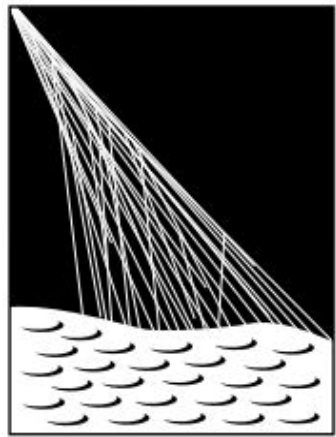


Bounds on diffuse and point source fluxes of UHE neutrinos with the Pierre Auger Observatory



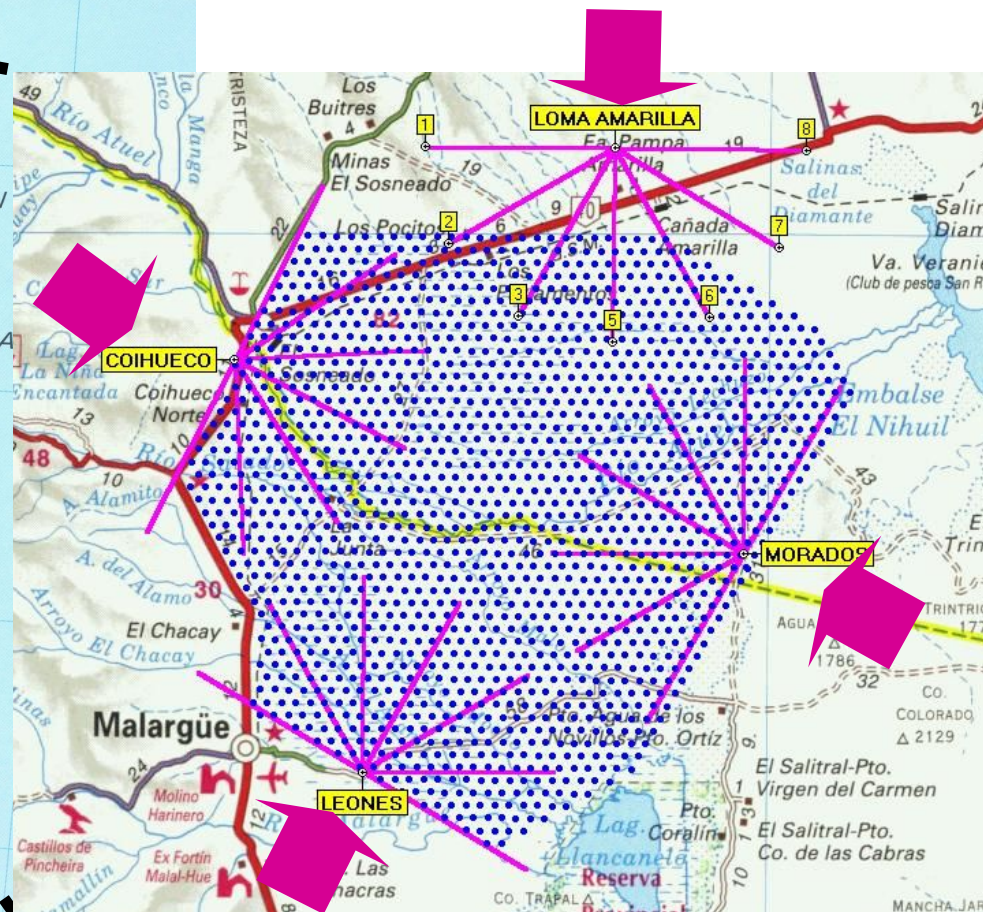
PIERRE
AUGER
OBSERVATORY

Francisco Pedreira
Univ. Santiago de Compostela, Spain
for the Pierre Auger Collaboration

36th International Cosmic Ray Conference
Madison, Wisconsin, USA
July 24 - August 1 2019

The Pierre Auger Observatory Malargüe, Mendoza (Argentina)

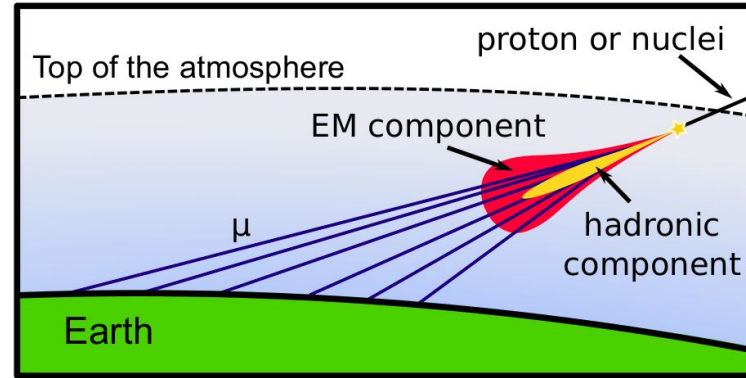
- SD 1500 = Surface Detector array of 1660 water-Cherenkov stations (3000 km²)
- ➔ FD = 4 Fluorescence buildings (24 + 3) detectors



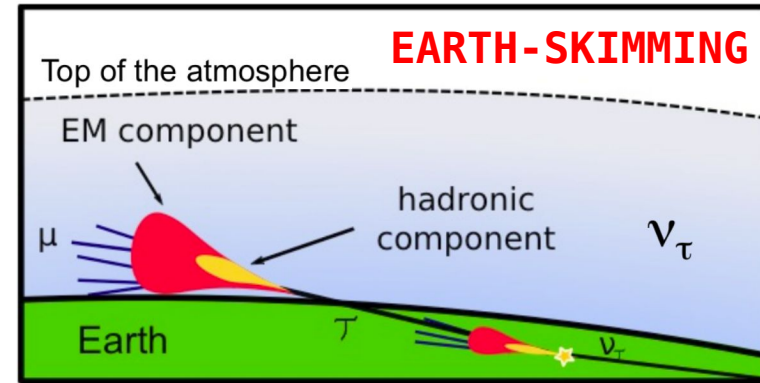
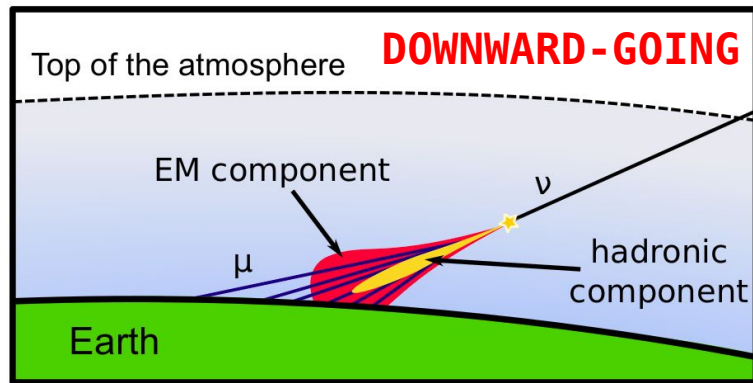
3000 km²

Neutrino identification in inclined showers

- Protons & nuclei initiate inclined showers high in the atmosphere.
Shower front at ground: mainly muons (small electromagnetic component).



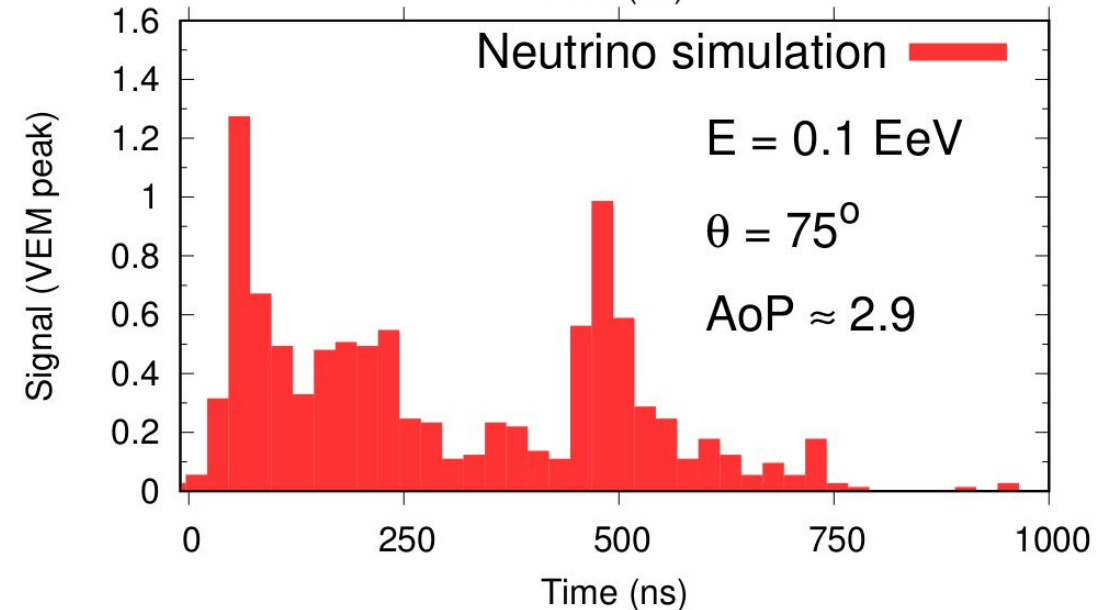
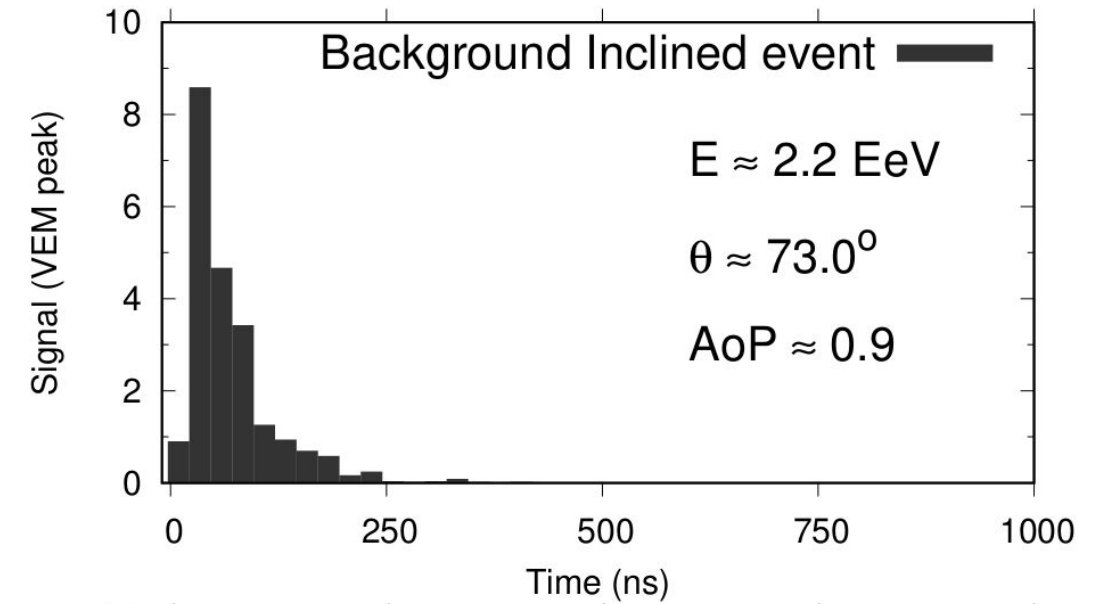
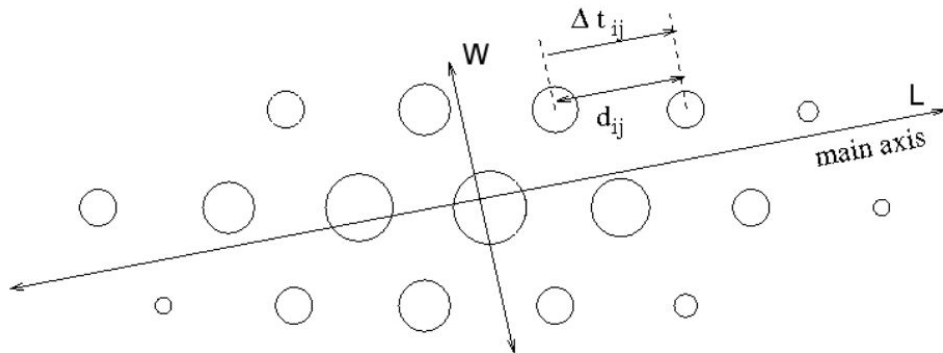
- Neutrinos can initiate “deep” showers close to ground.
Shower front at ground: electromagnetic + muonic components.



Neutrino search with Surface Detector

- Inclined showers:
 - Elongated signal footprints: large L/W
 - Signal apparent speed $\langle V \rangle \approx$ speed of light
 - Small RMS(V)
- Young showers:
 - Signals spread in time:
large Area-over-Peak

$$AoP = \frac{\text{area of signal trace}}{\text{peak value}}$$

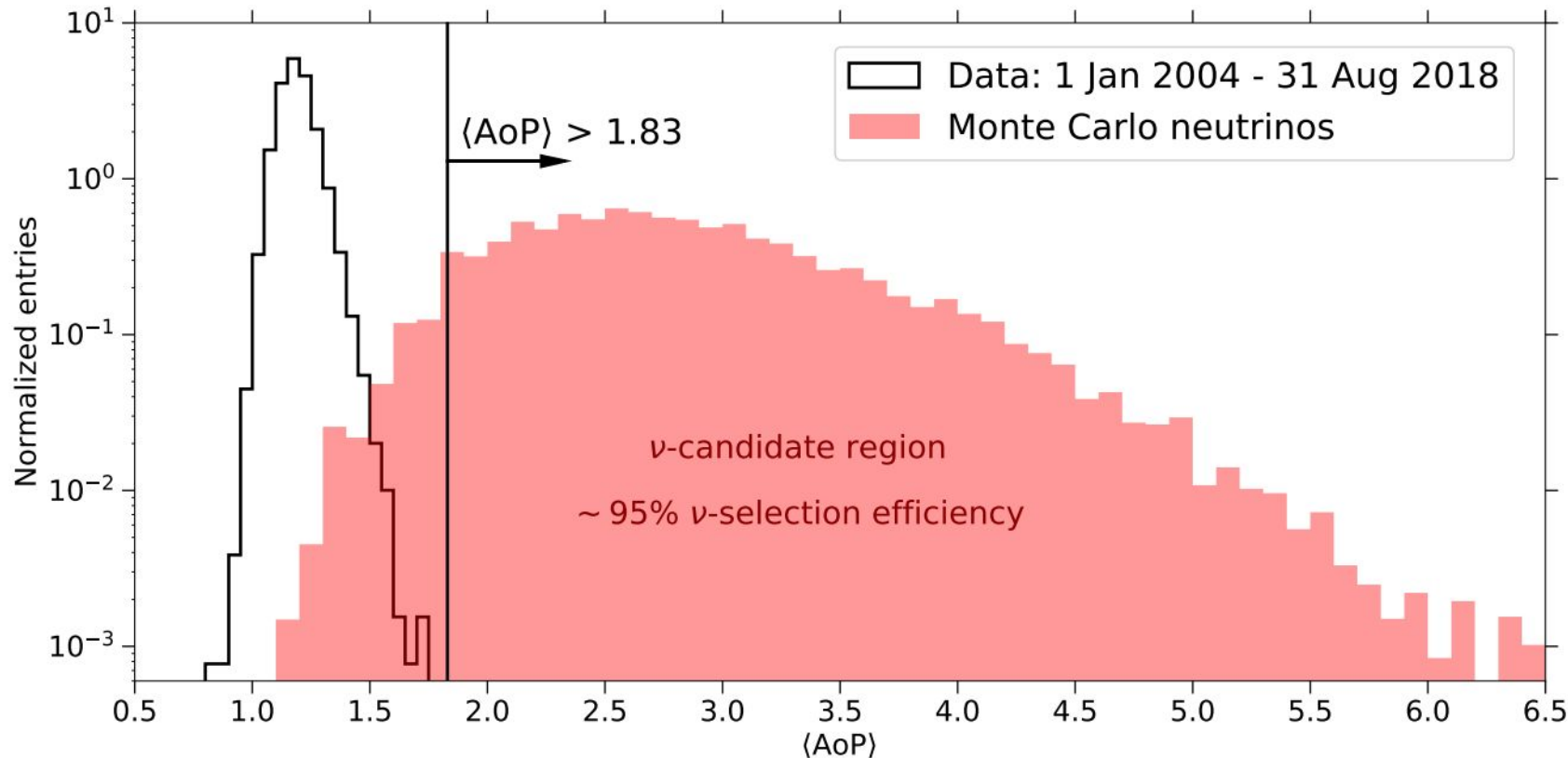


Results of the neutrino search

No neutrino candidate events found in the downward-going & Earth-skimming analysis

arXiv:1906.07422

Earth-skimming analysis



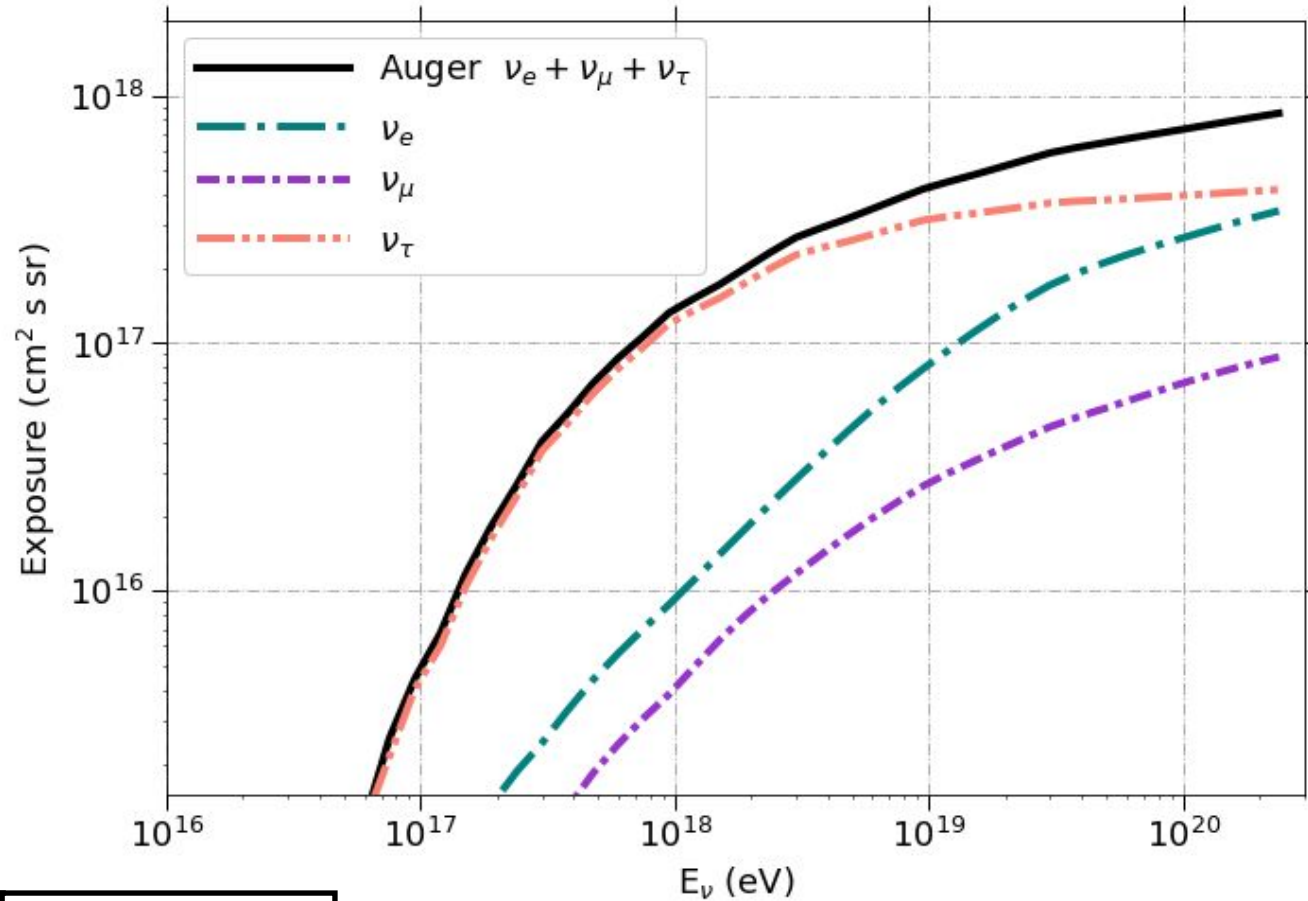
ν candidate if
 $\langle \text{AoP} \rangle > 1.83$

$\langle \text{AoP} \rangle$ = mean value
of Area-over-Peak
in event

SD Data:
Jan. 2004 –
August 2018

Flavor contributions to Exposure

arXiv:1906.07422



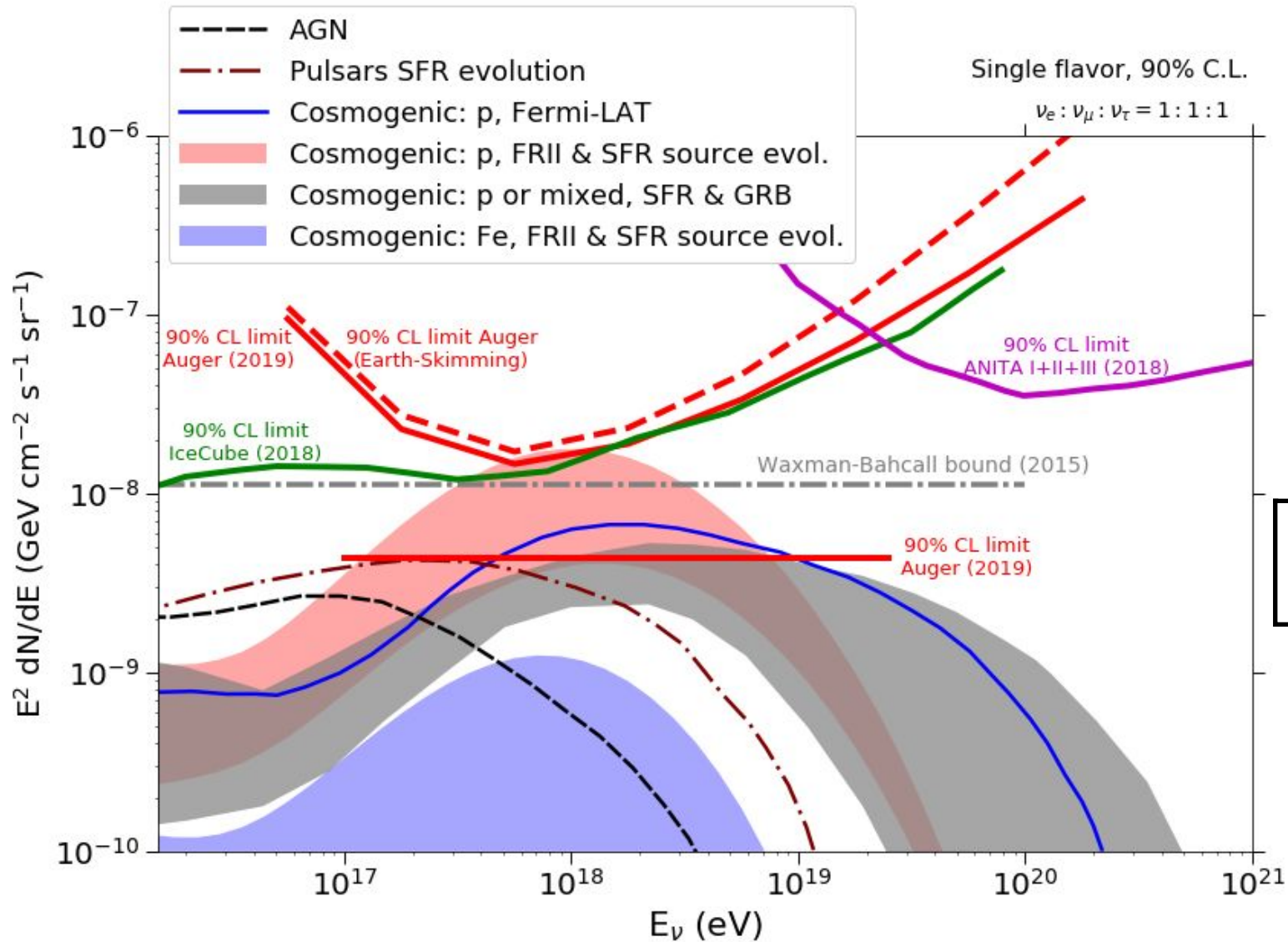
Flavor	Relative contribution
ν_e	0.10
ν_μ	0.04
ν_τ	0.86

Channel	Relative contribution
Earth-skimming ν_τ	0.79
Downward-going $\nu_e + \nu_\mu + \nu_\tau$	0.21

SD Data:
Jan. 2004 –
August 2018

Auger sensitivity dominated by tau-neutrinos

Limits to the diffuse flux of UHE ν



arXiv:1906.07422

Expected ν events:

Red band: 1.4 - 5.9
Gray band: 0.8 - 2.0
Blue band (top): 0.4

Auger Limit: $dN/dE = k E^{-2}$

$k \sim 4.4 \times 10^{-9} \text{ GeV cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$

SD Data:

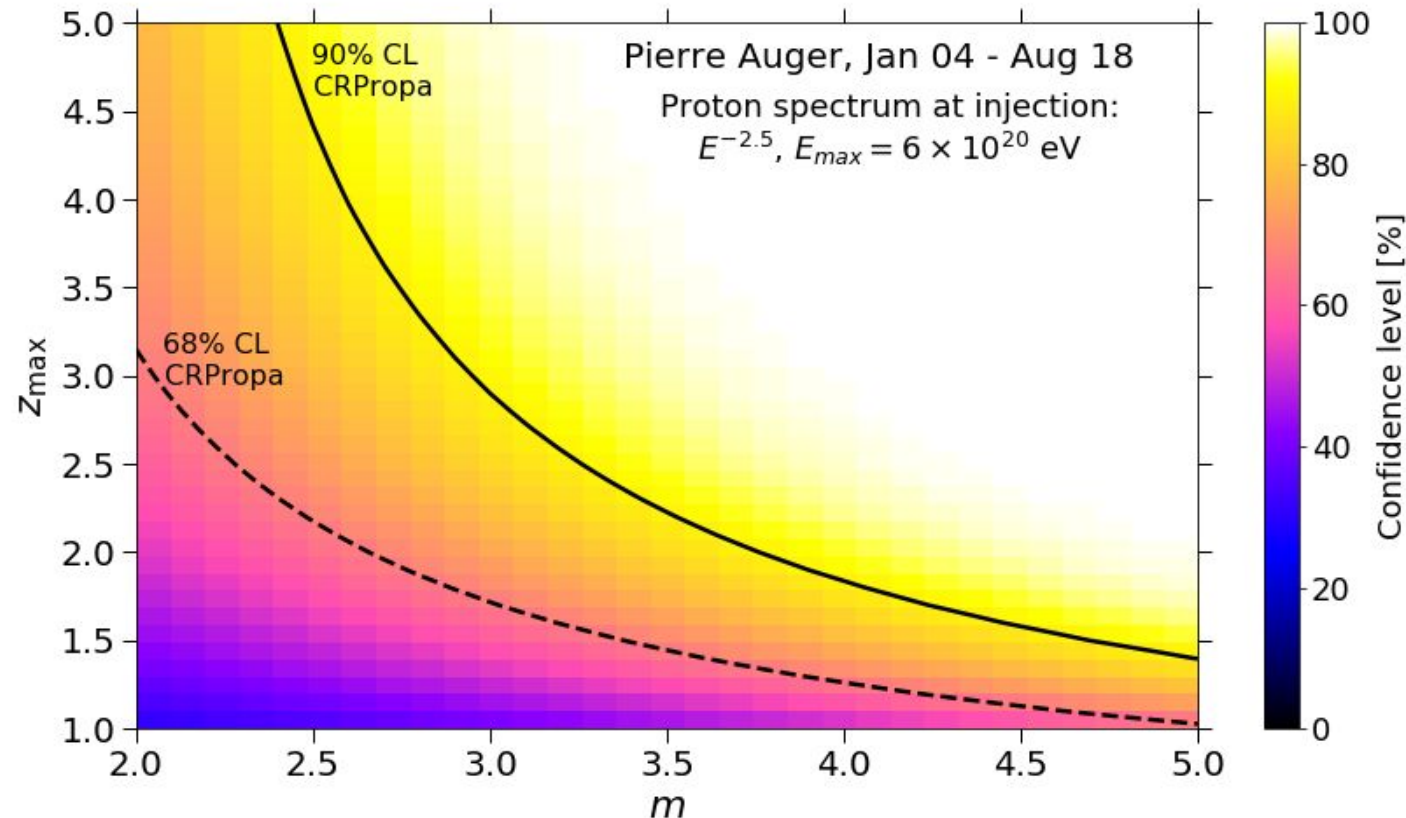
Jan. 2004 –
August 2018

Cosmogenic neutrinos: constraints on proton models

UHECR source evolution models parameterized as $\Psi(z) \propto (1+z)^m$

m : source evolution parameter

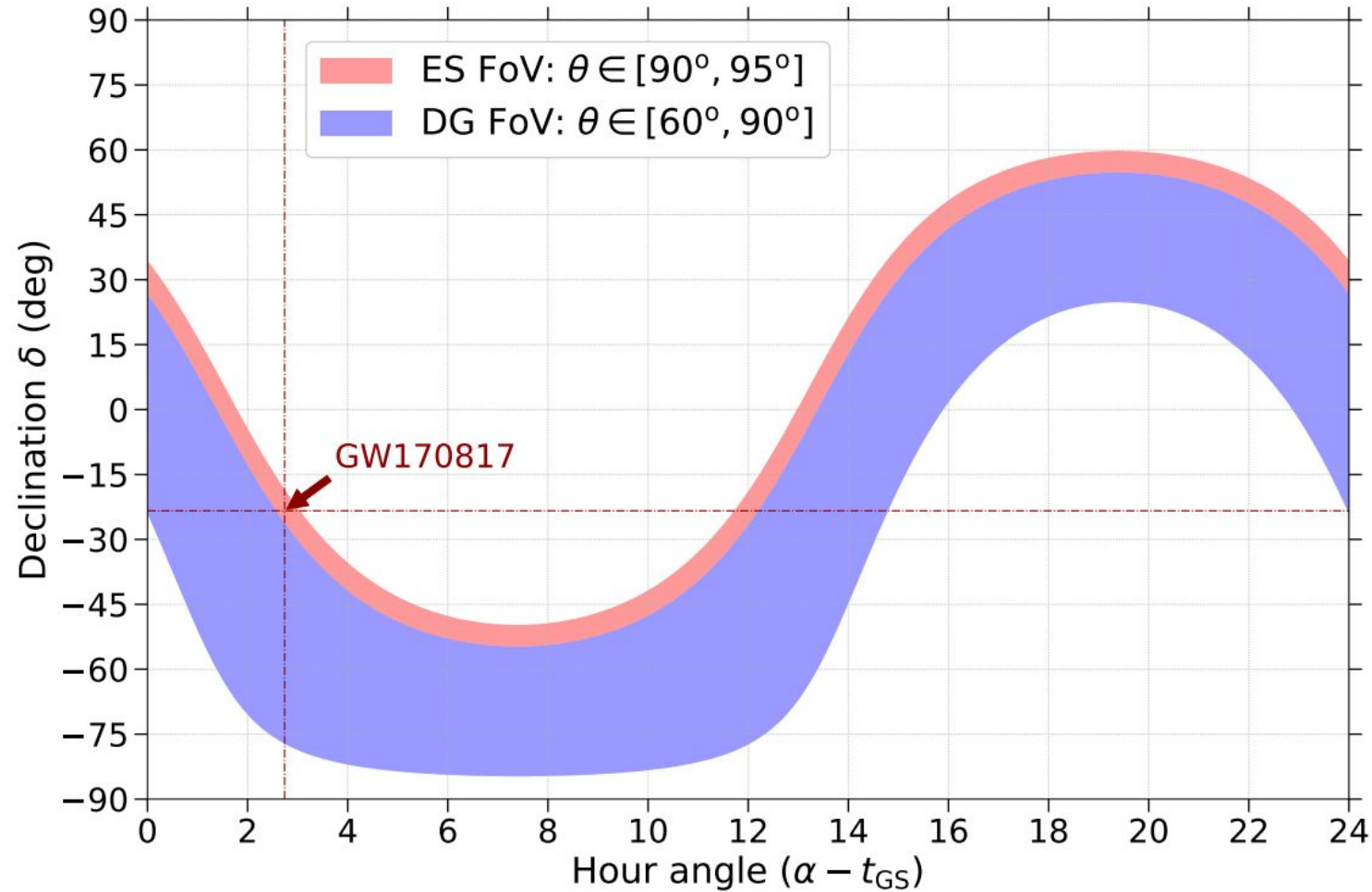
z_{max} : the maximal redshift at which UHECR are accelerated



arXiv:1906.07422

Significant region of the parameter space of z_{max} vs m is disfavored

Sensitivity to point-like, transient sources: field of view (FoV)



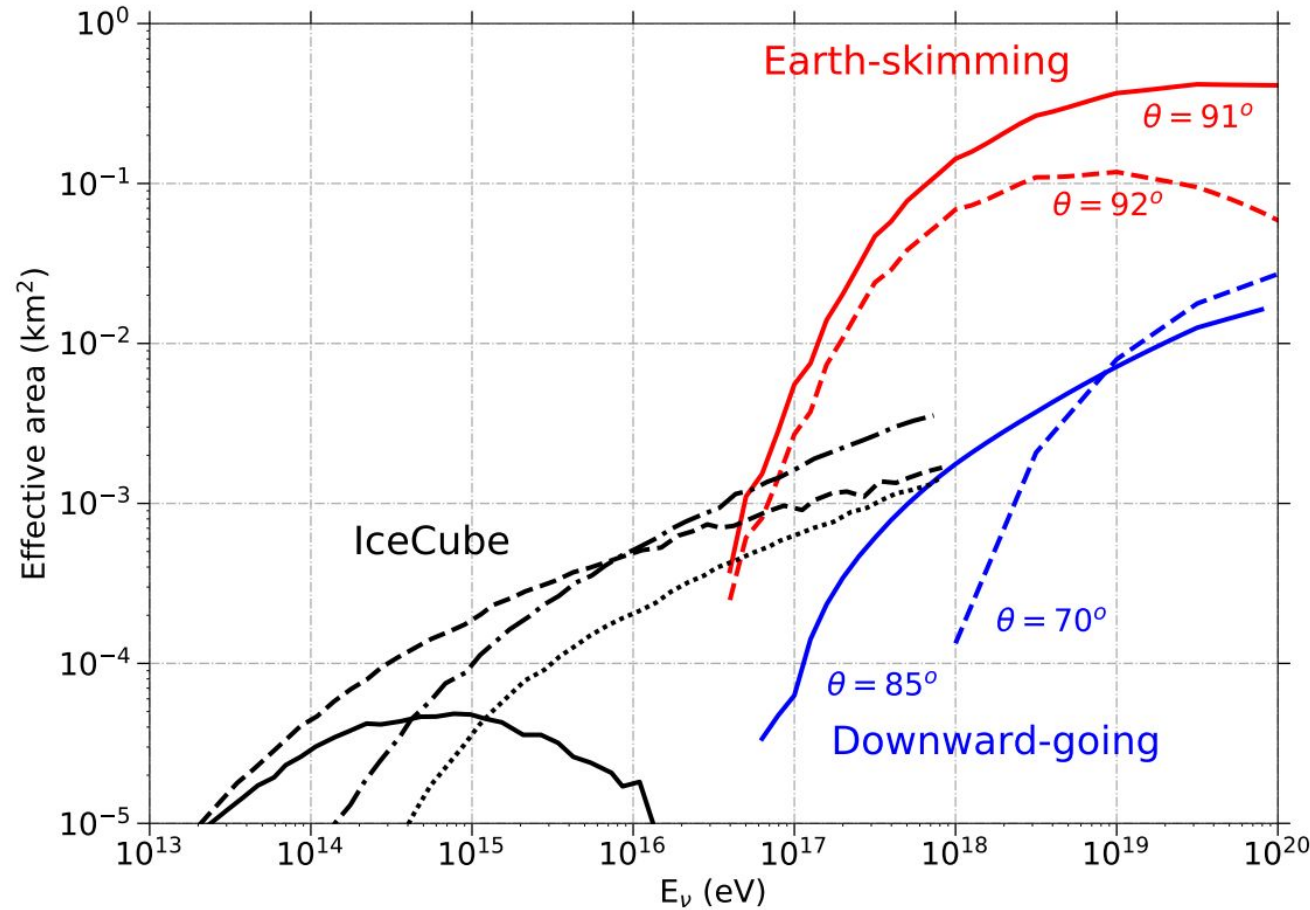
VISIBLE SKY:

Earth-skimming $\sim 5\%$

Downward-going $\sim 25\%$

Instantaneous FoV for Earth-skimming & downward-going

Sensitivity to point-like, transient sources: effective area

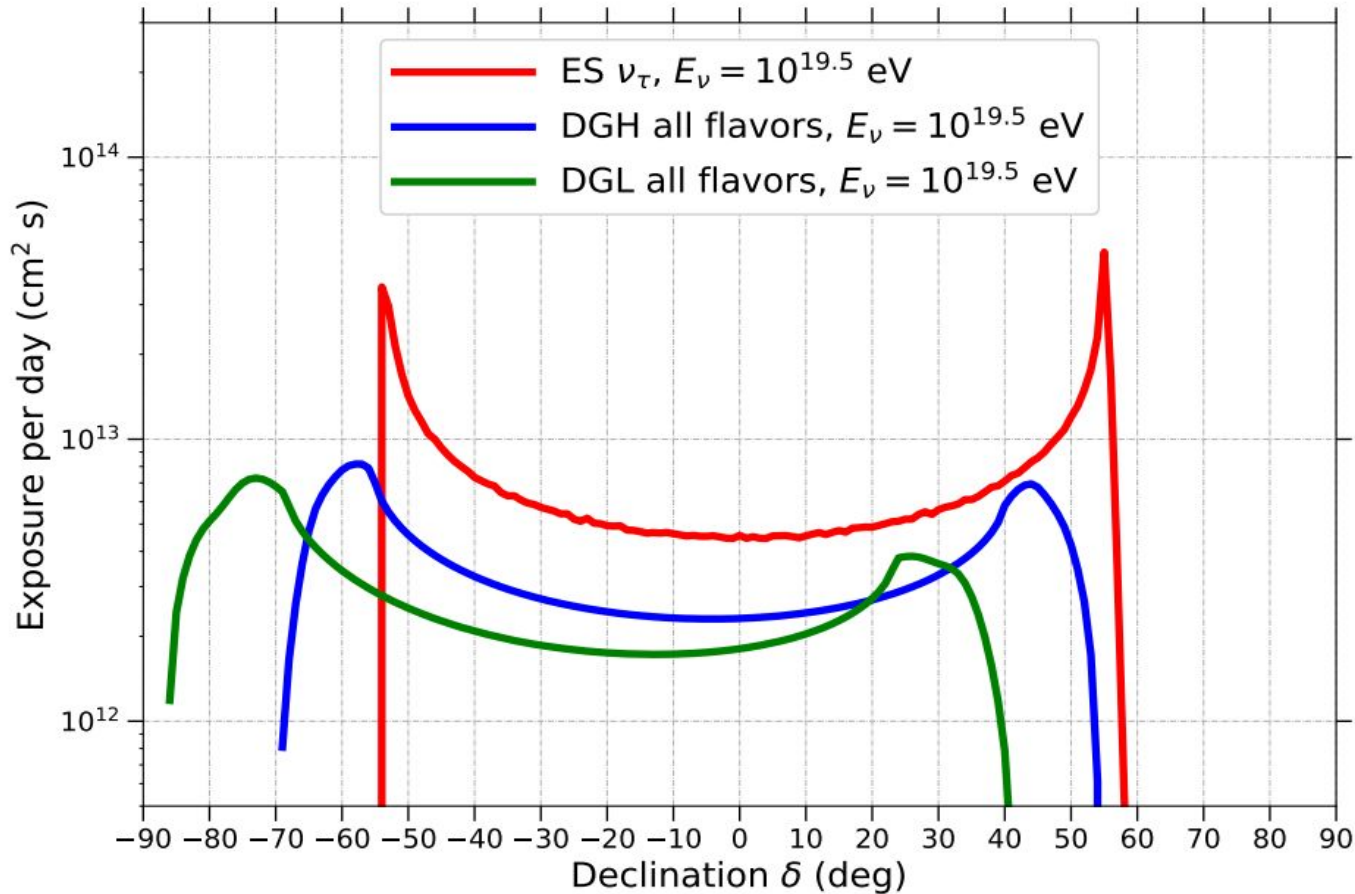


$$\frac{dN_i}{dt} = \int_{E_\nu} dE_\nu \phi_i(E_\nu) \mathcal{A}_i(E_\nu)$$

arXiv:1906.07419

Effective area very dependent on the position of the source,
optimal for source in Earth-skimming FoV

Exposure to point-like, steady sources



arXiv:1906.07419

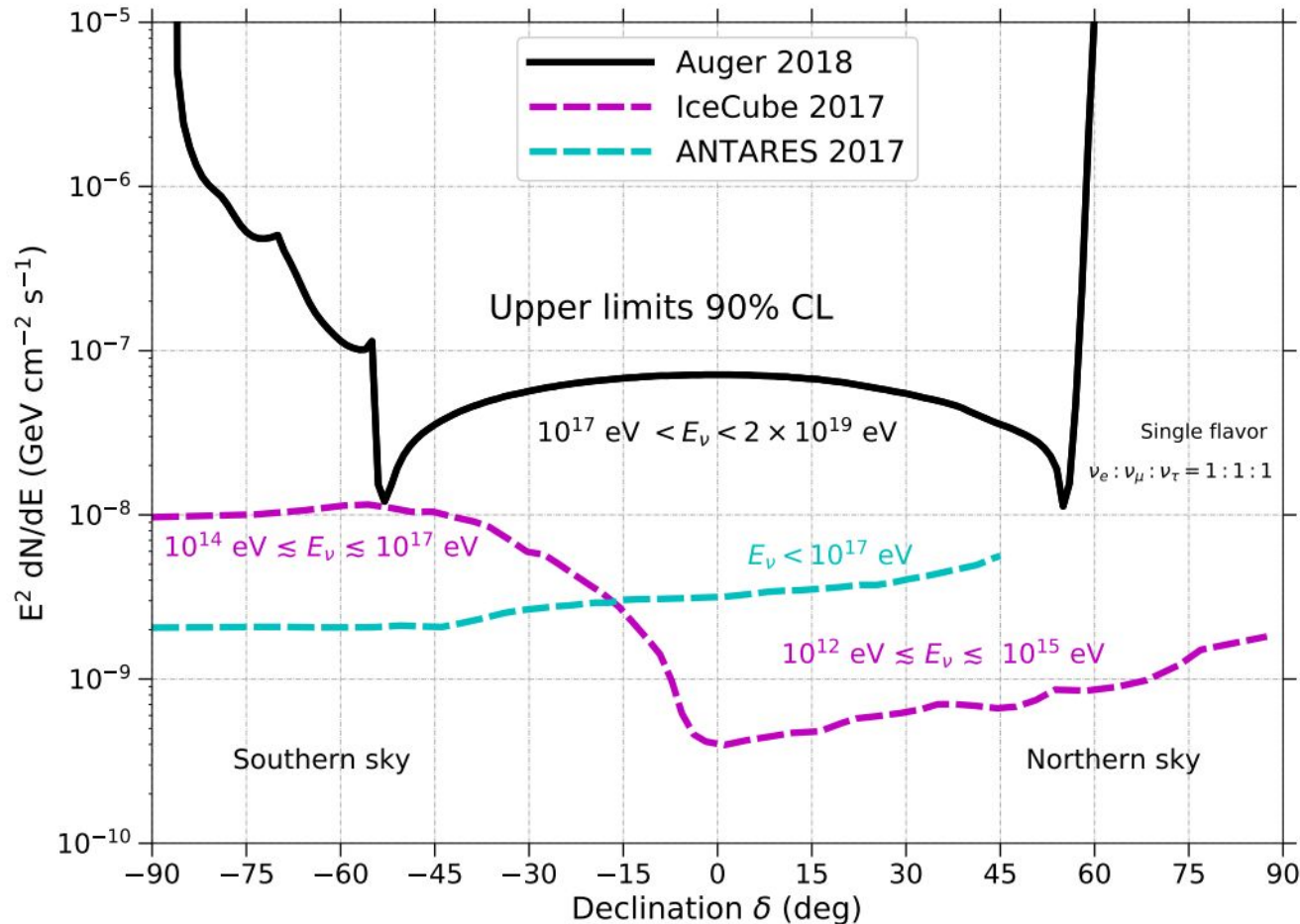
Downward-going channels:

Downward-going low (DGL): $60^\circ < \theta < 75^\circ$

Downward-going high (DGH): $75^\circ < \theta < 90^\circ$

Best exposure for sources at declinations -53° and 55° because they remain longest in the Earth-skimming field of view

Limit to point-like, steady sources of UHE ν



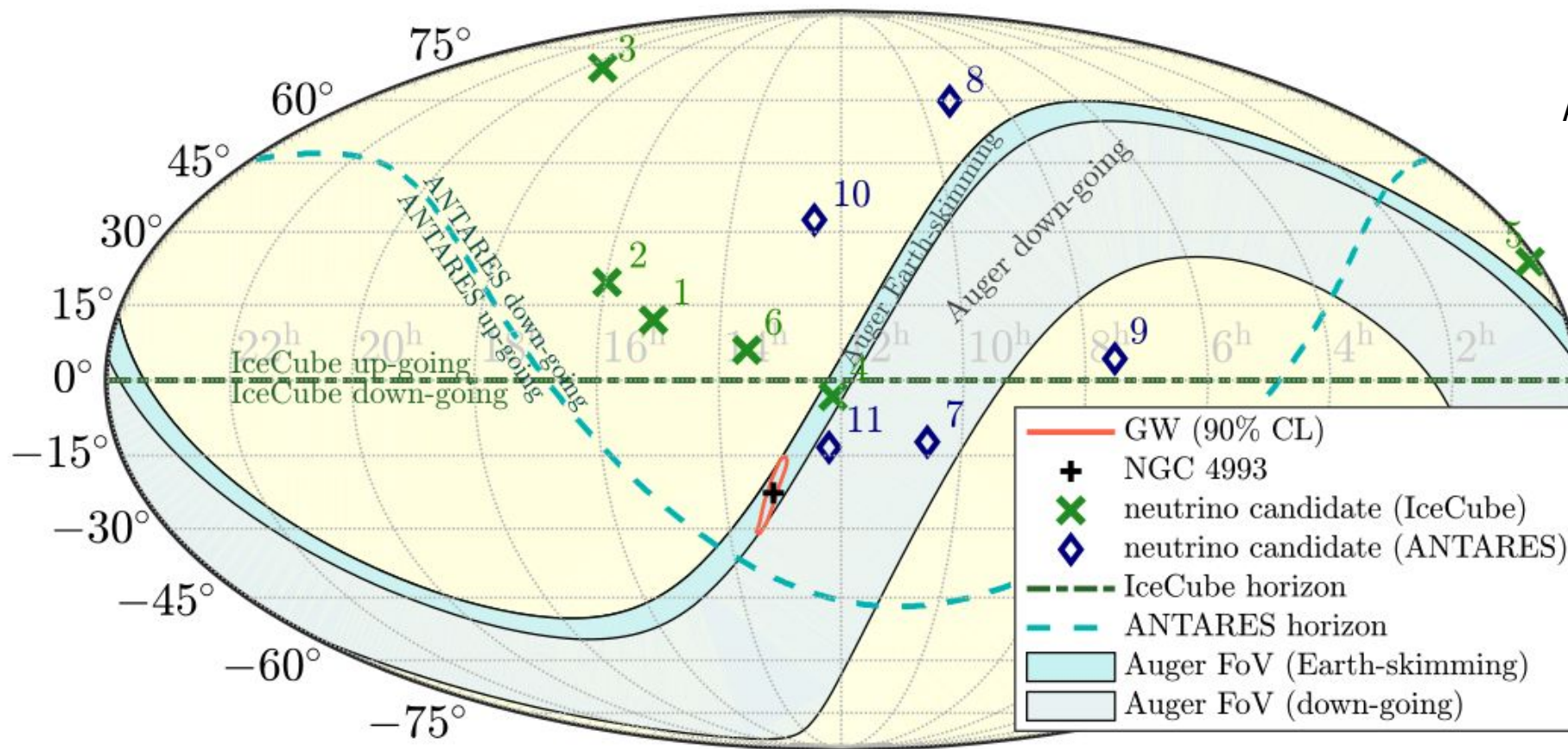
arXiv:1906.07419

SD Data:
Jan. 2004 –
August 2018

- Good sensitivity at EeV energies in a broad range in declination
- The best sensitivity at declinations -53° and 55° where sources spend more time in the field of view of Earth-skimming

Searching for neutrinos in coincidence with GW

- ANTARES, Icecube & Auger searched for ν in coincidence with GW170817 from TeV to EeV.
- Very good Auger sensitivity because source was in the FoV of ES at the moment of merger.



ApJ, 850, L35 (2017)

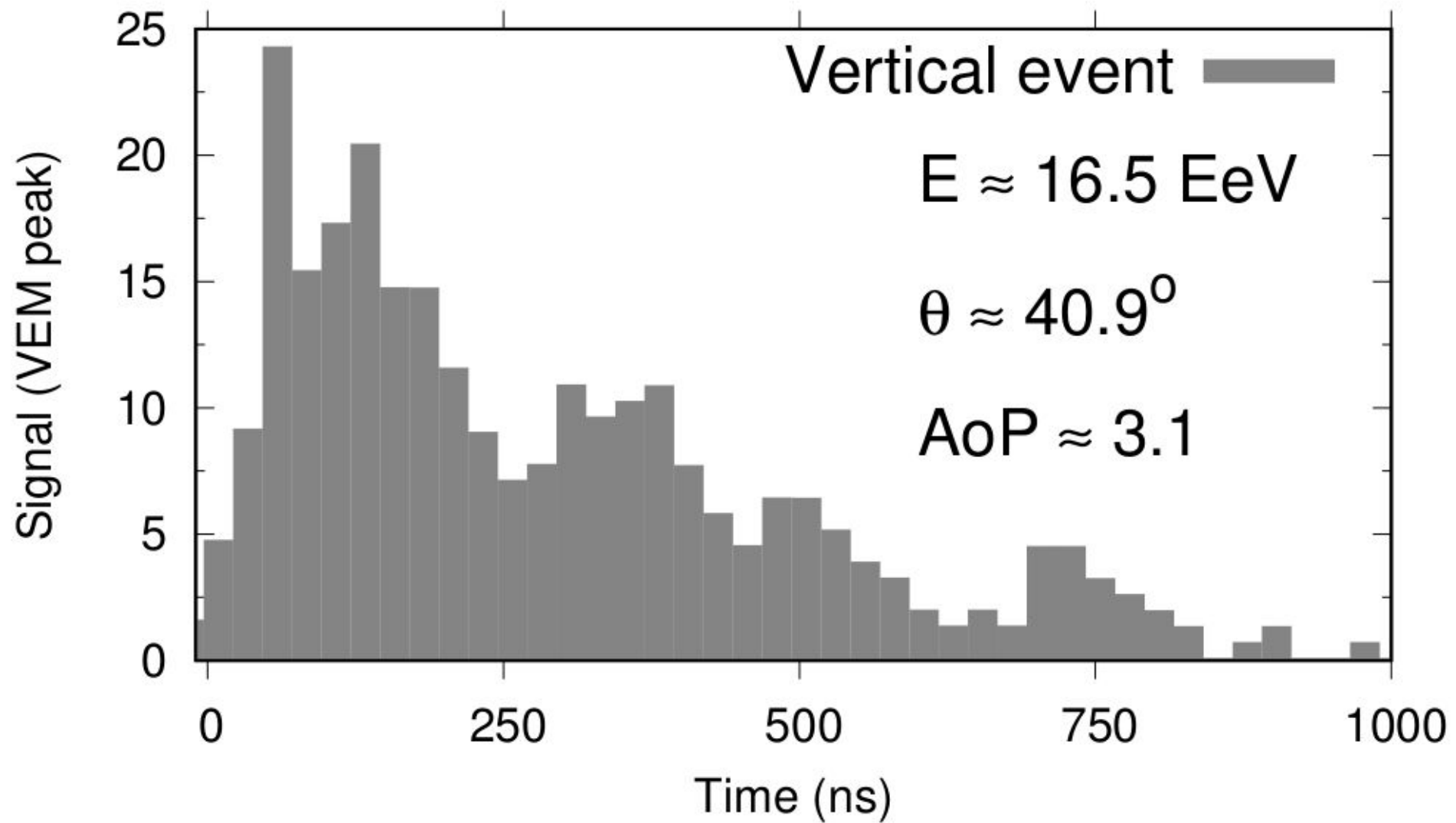
Conclusions

- Very restrictive limits to the diffuse flux of UHE neutrinos at energies around 10^{18} eV.
- Outstanding sensitivity to transient sources if located in the FoV of the Earth-skimming channel.
- Pierre Auger Observatory is a key detector in multi-messenger astronomy at EeV energies:
 - Very good sensitivity to UHE neutrinos with the Surface Detector.
 - Large fraction of the sky can be probed.
 - Auger followed-up BH-BH and NS-NS merger events detected in LIGO and Virgo run 02 & 03 (M. Schimp talk).

Thank you for your attention!!

BACKUP

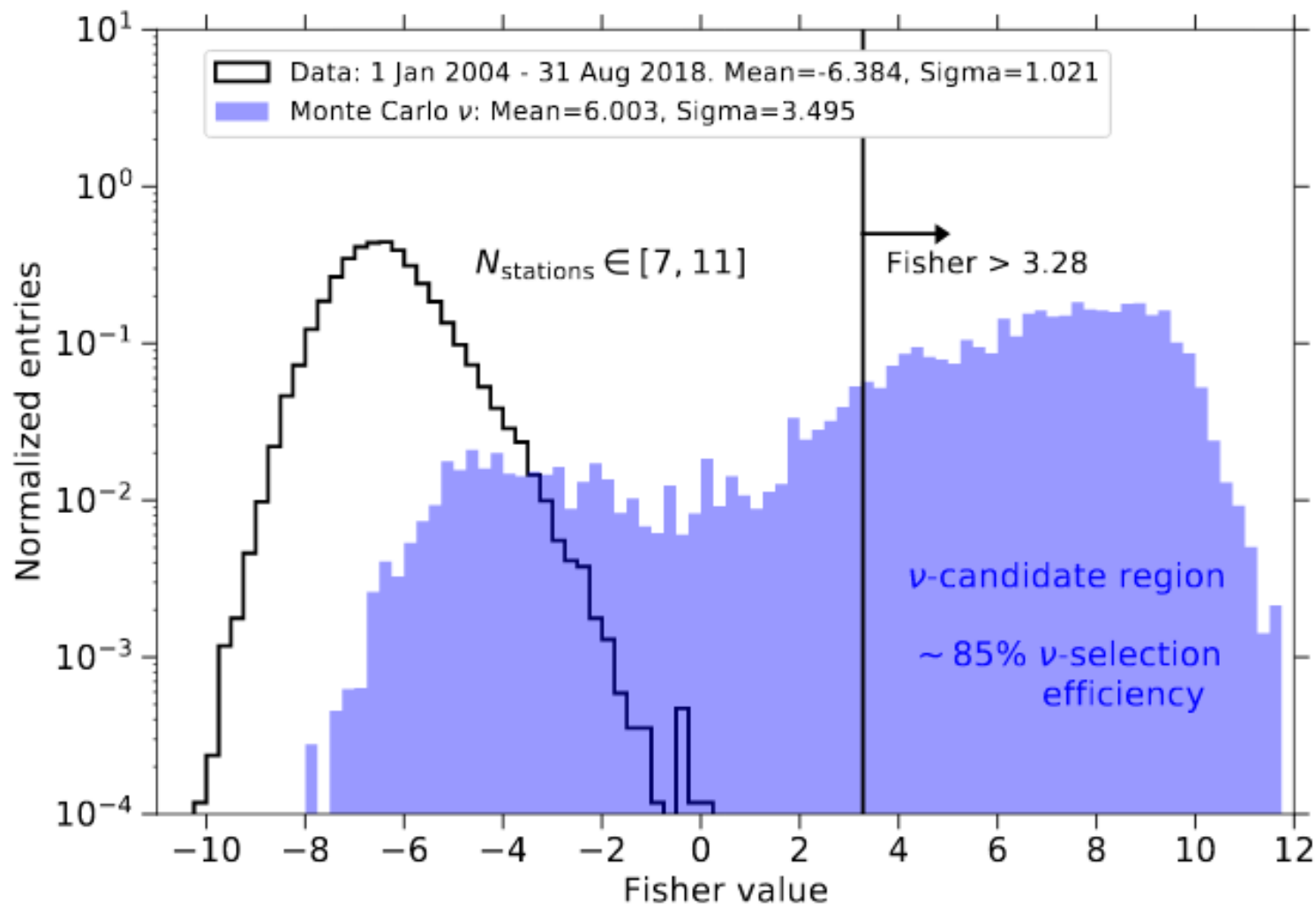
Signal vertical event



ν search results

Example: DGH, $6 < N_{\text{stations}} < 12$

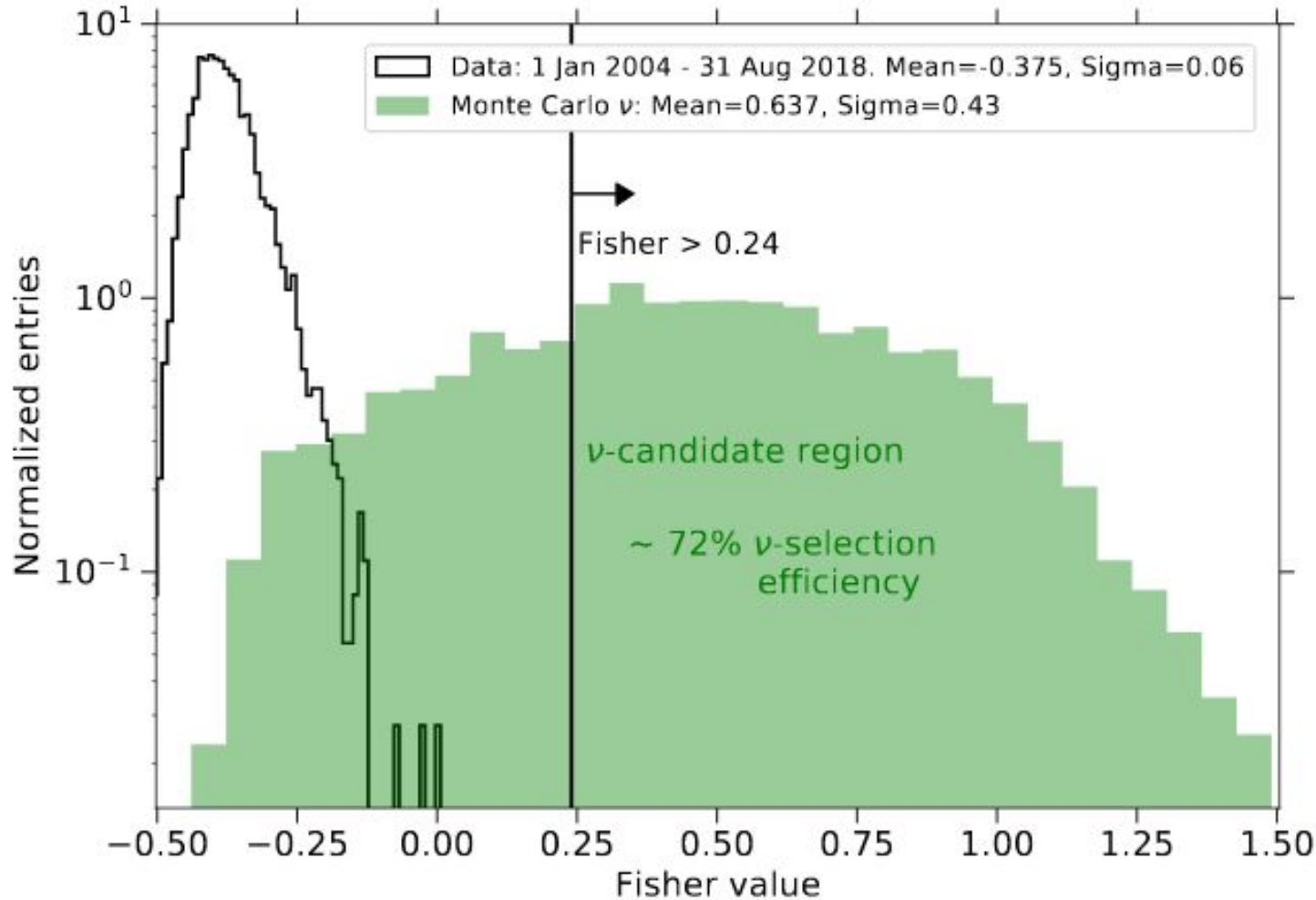
SD Data:
Jan. 2004 –
August 2018



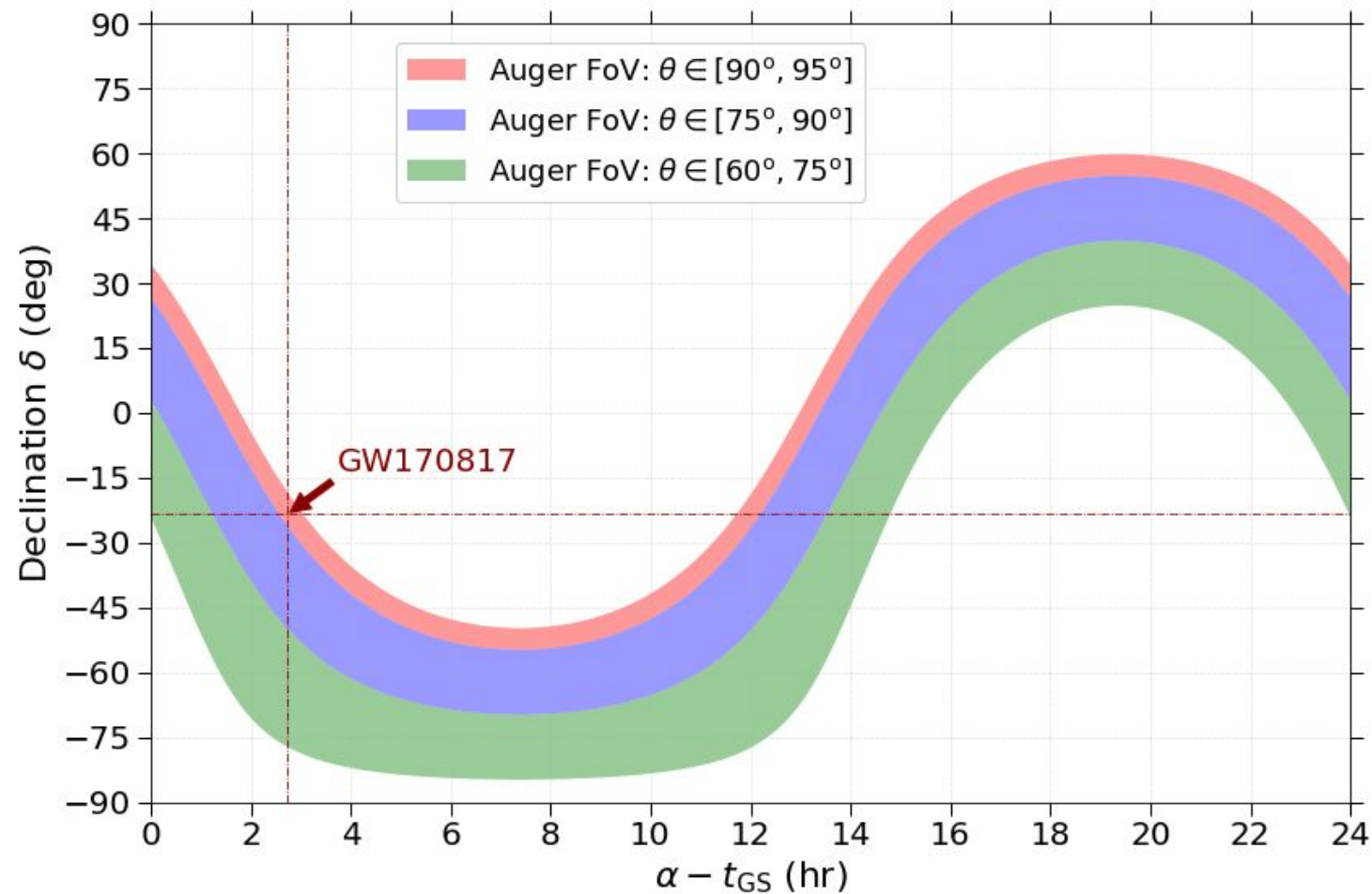
ν search results

Example: DGL, $64.5^\circ < \theta \leq 67.5^\circ$

SD Data:
Jan. 2004 –
August 2018



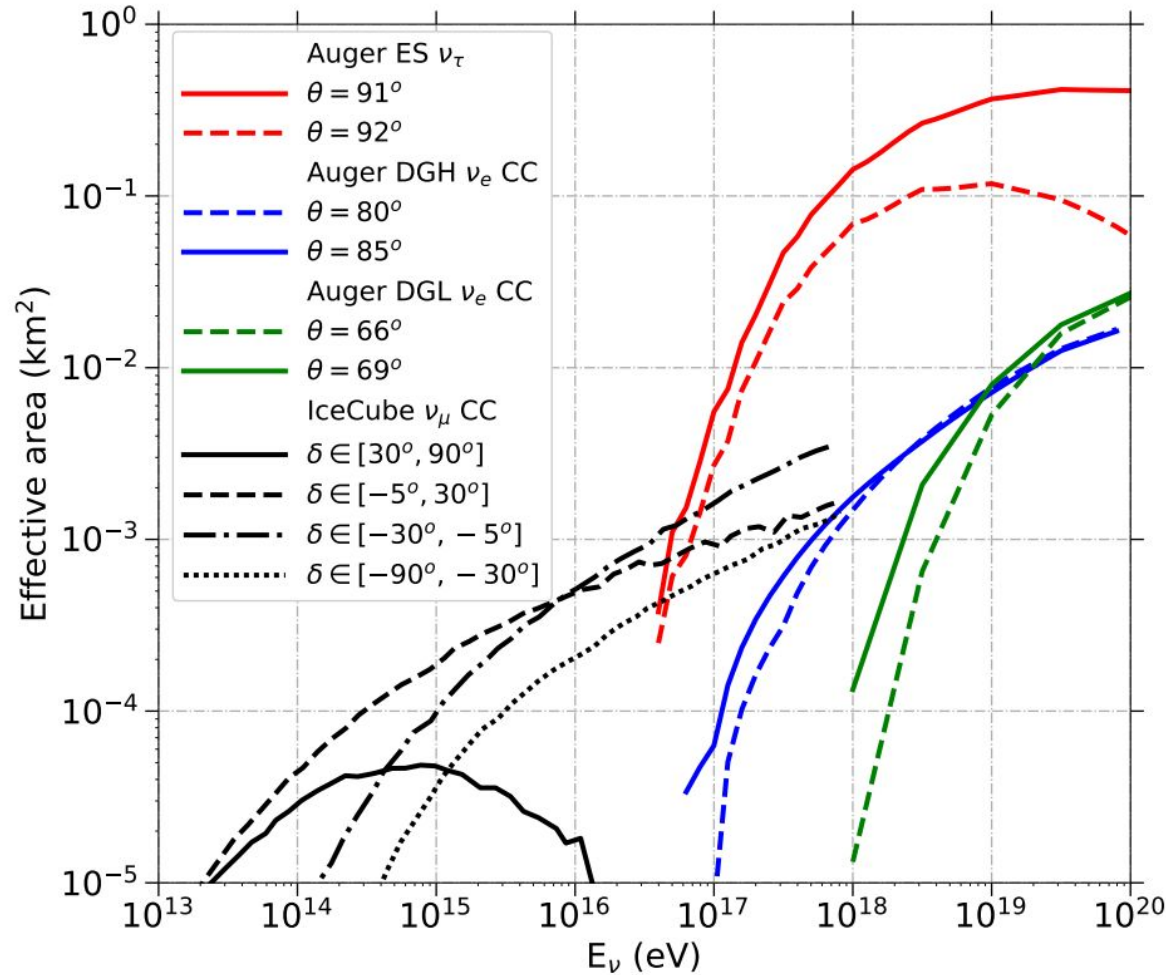
Sensitivity to point-like, transient sources: field of view (FoV)



VISIBLE SKY:
ES~5%
DG~25%

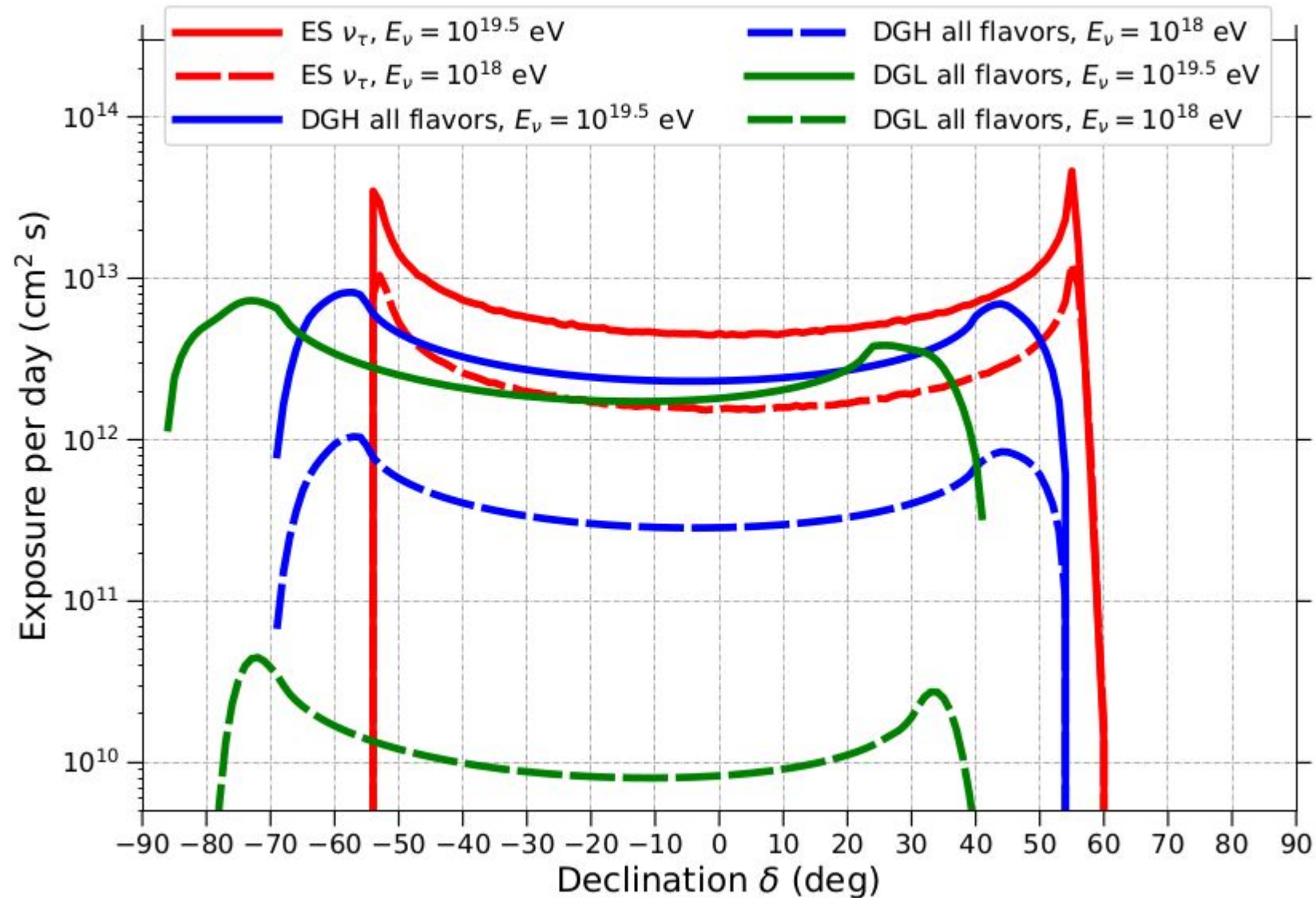
Instantaneous FoV for Earth-skimming & downward-going

Sensitivity to point-like, transient sources: effective area

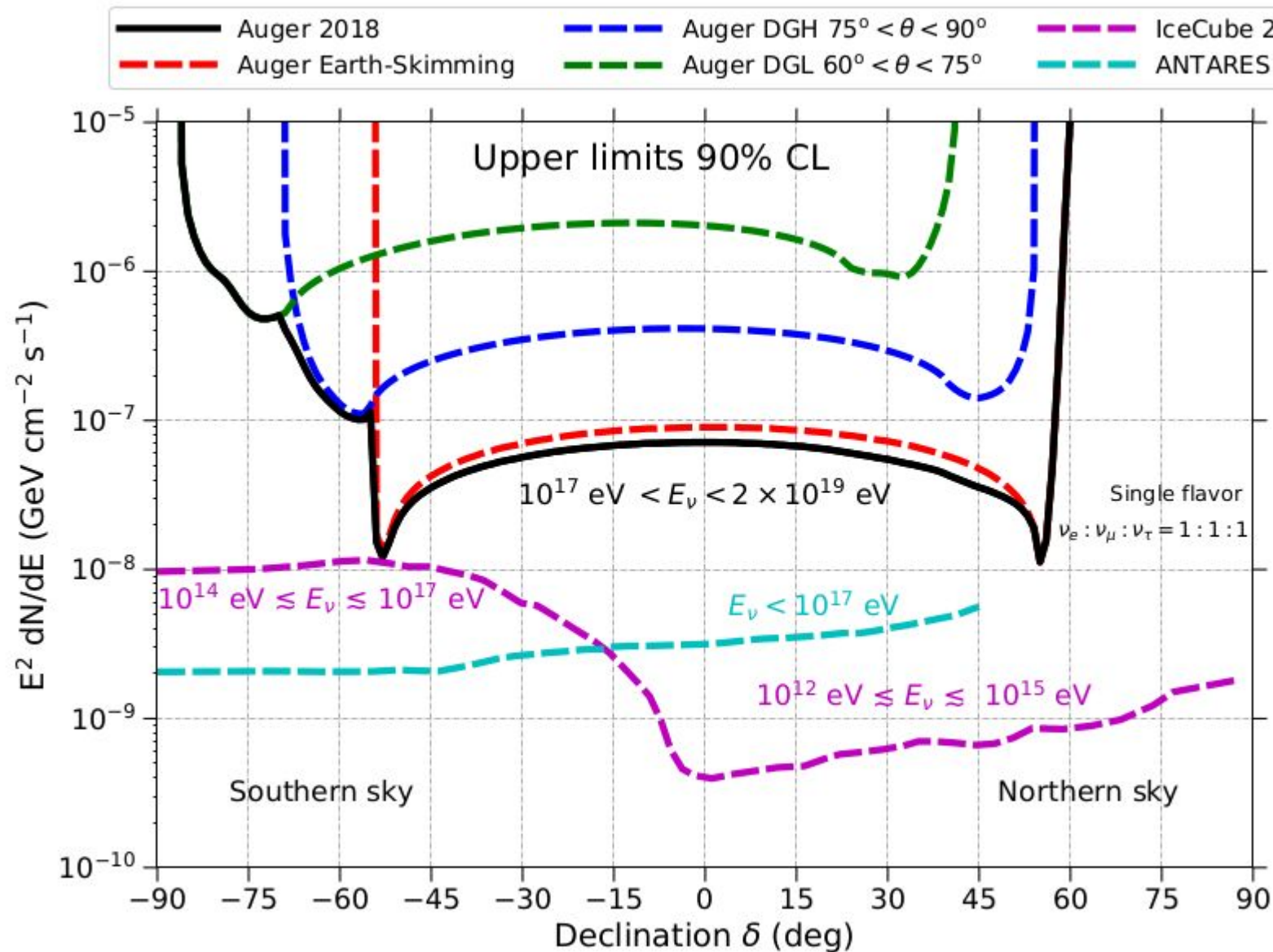


$$\frac{dN_i}{dt} = \int_{E_\nu} dE_\nu \phi_i(E_\nu) \mathcal{A}_i(E_\nu)$$

Exposure to point-like sources



Limit to point-like sources of UHE ν



Single flavor, 90% C.L.

<http://arxiv.org/abs/1906.07419>

SD Data:
Jan. 2004 –
August 2018

Limit BNS

