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ON THE POSSIBILITY OF DETECTING MULTIPLE PRODUCTION OF GAUGE BOSONS INDUCED BY COSMIC NEUTRINOS USING UNDERWATER DETECTOR NESTOR

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Using a Monte Carlo simulation we estimate the possibility of studying a non perturbative electroweak behaviour in neutrino-quark interactions at ultra high energies via the detection in the full proposed NESTOR array of muon-bundles originating from the leptonic decays of multiply produced gauge bosons.

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In the last few years, speculations on a possible non perturbative behaviour in the electroweak sector of the standard model at energies above a threshold $\sqrt{\hat{s}_0} \gg M_W$ have appeared in the literature [1].

The behaviour essentially consists in the production of as many gauge and Higgs bosons as allowed by phase space with predicted partonic cross sections of the order of $10^{-33} - 10^{-29}$ cm^2. We want to estimate the possibility that muonic decays of the abundantly produced gauge bosons could contribute to some anomalies found at very high energy in cosmic rays, like the anomalous muon content in ultra high energy extensive air showers [2], or an excess of deep underground muons coming from the direction of Cygnus X-3, observed in the NUSEX, Soudan 1, and (recently) in the Soudan 2 underground experiments [3].

In this note we evaluate the rate of multi-W events which could be detected by the full proposed NESTOR array [4] using several hypotheses for the cosmic neutrino flux and cross section. The estimate is necessarily very rough due to the large uncertainties in all the parameters that enter the calculation:

- The cross section for neutrino-quark interactions is predicted to vary over a very wide range: $10^{-33} - 10^{-29}$ cm^2.

- The threshold above which the non perturbative behaviour sets in could vary from $\sqrt{\hat{s}_0} \simeq 2$ TeV to about 20 TeV [1]. In the following analysis we have chosen a threshold corresponding to an incoming neutrino energy of 10 PeV (10^{16} eV).

- A further very important source of uncertainty is the lack of a precise knowledge for the incoming neutrino intensity and spectrum at energies above 10 PeV. Here again the theoretical predictions are extremely model-dependent and vary over several orders of magnitude.

According to Ref. [5] the integral neutrino flux at $E_\nu > 10$ PeV, $I_\nu(10\text{ PeV})$, from

Active Galactic Nuclei (AGN) could be estimated as $\sim 10^{-13}$ cm^{-2}s^{-1}sr^{-1}. Another important neutrino source, the Bright Phase of Galaxy Evolution (BPGE), can give $I_\nu(10\text{ PeV}) \sim 10^{-15}$ cm^{-2}s^{-1}sr^{-1}[see Ref. [6] for a review and Ref. [7] for different results]. In addition, there is not yet an agreement on the prediction for the atmospheric neutrino flux (including the contribution due to the decay of charmed hadrons) at very high energies [8]. We have chosen for the estimate the two values of $I_\nu(10\text{ PeV})$ quoted above, and we will neglect the atmospheric neutrino contribution.

Within the given assumptions the number of neutrinos which produce muon-bundles geometrically detectable in NESTOR, is

$$N_\nu(E_\nu > 10\,\text{PeV}) \approx \begin{cases} 3.6 \times 10^3\ \text{y}^{-1} & \text{for AGN } \nu\text{'s}, \\ 36\ \text{y}^{-1} & \text{for BPGE } \nu\text{'s}. \end{cases}$$

For the calculation of the rates, the partonic cross sections have been folded in with the proton structure functions following Ref. [9]. Then we have calculated the probability of detecting muon-bundles as a function of the zenith angle, θ, for different values of the cross section. For this purpose we have used the simplest parameterization for the muon energy loss, $a + bE_\mu$ (with energy-independent a and b obtained from Ref. [10]), disregarding muon range straggling due to radiative and photonuclear interactions, which is therefore a supplementary (but comparatively small) source of uncertainty in the calculation of the event rates.

The detection efficiency for muon-bundles decreases as a function of the cross section since for a high cross section neutrinos interact soon after entering the sea and the muons, with a typical energy $E_\mu \approx 150$ TeV cannot reach the detector with high probability.

In table 1 we report the detection efficiency ϵ for muon-bundles in NESTOR (we define muon-bundle an event with 2 or more muons reaching the detector), as a

function of the partonic cross section, $\sigma_{\nu q}$. It is important that ϵ is a rather slowly varying function of $\sigma_{\nu q}$ within a very wide interval.

Table 1

$\sigma_{\nu q}$ (cm^2)	ϵ
10^{-33}	0.80
10^{-31}	0.73
10^{-30}	0.67
10^{-29}	0.48

In fig. 1 the distribution of muon-bundle events expected in NESTOR during one year of exposure as a function of the cosine of the zenith angle for the two highest values of the partonic cross sections is given, for the case of AGN neutrinos. The figure shows that, due to the high partonic cross sections, only events above the horizon can reach the detector.

If the incoming neutrino flux is sufficiently high (AGN ν's), up to 100 events per year, could be detected within a zenith angle interval $70° \leq \theta \leq 80°$, where we expect a negligible background from muon-bundles generated in hadronic cascades in the atmosphere. If the incoming neutrino flux is low (as in the case of the BPGE ν's) we expect a few events during several years of NESTOR operation, but a more detailed analysis is in progress to see if it is possible to discriminate on kinematical grounds the characteristics of the events we are interested in, from the atmospheric muon-bundles.

In conclusion we are confident that during a few years of operation of the full NESTOR array one could identify a non perturbative electroweak behaviour in ultra high energy cosmic neutrino interactions, if it exists. Our results are in broad agreement with the more general analysis of Ref.[11].

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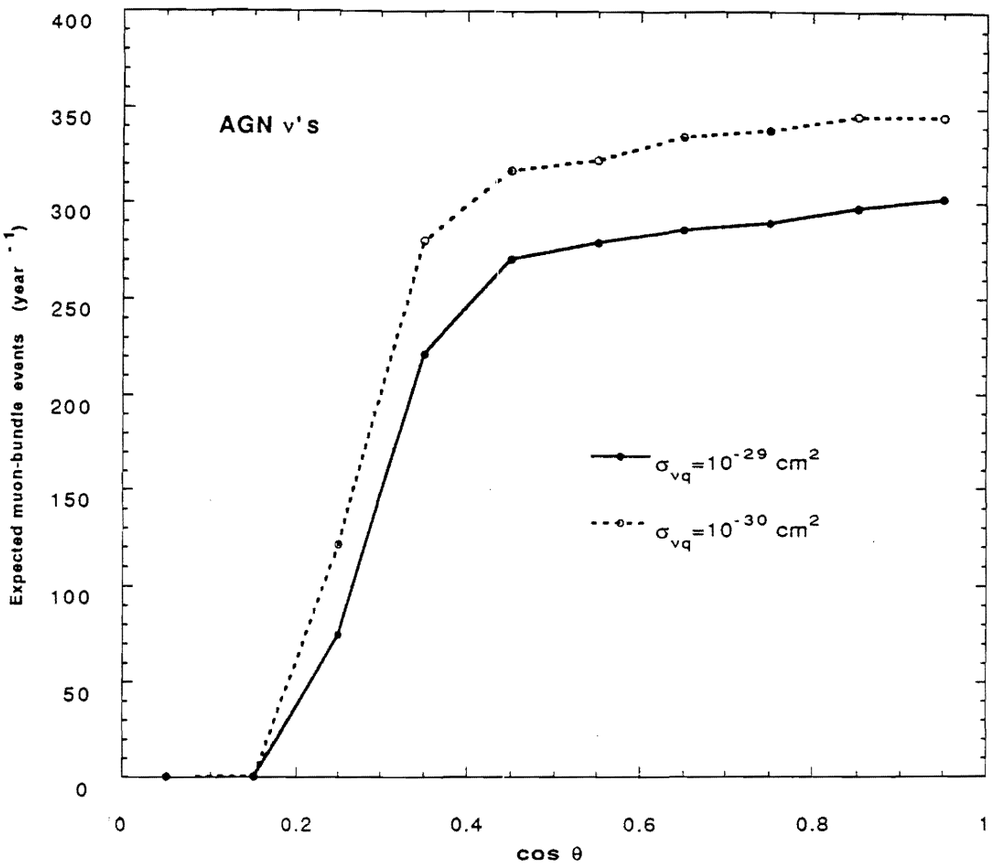

Figure 1. Expected number of muon-bundle events vs. the cosine of the zenith angle for $\sigma_{\nu q} = 10^{-29}$ and 10^{-30} cm^2 in the case of the AGN neutrinos in NESTOR.