Ultra-high energy neutrinos at the Pierre Auger Observatory

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- Neutrinos with energies above 100 PeV are detectable with the Surface Detector array (SD) of the Pierre Auger Observatory.
- Neutrino identification is efficient for neutrinos of all flavors at large zenith angles, as well as for Earth-skimming tau neutrinos.
- No neutrino candidates were found up to 31 March 2017.

- Upper limits to:
  - Diffuse flux of UHE neutrinos
  - Flux from point-like steady sources.
  - Energy in EeV neutrinos by BH-BH and NS-NS mergers.

**CONCEPT FOR ν IDENTIFICATION:** νs can penetrate large amounts of matter and generate a shower close to the surface detector with a significant electromagnetic component → search for inclined and young showers

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### Selection criteria

<table>
<thead>
<tr>
<th>Selection</th>
<th>Earth-skimming (ES)</th>
<th>Down-going high (DGH)</th>
<th>Down-going low (DGL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flavours &amp; interactions</td>
<td>ντ, CC</td>
<td>ντ, νe, νμ, CC&amp;NC</td>
<td>ντ, νe, νμ, CC&amp;NC</td>
</tr>
<tr>
<td>Angular range</td>
<td>θ &lt; 90º</td>
<td>θ &lt; (75º, 90º)</td>
<td>0 &lt; (60º, 75º)</td>
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<tr>
<td>L/W &gt; 5</td>
<td>θ &lt; (75º, 90º)</td>
<td>0 &lt; (58.5º, 76.5º)</td>
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<tr>
<td>νm(V) &lt; 0.08 m ns⁻¹</td>
<td>νm(V) &lt; 0.313 m ns⁻¹</td>
<td>νm(V) &lt; 0.08</td>
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<tr>
<td>νm(V)/νm &lt; 0.08</td>
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<tr>
<td>Inclined showers</td>
<td>sAoP &gt; 1.83</td>
<td></td>
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<tr>
<td>Fisher discriminant based on AoP of early stations</td>
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<tr>
<td>Fisher discriminant based on AoP of early stations close to shower core with ToT triggers</td>
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<tr>
<td>Young showers</td>
<td>AoP &gt; 1.4 if Nₑ &gt; 3</td>
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</tbody>
</table>

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### Data unbinding

Unbinding for Earth-skimming channel.
No candidates found in any channel (Earth-skimming & Downward-going) up to 31 March 2017.

### Limit to diffuse flux of UHE ν

Integral bound for a $kE^2$ neutrino spectrum:

$$k < 5 \times 10^9 \text{ GeV cm}^{-2} \text{s}^{-1}$$

Strong constraints on cosmogenic ν models assuming pure protons at the sources.

### Limit to point-like sources of UHE ν

Upper limits at 90% CL for $kE^2$ as a function of source declination

Gravitational wave 151226

Instantaneous field of view (colour bands) at the moment of coalescence of GW151226 and 90% CL contour of the GW (black line).

No ν candidates found in ±500s around time of GW or 1 day after GW.

The most restrictive upper limit on the total energy emitted per flavor in UHE ν achieved at declination δ~ 55º ($E_{ν,tot} < 0.44 M_Θ^{2}$).

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**Inclined cosmic ray**

**Earth-skimming ντ**

**Down-going ν**

**Signal traces in water cherenkov stations**

**Selection criteria**

**Data unbinding**

**Limit to diffuse flux of UHE ν**

**Limit to point-like sorces of UHE ν**

**Gravitational wave 151226**