Neutrino & γ-ray astronomy

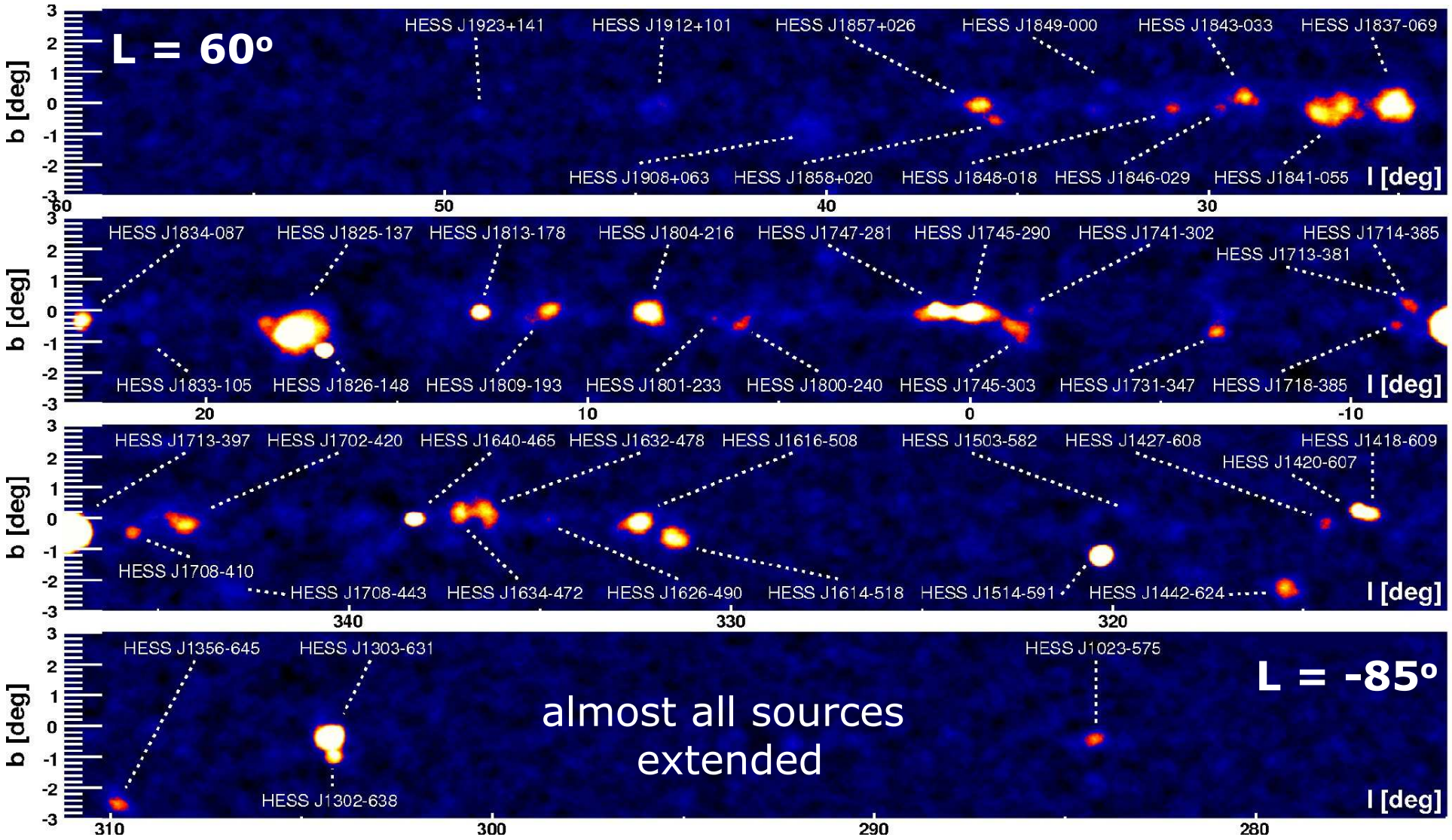
Looking for signals directly from cosmic-ray sources

Q: why is this needed?

Werner Hofmann, TeV PA 2009

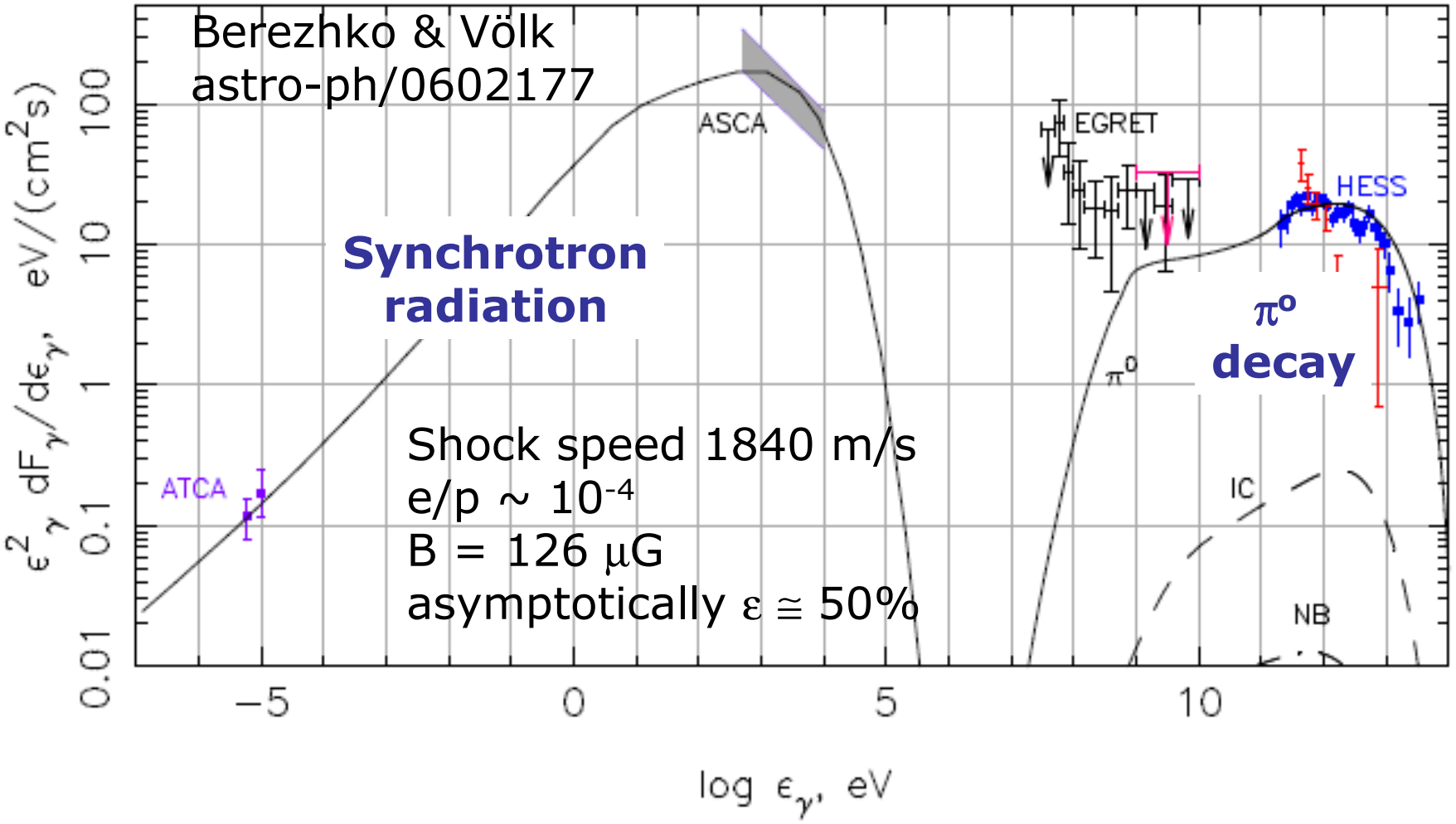
R. Chaves
ICRC 2009

The Galactic Plane in gamma rays



SNR models

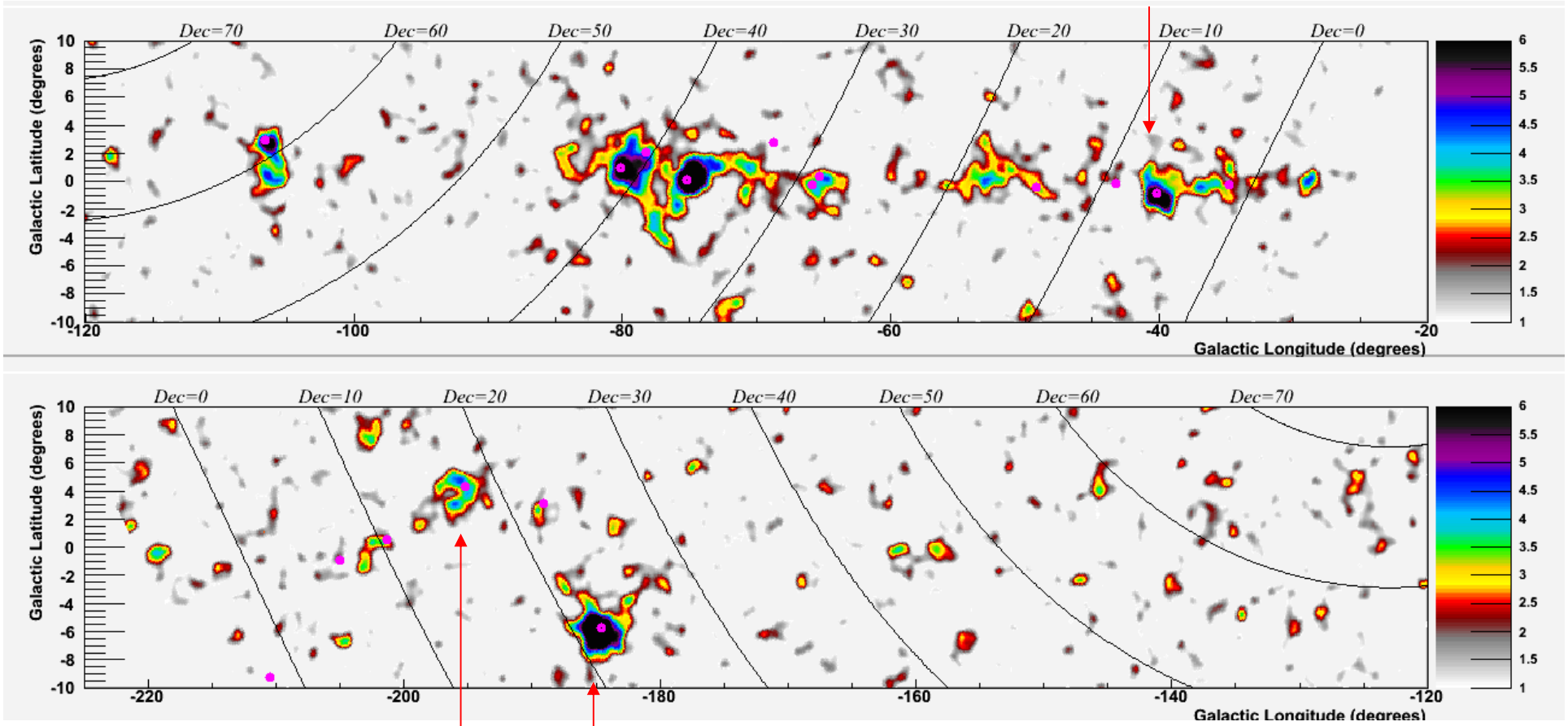
Slide from W. Hofmann
TeV PA 2009



Werner Hofmann, TeV PA 2009

B. Dingus

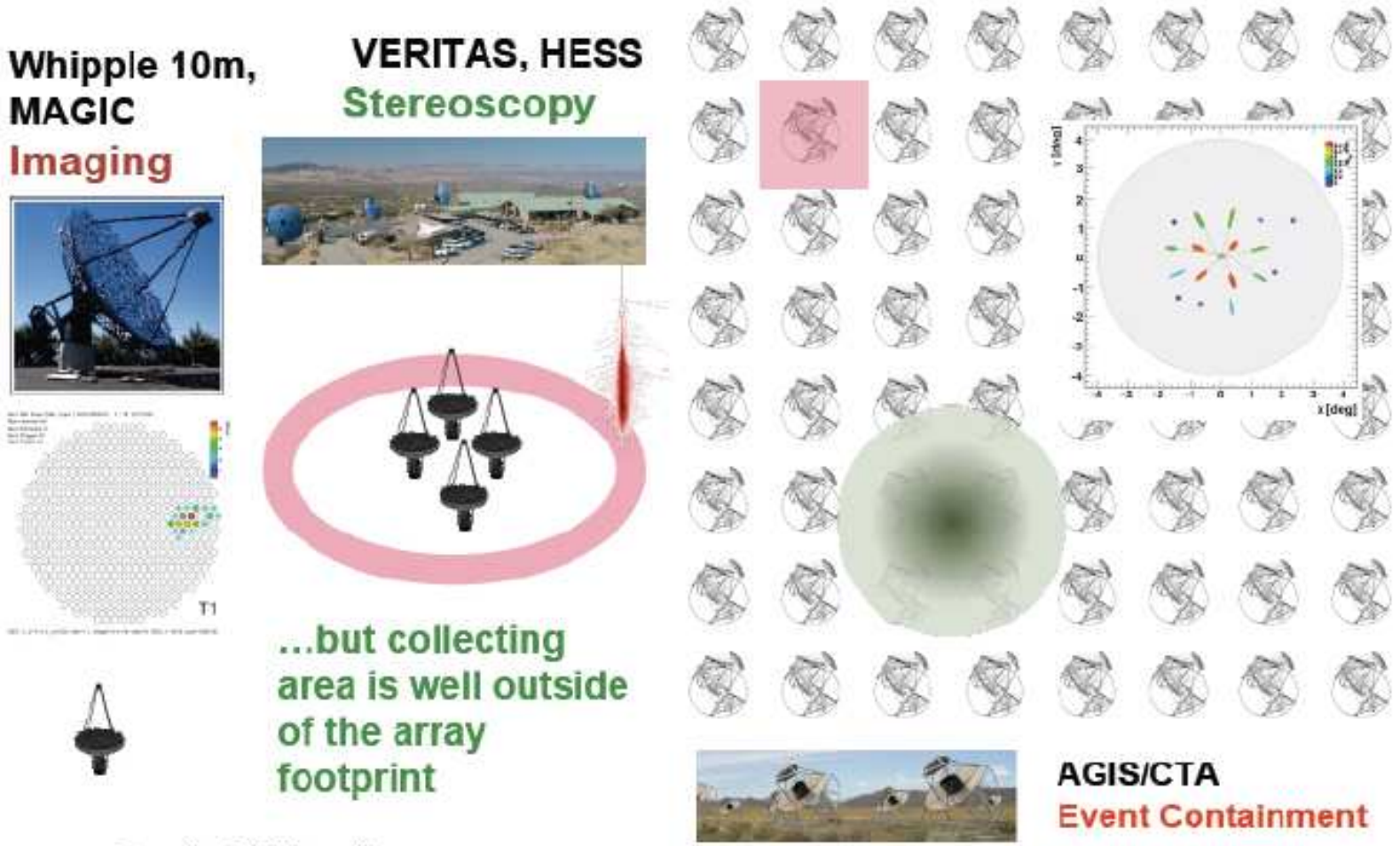
MILAGRO survey



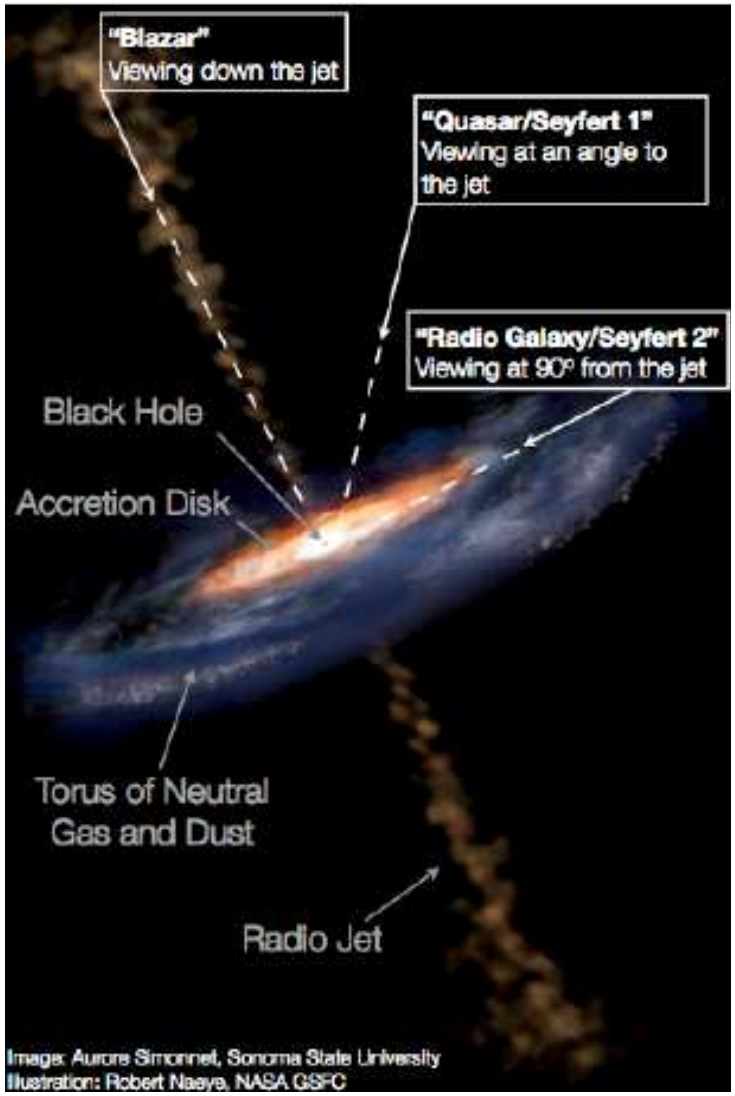
Energy range ~5 … 100 TeV

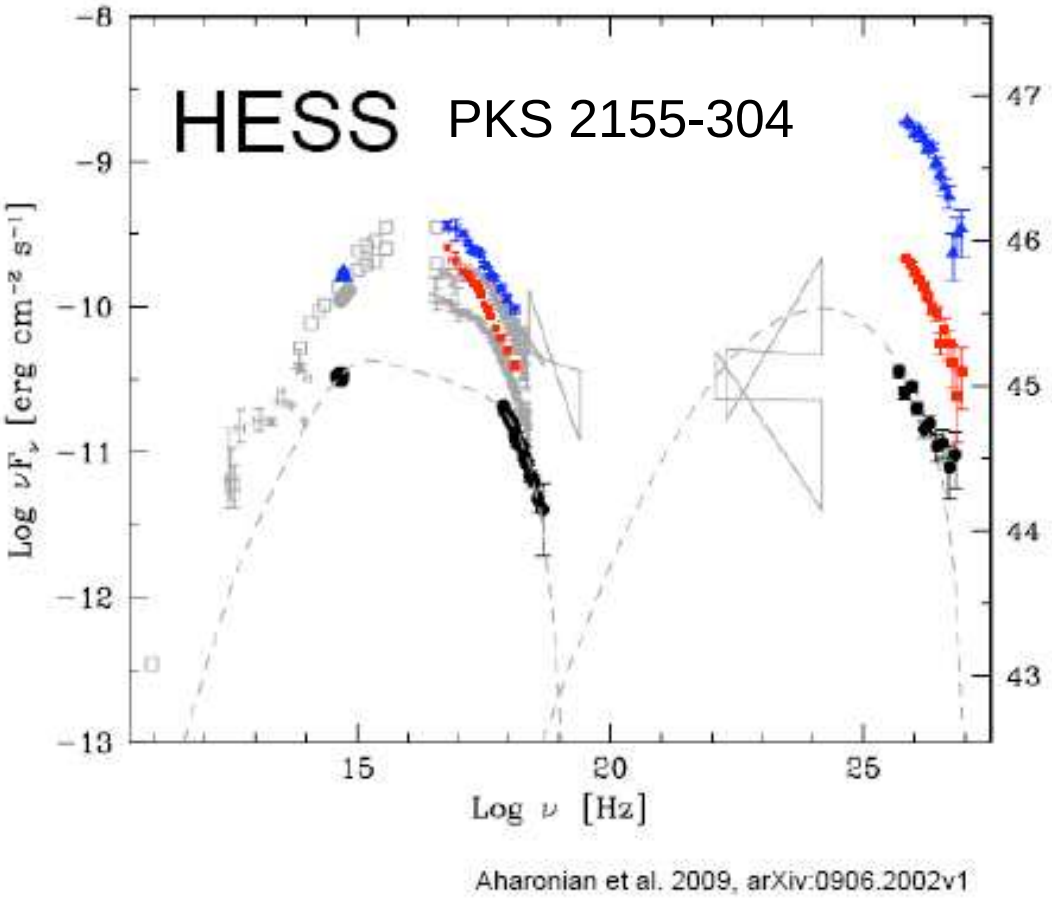
Future γ-ray telescope arrray: CTA / AGIS

from Stefan Funk's talk on future detectors at TeV PA 2009



Blazars

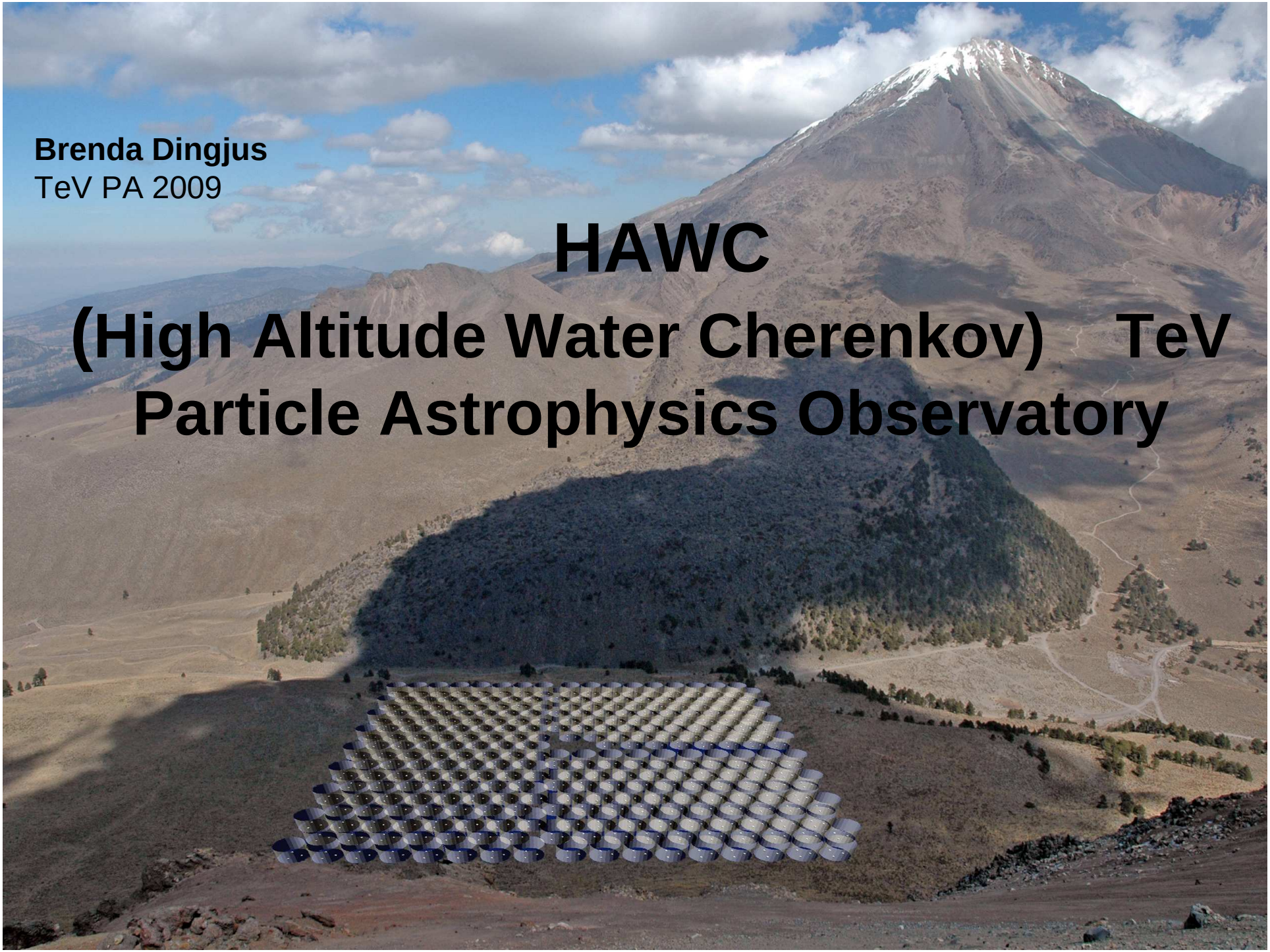




Aharonian et al. 2009, arXiv:0906.2002v1

Brenda Dingjus
TeV PA 2009

HAWC
(High Altitude Water Cherenkov) TeV Particle Astrophysics Observatory

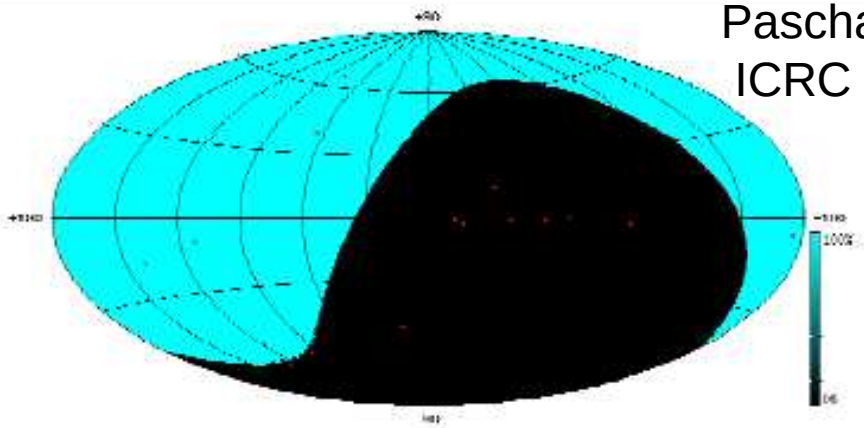


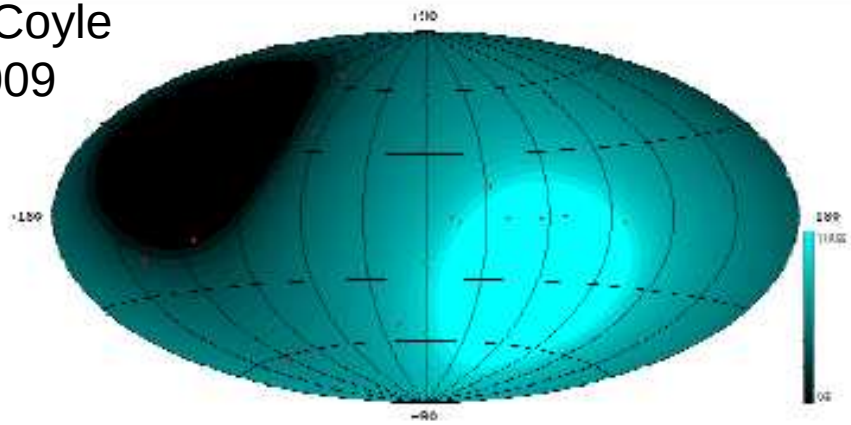
Region of Sky Observable by Neutrino Telescopes

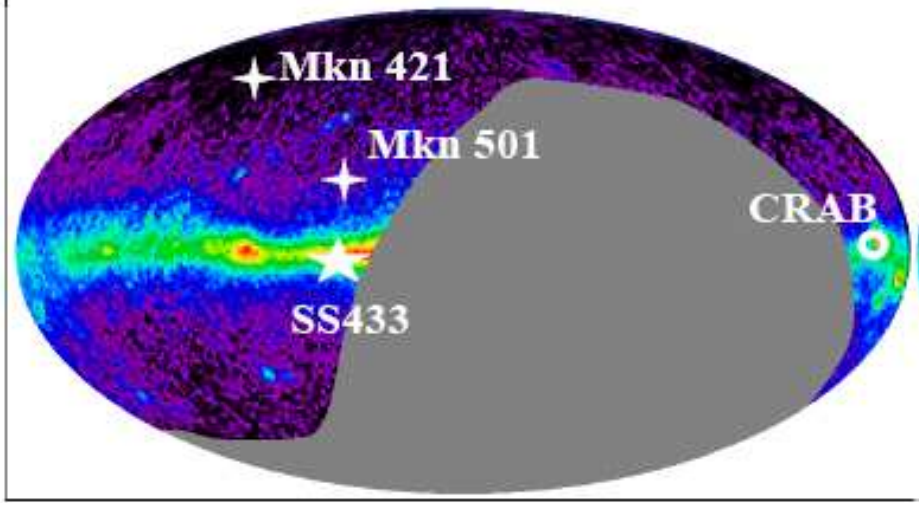
AMANDA/IceCube (South Pole)
(Ice: ~2°/0.6°)

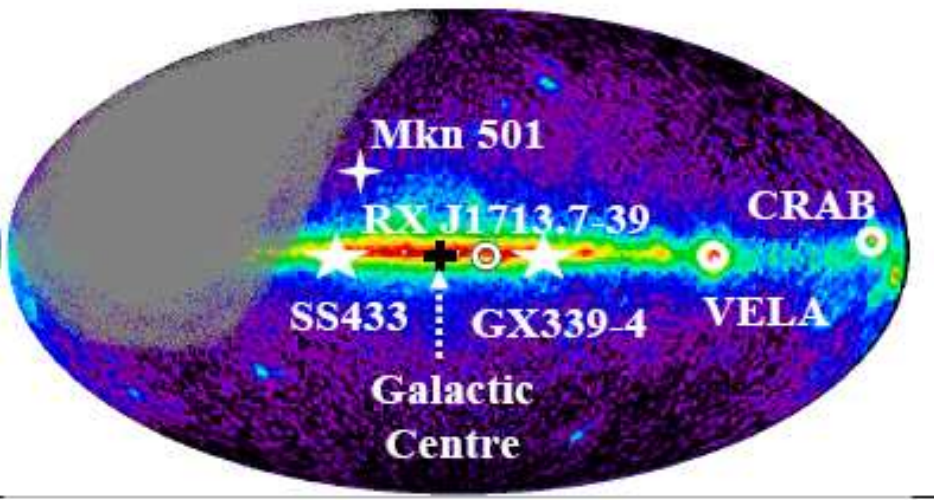
ANTARES/KM3 (43° North)
(water: ~0.2°/0.1°)

Paschal Coyle
ICRC 2009





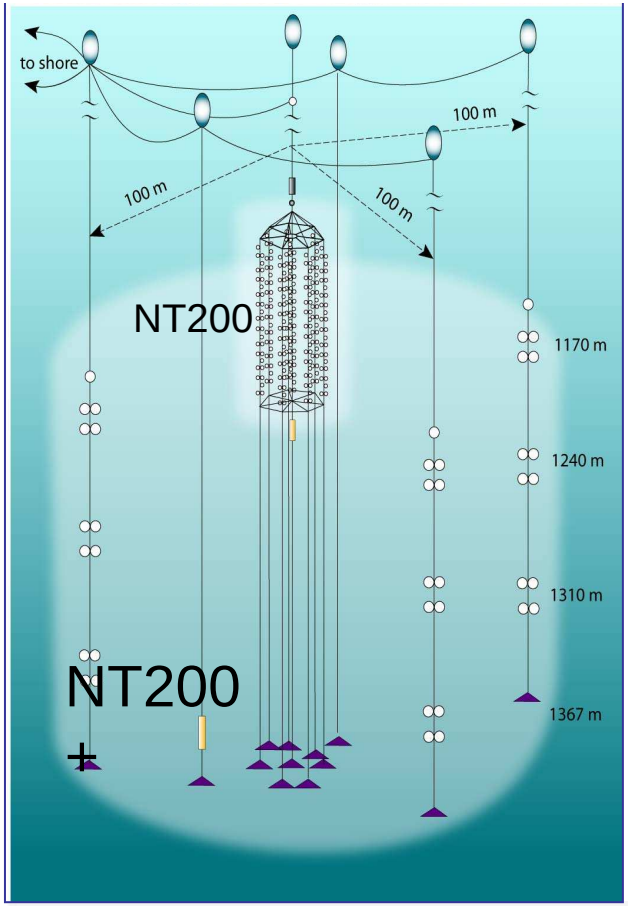




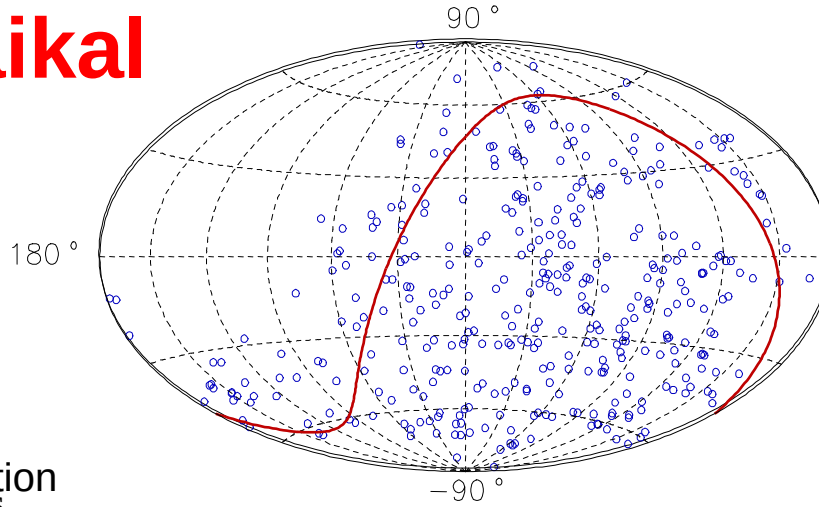
Atmospheric vs astrophysical ν

- Atmospheric
  - $\nu_\mu : \nu_e : \nu_\tau \sim 2:1:0$
  - Steady flux
  - $\sec(\theta)$ distribution
  - Steep spectrum
  - ν_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

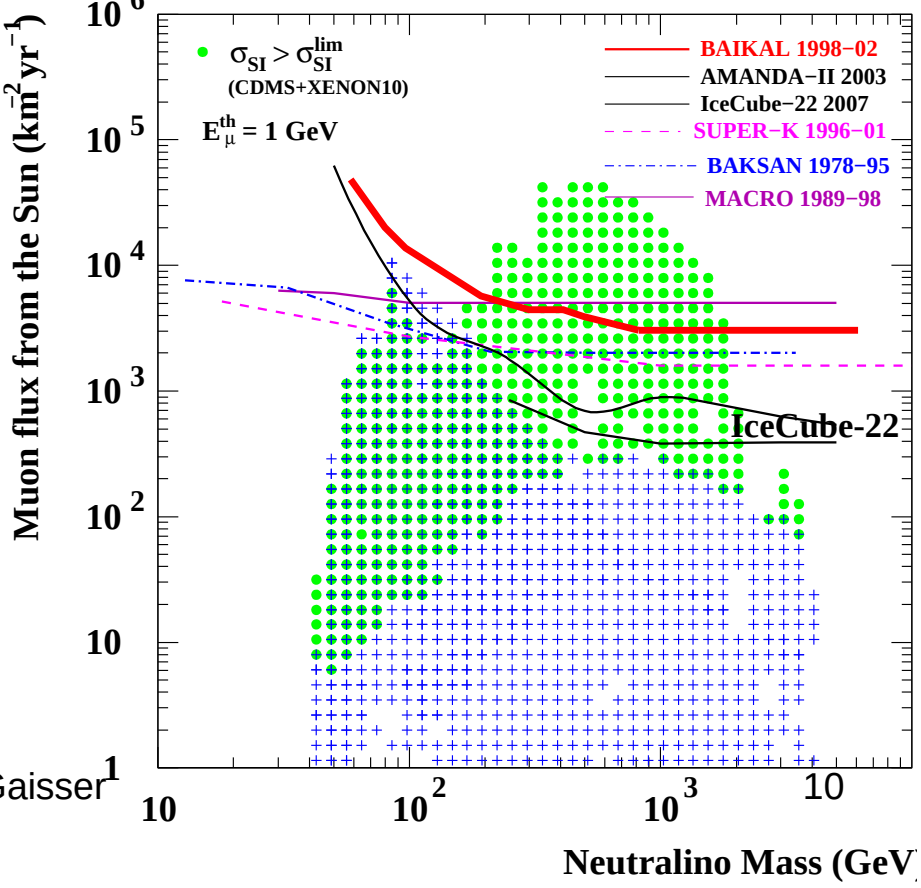
Lake Baikal

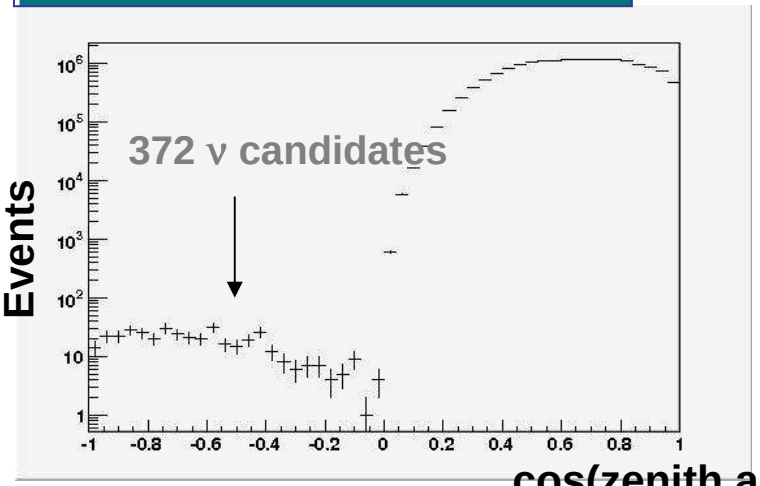


skymap



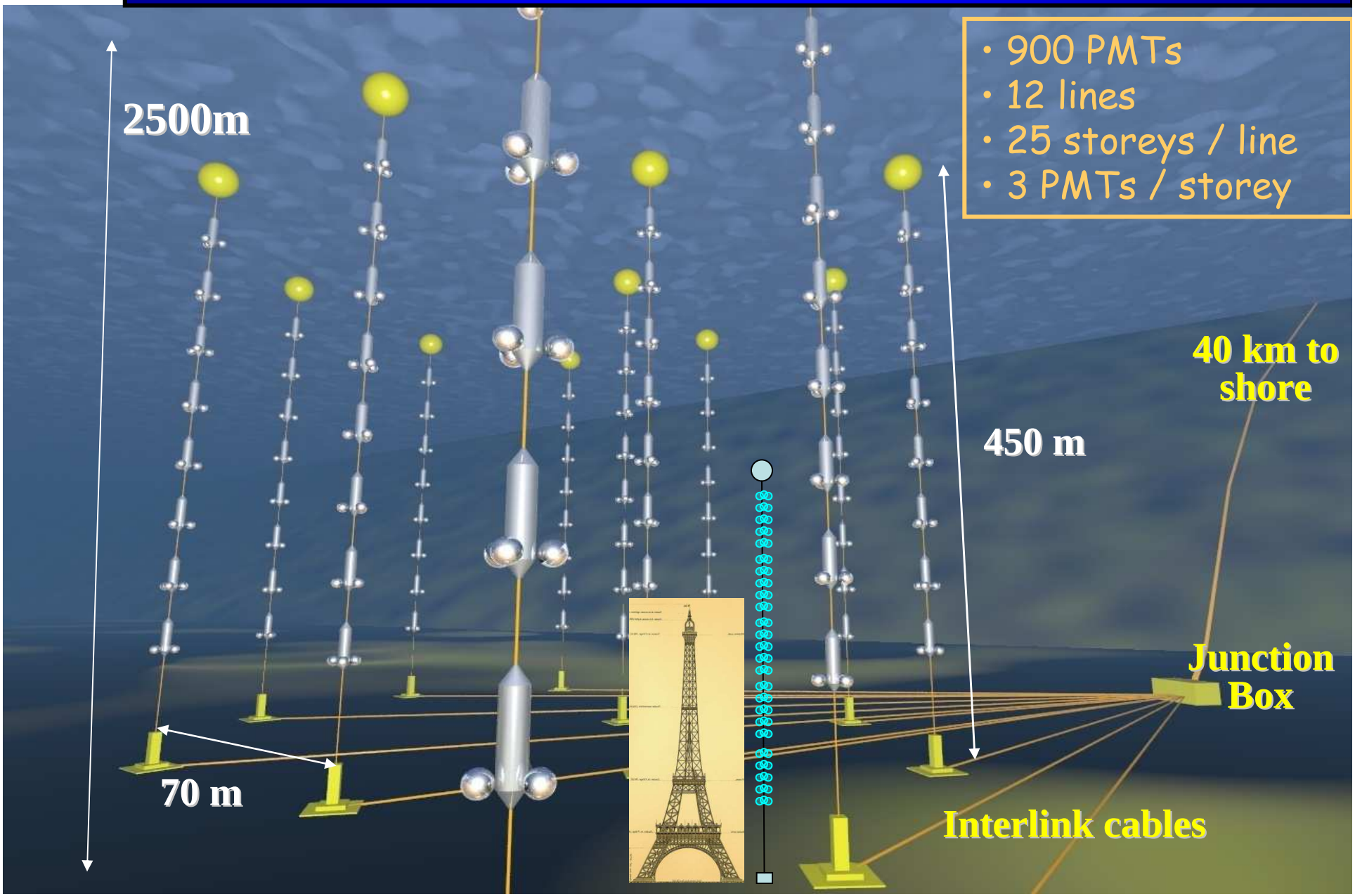
Limits on muon flux from WIMP annihilation in the Sun





Tom Gaisser

The ANTARES Detector



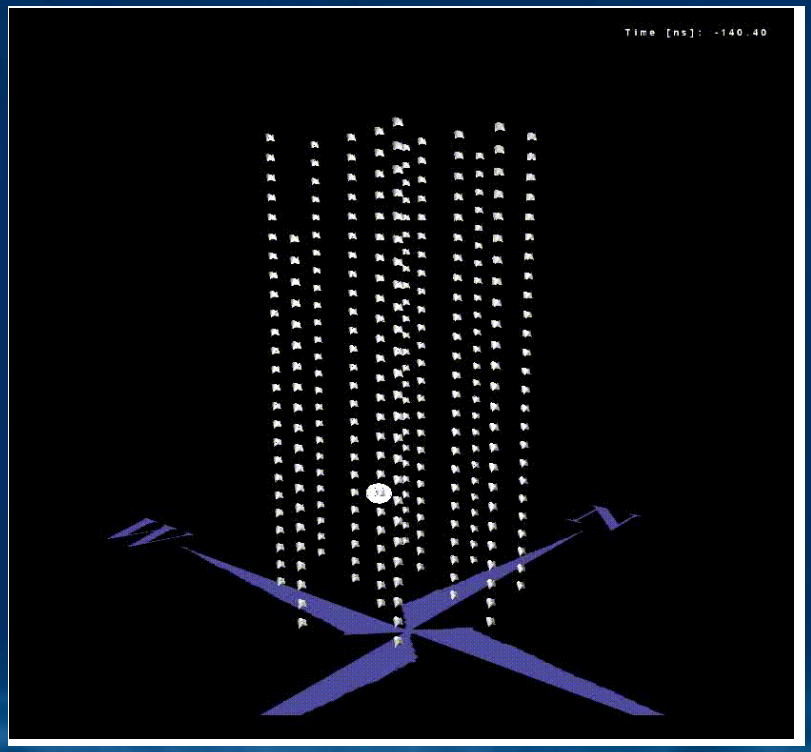
- 900 PMTs
- 12 lines
- 25 storeys / line
- 3 PMTs / storey

Water vs Ice

- Water
  - Scattering length >= absorption length
    - More direct hits, easier reconstruction
  - Noisy environment
- Ice
  - Scattering length < absorption length
    - More scattered light, complicates reconstruction
  - Very quiet environment
    - <~ 500 Hz

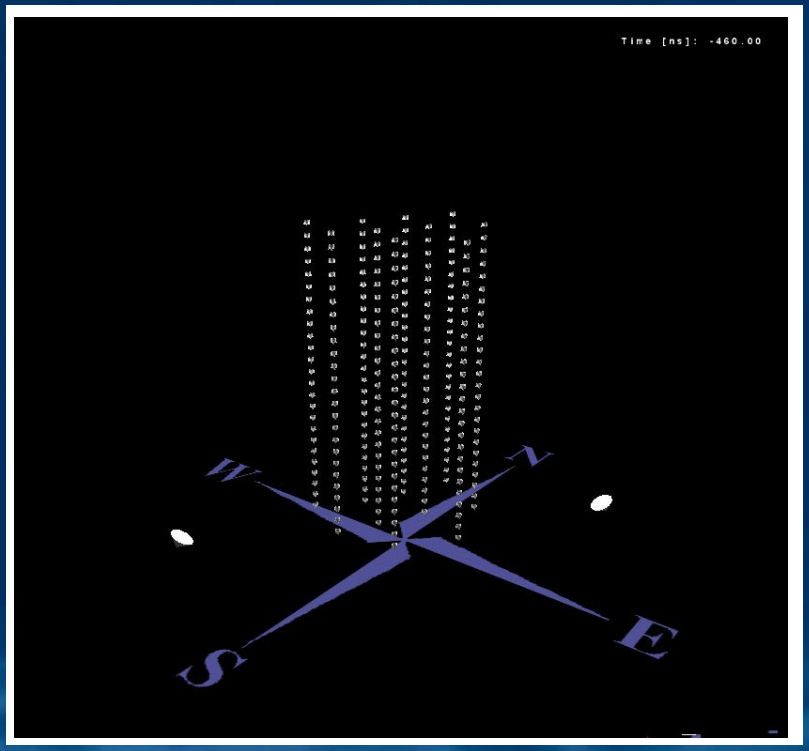
Atmospheric muons

Example of a reconstructed down-going muon, detected in all 12 detector lines:

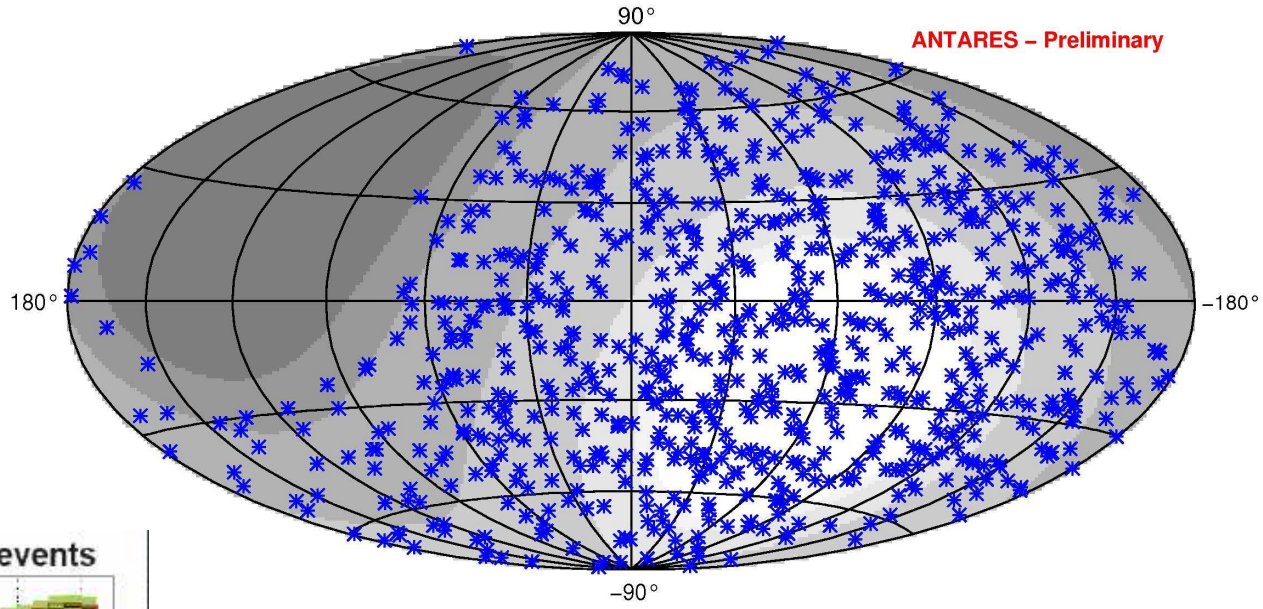


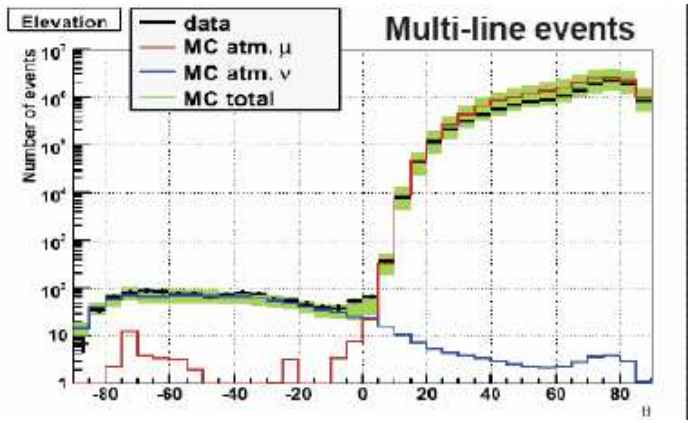
Neutrino-induced muon

Example of a reconstructed up-going muon (i.e. a neutrino candidate) detected in 6/12 detector lines:



Antares sky map





750 neutrino events from below, combined 2007-2008 data

(Paschal Coyle, ICRC 2009)

AMANDA 2000-2006

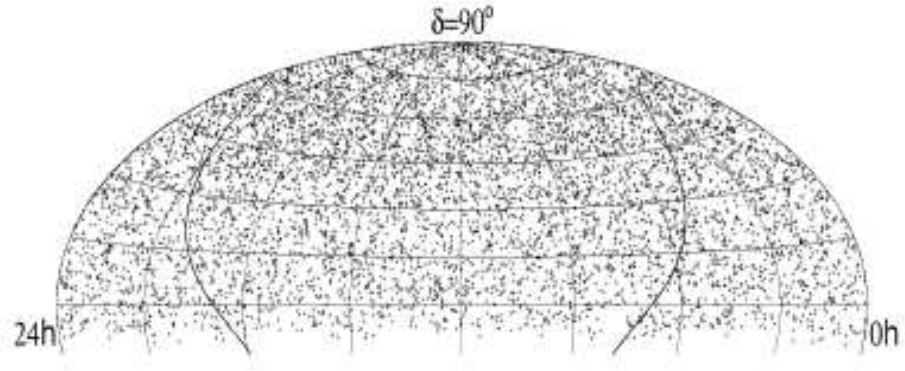


FIG. 1: Equatorial sky map of 6595 events recorded by AMANDA-II from 2000–2006.

AMANDA integrated into IceCube 2007 – 2008.

Coincident analysis in progress

AMANDA turned off on May 11, 2009

To be replaced by Deep Core sub-detector

IceCube

IceCube timeline

In the ice:

2005: 1 string

2006: 9 strings

2007: 22 strings (publishing)

2008: 40 strings (analyzing)

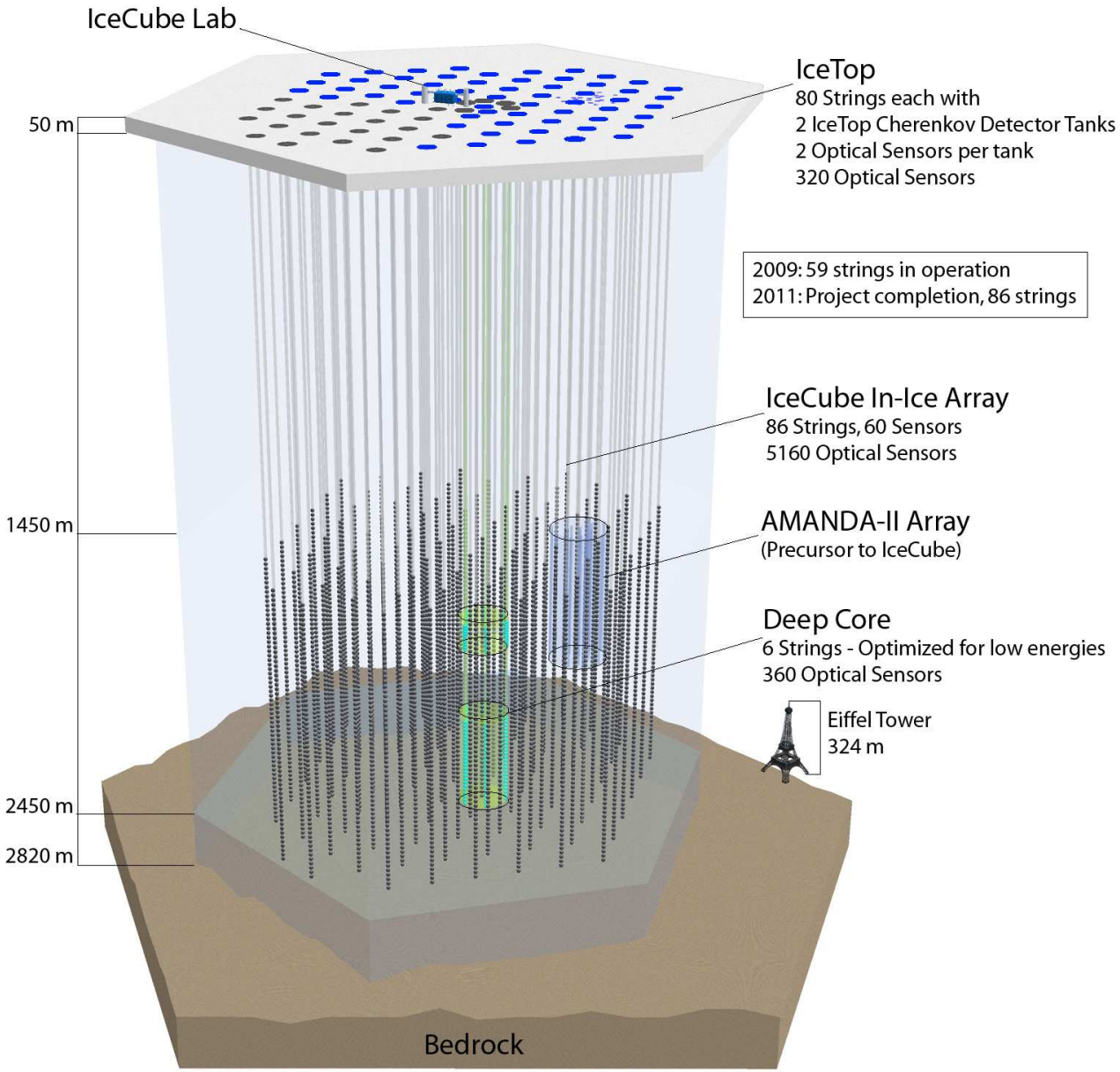
2009: 59 strings (running)
(includes 1 deep core)

Planned:

2010: 77 strings
(includes 6 deep core)

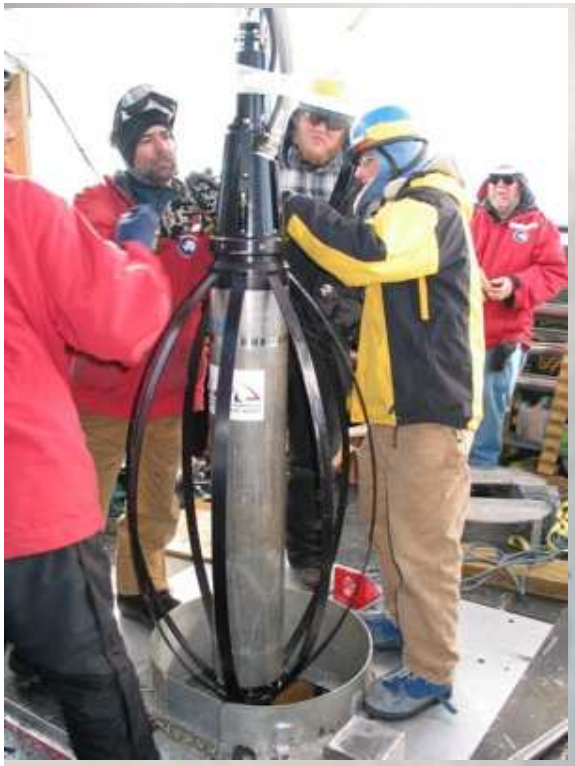
2011: 86 strings
(includes 6 deep core)

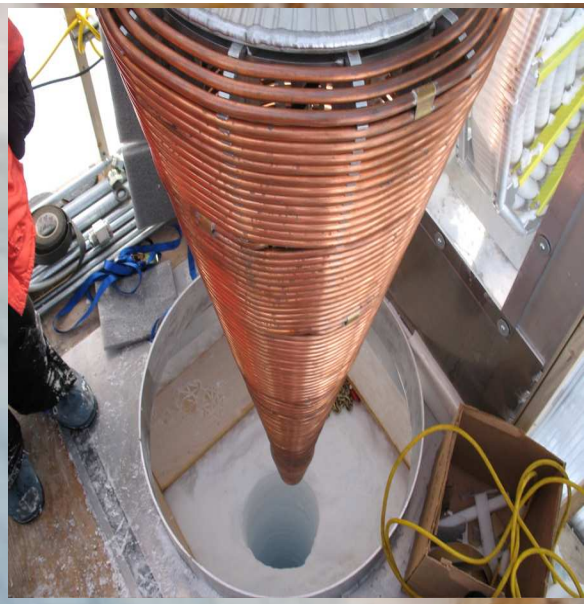
15-year design lifetime



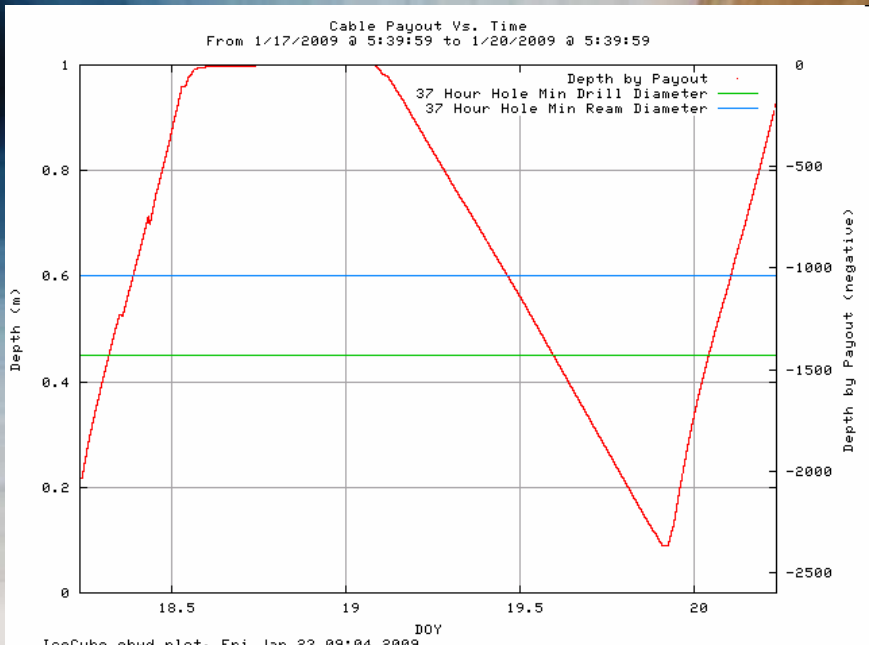
Berlin, 2 Oct 2009

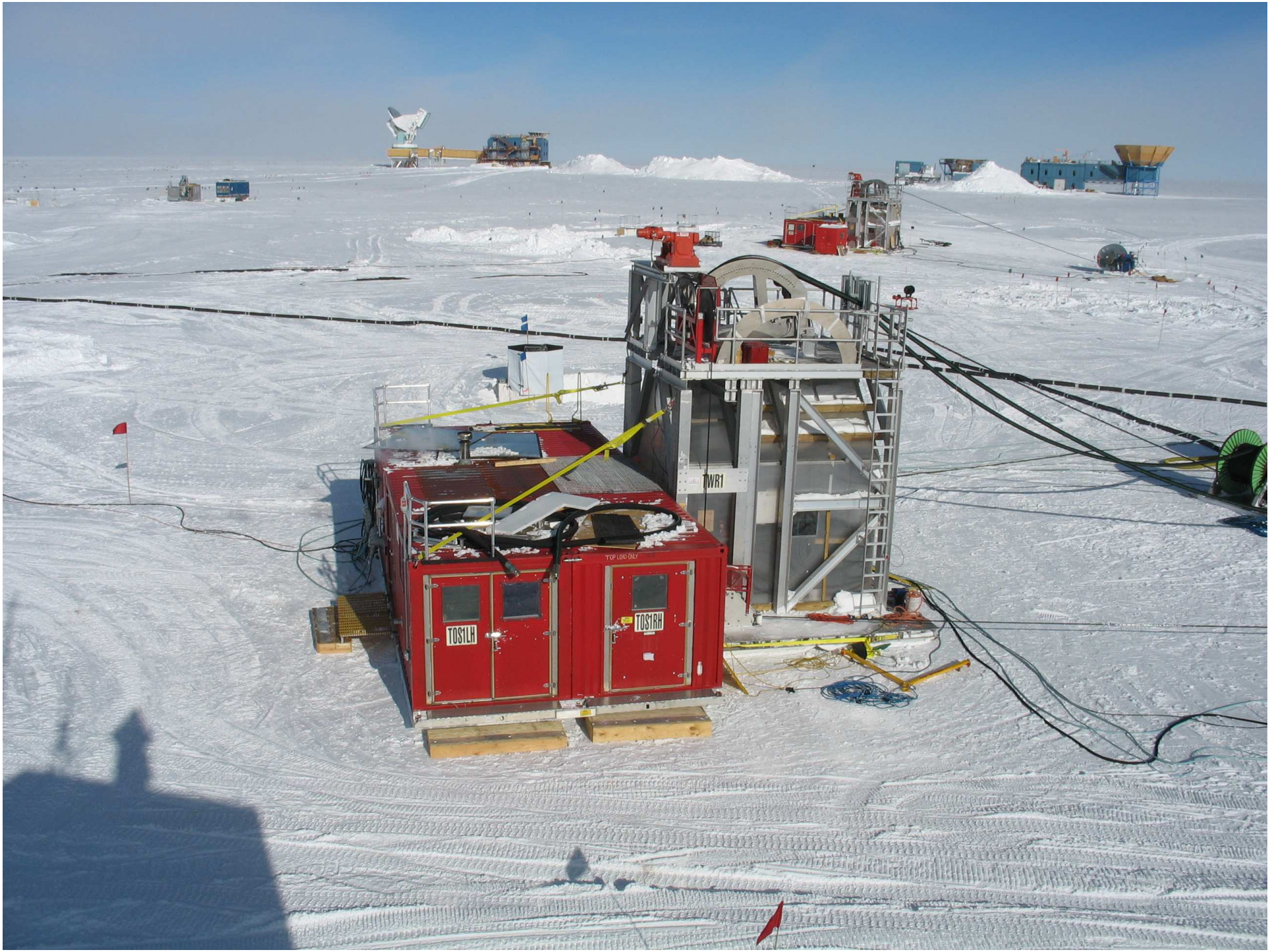
Drilling





Drill with hot water under high pressure
5000 gallons of fuel per hole




TOP LOAD ONLY
TOS1LH
TOS1RH
TWR1

Digital Optical Module (DOM)

IceTop

- **Two tanks per station for calibration**
- **High-gain, low-gain DOMs for dynamic range**
- **Waveforms give some μ/e discrimination at the surface**

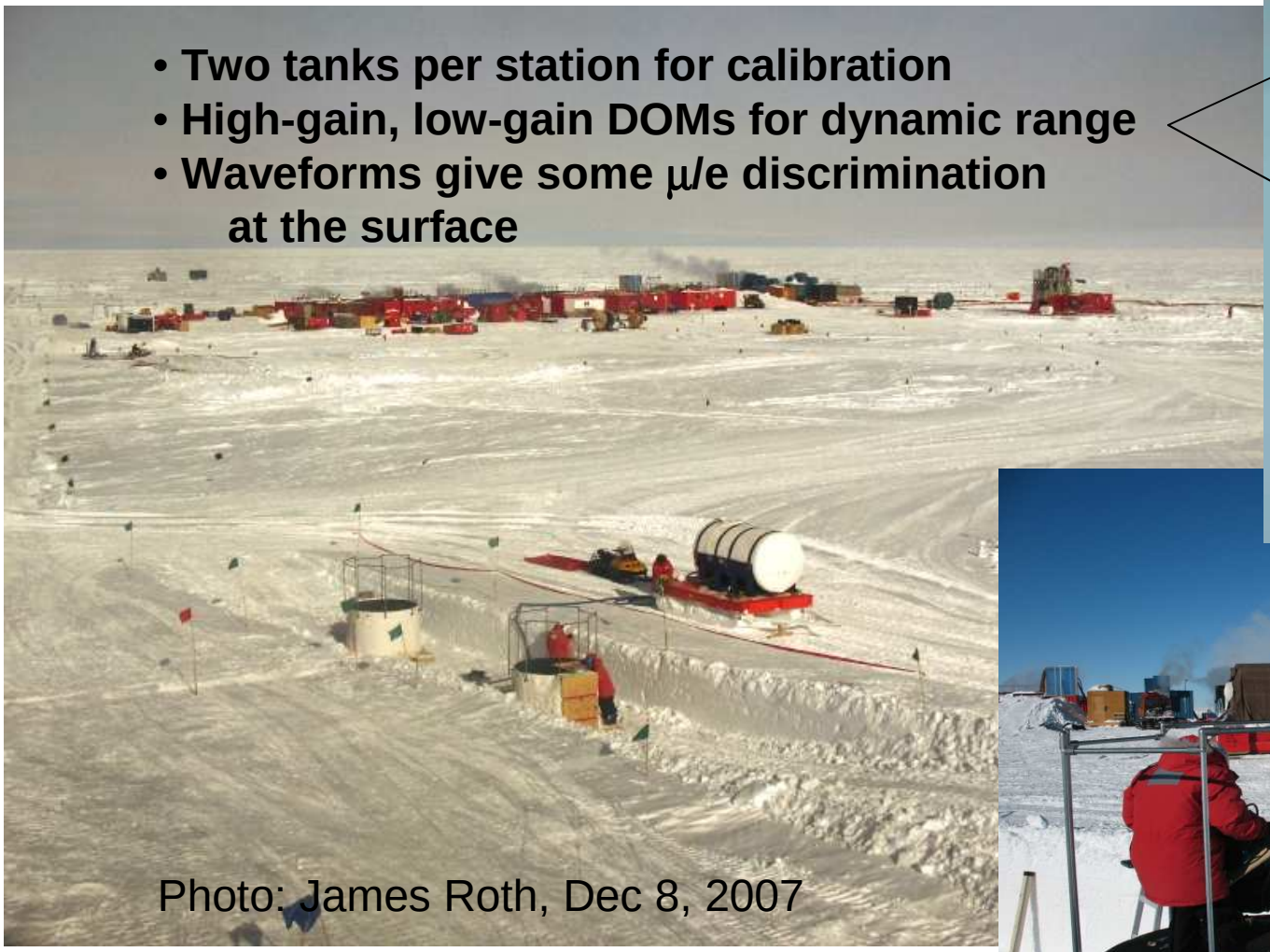
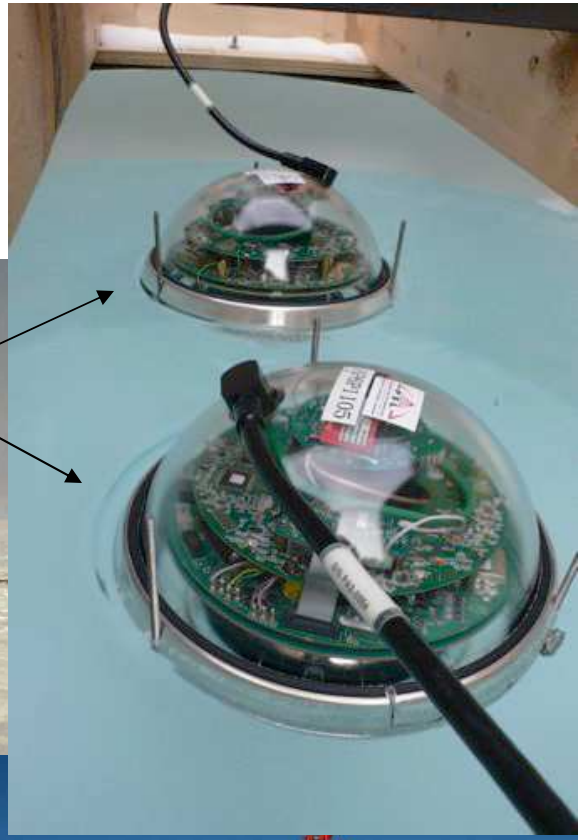


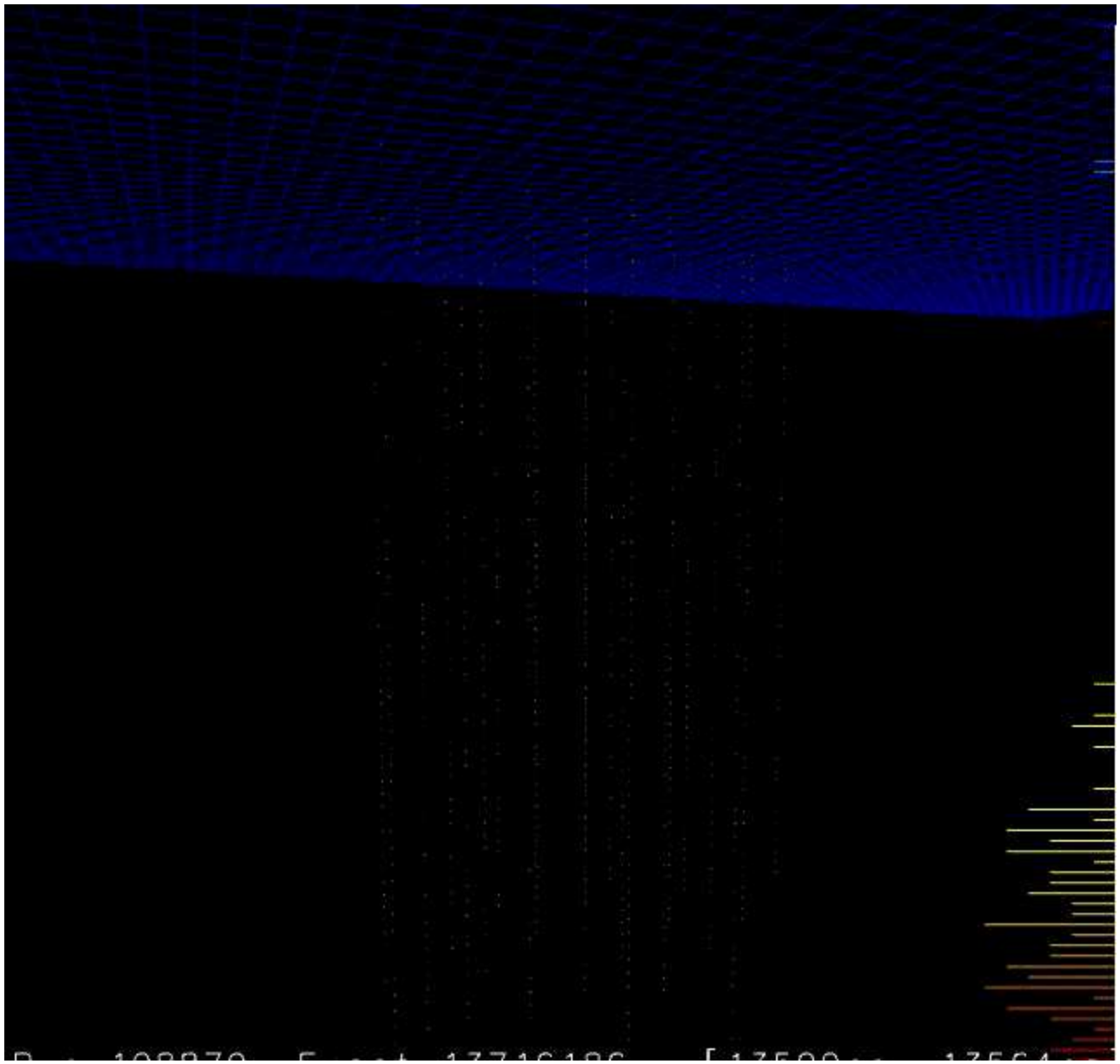
Photo: James Roth, Dec 8, 2007



Nov 23, 2007

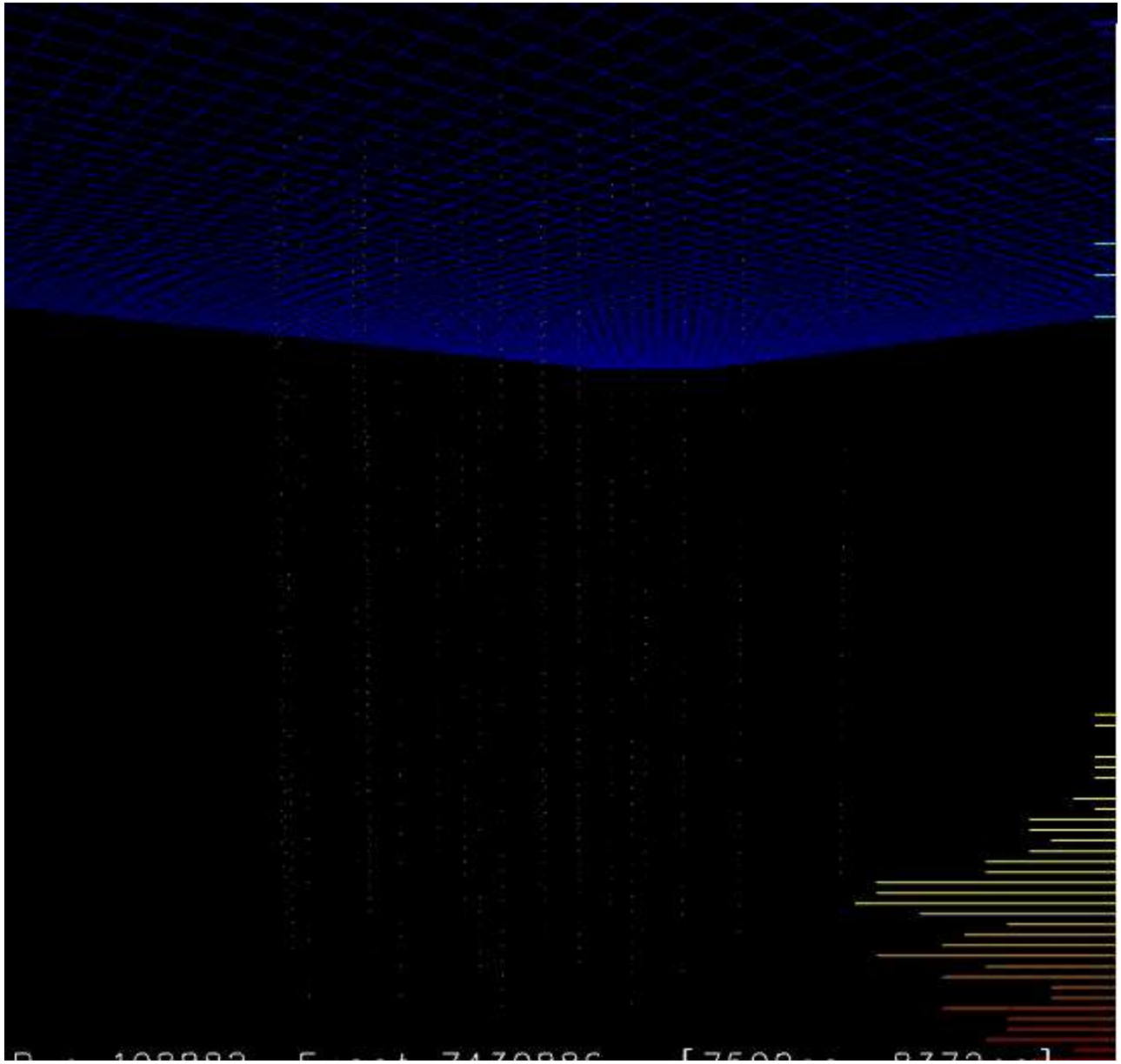
Photo: Jim Haugen

IC-22: Nearly horizontal atmospheric muon across top of detector

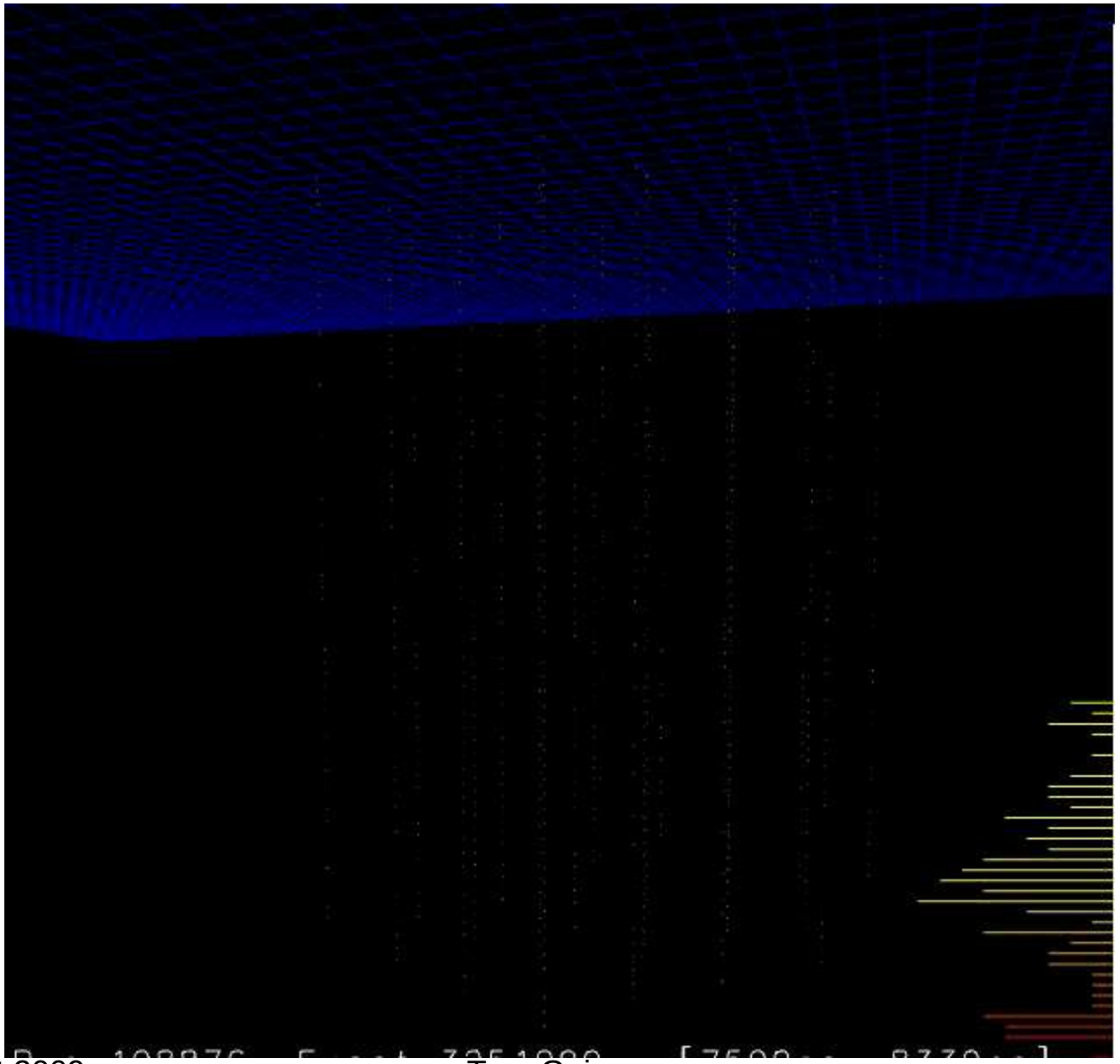


anim_07

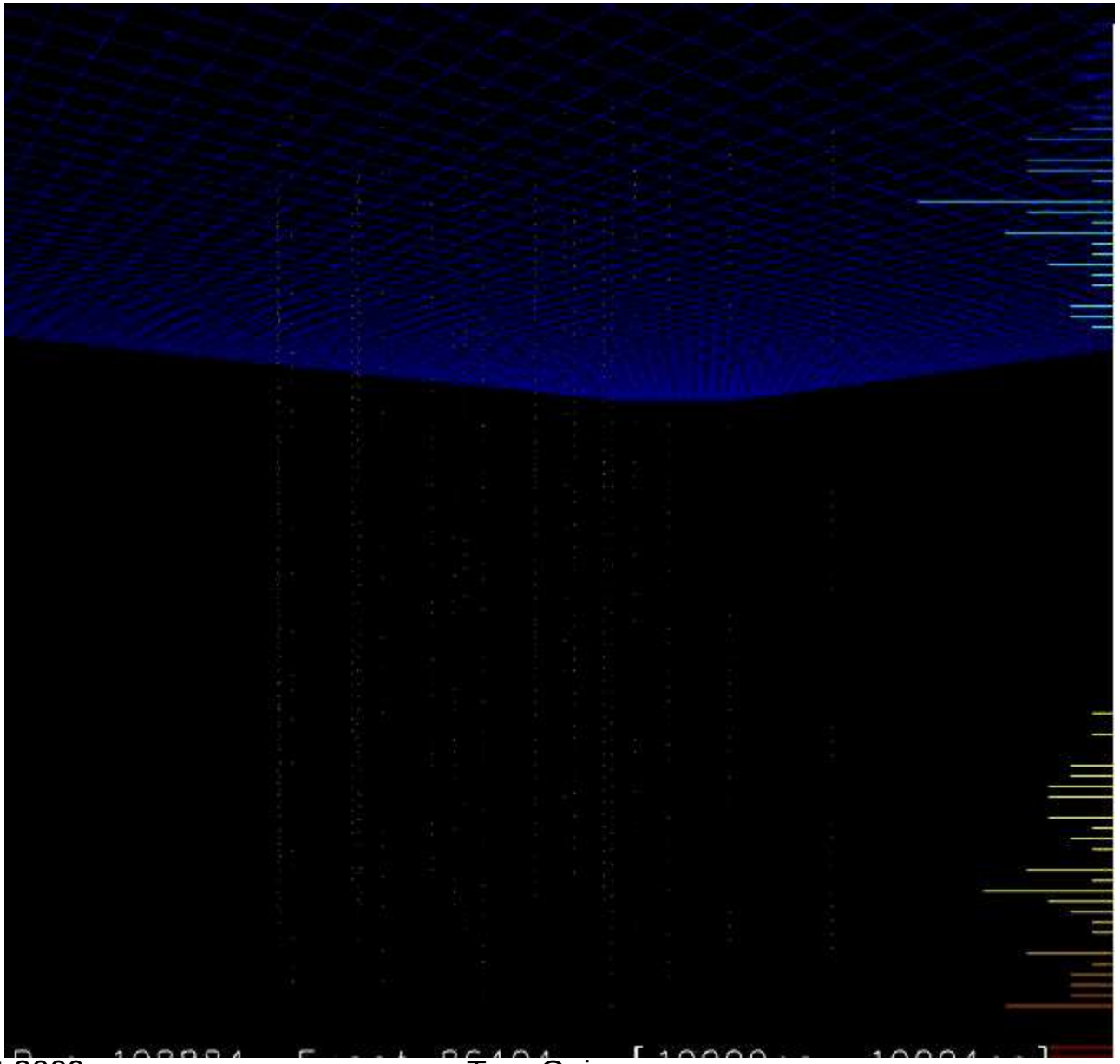
IC-22: Nearly horizontal atmospheric muon across bottom



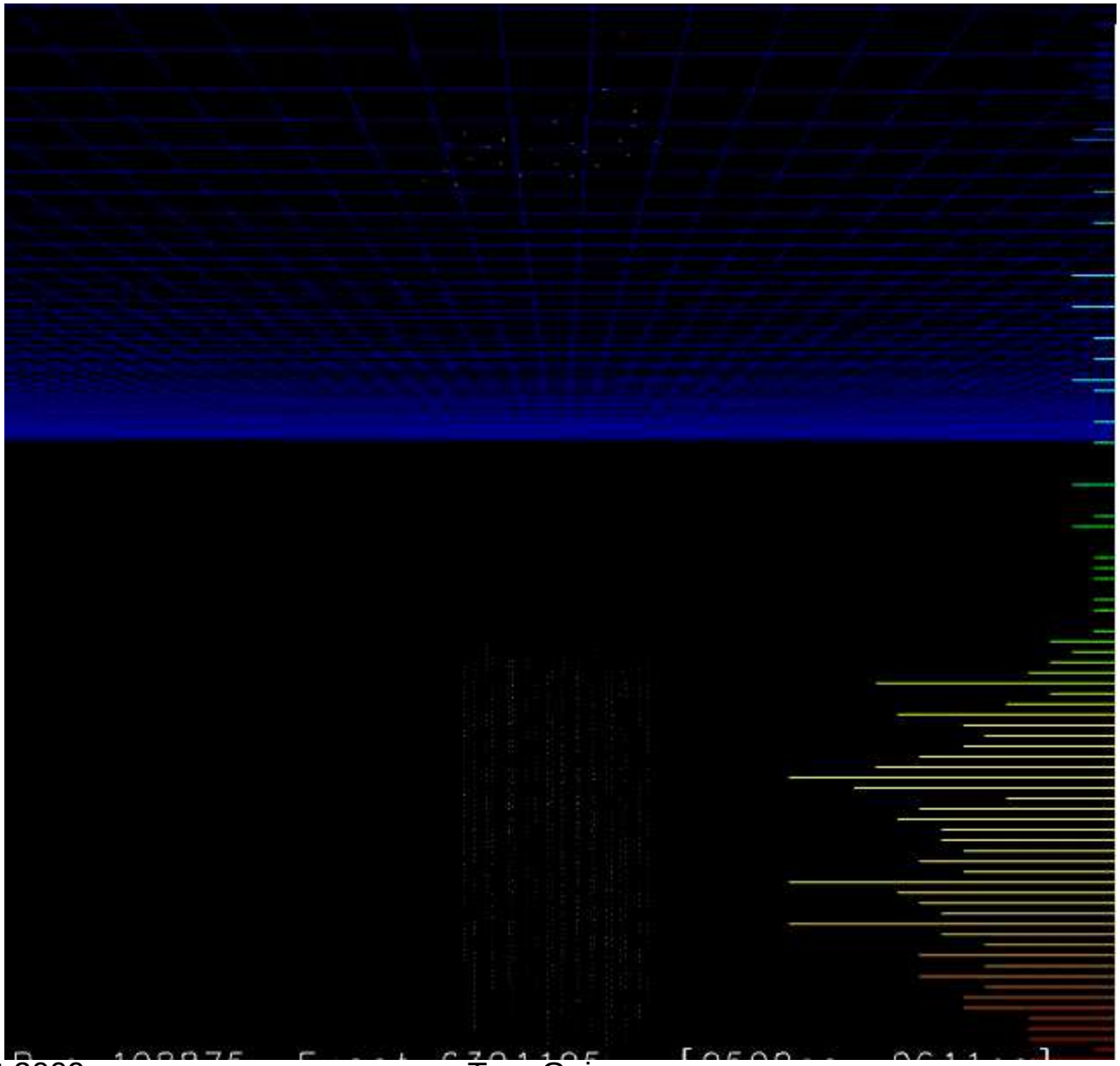
IC-22: Horizontal event in bottom of detector – neutrino candidate?



ICj-22: Two unrelated atmospheric muons

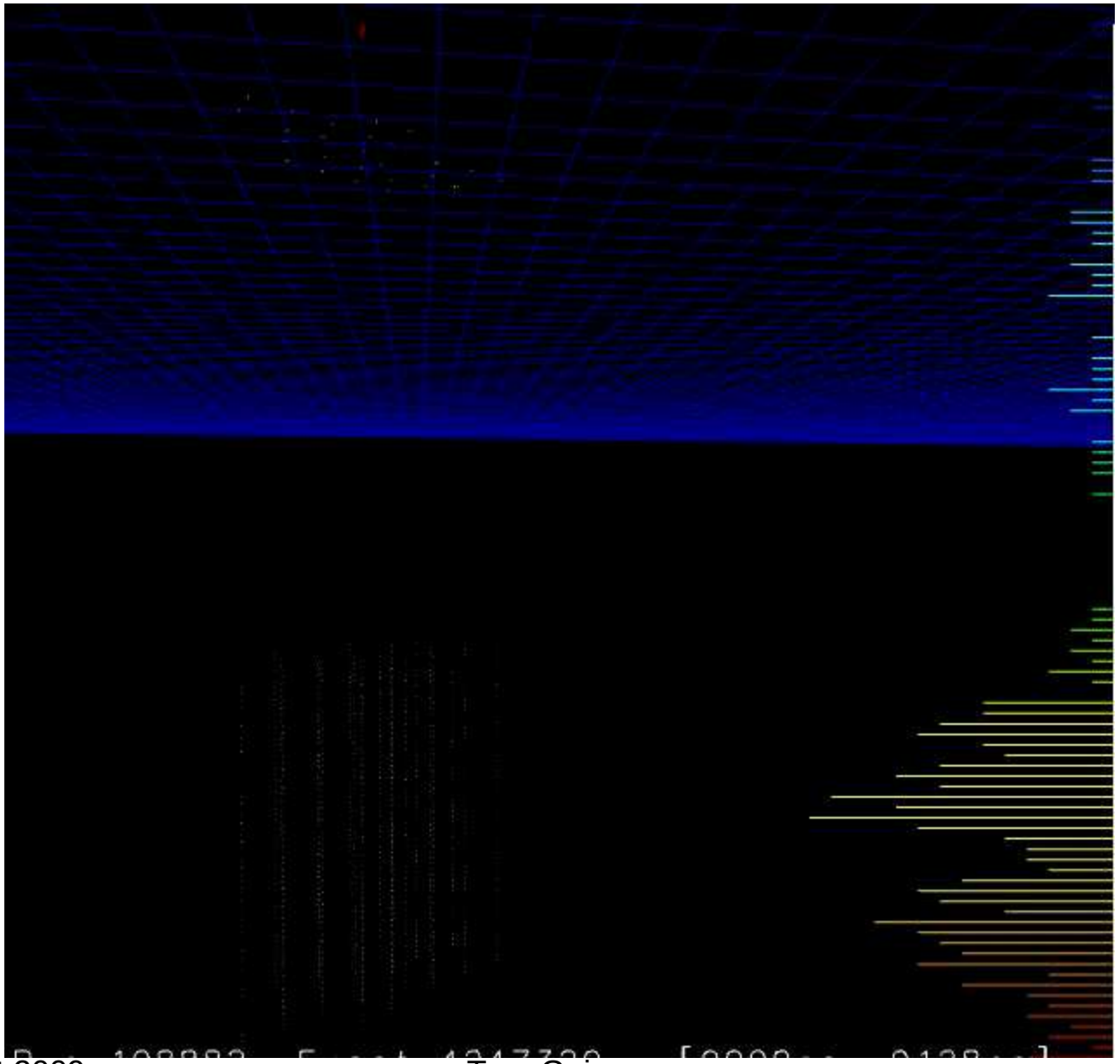


IC-22 / IT-26 coincident event



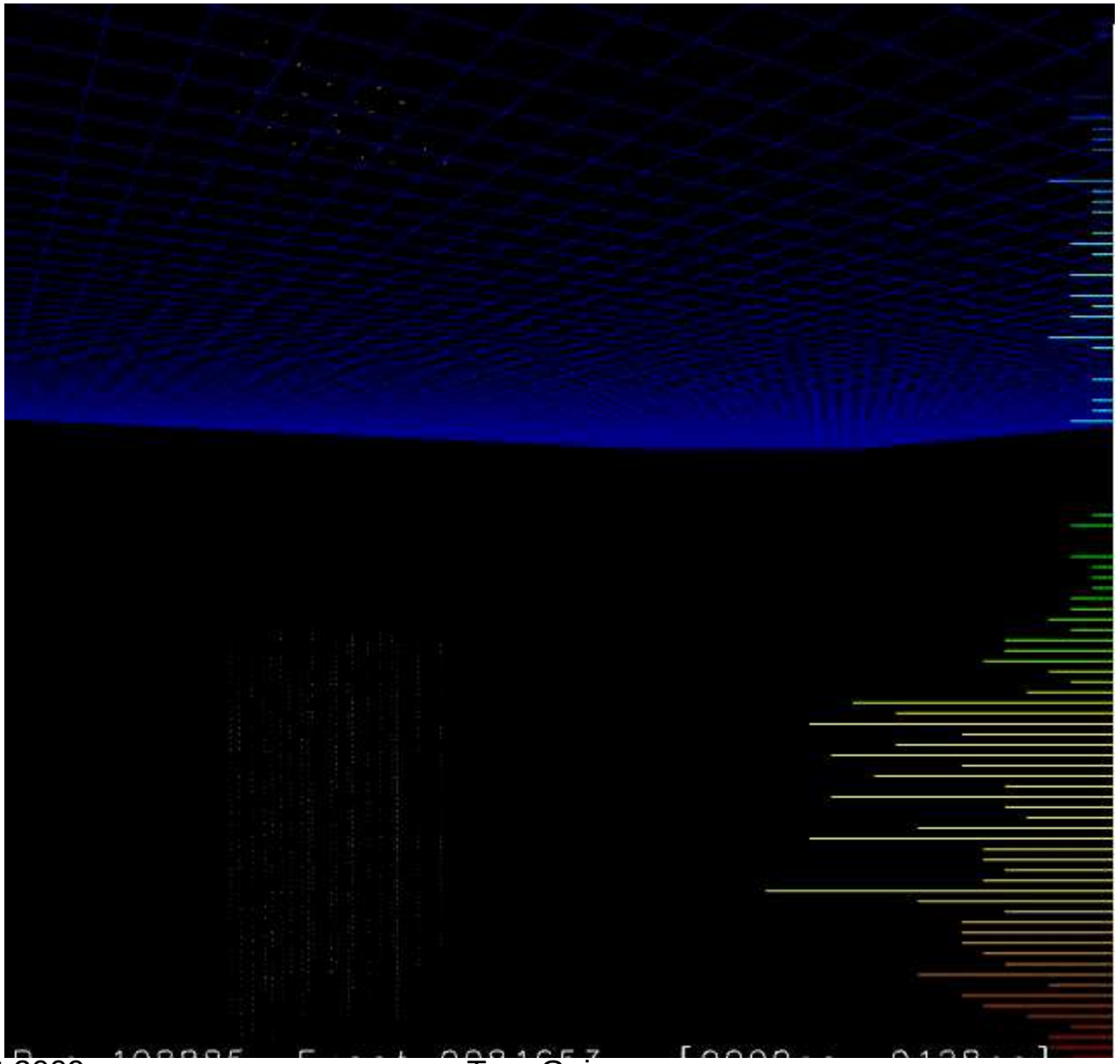
anim_co_01.mpg

IC-22 / IT-26 coincident event



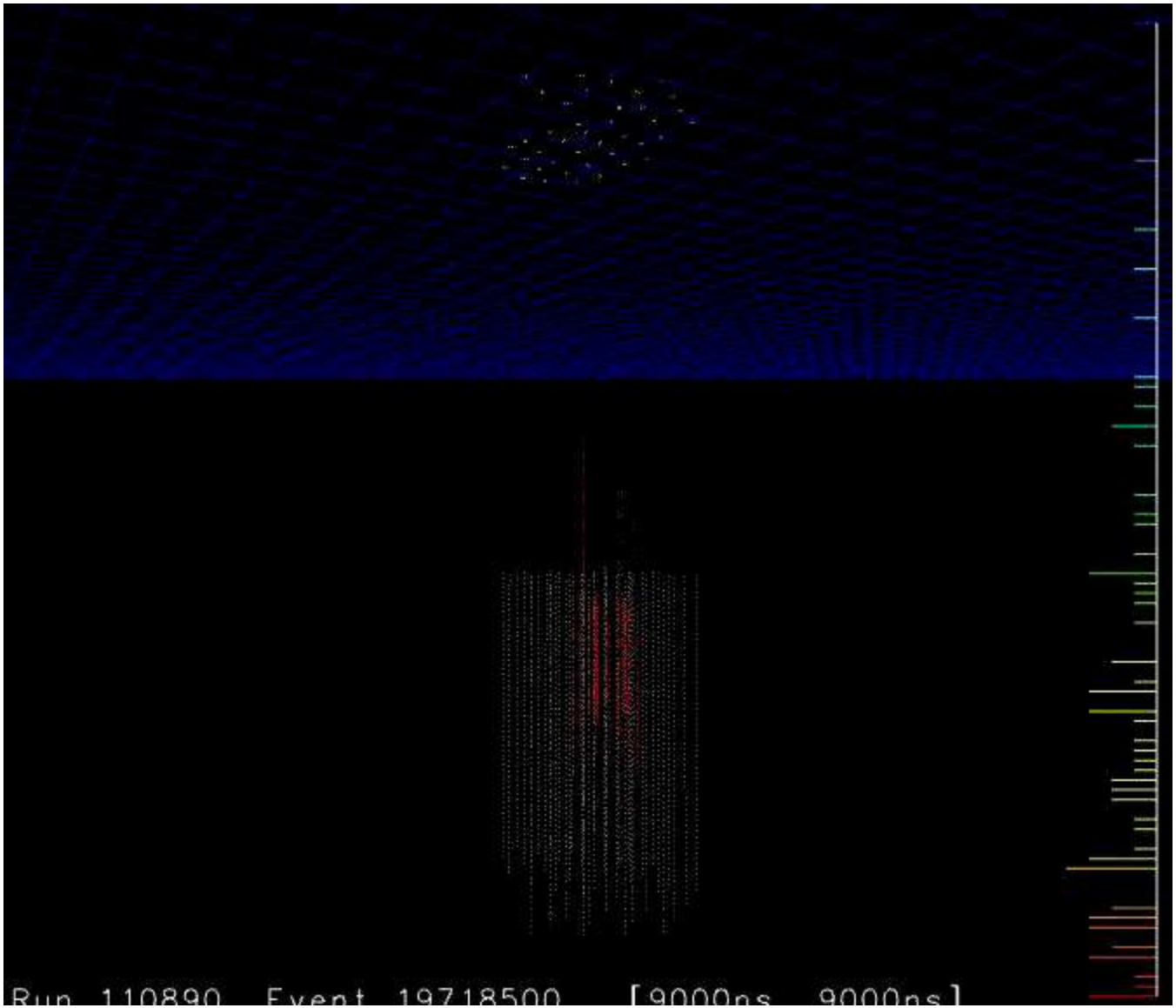
anim_co_02.mpg

IC-22 / IT-26 coincident event



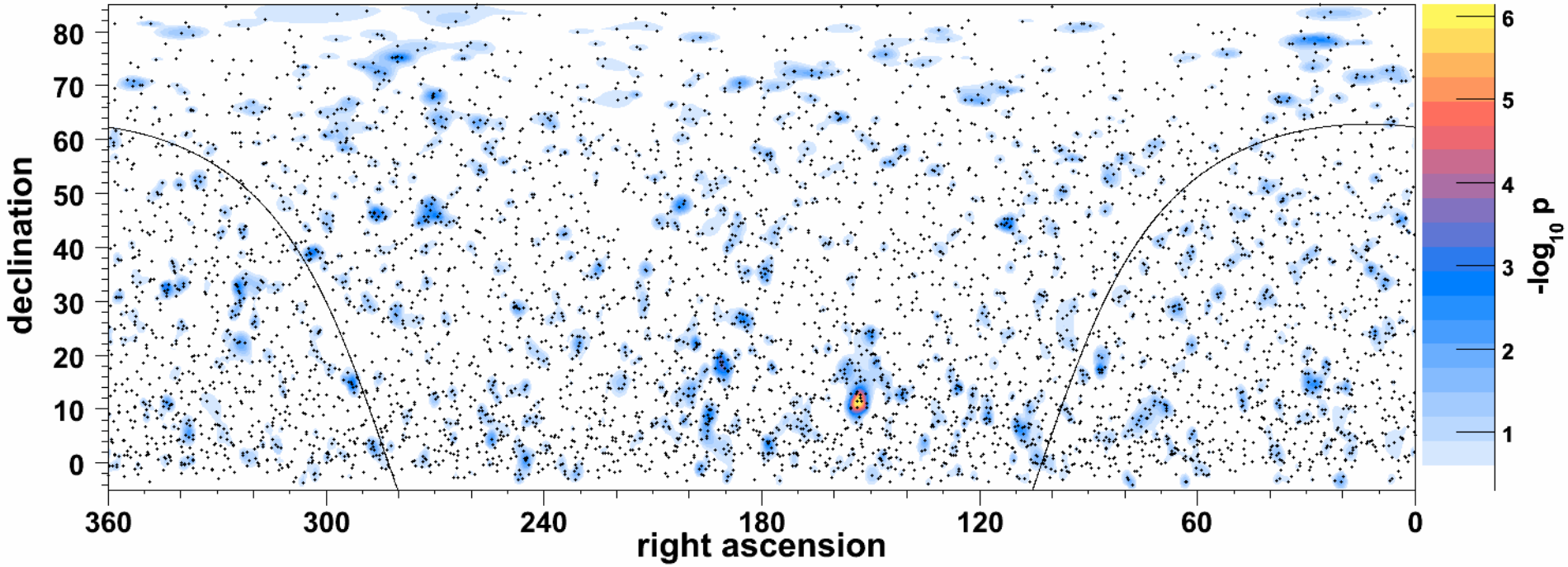
anim_co_03.mpg

IC-40: EeV coincident event (~2000 muons at 2 km of ice)



IC22 point source search

Ap.J.Letters (arXiv:0905.2253)

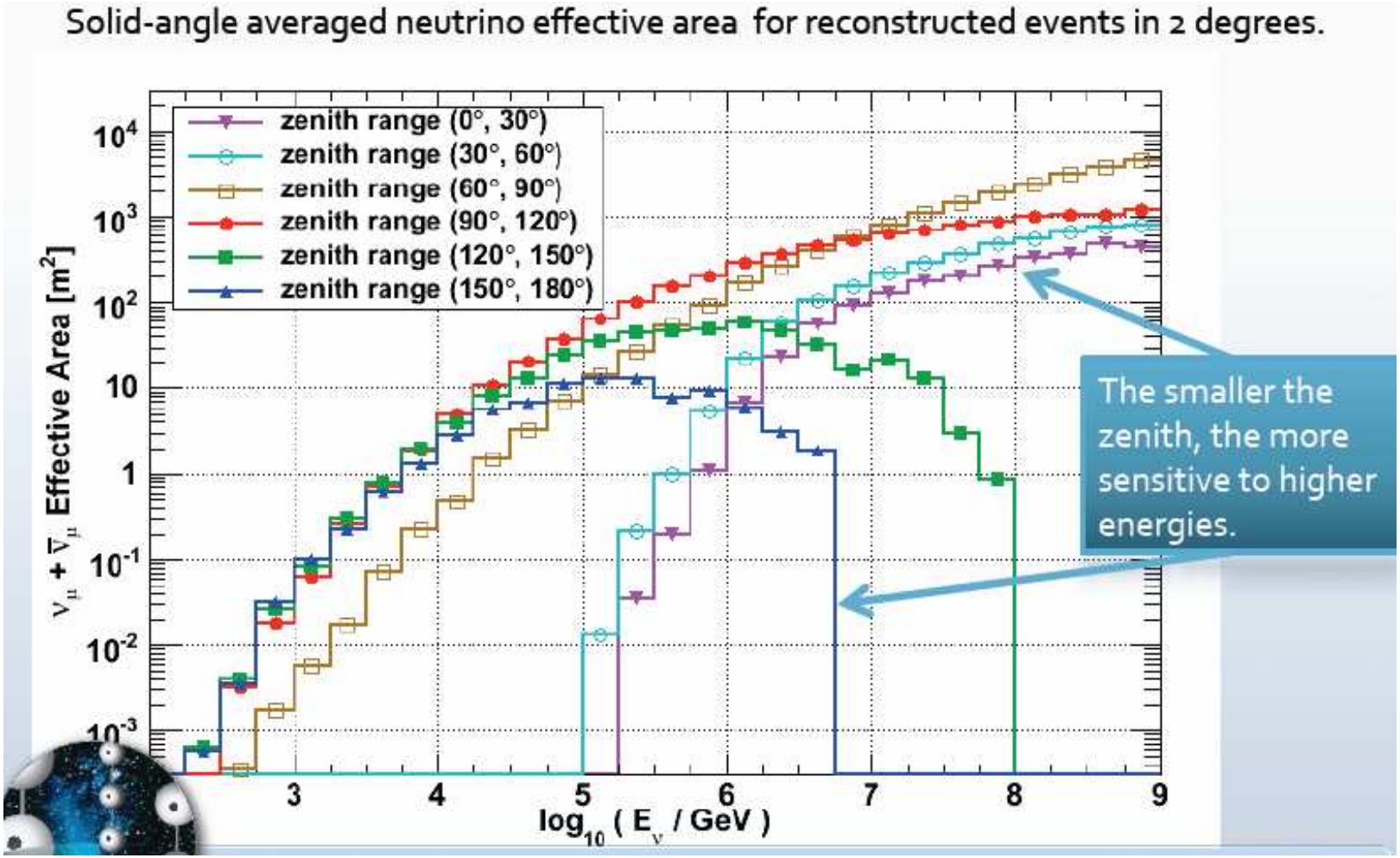


- 5114 neutrinos in 276 days live time with 95% on-time during operation.
- Unbinned maximum likelihood search (resolution-weighted direction + n-channel) with likelihood sampled every 0.25 r.a. x 0.25 dec.

Hottest spot: Cluster of 7-8 bright events
Post-trials probability of chance occurrence is 1.34%

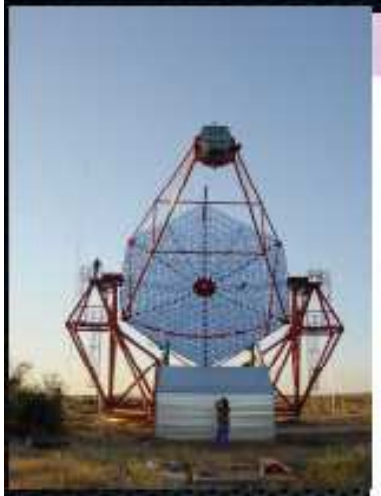
IceCube 40

Juan Antonio Aguilar
parallel session today



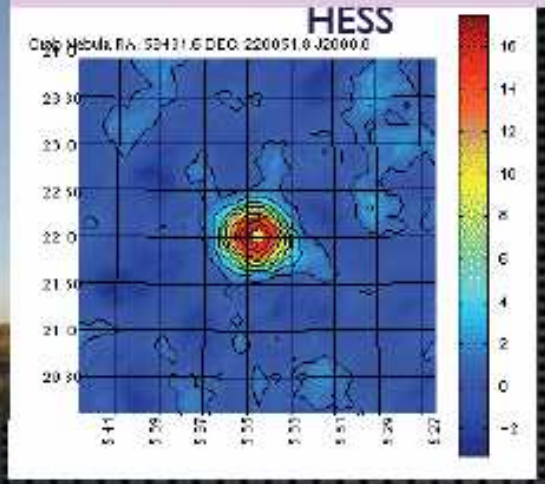
IC40 Moon shadow (slide from Teresa Montaruli, 15/7/09)

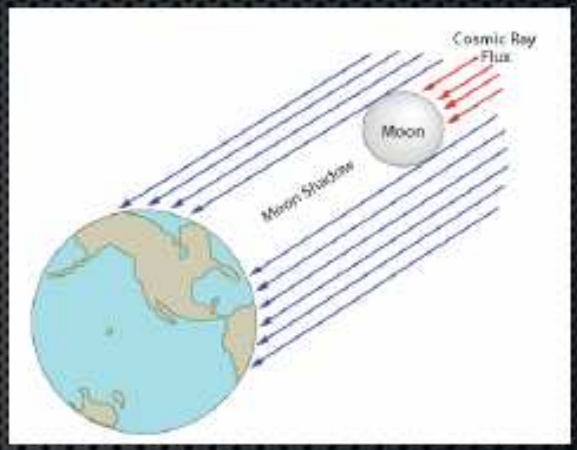
PSF in neutrino telescopes: Moon shadow



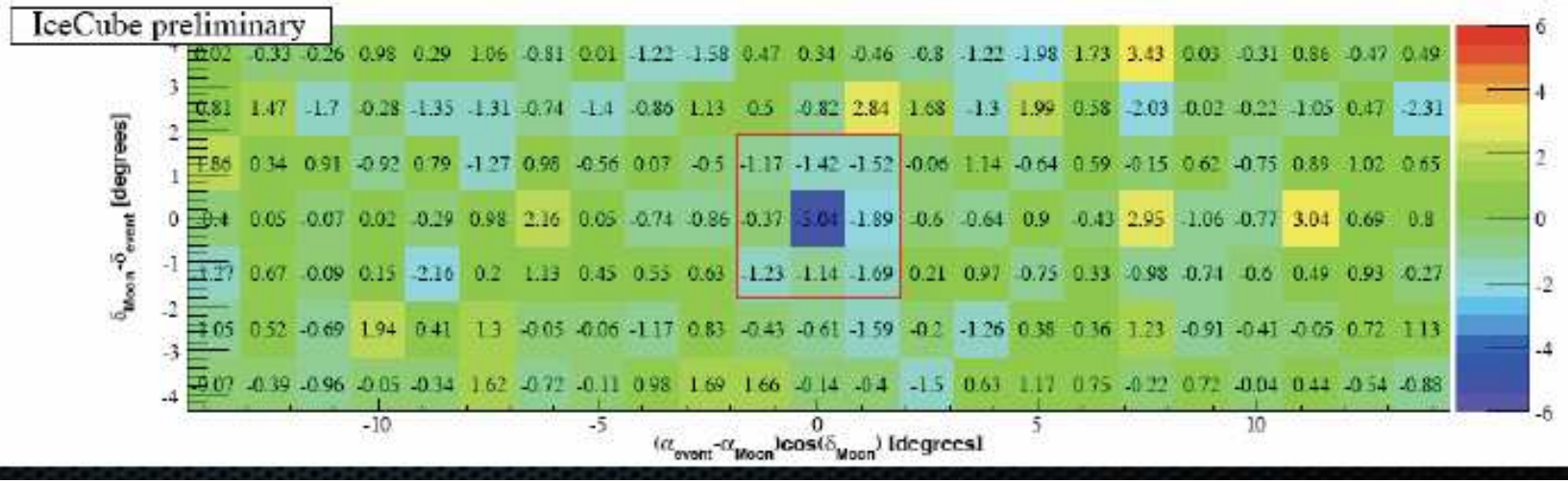
First Moon shadow in a neutrino telescope IceCube 5 sigma

OG 2.5 1173

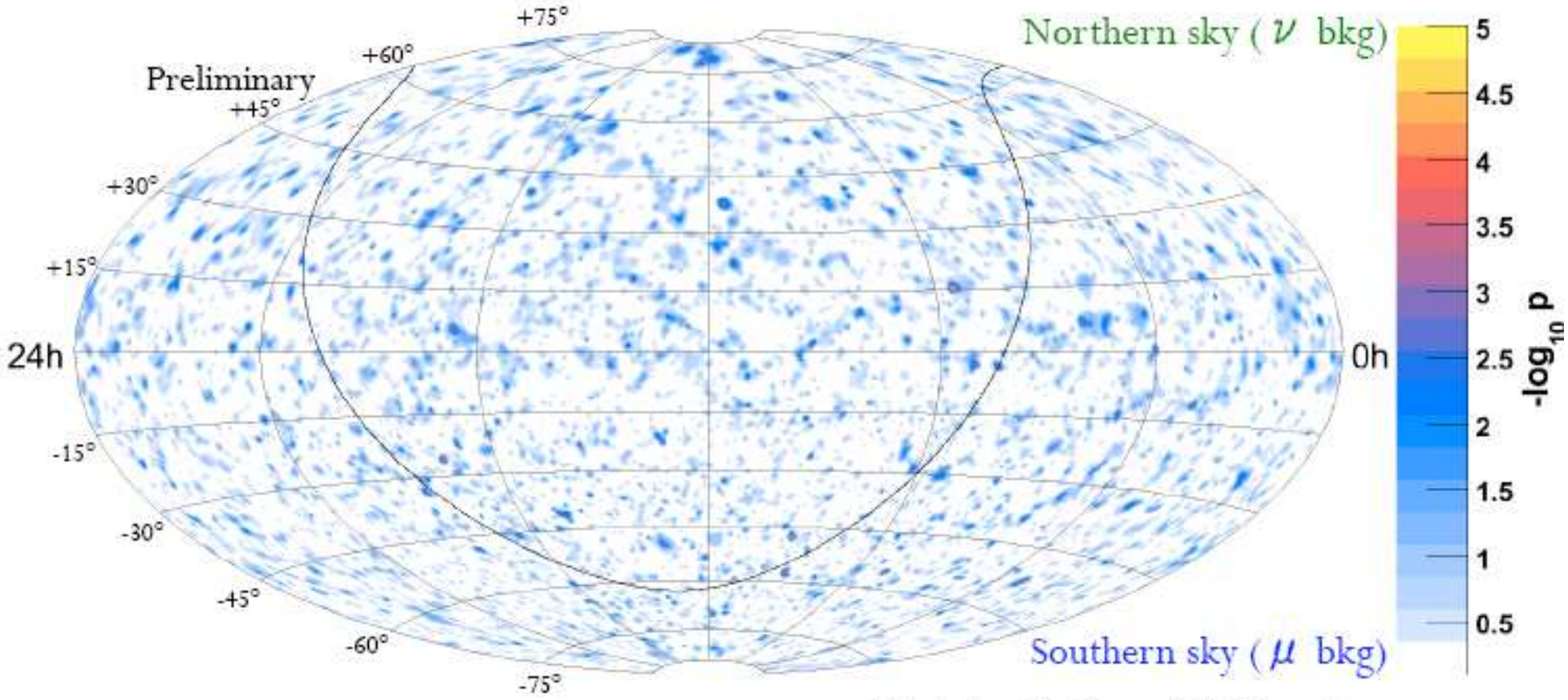




8 lunar months of IC40 data, 9M muons, 0.7° radius bins around Moon position



40-string 6-month all-sky results



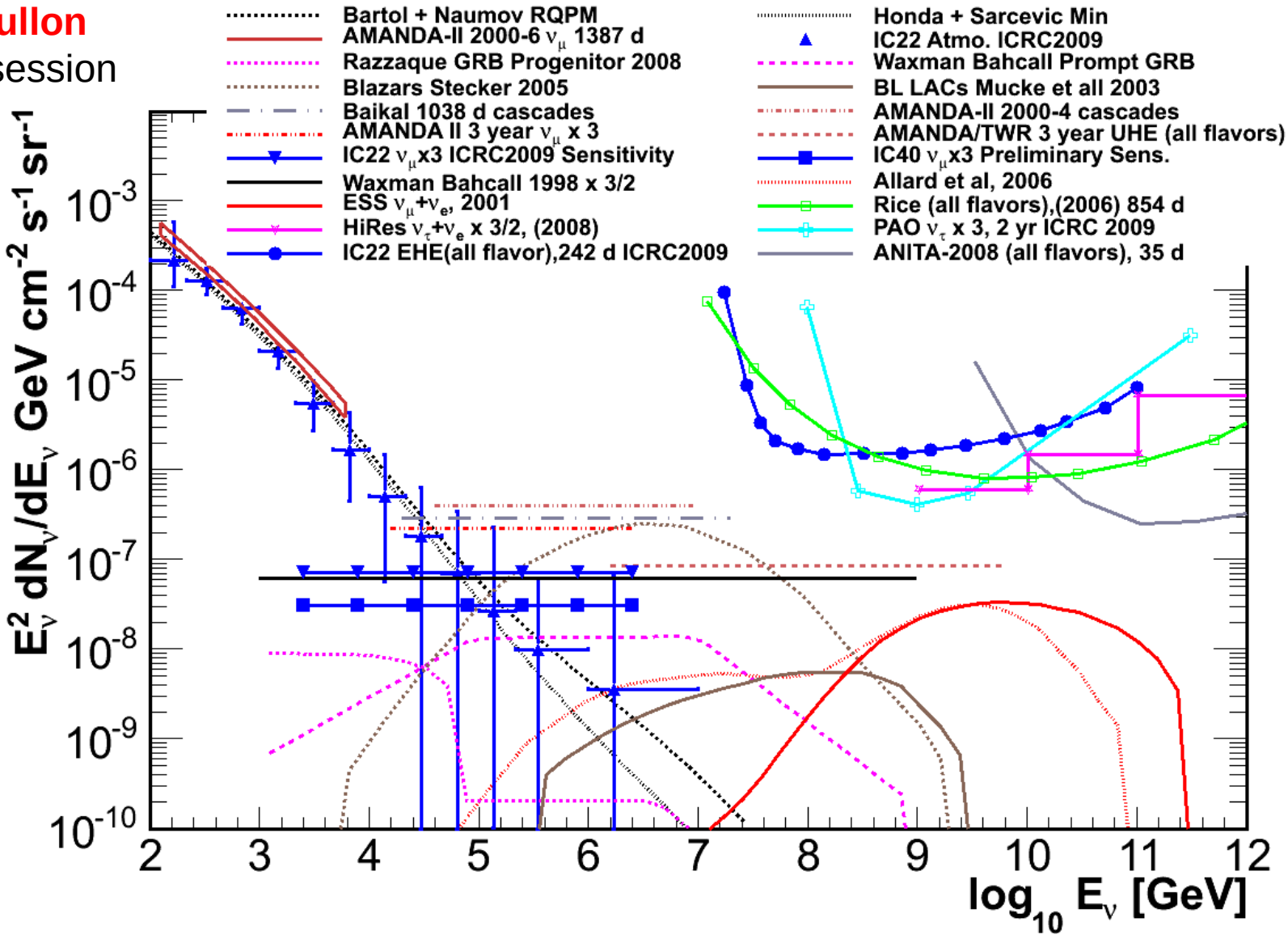
Hottest location in the all-sky search is:
r.a.=114.95°, dec.=15.35°

175.5 days livetime, 17777 events
6796 up-going, 10981 down-going

Jon Dumm, IceCube, ICRC2009
Juan Antonio Aguilar, parallel session today

Looking for diffuse fluxes above the background of atmospheric neutrinos

Sean Grullon
Parallel session



Monitoring the Universe

- Look for correlation with variable sources
  - e.g. AGN flares
- Externally triggered searches (GRB)
- Neutrino alerts (e.g. optical follow-up)
  - 2 or more ν from same direction in Δt
    - Alerts to ROTSE-III from IceCube since Oct. 2008
    - Alerts to TAROT from Antares since May 2009
  - Sudden excess in counting rate (IceCube)
    - Send SN alert to SNEWS
- Monitoring rates in surface detectors
  - IceTop, Auger
  - Solar particle events, modulation of galactic cosmic rays

GRB searches

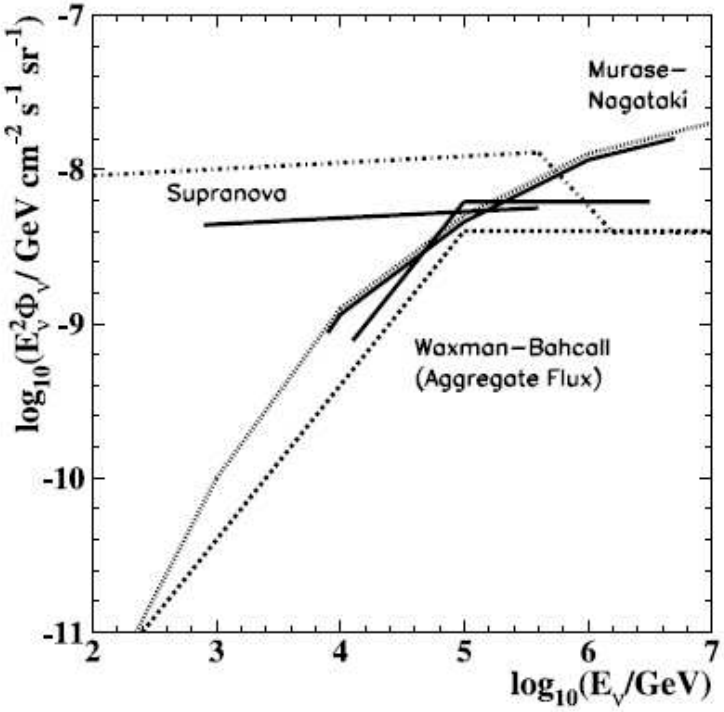


FIG. 9.—AMANDA flux upper limits (*solid lines*) for muon neutrino energy spectra predicted by the Waxman-Bahcall spectrum (Waxman 2003; *thick dotted line*), the Razzaque et al. spectrum (Razzaque et al. 2003a; *dot-dashed line*), and the Murase-Nagataki spectrum (Murase & Nagataki 2006a; *thin dotted line*). The central 90% of the expected flux for each model is shown. For the Waxman-Bahcall model we include both long- and short-duration bursts; for the other spectra, only long-duration bursts are included. Including short-duration bursts would improve the flux upper limits by approximately 13%. While our analysis was restricted to bursts located in the northern hemisphere (2π sr), all flux upper limits are for the entire sky (4π sr).

AMANDA 400 bursts 1997-2003
Ap.J 674 (2008) 357

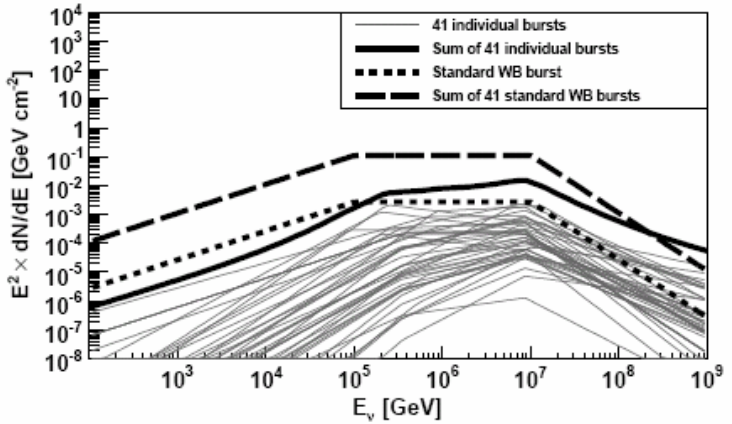
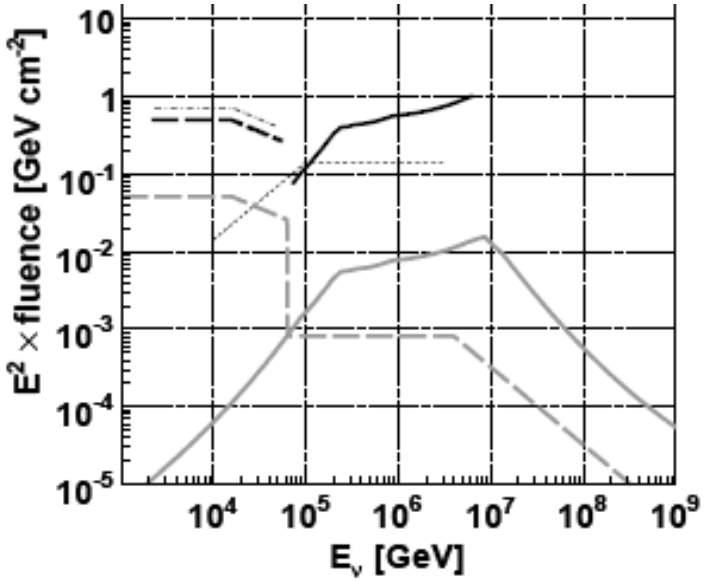


Fig. 1.— Calculated neutrino spectra for all 41 GRBs compared to the standard Waxman–Bahcall spectrum.

Limits

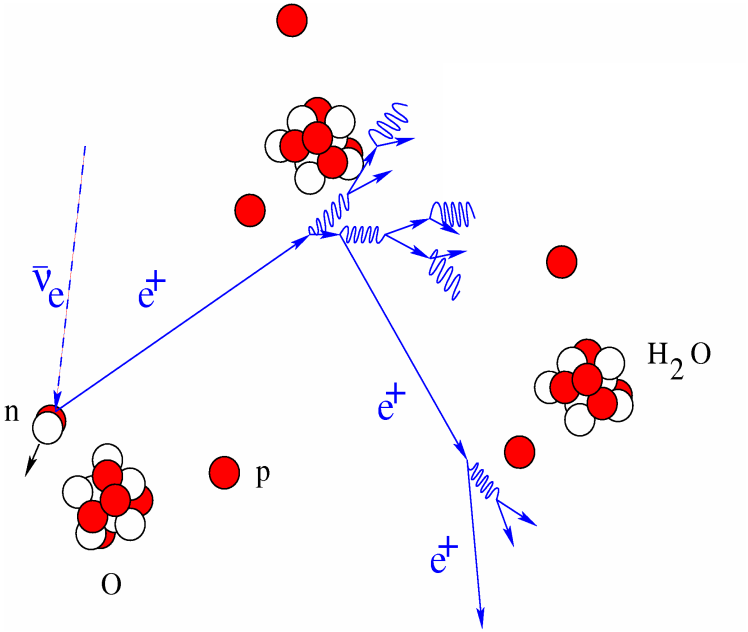


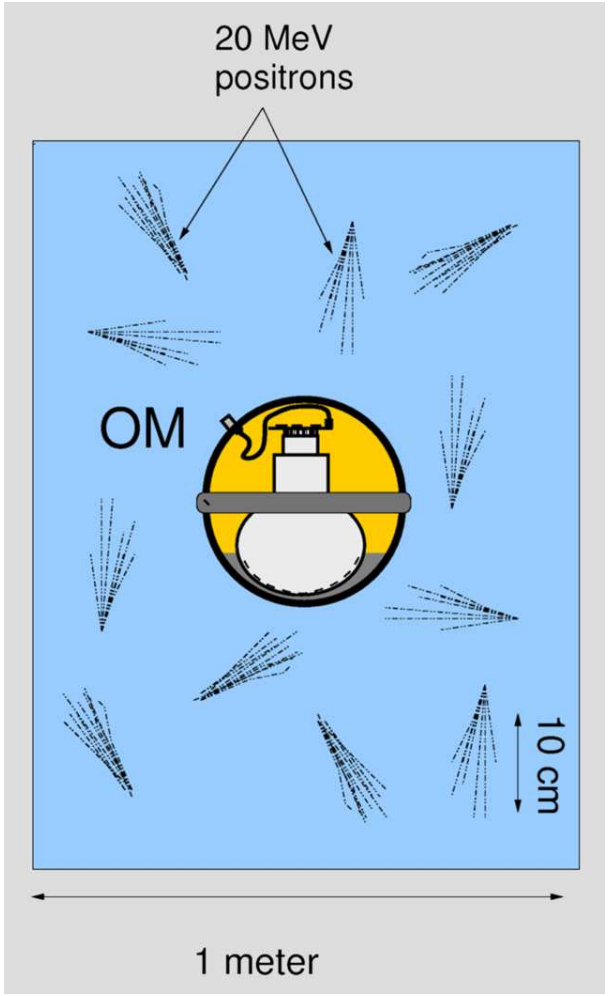
GRB search with IceCube 22 (arXiv:0907.2227)

- 41 bursts in 2007/08
- Realistic modeling of each burst according to Guetta et al. 2004
- Lowers expectation relative to WB

AMANDA/IceCube as MeV ν detector

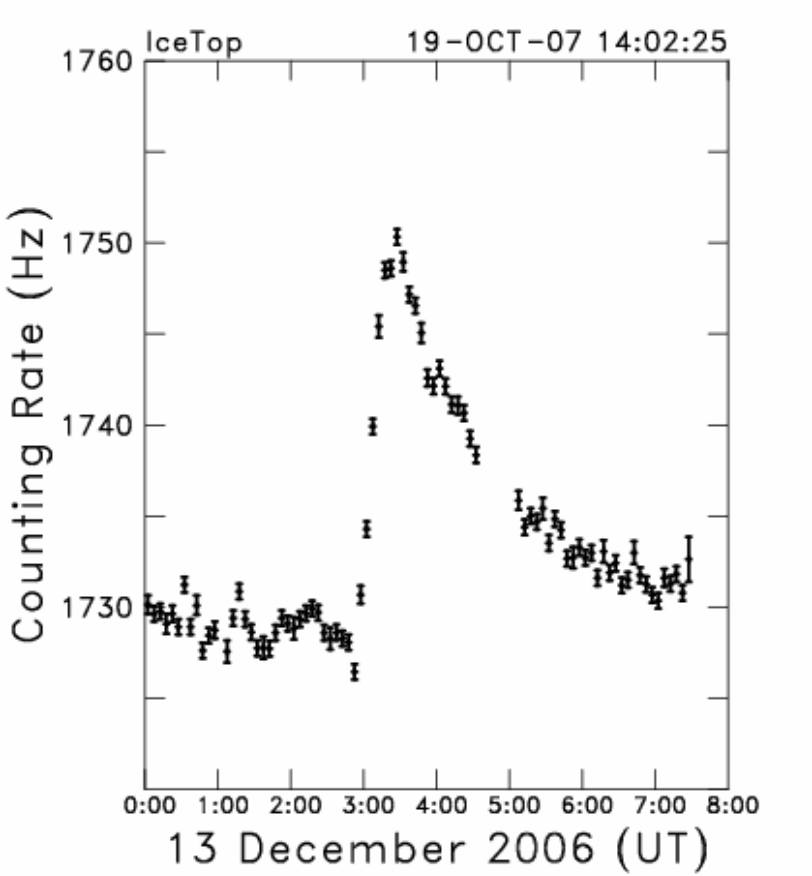
…first proposed by Halzen, Jacobsen & Zas, astro-ph/9512080



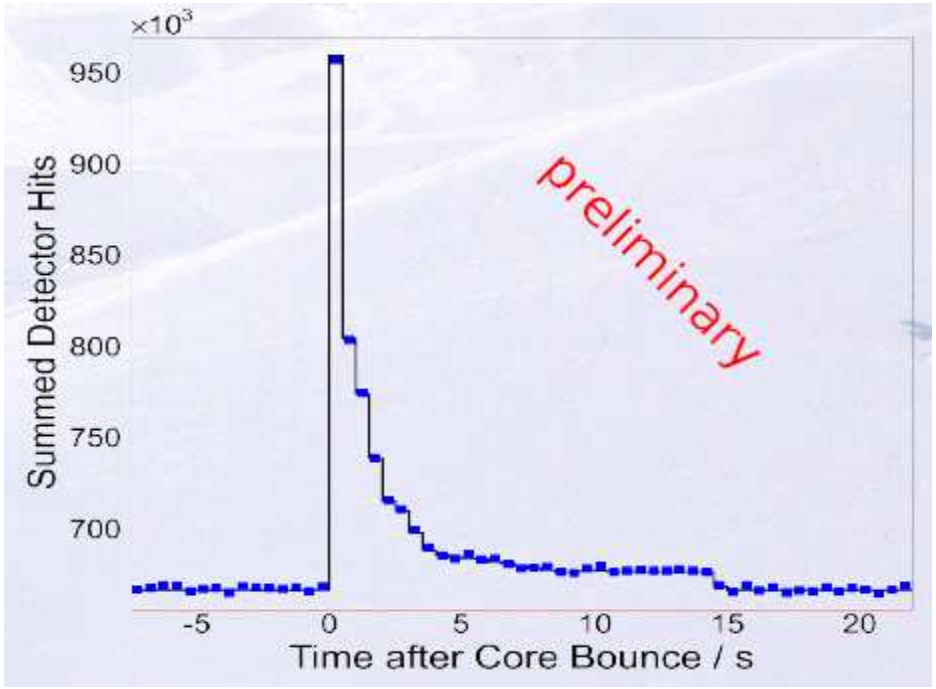


- PMT noise low (~ 300 Hz)
- ice uniformly illuminated
- detect correlated rate increase on top of PMT noise

Events in monitoring stream

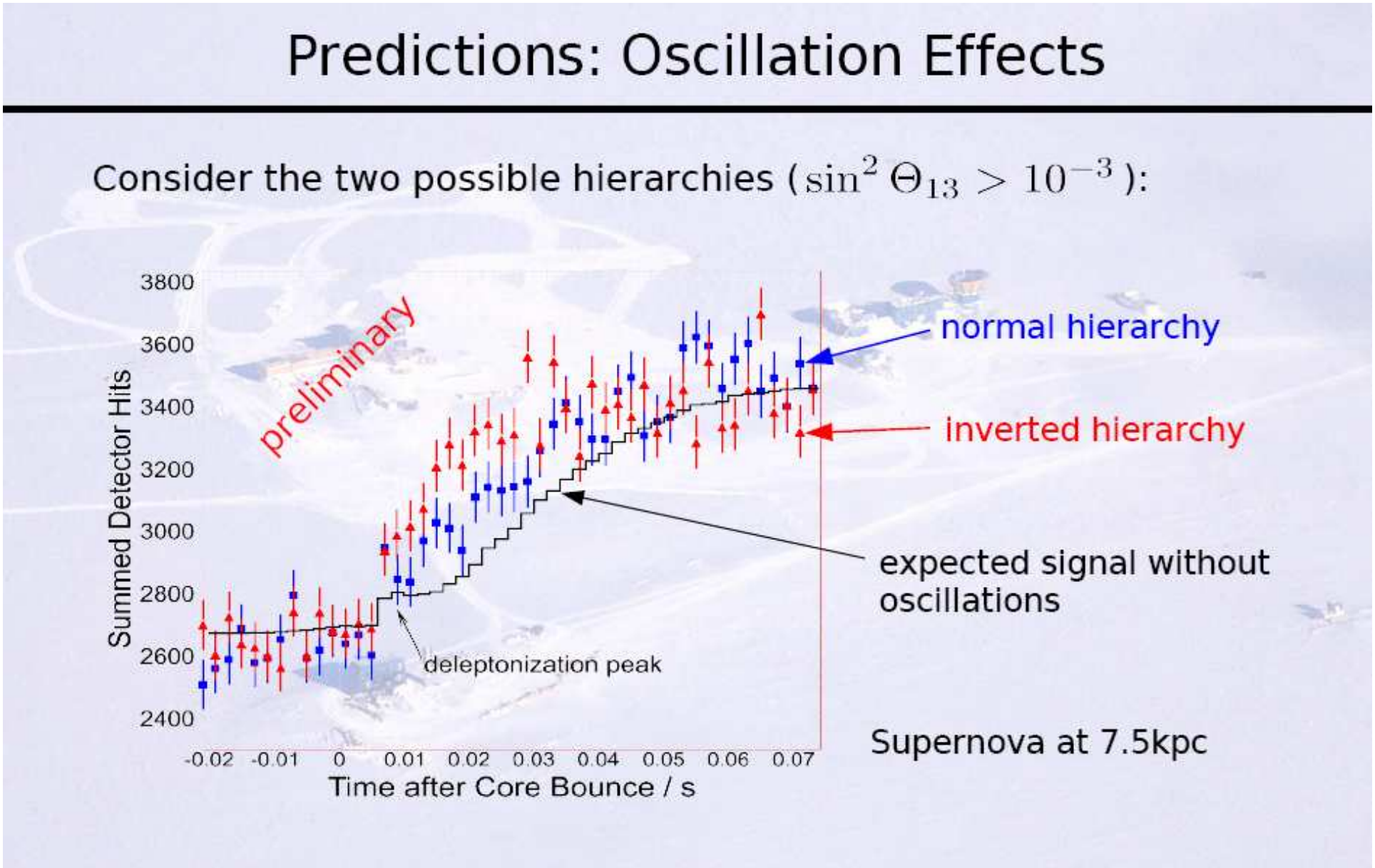


IceCube using IceTop
Ap. J. (Letters) 689 (2008) L65-L68

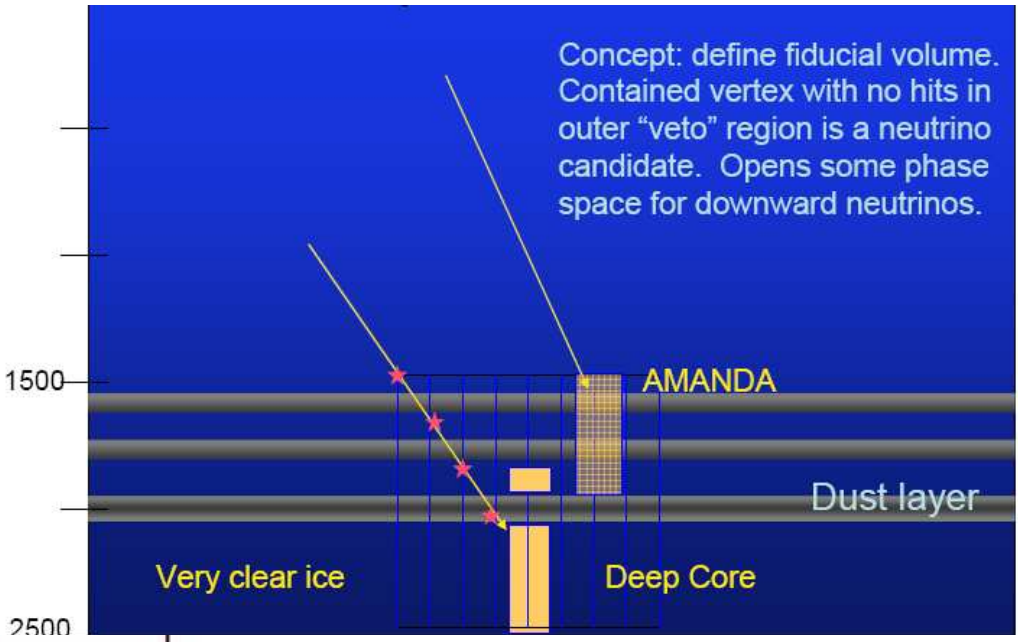


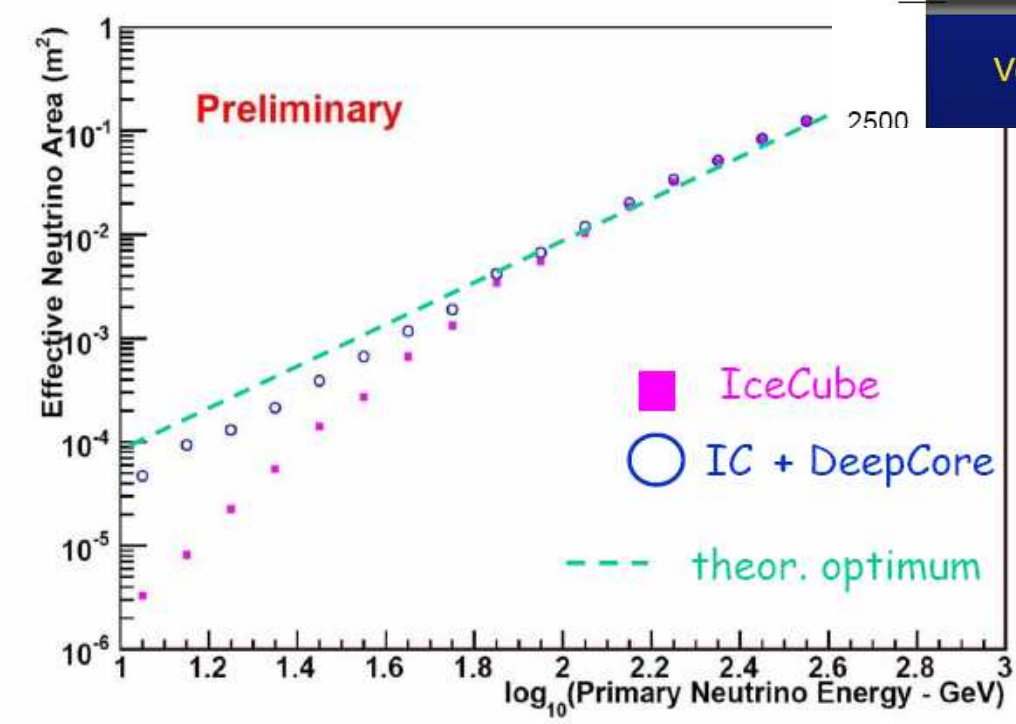
Counting rate in IceCube:
Sum of 4800 DOMs
for SN at Galactic center (34 σ)
Thomas Kowarik, ICRC 2009

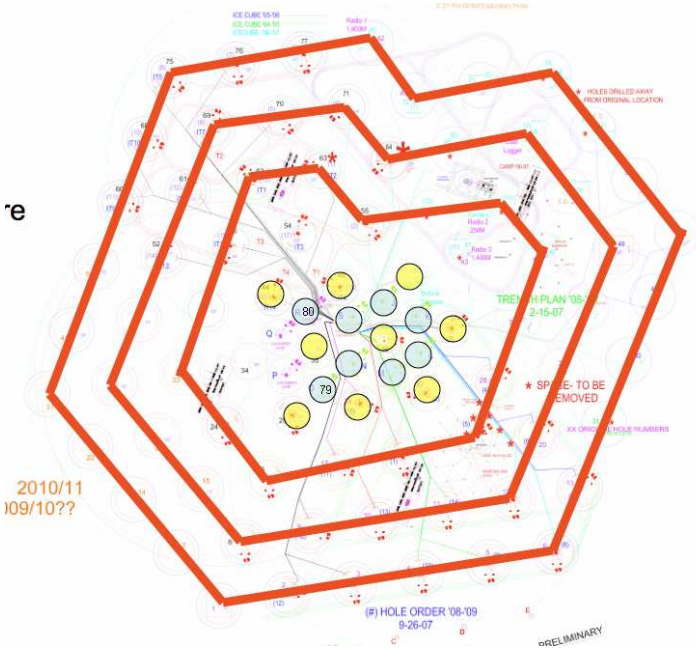
SN @ Galactic center in full IceCube



IceCube Deep Core replaces AMANDA

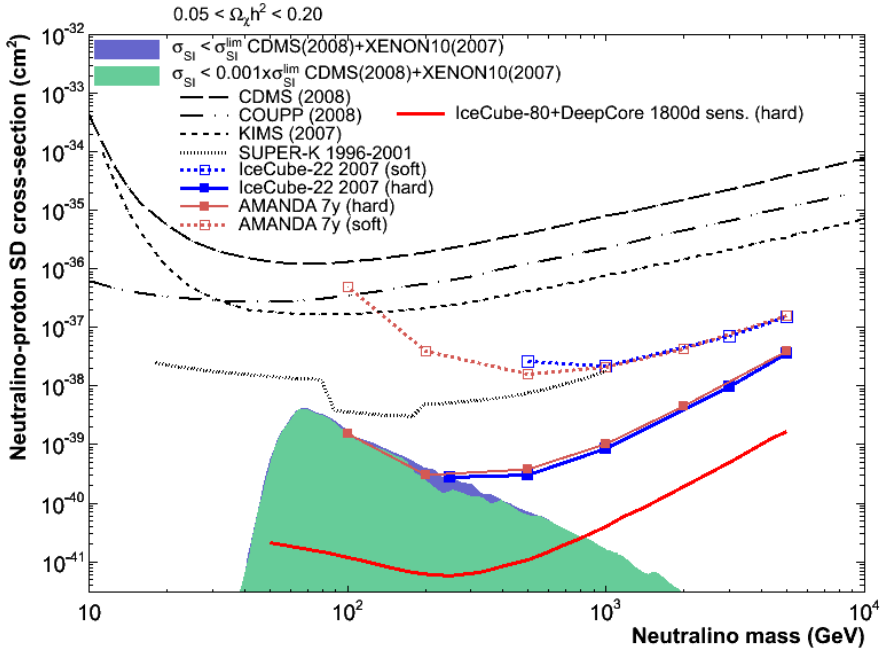




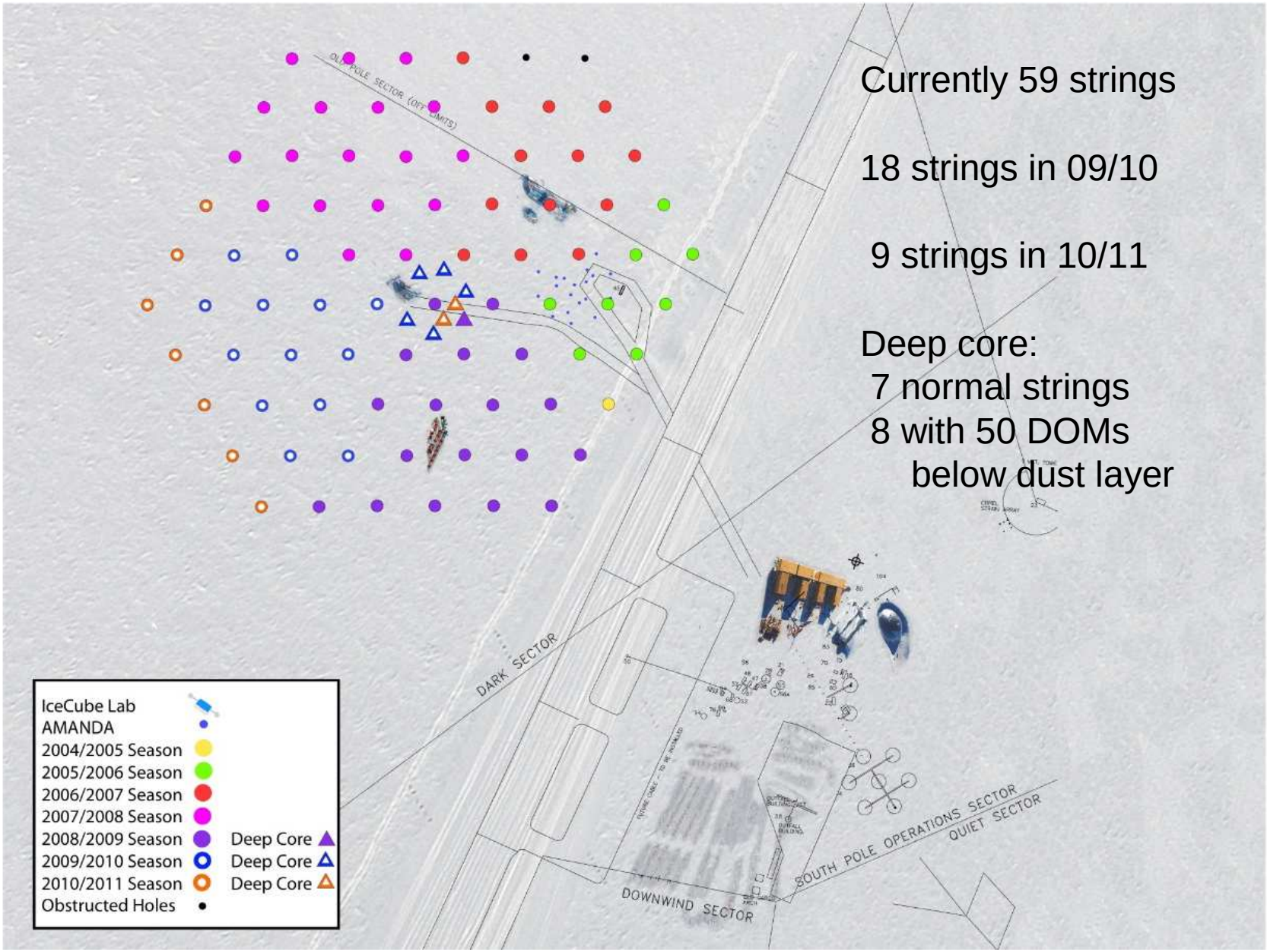


IceCube deep core motivation

- Open Southern hemisphere by using surrounding IceCube as a veto
- Increased sensitivity at low energy
  - Measure atmospheric neutrinos in region where oscillations are important
    - Irina Mocioiu, parallel session today
  - Improves search for WIMPs from Sun

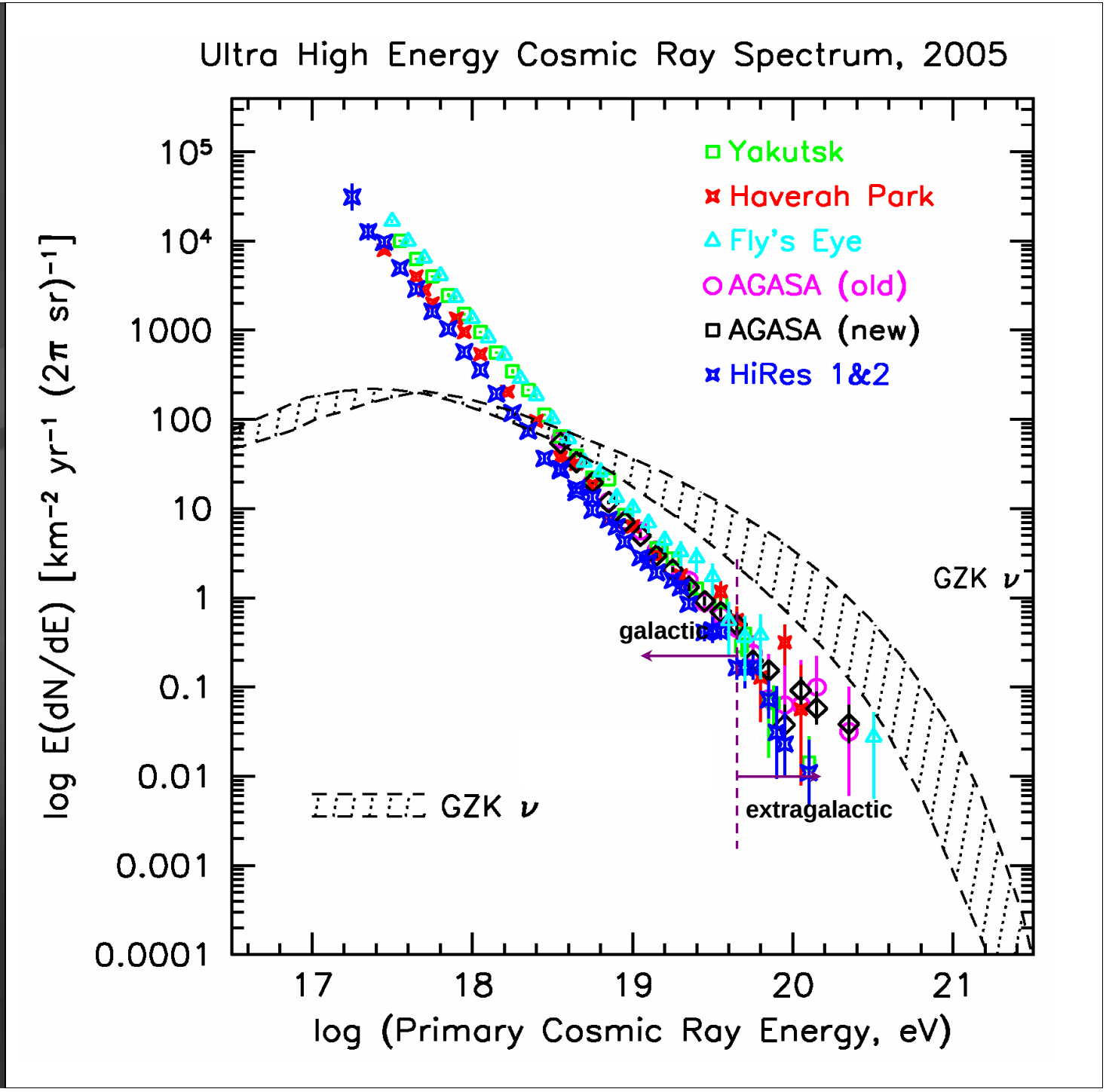


Plan for completion of IceCube

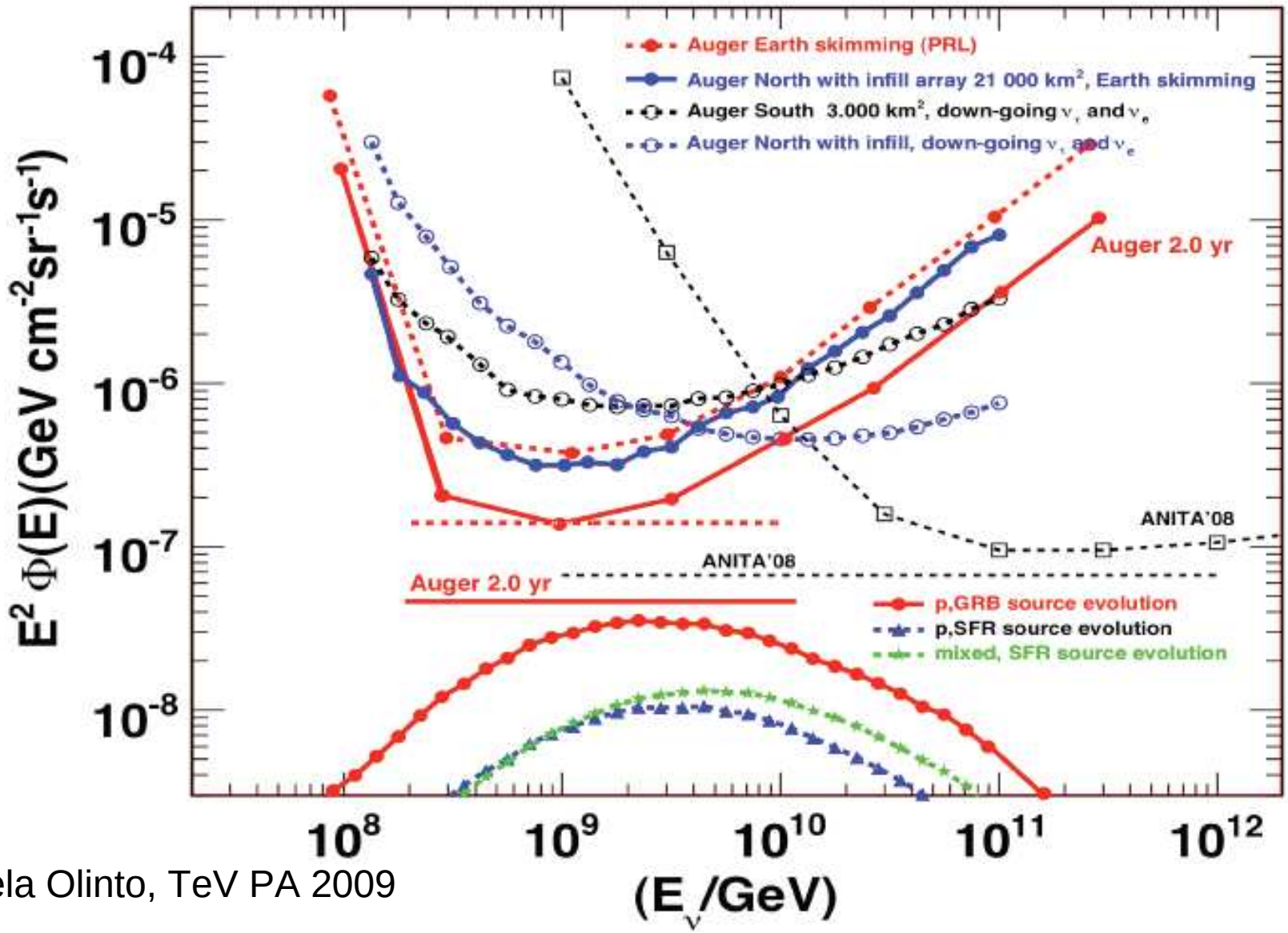


neutrinos from GZK interactions

Slide by
Francis Halzen



UHE neutrino limit



Angela Olinto, TeV PA 2009

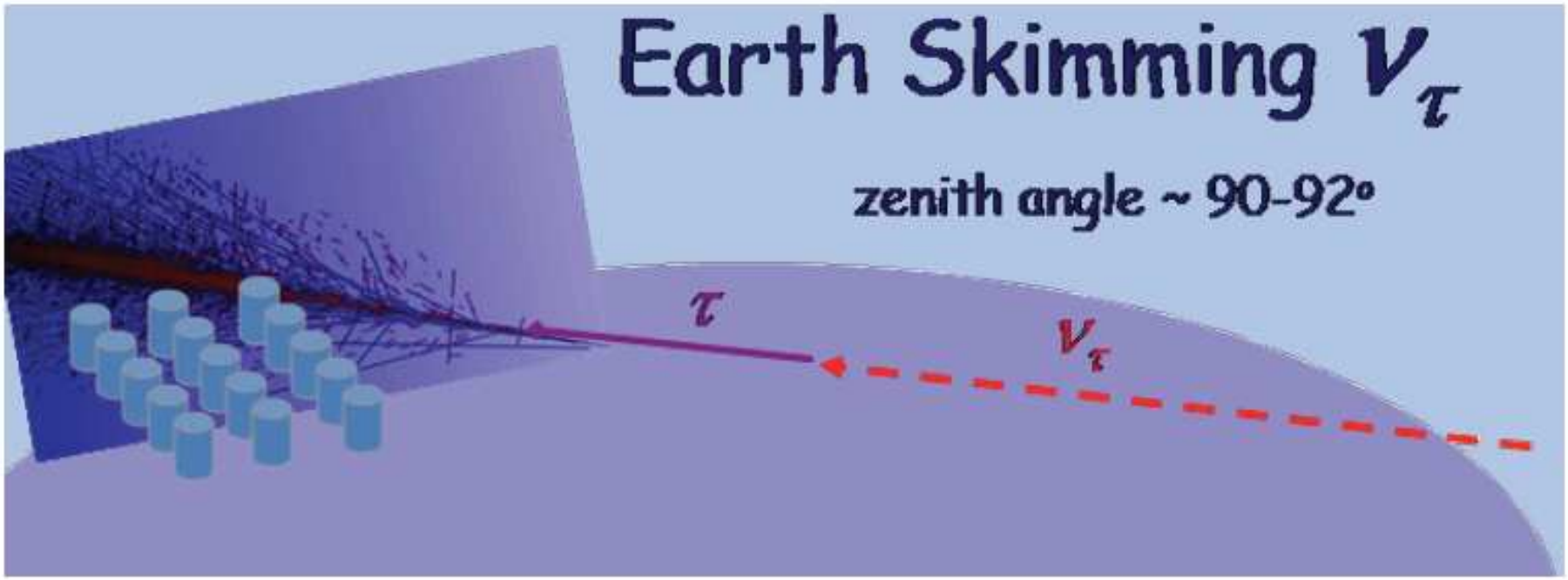
The Auger UHE Neutrino Observatory

Neutrinos can be identified as "young" showers at very great atmospheric slant depth (either upward or downward).

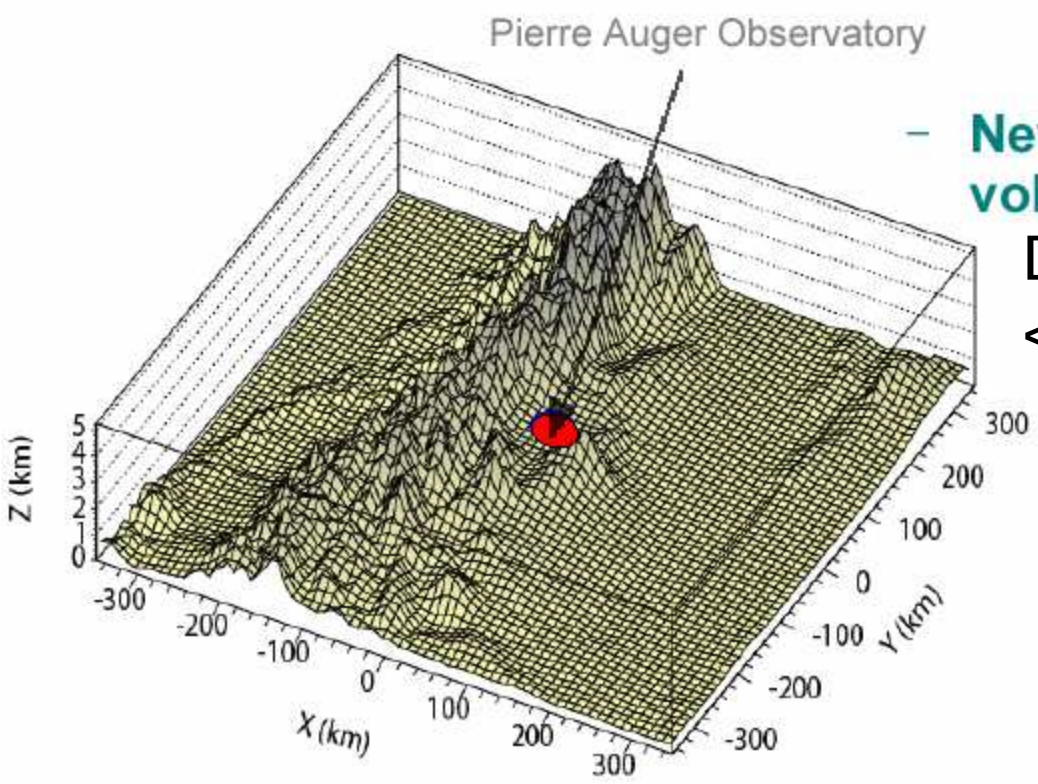
See Lukas Nellen's talk

Auger exposure to tau Neutrinos

TeV PA 2009



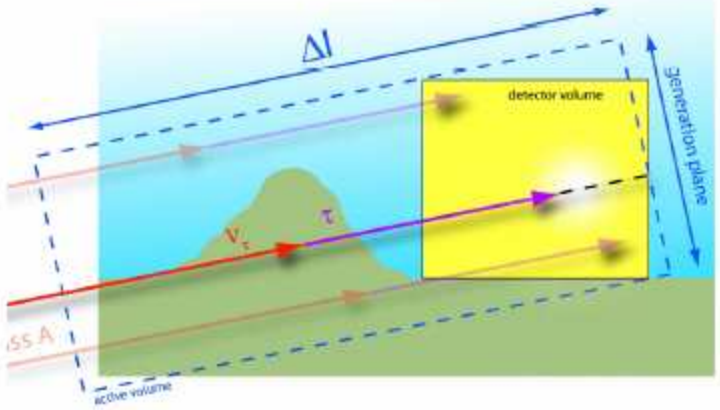
EeV ν_τ detection with Auger et al.



- **New definition of active volume**

D. Gora

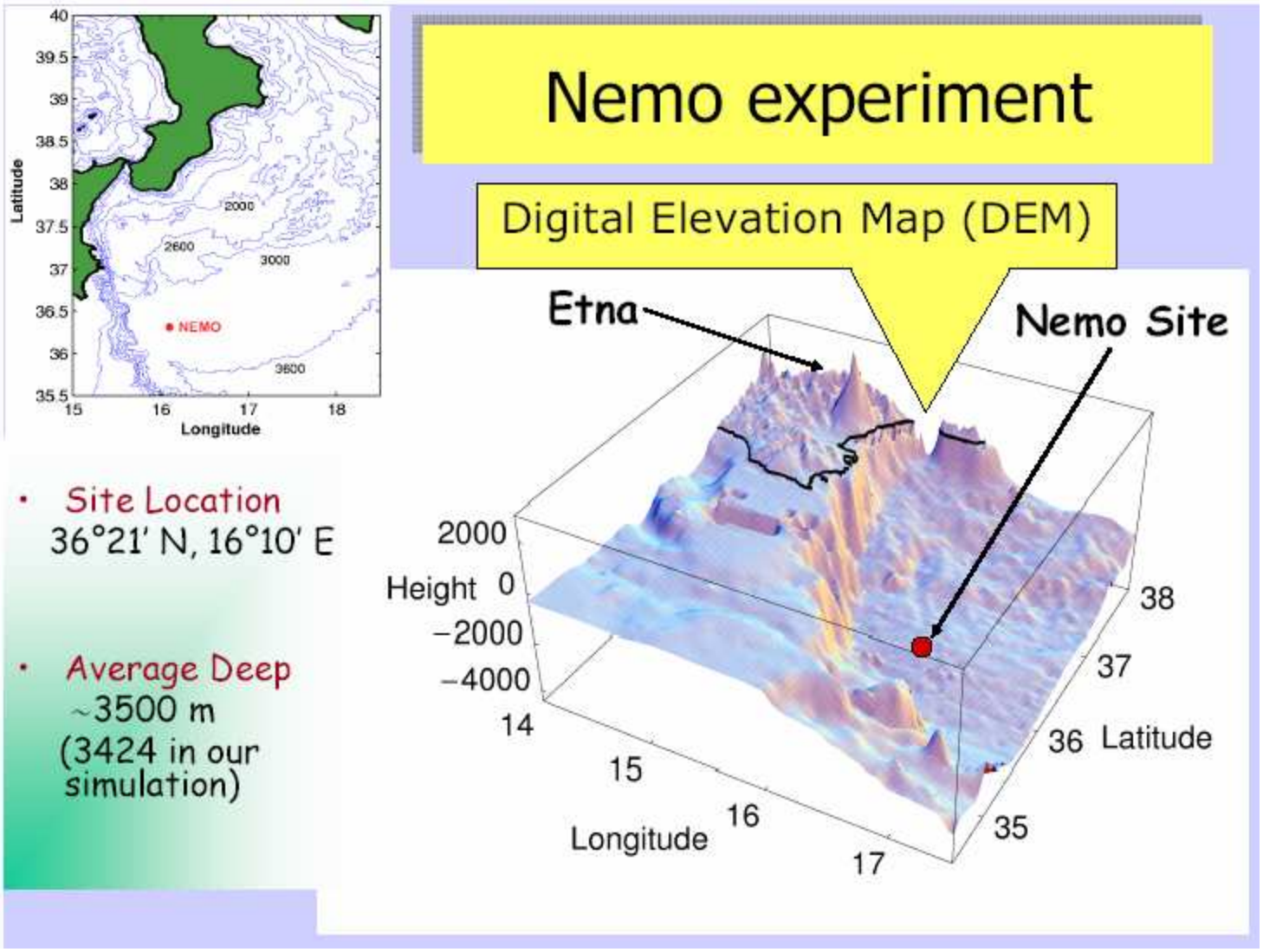
<~ 1 GZK ν_τ / year in Auger



$\Gamma c\tau$ ~ 100 km for E_τ ~ 2 x 10^{18} eV followed by τ-decay shower

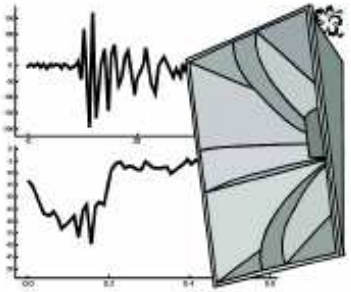
T. Weiler, D. Fargion

Km³ telescopes can also do ν_τ



G. Miele
--talk describes how to unfold neutrino Cross section

ANITA



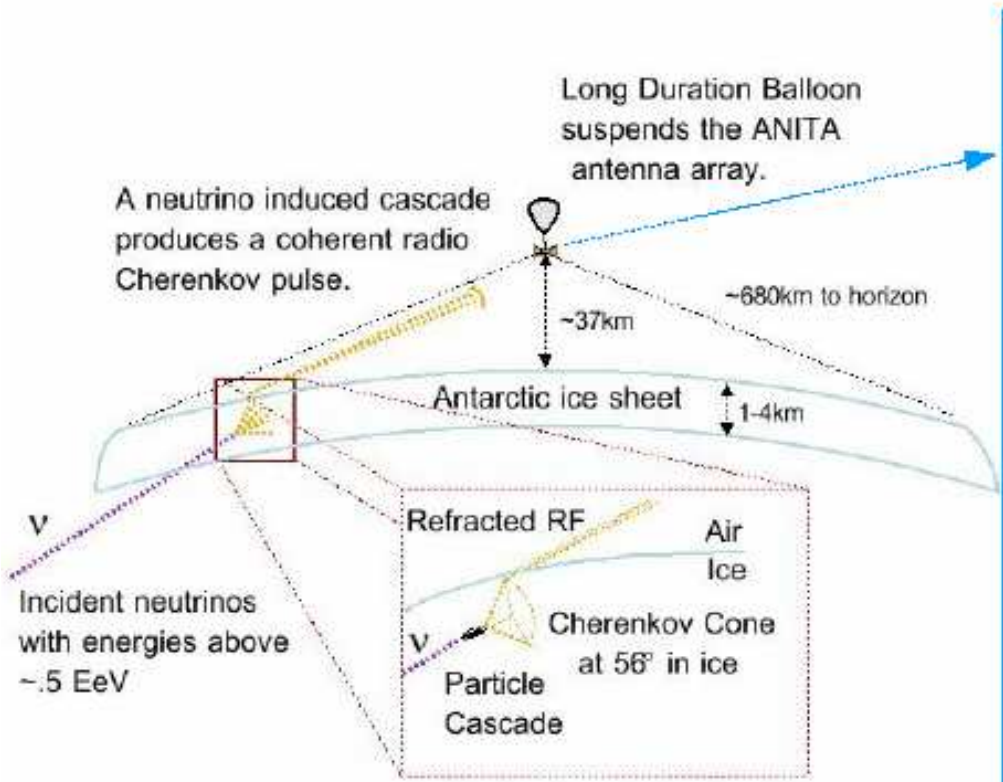
First Flight Overview and Detector Performance

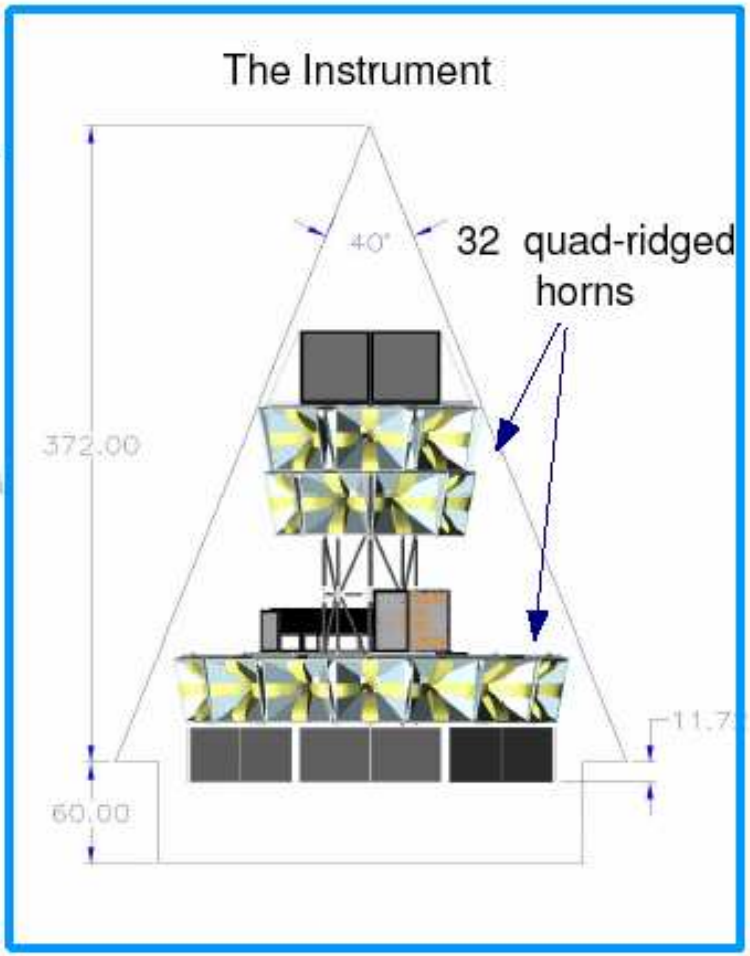
Detector was tested in pulsed electron beam at SLAC – Jeff Kowalski

THE OHIO STATE UNIVERSITY

for the ANITA Collaboration

The ANITA Concept



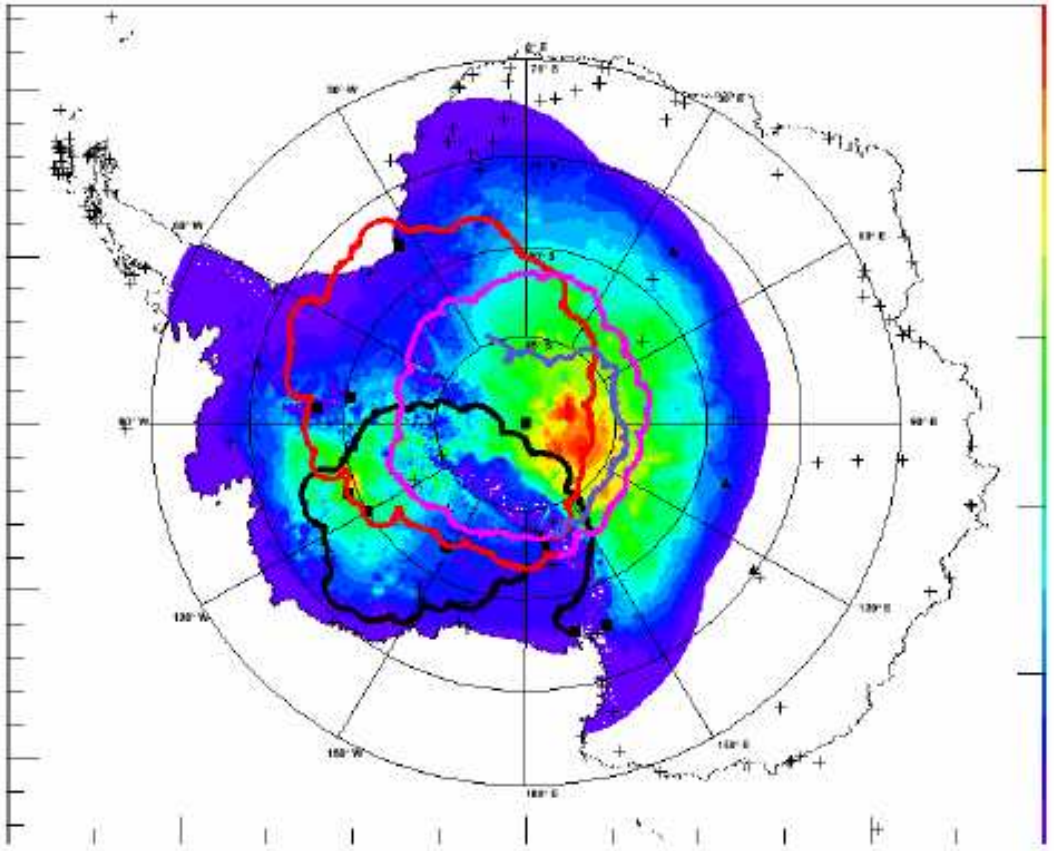


Ice in ANITA's Horizon

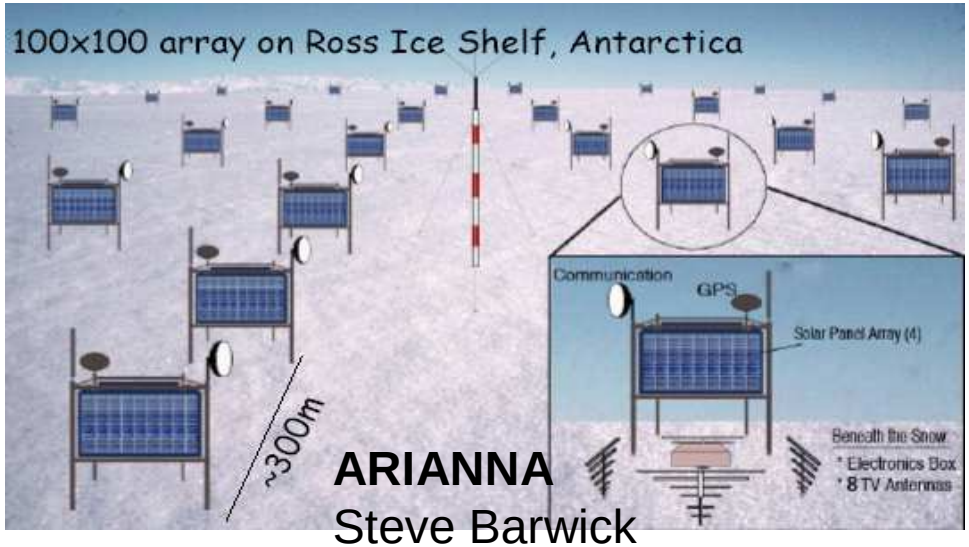
ANITA from the Pole

photo by James Roth

Ice in ANITA's field of view:
volume by time in view

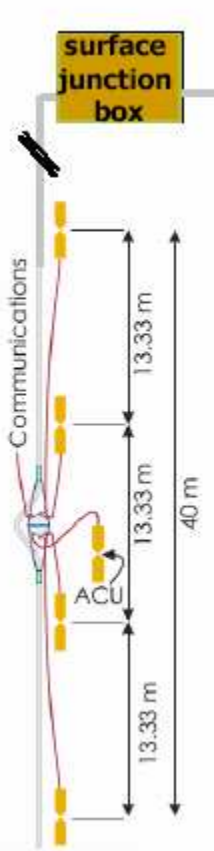


Proposed detectors

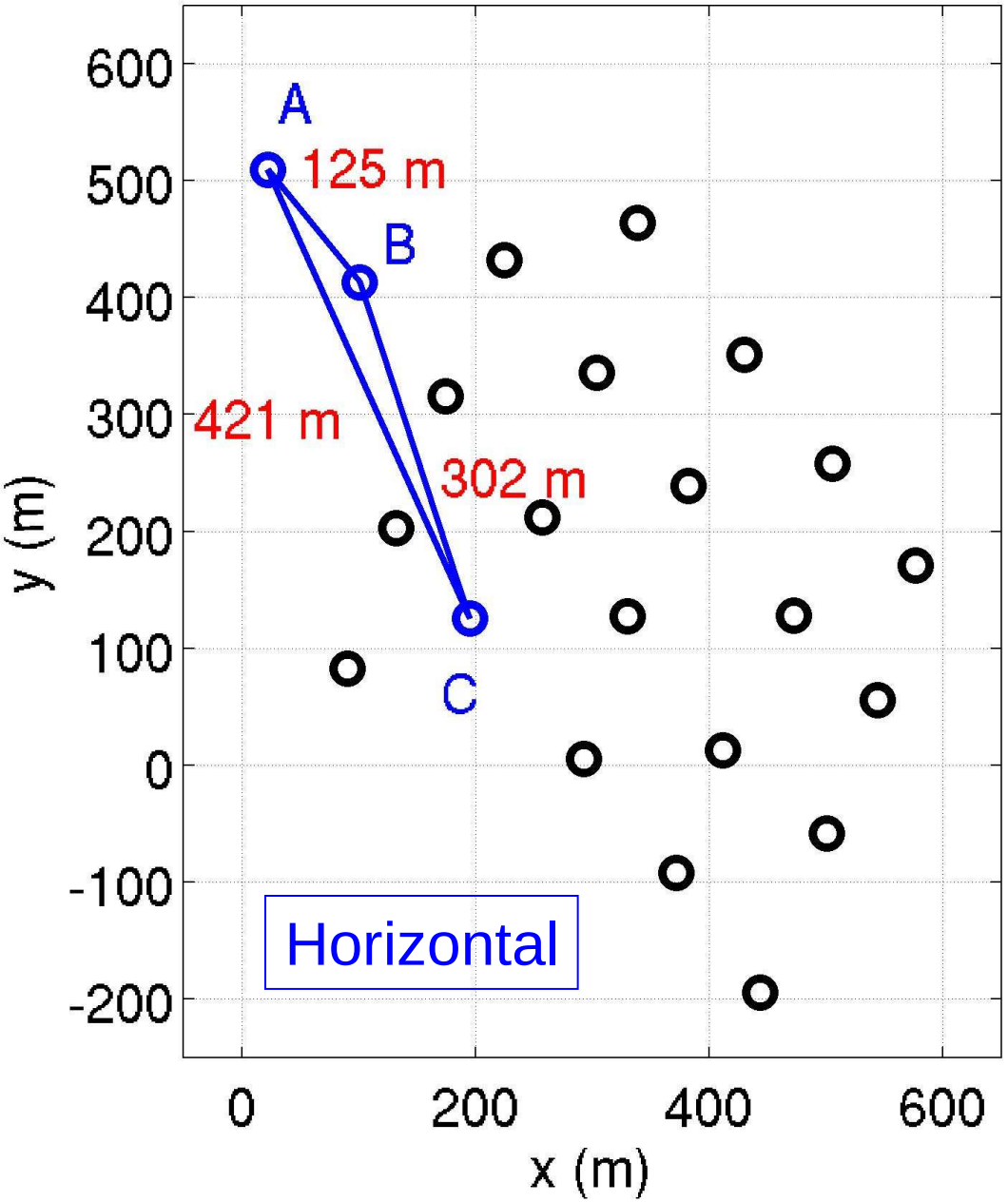


ARIANNA
Steve Barwick

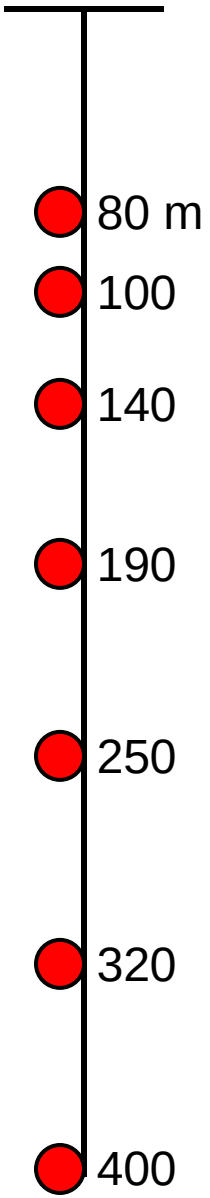
AURA at South Pole
digitize signal at antenna cluster
--Hagar Landsman



SPATS Geometry

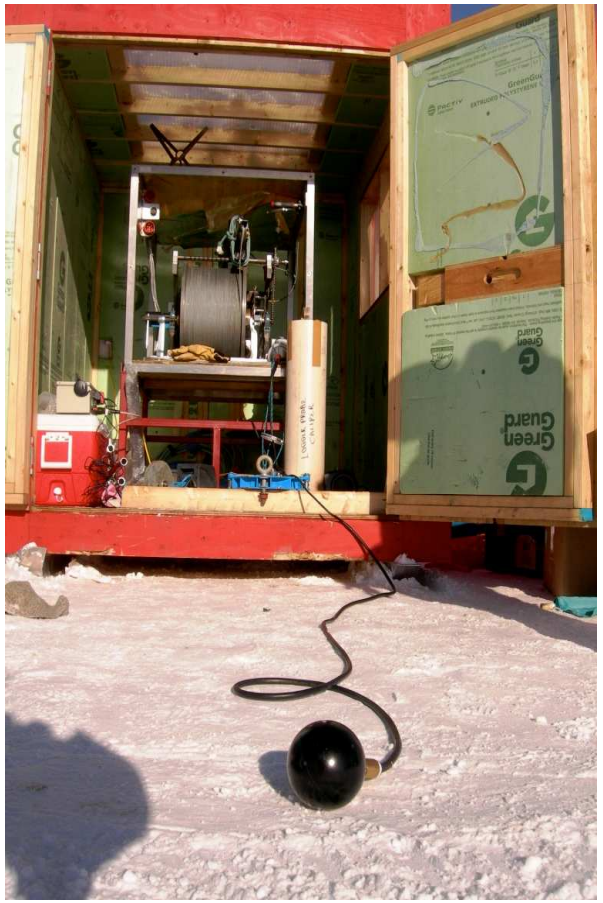


Testing acoustic detection at the South Pole
--Justin Vandenbroucke



IceCube as a test facility

- Radio antennas/transmitters to study future Askaryan radio array
- Acoustic pingers/receivers to measure speed of sound, attenuation length in ice
- Ultimate goal is 1000 X IceCube sensitivity for cosmogenic neutrinos
- Proposal for radio array is in preparation



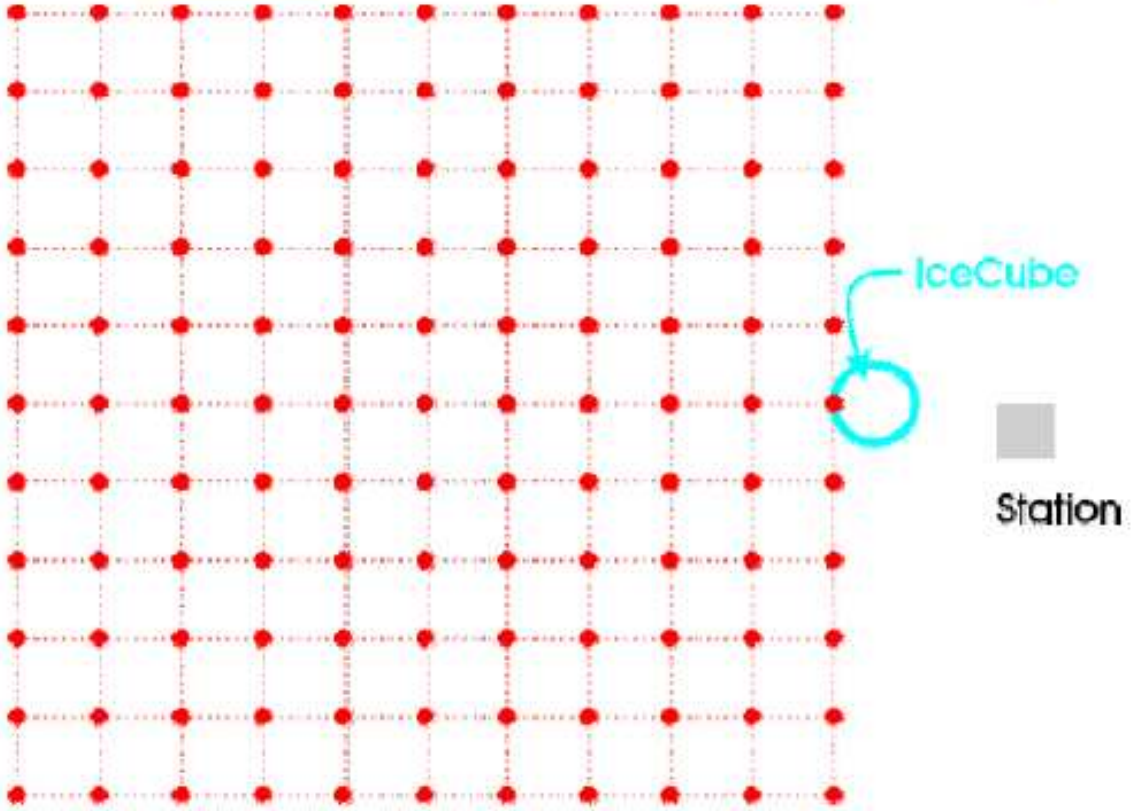
Acoustic pinger,
photo by Justin Vandenbroucke

Proposed Askaryan Radio Array

Moving to ARA (km-spaced Array)

121 nodes?

Distance to at least 12km.



KU THE UNIVERSITY OF KANSAS
Instrumentation Design Laboratory

David Besson, TeV PA 2009