Improving reconstruction of GeV-scale neutrinos in IceCube-DeepCore by direct event simulation

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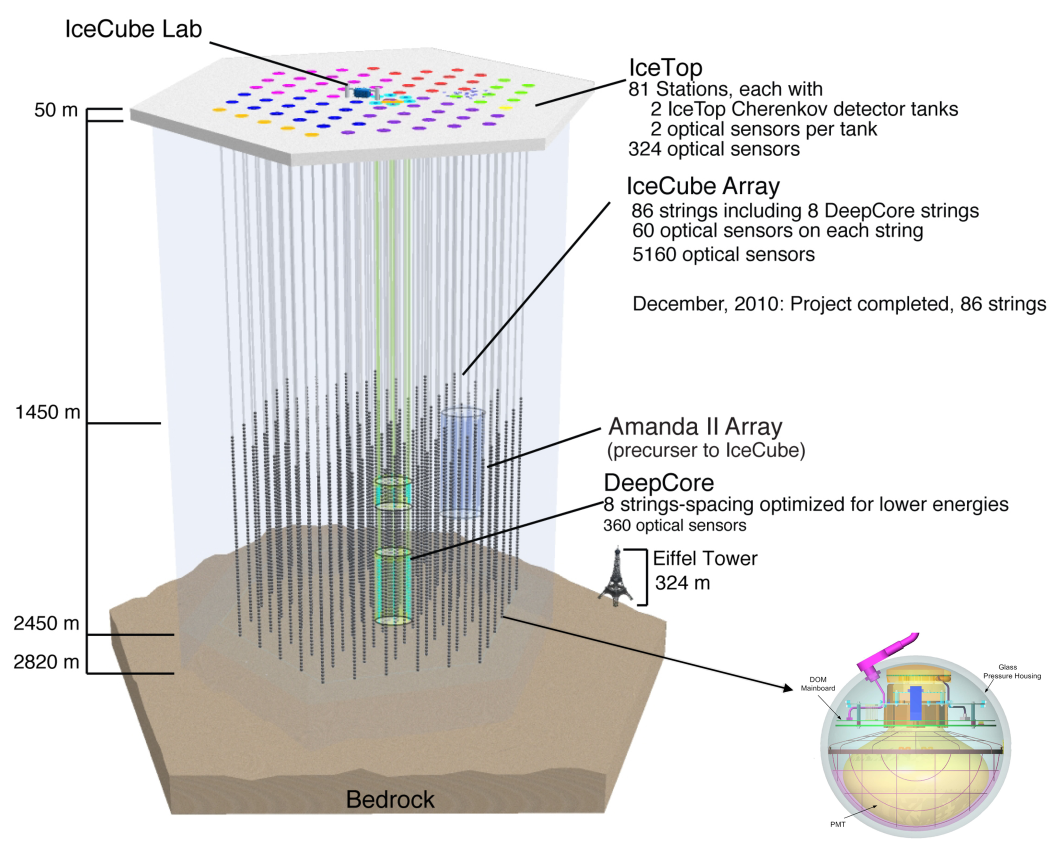
ICECUBE

The IceCube Detector

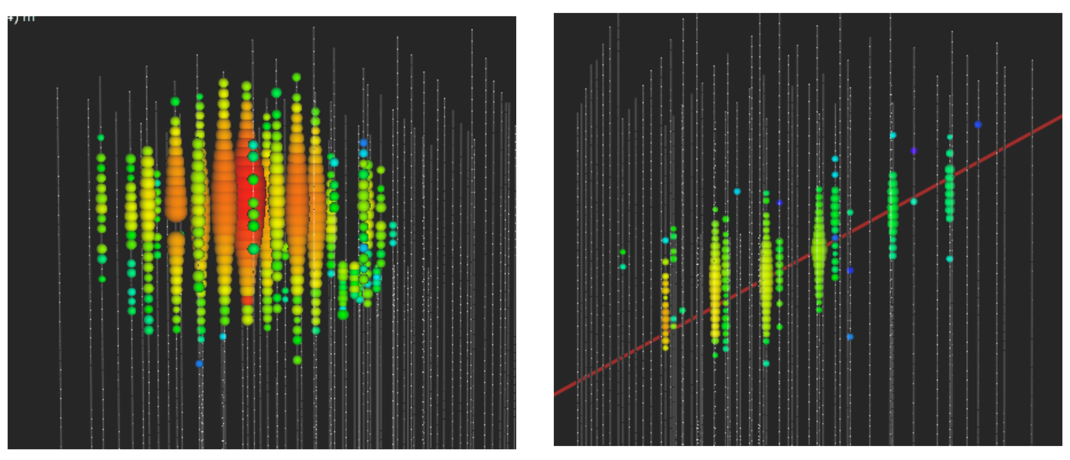


Digital Optical Module (DOM)

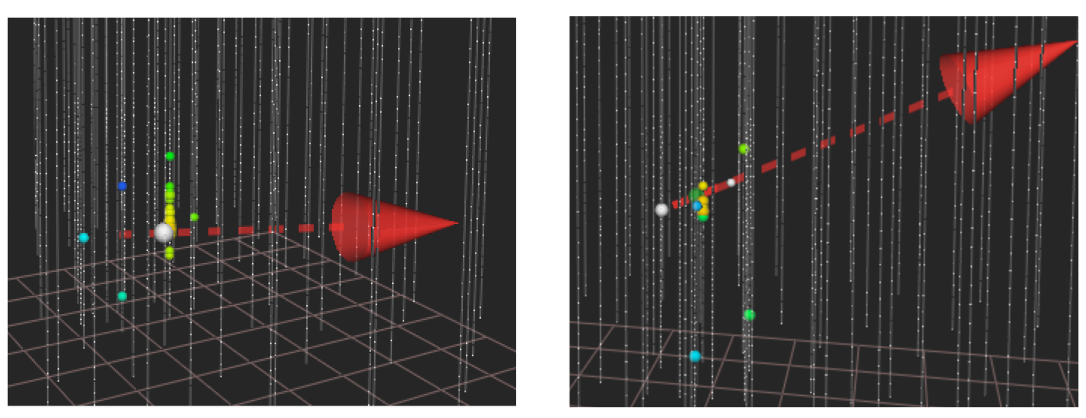
- Instrumented cubic-km of deep glacier at South Pole Station, Antarctica
- Designed to detect ~TeV to PeV astrophysical neutrinos
- Denser infill array, DeepCore, extends high sensitivity down to ~5 to 100 GeV neutrinos

Event Reconstruction Challenges

- Detected charge amplitude and timing from Cherenkov photons form the signal



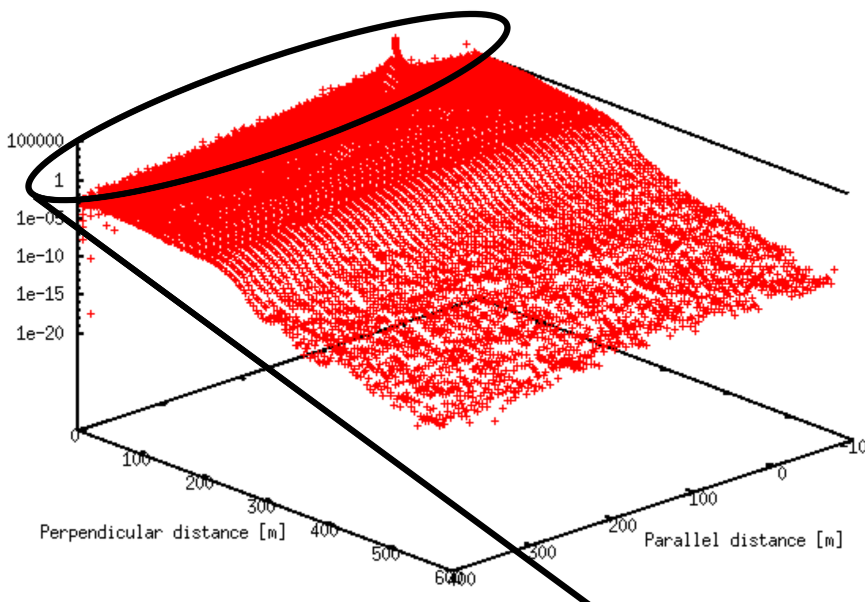
High energy event displays: ~1 PeV cascade-type (left) and ~ 340 TeV muon-type (right)



Low energy event displays: 30 GeV cascade-type (left) and 30 GeV muon-type (right)

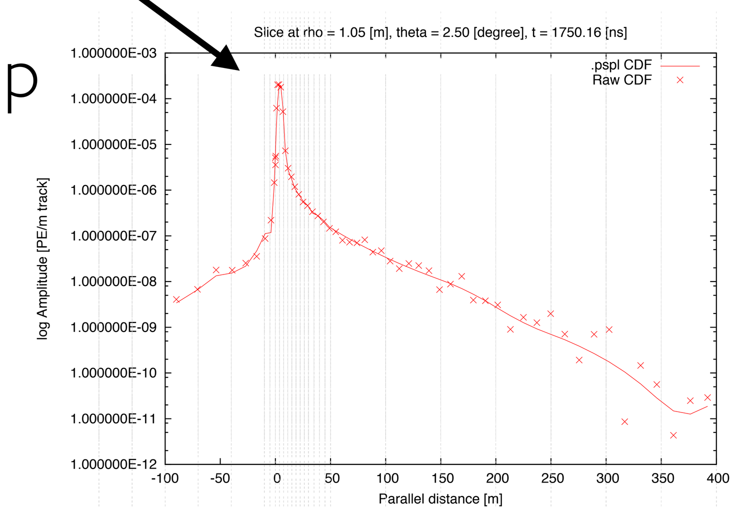
- Often only O(10) photo-electrons (pe) for neutrinos of O(10) GeV, compared to O(10000) pe for the PeV-scale
- Modelling details are critical with so few photons available per low-energy event

Motivation

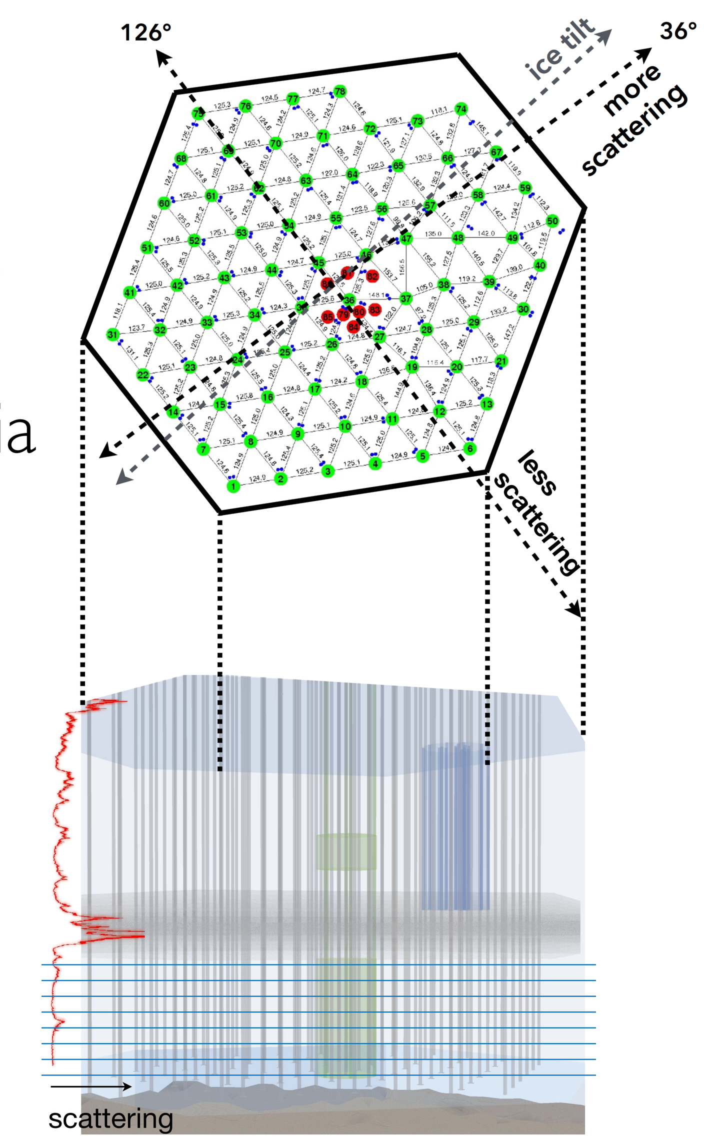


Photon look-up tables for muon: 2D slice (left) and 1D slice (below)

- 'Photon look-up tables' characterize propagation through ice



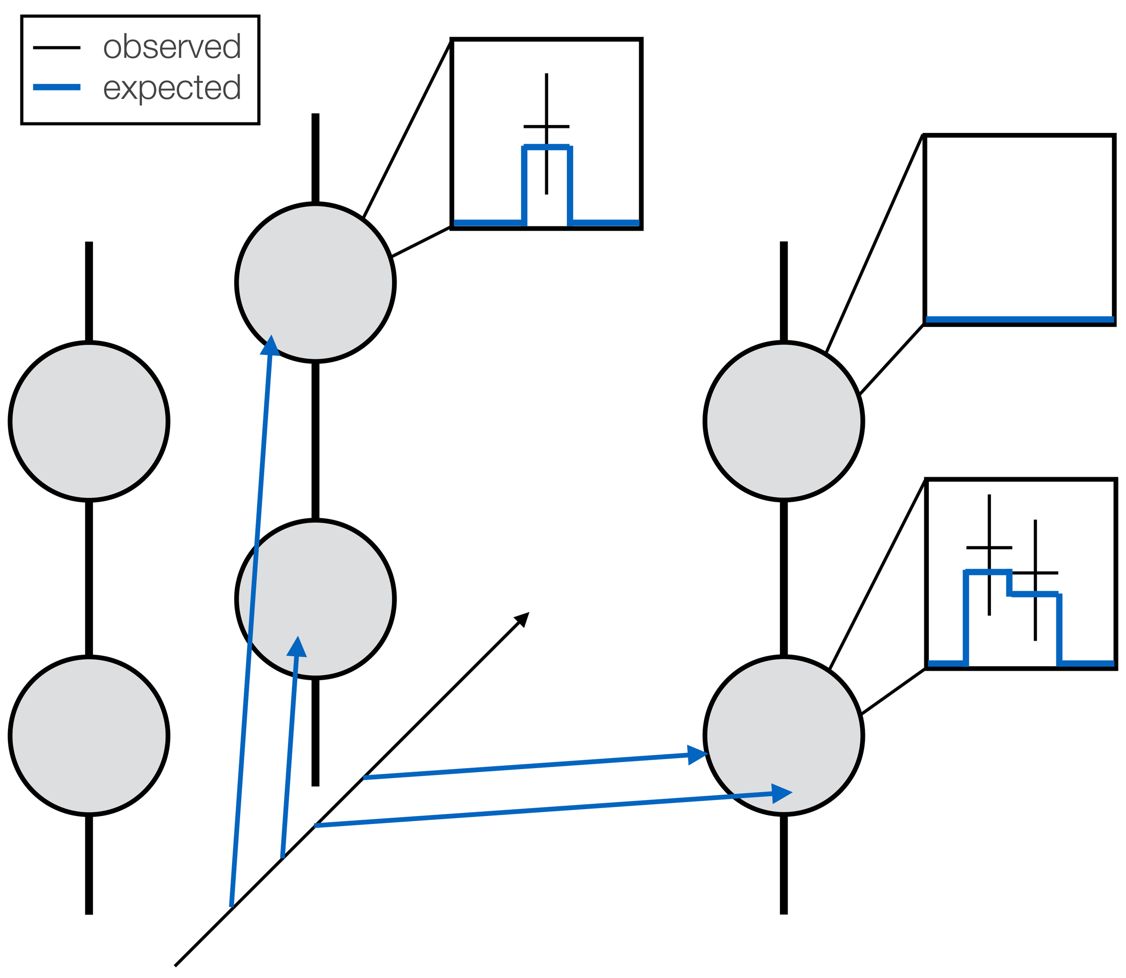
- Currently rely on pre-generated templates describing photon detection probabilities in a given layer/region
- The most advanced ice models are too complex to be implemented via this method



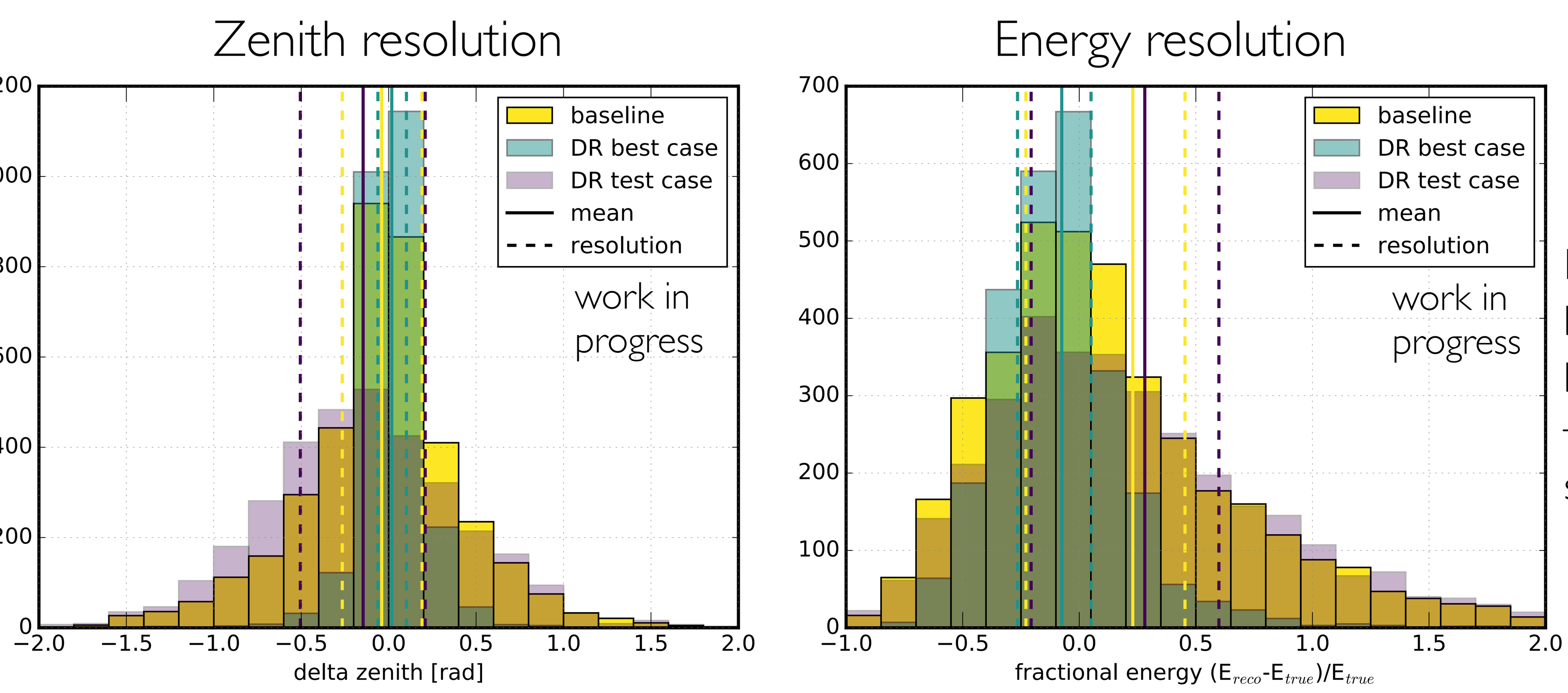
Ice is modelled in layers, with varying scattering and absorption. Later models include tilt of layers and anisotropy of scattering

DirectReco

- Key: replace look-up tables with real-time event simulation
- Event hypotheses are re-simulated to reduce statistical fluctuation
- Expected and observed charge are compared via a likelihood calculation
- A modified Poisson likelihood[1] is used to account for limited statistics of the prediction
- <u>Summary</u>: combines accurate photon prediction for choice of advanced ice models with highly optimized, existing software



Results



DR: DirectReco
baseline: current best
best case: truth seed
test case: baseline seed

- Evaluation of ~4000 final level analysis MC events
- Energy range: generated from 1 GeV to 1 TeV, with most events in the 1 to 100 GeV range
- Mean time: O(100) seconds
- Significant potential to improve resolution
- Optimization is underway!

References

1. Chirkin, D. (2013). Likelihood calculation for comparing data with simulation of limited statistics. *arXiv: 1304.0735.*

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