MONOPOLE, ASTROPHYSICS AND COSMIC RAY OBSERVATORY AT GRAN SASSO

The MACRO Collaboration[(1)]
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ABSTRACT

A new large area detector, MACRO, has been approved for installation at the Gran Sasso Laboratory in Italy. The detector will be dedicated to the study of naturally penetrating radiation deep underground. It is designed with the general philosophy of covering the largest possible area with a detector having both sufficient built-in redundancy and use of complementary techniques to study very rare phenomena. The detector capabilities will include Monopole investigations significantly below the "Parker" bound; Astrophysics studies of very high energy gamma ray and neutrino point sources; Cosmic Ray measurements of single and multimuons; and the general observation of rare new forms of matter in the cosmic rays.

1. Introduction. The Gran Sasso Laboratory, which is being constructed in Italy, is a unique facility in the world allowing a new generation of very sophisticated underground facilities. Unique features of the laboratory include impressively large halls with easy access and basic facilities typically available only at accelerator laboratories. The MACRO detector, described here, has recently been approved for installation at the laboratory.

MACRO is a large area detector optimized for the study of rare phenomena in the naturally penetrating radiation. The detector size will have a planar surface of $\sim$1400 m^2 with an acceptance for an isotropic particle flux $\sim$12,000 m^2sr.

The primary physics objective is to perform a definitive search for magnetic monopoles using excitation-ionization methods. The response of excitation-ionization detectors to monopoles is now well understood and represents the most practical means for reaching the very large areas required to address astrophysics limits. The importance to physics of the actual discovery of monopoles is obvious. In addition, it is worth noting that MACRO will be the first detector capable of setting a significant limit on the contribution of monopoles to the dark matter in the Universe, in the event of a negative result.

Another major objective of MACRO is to search for astrophysical point-like sources through the detection of muons induced by neutrino interactions. It is well established that some peculiar cosmic objects produce powerful mechanisms of particle acceleration. It is expected that some of these objects (e.g., Cygnus X-3, Vela X-1, LMC X-4, etc.), through secondary processes, are prolific emitters of high energy neutrinos and MACRO is large enough and has sufficient resolution to have the capability to open this observational window. In addition, the neutrino astronomy capability of the detector will allow a sensitive search for gravitational stellar collapse.

In a more general sense, the MACRO detector will perform systematic investigations of the penetrating component of the cosmic radiation yielding quantitative distributions and studies of possible anomalies in the cosmic rays. The abilities of the detector for accurate timing and directional measurements coupled with measurements of the dE/dx and β of particles crossing the detector will open an observational window to a wide variety of possible exotic effects.

2. Detector Description. The MACRO detector has been designed to be installed in Hall B of the Gran Sasso Laboratory. The initial design is shown in Figure 1. Although some modifications in the arrangement of modules are present under consideration, the final detector is

expected to have similar acceptance to the design described here. The active dimensions of the detector are 111.4 m along the hall; 12 m across, and 4.6 m high. The general mechanical design of the detector provides a concrete floor at a height of 5.7 m from the original floor which could be used for other experiments. The acceptance of this closed structure for an isotropic particle flux (e.g., monopoles) is $\sim 12{,}000\ m^2 sr$.

The main part of the detector is a horizontal structure consisting of two layers of liquid scintillator counters, ten layers of plastic streamer tubes and a sandwich of plastic track-etch detectors. These sensitive elements are distributed throughout a thick concrete structure as shown in Figures 2 and 3. The liquid scintillator counter system consists of 25 cm thick liquid scintillator counters providing accurate dE/dx and timing information, while the 10 layers of streamer tubes will provide tracking and ionization information.

The scintillator counters (572 total) consist of PVC boxes (12 m × 50 cm × 25 cm). A safe, stable, and highly transparent mineral oil based liquid scintillator fills the module, which utilizes total reflecting optics by lining each box with low index of refraction ($n = 1.35$) FEP TEFLON. A data acquisition system provides wide dynamic range pulse height information from each phototube.

The plastic streamer tubes consist of single cells of $3 \times 3\ cm^2$, having a wire of diameter 60μm. They are arranged in 8-tube units and have both x and d pickup for two dimensional localization. The units are 12 m long and 25 cm wide, so that two units cover one scintillator counter.

The combined detector will give a spatial accuracy in the streamer tubes of

$$\Delta x \sim \Delta y \sim \Delta z \sim 1\ \text{cm} \ .$$

The ten track points of through-going particles yield an angular accuracy

$$\Delta\theta \sim 0.2^\circ \ .$$

The scintillator counters in a single layer using phototubes at each end have spatial and timing accuracy

$$\Delta x \sim 15\ \text{cm} \quad \text{and} \quad \Delta t \sim 1\ \text{ns} \ ,$$

while the streamer tubes give

$$\Delta t \sim 50\ \text{ns} \ .$$

The ionization loss for minimum ionizing particles crossing both scintillators is measured with an accuracy

$$\frac{\Delta(\Delta E/\Delta x)}{(\Delta E/\Delta x)} \sim 5\% \ .$$

The ionization threshold for fully efficient detector triggering by the streamer tubes is

$$(\Delta E/\Delta x)_{\text{min}} \sim 10^{-2}\ (\Delta E/\Delta x)_{\text{min. ion. part.}} \ ,$$

while for scintillators the corresponding threshold is $\sim 10^{-1}\ (\Delta E/\Delta x)_{\text{min. ion. part.}}$.

The threshold for an individual scintillator counter to detect electrons with good background rejection is

$$E_e \sim 10\ \text{MeV} \ .$$

The average minimum energy for muons to cross the whole detector is

$$E_\mu \sim 3\ \text{GeV} \ .$$

3. Conclusion. The MACRO detector to be installed in the Gran Sasso Laboratory is a multipurpose device with impressive capabilities for monopoles, astrophysics, and cosmic ray investigations. The device is modular in construction with a proposed schedule of having the first module (about 12% of the total detector) operational in 1986 and the full detector completed in 1988.

Reference

1. MACRO is an acronym for Monopole, Astrophysics and Cosmic Ray Observatory. The collaboration is an international collaboration between Italy-U.S.-CERN groups with B. Barish and E. Iarocci serving as co-spokesmen.

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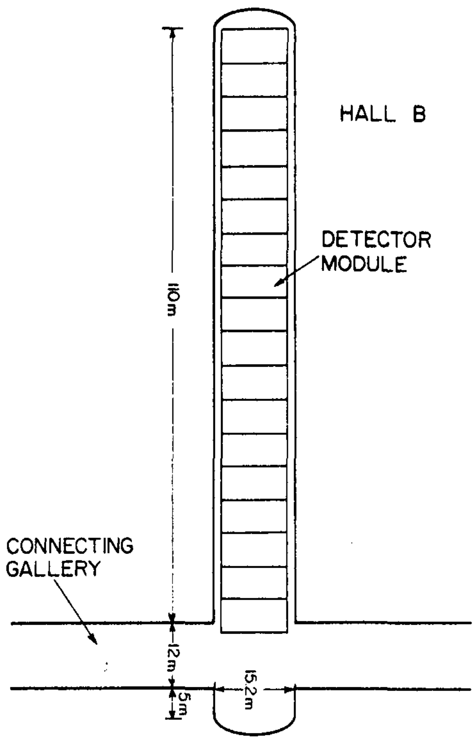

Fig. 1. Layout of the detector modules in Hall B of the Gran Sasso Laboratory.

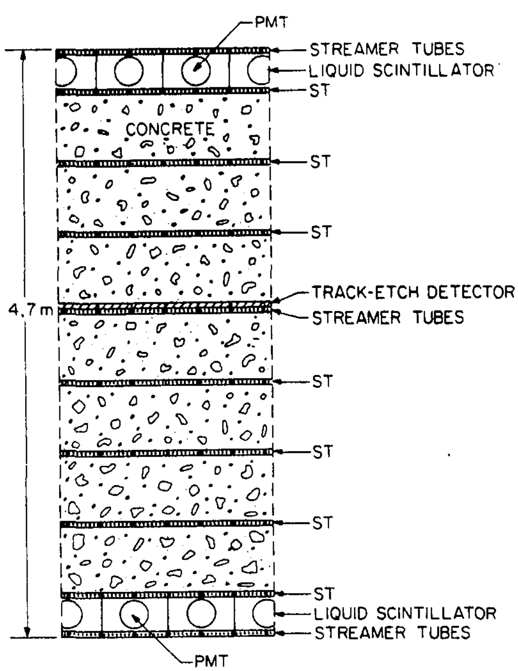

Fig. 2. Cross sectional sketch of the detector showing the relative position of the various components.

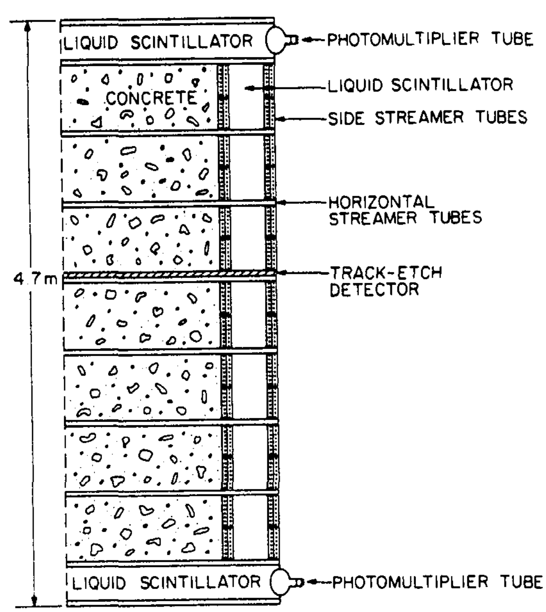

Fig. 3. Cross sectional sketch showing the active components which close the sides of the detector.