate that the transition temperature may be around 150 MeV. Frithjof Karsch of CERN examined the physics of the plasma phase of QCD and concluded that the simple picture of the hot QCD plasma as an ideal gas of quarks and gluons interacting perturbatively looks good so far, though much room remains for nonperturbative effects to be found.

Precision tests of the Standard Model, the determination of the Kobayasi-Maskawa angles, and the search for physics beyond the Standard Model all require a detailed understanding of hadronic weak matrix elements to exploit the large amount of data coming from increasingly sophisticated experiments. Lattice field theory methods are essential to the systematic analysis of the hadronic weak matrix elements. A great deal of important work has been done already in developing these difficult calculations, which was described by Claude Bernard of the Institute for Theoretical Physics in Santa Barbara, California. The prediction of the Q2 evolution of hadronic structure functions and form factors was one of the earliest successes of perturbative QCD, but prediction of the quantities themselves require lattice calculations. These were reviewed by Guido Martinelli of CERN. Chris Sachrajda of Southampton described the painstaking analytic work which has been done in setting up the operators of the Standard Model on the lattice.

The large-scale Monte Carlo simulation methods central to lattice gauge theory are being applied to other areas of physics as well, sometimes by people who also do lattice gauge theory. Jorge Hirsch of the University of California, San Diego, reviewed current theoretical ideas about high-temperature superconductivity. (Subtitle of Hirsch's talk: "What should a lattice gauge theorist be doing in his/her spare time?") Sasha Migdal of the Cybernetics Council in Moscow described recent progress in creating a lattice formulation of bosonic string theory. This work overlaps and extends analytic work on the subject based on Polyakov's conformal field theory approach. The fact that analytic and numerical calculations agree where both are supposed to be applicable is as important in this field as for QCD.

The last year has been the most active in the history of lattice gauge theory. The factor of 10^8 increase in combined algorithmic and hardware computing power which has been achieved over the last seven years will certainly be further increased by future developments. It now seems that calculations of hadron masses in the approximation of ignoring the effects of sea quarks are closing in on the reliability and accuracy already achieved for some simple calculations in pure gauge theory, and that calculation for full QCD, including the effects of the sea quarks, will not be too far behind. Then the exploration of the wide-open territory of all the nonperturbative aspects of the Standard Model and physics beyond the Standard Model will begin in earnest.

Reflections on the 15-ft Bubble Chamber

I.
Robert R. Wilson
(Professor Emeritus, Cornell University, and Director of Fermilab from its inception until 1978)

We had many exciting adventures in the course of building Fermilab. One of these involved the construction and use of the 15-ft Bubble Chamber, and now, as it reaches retirement, we can review that construction and use, we can celebrate its accomplishments, we can sentimentalize, perhaps we may even learn something of value for future projects of this kind. My recollections will be confined to how we came to build the 15-ft Bubble Chamber.

Now, the Berkeley Design Report for the 200-BeV Proton Accelerator had included some $60 million which, among other things, envisioned one $2m^3$, and one $100m^3$, and one large borrowed bubble chamber. When the scope of the project was drastically reduced, these were all thrown out of the authorization plan along with the reduction of machine intensity and the scope of the experimental areas. Of course, the elimination of the funding for the bubble chambers did not eliminate the need for them.

I can't say that I was an aficionado of bubble chambers, quite to the contrary. Still, I had been deeply impressed by what the Alvarez group at Berkeley had accomplished, and bubble chambers did seem to be the ideal instrument for a preliminary investigation of the new energy range we would be exploring at Fermilab. More importantly, the experimenters who would use the accelerator made it very clear that a large bubble chamber should be one of the necessary facilities of the project. When the first Aspen Summer Study in 1968 had finished, there had been a general agreement that a 25-ft bubble chamber would be required to do the job. The Brookhaven National Laboratory (BNL) physicists volunteered to design it along the lines of the 7-ft Bubble Chamber which was just moving into the last stages of construction at BNL. Their efforts resulted in an elegant design (the 25-ft Bubble Chamber, October 1969). Alas, the proposal was turned down with a finality that precluded any future appeal.

This article is excerpted from Reflections on the 15 Foot Bubble Chamber at Fermilab *[Mark Bodnarczuk, ed.] to be published by Fermilab. The monograph contains the proceedings of the "15 Foot Fest" held at the Laboratory on April 8, 1988, to mark the end of the 15-ft. Bubble Chamber program at Fermilab.*

Perhaps the Atomic Energy Commission (AEC) was so obdurate because its volume was more than twice that envisaged in the Berkeley Study, or perhaps it was because the estimated cost of the chamber ($15 million) seemed then to be so terribly high. At that point I decided that we could somehow squeeze the chamber out of our dwindling construction costs. And so we, and by we I mean Ned Goldwasser and other physicists working on the experimental facilities, asked the bubble chamber advocates to come up with a more modest, but yet still adequate, design. Just then a "Fairy Godmother" in the form of Bill Wallenmeyer of the AEC appeared, waved a magic wand, and pried out new funds, from whence I never did understand. That Brookhaven National Laboratory made the design, that the Argonne National Laboratory would build the huge superconducting magnet, and that the Stanford Linear Accelerator Center would build the piston were also vital ingredients in moving forward with the project.

The new funds were, as I remember, about $7 million. In the contriving that went into determining just how much they should be, I had made an obligation that it be a 15-ft bubble chamber. Somehow, in the rush to a new design, which meant essentially just doubling the 7-ft BNL design, the diameter was reduced to 14 feet. I insisted, for no other reason than my own credibility, that we stick to 15. So as not to have to make a whole new design, it occurred to me that a small, one-foot-long conical extension on the front of the chamber would keep me honest, and might even find some use in extending the length of the damn thing. I learned somewhat later that there were some comedians who referred to it, with egregious *lese majeste*, as the "Wilson Nose."

Soon after, Bill Fowler joined the Laboratory to see the project through - a great day for Fermilab. Not much later, Russ Huson joined him. I always felt that the sophistication of the engineering on the 15-ft Bubble Chamber far exceeded what we were doing on the Accelerator. It was a delight for me, every now and then, to pause in our mad race and admire the bravura performance of our clever new friends.

One of the fantasies that I had acquired during the lengthy discussions about the chamber was that it would sit out on the lone prairie in its shiny spherical magnificence about a mile from the Central Laboratory Building. In this case, architecture would not only reflect the function, it would be the function, or vice-versa. It finally become evident to me that the topography was such that the top of the chamber might just about stick up above ground, if that, and that the miserable Neutrino berm would conceal everything anyway. I was so angry that I didn't know whether to cancel the Neutrino experiments or the 15-ft Bubble Chamber itself!

The resolute Fowler and Huson were not to be deterred by my architectural whimsey. They came to me with wily smiles - they would fight fire with fire. The 15-ft Bubble Chamber would need an assembly building, they informed me. Aha, more money yet, I thought to myself. The new building, which would also be the operational center, would sit next to the bubble chamber, and it would have a huge bubble, indeed, a Fuller dome, sitting on top of it as a necessary part of it. That got to me. Soon my anger dissipated as we busily started the design. In fact, Russ already had a design in his pocket, and I even forgave him for that in the general euphoria of the moment.

When we turned our thoughts over to the professional architects of DUSAF, our architect/engineer consortium, they informed us that Fuller buildings had become expensive - way beyond what I was willing to spend. Still, the idea of a domed structure was irresistible, so we cut a deal with DUSAF that they would design and build the bottom floor of the building and we would take responsibility for the dome. Everybody seemed to get into the act, but Bob Sheldon, an innovative chemist working in the [magnet] coil factory at West Chicago, came up with a brilliant idea for a new kind of sandwich board that promised to be strong, cheap, and beautiful. It was to consist of two plastic layers between which beer cans would be stacked side by side in a hexagonal array and then cemented into place. Instead of a dome, I chose an icosahedron shape, which I thought would look like a jewel sitting on top of the rectangular-based building, but with its five sides it was something of a problem. Hank Hinterberger, our chief engineer, designed a steel structure to support the facets of the icosahedronic dome. The plates were triangles nine feet on each side and were made in our coil factory. The thin plastic layers were translucent and of different colors. The beer cans were collected from the parking area of the factory by a local Boy Scout Troop - our first community project. The tops and bottoms of the cans were removed so that when assembled, the translucent plastic took on the appearance of stained glass. The building was thoroughly satisfactory, even though the plastic decomposed in the sunlight over the years and has now been replaced by copper panels.

Well, I am getting deeper and deeper into superficialities which have little to do with the substance of the 15-ft Bubble Chamber, which is being addressed in the other contributions to this volume. Quite apart from the bubble chamber itself, building it brought a technical sophistication to Fermilab that was to permeate the whole Lab, and was eventually even to make the superconducting TEVATRON a realizable possibility. Memories, pleasant memories.

II.
Jim Ellermeier

(Formerly with the Operations Group, 15-ft. Bubble Chamber; now with the Research Division Cryogenics Department)

When Thornton [Murphy, "15 Foot Fest" Chairman] asked me if I'd say a few words today, I asked him what he had in mind, and basically he thought it would be a good idea to have someone who has been through the trenches say a few words. So I guess this talk is given by someone who's been in the trenches to those who were in the trenches with him.

First of all, there seems to be a misconception about the exact location of the 15-ft Bubble Chamber. If you got instructions to go to the bubble chamber, the person giving the instructions would probably say something like, "Well, just go to the end of the Neutrino beamline, Road A. There is this strange-looking building down there and it's got this really weird-looking roof on it. That's the 15-ft Bubble Chamber." So, people would walk into the building and ask "Where's the bubble chamber?" We'd say, "Well, you're pretty close to it, but actually you're about 200 feet away." A lot of people were very confused by that. Other people might ask, "Well, what do you do at the bubble chamber?" and still others would answer, "Well, they've got this huge sphere of 10,000 gallons of hydrogen that has this piston in it. They pulse it up and down and they shoot particle beams through it and take pictures." In point of fact, that is pretty close to exactly what went on out there. It's really kind of hard to describe all that went on at the Bubble Chamber. People would ask, "What do you do there?", and we'd describe what it was that we did and the longer we talked the more confused they got. Eventually I just simplified my answer to, "I work at Fermilab" and that would suffice.

Basically you had to be a jack-of-all-trades to work at Fermilab. You had to know a little bit about electronics, hydraulics, mechanics, cryogenics, and vacuum systems, and if you could master a few of those, you could do pretty well as a bubble chamber technician. During the interview for a job at the 15-ft Bubble Chamber they'd ask you a lot of questions, but you had no idea what they were talking about. You couldn't even fake an answer for a lot of things. When interviewing, they always asked two questions. The first one was, "Are you willing to get your hands dirty?" After you'd been hired you knew what that really meant was, "Are you willing to overhaul compressors?" The second question they always asked potential employees was, "Are you willing to work rotating shift work?" After a while, you knew that this question should be interpreted as, "Are you willing to work midnights on only two hours sleep?"

Shifts always rotated when we were taking physics data and that was an extremely tough time for a lot of people. Most people thought midnights were definitely the worst shift. I remember my first set of midnights. I had only been at Fermilab about two weeks and they said, "Well, we're ready to start shift work." I said "Well, here it comes." My shift was the one that was going to start at midnight, so I came in at a few minutes before 12 after only two hours sleep and John Stoffel, the Operations Chief, said to the crew, "Well, our assignment for tonight is to stack zinc in the vacuum space." (Bob Ferry was the Crew Chief and Jack Rossetto and Del Wilslef were there.) I said to them, "Well, I don't know what that means, but let's hit it." So, we walk down to Lab B and the building was literally full of pallets stacked with slabs of zinc which were about 18 inches long, an inch and a half thick, and 4 inches wide. We spent the next set of midnights putting that zinc into the vacuum space. Seven midnights and 60,000 pounds of zinc later, we completed the job. I'll remember that for the rest of my life. I said to myself, "If this is high-tech, then Fermilab is not the place for me."

When most people think about the 15-ft Bubble Chamber, they probably remember particular events and situations they were involved in and the people that they worked with. One of the big things that comes to my mind was the time that the chamber piston seized. The cap fell off of the emulsion box and became lodged at the side of the piston. We were taking pictures and all of a sudden we couldn't expand the chamber. It took some time before we figured out what was going on. We had to completely disassemble the device before we really knew what the problem was. That was a big job and a lot of work for a lot of people. As previously mentioned, we tested the integrity of our magnet only once. I happened to be there when it happened. There was a young technician on top of the chamber at the moment it happened and he must have thought that the end of the world was coming. When that rupture disk went, the noise was simply incredible and the vapor cloud went all the way to Casey's Pond. The lab behind us called the [Fermilab] Fire Department because they just knew we'd blown the place up.

A lot of us remember the old hydrogen compressor, better known as the "Red Lemon." What you had to do was overhaul that thing at least twice a week, typically on Sunday afternoon, so everyone hated Sundays. If you got to be lucky enough to double back, that was your gift for doubling back on our shift. Doubling back meant that you worked till midnight, then came in at 7:30 the next morning and got to overhaul the Red Lemon compressor. Then there were the stainless steel plates. A lot of us spent a lot of time polishing and grinding them so that they wouldn't boil in the chamber. The expansion system; a lot of us spent a lot of time down in the pit fixing oil leaks. There was nothing worse than working in Lab B and seeing a mist of oil coming from the expansion system because you knew exactly what was going on. There were so many improvements made on that system in the last few years that many of the newer technicians didn't know what it was like to work on that expansion system constantly.

Working at Lab B was always a "joy," too. It was hot in the summer and cold in the winter. We all can remember stacking up the expansion system in the pit and going through lots of long hours, particularly on midnights, putting that expansion system together. The original crew at the bubble chamber that started the cooldown in June and July of 1973 was made up of experienced people, mainly from Brookhaven and Argonne. Some of these people are still here at the Laboratory. The leaders at that time were George Mulholland and Hans Kautzky, and the emergency forces were Carl Pallaver and Paul Thorkelson. The crews consisted of John Stoffel, Asa Newman, George Athanasiou, John Foglesong, Bob Stover, Stan Tonkin, Denny Curtis, Bill Noe, Sr., Dick Almon, Jim Kilmer, and George Simon who just retired from the laboratory about a year ago. Then there were Frank Bellinger, Johnny Colvan, Colby Pitts, Gene Beck, Ron Davis, John Woodworth, Mike Morgan, Bob Ferry, Jim White, Jerry Kadow, Steve Johnson and Chuck McNeal.

These particular crews accomplished many "firsts" because they were the first crews to cool the apparatus down. The cooldown of the chamber started on June 23, 1973, and they had the first liquid in it nine days later on July 2, 1973. The chamber was full and controlling seven days later with no problems at all. This was quite an accomplishment given that it was all being done for the very first time. There weren't too many hitches. When we first started keeping our log books, everything went into a green log. I'm sure that anyone who's been around the chamber has certainly seen some of them. It's ironic, but we went through exactly 100 of these green log books in the 15 years that the bubble chamber operated. We finished our last run using log book number 100.

In our 15 years of operation, we had only one woman technician who worked at the bubble chamber. She was only with us for about a year and a half. In addition, we certainly depended a lot on our other female support staff, our secretaries Elsie Renaud, Denise Augustine, Norma Johnson, and Bert Forester. Bert started about two weeks before I did and worked at the bubble chamber for over ten years. She left about three years ago and was replaced by Claudia Foster who stayed about a year.

Then, of course, there were all of our welders and machinists: Larry Bingham (our first welder), Mark Krueger, Ivan Stauersboll, along with Sam Alexander, John Ramus, and Don Fisher, who replaced Sam when he retired about ten years ago. Then we had a member of the crew out there who was always on midnights, even when we weren't working shift work, and he was Dave Lyden. He'd call you at home because something was wrong and he'd do just about anything to fix the problem, anything except dump the fluid out of the chamber. We appreciated him a lot.

We didn't work all the time. We also had some fun. One of the things that was very enjoyable was the bubble chamber softball team. We were just a rag-tag bunch of guys who got together every once in a while to play ball and always had an annual game against the Accelerator Division. I don't know how that series came out, but I'm sure the bubble chamber ended up winning more games than Accelerator did. Bob Pucci was always our pitcher and we'd leave him in until he'd start walking runs home, then we would punish him by yanking him out of the game onto the bench and putting someone else in. They probably did worse than he would have, but we thought we had to do something about Pucci. George Mulholland, Wes Smart, and Jim Kilmer always cringed when they knew it was time to play a ball game because you could guarantee that the next day at least half of the crew had something wrong with them. George, Wes, and Jim would go around and make a health check on everybody and, at best, you were probably stiff and sore for two or three days after. Although there were a lot of muscle pulls and a number of broken fingers, we sustained a lot more injuries from what we called the "post-game festivities." If we had refreshments at the game, it would continue there after the game until it got dark, then we'd adjourn to the Users Center. We always felt this driving obligation to make sure that the Users Center closed on time and most of us saw that that happened.

We had six people who retired from the bubble chamber in 15 years. They were Stan Tonkin, Sam Alexander, Asa Newman, Harry Stapay, Paul Thorkelson (who is in Florida), and George Simon. Paul Thorkelson, for those that are interested, sent a letter and it's in the sign-up book. He regretted not being able to come.

I would like to make a comment about safety. I think that the technicians really deserve a lot of credit for keeping that place as safe as it was for 15 years. I remember one of the meetings we had right before this last run. Thornton was talking to us and he said, "I think this last run ought to really go off with a big bang." Then he said, "Wait a minute, wait a minute, no, no. That's not what I meant. I think you get the idea, but let's not do that."

In closing, I would like to give some credit to the wives and families of all the guys who worked at the bubble chamber over the years. We know that working on a rotating shift is very hard on the technicians, but it is very hard on the wives and families, too. There were a lot of things that we had to give up and miss; a lot of anniversaries, a lot of school functions, a lot of sporting functions that we just weren't able to attend. It's a big sacrifice for the family, too, so I think in appreciation of their sacrifice, I would like to say thank you to them. I think they deserve a round of applause.

Lab Notes

INFN (Milan) ACP System Commissioned...

A new Advanced Computer Program (ACP) computer system was commissioned in the Feynman Computing Center at Fermilab on Thursday, October 20, 1988. The 25-node system was purchased by the Italian National Institute for Nuclear Research (INFN) through the University of Milan. The Milan group is part of the heavy-quark photoproduction experiment E-687 in the Proton Area wideband beamline. The new system will be operated by the Computing Department for the INFN. First preference for its use will be given to the analysis of the E-687 data taken in the last fixed-target run.

(Fermilab photograph 88-1072-2)

The new INFN ACP system in the Feynman Computing Center with some of its owner/users and support staff. Left to right: Gian Alimonti, Dario Menasce, Margharitta Vittone (University of Milan), Paul LeBrun, Chip Kaliher, Arnaldo Valderrama, Peter Cooper, and Jim Meadows (Fermilab Computing Department/Research Division).

This system is the third production ACP system brought online at Fermilab. These three systems, totaling 142 ACP nodes, are used in the analysis of data taken by fixed-target experiments during the last run and the analysis of data from the CDF experiment, which is running now.

E-687 wrote 2000 data tapes in the last run. They will require 24 node-years (24 nodes working full time for one year) of computing on ACP systems to complete their primary data analysis. The totals for the fixed-target experiments from the last run plus Collider Detector at Fermilab data from the Collider run in progress are about 40,000 tapes and 400 node-years. The largest single experiment, the charmed hadro-production experiment E-769, has 10,000 tapes

*("**Lab Notes**" continued)*

and requires 170 node-years to complete its first-pass analysis. All of these experiments plan to use ACP systems for at least their primary data analysis. There are also plans to run large detector simulation Monte Carlo programs on ACP systems by some of the same experiments.

An ACP system is a group of micro-processors running in parallel to give a very large effective computing power. The system was designed and developed by the Advanced Computer Program group at Fermilab, for which it is named. Each node is a single-board computer with either 2 or 6 megabytes of memory. The computer chips used in a node are the same as those found in the Macintosh II personal computer. Together, the 25-node INFN system has more than half the computing power of the present Fermilab VAX Cluster. For problems like the analysis of individual events, where a computation can be broken into many small, similar parts, the ACP is a very cost-effective solution. The INFN system costs only a few per cent of the total cost of the VAX Cluster. For problems which cannot be easily subdivided, many processors running in parallel is of no advantage. The ACP is a cost-effective enhancement to Fermilab computing - particularly for the analysis of event data. It is not a replacement for general purpose computers.

The future plans for ACP central computing at Fermilab are for six systems with a total of 400 nodes. The third of these systems is now commissioned; the sixth should be available by February 1989. At that time, the central computing facilities at Fermilab will have available 55 VEQ (VAX 11/780 EQuivalents) on VAX systems, 120 VEQ on the Amhdal 5890/600E system, and 300 VEQ on ACP systems. This is an increase of a factor of two or more on each of the three kinds of systems over what is available today. At the same time, three CDC Cyber 175s will be decommissioned, reducing the total Cyber computing power from 50 VEQ to 30 VEQ. Of course, equivalent CPU power numbers do not summarize the entire evaluation of these systems. Such issues as input/output capability, peripheral device availability, connectivity, and higher level software are all important matters to consider.

In the finest traditions of computing, the needs have expanded to consume nearly all available computing power - even with a five-fold increase in the past few years. However, there are experiments to be analyzed today which could not have been contemplated without the knowledge that such large computing resources would be available. Large computing resources have become a tool for doing physics which couldn't be done before. - *Peter Cooper*

*(**"Lab Notes"** continued)*

Accolades:

Three from Lab Named as Fellows of the American Physical Society...

Each year, the American Physical Society (APS) honors a few of its outstanding members by electing them to the status of Fellowship. APS only designates members who have contributed to the advancement of physics by displaying independent, original research or who have rendered some other special service to the cause of the sciences.

This year, the APS announced that Jeffrey A. Appel, Head of Fermilab's Computing Department; Richard K. Ellis, of the Fermilab Theoretical Physics Department; and Thomas B. W. Kirk, on leave of absence from Fermilab to the SSC Central Design Group, have been elected as Fellows of the American Physical Society.

Appel's citation reads: "For co-discovering the upsilon, the first evidence of 'bottom' quarks, and for leadership in the development of detectors and in defining electronic and data acquisition directions for high-energy physics experimentation."

Ellis' citation acknowledges his "contributions to the theory of hard scattering processes in the QCD improved parton model."

Kirk's citation notes his "continued leadership over many years in the Fermilab muon scattering program, and his successful management of the Tevatron II Construction Project."

URA Appoints Search Committee for New Fermilab Director...

Universities Research Association, Inc., (URA) which manages Fermilab for the U.S. Department of Energy, has announced the makeup of the URA Search Committee for Director of Fermilab, which is seeking a replacement for Director Leon M. Lederman. Lederman has announced his retirement from the Directorship effective July 1, 1989.

Committee members from the URA Fermilab Board of Overseers are Harold K. Ticho (Chairman), Vice Chancellor for Academic Affairs, University of California, San Diego; Kenneth Heller, School of Physics and Astronomy, University of Minnesota; Albert Silverman, Newman Laboratory, Department of Nuclear Studies; and Robert R. Wilson, Professor Emeritus, Cornell University, and Director Emeritus, Fermilab. Raymond L. Brock, Department of Physics and Astronomy, Michigan State University, is representing the Fermilab Users' Executive Committee. *Ex-officio* members of the Search Committee are Edward

("Lab Notes" continued)

A. Knapp, President, URA; and Harry Woolf, Institute for Advanced Study, and Chairman of the URA Fermilab Board of Overseers.

Ezra D. Heitowit, Vice President of URA, noted that the presence of Harold Ticho, who chaired the committee which brought Lederman to the Directorship, is emblematic of URA's intention to hew closely to past search procedures. The committee has invited recommendations, placed an advertisement in prominent publications, and is conducting interviews at the Lab.

"URA is strongly committed to Fermilab," Heitowit said, "and we foresee a healthy physics program at the Lab for at least the next ten years, regardless of developments at the SSC.

"The committee is embarking on its search mindful that, while Leon Lederman cannot be replaced, we must find in his successor someone who will continue to guide Fermilab with equal vision and wisdom." - *R.B.F.*

Appointments:

Directorate

Richard Lundy, Associate Director for Technology, has also been appointed Acting Director for Administration.

Accelerator Division

Effective January 1, 1989, Gerald Dugan, formerly Head of the Pbar Source Department, has been named Head of the Accelerator Division. Michael Harrison, formerly Head of the Main Accelerator Department, is now Deputy Head of the Division, with emphasis on the proposed TEVATRON Collider upgrade.

In other Accelerator Division organizational changes, Stephen Holmes has become Head of the Main Accelerator Department, with David Finley, Associate Head (TEVATRON), and Philip Martin, Associate Head (Main Ring). John McCarthy is now Head of the Injector Department, with John Marriner, Associate Head (Pbar Source), Vinod Bharadwaj, Associate Head (Booster), and Gerald Jackson, Associate Head (Instrumentation).

Research Division

Robert Kephart has been appointed Head of the Collider Detector at Fermilab (CDF) Department. Melvin Shochet (University of Chicago) has joined Alvin Tollestrup (Fermilab) as Co-Spokespersons of the CDF Collaboration.

Richard Stanek has been named Head of the Research Division's Cryogenics Department.

*("**Lab Notes**" continued)*

Technical Support Section

As of November 1, 1988, the Technical Support Section Magnet Development and Test Facility was reorganized into two groups. Gerald Tool, formerly of the Accelerator Division Electrical/Electronics Support Department, became Head of the Magnet Test Facility. James Strait has been appointed Head of the Superconducting Magnet R&D Group at Lab 2.

Fermilab Celebrates Twentieth Year. . .

On December 2, 1988, Fermilab celebrated its twentieth anniversary with the theme, "The Next Twenty Years." The later portion of the celebration consisted of a party, while the earlier, more formal proceedings involved distinguished speakers who recalled the history of the Laboratory from the time it was still a twinkle in the eyes of many physicists.

It was in 1963 that the Ramsey Panel recommended to the United States Atomic Energy Commission (AEC) that it build a 200-BeV accelerator. A year earlier, Leon Lederman, Jack Steinberger, and Melvin Schwartz discovered the muon neutrino at the Brookhaven Alternating Gradient Synchrotron. With a large momentum driven by this and numerous other discoveries, the beginnings of the Standard Model were framed out and the need for new, higher energy accelerators was felt even more keenly. As a result, particle physicists in the United States were looking to this new machine proposed by the Ramsey Panel with excitement and as an investment in the future vitality of the field.

In 1967, Universities Research Association, Inc., signed the National Accelerator Laboratory (NAL) Design Study Contract with the AEC, appointing Robert R. Wilson as Director of the new laboratory. With the 1967 selection of a site and a construction authorization of $250 million, 1968 became the year that the Batavia site was occupied and the first ground broken for the construction of the Linac. Four years later, under the able leadership of Robert Wilson, the Main Ring reached its design energy of 200 GeV and R&D work began on the magnets for a superconducting accelerator. Having completed NAL as well as returning $6.5 million of the allocated funds to the United States government, the Laboratory was dedicated as the Fermi National Accelerator Laboratory with 400-GeV beams having become a routine part of operation.

The 1000-GeV TEVATRON was formally proposed by Wilson in 1975 before a conference at Woods Hole and the name "Energy Saver" was coined in relation to the formal Department of Energy project proposal in 1977. That same year, Leon Lederman was named Director Designate of Fermilab when Wilson resigned. With the construction of the Energy Saver well under way since

*("**Lab Notes**" continued)*

1979, preparations to exploit those higher energy beams was initiated with TEVATRON I in 1981 and TEVATRON II in 1982. The Energy Saver broke the Main Ring's 500-GeV record in 1983 when protons were accelerated to an energy of 512 GeV. This was the same year that the construction of the TEVATRON I Antiproton Source began.

1984 brought Fermilab into a new, higher energy era with the Energy Saver accelerating protons to 800 GeV. Not more than a year later, the Antiproton Source accumulated 10^9 pbars, which were used in the TEVATRON Collider to create 1.6-TeV center-of-mass collisions, which were successfully detected by the new Collider Detector at Fermilab (CDF). Rounding out the full breadth of the physics program here at Fermilab was an eight-month fixed-target physics run with the upgraded TEVATRON II facilities and an incident beam energy of 800 GeV. In the first run of the CDF detector in 1987, the Collider produced about 10^9 collisions, with CDF breaking new physics ground. Also that year, the productivity of the fixed-target program and the pay-back from the TEVATRON II investment was fully realized when the fixed-target physics program accumulated over 35,000 data tapes. Just a year later, in 1988, the TEVATRON reached a record luminosity of 2.06×10^{30} cm^{-2} sec^{-1} and CDF continues to accumulate data which far exceeds its initial goal of 1 inverse picobarn.

In addition to being a world-class laboratory at which to do high-energy physics, Fermilab's 20-year history has been one of continuing aesthetic changes to structures and the overall site which have become a statement about what high-energy physics is about. In addition to significant architectural additions like the new Muon Laboratory and the Feynman Computing Center, the entire 6800-acre site has continued to evolve as a place of beauty.

Probably the most deep and philosophically profound thought about Fermilab's previous 20 years and the next 20 was captured in a testimony that Leon Lederman gave before the House Committee on Science and Technology Sub-Committee on Energy Development in 1984. Lederman began, "Now, my colleagues will hasten to tell you that high-energy physics pays back because it enhances our culture, contributes to human dignity, broadens our view of the evolution of the universe and our own position in it. Some will tell you that society profits because we set standards for applied science, we recruit young people into science by the seduction of neutrinos and quarks and black holes. All this is true, but what is also true in that the predecessors of today's high-energy physicists changed the world, and there is no reason to believe that what we do now, abstract and remote as it may seem, will not have major effects on the lives of our children's children." - *Mark Bodnarczuk*

*("**Lab Notes**" continued)*

Dedication of the Feynman Computing Center at Fermilab. . .

In conjunction with, and on the same day as, the celebration of Fermilab's twentieth anniversary, the Laboratory looked to the future with the formal dedication of the Feynman Computing Center.

The late Richard P. Feynman (1918-1988), after whom the Center is named, was hailed by Fermilab Director Leon M. Lederman as "one of the giants of our age in theoretical physics. His contributions to the body of our understanding are as many as they are profound. Quantum electrodynamics was perhaps the jewel of his oeuvres, but his ability to teach and communicate were legendary and included Feynman diagrams ('computational power for the masses') and Feynman lectures for college freshmen (and their professors). . . In naming this Center after him, it is our fervent hope that out of this architecturally elegant computer house, good science will emerge which would have pleased him very much."

Feynman shared the 1965 Nobel Prize in Physics for his work in quantum electrodynamics. He also formulated the so-called "Feynman diagrams" as a way of visualizing the intricate mechanisms of sub-atomic physics, and as a guide to the calculations required to describe the basic interaction processes. These calculations are among those done on the computers at the Center.

(Fermilab photograph 88-1228-12)

Leon Lederman speaking at the dedication of the Feynman Computing Center. Behind him on the dias are (l. to r.) Carl Feynman, Gweneth Feynman, Jeffrey A. Appel, Hilary J. Rauch, Robert R. Wilson, and James D. Bjorken. Not pictured: Joan Feynman.

The dedication ceremony, which began at 12:00 noon at the Center, was attended by Richard Feynman's wife, Gweneth; his son, Carl; and his sister, Joan.

*("**Lab Notes**" continued)*

After introductions by Lederman, James D. Bjorken, until recently Associate Director at Fermilab and now with the Lab's Theoretical Physics Department, spoke on "Feynman the Physicist." Fermilab Director Emeritus Robert R. Wilson, who served as architectural consultant to the design of the building, reminisced about "Early Days with Feynman." Hilary J. Rauch, Manager of the Department of Energy's Chicago Operations Office, delivered "A Word from Our Sponsor," and Jeffrey A. Appel, Head of the Fermilab Computing Department, ended the ceremony with observations on "Building for the Future."

Designated the Central Computing Facility during construction, the Center is now home to the Lab's Digital Equipment Corporation VAX Cluster, the Amdahl 5890/300 scientific computer (soon to be doubled to an Amdahl 5890/600), and various support elements of the Computing Department, such as the Instrument Repair Group, the Data Acquisition Hardware Groups, and the Physics Research Equipment Pool.

Funded by a Congressional Line Item, the project's goals are stated to be a five-fold increase in "the computing capacity available for scientific applications and to provide new space for these and related activities," according to the Department of Energy's description.

"The new building provides growth space. . . for a decade and beyond," said Appel. "In addition, the facility allows for upgrades without interruption to the current system." - *R.B.F.*

Manuscripts and Notes

prepared or presented from November 1, 1988, to January 31, 1989. Copies of Fermilab TM's, FN's, and preprints (exclusive of Theoretical and Theoretical Astrophysics preprints) can be obtained from the Fermilab Publications Office, WH6NW, or by sending your request to (DECnet) FNAL::TECHPUBS or (BITnet) TECHPUBS@FNAL. For Theoretical Physics or Theoretical Astrophysics preprints, contact those departments directly. For papers with no Fermilab catalogue number, contact the author directly.

Experimental Physics Results

Experiment #665
S. Wolbers, "Deep Inelastic Muon Scattering at 500 and 100 GeV," (FERMILAB-Conf-88/153-E; presented at "DPF 88": the 1988 Meeting of the Division of Particles and Fields of the APS, Storrs, Connecticut, August 15-18, 1988)

Experiment #691
J. C. Anjos et al., "Experimental Study of the Semileptonic Decay $D^+ \rightarrow \overline{K^{*0}} e^+ \nu_e$," (FERMILAB-Pub-88/143-E; submitted to Phys. Rev. Lett.)

J. C. Anjos et al., "Observation of Excited Charmed Mesons," (FERMILAB-Pub-88/155-E; submitted to Phys. Rev. Lett.)

J. C. Anjos et al., "A Study of the Semileptonic Decay Mode $D^0 \rightarrow K^- e^+ \nu_e$," (FERMILAB-Pub-88/141-E; submitted to Phys. Rev. Lett.)

M. V. Purohit, "Charm Physics," (FERMILAB-Conf-88/200-E; presented at the BNL Workshop on Glueballs, Hybrids, and Exotic Hadrons, Brookhaven National Laboratory, Upton, New York, August 29-September 11, 1988)

Experiment #704
B. E. Bonner et al., "Analyzing-Power Measurement in Inclusive π^0 Production at High x_F," (Published in Phys. Rev. Lett. **61**, 1918, 1988)

Experiment #705
G. Zioulas et al., "An On-Line Trigger Processor for Large Transverse Energy Events," (FERMILAB-Conf-88/185-E; talk given by G. Zioulas at the 1988 IEEE Nuclear Science Symposium, Orlando, Florida, November 8-12, 1988)

Experiment #731
Y.-B. Hsiung, "Measurement of ε'/ε at Fermilab," (FERMILAB-Conf-88/164-E; talk given at the IX European Symposium on Antiproton-Proton Interactions and Fundamental Symmetries, Mainz, Germany, September 5-10, 1988)

Experiment #735
S. Banerjee et al., "Λ^0 and $\overline{\Lambda}^0$ Production from Proton-Antiproton Collisions at $\sqrt{s}$ = 1.8 TeV," (Published in Phys. Rev. Lett., **64** 12, 1989)

F. Turkot et al., "Quark Gluon Plasma - Overview and Experimental Results from E-735," (FERMILAB-Conf-88/199-E; presented at the 7th Topical Workshop on Proton-Antiproton Collider Physics, Fermilab, Batavia, Illinois, June 20-24, 1988)

Experiment #740
R. Raja,"Theoretical Implications of the W-Z Mass Difference and the Capabilities of the D0 Detector in Measuring It," (FERMILAB-Conf-88/198-E; invited talk given at the 7th Topical Workshop on Proton-Antiproton Collider Physics, Fermilab, Batavia, Illinois, June 20-24, 1988)

Experiment #741/CDF
F. Abe et al., "Measurement of the Inclusive Jet Cross Section in $\bar{p}p$ Collisions at $\sqrt{s}$=1.8 TeV," (FERMILAB-Pub-88/213-E; to be published in Phys. Rev. Lett.)

F. Abe et al., "A Measurement of W Boson Production in 1.8 TeV $\bar{p}p$ Collisions," (FERMILAB-Pub-88/207-E; submitted to Phys. Rev. Lett.)

Experiment #744
C. Foudas et al., "Neutrino Production of Charm at FNAL E744," (FERMILAB-Conf-88/160-E; presented by H. Schellman at the 16th SLAC Summer Institute on Elementary Particle Physics, July 27-29, 1988)

Experiment #769
D. Errede et al., "Design and Performance Characteristics of the E769 Beamline Transition Radiation Detector," (FERMILAB-Conf-88/180-E; talk given by M. Sheaff at the 1988 IEEE Nuclear Science Symposium, Orlando, Florida, November 8-12, 1988)

Experiment #778
A. Chao et al., "Experimental Investigation of Nonlinear Dynamics in the Fermilab TEVATRON," (Published in Phys. Rev. Lett. **61** 2752, 1988)

General Particle Physics

Y.-C. Chao and K.-Y. Ng, "Comments on ESME, a Tracking Code in the Longitudinal Phase Space," (FN-499)

D. Christian et al., "The Development of Two ASIC's for a Fast Silicon Strip Detector Readout System," (Presented by D. Christian at the 1988 IEEE Nuclear Science Symposium, Orlando, Florida, November 8-12, 1988)

D. Husby et al., "A Floating Point Engine for Lattice Gauge Calculations," (FERMILAB-Conf-88/165; talk presented by D. Husby at the 1988 IEEE Nuclear Science Symposium, Orlando, Florida, November 8-12, 1988)

A.K. Likhoded et al., "Bare Pomeron in Inclusive Processes," (FN-504)

J. A. MacLachlan, "Using the Circulating Beam in the Fermilab Antiproton Accumulator for Experiments," (FERMILAB-Conf-88/152; presented at "DPF 88": the 1988 Meeting of the Division of Particles and Fields of the APS, Storrs, Connecticut, August 15-18, 1988)

M. V. Purohit, "Heavy Quark Production and QCD," (FERMILAB-Conf-88/191; presented at "DPF 88": the 1988 Meeting of the Division of Particles and Fields of the APS, Storrs, Connecticut, August 15-18, 1988)

Accelerator Physics

R. Atac et al., "Crossbar Switch Backplane and Its Application," (FERMILAB-Conf-88/166; talk presented at the 1988 IEEE Nuclear Science Symposium, Orlando, Florida, November 8-12, 1988)

S. A. Bogacz, "Coherent Instability Limitations on pp and $\bar{p}p$ Upgrade Scenarios," (FN-498)

D. A. Edwards and M. J. Syphers, "An Introduction to the Physics of Particle Accelerators," (Based on lectures given at the 1988 US Particle Accelerator Summer School, Cornell University, Ithaca, New York, August 1-12, 1988)

J. D. Gonczy et al., "Thermal Performance Measurements of a Graphite Tube Compact Cryogenic Support for the Superconducting Super Collider," (FERMILAB-Conf-88/194 [SSC-197]; presented by J. D. Gonczy at ICEC 12, Southampton, England, July 12-15, 1988)

R. Johnson, "The Fermilab Pbar-P Collider; Present Status and Future Plans," (FERMILAB-Conf-88/169; talk presented at the 11th All-Union Conference on Charged Particle Accelerators, Dubna, U.S.S.R., October 25-27, 1988)

S. R. Mane, "Radiative Electron Polarization: Theoretical Predictions and Explanation of the SPEAR Data," (FN-503)

S. R. Mane, "Tuneshifts, Tunespreads and Decoherence," (FN-502)

A. Moretti et al., "An 805 MHz Disk and Washer Structure for the Fermilab Linac Upgrade," (FERMILAB-Conf-88/145; to appear in the proceedings of the 1988 Linear Accelerator Conference ["LINAC 88"], Williamsburg, Virginia, October 3-7, 1988)

K.-Y. Ng, "Lengthy Disturbances and Copper-to-Superconductor Ratio," (FN-501)

T. H. Nicol, "High Field Dipole Magnet Design Concepts," (FERMILAB-Conf-88/196; presented by the author at the 11th Annual Cryogenic Workshop - NBS, Colorado Springs, Colorado, October 16-19, 1988)

R. C. Niemann et al., "Second Generation Superconducting Super Collider Dipole Magnet Cryostat Design," (FERMILAB-Conf-88/195 [SSC-198]; presented at the 12th Annual Energy Sources Technology Conference, Houston, Texas, January 22-25, 1989)

R. C. Niemann et al., "Superconducting Super Collider Second Generation Dipole Magnet Cryostat Design," (FERMILAB-Conf-88/197; presented by R. C. Niemann at the 1988 Applied Superconductivity Conference, San Francisco, California, August 21-25, 1988)

Theoretical Physics

C. H. Albright and M. Lindner, "Hierarchical Chiral Symmetry Breaking and Quark Mass Matrices Revisited," (FERMILAB-Pub-89/17-T; submitted to Phys. Lett. B)

P. B. Arnold and M. H. Reno, "The Complete Computation of High-p_T W and Z Production in 2nd-Order QCD," (FERMILAB-Pub-88/168-T; to be published in Nucl. Phys. B)

Z. Bern and D. A. Kosower, "Absence of Wavefunction Renormalization in Polyakov Amplitudes," (FERMILAB-Pub-88/192-T; submitted to Nucl. Phys.)

J. D. Bjorken, "On the Determination of Phases of Generalized Kobayashi-Maskawa Matrix Elements from Their Magnitudes," (FERMILAB-Pub-88/124-T; submitted to Phys. Rev. Lett.)

D. Chang and W. Keung, "Hidden Higgs Boson Models and Stellar Energy Loss," (FERMILAB-Pub-88/112-T; submitted to Phys. Rev. Lett.)

D. Chang and W. Keung, "Higgs-Mediated Neutrinoless Double β-Decay and Neutrino Mass in a Majoron Model," (FERMILAB-Pub-88/193-T; submitted to Phys. Rev. Lett.)

R. K. Ellis, "Large Transverse Momentum and Higher Twist Phenomena," (FERMILAB-Conf-88/162-T; summary talk given at the Conference on Higher Twists and High p_t Physics, Paris, France, September 21-23, 1988)

R. K. Ellis, "Heavy Quark Production at Collider Energies," (FERMILAB-Conf-88/184-T; invited talk presented at the 7th Topical Workshop on Proton-Antiproton Collider Physics, Fermi National Accelerator Laboratory, Batavia, Illinois, June 20-24, 1988)

G. F. Giudice, "Dark Matter and Supersymmetry," (FERMILAB-Conf-89/15-T; talk presented at "Beyond the Standard Model," Ames, Iowa, November 18-20, 1988)

B. Grinstein and C. T. Hill, "The Trace Anomaly and Low Energy Phenomenological Implications of Wormholes," (FERMILAB-Pub-88/190-T; submitted to Phys. Lett. B)

M. Lindner et al., "Probing Vacuum Stability Bounds at the Fermilab Collider," (FERMILAB-Pub-88/206-T; submitted to Phys. Rev. Lett.)

P. Mackenzie et al., "Status of the Fermilab Lattice Supercomputer Project," (FERMILAB-Conf-88/167-T; talk given by P. Mackenzie at "DPF 88": the 1988 Meeting of the Division of Particles and Fields of the APS, Storrs, Connecticut, August 15-18, 1988)

R. D. Pisarski, "How to Compute Scattering Amplitudes in Hot Gauge Theories," (FERMILAB-Pub-88/113-T; based on talks given at "Quark Matter 88," Lennox, Massachusetts, September 1988, and at the Workshop on Thermal Field Theories and Their Applications, Case Western Reserve University, Cleveland, Ohio, October 3-5, 1988)

R. D. Pisarski, "Scattering Amplitudes in Hot Gauge Theories," (FERMILAB-Pub-88/123-T; submitted to Phys. Rev. Lett.)

J. Shigemitsu, "The Lattice $\lambda\phi^4$ Model with Yukawa Couplings to Staggered Fermions," (FERMILAB-Conf-88/140-T; talk presented at the 1988 Symposium on Lattice Field Theory, Fermi National Accelerator Laboratory, Batavia, Illinois, September 22-25, 1988)

Computing

I. Gaines et al., "Multi-Processor Developments in the United States for Future High Energy Physics Experiments and Accelerators, "(FERMILAB-Conf-88/211; presented by I. Gaines at the Adriatico Conference on the "Impact of Digital Microelectronics and Microprocessors on Particle Physics," International Centre for Theoretical Physics, Trieste, Italy, March 28-30, 1988)

T. Nash et al., "The Fermilab Advanced Computer Program Multi-Array Processor System (ACMAPS) - A Site Oriented Supercomputer for Theoretical Physics," (FERMILAB-Conf-88/111; presented at the Adriatico Conference on the "Impact of Digital Microelectronics and Microprocessors on Particle Physics," International Centre for Theoretical Physics, Trieste, Italy, March 28-30, 1988)

T. Nash, "Trieste Conference on Digital Microelectronics and Microprocessors in Particle Physics - Summary and Concluding Remarks," (FERMILAB-Conf-88/110; presented at the Adriatico Conference on the "Impact of Digital Microelectronics and Microprocessors on Particle Physics," International Centre for Theoretical Physics, Trieste, Italy, March 28-30, 1988)

Radiation Safety

S. W. Butala et al., "Measurements of Radioactive Gaseous Releases to Air from Target Halls at a High Energy Proton Accelerator," (FERMILAB-Pub-88/189; submitted to *Health Physics*)

Other

J. S. Russ et al., "Studies of LBL CMOS Integrated Amplifier/Discriminator for Randomly Timed Inputs from Fixed Target Experiments," (TM-1551; presented by J. S. Russ at the 1988 IEEE Nuclear Science Symposium, Orlando, Florida, November 8-12, 1988)

Colloquia, Lectures, and Seminars

by Fermilab staff, at Fermilab, November-December 1988, unless otherwise noted.

October 24
P. Garbincius, "The Discovery of the Muon-Neutrino - This Year's Nobel Prize-Winning Experiment," at the XXXI Congreso Nacional de Fisica de Sociedad Mexicana de Fisica

October 25
P. Garbincius, "The Fermilab TEVATRON Physics Program," at the XXXI Congreso Nacional de Fisica de Sociedad Mexicana de Fisica

November 3
D. McGinnis, "4-8 GHz Pickup Development for the Antiproton Source"

November 7
D. Kosower, "Recursion Relations for QCD Amplitudes," at Argonne National Laboratory

November 8
P. Constanta-Fanourakis and M. Votava, "Helical Scan Devices - EXABYTE, GIGASTORE"

H. Edwards, "Plans and Priorities for the Next Two Years"

November 9
P. Lucas et. al., "Progress Report on Controls Upgrade"

D. Ryu, "Distribution of Matter in a CDM-Dominated Universe," at the Department of Astronomy and Astrophysics, University of Chicago

November 10
S. Cihangir, "Neutron-Induced Pulses in CDF Forward Hadron Calorimeter," IEEE Nuclear Science Symposium, Orlando, Florida

November 11
R. McCarthy, SUNY/Stony Brook-Fermilab, "D0 Central Calorimeter Installation"

November 14
L. Chapman, M. Frey, and A. Waller, "Current Issues and Object-Oriented Programming"

R. Pisarski, "Scattering Amplitudes in Hot Gauge Theories," at Pennsylvania State University

November 18
M. Golden, "Finding Strongly Interacting Symmetry Breaking at the SSC," at "Beyond the Standard Model," Ames, Iowa

November 21
P. Griffin, "Correlation Functions and Characters of Parafermion Theories Via Bosonization," at Argonne National Laboratory

S. Stoy and R. Fast, "Liquid Helium II - The Superfluid Thermal Properties of Liquid Helium"

A. Lennox, Lectures on Neutron Therapy, at the IV International Course in Medical Physics, Bariloche, Argentina

November 30
H. Edwards, "TEVATRON Upgrade Plans"

R. Pisarski, "The Hadronic Phase Transitions," colloquium at the University of Arizona

December 1
R. Gerig, G. Jackson, and M. Syphers, "Recent Main Injector Studies"

December 5
R. Pisarski, "Scattering Amplitudes in Hot Gauge Theories," at Brookhaven National Laboratory

December 6
B. Denby, "The Fermilab Neural Networks Project"

J. Peoples and G. Dugan, "[Accelerator] Division Reorganization"

December 8
G. Dugan, Fermilab, "The Luminosity Model"

P. Griffin, "Bosonization of Parafermion Conformal Field Theories"

S. Hsueh, "Luminosity Calculation"

December 13
H. Melanson, "E-665 Experience with the Amdahl"

R. Pisarski, "Scattering Amplitudes in Hot Gauge Theories," at the Massachusetts Institue of Technology

December 20
C. Johnstone, "The 200 - 400-MeV Transfer Line"

December 22
J. Gonczy, "Superinsulation Systems and the SSC"

Index to the 1988 *Fermilab Reports*

Dates to Remember

March 20, 1989

Deadline for receipt of material to be considered at the April Physics Advisory Committee Meeting.

March 20-23, 1989

1989 Particle Accelerator Conference. Fermilab, Batavia, Illinois. For information, contact F. T. Cole or D. E. Young c/o 1989 Particle Accelerator Conference, Fermi National Accelerator Laboratory, P.O. Box 500, Batavia, Illinois, 60510.

April 5-7, 1989

Symposium on Particle Identification at High Luminosity Hadron Colliders. Fermilab, Batavia, Illinois. For information, contact Treva Gourlay, Fermilab, P.O. Box 500, MS 122, Batavia, IL 60510 or BITnet: PARTID@FNAL.

April 28-29, 1989

Physics Advisory Committee Meeting.

May 12, 1989

Deadline for receipt of material to be considered at the June Physics Advisory Committee Meeting.

May 19-20, 1989

Fermilab Users Annual Meeting. Fermilab, Batavia, Illinois. For information, contact Phyllis Hale, Fermilab Users Office, (312) 840-3111 or BITnet: USERSOFFICE@FNAL.

May 22-26, 1989

CP Violation in Particle Physics and Astrophysics. Château de Blais, France. For information: Recontres de Moriond: Bat 211, Universite de Paris Sud 91405, Orsay Cedex, France or BITnet: TRANTV@FRCPN11.

June 17-23, 1989

Physics Advisory Committee Meeting.

August 22-26, 1989

XIV International Conference on High Energy Accelerators. KEK, Nova Hall, Tsukuba, Japan. For information, contact S. Ozaki, HEACC 89 Conference Secretariat, KEK, 1-1 Oho, Tsukuba, Ibaraki, 305 Japan or BITnet: HEACC89@JPNKEKVM.