12th International Workshop on Next Generation Nucleon Decay and Neutrino Detectors (NNN11)
Zurich, Switzerland, 7-9 November 2011

KM3NeT – Status and Future

Uli Katz
ECAP / Univ. Erlangen
07.11.2011

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Friedrich-Alexander-Universität Erlangen-Nürnberg

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

KM3NeT

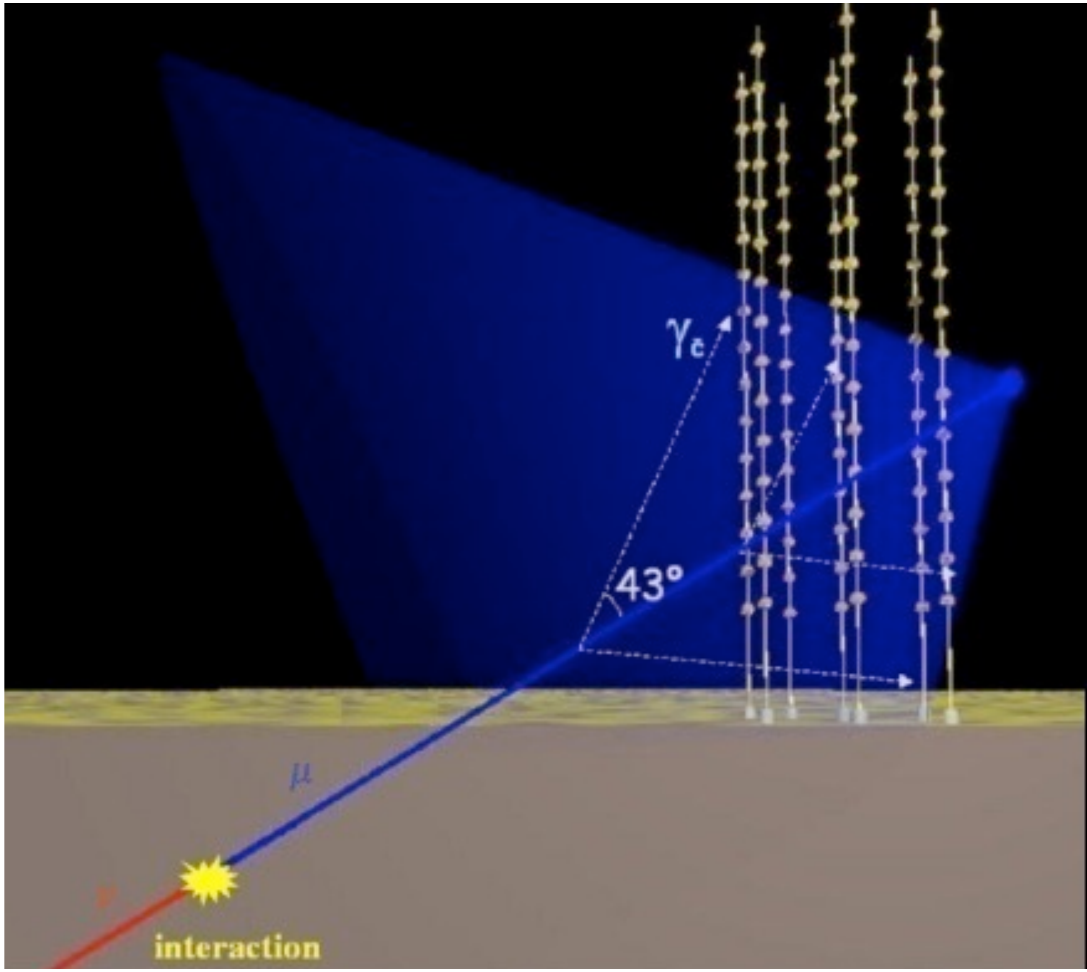
- Introduction
- Technical solutions: Decisions and options
- Physics sensitivity
- Implementation
- Summary

KM3NeT

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

What is KM3NeT ?

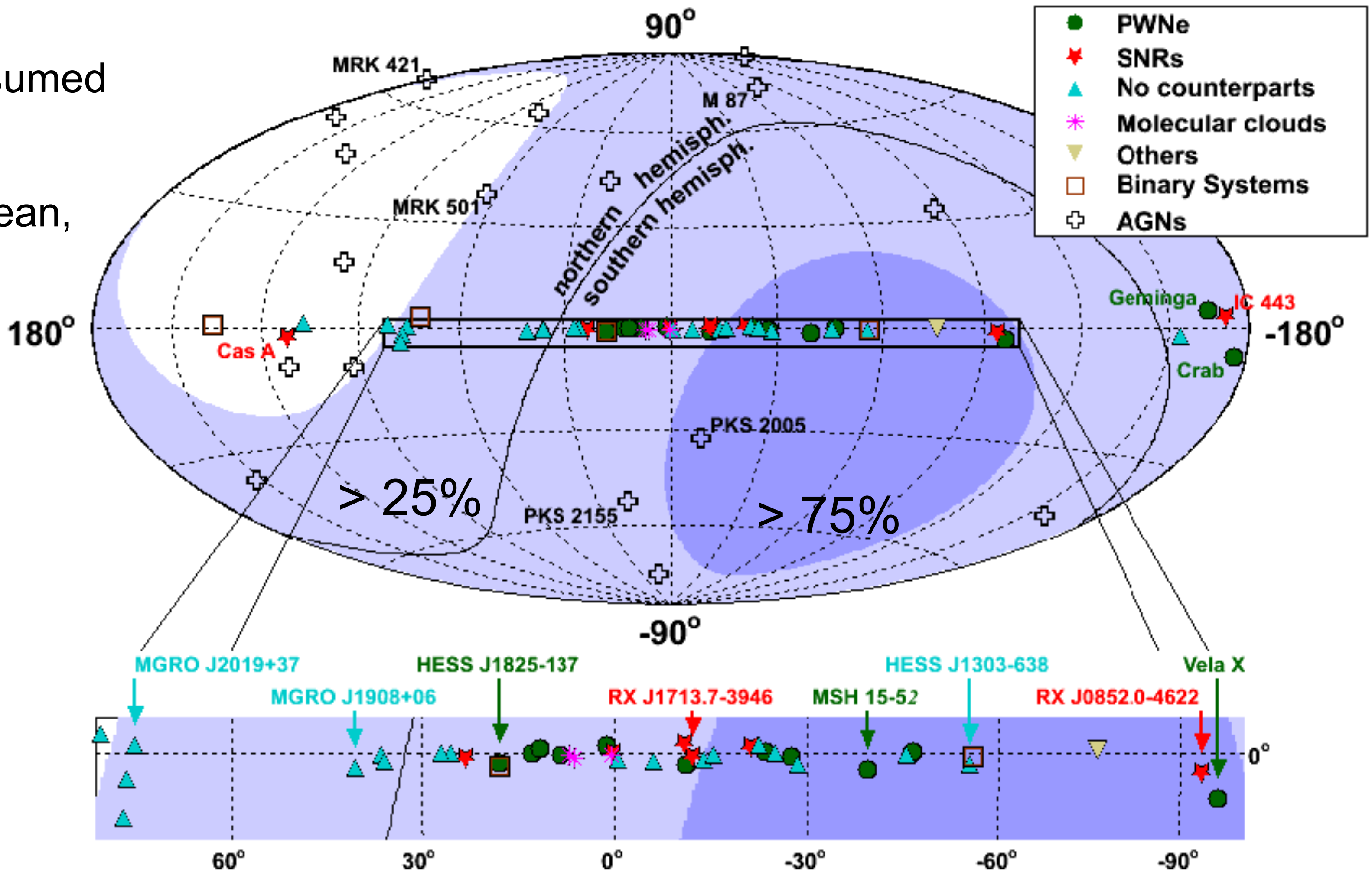
- Future cubic-kilometre scale neutrino telescope in the Mediterranean Sea
- Exceeds Northern-hemisphere telescopes by factor ~50 in sensitivity
- Exceeds IceCube sensitivity by substantial factor
- Provides node for earth and marine sciences



South Pole and Mediterranean Fields of View

2π downward sensitivity assumed

In Mediterranean, visibility of given source can be limited to less than 24h per day



ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

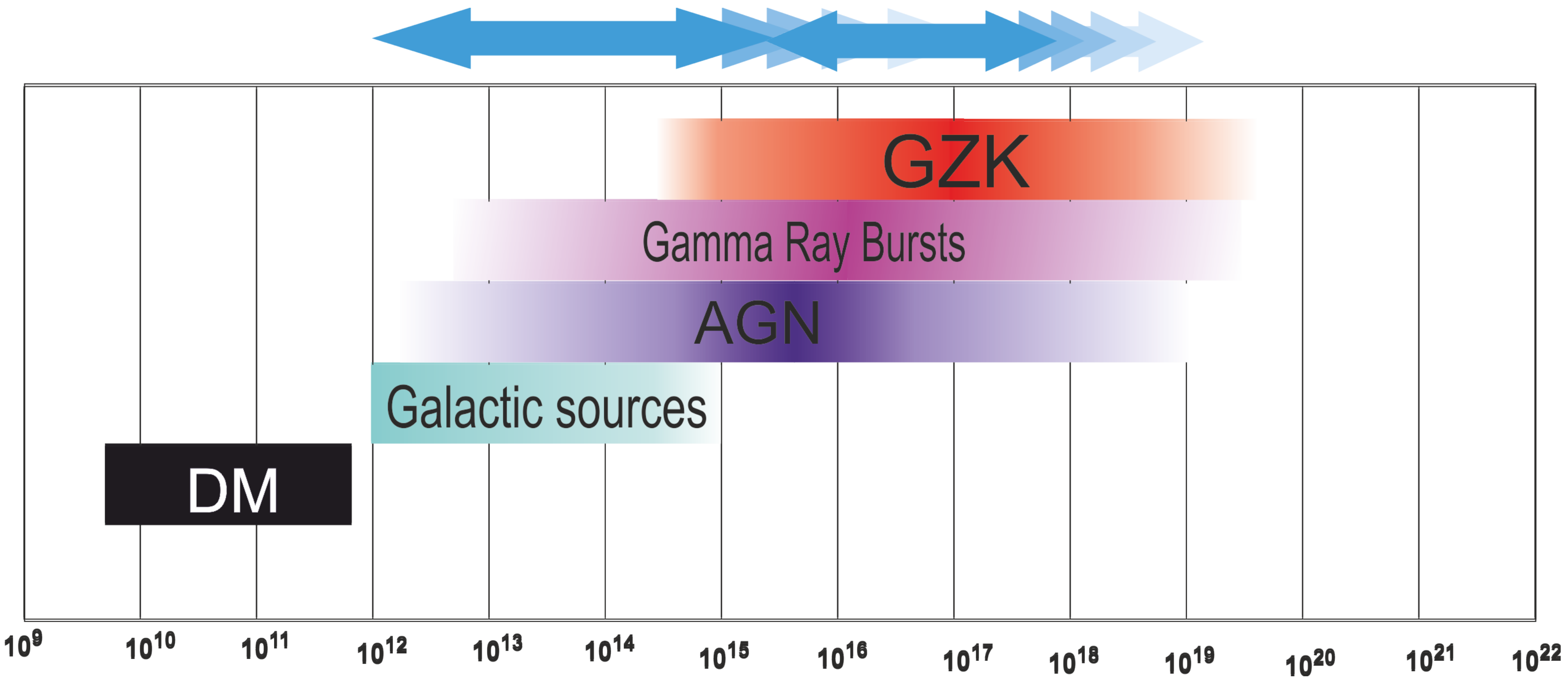
The Objectives

- Central physics goal:
  - Galactic neutrino “point sources” (energy 1-100 TeV)
- Further topics:
  - Extragalactic sources
  - High-energy diffuse neutrino flux
- Not in the central focus:
  - Dark Matter
  - Neutrino oscillations

- Implementation requirements:
  - Construction time ≤5 years
  - Operation over at least 10 years without “major maintenance”

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Sensitivity



For a fixed number of € we can optimise the sensitivity for different sources
Main parameter: photocathode density (area/volume)

Technical Design

Objective: Support 3D-array of photo-detectors and connect them to shore (data, power, slow control)

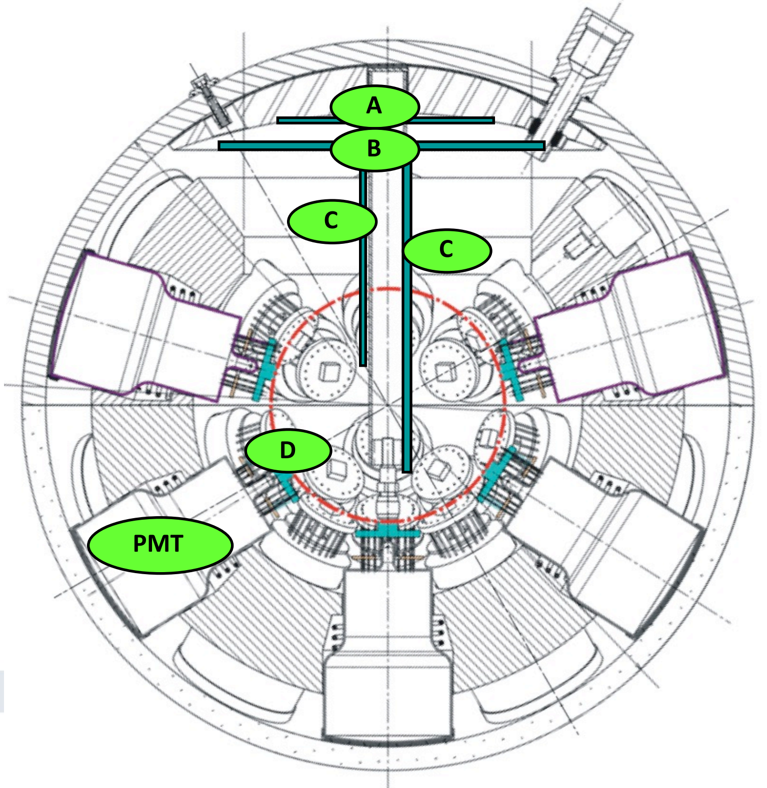
- → Optical Modules
- → Front-end electronics
- → Readout, data acquisition, data transport
- → Mechanical structures, backbone cable
- → General deployment strategy
- → Sea-bed network: cables, junction boxes
- → Calibration devices
- Shore infrastructure
- Assembly, transport, logistics
- Risk analysis and quality control

Design rationale:

Cost-effective
Reliable
Producible
Easy to deploy

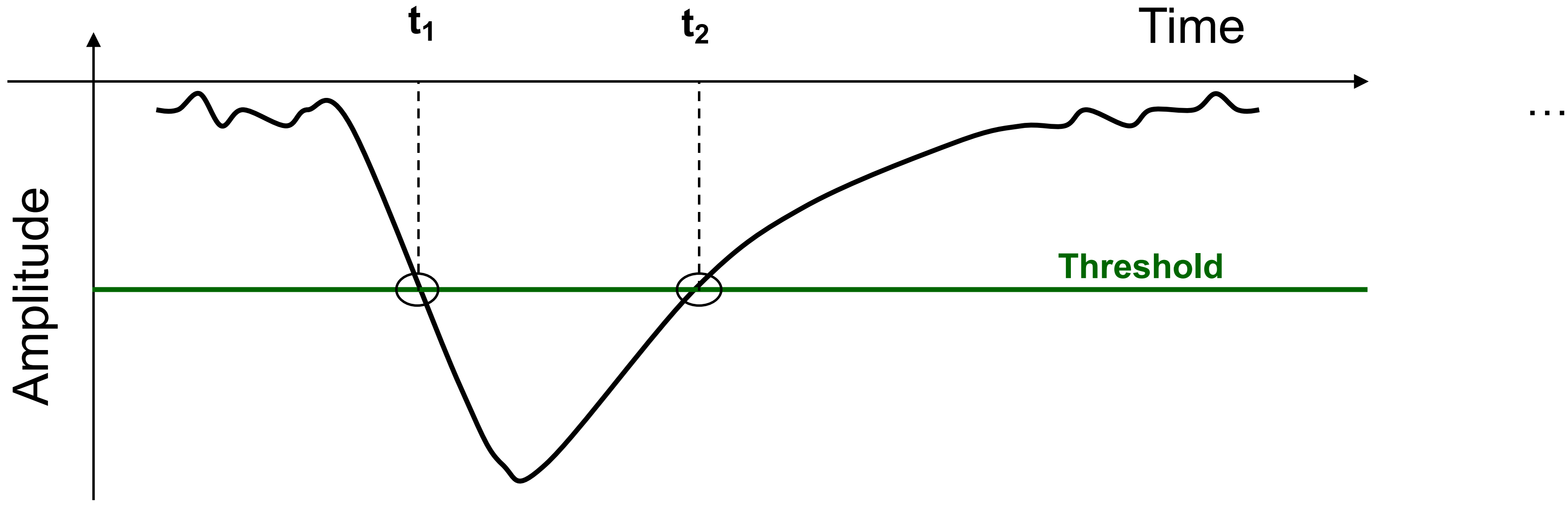
OM with many Small PMTs

- 31 3-inch PMTs in 17-inch glass sphere (cathode area~ 3x10” PMTs)
  - 19 in lower, 12 in upper hemisphere
  - Suspended by compressible foam core
- 31 PMT bases (total ~140 mW) (**D**)
- Front-end electronics (**B,C**)
- Al cooling shield and stem (**A**)
- Single penetrator
- 2mm optical gel
- Advantages:
  - increased photocathode area
  - improved 1-vs-2 photo-electron separation → better sensitivity to coincidences
  - directionality



Front-End Electronics: Time-over-Threshold

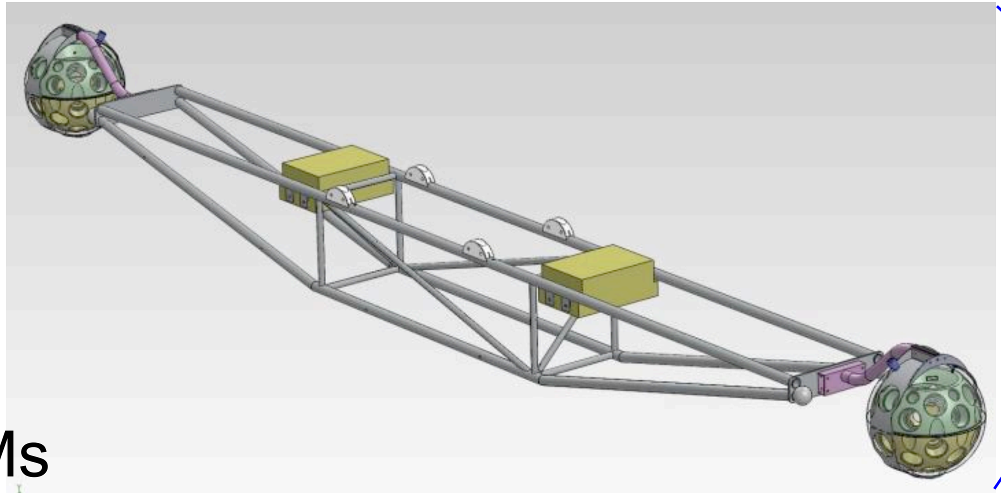
From the analogue signal to time stamped digital data:

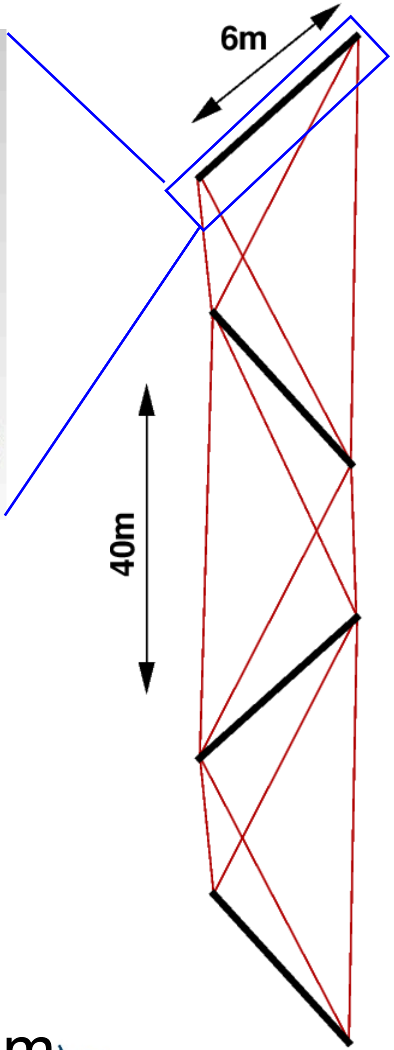


- Implemented through FPGA & System on chip contained in optical module
- All data to shore via ethernet link
- Time synchronisation and slow control

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

The Flexible Tower with Horizontal Bars





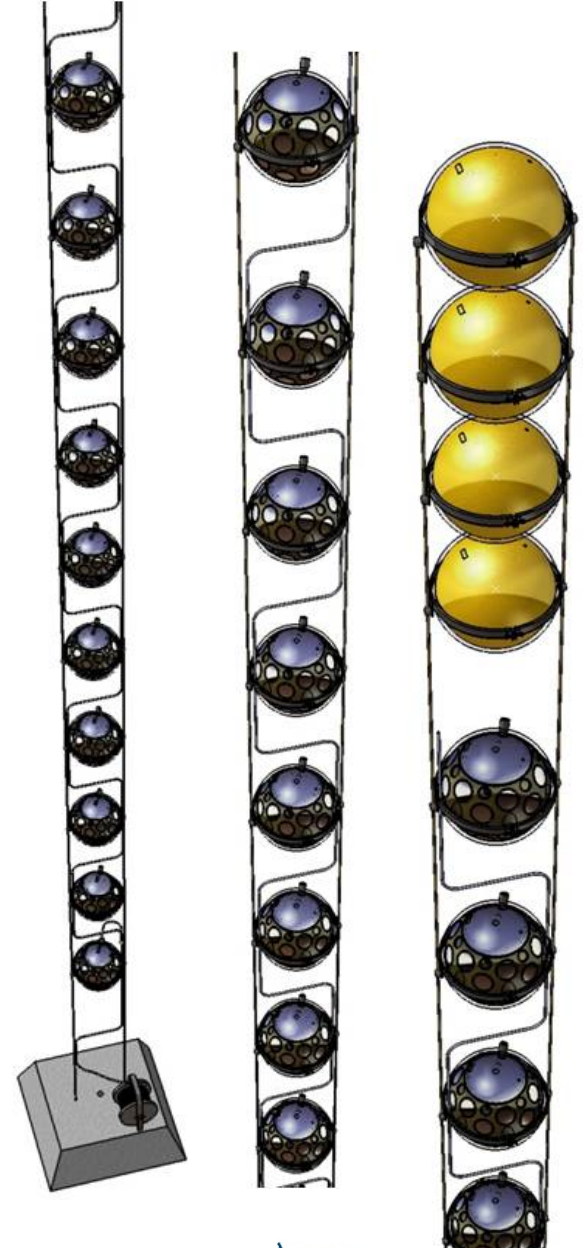
- 20 storeys
- Each storey supports 2 OMs
- Storeys interlinked by tensioning ropes, subsequent storeys orthogonal to each other
- Power and data cables separated from ropes; single backbone cable with breakouts to storeys
- Storey length = 6m
- Distance between storeys = 40 m
- Distance between DU base and first storey = 100m

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Backup Solution: Strings

- Mooring line:
  - Buoy (empty glass spheres, net buoyancy 2250N)
  - 2 Dyneema ropes (4 mm diameter)
  - 20 storeys (one OM each), 30 m distance, 100m anchor-first storey
- Electro-optical backbone:
  - Flexible hose ~ 6mm diameter
  - Oil-filled
  - 11 fibres and 2 copper wires
  - Star network between master module and optical modules

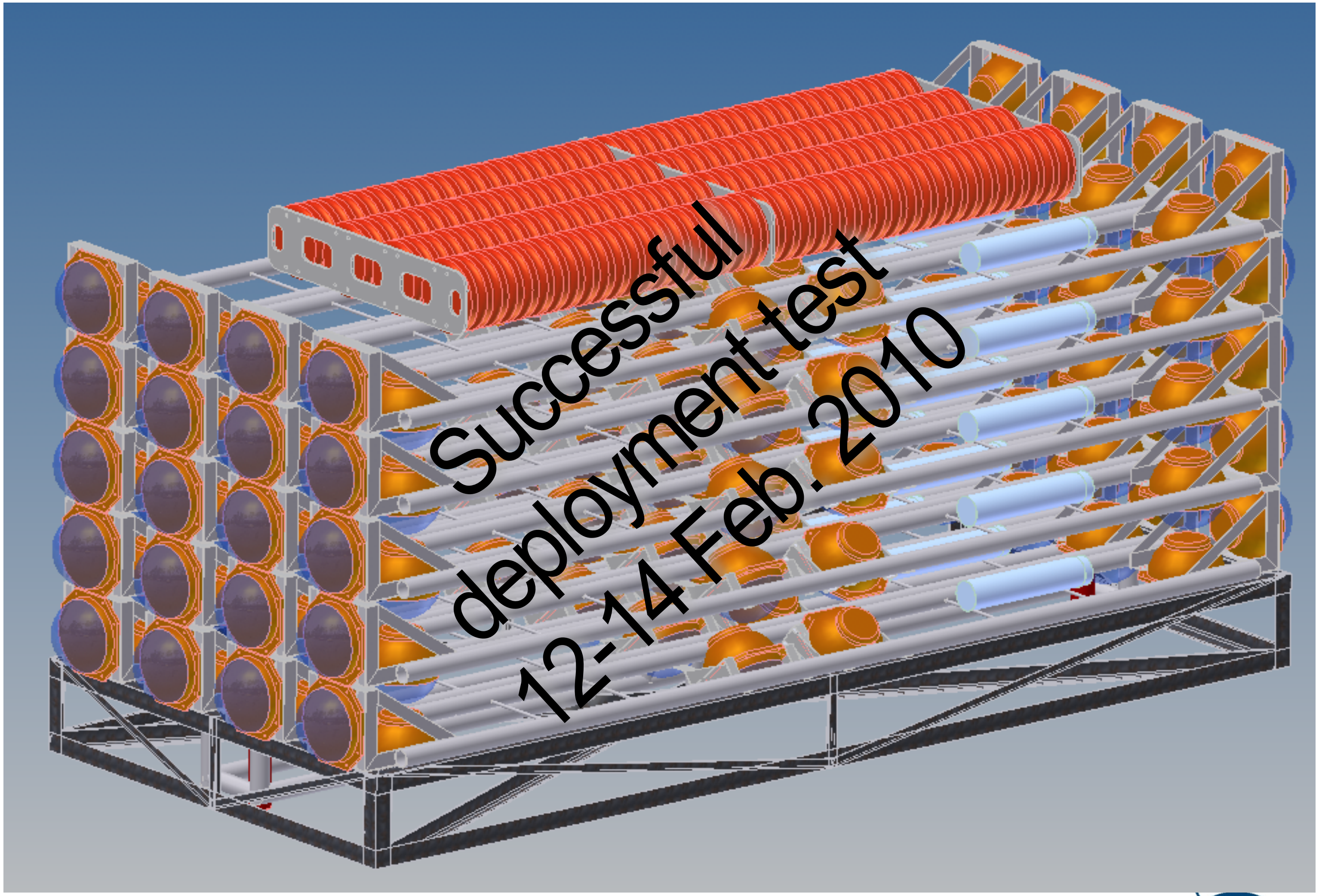
New concept, needs to be tested. Also for flexible tower if successful



Deployment Strategy

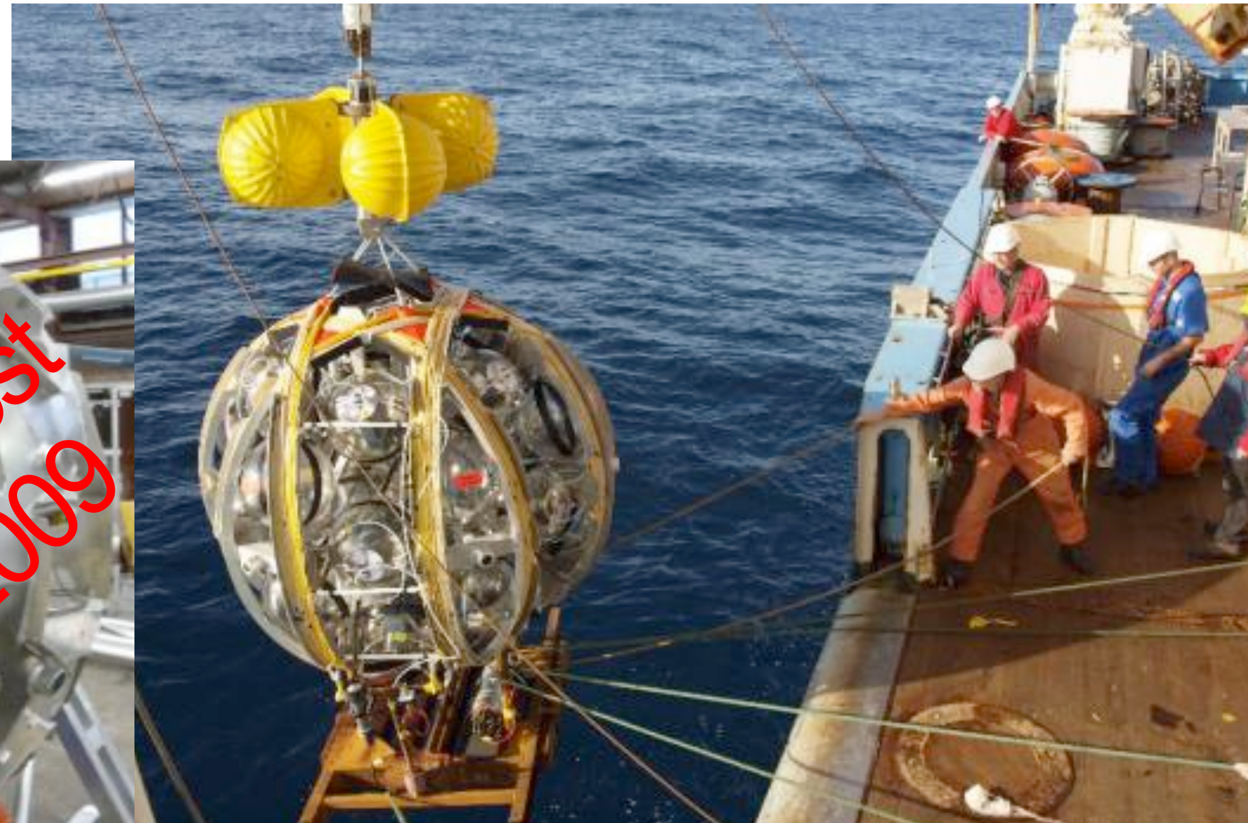
- Compact package – deployment – self-unfurling
  - Eases logistics
    (in particular in case of several assembly lines)
  - Speeds up and eases deployment;
    several units can be deployed in one operation
  - Self-unfurling concepts need to be thoroughly tested and verified
- Connection to seabed network by ROV
- Backup solution:
  "Traditional" deployment from sea surface

A Flexible Tower Packed for Deployment



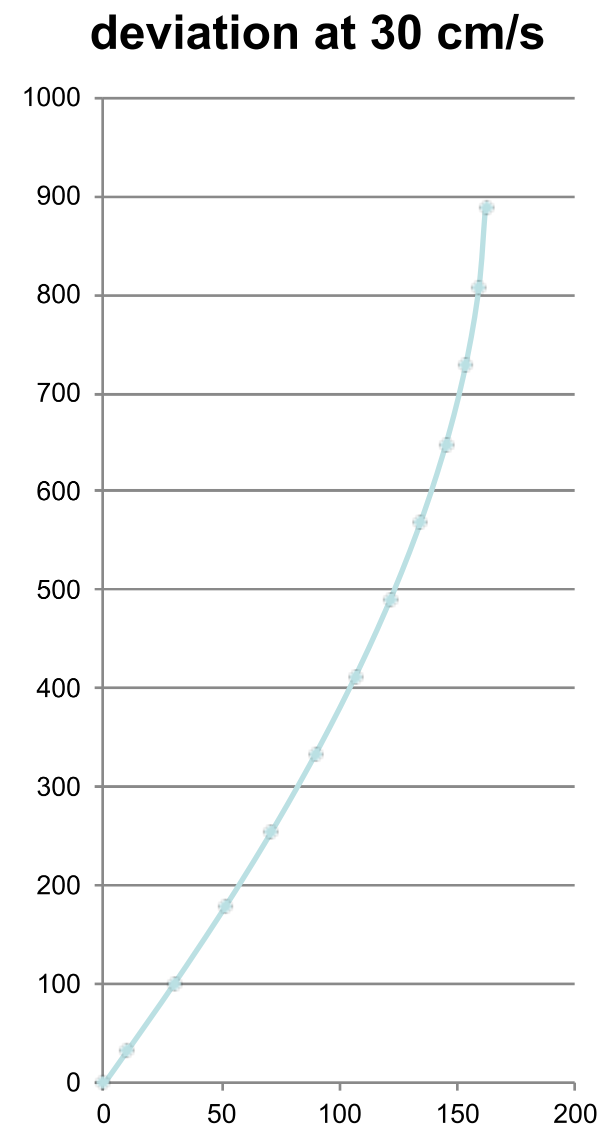
Compactifying Strings

Slender string rolled up for self-unfurling:



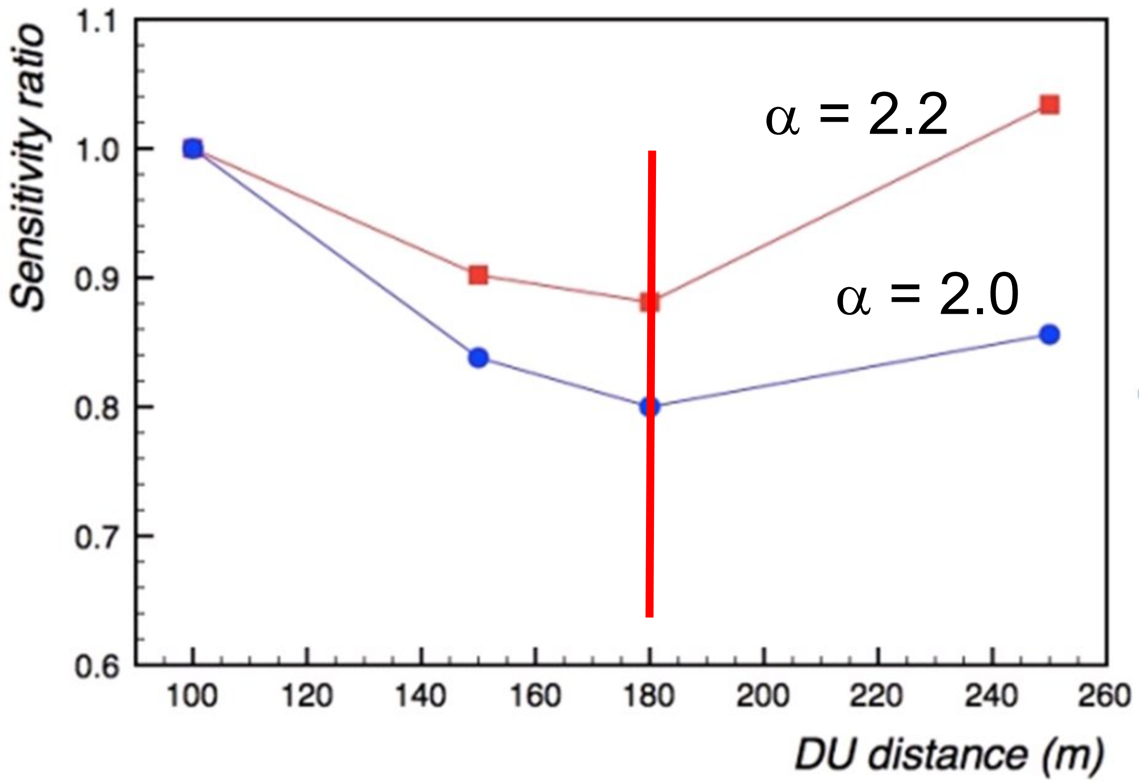
Hydrodynamic Stability

- DUs move under drag of sea current
  - Currents of up to 30cm/s observed
  - Mostly homogeneous over detector volume
  - Deviation from vertical at top about 150m at 30cm/s (can be reduced by extra buoyancy)
  - Critical current ~45cm/s (anchor starts to move)



Optimisation Studies

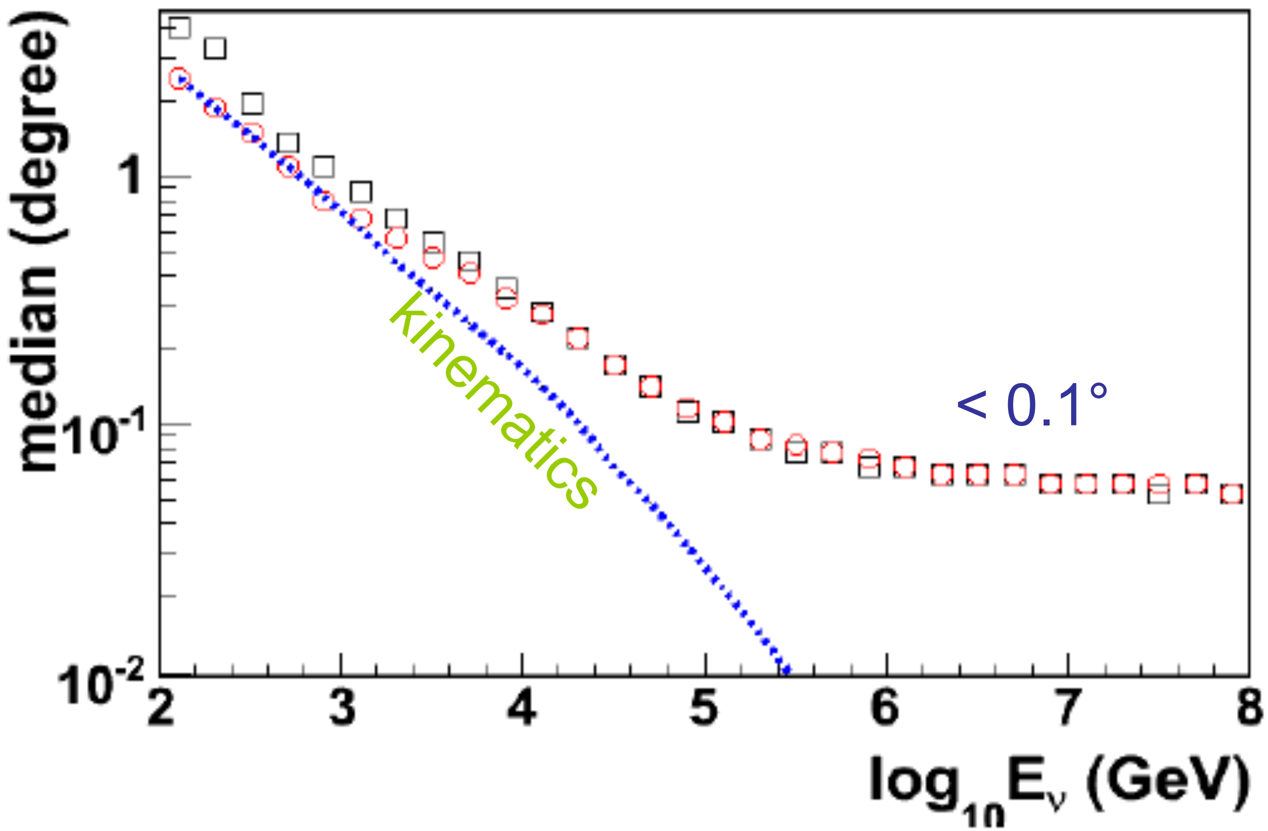
<u>Example</u>: Sensitivity dependence of point-source search on DU distance for flexible towers
(for 2 different neutrino fluxes ~$E^{-\alpha}$, no cut-off)



ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

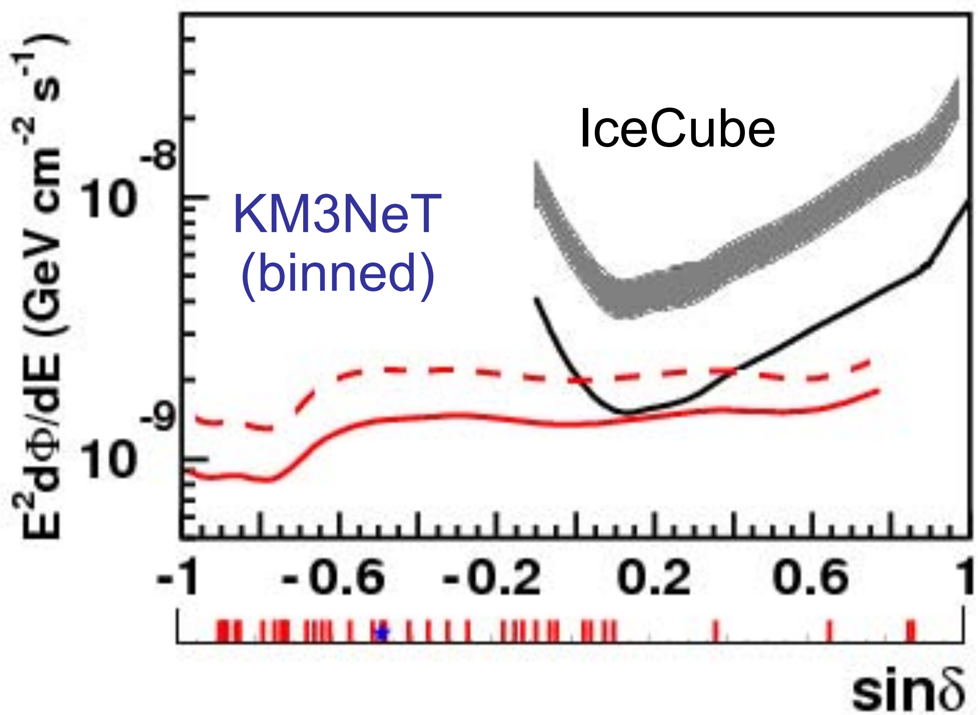
Angular Resolution

- Investigate distribution of angle between incoming neutrino and reconstructed muon
- Dominated by kinematics up to ~1TeV



Point Source Sensitivity (1 Year)

Expected exclusion limits / 5σ detection:



R. Abbasi et al. Astro-ph (2009) scaled – unbinned method

Discovery at 5σ with 50%

After optimisation for Galactic sources: Observation of RXJ1713 with 5σ within ~7-9 years (if purely hadronic)

Observed Galactic TeV-γ sources (SNR, unidentified, microquasars)
F. Aharonian et al. Rep. Prog. Phys. (2008)
Abdo et al., MILAGRO, Astrophys. J. 658 L33-L36 (2007)

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Footprint Considerations

- Detector will be constructed in 2 or more building blocks (technical reasons: power, data bandwidth, cables, deployment operations, complexity of floor network, …)
- Geometry described in TDR:
  Hexagonal blocks with 154 ,
  180m between towers
- Now: Optimise r Galactic sources
  (energy cut 10 TeV)
  → Distance b en tower reduced to 100-130m
  → Effective area increases at intermediate and decreases at high energies

Footprint
optimisation is ongoing

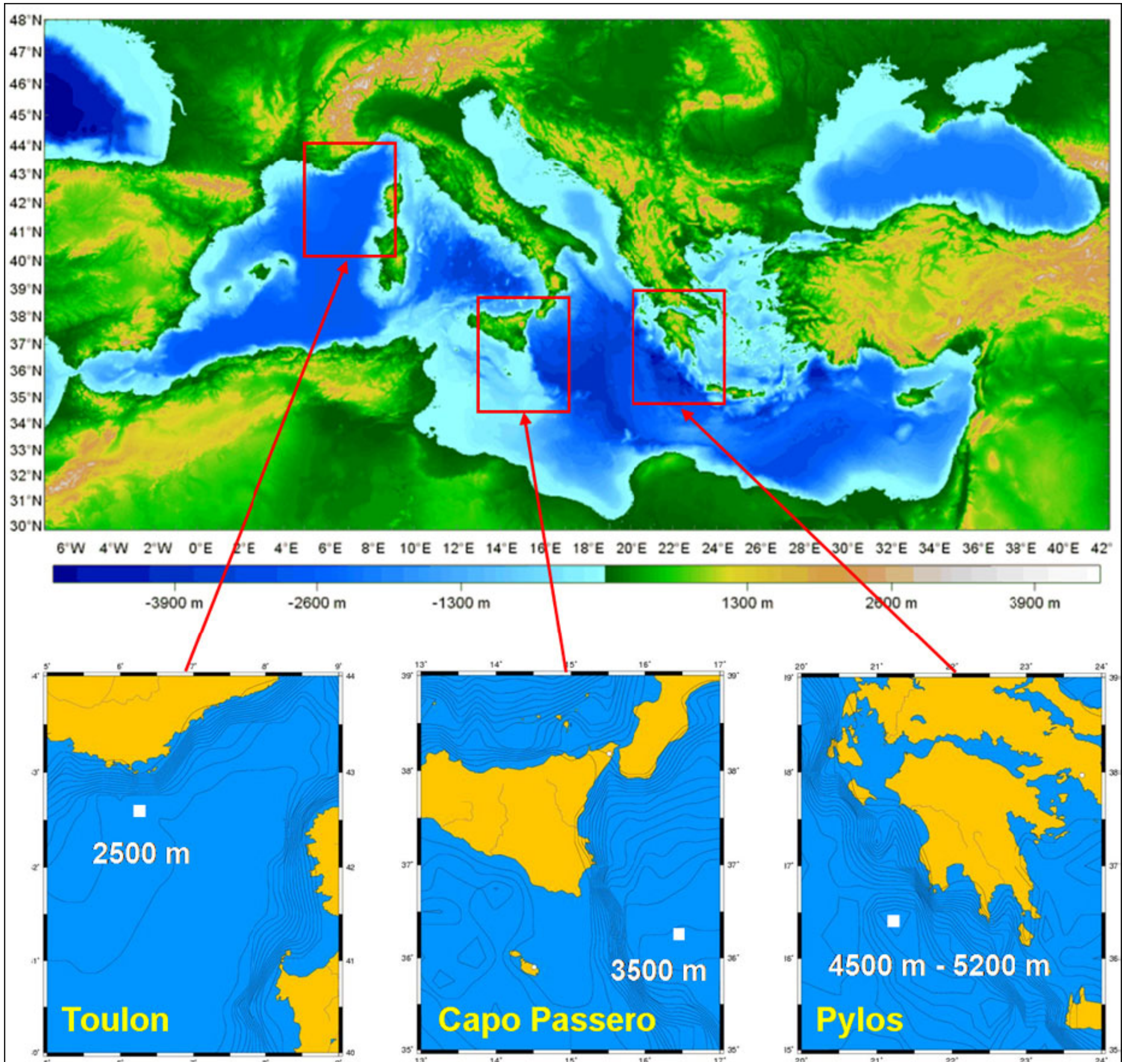
ERLANGEN CENTRE
FOR ASTROPARTICLE
PHYSICS

Prototype Schedule

- Reflective readout
  - ➢ Performed in lab 50ps over 100km
- OM including readout electronics
  - ➢ First four Dec.-Feb.
- Tower mechanical structure
  - ➢ First 6 in Dec.-Jan.
  - ➢ Full structure Q2-3 2012
- Vertical cable
  - ➢ Q1-2 2012

Candidate Sites

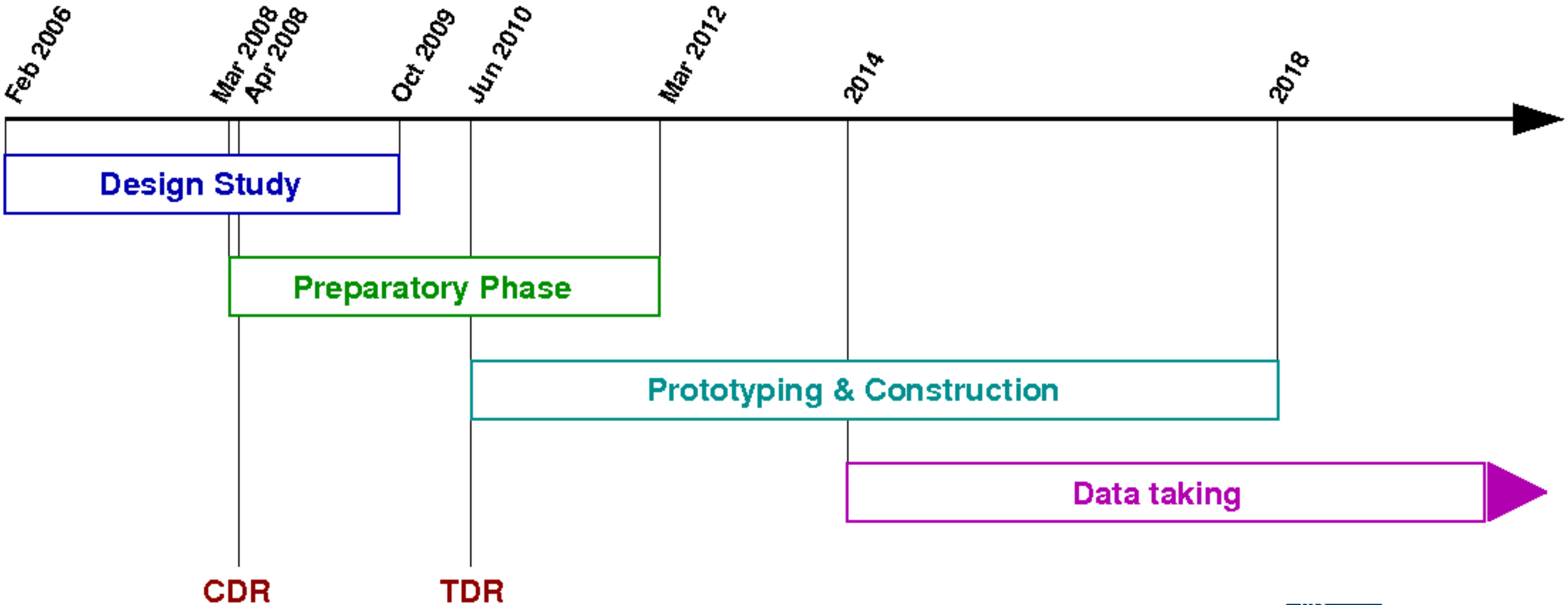
- Locations of the three pilot projects:
  - ANTARES: Toulon
  - NEMO: Capo Passero
  - NESTOR: Pylos
- Long-term site characterisation measurements performed
- Political and funding constraints
- Possible solution: networked, distributed implementation



ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

Next Steps and Timeline

- Next steps: Prototyping and design decisions
  - TDR public since June 2010
  - convergence of technical design
  - site decision in preparation
- Timeline:



Conclusions

- A design for the KM3NeT neutrino telescope complementing the IceCube field in its of view and surpassing it in sensitivity by a substantial factor is presented.
- Readiness for construction expected after ongoing prototype studies.
- An overall budget of ~250 M€ will be required. Staged implementation, with increasing discovery potential, is technically possible.
- Installation could start in 2013 and data taking soon after.