August 31, 2010

Physics Advisory Committee Meeting

August 27, 2010

Comments and Recommendations

CHARGE

The PAC is asked to consider the physics value of extending the current Collider Run. Is there an unassailable argument for doing so?

Please consider two funding scenarios in making a recommendation:
1) No additional funding to Fermilab for the added costs of an extension; and
2) Additional funding of about $150 M over three years to limit delays in future projects at the Laboratory.

The physics results of the NuMI program would be delayed by an extension of the Collider Run. What can be said about such a delay in the context of likely developments in neutrino experiments around the world?

Overview

The Fermilab Physics Advisory Committee (PAC) first considered the question of the extension of the current Tevatron run at the June 2010 Aspen meeting. The Committee considered it to be an exciting and compelling physics opportunity, but did not make a recommendation at that time. More information was requested on the issue as well as details on the impact on the Laboratory and other experiments. The Committee thanks the proponents and others for their comprehensive responses.

Comments

Understanding the mechanism of electroweak symmetry breaking is the most important issue in High Energy Physics and is the primary motivation for the Tevatron run extension. Observation and measurement of the properties of the Higgs boson are longstanding key objectives. An extension of the Tevatron run can add important information that is complementary to what will be obtained at the LHC over a similar time frame. Since physics beyond the Standard Model (SM) may influence the production and decays of the Higgs boson, it is crucial to observe as many of its properties as possible. This opportunity has arisen due to the excellent performance of the Tevatron Collider and the CDF and DØ detectors as well as remarkable improvements in the data analysis by the detector collaborations and a consequent extended physics reach of this program.

Based on current understanding, and plans for further data analysis improvements, extending the Tevatron run for three years to obtain a delivered luminosity approaching 20 fb^{-1} would give 3σ or better combined CDF-DØ sensitivity[1] to a Standard Model Higgs boson over the full mass region favored by electroweak precision measurements: m_h = 115 – 158 GeV (with the most probable value being 120 GeV). Within this favored range, CDF and DØ have demonstrated that the mass of the Higgs boson could be determined with precision better than 10% for m_h < 130 GeV. Furthermore, in the SM a low-mass Higgs boson decays almost exclusively to a bottom quark and antiquark pair and the Tevatron experiments could provide evidence for the light Higgs in this channel. This would be complementary to the LHC where observation of a light Higgs is expected first in the $\gamma\gamma$ final state. Observing the Higgs boson in the bottom quark and antiquark decay channel would provide an essential contribution to our understanding of the electroweak symmetry breaking sector. In addition, as Higgs to bottom quark and antiquark is identified in association with a gauge boson, observation of this process is a demonstration that the Higgs couples to electroweak gauge bosons. If evidence for a low-mass Higgs boson were not found, then there would be a conflict with electroweak precision data that would indicate the existence of new physics.

A significance of a signal at the level of 3σ or more is the standard in the field for claiming evidence. If the Tevatron run were not extended, the sensitivity of the Tevatron experiments would remain below this threshold for the entire critical region of low Higgs mass (115 – 150 GeV), precluding the possibility of the experiments providing independent evidence of the Higgs boson in the important decay to bottom quark and antiquark.

In addition to this primary motivation, there are a number of exciting measurements that would be enabled by the extended run: the search for supersymmetric Higgs bosons at large $\tan\beta$, measurement of the forward-backward asymmetry of the top quark, and the di-muon charge asymmetry in neutral B decay, as well as further improvement in the measurement of the top-quark and W-boson masses. In all, the Tevatron boasts a very broad physics program that has the capability to foster numerous Ph.D. students.

The Committee considers this extension to be an exciting and compelling physics opportunity with potentially historic importance that is complementary to the LHC program, also with strong U.S. participation, and would significantly add to the worldwide knowledge of the electroweak symmetry breaking sector.

The Committee is very impressed by the studies done by the Tevatron experiments to quantify the sensitivity in Higgs searches over the extended run. Since the last PAC meeting in June 2010, the Tevatron experiments have updated their results based on 6 fb^{-1} of data, which were presented at ICHEP. Based on these results, the SM Higgs boson is

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[1]median of the sensitivity statistical distribution; see http://arXiv.org/pdf/0911.3930.

excluded at 95% CL in the mass range of 158 – 175 GeV compared to a 162 – 166 GeV exclusion range before ICHEP. The improvement in the result is more significant than one would expect based solely on the amount of additional data taken due to the improvements in the algorithms and addition of new decay channels. The observed result would have been possible only with an integrated luminosity of 8 fb^{-1} compared to 6 fb^{-1} if no improvements were made. This gives additional confidence that the collaborations' detailed projection of further improvements would yield the expected gain for the extended run.

The CDF and DØ collaborations performed careful studies of the effect of the detector degradation on the sensitivity of the Higgs searches. The main effect is due to radiation damage to the tracking systems. Both experiments have radiation-hard innermost silicon layers that mitigate the effects of radiation damage. Overall, the effect on the Higgs sensitivity is projected to be of the order of a few percent. The Tevatron collaborations also presented a detailed plan for improvements in the sensitivity of the Higgs-search analyses including modified triggers, optimized lepton identification, and improved multivariate techniques, as well as adding new search channels. Both the detector degradation effects and analysis improvements were incorporated in the sensitivity projections of each experiment.

The collaborations also presented results of surveys resulting in estimates of personnel for operations and physics analysis until 2014. The Committee is confident that there is enough committed manpower within the Tevatron collaborations to take advantage of the extended run.

The Committee considered the impact on the NuMI program and the consequences for neutrino physics knowledge in the relevant time period due to the proposed extension of the Tevatron run. NOνA has two capabilities that are unique among current experiments: (i) comparing oscillation parameters for neutrinos and anti-neutrinos in the disappearance channel, and (ii) if θ_{13} is large, determining the mass hierarchy for a significant fraction of the values of δ, the CP-violating phase, by comparing neutrinos and anti-neutrinos in the appearance channel. For large values of the angle θ_{13}, other experiments will likely dominate the discovery of this important physics parameter. With extended running of the Collider program the NOνA detector construction and operation remains on schedule, although the NuMI beam power will be limited to about 400 kW during Collider operation. The ramp up to 700 kW would be delayed until the Recycler Ring re-commissioning is accomplished. This would lead to a stretch-out of the NOνA Run-1 physics program by 1.5 years. The Committee understands there may be ways to mitigate this effect.

In addition, the extension of the Tevatron running will decrease the availability of scientists and other personnel for the Laboratory's longer-term projects such as the Long-Baseline Neutrino Experiment (LBNE), Mu2e, and Project X, which may therefore be slowed down in the short term. The Committee believes that these potential delays, which should be minimized as much as possible, are justified by the arising opportunity to provide unique information on the electroweak symmetry breaking.

Recommendation

The Committee strongly endorses the extension of the Tevatron run for three years during 2011–2014 under either funding scenario presented in the charge. The Committee is aware that the development of the future programs might be severely affected and projects delayed by the Collider run. The Committee recommends that efforts be made to mitigate the effects. While the Tevatron run extension would take advantage of a compelling opportunity, the long-term plans of the Laboratory and of the field, as outlined by the P5 report, should be pursued vigorously.