SURVEY OF THE NOvA NEAR DETECTOR AT FERMILAB

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Abstract

The primary goal of the NOvA experiment at Fermilab is to search for evidence of muon to electron neutrino ($\nu_\mu \rightarrow \nu_e$) oscillations. NOvA will use two detectors, the near detector located underground at Fermilab in the NuMI tunnels and the far detector located 810 km from Fermilab on the US-Canada border in Ash River, Minnesota. This paper discusses the survey of the NOvA Near detector.

INTRODUCTION

NOvA (NuMI Off-Axis ν_e Appearance) is a second generation experiment on the NuMI (Neutrino at Main Injector) beamline designed to search for oscillations of muon neutrinos to electron neutrinos ($\nu_\mu \rightarrow \nu_e$) by comparing electron neutrino rates at Fermilab with electron neutrino rates observed 810 km from Fermilab (Figure 1) [1].

THE NOvA EXPERIMENT

The NOvA experiment is an upgrade of the NuMI beam intensity from 400 kW to 700 kW. NOvA consists of a 222 metric-ton near detector at Fermilab and a much larger 15 kTon far detector in Ash River, Minnesota just south of the U.S.-Canada border (Figure 2). The NOvA far detector will be located in a new building that is 20.4 m wide by 113.8 m long with the detector section sunk 16 m below the existing grade into granite rock at the site. The NOvA far detector will be sited 13.6 mrad off the NuMI beam axis, at a distance 810 km (Figure 3). The NOvA near detector will be located underground on the Fermilab site, in a new cavern adjacent to the MINOS access tunnel, downstream of the MINOS shaft (Figure 4). It is identical to the far detector sited 13.6 mrad off the NuMI beam axis at a distance of 1 km. NOvA uses liquid scintillator contained in rigid, highly reflective PVC cells to detect neutrino interactions. The charged particles produced by the neutrino interaction inside the detector cause the liquid scintillator to produce light that is captured by optical fibers and carried to light-sensitive detectors. This paper will focus on how the detectors are assembled using the PVC cells to construct planes and blocks used to make the detectors and how the near detector is surveyed.

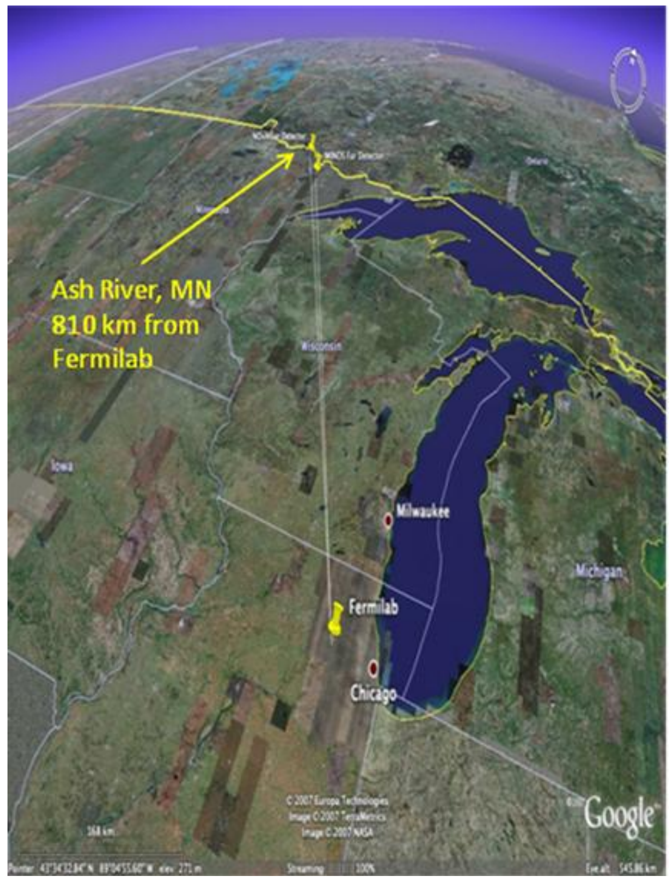

Figure 1: Beam trajectory from Fermilab to Ash River, Minnesota.

NOvA DETECTORS

Far Detector

The 15 kTon far detector will be 15.7 m wide, 15.7 m tall and 67 m long (Figure 5). This detector will be composed of 385,000 cells of extruded PVC plastic in a cellular structure. Each cell is 3.9 cm wide by 6.0 cm deep and is 15.7 m long. The cells are filled with a total of 3.3 million gallons of liquid scintillator. The liquid scintillator comprises 70% of the total detector mass, making this a totally active tracking calorimeter detector optimized for identification of electron neutrino (ν_e) interactions.

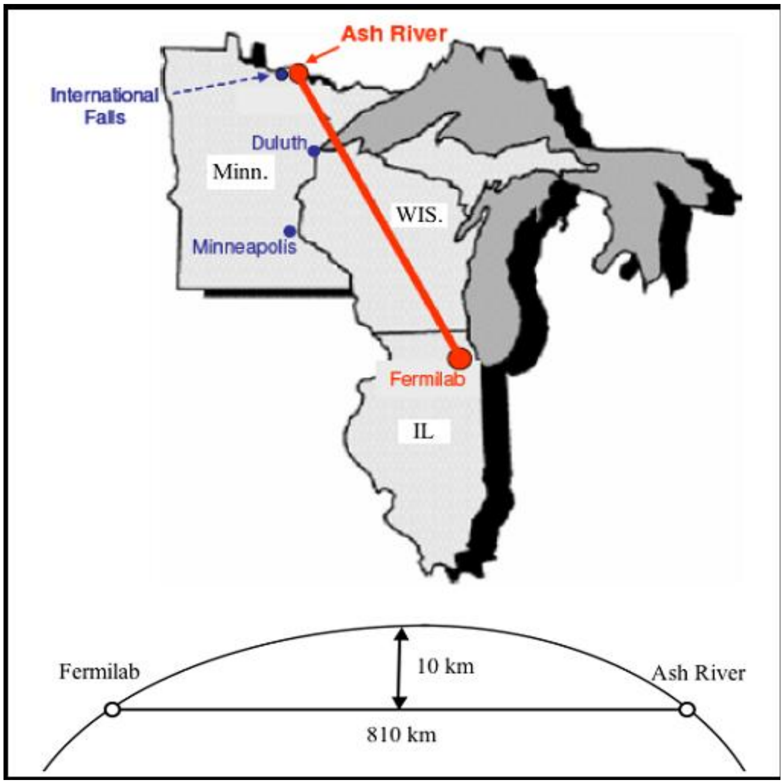

Figure 2: Ash River located 810 km from Fermilab.

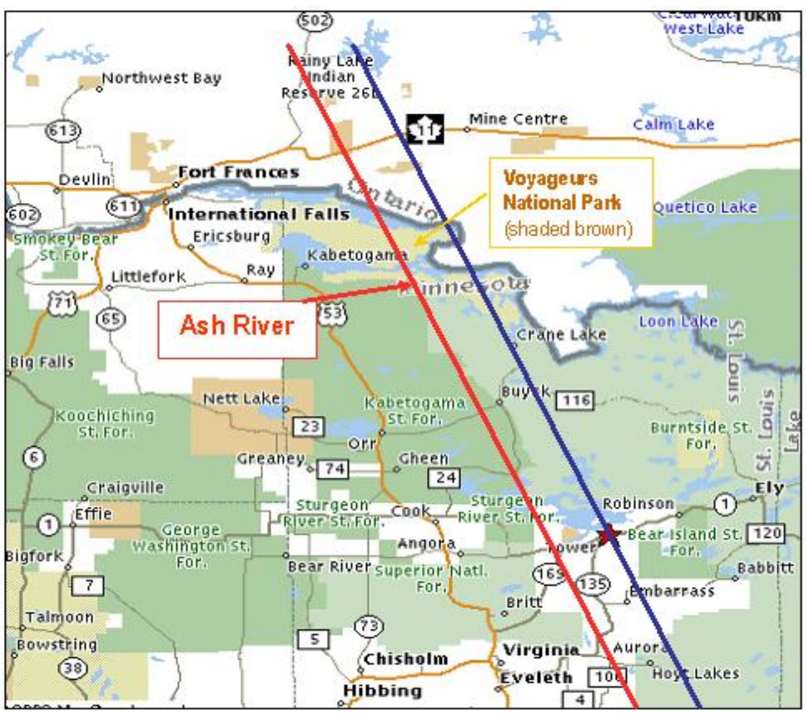

Figure 3: Ash River site is sited 13.6 mrad off the NuMI beam axis.

The detector is read out via 13,000 km of 0.7 mm diameter optical wave-shifting fiber into 12,000 avalanche photodiodes (APD) with associated electronics. The far detector consists of 33 blocks of 31 planes for a total of 1003 plane.

Near Detector

The 222 ton near detector will be 2.9 m wide, 4.2 m tall x 14.3 m long (Figure 5). This detector is an identical copy of the far detector except that the length of the extrusion modules is 4.2 m. The near detector consists of 6 blocks of 31 planes and the muon catcher. The muon catcher is a set of 10 planes of liquid scintillator interspersed with planes of steel to tag muons from ν_μ charged current events (Figure 6). The beam comes from the lower left in this diagram. The upstream 6 planes form a veto region (red). The next 108 planes are the fiducial region (green) with transverse containment indicated. The fiducial volume is followed by a 72 plane shower containment region (yellow). All parts of these three sections are fully active liquid scintillator cells identical to the Far Detector and the colored areas just represent a logical assignment. Downstream of this active region is a 1.7 m long muon catcher (black and white).

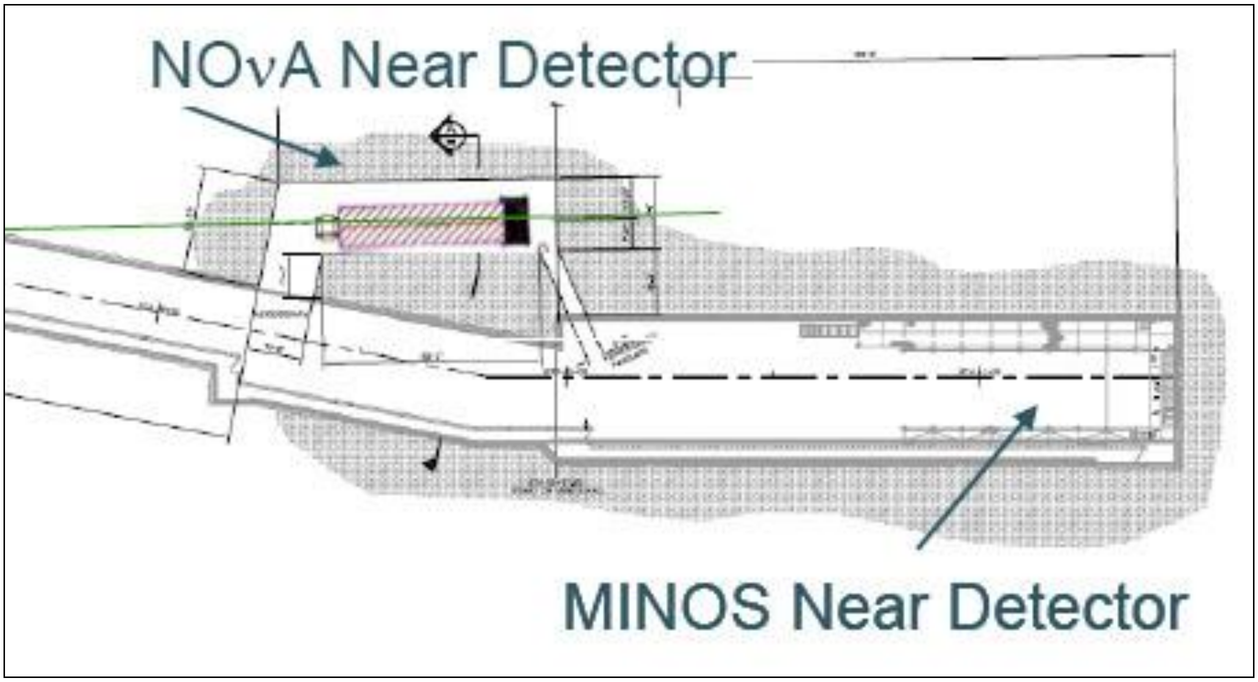

Figure 4: The NOvA Near Detectors in a cavern adjacent to the MINOS access tunnel.

Integration Prototype Near Detector

Integration Prototype Near Detector (IPND) is an early prototype of the near detector and will be assembled as part of the R&D effort for NOvA. This prototype serves as a venue to test all the parts of the NOvA detector together [1]. This integration is the main goal of the IPND. The 84 ton near detector will be 2.9 m wide, 4.2 m tall x 8.4 m long (Figure 5). The IPND consists of 4 blocks of 31 planes of PVC extrusions (Figure 6). The plan is to operate the IPND on the surface in the NOvA Near Detector Surface Building at Fermilab (Figure 7). The NOvA Near Detector Surface Building is about 107 mrad off-axis to the NuMI beam.

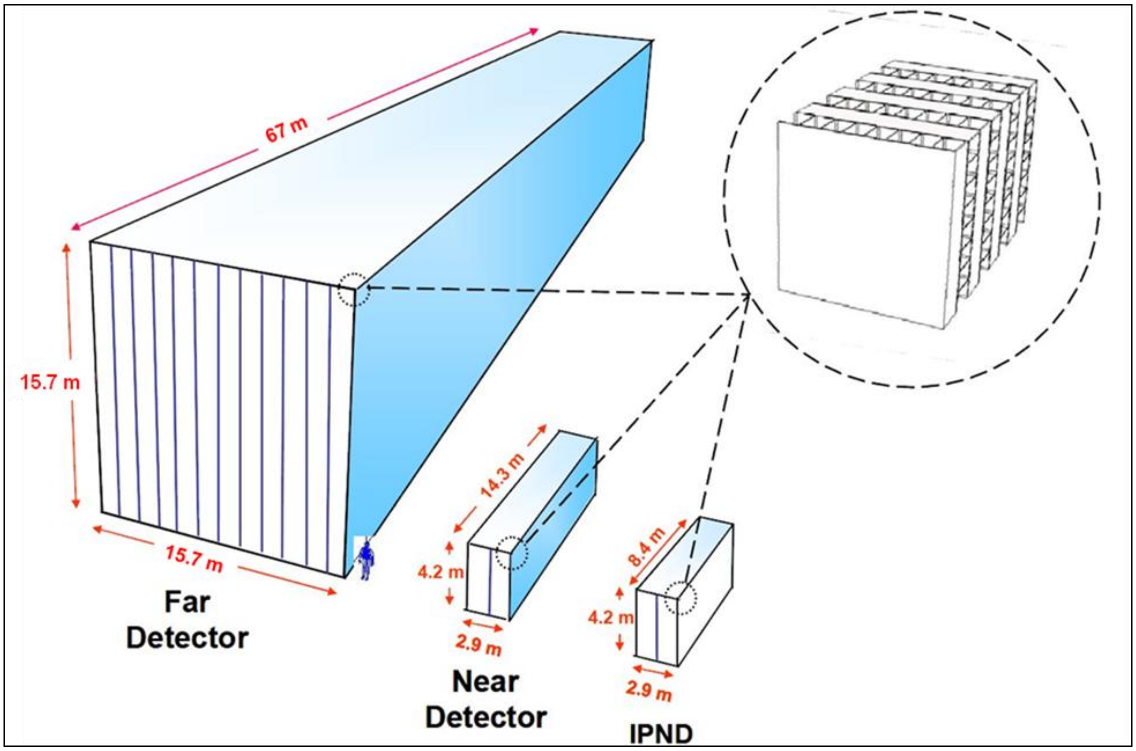

Figure 5: The NOvA Detectors.

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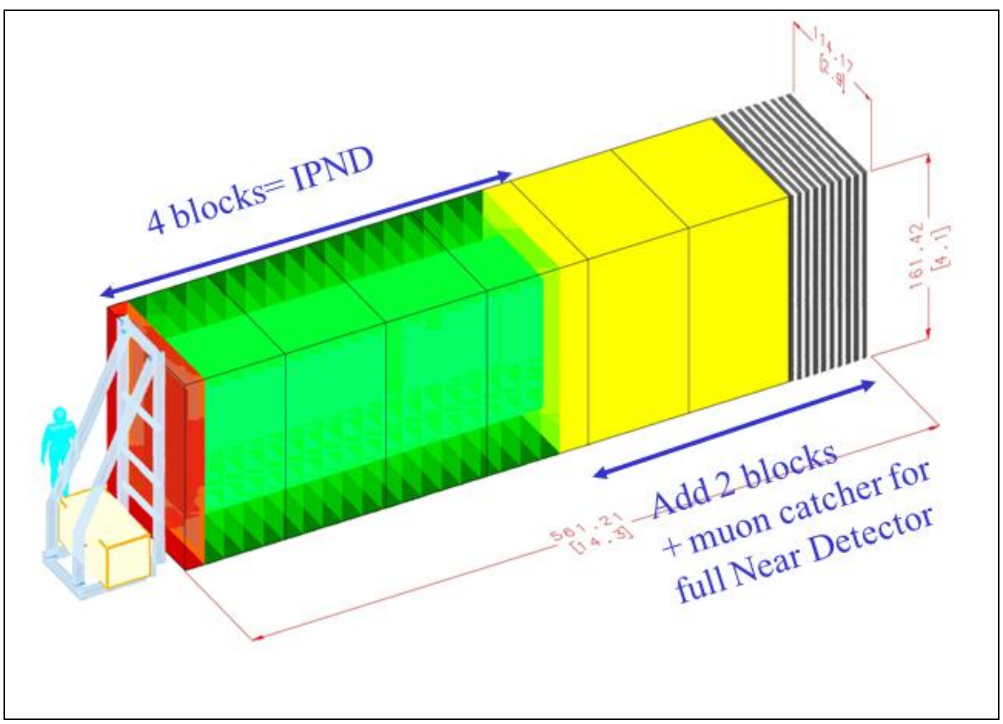

Figure 6: The NOvA Near Detector.

NOvA DETECTOR ASSEMBLY

Rigid PVC Extrusions

Rigid PVC extrusions are the basic building blocks of the Nova detectors. They are the structural elements, the reflectors of scintillation light and the primary containment vessels for liquid scintillator [1]. The mass of PVC used to make the far detector is 4.5 kilotons, which is 30% of the total far detector mass. Extrusions have a cellular structure, with 16 isolated cells per extrusion. The length of the rigid PVC extrusions with 16 cells extruded together in a unit is 0.635 m wide (Figure 8). Two different extrusions are required. The horizontal cells have exterior PVC walls 3 mm thick with 2 mm thick interior webs between cells. The vertical cells contain more PVC with 4.5 mm thick exterior walls and 3 mm thick interior webs. The extrusion thickness is 6.6 cm for both types, so the interior cells of the horizontals and verticals are slightly different in size. All far detector extrusions are 15.494 m long. Extrusions for the near detector are 2.63 m long (horizontal extrusions) and 3.94 m long (vertical extrusions). Detector modules are made by joining two 16-cell PVC extrusions at the sides (Figure 9).

Figure 7: NOvA Near Detector Surface Building at Fermilab.

Figure 8: Rigid PVC extrusions.

NOvA Extrusion Modules

Nova modules consist of two 16-cell PVC extrusions glued together to make a 32-cell extrusion assembly. Two 16 cell objects are attached with glue and the extrusion module is cut to an exact length. The module assembly shown in Figure 9 defines a model plane. There are two types of module planes: vertical and horizontal. Both vertical and horizontal modules have the same configuration. The extrusion modules are capped at one end by a simple PVC end plate or cap to contain the liquid scintillator and are capped at the other end by a more complicated fiber manifold which contains the liquid (in horizontal modules) and also routes the 64 fiber ends to 32 avalanche photodiode pixels. The assembled extrusion modules with fiber manifolds and end caps are 15.7 m long for the far detector. The end caps and fiber manifolds link the entire 32 cells into a common liquid volume. Therefore the 1.3 m by 15.7 m extrusion module forms the primary containment vessel for the liquid scintillator. The length of the extrusion modules for the near detector is 4.2 m. The manifold assembly is also sealed giving a module assembly that is a leak-tight container for liquid scintillator [1].

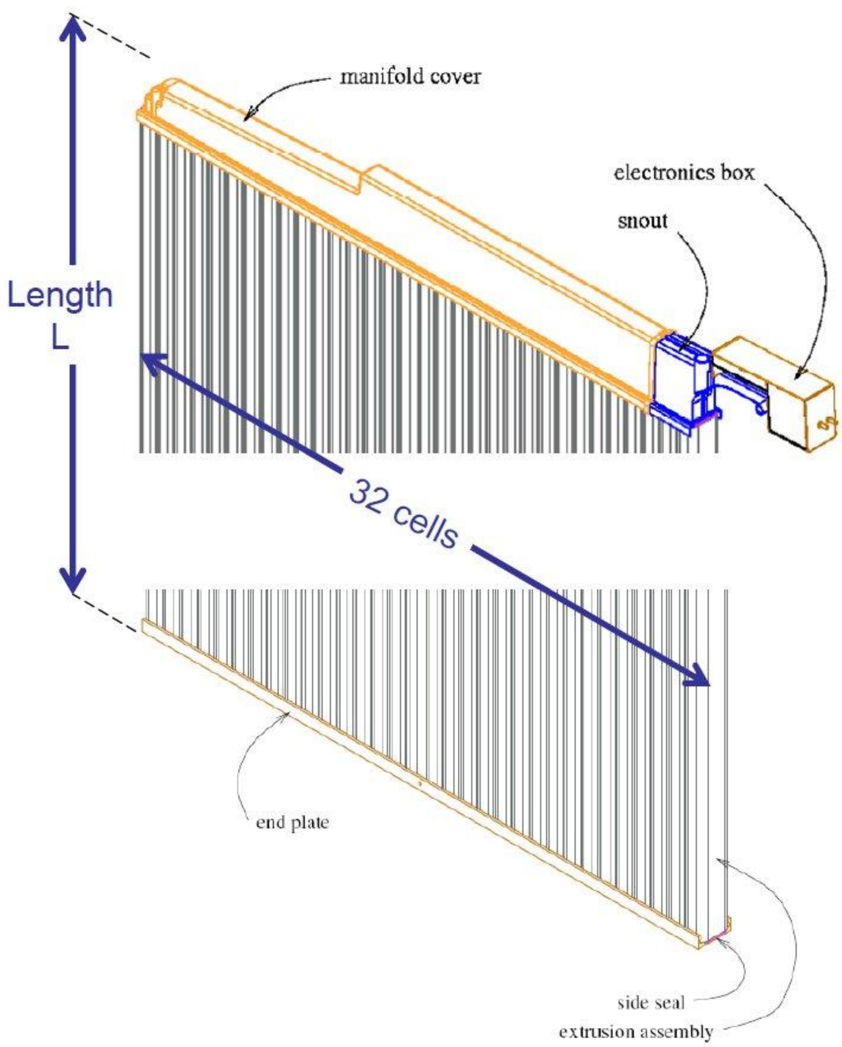

Figure 9: PVC extrusion modules (Two 16 cells).
L = 15.7 m for Far Detector; L = 4.2 m for Near Detector.

NOvA Block

The NOvA detector is constructed from alternating layers (planes) of vertical and horizontal PVC extrusion modules, connected together by glue between layers. The basic structural unit of the detector is a subassembly of 31 planes of PVC extrusion modules called a block. The modules in each block are glued together in a horizontal orientation on a block pivoter. With an odd number of planes per block, there are two possible configurations:

i) the vertical block (**V**) when the first and last planes are vertical modules

$$\mathbf{V = v_0h_1v_2h_3v_4h_5v_6h_7v_8h_9v_{10}h_{11}v_{12}h_{13}v_{14}h_{15}\ldots}$$
$$\mathbf{..v_{16}h_{17}v_{18}h_{19}v_{20}h_{21}v_{22}h_{23}v_{24}h_{25}v_{26}h_{27}v_{28}h_{29}v_{30}}$$

ii) the horizontal block (**H**) when the first and last planes are horizontal modules

$$\mathbf{H = h_0v_1h_2v_3h_4v_5h_6v_7h_8v_9h_{10}v_{11}h_{12}v_{13}h_{14}v_{15}\ldots}$$
$$\mathbf{..h_{16}v_{17}h_{18}v_{19}h_{20}v_{21}h_{22}v_{23}h_{24}v_{25}h_{26}v_{27}h_{28}v_{29}h_{30}}$$

where **v** is the vertical plane and **h** is the horizontal plane. The number of planes is counted from 0 through 30.

Far Detector Assembly

The far detector (**FD**) consists of 33 blocks in the detector. Each of the 33 blocks in the detector is rotated to a vertical orientation after completion. Each plane block is 15.7 m wide by 15.7 m high by 2.05 m thick. The PVC in a 31 plane block weighs about 139 metric tons and when filled with scintillator, the weight of a 31-plane block is about 460 metric tons. The far detector is constructed from vertical (**V**) and horizontal (**H**) blocks. Sets of five sequential blocks, called Superblocks, are separated by 2-cm expansion gaps, to accommodate the swelling of the PVC extrusions under hydrostatic pressure. Every Superblock (**SB**) begins and ends with a **V** block, but **V** and **H** blocks alternate within a Superblock:

$$\mathbf{SB \rightarrow V_0H_1V_2H_3V_4}$$

where the number of blocks is counted from 0 through 4. In addition to these Superblocks, a single 3-block Superblock is required to complete the 33-block detector. The far detector consists of 20 “**V**” and 13 “**H**" blocks:

$$\mathbf{FD \rightarrow V_0H_1V_2H_3V_4V_5\ldots\ldots\ldots V_{25}H_{26}V_{27}H_{28}V_{29}V_{30}H_{31}V_{32}}$$

where the number of blocks is counted from 0 through 32. A Superblock is composed of 155 planes. The total number of planes in the far detector is 1003 (505 vertical, 498 horizontal), 32 blocks with 31 planes each and 1 block with 11 planes. Twelve (12) extrusion modules get placed side by side on a flat assembly table to form one plane of the far detector.

Near Detector Assembly

The near detector consists of 6 blocks of 31 planes and the muon catcher as shown in Figure 6. Each plane block is 2.9 m wide by 4.2 m high by 2.09 m thick. The 1.7 m long muon catcher consists of ten steel plates that are each 2.9 m wide by 4.2 m high by 0.1 m thick.

The block configuration starting from the upstream end is:

$$\mathbf{ND \rightarrow V_0H_1V_2H_3V_4V_5}$$

where **V** is the vertical block, **H** is the horizontal block and the number of blocks is counted from 0 through 5. The blocks are currently being constructed at Argonne National Laboratory using a considerably scaled down version of the procedure envisioned for the Far Detector. Part of the cradle, which will later be used to transport the block, is used to support it during construction. Blocks are constructed in a horizontal orientation (prone position), with successive planes stacked upon each other (Figure 10). The modules are stacked against the steel base plate of the cradle. Module stops are attached to one side to assure alignment. The first step for each module is glue applied to the top by a glue dispenser. Next the module is flipped about its long axis by hand so that the glue side is on the bottom. It is then moved by a vacuum lifting fixture to its designated location in the currently active plane. After a block is completed it is transported to the MINOS Service Building at Fermilab (Figure 11) and then rotated to its final upright position. Figure 12 shows a Vertical Block in the prone position inside MINOS Service Building and Figure 13 shows the same block in the upright position. Each block is then moved in the upright position into the NOvA Near Detector Surface Building to be connected sequentially.

The total number of planes in the six near detector blocks is 186 (94 vertical, 92 horizontal). Two extrusion modules (64 cells wide) make up a vertical plane and three extrusion modules (96 cells high) form a horizontal plane.

IPND Assembly

The **IPND** length is four blocks of 31 planes as shown in Figure 6. The plan is to operate the IPND in the NOvA Near Detector Surface Building. The block configuration starting from the upstream end is:

$$\mathbf{IPND \rightarrow V_0H_1V_2H_3}$$

where **V** is the vertical block and **H** is the horizontal block and the number of blocks is counted from 0 through 3.

Figure 10: Block construction at Argonne National Laboratory

Figure 11: Left: MINOS Service Building at Fermilab.
Right: NOvA Near Detector Surface Building at Fermilab.

Figure 12: Vertical Block in Prone position inside MINOS Service Building.

SURVEY OF THE NOvA NEAR DETECTOR

The goal is to determine the relative positions of the modules within each detector block, the relative positions of the detector blocks with respect to each other, and the relative position and orientation of the full detector with respect to the beamline.

Survey Methodology

The survey instrumentation that is being used for the near detector survey is as follows:

i) An API Tracker3 Laser Tracker and Spatial Analyzer™ software are used for establishing control points in the NOvA Near Detector Surface Building, the MINOS Service Building. It is also being used for the entire block survey of the near detector. The Laser Tracker uses laser feed-back and motorized steering mirrors to track the location of a spherical mounted retroreflector (SMR). It also uses a Heterodyne distance measuring interferometer to measure radial distance to SMR.

The encoders on steering mirrors measure the azimuth and elevation angles. The software can record three-dimensional location of SMR in a variety of coordinate system and units. The Laser Tracker Accuracy and Performance are specified as follows [2]:

Three-dimensional Accuracy
Accuracy of a Coordinate: ± 5 μm/m
Static (2 sigma): ± 25 μm at 5 m
Static (2 sigma): ± 50 μm at 10 m

IFM (Interferometer) Performance
Accuracy of IFM: 1 μm/m
Range of IFM: 0 - 60+ m

ADM Performance
Accuracy ±15 μm or 1.5 μm/m,
(whichever is greater)
Static (2 sigma): ± 15 μm at 10 m
Static (2 sigma): ± 30 μm at 20 m
Range (ADM) 0 - 60+ m

Figure 13: Vertical Block in Upright position

ii) Leica HDS6100 Laser Scanner system and its associated software will be used for the entire survey of the far detector. It is being used on the block surveys for gaining experience toward the far detector assembly. The Leica HDS6100 has a full 360° x 310° field-of-view and extended range of up to 79 m. The accuracy of single measurement is [3]:

- Position 5 mm, 1 m to 25 m range; 9 mm to 50 m range
- Distance ≤2 mm at 90% albedo up to 25 m; ≤3 mm at 18% albedo up to 25 m ≤3 mm at 90% albedo up to 50 m; ≤5 mm at 18% albedo up to 50 m (Albedo is a measure of the reflectivity of the earth's surface).
- Angle (Horizontal/vertical)125 μrads/125 μrads (7.9 mgon/7.9 mgon) one sigma.

Local Tracker Control Network

A three-dimensional control network was established to bring horizontal and vertical controls into the NOvA Near Detector Surface Building (NDSB). The network consisted of both horizontal and vertical networks using several wall monuments and pass points. The NDSB horizontal network was tied to the existing surface network used for the NuMI project. Hard elevations were also measured. The NDSB network was based on the Local Tunnel Coordinate System (LTCS) [4]. The monuments were defined by magnet rings (Figure 14). Each magnet ring is a 19 mm OD, 12 mm ID and 10 mm thick N40 super magnet. The magnet rings were glued to the points of interest with a 24-hour epoxy. The location of each point was defined by the center of the SMR as it precisely sat on the magnet ring.

Figure 14**:** Magnet Rings.

A three-dimensional local Laser Tracker network was also established in the MINOS Service Building. This network was solely used for referencing purposes using several pass points. The network was not tied to any existing surface network. Magnet rings were used as monuments.

NOvA Module and Block Survey and Alignment Tolerances

The NOvA module and block survey and alignment tolerances were specified as follows [5]:

Overall Tolerance:

Relative 2 mm (Horizontal) edge to edge;

Relative 0.75 mm or better (Vertical) between adjacent pieces;

Angular tolerance of ± 2 mm/15.7 m = ± 0.13 mrad.

Block Fiducialization

Several survey fiducials were mounted at suitable locations on the outside edges of each block (Figure 15). Magnet rings shown in Figure 14 were used as fiducials. The magnet rings were glued to the points of interest with a 24-hour epoxy. The location of each fiducial was defined by the center of the SMR as it precisely sat on the fiducial. A total of 24 fiducials were used for each block, 18 on the model extrusions and 6 on the blue steel base plate. There were 9 fiducials on the extrusions at about the first, middle and last planes and 3 on the base plate on the east side of the block. The same number of fiducials was used on the west side.

Block Coordinate System

Each block was referenced in a right-handed local orthogonal coordinate system defined such that its origin is at the center of the block, y is positive downstream along beam direction, x is positive right and perpendicular to y, and z is positive up. A block was defined by the eight corners ABCDJKLM (Figure 16). The eight corners were used to determine the block coordinate system.

Six planes were created from Laser Tracker measurements made on six sides of the block – upstream (ABCD), downstream (JKLM), top (ADMJ), bottom (BCLK), beam left (DCLM), and beam right (ABKJ) planes (Figure 16). Using all possible combinations of three planes, a three-plane intersection was used to determine all the eight corners of the rectangular block – ABCD on the upstream side and JKLM on the downstream side. The center of each plane formed by the four corners of the block was computed by intersecting the lines constructed between the diagonal points.

The upstream entrance point $[x_{US}, y_{US}, z_{US}]$ of the block is determined by the intersection of the line (AC) and line (BD) constructed from the diagonal points ABCD. The downstream exist point $[x_{DN}, y_{DN}, z_{DN}]$ was determined by the intersection of the line (MK) and line (JL) constructed from the diagonal points JKLM. Similarly, the coordinates of bottom center (BC) and top center (TC) were computed from BCLK and ADMJ respectively. A line (Y_{USDS}) was constructed from points US and DS and line (Y_{BCTC}) was constructed from points BC and TC.

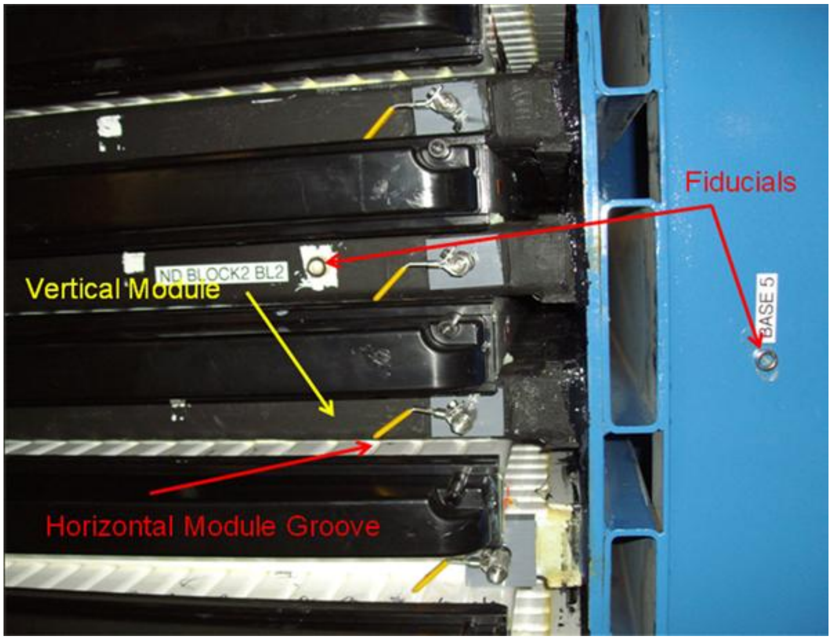

Figure 15: Fiducial on Module Extrusion.

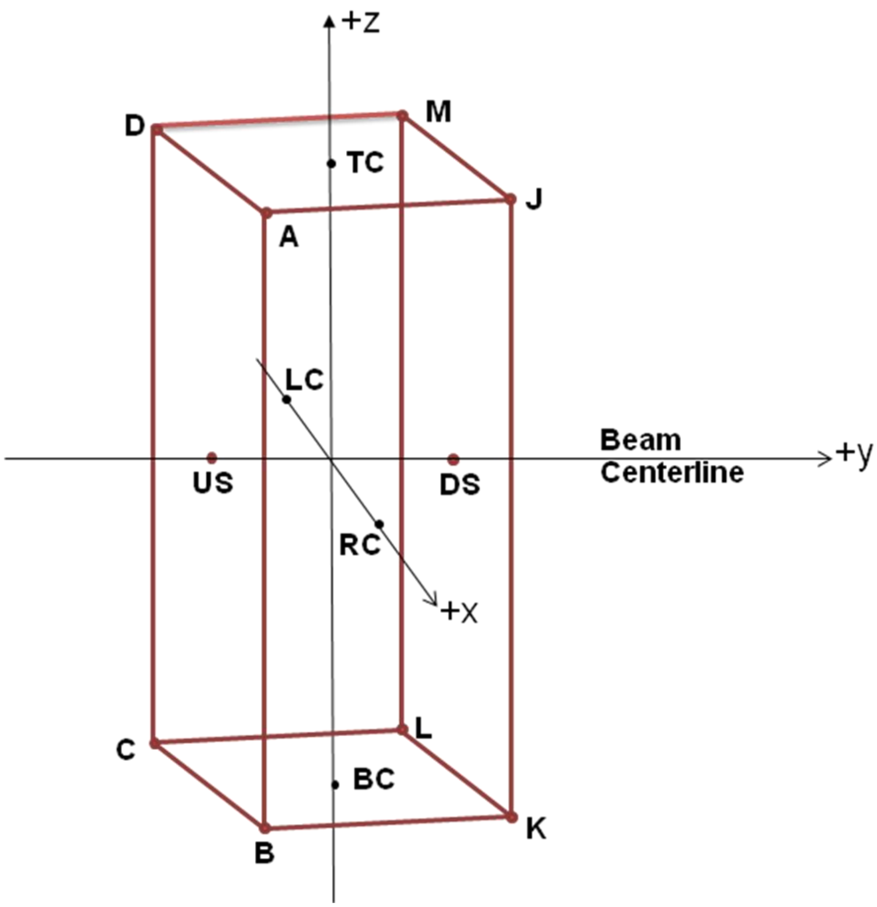

Figure 16**:** Eight corners (ABCDJKLM) define each block

A frame is defined such that the origin [x_{ORIGIN} , y_{ORIGIN} , z_{ORIGIN}] is determined by the intersections of line (Y_{USDS}) and line (Y_{BCTC}). An orthogonal frame was constructed such that the primary axis (+y) was defined by the line (Y_{USDS}) positive downstream. The secondary axis (+z) was defined by the line (Y_{BCTC}) positive up. The +x-axis is perpendicular to the +y-axis and parallel to the line (Y_{LCRC}).

Block Referencing

The fiducialized blocks were referenced using the Laser Tracker in a local block coordinate system in the MINOS Service Building prior to installation in the NOvA Near Detector Surface Building.

Reference Part 1: Block in Prone Position

The Block was first referenced in the prone position with the downstream surface lying on the MINOS Service Building floor (Figure 17). Laser Tracker measurements were first made to the local control points in the building followed by measuring all 24 Block fiducials. Several Laser Tracker measurements were made on the beam right (west side), beam left (east side), and top sides. Measurements were also made on the manifold grooves, manifold covers and end caps. In addition, the top surface of the blue steel base plate was mapped where it touched the end caps (Figure 18). The upstream and downstream surfaces of the block were not accessible for measurements in the prone position.

To determine the module positions, groove measurements were made at specified locations by placing the SMR where the horizontal module grooves intersect the extreme end of the vertical plane. On the west side, the bottom of the SMR was placed in the groove while the one side of the SMR touched the vertical plane (Figure 18). On the top side, the bottom of the SMR was placed in the groove where manifold covers were glued to extrusion cells. Measurements were also made on the manifold covers on the top side. On the east side, the bottom of the SMR was placed in the groove where the end caps were glued to extrusion cells (Figure 18). Measurements were also made where the end caps touched the top of the block bottom base plate as shown in Figure 18.

A scheme was developed for the groove locations. For the first block (Block_0), the SMR was placed in the middle groove (0) and every third groove from the left (-13) and right (+13) edges of the 32 cell module (Figure 19). The middle groove was found not to be reliable because of varying glue thickness. In order to avoid the glue joints for the subsequent blocks, a new scheme was developed to place the SMR on every third groove from the left (-13) and right (+13) edges of the module, and every third groove from the left (-3) and right (+3) of the middle groove (Figure 20).

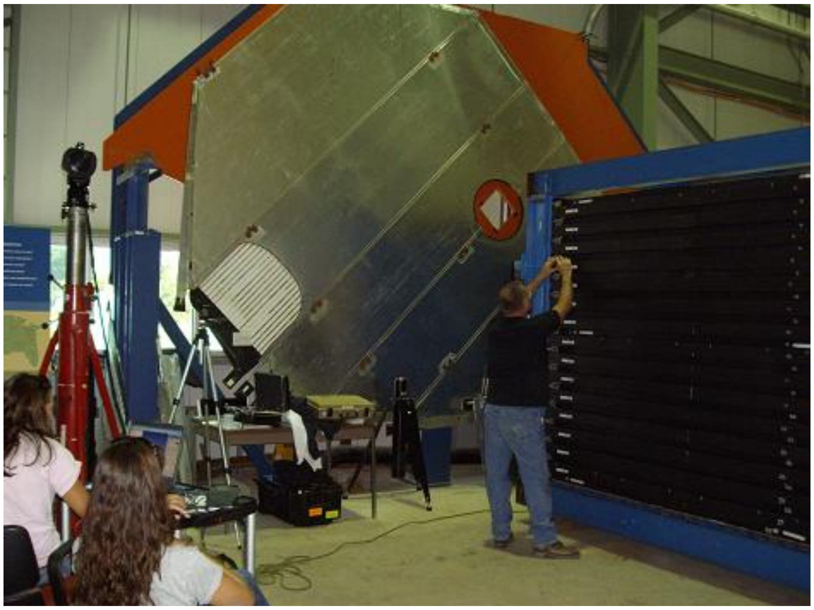

Figure 17: Reference Part 1: Block in Prone Position

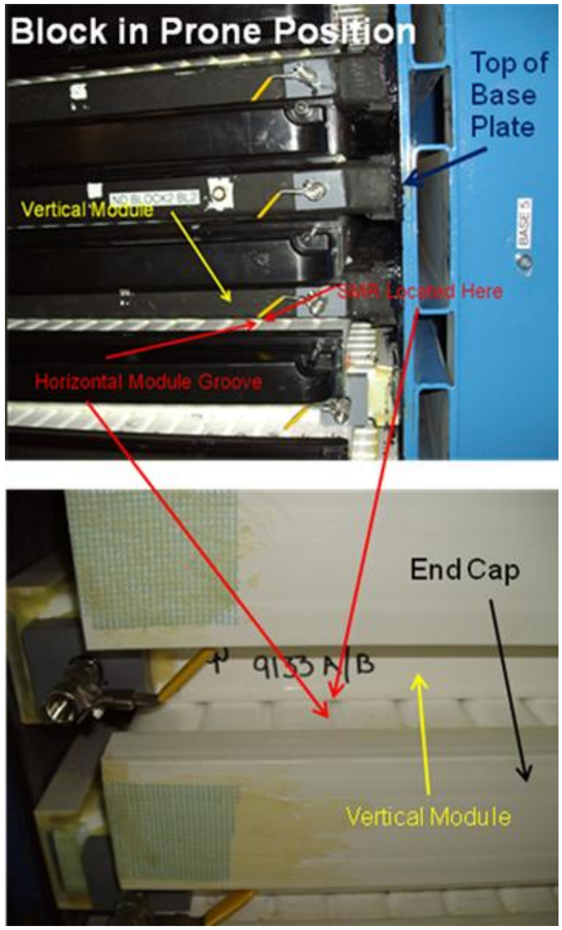

Figure 18: Module Grooves

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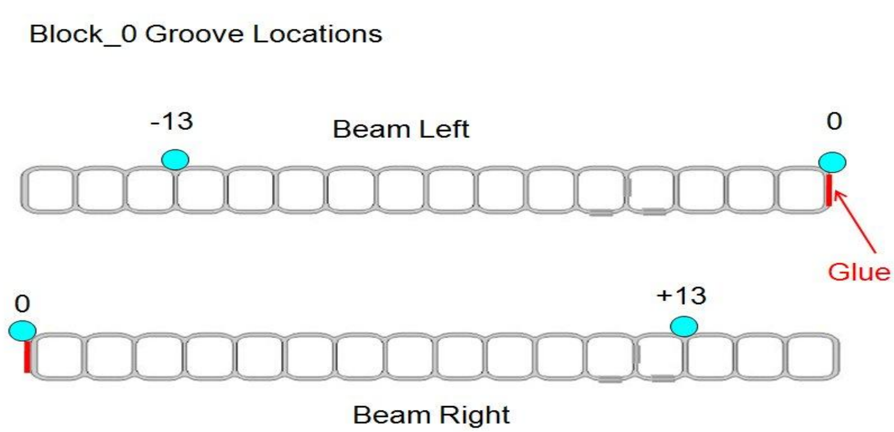

Figure 19: Horizontal Grooves Location for Block_0

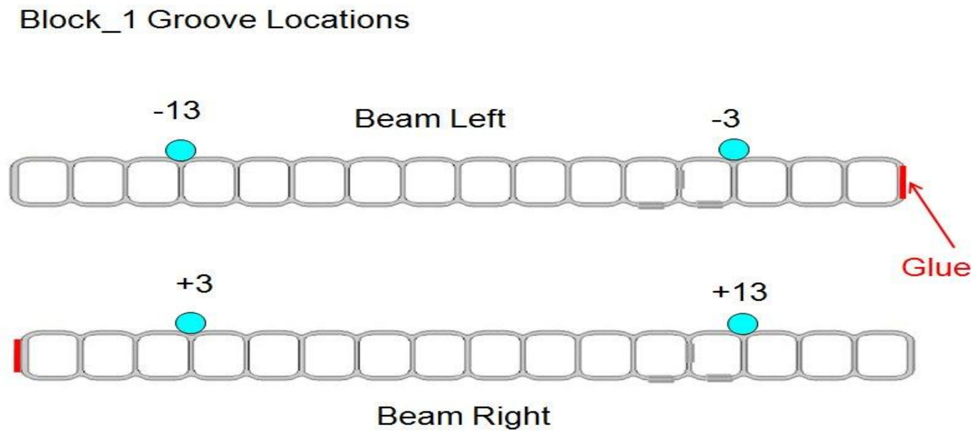

Figure 20: Horizontal Grooves Location for Block_1 and other Blocks.

Reference Part 2: Block in Upright Position

Laser Tracker measurements were first made to the local control points in the MINOS Service Building followed by measuring all 24 Block fiducials. A best-fit transformation was performed to transform all the prone position measurements [x_{PRONE} , y_{PRONE} , z_{PRONE}] into the upright position measurements [$x_{UPRIGHT}$, $y_{UPRIGHT}$, $z_{UPRIGHT}$] as follows:

$$\begin{pmatrix} x_{UPRIGHT} \\ y_{UPRIGHT} \\ z_{UPRIGHT} \end{pmatrix} = \begin{pmatrix} x_{TRANS} \\ y_{TRANS} \\ z_{TRANS} \end{pmatrix} + S * \mathbf{R}(\varepsilon_X,\varepsilon_Y,\varepsilon_Z) * \begin{pmatrix} x_{PRONE} \\ y_{PRONE} \\ z_{PRONE} \end{pmatrix}$$

where [x_{TRANS} , y_{TRANS} , z_{TRANS}] is the vector containing the translation parameters in XYZ; $\mathbf{R}(\varepsilon_X,\varepsilon_Y,\varepsilon_Z)$ is the rotation matrix; and S is the scale. For this survey the scale is fixed at S = 1.0.

The vector differences between the transformed prone position fiducial measurements and the upright measurements were depicted graphically for each block as shown in Figure 21. The upstream and downstream surfaces of each block were measured with eight scans along the edges of each module. Plane fits were computed for each surface and the vector differences between the plane and the individual measurements were also reported graphically (Figure 22).

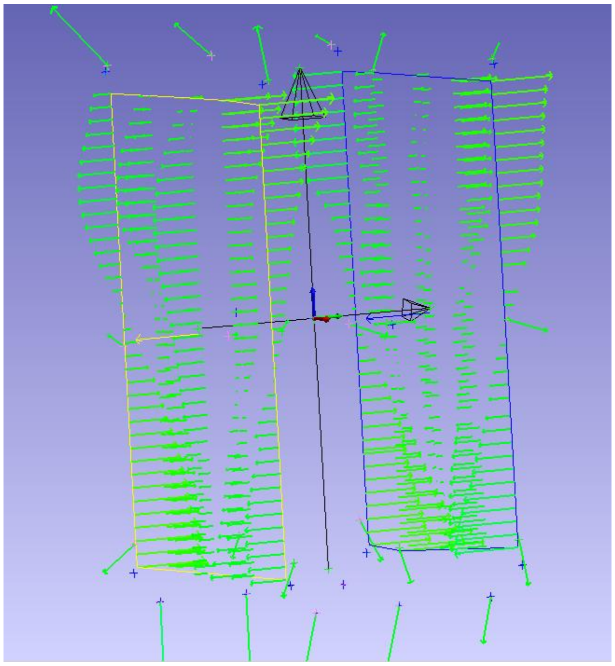

Figure 21: Vector comparisons of prone and upright fiducial measurements
for Vertical Block_4

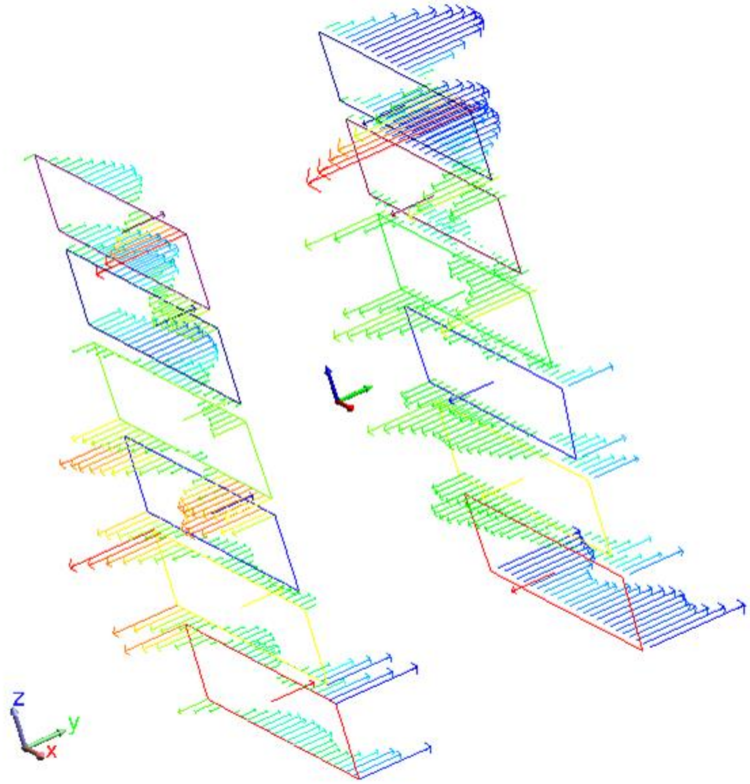

Figure 22: Vectors arrows of measurement to the best fit plane and
for horizontal Block_3.

Block Data Analysis Data Reporting

Roll, pitch, yaw, twist and coordinate differences dX, dY, dZ were computed for each module from the beam right and beam left coordinates of groove locations for each module. The lengths of the manifold covers to the end caps were also computed. Graphical outputs of roll, pitch, yaw and (dX, dY, dZ) allowed easy identification of missing groove measurements and/or outliers due to excessive glue. Figure 23 shows the roll angles for the horizontal modules of horizontal block Block_1.

Final data reporting will be done by performing best-fit transformations to transform all the Ideal groove position locations [x_{IDEAL} , y_{IDEAL} , z_{IDEAL}] generated for each module into the Measurement coordinate system [x_{MEAS_IDEAL} , y_{MEAS_IDEAL} , z_{MEAS_IDEAL}] as follows:

$$\begin{pmatrix} x_{MEAS\_IDEAL} \\ y_{MEAS\_IDEAL} \\ z_{MEAS\_IDEAL} \end{pmatrix} = \begin{pmatrix} x_{TRANS} \\ y_{TRANS} \\ z_{TRANS} \end{pmatrix} + S * \mathbf{R}(\varepsilon_X,\varepsilon_Y,\varepsilon_Z) * \begin{pmatrix} x_{IDEAL} \\ y_{IDEAL} \\ z_{IDEAL} \end{pmatrix}$$

where [x_{TRANS} , y_{TRANS} , z_{TRANS}] is the vector containing the translation parameters in XYZ; $\mathbf{R}(\varepsilon_X,\varepsilon_Y,\varepsilon_Z)$ is the rotation matrix; and S is the scale. For this survey the scale is fixed at S = 1.0. Also computed is the vector [Δx , Δy , Δz] containing the differences between the actual measured and the transformed ideal measurements:

$$\begin{pmatrix} \Delta x \\ \Delta y \\ \Delta z \end{pmatrix} = \begin{pmatrix} x_{MEASURED} \\ y_{MEASURED} \\ z_{MEASURED} \end{pmatrix} - \begin{pmatrix} x_{MEAS\_IDEAL} \\ y_{MEAS\_IDEAL} \\ z_{MEAS\_IDEAL} \end{pmatrix}$$

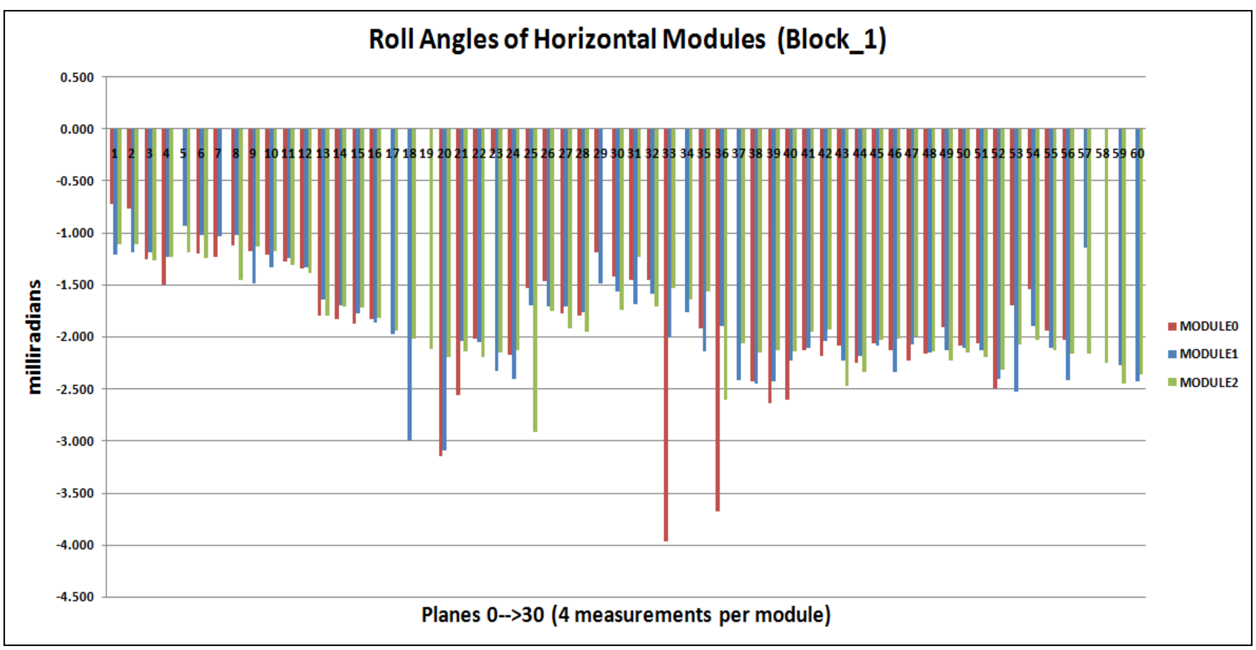

Figure 23: Graphical Output: Pitch.

Challenges

After each block was moved into the MINOS Service Building, the east, west, and the top sides were painted with black paint in the prone position. The upstream and downstream surfaces are also painted black with the block in the upright position. Some of the problems encountered during data collection were identified as follows:

i) Excessive glue in the grooves;
ii) Residual black paint in the grooves and on the vertical modules (Figures 24 and 25);
iii) RTV silicone adhesive on the vertical modules (Figure 25).

Efforts were made to scrape off the residual black paint before measurements, but excessive glue could not be removed.

Figure 24: Modules painted black

Figure 25: Black paint and RTV adhesive on Modules.

Final Survey of NOvA Near Detector

The NOvA Blocks were moved into the NOvA Near Detector Surface Building for assembly after the referencing was completed. Five out of six Blocks had been assembled so far as shown in Figure 26.

The survey of the NOvA near detector will be done in situ after the 6^{th} block and the muon catcher are referenced and installed. Only the first four blocks will be filled liquid scintillator. The final survey will be done once the blocks have been filled.

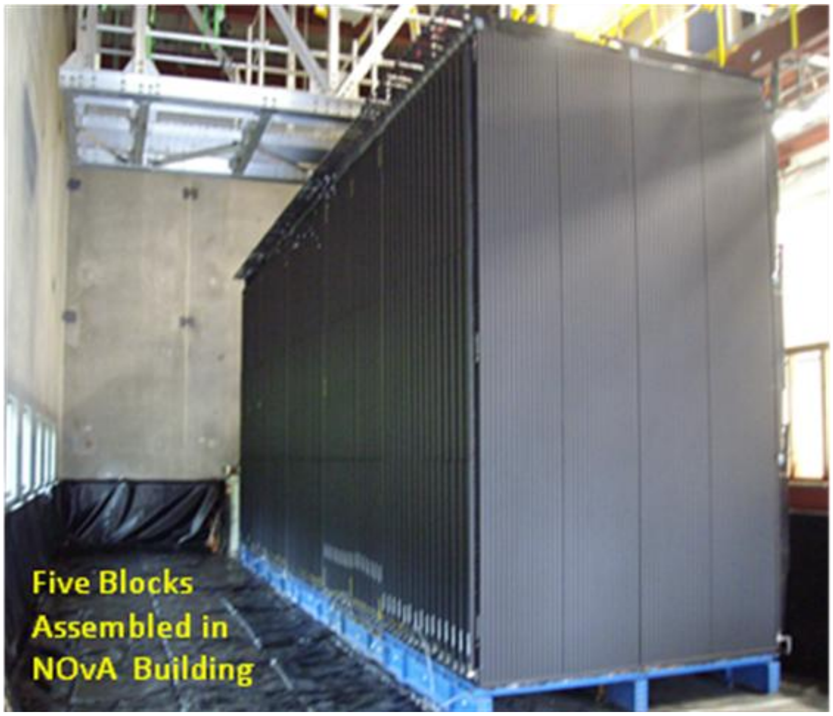

Figure 26: The NOvA Near Detector.

CURRENT STATUS OF THE NOvA NEAR DETECTOR

The IPND installation with four blocks has been completed. None of the module extrusions has been filled with Liquid Scincillator yet. The 6th Block will be referenced and installed by the beginning of October 2010. The muon catcher will be referenced and installed by the middle of October 2010. The survey of the all the 6 blocks and muon catcher in the NOvA Near Detector Building will be done by the end of October 2010. The 4th detector block will be ready to take data (IPND) by the beginning of November 2010. The NOvA near detector will be ready to take data by the middle of November 2010. The survey of the NOvA near detector in the MINOS Tunnel will be done by Fall of 2011.

CONCLUSION

The survey methodology used has been presented. The NOvA Near detector survey is still in progress.

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