

CREDO ON-LINE EXPERIMENTS: THE SCENARIOS

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CREDO Project Meeting, Comenius University, Bratislava, 19.03.2018

• Visegrad Fund



SINGLE CR VS. CR ENSEMBLES



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Various types of ensembles of cosmic rays arriving at the Earth. Question marks represent known or unknown physics processes at UHE.

Preshower:

- Cascade of EM particles produced by interaction of UHE photons with geomagnetic field.
- $\bullet\,$ Typical altitude $\sim\,1000$ km a.s.l.
- $N_{
 m part}$ at the top of the Earth's atmosphere \sim 100.



Super-preshower (SPS):

- Cascade of particles produced due to exotic/non-exotic processes.
- Typical distance of cascade development is very far.
- $N_{
 m part}$ at the top of the Earth's atmosphere $\gg 100$.

Simulation using mofidied PRESHOWER:

- First studies were performed using magnetic field of the Sun modelled as **dipole** field with Magnetic moment of Sun $M_{\rm S} = 6.87 \times 10^{32} \, {\rm G} \cdot {\rm cm}^3$ (good for sanity check!).
- Dipole quadrupole current sheet (**DQCS**)model replaces it now (more realistic than the dipole model even at larger distances from the Sun).
- Tracking of particle motion (both position and time) in solar magnetic field.
- Inclusion of emission angles for synchrotron photons.





DQCS model

Dipole model

Example 1: Magnetic moment of the Sun is along its rotation axis. Primary photon heading towards Earth travels in the Sun's **equatorial** plane.



Distribution of photons (with $E > 10^{13}$ eV) at the top of the Earth's atmosphere. Energy of the primary photon = 100 EeV, impact parameter = 2.5 R_{\odot} .



Zoomed-in, previous plot

Example 2: Magnetic moment of the Sun is along its rotation axis. Primary photon heading towards Earth passes through the Sun's "**mid-latitude**" side.



Distribution of photons (with $E > 10^{13}$ eV) at the top of the Earth's atmosphere. Energy of the primary photon = 100 EeV, impact parameter = 2.5 R_{\odot} .

Typical particle distribution at the ground from CORSIKA simulation of SPS.



Distribution of particles at the ground weighted by energies for SPS initiated by a 30 EeV primary photon traveling in the Sun's equatorial plane

QUEST FOR THE UNEXPECTED: MULTIPLE PARTICLES

Multiple correlated particles arriving at Earth from astrophysical distances.



An example of energy-weighted ground particle distribution of two "close" γ s arriving at the Earth. Primary energy of each γ is 5 EeV. Another scenario interesting for CREDO

QUEST FOR THE UNEXPECTED: CR BURSTS





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$N_{ATM} > 1$ motivated by data! (1)



EXAMPLE: DOUBLETS IN SMARTPHONE DATA

Cosmic ray hits from user 106



Scan of latter part of the data from timestamp 1517007600 to 1520982000 seconds for doublets in 5 minutes window \implies 30 doublets. Number of intervals \implies 8640 & $N_{\rm hits} = 525$. With a mean of 0.06 hits per interval, $p_{\rm doublet} = 0.0017$ $\implies N_{\rm expected} \approx 15$.

EXAMPLE: DOUBLETS IN SMARTPHONE DATA

The observed rate is twice the expected! So, what is the plausible cause for this?

htime



Most probably, uptime of the smartphone is not correctly accounted for (somewhat evident from "fluctuations" seen in the above distribution). Future update of the app will store the uptime information.

SUMMARY

- CREDO offers possibilities for exploration of various physics scenarios- both the expected and the unexpected ones! For example:
 - Search for flares/bursts (Gora's talk) using time-clustering algorithm.
 - Search for super preshowers and N > 1 scenarios.
 - Search for space clusters.
- Already some smartphone data is available for preliminary analysis and sanity checks.