High Energy ν Astronomy with ANTARES

Motivation: open new window on universe using ν's in the 10 GeV - 10 PeV energy range

Why νs ?

- Complementary information to γ-ray astronomy (c.f. Solar ν's, Supernova 1987a)
- Probe deep into core of source
  1 TeV ν m.f.p. = 10^{11} g cm^{-2}
  1 TeV γ m.f.p. = 10^{2} g cm^{-2}
  [γ's attenuated by interaction with I.R. & CMB photons above ~ 10-100 TeV]
- Link to Question of Origin of Cosmic rays (v. difficult to accelerate protons without producing ν's) ν's point back to source.
- Dark matter search WIMP annihilation $\Rightarrow$ νs
- Study νs $\Rightarrow$ neutrino mass

M. Moorhead
Birmingham '97.

ν's from Cosmic Accelerators

Several astrophysical objects can accelerate protons to very high energies (up to 10^{20} eV). These HE protons can produce νs and γs through $p\gamma$ or pp interactions:

$$pp \text{ or } p\gamma \rightarrow \pi^0 \text{ or } \pi^+ + \ldots$$

$$\pi^0 \rightarrow \gamma + \gamma$$

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

$$\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$$

ν/γ ratio at Source ≈ 1

Possible Proton Accelerators

1. Extragalactic sources
   - AGNs (active Galactic Nuclei)
   - GRBs (Gamma Ray Bursters)
2. Galactic Sources
   - X-ray Binaries
   - Pulsars
   - Young Supernovae Remnants.

Gamma Ray Bursts

- Recent Evidence for Cosmological origin
  GRB 970508 Red-shift measurement $z \geq 0.85$
- Many models consider Coalescing neutron stars
- Waxman & Bahcall: "Fireball model" with proton acceleration ⇒ Successfully account for afterglow luminosity in X-rays, optical & radio

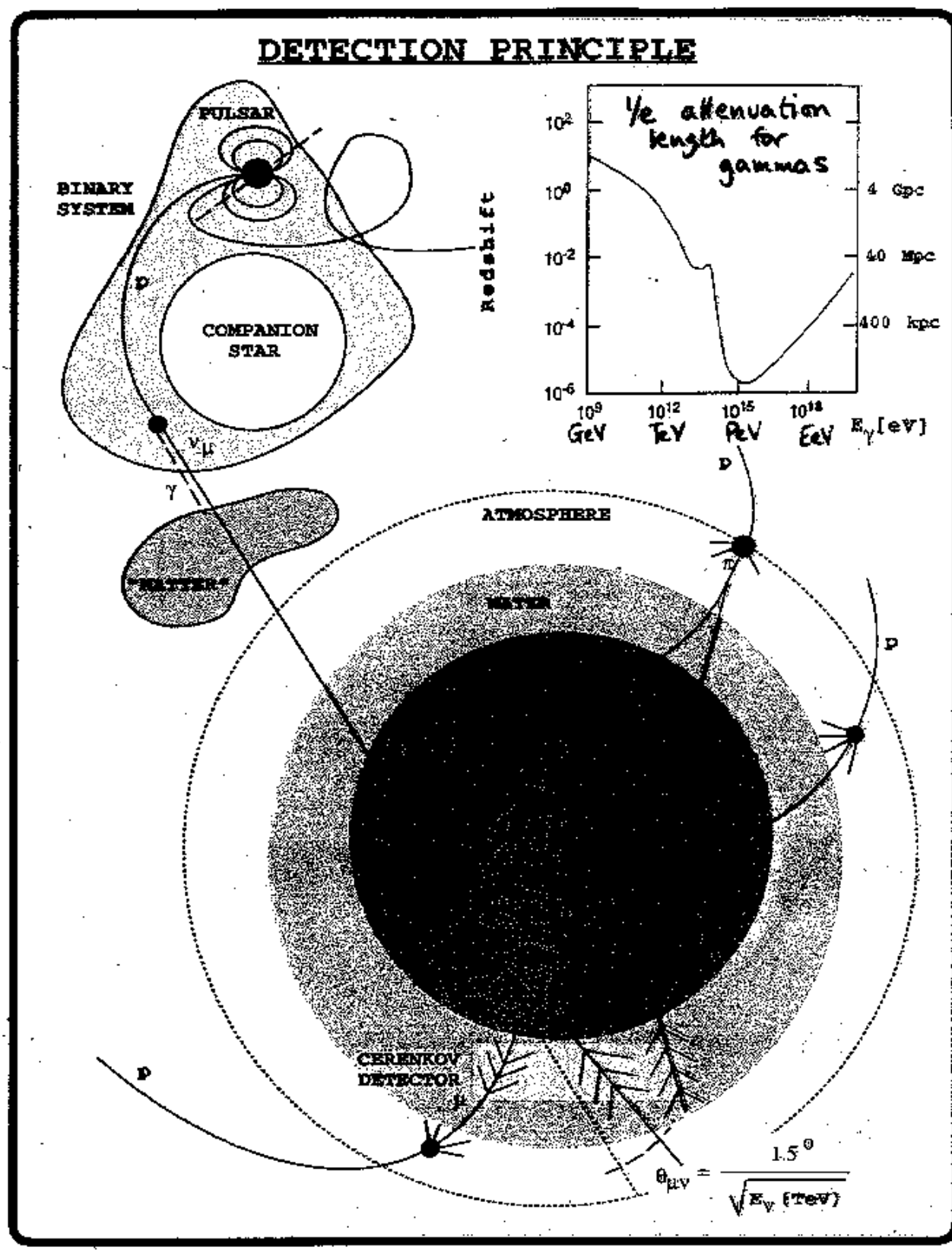
  Model explains UHE cosmic rays (up to 10^{20} eV)

  Prediction: 30 - 100 100 TeV ν events per km^2 detector per year
- Atmospheric ν background ≈ 0.1 event/year [using time correlation with GRB signal]
- Possibility of Kinematic ν mass measurement by observing time lag between νs & γs (a la SN 1987a)

  If $\Delta t \approx 1$ mS $\frac{\ell}{c} \approx 3 \cdot 10^9$ light Years

  ⇒ 10 eV M_ν can be probed with 100 GeV ν's

DETECTION PRINCIPLE



ANTARES Collaboration

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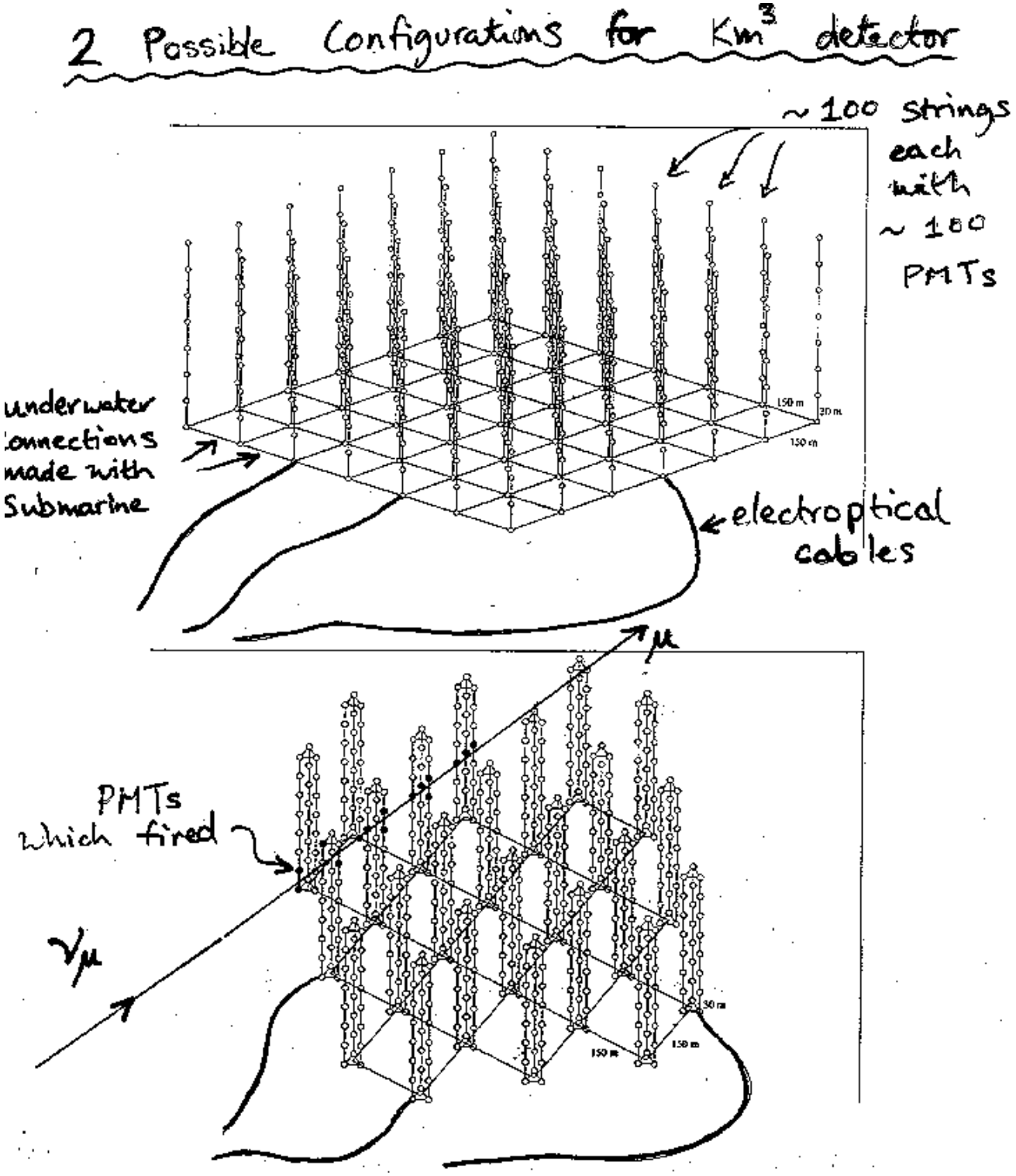


Figure 9: Two possible configuations for a neutrino telescope.

Schematic of 'Demonstrator'
(to be deployed in '99)

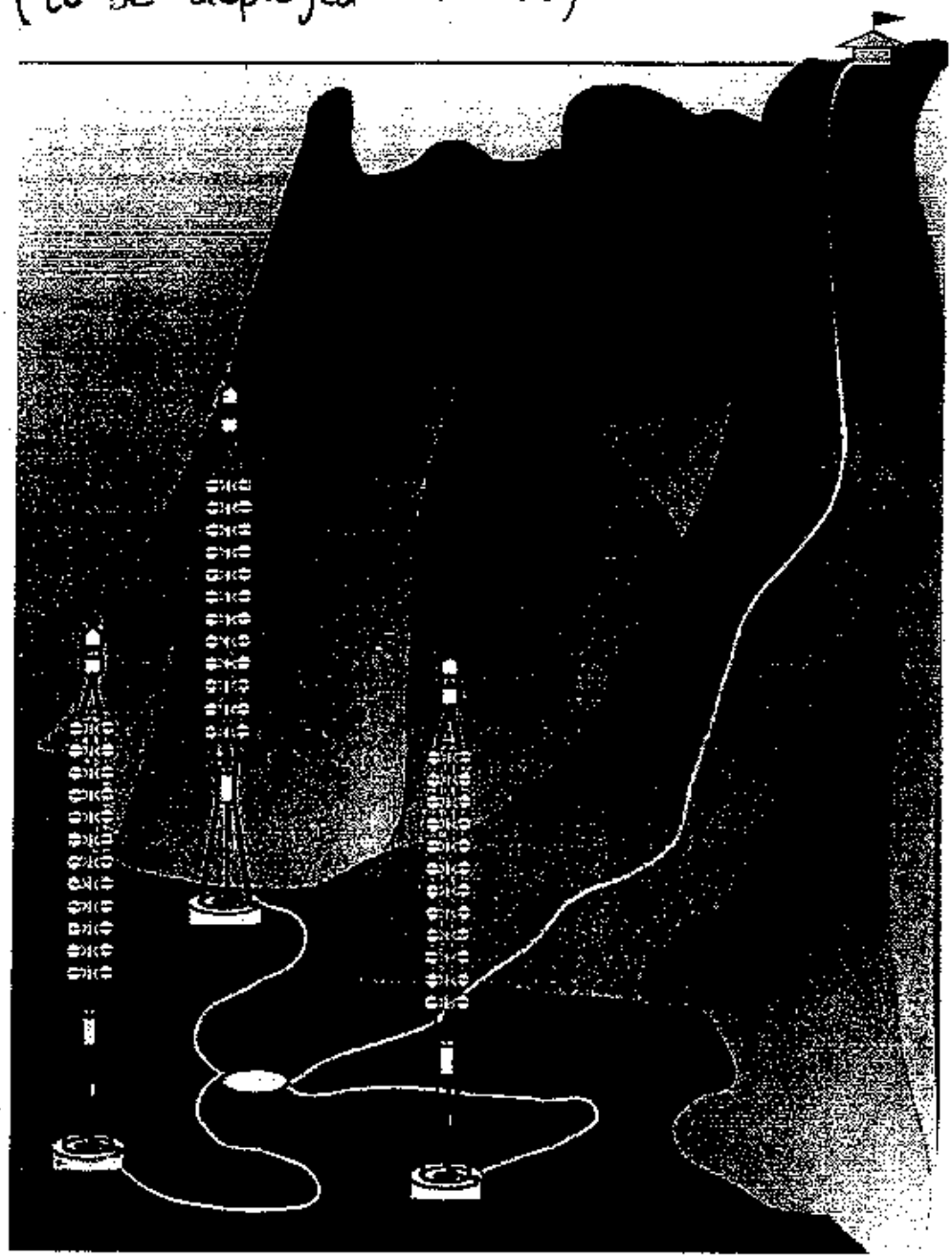


Figure 14: Possible set-up of a 3D array of optical modules with 3 strings 100 meters apart (not to scale).

Autonomous Strings for Site Evaluation

(1) Background noise rate in photomultipliers
⇒ ^{40}K & Bioluminescense

(2) Optical fouling of transparent surfaces
⇒ sedimentation vs. angle

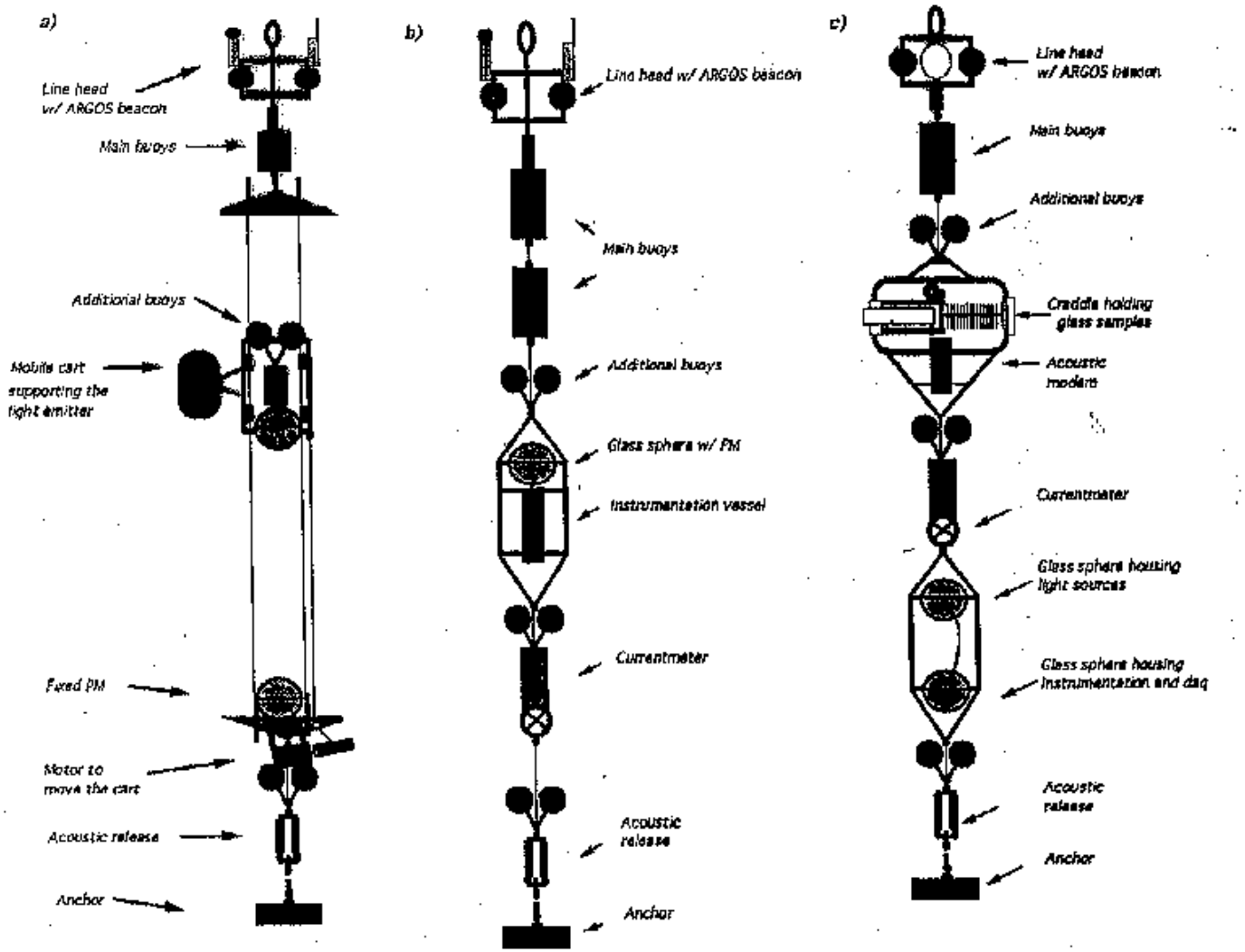
(3) Water transparency (absorption & scattering)

Over the last year, 9 deployments and 8 recoveries have been successfully carried out at the Toulon site (30km off coast, 2300m depth)

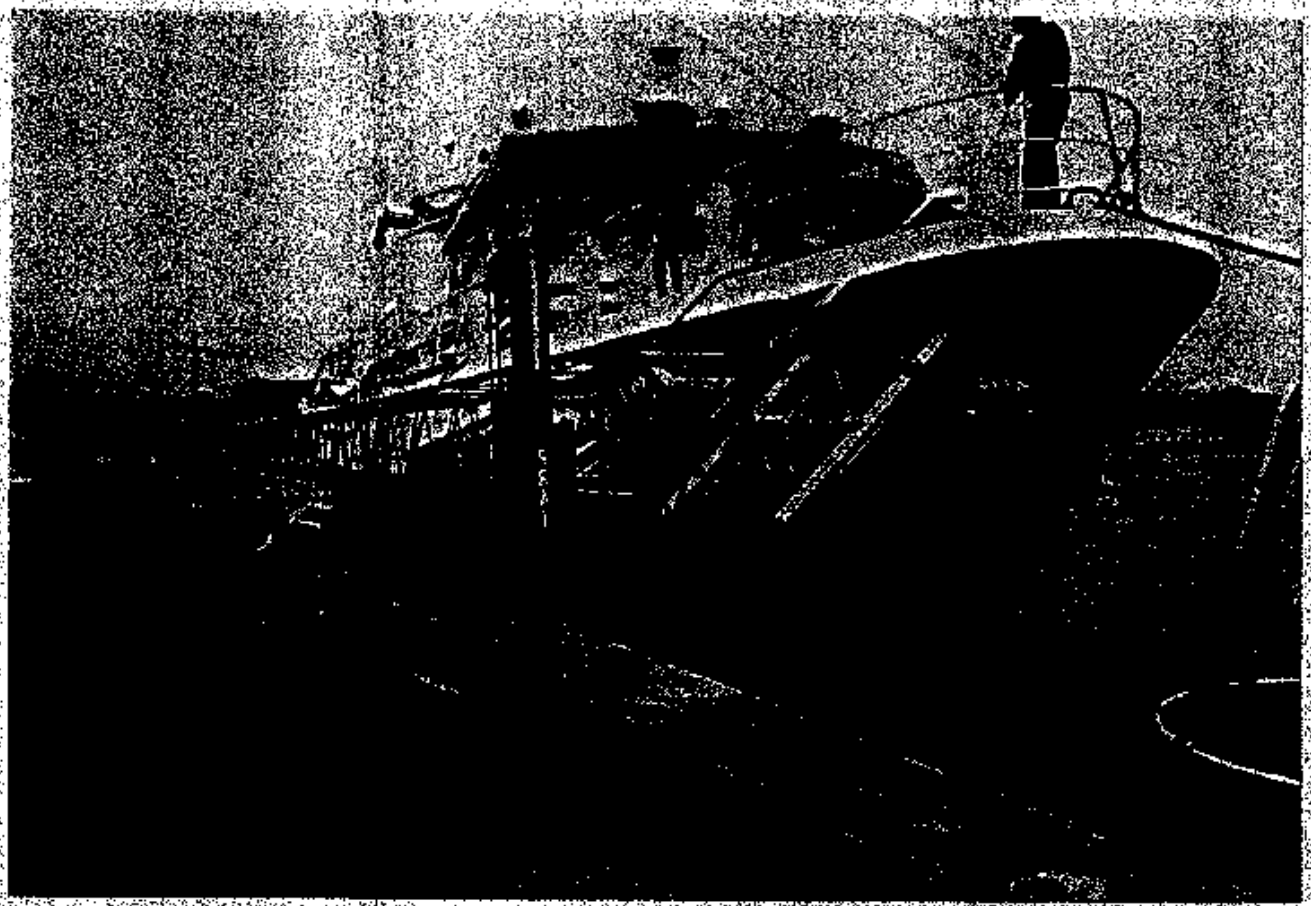
Water transparency

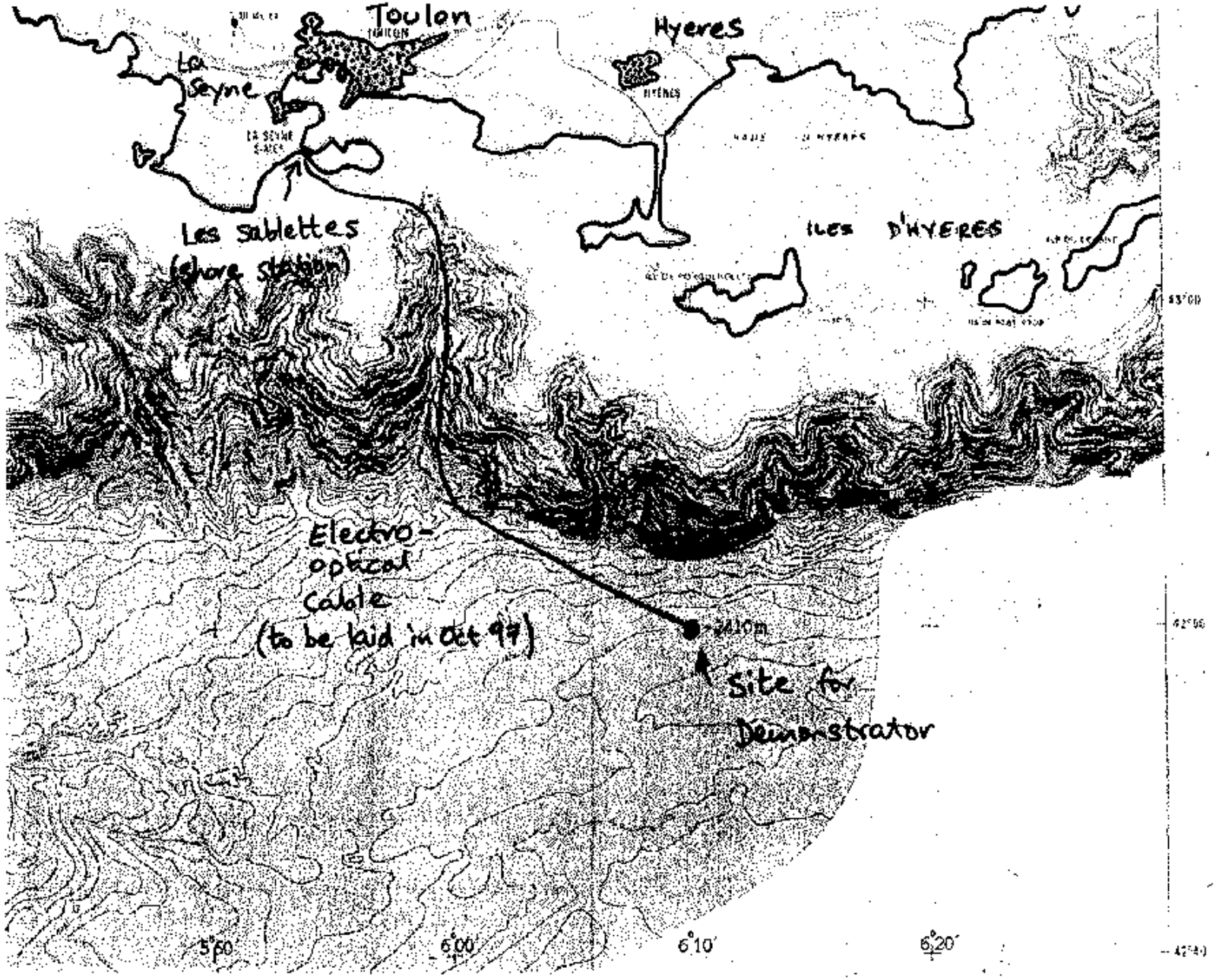
PMT Background noise rate

Optical Fouling rate



Schematics of autonomous test strings




Toulon
Hyeres
La Seyne
Les Sablettes
(shore station)
Iles d'Hyeres
Electro-
optical
Cable
(to be laid in Oct 97)
-2410m
Site for
Demonstrator
5°50
6°00
6°10'
6°20'
43°00
42°50

Summary & Future Plans

1. '96-'97: Successful campaign of test string deployments at Toulon site
2. '98: Deploy & recover single string connected (in boat) to Electro-optical cable
3. '99: Demonstrator: deploy 2 more strings and make underwater connection
4. '97-'99: Deploy autonomous test strings (1, 2 & 3) at all potential sites
5. '97-'99: Perform simulations for detector optimization
6. 2000-2002: build and deploy a $0.1\ km^2$ at optimal site ⇒ start doing physics!

Test AGN models
GRB models
dark matter search.

[next collaboration meeting: Dec 11 & 12, CERN]