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MicroBooNE light collection system

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ABSTRACT: MicroBooNE is a neutrino experiment located on axis in the Booster Neutrino Beamline, at Fermi National Accelerator Laboratory, scheduled to begin data collection in 2014. The MicroBooNE detector consists of two main components: a large liquid argon time projection chamber (LArTPC), and a light collection system. Thirty two 8-inch diameter cryogenic photomultiplier tubes (PMTs) will detect the scintillation light generated in the liquid argon. In this article, we describe the basic features of the system and current status of MicroBooNE light collection system.

KEYWORDS: MicroBooNE, Liquid argon, cryogenic photomultiplier tube, light guide.

Contents

1. PMT array

The 170 tons of liquid argon of the MicroBooNE cryostat contains $2.5 \times 2.4 \times 10.4$ m^3 TPC drift volume. The basic strategy of the MicroBooNE PMT array largely follows the ICARUS T600 light collection system [1]. PMTs are located behind the wire planes to observe the argon scintillation light. The important feature of the light collection system is its ability to measure the event time at the $\sim$ns level. Since prompt light from the liquid argon is emitted on a 3-6 ns time scale, detection of the scintillation light allows the LArTPC to be triggered, where drift of electrons take $\sim$ms.

Figure 1 shows the PMT configuration. It also shows how light guide paddles are configured, described later. To achieve a uniform response, the PMTs are evenly distributed. The PMTs are additionally located to avoid the TPC frame which make several "crosses" in front of the PMTs. Since the wire planes are located inside of the TPC frame, the distance from the collection wire plane to the PMT surface is about 10 cm.

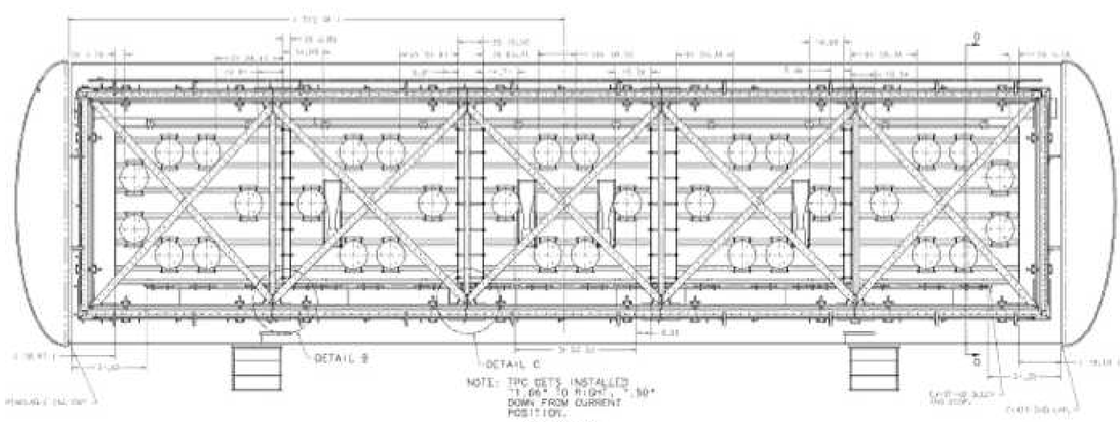

Figure 1. A drawing to show the configuration of PMTs and light guide paddles in the MicroBooNE cryostat. Notice 32 PMTs (circles) and 4 light guide paddles (rectangular objects in middle row of central area) are located to avoid TPC frame "crosses".

Figure 2. A picture of the mechanical model of the MicroBooNE PMT unit in the test facility. The picture is taken from [2].

PMT unit

Each PMT is fit inside of the PMT mount, which is surrounded by the cryogenic magnetic shield. Finally, wave length shifter coated acrylic plate (TPB plate) is equipped in front of the PMT window. This makes one PMT unit, and 32 PMT units are mounted on the PMT rack. Figure 2 shows the mechanical model of the MicroBooNE PMT unit.

PMT

We use 32 Hamamatsu R5912-02mod 14 stages cryogenic 8-inch hemi-spherical PMTs. Large photocathode PMTs provide a cost-effective solution to maximize photocathode coverage; this design yields a 0.9% photocathode coverage. It is known that a PMT gain drops in a cryogenic environment, therefore high gain PMT, such as R5912-02mod, can adjust the gain drop by increasing the high voltage value. We tested all PMTs used for the experiment, and confirmed this gain drop can be recovered easily by increasing the high voltage by 200 V [2].

PMT mount

A spring loaded, Teflon coated ring wire is pulled down to fix the PMT on to the Teflon pieces fit in the aluminum ring. Figure 3 shows a schematic drawing. Notice all metal-glass contacts are avoided by Teflon. On the other hand, the thermal contraction of aluminum and Teflon is managed by the metal springs.

Cryogenic magnetic field shield

A standard 304L stainless steel vessel, such as the MicroBooNE cryostat, is non-magnetic. However, it is shown that a hemi-spherical PMT is rather vulnerable to weak ambient magnetic fields [3] such as the earth's magnetic field ($\sim$300 mG). Therefore, all PMTs are installed inside of a cryogenic magnetic shield [4]. Note permeability generally decreases with temperature, however, specially made cryogenic magnetic shields have higher permeability in the cryogenic environment.

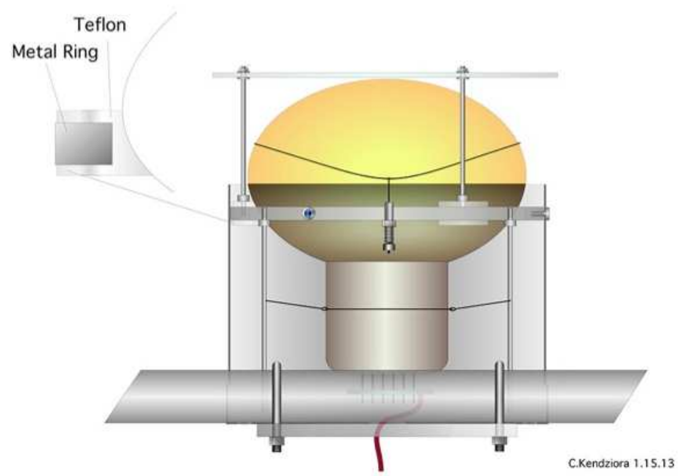

Figure 3. A schematic drawing of the PMT mount with a PMT. A wire ring is pulled down by 3 spring loaded wires to an aluminum ring. Direct contact of the PMT to the aluminum ring is avoided by Teflon blocks. The magnetic shield and the TPB plate are fixed on to the PMT mount.

The effectiveness of the cryogenic magnetic shield has been tested in a specially made PMT test stand, by tilting PMT unit to see the effect of the earth magnetic field with and without the cryogenic magnetic shield.

TPB plate

Since the scintillation light from argon is 128 nm, we need a wave length shifter to detect the scintillation light by the PMTs. Tetra phenyl Butadiene (TPB) is widely used in this community. Although there are several choices how to deposit TPB, we decided to paint an acrylic plate equipped in front of the PMT using a TPB-polystyrene mixture (50%-50% by mass) [5]. Since the TPB plate is easy to produce, in this way, the quality control of the wave length shifter is easier. The quality control of the TPB plate is important since TPB is known to be degraded by exposure to UV light [6] through the production of benzophenone [7]. Consequently, the production of TPB plates will be the last stage of installation of the light collection system.

2. Light guide paddle

Recently, TPB coated light guide have been developed [8] as a candidate light collection detector for the LBNE experiment. Main advantage is that such light guide can locate between a narrow region of 2 collection wire planes. Installation of light guide paddles in the MicroBooNE cryostat is under discussion by the technical board. Fig. 1 shows 4 light guide paddles. Each paddles are made from acrylic, coated with a TPB-acrylic mixture, adiabatically bended to the window of a 2-inch R7725-mod cryogenic PMT. A comparison of PMT signals and light guide signals would explore the potential of such light collection for future LArTPC detectors.

3. Installation

32 of PMT units and 4 of light guide paddles are mounted on five separated PMT racks. A PMT

Figure 4. A picture taken during the PMT rack installation practice. First, the PMT rack is lifted by a crane, then the PMT rack slides in to the cryostat on the linear rail extended from the inside of the cryostat.

rack has an ability to slide in the gap between the cryostat wall and the TPC frame, through a linear rail by an oil free Teflon coated linear bearing. In this way, we can install all PMTs after the installation of the TPC frame, to minimize the exposure of TPB plates to ambient light and moisture . Figure 4 is the picture taken during the PMT rack installation practice. We are aiming to install the light collection system during summer 2013.

Acknowledgments

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