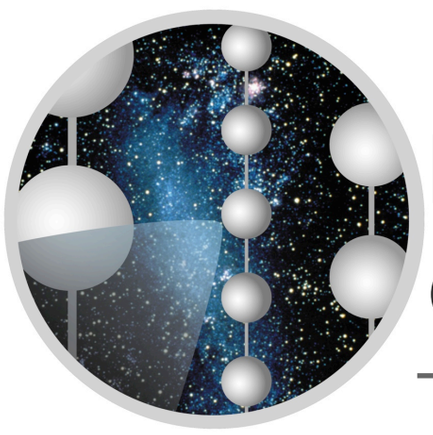

Improved IceCube event reconstructions using direct-tracking photon tables

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Department of Physics
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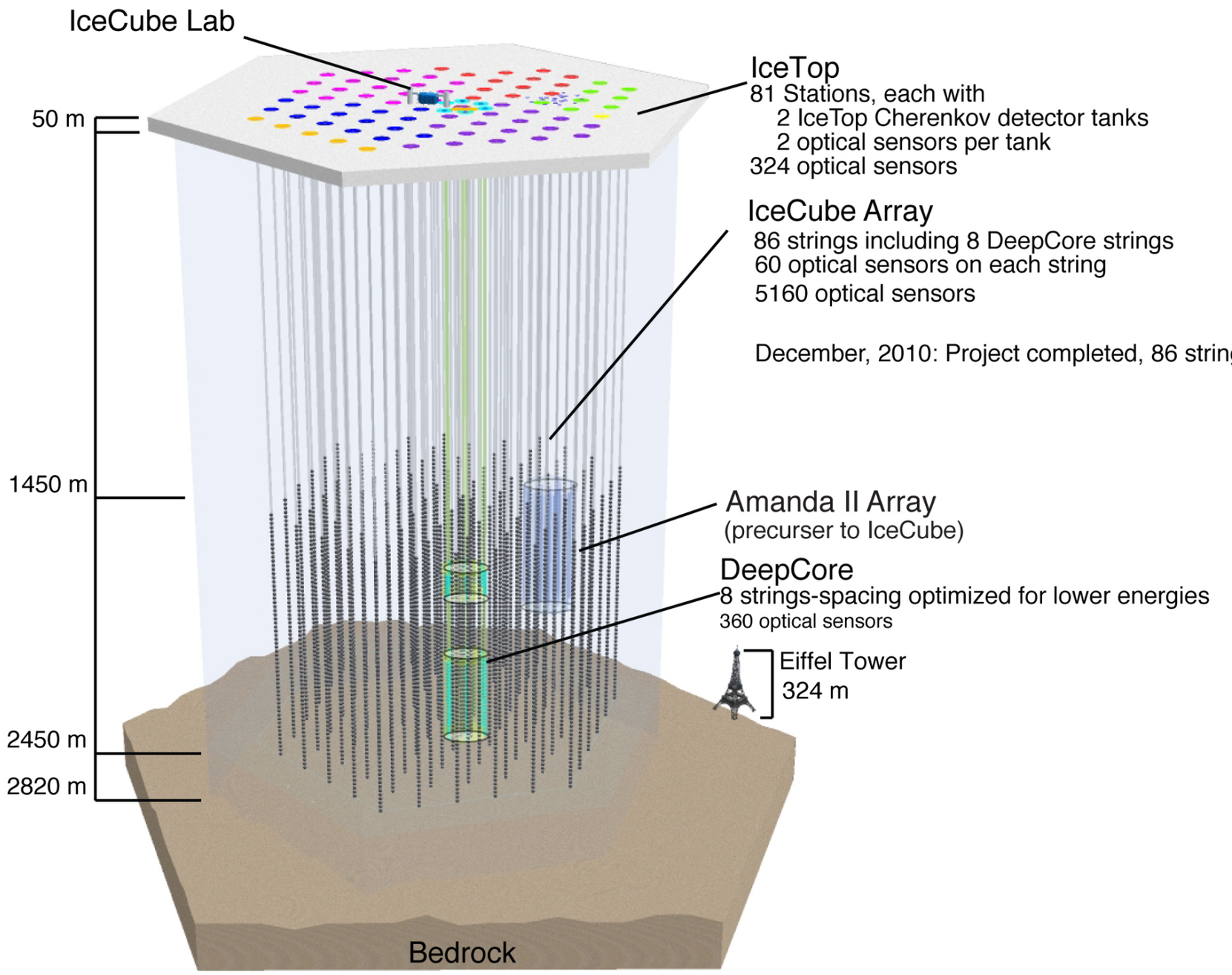
Canadian Association of Physicists Congress
Sudbury, ON, Canada
June 19th, 2014

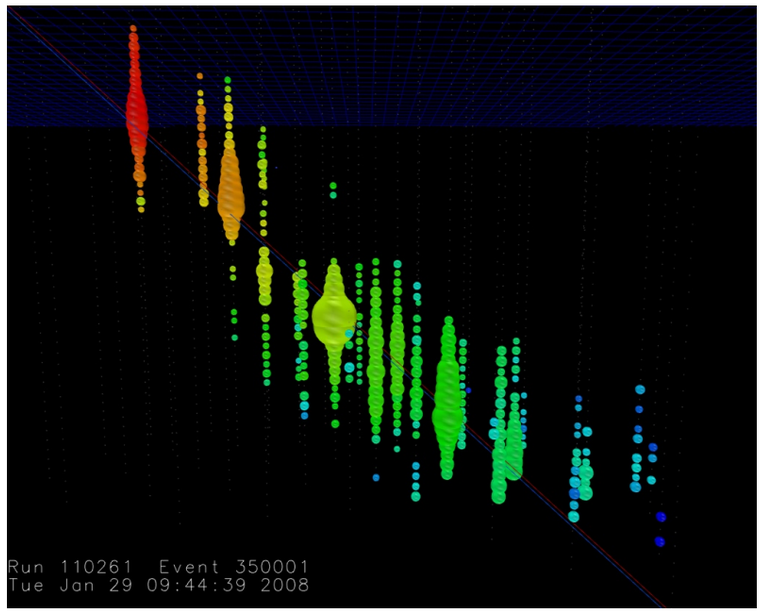
IceCube, the detector!

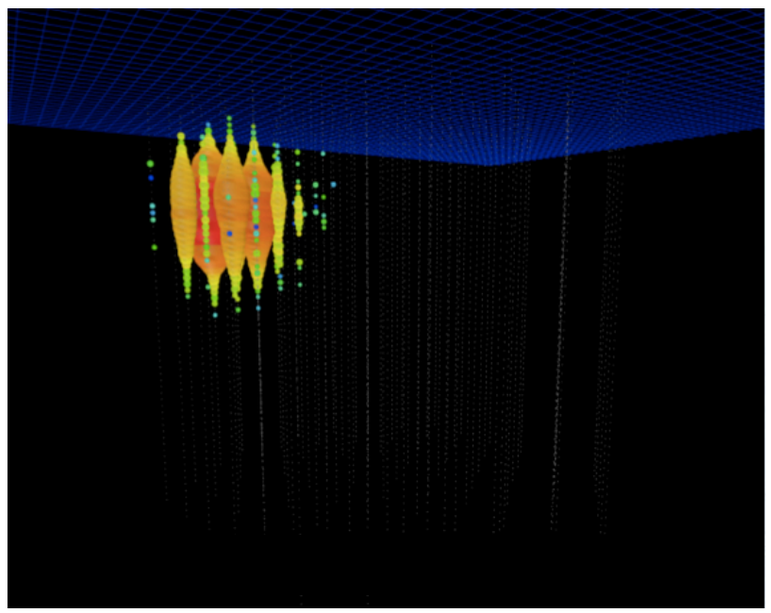
IceCube has the capacity to produce results from astrophysical energies (10^9 GeV) down to much lower neutrino oscillation energies (10 GeV)

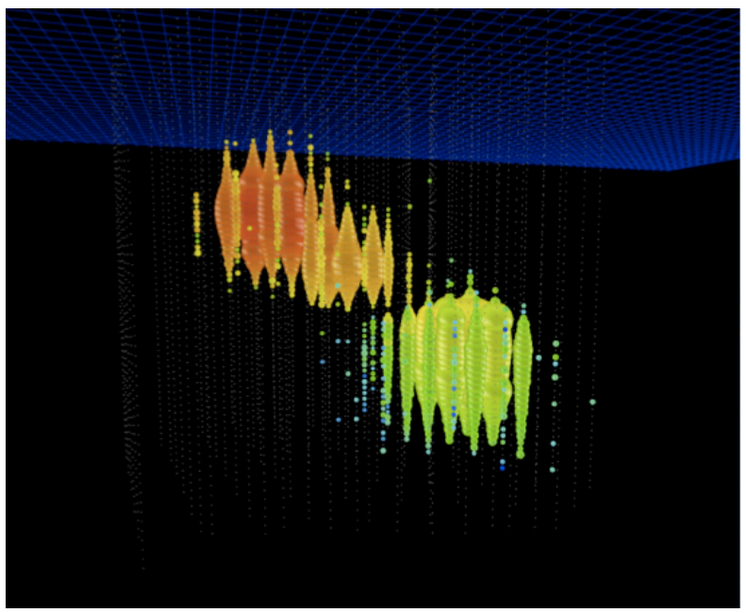
Analyses rely on being able to accurately record and reconstruct the neutrinos, requiring a detailed knowledge of the photon distributions in the ice



What can we see in IceCube?







Tracks

muons leave cylindrical tracks due to their Cherenkov cone

very good pointing resolution at ‘high’ energies ~1°

Cascades

charged current events for nue and (‘low’ energy) nutau

all flavours of neutral current events

energy resolution ~10% in log(E)

Composites

starting tracks

‘high’ energy nutau

good directional and energy resolution

What is a photon table and why is it useful?

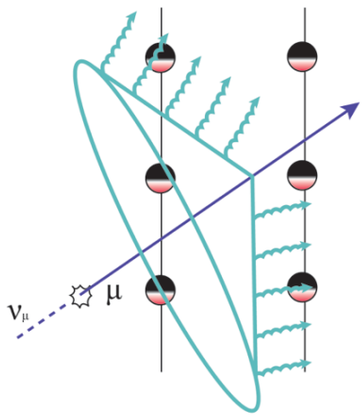
All event simulation and reconstruction algorithms rely on accurate description of photon propagation through the ice. Most accurate: direct simulation (only recently possible by parallelized algorithms on GPUs), but too computationally expensive for reconstruction

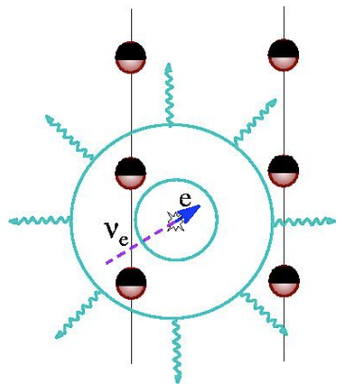
Photon lookup tables to the rescue! Tables parametrize the light emission using ice properties and allow the extraction of an event energy, direction, etc. At this stage, this creates 2 issues:

- Still slow - requires many calls to the tables to get values for likelihoods, which need to be minimized

- Current tables are based on parametrizations of cascades and muons, an approximation which does not reflect reality for expected light topology

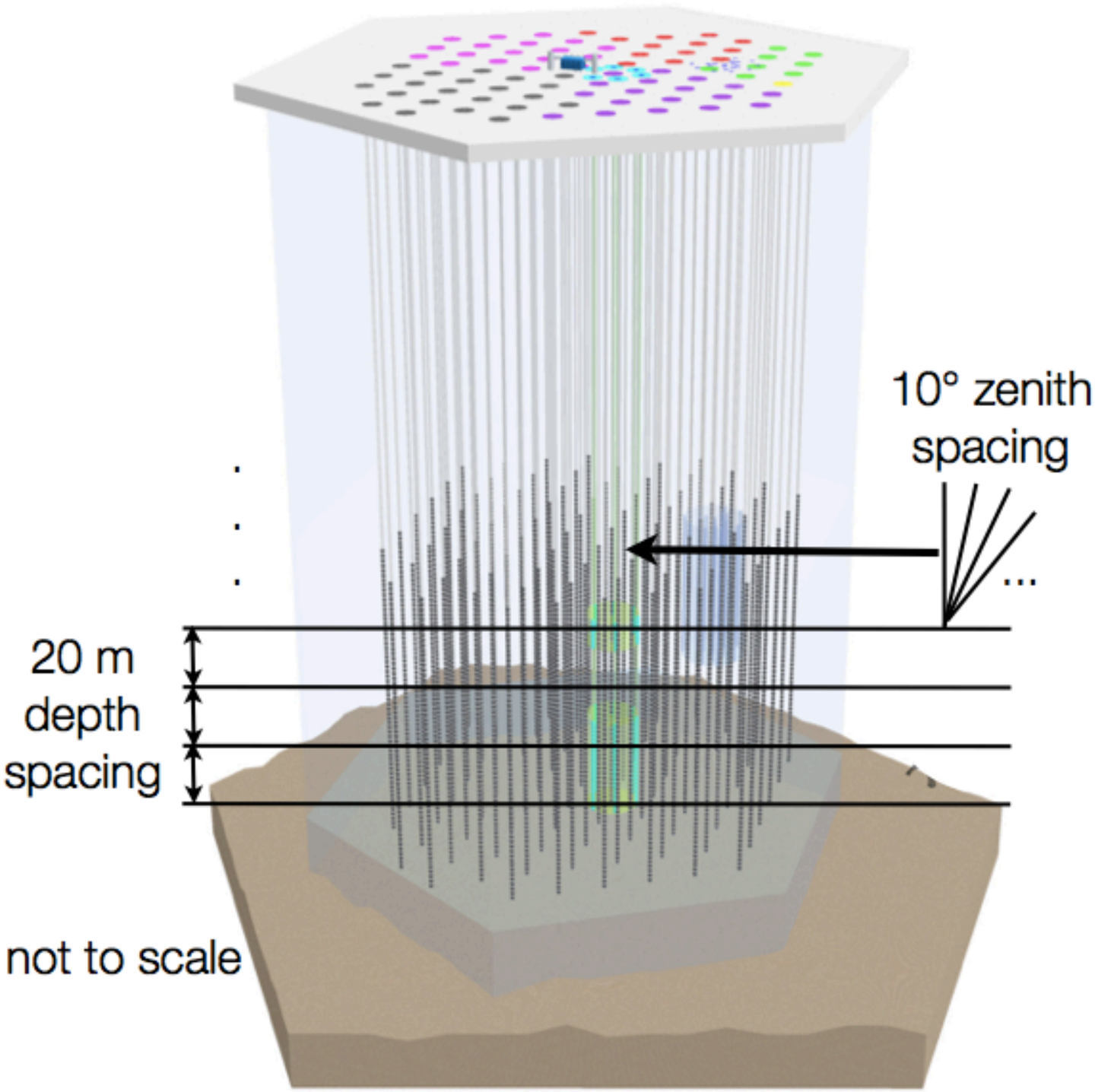
track-like event





cascade-like event

How do we make these direct-tracking tables?



Create a set of tables across the detector - each table has a given depth and zenith angle of light source (leptons)

Tables are ‘stacked’ into a single table object used in reconstructions

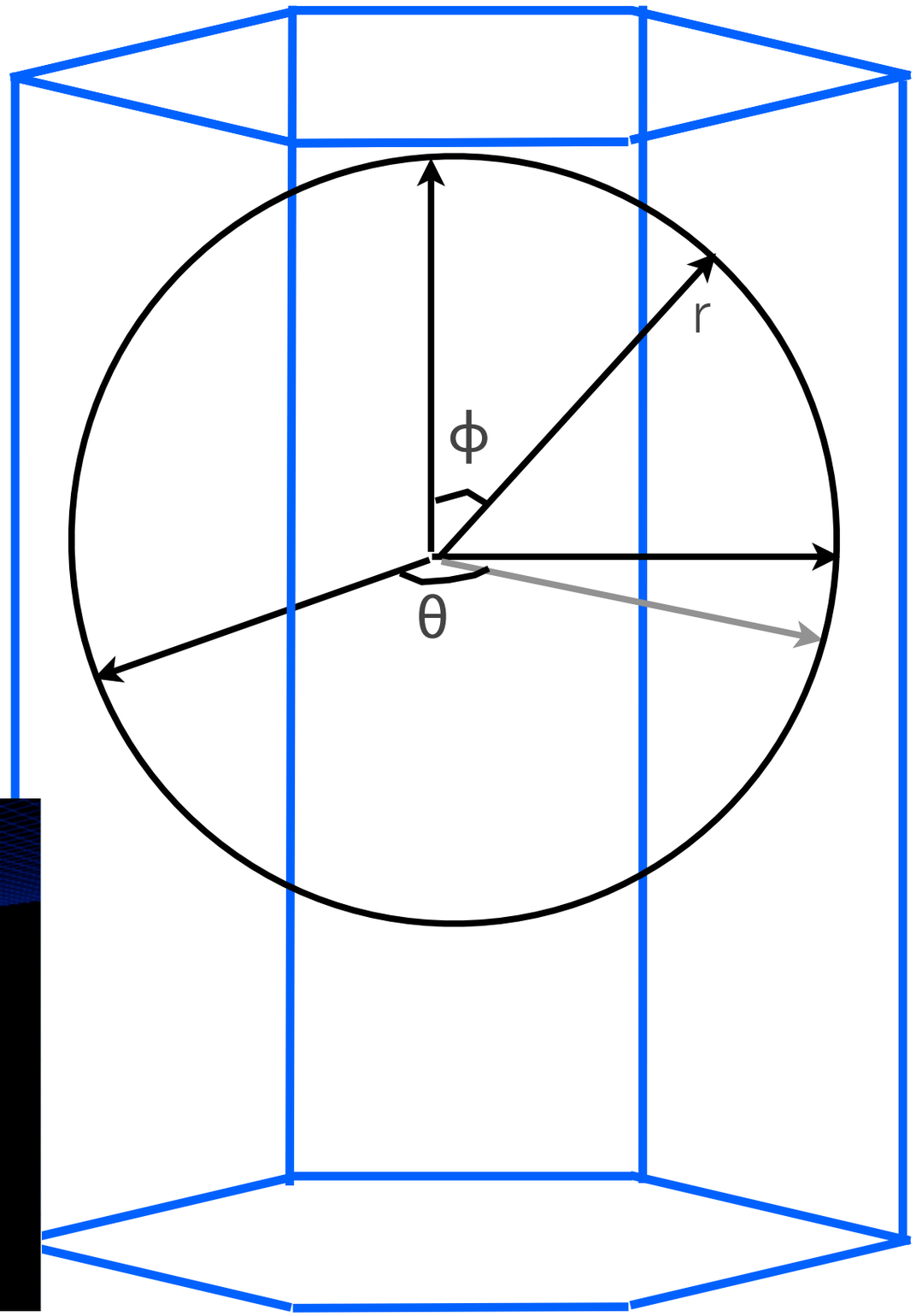
depth range:
-650m → 650m

zenith angle:
0° → 180°

Full set: 1254 tables!!

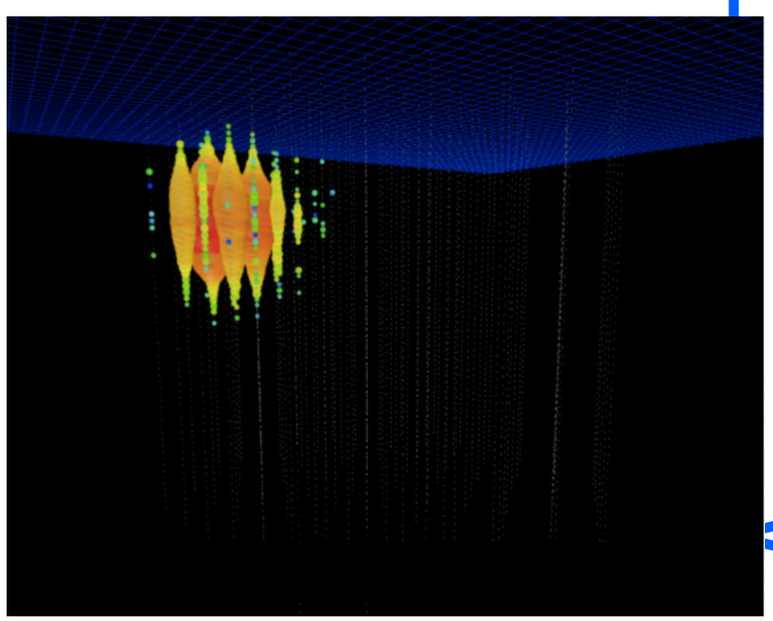
What sort of geometry do these direct-tracking tables use?

For the cascade tables



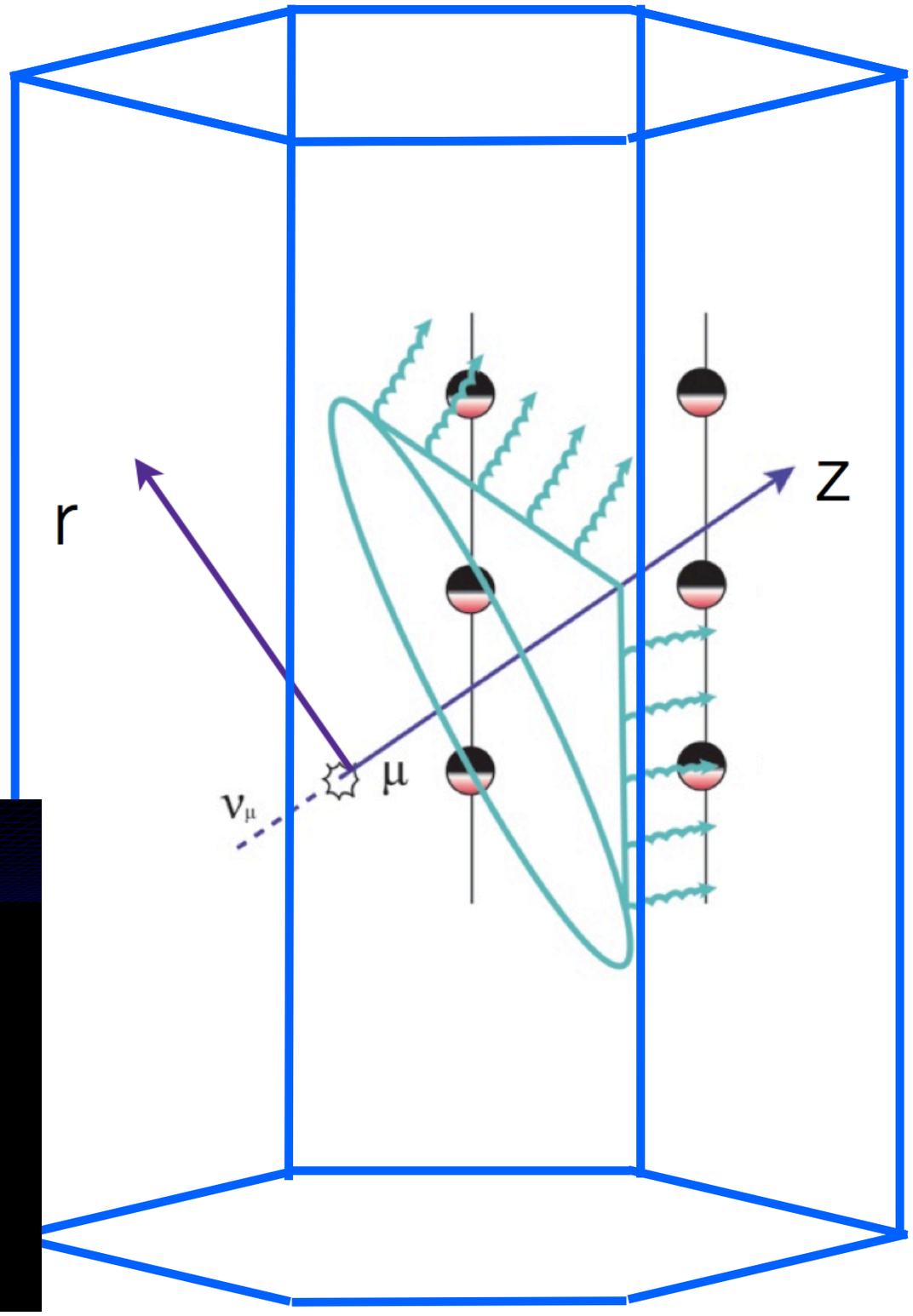
IceCube geometry

local (spherical) geometry



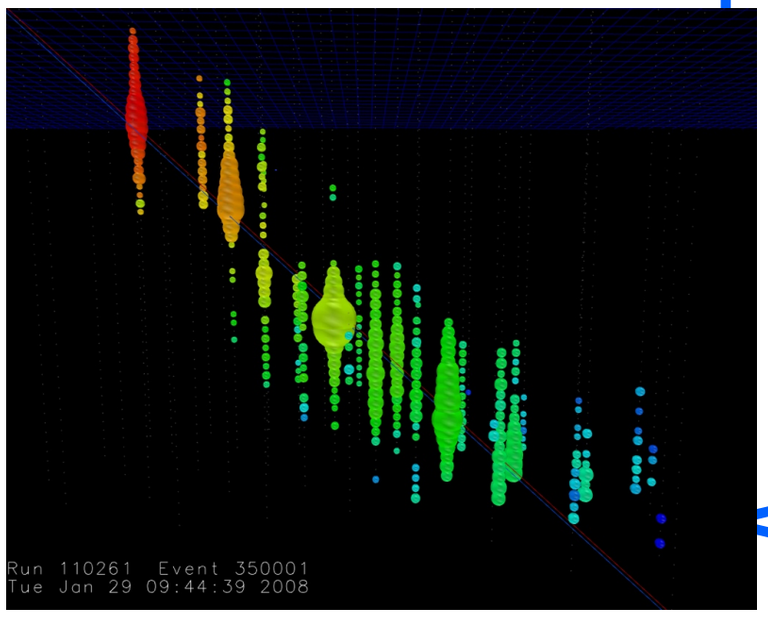
What sort of geometry do these direct-tracking tables use?

For the muon tables

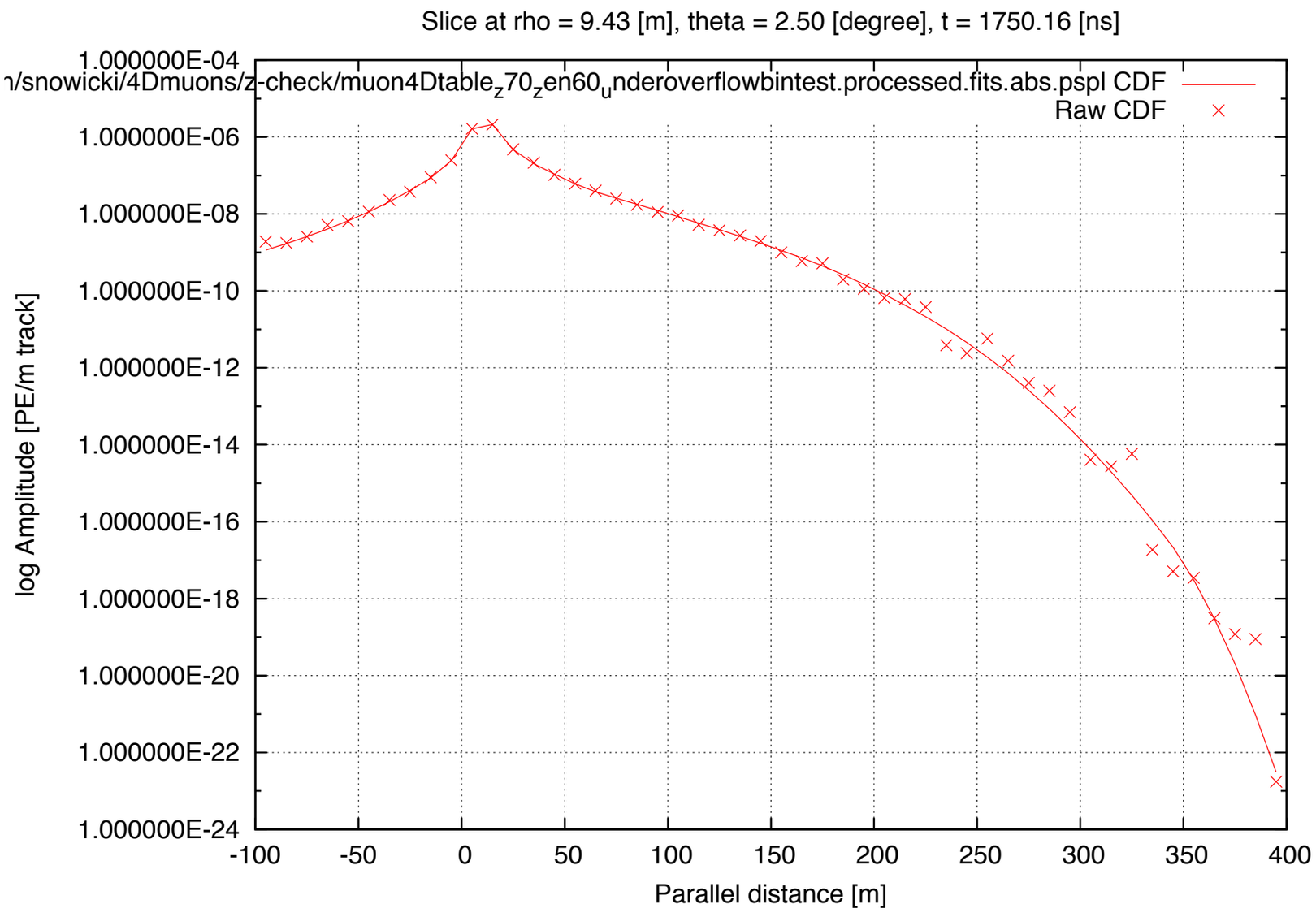


IceCube geometry

local (cylindrical) geometry

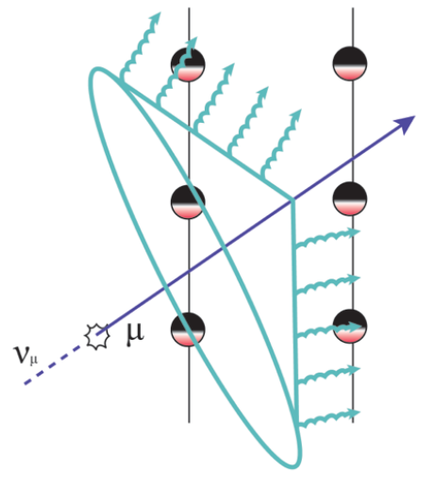


How did the photon tables get faster?



Fit a multi-dimensional penalized spline surface to the discrete table data points

Decreases table size dramatically, removes interpolation error



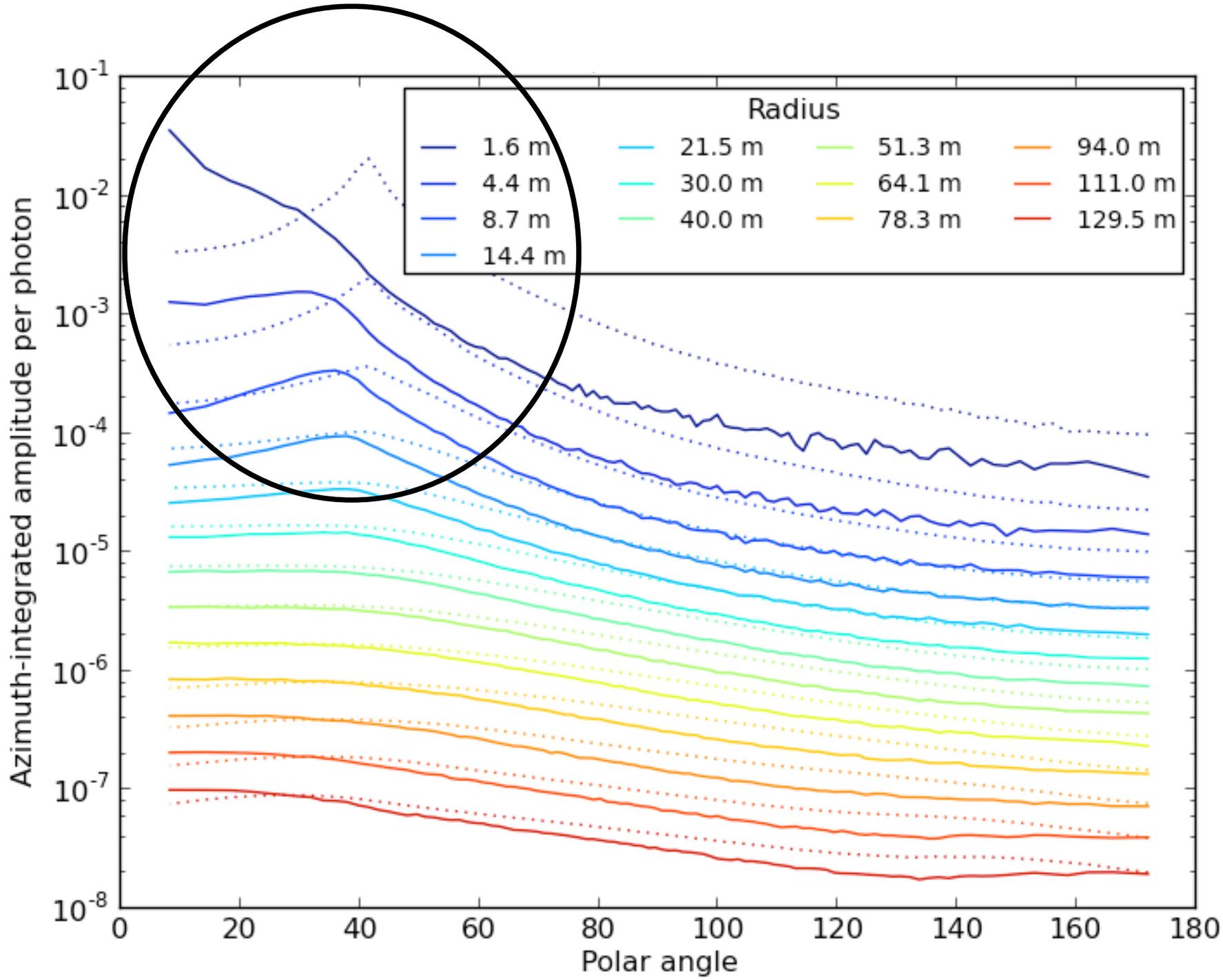
Parametrized vs direct-tracking cascade table

Old (parametrized) table: dotted lines

New (direct-tracking) table: solid lines

Cherenkov peak smeared in direct-tracking (parameterized perfect point emission vs full GEANT propagation)

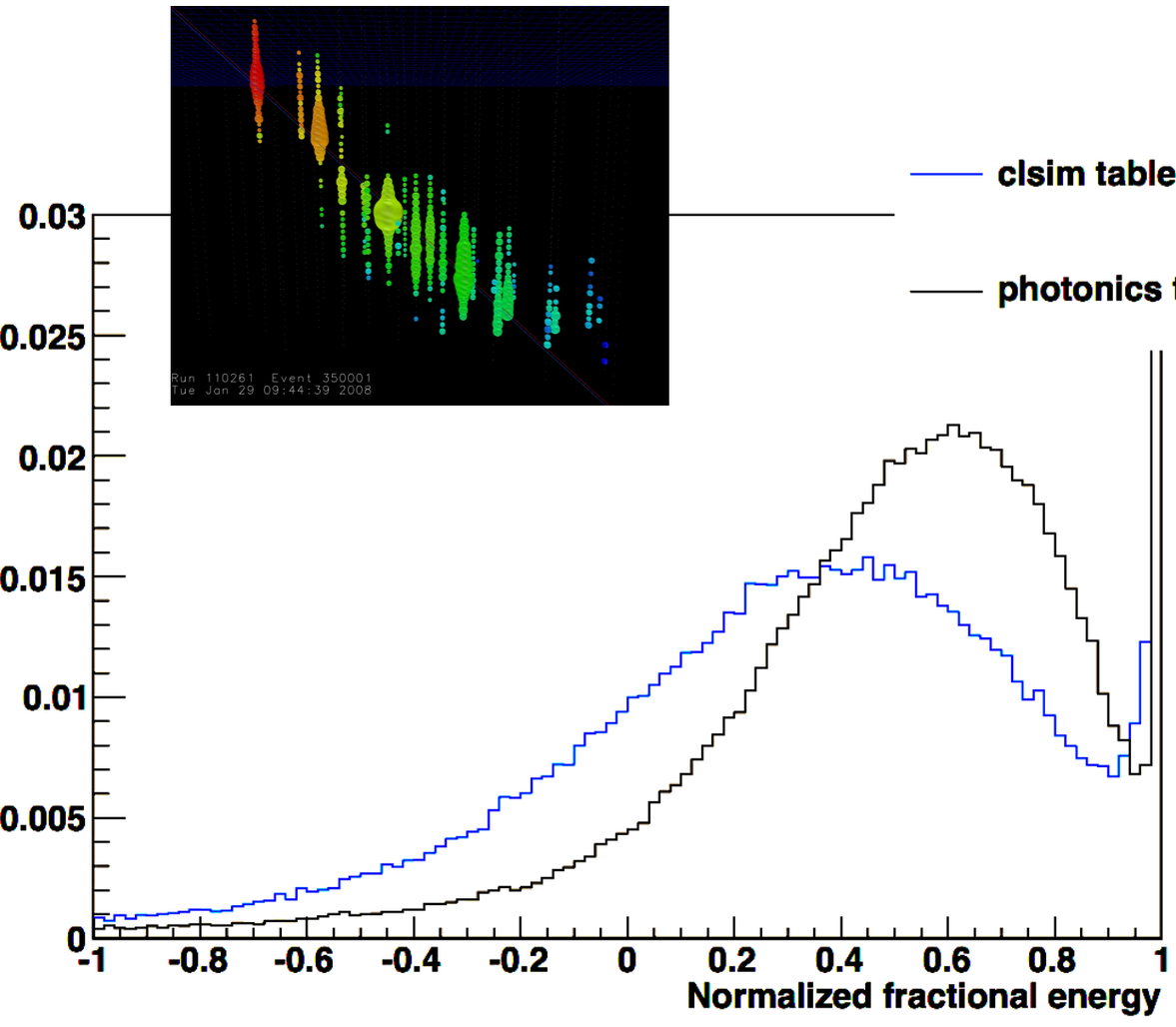
Amplitude shift at small radius

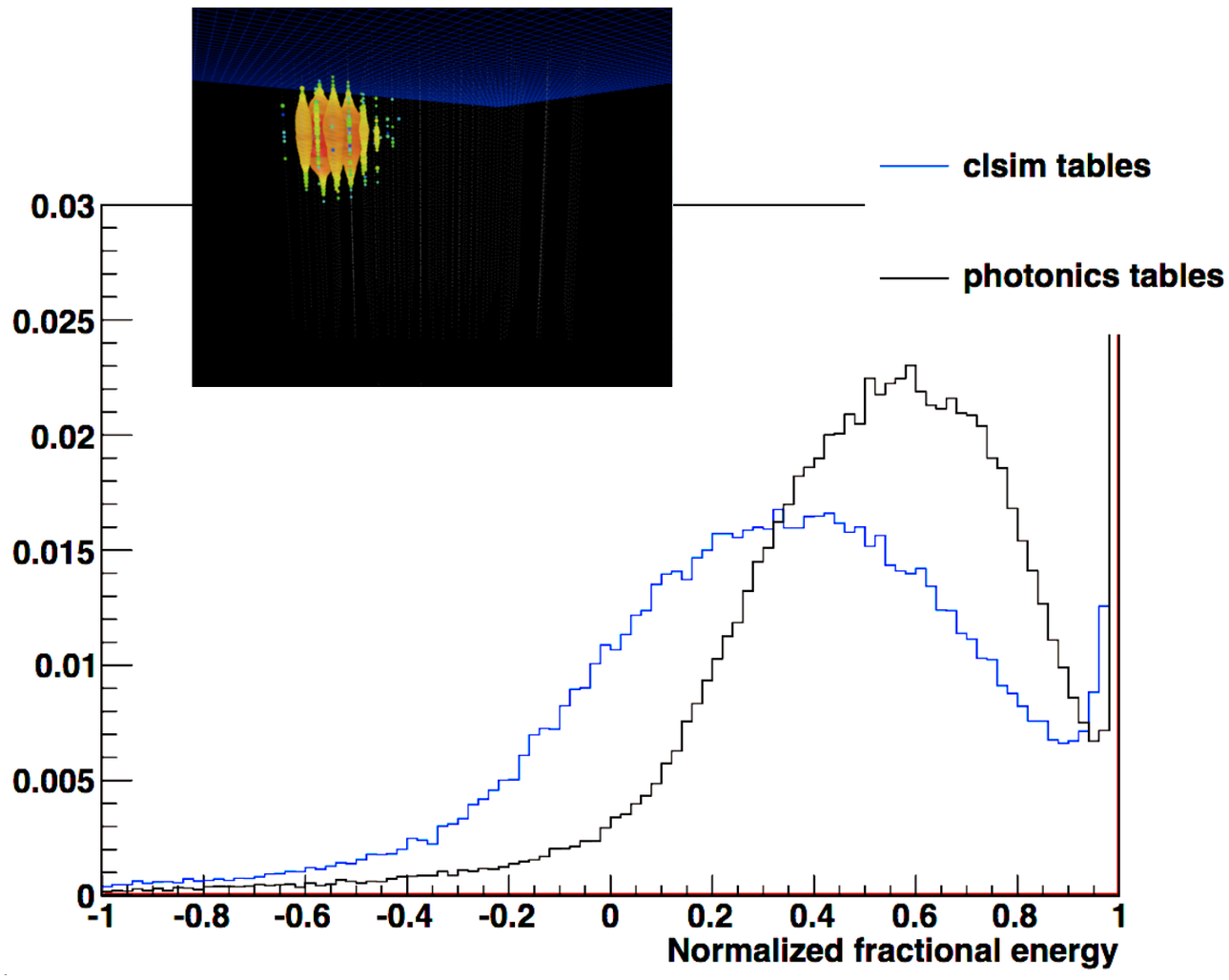


source at depth = 10m; zenith angle = 90°

Event reconstruction - energy resolution

Using a reconstruction algorithm that uses only the cascade tables, the direct simulation tables show better agreement with the true event information (blue = new tables, black = old tables)



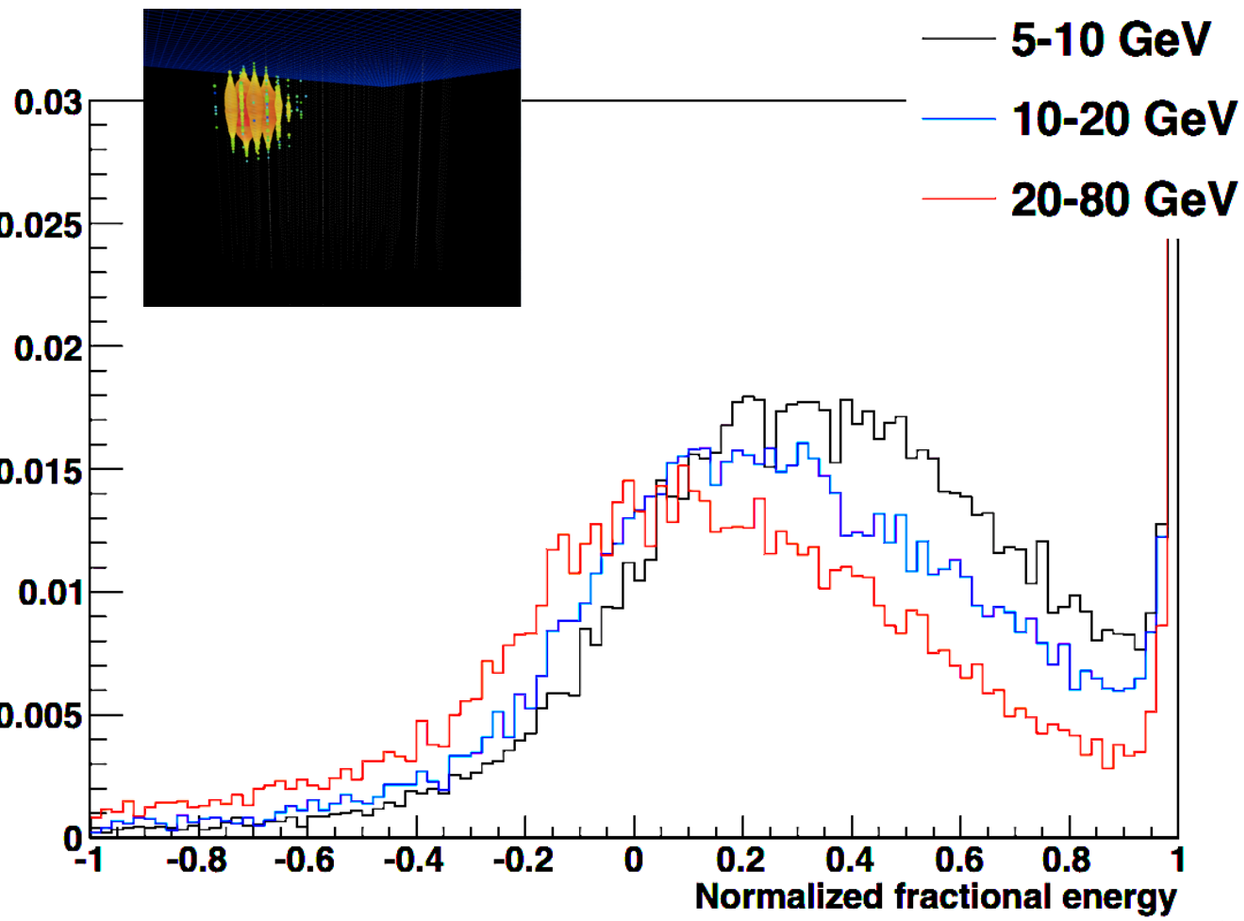


$(E_{true}-E_{reco})/E_{true}$

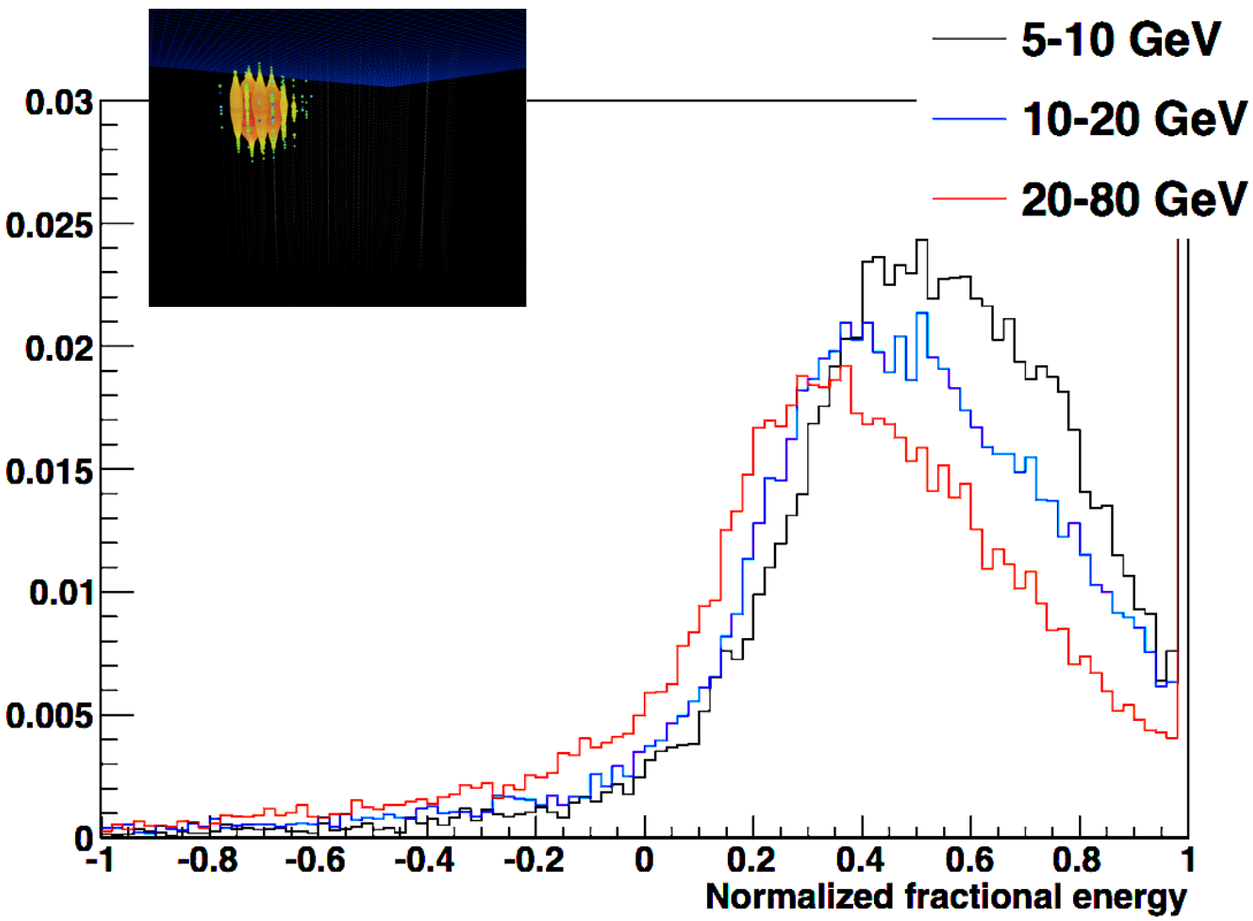
Event reconstruction - energy resolution

Using a reconstruction algorithm that uses only the cascade tables, the direct simulation tables show better agreement with the true event information

<u>direct-tracking</u> table results



<u>parametrized</u> table results

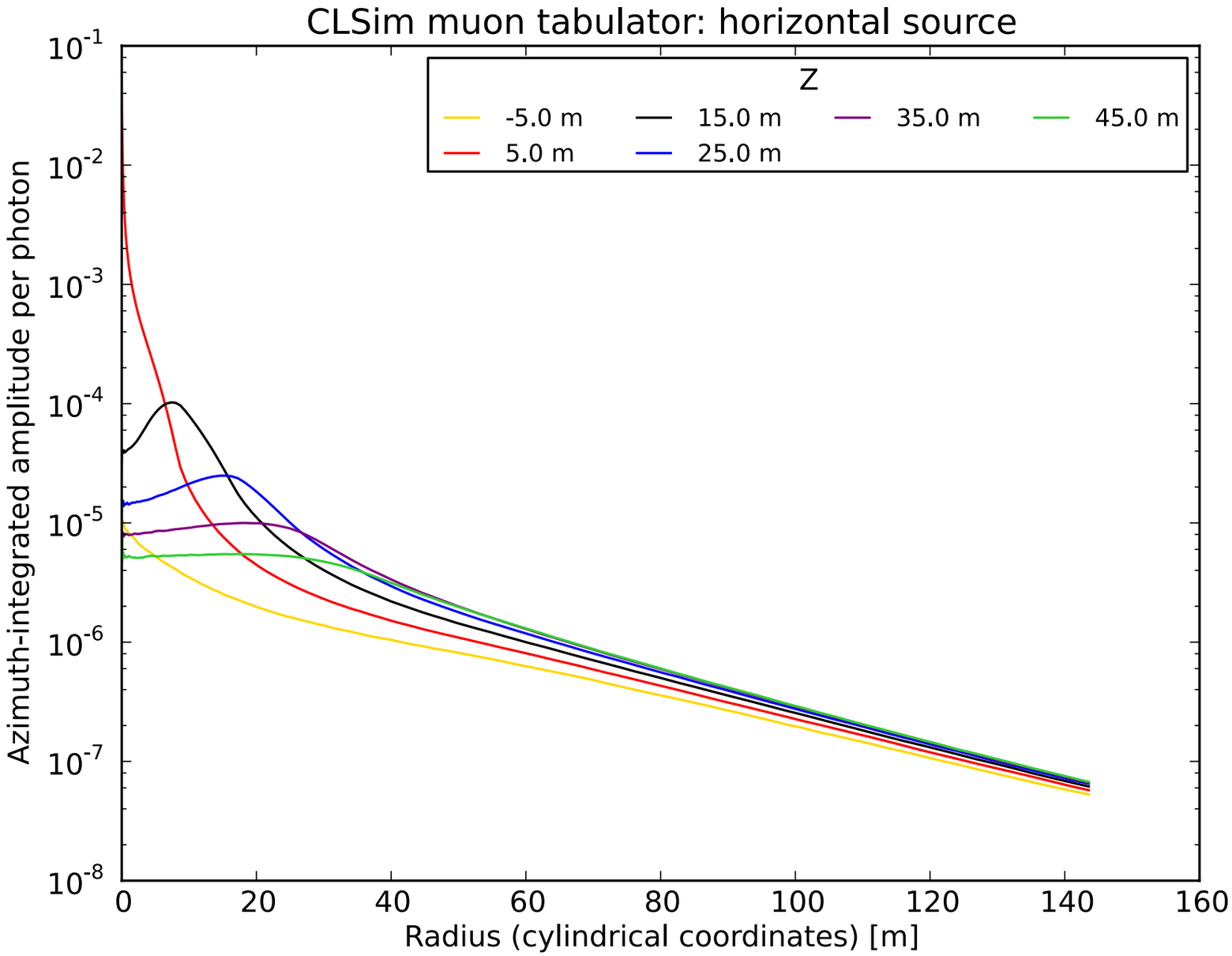


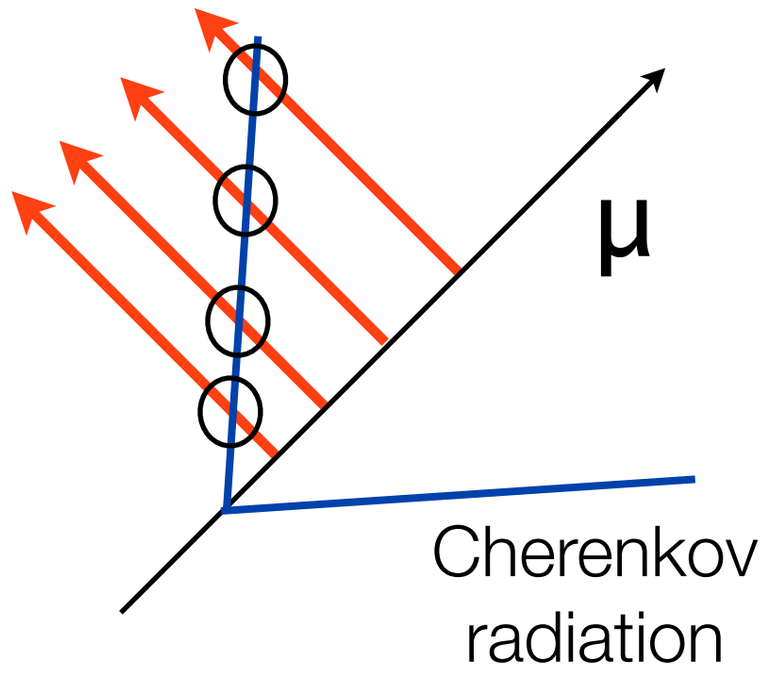
$(E_{true}-E_{reco})/E_{true}$

Muon tables are coming along...

A full set of muon tables have been created - raw tables look good!

Splined tables in progress - fine-tuning for the cylindrical geometry is required





Summary and conclusions

IceCube requires accurate description of the photon distributions in the ice for event simulation and reconstruction. We require tables describing track-like events and tables describing cascade-like events.

Direct simulation is currently too slow to perform reconstructions for full data sets - use photon lookup tables instead.

Previous methods drew from a parametrization to create the tables. Directly tracking leptons and photons and tabulating that data is being done to improve the physical accuracy of the tables, particularly for low energy.

Event reconstruction using the current suite of cascade tables shows improvement in the reconstructed energy compared to the parametrized method.

A complete reconstruction of all IceCube events from muon and cascade direct-tracking tables will be available soon!

The IceCube–PINGU Collaboration

International Funding Agencies

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