(Towards) a km^3 detector in the Mediterranean Sea

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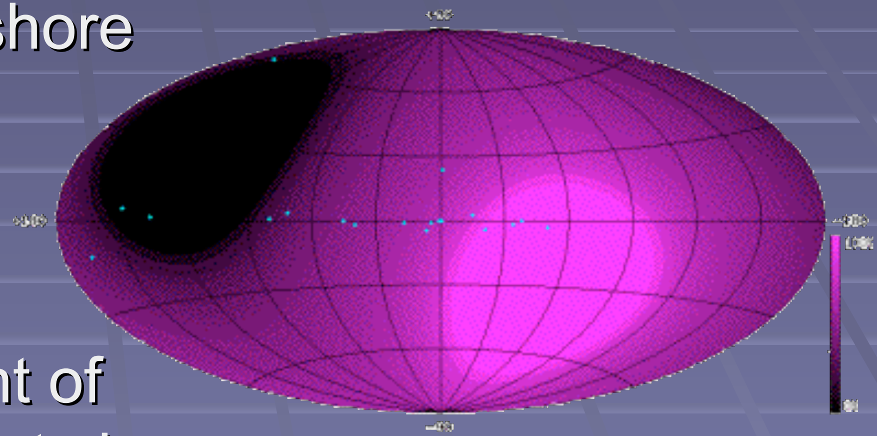
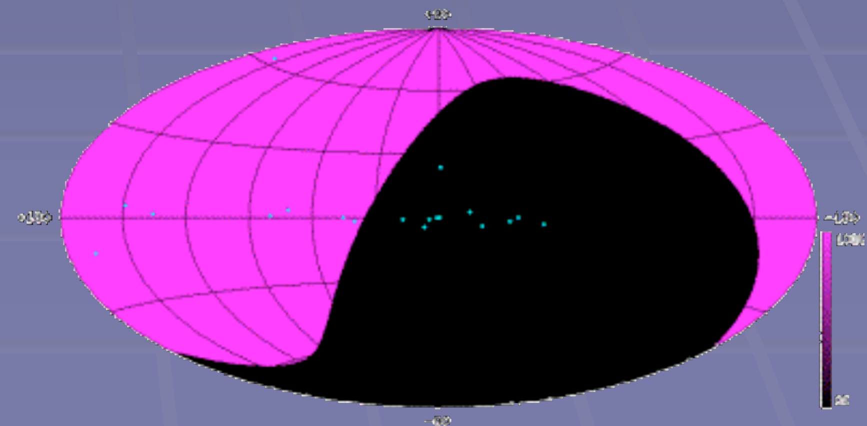
Introduction

- Previous talks (ANTARES, BAIKAL, NEMO, NESTOR) have summarised the current situation with water-based optical Cerenkov telescopes
  - *ANTARES/NESTOR - building and deploying first generation devices in the Mediterranean*
  - *NEMO - studying technological options for km3 infrastructure*
- This talk looks to the future - cubic kilometre scale devices
- Since Neutrino 2002:
  - *First cubic kilometre workshop - VLVνT in Amsterdam in October 2003 - also industrial presentations e.g. Hamamatsu, Photonis, ETL, Saclant, etc.*
  - *KM3NET EU FP6 Design Study written and submitted in March 2004*

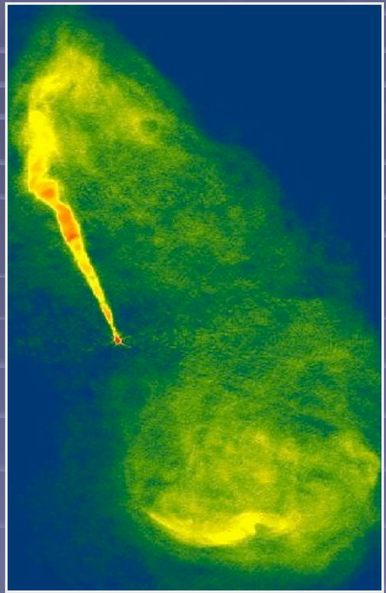
Why the Mediterranean?

- Obvious complementarity to ICECUBE
- Availability of deep sites - up to ~5000m
- Candidate sites often close to shore
  - logistically attractive
- Long scattering length leads to excellent pointing accuracy
- Re-surfacing and re-deployment of faulty/damaged detector elements is feasible



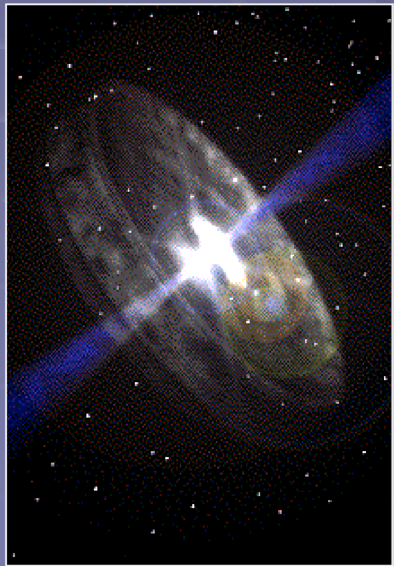


Motivation and Objectives



- Scientific programme addressed by a cubic kilometre scale detector involves
  - *Observation of high energy neutrinos from astrophysical point sources*
  - *Measurement of the diffuse flux*
  - *Indirect search for neutralino dark matter accumulated in astrophysical bodies from the neutralino annihilation products*

  larger effective area will permit this to be done with improved precision and sensitivity



- In order to do this it is necessary to optimise
  - *Neutrino detection efficiency (effective volume/area)*
  - *Reconstruction of neutrino direction*
  - *Rejection of backgrounds (atm. neutrinos, muons)*

  whilst keeping costs to a minimum!

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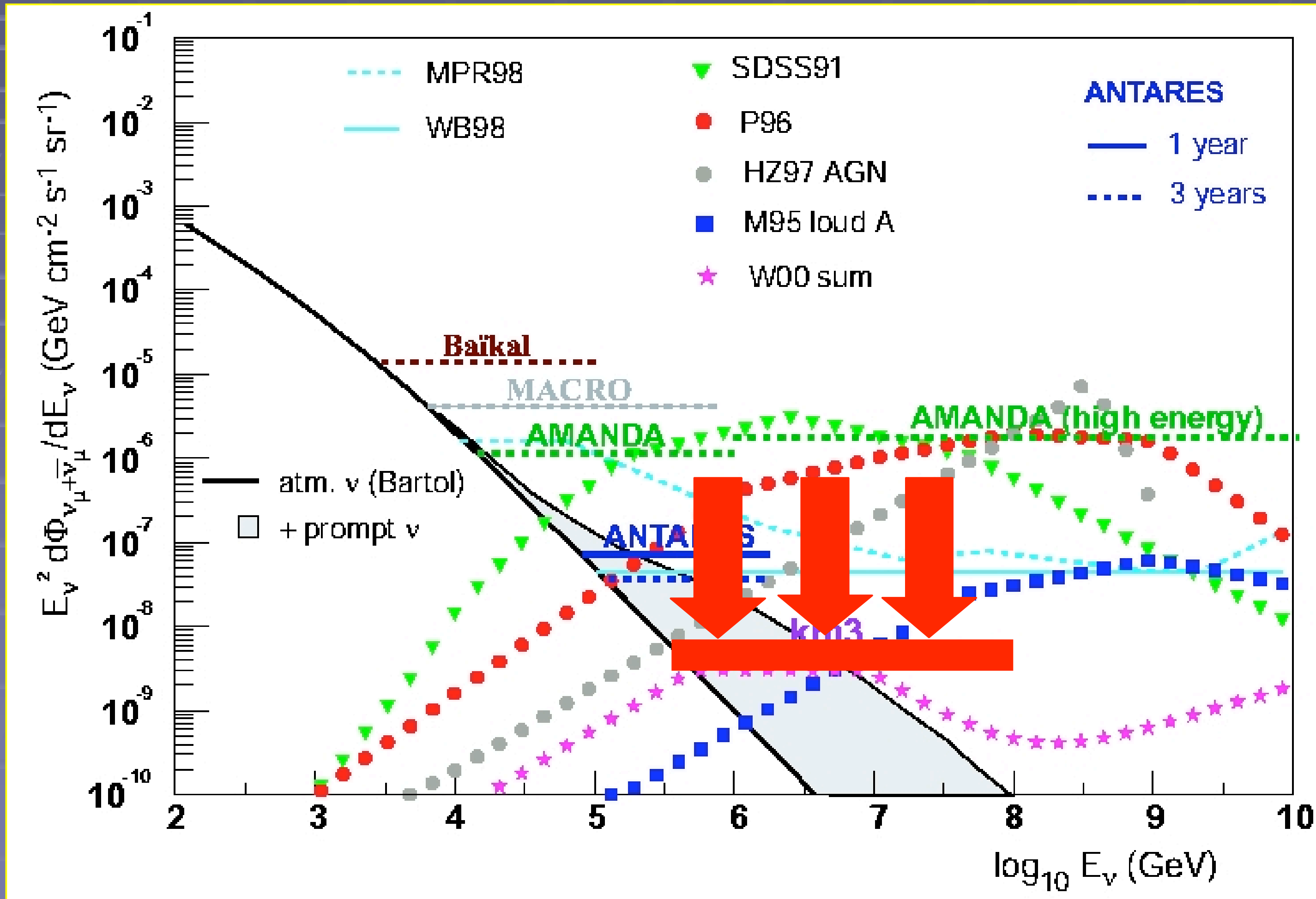
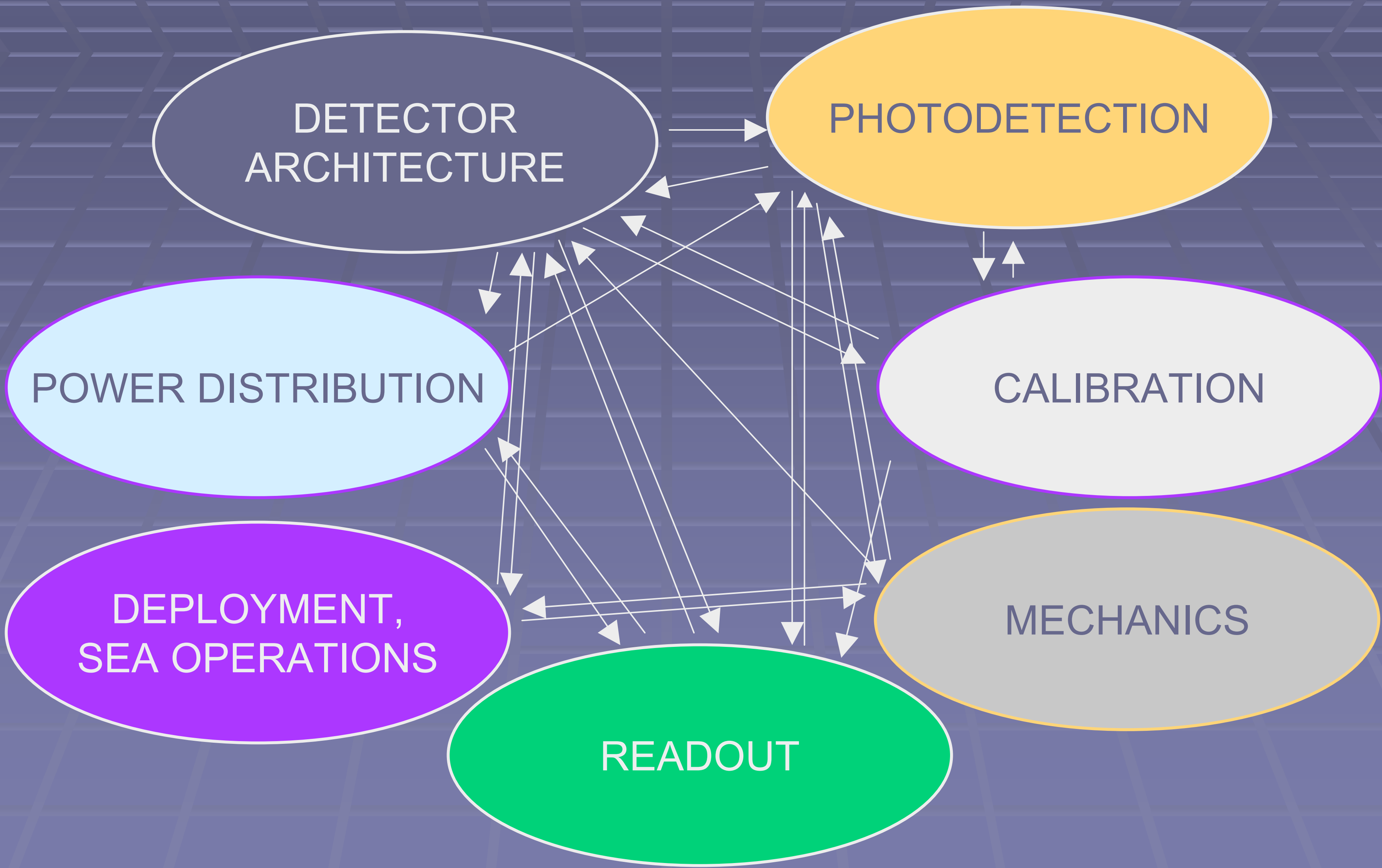
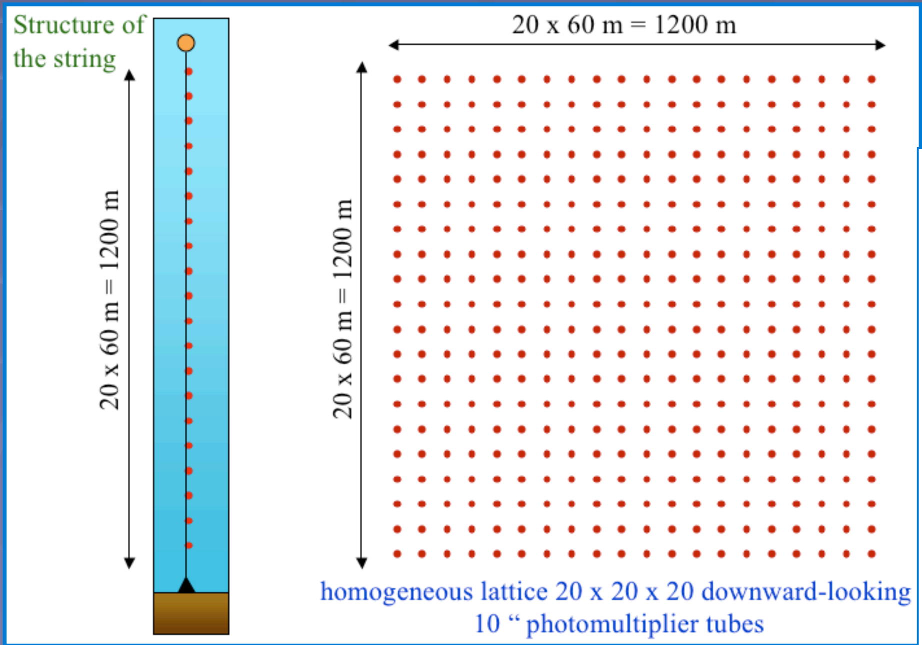


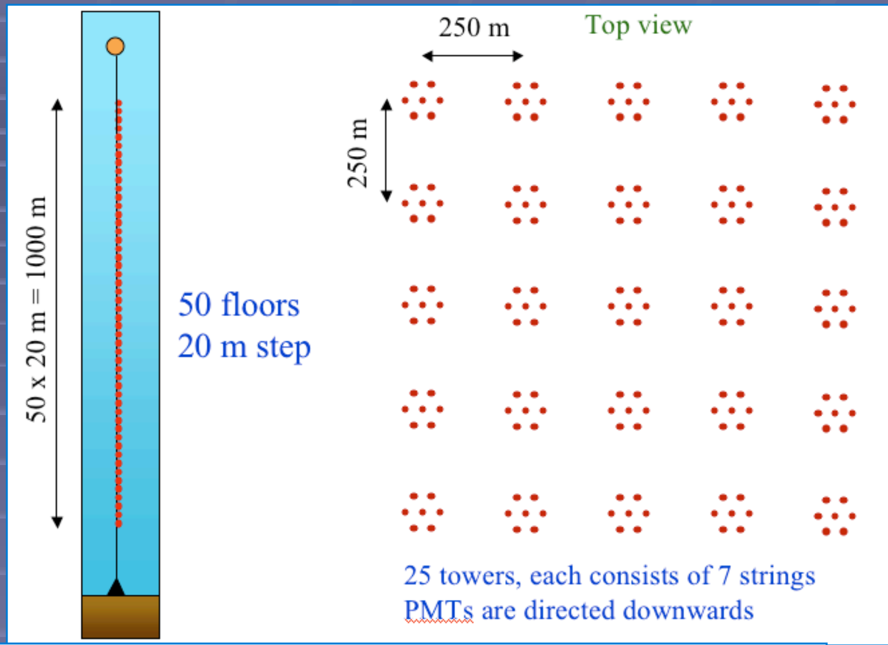
KM3 Design Considerations

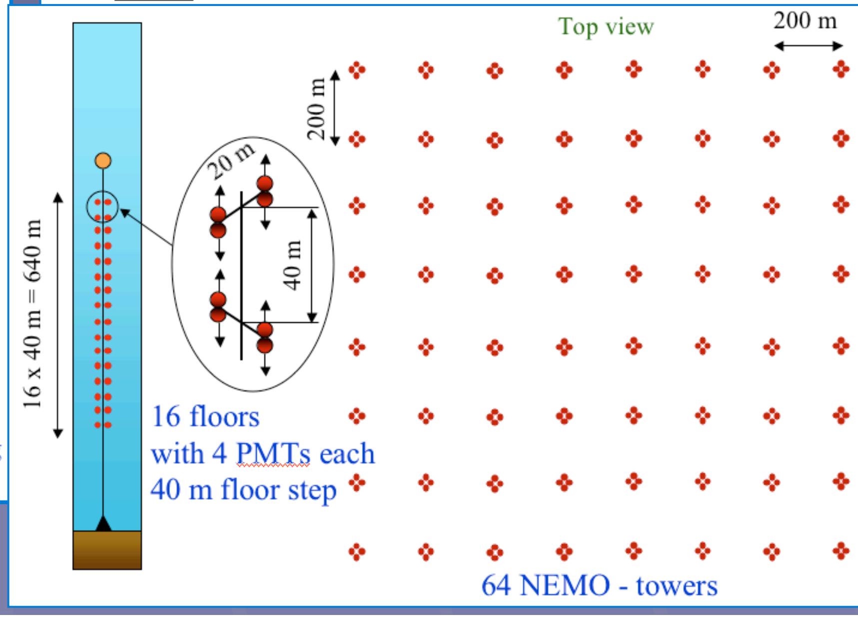


Detector Architecture

- A number of different solutions exist:
  - *Homogeneous strings*
  - *Towers*
  - *Nested arrays*
- How many OMs up/down?







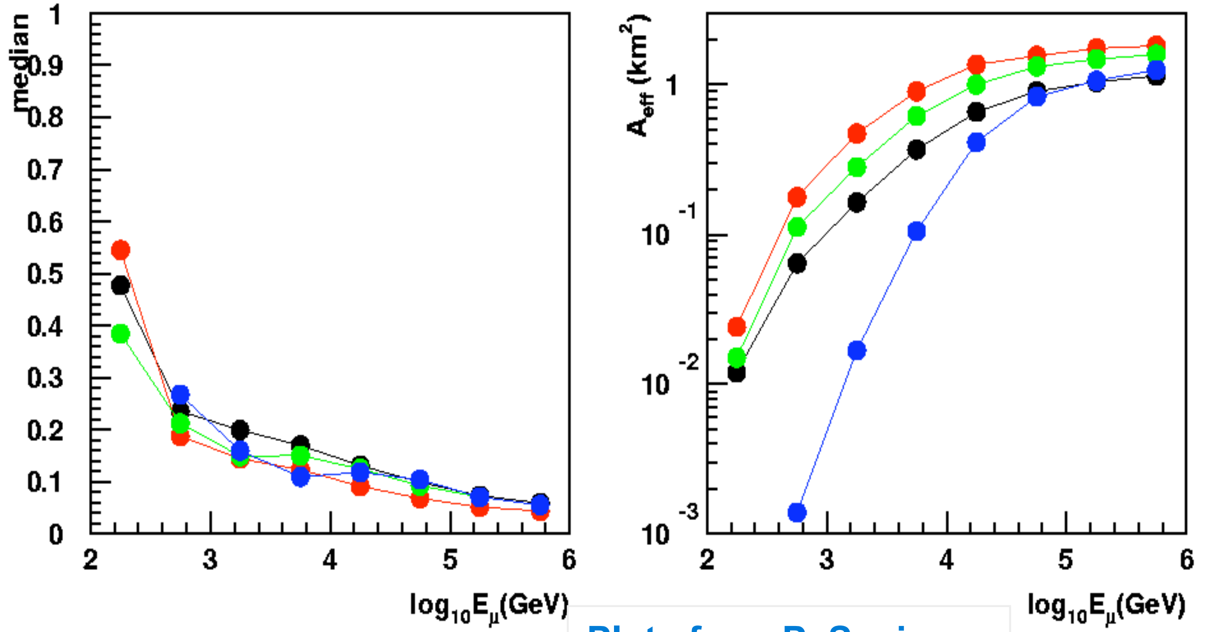
Plots from D. Zaborov

Detector Performance

- Very many parameters - some well known, some less well known, e.g.:
  - *Detector layout*
  - *Water properties (absorption, scattering, dispersion)*
  - *Optical backgrounds*
  - *Currents*
  - *Sedimentation*
- Want to determine
  - *Effective area/volume*
  - *Angular resolution*
  - *Energy resolution*
  - *Sensitivity to cascades*

as a function of cost

Example of types of calculations being made:
Effective area and angular resolution for a 5600 PMT detector with different levels of ^{40}K backgrounds

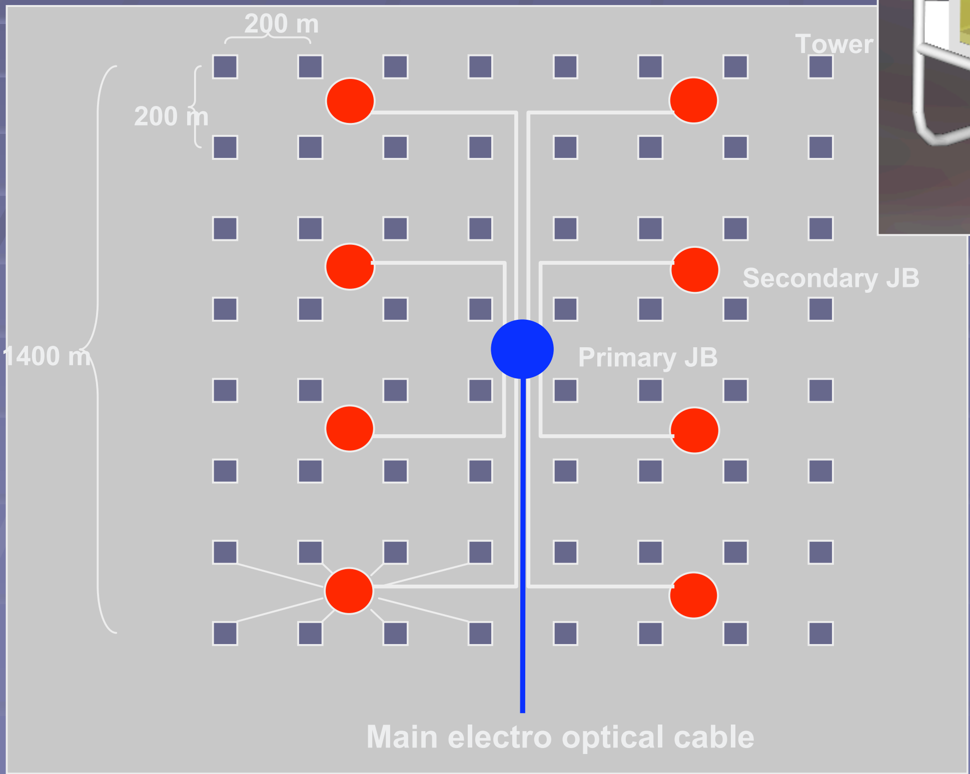


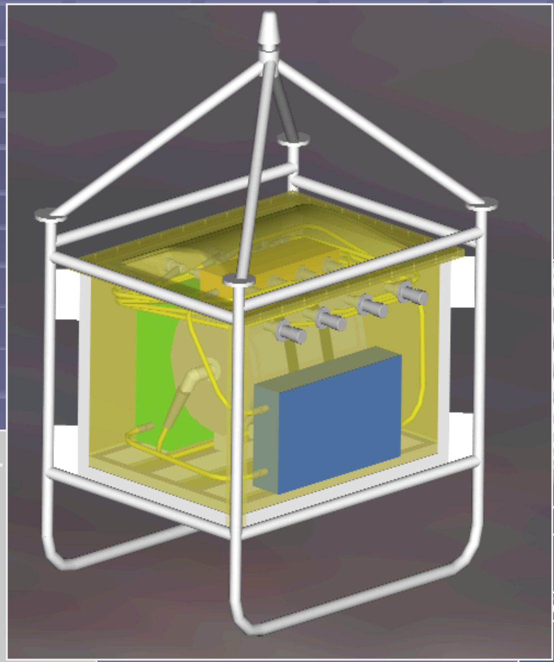
Plots from P. Sapienza

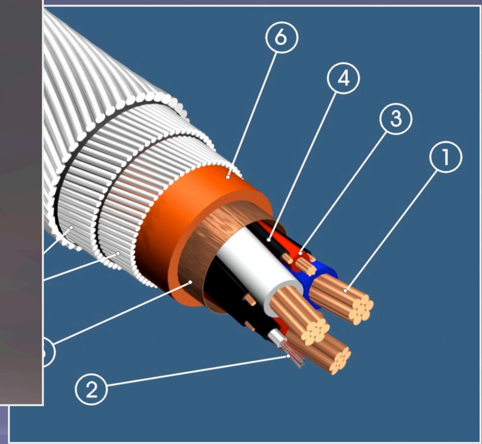
Power, Mechanics

- AC or DC, shore to detector?
- Redundancy? (>1 cable)
- Wet-mateable vs. dry-mateable (underwater) connectors
- Reduce number of connectors due to relatively high cost

Power Budget:
ANTARES:
16kW over 40km
NEMO:
34kW over 100km



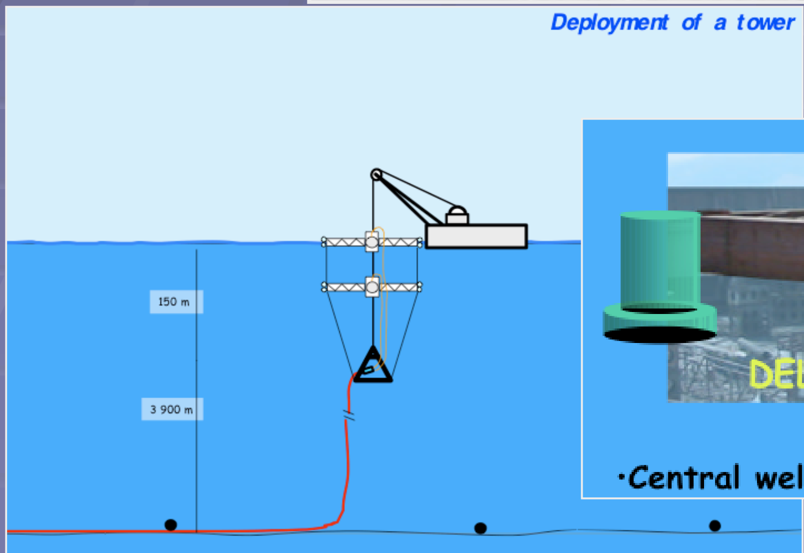


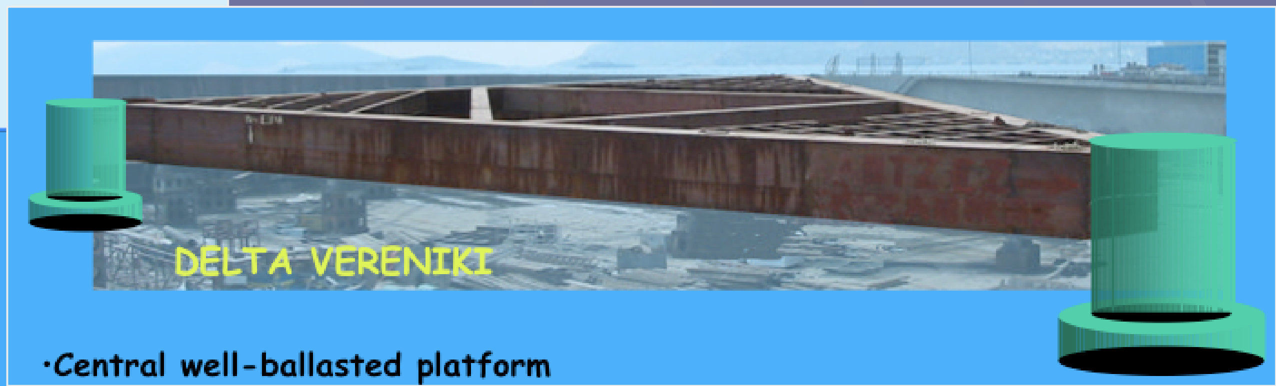


- Power distribution scheme (how many junction boxes, hierarchy, etc.)
- Materials: anti-corrosion, pressure-resistant, water blocking
- New ideas: encapsulation

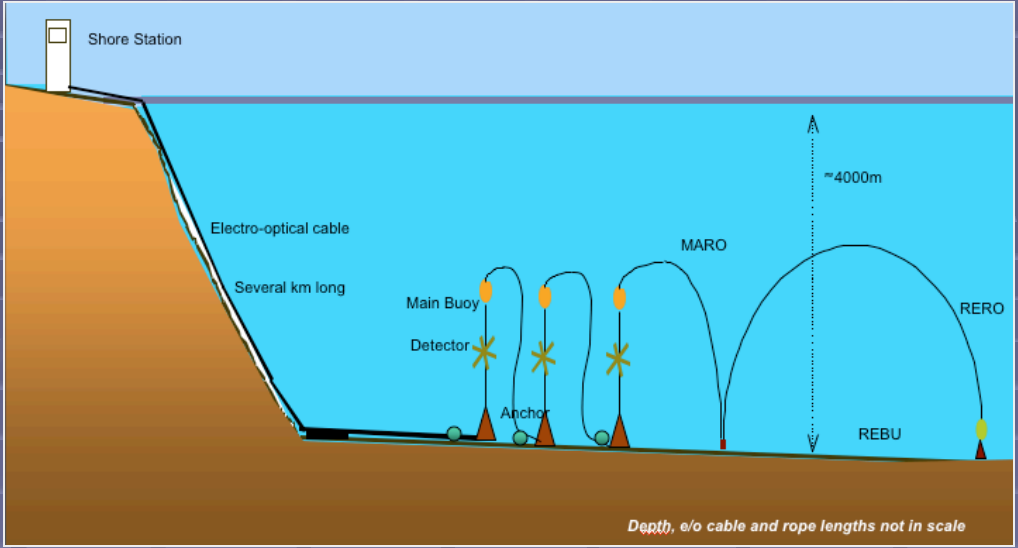
Sea Operations (I)

- Rigid/semi-rigid towers vs. flexible strings
- Also different construction-connection-deployment approaches e.g.:
  - *Connect in air then deploy (no need for ROVs, etc.)*
  - *Deploy then connect undersea*
- Other options, use of ship or deployment platform

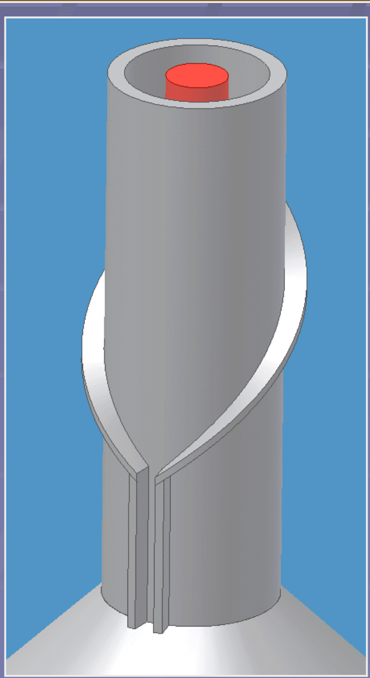


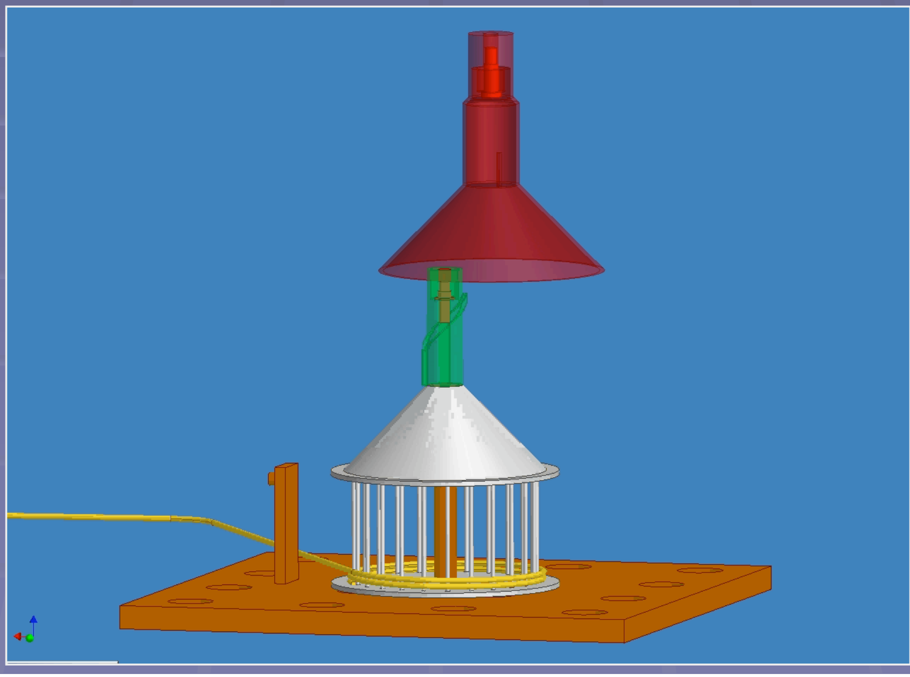


Sea Operations (II)



- Different deployment strategies, central "star" arrangement vs linear (surface connected) topology a la NESTOR
- Possible "self connecting" systems that obviate the need for ROVs/submarines





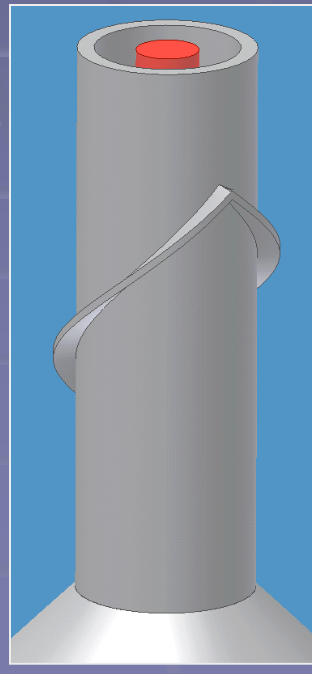
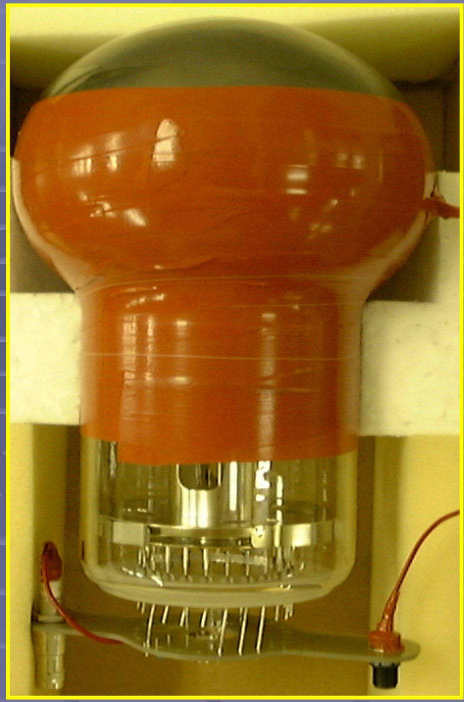
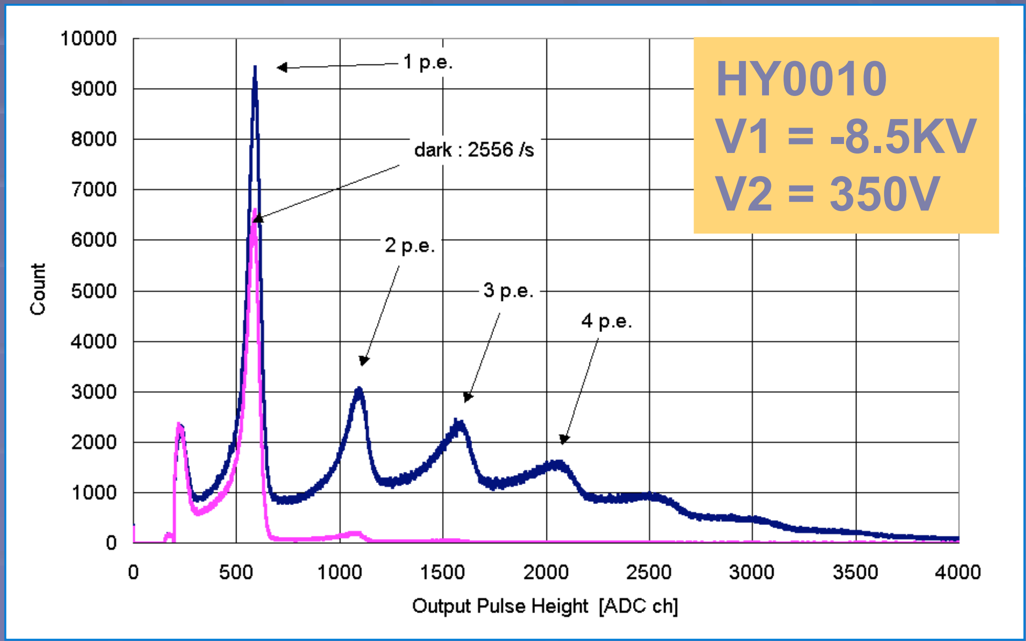


Photo detection (I)

- Presently limitation comes from size of the pressure housings available for the optical modules (17”)
- Largest PMT that can fit into this housing is the Hamamatsu 13” used by NESTOR
- Design requirements include:
  - High quantum efficiency
  - Large photocathode area
  - Wide angular coverage
  - Good single photon resolution
  - High dynamic range

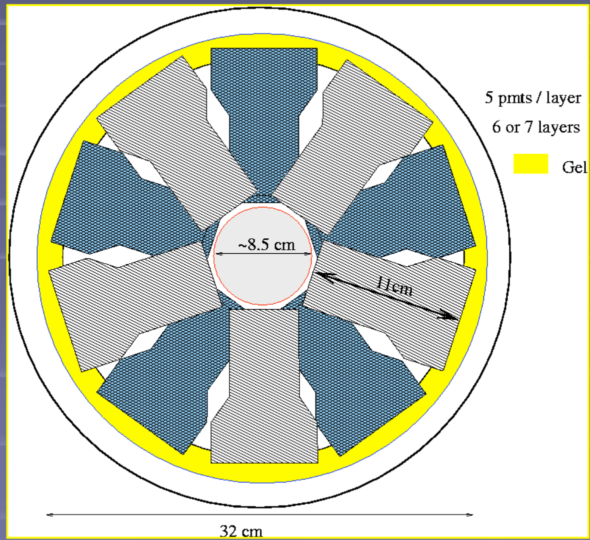


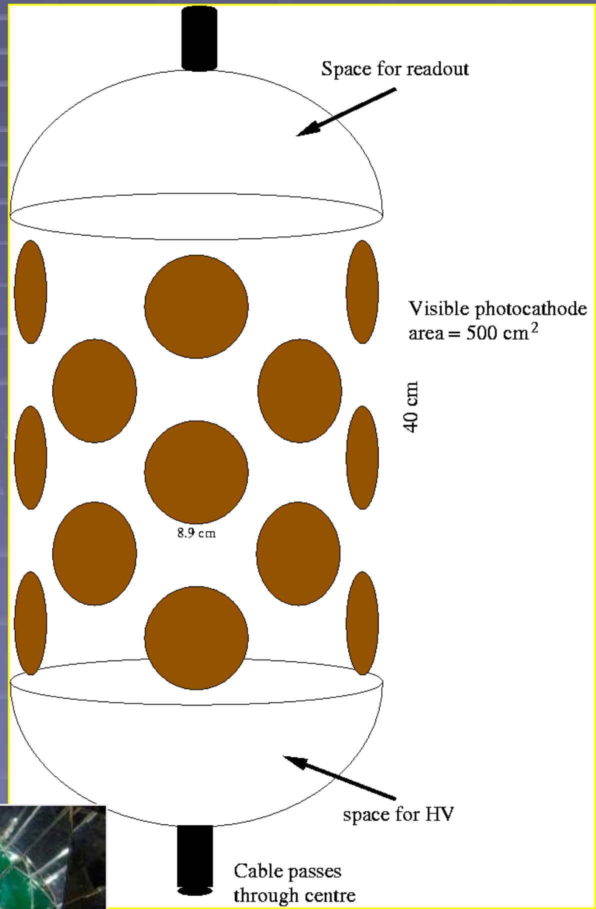


Example of new devices discussed:
Hamamatsu HY0010 HPD
Excellent np.e. resolution

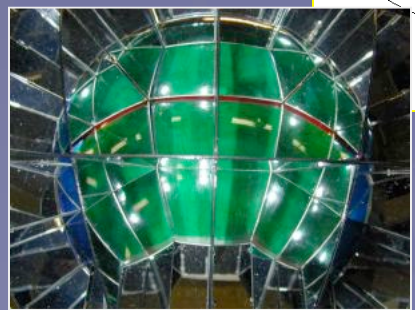
Photodetection (II)

- Other novel ideas include increasing photocathode area with arrays of small PMTs packed into pressure housings - low cost!



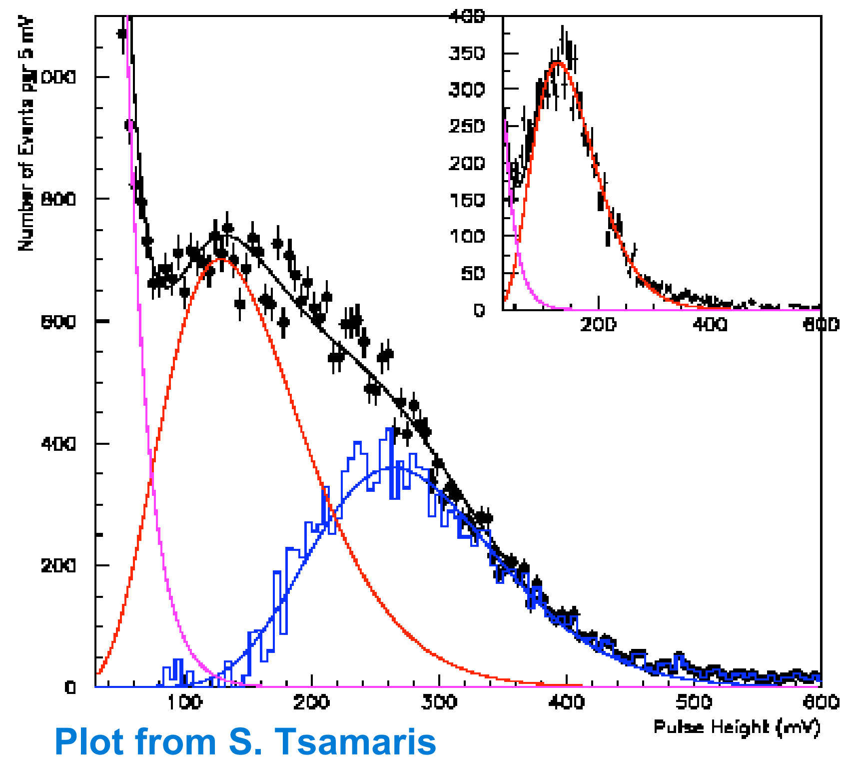


- Also on the "wish list" possibility of determining the photon direction via, e.g.
  - *Multi-anodic PMTs plus a matrix of Winston cones*



Calibration

- Three main areas:
- Timing calibration - high accuracy needed for relative calibration - determines angular resolution at high energies. Affected by choice of photosensor, dispersion in the medium, electronics delays, etc.
- Will require distributed clock system plus pulsed light sources
- Monitoring of positioning of optical detector elements, also important in determining overall detector performance
- Amplitude calibration - gain from ^{40}K.
- Scalability of current calibration systems to cubic kilometre

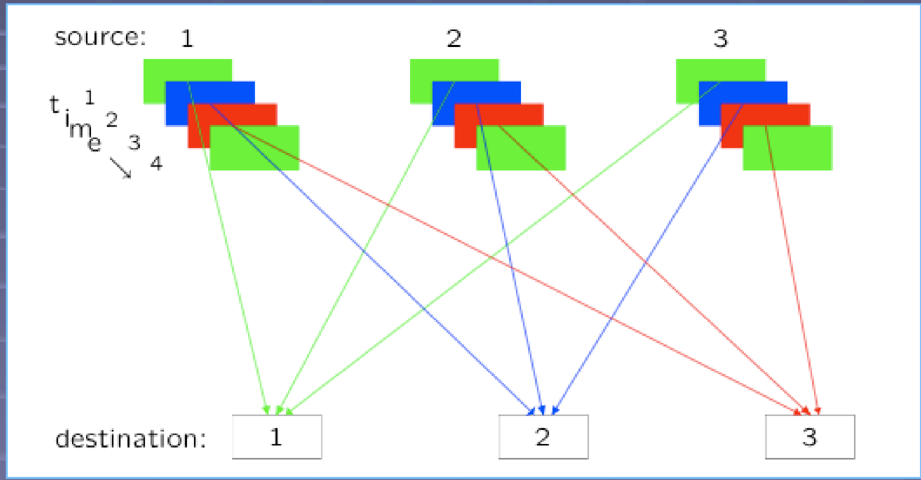


Plot from S. Tsamaris

Single p.e.	red line
Two p.e.	blue line
Dark Noise	pink line
Sum	black line

Readout and Data Transfer

- The data rate from a KM3 detector will be high - estimated at 2.5-10 Gb/s
- Questions addressed included:
  - *Optimal data transfer to shore (many fibres + few colours, few fibres + many colours, etc.)*
  - *How much processing to be done at the optical module*
  - *Analogue vs. digital OMs - implies differing approaches to design of front end electronics*
  - *Data filtering will play an important role*



- One possible data distribution concept
- Also discussed: application of current PP GRID technologies to some of these open questions

EU FP6 Design Study: KM3NET

- Collaboration of 8 Countries, 34 Institutions
- Aim to design a deep-sea km^3-scale observatory for high energy neutrino astronomy and an associated platform for deep-sea science
- Request for funding for 3 years - end product will be a TDR for KM3 in the Med

WORK PACKAGES

Astroparticle Physics	Physics Analysis	System and Product Engineering
Information Technology	Shore and deep-sea structure	Sea surface infrastructure
Risk Assessment Quality Assurance	Resource Exploration	Associated Science

A TDR for a Cubic Kilometre Detector in the Mediterranean

Site Evaluation

- Final choice of site will depend on a number of factors including:
  - *Depth*
  - *Accessibility*
  - *Distance from shore*
  - *Potassium-40 rate*
  - *Bioluminescence rate*
  - *Sedimentation*
  - *Sea current*
  - *… etc.*

The selection of the optimal site for the infrastructure presents a unique challenge to our scientific community due to the intricate interplay between scientific, technological, financial and socio-political/regional considerations. It is our intention to deliver a clear prioritisation of site qualities based on scientific, technological and financial aspects only. However, depending on the strength of this prioritisation, the final site selection may well be determined by socio-political/regional considerations. Whether weak or strong, this Design Study prioritisation will provide a sound, rational basis for decision-makers.

Conclusions / The Future

- Previous talks have highlighted the current status and successes of "first generation" water-based optical Cerenkov telescopes
- *There is a compelling scientific argument for complementing the planned ICECUBE array with a cubic kilometre scale detector in the Northern hemisphere*
- Since Neutrino 2002 these has been much positive progress in bringing the EU HE neutrino community together towards this goal e.g. cross-calibration of sites, design working group
- *A document detailing the studies required to design such a device has been written and submitted to the EU for FP6 funding - eagerly awaiting response from the EU*
- **The first step towards a cubic kilometre detector in the Mediterranean**