Direction Reconstruction

using a CNN for GeV-scale Neutrinos in IceCube

For the IceCube Collaboration

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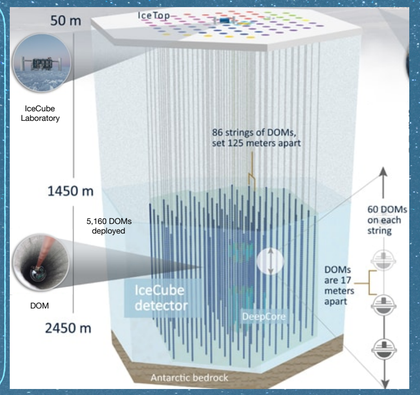
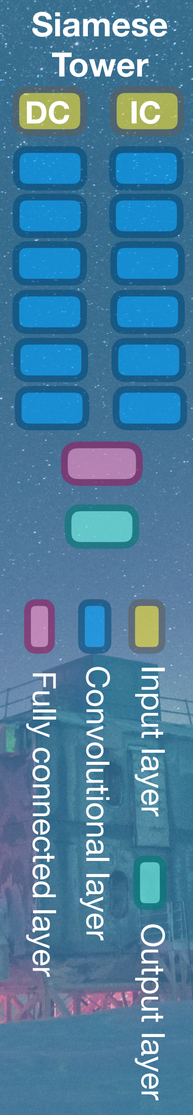
Introduction

- IceCube Neutrino Observatory: a Cherenkov detector observes neutrinos interacting deep within ice by detecting Cherenkov photons.
- DeepCore (DC):
  - subdetector at lower center of IceCube (IC)
  - lowers observable neutrino energy to GeV-scale
- Precisely measuring neutrino direction (zenith) is critical in studying neutrino oscillations
- Reconstruct value of zenith using a CNN

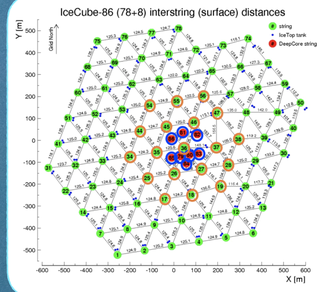


Convolutional Neural Network (CNN)

8 DC and 19 surrounding IC string as separate inputs:
- 60 digital optical modules (DOMs) per string
- 5 variables calculated from the pulse series per DOM: sum of charges, time of first (last) pulse, charge weighted mean (standard deviation) of time of pulses

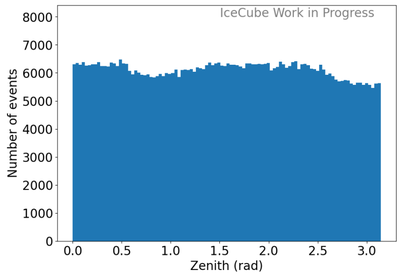


Training



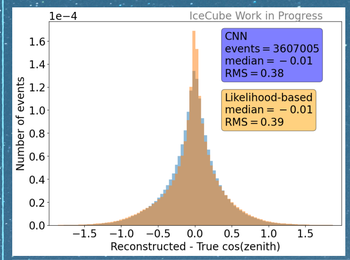
- 5~300 GeV NuMu CC
- True vertex contained:
  - vertex z in (-505, 500) m
  - $\rho_{36} < 260$ m
- Flat zenith distribution

Training set: 4 million;
Validation set: 1 million

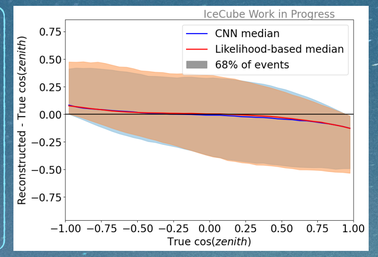


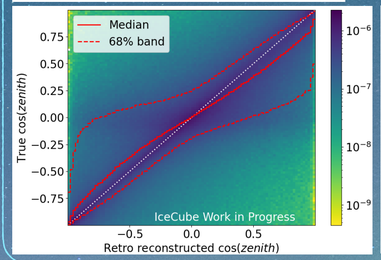
Performance

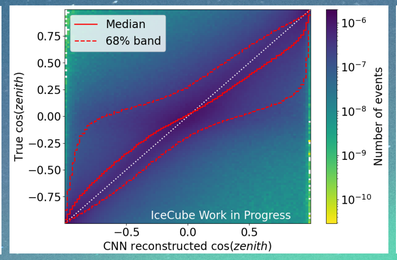
NuMu CC with current likelihood-based reconstruction ("Retro") cuts:
5 GeV < E < 300 GeV; -500 m < z < -200 m; $\rho_{36} < 300$ m

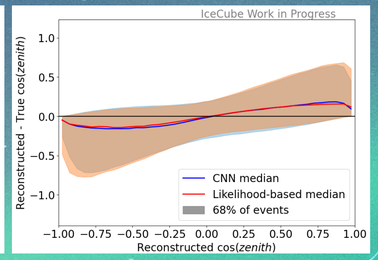


- Smaller overall RMS
- Comparable bias against both true and reconstructed cos(zenith)









Summary & Future

Processing Speed

Time (s) /Event	GPU	CPU
CNN	0.0044	0.108
Retro	—	44.97

- Improved RMS by 2.5%
- Up to 10,000 times faster than current processing
- Comparable bias
- Investigating improvements to systematic uncertainties

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