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- High number of events  
( $\sim 10^7$  simulation & data in final selection)
- Current baseline algorithm:  
 $\sim 40$  s per event reconstruction

→ Very long processing times!

## IceCube Upgrade will add new detector strings and model architectures

→ Will increase reconstruction time!

Requirements for new algorithm:

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

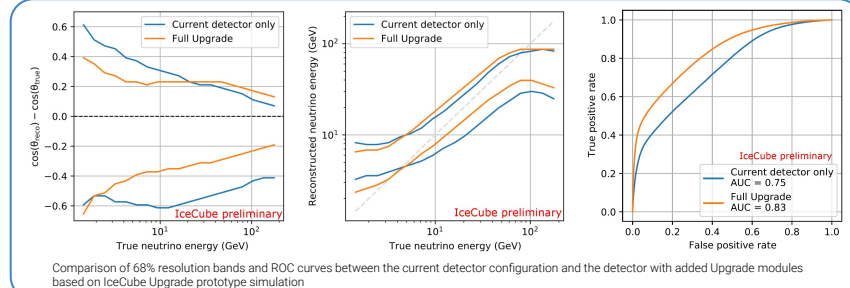
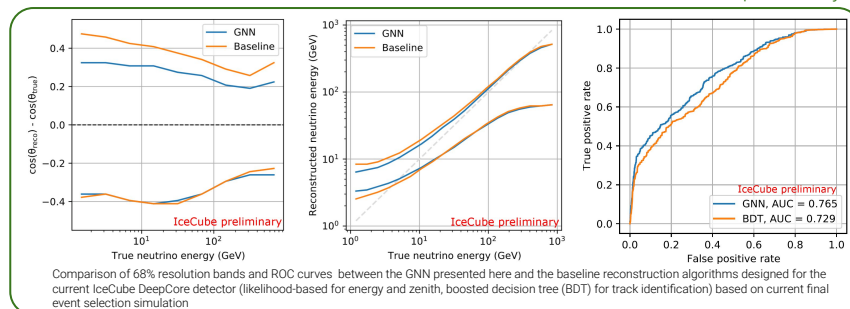
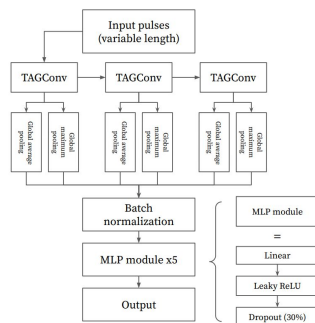
## Graph neural networks (GNNs)

- Information represented by nodes
- Nodes are connected by edges, based on their relationship

→ 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)



## IceCube Upgrade



## Results

- Applicable on detector simulation for both current detector and future IceCube Upgrade
- Resolution improved compared to baseline for all reconstructed parameters
- Speedup of  $\sim 10^4$