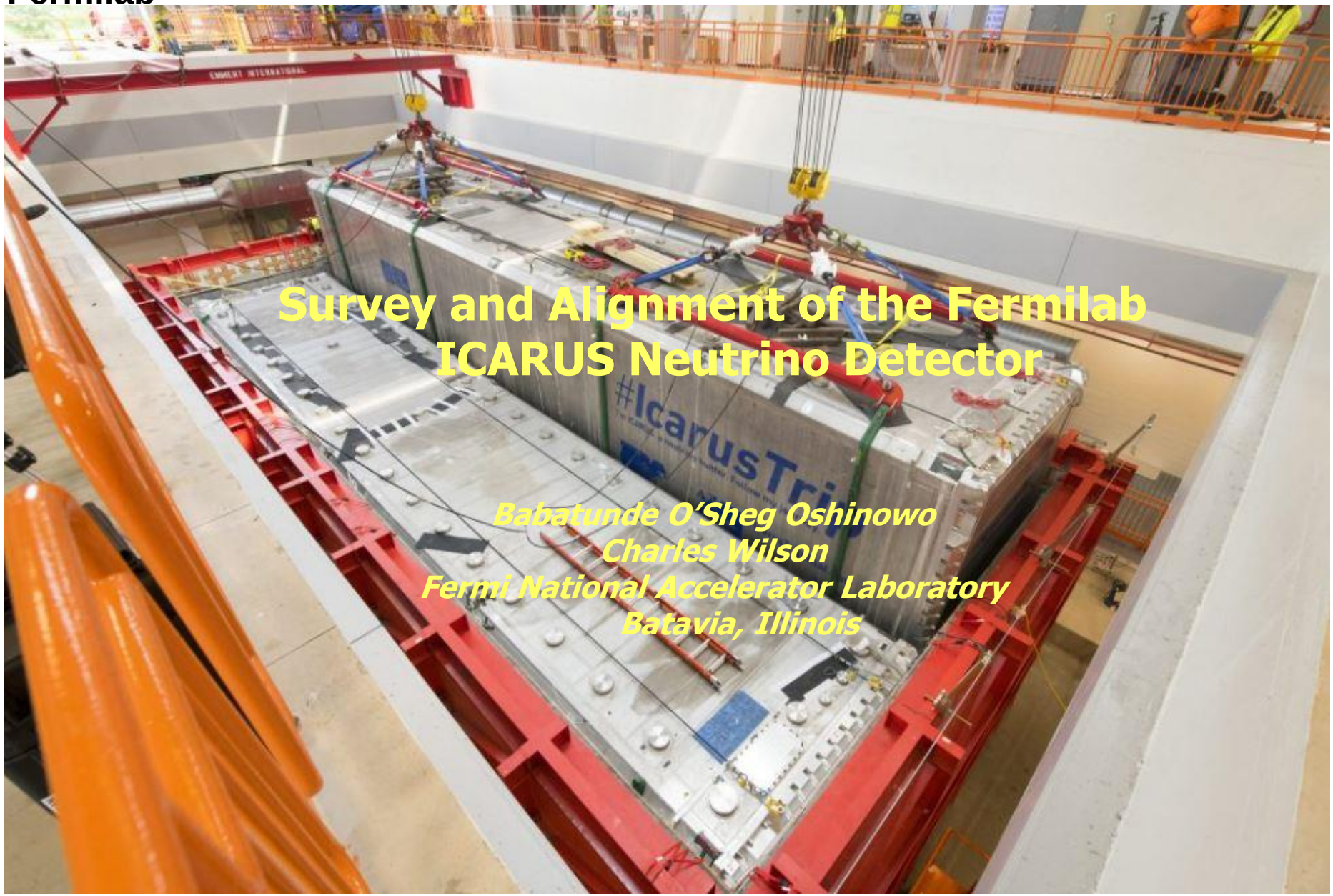
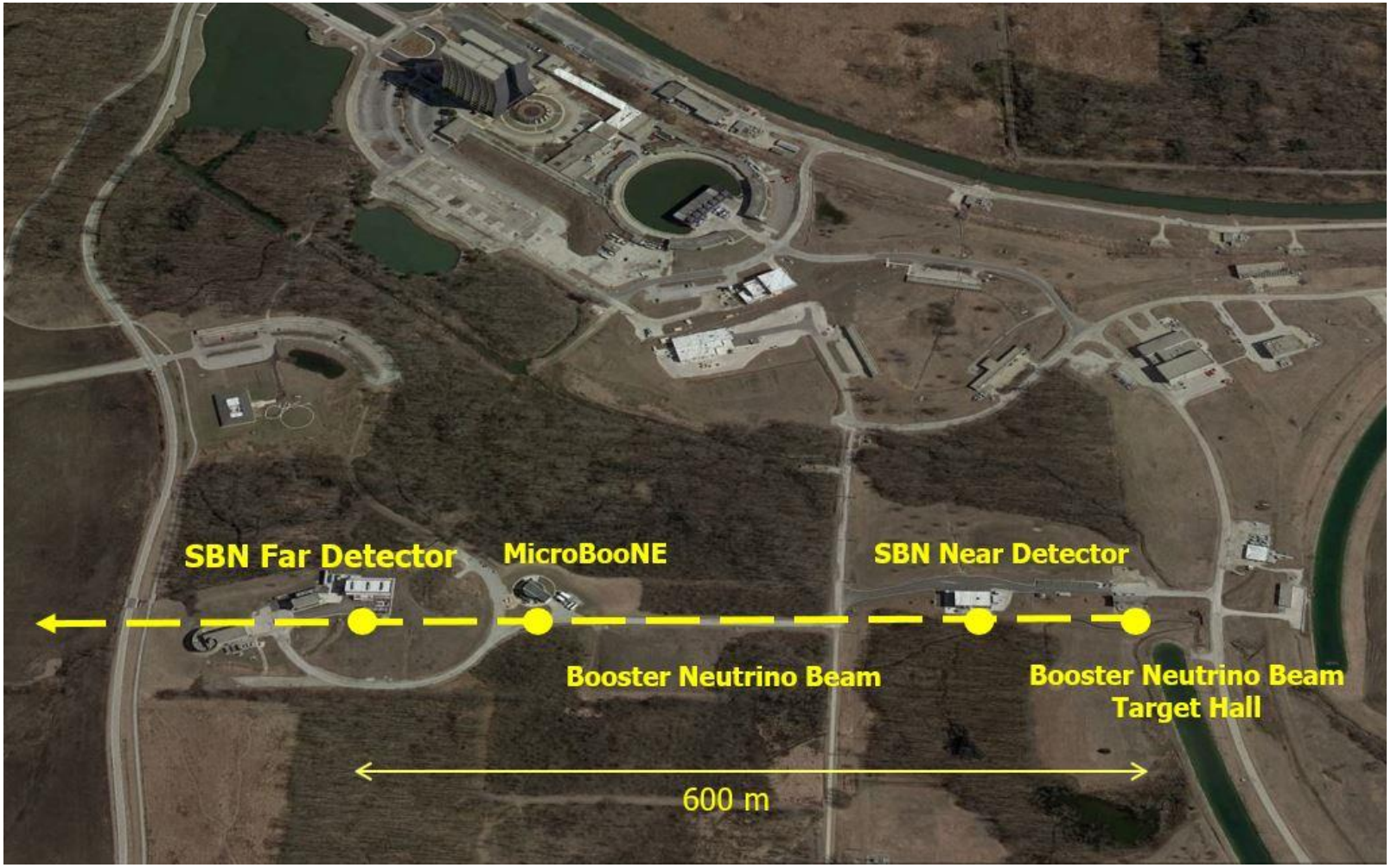


Survey and Alignment of the Fermilab ICARUS Neutrino Detector

Babatunde O'Sheg Oshinowo
Charles Wilson
Fermi National Accelerator Laboratory
Batavia, Illinois

ICARUS Neutrino Detector

Dr. O'Sheg Oshinowo
IWAA 2018 Conference
Fermilab, Batavia, IL, USA
October 8-12, 2018



- **Short Baseline Neutrino Far Detector (SBN-FD)** is the ICARUS neutrino detector, located in a new building 600 meters from the Booster Neutrino Beam (BNB) target

- SBN-FD, MicroBooNE Detector and the in-progress Short Baseline Near Detector (SBND) are part of the Fermilab SBN Program. The goal of the SBN Program is to explore the neutrino oscillations

SBN Far Detector Building

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- ICARUS Detectors are located in the SBN-FD Building
- The Detector Hall houses the ICARUS Detectors

ICARUS Neutrino Detector

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October 8-12, 2018

- ICARUS neutrino detector is the largest liquid-argon neutrino detector in the world
- It measures 20 meters long and weighs 760 tons and serves as the Fermilab's Short Baseline Program Far Detector
- It consists of two cryostats, ICARUS1 and ICARUS2
- Each is approximately 4 m high, 4 m wide and 20 m long.

ICARUS Detector

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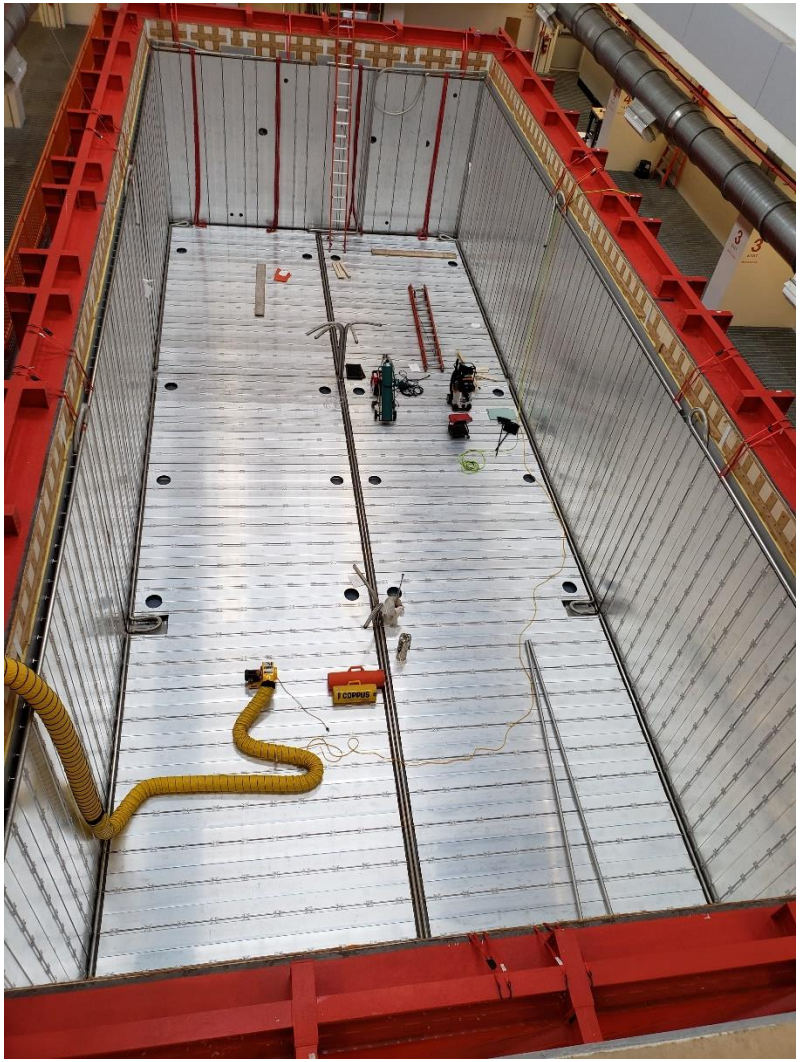
- Each cryostat holds liquid argon time projection chamber modules and photodetectors.

ICARUS Detector

- ICARUS detector was previously installed in the underground Italian Institute for Nuclear Physics (INFN) Gran Sasso National Laboratory from 2010 to 2013
- In 2014 the detector was moved to CERN, where it was refurbished, preparing it for its voyage to Fermilab
- ICARUS detectors arrived at Fermilab in 2017

ICARUS Detector

ICARUS1 and ICARUS2, also known as Cold Vessels, were installed inside a Warm Vessel (Red Box) in the SBN-FD Building Detector Hall



ICARUS Detector

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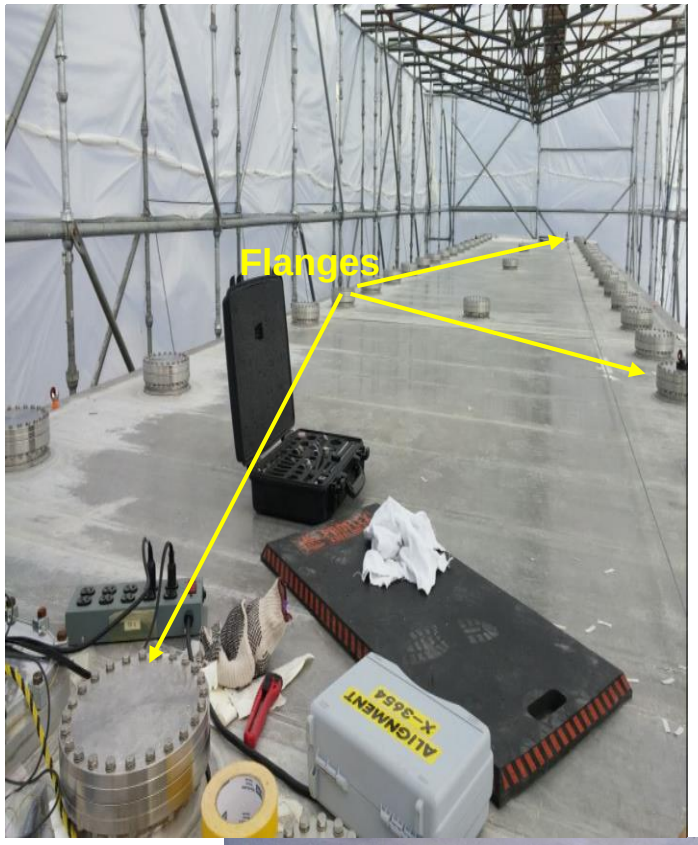

- Each ICARUS detector has 10 Cold Feet at the Bottom
- The Shims and the Cold Feet were installed at Fermilab, only the Cold Foot holes were measured at CERN
- Each ICARUS detector has 47 Flanges at the Top

CERN and Fermilab Fiducials

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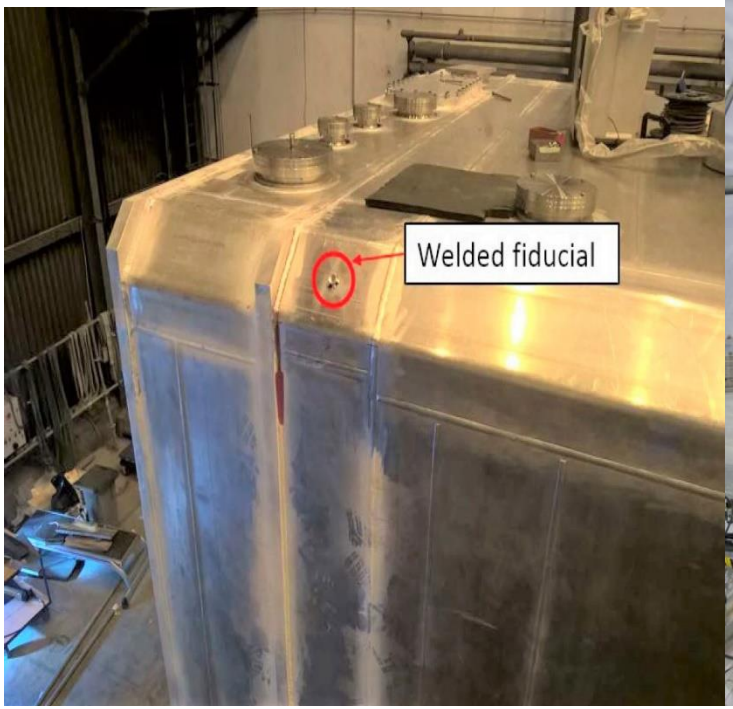

- 6 fiducials were welded to the top of each ICARUS at CERN, 3 on each side. These fiducials were referenced to the components inside the ICARUS (courtesy of Dirk Mergelkuhl and Co.)
- 16 fiducials were glued to the top of each ICARUS at Fermilab, 5 on each long sides 3 on each short sides

ICARUS Survey and Alignment

Dr. O'Sheg Oshinowo
IWAA 2018 Conference
Fermilab, Batavia, IL, USA
October 8-12, 2018

GOAL:

- Survey ICARUS1 and ICARUS2 detectors in the SBN-FD parking lot
- Tie all the top Flange and glued fiducial measurements and the bottom Cold Feet measurements to 6 CERN fiducials
- Align the detectors while being installed live in the Warm Vessel in the SBN-FD detector hall

Survey Methodology

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- All Survey for the ICARUS was done with:

- An API Radian and T3 Laser Tracker
- and Spatial Analyzer™
- Leica Absolute Tracker AT40x, x = 1,2,3…
- Trimble S6 Total Station
- Geodimeter Total Station
- Leica DNA03 Digital level
- Leica ScanStation P40 Laser Scanner

ICARUS Measurements in Parking Lot

Dr. O'Sheg Oshinowo
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- All survey measurements were done inside a tent built around the ICARUS detectors. The tent was for the welders for welding the detector gates
- Average temperature inside the tent was 40.6°C (105°F) at the top and 30°C (86°F) at the bottom.
- Measurements at CERN was done in a controlled environment

Top Measurements

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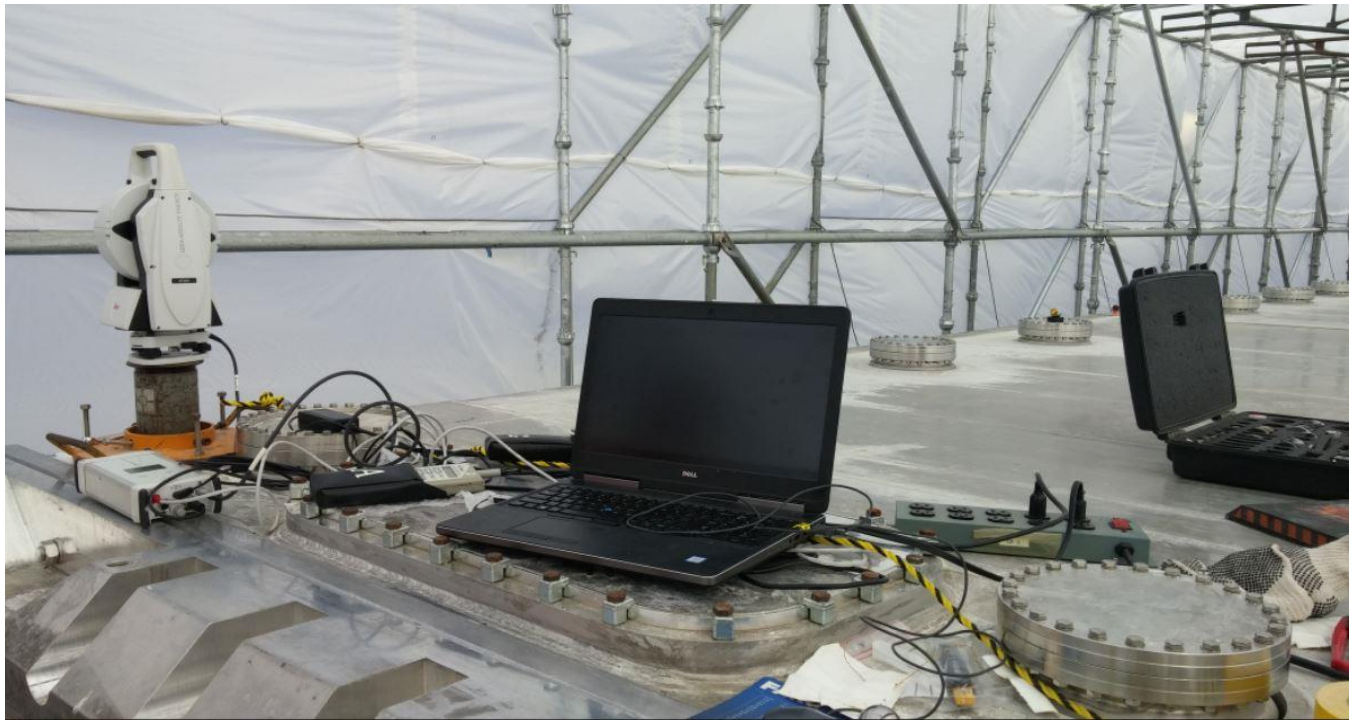
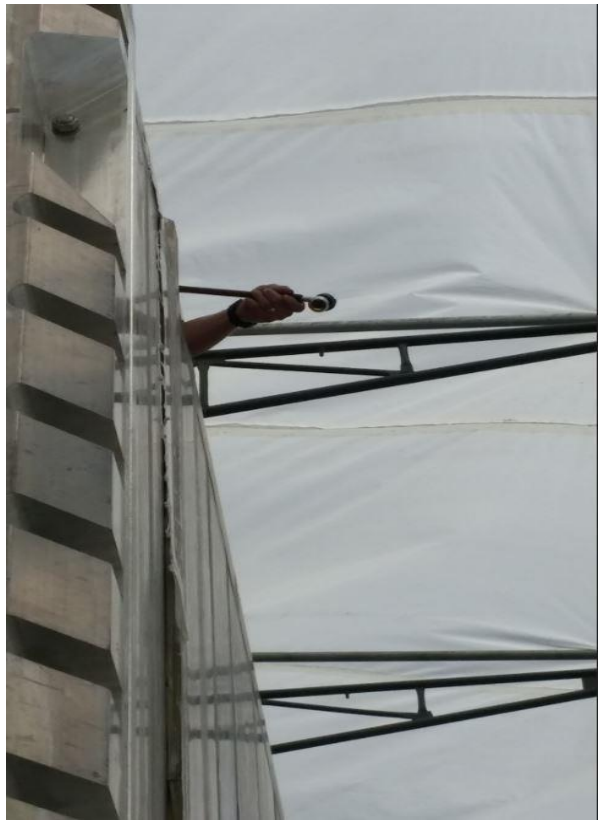


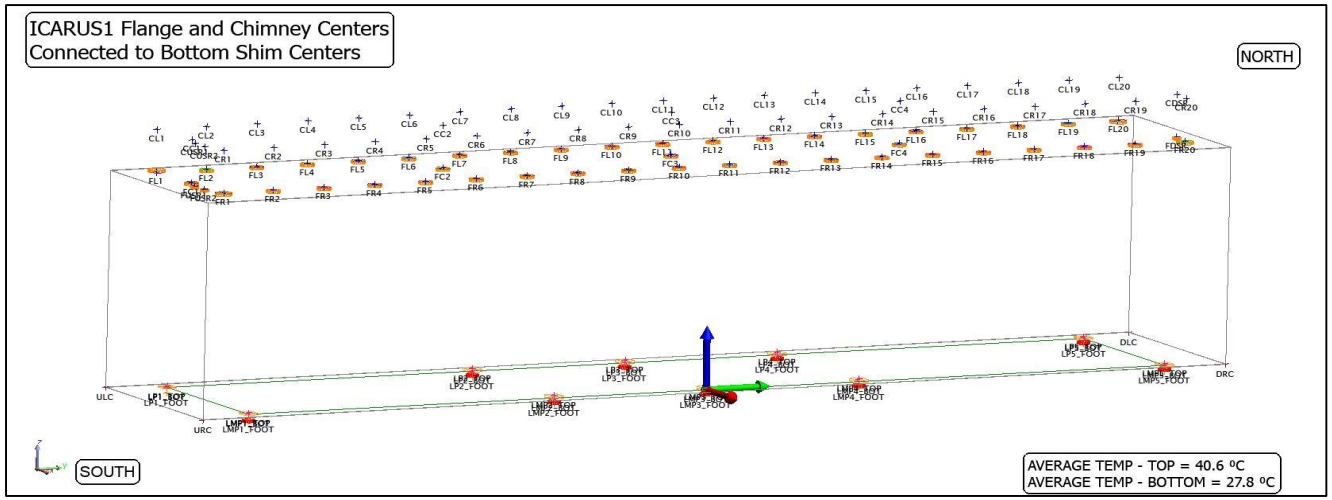
- Top Flanges were measured as circles. Centers determined from circle fits to measurements
- Chimney centers were projected vertically by 840 mm
- All 6 CERN fiducials and glued fiducials were measured

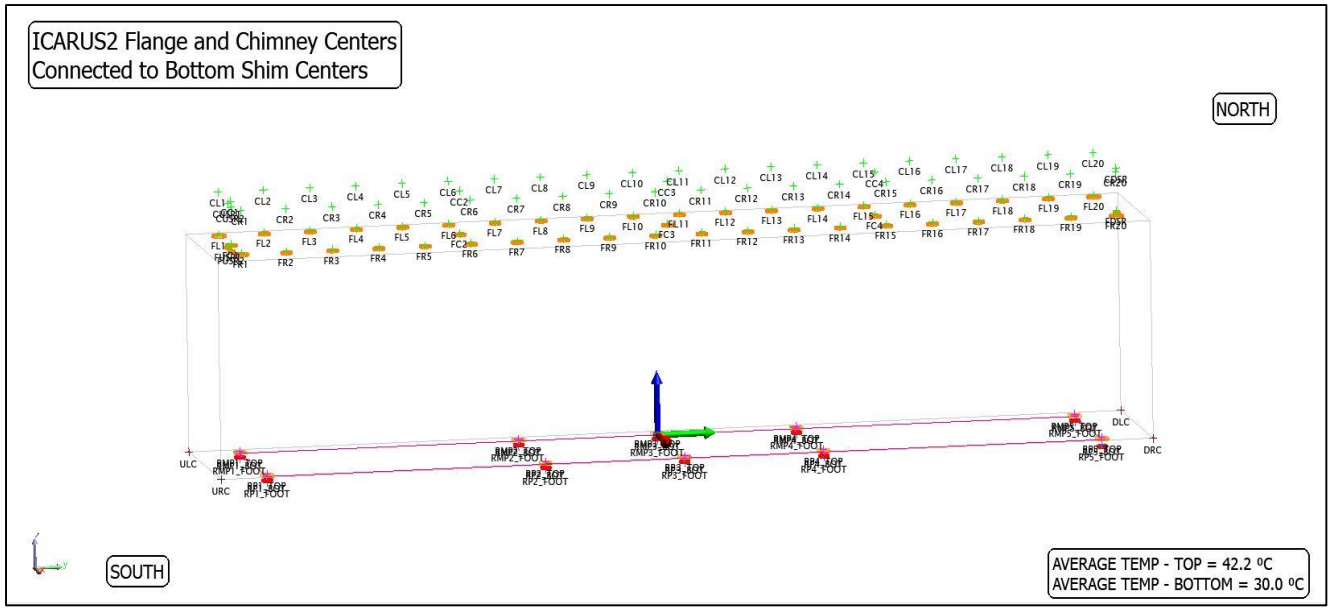
Bottom Measurements



- Bottom Cold Feet were measured as circles. Centers determined from circle fits to measurements
- The 6 CERN fiducials with Radius Rods as spheres. The magnets at the center of the fiducials were demagnetized due to much welding. Centers determined from sphere fits to measurements

ICARUS Measurements Results for the parking lot measurements





SBN-FD Control Network

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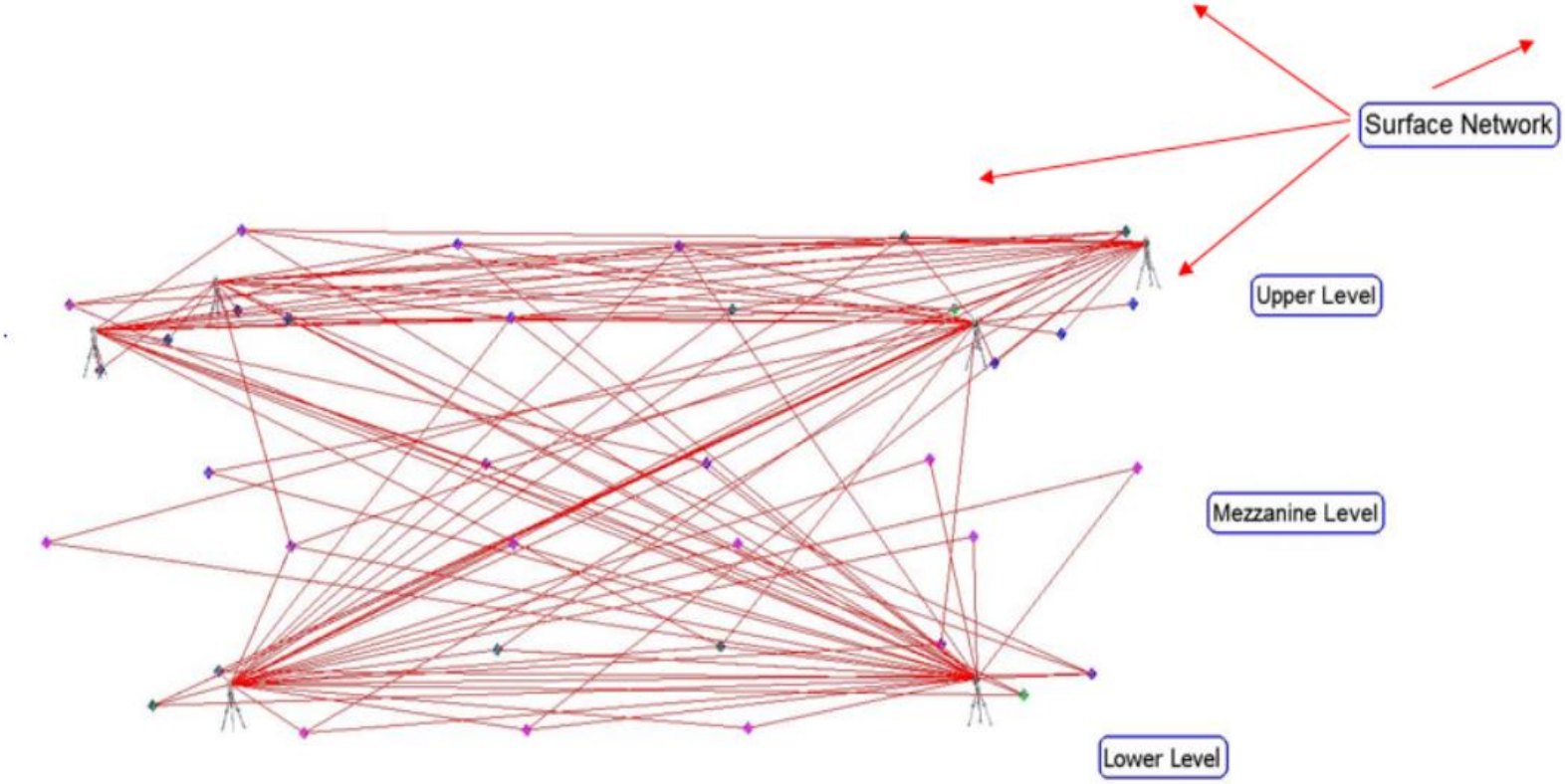
October 8-12, 2018



- Established a precision control network in the Far Detector Hall and building for positioning the Far Detector using the Leica AT401 Tracker

- Extended control network on the mezzanine and lower levels of the building using the AT401 Tracker

- Tied the new building control network to the surface network using the Geodimeter Total Station

Scanning Warm Vessel

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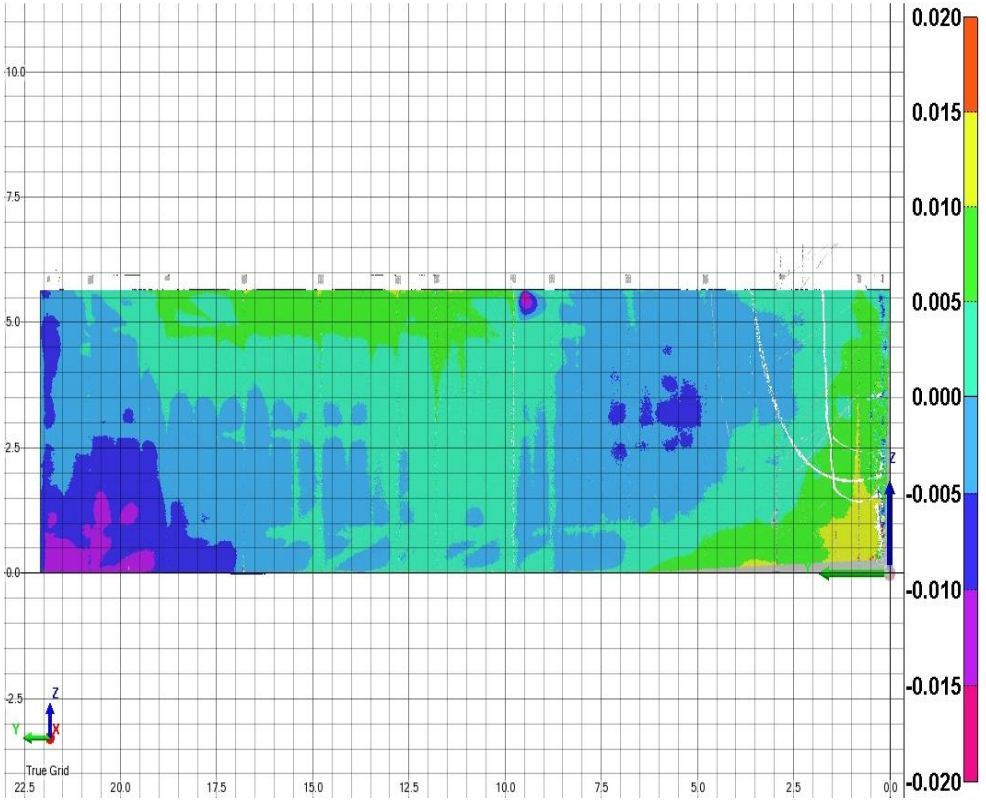
October 8-12, 2018



- Scanning of the Warm Vessel was done using the Leica ScanStation P40 Laser Scanner from five different locations inside of the Warm Vessel

- Purpose was to verify the flatness of the welded panels

East Wall

POSITIVE values are towards exterior of the Warm Vessel

NEGATIVE values are towards interior of the Warm Vessel

Cold Feet Steel Plates

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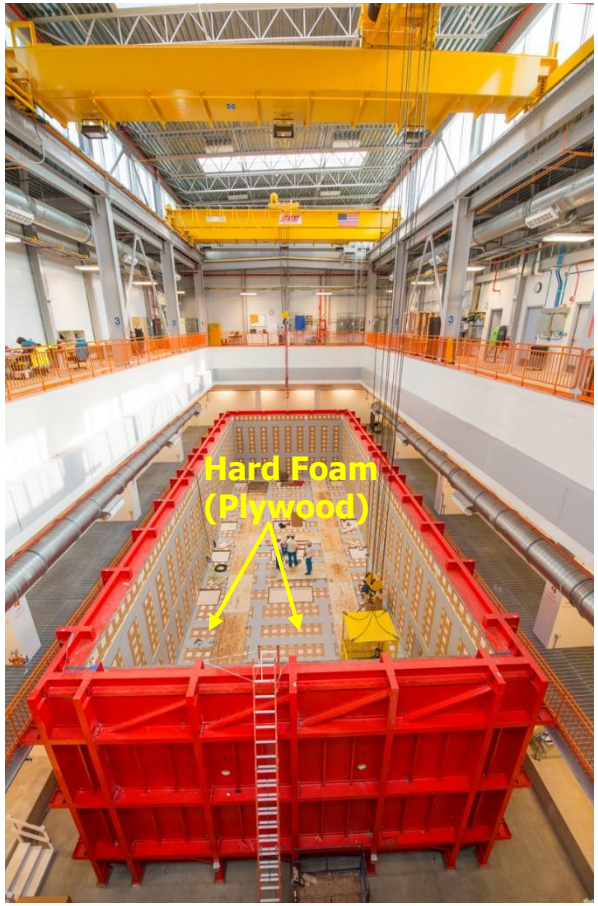

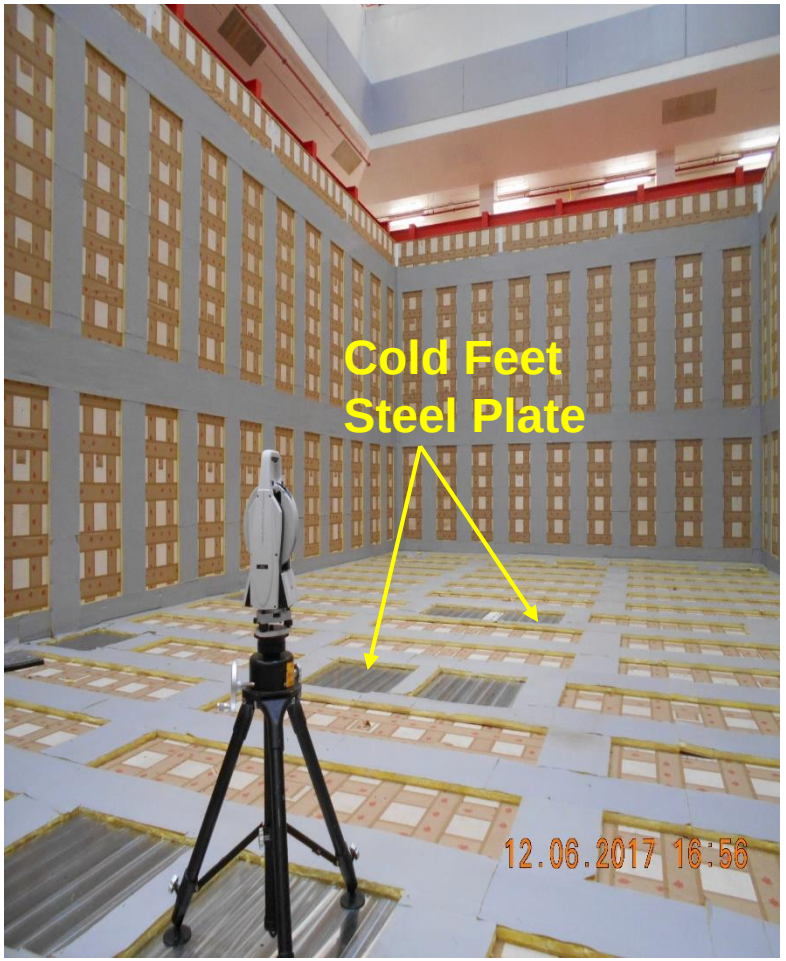

- 20 Steel Plates for the ICARUS 20 Cold Feet were installed on the Warm Vessel floor and measured

- Hard foam insulation (a.k.a. Plywood) were installed on the floor and walls and measured for flatness

Sliding Pads and Guiding Rails

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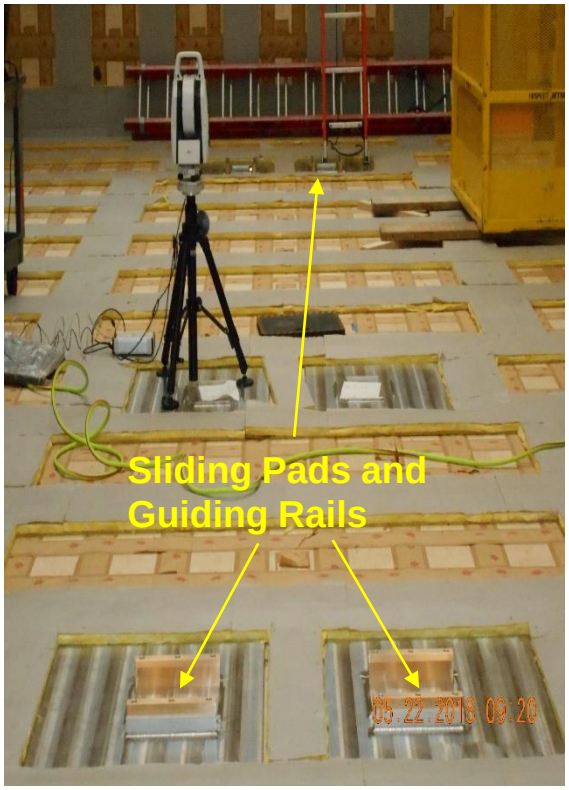

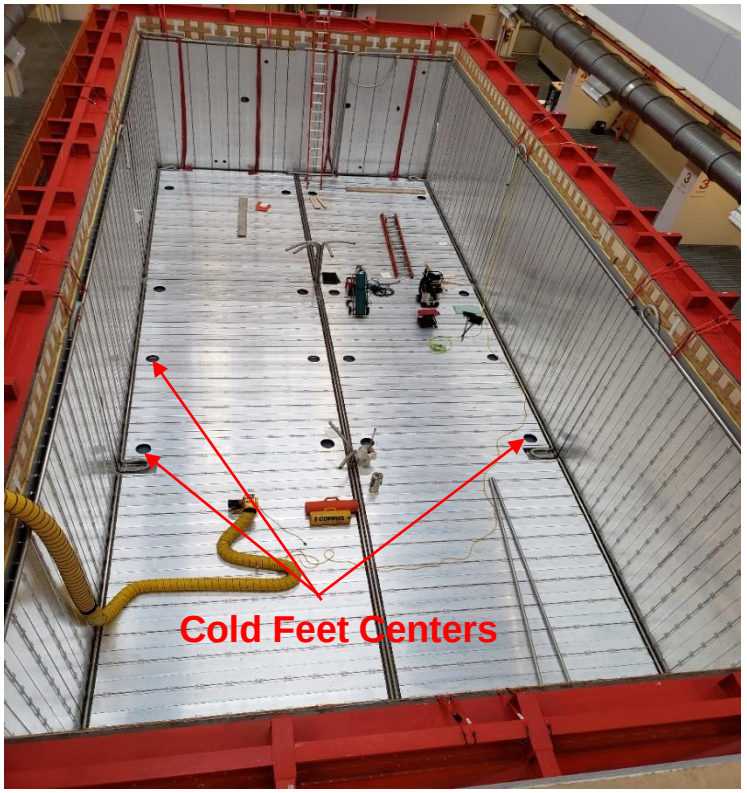

- Sliding Pads and Guiding Rails for the Cold Feet were installed and the centers measured
- The centers are called Cold Vessel Feet Centers where the ICARUS detectors will be positioned
- Cold Shield insulation was installed and surveyed with the Trimble S6
- Could not set up on the Cold Shield due to its unstable surface

Pre-Installed Locations of ICARUS Detectors

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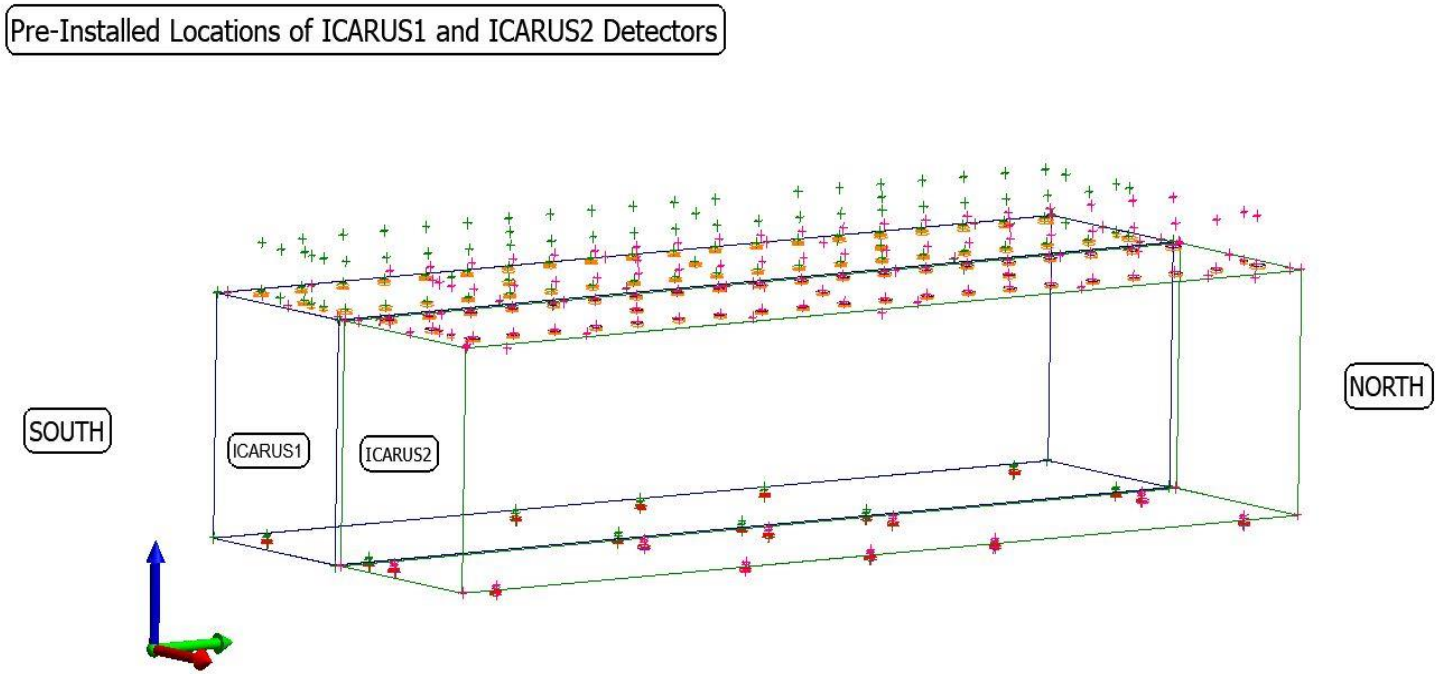

Pre-Installed Locations of ICARUS1 and ICARUS2 Detectors inside the Warm Vessel were determined by transforming the measured detectors in the parking lots into the Cold Feet centers measured inside the Warm Vessel, in the SBN-FD Building Coordinate System

Installation of ICARUS1 Detector

Dr. O'Sheg Oshinowo
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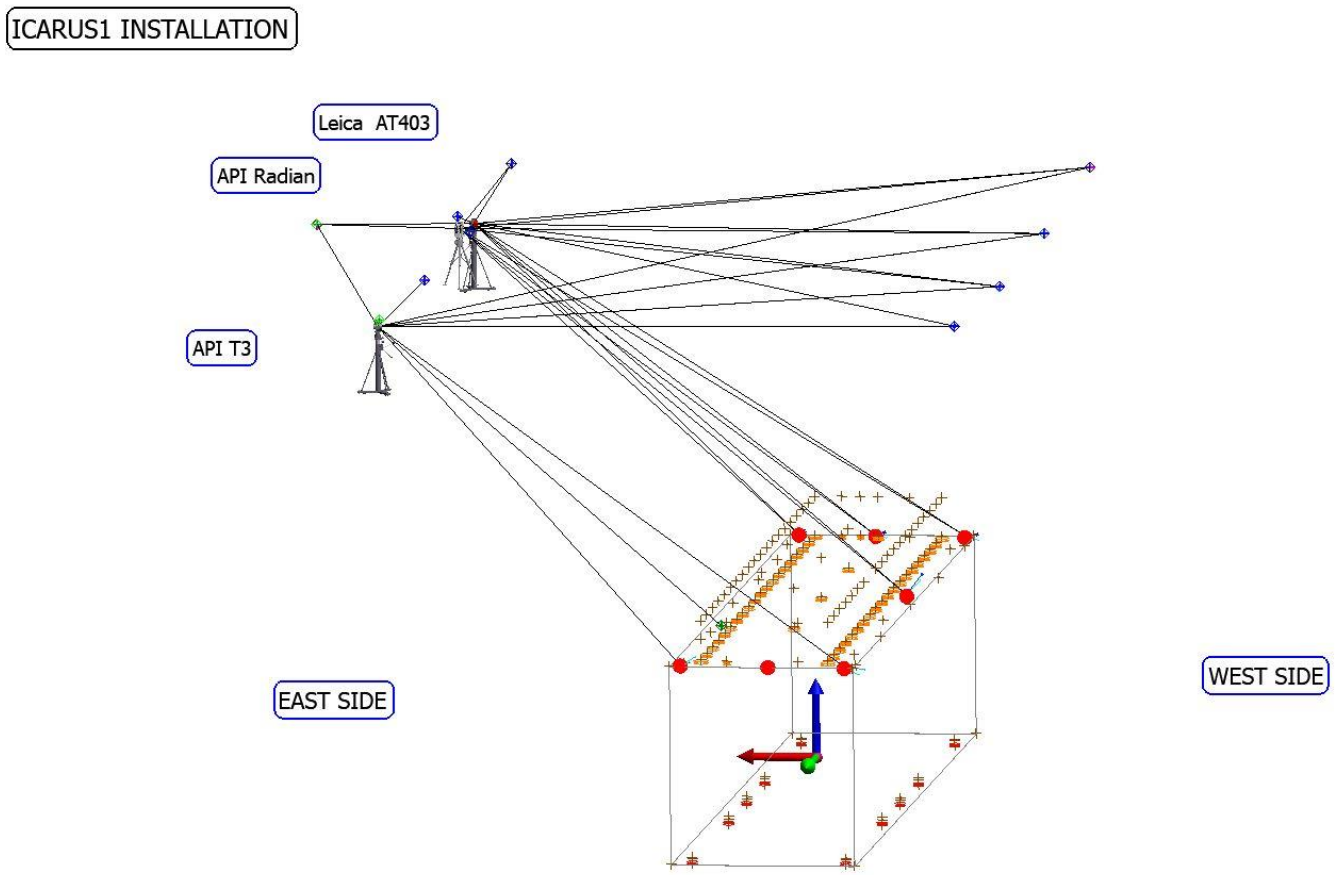

- Three different Laser Trackers were setup on the East Side simultaneously measuring three different fiducials on the north and south ends of the detector
- All visible fiducials were measured after ICARUS1 was positioned

Installation of the ICARUS1 Detector

Dr. O'Sheg Oshinowo
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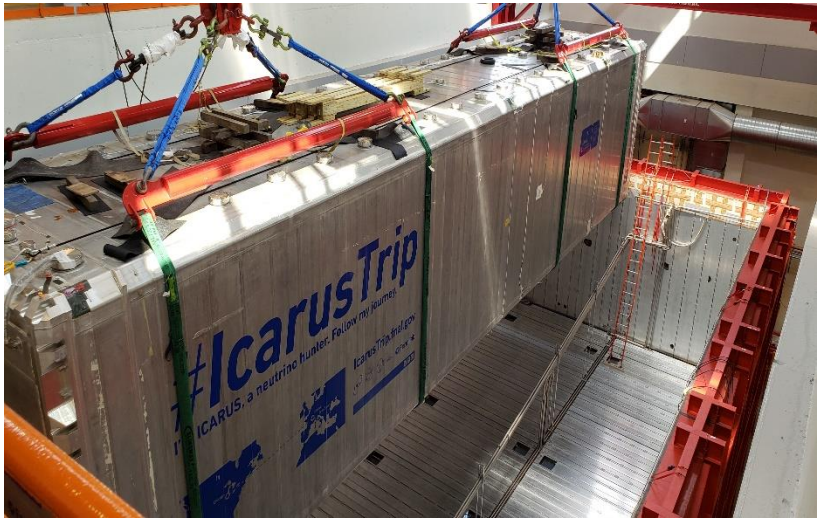

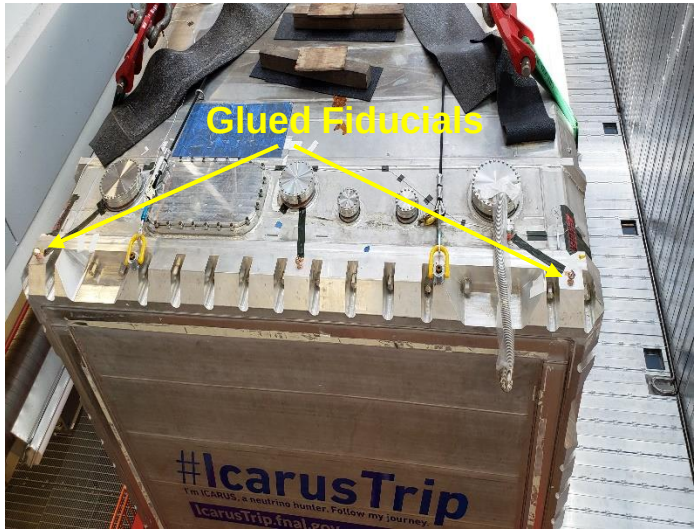

- Watch Window in the SA software was used to display the measured coordinates in real time as the detector was being lowered
- The crane operator used the Watch Window display to remove Roll, Pitch or Yaw
- Installed on August 9, 2018

ICARUS1 Detector Installed

Dr. O'Sheg Oshinowo
IWAA 2018 Conference
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October 8-12, 2018

All Vectors Summary: Vector Group
BOO_CALCS::ICARUS1 INSTALLED - ICARUS1 Pre-Installed

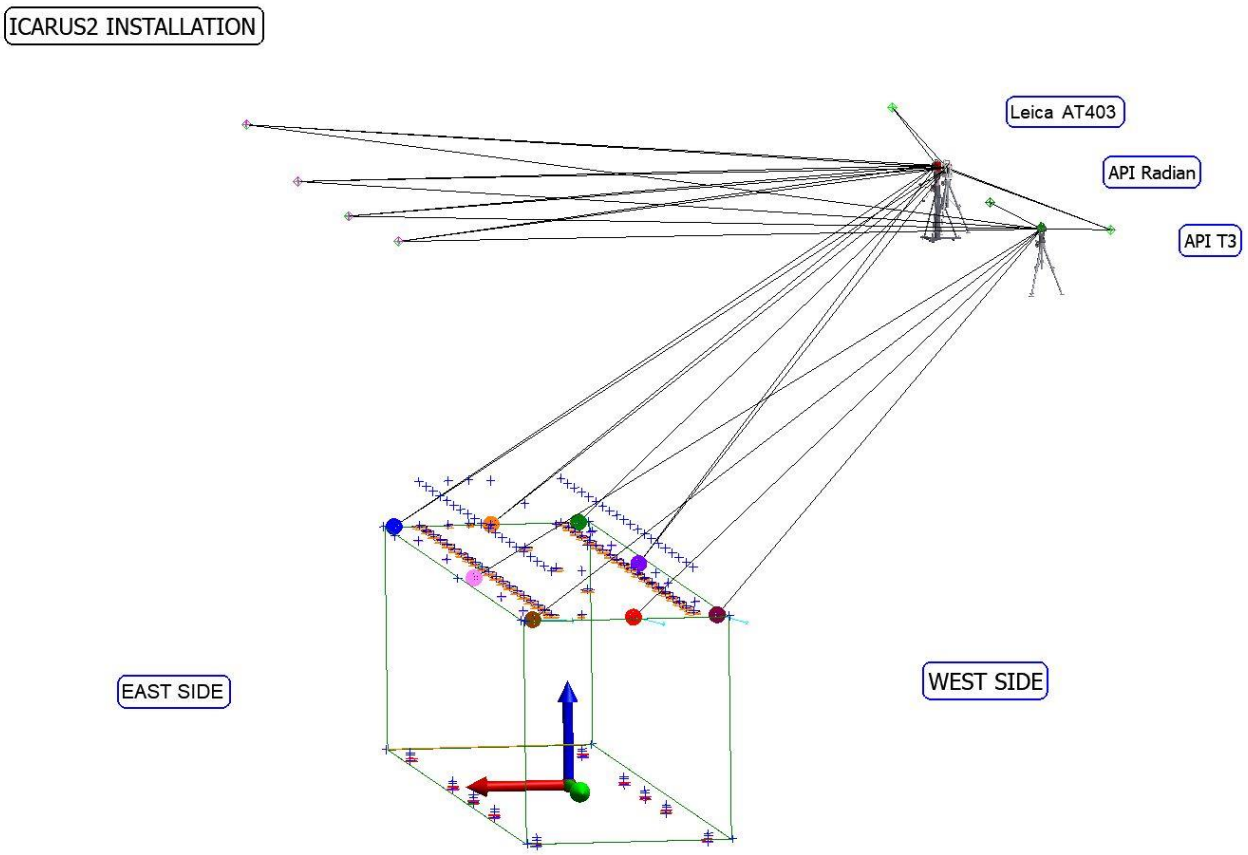
Statistic	dX (mm)	dY (mm)	dZ (mm)	Mag (mm)
Min	-3.6	-5.7	-1.9	3.2
Max	-1.1	2.0	2.9	6.5
Average	-2.3	-2.5	-0.4	5.1

Vector Group
BOO_CALCS::ICARUS1 INSTALLED - ICARUS1 Pre-Installed

Name	Begin			End			Delta				
	X1 (mm)	Y1 (mm)	Z1 (mm)	X2 (mm)	Y2 (mm)	Z2 (mm)	dX (mm)	dY (mm)	dZ (mm)	Mag (mm)	
ICARUS1-T_P	-3876.6	24292.8	5460.8	-3880.2	24294.7	5459.2	-3.6	1.9	-1.6	4.3	+
ICARUS1-T_R	-351.9	24310.7	5465.4	-354.3	24312.6	5466.4	-2.4	2.0	1.0	3.2	+
ICARUS1-T_C	-3796.6	13519.9	5478.7	-3799.4	13517.9	5481.6	-2.8	-1.9	2.9	4.5	+
ICARUS1-T_M	-1936.0	4527.7	5461.7	-1937.7	4522.0	5460.2	-1.7	-5.7	-1.5	6.1	+
ICARUS1-T_L	-3853.6	4504.4	5464.0	-3856.1	4498.7	5462.1	-2.5	-5.7	-1.9	6.5	+
ICARUS1-T_N	-278.7	4509.8	5465.1	-279.8	4504.2	5463.7	-1.1	-5.6	-1.4	5.9	+

Installation of ICARUS2 Detector

Dr. O'Sheg Oshinowo
IWAA 2018 Conference
Fermilab, Batavia, IL, USA
October 8-12, 2018



- Three different Laser Trackers were setup on the West Side simultaneously measuring three different fiducials on the north and south ends of the detector
- All visible fiducials were measured after ICARUS2 was positioned

Installation of the ICARUS2 Detector

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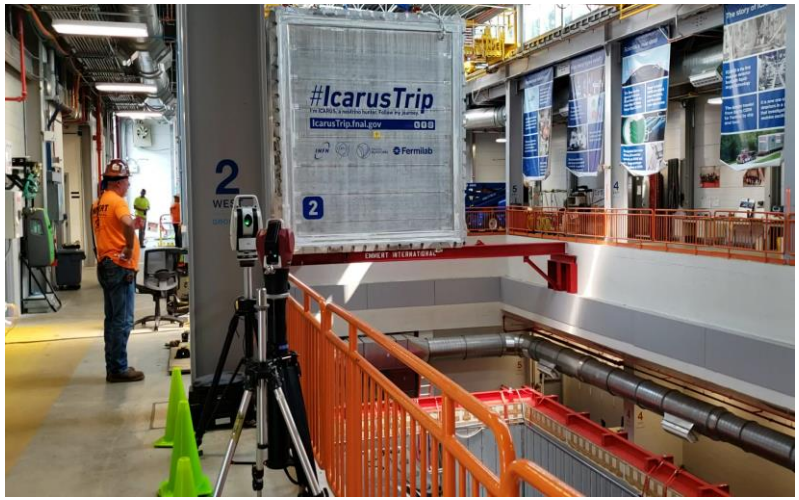
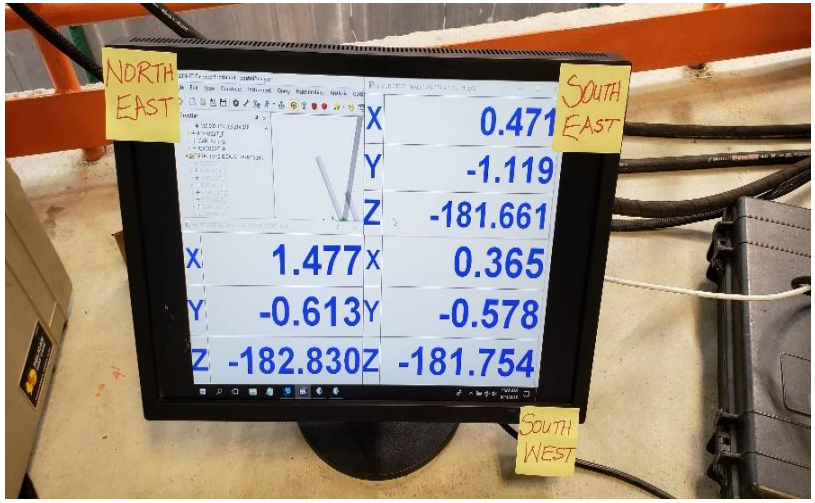
IWAA 2018 Conference
Fermilab, Batavia, IL, USA
October 8-12, 2018





- Watch Window in the SA software was used to display the measured coordinates in real time as the detector was being lowered
- The crane operator used the Watch Window display to remove Roll, Pitch or Yaw
- Installed on August 14, 2018

ICARUS2 Detector Installed

Dr. O'Sheg Oshinowo
IWAA 2018 Conference
Fermilab, Batavia, IL, USA
October 8-12, 2018

All Vectors Summary: Vector Group BOO_CALCS::ICARUS2 INSTALLED - ICARUS2 Pre-Installed				
Statistic	**dX**	**dY**	**dZ**	**Mag**
	(mm)	(mm)	(mm)	(mm)
Min	-7.8	-3.6	-1.9	2.2
Max	0.6	1.3	2.6	7.9
Average	-2.6	-1.5	-0.1	4.4

Vector Group BOO_CALCS::ICARUS2 INSTALLED - ICARUS2 Pre-Installed											
Name	**Begin**			**End**			**Delta**				
	X1	Y1	Z1	X2	Y2	Z2	dX	dY	dZ	Mag	
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	
ICARUS2-T_N	3908.7	4530.0	5473.9	3909.3	4526.5	5474.2	0.6	-3.6	0.3	3.6	+
ICARUS2-T_M	2037.6	4540.1	5469.1	2038.1	4536.9	5468.9	0.4	-3.1	-0.2	3.2	+
ICARUS2-T_L	349.5	4541.9	5471.1	349.9	4539.2	5470.6	0.4	-2.7	-0.5	2.8	+
ICARUS2-T_C	362.0	13354.5	5475.9	361.4	13352.7	5477.0	-0.6	-1.8	1.1	2.2	+
ICARUS2-T_H	3818.3	15408.1	5471.5	3816.9	15407.8	5474.1	-1.4	-0.3	2.6	3.0	+
ICARUS2-T_P	308.4	24287.7	5482.2	302.3	24286.4	5480.3	-6.1	-1.3	-1.9	6.6	+
ICARUS2-T_Q	1927.0	24291.2	5478.8	1921.0	24291.2	5477.2	-6.1	-0.1	-1.6	6.3	+
ICARUS2-T_R	3873.1	24299.9	5478.9	3865.4	24301.1	5478.6	-7.8	1.3	-0.3	7.9	+

ICARUS1 and ICARUS2 Detector Installed

Dr. O'Sheg Oshinowo
IWAA 2018 Conference
Fermilab, Batavia, IL, USA
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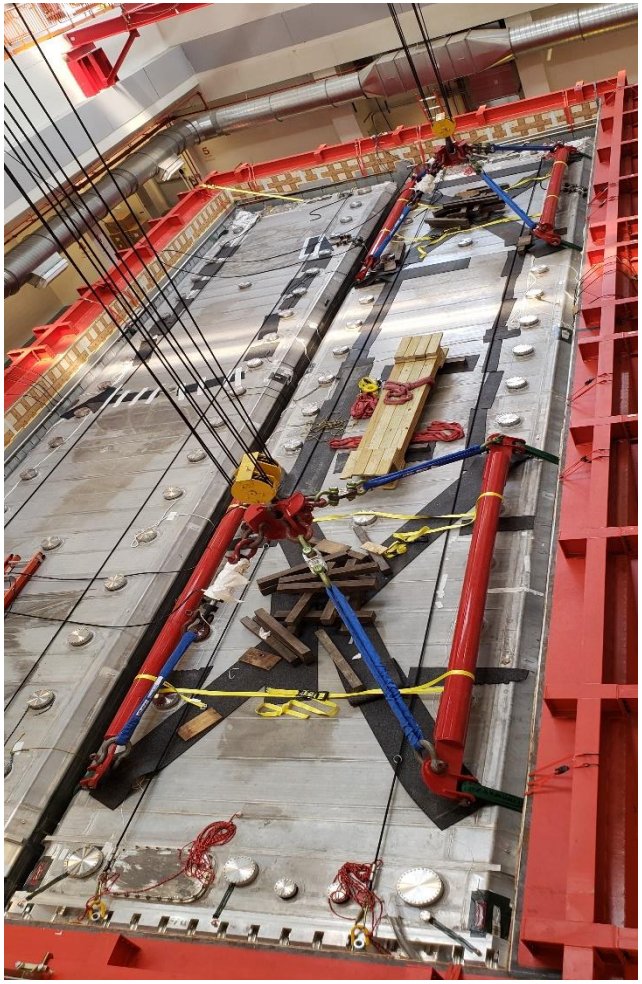
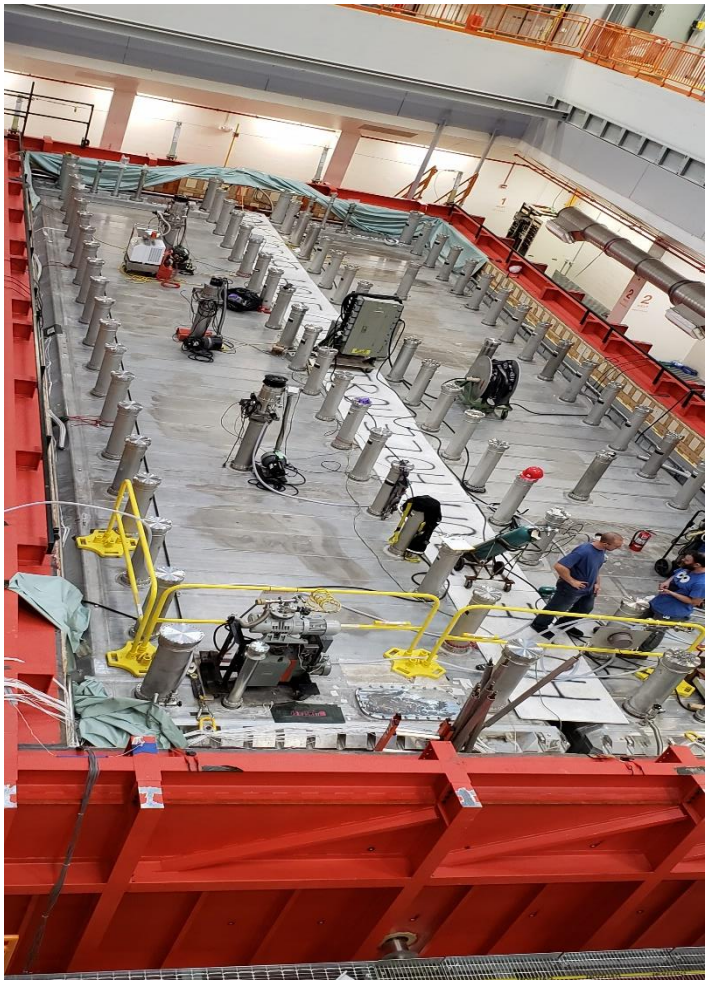


- ICARUS1 and ICARUS2 as installed on August 14, 2018



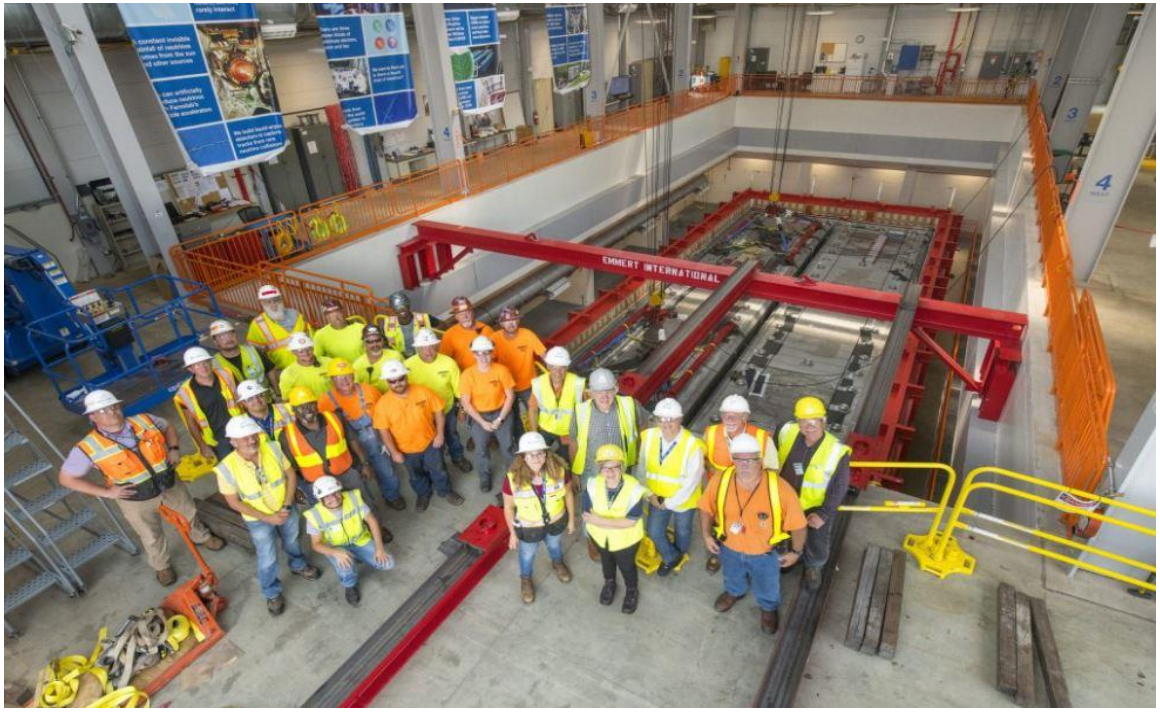
- ICARUS1 and ICARUS2 on October 5, 2018 with the Chimneys installed

Acknowledgment

❑ I would like to thank

• Alignment and Metrology Department members who participated in the ICARUS Neutrino Survey, especially Chuck Wilson

Questions?



ICARUS Neutrino Detector Installation at Fermilab

https://www.youtube.com/watch?v=1Qmr7WEKy-Q