Ensembles of Cosmic Rays: Unique Signatures at Earth

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MOTIVATION: SINGLE CR VS. ENSEMBLE OF CRS





Preshower:

Cascade of EM particles produced by interaction of $\gamma_{\rm UHE}$ with $B_{\rm Geo}.$ Typical altitude \sim 1000 km a.s.l. $N_{\rm part}$ at the top of atm \sim 100.



Super Preshower:

Typical altitude much higher. $N_{\rm part}$ at the top of atm > 1000.

Super-preshower: $\gamma_{_{ m UHE}}$ passing through $B_{ m Sun}$

$$\begin{array}{ccc} \gamma_{\rm UHE} \xrightarrow{B_{\rm Sun}} e^+ & + & e^- \\ & & e^{\pm} \xrightarrow{B_{\rm Sun}} \gamma \end{array}$$

$$\theta = \frac{m_{\rm e}}{E}, \qquad \phi = \mathcal{U}(0, 2\pi)$$

 \implies Larger deflections for smaller energies, and vice-versa.



Schematic of deflection of emitted γs

Super-preshower: γ_{uhe} passing through B_{Sun}

SPS Simulation with modified $PRESHOWER^1 + CORSIKA^2$



Distribution of photons ($E > 10^{13}$ eV) at the top of the atmosphere. $E_{\rm Y} = 10$ EeV, Impact parameter $= 2.5 R_{\rm S}$.

¹ Homola et al. 2005, Comput. Phys. Commun. ² Heck et al. 1998, EZKA

Super-preshower: $\gamma_{\rm uhe}$ passing through $B_{\rm Sun}$

Distribution of photons weighted by their energies.



Distribution of photons ($E>10^{13}$ eV) at the top of the atmosphere. $E_{\rm Y}$ = 10 EeV, Impact parameter = $2.5R_{\rm S}.$



Distribution of particles at the ground weighted by energies. The SPS is initiated by a γ with E=30 EeV, and has an impact parameter 2.5 $R_{\rm S}$



Energy distribution of particles at the ground for the same SPS.

OTHER POSSIBLE SCENARIOS

E.g., Multiple correlated particles arriving at Earth from astrophysical distances.



An example of energy-weighted ground particle distribution of two "close" γs arriving at the Earth. Primary energy of each γ is 5 EeV.

SUMMARY AND OUTLOOK

- Necessary modifications in PRESHOWER to simulate SPS development for UHE γ passing through the vicinity of the Sun.
- CORSIKA for the simulation of EAS development in the atmosphere for the particles in SPS.

A very extended spatial distribution of particles at the ground for Sun SPS – CREDO well suited for the detection.

- Possibility of performing EAS simulations for ensembles of CR particles other than Sun induced SPS.
- A study of the sensitivity of CREDO to SPSs is underway.