RESPONSE OF ICETOP TANKS TO LOW-ENERGY PARTICLES

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Solar Events

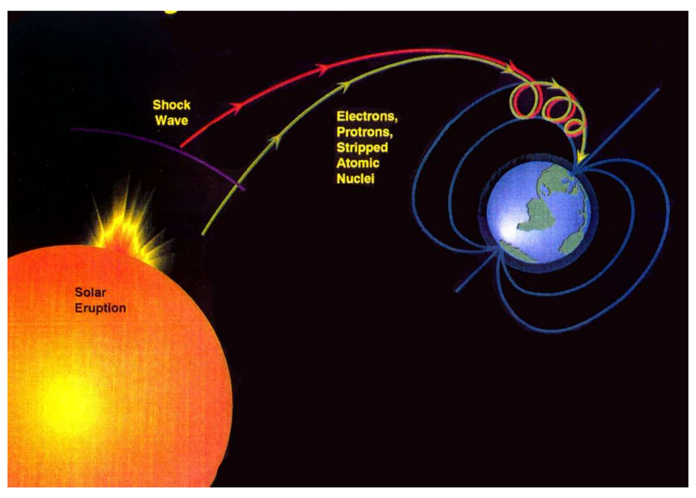

FIGURE 1: A Solar Event[1].

Our sun provides a local laboratory to test various astrophysical mechanisms such as particle acceleration. During some powerful solar events high energy particles are expelled into the interplanetary medium. Upon entering the Earth's atmosphere they will lead to an increase of particle flux at the ground level. The resulting spectrum will deviate from the steady galactic spectrum, so that various characteristics of the event can be studied.

The IceTop Array

FIGURE 2: IceTop tanks at the South Pole.

IceTop tanks are deployed close to the geographical South Pole. Water is filled into the tanks and allowed to freeze under controlled conditions to ensure bubble-free, clear ice.

Simulations

Simulations are done using the FLUKA[2] package ("AIR", [3]) and a combination of CORSIKA[4]/GEANT4[5] ("tanktop").

In the AIR model, protons, alphas, carbon, silicon and iron are generated within a rigidity range of 0.5 GV-20TV. The particles are propagated through the atmosphere using FLUKA.

In the tanktop simulation, air showers generated with CORSIKA are injected into GEANT4 which then simulates the detector response.

Inside the Tank

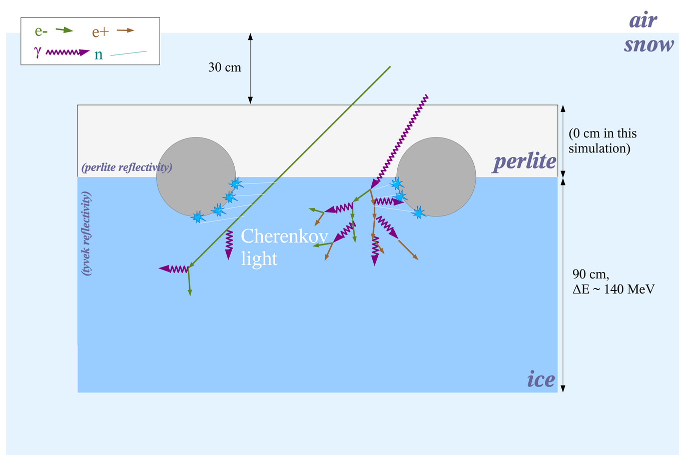

FIGURE 3: Cherenkov light from electromagnetic processes.

Apart from muons, electromagnetic particles contribute to the light seen by IceTop tanks. Their main contribution is at low number of photo electrons (PE), typically below 20 PE. In air-shower mode, tanks are run in coincidence to reduce the rate of uncorrelated events in single tanks.

Secondary Particle Fluxes

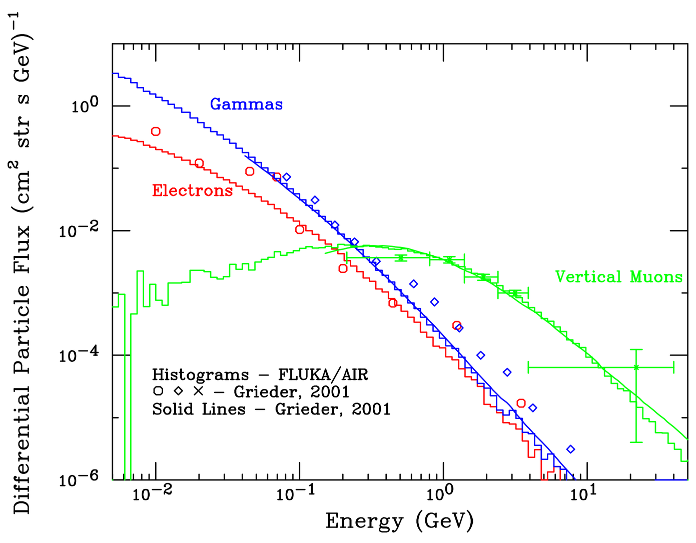

FIGURE 4: Secondary particle fluxes[6].

The secondary particle flux is dominated by electrons and gammas produced by the electromagnetic part of the cascade. We show here the flux of secondary particles expected by our calculations and compare to some experiments. The calculations are in reasonable agreement with the experiments.

Light yield

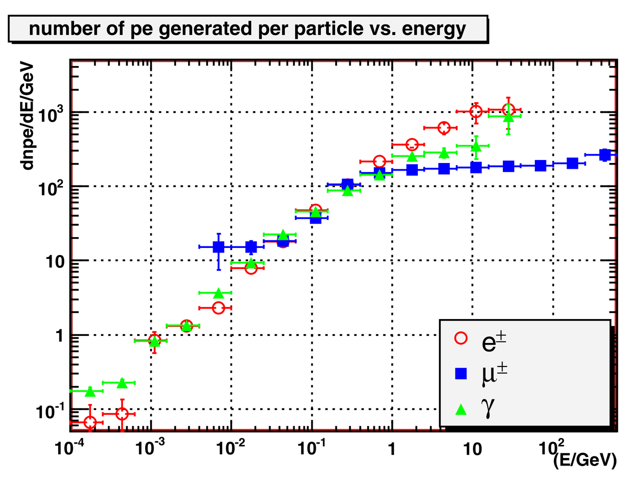

FIGURE 5: Light yield of secondary particles. Fit function based on [7].

The light yield in the tank for various particles is a function mainly of energy for electrons and gammas. Above 1 GeV most muons have enough energy to pass through the full detector volume depositing a constant amount of energy whereas below these energies the tank operates in calorimeter mode. The slight rise in light production is due to the increasing number of secondaries produced by the muon at higher energies.

NPE Spectra by Particle

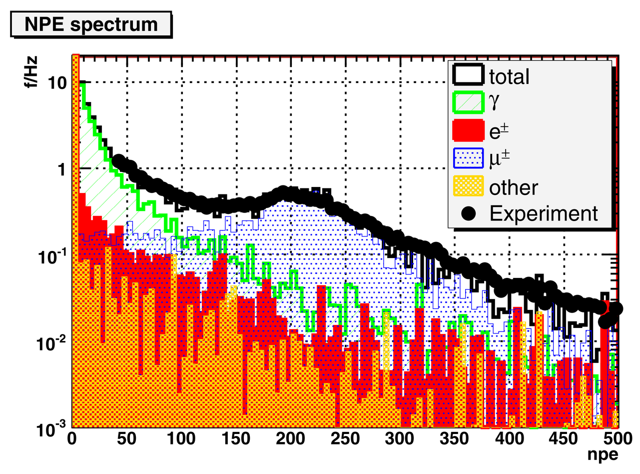

FIGURE 6: NPE Spectra for different secondaries.

In simulation, we can study the light output from different types of particles in the tank. This is important to understand at which PE level to search for a change in rate. Especially at lower energies, gamma rays produce the dominant contribution, followed by electrons and positrons. Muons start to play the major role at about 200 PE, allowing for calibration of the tank. Other particles, such as neutrons, protons and various mesons, contribute by about 1%. Comparing the simulation to measurements at an actual tank (DOM 63 of station 29) we find that the simulation desribes the experiment sufficiently well.

IceTop Yield function

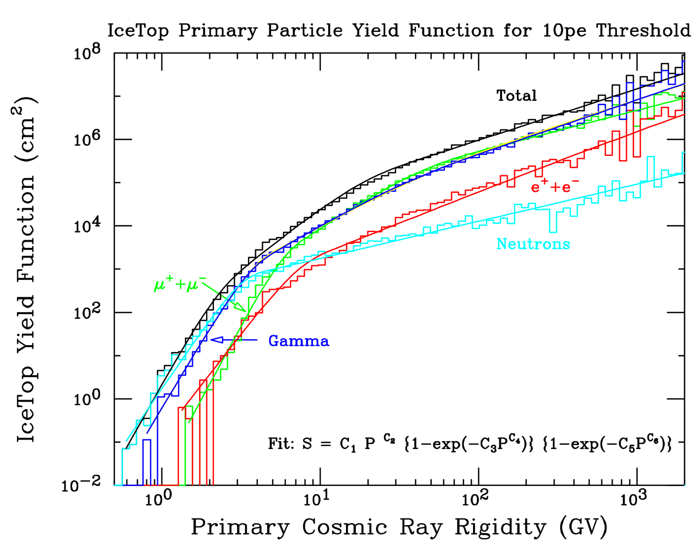

FIGURE 7: IceTop yield function, for individual contributions by secondary components.

The yield function $S(P,z)$ describes the primary cosmic ray detection efficiency of a full sky illumination of particle averaged over all arriving angles (uniform in $\cos^2(\theta)$). It is related to the count-rate $N(P_C,z,t)$ by

$$N(P_C,z,t) = \int_{P_C}^{\infty} \sum_i (S_i(P,z)\, j_i(P,t))dP$$
$$= \int_{P_C}^{\infty} (S(P,z)\, j(P,t))dP.$$

where

P: Rigidity

P_C: Geomagnetic cutoff (practically 0 at Pole)

z: Atmospheric depth

$S_i(P,z)$: Single mode IceTop yield function

$j_i(P,t)$: Rigidity spectrum for primary particle i

Counting Rates

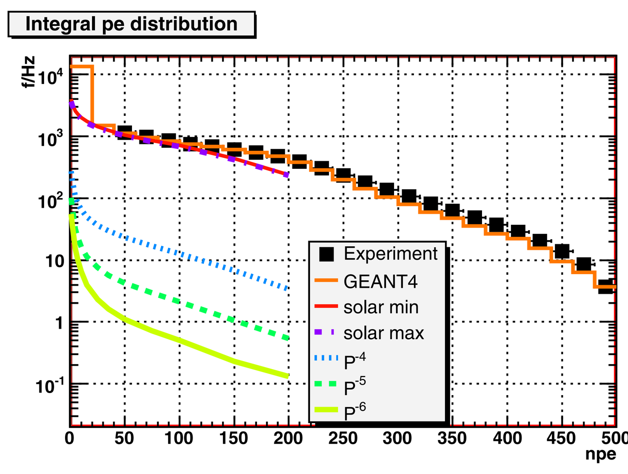

FIGURE 8: IceTop single tank NPE counting rates.

Finally, we show the integral counting rate for "normal" conditions and the rates for $P^{-4,-5,-6}$ spectra expected for Solar Events. They will expose themselves by counting rates about 2-3 orders of magnitude below the ones expected for quiet periods. IceTop is thus very well suited for the detection of Solar Events.

Conclusion

The IceTop tanks are sensitive to low energy particles produced in cascades by cosmic radiation. The response of the IceTop detectors is understood reasonably well in terms of the simulation. This allows predictions of rate changes induced by changes in the primary particle spectrum. We expect count rate drops beyond variations induced by atmospheric variations, leading to good detectability of solar events.

Acknowledgements

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References

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