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Observability of the Neutrino Flux from the Inner Region of the Galactic Disk

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OBSERVABILITY OF THE NEUTRINO FLUX FROM THE INNER REGION OF THE GALACTIC DISK

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ABSTRACT

We explore the observability of galactic neutrinos in a detector of 10^{10} tons of water with an observing time of a few years. Although the atmospheric flux exceeds the galactic flux considerably at energies $\geq$ 1 TeV, the latter may still provide a marginally observable signal owing to its directionality. Galactic muon neutrinos ($\nu_\mu + \bar{\nu}_\mu$) with energy $\geq$ 1 TeV will produce a signal $\sim 2\sigma$ above the atmospheric background over a four year period. If electron neutrinos ($\nu_e + \bar{\nu}_e$) can also be studied with DUMAND, then galactic electron neutrinos above 1 TeV would give an $\sim$ 4-5σ signal above the $\nu_e + \bar{\nu}_e$ background over a four year integration time.

I. INTRODUCTION

The flux of galactic neutrinos and the corresponding event rate in DUMAND has been calculated by one of the authors (Stecker, 1978; see these Proceedings, 1979). The flux is less than that estimated by earlier authors. In the same paper the flux of prompt atmospheric neutrinos was calculated from the latest experimental data, and found to be of the same order of magnitude as the flux from the inner region of the galactic disk--it could even exceed the latter by a factor of ~ 3. Furthermore, Allkofer et al. (1978) have calculated new values of the π - and K-generated atmospheric $\nu_\mu + \bar{\nu}_\mu$ and $\nu_e + \bar{\nu}_e$ fluxes, from vertical and horizontal directions. Using these new results, we discuss the problem of the observability of the inner galaxy using a DUMAND type detector.

II. CRITERIA ADOPTED FOR OBSERVABILITY OF A SIGNAL

Consider a search with a counter telescope for unknown sources, subdividing the sky into, e.g., 10^4 cells. Then a signal exceeding the mean by at least 6 standard deviations would be significant, since, out of 10^4 cells, 7 are expected to exhibit fluctuations of ~ 5 standard deviations by chance. However, for a known source, 2 or 3 standard deviations would be significant. A galactic ν event rate detected even at this level can reveal important information about cosmic rays of energy above 10 TeV in the inner regions of the Galaxy.

III. CALCULATION OF GALACTIC AND ATMOSPHERIC EVENT RATES

The number of galactic neutrinos ($\nu_\mu + \bar{\nu}_\mu$) observed in one year at energies $E > 10$ TeV in a detector of 10^{10} tons is ≈ 45 for a proton energy spectrum $dJ/dE \propto E^{-2.67}$ and ≈ 18 for $dJ/dE \propto E^{-2.75}$. The latter, more conservative value, based on the steeper spectrum (Ryan et al. 1972), will be used in the present calculation. This spectral index is also more consistent with the results of Allkofer et al. (1978) which we adopt for the atmospheric neutrino spectrum from pion and kaon decay. At 1 TeV, the event rate is 16 times higher.

About 45% of the expected events due to high energy neutrinos originating in our Galaxy come from the inner ~ 5 kpc of the Galaxy, which we will call the galactic central region (G.C.), $\pm 8°$ in latitude and $\pm 50°$ in longitude in the usual galactic coordinates. This value is calculated from the latitude distribution of the γ-ray flux near the galactic center (Fig. 6, Stecker, 1978) and the observed longitude distribution (see also Stecker 1977).

We shall now proceed to calculate the event rates of atmospheric neutrinos from the prompt and π, K-decay processes.

At energies ≥ 1 TeV it becomes necessary to consider the flux of prompt atmospheric neutrinos. (Stecker 1978, 1979 and references therein). We adopt for the production ratio R of prompt neutrinos to pions, values of 10^{-4} and 10^{-3}. To estimate the background of prompt atmospheric neutrinos in the galactic central region (G.C.), we use Figures 7 and 8 (given for $\leq 2°$) of Stecker (1978), and consider the number of prompt neutrinos in an 0.5 sr region of sky defined by galactic latitudes $|b| \leq 8°$ and longitudes $|\ell| \leq 50°$.

Next we evaluate the event rate for the atmospheric neutrino flux from π, K decay. The atmospheric neutrino flux from π and K decay which we adopt is that of Allkofer et al. (1978). The mean atmospheric neutrino flux from π and K decay is ≈ 0.5 of the horizontal flux at 1 TeV and ≈ 0.3 at 10 TeV (Maeda 1964).

The event rates for a 10^{10} ton detector are then calculated from the formula

$$\frac{dN_\nu}{dt} = 6\times10^{39} \int_E^{\infty} dE\, I_\nu(E)\sigma_\nu(E)\ s^{-1}sr^{-1}(\Delta\Omega)_{G.C.}$$

where the $\Delta\Omega_{G.C.} \simeq 0.5$sr and the cross section was taken from Fig. 9 of Stecker (1978).

It can be seen that the inner region of the Galaxy may be detectable using observing runs of 4 yr or longer.

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Table 1. Observability of Central Region (G.C.) of Galactic Disk

	Energy (TeV)	N_{Prompt} ($R=10^{-3}$)	$N_{\pi K}$	$N_{pr}+N_{\pi K}$	$(N_{pr}+N_{\pi K})^{1/2}$	Number of ν's from G.C./yr.	Standard Deviations of G.C. Events Above Atmospheric Background (1 yr.)	(4 yr.)
		Number of Atmospheric Neutrino Events/yr.						
($R=10^{-3}$)								
$\nu_\mu + \bar{\nu}_\mu$	1	380	17,600	18,000	130	130	1.0	2.0
	10	23	120	140	12	8	0.7	1.4
$\nu_e + \bar{\nu}_e$	1	380	790	1,200	34	65	1.9	3.8
	10	23	4	27	5.2	4	0.8	1.5
$\nu_\mu + \bar{\nu}_\mu$	1	760	18,400	19,200	140	195	1.4	2.8
$+\nu_e + \bar{\nu}_e$	10	46	120	170	13	12	0.9	1.8
($R=10^{-4}$)		($R=10^{-4}$)						
$\nu_\mu + \bar{\nu}_\mu$	1	38	17,600	17,600	130	130	1.0	2.0
	10	2.3	120	120	11	8	0.7	1.4
$\nu_e + \bar{\nu}_e$	1	38	790	830	29	65	2.2	4.5
	10	2.3	4	6.3	2.5	4	1.6	3.2
$\nu_\mu + \bar{\nu}_\mu$	1	76	18,400	18,500	140	195	1.4	2.8
$+\nu_e + \nu_e$	10	4.6	120	120	11	12	1.1	2.2

The aperture considered for the atmospheric neutrinos is the same as for the G.C. ±50° in galactic longitude, and ±8° in latitude.