A new very inclusive trigger selection for the SM WH discovery channel at CDF

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1 Introduction

In order to increase the sensitivity of CDF to the low mass Standard Model (SM) Higgs Boson produced in association with a W boson, a new trigger based on calorimetric requirements has been designed, exploiting the enhanced capabilites of the upgraded CDF trigger system. This new trigger, named MET_DIJET, is meant to be complementary to the standard WH selections and it is demonstrated to provide an effective gain in signal efficiency at trigger level.

2 The CDF Detector and its Trigger System

CDF II is a large multi-purpose detector, installed at the B0 interaction point of the Tevatron collider. It consists of an inner silicon vertex detector, which provides three-dimensional track reconstruction; an outer multiwire drift chamber, designed to measure particle momenta; a superconducting solenoidal magnet which supplies a uniform 1.4 T magnetic field inside the trackers; electromagnetic and hadronic calorimeters segmented in projective towers; drift chambers and scintillator counters to detect muons escaping the calorimeters and additional steel absorbers.
CDF is organized in a three level trigger system. Level-1 and Level-2 use custom-designed hardware to find physics objects based on subsets of the detector information. Level-3 uses the full detector information to reconstruct complete events in a processor farm. The goal of each stage is to reject a sufficient fraction of events to allow processing at the next stage with acceptable deadtime. At the Tevatron proton and antiproton bunches collide at a maximum rate of 2.53 MHz, so that maximum accept rates for the whole trigger system are 35 kHz for Level-1, 600 Hz for Level-2 and 100 Hz for Level-3.

A detailed description of the CDF detector and its trigger architecture can be found elsewhere [1].

3 Underlying strategy of the new WH trigger

The experimental signature of $WH \rightarrow l\nu_l b\bar{b}$ events, with $l = e, \mu, \tau$, is characterized by two energetic jets coming from the Higgs boson decay, a high transverse momentum (p_T) lepton and a large missing transverse energy ($\not{E}_T$), due to the undetected neutrino, coming from the W.
Current CDF analyses [2] are mainly based on high-p_T lepton samples (e.g. electron and muons with $p_T > 18$ GeV/c), where the tight lepton selections allow to keep under control the trigger rates, with the disadvantage of a compromised signal efficiency. The capabilites of recent hardware upgrades of CDF, like the improved Level-2 calorimetric trigger energy resolution and the new sophisticated trigger cone clustering algorithms [3], give the possibility to explore new complementary strategies for the WH channel. The idea is an implementation of a new trigger path, based entirely on calorimetric requirements: a selection which relies only on missing energy and jet information allows to recover sizably the WH efficiency at analysis level, by using looser offline lepton definitions. Moreover, alternative and more powerful identification tools, like neural networks, can be adopted without biases potentially introduced by the trigger requirements.
On the other hand, such an approach keeps the drawback of a higher acquisition rate. An optimization procedure was performed and the results represent a compromise between good signal efficiency and the maximum reasonable acquisition rate at disposal, which must be kept under control at all three trigger levels. Considering the total available bandwidht, we set *a priori* the following approximate rate limits for the new MET_DIJET at the maximum expected luminosity of $3 \times 10^{32} cm^{-2} s^{-1}$: 2000 Hz at Level-1, 100 Hz at Level-2 and 30 Hz at Level-3. The choice of the most suitable variables, on which operates the trigger selection, and their cut values, are driven by these rate limits.
In order to predict the efficiency of a given set of cuts, we used a Monte Carlo sample of WH events with full detector and trigger simulation, where the W is forced to decay leptonically and the Higgs is forced to decay into a $b\bar{b}$.
The background is estimated in the SingleTower10 data sample. This trigger path requires at least one calorimeter tower with a total energy deposit of at least 10 GeV at Level-1. The efficiency of this sample for WH is very high (about 97%) so it is a very good starting point for any trigger study aimed at WH. The predicted acquisition rate, as a function of instantaneous luminosity, is obtained as the product of the unprescaled rate of the SingleTower10 times the reduction factor caused by the

simulated set of trigger cuts.

4 Trigger cuts optimization

- At Level-1 we added a cut on the missing transverse energy, $\not{E}_T > 15$ GeV, to the request of a tower with E_T >10 GeV, reaching a global efficiency of 87.3%. The expected corresponding rate at 300 $\times 10^{30} cm^{-2} s^{-1}$ is about 1900 Hz.
- At Level-2 we implemented a multiparameter optimization procedure, which maximizes the signal efficiency at a fixed background reduction factor, scanning the $\not{E}_T$ and jet E_T variables. The final Level-2 selection is: at least two jets with $E_T \geqslant$3GeV and $\not{E}_T \geqslant 28$ GeV, with a WH efficiency of 71.3% and a rate of about 80 Hz at 300 $\times 10^{30} cm^{-2} s^{-1}$ of luminosity.
- At Level-3 we decided to keep the selection as simple as possible. The single cut on missing transverse energy at 30 GeV satisfies already the bandwith constraint: we obtain a cross-section of about 35 Hz at 300 $\times 10^{30} cm^{-2} s^{-1}$, where the corresponding global efficiency for WH is 63.9%.

Table 1 summarizes the final MET_DIJET trigger selection.

L1	$\not{E}_T^{L1} > 15$ GeV at least one trigger tower with $E_T > 10$ GeV
L2	$\not{E}_T^{L2} > 28$ GeV two jets with $E_T > 3$ GeV and $\lvert\eta\rvert \leqslant 3.6$
L3	$\not{E}_T^{L3} > 30$ GeV

Table 1: MET_DIJET trigger selection.

5 Trigger performances

Before the final implementation, a first version of the MET_DIJET trigger with similar requirements and an additional precautionary prescale factor of 10 was tested. Figure 1 shows the on-line measured cross-sections (coloured dots) for Level-1 and

Level-2 selections of this test version, as a function of instantaneous luminosity, compared with the estimated distributions (points with error bars). The full line is a second order polynomial fit of the estimated cross-section points, while dashed lines connect points corresponding to the same rate. Plots indicate that rates are kept under control, as desired, and that our model well simulates the real behaviour of the trigger, over a wide range of instantaneous luminosity.

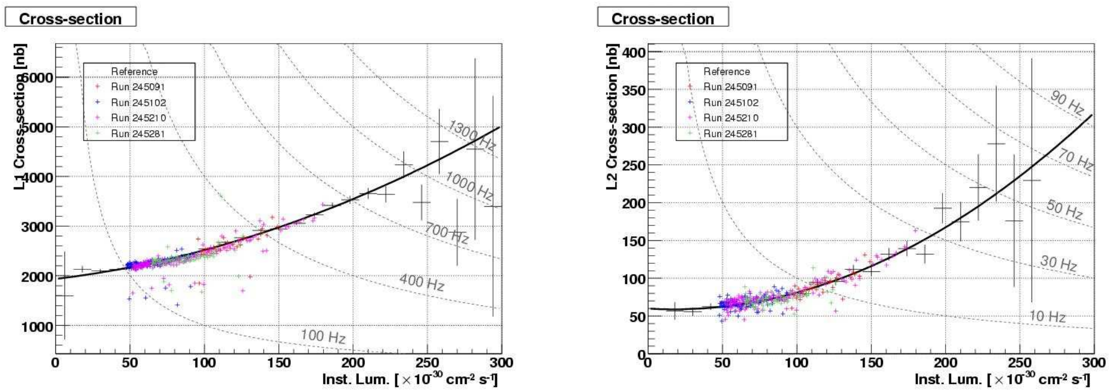

Figure 1: Measured and predicted cross-sections fo the Level-1 (left) and Level-2 (right) selections of the new MET_DIJET trigger, as a function of instantaneous luminosity. Predicted points have been fit to a second order polynomial. Dashed lines connect points corresponding to the same rate.

Trigger efficiencies for WH signal, evaluated for different Higgs mass hypotheses in the range 110-130 GeV/c^2, are reported in table 2, along with the the corresponding expected number of Higgs bosons collected in 5 fb^{-1}.

M_H[GeV/c^2]	110	115	120	130
L1 efficiency	86.2%	87.0%	87.3%	88.8%
L2 efficiency	69.8%	70.8%	71.3%	73.6%
L3 efficiency	61.6%	63.0%	63.9%	65.9%
Higgs in 5 fb^{-1}	148	123	105	66

Table 2: MET_DIJET trigger efficiency for WH, for different Higgs mass hypotheses.

We also considered the efficiency separately for all the leptonic decay modes of the W boson, with a Higgs mass of 120 GeV/c^2, as shown in table 3. By taking into account the signal overlap between different WH trigger selections, we evaluated the effective gain in efficiency provided by the MET_DIJET. Cumulative efficiencies are reported in table 4.

	WH		
	$e\nu_e b\bar{b}$	$\mu\nu_\mu b\bar{b}$	$\tau\nu_\tau b\bar{b}$
L1 efficiency	91.8%	85.5%	84.5%
L2 efficiency	75.8%	71.2%	66.9%
L3 efficiency	66.3%	65.7%	59.5%
Higgs in 5 fb^{-1}	36	36	33

Table 3: MET_DIJET trigger efficiency for WH (M_H=120 GeV/c^2), separately for the three leptonic decay modes of W boson.

	WH efficiency	
	lepton-based triggers	cumulative with MET_DIJET
e	61.2%	85.4%
μ	22.1%	74.5%
τ	11.3%	62.8%

Table 4: WH efficiency (M_H=120 GeV/c^2) for the lepton-based CDF triggers, and cumulative values with the introduction of the new MET_DIJET.

6 Conclusions

We designed and implemented a new calorimetric trigger, optimized for the detection of a low mass SM Higgs Boson, produced in association with a W boson. We demonstrated that this new online selection, complementary to the high p_T-based lepton triggers, allows to consistently increase the efficiency for all three leptonic decay modes of the W boson. We also estimated the MET_DIJET trigger rate sustainable up to 300 $\times 10^{30} cm^{-2} s^{-1}$ at Level-1, Level-2 and Level-3, and tested the validity of our prediction model. The trigger was approved in Autumn 2007 and officially introduced in the CDF trigger table. By the end of Tevatron Run II we expect to collect about 5 fb^{-1} of data with this new selection, with a significant contribution to the SM Higgs analyses of CDF.

References

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[3] A.A.Bhatti *et al.*,FERMILAB-CONF-07-165-E.