***Physics of Run II*, Excerpt from Physics Advisory Committee Comments and Recommendations, June 2003.**

C. *Physics with 2 fb^{-1}*

An integrated luminosity of 2 fb^{-1} corresponds to almost 20 times as much data as was collected in Run I. This will significantly sharpen our understanding of the Standard Model, and provide new possibilities in the search for new physics.

The top quark, discovered at the Tevatron in 1995, occupies a central role in Run II physics. The properties of the top quark will be more precisely measured, looking for any deviations from the predictions of the Standard Model. This includes measurements of the top-quark production cross section and the angular distribution of its decay products. An improved measurement of the top-quark mass is particularly interesting in the context of precision electroweak analyses (see below). The electroweak production of single top quarks via *t*-channel *W* exchange, $qb \rightarrow q't$, will be observed for the first time. This yields a direct measurement of $|V_{tb}|$ with an accuracy of 10%.

The top-quark mass, combined with a precision measurement of the *W* mass, yields a very sensitive test of the Standard Model. These measurements currently indicate that the Higgs boson is relatively light. However, the internal consistency of the precision electroweak data is marginal. The anticipated measurements, with an accuracy of $\delta M_W \sim 30$ MeV and $\delta m_t \sim 3$ GeV per experiment, might alleviate or exacerbate this tension, and will tighten the allowed range of the SM Higgs boson mass to an accuracy of about 45%.

An integrated luminosity of 2 fb^{-1} will yield many interesting results in *B* physics. Among the most important measurements is likely to be the rate of B_s mixing. This will allow the extraction of $|V_{td}|$ with about half its current uncertainty which, when combined with measured B_d mixing, provides a sensitive test of the CKM model of quark mixing. Even more interesting would be a limit on B_s mixing that is in conflict with the CKM model.

There will also be interesting measurements of basic QCD processes. The production of *B* and J/ψ mesons in Run I did not agree well with theoretical expectations. We hope to understand these discrepancies with much larger data sets, which will allow more detailed comparisons of theory and experiment. The production of jets will probe QCD at the highest energies available, and will test our understanding of parton distribution functions at large values of x_{BJ}.

In addition, we hope to find physics beyond the Standard Model. The Tevatron will be sensitive to new physics in the 100 - 1000 GeV range, a region that has not yet been explored. It is possible that extensions of the Standard-Model gauge group may be found, manifested in heavy *Z′* or *W′* gauge bosons. Rare *B* decays offer another avenue to search for new physics. Evidence could be found supporting the theory that our three-dimensional space is embedded in a space of larger dimensions. An attractive possibility is that nature is supersymmetric at the weak scale; Run II could reveal the superpartners of the known particles, including the particle responsible for the dark matter content of the universe. Any new physics that we uncover in Run II will be a major discovery that will change the landscape of particle physics and could have major implications for our understanding of the cosmos.

D. ***Physics Beyond 2 fb^{-1}***

Integrated luminosities beyond 2 fb^{-1} will allow us to further sharpen our understanding of the Standard Model, and to increase the sensitivity with which we probe for new physics. We do not know at exactly what energy this new physics might appear, so each additional fb^{-1} represents a new opportunity for a major discovery. Because the Committee is reconsidering the need for silicon vertex detector upgrades, the following discussion will be presented in terms of the *b*-tagging requirements of various physics analyses. When specific numbers are quoted, they are taken from the D0 studies summarized at this meeting.

Many Standard Model measurements do not require *b*-tagging. With 10 fb^{-1} of integrated luminosity, the *W* mass can be measured with an accuracy of $\delta M_W \sim 20$ MeV, and the top-quark mass can be measured in the dilepton mode with an accuracy of $\delta m_t \sim 2$ GeV per experiment. These two measurements combined will provide an indirect determination of the SM Higgs mass with an accuracy of about 30% per experiment. This approaches the accuracy with which the top-quark mass was indirectly determined by precision electroweak analyses prior to its discovery at the Tevatron.

In addition, many searches for new physics do not require *b*-tagging. The search for a *Z'* boson via its leptonic decay reaches 1 TeV per experiment with 10 fb^{-1} of integrated luminosity. The search for the supersymmetric partners of electroweak bosons via a trilepton signal can be improved significantly with increasing luminosity if these particles are relatively light. The supersymmetric partners of gluons and quarks may be sought via their decays to jets and leptons accompanied by large missing transverse energy.

With the exception of the dilepton signal discussed above, most top physics requires at least one *b*-tag in order to separate the signal from backgrounds. The top-quark mass will be measured with an accuracy comparable to or greater than that of the dilepton mode using the *W*+4 jet signal with one or two *b*-tags. Single-top production via *t*-channel *W* exchange requires a single *b*-tag, and yields an accuracy on $|V_{tb}|$ of 8% per experiment with 10 fb^{-1} of integrated luminosity. Supersymmetric models include particles whose decays result in final-state *b*-jets.

With more than 2 fb^{-1} it will also be possible to observe *s*-channel single-top production, $\overline{q q'} \rightarrow t\bar{b}$, which relies on two *b*-tags. This yields the most accurate measurement of $|V_{tb}|$, with an uncertainty of 6% per experiment with 10 fb^{-1}. Double *b*-tagging also yields the purest sample of $t\bar{t}$ events, with almost no background and the minimal combinatoric ambiguity.

The most prominent physics goal that requires two *b*-tags is the search for the Standard-Model Higgs boson via *Wh* or *Zh* with $h \rightarrow b\bar{b}$. As mentioned above, precision electroweak analyses indicate that the Higgs boson is relatively light; in addition, the minimal supersymmetric model requires $m_h < 135$ GeV. At the current lower bound on the Higgs mass, $m_h > 114.4$ GeV, and combining both experiments, a 3σ (5σ) signal requires 3.5 (10) fb^{-1} of integrated luminosity; m_h =130 GeV requires 10 (30) fb^{-1}. (These figures are presently under study by the collaborations.)

The minimal supersymmetric model has two Higgs doublets (with vacuum-expectation values v_1, v_2), which results in several Higgs bosons (h^0, H^0, A^0, $H^{\pm}$), some of which have enhanced coupling to the *b*-quark for large values of $\tan\beta = v_2/v_1$. If they are sufficiently light and $\tan\beta$ is sufficiently large ($4 < \tan\beta \leq 50$ is the most plausible range), these Higgs bosons may be observed using $gb \rightarrow hb$ with $h \rightarrow b\bar{b}$, which requires three *b*-tags. This search reached the LEP limit with $\tan\beta = 50$ in Run I, so Run II is entering unexplored territory. A supersymmetric Higgs boson (A^0) of mass 150 GeV can be excluded for $\tan\beta > 27$ with 10 fb^{-1} of integrated luminosity.

The search channels for the Standard-Model Higgs and the supersymmetric Higgs described above have much higher backgrounds at the LHC than at the Tevatron. Thus the Tevatron, with sufficient luminosity, could prove to be complementary to the LHC for low-mass Higgs sensitivity.