Reconstruction of Neutrino Events in IceCube using Graph Neural Networks Martin Ha Minh (Technical University Munich) for the IceCube collaboration

1000m 1000m 100m 100m

Low-energy IceCube events

- High number of events (~10⁷ simulation & data in final selection)
- Current baseline algorithm:
 - \sim 40 s per event reconstruction
- \rightarrow Very long processing times!

IceCube Upgrade will add new detector strings and model architectures

 \rightarrow Will increase reconstruction time!

Requirements for new algorithm:

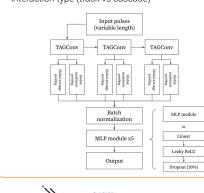
- Fast
- Adaptive to new geometries and detector modules
- Preserves the complete event information
- \rightarrow Graph neural networks

Graph neural networks (GNNs)

- Information represented by nodes
- Nodes are connected by edges, based on their relationship
- \rightarrow Possibility to encode information with irregular shapes

Description of technique

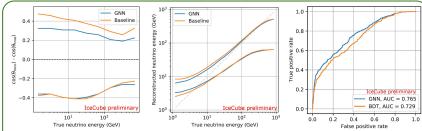
- Each event is a graph, each pulse in the event is a node in abstract space of x-, y-, z- position, time, and charge (+ PMT direction and detector module type for IceCube Upgrade)
- k nearest neighbors based on Euclidean distance in position and time are connected by edges
- Convolutional layer expands information onto additional dimensions
- Graph pooling for further processing by Multilayer
 Perceptrons
- Prediction of neutrino energy, zenith angle, and interaction type (track vs cascade)



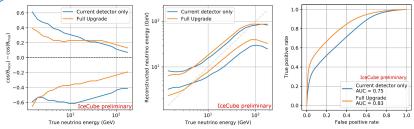
SFB 1258

Dark Matter Messengers Deutsche

orschungsgemeinschaft



Comparison of 68% resolution bands and ROC curves between the GNN presented here and the baseline reconstruction algorithms designed for the current lceCube DeepCore detector (likelihood-based for energy and zenith, boosted decision tree (BDT) for track identification) based on current final event selection simulation



Comparison of 68% resolution bands and ROC curves between the current detector configuration and the detector with added Upgrade modules based on IceCube Upgrade prototype simulation

IceCube Upgrade

ICRC 2021



Results

- Applicable on detector simulation for both current detector and future lceCube Upgrade
- Resolution improved compared to baseline for all reconstructed parameters
- Speedup of ~10⁴

martin.haminh@icecube.wisc.edu PoS(ICRC2021)1044

IceCube DeepCore only