Reconstruction and simulation with multi PMT optical moduls for IceCube-Gen2

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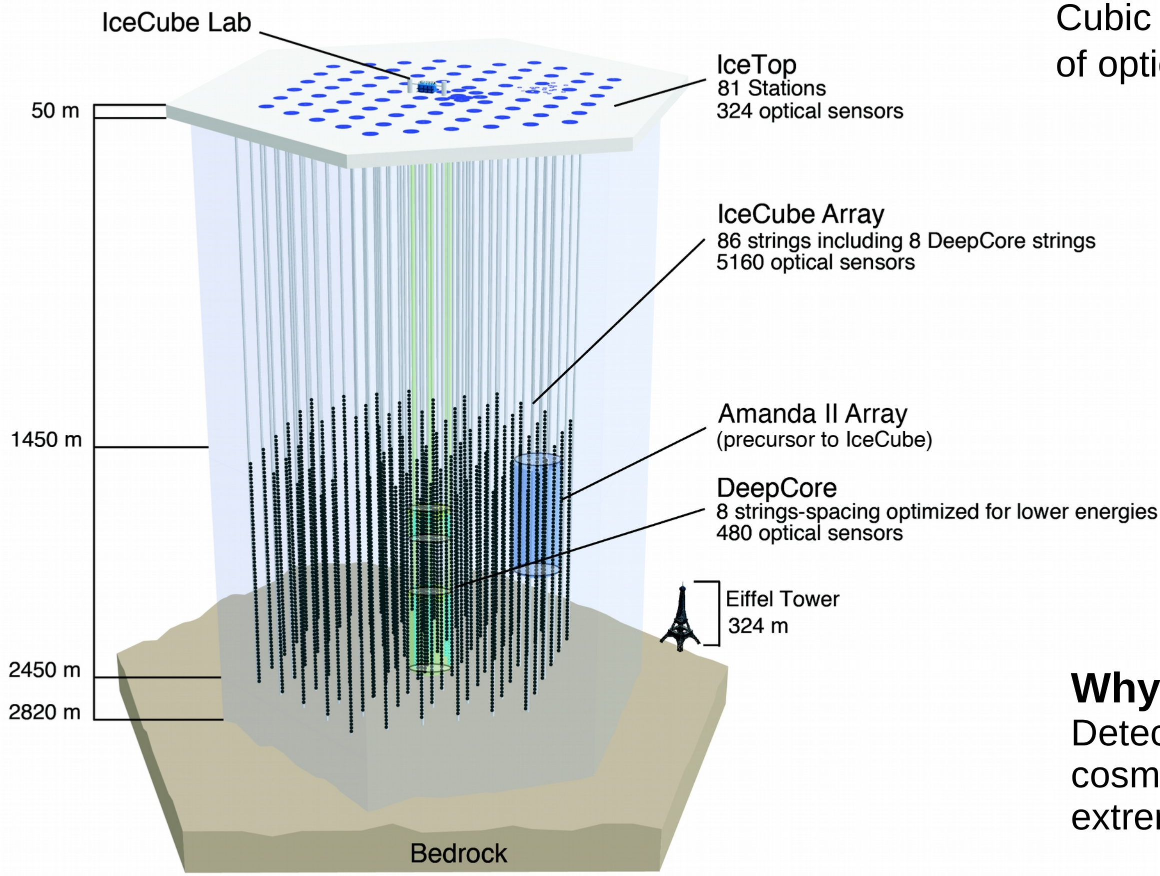
IceCube Neutrino Observatory



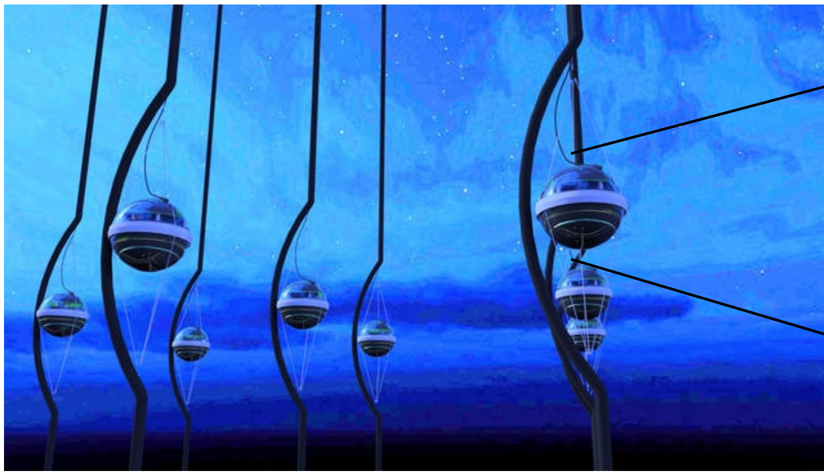
What
Cubic kilometer array of optical sensors

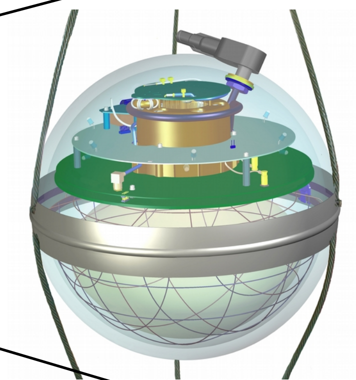
Where
In a depth of 1.5km to 2.5km within the ice of the south pole

How
Detection of Cherenkov light emitted by secondary particles created in neutrino interactions

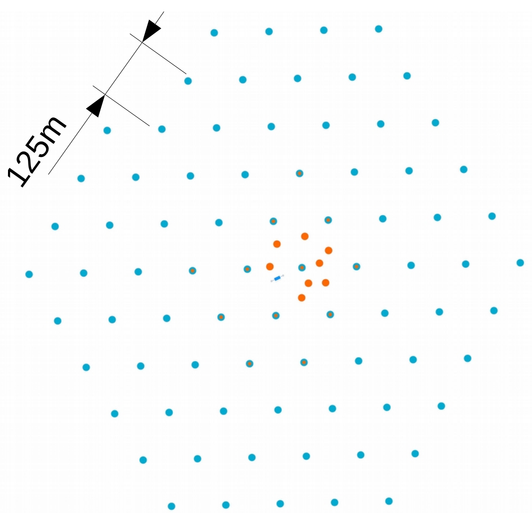
Why
Detection of high energetic cosmic neutrinos created in extreme cosmic environments

IceCube Neutrino Observatory



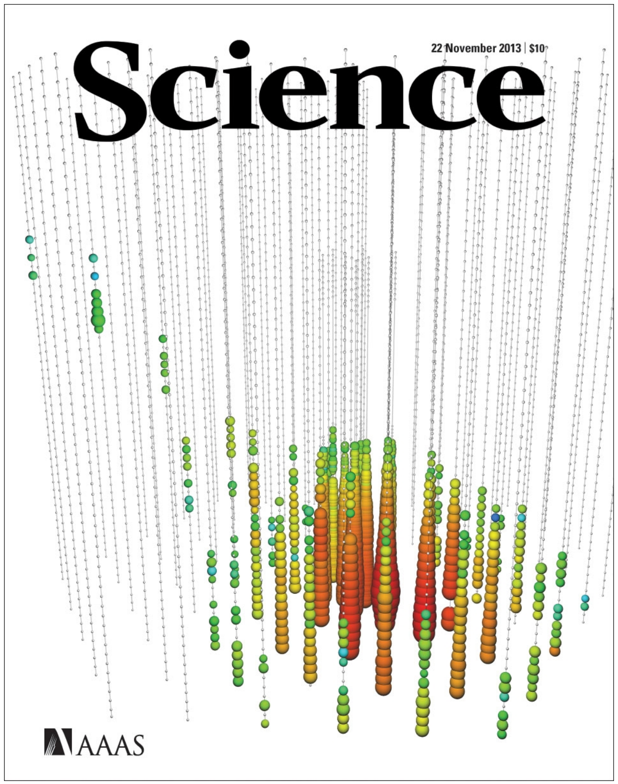


Optical sensor
10” photo multiplier and readout electronics in a pressure resistant glass sphere also called Digital Optical Module (DOM)



String
One string consists of 60 DOMs with ~17m spacing in between each module. Between two strings there is a distance of ~125m.

IceCube Neutrino Observatory

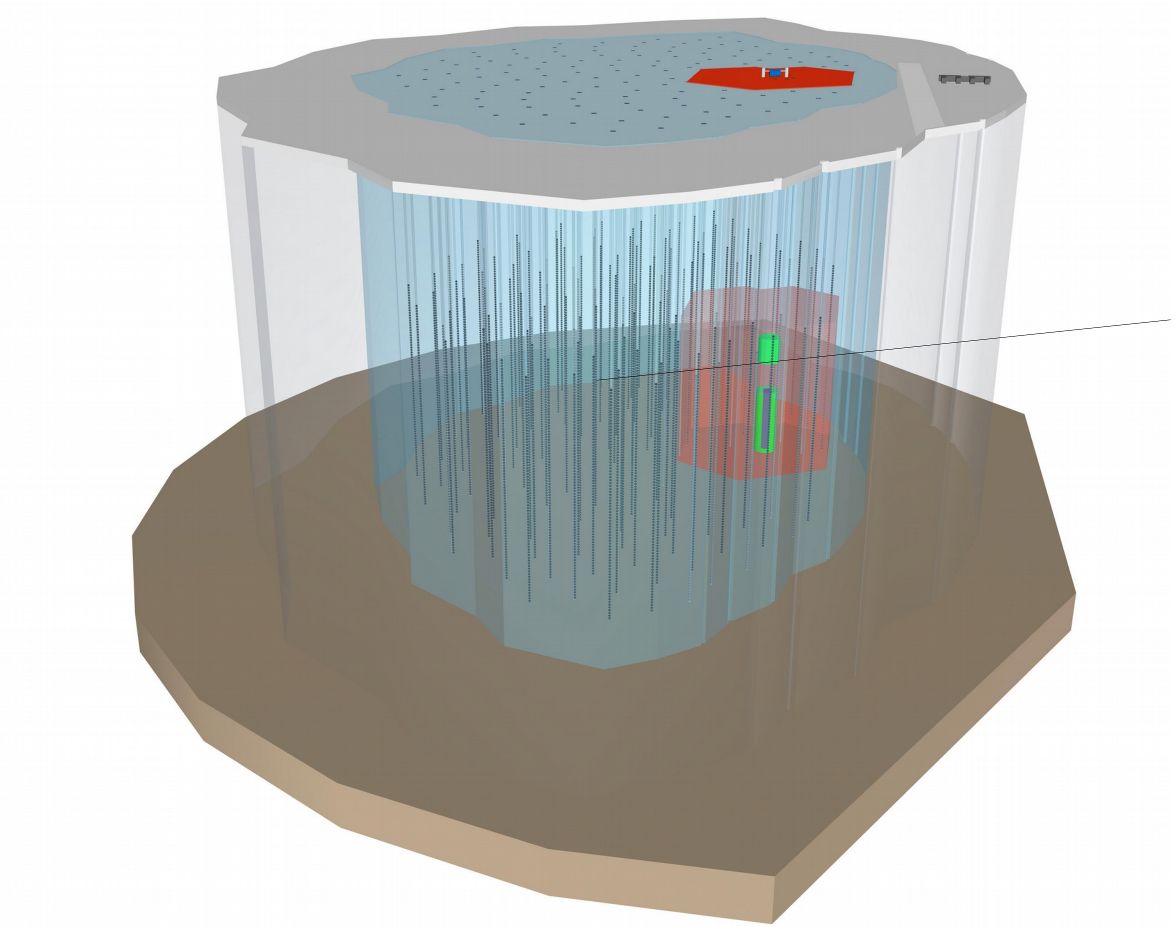


(Starting track event with a
deposited energy of ~250TeV)

Achievements
First detection of extra-terrestrial high energetic neutrinos (arXiv:1311.5238)

Limitations
No cosmic neutrino sources were detected due to the small neutrino flux
=> increase instrumented volume

IceCube-Gen2



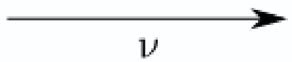
High Energy Array (HEA)

- ~120 addional strings
- ~250m string spacing
- Instrumented volume ~7 times larger then IceCube
- Target neutrino energy >=100TeV

Multi PMT Digital Optical Module (mDOM)

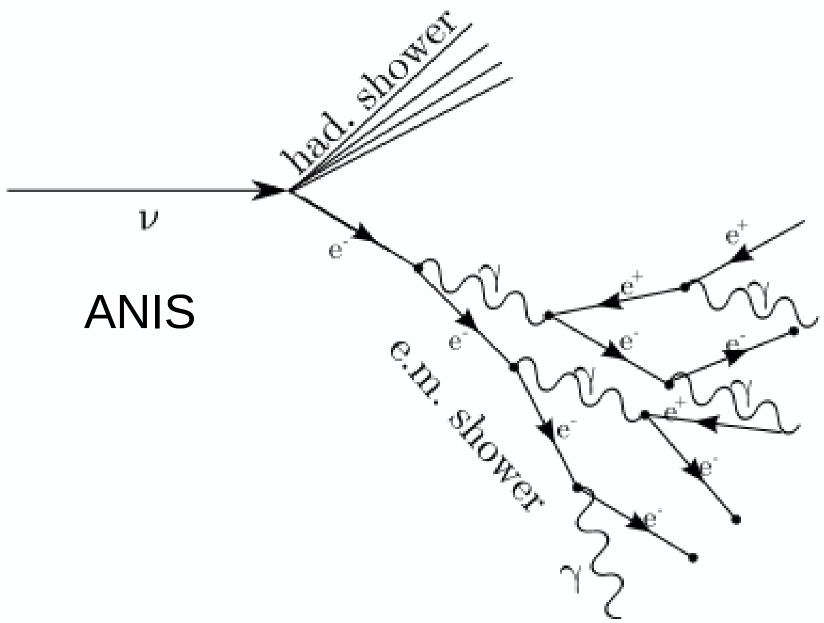
- One mDOM with 24 3“ PMTs
- 4π acceptance
- Detection of local coincident hits
- Intrinsic direction information

Event simulation



ANIS

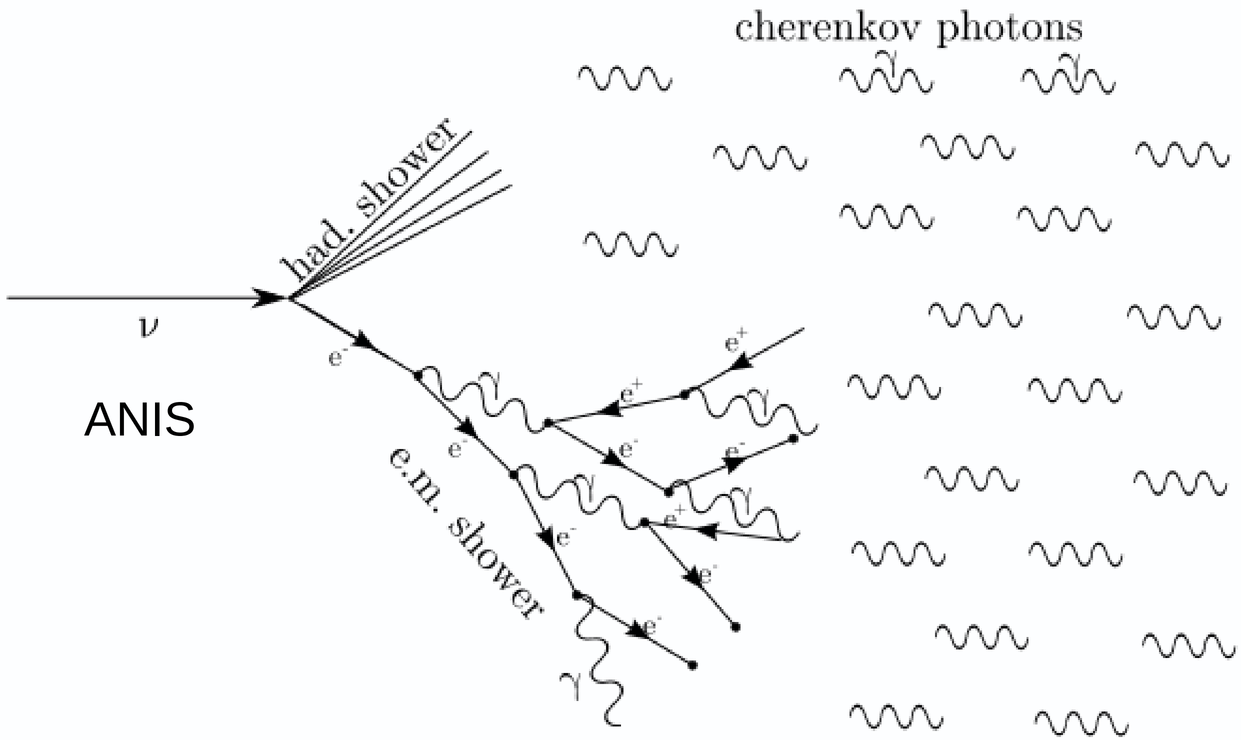
Event simulation



ANIS

Geant 4 (up to 1TeV)
or parameterized function

Event simulation



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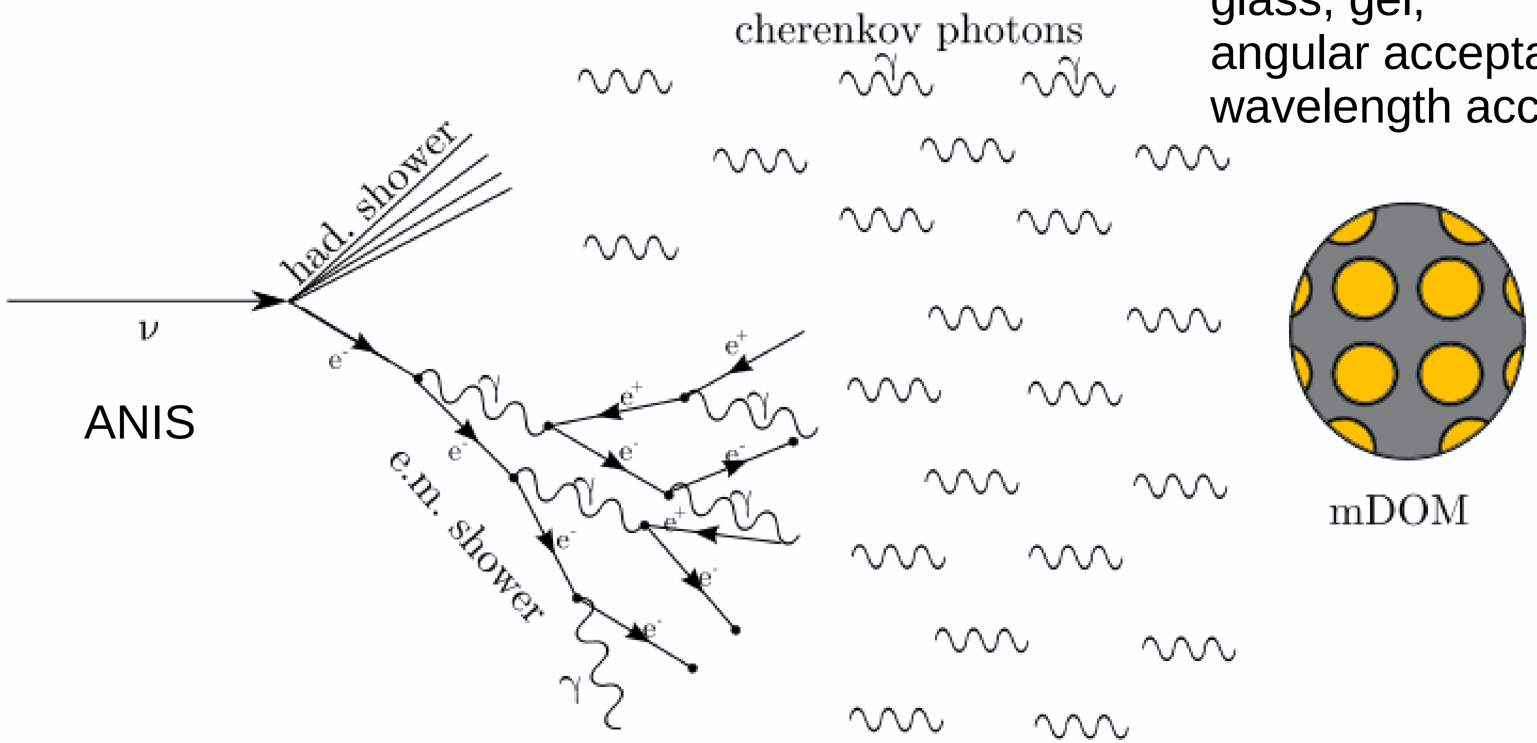


glass, gel,
angular acceptance,
wavelength acceptance

ANIS

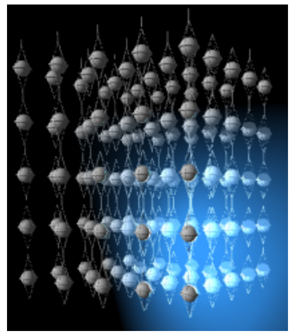
Geant 4 (up to 1TeV)
or parameterized function

Data / Simulation processing

Detection process / Simulation

ν

Energy, direction ,vertex



Detector

Detector response (detected photons over time per PMT)

Reconstruction algorithm

Neutrino energy, direction, flavor, vertex

Physical analysis

Reconstruction + Analysis

Reconstruction strategies

Simple reconstruction strategies

- Vertex: Center Of Gravity (COG) for the detected light within the detector

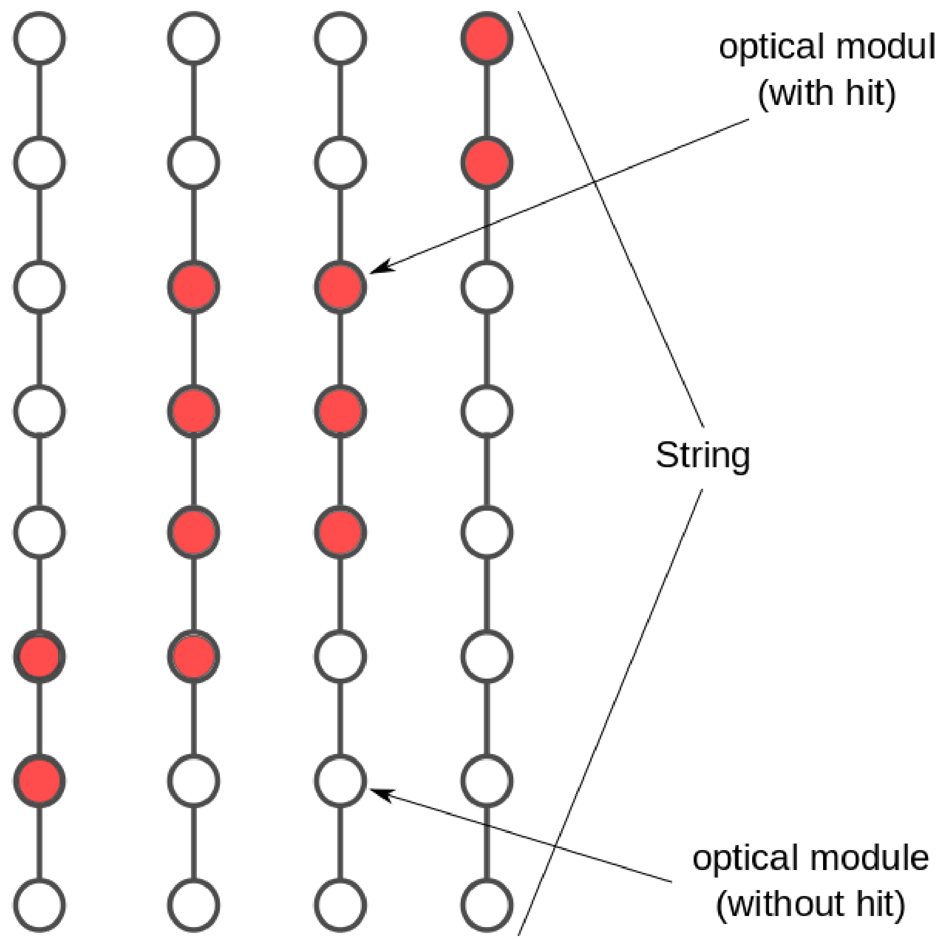
- Direction: Least square fit of timing information of detected light

- Energy: Number of hit DOMs or collected light as energy proxy

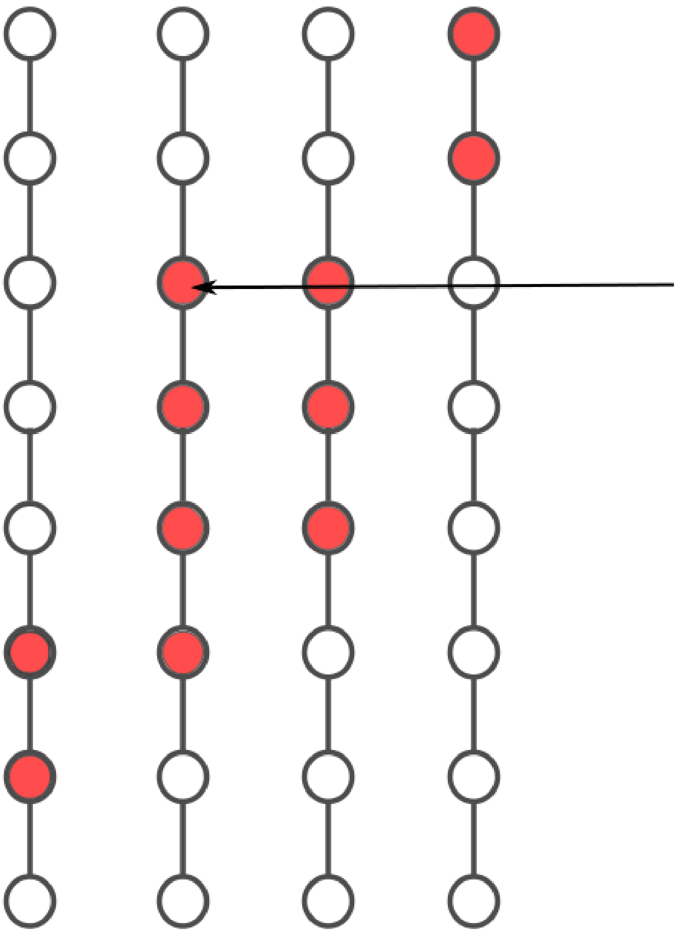
More advanced reconstruction strategy

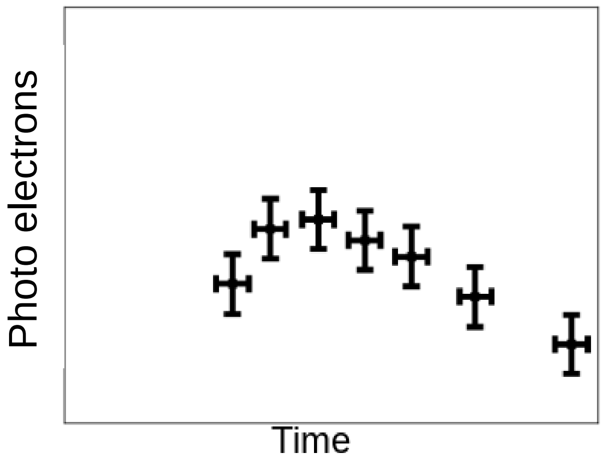
- Reconstruct the event parameters using a maximum LLH approach

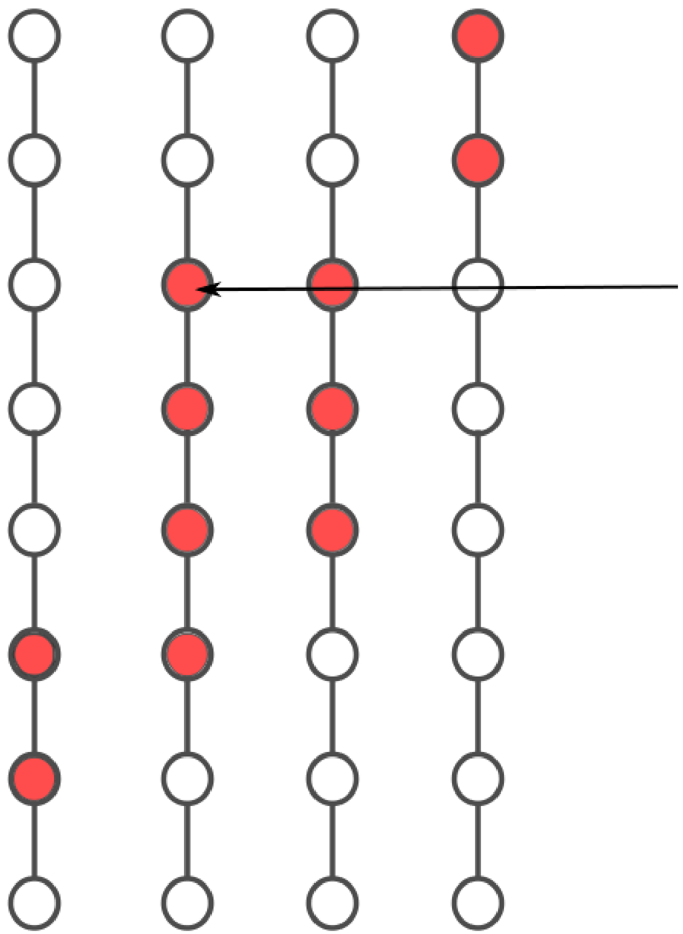
Max LLH event reconstruction

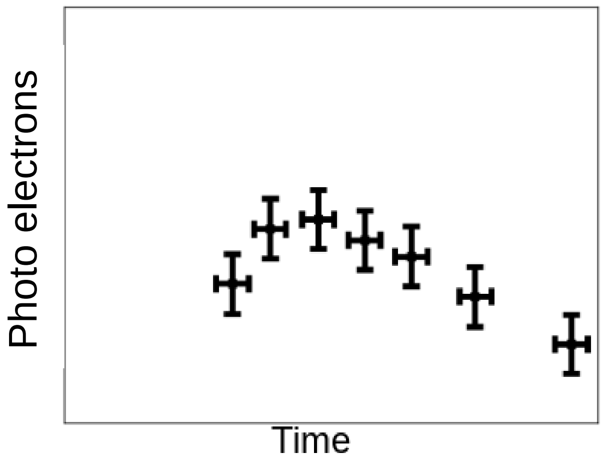


Max LLH event reconstruction





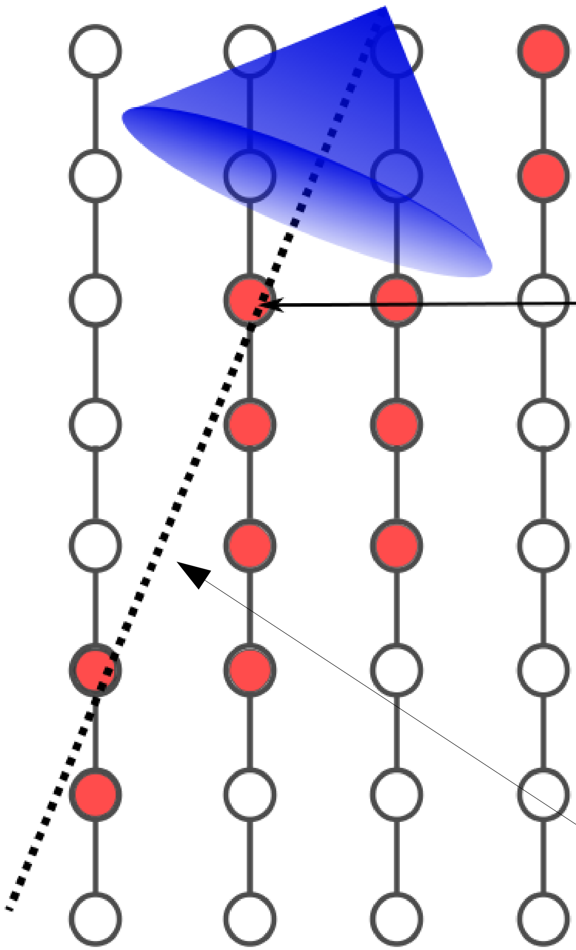


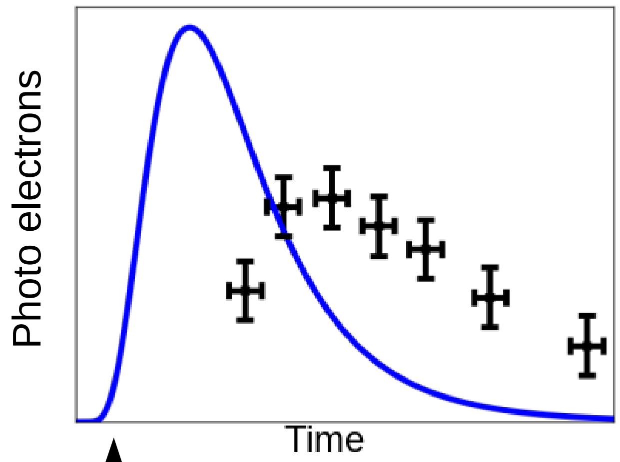


simple reconstruction algorithms

est. source parameter (energy, direction, vertex)

Max LLH event reconstruction

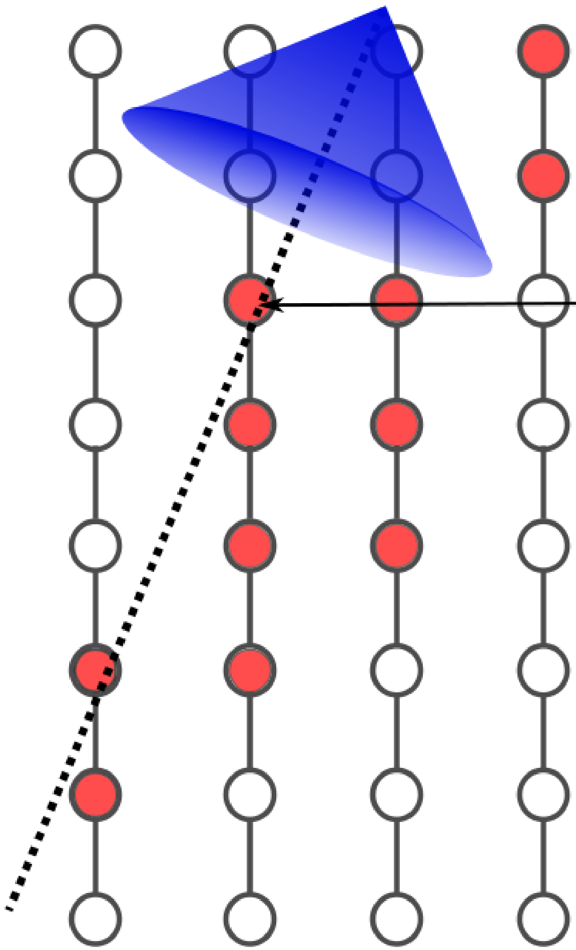


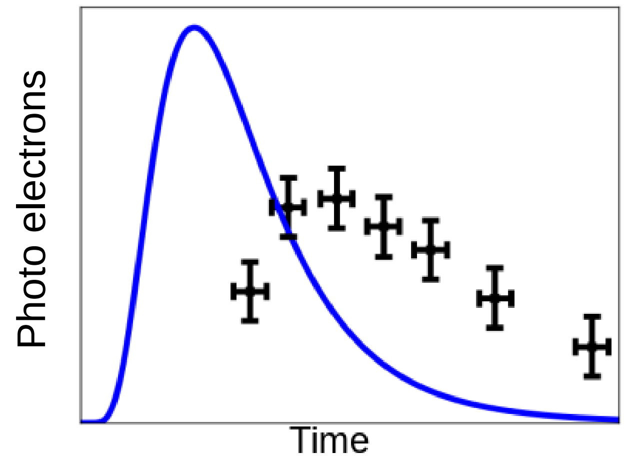


Lookup tables

est. source parameter
(energy, direction, vertex)

Max LLH event reconstruction

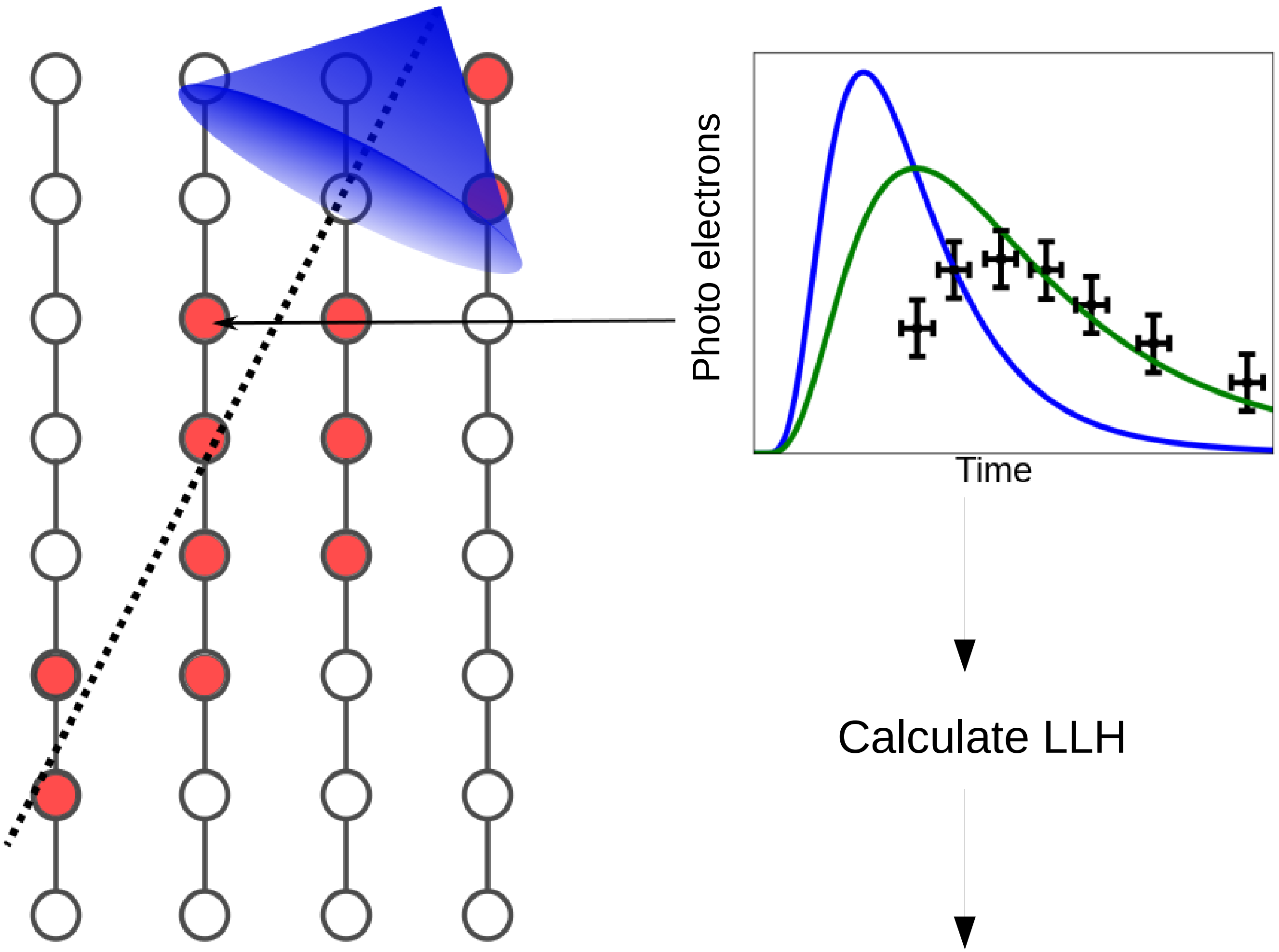




Calculate LLH

Vary source parameter
(using a minimizer)

Max LLH event reconstruction



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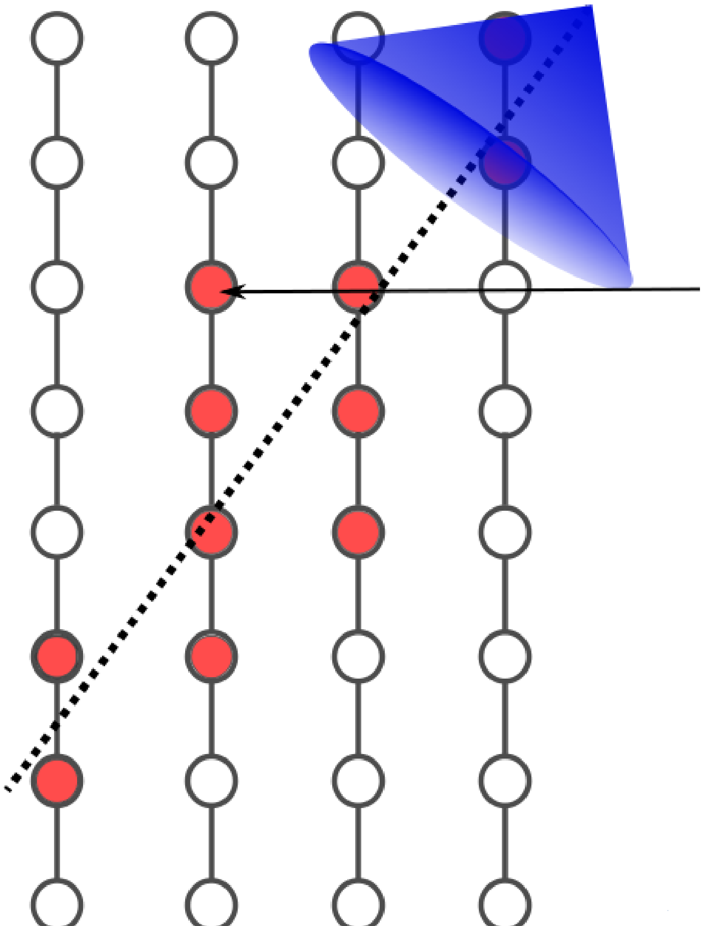
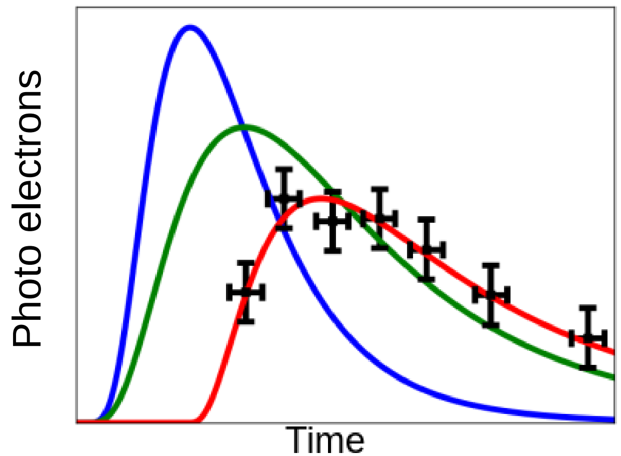
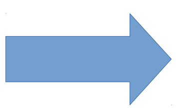




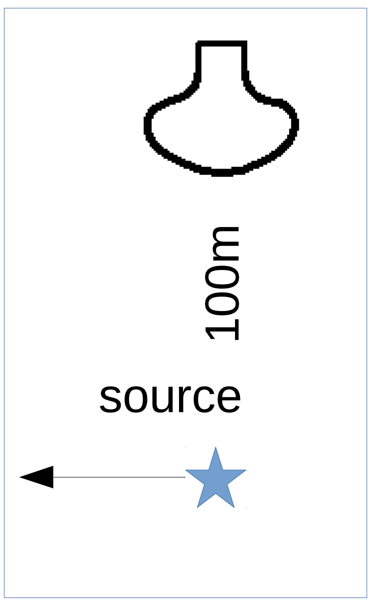
- Find maximum LLH
- Return respective source parameter

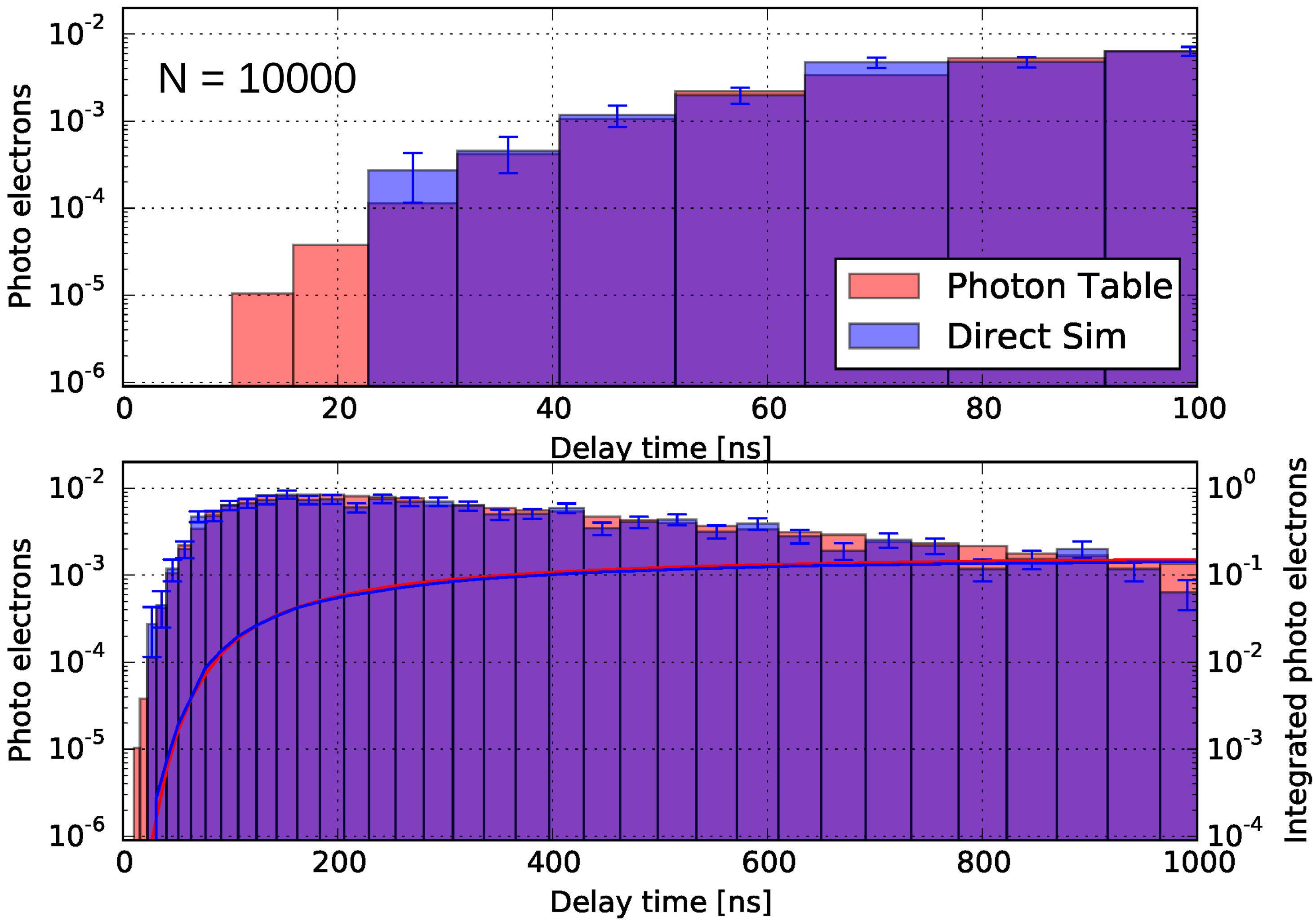


Reconstruction only successful when lookup tables are correct !

Evaluation of lookup tables

Example config:
Energy = 1TeV
Angle = 90°
Distance = 100m





Summery and Outlook:

- Sensitivity studies for IceCube Gen2 with mDOMs require:
  - Simulations (Toolset ready and working)
  - Reconstructions methods (not tested yet)
- Preformance studies will be started soon
- Direct comparison between IceCube DOMs and mDOM (and other possilble modules) possible
- Possibility of Direct Reconstruction (no lookup tables needed) will be investigated

Event reconstruction with max LLH

Event topology
(detector signal)

Simple first guess
reco. algorithms

Event hypothesis
(Energy, Pos, Dir, etc.)

Lookup table

Calculate LLH for
event hypthesis to
look like the actual
event

Use minimizer to vary
<energy, pos, dir> until local
min is reached