GDR Neutrino 2018 - Paris, 11-12 June

Atmospheric Neutrino Oscillations with ANTARES
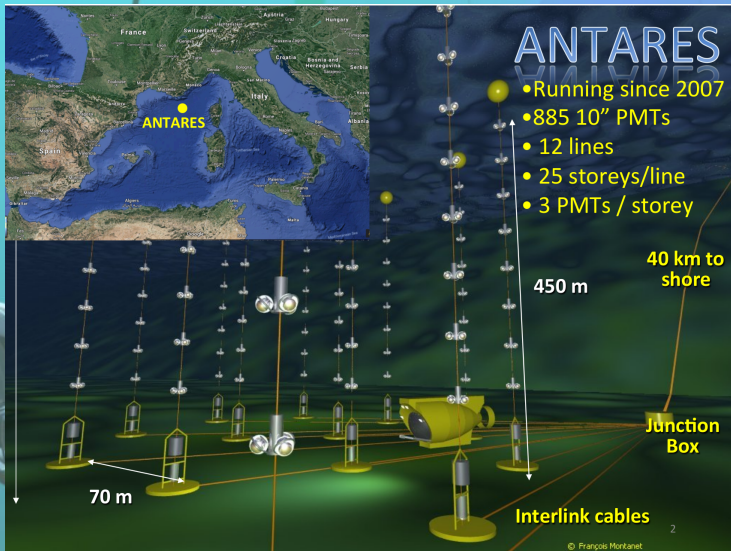
Status & Prospects for KM3NeT/ORCA

Ilenia Salvadori
(on behalf of the ANTARES & KM3NeT collaborations)

Outline

- The ANTARES neutrino telescope;

- Neutrino Oscillations with ANTARES;

- Sterile neutrino constraints with ANTARES;

- KM3NeT: the new generation of neutrino telescopes in the Mediterranean Sea;

- KM3NeT/ORCA.

The ANTARES neutrino telescope

ANTARES

- Running since 2007
- 885 10" PMTs
- 12 lines
- 25 storeys/line
- 3 PMTs / storey

450 m

40 km to shore

Junction Box

Interlink cables
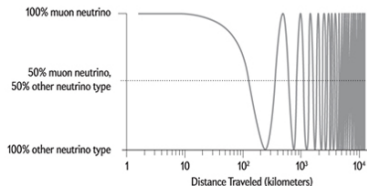
70 m

© François Montanet

The ANTARES neutrino telescope

- Optimized for detection of high energy neutrinos;
- Searches for (extra-)galactic sources;
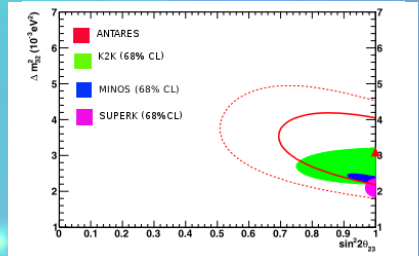- Multimessenger astronomy.

- Low energy threshold $\sim 20\,\text{GeV}$;
- First oscillation minimum for vertically up-going ν_μ is detectable;
- Neutrino oscillation studies are possible!
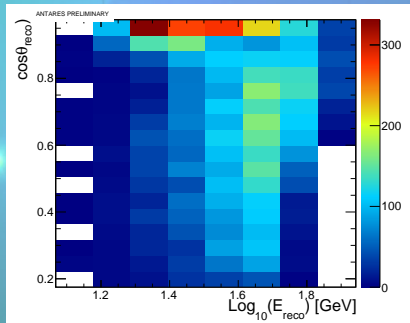
Neutrino Oscillations with ANTARES

- Previous analysis done in 2012;
- 3 years of ANTARES data;
- Simplified systematic treatment;
- 1-dim χ^2 fit in E/L.

- Much more data are available now;
- Refinements in the analysis chain are possible;
- A new analysis has been done!

Neutrino Oscillations with ANTARES

- 2830 days of lifetime (2007-2016);
- Track channel only;
- 2 track reconstructions combined;
- E_{reco} estimated from muon range;
- 7710 selected events;
- 2-dim fit in $\log_{10} E_{reco}$ and $\cos \theta_{reco}$;
- Log-likelihood approach.

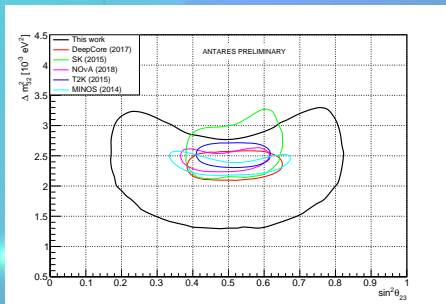# Neutrino Oscillations with ANTARES
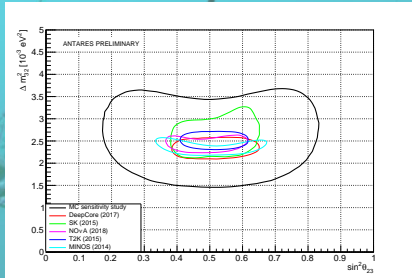
MC sensitivity (90% CL)!

- Free normalization for neutrinos;
- Spectral index correction;
- Flux ratio uncertainty (from Barr et al. and parametrized by IceCube);
- Cross-section systematic (calculated with GENIE);
- Atmospheric muon bkg extrapolated from data and fitted with a prior;
- MC sensitivity study done to optimize the analysis chain.

Neutrino Oscillations with ANTARES
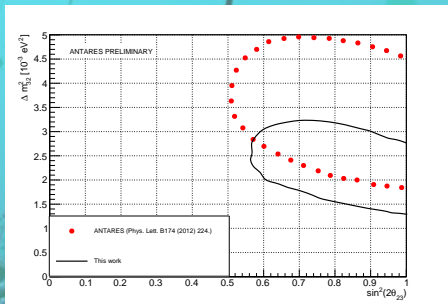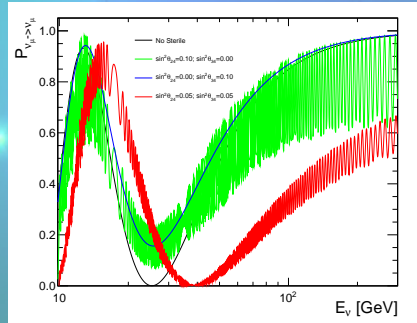

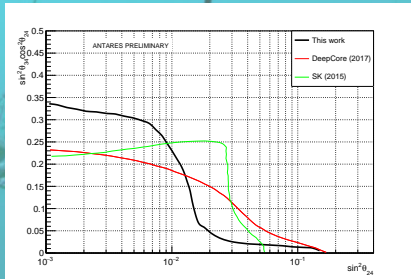**Results at 90% CL**   **Results at 90% CL**

- Best fit for θ_{23} found compatible with maximal mixing;
- $\Delta m_{32}^2 = 2.0 \times 10^{-3}$ eV^2;
- Non-oscillation hypothesis discarded at 4.6σ (vs 2.2σ of previous analysis).

Sterile neutrino constraints with ANTARES

- Sterile neutrinos have been hypothesized and could explain some observed anomalies;

- A ν_s would modify the *standard* oscillation probability;

- At $E_\nu \sim 20\text{-}30$ GeV the effect is regulated by θ_{24} and θ_{34};

- The same data set as for the oscillation analysis can be used to constraint these parameters.

# Sterile neutrino constraints with ANTARES

Results at 99% CL

- Δm_{32}^2 and θ_{23} are treated with a prior;

- Atmospheric muon contamination is fixed at the the BF found in the oscillation analysis;

- Other systematic are treated as in the oscillation analysis;

- One of the sterile phase (δ_{24}) is fitted.

KM3NeT: the new generation of neutrino telescopes in the Mediterranean Sea

- 15 Countries;
- >40 Institutions;
- >220 Scientists.
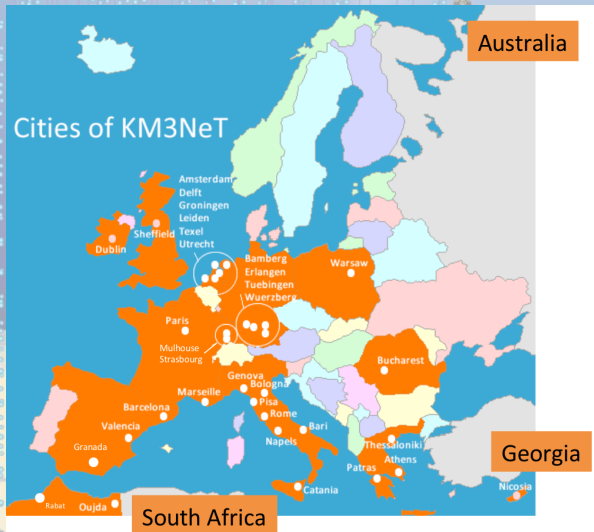
KM3NeT: the new generation of neutrino telescopes in the Mediterranean Sea
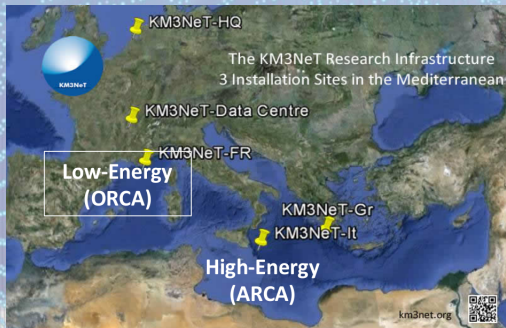
Single...
- Collaboration;
- Technology;
- Management

Multiple...
- Sites (France, Italy, Greece);
- Purposes

- ORCA: low-energy studies (ν mass hierarchy, oscillations, SN)
- ARCA: high-energy studies (origin of cosmic neutrinos).

# KM3NeT: the new generation of neutrino telescopes in the Mediterranean Sea

	ORCA	**ARCA**
STRINGS	115	2×115
DOMs/STRING	18	18
PMTs/DOM	31	31
STRING SPACING	23 m	90 m
DOMs SPACING	9 m	36 m
DEPTH	2470 m	3500 m
INSTRUMENTED MASS	8 Mton	0.6×2 Gton

KM3NeT/ORCA – Effective Mass

- After trigger, atmospheric μ rejection and soft containment cuts;

- Energy threshold determined by DOMs spacing;

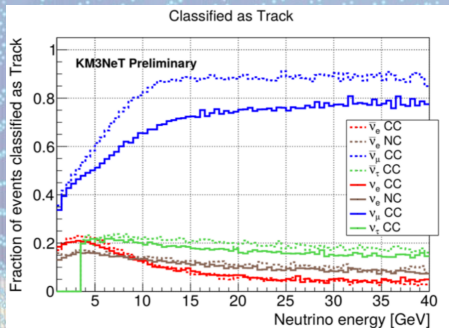- 8 Mton @10 GeV for ν_μ CC;

- 50% efficiency at 5 GeV
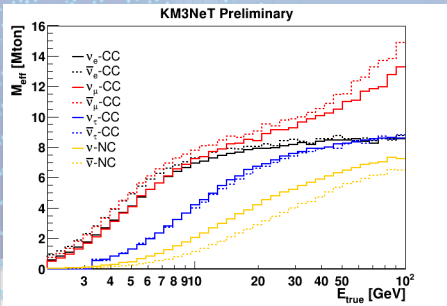
KM3NeT/ORCA - Angular and Energy Resolutions
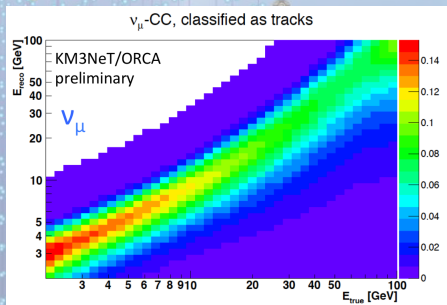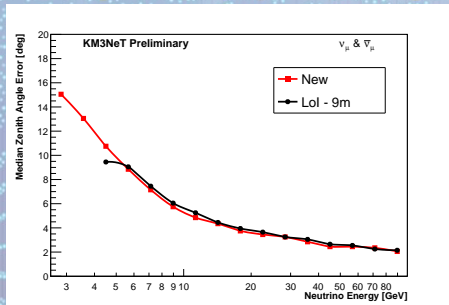
- Median angular error $< 5°$ @ 10 GeV;

- Energy resolution better than 30% in relevant range;
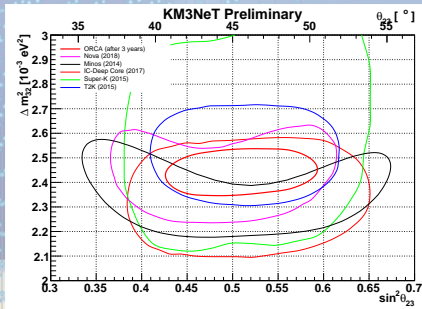
- The shape is close to Gaussian.

KM3NeT/ORCA - Shower/Track Identification

- Discrimination based on Random Decision Forest;

- 90% corrected identification of ν_e CC @10 GeV;

- 70% corrected identification of ν_μ CC @10 GeV.
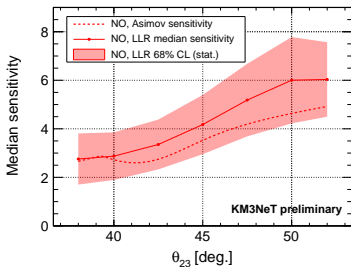
KM3NeT/ORCA - Neutrino Oscillations

- After 3 years of data taking;

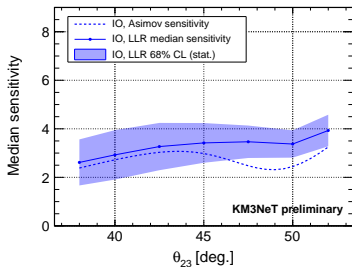- 90% CL contours;

- Expected 5% error in θ_{23} and 2% in Δm_{32}^2.

KM3NeT/ORCA - Neutrino Mass Hierarchy

Asimov and LLR median sensitivity after 3 years, $\delta_{CP} = 0$

- NO, Asimov sensitivity
- NO, LLR median sensitivity
- NO, LLR 68% CL (stat.)

KM3NeT preliminary

Asimov-LLR comparison: Median sensitivity ($\delta_{CP} = 0$)

- IO, Asimov sensitivity
- IO, LLR median sensitivity
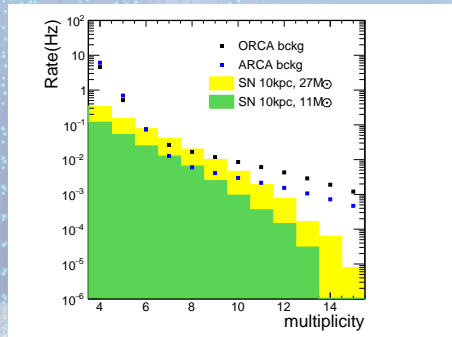- IO, LLR 68% CL (stat.)

KM3NeT preliminary

- After 3 years of data taking;

- Two methods tested: Asimov approach and LLR;

- $>3\sigma$ for the most optimistic scenario (NO, $\theta_{23} > 45°$).

KM3NeT/ORCA - ν_τ APPEARANCE
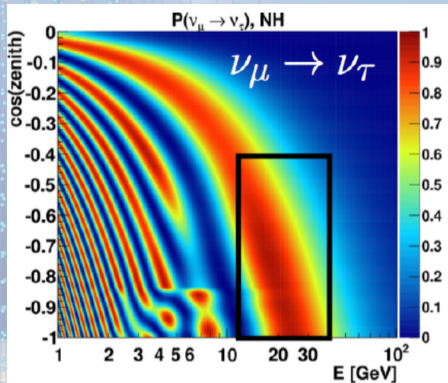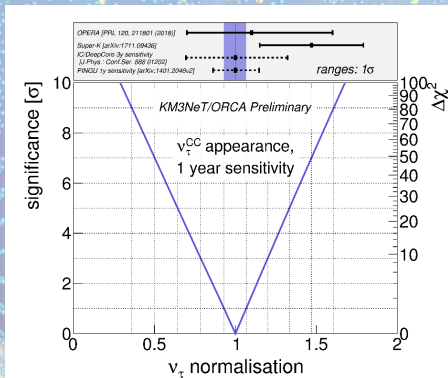
- ~ 3000 ν_τ CC events/year detected;
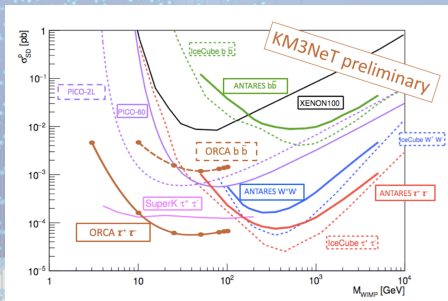- Rate constrained within 10% after 1 year.

KM3NeT/ORCA - Super Novae Detection

- Look for an excess of coincidence signals on individual OMs;
- >80% of galactic SN with single building block.

KM3NeT/ORCA - Dark Matter

- After 3 years of ORCA data;

- Combining tracks and showers;

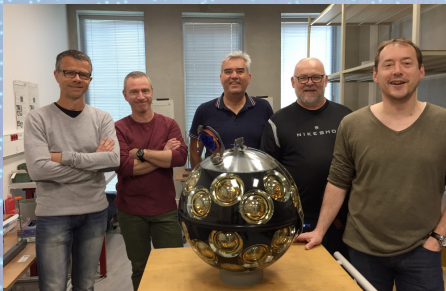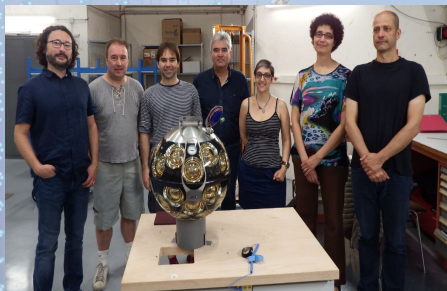- Competitive for spin-dependent coupling.

KM3NeT/ORCA - Status

- Construction has started;
- The first line has been deployed in 2017;
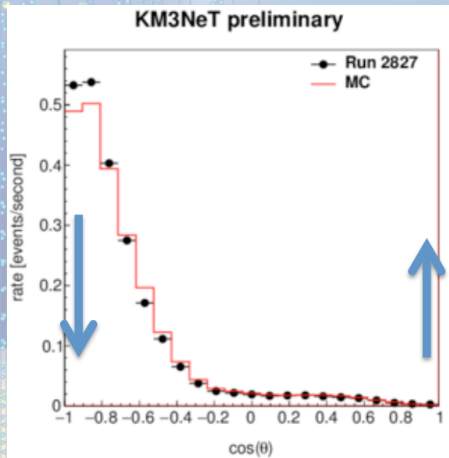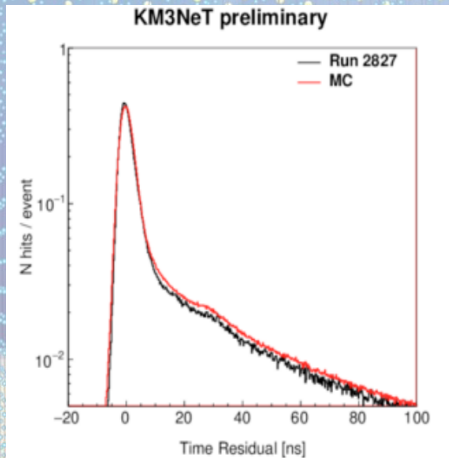- Several new lines are expected to be deployed after summer.

KM3NeT/ORCA - Status

Subatech-Nantes   **IPHC-Strasbourg**

- 2 dedicated sites in France for DOMs production;
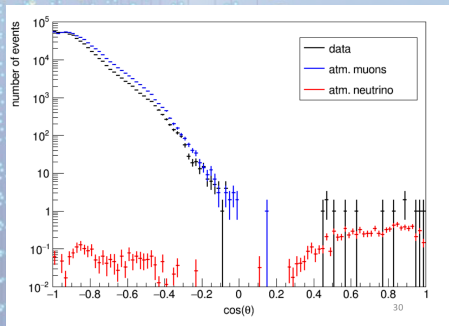
- First French KM3NeT DOMs produced.

KM3NeT/ORCA - Status

Very good data/MC agreement from first data/MC comparisons!

KM3NeT/ORCA - Status

|	$\cos\theta > 0$	$\cos\theta > 0.5$
DATA	13	10
MC ATM μ	1	0
MC ν	8.33	7.36
MC ν_μ	5.44	4.89
MC ν_e	1.36	1.17
MC ν_τ	0.96	0.83
MC ν_{NC}	0.57	0.47

- First analysis made with 82 days of data taking with 1 string of ORCA;

KM3NeT/ORCA - Summary

- First ORCA line successfully deployed;
- First data allowed to test MC and showed a good agreement;
- First neutrino analysis has been performed;
- Large scientific program will be covered;
- Several new lines expected after summer.

Stay tuned!

Thank you for your attention!
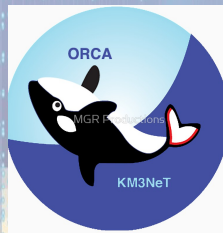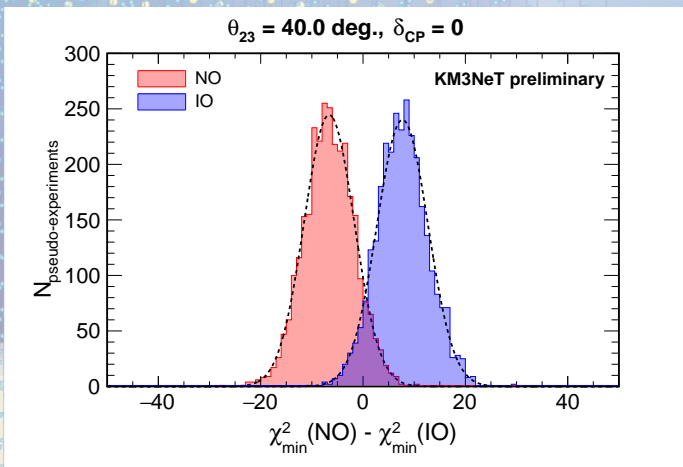
Workshop on supernova neutrino detection

IPN Orsay – July 4 and 5, 2018

https://indico.in2p3.fr/event/17490/timetable/
(part of a longer program on GRBs and CCSNs taking place in Orsay in June/July)
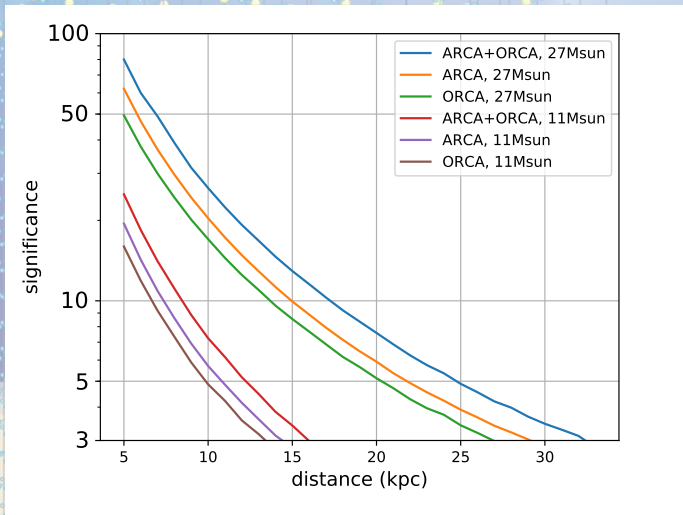
registration: coleiro@apc.univ-paris7.fr

KM3NeT/ORCA - Neutrino Mass Hierarchy

Example distribution of LLR

KM3NeT/ORCA – Super Novae Detection

Expected sensitivity as a function of SN distance for ARCA+ORCA combined.