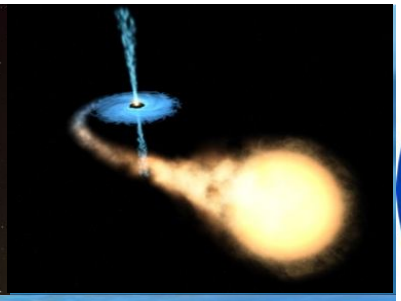
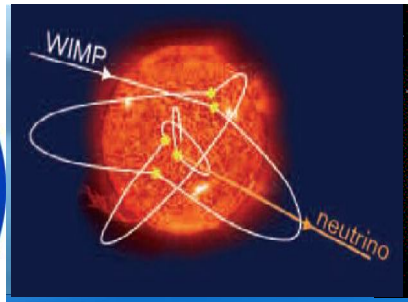
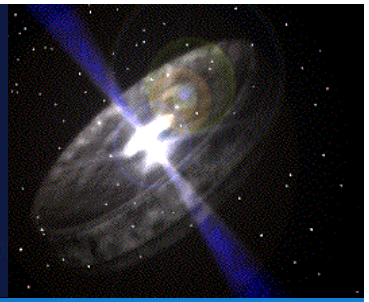
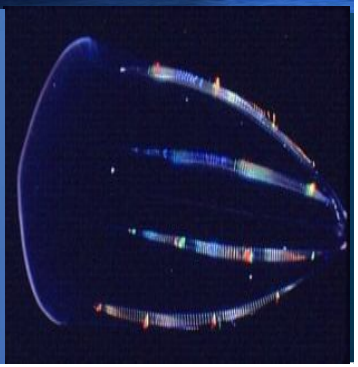
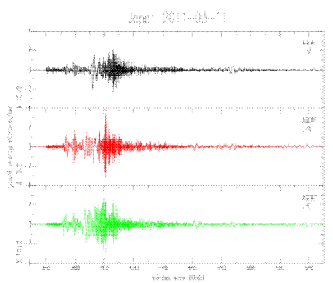
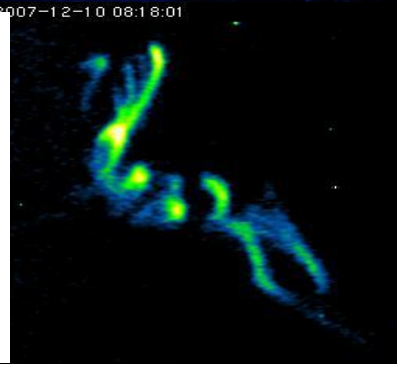




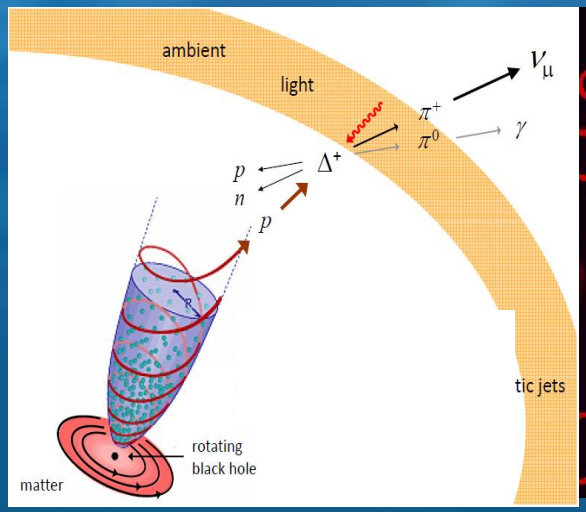


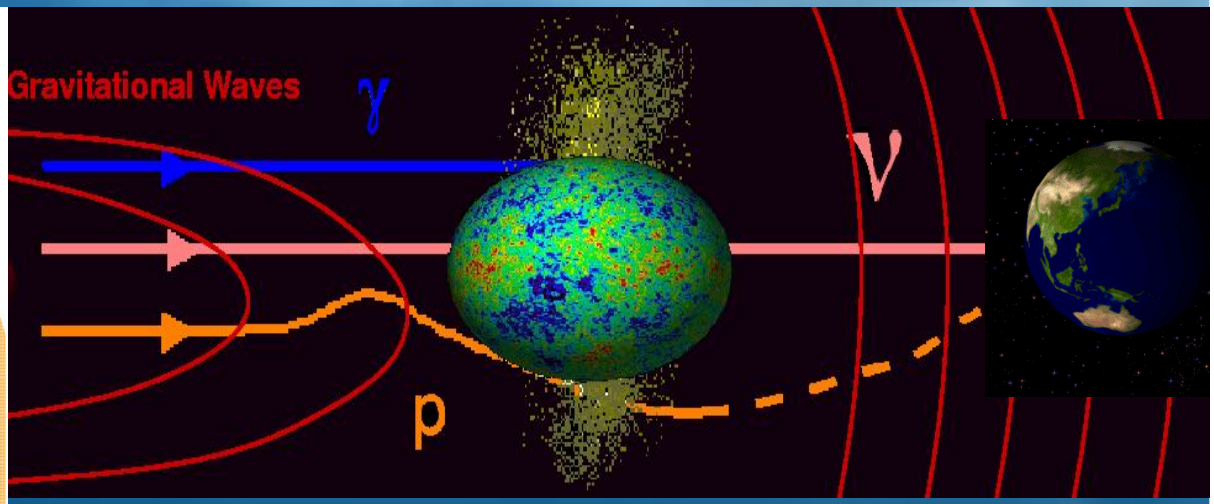
The ANTARES Deep Sea Neutrino Telescope
Conseil Scientifique IN2P3
2 Feburary 2012

Paschal Coyle
Centre de Physique des Particules de Marseille

Neutrinos and Multi-Messenger Astronomy





Protons/ Cosmic Rays:

- Detected on Earth up to extremely high energies: 10^8 TeV
- Hard to study sources due to deflection by magnetic fields
- Large time delay w.r.t. optical signals

→ hadronic accelerators exist, but where?

Photons

- Produced in leptonic and hadronic processes
- Absorbed at higher energies and large distances

Neutrinos

- Unambiguous signature of hadronic acceleration
- Not deflected by magnetic fields or absorbed by dust
- Horizon not limited by interaction with CMB/IR
- Can escape from region of high matter density
- Can be time correlated with optical signals

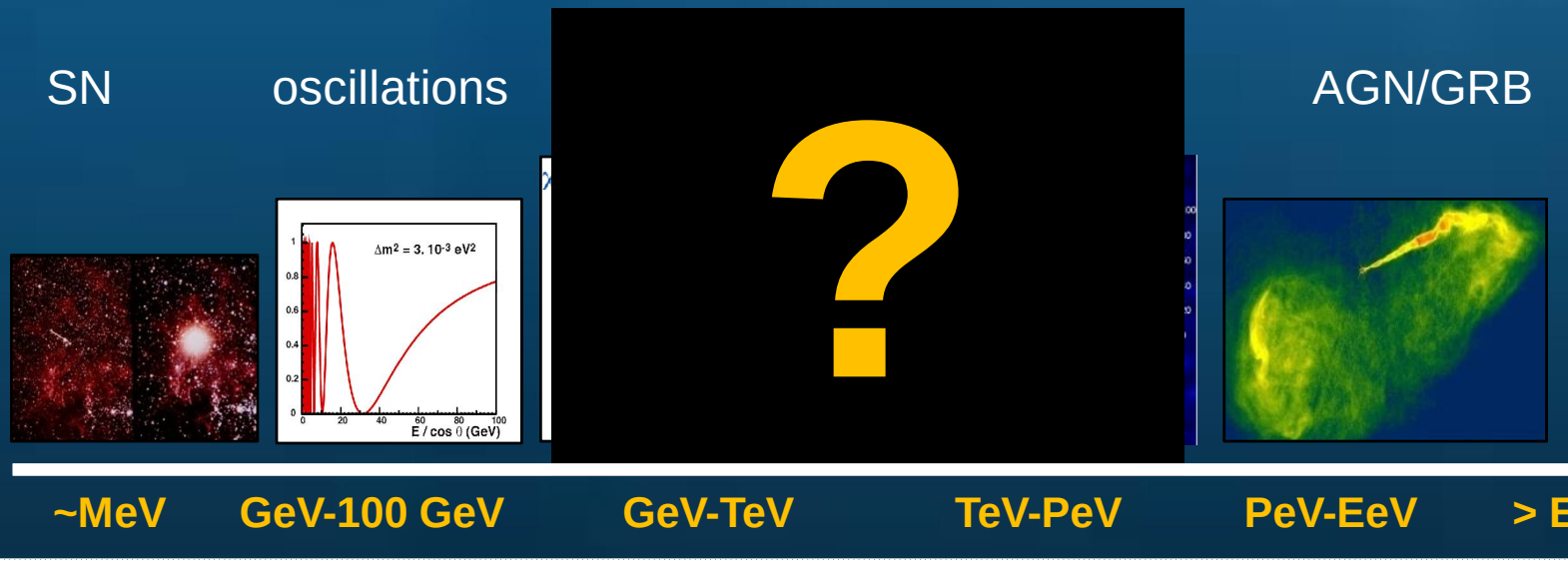
→ identify cosmic ray sources

Science with Deep Sea Neutrino Telescopes

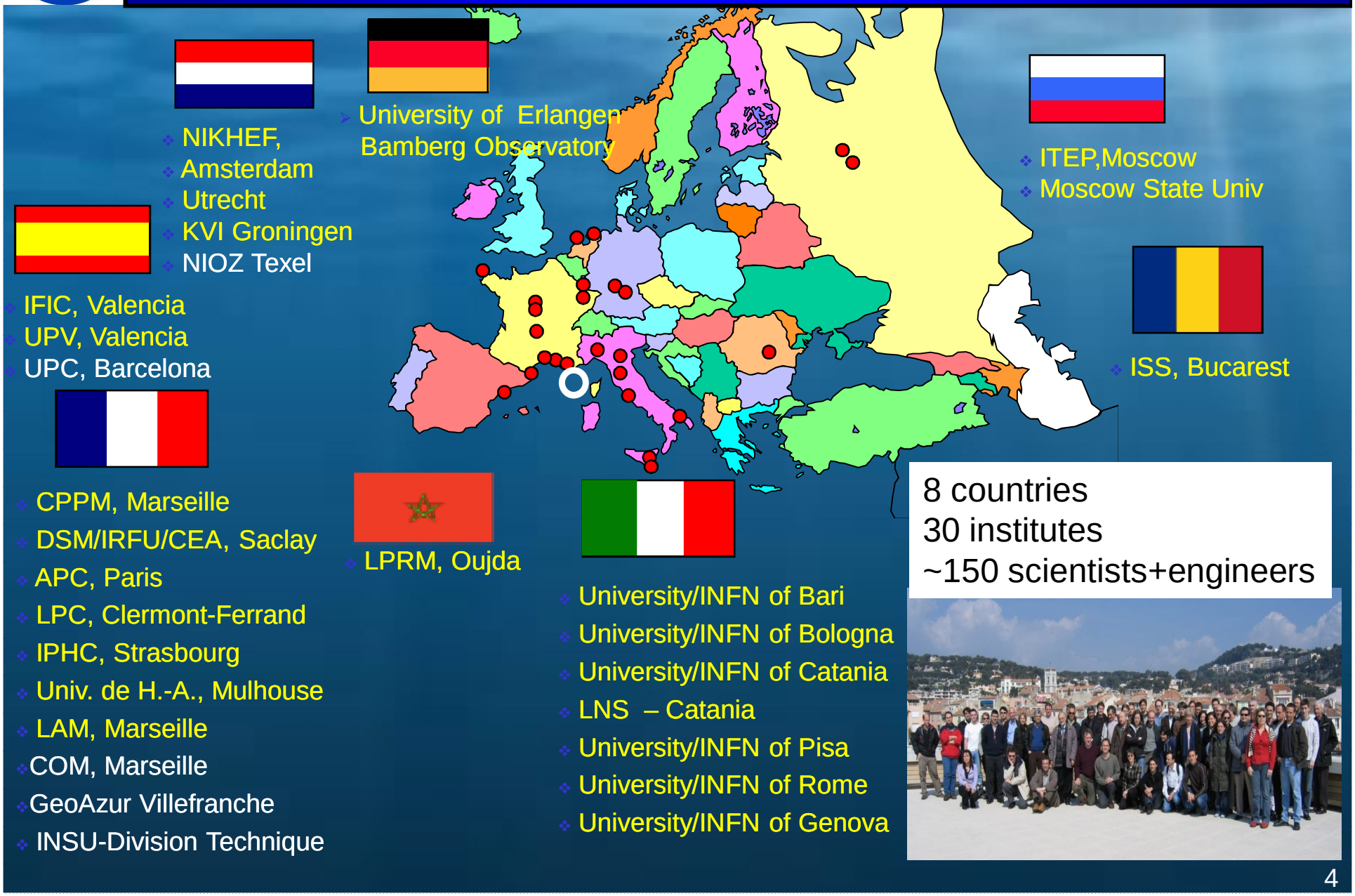
- **High energy neutrino astrophysics**:
  galactic: SN, SNRs, μ-quasars, molecular clouds, etc...
  extra-gal: AGNs, GRBs, dark-GRBs, GZK, etc....

- **Search for New Physics**:
  Dark matter (Sun, Galatic Centre), Monopoles, nuclearites, ??

- **Earth-Sea Science:**
  oceanography, sea biology, seismology, environmental monitoring...



The ANTARES Collaboration



- NIKHEF, Amsterdam
- Utrecht
- KVI Groningen
- NIOZ Texel

- University of Erlangen
- Bamberg Observatory

- ITEP,Moscow
- Moscow State Univ

- IFIC, Valencia
- UPV, Valencia
- UPC, Barcelona

- ISS, Bucarest

- CPPM, Marseille
- DSM/IRFU/CEA, Saclay
- APC, Paris
- LPC, Clermont-Ferrand
- IPHC, Strasbourg
- Univ. de H.-A., Mulhouse
- LAM, Marseille
- COM, Marseille
- GeoAzur Villefranche
- INSU-Division Technique

- LPRM, Oujda

- University/INFN of Bari
- University/INFN of Bologna
- University/INFN of Catania
- LNS – Catania
- University/INFN of Pisa
- University/INFN of Rome
- University/INFN of Genova

8 countries
30 institutes
~150 scientists+engineers

The ANTARES Collaboration

A mixture of Astroparticle and Sea Science institutes:

All flavours of institutes contribute to common fund and votes

Two different cultures

ESS papers signed first by contributors + ‘The ANTARES Collaboration’

New MOU signed recently;

Continue operation until 2016

Allows KM3NeT members to access data without paying common fund
They can sign a paper if they have made significant contribution

ANTARES a testbed for KM3NeT R&D and soft (within reason)

Total operation/maintenance costs 440k€ (IN2P3:88k€, INSU:44k€)

IN2P3 Physicists (CDI, CDD, Student)

APC

Baret
Creuzot
Donzaud
Kouchner
Van Elewyck
Bouhou

CPPM

Aubert (emeritus)
Bertin
Busto
Brunner
Carr
Costantini
Coyle
Dornic
Ernenwein
Escoffier
Hallewell
Vallee
Riviere CDD-PD
Samurai CDD-ATER
Core
Galata
Charif
Yatkin

IPHC

Pradier

LPC

Carloganu
Gay
Guillard CDD-PD
Dumas

~20% of Collaboration

IN2P3 Contributions

APC

Charge calibration
OM characterization
Data quality

GWHEN
Neutrino velocity

CPPM

Detector maintenance
Detector operation
TaToO operation
Sea operations
Slow control
Acoustic positioning
Clock system
Surface array
Run-by-run Monte Carlo

Dark matter
Oscillations
Point sources
AGN, Microquasars flares
TaToO GRB, SN
GRBs
Magnetic monopoles
UHE
Moon shadow

IPHC

ELOG

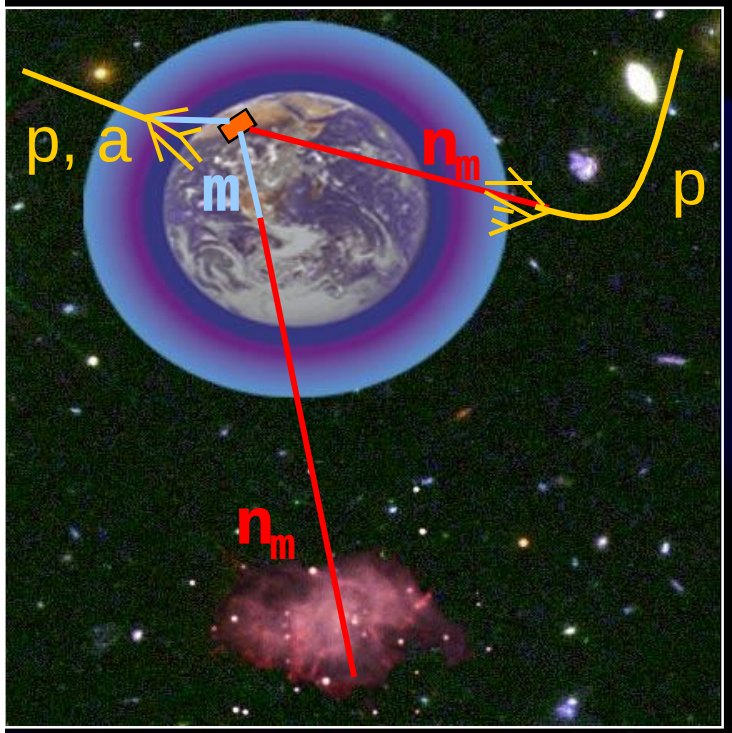
GWHEN

LPC

Simulation soft
Internal LED
Low energy recon.

Oscillations
Dark matter

Detection Principle



3D PMT array

Cherenkov light from m

42°

Sea floor

m

ν_m

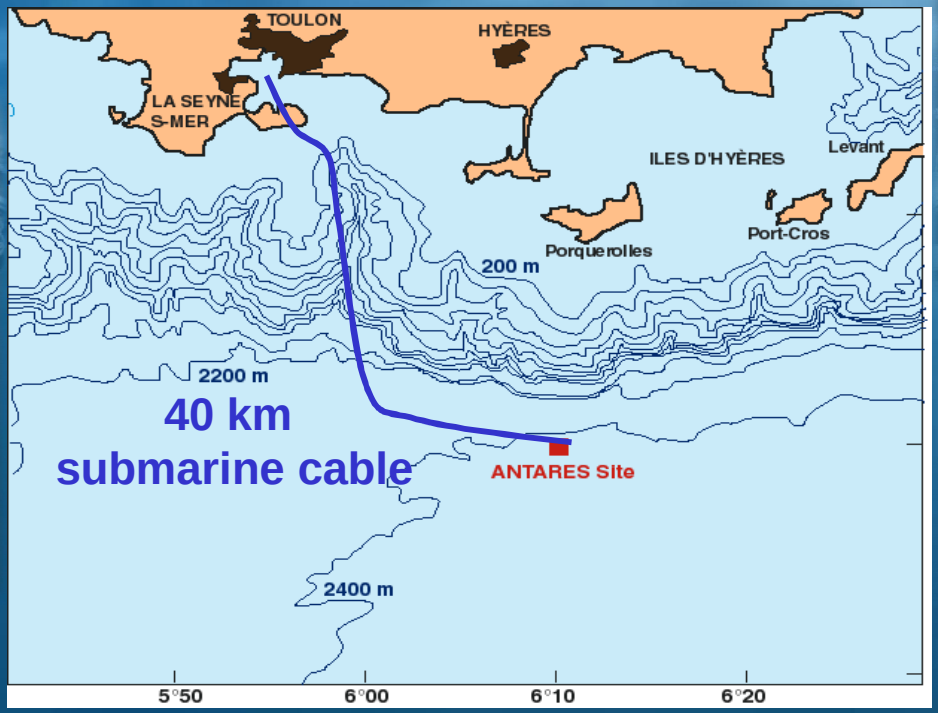
interaction

The reconstruction is based on local coincidences compatible with the Cherenkov light front

- Main detection channel: ν_μ interaction giving an ultra-relativistic μ (ν_e and ν_τ also)
- Energy threshold ~ 20 GeV
- 24hr operation, more than half sky coverage

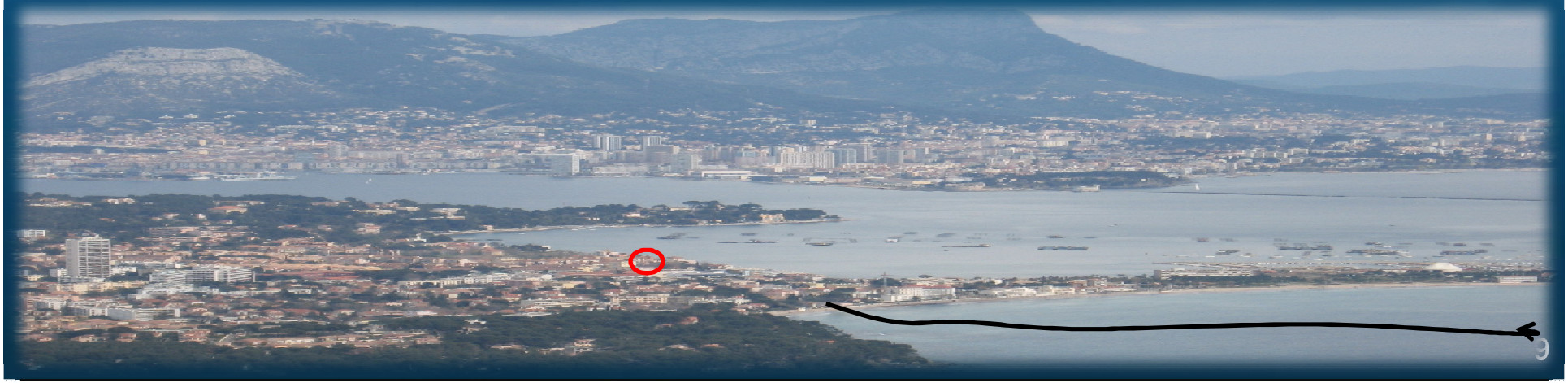
The ANTARES Site & Infrastructure

IFREMER Toulon Centre



Shore Station

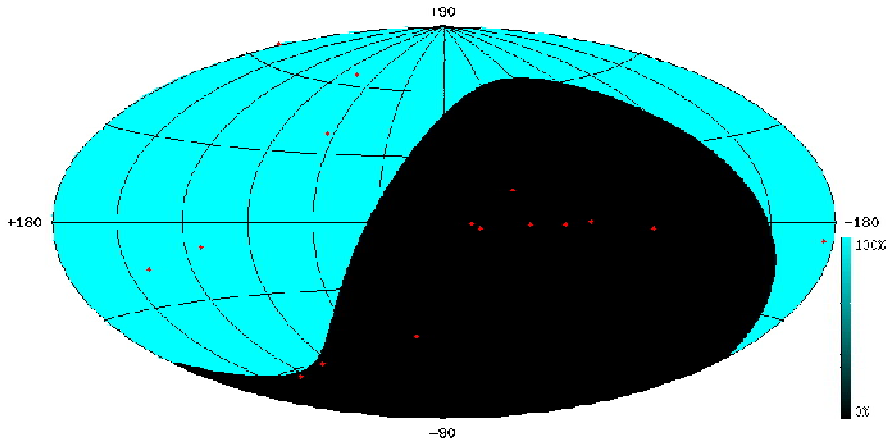
FOSELEV Marine

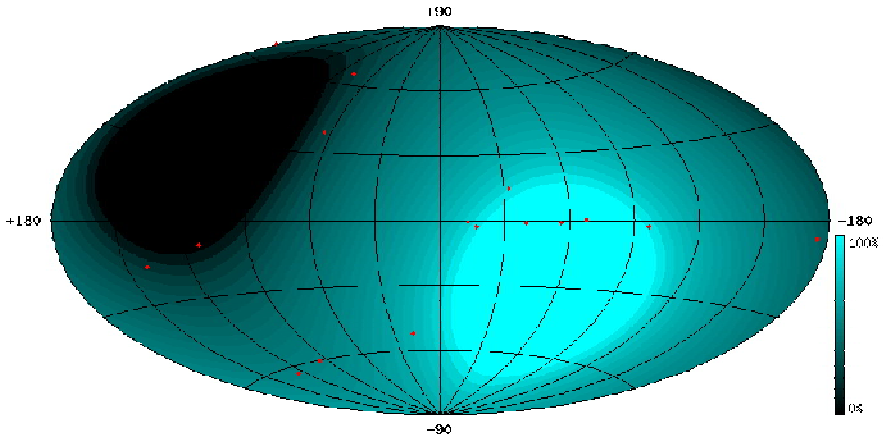


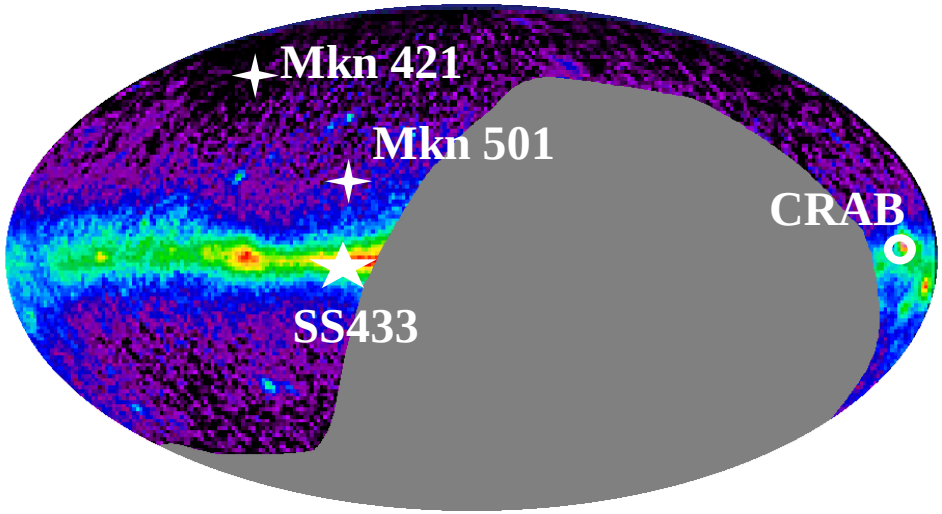
Region of Sky Observable by Neutrino Telescopes

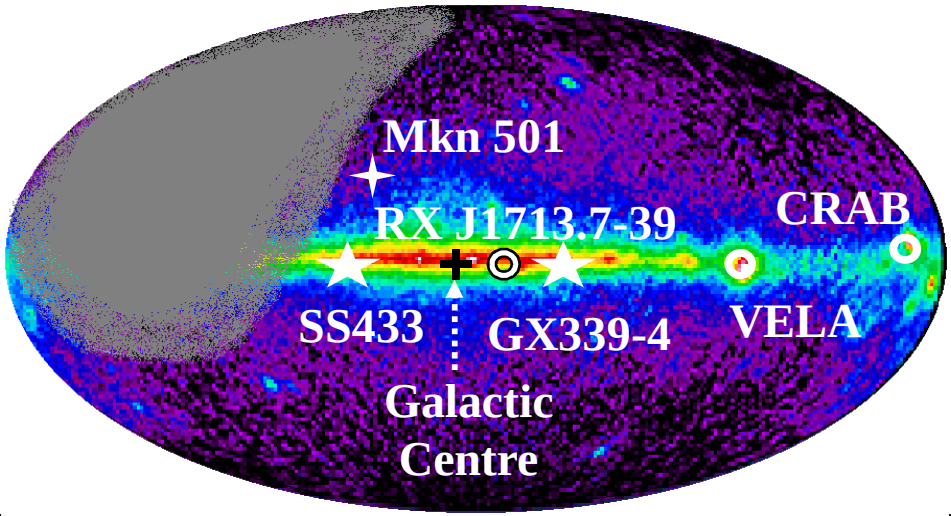
AMANDA/IceCube (South Pole)
(Ice: ~2°/0.6°)

ANTARES/KM3 (43° North)
(water: ~0.3°/0.1°)

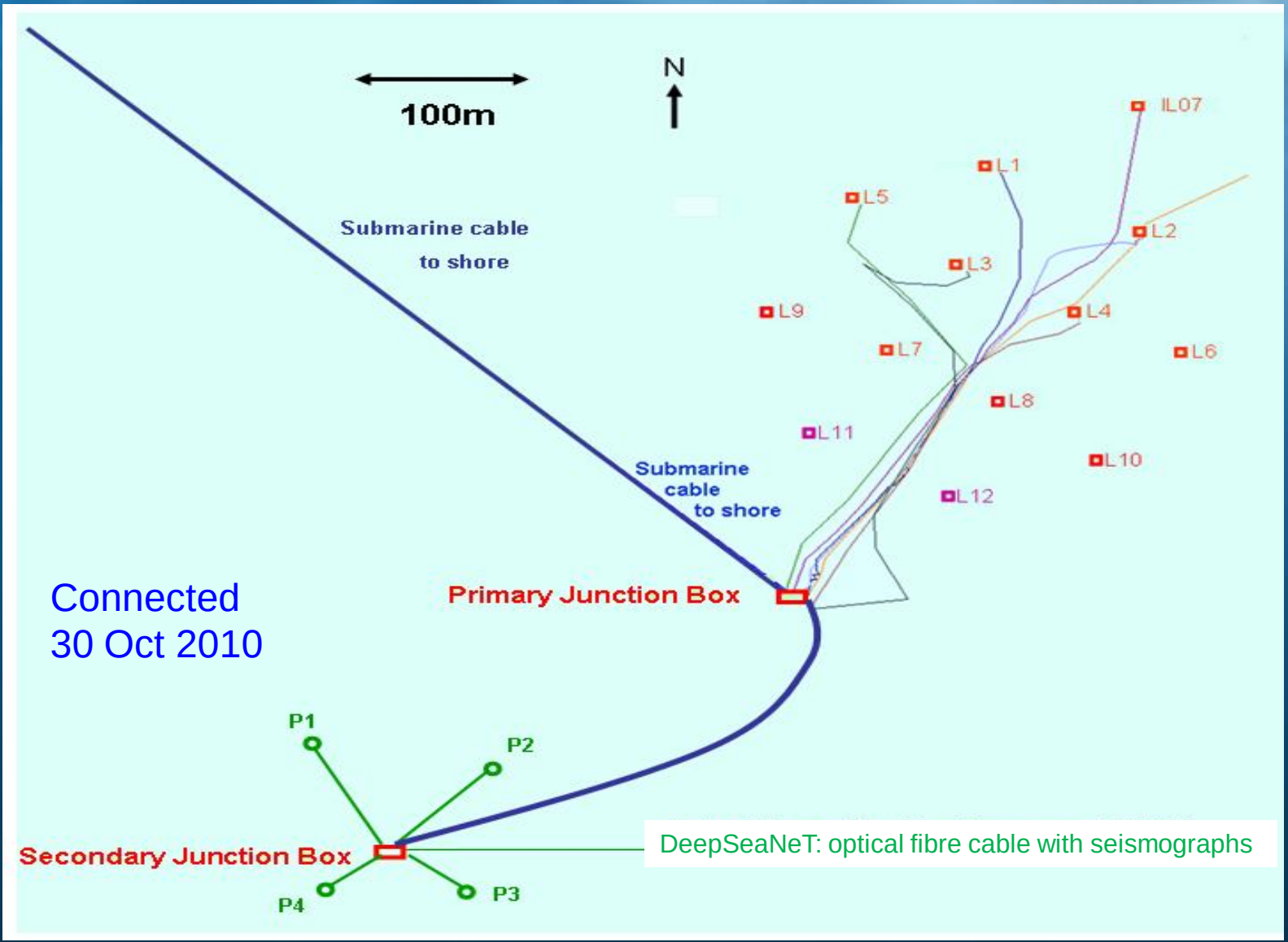




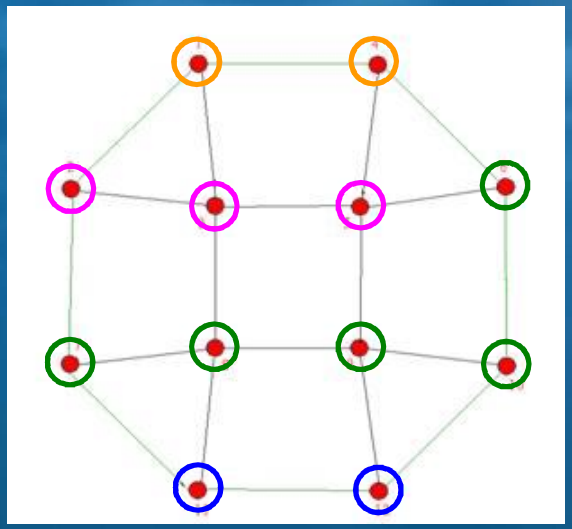




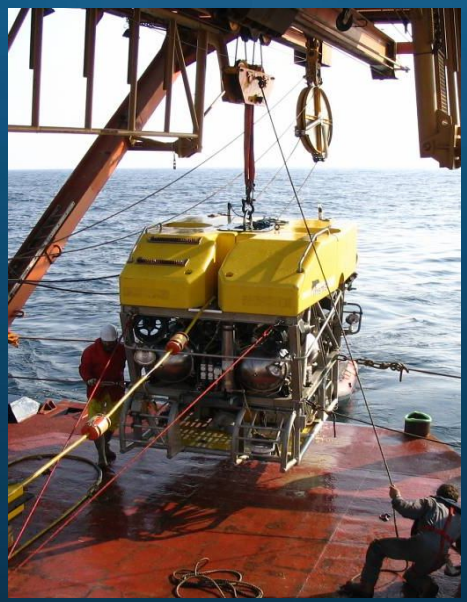
ANTARES Infrastructure

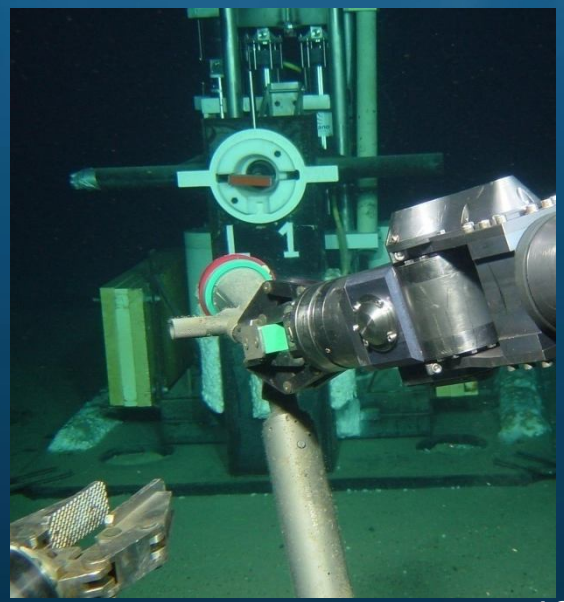


2006 – 2008: Building phase of the Detector

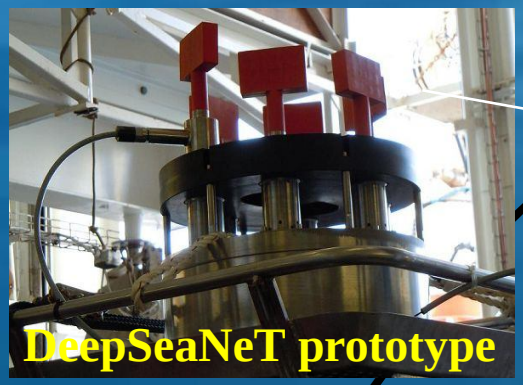


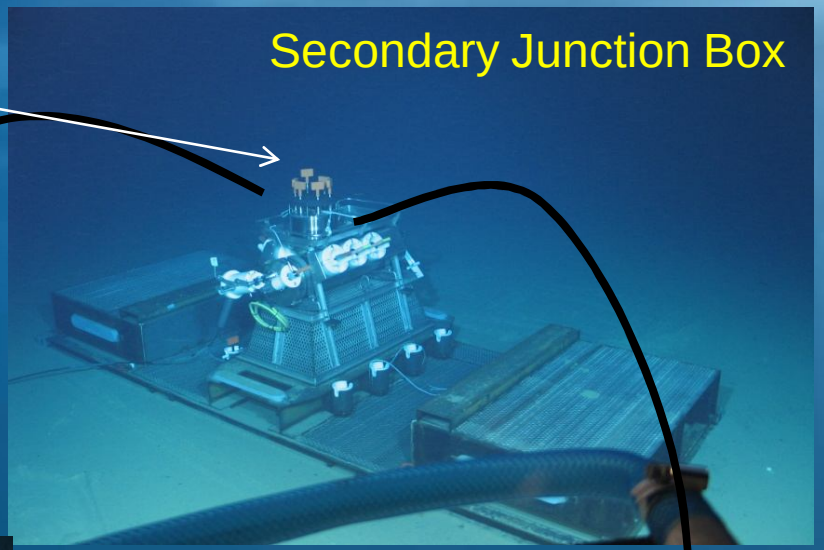
- **Junction box** **2001**
- **Main cable** **2002**
- **Line 1, 2** 2006
- **Line 3, 4, 5** 01 / 2007
- **Line 6, 7, 8, 9, 10** 12 / 2007
- **Line 11, 12** 05 / 2008



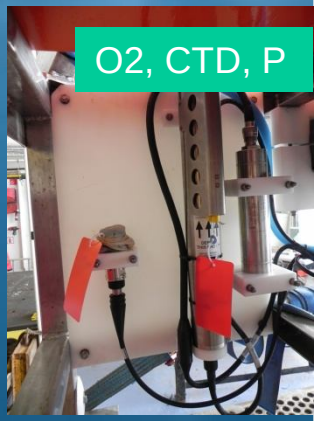


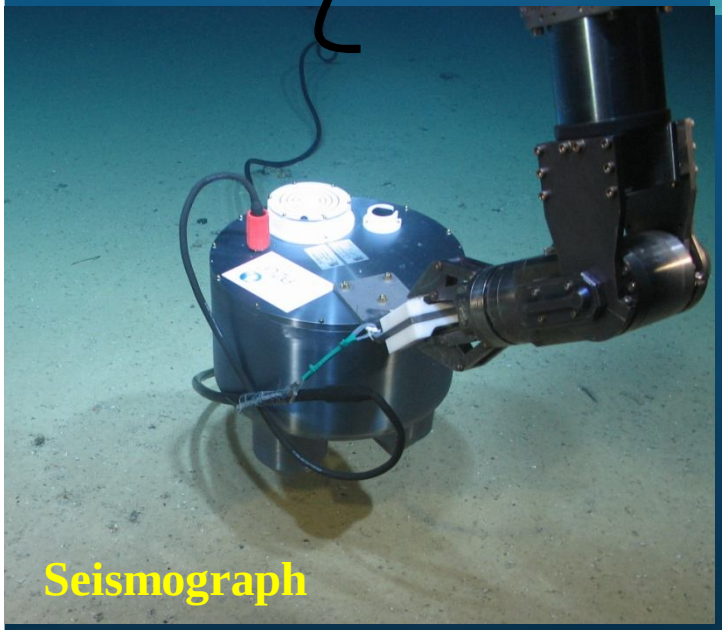
Secondary Junction Box

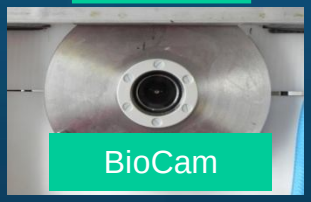


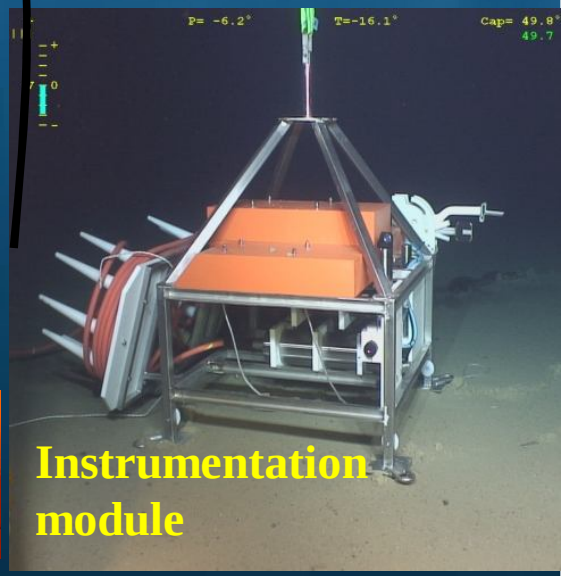


Connected
30 Oct 2010

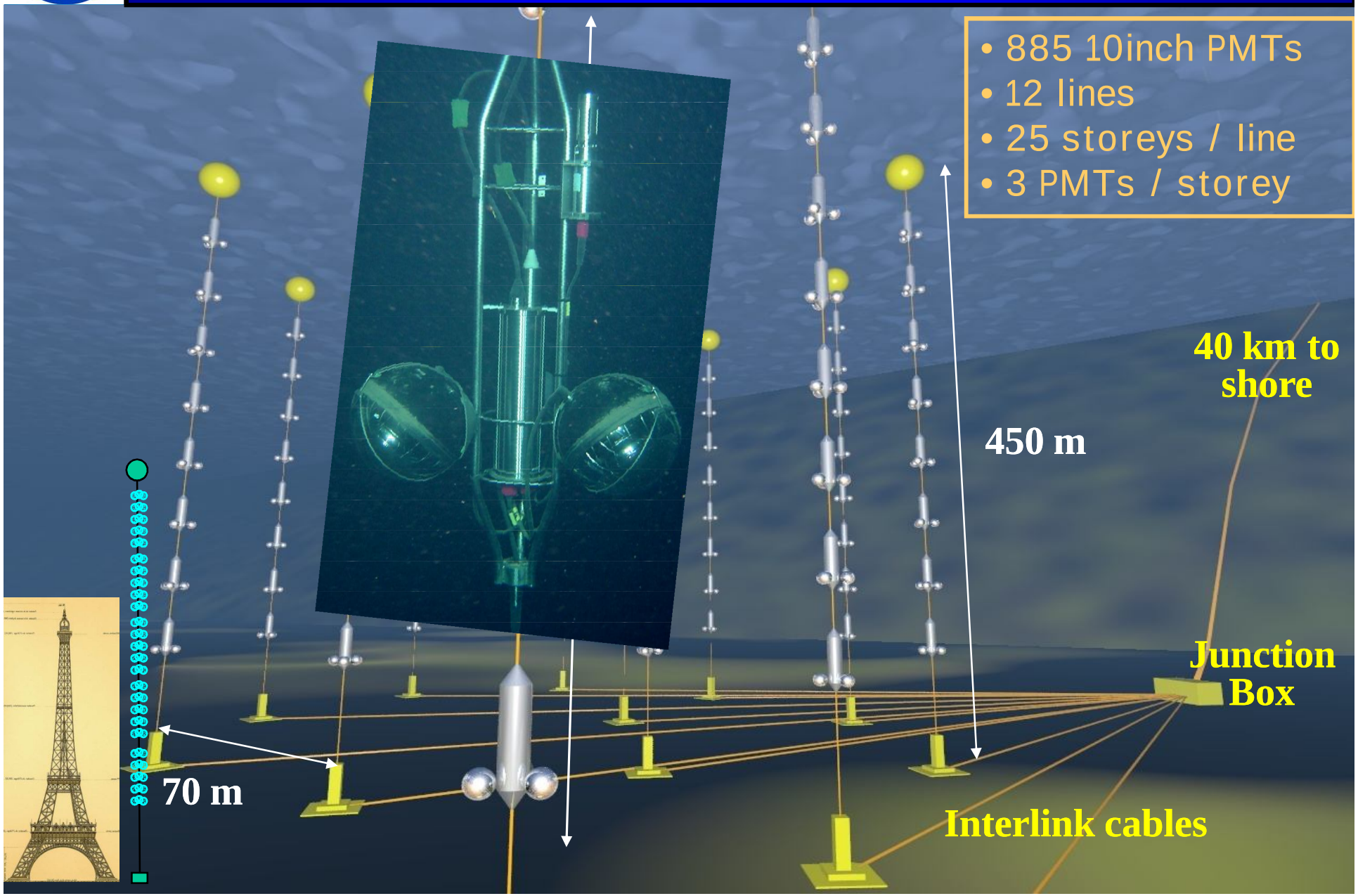




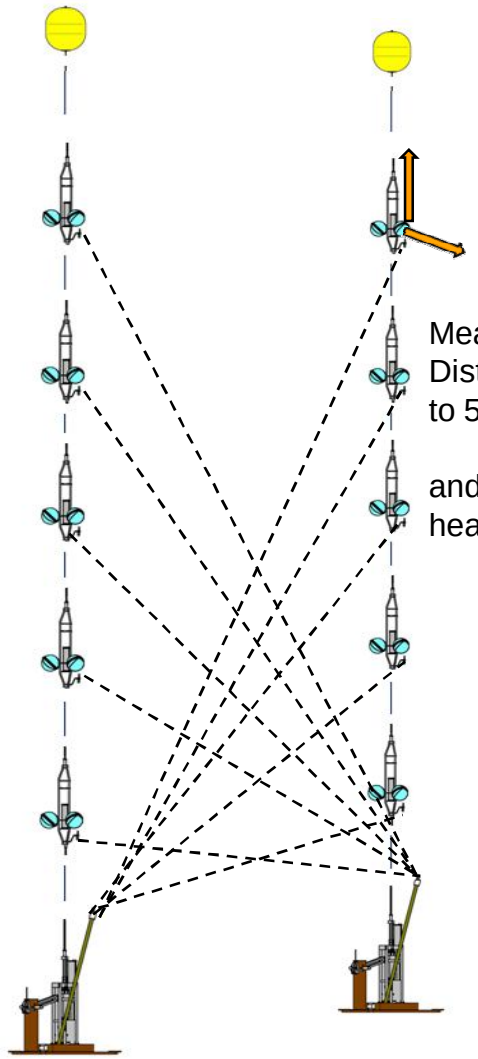




The ANTARES Detector



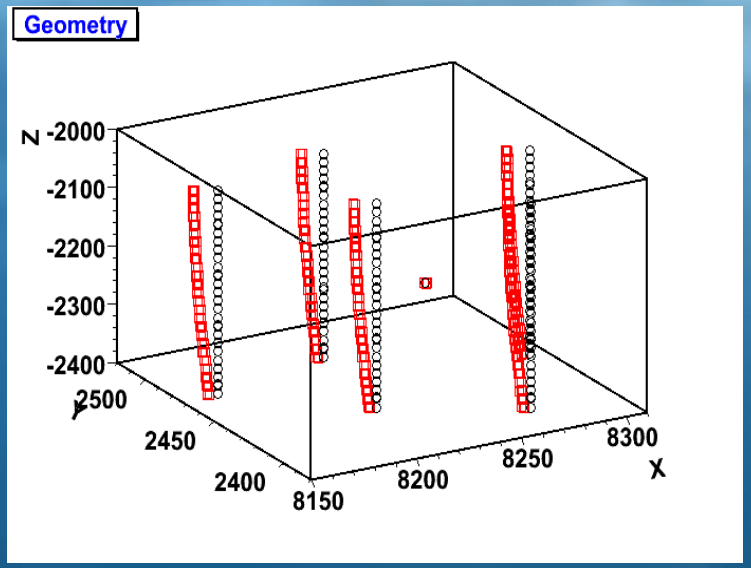
Acoustic Positioning

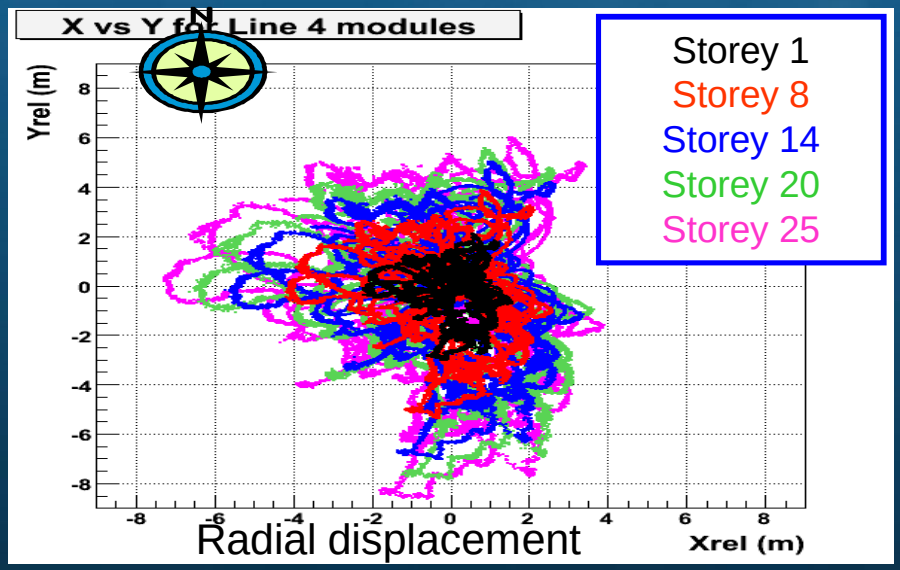


Measure every 2 min:
Distance line bases
to 5 storeys/line

and also storey
headings and tilts

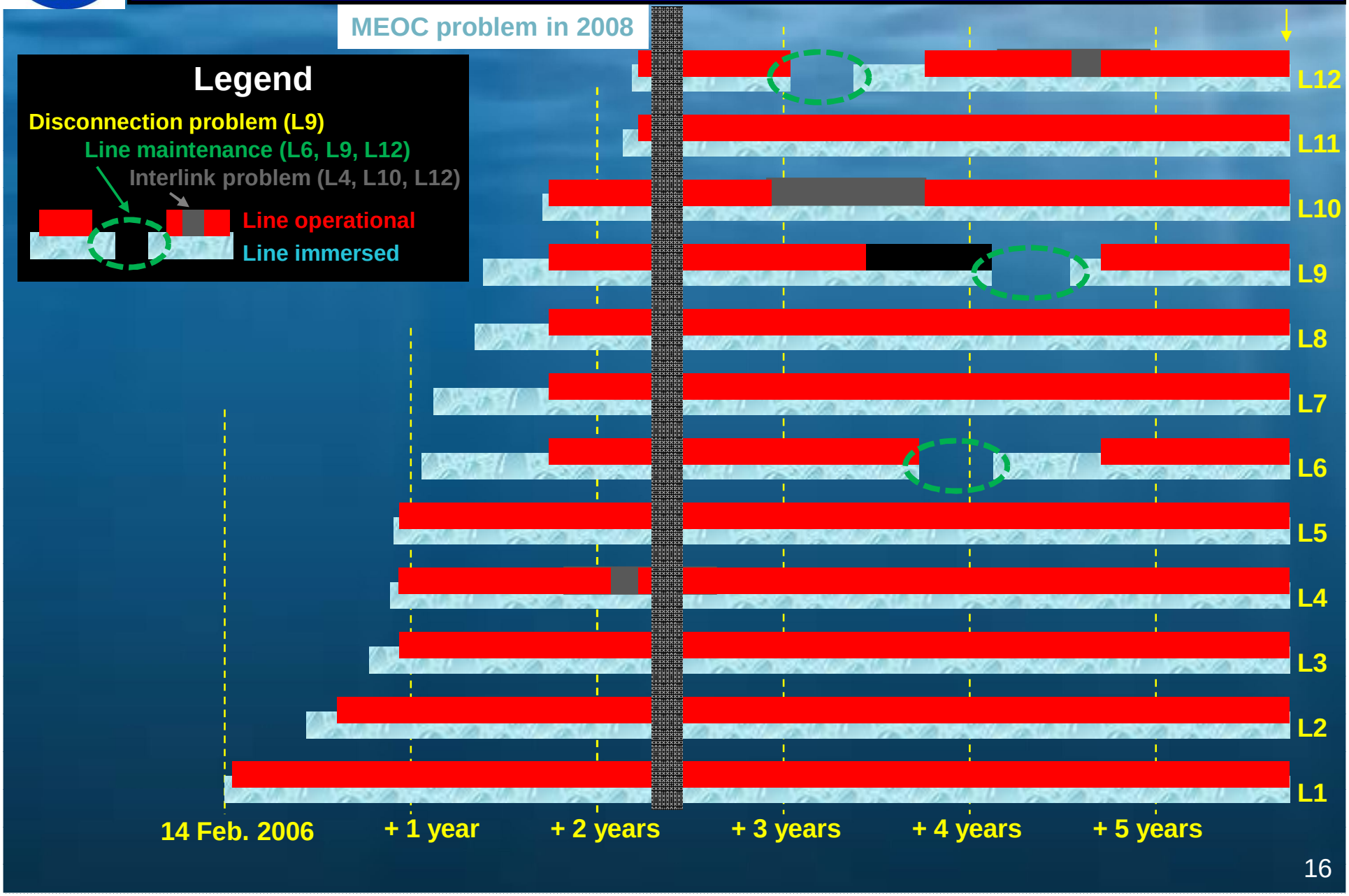
Precision ~ few cms



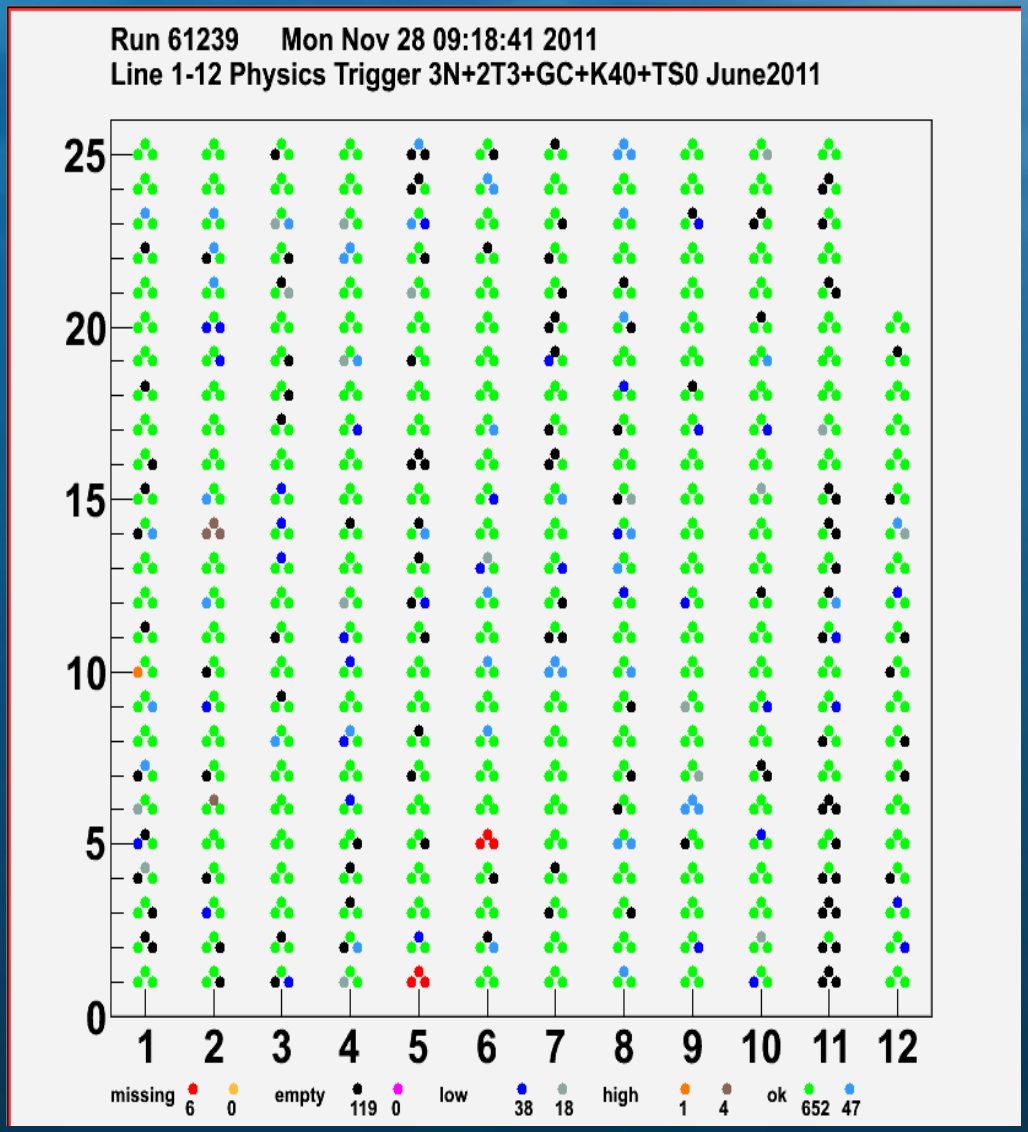


Radial displacement

Detector Evolution



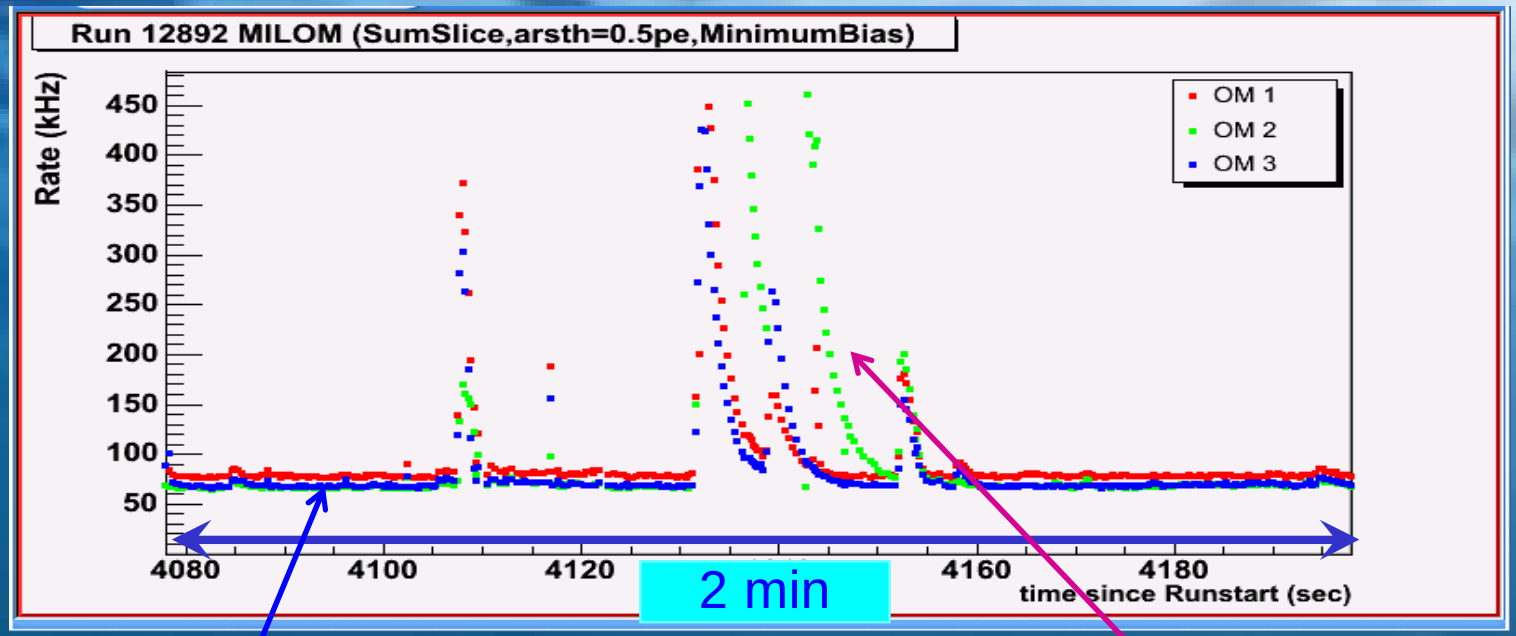
Current Detector Status



- 885 PMTs in total
- 13% dead channels
  - 3% flooded (from beginning)
  - 5% electronics
  - 5% dead OMs

Problem in pressure valve-
removed in KM3NeT design

Counting Rates (short timescale)



Continuous baseline:

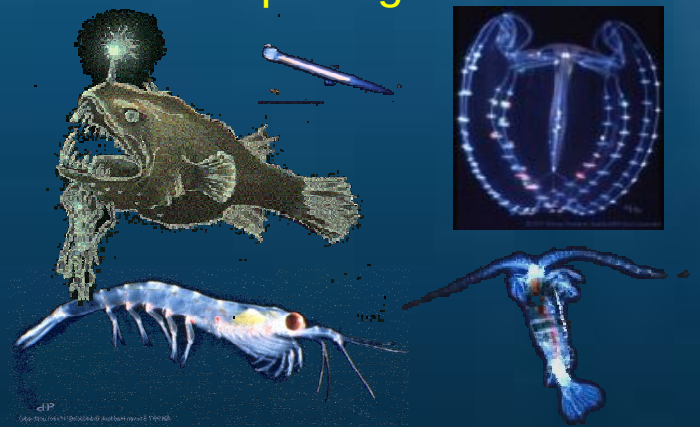
Radioactivity in the sea (^{40}K)
+ bioluminescent bacteria

^{40}K

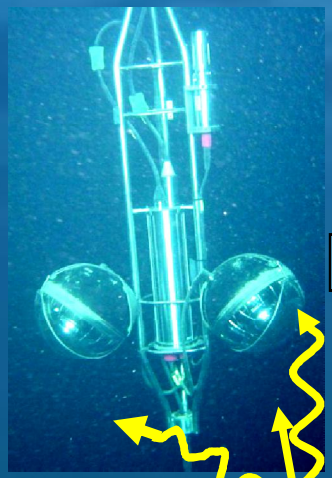
$$^{40}_{19}\mathrm{K} \rightarrow {}^{40}_{20}\mathrm{Ca} + e + \bar{\nu}_e$$

Bursts:

bioluminescence from
Macroscopic organisms



In situ calibration with Potassium-40

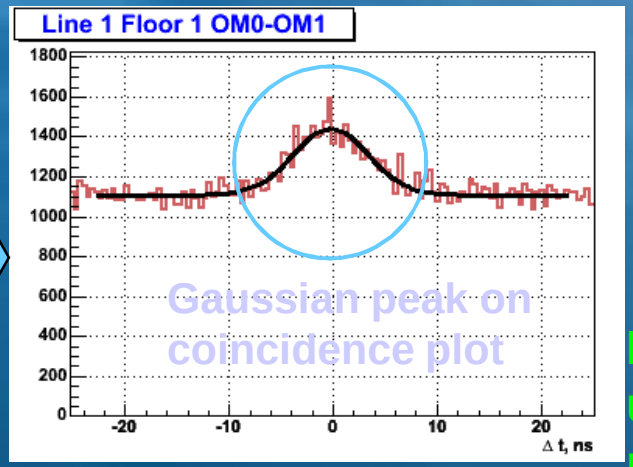


g
Cherenkov

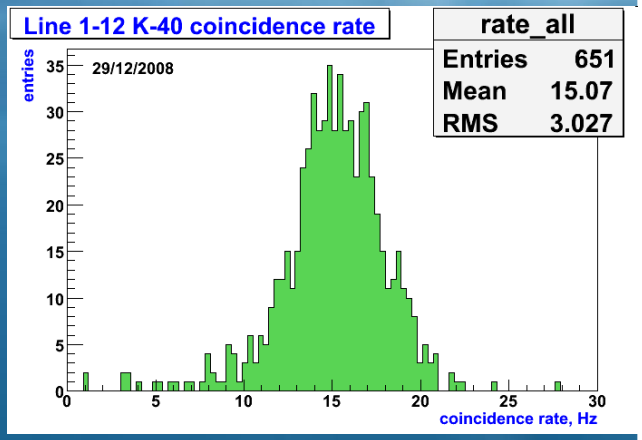
e^- (b decay)

^{40}K

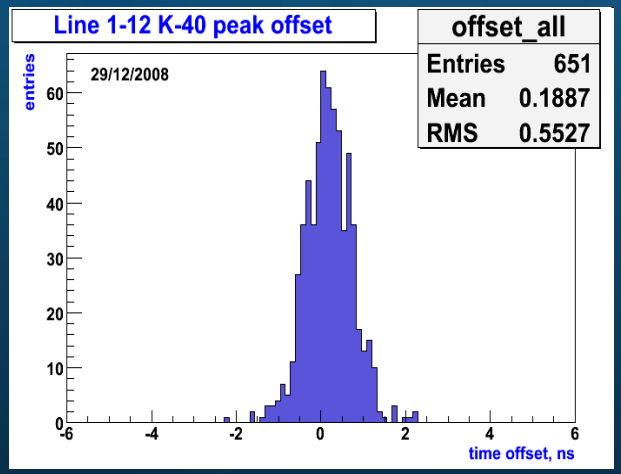
^{40}Ca



Integral under peak



Peak offset



Precision (~5%) monitoring of OM efficiencies

Cross check of time calibration from optical beacons

PMT Testbench at APC

Blackbox and experimental setup.

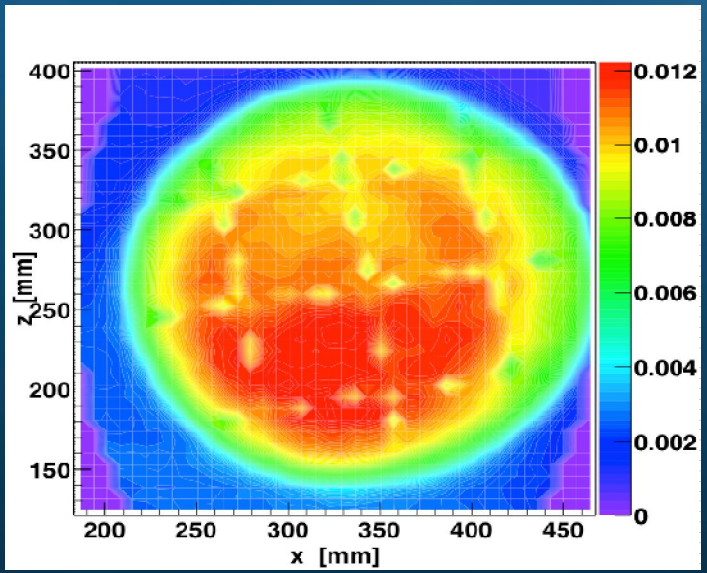
inside: OM, light source, motor

Features:

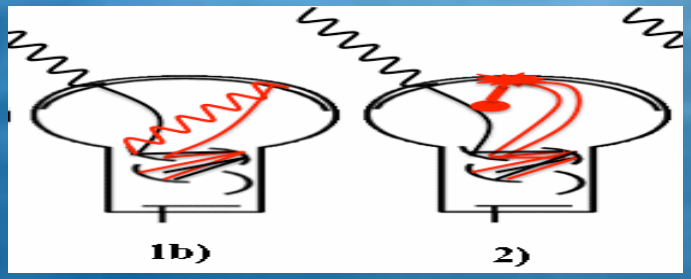
• 5 dimensional scan : X,Y,Z,θ, φ
Measurements at the p.e. level

• light sources :
-blue LED + integrating sphere
-pulsed-laser (405 nm) + attenuator

• Late- and after- pulse studies



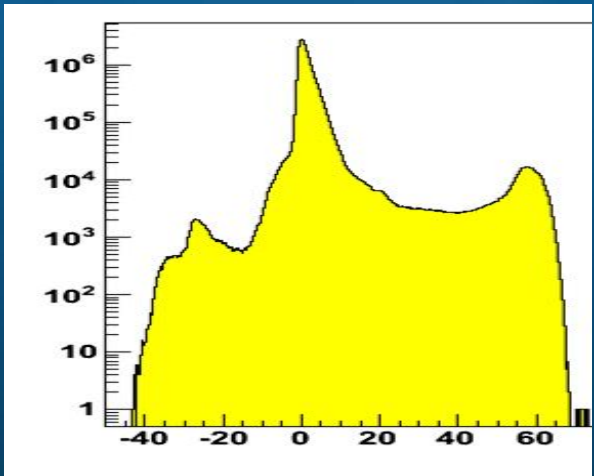
Understanding the PMTs

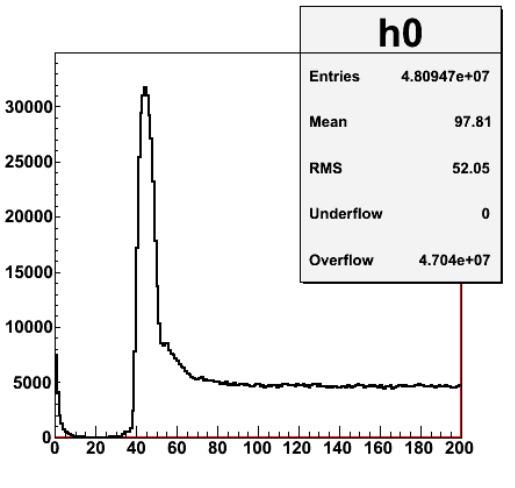


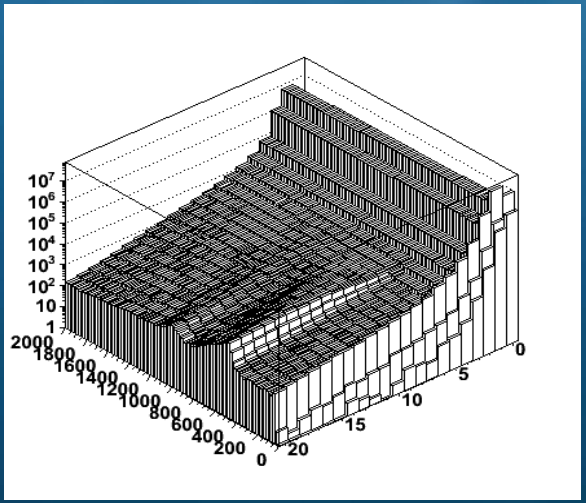
TTS is non-Gaussian
+prepulses, late pulses

Early afterpulses (spe)
(more important than K40)

Late afterpulses
Have large charge

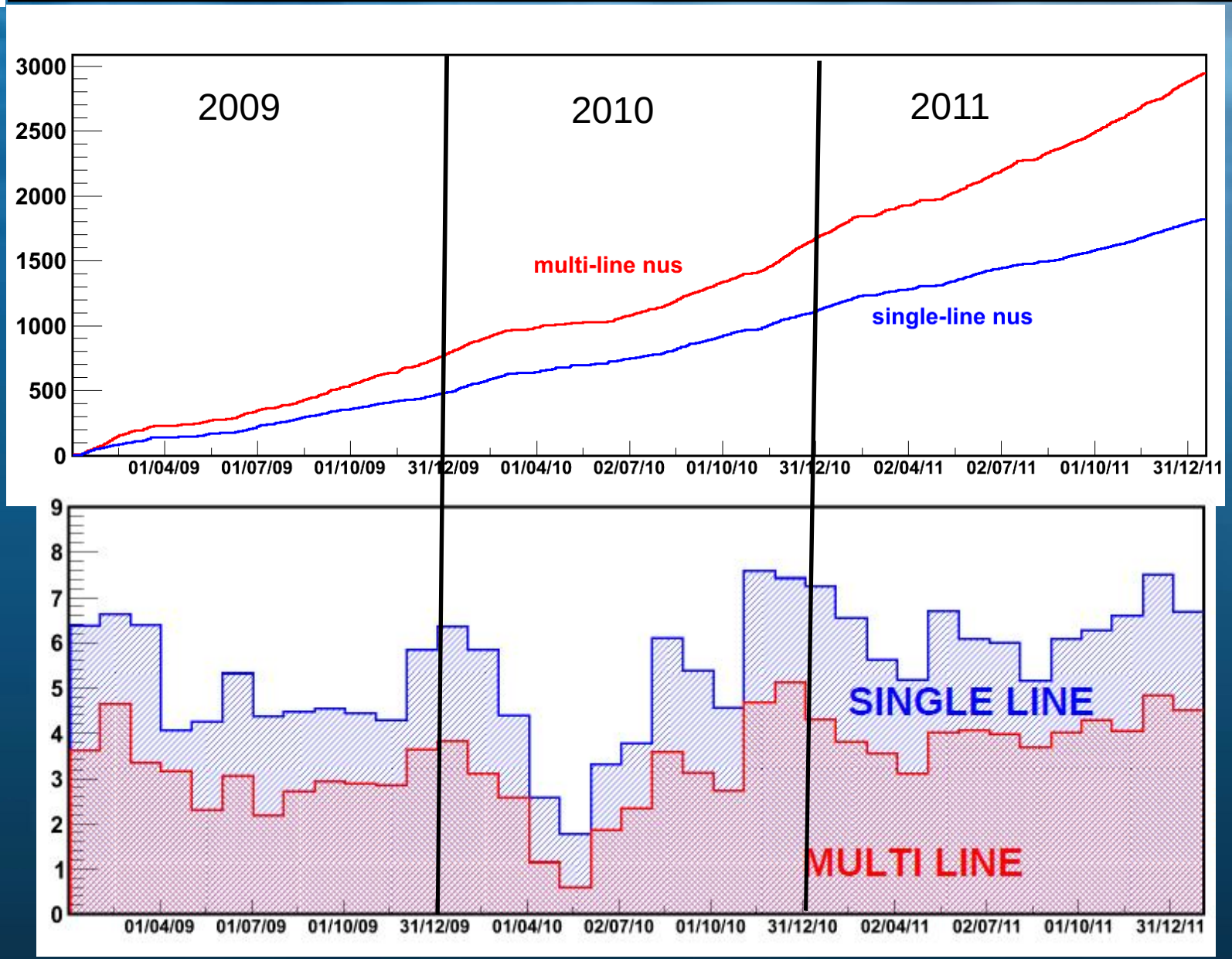






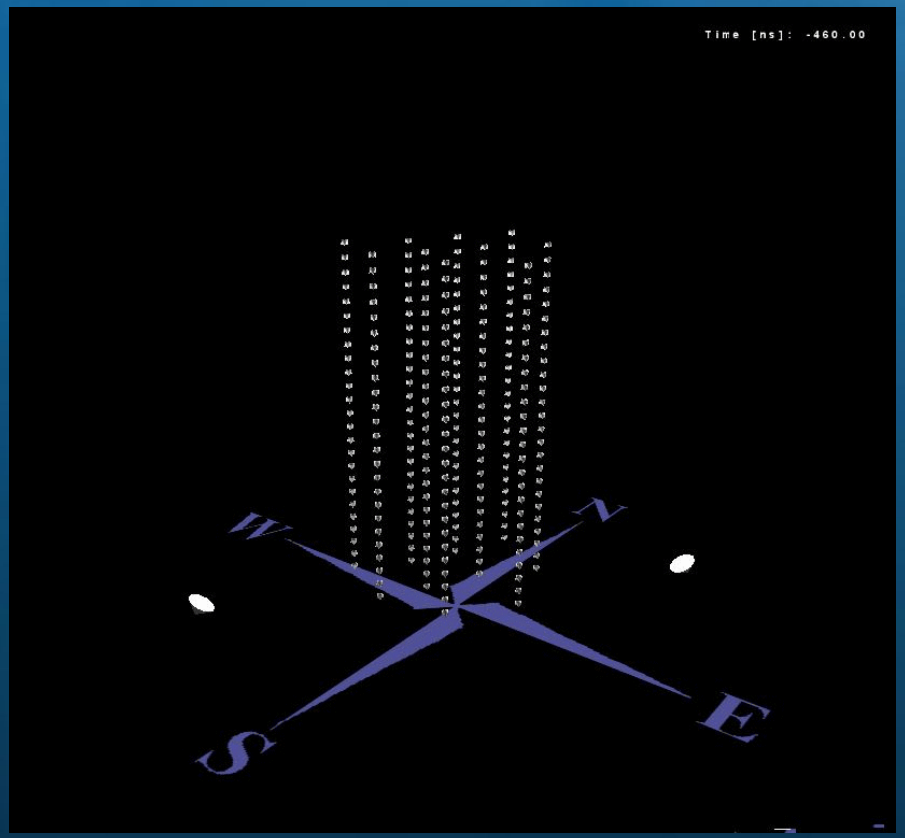
Large amplitude hits are not necessarily a signature of multiple Cherenkov photons
→ MC and hit selection modifications necessary to get good MC/data agreement
→with KM3NeT multiPMT photon counting is unambiguous

Online Neutrinos



Some Events

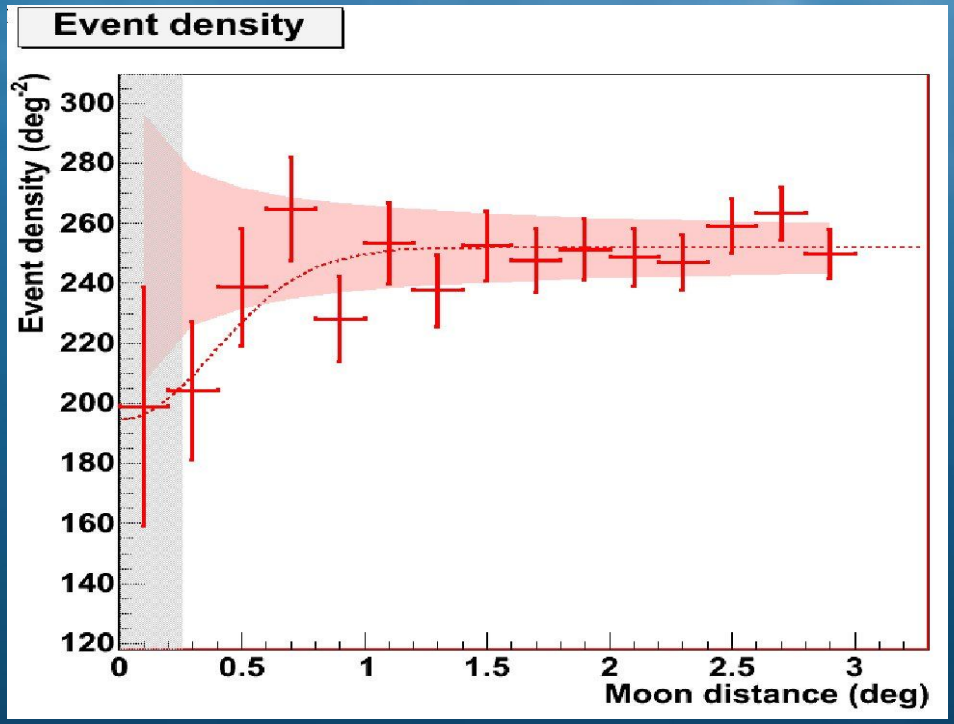
reconstructed up-going neutrino:
detected in 6/12 detector lines:



reconstructed down-going muon:
detected in all 12 detector lines:

Absolute Pointing: Moon Shadow

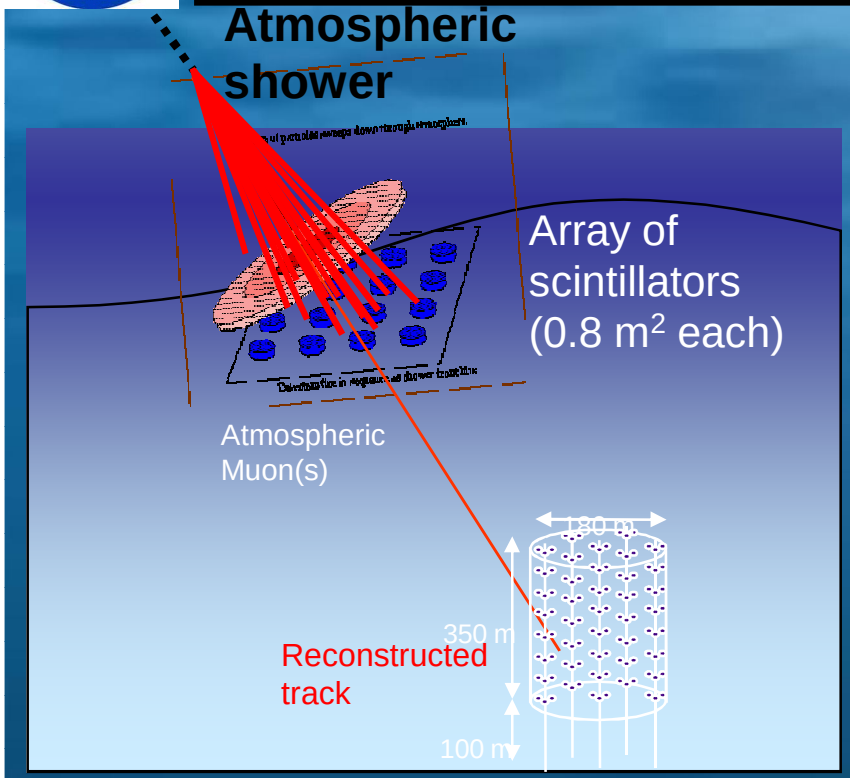
884 livetime days (2007-2010)
2.7 sigma significance

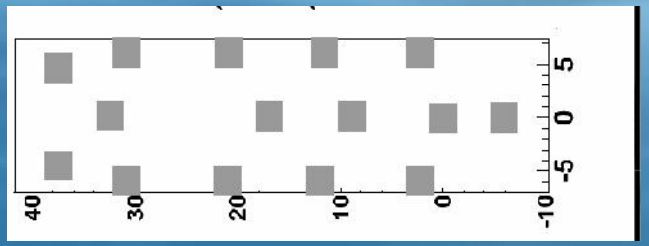


Agrees with Monte Carlo expectations

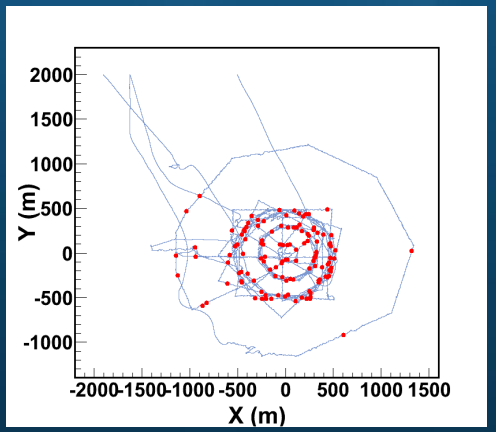
Encouraging, but due to lack of statistics, can not put useful constraints on ANTARES pointing capabilities

Absolute Pointing: Surface Array

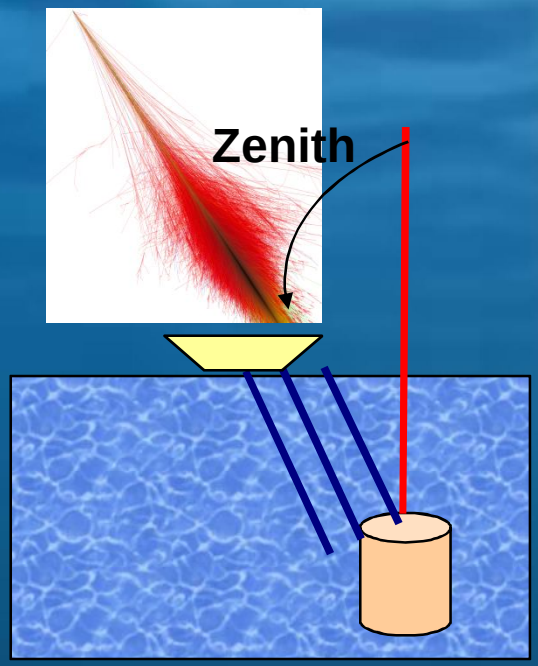


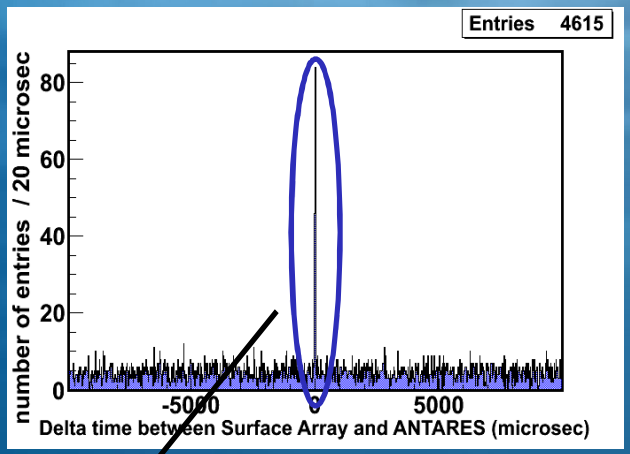


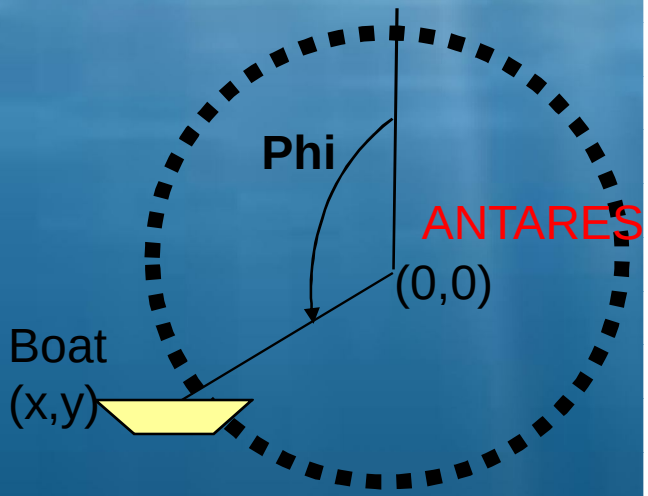
1st campaign 17-23 Oct
15 Detection units

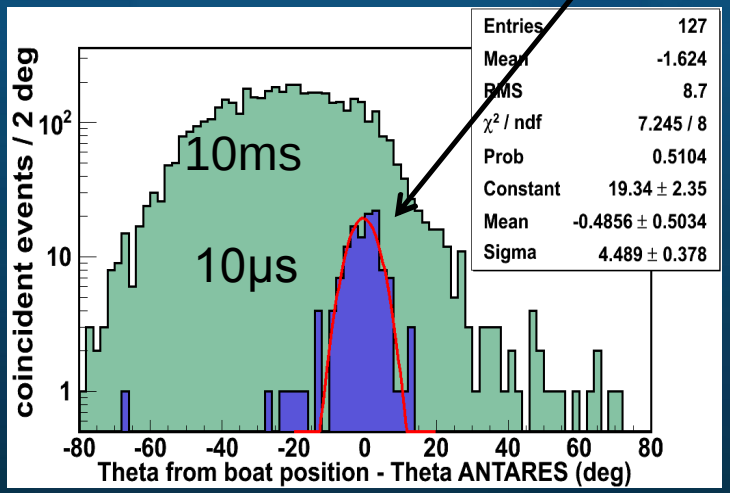


Absolute Pointing: Surface Array







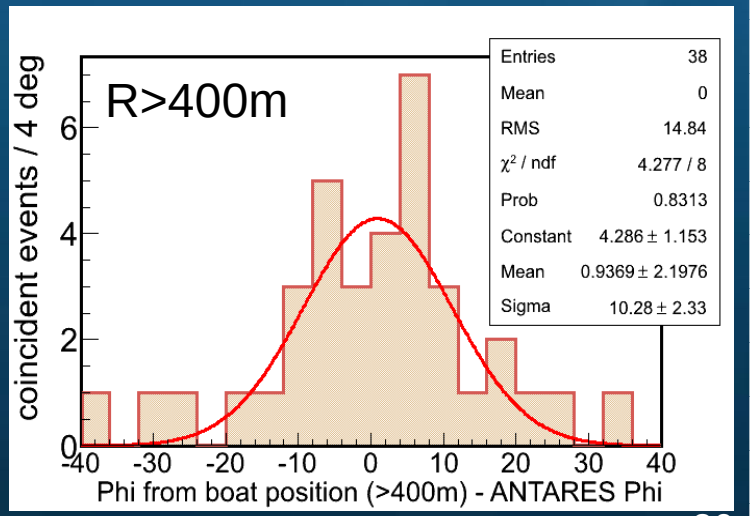


Constraints

Zenith: -0.5±0.5°

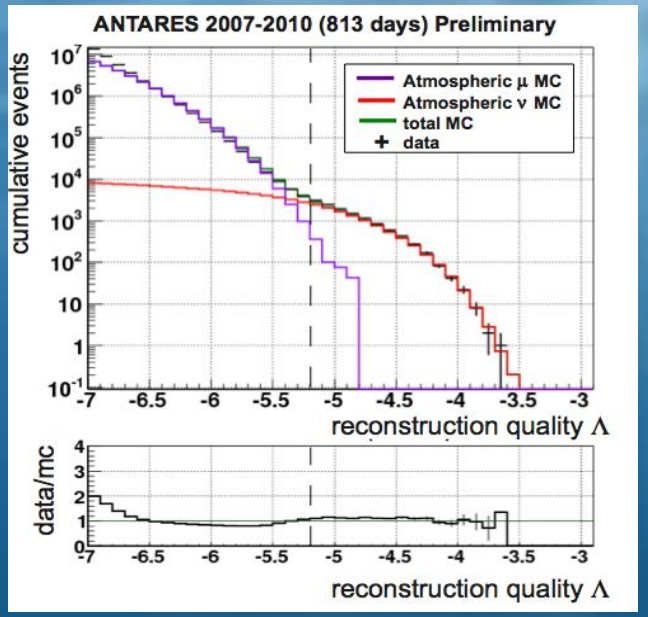
Azimuth: 0.9±2.2°

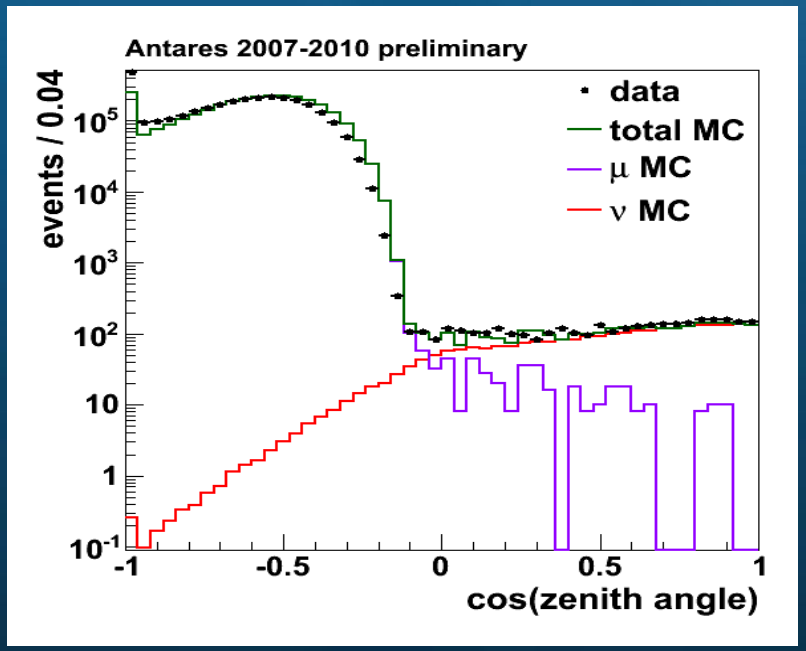
5 more days in the summer 2012

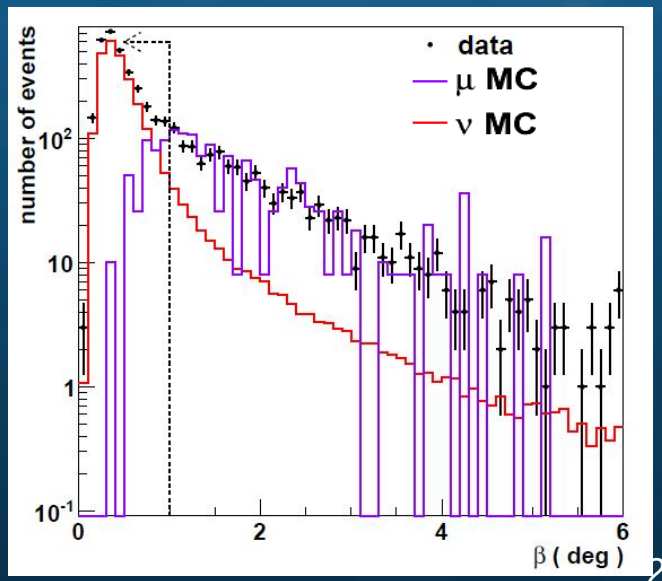


Track Reconstruction

- Maximum likelihood track fit to muon hypothesis (beta=1)
  - Pdfs for Cherenkov & ^{40}K bkgds
  - multiple starting directions
  - Estimation of uncertainty on track direction
- Good agreement data vs MC

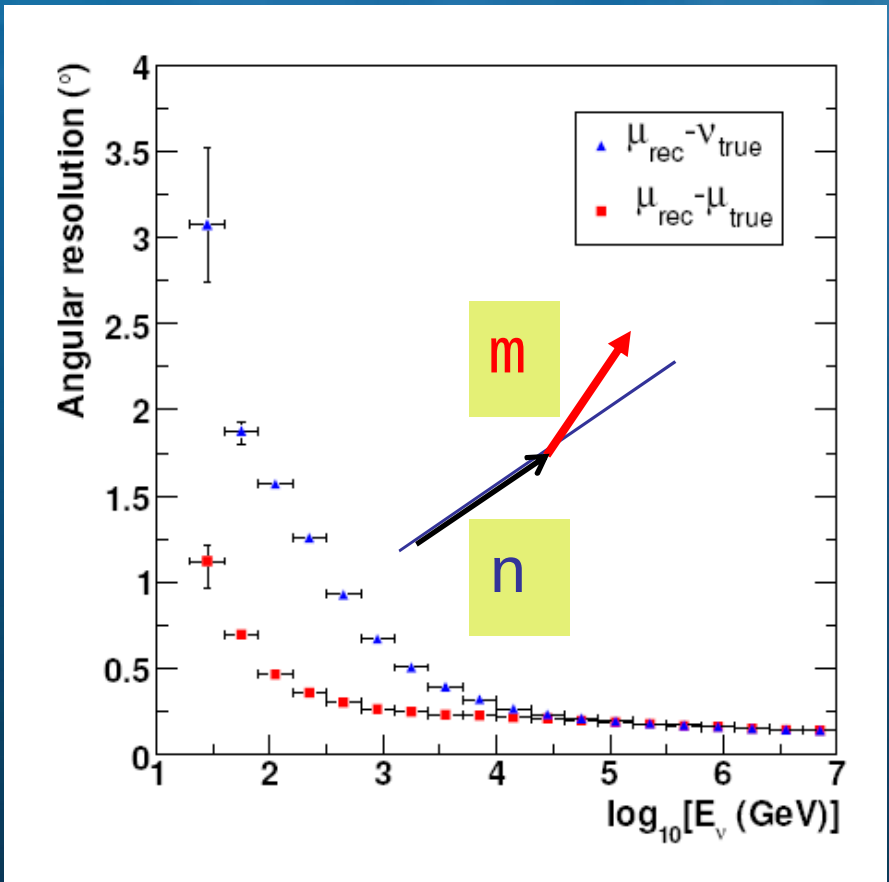


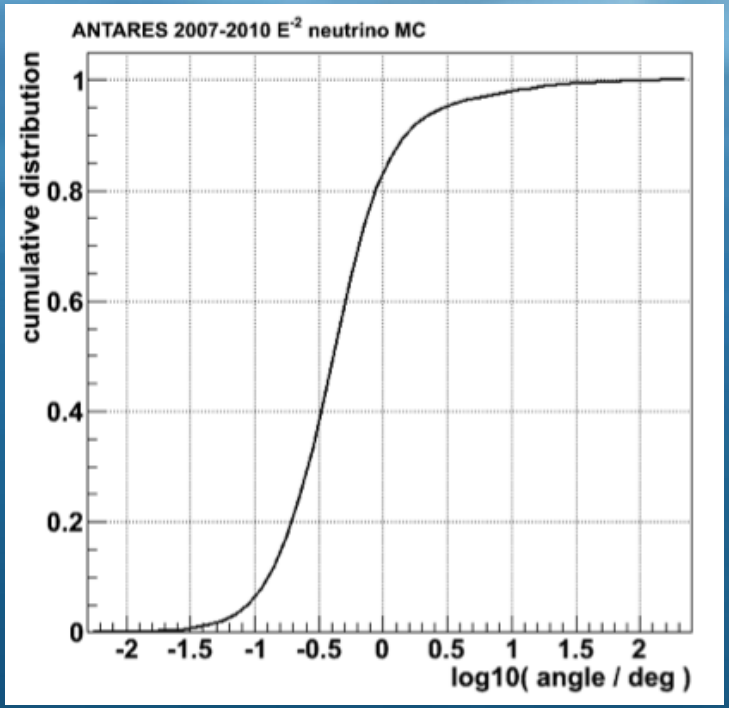




Angular Resolution for Upgoing Neutrinos

Full 12 line detector

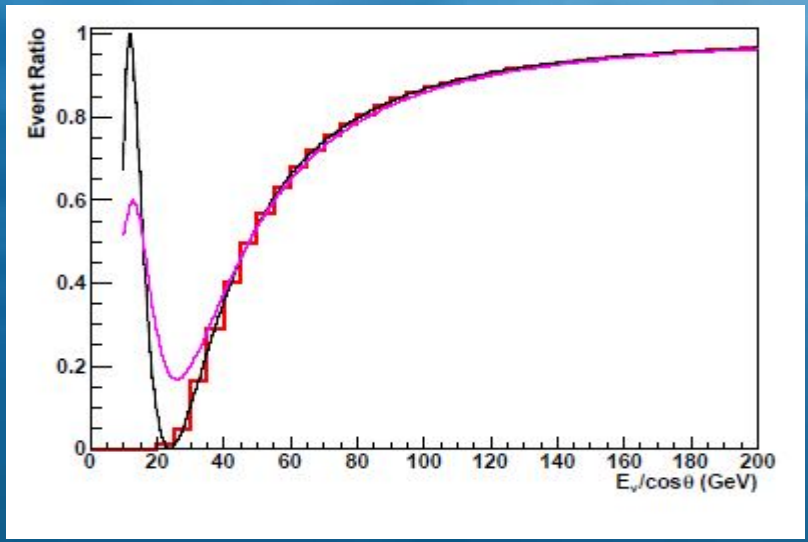


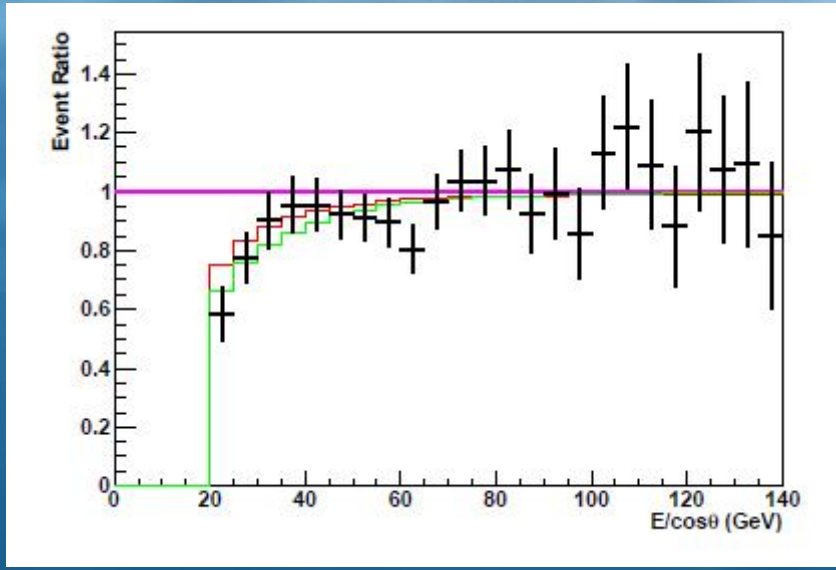


cumulative distribution of the angle between the true neutrino track and the reconstructed muon event that passes the selection criteria (assuming E^{-2} spectrum).

The median is 0.46°.
83% of the events are reconstructed better than 1°

Neutrino Oscillations





E/L Distribution

E from range: E(GeV) = (zmax-zmin)/5./cosθ

L=2 R_{Earth} cosθ

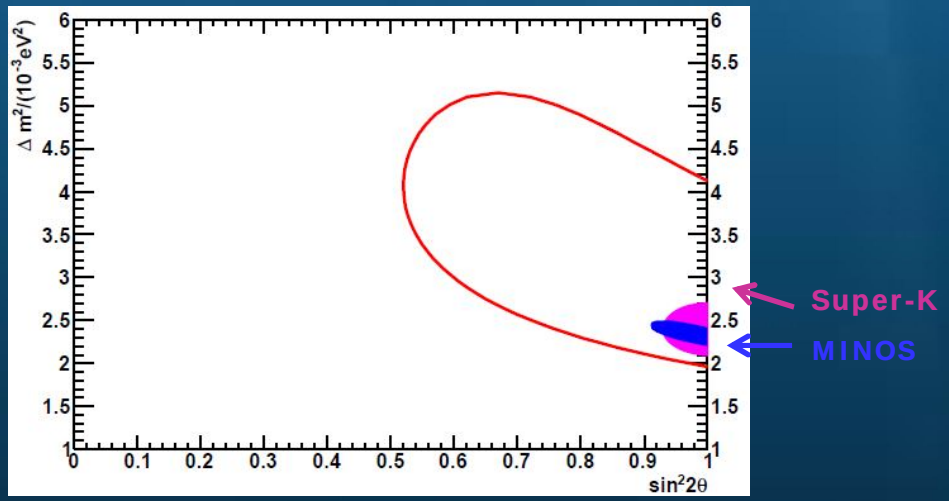
Fit result

Δm^2 = 3.2 10^{-3} eV^2 , $\sin^2 2\theta$ = 0.98

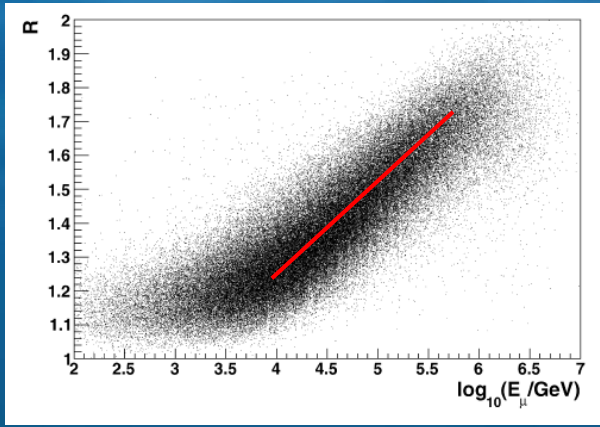
R(data/MC) = 0.85 , χ^2/ NDF = 39.8 / (48-3)

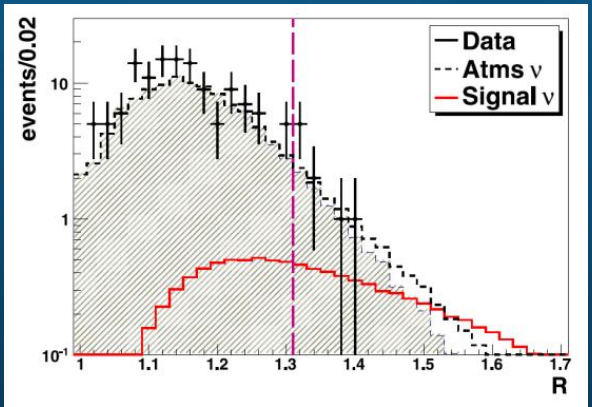
Assuming maximal mixing

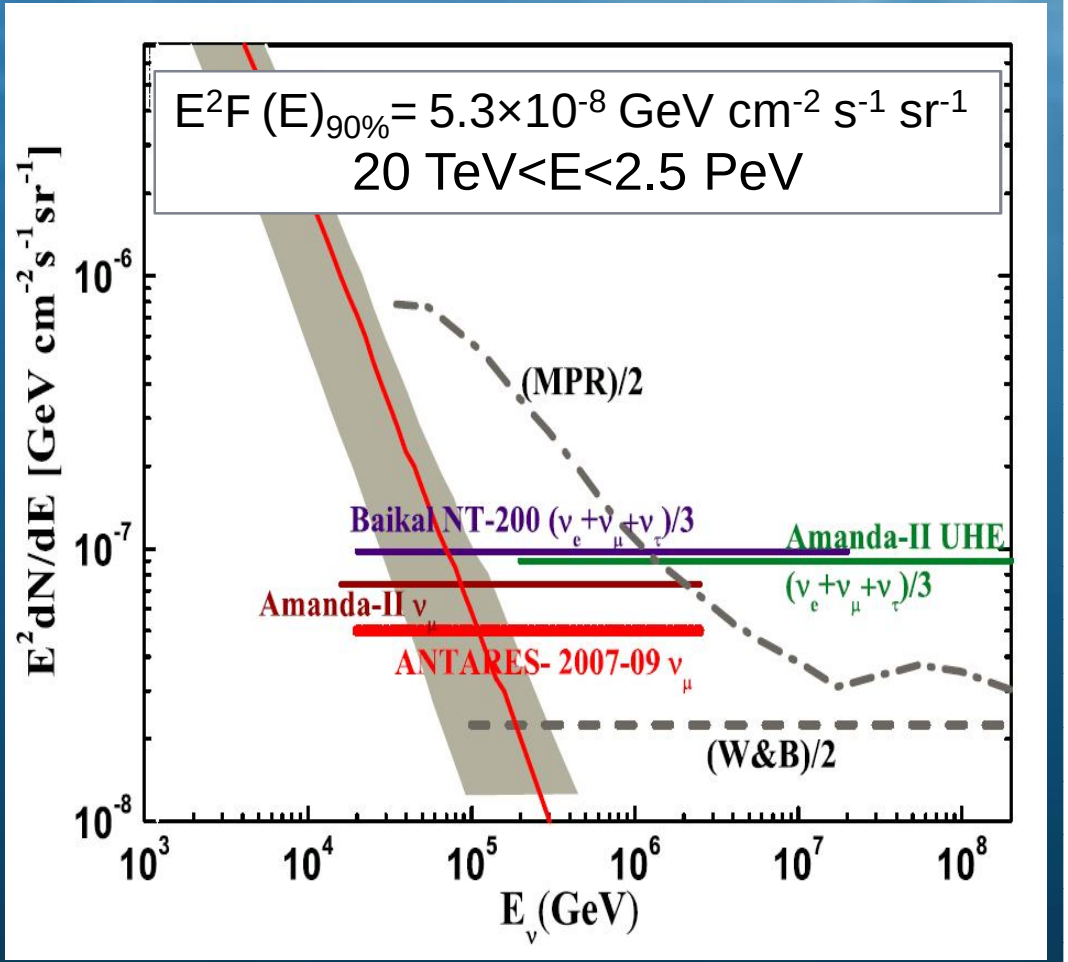
$\Delta m^2 = (3.2\text{-}1.1\text{+}0.7)\ 10^{-3}\ eV^2$



Diffuse n_m flux



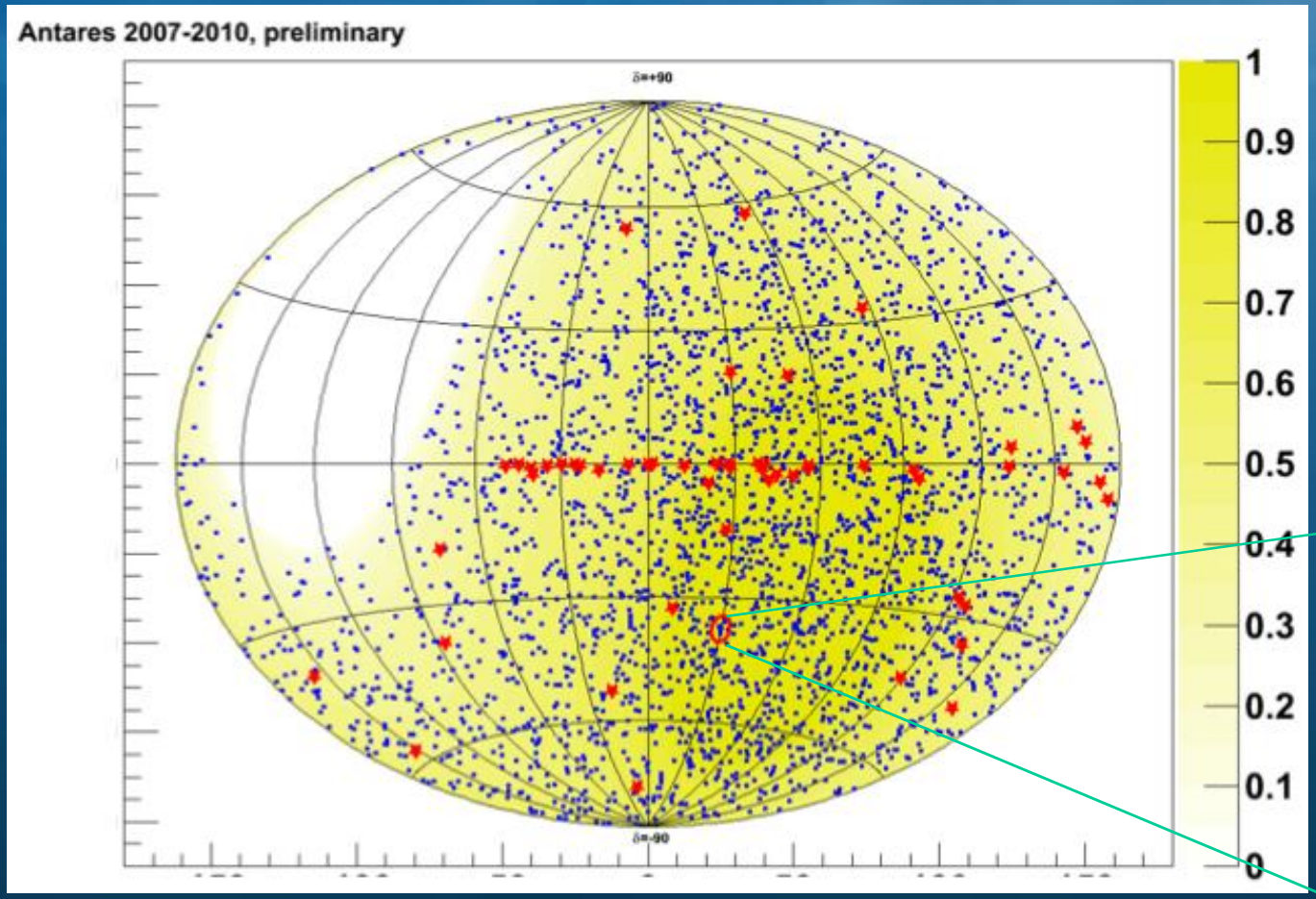




Full-Sky Search (2007-2010)

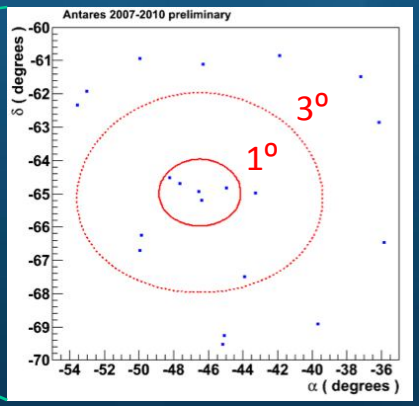
Sky map in Galactic Coordinates
Background colour indicates **visibility**

- Blue points: selected events (3058)
- ★ Red stars: candidate source list



Most significant cluster at:
R A= −46.5°,
δ= −65.0°

N_{sig} = 5
Q = 13.02
p-value = 0.026
Significance = 2.2 σ



Result compatible with the background hypothesis

Source candidate list

Look in the direction of a list of 51 predefined candidate sources
(selection of sources mostly based on γ-ray flux and visibility)

First eleven sources sorted by Q-value.
Last column shows the 90% CL upper limit on the flux $(E / GeV)^{-2}\ GeV^{-1}\ cm^{-2}\ s^{-1}$

3σ	5σ
~2.4	~8.5

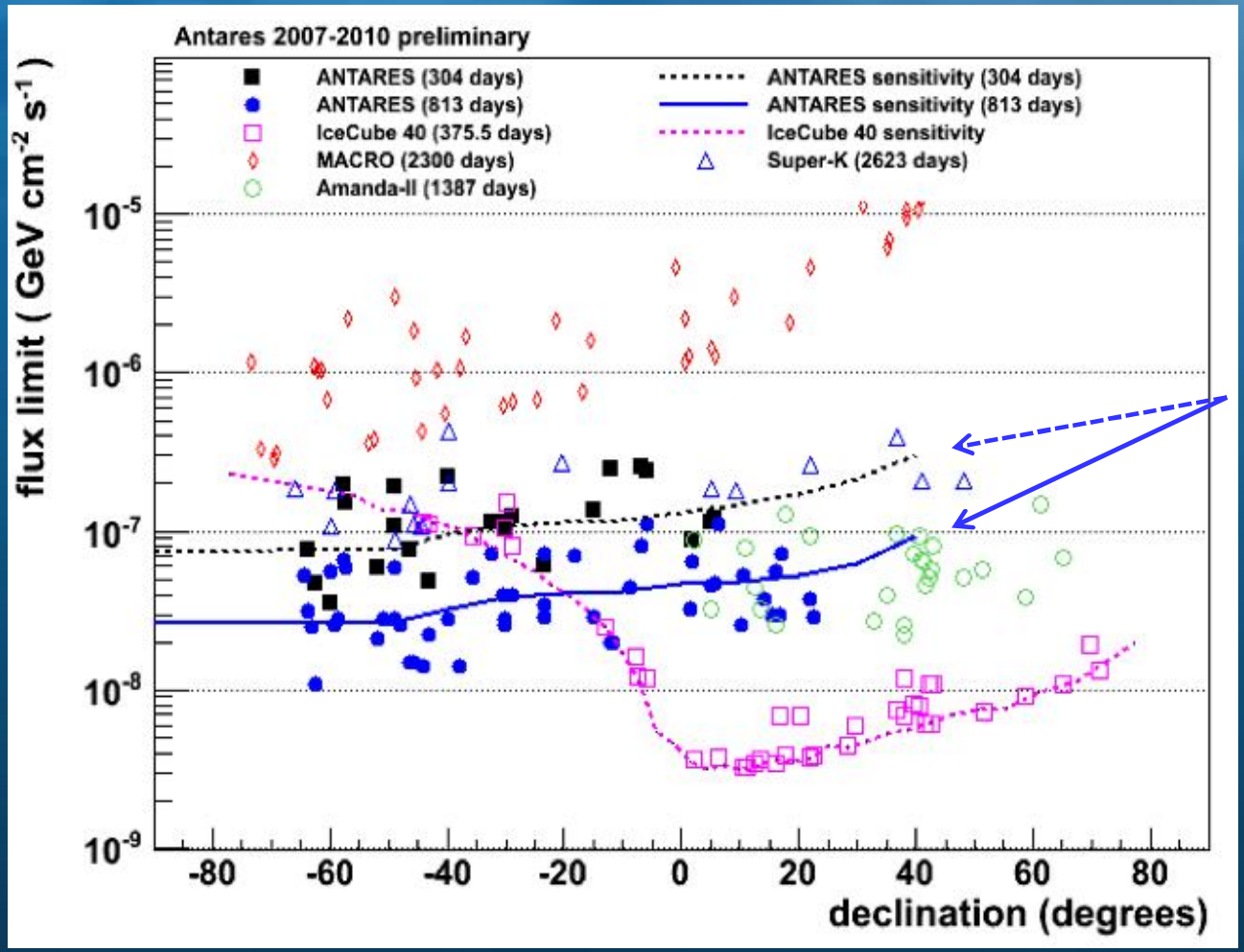
name	ra	decl	Nsigfit	Q	p-value	nsigma	lim_Nsig	lim_flux
HESS J1023-575	155.83	-57.76	1.97	2.35	0.41	0.82	5.62	6.6e-08
3C 279	-165.95	-5.79	1.11	2.15	0.48	0.71	5.35	1.0e-07
GX 339-4	-104.30	-48.79	1.26	1.49	0.72	0.36	5.10	5.8e-08
Cir X-1	-129.83	-57.17	1.52	1.31	0.79	0.27	5.00	5.8e-08
MGRO J1908+06	-73.01	6.27	0.90	1.22	0.82	0.23	4.59	1.1e-07
ESO 139-G12	-95.59	-59.94	0.98	0.76	0.94	0.08	4.63	5.4e-08
HESS J1356-645	-151.00	-64.50	0.76	0.49	0.98	0.03	4.37	5.1e-08
PKS 0548-322	87.67	-32.27	0.77	0.39	0.99	0.02	4.23	7.1e-08
HESS J1837-069	-80.59	-6.95	0.59	0.26	0.99	0.01	4.12	8.0e-08
PKS 0454-234	74.27	-23.43	0.39	0.09	1.00	0.00	3.83	7.0e-08
ICECUBE	75.45	-18.15	0.34	0.07	1.00	0.00	3.83	7.0e-08

HESS J1023−575 most signal-like, p–value 40% (post trial)

Compatible with the background hypothesis

3C279, GX339-4, Cir X-1 are flaring sources....

Candidate List Search – Flux Limits



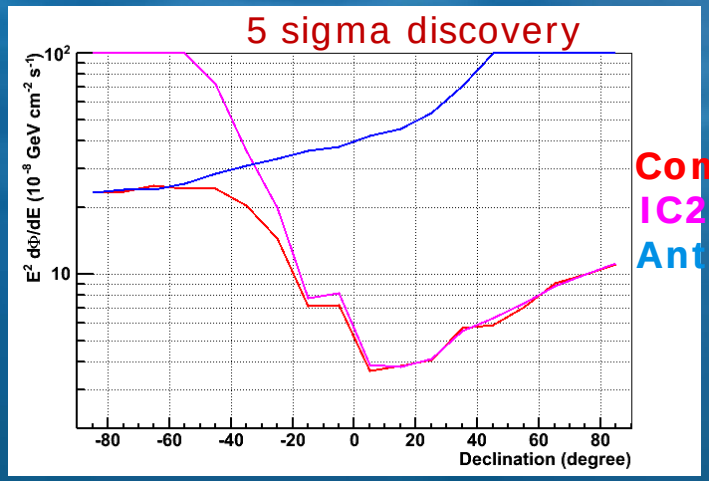
Assuming an E^{-2} flux for a possible signal

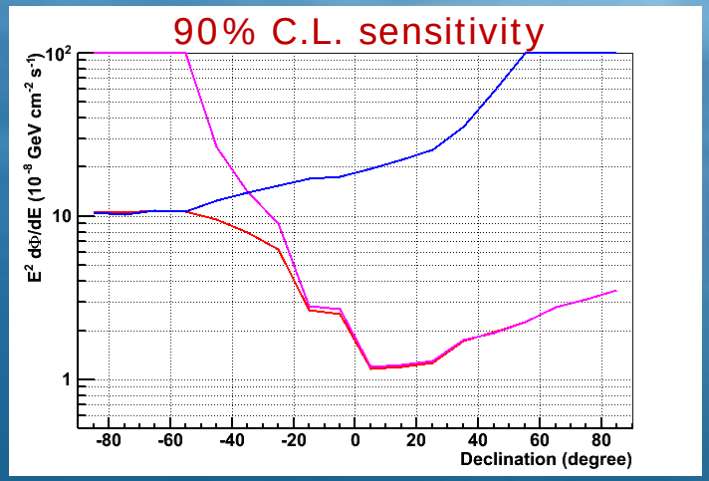
ANTARES 2007-2010
813 days
× 2.5 improvement w.r.t. previous analysis (**304 days**)

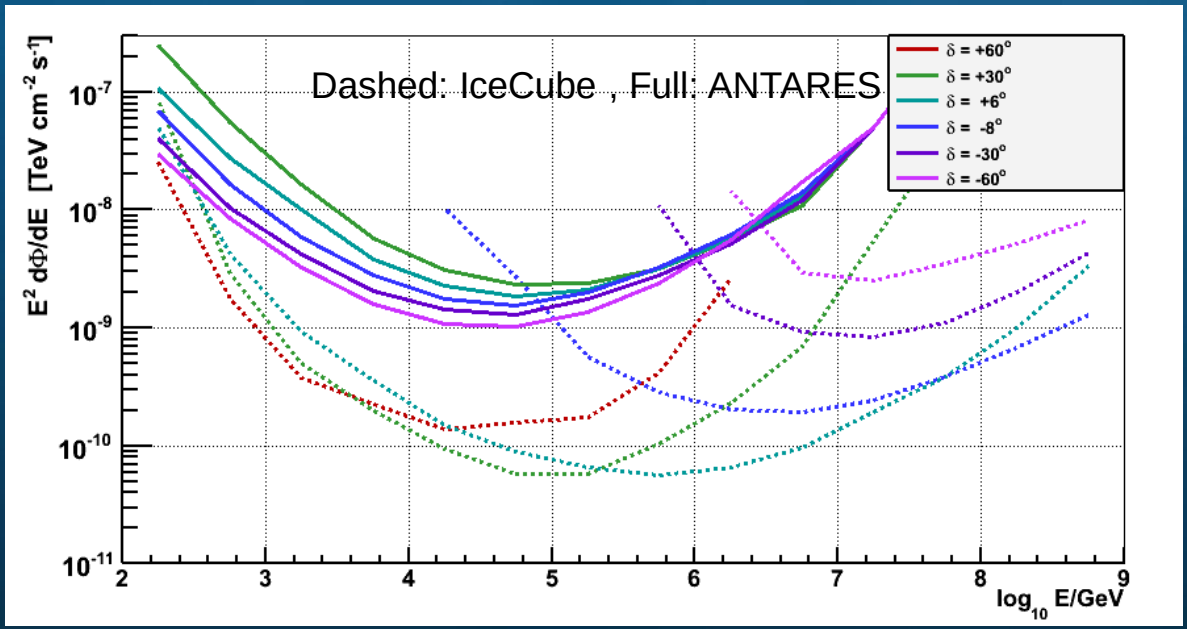
For most of the sources ANTARES gives the most stringent limits for Southern Sky

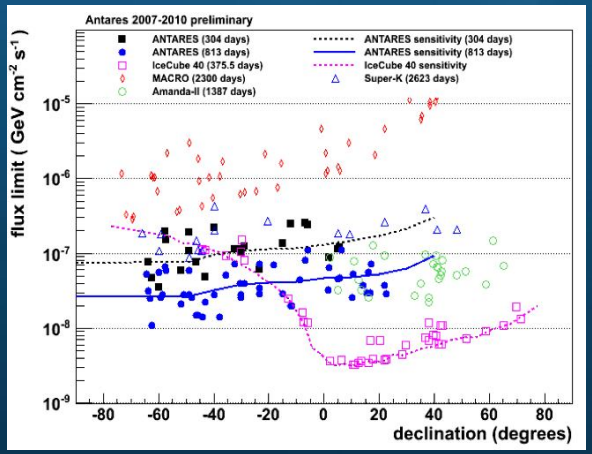
(IceCube requires very high energy component (E >1 PeV) for Southern Sky).

Combined Antares/IceCube



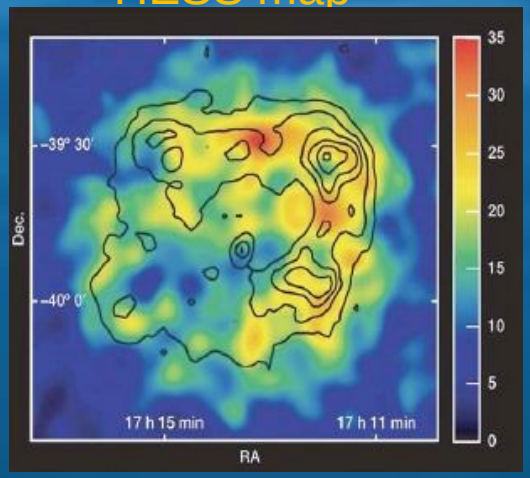




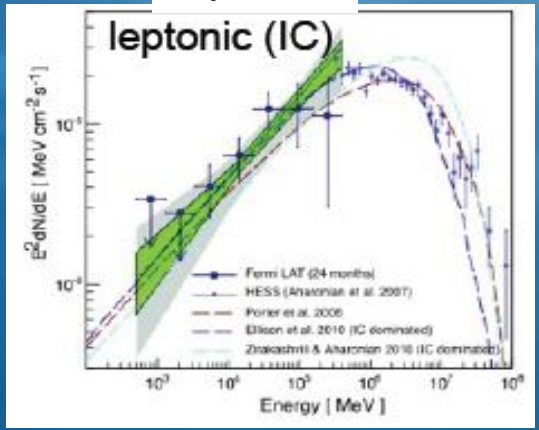


Closer Look at SNR: RXJ1713.7-3946

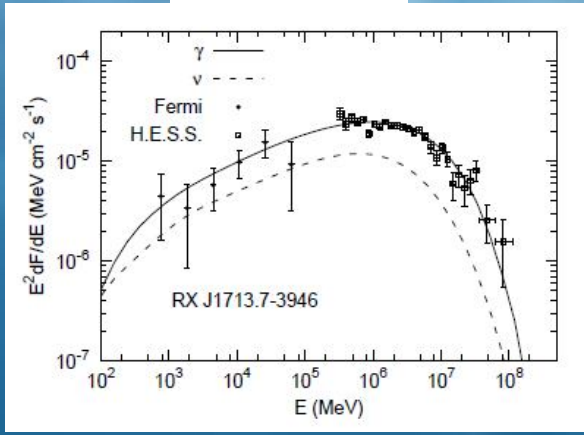
HESS map



leptonic

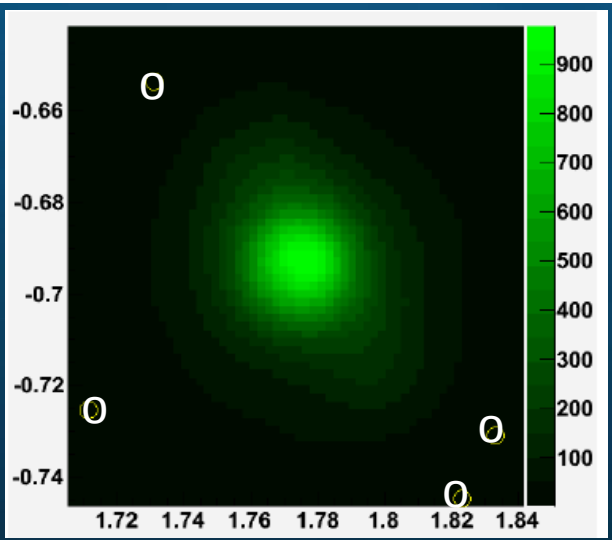


hadronic



arXiv:1010.1901v2 (21/3/2011)

Smeared by ANTARES PSF



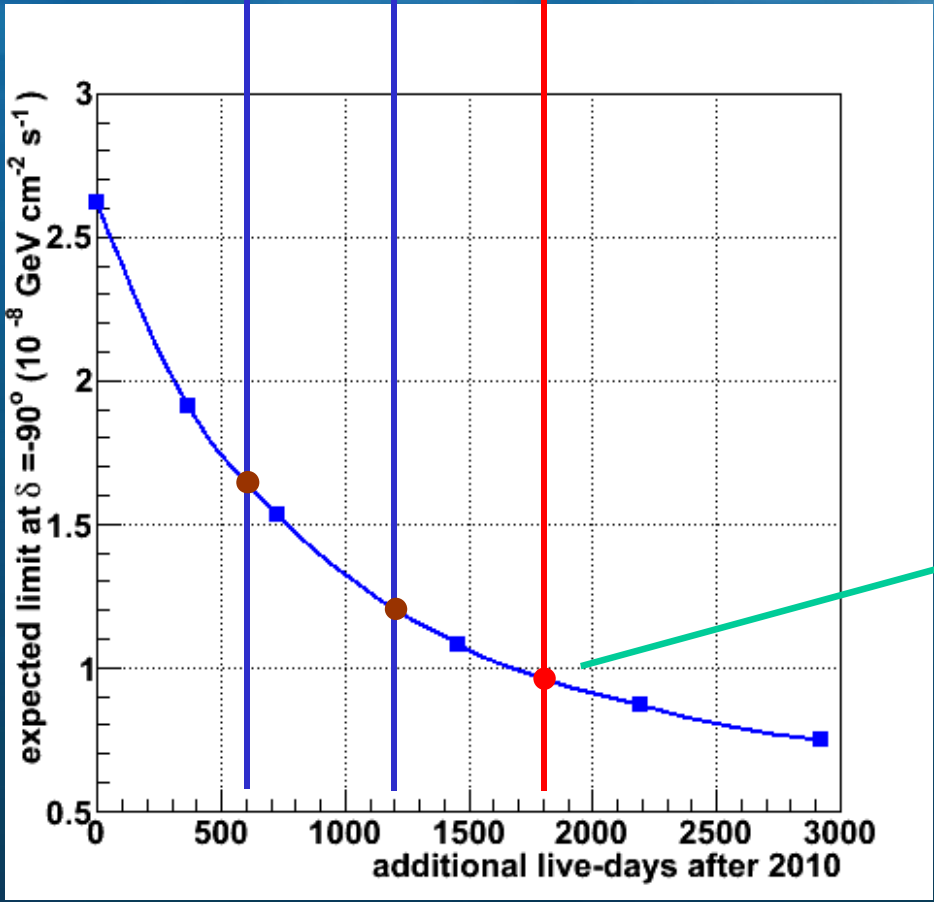
Reasonable fits to both leptonic and hadronic models (depending on assumptions)

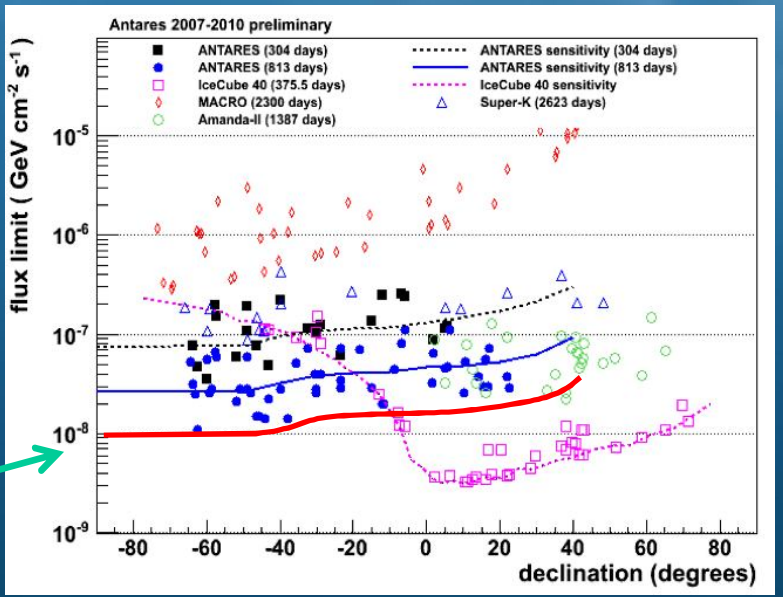
Dedicated analysis taking into extended morphology -> Model Rejection Factor=8.1

Cuts optimised for E^{-2} flux,
dedicated analysis for RXJ1713 flux in progress

Point Sources-additional data

2012 2014 2016



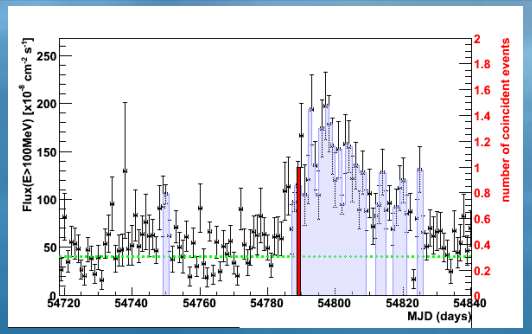


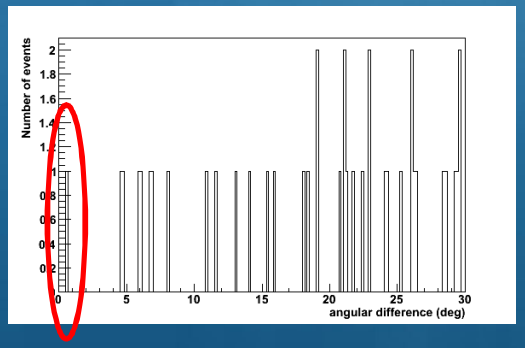
Assuming 300 live days/year

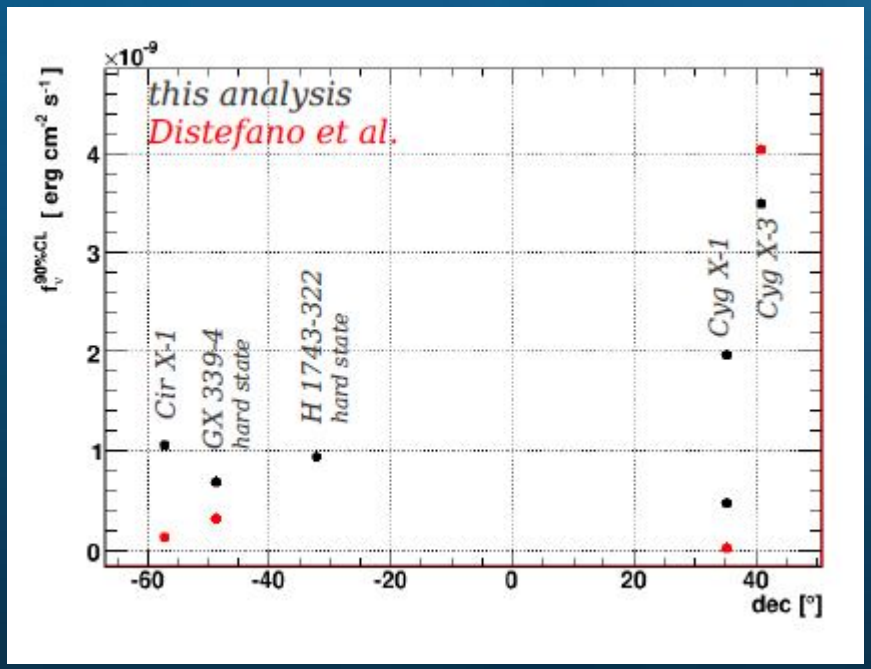
Neutrinos from Flaring γ and x-ray Objects

10 flaring blazars in 2008:
PKS0208-512, AO0235+164, PKS1510-089, 3C273, 3C279, 3C454.3, OJ287, PKS0454-234, Wcomae, PKS2155-304

For 9 sources: 0 event
For 3C279: 1 event compatible with the source direction (Δα=0.56°) and time distribution.
Post trial value 10%
Upper-limit on the neutrino fluence





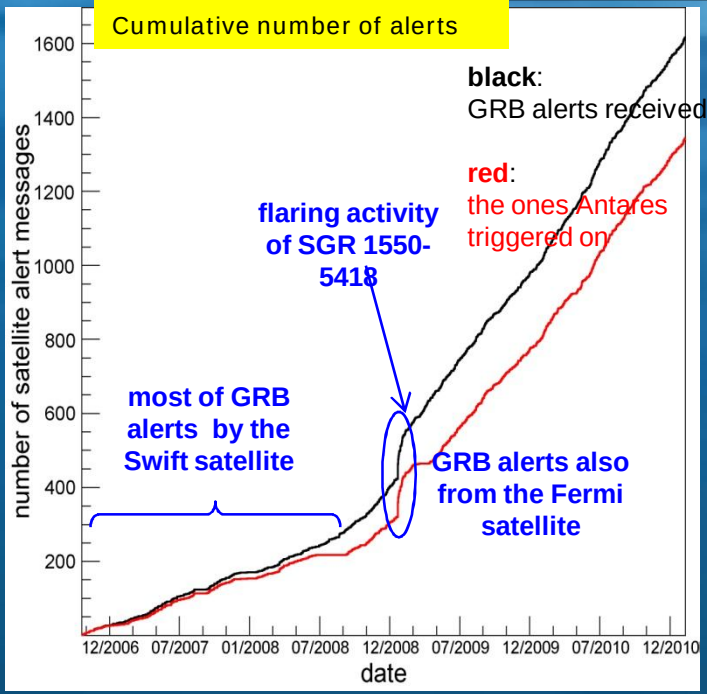


6 flaring microquasars in 2007-2010:

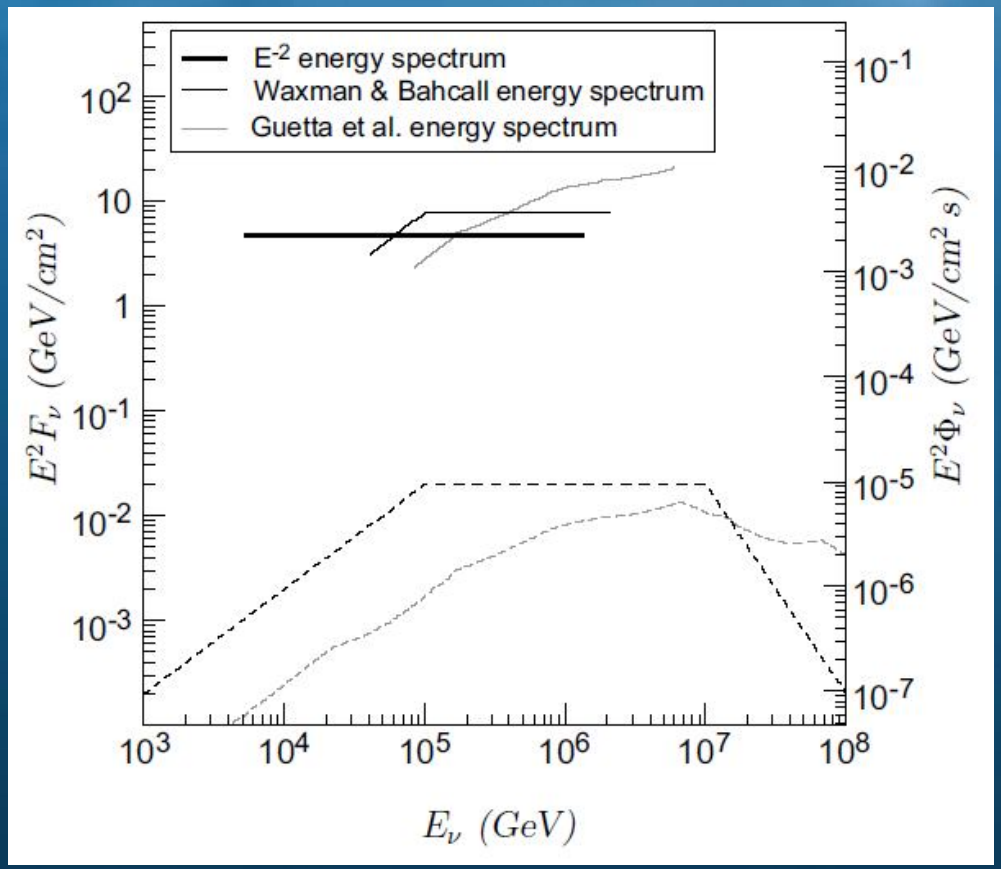
Circinus X-1, GX339-4, H 1743-322, IGRJ17091-3624, Cygnus X-1, Cygnus X-3

No neutrinos found in coincidence with outbursts

GRB triggered Search



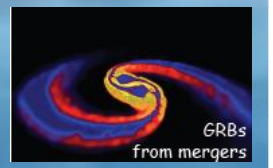
90% CL Upper limits on fluxes from 40 stacked GRBs



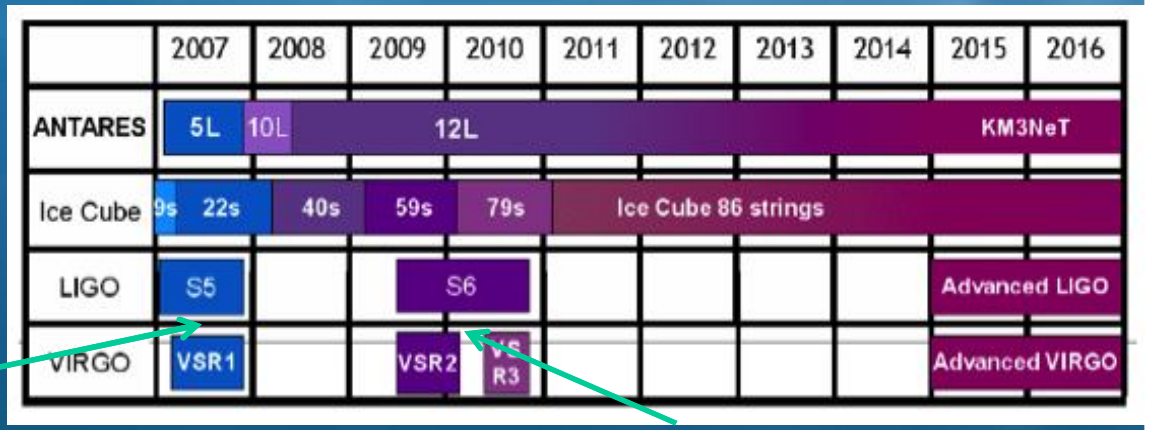
- > 1300 alerts from GCN have been recorded (Jan 2011)
- Lines 1-5 data unblinded: 40 GRB alerts
- The total prompt emission duration of the 40 GRBs is 2114 s

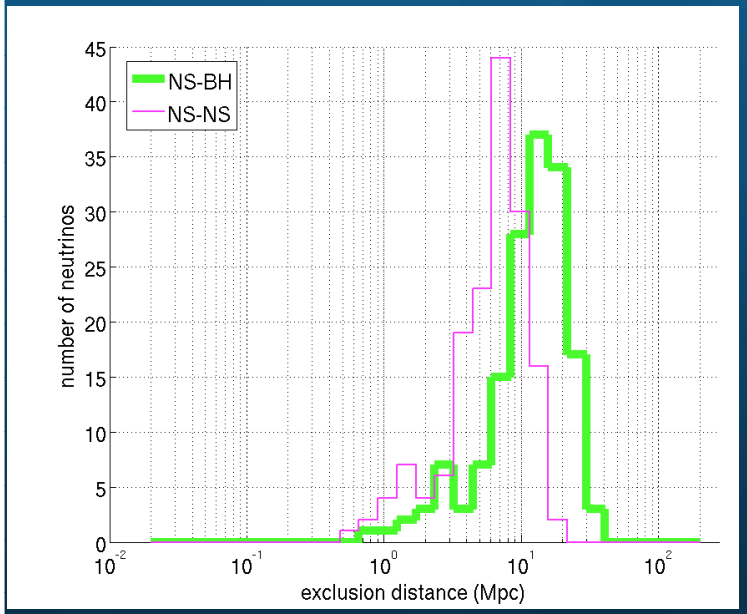
Correlation with Gravitational Waves

Main motivations:
- plausible common sources (microquasars, SGR, GRBs)
- discovery potential for hidden sources (e.g. failed GRBs)



First analysis of 2007 data performed and reviewed by both collaborations
No detection→limits.
Paper is drafted
Should be published by summer



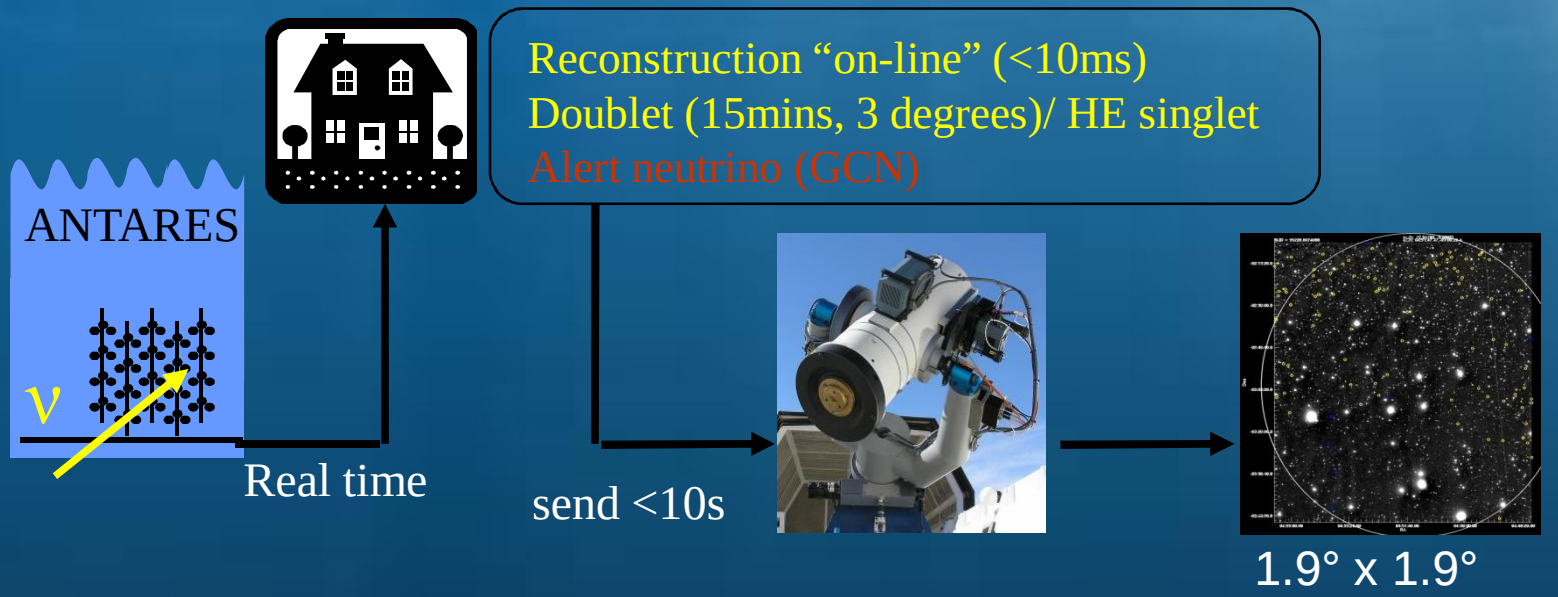


Analysis of remaining data ongoing with improved reconstruction and dedicated GW pipeline

The MoU between Antares and VIRGO-LIGO has been extended until late 2013.

TaToO: Telescopes and ANTARES Target of Opportunity

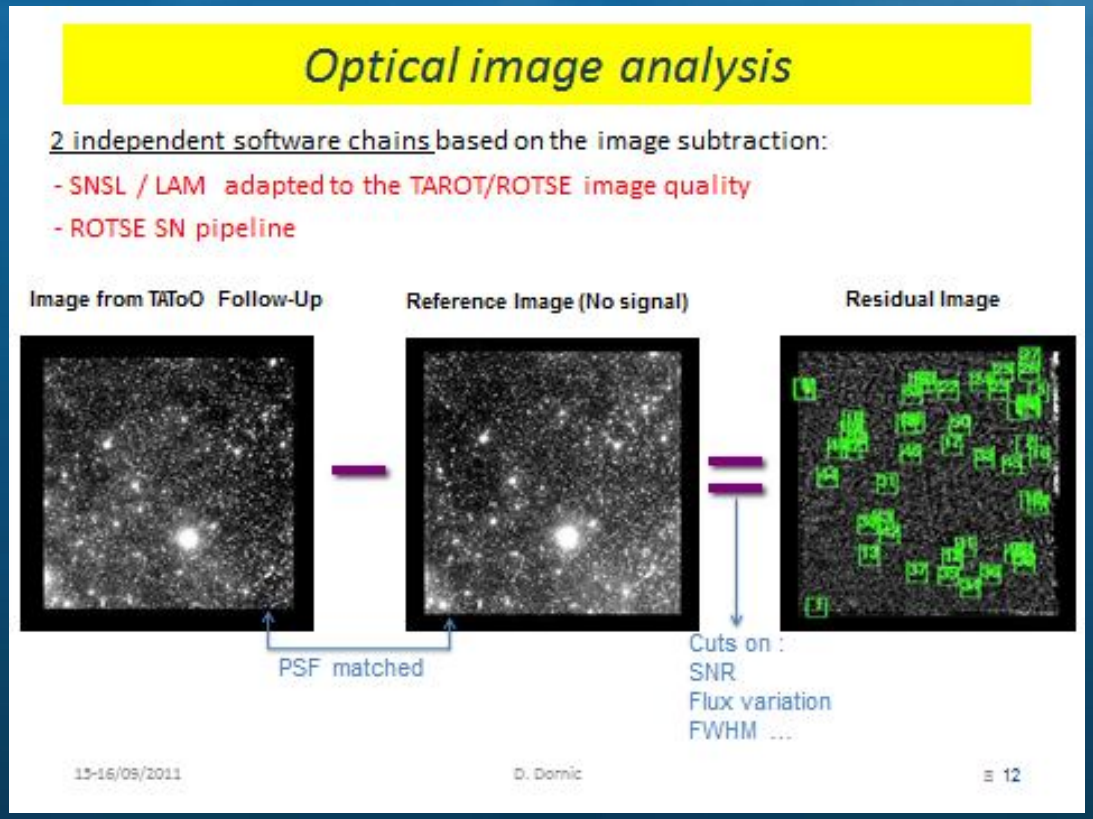
TATOO: optical follow-up of neutrino alerts in order to search for transient sources (GRBs, choked GRBs, AGN flares…)

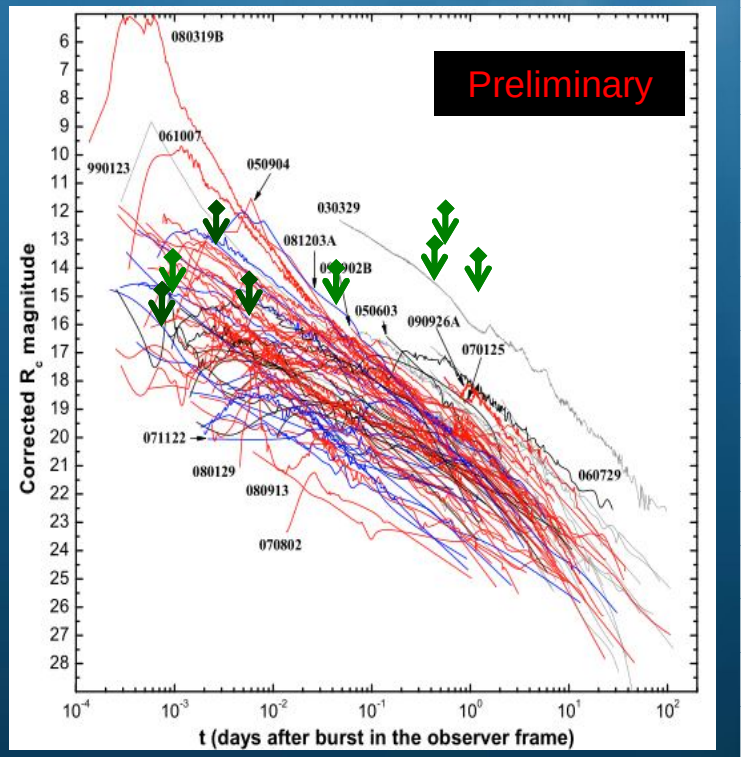


Large sky coverage (>2π sr) + high duty cycle
Improved sensitivity (1 neutrino⇒ 3 sigma discovery)
No hypothesis on the nature of the source
Independent of availability of external triggers

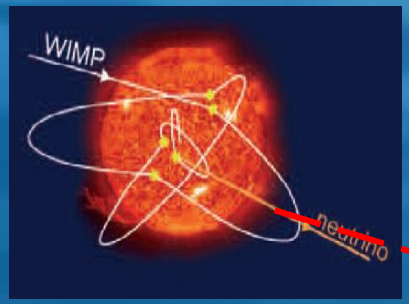
TaToO: GRB Analysis

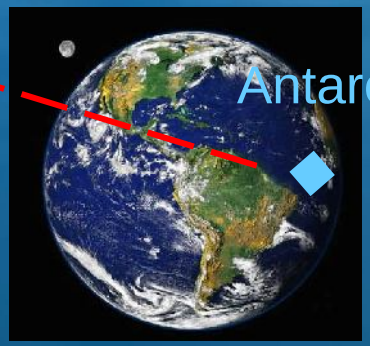
For each neutrino alert -> search for counterpart in optical orginating from GRB (54 alerts sent since mid 2009)



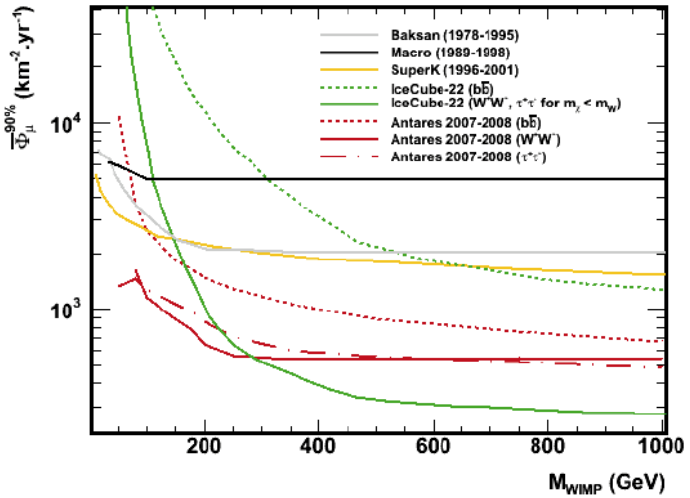


Search for Dark Matter (Sun)

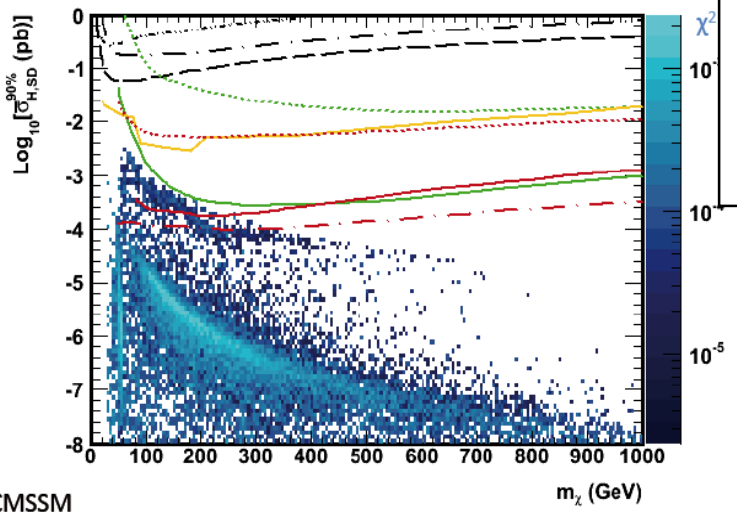




Muon flux sensitivity 2007-2008



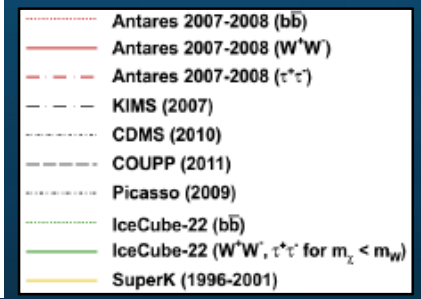
CMSSM



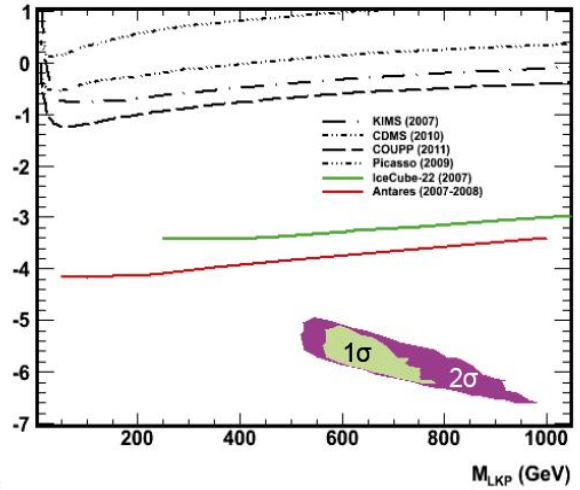
CMSSM

Spin Dependent Sensitivity

Compare SUSY or mUED predictions to observables as sparticles or KK masses, collider observables, dark matter relic density, direct detection cross-sections, etc



Extra-Dimensions



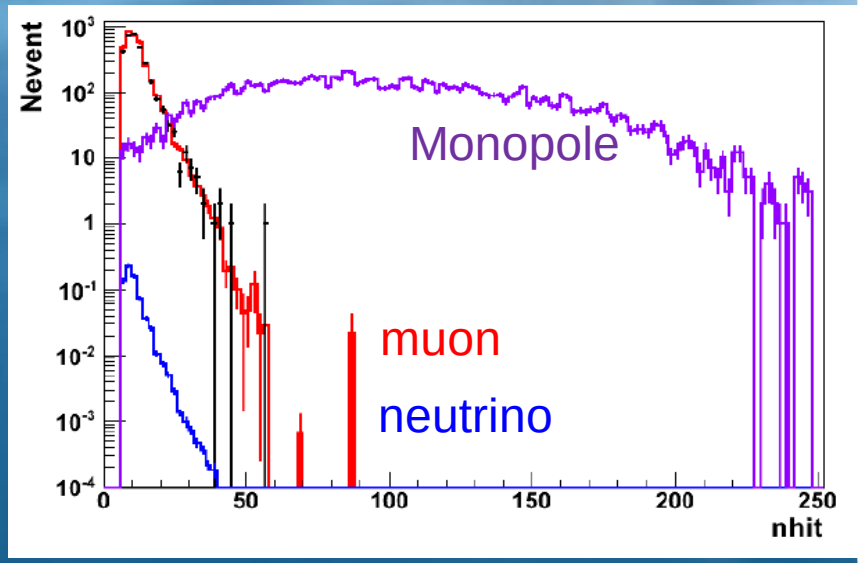
mUED

Magnetic Monopoles

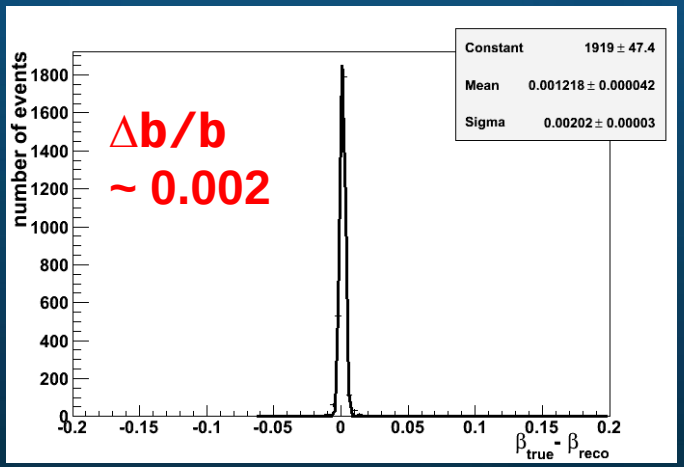
- Required in many models of spontaneous symmetry breaking (‘t Hooft, Polyakov)

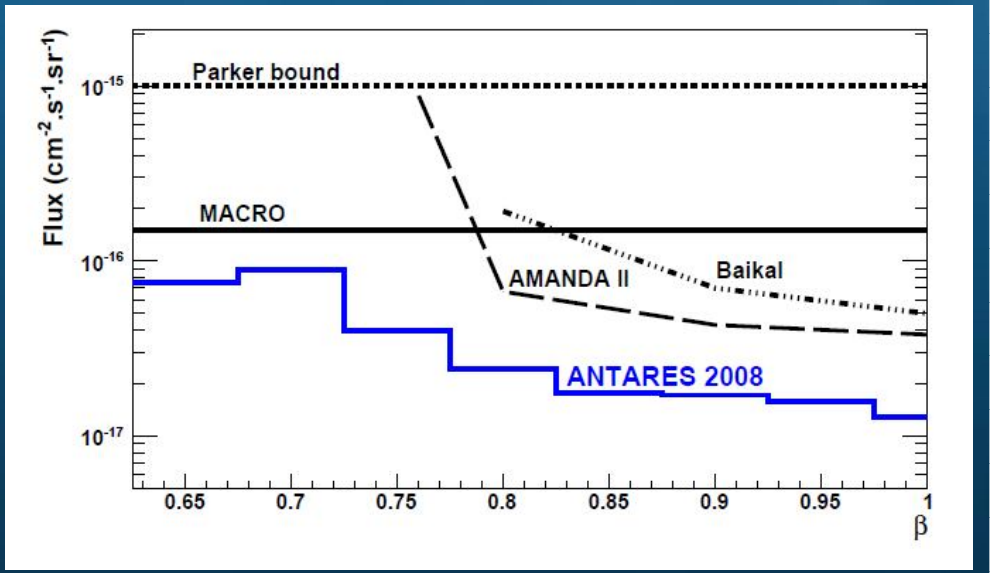
  upgoing ⇒ masses less than ~10^{14} GeV

- High photon yield (8.5×10^3 times μ)
  Cherenkov threshold b > 0.74
  secondary δ-rays β ≥ 0.5



Modified track reconstruction with b free





Publications (2010-2011)

Accepted (13)

Measurement of flux of atmospheric muons with 4 GeV threshold…	-Astroparticle Physics 33 (2010)
Zenith distribution and flux of atmospheric muons measured with the 5 line ANTARES	-Astroparticle Physics 34 (2010)
Performance of the front-end electronics of the ANTARES……	-NIM A 622 (2010)
Amadeus - the acoustic neutrino detection test system of ANTARES	-NIM A 626 (2011)
Search for a diffuse flux of high energy nu_mu with the ANTARES neutrino telescope	-Phys. Lett B 696 (2011)
Time calibration of the ANTARES neutrino telescope	-Astroparticle Physics 34 (2011)
A fast algorithm for muon track reconstruction and its application to ANTARES	-Astroparticle Physics 34 (2011)
Acoustic and optical variations during rapid downward motion episodes...	-Deep Sea Research 58 (2011)
ANTARES: First Undersea Neutrino Telescope	-NIM A 656 (2011)
First search for point sources of high energy cosmic neutrinos with the ANTARES ...	-Astrophysical Journal letter 743 (2011)
The ANTARES Telescope Neutrino Alert System	-Astroparticle Physics, arXiv:1103.4477
Measurement of the Group Velocity of Light in Sea Water at the ANTARES Site	- Astroparticle Physics, arXiv:1110.5184
A method for detection of muon induced electromagnetic showers with the ANTARES detector	-NIM, arXiv:1106.0426

Submitted (5)

Enhancement of deep-sea pelagic activity by dense water formation	-Nature GeoScience
Search for Relativistic Magnetic Monopoles with the ANTARES Neutrino Telescope	-Astroparticle Physics, arXiv:1110.2656
Search for Neutrino Emission from Gamma-Ray Flaring Blazars with the ANTARES Telescope	-Astroparticle Physics, arXiv:1111.3473
In situ Oxygen Dynamics Autosampler	-Limnology and Oceanography methods
The Positioning System of the ANTARES Neutrino Telescope	-Astroparticle Physics

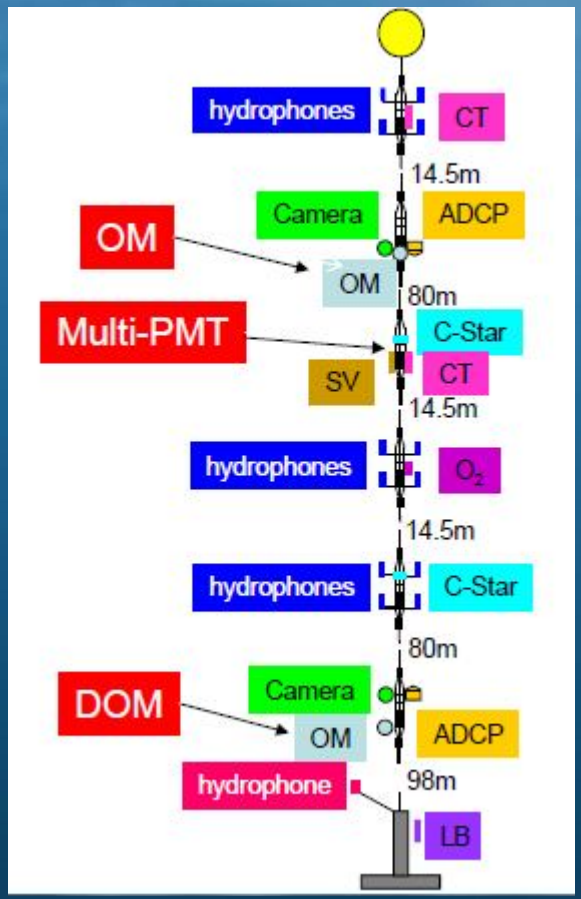
In the Pipeline (13)

GRB 5-lines	(passed through PC)	Bouwhuis
Auger Correlation	(passed through PC)	Petrovic
GWHeN	draft	Pradier
Nuclearites	draft	Popa
The ANTARES real time ocean bottom Seismometer	draft	Deschamps
TaToO GRBs	draft	Basa
Pt source 2007-2010	draft	Nikhef/Valencia
Neutrino Oscillations	draft	Brunner
ANTARES/IceCube Combination		Brunner
Dark Matter from Sun		Lambard/Charif
Microquasars		Galata
Fermi bubbles		Vladimir

Instrumentation Line

Monitoring of environmental parameters 2007→nov 2010

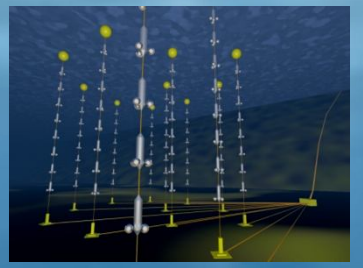
- **CSTAR** light transmission
- **CT** = Conductivity-Temperature
- **SV** = sound velocity
- **ADCP** = Current meter
- 2 Optical Modules
- Acoustic positioning
- Oxygen meters
- 2 video cameras
- 3 storeys of UHE neutrino acoustic detectors (AMADEUS)
- 2 KM3NeT Optical modules



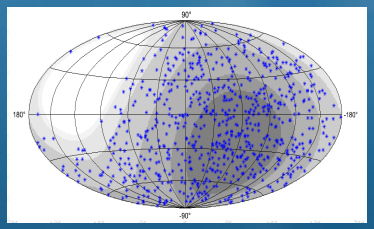
Recovery, upgrade and reconnection summer 2012 with 2 KM3NeT (multi-PMs) Optical Modules

Summary

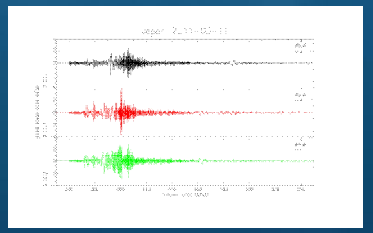
- ANTARES infrastructure completed:
  - Only operating deep sea neutrino telescope
  - Largest neutrino telescope in the Northern hemisphere
  - Operating smoothly, maintenance capability proven
  - Good understanding of detector
  - Important testbed for KM3NeT R&D and software



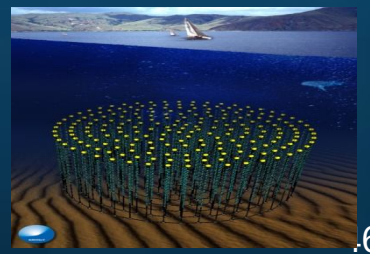
- Exciting physics program in progress….
  - Unexplored regions of sensitivity for galactic sources
  - Steady/transient sources, monopoles, DM, oscillations ……
  - Strong multi-messenger program (optical, satellite, GW)



- Real-time readout and in-situ power capabilities facilitates a large program of synergetic multi-disciplinary activities: acoustics, biology, oceanography, seismology……



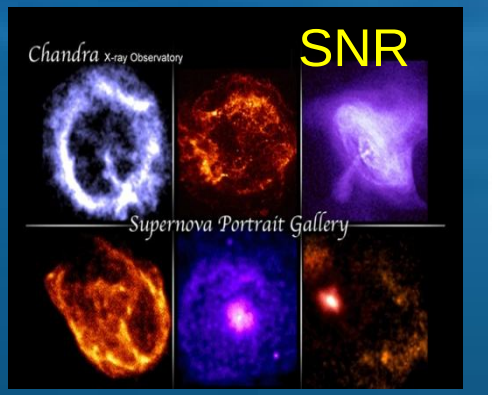
- Major step towards a multi-kilometre cube deep-sea NT: KM3NeT

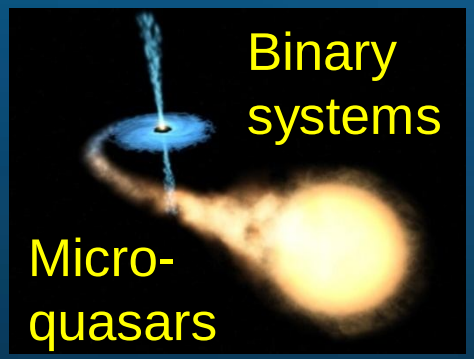


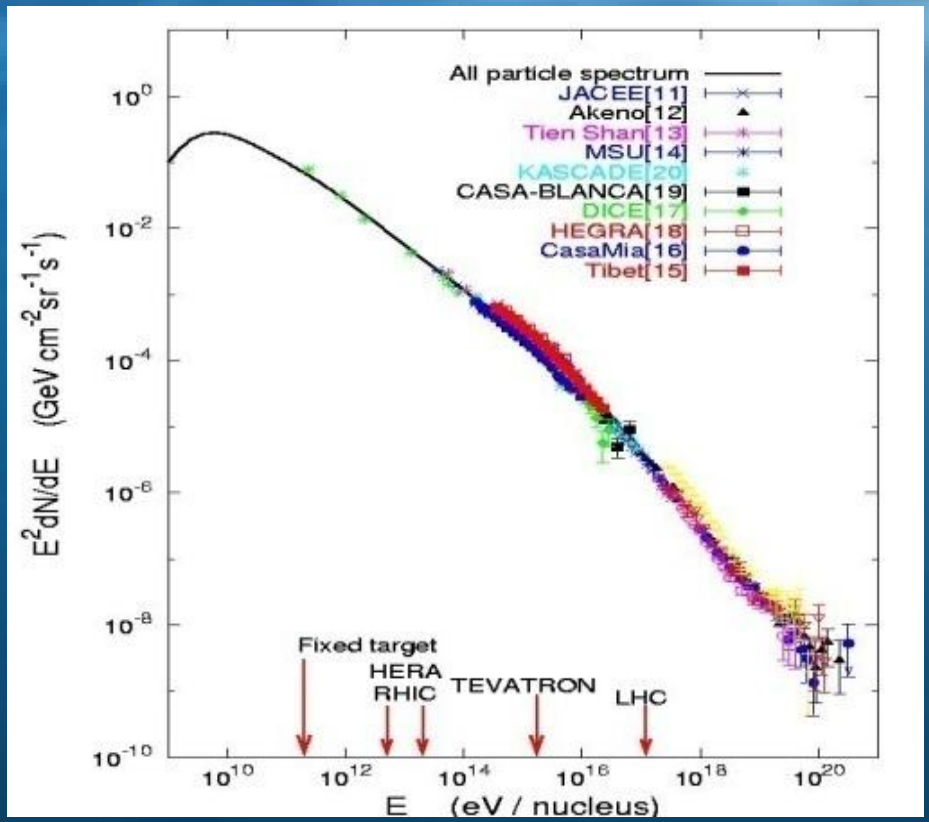
Origin of Cosmic Rays?

HE protons are accelerated - but where?

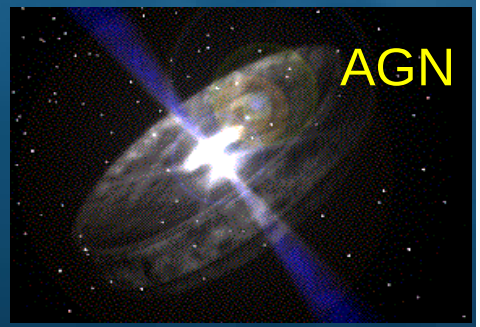
Galactic







Extra-Galactic



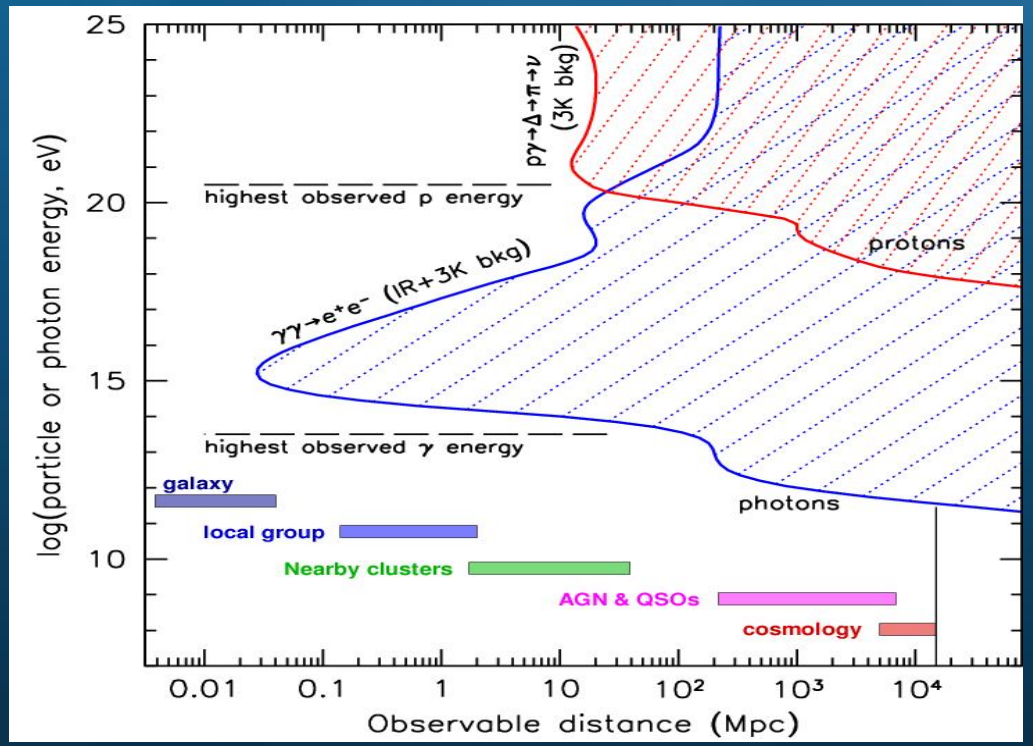
$\Rightarrow$ Natural candidates for neutrino sources

Universe is Transparent for Neutrinos

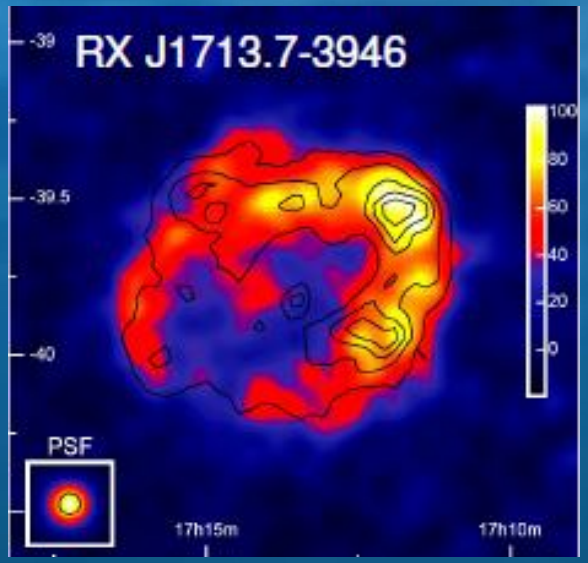
Not the case for HE photons or nuclei

absorption		cut-off	mean free path
γ-rays:	$\gamma + \gamma_{2.7k}$	$>10^{14}$eV	10 Mpc
proton:	$p + \gamma_{2.7k} \rightarrow \pi^0 + X$	$>5.10^{19}$eV	50 Mpc
neutrinos:	$\nu + \nu_{1.95K} \rightarrow Z+X$	$>4.10^{22}$eV	(40 Gpc)

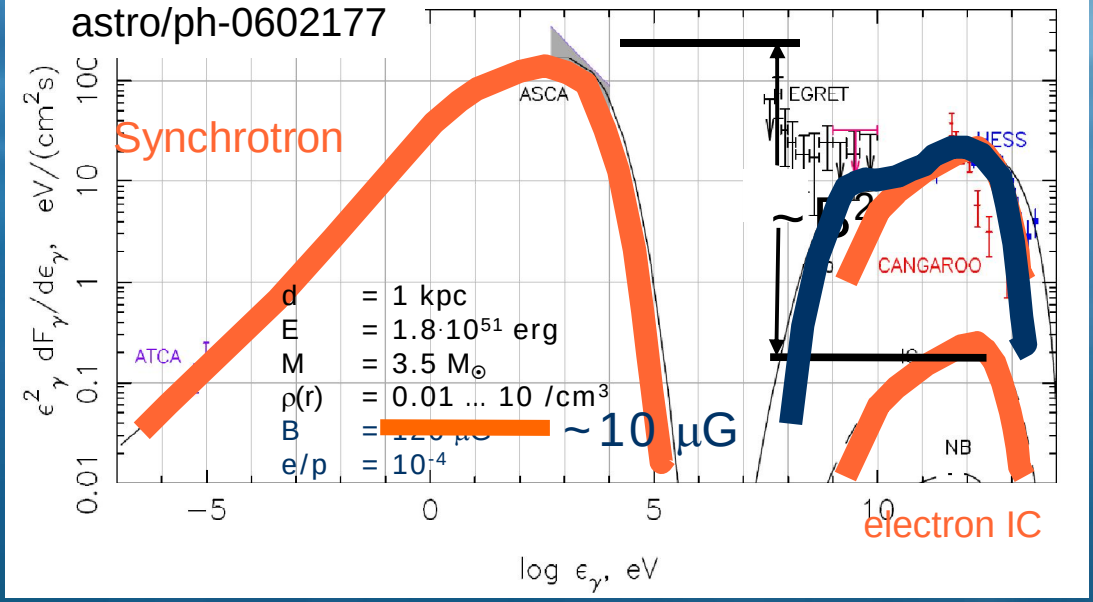
neutrons decay: $\gamma ct = E/m\ ct \sim 10$ kpc for $E \sim 10^{18}$ eV

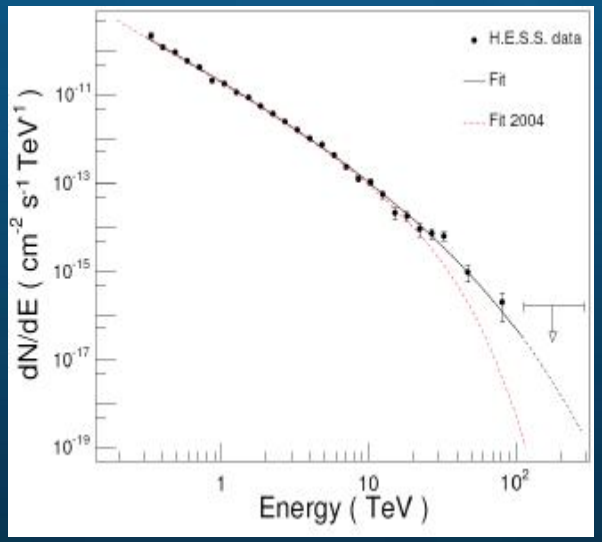


Supernova Remants: RXJ1713.7-3946



Berezkho & Völk
astro/ph-0602177





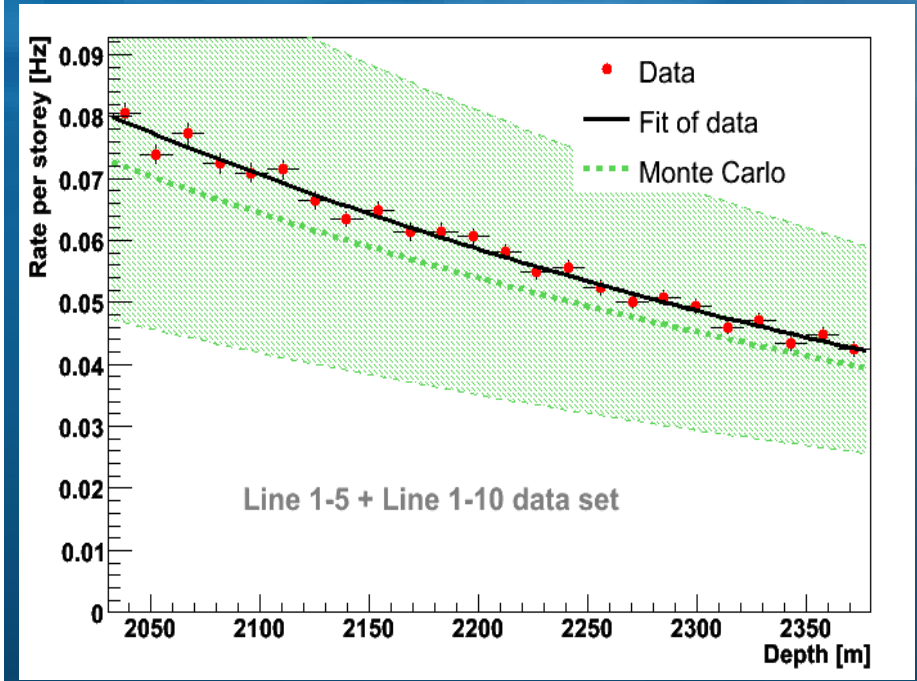
Search for Astrophysical Neutrino Point Sources at Super-Kamiokande

"We find interesting signatures from two objects—RX J1713.7-3946 (97.5% CL) and GRB 991004D (95.3% CL)"

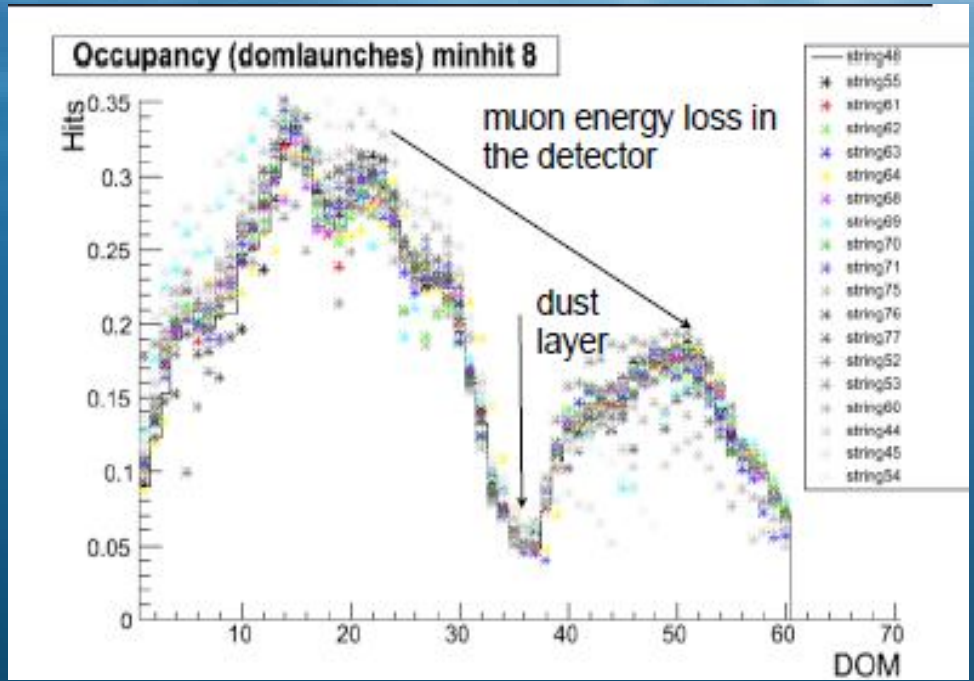
arXiv:0907.1594v3 [astro-ph.HE] 21 Aug 2009

ANTARES vs ICECUBE: Scattering

ANTARES



ICECUBE

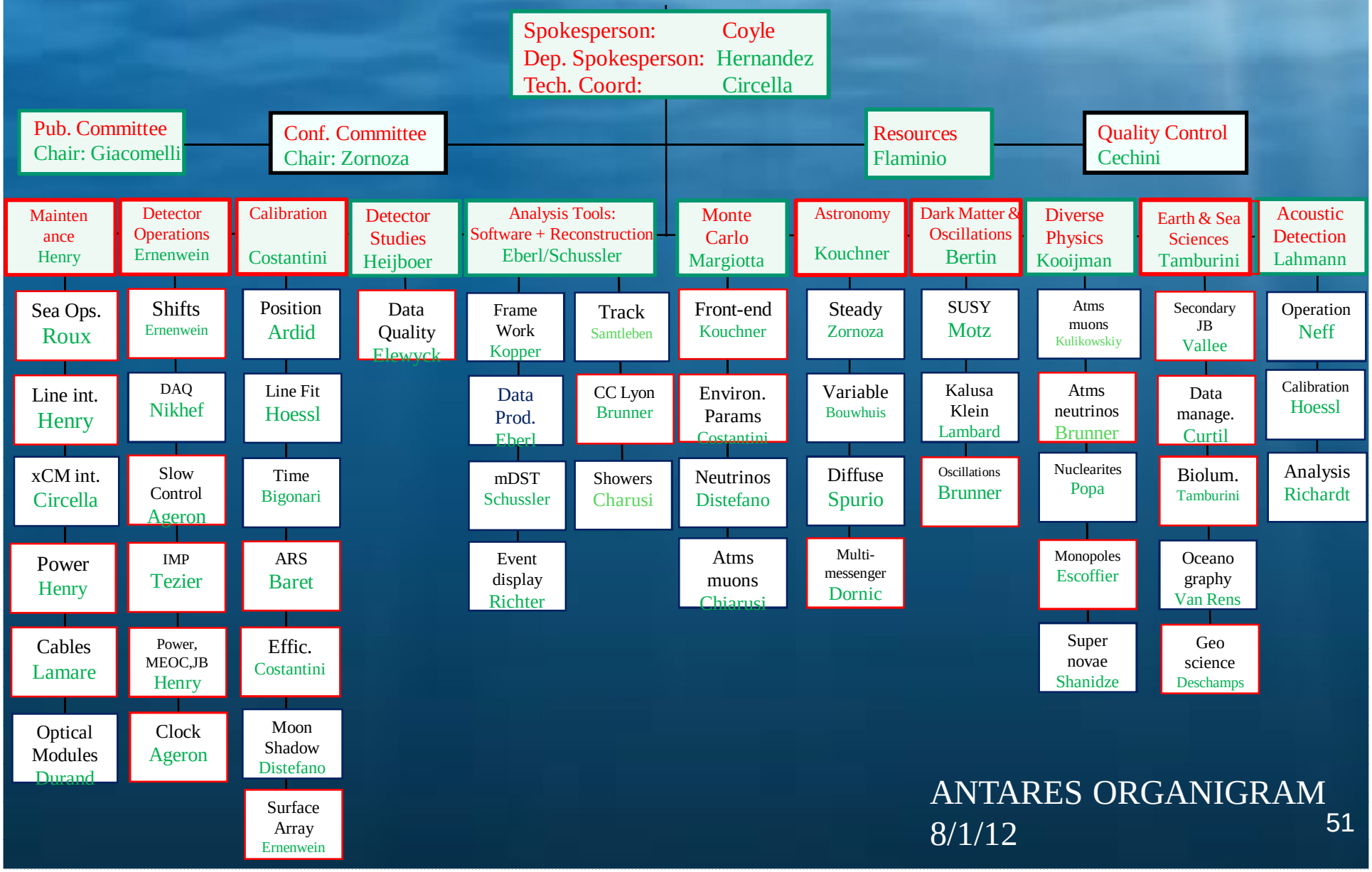


water: ~0.2°

Ice: ~2°/0.7°

Scattering in ICE an issue

ANTARES ORGANIGRAM



Optical Follow-Up

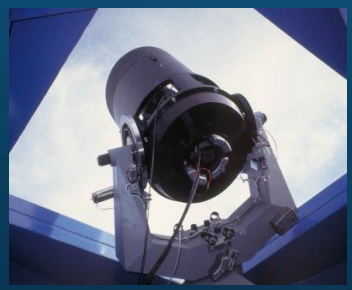
More than 50 alerts sent in 2010: all followed by optical telescopes

TAROT: two 25 cm telescopes

- fov 1.86° x 1.86°
- Magnitude V<17 (10s), V<19 (100s)
- slewing time ~ 10s

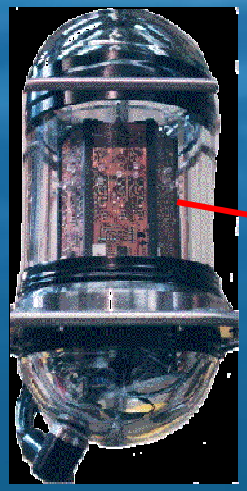
ROTSE: four 45 cm telescopes

- fov 1.85° x 1.85°
- Magnitude V~19 (60s)
- slewing time < 6-8 s

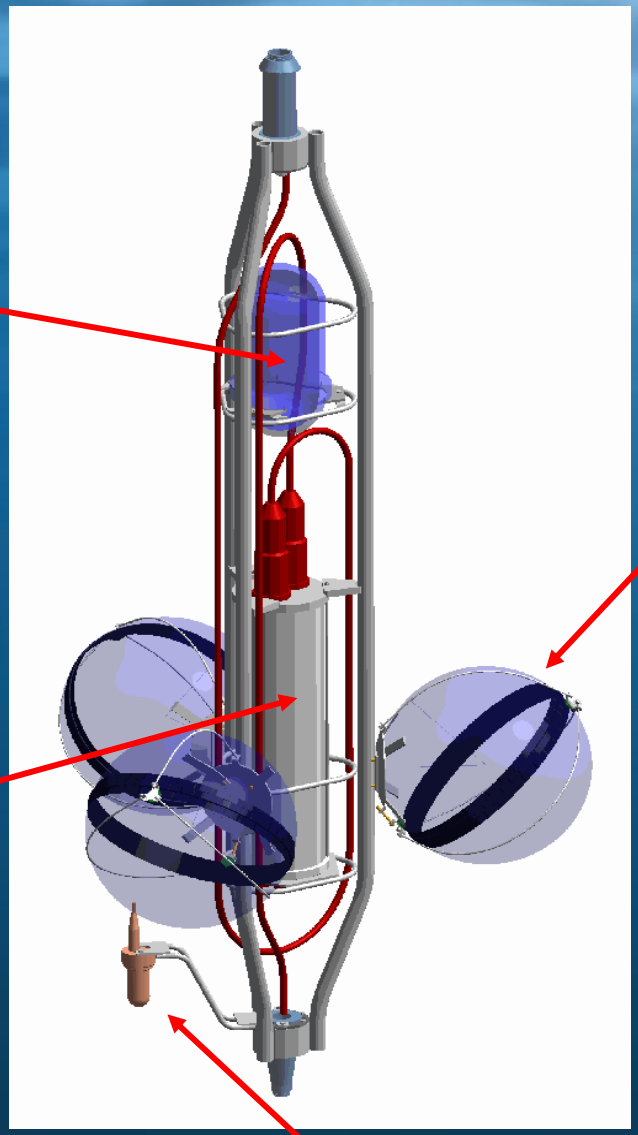


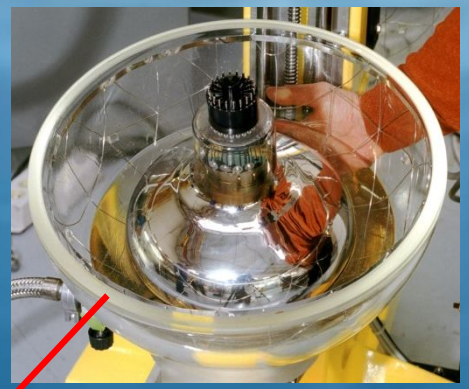
Basic detector element: storey

Optical Beacon for timing calibration (blue LEDs)

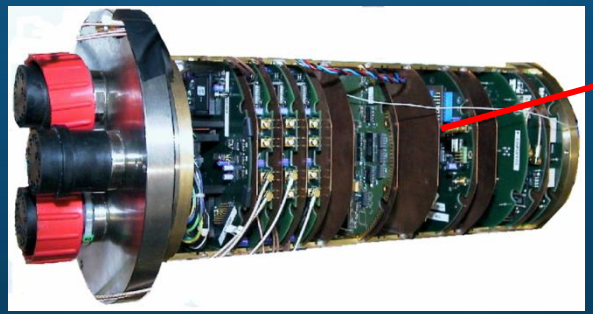


(4 beacons/line)





17” glass sphere
10” PMT Ham. R7081-20
(14 stages)

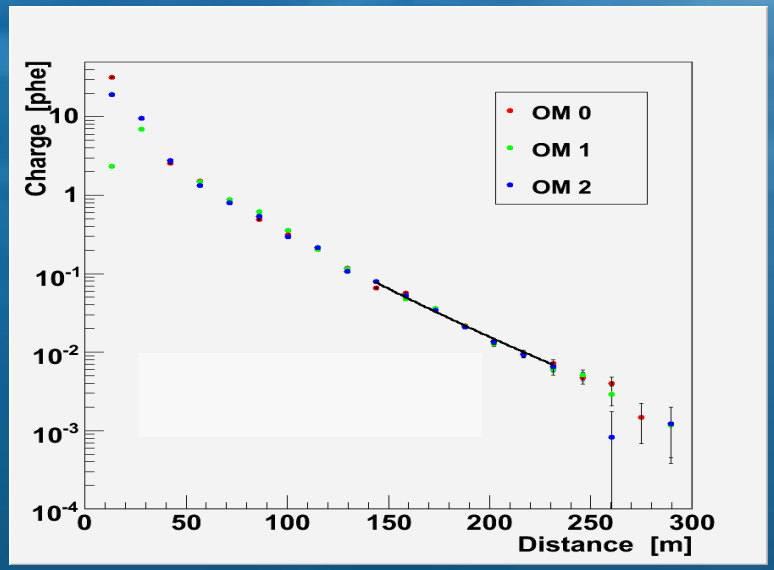


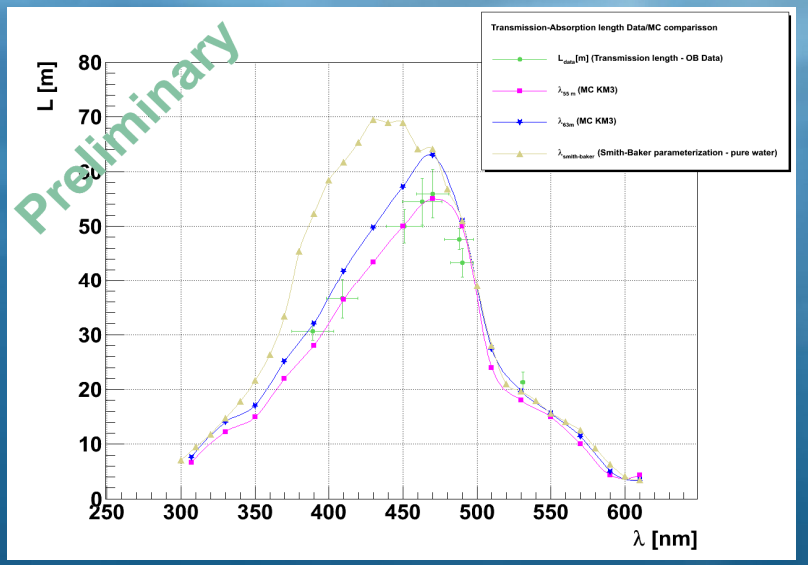
Local Control Module
(inside a titanium cylinder)

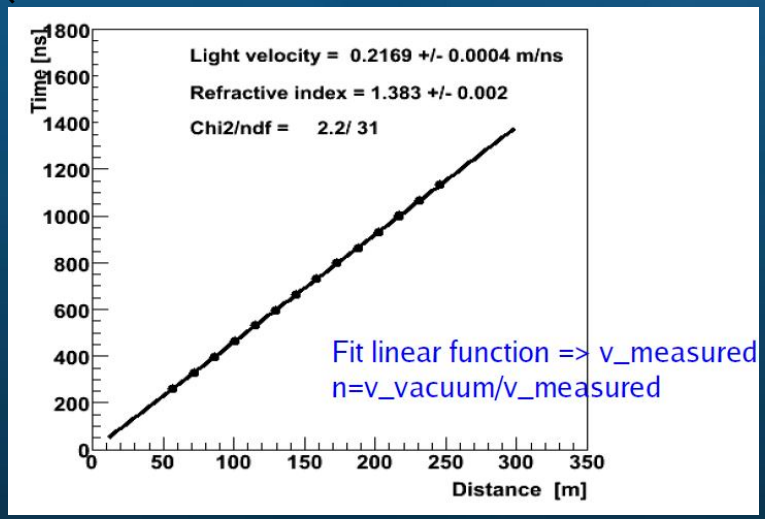
Hydrophone Rx

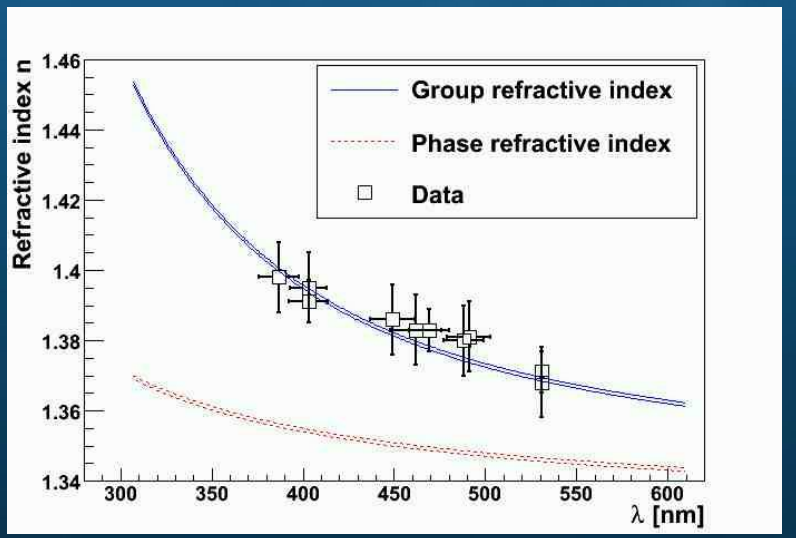
(5 RX + 1 RxTx/line)

Multi-Wavelength Optical Beacon

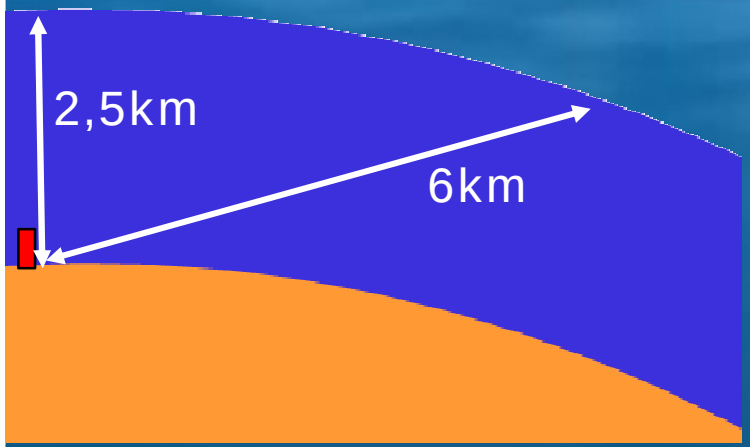


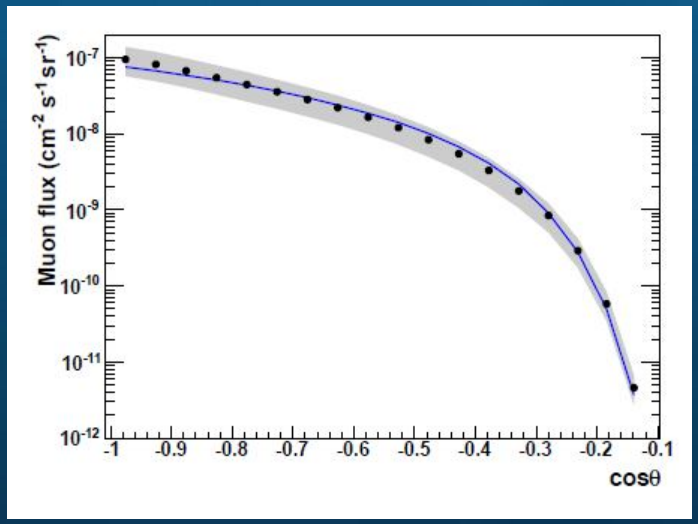




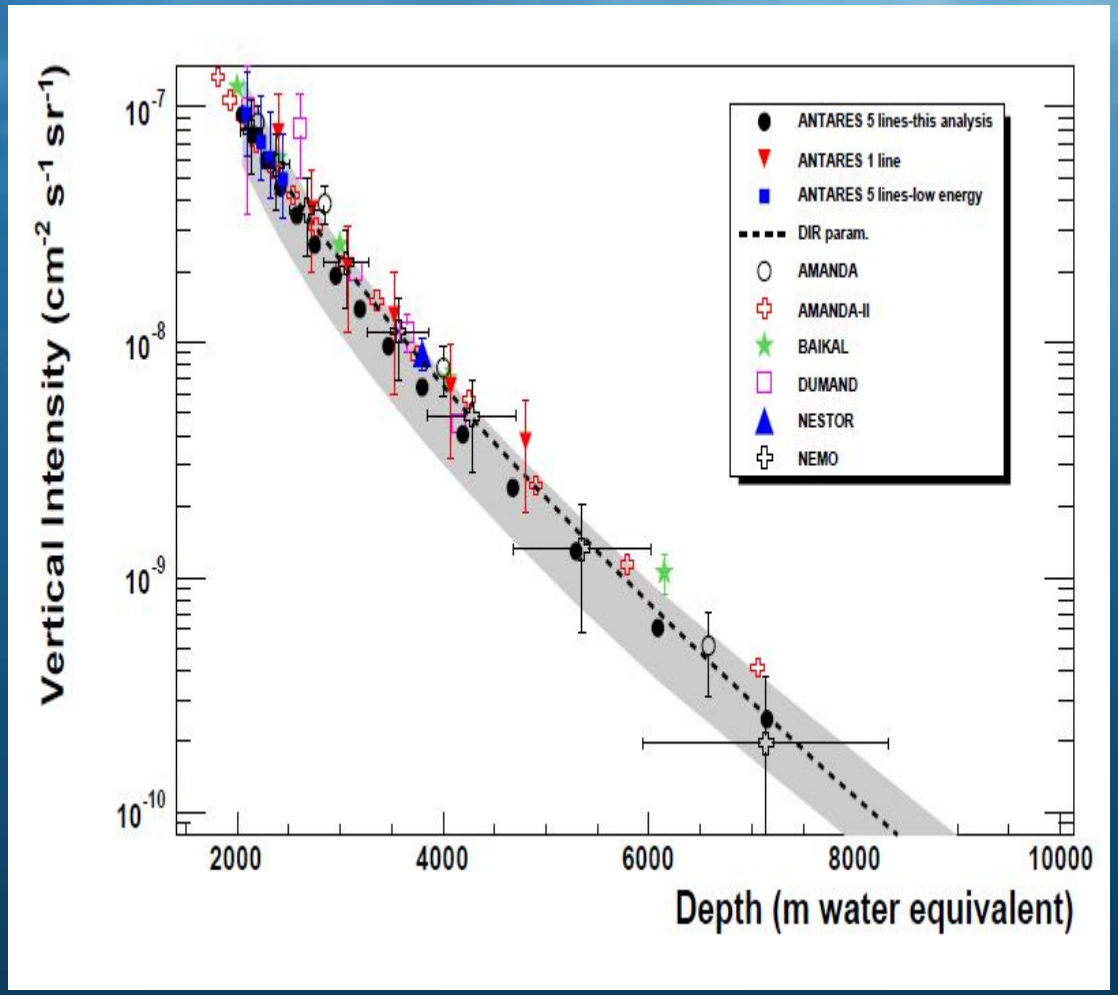


Depth Intensity Relation from Zenith Distribution





Zenith angle distribution of muon flux at 2000 m



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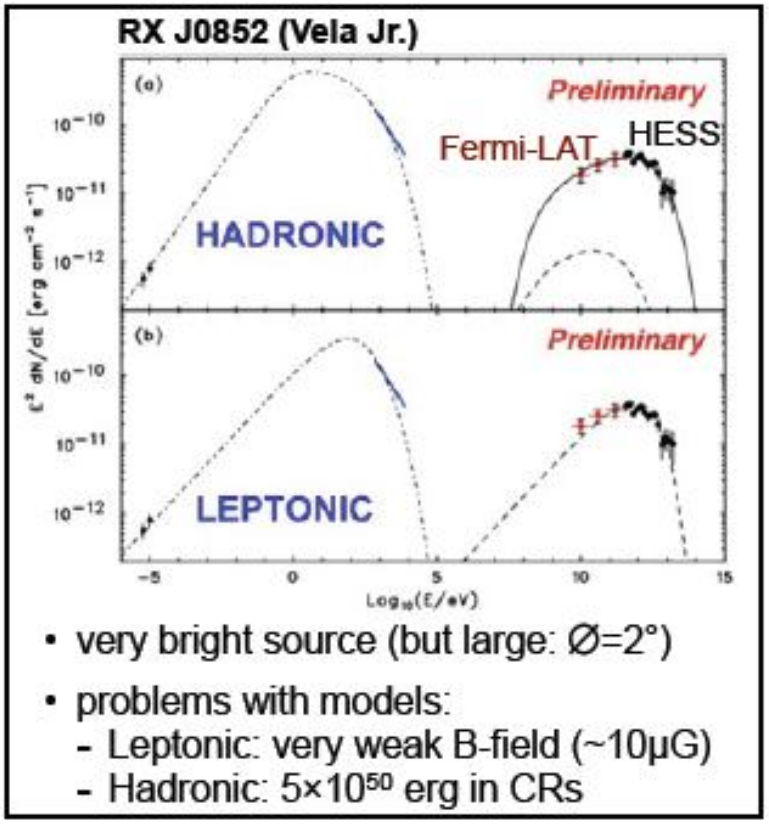
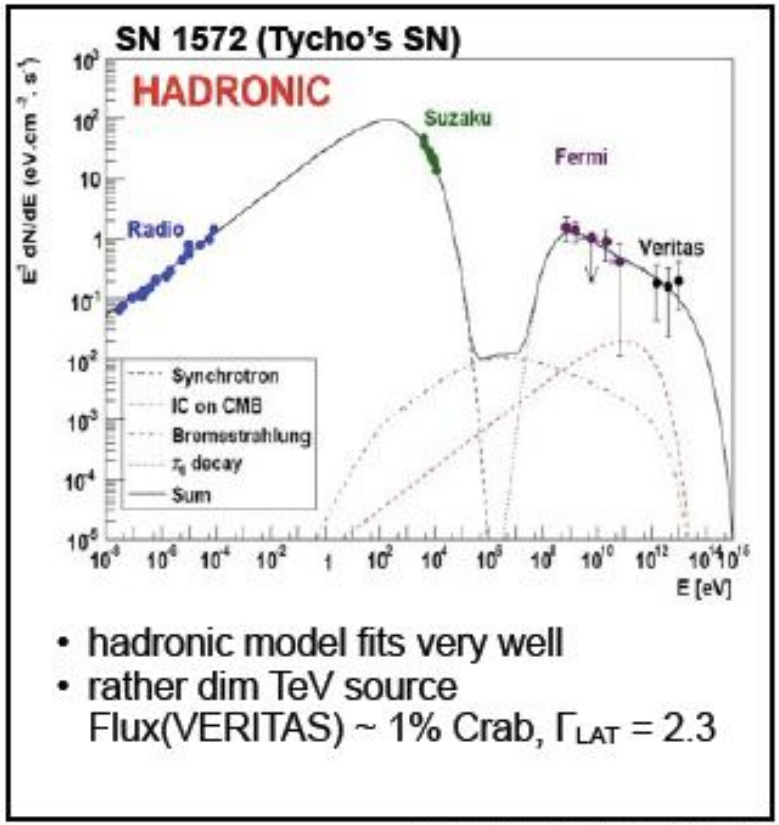
Other SuperNova Remnants

Other supernova remnants



- very bright source (but large: Ø=2°)
- problems with models:
  - Leptonic: very weak B-field (~10μG)
  - Hadronic: 5×10^{50} erg in CRs



- hadronic model fits very well
- rather dim TeV source
  Flux(VERITAS) ~ 1% Crab, $\Gamma_{LAT} = 2.3$

Razzaque, Nusky 2011

- Old SNRs ($\gtrsim$ 10kyr): hadronic model work/favored but low fluxes

Official plots

P-value sky map obtained scanning each point of the sky and computing the corresponding p-value (post trial).