Lowering IceCube's energy threshold for point source searches in the southern sky

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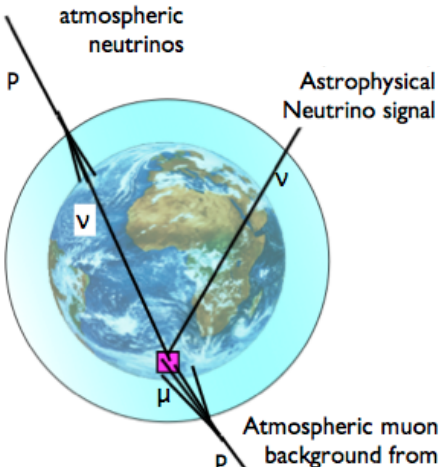
Garching

Contents

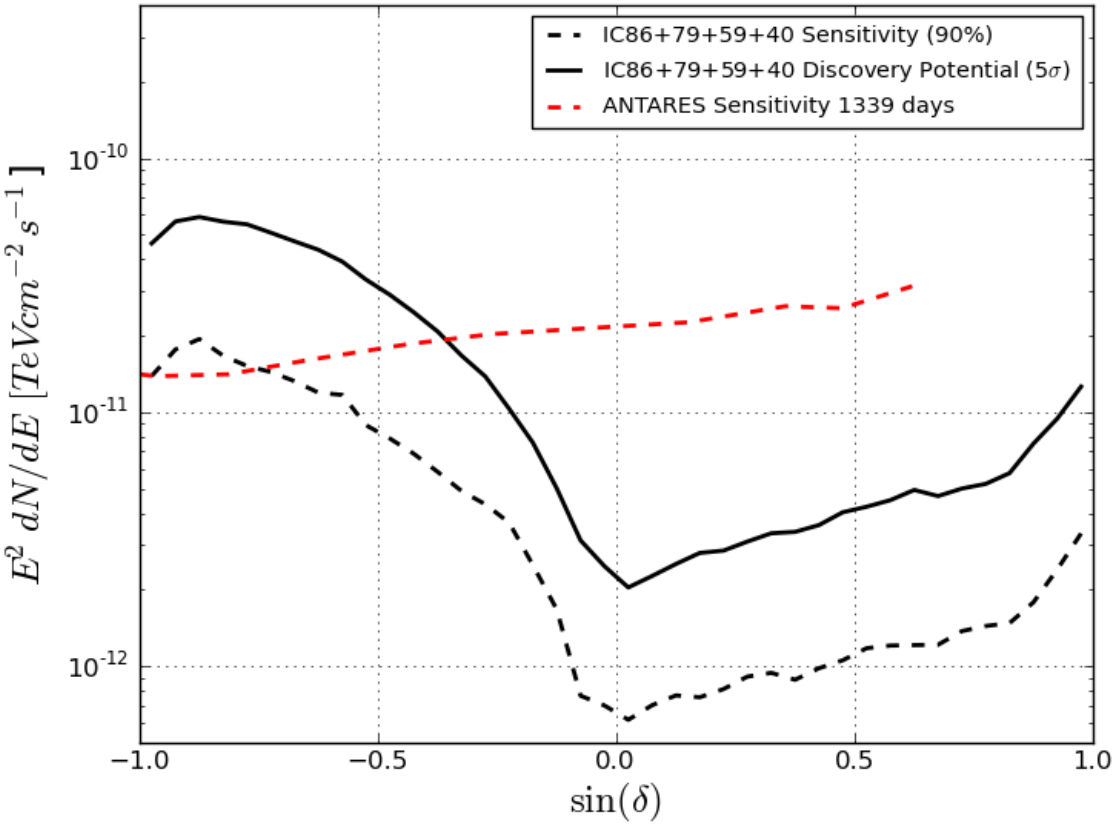
- “Traditional” point source searches in IceCube
- Motivation for looking in the Southern sky
- Contained vertex event selection
- Analysis method
- Sensitivities and discovery potentials
- Future analyses

We use IceCube to search for point sources in both hemispheres



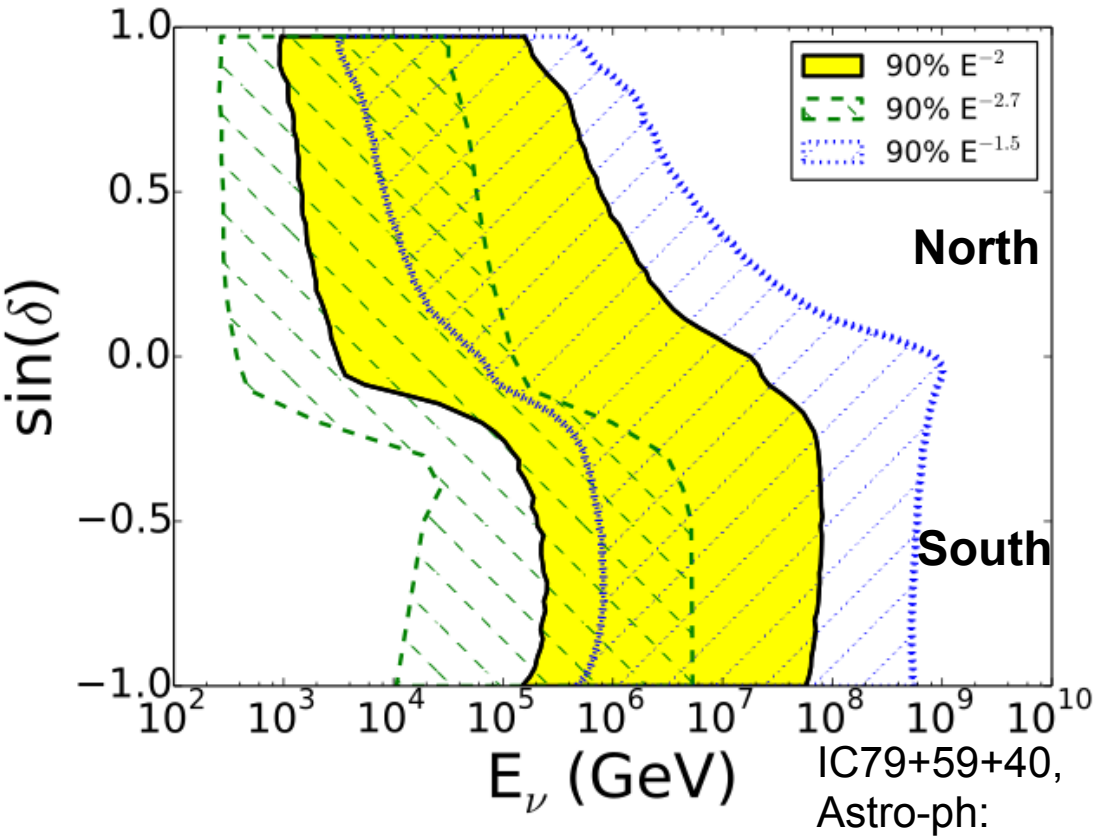
- Northern sky:
  - Use Earth to shield cosmic rays, look for astrophysical neutrinos above background of atmospheric **neutrinos**
- Southern sky:
  - Make energy cuts to reduce data rate, look for astrophysical neutrinos above background of atmospheric **muons**

Discovery potential and sensitivity for E^{-2} flux



Traditional IceCube analysis is sensitive to high-energy fluxes in Southern sky

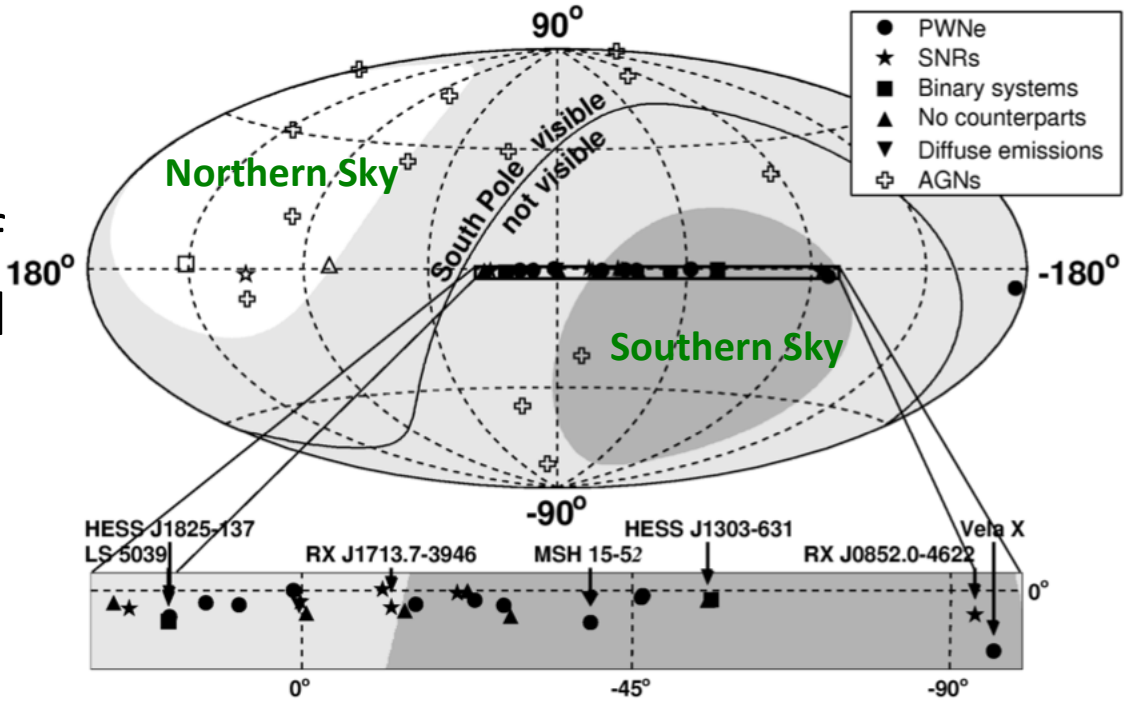
- Very large background from downgoing atmospheric muons
- To reduce the background, we make strong cuts in event quality and energy
- Applies an energy threshold of 100 TeV – 1 PeV
- Recent efforts to distinguish muon bundles from single muons help to lower threshold



IC79+59+40, Astro-ph: 1307.6669

The southern sky has a lot of point source potential

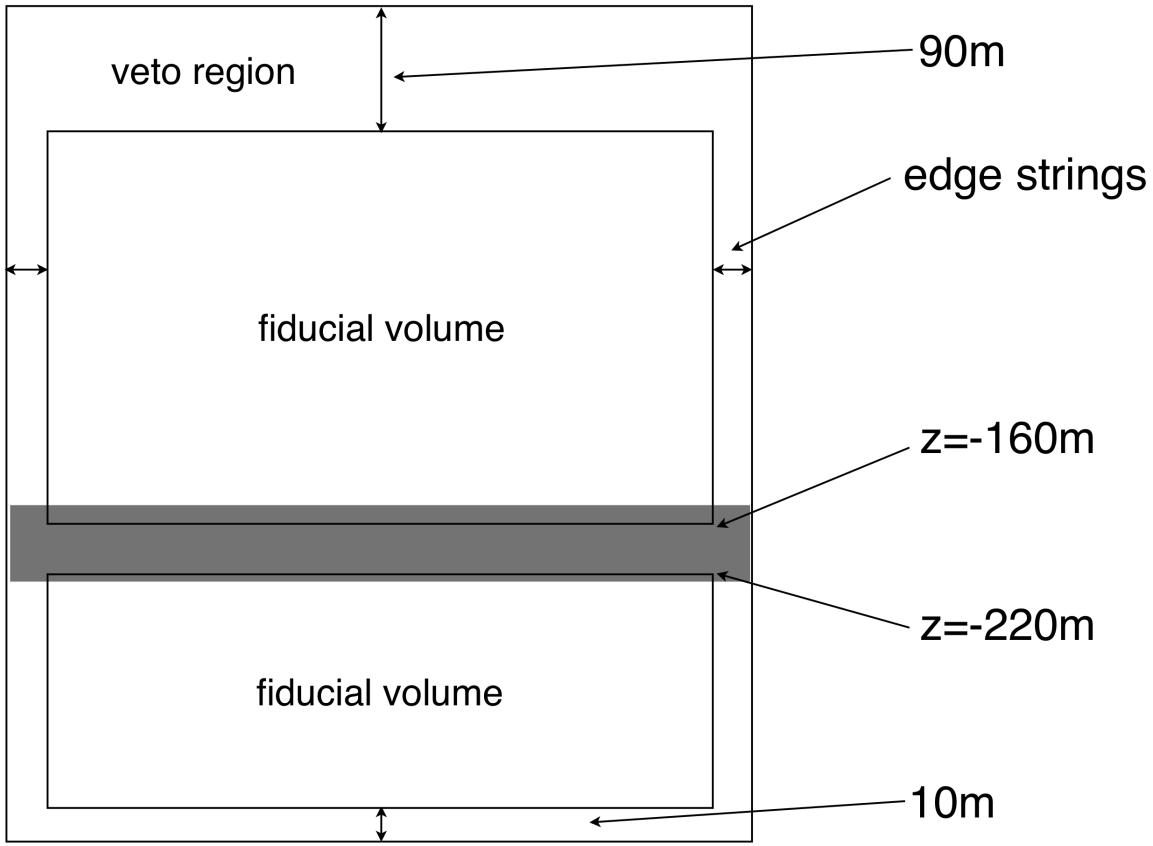
- Galactic sources
  - Low-energy cutoffs, below the threshold of IceCube's conventional analysis
- HESE hotspot
- ANTARES hot spot
  - 2.2σ post trials!



Kappes et. al., arXiv:0607286v3

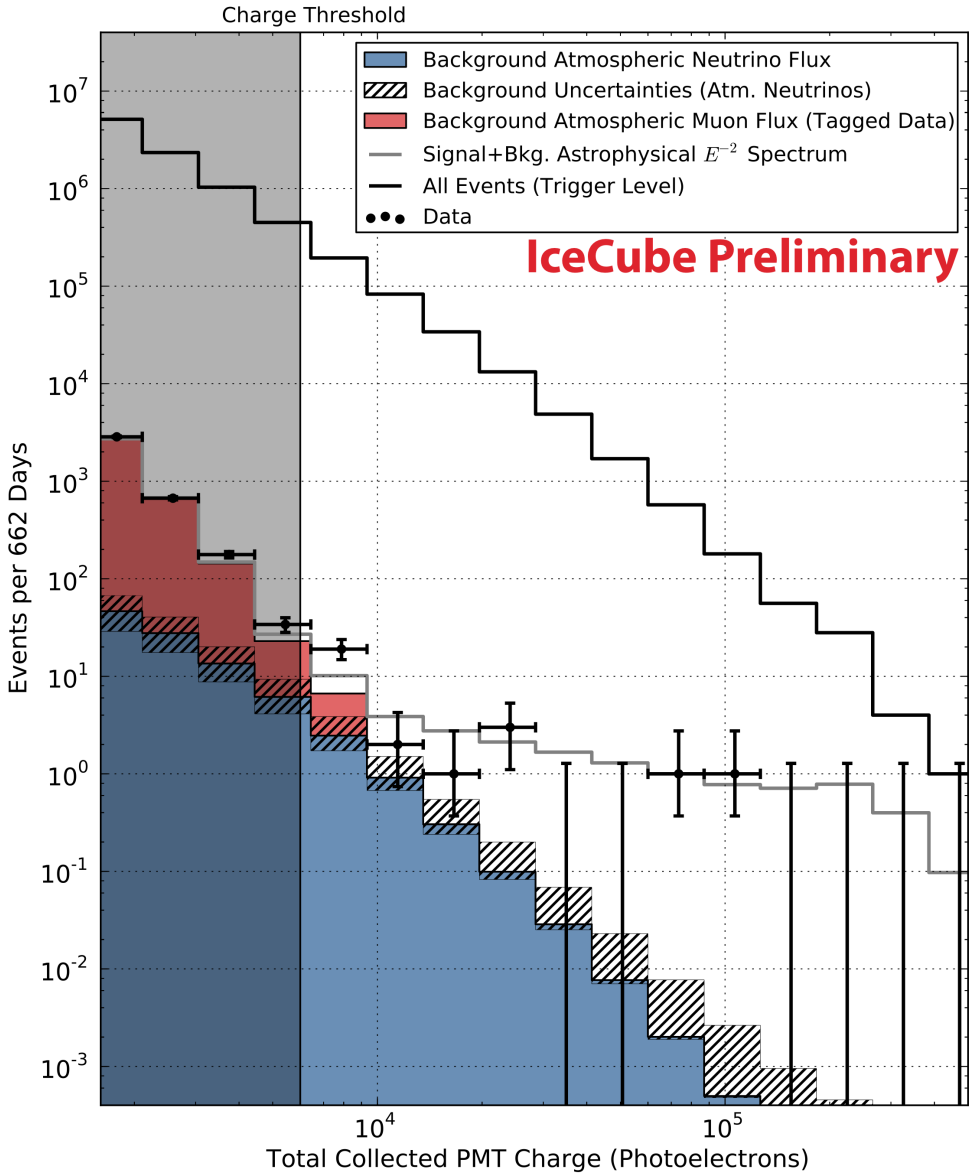
Idea: Use medium energy events with contained vertices to find point sources

- Look for events that "start" in the detector
- Same veto requirements as was used to find the 28 events
  - Light in the outermost detector region cannot come at the beginning of the event



Idea: Use medium energy events with contained vertices to find point sources

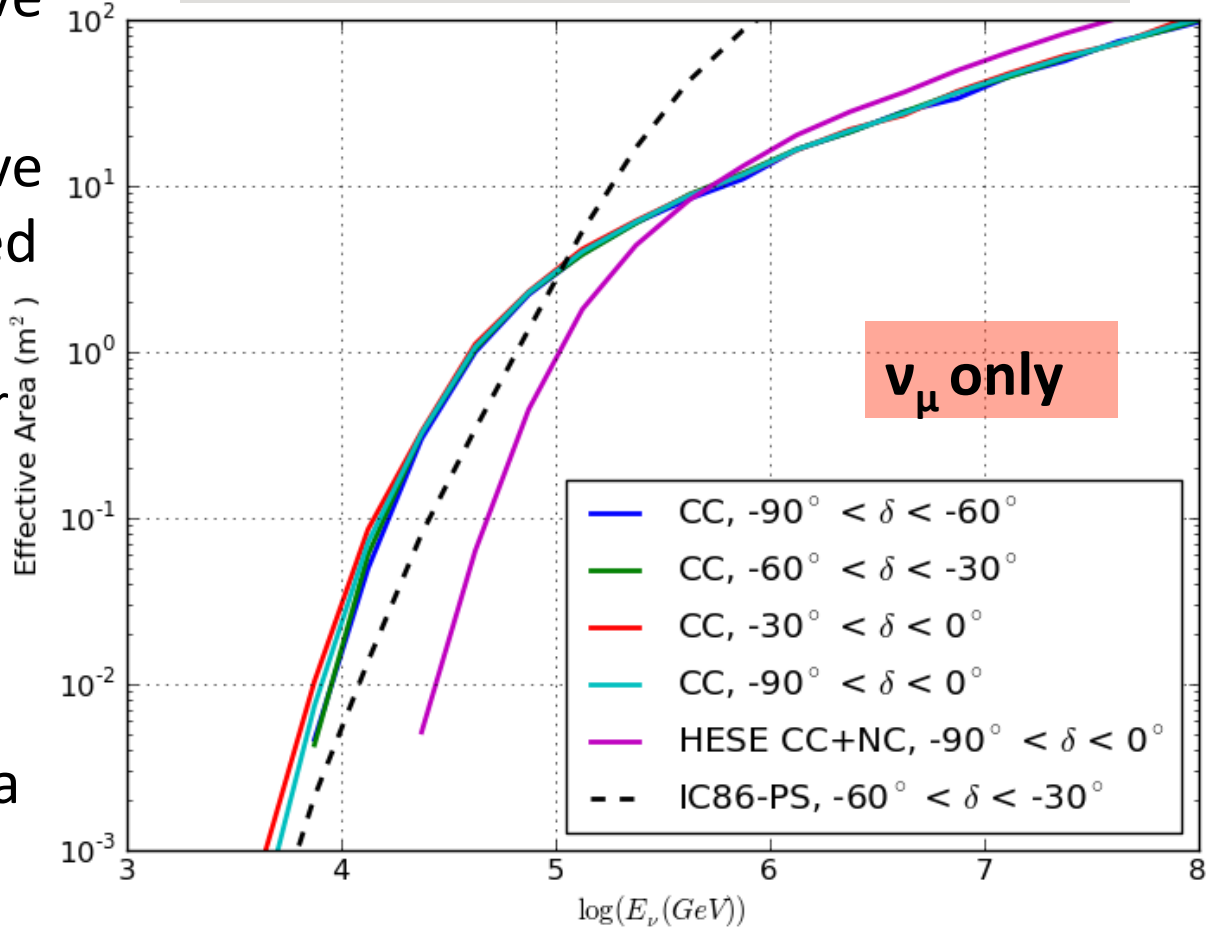
- Look for events that "start" in the detector
- Same veto requirements as was used to find the 28 events
  - Light in the outermost detector region cannot come at the beginning of the event
- Energy cut: Qtot > 1500 (instead of 6000)
  - Increases response below 500 TeV
- 4000 events/year, dominated by downgoing atmospheric muons



We get more signal by lowering the energy cut

- Greatly increase effective area below 500 TeV
- Greatly increase effective area to neutrino-induced muons
  - Tracks with good angular resolution!
- Effective area bigger than “traditional” point source analysis in Southern sky, while data rate is ~20x lower

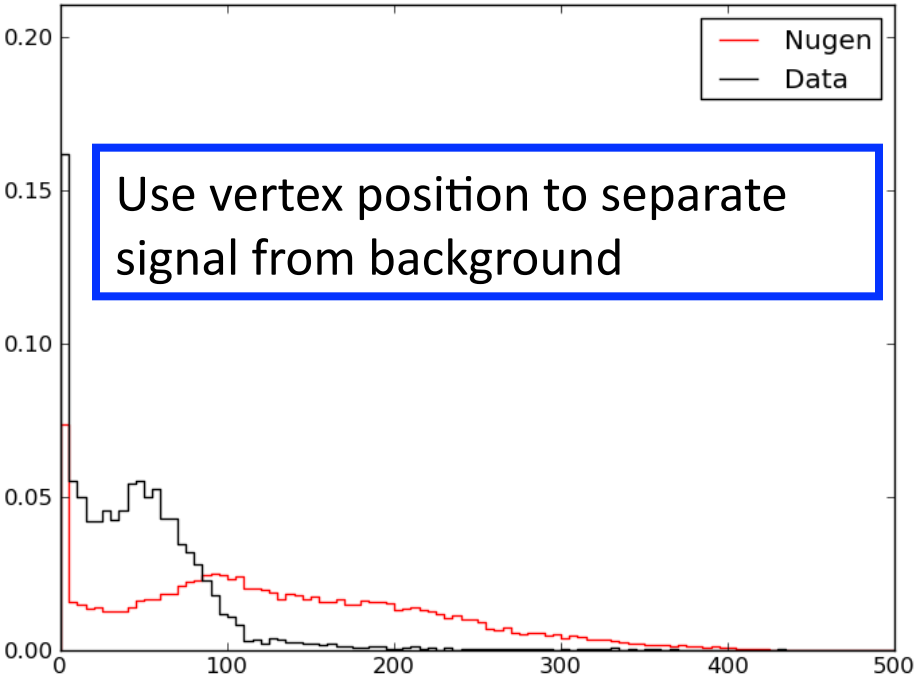
Starting events, medium energy
Starting events, high energy
IC86 Standard Point Source



Analysis follows unbinned maximum-likelihood point source analysis, with extra information

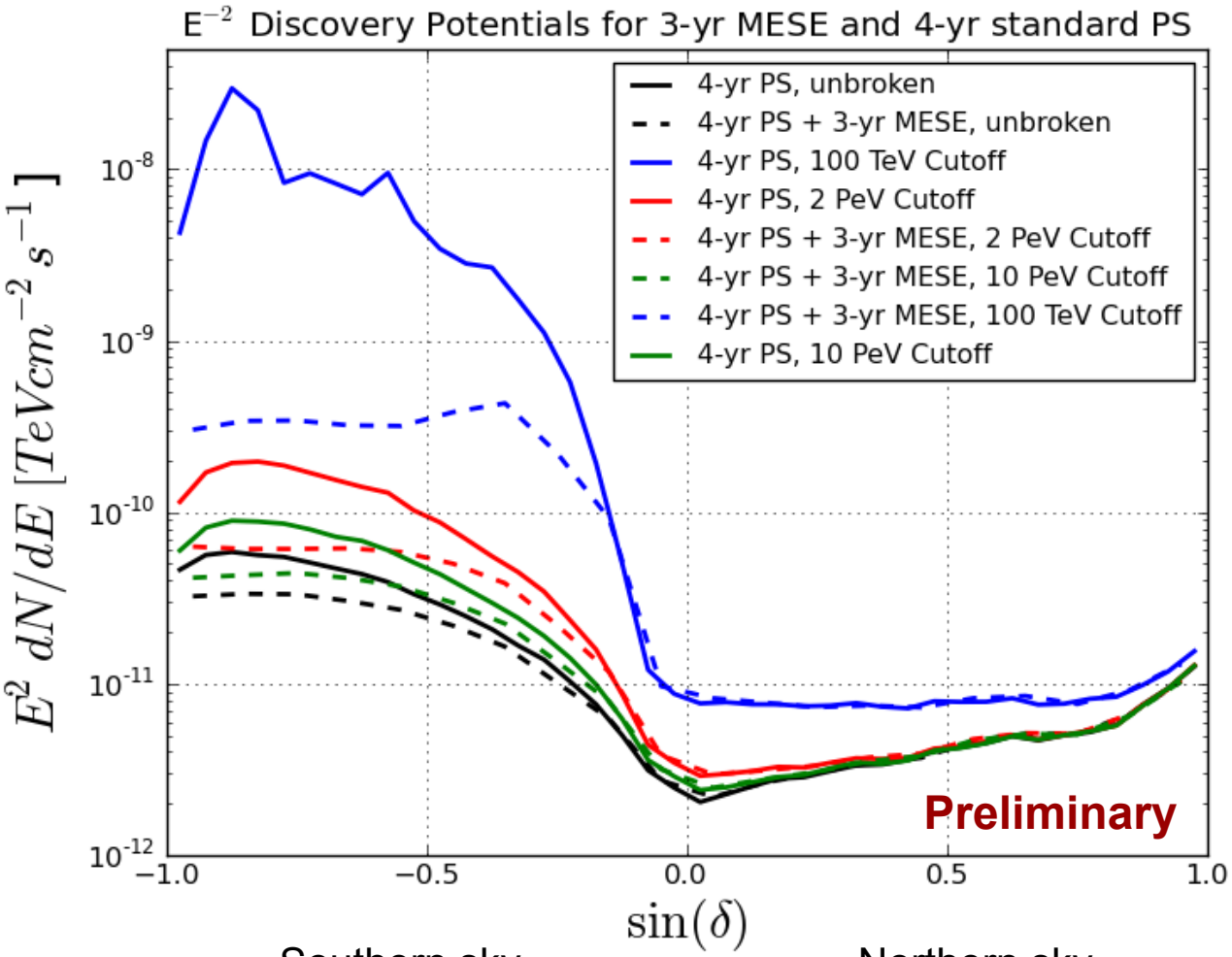
- Un-binned likelihood
  - Spatial probability distribution for signal modeled as a 2D gaussian
  - Width from reconstruction uncertainty
  - Energy used to weight events
  - Vertex position also used to weight events

At each point in the sky, use likelihood to fit for # of signal events and neutrino spectral index



Distance from the first reconstructed energy loss to detector boundary

Medium energy starting event (MESE) analysis boosts sensitivity for a variety of source spectra



Discovery potentials for E^{-2} spectra ending at:

100 TeV

2 PeV

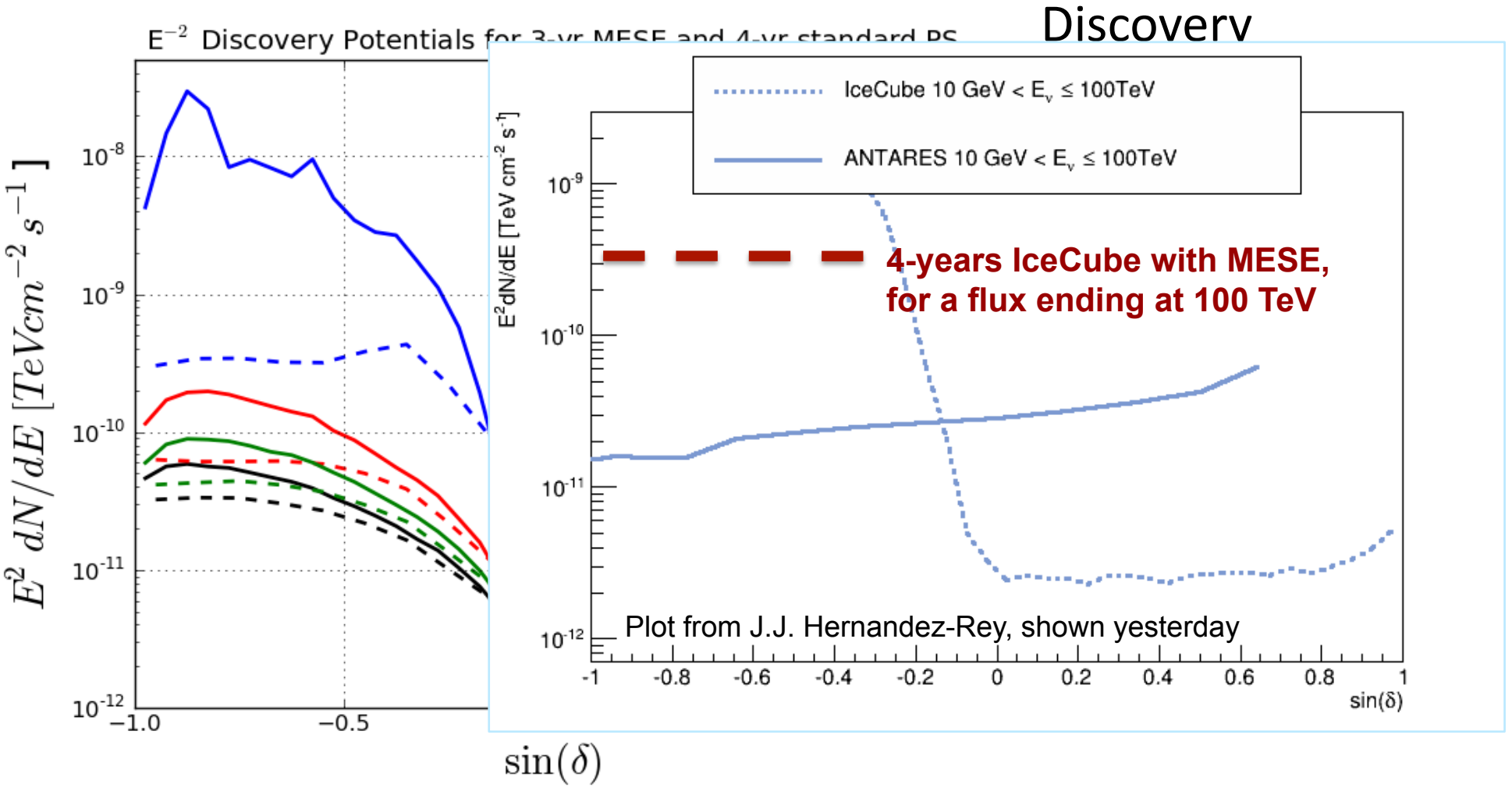
10 PeV

1000 PeV

Solid – 4-yr standard point sources

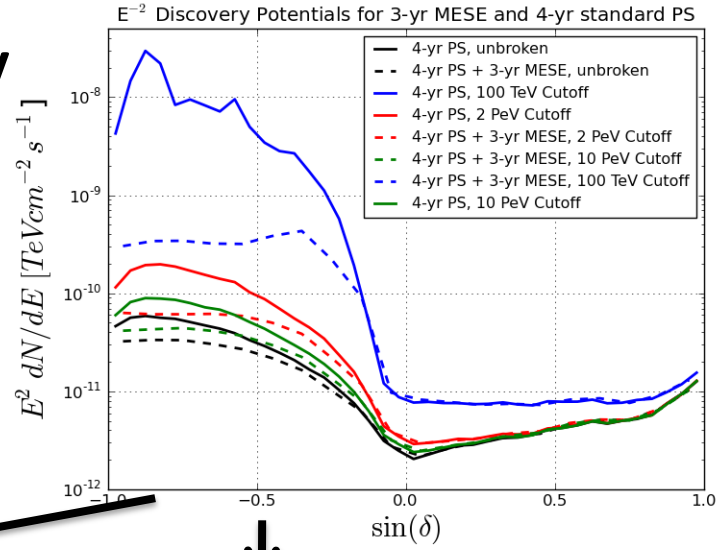
Dashed – 4-yr PS + 3-yr MESE

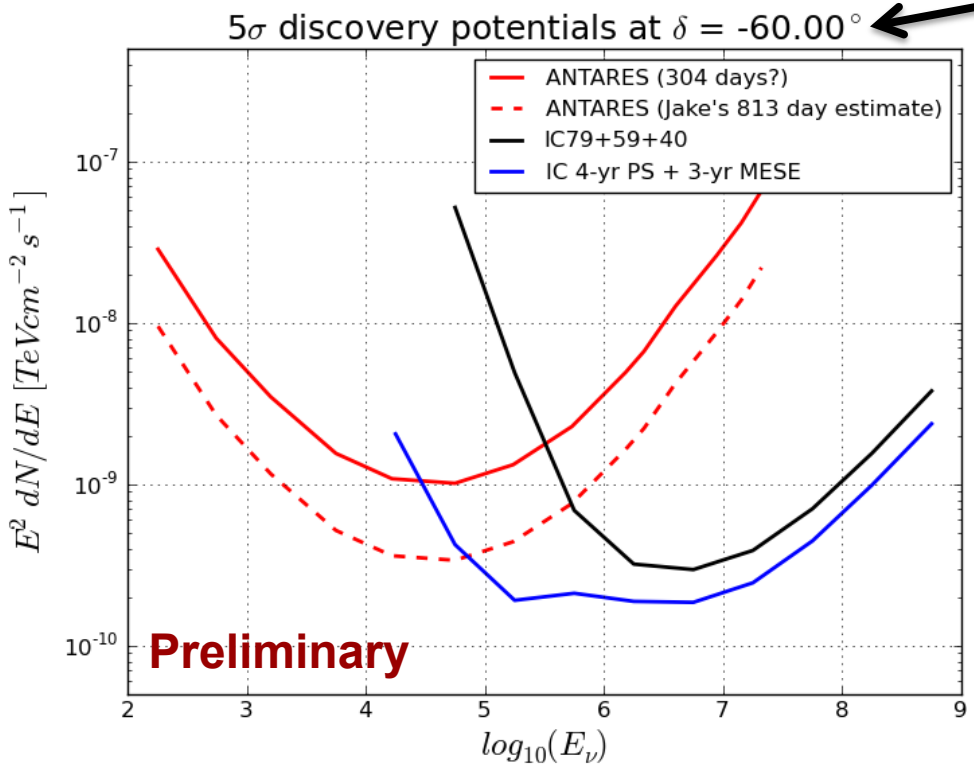
Medium energy starting event (MESE) analysis boosts sensitivity for a variety of source spectra

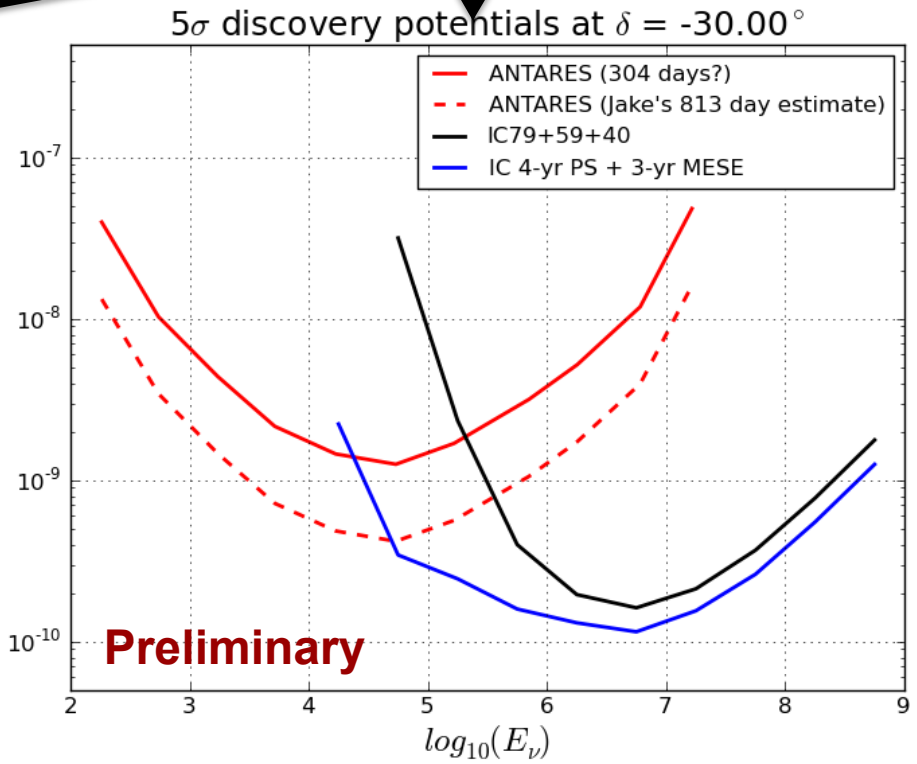


MESE lowers IceCube's energy threshold in the Southern sky

ANTARES
3-yr PS (IC79+59+40)
4-yr PS + 3-yr MESE

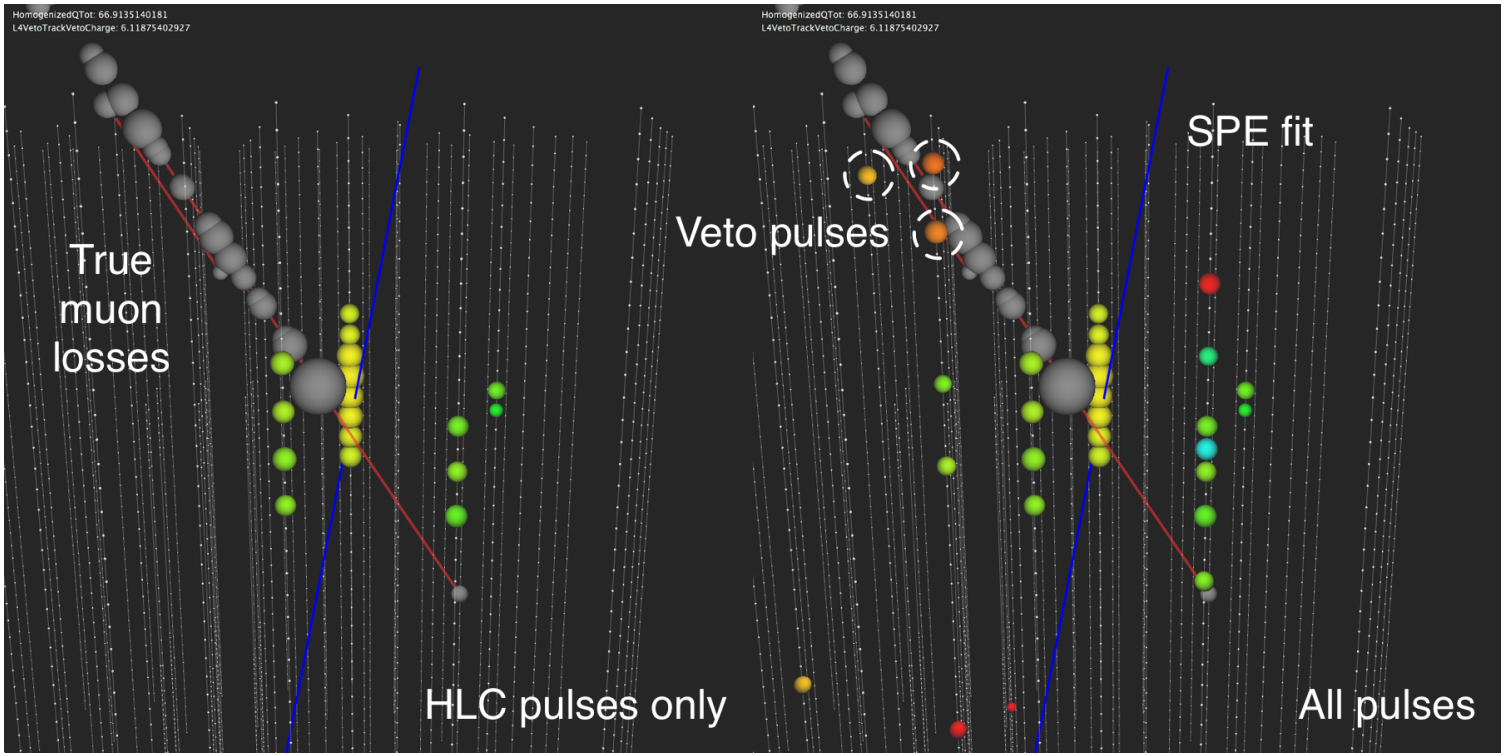






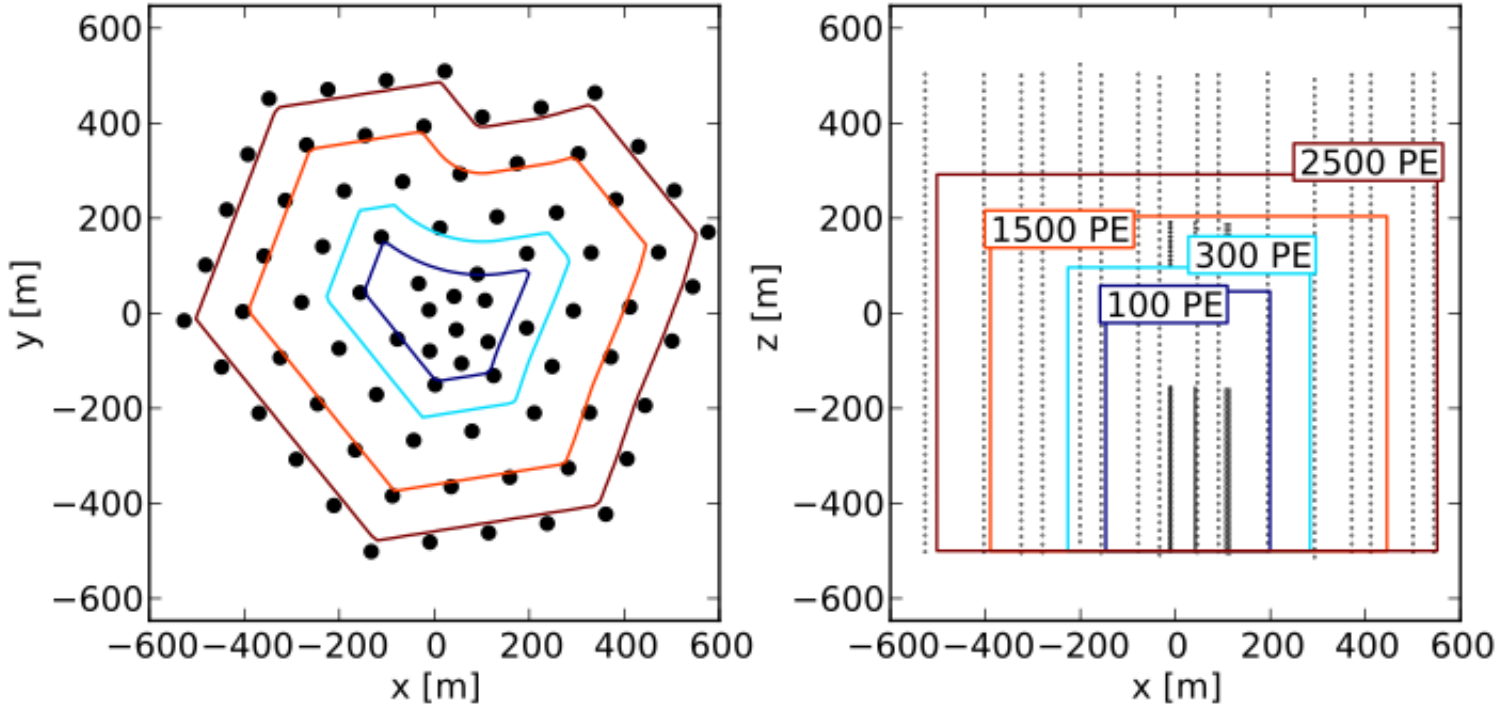
Future analyses will include more sophisticated vetos

- Borrow work done for cascade analyses, but adapt to track events
  - Use track direction to select pulses for veto



Future analyses will include more sophisticated vetos

- Borrow work done for cascade analyses, but adapt to track events
  - Use track direction to select pulses for veto
  - Veto region can scale with energy



Summary

- The Southern sky continues to be a very interesting place to look for point sources
- We select for starting track events above 10 TeV
- Analysis improves medium-energy point source sensitivity by more than an order of magnitude
  - More signal at lower energies
  - Less background
- Future analyses will further improve this using more sophisticated vetos

Backup

Idea: Use medium energy events with contained vertices to find point sources

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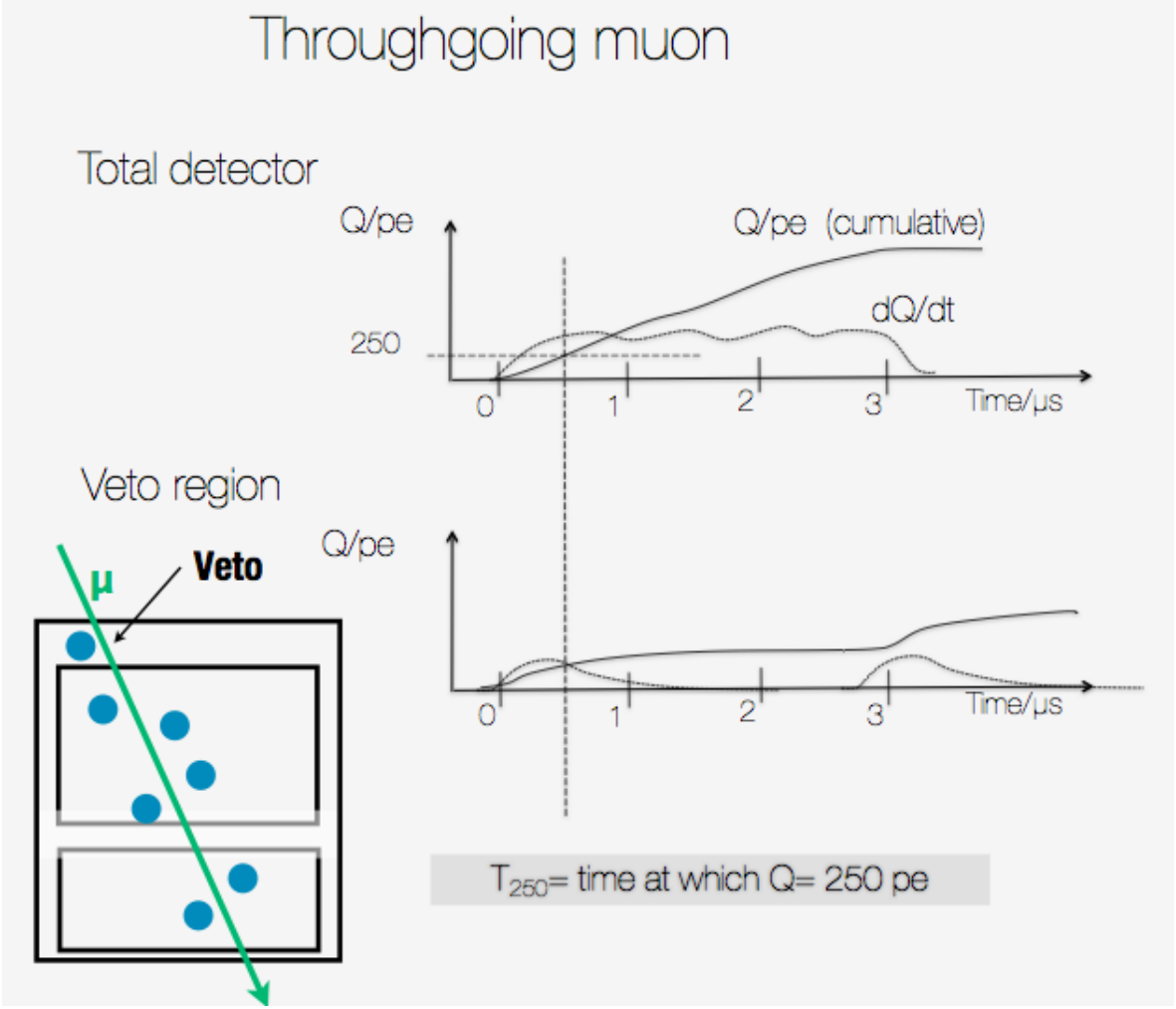
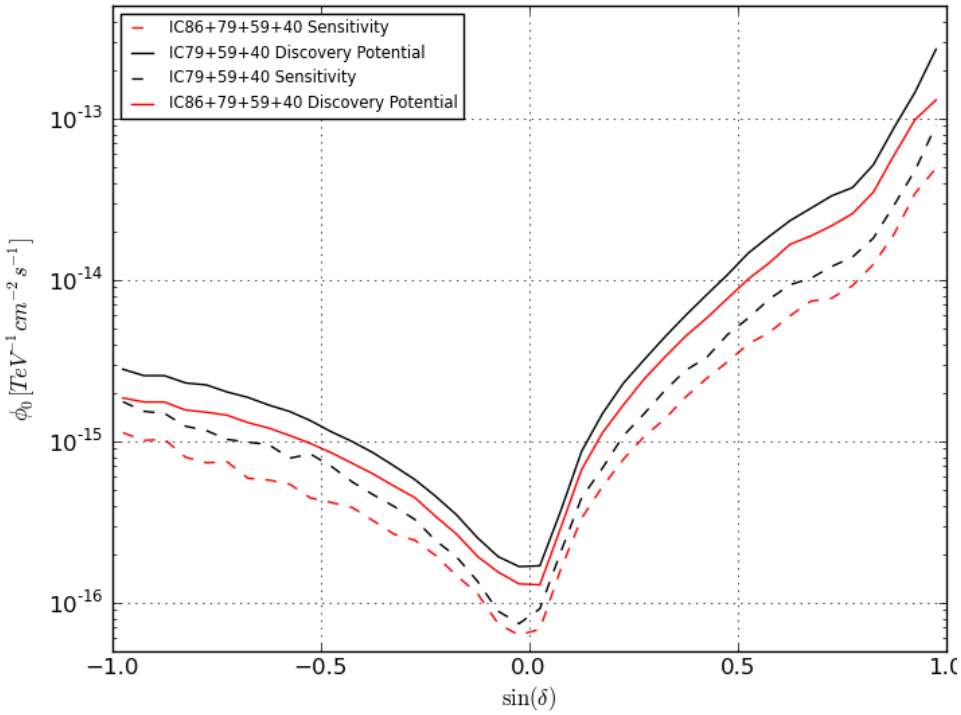
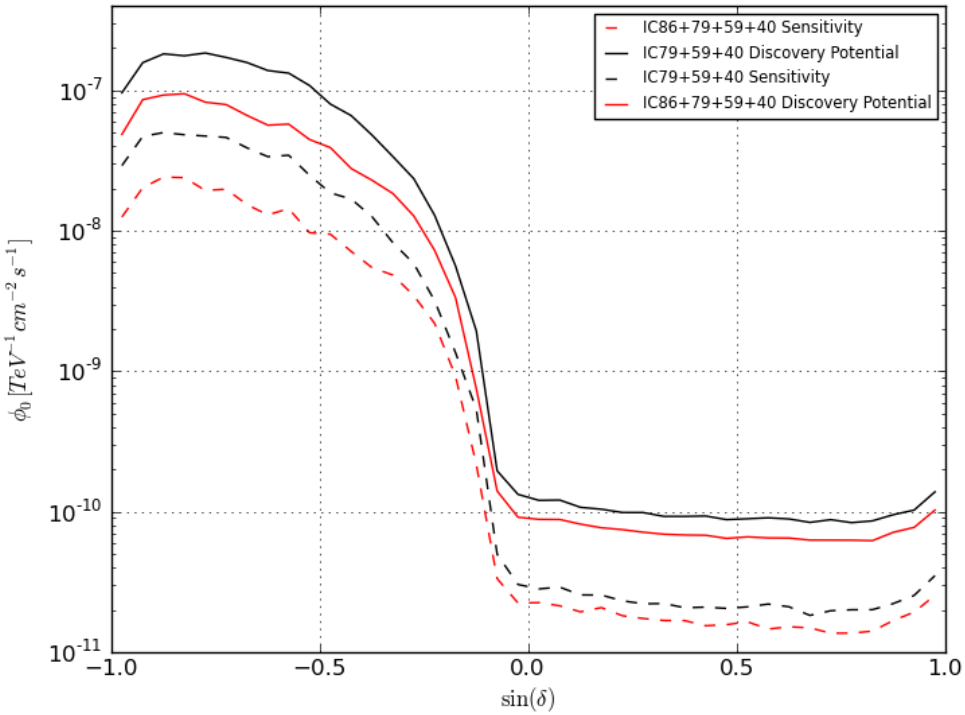


Discovery Potentials for 4 Years of IceCube (without starting tracks)

E^{-1} injection spectrum

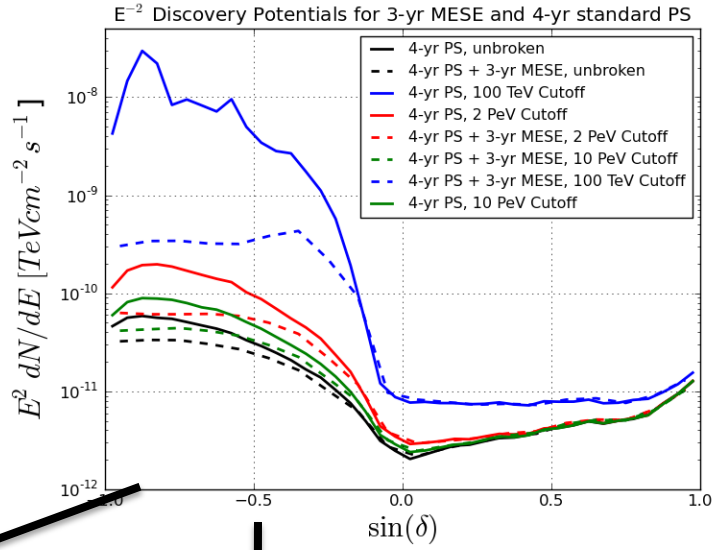


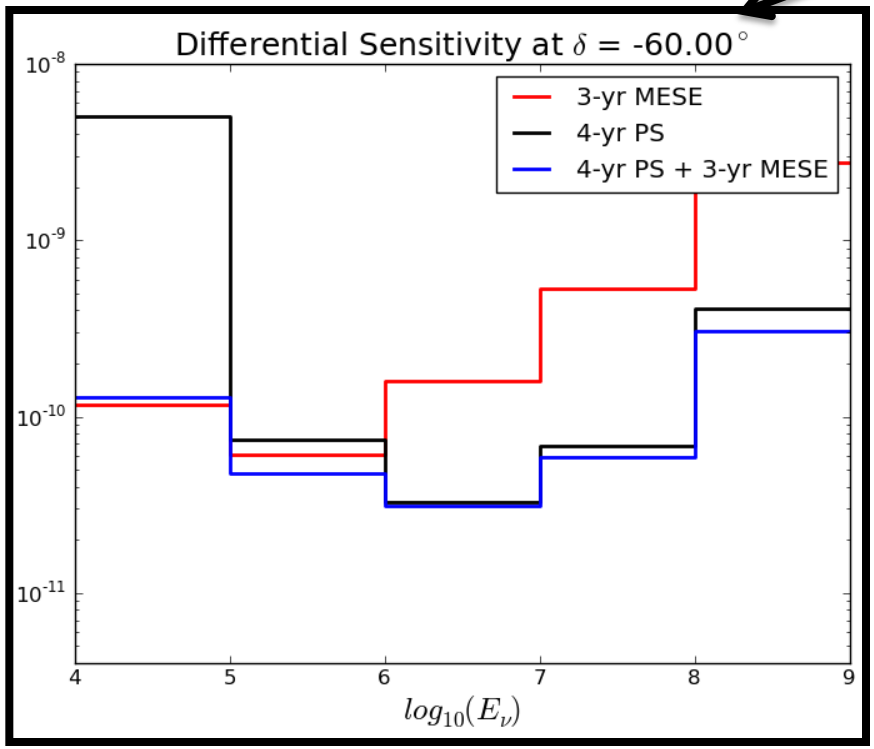
E^{-3} injection spectrum

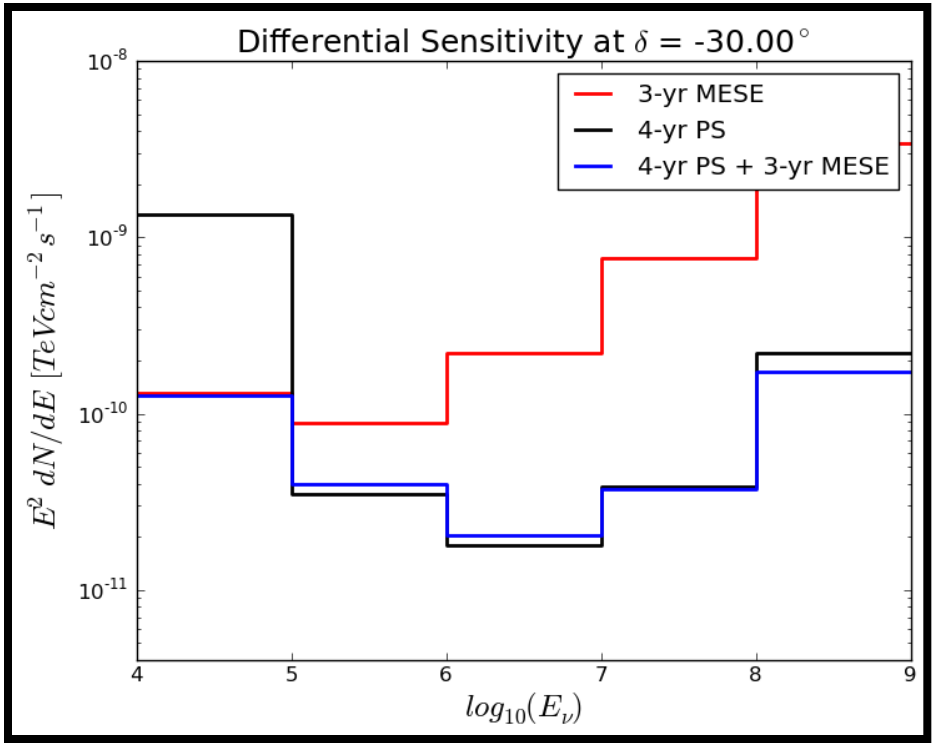


3-yr MESE analysis performs best in 10 TeV – 1 PeV regime

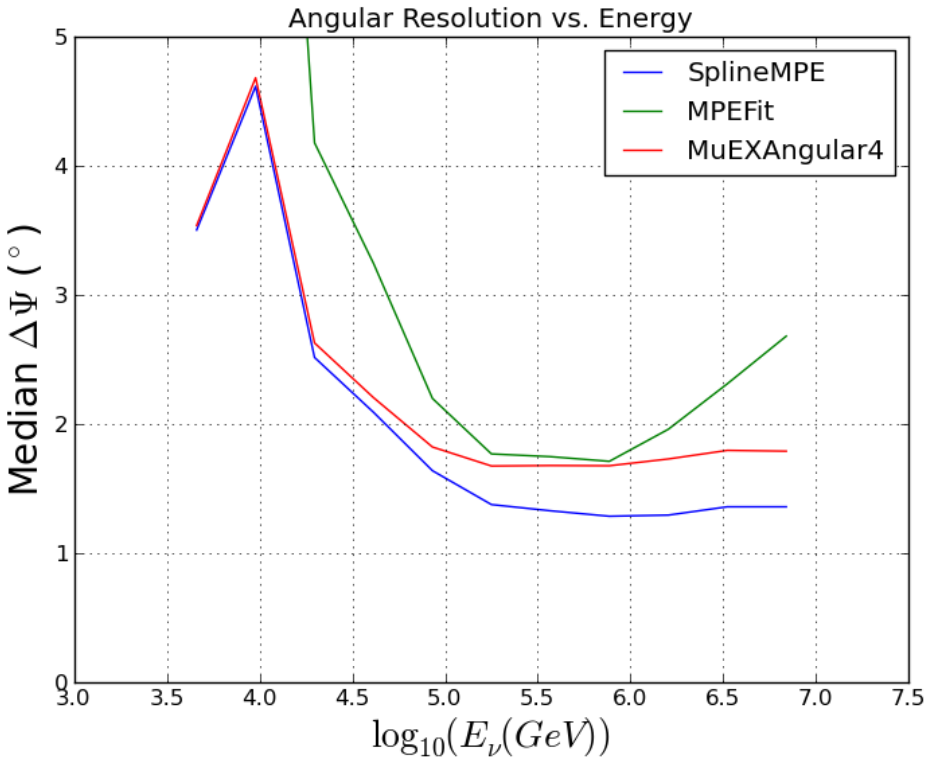
- Due to contained selection, MESE is not competitive above 1 PeV
- Below 100 TeV, all power comes from MESE







Standard reconstructions appear to work well for starting tracks in MESE sample



ν_μ charged current events are reconstructed within 1°-2°