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High energy neutrinos as cosmic messengers: AMANDA & IceCube …one branch…

IceCube

http://amanda.uci.edu

http://icecube.wisc.edu

SN explosion

GRB
Fireball models

AGN models, jets
hadronic vs leptonic models

Dark matter
neutralino annihilations in the center of the Earth or of the Sun

CR origin
Sources of high energy protons exist and dominate the CR spectrum at E> $10^{18.5}$ eV

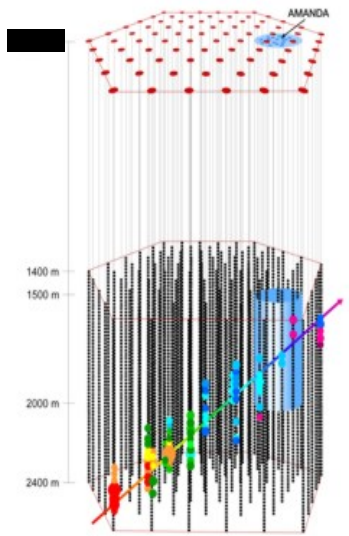
Exotic particles
decaying superheavy relic particles, topological defects, Z-bursts from energetic neutrinos

Cosmology

Astrophysics

Particle Physics

Atmospheric neutrinos
ultimate background



Digital Optical Module (DOM)

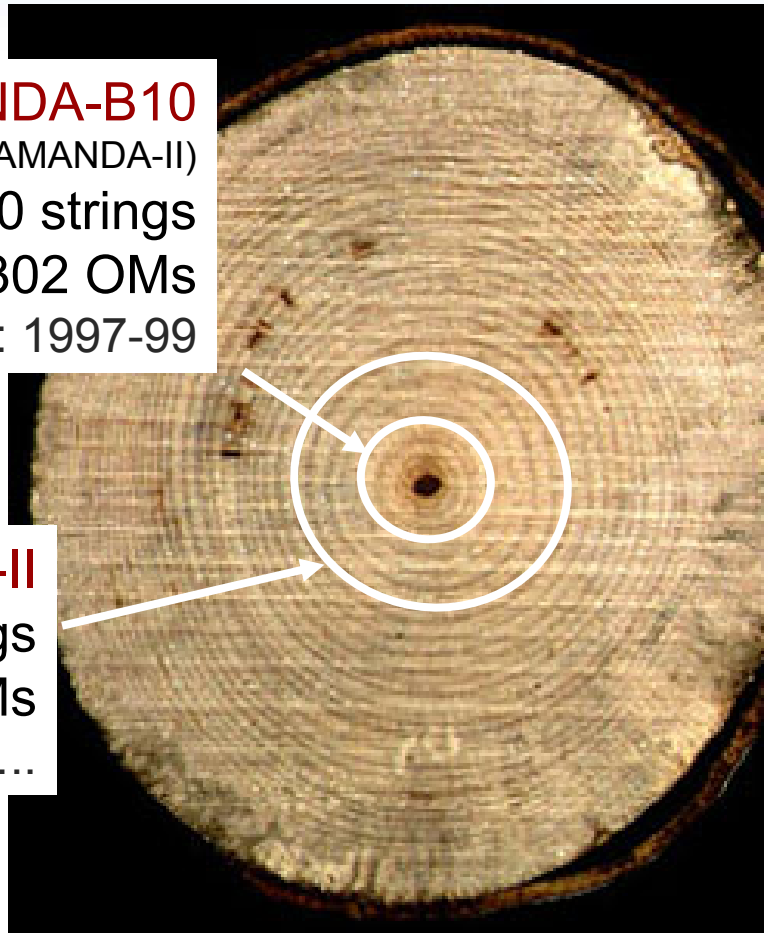
Detector medium (ice) properties

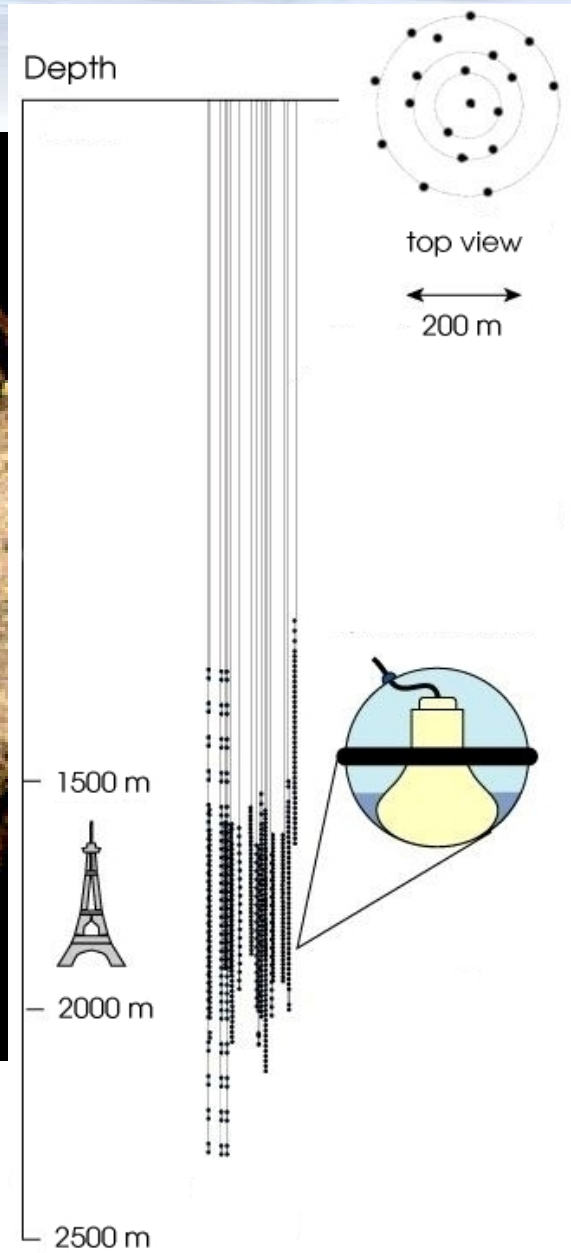
Neutrino production models, mixing …

The trunk(1): Antarctic Muon and Neutrino Detector Array (AMANDA)

AMANDA-B10
(inner core of AMANDA-II)
10 strings
302 OMs
Data years: 1997-99

AMANDA-II
19 strings
677 OMs
Data years: 2000-…..





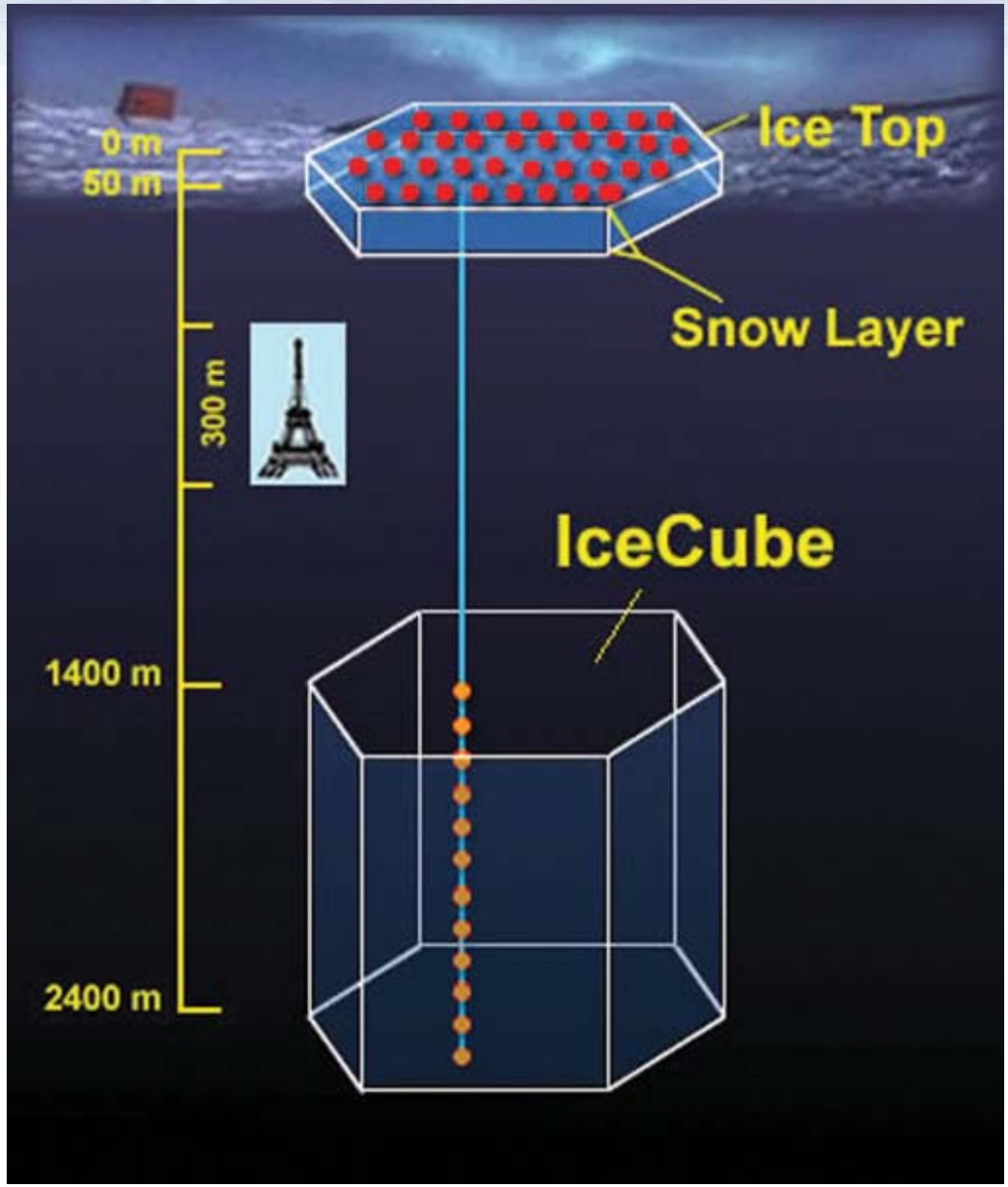
The trunk(2): IceCube ... the future

Deep ice array

- 80 strings / 60 OM's each
- 17 m OM spacing
- 125 m between strings
- hexagonal pattern over 1 km²
- geometry optimized for detection of TeV – PeV (EeV) ν's

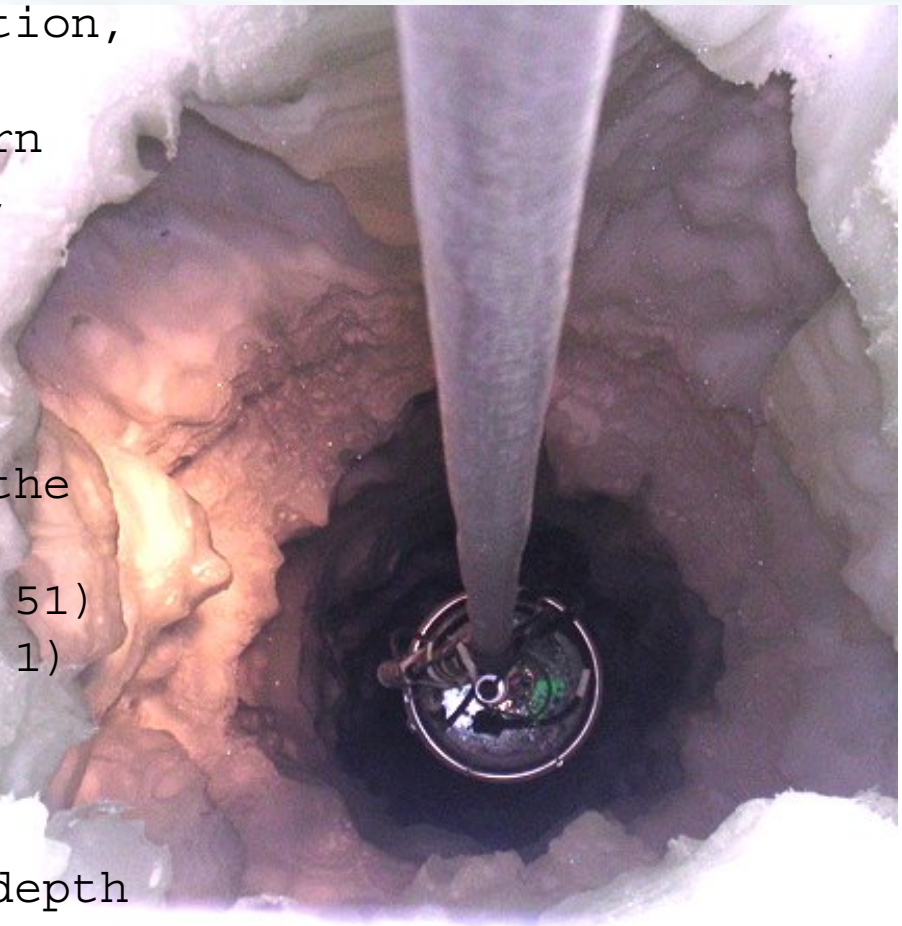
Surface array IceTop

- 2 frozen-water tanks (2 OM's each) on top of every string

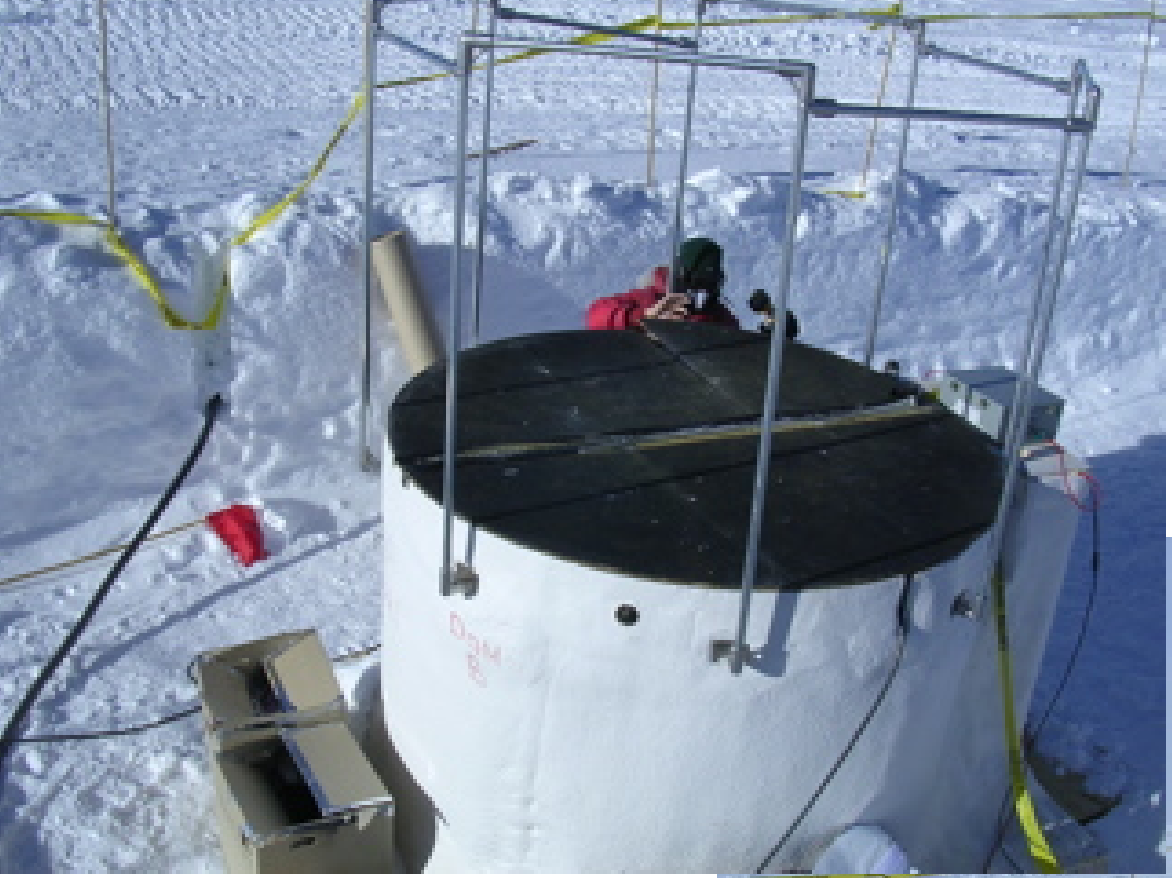


The trunk(3): IceCube ... the present

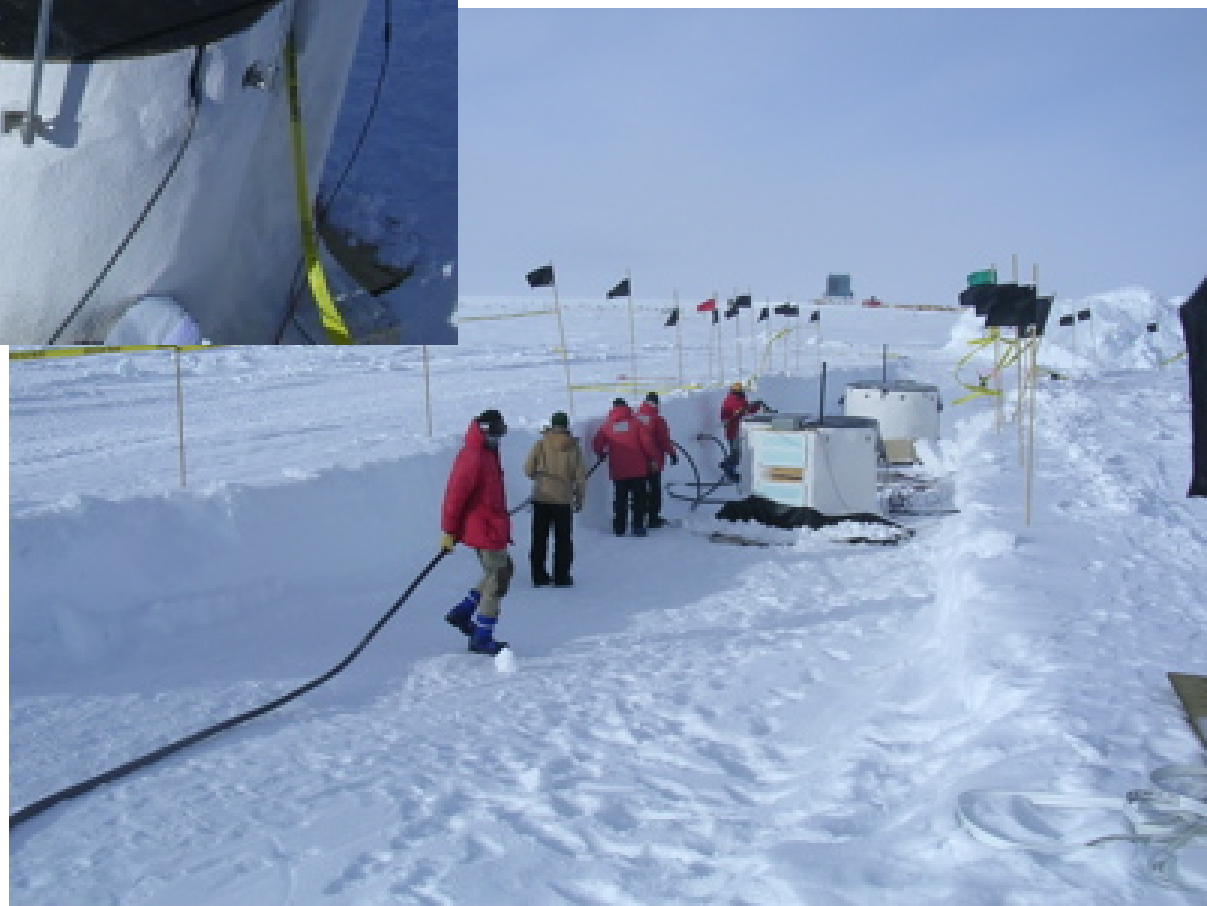
1/27,10:08h:Reached maximum depth of 2517 meters, reversed direction, started to ream up
1/28,7:00h:drill head and return water pump are out of the hole, preparations for string installation start
7:52h:Handover of hole for deployment
9:15h:Started installation of the first DOM (DOM 60)
12:06h:10th DOM installed (DOM 51)
22:36h:60th DOM installed (DOM 1)
Typical time for DOM installation:12 minutes
22:48h:Start drop
1/29,1:31h: String secured at depth of 2450.80 meters
20:40h:First communication to DOM



On-Ice Report on the first string, A. Karle, January 29, 2005



An IceTop tank is being closed.
2 IceTop tanks in 03-04
8 IceTop tanks in 04-05

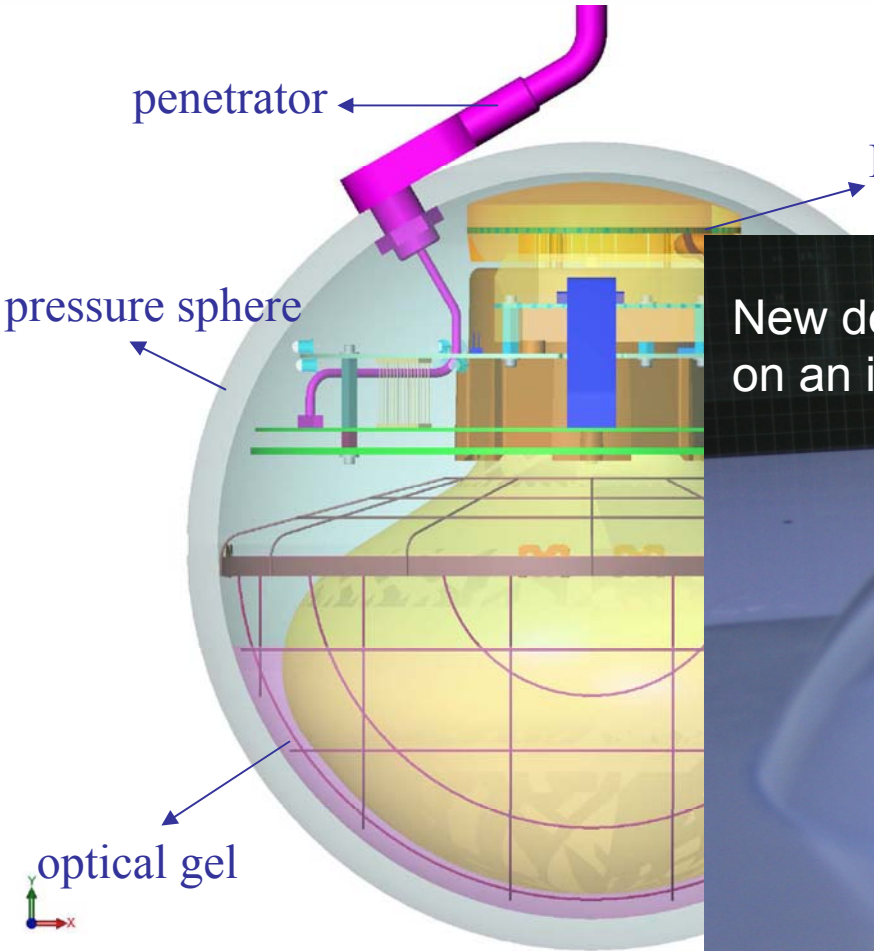


January 29: Surface cable is brought to the IceTop trench

The trunk (4): the Digital Optical Module

PMT = 10 inch Hamamatsu R-7081

Self-contained ”mini”-DAQ



New development: plastic Wavelength shifter based on an innovative polymer
(in coll. with MPIK-Heidelberg)

MARIE CURIE FELLOWSHIPS

The roots (1): ν production/spectrum/propagation

ν (E>TeV) production:
associated with the sources of high(est) energy cosmic rays

1. **bottom-up scenarios:**
   "cosmic accelerators"
   - accreting black holes (e.g. AGN)
   - colliding neutron stars/black holes
     $\rightarrow$ fireball (e.g. GRB)

From pp or pγ:

$$\pi^+ \rightarrow \nu_\mu + \mu^+ \quad \mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$$

$$\pi^- \rightarrow \bar{\nu}_\mu + \mu^- \quad \mu^- \rightarrow e^- + \nu_\mu + \bar{\nu}_e$$

2. **top-down scenarios**: decays (annihilation) of massive cosmological relics ($M_X \sim 10^{21\text{-}24}$ eV)

ν-spectrum at the source: (in case 1.) $\propto E^{-2}$ (Fermi acceleration mechanism), up to $E \sim 10^{20}$ eV

ν-propagation:

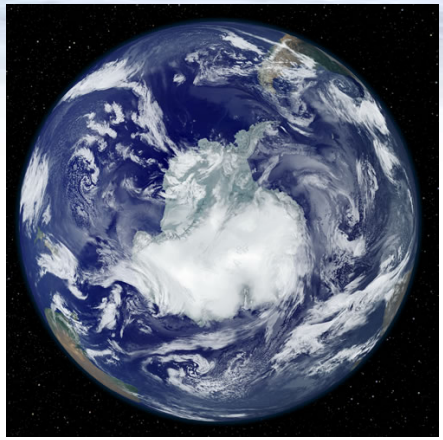
$\nu_e : \nu_\mu : \nu_\tau \sim 1:2:<10^{-5}$ @ the source

$\nu_e : \nu_\mu : \nu_\tau \sim 1:1:1$ @ the detector
(maximal $\nu_\mu \leftrightarrow \nu_\tau$ mixing)

No spectral shape deformation expected

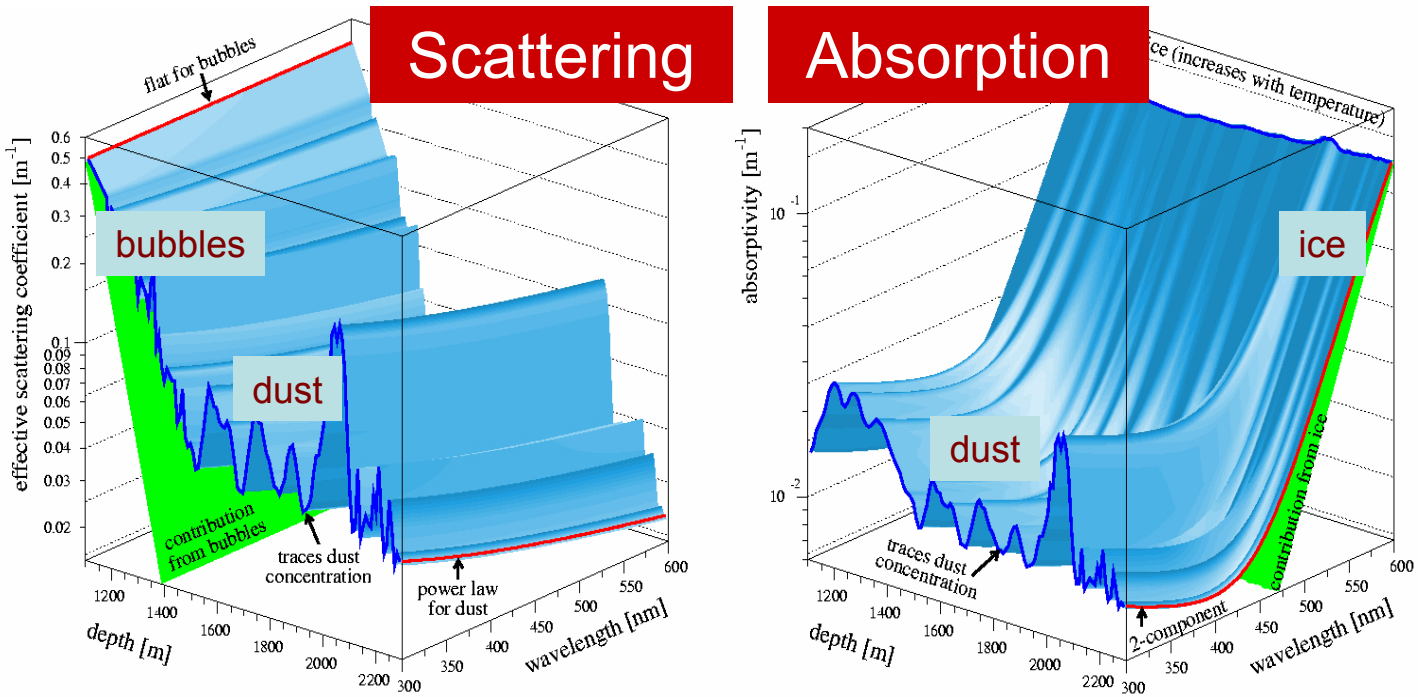
The roots (2): the optical properties of the Antarctic ice-cap

Instrumented natural medium (IceCube ~ 1km^3) inside the Antarctic ice-cap



Average optical ice parameters:

λ_{abs} ~ 110 m @ 400 nm
λ_{sca} ~ 20 m @ 400 nm

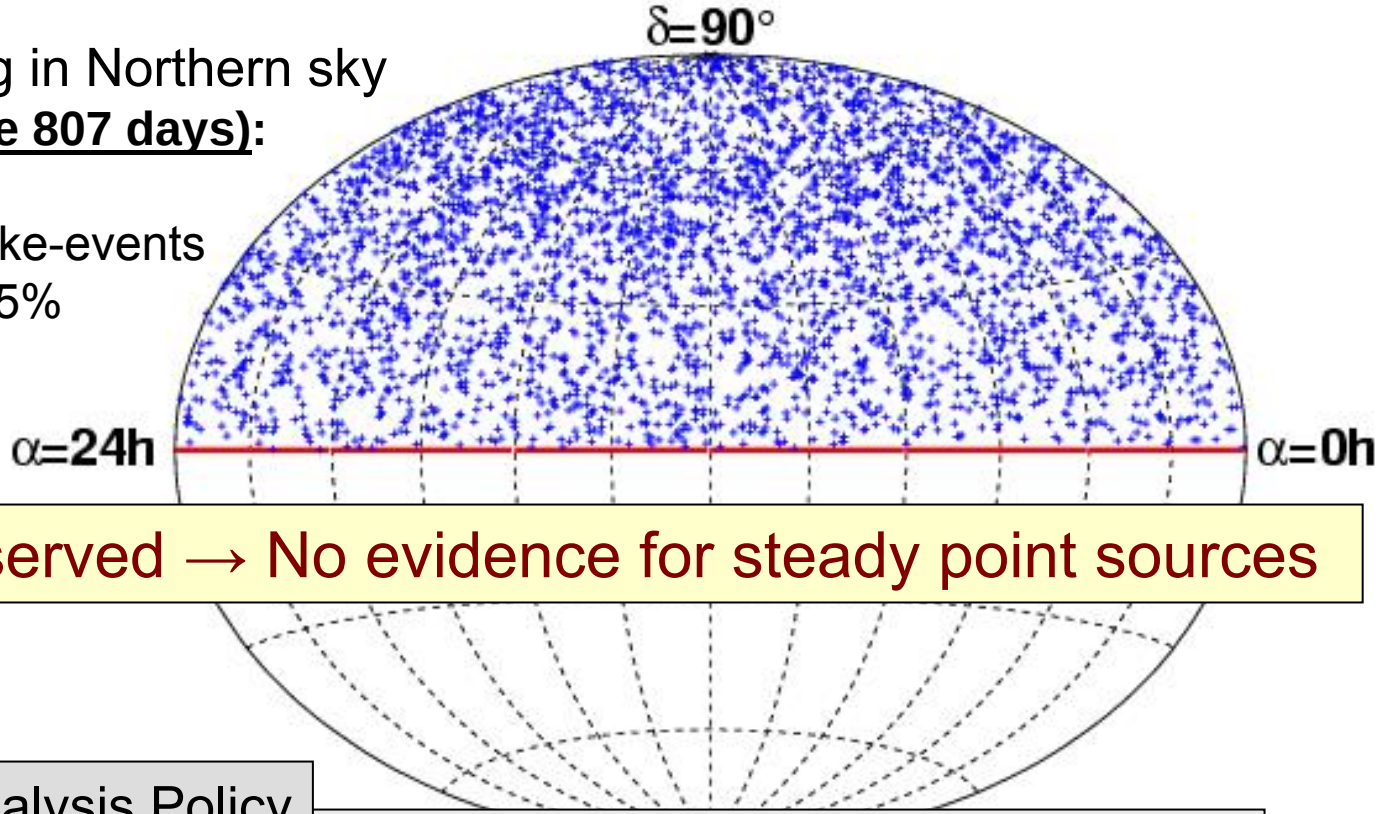


Measurements: in-situ light sources & atmospheric muons

One Branch: Point Source (PS) Search
Sub-branch: **s t e a d y** PS

 = 2π  = 00-03 combined

Search for clustering in Northern sky
The **Sky-plot (livetime 807 days):**
3369 events selected
Contamination from fake-events (mis-reconstructed) < 5%



No clustering observed → No evidence for steady point sources

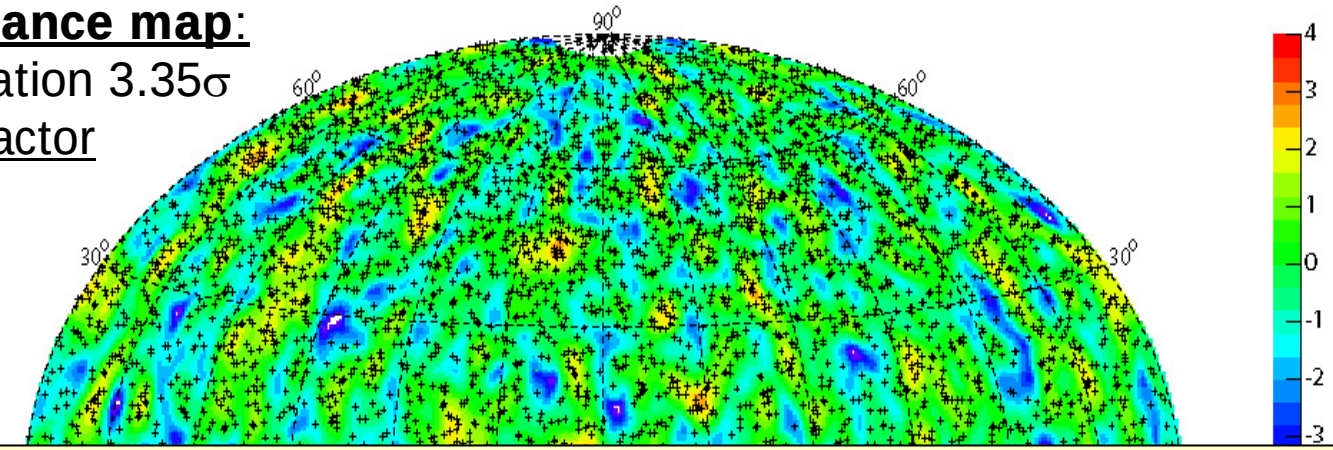
Collaboration Analysis Policy

'blindness'

= cuts are optimized on fraction of data or on a time-scrambled data set
(except for SN searches which are based on detector noise rate monitoring)

Unbinned statistical analysis: use track resolution (pdf) for each event

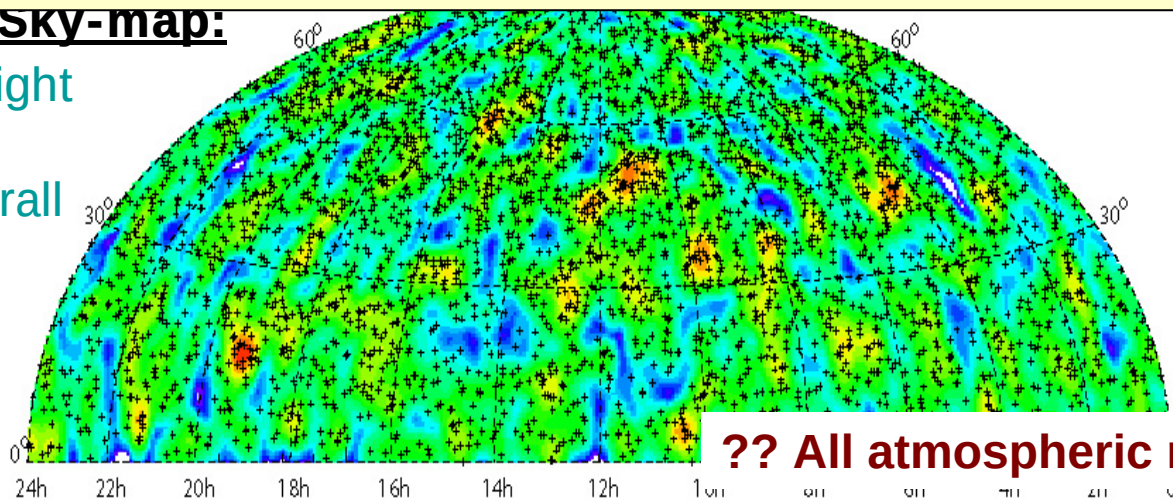
The **Significance map**:
Highest deviation 3.35σ
before trial factor correction



No statistically significant excess from steady point sources
(4 years average)

Scrambled Sky-map:

Randomize right ascension to evaluate overall probabilities



?? All atmospheric neutrinos ??

Sub-branch: **t r a n s i e n t** PS search
Sub-sub-branch: TeV B L A Z A R

 = limited to few sources  = limited to most favorable periods

TeV neutrino candidates sources like BLAZAR often show **F L A R E S** = **large and violent variations in the complete electromagnetic spectrum**

IMAGE CREDIT: NASA/Honeywell Max Q Digital Group, Dana Berry

Matter falling into a massive black hole forms a jet of material

If the black hole is oriented so the jet is pointed towards earth, we see a bright source of gamma-rays

Other (extremely) variable sources (not discussed here):
- Microquasar ..
- GRB

Sub-sub-branch: TeV B L A Z A R (Multiwavelength approach…first trial)

<u>ν flux correlated with TeV gamma-ray flux</u>

search for neutrino emissions from the jets of blazar using the TeV gamma-ray light curve

⇒ reduction of the temporal (and spatial) space

<u>TeV gamma-ray limitations</u>

- data not continuous in time
- biased by alert from satellites

<u>X-TeV time correlation evidence</u>

- studied on various flares and tin
- predicted in leptonic models but contradiction with hadronic models
- observed “orphan” flares

<u>X-ray advantages</u>

- from ASM-RXTE nearly continue monitor (not very precise)
- data available

Mkn 421 - March 2001 RXTE/Whipple/HEGRA Campaign

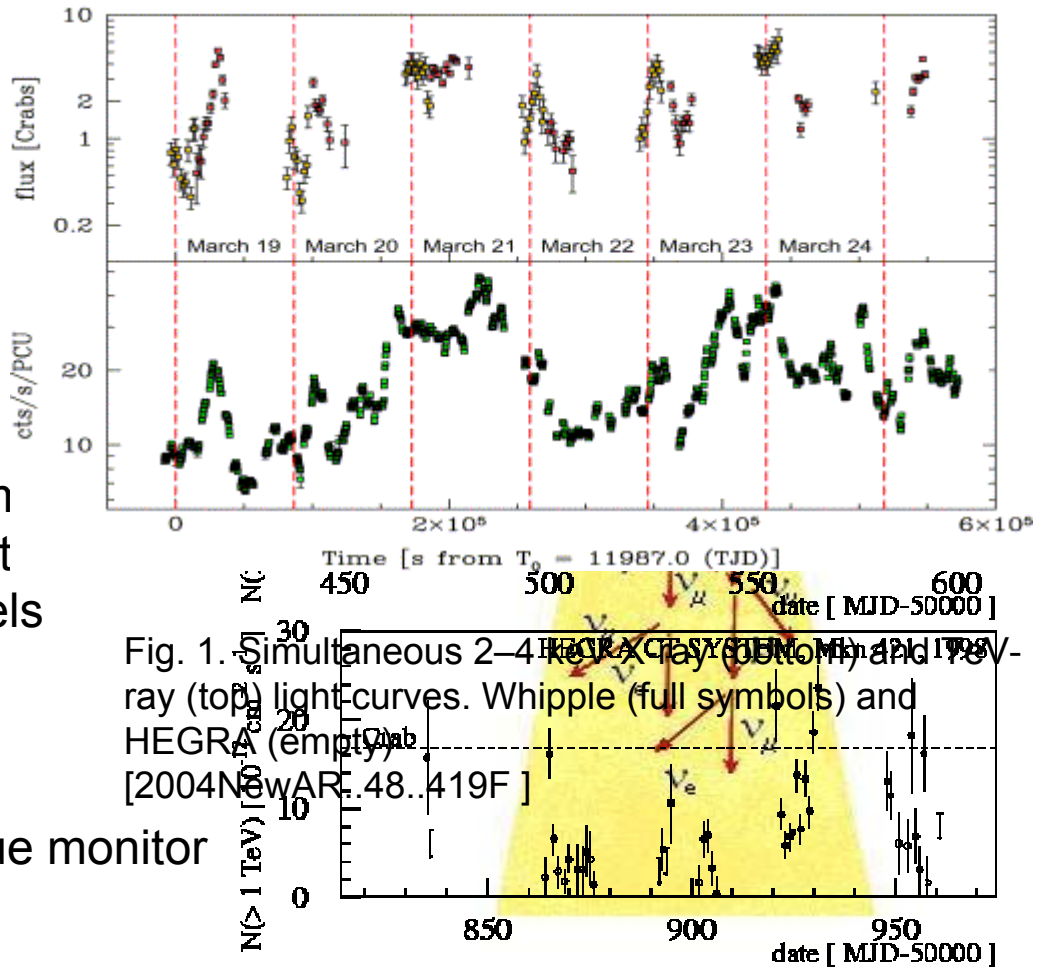


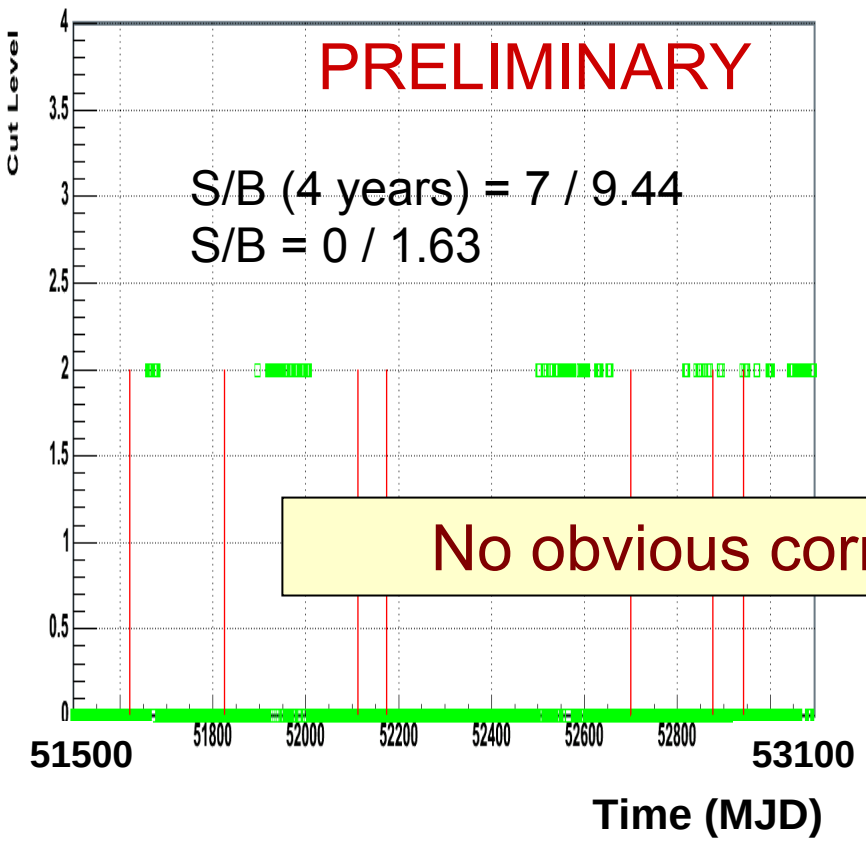
Fig. 1.- Simultaneous 2–4 keV X-ray (bottom) and 1 TeV-ray (top) light curves. Whipple (full symbols) and HEGRA (empty) [2004NewAR..48..419F]

Sub-sub-branch: TeV B L A Z A R (Multiwavelength approach…first trial)

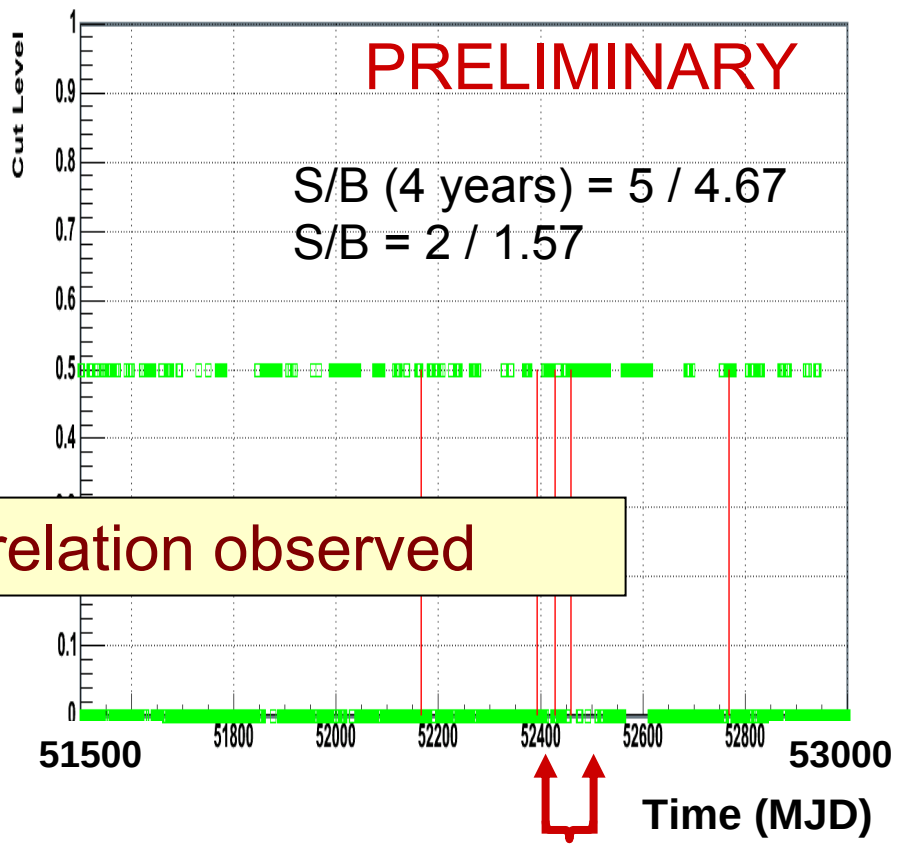
Periods selected on the **X flares** (2-10 KeV, ASM-RXTE) before unblinding for **Mkn 421** and **1ES1959+650**

Data sample: **4 years (00-03) combined** (re-optimized)

Source: **Mkn 421**

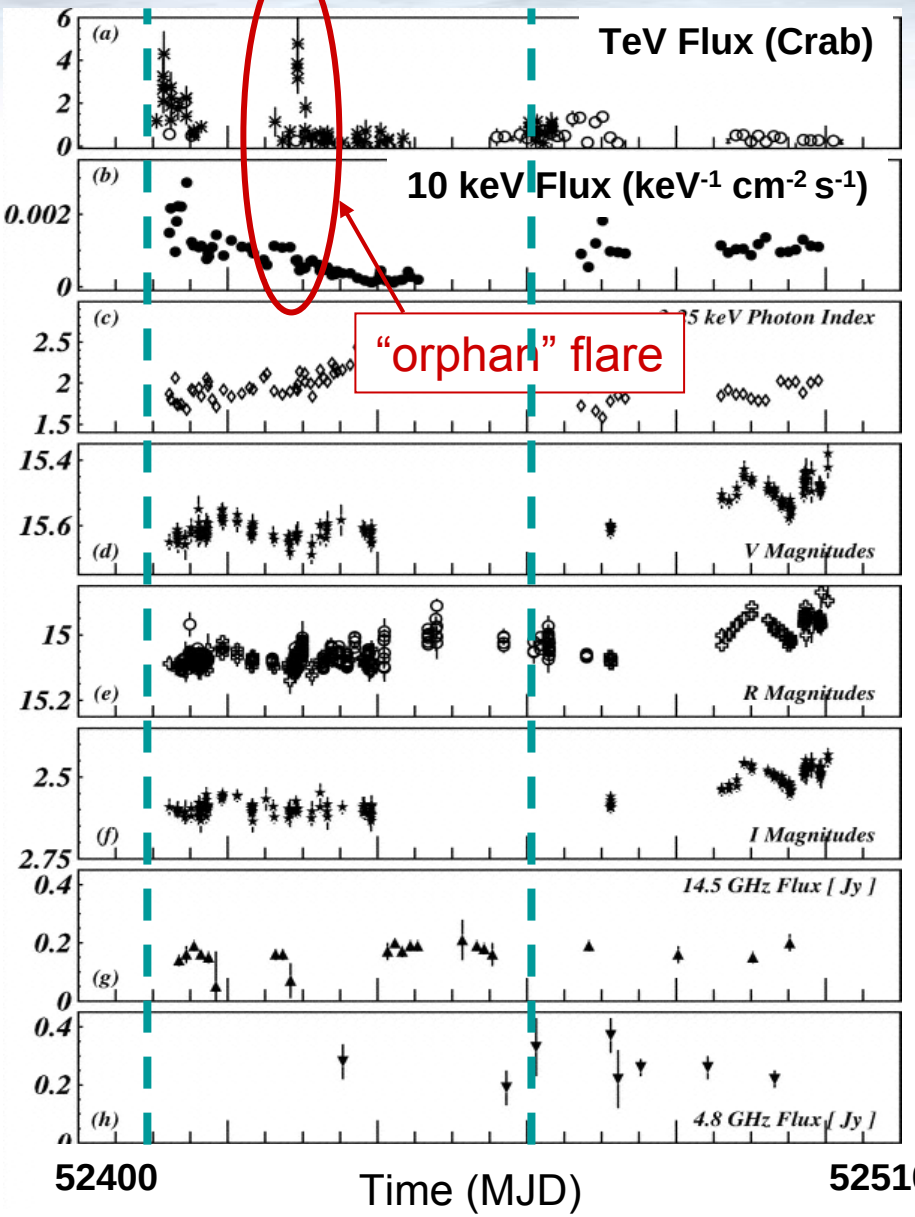


Source: **1ES1959+650**

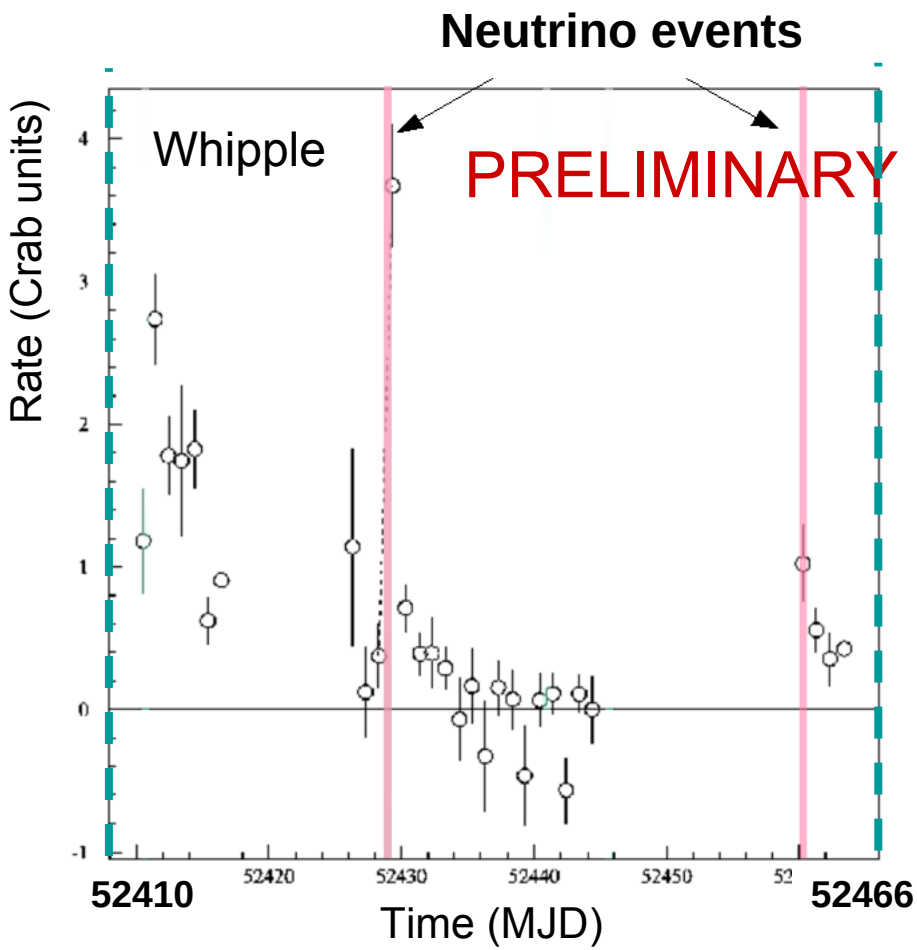


No obvious correlation observed

An interesting hint;
wait for future data to substantiate



H. Krawczynski et al, 2004ApJ,601 151K
'Multiwavelength Observations of Strong Flares from the TeV Blazar 1ES 1959+650'



Conclusions

1. AMANDA-II is ‘performing’: 5 years good data; on-line monitor; on-line filtering; different analysis methods developed; many branches.

2. IceCube is for real: first string deployed this season

3. Cosmic neutrinos near to deliver their message …..