Exotic resonances in semileptonic HZ final state

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1 Introduction

In the BSM scenario there are many theories that predict the existance of new particles at the energy scale of TeV (extra dimentions, composite Higgs, ect.). Since these heavy resonances should strongly couple with the SM gauge and Higgs bosons, it is easier to look for them observing heavy excitations of SM bosons.

We want to study a new channel never investigated, resonances decaying in ZH. This final state is predicted by partial compositeness model.

Thi analysis is based on semileptonic ZZ analysis recently approved as preliminary.

2 Highly boosted jets

The analysis is performed in a high mass region (TeV) and the yields are expected to be strongly boosted. The two quarks coming from the H decay hadronize into one merged jet (fig. 1). The final state sought in the analysis is made by two leptons and one fat jet (reconstructed with the CA8 clusterng algorithm):

$$x \to ZH \to ll\,1jet$$

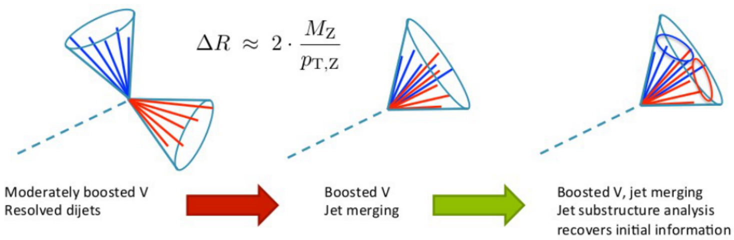

Figura 1. Highly boosted jet merging.

In this analysis the main background is given by Z+jet production. Because the QCD background is much larger for 1 jet than for 2 jets, so we have to figure out new tecniques to distinguish QCD jets from jets coming from H decay (H-jets).

Pruned mass The first property to exploit is the jet mass, that should be peaked around the mass value for bosons decaying in jet and exponentially decreasing for QCD jet (fig. 2). The separation power can be enhanced by applying a pruning altoritthm on the jets (jet pruning).

Jet pruning removes soft and large angle tracks from the jet.

N-subjettiness N-subjettiness is defined as

$$\tau_N = \frac{1}{d_0} \sum_k p_{T,k}\, min(\Delta R_{1,k}, \Delta R_{2,k}, \dots, \Delta R_{N,k}) \tag{1}$$

and it represents the compatibility of the jet structure with a N-subjet hypothesis. Studies have prooved that the most disctriminant variable is the ratio

$$\tau_{21} = \frac{\tau_2}{\tau_1}. \tag{2}$$

This was expected because QCD jets have clearly a monopole-like inner structure, while the H-jets should contain two subjets corresponding to the two quarks or gluons (fig. 3).

3 Analysis

The signal sample is simulated at three mass points with Madgraph5, respectively 1000, 1500 and 2000 GeV. The backgrounds considered are $t\bar{t}$, Z+jet, ZZ, WW and WZ.

3.1 Preselection level

A study on the composition of the Higgs poducts is performed, restricting just to the $b\bar{b}$, $c\bar{c}$ and gg decays. The jet pruned mass and τ_{21} distributions are reported in figures 2 and 3.

The Higgs boson is reconstructed similarly in all the three cases and the peak is around 120 GeV.

In the τ_{21} distribution good signal/background separation is observed, as well as the difference between $H \to qq$ and $H \to gg$.

This happens because gluons radiates more while quark jets are tipically composed by harder tracks.

In figure 4 is reported the discriminating power of the H-tag and the expected number of background events at this step of the analysis.

3.2 Optimization

The τ_{21} discriminant is used to separate the signal from background. The best cut is required to maximize the Punzi figure of merit defined as

$$F_o M = \frac{\varepsilon_S}{1 + \sqrt{B}}. \tag{3}$$

Figure 5 shows the optimization for the three simulated mass points.

The optimized cut is a function of mass: the higher the mass is, the more relaxed should be the selection. For $M_X = 2000$ GeV where ther is very

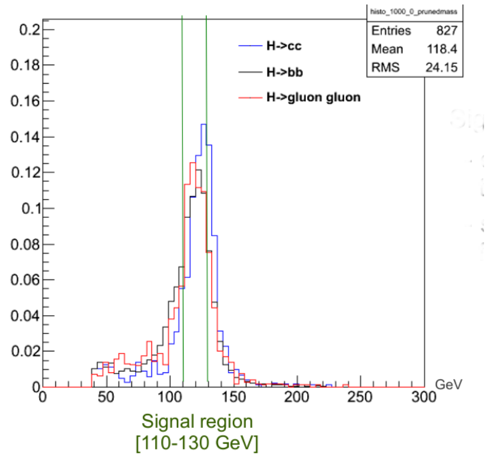

Figura 2. Reconstructed pruned jet mass for the different Higgs decay channels. The mass region of the analysis is indicated by the two green lines.

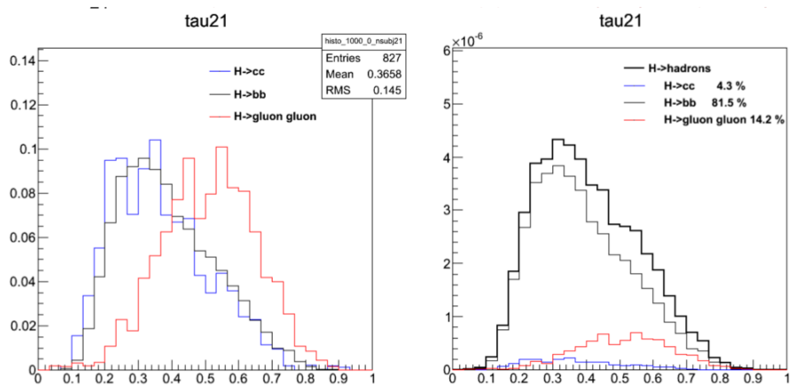

Figura 3. Left: distributions for different H decay channels are ormalized to unity independently; right: H decay channels are summed up taking in account their branching ratios.

little background, the optimization suggests to relaxe completely the τ_{21} cut in order not to loose signal efficiency.

3.3 Full selection

In the final analysis we will define two categories based on the value of τ_{21}:

- **1JHP**, $\tau_{21} < 0.5$ (high purity),
- **1JLP**, $0.5 < \tau_{21} < 0.75$ (low purity),

Figures 6 and 7 show the ZH resonance mass after the pruned mass cut respectively for the high purity and low purity category.

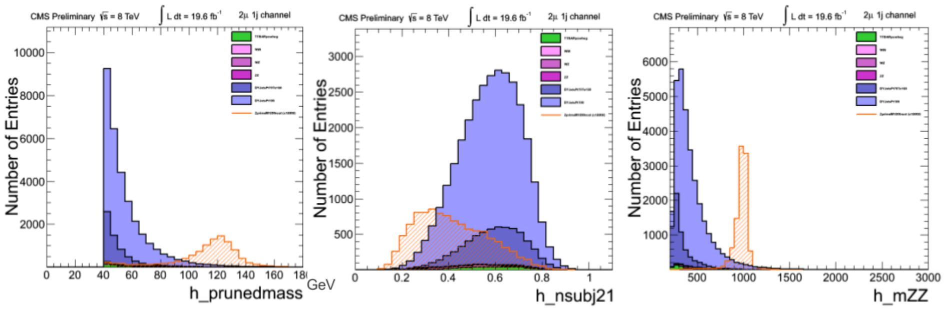

Figura 4. Jet pruned mass (left), τ_{21} (center) and the invariant mass of the ZH system (right) at reselection level. Signal is moltiplied by a factor of 10000.

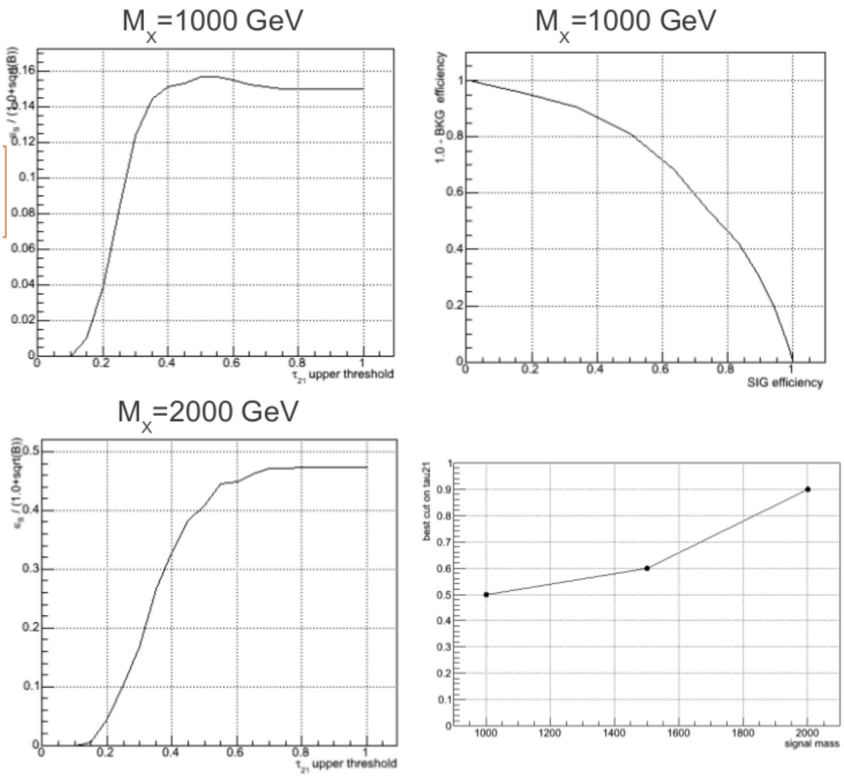

Figura 5. (left) Punzi significance for $M_X = 1000\,GeV$ and $M_X = 2000\,GeV$; (top right) ROCcurve for $M_X = 1000\,GeV$; (bottom right) optimized τ_{21} cut as a function of the resonance mass.

4 Conclusion

A complete MC study on the expected signal shape is performed for a semileptonic ZH resonance with the Z decaying leptonically and considering the decay channels $H \to c\bar{c}$, $H \to b\bar{b}$ and $H \to gg$ merged in a single jet.

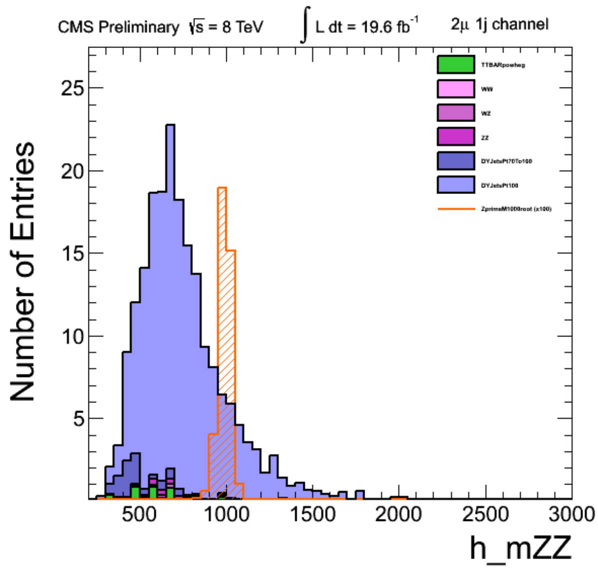

Figura 6. Full selection mass resonance for high purity category, signal is moltiplied by a factor of 100.

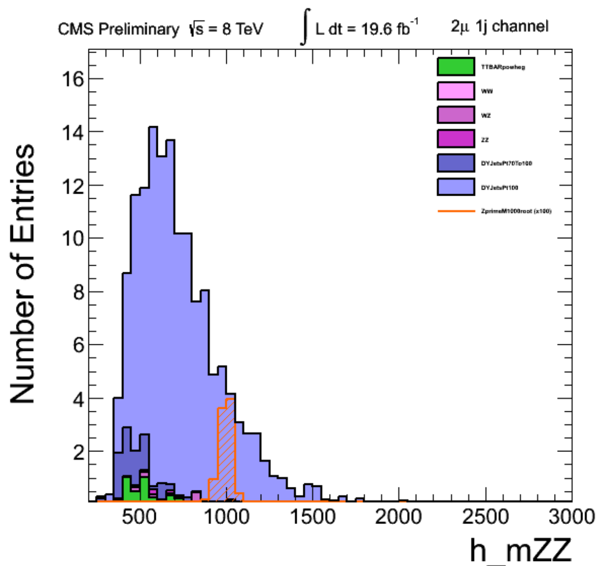

Figura 7. Full selection mass resonance for low purity category, signal is moltiplied by a factor of 100.

Possible expansion of the analysis could be adding other Higgs fully hadrinic decay channels ($H \to WW$ and $H \to ZZ$) and implementing subjet b-tagging that should contribute to strongly reduce the background.