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Electronics and data acquisition system for the ICAL prototype detector of India-based neutrino observatory

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ABSTRACT

The India-based Neutrino Observatory (INO) collaboration has proposed to build a 50 kton magnetized Iron Calorimeter (ICAL) detector with the primary goal to study neutrino oscillations, employing Resistive Plate Chambers (RPCs) as active detector elements. A prototype of the ICAL detector has been built in order to develop and characterize the intrinsic sub-systems, like RPCs, gas system, electronics and data acquisition system, etc. This paper describes in detail the readout electronics as well as the VME-based data acquisition system for the prototype detector.

1. Introduction

The India-based Neutrino Observatory (INO) collaboration is planning to build a 50 kton magnetized Iron Calorimeter (ICAL) detector to study atmospheric neutrinos and to make precision measurements of neutrino oscillation parameters [1]. Around 28,800 Resistive Plate Chambers (RPCs) will be used as sensitive detector elements to search for muon neutrino induced charged current interactions inside the detector mass. A prototype of the ICAL detector has been constructed to develop and study the individual detector components, including RPCs, gas system, front-end electronics and the data acquisition system. The prototype detector (without the magnet) consists of 12 layers of RPCs of 1 m $\times$ 1 m lateral area, and is continuously tracking cosmic ray muons [2]. The front-end electronics for the prototype detector has been developed in-house. During the initial phase of the prototype development, the back-end of the data acquisition system was built using CAMAC [3]. However, in order to overcome the underlying limitations posed by the CAMAC hardware, the back-end has been upgraded to a VME-based system. The data acquisition software is also upgraded along with the hardware and is automated to a large extent. In this paper, various features of the front-end readout electronics and the hardware as well as the software components of the VME-based data acquisition system are described. The functionality of other sub-systems, such as the power supply systems and the ambient parameter monitoring system, is also discussed.

2. The ICAL detector

The ICAL detector is envisaged as a detector for atmospheric neutrinos as well as a future far detector for a neutrino factory beam. It will use magnetized iron as the target mass and Resistive Plate Chambers (RPCs) as the active detector medium. One of the major physics goals of the ICAL detector is the unambiguous estimation of the neutrino oscillation parameters. The detector will be magnetized to a field of 1.3 T which will also facilitate the study of matter effects for ν_μ (muon neutrino) and $\overline{\nu_\mu}$ (muon anti-neutrino) through electric charge identification of muons in charged current interactions. This will lead to the possible determination of the neutrino mass hierarchy.

The detector will consist of three identical and adjacent modules made up of 151 horizontal layers of 56 mm thick low carbon iron plates interleaved with 40 mm gaps to house the RPC units. Fig. 1 is a schematic of the ICAL detector with a view of the top of the magnet coils. Table 1 lists some important parameters of the ICAL detector structure.

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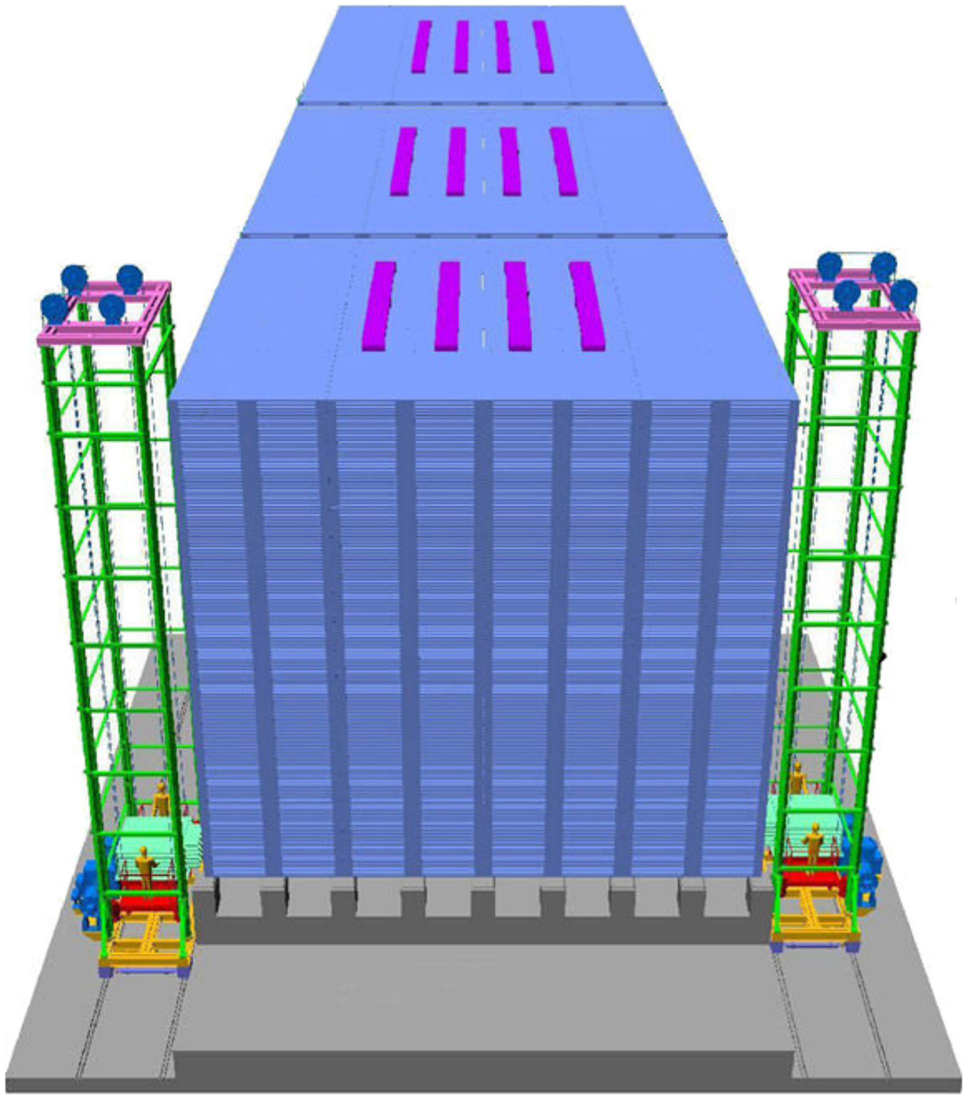

Fig. 1. Schematic diagram of the ICAL detector (48 m × 16 m × 14.5 m) with a view of the top of the magnet coils.

Table 1
ICAL detector parameters.

Modules	3
Module dimension	16 m × 16 m × 14.5 m
Detector dimension	48 m × 16 m × 14.5 m
Iron layers	151
Iron plate thickness	56 mm
RPC layers	150
Gap for RPC units	40 mm
RPC units/layer/module	64
RPC units/module	9600
Total RPC units	28,800
Magnetic field	1.3 T

3. The prototype detector

A magnet-less prototype of the ICAL detector has been developed as a precursor to building the final detector. The prototype detector consists of 12 layers of 1 m × 1 m RPCs. Each RPC is made of two float glass plates, of thickness 3 mm, with an intermediate gas gap of 2 mm. The glass plates are coated with a semi-resistive paint and a differential voltage of ± 4.9 KV is applied across the glass plates using copper tape contacts on the coating. The RPCs are operated in avalanche mode using a gas mixture of Freon (R134a), Isobutane and SF_6 in the proportion of 95.5:4.2:0.3 by volume. The average chamber current is about 100 nA. Orthogonal pick-up panels are mounted on either side of the gas gap, each having 32 pick-up strips with a strip pitch of 30 mm, which provide the particle hit coordinates in a horizontal plane. A detailed description of the activities related to the fabrication and the characterization of glass RPCs, undertaken during the development of the prototype stack, can be found in Ref. [4].

Fig. 2 shows the prototype detector with the front-end readout electronics on either side.

The data acquisition system records the RPC strip hit profile and the timing information following the passage of a charged particle through the detector provided the track hit pattern satisfies the trigger criteria set by the user. The data collected is used to characterize the detector performance by estimating RPC efficiency, multiplicity, timing resolution, etc. In addition, the detector noise rate and the ambient parameters are periodically recorded by the data acquisition system in order to monitor the long term stability of the detector. These results are also used to optimize a number of parameters related to the RPC design, gas mixture and readout electronics.