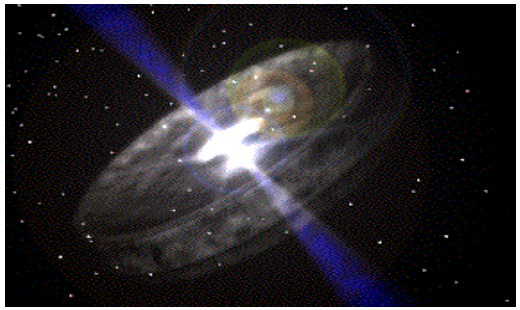
Status and prospect of KM3NeT

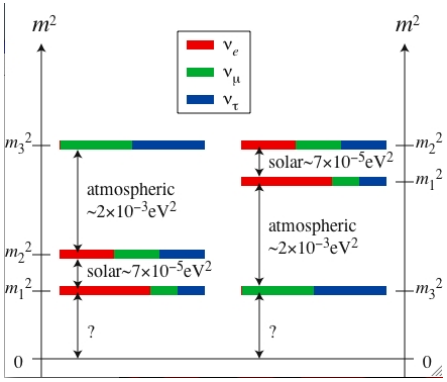
Piera Sapienza Laboratori Nazionali del Sud – INFN, Fermi Collaboration Meeting - Pisa 15th March 2018

KM3NeT Physics case

KM3NeT is a network of neutrino telescopes in the deep Mediterranean Sea

- observe high energy cosmic neutrinos and discover their sources with KM3NeT/ARCA @ 3500 m depth off shore Capo Passero, Italy
- determine neutrino mass hierarchy with KM3NeT/ORCA @2500 m depth off shore Toulon, France





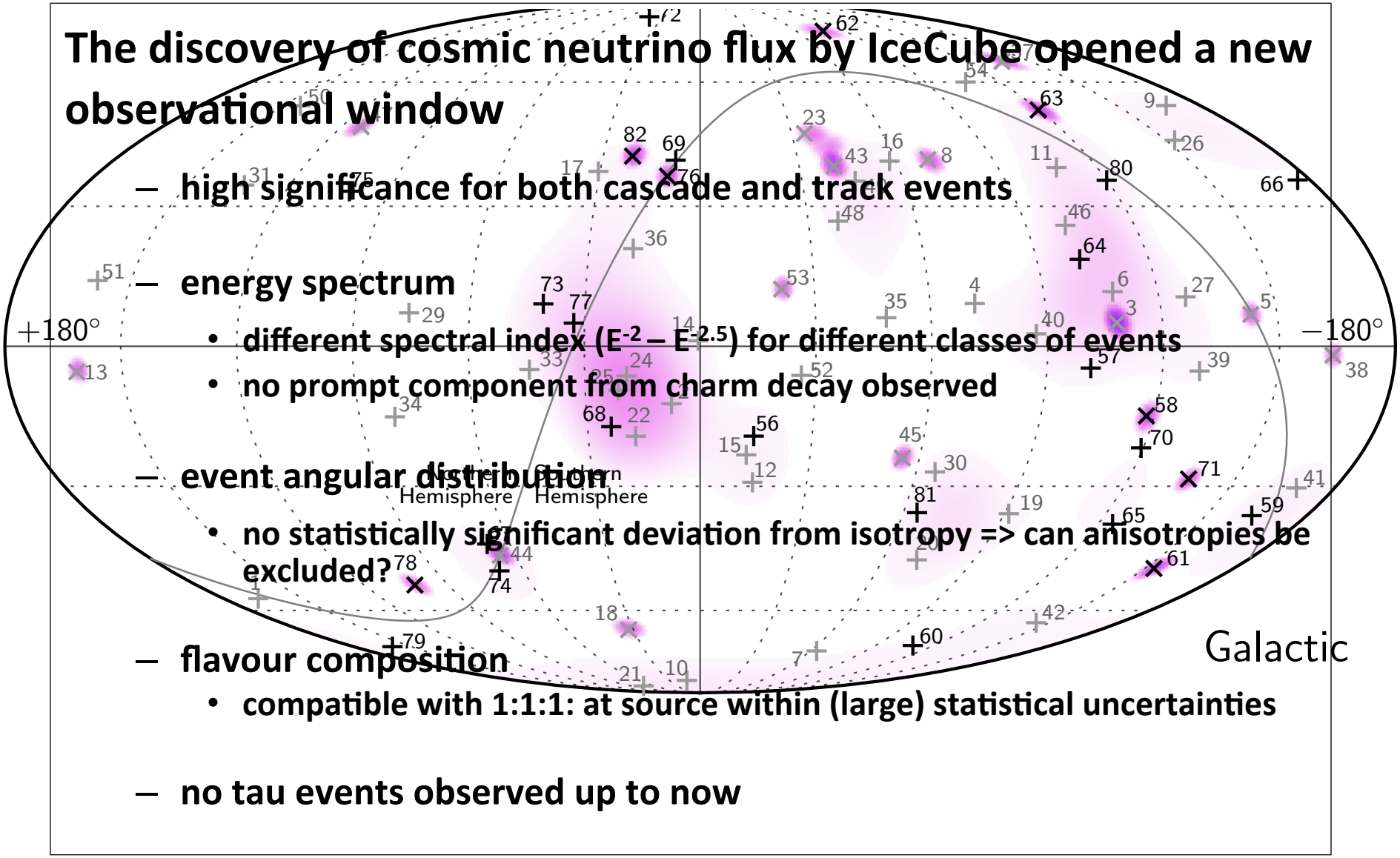
Same collaboration, same technology, two installation sites
LoI

This talk is devoted to ARCA and its perspectives in high energy neutrino astronomy

STATE OF ART OF HE NEUTRINO ASTRONOMY
ICECUBE RESULTS

The discovery of cosmic neutrino flux by IceCube opened a new observational window

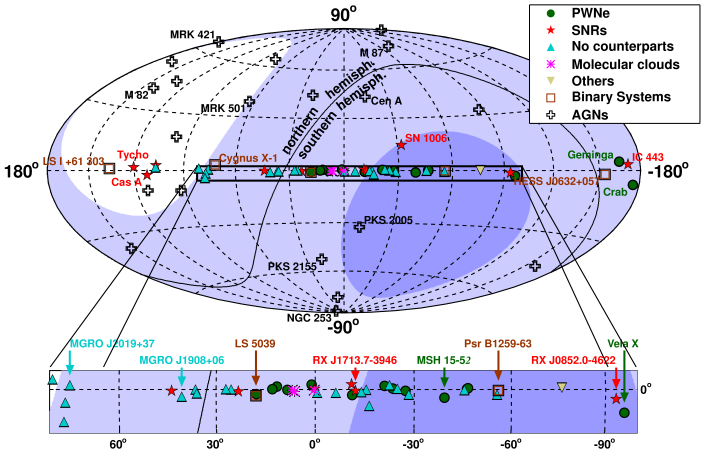
- **high significance for both cascade and track events**
- **energy spectrum**
  - **different spectral index ($E^{-2} - E^{-2.5}$) for different classes of events**
  - **no prompt component from charm decay observed**
- **event angular distribution**
  - **no statistically significant deviation from isotropy => can anisotropies be excluded?**
- **flavour composition**
  - **compatible with 1:1:1: at source within (large) statistical uncertainties**
- **no tau events observed up to now**



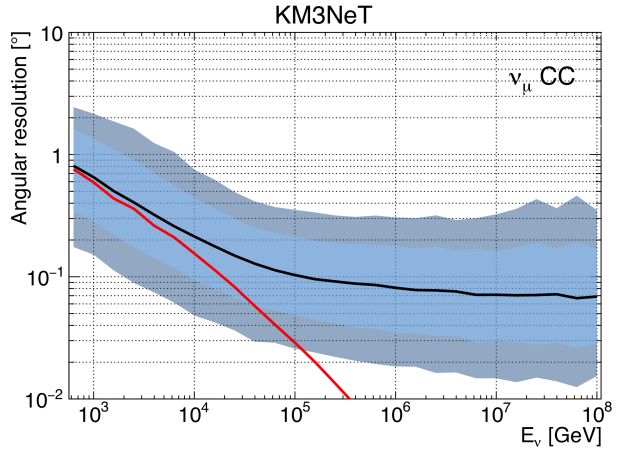
KM3NeT/ARCA

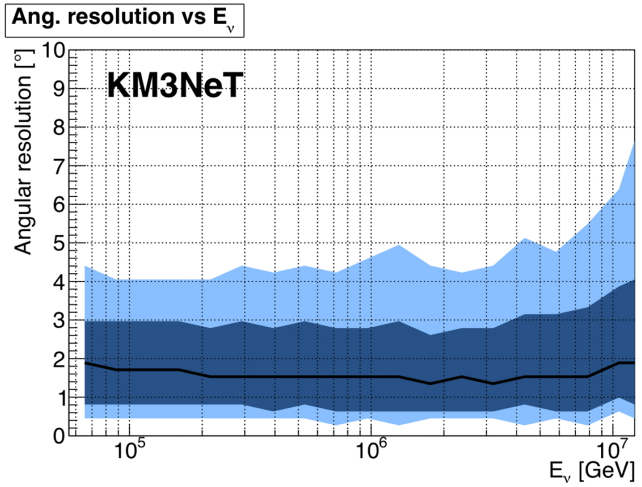
Very large field of view for up going μ

- 87% sky coverage including most of Galactic Plane and Galactic Centre

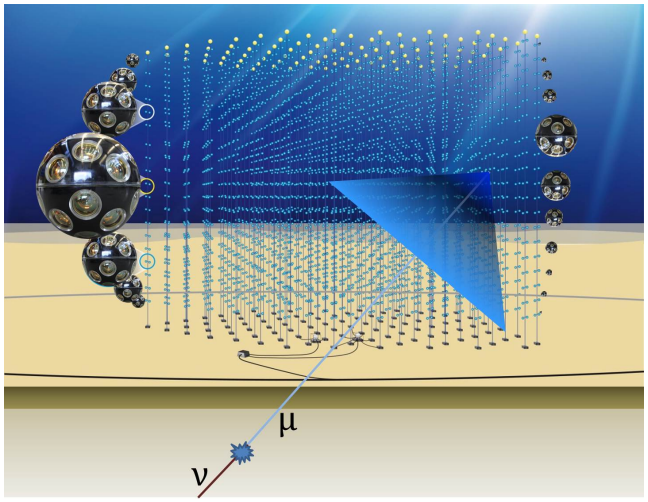


Superior angular resolution due to large $\lambda_{scattering}$ in deep sea water





THE KM3NET TELESCOPE

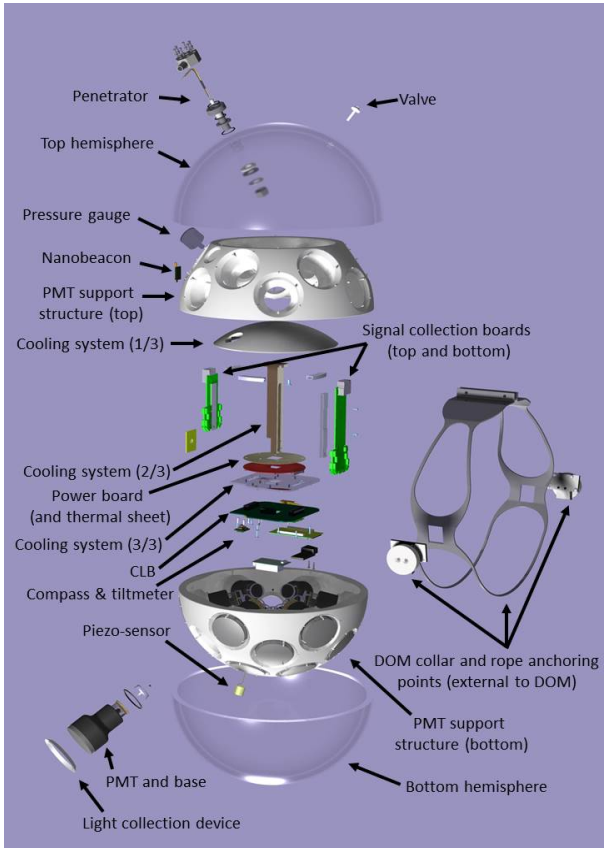


Very hostile enviroment due to huge pression (350 bar), corrosion, difficult access (installation, maintainance) …

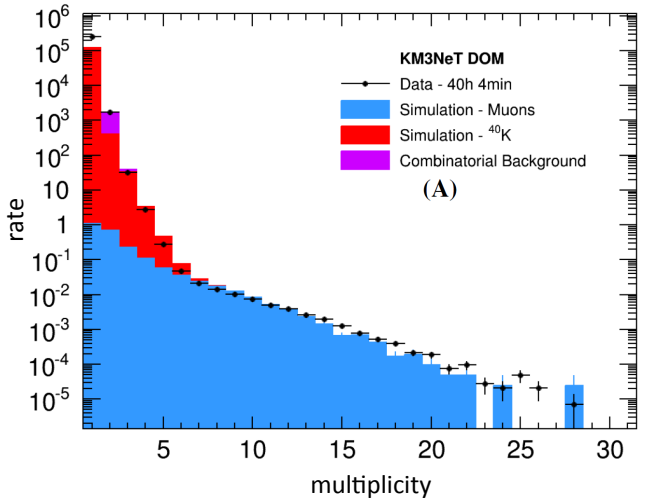
- Exploit optical Cherenkov radiation
  - all flavour detection in the TeV-PeV region
  - 1 km^3 of sea water equipped with a 3D array of optical sensors
  - two building blocks of 115 Detection Units (DU)
    - each DU hosts 18 multi-PMT Digital Optical Modules (DOM) with 36 m spacing
    - a backbone cable with breakouts at DOMs distributes power and data
  - Sea network of submarine cables and Junction Boxes provide power and data transmission to shore via a main electro-optical cable
- All data to shore

DOM - Digital Optical Module

- Digital photon counting
- Improved rejection of optical background
- Directional information and wide angle of view
  - high acceptance (nearly 4π)
  - good reconstruction (also for down-going events)
- Compact and cost effective design: 1 DOM equivalent to 3 Antares/IceCube OMs
- Photocatode Area
  ARCA = 2.35 X IceCube



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

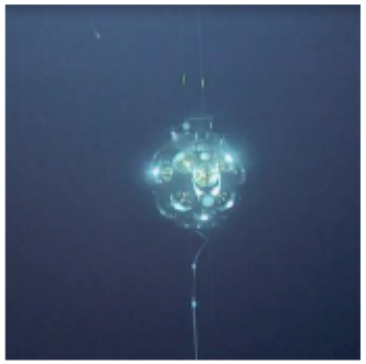


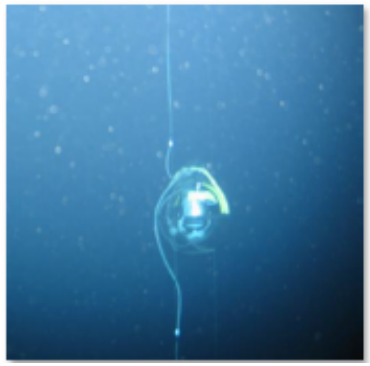
Photon counting capabilities and directional DOM sensitivity *Eur. Phys. J. C (2014) 74:3056*

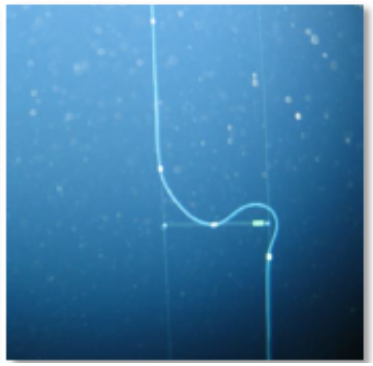
ARCA Detection Unit

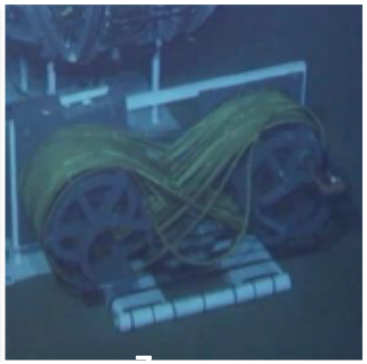
- String (700 m) with 18 optical modules (DOM)
- 36 m DOM spacing, 90 m DU spacing
- Mechanical structure made of two Dyneema ropes, anchor and buoys
- Backbone (VEOC) made of a 6mm oil filled tube hosting two conductors and 18 fibres with breakouts at each DOM
- Base module with optoelectronics for data transmission
  - DWDM, White Rabbit, All-data-to-shore
- Interlink cable for connection to the sea-floor network
  - connection operated by a ROV (Remote Operable Vehicle)

Launcher vehicle

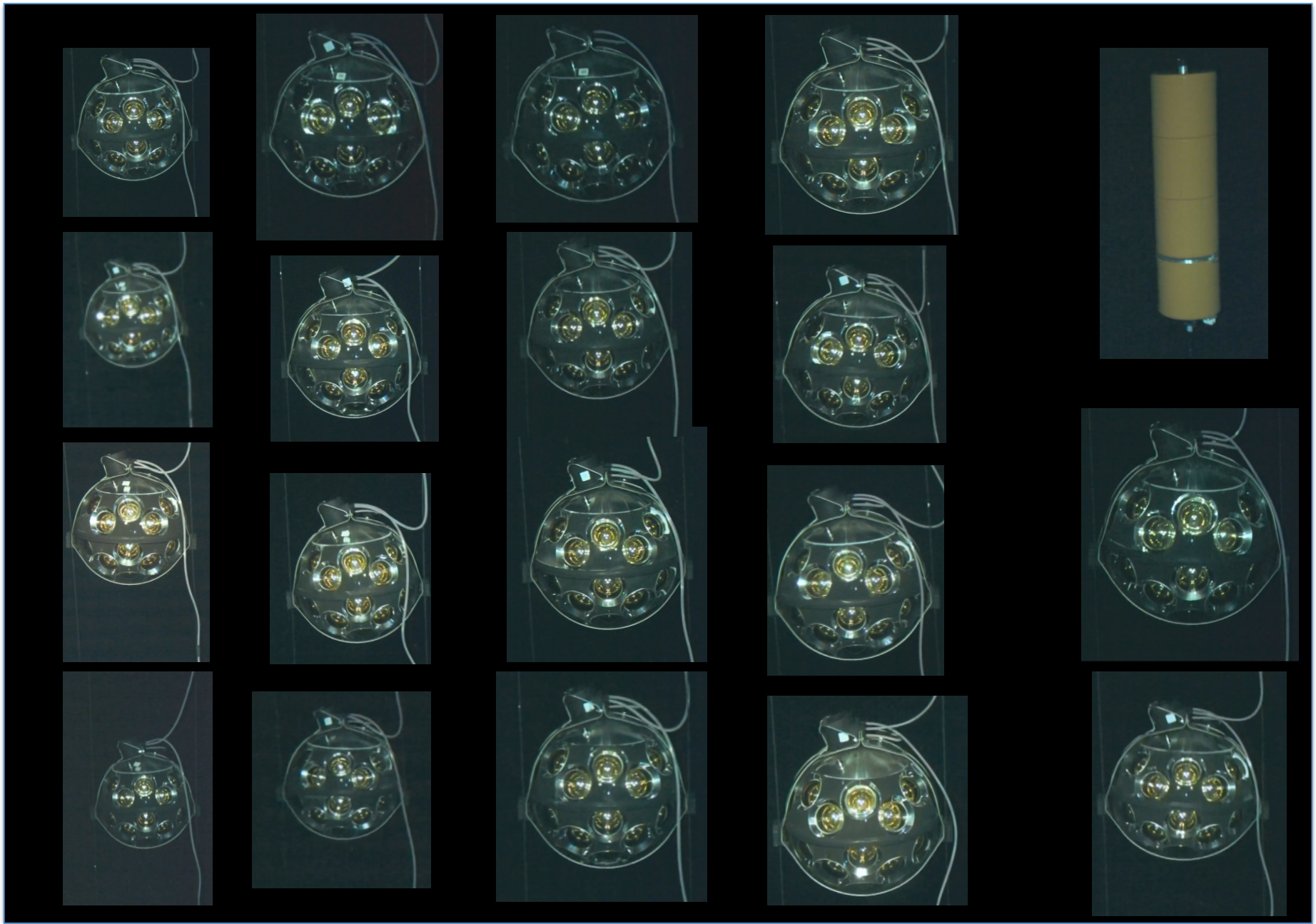




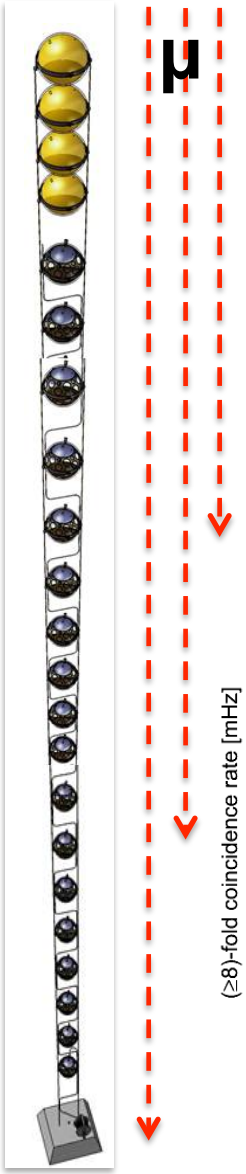


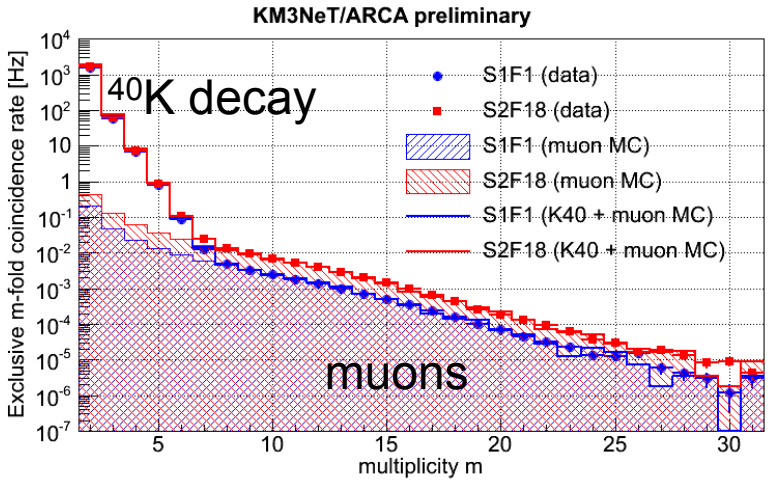


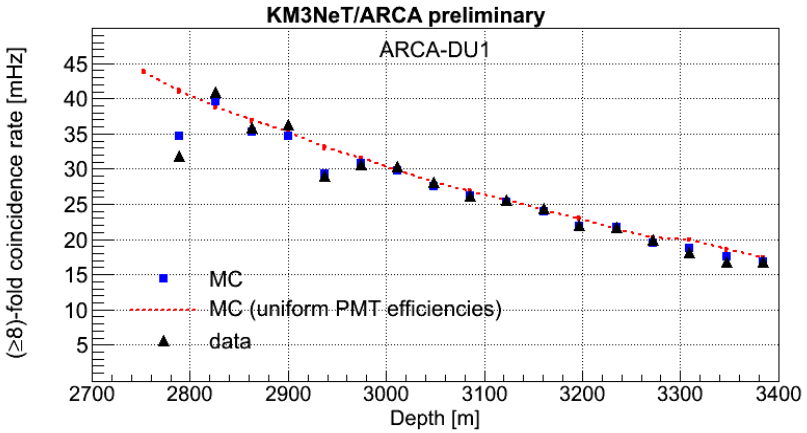
1st DU at 3500 m depth off-shore CapoPassero (IT)

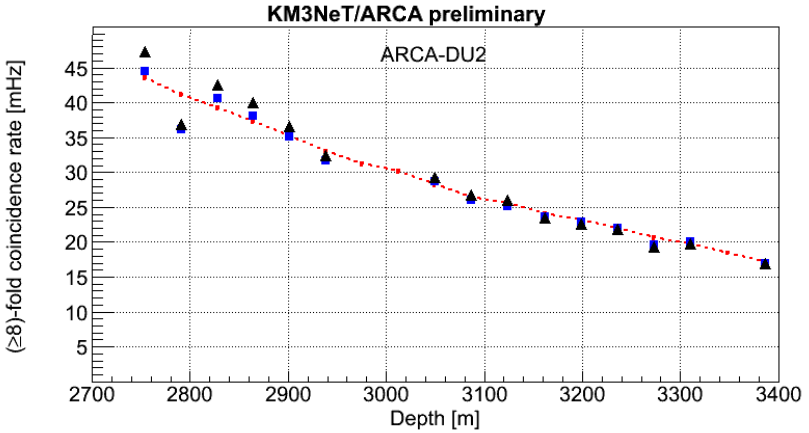


Muon Depth Dependence









A phased approach towards km3 telescope

PHASE	BLOCKS	PRIMARY DELIVERABLES	FUNDS
ARCA phase 1	0.2 0.1 km3	Proof of feasibility and first science results	fully funded
ARCA phase 2	2 1 km3	Study of neutrino signal reported by IceCube All flavor ν astronomy	partially funded

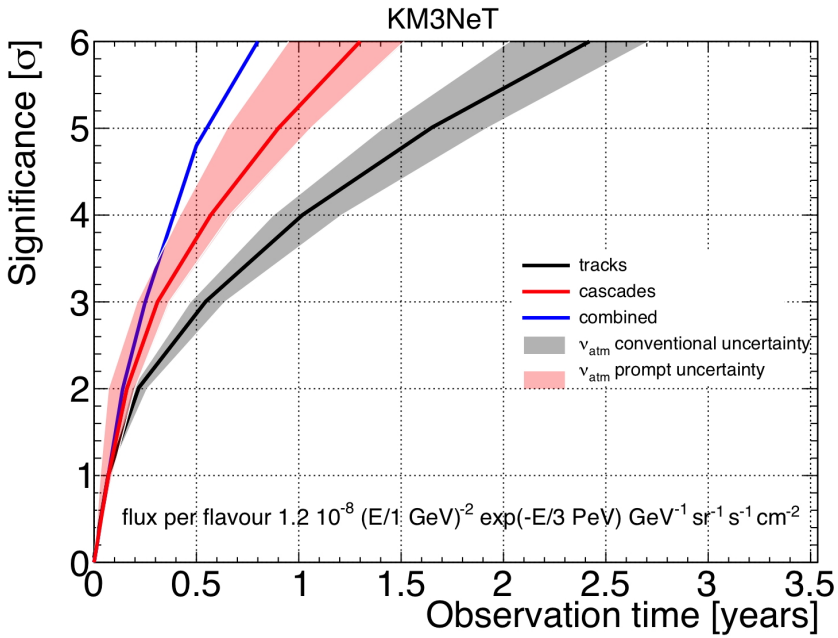
- Two DUs installed at nominal position at 3500 m depth
- more than one year data collected
- data analysis in progress
- system off due to short circuit
- sea campaign to resume DU foreseen

ARCA phase 1 volume = 10 x Antares volume

SENSITIVITY TO ICECUBE NEUTRINO FLUX

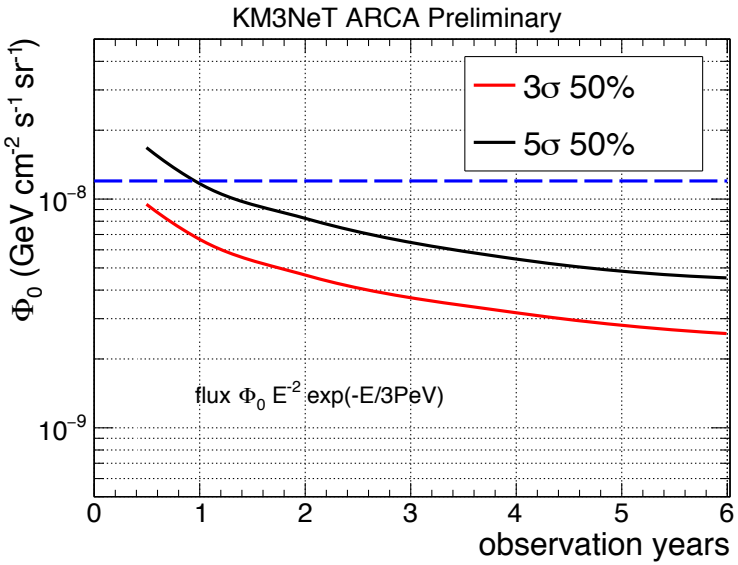
ALL FLAVOR ANALYSIS

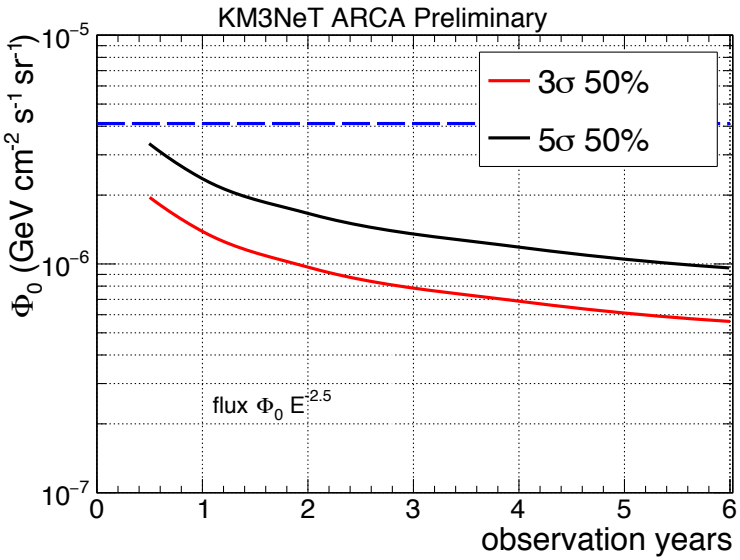
- **Track channel:** analysis for up-going events based on Max. likelihood
  - θ_{zen} >80°, Λ (reconstruction quality parameter), N_{hit} (number of hits -> parameter related to the muon energy)
- **Cascade channel**: contained events
  - **Vertex cut**: cut on position of reconstructed vertex (z<200m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



Discovery at 5σ significance (50% probability) in less than one year with combined analysis
Results from the KM3NeT Letter of Intent

SENSITIVITY TO ICECUBE NEUTRINO FLUX - UPDATE ON TRACK ANALYSIS-

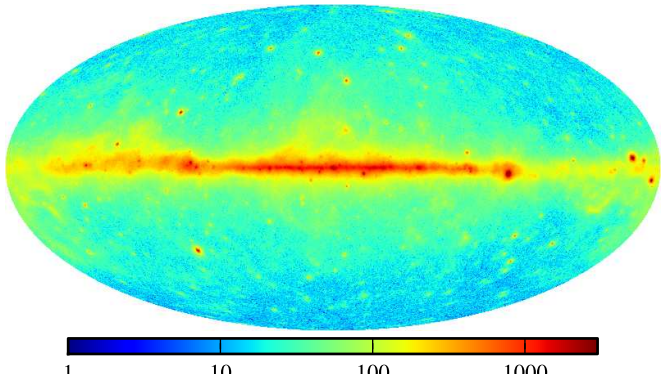




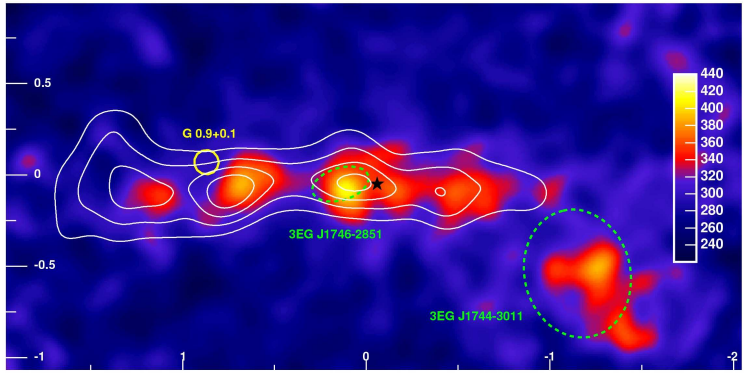
Discovery potential depend on spectrum parametrization of IceCube data
5σ discovery expected in 1 year or less with only muons

EMISSION FROM GALACTIC RIDGE

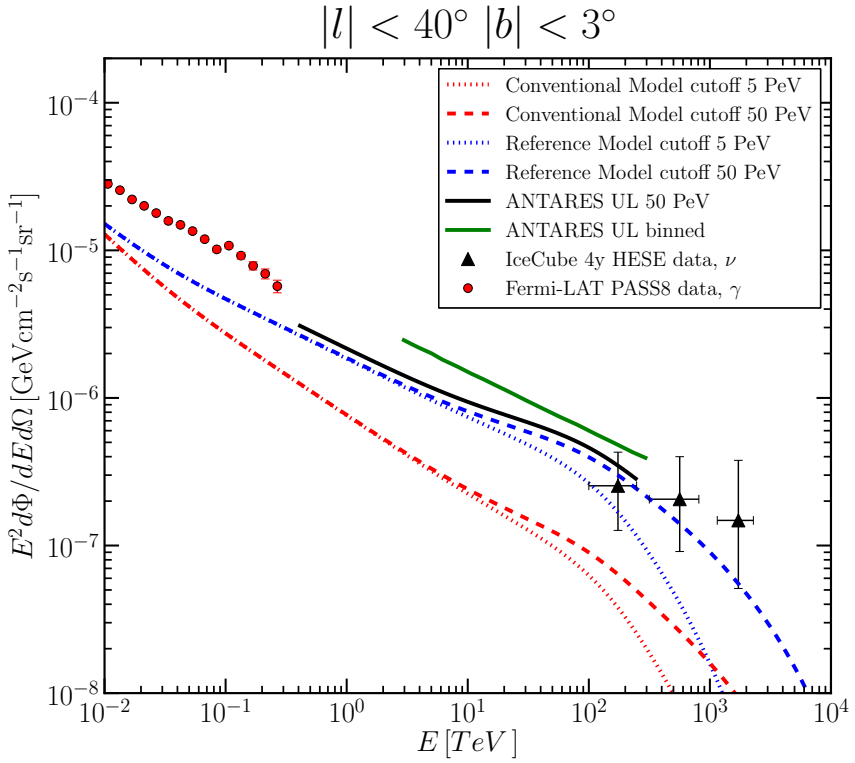
Enhanced γ emission observed in Fermi data in a region around the GC and also by HESS at higher energy



Fermi-LAT - M. Ackermann et al. Astrophys. J., 2012



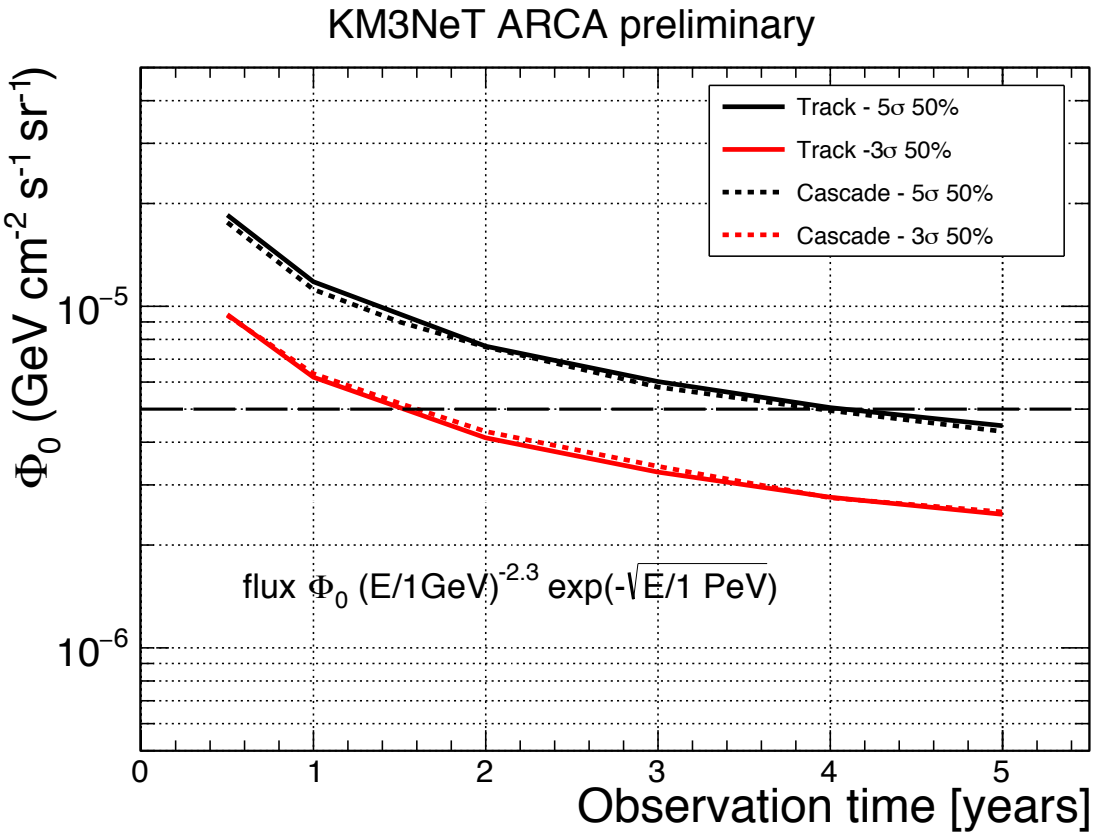
HESS- F. Aharonian et al. Nature, 2006.



Antares -A. Albert et al. Phys. Rev. D 96,2017

All flavour GR neutrino search ANTARES with 9 years data taking (2007-2015) show Upper limit close to Gamma model with 50 PeV cut off and put an limit on percentage of IC events from Galactic Plane

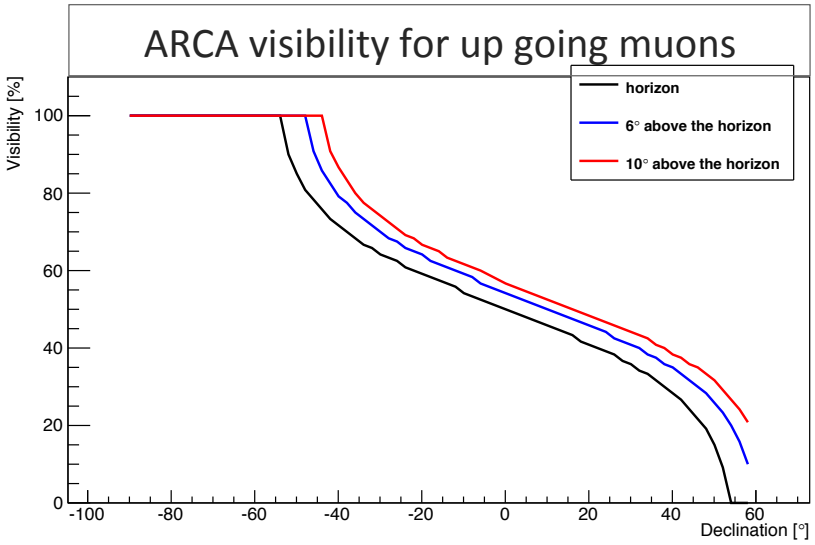
GALACTIC RIDGE SENSITIVITY



Discovery at 5σ in about four years for muon channel (KRAγ model)
Promising expectations for cascade and track combined analysis (to be done)

GALACTIC SOURCES

The search for neutrino galactic sources, although very challenging, is one of the prime goal of km3net. Muons are the golden channel for neutrino astronomy



Visibility of selected HE γ galactic sources

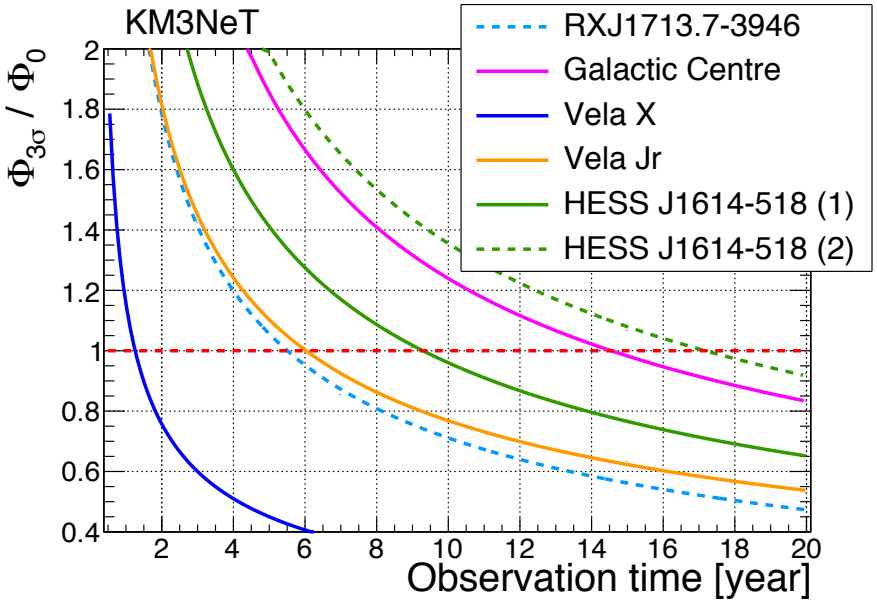
HE γ sources	δ	θ_{zenhit} > 90°	θ_{zenhit} > 80°
HESS J1614-518	-51.82°	92%	100%
Vela Jr	-46.36°	79%	100%
Vela X	-45.6°	78%	100%
RXJ 1713.7-3946	-39.77°	72%	87%
Galactic Center	-28.87°	64%	74%
MGRO J1908+06	+6.27°	48%	55%

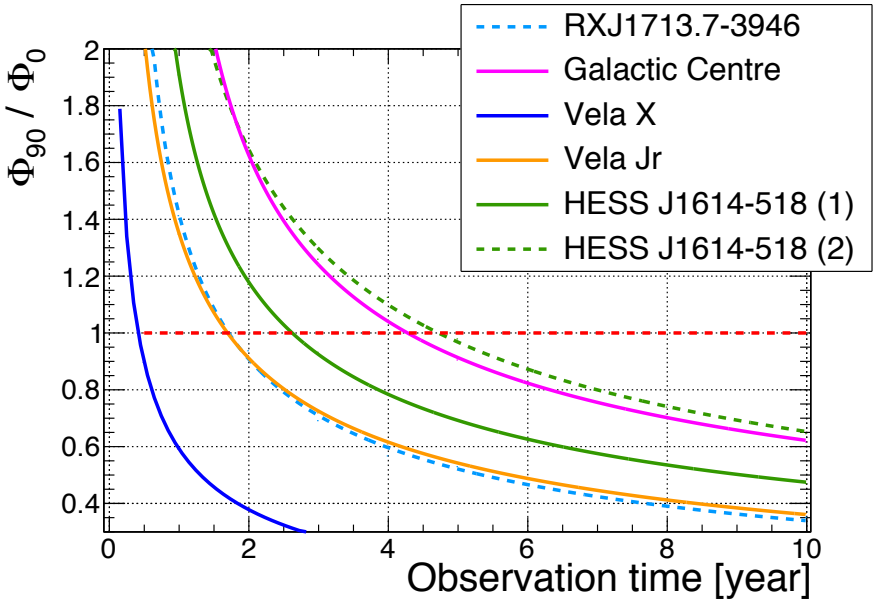
GALACTIC SOURCES

Sensitivity to Galactic sources calculated with ν fluxes withthe Vissani model starting from HE γ observed fluxes in the hypothesis of fully hadronic emission and 100% transparent sources

Only most intense HE g sources extending to tens of TeV considered

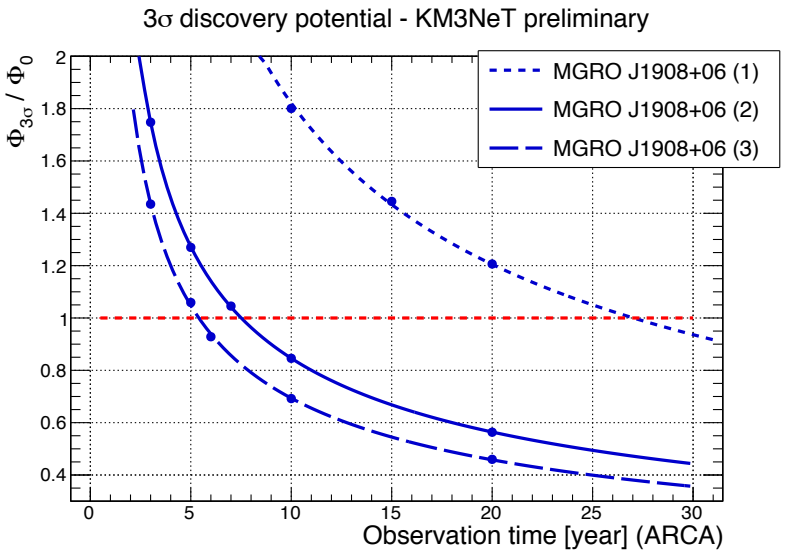
HESS GALACTIC SOURCES

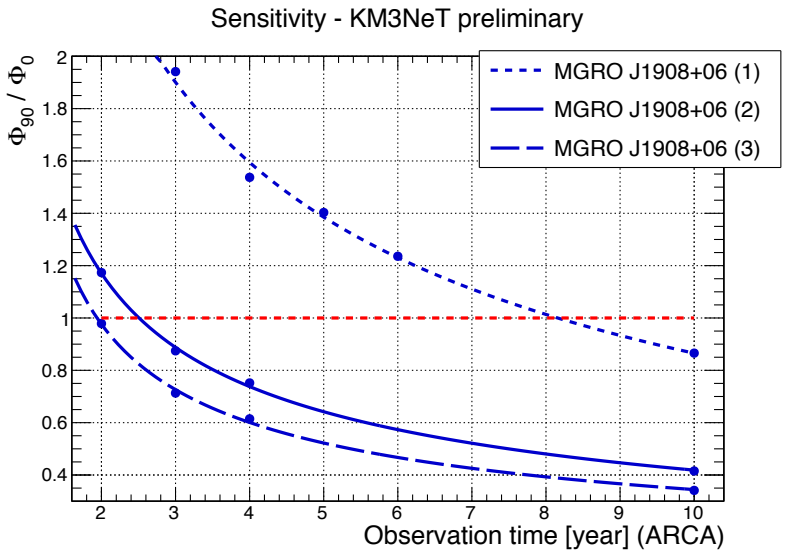




Good perspectives for ν detection and/or model constraints

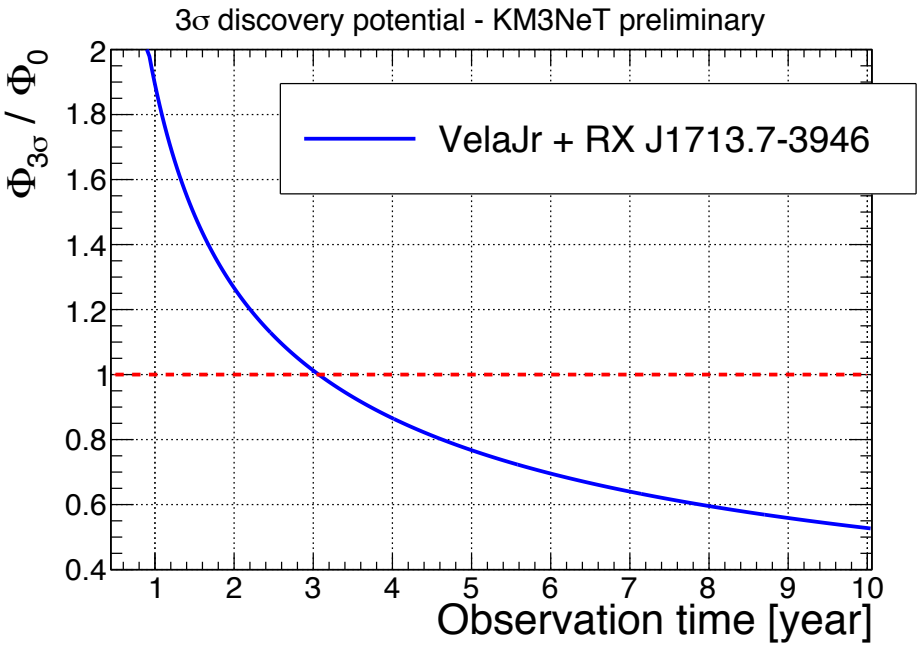
SENSITIVITY TO MGRO J1908+06 SOURCE





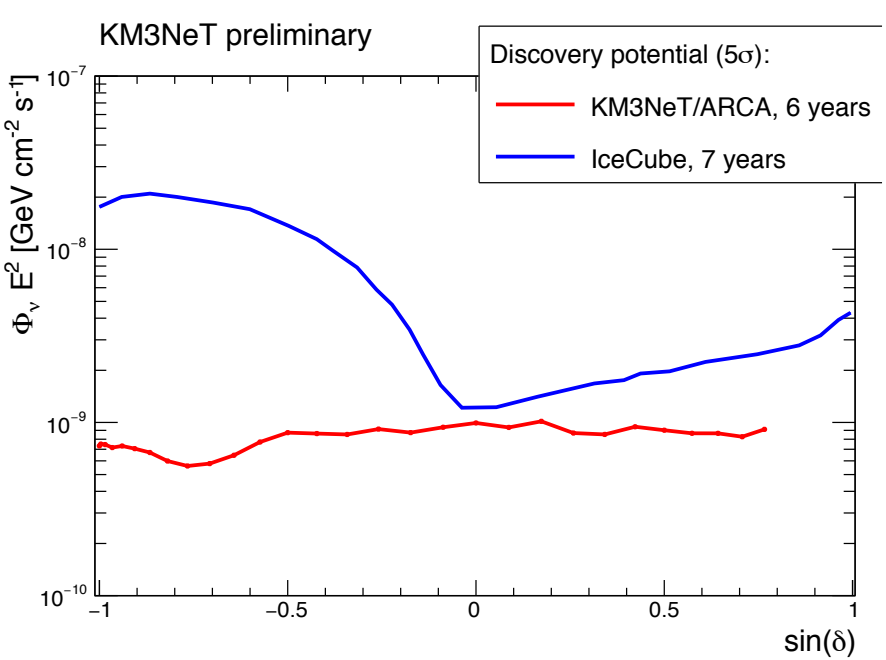
- KM3NeT sensitive also to sources at positive declination
- Different spectrum parametrization lead to very different neutrino flux expectation

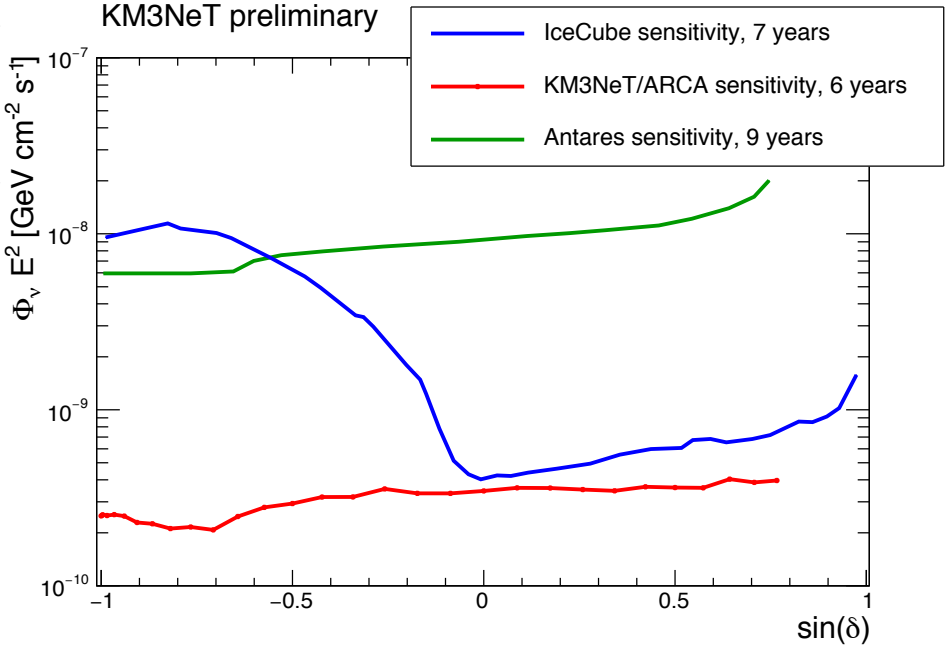
SNR stacking analysis



Stacking analysis of RXJ1713 (HESS 2016 data) and Vela Junior lead to a 3σ significance in 3 years

Sensitivity to E^{-2} point-like sources for up-going ν_μ





ARCA will survey almost the whole sky with a discovery potential @ 5σ about one order of magnitude better than IceCube in the Southern hemisphere for equivalent exposure

CONCLUSIONS

- KM3NeT will contribute to all-flavour neutrino astronomy with almost complete sky coverage, higher sensitivity and unprecedented angular resolution
- KM3NeT entered construction phase
  - first two strings installed in Capo Passero site operated for more than 1 year before stopping due to short circuit
  - mass production started
  - performance according to design expectation
  - data in agreement with MC
- IceCube data expected to be confirmed in less than 1 year of ARCA
- Due to KM3NeT location very good perspectives for neutrino detection from Galactic plane and 3σ significance for most intense galactic sources
- KM3NeT will have unprecedented performance for point like sources
- Moreover with ORCA, KM3NeT will contribute to determining the neutrino mass hierarchy