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ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

# KM3NeT/ARCA sensitivity to a diffuse flux of cosmic neutrinos

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## KM3NeT/ARCA (Astroparticle Research with Cosmics in the Abyss)

KM3NeT is a future research infrastructure hosting the next-generation underwater neutrino observatory in the Mediterranean Sea. Within KM3NeT, ARCA is planned as an intermediate step devoted to the observation of neutrinos both in diffuse (this poster) and in point-source mode [1].

**Sensitivity to diffuse neutrino flux:**

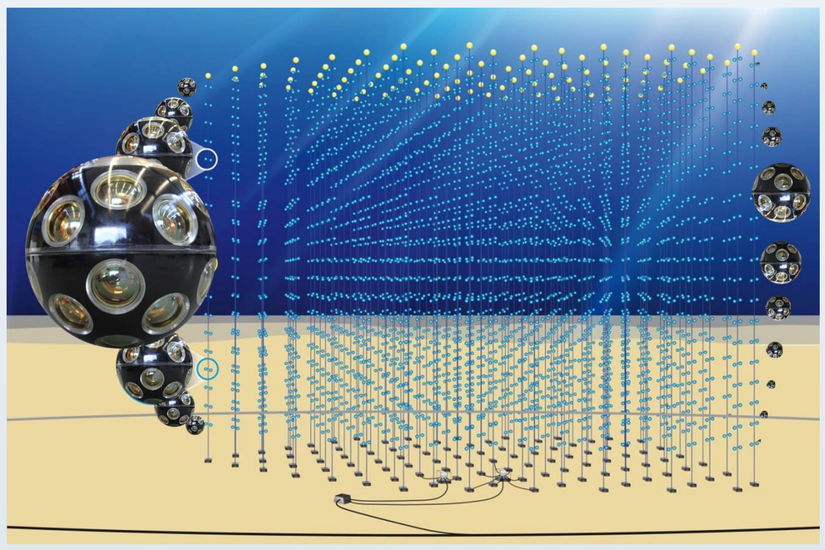
- cut-and-count procedures developed to get a high purity event sample (based on simple decision an event being accepted or not) → allows detailed investigation of surviving high-quality events
- final sensitivity via maximum likelihood method at earlier cut stages

**ARCA detector:**

- total of 1 km$^3$ instrumented volume
- 2 detector blocks
- 115 strings per block
- 18 DOMs per string
- 31 PMTs per DOM

**Full KM3NeT detector:**

- total of 3 km$^3$ instrumented volume
- 6 detector blocks
- includes ORCA (Oscillation Research with cosmics in the abyss [2])



Artist's impression of a KM3NeT/ARCA detector block.

## Signal, Background and Simulation

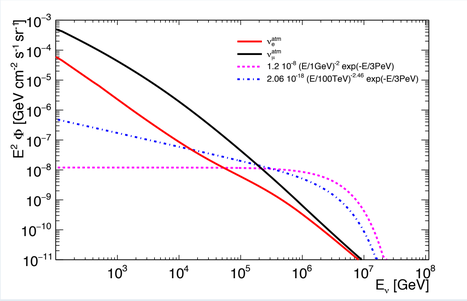
**Signal:**

- diffuse cosmic neutrino flux as discovered and reported by the IceCube collaboration [3] with a cut-off added at 3 PeV:

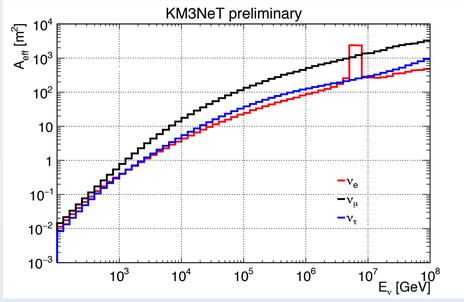
$$E_\nu^2 \frac{d\Phi(E_\nu)}{dE_\nu} = 1.2 \cdot 10^{-8} e^{-E_\nu/3\mathrm{PeV}} \ \mathrm{GeV\ cm^{-2} s^{-1} sr^{-1}}$$

**Background:**

- atmospheric muons
- conventional atmospheric neutrinos (Honda et al. [4])
- prompt atmospheric neutrinos (Enberg et al. [5])



Signal and background neutrino fluxes.




All-sky averaged effective area at trigger level.

**Simulation:**

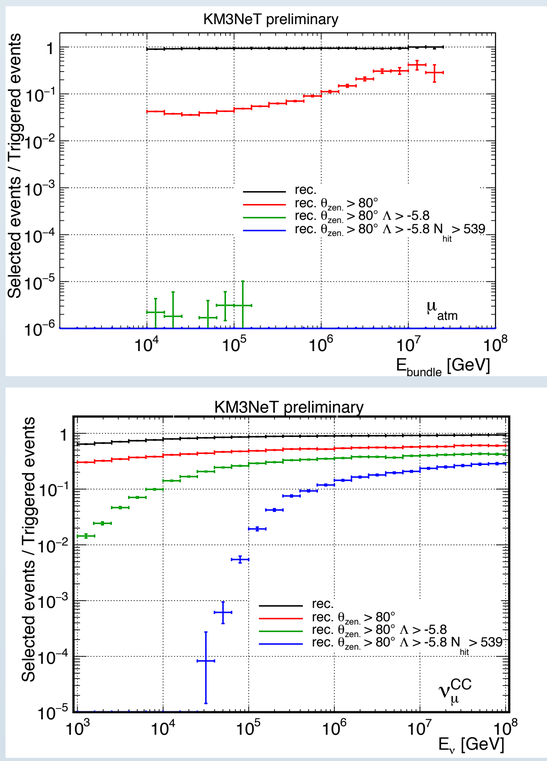
- event generation: $\nu_e$, $\nu_\mu$, $\nu_\tau$, NC + CC, atmospheric $\mu$
- secondary particle and light propagation
- $^{40}$K background, triggering → effective area at trigger level
- event reconstruction [6,7]

## Cut-and-Count – Track Channel

- sensitive to $\nu_\mu$ and $\nu_\tau$ CC track events

**cut procedure to isolate signal events:**

- cut on reconstructed zenith angle to remove atmospheric muons: $\theta_{zen} > 80°$
- cut on $N_{hit}$ and reconstruction parameter $\Lambda$ to reject atmospheric neutrinos and misreconstructed atm. muons [7]
- MDP minimisation to find optimal cuts:
  - $\Lambda > -5.8$
  - $N_{hit} > 539$
- after final cuts:
  - no atmospheric muons left
  - 5.4 background events per year
  - 7.6 signal events per year



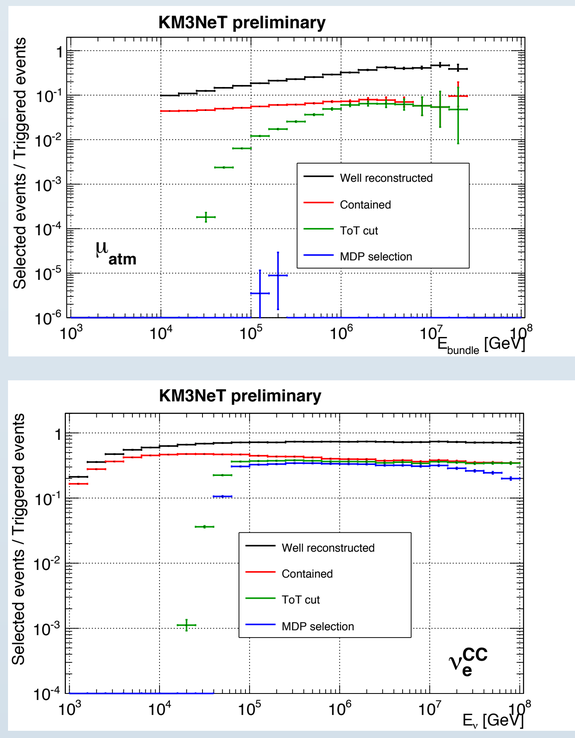

Cut efficiencies at each cut stage for atmospheric $\mu$ (top) and $\nu_\mu$ CC events (bottom).

## Cut-and-Count – Shower Channel

- sensitive to NC events of all flavours and $\nu_e$ and $\nu_\tau$ CC shower events

**cut procedure to isolate signal events:**

- containment cut to remove through-going tracks: R < 500 m, z < 200 m
- charge related cut to remove low-quality and low-energy events: 'total sum of PMT response times' = ToT > 12 $\mu$s
- MDP minimisation for final cut, uses:
  - machine learning algorithm: output parameter $\rho > 0.5$
  - reconstructed energy: $E_{rec} > 50$ TeV
- after final cuts:
  - 8.4 background events per year
  - 16.1 signal events per year




Cut efficiencies at each cut stage for atmospheric $\mu$ (top) and $\nu_e$ CC events (bottom).

## Sensitivity to diffuse flux of cosmic neutrinos

A maximum likelihood method is performed to get to the final sensitivity (figure on the right). Signal and background distributions are used as input for the likelihood as probability distribution functions (PDFs).

**Track channel:**

- model PDF from signal and background $N_{hit}$ distributions after $\theta_{zen}$ and $\Lambda$ cut
- significance of 4.0 $\sigma$ after one year with 50 % detection probability

**Shower channel:**

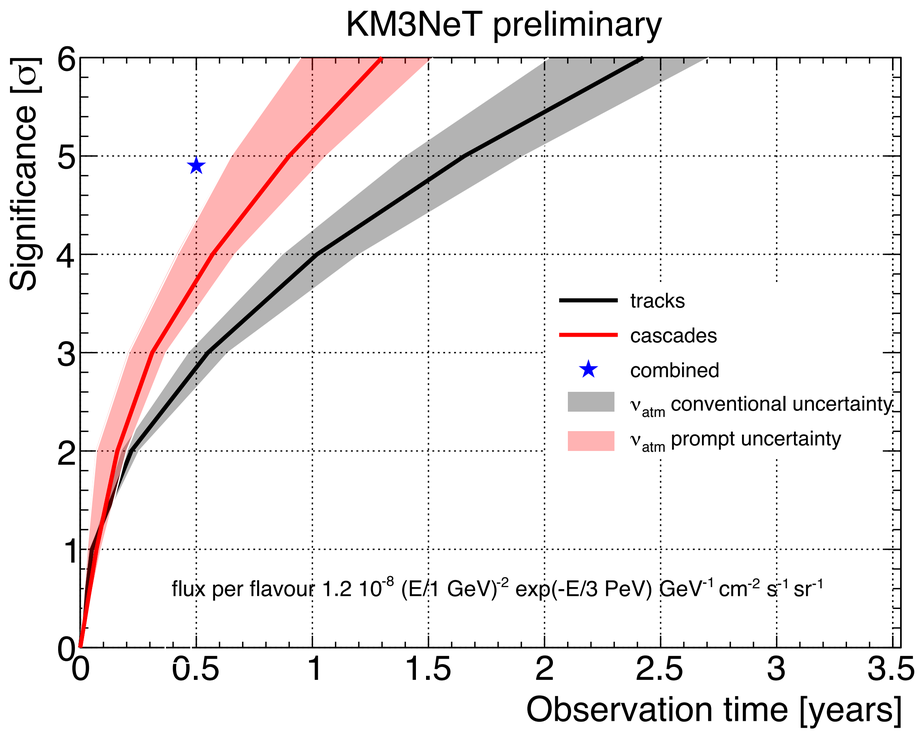
- model PDF from signal and background distributions in $\rho$ and $E_{rec}$ after containment and ToT cut
- significance of 5.3 $\sigma$ after one year with 50 % detection probability

**Combined track and shower channel:**

- both channels almost independent – 2 % overlap in final event samples
- final sensitivity equivalent to combination of individual results
- significance of 4.8 $\sigma$ after half a year with 50 % detection probability

**Systematic uncertainties:**

- all relevant uncertainties are considered in the analyses
  - only minor impact from detector uncertainties
  - conventional atmospheric neutrino flux as major impact for track channel
  - prompt atmospheric neutrino flux as major impact for shower channel




References:
[1] A. Trovato et al., for the KM3NeT Collaboration, proceedings of this conference ID 1113.
[2] J. Brunner et al., for the KM3NeT Collaboration, proceedings of this conference ID 1140.
[3] M. G. Aartsen et al. (IceCube Coll.), 2013 Science 3421242856.
[4] M. Honda et al., Phys. Rev. D 75 043006 (2007).
[5] R. Enberg et al., Phys. Rev. D 78 043005 (2008).
[6] D. Stransky et al. for the KM3NeT Collaboration, proceedings of this conference ID 1108.
[7] A. Trovato et al. for the KM3NeT Collaboration, proceedings of this conference ID 1114.

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