The Use of Multivariate Techniques for the Energy of B-quark Jets

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The jets of hadrons originated from bottom quarks are called b-quark jets in the experiments of particle physics. It plays an important role in the discovery of new physics. The study of the improvement of energy scale and resolution using the multivariate regression technique will be presented in this poster. Its improvement to the mass resolution will be tested on a resonance decaying into a pair of b-quark jets.

INTRODUCTION

At m_H ≈125 GeV, the standard model Higgs boson decays predominantly into a bottom quark-antiquark pair ($b\bar{b}$) with a branching fraction of ≈58%. The predicted branching ratio of the Higgs boson is shown in Fig. 1. The observation and study of the H → $b\bar{b}$ decay, which involves the direct coupling of the Higgs boson to bottom-type quarks is, therefore essential in determining the nature of the newly discovered boson.[1].

Depending on the measured mass of the Higgs boson different decays are more or less likely[2].

However, the jet energy resolution comparing to electron's and muon's is poor. It is important to improve the b-quark jet energy resolution. In this study, the TMVA is employed to regress the energy of b-jets.

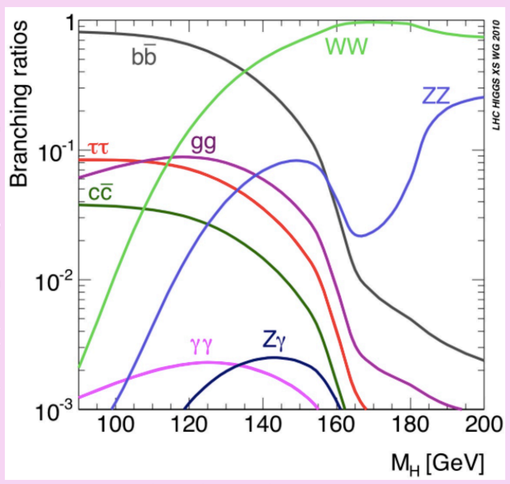


Fig. 1. The branching ration as a function of Higgs boson mass.

EVENT SELECTION

For the training sample, the generator level leading and trailing b jets should decay from tt and match to the generator level b-quarks. The transverse momentum of b-quark jets are required to be larger than 20 GeV, and pseudorapidity within $|\eta| < 2.4$.

For the validation sample, the leading and trailing b-quark jets should decay from the Higgs boson and match to the generator level. The transverse momentum of b-quark jets are required $P_T >$ 20 GeV, and pseudorapidity within $|\eta| < 2.4$.

After the regression, the transverse momentum of reconstruction level b-quark jets are required to be larger than 20 GeV.

TRAINING VARIABLES

We followed the 16 variables from the LHC run I b-quark jets regression. We found adding missing E_T and $\Delta\phi$ between b-quark jet and missing E_T can improve the energy resolution better. Fig. 2. show the energy resolution of the three variables used in the regression.

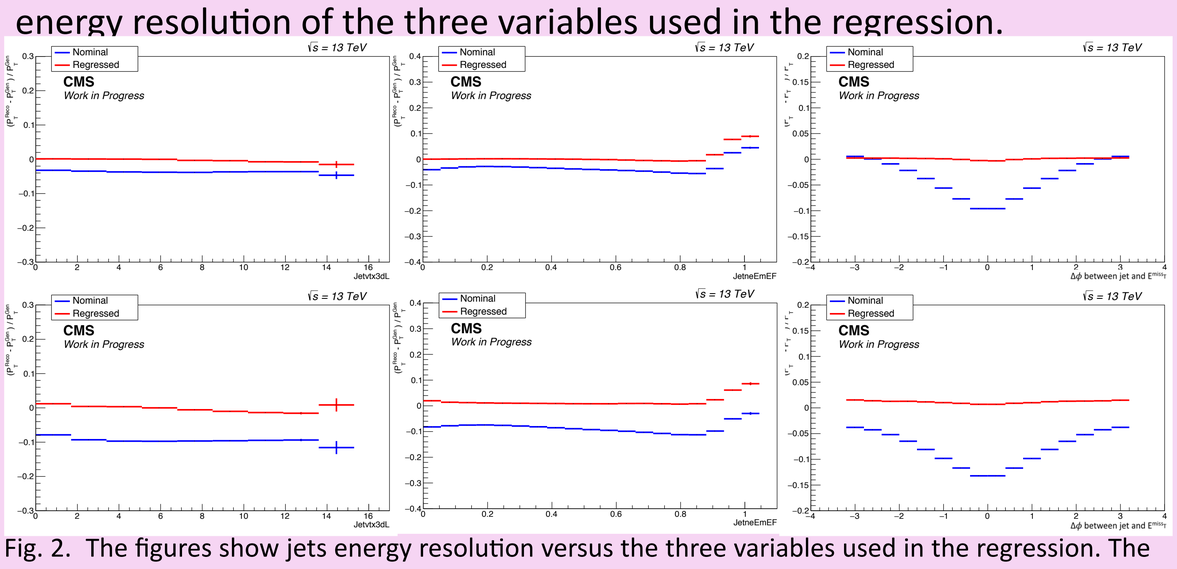


Fig. 2. The figures show jets energy resolution versus the three variables used in the regression. The first row is for leading jets and the second row is for trailing jets. From left to right, the variables are the 3-d flight length between the jet's secondary vertex and leading track particle (jetvtx3dL), photon energy fraction (jetneEmEF), $\Delta\phi$ between b-quark jet and missing E_T ($\Delta\phi$ between jet and E^{miss}_T). After the regression, all of their energy resolution is improved.

MASS OF VH(→$b\bar{b}$)

Fig. 4. shows the regression results of $t\bar{t}$ sample applied on VH sample. After the regression, the Higgs mass resolution and scale is improved well. After the regression the Higgs mass is reconstructed by $b\bar{b}$ jets is closer to m_H≈125 GeV. The effective sigma is improved from 37 GeV to 34 GeV(8%). The effective sigma is defined the narrow width containing 68.3% of the distribution.

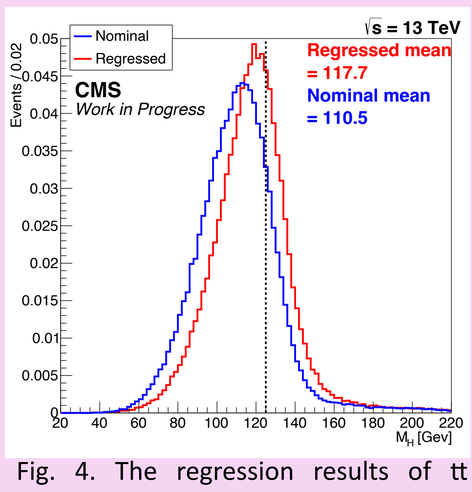
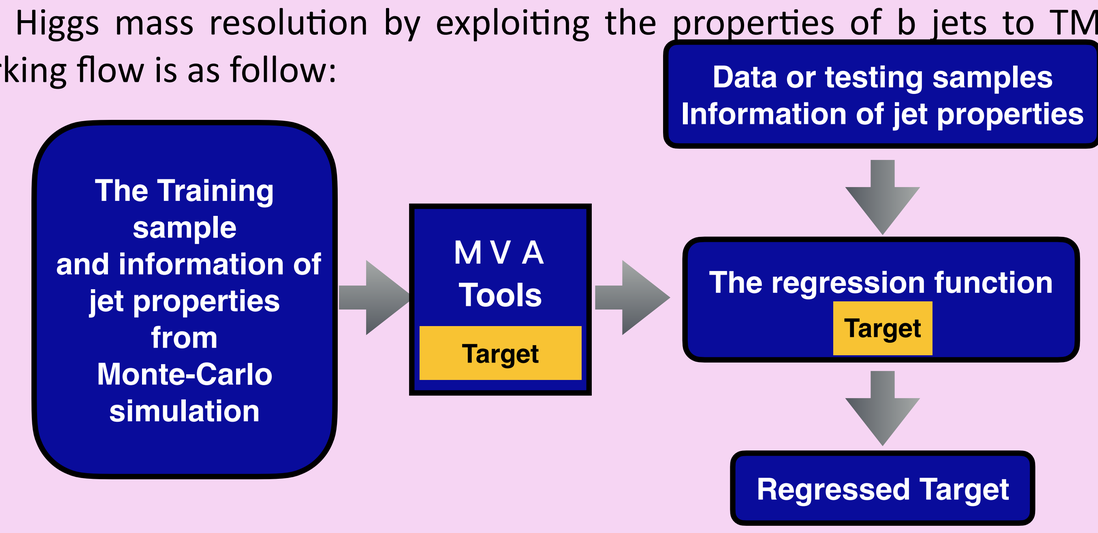


Fig. 4. The regression results of tt sample applied on VH sample.

B JET REGRESSION METHOD

The regression is a kind of algorithm to improve the energy resolution of b jets and Higgs mass resolution by exploiting the properties of b jets to TMVA. The working flow is as follow:



- **Target:** The reconstructed b jets transverse momentum P_T^{jet} will be regressed to $P_T^{b-quark}$
- **Training sample:** Simulation of $t\bar{t}$ events. The leading jets and trailing jets are trained separately from the sample.
- **Jet properties:** 18 variables of jets properties above include the jet kinematic information, and the second vertex information.
- **Testing sample:** Simulation of resonant process VH with H → $b\bar{b}$.

RESULTS

JET ENERGY RESOLUTION

Fig. 3. and 4. show the nominal and regressed plots for the leading b jets, trailing jets in tt sample. Half of the sample was used for training, and the output was tested using the full tt sample. After the regression the resolution and scale are improved well, the mean value is closer to the zero than nominal.

Fig. 5 and 6 show the nominal and regressed plots for the leading b jets, trailing jets in VH sample.

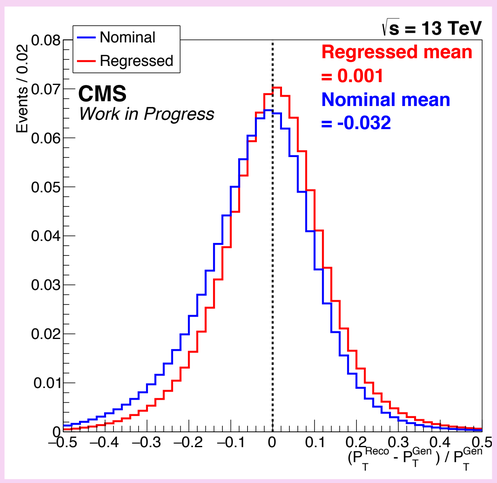


Fig. 3. The nominal and regressed plots for the leading b jets in $t\bar{t}$ sample.

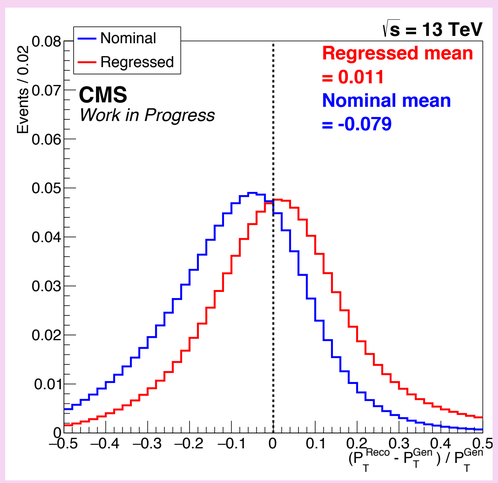


Fig. 4. The nominal and regressed plots for the trailing b jets in $t\bar{t}$ sample.

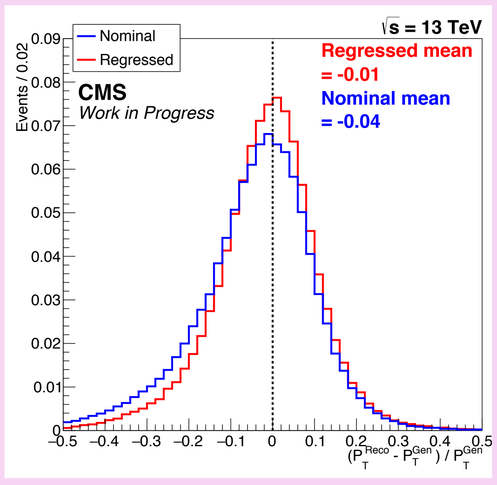


Fig. 5. The nominal and regressed plots for the leading b jets in VH sample.

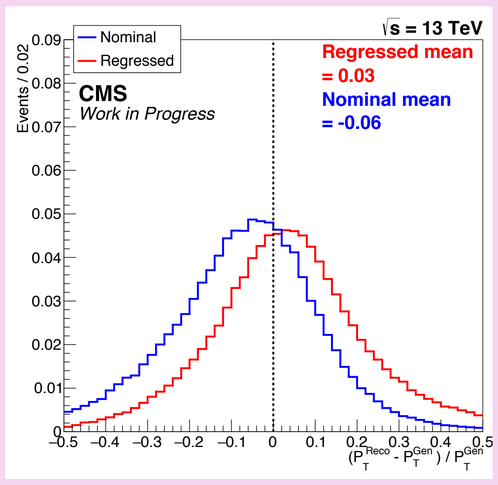


Fig. 6. The nominal and regressed plots for the trailing b jets in VH sample.

CONCLUSION

The regression with 18 variables by separating jets can improve the jet energy resolution and the Higgs mass resolution. The effective sigma of H(→bb) mass was improved to 8%.

REFERENCE

[1] PHYSICAL REVIEW D 89, 012003 (2014)
[2] http://www.ph.ed.ac.uk/higgs/searches