

GPUs in IceCube

HOW2019

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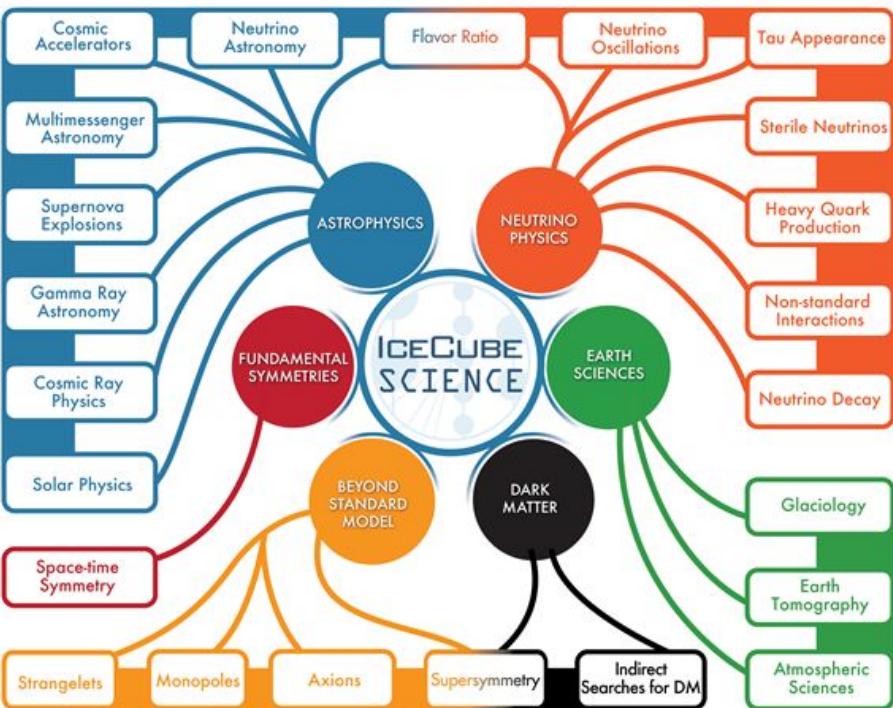
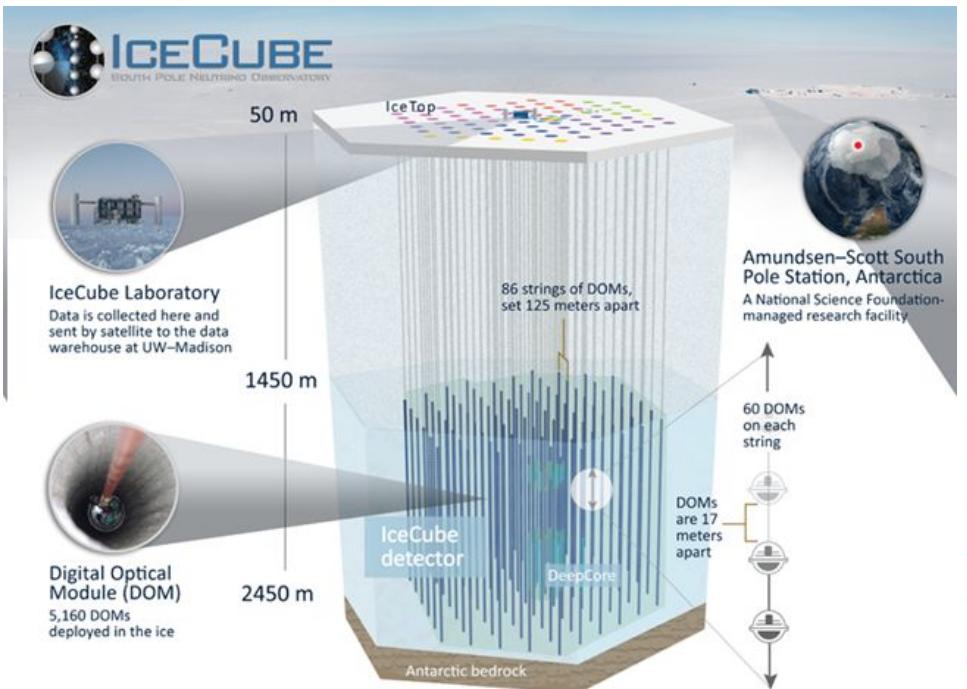


Outline



- IceCube Detector
- Simulating photon propagation in ice
- Production infrastructure - making it go at scale
- Reconstructions on GPUs

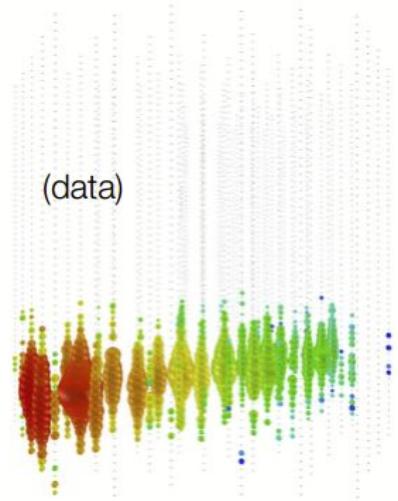
IceCube Detector and Science



Event Types



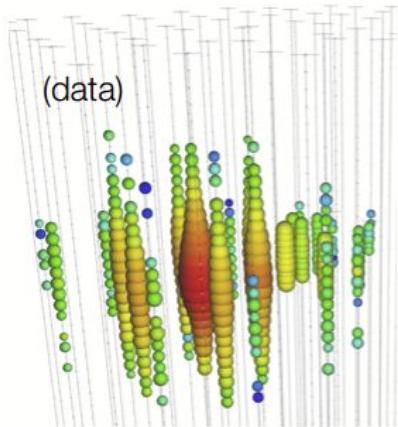
Charged-current ν_μ



Up-going track

Factor of ~2 energy resolution
< 1 degree angular resolution

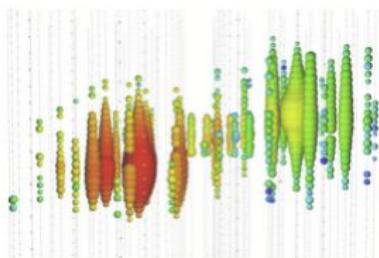
Neutral-current / ν_e



**Isolated energy deposition (cascade)
with no track**

15% deposited energy resolution
10 degree angular resolution (above 100 TeV)

Charged-current ν_τ



"Double-bang"

(none observed yet: τ decay length is 50 m/PeV)



Photon Propagation

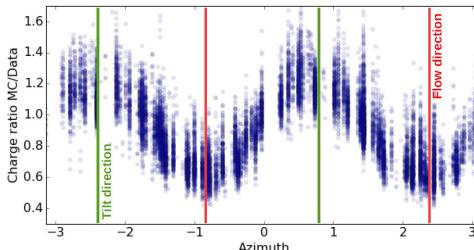
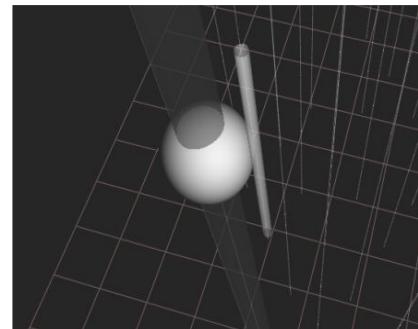
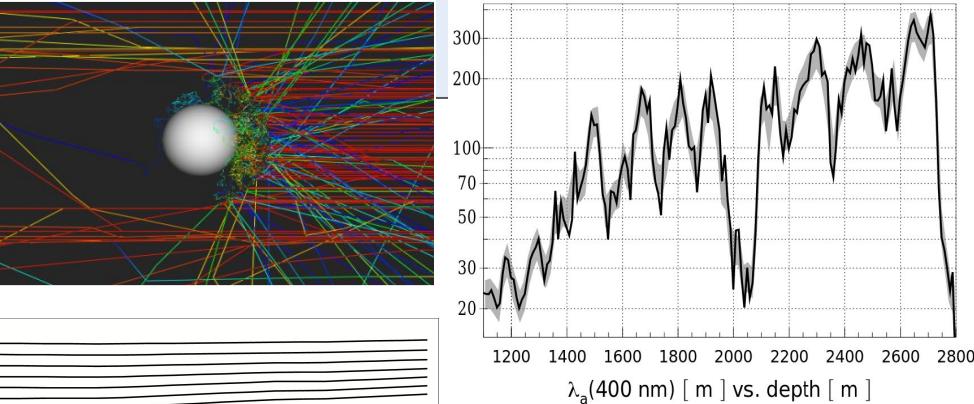
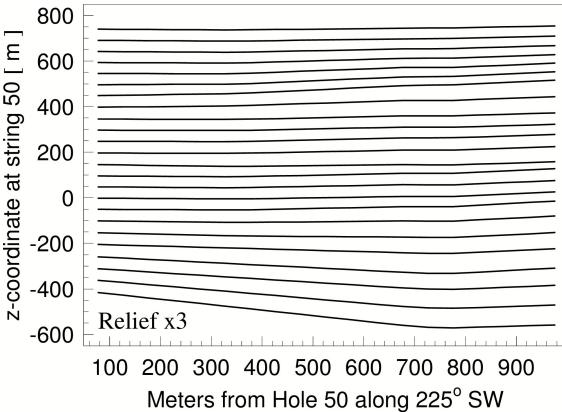


Neutrinos and Ice

Neutrino interactions produce particles that travel faster than light in ice - “Cherenkov Effect”

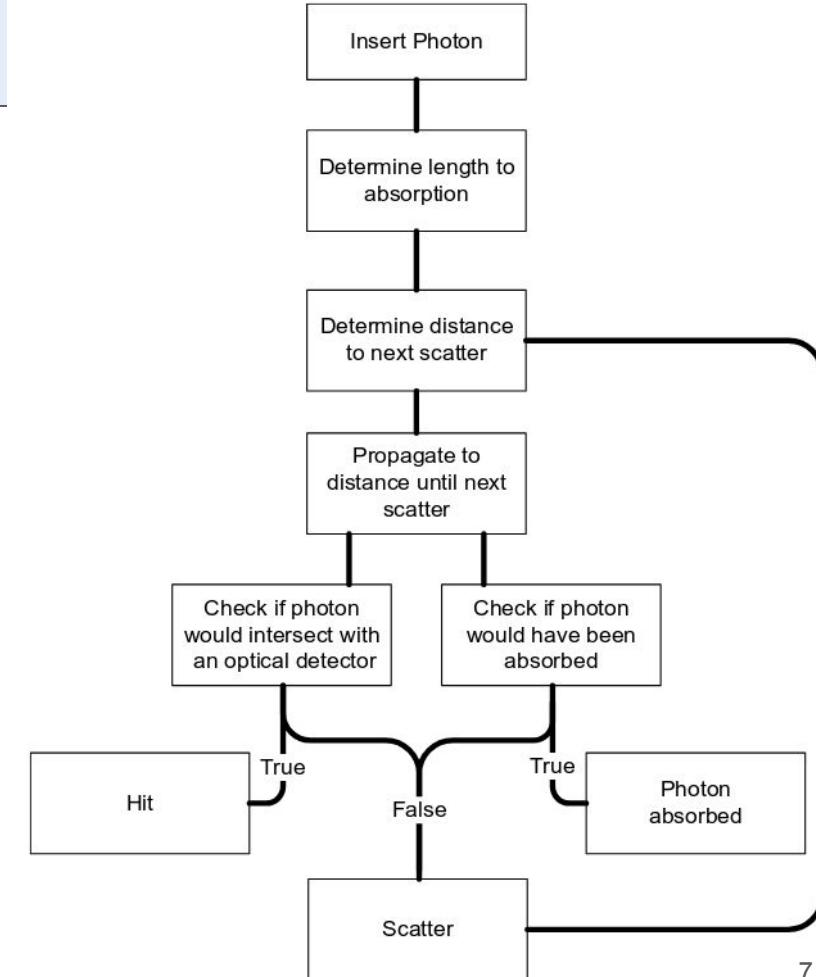
Ice is optically complex

- One of the clearest materials on Earth - Absorption length of 300m
- Tilt of ice layers along height of glacier
- Varying ice properties as a function of polar angle
- Known Unknowns - Hole Ice? Birefringence? Cable Position?



The Algorithm

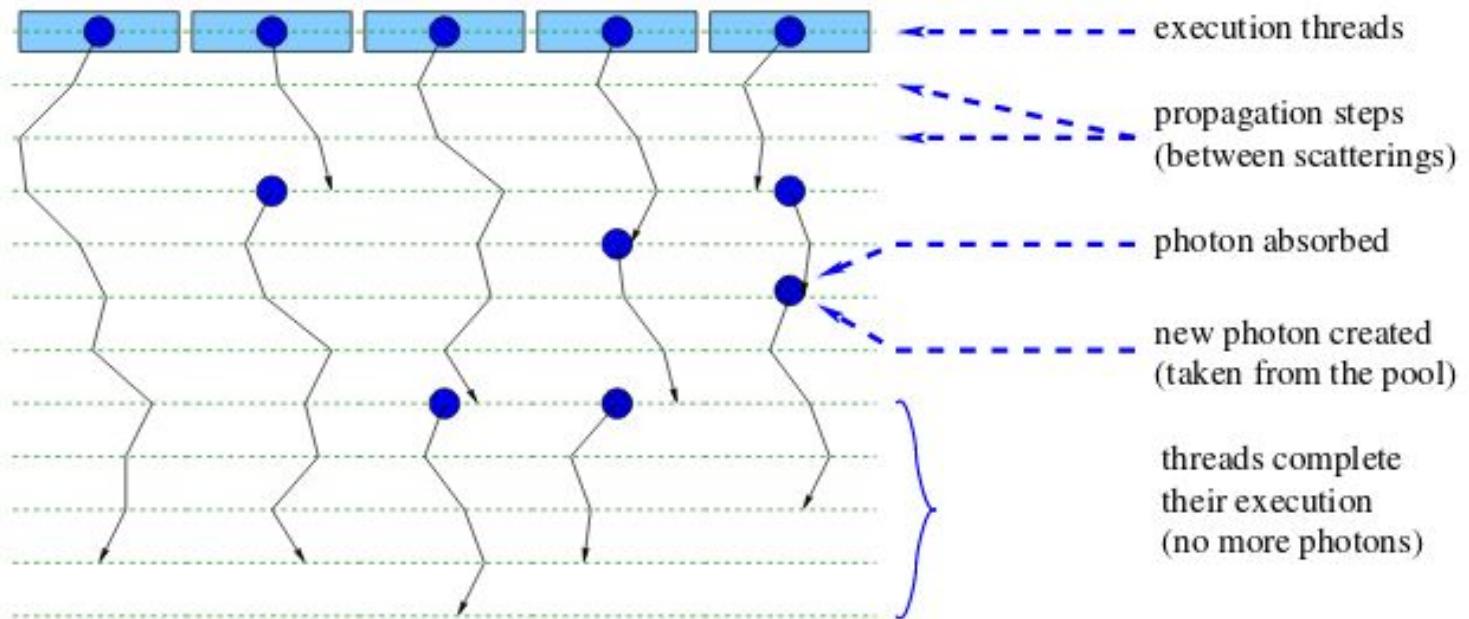
- Simple algorithm
- Pleasantly parallel - Each photon is independent
- Why use brute force?
 - Previously used methods could not account for all physical features of medium - Tilt, anisotropy
 - Method needed to explore new possible properties - Birefringence



The Algorithm



Thread execution model



Production Infrastructure



Accessing GPUs



OpenCL

- Cross-platform: CPUs, GPUs, KNL (though not officially supported), etc.

Glideins

- Create uniform environment for jobs, e.g. CUDA_VISIBLE_DEVICES

CVMFS environment setup

- Set up OpenCL on CPUs

Performance



Require only single precision floating point - Consumer cards work well, and are less pricey

Have explored half precision - Does not work

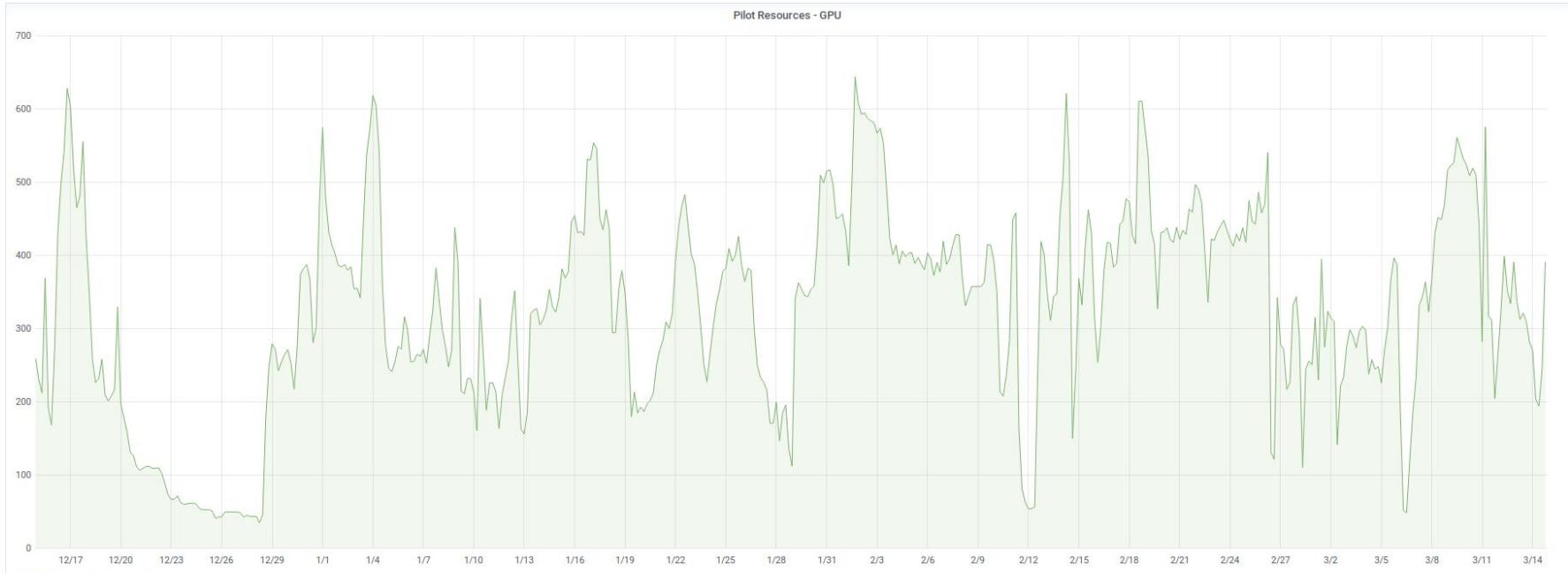
Generational improvements every 2 years

GPU	Nominal FP32 (TPLOPS)	Utilization (%)	Power (W)	Temperature (°C)	ns/photon	photons/s/W ($\times 10^6$)
Tesla P4 [26]	5.4	98.8	45	65	16.77	1.32
GTX 1080 Ti [22]	11.3	96.5	200	69	7.39	0.67
RTX 2080 Ti [23]	13.4	95.4	250	80	4.37	0.92

Scaling it Up



Pilot Resources - GPU



Last 3 months - Avg: 325 Max: 644

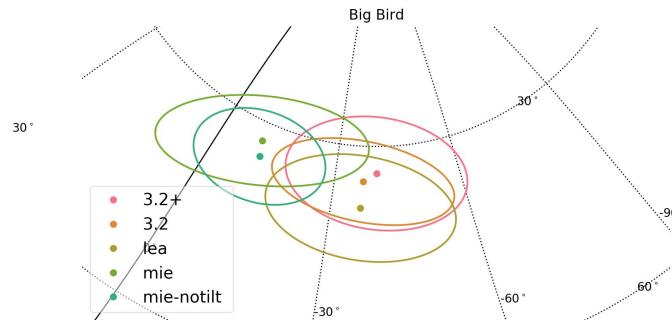
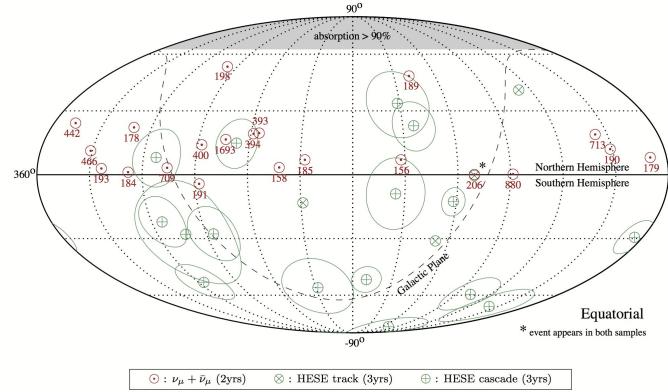
Reconstruction using GPUs



Reconstruction in IceCube



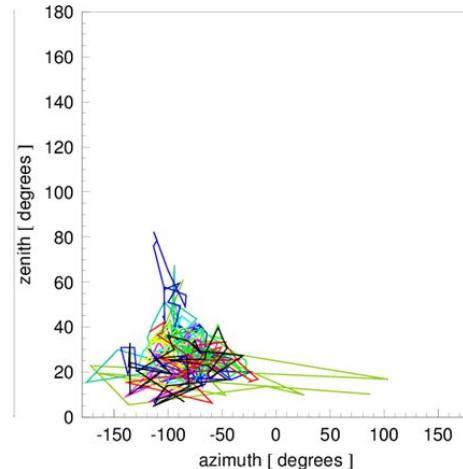
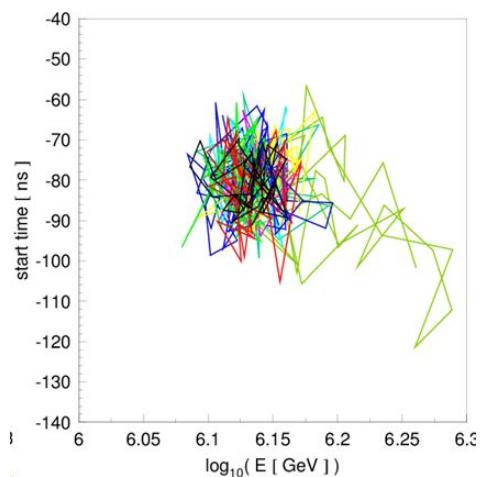
- “Standard” reconstruction in IceCube uses Likelihood Maximization - Timing, position of detectors, charge on participating detectors, noise rate, and ice model
- Ice model parameterized - Cannot include all parameters/features
- Ice models shift events significantly - Bad for EM follow-up observations (large error compared to EM observatory field of view)



Reconstruction using Photon Propagation



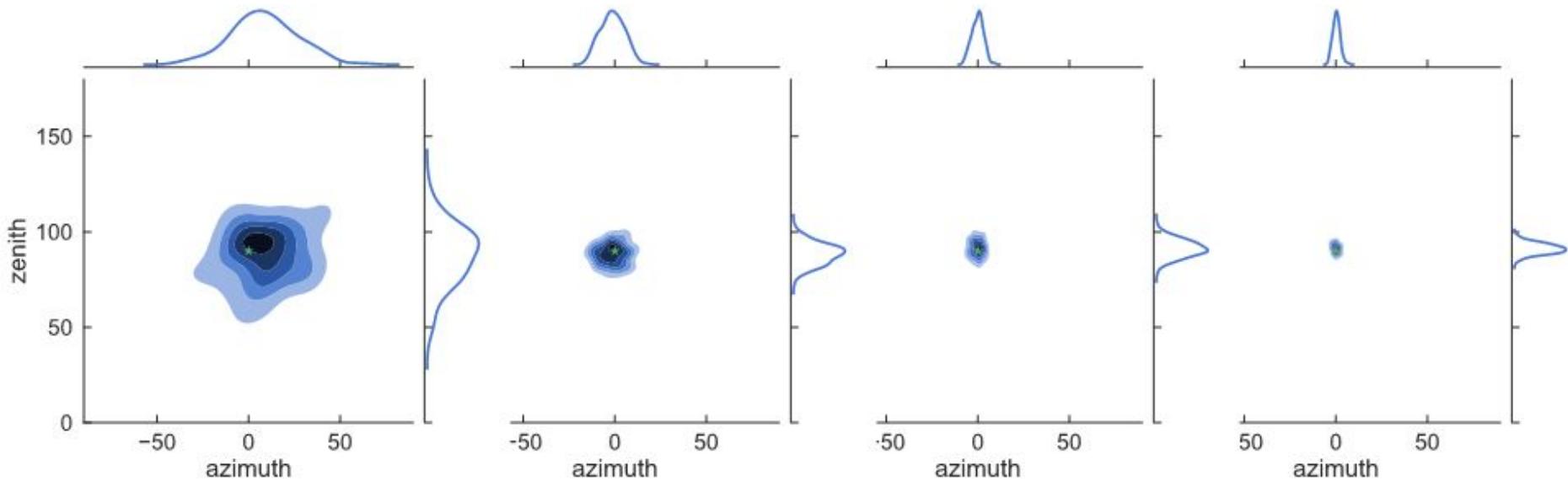
- Developing new methods to reconstruct the energy and direction of events replacing ice model parametrization with re-simulation of events



Reconstruction using Photon Propagation



PRELIMINARY



Better modeling of ice around DOMs yields improved angular resolution

Thank you