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STATUS REPORT OF THE MACRO EXPERIMENT AT GRAN SASSO

The MACRO Collaboration

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The half of the MACRO detector, a large area Monopole, Astrophysics, Cosmic Ray Observatory is nearly completed in Hall B of the Gran Sasso Laboratory. One supermodule is already taken data and the remainder will be activated in few months. A general overview of the MACRO detector, together with it's physics capabilities as far as the search for point sources of high energy neutrino is concerned, will be presented.

1. INTRODUCTION

The MACRO detector [1] is presently under construction at Hall B of the Gran Sasso Laboratory at the depth of 3600 mwe.

The general purpose of the experiment is to search for possible rare constituents of the penetrating cosmic radiation (monopoles, exotics), to study the cosmic ray flux and composition, and to search for γ or ν astrophysical sources and supernova bursts.

A distinctive and unique feature is offered by the possibility of combining the information coming from the MACRO detector and the EASTOP array [2], on top of the Gran Sasso Laboratory, in order to perform a direct measurement (from shower size) of the energy of the nucleus associated to the μ detected underground.

One supermodule (1/6 of the total apparatus) is operational since February and will take data until the end of May, in order to collect a first sample of about 2×10^5 cosmic ray muons.

2. THE DETECTOR

The MACRO apparatus (fig. 1) consists of a modular array of liquid scintillators counters, plastic streamer tubes and track etch detectors, which fill a 12 m wide, 4.5 m

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Presented by P.Campana, Laboratori Nazionali di Frascati

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high, 78 m long rectangular box. The detector is designed to have a large acceptance (~10000 m^2 sr), to measure particle trajectory, velocity and ionization, and to have a redundancy of detection techniques.

The detector, at present, is made of a horizontal sandwich of two scintillation counters, 10 streamer tube layers and one track etch multilayer (fig. 2). A passive absorber ($CaCO_3$) lies in between the sensitive layers, setting a threshold for through passing muons at about 1 GeV.

The lateral sides of the apparatus are closed by one layer of scintillation counters and six layers of streamer tubes. In the future, an extension of the upper part of the detector is foreseen, in order to increase the acceptance.

The liquid scintillation counters are 75 cm wide, 26 cm thick and 12 m long PVC boxes containing pseudocumene dissolved in mineral oil. Each end of the counter is viewed by a couple of 20 cm PMTs, immersed in a non scintillating oil, to get rid of large light pulses produced by soft electrons (fig. 3). The scintillation counters exhibit a light attenuation lenght of 7 m, a 5 MeV trigger energy threshold and a 1 ns time accuracy.

The streamer tube layers, providing the tracking system, consist of 3 x 3 cm^2 x 12 m active cell with 100 μm anode wire and PVC graphite cathode. The tubes are flowed with a gas mixture of He, CO_2 and n-pentane.

The bidimensional localization is achieved reading out the wire planes and pickup strips positioned at an angle of 30° with respect to the wires. Space accuracy turns out to be about 1 cm in both views, while the angular localization is achieved with an accuracy of 0.1°, smaller than the spread due to the multiple scattering of muons along their transit in the rock.

The track etch layer [4] is made of a sandwich of lexan and CR39 plastic sheet, with an aluminium absorber in between.

The first supermodule is taking data since the end of February 89. At present the number of collected single muons is ~10^5 at rate of about 2 / minute.

The muon trigger requires one scintillator hit or at least six streamer tube planes fired. In fig. 4 and 5 some single

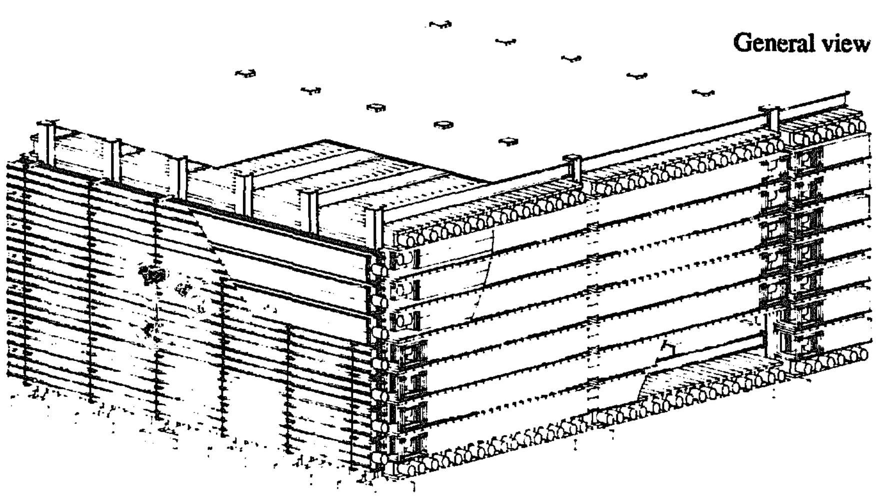

FIGURE 1
General view of one of the 12 MACRO supermodules.

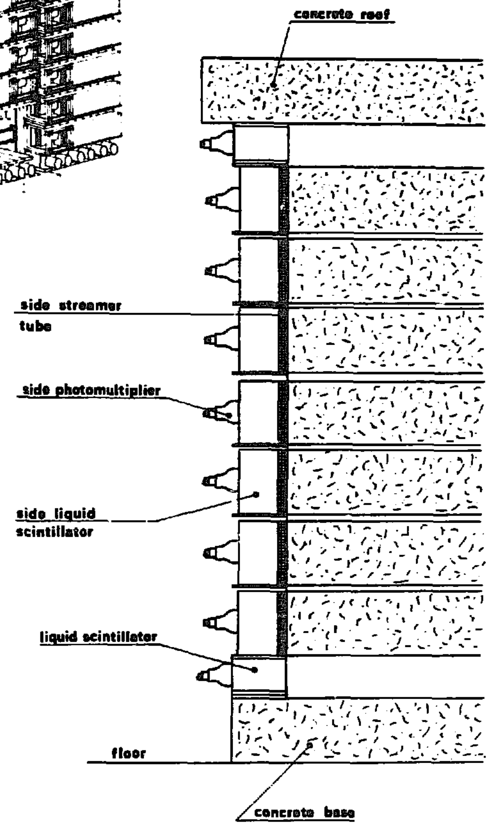

FIGURE 2
Detector cross section.

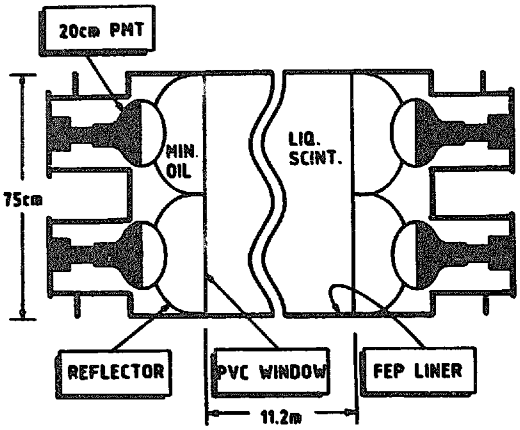

FIGURE 3
Scintillation counter schematic design.

and multimuons events are shown.

This first run of the experiment will be used to study trigger efficiency, backgrounds, to test readout circuits, online and offline software. The second and the third supermodule are already mounted and will be equipped with electronics during this summer. The remaining supermodules will be operational by the beginning of 1990.

A systematic study of the collected data sample is, at present, undergoing, concerning various subjects in the field of cosmic ray physics (flux and chemical composition of the primary spectrum, anisotropies, etc...) and also of particle physics (muons in a bundle with an anomalous high p_T, delayed tracks, etc....). In this respect we expect to collect in this data taking about 10^4 muon bundles.

As far as the MACRO - EASTOP correlation is concerned, an offline coincidence procedure has been established, based on the reciprocal arrival times and reconstructed angles. The expected rates of event in coincidence is about 50 / week.

3. NEUTRINO FROM COSMIC SOURCES

The study of point sources in X and γ ray astronomy has revealed powerful acceleration mechanisms in peculiar celestial bodies, involving the interactions of high energy particles accelerated by compact sources.

Large fluxes of neutrinos are likely to be produced in any source which accelerates protons to high energies.

Referring to a conceptual scheme similar to that suggested for the production of pulsated γ rays, based on the acceleration in a compact object orbiting around a companion star, neutrino emission via π decay can be expected during the entire eclipse time, giving a luminosity as high as 0.1-0.3 of that of the proton.

Making use of the combined information coming from the tracking (streamer tubes) and timing systems (scintillation counters) it is possible to detect muons produced by ν interactions in the surrounding rock (fig.6). Due to the large flux of downward going cosmic ray muons, we use only upward-going muons tagged by the timing system to identify neutrino interactions in the rock. Therefore, the field of view for extra-terrestrial neutrino sources is limited to approximately one half of the sky, covering mainly the southern emisphere (fig. 7). Two candidate sources in the sky are Vela X1[5] and LMC X4 [6].

Due to the good angular resolution, discrete sources are identified by a clustering of events coming from known celestial objects. Montecarlo calculations performed

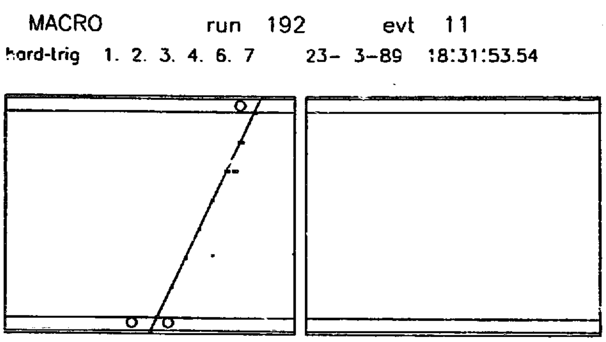

FIGURE 4
Single cosmic ray muon in the MACRO detector.

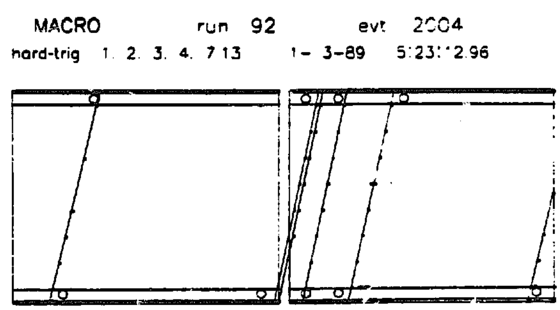

FIGURE 5
Muon bundle in the MACRO detector.

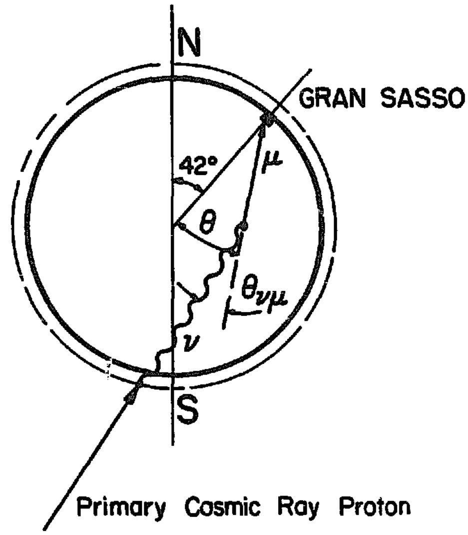

FIGURE 6

Detection of atmospheric and astrophysical neutrinos in the MACRO apparatus.

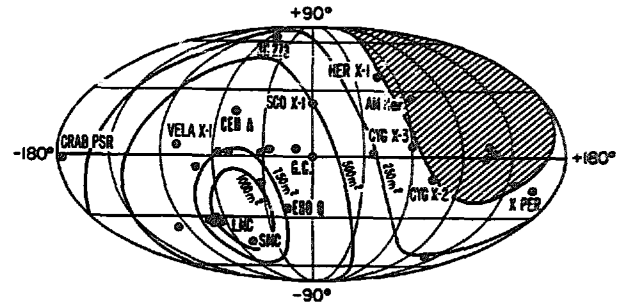

FIGURE 7

Detector field-of-view in Galactic coordinates: countours represent time-averaged exposed areas.

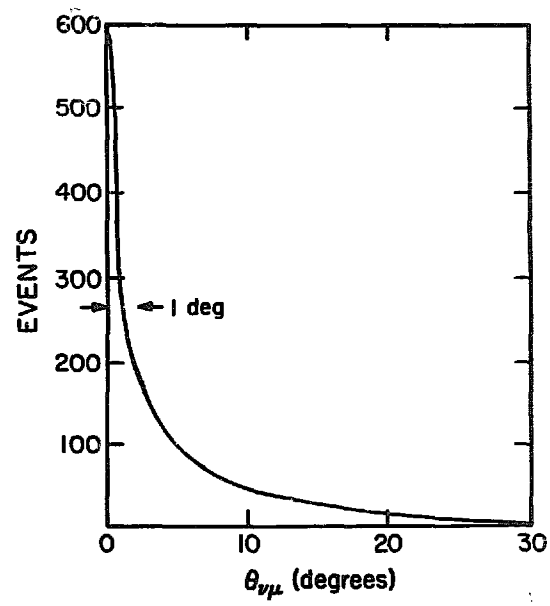

FIGURE 8

Angular dispersion of detected muons with respect to the original neutrino direction.

assuming a -2 spectral index, show that detector response is proportional to E_ν^2 up to a neutrino energy of 1 TeV and flattens above due to additional energy losses of the muon (bremmstrahlung and nuclear interactions). This behaviour of the effective area results into a median muon energy in the MACRO detector of the order of some TeV and, consequently, a very small angular spread of the muon with respect to the incoming neutrino direction (see fig. 8).

With an anticipated background rate of about 250 upward going muons per year, we expect less than 0.1 counts/year in a 2° x 2° bin. An evaluation of the flux coming from Vela X1 leads to 5-20 counts/year.

One year of running of MACRO will be sensitive to neutrino sources producing a flux of 10^{-14} cm^{-2} s^{-1} upward muons passing in the detector.

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