Surface detector R&D

Context to M&O and to Extensions

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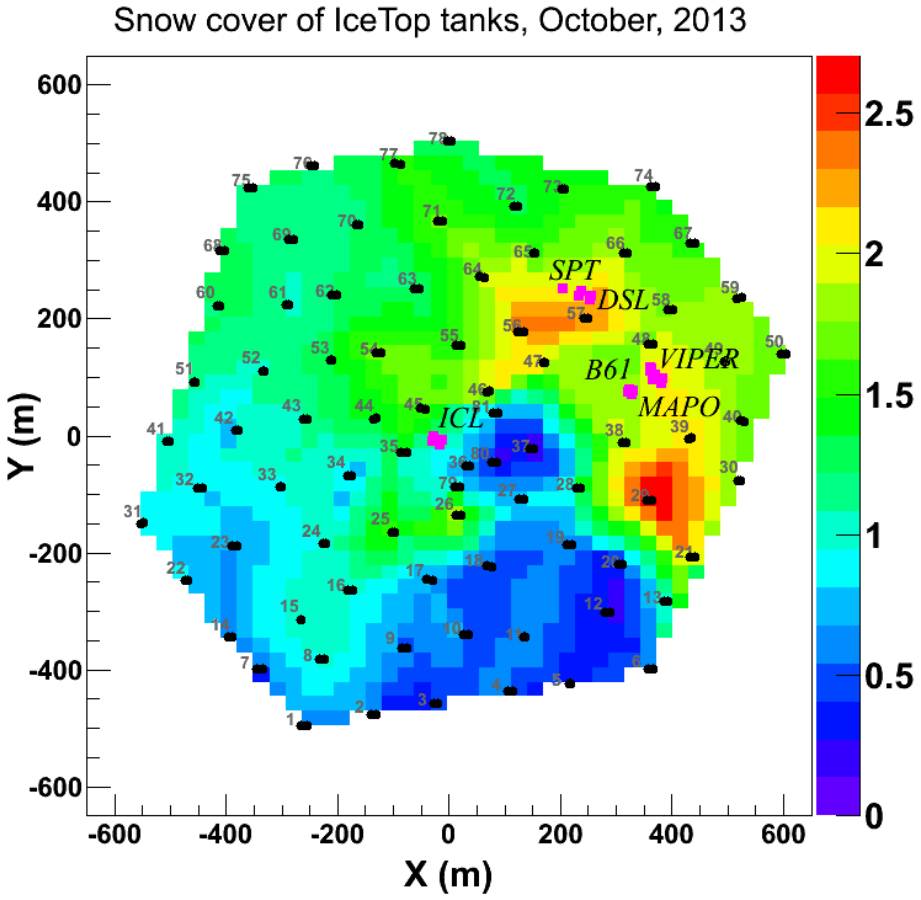
Snow management and IceTop maintenance

- NSF has circulated a plan, which results in ending the snow management. That means IceTop stations will begin to sink deeper.
- We did not fight this very hard since it is literally an uphill battle and the amounts of snow were substantial.
- Here I discuss an alternate approach.



Snow management and IceTop maintenance

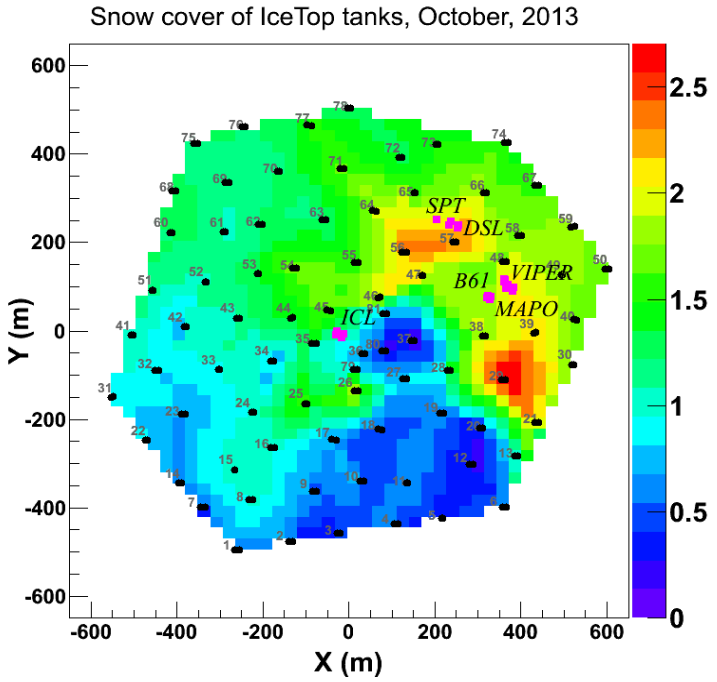
- Response:

  IceCube Maintenance includes maintenance of IceTop which is integral part of IceCube.

- Mitigation:

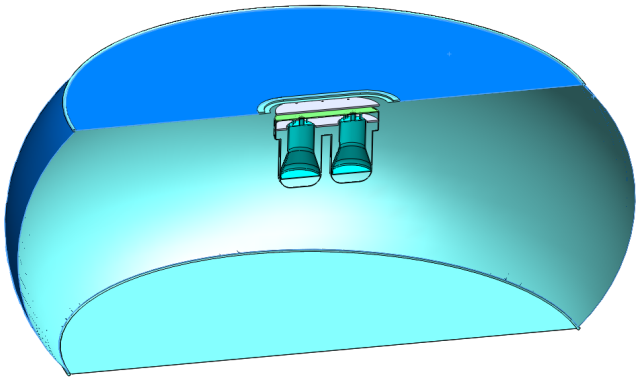
  Design, build and deploy surface detectors that can be added to IceTop stations that are most affected.

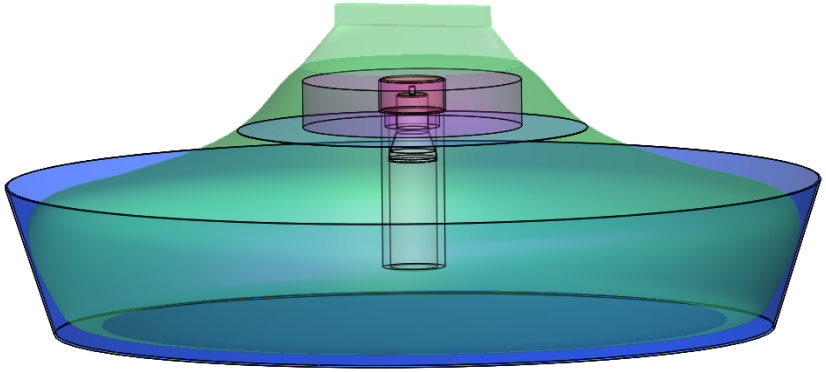
- Have a verbal agreement by program officer (V.P.) for that approach. I think the expectation is that it it does not add cost or not significant and that it is not too big of a deal.
- Have added language in next year M&O plan to perform some R&D towards this goal.
- Will add a task to the M&O proposal that performs this. However make not too much fuzz about it.



Earlier ideas for IceVeto modules focused on water/ice tanks, bags

Talks at previous collaboration meeting Sessions.





Suggested approach:
Scintillators with WLS fiber readout

- Started to have a closer look at MINOS scintillators (Thanks to our friends at MINOS for helpful discussions and materials, J. Thomas, K. Lang, others.)
- Possibility to try out actual MINOS scintillator.
- Possible field activity next season (2015/16)?

Questions/assumptions

- A scintillator would be a valuable as additon to IceTop

  - could be justified as maintenance. (Has zero discrimination of muons and electrons/gammas. But we still have IceTop)
- Readout individual fibers or just the analog sum (multi or single channel photodetector)?
- What cable connection: IceTop freeze control cables or something different?

Suggested approach: Scintillators with WLS fiber readout

- This R&D effort should be compatible and at least synergistic with R&D for a future extension.
  - This is not only about IceTop maintenance.

  That means we want to keep requirements for a large detector array in mind.

  This does not mean that other veto strategies should not be considered and pursued. However this one, I believe, we can justify within M&O.
- Low impact deployment
- Water/ice tank deployment seems hard to imagine on a scale of 1000s of detectors
- Light weight, 2 people should be able to carry a 2 m^2 detector.
- Probably cost effective.
- ….
- Goal of afternoon session to explore this option

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MINOS FAR DETECTOR

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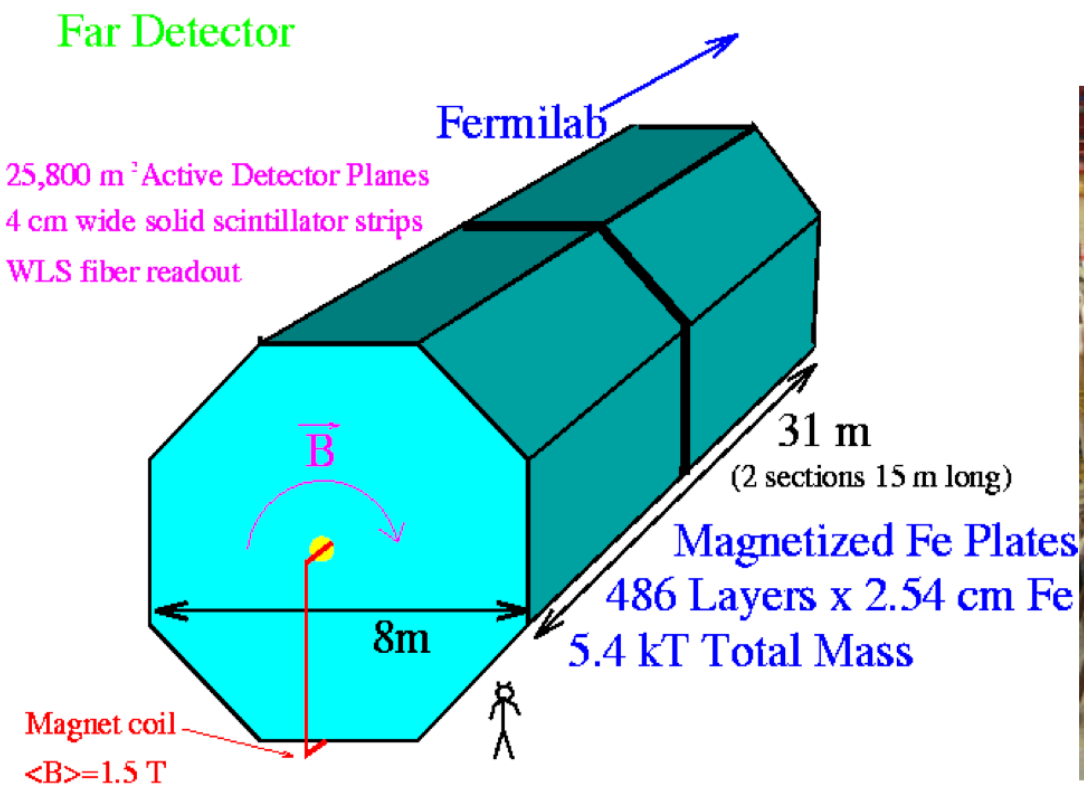
MINOS



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STEEL & SCINTILLATOR PLANE LAYOUT

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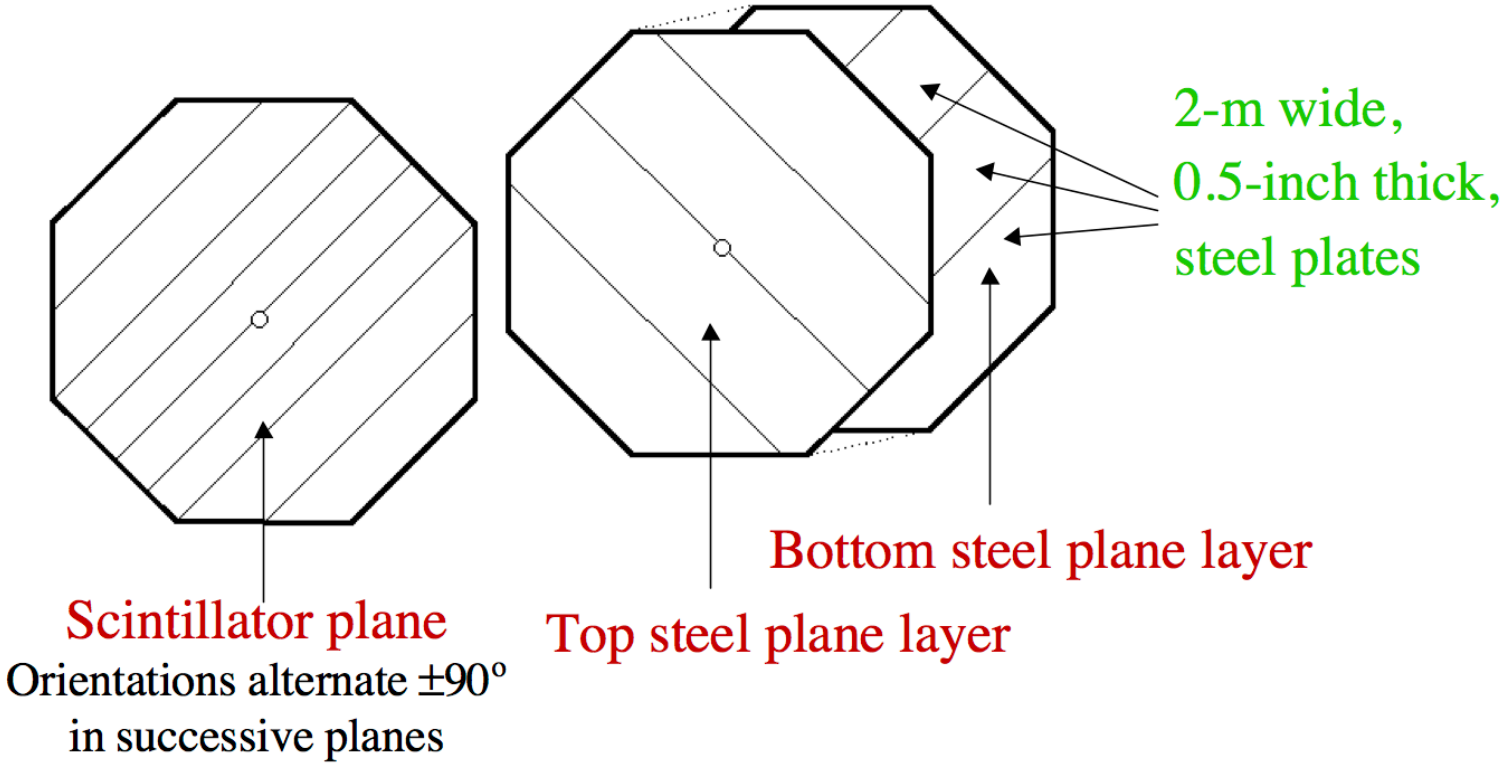
MINOS



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SCHEMATIC VIEW OF THE MINOS SCINTILLTOR SYSTEM

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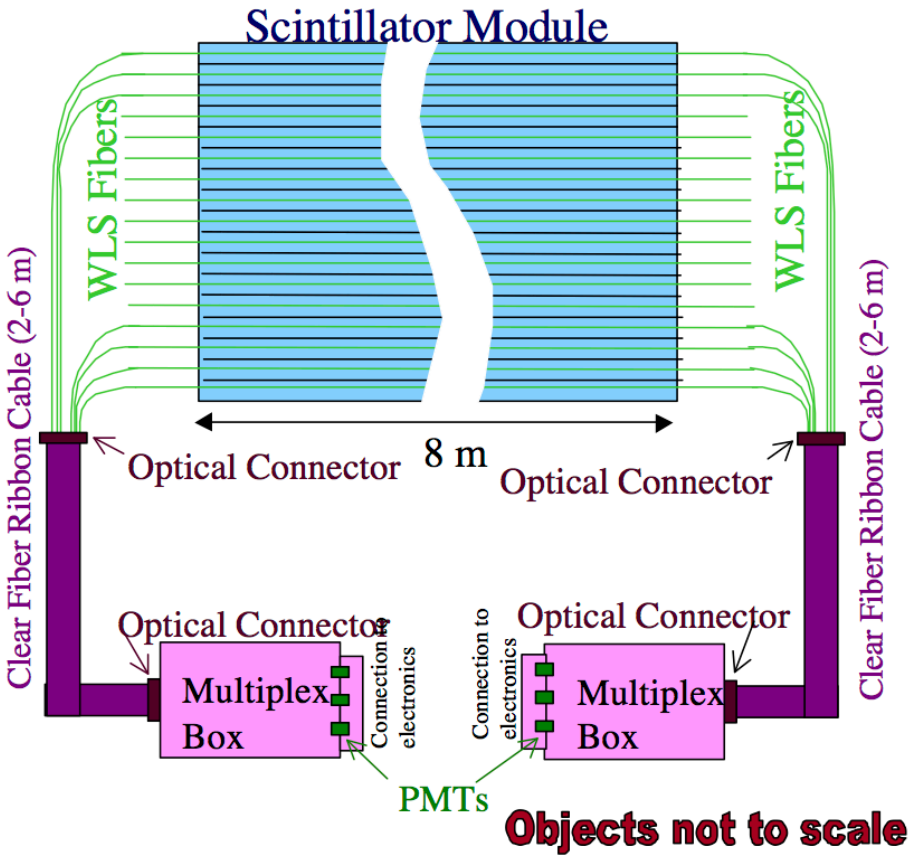
MINOS

- Extruded scintillator, 4cm wide
- Two-ended WLS fiber readout.
- Strips assembled into 20 or 28-wide modules.
- WLS fibers routed to optical connectors.
- Light routed from modules to PMTs via clear fibers.
- 8 Fibers/PMT pixel in far detector. (Fibers separated by ~1m in a single plane.
- 1 Fiber/PMT pixel in near detector (avoids overlaps).
- Multi-pixel PMTs (Hamamatsu M16)



- Scintillator: Extruded Polystyrene with 1.0% PPO + 0.030% POPOP.
- Module cost in MINOS: 260 $/m^2 (could be less if we can use those)
- Add housing and electronics for a module of scale 2 m^2,
  - Possibly below 1.5k for 2 m^2 modules
  - 3000 such modules - $5M + cables and deployment

- Other discussion, …

Requirements for HEX

- Energy threshold
  - IceCube diffuse numu best fit (E^-2.2):
    - 12 signal and 12 background events/yr above 52 TeV
    - Requirement: Good efficiency at 50TeV?
- Veto extension:
    - Can double background free neutrino events above some energy, ~100 TeV
    - Cost effective way to add neutrinos?
- It's not easy: Every veto gets hard at energies at or below 100TeV
  - In-Ice veto with 250m spacing is hard and always has reduced volume, but should do ok at zenith >65°
  - Surface veto also gets hard, but should do ok at zenith <65°

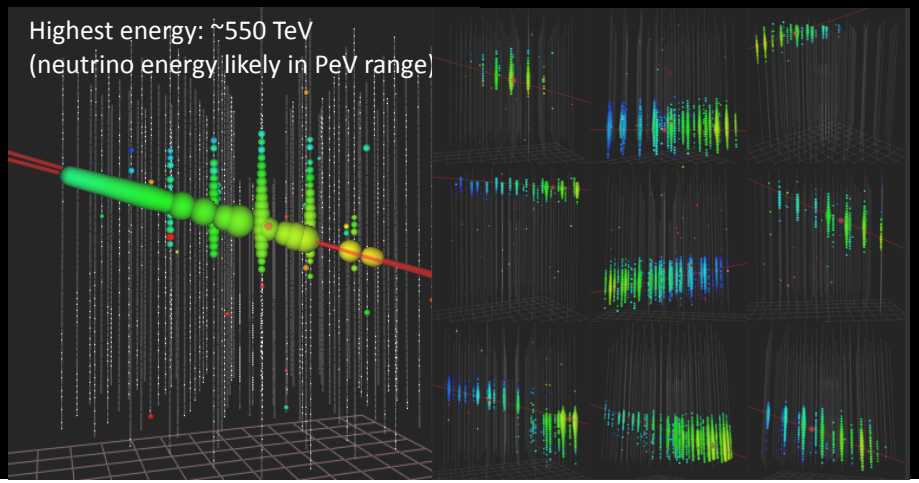
IceCube results

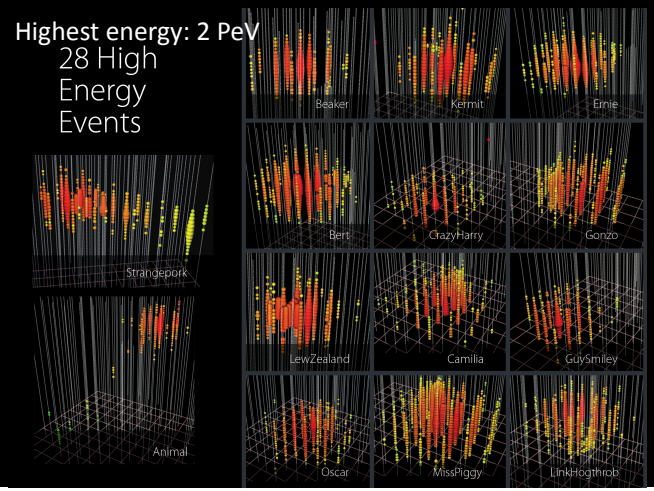
Through going muons

- Northern hemisphere
- Neutrino events (best fit) above 50 TeV "true" muon energy:
  - Astrophysical: 12 events/yr
  - Atmospheric: 12 events/yr
- Significance: ~2.7 sigma/yr

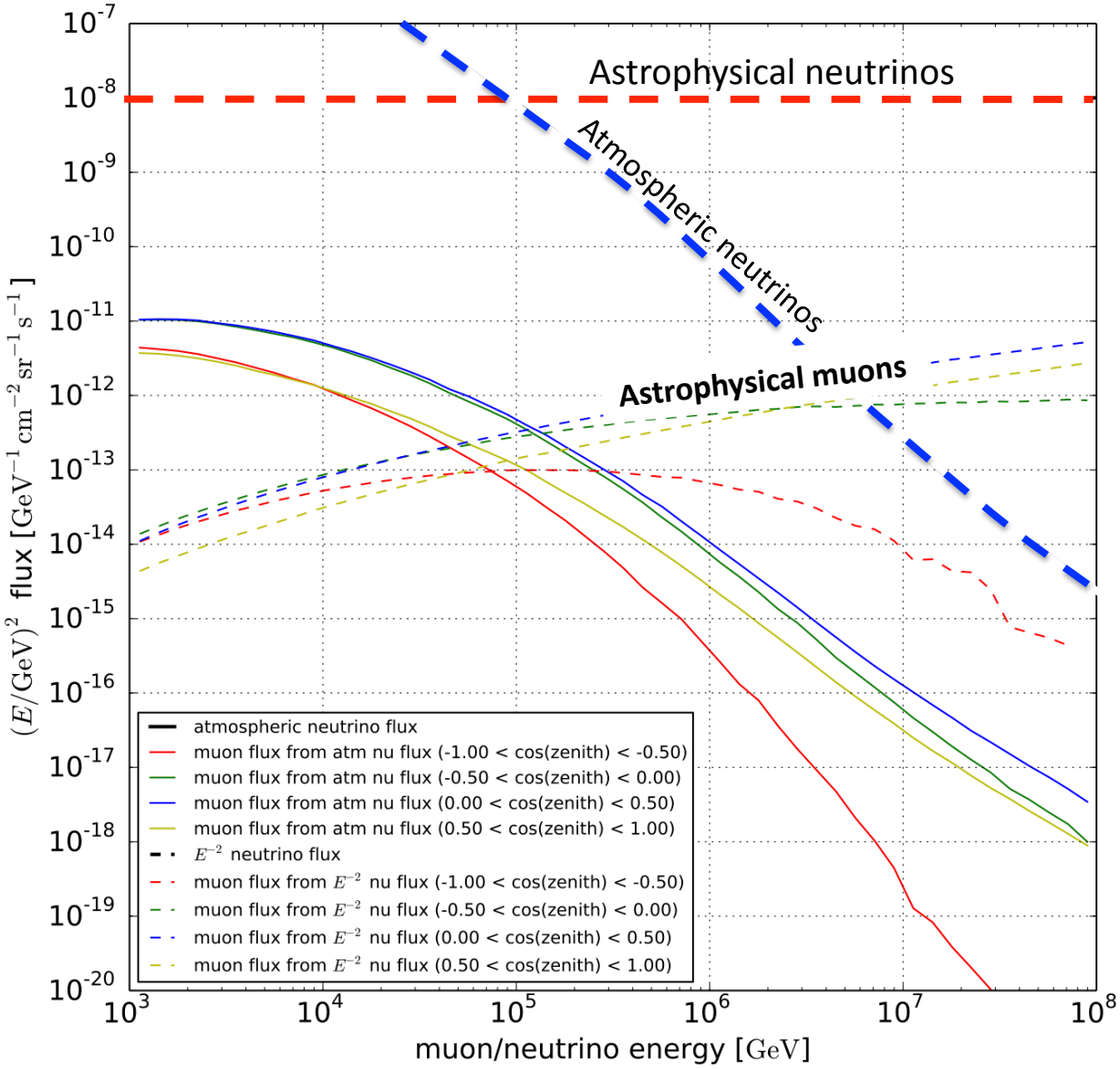
Events with contained vertex

- Mostly Southern hemisphere
- Neutrino events above 60 TeV:
  - Astrophysical: 6 /yr
  - Atmospheric: 1/yr
- Significance: ~3 sigma/yr





Neutrino and muon fluxes



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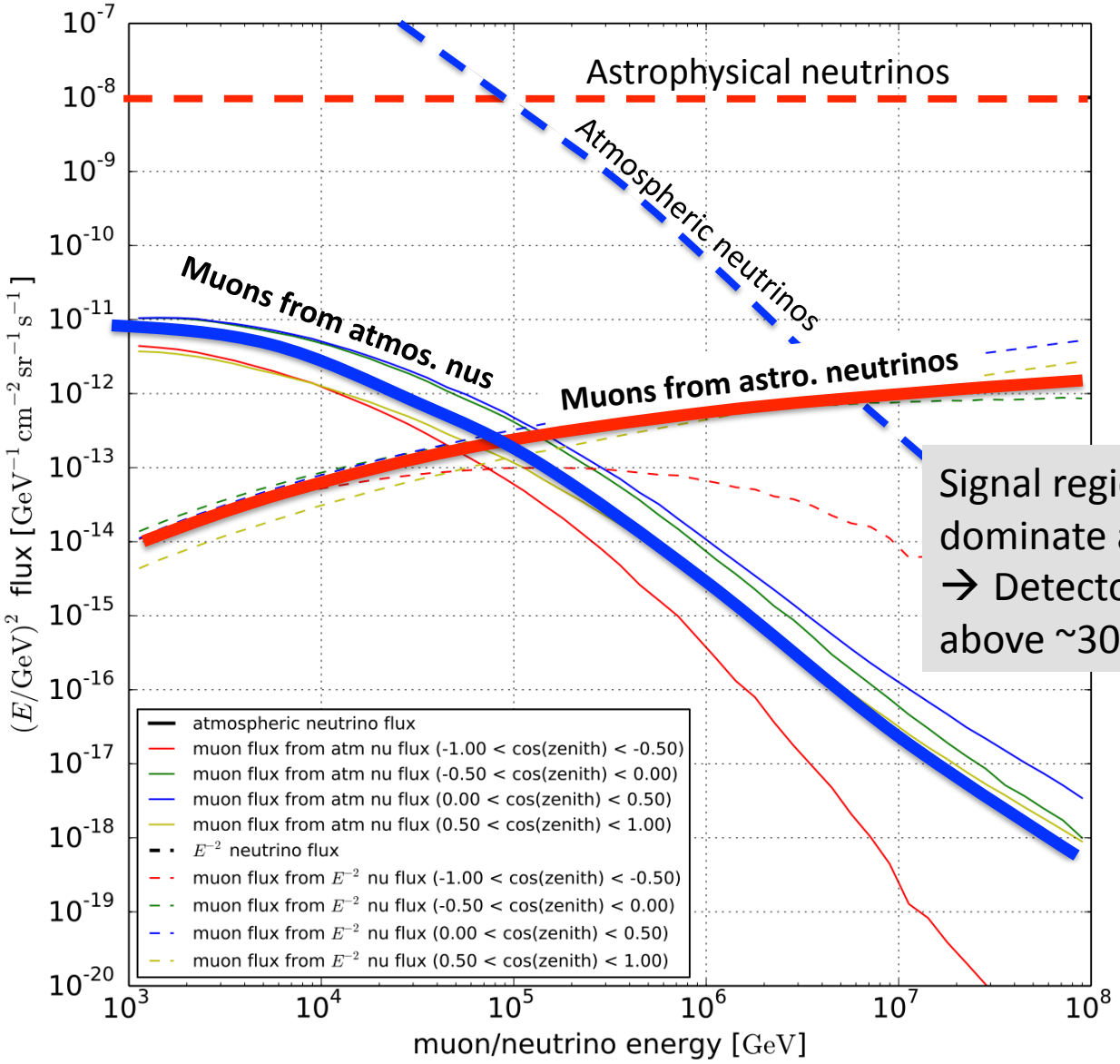
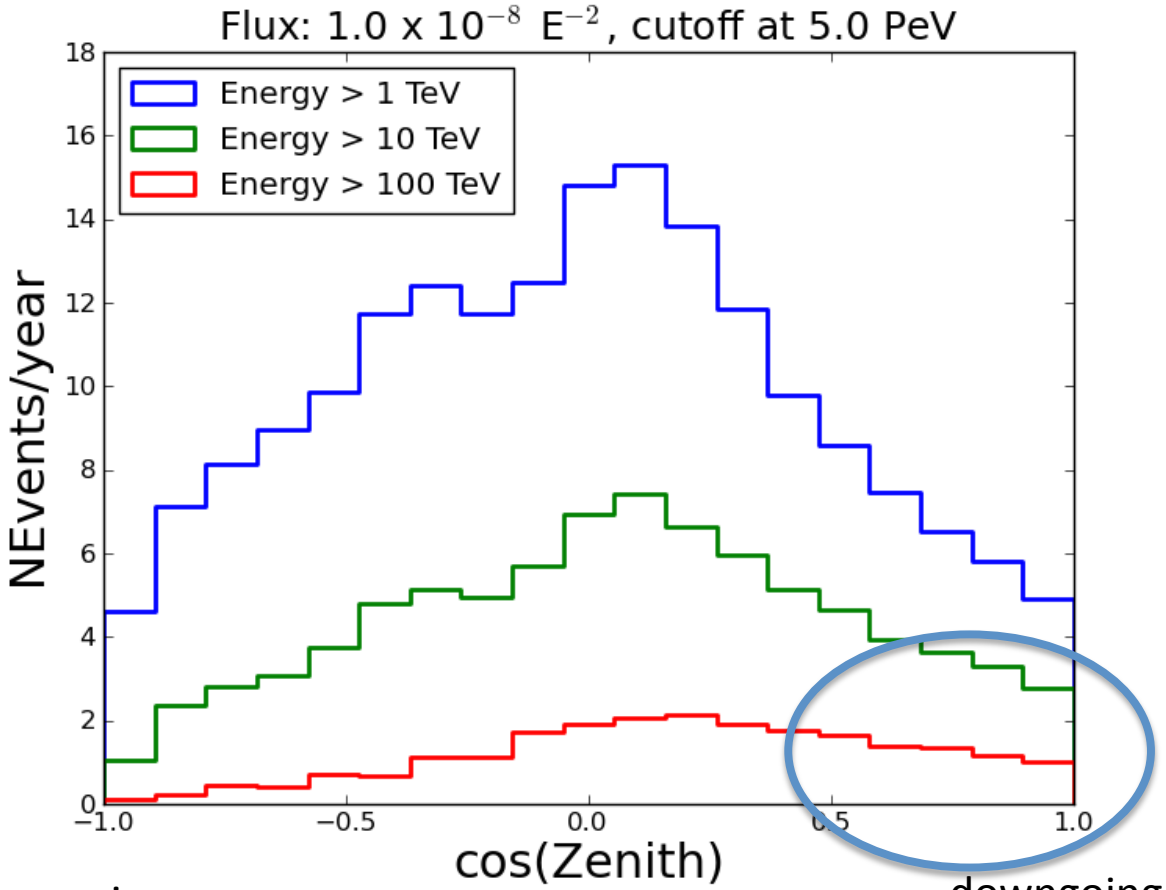


Signal region begins to dominate above ~80 TeV
→ Detector should be efficient above ~30 TeV?

Muon rates from astrophysical flux in IceCube vs zenith angle

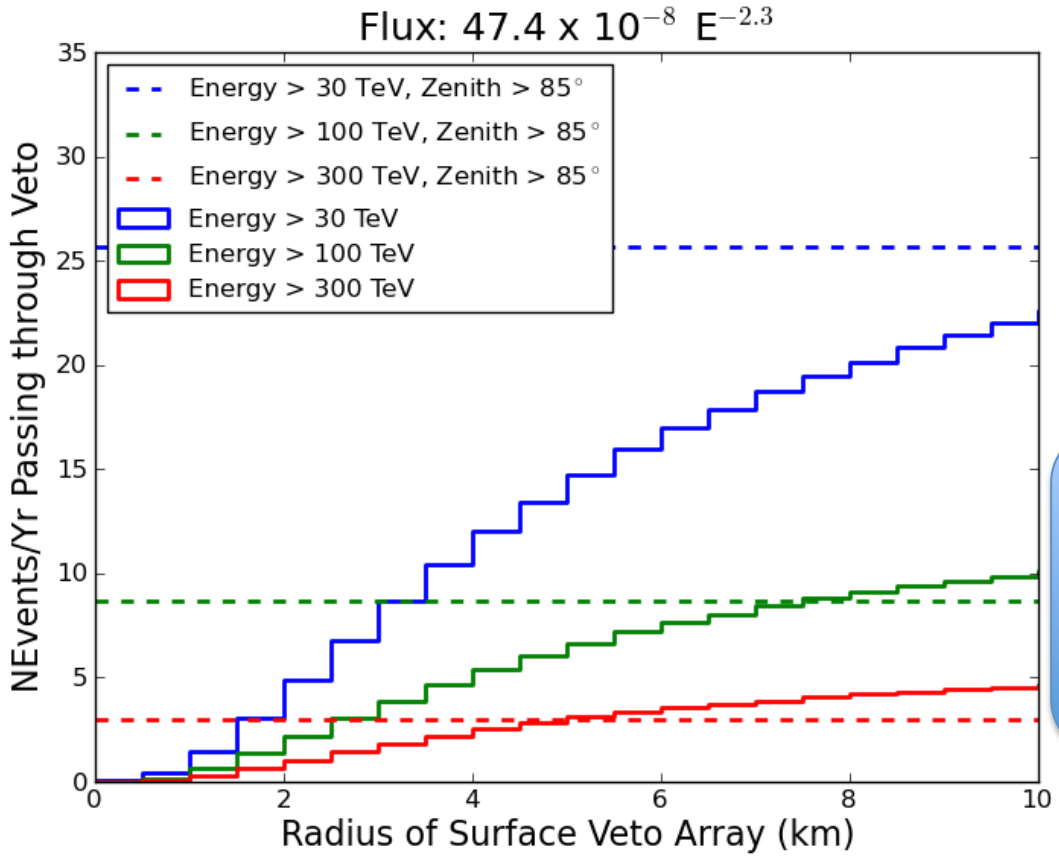


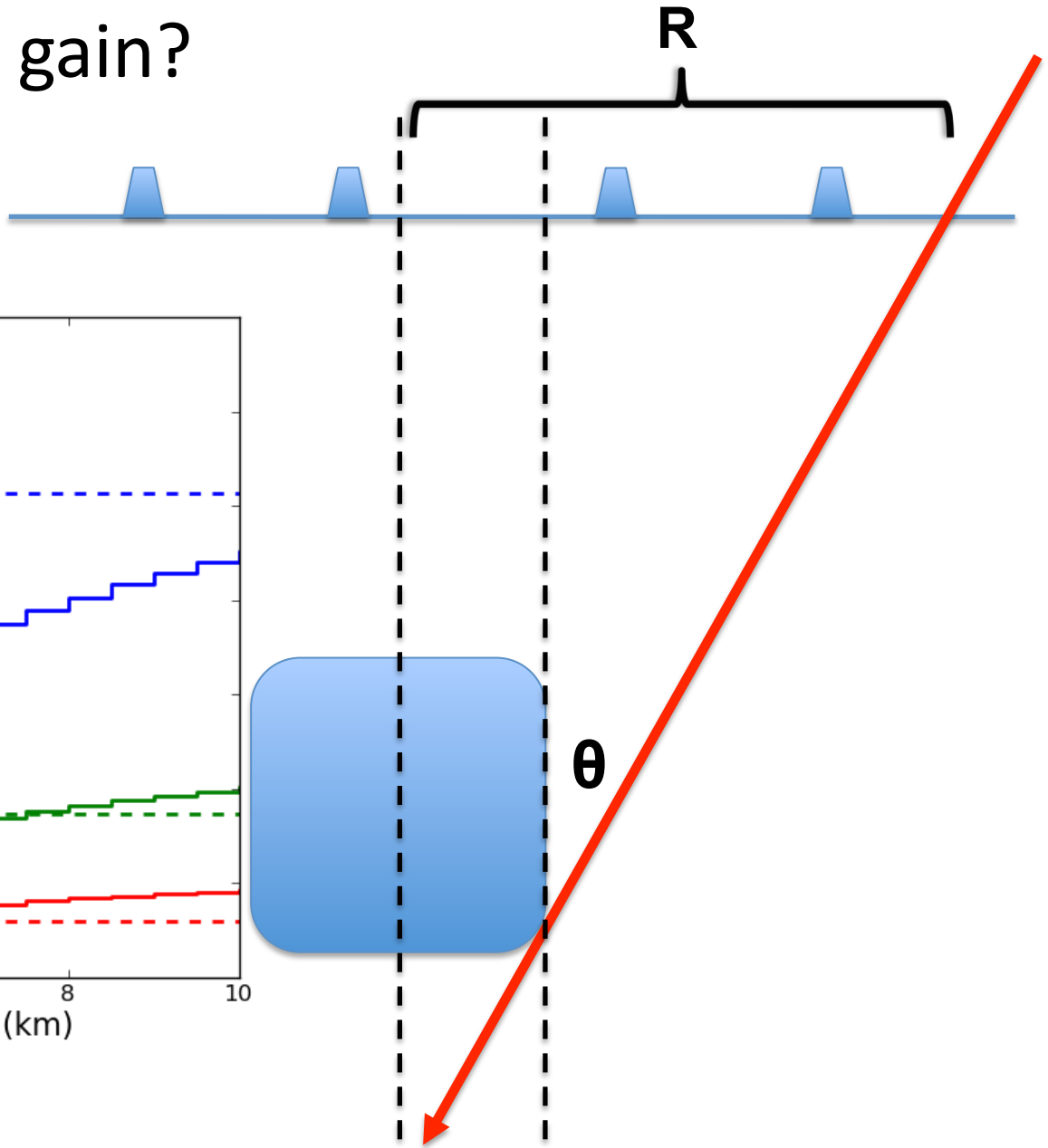
upgoing

downgoing

Can we detect some more of these?
We do that already at some level in the HESE analysis (contained neutrino vertex)

If we had a surface veto, how many signal events would gain?





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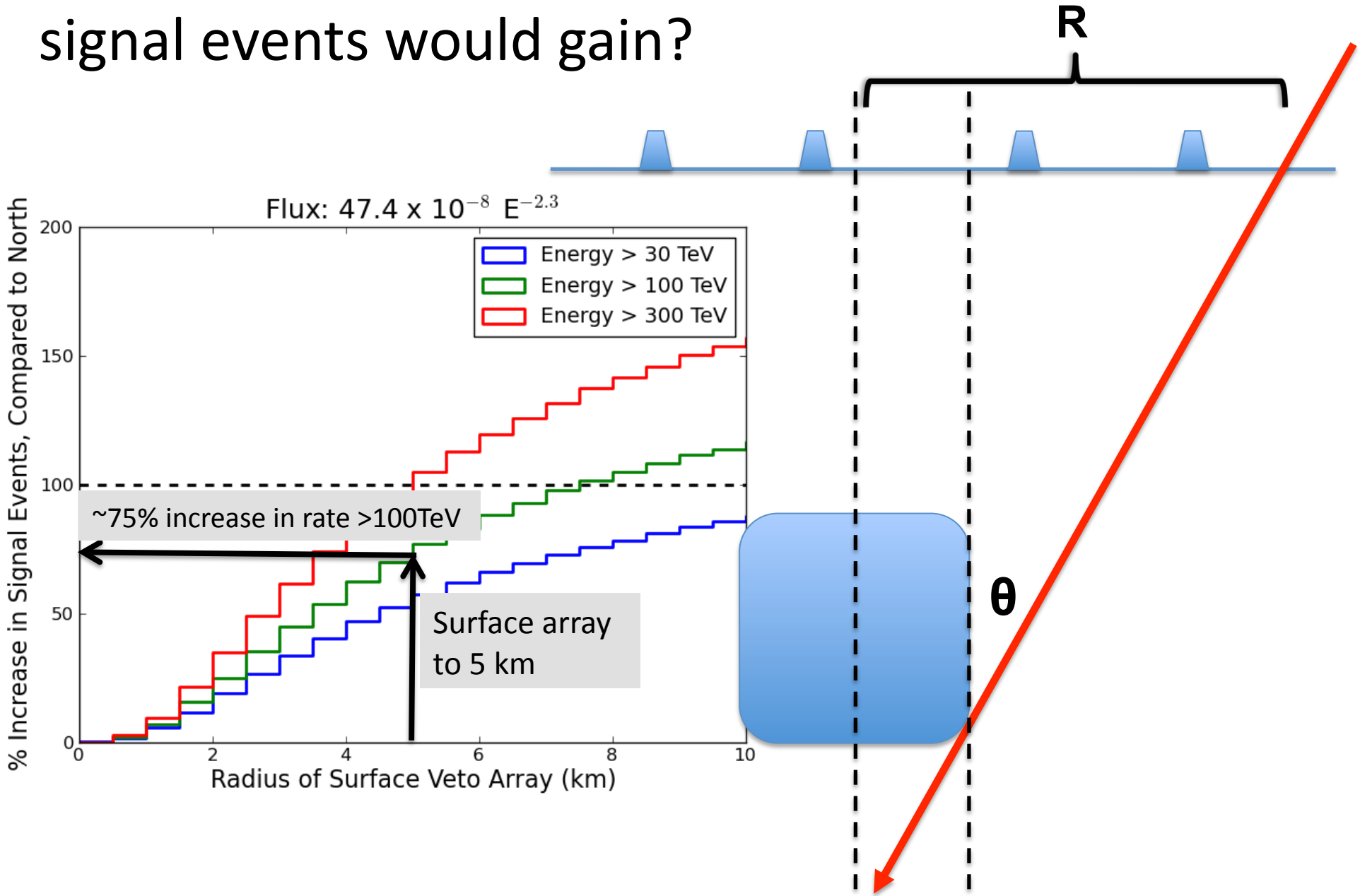
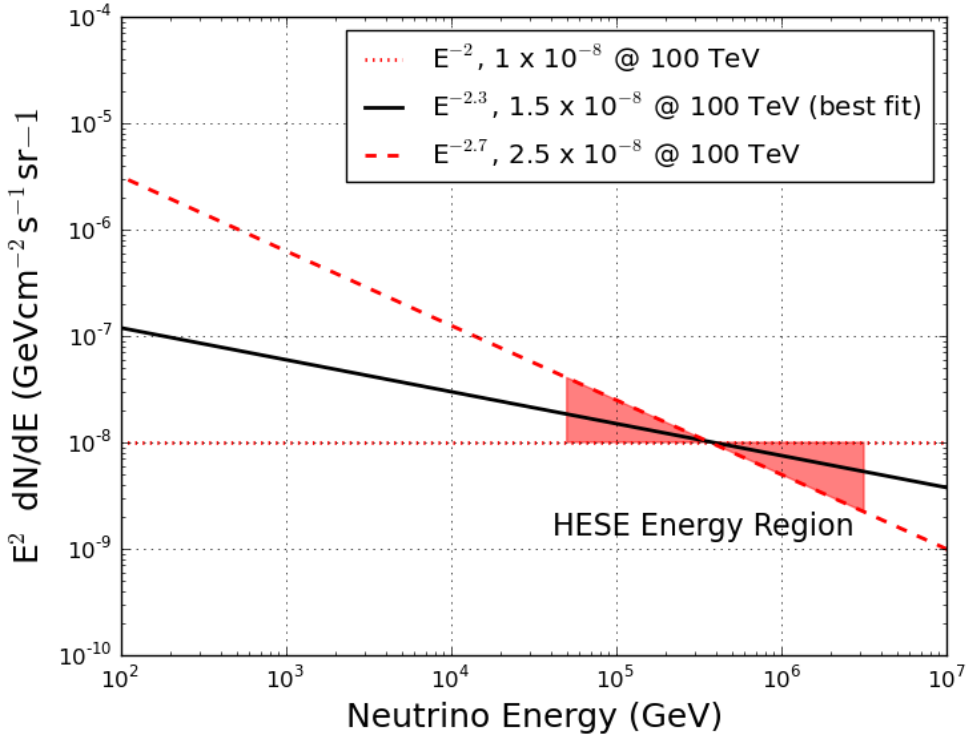


If we had a surface veto, how many signal events would we gain? *IceCube only numbers*

- Normalizations for each flux chosen using IceCube flux results (HESE contours)
- All fluxes are simulated without any cutoff



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Northern hemisphere (upgoing, zenith > 85°)

Flux	# of Events/year above Muon Energy		
	1 TeV	10 TeV	100 TeV
E^{-2}	110	44	11
$E^{-2.3}$	220	60	**9**
$E^{-2.7}$	740	110	7
Atm.	15000	500	5

Southern hemisphere (< 85°) (downgoing, zenith < 85°)

Flux	# of Events/year above Muon Energy		
	1 TeV	10 TeV	100 TeV
E^{-2}	80	44	18
$E^{-2.3}$	160	57	**13**
$E^{-2.7}$	590	100	10
Atm.	10500	350	5