Multivariate Analysis of the Phase 0 Experiment Data with TMVA

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The first experiment of the HypHI collaboration aimed to demonstrate the feasibility of the hypernuclear spectroscopy by means of heavy ion beam induced reactions. The phase 0 experiment was performed with a ^{6}Li beam at $2A$GeV impinged on a stable ^{12}C target material. The main goal of the experiment was to produce, reconstruct and identify decay vertexes of Λ particle and $^3_\Lambda$H, $^4_\Lambda$H and $^5_\Lambda$He hypernuclei [1]. With the finalized data analysis of Phase 0 experiment, the first results show that the experimental method is viable for the study of hypernuclei.

The current analysis method involved series of rectangle cut over several geometrical observables in order to increase the signal-to-background ratio of the hypernuclear signal over the combinatorial and physical background. The hypernuclear events are reconstructed by the invariant mass of the mother system which had decayed into 2- or 3-body daughter particles and fragments. The invariant mass distribution is the principal observable used to determine the significance of the hypernuclear signal proportion.

The TMVA package included inside the ROOT framework allows multivariate analysis of the data sets [2, 3]. Those analysis methods have been employed to improve the quality and purity of the hypernuclear data sets from the experimental data of the Phase 0 experiment. For each species of interest, Λ, $^3_\Lambda$H and $^4_\Lambda$H, a set of input observables were selected for the discrimination of the signal and background component of the invariant mass distribution. The signal data set used for the training of the different classifiers was characterized to be in the mass interval $\bar{m} \pm 3\,\sigma_m$, where $\bar{m}$ and σ_m were obtained from the signal+background global fit of the invariant mass. The background data set is then characterized by the side bands of the peak region ($[\bar{m}-6\sigma_m, \bar{m}-3\sigma_m]$ and $[\bar{m}+3\sigma_m, \bar{m}+6\sigma_m]$). After the training of the classifiers of interest over a partial sample of the experimental data, those classifiers are tested to estimate their background rejection power and signal efficiency. The top panel of Fig. 1 shows the results of several multivariate classifiers over the $^3_\Lambda$H data set. The used classifiers were based on the Projective Likelihood method (*LikelihoodPCA*, *LikelihoodKDE*), the Linear Discriminant method (*LD*) and Artificial Neural Network methods (*MLP*, *MLPBNN*). In the case of the named *MLPBNN* classifier, its output is shown in the bottom panel of Fig. 1. An output value close to 0 means that the event is considered as part of the background, while a value close to 1 would mean a $^3_\Lambda$H event. A threshold cut can be applied in order to select the most probable $^3_\Lambda$H events. Thanks to the classification of the events, the background contribution inside of the signal region $\bar{m} \pm 3\,\sigma_m$ can be identified and thus rejected. By using the best classifier from the multivariate analysis, one can obtain a data set of most probable hypernuclear events which can then be used for extracting diverse physical observables with good statistics.

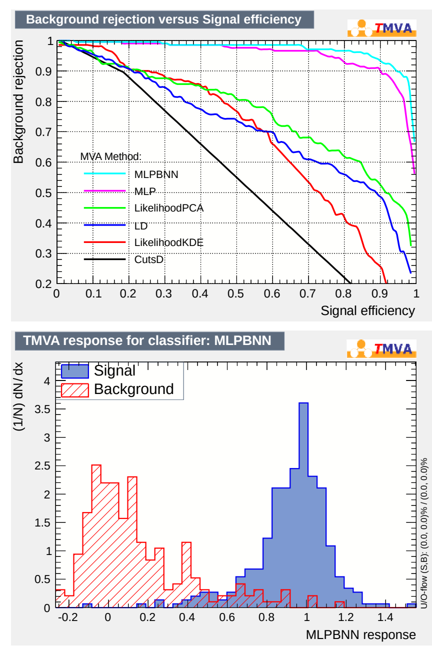

Figure 1: Top panel : the Reciever Operating Characteristics“ROC” curve of the multivariate analysis of experimental data for the $^3_\Lambda$H hypernucleus. It represents background rejection power as function of the signal efficiency obtained for each classifier used for different multivariate analysis. Bottom panel : Output of the Multilayer perceptron (artificial neural network) classifier used to discriminate the signal of $^3_\Lambda$H hypernucleus (blue distribution) to the background component (red distribution).

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References

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