"Workshop on Physics at Fermilab in the 1990's"

by Mark Bodnarczuk

High-energy physics workshops are designed to be highly focused "brain-storming" sessions where new ideas for ground-breaking physics can emerge. Consequently, they are often held in settings that are conducive to creativity. Such was the case with the "Workshop on Physics at Fermilab in the 1990's" recently held in the Rocky Mountains at Breckenridge, Colorado. The workshop was co-sponsored by the Fermilab Users Executive Committee and Fermilab.

When the majority of high-energy physics experiments moved from using incident beams that were "naturally" produced by cosmic rays, to beams created by high-energy particle accelerators, a symbiotic relationship was formed between the available accelerator parameters and the experiments that could be performed at the end of external fixed-target beamlines or in interaction regions within the accelerator itself. When designing a new accelerator, the physics community must carefully interweave state-of-the-art accelerator technology, existing experimental data, theoretical predictions, cutting-edge detector techniques, and ever-increasing demands for computing power into a tailored tapestry that will define the topography of the subsequent physics options. Consequently, the design decisions made early-on in the process of giving birth to a new machine are of fundamental importance to the direction of a laboratory like Fermilab.

The workshop was one of the most important in the 20-year history of Fermilab. Since 1985, the future of Fermilab has been intimately tied to the possibility of siting of the Superconducting Super Collider (SSC) in Illinois. With the recent siting of the SSC in Texas, Fermilab must now hammer out a unique identity in support of, but ultimately separate from, the new SSC Laboratory. This scenario created a high level of expectation at the workshop and a boundary-pushing intensity that was eloquently reflected in the quote from Einstein which hung on the wall of the workshop computing room: "Great spirits have always encountered violent opposition from the mediocre minds." As many workshop participants labored long into the night in the computing room, there was often a waiting line for access to one of the 40 terminals which were part of a local VAX cluster totaling 27 MIPS of computing power.

In the workshop, participants addressed the physics that could be carried out over the next decade given the fact that Fermilab's Tevatron (at 2 TeV in the center of mass) will remain the world's highest energy accelerator well into the next decade. With the contemplated upgrade in luminosity, data samples of 100 inverse picobarns (and possibly 1000 inverse picobarns) will become a reality. There will
be two large collider detectors, feeding on that unique data stream. With the goal of exploring the mass region beyond the W and Z and below that reached by the SSC in the collider mode, Fermilab has begun to define this new identity by proposing a three-phase upgrade of which the first phase (the Linac Upgrade) is already under way. In mid-May, interested physicists came together at Fermilab to study the second phase of the upgrade, called the Main Injector, in a workshop on physics at the Main Injector. The Main Injector will be located in a sub-surface enclosure separate from the Main Ring tunnel and is a 120-GeV, large-aperture, rapid-cycling proton synchrotron designed specifically to address the limitations inherent in the Main Ring when using it for Collider operations. The combination of the Linac Upgrade and the Main Injector will provide a factor of two more flux than is currently available, and most importantly, a luminosity increase to 5 x 10^{31} cm^{-2} sec^{-1} for the Collider. Increased luminosity is crucially important because when multiplied by the cross section for a given reaction, it gives the average number of events per second for that reaction. The increased intensity of the Main Injector will allow higher mass regions to be explored by Fermilab Collider experiments.

Another important feature of the Main Injector is the ability to extract 120-GeV protons to the fixed-target experimental areas simultaneously with Collider operations. This means that Fermilab will now have particle beams available year round. The Main Injector Workshop focused on the types of fixed-target physics that could be done with this higher intensity beam, including high-sensitivity K^0_L decays, high-flux neutrino and pbar initiated processes, and detector and beamline design requirements. The Breckenridge Workshop was the next logical step because it more fully defined the future fixed-target and colliding-beams physics options that will be available with the Main Injector. Another topic that received some lively discussion was a “Dedicated Collider” proposal using 6.6-8.6 tesla superconducting magnets, yielding a center-of-mass energy of 6-8 TeV, depending on the magnetic field strength. This machine, called the LINCOLN (Large Independent Collider Nearby) would be a possible step beyond the Main Injector.

Emerging from the working group summaries was a multidimensional framework within which the upgraded accelerator and physics options at Fermilab could be defined during the next decade and beyond. Of major importance was clearly identifying the most pressing theoretical issues in the 1990s, the tell-tale signatures of those effects, as well as the methods for unambiguously detecting these low-cross-section events and extracting them from a background of stable but less interesting physics. In his workshop summary, Jonathan Rosner (Chicago) described an exciting menu of physics topics that emerged from workshop discussions, in-
cluding studies on W, Z radiative corrections, new electroweak tests, precise measurements of sin^2θ_W, quark mixing parameters, and CP violation measurements.

The summary sessions began with Mitchell Golden (Fermilab) and Keith Ellis (Fermilab) laying out the theoretical geography of physics with the Main Injector and beyond. With the theoretical issues out on the table, discussions then moved to defining the myriad physics options made possible with a higher intensity and luminosity upgraded machine. There were some common questions which provided a focus for all the reports that were given. For example, what types of physics can be done only with the Main Injector? How can experiments accumulate large data samples with good statistics given the allowable parameters? What are the significant background problems and how can these be addressed? Are there other ways to measure an effect which give better resolution using a more cost effective detector design? Can more than one measurement be made in one detector? Can more than one experiment use the same detector to obtain different measurements? One of the main goals of the working groups studying future physics options was to take questions like these and look deeply into the realities of experimental design, given the parameters of the proposed machine.

One topic of major interest was future charm and B-physics experiments in both the fixed-target and Collider modes. Joel Butler (Fermilab) showed that, currently, fixed-target experiments dominate measurements of the lifetimes of charmed particles and are quite competitive with e^+e^- colliders for both rare decay modes and heavier charm states like the D^{**}. His conclusion was that charm physics is still a viable route and that Fermilab experiments are quite competitive.

In the fixed-target beauty sector, the first high-sensitivity B experiments will begin taking data in the upcoming run. A key to future fixed-target B-physics at Fermilab involves the low signal-to-background ratio obtainable compared to e^+e^- and even high-energy hadron colliders. Because the available fixed-target "luminosity" is so high (1 x 10^{34}), the potentially large yields are tantalizing even though they are difficult to pull out of such high backgrounds. The answer that emerged is that continued and increased work on detector technology, triggering strategies, data acquisition speed and capacity, and data analysis capability is necessary. Interaction rates of order 100 MHz are expected, with a goal of examining 1 million tagged beauty events in an open geometry, yielding 10,000 fully reconstructed B's.

In his summary talk, Carl Haber (LBL) discussed two approaches to B-physics in the Collider mode. The first approach uses the existing Collider Detector at Fermilab and D0 detectors ("high-P_T" experiments) which can study B's produced on the tail of the B spectrum. The second approach is a proposed Bottom Collider Detector (BCD), a large-acceptance spectrometer designed to take advantage of the
total B cross section for a broad study of B-physics, especially CP violation in the B system.

The working group summary on symmetry violations and rare decays was given by Bruce Winstein (Chicago) who summarized papers given at the workshop on rare K decays (Y.W. Wah· Chicago), e'/e Fermilab E-731 (B. Hsuing), K_{L}^0 → \mu e BNL E-845 (H. Greenlee), K_{L}^0 → \mu e KEK E-137 (T. Skinkaura) and CP at LEAR (J. Fry). An important point in this area centered on detector issues and the need for more development work in the areas of sophisticated Transition Radiation Detectors, EM Calorimetry (BaF2, CsI, PbF2 fibers), and high-rate wire chambers. Positive solutions to envisioned problems in future CP violation experiments were enhanced by the collaborative work done at the workshop between the CP violation working group and the detector working group.

There was much discussion about the place of fixed-target experiments at Fermilab in the light of the demand for SSC test beams and in an increasingly Collider-oriented environment. The sentiment of many workshop participants was that fewer, more carefully chosen fixed-target experiments should be approved and run, with the full resources of the fixed-target program being brought to bear on them. This approach would decrease the total time needed to bring an experiment from the proposal stage to the completion of data analysis.

In closing the workshop, Fermilab’s Director, John Peoples, re-affirmed the wide variety of physics possibilities available and Fermilab’s desire to carry out a finely focused, intensive assault on the most promising physics topics. He also re-affirmed the need for the next logical step in this process, the Main Injector.

The proceedings of the workshop will be published by World Scientific later this year.