**Vertex and Energy Reconstruction in JUNO with Machine Learning Methods**

Ziyuan Li
(On behalf of the JUNO collaboration)
Sun Yat-sen University, Guangzhou, P.R.China

## Introduction

The ability to accurately reconstruct events in JUNO is critical to the success of the experiment: the energy resolution is expected to be $3\%/\sqrt{E}$ (MeV), and the vertex resolution is expected to better than 10 cm.

In this poster, four machine learning (ML) methods applied to the vertex and the energy reconstruction will be presented, including Boosted Decision Trees (BDT), Deep Neural Networks (DNN), Convolutional Neural Networks (CNN), and Graph Neural Networks (GNN).

## Data Preparation

The training and testing of neural networks has been performed on Monte Carlo (MC) samples generated with the official JUNO software and further processed to include the most relevant effects of the electronics response.

**Simple models : BDT and DNN**

The models of BDT and DNN are trained with aggregated information, pre-calculated from PMT signal, which allows getting reasonable predictions at a very low computational cost.

**Complex models : CNN and GNN**

The CNN and GNN are more complex and able to deal with more granular input, therefore provide better precision by processing the full information.

## Reconstruction Performance

The CNN and GNN are more complex and able to deal with more granular input, therefore provide better precision by processing the full information.

![Fig. 1: Schematic view of JUNO detector.](image)

![Fig. 2: Data structure of a single event.](image)

![Fig. 3: SHAP values for the vertex (left) and for the energy (right) prediction of DNN model.](image)

Both BDT and DNN have been tuned for JUNO.

![Fig. 4: ResNet network architecture for CNN reconstruction with 53 weight layers.](image)

![Fig. 5: Prediction time and memory usage for different models.](image)

**Conclusion**

- For the first time, ML has been applied to event reconstruction of large liquid scintillator detectors with a large number of PMTs, and the results look very promising.

More detail can be found in arXiv:2101.04819.

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