Crown Detectors Arrays to Observe Horizontal and Upward Air-Showers

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Abstract

Terrestrial Cerenkov Telescopes at tens GeV gamma energy and Scintillators set on a Crown-like array facing the Horizons may reveal far Cosmic Rays Showers or nearer PeVs Neutrino $\bar{\nu}_e - e \rightarrow W^-$ shower in air as well as upgoing $\nu_e + N \rightarrow \tau + X, \tau \rightarrow$ Earth-Skimming tau air-showers. Even UHE SUSY $\chi^0 \rightarrow e \rightarrow \chi^0 + e$ at tens PeVs-EeV energy may blaze at Horizons, as $\bar{\nu}_e - e \rightarrow W^-$ shower. We show first estimate on down and up-going Horizontal Showers traces for present and future Magic-like Crown Arrays and their correlated Scintillator-like twin Crown Arrays. The one mono or stereo-Magic elements facing the Horizons are already comparable to present Amanda underground neutrino detector.

Key words: Cosmic Rays, Neutrino, Tau, Showers

1 Horizons: A new Frontier of High Energy Astrophysics

Downward but inclined or horizontal Cosmic Ray (C.R.) Showers ($70^\circ - 90^\circ$ zenith angle) produce secondary ($\gamma, e^\pm$) mostly suppressed by high atmosphere column depth. The Upward Air-Showers are totally absorbed by the Earth shadows and in principle are free from any background. Most inclined downward C.R. air-shower produce in high altitudes Cherenkov photons that are diluted by the large distances and by air opacity, while their secondary penetrating, $\mu^\pm$ and their successive decay into $e^\pm, \gamma$, may revive the optical signal by additional Cerenkov lights. Tiles of scintillators (see also \cite{16}), set in a circular crown array facing the Horizons may be able to inspect a wide solid angle, recording the muon tracks, as well as their eventual electromagnetic companion bundles. An hybrid Crown made by a circular Cerenkov light...
Telescopes and by Muon-gamma-electron scintillator arrays, may be an ideal detector for horizontal Cosmic Rays and Tau Air-Shower signals. A few arrays of such Crown Detectors located at a few kilometer one from the other may even better probe the horizontal air-shower arrival, structure and lateral distribution.

The larger horizontal distances widen the shower’s cone into wider areas, while the geo-magnetic field open the positive-negative charges in a very characteristic fan-like shape, polarized by, and, aligned orthogonal to, the local geo-magnetic field vector. These elongated inclined showers are thin, collimated, fork-shaped and diluted in elongated areas; because of it they occur in proportion more frequently, up to two-three order of magnitude (respect to near but dense vertical showers). The GeVs $\gamma$ telescopes at the top of the mountains or in Space may detect at the horizons both PeVs up to EeV (or more energetic) hadronic cosmic rays secondaries. Correlated details on arrival angle and crossed column depths, the shower shape, its timing signature and photon flash intensity, may inform us on the altitude interaction, primary UHECR composition, lateral dispersion, off-axis geometry and total shower energy. Additional muon-gamma Crown detectors may capture various leptons, $\pm \mu$, and their decayed $\pm e$ and $\gamma$ tracks better defining the shower composition and development.

Horizontal muon secondaries at high energy (hundred TeV) leading to muon catastrophic electromagnetic shower in air horizons are also leading to penetrating electromagnetic air-showers: their rate at a hundred TeVs is $\Phi_\mu(E_\mu = 10^{14} eV) \simeq 3 - 5 \cdot 10^{-12} cm^{-2} sr^{-1} s^{-1}$ is comparable to up-going atmospheric muon (at GeVs energy) induced by atmospheric neutrino; however they they are not deflected and are well above the horizons; their consequent bright Cerenkov ring cannot compete with the higher energy searched up-going neutrino signals. At PeVs energies even prompt muons (by the decay of charmed hadrons) are leading to a limited flux $3 - 5 \cdot 10^{-15} cm^{-2} sr^{-1} s^{-1}$ (see ref. fig.1 [18]) even smaller than expected by muon secondaries of upgoing tau air-showers. Therefore we shall neglect the atmospheric up-going muon showering out of the competitive astrophysical UHE muon and tau originated by PeVs-EeVs neutrinos in Earth.

Indeed below the horizons, at zenith angle (90°−99°) among quite rare ”single” albedo muons, more rare up-going showers traced by muon ($e^\pm, \gamma$) bundles would give evidence of rare Horizontal Tau Air-Showers (HorTaus or Earth-Skimming neutrinos), originated by $\nu_\tau$, $\bar{\nu}_\tau$, ($\nu_\tau + N \rightarrow \tau + X, \tau \rightarrow$ hadrons and/or electromagnetic shower around EeVs energies. See [6],[7],[2],[13],[15]; their energy losses in matter has been studied for underground detectors in first approximations [6],[7], and more in details [9], [17], [22], [10], [11].

Their rate may be comparable or competitive with 6.3 PeVs $\bar{\nu}_e - e$ neutrino (by
Ultra High Energy Cosmic Rays (UHECR) Showers (PeVs - EeVs) born at high altitude in the atmosphere may be detected by telescopes such as Magic provided that they are pointed towards the horizon. These Cerenkov telescopes, set in a crown circular array toward the Horizons, may be correlated by an analogous scintillator one able to trace muons and electromagnetic shower particles. The earliest gamma and Cerenkov lights produced by any down-ward horizontal, zenith angle (85° − 90°), cosmic rays (CR), observed by a high (> 2 km) mountain (whose C.R. nature is mainly hadronic), while crossing the atmosphere are severely absorbed by the thick horizontal air column depth (10^4 − 5 · 10^4 g · cm^−2). However the most energetic C.R. blazing Cerenkov shower must survive and also revive during their propagation. Indeed one has to expect that these CR showers contain also a diluted but more penetrating component made of muon bundles (20), (21), which can be detected in two ways: a) by their Cerenkov lights emitted after they decay into electrons nearby the Telescope; b) while the muons hit into the Telescope, blazing ring or arc of the same muon Cerenkov lights. The latter muons are less abundant compared to the early peak gamma photons produced in the shower (roughly 10^{-3} times lower) but more penetrating. They are produced at high altitudes and at an horizontal distance of 100 − 500 km from the observer (placed at 2.2km above the sea level, and assuming a zenith angle of 85° − 91.5°). Therefore these hard muon bundles (hundred GeV) might spread in large areas of tens - hundred km^2 while they travel towards the observers. They are partially bent by the local geomagnetic field, (in azimuth dependence) and they are aligned along an axis orthogonal to the field and they decay into electrons producing optical Cerenkov flashes. The geo-magnetic spread of the shower leads to a aligned
Cerenkov blaze whose shape (a thin elliptic splitted twin-lightening shower) may probe the magnetic field and the CR origination.

One of the characteristic consequence of this geomagnetic splitting is the twin Cerenkov lights and dots appearing in the Magic telescope as a very unique signature of the bending trajectories. The estimated angle separation range in $0.5^\circ - 3^\circ$ a value that is within angular resolution of Cherenkov telescopes. This may be the imprint and the trigger signal of most horizontal air-showers. Such a characteristic signature may be detected by the largest gamma telescope arrays as Hess, Veritas, or better by forthcoming stereoscopic version of Magic. We argue that their Cerenkov flashes, either single or clustered, must take place, at detection threshold, at least tens or hundreds times a night for Magic-like Telescope pointing toward horizons at a zenith angle between $85^\circ$ and $90^\circ$. Their easy ”guaranteed” discover may offer, we hope, a new gauge and ”meter” in CR and UHECR detection. Their primary hadronic shower secondaries might be hidden by the distance (but not their Cerenkov flashes); the late shower tail may arise in a new form by its secondary muon-electron-Cerenkov chain of the electromagnetic showering. Moreover a rarer but more exciting PeV - EeV Neutrino $\nu_\tau$ Astronomy (whose flux is suppressed by three-four orders of magnitude respect CR one) may arise below the horizon with the Earth-Skimming Horizontal Tau Air-Showers (HorTaus) (6),(7); below the horizons there are not other shower at all. These UHE Taus are produced inside the Earth Crust by the primary UHE incoming neutrino $\nu_\tau$, $\bar{\nu}_\tau$, and they are generated mainly by the muon-tau neutrino oscillations from galactic or cosmic sources, (7), (8), (9). Finally we expect also that just above or below the horizon edge, (within a distance of a few hundreds of km), air-showers due to the fine-tuned $\bar{\tau}_e - e \rightarrow W^- \rightarrow X$ Glashow (14) resonance at 6.3 PeV might be detectable. The W main hadronic (2/3) or leptonic and electromagnetic (1/3) signatures may be well observed and their rate may be used to calibrate a new horizontal neutrino multi-flavor neutrino Astronomy (7). Again we argue that such a signature of nearby nature (respect to most far away ones at same zenith angle of hadronic nature) would be better revealed by a Stereoscopic twin telescope such as Magic or a Telescope array like Hess, Veritas. As mentioned above additional Horizontal flashes might arise by Cosmic UHE $\chi_o + e \rightarrow \tilde{e} \rightarrow \chi_o + e$ electromagnetic showers within most SUSY models, if UHECR are born in topological defect decay or in their annihilation, containing a relevant component of SUSY particles. The UHE $\chi_o + e \rightarrow \tilde{e} \rightarrow \chi_o + e$ behaves (for light $\tilde{e}$ masses around Z boson ones) as the Glashow (14) resonance peak (1). The total amount of air inspected within the characteristic field of view of MAGIC $(1^\circ \cdot 2^\circ)$ at the horizon (360 km.) corresponds to a (water equivalent) volume-mass larger than $V_w \simeq 1km^3$. However their solid angle detectable beamed volume corresponds to a narrower beamed volume $V_w \simeq 1.36 \cdot 10^{-2} \ km^3$, yet comparable to the present AMANDA confident volume (for Pevs $\bar{\nu}_\tau + N \rightarrow \tau \rightarrow$ showers). Greater volumes and masses (up to $75km^3$) are estimated for upward EeV tau events (12) making
2 Cerenkov Flashes at Horizons by Showers and Muons

The ultrahigh energy cosmic rays (UHECR) have been studied in the past mainly through their secondary particles ($\gamma$, $e^\pm$, $\mu^\pm$) collected vertically in large array detectors on the ground. UHECRs are rare events, however the multiple cascades occurring at high altitudes where the shower usually takes place, expand and amplify the signal detectable on the ground. On the other hand, at the horizon the UHECR are hardly observable (but also rarely searched). They are diluted both by the larger distance they have to cover and by the atmosphere opacity suppressing exponentially their electromagnetic secondaries (electron pairs and gammas); also their optical Cerenkov emission is partially suppressed by the horizontal air opacity. However this suppression acts also as a useful filter leading to the selection of higher CR events. Their Cerenkov lights will be scattered and partially transmitted ($1.8 \cdot 10^{-2}$ at 551 nm., $6.6 \cdot 10^{-4}$ at 445 nm.) depending on the exact zenith angle and the seeing: assuming an average suppression factor $-5 \cdot 10^{-3}$- and the nominal Magic threshold at 30 GeV, this corresponds to a hadronic shower coming from the horizon with an energy above $E_{CR} \simeq 6$ PeV. Their primary flux may be estimated considering the known cosmic ray fluxes at the same energy on the top of the atmosphere (both protons or helium) (see DICE Experiment referred in [15]): $\phi_{CR}(E_{CR} = 6 \cdot 10^{15} eV) \simeq 9 \cdot 10^{-12} cm^{-2} s^{-1}$. Within a Shower Cerenkov angle $\Delta \theta = 1^\circ$ at a distance $d = 167 km \cdot \sqrt{\frac{h}{2.2 km}}$ (zenith angle $\theta \simeq 87^\circ - 88^\circ$) giving a shower area $[A = \pi \cdot (\Delta \theta \cdot d)^2 \simeq 2.7 \cdot 10^{11} cm^2 (\frac{d}{10 km})^2]$, the consequent event rate per night for a Magic-like telescope with a field of view of $[\Delta \Omega = (2^\circ \cdot 2^\circ) \pi \simeq 3.82 \cdot 10^{-3} sr.]$ is

$$N_{ev} = \phi_{CR}(E = 6 \cdot 10^{15}eV) \cdot A \cdot \Delta \Omega \cdot \Delta(t) \simeq 401/12 h$$

Thus one may foresee that nearly every two minutes a horizontal hadronic shower may be observed by Magic if it were pointed towards the horizon at zenith angle $87^\circ - 88^\circ$. Increasing the altitude $h$ of the observer, the horizon zenith angle grows: $\theta \simeq [90^\circ + 1.5^\circ \sqrt{\frac{h}{2.2 km}}]$. In analogy at a more distant horizontal edges (standing at height 2.2km as for Magic, while observing at zenith angle $\theta \simeq 89^\circ - 91^\circ$ still above the horizons) the observation range $d$ increases : $d = 167 \sqrt{\frac{h}{2.2 km}} + 360 km = 527 km$; the consequent shower area widen by more than an order of magnitude (and more than three order respect to vertical showers) and the foreseen event number, now for much harder CR...
at $E_{CR} \geq 3 \cdot 10^{17} eV$, becomes:

$$N_{ev} = \phi_{CR}(E = 3 \cdot 10^{17} eV) \cdot A \cdot \Delta \Omega \cdot \Delta(t) \simeq 1.6/12h$$

Therefore at $\theta \simeq 91.5^\circ$, once per night, a UHECR around EeV energies, may blaze the Magic (or Hess, Veritas, telescopes). A long trail of secondary muons is associated to each of these far primary Cherenkov flash in a very huge area. An additional characteristic of the horizontal muon bundle are their common final separated net bundle charge (all positive or negative); also earlier electron shower pairs are separated but effectively only at highest altitudes (few tens km) where air density is negligible. These earlier shower rings shine at wider angles some additional Cherenkov precursor lights.

The muon bundle showering nearby the telescope, while they decay into electrons in flight, (source of tens-hundred GeVs mini-gamma showers) is also detectable at a rate discussed in the following section (see also important earlier studies[4],[20],[21] on muon bundles at horizons).

### 3 Three Muon Cerenkov Signature: Arcs, Rings and Gamma by $\mu^{\pm} \rightarrow e^{\pm} \rightarrow \gamma$,

As already noted the photons from a horizontal UHECR may be also revived by its secondary muons produced at tens-hundred GeVs muons: they can either decay in flight as a gamma flashes, or they may hit the telescope and their muon Cerenkov lights ”paint” arcs or rings within the detector. Indeed these secondary very penetrating muon bundles may cover distances of hundreds km ($\simeq 600 km \cdot \frac{E_{\mu}}{100 GeV}$) away from the shower origin. To be more precise a part of the muon primary energy will dissipate along a path in the air of 360 km (nearly a hundred GeV energy), thus a primary $130 - 150$ GeV muon will reach a final $30 - 50$ GeV energy, the minimal Magic threshold value. Let us remind the characteristic multiplicity of secondary muons in a shower:

$$N_{\mu} \simeq 3 \cdot 10^{5} \left( \frac{E_{\mu}}{100 GeV} \right)^{0.85}$$

for GeV muons. For the harder component (around 100 GeV), the muon number is reduced almost inversely proportionally to energy $N_{\mu}(10^{2} \cdot GeV) \simeq 1.3 \cdot 10^{4} \left( \frac{E_{\mu}}{6 GeV} \right)^{0.85}$. These values must be compared to the larger peak multiplicity (but much lower energy) of electro-magnetic showers:

$$N_{e^{+}-e^{-}} \simeq 2 \cdot 10^{7} \left( \frac{E_{\gamma}}{10^{4} GeV} \right) ; N_{\gamma} \simeq 10^{8} \left( \frac{E_{\gamma}}{10^{4} GeV} \right)$$. As mentioned before, most of the electromagnetic tail is lost (exponentially) at horizons (for a slant depth larger than a few hundreds of $g cm^{-2}$), excluding re-born, upgoing $\tau$ air-showers[8],[10] to be discussed later. Therefore gamma-electron pairs are only partially regenerated by the penetrating muon decay in flight, $\mu^{\pm} \rightarrow \gamma, e^{\pm}$ as a parasite electromagnetic showering[11],[15]. Indeed $\mu^{\pm}$ may decay in flight (let say at 100 GeV energy, at $2 - 3\%$ level within a $12 - 18$ km distances) and they
may inject more and more lights, to their primary (far born) shower beam. The ratio between $\gamma$ over $\pm\mu$ offer a clear hint of the Shower evolution (10). These tens-hundred GeVs horizontal muons and their associated mini-Cerenkov $\gamma$ showers are generated by either a single muon mostly produced at hundreds of kilometers by a single primary hadron with an energy of hundreds GeV-TeV or rarer muons, part of a wider horizontal bundle of large multiplicity born at TeVs-PeV or higher energies, as secondary of an horizontal shower. Between the two cases there is a smooth link. A whole continuous spectrum of multiplicity begins from a unique muon up to a multi muon shower production. The dominant noisy "single" muons at hundred-GeV energies will lose memory of their primary low energy and hidden mini-shower, (a hundreds GeV or TeVs hadrons ); a single muon will blaze just alone. The frequency of muon "single" rings or arcs is much larger than the muon bundles and it is based on solid observational data (16 ; 15),(20),(21) as shown in Fig.2 see also the references on the MUTRON experiment therein). The event number due to these "single noise" is:

$$N_{ev-\mu}(\theta = 90^o) = \phi_{\mu}(E \simeq 10^2 eV) \cdot A_{\text{Magic}} \cdot \Delta \Omega \cdot \Delta(t) \simeq 120/12h$$

Their muon abundance (TeV primary over PeV primary CR) is nearly 20. The additional gamma mini-showers around the telescope due to a decay of those muons in flight (with a probability $p \simeq 0.02$), is even a more frequent source of noise (by a factor $\geq 8$):

$$N_{ev-\mu-\gamma} \geq \phi_{\mu}(E \simeq 10^2 eV) \cdot p \cdot A_{\gamma} \cdot \Delta \Omega \cdot \Delta(t) \simeq 960/12h$$

These single background gamma-showers must take place nearly once per minute (in a negligible hadronic background) and they represent a useful tool to calibrate the possibility of detecting Horizontal CR.

4 Muons clustering with their early Showers Blaze

On the contrary PeVs (or higher energy) CR shower Cerenkov lights maybe observed, more (nearly twenty times) rarely, in coincidence both by their primary and by their later secondary arc and gamma mini-shower. Their $30-100$ GeV energetic muons are flying nearly un-deflected $\Delta \theta \leq 1.6^o \cdot \frac{100\text{-GeV}}{E_{\mu}} \cdot \frac{d}{300\text{km}}$ for a characteristic horizons distances $d$, only partially bent by the geo-magnetic fields ($\sim 0.3$ Gauss). As mentioned, to flight through the whole horizontal air column depth (360 km equivalent to 360 water depth) the muon lose nearly 100 GeV; consequently the initial muon energy should be a little above this threshold to be observed by Magic: (at least $130-150$ GeV). The deflection angle is small: $\Delta \theta \leq 1^o \cdot \frac{150\text{-GeV}}{E_{\mu}} \cdot \frac{d}{300\text{km}}$. Given the area of Magic ($A = 2.5 \cdot 10^6 cm^2$) we expect roughly the following number of events due to direct muons hitting the Telescope, flashing as rings and arcs, each night:
\[ N_{ev} = \phi_{CR}(E = 6 \cdot 10^{15} eV) \cdot N_\mu(10^2 \cdot GeV) \cdot A_{Magic} \cdot \Delta \Omega \cdot \Delta(t) \simeq 45/12h \]

to be correlated (at \( \simeq 10\% \) probability or less) with the above results of 401 primary Cerenkov flashes at the far distances. Moreover, the same muons are decaying in flight at a minimal probability 2% leading to mini-gamma-showers in a wider area \((A_\gamma = 10^9 cm)\). The related mini-gamma shower number of events we expect is:

\[ N_{ev} = \phi_{CR}(E = 6 \cdot 10^{15} eV) \cdot N_\mu(10^2 \cdot GeV) \cdot p \cdot A_{\gamma} \cdot \Delta \Omega \cdot \Delta(t) \simeq 360/12h \]

Therefore, at 87° – 88° zenith angle, there is a flow of dozens event a night of primary CR (at \( E_{CR} \simeq 6 \cdot 10^{15} eV \)), whose earliest showers, consequent secondary muon-arcs as well as nearby muon-electron mini-shower take place at comparable rate (one every 120 – 600 in twin correlation or one an hour for multi-correlation ). These certain and frequent clustered signals offer an unique tool for calibrating Magic (as well as Hess,Cangaroo,Veritas Cerenkov Telescope Arrays) for Horizontal High Energy Cosmic Ray Showers. Rarer events (a dozen a night) may contain at once both Rings,Arcs and tail of gamma shower and twin dots at a few \((1 - 2)\) degree separation (due to geomagnetic splitting) by Cerenkov primary forked shower. It is possible to estimate also the observable muon-electron-Cerenkov photons from up-going albedo muons observed by the most recent ground experiments (20) (21)\): their flux is already suppressed at zenith angle 91° by at least two orders of magnitude and by four orders for up-going zenith angles 94°. Pairs or bundles are nevertheless rarer (up to \( \phi_\mu \leq 3 \cdot 10^{-13} cm^{-2} s^{-1} sr^{-1} \)) (20) (21). They are never associated to up-going showers (excluding the case of tau air-showers or the Glashow \( \bar{\nu}_e - e \to W^- \) and the comparable \( \chi^0 + e \to \tilde{e} \) and not competitive to up-going tau secondaries discussed below.

5 UHE \( \bar{\nu}_e - e \to W^- \) and \( \chi^0 + e \to \tilde{e} \) resonances versus \( \tau \) air-showers

The appearance of horizontal UHE \( \bar{\nu}_\tau \nu_\tau \to \tau \) air-showers (Hortaus or Earth-Skimming neutrinos) has been widely studied (6),(7),(2),(13); see also (8),(9),(17), (22),(19), (3) and more recent (10). Their rise from the Earth is source of rare clear signals for neutrino UHE astronomy (see fig.3). However also horizontal events by UHE 6.3 PeV, Glashow \( \bar{\nu}_e - e \to W^- \) and a possible comparable SUSY \( \chi^0 + e \to \tilde{e} \) (11) hitting and showering in air have a non negligible number of events; one should remember that at peak resonance the probability conversion is \( 3 \cdot 10^{-3} \) at 150 km air distance:

\[ N_{ev} = \phi_{\bar{\nu}_\tau}(E = 6 \cdot 10^{15} eV) \cdot A \cdot \Delta \Omega \cdot \Delta(t) \simeq 5.2 \cdot 10^{-4}/12h \]
assuming the minimal GZK neutrino flux: \( \phi_{\bar{\nu}_e} (E = 6 \cdot 10^{15} eV) \simeq 5 \cdot 10^{-15} \text{eV cm}^{-2}s^{-1} \text{sr}^{-1} \). Therefore in a year of observations, provided that the data are taken at night, assuming a minimal GZK flux, a crown array of a 90 Magic-like telescopes set on a circle \((2 \cdot \pi = 360^\circ)\) and facing the horizon, would give a number of events comparable to a \(Km^3\) detector, (nearly a dozen per year). Indeed Magic pointing at the horizon offers a detection comparable to the present AMANDA \(\simeq 1\%Km^3\) effective volume. A better efficiency (but not higher rate) occurs at EeV energies for tau (by GZK neutrino) induced air-showers \[^{[12]}\]. The same result may be improved assuming the coexistence of a scintillator Crown Array able to verify the electromagnetic and muon shower in coincident arrival time. The result may be greatly increased by a number of multiple crown array located at different (km) distances and altitudes. The Crown Area may encompass a large area as hundreds square meters array (see last figure) and its structure may be added around the Cerenkov Crown telescope array at the same mountain top. Its ability to discover muons (sometimes in correlation with the Cerenkov telescope) as well as the electromagnetic trace \(\gamma, e^+, e^-\) nature, for a total area of 63 \(m^2\), is superior by a factor two respect a (single ) Magic telescope, because it enjoys a larger solid angle and a longer recording time. Magic-Crown and Muon Crown array may reveal tens of thousands horizontal CR shower and a ten of up-going neutrino induced air-shower a year (for GZK minimal fluxes). To conclude, while Magic looks upward to investigate the Low Gamma GeVs Astronomy, the same telescope looking at the horizon may well see higher (PeVs-EeVs) CR, and rarely along the edge, GZK \(\bar{\nu}_e - e \rightarrow W^-\) neutrinos; finally, below the horizons \(\nu\tau \rightarrow \tau\) air-showers arise and, surprisingly even SUSY \(\tilde{e}\) lights may come in the sky (with electromagnetic showers). Finally the possible detection of up-going few-tens GeV muons (induced by energetic Solar Flare) at a rate \(\phi_\mu \simeq 10^{-10} \text{cm}^{-2}s^{-1}\), for few minutes, during the maximal solar flare activity, might also be a target of such New Muon-Cerenkov astronomy \[^{[23]}\].

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Fig. 1. The Earth view from Canarie sites for a Magi-like Crown Telescope Array facing the Horizons, blazed, in dark nights, by CR showers and rare up-going Tau Air-Shower Cerenkov flashes; the telescopes in circular array (of tens telescopes at 360°) may test a wide area volume, nearly a km³ of air mass. The present (real) single Magic telescope is located in the bottom left corner of the picture.

Fig. 2. Muon fluxes at different zenith angle from observational data [16], [15]

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Fig. 3. Differential Tau Number flux by GZK neutrino flux and consequent Horticau Earth Skimming flux rate from the Earth

\[
\frac{dN_\tau}{d\theta dE} = E \text{ cm}^{-2} \text{ sec}^{-1} \text{ sr}^{-1}
\]

\[
\begin{align*}
1 \times 10^{-19} & \quad 1 \times 10^{-21} \\
1 \times 10^{-21} & \quad 1 \times 10^{-23}
\end{align*}
\]

\[
\theta \text{ (rad)}
\]

Fig. 4. Consequent Differential Muon Number flux by GZK neutrino and Tau flux Horticau Earth Skimming the Earth, and consequent secondary muons: because a different acceptance at different height the flux depend on the observer quota

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Fig. 5. A schematic figure of a Crown circular detector array in Balloon (or located on the top of a mountain) by a \( \approx 10 \) meter radius size, whose inner-outer aligned tiles are able to reveal, by time of flight, the crossing and the azimuth directions of horizontal muons (and electron pairs and gamma) bundles; in the picture one an upward Horizontal Tau Air-Shower (label by \( \tau \)); the 360\(^\circ\) tile disposal guarantees a wide azimuth solid angle view. The twin (upper and lower) rings distance (tens- or hundred meters) is able to better disentangle the zenithal arrival direction of the Horizontal Shower particles above or below the edges.