KM3NeT-ARCA

Astroparticle **R**esearch with **C**osmics in the **A**byss

XVII International Workshop on Neutrino Telescopes

13-17 March 2017, Venice

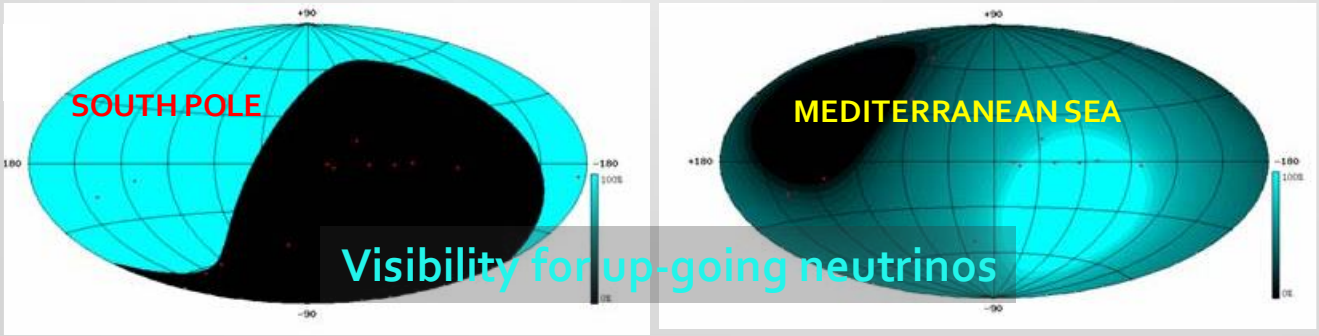
Mauro Taiuti on behalf of the **KM3NeT** Collaboration

Outline

- Introduction
- The Collaboration and the Project
- Expected performances
- Conclusions

Motivations & Objectives

- The **IceCube** discovery of HE cosmic neutrinos enforces the physics case of a km^3 neutrino telescope in the Mediterranean sea that surveys a large fraction of the sky including most of the galactic plane and the Galactic Centre
- Galactic versus extra-galactic contribution in **IceCube** data
  - quasi isotropic dominant component at high energy (E>100TeV) suggest extragalactic origin
  - some hints for a galactic contribution at lower energy, but can be probed only marginally with **IceCube** and **Antares**
- A much better angular resolution is achieved in deep sea w.r.t to ice

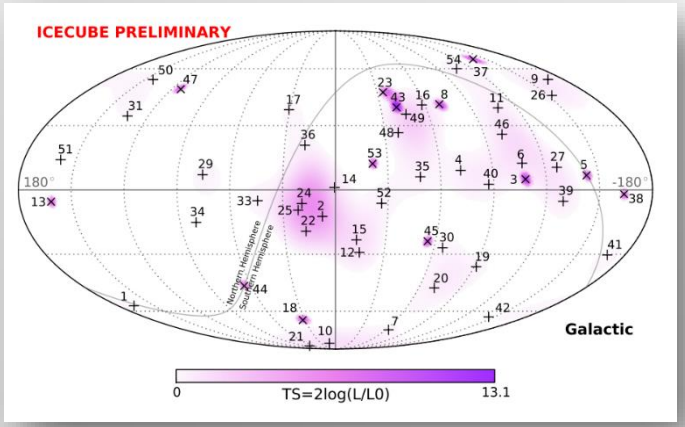


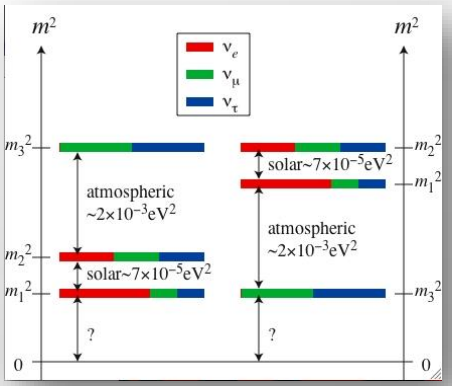
Physics Case

- **KM3NeT** is the neutrino research infrastructure in the deep Mediterranean Sea
  - discover and observe high neutrino sources in the Universe

    ARCA (off shore Capo Passero, It @ 3500 m depth) – this talk
  - determine neutrino mass hierarchy

    ORCA (off shore Toulon, Fr @2500 m depth) – J. Brunner talk





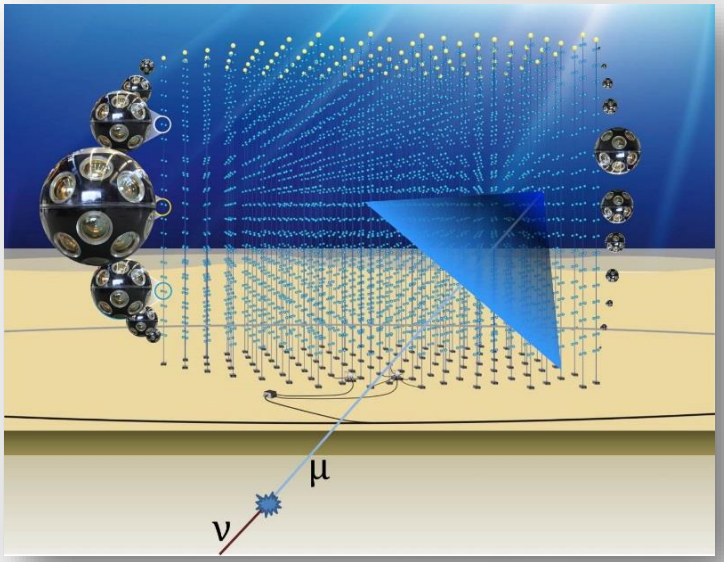
- Same collaboration, same technology, two installation sites
- Since 2016 **KM3NeT** is back in the ESFRI road map
- LoI: *J. Phys. G*, **43** (2016) 084001

KM3NeT Collaboration

- 12 Countries
- >40 Institutes
- >220 Scientists

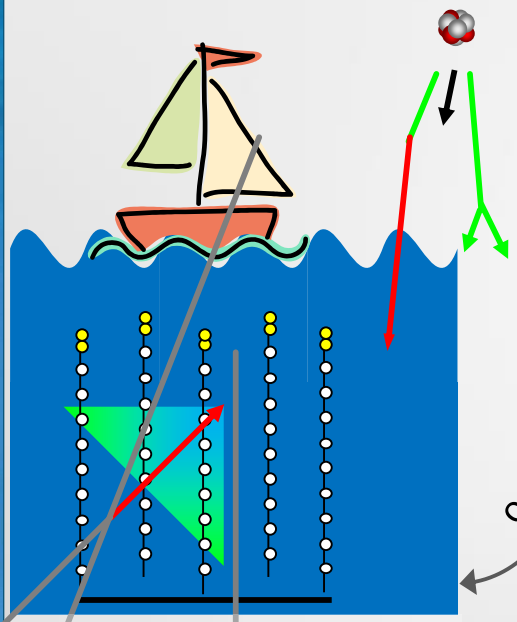
KM3NeT Telescope Design

- Detection principle Optical Cherenkov radiation
  - 6 order of magnitude in energy (GeV-PeV)
  - All flavour detection
- A 3D array built with a modular design
- Optical sensor: multi-PMT (DOM)
- Detection units (DU)
  - vertical slender strings host 18 DOMs
- Building blocks of 115 DUs each
- Power and data distributed by a single backbone cable with breakouts at DOMs
- Sea network of submarine cables and Junction Boxes connected to shore via a main e/o cable
- All data to shore



	ARCA	ORCA
Location	Italy	France
DU distance	90 m	20 m
DOM spacing	36 m	9 m
Instrumented mass	2*500 Mton	5.7 Mton

KM3NeT Architecture

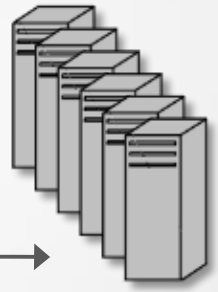


neutrino telescope

0.1–1 Tb/s

shore station

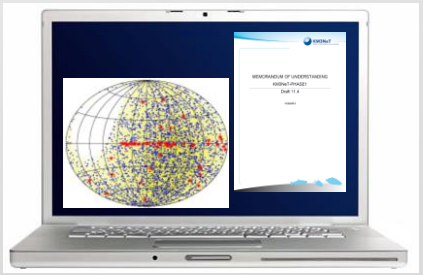
10–100 Mb/s



computer center

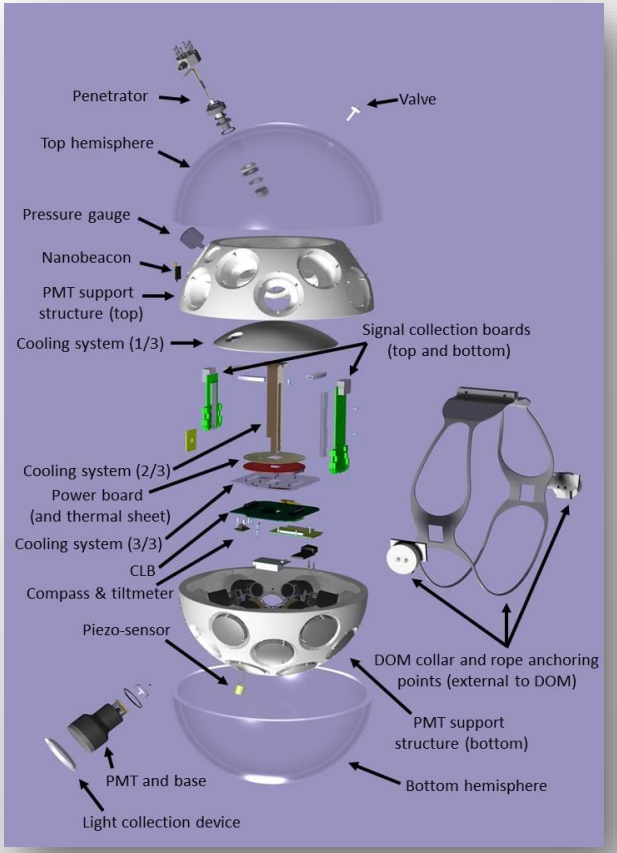
remote operation

remote access to data



DOM - Digital Optical Module

- 31 x 3" PMTs
- LED & acoustic piezo inside
- Tiltmeter/compass
- Gbit/s fibre DWDM
- Hybrid white rabbit



- Digital photon counting
- Directional information
- Wide angle of view
- Improved background rejection
- Compact and cost effective design: 1 DOM equivalent to 3 Antares OMs

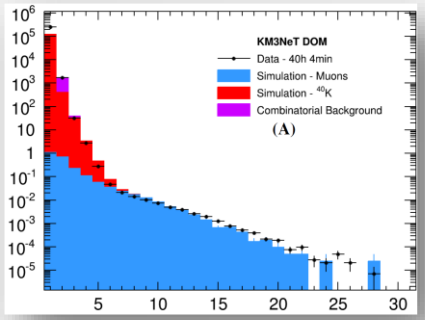
ARCA Detection Unit

- 18 DOM integrated on vertical slender strings supported by two parallel Dynema ropes

- Strings arranged on the LOM, mounted on the anchor and ready for deployment

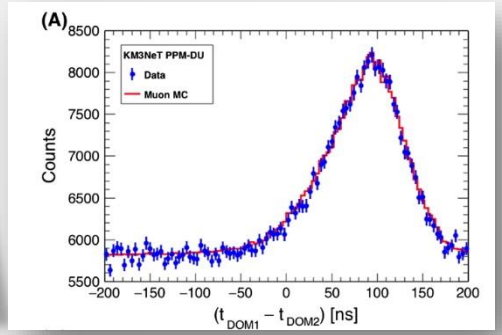
From Validation to Construction

Prototype DOM deployed at Antares site April 2013



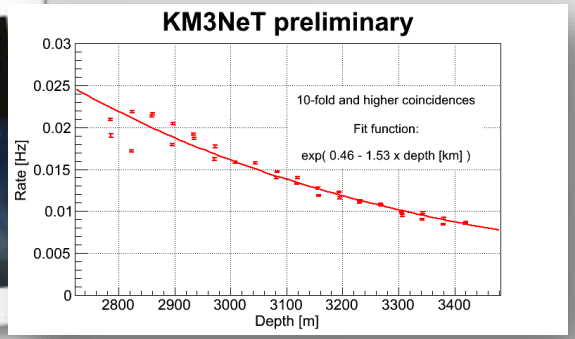
Test of photon counting capabilities and directional sensitivity of DOM
Eur. Phys. J. C (2014) 74:3056

Prototype DU (three DOMs) deployed in Capo Passero May 2014

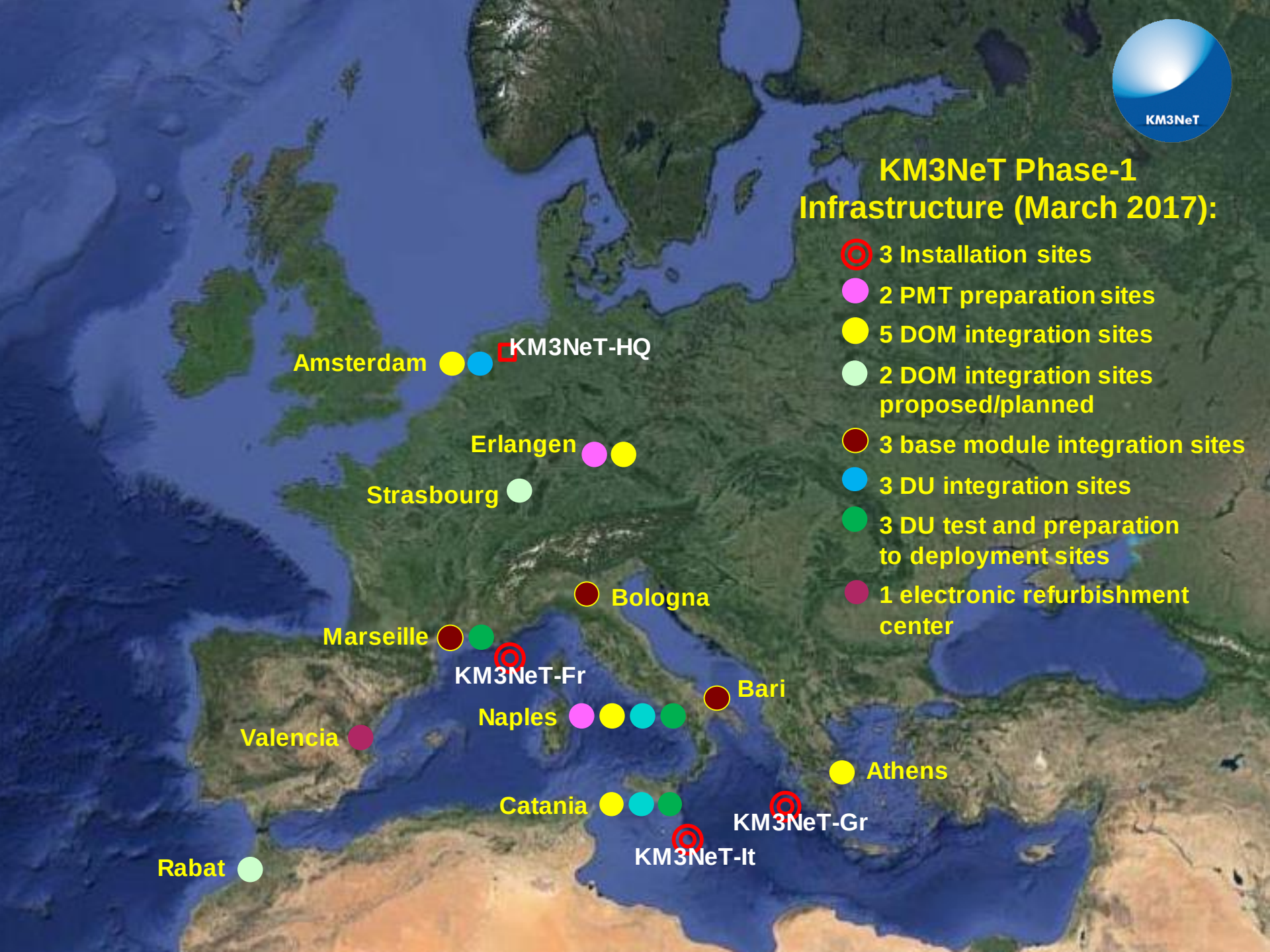


Test of DU structure functionality
Test of intra-DOM and inter-DOM calibration - *Eur. Phys. J. C (2016) 76:54*

First ARCA DU deployed in Capo Passero December 2015



Muon flux dependence on depth
DU calibration
Trigger implementation
Track reconstruction e MC comparison
...
work in progress

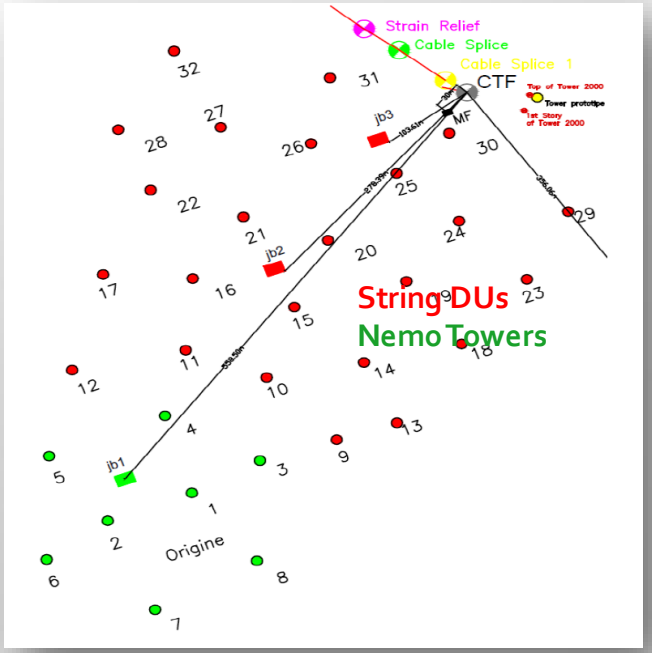

KM3NeT
KM3NeT Phase-1 Infrastructure (March 2017):
3 Installation sites
2 PMT preparation sites
5 DOM integration sites
2 DOM integration sites proposed/planned
3 base module integration sites
3 DU integration sites
3 DU test and preparation to deployment sites
1 electronic refurbishment center
Amsterdam
KM3NeT-HQ
Erlangen
Strasbourg
Bologna
Marseille
KM3NeT-Fr
Bari
Naples
Valencia
Athens
Catania
KM3NeT-Gr
KM3NeT-It
Rabat

A Phased Approach

PHASE	BLOCKS	PRIMARY DELIVERABLES	FUNDS
1	0.2	Proof of feasibility and first science results 24 ARCA strings	Fully funded
2	2	Study of neutrino signal reported by IceCube All flavor neutrino astronomy 2x115 ARCA strings	1 block almost funded
3	6	Neutrino astronomy including Galactic sources	Not yet

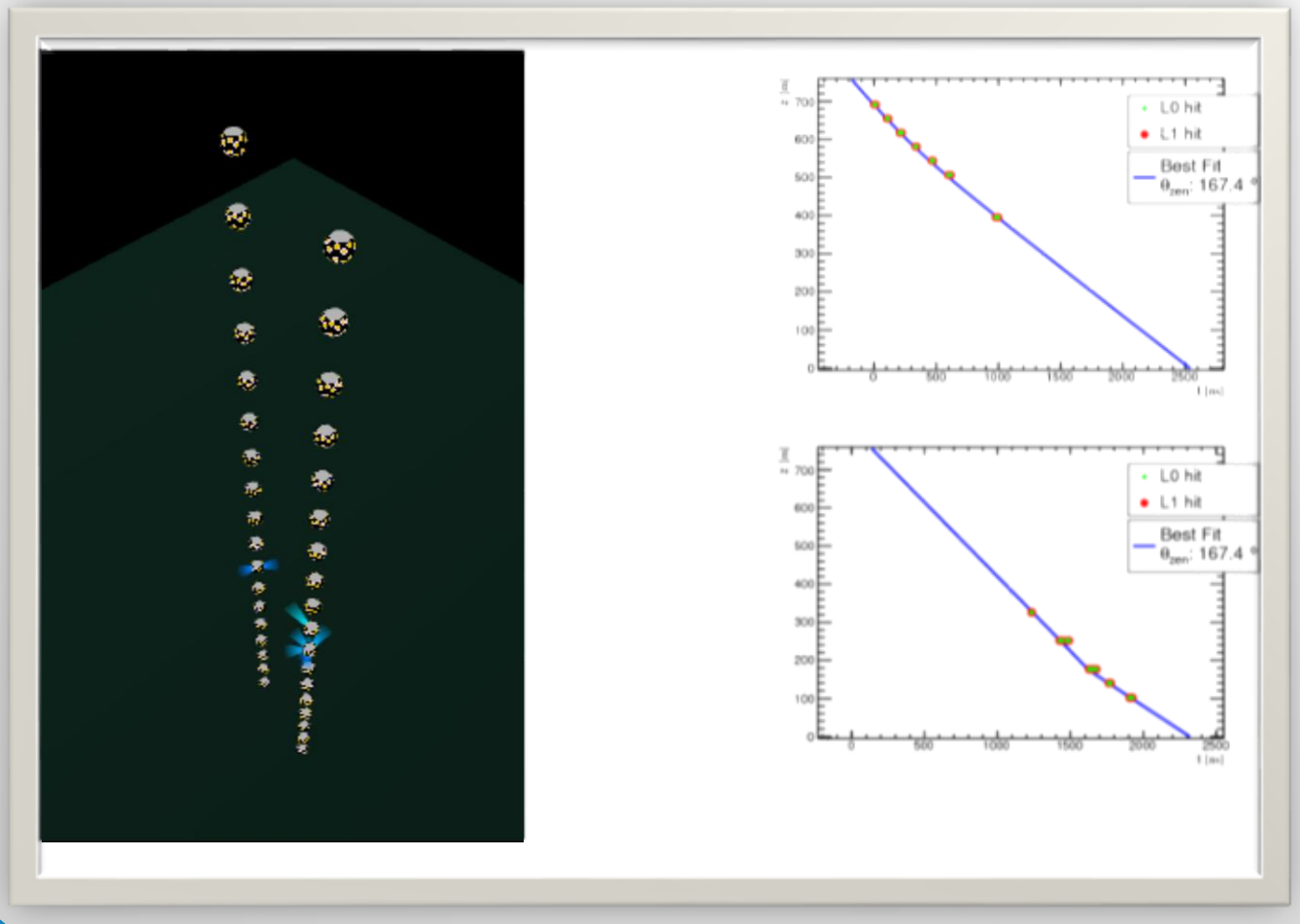
ARCA Phase-1

- Proof of feasibility of network of neutrino detectors:
- **KM3NeT** funded with 31 M€
- 24 detection units will be deployed at **KM3NeT-It** off shore Capo Passero
- Three DUs deployed at Capo Passero site
  - one not working => recovered at the end of July for inspection
- **ARCA Phase-1** will be the largest neutrino telescope in the Northern hemisphere
  - 0.1 km3, i.e. 10 x Antares!



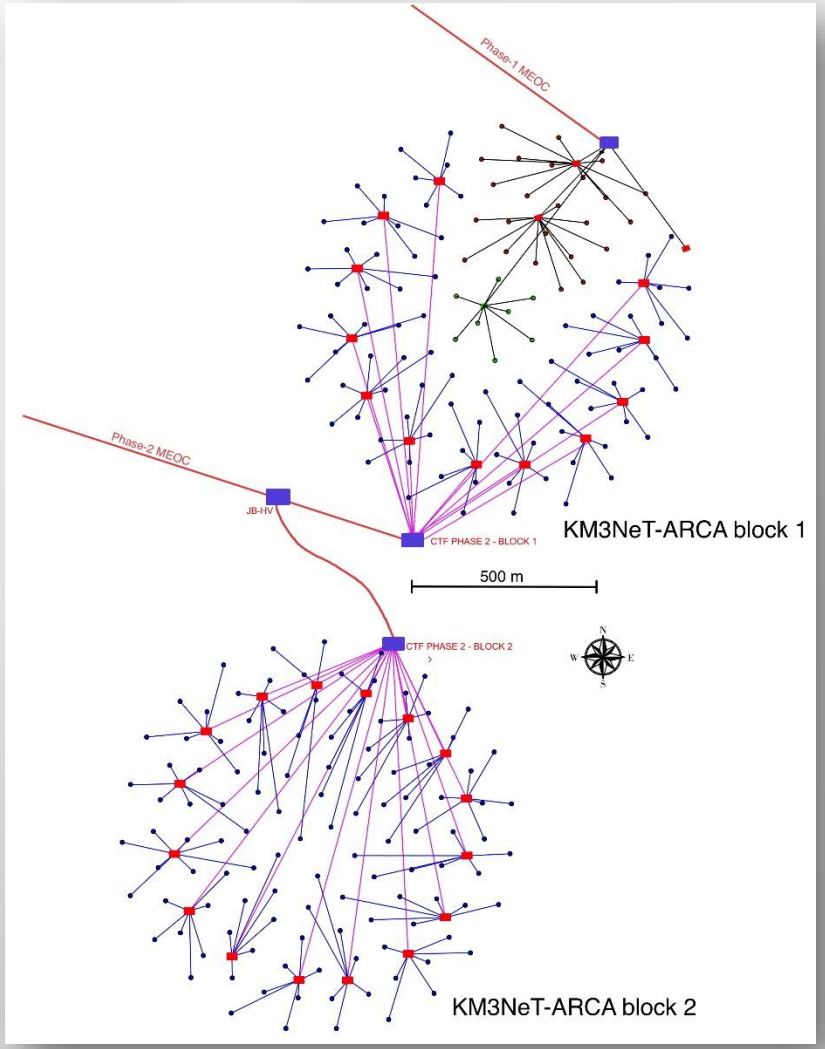
ARCA Track Reconstruction

- Two **ARCA** DUs in data taking since May 2016



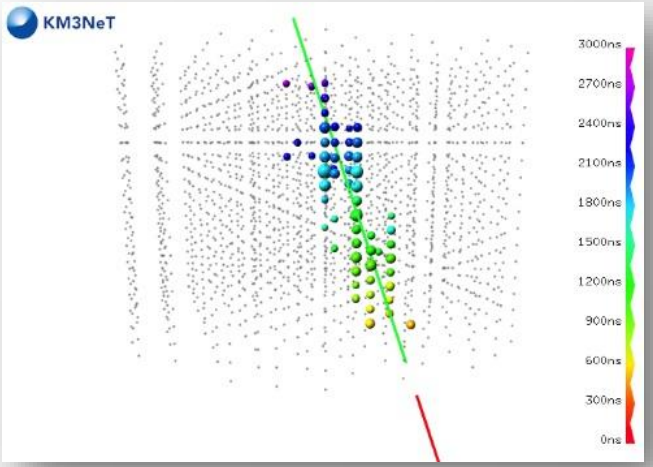
ARCA Short Term Activities

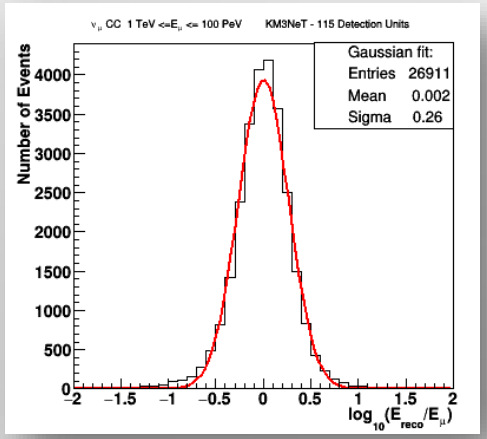
- When completed **ARCA** will consists of two blocks with 115 DUs each
- Presently **ARCA Phase-1** includes Phase-1 MEOC and 24 DUs of block 1
  - Integration is in progress and deployment foreseen next year
- In the short term **ARCA Phase-2** foresees Phase-2 MEOC and the completion of block 1 (115 Dus)
  - Procurement starting this year
  - Time profile 3-4 years



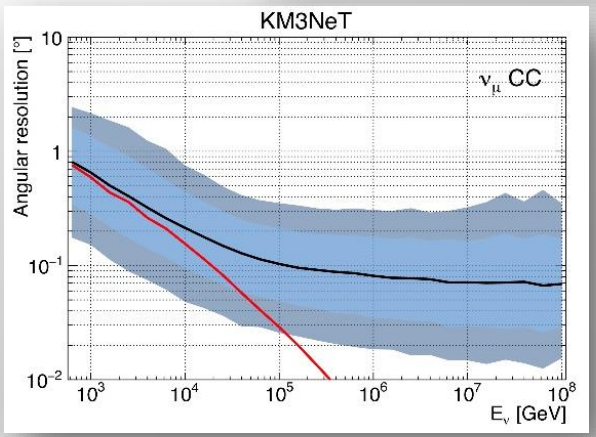
ARCA Event Topologies and Detector Response

- ν_μ are the golden channel for neutrino astronomy
- Deep sea water properties, i.e. long scattering length allow to achieve very good angular resolution





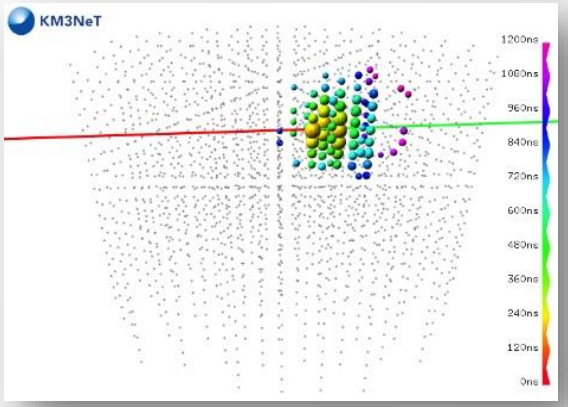
Energy resolution about 0.3 in $\log E_\mu$

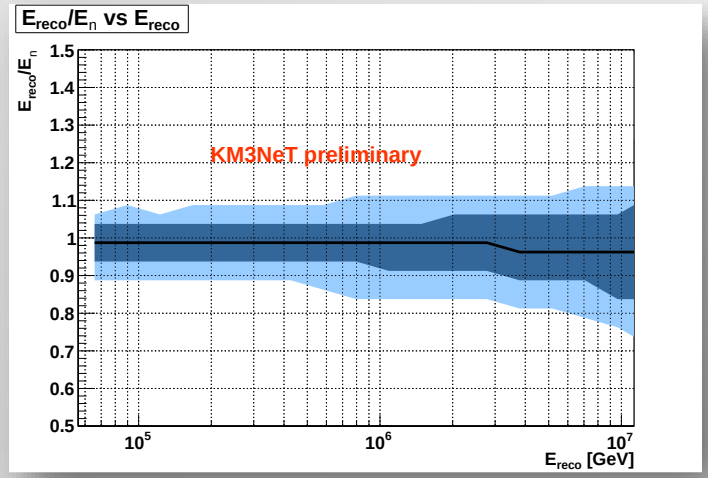


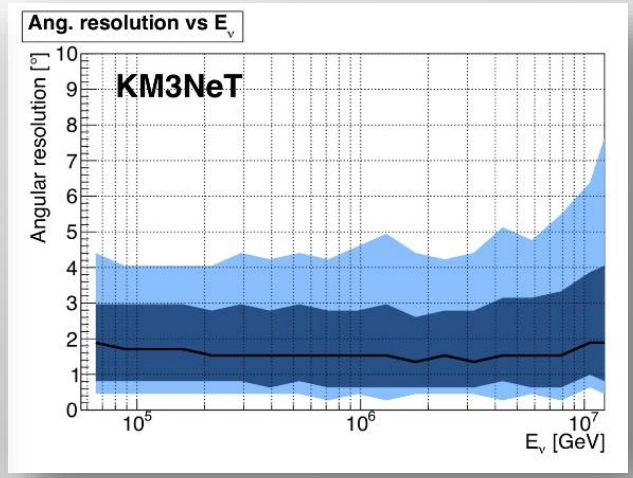
Angular resolution about 0.1° (E_ν>10 TeV)

ARCA Event Topologies and Detector Response

- Contained shower ν_e







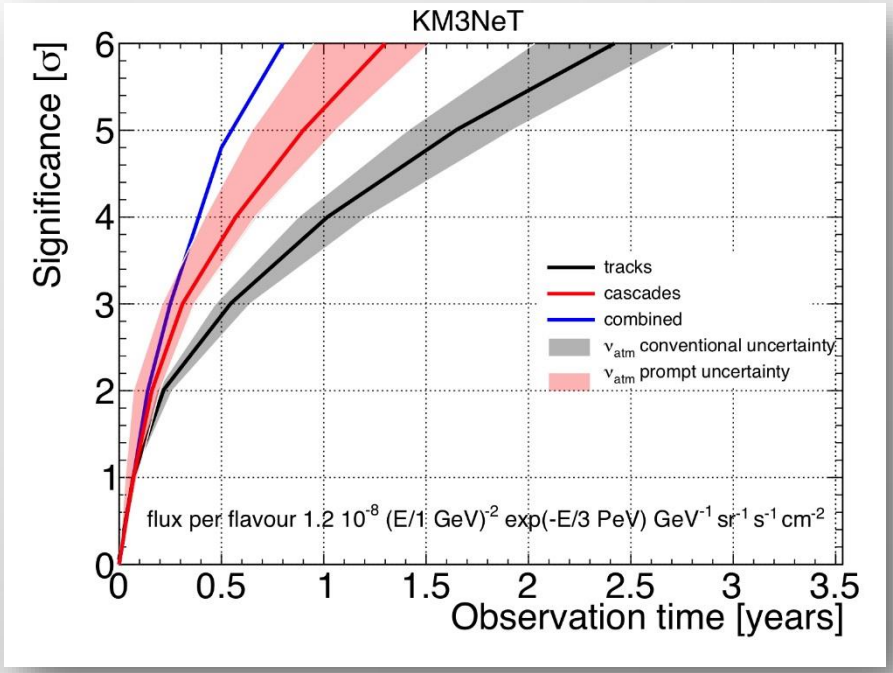
Energy resolution about 10%

Angular resolution about 2° (E_ν>10 TeV)

ARCA Sensitivity to Diffuse Neutrino Flux

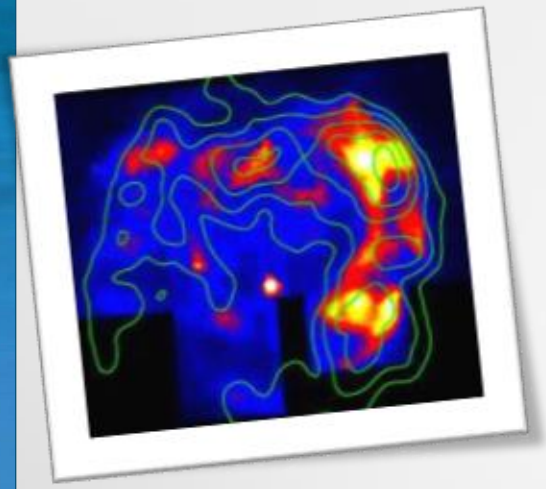
EVENT ANALYSIS

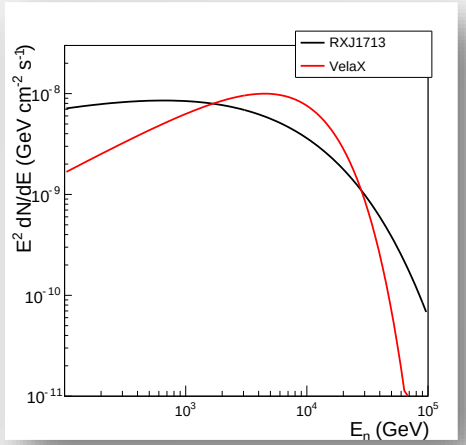
- **Track channel:** analysis for up-going events based on Max. likelihood
  - Pre-Cuts on θ_{zen} >80°, Λ (reconstruction quality parameter), N_{hit} (number of hits -> parameter related to the muon energy)
- **Cascade channel**: contained events
  - **Vertex cut**: cut on position of reconstructed vertex (z<200m AND r<500m)
  - **Energy cut**: cut on the total ToT of the event (ToT>12 μs)

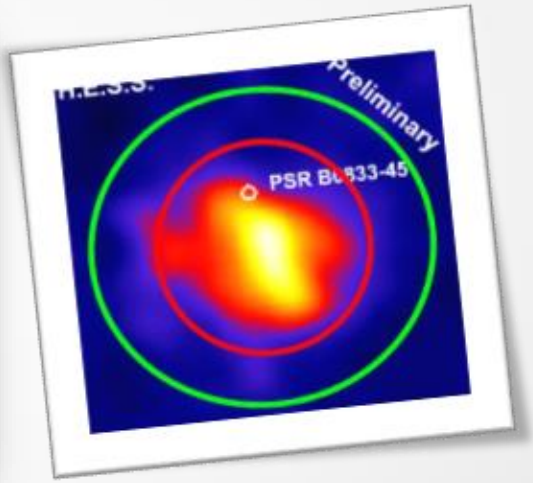


Discovery at 5σ significance in less than one year

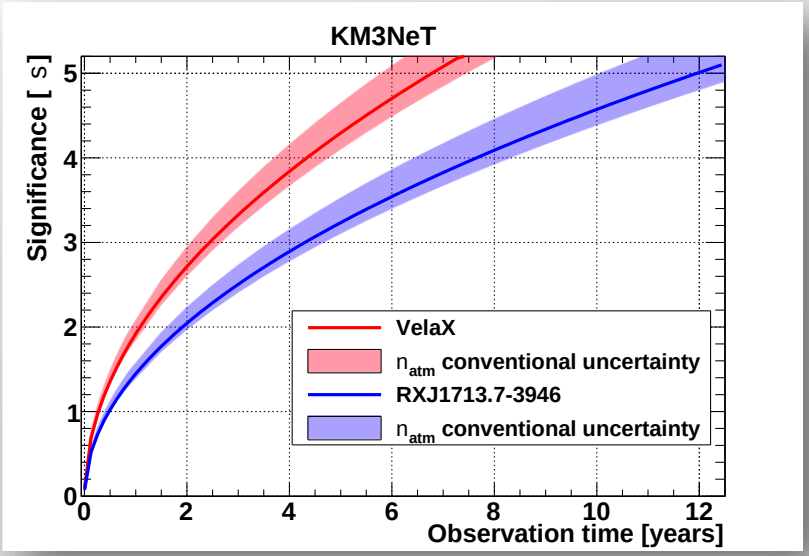
Sensitivity to Point-like Galactic Sources







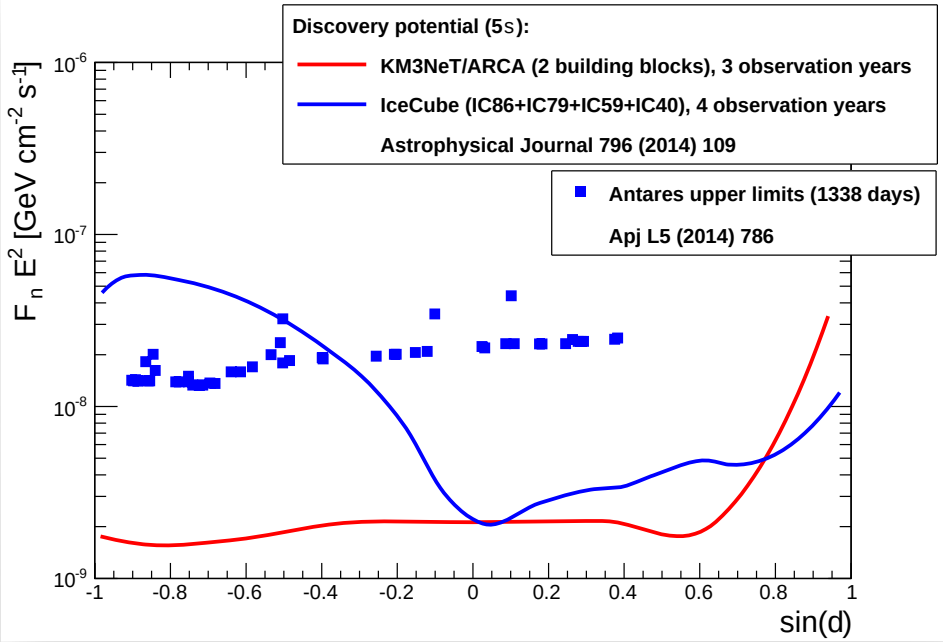
- HE gamma emission observed by HESS in SNRs
- Neutrino spectra predicted using gamma spectra
  - ¶ S.R. Kelner, *et al.*, PRD 74 (2006) 034018
  - § F.L. Villante and F. Vissani, PRD 78 (2008) 103007
- Hypotheses: 100% hadronic emission and transparent source



Sensitivity to Point-like Sources E^{-2} up-going ν_μ

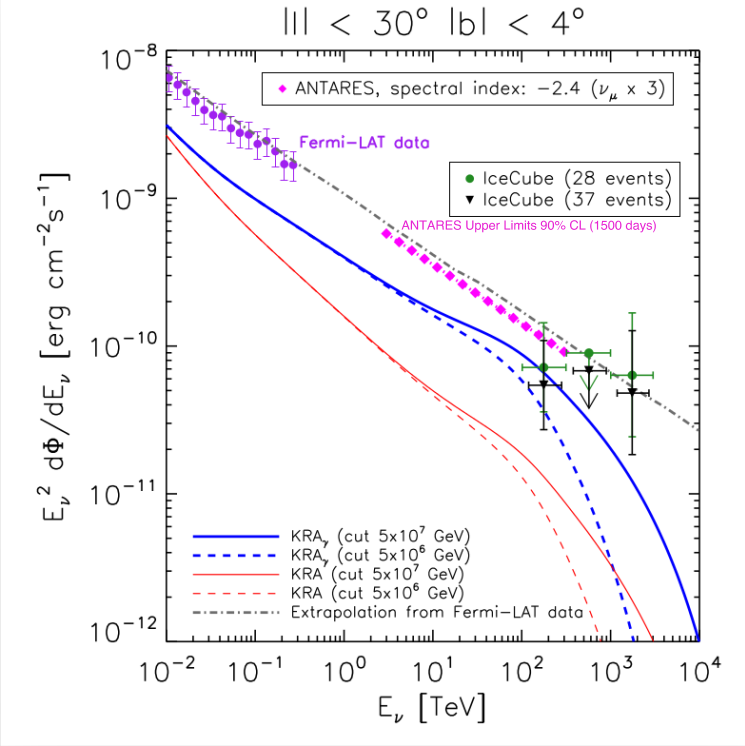
- **ARCA** can survey almost the whole sky with a discovery potential @ 5σ about one order of magnitude better than **IceCube** for equivalent exposure

(**ANTARES** upper limit for 1338 day also reported)

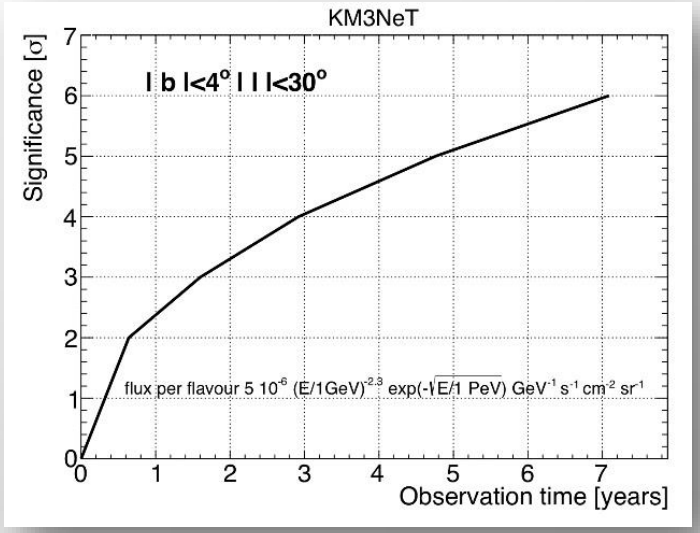


Diffuse Flux from the Galactic Plane

- **ARCA** sensitivity to a flux from a region of the Galactic Plane near the Galactic Center Neutrino flux estimate based on a radially-dependent cosmic-ray transport properties



D. Gaggero et al., proceedings ICRC2015



Discovery at 5σ significance in about 5 years

Conclusions

- **Phase-1**
  - Technology is being validated
  - Two **ARCA** strings in operation since 1 year
  - Good quality data - Analysis in progress
- **Phase-2**
  - Money are becoming available
  - Procurement already started
  - Construction will start in a year from now
- **KM3NeT-ARCA** is going to become a key infrastructure for neutrino astronomy in the next decade

Thank you!