HIGGS PROSPECTS AT THE TEVATRON*

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Searching for the Higgs boson is one of the main physics aims for the CDF and DØ collaborations at the Tevatron collider and Run II should have the sensitivity to cover much of the parameter space favoured by electroweak fits. The search strategy at the Tevatron is highly constrained by the hadronic physics environment. For all the searches the ability to trigger on the decay of heavy vector bosons and accurate lepton identification are essential. In the case of a light Higgs (mass less then ~135 GeV) b-tagging is crucial in order to identify the Higgs. The Tevatron is currently taking data and results are presented from DØ and CDF which highlight the ability to identify the basic elements required for a successful Higgs search.

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1. Introduction

The search for the Higgs boson is one of the fundamental quests in modern particle physics and the Tevatron collider at Fermilab is in a unique position to contribute, being the only accelerator currently performing a direct search. There are various limits on the Higgs mass from both theory and experiment. The current experimental limits constrain the Higgs mass to be less than ~195 GeV at 95% confidence limit from χ^2 fits to electro-weak data and above ~114 GeV from the direct search at LEP [4].

2. Search strategies

At the Tevatron there are three primary production modes of interest for the Standard Model as shown in Fig. 1. The dominant process is gluon–gluon fusion. Roughly a factor of about 3 lower in cross-section are the other

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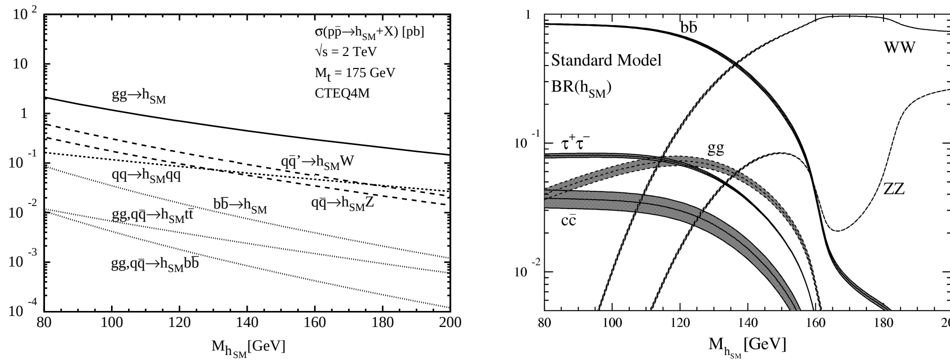


Fig. 1. Higgs production cross-section (left) and Higgs branching ratios. Cross-section for Higgs production at the Tevatron expressed in pb.

two, associated production of Higgs and Z boson or W boson. The branching ratios for the Higgs are shown in Fig. 1; for a light Higgs (mass less then $\sim$135 GeV) the decay is predominantly to $b\bar{b}$. For a heavier Higgs the decay is mainly to W W. This segments the search into two scenarios. The decay to $b\bar{b}$ implies that the gluon–gluon fusion mechanism cannot be exploited due to the large QCD dijet background. Hence one has to resort to the vector boson as a handle on the production and use the b-jets in order to identify the Higgs. For the heavier Higgs one can take advantage of the higher gluon–gluon fusion cross-section and reconstruct the Higgs from the decay of the two vector bosons.

An effective Higgs search at the Tevatron has to take into account the method of triggering the events as well as tackle the crucial offline analysis aspects. At the trigger level the requirements are good lepton identification and the ability to trigger on missing energy. Furthermore, on-line b-tagging is needed if one wants to use the hadronic decays of the Z and W for the light Higgs production. Major offline issues for light Higgs production are b-tagging, which is crucial to reduce backgrounds such as Z/W production with jets, as well as good dijet mass resolution in order to isolate the Higgs signal. Central to most channels is accurate lepton reconstruction for the leptonic decays of the W and Z.

3. Lessons from Run I

The CDF collaboration performed a search for the Standard Model Higgs boson in all the associated production channels using the Run I data set [1]. The results were expressed as an upper limit on Higgs boson production cross-section in this mode and were an order of magnitude above the Standard Model predictions. CDF also observed $Z \to b\bar{b}$ using 110 pb^{-1} from the Run I data set [5]. Observation of this decay channel is important for the Run II Higgs search due to its similarity with the light Higgs decay. It is a proof of principle, if one can see this decay then there is the potential for detecting the Higgs via the $b\bar{b}$ channel. This decay will also be used to calibrate the jet energy scale for b-jets and the tuning and understanding of the di-b-jet mass resolution. In order to exploit these factors and collect an enriched sample both Tevatron experiments have added secondary vertex triggers.

4. Tevatron and detector upgrades

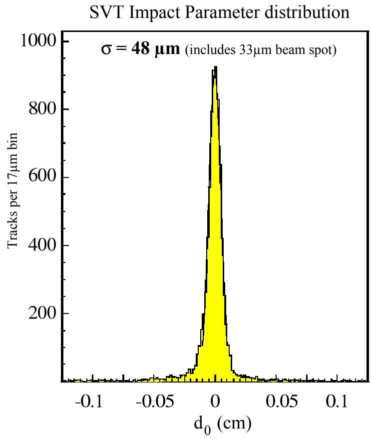
The Tevatron and the DØ and CDF detectors have undergone major upgrades in order to meet the Run II physics goals and to cope with the new Tevatron environment. The main Tevatron upgrades have been an increase in centre of mass energy from 1.8 to 1.96 TeV and an initial decrease in bunch spacing from 3500 to 396 ns. Eventually this will decrease to 132 ns. Furthermore, the instantaneous luminosity is set to increase from 0.16×10^{31} to 0.86×10^{32} cm^{-2}s^{-1} and eventually to 2×10^{32} cm^{-2}s^{-1}. After the first 2 fb^{-1} the instantaneous luminosity is planned to increase again to 5×10^{32} cm^{-2}s^{-1} which will yield approximately 5 fb^{-1} per year.

The DØ detector [2] has had significant upgrades to components relevant to Higgs searches. Most noticeably a 2 Tesla magnetic field has been added to take full advantage of the new Central Fibre Tracker and the addition of the Silicon Microstrip Tracker. The silicon system consists of six barrels composed of 4 layers of single and double sided silicon. In addition there are 16 physical disks for tracking and b-tagging in the forward region. The system is capable of 3D track reconstruction and b-tagging using secondary vertices out to $|\eta| < 3.0$. A secondary vertex trigger, using information from the barrels, will be operational toward the end of summer 2002. The muon detector has been upgraded to permit fast triggering on muons and has a coverage out to $|\eta| < 2.0$. Pre-showers have been added to improve electron identification and energy resolution.

The CDF collaboration [3] has replaced their silicon system used in Run I. The new system consists in 3 separate parts: layer 00 a single layer strip placed on the beam pipe, the SVX II consisting of 3 barrels of 5 layers of double sided silicon out to $|\eta| < 1.0$ and the ISL which adds an extra layer in the central and 2 layers between $1.0 < |\eta| < 2.0$. The whole system allows b-tagging from secondary vertices and 3D track reconstruction. Furthermore, the CDF Silicon Vertex Tracker (SVT) is operational and allows triggering on displaced vertices by track fitting and pattern recognition in the transverse plane. In order to increase lepton acceptance CDF has increased their muon system by 50% to $|\eta|$ of 1.5 and shower max strip wire chambers were added to increase electron purity in both the forward and the central region. The plug calorimeter was extended to cover $1.1 < |\eta| < 3.64$.

5. Recent results

Both detectors are currently taking data and have already demonstrated the capability to successfully reconstruct the objects needed for the Higgs search. Fig. 2 shows the distance of closest approach for tracks associated



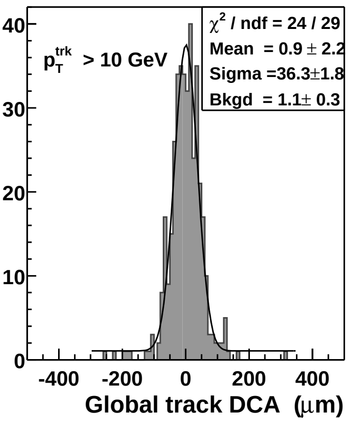
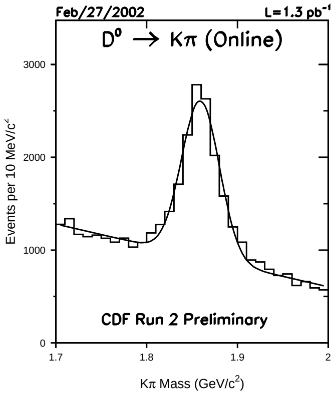


Fig. 2. Plots of distance of closest approach for CDF (left) and DØ (right).

with the primary vertex, the figure from CDF plotted directly from the SVT readout. Fig. 3 shows the capability for b-tagging, the CDF charm meson mass peak was selected and reconstructed using the information from the secondary vertex tracker. The plot from DØ shows the signed impact parameter significance, an excess of positive signed events is evident in this b-enriched sample. Lastly Fig. 4 shows reconstructed W and Z bosons from the two experiments.



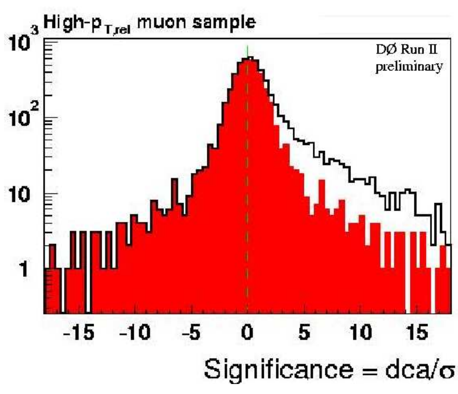


Fig. 3. b-tagging capabilities. Charm mass peak from CDF (left) and signed impact parameter plot from DØ .

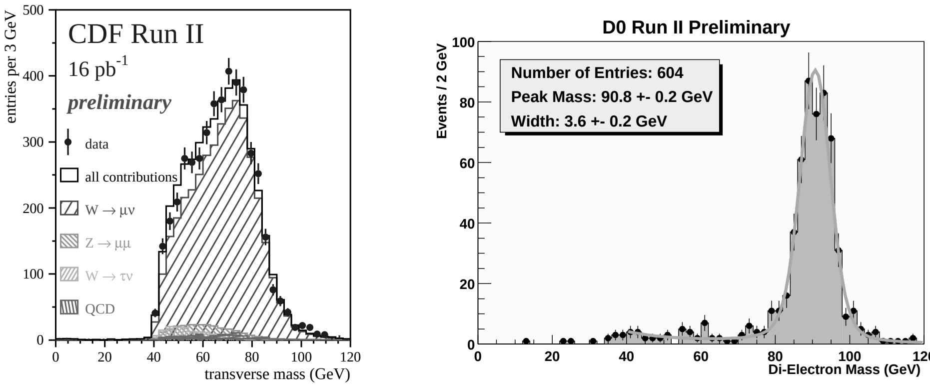


Fig. 4. Reconstruction of W and Z bosons from CDF and DØ .

6. Prospects

The best estimate for the sensitivity of Higgs searches at the Tevatron is still given by the results of the SUSY Higgs Workshop [1] shown in Fig. 5. The workshop used parametrised Monte Carlo, though jet and lepton identification was implemented at some level and extrapolations were made for the expected b-tagging efficiency and dijet mass resolution based on Run I experience. From the studies it is predicted that with 2 fb^{-1} per experiment the Tevatron can exclude at a 95% confidence level a Higgs mass up to 120 GeV. Furthermore, with 15 fb^{-1} per experiment an exclusion up to 180 GeV is possible which would eliminate most of the theoretically allowed region if there is no physics beyond the Standard Model. With the same luminosity a 3σ discovery up to 130 GeV and in the range 155–175 GeV can be obtained.

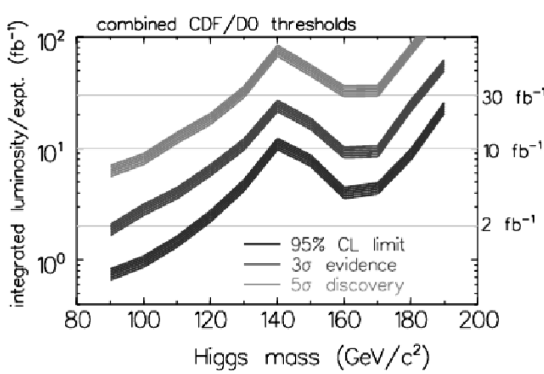


Fig. 5. Sensitivity of the Higgs search from SUSY Higgs workshop.

In conclusion the Tevatron is in a unique position to contribute to the search for the Higgs boson; both detectors are operational and are able to trigger on and reconstruct the basic elements needed for a successful search. A promising start to the quest for the Higgs boson at Fermilab during Run II has been made.

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