

# WG4: High-Energy Neutrinos – Mainly Neutrino Telescopes

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- Projects
- Some background information
- Project summaries & resources

## Physics objectives

- Detect cosmic neutrinos with energies above some 10 GeV
- Physics goals:
  - Find and study accelerators of cosmic rays
  - Measure diffuse flux of neutrinos
  - Detect cosmogenic neutrinos (GZK)
  - Detect neutrino from Dark Matter annihilation
  - ...
- Reminder: Huge target masses needed;
- Neutrino astronomy is and will always be a small-statistics discipline

# The Working Group

- Meeting in Amsterdam 20.02.2007
  - WG3 (Cosmic rays) and WG4 (high-energy neutrinos) cooperate but don't merge
  - Formation of WG4:
    - Antonio Capone
    - John Carr
    - Paschal Coyle
    - Els de Wolf
    - Vincenzo Flaminio
    - Juanjo Hernandez
    - Uli Katz (Co.)
    - Paolo Lipari
    - Emilio Migneco
    - Luciano Moscoso
    - Rolf Nahnauer
    - Paolo Piattelli
    - Miquel Ardid Ramirez
    - Petros Rapidis
    - Andrea Santangelo
    - Subir Sarkar
    - Olaf Scholten
    - Mauro Taiuti
    - Lee Thompson
    - Spyros Tzamarias

# The projects

- **First-generation neutrino telescopes**
  - South Pole: AMANDA
  - Mediterranean: ANTARES, NEMO, NESTOR
  - Lake Baikal
- **2nd-generation neutrino telescopes**
  - IceCube
  - KM3NeT
- **Neutrino chances for UHE cosmic ray experiments**
  - Pierre Auger South & North
  - JEM/EUSO
- **Radio detection**
  - NuMoon, LOFAR, ANITA, ARIANNA
  - IceCube extensions
- **Acoustic detection**
  - R&D: IceCube, Mediterranean (ANTARES)
  - ACORNE, SAUND, ...

## Projects considered in WG4 (1)

- **First-generation neutrino telescopes**
  - South Pole: **AMANDA**  
Has become part of IceCube, no separate resources needed
  - Mediterranean:
    - ◆ **ANTARES** (200 scientists, 100% EU) :  
Resources needed for operation & exploitation
    - ◆ **NEMO** (25 scientists, 100% EU)  
Resources needed for commissioning & operation
    - ◆ **NESTOR** (~20 scientists, 100% EU)  
Will be embedded in KM3NeT
  - **Lake Baikal**  
Plans for low-density km<sup>3</sup>-scale extension,  
but no European participation.

## Projects considered in WG4 (2)

- **2nd-generation neutrino telescopes**
  - **IceCube** (100 scientists, funding 15% EU / rest US)  
Core experiment (optical Cherenkov) fully funded & on schedule (construction not an issue for the roadmap).  
Extensions under discussion:
    - ◆ Low-energy dense subarray (DeepCore)
    - ◆ Large acoustic/radio hybrid array Deep-ice radio and acoustic detection (“Kilo-Cube”)
    - ◆ Surface radio array for neutrinos and air showers (“IceRay”)
  - **KM3NeT** (250 scientists, 100% EU)  
Design Study going on (2006-2009)  
coming up: Preparatory Phase project (EU/FP7, 2008-2010)  
construction should/could start soon thereafter (2011)  
**Major investment required.**

## Projects considered in WG4 (3)

- **Neutrinos @ UHE cosmic ray experiments**

- Pierre Auger South & North
- JEM/EUSO

No particular additional investments necessary for neutrino studies  
Both experiments included in WG3 (cosmic rays)

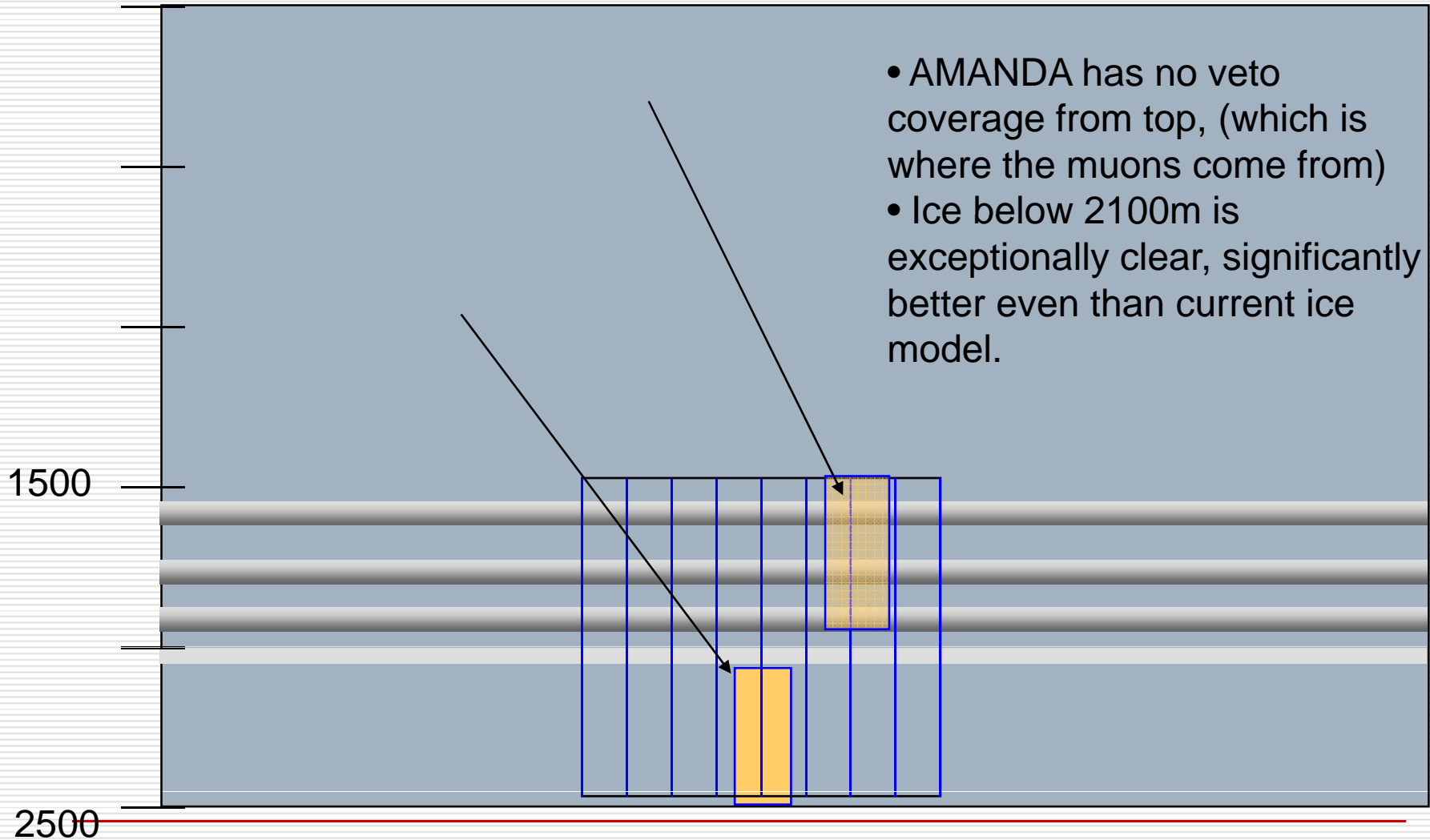
- **Radio detection**

- NuMoon, LOFAR in WG3
- ANITA: mainly US, but some UK contribution
- ARIANNA: no EU contribution
- IceCube extensions → see IceCube

- **Acoustic detection (~50 scientists in Europe)**

- R&D for ice → see IceCube  
for water: Mediterranean (ANTARES, NEMO)  
for rock salt: Mostly US  
sensor/detector development, etc.
- Data from ACORNE, SAUND, ...

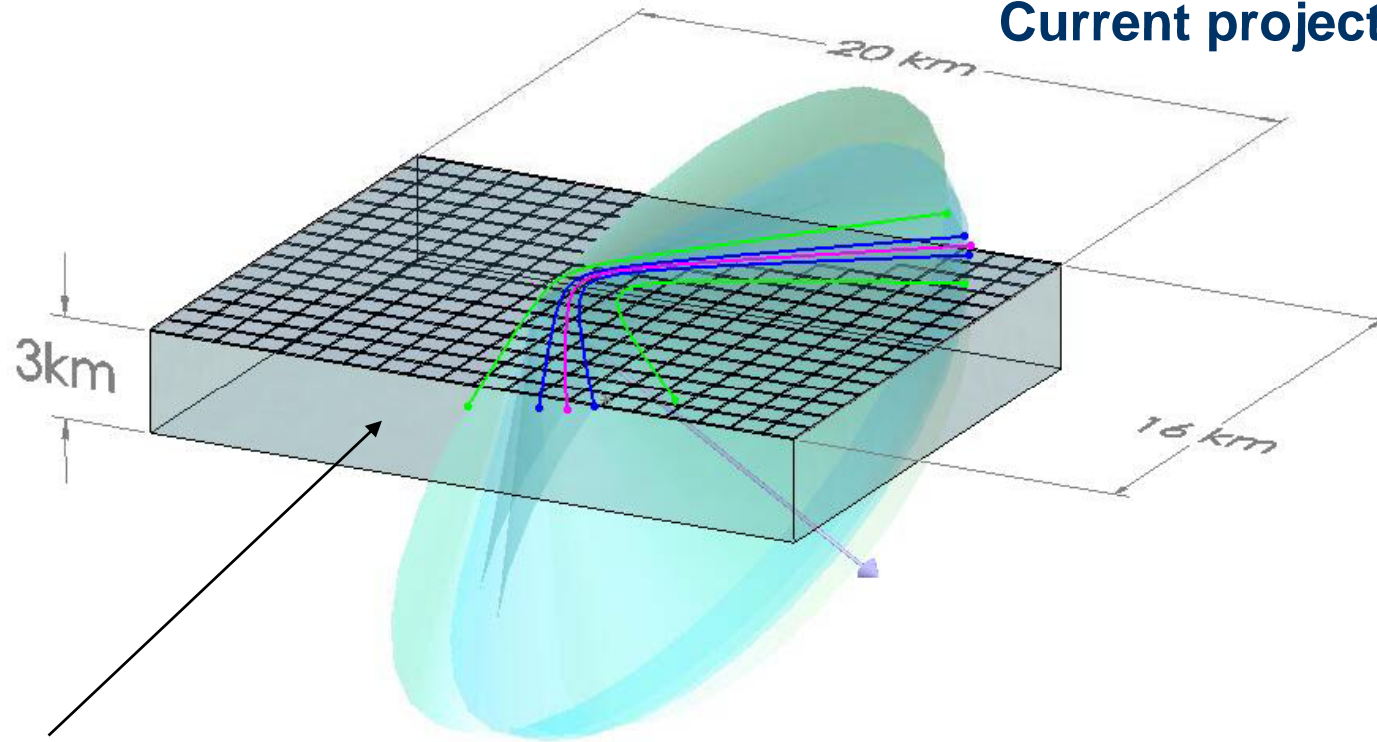
# A low-energy core for IceCube





# "Kilo-Cube" Array (here: Radio)

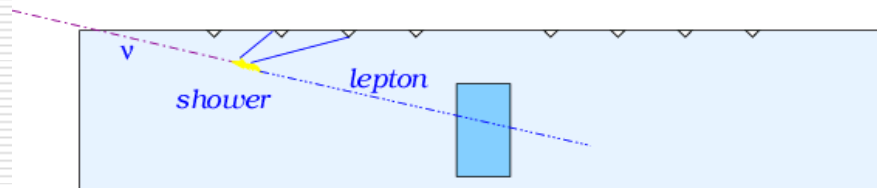
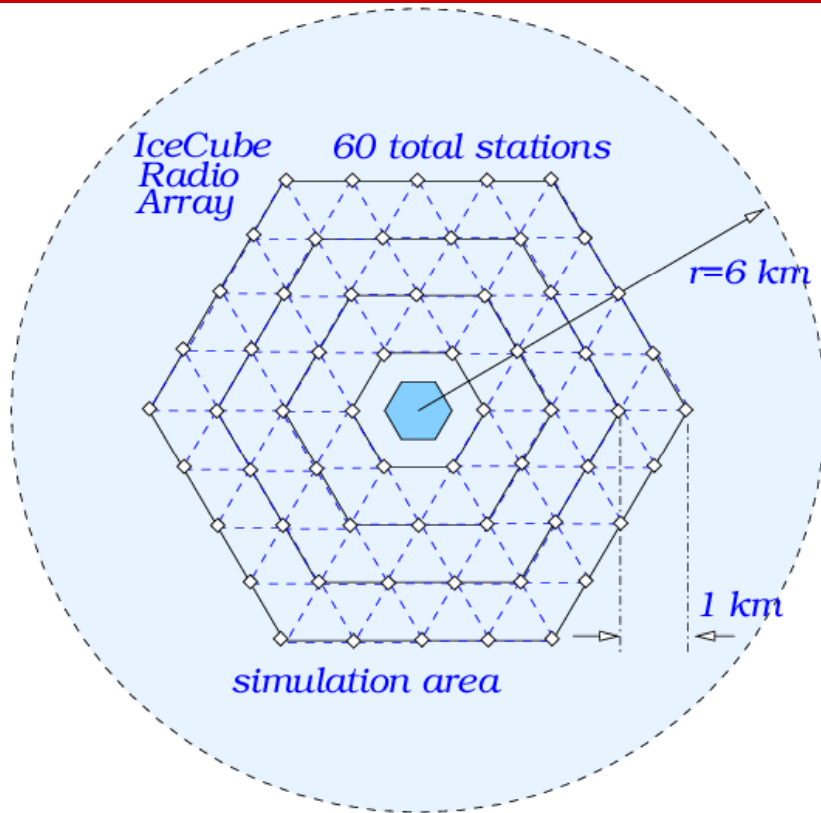
Current project: AURA



Sensor plane located near firn/ice boundary to avoid signal loss from refraction

**~3000 sensors for 1000 km<sup>3</sup>**

# IceCube Radio Array (IceRay)



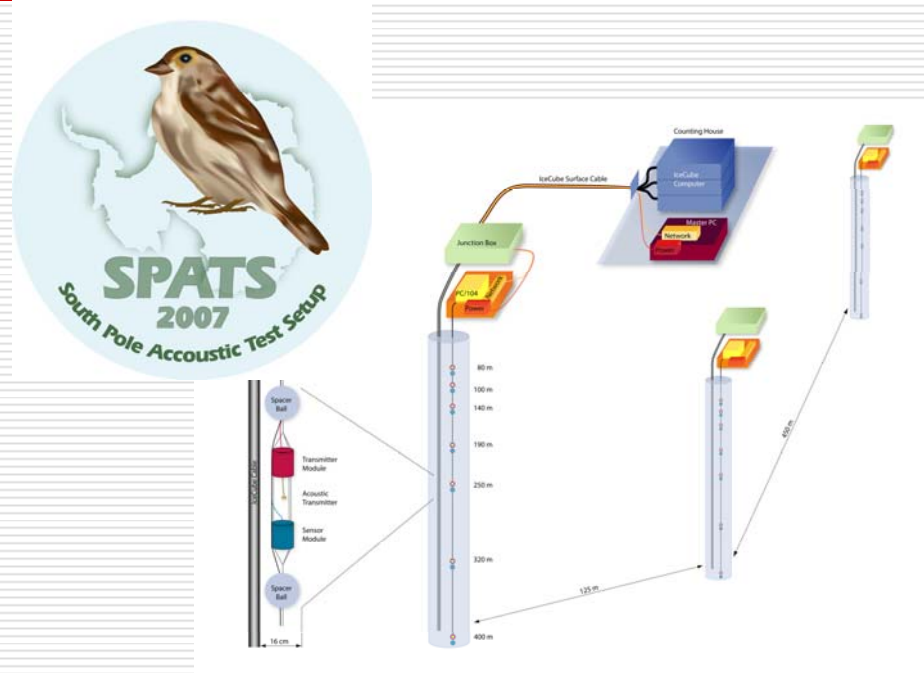
## Goals:

- GZK neutrinos ( $10^{17-19.5}$  eV)
- Lowest possible cost
  - Surface array, sparse
  - Give up resolution for volume
- Hybrid events with IceCube
  - Primary vertex calorimetry in radio, HE muon or tau secondary in IceCube
  - (Acoustic possible from surface??)

# Acoustics @ IceCube: Status & plans

## SPATS:

- Deployment successful
- Detector operates well
- Data taking ongoing
- First preliminary results available
- Exploration phase continues



## Long-term plan:

**Build a hybrid optical-radio-acoustic detector of ~ 100 km<sup>3</sup> instrumented volume around icecube, ready for operation**

**in ~10 years (2017)**

# The KM3NeT Design Study

- 3-year FP6 Design Study, Feb. 2006 – Jan. 2009, 9 M€ from EU, overall budget ~20 M€

- Participants:

30 Particle/Astroparticle institutes +  
7 Sea science/technology institutes

} from 10 EU countries:



- Main Deliverables

- Conceptual Design Report (fall 2007)
- **Technical Design Report (early 2009)**

**+Romania**

## KM3NeT: Activities and plans

### ■ FP6 Design Study

- started 1. Feb. 2006
- towards Conceptual Design Report end of 2007  
(basis for rough cost estimates)
- Technical Design Report 2009  
(basis for solid cost estimates)

### ■ FP7 Preparatory Phase

- proposal submitted May 2007
- evaluated favourably, negotiations ongoing
- provides framework (and 5M€ funding) for path to start of construction in 2010-2011

### ■ ESFRI

- opened door to Preparatory Phase call
- stimulated already substantial political activity/commitments

# Current National/Regional Funding

## ■ Pilot projects:

-	ANTARES (cap. investment only)	20.1 M€
◆	FR, GER, IT, NL, ES funding agencies	14.5 M€
◆	France: Regional sources	1.9 M€
◆	FEDER/France	3.7 M€
-	NEMO (IT, cap. investment only)	17.0 M€
◆	IT funding agencies	10.9 M€
◆	FEDER/Italy	6.1 M€
-	NESTOR (GR, cap. investment only)	8.0 M€
◆	Greek government	6.5 M€
◆	FEDER/Peloponnese	1.5 M€

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**45.1 M€**

■	KM3NeT (cap. + pers.)	ca.	<b>17.0 M€</b>
◆	CY, FR, GER, GR, IRL, IT, NL, RO, ES, UK funding agencies and other sources		

# Acoustic detection

## ■ European Activities

- IceCube/SPATS & future plans for large hybrid detector
- Acoustics @ ANTARES  
(feasibility study for large acoustic water detector)
- Acoustics @ NEMO
- ACORNE
- ...

## ■ General status

- Approaching “decision point” for large project(s)
- Time scales not clear, but <10 years for positive developments
- European lead in the field

# KM3NeT: European resources

R&D	15500 k€	170 FTE	2008-2010
Construction	200000 k€	440 FTE	2011-2014
Commissioning	6000 k€	30 FTE	2013-2014
Operation	32000 k€	180 FTE	2012-2018
<b>Total</b>	<b>253500 k€</b>	<b>820 FTE</b>	<b>2008-2018</b>

- All numbers are rough estimates;  
more solid costing after CDR / TDR.
- R&D does not include EU contribution to Design Study and Preparatory Phase project.
- Partial funding through European non-ASPERA sources possible (e.g. European Regional Development Funds, marine sciences).
- International partners will be sought (Preparatory Phase)



# IceCube: European resources

R&D	1770 k€	36 FTE	2008-2011
Construction	9525 k€	51 FTE	2008-2011 2013-2016
Commissioning	520 k€	8 FTE	2008-2011
Operation	11110 k€	223 FTE	2008-2018
<b>Total</b>	<b>22925 k€</b>	<b>318 FTE</b>	<b>2008-2018</b>

- **Extensions included:**
  - DenseCore (low energy), construction 2008-2011
  - Radio/acoustic hybrid array, construction 2013-2016

Final approval of extensions pending.
- **Commissioning and operation also for core detector**
- **Further contributions from US (~50% for extensions?)**

# ANTARES & NEMO: European resources

## ■ ANTARES

Operation	1100 k€	220 FTE	2008-2018
<b>Total</b>	<b>1100 k€</b>	<b>220 FTE</b>	<b>2008-2018</b>

## ■ NEMO

R&D	3000 k€	15 FTE	2008-2010
Construction	3000 k€	15 FTE	2008
Commissioning	600 k€	10 FTE	2008-2010
Operation	2700 k€	60 FTE	2008-2011
<b>Total</b>	<b>9300 k€</b>	<b>100 FTE</b>	<b>2008-2011</b>

- Conclusion of pilot projects according to current planning.
- **ANTARES**: Includes Common Funds and personnel for exploitation.
- **NEMO**: Construction already approved and funded.

# Acoustic detection: European resources

R&D	900 k€	100 FTE	2008-2012
<b>Total</b>	<b>900 k€</b>	<b>100 FTE</b>	<b>2008-2018</b>

- **Very rough estimate for acoustic activities outside IceCube**  
(water, sensor/detector R&D, use of existing/new arrays)
- IceCube extension not included.
- Assumption: Convergence to a common acoustic detection project around 2012 (or end of activities).  
The corresponding resources are unknown and cannot be included in spending profile (→ reserve).
- Substantial activities also in US

# ANITA/radio: European resources

Commissioning	60 k€	10 FTE	2008
Operation	120 k€	15 FTE	2008-2009
<b>Total</b>	<b>180 k€</b>	<b>25 FTE</b>	<b>2008-2009</b>

- Resources for second circumpolar flight (2008), no further flights planned.
- Overall project cost ~2.5 M€, EU contribution through UK
- Further radio/neutrino projects with European contribution may be coming up → Need of “reserve” for R&D and future projects

## Resource breakdown by years

2008	18.0 M€	260 FTE
2009	13.8 M€	193 FTE
2010	12.9 M€	179 FTE
2011	76.3 M€	239 FTE
2012	68.8 M€	214 FTE
2013	61.6 M€	204 FTE
2014	32.4 M€	210 FTE
2015	10.4 M€	98 FTE
2016	10.4 M€	90 FTE
2017	7.8 M€	80 FTE
2018	7.4 M€	78 FTE
<b>Total</b>	<b>319.8 M€</b>	<b>1801 FTE</b>

- The numbers look more precise than they are.
- **KM3NeT** is major project of next decade
- Peak of resource needs around **2011-2014**
- **New projects** (acoustics, radio, etc.) may enter the schedule after ~2015

# IceCube time scales and vision

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- **2007:**
  - prototypes in radio and acoustics in ice
  - New Proposal for a km scale AURA (?)
  - Letter of intent for future large array (too early?)
- **2008:**
  - Continue building AURA
  - Take data
  - R&D
- **2009:**
  - sizeable detector in place, mature technology
  - Design study for integrated radio, acoustic, optical hybrid array, technical design document
- **2010: proposal for a large scale GZK detector**

# The KM3NeT Preparatory Phase proposal

- Application be same partners as in Design Study, except some marine research institutions (EMSO)
- Work package structure
  - WPA Management
  - WPB Political convergence
  - WPC Legal, governance, financial engineering and site issues
  - WPD Strategic issues and international networking
  - WPE Marine and environmental agencies and networks
  - WPF Production preparation of telescope components
  - WPG Industrial partnerships for auxiliary vessels
  - WPH Industrial production of deep-sea components and partnership for deep-sea infrastructures
  - WPJ Data handling and dissemination