hep-ex 1201.6026

arXiv:1201.6026v1 [hep-ex] 29 Jan 2012

Search for WH associated production at Dø Tevatron

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Abstract. The Higgs mechanism introduced in 1964 gives a satisfactory solution to a major problem of the standard model of elementary particles: the origin of the mass. It predicts the existence of the Higgs scalar boson, which has not been discovered experimentally yet. The Tevatron, a hadron accelerator based at Fermi National Accelerator Laboratory near Chicago, has delivered data to its two multi-purpose detectors CDF and DZERO since 1983 up to september 2011. Leaving us about 11 fb^{-1} of data per experiment to analyze. Associated production of a Higgs boson and a vector gauge boson W or Z is the main search channel for a light standard Higgs boson (i.e. below 135 GeV/c^2). Using data collected by DZERO, we are looking for this production mode taking advantage of sophisticated techniques to improve the signal sensitivity such as b-jet identification and multivariate discriminants. In the end, a statistical approach allows us to set an upper limit on the ratio between the observed (resp. expected) Higgs production cross section and its theoretical cross section. The latest result obtained in the WH channel using 8.5 fb^{-1} at DZERO is 4.6 (resp. 3.5) for a 115 GeV/c^2 Higgs boson.

1 Introduction

The mass of the Higgs boson is unpredicted by the Higgs mechanism of the standard model. Nevertheless, theoretical constraints exist but are very loose (considering triviality and vacuum stability). Combination of direct searches at colliders, and precision measurements of electroweak observables depending on the Higgs mass allows a more strict constraint over the mass range. We show on the figure 1 the LEP exclusion up to 114.4 GeV/c^2 and the latest Tevatron exclusion ($156 < m_H < 177\ GeV/c^2$) along with the standard fit on the electroweak parameters measurements [2] . These results clearly show a preference for the low mass region.

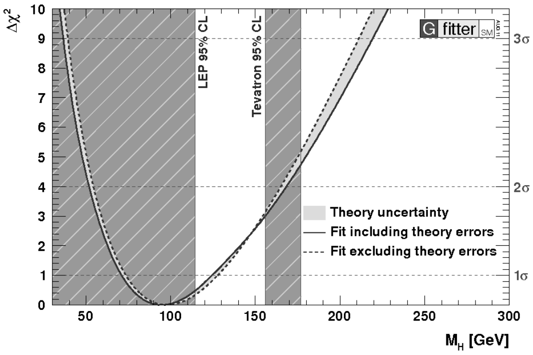

Fig. 1. Direct and indirect experimental constraints on the Higgs boson mass.

Production decay modes are well established in the standard model as a function of the mass of the Higgs boson. Gluon fusion has the greatest cross section over all the mass region. But at low mass, the Higgs boson decays in two b quarks, making its signal impractical to extract within the overwhelming QCD background generated at a hadronic collider. Thus, the most sensitive channel are the WH and ZH associated production. The decay products of the W or the Z allowing to drastically reduce the hadronic background.

We present here the search for WH associated production at Dø Tevatron. Dø is one the two Tevatron's multipurpose detector, designed to study high mass states and large transverse momentum phenomena, design that suits very well the search for a standard Higgs boson. We will present the WH analysis strategy, starting in the section 2 with its selection, we will then in the sections 3 and 5 look at the techniques used to improve the signal efficiency by selecting the final state with b-jets identification algorithms and combining discriminant variables with multivariate analysis (MVA). We will also present in the section 4 how we partly recover radiation jets to improve the di-jet mass in the 3 jets channel using a radiation recovery method.

2 The WH analysis selection

The search is based on events with the following kinematical and topological characteristics :

- The reconstructed primary vertex must lay in the central region 60 cm around the center of the detector along the beam axis.
- One central ($0 \leq \eta \leq 2.5$) charged lepton (electron or muon) with a transverse momentum higher than 15 *GeV* must be present.
- We select events with a missing transverse energy above 15 *GeV*, signature of a neutrino coming from the decay of the W boson.
- We consider only the events with 2 or 3 central ($0 \leq \eta \leq 2.5$) jets with a transverse momentum higher than

- We also require a minimal value on a multivariate discriminant referred as MVA QCD aiming at reducing the QCD background.
- Other leptons are vetoed in order to be orthogonal to the $ZH \rightarrow llbb$ analysis.

The analysis is then separated in two orthogonal channels with exactly two jets and three jets. These channels are further divided in orthogonal sub-channels with exactly one b-tagged jet and 2 b-tagged jets [3].

3 b-jet identification

Being able to discriminate b-jets from lighter flavor jets is crucial for the low mass Higgs search. This tool relies on the characteristics of b quarks and B mesons. Indeed b-quark is the heaviest quark that lead to hadronisation before its decay and the resulting B-hadron has a very long lifetime (about 1.5 ps). These illustrated by figure 2 attributes lead to :

- A secondary vertex, about 3 mm apart from the primary vertex.
- High impact parameter tracks produced by the B-hadron decay.
- A higher secondary vertex mass and a distinctive jet angular opening.
- The possible presence of a muon in the jet reconstruction cone.

Several algorithms have been developed at Dø to take advantage of these features [4].

- SVT (Secondary Vertex Tagger) : based on the reconstruction of a secondary vertex using a Kalman filter.
- JLIP (Jet LIfetime Probability tagger) : takes advantage of the impact parameter significance of tracks associated to a jet, to construct the probability that this jet is coming from the primary vertex and therefor more likely to be a light jet. Heavy flavor jets are distributed at low values of this variable.
- CSIP (Counting Signed Impact Parameter tagger) : counts the number of tracks with high impact parameter.

Each of these algorithms show good performances in b-jets identification. As it has been observed that information given by each algorithm is not 100% correlated since they don't exploit exactly the same b-jet features, it has been decided all these variables into a more powerful one using multivariate analysis. Contrarily to sequential cuts, a multivariate analysis allows to take into account the correlations between input variables. On figure 3 is shown the Higgs invariant mass reconstructed in the 2 jets channel with 2 jets b-tagged using the b-tagging multivariate analysis.

4 Three jets channel special treatment: radiation recovery

Higgs invariant mass is the most powerful single variable to search for a Higgs signal. In the 3 jets channel, its reconstruction is less straightforward than in the 2 jets chan-

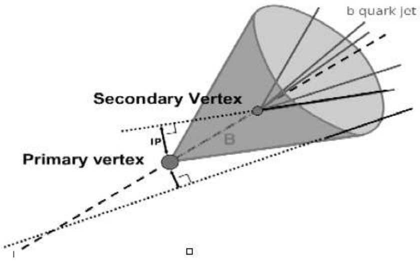

Fig. 2. Diagram of a b-jet. IP corresponds to the track impact parameter

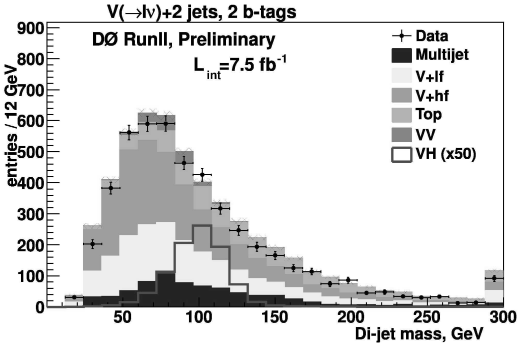

Fig. 3. Higgs invariant mass for the 2 jets channel with 2 b-tagged jets

a b-jet (FSR) to reconstruct the Higgs invariant mass but we have to be careful not to use an initial state radiation (ISR) jet to do so. Figure 4 shows Monte Carlo simulations of a 115 GeV Higgs, about 25% improvement is achieved on the dijet-mass resolution if we recover every FSR jets. But in the detector, there's no simple way to discriminate a FSR jet from an ISR jet. We show that the minimal angle between the third and first or second jet (referred to *alphamin*) is efficient to discriminate these two cases. In the end, the problem in a three jets selection is to find the right jet combination to reconstruct the Higgs invariant mass. The FSR recovery method consists in two steps :

- First, jets are ordered by decreasing b-jet identification variable value. This way, the two leading jets are the most likely to be the b-jets coming from the Higgs.
- Knowing that the remaining jet is very likely to be the FSR or ISR jet, we add it to the invariant mass calculation if the value of *alphamin* is below an optimum cut that we found to be 1.

The method is currently implemented in most of the low mass analyses at Dø and shows up to 20% improvement on the limit obtained in the 3 jets channel.

5 Optimization using a multivariate analysis

The same way multivariate analysis helped to achieve better performances of the b-tagging procedure, it can be very helpful to optimize the sensitivity to a Higgs signal by taking advantage of the discriminating power of less important variables and not only the invariant mass. The method