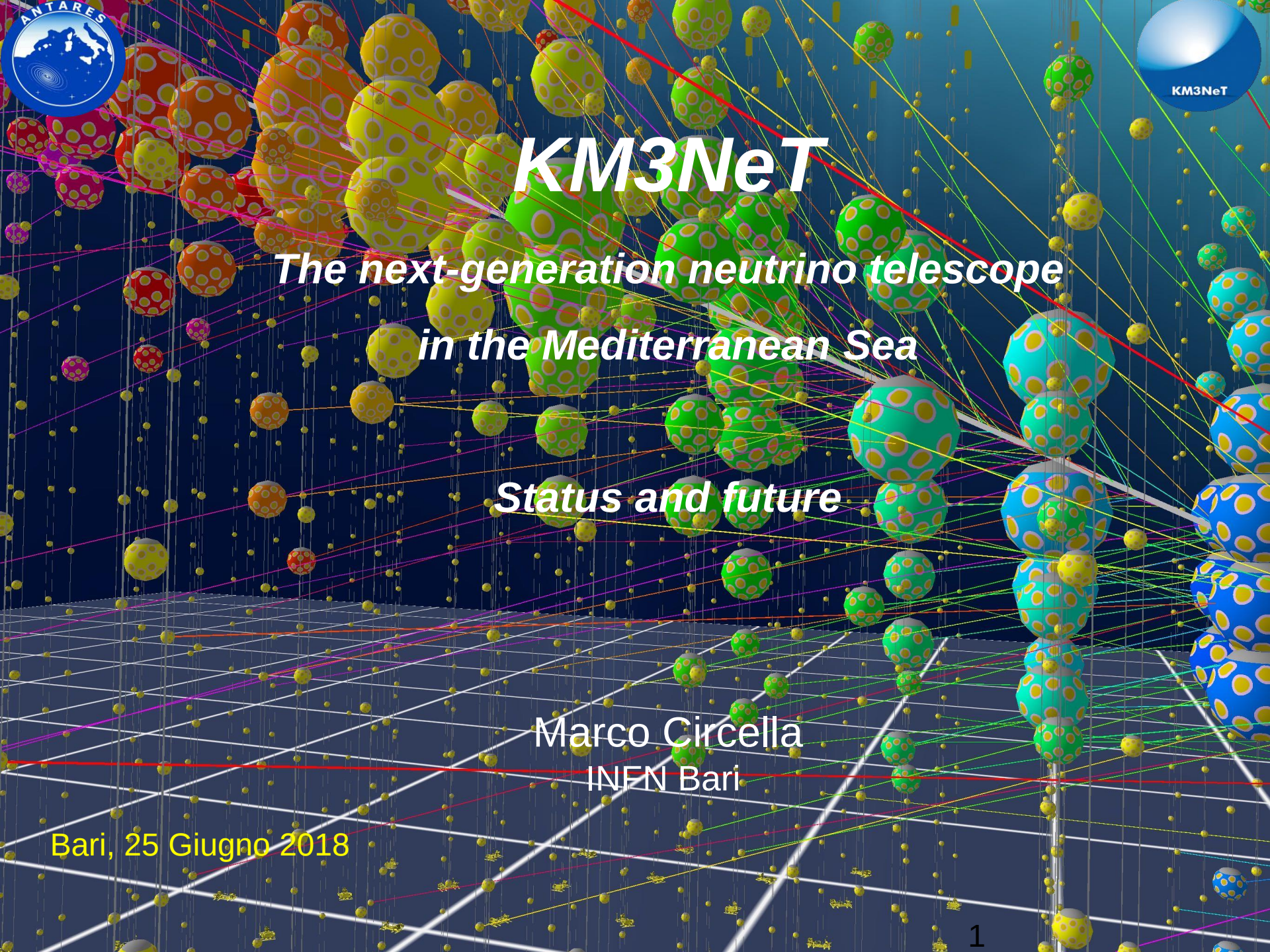


KM3NeT

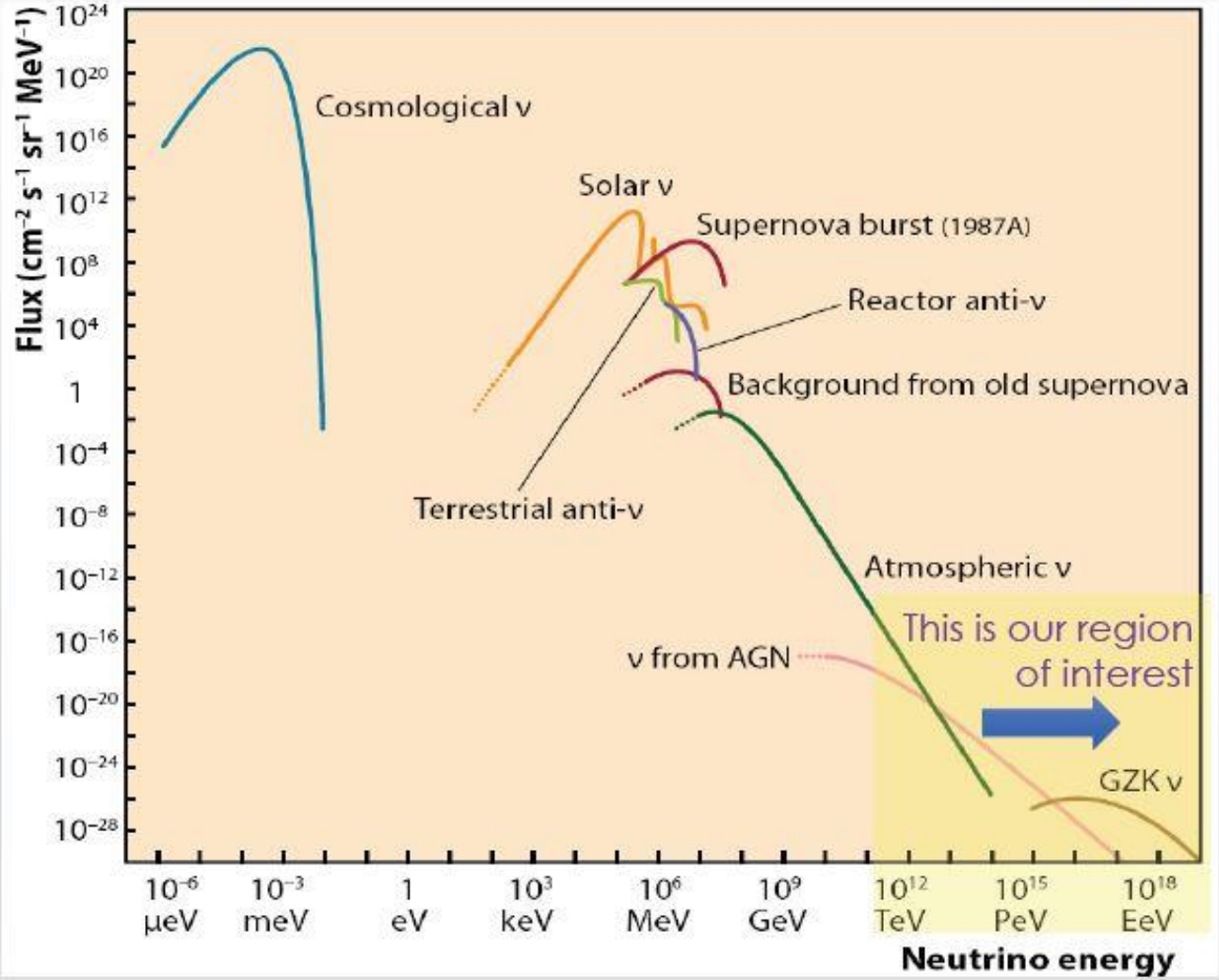
The next-generation neutrino telescope in the Mediterranean Sea

Status and future

Marco Circella
INFN Bari

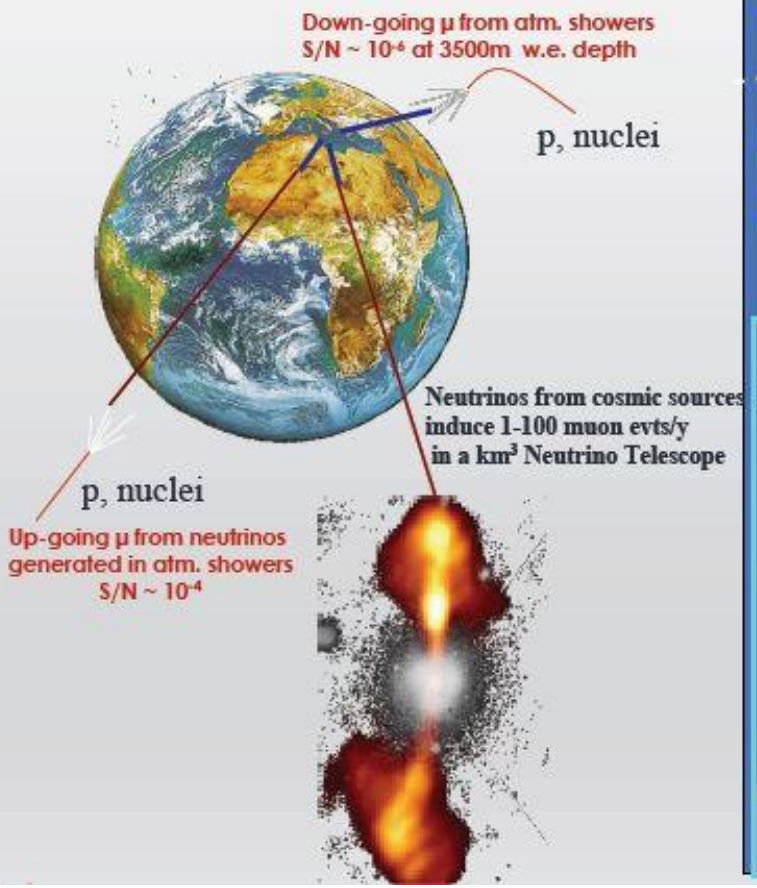
Bari, 25 Giugno 2018

Neutrino fluxes: what do we know/expect ?



Cherenkov ν Telescope: Detection principle

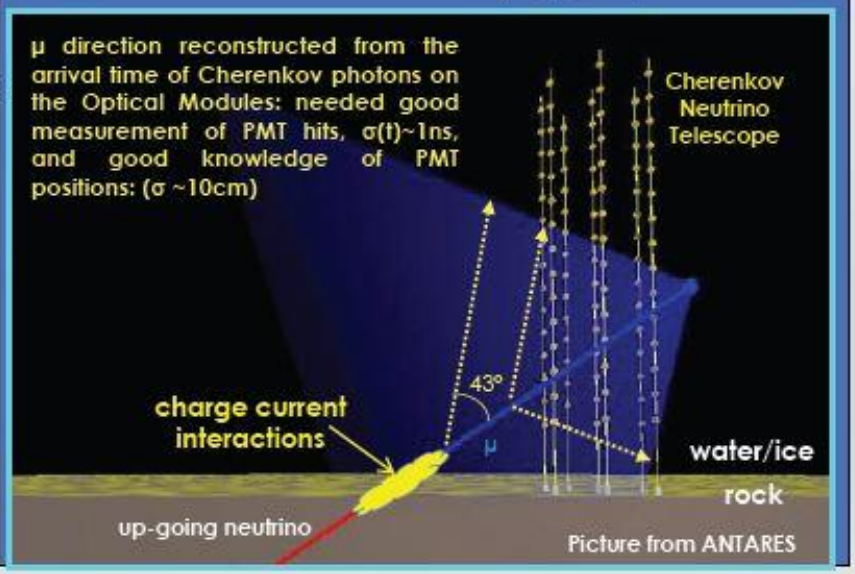
Search for neutrino induced events, mainly $\nu_\mu N \rightarrow \mu X$, deep underwater



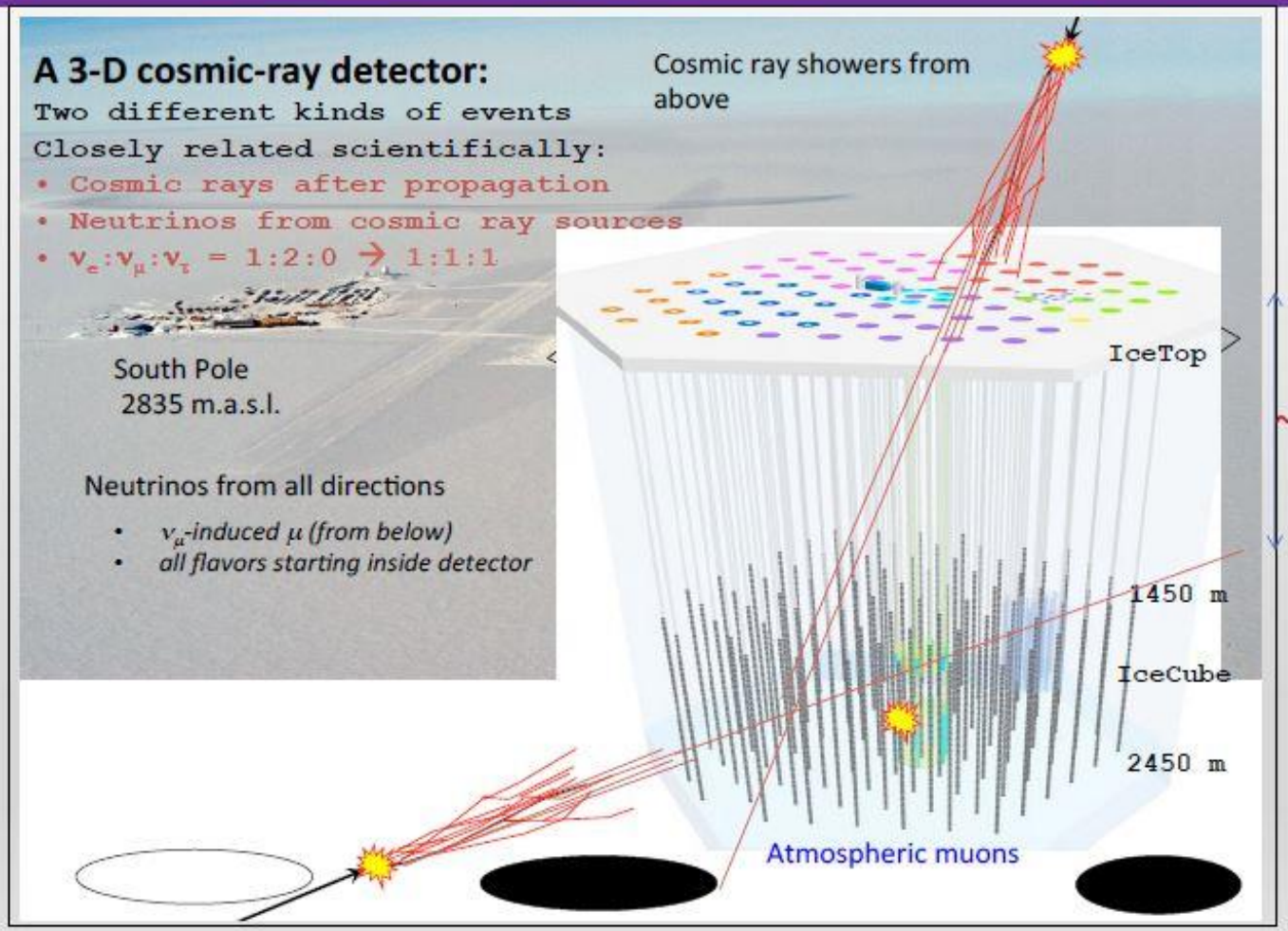
- Atmospheric neutrino flux ~ E_ν^{-3}
- Neutrino flux from cosmic sources ~ E_ν^{-2}
  - Search for neutrinos with E_ν>1÷10 TeV

- ~TeV muons propagate in water for several km before being stopped
  - go deep to reduce down-going atmospheric μ backg.
  - long μ tracks allow good angular reconstruction

$$For\ E_\nu \geq 1TeV \quad \theta_{\mu\nu} \sim \frac{0.7^\circ}{\sqrt{E_\nu[TeV]}}$$

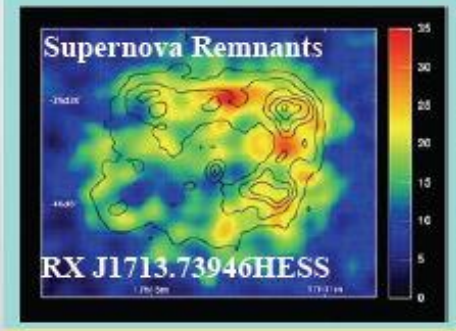


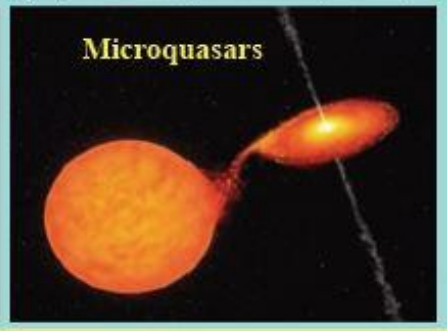
IceCube – The Neutrino Telescope at the South Pole



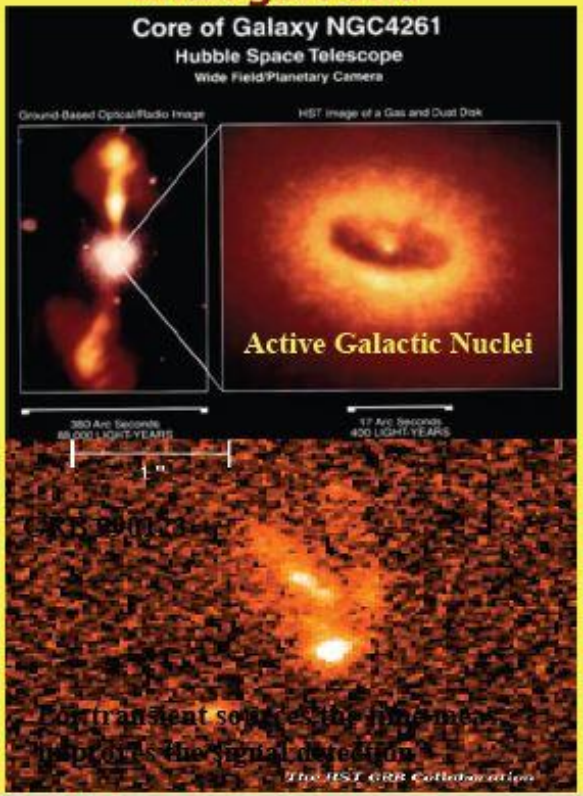
Neutrino Telescope physic's goals: search for point-like cosmic Neutrino Sources

Galactic





Extragalactic



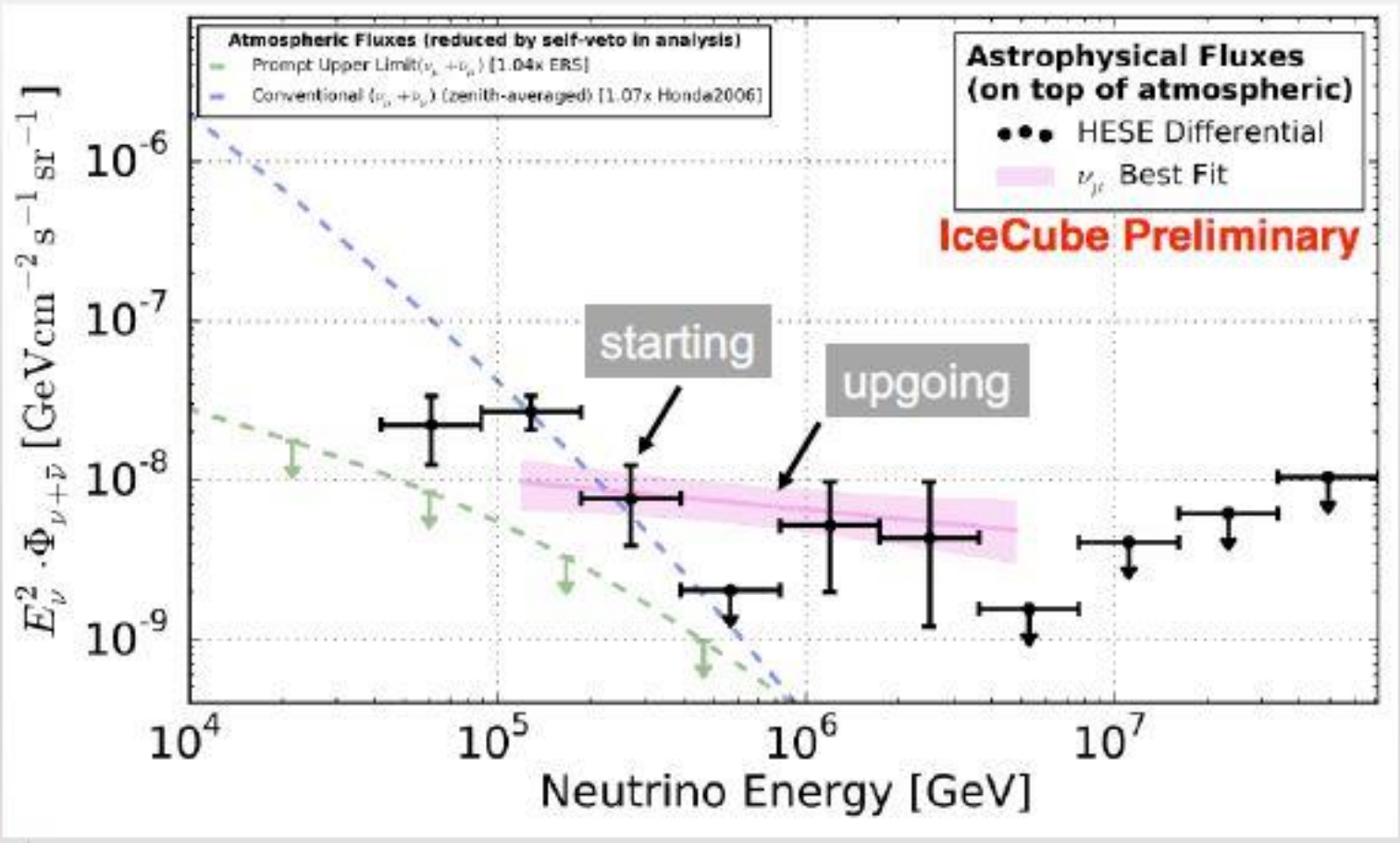
- Their identification requires a detector with accurate angular reconstruction

$$\sigma(\vartheta) \leq 0.5^{\circ} \text{ for } E_{\nu} \geq 1 TeV$$

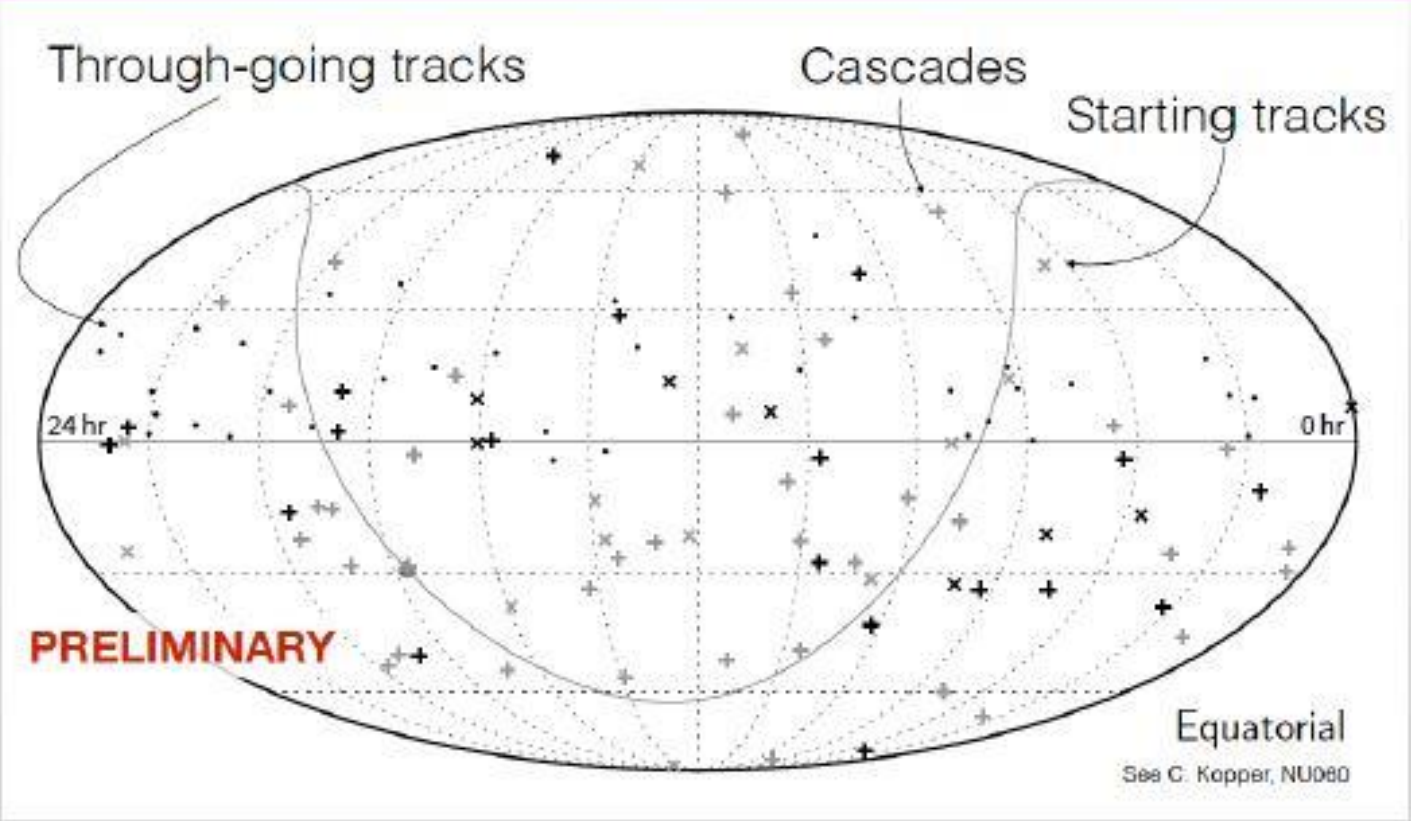
Experimental signal : statistical evidence of an excess of events coming from the same direction

IceCube 2017

High Energy Staring events (showers) and up-going muons analyses give consistent results



Where these neutrinos are coming from ??



A diffuse flux from extragalactic sources

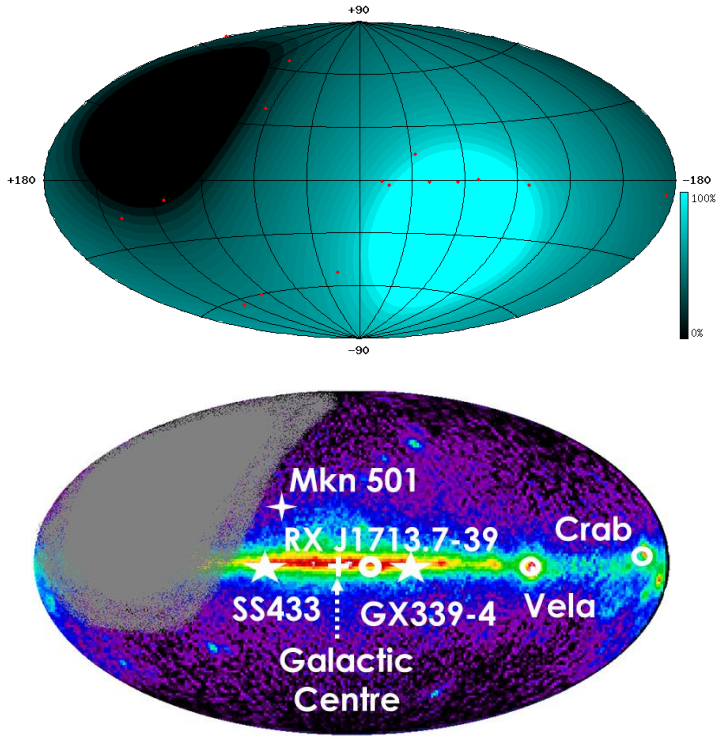
A subdominant Galactic component cannot be excluded

Mediterranean Neutrino Telescopes

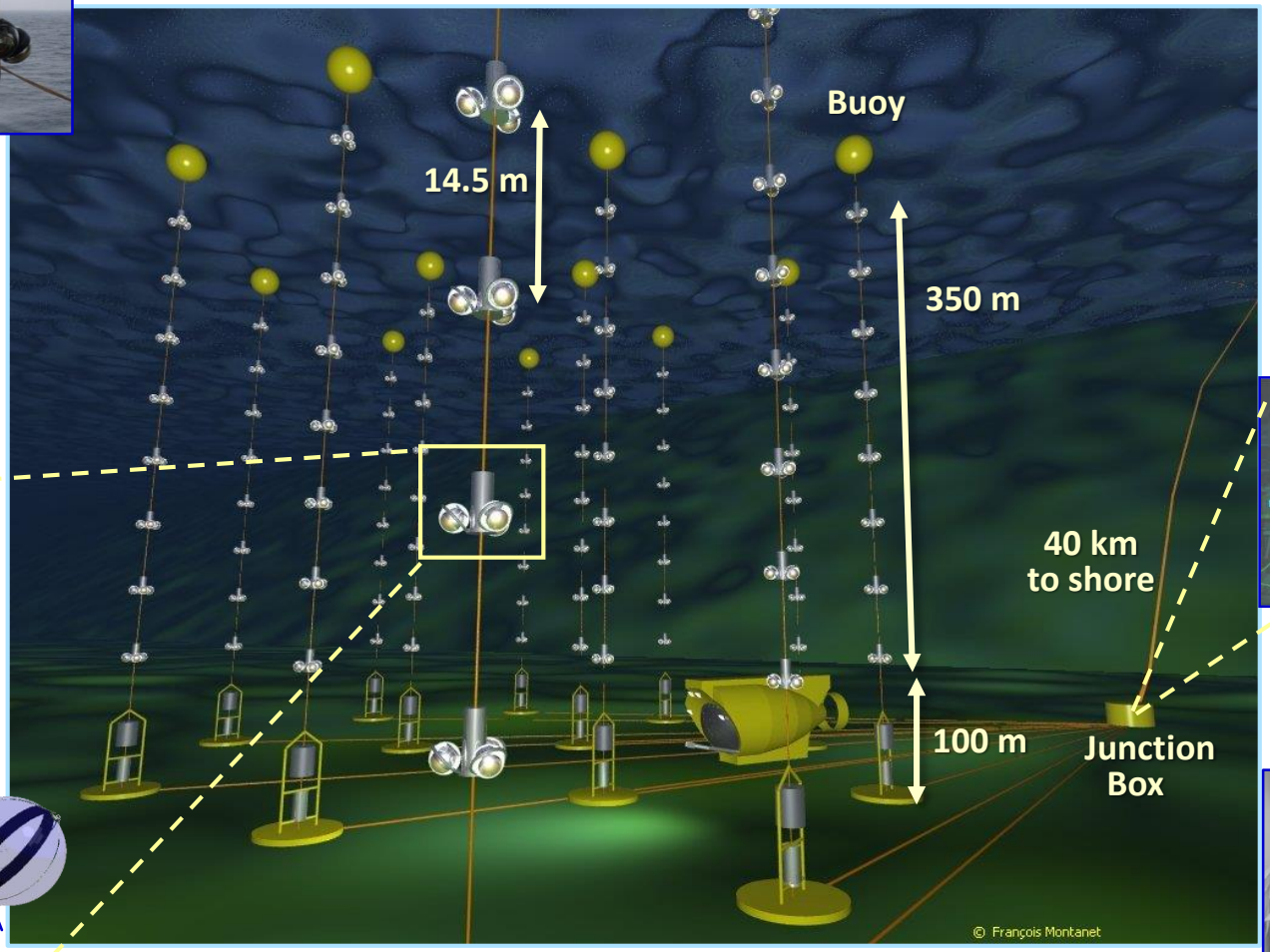
Two advantages:

- Location:
  - Northern terrestrial hemisphere:
  - Complementary to IceCube
  - Golden channel for southern sky sources. “Milky-Way optimized”

- Medium:
  - Deep Sea water
  - Very small light scattering (good angular resolution)
  - Natural backgrounds (^{40}K and biolum) can be handled.



ANTARES



12 lines (885 PMTs)

25 storeys / line

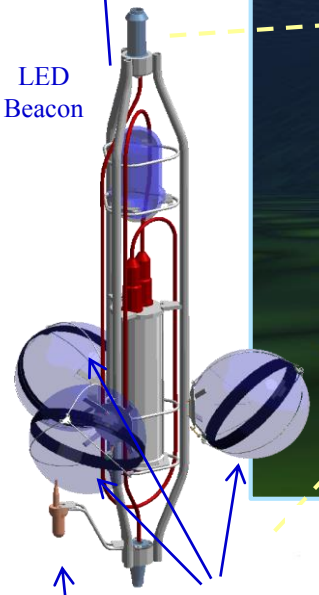
3 PMTs / storey

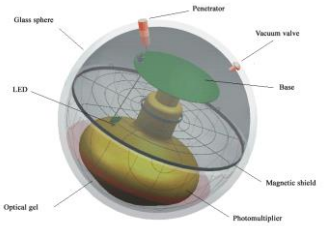
Completed in 2008

In operation until 2019 (at least)

Junction Box

Shore station





Mediterranean Sea
(near Toulon)
at **2500 m** depth

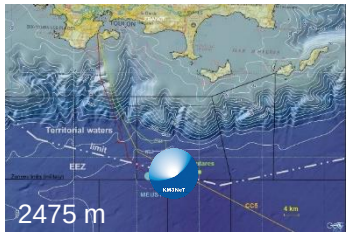
NIM **A484** (2002) 369, AP **19** (2003) 253
AP **23** (2005) 131, NIM **A555** (2005) 132
AP **26** (2006) 314, NIM **A570** (2007) 107
NIM **A578** (2007) 498,NIM **A581** (2007) 695
AP **31** (2009) 277, NIM **A622** (2010) 59-73
AP **34** (2011) 539, NIM **A656** (2011) 11

KM3NeT

ARCA
Astroparticle **R**esearch with **C**osmics In the **A**byss

Capo Passero, Sicily, Italy

ORCA
Oscillation **R**esearch with **C**osmics in the **A**byss

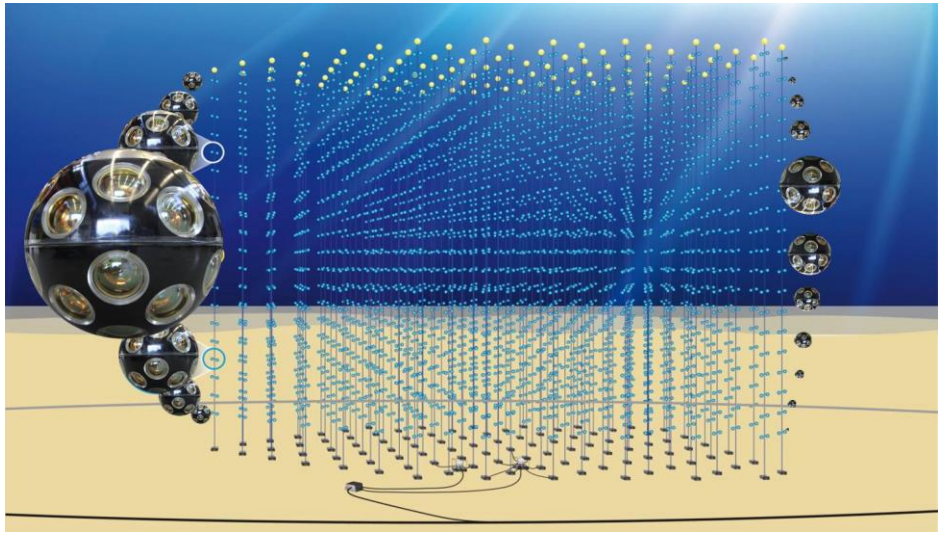


Toulon, Var, France

- ARCA (Astronomy)
  - Building Block:
    - 115 strings
    - 18 DOMs / string
    - 31 PMTs / DOM
    - Total: 64k*3¨ PMTs

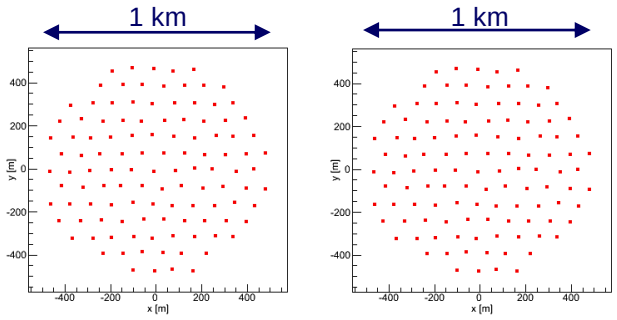
- ORCA (NMH+ ν properties)
  - Same technology, denser layout

	ORCA	ARCA
String spacing	23 m	90 m
OM spacing	9 m	36 m
Depth	2470 m	3500 m
Instrumented mass	5.7 Mton	0.6*2 Gton

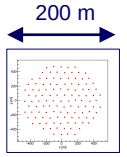


- Stages:
  - Phase 1: 24 ARCA + 6 ORCA strings (already funded, being built)
  - KM3NeT 2.0: 2 ARCA +1 ORCA blocks (~50% funded)
  - Phase 3: 6 ARCA + 1 ORCA blocks

ARCA



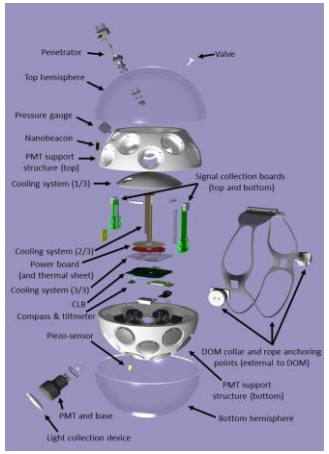
ORCA



KM3NeT Technology

Digital Optical Module

- DOM: 31 3” PMTs
- Digital photon counting
- Directional information
- Wide acceptance angle
- Cost reduction



- All data to shore
- Gbit/s on optical fibre
- Hybrid White Rabbit
- LED flasher & hydrophone + tiltmeter/compass for time/position calibration

String (Detector Unit)

- High modulus dyneema ropes
- Oil-filled backbone
- Low drag
- Low cost

Deployment Vehicle

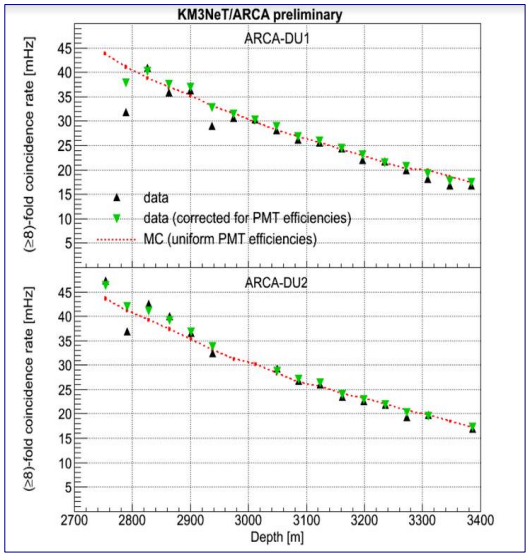
- Rapid deployment
- Multiple strings in one sea campaign

- Unfurling started by ROV
- Reuseable

J. Phys. G: Nucl. Part. Phys. 43 (2016) 084001

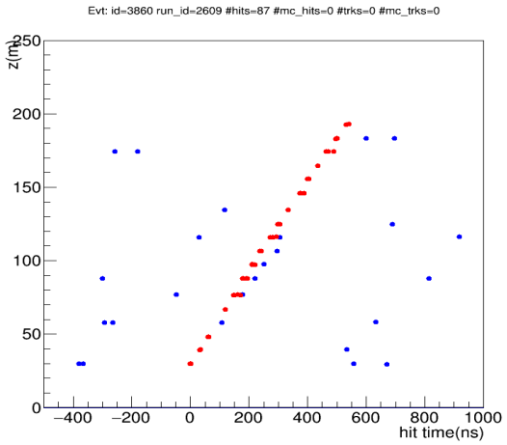
First KM3NeT Detection Units

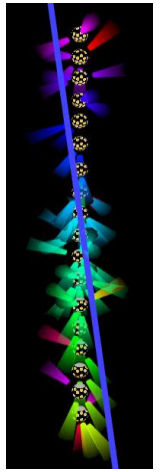
- Two full strings in ARCA site
  - Dec 2015 and May 2016
  - Muon reconstruction
  - Muons vs depth



- One full string in ORCA site
  - Sept 2017
  - Atmospheric neutrinos

- Some seafloor infrastructure teething problems being fixed





Installation of first ORCA DU (22 Sept. 2017)

Operation performed with 2 ships

A deployment ship (Foselev Castor) transports sets of (up to) 4 detection units, in packed configuration, and installs them on the sea floor

Ship controlled with Dynamic Positioning

Accuracy of installation of detection units: within ~1 m from target position

The ROV Apache of COMEX, operated from the Janus

← A ROV (Remotely Operated Vehicle) is controlled from a second ship (Comex Janus) to:

Assist deployment of structures on the sea bed (at proper location and with proper orientation)

Perform submarine connections

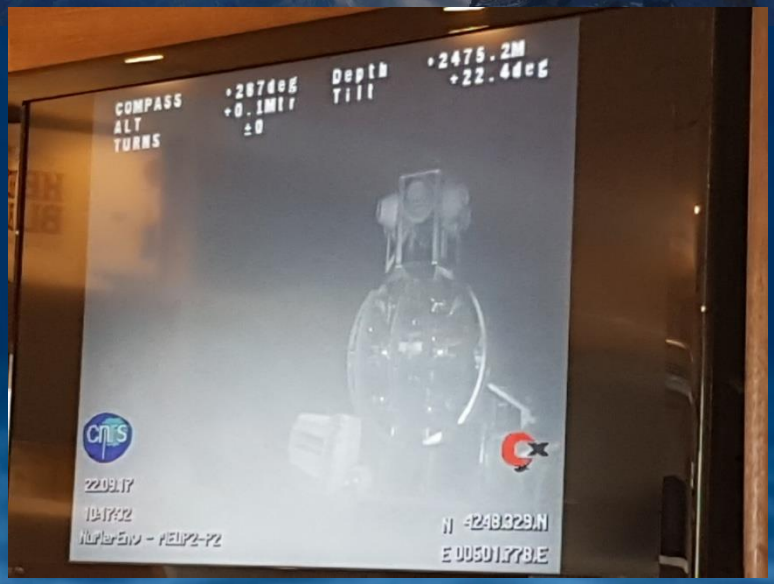
Trigger DU unfurling

Inspect the structure after unfurling

Installation of first ORCA DU (22 Sept. 2017)

The DU is overboarded from the back deck and transferred to the deep-sea winch

The journey to the abyss is started!



The meeting with the ROV is at the sea bed

Installation of first ORCA DU (22 Sept. 2017)

Wet-mateable connectors on the submarine node

Inspection of the DU after unfurling

After connection to the submarine node,
the DU is tested and then unfurled to reach its full size.

The LOM is recovered after unfurling

Bari contribution to the KM3NeT Detection Units

Base module preparation

Base module sealed

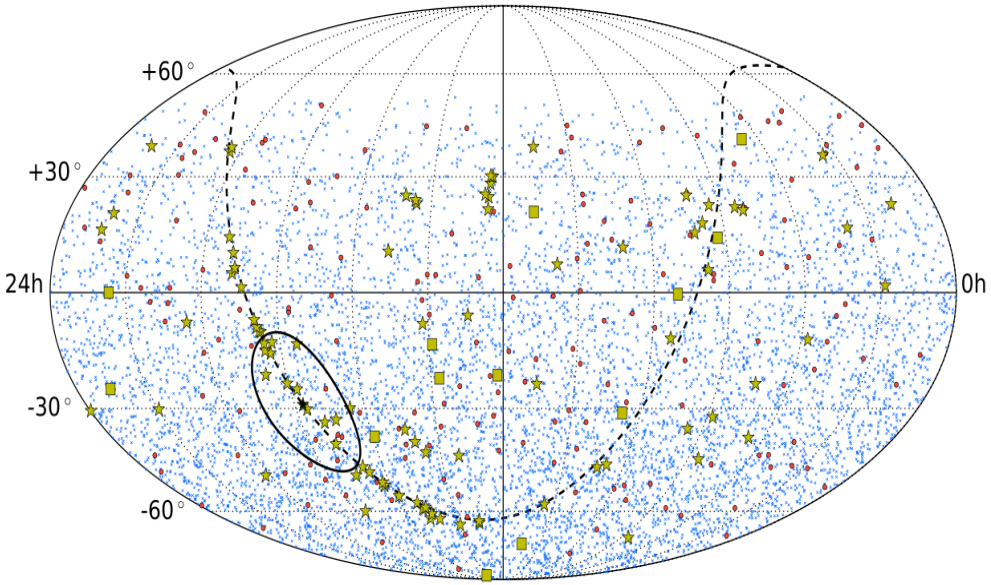
Deployment of ARCA DUs (May 2016)

The team in Bari took care of:

- Design of anchor
- Design and construction of base modules
- Design of hoisting frame
- Design of ROV-operable mechanisms
- Validation of all such solutions
- Coordination of DU integration

ANTARES - Point Sources

- Sample:
  - 2007-2015
  - 2424 days of live time
  - 7629 Tracks, 180 Showers (all flavour analysis)



Track
Showers
Source candidate
HESE track

Phys. Rev. D 96, 082001 (2017)

- *Full-sky Search*
- *Candidate list Search*
  - 106 objects (pulsars, SNRs, etc.)
  - 13 IceCube HESE tracks
- *Galactic Centre Region*
  - Ellipse 15°x 20°
  - Test:

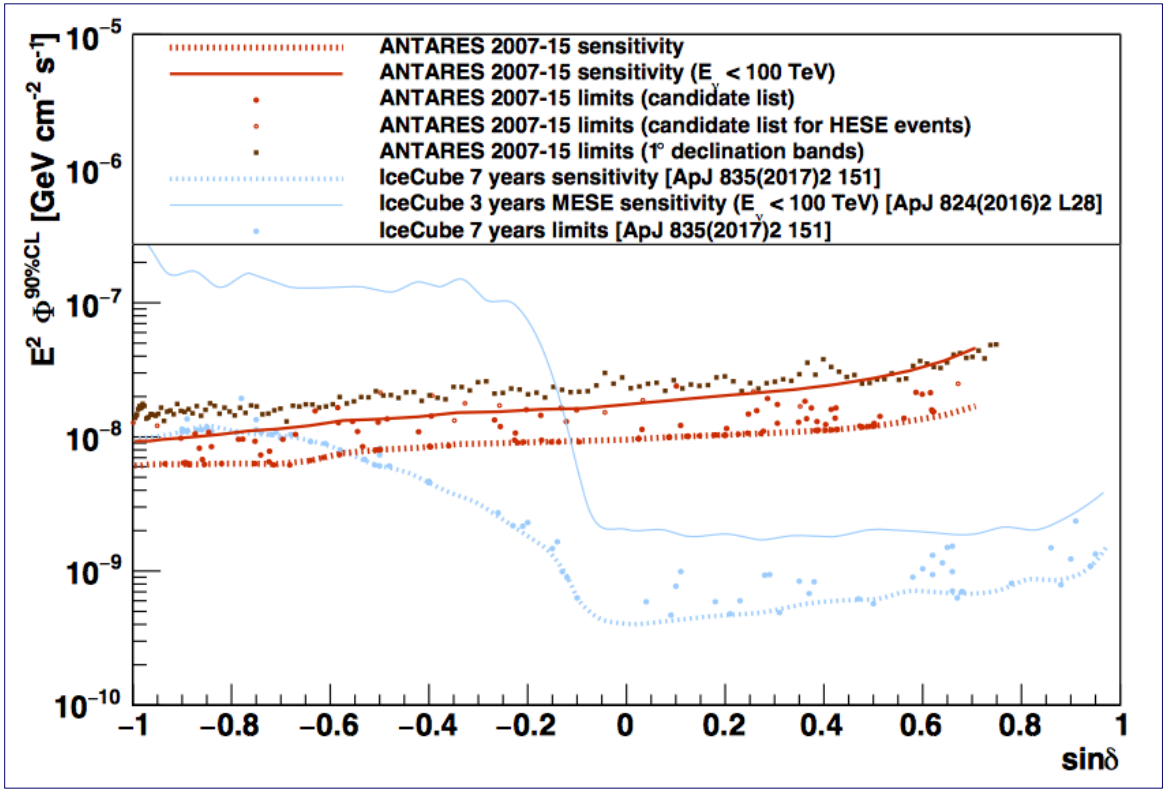
  Spectral indices γ = 2.1, 2.3, 2.5

  Extension σ = 0.5°, 1.0°, 2.0°
- *Sagittarius A* location*
  - Extended source. Gaussian profile of various widths:

  σ = 0°, 0.5°,1.0°, 2.0°

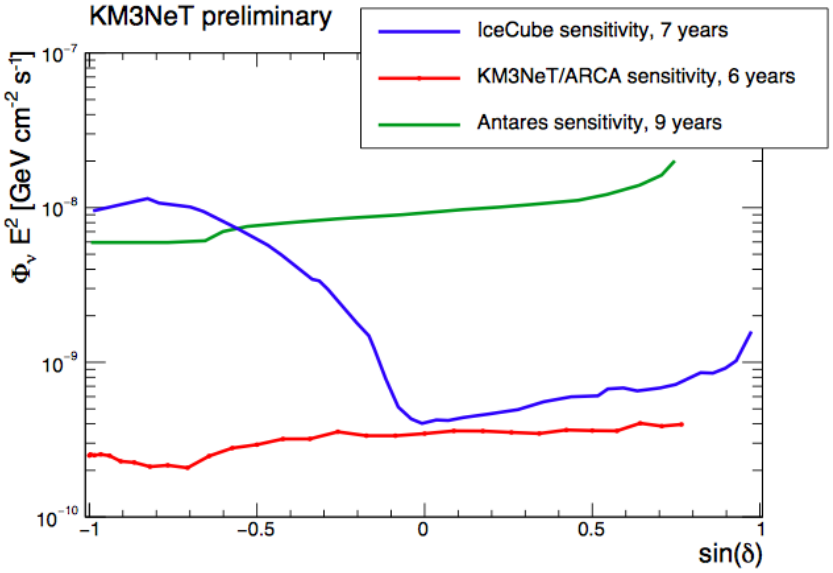
ANTARES Full-sky & candidate list searches

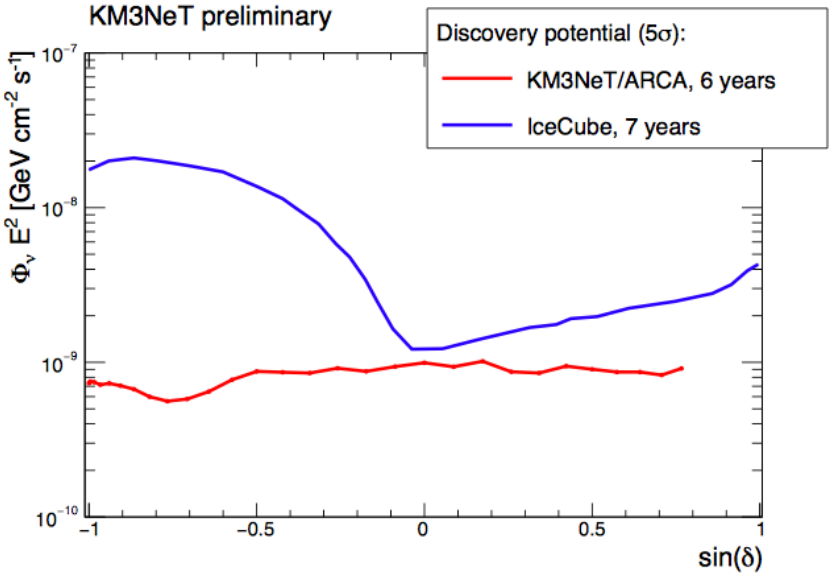
Sensitivities and upper limits at a 90% C.L. on the signal flux from the Full-sky and the Candidate list searches



ANTARES provides the best results for low declination or soft spectra or 100 TeV-ish cutoff

KM3NeT/ARCA Expectations (E^{-2} Spectrum)





KM3NeT/ARCA is expected to have more than one order of magnitude better sensitivity than IceCube in the southern sky.

➞ Due to the good angular resolution for shower events, the shower point-source search is also very efficient.

➞ Expect better performances for transient neutrino sources (GRB, etc.)

KM3NeT in the national & international research strategies

In Europe:

- KM3NeT included in the ESFRI (European Strategy Forum on Research Infrastructures) roadmap 2006 (Design Study and Preparatory Phase supported by EU in the 6th and 7th Framework Programme, resp.)
- KM3NeT Collaboration formally established in 2013
- KM3NeT 2.0 included in the ESFRI roadmap 2016
- Included in the APPEC (AstroParticle Physics European Consortium) roadmap 2017-2026

In Italy:

- Included in the PNIR (Piano Nazionale delle Infrastrutture di Ricerca) 2014-2020
- Included in the list of research infrastructures invited recently to apply for PON funding, among a total of 4 INFN-led projects:
  - DHTCS/IPCEI
  - KM3-NET
  - LNGS
  - LNS

What's a research infrastructure?

"**Research infrastructure** means facilities, resources and related services that are used by the scientific community to conduct top-level research in their respective fields and covers major scientific equipment or sets of instruments; knowledge-based resources such as collections, archives or structures for scientific information; enabling Information and Communications Technology-based infrastructures such as Grid, computing, software and communication, or any other entity of a unique nature essential to achieve excellence in research. Such infrastructures may be "single-sited" or "distributed" (an organised network of resources)"

(ESFRI definition)

Il PIR

- Obiettivo: "(...) finanziamento di progetti finalizzati al potenziamento delle infrastrutture di ricerca individuate dal MIUR come prioritarie nel PNIR 2014-2020 e ammissibili per l'accesso ai fondi del PON…" (inclusi nella strategia ESFRI, con notevole impatto sulla SNSI, che si possano sostenere nel medio e lungo termine, e siano collocati nell'Area del Programma)

Area del Programma:
- Area in Transizione (TR)
- Area Meno Sviluppata (MS)

- Effetti del potenziamento devono avere efficacia per >10 anni dopo completamento del progetto
- Finanziamento è per 100% dei costi ammissibili per un costo di progetto massimo di 20 M€ (minimo: 5 M€)
- Durata del progetto: 32 mesi (eventualmente estensibili, in itinere, a 36)
- Scadenza per le domande: 12:00 (CET) del 15 giugno
- Esito atteso 180 giorni dopo

=> nominalmente l'implementazione sarà da inizio 2019 ad autunno 2021

Il PACK

Potenziamento Appulo-Campano di KM3NeT:

- Compagine: INFN (Bari, Napoli) + Università della Campania (Caserta)
- Coordinatore Scientifico: M. Circella; Responsabile Amministrativo: M. Buonfiglio
- 17.8 M€ totali:
  - ~15 M€ per potenziamento telescopio sottomarino (28 Detection Units)
  - ~2.8 M€ per potenziamento strutture a Bari, Caserta, Napoli

Per Bari (totale investimento: ~850 k€):

- Potenziamento Officina Meccanica
- Potenziamento Laboratorio di Integrazione
- Stazione di Metrologia

Attività previste a Bari:

- Messa in opera delle nuove attrezzature
- Preparazione e supervisione (include: finalizzazione dei disegni, validazione dei prototipi) della produzione di parti delle Detection Units
- Produzione (integrazione e test) dei 28 moduli opto-elettronici di base

OFFICINA MECCANICA

MACCHINA CNC DELLA SEZIONE

Area di lavoro (mm) X= 960 Y= 320 Z= 300
Precisione: da collaudo 20 micron su 300 mm

MACCHINARI PROPOSTI NEL PON

Macchina CNC a tre assi
Area di lavoro X= 1000 Y= 500 Z= 600 mm
Precisione di posizionamento per asse ± 20 micron(NormeVDI3441)

+

MACCHINE PER FINITURA SUPERFICIALE PEZZI MECCANICI

- macchina di sabbiatura
- macchina molatrice

PREVENTIVO SPESA TOTALE 150 k€

LABORATORI: **METROLOGIA+ INTEGRAZIONE**

UBICAZIONE: LOCALE EX ACCELERATORE
ESTENSIONE: 90 m^2 (H= 4 m)
CONFINAMENTO VOLUME 360 m^3: PANNELLI MOBILI AUTOPORTANTI
+ CONTROSOFFITTO PEDONABILE. TUTTO IL MATERIALE CHE SARA' UTILIZZATO E' IDONEO ALL'ALLESTIMENTO DI CAMERE PULITE
PAVIMENTAZIONE IN PVC (STANDARD DI PROTEZIONE ESD)
IMPIANTI:

- CONDIZIONAMENTO TEMPERATURA- UMIDITA'
- RIPRISTINO LINEE DISTRIBUZIONE GAS COMPRESSI
- LINEA VUOTO EX NOVO

PREVENTIVO SPESA TOTALE 185 k€

LABORATORIO METROLOGIA: MACCHINA DI MISURA A CONTROLLO

	HEXAGON	MITUTOYO
Measuring Range (mm)	X= 900 Y=1600 Z= 800	X= 900 Y=1600 Z= 600
Max. Permissible Error (µm)	1.4 + L/333	(1.9 + 0.3L/100)

DOTAZIONE

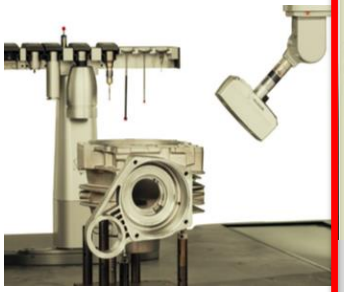
Testa motorizzata indexata ogni 5°

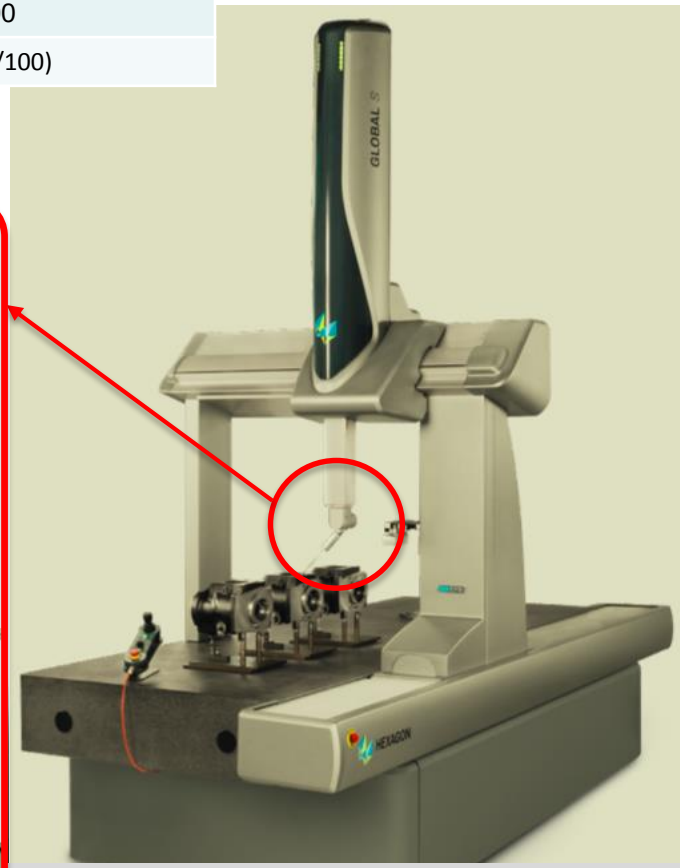
Tastatore per misurazione in continuo e punto a punto. Risoluzione: < 0.1 µm

Cambio utensili automatico

Testa di scansione Laser

- Completamente automatico – Nessun settaggio o parametro
- Maximum Permissible Probing Form Error 22 µm
- Adatto per la misura della maggior parte dei materiali, la verifica di elementi geometrici e di superfici sculturate (confronto con il modello CAD) e operazioni di reverse engineering.

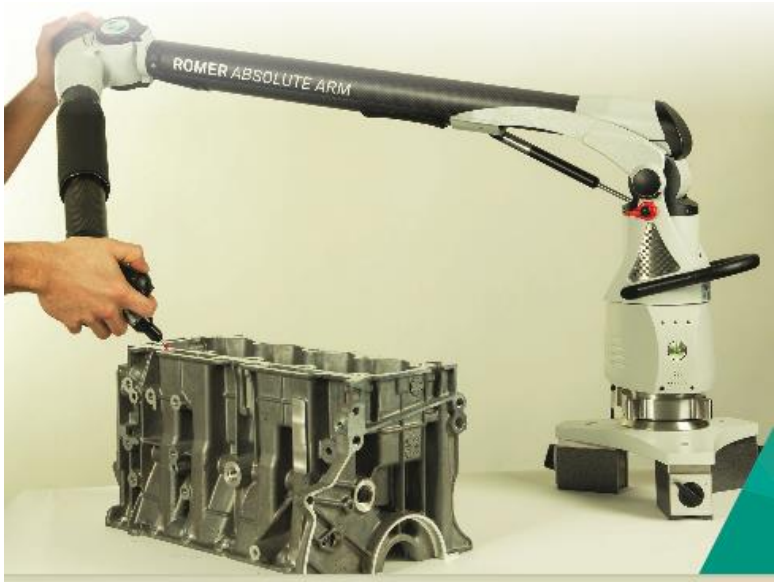




PREVENTIVO SPESA 189 k€

LABORATORIO METROLOGIA: BRACCIO DI MISURA “PORTATILE”

- Può essere collocato ovunque, anche all'interno di un centro di lavorazione meccanica o laboratori
- permette la digitalizzazione delle misure ed è interfacciabile con una macchina a coordinate
- in grado di effettuare misure in un volume di 2.5 m^3 con una precisione di rilevamento di 38 micron
- ripetibilità sul punto: 27 micron
- può essere montato anche lo scanner della macchina di misura a controllo proposta

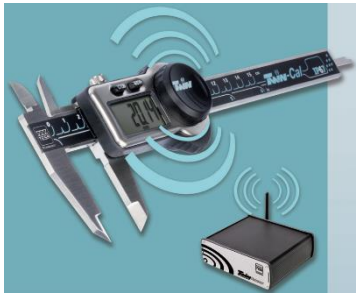


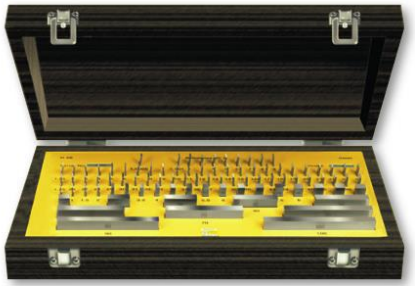
PREVENTIVO SPESA TOTALE 56 k€

LABORATORIO METROLOGIA: STRUMENTI DI MISURA DIGITALI CONVENZIONALI

N° 31 ARTICOLI

- CALIBRI DI DIVERSE DIMENSIONI E APPLICAZIONI
- MICROMETRI PER INTERNI ED AUTOCENTRAGGIO E AUTO ALLINEAMENTO
- ALESAMETRI
- SET DI MICROMASTER ELETTRONICI A INDICAZIONE NUMERICA
- COMPARATORI
- PIANO DI RISCONTRO
- SERIE DI BLOCCHETTI DI RISCONTRO
- TRUSCHINO
- DUROMETRO RUGOSIMETRO
- ….
- RUGOSIMETRO





PREVENTIVO SPESA TOTALE 48 k€

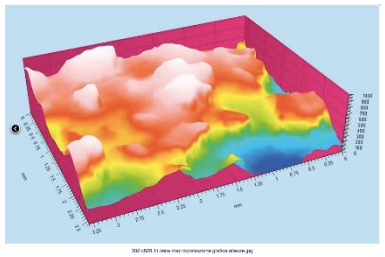
LABORATORIO METROLOGIA: MICROSCOPIO E TELECAMERA

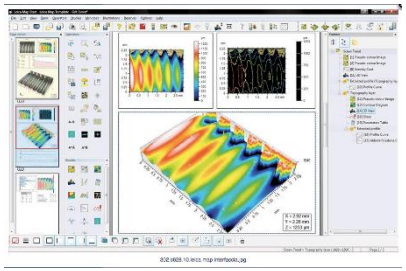
- Microscopio Leica DM2500 MH RL
- Revolver portaobiettivi a 6 posizioni
- Obiettivi 2.5x-----100x

- Tavolino motorizzato xy
- Precisione +/- 2 micron
- Corsa (cm) 15.24 x 10.16

- Colonna messa a fuoco motorizzata
- Precisione +/- 1 micron
- corsa (cm) 42

- Software ricostruzione e misura 3D
- Workstation





- Postazione di lavoro

PREVENTIVO SPESA TOTALE 42 k€

LABORATORI0 METROLOGIA: TERMOCAMERA

TERMOCAMERA IN DOTAZIONE (GR.III):
FLYR Risoluzione 320x240 ≈ 10 ANNI

TERMOCAMERA PROPOSTA NEL PON

- Messa a fuoco automatica LaserSharp®
- Risoluzione del sensore 1280 x 960
- Precisione ± 2 °C
- Obiettivo grandangolare a infrarossi
- Teleobiettivo a infrarossi
- Range di misura della temperatura da ≤ -10 °C a 1000 °C

PREVENTIVO SPESA TOTALE 20 k€

Sostenibilità: il team

Il team KM3 a Bari comprende:

M. Circella

- Technical Project Manager di KM3NeT 2013-2016 (e, ad interim, 2018)

I. Sgura (ex art. 23 TD, in fase di stabilizzazione)

- Membro dello Steering Committee di KM3NeT - coordinatrice della costruzione delle Detection Units

A. Sánchez Losa (assegnista di ricerca)

- Coordinatore del gruppo di studio di segnali di neutrini correlati ad eventi transienti in ANTARES
- Run coordinator in KM3NeT

con la partecipazione sostanziale del Servizio di Progettazione Meccanica (M. Mongelli)

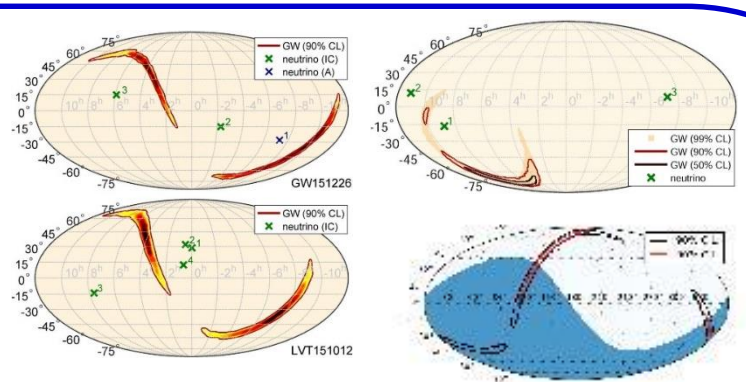
Cosa occorre:

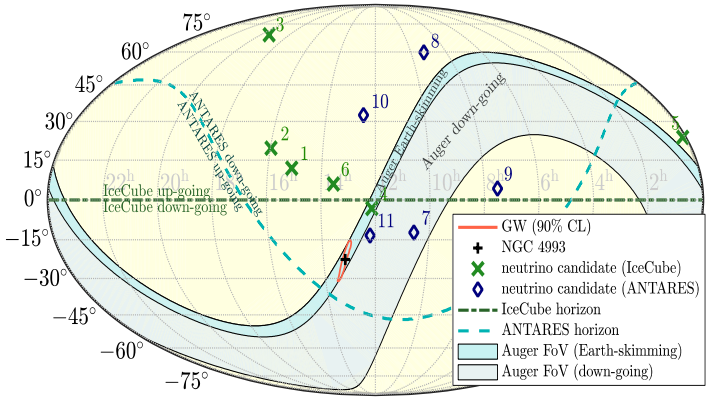
- Cosimo Pastore è responsabile scientifico dell'obiettivo realizzativo "Laboratorio di prototipazione, integrazione e accettazione di strumentazione sottomarina"
- Richieste ai servizi di Sezione da quantificare
- 1 tecnico meccanico (montatore-disegnatore)
- 1 nuovo assegnista di ricerca

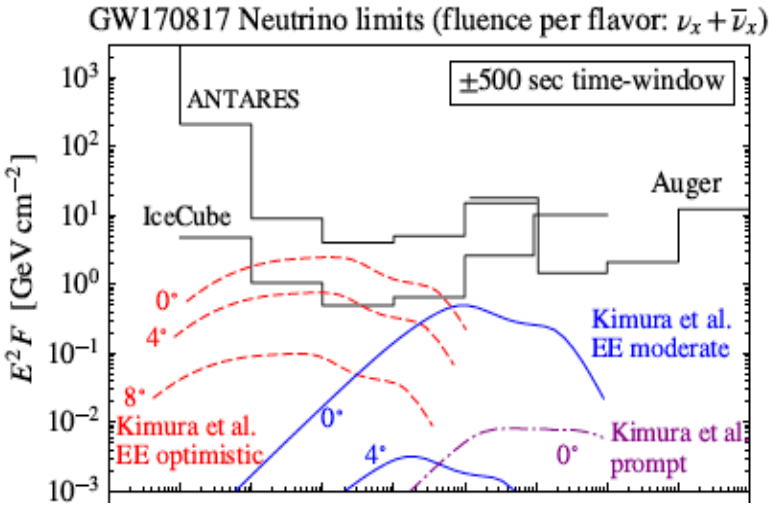
Gravitational Waves

- Search ν in coincidence with:
  - BBH's: GW150914, LVT151012, GW151226, GW170104
  - BNS: GW170817
- Search features:
  - Most recent reconstruction (offline search advantage).
  - ± 500 s around GW time
  - Individual optimization (3σ detection if event within 90% GW contour)
  - Combined IceCube-Antares analyse
- No coincident events found
  - GW151226 (1 event)
  - GW170817 (5 events/downgoing)
  - Upper limit on fluences:

  $E_{iso} < 10^{51} – 10^{54}$ erg







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