HE2: Muons and Neutrinos

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Searching for possible hidden chambers in the Pyramid of the Sun

Muon tomography

ICRC-2007, Mérida

Searching for possible hidden chambers in the Pyramid of the Sun

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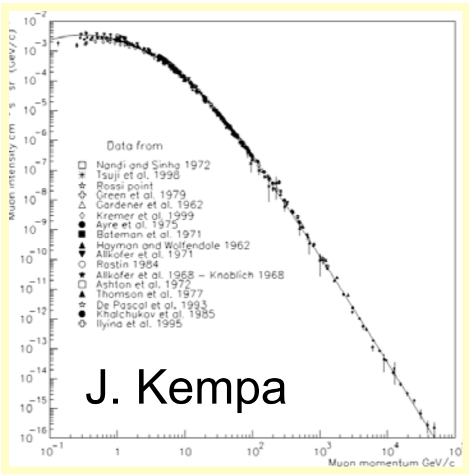
Muons, the gold standard of cosmic-ray physics

- Muon tomography works because the spectrum of muons is very well-measured up to several hundred GeV
- Genetic relation to neutrinos constrains neutrino flux:
  - $\pi^+ \rightarrow \mu^+ + \nu_\mu$; $\mu^+ \rightarrow e^+ + \nu_e + \nu_\mu$,
  - $K^+ \rightarrow \mu^+ + \nu_\mu$; etc.



- Major uncertainties in μ and ν fluxes:
  - E > TeV: K component
  - E > 100 TeV: charm component
  - Overall normalization

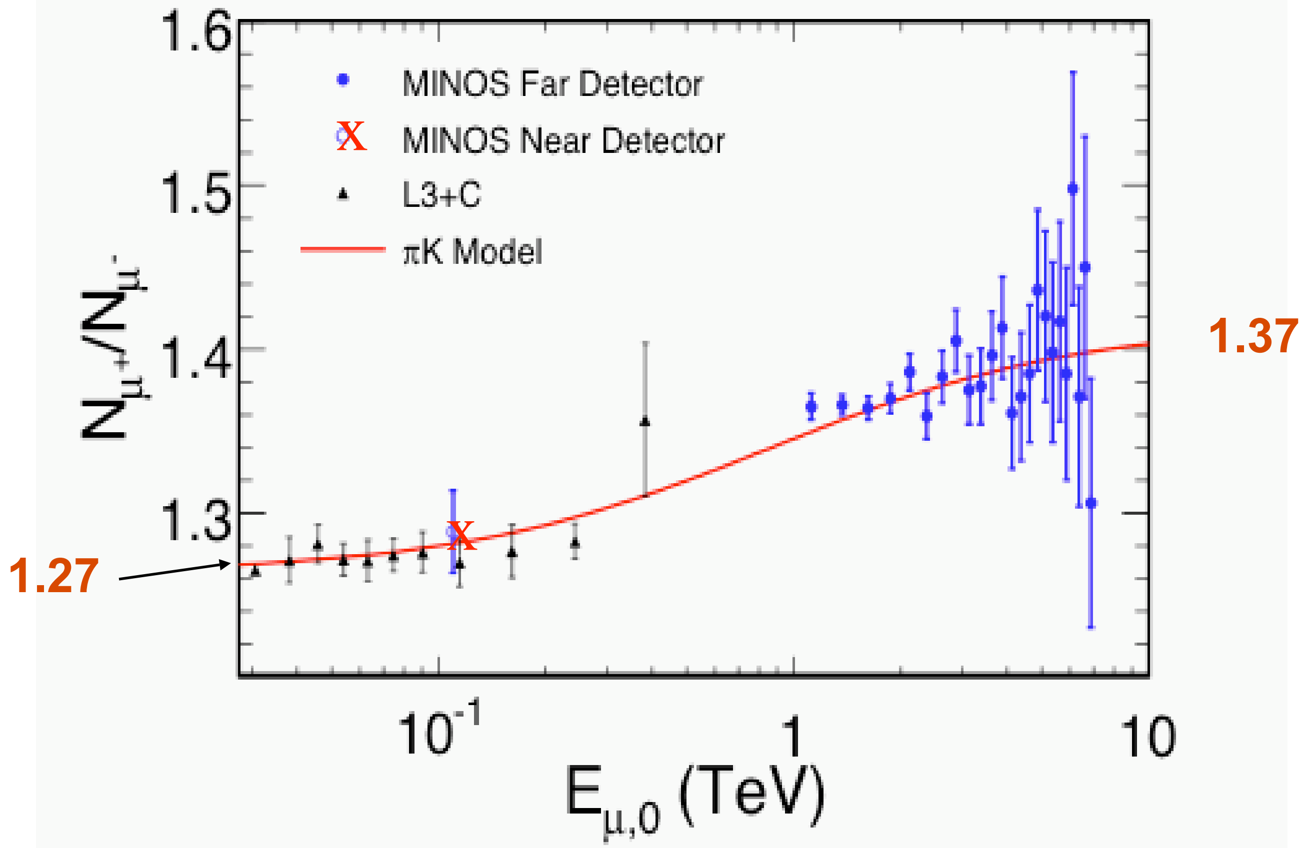
μ^+/μ^- with MINOS

- MINOS far detector
  - $10 < E_\mu < 250$ GeV at $2 < X \cos\theta < 4$ km w. e.
  - Equivalent to $1 < E_\mu < 7$ TeV at surface
  - First high-statistics measurement of muon charge ratio in TeV energy range
  - Realize goal of Zatsepin & Kuz’min (1960)*
    - “…in the energy range of $10^{11} – 5\text{x}10^{12}$ eV the μ-meson angular distributions depend significantly on their production mechanism” (*JETP 39, 1677-1685, 1960)

(3) $$\Phi_{\mu^+} = C E^{-1.7}\left[\frac{A_{\pi^+}}{1+B_{\pi}E\cos\theta^*/\epsilon} + \frac{A_{K^+}}{1+B_{K\mu}E\cos\theta^*/\epsilon_K}\right]$$

(4) $$\Phi_{\mu^-} = C E^{-1.7}\left[\frac{A_{\pi^-}}{1+B_{\pi}E\cos\theta^*/\epsilon} + \frac{A_{K^-}}{1+B_{K\mu}E\cos\theta^*/\epsilon_K}\right]$$

Charge Ratio Model Results



- MINOS measure μ+ / μ^- and fit to formulas
- best fit values: $f_{\pi+} = A_{\pi+} / A_{\pi^-} = 0.55$; $f_{K+} = A_{K+} / A_{K^-} = 0.67$

π / K ratio

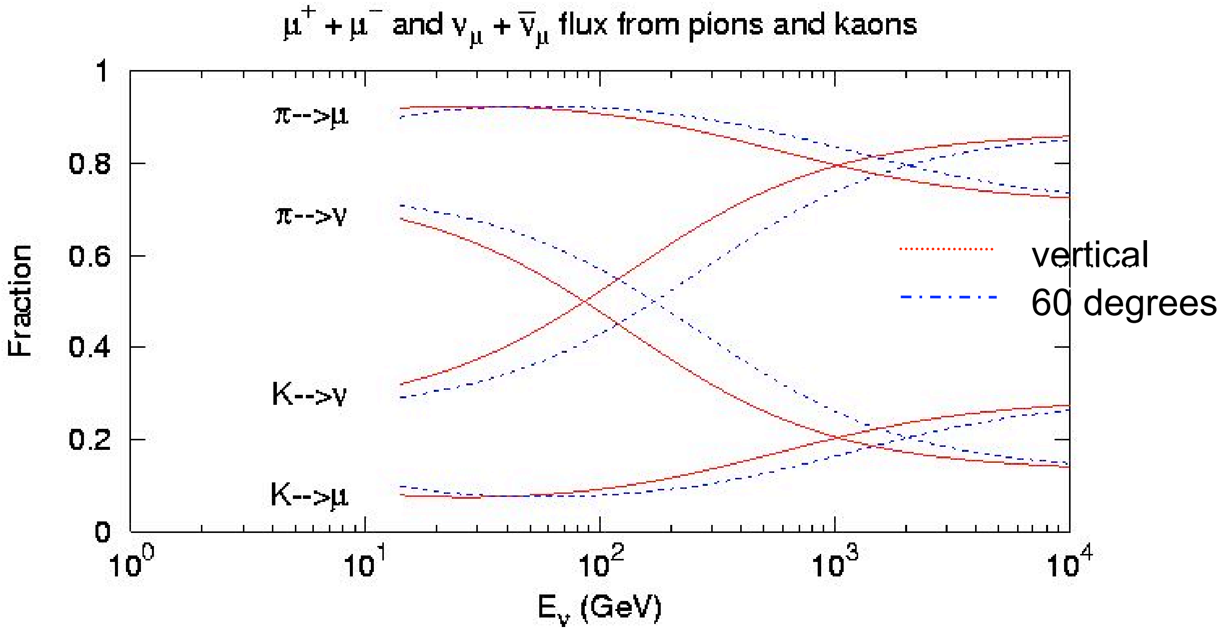
- Critical energy for interaction vs decay:
  - $\varepsilon_\pi = m_\pi c^2 / c\tau_\pi \sim 115$ GeV
  - $\varepsilon_K = m_K c^2 / c\tau_K \sim 850$ GeV

Steep spectrum → K contribution increases when E > ε_π

- Effect bigger for K by kinematics:

  $1 - m_\mu/m_K \sim 1$

  $1 - m_\mu/m_\pi << 1$



Implications for > TeV atmospheric ν

- $f_{K+} = 0.67 \rightarrow A_{N\rightarrow K^+} / A_{N\rightarrow K^-} = 2$
- Substantial contribution of associated production ($p \rightarrow \Lambda K^+$)
- Effect is amplified for ν's: $\nu_\mu / \bar{\nu}_\mu \rightarrow 2$
- Important for atmospheric neutrino background in neutrino telescopes
- MINOS measurement will lead to improved calculation of >TeV ϕ_ν

Super-Kamiokande and status of neutrino oscillations

- SK-III operating since July 12, 2006
- Hardware and software upgrades
- Full complement of >11 thousand 20” PMTs plus outer (veto) detector
- Recalibration finished and first year data in good agreement with SK-I + SK-II
- Potential for lower threshold for solar neutrino analysis

1. Introduction: History of Super-Kamiokande

M. Miura

SK– I

- 1996.4 Started data taking (SK– I)

Evidence of Atm. ν ocsillation(98')

- 1999.6 K2K started

Evidence of Solar ν oscillation(01')

- 2001.7 Stopped data taking for detector upgrade
- 2001.11 Accident
  - <u>partial reconstruction of the detector</u>
- 2002.10 Resumed data taking (SK– II)
- 2002.12 Resumed K2K beam (K2K–II)

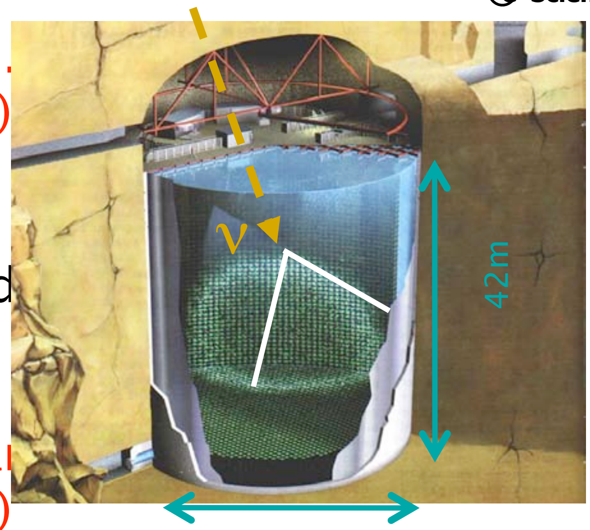
SK– II

- 2004.11 K2K finished

Confirm ν oscillation by accelerator ν

- 2005.10 Stopped data taking for <u>full reconstruction</u>

© Scientific American



Water Cherenkov detector

- 1000 m underground
- 50,000 ton (22,500 ton fid.)
- 11,146 20 inch PMTs
- 1,885 anti–counter PMTs
- E > 5 MeV
- E resolution: 14 % @10MeV

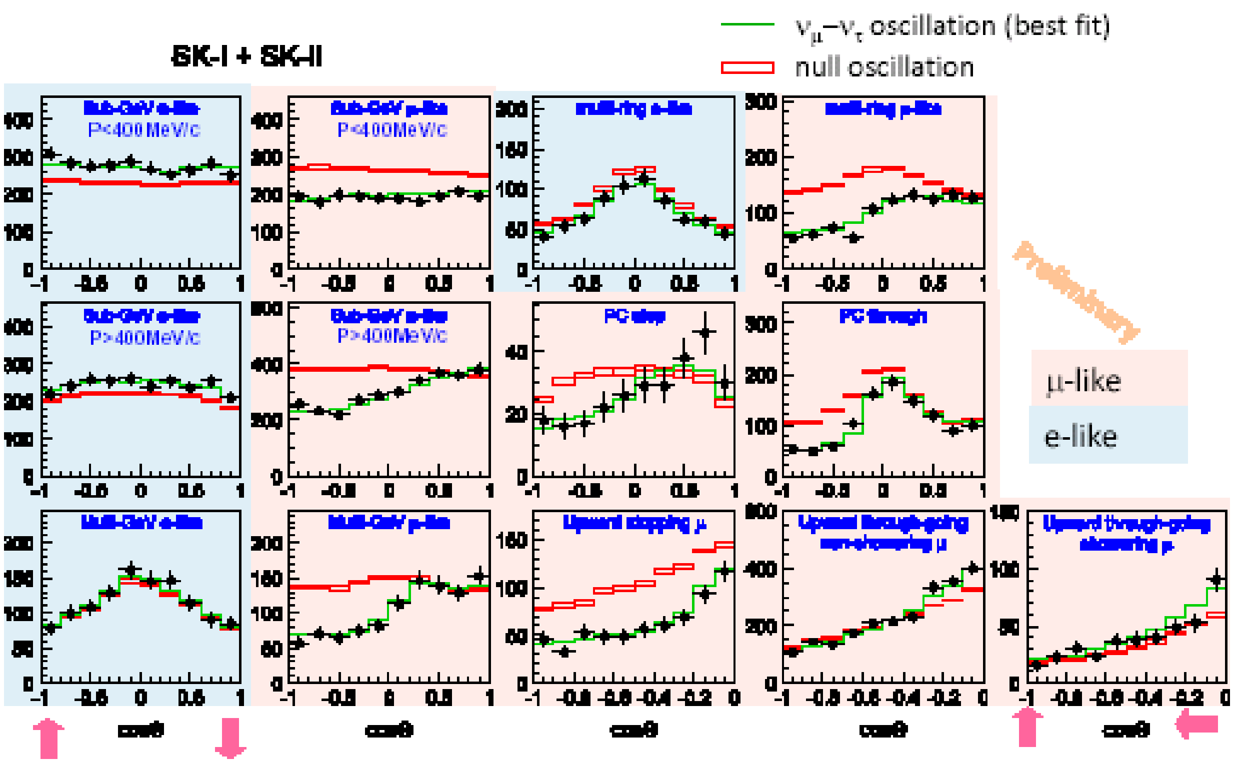
- 5,182 20 inch PMTs
- E > 7 MeV
- E resolution: 21 % @10MeV

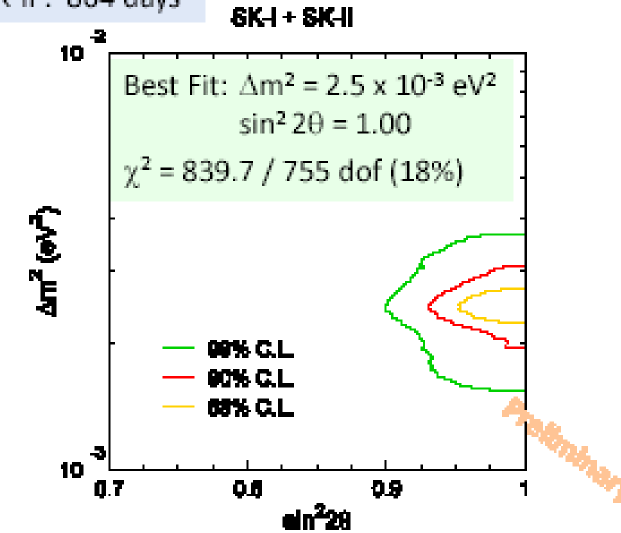
SK-I, SK-II combined analysis

Yumiko Takenaga

Zenith Angle Distributions (SK-I + SK-II)

SK-I : 1489 days
SK-II : 804 days



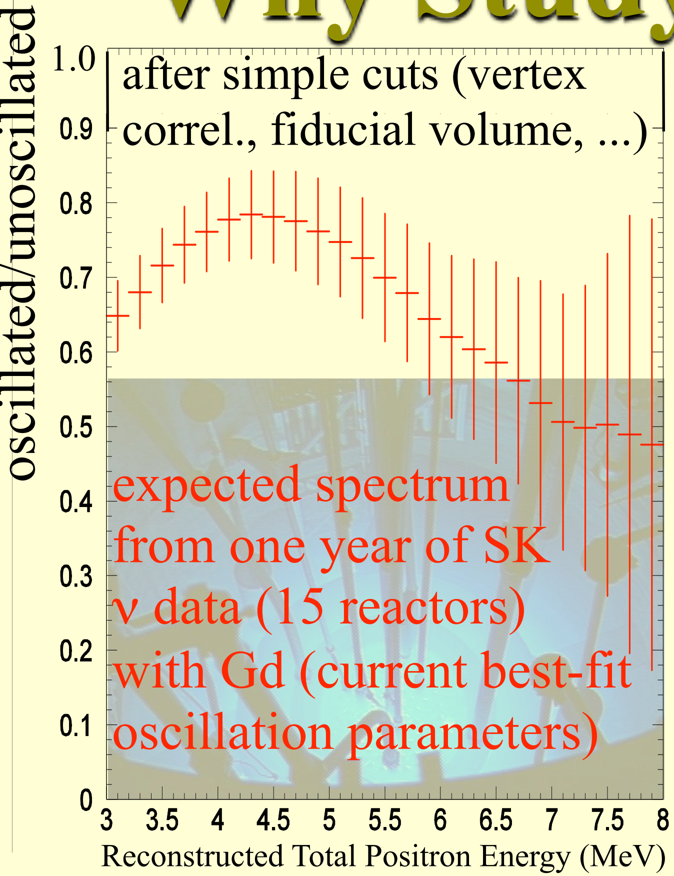


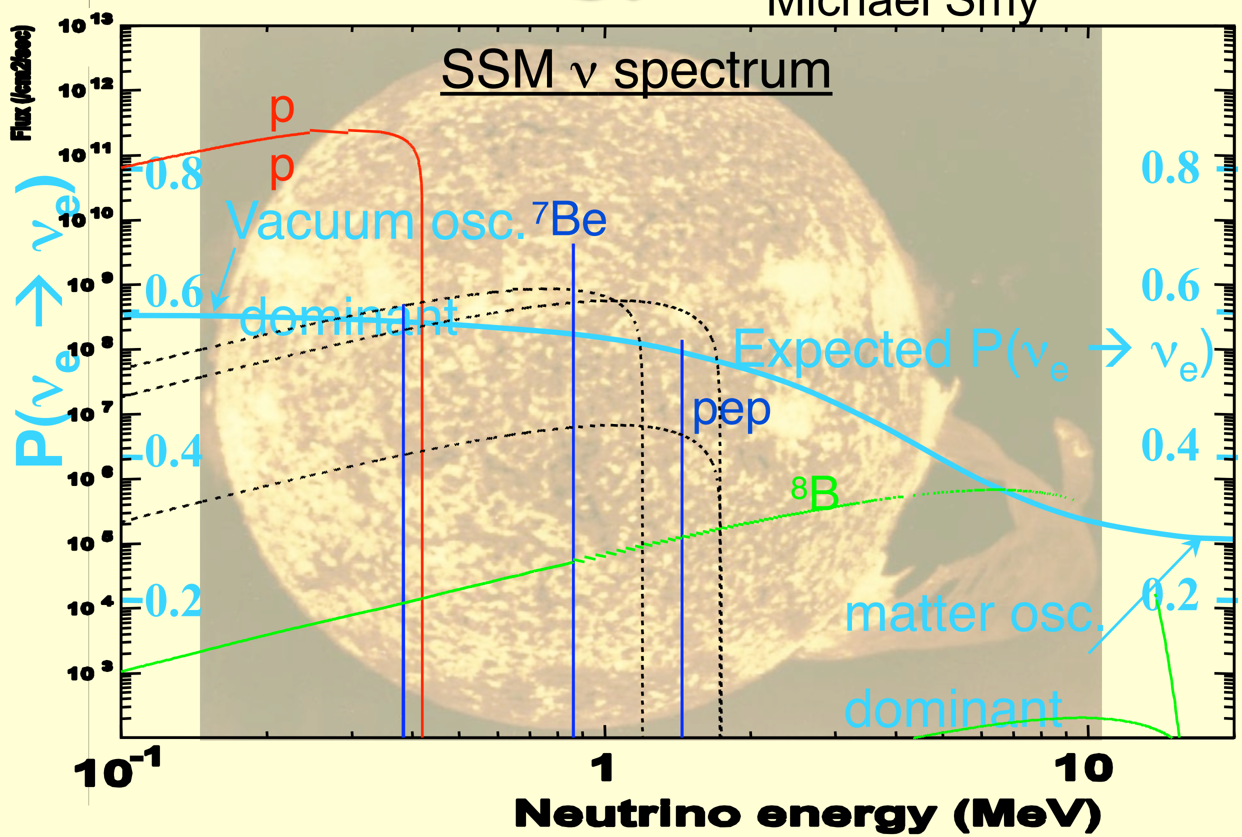
SK extension to low energy

- Reconstruction algorithms were refined during SK-II to overcome loss of PMTs
- Potential to extend threshold to ~3 MeV
- Solar neutrinos in transition region
- Reactor anti-neutrinos
  - Detection of low-energy $\bar{\nu}_e + p \rightarrow n + e^+$ requires addition of Gd to detect recoil n
  - Bonus: this will allow improved search for relic supernova $\bar{\nu}_e$

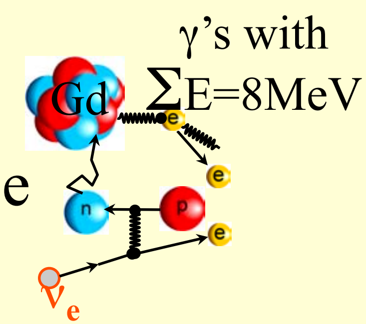
Why Study Low Energy Events?

Michael Smy





- precision measurement of solar neutrino oscillation parameters with reactor neutrinos
- need 0.1% $GdCl_3$ to tag neutrons in delayed coincidence
- MSW transition for solar neutrinos oscillations
- both require very low energy threshold & precise energy calibration



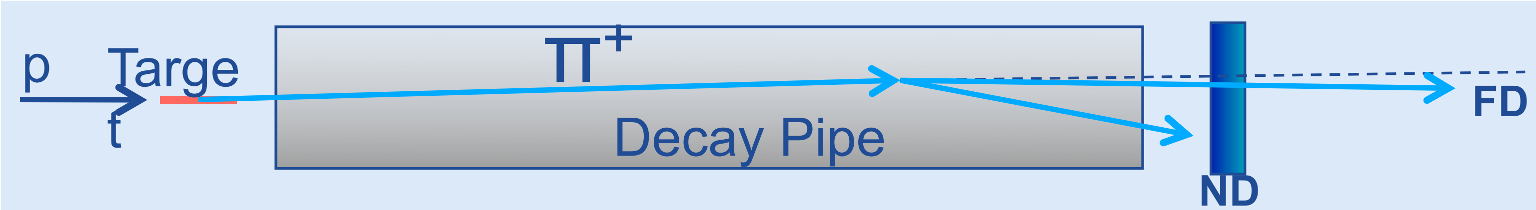
Courtesy K. Bays, UC Irvine & M. Nakahata, ICRR

Neutrino oscillation status

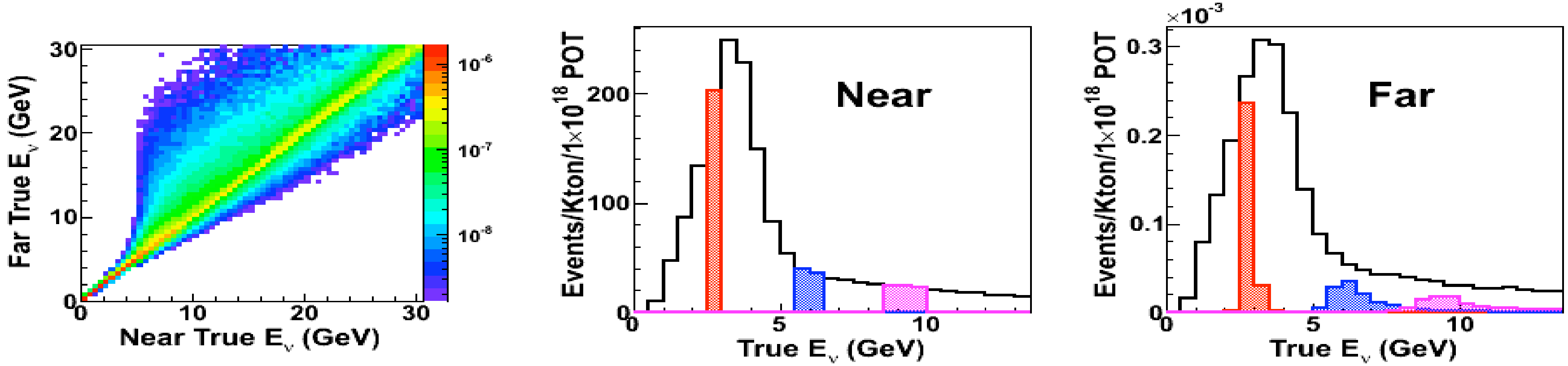
- L/E dip seen at first oscillation minimum
- No evidence yet for any non-standard oscillations, only upper limits for
  - sterile neutrinos
  - oscillations increasing with energy
- No sign yet of possible second-order oscillation effects
  - three-neutrino effects
  - θ_{13}
- MINOS in NuMi beam results consistent with SK

Predicting Unoscillated FD Spectrum

MINOS in NuMi neutrino beam, Alexandre Sousa



- Start with Near Detector data and perform extrapolation to the Far Detector
- Use knowledge of pion decay kinematics and beamline geometry to construct a **beam transport matrix** and predict FD spectrum from measured ND spectrum
- The "Beam Matrix" method is the primary method used in the MINOS CC analysis

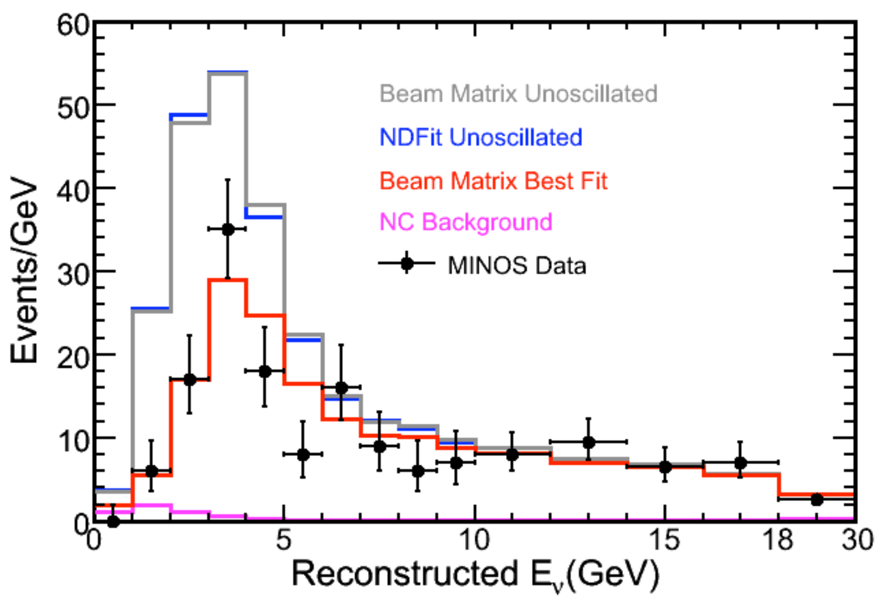


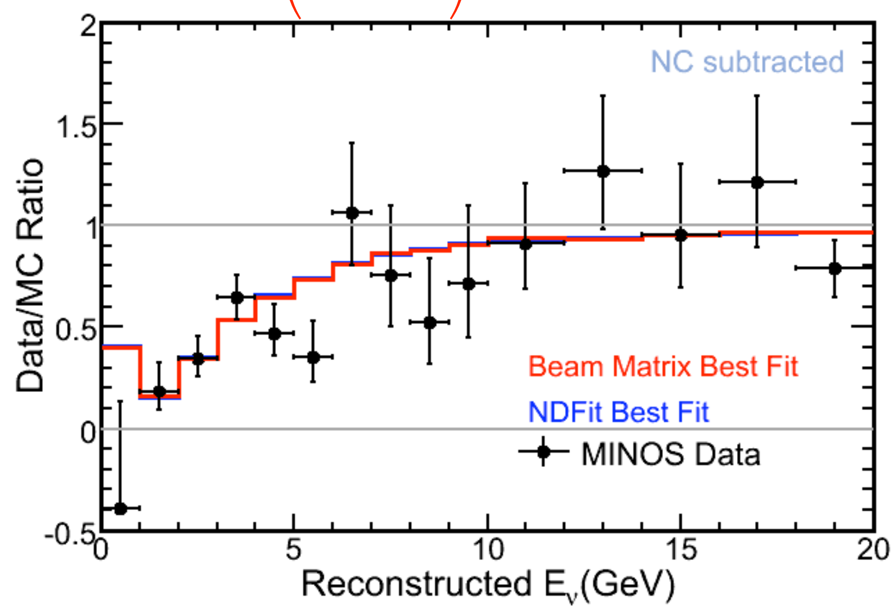
MINOS Best Fit Spectrum

PRL 97, 191801 (2006)

Best fit energy spectrum and Data/MC Ratio for 1.27×10^{20} POT

$$P\left(í_{ì} \to í_{ì}\right) = 1 - \sin^2 2è \sin^2\left(\frac{Äm^2 L}{E}\right)$$





$$\left|\Delta m^2_{32}\right| = 2.74^{+0.44}_{-0.26}\ (\text{stat} + \text{syst}) \times 10^{-3}\,\text{eV}^2$$

$$\sin^2\left(2\theta_{23}\right) = 1.00_{-0.13}\ (\text{stat} + \text{syst})$$

Normalization = 0.98

Constrained to $\sin^2\left(2\theta_{23}\right) \le 1$

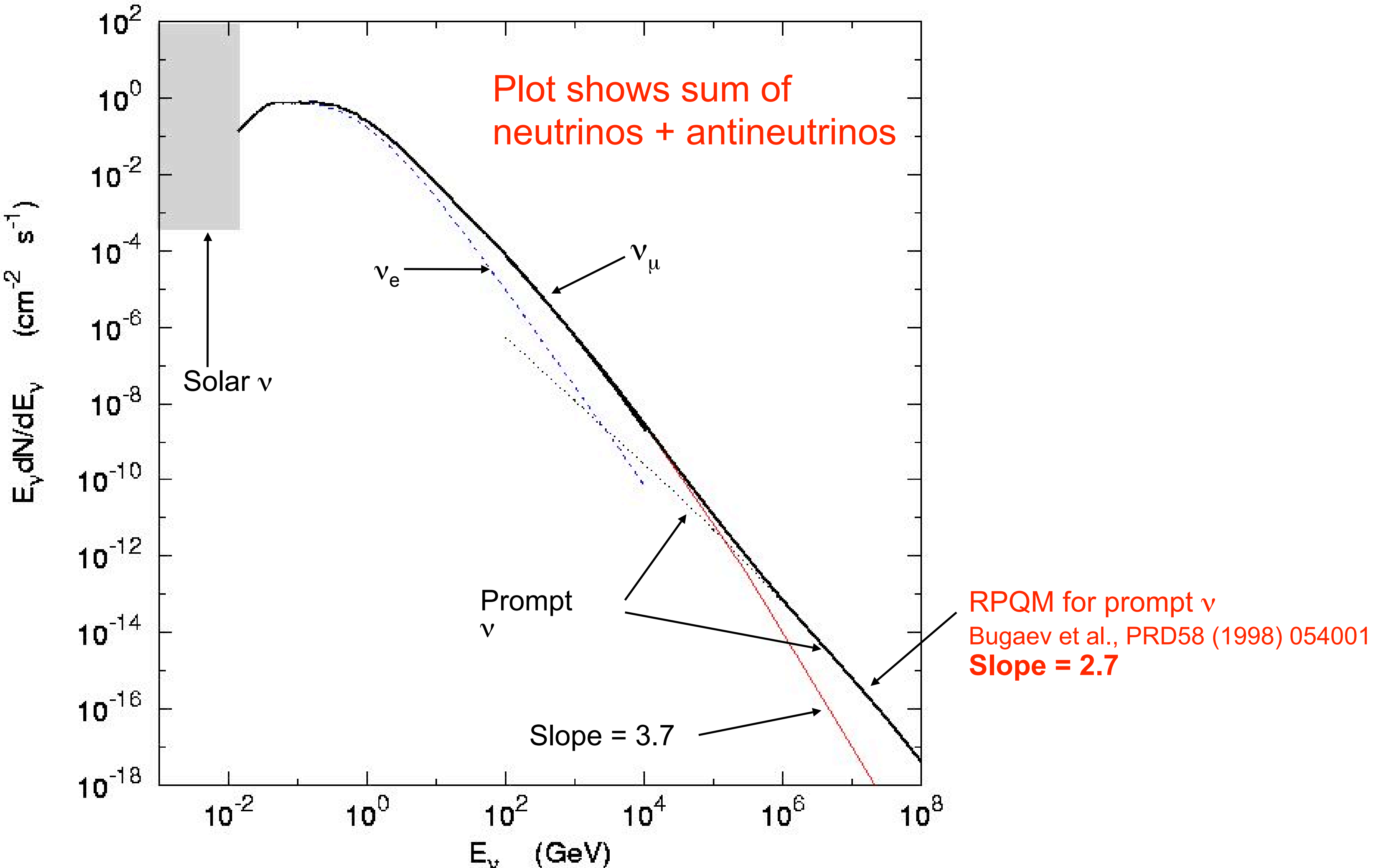
Sample	Observed	Expected (Unoscillated)
ν_μ (<30 GeV)	215	336.0±14.4
ν_μ (<10 GeV)	122	238.7±10.7
ν_μ (<5 GeV)	76	168.4±8.8

Atmospheric neutrinos in MINOS

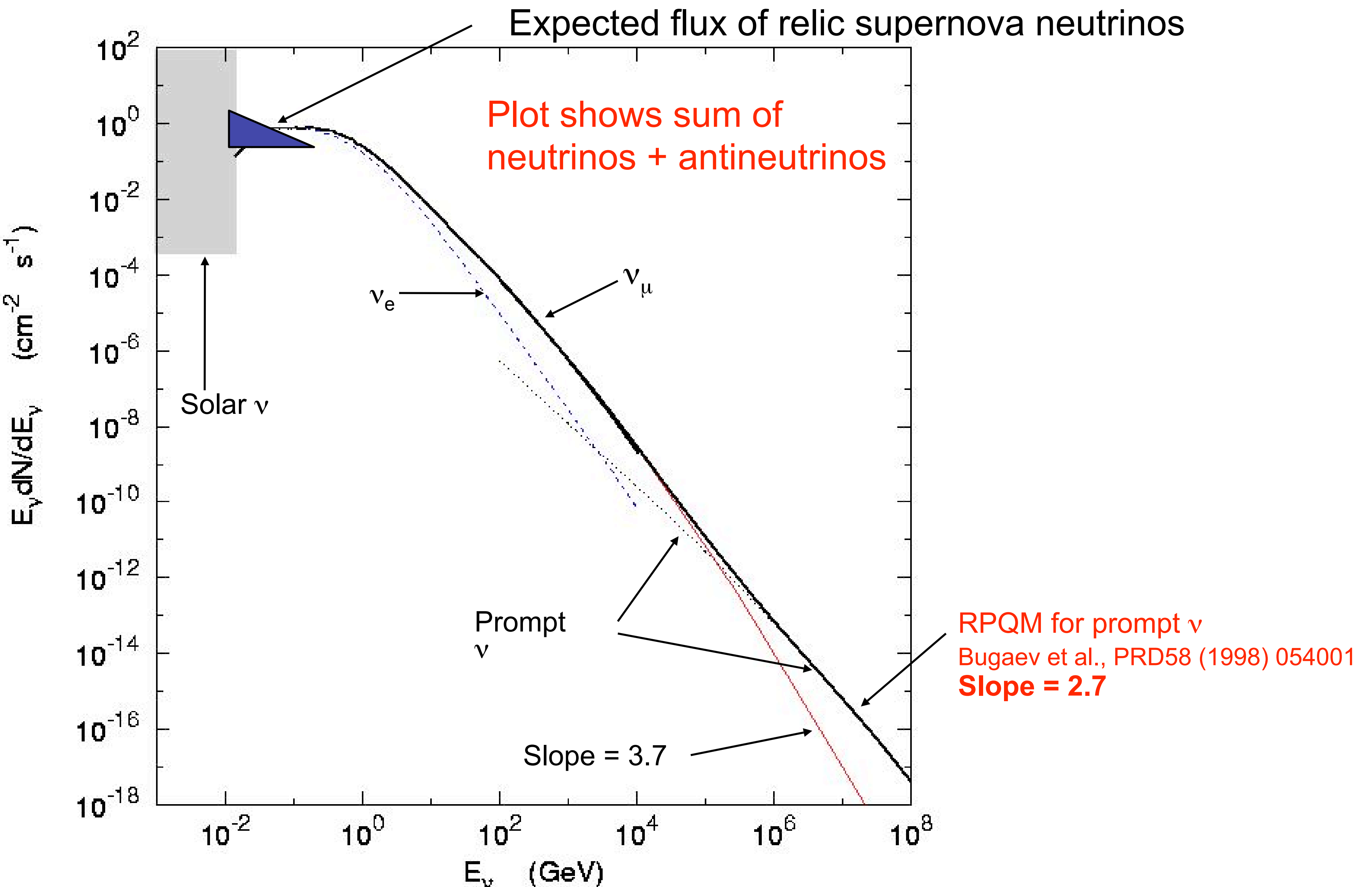
- First detector with ability to determine sign of atmospheric neutrinos
- Too small to obtain good statistics
- Note reversal of muon charge ratio:
  - muon neutrino / muon anti-neutrino > 1
  - therefore μ^- / μ+ > 1

p_{fit} (GeV)	Data	Bkgd	MC
		μ^-	
1 – 10 (L)	21	2.2	37.5
10 – 100 (H)	20	0.2	17.5
		μ^+	
1 – 10 (L)	16	1.3	19.3
10 – 100 (H)	13	0.2	8.6
		U	
unknown (U)	70	0.7	76.5

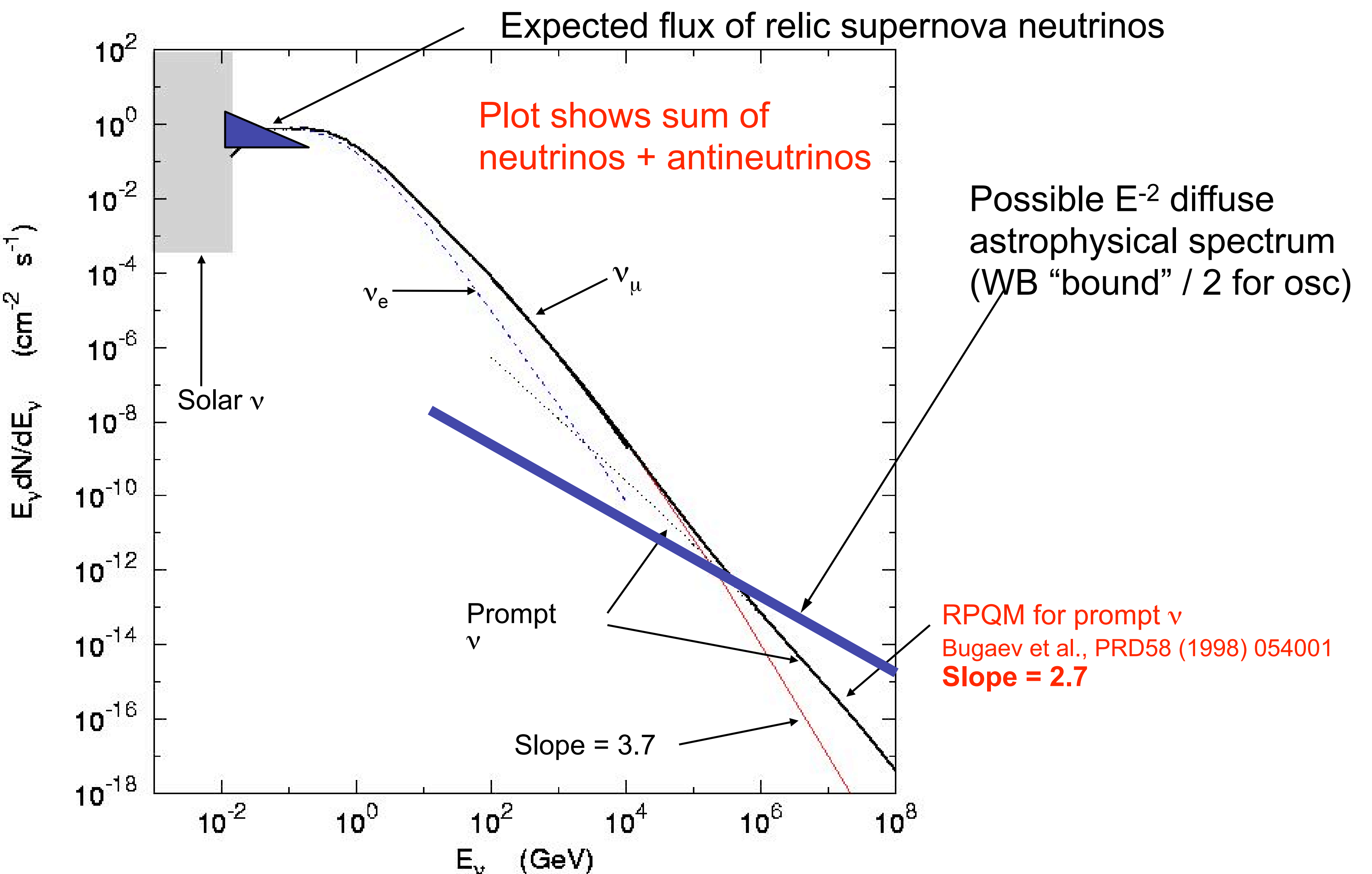
Atmospheric ν as background



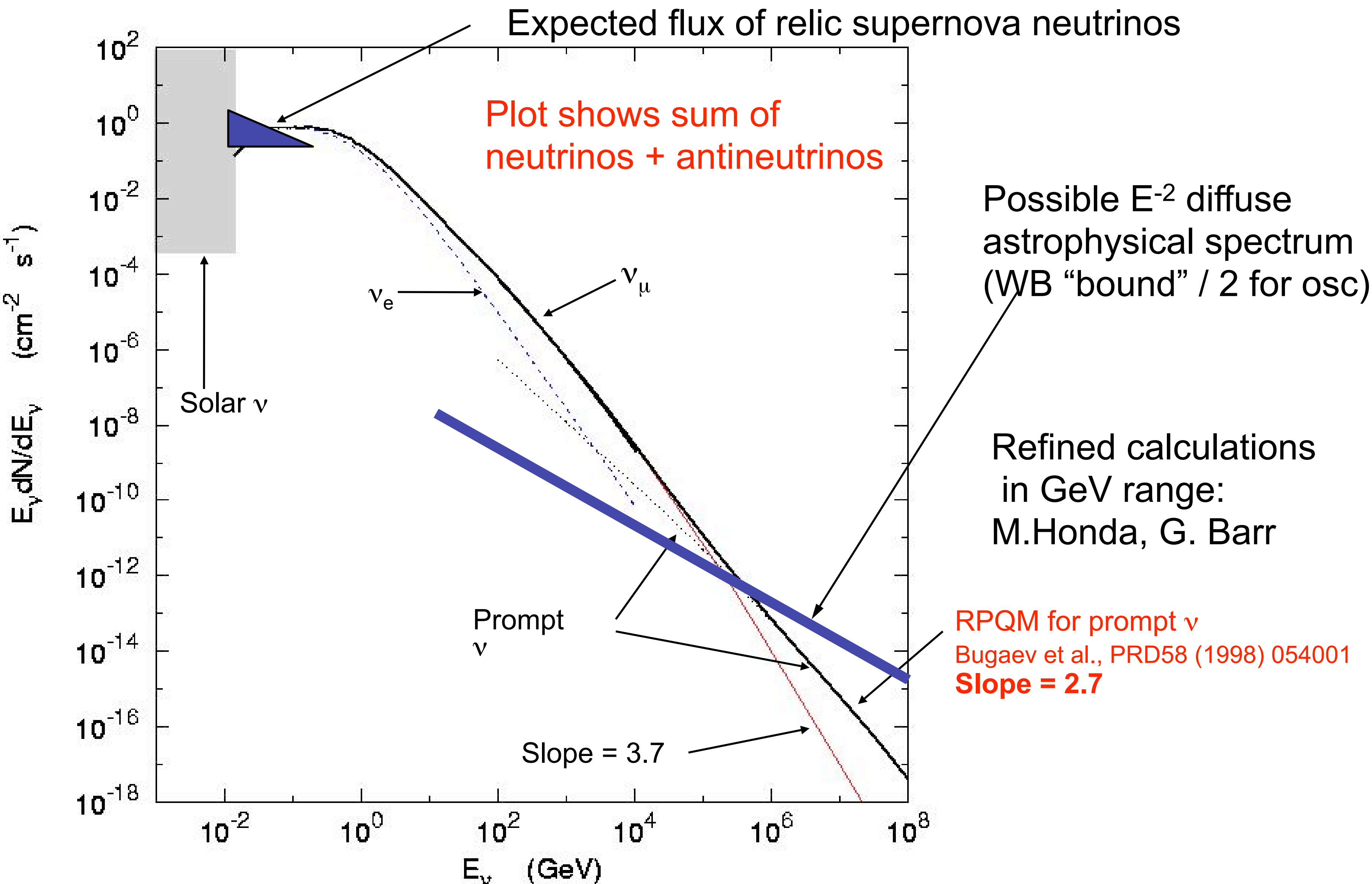
Atmospheric ν as background



Atmospheric ν as background



Atmospheric ν as background



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

Supernova Relic Neutrino (SRN)

- Supernova Relic Neutrino(SRN) is diffuse supernova neutrino background from all past supernova.

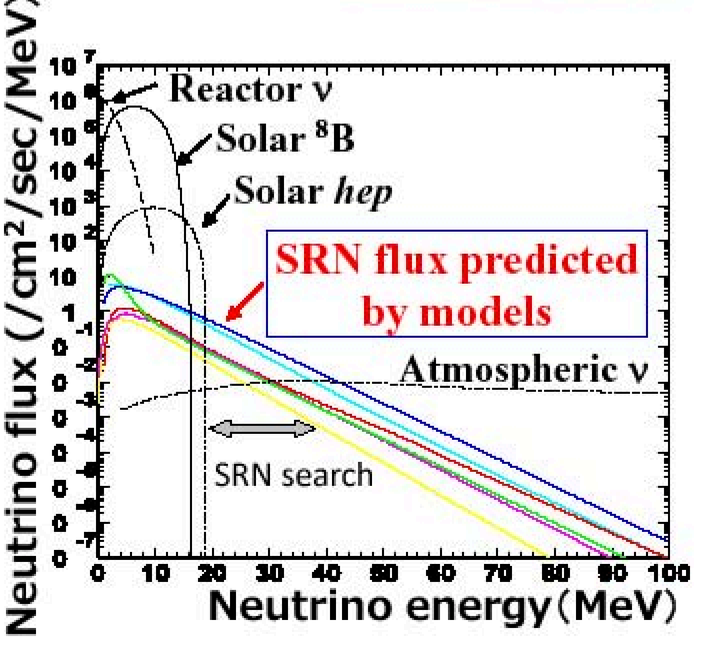
◎ Motivation

SRN Measurement will enable us to investigate the history of past Supernova. For example, the flux of SRN would show the star formation rate and supernova rate in galaxies.

◎ Interaction in SK

The main interaction for SRN search in the SK detector is charged current quasi-elastic interaction (inverse β decay).

$$\bar{\nu}_e + p \rightarrow e^+ + n$$



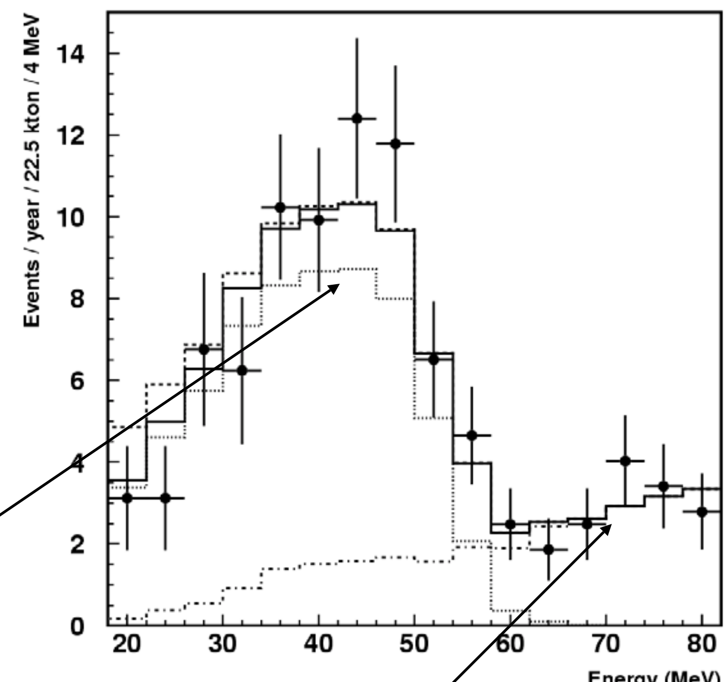
◎ Energy region for SRN search

SRN is dominant neutrino in 18 - 40 MeV

Diffuse, relic supernova neutrinos

- Super-K limit is from $\bar{\nu}_e + p \rightarrow n + e^+$
- Neutron not detected in current Super-K
- Backgrounds:
  - atmospheric ν_e and $\bar{\nu}_e$
  - solar ν_e and reactor $\bar{\nu}_e$
  - atmospheric $\nu_\mu \rightarrow \mu$

    (E_μ < 50 MeV)



Improvement with tagged neutron

Beacom & Vagins,
PRL 93 (2004) 171101

Prescribe gadolinium additive to detect neutrons and eliminate background and select anti-ν_e only

Improvement with tagged neutron

SK flux limit VS predicted flux

Beacom & Vagins,
PRL 93 (2004) 171101

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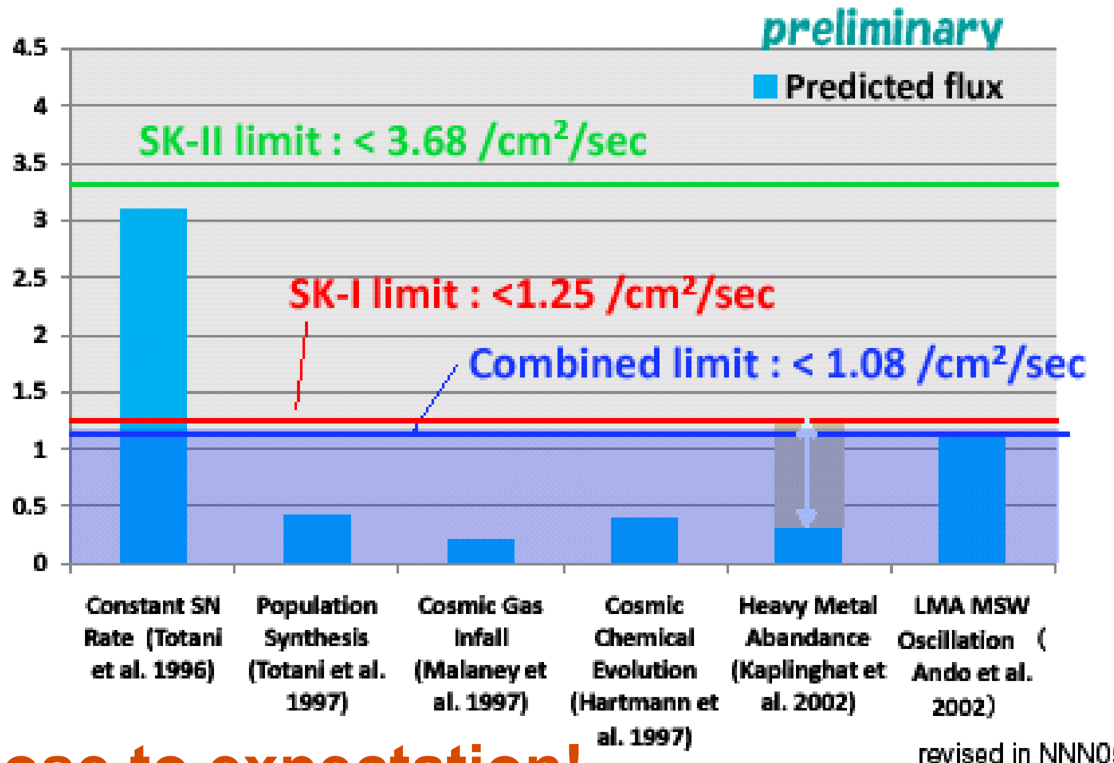
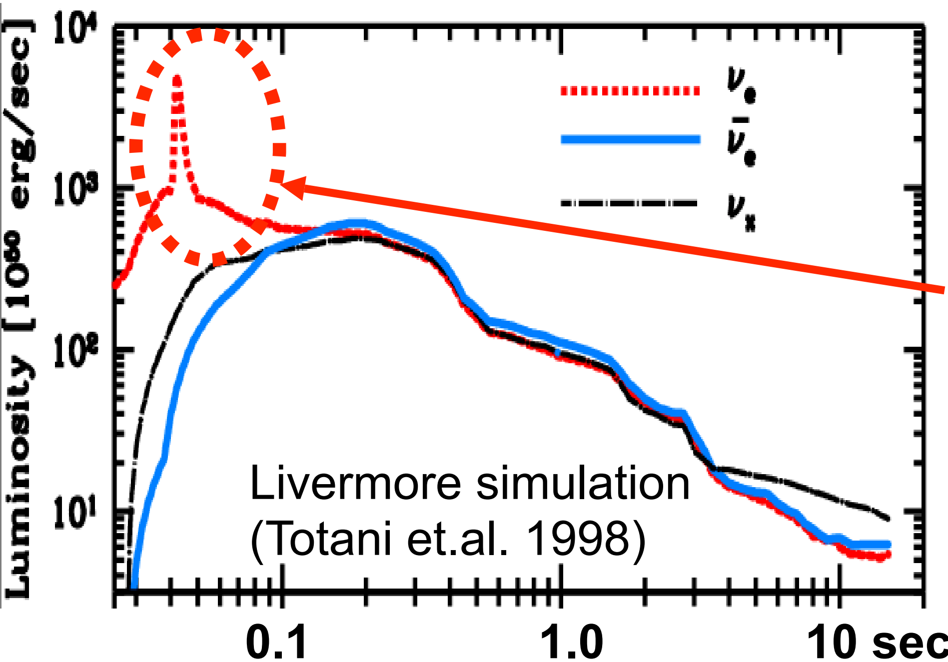


Current limits close to expectation!

Time Information: Sliding Window Search



Time Profile of SN burst

M. Ikeda, Super-K

Time duration of main burst is about **10 sec**.

Prompt burst of ν_e is so called **neutronization burst** whose time duration is expected as **~10msec.**

Sliding Time window search

1. Set **timewindow (Δt)** and **multiplicity threshold ($M_{thr.}$)**

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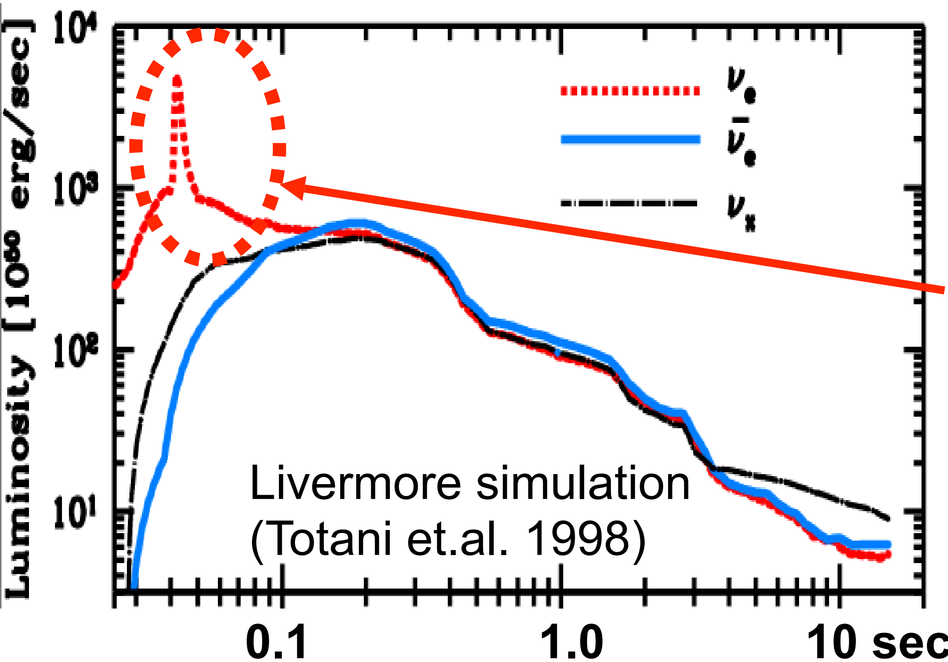

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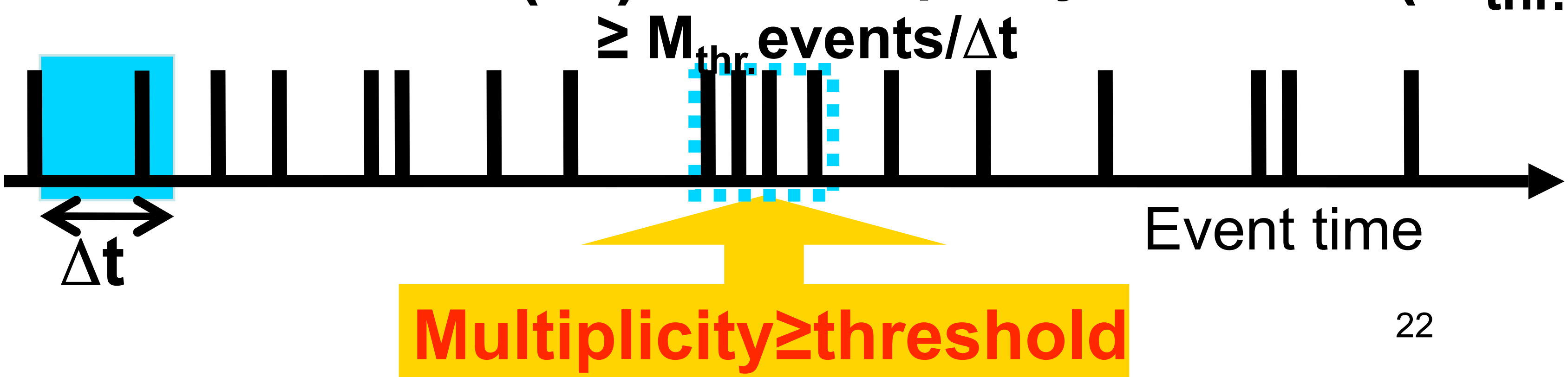


S-K Summary (SN burst search)

- Using data from Super-K,
  3 methods of supernova searches with newly installed criteria was conducted.
- Data set : from May 1996 to Oct 2005
  Total livetime: 2589.3 days
  (Livetime for 3rd analysis : 2381.3 days)
- No candidate was observed
- 100% detection probability up to 100 kpc
- SN rate within 100kpc(LMC,SMC,our Galaxy) is estimated
  < 0.32 SN/yr @ 90% C.L.
- Detection probability is maintained at a level of
  7% for SN at Andromeda.
- No candidate of neutronization burst observed

RUN	Since:	To:	Uptime [days]	Duty Cycle	Mass [tonn]	PUBLISHED
RUN 1	Jun 6th '92	May 31st '93	285	60%	310	23rd ICRC 1993
RUN 2	Aug 4th '93	Mar 11th '95	397	74%	390	24th ICRC 1995
RUN 3	Mar 11th '95	Apr 30th '97	627	90%	400	25th ICRC 1997
RUN 4	Apr 30th '97	Mar 15th '99	685	94%	415	26th ICRC 1999
RUN 5	Mar 16th '99	Dec 11th '00	592	95%	580	27th ICRC 2001
RUN 6	Dec 12th '00	Mar 24th '03	821	98%	842	28th ICRC 2003
RUN 7	Mar 25th '03	Feb 4th '05	666	>99%	881	29th ICRC 2005
RUN 8	Feb 5th '05	May 31st '07	846	>99%	936	30th ICRC 2007

Total 4919 days

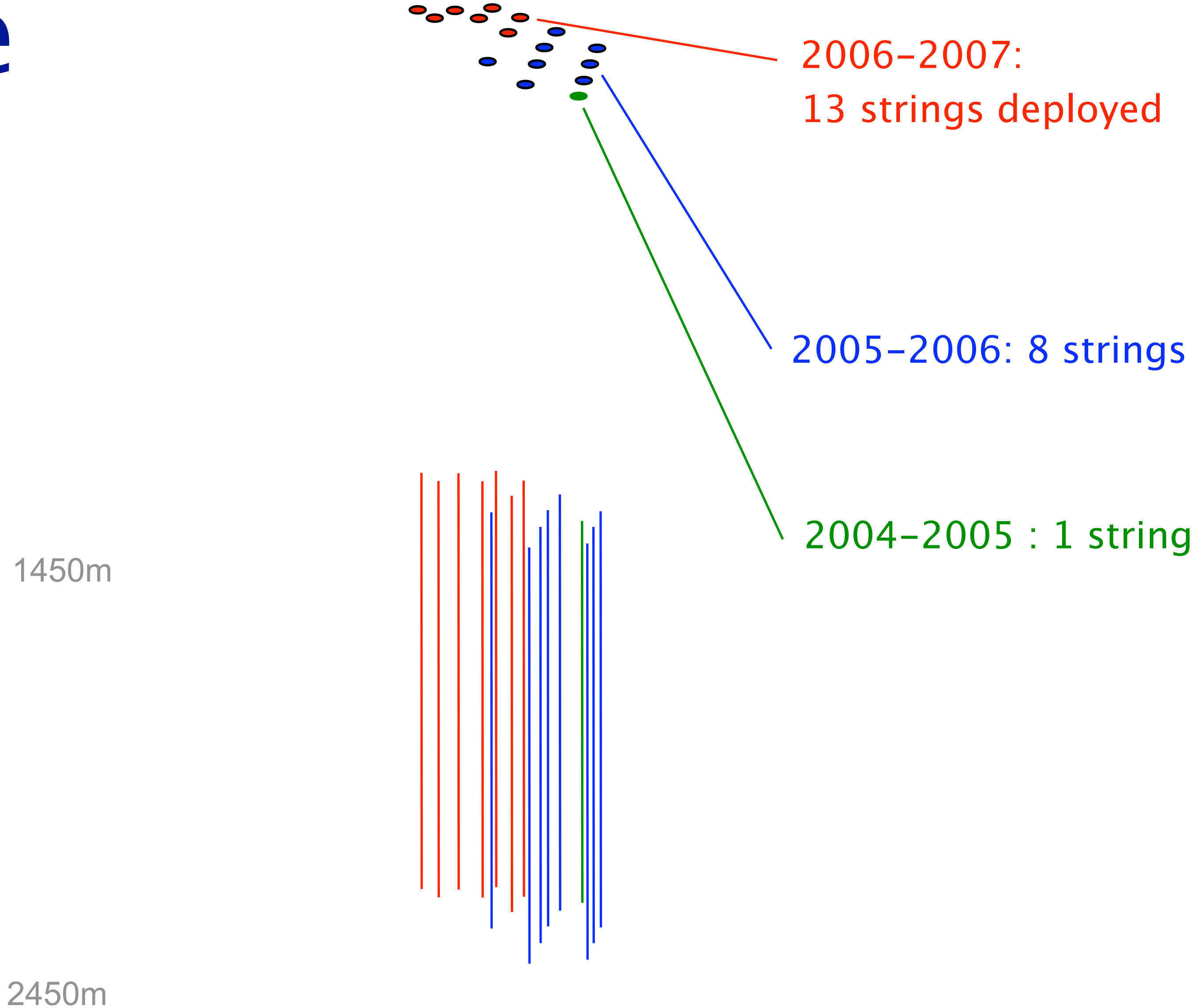
Upper Limit to SN event in the Milky Way

0.17 /year (90% c.l.)

Detectors sensitive to high-energy neutrinos

- Neutrino telescopes
  - Primarily aimed at >TeV, upward ν_μ-induced ν
  - e.g. IceCube/AMANDA, Baikal, Antares, Nestor, KM3net
  - Also sensitive to PeV, EeV ν, but limited area
- Radio, acoustic detection
  - Threshold in EeV range
- Giant EAS detectors sensitive to ~EeV ν
  - e.g. Auger, HiRes, CRTNT

IceCube


2006-2007:
13 strings deployed
2005-2006: 8 strings
2004-2005 : 1 string
1450m
2450m

IceCube

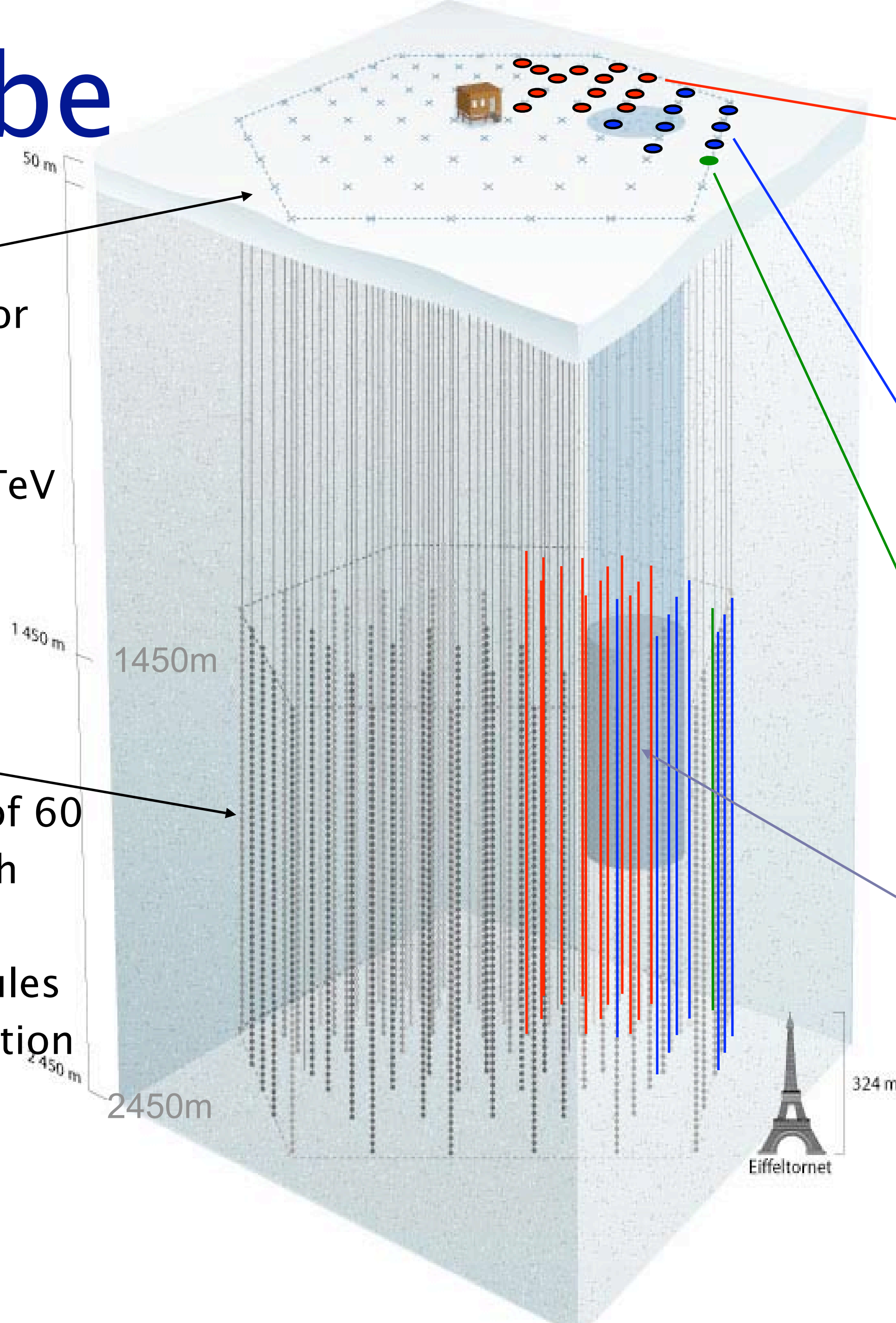
IceTop

Air shower detector
80 pairs of ice
Cherenkov tanks
Threshold ~ 300 TeV

InIce

Planned 80 strings of 60
optical modules each

17 m between modules
125 m string separation



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Current configuration
- 22 strings
- 52 surface tanks

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AMANDA-II
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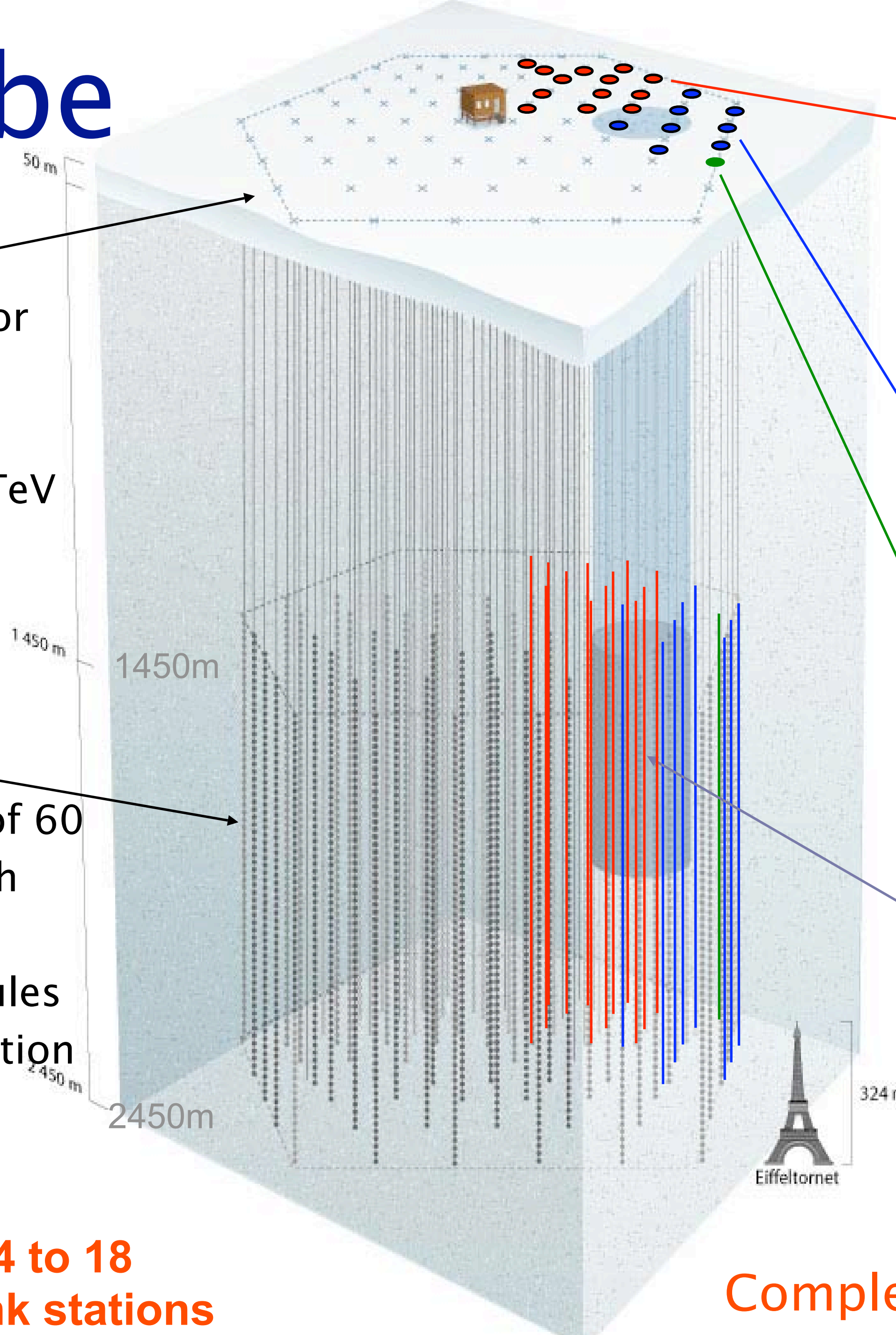

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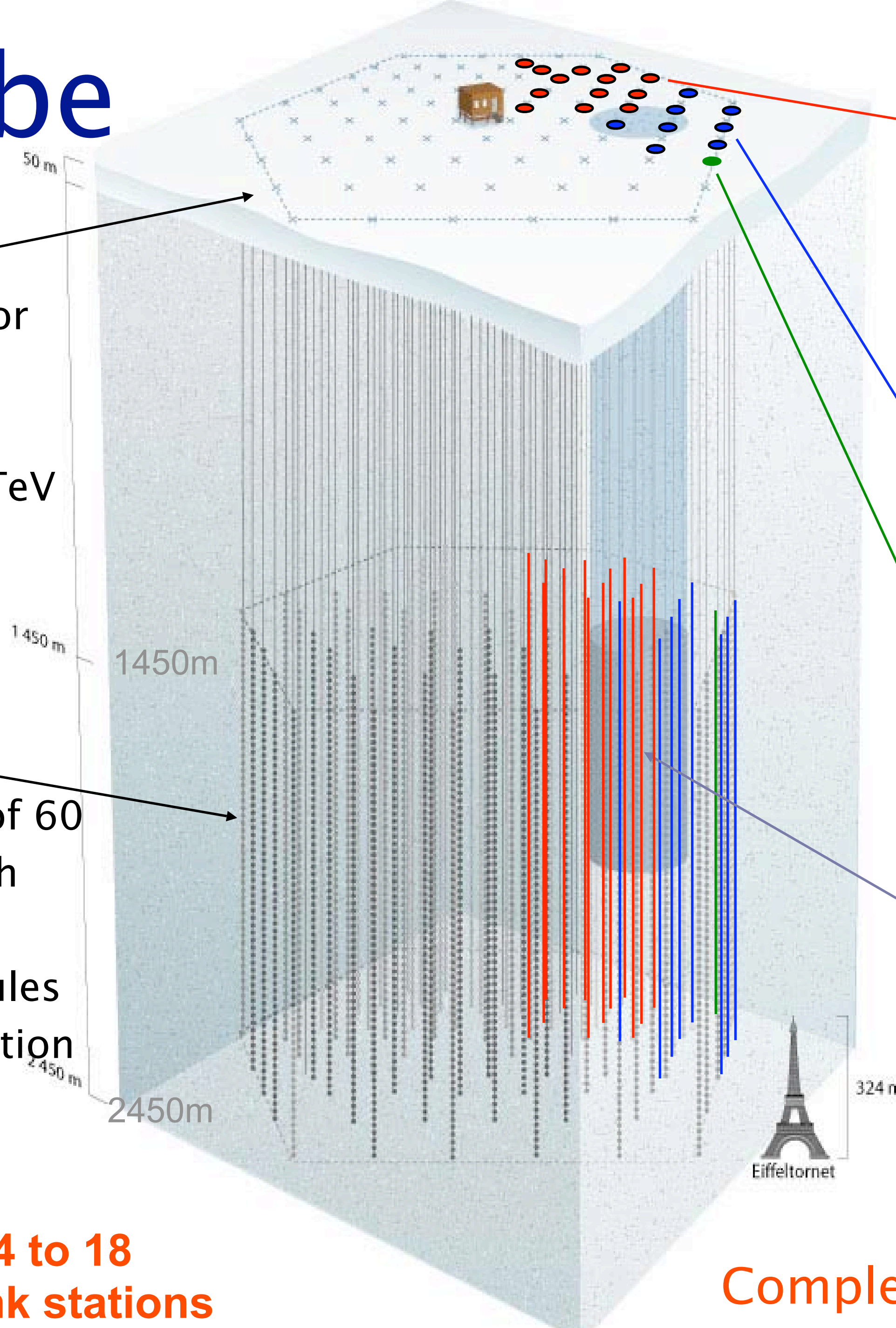
Completion by 2011.

IceCube



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677 modules

AMANDA now
operating as part
of IceCube
-talk of A. Gross

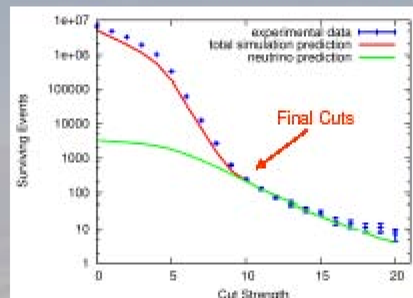
2007/08: add 14 to 18 strings and tank stations

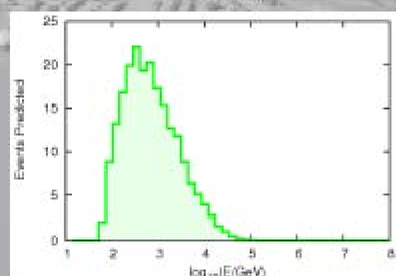
Completion by 2011.

Atmospheric neutrinos in IceCube

2006 Atmospheric ν_μ search

- 137.4 Live Days
- Reconstructed with AMANDA-based likelihood reconstruction
- Reject down-going events
- Up-going events dominated by mis-reconstructed down-going events.
  - Quality cuts on number and length of Direct (unscattered) hits
  - N_{dir} >= 10 L_{dir} > 250 meters for the final sample
- 211 ±76.1(syst) ± 14.5(stat) events expected from atmospheric neutrinos
- 234 events measured

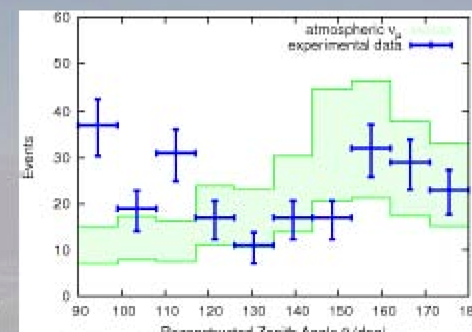


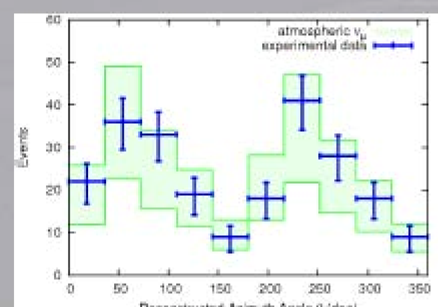


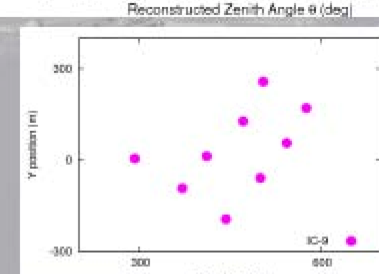
Paolo Desiati, John Pretz

IC-9 Final Event Selection

- Excess at the horizon is expected to be residual background.
  - Good agreement above 120 degrees
- Peaks in azimuth correspond to long horizontal axes of the detector



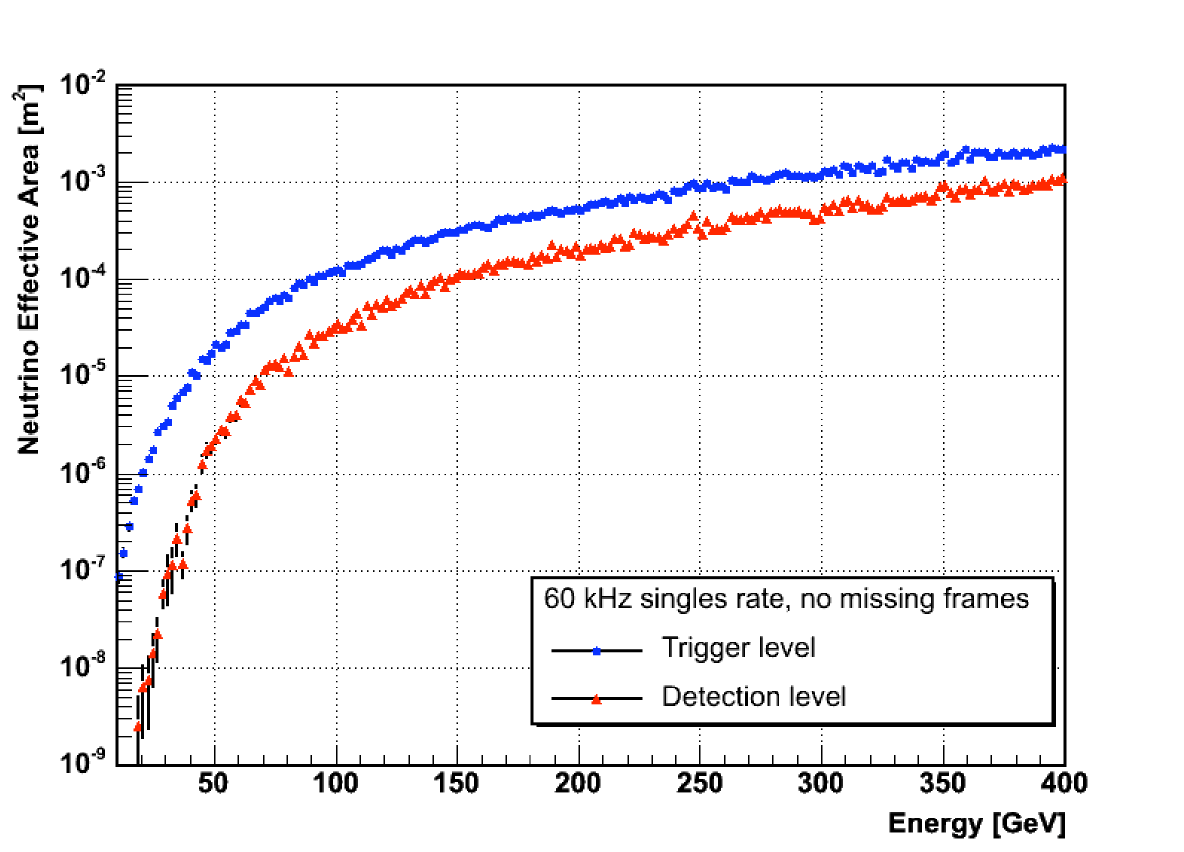




Goals for neutrino astronomy

- Point source searches
  - Unbinned search improves sensitivity (Braun, Aguilar)
  - Search for clusters in time and space (E. Bernardini, R. Porrata)
  - Search for neutrinos from identified GRB (I. Taboada)
  - Multi-messenger "Target of Opportunity" in coincidence with gamma-ray telescope
- see Gavin Rowell's rapporteur talk for details of the ν/γ connection
- Atmospheric ν and search for diffuse astrophysical ν covered here

Neutrino effective area for ANTARES



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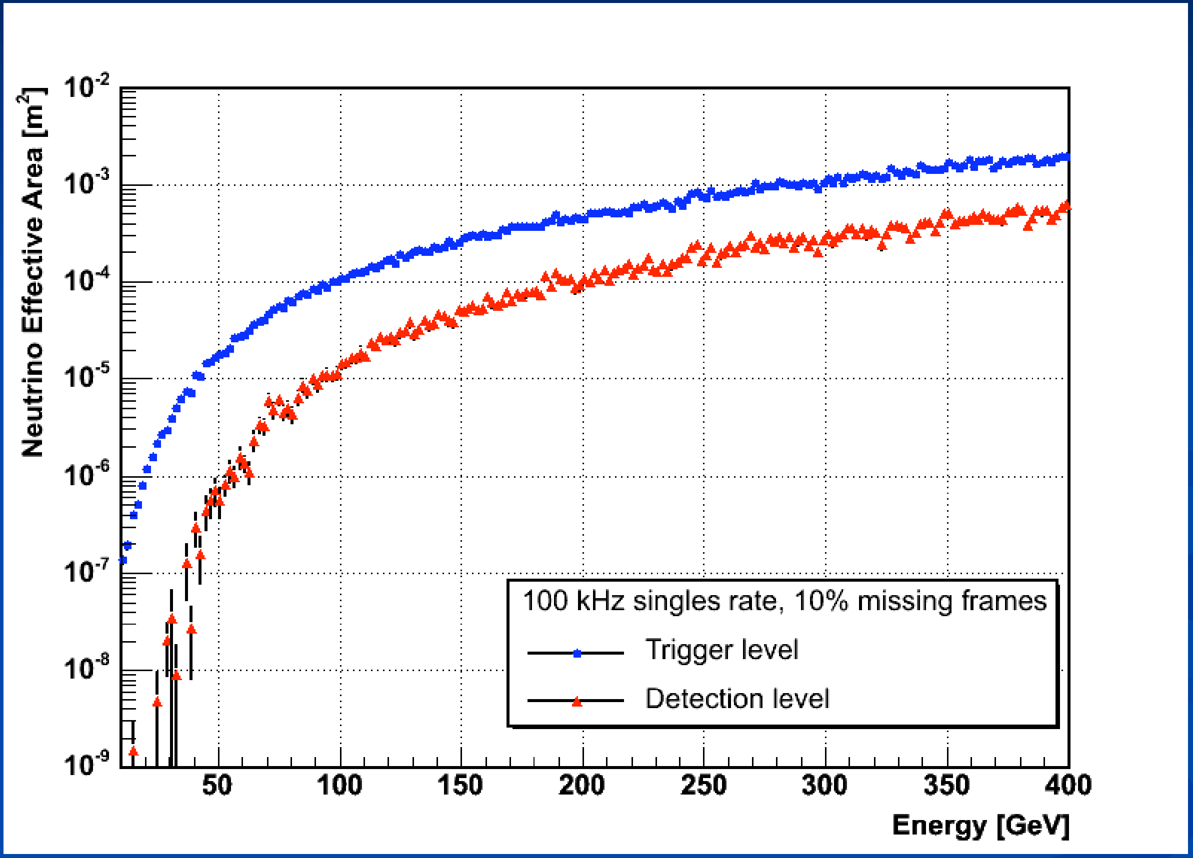
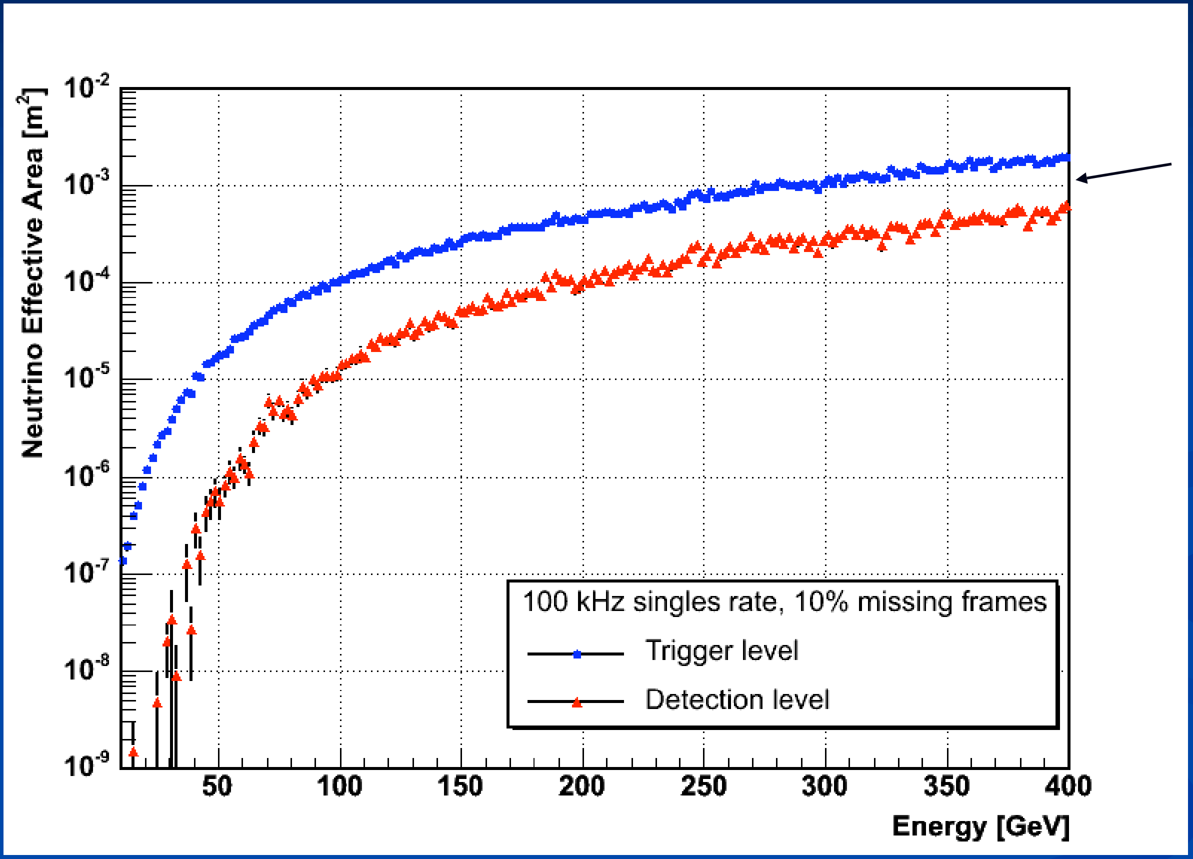
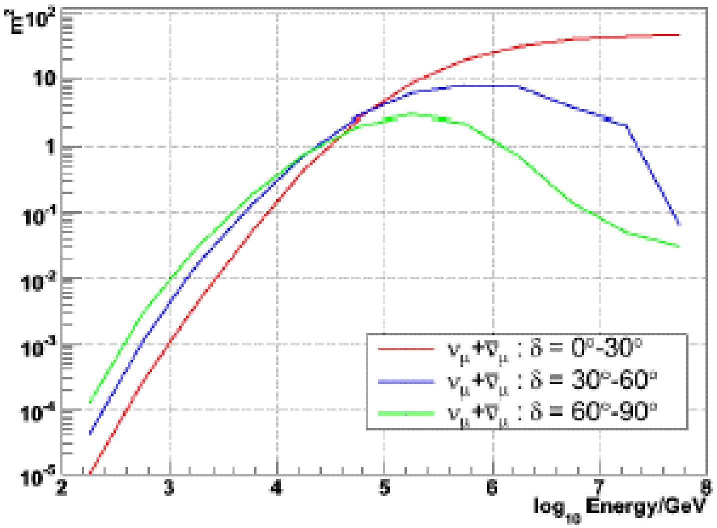


Neutrino effective area for ANTARES



10 cm^2

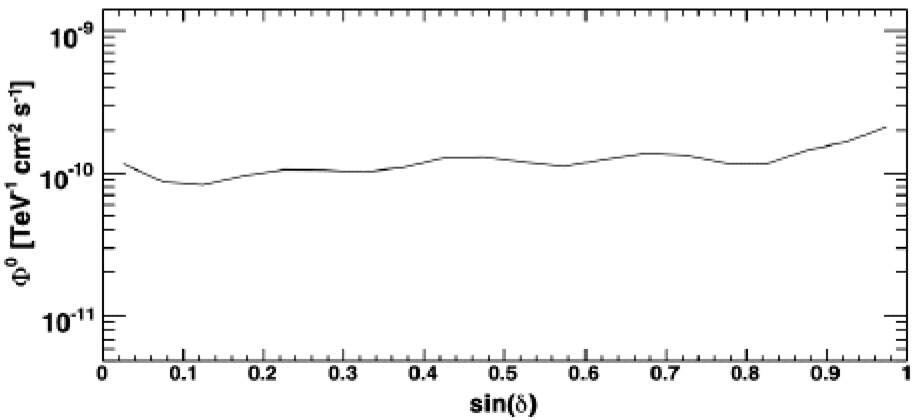
Point source search with IceCube-9



IC9: Neutrino effective area

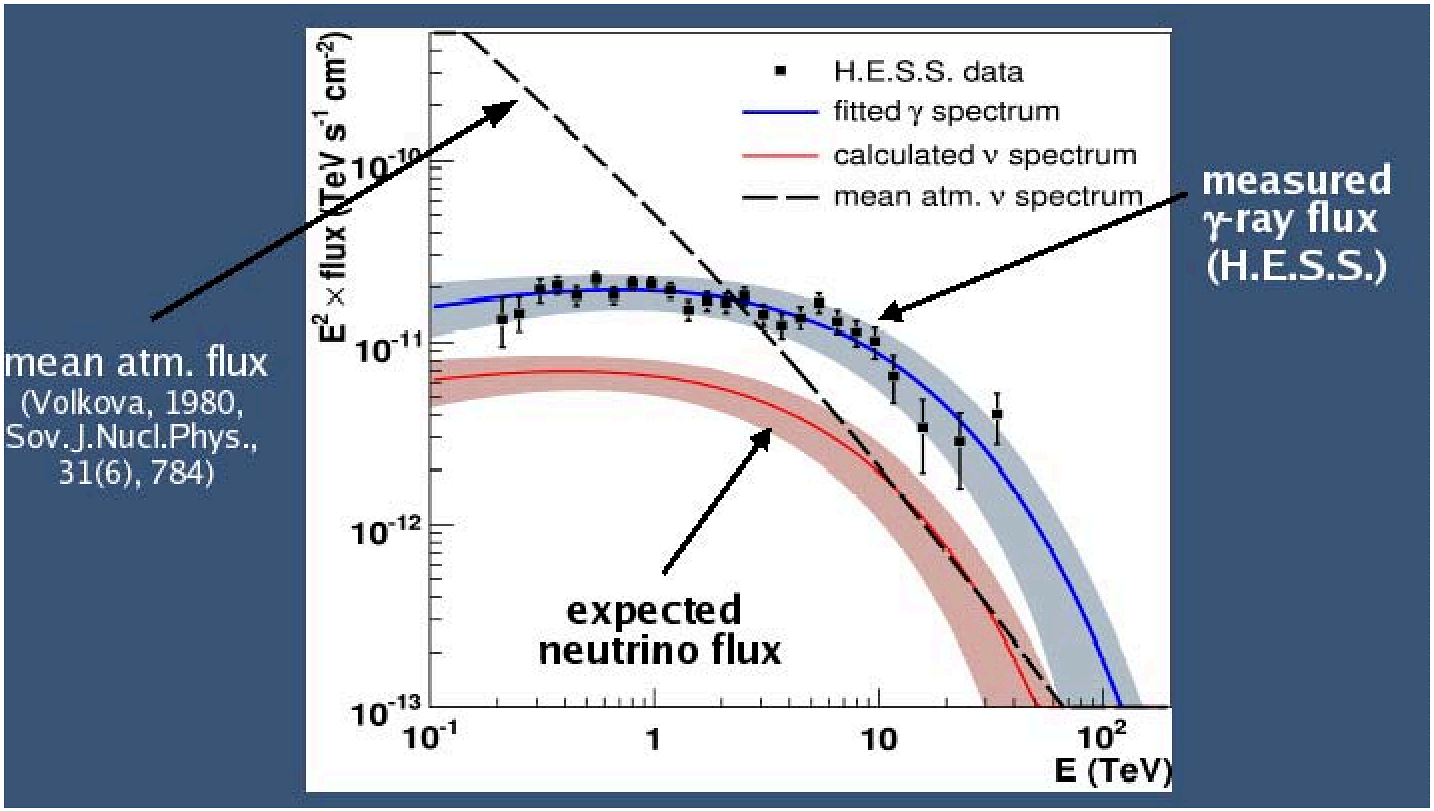
Chad Finley

IC9 point source limit



Median 90% confidence level flux upper limit Φ^0 (as a function of declination) for point sources with differential flux: $d\Phi/dE = \Phi^0 \, (E\,/\,\mathrm{TeV})^{-2}$.

Expected ν flux from galactic point sources, example: RXJ 1713-3946



Christian Stegmann et al.

Note importance of background of atmospheric ν in a km^3 detector

Neutrino Event Rates (II)

- γ-ray sources with observed cut-off (KM3NeT, 5 years)

			E > 1TeV		E > 5TeV	
	Type	Dia. [º]	src	bck	src	bck
- Vela X	PWN	0.8	9 – 23	23	5 – 15	4.6
- RX J1713.7-3946	SNR	1.3	7 – 14	21	2.6 – 6.7	8.2
- RX J0852.0-4622	SNR	2.0	7 – 15	104	1.9 – 6.5	21
- HESS J1825–137	PWN	0.3	5 – 10	9.3	2.2 – 5.2	1.8
- Crab Nebula	PWN	<0.1	4.0 – 7.6	5.2	1.1 – 2.7	1.1
- HESS J1303–631	NCP	0.3	0.8 – 2.3	11	0.1 – 0.5	2.1
- LS 5039* (INFC)	Binary	<0.1	0.3 – 0.7	2.5	0.1 – 0.3	0.5

NCP: no counterparts at other wavelength

* no γ-ray absorption

- 23 further γ-ray sources investigated:
  - All γ-ray spectra show no cut-offs (but limited statistics)
  - Event numbers mostly below 1 – 2 in 5 years

Merida,

Christian Stegmann, Galactic Neutrinos, ICRC 2007

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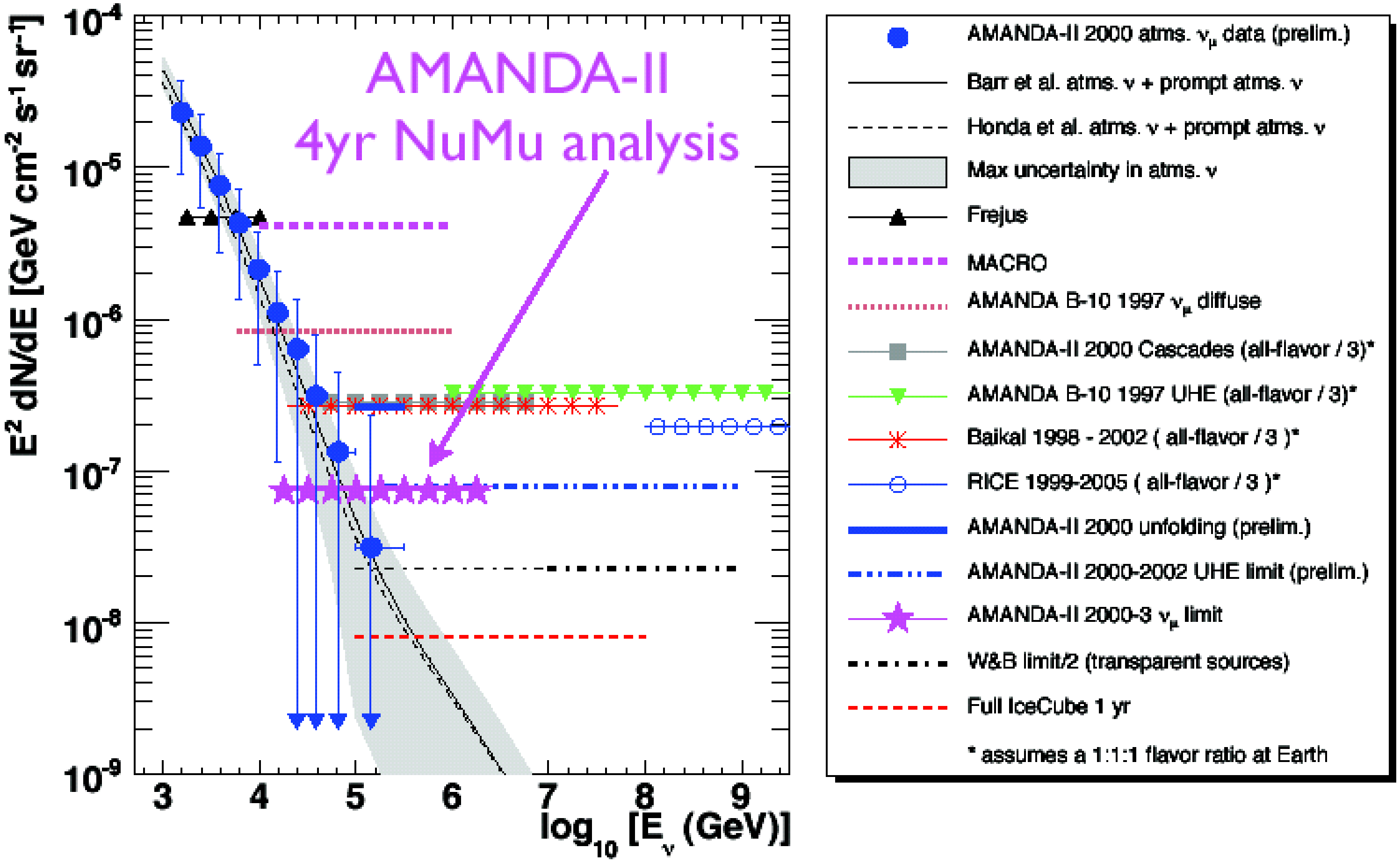
Christian Stegmann, Galactic Neutrinos, ICRC 2007

Search for diffuse ν with hard spectrum

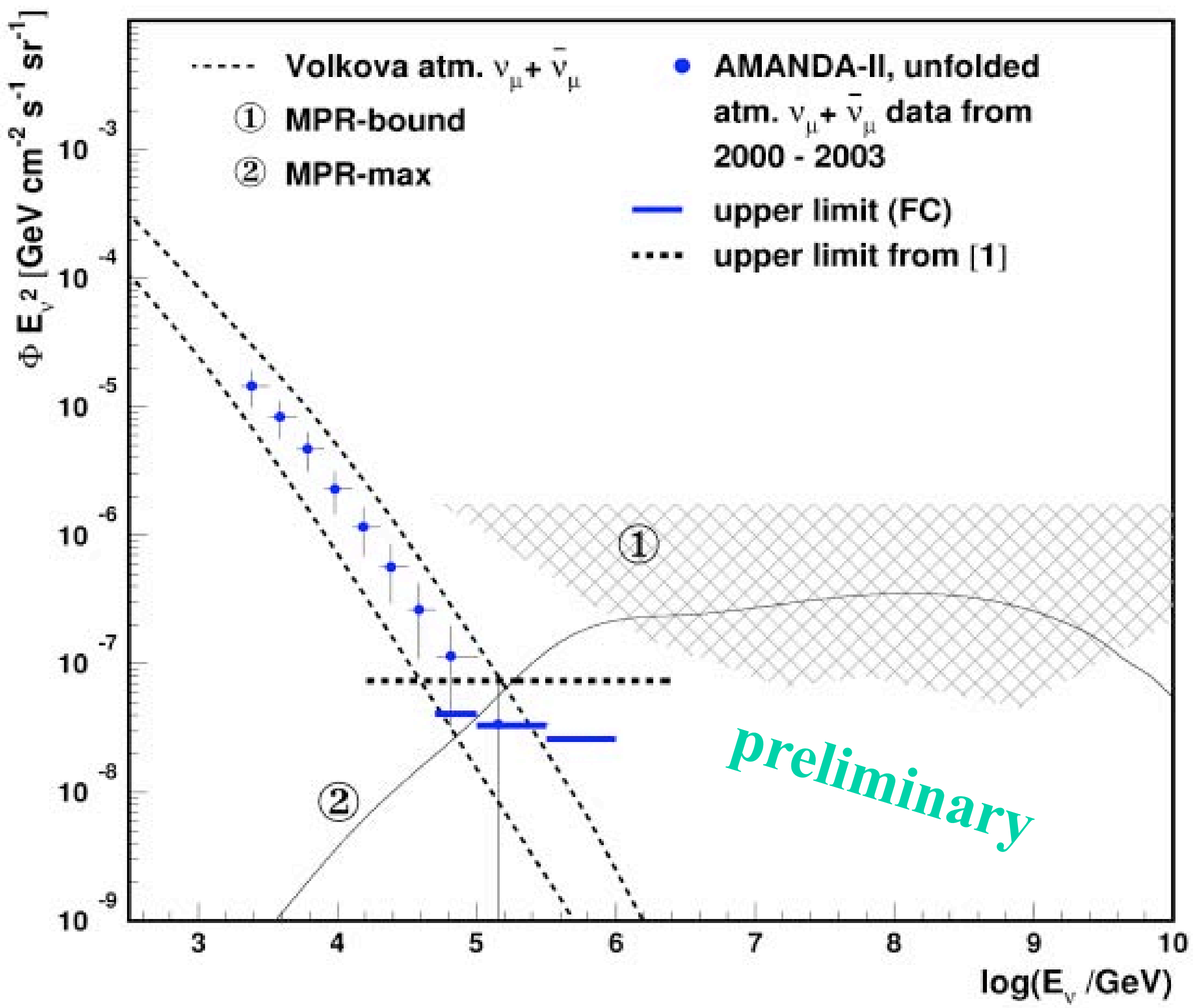
AMANDA-II 2000-2003 integrated analysis Upper Limit

Gary Hill et al.



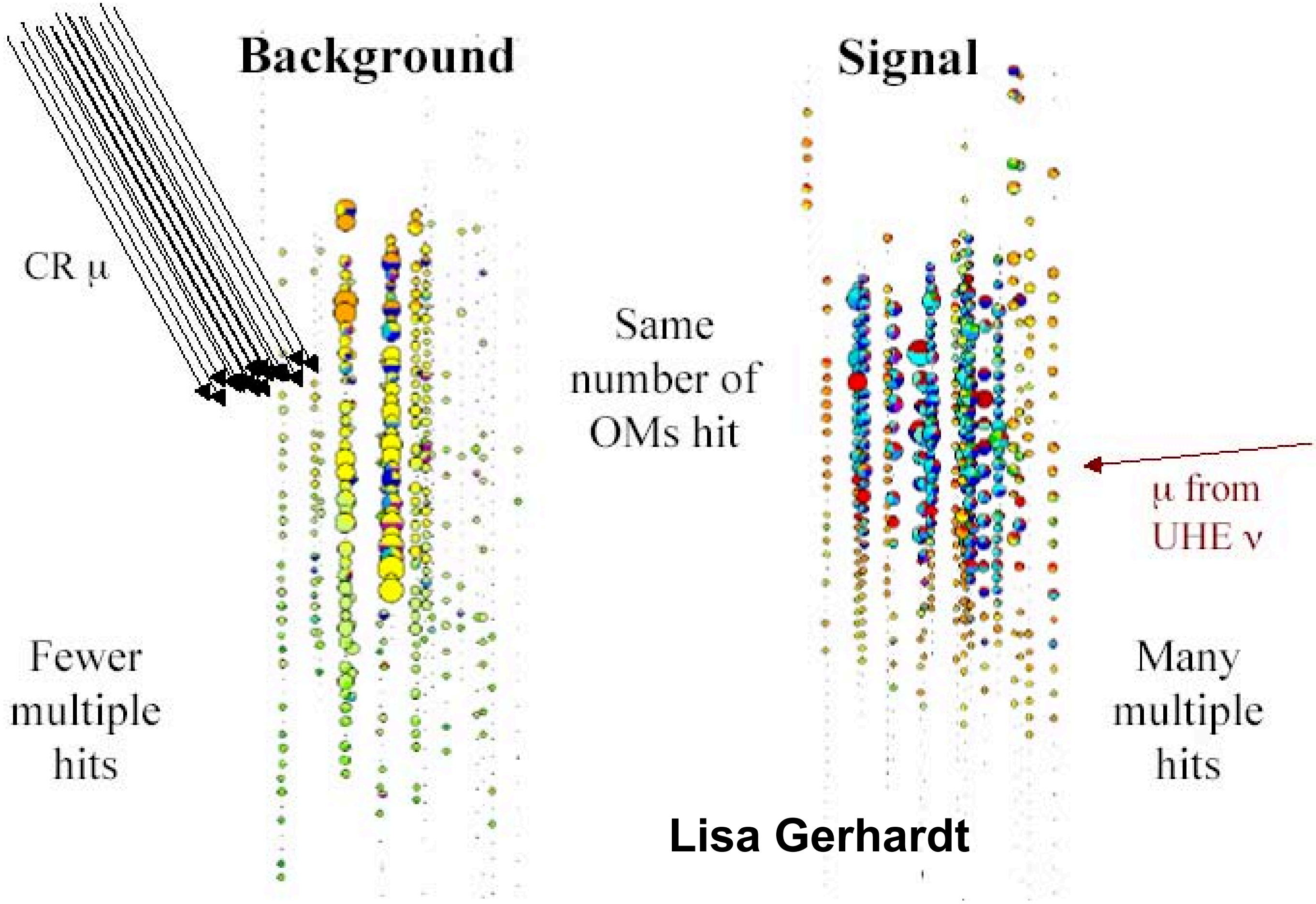
M

AMANDA 4 yrs atmospheric ν



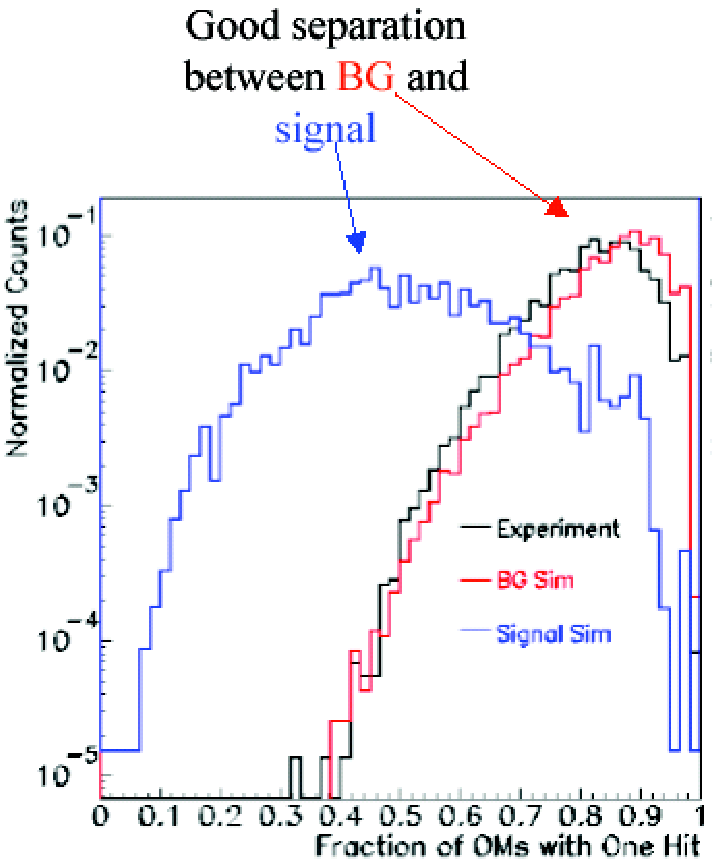
[1] Achterberg et al., astro-ph/0705.1315

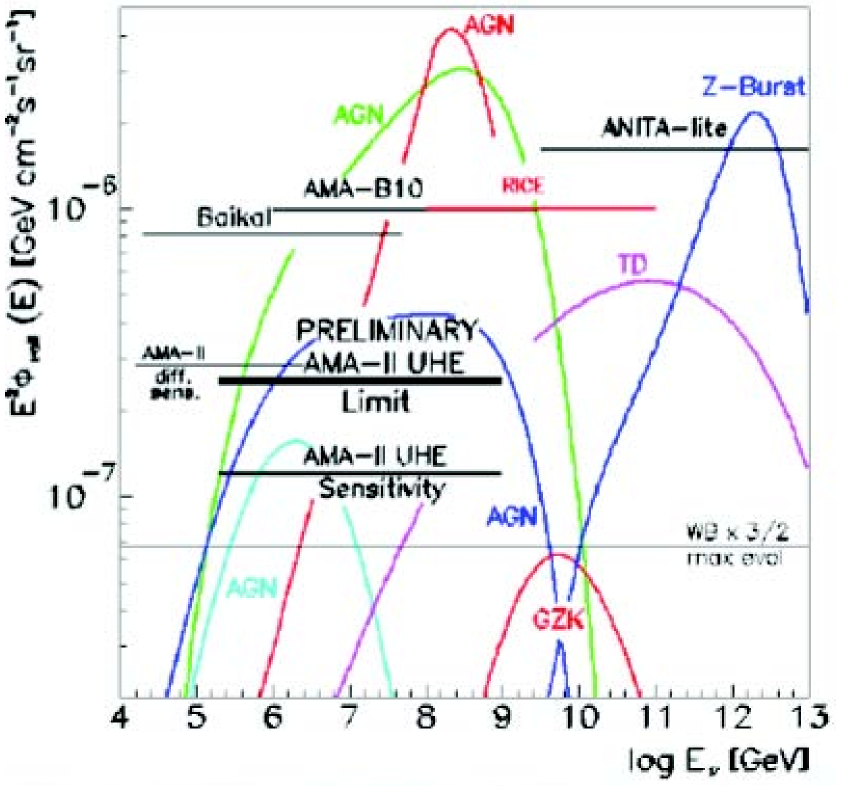
AMANDA cascade searches (>PeV)



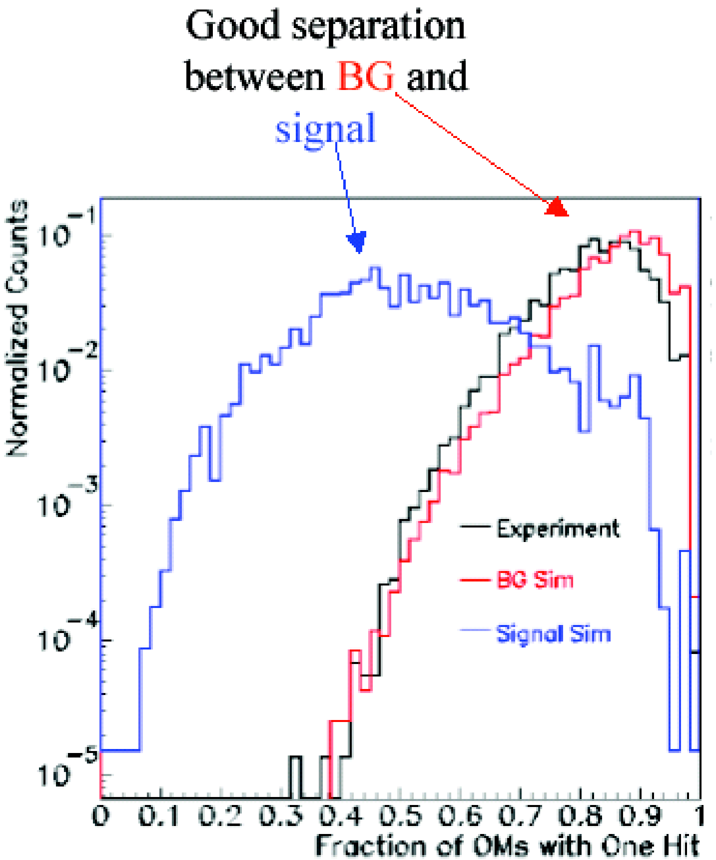
Lisa Gerhardt

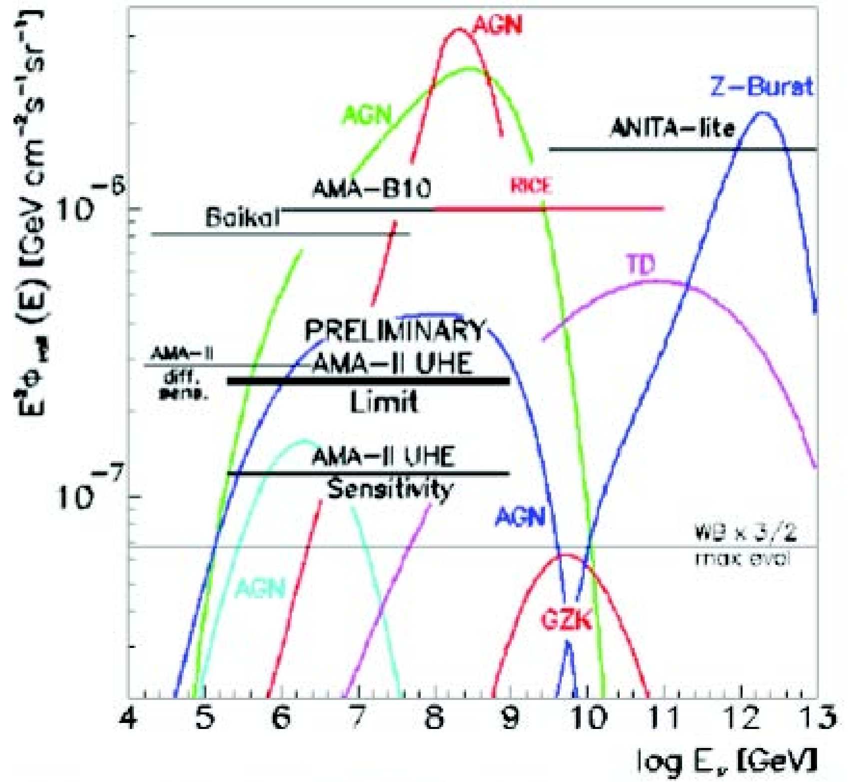
AMANDA cascade searches



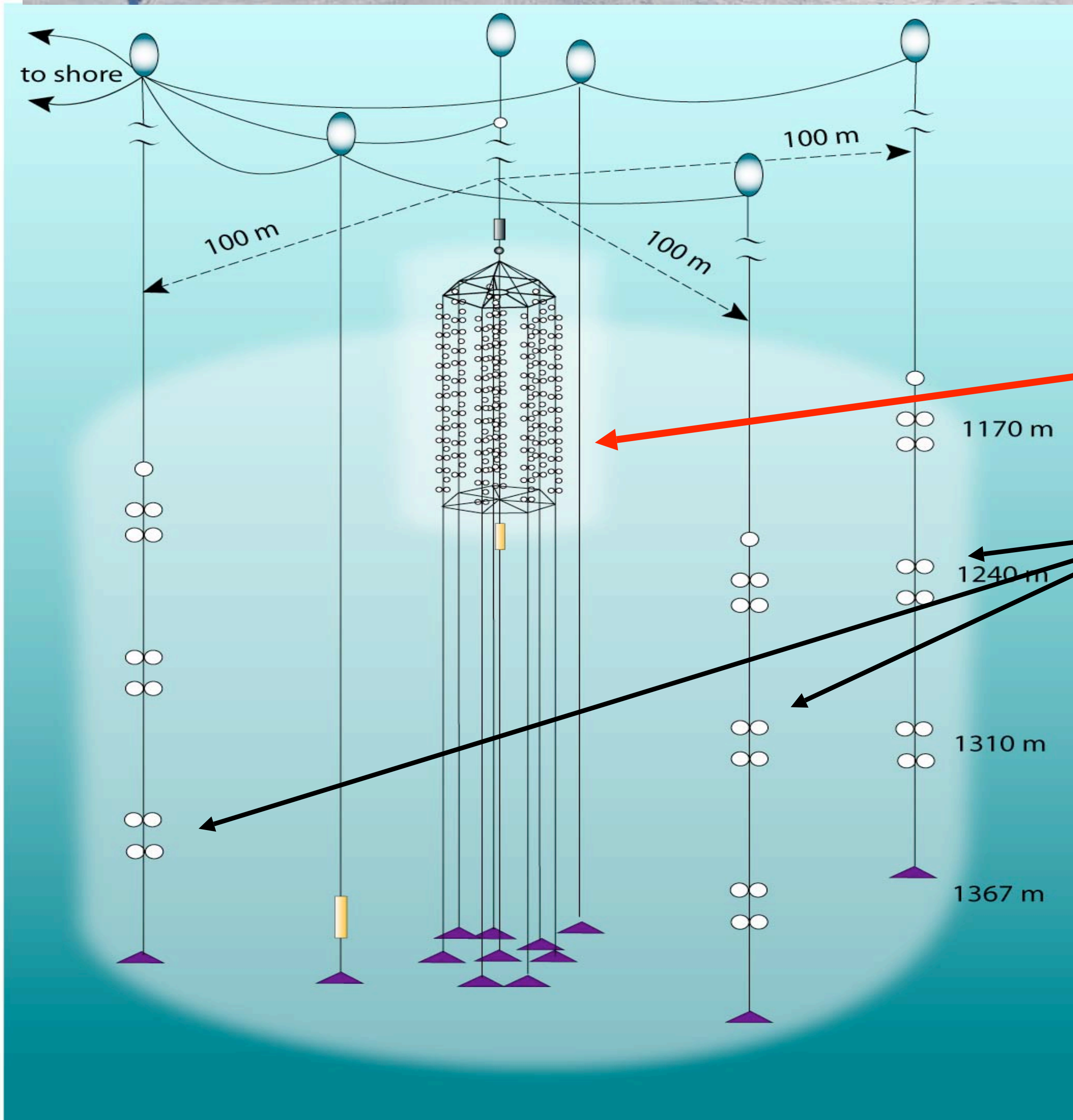


AMANDA cascade searches





Similar cascade search with different energy-dependent variable in paper by Oxana Tarasova for AMANDA



BAIKAL, Ralf Wischnewski

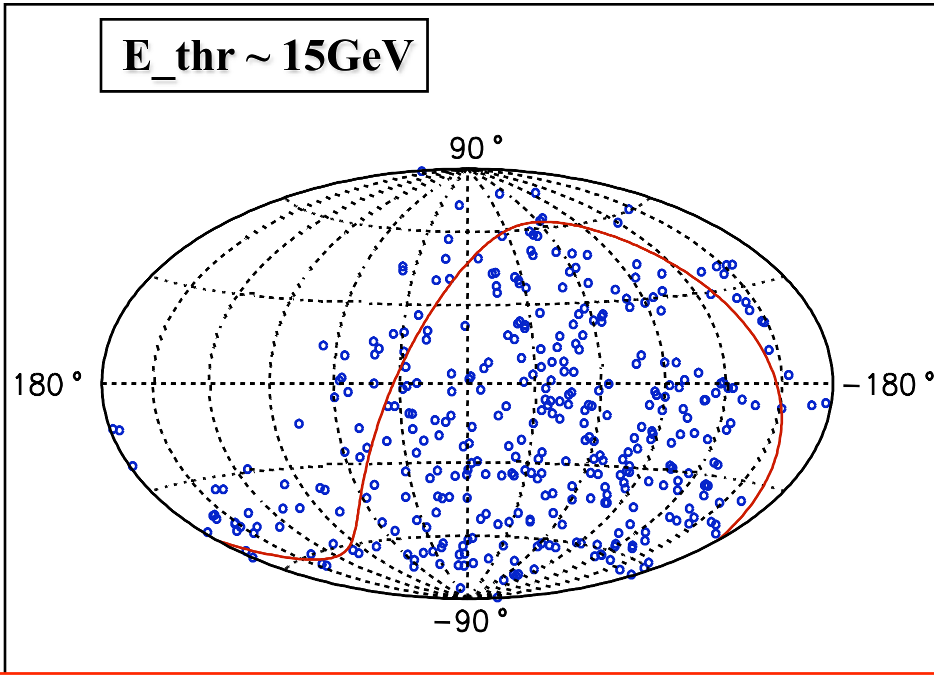
NT200+
=
NT200
+
3 long outer

Km³ planned

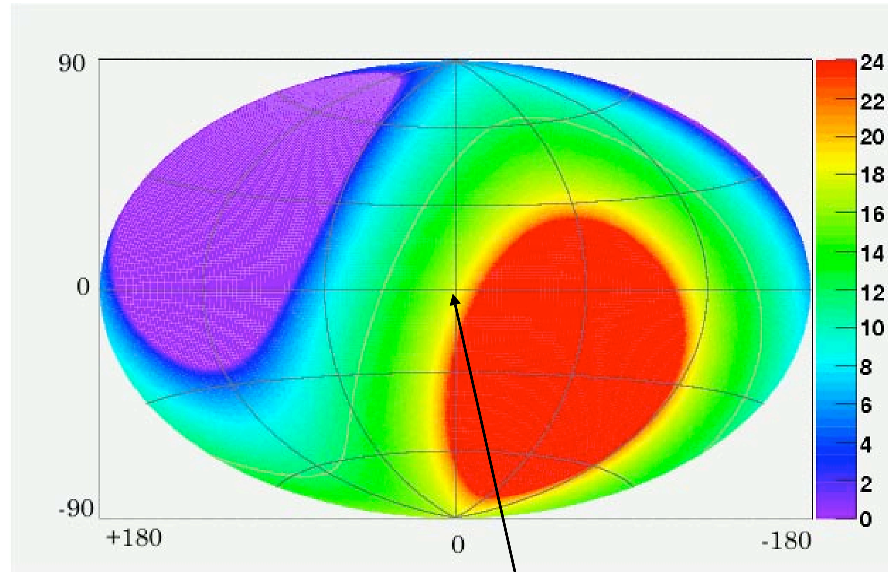
- **Height = 210m**
- **∅ = 200m**
- **Geom.Volume ~ 5 Mton**

R.Wischnewski ICRC, Merida, 2007

Atmospheric Muon-Neutrinos



Skyplot of NT200 neutrino events / 5 years
(galactic coordinates)



Galactic center visible 18 hours per day

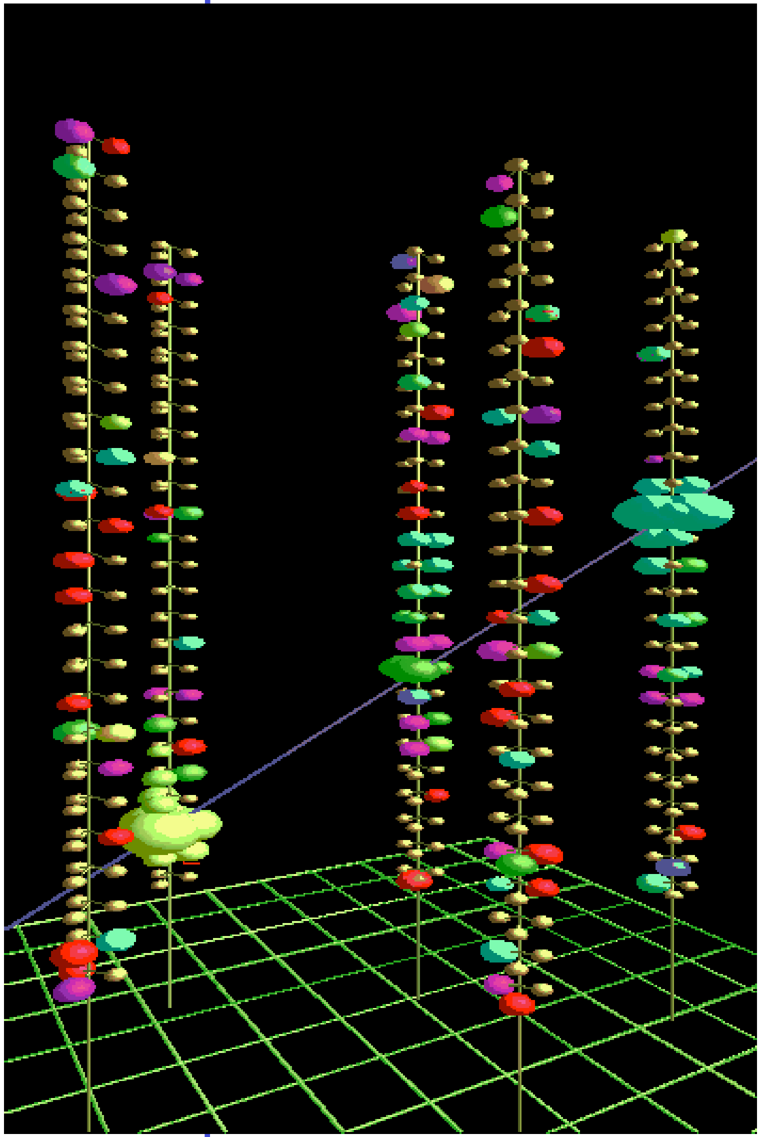
- Data: 372 upward ν events (1998-2002). (N_μ(>15GeV)/N_μ(>1GeV)~1/7)
- MC: 385 ev. expected (15%BG).

→ A high statistics neutrino sample for

Point-Source Search, incl. GalCenter. **No evidence for non-atmosph. ν's.**

ANTARES: Conclusions and Outlook

Antoine Kouchner



- Major step forward during the last year
- Detector working well within design specifications:
  - Junction Box in operation since Dec. 2002
  - 5 lines delivering data on the site
  - All technical problems solved
- 12 lines detector complete early 2008:
  Operation for science ≥ 5 years
- Milestone towards a KM^3 underwater detector

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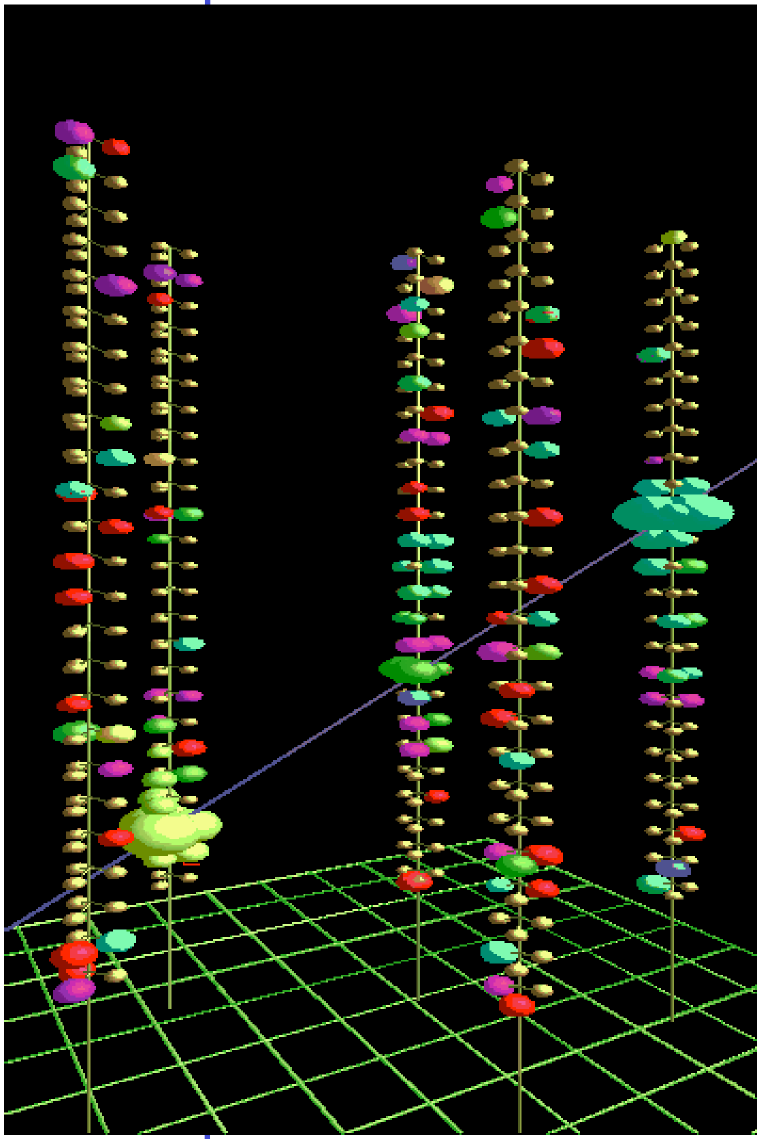

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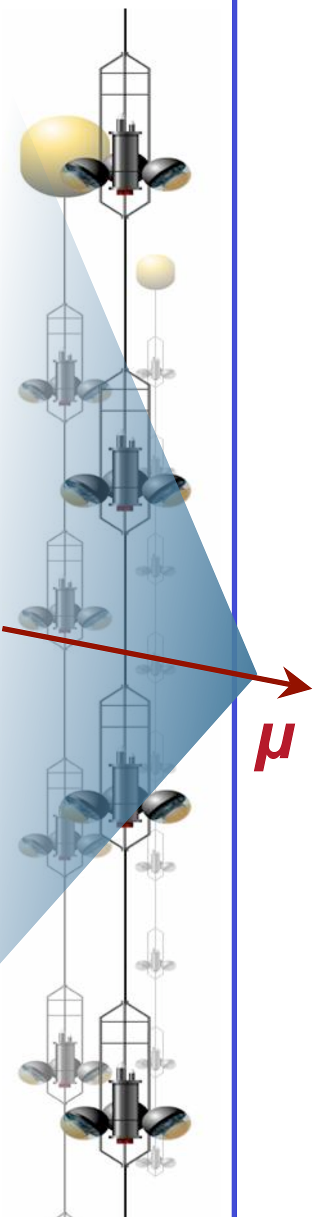
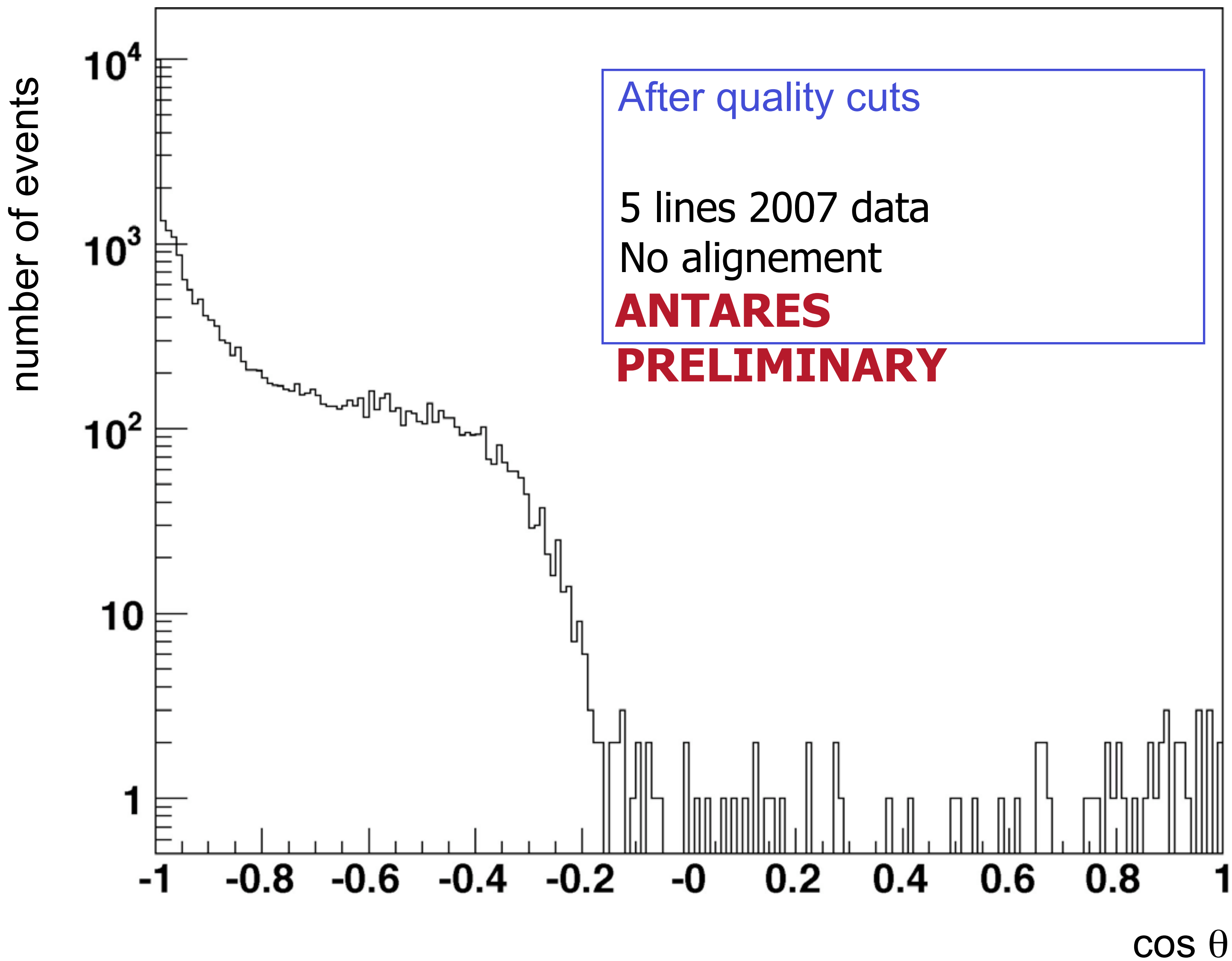
Candidates for

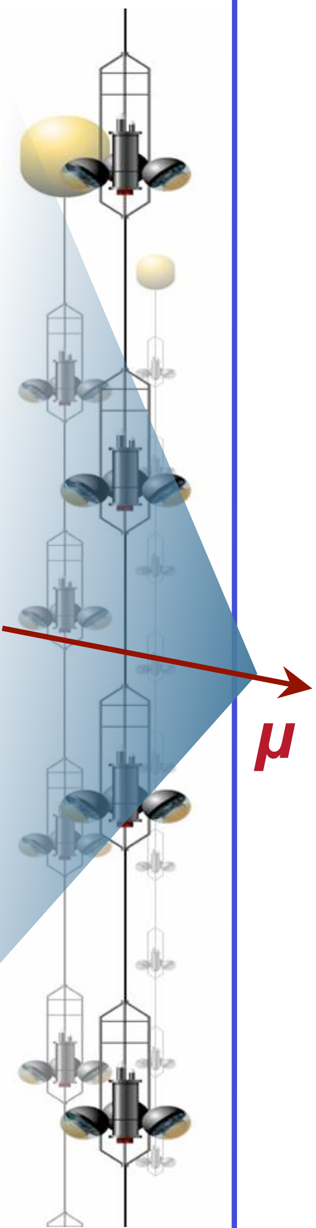
first undersea neutrino !!

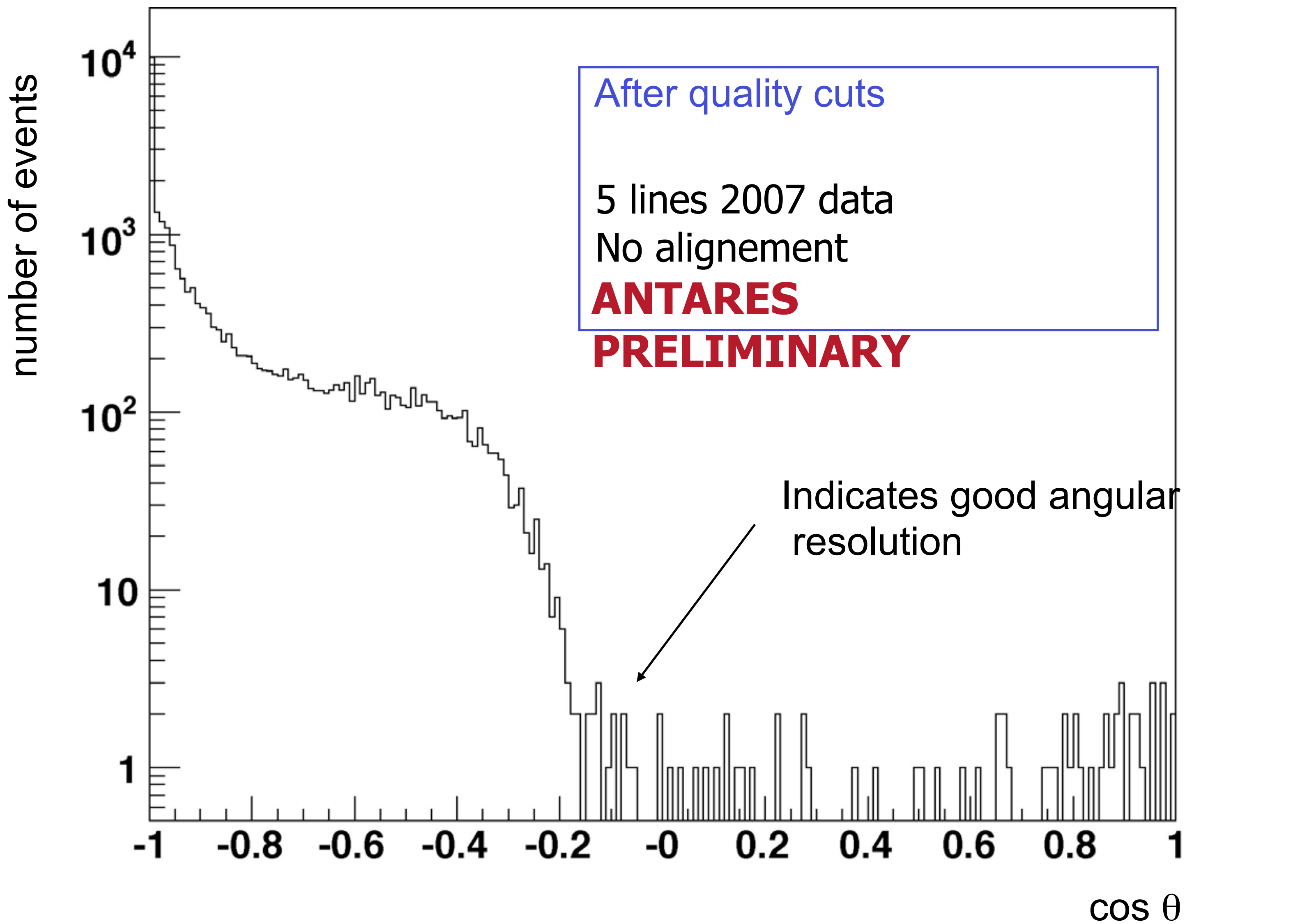
Zenith angle distribution



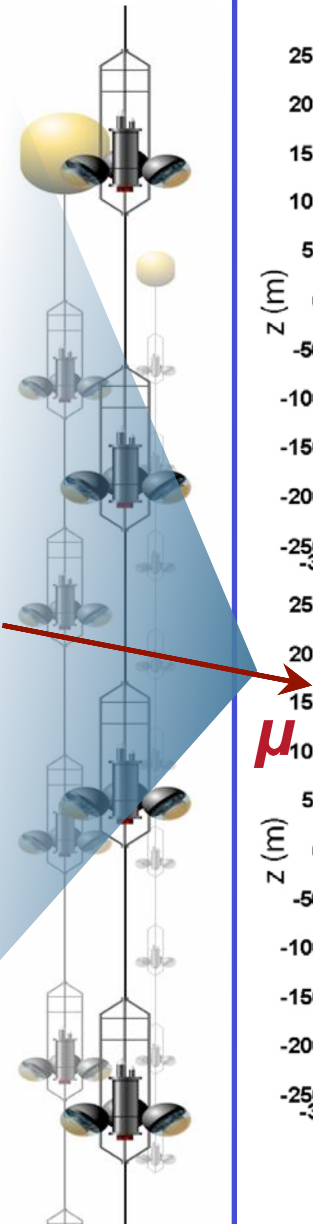


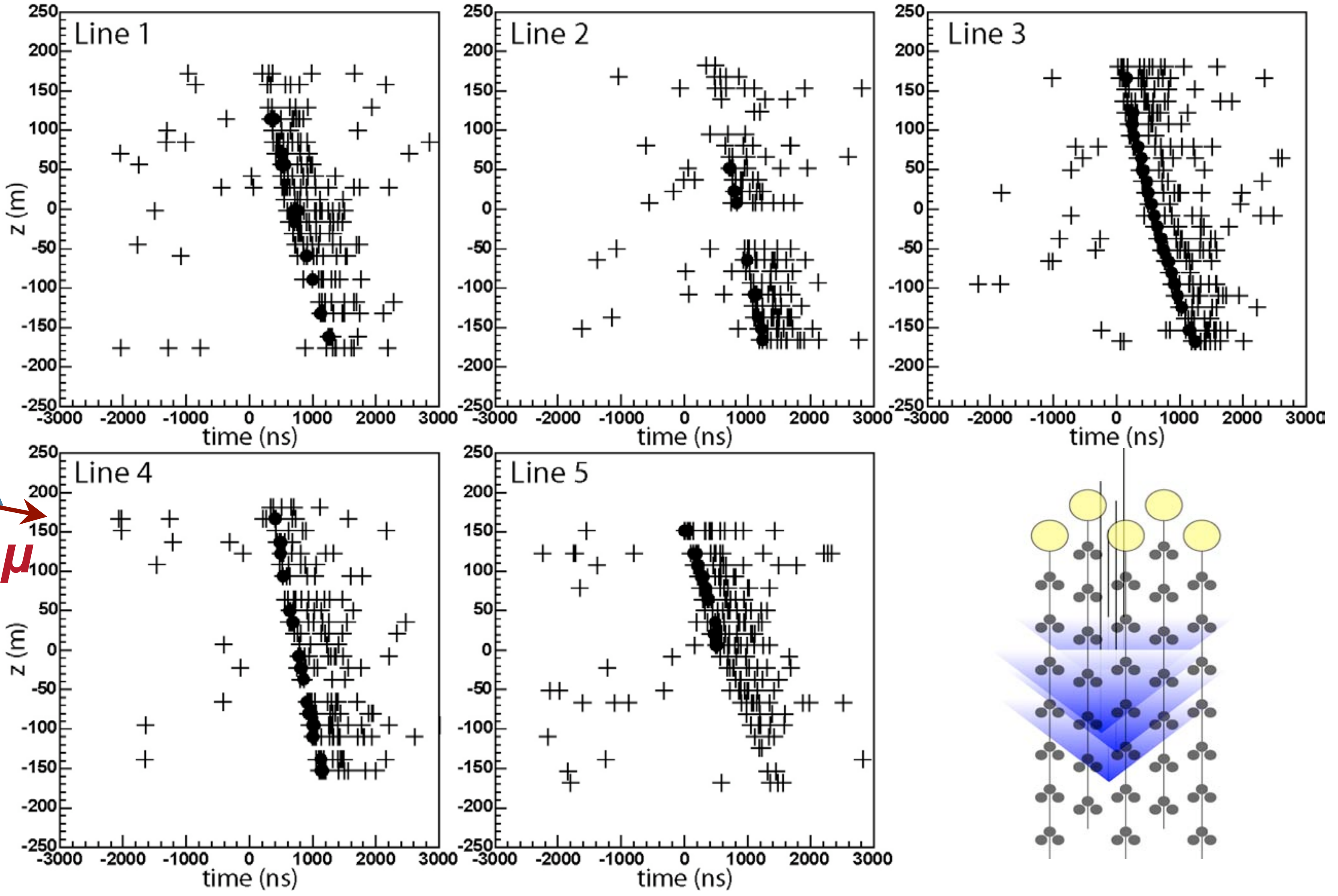
Zenith angle distribution



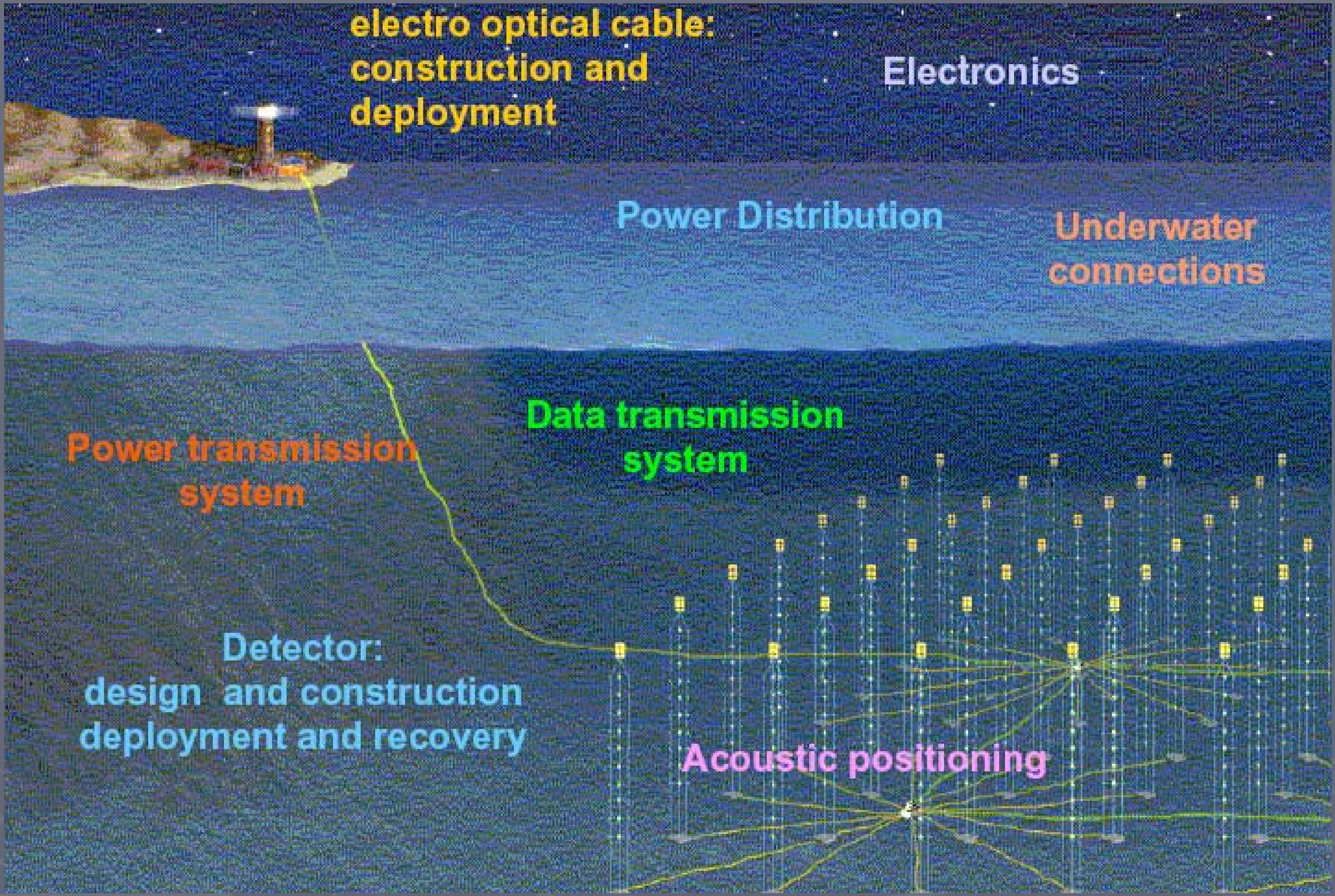


5 line detector displays





NEMO km^3 Conceptual Design



Toward the ν-Telescope

- EU funded the joint activity for a European-scale Design Study for a km^3 ν-telescope in the Mediterranean Sea
  - KM3NeT: ANTARES-NEMO-NESTOR consortium

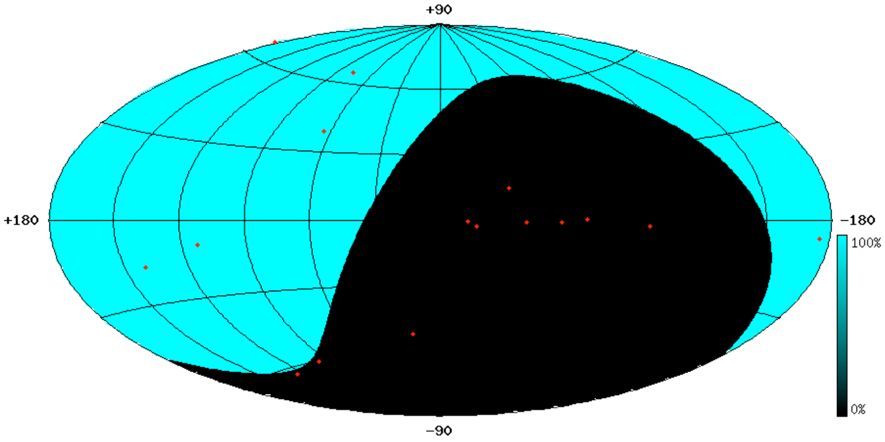
http://www.km3net.org/

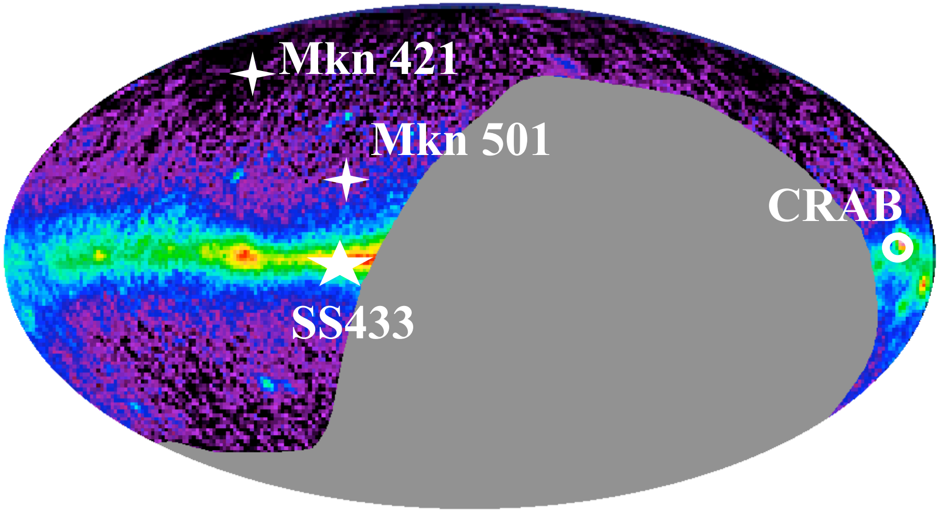
- The experience gained will contribute to the advancement of the KM3NeT activities

Region of sky observable by Neutrino Telescopes

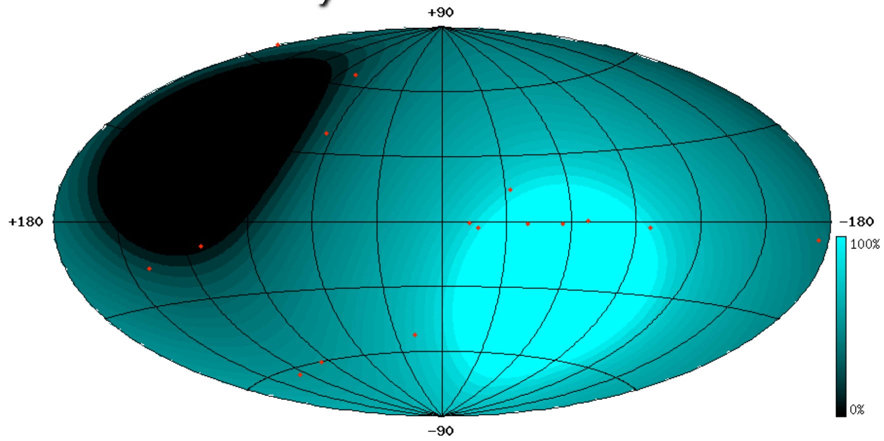
John Carr

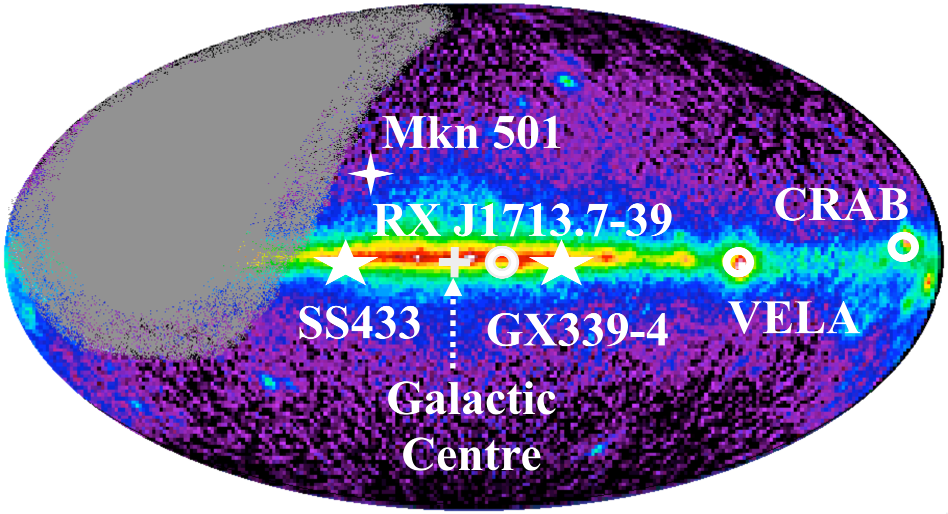
AMANDA (South Pole)





ANTARES (43° North)





Quest for cosmogenic ν

- Motivated by indication of GZK feature in UHE cosmic-ray spectrum
- Cosmogenic ν (from $p + \gamma_{2.7} \rightarrow n + \pi^{+} \rightarrow \nu$)
  - Probe evolution, composition, spectra of extra-galactic cosmic-ray sources
  - Goal: >1000 $km^3 sr$, > 100 events/yr, E >10^{18} eV
  - RICE, AURA, ANITA, ARIANNA at this conference
  - Acoustic detection in Ice another possibility

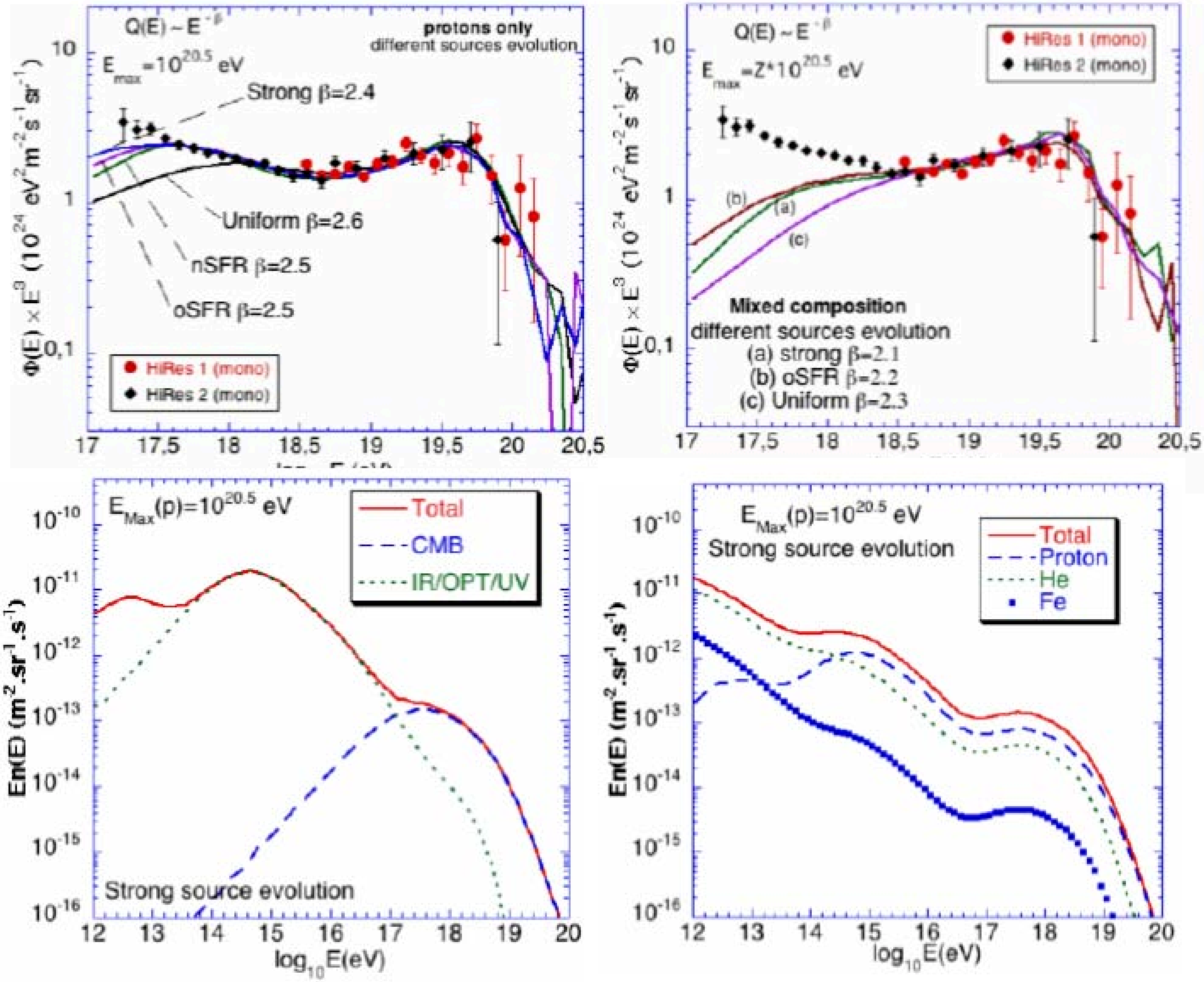
Model dependence of cosmogenic ν

N. Busca

Pure protons | **Mixed**

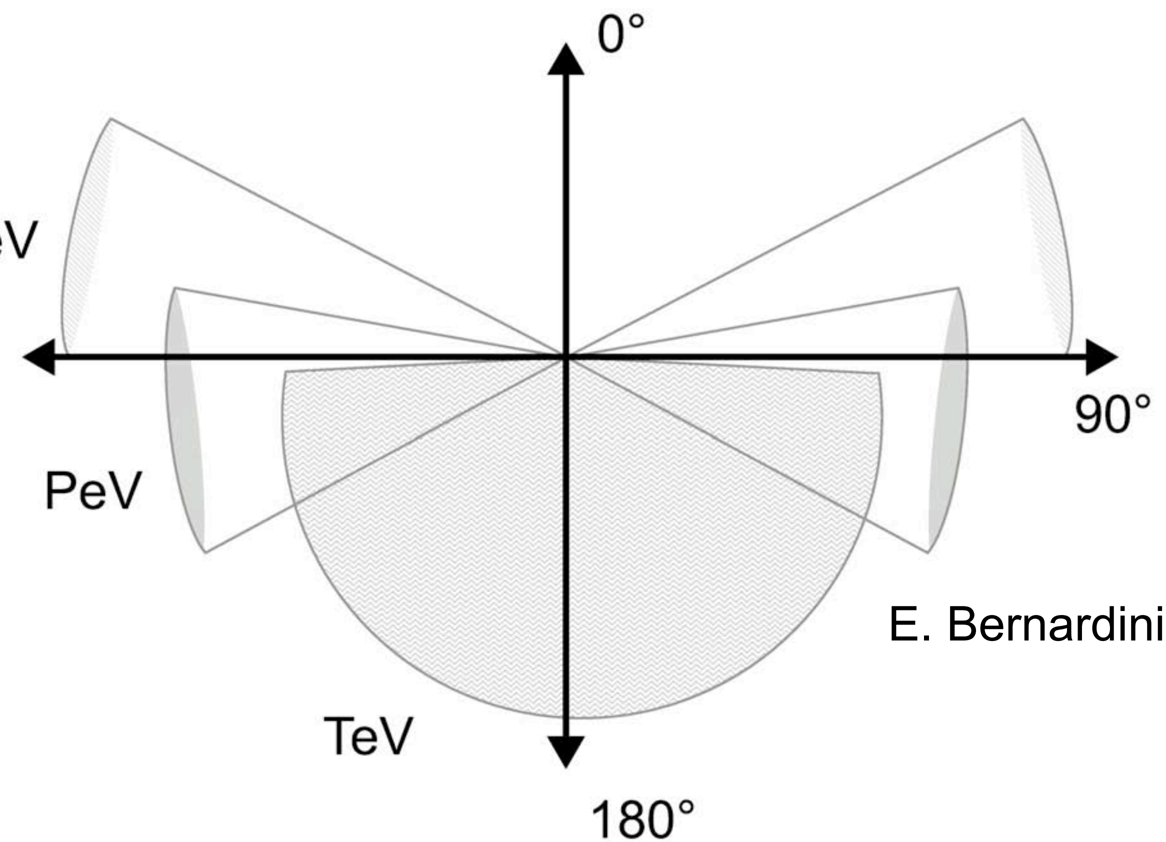
Cosmic rays

Neutrinos



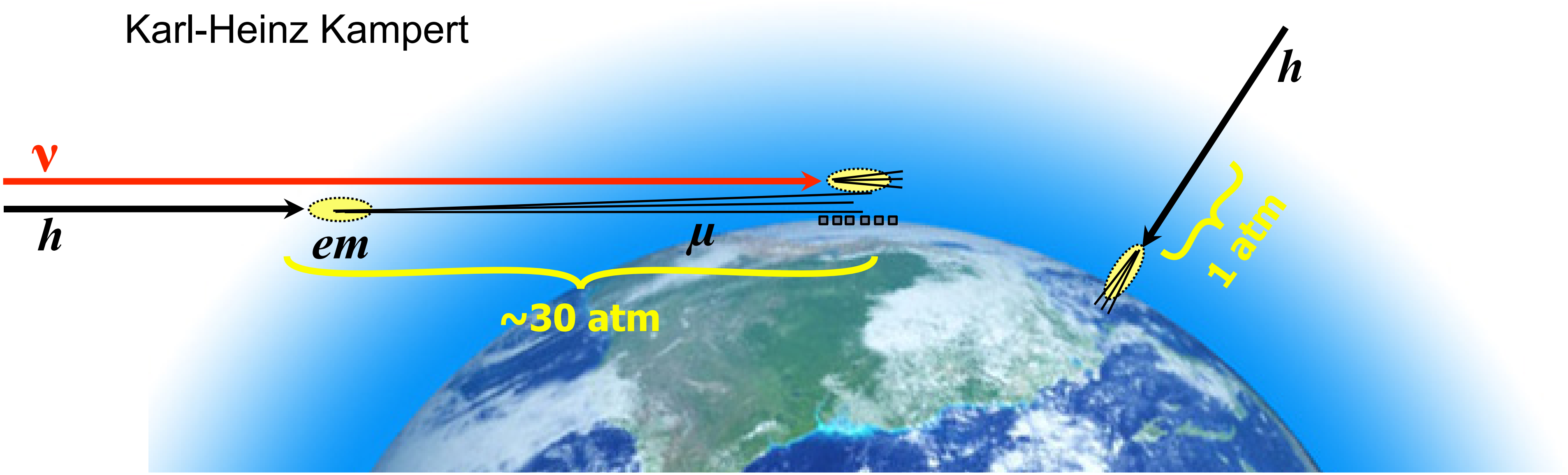
>PeV ν absorbed in the Earth

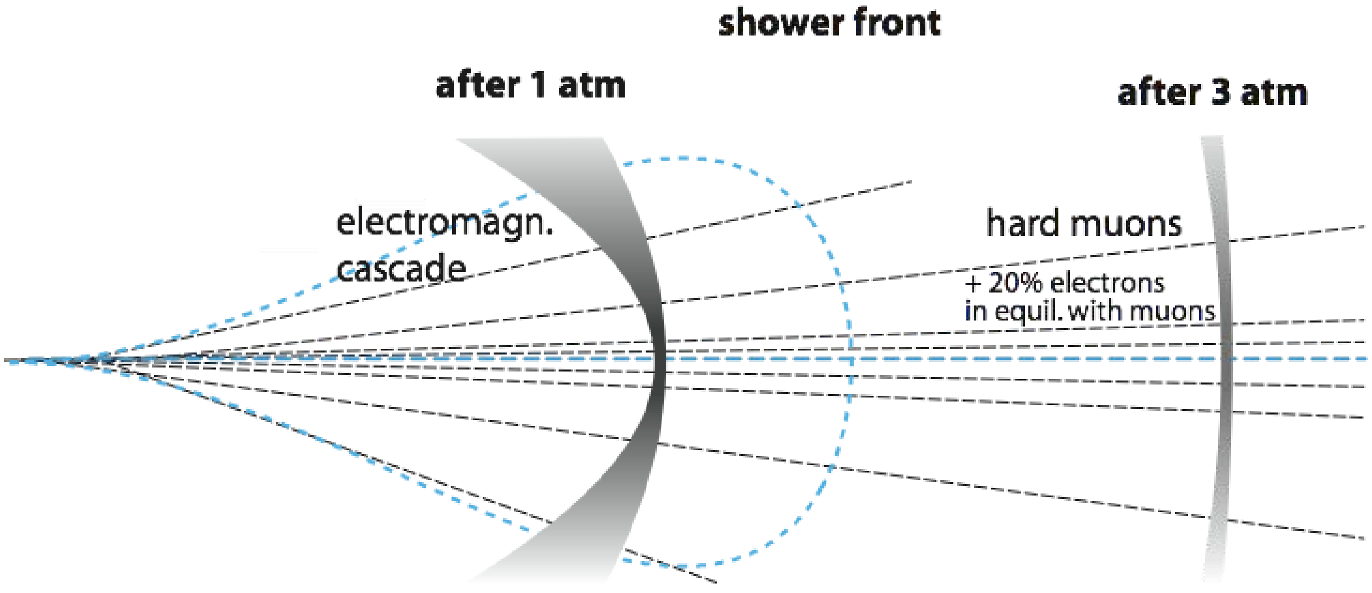
Earth-skimming ν



Neutrinos: important bi-product in Auger

Karl-Heinz Kampert

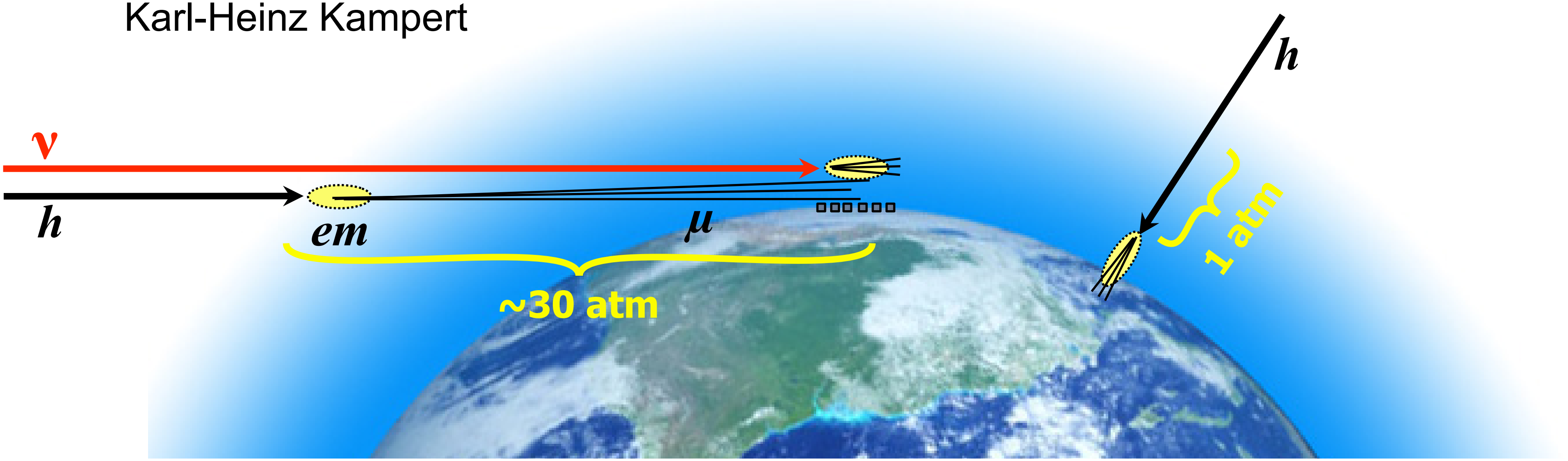


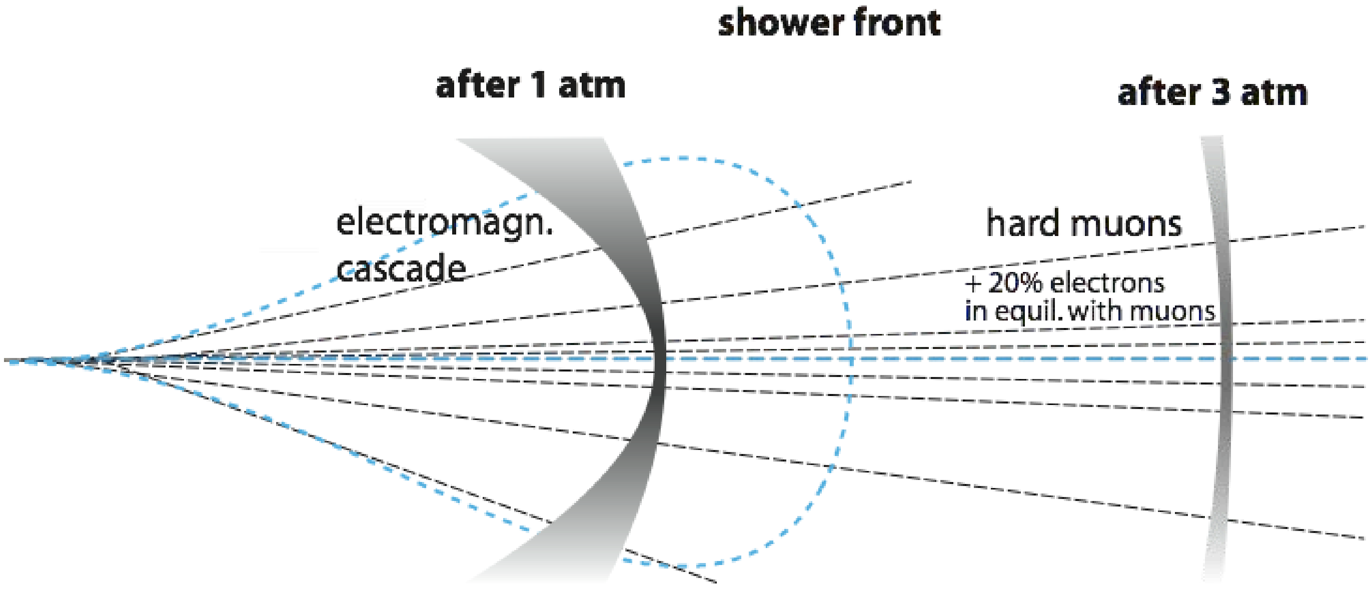


Neutrinos: important bi-product in Auger

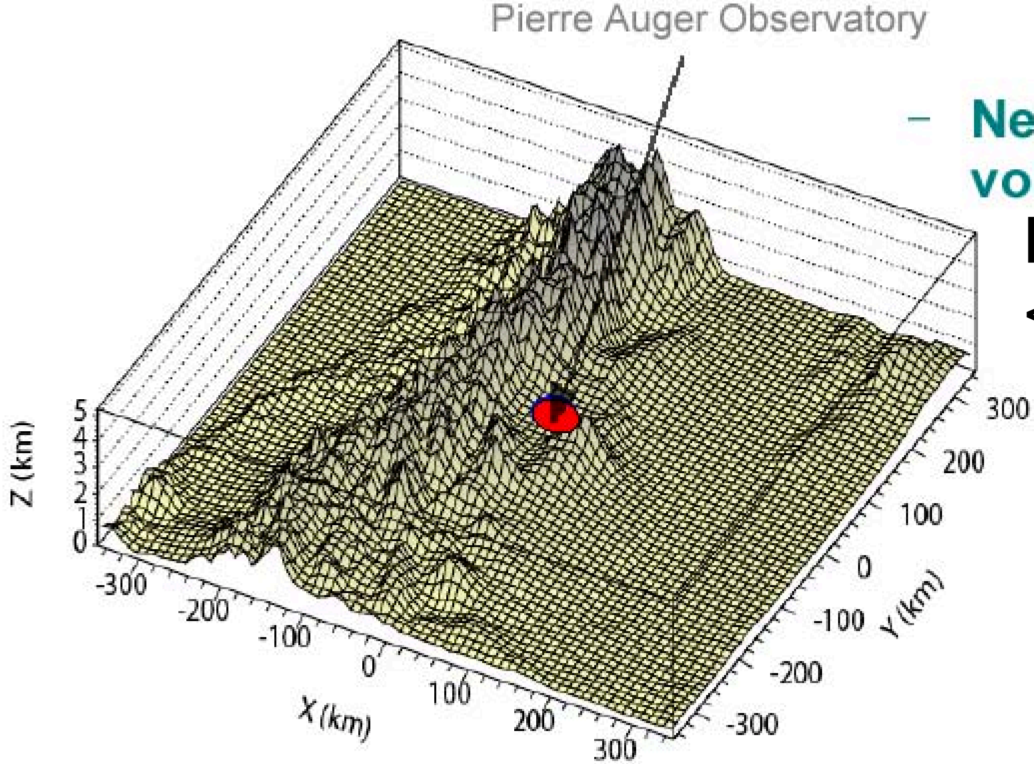
A neutrino can induce a young horizontal shower !

Karl-Heinz Kampert





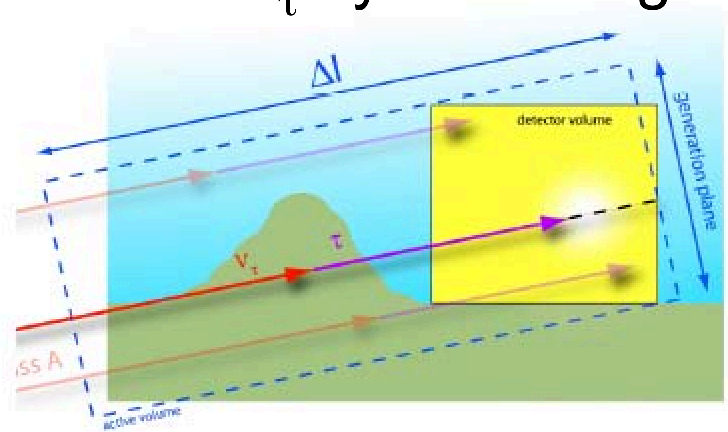
EeV ν_τ detection with Auger et al.



- **New definition of active volume**

D. Gora

<~ 1 GZK ν_τ / year in Auger



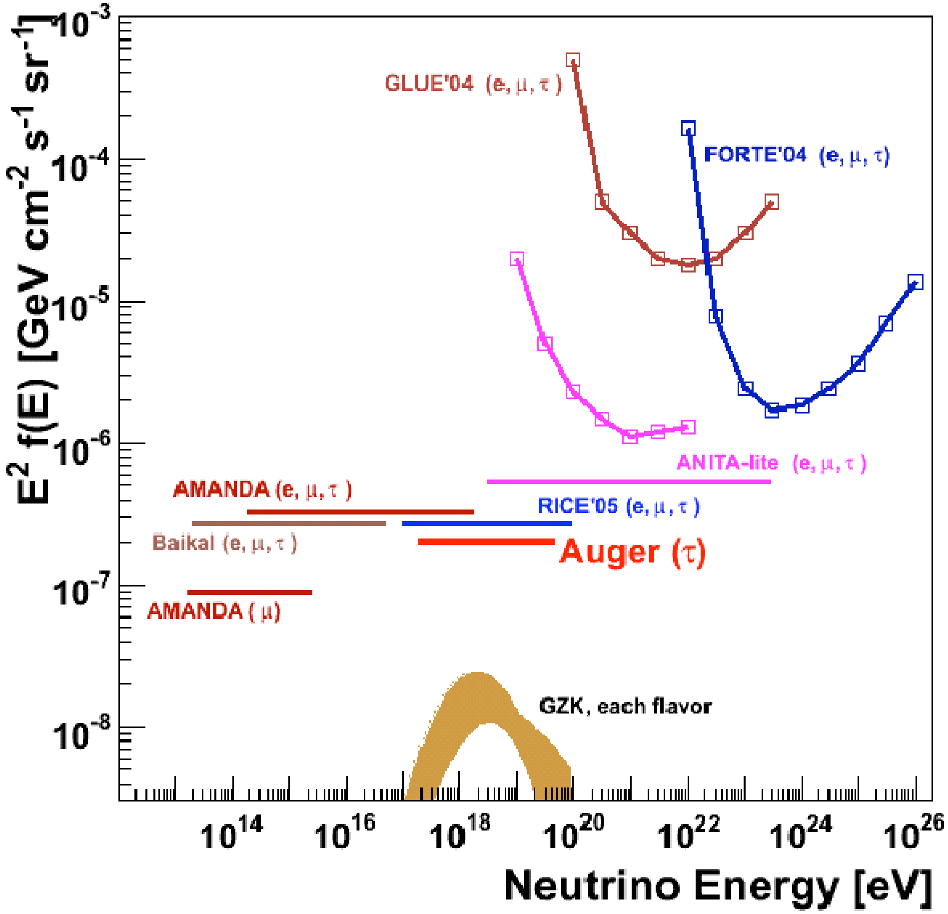
$\Gamma c\tau$ ~ 100 km for E_τ ~ 2 x 10^{18} eV followed by τ-decay shower

T. Weiler, D. Fargion

Current upper limit from Auger

Oscar Blanch-Bigas

90 % CL for each flavour with the worst systematic scenario and assuming: $\frac{dN_{\nu_\tau}}{dE} = f_0 E^{-}$



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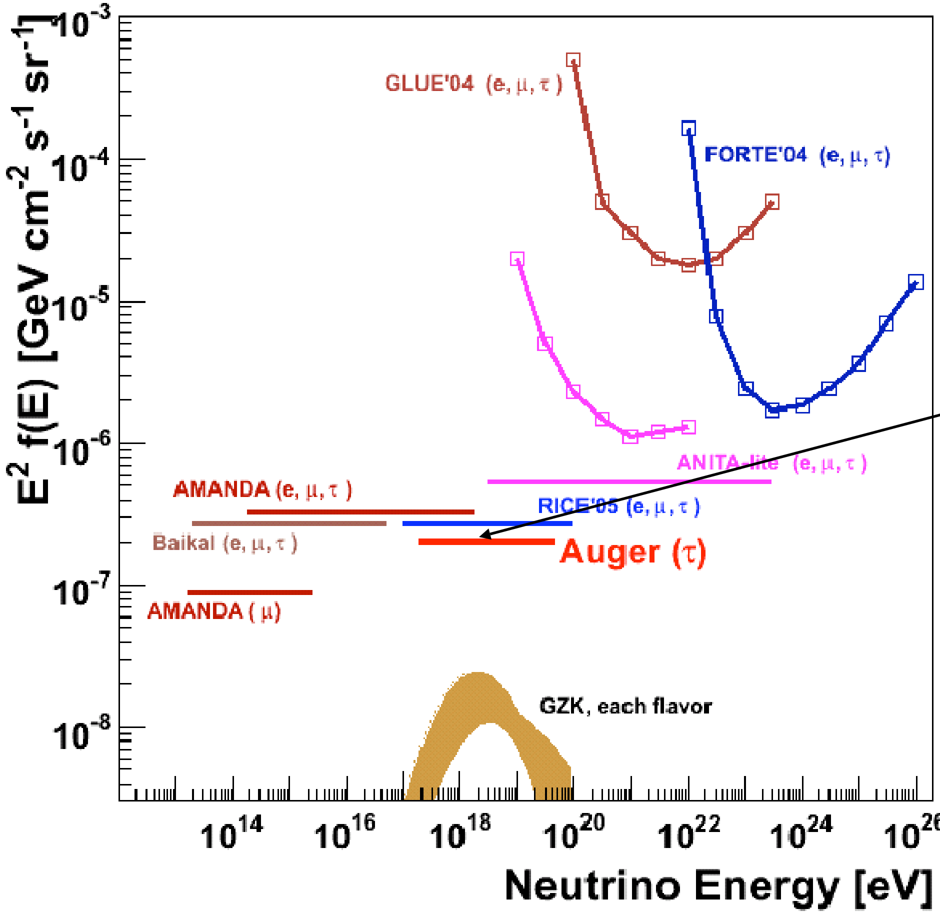
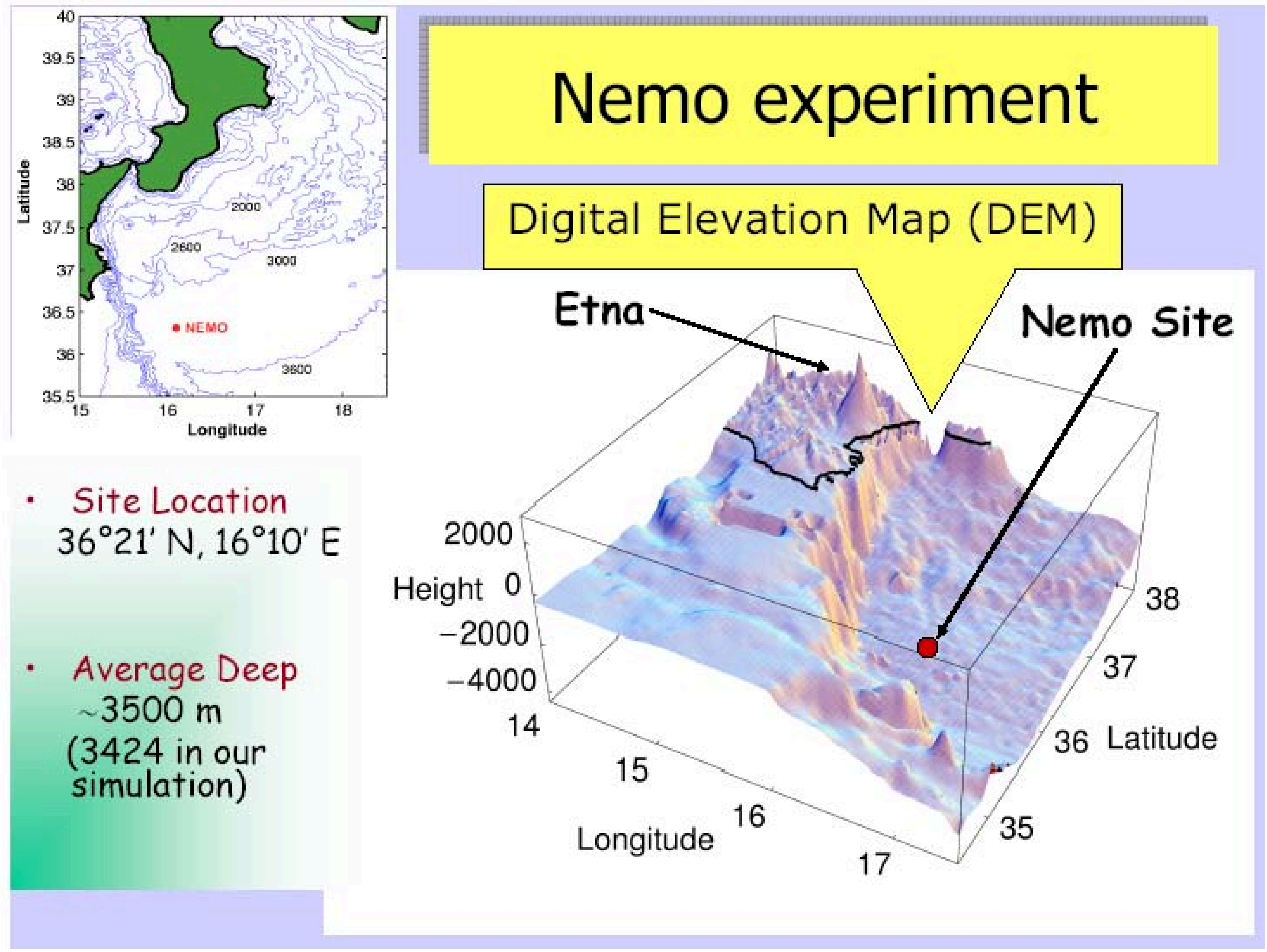


HiRes limit
$10^{18} < E_n < 10^{19}$ eV
slightly above Auger limit
--Kai Martens

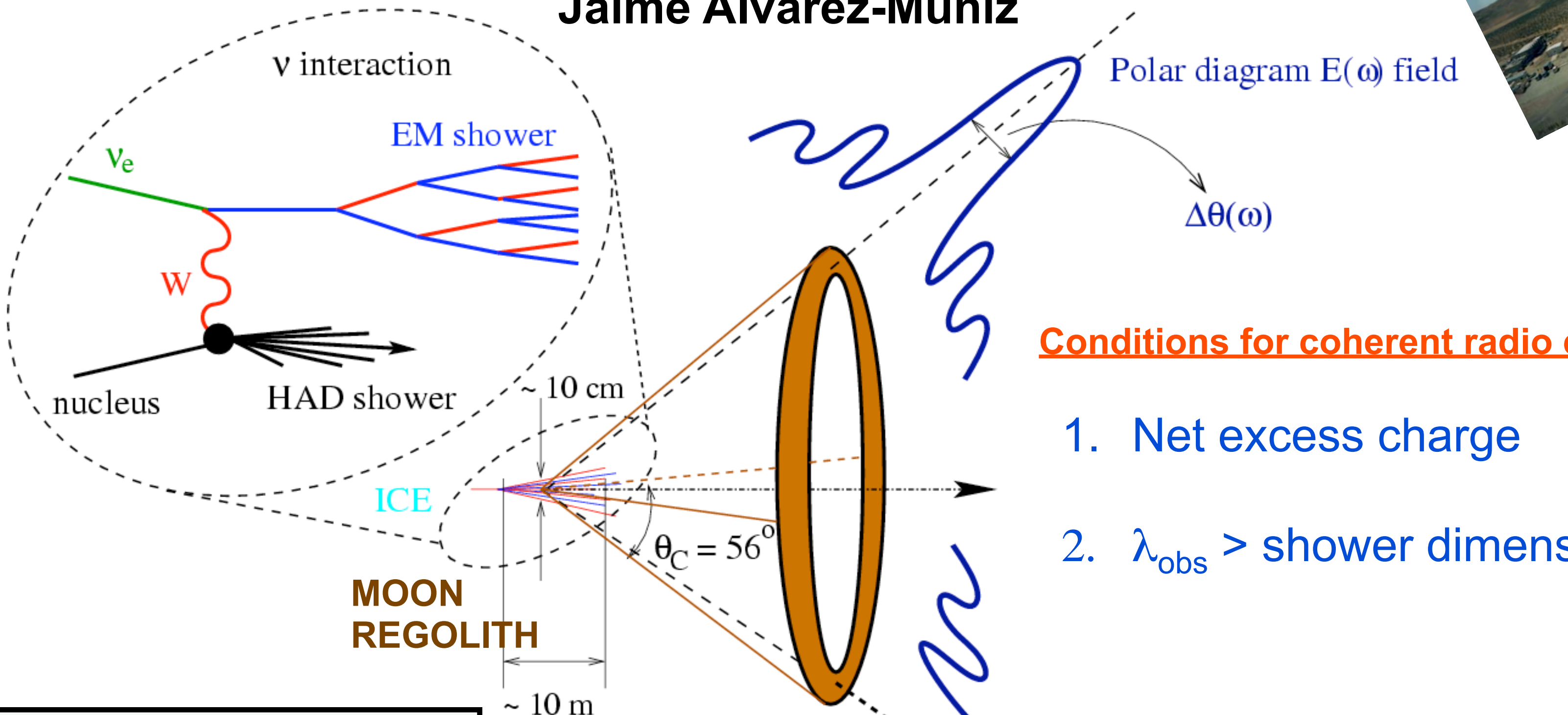
Km^3 telescopes can also do ν_τ

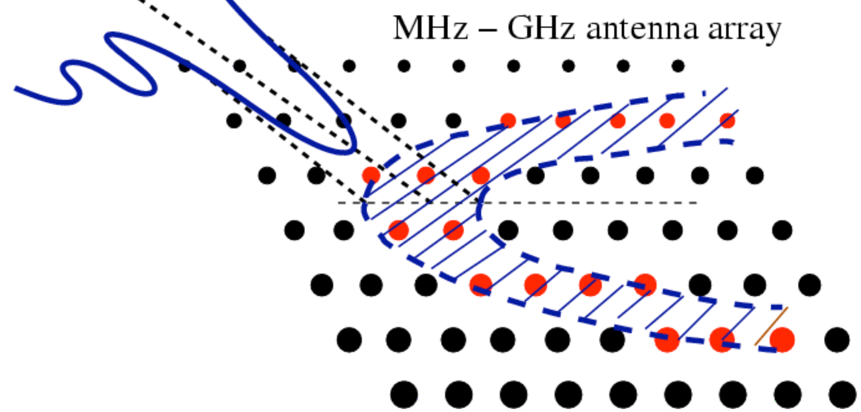


G. Miele
--talk describes how to unfold neutrino Cross section

The radio technique

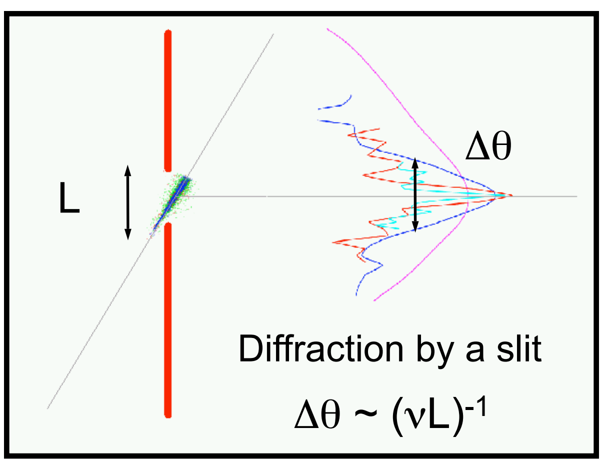
Jaime Alvarez-Muniz





Conditions for coherent radio emission

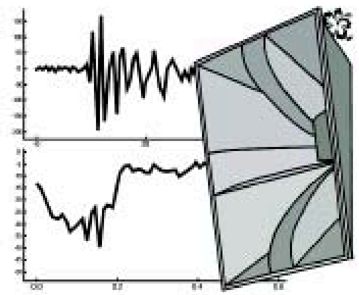
1. Net excess charge
2. λ_{obs} > shower dimensions



Diffraction by a slit

$\Delta\theta \sim (\nu L)^{-1}$

J. Alvarez-Muñiz et al. ICRC 2007, Mérida (México)

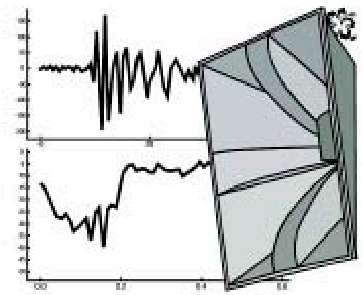


First Flight Overview and Detector Performance

Kimberly J. Palladino

THE OHIO STATE UNIVERSITY

for the ANITA Collaboration

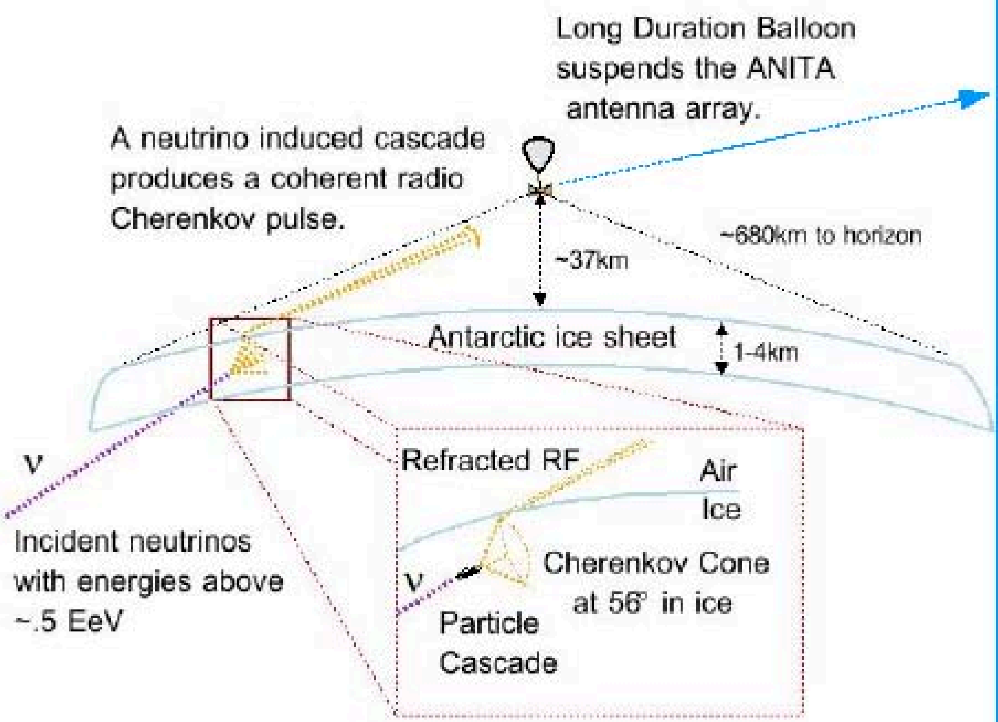


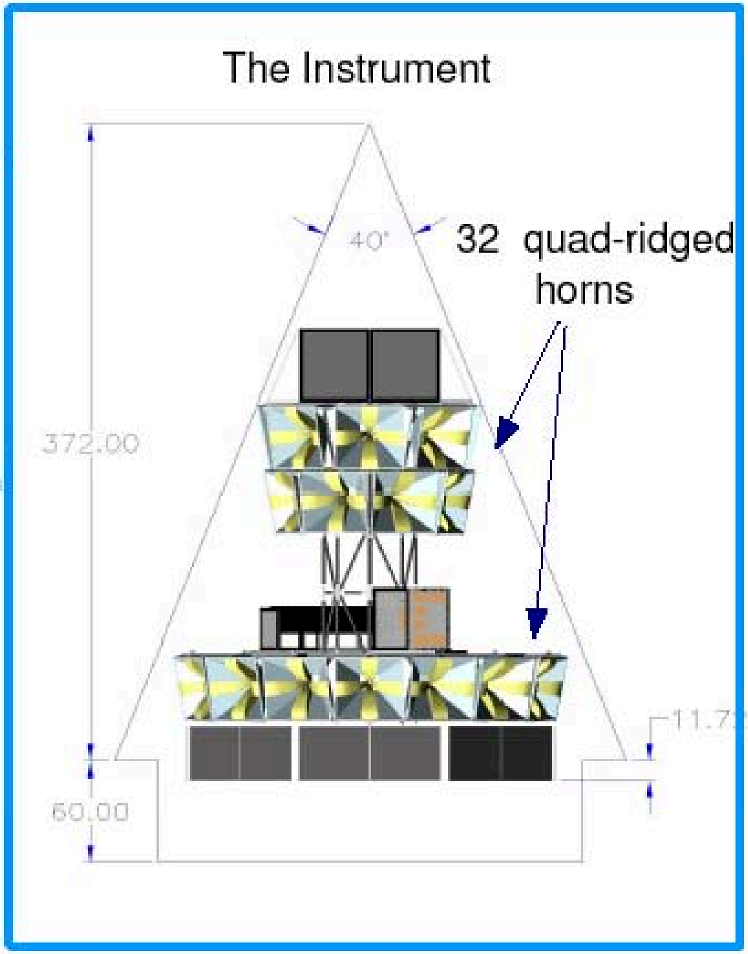
First Flight Overview and Detector Performance

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

for the ANITA Collaboration

The ANITA Concept



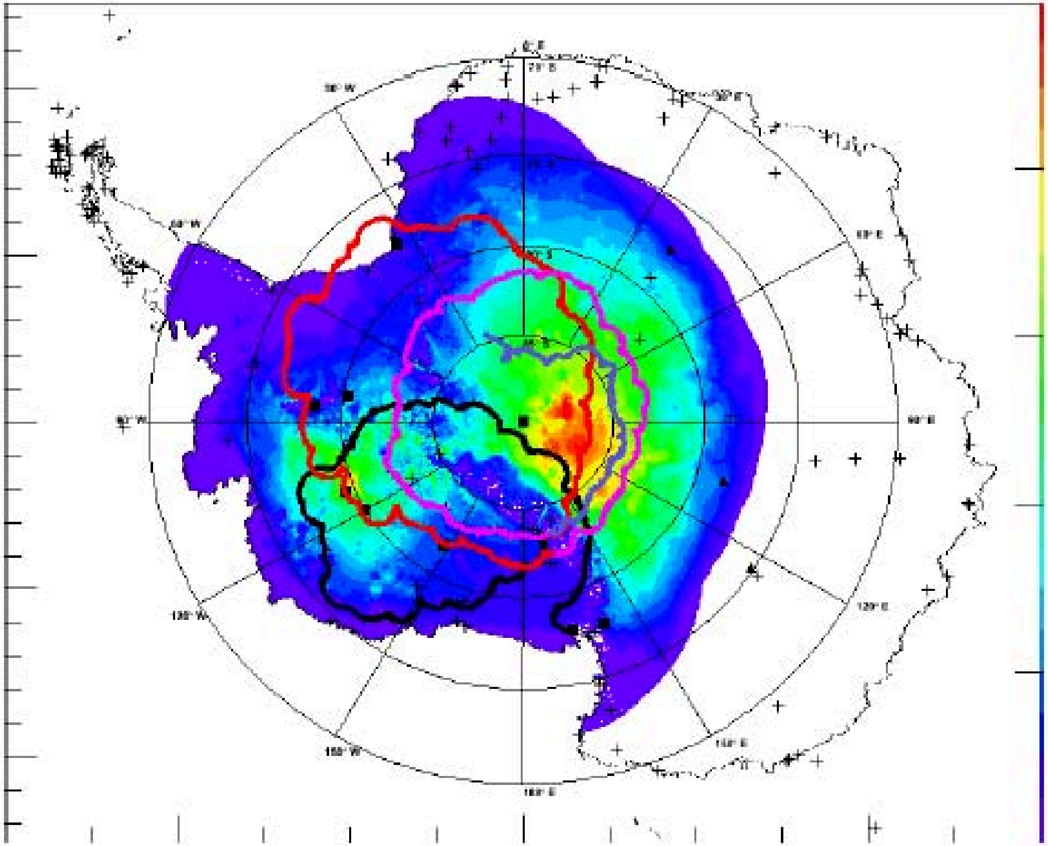


Ice in ANITA's Horizon

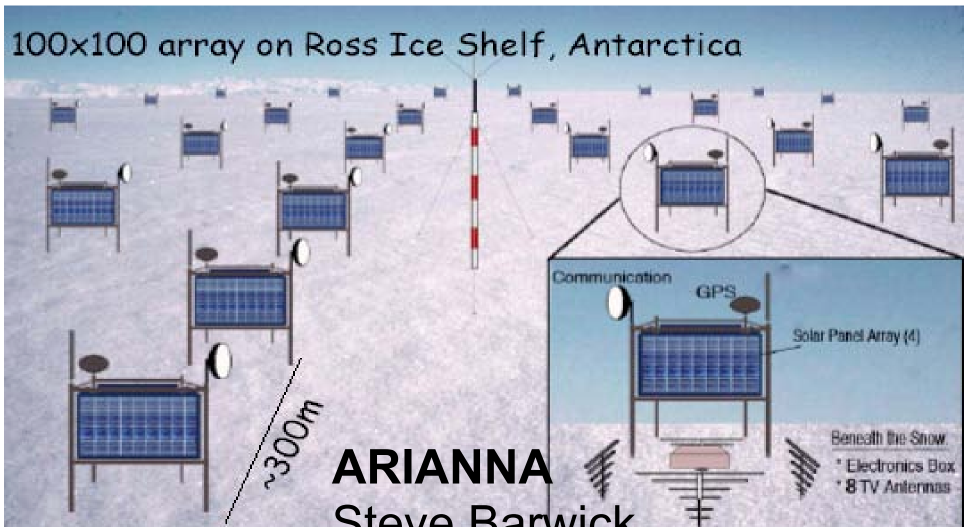
ANITA from the Pole

photo by James Roth

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

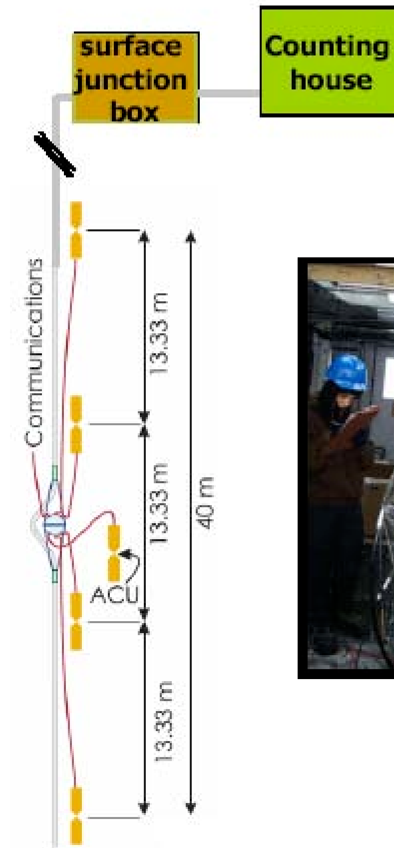


Proposed detectors

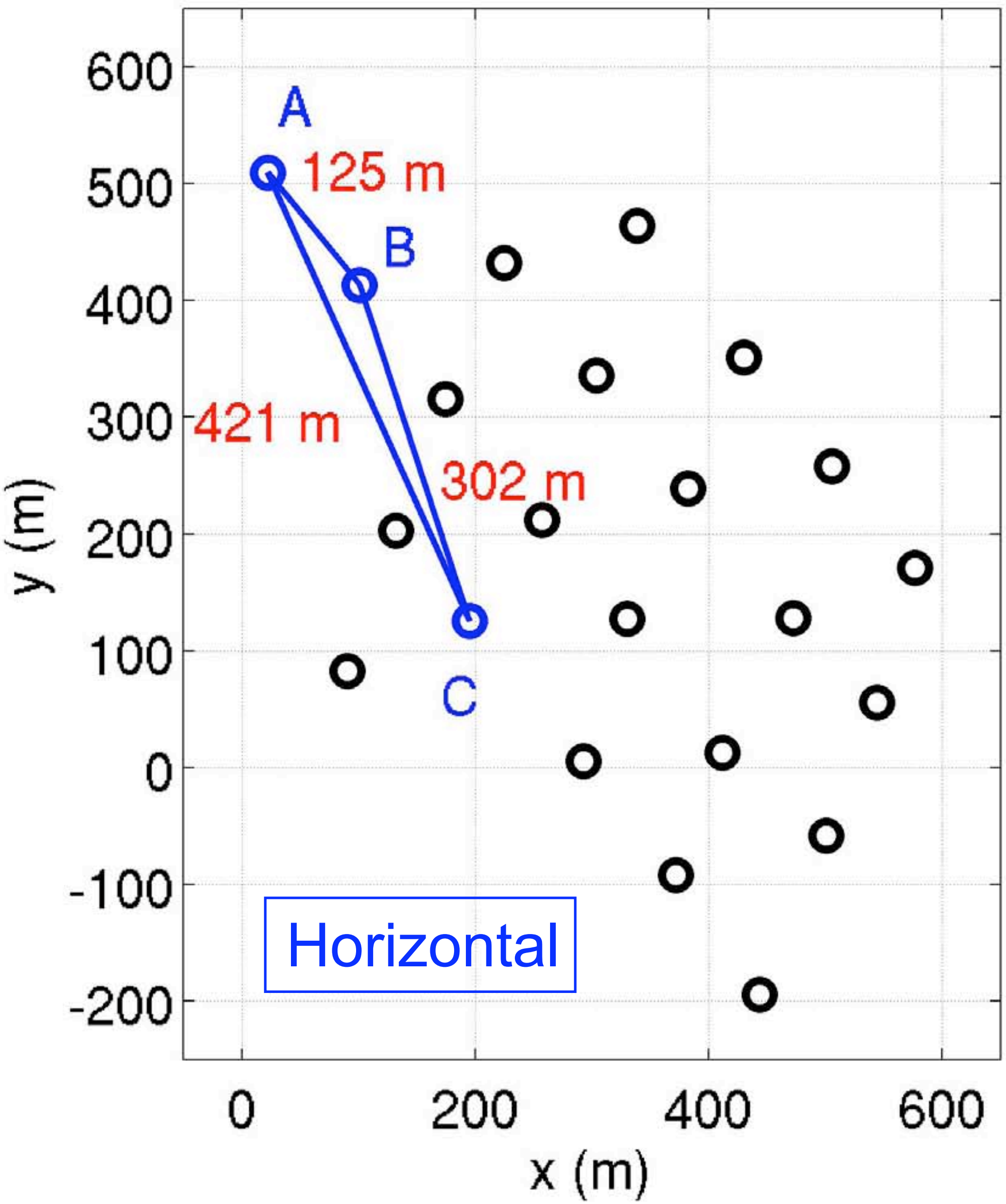


ARIANNA
Steve Barwick

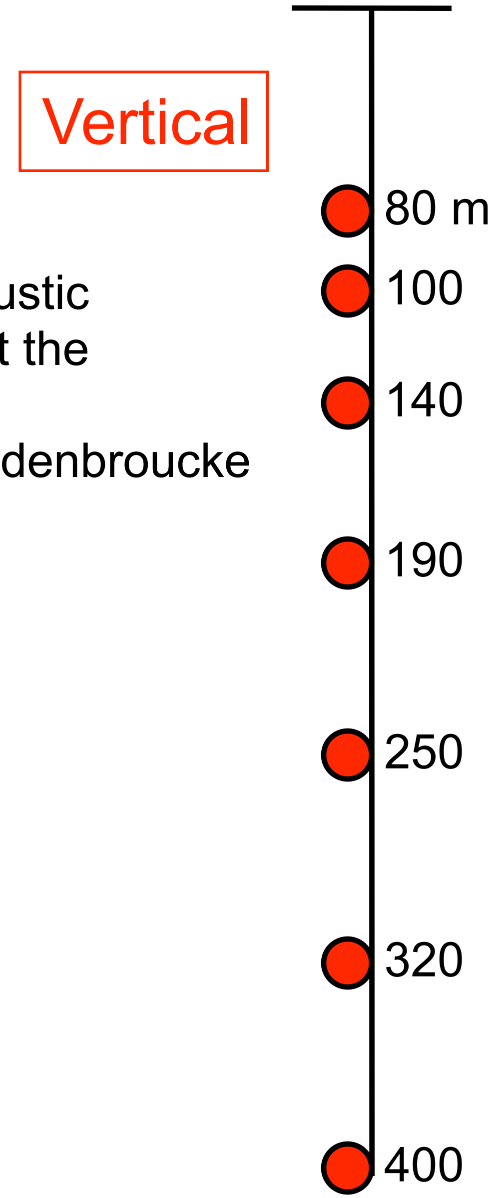
AURA at South Pole digitize signal at antenna cluster --Hagar Landsman



SPATS Geometry

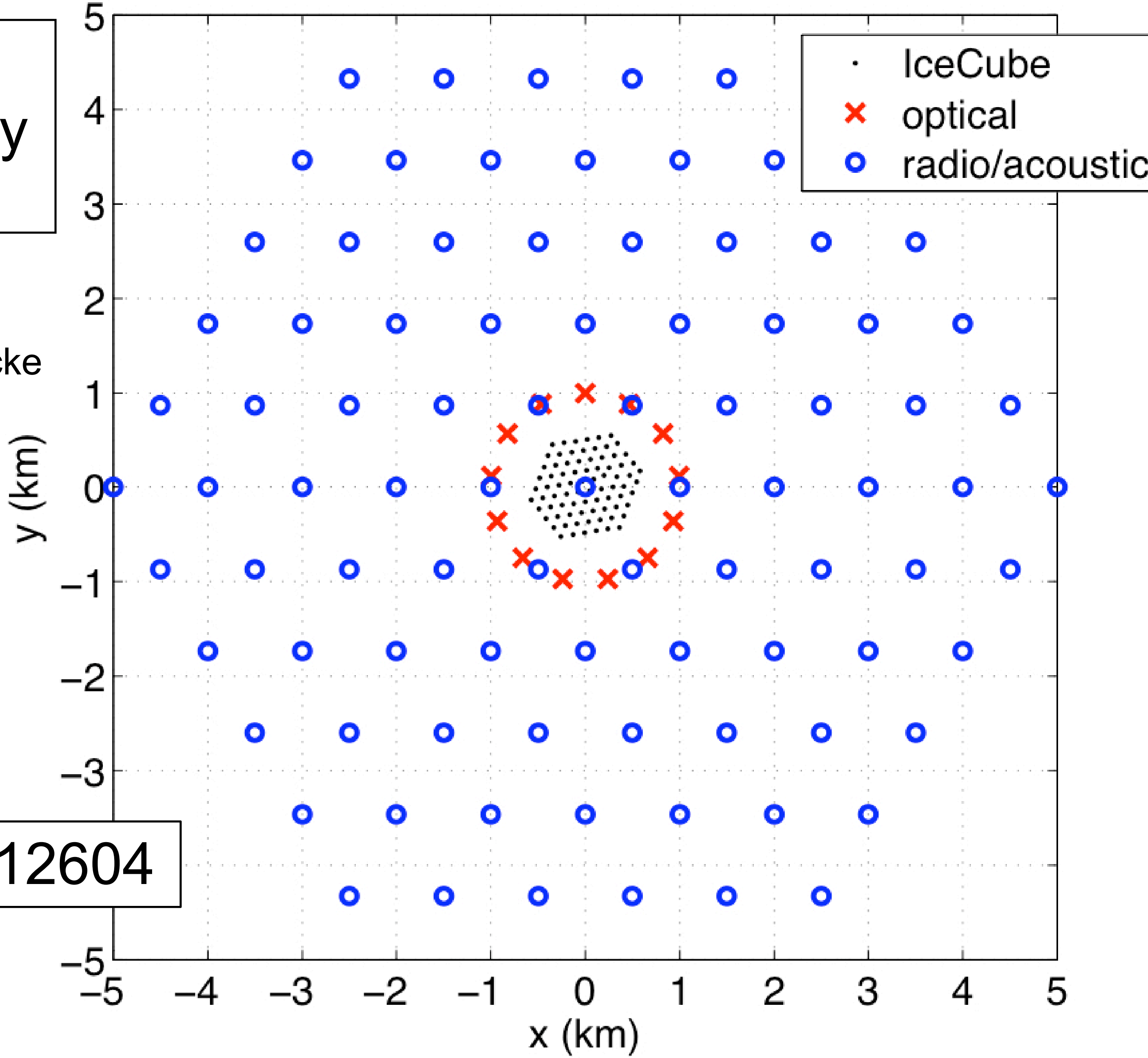


Testing acoustic
detection at the
South Pole
--Justin Vandenbroucke



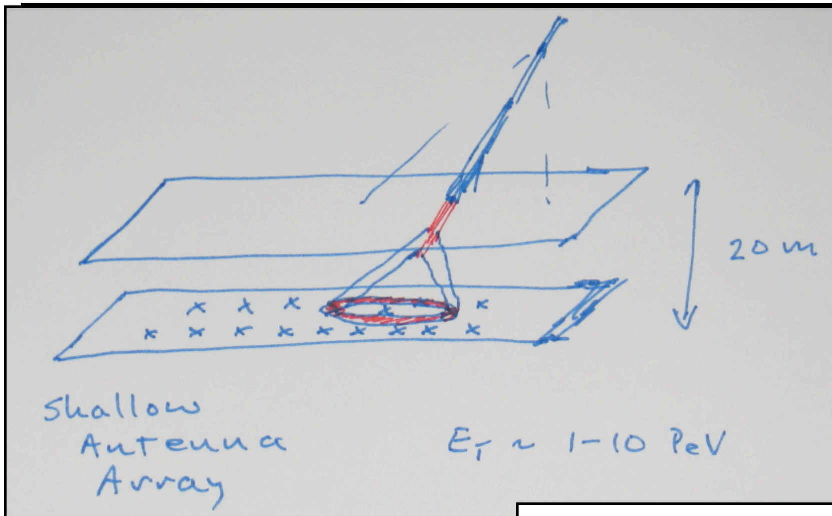
Simulated hybrid array geometry

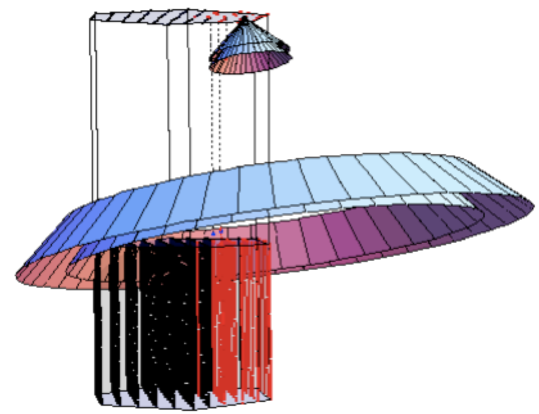
J. Vandenbroucke

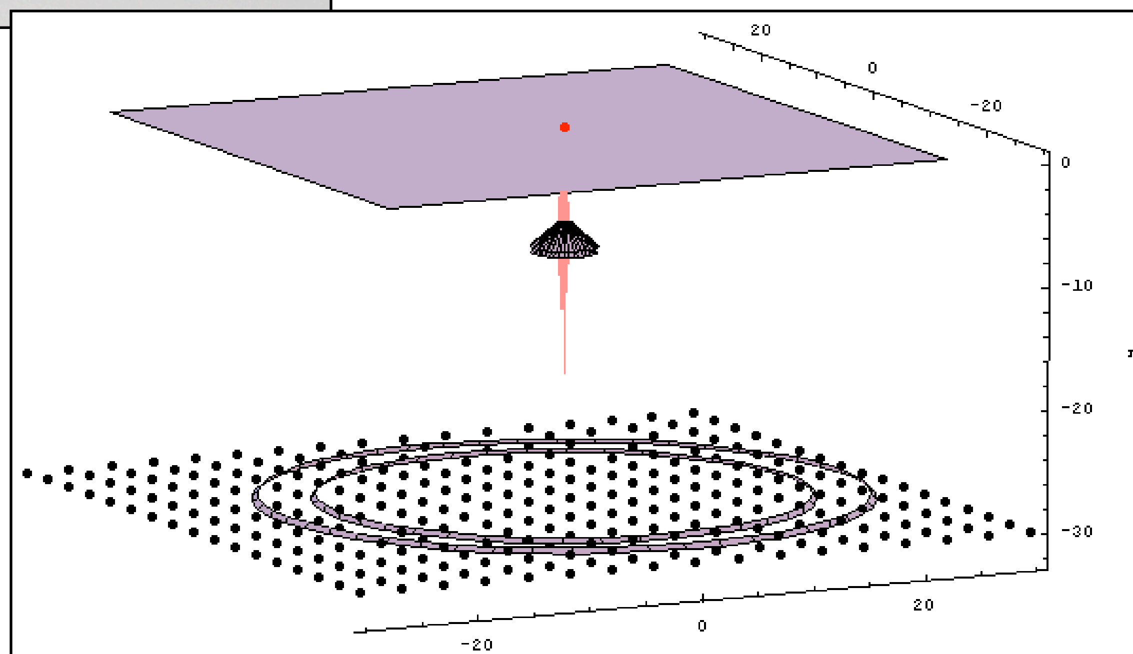


astro-ph/0512604

Calibrate radio technique with Askaryan pulses from air

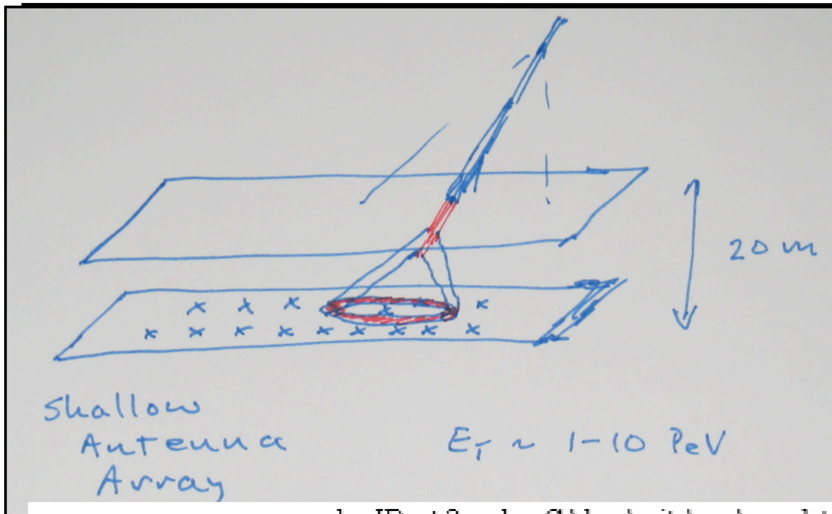


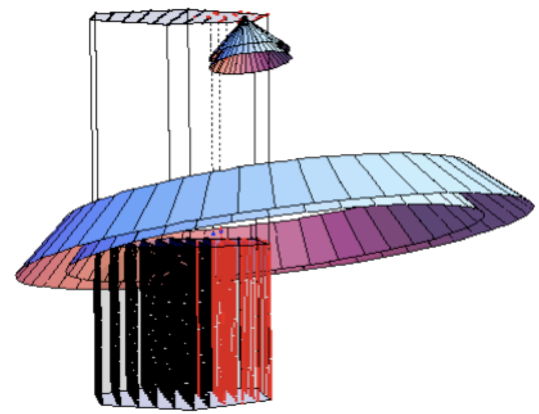




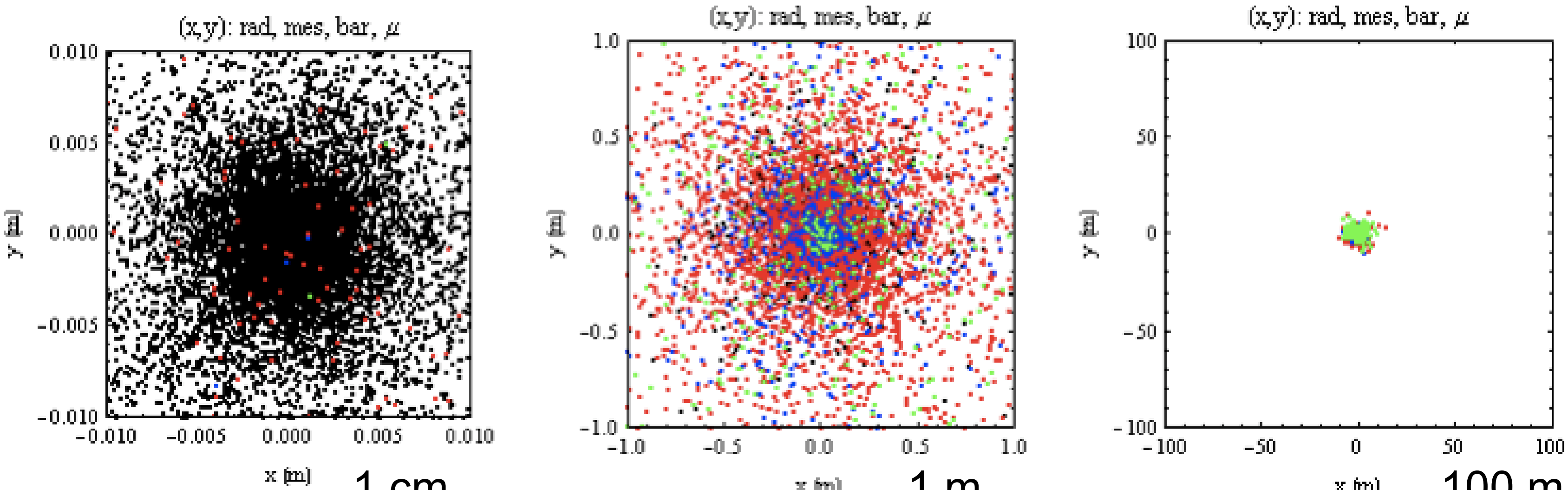
Askaryan pulses from air shower cores, Merida, 30th ICRC, July 10 2007 (Seckel)

Calibrate radio technique with Askaryan pulses from air





xy by ID, at 3 scales: C:\dave\anita\amc\eas_data\corsika\corsika_binaries\DAT000029. (EeV Prim, TeV cut)

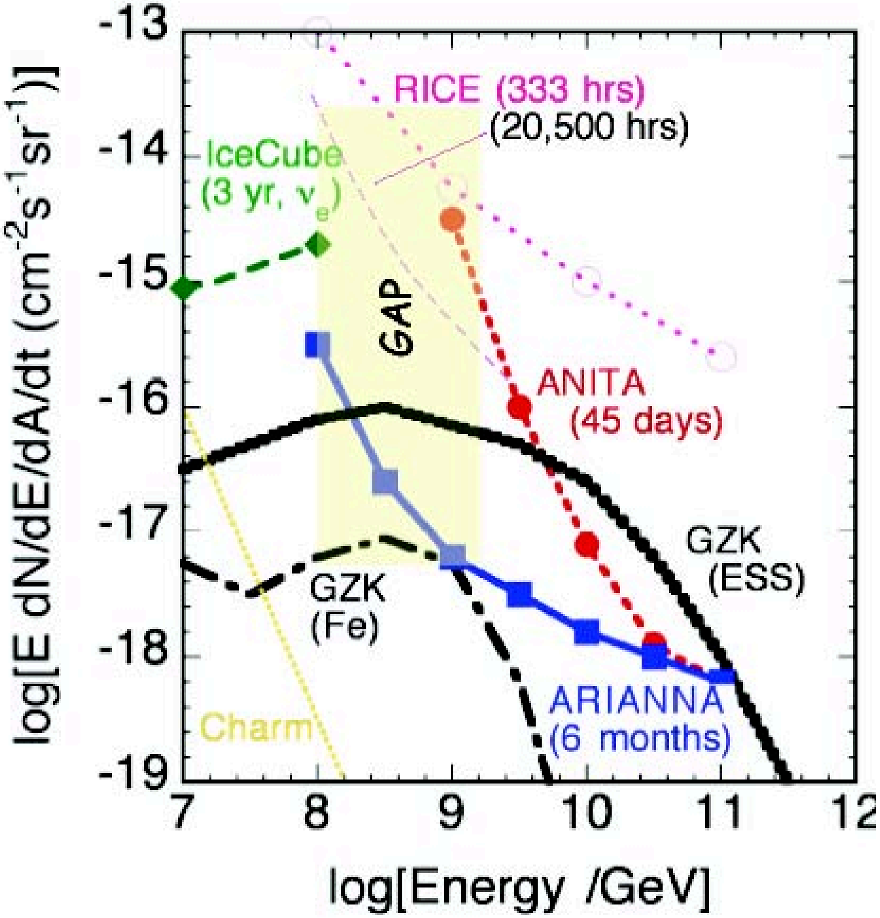


1 cm
1 m
100 m

-20

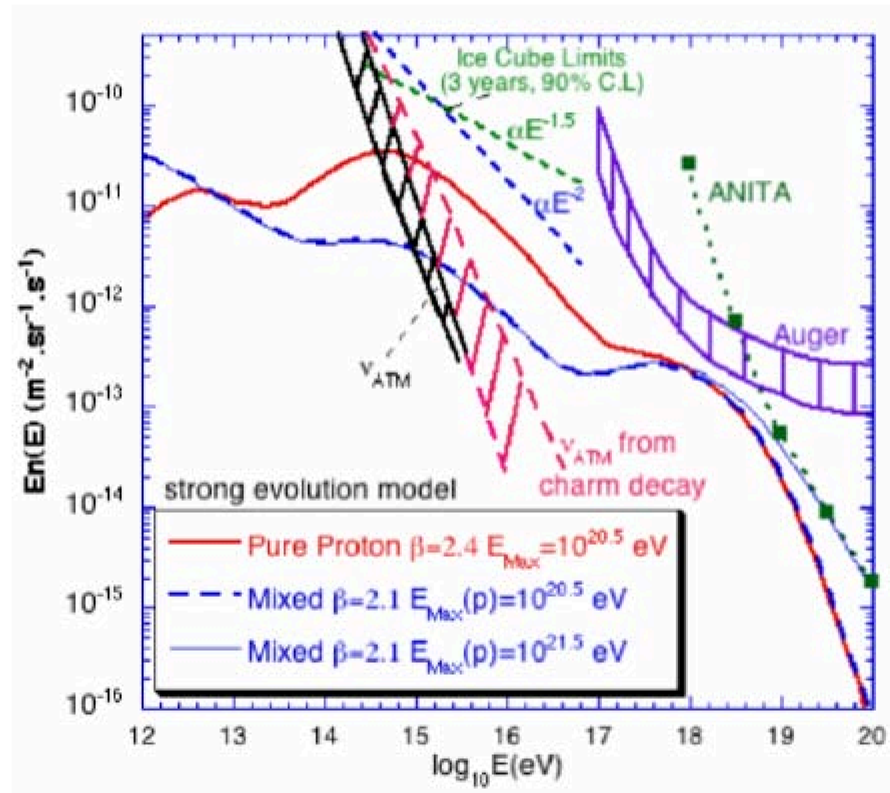
Askaryan pulses from air shower cores, Merida, 30th ICRC, July 10 2007 (Seckel)

Sensitivity and limits



S. Barwick, ARIANNA

Comparison with experiments



Normalized to AGASA (80% lower for HiRes)

N. Busca

Concluding comments

- TeV muon charge ratio
  - important new result from MINOS
  - Implications for >TeV atmospheric neutrinos
- SK-III fully operational for one-year
  - Expect lower threshold, doping with Gd
  - Expect to find Supernova relic neutrinos
- IceCube running with 22 strings, completion by 2011
- Antares progressing well; Km3net plan km-scale neutrino telescope in the Mediterranean
- Intense interest in detecting GZK neutrinos
  - Goal should be 1000 km^3 for 100 GZK ν per year
  - Need to calibrate the technique—use EAS cores?

Late news

July 10, 2007
The National Science Foundation (NSF) today announced selection of a University of California-Berkeley proposal to produce a technical design for a Deep Underground Science and Engineering Laboratory (DUSEL) at the former Homestake gold mine near Lead, S.D. The Homestake team, headed by Kevin Lesko, could receive up to $5 million per year for up to three years.

http://www.nsf.gov/news/news_summ.jsp?cntn_id=109694&org=NSF&from=news

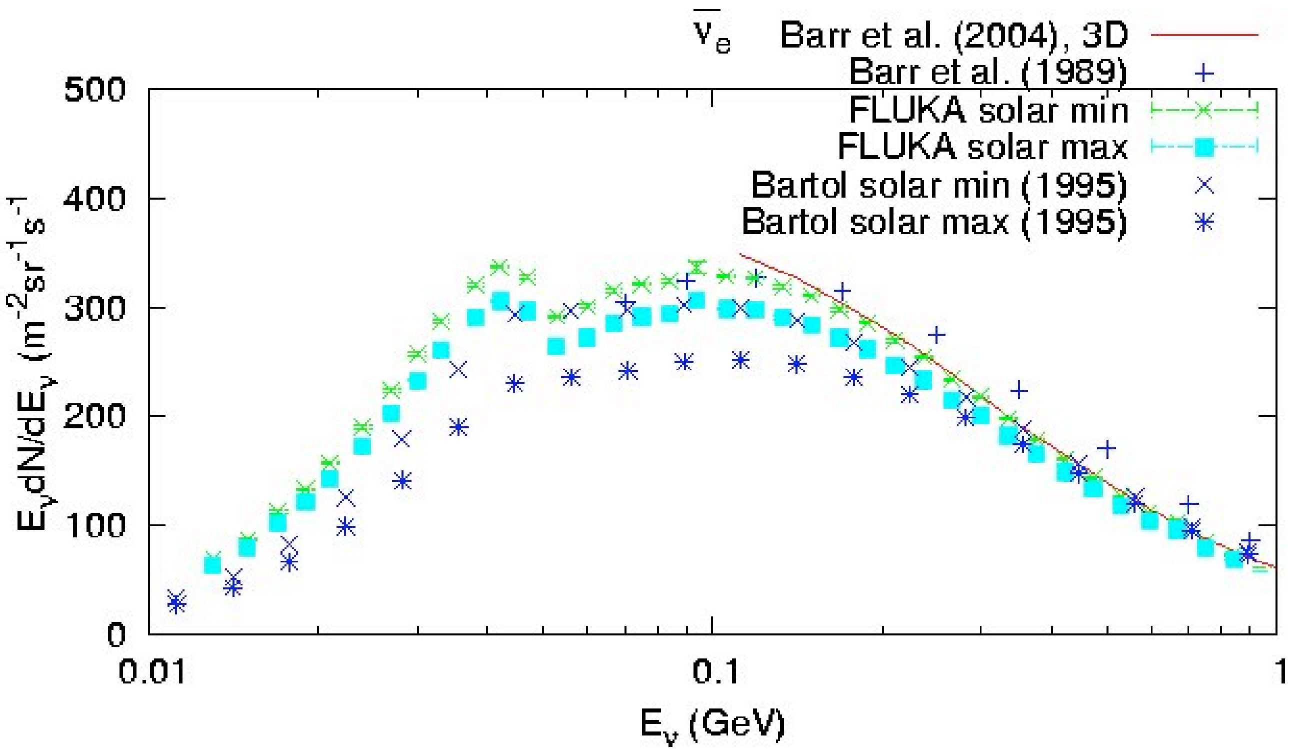
Extras

Calculations of anti-ν_e background 10-100 MeV

Note dependence on phase of solar cycle:

• 10 – 20% variation a signature of back-ground, not of signal

• similar to response of neutron monitors



FLUKA 10-100 MeV
Battistoni et al.(2004): http://www.mi.infn.it/~battist/neutrino.html

All flavor limits by AMANDA

Ignacio Taboada