WARNING: IN THIS PRESENTATION VARIOUS ICECUBE NON-OFFICIAL PLOTS ARE USED FOR ILLUSTRATION PURPOSE. THEY ARE NOT MEANT TO BE CIRCULATED TO A LARGER GROUP.

# About PINGU Simulation and Reconstruction

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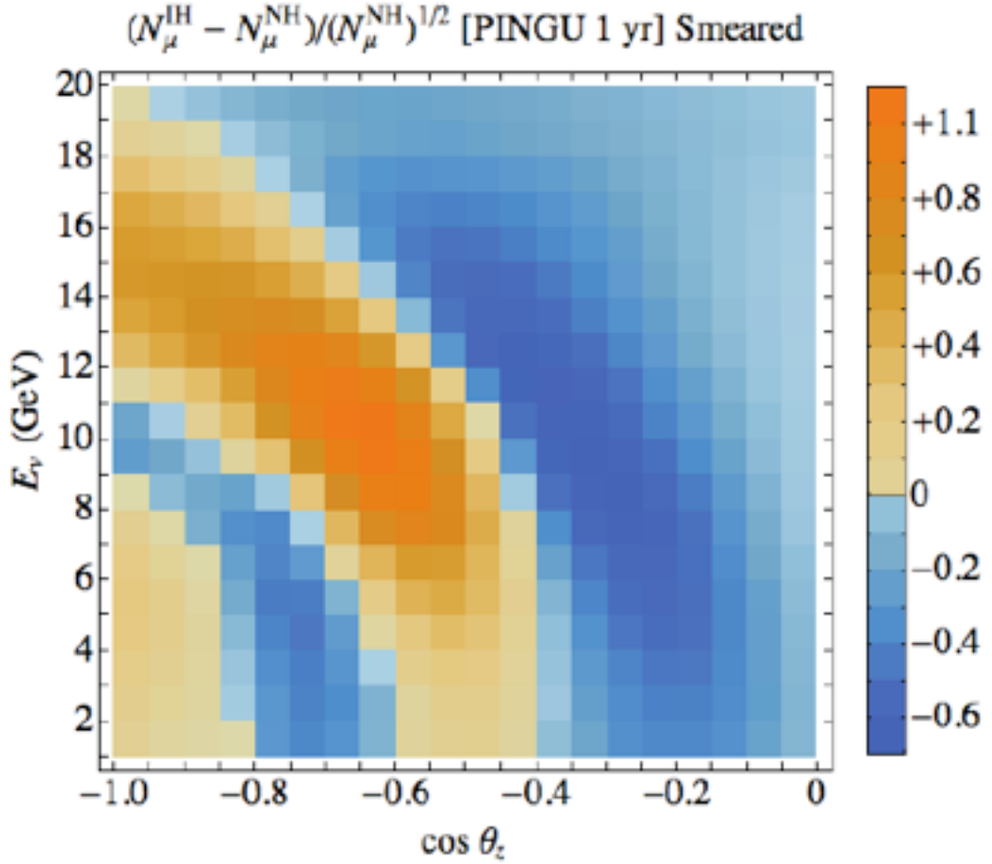
for IceCube

with few additions from my side

# Simulation Goals

- which physics measurements can be achieved (and on which time scale)?
- what is the optimal configuration to achieve these?
  - effective volume
  - angular and energy resolution
  - veto power and background rejection
- testbed for the development of statistical analyses for mass hierarchy

# What do we simulate?




main focus on muon neutrinos

simulating 1-80 GeV

(most important range 1-20 GeV)

all-sky

different 20 string geometries

(simulation of larger geometries possible if 20 strings are not enough)

E. Akhmedov,, S. Razzaque, and A. Smirnov, http://arxiv.org/1205.7071

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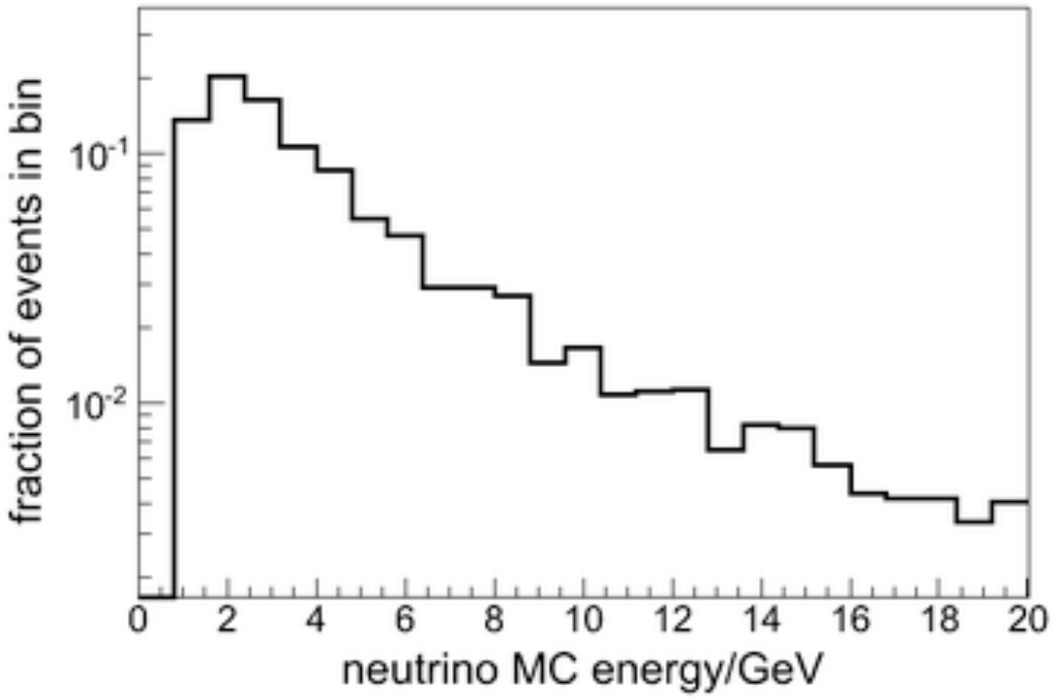


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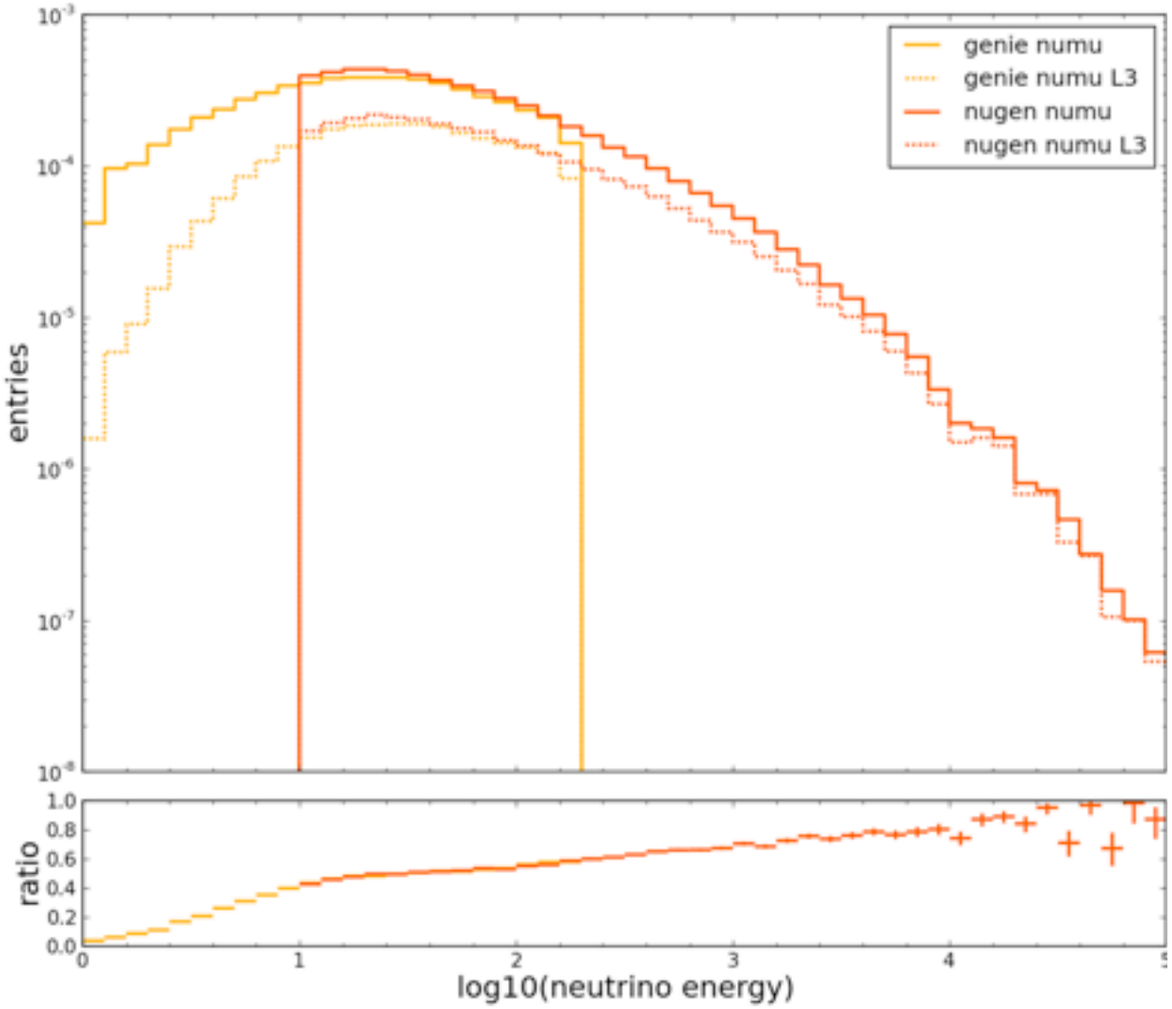
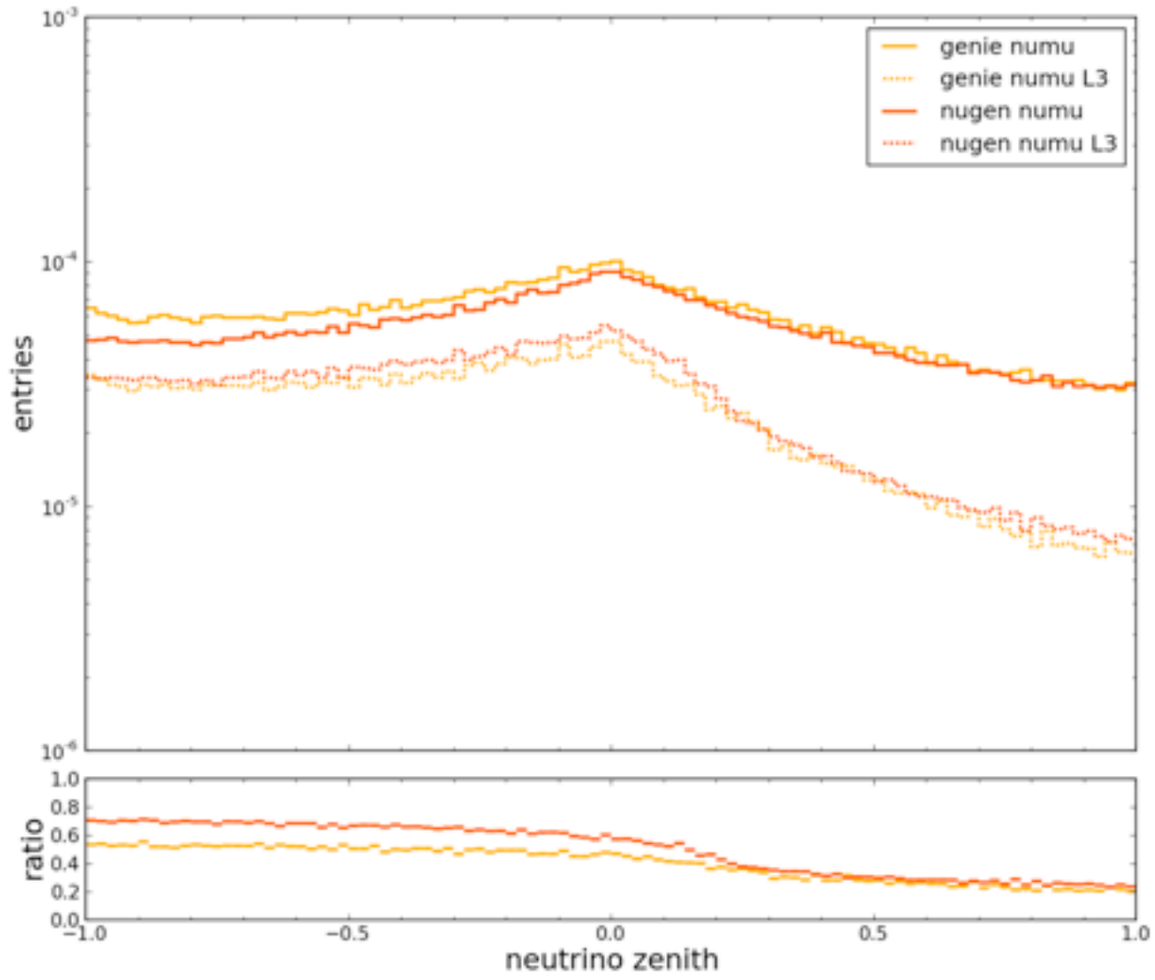
# Simulation Setup

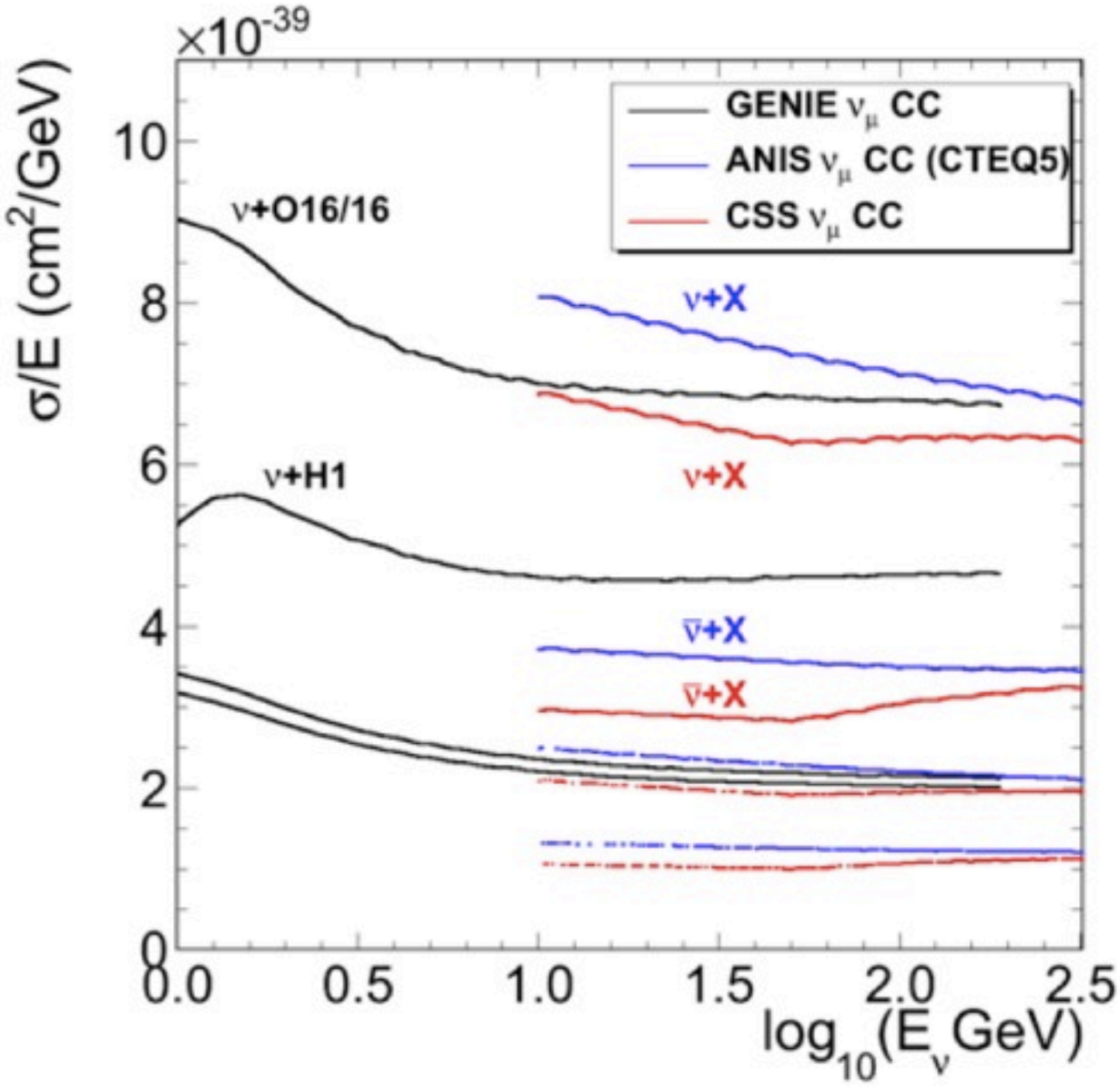
- benefits from experience with IceCube and DeepCore
- part of icetray
- neutrino generator: genie instead of nugen
- direct photon propagation
- event weighting to account for oscillations and atmospheric spectrum

# Genie


genie numu
genie numu L3
nugen numu
nugen numu L3
entries
ratio
log10(neutrino energy)


genie numu
genie numu L3
nugen numu
nugen numu L3
entries
ratio
neutrino zenith

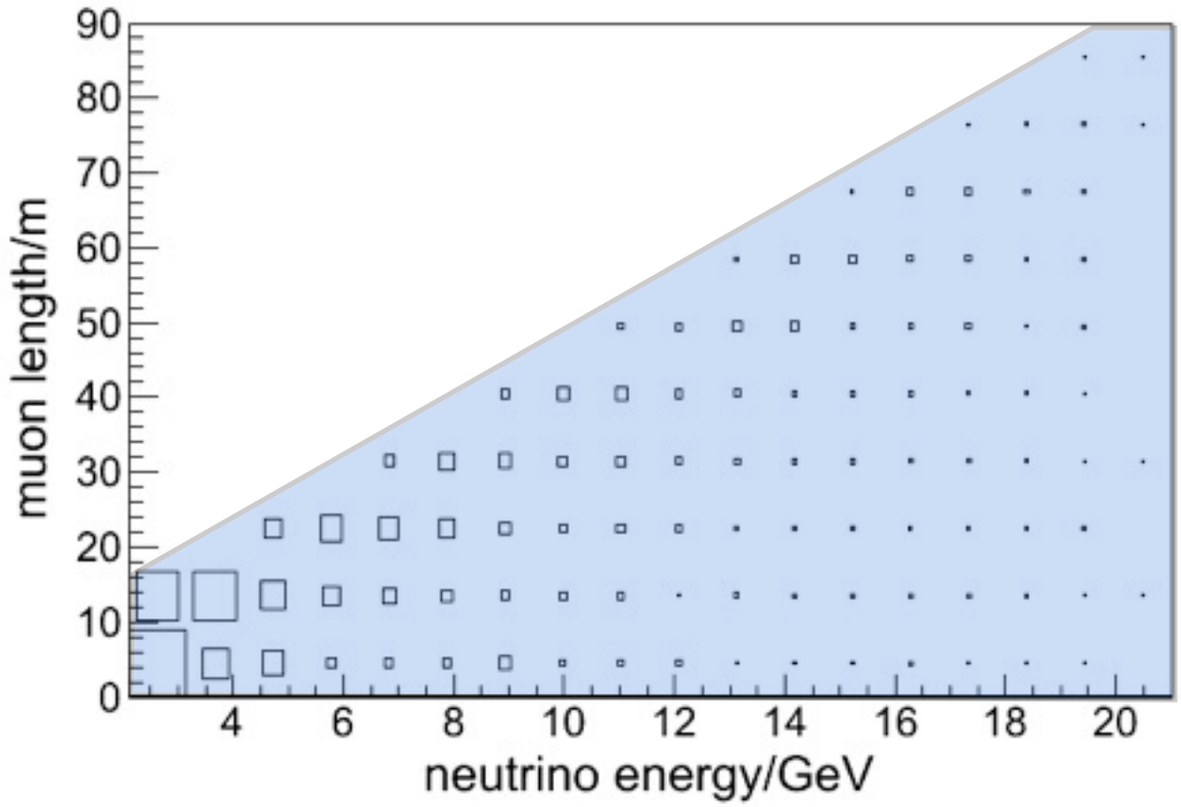
# CROSS SECTIONS COMPARISON




apologize, I could not find the reference ...

# Detector Layout

- discrete set of geometries
- make best possible use of IceCube as veto and DeepCore strings as part of PINGU
- scale of distances approximately set by muon length in numu CC events
- explore between limits of densest instrumentation and largest volume



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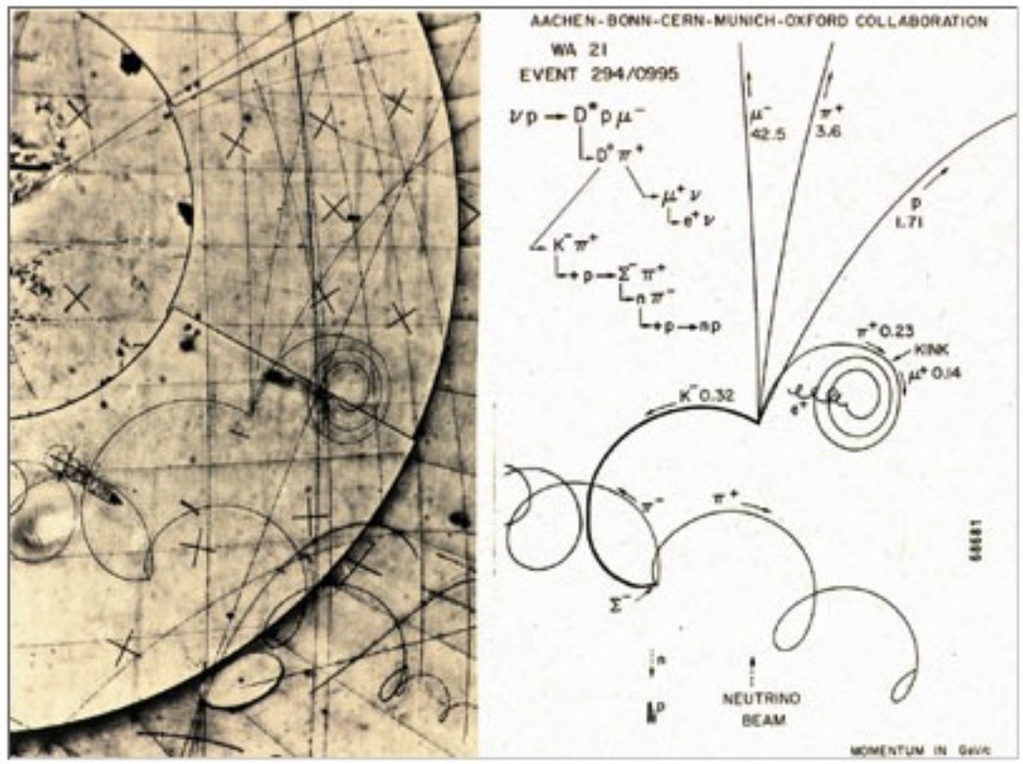


A "textbook" picture from the BEBC bubble chamber. A neutrino interacts with a proton in the liquid hydrogen to produce a negative muon, a proton and an excited charmed meson ($D^*$). The $D^*$ decays to a charmed $D^0$ meson plus a positive pion and the $D^0$ itself decays to a negative kaon and another positive pion. After stopping in the liquid the kaon interacts with another proton to produce a hyperon.

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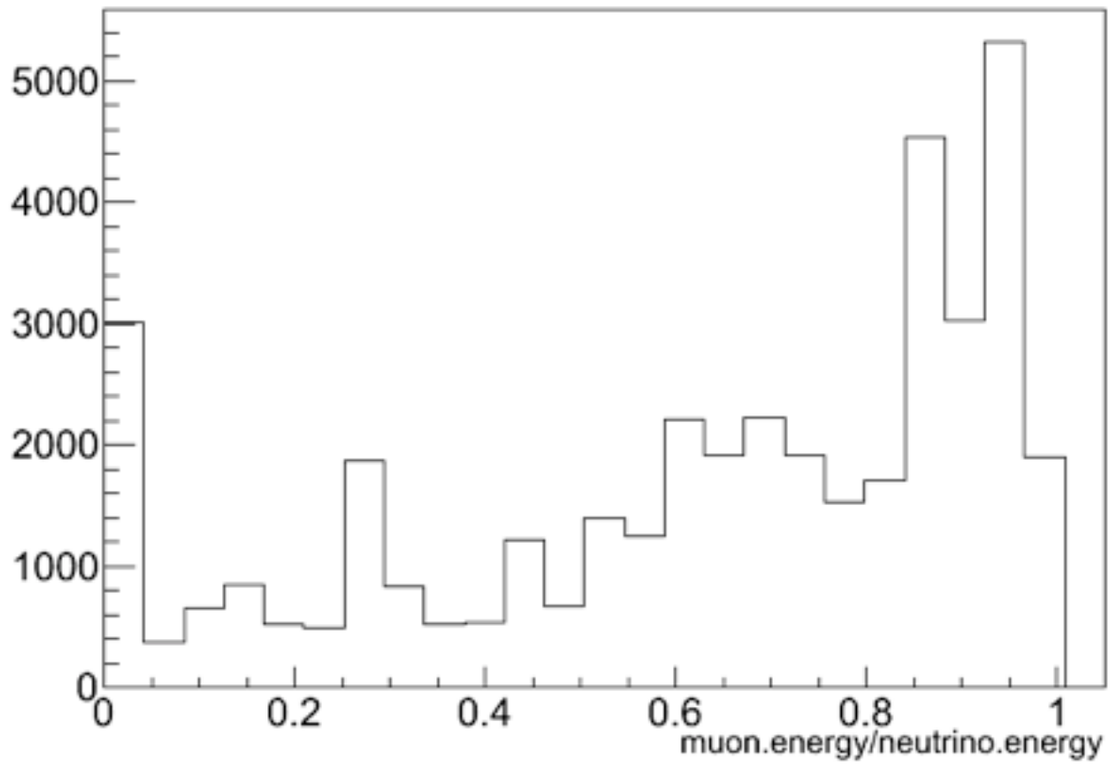
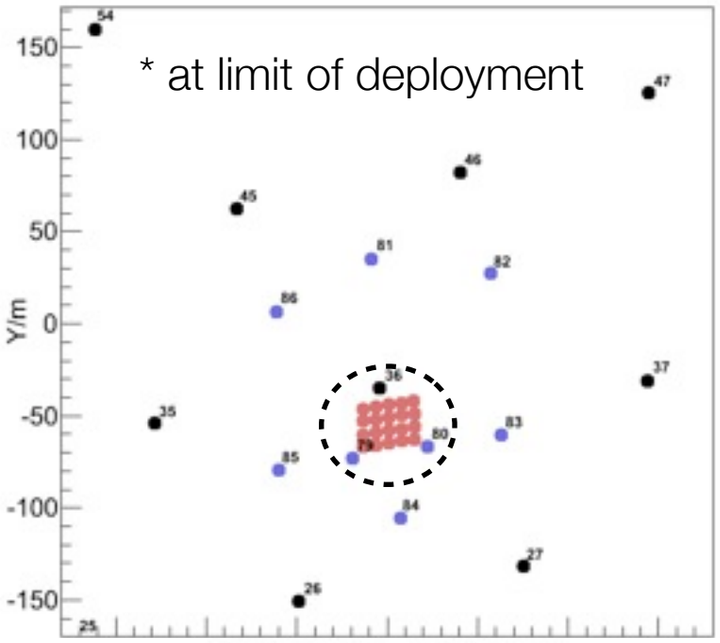


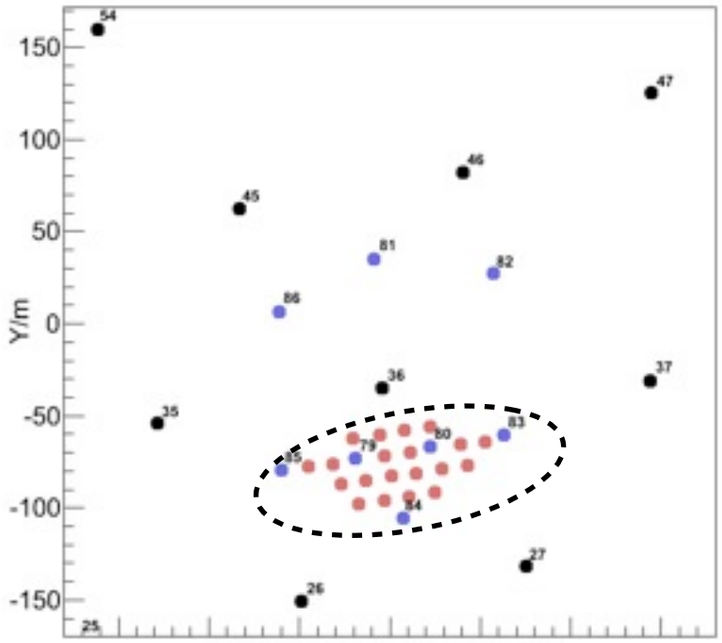
# A Range of Geometries

PINGU v3 - Top View

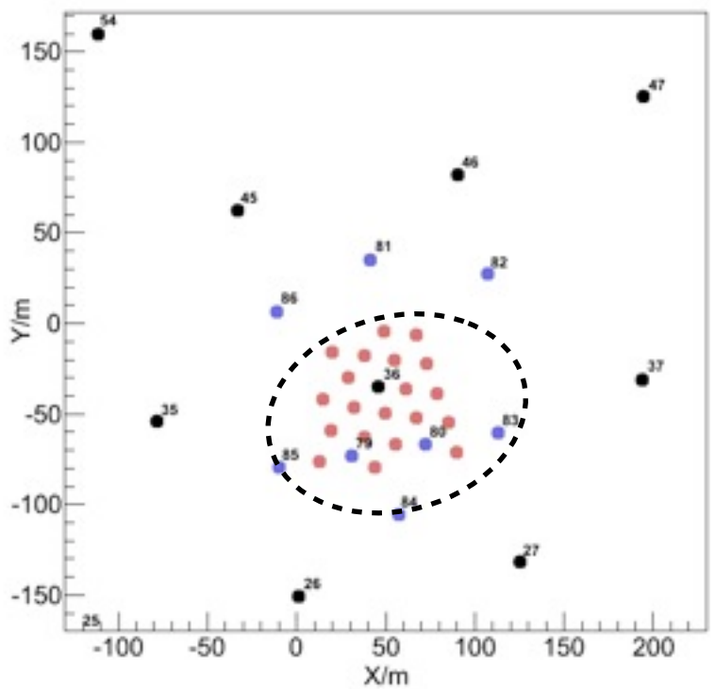



| string spacing | DOM spacing | version |
|---|---|---|
| 7m | 3m | v3 |
| 14m | 5m | v5 |
| 18m | 5m | v8 |
| 22m | 5m | v7 |
| 26m | 5m | v6 |

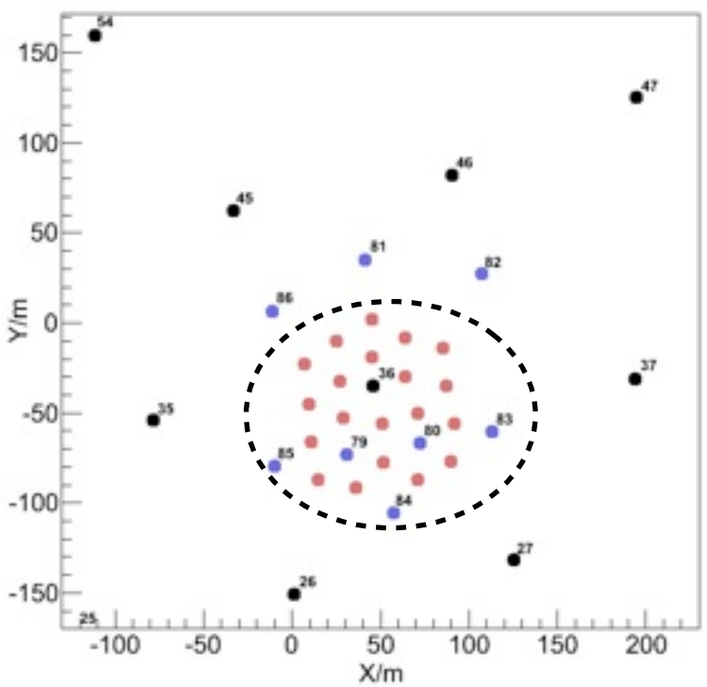
PINGU v5 - Top View



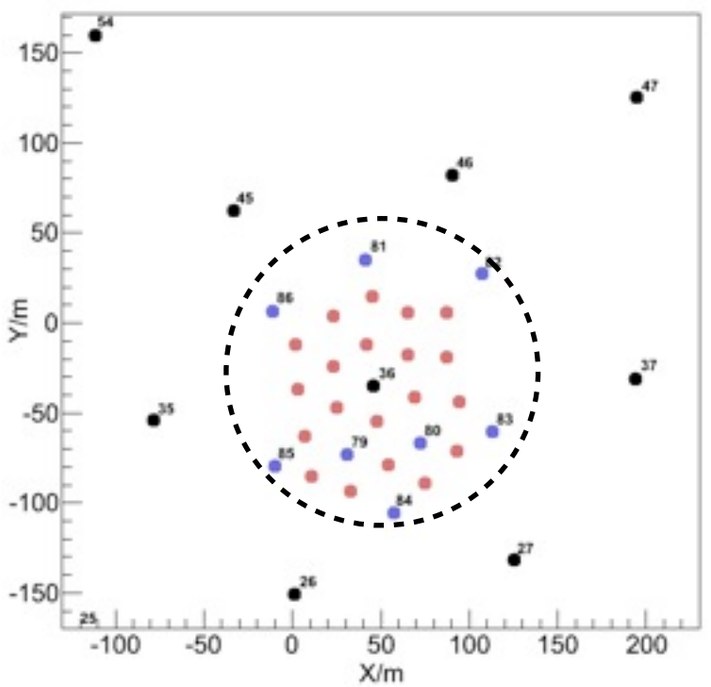

PINGU v8 - Top View




PINGU v7 - Top View




PINGU v6 - Top View



# Comparison of Geometries

- currently using a cut on the number of hits to indicate that the events can be reconstructed

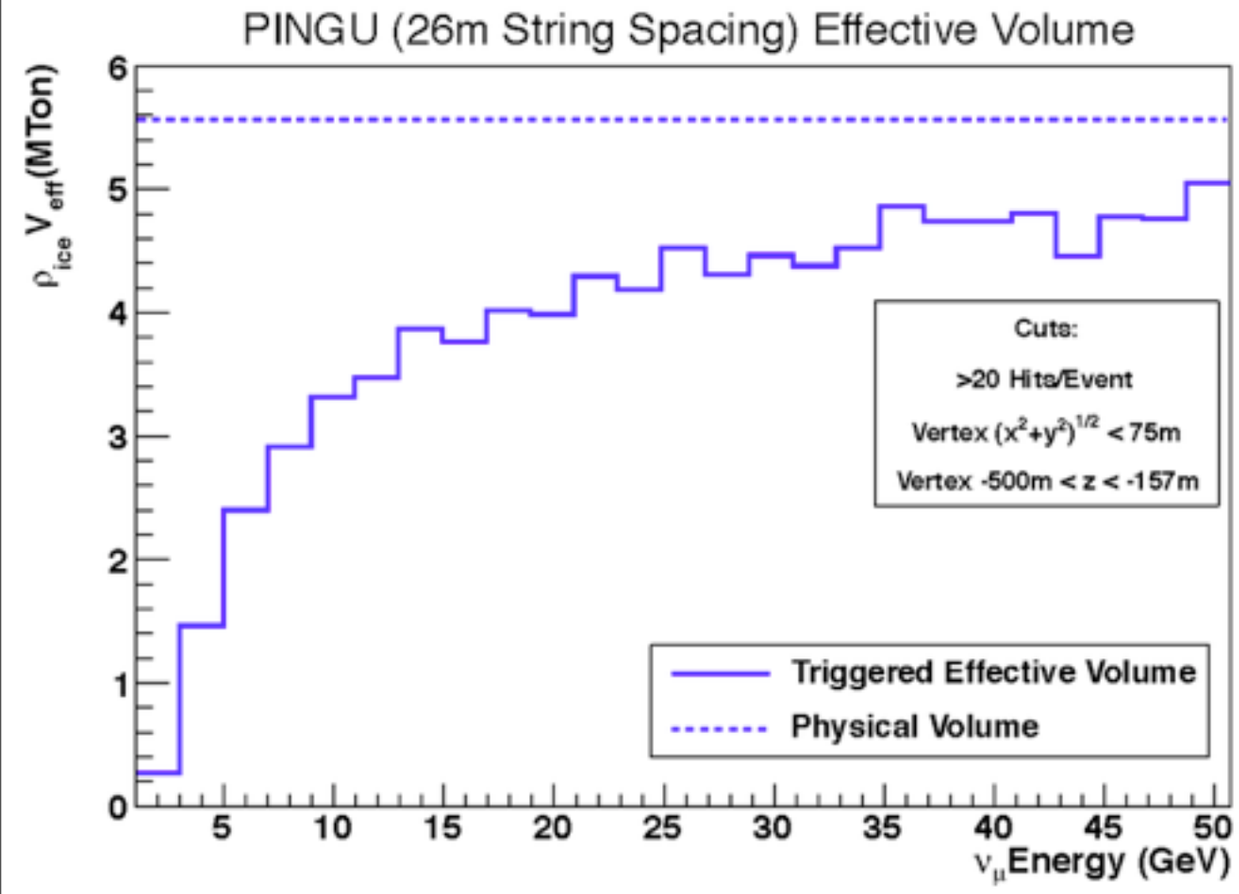
- alternative figures of merit to be investigated in the future

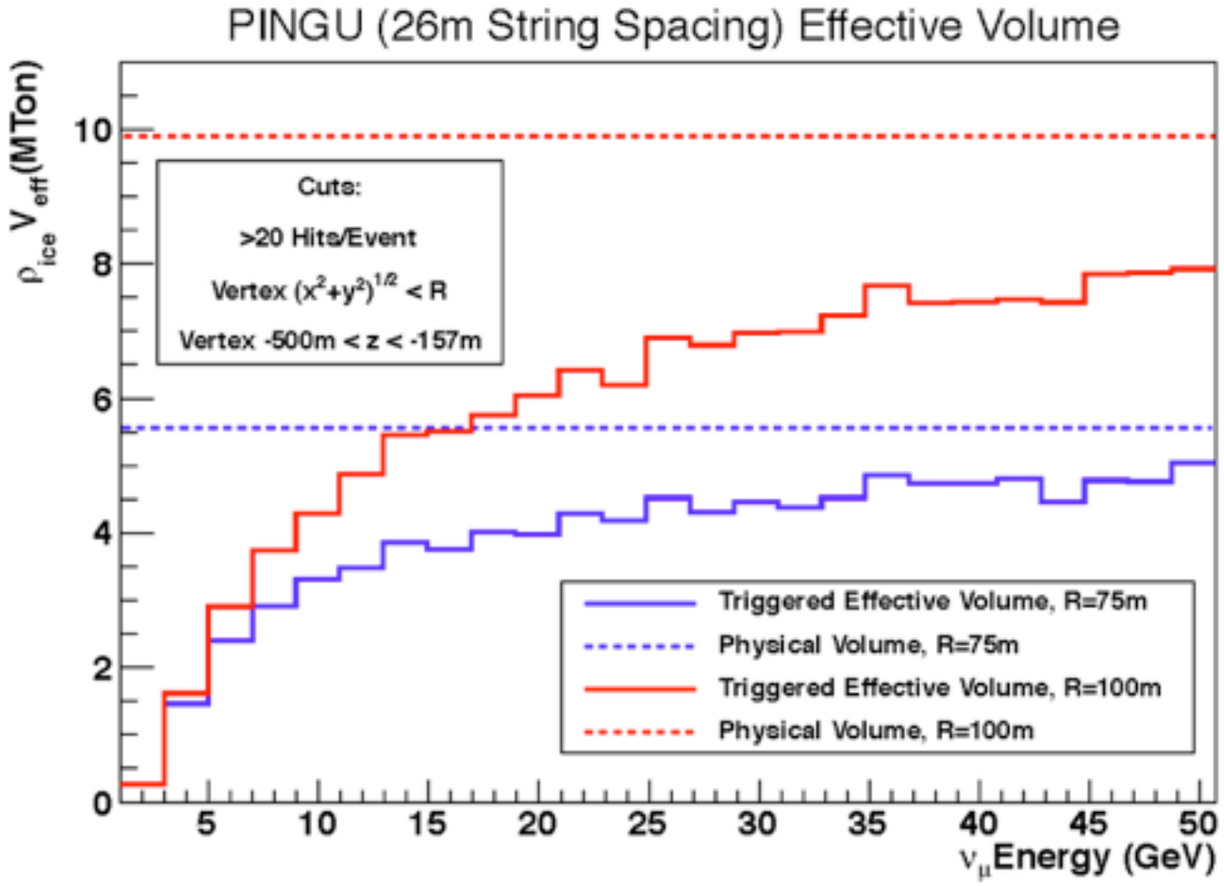
  - effective volume using direct hits (?) (matters for first-guess reconstructions but not so much for high-level ones)

  - effective volume after reconstruction

  - effective volume with benchmark background rejection

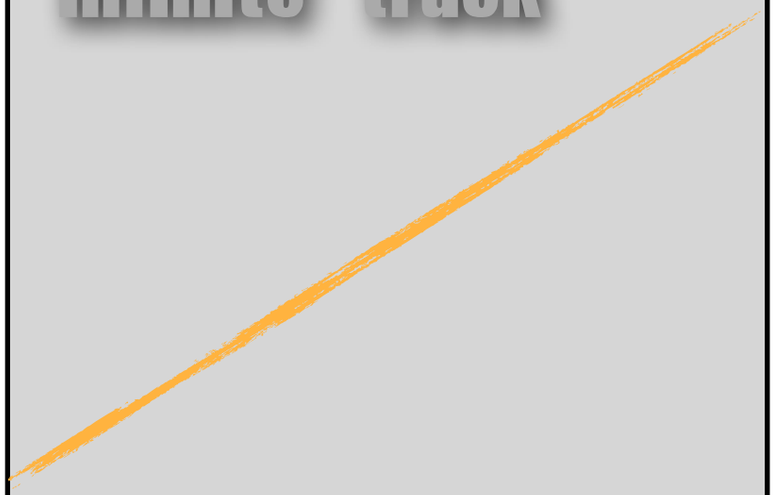
# Comparison of Geometries



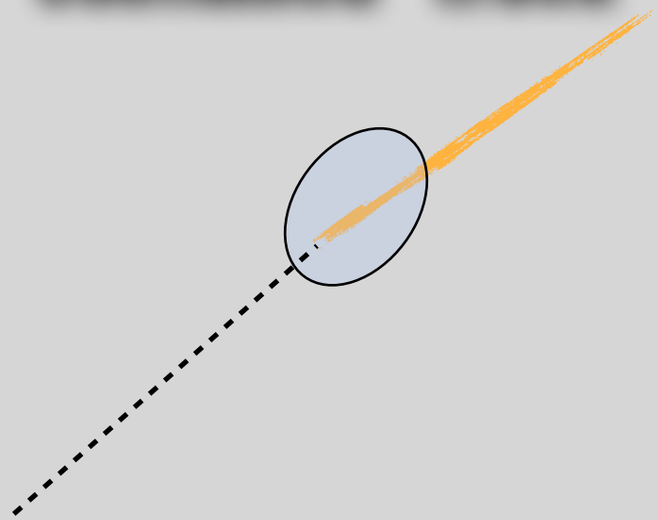
# Dominant Muon Neutrino Event Signature (CC)

infinite track



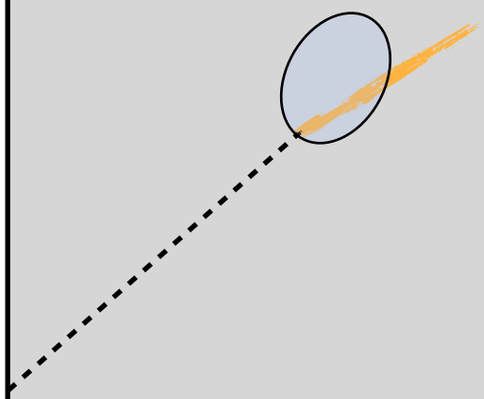
IceCube Energies

contained track



DeepCore Energies

short contained track



PINGU Energies

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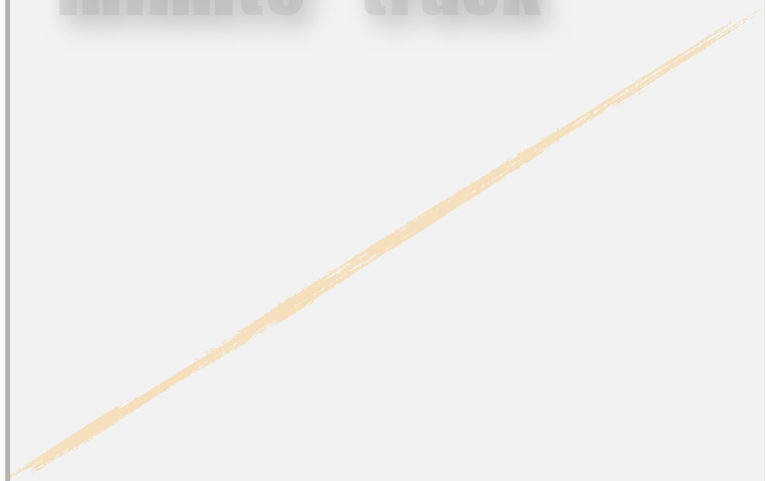


IceCube Energies

contained track

Hadronic cascade matters

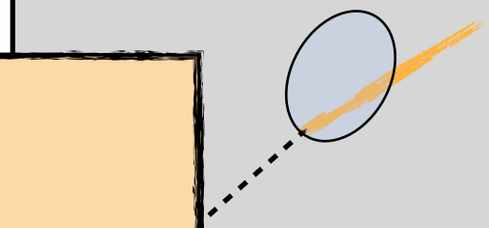
Infinite track hypothesis is a bad approximation

identification of events with tracks more difficult

(larger impact of scattering?)

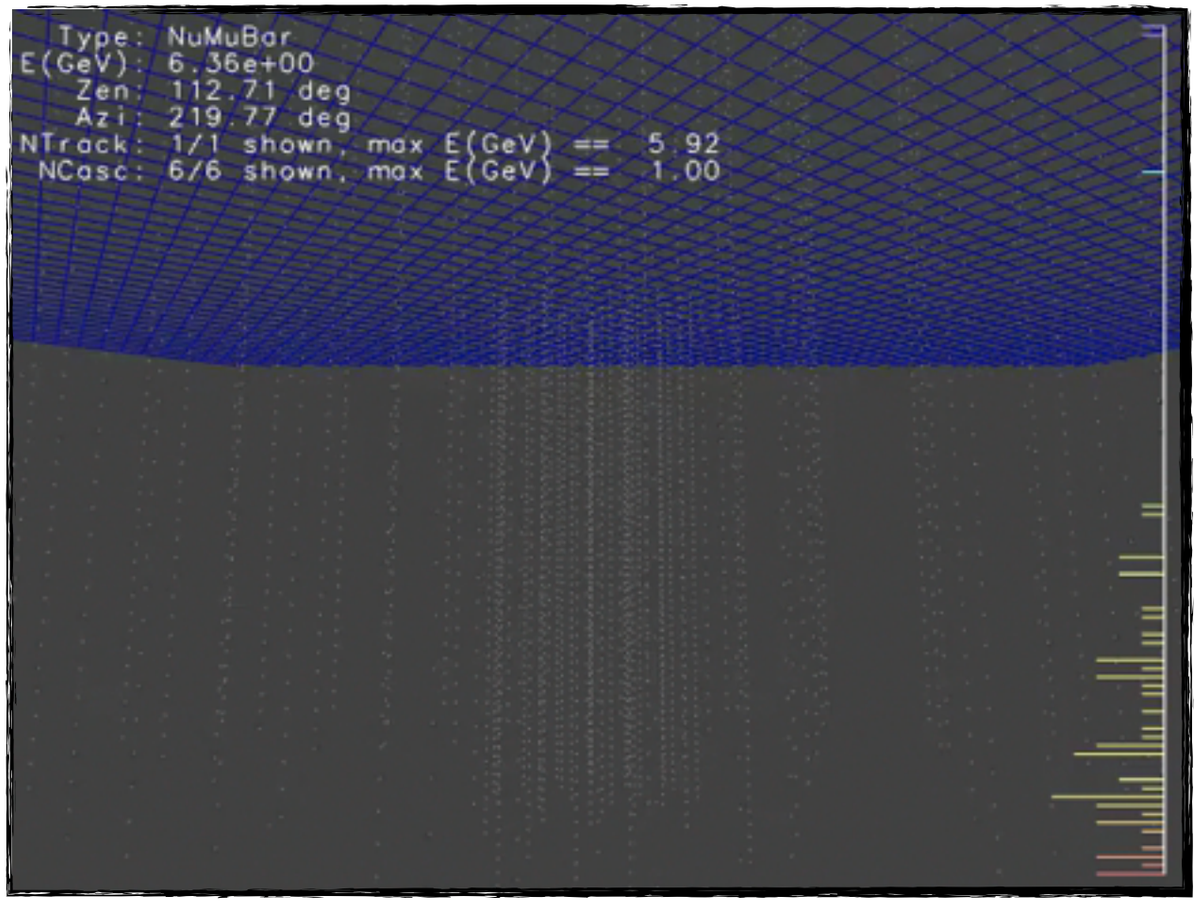
DeepCore Energies

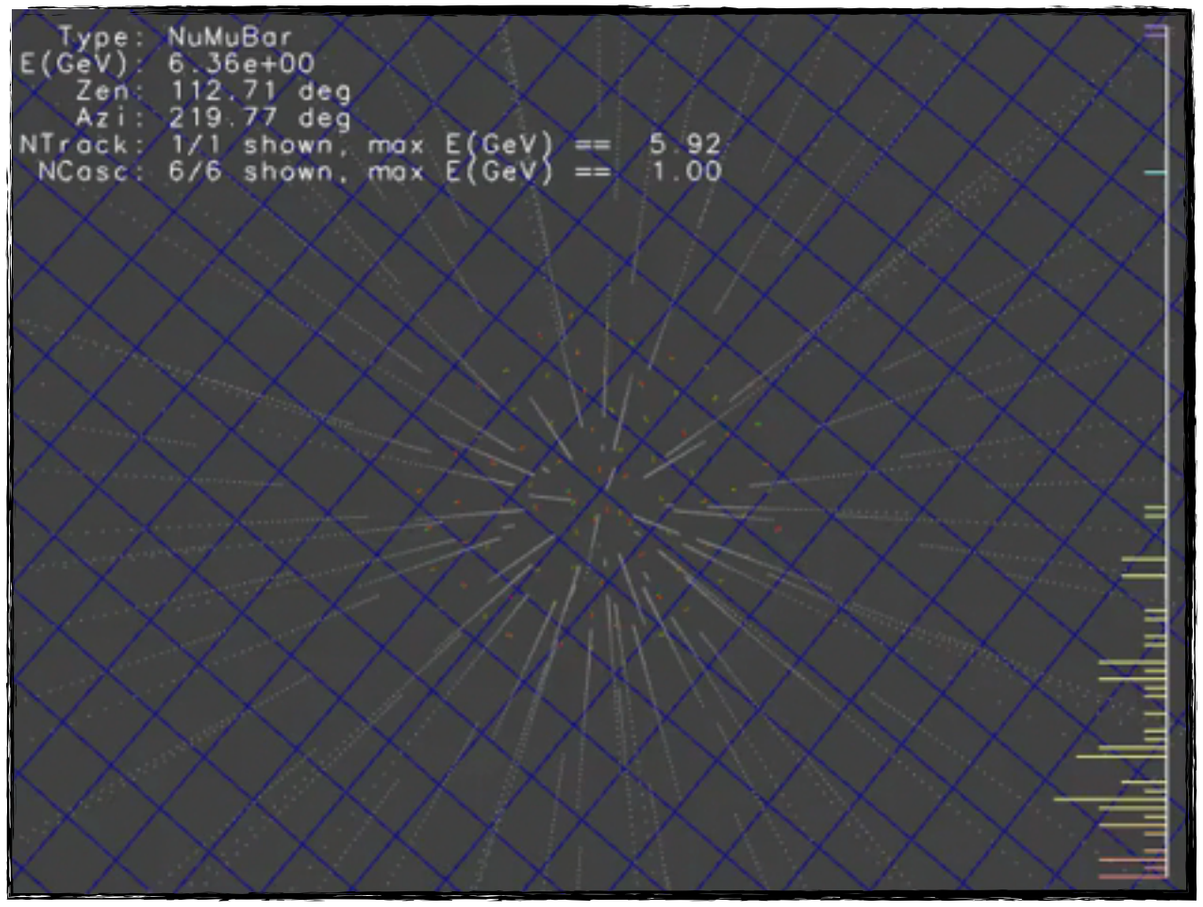
short contained track



PINGU Energies

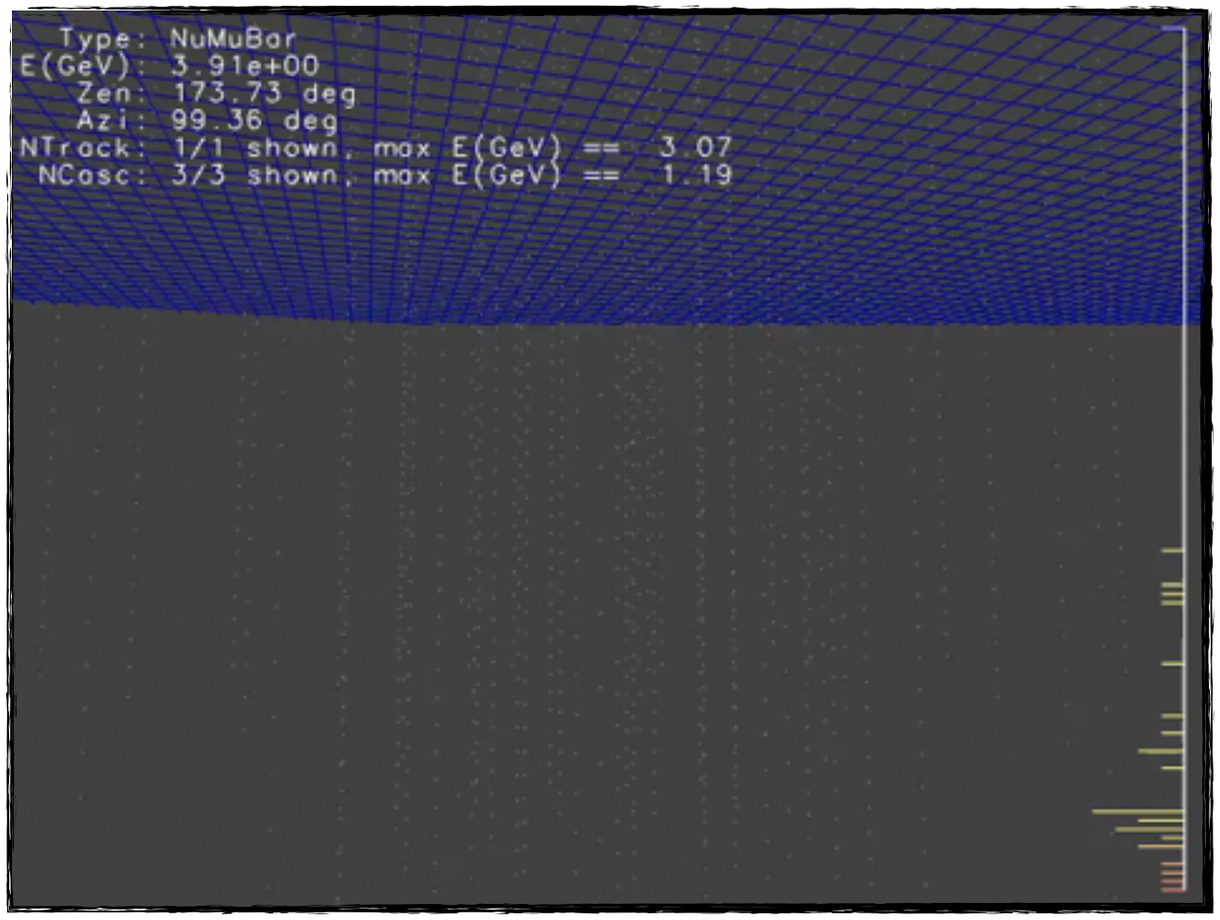
# Example Events - Geometry v6

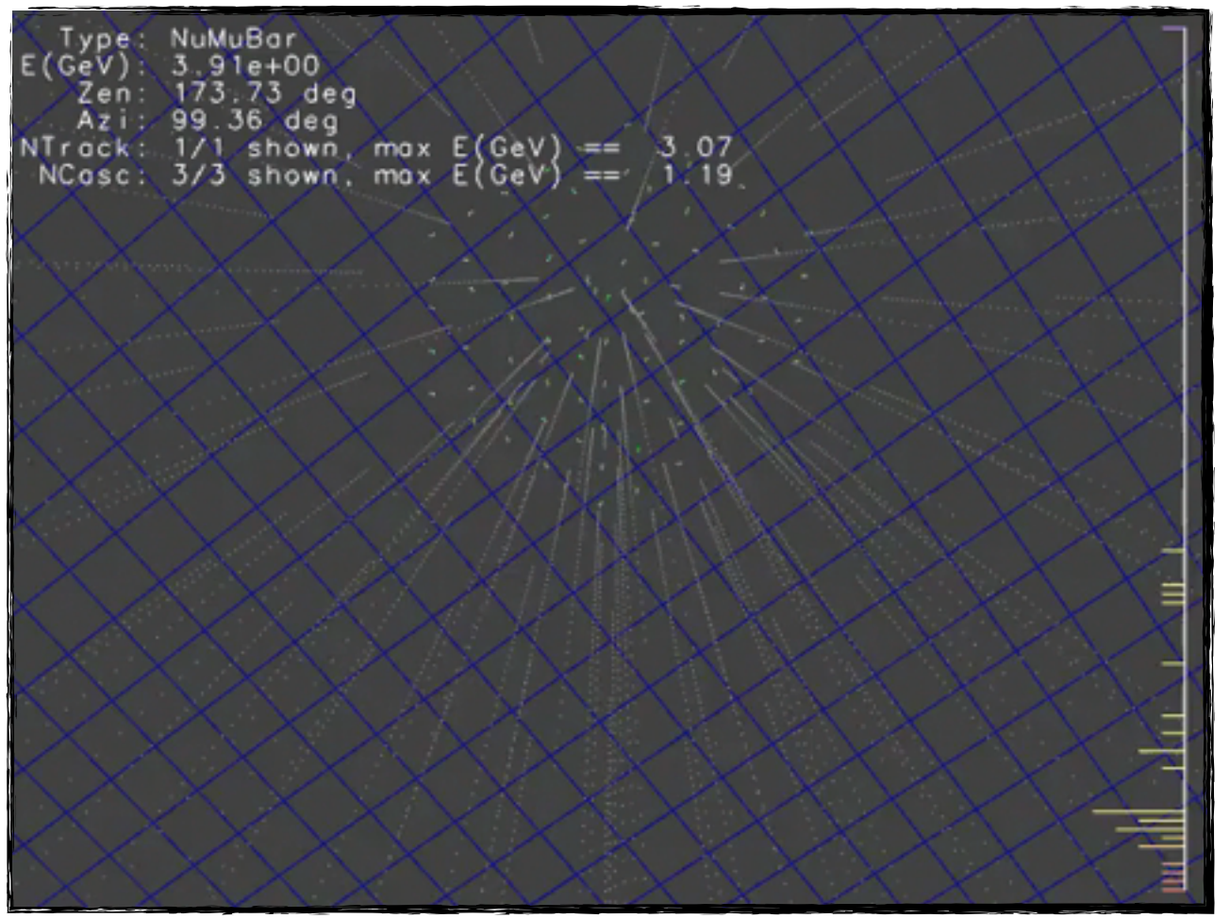



this is a mc event (of course!) - all hits are „physics“ hits - colors indicate time (red - blue) - size of hits indicates charge - the yellow/green line shows the neutrino/muon direction

# Example Events - Geometry v6

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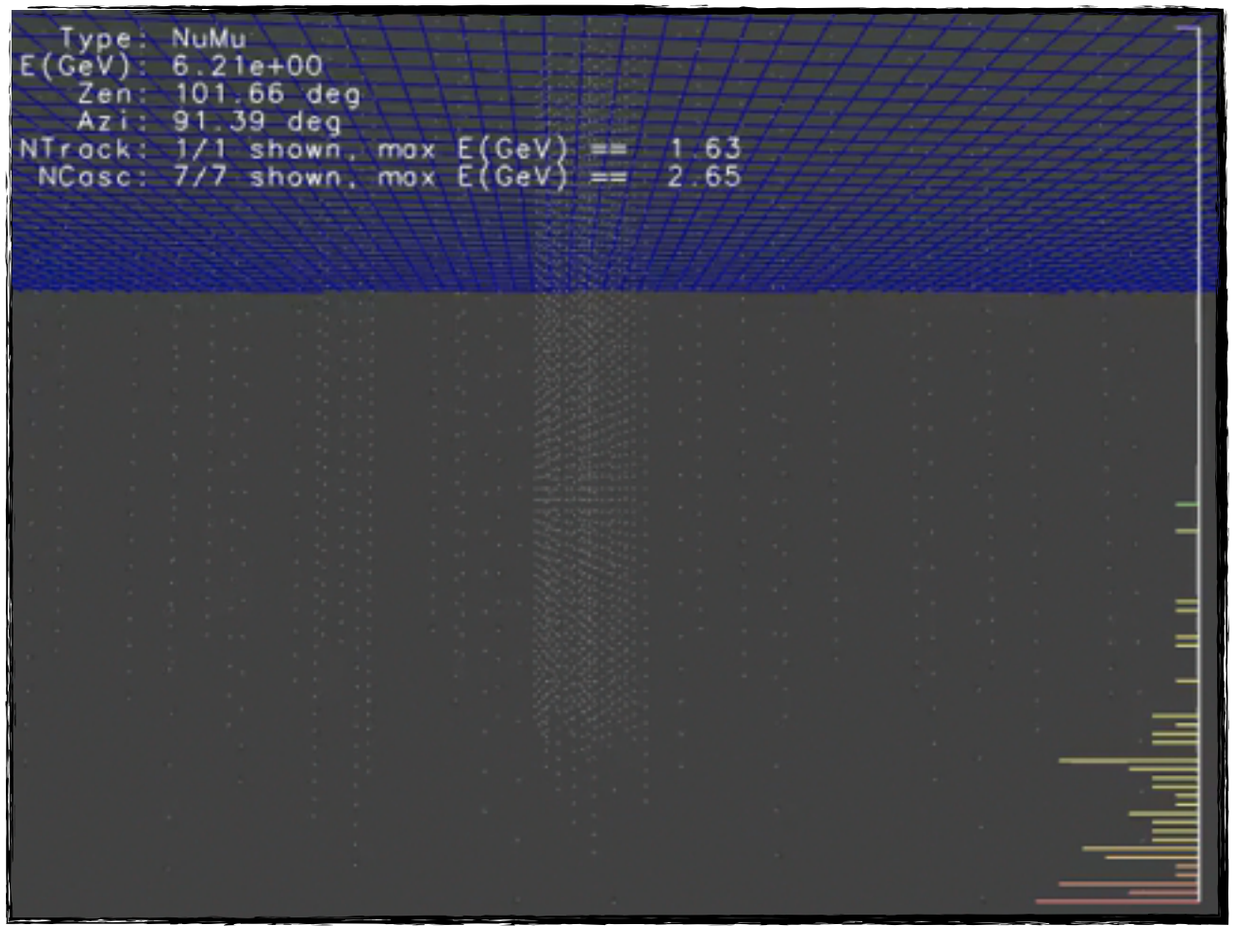


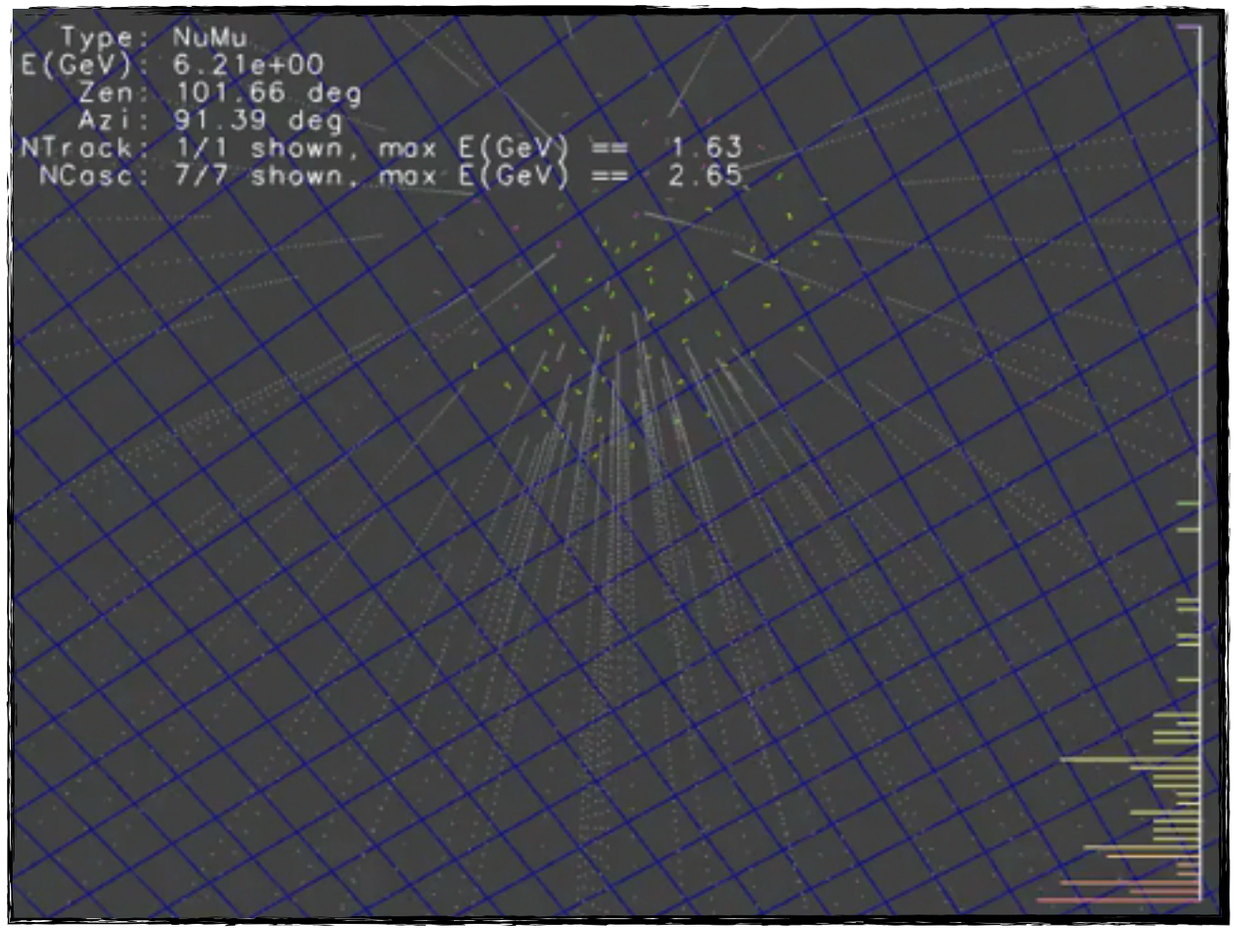


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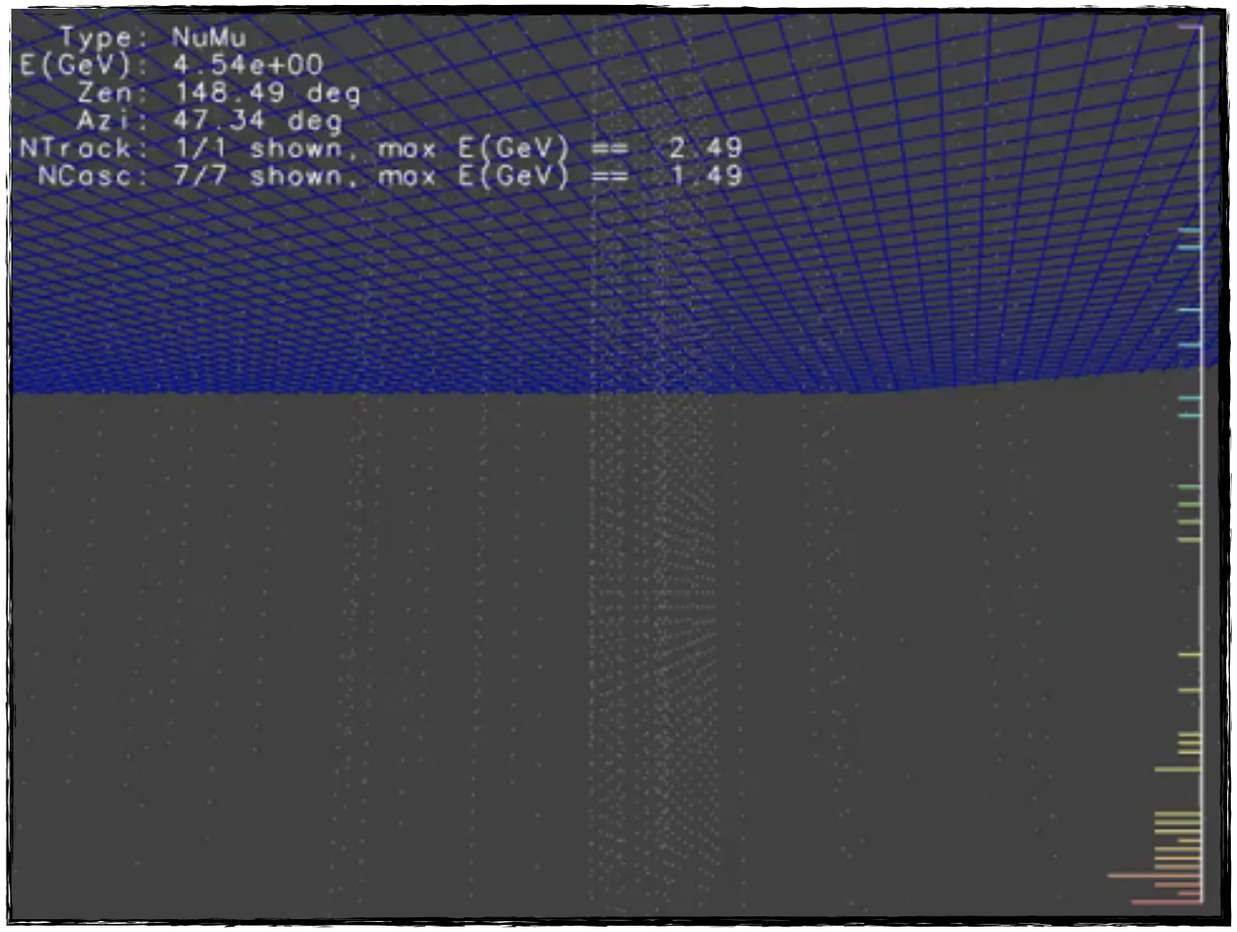


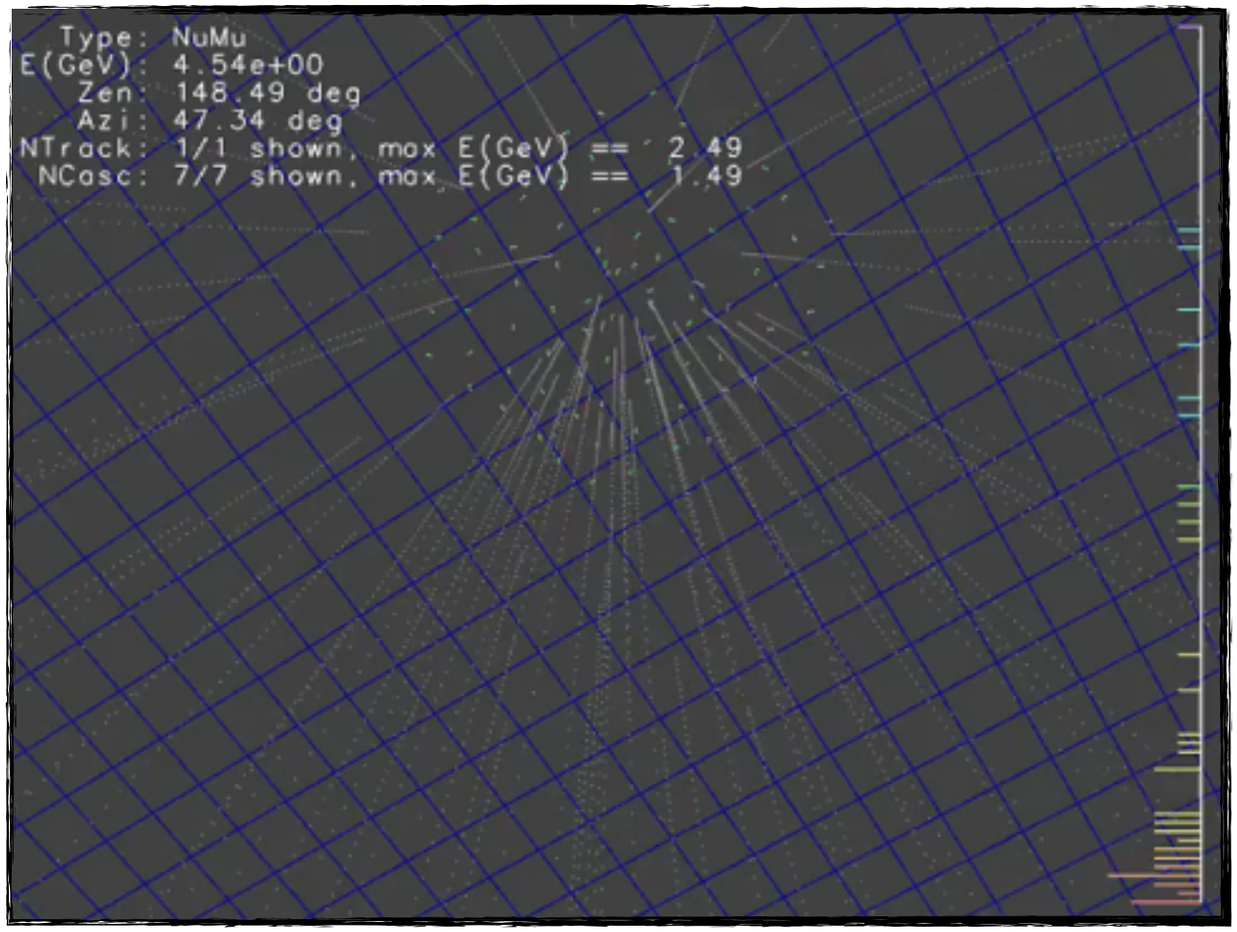


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# Reconstruction

First-Guess Reconstruction → seed for → Likelihood Reconstruction

These reconstructions do not take the ice properties or the event topology into account.

Possibilities under investigation:

**LineFit** - straight line fit through the hits ignores Cherenkov cone and scattering
**SANTA** - uses the geometry of the Cherenkov cone and a stringent hit cleaning (as in ANTARES paper)
**JAMS** - a simple pattern recognition algorithm used in AMANDA

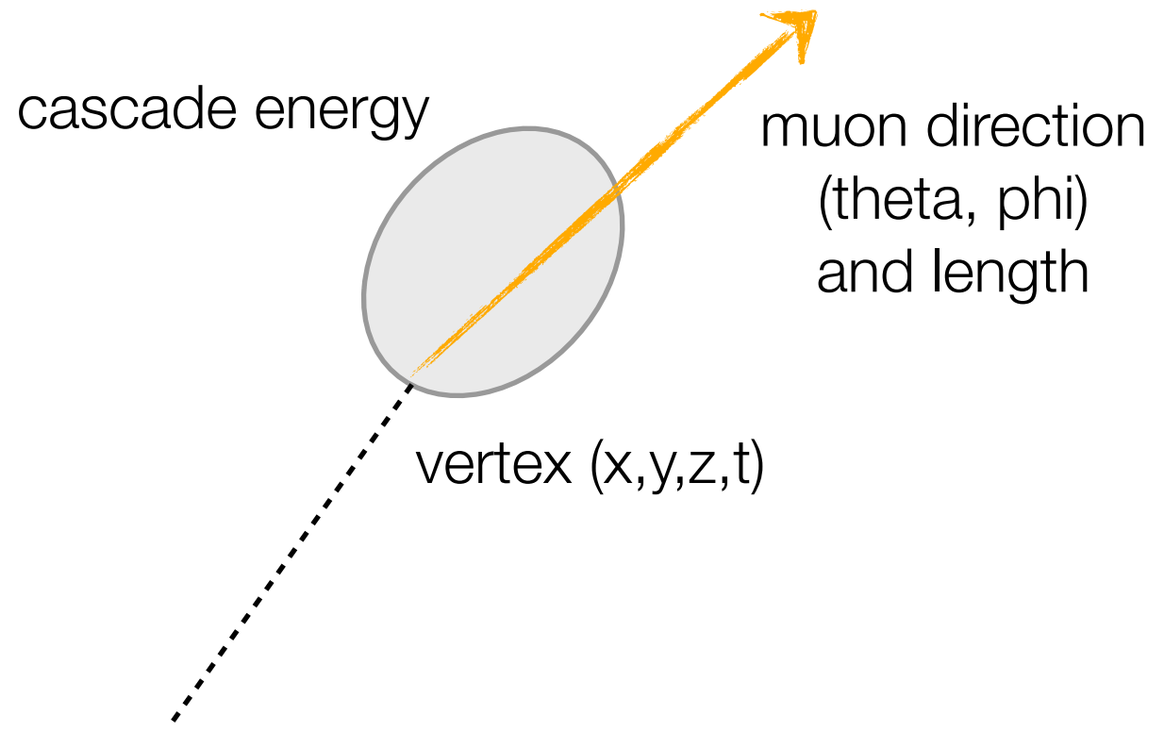
may apply several llh reconstructions with increasing complexity

using ice properties and event topology

high-end likelihood reconstruction on next slide

# Likelihood Reconstruction of contained events

- Reconstruct the full event:
  - hadronic cascade + muon track
- Use tabulated pdfs for photon arrival times -> best possible use of ice information
- Under comparison and study many different options: from first look energy resolution looks promising, track resolution still problematic …. but tomorrow is another day and things will look differently!



# Summary & Conclusions

- Fully-functioning simulation framework is set up using the tools and experience of IceCube

- Investigation of different geometries well-under way

- With small muon lengths,
  - we should reconstruct the muon length to measure its energy
  - the cascade forms an important part of the event

- High-Level Reconstruction should take the nature of the events into account