FIRST EXPERIENCE UTILIZING A HIGH-DENSITY LASER SCANNER FOR THE NOVA PROJECT*

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Abstract

The NuMI Off-Axis ν_e Appearance Experiment (NOνA) project is currently in its construction phase and estimated to be operational around 2015. This experiment is an extension of the Neutrino at Main Injector (NuMI) project that has been operational for several years now. For NuMI a Neutrino beam is produced at Fermilab and directed to a detector located underground at the Soudan Mine in Minnesota. NOνA requires a near and far detector to be placed at a divergence angle of 13.6 mrad of nominal NuMI beam center line for the detection of Neutrinos at a different energy state. These detectors are constructed from plastic extrusions filled with silicon oil. This paper concentrates on the construction of the larger far detector, its dimensional tolerance requirements and the measurement approach utilizing the HDS6100 scanner for documenting the parts location during the detector construction.

PROJECT OVERVIEW

The NOνA project utilizes the NuMI beam directed to a 700 m below ground detector at the Soudan Mine in Minnesota about 735 Km due North of Fermilab. The new NOνA far detector is placed at Ash River, Minnesota about 75 Km further north and 11 Km off-axis intercepting the neutrino beam under a 13.6 mrad divergence angle [1, 2]. NOνA also requires an upgrade of the Main Injector to increase the beam intensity.

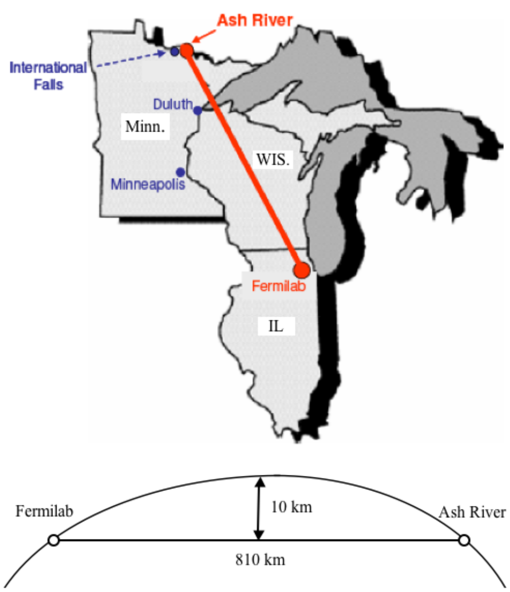

Figure 1: NuMI/NOνA Neutrino Beam and approximate cross section.

NOVA FAR DETECTOR DESIGN

Both the near and far detectors for this project are created from PVC plastic extrusions that are filled with a liquid scintillator and contain light detecting PMMA fibers. About 73% or 18.5 Ktons of the far detector's mass is attributed to the mineral oil scintillator while 21,600 km of wavelength-shifting fibers are required for the detector. For more details on the far detector see [3]. The dimensions of the far detector as shown in figure 2 are 67m long, 15.7m tall and 15.7m wide. The plastic extrusions as displayed in figure 3 are stacked at 90° to each other and bonded together using epoxy glue.

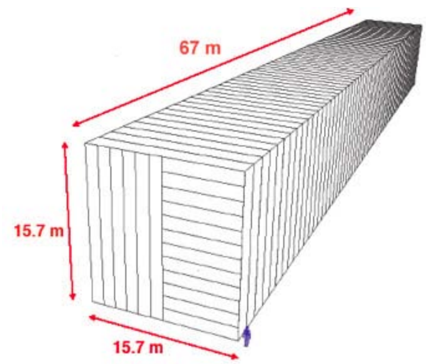

Figure 2: Far Detector Dimensions

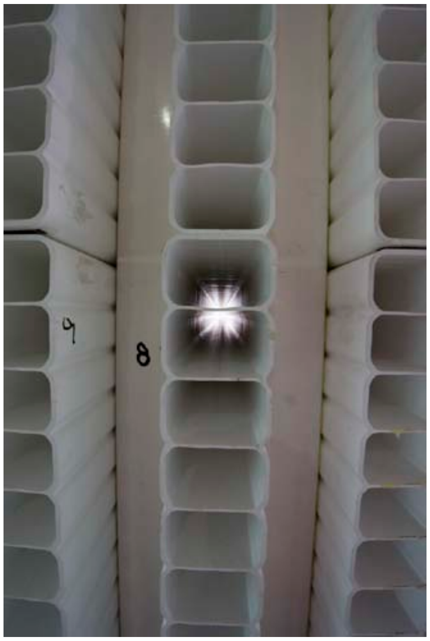

Figure 3: Plastic Extrusions

The entire detector is constructed of 32 blocks each approximately 2.5m wide while each block is assembled of 31PVC extrusions resulting in 1003 PVC extrusion for the entire detector. Initially each block is created in the assembly hall on a movable block pivot system operating on rails as shown in figure 4.

Far Detector construction Tolerances

The structural integrity of these detector blocks is linked to the glue thickness and distribution between the individual PVC layers. Therefore small glass spheres 0.5mm in diameter have been mixed into the adhesive to warrant the minimum adhesive thickness. On the other hand if the voids to be filled are too large the adhesive loses its optimum strength compromising the block structure during its envisioned lifespan. This lead to a tolerance requirement of ±1mm in elevation changes between adjacent modules as shown in figure 5 and involves the Fermilab Alignment and Metrology Group (AMG) supporting this QC aspect of the project during detector construction.

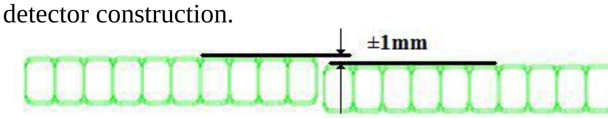

Figure 5: Elevation Tolerance between adjacent Modules

Initially it was envisioned to utilize photogrammetric methods to status the conformance of each extrusion plane. This however, would have been an enormously time consuming task for a trained crew as each plane needs to be prepared with hundreds of photogrammetric targets that also have to be removed before the next extrusion layer can be assembled and glued.

Structured light may have been an option however these systems are usually sized for the measurement of small objects. Such a system has to be powerful enough to cover an area of 15.7x15.7m at a distance of 15 to 20m with an appropriate light pattern. It was at that point that we started to investigate utilizing a laser scanner system for this task.

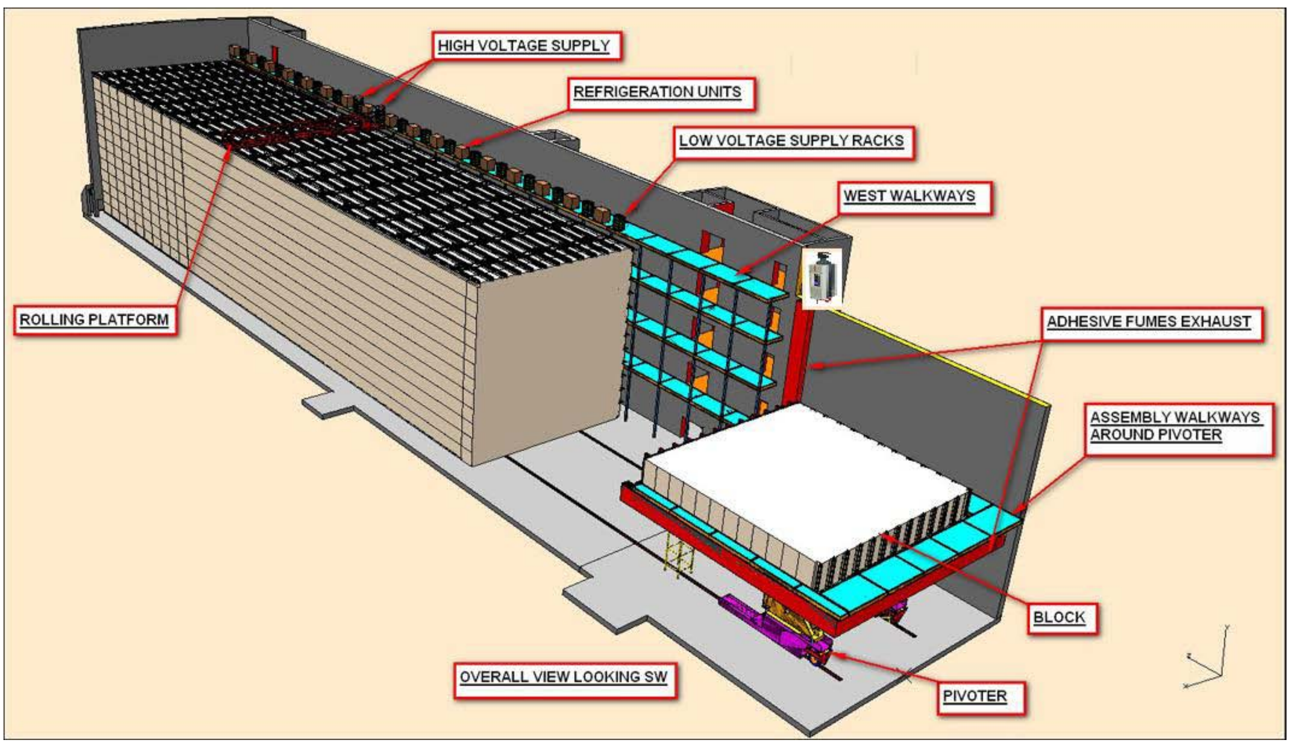

Figure 4: Schematic of the Far detector assembly hall with movable pivot system.

THE LEICA HDS6100 LASER SCANNER

After a long study of the existing literature on laser scanner performance [4, 5, 6] and a multitude of tests of instruments from various vendors we decided on the purchase of the LEICA HDS6100 predominantly for its ability to operate inverted, its low noise level of about ±0.5mm when using white objects with 80% reflectivity and the LEICA Cyclone software [7] providing scripting tools to automate the measurement process.

The instrument is in our possession since the spring of 2010 and we received the basic training for operating the HDS6100. In addition we added PolyWorks from InnovMetric Software Inc. [8] for the semi automatic post processing of the data. As shown in figure 5 we operated the device hanging inverted from a crane trolley and performed test scans of almost all Near Detector blocks that will be installed at Fermilab in the next year for early testing of the assembled system.

It is envisioned that the scanner will be permanently mounted to the ceiling, centred above the assembly area approximately 10 to 15 m above the pivoter platform.

Figure 5: Inverted operation of the HDS6100

PROCESS OUTLINE

We are currently in the process to outline the measurement sequence followed by the analysis. Figure 6 shows a scanned ear detector block. As the AMG will not be able to supply a full time staff person for the detector construction phase we strive to automate as much as possible of this process so that a trained person should be able to handle this part. We will always be able to provide long distance support via the Internet and remote access to the analysis tools.

For the measurements several permanent targets mounted to the assembly hall walls and the pivoter will be utilized. As these and the scanner position remain unchanged between scans one can devise a measurement script that performs this task automatically.

As fast feedback to the assembly floor is required to determine if the layer meets specification or may need rework, we split the post processing in two parts. One provides fast feedback and a second that performs a more indebt analysis offline. In any case a clean-up and data reduction step is required in Cyclone utilizing the region grow function. Figure 7 shows on the left the raw data including outliers and right the remaining data after region growth. One can see that the outliers have been eliminated and the valleys of the grooves have been cut out leaving only a small skin of the top surfaces.

This data set can now be imported into PolyWorks to produce a triangular irregular network (TIN) and scripts to create cross-sections intersecting planes along the groves of adjacent extrusions as shown in figure 8. A report is generated that shows the coordinates of these intersections i.e. the elevations of adjacent modules and with that the elevation differences flagging those parts that exceed the tolerance limits. This report is send back to the assembly floor for evaluation before the next layer of extrusions is installed.

The second part of the analysis offline is more time consuming. This entails the creation of a colour coded elevation map showing the long wavelength deformations. An example of this process is shown in figure 9.

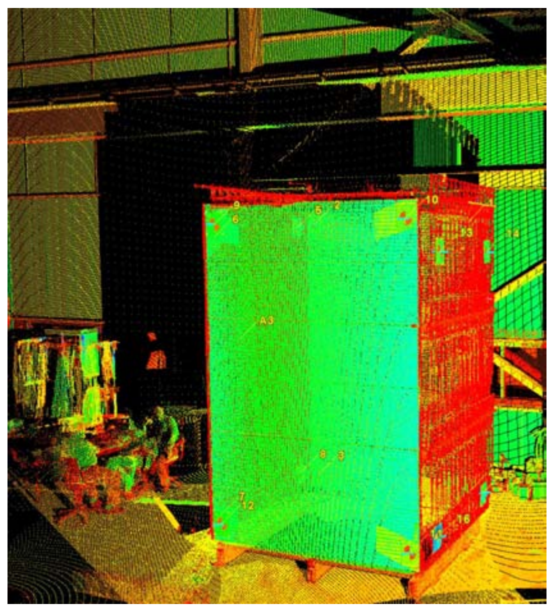

Figure 6: NOνA near detector block assembly

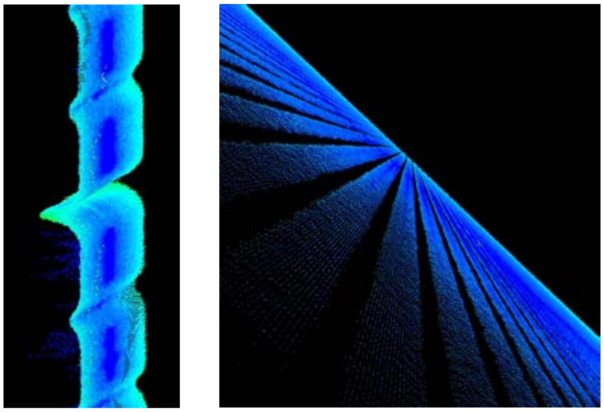

Figure 7: Left: Raw data; Right: Cleaned data set

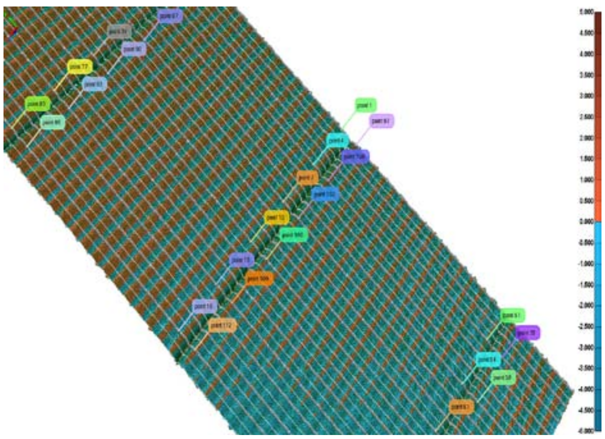

Figure 8: Cross-section points of adjacent modules

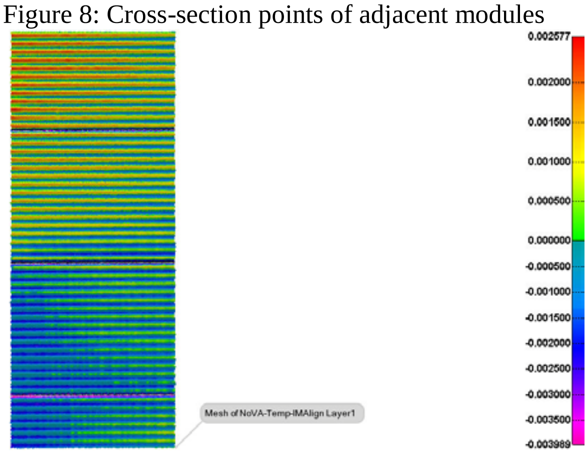

Figure 9: Colour coded elevation map

SUMMARY

- Next year the NOνA project starts the assembly of the far detector.
- As outlined we will be utilizing a laser scanner to perform the quality measurements during the assembly of the detector blocks.
- The Cyclone and PolyWorks software will be used for this task.
- An outline of the measurement process and post analysis has been presented.
- As of the time of writing this paper several of these components still need to be thoroughly tested and implemented.

ACKNOWLEDGEMENT

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