Associated Higgs Production at Tevatron and LHC

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The search for the Standard Model Higgs Boson for masses above the LEP exclusion limit of 114.1 Gev/c^2 is an important topic of research at the Tevatron at Fermilab in Chicago as well as the future Large Hadron Collider (LHC) at CERN in Geneva. The Higgs Boson is a scalar particle which could explain the appearance of massive weak gauge bosons and fermions.

Our group participates in the search for the Higgs boson at both Tevatron and LHC as part of the DØ and ATLAS collaboration. Both experiments, DØ and ATLAS, are multi-purpose experiments, the former started taking data in spring 2001, the latter will start operation at the LHC in 2007.

An analysis was carried out in search for a Higgs Boson in the intermediate mass range of 115 Gev/c^2 up to 130 Gev/c^2, comparing the prospects of a discovery of the Higgs boson at 2 TeV center of mass energy at the Tevatron and 14 TeV center of mass energy at the LHC.

A Standard Model Higgs Boson in the intermediate mass range would dominantly decay to a bottom quark-antiquark pair. The associated production of a Higgs Boson with a W or Z gauge boson, denoted by

$$W^{\pm} + H \quad \rightarrow l^{\pm}\nu + b\bar{b},\ l = e, \mu$$

$$Z^{0} + H \quad \rightarrow l^{+}l^{-} + b\bar{b},\ l = e, \mu$$

allows for reducing the dominant QCD background by demanding one – or two, respectively – light leptons in the final state.

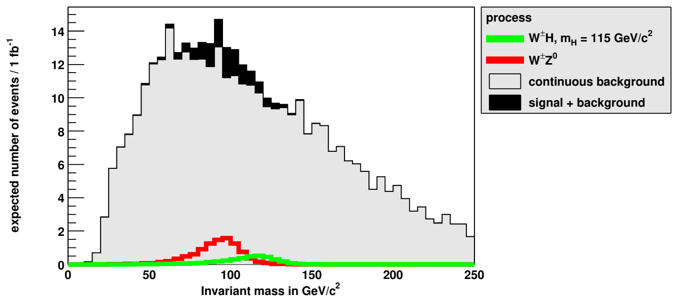

Fig. 1: Mass spectrum of b-jet pairs, process Z^{0}H

The background processes can be classified as either continuous or resonant. In the latter case a Z boson decaying to two bottom quarks is observed as a resonant peak in the b-jet mass spectrum located at the Z boson mass, which has to be separated from the peak associated to the Higgs boson. In continuous background processes the mass spectrum does not include a resonant peak.

For the process W$^\pm$H the continuous background processes considered are b$\bar{\text{b}}$, t$\bar{\text{t}}$ with one W boson in the intermediate state decaying leptonically, single top production and W$^\pm$b$\bar{\text{b}}$, the resonant background is W$^\pm$Z^0.

For the process Z^{0}H the continuous background processes considered are b$\bar{\text{b}}$, t$\bar{\text{t}}$ with both W bosons in the intermediate state decaying leptonically, single top production and Z^{0}b$\bar{\text{b}}$, the resonant background is Z^{0}Z^0.

The Monte Carlo samples for the processes W$^\pm$b$\bar{\text{b}}$ [1] and Z^{0}b$\bar{\text{b}}$ [2] were generated using new external matrix element calculations added to the Pythia Monte Carlo Generator.

Comparing the production cross sections for Tevatron and LHC the signal processes are a factor 10 higher at LHC energies, while background processes are a factor 10 to 100 higher at 14 TeV. The mass spectra for the process Z^{0}H and backgrounds after applying selection cuts are shown in fig. 1 for the case of DØ and a Higgs mass of 115 Gev/c^2.

Both the DØ and ATLAS detector were simulated using fast simulations. In case of the ATLAS detector a standard ATLFast [3] simulation was used, in case of the DØ detector a modified ATLFast version taking into account the DØ detector layout was set up and compared to the DØ PGS fast simulation [4].

For the discrimination of background and signal the two dominant influences were found to be the b-tagging efficency and the resolution of the di-jet mass. In addition the influence of the cone radius used in the jet reconstruction and of initial and final state radiation on the mass spectrum were studied.

The combined significance (Gaussian approximation) for both signal processes at Tevatron and LHC can be seen in fig. 2 (Tevatron) and 3 (LHC). From the analysis one can conclude that for a 5 σ discovery of the Higgs boson in the intermediate mass range an analysis of the processes W$^\pm$H and Z^{0}H alone is not sufficent at both Tevatron and LHC, unless significant improvements in analysis and a combination with new processes are undertaken.

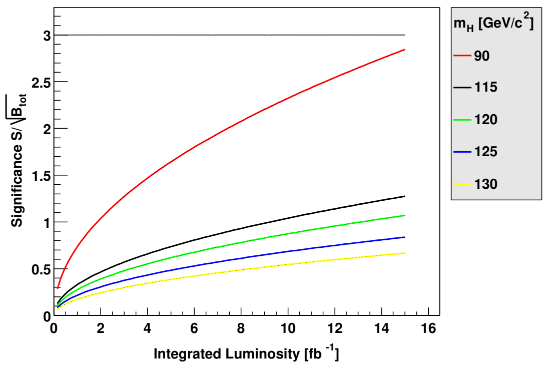

Fig. 2: Combined significances, Tevatron

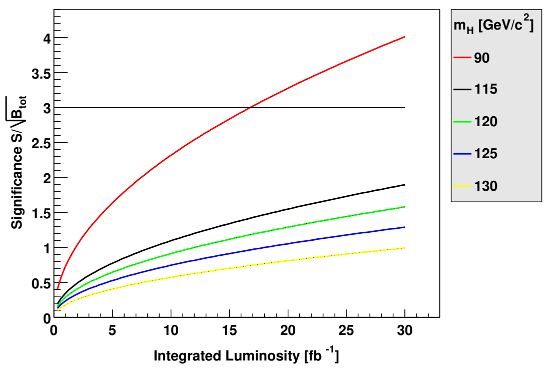

Fig. 3: Combined significances, LHC

References

[1] B. Kersevan et. al., ATL-PHYS-2001-020
[2] B. Kersevan et. al., ATL-PHYS-2001-021
[3] E. Richter-Waş et. al., ATLFast 2.0 – a fast simulation package for ATLAS, ATL-PHYS-98-131
[4] M. Carena et. al., Report of the Tevatron Higgs Working group, hep-ph/0010338