Block Structure as Part of Block Instrumentation

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Summer Internship in Science and Technology (SIST) Program 2012

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Abstract

The NOνA experiment aims to study the mixing behavior of neutrinos and will attempt to resolve the neutrino mass hierarchy. The experiment will depend on data collected at two detectors, one near Fermilab's NuMI (Neutrinos at the Main Injector) target called the Near Detector and the other 810km north at Ash River, MN (Far Detector) . NOνA has many sub projects and one is the block structure as part of the block instrumentation group. This project will detail the attributes of the prototype detector (FHEP) and the Far detector. Distance sensors help with the placement of the block, measures the definition of the block, and when the block is filled with oil distance sensors help measure its swelling so we need a way to display to help keep track of all the characteristics that close to 800 sensors are detecting. The project consisted of creating displays using the in-house program Synoptic which is similar to LabVIEW. The goals were to create three main displays that will feed information through ACNET to be displayed in the control room, finalize the prototype display, create the future Far Detector display and set up every display to be alarm triggered when a certain value is not met. The events that were found after the prototype display was made were significant to the initial thoughts of the way the detector should work and the display now runs in the NOνA control room. The Far Detector display was based on the prototype's attributes and was successfully created. The goals of this sub project were met but will continue as more research is done on the NOνA experiment.

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Introduction of NOvA

1.1 The Neutrino

Wolfgang Pauli proposed the solution for the missing energy in the nuclear beta decays, in 1930 he said that a neutral particle passed them and in 1933 Enrico Fermi named the particle the neutrino which is Italian for "little neutral one". The NOvA experiment is an unique experiment in which we set out to determine the properties of neutrinos and the oscillation of muon neutrinos into electron neutrinos. We can consider neutrinos to act as leptons, muon neutrinos are elementary particles which have the symbol ν_μ and no net electric charge, electron neutrinos also known as lepton is a stable elementary particle in the lepton family.

1.2 Overview of NOvA Experiment

NOvA is a unique experiment that is intended to seek the properties of Neutrinos and their behavior. The History of the Neutrino starts as early as the 1930s. NOvA has a project called Block Structure as a part of the Block Instrumentation Group. The findings of this project consisted of collecting data to be displayed for two detectors the FHEP and the Far Detector. This paper gives an overview of the Block Structure project and on the construction of the detectors and its confinements. Synoptic is an in-house created program that was used to write a code for the block structure displays.

Scientists suspect that neutrinos played a major role in the evolution of the universe, contributing to its mass as much as stars and planets. The NOνA experiment will study the unique characteristics of neutrinos, especially the elusive transition of muon neutrinos into electron neutrinos. The experiment will start taking data in 2013 and construction will be complete in 2014. The first run will last six years. NOνA is a novel solution to the problem that confronts all neutrino experiments: How to achieve a large mass detector with the ability to take resolution pictures of neutrino interactions?

1.3 Purpose of Research

Neutrino physics studies have seen various attempts at explaining the various properties of neutrinos. The NOνA experiment at Fermi National Accelerator Laboratory seeks to answer three fundamental questions:

1. Can we observe the oscillation of muon neutrinos to electron neutrinos?

2. What is the ordering of neutrino masses?

3. What is the symmetry between neutrinos and antineutrinos?

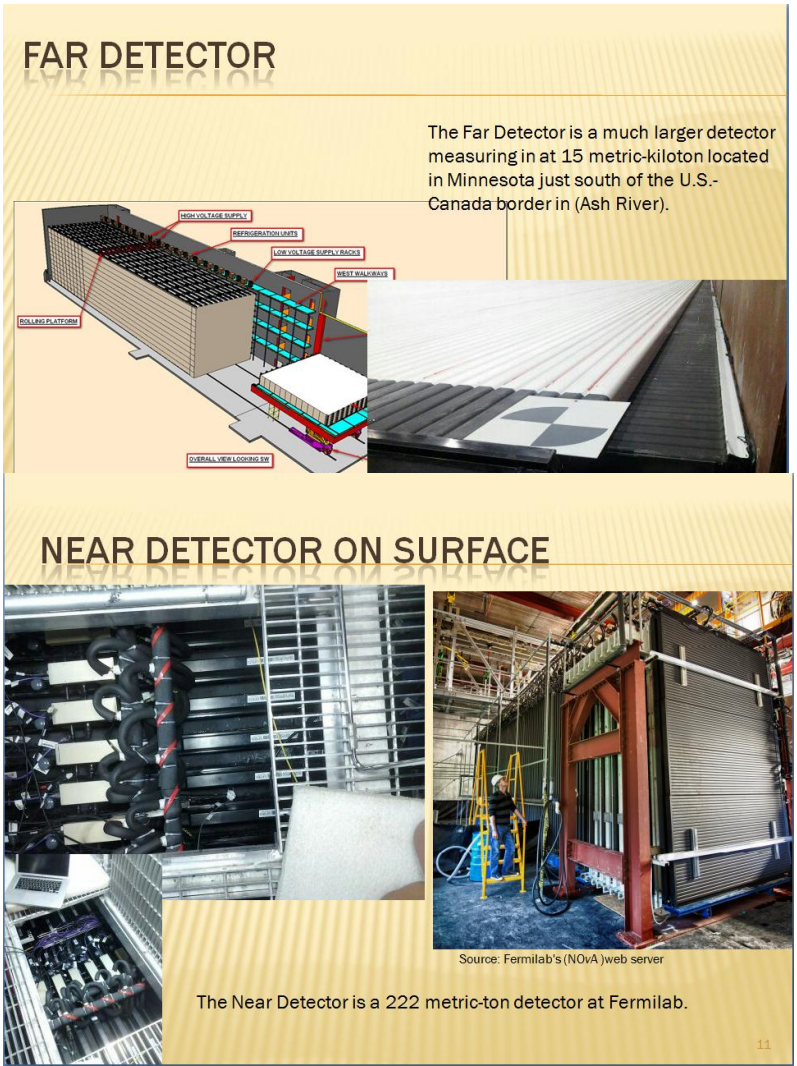
A big part of the NOνA experiment is the Near Detector and Far Detector.

The Near Detector is a 222 metric-ton detector at Fermilab. The Far Detector is a much larger detector measuring in at 15 metric-kiloton located in Minnesota just south of the U.S.-Canada border in (Ash River). The detectors are made up of 385,000 cells of extruded, highly reflective plastic PVC filled with liquid scintillator. Each cell in the far detector measures 3.9 cm wide, 6.0 cm deep and 15.5m long. When a neutrino strikes an atom in the liquid scintillator, it releases a burst of charged particles. As these particles come to rest in the detector, their energy is collected

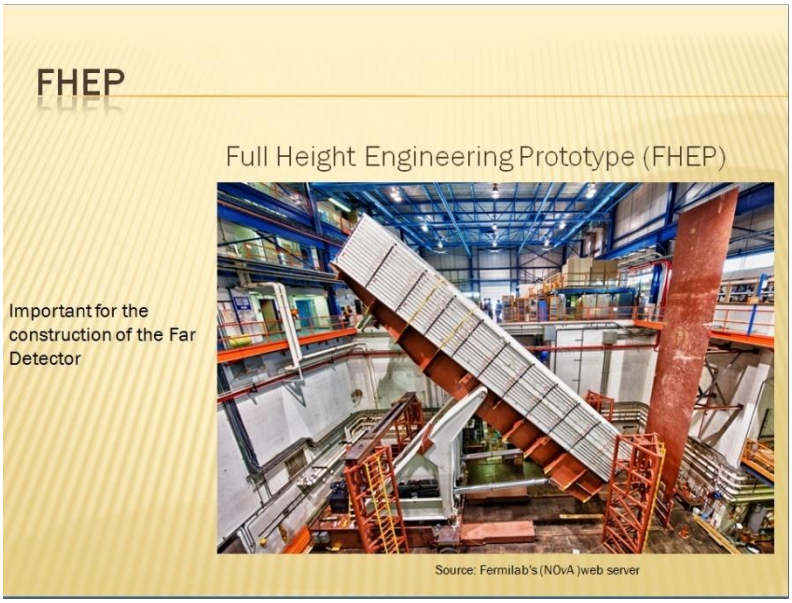
using wavelength-shifting fibers connected to photo-detectors. Using the pattern of light seen by the photo-detectors, scientists can determine what kind of neutrino caused the interaction and what its energy was. [2]

A neutrino beam, much like a beam of light from a flashlight, gradually spreads apart as it travels. The width of the NuMI beam at Fermilab starts at about six feet and grows to several miles by the time it reaches the far detector in Minnesota. The NOvA detector is located slightly off the centerline of the neutrino beam coming from Fermilab. At this off-axis location, scientists find a large flux of neutrinos at energy of 2 GeV, the energy at which oscillation from muon neutrinos to electron neutrinos is expected to be at a maximum. [2]

The Detectors



The Prototype Detector



Introduction of Block Structure

2.1 Block Structure as Part of Block Instrumentation

Block Structure as Part of Block Instrumentation is a sub project of NOvA to characterize the definition of the detectors. To characterize the FHEP and Far Detector we used distance sensors. Distance sensors help with the placement of the block, measures the definition of the block, and when the block is filled with oil distance sensors help measure its swelling so we need some type of display to help keep track of all the definitions of what close to 800

sensors are detecting. The Far and FHEP Detectors are equipped with distance sensors on the North End, South End, and North and South Book Ends.

2.2 Overview of the Project

The project was to analyze block structures as a part of block instrumentation. I wrote a code using the in-house created program Synoptic similar to LabVIEW. The project consisted of making displays to transmit data though ACNET which is similar to EPICS to Synoptic, data is fetched from ACNET using a Java API. The purpose was to create and simulate a prototype display to better prepare us for issues with the future Far Detector.

2.3 Purpose of Research

The objective of this project was to analyze the sensor attributes of the Full Height Engineering Prototype (FHEP) and Far Detector while creating full functioning displays. The project consisted of creating three displays that will feed information from ACNET to Synoptic to be displayed in the control room. Also, making each to be alarm triggered when a certain value is not met.

The goals were to:

1. Create a display for the FHEP and which is one block to monitor its sensors
2. Create a functioning display for the future Far Detector.
3. Have the FHEP be displayed in the control room
4. Monitor and edit the FHEP displays daily to help create a well functioning Far Detector Display
5. Completion of Far Detector Display before the first block goes up

Below is a Distance Sensor on the FHEP.

Theory

3.1 Block Structure

The FHEP is housed in CDF at Fermilab. The Far detector will have 32 planes stacked high to complete one block and will be consisted of 28 blocks. So, all 28 blocks will be identical and each of them will have 32 planes. On a recent trip to Ash River I saw that two planes were already up for the first block. Construction of the Far Detector should be complete in 2014. To be south of the base the detector blocks must be installed with a slight tilit where the upper end is arranged. The normal tilt will be 1.0±0.5".

The Sensor display plays a big part in the installation of the blocks. The installment of the blocks will have a 0.25±0.25 (quarter inch gap) between them. So that all blocks are adjacent the gaps will be filled with spacers at the top of the blocks. Between gaps on each side will be

distance sensors measuring the gap between each block and for the Prototype the distance sensors measure the gap from the block to the wall.

So why would we place the Far Detector at Ash River but place the Near Detector at Fermilab?

1. Theoretically you would point the beam right at your detector.
2. We are looking for a needle in a haystack so we want to be off to the side
3. We would like to be as far away from Fermilab as possible to study possible effects of matter on the muon to electron rate of conversion.
4. We want to study the composition using the Near Detector

The NOvA experiment will generate a beam of neutrinos to send to a 15,000-ton detector(Far Detector) in Ash River, Minnesota. The particles will complete the 500-mile interstate trip in less than three milliseconds.

3.2 Expectations

The expectations of this project are to possibly create a display for the Prototype Detector (FHEP) to monitor its sensors and have it be monitored in the control room. Also, to monitor and edit the FHEP displays daily to help create a well functioning Far Detector display. The completion of the Far Detector display should also be complete before the first block goes up this year.

Method

4.1 Details of Synoptic and ACNET

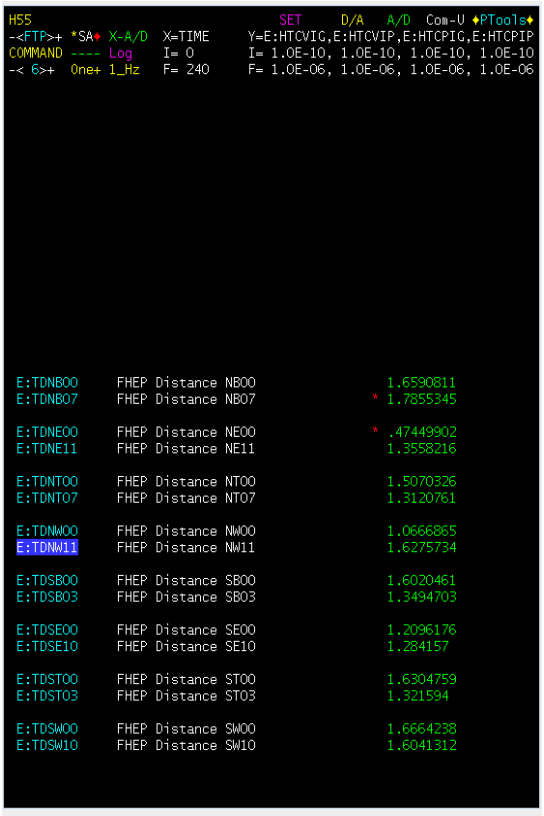
Synoptic display shows real-time data from the Accelerator Control System at Fermilab. Synotic was used throughout this whole project to obtain data and build data structures. Accelerator Control Network better known as ACNET was the brains of synoptic. ACNET helped store all information and numerical values of the sensor. The displays were created by using different components from the Synoptic builder and creating actual sensor displays that are being monitored. I received real time information and device names from ACNET. Those device names were put into each sensor for the FHEP display in synoptic to display a device in inches.

4.2 ACNET Console

ACNET was such an important factor in my project. ACNET controlled all the characteristics of each sensor. Since the sensors measures the swelling of the display we had to set alarms. The prototype detector was a variation of numerical gaps from 0.48 in. to 1.79 in. Those measurements were wall to wall of the detector. For the prototype we set the alarms to be

trigged at a distance of 1.05in.-1.7in.; because we knew there were two devices that didn't meet those criteria. The mock trail of the alarms was done for the display to prepare for future problems. In the event of a real situation with the Far Detector this display will better prepare us to dill with its problems and identify an exact sensor right away. The Far Detector will only have quarter inch gaps from block to block so these displays are critical.

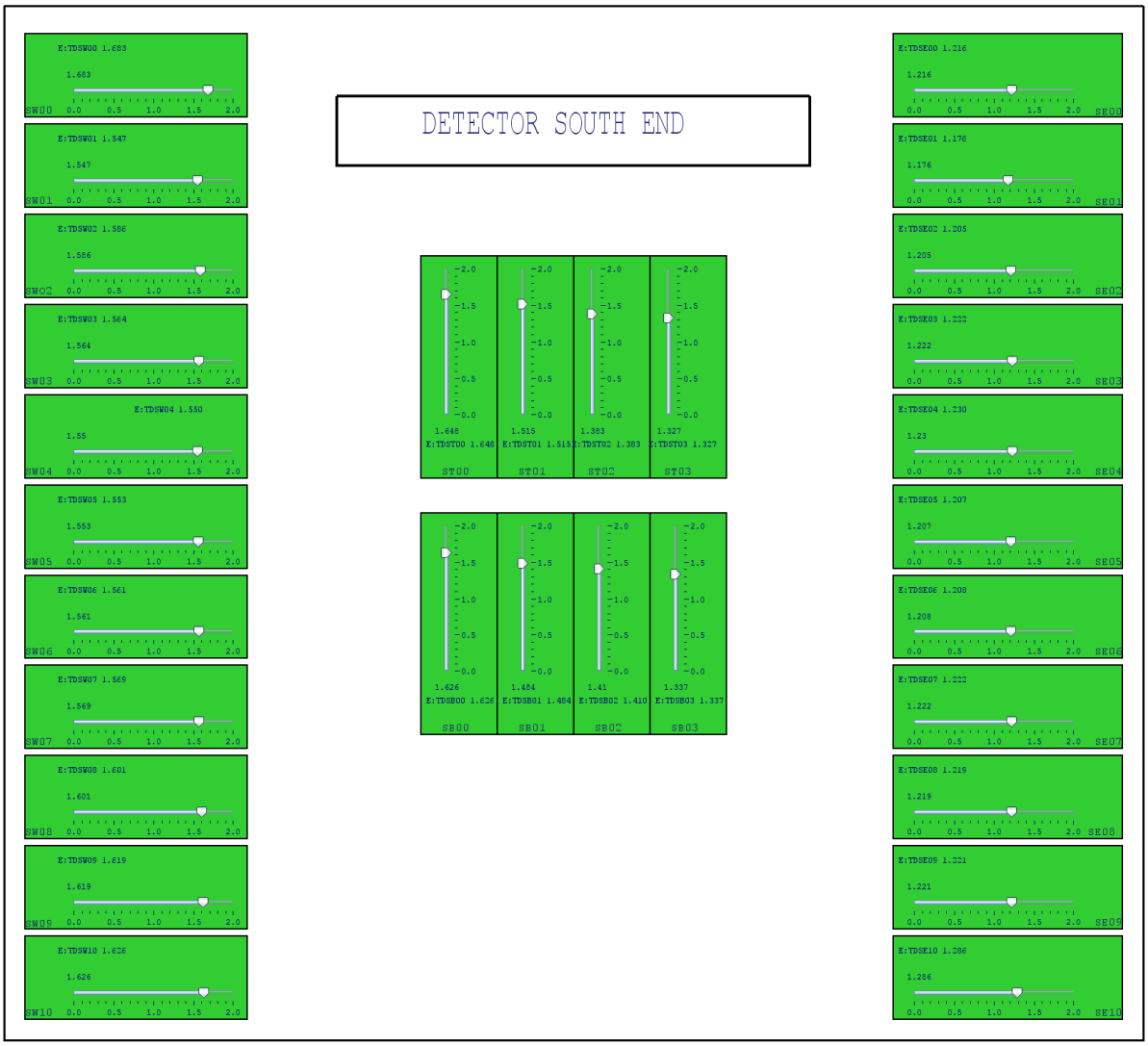
Below is a picture of the ACNET Console and the sensors from my display which are logged. The events that have a red star by them are values that trigged the alarm.



Results and Observations

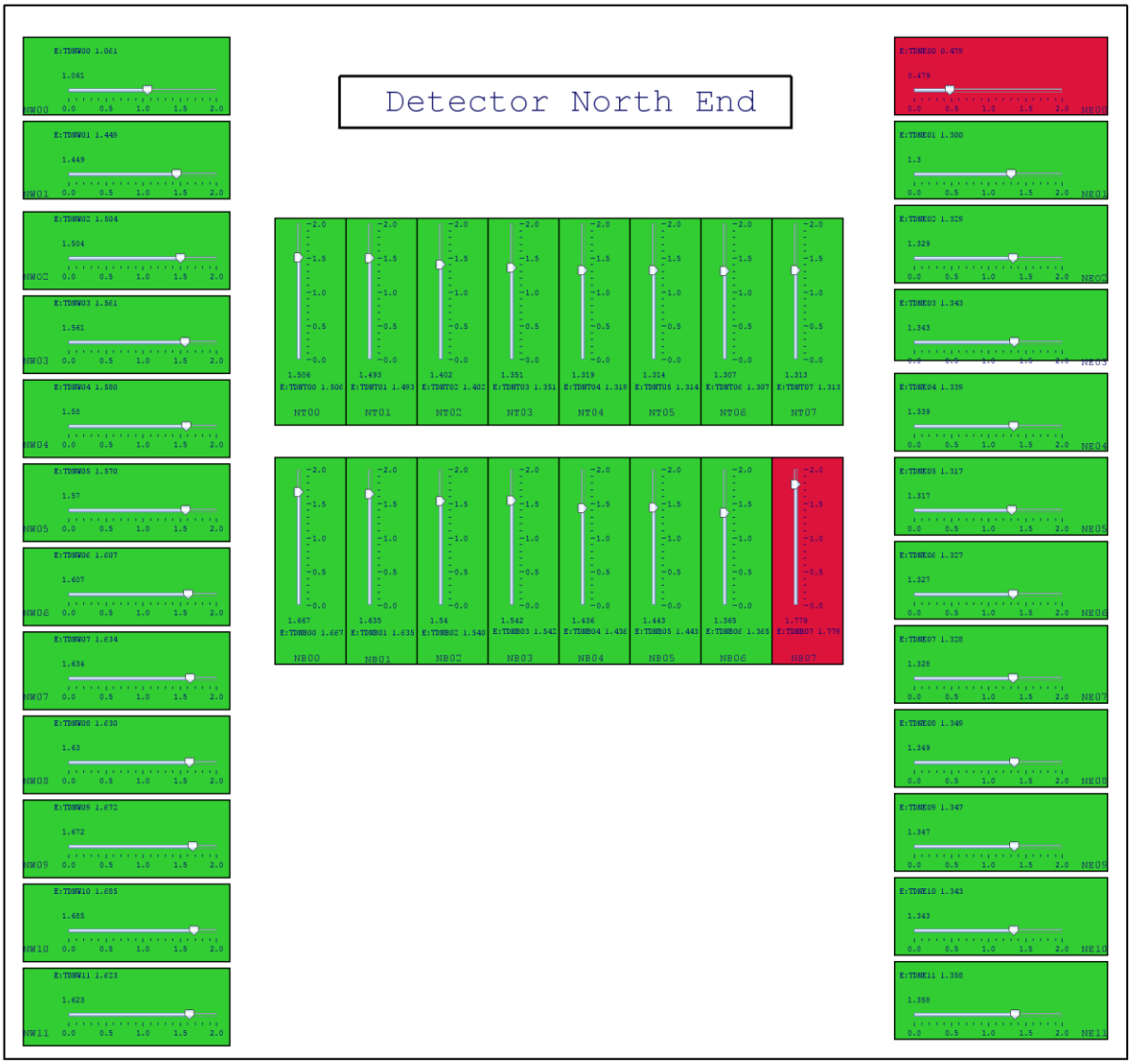
5.1 FHEP Display South End

Consisting of 32 Sensor and all met the limits for the alarms so they show green.



5.2 FHEP Display North End

Consisting of 40 Sensor and two did not meet the limits for the alarms so they show red because they were values outside of 1.05in.-1.7in.



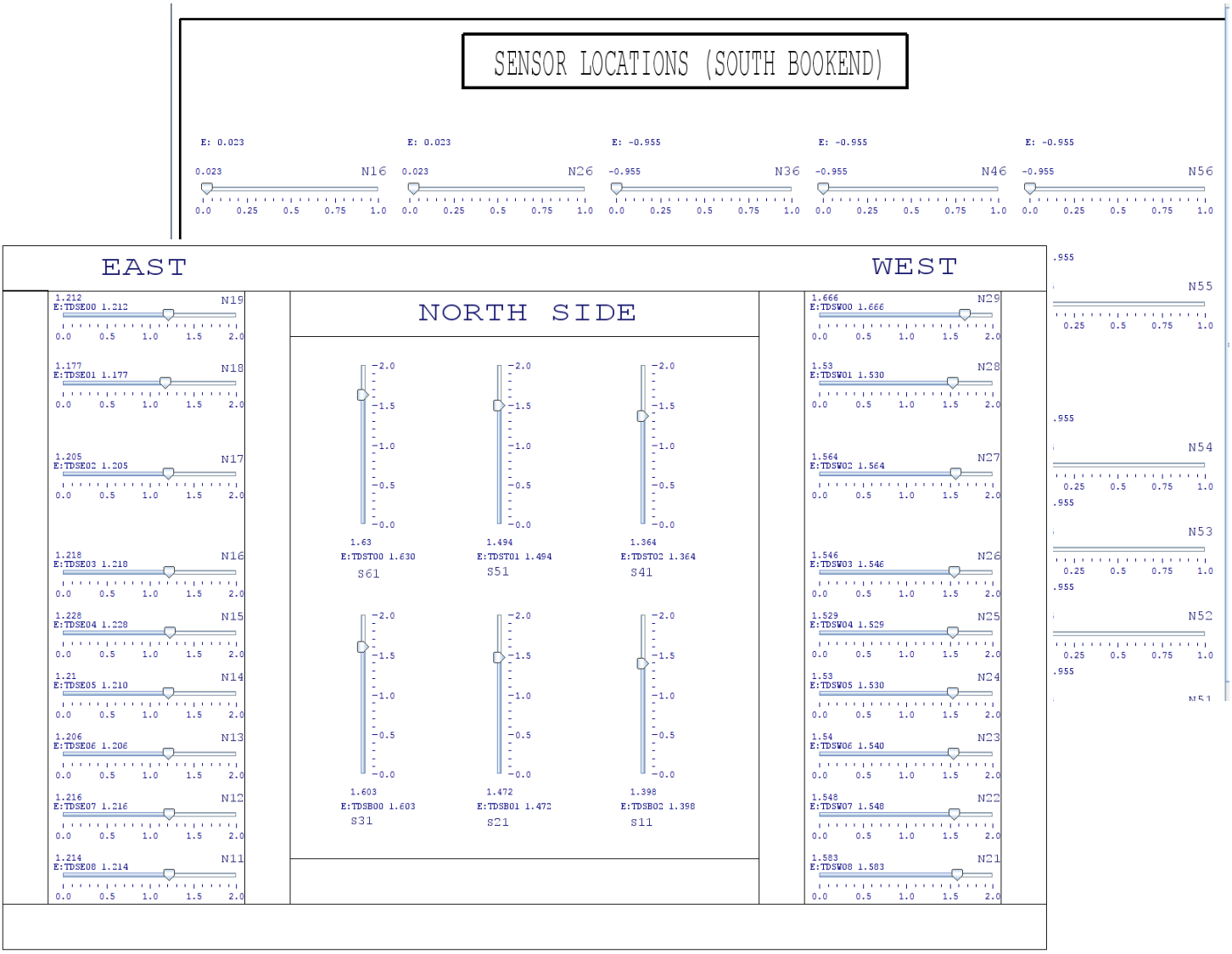
5.3 FHEP Overview Display

The Overview allows the user to click on previous displays on one page and will highlight the side that sensors trigged an alarm.

The Overview Display Can Be Found Below and Runs in the NOvA Control Room
http://synoptic.fnal.gov/

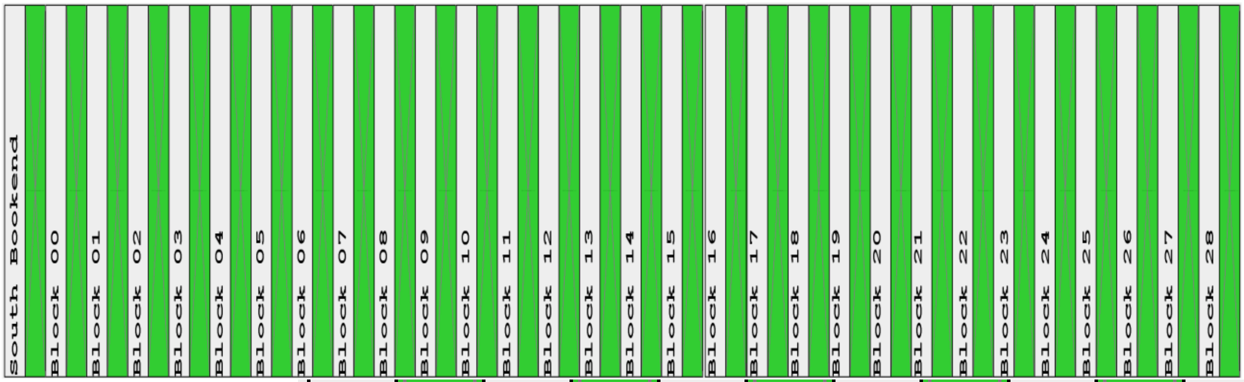
5.4 Far Detector Displays South Bookend and Sides

They are over 800 sensors so I created a display for the south booked of the Far Detector and it is 28 block. Below are the actual displays for the gaps. Each gap has a display with like the one below that list its EAST, NORTH and WEST sensors.



5.5 Far Detector Overview Display

The display below shows an overview of the complete Far Detector display. If one runs Synoptic and click on the gaps one will see the previous results show up.


South Bookend
Block 00
Block 01
Block 02
Block 03
Block 04
Block 05
Block 06
Block 07
Block 08
Block 09
Block 10
Block 11
Block 12
Block 13
Block 14
Block 15
Block 16
Block 17
Block 18
Block 19
Block 20
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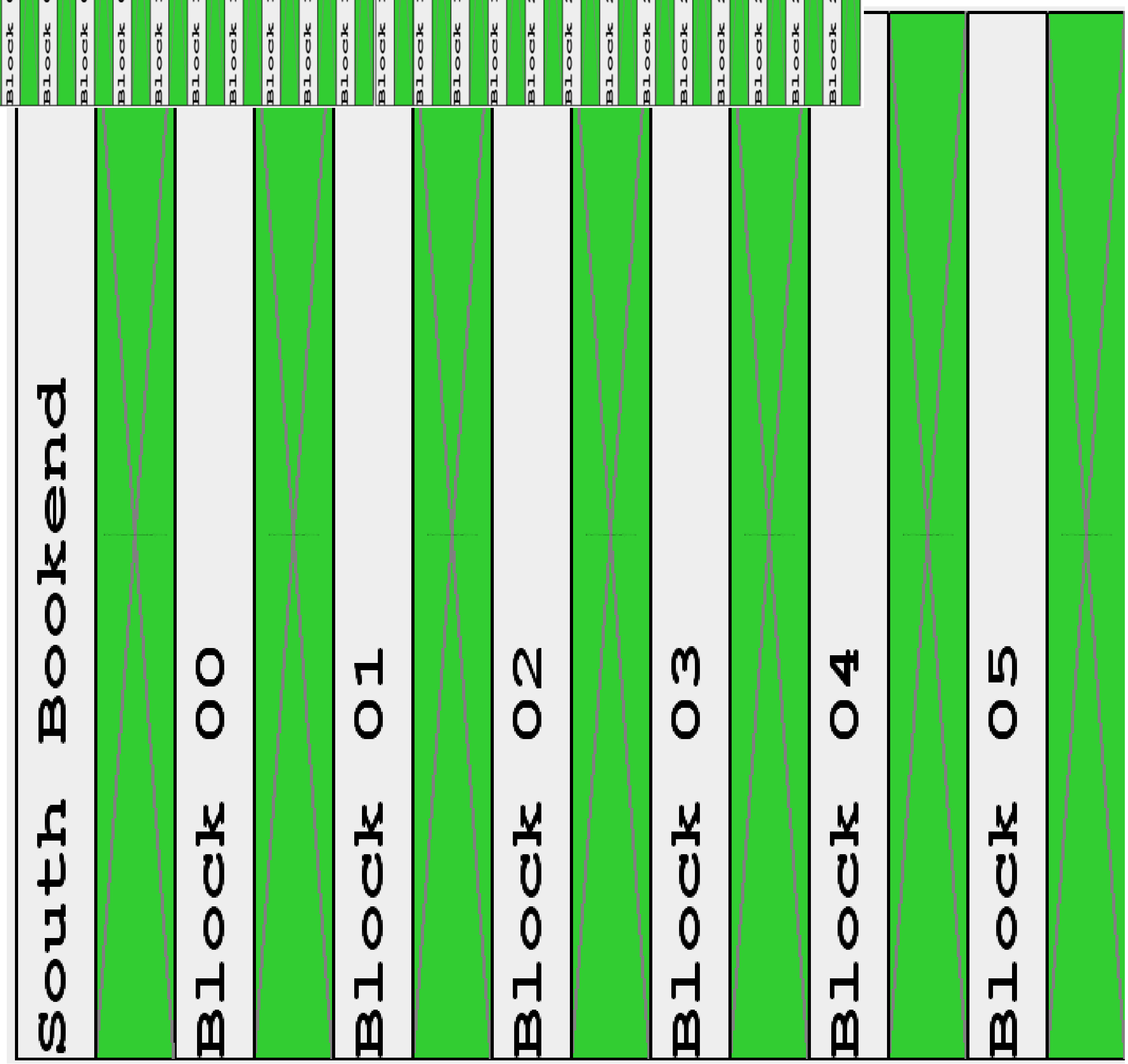
Block 27
Block 28


South Bookend
Block 00
Block 01
Block 02
Block 03
Block 04
Block 05

Conclusion and Discussion

6.1 Conclusion

Each display for the FHEP showed the same results from the theory of this project. We knew that because of how the FHEP was put in at CDF that two sensors would trigger the alarm set values. For the most part all of the sensors on each display stayed within the limits which were set. A leak was detected in the FHEP at Fermi and when the problem is fixed the display will measure its swelling. The events that were seen are significant to the initial thoughts of the whole detector prototype should would work. The display for the prototype was successful and helped to create the new display for the Far Detector which will be set up at Ash River in Minnesota. The Far Detector is a total of 28 blocks and its display was successfully created using Synoptic which will run in the control room as soon as the first block goes up at ash river.

All goals were met with this project. The FHEP display contributed much to the process of how we should analyze data for the Far Detector and runs in the control room. The Far Detector display is ready to be implemented at Ash River as soon as sensors are installed. Future research and work will continue on this project

6.2 Discussion

I ended this project with a trip to Ash River in Minnesota to actually see the progress of the Far Detector and to attend the 2012 NOνA Collaboration Meeting. On this trip I saw that two planes were already setup for the first block of the detector and just 30 more to go. After the completion of the first block the display that I created will be used at Ash River to

make sure they meet the requirement of the quarter inch gap. The Ash River trip gave me more insight on my project and really helped with the overall vision of my project.

NOvA Block Structure Dictionary

ACNET- Controls software that was written by the accelerator division at Fermilab.

Beta Decay-is a type of radioactive decay in which a beta particle (an electron or a positron) is emitted from an atom. Beta decay occurs when, in a nucleus with too many protons or too many neutrons, one of the protons or neutrons is transformed into the other.

Electron Neutrinos- (lepton) a stable elementary particle in the lepton family having a mass of zero, or very close to zero and no charge

Muon Neutrinos –elementary particles which has the symbol ν_μ and no net electric charge

Neutrinos-are like leptons

Subatomic particle- Any of various units of matter below the size of an atom, including the elementary particles and hadrons.

References

1. Fermi National Accelerator Laboratory

2. https://docs.google.com/viewer?a=v&q=cache:a8EGrfsFMdwJ:www-nova.fnal.gov/reviews_summer_2012/PVC%2520Structure%2520Change%2520since%2520TDR.doc+block+structure+NOvA+site:fnal.gov&hl=en&gl=us&pid=bl&srcid=ADGEESiZTl9XmOLdSN78DRRK0u6CNocbACNZVTAHdIpF3LqMGy1UZFCQKhwxm3Eb8yFN4mkwN_xHvyml2tDTxkI4wGBCDoJpTFDnk-tkG3niUFwVKmAw-ReNkWPb9BspS50GN1TzLAaj&sig=AHIEtbQOAUvwDjeZtNDe7gFpcFuI5V0t9Q

3. http://www-nova.fnal.gov/

Acknowledgements

SIST Internship Program

Special Thanks to:

Dianne M. Engram

Linda M. Diepholz

Dr. Davenport

Fermi National Accelerator Laboratory

Dr. Martin Frank

University of Virginia

Grambling State University

Southern University at Shreveport

A Big Thank You to Dr. Martin Frank, Mrs. Dianne Engram, Mrs. Linda M. Diepholz, The Entire SIST Program Team, University of Virginia and Grambling State University for support to the research conference and trip to Minnesota!