Reconstructing Neutrino Energy using CNNs for GeV Scale IceCube Events

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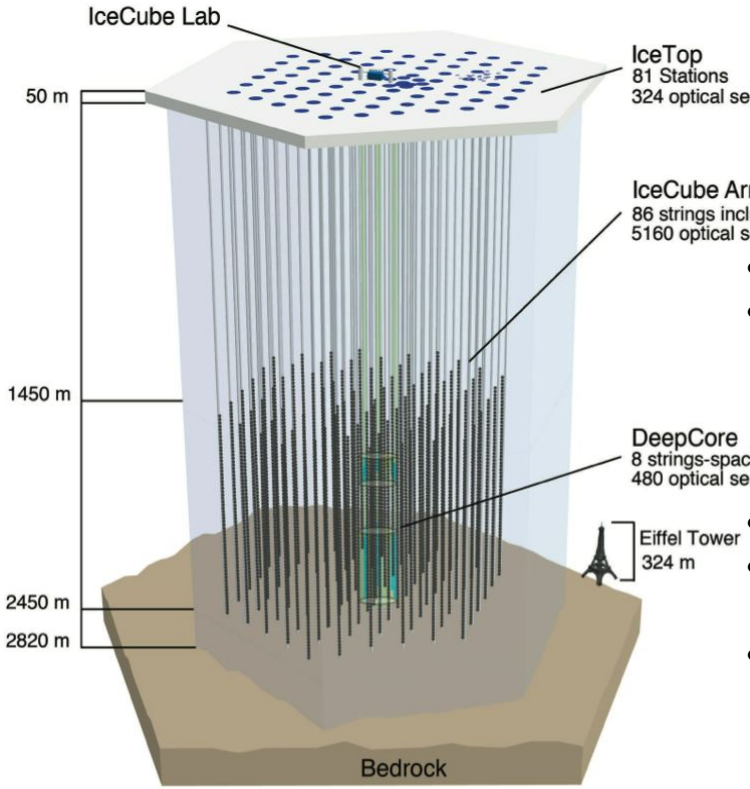
IceCube Neutrino Observatory

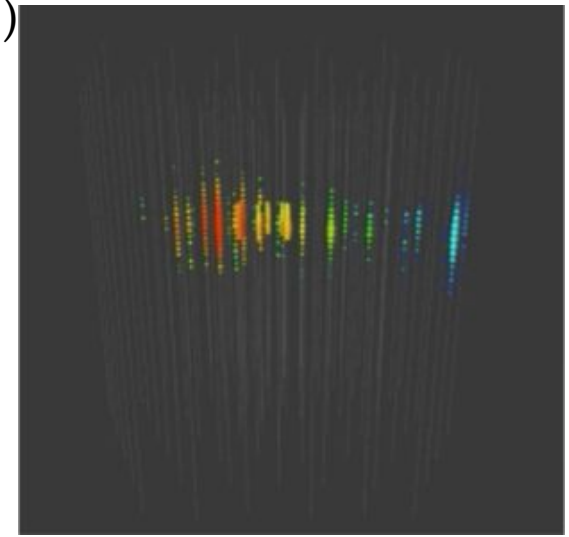


- 125 meters between strings
- 17 meters between optical modules on string

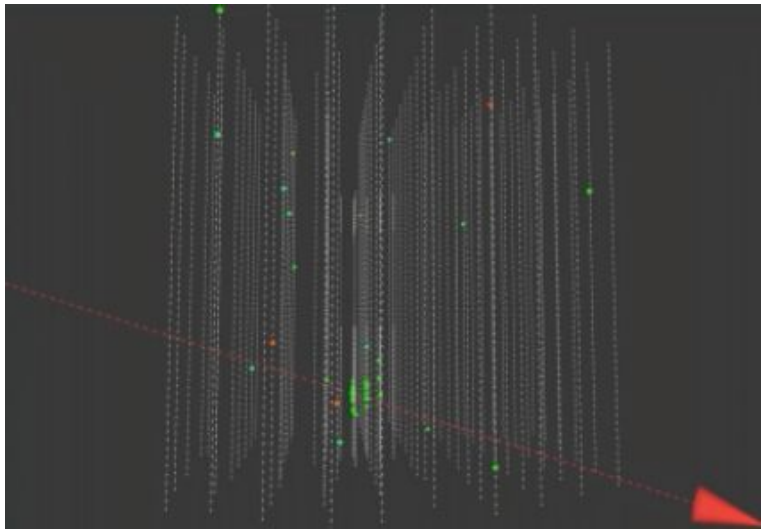
- 72 meters between strings
- 7 meters between optical modules on string
- Optimized to detect lower energy events (GeV-scale)

Event Signatures in IceCube

High energy ν_μ CC event (71 TeV)

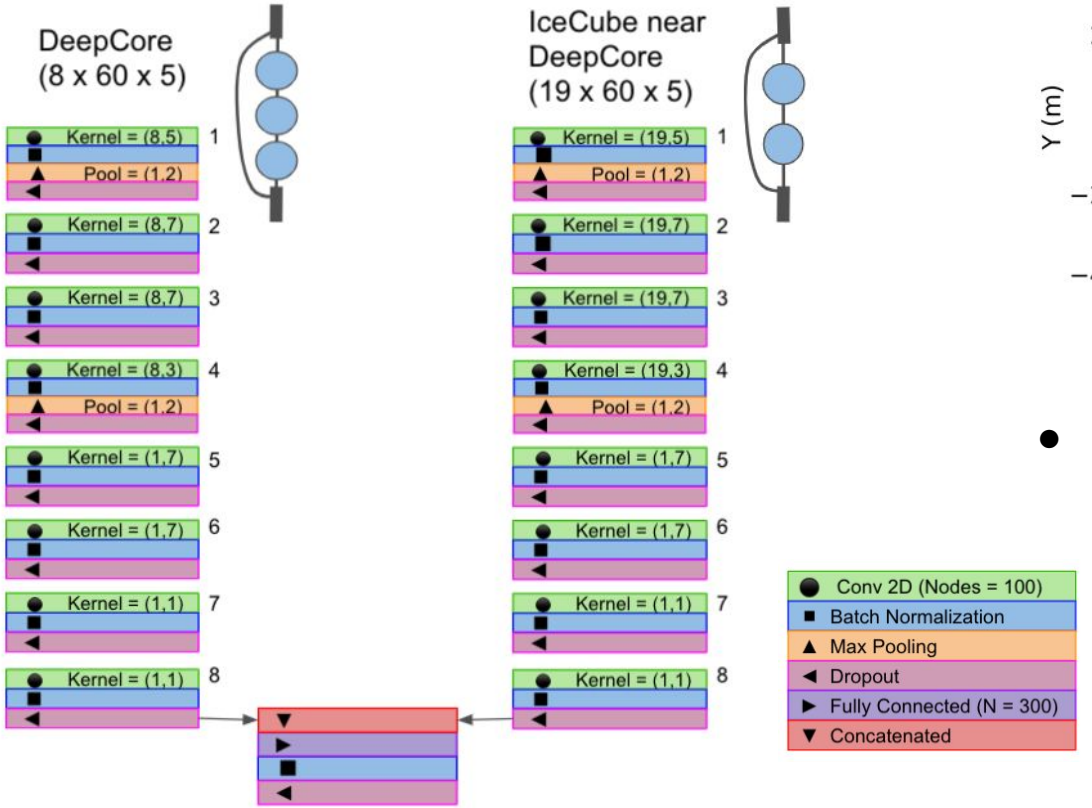


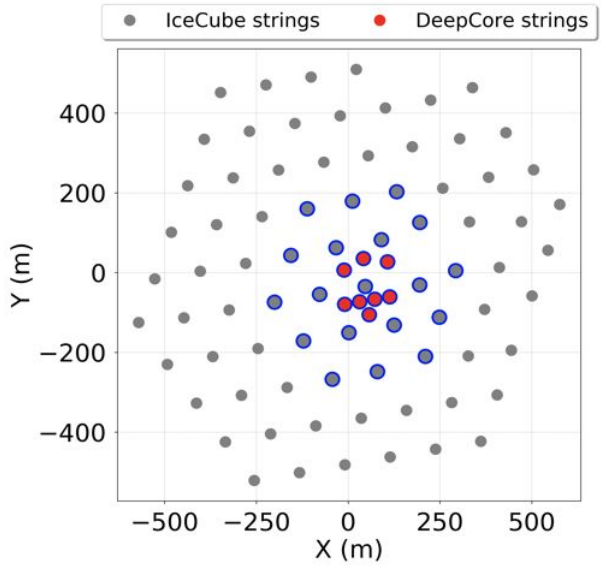
Low energy ν_μ CC event (12 GeV)



- Less light produced per event means fewer optical modules record pulses
- Must leverage DeepCore array
- Need to optimize neural network specifically for these events

GeV-Scale CNN Architecture



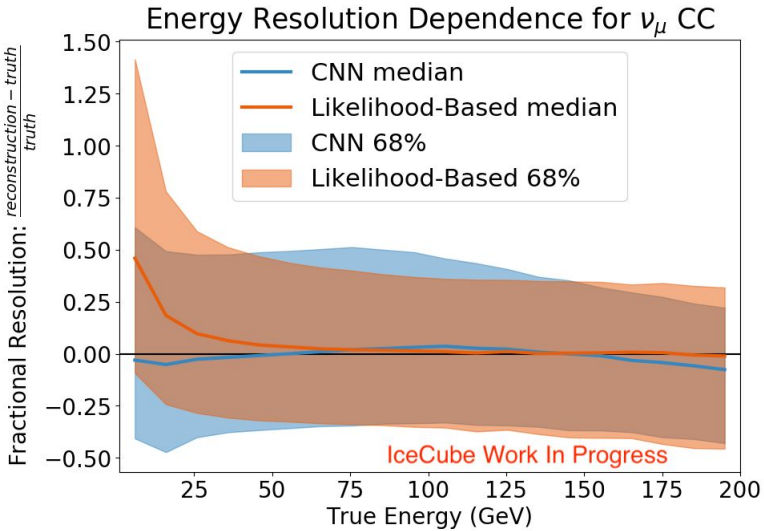


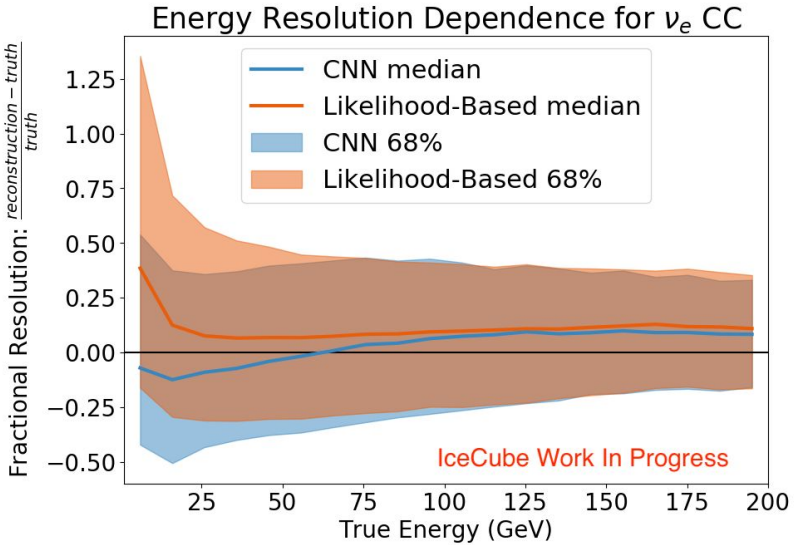
Blue circles indicate strings used for CNN

- Inputs: 5 variables that summarize all pulses hitting optical module
  - Sum of charge
  - Time of first hit
  - Time of last hit
  - Charge weighted mean of times
  - Charge weighted σ of times

CNN Energy Performance Testing on ν_μ CC & ν_e CC

- ✓ CNN does well at lowest energies
- ✓ Comparable to current likelihood-based reconstruction





CNN Significantly Reduces Reconstruction Time

- ✓ 10^5 runtime improvement possible in serial!
- ✓ In parallel, CNN reconstruction will take a day (vs weeks for likelihood-based)

	Events per day per single core
CNN on GPU	11,000,000
CNN on CPU	320,000
Likelihood-based method on CPU*	2,100

*Likelihood-based method outputs 8 reconstructed variables

Conclusions

- The GeV-scale CNN shows comparable resolution (to previous methods) for IceCube's low energy ν_μ & ν_e CC events
- Reconstruction speed is much faster than previous methods!
- Future work currently in progress:
  - Populating higher energies for training sample
  - Optimizing reconstruction for other variables:
    - Direction -- see Shiqi Yu's poster!
    - Particle identification classification
    - Interaction vertex reconstruction

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