THE LARGE VOLUME DETECTOR (LVD) at GRAN SASSO

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Abstract

The Large Volume Detector (LVD) at Gran Sasso is described. LVD is a modular detector with 190 identical modules. It consists of 1800 tons of scintillator detectors and 1800 tons of steel, all surrounded with tracking detectors. The geometric acceptance is 7000 m^2sr, and the angular resolution is 0.5 degrees. The equipment is well suited for the studies of stellar collapse and neutrino oscillations.

I. LVD COLLABORATION.

The LVD Collaboration consists of institutions from Italy (U. Bologna, Calabria U., U. Firenze, INFN Frascati, U. of L'Aquila, U. Lecce, U. Palermo, U. Perugia, U. Torino, and U. of Urbino), from the Soviet Union (Ioffe Phys. Tech. Inst. Leningrad, and Inst. Nucl. Research Moscow), from the United States (Brown U., U. Houston, Indiana U., M.I.T., and Northeastern U.), from China (Inst. High Energy Physics Beijing), from Brazil (U. Campinas), from Japan (Kinko U., Okayama U., Okayama U. of Science, Saitma U., and U. Tokyo), and from Switzerland (CERN).

II. OVERVIEW OF THE DETECTOR

The LVD detector is being assembled inside the Gran Sasso Laboratory 120 km east and north of Rome.

The laboratory itself consists of three major halls, A, B, and C. The main LVD detector is located in the northern half of Hall A while the electronics and assembly area for LVD is located in the southern third of Hall B. This is shown in Figure 1.

The LVD detector is composed of 190 identical modules assembled into 5 towers. These towers are connected in such a manner as to be earthquake proof and to allow easy access to all electronic components. This is illustrated in Figure 2 and 3. In Figure 3 it is shown that the LVD modules consist of eight scintillation counters and a horizontal and vertical tracking plane.

The horizontal and vertical tracking planes of each module are logically joined together so as to create large planes that cover the whole LVD detector. Figure 4 is a sketch showing a view of LVD along Hall A. This figure indicates how the individual module tracking plans are joined together to make the large LVD tracking planes. The main characteristics of LVD are shown in Table I.

Table I

LVD CHARACTERISTICS

Area	2,332 m^2
Geom. Acceptance	~7,000 m^2 sr
Length	40 m
Width	13.2 m
Height	12 m
Volume of Scintillator	2,280 m^3
Mass of Scintillator	1,800 t
Mass of Steel	1,800 t
Number of Tracking Channels	100,000
Number of Streamer Tubes	20,000
Number of Phototubes	4,560
Analogue Channels	9,120
Tracking Spatial Resolution	2 cm
Energy Resolution	~20% (contained events)

III. SCINTILLATION SYSTEM

As previously noted, each LVD module contains eight scintillation detectors. Each scintillation detector contains three phototubes, each with a fifteen centimeter photocathode. These detectors are well tested as they are identical to the detectors in LSD. These LSD detectors are a result of the collaboration between the Institute for Nuclear Research in Moscow and the Institute of Cosmo-Geophysics in Torino.

Figure 5 is a sketch of a scintillation detector. The outputs of the three phototubes are put into a triple coincidence to reduce the dark current noise.

A. Energy Resolution

The large photocathode area of the combined three phototubes and the compact volume of the scintillator tank have been chosen to optimize the energy resolution of these detectors. In a special circuit, the outputs of the three photomultipliers are used to estimate the energy of the event. The energy resolution for contained events (all the energy is in one scintillation detector) is of the order of $20\%/\sqrt{E}$.

B. Time of Flight

The scintillation system in conjunction with the information from the tracking planes will furnish (off line) 2-3 ns time of flight resolution.

C. Anti-Neutrino Identification

The LVD scintillation detectors have the capacity to identify anti-neutrino interactions. This identification is done by means of the following set of reactions:

$$(1) \quad \nu + p \rightarrow N + e^{+}$$
$$\quad\quad\quad\quad \hookrightarrow e^{+} + e^{-} \rightarrow 2\gamma$$

$$(2) \quad N + p \rightarrow D + \gamma$$

Reaction (1) is prompt and is the trigger for the event. Reaction (2) is delayed with a delay time of 170 μs. The deuteron fusion gamma ray has a line spectrum of 2.2 MeV. The collaborators from Moscow and Torino have used these scintillation counters to measure reaction (2).

The measurement was made with the help of a californium 252 source. A californium 252 source was placed inside a liquid tight can along with a solid state particle detector. This can was placed inside the scintillation detector. The solid state detector created a trigger when it detected the following reaction:

$$^{252}CF \rightarrow N + \gamma + X$$

This trigger opened a 500 μs gate and the summed output of the three photomultipliers was analyzed by a multichannel analyzer. The output of the multichannel analyzer is shown in Figure 6. A clear peak, well above background is seen centered at 2.2 MeV. This 2.2 MeV signal is due to the capture of the neutron from the californium 252 decay by a proton in the liquid scintillator creating a deuteron and the fusion gamma ray.

$$N + p \rightarrow D + \gamma \;\; (E\gamma = 2.2 \text{ MeV})$$

The moderation time for the neutron is 170 μs. Figure 7 is the time distribution of the detection of the fusion gamma ray after the trigger. The slope of the data in Figure 7 matches the moderation time.

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The data in Figures 6 and 7 demonstrates the ability of the counters to identify anti-neutrino induced reactions.

The above properties of the scintillation detectors make them ideal instruments for the study of stellar collapse. Combined with tracking information these detectors are also ideal for a neutrino oscillations search.

IV. TRACKING SYSTEM

The tracking system consists of 190 L shaped streamer tube detectors which cover the bottom and one side of each module. This is shown in Figure 8. Figure 9 shows a sketch of how the tracking detectors are constructed. Each detector system consists of two layers of streamer tubes, each with X and Y readout strips. Each strip is 4 cm wide. The two layers are staggered by 2 cm. Hence the effective spatial resolution is
2 cm for the detector. The angular resolution of the complete LVD detector is less than 0.5 degrees. This tracking system plus the time resolution of the scintillation system is well suited for the measurement of neutrino oscillations. It will allow the discrimination between muons created inside LVD and muons stopping in LVD.

V. DATA ACQUISITION SYSTEM

LVD consists of five towers with four corridors for each tower. There will be CAMAC crates in each tower. This is illustrated in Figure 10.

The CAMAC crates for each tower will be controlled by a Fisher crate system and a Microvax II computer. Each Fisher crate system will contain a **"Star Burst Controller."** This controller is the equivalent of a PDPII-70. A schematic sketch of this Fisher crate system is shown in Figure 11.

The full LVD data acquisition system consists of five Microvax II computers, one Microvax II full boot node computer and a main Vax 8200 computer. The communication links between these computers are shown in Figure 12.

This system can handle a continuous trigger rate of 500 Hz with a 10% dead time. It can handle a 2,000 Hz 20 second burst with a few percent dead time. Hence this system can handle a stellar collapse in our galaxy with little or no loss. In addition, it can handle a large background with little data loss which implies LVD can operate with a relatively loose trigger.

VI. SUMMARY

LVD is a modular detector (190 identical modules)

The tracking and scintillation systems are highly segmented.

The detector is homogeneous with respect to tracking systems and scintillation systems.

The data acquisition system will respond to a continuous 500 Hz trigger rate and a 20 second 2,000 Hz burst.

Anti-neutrino events can be identified.

Time of flight of the scintillation system plus the segmentation of the tracking system allows for discrimination between muons created inside LVD and muons stopping in LVD.

LVD can investigate a wide variety of astro-physics and elementary particle topics, but it is uniquely suited to study stellar collapse and neutrino oscillations.

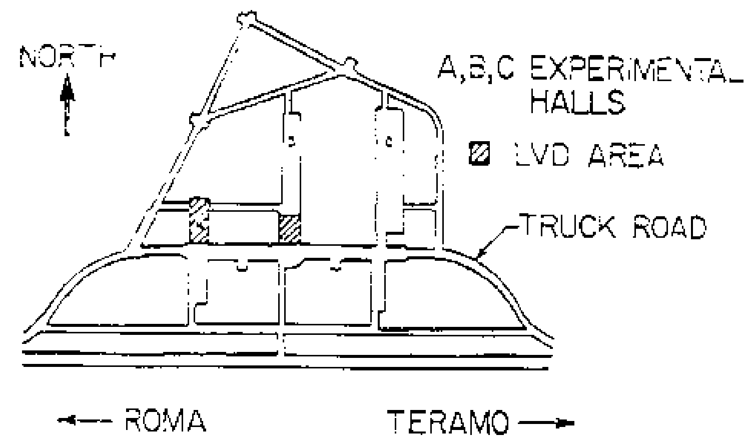


FIGURE 1

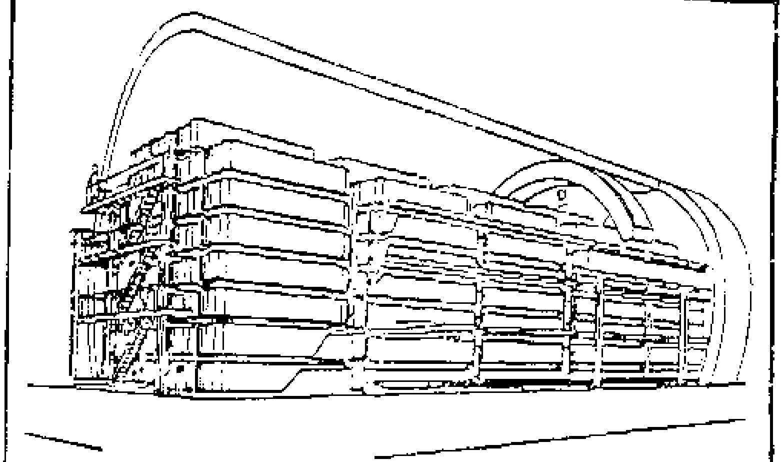
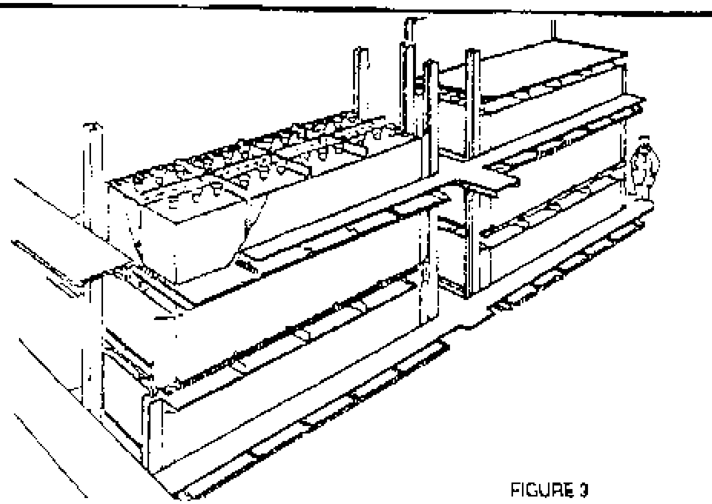


FIGURE 2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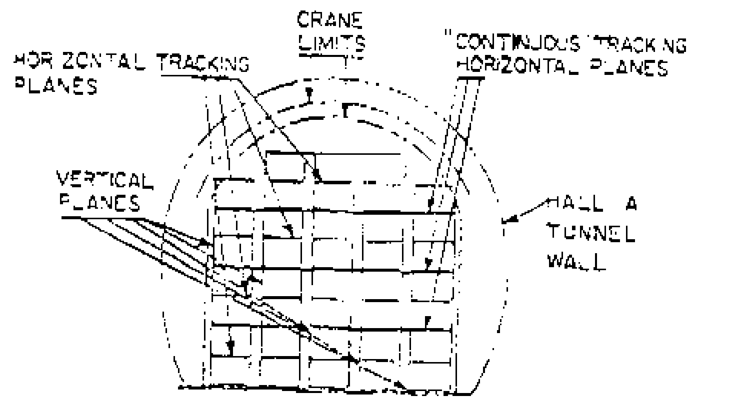

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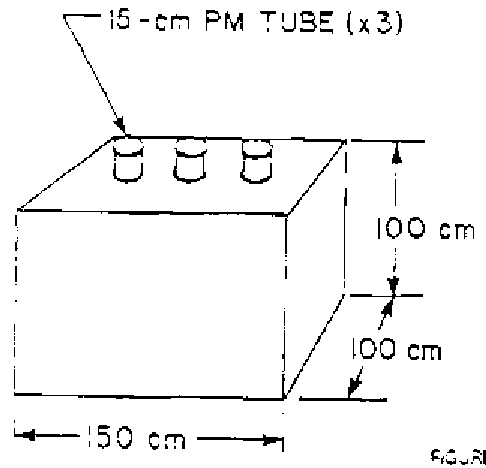

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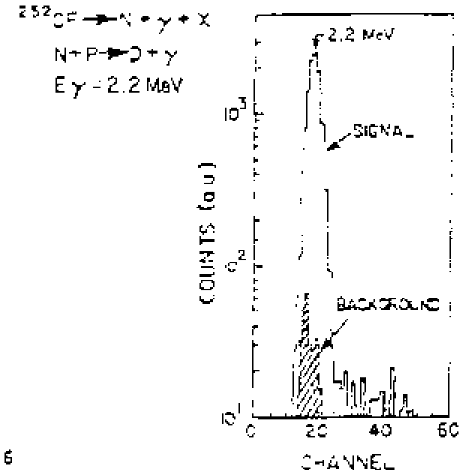

FIGURE 6

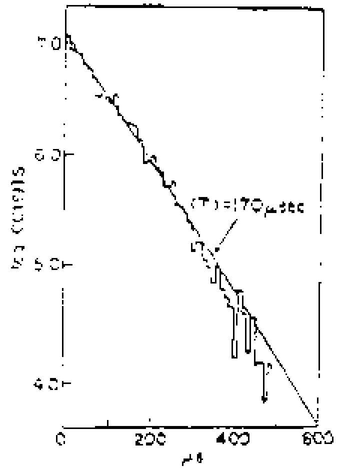

FIGURE 7

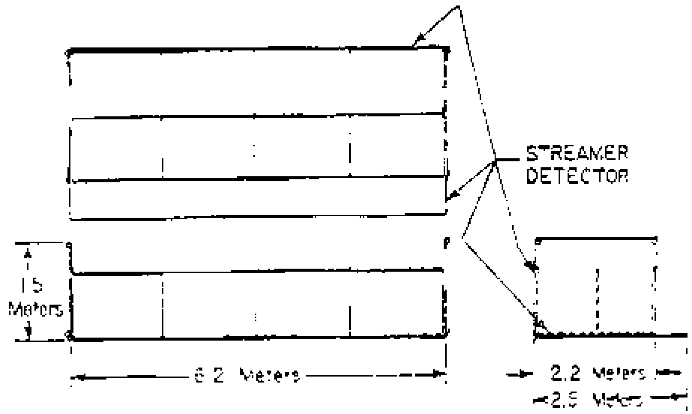

FIGURE 8

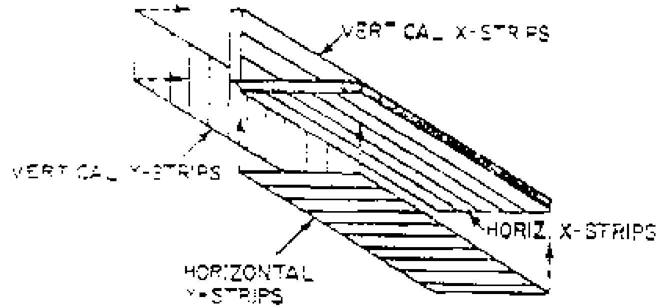

FIGURE 9

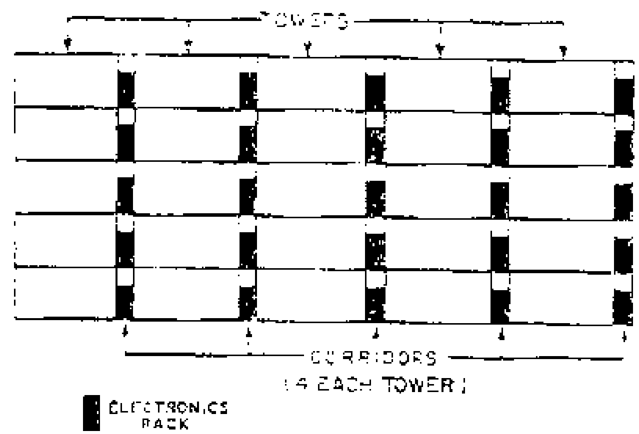

FIGURE 10

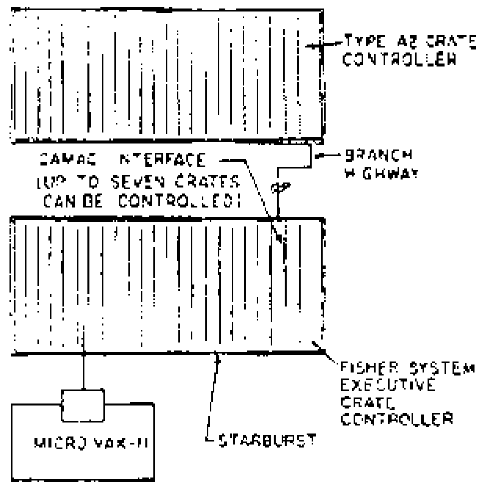

FIGURE 11

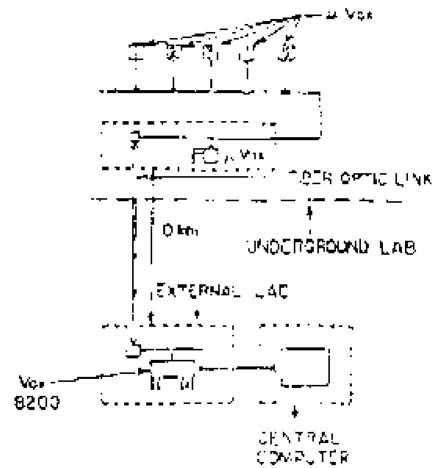

FIGURE 12