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Run II Extrapolation of CDF Results on a Search for Higgs Bosons Produced in Association with a Vector Boson Through $p\bar{p} \rightarrow V + H^0$ $(V = W, Z)$

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Run II Extrapolation of CDF Results on a Search for Higgs Bosons Produced in Association with a Vector Boson through $p\bar{p} \rightarrow V + H^0$ $(V = W, Z)$

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Abstract. CDF has recently published [1] a search for Higgs bosons produced in association with vector bosons in 91 ± 7 pb^{-1} of Run I data. Observations are consistent with background expectation. 95% confidence level upper limits are set as a function of the Higgs mass on $\sigma(p\bar{p} \rightarrow H^0 V) \cdot \beta$, with β the branching ratio of the Higgs decays to $b\bar{b}$ and $V = W, Z$. The sensitivity of the search is limited by statistics to a cross section approximately two orders of magnitude larger than the predicted cross section for standard model Higgs production. In this paper we extrapolate the results from [1] to the next Tevatron Run II where we hope for an approximately twenty-fold increase in the total integrated luminosity as well as a significant improvement in the total acceptances.

DATA SELECTION

The results from [1] are based on a data sample recorded with a trigger which requires four or more clusters of contiguous calorimeter towers, each with transverse energy $E_T \geq 15$ GeV, and a total transverse energy $\sum E_T \geq 125$ GeV. Further steps in the data reduction are: 1) four or more reconstructed jets with uncorrected $E_T > 15$ GeV and $|\eta| < 2.1$. Jets are defined as localized energy depositions in the calorimeters and are reconstructed using an iterative clustering algorithm with a fixed cone of radius $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.4$ in $\eta - \phi$ space. After this initial selection the sample contains 207,604 events; 2) at least two among the four highest-E_T jets in the event are identified (tagged) as b quark candidates [3]. There are 764 events with four or more jets and two or more b-tags; 3) a cut on the transverse momentum of the $b\bar{b}$ system, $p_T(b\bar{b}) \geq 50$ GeV/c^2 strongly discriminate against QCD direct production and flavour excitation of heavy quarks. A total of 589 events remain after this cut.

BACKGROUNDS AND EFFICIENCIES

The main source of background events is QCD heavy flavor production. The heavy flavor content of QCD hard processes are conventionally classified in three groups: direct production, gluon splitting, and flavor excitation. The relative contributions have been modelled with the PYTHIA Monte Carlo program [2]. No attempt to estimate the normalization of QCD background directly from Monte Carlo is made due to the large number of uncertainties in the predictions. Instead, a fit to the data will be used as it is shown later.

Other backgrounds are $t\bar{t}$ production, Z + jets events with $Z \rightarrow b\bar{b}/c\bar{c}$ and fake double-tags. The first two are estimated from Monte Carlo and the last one from data. After trigger, kinematic and b-tag requirements we expect 26 ± 7 and 17 ± 4 $t\bar{t}$ and Z + jets background events, respectively. The current data set is estimated to contain 89 ± 11 fake double-tag events.

The combined trigger and acceptance efficiency is determined using PYTHIA followed by detector and trigger simulations. It depends on the Higgs mass and increases from $8 \pm 1\%$ for $M_{H^0} = 70$ GeV/c^2 to $31 \pm 3\%$ for

TABLE 1. Summary of the CDF Run I hadronic analysis fit results, standard model predictions for $\beta\sigma$, and 95% C.L. upper limits.

	M_{H^0} (GeV/c^2)							
	70	80	90	100	110	120	130	140
Fit $\beta\sigma$ (pb)	44 ± 42	0^{+19}_{-0}	$0.0^{+9.7}_{-0.0}$	$0.0^{+7.6}_{-0.0}$	$0.0^{+6.3}_{-0.0}$	$0.0^{+5.9}_{-0.0}$	$0.0^{+5.5}_{-0.0}$	$0.0^{+5.1}_{-0.0}$
SM $\beta\sigma$ (pb)	1.13	0.76	0.55	0.41	0.30	0.20	0.12	0.06
Limit $\beta\sigma$ (pb)	117.3	53.2	28.9	22.8	18.7	17.6	16.7	15.3

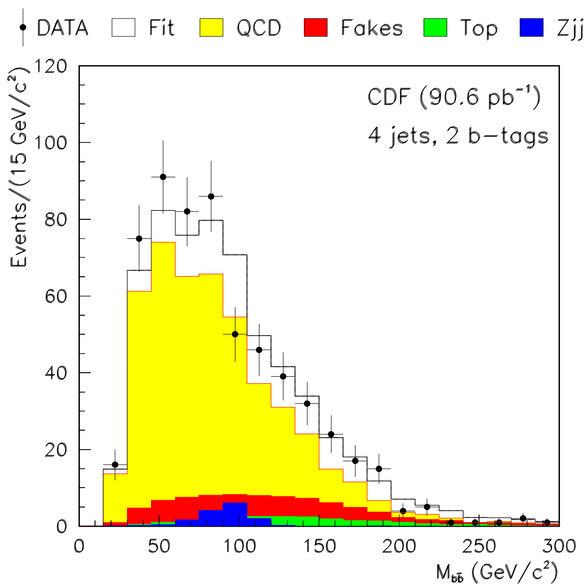

FIGURE 1. Invariant mass distribution, $M_{b\bar{b}}$, for 90.6 pb^{-1} of CDF data (points) compared to the fit prediction. The solid line is the sum of the QCD, fakes, $t\bar{t}$, and Z + jets components.

$M_{H^0} = 140$ GeV/c^2. The SVX double b-tagging efficiency is calculated with a combination of data and Monte Carlo samples and is $14 \pm 3\%$ with a small dependence on the Higgs mass. The total efficiency increases linearly from $0.6 \pm 0.1\%$ to $2.2 \pm 0.6\%$ for Higgs masses ranging from 70 GeV/c^2 to 140 GeV/c^2.

CDF RUN I RESULTS

The shape of the observed b-tagged dijet invariant mass distribution is fit, using a binned maximum-likelihood method, to a combination of signal, QCD heavy flavor, $t\bar{t}$, Z + jets and fake double-tag events. The QCD heavy flavor and signal normalizations are left free in the fit while the normalizations of the $t\bar{t}$, Z + jets and fake double-tags are constrained by Gaussian functions to their expected values and uncertainties. The fit yields $\sigma_{VH^0} \cdot \beta = 44 \pm 42$ pb for $M_{H^0} = 70$ GeV/c^2, statistically compatible with zero signal. For larger masses, zero signal contribution is preferred. Table 1 shows the result of the fits as a function of the Higgs mass and Figure 1 shows the b-tagged dijet invariant mass distribution for the data compared to the results of the fit for $M_{H^0} \geq 80$ GeV/c^2.

CDF RUN II EXTRAPOLATION

Figure 2 shows the CDF Run I results for the 95% CL upper limits on $\sigma\beta$ as a function of the Higgs mass. In general, the obtained 95% CL statistical limits agree very well with the expected ones, except for the region

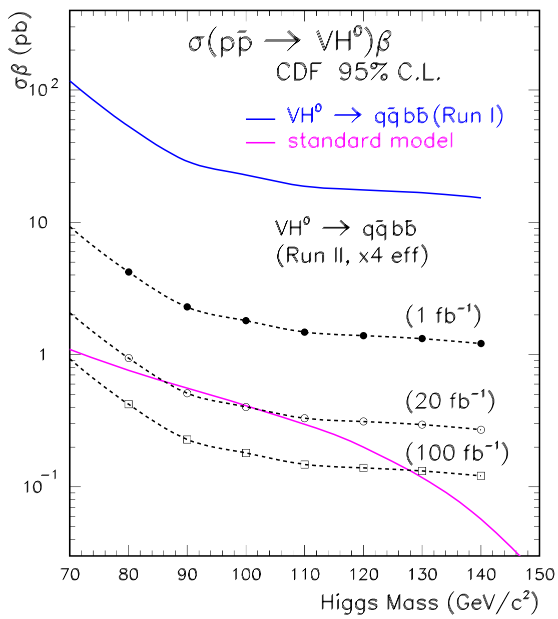

FIGURE 2. The Run I CDF 95% C.L. upper limits on $\sigma(p\bar{p} \to VH^0) \cdot \beta$ where $\beta = \mathcal{B}(H^0 \to b\bar{b})$. Also shown is the extrapolation for three different enhanced luminosity scenarios and Run II acceptances.

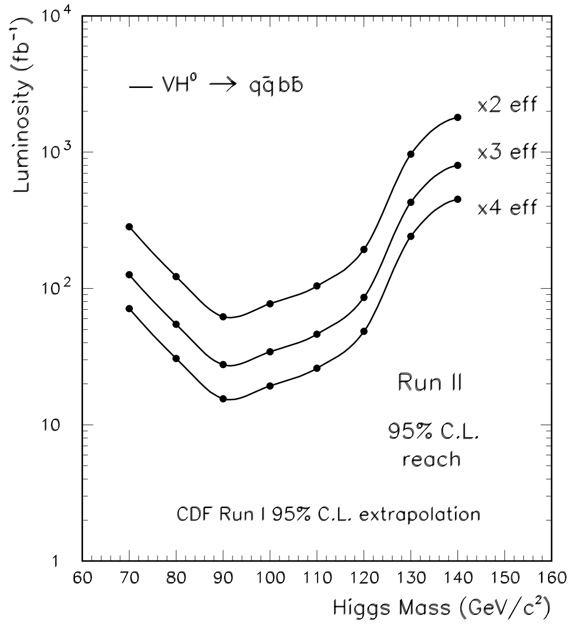

FIGURE 3. Luminosity as a function of the Higgs mass for a 95% CL limit reach in Run II.

of very low masses were the magnitude of the limits is strongly influenced by the fluctuation structure of the data.

A simple extrapolation to account for the expected increase in luminosity and in the total acceptances lead to improved limits by, at least, a factor $1/\epsilon\sqrt{\mathcal{L}}$. Here ϵ and $\mathcal{L}$ represent the increased acceptances and luminosity factors with respect to Run I. The general expresion used is:

$$\sigma_{95\%CL}^{RunII} = \sigma_{95\%CL}^{RunI} \cdot \frac{\varepsilon^{RunII}}{\varepsilon^{RunI}} \cdot \sqrt{\frac{\mathcal{L}^{RunI}}{\mathcal{L}^{RunII}}} \tag{1}$$

We consider three different luminosity scenarios for Run II and beyond: 1, 20 and 100 fb^{-1}. In addition we consider the increased geometrical acceptance of the new Run II CDF silicon vertex detector SVX II, which will extend the b-tagging capabilities up to the range $|\eta| < 2$. A Monte Carlo study for the process $p\bar{p} \to V + H^0 \to jjb\bar{b}$ indicates a total signal improvement of $\sim 80\%$ in double b-tag efficiencies (assuming Run I central b-tag intrinsic efficiencies per jet). We finally consider an optimized multijet trigger for associated Higgs production in Run II. The requirement of displaced tracks with large impact parameter at the trigger level makes it possible to relax the Run I multijet criteria to only 3 jets with uneven E_T cuts and a lower $\sum E_T$ threshold. A preliminary study [4] shows that these cuts result on a few-fold increase in signal efficiencies without compromise the total trigger rates.

Figure 2 shows the CDF Run I 95% CL extrapolated limits for the different luminosity scenarios combined with the approximately x4 improved acceptance for Run II. Figure 3 shows the 95% CL upper limit reach as a funcion of the required luminosity and the Higgs mass for three different improved acceptances.

REFERENCES

1. F. Abe *et al.*, Phys. Rev Lett. **81**, 5748 (1998).
2. T. Sjöstrand, Comput. Phys. Commun. **82**, 74 (1994).

3. F. Abe *et al.*, Phys. Rev. Lett. **74**, 2626 (1995).
4. P. Maksinovic, Talk at the SUSY/Higgs Workshop, Nov. 6, 1998.