Das Neutrinotelekop ANTARES

ERLANGEN CENTRE
FOR ASTROPARTICLE
PHYSICS

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Contents

- Physics Motivation
- Antares Detector
- First Results
- Future

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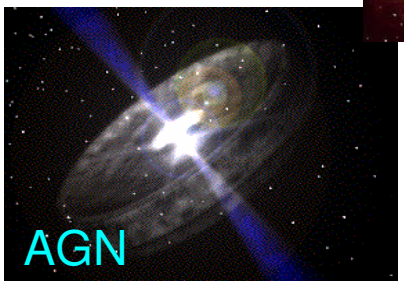
Candidate Sources of High Energy Neutrinos

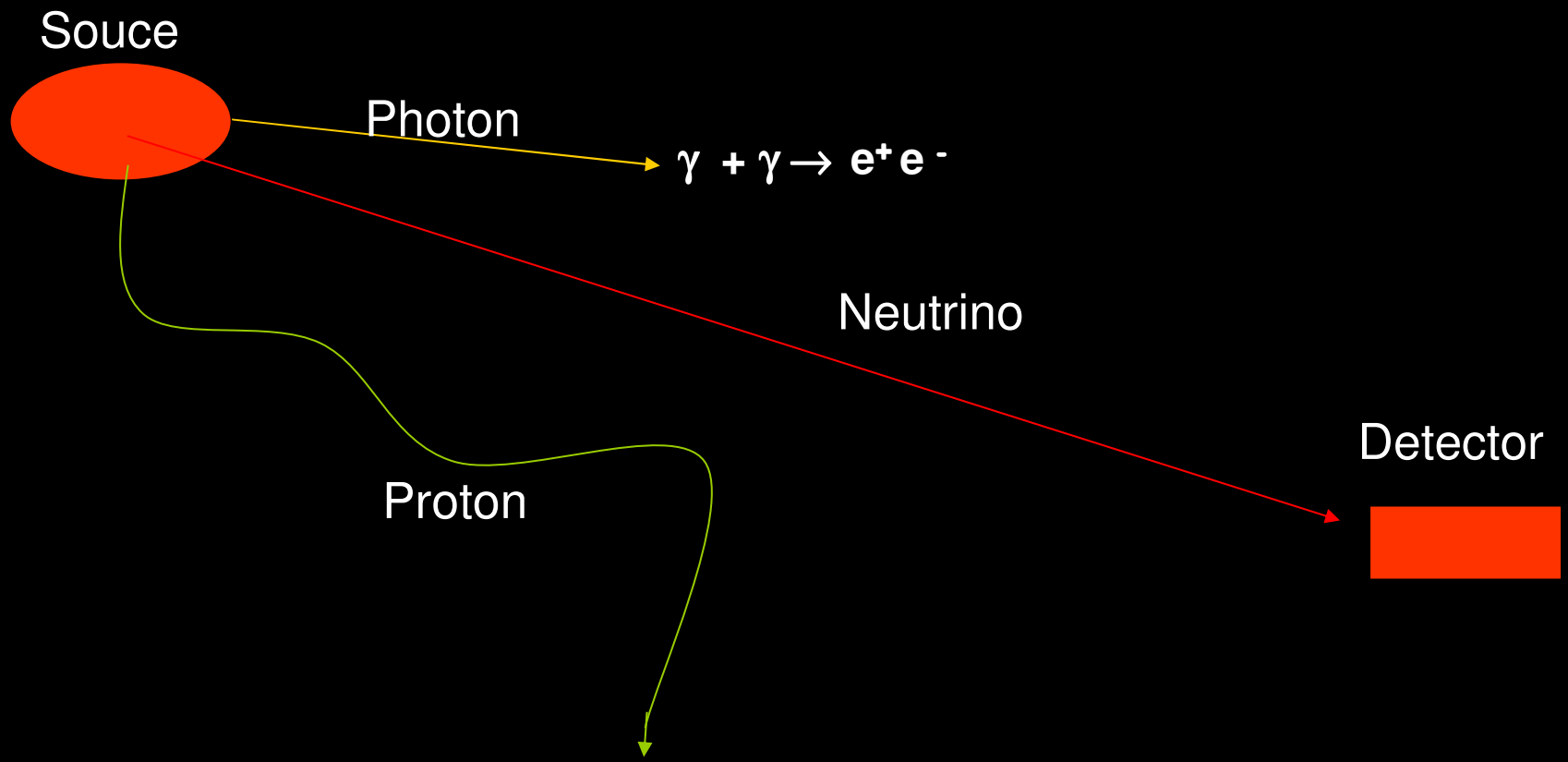
Galactic Sources
- Pulsars
- Super Nova remnants
- Microquasars

Extragalactic Sources
- Gamma Ray Bursts
- Active Galactic Nuclei

Dark Matter
- WIMP annihilation in the Sun or GC

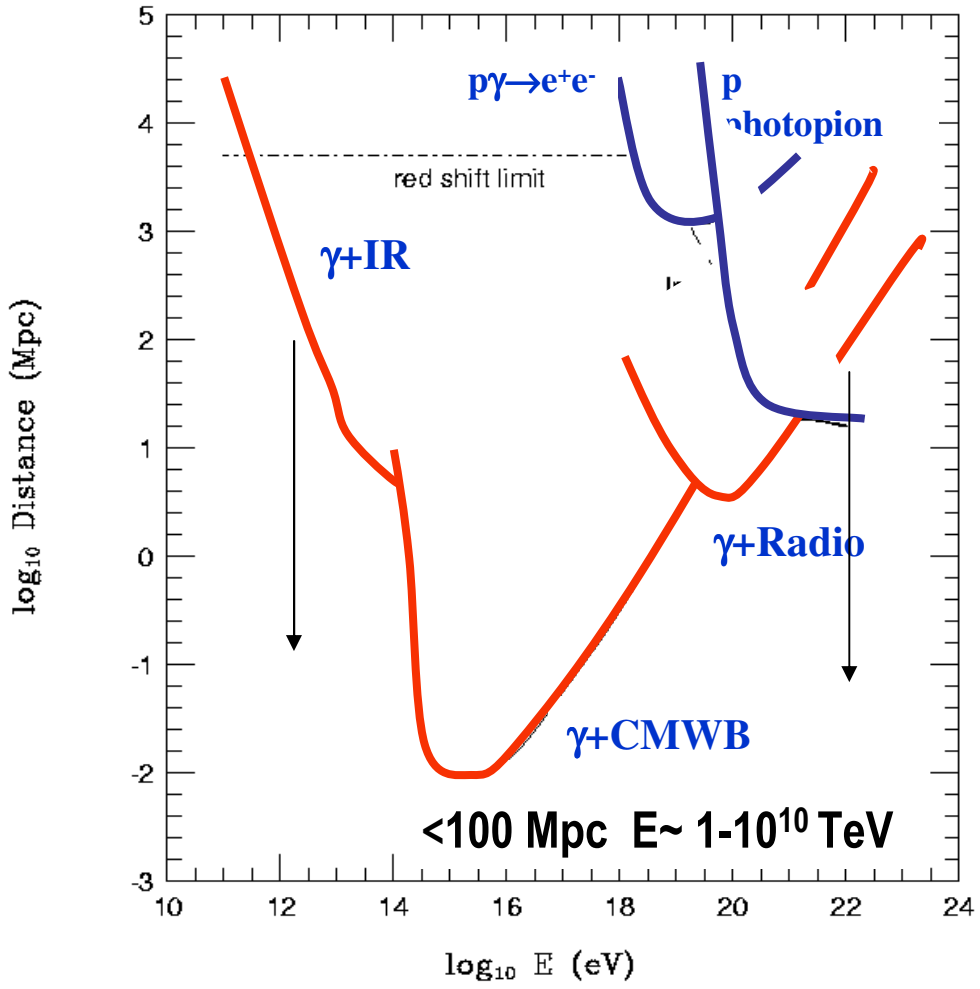


Messengers for Astronomy



Bending in magnetic fields;
GZK: $p + \gamma \rightarrow \Delta^+ \rightarrow \pi^0 p$, $\pi^+ n$

Absorption length of photons and protons



Mrk 501

M87

Gal Cen

Production of Neutrinos

1) Photons and gas around sources, e.g.
SN remnants, accretion discs around BHs, GRBs

$$p + \gamma \rightarrow p + \pi^o \rightarrow p + \gamma + \gamma$$
$$\searrow\ n + \pi^+ \rightarrow n + \nu_\mu + \mu$$
$$\searrow\ e^+ + \nu_\mu + \nu_e$$

$$p + p \rightarrow N + N + \pi \rightarrow \gamma, \nu \ldots$$

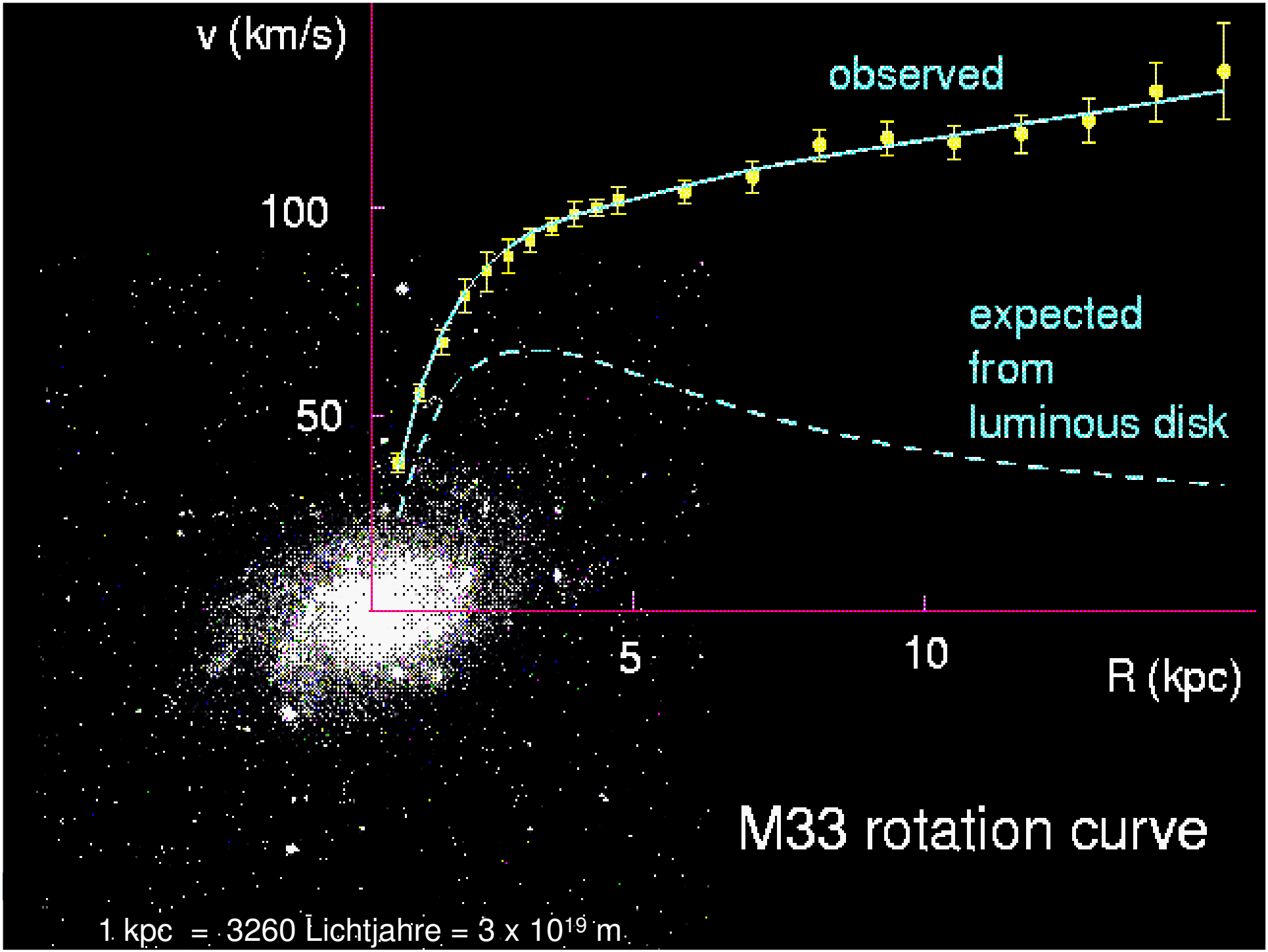
2) Molecular clouds

$$p + p \rightarrow N + N + \pi \rightarrow \gamma, \nu \ldots.$$

3) CMB photons

$$p + \gamma \rightarrow \Delta \rightarrow N + \pi \rightarrow \gamma, \nu \ldots$$

Dark Matter in Galaxies


v (km/s)
observed
100
50
expected
from
luminous disk
5
10
R (kpc)
M33 rotation curve
1 kpc = 3260 Lichtjahre = 3 x 10^19 m

Particle Production in the Big Bang

Birth of the Universe: „big bang“

High energy density:
particles are produced and annihilated/decay in equilibrium;
all particles with equal abundances;

Cooling:
decays dominate:
heavy particles → light particles

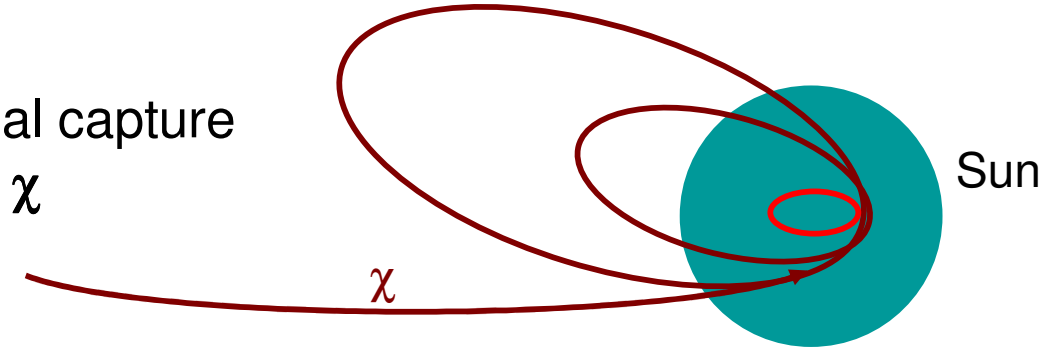
Lightest „normal“ particles: Electrons, u, d – Quarks

Lightest supersymmetric particle: WIMP

Indirect Detection of Dark Matter

Accumulation of WIMPs:

Gravitational capture of χ

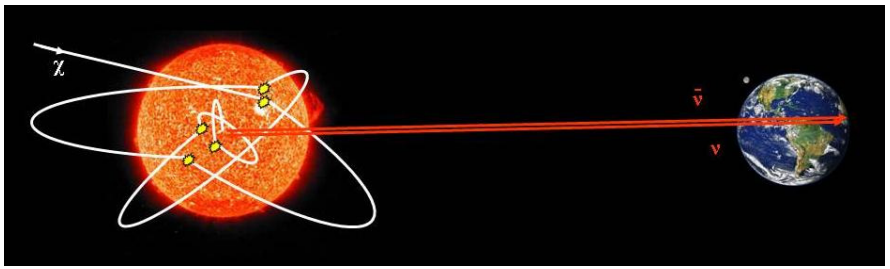


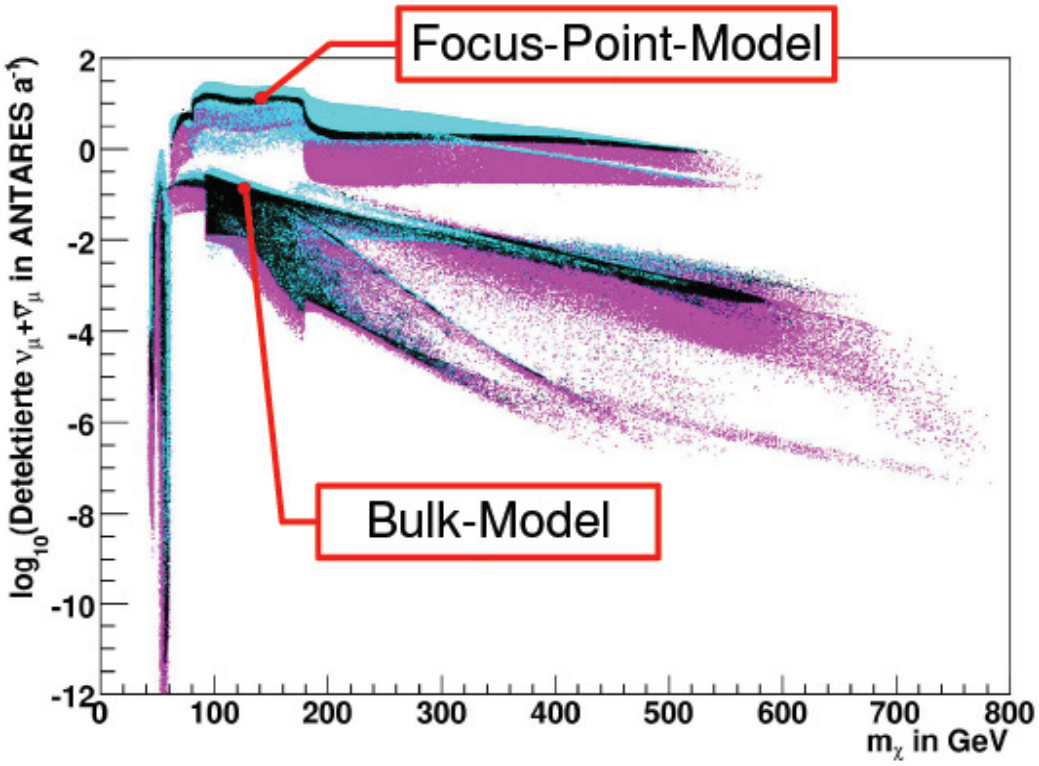
Annihilation of WIMPs in Earth, Sun, gal. Centre :

$$\chi\,\chi \rightarrow WW,\ ff \rightarrow \nu\,\nu\,X$$

to be seen in telescope

Expected Neutrino Events from Dark Matter Annihilation





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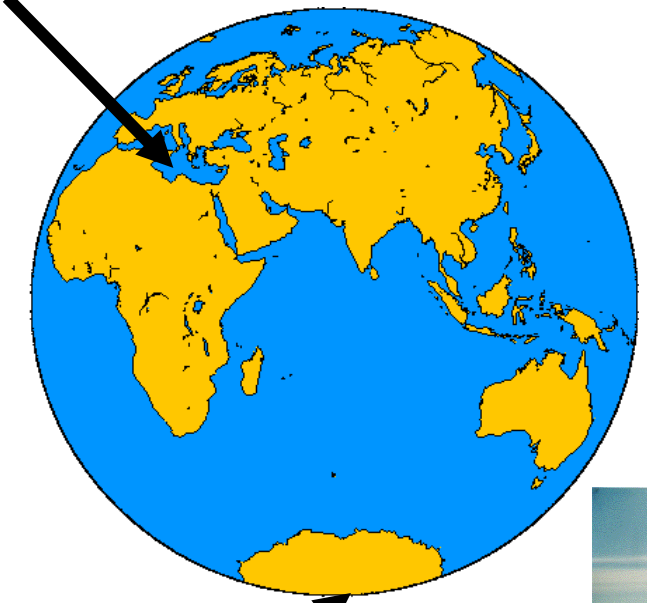
Neutrino Telescop Projects

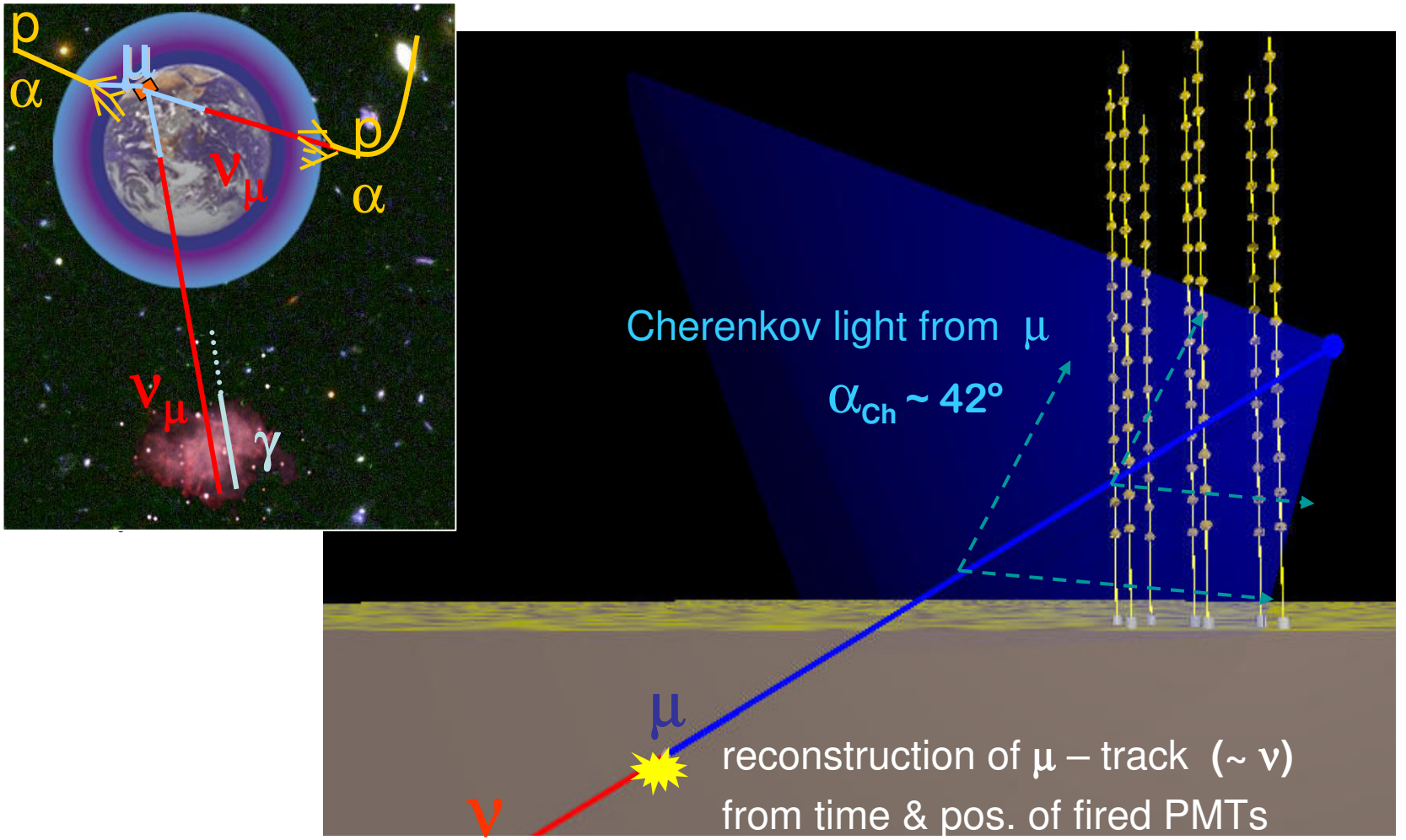
ANTARES La-Seyne-sur-Mer, France
(NEMO Catania, Italy, NESTOR, Greece)



KM3NeT
(European design study)

AMANDA und IceCube, Südpol, Antarktis

Detection principle of a neutrino telescope



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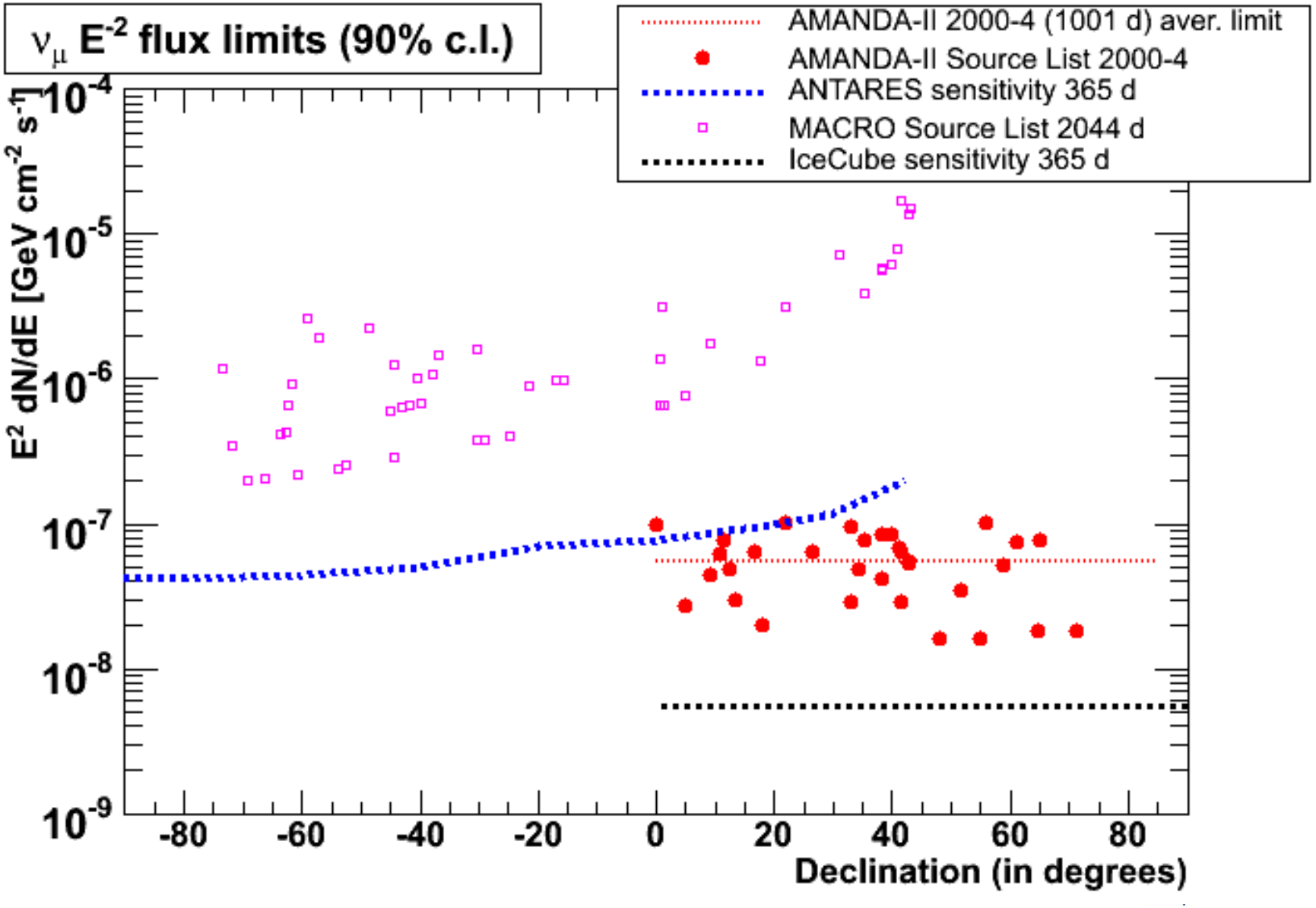
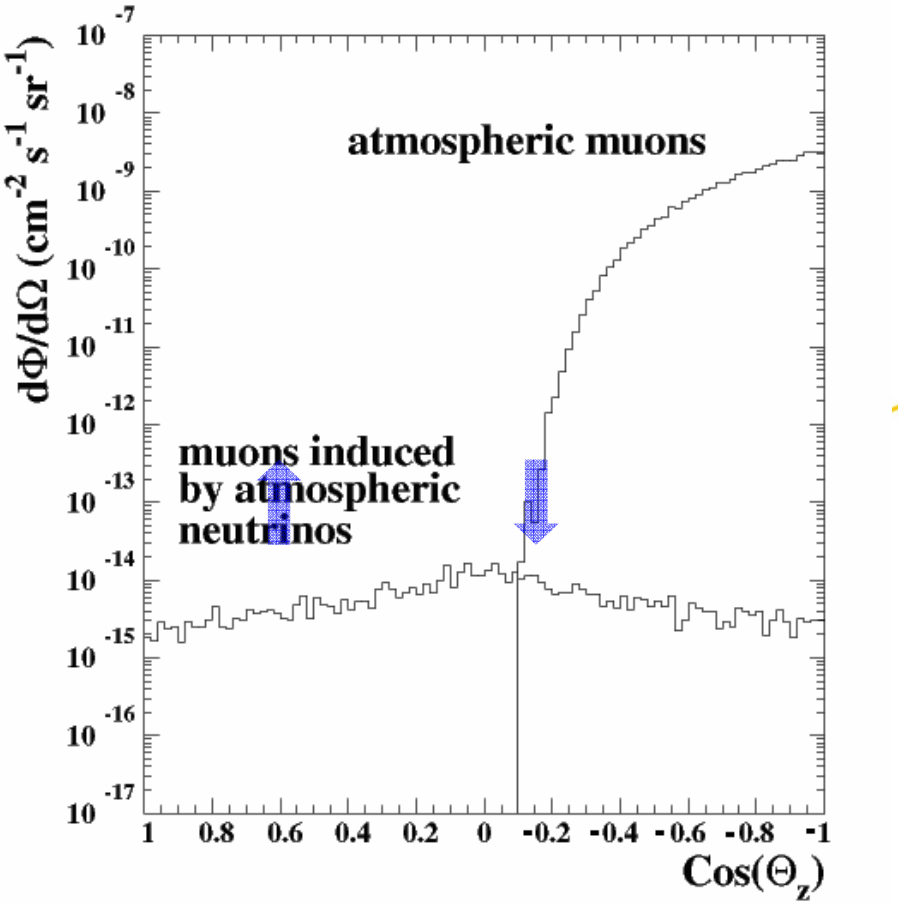
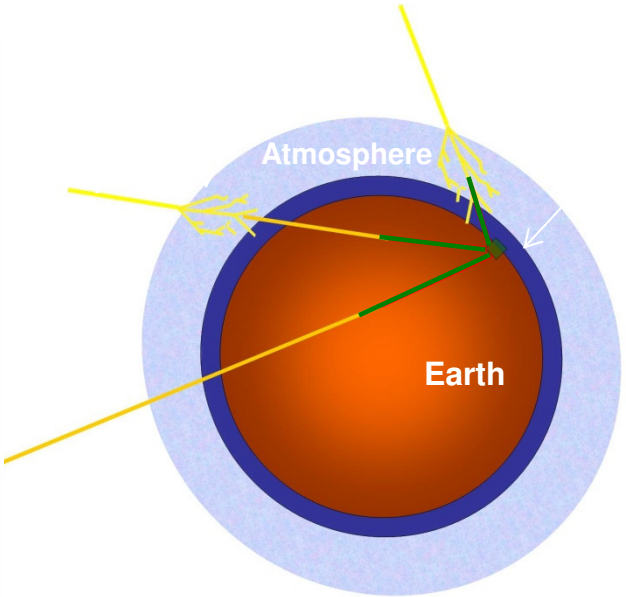
Expected limits for point-like sources



Background: atmospheric muons





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IceCube at the South Pole

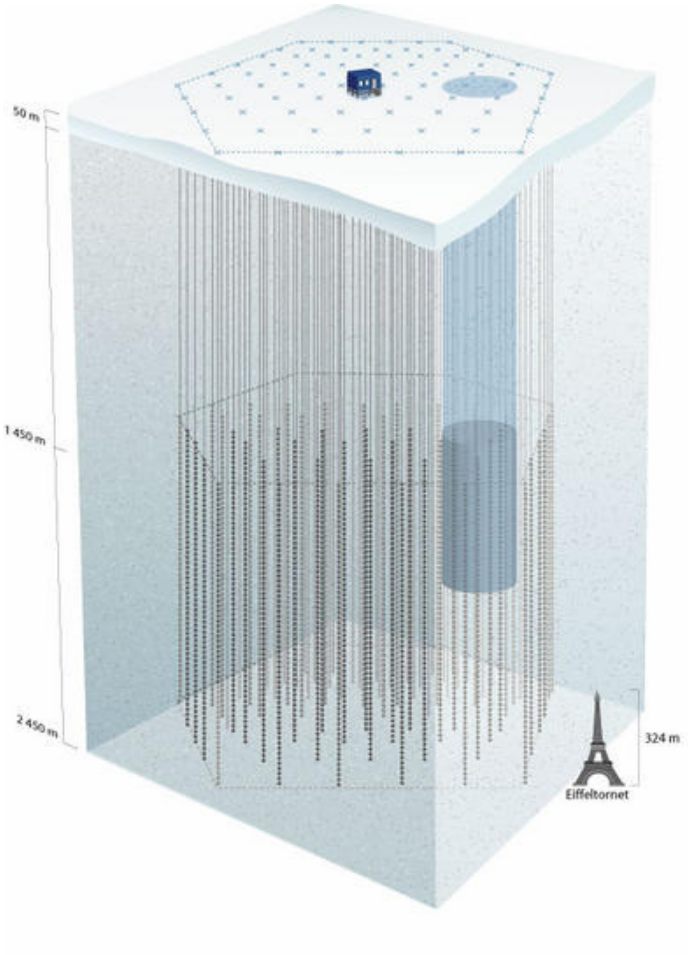
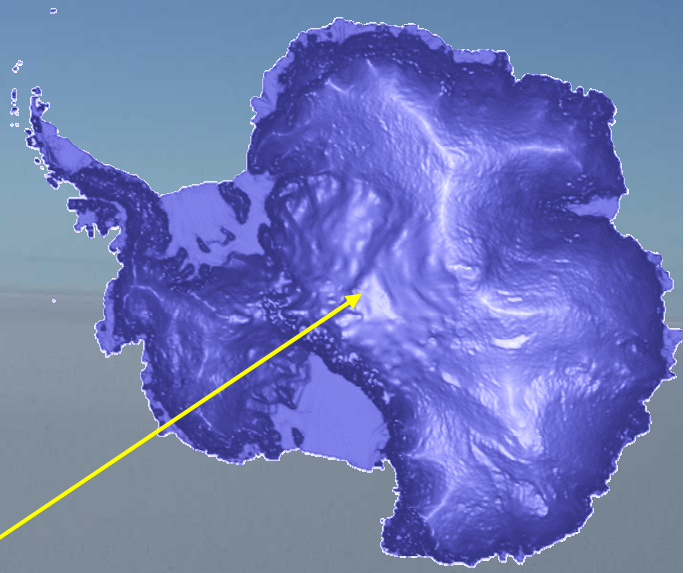


Foto und Zeichnung: IceCube Kollaboration

AMANDA / ICECUBE

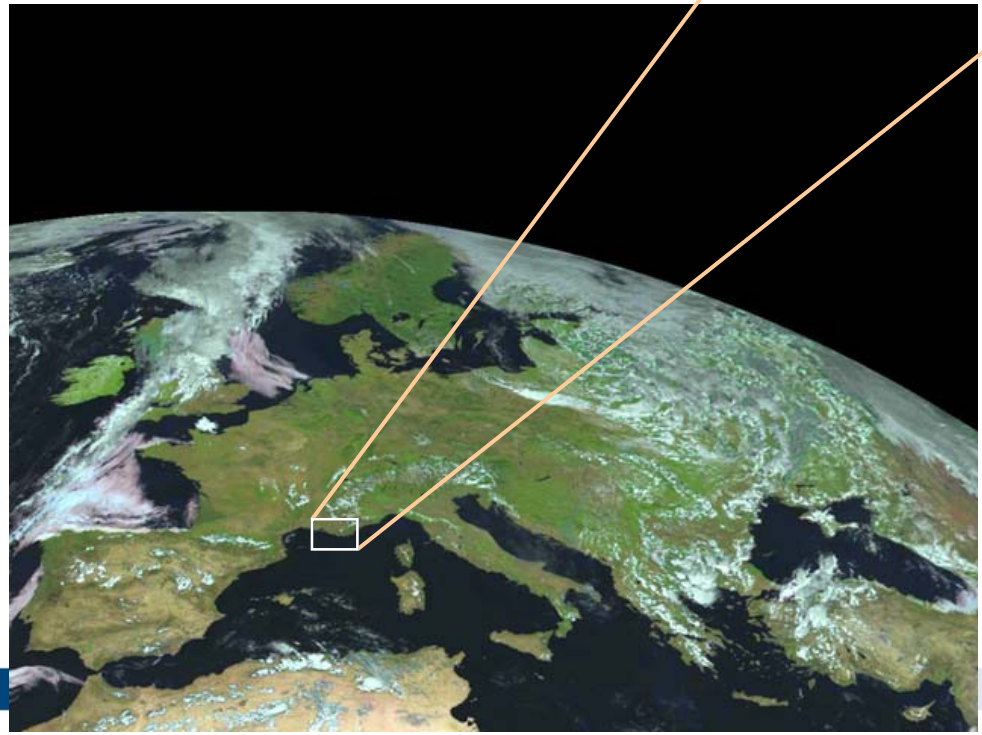
1993 First strings AMANDA A
1998 AMANDA B10 ~ 300 Optical Modules
2000 AMANDA II ~ 700 Optical Modules
2007 ICECUBE ~600 Optical Modules
2011 ICECUBE ~4800 Optical Modules

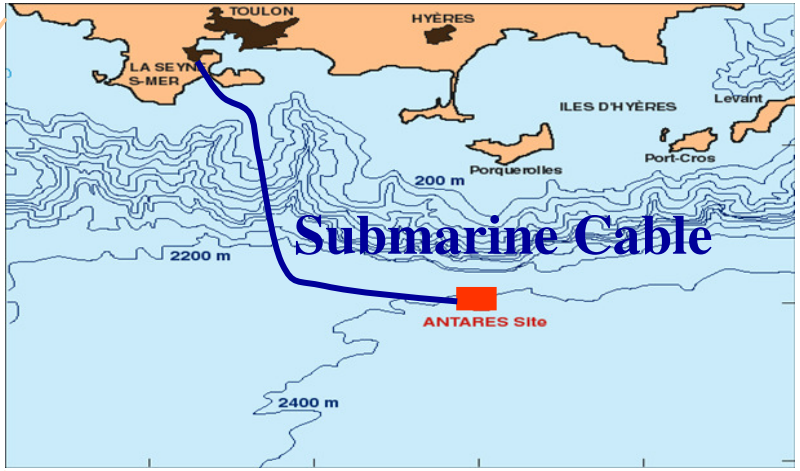


ANTARES Site

Location: Toulon (France)
42°50'N, 6°10'E

Depth: 2500 m





Shore station : La Seyne sur Mer

Control room: Institute Michel Pacha

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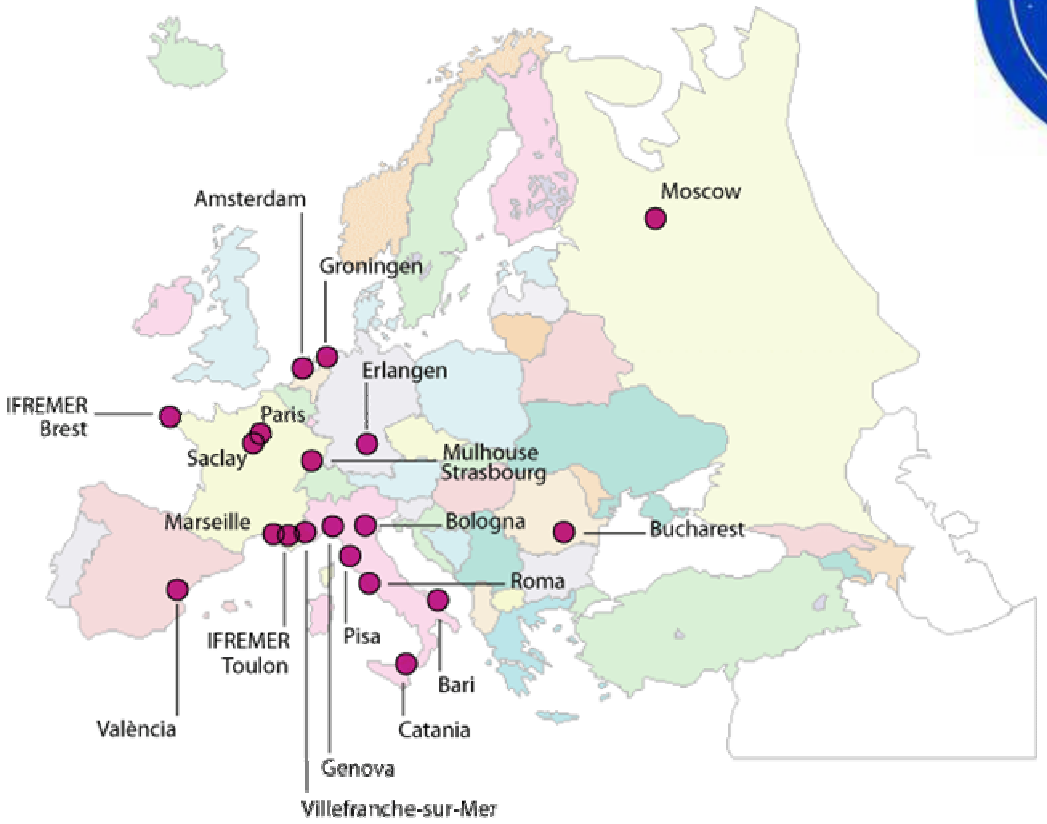
The ANTARES Collaboration



23 institutes in 7 European countries

ANTARES Detector

350 m

storey

14.5 m

100 m

~70 m

Anchor/line socket

cable to shore

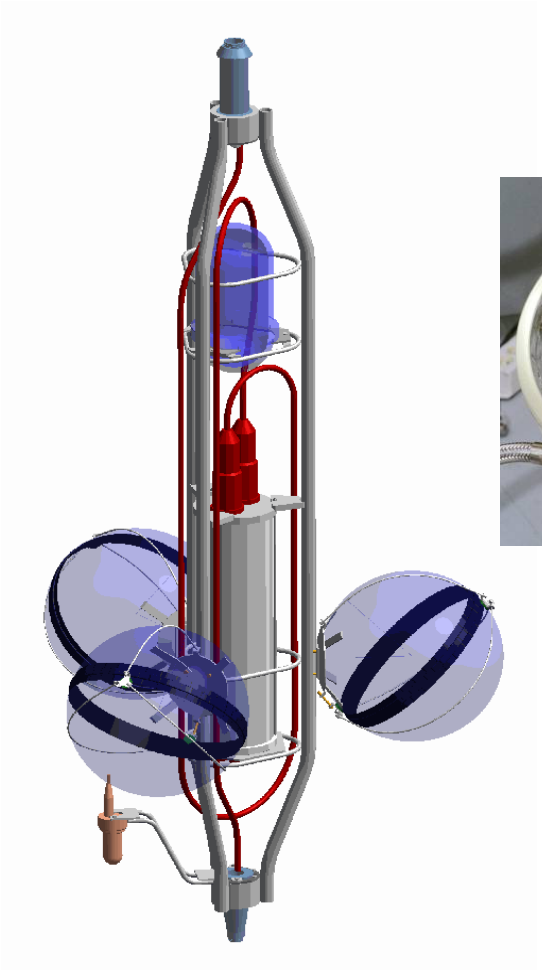
2500m depth

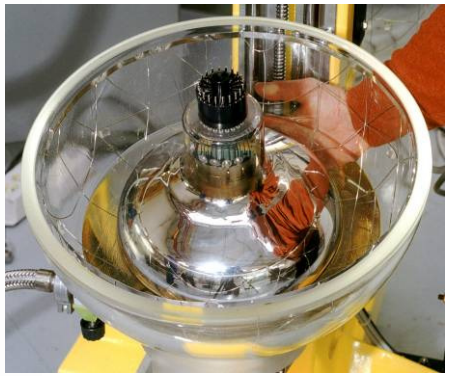
Junction Box

Link cable

P. Vernin from F. Montanet

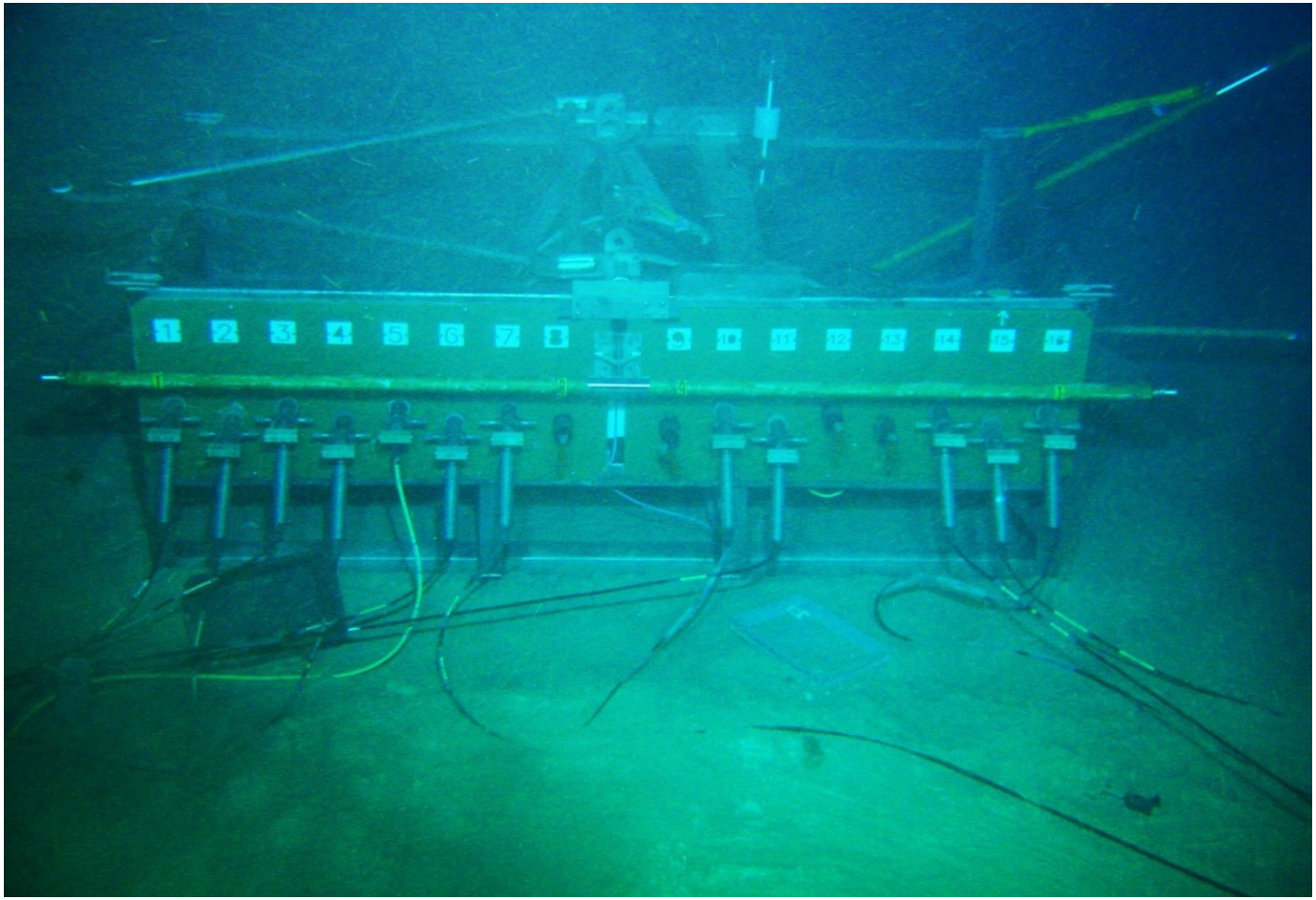
The „Eyes“ of ANTARES





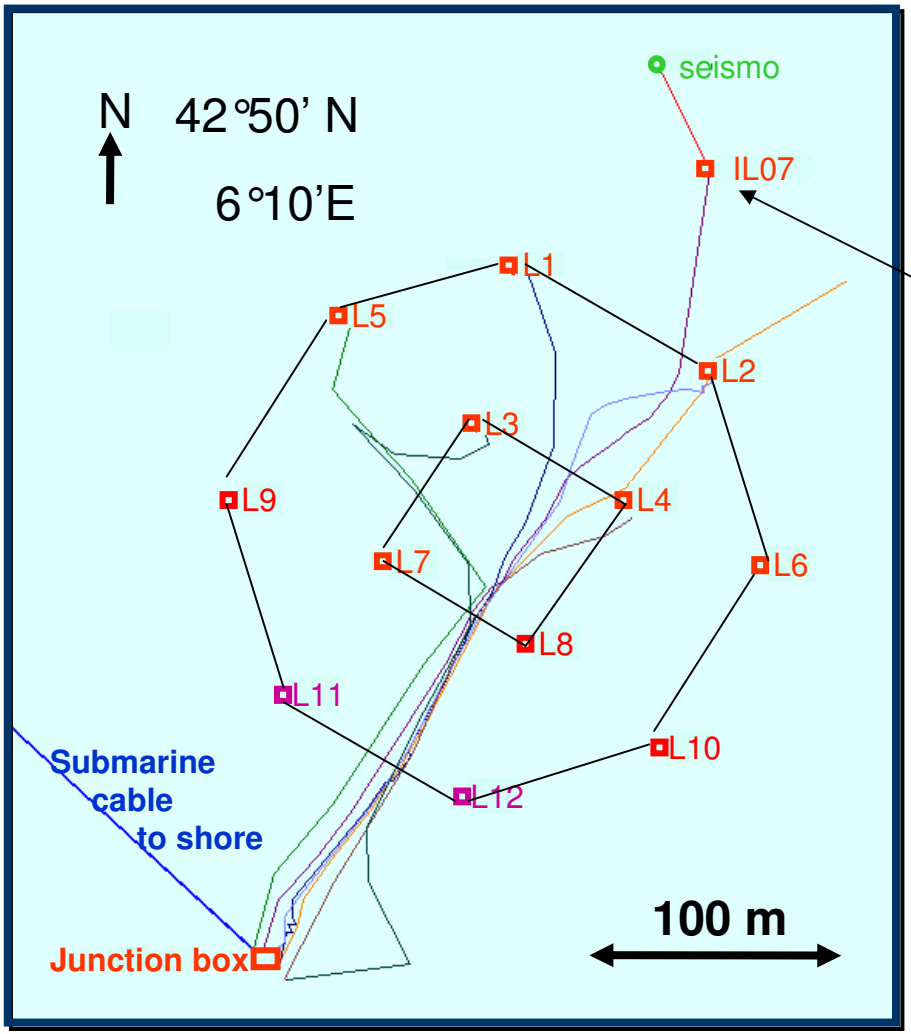
Deployment/ Connection

Line Connection



The Junction Box at the Main Electro-Optical Cable

Status: Detector complete since May 30, 2008

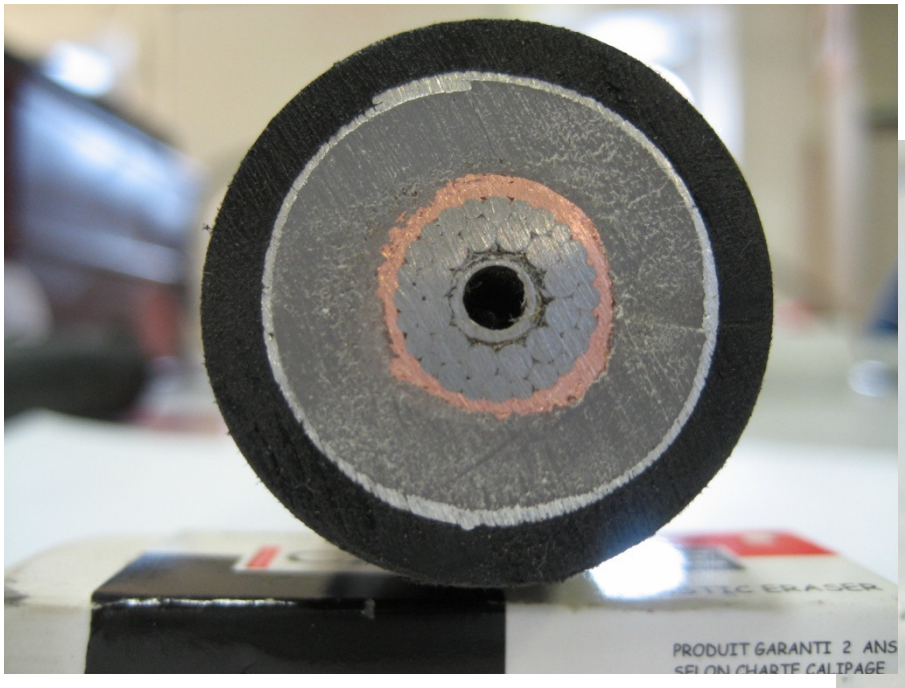


12 lines with 900 PMTs

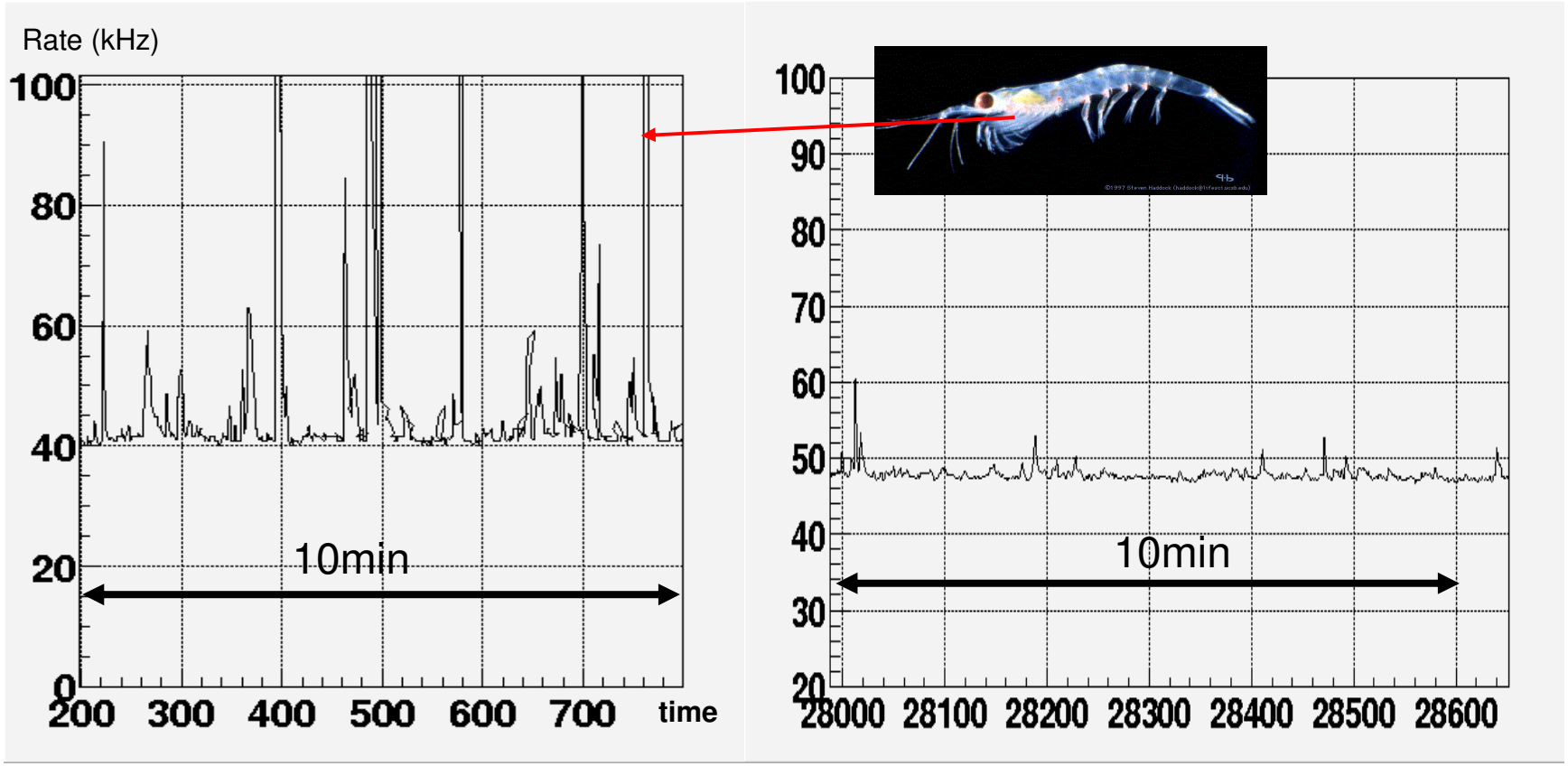
and

1 instrumentation line IL07 for the control of environmental parameters (e.g. sea current, temperature, ...)

Damage of Main Cable in June 2008



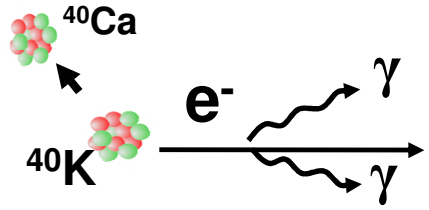
Photon rates



Optical background rates

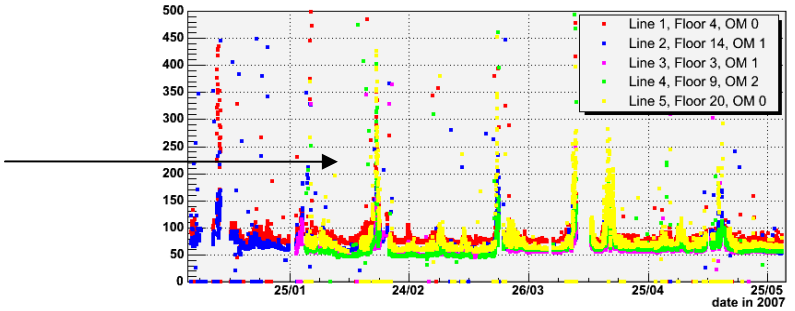
Dominated by 2 effects

1. β – decay of ^{40}K



2. bioluminescent organisms

e.g.



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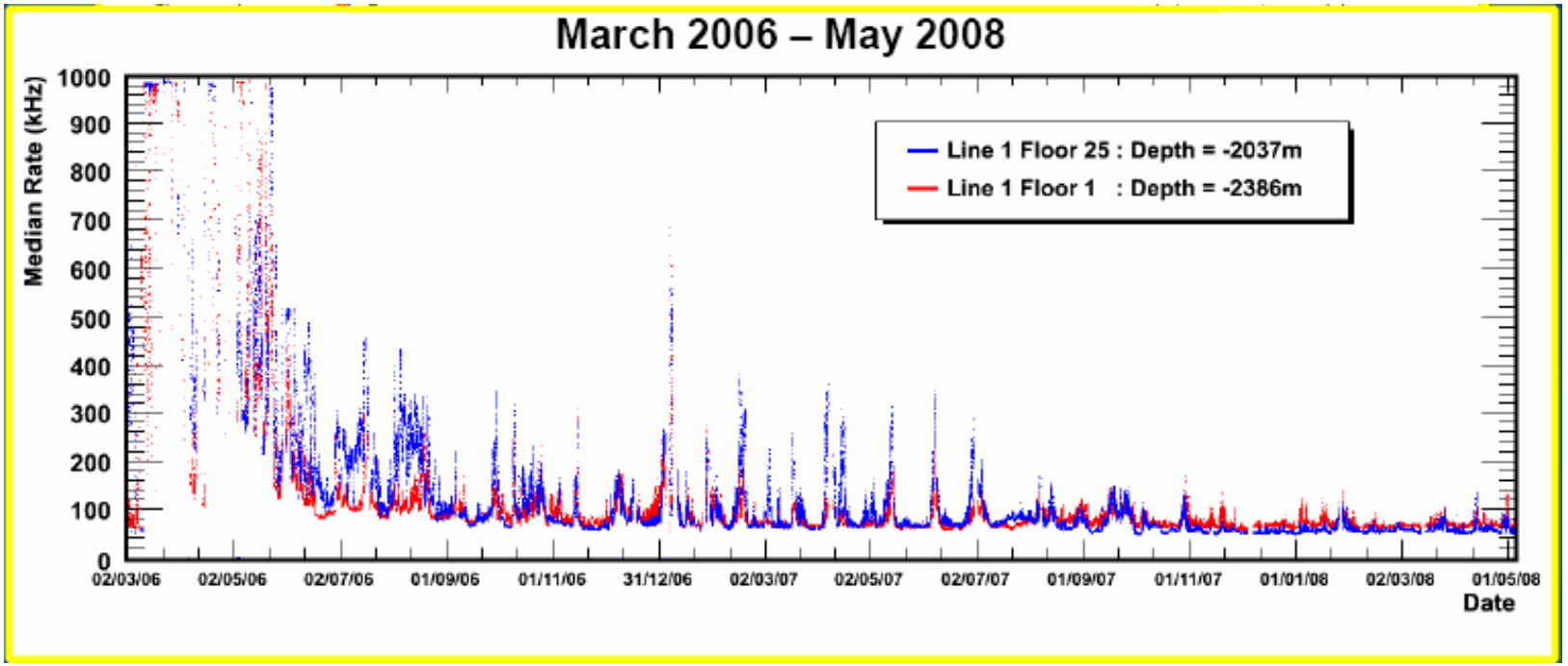
Photon rate



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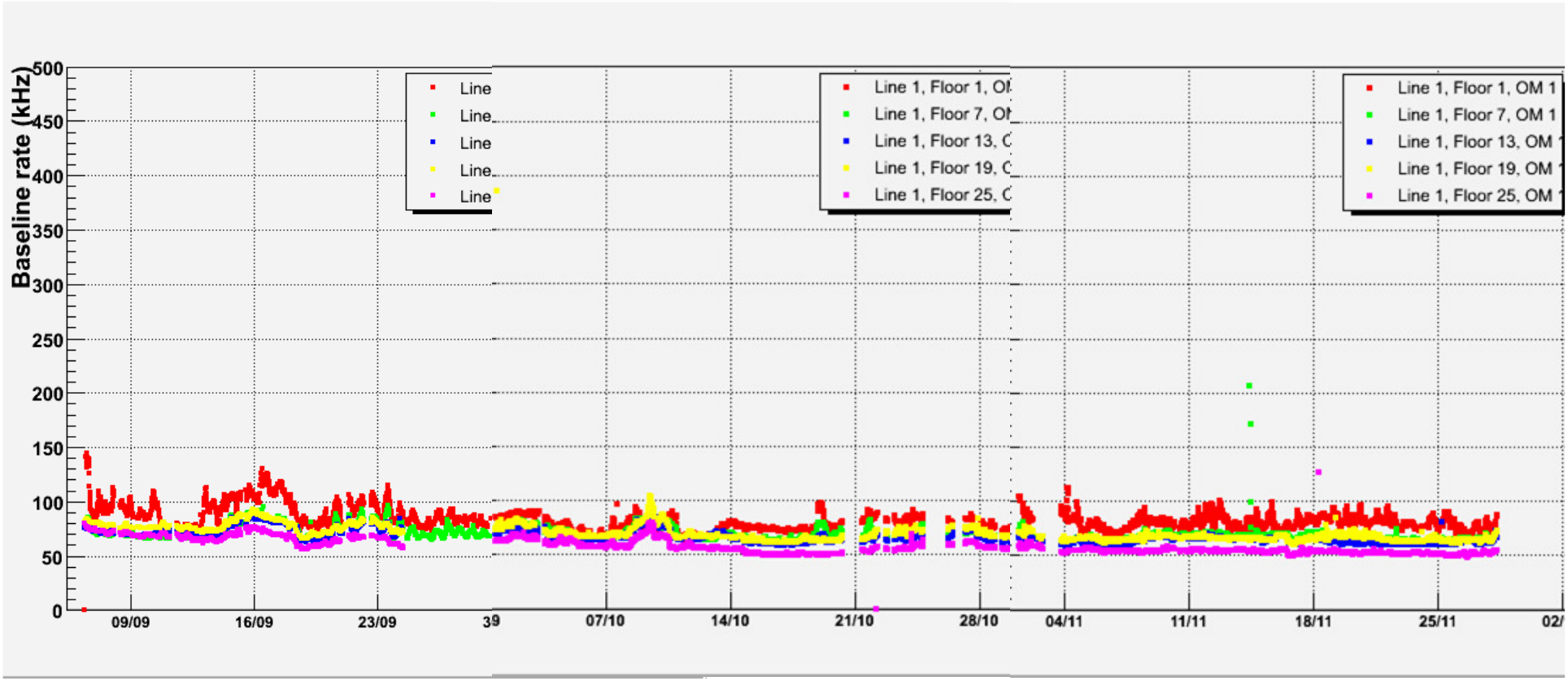
Photon rate



September 2008 October 2008 November 2008

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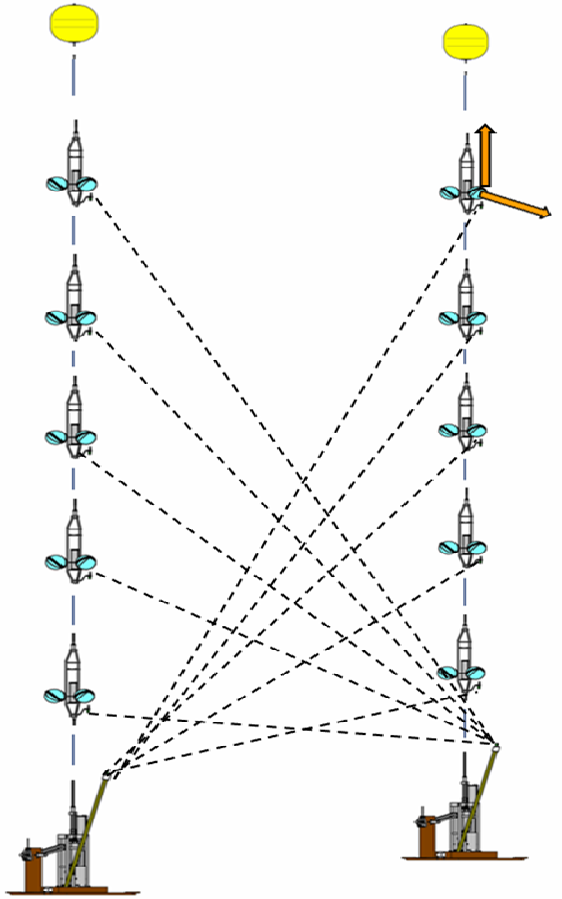
Positioning and Heading

Determination of line shape and of module coordinates once per minute by

1. Acoustic triangulation

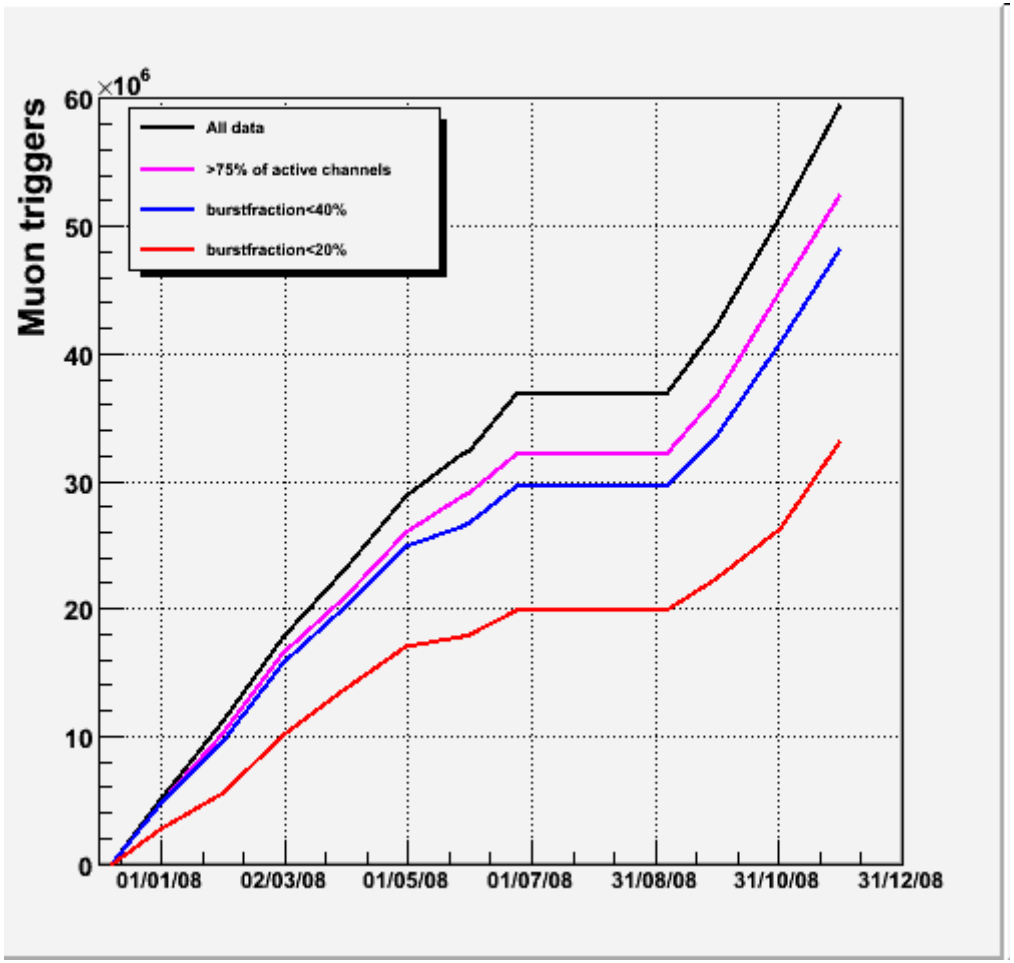
1. Compass data of storeys: headings and tilts



Data Quality

- **Trigger rate**:
  ~10 Hz (12 lines)

- **Detected muons**:
  19×106 (with the 5 Lines)
  60 ×106 (full detector)



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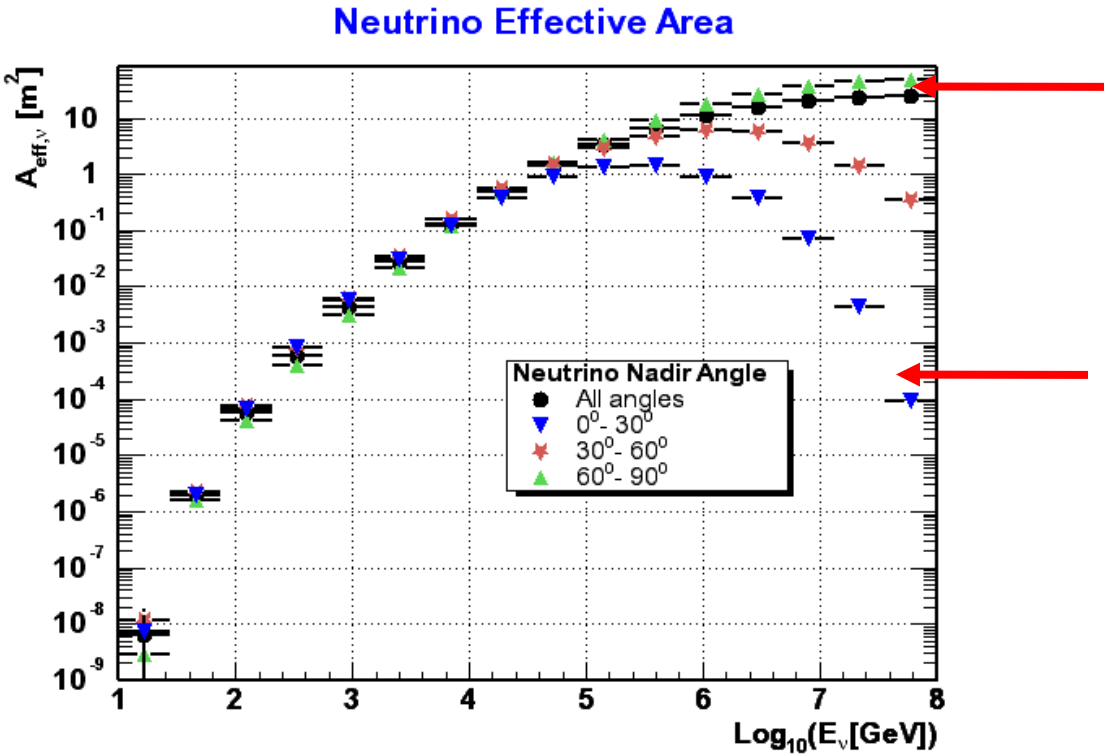
Neutrino effectice area



$$\text{Event rate} = \int (\text{neutrino flux}) \times (\text{neutr.eff.area})\ dE_\nu$$

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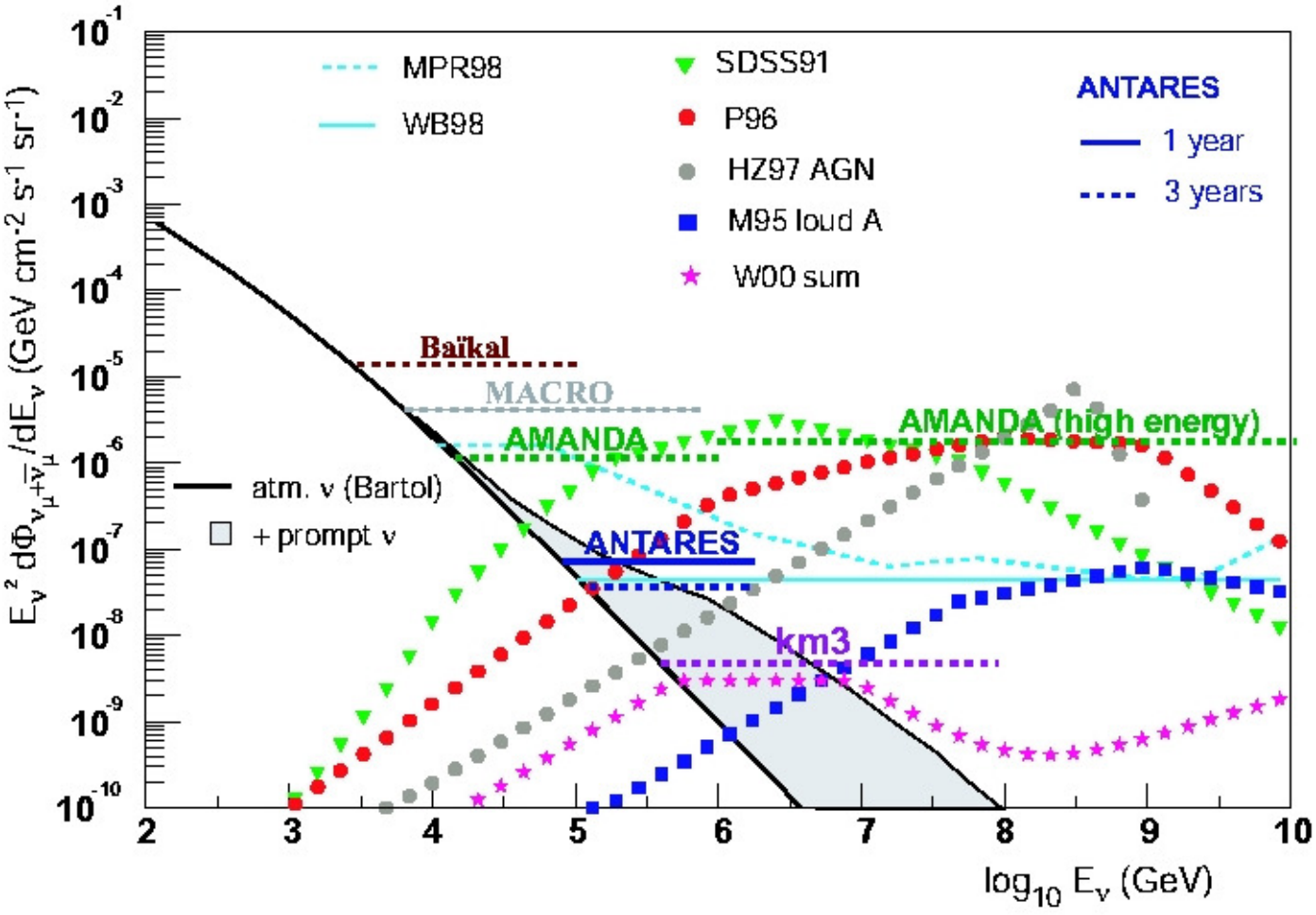
Neutrino diffuse flux sensitivity



90% cl

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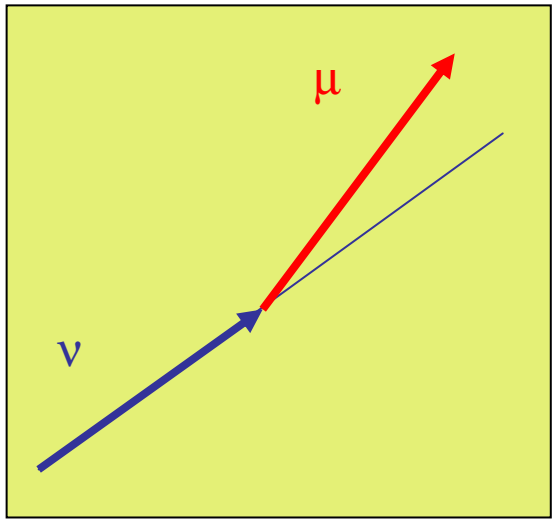
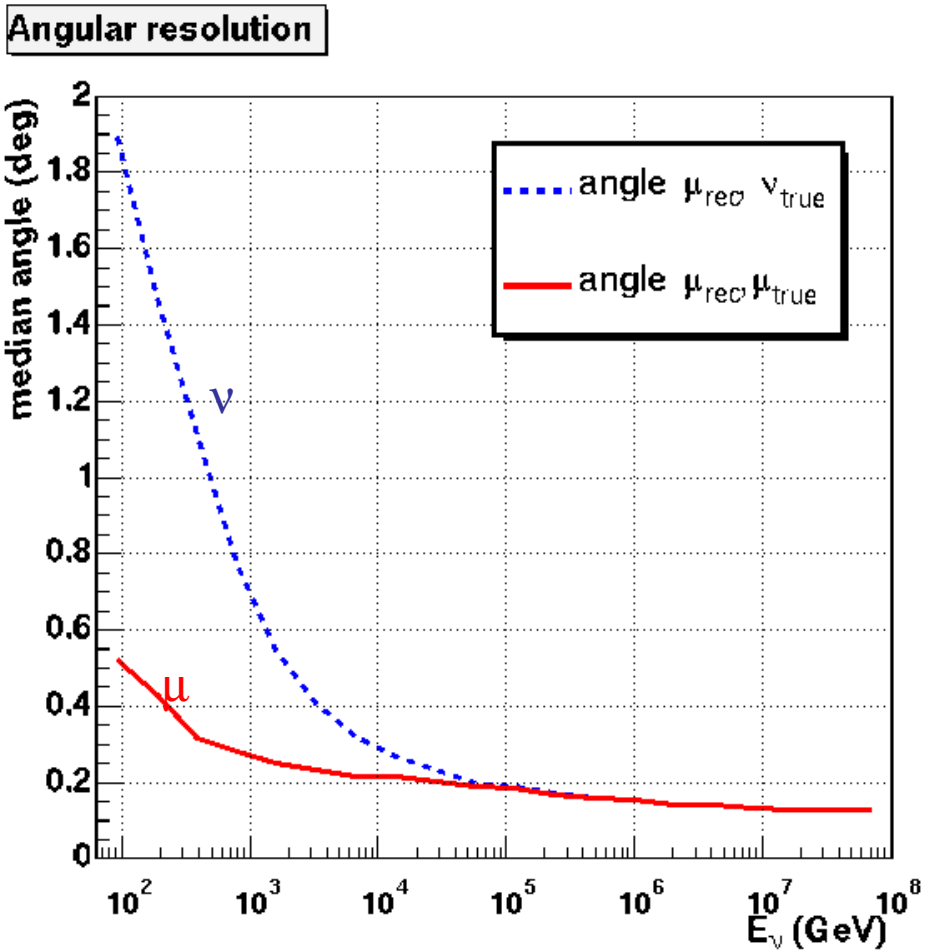
Angular resolution





for high energies:

$\sigma_\theta < 0.3^o$

(Quality of water!)

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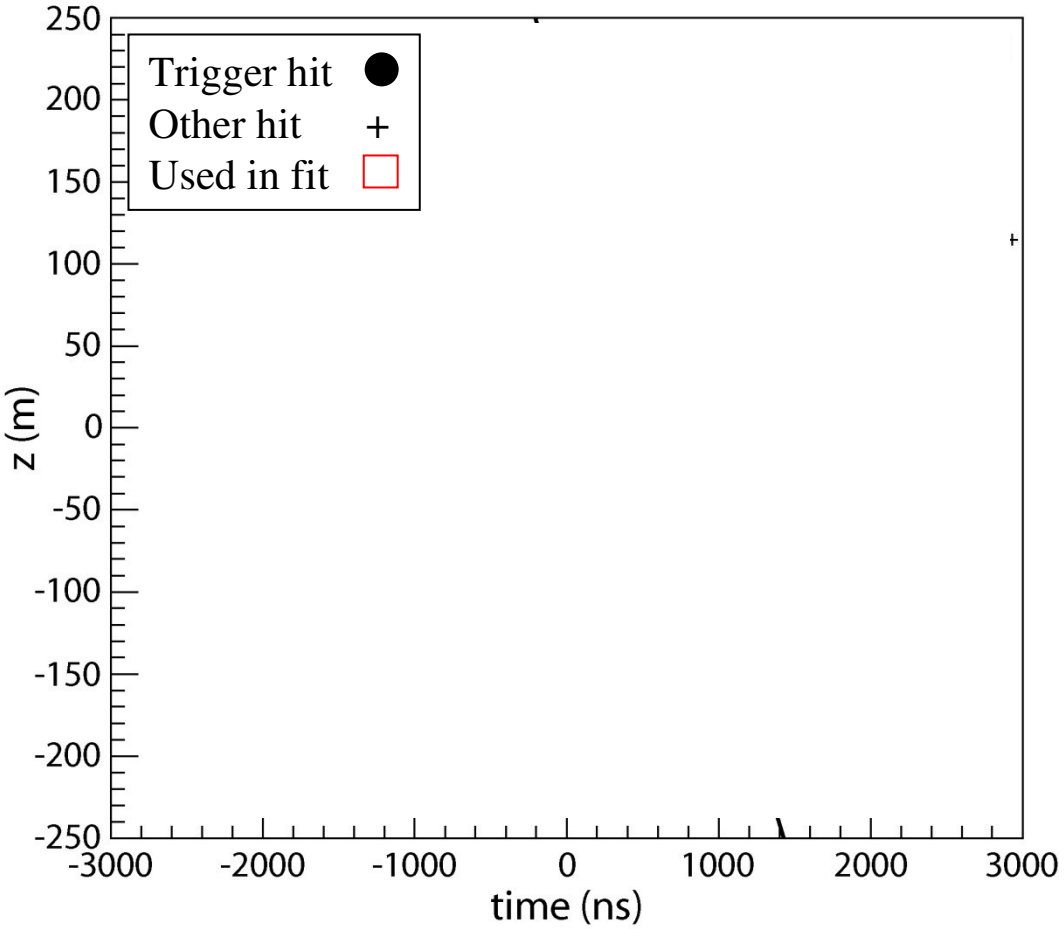
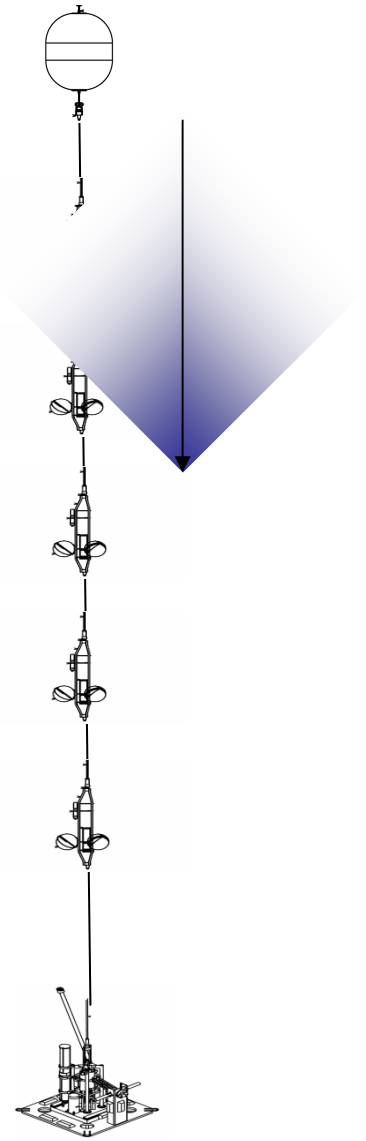
Downward going Event





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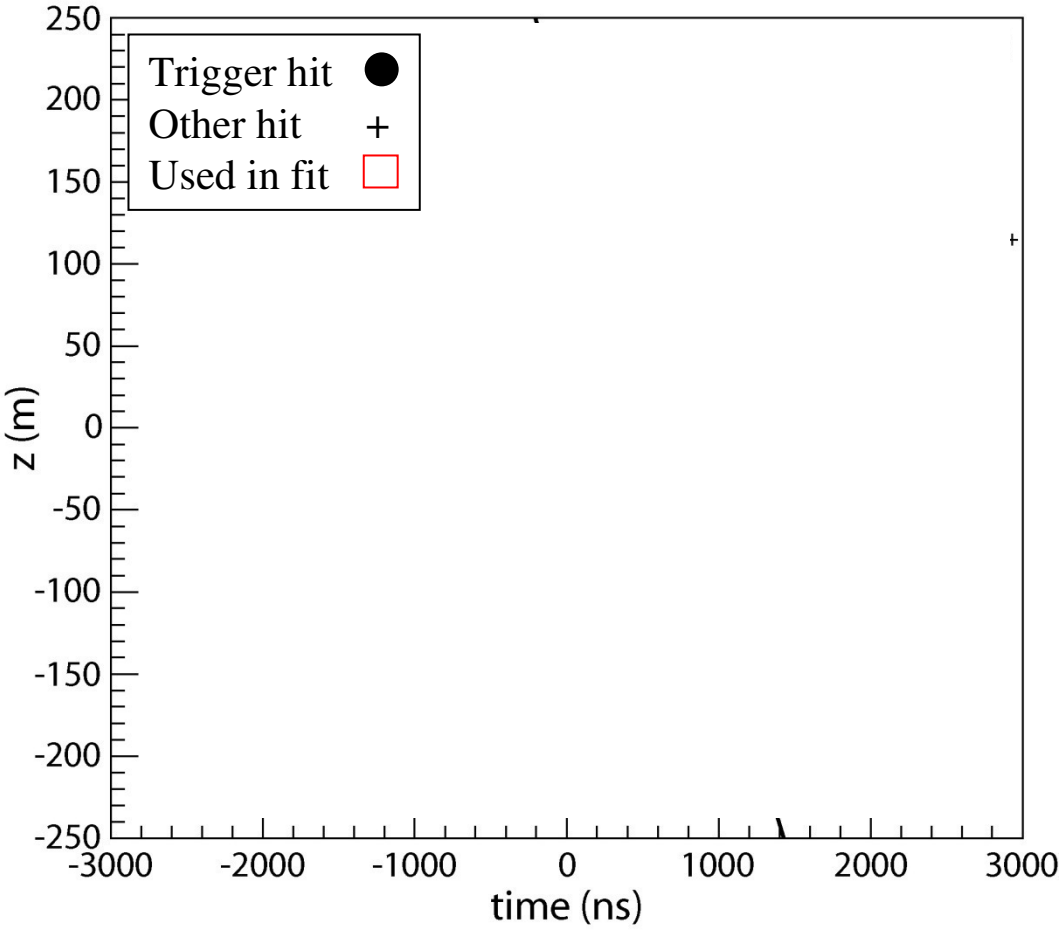
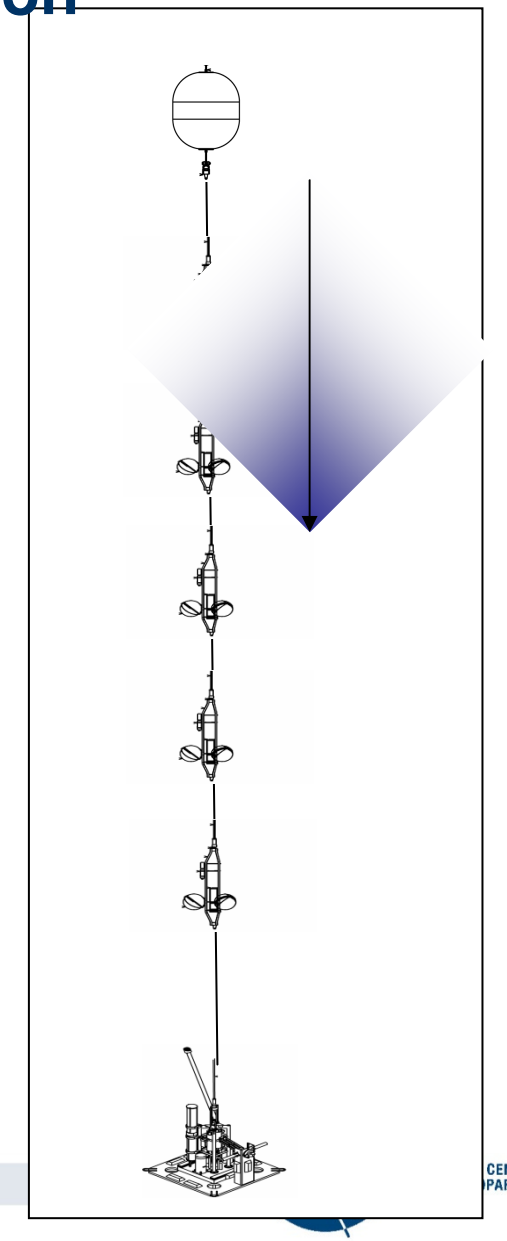
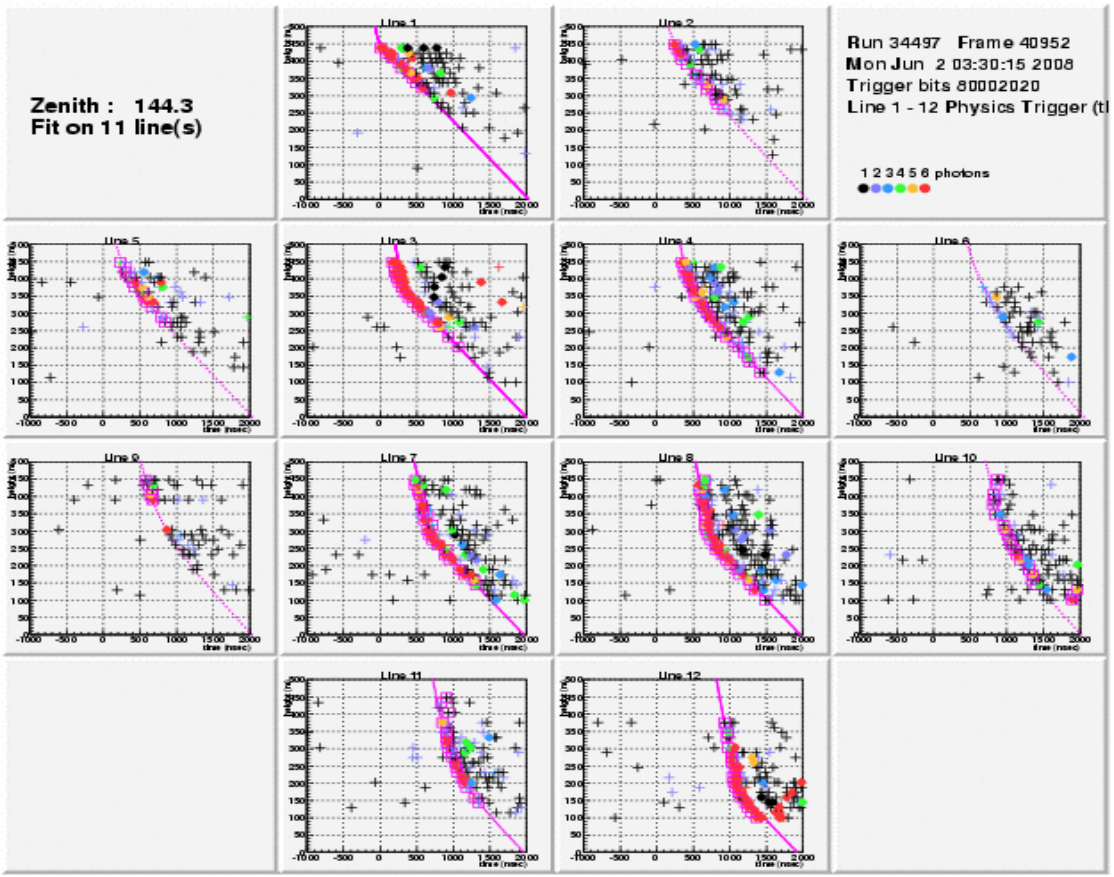
Event Display: Downward going Muon



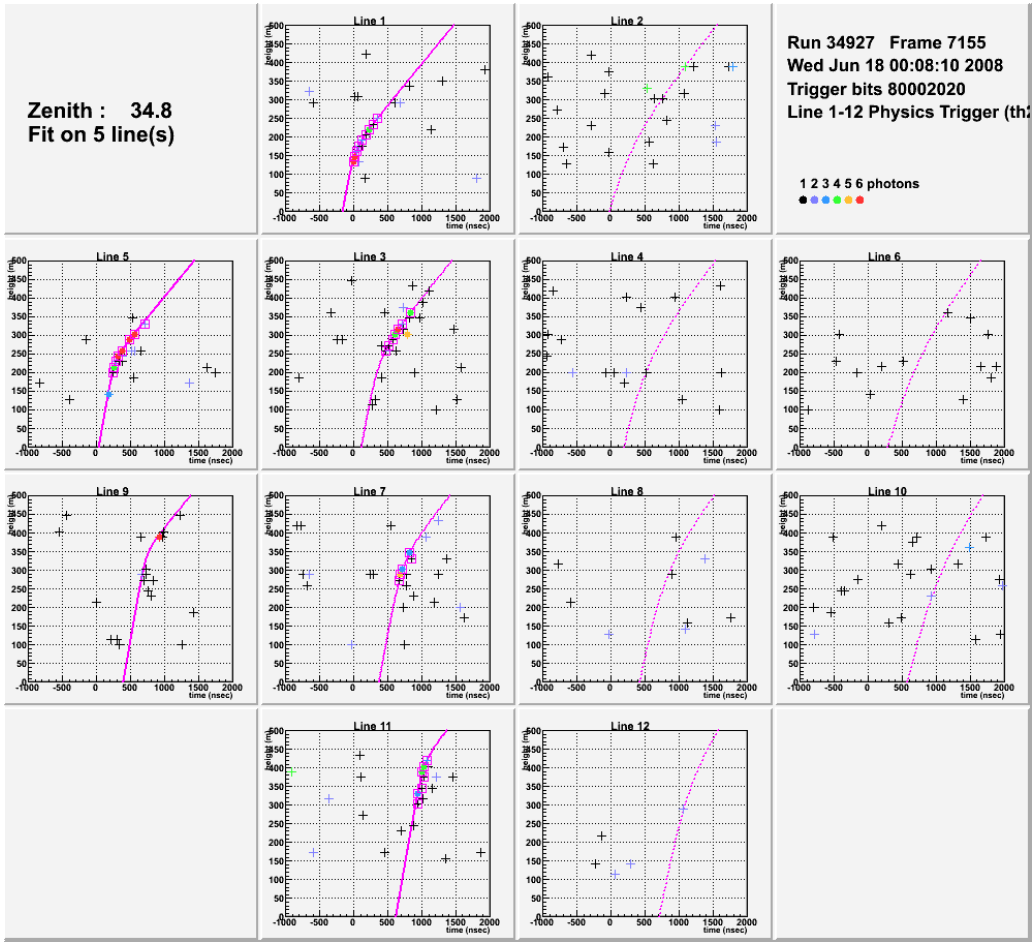


Downward going Event

Bright muon bundle event !



Upward going track



Neutrino candidate

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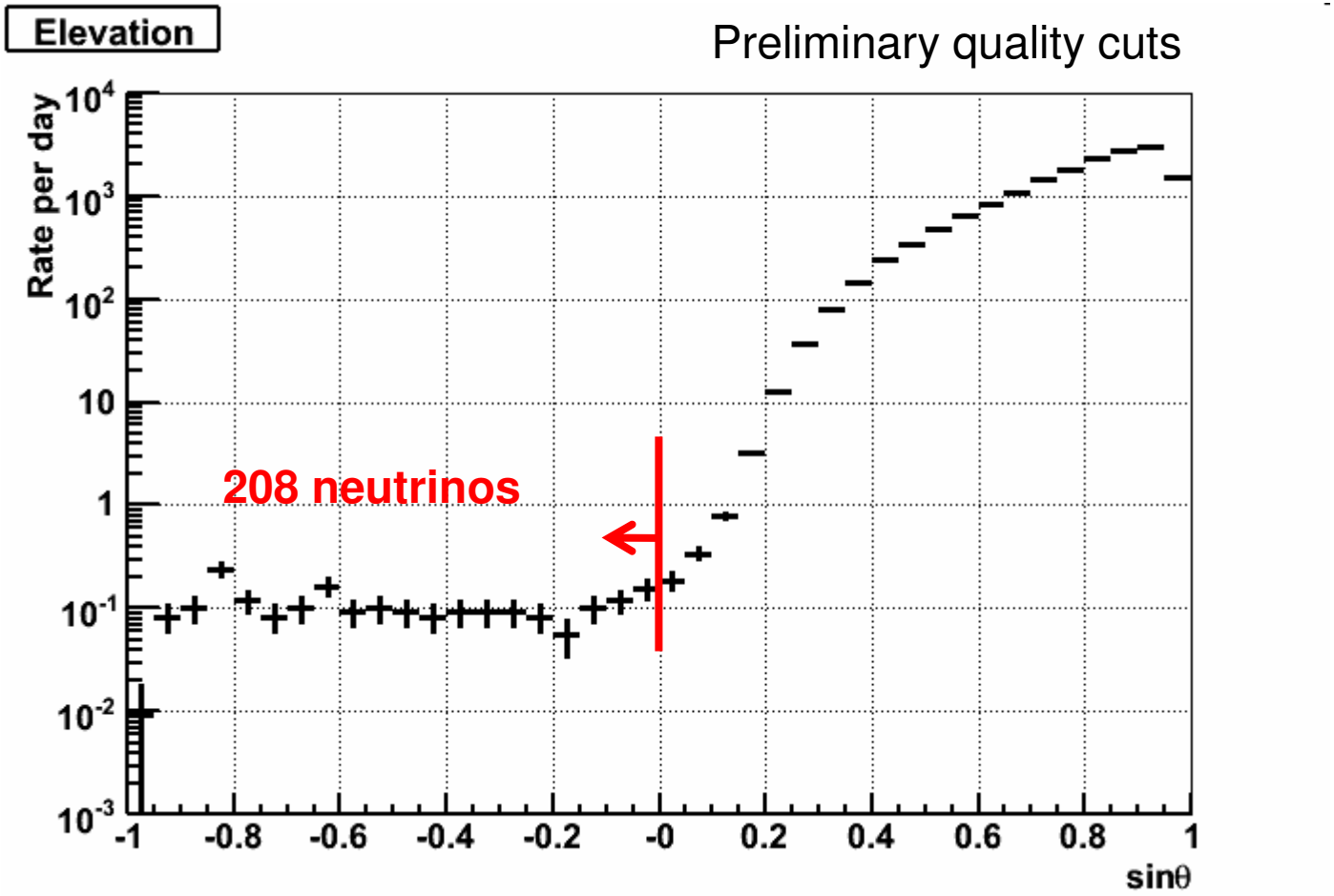
Preliminary analysis of 10 line data



Dec 2007 – Apr 2008 : 100 days live time

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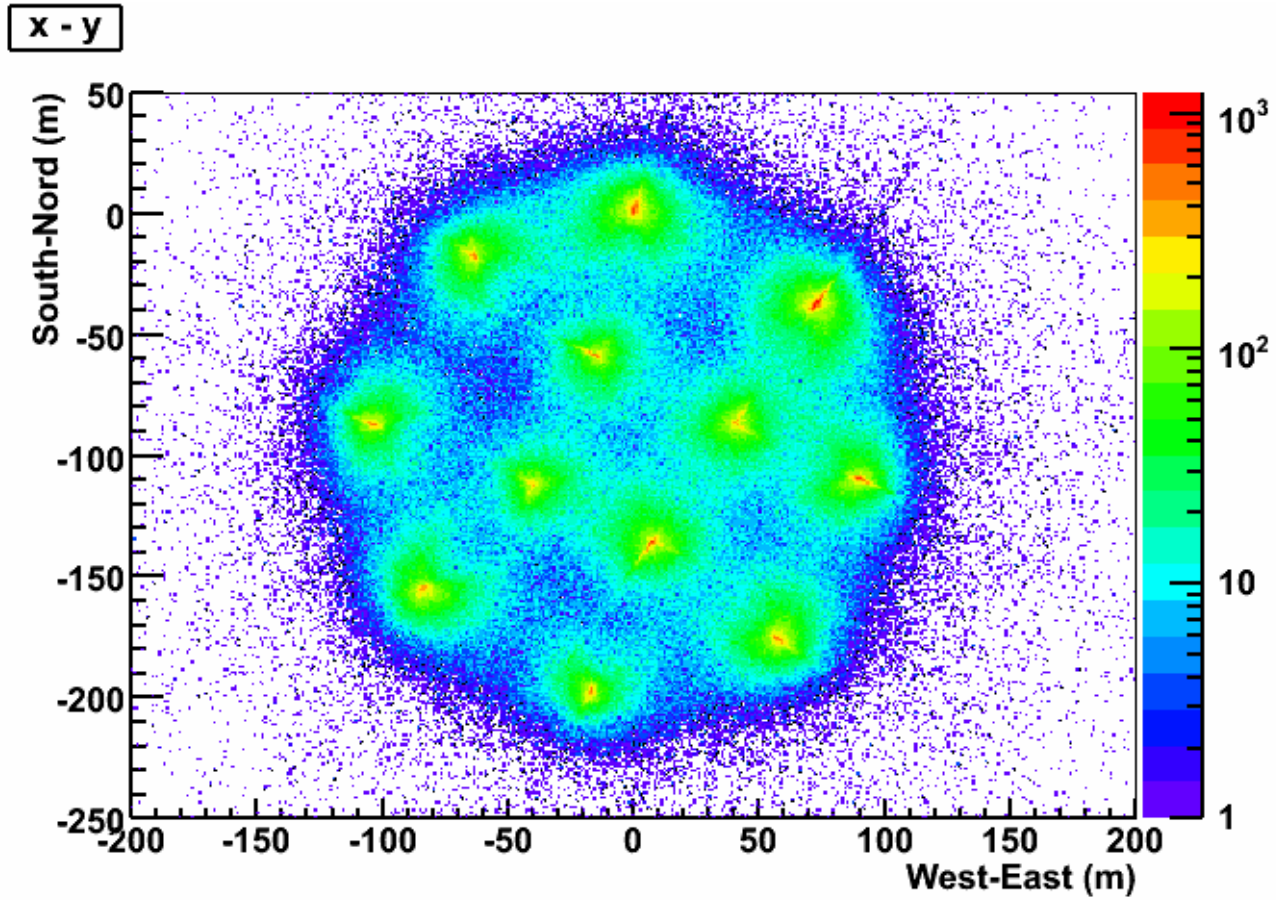
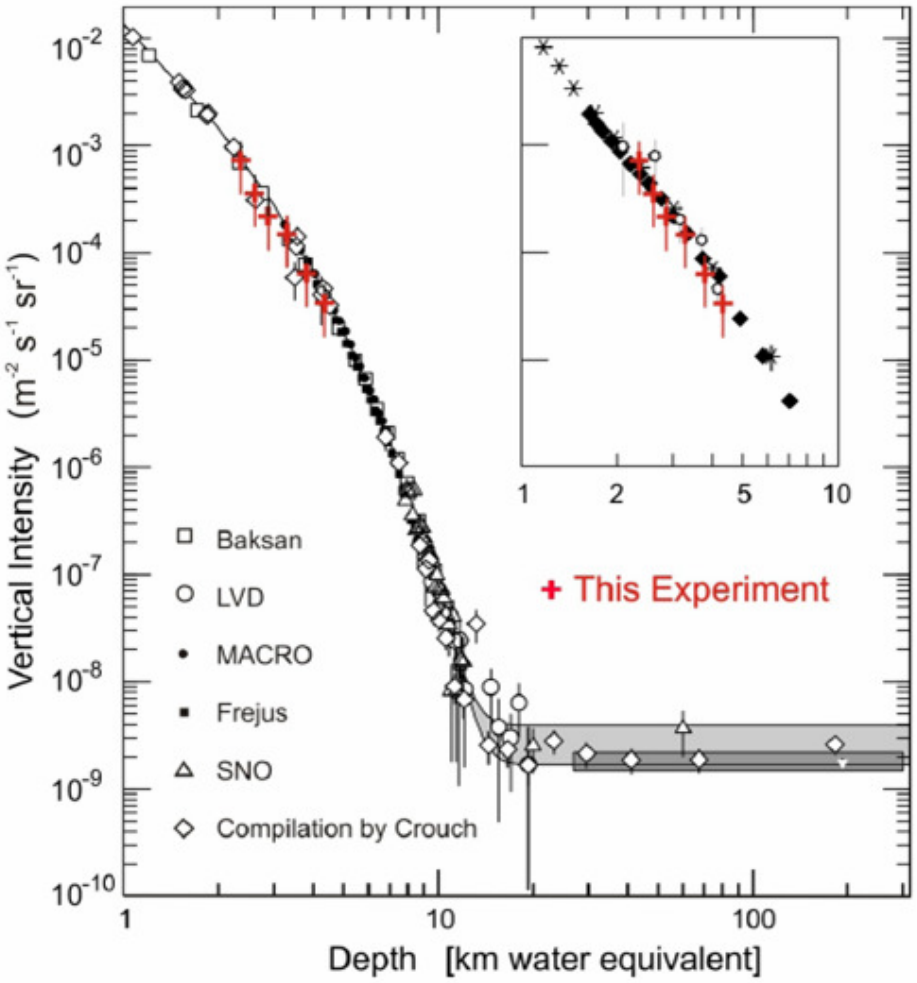
Detector Footprint



Reconstructed position of muon track at time of first triggered photon

Muon Intensity versus Depth



Effective depth due to angle of muon track

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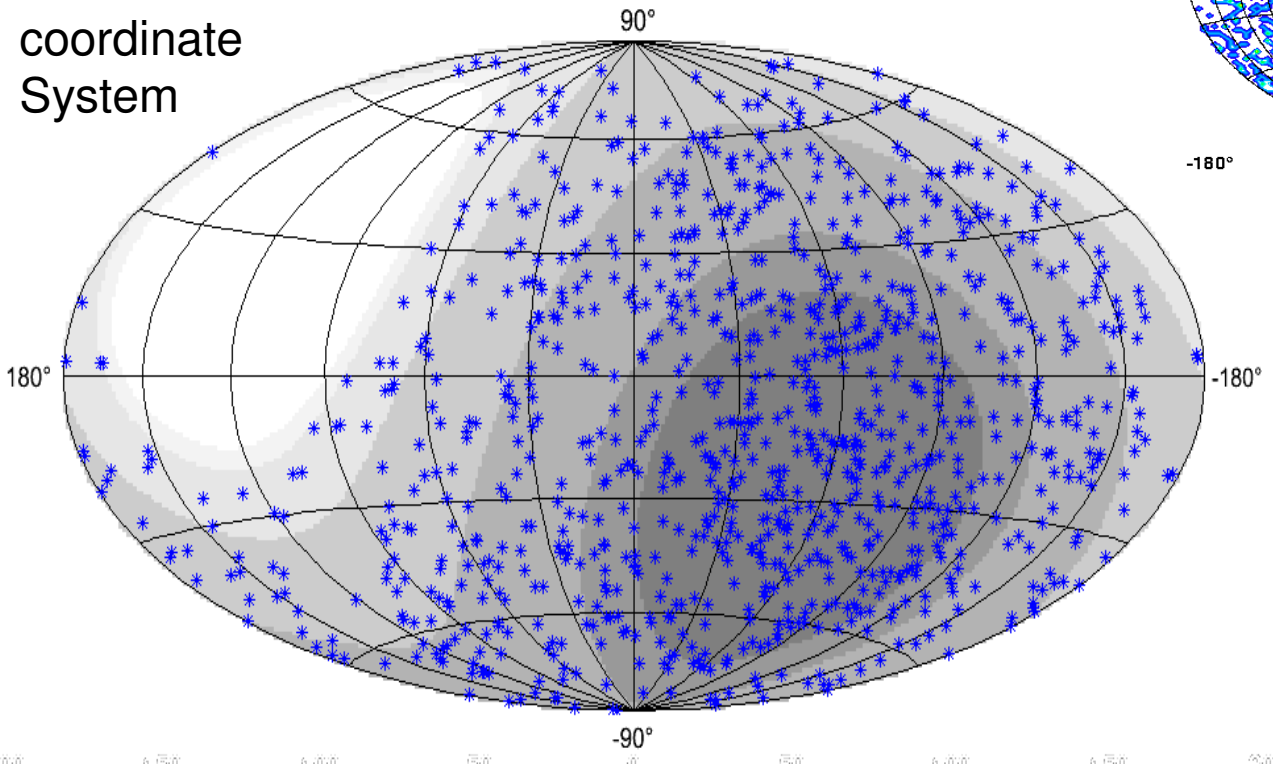
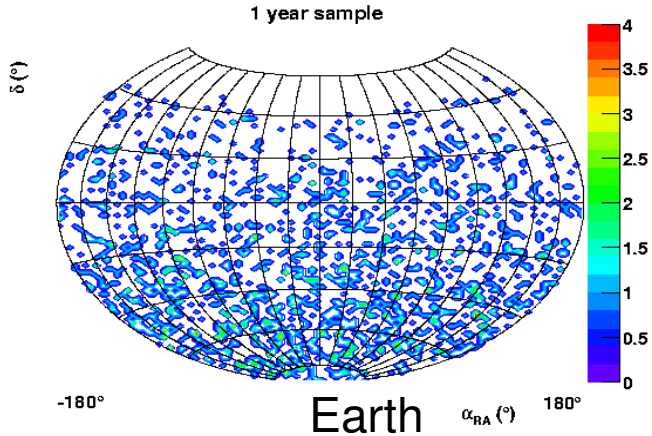
Sky Map of 1000 Neutrinos

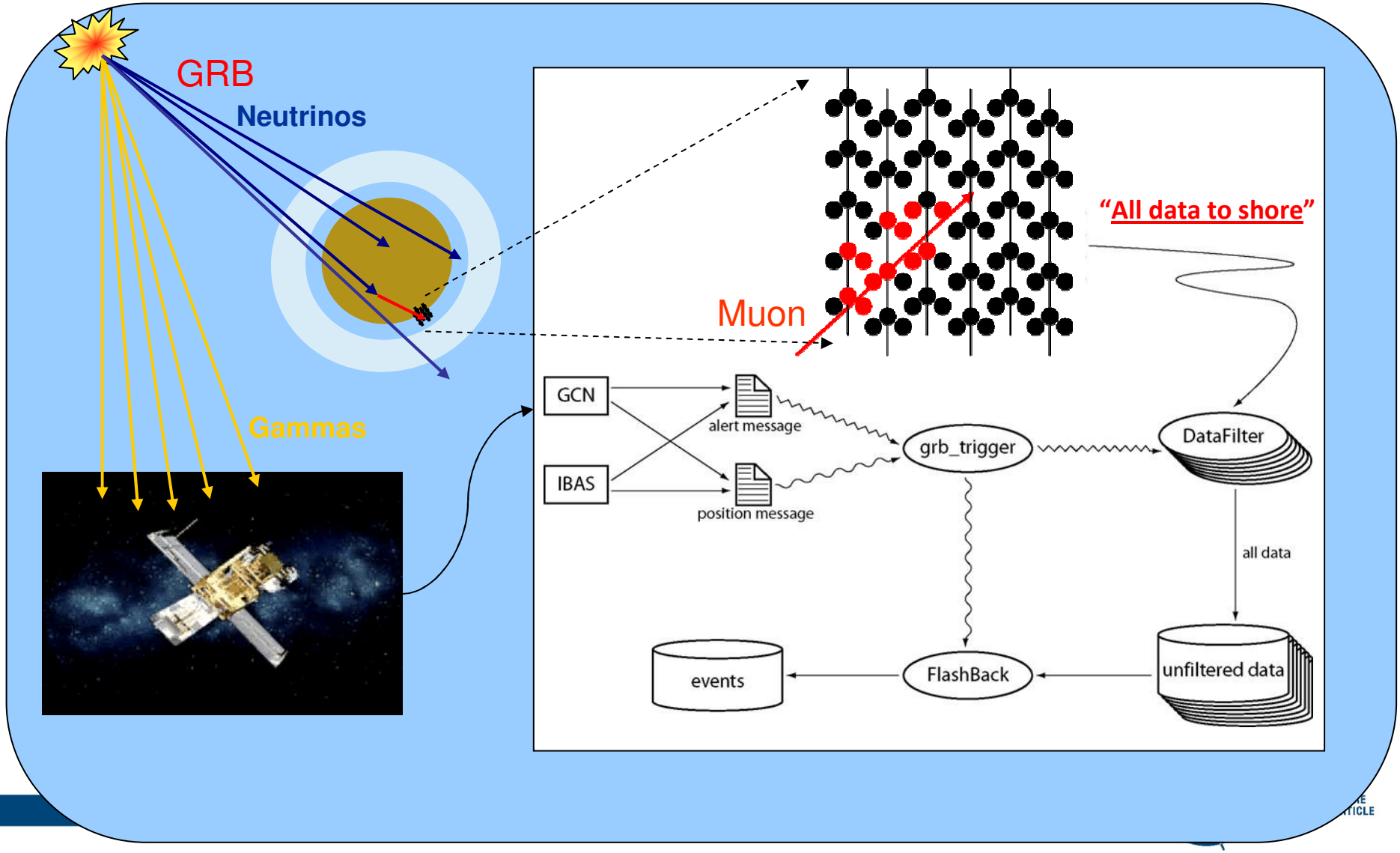
Galactic coordinate System





Earth coordinate System

Triggered search of transient sources



Neutrino Alerts

Collaboration with the TAROT telescopes array

TAROT: two 25 cm telescopes located at Calern (South France) and La Silla (Chile)

- fov 1.86° x 1.86°
- Magnitude V<17 (10s)
  V<19 (100s)
- ~ 10s repositioning after the alert reception

TAROT La Silla

Observation strategy:

Real time (T_0) 6 images of 3 minutes

T0+1 day, +3 days, +9 days and +27 days

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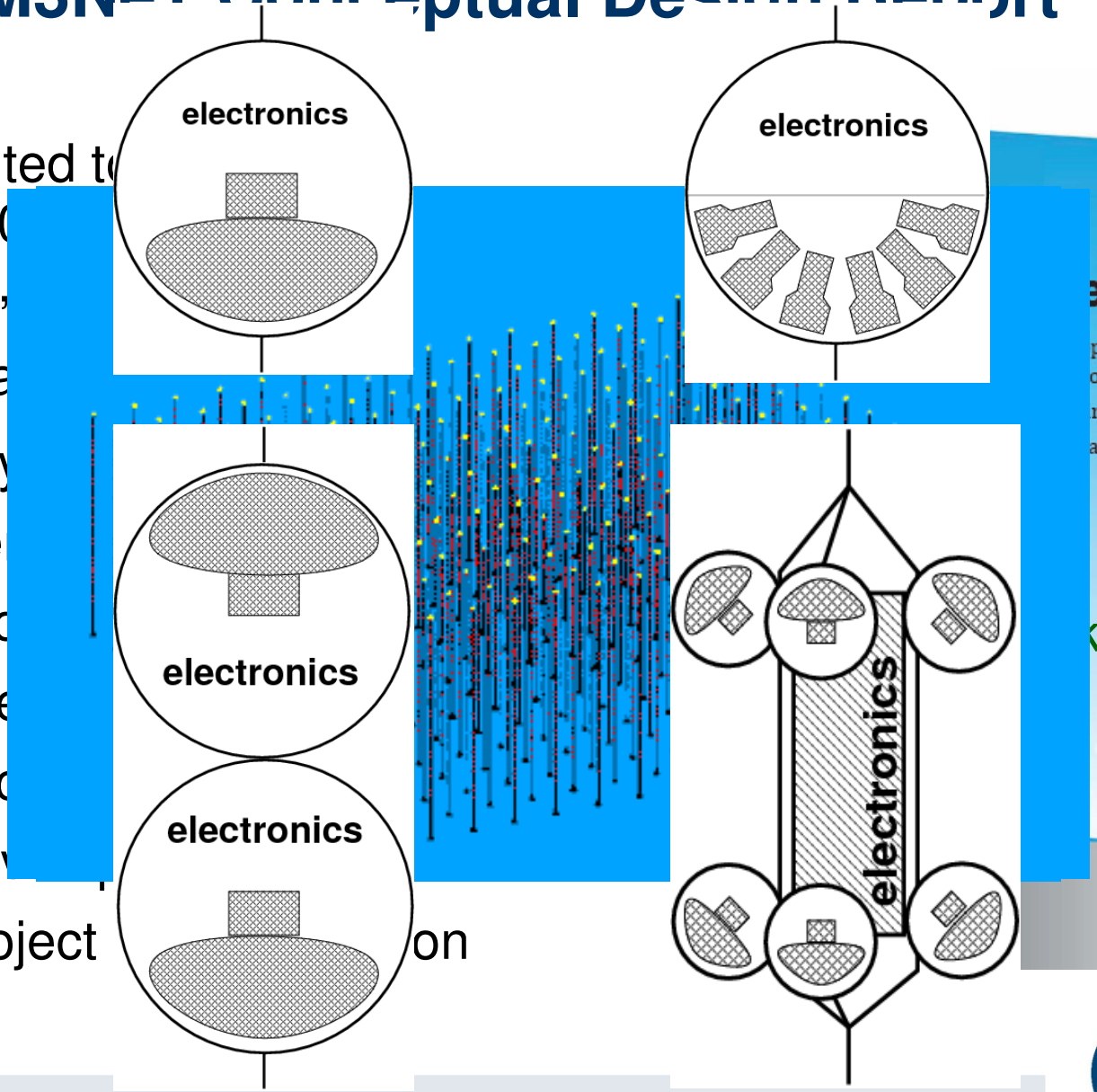
What is KM3NeT ?

- Future cubic-kilometre scale neutrino telescope in the Mediterranean Sea based on expertise of all pilot projects: ANTARES, NEMO and NESTOR
- EU-funded design study (9M €, 2006-2009)
- ESFRI roadmap project →Preparatory Phase (2008-2011)

- Exceeds Northern-hemisphere telescopes by factor ~50 in sensitivity
- Exceeds IceCube sensitivity by substantial factor
- Focus of scientific interest: Neutrino astronomy in the energy range 1 to 100 TeV

The KM3NeT Conceptual Design Report

- Presented t
  VLVnT
  Toulon,
- Summa
  - Phy
  - Ge
  - Pilo
  - Site
  - Tec
  - De
  - Project on



ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Summary

- Full ANTARES detector in operation
- Continous data taking
- First sky plot
- Cooperation with other telescopes
- Future: KM3NeT

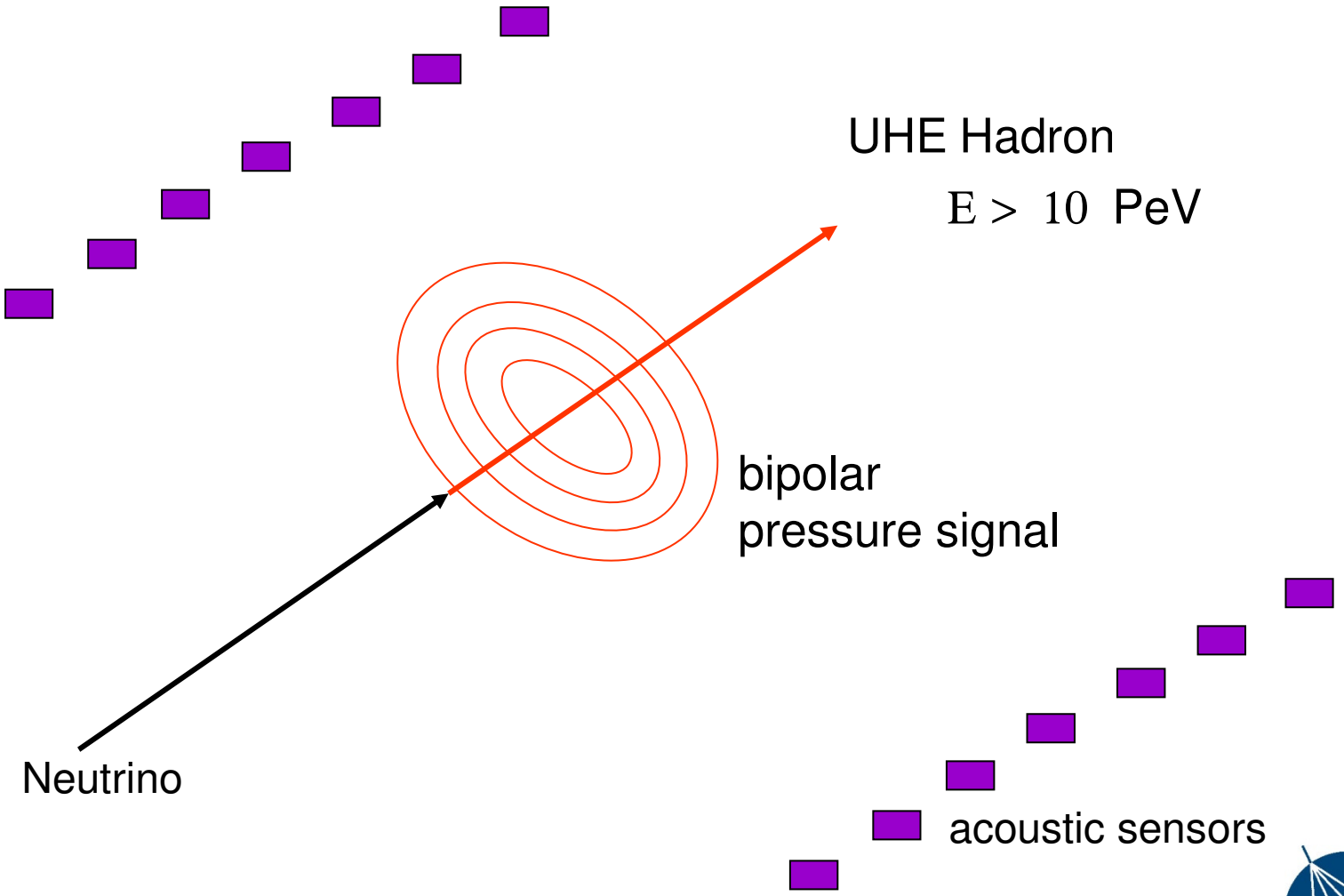
Summary

- ANTARES is complete and
  the first operational deep-sea neutrino telescope
- Technology is proven
- Detector and Calibration is being understood
- Data analysis:
  - more than 1000 neutrino events selected
  - first physics publications expected soon

- Ready for next step with KM3NeT Detector …

A view from ANTARES control room

Acoustic particle detection



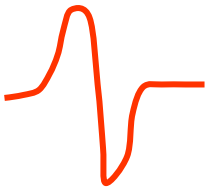
Acoustic particle detection

acoustic absorption length: ~ 1 km

optical absorption length: ~ 60 m

signal amplitude: ~ mPa

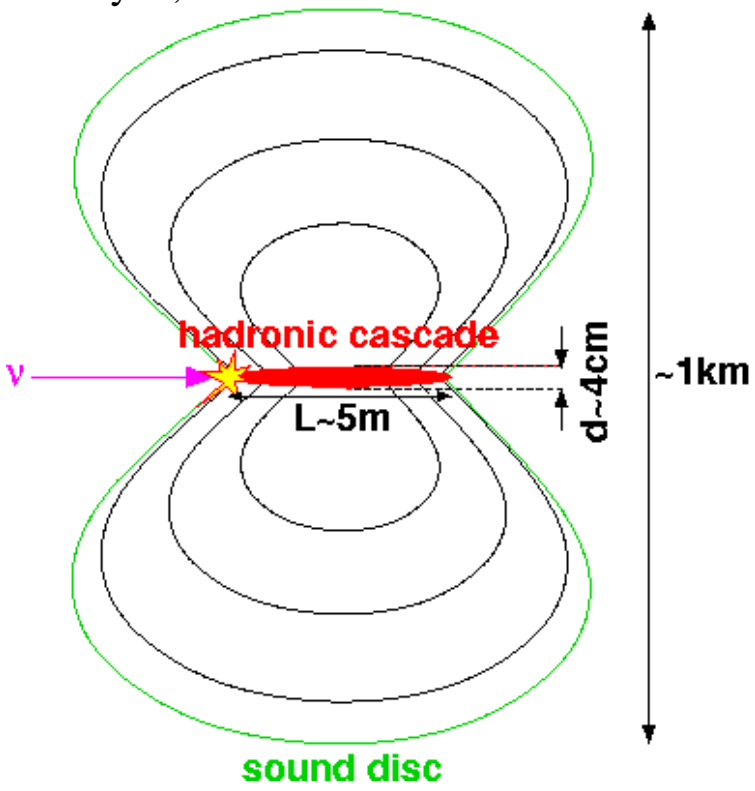
signal duration: ~ 50µsec



acoustic background ?? !!

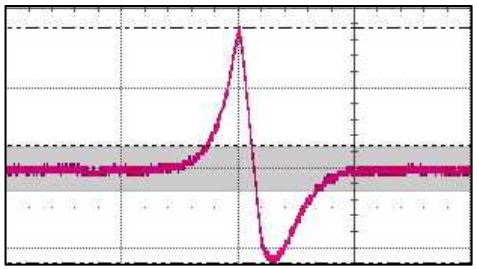
Acoustic Signatur of UHE Shower

Askaryan, 1979



- Energy deposition
  - Water gets heated (nK)
    - Expansion
      - Pressure Puls

$$P \sim (\alpha/C_p) \times (c_s/d)^2 \times E$$



P~1mPa
for
E~1EeV

Advantage: acoustic absorption length ~ km !!! (???)

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