Neutrinos from the Galactic Plane with ANTARES

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05/10/2016

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Neutrinos from the Galactic Plane

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- 1. Cosmic Rays and Neutrinos
 - CR and correlation with neutrinos
 - Possible neutrino sources
- 2. Search for neutrinos from the Galactic Plane
 - Neutrino Telescopes
 - Gamma-rays observations
 - Neutrinos observations
- 3. Data analysis
 - Research method
 - Data Analysis
- 4. Summary and Overview

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Cosmic Rays (CR) and correlation with neutrinos



Figure : CR spectrum measured by several experiments.

- The charged component is deflected by galactic and extragalactic magnetic fields → loss of information about sources
- The neutral component (photons and *v*) has lower probability of interaction with matter → going back to sources is possible.

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CR accelerators and possible neutrino sources



Figure : Crab Nebula, a SNR in the Milky Way, via NASA.

- Galactic sources:
 - Supernovae remnants (SNR)
 - CR propagation in the Galaxy
- Extragalactic sources:
 - Active Galactic Nuclei (AGN)
 - Gamma Ry Bursts (GRB)

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During the propagation, primary cosmic rays can interact with the interstellar medium (IM). These proton fragmentation lead to the formation of mesons, in particular pions and kaons. Pions, in particular, decay as it follows:

$$\pi^+ \to \nu_\mu + \mu^+ \\ \pi^- \to \overline{\nu_\mu} + \mu^-$$
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Neutrino telescopes: ANTARES

- It is located in the Mediterranean Sea, 10 km from Toulon (FR)
- 12 lines of 75 PMTs
- 25 storeys/line 3 PMTs/storey
- 885 emispherical PMTs



Figure : An Optical Module.



Figure : Schematic view of the ANTARES detector.

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ANTARES working principle



Figure : Reconstruction of different tracks with the ANTARES detector. Via indico.cern.ch

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Neutrino flux from Gamma-rays observations: Fermi-LAT

- Fermi-large area telescope (LAT) is a gamma-ray telescope situated on the Fermi spaceship, which is orbitating around the lower Earth's since 2008.
- It has the best visibility of the Galactic Plane among other γ-rays telescopes
- Energy range between 20 MeV and above 300 GeV

Neutrino flux from Gamma-rays observations: Fermi-LAT



Figure : Map of Gamma-ray flux measured by Fermi-LAT.

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Observation of cosmic neutrinos: IceCube



Figure : Arrival direction of IceCube telescope's down-going events in galactic coordinates.

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Figure : Test region in galactic coordinates $|l_{cut}| \le 40^{\circ}$ and $|b_{cut}| \le 3^{\circ}$. On-zone in red and off-zones in blue.

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Figure : Events in the test region where $|b_{cut}| \le 3^\circ$, having cut on $\Lambda > -5.2$ and $\beta < 1$, in red the events with $E_{ANN} \ge 10$ TeV.

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(a) $|b_{cut}| \leq 2^{\circ}$, 12 off-zones

E_{ANN} cut	On	Off
No E_{ANN} cut	66	66
1 TeV	49	48
3 TeV	21	21
5 TeV	15	14

(c) $|b_{cut}| \le 4^\circ$, 8 off-zones

E_{ANN} cut	On	Off
No E_{ANN} cut	123	135
1 TeV	92	97
$3 { m TeV}$	39	41
$5 \mathrm{TeV}$	25	27

(b) $|b_{cut}| \leq 3^{\circ}$, 9 off-zones

E_{ANN} cut	On	Off
No E_{ANN} cut	102	97
1 TeV	74	70
$3 { m TeV}$	27	30
5 TeV	18	20

(d) $|b_{cut}| \leq 6^{\circ}$, 6 off-zones

E_{ANN} cut	On	Off
No E_{ANN} cut	187	195
1 TeV	135	139
$3 { m TeV}$	57	60
$5 { m TeV}$	32	38

(e) $|b_{cut}| \leq 8^{\circ}$, 5 off-zones

$E_{ANN} >$	On	Off
No E_{ANN} cut	259	263
1 TeV	189	190
3 TeV	76	82
5 TeV	41	51

Figure : Number of events in function of the reconstructed energy for the different test regions

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Summary and Overview

- In this report events inducted by muonic neutrinos in ANTARES, aquired from 2008 to 2013, were used.
- Using 5 test regions, with different dimensions, an excess of events from the central part of the Galaxy has been searched.
- Neutrinos from this region may be producted by CR propagation.
- No excess was observed, but superior limits on the neutrino flux can be derivated.

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