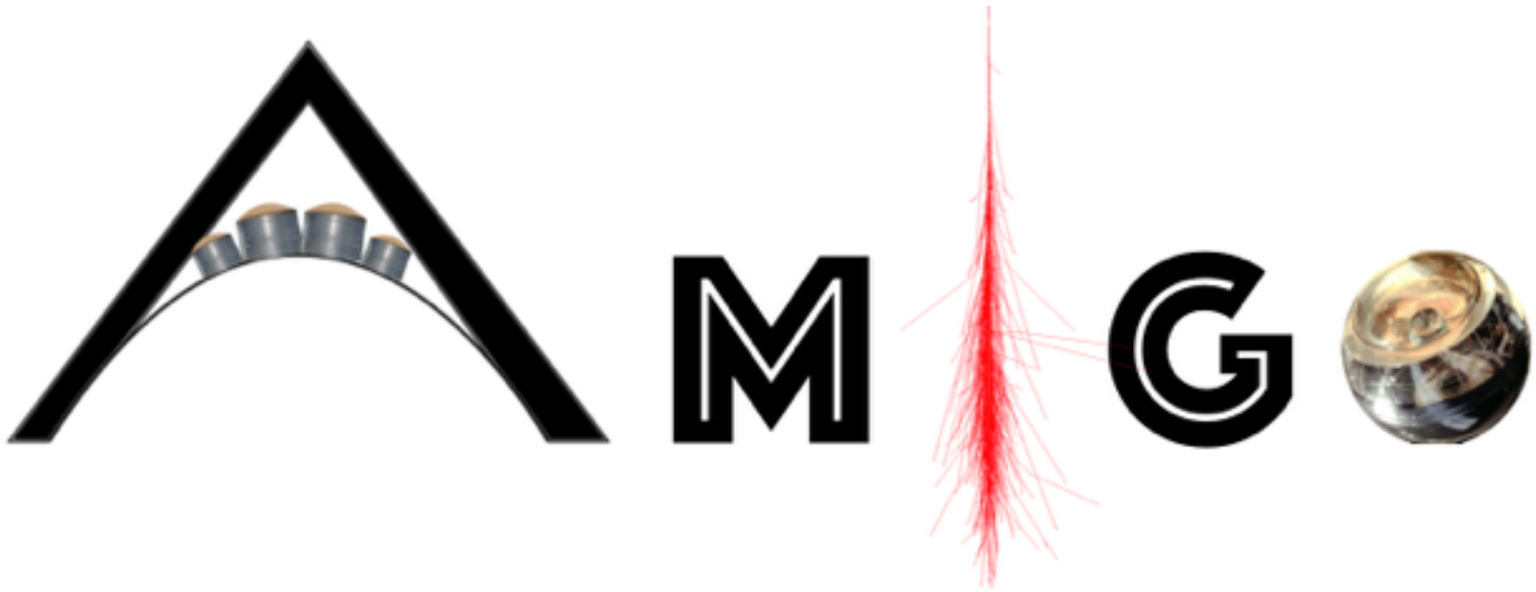
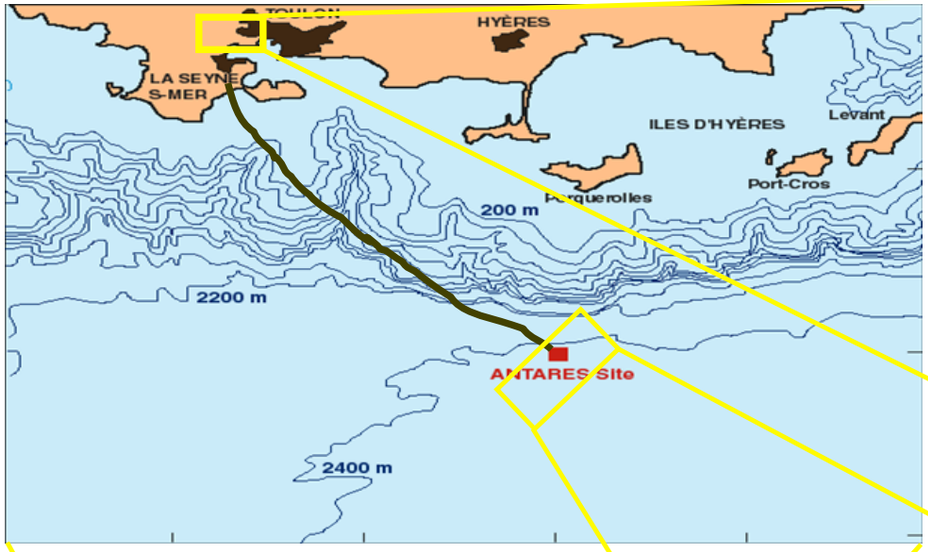


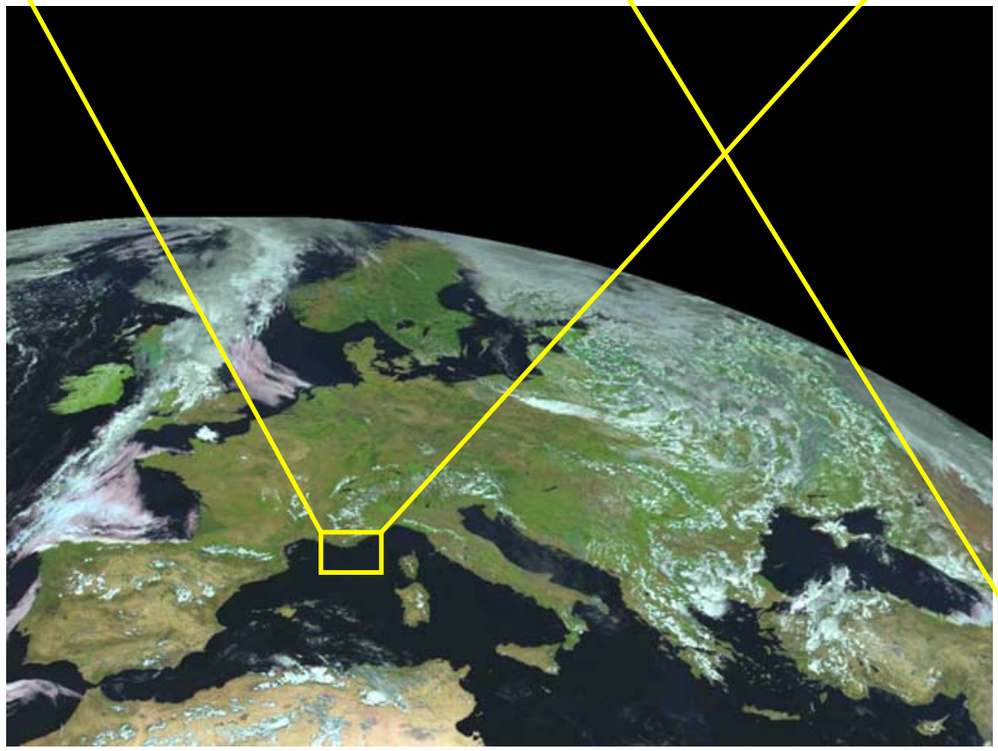
Antares **M**odules **I**n A **G**amma-ray **O**bservatory

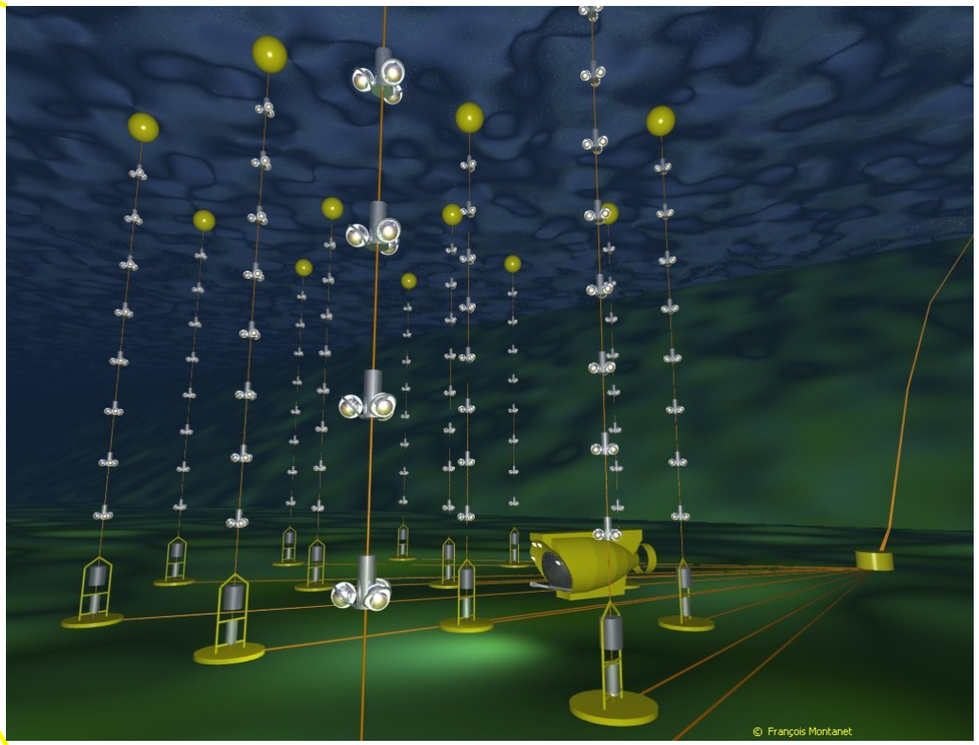
Fabian Schüssler, Irfu / CEA-Saclay
Puebla, 2016-11-11

The ANTARES neutrino telescope

- Off the coast of Toulon/France
- Depth ~2500m



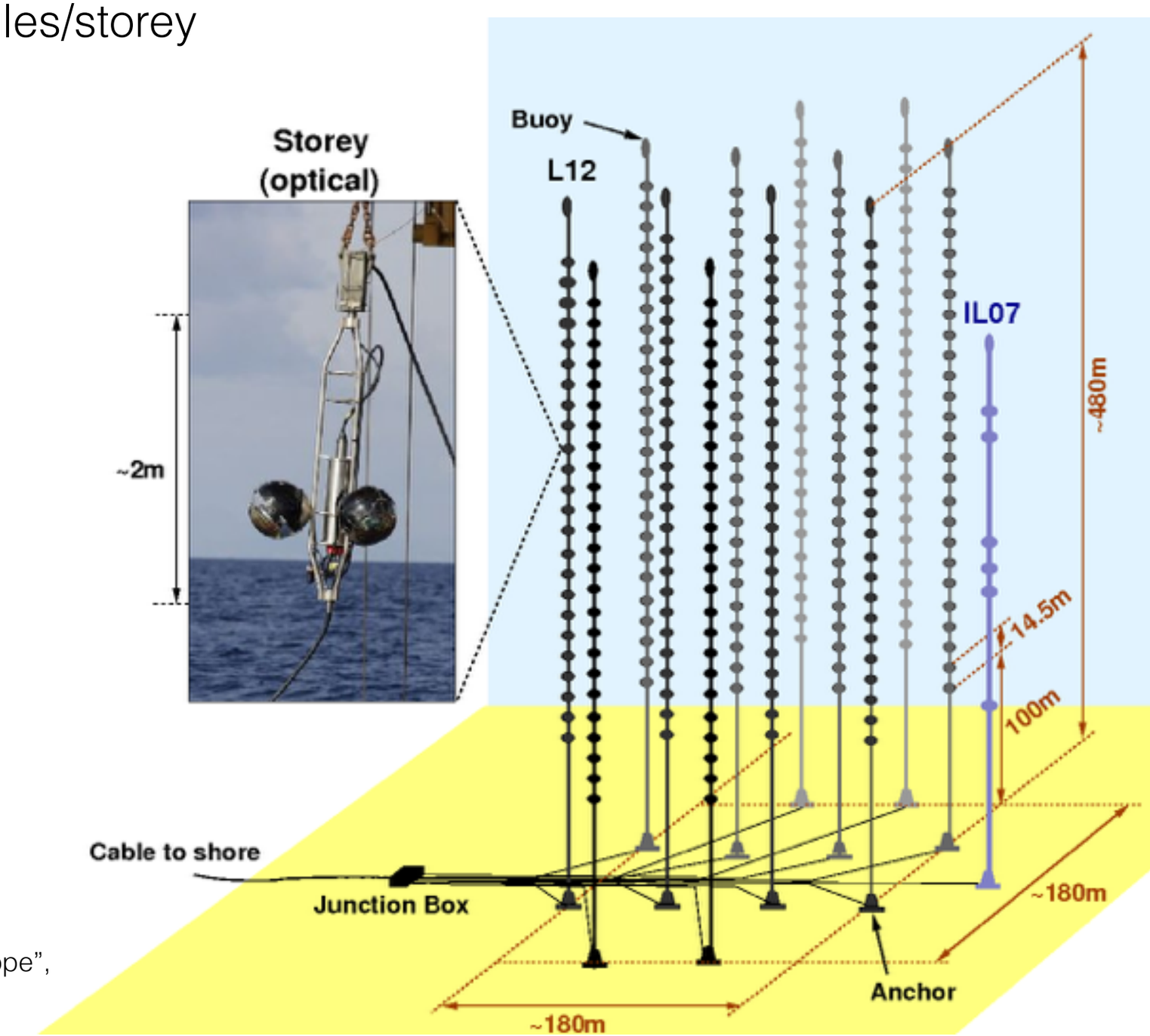




J.A. Aguilar et al., ”ANTARES: the first undersea neutrino telescope”, NIM A 656 (2011) pp. 11-38 (ArXiV:1104.1607v1)

The ANTARES neutrino telescope

- Off the coast of Toulon/France
- Depth ~2500m
- line installation started 2006
- 12 lines, 25 storeys each, 3 modules/storey



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- Off the coast of Toulon/France
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- line installation started 2006
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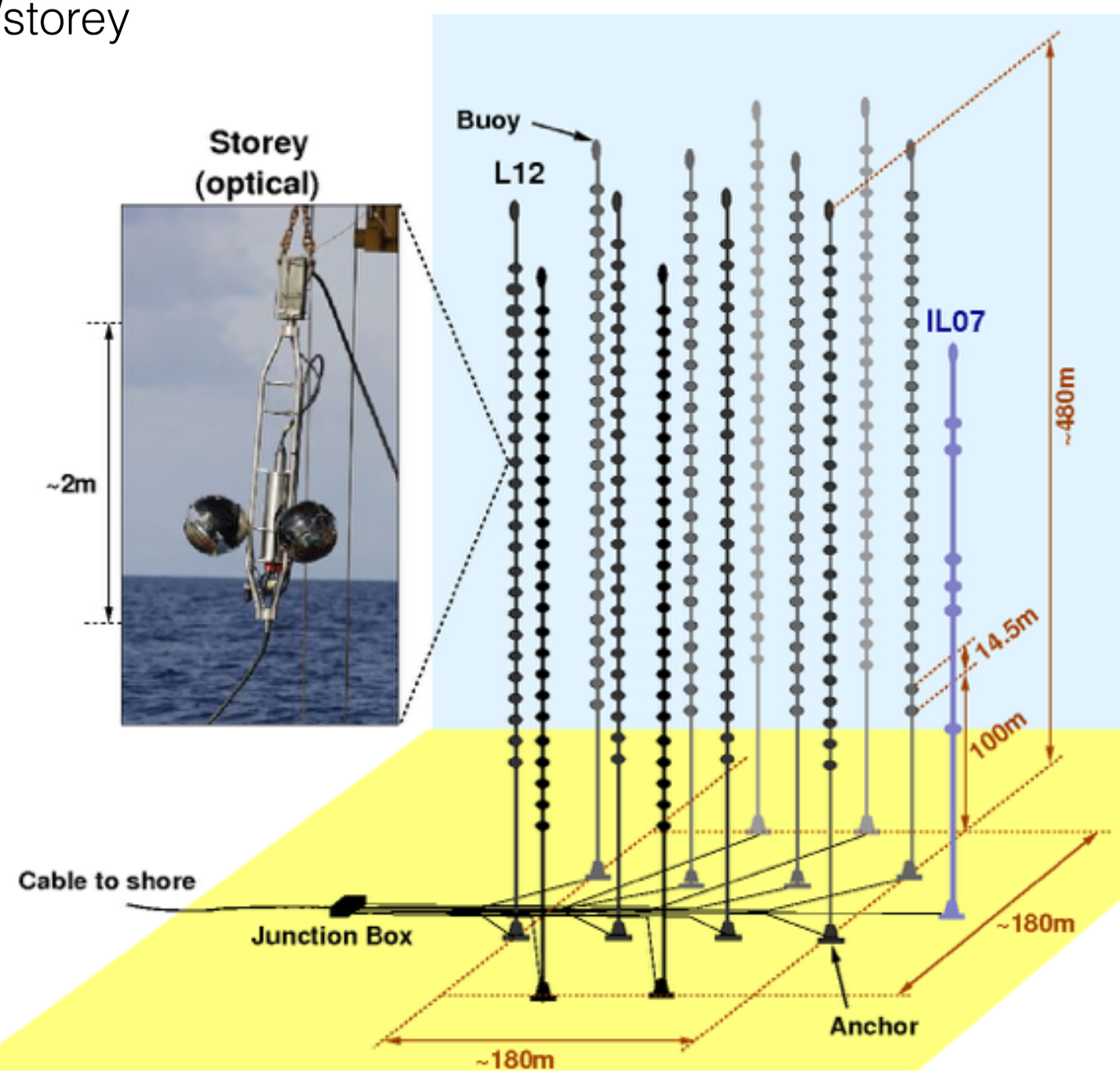
- decommissioning 2017
  - cutting the lines
  - removing modules from storeys
  - cleaning/storage at shore station



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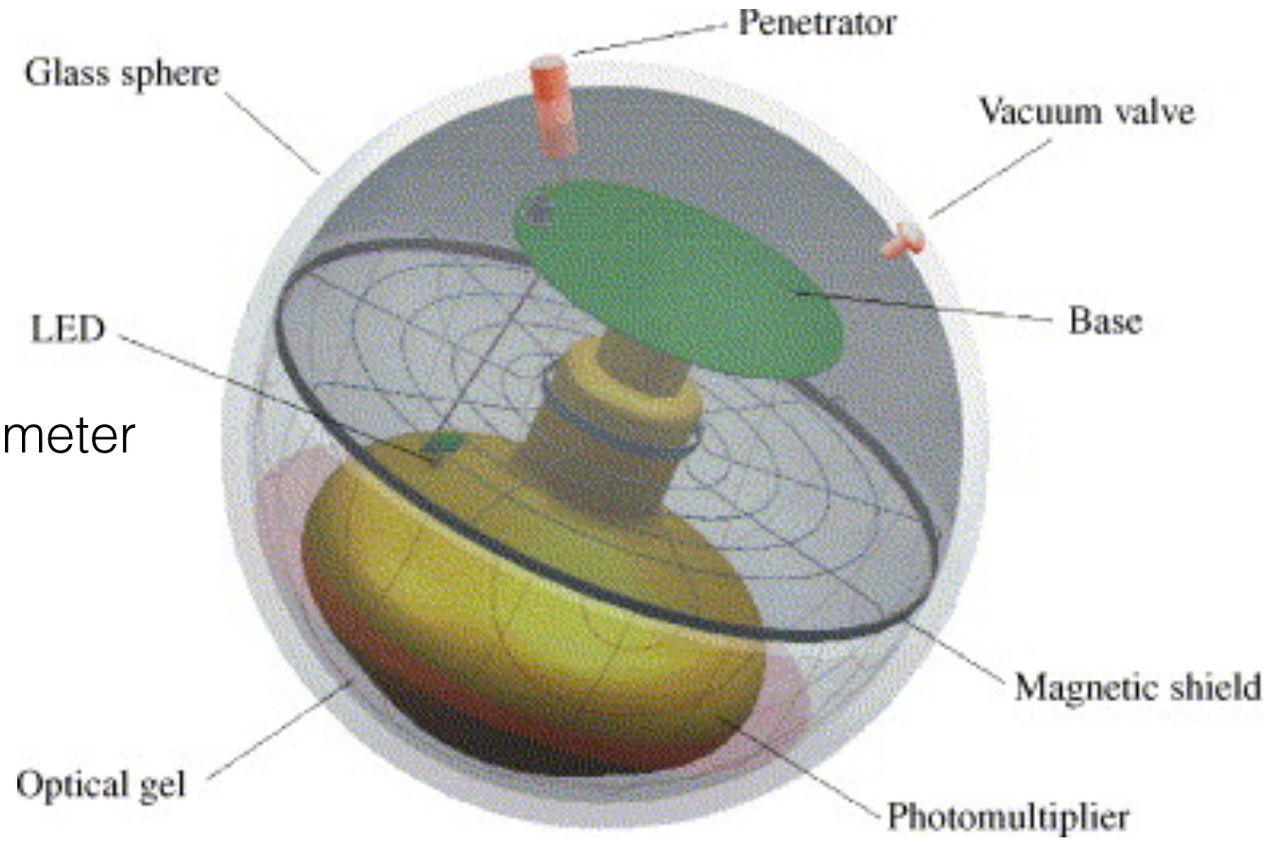
The ANTARES modules

- 14-stage 10 inch hemispherical tube from Hamamatsu type R7081-20 in a 17 inch glass sphere
  - photocathode area 500 cm^2
  - quantum efficiency 20 % and collection efficiency >80 %
  - transit time 70 ns and transit time spread below 3 ns (monitored with a flashing blue LED glued on the rear part of the bulb)
  - DC powered active base from iSeg Technologies Germany GmbH, applying a focusing voltage of 800 V between photocathode and first dynode, and amplification voltage up to 1600 V spread from first dynode to anode
  - overall operating voltage from 1600 V to 2000 V for the required gain of 5×10^7, resulting in 8 pC signal for a SPE integrated over the typical pulse duration of 25 ns
  - dark count rate below 2 kHz at 1/3 SPE threshold without glass sphere (3kHz with sphere due to ^{40}K)

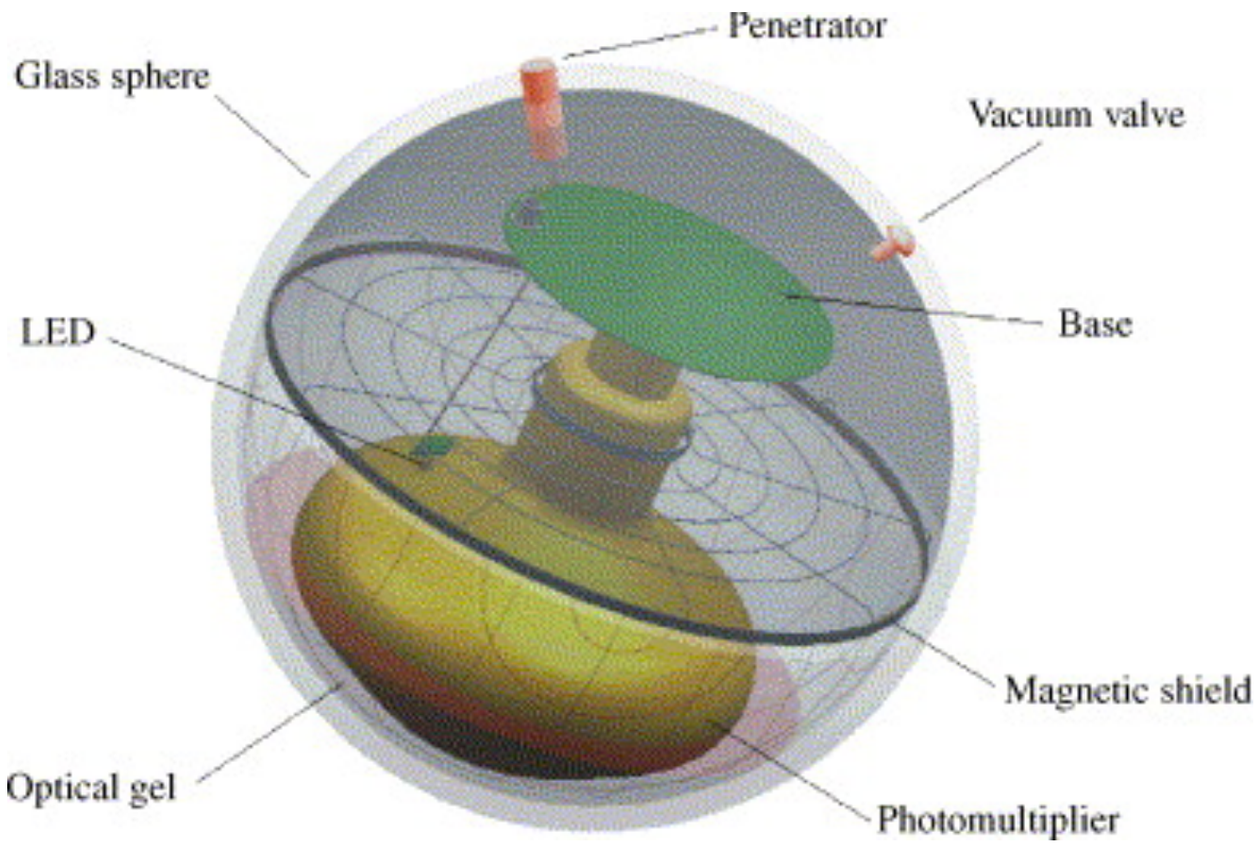
- PMT coupled to glass sphere with transparent gel
- μ-metal cage to reduce influence of magnetic field
- black half with penetrator, vacuum valve and manometer



P. Amram et al., "The ANTARES optical module", NIM A 484 (2002) 369
J. A. Aguilar et al., "Study of large hemispherical photomultiplier tubes for the ANTARES neutrino telescope", NIM A 555 (2005) 132-141

The ANTARES modules: readout

- readout available via BH12F sockets from MacArtney Underwater Technology
  - IN: 48 V DC power to the active base
  - IN: low voltage (0-4 V) to create amplification voltage (0-1600 V)
  - IN: pulse (0-24 V) to flash the internal LED (monitoring of transit time)
  - OUT: low voltage monitoring
  - OUT: dynode 12 signal
  - OUT: dynode 14 signal
  - OUT: anode signal



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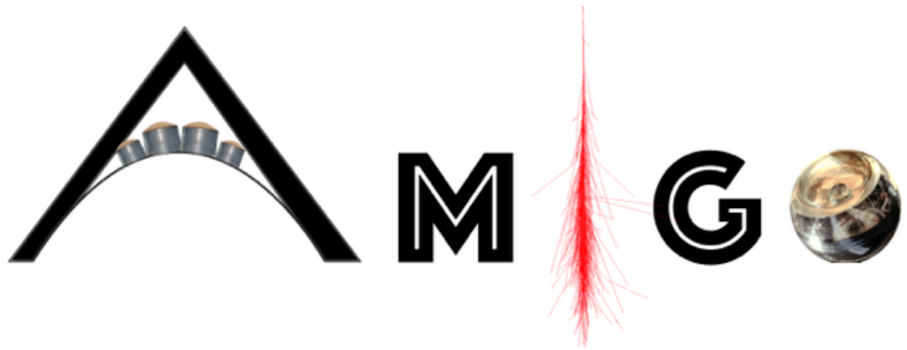


Antares **M**odules **I**n A **G**amma-ray **O**bservatory

- **agreement of the ANTARES Collaboration to use the ANTARES optical modules in a next generation high-altitude water Cherenkov observatory**
- definition of a non-destructive decommissioning operation of the ANTARES detector, i.e. keeping the OMs, the penetrators and the connected cables intact
- transport and storage of the OMs (incl. their connectors, etc.) at a nearby shore station (e.g. the Foselev instrumentation hall)

Link: latest version (2016-10-11)

Tests + Prototypes

- ALTO
  - 2 spare ANTARES modules available at LnU/Sweden
  - will be used in the full station prototype in 2017

- HAWC
  - 2 spare ANTARES modules available at LANL/US
  - being tested on the HAWC PMT test bench
  - if conclusive, might be put into a HAWC tank

- LATTES
  - prototype WCD (?)

We are open to provide additional modules for new ideas/tests/prototypes

Towards a next-generation observatory

My assumption: we'll (at best) get only one new high-altitude water Cherenkov observatory for high-energy gamma-ray astronomy

- will need a joint effort to find the best/most efficient design
- starting point might be this meeting

No design favored in the AMIGO proposal

AMIGO is not a detector proposal, but a general idea on how to re-use the Antares modules

contributions from all interested parties (ALTO, LATTES, HAWC, NectarCAM, FlashCAM, etc.)

Expression of interest

Version: Tuesday 11th October, 2016

U. Barres de Almeida[4], G. Anton[20], Y. Becherini[2], S. BenZvi[15], M. Böttcher[13], P. Brun[1], S. Carius[2], E. Delagnes[1], V. de Souza[19], B. Dingus[9], M. DuVernois[12], T. Eberl[20], R. Engel[18], S. Funk[20], J.-F. Gliçenstein[1], J. Goodman[10], A. Haungs[18], J. Hinton[14], U. Katz[20], K. Kosack[1], K. Kotera[5], J.-P. Lenain[11], R. López Coto[14], O. Martineau-Huynh[11], F. Mirabel[1], M. Mostafa[8], E. Moulin[1], L. Nellen[16], B. Peyaud[1], T. Pradier[7], J. Pretz[8], M. Punch[2,3], C. Rivière[10], M. Roth[18], A. Sandoval[16], M. Santander[17], H. Schoorlemmer[14], F. Schüssler[1], M. Seglar Arroyo[1], T. Stolarczyk[1], S. Thoudram[2], B. Vallage[1], C. van Eldik[20], M. Vecchi[19], R. Wischnewski[6]

[1]: Institut de recherche sur les lois fondamentales de l'Univers (IRFU), Saclay/France
[2]: Linnaeus University, Växjö/Sweden
[3]: Laboratoire Astroparticules & Cosmologie (APC), Paris/France
[4]: Centro Brasileiro de Pesquisas Fisicas (CBPF), Rio de Janeiro/Brasil
[5]: Institut d'Astrophysique de Paris (IAP), Paris/France
[6]: Deutsches Elektronen Synchrotron (DESY), Zeuthen/Germany
[7]: Institut Pluridisciplinaire Hubert Curien (IPHC), Strasbourg/France
[8]: Pennsylvania State University, University Park/USA
[9]: Los Alamos National Laboratory (LANL), Los Alamos/USA
[10]: University of Maryland, College Park/USA
[11]: Laboratoire de physique nucléaire et de hautes énergies (LPNHE), Paris/France
[12]: University of Wisconsin-Madison, Madison/USA
[13]: North-West University, Potchefstroom/South Africa
[14]: Max-Planck-Institut für Kernphysik (MPIK), Heidelberg/Germany
[15]: University of Rochester, Rochester/USA
[16]: Universidad Nacional Autónoma de México (UNAM), Mexico City/Mexico
[17]: Barnard College / Columbia University, New York/USA
[18]: Karlsruhe Institute of Technology (KIT) / Institut für Kernphysik, Karlsruhe/Germany
[19]: Universidade de São Paulo, São Paulo/Brazil
[20]: Erlangen Center for Astroparticle Physics (ECAP), Erlangen/Germany

- Disclaimer: The above list denotes colleagues that expressed their personal interest as physicists in seeing the ANTARES modules re-used in a high-altitude gamma-ray observatory. It does not imply any commitment to form a new collaboration or actively contribute to an experiment.

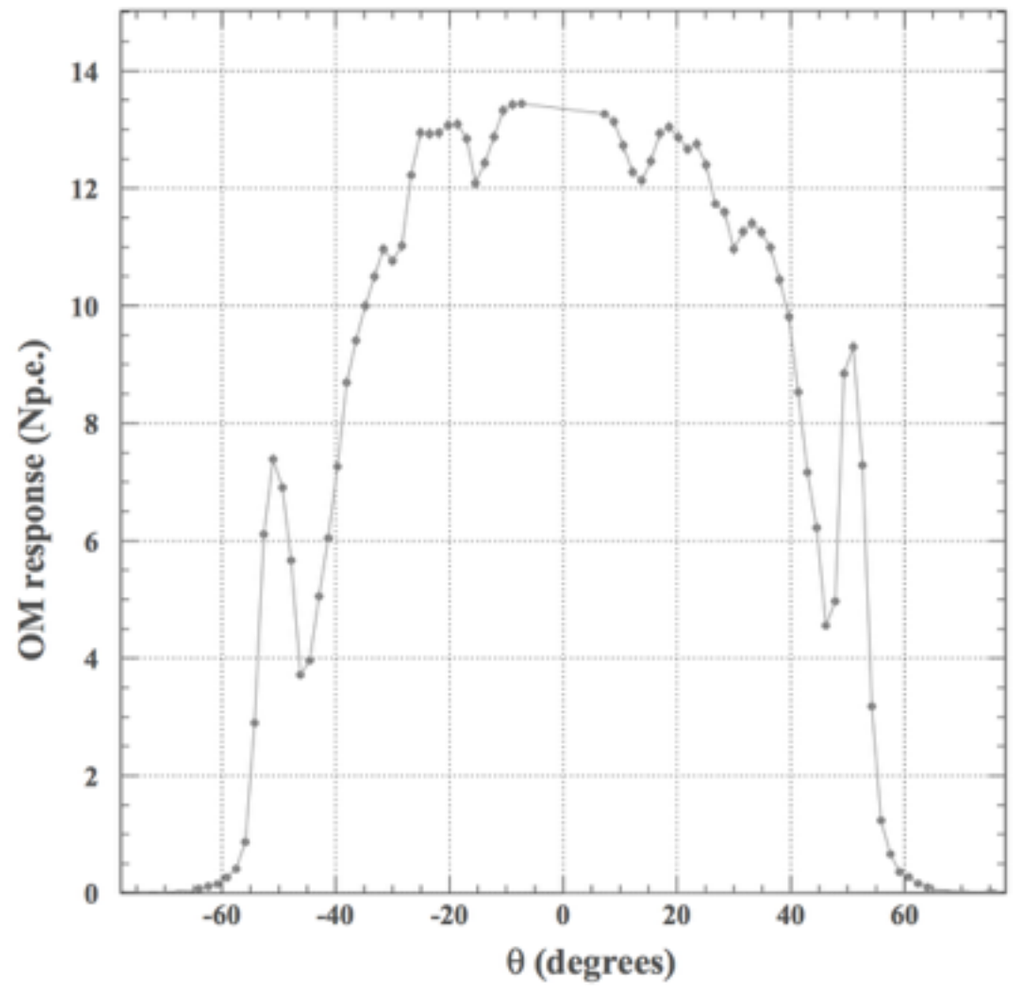
AMIGO: implementation + status

- The signatories of this proposals are available to support the outlined program and, if deemed necessary, participate in the foreseen recovery and storage operations. Especially on-shore activities like cleaning, sorting and preparations for the storage of the recovered optical modules could be handled by volunteers among the signatories.

- **Submission to ANTARES 2016-09-15**
  - currently the only formal proposal
- **Discussion at the ANTARES Institute Board meeting (2016-09-29)**
  - no decision yet
  - call for proposal from KM3NeT
  - next collaboration: meeting February 2017

AMIGO: open issues

- angular acceptance vs. WCD-station layout
- need new readout electronics
  - e.g. CTA-Nectar based: improved version of original ANTARES readout
- number of modules insufficient (?)
  - starting point to build a core array
  - outriggers
  - mixed setup like HAWC
- …



P. Amram et al., ”The ANTARES optical module”, NIM A 484 (2002) 369

Summary + conclusions

- ANTARES decommissioning foreseen for 2017

- Inspired by the reuse of Milagro PMTs in HAWC
  - reuse the ANTARES modules in a next generation large FoV gamma-ray observatory

- Proposal submitted, not a definitive process: get involved if interested!

- Reasonably good chances for success
  - testing on test benches and prototypes ongoing
  - angular acceptance vs. WCD design
  - prepare dedicated readout electronics

- White paper: use the AMIGO document as starting point (?)