ANTARES - latest news

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IOP Futures Meeting
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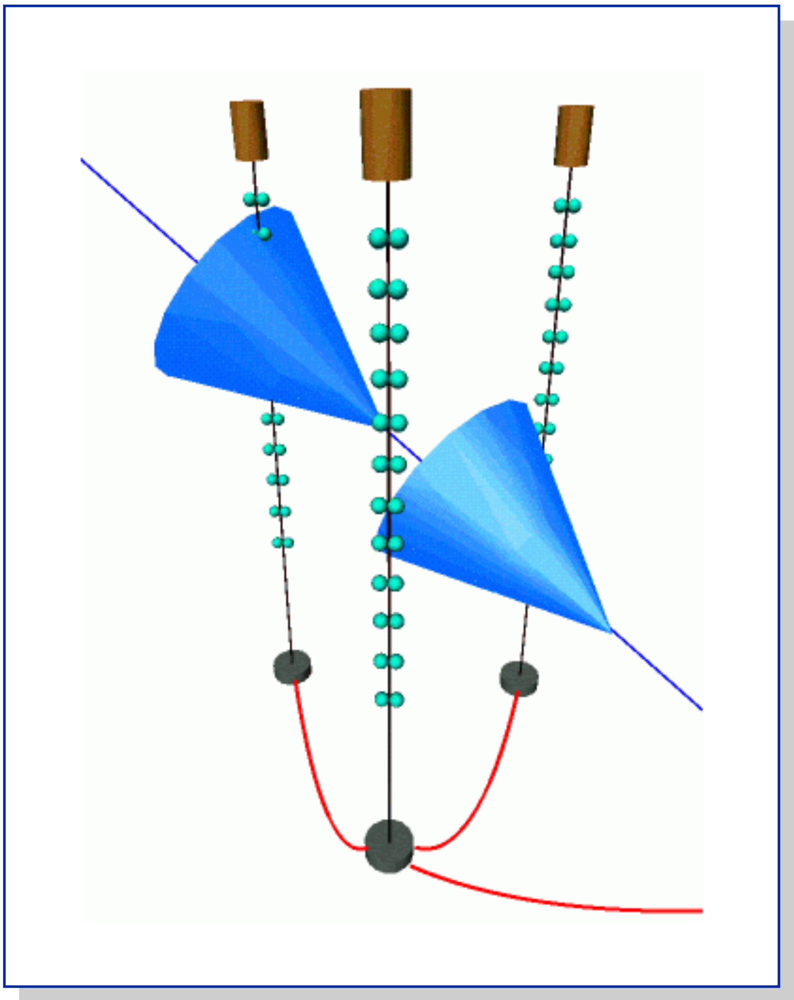
ANTARES Project R&D Phase Aims

- **To identify and measure a suitable deep-sea site to construct a neutrino telescope**
  - ¤ ***optical backgrounds***
  - ¤ ***optical fouling***
  - ¤ ***water transparency***
  - ¤ ***site survey***
- **To test the mechanics and logistics of deploying detector strings to this depth**
  - ¤ ***prototype line deployment and retrieval***
  - ¤ ***line deformation and positioning***
  - ¤ ***optical cable connection tests***
- **To develop software tools to reconstuct muon tracks and energies and to aid in the overall detector design optimisation process**
  - ¤ ***detector performance vs configuration***
  - ¤ ***physics simulations and predictions***

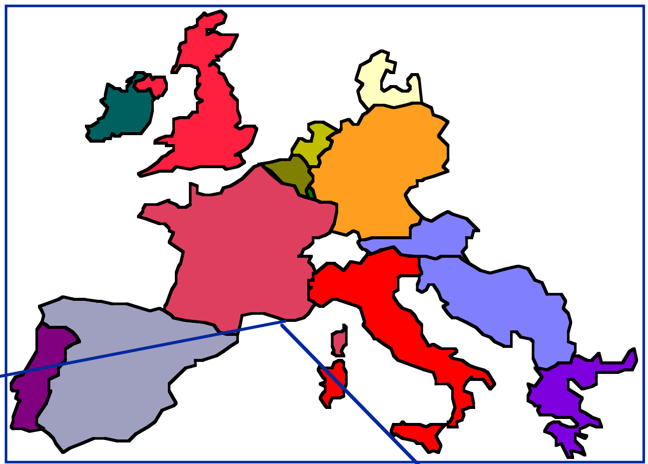
Detector Strategy

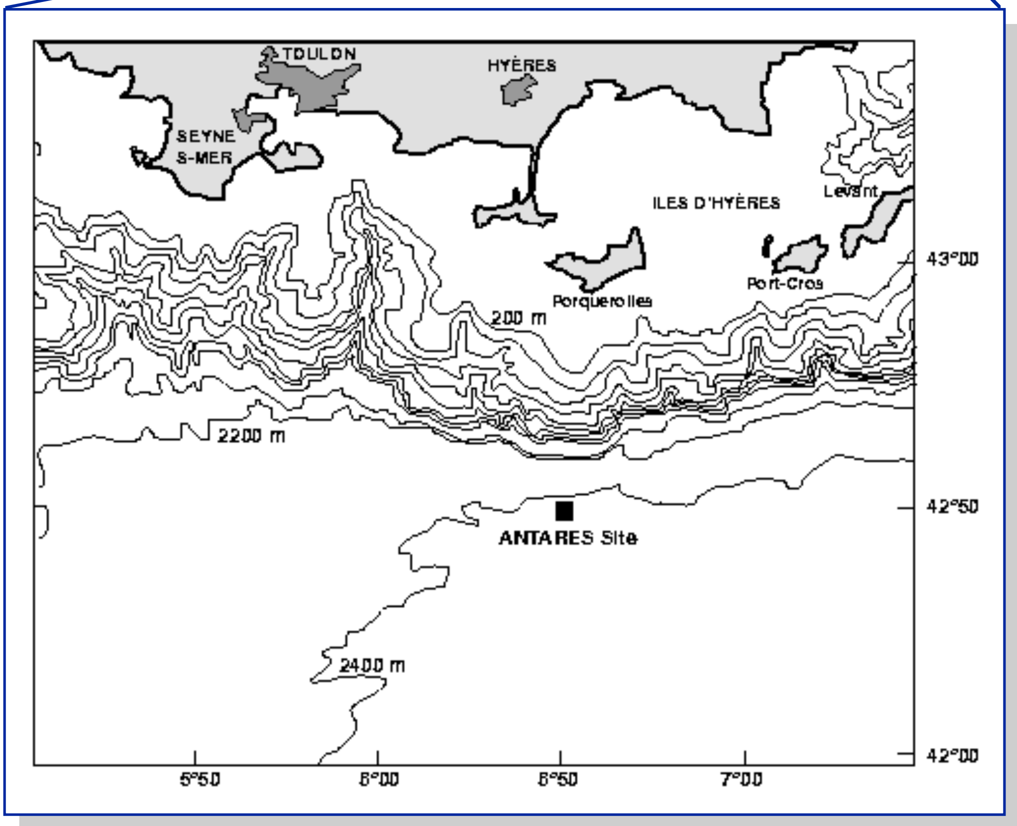
- A neutrino telescope detects muons originating from the charged-current interaction of neutrinos with nuclei.
- In a suitable radiator (such as water or ice) these long-range muons radiate Cerenkov photons
- Therefore a 3-D matrix of optical sensors such as PMTs will record the passage of the muon through the detector
- A detector that looks down uses the Earth as a shield against all particles except neutrinos



Site Evaluation

- Proposed site is at 2400m depth and is 40km from the southern French coast
- 3.5π sr of the sky is visible. 0.6π sr overlap with AMANDA





- Site parameters investigated via the regular deployment and retrieval of test strings

Water Transparency

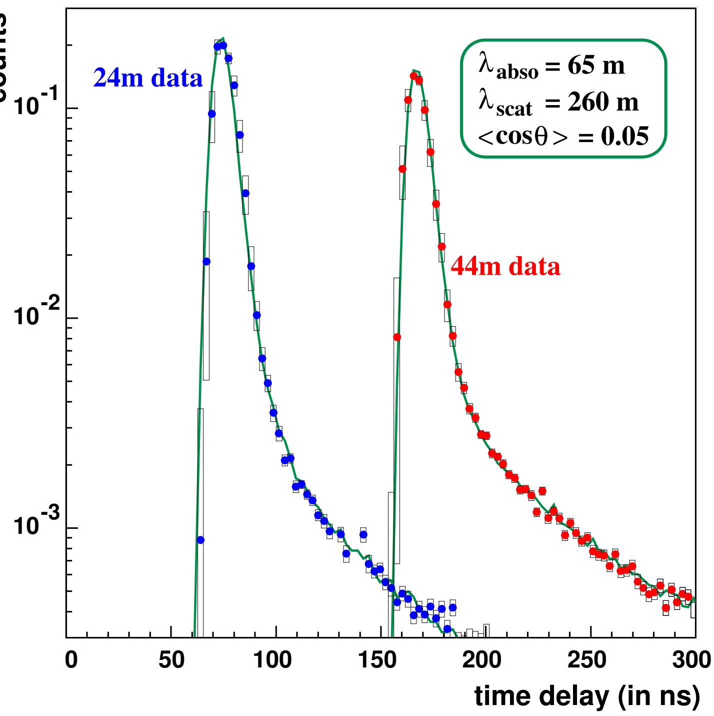
- Last summer a new technique was deployed using a pulsed blue LED flasher along with a TDC for timing information. This enables information on both the absorption and scattering lengths to be determined
- Data taken with this experimental setup in July '98 and March '99 are well reproduced with

  Λ_{abs} ~ 50-65m

  Λ_{scat} ~ 250m

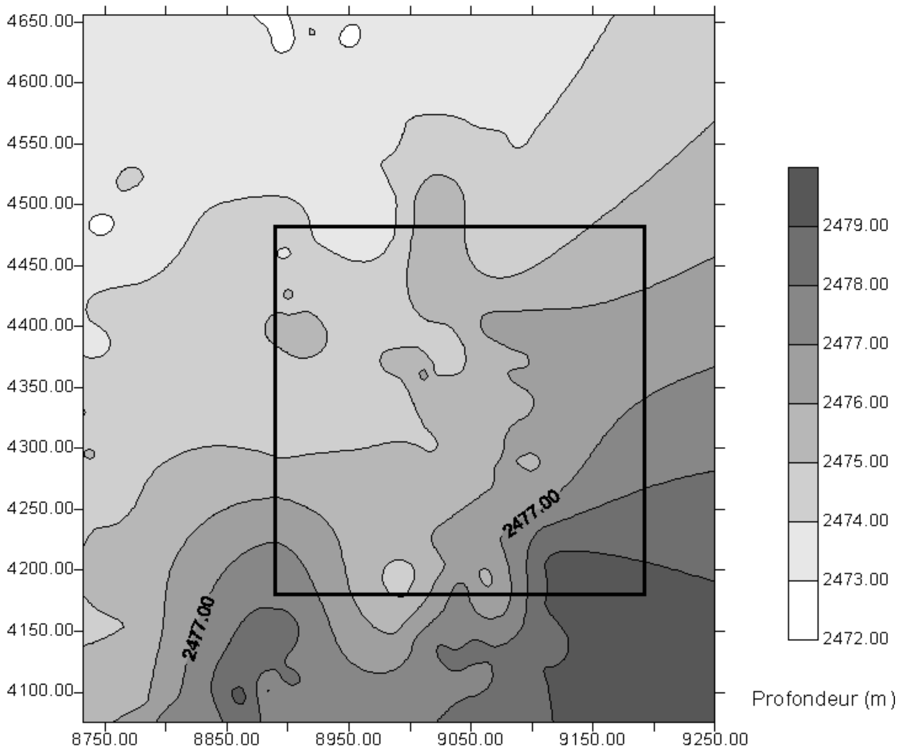
  < cos Θ> ~ 0.0
- Some evidence of seasonal variations

Arrival time distribution of photons from a pulsed isotropic source



Site Survey

- Performed by the manned submarine “Nautile” in December



- No evidence of problems, sea floor sloping gently, no abrupt features

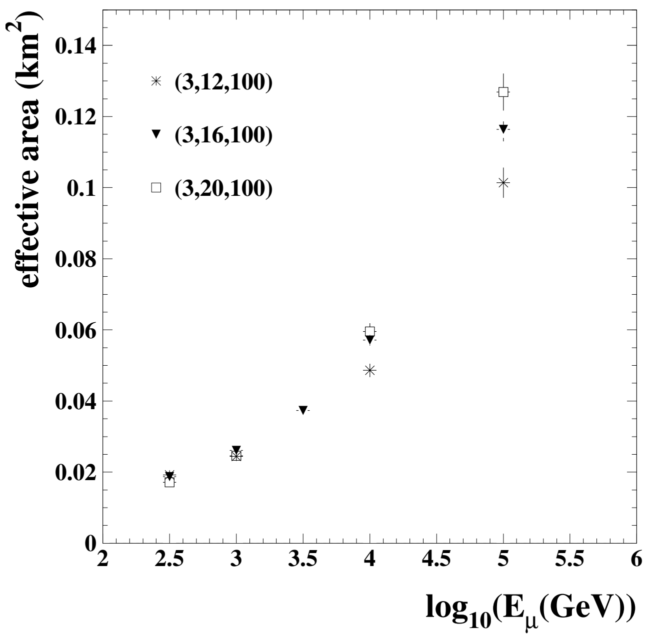
Detector Deployment

- **A full-scale 340m long un-instrumented string was deployed (and retrieved!) to full immersion depth in Autumn '98**

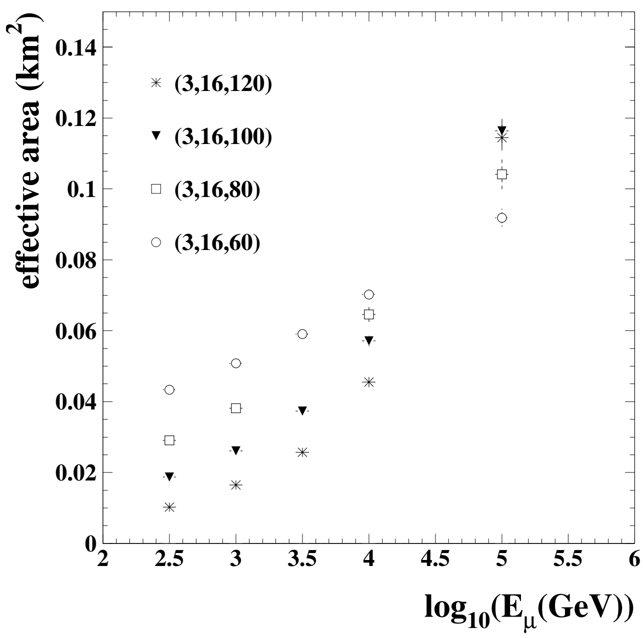
- **In April '99 "Operation Poisson" took place involving two 400m long strings and a dynamical positioning ship**
  - ¤ ***The aim was to deploy and anchor one string 50m from the other***
- **Successful - 3 such deployments done at different positions, all within 5-10metres of nominal position**

Performance

- Software studies have been made to look at the detector performance as a function of many detector parameters including
  - ¤ *number of PMTs per floor*
  - ¤ *PMT orientation*
  - ¤ *distance between floors*
  - ¤ *distance between strings*
- The metric used to measure the performance is the effective area of the detector



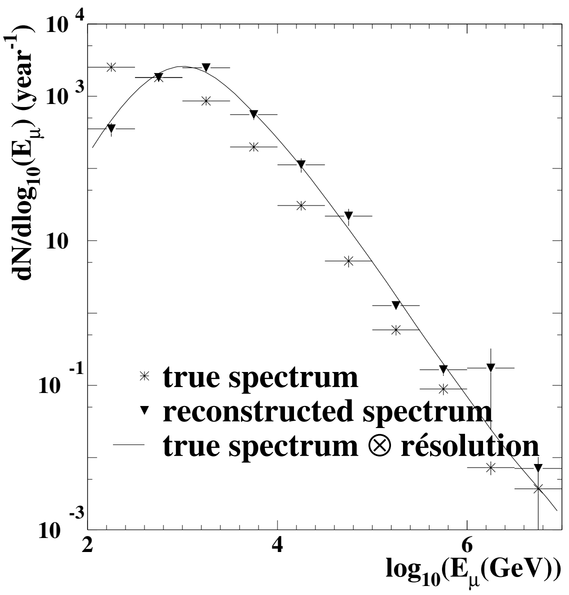
Performance vs. inter-floor spacing



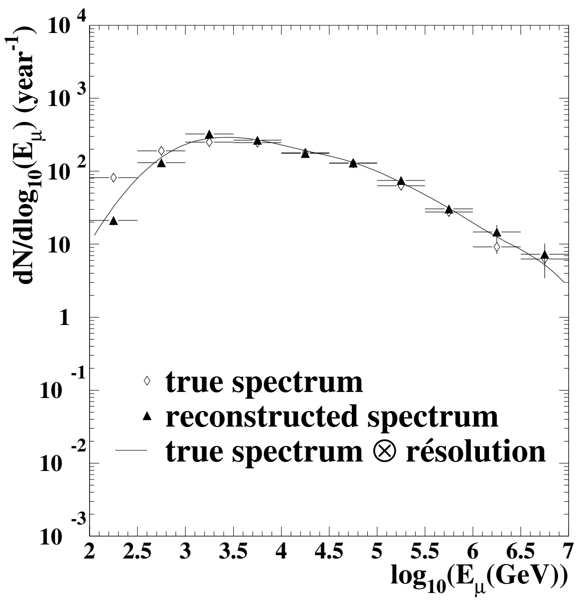
Performance vs. inter-string spacing

Energy Resolution

- Different techniques are used in different energy regimes
- At energies above 1 TeV the muon energy loss is dominated by catastrophic energy loss (bremsstrhlung, pair production) which increases with energy. A truncated mean parametrization is used
- The corresponding energy resolution is a factor of 3 at E > 1 TeV and a factor of 2 at E > 10 TeV
- Below 100 GeV the energy can be estimated from the range of the muon - this requires contained events



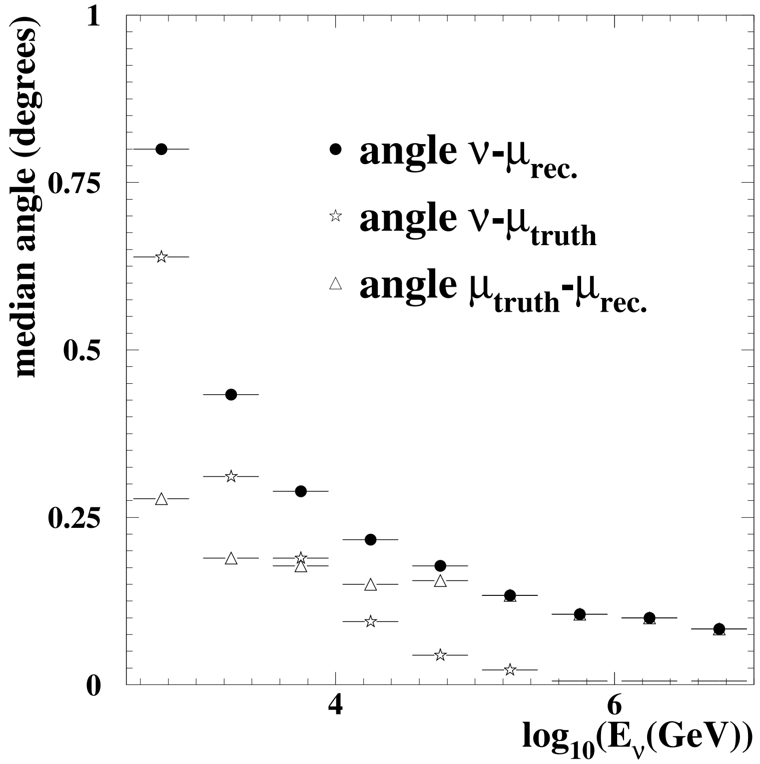
Atmospheric Neutrinos



AGN

Angular Resolution

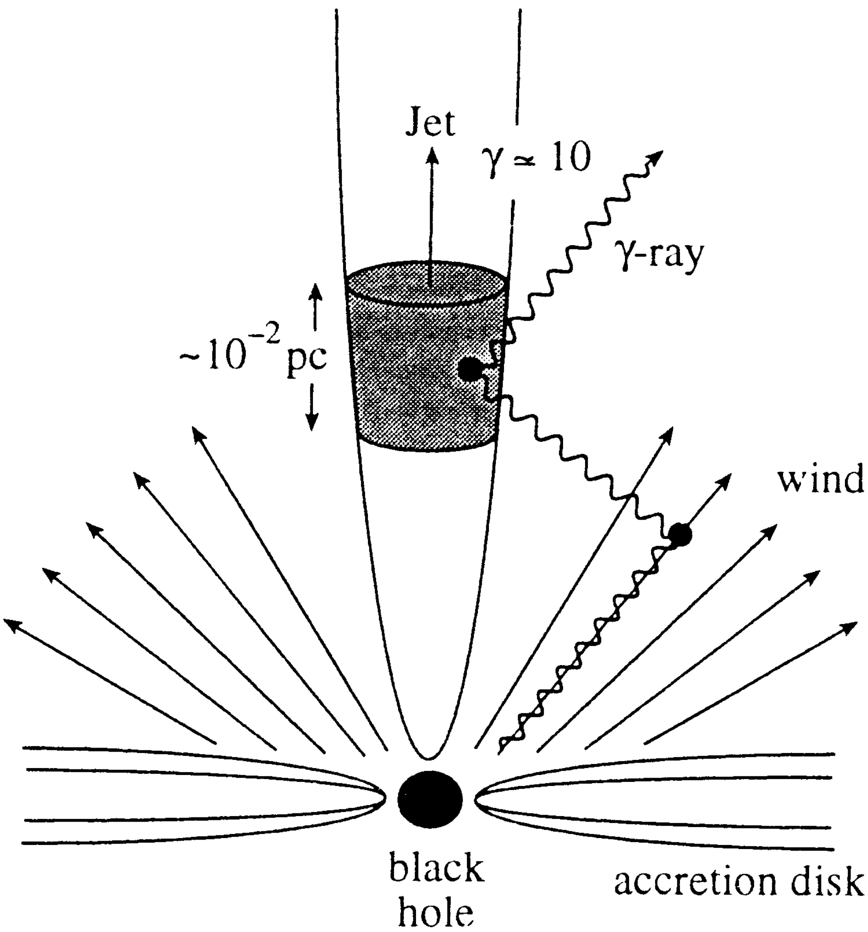
- The angular resolution of the detector depends on
  - *reconstruction algorithms*
  - *selection programs*
  - *timing accuracy (PMT timing error, positional error on OMs, timing calibration error)*



- **Half of the reconstructed neutrinos from a $1/E_\nu^2$ point source fall inside a circular region of radius 0.2 degrees.**
- **Note: high energy error is dominated by reconstruction errors**

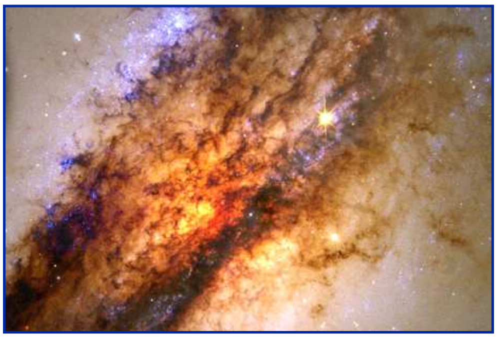
Active Galactic Nuceli

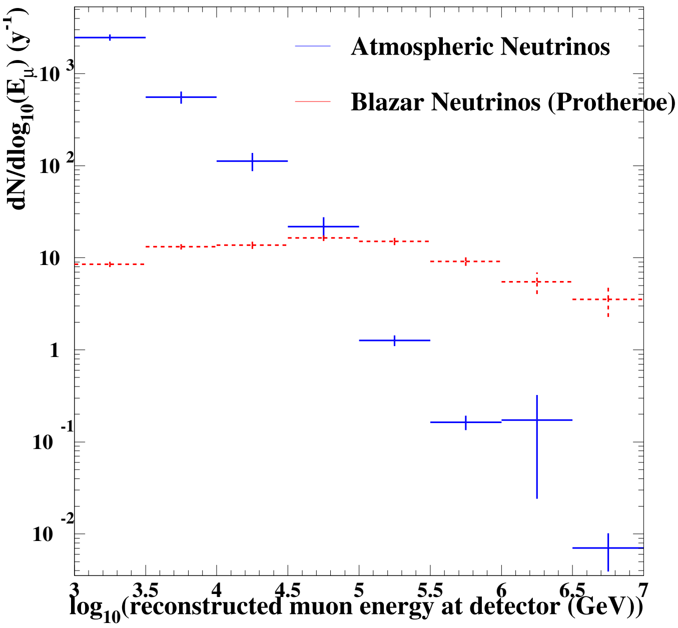
- AGNs are amongst the most luminous sources in the Universe
- Consist of a very energetic, compact central "engine" (presumably a supermassive black hole), mass accretion disk and relativistic particle jets aligned to the black hole's rotation axis ("blazars")



Active Galactic Nuclei

- Electromagnetic emission from radio waves to TeV gammas has been observed
- Mechanism for generating these high energy photons and the exact composition of the jet are still a matter of some debate
- Neutrinos could probe regions hidden by obscuring dust and help to solve these questions



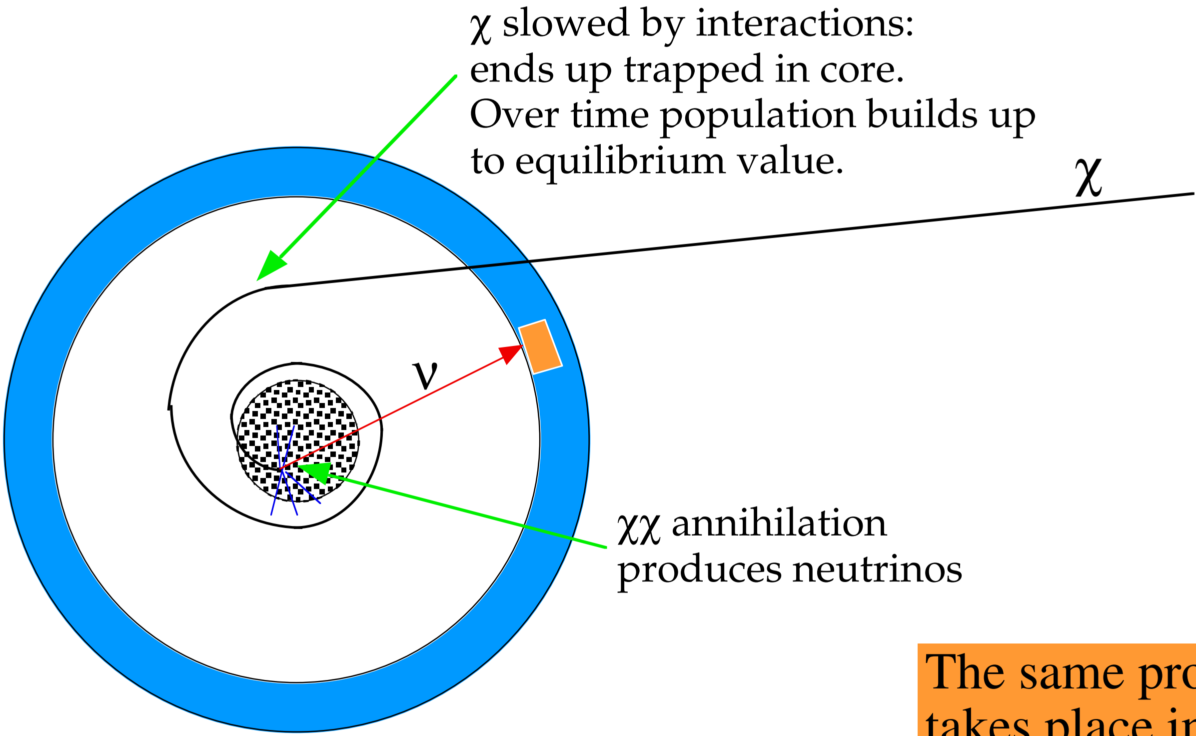


	Reco. Muon Threshold	
Model	**10 TeV**	**100 TeV**
Atmosph	68 ± 13	0.8 ± 0.1
AGN I	251 ± 12	134 ± 10
AGN II	217 ± 9	64 ± 4
Blazar I	34 ± 2	21 ± 2
Blazar II	7.8 ± 0.4	2.6 ± 0.3

Extrapolation of 2nd EGRET Catalogue

- For a 0.1 km^2 detector with one year of running then summing over the 42 possible AGN a total of 8 to 67 events (background + signal) is expected compared to 2.7 events (background only)

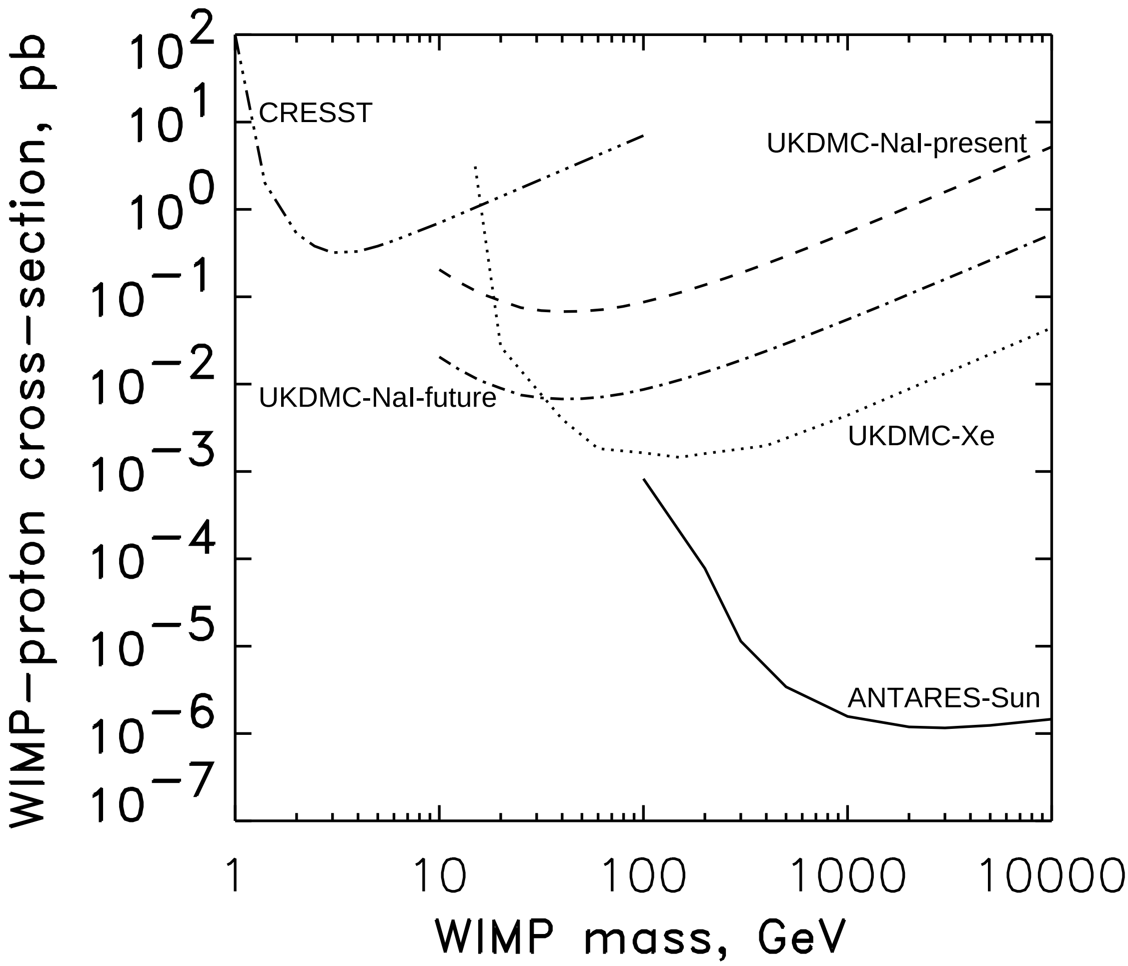
Dark Matter detection principle



The same process takes place in the core of the Sun

- **Neutralinos self-annihilate into fermions or combinations of gauge and Higgs bosons**
- **Subsequent decays of c,b and t quarks, τ leptons and Z, W and Higgs bosons can produce a significant flux of high-energy neutrinos.**
- **Neutralino-induced muons coming from the centre of the Earth are nearly vertical**

Neutralino Limits



- **Detection limits for 3 years running with a 0.1 km^2 neutrino telescope for neutralino annihilation in the centre of the Sun**
- **Other possibilities include neutralinos from the centre of Earth and galaxy**

Current Status

- **With all of the goals of the R&D phase successfully completed the project is now moving to the construction phase.**
- **A 12 string detector has been designed of area 0.1 km^2 comprising:**
  - ¤ ***4 densely populated strings (8m spacing)***
  - ¤ ***8 sparsely populated strings (16m spacing)***
- **Construction will run from 1999 to 2003. The final strings will be deployed in 2003.**
- **Approximate cost of the 0.1 km^2 detector is 97 MFF.**
- **Successful funding bids to CEA, IN2P3 and the EU mean that more than half of this money (~50 MFF) is available.**
- **Remainder of funding being sought from UK, Netherlands, Spain and EU.**

ANTARES Collaboration

France

- ¤ *CPPM (Marseille)*
- ¤ *DAPNIA-DSM-CEA (Saclay)*
- ¤ *Mulhouse-Strasbourg*
- ¤ *Centre d'Oceanologie de Marseille*
- ¤ *Institut Francais de Recherche pour l'Exploitation de la Mer (IFREMER)*
- ¤ *INSU-CNRS/IGRAP (Provence)*

Netherlands

- ¤ *NIKHEF*

Spain

- ¤ *IFIC Valencia*

United Kingdom

- ¤ *University of Birmingham*
- ¤ *University of Oxford*
- ¤ *University of Sheffield*

Russia

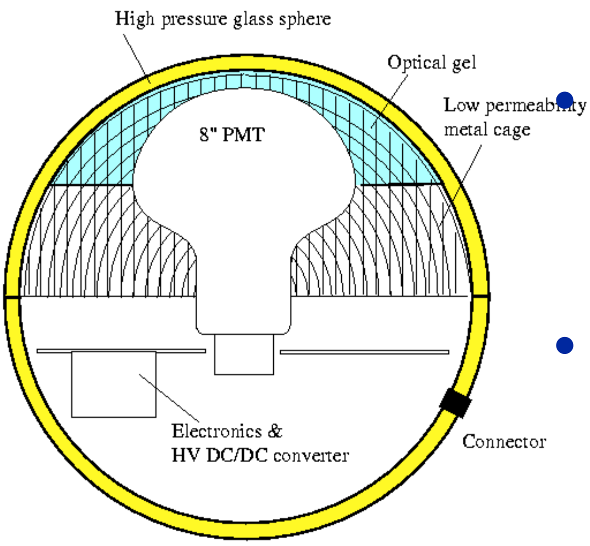
- ¤ *ITEP (Moscow)*

France Telecom Cable, Electron Tubes Ltd.,etc.

UK Involvement

- **The Birmingham, Oxford and Sheffield groups have physics analysis interests in**
  - ¤ ***Neutrino Astronomy (AGN, GRBs, etc.)***
  - ¤ ***Searches for neutralinos***
- **Hardware committments focus around a common theme of design, provision, testing and assembly of electronics components in the optical modules and of light sources for detector calibration and water quality monitoring:**
  - ¤ ***design of OM motherboards (Birmingham)***
  - ¤ ***testing of digital readout chips (Oxford)***
  - ¤ ***provision of OM LED circuits (Sheffield)***
  - ¤ ***assembly of OM electronics (Birmingham)***
  - ¤ ***optical transparency measurements (Oxford)***
  - ¤ ***design of optical beacons for calibration (Sheffield)***

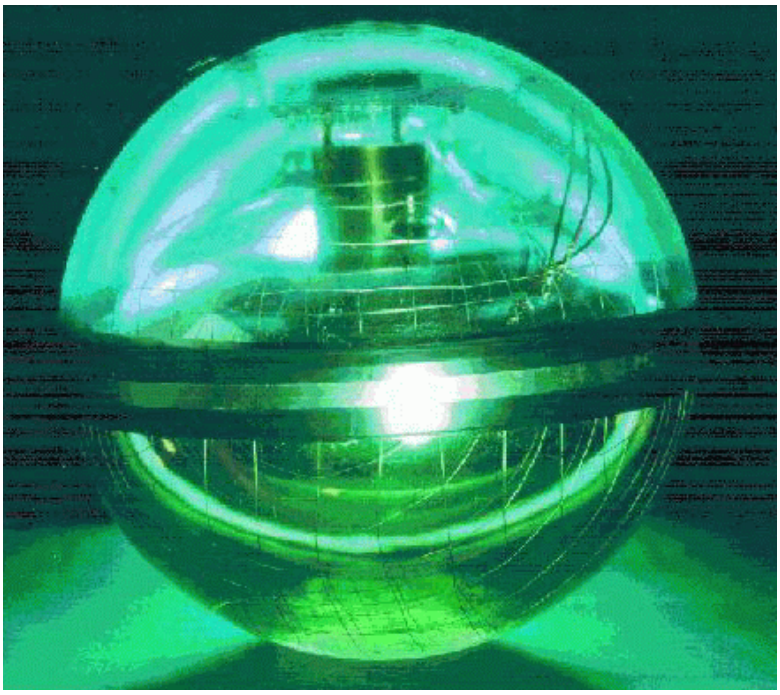
ANTARES Optical Modules



- Optical modules are grouped in 2 or 3 on floors
- Data is readout to local controllers (1 per floor) and multiplexed to shore over electro-optical cable

- Each optical module comprises
  - ¤ *a PMT*
  - ¤ *a μ-metal cage*
  - ¤ *digital readout*
  - ¤ *high voltage feed-through*

all inside a high pressure-resistant glass sphere



Summary and Outlook

- A large-area neutrino telescope enables a broad science mission capable of addressing a large number of topics in astronomy, astrophysics and particle physics.
- The collaboration is still less than 3 years old and has made excellent progress.
- As the first phase of the programme (R&D) draws to a successful conclusion a first operational string will be deployed in Summer 1999.
- In the past month the French funding agencies (CEA and IN2P3) have fully supported bids by the French ANTARES institutes (~ 50 MFF).
- The 0.1 km^2 detector is designed and will be built! Expect 12 strings by the end of 2003.
- To find out more see http://antares.in2p3.fr/proposal99.html
- New collaborators are always welcome!