Physics Laboratory
School of Science and Technology
Hellenic Open University

KM3NeT
Opens a new window on our universe
www.km3net.org

Towards the Very Large Volume Mediterranean Neutrino Telescope, KM3NeT

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on behalf of the KM3NeT consortium

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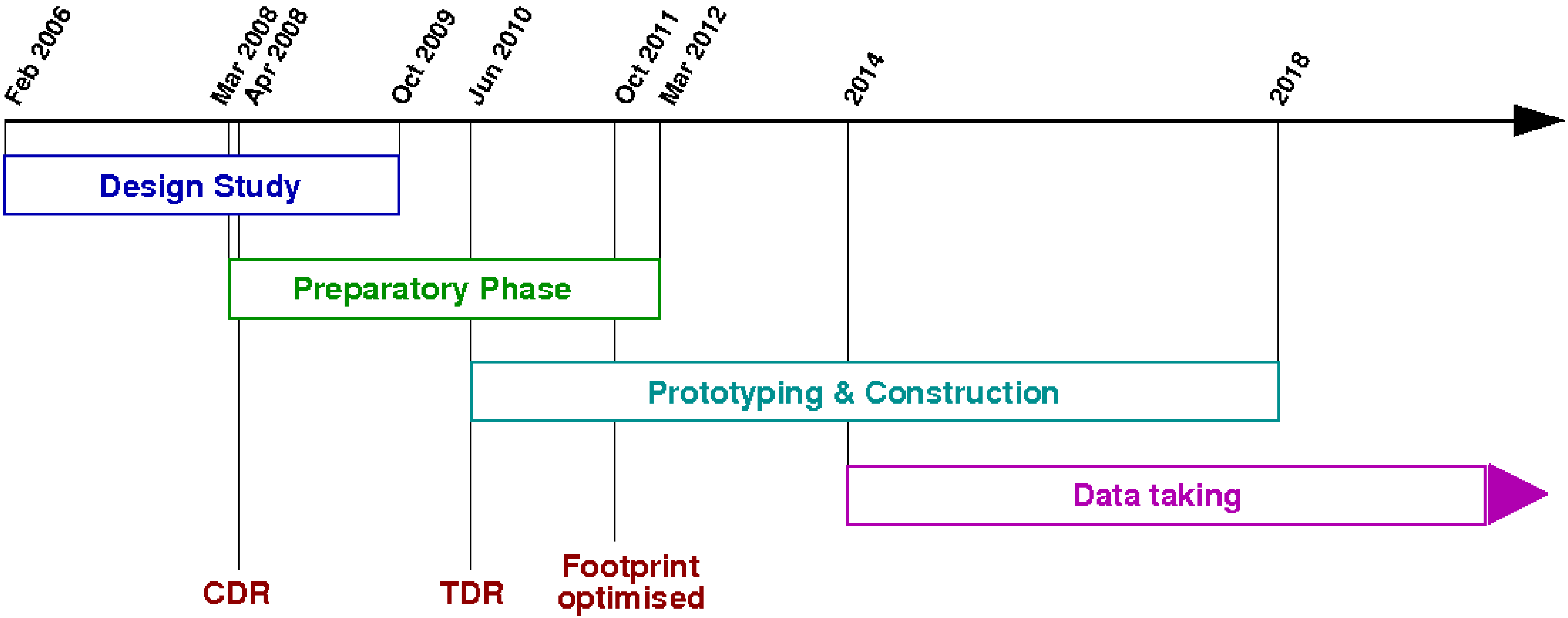
European Physical Society
HEP 2011

OUTLINE

- Physics case & Main objectives
- KM3NeT Design
- Telescope performance
- Conclusions

KM3NeT Project Timeline



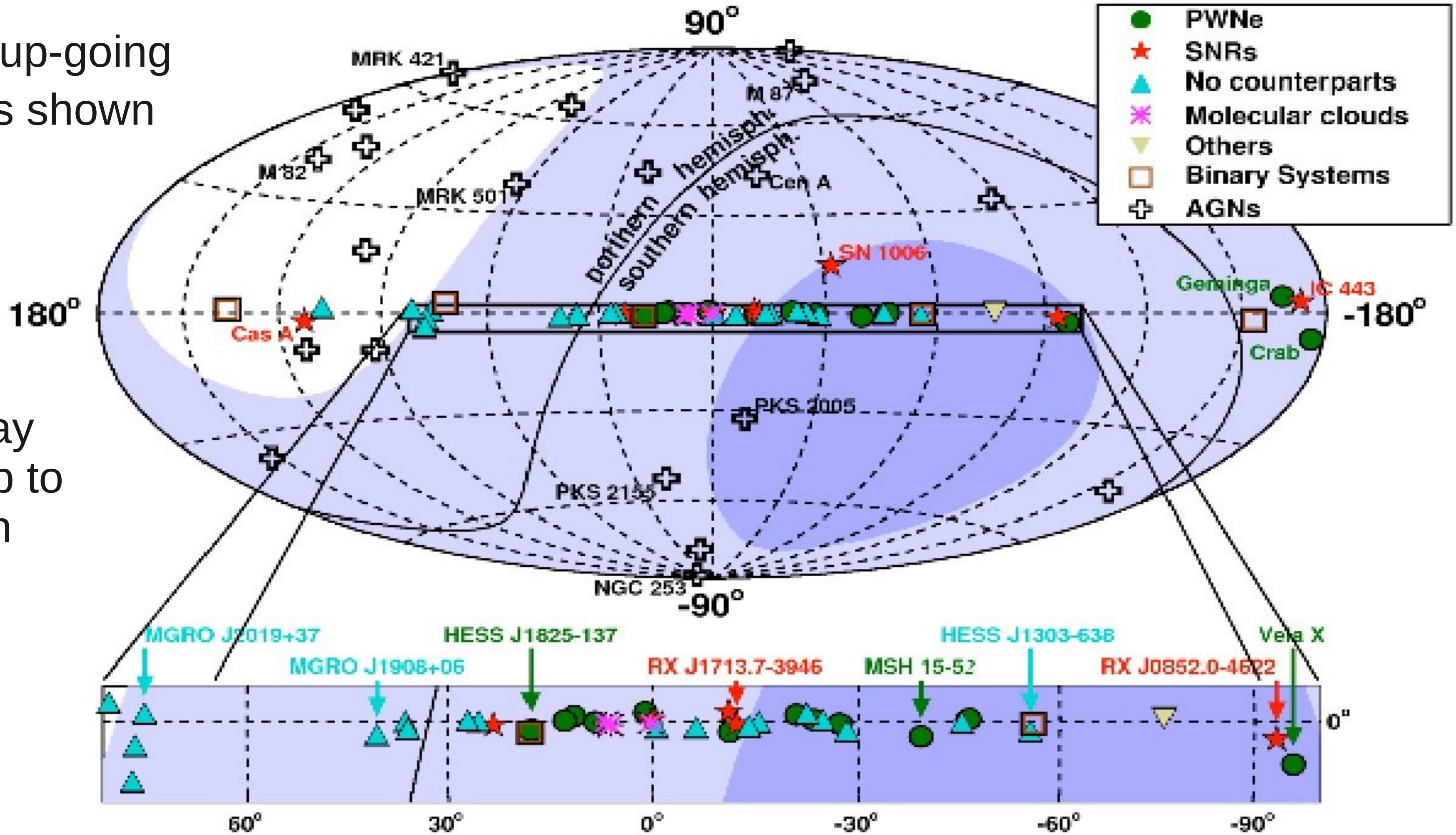
Physics Case & Main objectives

- <u>Main physics goals</u>
- Origin of Cosmic Rays and Astrophysical ν sources
  - Galactic Candidate ν Sources (SNRs, Fermi Bubbles, microquasar,…)
  - Extragalactic Candidate ν Sources (AGN, GRB, …)
  - Diffuse Fluxes
- <u>Implementation requirements</u>
  - Construction time ≤5 years
  - Operation over at least 10 years without “major maintenance”
- <u>Cabled platform for deep-sea research</u>
  - Environmental sciences
  - Geology and geophysics
  - Marine biology and oceanography

Sky view of the KM3NeT

FOV for up-going neutrinos shown

24h per day visibility up to declination δ~-50°



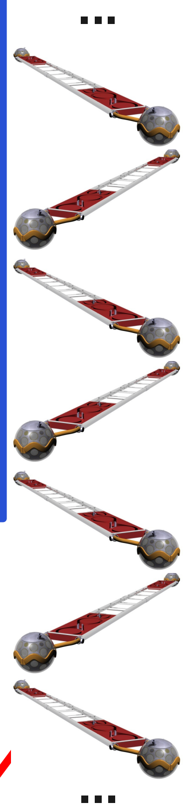
Visibility > 25% of time

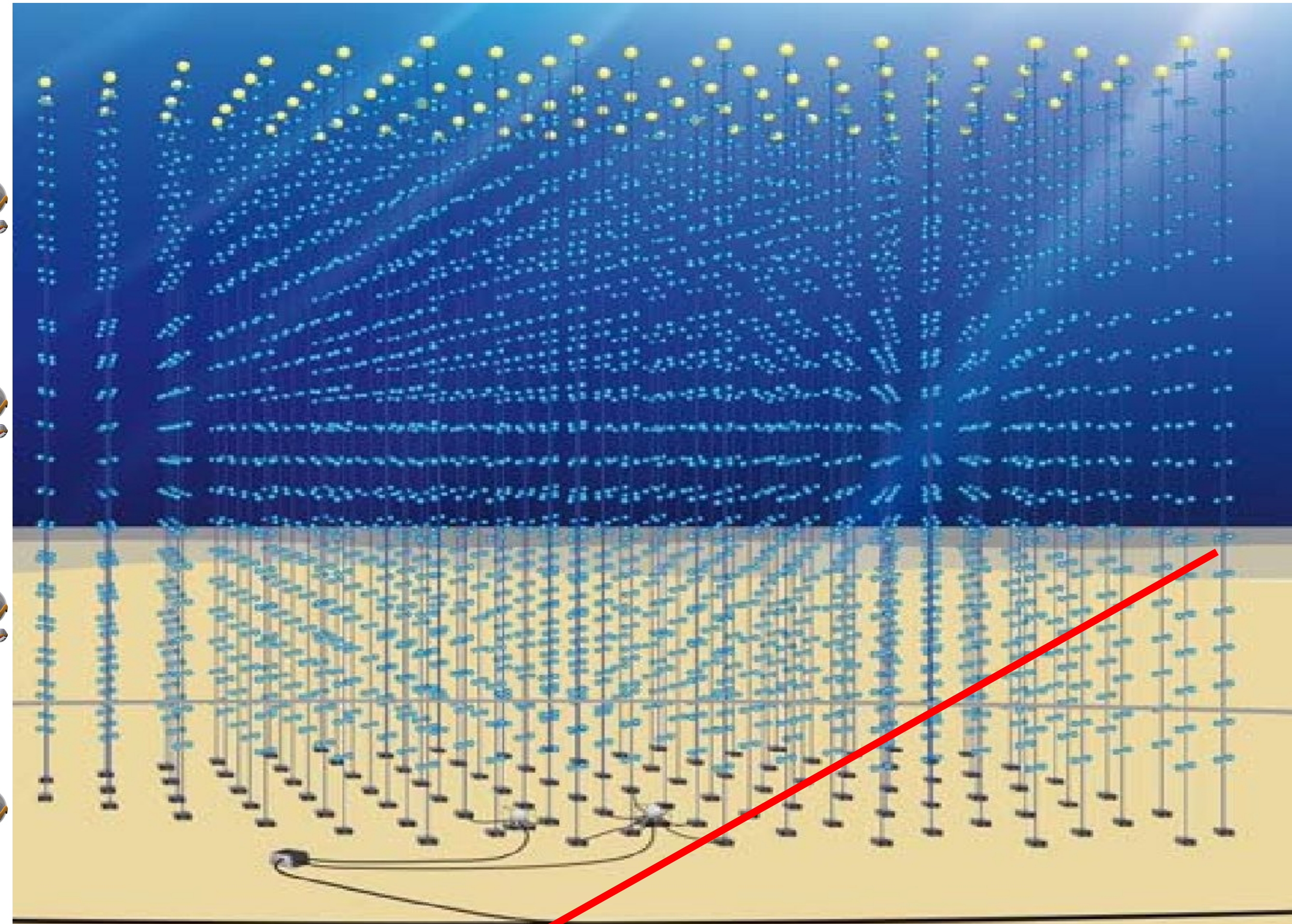
Visibility > 75% of time

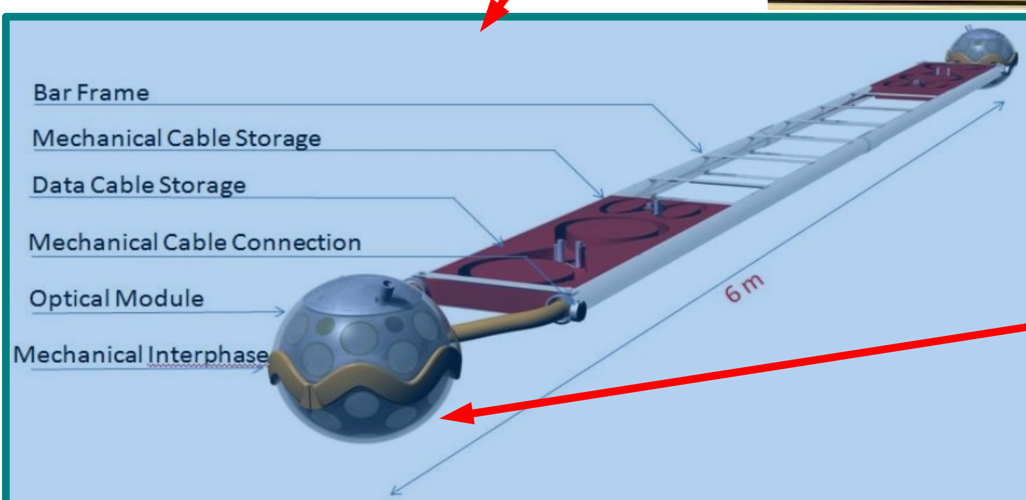
KM3NeT covers most of the sky (87%) including the Galactic Centre

KM3NeT lay-out

KM3NeT in numbers
- ~ 12000 OMs
- ~300 DU
- 20 storey/DU
- ~40m storey spacing
- ~1 km DU height
- ~180m DU distance
- ~5 km³ volume
- ~220 MEuro cost







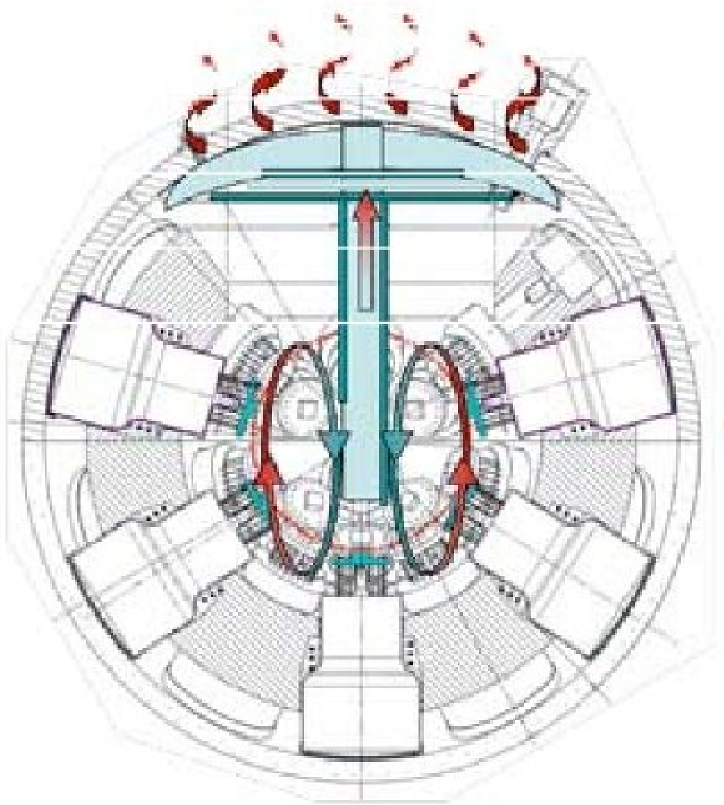
Detection Unit (DU): mechanical structure holding OMs, enviromental sensors, electronics,...

DU is the building block of the telescope

Optical Module (OM): pressure resistant sphere cointaining photo-multpliers

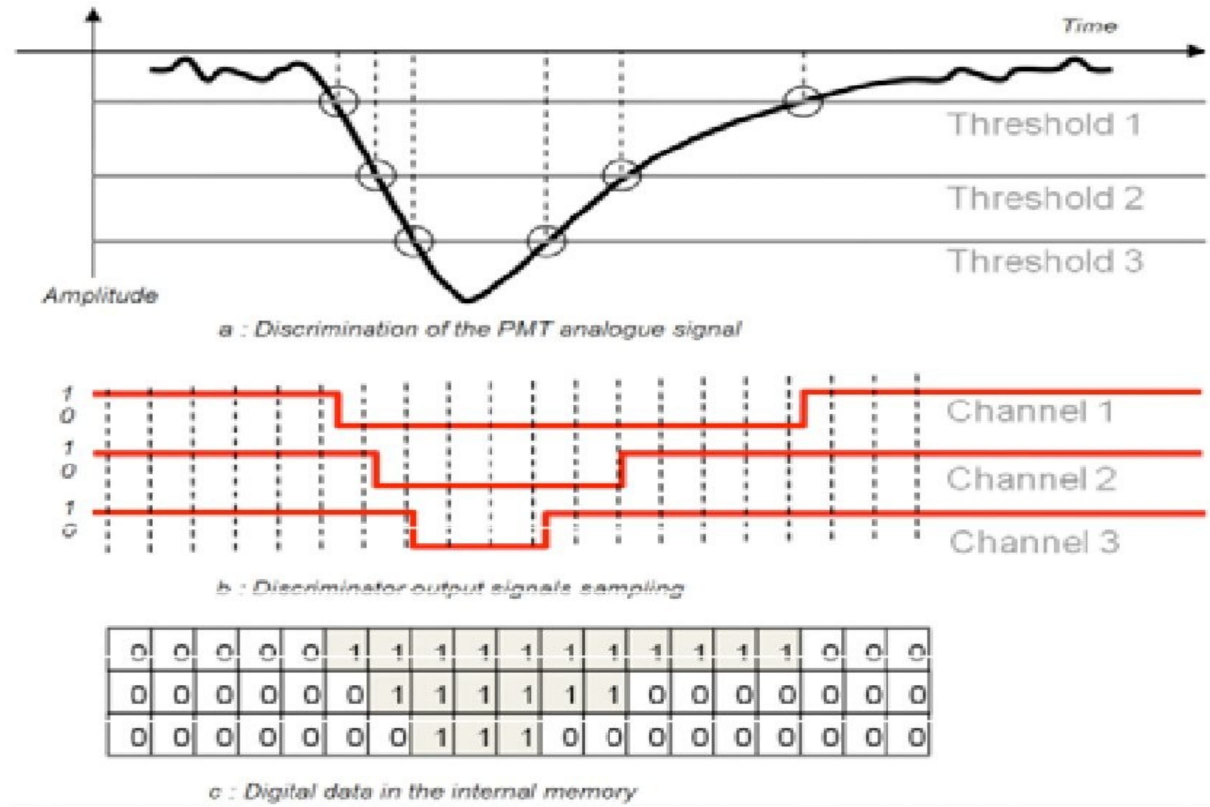
Optical Module - Multi-PMT

- 31 3” PMTs (~30% max QE) inside a 17” glass sphere with 31 bases (total ~6.5W)
- Cooling shield and stem
- First full prototype under test
- Single vs multi-photon hit separation
- Large (1260 cm^2) photocade area per OM

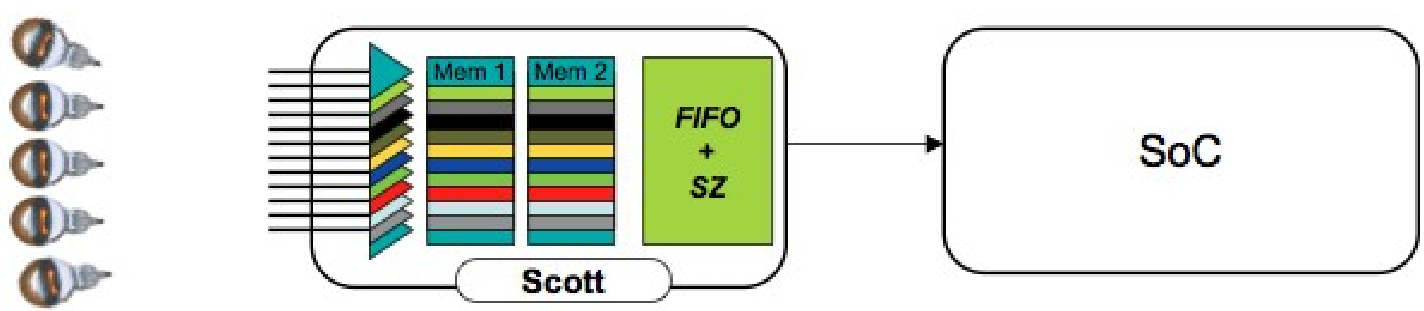


Front End Electronics

- Read-out SCOTT ASIC
  - Time over threshold with adjustable thresholds
  - Digitised output
  - Zero suppression

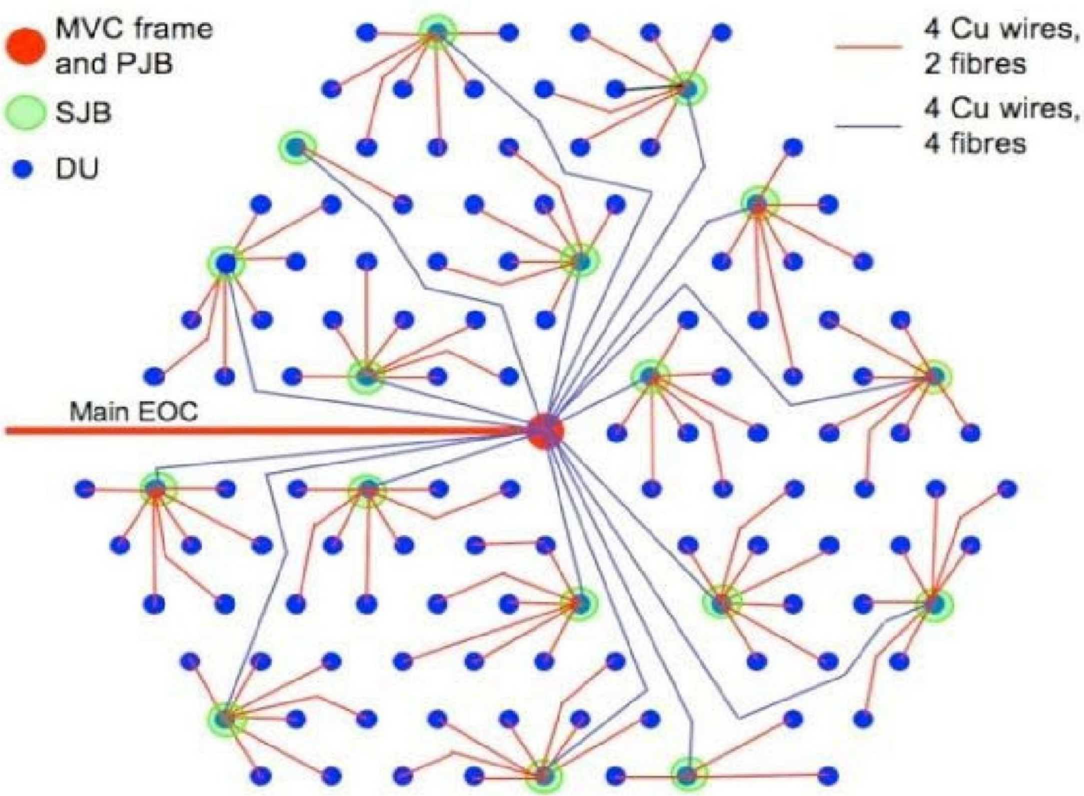


- System on chip
  - FPGA for data buffering and formatting

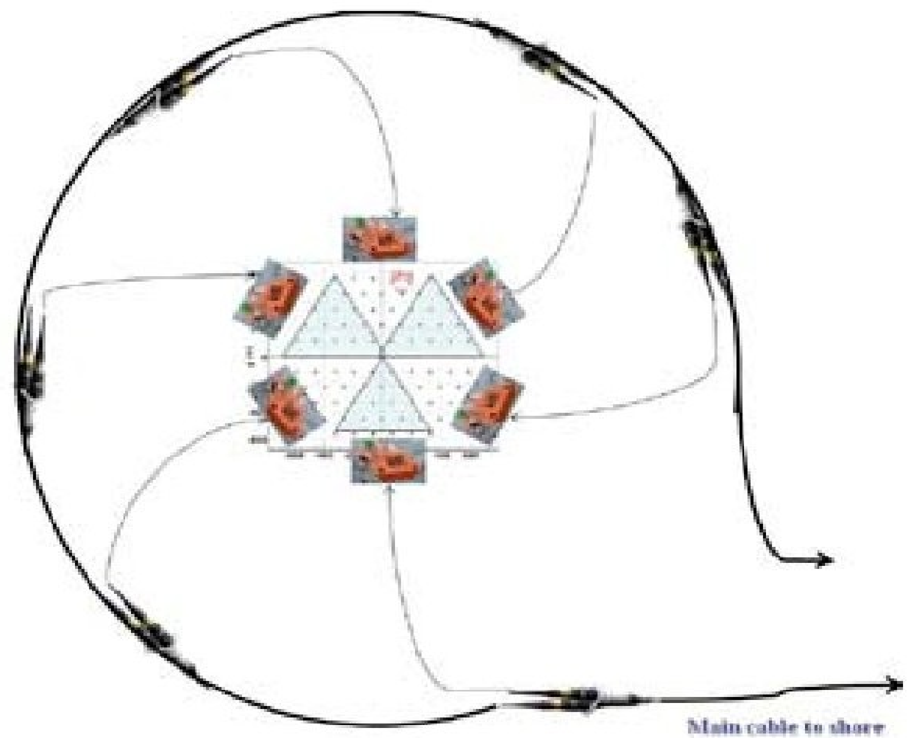


Data Network and transmission

- All data to shore (no trigger undersea)
- Data transport on optical fibers (data, slow control)
- Optical point-to-point connection to shore
- DWDM technique =>minimize numbers of fibers



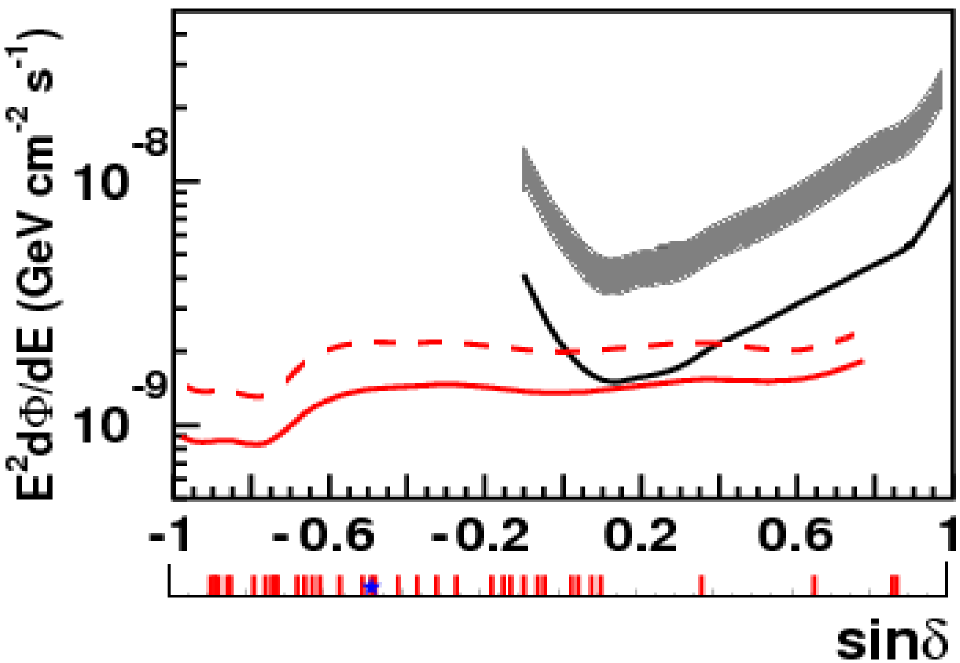
Star layout



Ring layout

Point source Sensitivity & Discovery potential
Full detector (308 DUs)

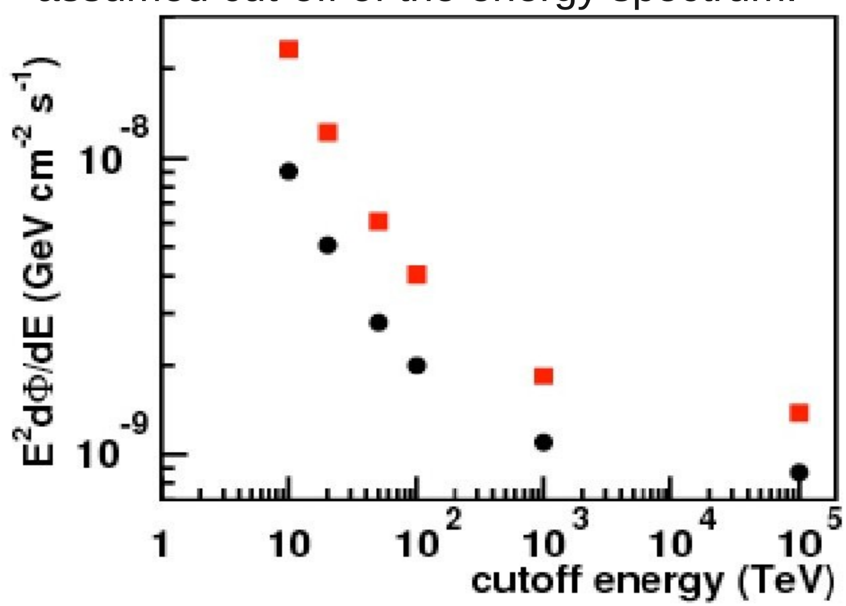
1 year of data taking – E^{-2} ν-spectrum



- KM3NeT sensitivity 90%CL
- KM3NeT discovery 5σ 50%
- IceCube sensitivity 90%CL
- IceCube discovery 5σ 50% 2.5÷3.5 above sensitivity flux. (extrapolation from IceCube 40 string configuration)

|Observed Galactic TeV-g sources (SNR, unidentified, microquazars)
F. Aharonian et al. Rep. Prog. Phys. (2008)
Abdo et al., MILAGRO, Astrophys. J. 658 L33-L36 (2007)
★Galactic Center

flux sensitivity and **discovery flux (5σ, 50% probability)** for point sources at δ=-60° vs the assumed cut-off of the energy spectrum.



Apostolos G. Tsirigotis , HEP 2011

Galactic Candidate ν Sources – SNRs

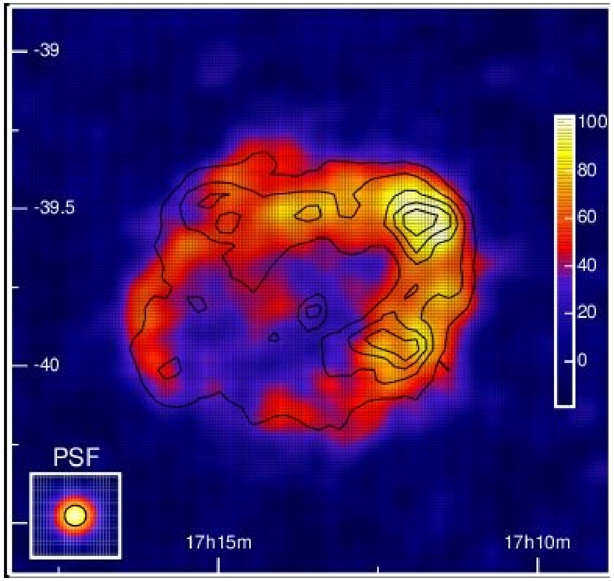
Origin of Cosmic Rays => SNR paradigm

Assuming that VHE γ emmiters are CR accelerators.

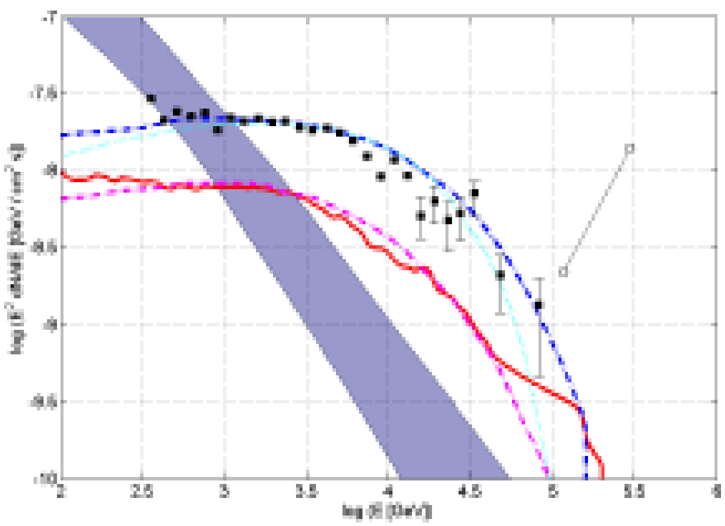
As an example, assuming that the RXJ1713.7-39.46 (the most luminous γ ray source) is a hadron accelerator then the ν spectrum can be calculated from the γ spectrum:

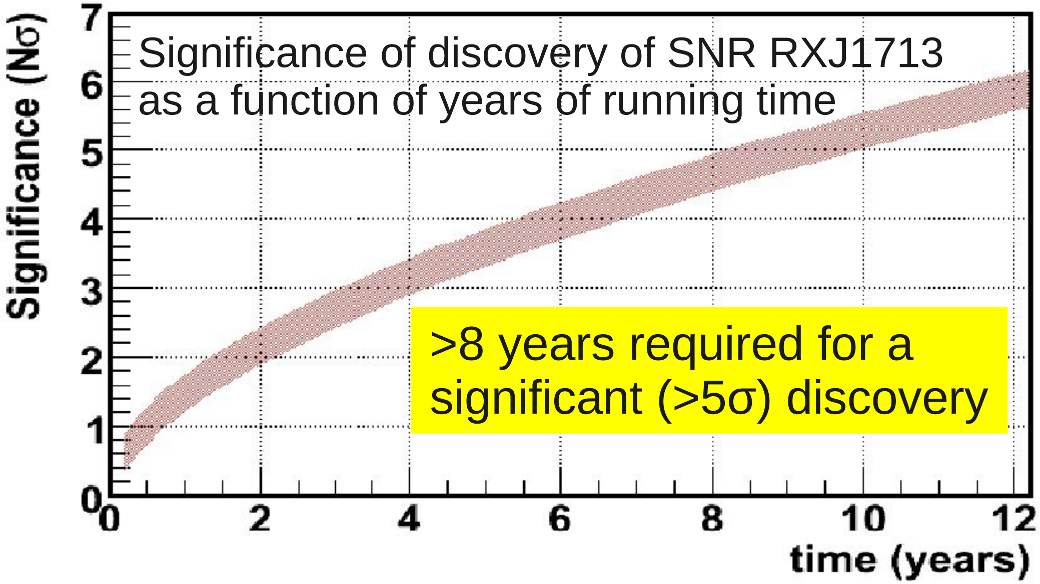
(S.R. Kelner, F.A. Aharonian and V.V. Bugayov Phys. Rev D 74, 034018 (2006))

Hess RXJ1713.7-39.46



$$\Phi(E) = 16.8 \times 10^{-15} \left[\frac{E}{\mathrm{TeV}}\right]^{-1.72} e^{-\sqrt{\frac{E}{2.1\ \mathrm{TeV}}}} \ \mathrm{GeV}^{-1}\,\mathrm{s}^{-1}\,\mathrm{cm}^{-2}$$

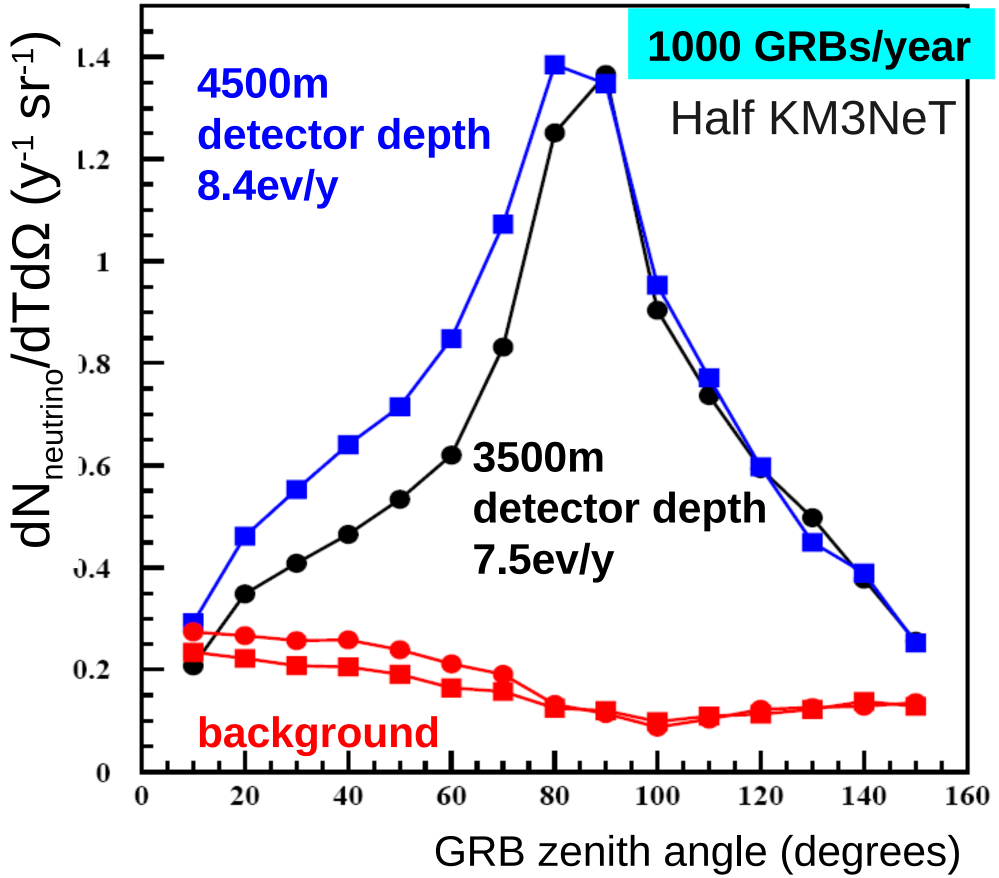




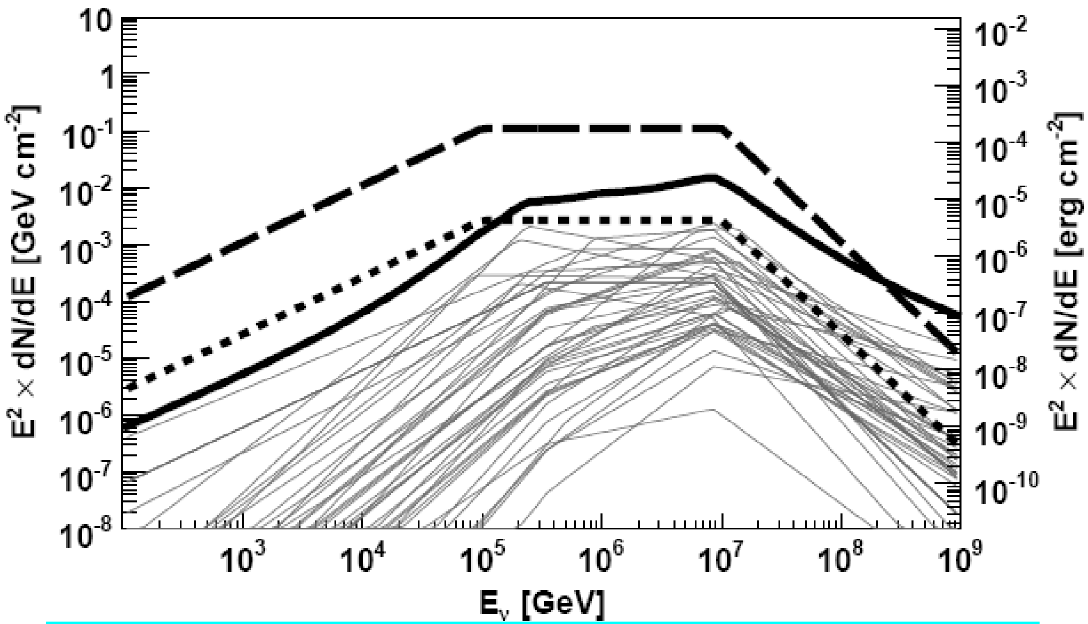
Extragalactic ν Sources – GRBs

- Alert from satellite detectors (known time & direction)
- Short time window (<2h) for GRB prompt neutrino emission
- High energy neutrinos (> 100TeV)
- Application of energy cut on the reconstructed muon energy

} Detection of down-going GRB neutrinos events is feasible



The expected number of detected neutrino events from GRBs per year and steradian.



Expected Neutrino fluence from GRBs
R. Abbasi, et al., IceCube Collaboration, Astrophys. J. 710 (2010) 346

300 GRBs/year (4500m depth) Half KM3NeT

} $\frac{\text{2.5 signal events/year}}{\text{0.45 background events/year}}$

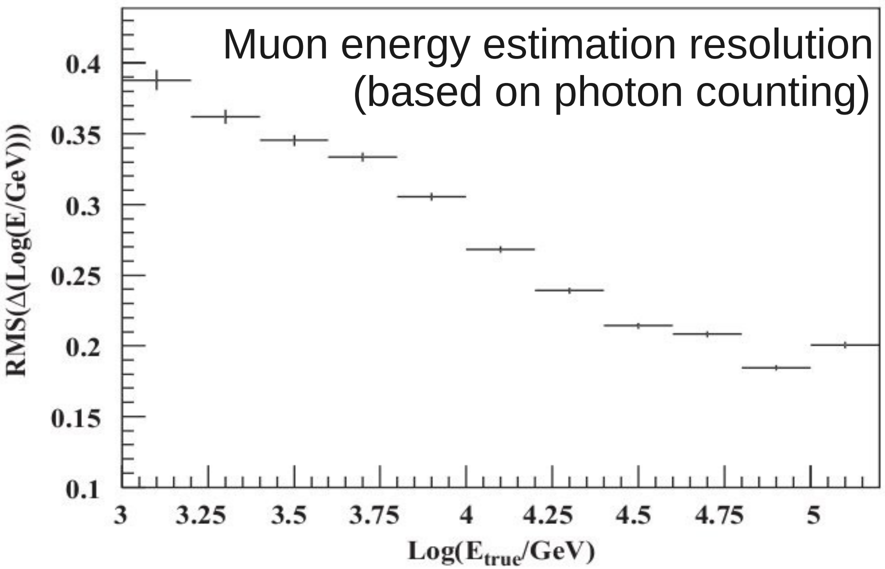
Diffuse Flux ν

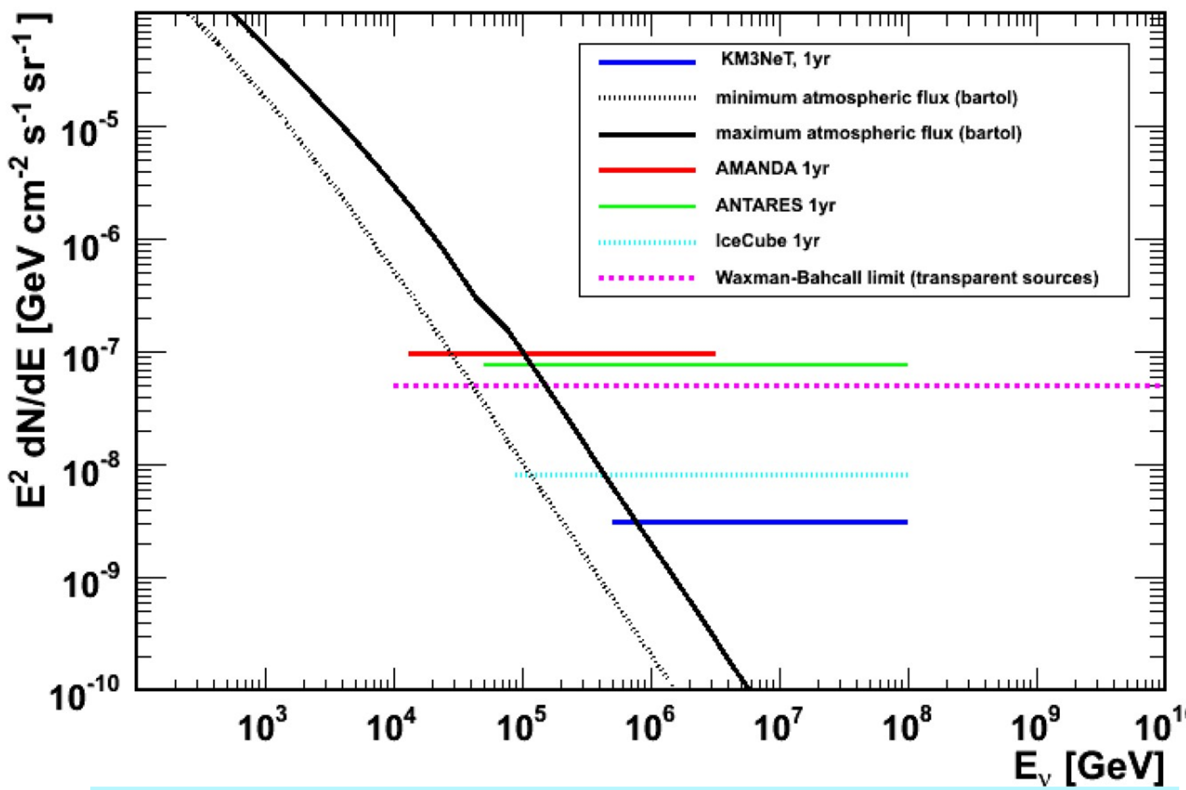
Ultra high energy neutrinos from

- A multitude of objects such as Active Galactic Nuclei or GRBs
- The interaction of cosmic rays with intergalactic matter, radiation, cosmic microwave background

} isotropic diffuse flux

- No tight angular cut for reducing the background of atmospheric neutrinos
- Rely on a cut on the reconstructed muon energy.

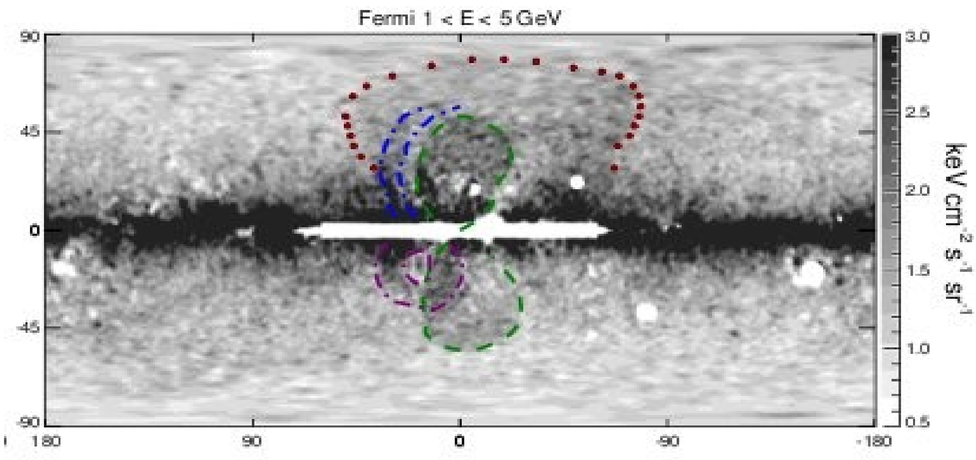


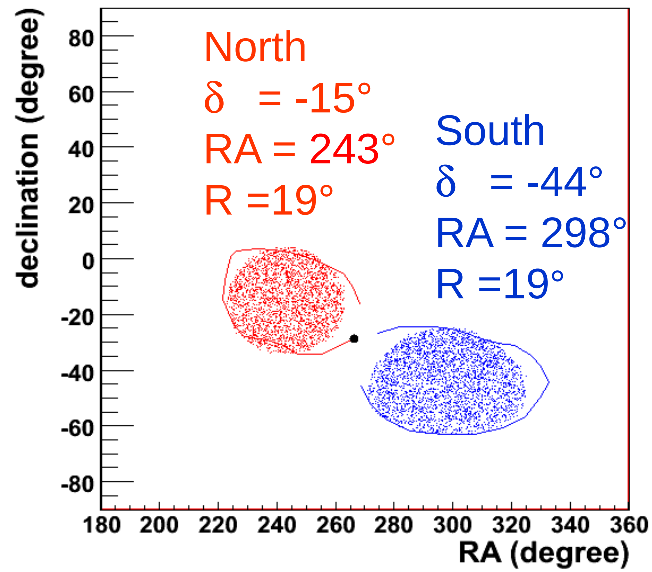


Diffuse flux sensitivity of the KM3NeT neutrino telescope for one year of observation time.

KM3NeT (E^{-2}) diffuse ν flux sensitivity (effective energy cut E_ν > 500 TeV) ⇨ $3 \cdot 10^{-9}$ (GeV^{-1} cm^{-2} s^{-1} sr^{-1})

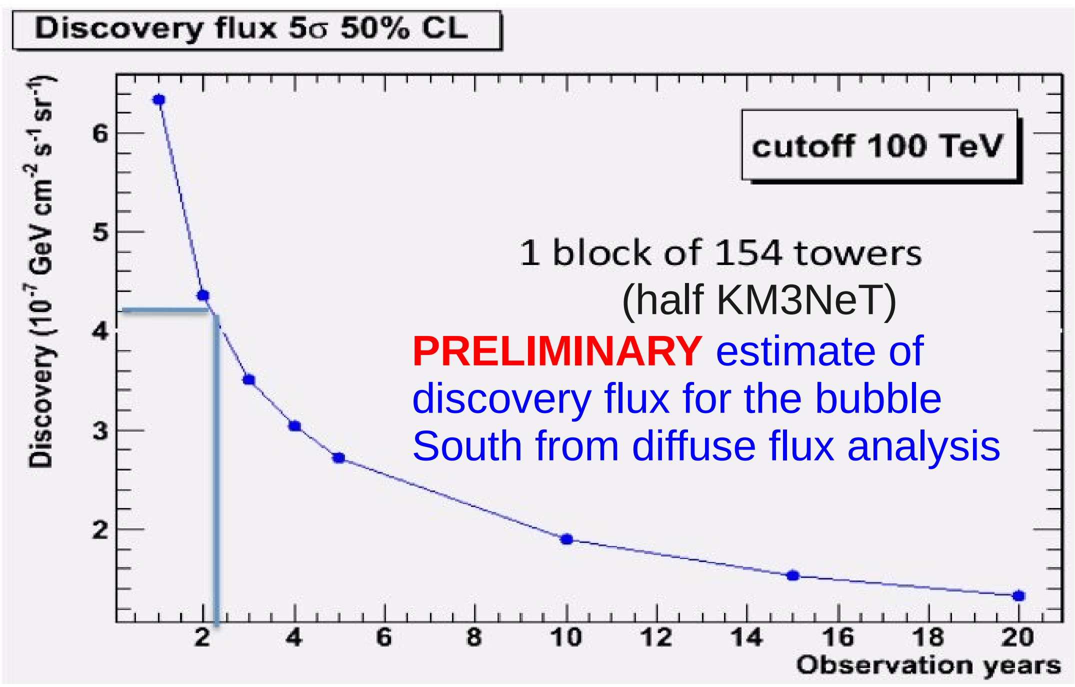
Response of the KM3NeT detector to neutrinos from Fermi bubbles





The expected neutrino flux for one bubble is

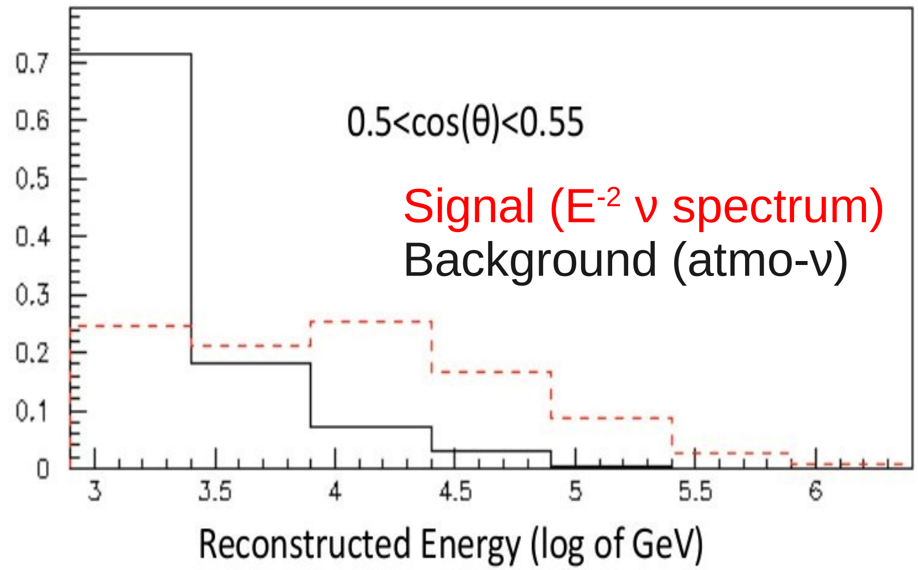
$E^2 F_\nu \sim 4\ 10^{-7}\ GeV^{-1}\ cm^{-2}\ s^{-1}\ sr^{-1}$

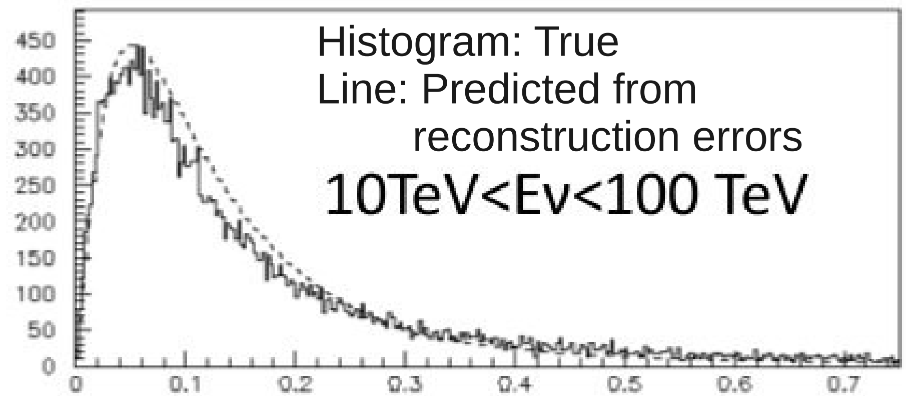


Galactic Candidate ν Sources – Discovery Improvements

Use of the full experimental information on a track by track basis:

- reconstructed muon energy, and
- track resolution (muon reconstruction parameter errors)





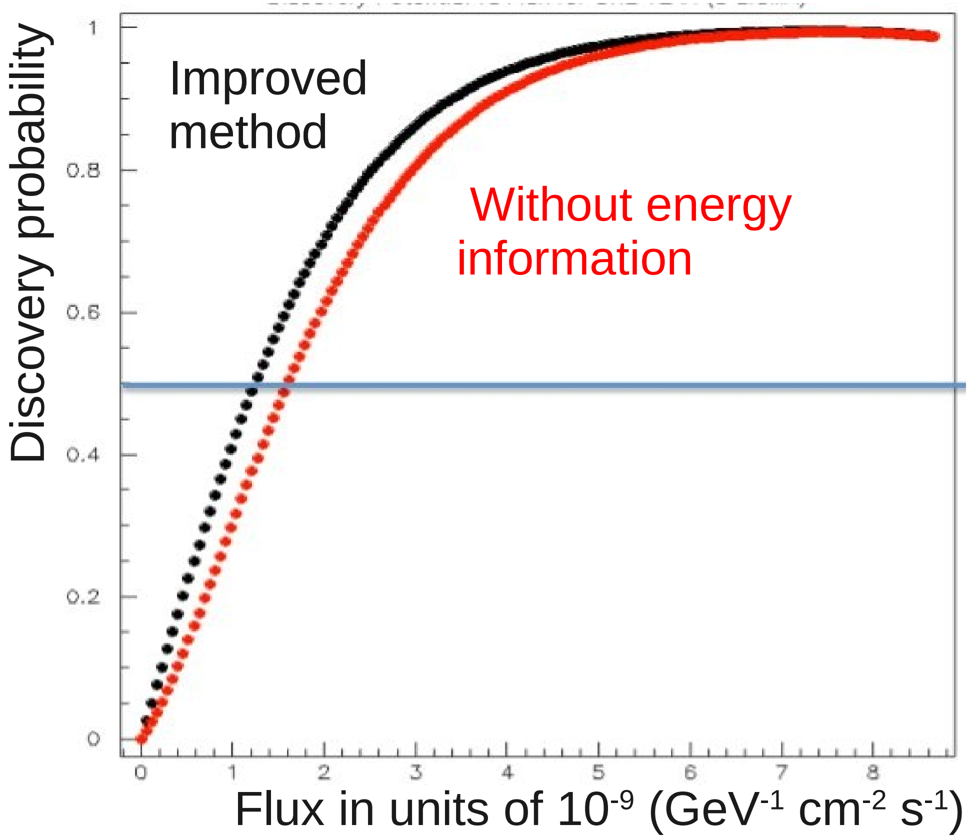
Angle between reconstructed muon track and parent neutrino (Degrees)

Galactic Candidate ν Sources – Discovery Improvements

154 DUs (half KM3NeT)

E^{-2} ν point source at -60° declination

Discovery Potential (3 sigma) vs Flux for one year of data taking

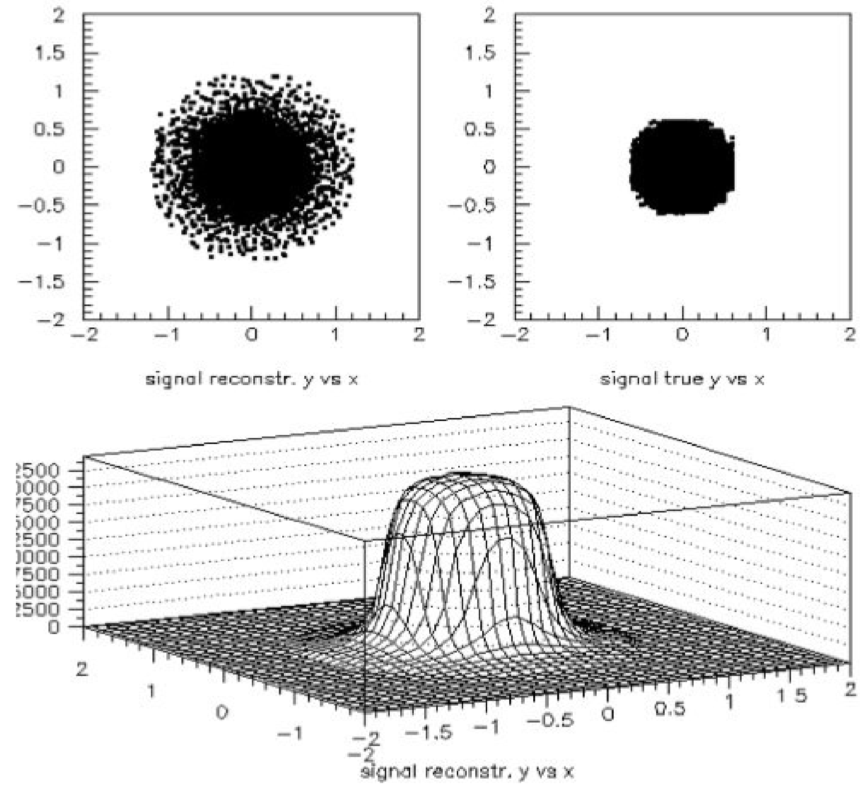


Without energy information: 1.6×10^{-9} (GeV^{-1} cm^{-2} s^{-1})

Using full exp. information: 1.2×10^{-9} (GeV^{-1} cm^{-2} s^{-1})

Binned technique: 2.5×10^{-9} (GeV^{-1} cm^{-2} s^{-1})

RXJ1713.7-39.46 (0.6° angular radius)



1y Discovery potential **WITH** energy and shape

- 3σ : 3.0 x RXJ1713 flux for 50% discovery
- 4σ : 4.1 x RXJ1713 flux for 50% discovery
- 5σ : 5.6 x RXJ1713 flux for 50% discovery

1y Discovery potential **WITHOUT** energy and shape

- 3σ : 3.7 x RXJ1713 flux for 50% discovery
- 4σ : 4.6 x RXJ1713 flux for 50% discovery
- 5σ : 7.2 x RXJ1713 flux for 50% discovery

Conclusions

- KM3NeT will cover most of ν sky with unprecedented sensitivity ⇨ Promising Galactic Candidate ν Sources
- KM3NeT-Preparatory Phase ongoing ⇨ Final design and prototyping activities in progress
- Discovery potential for Galactic Candidate ν Sources can be further improved using the reconstructed energy estimation, the angular resolution on a track by track basis and the application of advanced filters using the known source's direction

Acknowledgments
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