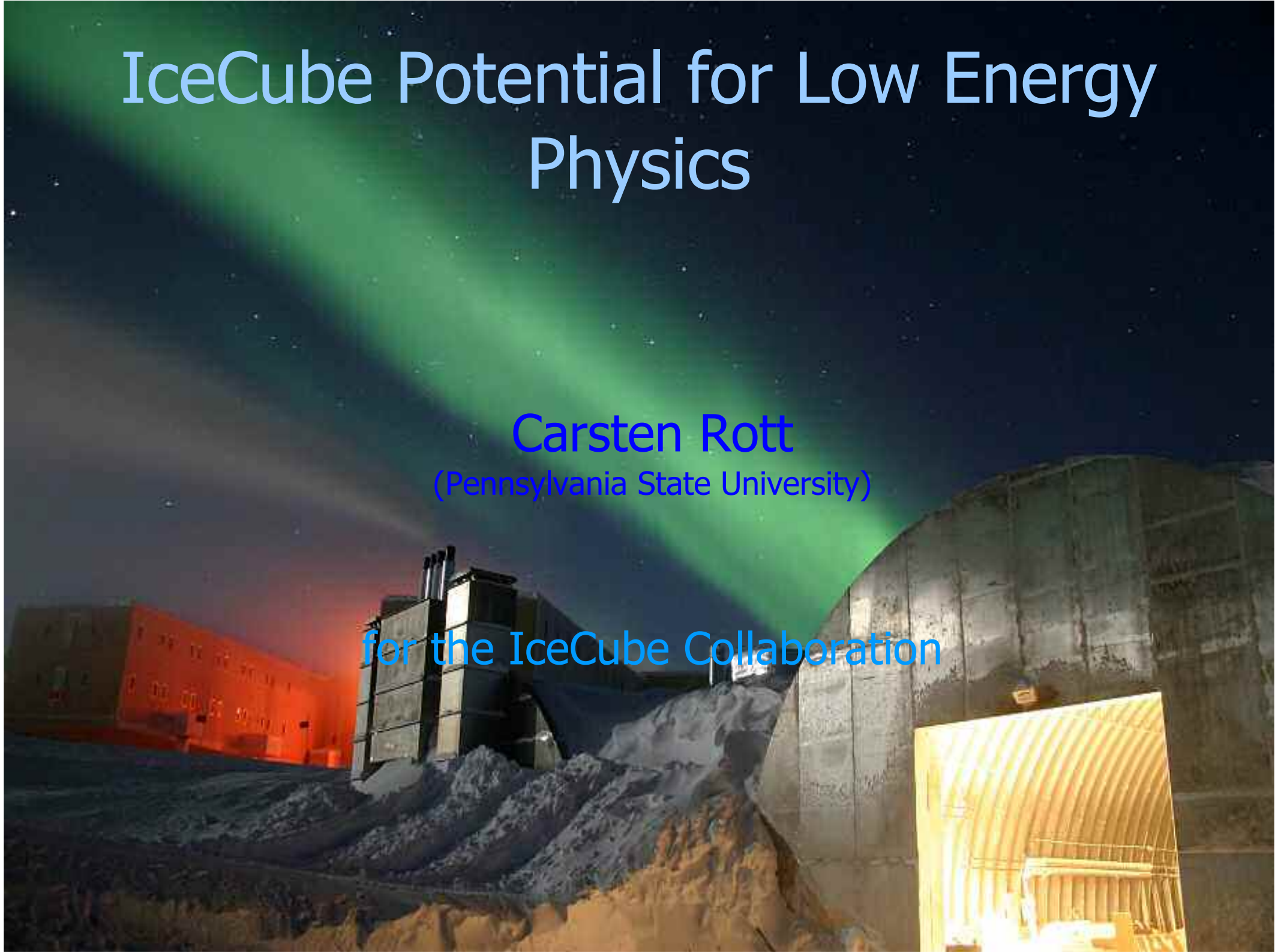
# IceCube Potential for Low Energy Physics



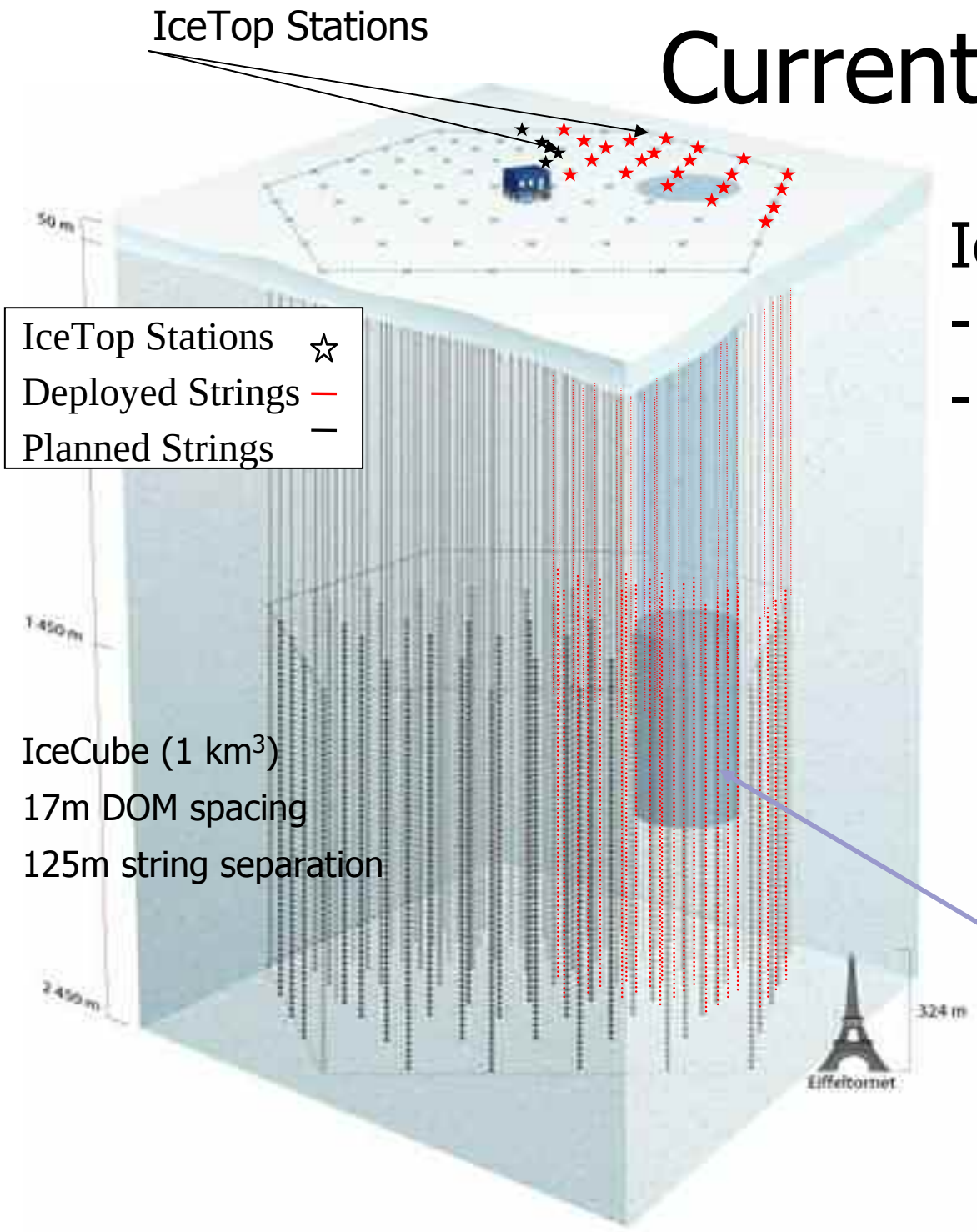
Carsten Rott
(Pennsylvania State University)

for the IceCube Collaboration

# What's Low Energy in IceCube ?

- Atmospheric neutrinos
  - Oscillations (30 – 100 GeV)
- Astroparticle physics
  - Point sources (>100 GeV)
  - Wimps
    - Solar / Earth / Galactic center

# Current Detector Status

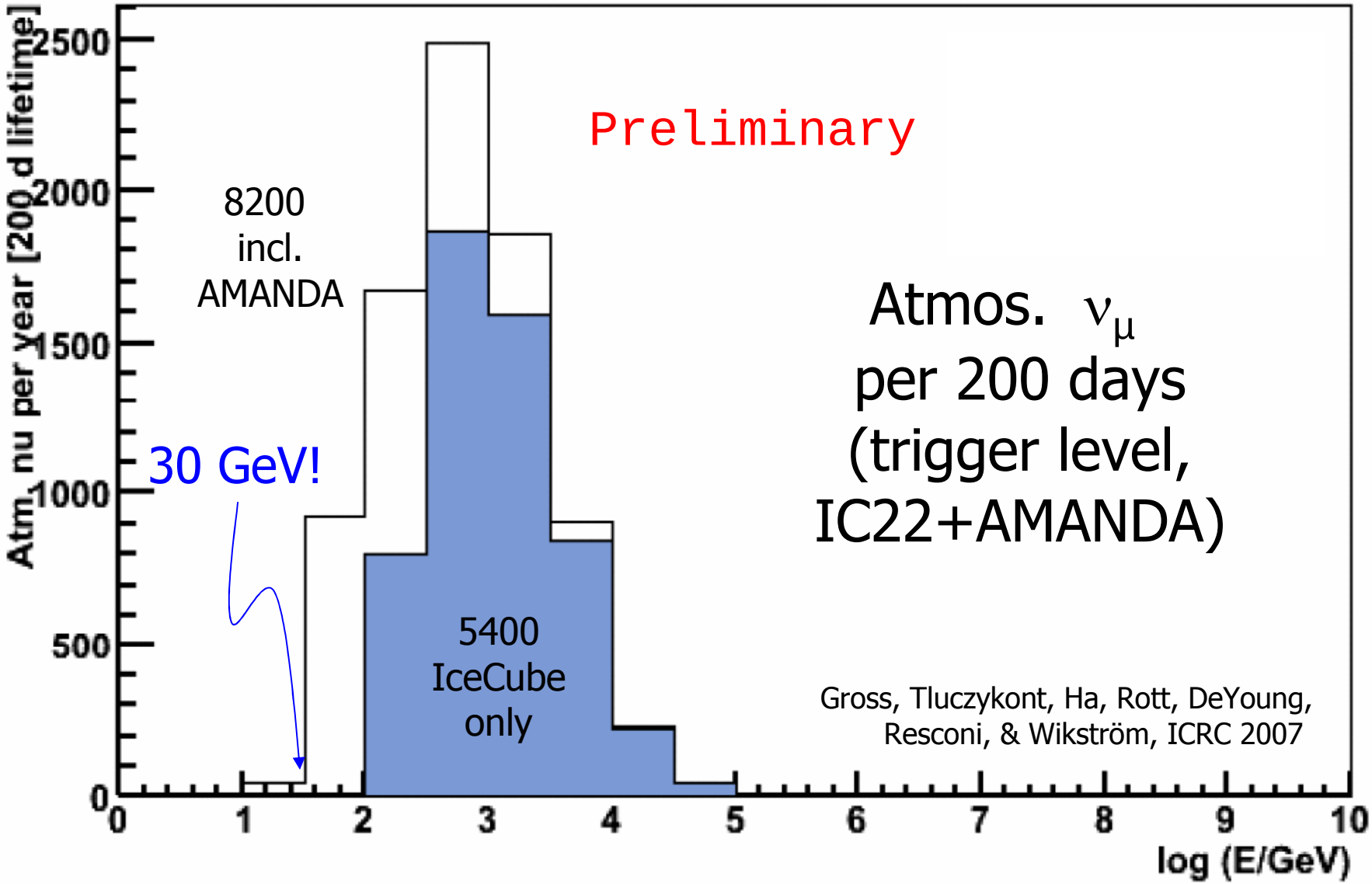



IceCube
- 22 strings
- 26 surface stations

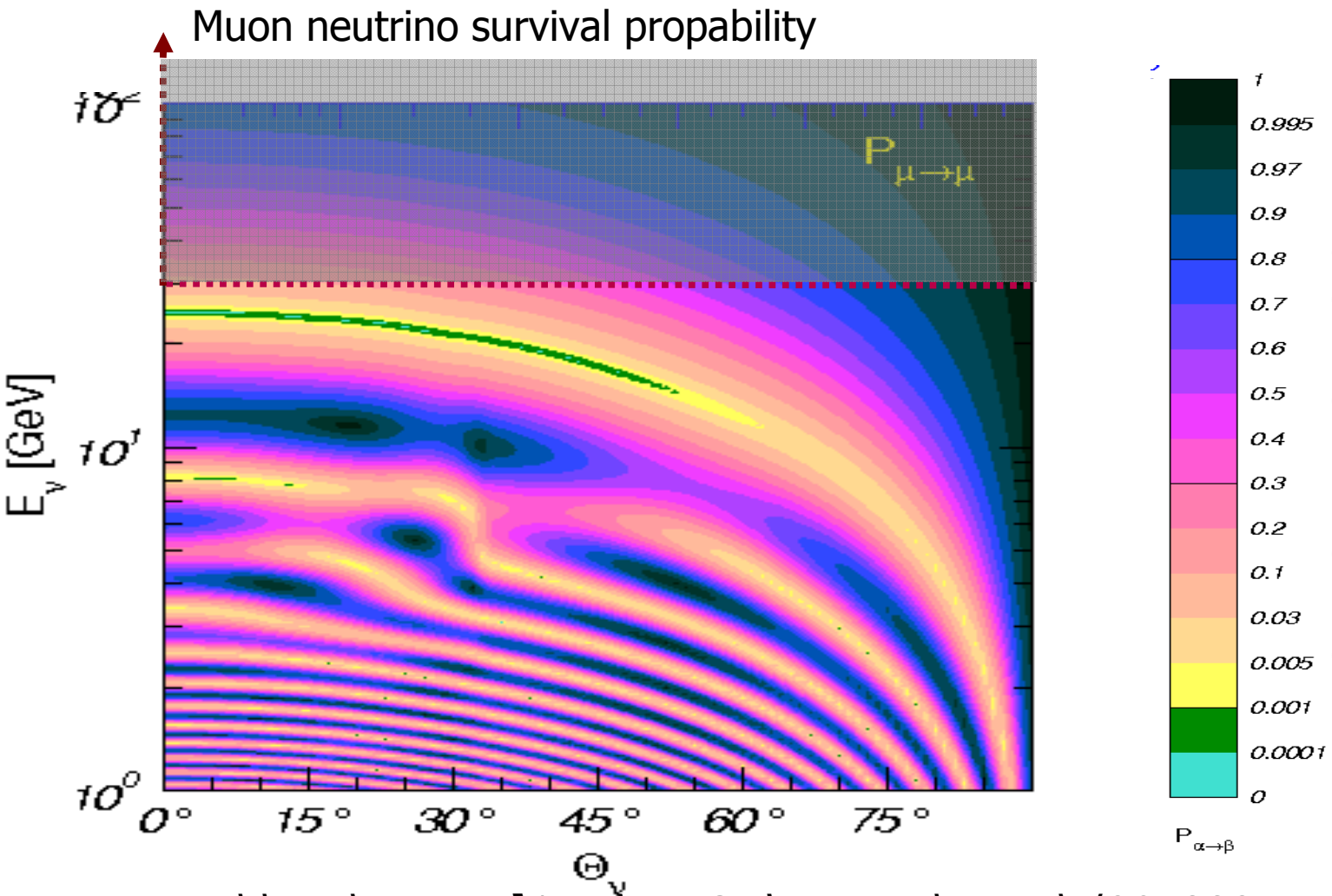
AMANDA operating as part of IceCube
- Combined Trigger
- Event building

AMANDA-II
19 strings
677 modules
(New AMANDA DAQ system operates at lower threshold)

# Atmospheric Muon Neutrino Sensitivity



# Neutrino Oscillations



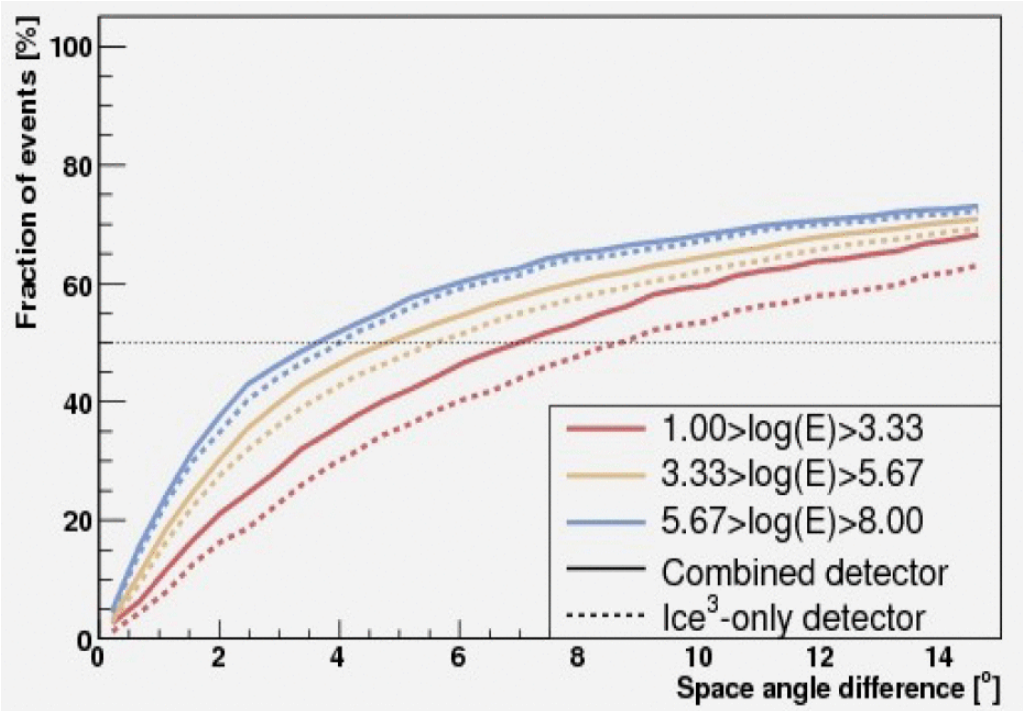

Combined detectors allow for a better energy estimate by using contained events

Study oscillation effects in an energy band never before explored

Akhmedov, Maltoni & Smirnov, hep-ph/0612285

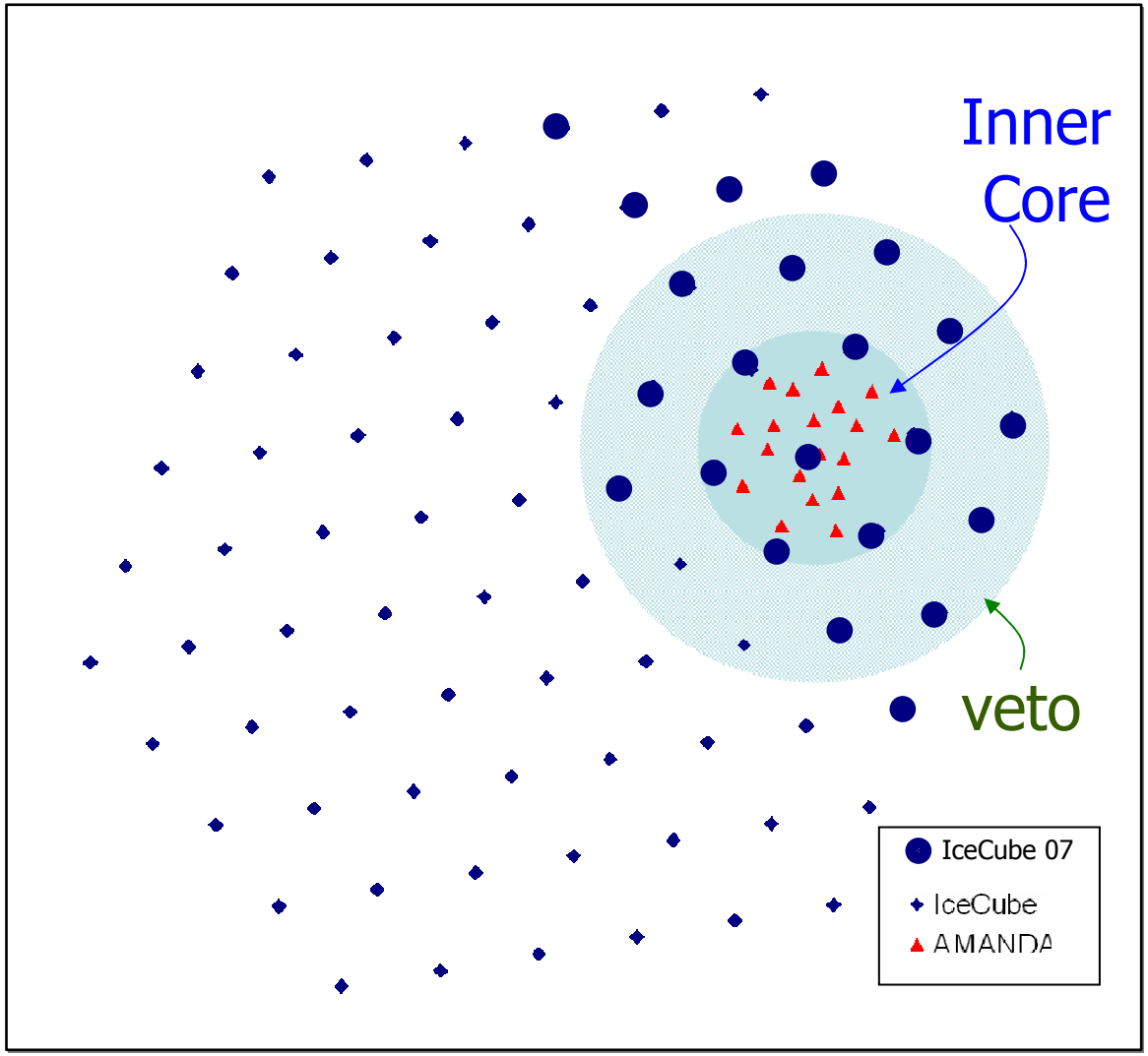
# Combined IceCube & AMANDA Detector

- Combined detector significantly increases performance at low energies
- Greater effective area
- Improved angular resolution
- Outer strings can be used as veto




[See poster from Martin Tluczykont & Andreas Gross]

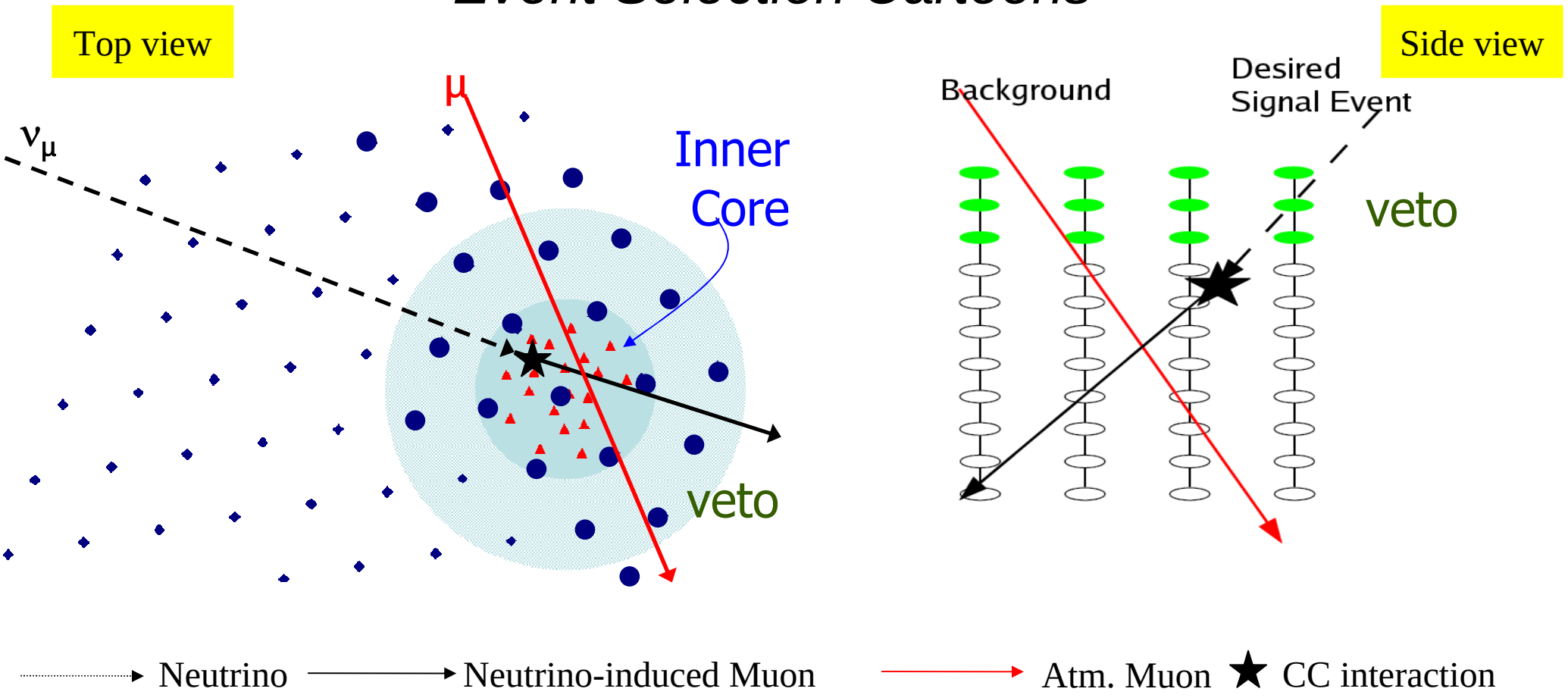
# Contained and Partially contained events




- 7 IceCube + 18 AMANDA strings form a densely instrumented "Inner Core"
  - Lower energy threshold
- Peripheral IceCube strings form veto volume
  - Especially useful for physics with contained and partially-contained events

# Contained and Partially-contained Events

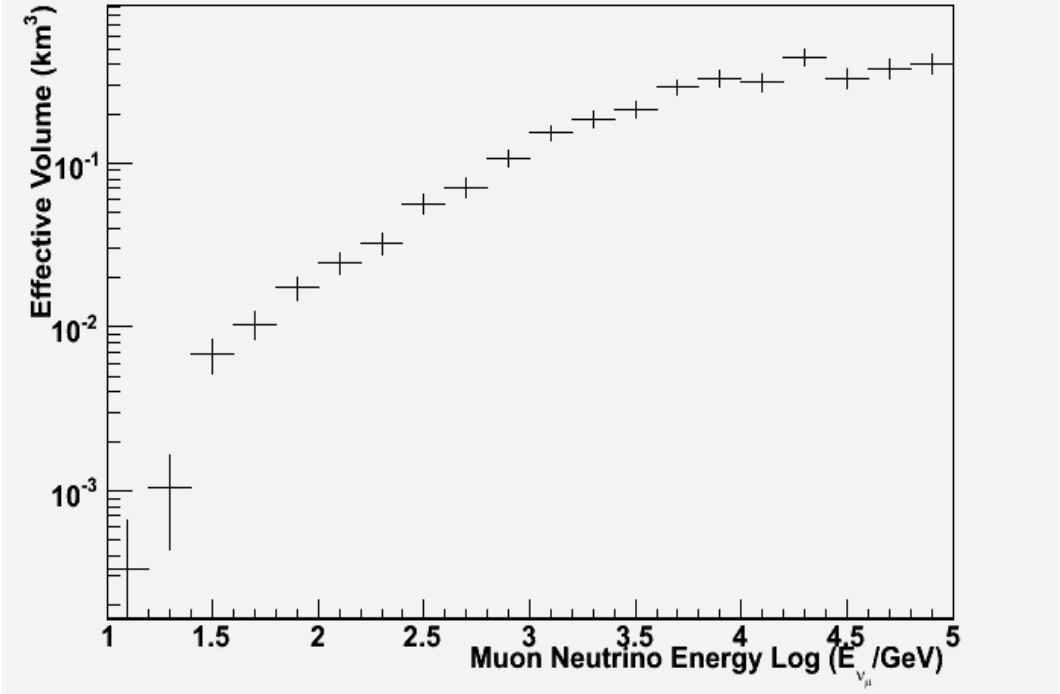
*Event Selection Cartoons*




Defined sub-detection volume in blue color (starting tracks in this region)
Peripheral strings and DOMs in the top section of the strings are used as veto

# Low Energy Events Filter

$V_{eff}$ for contained events filter



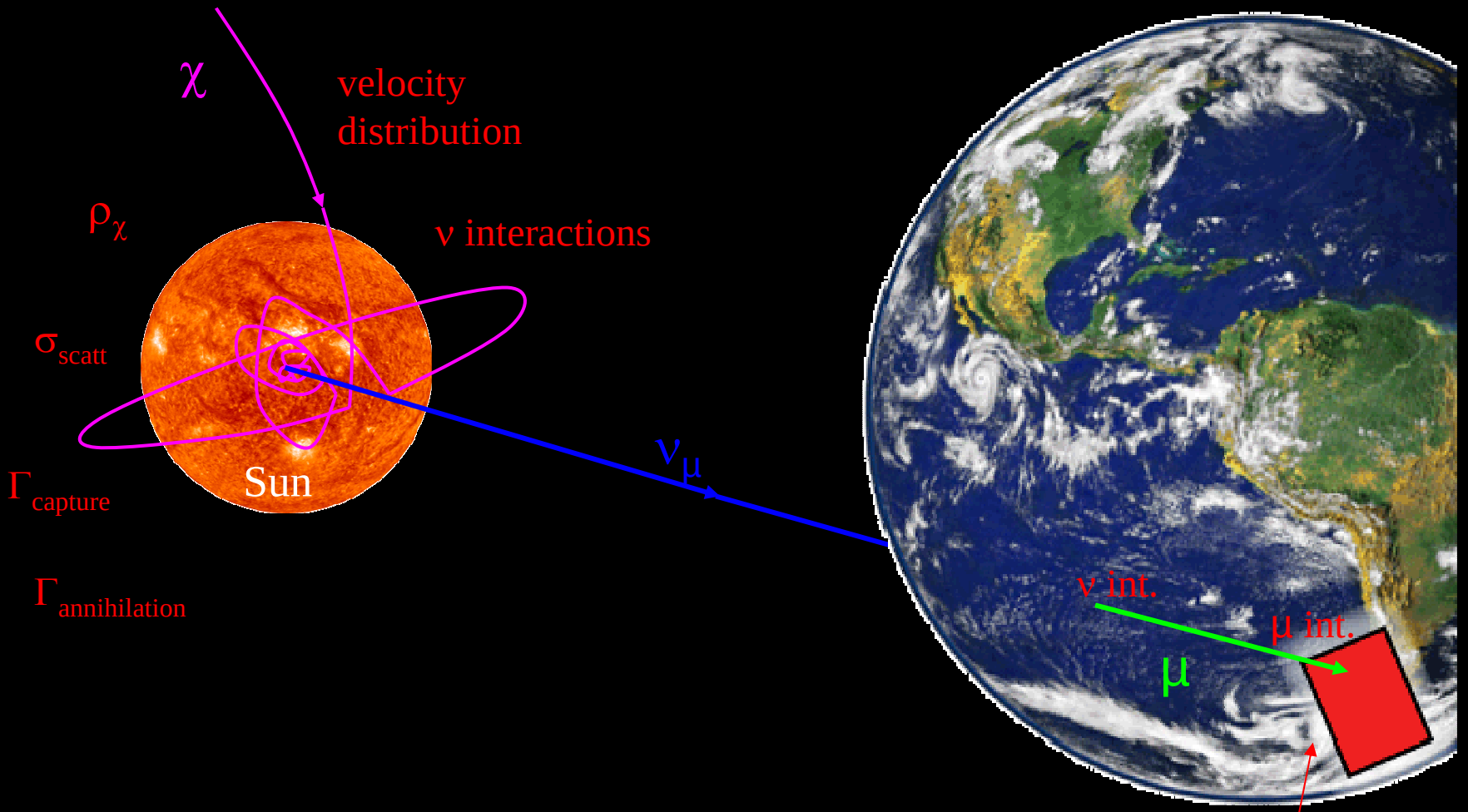

Effective Volume for signal events after filter selection cuts for the contained events filter

Signal events were defined as muon neutrinos with a charged current interaction in the inner detector region

$4\pi$ sensitivity

- Event recorded at pole get filtered for transfer via satellite
- Full triggered dataset on tapes

# Indirect Search for Dark Matter



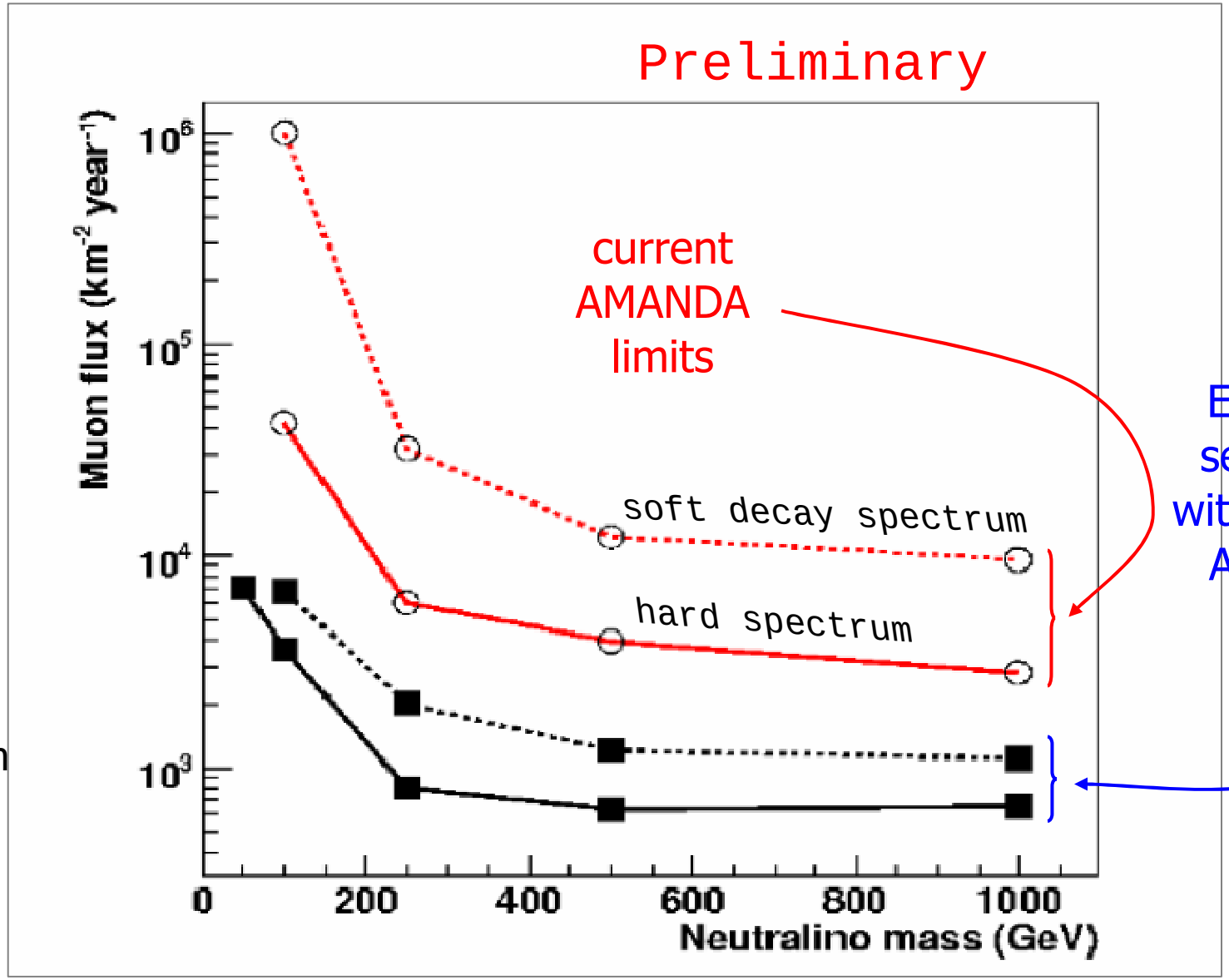

Silk, Olive and Srednicki, ’85
Gaisser, Steigman & Tilav, ’86
Freese, ’86

Krauss, Srednicki & Wilczek, ’86
Gaisser, Steigman & Tilav, ’86

# Solar WIMP Sensitivity

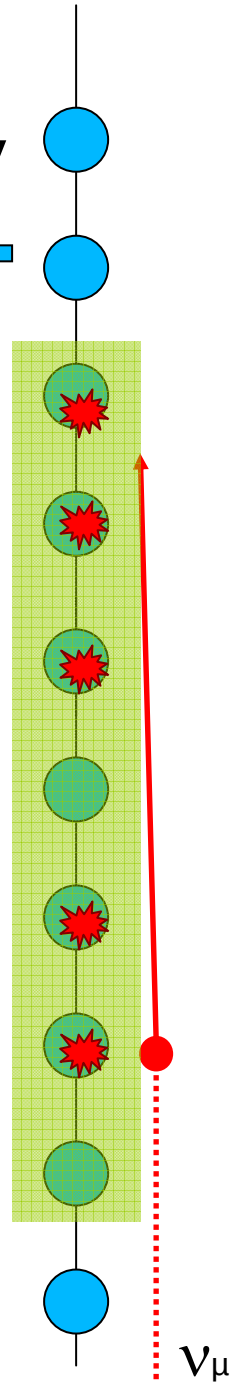
AMANDA limits: astro-ph/ 0508518

Expected sensitivity: G. Wikström ICRC 2007



# IceCube Triggers and Sensitivity

- Topological trigger allow to lower the energy threshold further
  - Selects events based on a certain pattern present in the detector
- IceCube geometry especially sensitive to vertical events
- String Trigger selects events consistent with vertically up/down-going muons



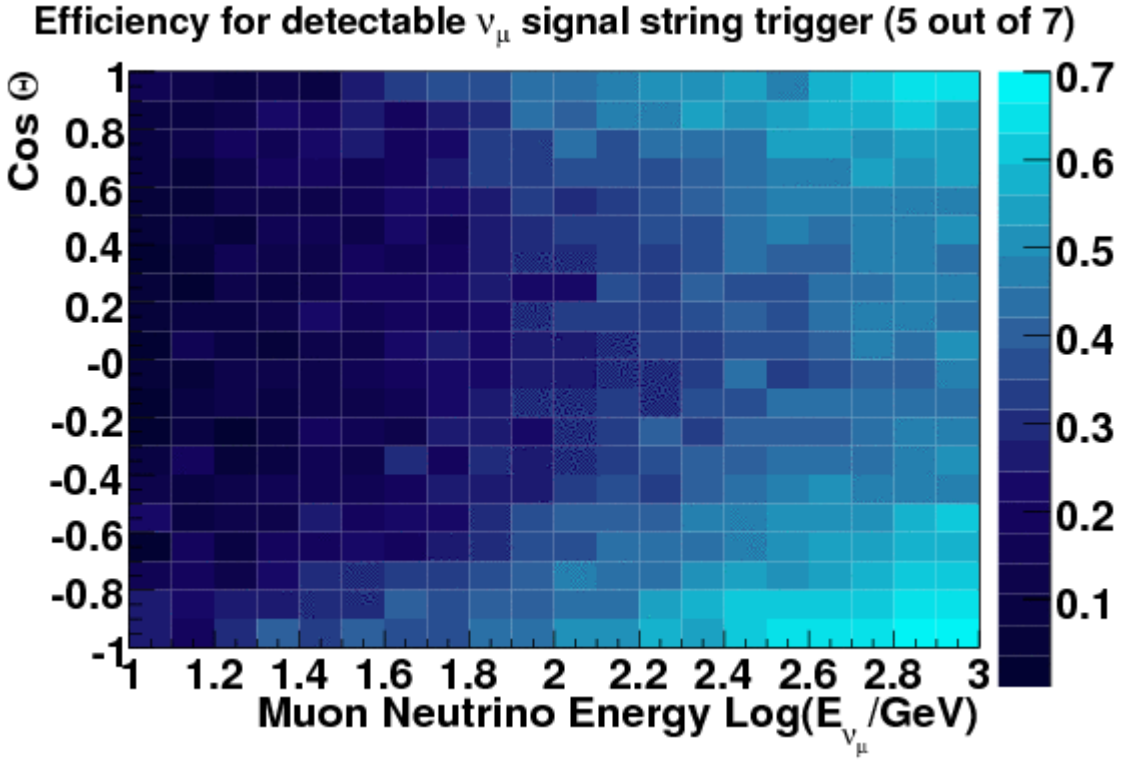
# IceCube String Trigger

Specialized low energy vertical events trigger

Detect low energy neutrinos (>30GeV)

Substantially lower energy threshold compared to default IceCube multiplicity trigger

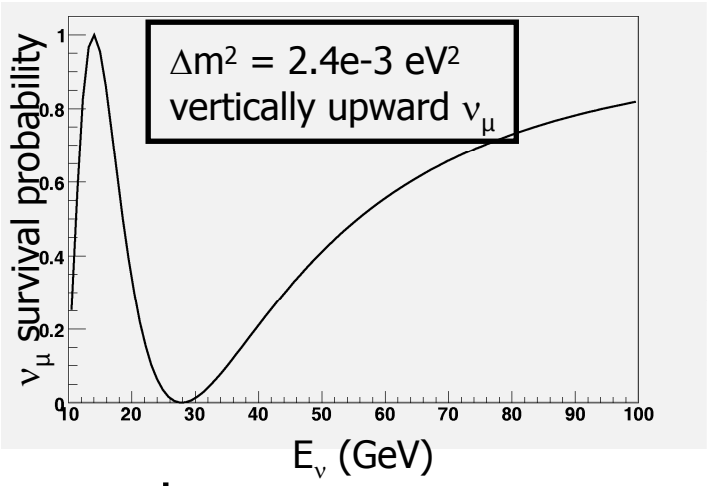
Especially add sensitivity to vertical events

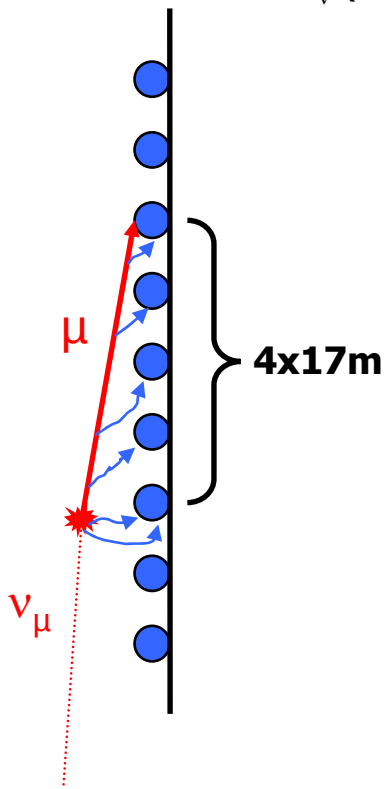



Detectable events were defined as events that have at least one hit in the detector

# Another approach to Atmospheric ν Oscillations

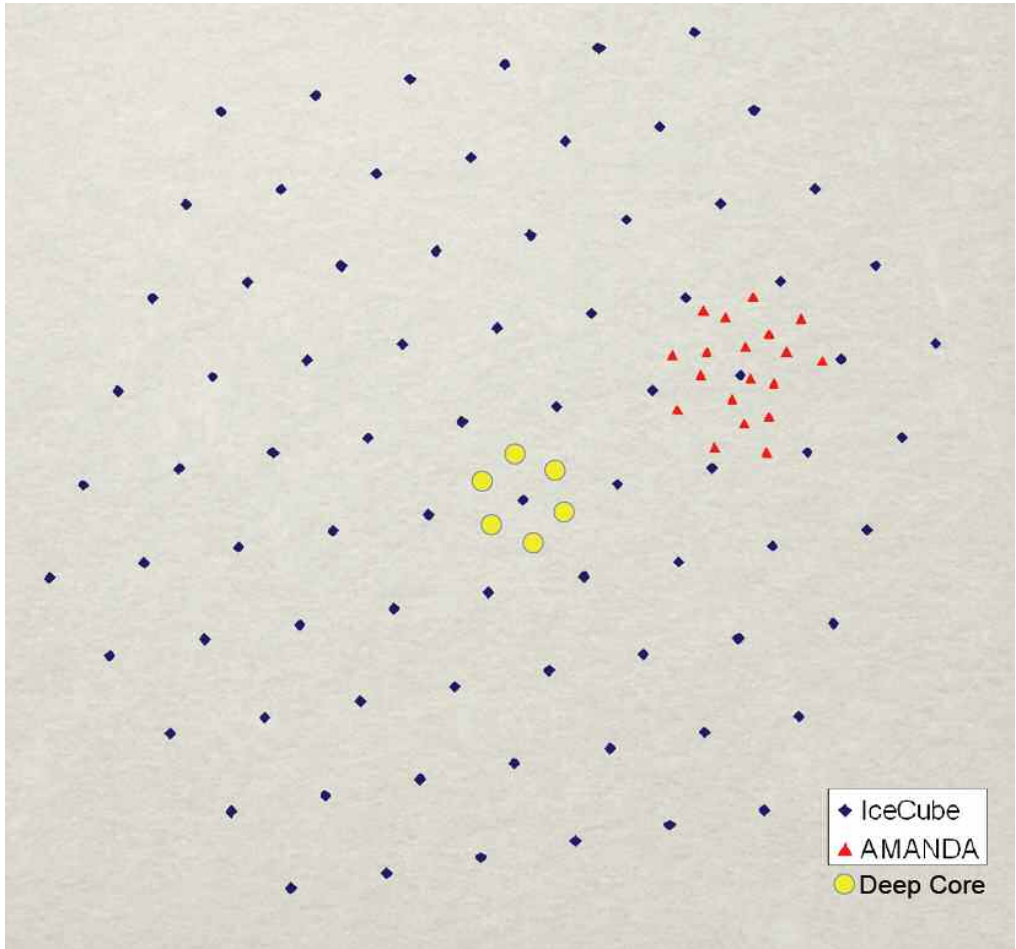
- Lowest energy threshold is realized in vertical events
- Reconstruction might be possible for those events due to the IceCube geometry
- E<30 GeV may be reachable with vertical muons
  - 17m spacing in z-dimension
    - muon travels ~4 m/GeV
    - need at least 5 DOMs: 68 m
    - $E_{\mu,min} = 68/4 = 17$ GeV ($E_{\nu,min}$ = ~25 GeV)
  - Look at $\mu_{up}/\mu_{down}$ as a function of μ track length
    - Track length (and initial shower) to estimate E
  - Related idea discussed in Albuquerque and Smoot, PRD.64.053008
  - issues:
    - Kinematic ν-μ angle
    - ~flat inelasticity (y) distribution
    - Atmospheric muon background



# Future

- Dense sub-array detector under investigation
- Same technology as IceCube
- Large veto region can effectively remove down-going muon background
- Would be deployed in the deep ice
  - Lower atmospheric muon background
  - Clear ice (below 2100m)
  - Effective Veto from surrounding IceCube strings and DOMs above



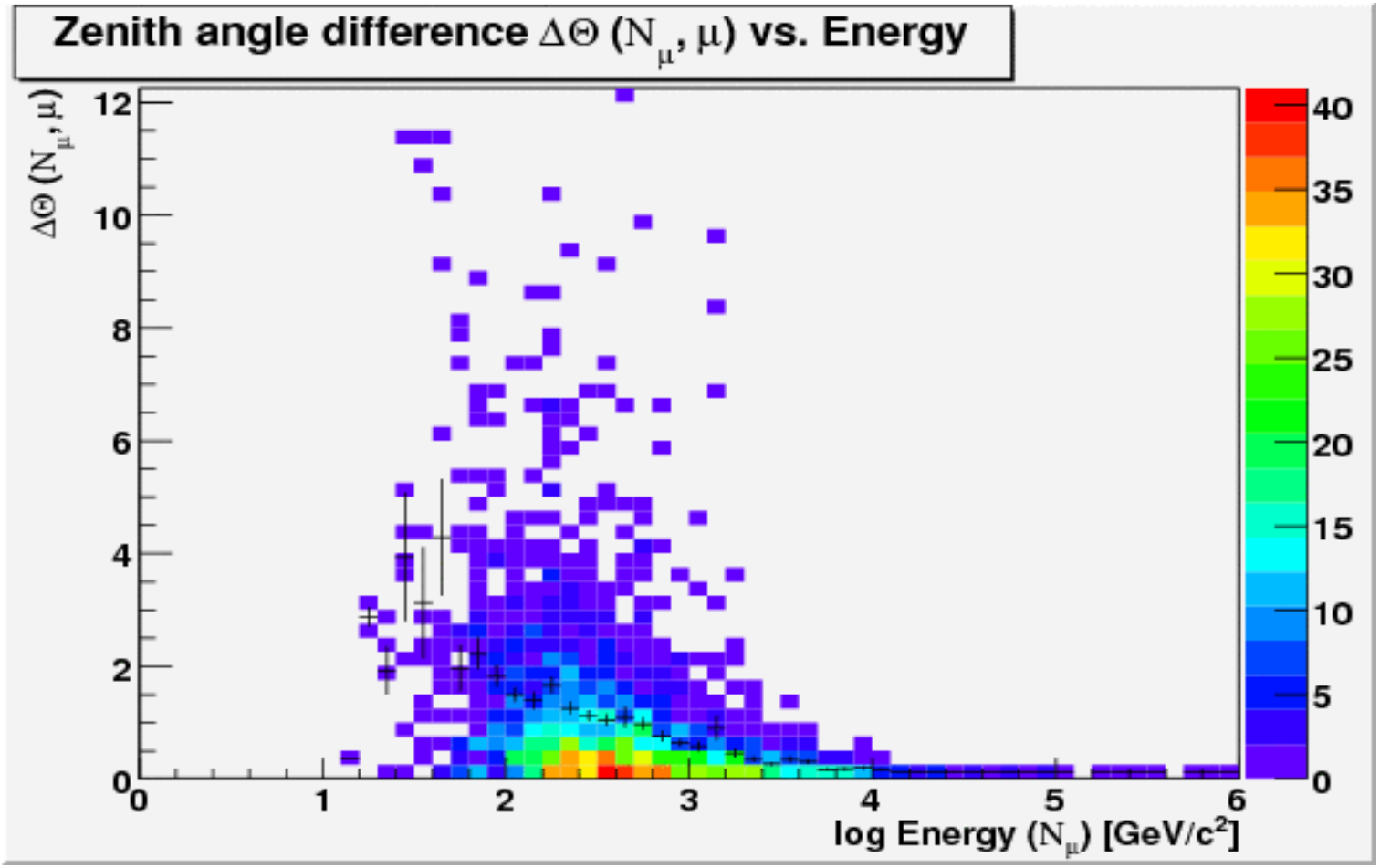
# Conclusions

- AMANDA and IceCube are operating jointly and collecting data
- Dataset especially interesting towards low energy analysis
- New searches for WIMPs, Neutrino Oscillations, ... underway
- Studies towards new deeper low energy core

# Backup Slides

# Kinematic $\nu_\mu$-$\mu$ angle

- Intrinsic uncertainty in angular resolution



# Atmospheric vs astrophysical ν

- Atmospheric
  - $\nu_\mu : \nu_e : \nu_\tau \sim 2:1:0$
  - Steady flux
  - sec(θ) distribution
  - Steep spectrum
  - $\nu_e$ very steep
  - "prompt" neutrinos
    - $\nu_\mu : \nu_e = 1:1$
    - normalization uncertain
    - harder spectrum
- Astrophysical
  - $\nu_\mu : \nu_e : \nu_\tau \sim 1:1:1$
  - Flux may be variable
  - Point sources expected
  - Harder spectrum
  - All flavors similar spectra
  - Charm decay is important background for search for astrophysical neutrinos

# Low Energy Events in IceCube

- Low Energy threshold driven by geometry and trigger condition
- Analysis related:
  - Is there a potential to reconstruct events ?
  - Atmospheric Muon background increases
    - ... deeper is better