VII: Peculiar signatures

Importance of identifying presence of neutrinos or photons in the UHECR.

The shower development reflects the particle's nature.

- Horizontal "old" (proton/photon) or "young" (neutrino) showers
- Vertical "young" showers (LPM gamma)
- X_{max} correlation with the Earth magnetic field orientation (gamma)

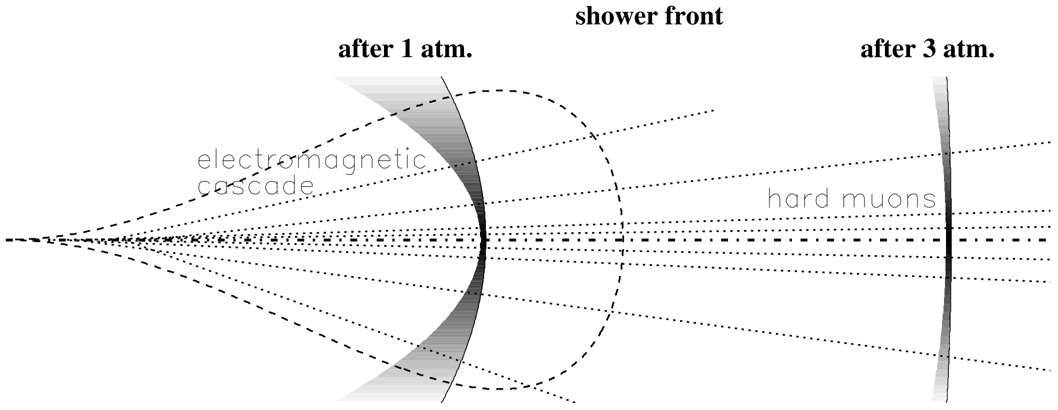
For neutrinos the cross section becomes large enough so that they can interact in the atmosphere above our detector. For photons or protons showers are very old (hundreds X_0) when they reach the detector.

For gammas 2 effects strongly modify the shower initial development :

- Interactions with the Earth magnetic field (Pair creation and synchrotron loss of electrons)
- The LPM effect (cross section decrease with medium density)

These effects allow to identify neutrino with certainty and the presence of a small fraction of photons (as low as a few percent)

Shower development



"Old" showers :

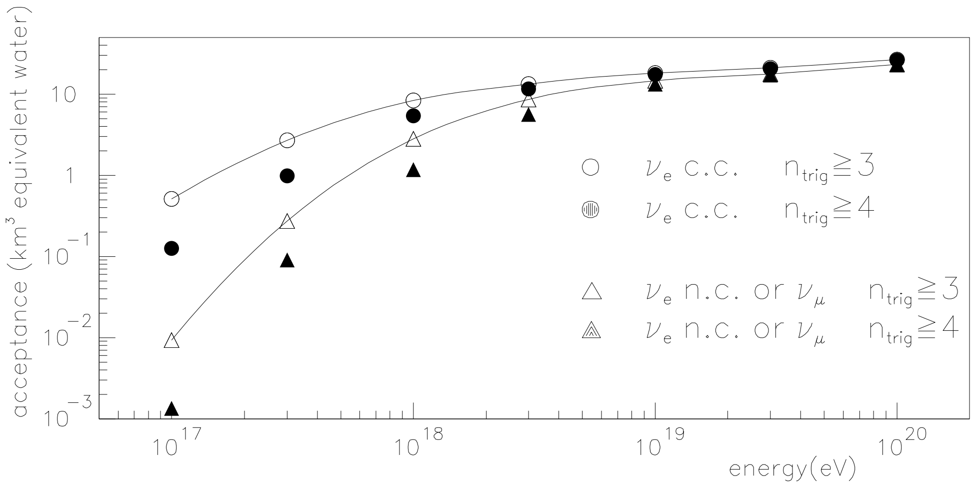
- very flat and narrow front
- No EM component only perfectly timed muons

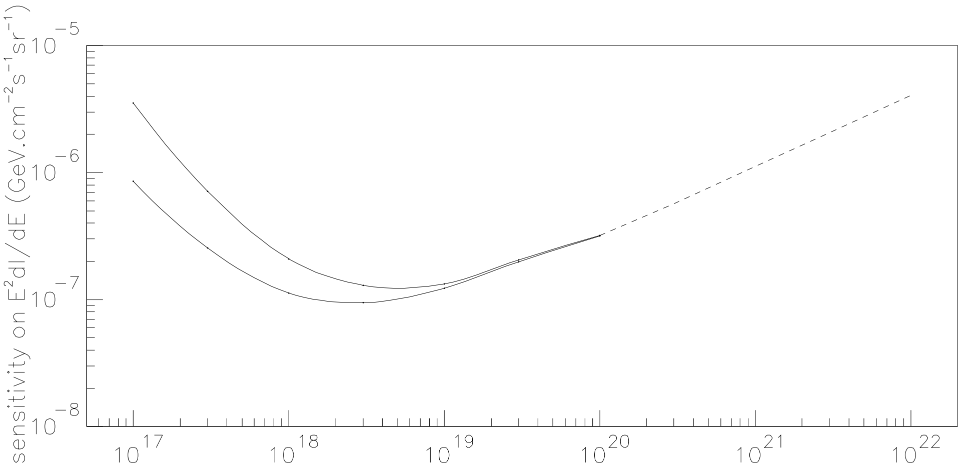
"young" showers :

- the the shower front is curved and thick
- EM and muons are present

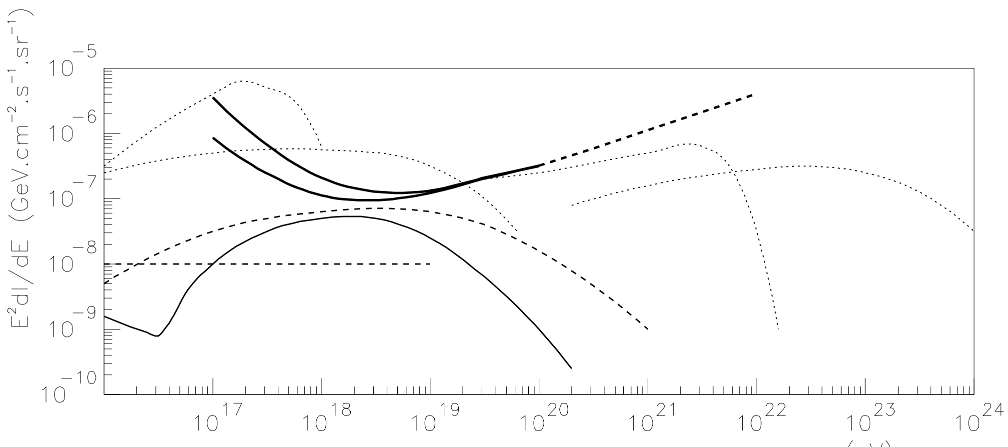
Neutrinos

P.Billoir (Neutrino Telescopes '99)





Sensitivity threshold of 0.3 evt/year/decade E (eV)



Auger threshold and Protheroe's model fluxes.

Dot : speculative, Dash : probable, Solid : certain

LPM and Geomagnetic field

LPM effect reduces the electron Bremsstrahlung and photon conversion cross section. It takes place when the distance between two collisions is of the order of the collision length.

$$X_0 \frac{m}{E_{LPM}} \sim a_\infty$$

Thus

$$E_{LPM} \sim \frac{X_0}{1\ m} 10^{16} eV \sim 3 \times 10^{18} eV \text{ in air}$$

Pair production in a magnetic field is governed by the dimensionless parameter:

$$\chi = \frac{E_\gamma}{2m_e c^2} \frac{B_\perp}{B_{cr}}$$

where the critical filed is such that :

$$\mu_B . B_{cr} \sim m_e c^2 \longrightarrow B_{cr} \sim m_e c^2 / e\hbar \simeq 4 \times 10^9 T$$

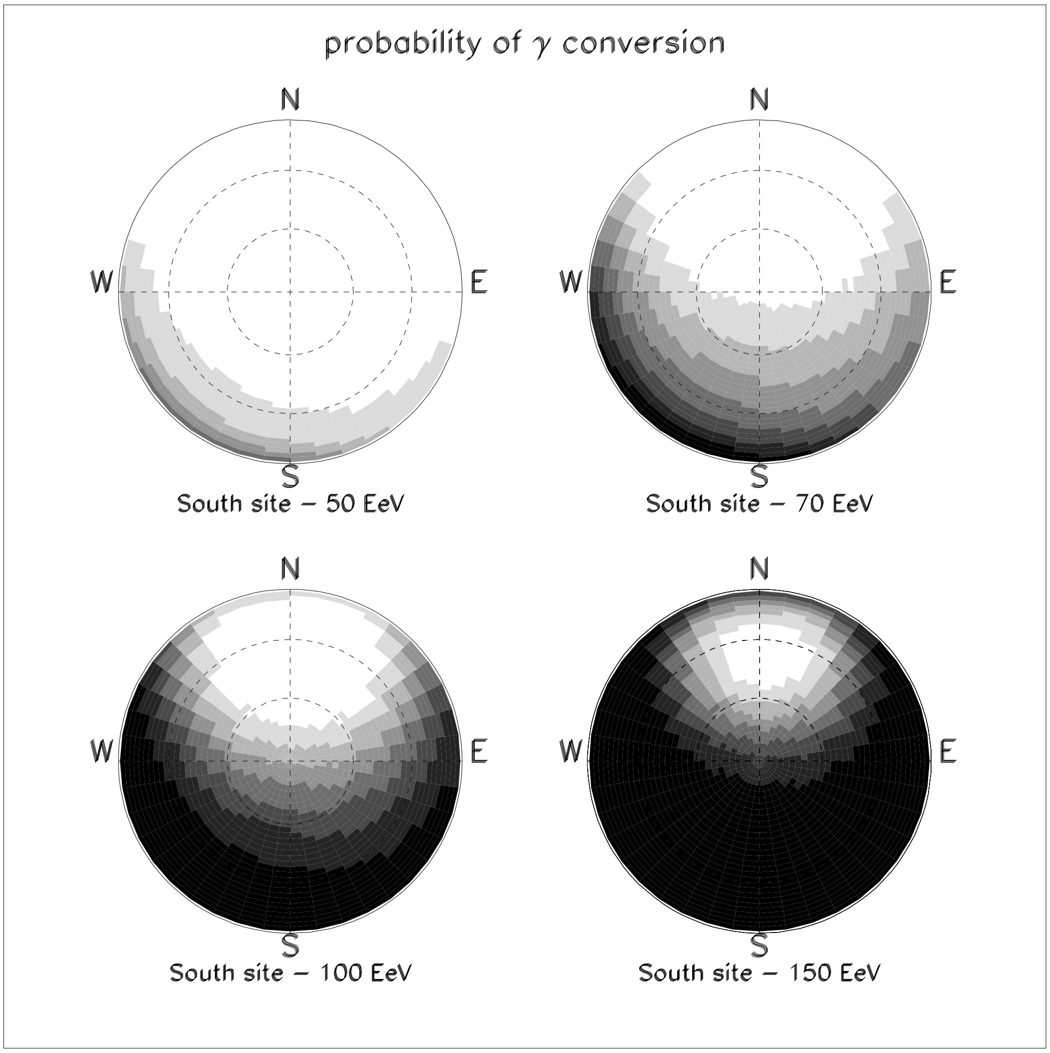
For the Earth field at intermediate latitudes the conversion occurs almost surely for $E_\gamma > 10^{20} eV$

If a high energy photon does not convert in the geo-magnetic field, LPM effect will make the shower development extremely slow (density increase with depth into the atmosphere).

Very young showers oriented along the magnetic field line will sign almost surely 10^{19-20}eV photons showers.

Photons

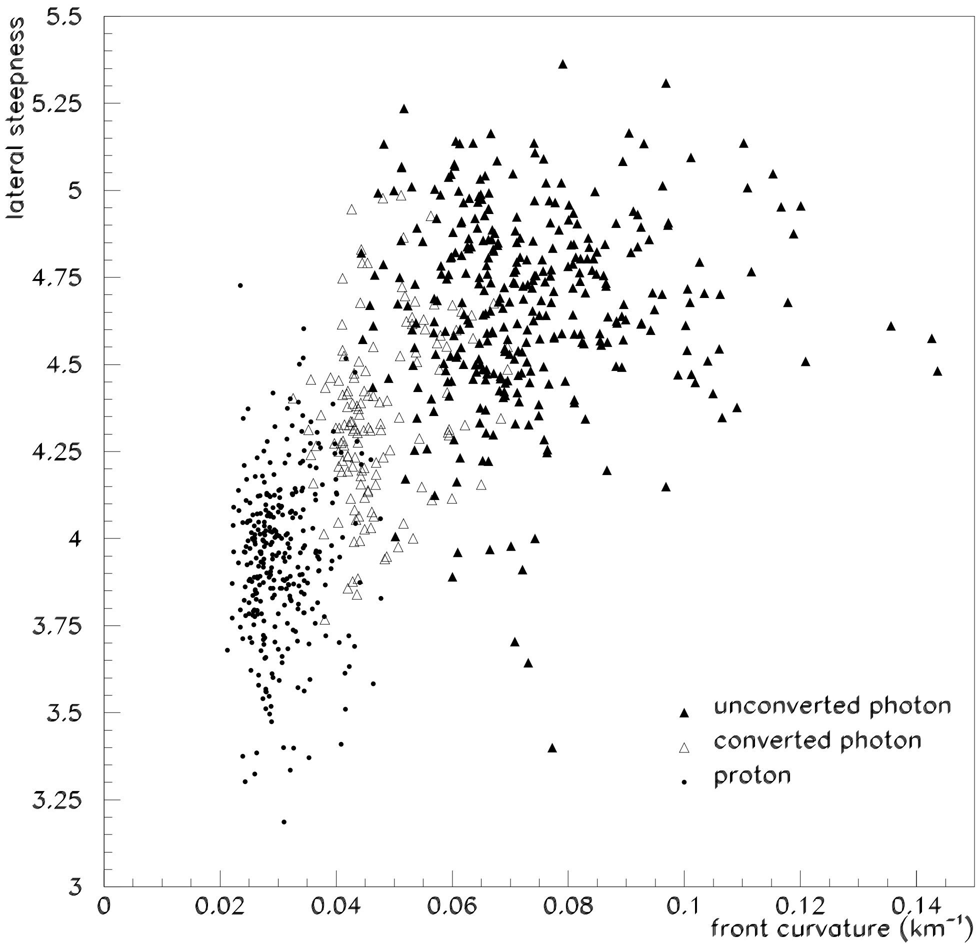
Bertou, Billoir et Dagoret-Campagne (Astropart. Phys.).



Conversion probability. Auger southern site

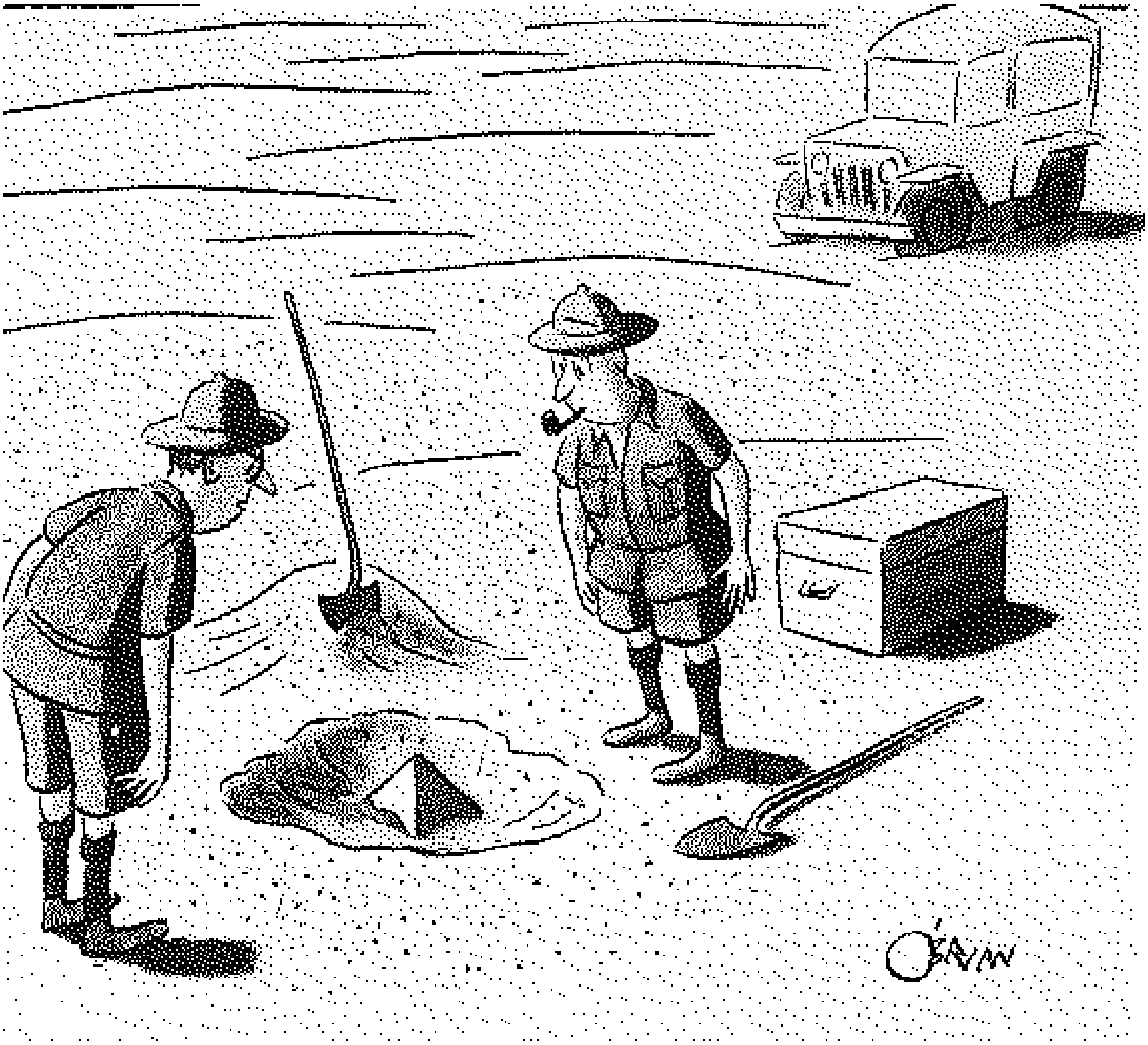
Photons (cont'd)

Bertou, Billoir et Dagoret-Campagne (Astropart. Phys.).



Combination of discriminating variables from Auger ground array measurements (front curvature and lateral steepness) Auger southern site, flat log(E) distribution of showers with 30 to 300 EeV

Conclusion



"This could be the discovery of the century. Depending, of course, on how far down it goes."