High energy neutrino detection with KM3NeT/ARCA

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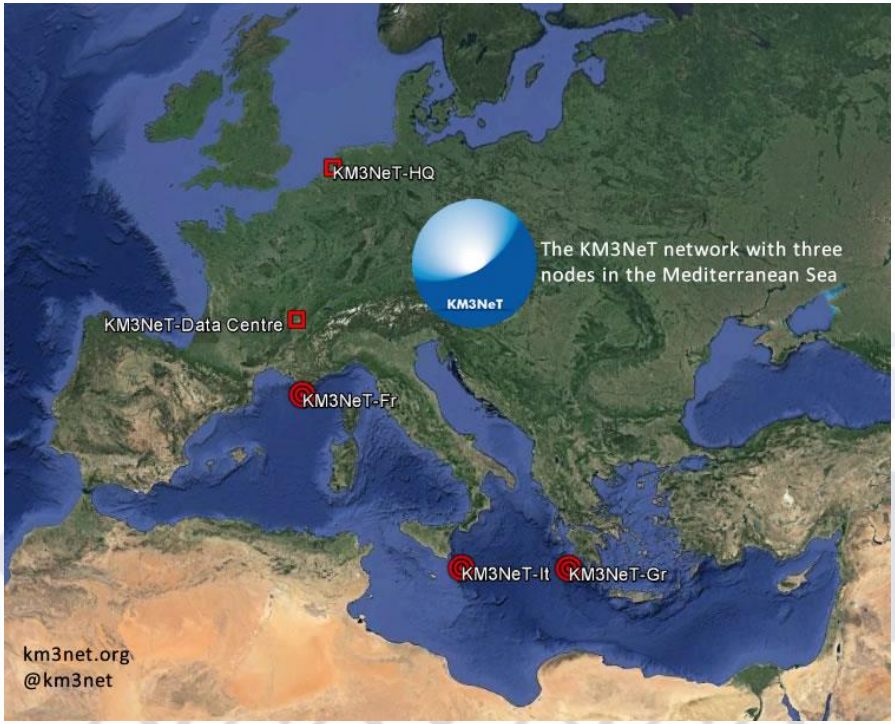
What is KM3NeT?

KM3NeT aims to be the largest deep sea infrastructure in Mediterranean Sea consisting of a network of neutrino telescopes with user ports for earth and sea sciences. Its physics goals are:

- High energy neutrino astronomy (TeV-PeV energy range)
- Measurement of fundamental neutrino properties (GeV energy range)



ARCA- Astroparticle Research with Cosmics in the Abyss @KM3NeT-It

ORCA- Oscillation Research with Cosmics in the Abyss @KM3NeT-Fr

(see KM3NeT – ORCA: Measuring the neutrino mass hierarchy in the Mediterranean Antoine Kouchner this conference)

Single Collaboration
Single Technology
Single Management

Physics with a Neutrino Telescope

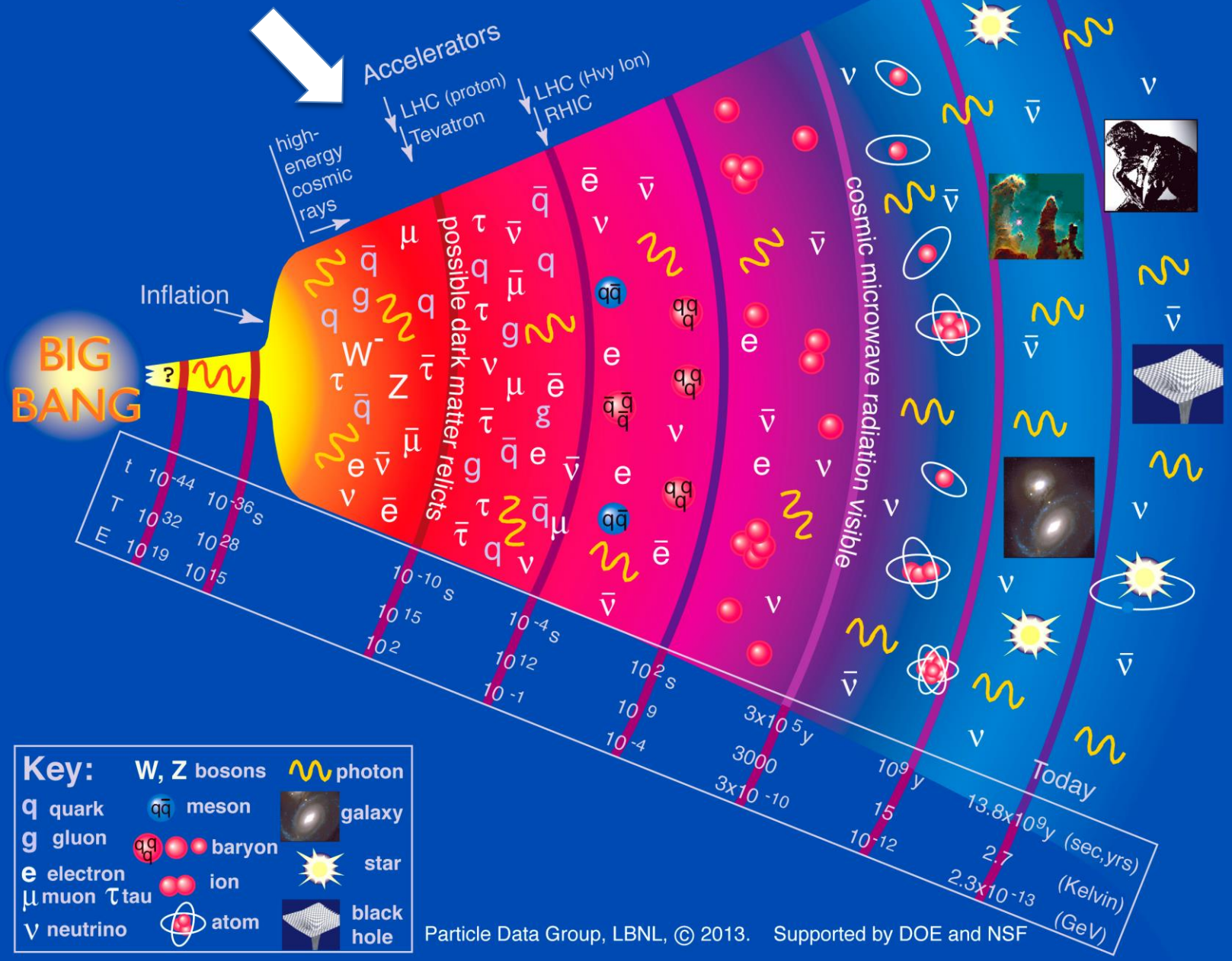
Opening a new window on the universe

- Supernova neutrinos
- Cosmic rays
- Atmospheric neutrinos
- Diffuse astrophysical neutrino fluxes
- Extended neutrino sources
- Point sources
- Transient sources

Closing in on fundamental physics

- Charm production
- Neutrino oscillations
- Dark Matter
- Exotic particles (magnetic monopoles, Q balls)
- Lorentz invariance violation
- Quantum decoherence

History of the Universe



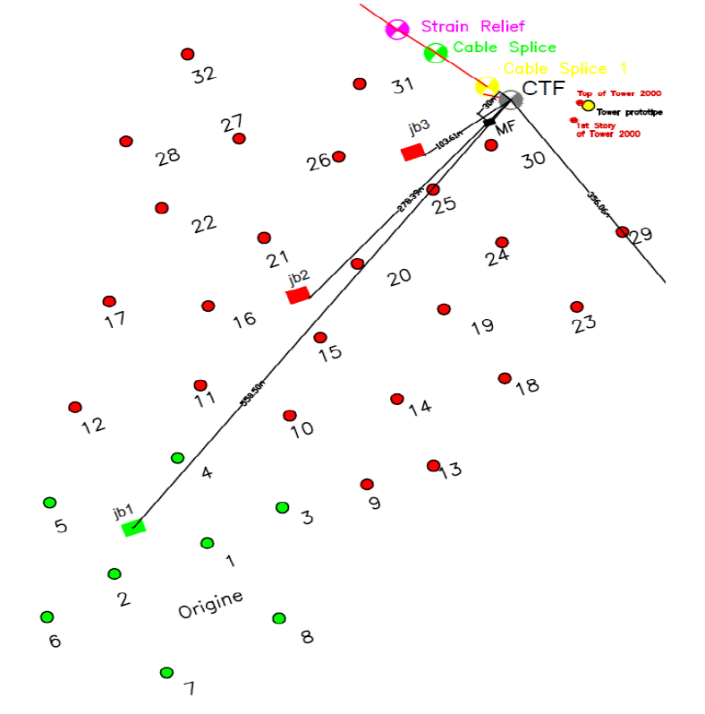
Phased implementation

Phase	Blocks	Primary deliverables
1	0.2	Proof of feasibility and first science results (6 ORCA strings/24 ARCA strings by end 2016)
2.0	2 *ARCA* at KM3NeT-It	*<u>Neutrino astronomy with ARCA</u>* *– focus on Galactic sources ("Raison d'être")* *– measurement of the IceCube signal with different methodology, improved resolution and complementary field of view* *– break-through capability of doing all-flavour neutrino astronomy*
	1 *ORCA at* *KM3NeT-Fr*	*<u>Neutrino physics with ORCA</u>* *– first determination of neutrino mass hierarchy (faster, better and cheaper)* *– improve measurements of neutrino oscillation parameters* *– essential and timely input for CP-violation experimentts*

KM3NeT Phase-1

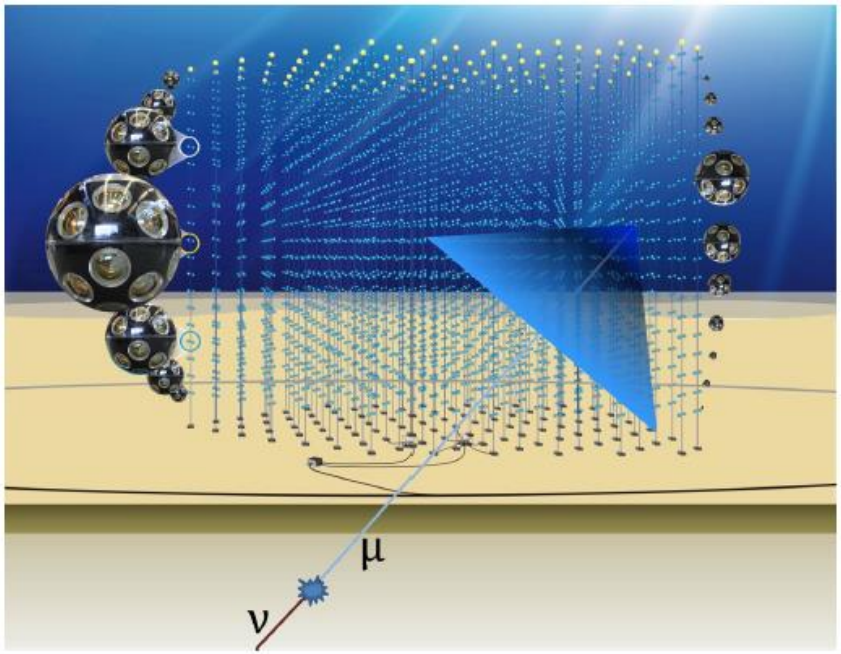
KM3NeT Phase-1: Proof of feasibility of network of neutrino detectors

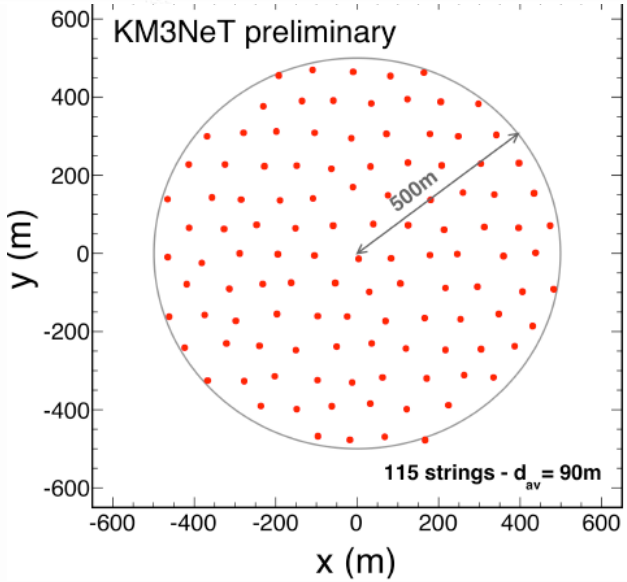
- Started in January 2014
- Funded with 31 million Euro
- Detection Unit deployment in 2015-2016
- Two sites
  - KM3NeT-It (24 Strings + 8 towers)
  - KM3NeT-Fr (7 DUs)

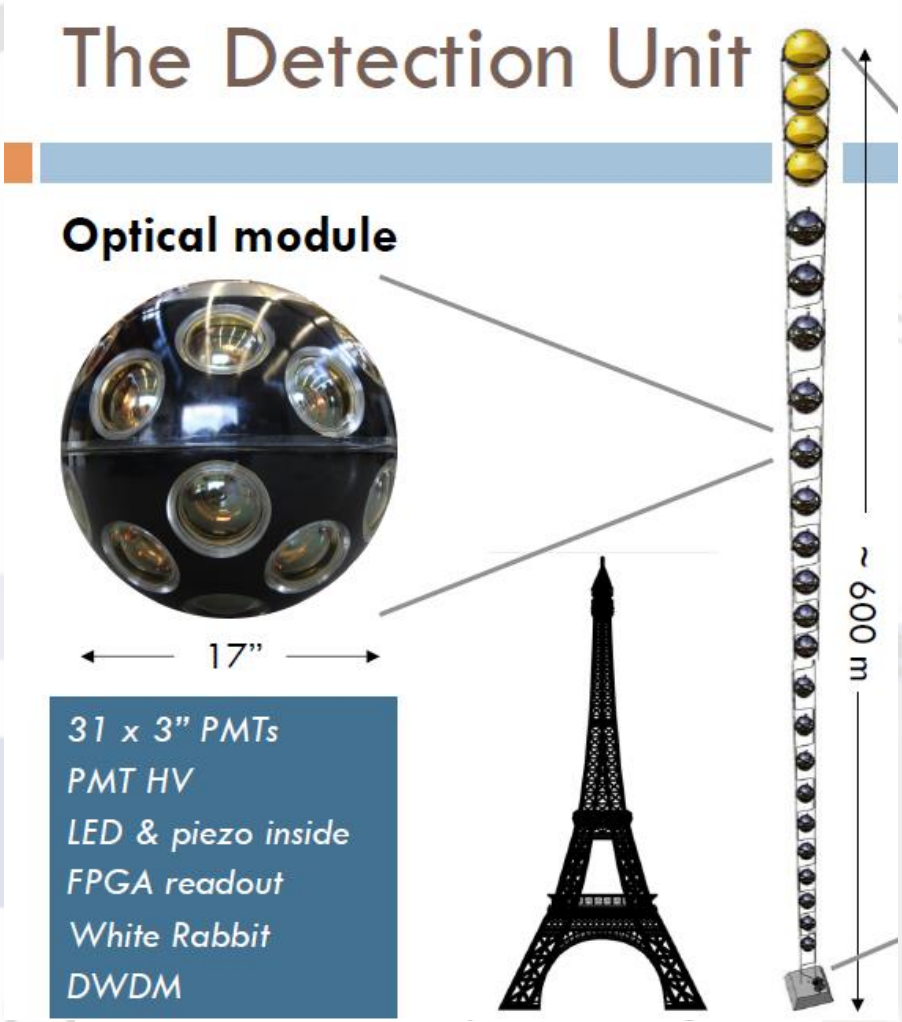


KM3NeT-It instrumented volume is 0.1 km^3, i.e. 10 times larger than Antares

KM3NeT building Block (115 DUs)







18 DOM per DU

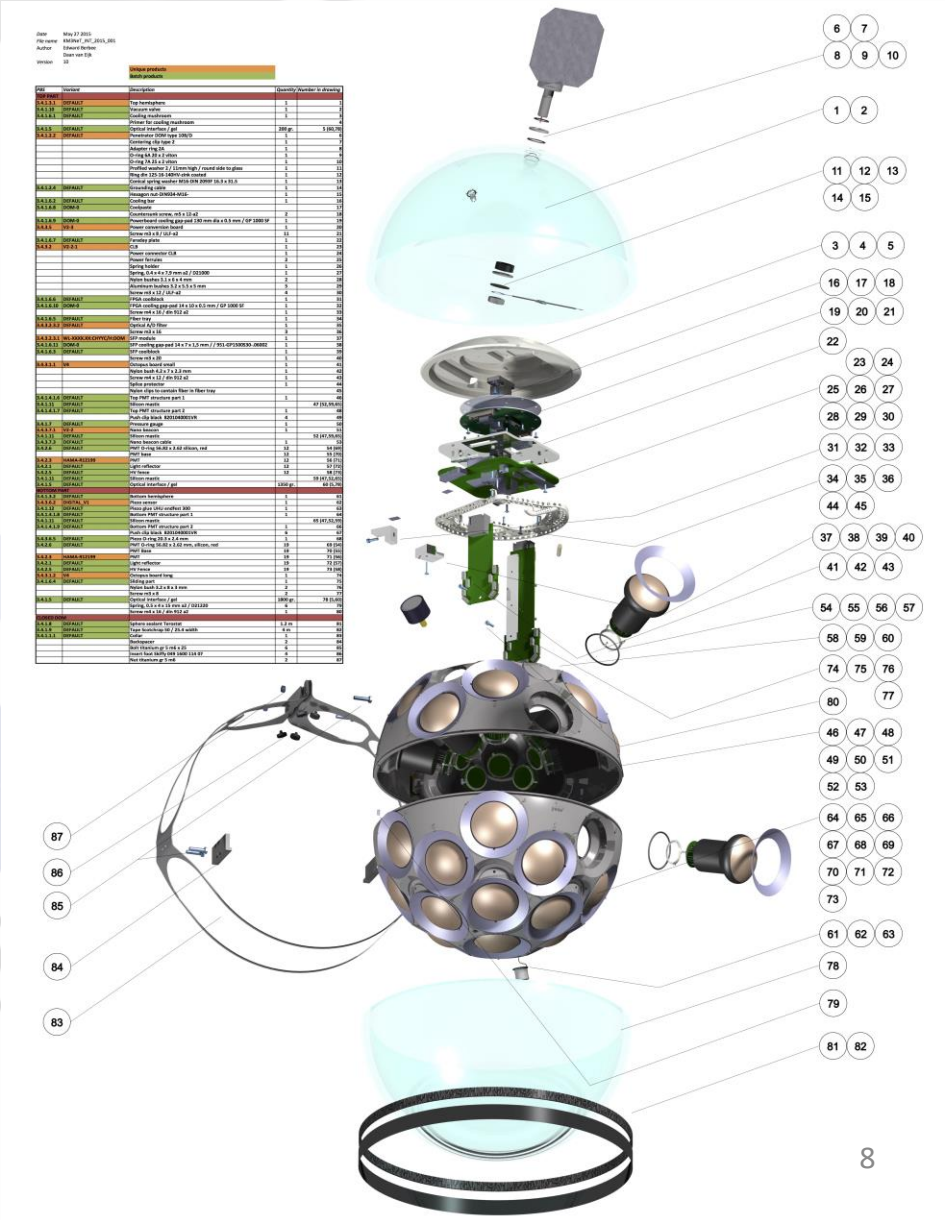
Vertical DOM spacing 36 m

Inter-DU spacing 90 m

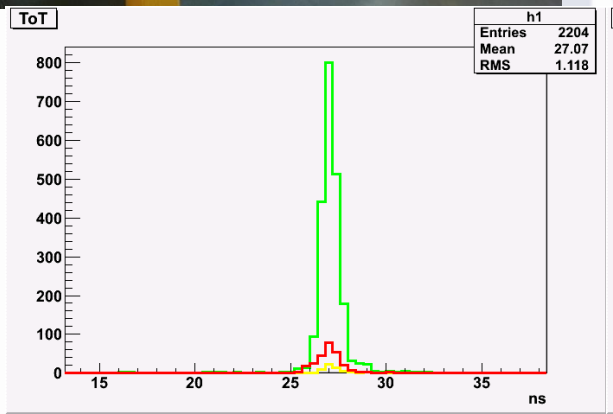
The Multi-PMT Digital Optical Module

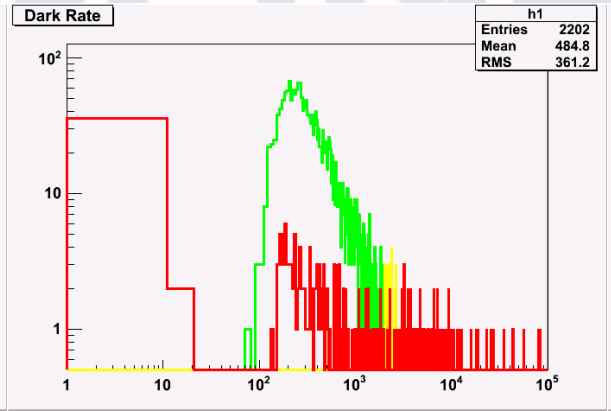
17 inch

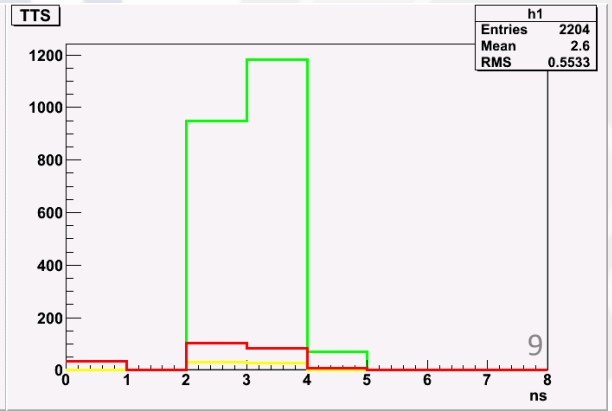
- Digital photon counting
- Directional information
- Wide angle of view



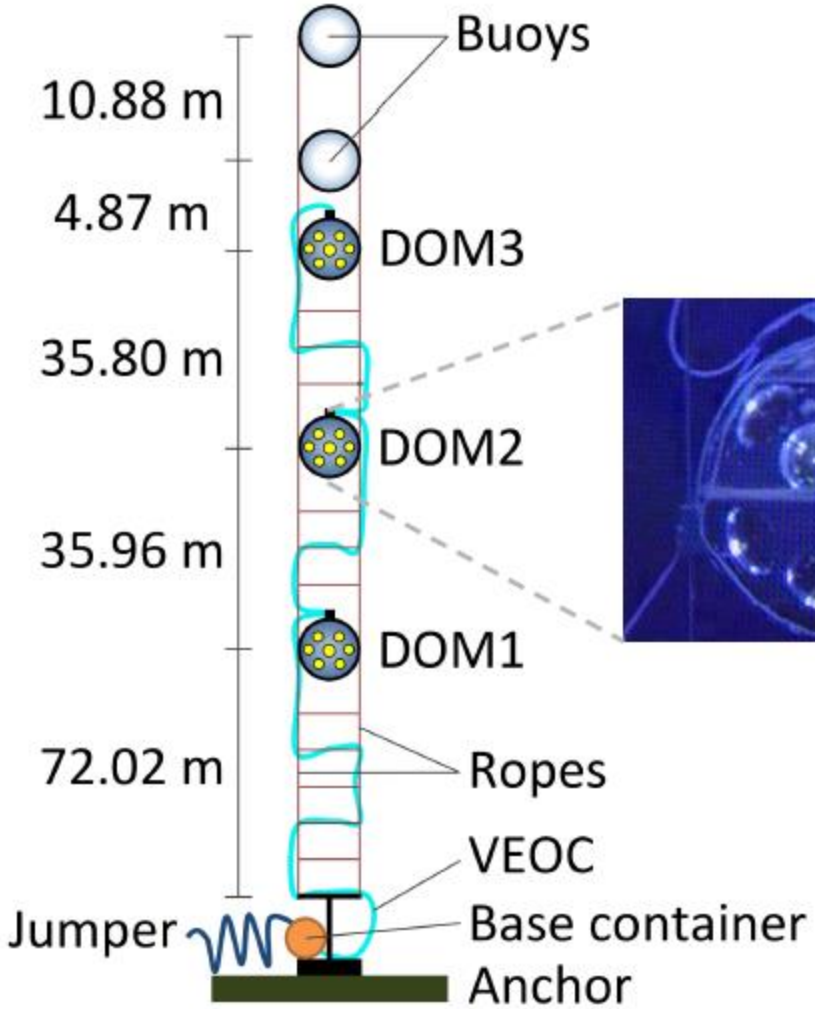
Each single PMTs is tested and calibrated.
120 PMTs are tested daily







Detection Unit prototype (PPM-DU)



Prototype DU with three DOMs

Deployed at the KM3NeT-It site at 3500m depth

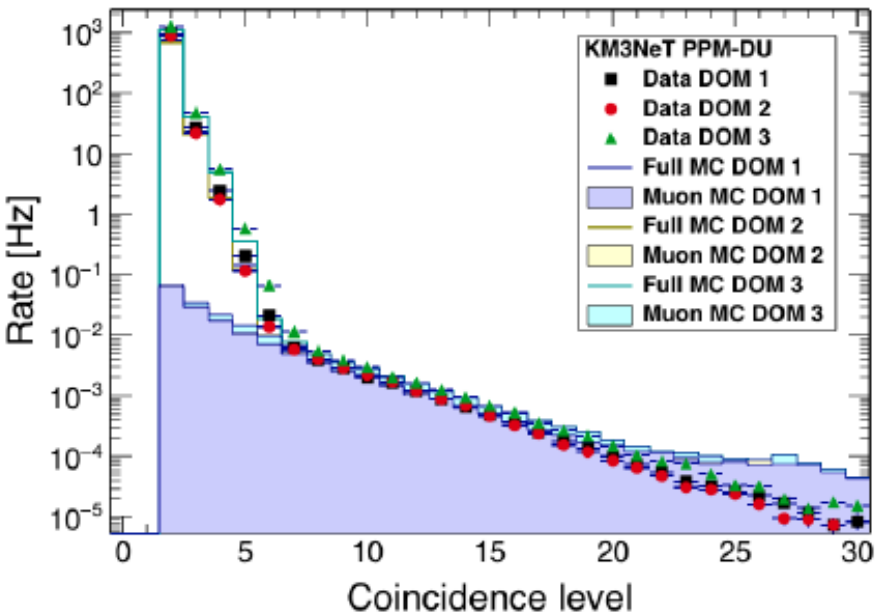
Followed successful operation of prototype DOM at the ANTARES site

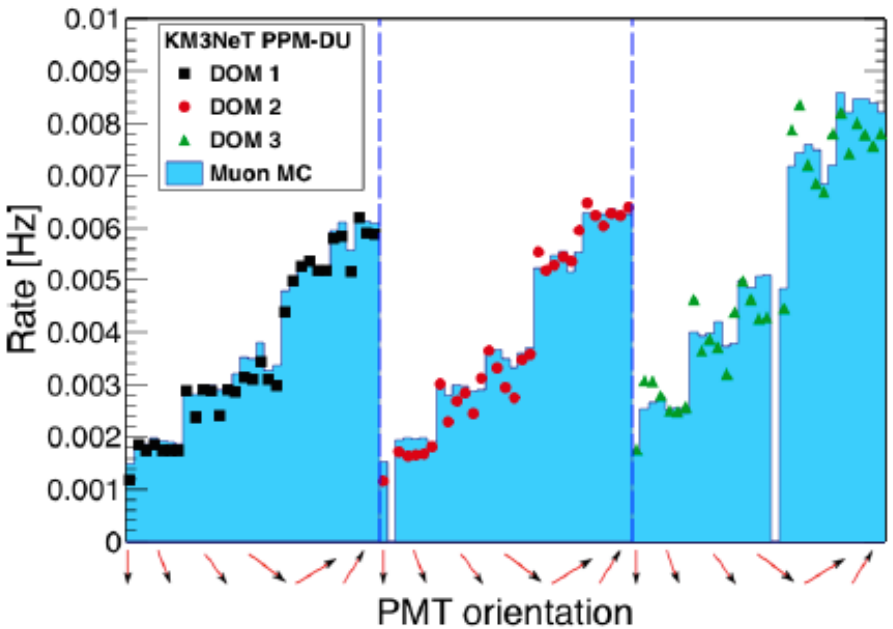
Operational since May 2014

Proof of DU concept functionality

Test of readout, DAQ, connection, intra-DOM and inter-DOM syncronization

PPM-DU results





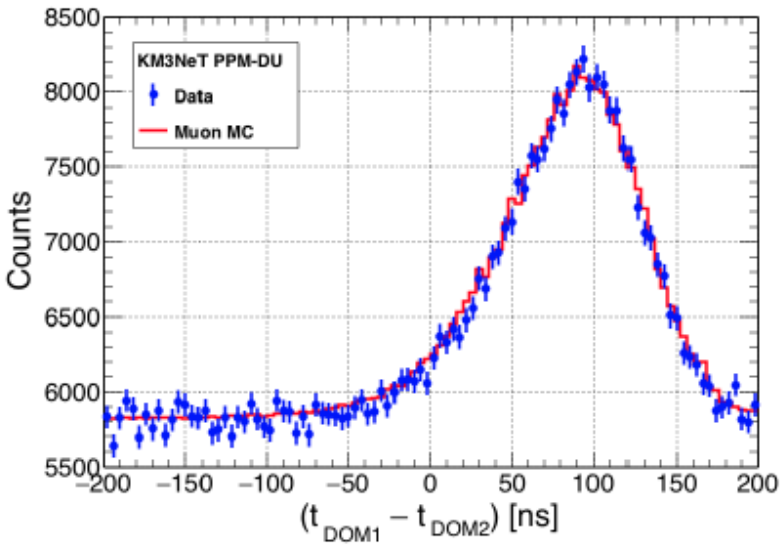
Photon counting

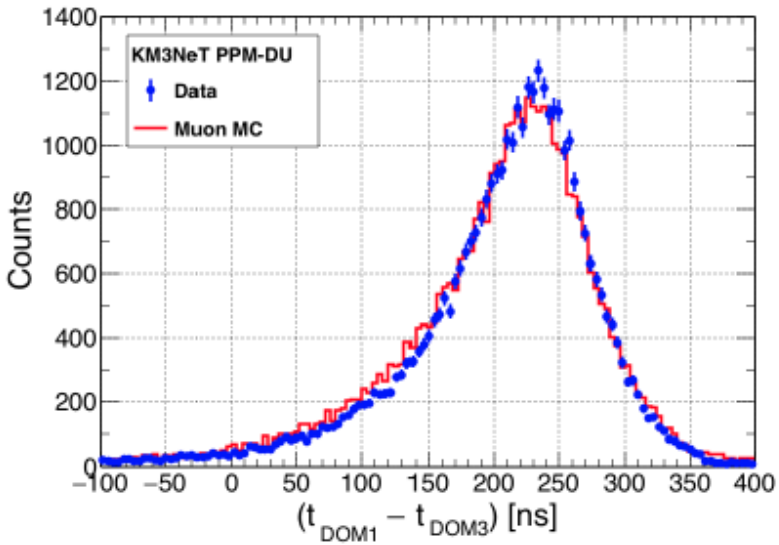
High level coincidences cleanly select muon events

Directional sensitivity

Muon events (coincidence level > 7)

PPM-DU: DOM intra&inter-calibration





DOM intra-calibration is performed by using ^{40}K

DOM inter-calibration is performed by using dedicated runs with the LED nanobeacon activated

The distribution of the time differences between DOM1&DOM2 and DOM1&DOM3 when all 3 DOMs are in coincidence is shown.

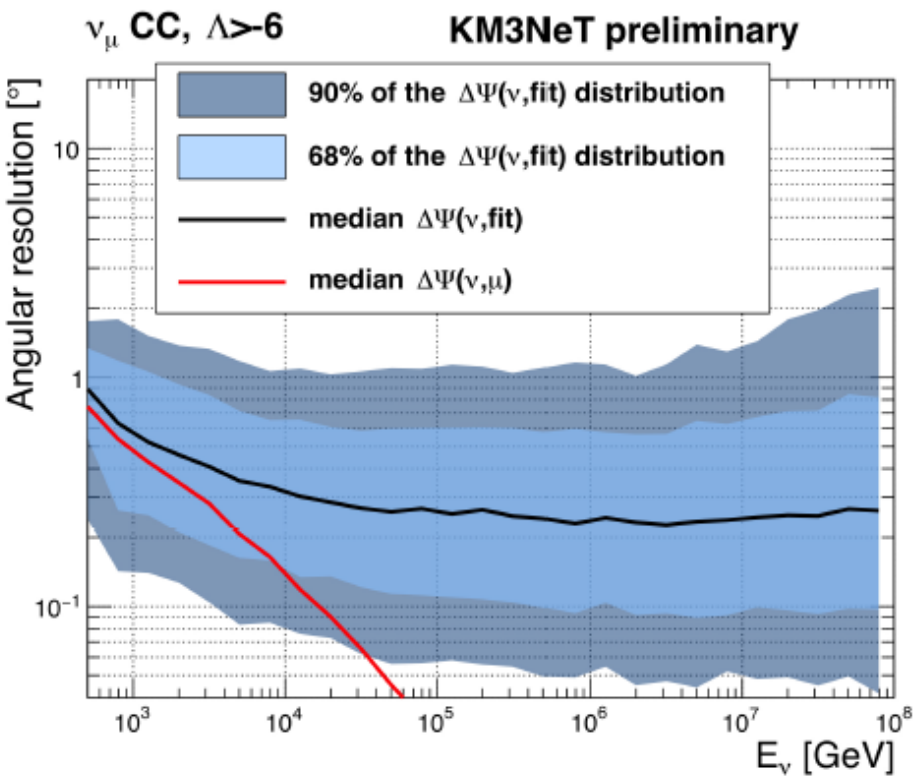
DUs constructed and under construction

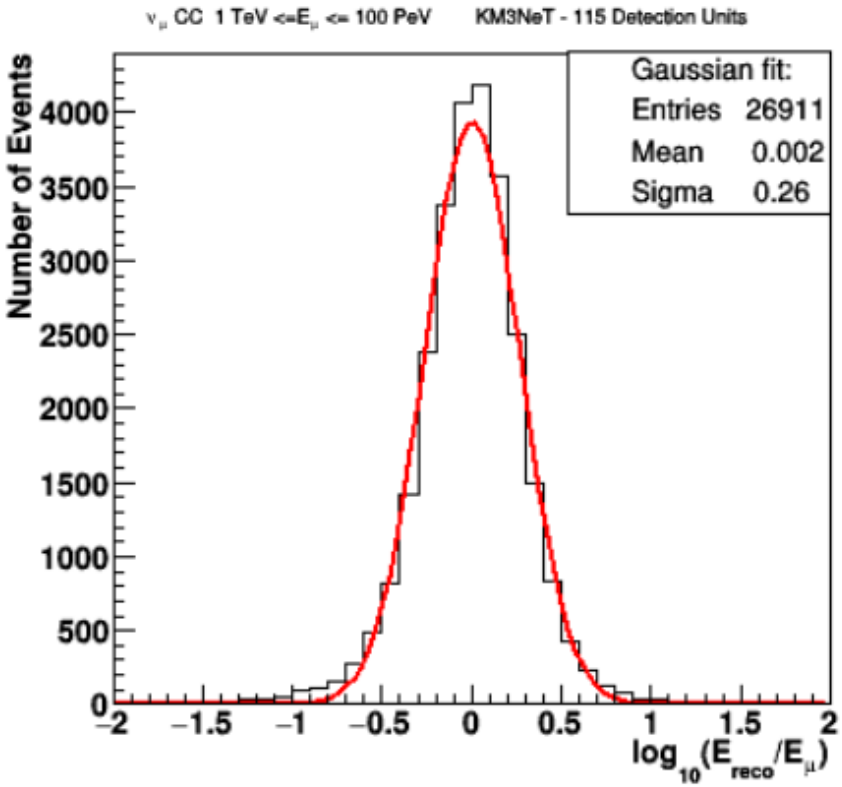
First full DU already integrated and ready for deployment at the KM3NeT-Fr site

Integration of the second DU in progress. To be deployed at the KM3NeT-It site

Resolution for track reconstruction

After cuts optimized for track reconstruction



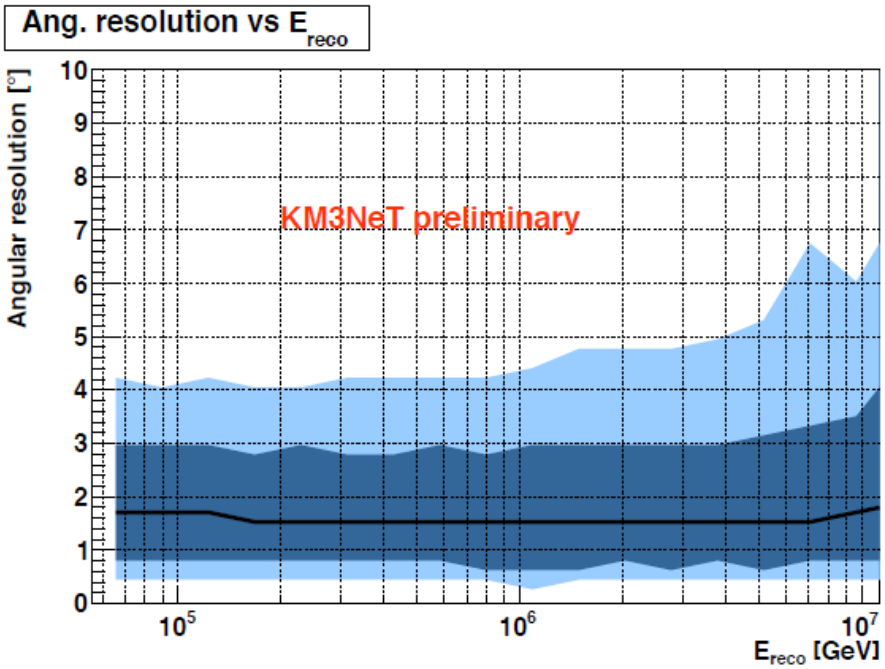


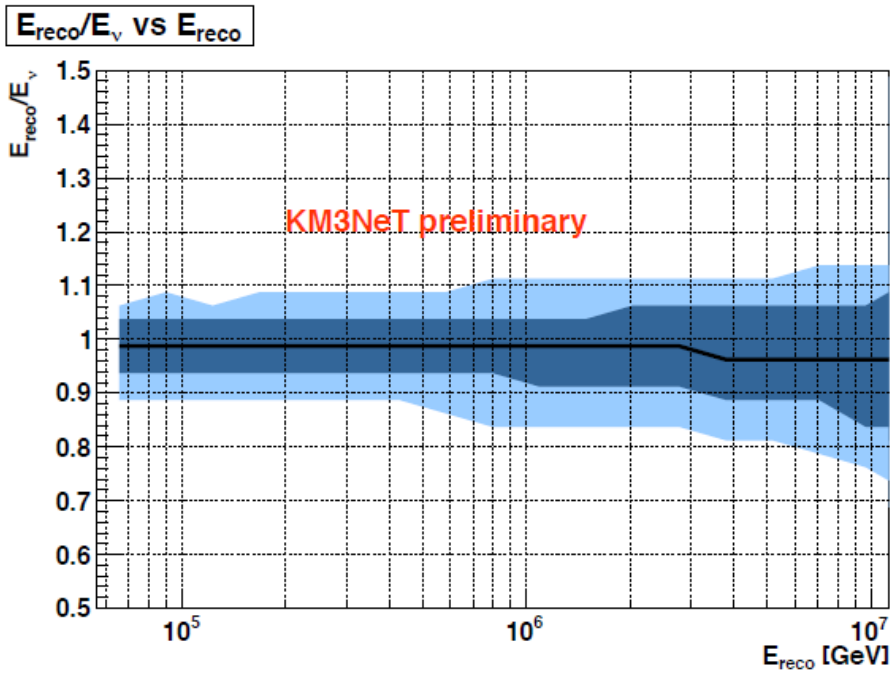
Angular resolution
about 0.2° (E_ν >10 TeV)

Energy resolution
0.26 in $\log E_\mu$
(1 TeV < E_ν < 100 PeV)

Resolution for shower reconstruction

Angular and energy resolution for the event sample after the final cuts of the diffuse cascade analysis





Angular resolution about 2°

Energy resolution < 10%

KM3NeT/ARCA main physics goals

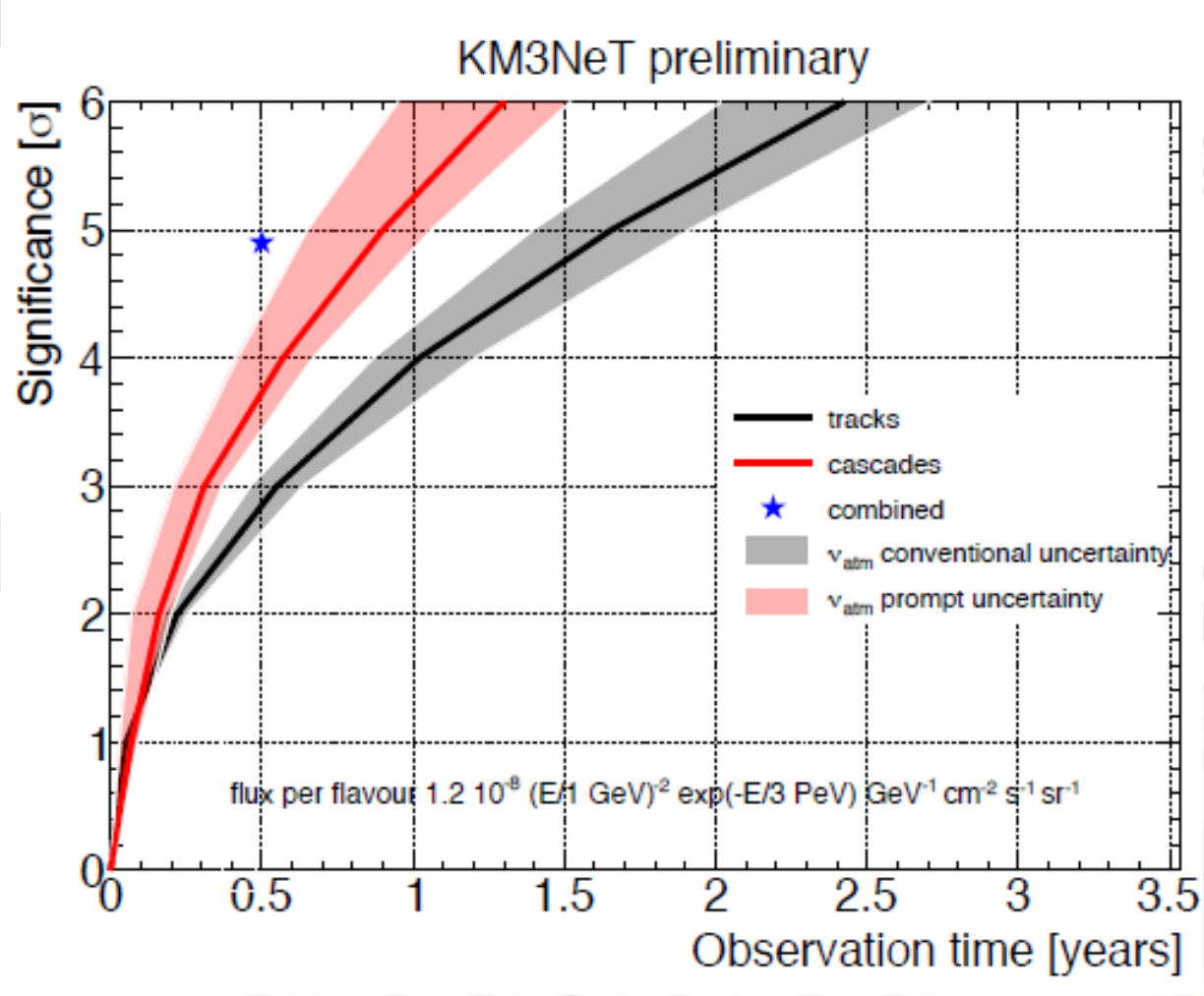
- Diffuse high-energy neutrino fluxes
  - We assume as benchmark the IceCube flux (isotropic and flavour symmetric)

$$\Phi(E) = 1.2 \cdot 10^{-8} \left(E/1\ \mathrm{GeV}\right)^{-2} \exp\left(-E/3\ \mathrm{PeV}\right)\ \ \mathrm{GeV}^{-1}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}\ \mathrm{sr}^{-1}$$

M.G. Aartsen et al., Science 342 (2013) 1242856

- Neutrino point-like sources
  - We assume as benchmark the most intense galactic TeV gamma sources

Sensitivity to neutrino diffuse flux

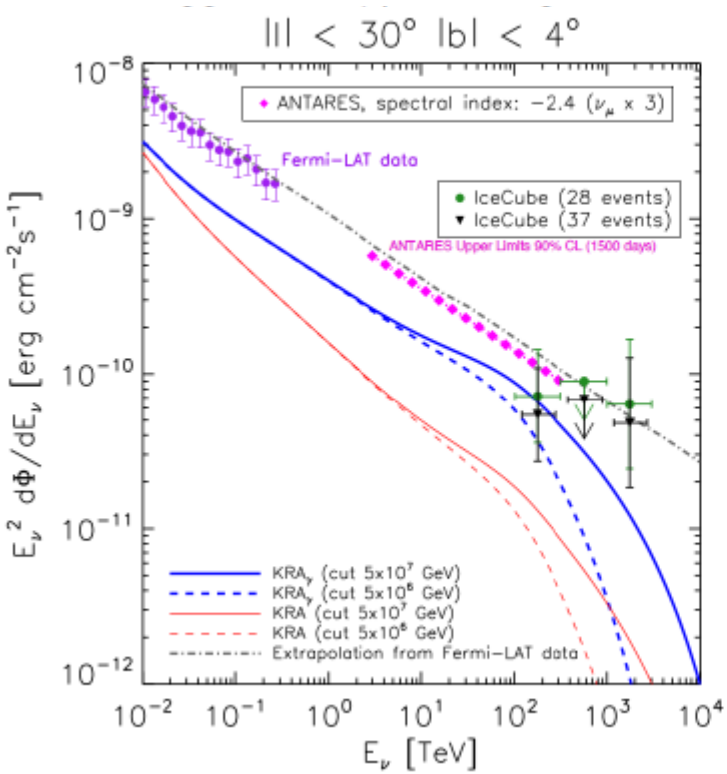


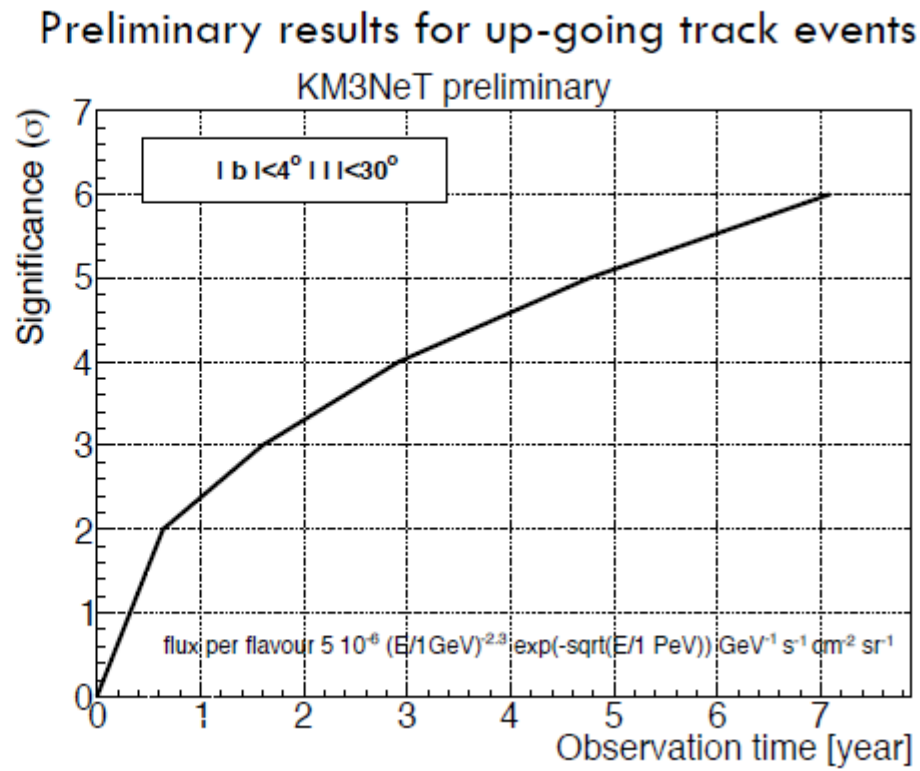
Time needed to perform a 5σ significance discovery with a 50% probability

Diffuse flux from the galactic plane

ARCA performance to a flux from a region of the Galactic Plane near the Galactic Center Evaluation of the neutrino flux based on a radially-dependent cosmic-ray transport properties

D.Grasso this conference





Time needed to perform a 5σ significance discovery with a 50% probability

Galactic sources with ARCA

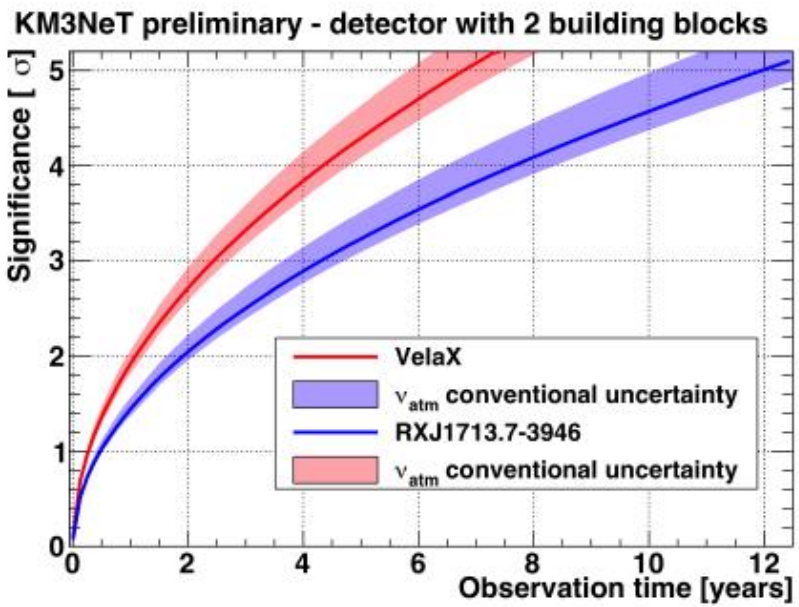
HE gamma emission observed by HESS in SNRs

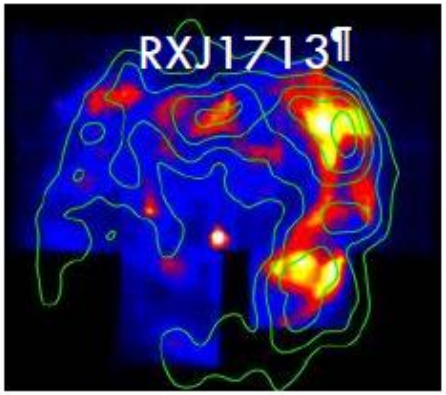
Neutrino spectra predicted using gamma spectra

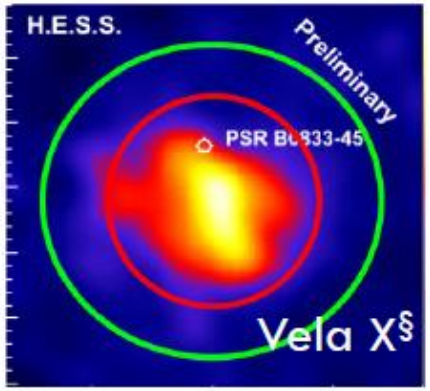
¶ S.R. Kelner, *et al.*, PRD 74 (2006) 034018

§ F.L. Villante and F. Vissani, PRD 78 (2008) 103007

Hypotheses: 100% hadronic emission and transparent source

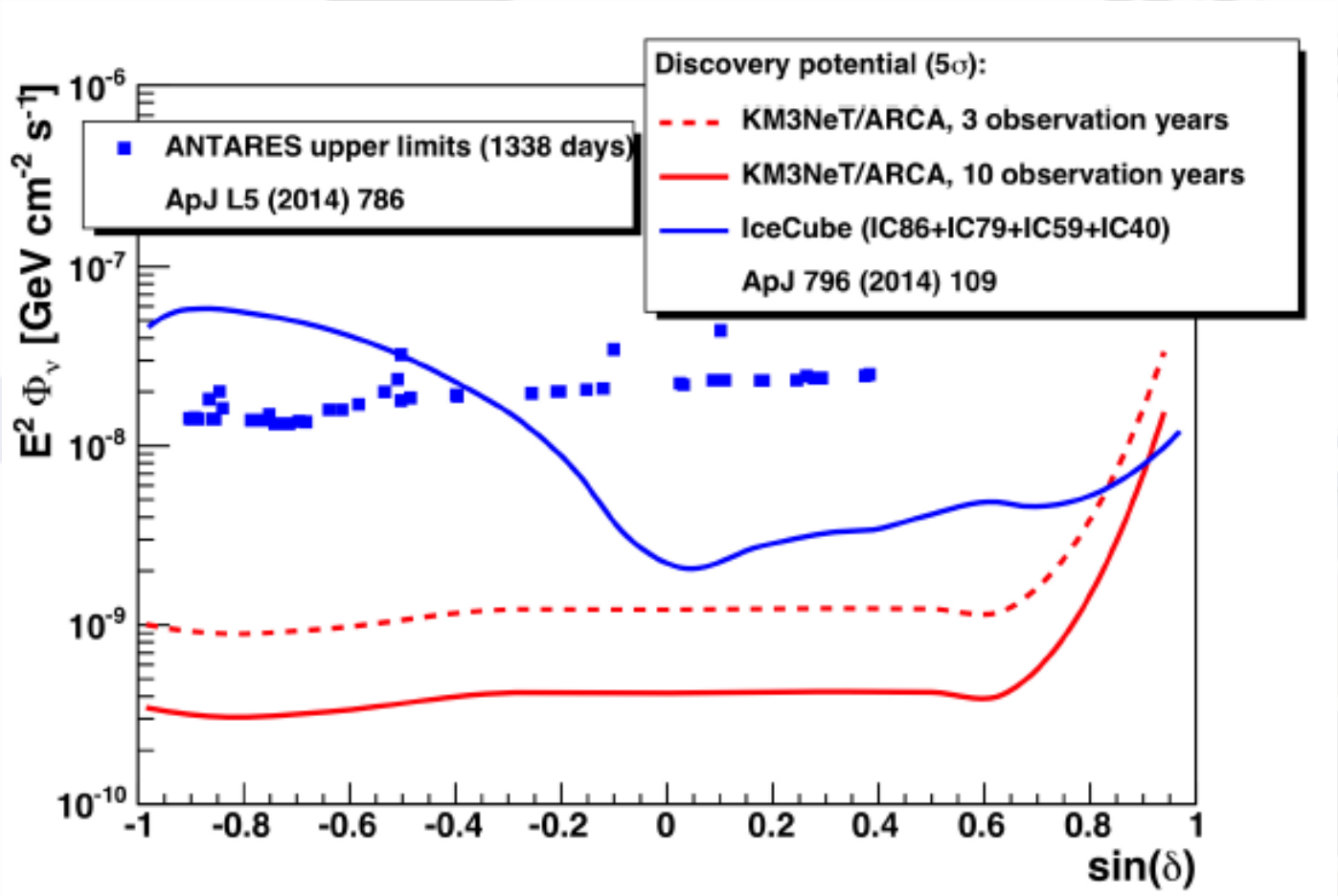






Vela X: 3σ in about 2 years
RXJ1713: 3σ in about 4 years

ARCA discovery potential for E^{-2} sources



Better sensitivity (for equivalent exposure) and better sky coverage than IceCube

Conclusion

- First phase of Km3NeT is fully funded and under construction
- ARCA (about 1km^3) will be installed at the KM3NeT-It node of the KM3NeT infrastructure
- Very interesting and exciting physics
  - Investigate the neutrino sky with unprecedented resolution and sky coverage