Analysis of the Events Recorded by the LVD Neutrino Detector From Large Solar Flares During High Solar Activity

M.Aglietta[14], E.D.Alyea[7], P.Antonioli[1], G.Badino[14], G.Bari[1], G.Basile[1], V.S.Berezinsky[9], M.Bertaina[14],R.Bertoni[14], G.Bruni[1], G.Cara Romeo[1], C.Castagnoli[14], A.Chiavassa[14], J.A.Chinellato[3], L.Cifarelli[1], F.Cindolo[1], A.Contin[1], V.L.Dadykin[9], G.D'Onofrio[15], L.G.Dos Santos[3], R.I.Enikeev[9], N.Finetti[15], W.Fulgione[14], P.Galeotti[14], M.Garbini[1], P.Ghia[14], P.Giusti[1], F.Gomez[14], F.Grianti[1], G.Iacobucci[1], E.Kemp[3], F.F.Khalchukov[9], E.V.Korolkova[9], P.V.Korchaguin[9], V.B.Korchaguin[9], V.A.Kudryavtsev[9], M.Luvisetto[1], A.S.Malguin[9], H.Menghetti[1], N.Mengotti Silva[3], C.Morello[14], R.Nania[1], G.Navarra[14], K.Okei[10], L.Periale[14], A.Pesci[1], P.Picchi[14], I.A.Pless[8], A.Porta[14], A.Romero[14], V.G.Ryasny[9], O.G.Ryazhskaya[9], O.Saavedra[14], K.Saitoh[13], G.Sartorelli[1], M.Selvi[1], N.Taborgna[5], N.Takahashi[12], V.P.Talochkin[9], G.C.Trinchero[14], S.Tsuji[11], A.Turtelli[3], P.Vallania[14], S.Vernetto[14], C.Vigorito[14], L.Votano[4], T.Wada[10], R.Weinstein[6], M.Widgoff[2], V.F.Yakushev[9], G.T.Zatsepin[9], A.Zichichi[1]
(1) University of Bologna and INFN-Bologna, Italy
(2) Brown University, Providence, USA
(3) University of Campinas, Campinas, Brazil
(4) INFN-LNF, Frascati, Italy
(5) INFN-LNGS, Assergi, Italy
(6) University of Houston, Houston, USA
(7) Indiana University, Bloomington, USA
(8) Massachusetts Institute of Technology, Cambridge, USA
(9) Institute for Nuclear Research, Russian Academy of Sciences,Moscow, Russia
(10) Okayama University, Okayama, Japan
(11) Kawasaki Medical School, Kurashiki, Japan
(12) Hirosaki University, Hirosaki, Japan
(13) Ashikaga Institute of Technology, Ashikaga, Japan
(14) Institute of Physics of Interplantary Space, IFSI, CNR, Torino, University of Torino and INFN-Torino, Italy
(15) University of L'Aquila, L'Aquila, Italy

Abstract

The results of the analysis of events recorded by the LVD neutrino detector at Gran Sasso Laboratory during the maximum peak of the high solar activity (including the very intense Bastille solar flare) are reported. The analysis of

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events, candidates as neutrinos, is done by selection of data taking into account the behavior of each scintillation internal counter over a period of 48 hours centred around the solar flare time. After the analysis of the sovrapposition of data related to the 23 solar flares in exam, the upper limits (90% C.L.) for the integral neutrino and antineutrino flux of different flavors are given.

1. Introduction

The production of neutrinos during large solar flares are due to accelerated protons which can interact with solar matter producing pions and kaons which decay in neutrinos. We have analyzed the LVD data recorded during a period of maximum of solar activity (23° cycle) in coincidence the occurrence of 23 intense flares observed in the years 2000, 2001, 2002. Although some previous research for neutrinos from solar flares have been done [3,4], but in different periods, it could be interesting to explore the possiblity a detecting neutrinos produced during a maximum of solar activity period as the present 23° cycle.

2. The LVD neutrino detector

The Large Volume Detector (LVD) in the Gran Sasso underground laboratory, Italy, consists of an array of 840 scintillator counters (1.5 m^3) interlayed by streamer tube and arranged in a compact and modular geometry (see Aglietta et al.[1]), with an active scintillator mass M=1000 tons. The main purpose of LVD is to detect antineutrino burst from gravitational collapses through the antineutrino capture of free protons ($\bar{\nu}_e$,p)→(n,e^+). The energy threshold is $\mathcal{E} \approx 4$ MeV for the internal tanks and $\mathcal{E} \approx 7$ MeV for the external tanks. After each trigger this threshold is lowered to 0.8 MeV during a time gate of $\approx 1000 \mu s$ in order to detect the gamma capture signal. Besides the antineutrino-proton interaction, $\nu_e, \bar{\nu}_e, \nu_\mu, \bar{\nu}_\mu$ could be detectable thorough their interactions with ^{12}C nuclei. The energy threshold of this interacion are higher and the cross section (Fukugita et al.[2]) are about one order of magnitude lower. The elastic scattering of neutrinos on electrons, (because of its even lower cross section), as well as the neutral current reactions on carbon have not been consider in this preliminary work. The duration of neutrino burst is expected to be ≈15 minutes and we will take this same time duration as it has been done by Aglietta et al.[3]. For this analysis we have used only the internal tanks of LVD, in this way we reduce the active mass to 57% of the total mass.

3. Analysis of LVD events

The selection of the data analysis was restricted to an interval of 48 h centred around the solar flare time. We analyzed the time distribution of all

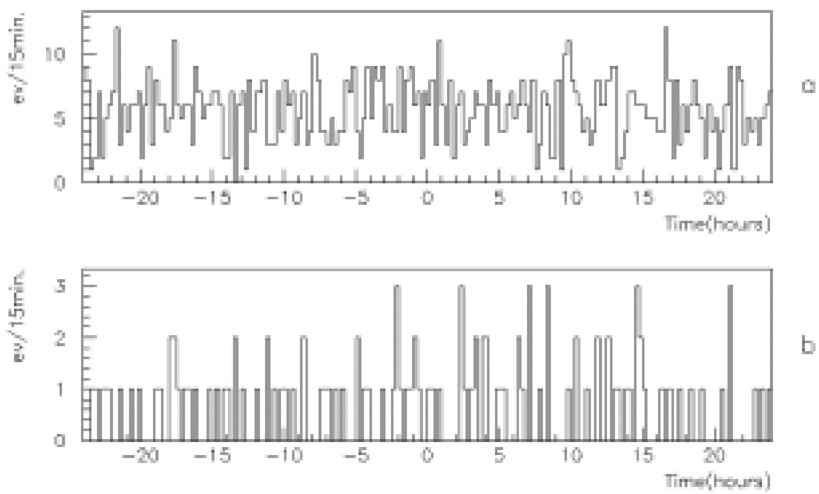

Fig. 1. Time distribution of neutrino interaction summed over 23 flares.

neutrino canidated events mainly for the two types of neutrino interactions above mentioned. The first selection criteria applied to LVD of events was to exclude the pulses due to muons which involve more than two tanks in coincidence. We have eliminated all tanks which have some anomalous behavior due to electronics or to calibration of the trigger signal becaues they can give an abnormal frequency. An accurate analysis of the multiplicity of low energy pulses for each tank has been made. Among the internal counters, a further grouping of tanks, selected according to their geometrical position inside the LVD detector, were observed to have different response to the background. The most important characteristics of the 23 solar flares together with proton flux, X-class and optical importance classification, are shown in table 1, it is also included the Bastille solar event. In fig.1 are shown the time distribution of neutrino interactions summed over 23 flares. Fig.1.a is related to all reactions ($\bar{\nu}_e$,p) followed by a low energy pulse in the gate. Fig.1.b is related to the charge current reactions (ν,^{12}C) followed by a second pulse trigger with energy $\mathcal{E}$ $\geq$4 MeV within 50 ms observed in the same tank. From the analysis of each single flare no significant excess has been found in coincidence (within 48 h) with any of 23 solar flares. Therefore we have summed over all the flare time distributions obtaining the same negative results for both neutrino interactions under analysis.

The upper limits obtained for the integral neutrino flux (CL=90%) are: for $\bar{\nu}_e$ the limit is $2 \cdot 10^9$ cm^{-2}, for $\bar{\nu}_e$(E> 20MeV) it is $5 \cdot 10^8$ cm^{-2} and for ν_{cc} it is $8.7 \cdot 10^9$. This upper limits were obtained by using 3275 selected tanks with a total mass of 3.930 kt.

Table 1. List of the selected flares. The proton flux is given in $Prot. \cdot cm^{-2}s^{-1}Sr^{-1}$

Month	Day	h (UT)	Year	Prot.Flux>10MeV	X-Class	Opt.Imp.	Location
7	14	10,24	2000	24000	X5.7	3B	N22W07
1	28	16,00	2001	49	M1	1N	S04W59
3	29	10,15	2001	35	X1	1N	N14W12
4	10	05,26	2001	355	X2	3B	S23W09
4	28	13,12	2001	57	M7	2B	N17W31
5	07	19,15	2001	30			NW limb
6	15	17,50	2001	26			W limb
8	10	11,22	2001	17	C3		Disk center
8	16	01,35	2001	493			Backside
9	15	11,28	2001	11	M1	1N	S21W49
9	24	10,38	2001	12900	X2	2B	S16E23
10	19	16,30	2001	11	X1	2B	N15W29
10	22	17,59	2001	24	X1	2B	S18E16
11	04	16,20	2001	31700	X1	3B	N06W18
11	17	05,25	2001	3	M2	1N	S13E42
11	22	23,30	2001	18900	M9	2N	S15W34
12	28	20,45	2001	76	X3		S26E90
1	8	20,25	2002	91	C9		E limb
1	14	06,27	2002	15	M4		W limb
2	20	06,12	2002	13	M5	1N	N12W72
3	15	23,10	2002	13	M2	1F	S08W03
3	18	02,31	2002	19			S09W46
3	22	11,14	2002	16	M1		W limb

Moreover, we are analysing the LVD events taking into account the scintillator counter signals in coincidence with the tracking system data in order to reduce further the backgorund.

4. References

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