Using Machine learning to segregate cosmic muons from background gammas

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Introduction

Cosmic muons are high-energy charged particles originating from cosmic rays in the upper atmosphere and reaches the Earth surface. These cosmic muons has the mean energy of $\sim$ 3-4 GeV, which make them a particularly useful probe for applications like Muon Tomography, and can also be used as a probe to calibrate particle detectors. In addition to cosmic muons there are several order of magnitude more background gamma are also available in our environment. Hence, these cosmic muons need to be segregated from background gammas, inorder to be used for any application. In the current we will present a Machine Learning based approach to segregate these cosmic muon from background gamma for plastic scintillator detector.

Detector Setup

The detector setup consist of a plastic scintillator bar (10 cm $\times$ 10 cm $\times$ 100 cm) coupled to Photo Multiplier Tube (PMT) at both ends, which are used to get the timing and integrated charge. The integrated charge corresponds to the energy deposited in the scintillator by the incident radiation, and is key to segregate the cosmic muon from background γ, as it is seen from the GEANT4 [1] simulation that cosmic muons deposit $\sim$2MeV/cm for the material used in the scintillator bar. The energy based segregation procedure requires the energy calibration to be applied on the integrated charge, so that it integrated charge represents the energy deposited.

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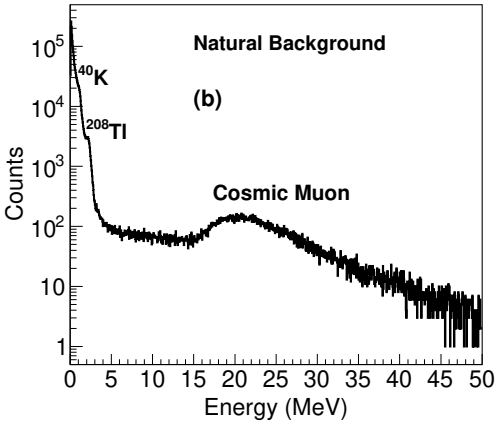

FIG. 1: A figure caption. The figure captions are automatically numbered.

Conventional energy deposition based cosmic muon segregation

The energy calibration of these detectors are conventionally done using different radioactive sources of known energy to get a parameterization to map the integrated charge to energy. The parameterization will then be applied on the experimental data to get the energy deposited by incident radiation. The Fig. 1 shows the plot of energy deposited by cosmic particles after the application of energy calibration. From here one can see that the energy deposited by cosmic muons peaked at $\sim$20MeV, which is also verified using GEANT4 simulation **??**. Hence, an energy threshold of 10 MeV is chosen to segregate the cosmic muons from the background γ.

Machine learning based cosmic muon segregation

The conventional approach needs energy calibration procedure to be applied on individual event and in the second step takes the decision based on the selected threshold. This makes the job computation intensive as background γ-s are orders of magnitude more then muon events. This problem can be solved the building a machine learning model, that can quickly discriminate γ and muon events. Hence the problem of cosmic muon segregation can be mapped to binary classfication problem in machine learning, as we just want to classify events as muon events or background γ events. Calibrated data is required only in the learning phase, so that the individual events can be labelled as muon event or background γ events.

Data Sets

As mentioned above the data from experiment consist of timing and integrated charge, where the mean of the integrated charge is proportional to the energy deposited. In the present work, only the energy is used for the segregation of cosmic muon segregation. Hence in the learning phase of the model we are using the integrated charge obtained from both the PMTs as the input features, and the event is labelled as muon event if the calibrated energy deposited is more than 10 MeV, otherwiser it is labelled as background γ event. A classfication model is trained using 3×10^5 events of labelled data.

Results

Result

Conclusion

By harnessing the power of advanced machine learning classification algorithms, a successful segregation between cosmic muons and background *gamma*-rays is obtained based on their distinct energy deposition patterns. This has yielded the promising results with significant implications for applications like Muon Tomography.

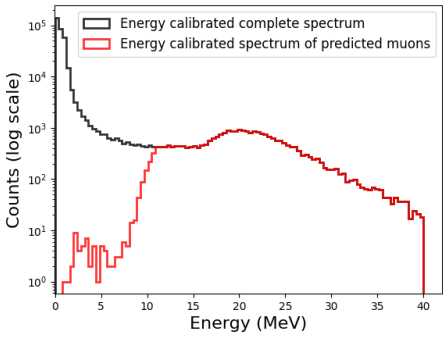

FIG. 2: A figure caption. The figure captions are automatically numbered.

Acknowledgments

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References

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