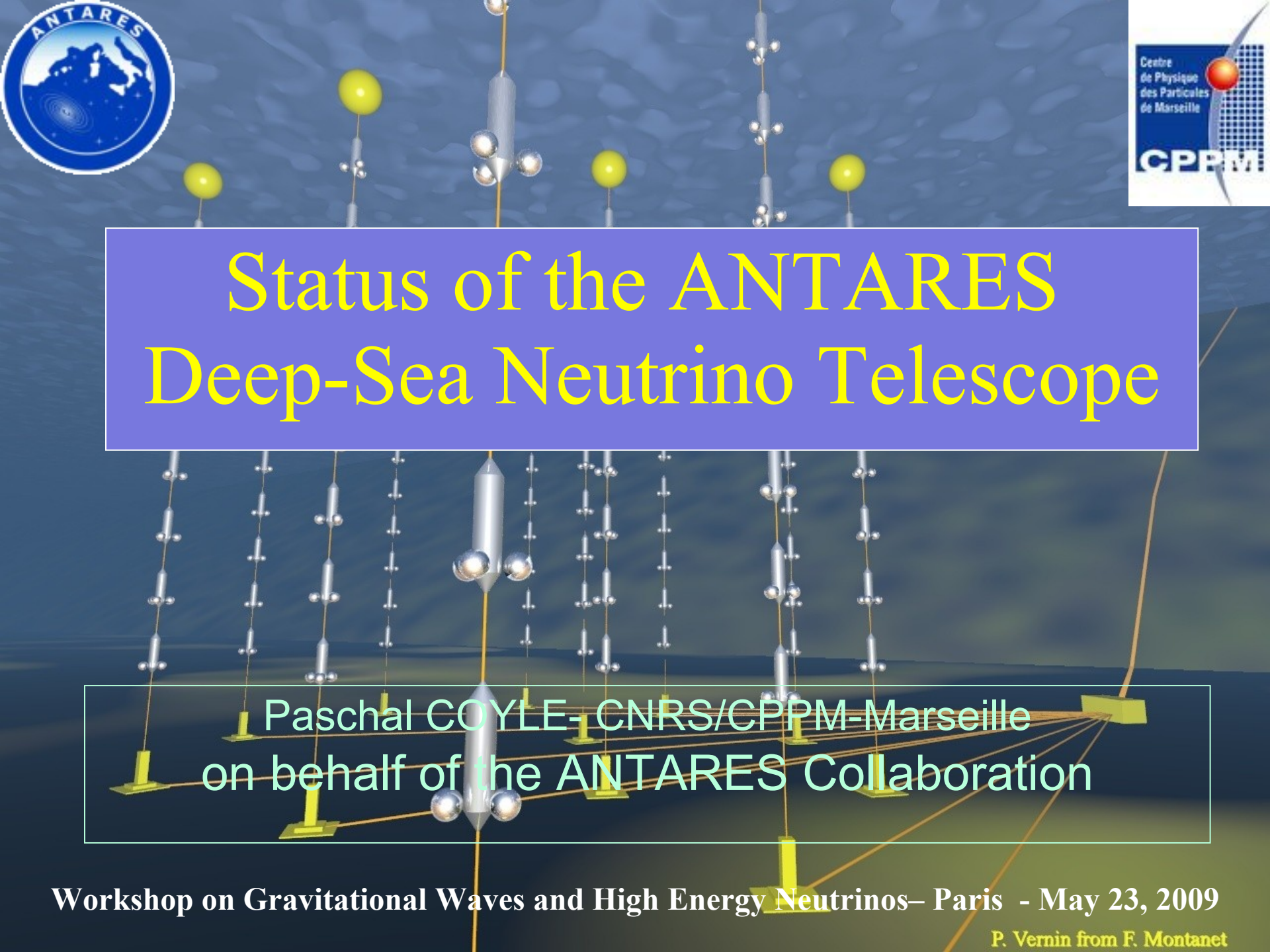


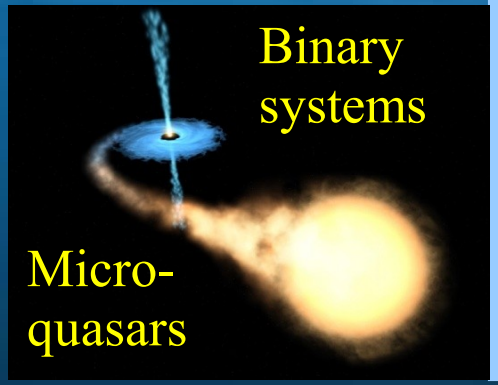
Status of the ANTARES Deep-Sea Neutrino Telescope

Paschal COYLE- CNRS/CPPM-Marseille
on behalf of the ANTARES Collaboration

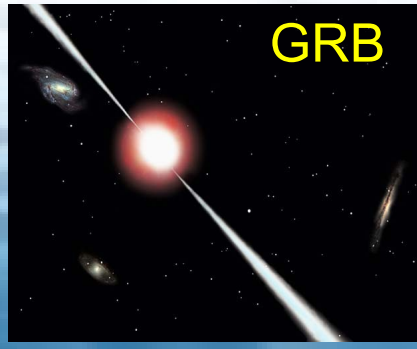
Workshop on Gravitational Waves and High Energy Neutrinos– Paris - May 23, 2009

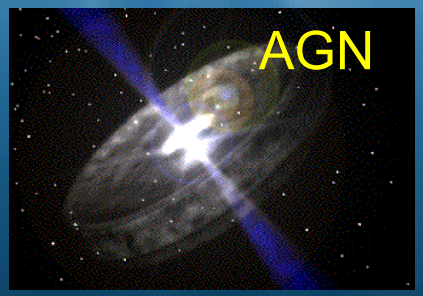
P. Vernin from F. Montanet

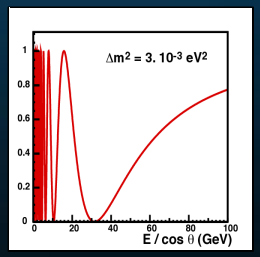
ANTARES Science

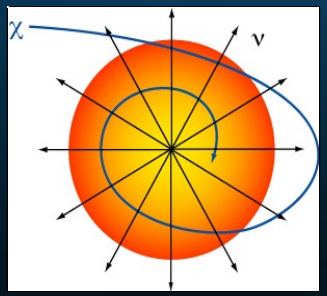


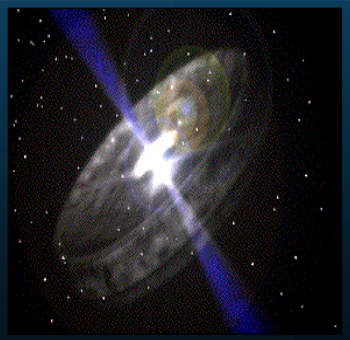
- **High energy neutrino astrophysics**: Active Galactic Nuclei, Gamma Ray Bursts, Galactic Centre, SN Remnants, μ-quasars...
- **Search for New Physics**: Dark matter, Monopoles...
- **Earth-Sea Science:** oceanography, sea biology, seismology, environment monitoring...

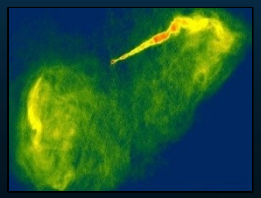








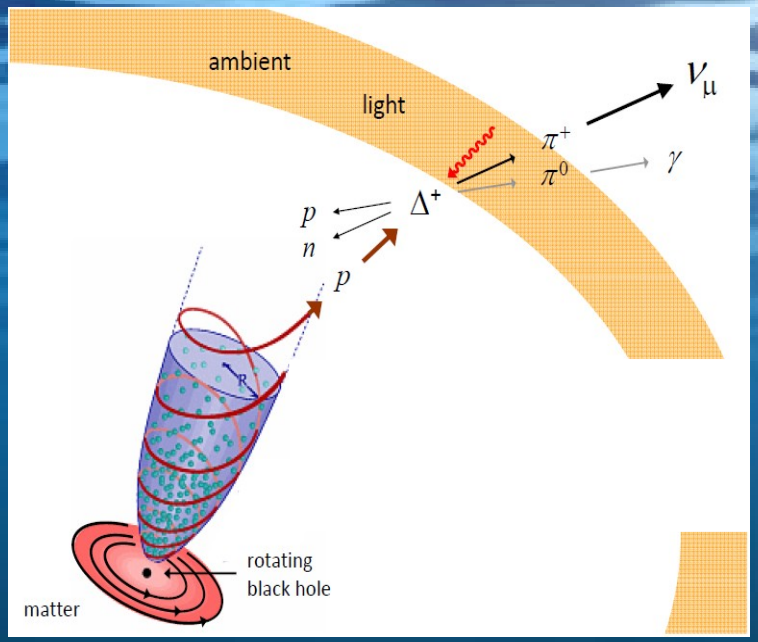




?

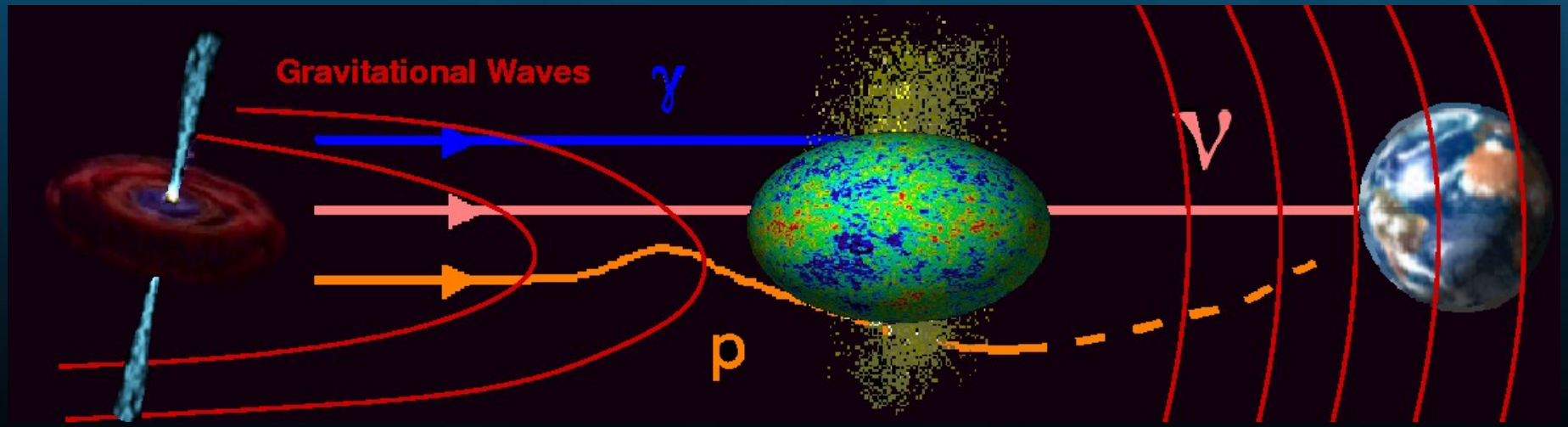
~MeV GeV-100 GeV GeV-TeV TeV-PeV PeV-EeV > EeV

Neutrinos and Multi-Messenger Astronomy

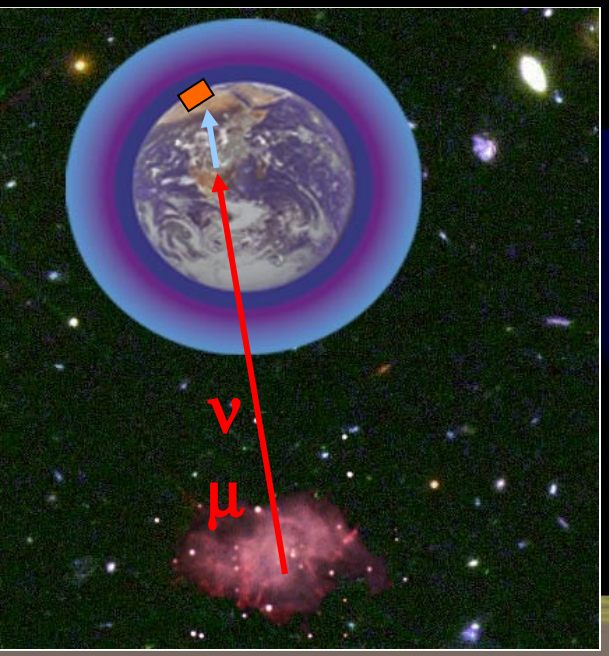


Neutrinos

- Not deflected by magnetic fields
- Not absorbed by dust
- Distance horizon not limited by interaction with CMB/IR
- Unambiguous probe of hadronic processes
- can be correlated with optical signals
- Identify source of cosmic rays



Detection principle



3D PMT array

Cherenkov light from μ

42°

Sea floor

μ

ν

μ

interaction

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

- Main detection channel: ä ö interaction giving an ultra-relativistic **P**
- Energy threshold ~ 10 GeV

The ANTARES Collaboration

- NIKHEF, Amsterdam
- KVI Groningen
- NIOZ Texel

- University of Erlangen

- IFIC, Valencia
- UPV, Valencia

- CPPM, Marseille
- DSM/IRFU/CEA, Saclay
- APC, Paris
- LPC, Clermont-Ferrand
- IPHC (IReS), Strasbourg
- Univ. de H.-A., Mulhouse
- IFREMER, Toulon/Brest
- C.O.M. Marseille
- LAM, Marseille
- GeoAzur Villefranche

- 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

- ITEP,Moscow

- ISS, Bucarest

The ANTARES Site & Infrastructure

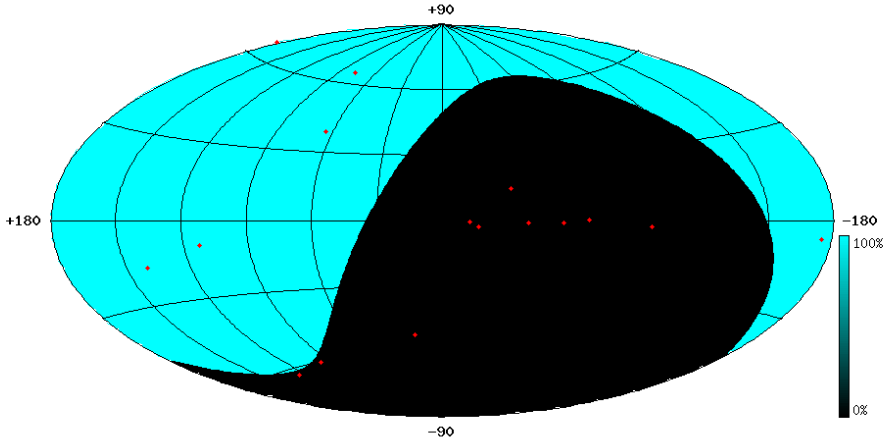
IFREMER Toulon

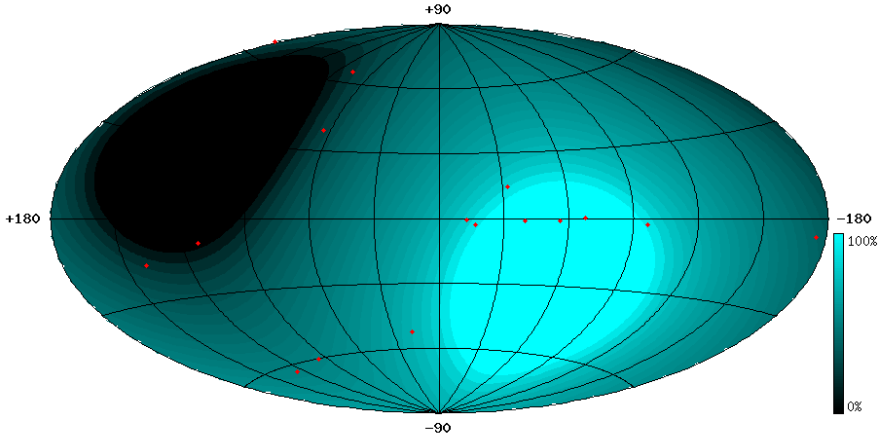
FOSELEV Marine

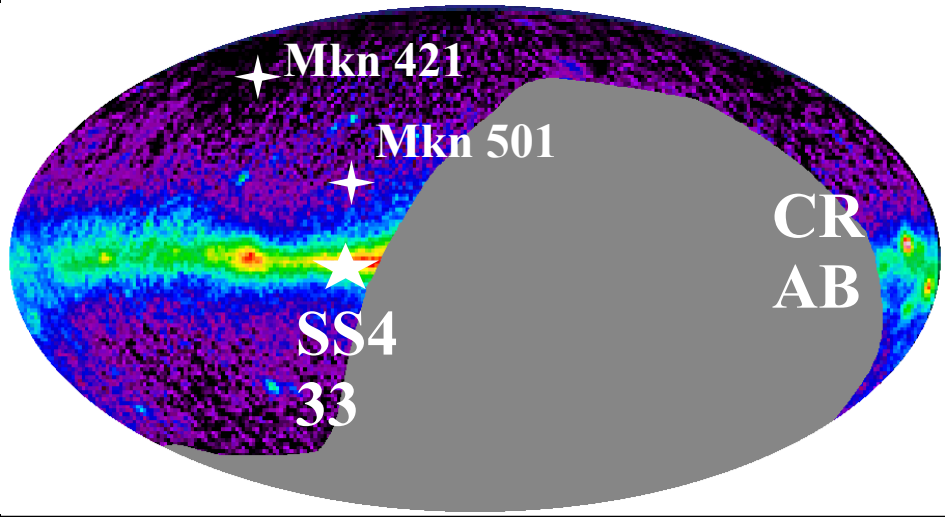
Region of sky observable by Neutrino Telescopes

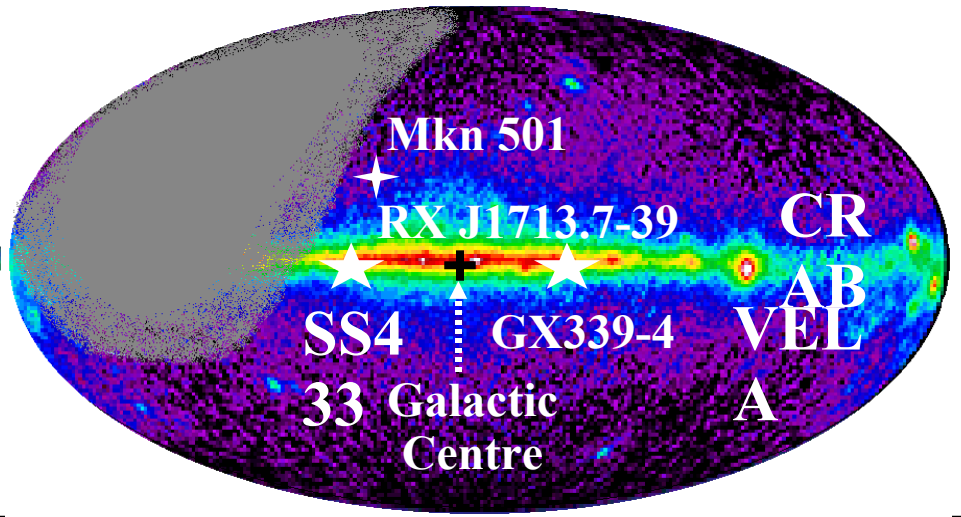
AMANDA/IceCube (South Pole)
(Ice: ~2°/0.6°)

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

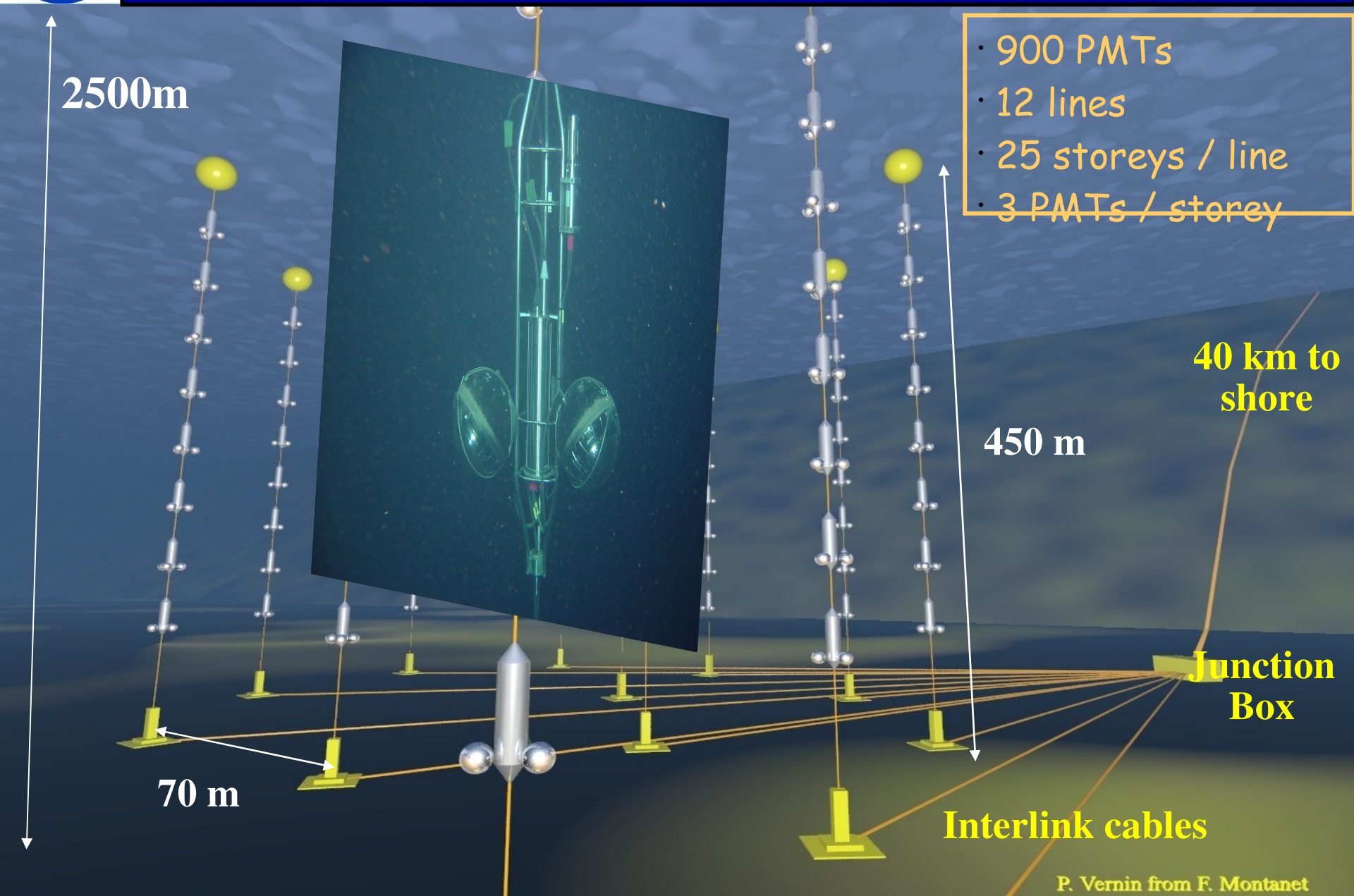








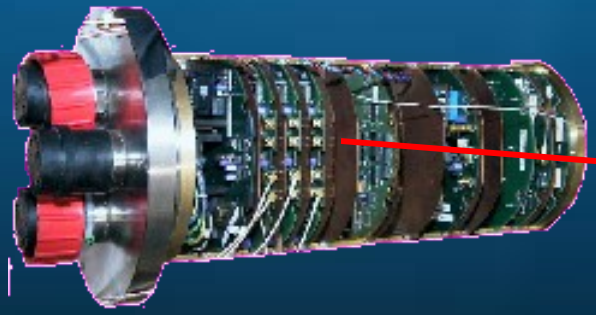
The ANTARES Detector



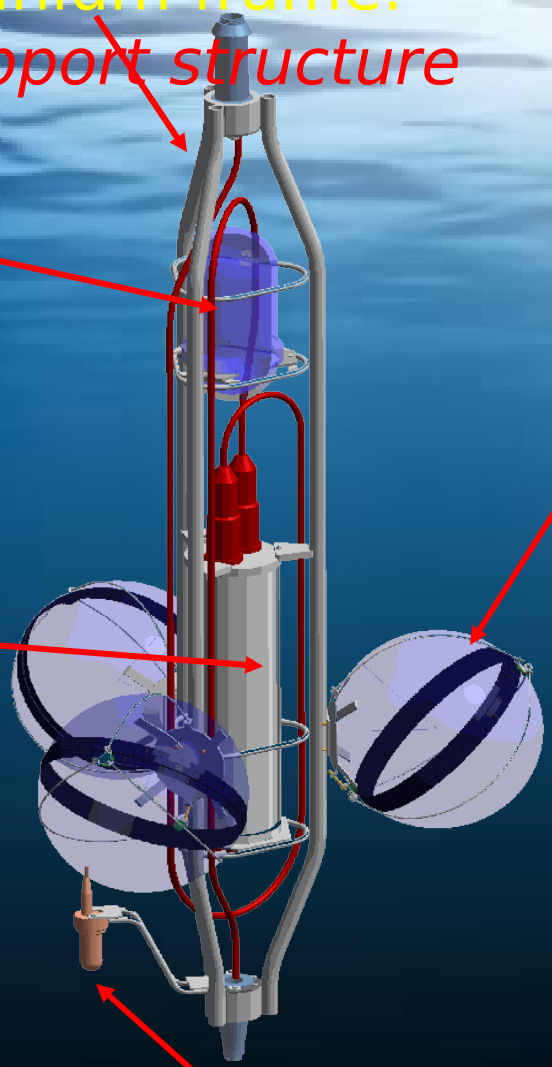
Basic Detector Element: a storey

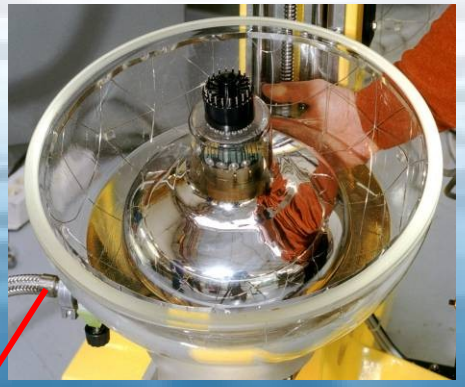
titanium frame:
support structure

Optical Beacon with blue LEDs:
timing calibration



Local Control Module (in Ti cylinder):
Front-end ASIC, DAQ/SC, DWDM





Optical Module:
10” Hamamatsu PMT
in 17” glass sphere
($\sigma_{TTS} \approx 1.3$ ns)
photon detection

Hydrophone:
acoustic

ANTARES Site Exploration

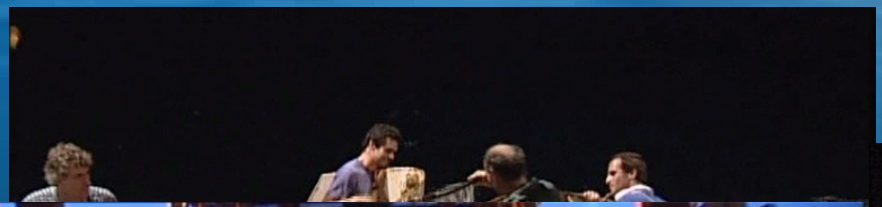
1996 - 2000 Measurements with autonomous lines

1) Optical background study: 15 deployments
2) Biofouling-sedimentation study: 4 deployments
3) Optical properties study: 28 deployments

Building the Detector - 1
Main Cable and Junction Box

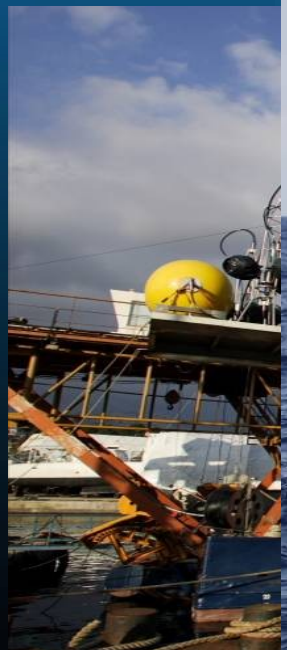
2001 Deployment of 45 km electro-optical cable (Alcatel)

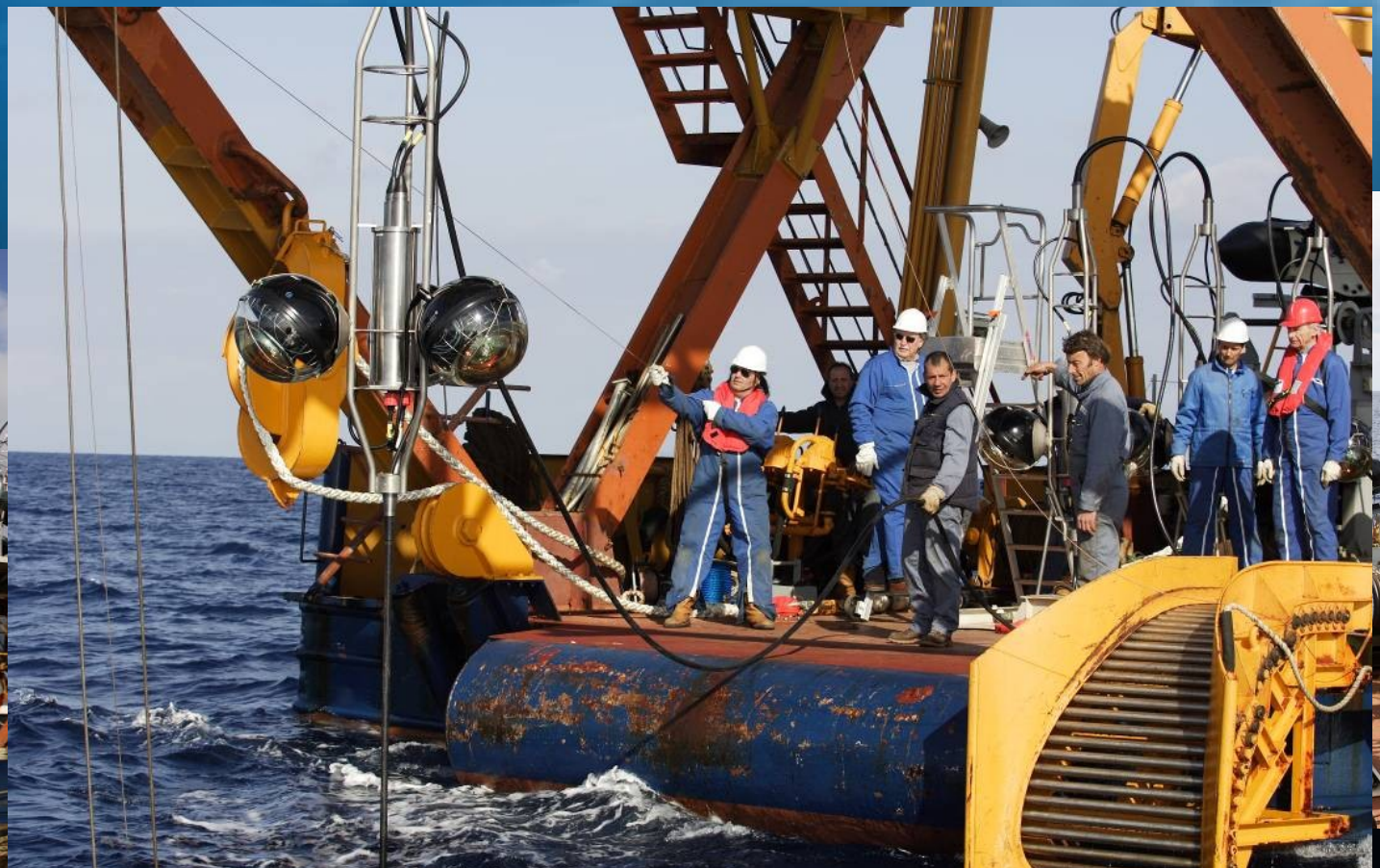
2002 Deployment of Junction Box



Building the Detector - 2
Line Deployment

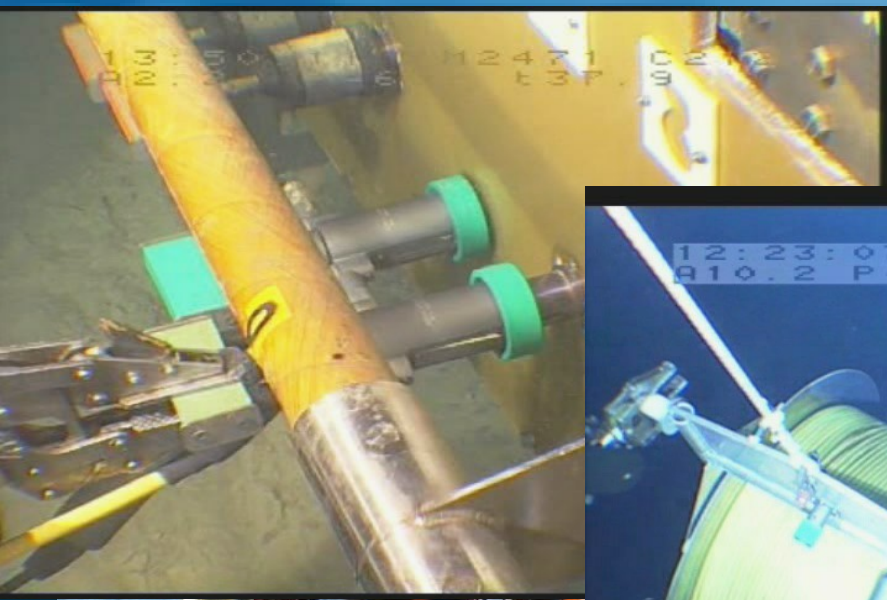
- 2003-2005 Various prototype lines
- 2006 Lines 1, 2
- 2007 Lines 3, 4, 5, 6, 7, 8, 9,10
- 2008 Lines 11, 12

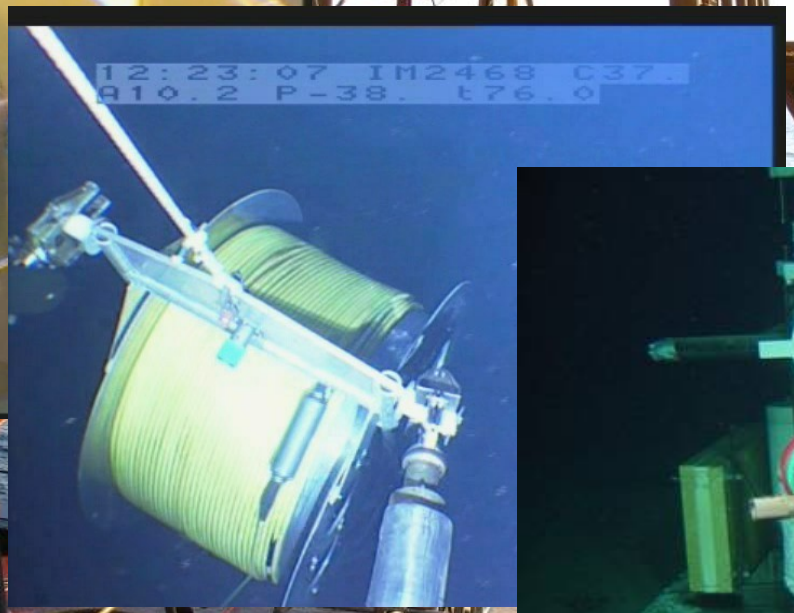


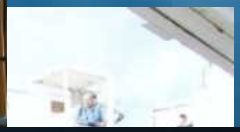
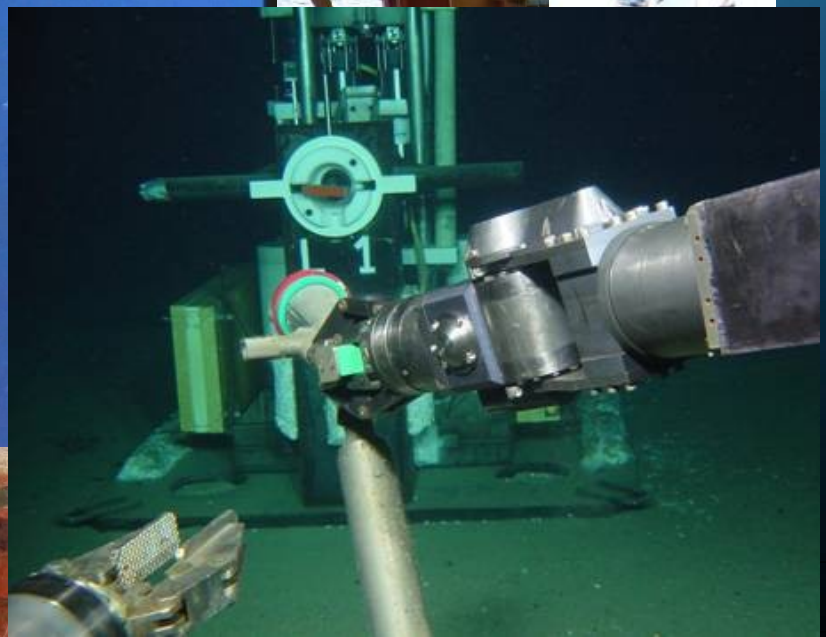
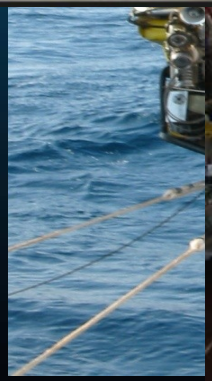


Building the Detector - 3
Line Connections

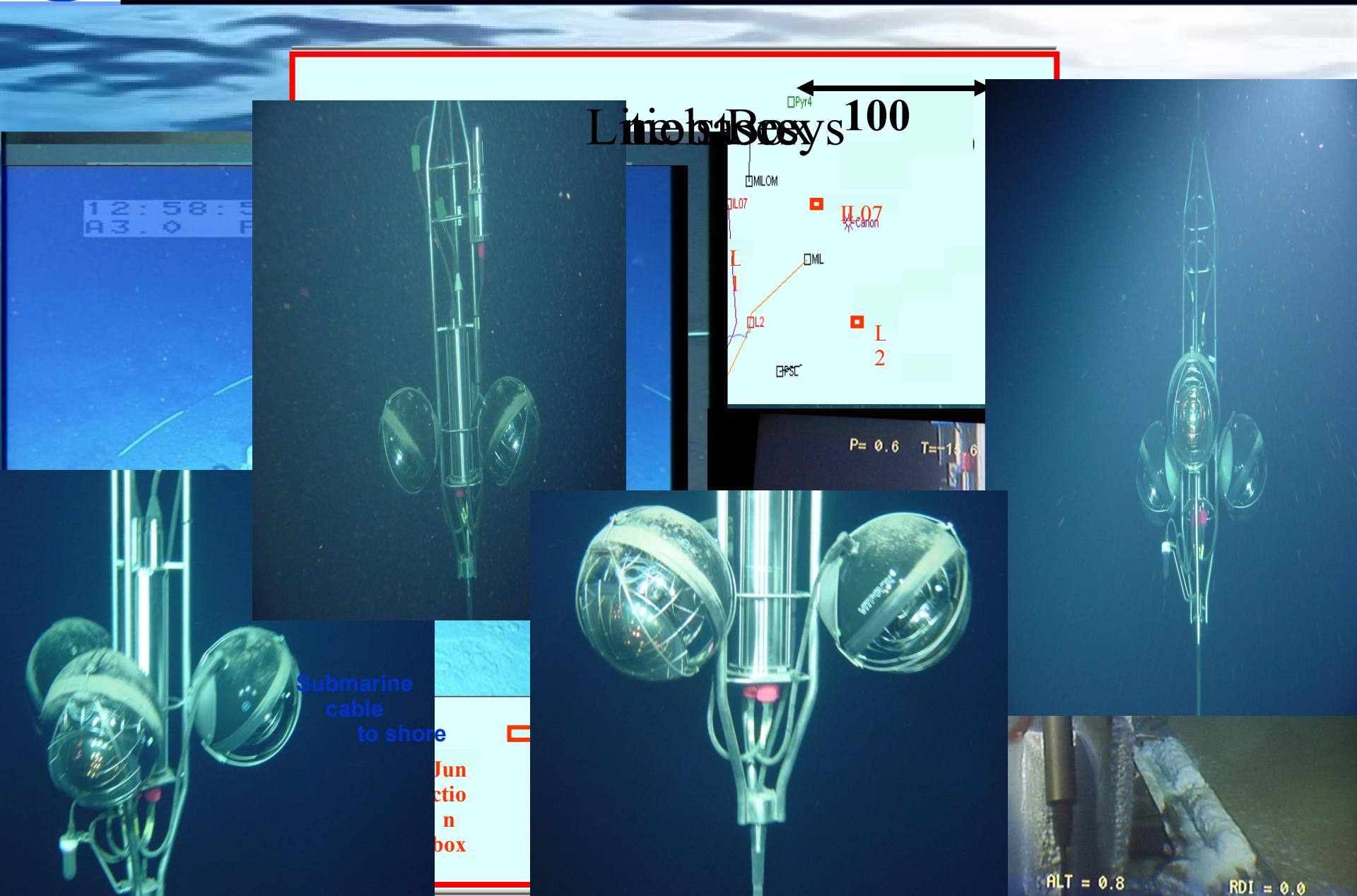
- 2006 Line 1, Line 2
- 2007 Lines 3 - 5, Lines 6 -10
- 2008 Lines 11, 12





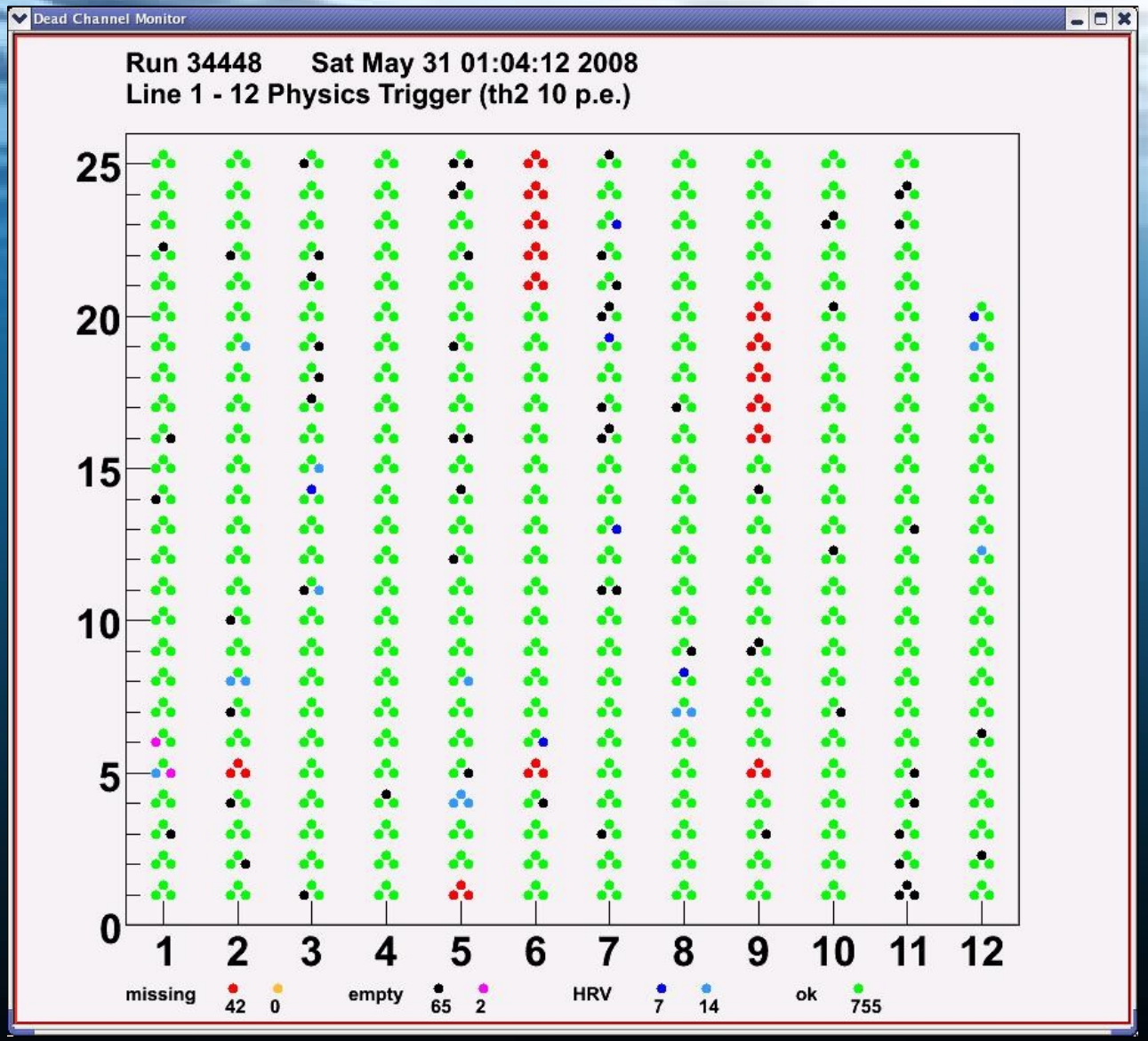





Detector on Seabed

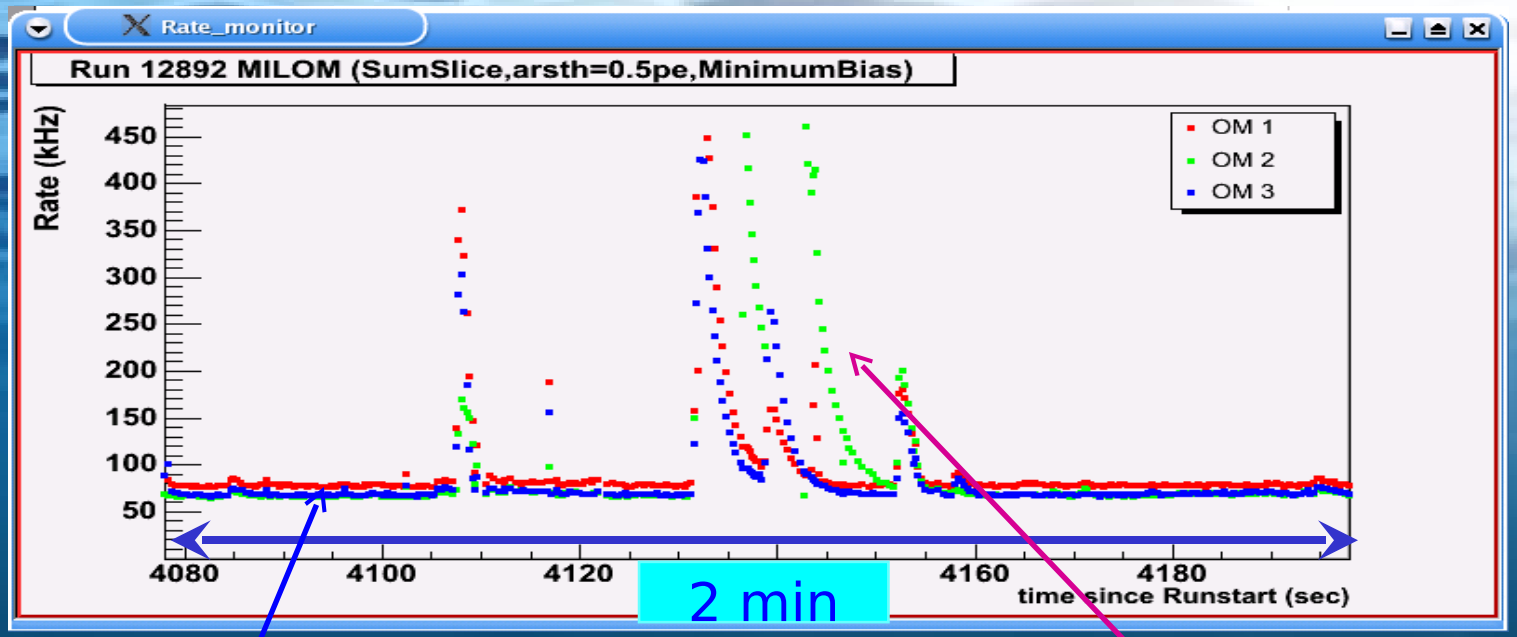


Detector status after completion

- 88% of modules operational
- Regular maintenance of in-situ infrastructure foreseen



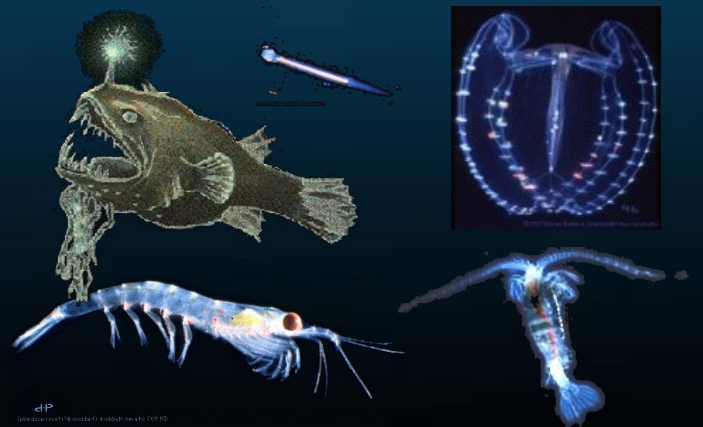
Counting Rates (short timescale)



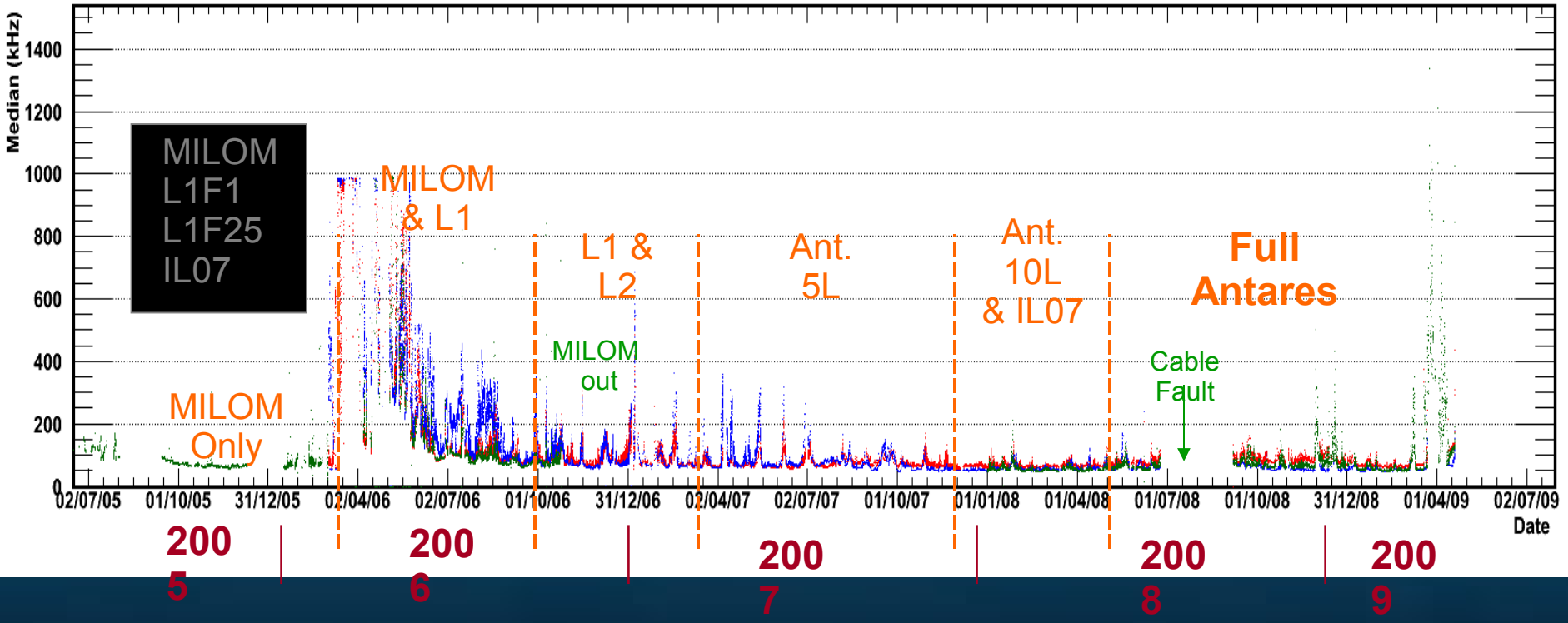
Continuous baseline:
Radioactivity in the sea (40K)
+ bioluminescent bacteria

40 K

Bursts:
bioluminescence from Macroscopic organisms

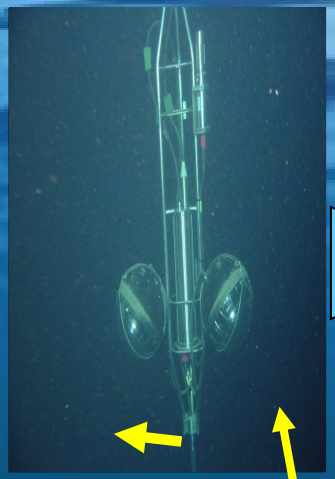


Counting Rates (long timescale)



Long term variations due to seasonal and sea current variability

In situ calibration with Potassium-40

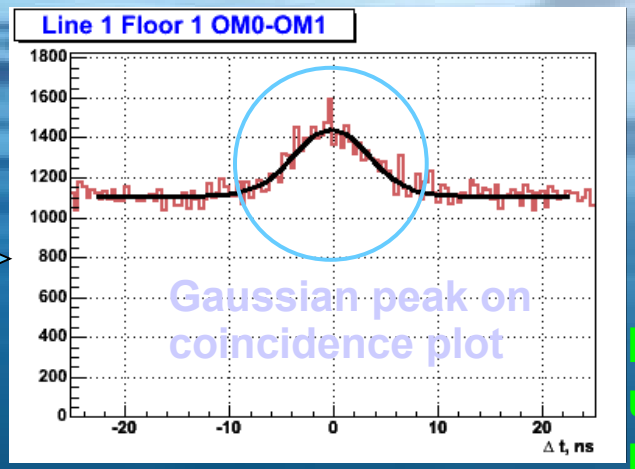


Cherenkov γ

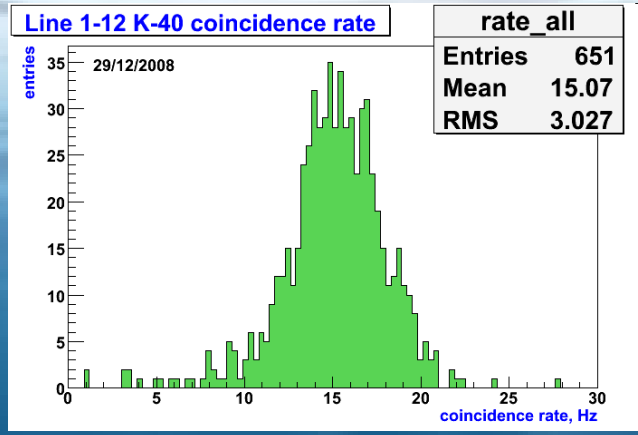
e- (β decay)

40K

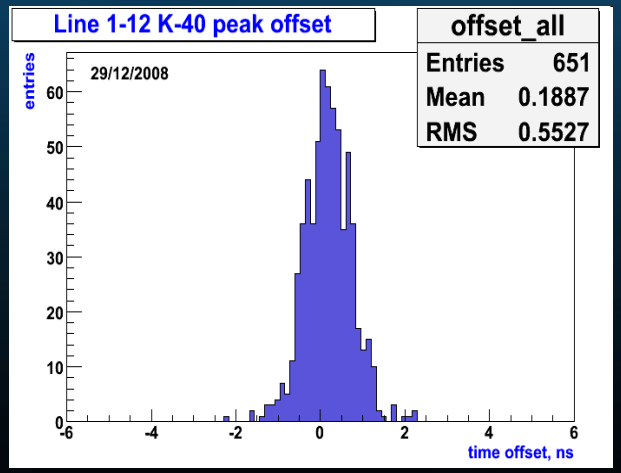
40Ca



Integral under peak



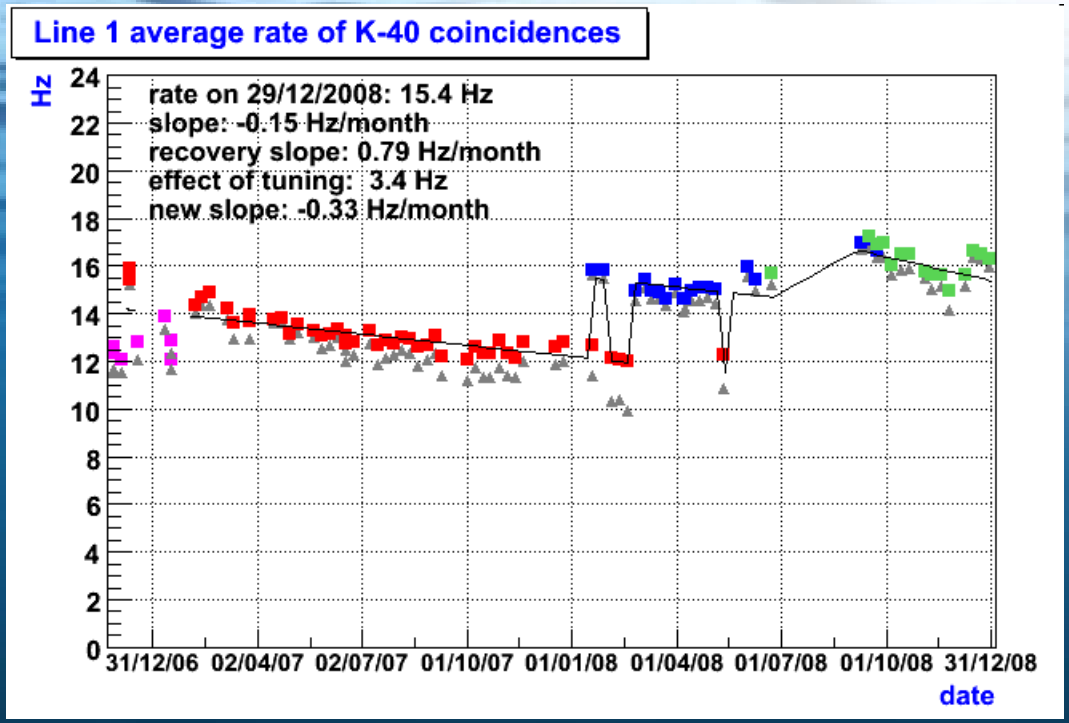
Peak offset



Precision (~5%) monitoring of OM efficiencies

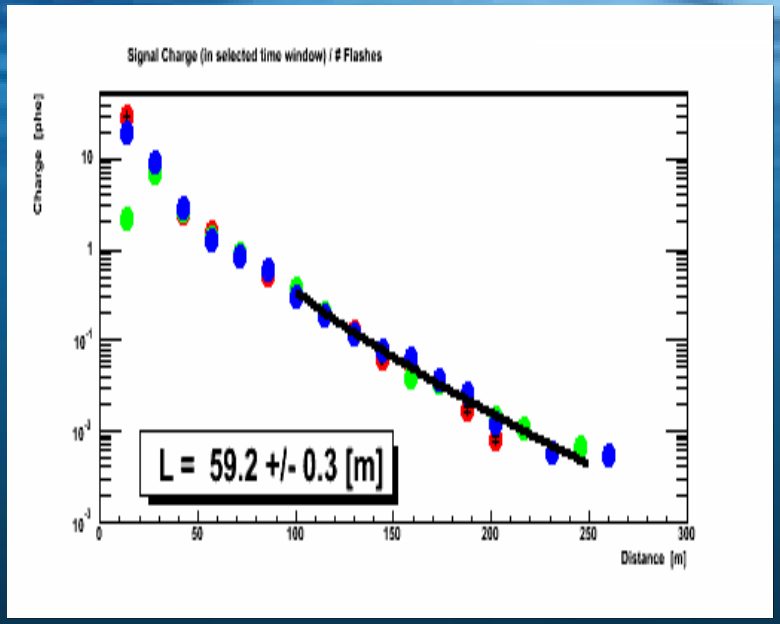
Cross check of time calibration

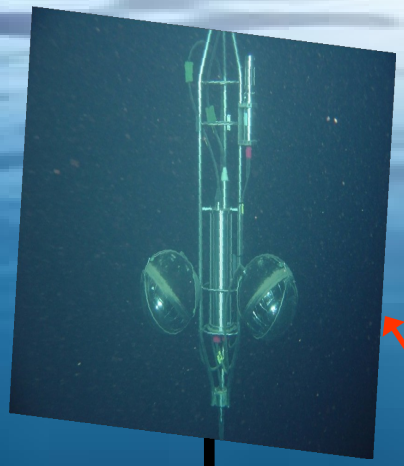
Time evolution of K40 coincidence rate

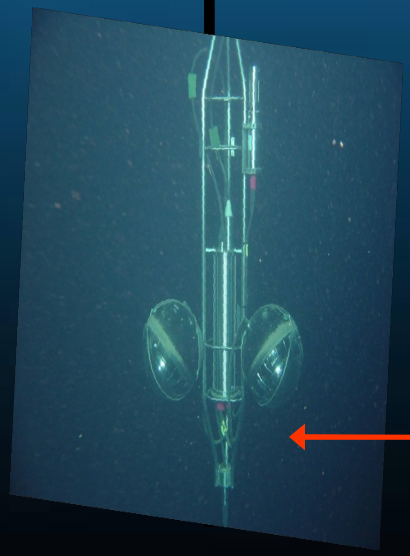


- All OM pairs of Line1 during more than 2 years
- OM gain drop reduces efficiency
- Recovery after threshold retuning
- Recovery due to HV off during period of cable repair

Light Absorption Measured using Beacons

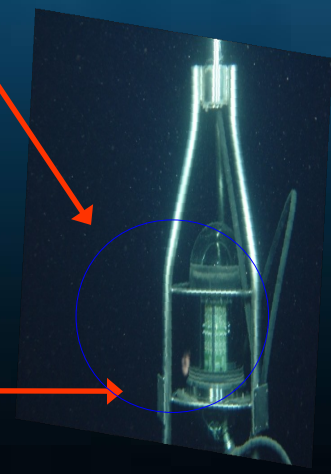




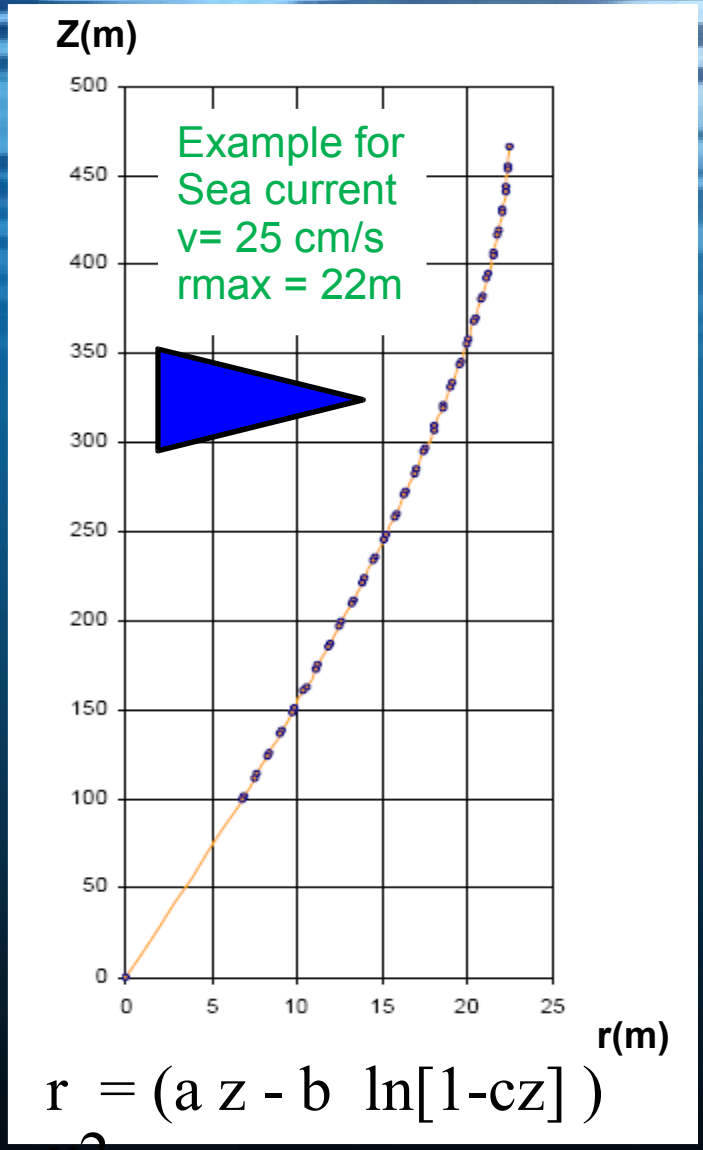


~150 m

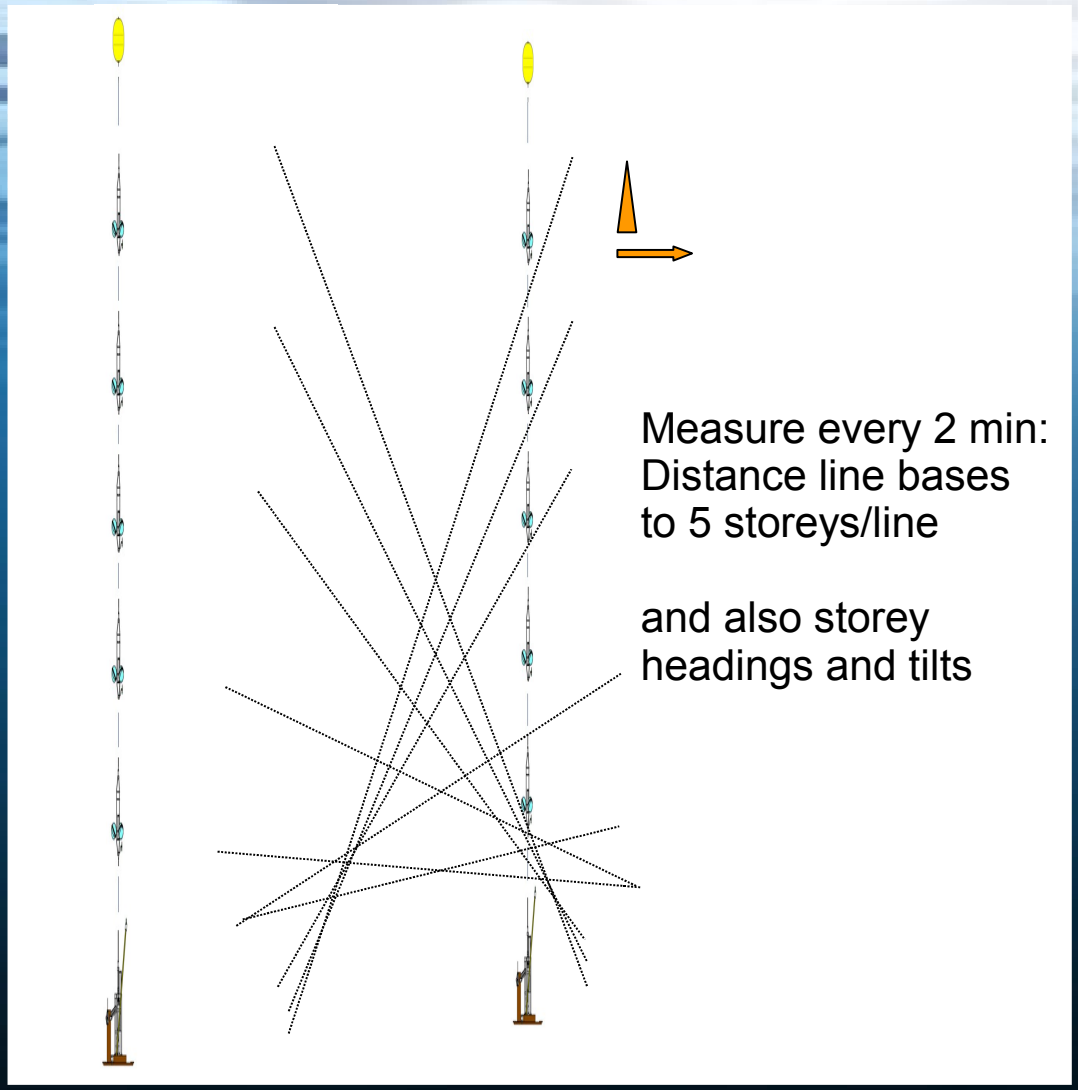
~70 m



Position Alignment



$$r = \frac{(a\,z - b\,\ln[1-cz])}{v2}$$

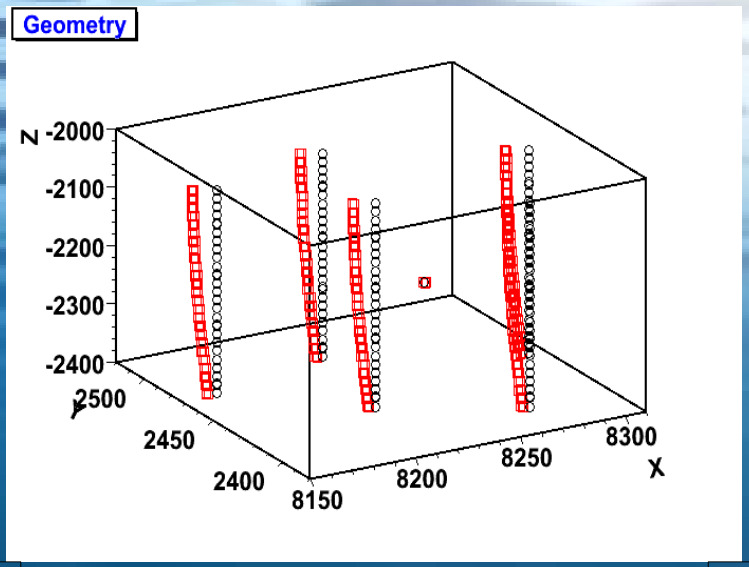


Measure every 2 min:
Distance line bases
to 5 storeys/line

and also storey
headings and tilts

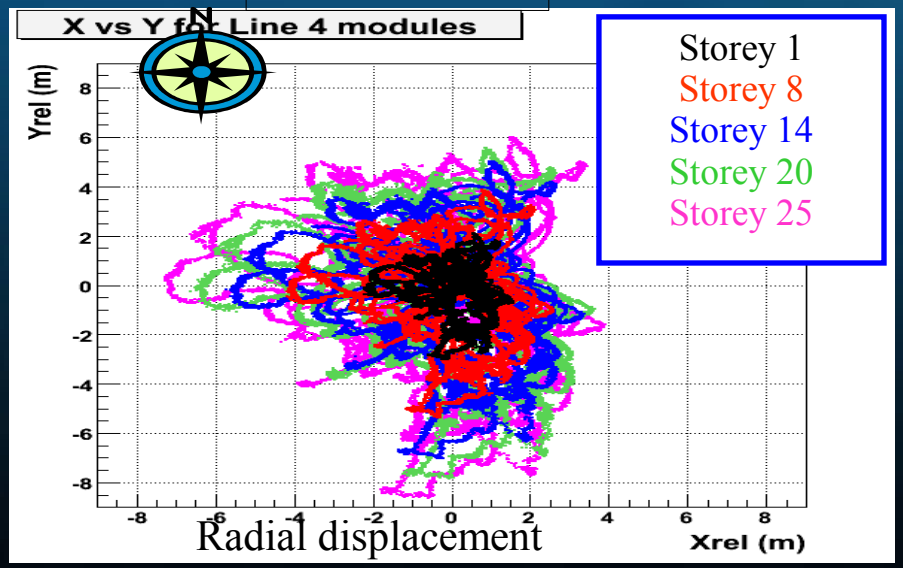
Line position measurements

Acoustic positioning:
Hydrophone positions from July, Dec 2007

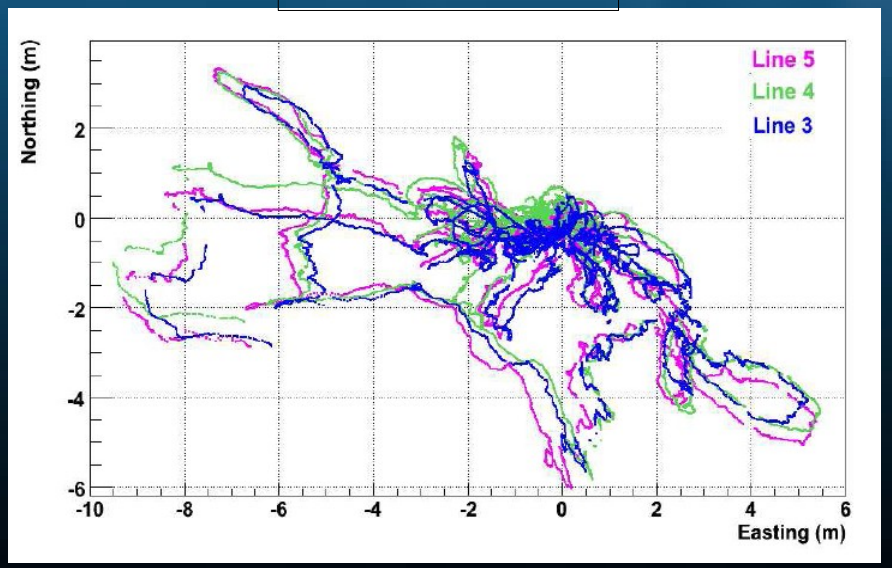


Acoustic positioning:
Precision ~ few cms

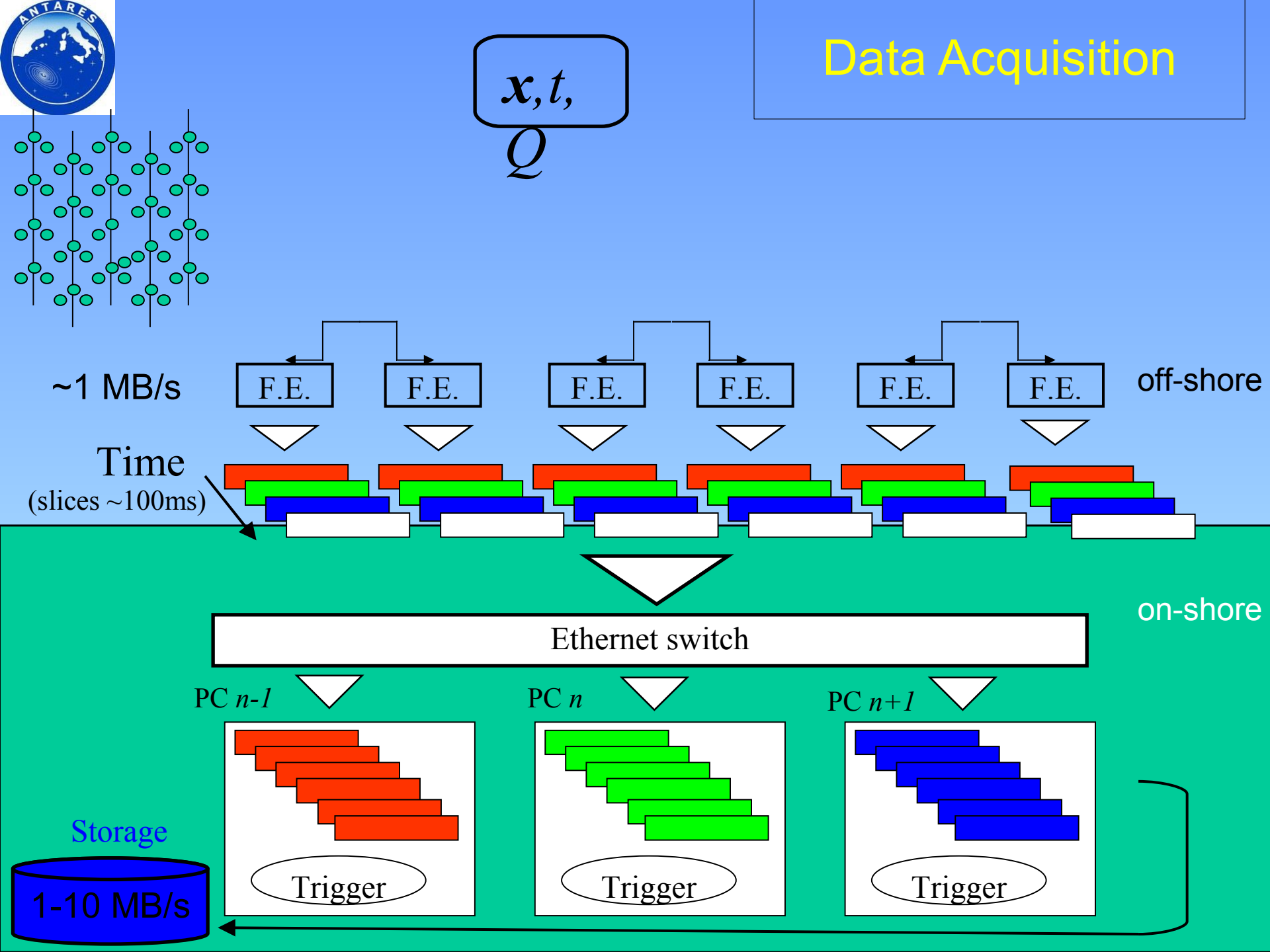
Within a line



Between lines

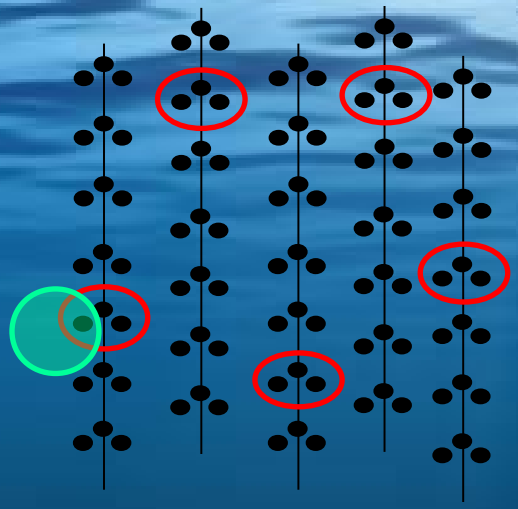


Data Acquisition



Online Triggers

3N- directional scan



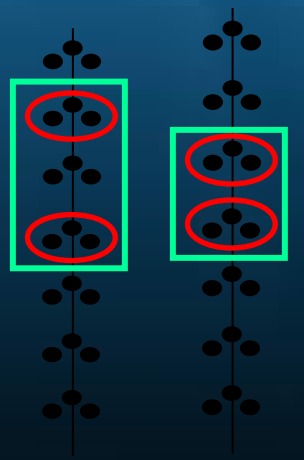
= 1 local coincidence (20ns) of 2 out of 3
or a single large amplitude (>3spe)

Trigger 3N = 3 within 2.2 s,
and causally related

2T3

Trigger 1T3 = 2 in 3 adjacent storeys

Trigger 2T3 = 2 x 1T3 within 2.2 s

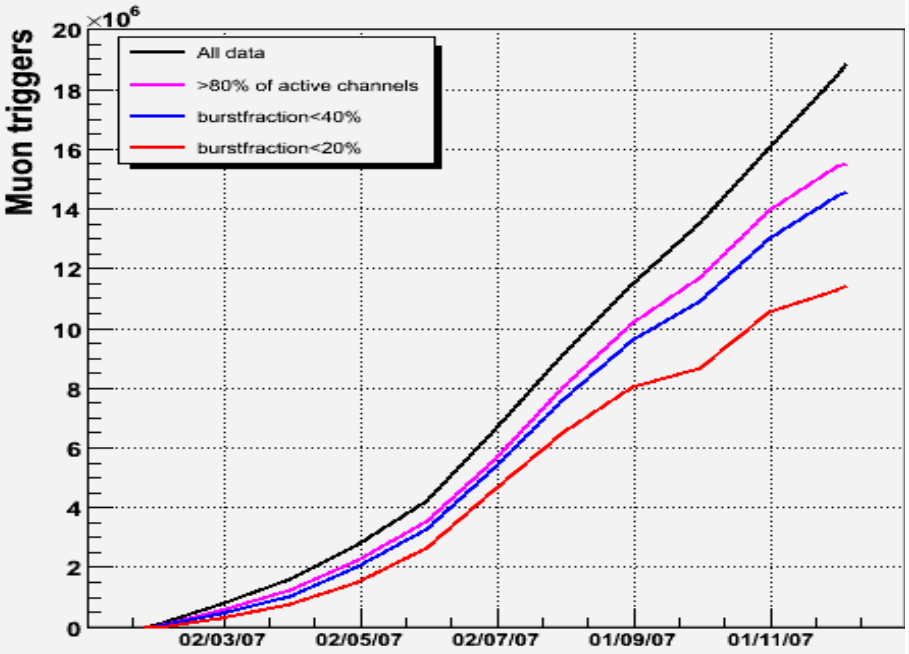


Galactic Centre-directional trigger

Number of triggers

5 lines (2007)

19.106 μ

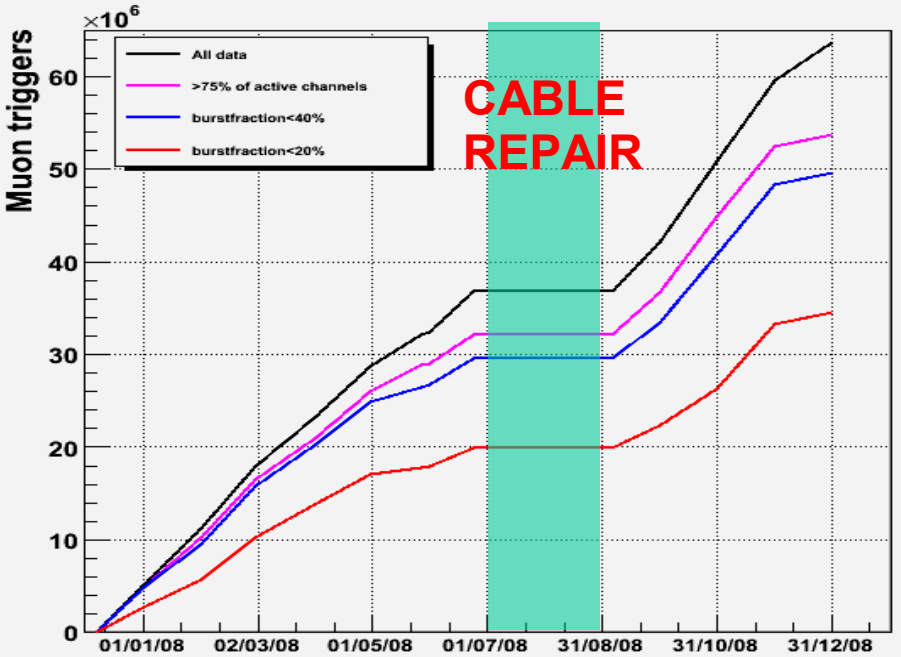


Total : 240 days = 80% of calendar

Selected :167d = 70% of total

10 or more lines (2008)

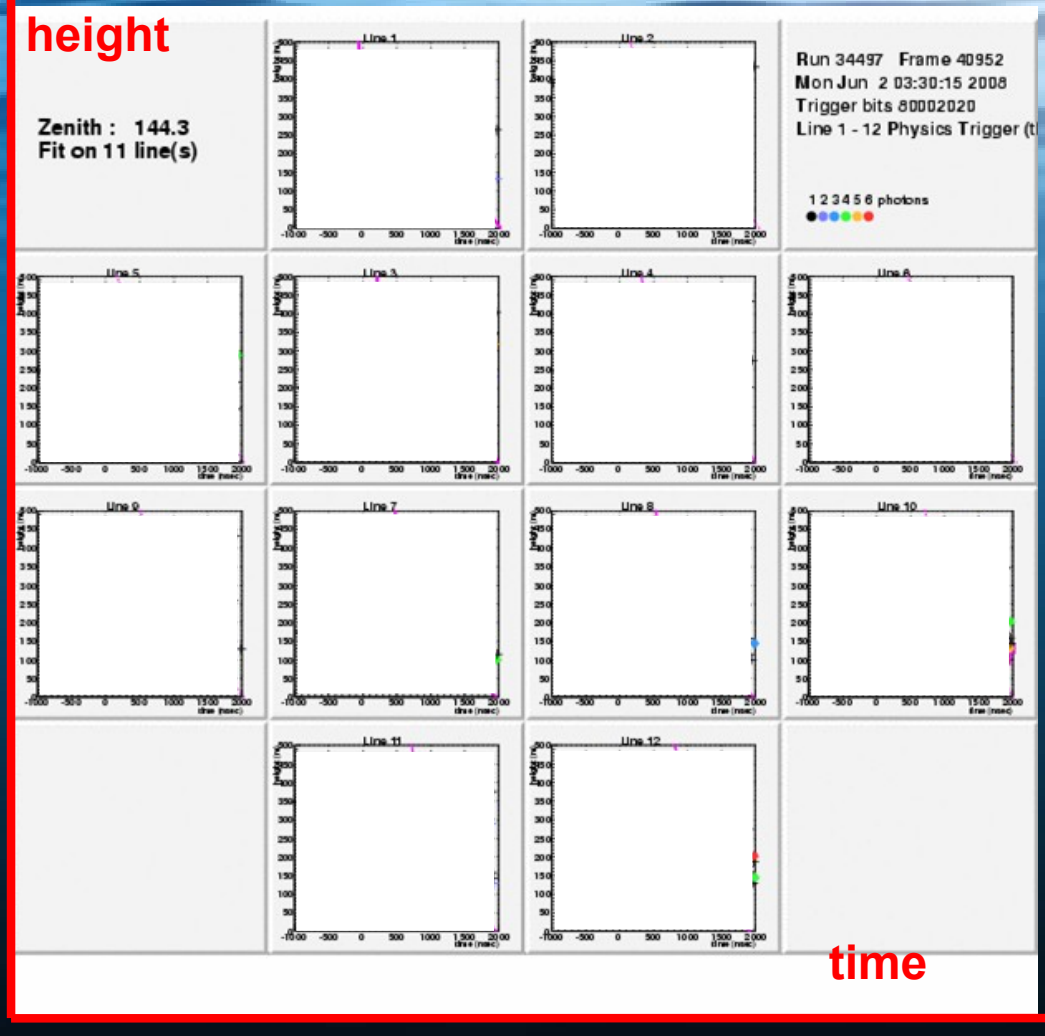
65.106 μ



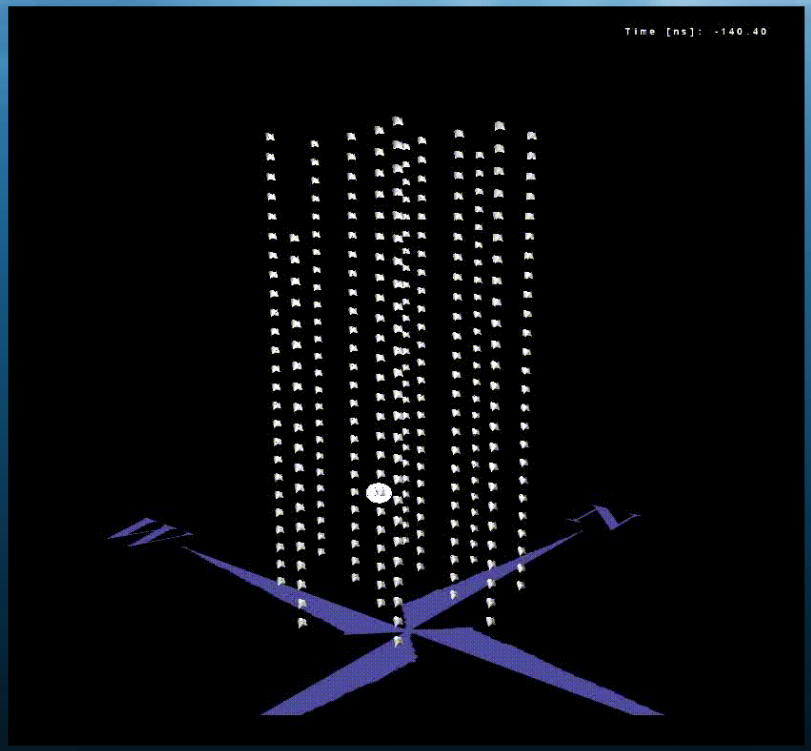
Total : 243 days = 83% of calendar

Selected :173d = 71% of total

Atmospheric Muons

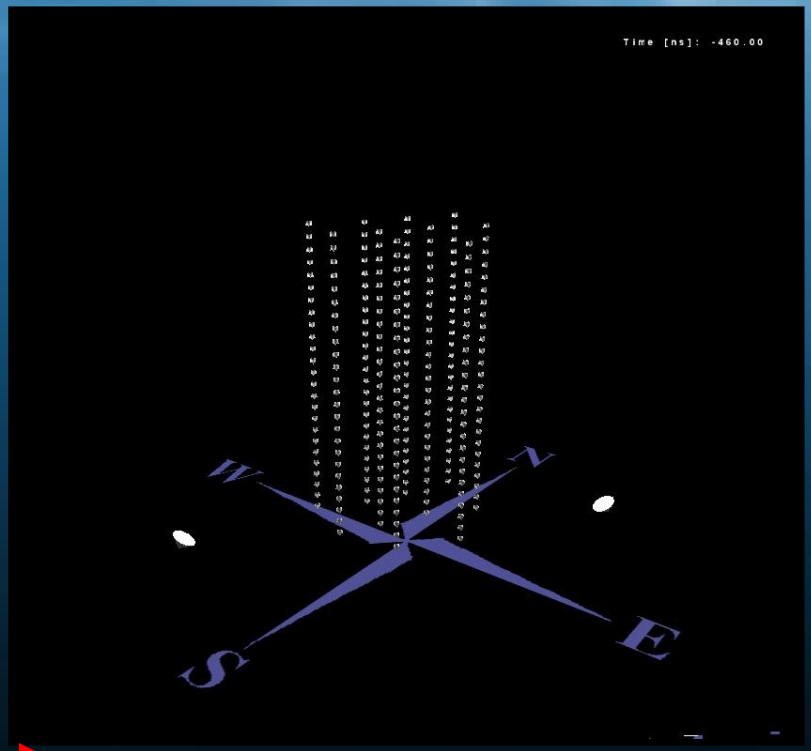


Example of a reconstructed down-going muon, detected in all 12 detector lines:

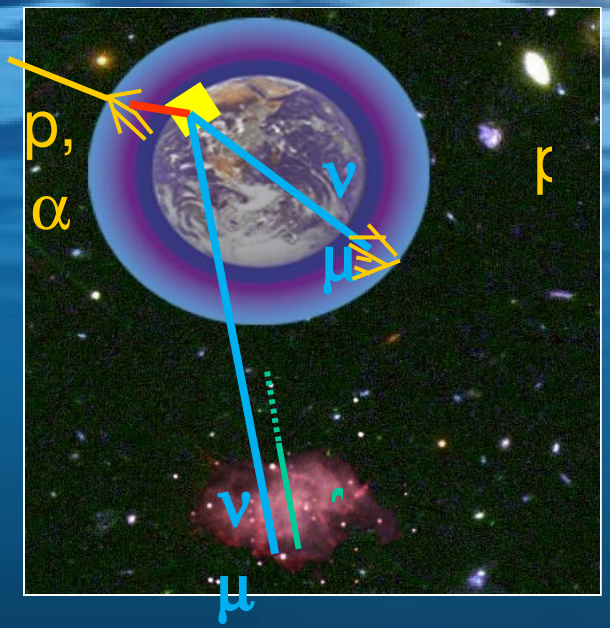


Neutrino-induced muon

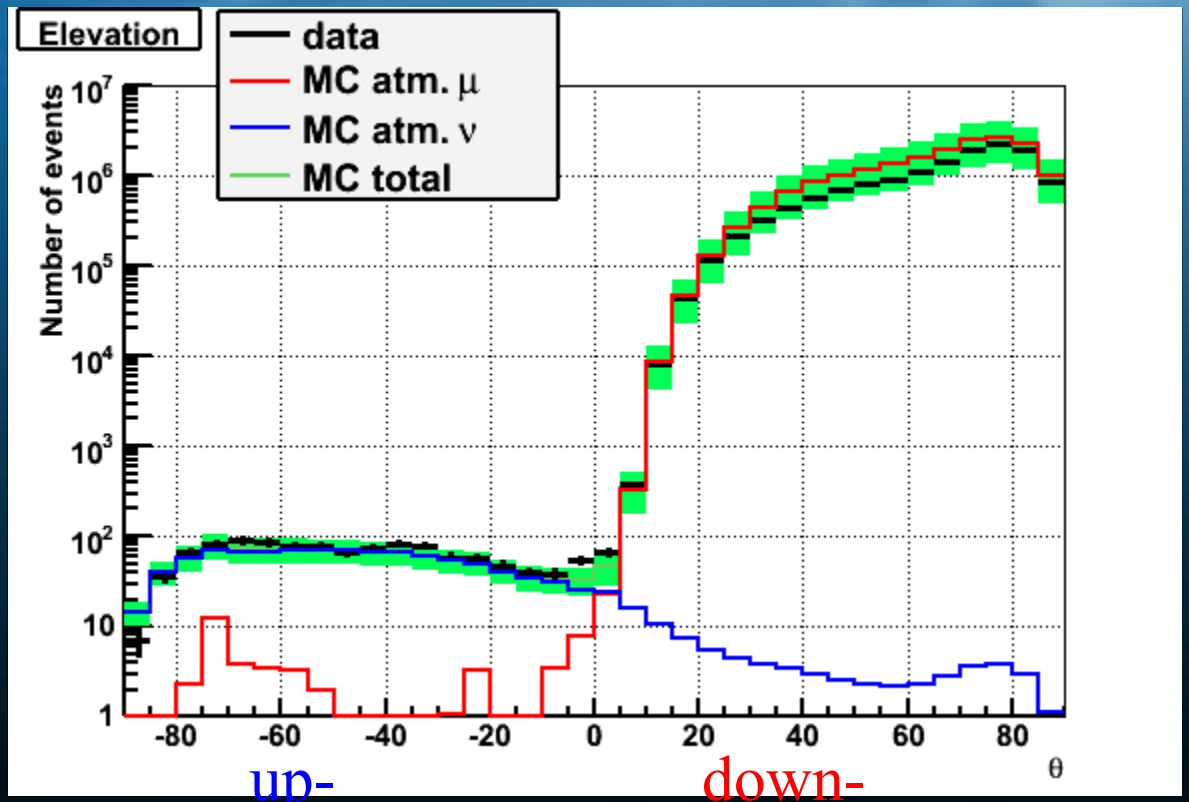
Example of a reconstructed up-going muon (i.e. a neutrino candidate) detected in 6/12 detector lines:



Detected Neutrinos

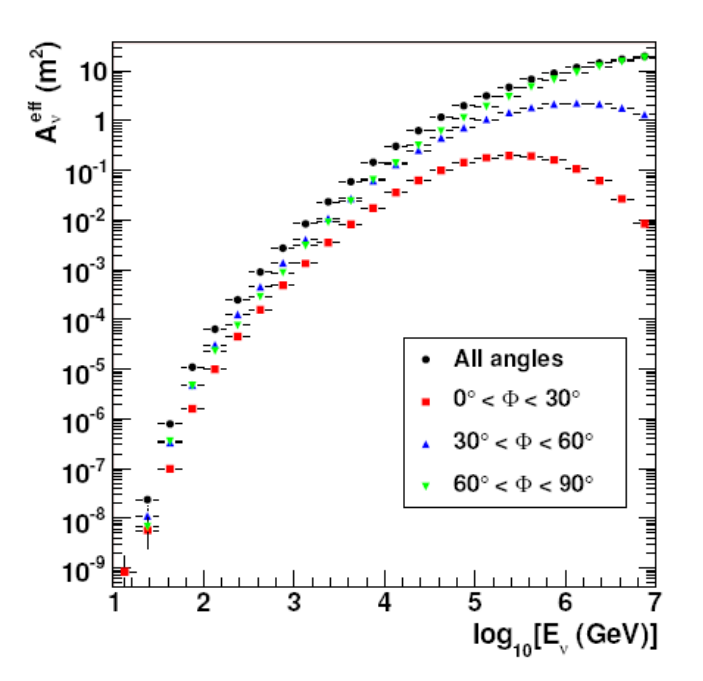


June 2007 – Dec 2008: 5+10+12 lines
313 active days
1111 upward neutrino candidates



Expected Performance (full detector)

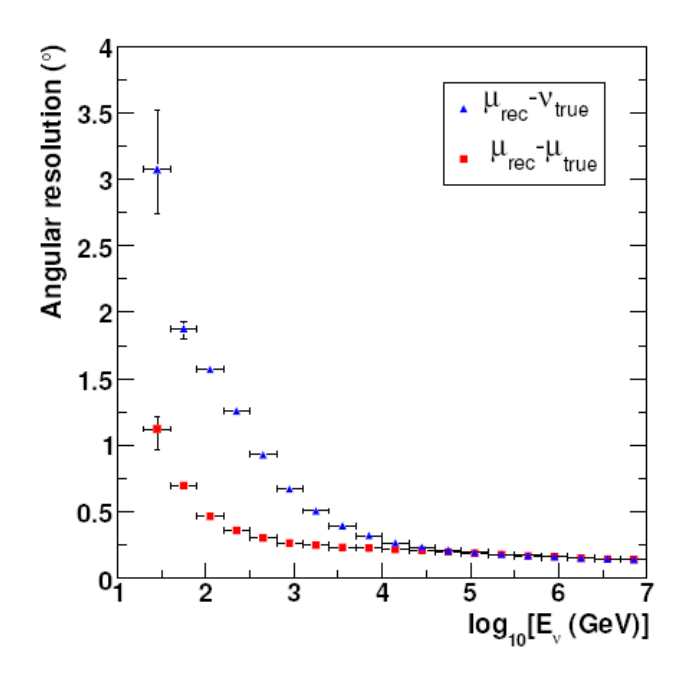
Neutrino effective area



· For E□<10 PeV, Aeff grows with energy due to the increase of the interaction cross section and the muon range.

· For E□>10 PeV the Earth becomes opaque to neutrinos.

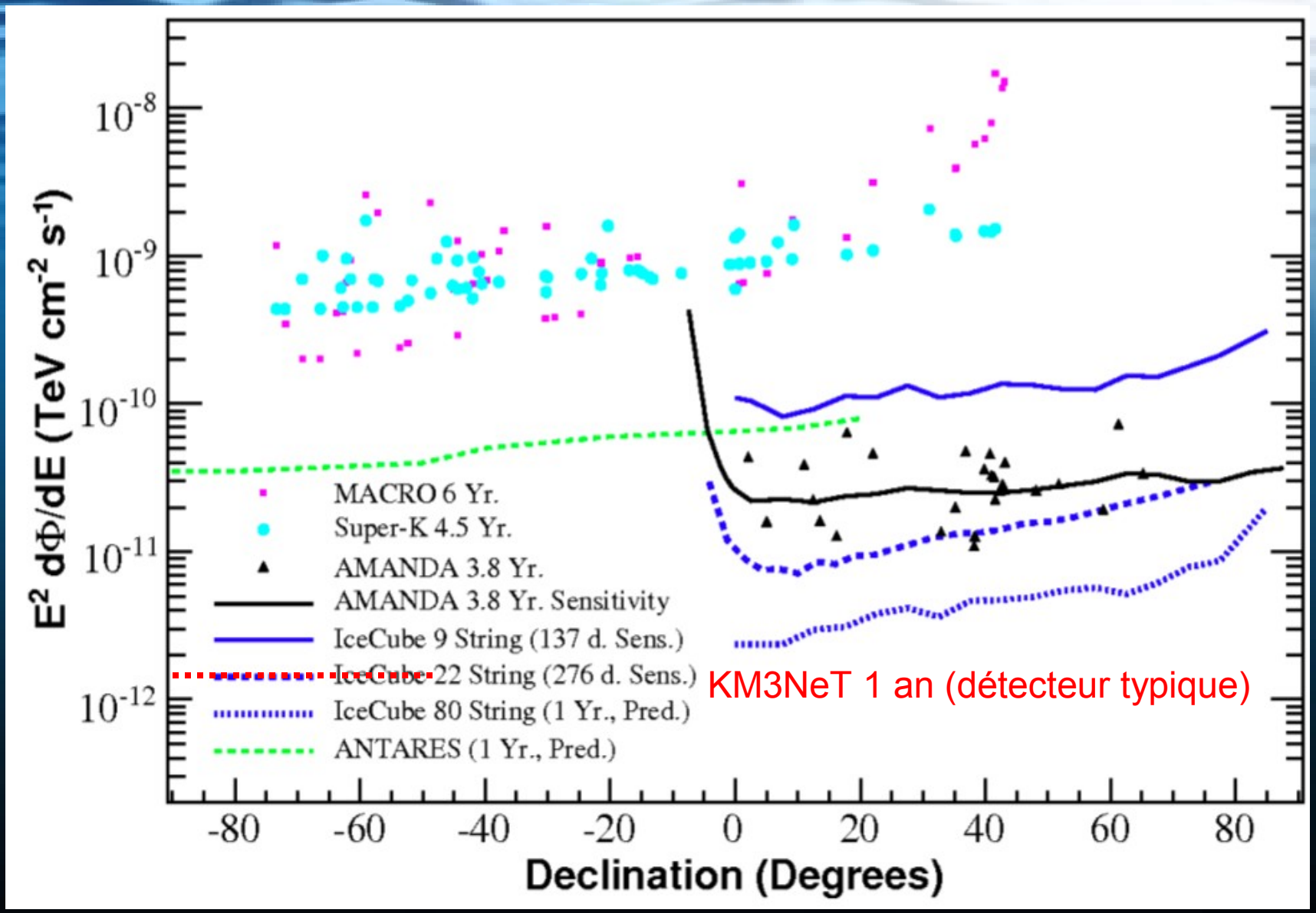
Angular resolution



· For Eâ <10 TeV, the angular resolution is dominated by the □-□ angle.

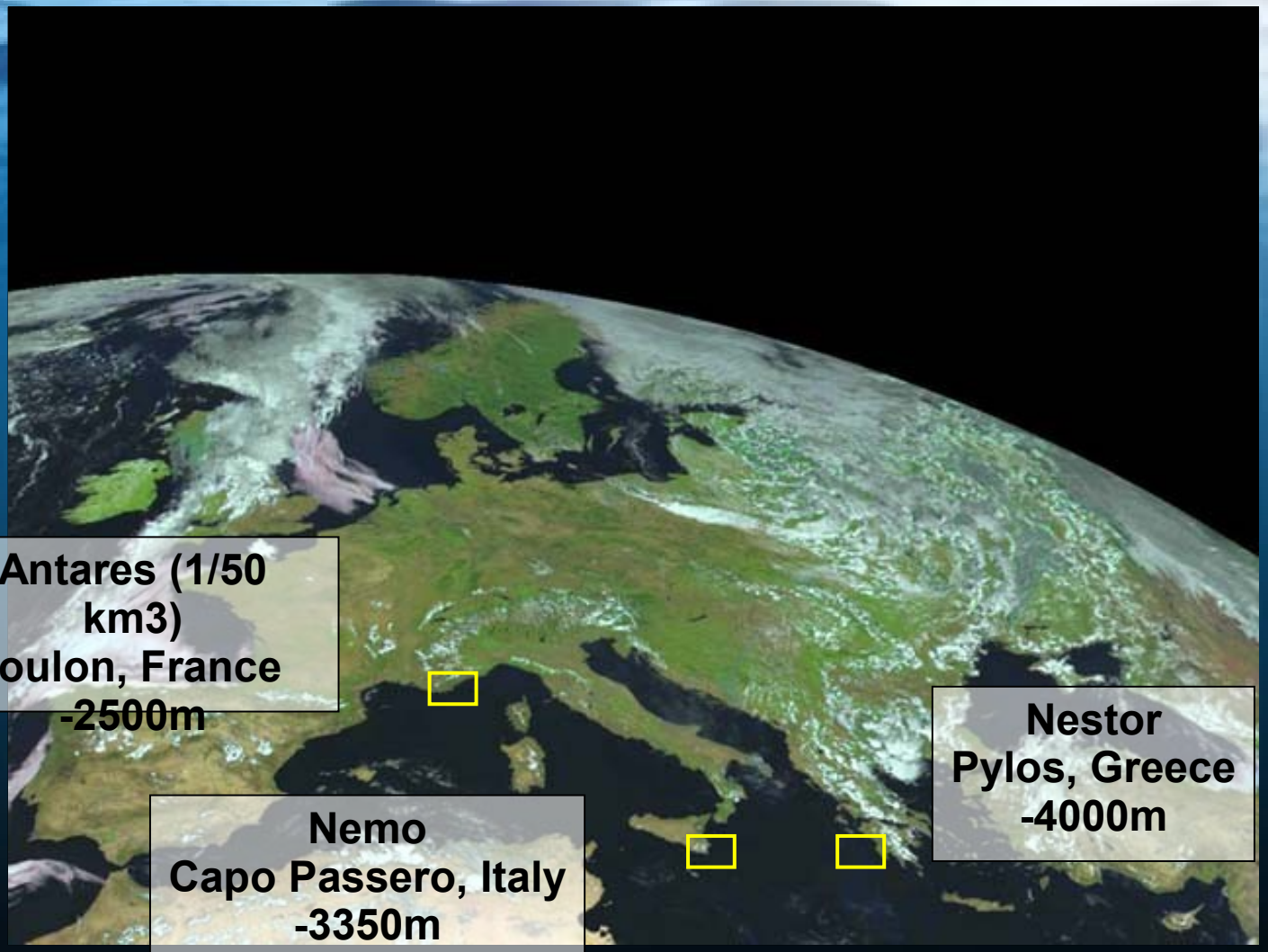
· For E□>10 TeV, the resolution is limited by track reconstruction errors.

Point Source Sensitivity

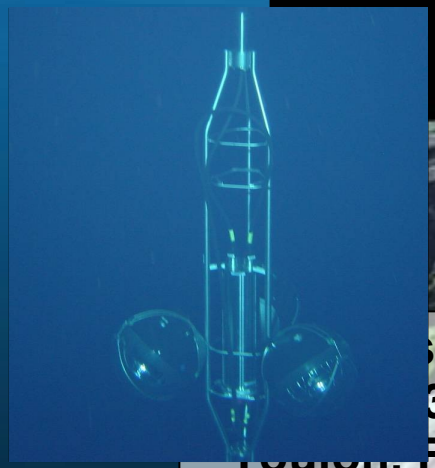


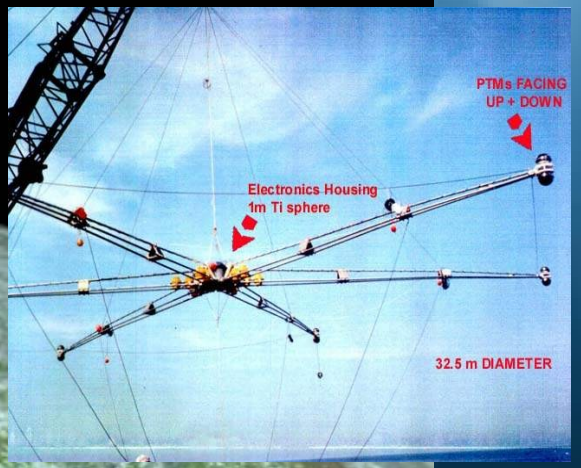
Toward a km3-scale detector

in the Mediterranean sea



Mediterranean Efforts





Since 1996
Data taking
150
members

Nemo
Capo Passero, Italy
-3350m

Since 2000
R&D
80
members

Nestor
Pylos, Greece
-4000m

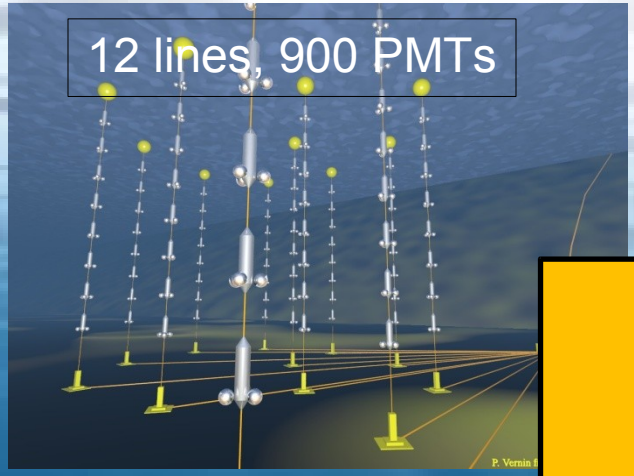
Since 1990
R&D
30
members

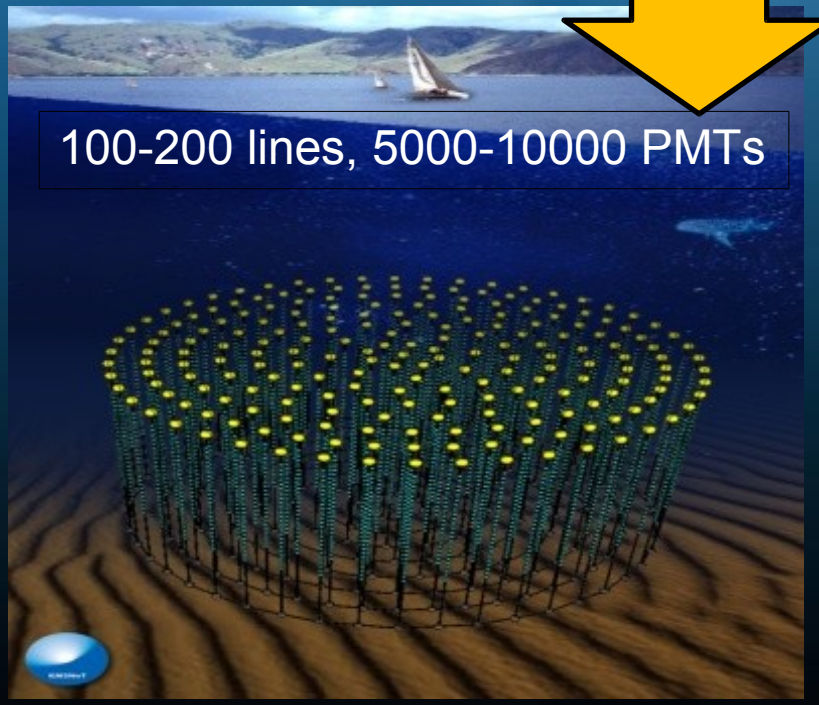
The challenge

- Maximise physics potential
  - Instrumented volume >1km3
  - Angular resolution ~0.1 degrees (E>10 TeV)

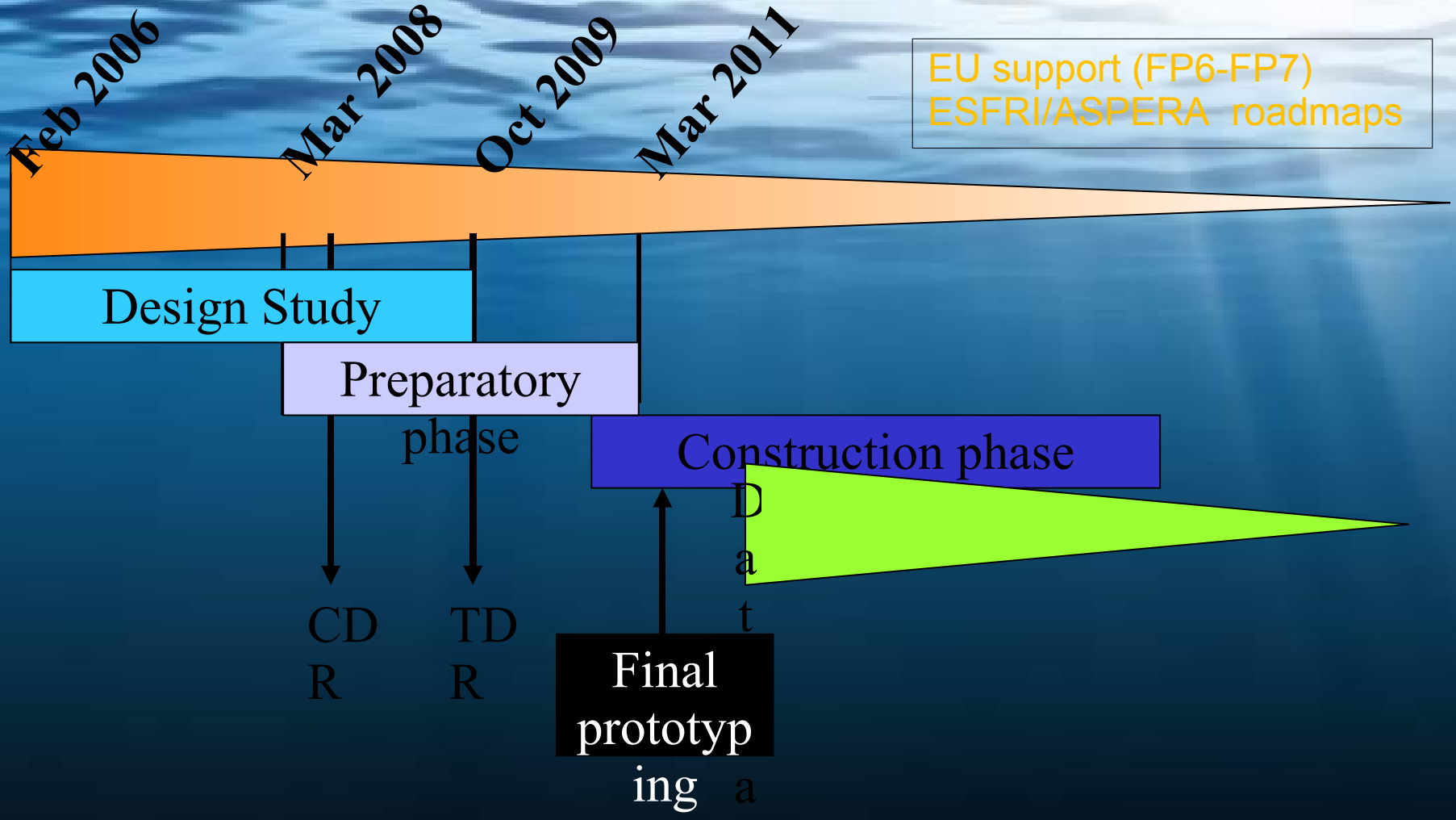
- Build in a reasonable time W4 years
  - New deployment techniques
  - Speed-up integration time
  - Sub contract part of the production
  - …

- At a reduced cost
  - Simplified architecture
  - Reduced maintenance
  - Multi-line deployments
  - …





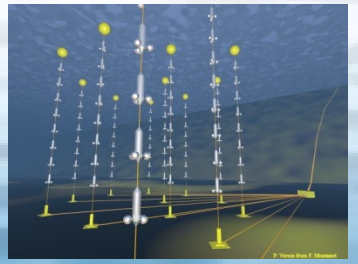
Timeline towards construction



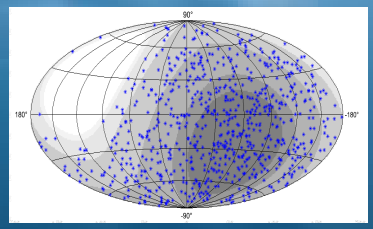
Good match to advanced LIGO/VIRGO facilities

Outlook

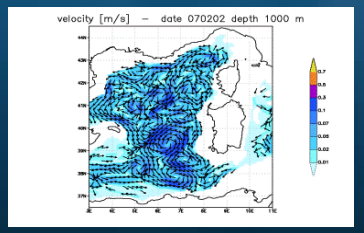
- ANTARES infrastructure completed since May 29th 2008
  - First lines in operation since 2006
  - Detector operation and calibration under control
  - Maintenance capability demonstrated



- Exciting physics program ahead
  - Over a thousand neutrino reconstructed
  - Unexplored region of the sky
  - astronomical sources, dark matter, oscilllations, ……)
  - Multi-messenger approach strongly encouraged



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



- Major step towards the KM3NeT multi-disciplinary deep-sea research infrastructure