Applying Neural Network Techniques in Data Analysis

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Aim of the Project

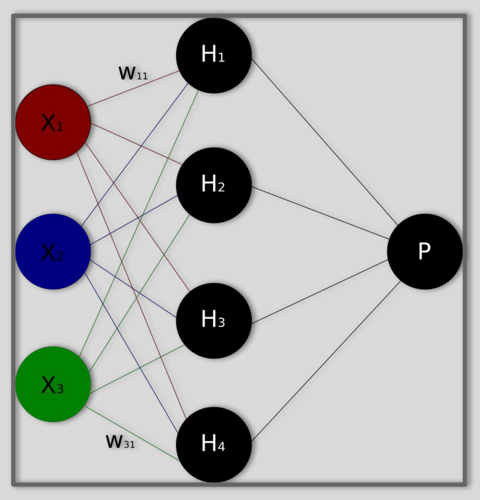
The aim of this project was the implementation of a neural network to analyze data obtained by the BES III.
For the scope of the project we focused on measurements of the Lambda decay.

BES III

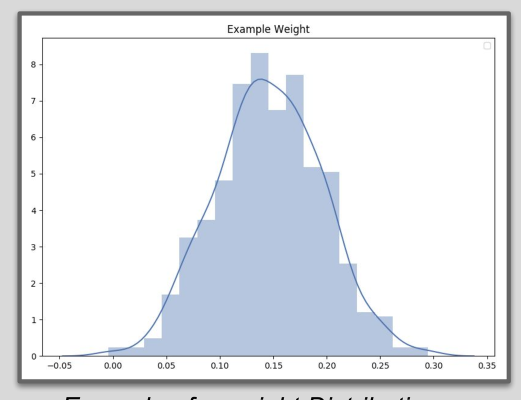
The Beijing Spectrometre III performs its measurements on the Beijing Electron-Positron Collider II (BEPCII).
It forms the basis of important research in the field of High Energy and Hadron Physics.

Bayesian Neural Network

In contrast to a conventional Neural Network a Bayesian Neural Network (BNN) does not have fixed weights, but each weight will be a distribution.
This adds more flexibility during the training.



Schematic Representation of a NN



Example of a weight Distribution

Interfaces and Tools

ROOT with TMVA
TMVA: Toolkit for Multivariate Analysis

ROOT Data Analysis Framework

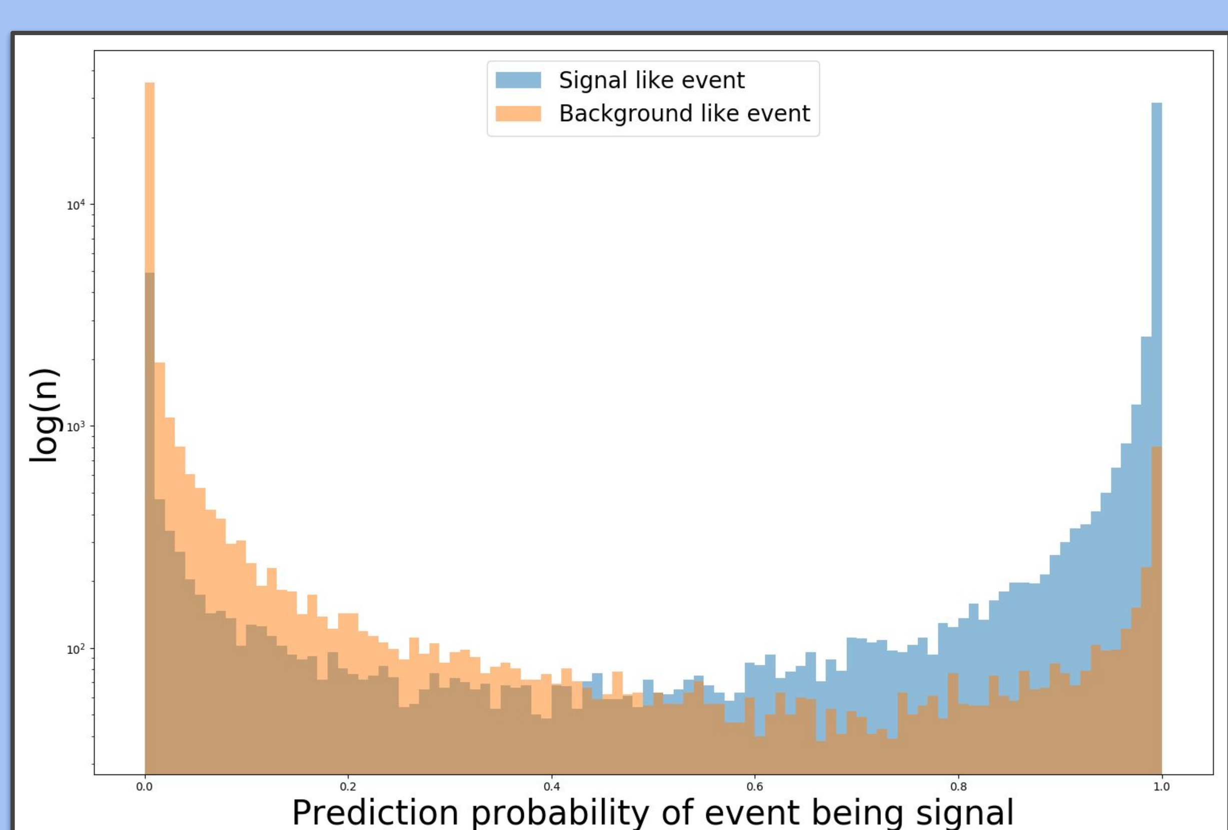
Tensorflow with Keras

TensorFlow

Training

The final input included Vertex Coordinates, Track Coordinates, 4-Vector and the Decay Length.

The labeled data set is split into training and testing data. predictions performed on the testing data set are represented in the histogram below.



Histogram of the Testing Data Predictions

This histogram was not only used to determine a potential over-training of the network but also to investigate the confidence of the model.
As you can see by the vale in the middle, the model is pretty confident about its predictions. Also there is a slight peak of signal-predictions for background events and vice versa.

This is some misclassification which can happen due to the nature of the labeled dataset, which was actually contaminated with wrong labels.

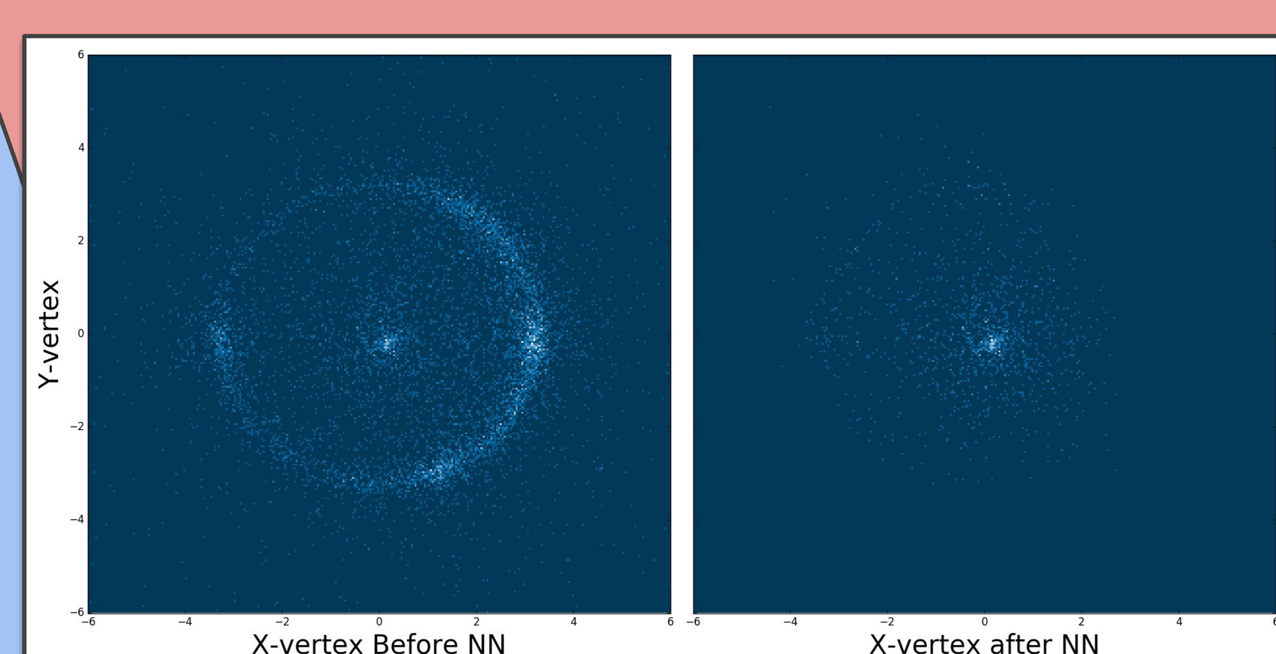
Results

To analyse how well the neural network performs we look in the signal region and counts the amount of signal events before the neural network and after.

Before BNN	
Amount of signal events:	1094
Level of background:	35%
After BNN	
Amount of signal events:	768
Level of background	7.8%
Accuracy	
Prediction accuracy	85%

The amount of signal events and level of background before and after the NN

The accuracy of the neural network is 85% on the unlabeled data and the level of background is reduced from 35% to just 7.8%.



Lambda vertices in X-Y direction before and after the NN

By plotting observables from the data set before and after the neural network is applied one can visualise where the the background and signal events are.

Acknowledgements

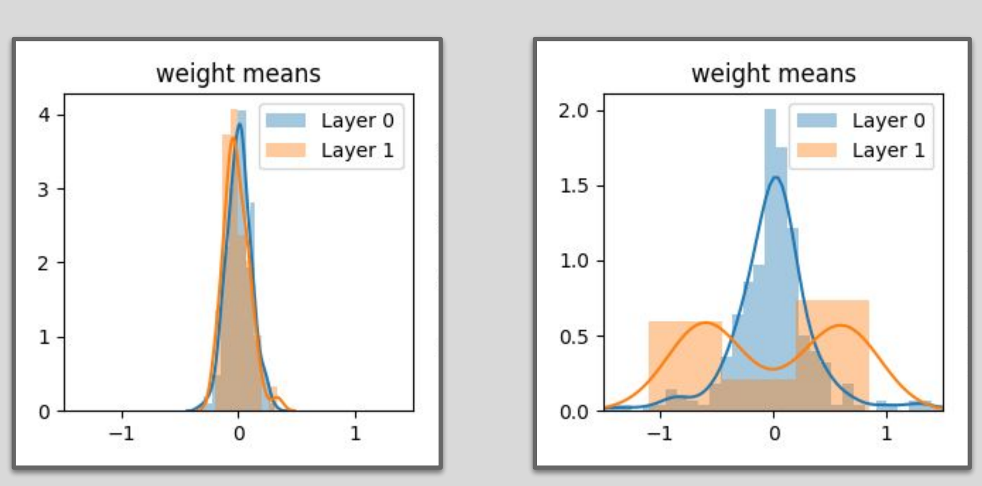
We would like to thank the group of nuclear physics for the great help and guidance throughout this project by providing valuable knowledge in hadron physics and neural networks.

A special thanks to our supervisor Jacek Biernat for the numerous discussions that helped us get through the tough tasks of the project.

Conclusion

Based on the vaguely labeled training data set, the Bayesian Neural Network actually performed better than expected.

In the figure below shows the means of the weight distributions initially and after the training.



Weight means of the Bayesian Neural Network before (left) and after (right) Training

Take-Home Message

To sum up, here we give a possible future outlook and some key points to take away from this project.

- This algorithm could be used in more applications than the Lambda decay and investigated even on measurements of other facilities than BESIII
- Bayesian Neural Networks offer an interesting alternative to conventional NNs
- The usage of image data is not necessary to apply the BNN
- To get optimal results a well processed training data set is crucial