Search for UHE neutrinos – in coincidence with LIGO GW150914 event – with the Pierre Auger Observatory

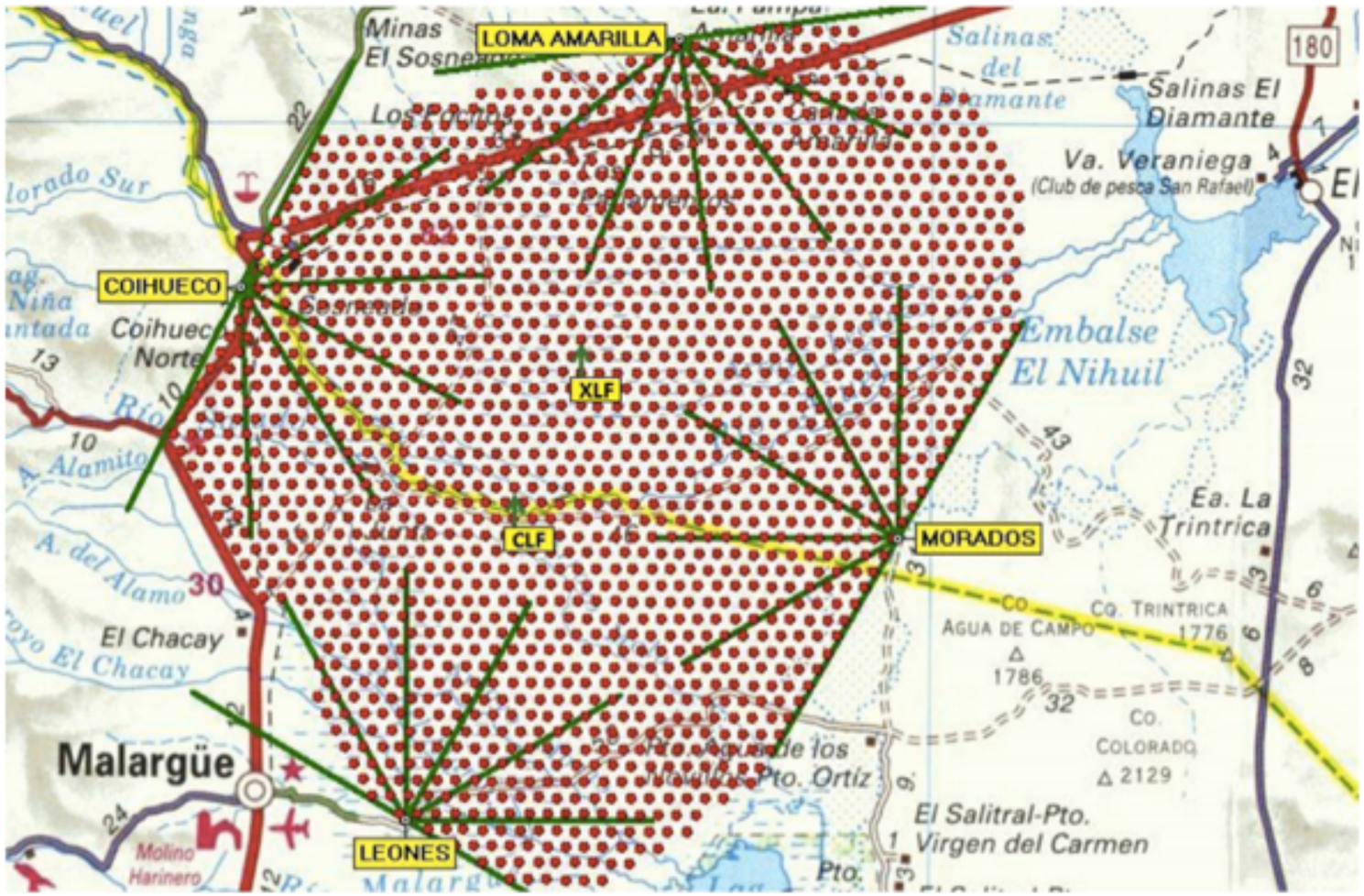
Lili Yang
University of Nova Gorica
(on behalf of the Pierre Auger Collaboration)

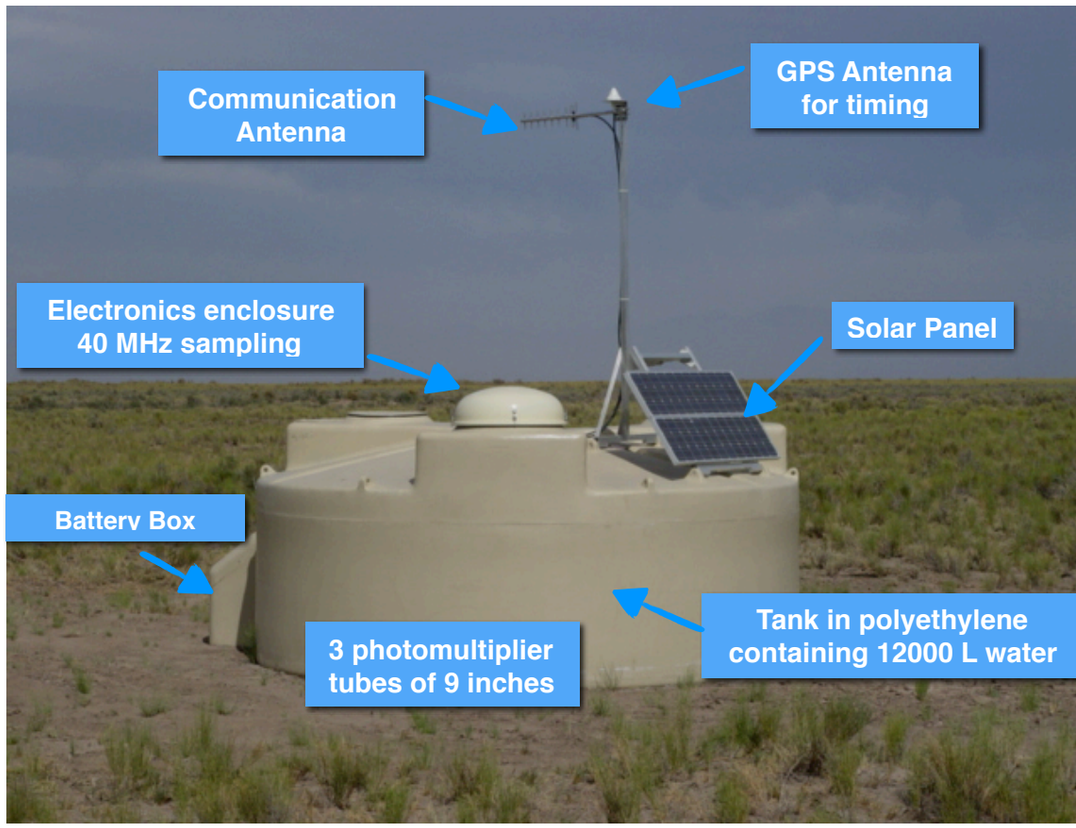
arXiv:1608.07378

Pierre Auger Observatory

The surface detector array
~ 3000 km^2
~ 1660 water Cherenkov stations
~ 24 hour per day

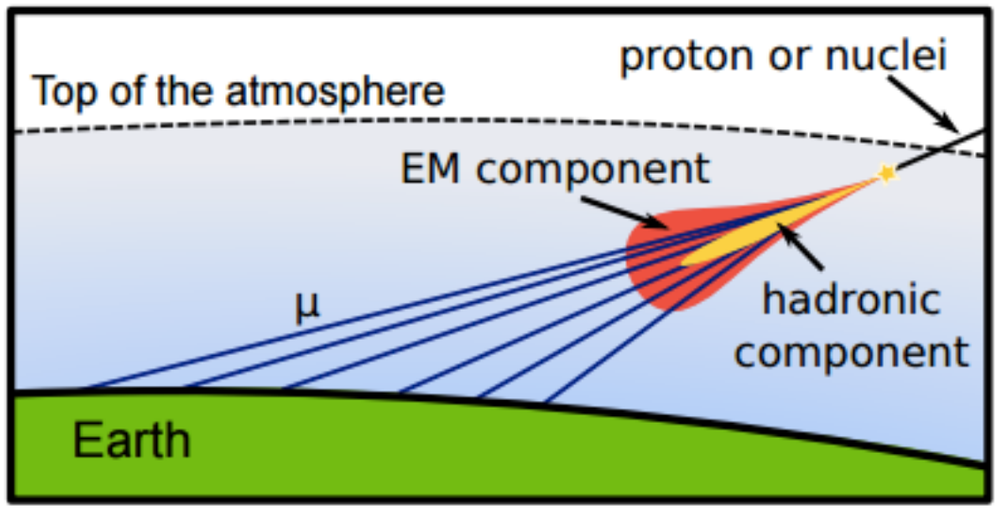
→ sensitive to electromagnetic and muonic component (not separately)
→ can measure the time structure of the signal induced by electrons and muon

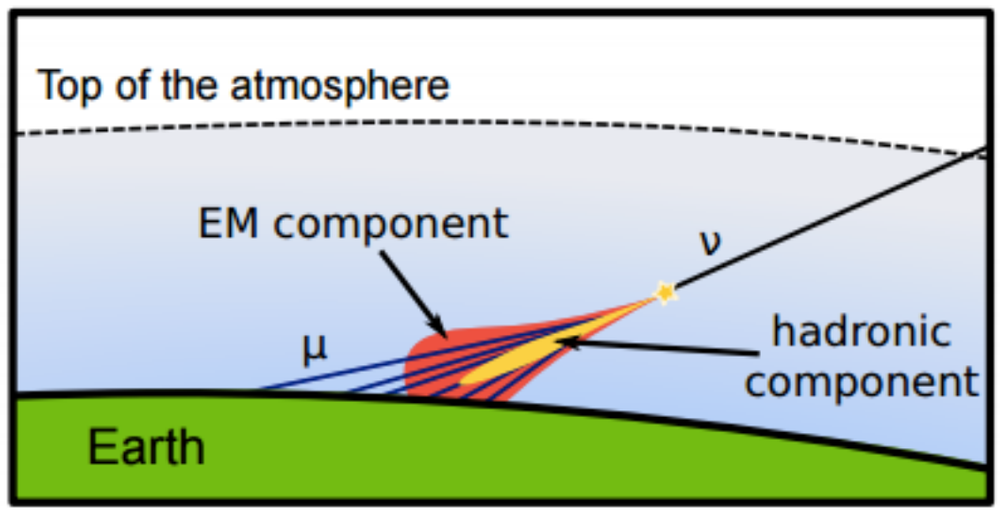


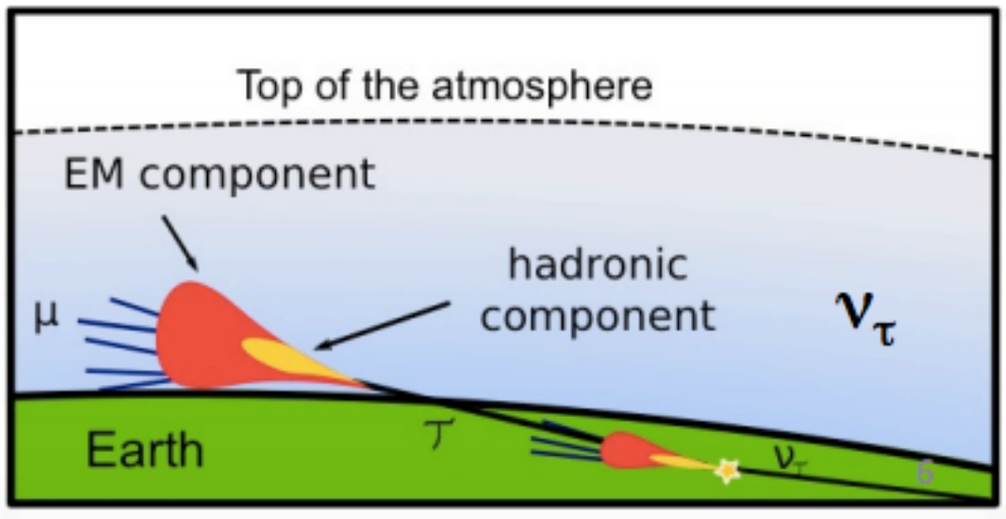


35.5° S, 69.3° W
1400 m a.s.l. (880 g cm^{-2})

Inclined showers





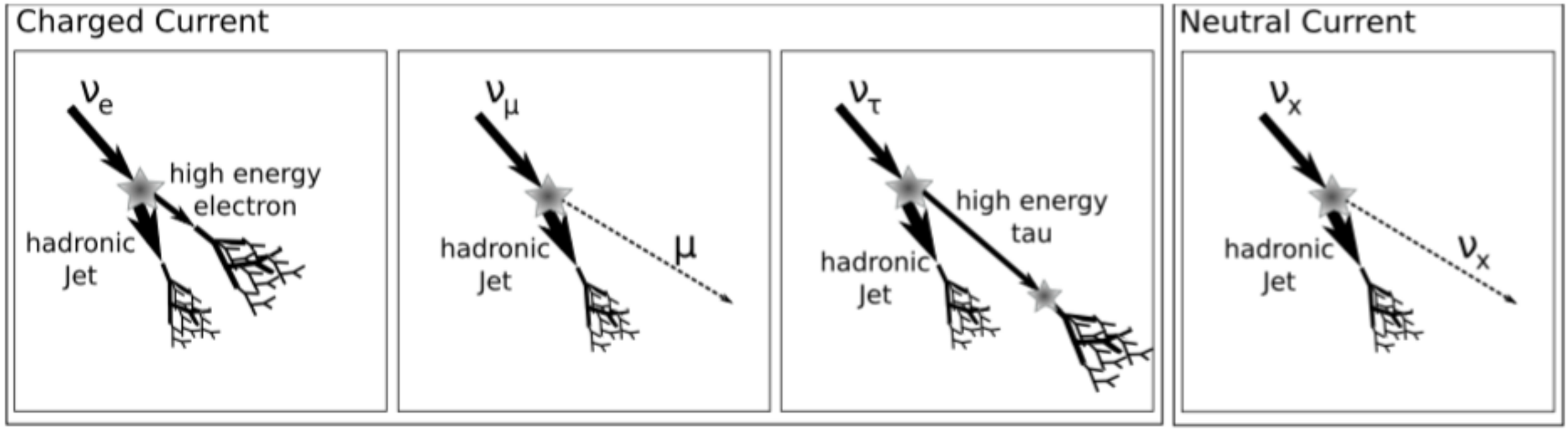


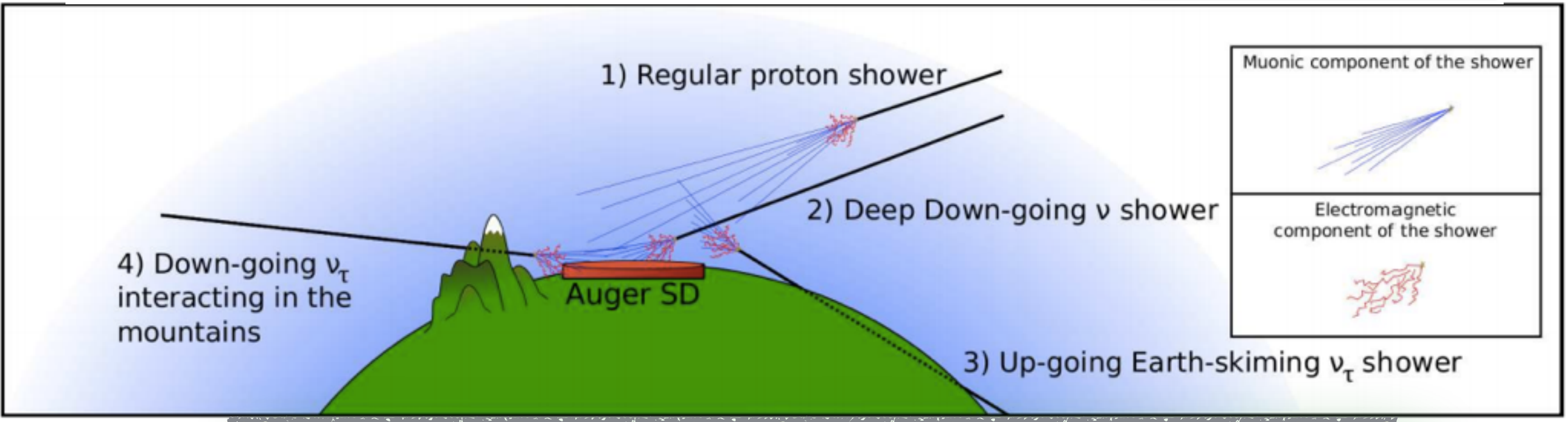
- Protons & nuclei initiate inclined showers high in the atmosphere.
  - ✓ Shower front at ground:
  - electromagnetic component absorbed in atmosphere.
  - mainly muons remaining

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

Searching for neutrinos searching for inclined showers with electromagnetic component

Inclined UHE neutrino search





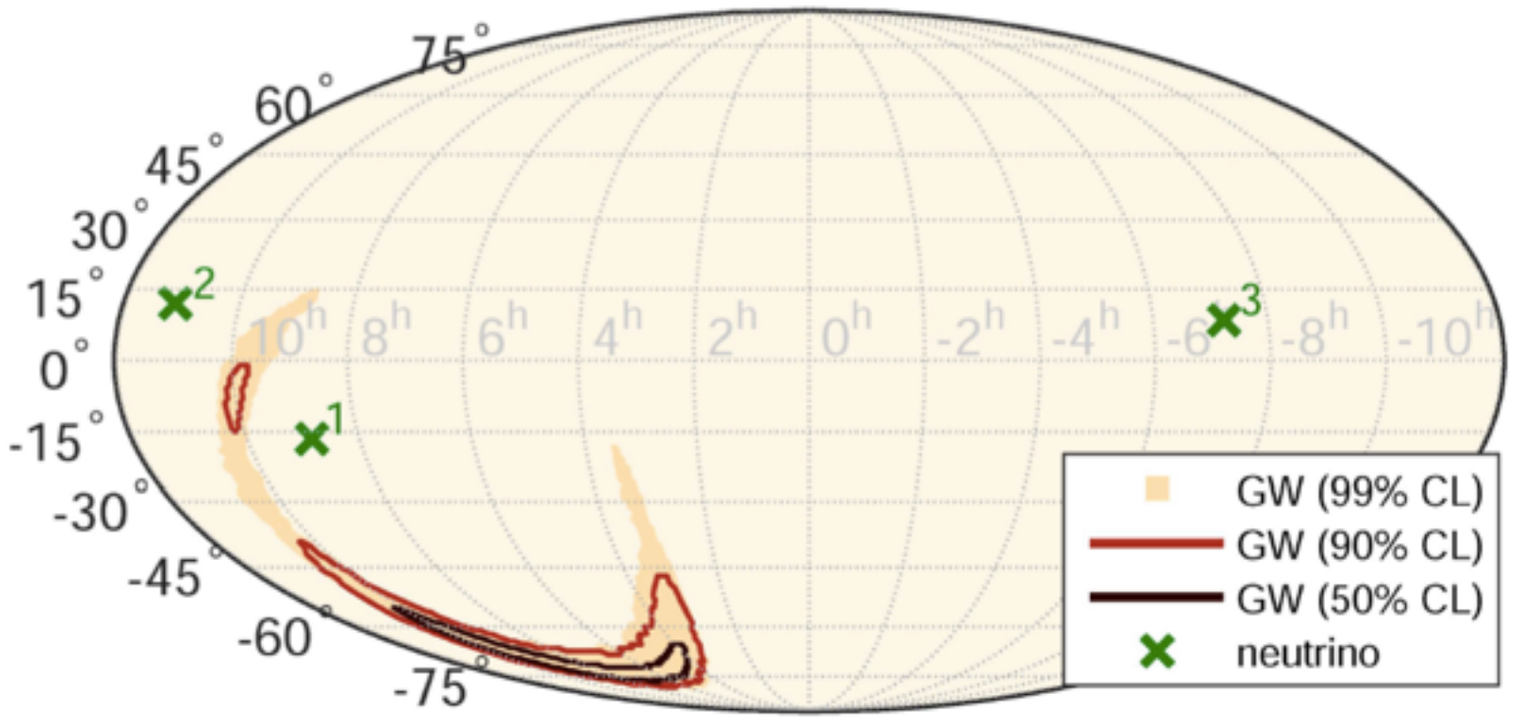
Two criteria:

Down-going high angle (2 and 4) DGH (75° — 90°)

Earth skimming (3) ES (90° — 95°)

LIGO GW150914

- Gravitational Waves detected by Advanced-LIGO
  - Inferred source: merger of 2 black-holes at D=410(+160)(-180) Mpc
  - Energy radiated in Gravitational wave ~ 5.4×10^{54} ergs
  - Position in the sky uncertain: assume 90% CL contour



ANTARES Collab., IceCube Collab., LIGO Scientific Collab., and Virgo Collab.

LIGO GW150924

- Gravitational Waves detected by Advanced-LIGO
  - 14 September 2015 at 09:50:45 UTC
  - Inferred source: merger of 2 black-holes at D=410(+160)(-180) Mpc
  - Position in the sky uncertain: assume 90% CL contour position
- Models predict Gamma-Ray-Burst (GRB) after merger of compact objects where neutrinos can be produced:
  - GRB "prompt" emission may last up to 500 s
  - GRB "afterglow" timescale is hours — days

Auger sensitivity to GW150914

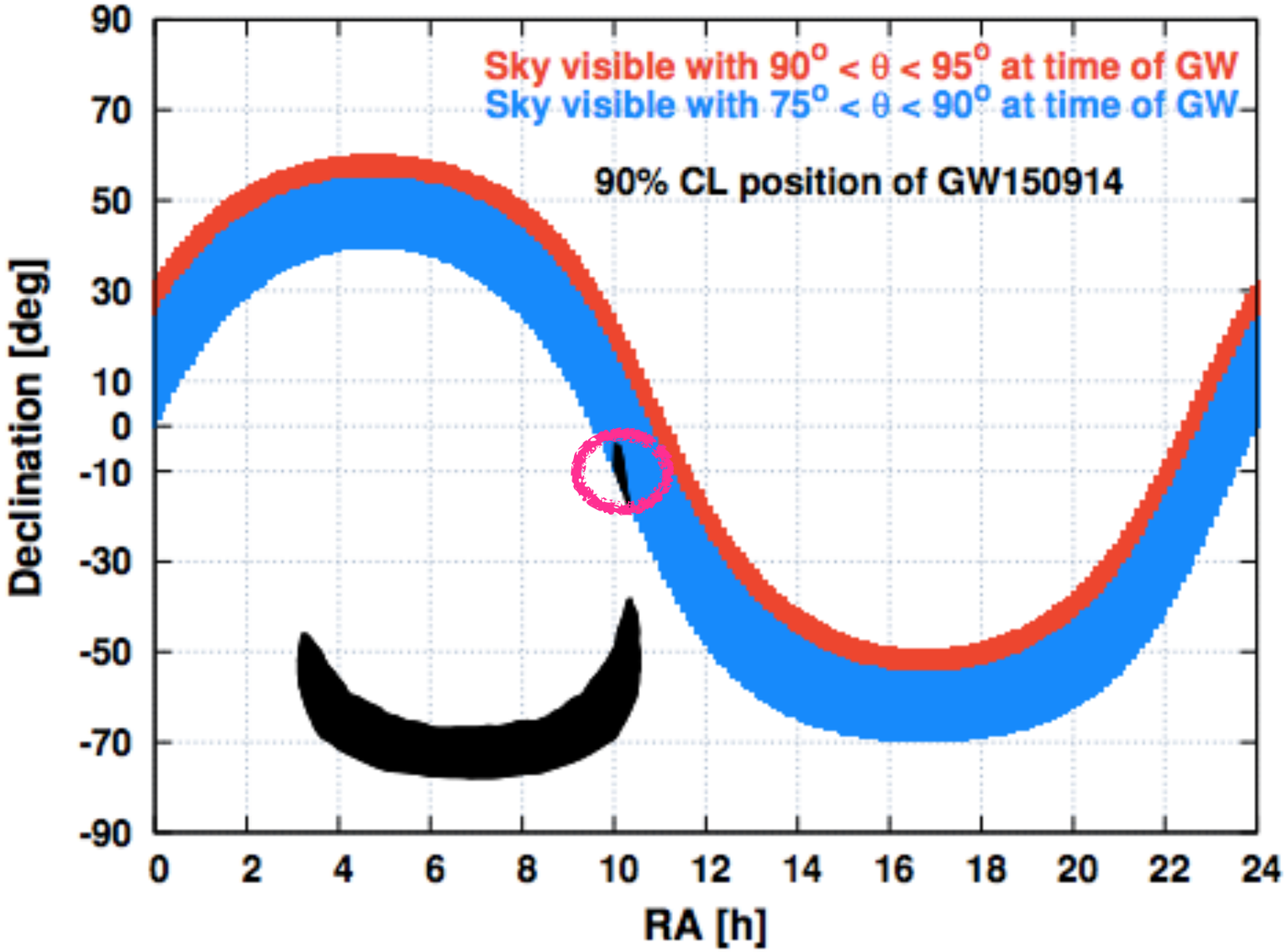
- Sensitivity to UHEv limited to large zenith angles
- At each instant of time neutrinos can only be detected from a specific portion of the sky
- GW150914 not visible in ES (90º, 95º) within ±500s of its UTC time but visible in DGH (75º, 90º) angular bin
- GW150914 visible in ES & DGH a significant fraction of 1 day after occurring

GW150914 as viewed from Auger

instantaneous field of view

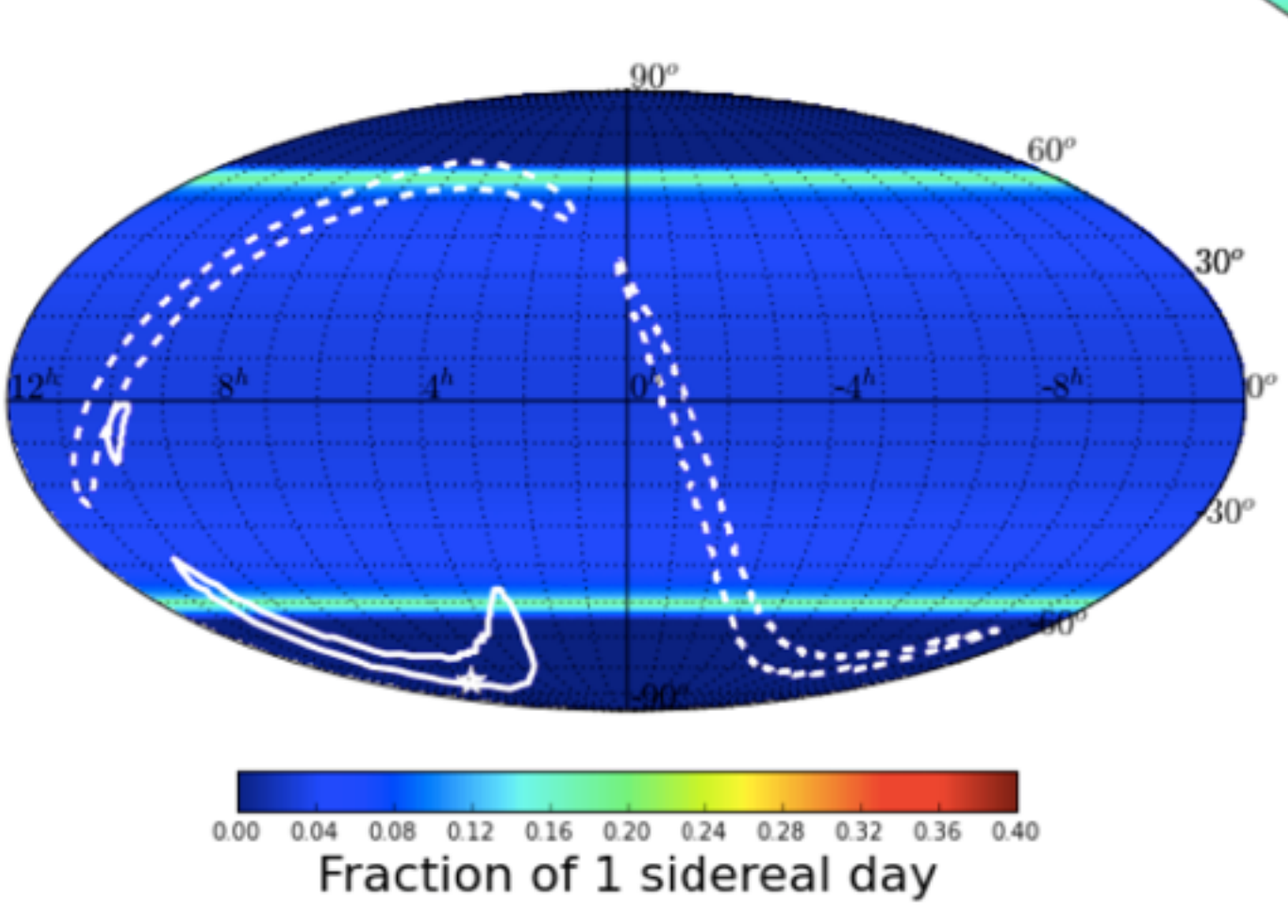
Latitude of Auger : -35.2°

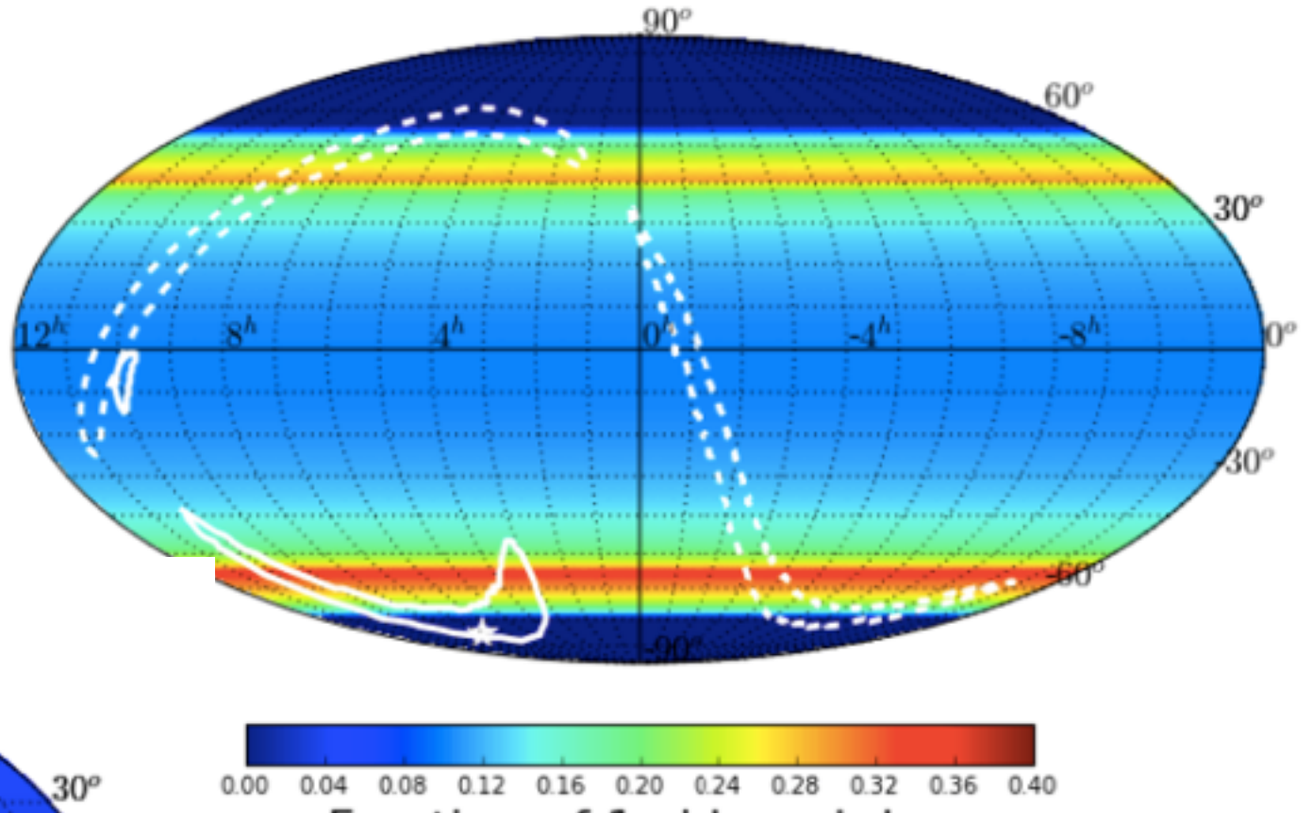
On September 14, 2015 at 09:50:45 UTC



Fraction of visible time

ES channel





DGH channel

Unblinding results

No neutrino candidates found in any of the data periods unblinded

- Data +/- 500 s around GW150914:

– No inclined events found in ES selection

– No inclined events found in DGH (75° - 90°) selection

- Data 1 day after GW150914:

– 12 inclined events found in ES selection, none passed young shower selection => no candidates

– 24 inclined events found in DGH (75° - 90°), none passed young shower selection => no candidates

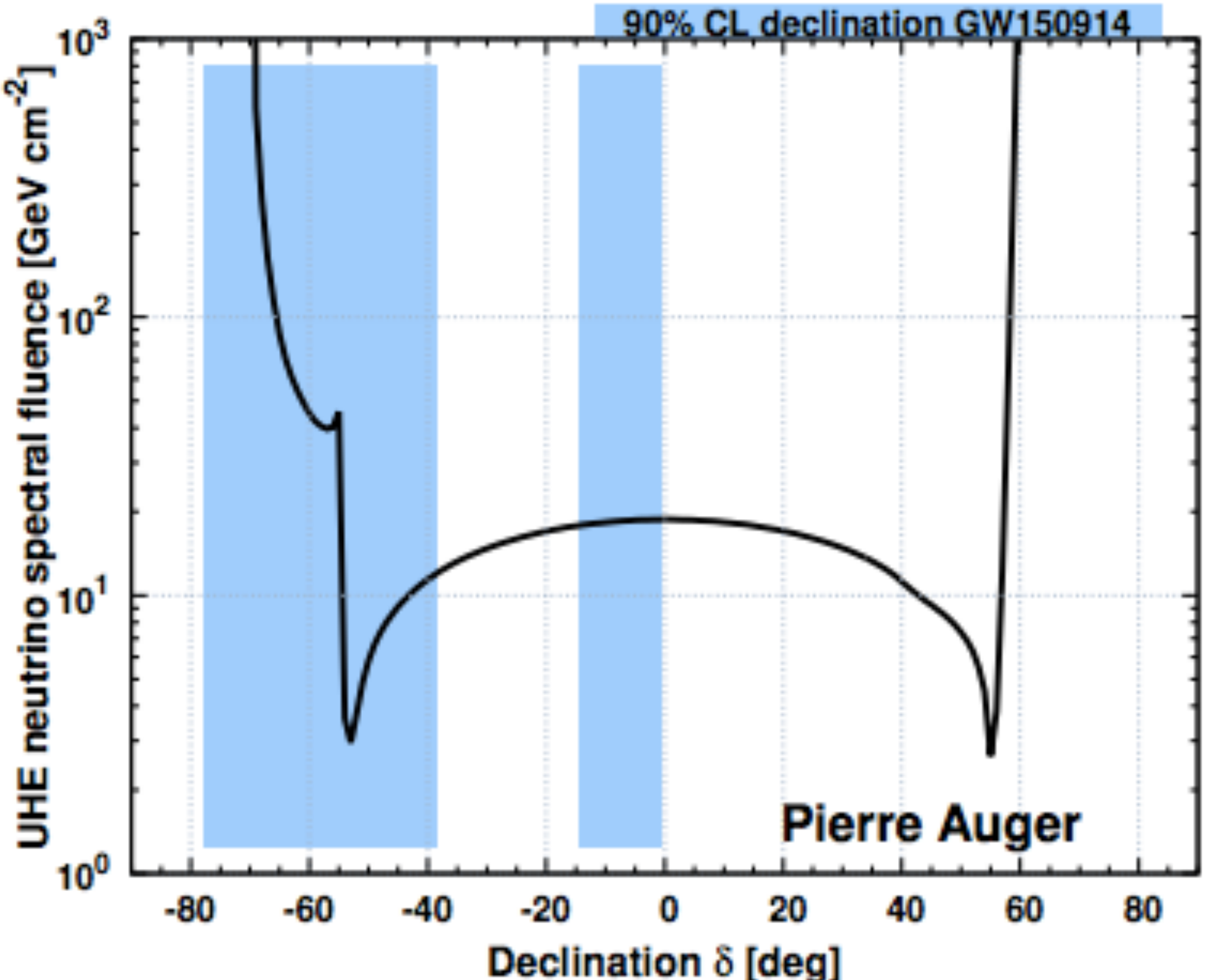
Constraints

Assuming a standard E^{-2} spectrum → $\frac{dN_\nu^{GW}}{dE_\nu} = k^{GW} E_\nu^{-2}$

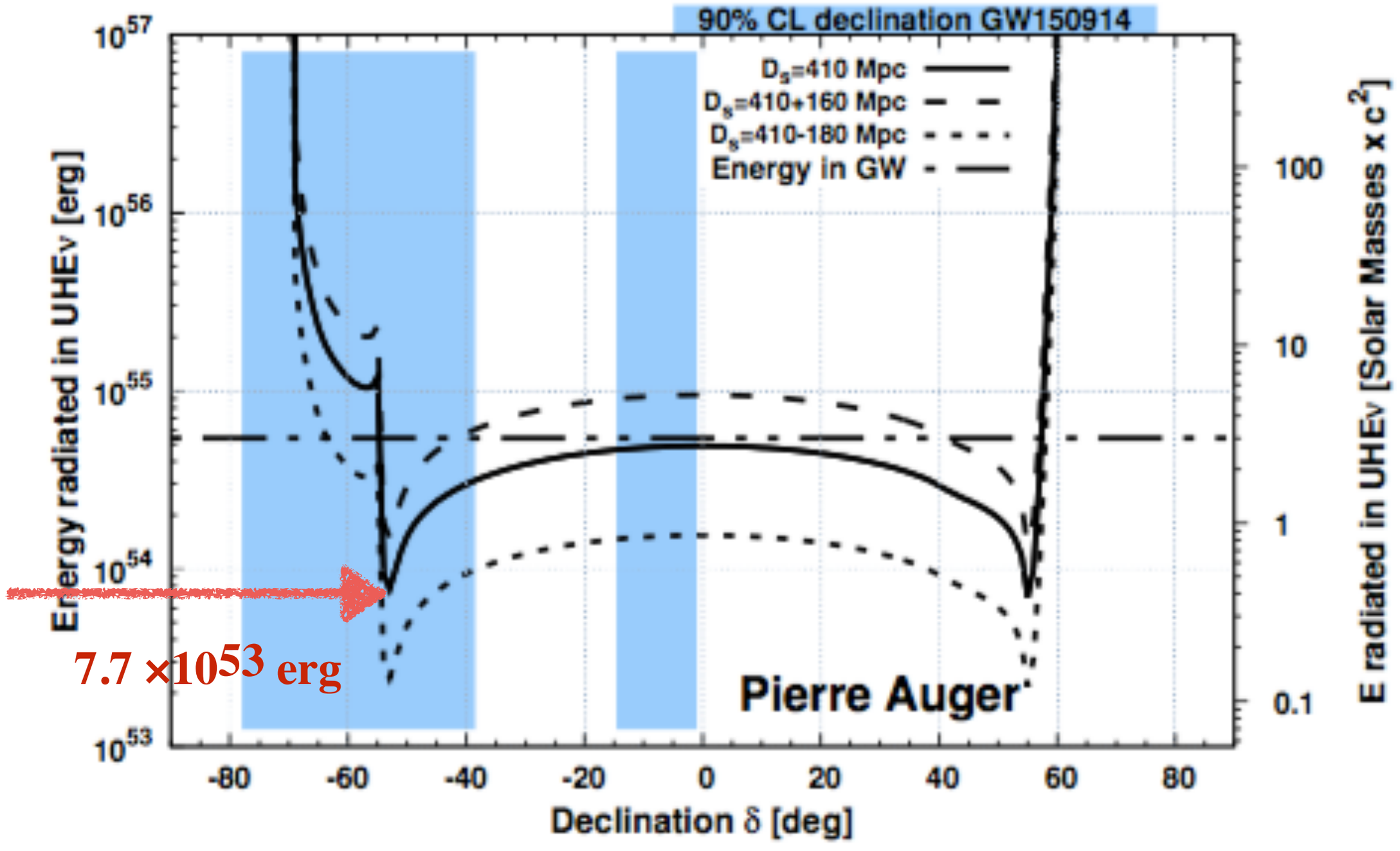
90% CL upper limit → $k^{GW}(\delta) = \frac{2.39}{\int_{E_\nu} E_\nu^{-2} \varepsilon_{GW}(E_\nu, \delta) dE_\nu}$

Upper limits to neutrino fluence → $E_\nu^2 \frac{dN_\nu}{dE_\nu} \times T_{search} = k^{GW}(\delta) T_{search}$

Constraints on UHEv flux normalization



Constraints on $E_{\nu,tot}$ the energy radiated in UHE neutrinos



$$E_{\nu,tot}(\delta) = F_\nu(\delta) \times 4\pi D_s^2$$

Summary

- No candidates found, The first following of GW events with vs of > 100 PeV

- The most stringent upper limit to the total energy in the form of UHE vs for GW150914 event

Theory by Kotera and Silk

$$E_\nu^2 \frac{dN_\nu}{dE_\nu} \lesssim (1.5 - 6.9) \times 10^{-8} GeV\, cm^{-2} s^{-1} sr^{-1}$$

Auger

$$E_\nu^2 \frac{dN_\nu}{dE_\nu} < 6.4 \times 10^{-9} GeV\, cm^{-2} s^{-1} sr^{-1}$$

- Place a most stringent upper limit on the fraction of GW energy channeled into neutrinos of ~ 14%

- Multi messenger observations reveal properties of the sources

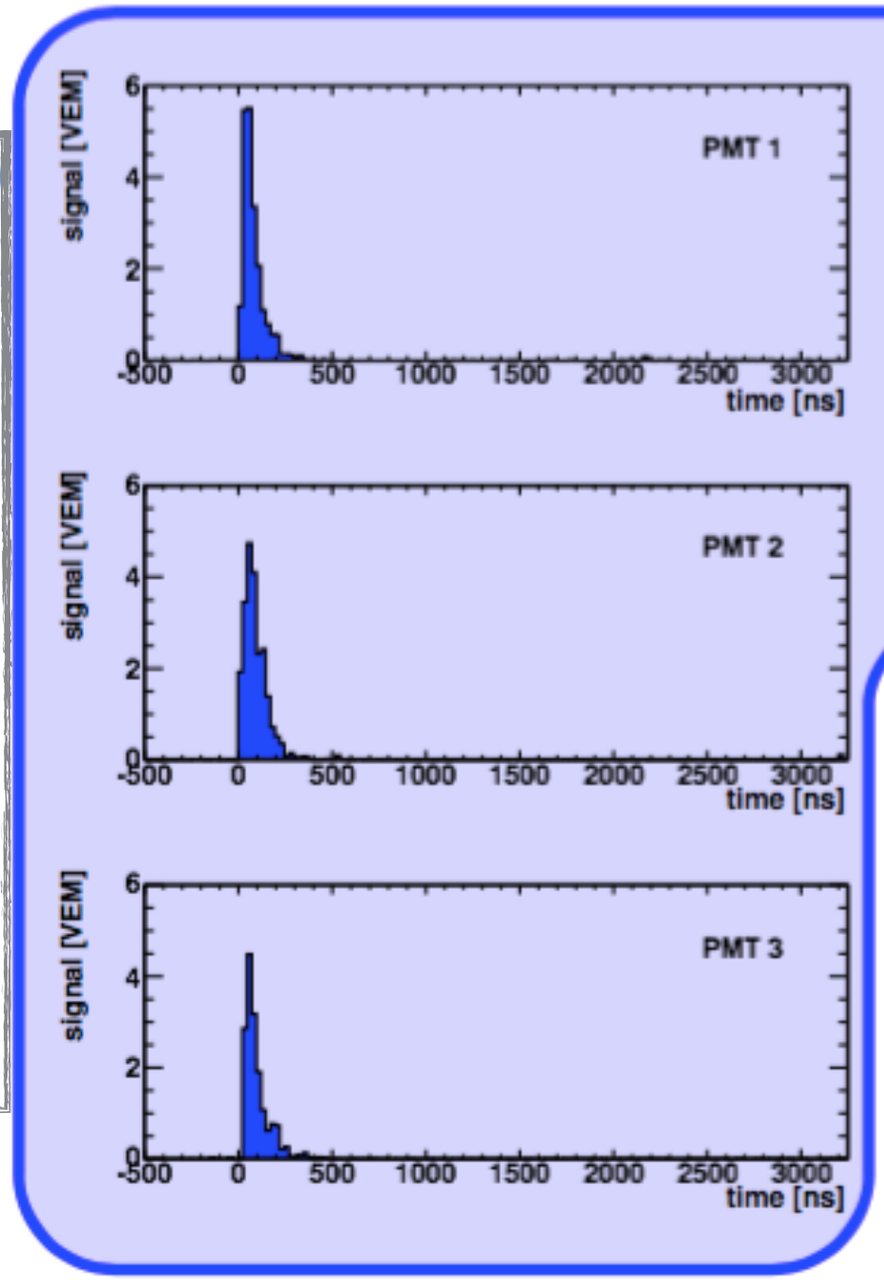
Thank you!

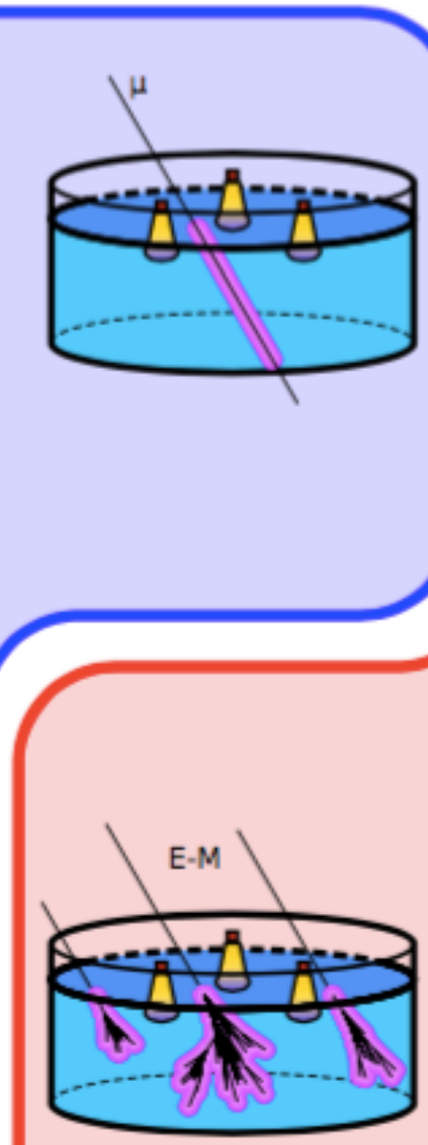
Questions and comments?

Identifying vs in data collected at SD

With the SD, we can distinguish muonic from electromagnetic shower fronts (using the time structure of the signals in the water Cherenkov stations).

Muonic shower front





EM shower front