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Report from Fermilab

for the

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The excitement of record-setting current operations and the roller-coaster ride of funding and the future program at Fermilab is palpable. First, let's look at the physics program. It is nice to note that three of the ten best physics news stories of 2007 as cited the by the American Institute of Physics are part of the Fermilab program (Tevatron collider, MiniBooNE, and the Pierre Auger Observatory).

The Fermilab accelerators are setting records regularly, both for the Tevatron collider program and the Main Injector (MI) and Booster neutrino programs. The particle astrophysics program is also achieving acclaim for its productivity.

A sample of the accelerator records includes:

Highest initial luminosity – 3.18 x 10^{32} cm^{-2} sec^{-1} (July 5, 2008)
  Record at end of FY 2007 – 2.92 x 10^{32} cm^{-2} sec^{-1} (February 25, 2007)
Highest delivered luminosity for one week – 57.1 pb^{-1} (June 30, 2008)
  Record at end of FY 2007 – 44.8 pb^{-1}(January 7, 2007)
Highest integrated luminosity in one month – 221 pb^{-1} (May, 2008)
  Record at end of FY 2007 – 167 pb^{-1} (January, 2007)
Highest number of antiprotons accumulated in an hour – 27 x 10^{10} (June 3, 2008)
  Record at end of FY 2007 – 23 x 10^{10} (March 23, 2007)
Highest number of antiprotons accumulated in a week – 3460 x 10^{10} (July 6, 2008)
  Record at end of FY 2007 – 2807 x 10^{10} (March 3, 2007)
Highest typical protons per pulse for the NuMI neutrino beam – 3.1 x 10^{13} protons per pulse with p_bar production (May 19, 2008), 3.7 x 10^{13} when alone (May 19, 2008)
  Record at end of FY 2007 – 3.35 x 10^{13}, when alone (July 9, 2007)
Highest number of 120 GeV protons on target in a week for NuMI neutrino beam – 7.23 x 10^{18} at an average power on target of 234 KW (May 19, 2008)
  Record at end of FY 2007 – 5.68 x 10^{18} (October 23, 2006)
Highest number of 8 GeV protons on target in a week for the Booster Neutrino Beam – 1.16 x 10^{19} (June 30, 2008)
  Record at end of FY 2007 – 1.13 x 10^{19} (August 27, 2006)
Highest number of 8 GeV protons on target in a month for the Booster Neutrino Beam – 4.3 x 10^{19} (June 30, 2008)
  Record at end of FY 2007 – 3.9 x 10^{19} (March, 2005)

The dates for these records are quite recent, only because records are falling with regularity these days. The achievements have been made possible by good reliability of the many machines contributing to each capability, attention to optimized and stable orbits, shorter set-up times, and for the collider and NuMI neutrino programs, newly implemented operation in mixed mode, with slip-stacking of two Booster batches for antiproton production and nine batches for the NuMI beamline.

The total integrated luminosity delivered to each of the two Tevatron collider experiments, CDF and DZero, is now almost four and a half inverse femtobarns, already nearly the so-called base projection made for running through 2009. The total protons-on-target for NuMI is now 4.19 x 10^{20}, and for the Booster Neutrino Beam (running in both neutrino and antineutrino modes) is 11.1 x 10^{20}.

The experiments are making excellent use of the delivered beams. Each year, the two collider experiments have had about 70 PhD theses granted, about 90 physics-result publications in the major refereed journals, and very large numbers of presentations at conferences and workshops – among all this output some of the most cited results, including new observations (measurements of B_s mixing, new bottom baryons, discovery of WZ production, and evidence for single top-quark production) and more precise measurements of fundamental parameters (top-quark mass and W-boson mass and width). Sensitivities to New Physics such as Higgs and SUSY particles have been improving, relative to earlier results, even faster than projected sensitivities based on the amount of data collected. Improved analysis techniques and the addition of new search channels have both played important roles in this achievement.

In neutrino physics, there are three running experiments: SciBooNE and MiniBooNE in the Booster Neutrino Beam, and MINOS in the NuMI beam. SciBooNE has just achieved its desired goal of receiving 2 x 10^{20} protons on target for the combination of neutrino and antineutrino production. The experiment will complete its run August 18, 2008. It is measuring cross sections at energies specially relevant for understanding backgrounds at the future T2K neutrino-oscillation experiment in Japan. The MiniBooNE experiment demonstrated that the signal reported by the LSND experiment at Los Alamos National Laboratory cannot be explained as a simple neutrino oscillation effect – since MiniBooNE did not observe the LSND-projected signal at the same energy divided by distance as at LSND. MiniBooNE did observe an excess of events at low energy which is still unexplained and remains under investigation. MiniBooNE is also measuring cross sections. MINOS is observing higher-energy neutrino oscillations by comparing rates in a detector in the Soudan Mine in Minnesota to those in a near detector, measuring the atmospheric-neutrino oscillation parameters with precision. MINOS also searched for evidence of sterile neutrinos by comparison of neutral-current-like events in the two detectors. No evidence for sterile neutrinos was found. Finally, the MINERvA experiment has received DOE construction funding starting this year, and will measure higher energy neutrino cross sections relevant for oscillation experiments using the NuMI beam, MINOS, NOvA, and DUSEL.

In particle astrophysics, the Sloan Digital Sky Survey continues to be immensely successful in its output. Its annual results have led again to its being recognized as the “most cited astrophysics observatory” in the world. Two experiments with strong Fermilab participation, the Pierre

Auger Observatory and the Chicagoland Observatory for Underground Particle Physics (COUPP) have important and popularized results appearing in “Science” this year. Auger reported measurement of anisotropy in the distribution of ultra-high cosmic rays, and their apparent origin in active galactic nuclei. COUPP was cited for resurrecting the bubble chamber technique in a new way in pursuit of the search the direct observation of dark matter. In its engineering run underground at Fermilab, COUPP pushed the search for dark matter via spin-dependent interactions to higher sensitivity for low-mass WIMPS. Fermilab’s other dark-matter search-experiment, the Cryogenic Dark Matter Search (CDMS) regained the sensitivity lead in searching for WIMPs above 40 GeV in mass. A quick axion search experiment, GammeV, published a null result, closing the last possible open window in parameter space suggested by an earlier PVLAS experiment observation.

As part of its participation in this broad range of physics research, the Laboratory has had the underpinning of very strong groups in particle theory and in astroparticle theory. These groups have helped the Laboratory and its users in both the ongoing programs and in investigating and choosing directions for the future. Both theory groups continue to have very active visitor programs to enhance the depth of local discussions and the amount of physics output. Typically, there are some 75 theory papers per year in refereed journals with at least one Fermilab staff theorist author.

Fermilab is the home institution for the US CMS collaboration. The Laboratory has developed an LHC Physics Center and a Remote Operations Center as part of its participation in LHC physics. These facilities and organizations will provide US scientists a location for concentrated effort on CMS, a critical mass of people and expertise to help university groups maximize their contributions to CMS physics, and to keep Fermilab involved directly in the Energy Frontier for the future. Similarly, Fermilab remains the most likely US site for an ILC should it be built in the US, and is continuing to build its superconducting rf and other infrastructure to be a major player in a future such machine. In the meantime, Fermilab is developing plans for Project X, a new 8 GeV superconducting linac which will allow the Laboratory to strengthen its program at the Intensity Frontier, both for neutrinos and for beams of hadrons and muons.

In pursuit of understanding current developments in particle physics and the definition of its future, Fermilab has been host to many conferences and workshops. These include the Hadron Collider Physics Workshop, a Workshop on Polarization in the Cosmic Microwave Background, one workshop on the Project X accelerator, and three workshops on the Physics of Project X. In the area of science and technology, the Laboratory has had recently and will soon have workshops on topics as varied as the ILC, pixel detectors, and materials used in superconducting rf devices. The Laboratory has also hosted multi-week schools dedicated to hadron collider physics, neutrino physics, and ILC accelerator physics.

Physics from previous fixed-target runs of particular interest to readers of the Newsletter of the APS Topical Group on Hadronic Physics include recent results from the FOCUS, HyperCP, KTeV, NuTeV, and SELEX experiments, all of which continue to publish new results. Both HyperCP and KTeV have just completed the final results on their flagship measurements, the hyperon CP asymmetry measurement and the kaon epsilon prime over epsilon, respectively. There are 16 new papers submitted or just published from these experiments.

The total number of PhD theses using data from Fermilab-related experiments and listed in the program of the Annual Fermilab Users Meeting, was 150. This is a large fraction of the physics PhD's granted per year.

At the same time as all this physics output has been occurring, it has been an up-and-down year for funding. Fiscal year 2008 began with increases in the anticipated budget, based on both the President's proposal and actions in Congress. Then, the omnibus budget bill cut Fermilab funding by $52 million and prevented the start of construction on NOvA, the next-generation, off-axis neutrino oscillation experiment. Fermilab also had to stop virtually all work on the R&D for the International Linear Collider. Furthermore, the funding level required all staff to take unpaid leave (furloughs amounting to a 12% salary reduction for 8 months) and a nearly 200-person reduction in staff. Halfway through the furlough program, a generous, anonymous gift to the University of Chicago allowed the Laboratory to terminate the program. On June 30, the President signed into law a supplemental funding bill that goes far to restoring Fermilab funds. It will allow resumption of work on NOvA. Moreover no involuntary staff reductions will be necessary – although the size of the staff has already been reduced by about 6% due to voluntary departures.

Fermilab is facing a redefinition of itself as the LHC prepares to wear the mantle as the world's highest energy accelerator. Fermilab is now operated for the Department of Energy by the Fermi Research Alliance, a joint effort of the University of Chicago and URA, the former operator of the Laboratory. Also, Fermilab is now the only US national laboratory dedicated to particle physics. In this era of change, Fermilab sees itself in the future continuing to play a leadership role at the Energy Frontier, one of the three frontier areas identified by the DOE-NSF Particle Physics Project Prioritization Panel (P5): the Energy Frontier, the Intensity Frontier, and the Cosmic Frontier. In fact, Fermilab anticipates being a leader in all three Frontiers. Fermilab has had a significant role in building the LHC and the CMS experiment, and considers this program to be very important in its future. Fermilab's contributions to ILC R&D and the Laboratory's developing expertise in superconducting rf will position it to play as large a role as funding and siting of the ILC allow. As for the Intensity Frontier, Fermilab is already supplying the world's most intense neutrino beams. Staged increases in proton flux, leading to that available with the Project X linear accelerator, will allow Fermilab to continue to be a leader in this line of research for neutrinos, and also provide capability for the most intense beams of pions, kaons, and muons. The Cosmic Frontier has been explored at Fermilab for decades, the Laboratory having had the first particle astrophysics groups at any national laboratory. This will continue in the future with new projects, including the Dark Energy Survey, an experiment based on a new camera built at Fermilab and operated at the Cerro Tololo Inter-American Observatory in Chile, and participation in the SNAP experiment, candidate for the DOE-NASA Joint Dark Energy Mission.

Thus, Fermilab will continue to contribute to the directions that remain the most opportune to increase our understanding of fundamental physics and will remain one of the most exciting places to pursue particle physics research.