A search for partially contained neutrino induced particle showers with IceCube

Achim Stößl for the IceCube collaboration

DESY

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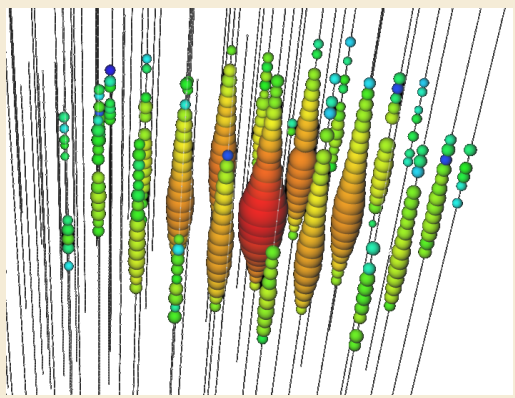
Diffuse analysis - overview

- Search for superposition of individual Point Source flux
- All-sky ν_e, ν_τ, ν_μ(*cascades*), Northern sky ν_μ (tracks)
- Energy spectrum properties allow conclusions about source populations

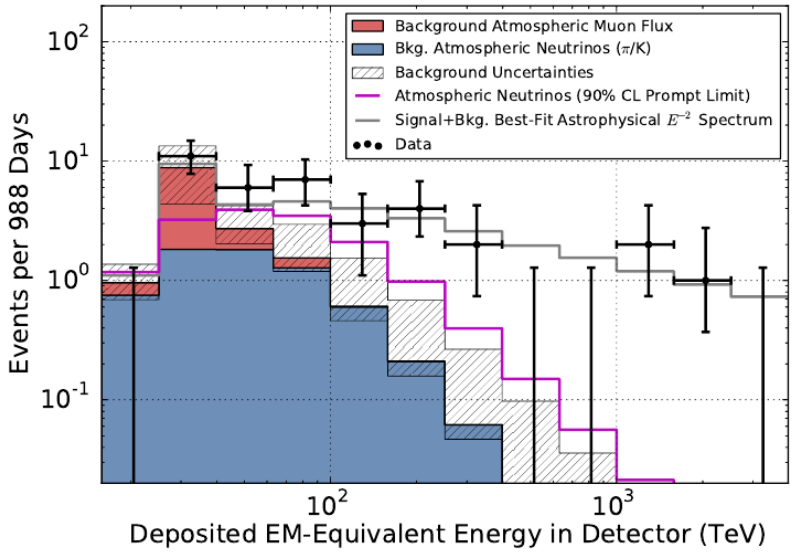
Event signature

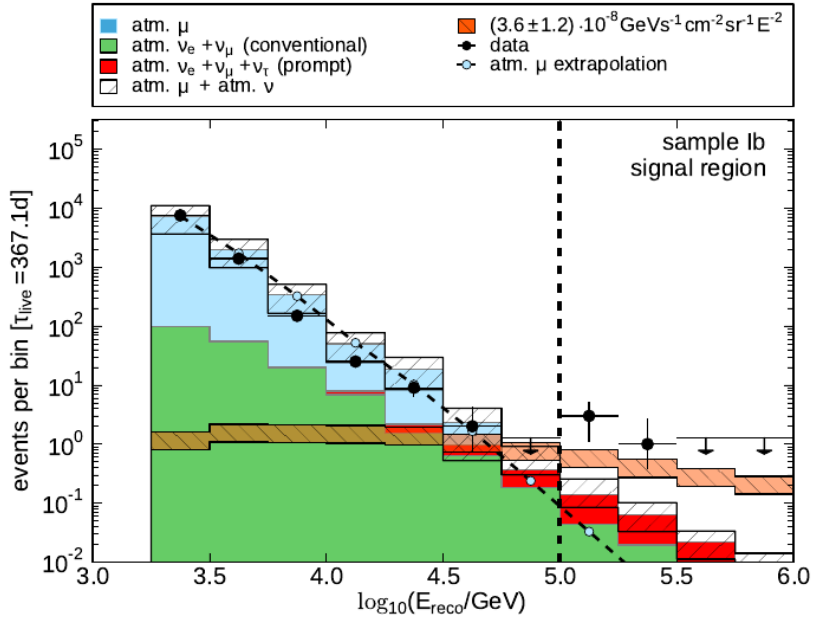
- Particle shower ("cascade")
- all-flavor NC, ν_e CC
- calorimetric energy measurement



IceCube's diffuse results

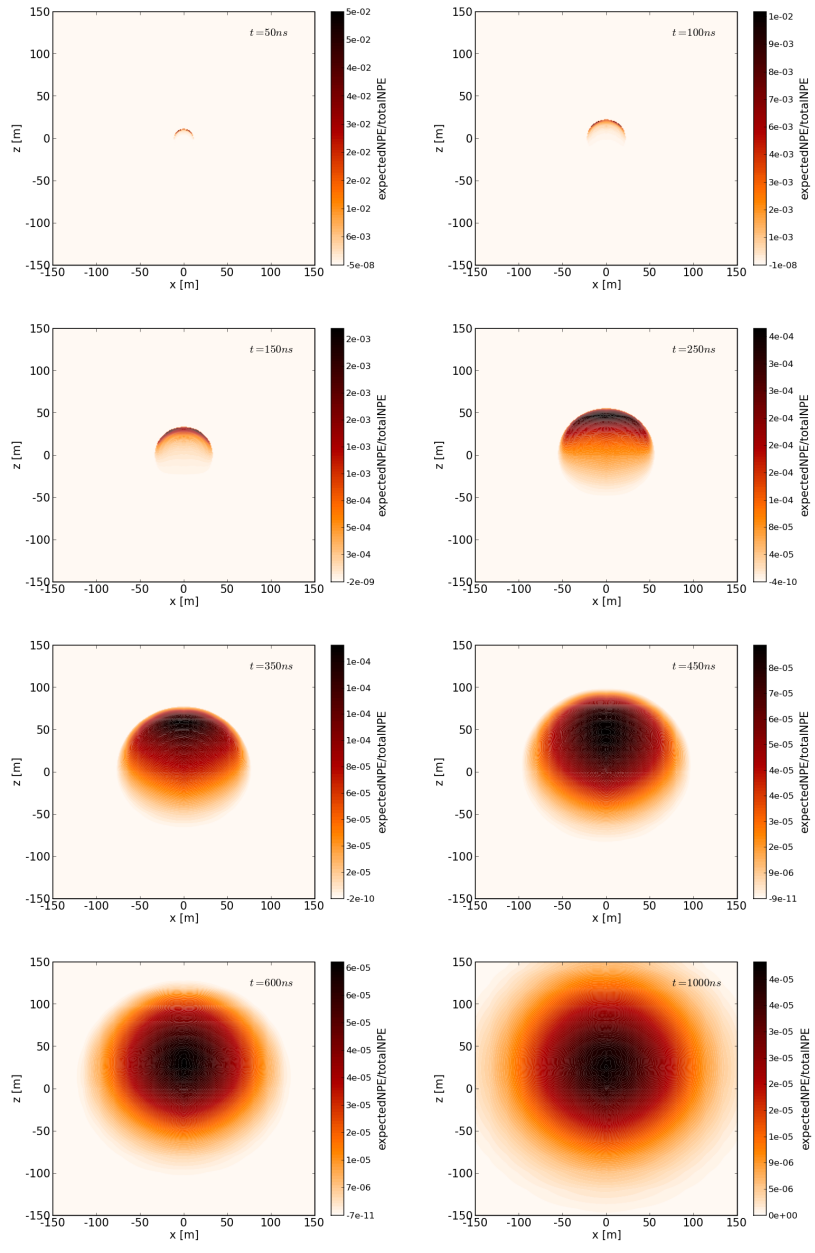
- HESE search: 5.7σ over atmospheric ν arXiv:1405.5303
- IC40 contained cascades: 2.7σ arXiv:1312.0104
- IC59 throughgoing tracks: 1.8σ arXiv:1311.7048
- Currently efforts on combining the results and setting further constraints on the spectrum





Cascade reconstruction

- 7-parameter Poisson likelihood reconstruction (energy,vertex,direction)
- Includes no-hit term
- Different ice-models can be plugged in
- Uses timing and charge information

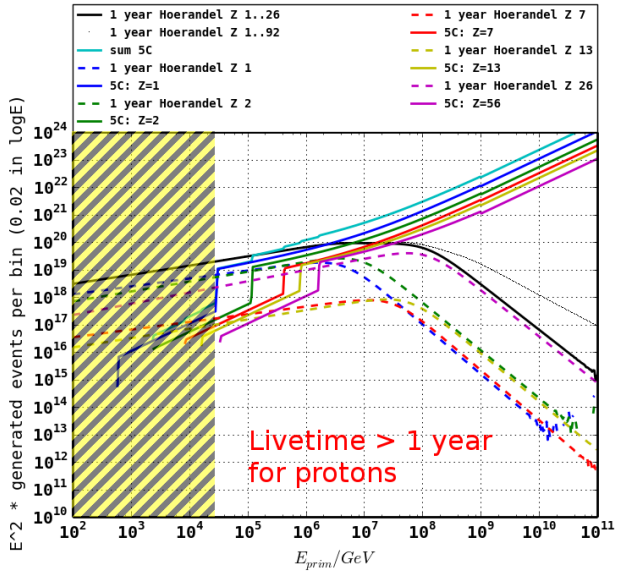


Analysis overview

target	$E^{-2}\nu$ all-flavor, all-sky
sensitivity	$2.1 \cdot 10^{-8} GeV s^{-1} sr^{-1} cm^{-2}$ (cut and count)
technique	Straight cuts
method	Partially contained cascades
background	MC Background prediction

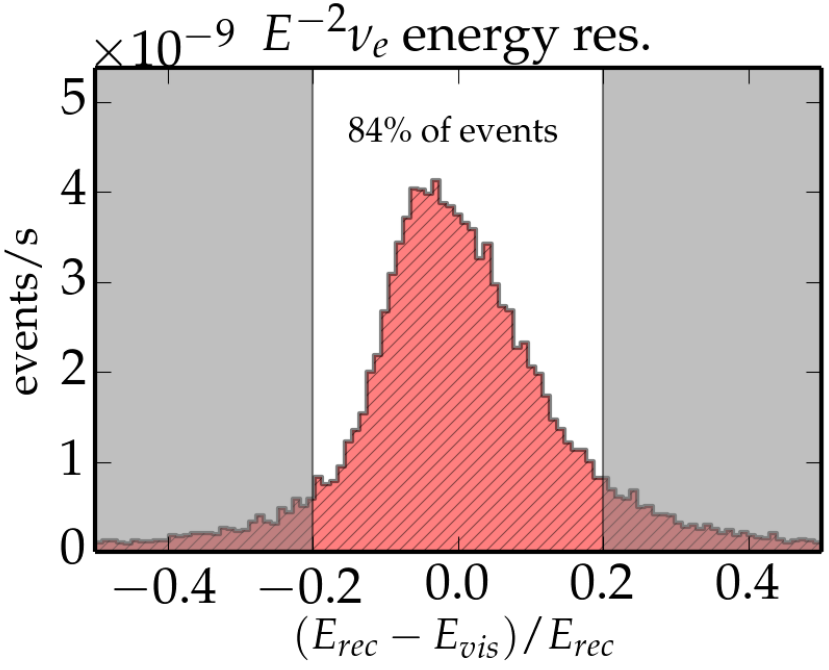
Analysis - IceCube data

- Data of 79 string configuration used (330 days)
- 10% data used for cut development

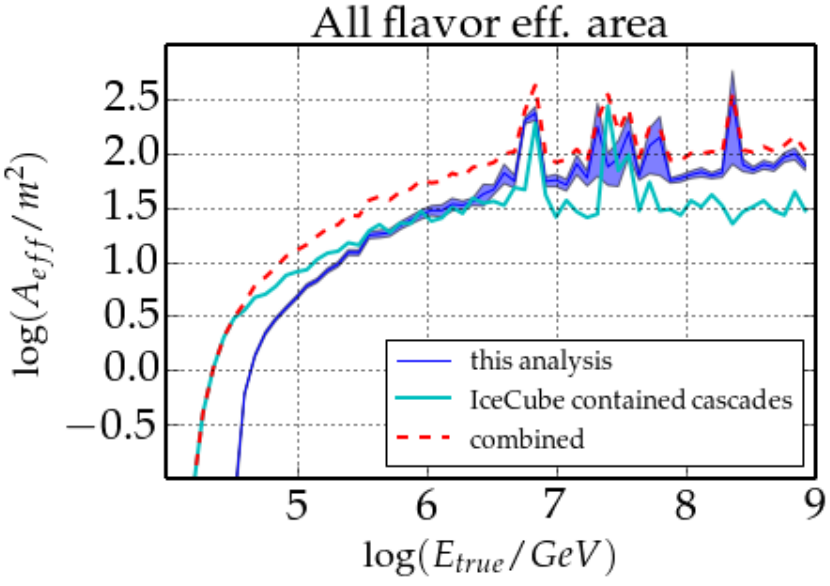


Background simulation: At 30TeV/Nukleon, the simulated proton live time exceeds the expectations from the cosmic ray proton flux [Hoerandel,arXiv:astro-ph/0402356]

Analysis performance



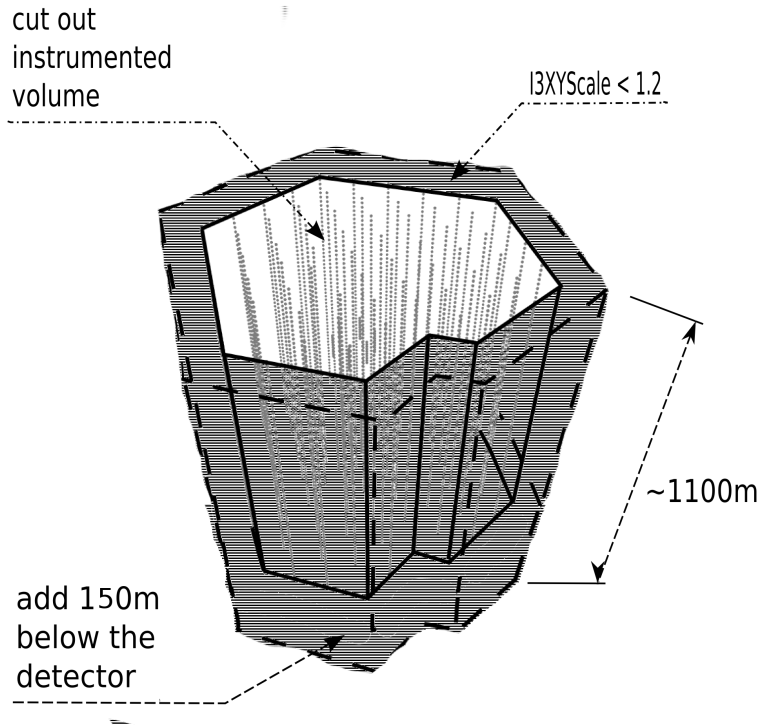
energy resolution for final sample, 84% of events within ± 20% error band

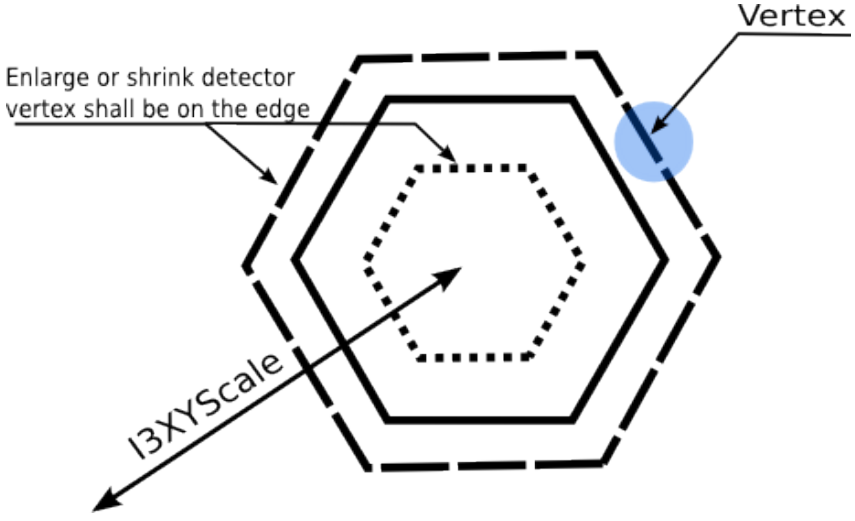


all-flavor effective area, comparison with recent IceCube contained analysis

Containment definitions

- Designed for minimal overlap with contained searches
- Cascade vertex position in "shell" region
- $\approx$ 1 string spacing in xy, $+150$ m below detector, 50m of these instrumented
- highest sensitivity in bottom region
- use scaling variable for xy scaling

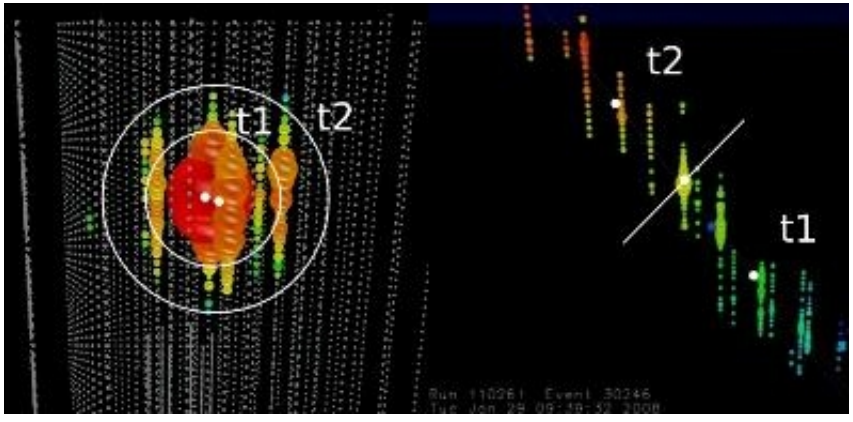


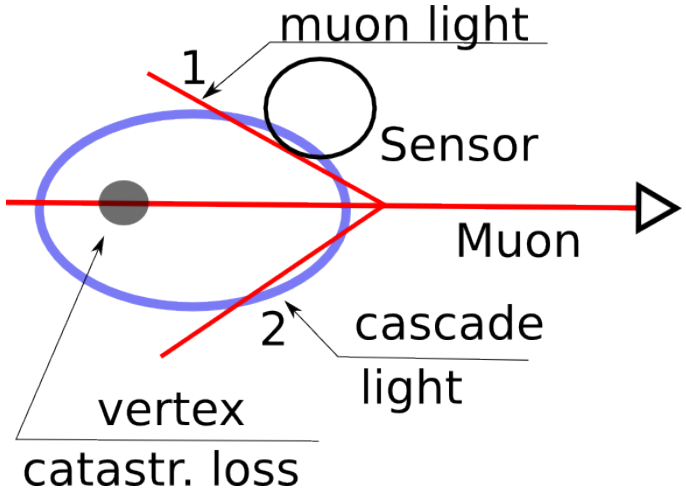


Event selection - variables

"Simple" variables:

- quality
- timing
- topology
- direction
- geometry



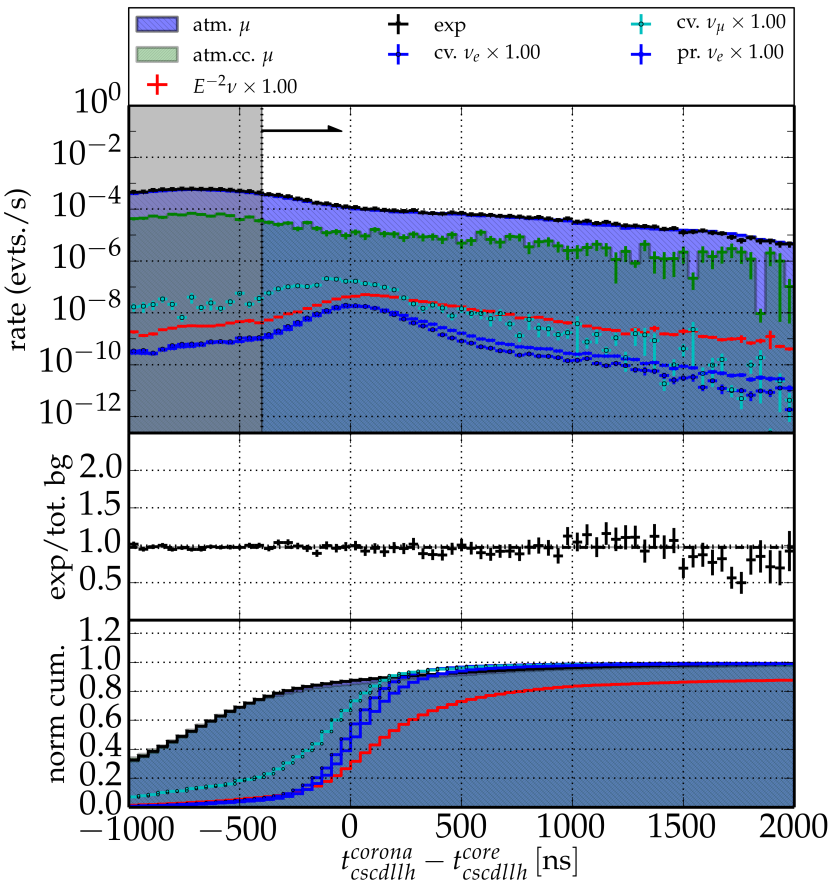


DTNearly (superluminosity): Time difference of first detected light (1) and expected first hit (2) from a cascade hypothesis with reconstructed vertex.

Negative values indicate for misreconstructed events or atmospheric muons with catastrophic losses.

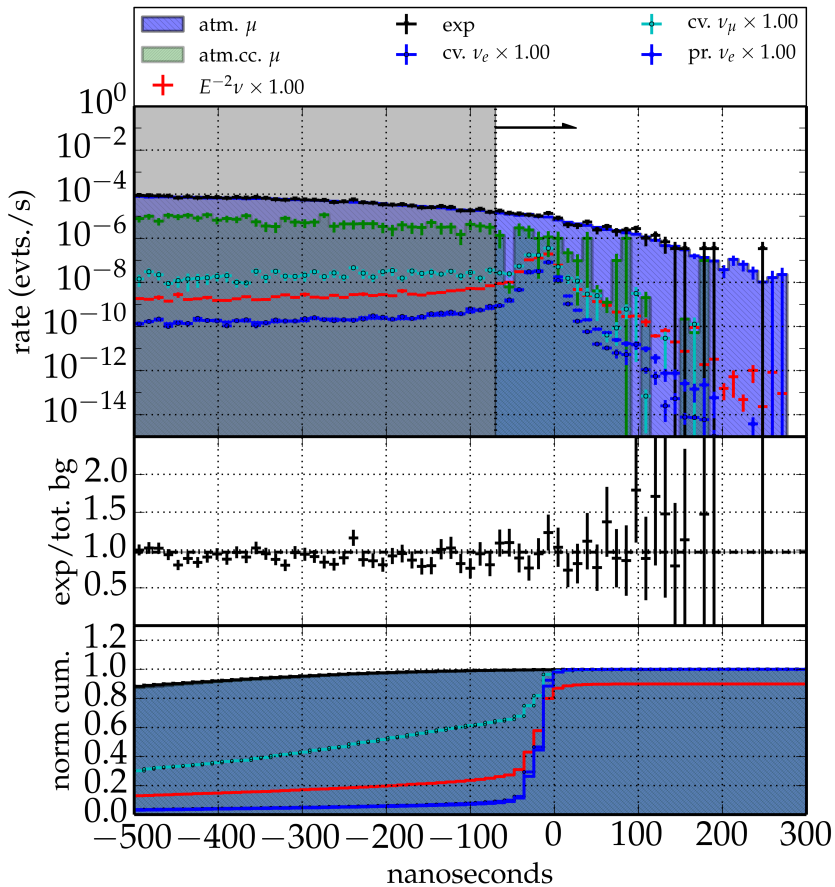
Example variable distributions

coronasplit-dt@4



CoronasplitDT: Time difference of two vertex reconstructions A and B - A uses only pulses in a sphere around a seed vertex, B uses pulses in a spherical shell further out

dt-nearly-ice@4

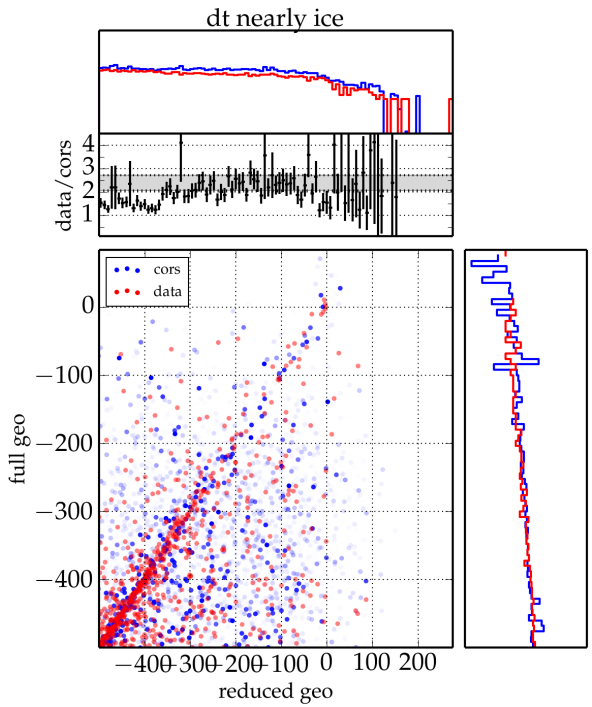


DTNearly: Time difference of first detected light and sum of reconstructed vertex time and geometrical flight time.

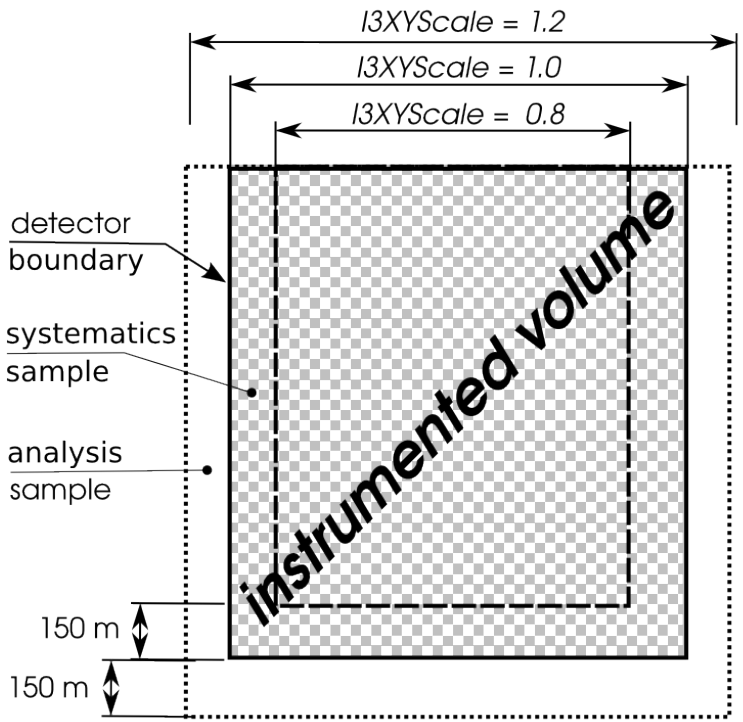
A perfectly reconstructed cascade would yield a value of 0 if the first hit is not scattered.

Systematic Studies

- Off-signal region defined for systematic checks
- Check influence of geometry on each variable

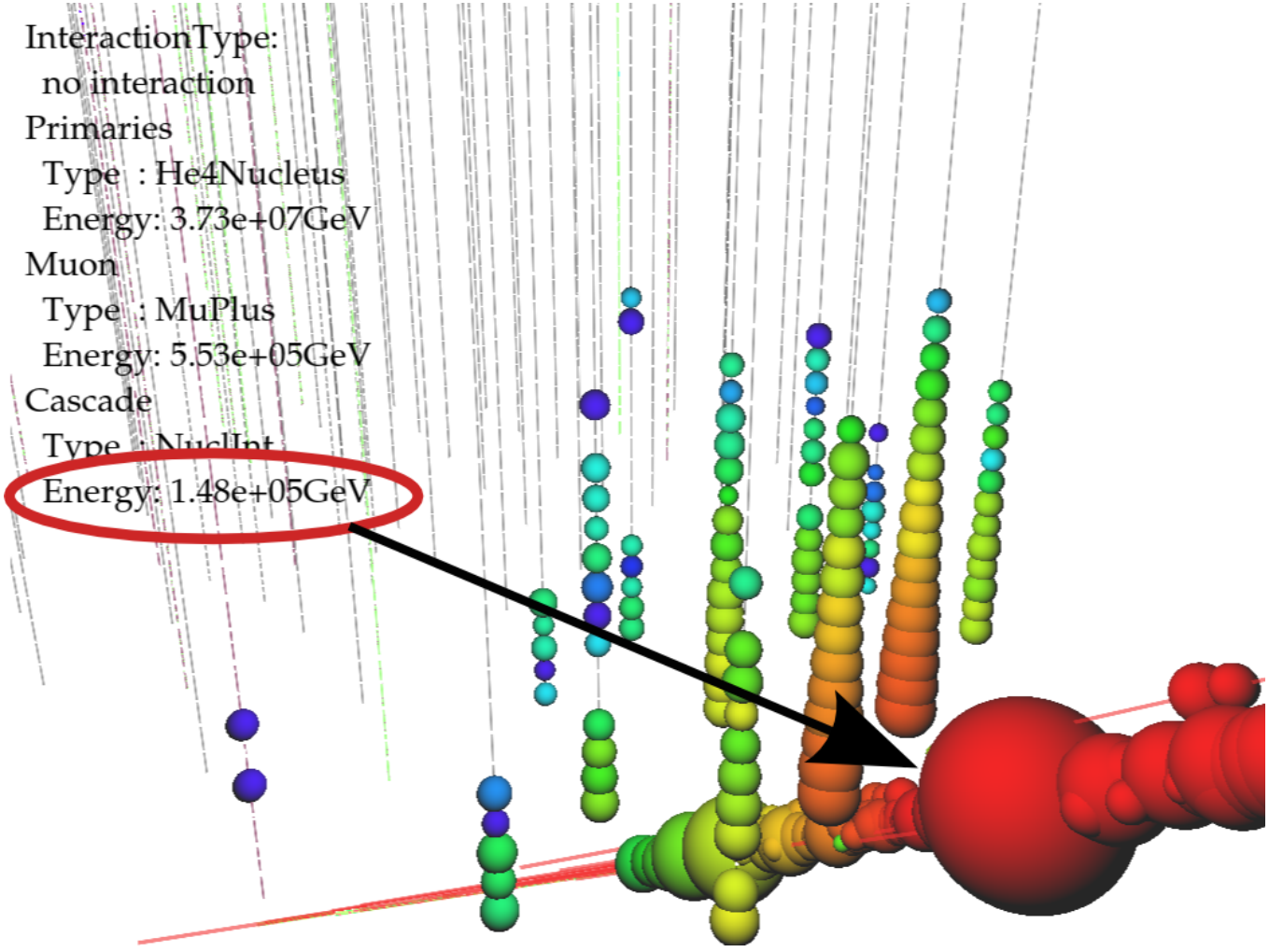


- Full-year data for off-signal region yields consistent results
- Also consistent with IceCube contained search



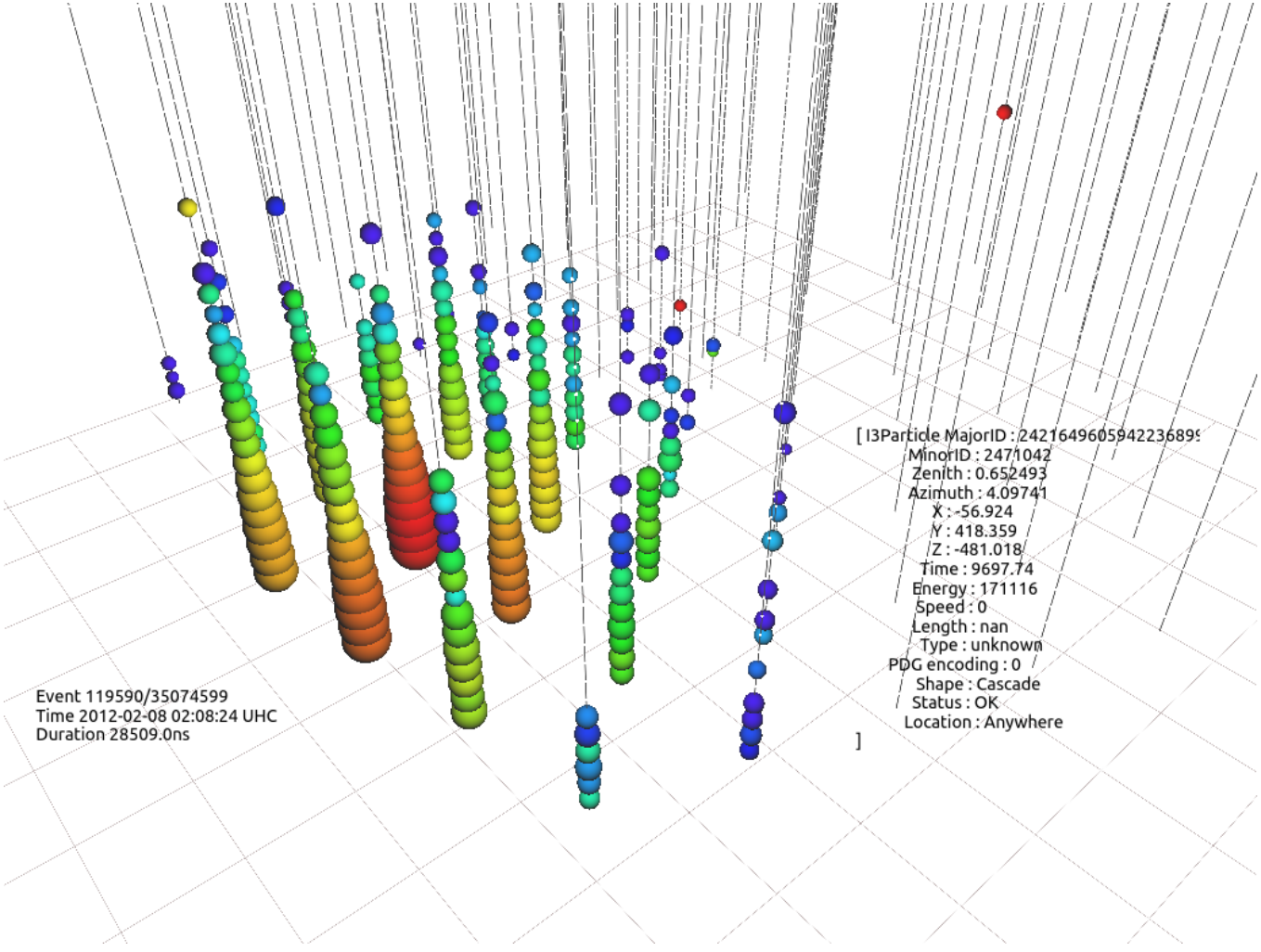
Dominant muon background

- $\approx$ 1.60 atmos. μ expected in final sample

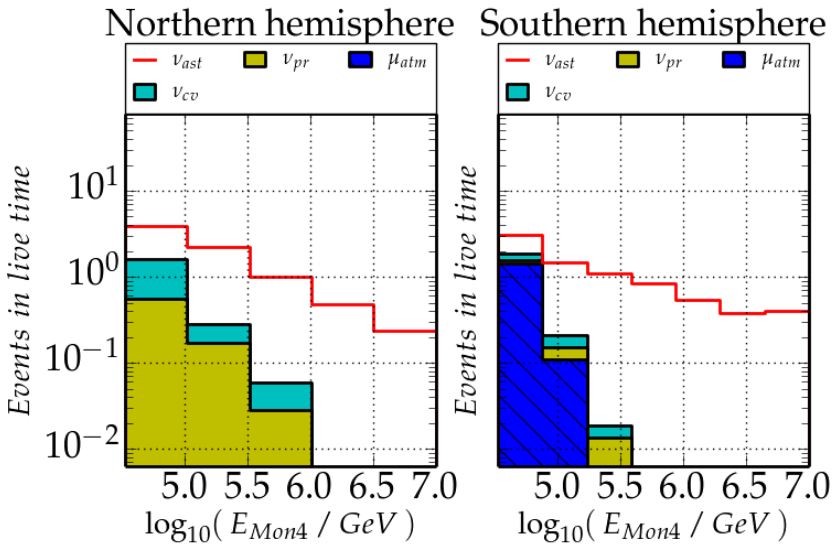


Best candidate event

- from 2011/2012 season
- 171 TeV reconstructed energy
- starting on an inner string



Final sample



- Final energy cut at $E_{rec} > 34$ TeV
- Zenith resolution allows hemisphere split
- Better handle on atmos. μ

Expectations

- no data event in 10% development sample
- atmos. μ (H3a)
  $\approx 1.60 \pm 0.91$ events/330d
- conv. ν (Honda2006 + knee)
  $\approx 1.83 \pm 0.20$ events/330d
- prompt ν (ERS + knee)
  $\approx 1.33 \pm 0.01$ events/330d
- $E^{-2}\nu$
  $\approx 7.39 \pm 0.11$ events/330d

errors are only statistical

Summary

- Partially contained cascade channel seems to yield promising results for high energy tail of the spectrum
- Energy threshold 34 TeV reconstructed energy
- Event selection tested in off-signal region, results consistent