High Energy Physics Advisory Panel
Special Called Meeting
October 26, 2010
Hilton Hotel and Conference Center
Rockville, Maryland

HEPAP members present:

Daniel Akerib
Marina Artuso
Edward Blucher
Raymond Brock
Andrew Cohen
Lance Dixon
Bonnie Fleming
Graciela Gelmini
Douglas Glenzinski
Donald Hartill
Stuart Henderson
Steven Kettell
Wim Leemans
Regina Rameika
Ian Shipsey
Kate Scholberg
Melvyn Shochet, Chair
Henry Sobel
William Trischuk
Herman White

HEPAP members absent:

Hiroaki Aihara
Patricia Burchat
Daniel Marlow
Ann Nelson
Paris Sphicas

Also participating:

Dante Amidei, Physics Department, University of Michigan
Charles Baltay, Department of Physics, Yale University
William Brinkman, Director, Office of Science, USDOE
Robert N. Cahn, Physics Division, Lawrence Berkeley National Laboratory
Glenn Crawford, HEPAP Designated Federal Officer, Office of High Energy Physics, Office of Science, USDOE
Joseph Dehmer, Director, Division of Physics, National Science Foundation
Gary Feldman, Department of Physics, Harvard University
Thomas Ferbel, Department of Physics and Astronomy, University of Rochester
Richard Gaitskell, Department of Physics, Brown University; DUSEL Users Group
Nicholas Hadley, Physics Department, University of Maryland
Young-Kee Kim, Deputy Director, Fermi National Accelerator Laboratory
John Kogut, HEPAP Executive Secretary, Office of High Energy Physics, Office of Science, USDOE
Dennis Kovar, Acting Associate Director, Office of High Energy Physics, Office of Science, USDOE
Donna Nevels, Oak Ridge Institute for Science and Education
Piermaria Oddone, Director, Fermi National Accelerator Laboratory
Frederick O'Hara, HEPAP Recording Secretary, Oak Ridge Institute for Science and Education
Alan Stone, Office of High Energy Physics, Office of Science, USDOE

About 85 others were in attendance.

The chair, **Melvyn Shochet**, called the meeting to order at 9:00 a.m. **Charles Baltay** was asked to present the report of the Particle Physics Project Prioritization Panel (P5) Subpanel, which had been asked about the desirability of extending the Tevatron run at Fermilab past the presently scheduled turnoff at the end of 2011.

P5 examined its 2008 plan and reaffirmed it as the best way forward for the field of high-energy physics. However, a new opportunity has presented itself. The Collider Detector at Fermilab (CDF) and the Collider Detector at D0 Interaction Region (D0) have performed extremely well in the past 2 years. They are now in play in the Higgs game. Their sensitivity (95% exclusion) has excluded a mass region from 158 to 175 GeV/c^2. Of interest now is the range from 115 to 158 GeV. The region below 135 GeV is very interesting; there, $b\bar{b}$ is the favored decay mode. Above 135 GeV, the WW mode dominates.

Typically, 85% of the luminosity of the Tevatron is usable in Higgs searching. If there is an extension, the Higgs sensitivity would be above 3σ in the region of interest. That is why the extra running is worth doing.

The largest branching fraction, and therefore the best decay mode at the Tevatron, for a light Higgs in the most likely mass range of 115 to 135 GeV, is $b\bar{b}$. An observation of the Higgs-to-$b\bar{b}$ decay would provide information on the product of the Higgs production cross-section times its decay branching ratio. Comparing this with the Standard Model prediction would give an indication whether the Higgs is a Standard Model Higgs or something more complicated. (This is a check to make sure that one is dealing with a Standard Model Higgs.) The Tevatron's sensitivity is better than that of the large Hadron Collider (LHC) in the region of interest. The analysis techniques are increasing at the same time, so 16 fb^{-1} would give coverage of the region at the Tevatron.

A major question is what the LHC is going to do. It will accumulate 1 to 2.5 fb^{-1} by the end of 2011 when the machine will be shut down for the 14-TeV upgrade. It could run to 2012 to accumulate 5 fb^{-1}, but that would delay 14-TeV running by a year. Even then, the LHC could not rule out all the region of interest by 2012. To get down to 114 GeV takes 14 TeV, so that region will not be investigated until the 14-TeV upgrade of the LHC is complete. The two colliders complement each other in the low-mass region; the two colliders will explore the Higgs in different channels.

Extensions of the Standard Model suggest a more complicated Higgs structure. In many of these scenarios, the Higgs-to-γγ mode is suppressed while the dominant Higgs-to-$b\bar{b}$ decay mode is more robust. Such a suppression might delay the discovery via the γγ mode, which is the major channel at the LHC for a low-mass Higgs.

Eventually, after reaching 30 fb^{-1} at 14 TeV, the LHC will be able to clearly detect the Higgs-to-$b\bar{b}$ mode. This can be combined with the Tevatron measurements to yield an estimate of the energy dependence of the Higgs production cross-section. This will be another valuable check on the nature of the Higgs.

The Tevatron is a proton–antiproton collider, while the LHC is a proton–proton collider. The difference in accelerated particles makes a difference in what is measured, making the results of the two machines complementary.

An extended Tevatron run will provide more-precise measurements of the W and the top masses. The case rests on the Higgs, but, one way or the other, CDF and D0 will produce a rich mix of new physics. The price tag would be $35 million per year. P5 looked at where $35 million could be cut out of the planned program (LHC, International Linear Collider and accelerator R&D, neutrino program, muon to electron conversion, proton decay, dark matter, and dark energy) and could not find any place to make such a cut.

What would be the impact on Fermilab? Some of the costs of the Tevatron extension can be taken from Fermilab by "belt tightening" by delaying the muon-to-electron experiment by 6 months and delaying the intensity upgrade (from 400 kW to 700 kW) for NOνA [the NuMI Off-Axis ν_e Appearance experiment]. This is not so much a fiscal issue because the Recycler needs to be converted to protons for 700-kW operation. It cannot happen while the Recycler is running with antiprotons for the Tevatron. This mode of operation will reduce the protons on target for NOνA for its first 3 years.

P5 therefore recommends that the agencies proceed with a 3-year extension of the Tevatron program if the resources required to support such an extension become available in addition to the present funding for HEP. Given the strong physics case, it encourages the funding agencies to try to find the needed

additional resources. Coming back to the hit on NOνA, P5 felt that Fermilab should explore the possibility of increasing the proton intensity beyond 400 kW without refitting the Recycler and increasing the detector target mass beyond 14 kt. (The detector hall is large enough to accommodate 18 kilotons.) Given the importance of neutrino physics, which is the heart of the future Intensity Frontier program at Fermilab, P5 recommends that Fermilab make a strong effort to minimize the impact of an extended Tevatron run on the NOνA experiment.

The report is unanimously supported by the P5 subpanel.

Additional issues were also addressed. Refitting of the Recycler from antiprotons to protons would be delayed from 2012 to 2015. This is independent of funding. There is also a hit on the MicroBooNE [Booster Neutrino Experiment]. NOνA would run for 3 years at 400 kW instead of 700 kW. The shutdown to achieve 700 kW would occur in FY15 (when the detector is complete) instead of in FY12 (when a only a small fraction of the detector is complete). The delay in reaching full equivalent sensitivity is 2 years. After early running, in 2015, half the planned integrated protons would be on target. Between 2015 and 2018, the integrated number of protons on target would be decreased, affecting NOνA's sensitivity. It may be possible to increase the proton intensity beyond 400 kW without refitting the Recycler and without great expense. There may be some unused NOνA contingency funds that could be used for increasing the detector target mass beyond 14 kt.

If an LHC run were extended through 2012, the LHC might discover a Higgs or find evidence for a light-mass Higgs or exclude a Higgs in the interesting mass region sooner by relying on the $\gamma\gamma$ mode at the lowest masses. Such an extended run would delay running at 14 TeV by a year, so the LHC would see Higgs-to-$b\bar{b}$ decay a year later. This would give the Tevatron a possibility of doing something clever during this time frame. Funding for university groups is included in the $35-million estimated cost. Federal funding is governed by an annual cycle, and the program is reevaluated annually as a matter of course.

Akerib asked what Higgs physics would look like if the Tevatron run were not extended. Baltay replied that it would be what the LHC program is expected to be. If the $\gamma\gamma$ mode is not suppressed, there might be discovery of that. A 5σ discovery would not come until they get to 14 GeV, and the $b\bar{b}$ mode would likely not be explored until 30 fb^{-1}. In a sense, the LHC will do most of it; it is the Higgs machine. But the Tevatron could discern a 3σ bump a year or two sooner, and the LHC would get to confirm it, and the Tevatron would get a piece of the action.

Scholberg asked if the recommendation were all-or-nothing or might there be a partial use of resources. Baltay responded that P5 talked about this issue. There is an infinite number of possibilities between zero and $35 million. How much is budgeted will be an agency decision. If it is close to the $35 million, they should go ahead; if it is close to zero, they should not.

Artuso asked what other effects there would be on other U.S. experiments. Baltay answered that NOνA would be affected. MicroBooNE would also be affected because the accelerator would be upgraded to increase the intensity to NOνA. At worst, it could delay the program by 1 year. There is money in the $35 million for support of postdocs to mitigate other effects on the field. However, running the Tevatron for several more years is very attractive.

Blucher asked Baltay if he meant to say that, if additional funds are not available, the extension should not be done. Baltay replied, yes.

Fleming asked if the additional resources for people were for extended Tevatron running or for mitigating the slower transition from the Tevatron to the LHC. Baltay replied, some of each. It would depend on the migration pattern.

Cohen asked what the cost would be for increasing the mass of the NOνA detector. Baltay answered that the Subpanel was not told that amount. The question was referred to Kim, and she deferred to Feldman. The experiment is currently in the middle of being built. It is 60% obligated and 30% spent. It is anticipated that 14 kt will be delivered; 15 kt is within the contingency. Going to 18 kt would require $30 million more. Doing what is being recommended here would cost an additional $20 to $30 million.

Cohen asked, if in the third year something were found, whether the Tevatron run would be continued some more. Baltay responded that the LHC would take off like a rocket by that time, and the Tevatron would be outclassed.

Gelmini asked if the European collaborations would continue. Baltay replied in the affirmative. Letters of intent and commitment have been signed. There is a large enough group to keep the detectors running. Enthusiasm is high; this is the biggest question in physics today.

Shipsey stated that the Higgs is one of the biggest questions mankind has ever posed. It is the origin of mass. The electron's mass determines the radii of the electron shells. If there were no mass, there would be no atoms or nuclei. This is central to the understanding of the universe. To make progress on dark matter and dark energy, one must understand the Higgs first. D0 and CDF have discovered a massive amount of science. These experiments have been supported since the 1980s, and have been upgraded recently. The summit is almost in sight. But it is not just being first to the summit that matters. The mountain has more than one summit. Different teams may get to different summits first, coming to a better understanding of the mountain.

Brock asked how much of the $35 million would go to university groups. Oddone said that about $10 million or 50 new positions would be funded out of the $35 million.

The floor was opened to public comment.

Hadley noted that, from 1970 to 1990, theory and experiments did not converge until the top quark was discovered. The same will be true with the Higgs.

Fleming asked if the impact on the muon g-2 experiment had been considered by P5. Baltay responded, no.

Amidei noted that the Higgs hunt is a background-dominated process and that, without the Tevatron, it would be difficult to tell if the sensitivity or the interpretation of the $\gamma\gamma$ mode were off. The Tevatron's complementarity would be very helpful.

Akerib said that he would be happy to learn more about the $b\bar{b}$ sensitivity at the LHC. Shochet responded that that is relatively new but is seen as difficult but possible to be done at the LHC.

Amidei suggested appealing to history and asking "what would Chadwick do?" Chadwick discovered the neutron, searching for an answer for 12 years. Joliot and Curie's paper in 1931 showed how to pin down the neutron. Chadwick could have deferred exploiting this opportunity because of his administrative duties, but he came in early every morning and stayed late every evening after doing his administrative chores. In three weeks, he solved the question of the neutron.

Glenzinski pointed out that, in 2007, the sensitivity of the Tevatron was much lower, and the uncertainty about discovering the Higgs was much higher.

Cahn asked how one would know that the additional $35 million would be in the FY13 and FY14 budgets.

Ferbel noted that the P5 Subpanel had emphasized the $35 million per year. There will be pressure on Oddone to squeeze it into his program at Fermilab. The program is at its peak and very attractive to scientists, young and old.

Gaitskell asked if the Subpanel had considered how brittle the proposal is (i.e., how sensitive to lesser funding). Putting such a brittle object in the budget is a great risk. Baltay acknowledged that there are a lot of uncertainties, but P5 felt that the risk was worth it.

Cahn asked again what would happen if a budget was received back in FY13 that was $35 million less than the FY12 budget. Baltay said that one needs to face the issues when they come. From the current vantage point, this is a good risk.

Feldman said that NOνA is the flagship experiment in the U.S. accelerator program. It fell behind by a year because of the 2007 Omnibus Funding Bill. With ARRA [American Recovery and Reinvestment Act] funds, the program was accelerated a bit and is conserving its contingency funds. Complementary experiments had delays in their programs. The complementary reactor experiments will be reporting data as will the Tokai-to-Kamioka (T2K) experiment. A 60% increase in data at the Tevatron would be significant. The provision of those data is the physics concern. There are also intangible effects to be

considered: Europeans do not consider the United States to be a reliable partner. Attracting personnel will be more difficult if the experiment is delayed.

Brock said that he was impressed with the overwhelming support that the high-energy-physics community has lent to this extension. The Tevatron is running like a Swiss watch, and the data analysis is highly developed. The future output is predictable. The complementarity of the Tevatron current output is important. This has to be done, but something else will probably have to be given up.

Artuso noted that there are three frontiers. There is the Higgs, but the most exciting work is proof of physics beyond the Standard Model. Baltay said that that is why P5 is protecting the other efforts.

Shochet asked for a vote on accepting the P5 report. There were 17 votes in favor of accepting the report and 1 against. The report was accepted, and the meeting was adjourned at 10:30 a.m.

Respectfully submitted,
Frederick M. O'Hara, Jr.
Recording Secretary
October 31, 2010

Corrected by
Melvyn Shochet
HEPAP Chairman
November 15, 2010

The minutes of the High Energy Physics Advisory Panel meeting held at the Hilton Hotel, Rockville, Maryland, on October 26, 2010, are certified to be an accurate representation of what occurred.

Signed by Melvyn Shochet, Chair of the High Energy Physics Advisory Panel on November 15, 2010.