



LATEST RESULTS FROM THE SEARCHES OF ULTRA-HIGH ENERGY NEUTRINOS AT THE PIERRE AUGER OBSERVATORY



BERGISCHE UNIVERSITÄT **WUPPERTAL**



Bundesministerium für Bildung und Forschung

25-10-2023 SRIJAN SFHGAI FOR THE PIERRE AUGER COLLABORATION **XX INTERNATIONAL WORKSHOP ON NEUTRINO TELESCOPE**

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PIERRE AUGER OBSERVATORY



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- Largest cosmic ray detector~ 3000km²
- - 1660 water Cherenkov stations
 - Detects EAS via secondary particles at ground
- - 4 sites with 27 telescopes
 - Measures longitude development via fluorescence
- Duty Cycle SD~100%, FD ~15%
 - Ongoing AugerPrime upgrade
 - Increases mass composition sensitivity
 - Potential for increasing neutrino sensitivity
 - And much more









- Proton cascade main background, higher separation > 60°
- Divided into two angular ranges to maximise search efficiency



• Ultra High Energy Neutrinos (UHE, E $\gtrsim 10^{17}$ eV) offer indirect probes for UHE cosmic ray sources Neutrinos can be detected at the Pierre Auger Observatory indirectly via Extensive air showers

Down Going ~ 60°-90°

Earth Skimming ~ 90°-95°





NEUTRINO DETECTION WITH THE AUGER SD

AoP>1





- Selecting higher zenith angles (θ)
- Signal Area over Peak (AoP) = $\frac{\text{Integrated Signal } \times \text{Calib.}}{-1}$ Peak
- AoP ~1 , narrow signal (muons)

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[Pierre Auger Coll.]

RECIPE FOR NEUTRINO SHOWER DETECTION WITH THE SD



UPDATE ON THE DIFFUSED NEUTRINO SEARCHES

- Analysis uses quality cuts to select long signals for an inclined shower
- Dataset: SD data from 1 January 2004 until 31 December 2021



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Fisher analysis based on AoP and trained on simulations used to obtain high selection efficiency

[M. Niechciol (Pierre Auger Coll.), PoS (ICRC 2023) 1488]





UPPER LIMITS ON DIFFUSED FLUX OF UHE NEUTRINOS



[M. Niechciol (Pierre Auger Coll.), PoS (ICRC 2023) 1488]

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- Auger most sensitive to neutrinos slightly below 10¹⁸ eV
- Integral limit between 10¹⁷ eV and 2.5×10¹⁹ eV: $3.5 \times 10^{-9} \,\text{GeV}\,\text{cm}^{-2}\text{s}^{-1}\text{sr}^{-1}$
- The non observance of cosmogenic neutrino flux helps constrain characteristics of UHECR sources









GRAVITATIONAL WAVE (GW) FOLLOW UP

- Example: Follow-up of GW170817 (binary neutron star merger)
 - Source was within FoV
 - No neutrinos detected by ANTARES, IceCube or Auger
 - Manual unblinding was necessary
- Since then: Routine follow-up of gravitation wave alerts sent through GCN
 - Neutrino search performed with a latency of almost 15 minutes
 - Manual check initiated if a neutrino is found
 - Upcoming: Automated generation of Auger GCN response with the limits for the event



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[Antares, IceCube, Pierre Auger, Ligo Scientific and Virgo Colls.,:ApJL 850 (2017) L35]





LIMITS ON UHE NEUTRINOS FROM BBH MERGERS

- Virgo in runs O1-O3
- Assumptions: Constant emissions within 24 hr and 60 day windows after the merger

Constant luminosity for all mergers with an E_{ν}^{-2} spectrum



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• UHE neutrino luminosity limit obtained via stacking analysis of observed BBH mergers by LIGO/





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- Limit on total energy emitted in UHE neutrinos per source (90% CL)~ 2.3 × 10⁵³ erg
- Upper limit on ratio of energy emitted in UHE neutrinos to GWs ~ 5%



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[Pierre Auger Coll., in preparation] [M. Schimp (Pierre Auger Coll.), PoS (ICRC 2021) 968] [M. Niechciol (Pierre Auger Coll.), PoS (ICRC 2023) 1488]





UPWARD-GOING AIR SHOWER SEARCHES

- Anomalous high energy events observed by ANITA consistent with upward-going air showers Possible τ decay
- Energy_{1,2} > 0.2 EeV, Observed zeniths: 117°, 125°
- Cannot be explained via Standard Model scenarios
- Could be explained via Beyond Standard Model(BSM) Physics



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[B. Yue(Pierre Auger Coll.)]

Sketch not to scale

[I. Caracas:Pierre Auger Coll.]







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- Upward going air showers searched with FD at the Pierre Auger Observatory



Auger limits 100(30) times lower than inferred ANITA fluxes for E⁻¹(E⁻²) spectrum for both ANITA I & ANITA III

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[Pierre Auger Coll., in preparation] [E. De Vito (Pierre Auger Coll.), PoS (ICRC 2023) 1099]







BSM CONSTRAINTS FROM NON DETECTION OF UPWARD GOING AIR SHOWERS

- nearby Earth's surface going shower
- Search split into three angular bins [110°, 124.2°], [124.2°, 141.3°], [141.3°, 180°]
- Tau generation limit calculated and further converted to BSM limits

Assumption: BSM particle flux interacting with matter at variable cross section produces a tau lepton

The tau lepton propagates into the atmosphere and by its decay produces an upward



[B. Yue(Pierre Auger Coll.), PoS (ICRC 2023) 1095]



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- Tau generation limit calculated and further converted to BSM limits
- Several BSM scenarios can be ruled out by the Auger FD and SD



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- The Pierre Auger Observatory offers large exposure to UHE neutrinos
- Continues to set stringent upper limits on the diffuse fluxes for UHE neutrinos
- GW follow-ups
- Can also constrain different BSM scenario
- Other efforts such as optimising the detector further also in progress
- The ongoing AugerPrime upgrade can increase the detection capabilities for neutrinos

Will continue being an important contributor to multi messenger astronomy eg.



[ISS Masterclass, Gina Isar:Pierre Auger Coll.]





THANK YOU



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[Pierre Auger Coll., JCAP 10 (2019) 022]







[B. Yue(Pierre Auger Coll.), PoS (ICRC 2023) 1095]

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ν point source sensitivity limits

[Limits on point-like sources of ultra-high-energy neutrinos with the Pierre Auger Observatory :DOI:10.1088/1475-7516/2019/11/004]

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