Ultra-High Energy neutrinos at the Pierre Auger Observatory

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2 – Full author list at www.auger.org/archive/authors_2020_06.html

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Outline

- The Pierre Auger Observatory: a brief reminder
- Using the Surface Detector to search for **neutrinos above 100 PeV**
- Results of data unblinding 01/2004 – 08/2018
- Constraints to the flux of **cosmogenic neutrinos**

- Auger in the **multi-messangers** era:

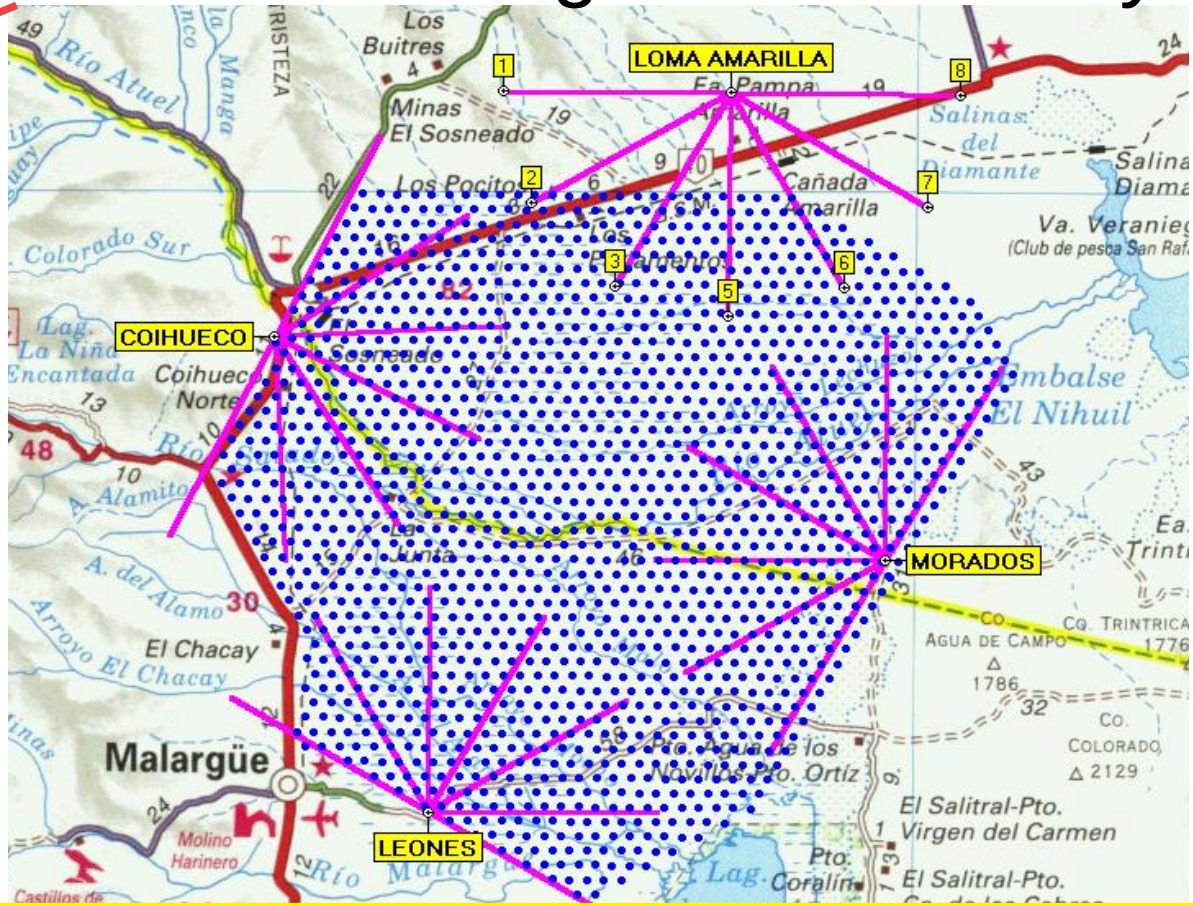
  steady point sources

  transients: follow-up search of BNS merger GW170817

The Pierre Auger Observatory

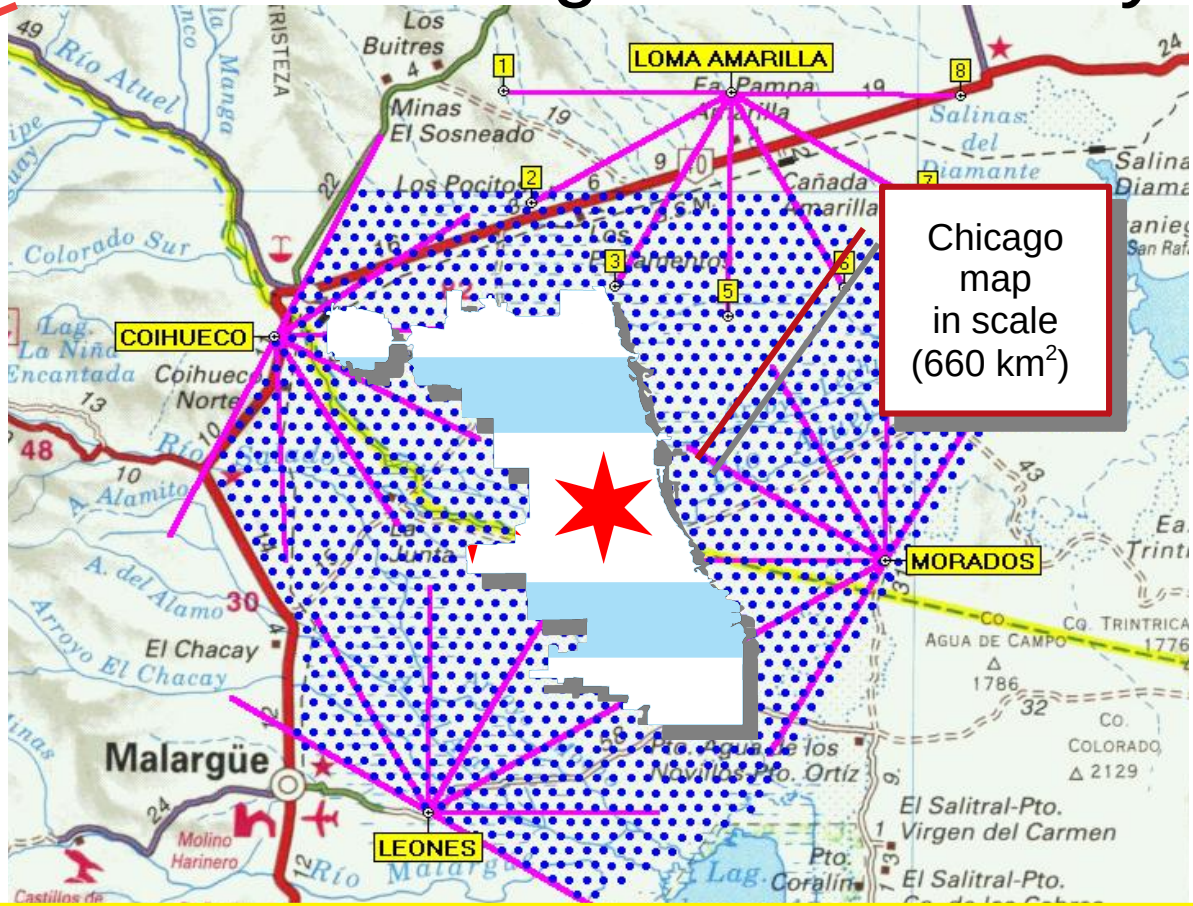
35.5º S, 69.3º W

1400 m a.s.l.
(880 g cm^{-2})



Surface Detector: 1,660 Water Cherenkov Stations - 3,000 km²

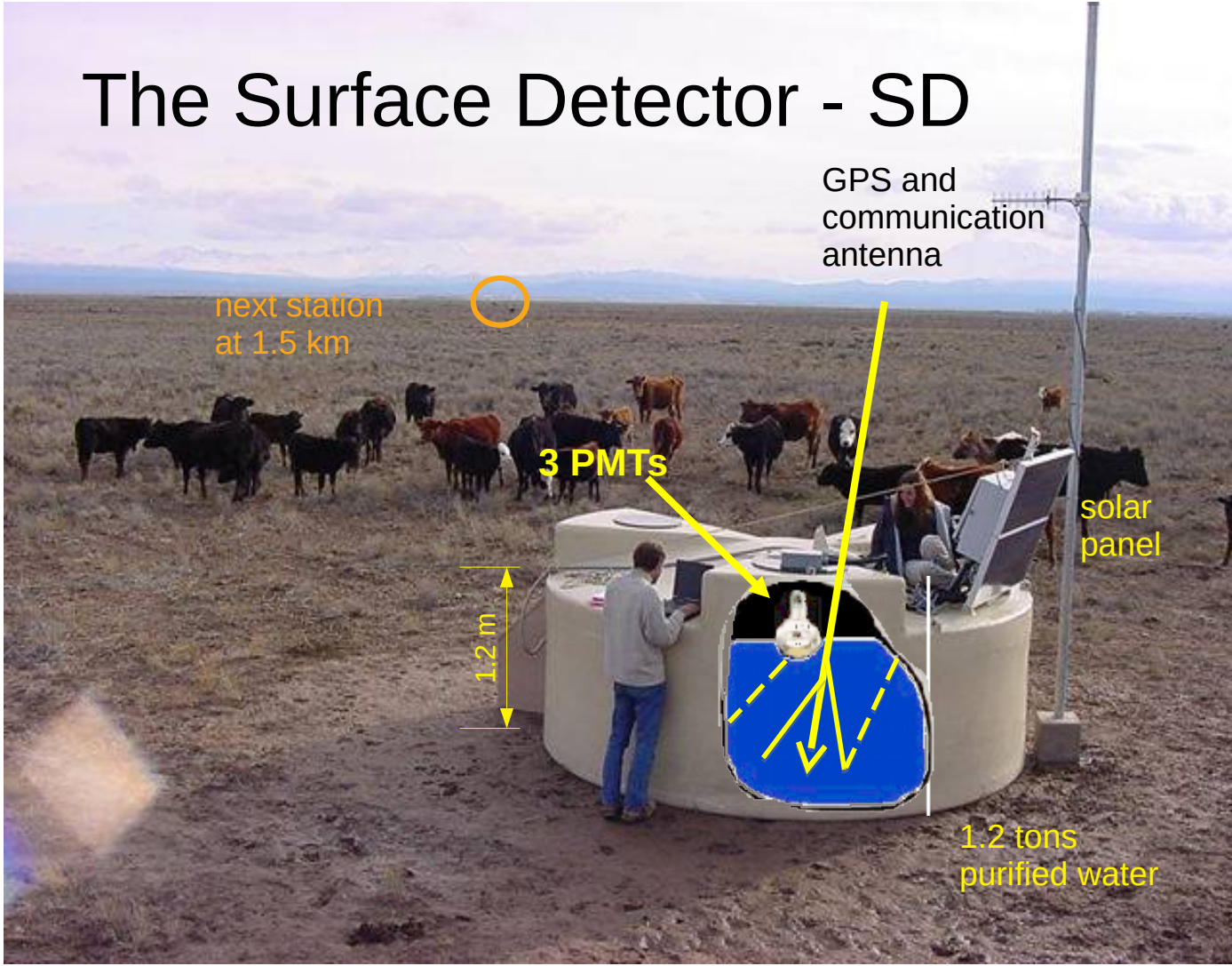
The Pierre Auger Observatory



Surface Detector: 1,660 Water Cherenkov Stations - 3,000 km²

wehavenoidea.com

The Surface Detector - SD



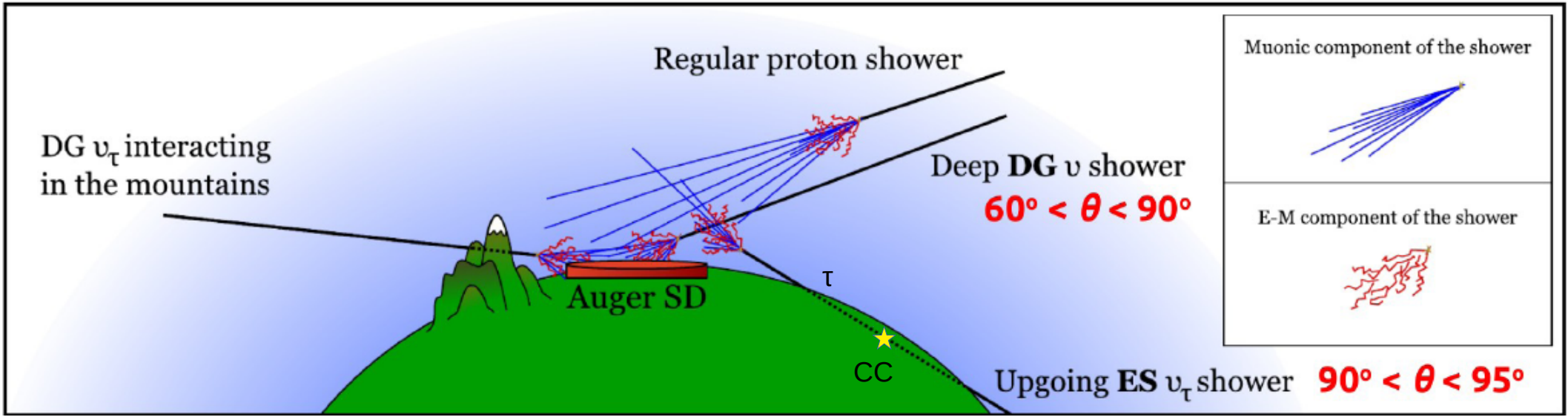
Primary goal: **study of UHECRs**

Detection of extensive air showers initiated by primaries in the atmosphere: sampling of shower particles at ground level (Cherenkov radiation in water)

~ 100% duty cycle

Typical energy: **EeV = 10^6 TeV**

Searching for neutrinos with and air-shower detector

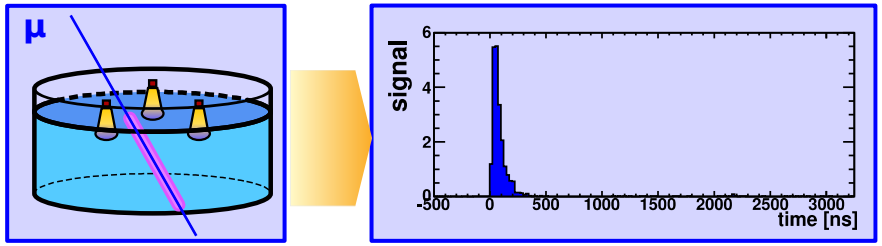


λ_τ ~50 km @ 1 EeV

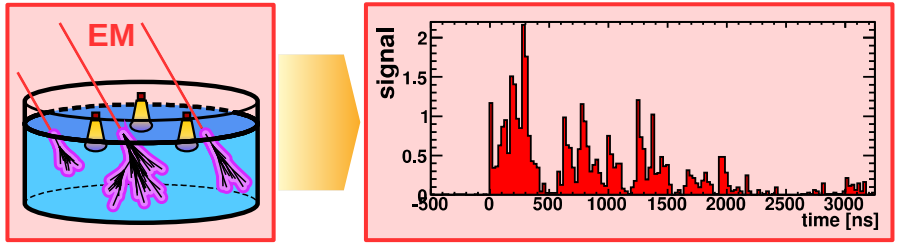
→ Down-going (**DG**) showers: all flavours

→ Earth-skimming (**ES**): ν_τ only

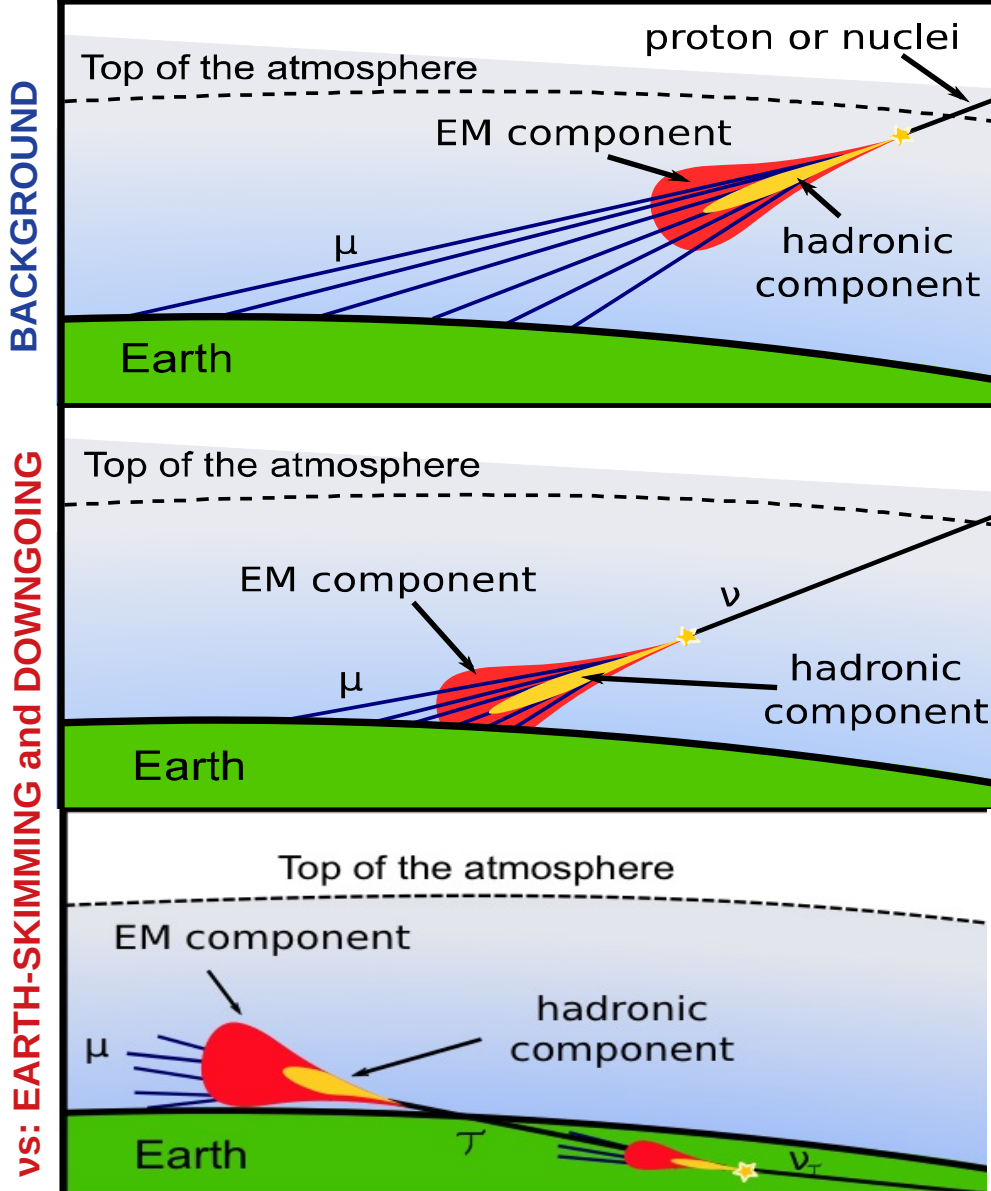
Zenith θ > 60° → atmospheric depth > 1700 g/cm^2



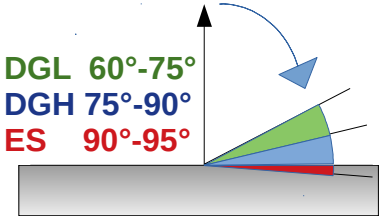
p, Fe: mostly muons → short signal

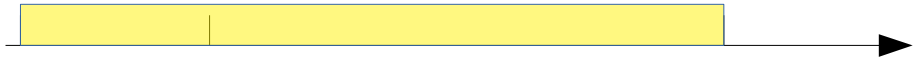


deep ν-induced shower → broader signal



Unblinding of data





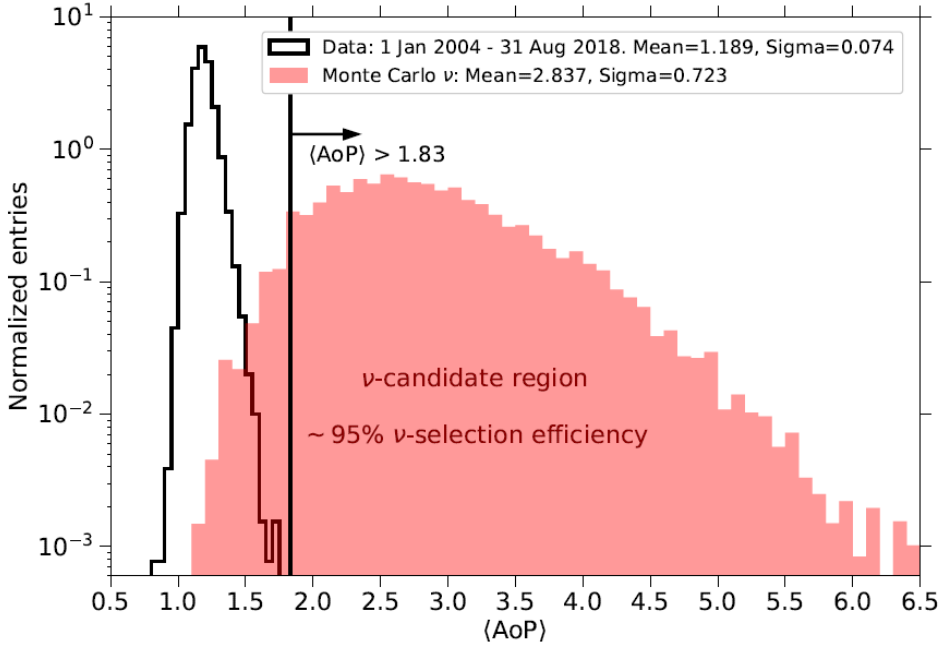
Jan 2004
start of
data taking

2008
SD completed

Aug 2018

14.7 yr of operation
= **9.7 yr** complete SD

Bkg expected: <1 event in 50 years



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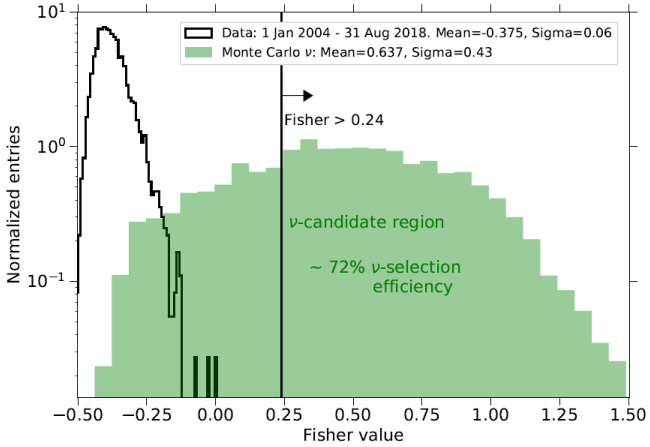

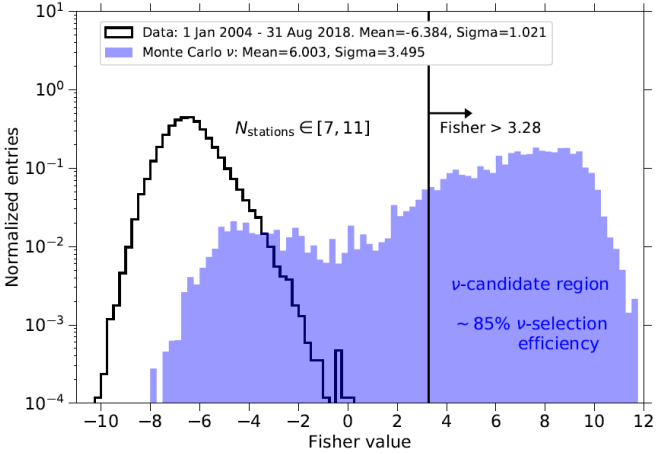

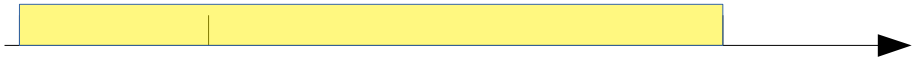

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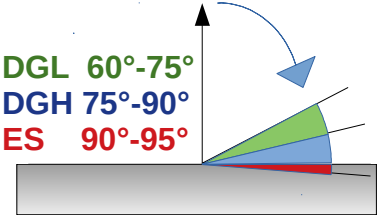

14.7 yr of operation
= **9.7 yr** complete SD

DG split in two channels
to optimize the search
→ different combination
of observables
→ same principle

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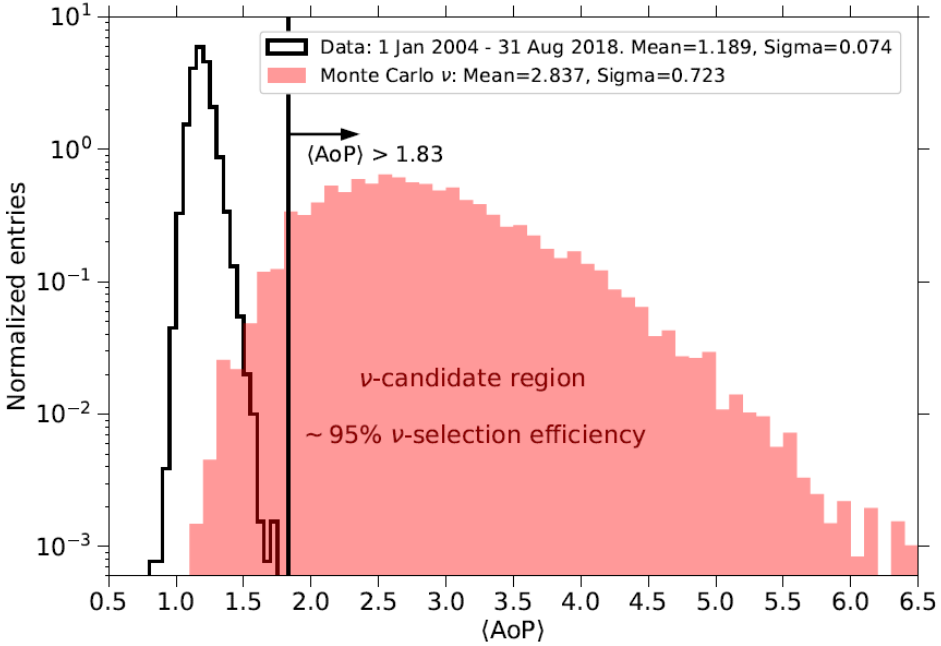
Bkg expected: <1 event in 50 years

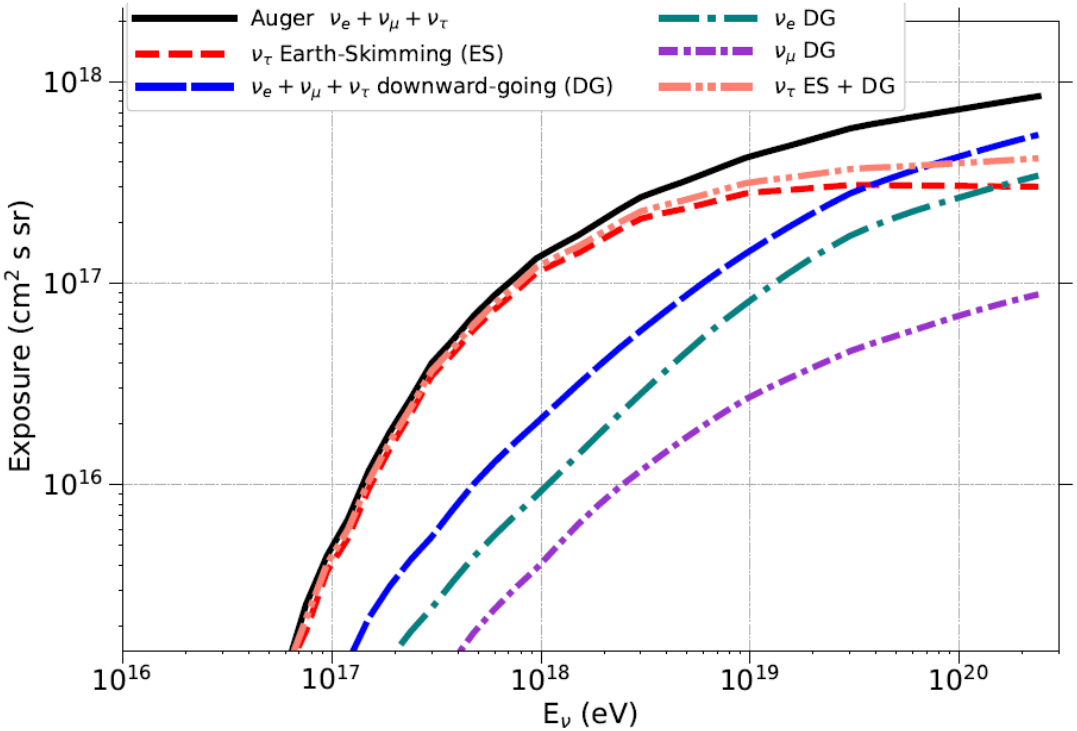


No neutrino candidate found

Energy range and exposure

$$N_{evt} = \int_{E_\nu} \frac{dN_\nu}{dE_\nu}(E_\nu)\,\varepsilon_{tot}(E_\nu)\,dE_\nu$$

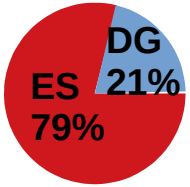
integrated over the solid angle



Sensitivity to ν_τ is dominant

- For a E^{-2} spectrum (1:1:1)

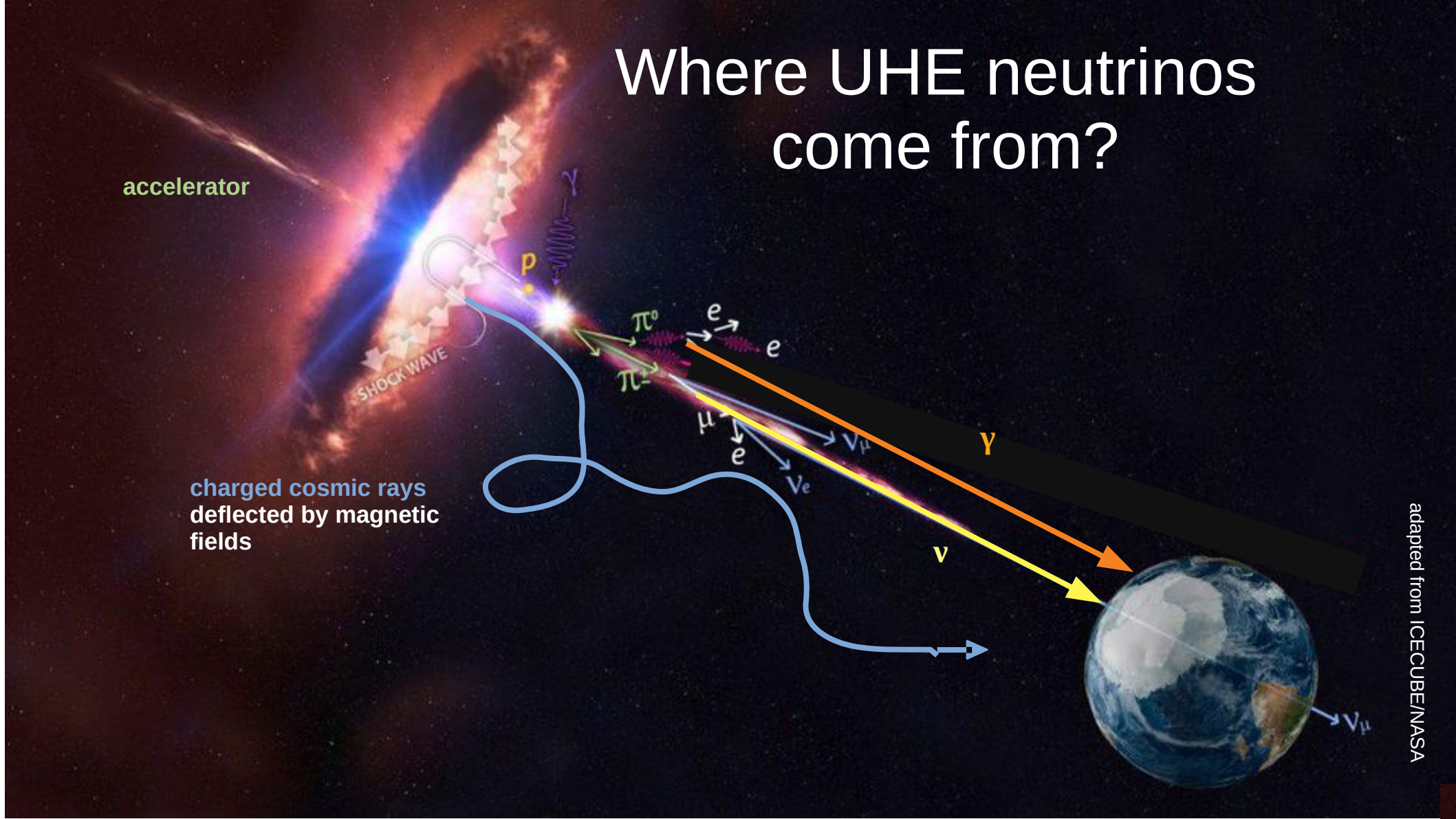
channel relative contribution



→ flavour relative contribution **0.86 : 0.10 : 0.04**

→ 90% of the events in the range **0.1 - 25 EeV**

Where UHE neutrinos come from?



adapted from ICECUBE/NASA

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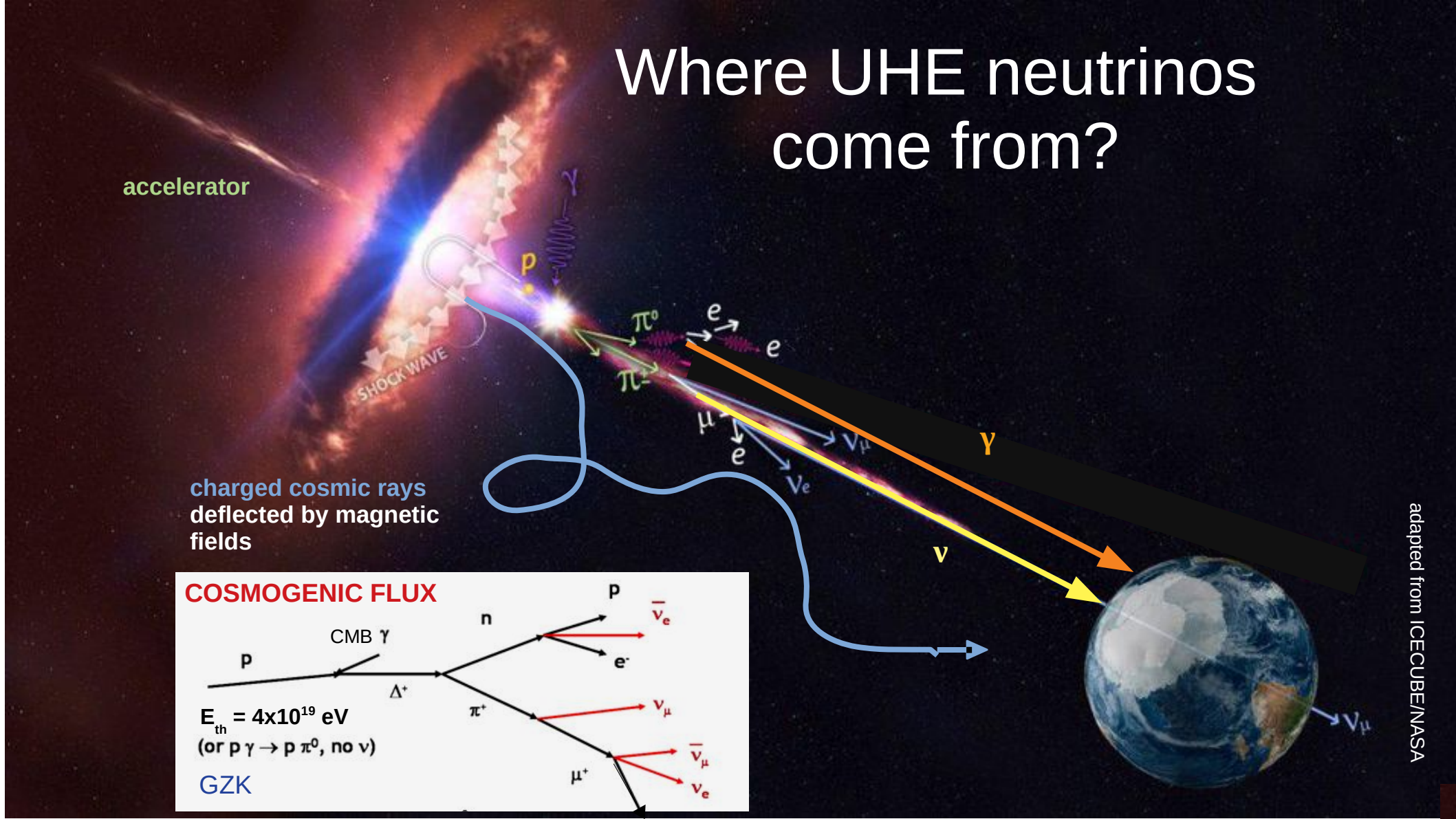
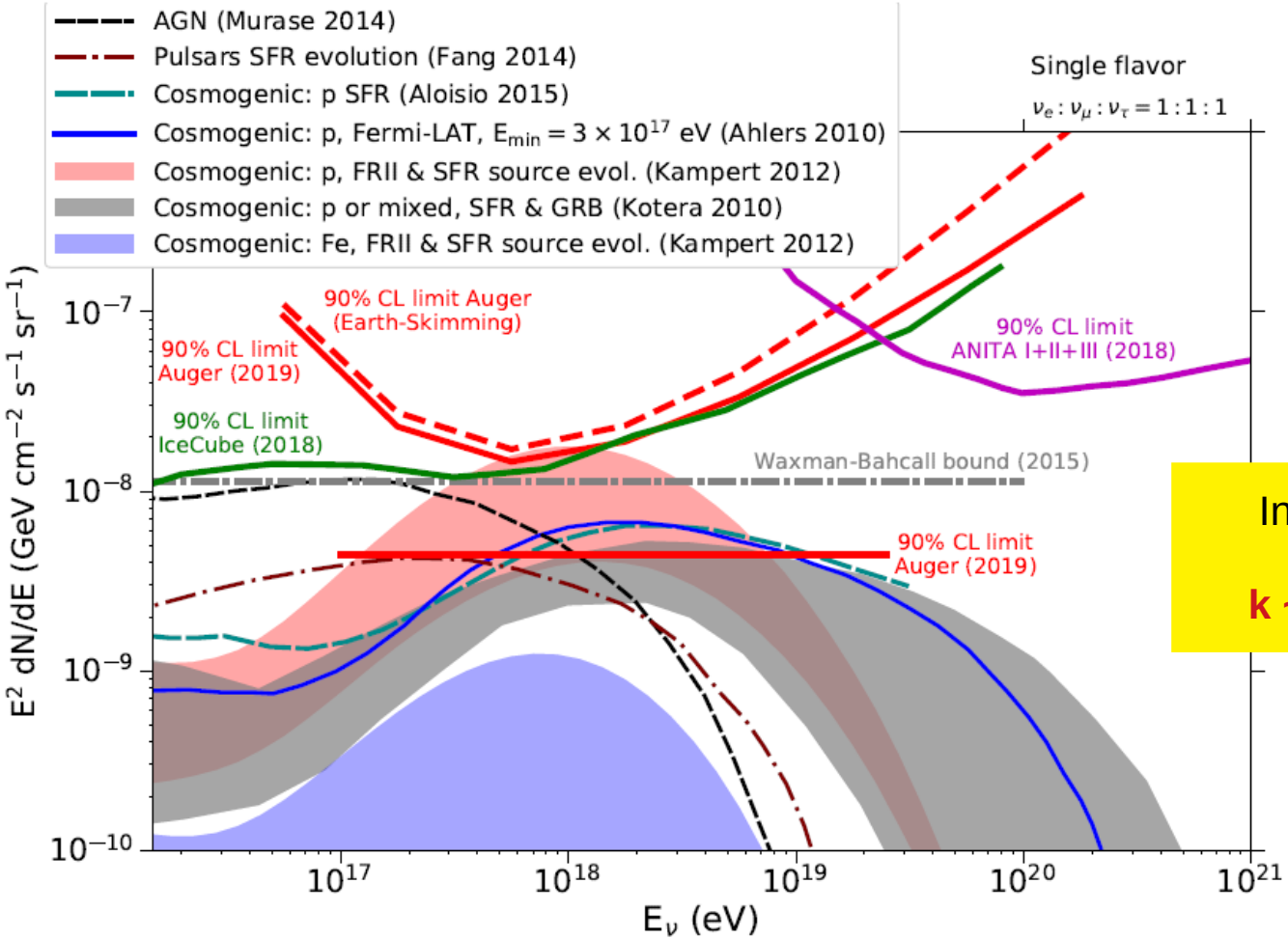


adapted from ICECUBE/NASA

Limits to the diffuse flux of UHE neutrinos

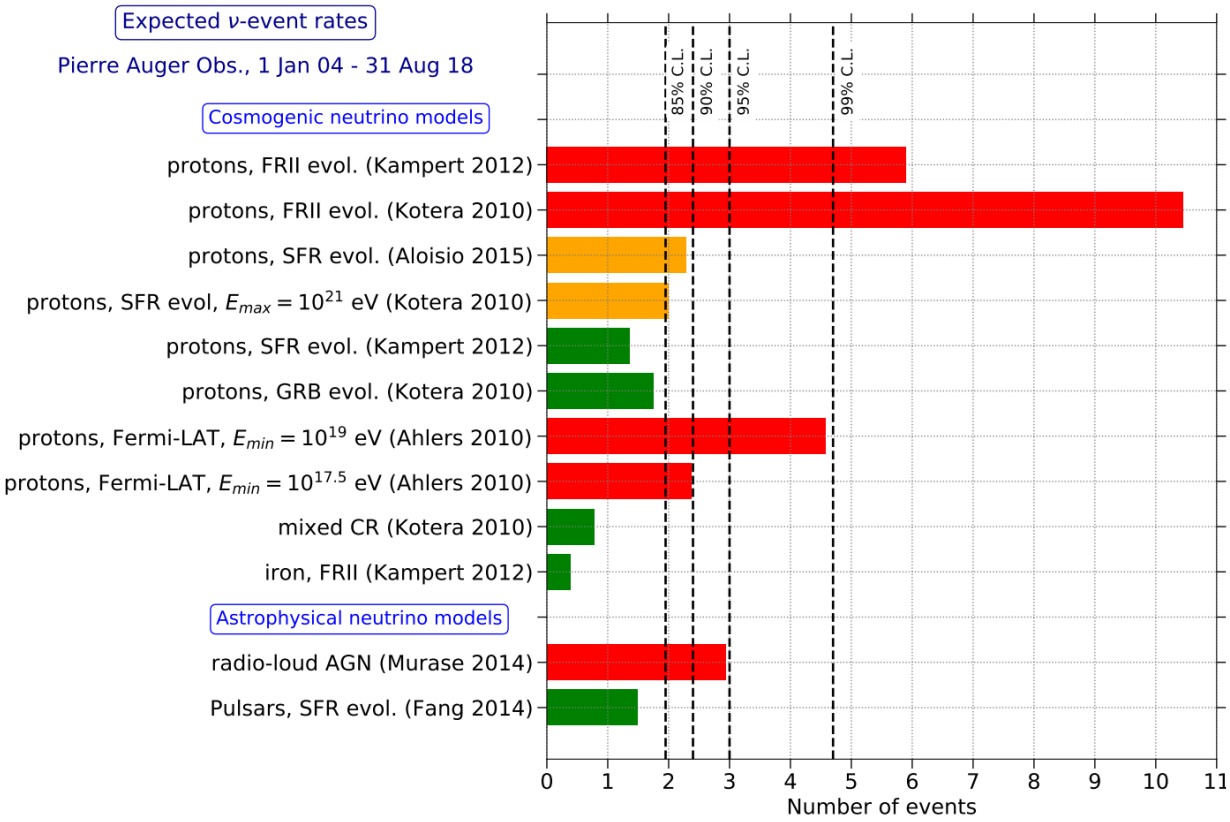


Best sensitivity ~ 1 EeV

Integral UL for a k E^{-2} spectrum

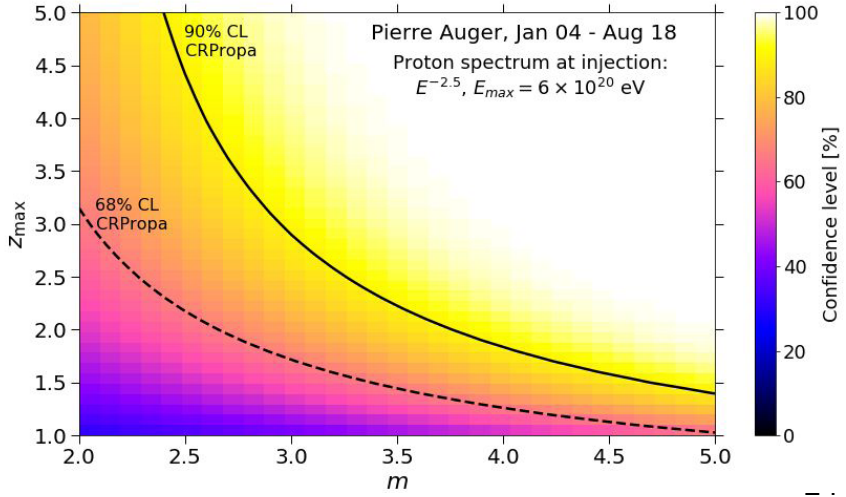
k ~ 4.4 x 10^{-9} GeV cm^{-2} s^{-1} sr^{-1}

Pierre Auger Coll., JCAP10 (2019) 022

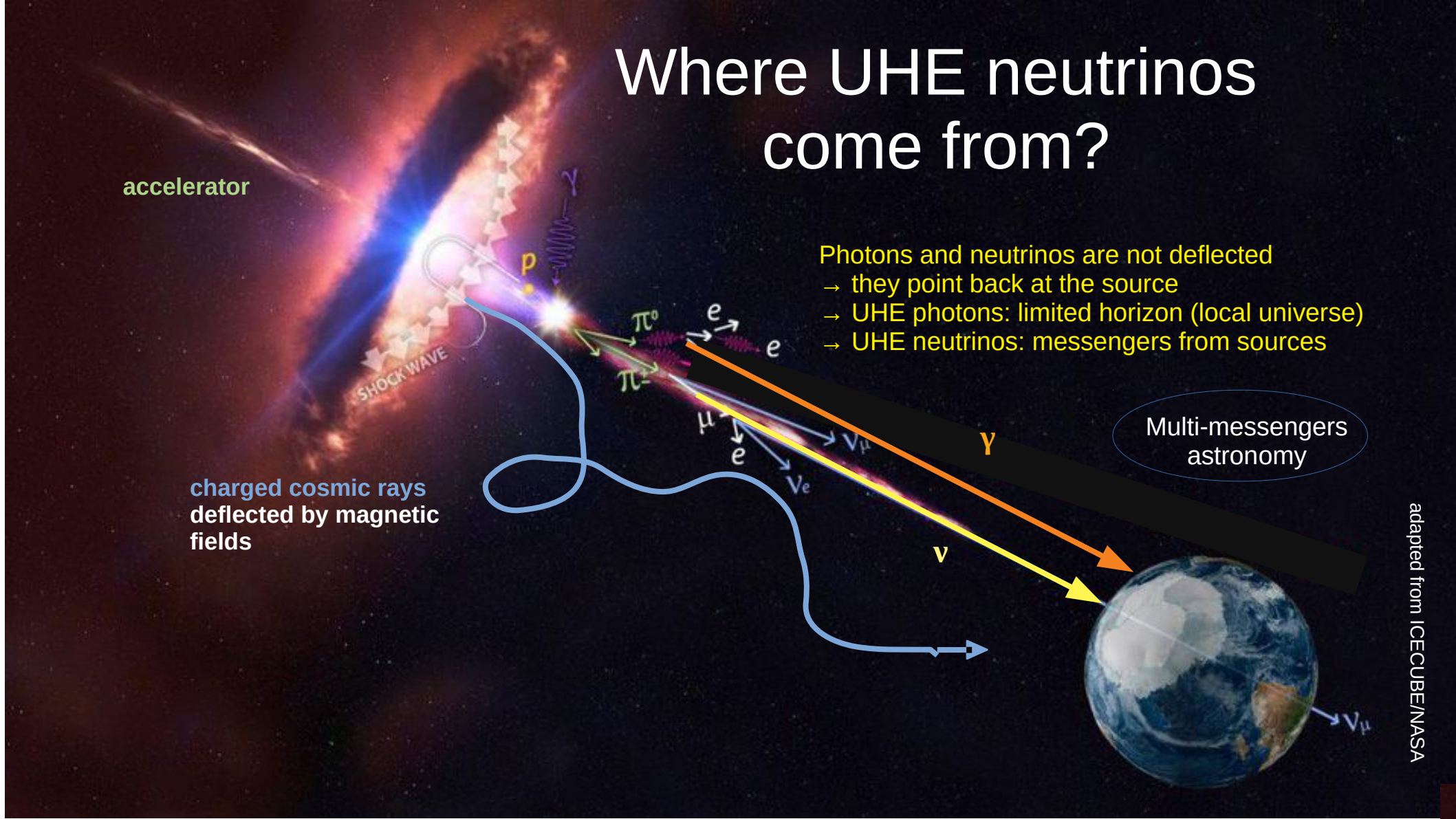


Heavy constraints on scenarios assuming sources accelerating only **p** and with strong evolution with z

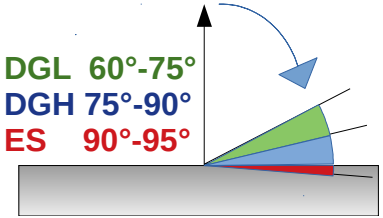
Constraints on proton models
→ sources evolution ~ $(1+z)^m$ up to z_{max}

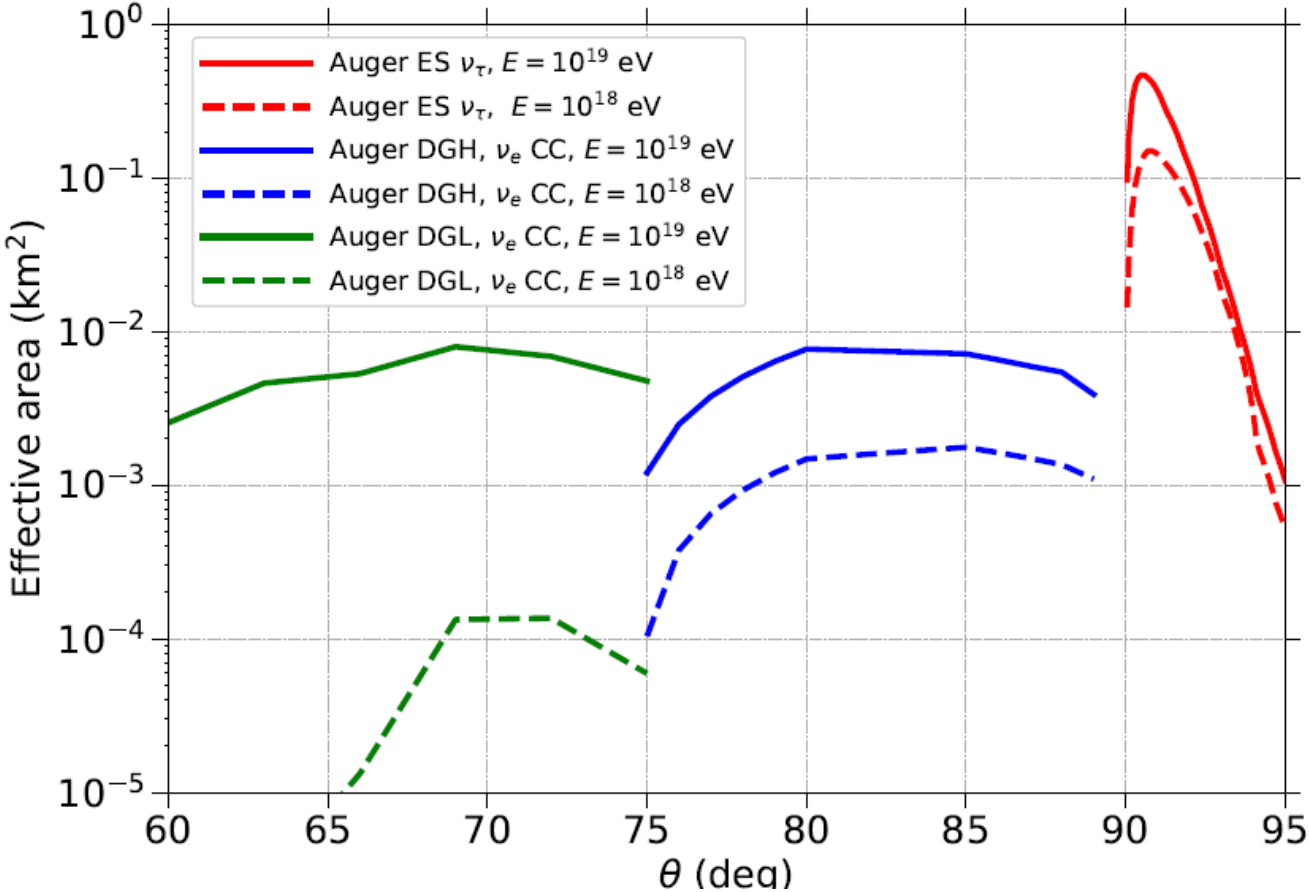


Where UHE neutrinos come from?



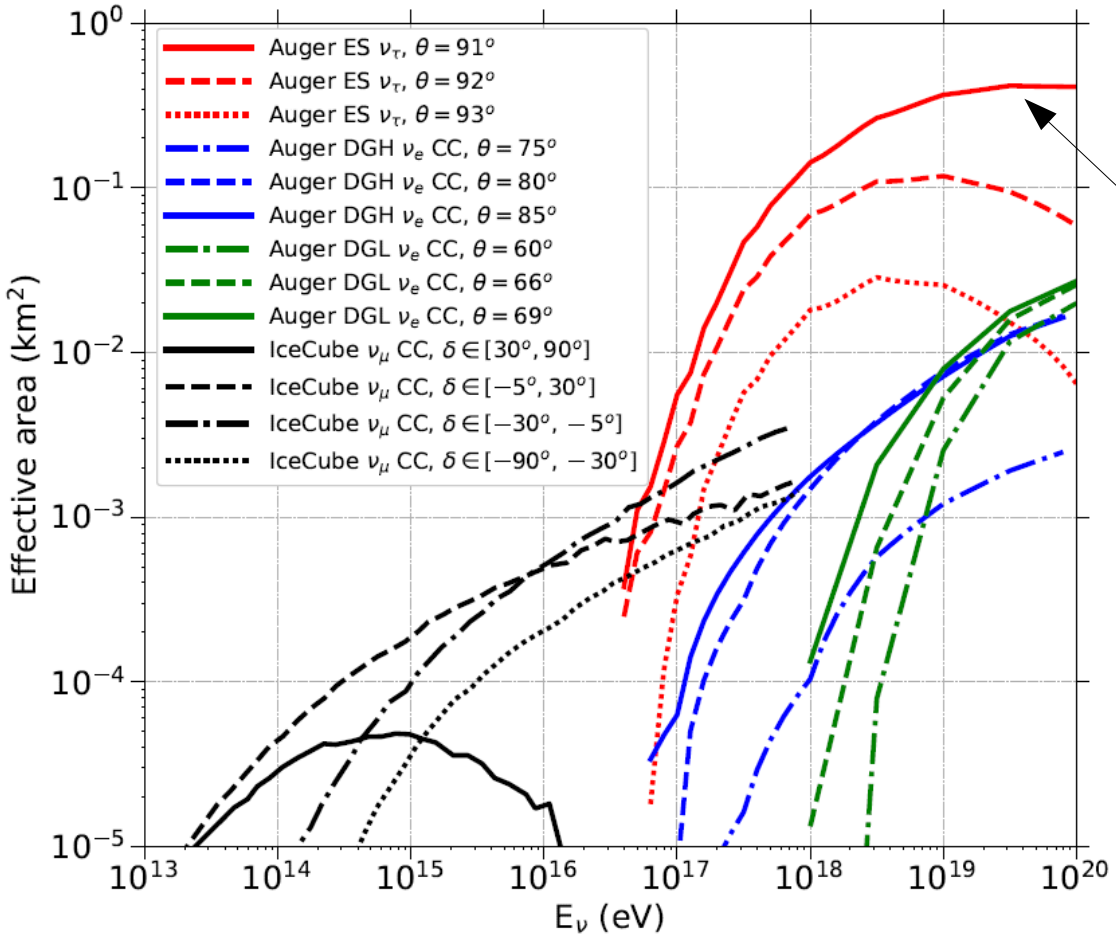
Istantaneous effective area

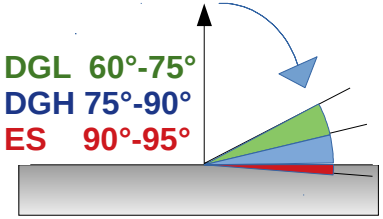




Strong dependence on the zenith angle

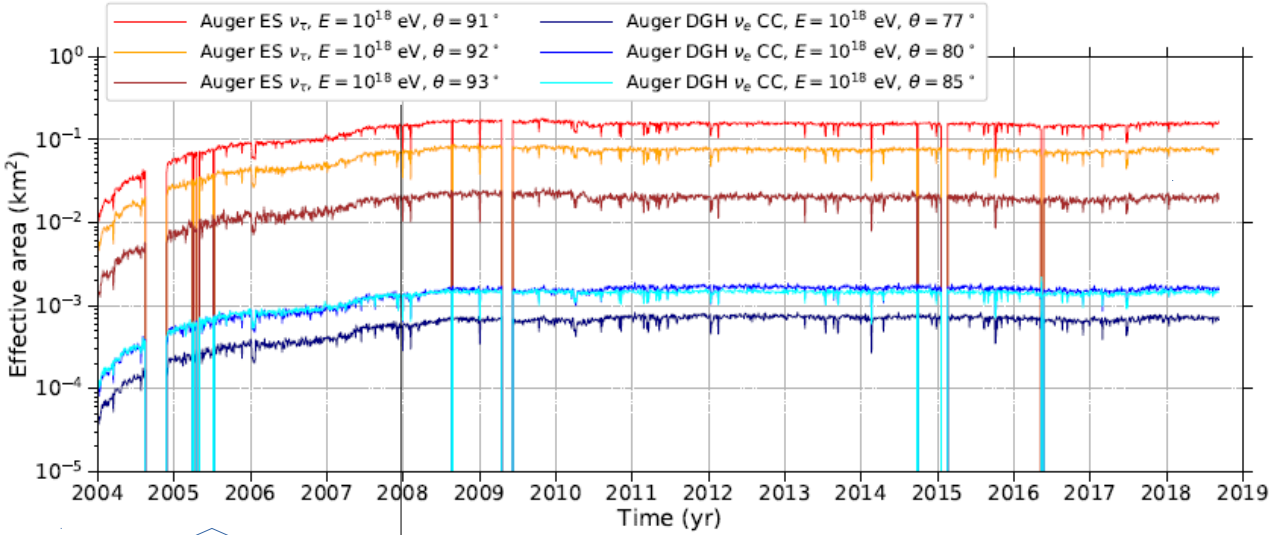
For point sources (steady and transient) the capabilities of observation depend on where the source is in the FoV of the SD





Optimal observation position: source in the field of view of the Earth-skimming channel (right below the horizon)

Point-like steady sources (and long transients)

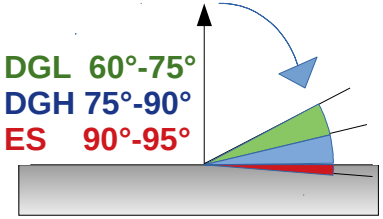


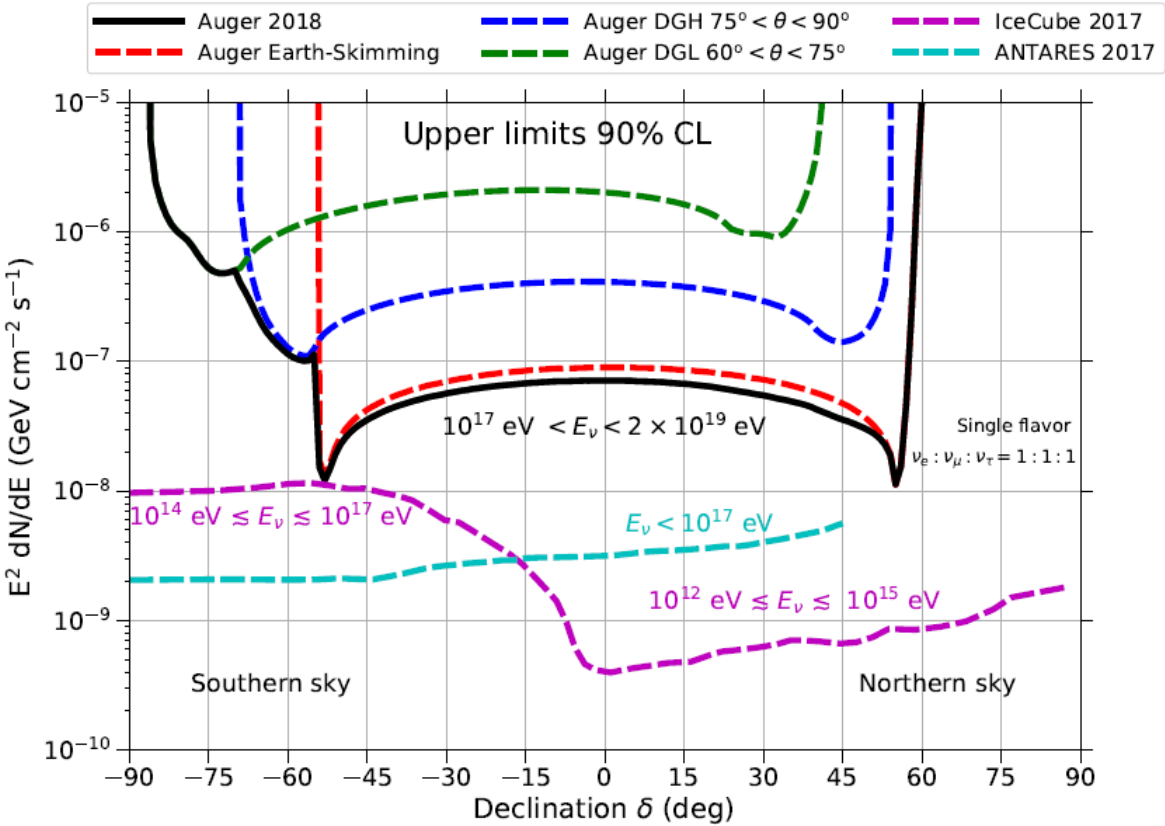
SD deployment (area increasing)

Effective area ~ constant in time

The total exposure depends on the **source declination** as it defines the fraction of sidereal day spent by the source in each search channel

Limits to point-like steady sources





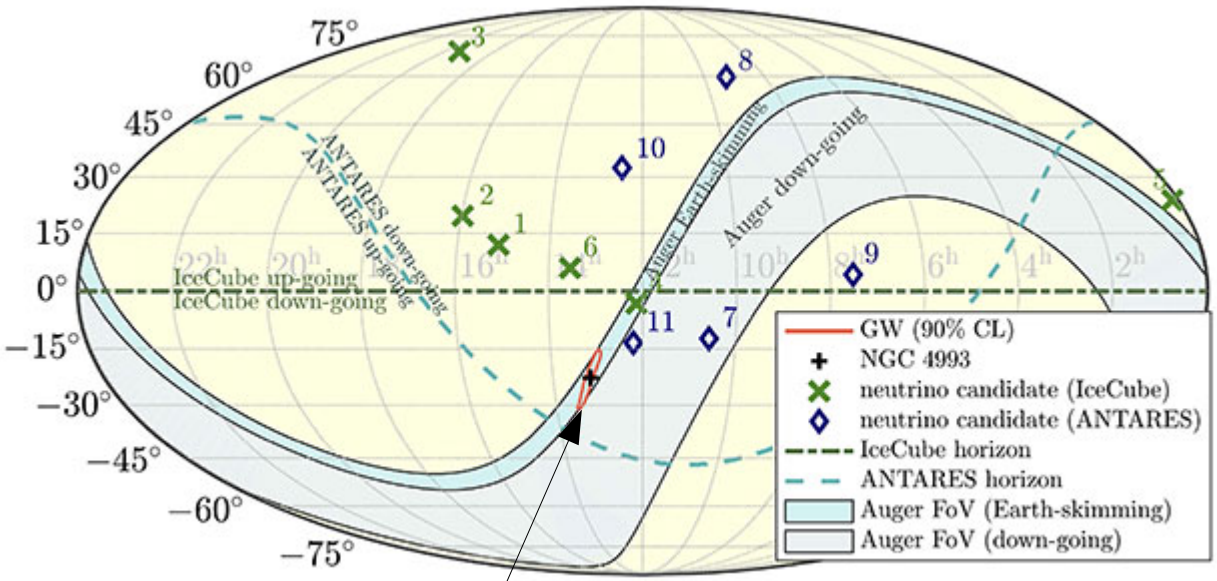
→ Good sensitivity in the EeV range in a broad range of declination

→ **Maximum sensitivity at declinations -53° and 55°** (the source spends more time in the Earth-skimming channel)

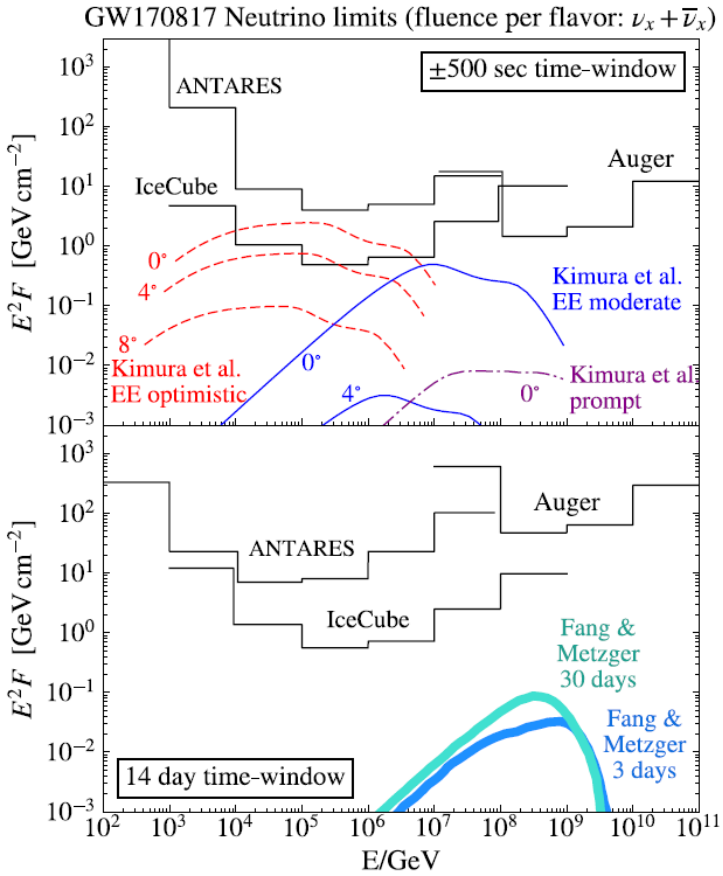
Pierre Auger Coll., JCAP11 (2019) 004

Searching for UHE neutrinos in coincidence with a GW event: BNS merger GW170817 + short GRB

ApJ, 850, L35 (2017)



In the ES channel: sweet spot for Auger detection



Conclusions

- The Surface Detector of the Pierre Auger Observatory can be used as a large area detector for neutrinos at UHE energies (0.1 – 25 EeV)
- Mostly sensitive to tau neutrinos
- Strict limits to the flux of cosmogenic neutrinos

- Auger as key detector in multi-messenger astronomy at UHE energy:

  → Excellent sensitivity to neutrinos in the EeV range

  → Coverage of a large fraction of the sky

More results, including the follow-up search of Ligo/Virgo O1-O3 BBH mergers

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M. Schimp

PIERRE AUGER OBSERVATORY

November 2019

Malargue Argentina

Celebration of the (first) 20 years of the Observatory