

Survey of the Fermilab Short Baseline Neutrino Far Detector

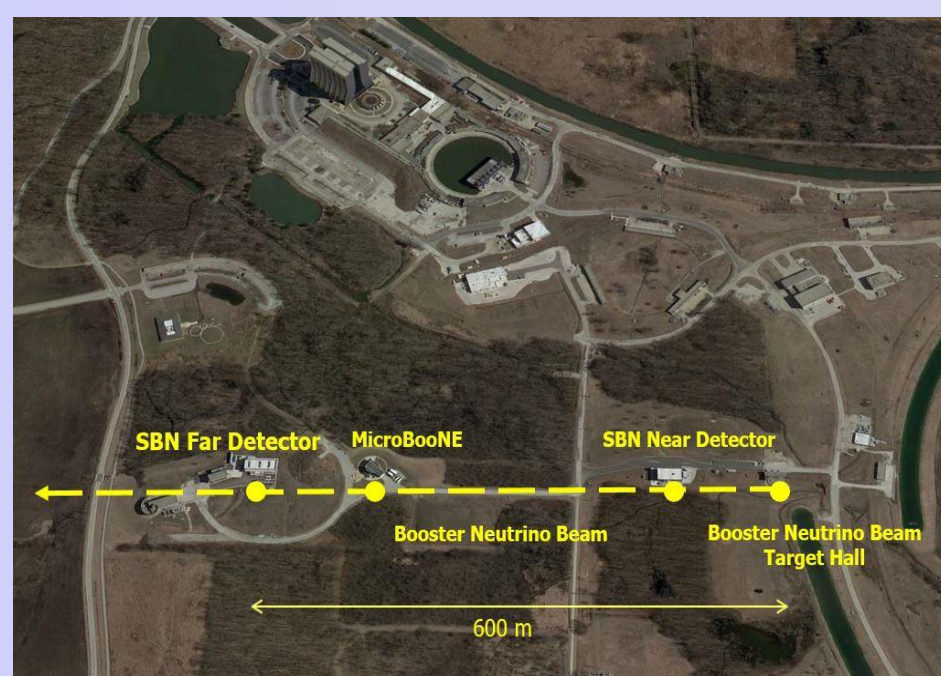
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Short Baseline Neutrino (SBN) Program

Consists of:

- Short Baseline Neutrino Far Detector (SBN-FD)** is the ICARUS neutrino detector, located in a new building 600 m from the Booster Neutrino Beam (BNB) target.
- MicroBooNE Detector**, which has been taking data with the BNB since 2015, is located at 470 m from the target.
- Short-Baseline Near Detector (SBND)**, is located 110 m from the BNB target.



Short Baseline Neutrino Far Detector (SBN-FD)

- Short Baseline Neutrino Far Detector are located in the SBN-FD Building
- The Detector Hall houses the ICARUS Detectors



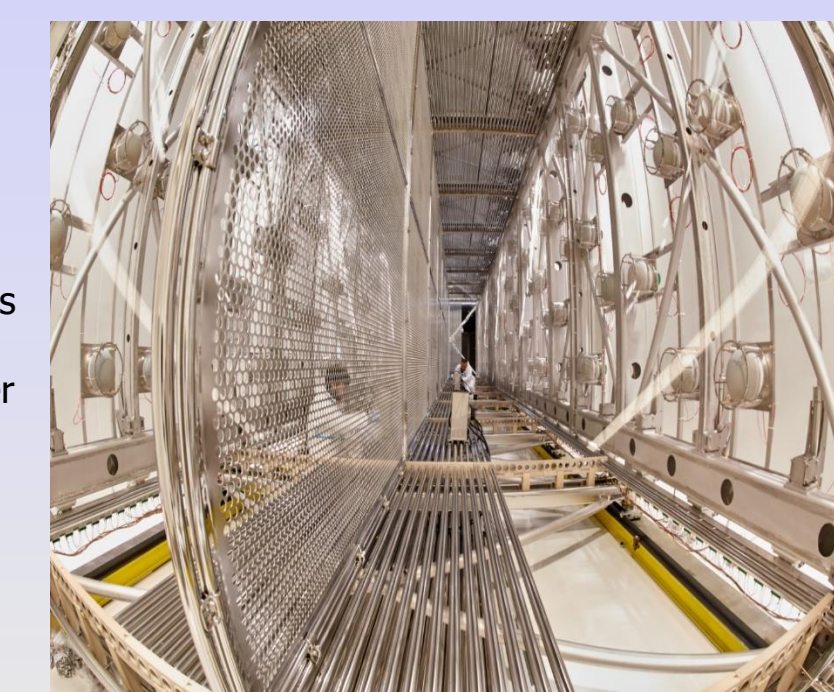
ICARUS Detectors

- ICARUS neutrino detector is 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

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



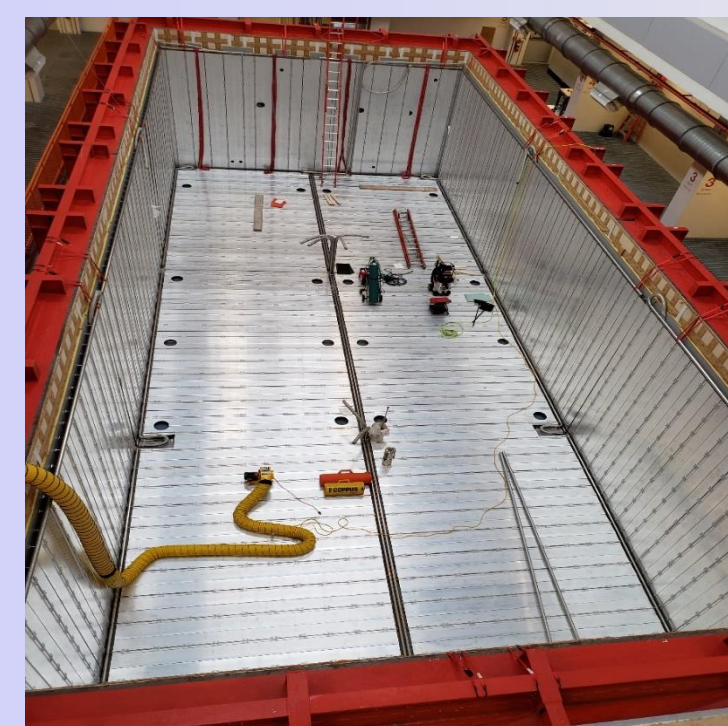
ICARUS Detector

- 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



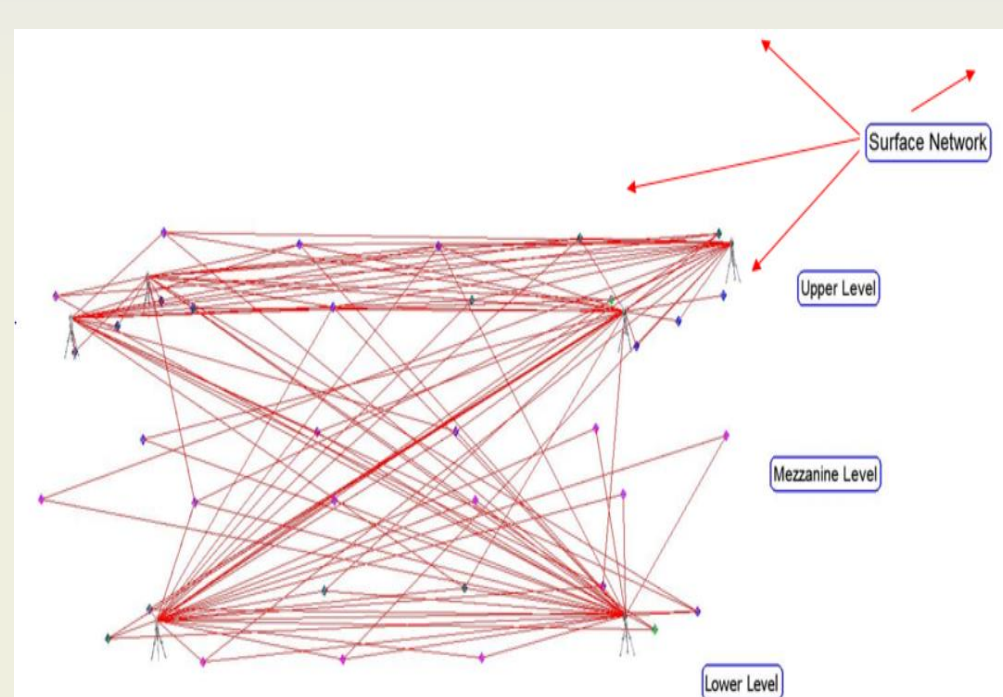
Warm Vessel

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



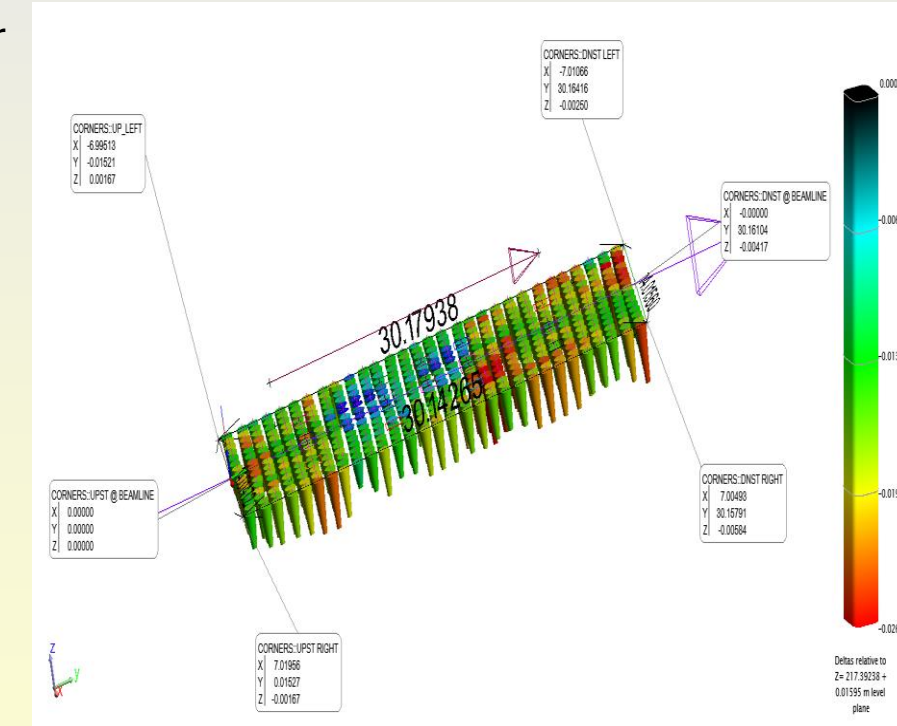
SBN-FD Control Network

- 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

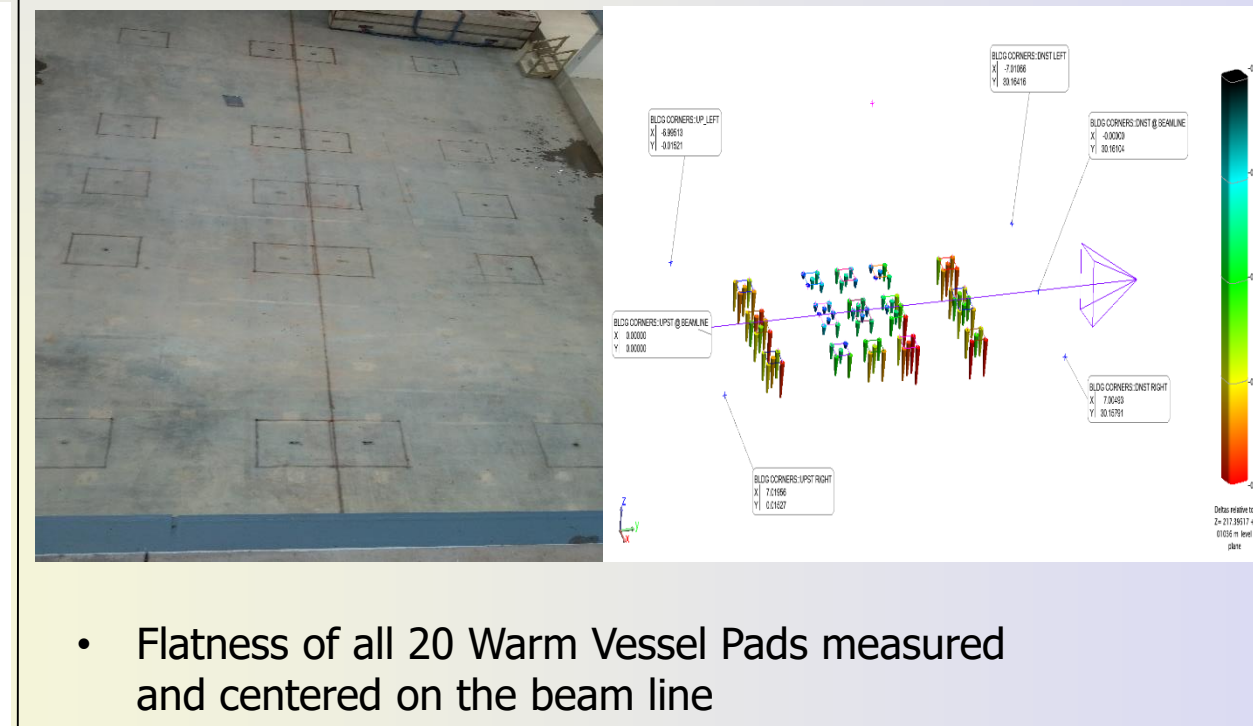


SBND-FD Floor Flatness Measurements

- Floor Flatness measurements of the SBN Far Detector building floor using a 1 m x 1 m grid centered on the beam line made with the API Radian Laser Tracker
- Height Deltas relative level average fitted plane range from -26.5 mm to 0 mm
- Building corners were located to define local Building Coordinate System
- Measurement results are used build 20 concrete pads for the Warm Vessel that holds the ICARUS detector to sit on

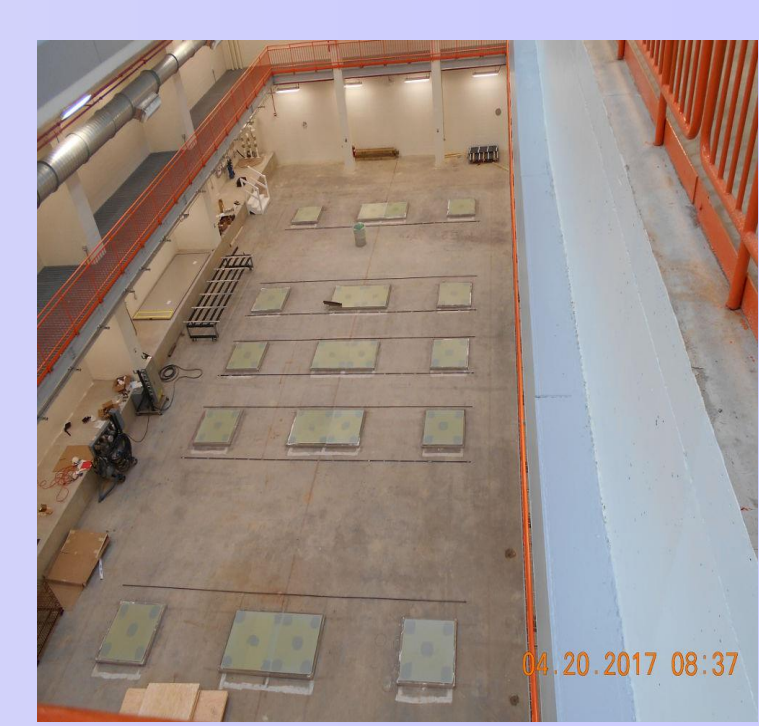


Warm Vessel Pads Flatness

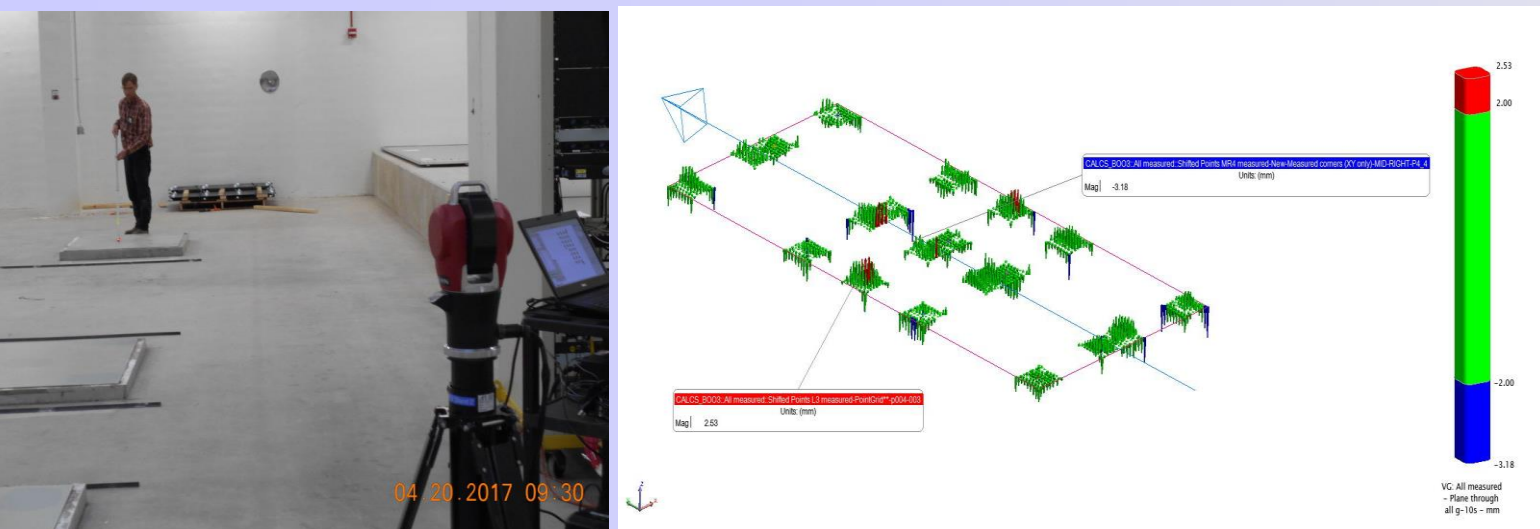


Warm Vessel Pads

- Measurement results were used build 20 concrete pads for the Warm Vessel that holds the ICARUS detector to sit on

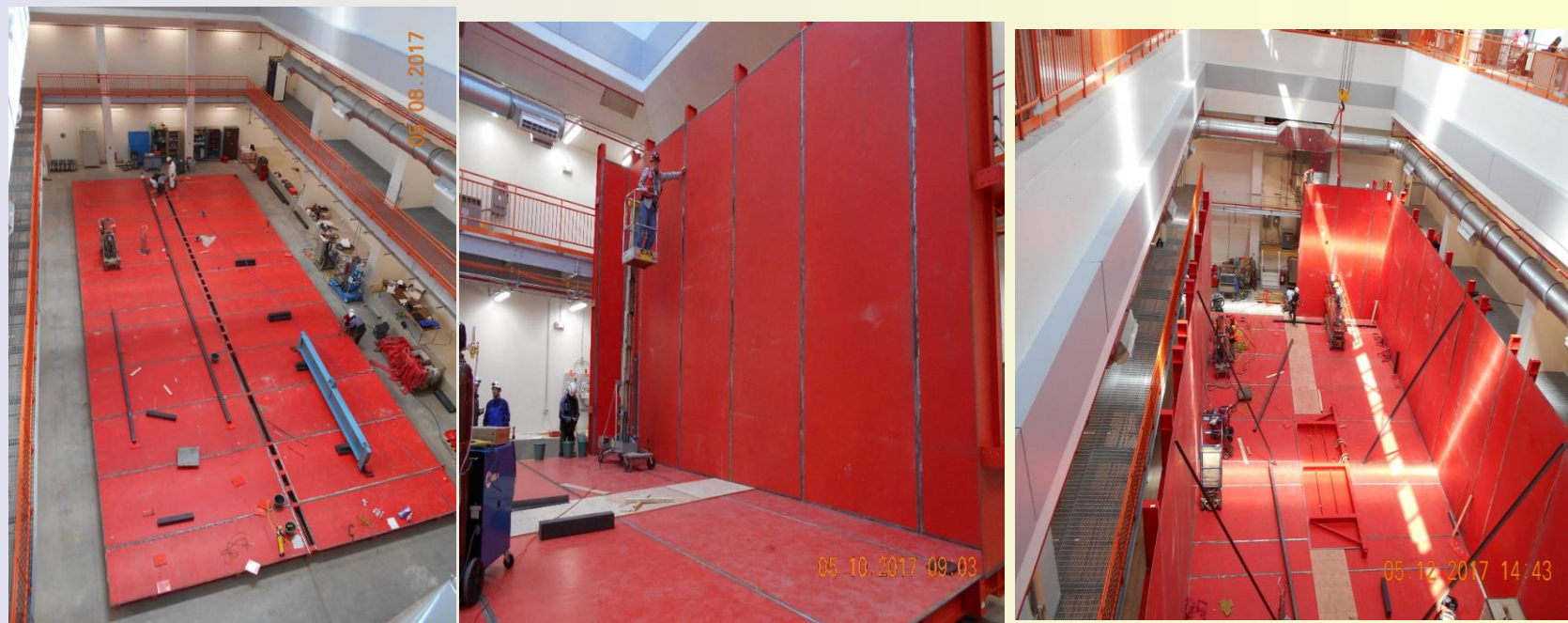


Warm Vessel Pads Flatness

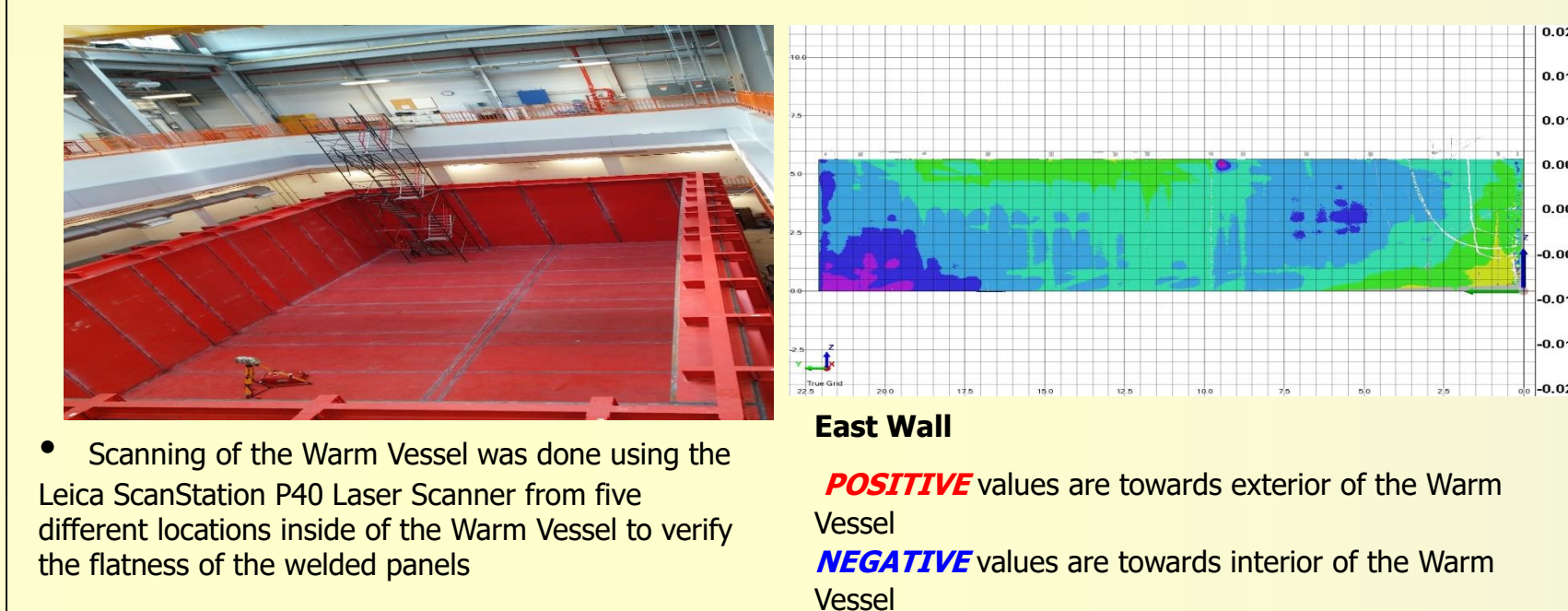


Warm Vessel Pads were steel plates grouted with concrete. A G-10 material was glued on top each steel plate. Flatness measured and centered on the beam line

Warm Vessel Construction

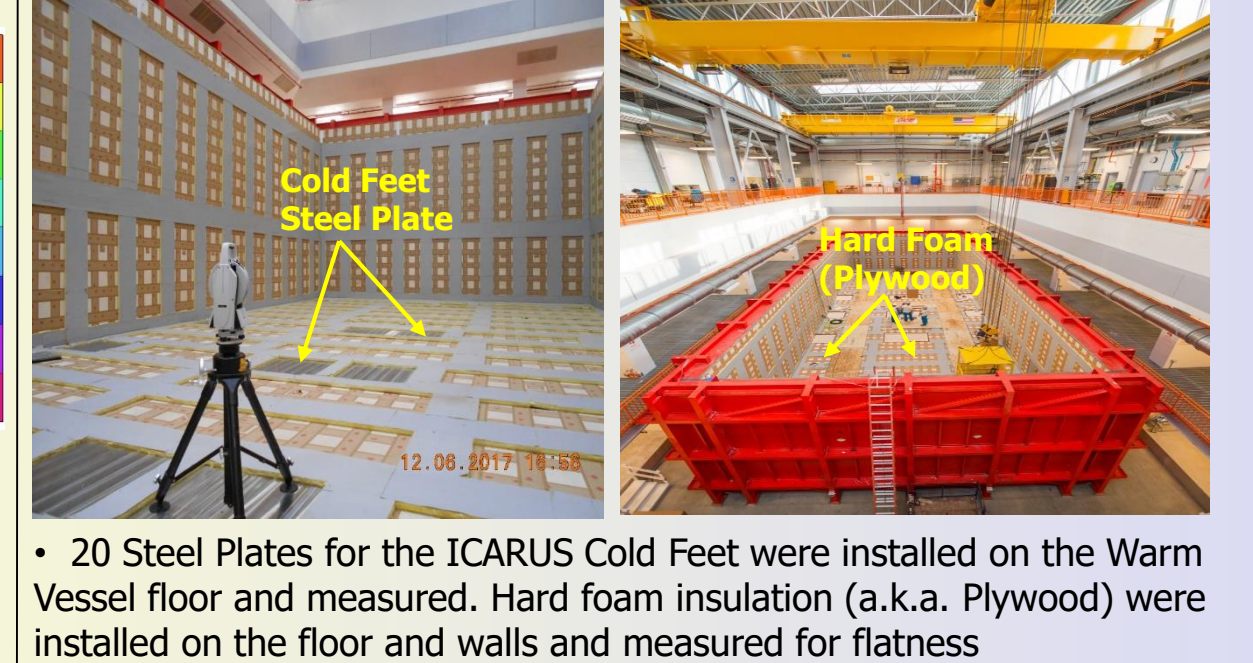


Scanning Welded Warm Vessel



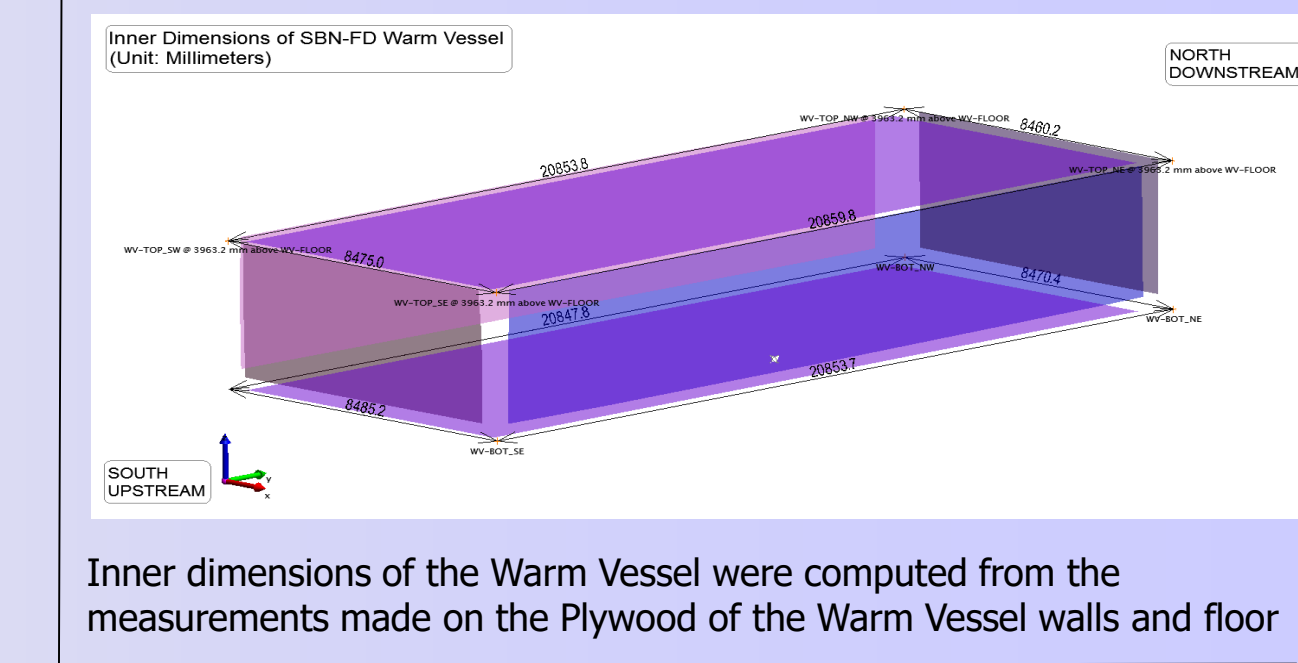
Scanning of the Warm Vessel was done using the Leica ScanStation P40 Laser Scanner from five different locations inside of the Warm Vessel to verify the flatness of the welded panels

Welded Warm Vessel Insulation



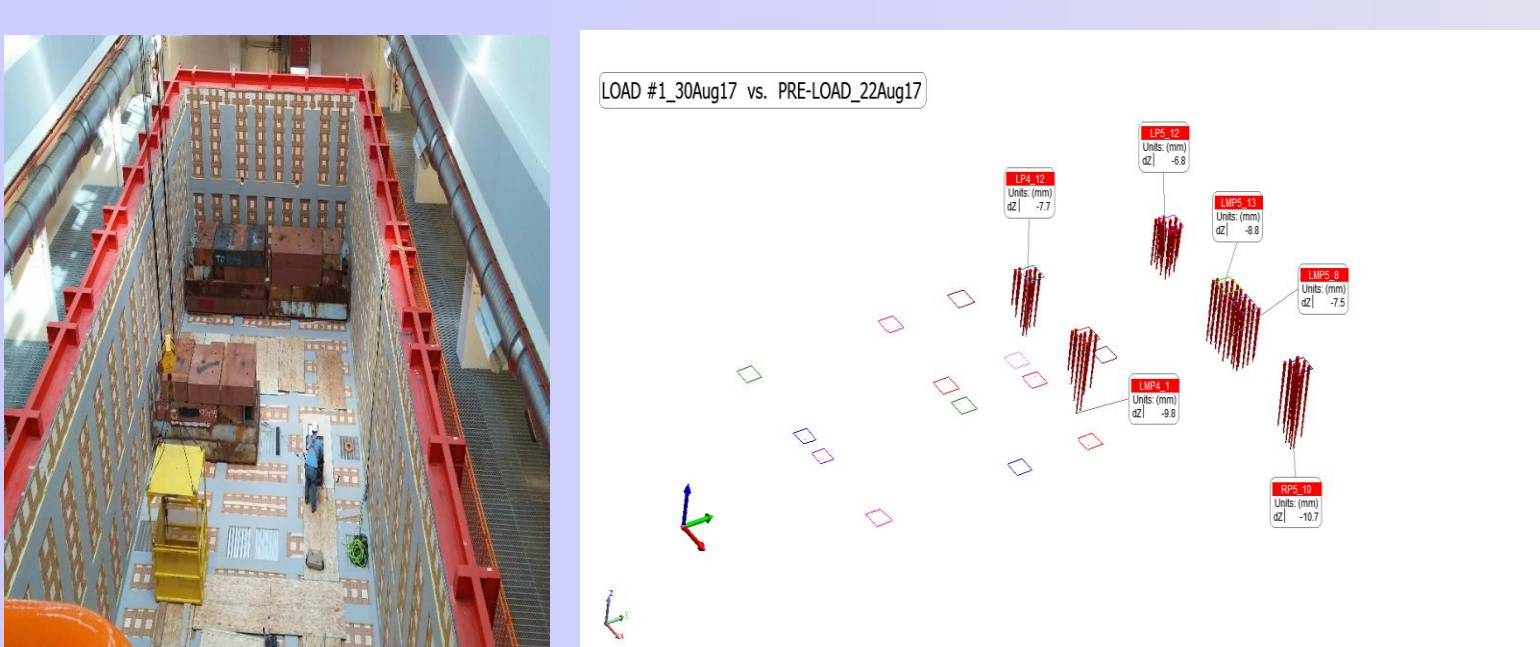
- 20 Steel Plates for the ICARUS Cold Feet were installed on the Warm Vessel floor and measured. Hard foam insulation (a.k.a. Plywood) were installed on the floor and walls and measured for flatness

Inner Dimensions of the Warm Vessel



Inner dimensions of the Warm Vessel were computed from the measurements made on the Plywood of the Warm Vessel walls and floor

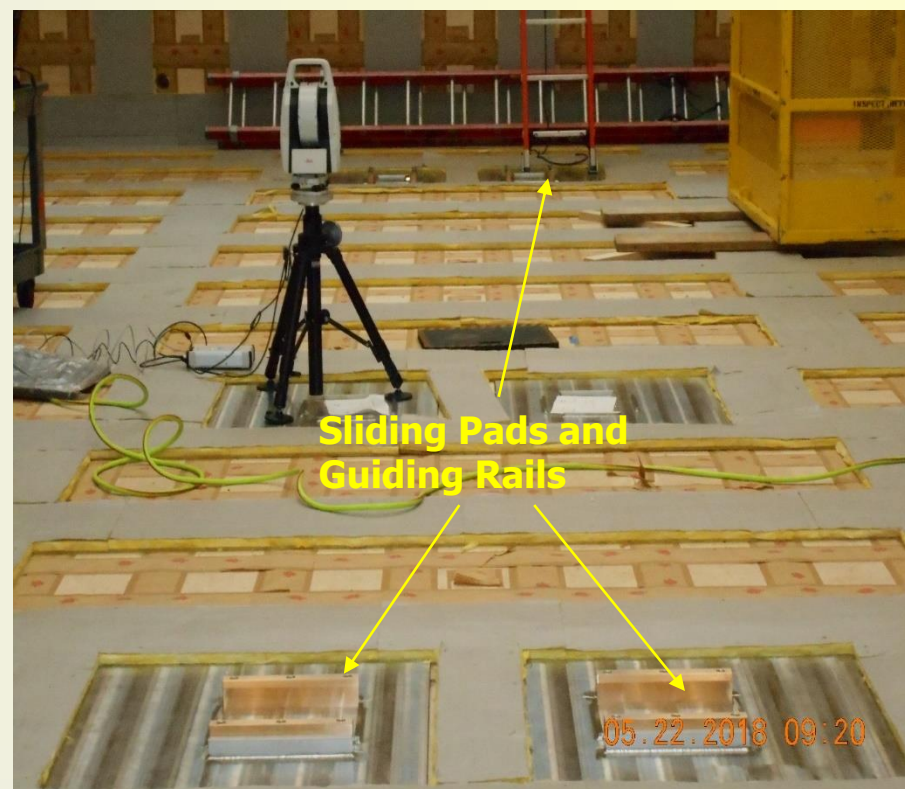
Foam Compression Test



Foam Compression Test was performed inside the Warm Vessel. Measurements were made on the Island Steel Plates with the LT401 Laser Tracker.

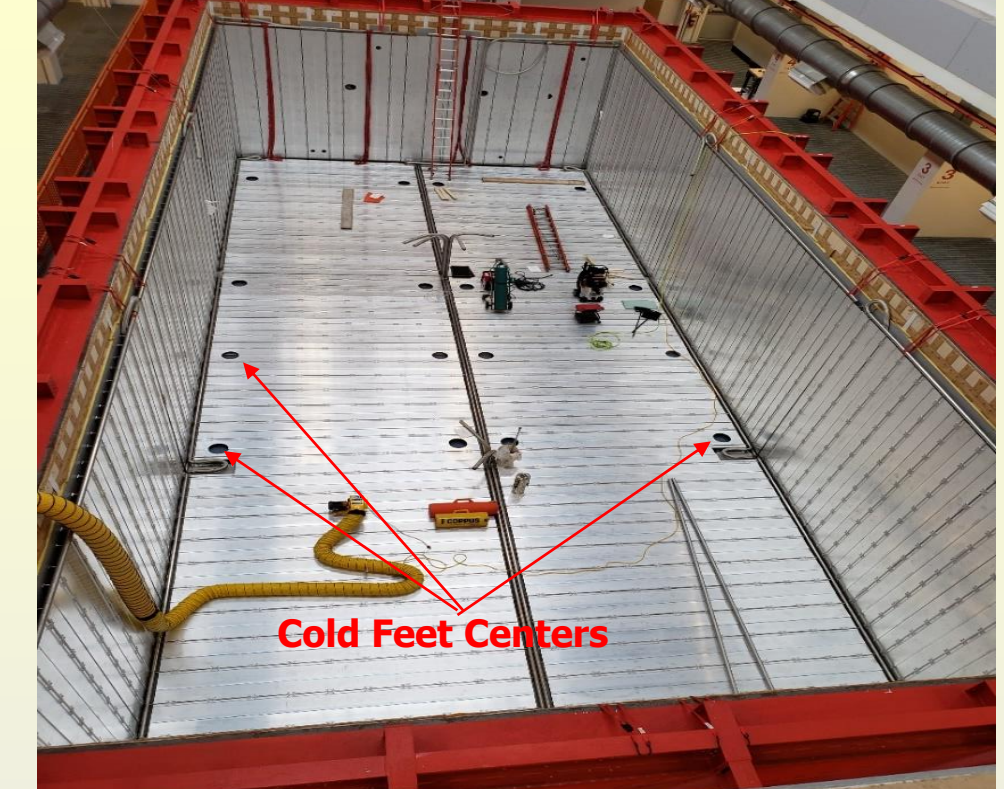
Cold Feet Sliding Pads and Guiding Rails

- 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

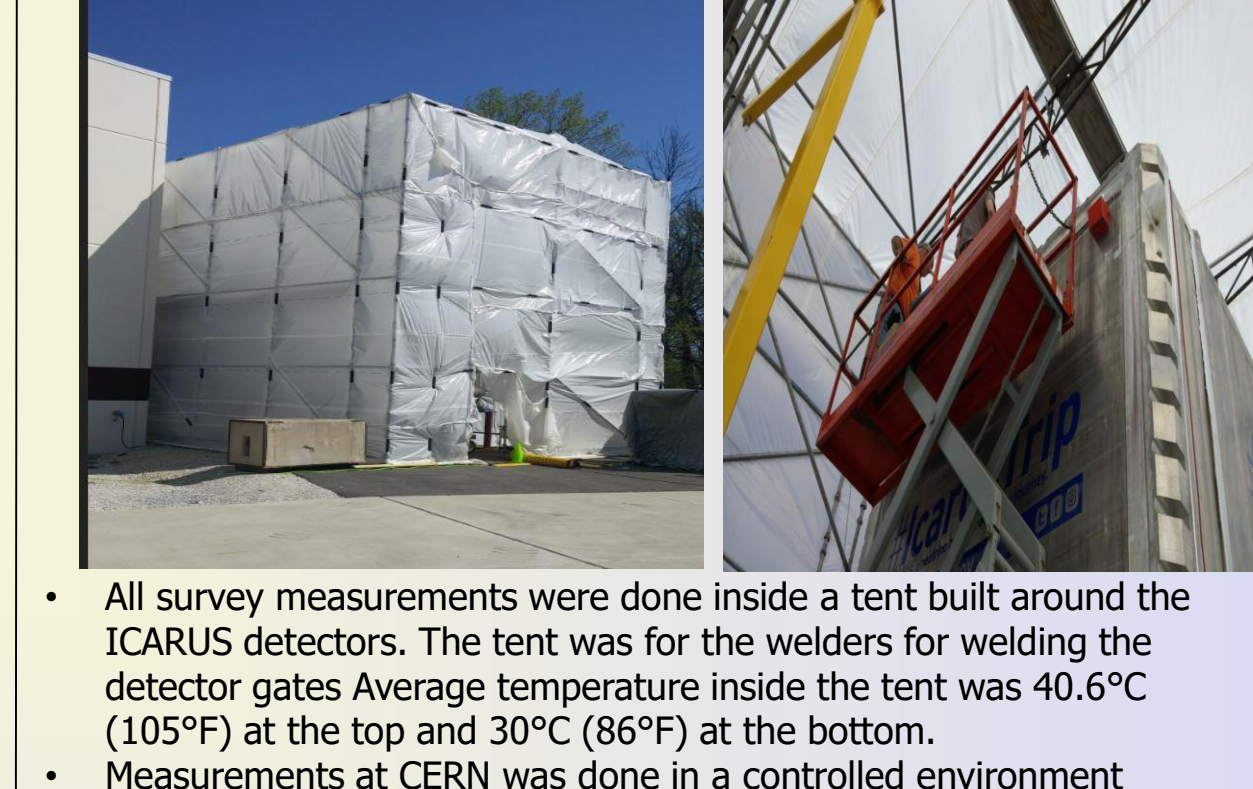


Cold Shield Insulation

- Cold Shield insulation was installed and surveyed with the Trimble S6
- Could not set up on the Cold Shield due to its unstable surface

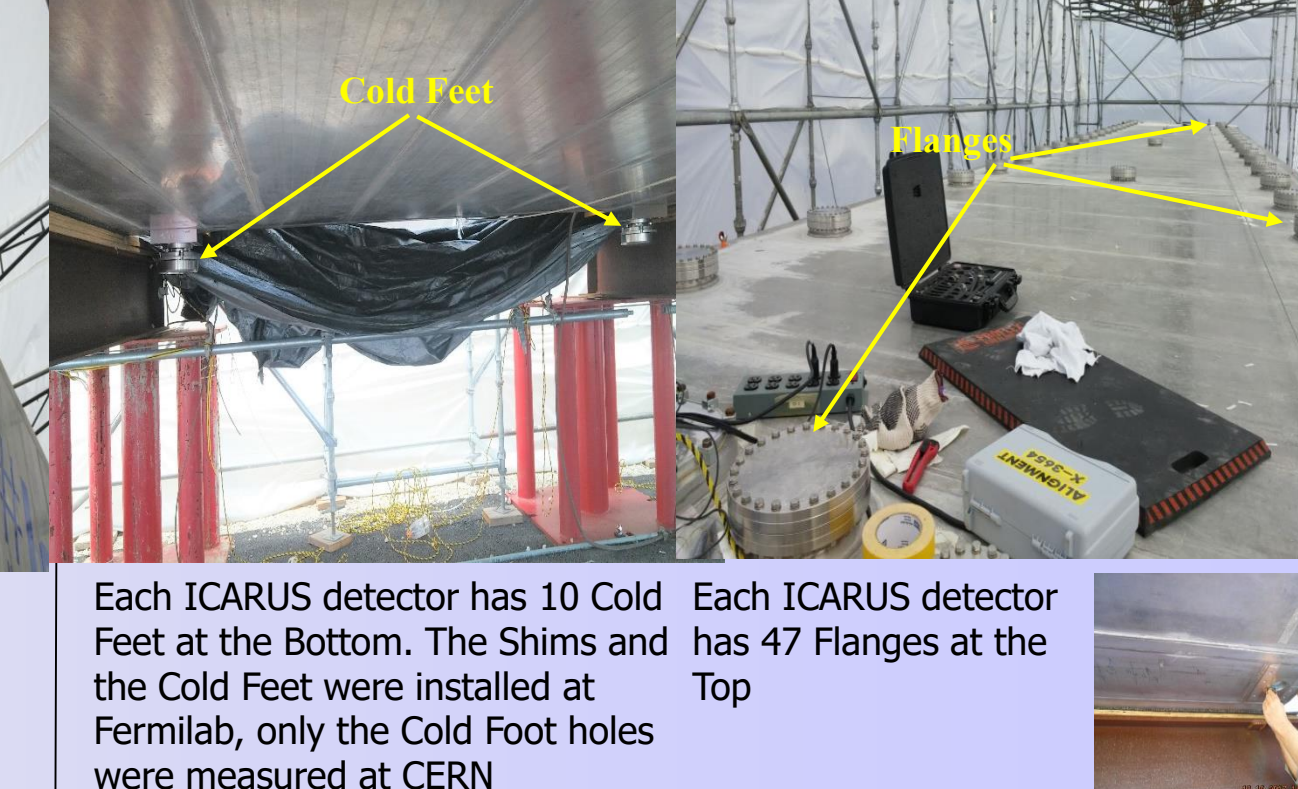


ICARUS Measurements in Parking Lot



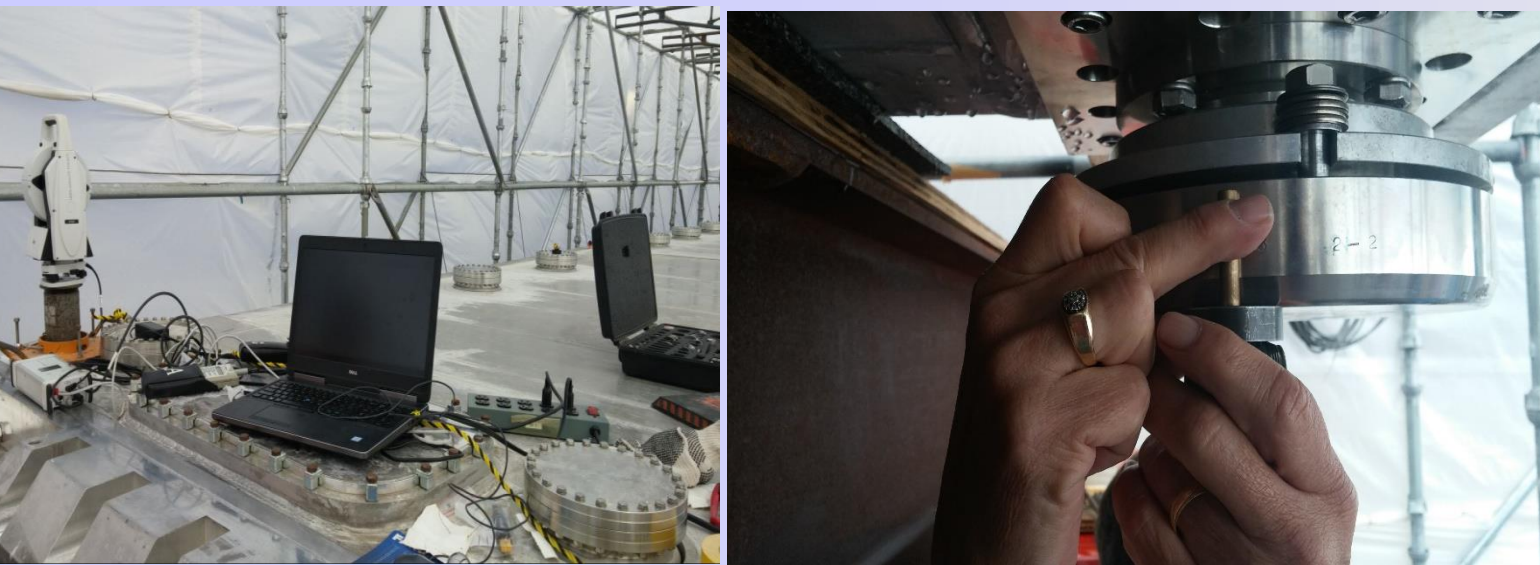
- All survey measurements were done inside a tent built around the ICARUS detectors. The tent was for the welders for welding the detector gates Average temperature inside the tent was 40.6°C (105°F) at the top and 30°C (86°F) at the bottom.
- Measurements at CERN was done in a controlled environment

ICARUS Measurements in Parking Lot



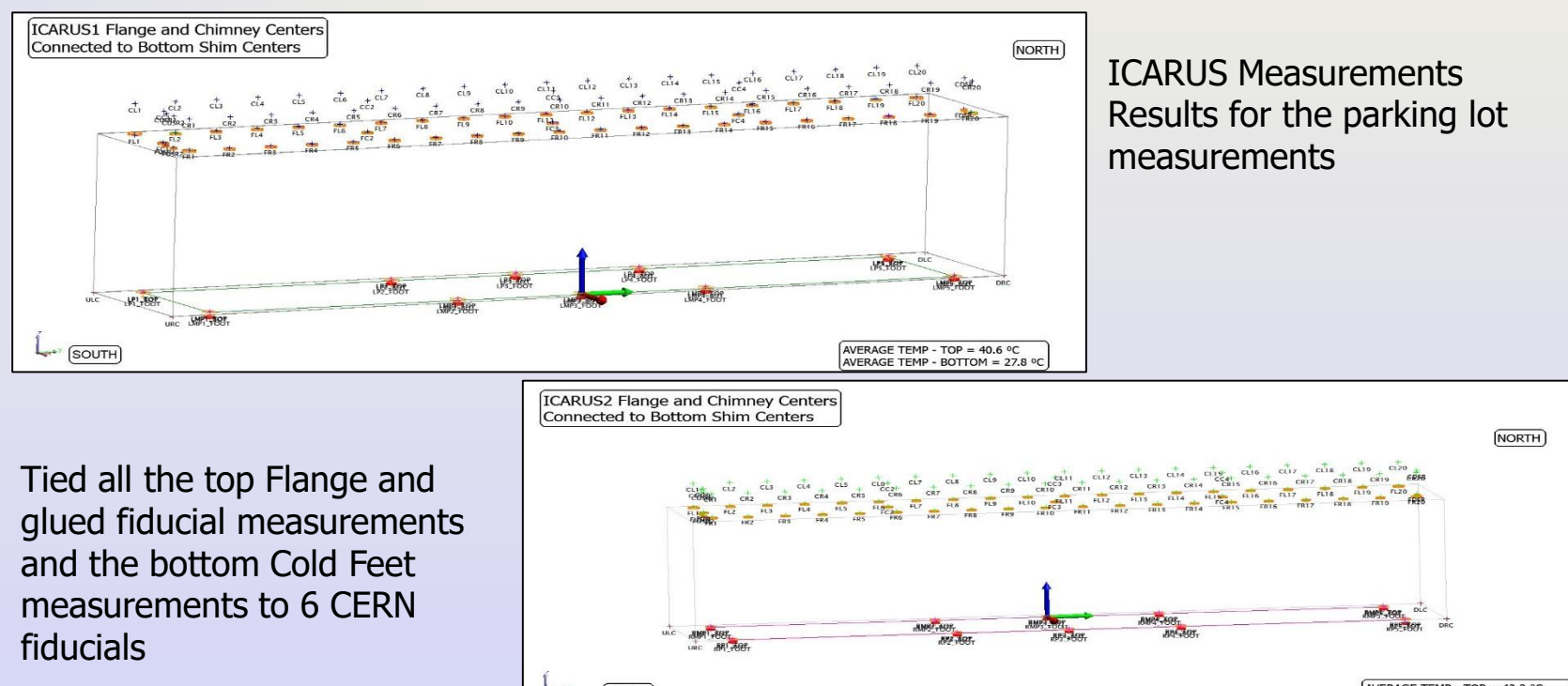
Each ICARUS detector has 10 Cold Feet at the Bottom. The Shims and Flanges were installed at Top Fermilab, only the Cold Foot holes were measured at CERN

ICARUS Measurements in Parking Lot



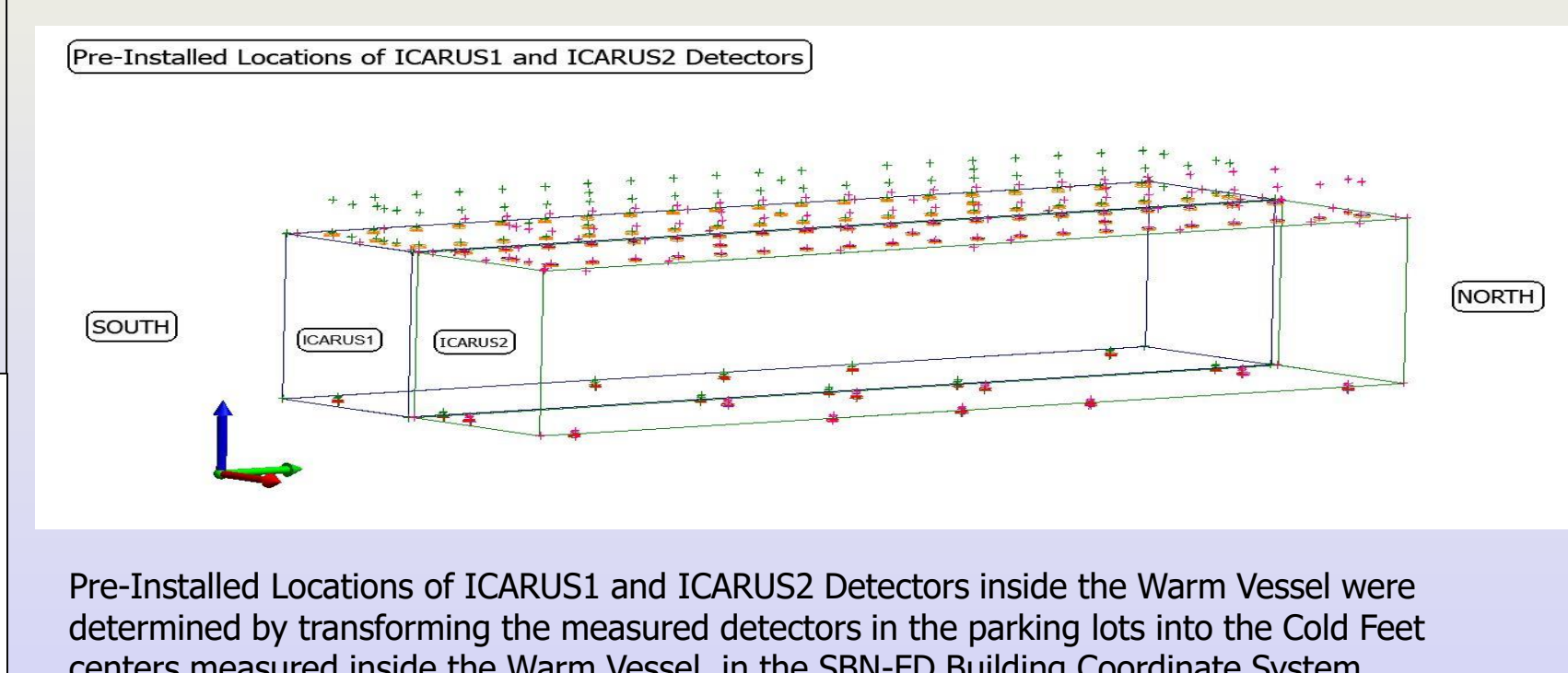
Top Flanges were measured as circles. Centers determined from circle fits to measurements. Chimney centers were projected vertically by 840 mm. Bottom Cold Feet were measured as circles. Centers determined from circle fits to measurements

ICARUS Measurements Results



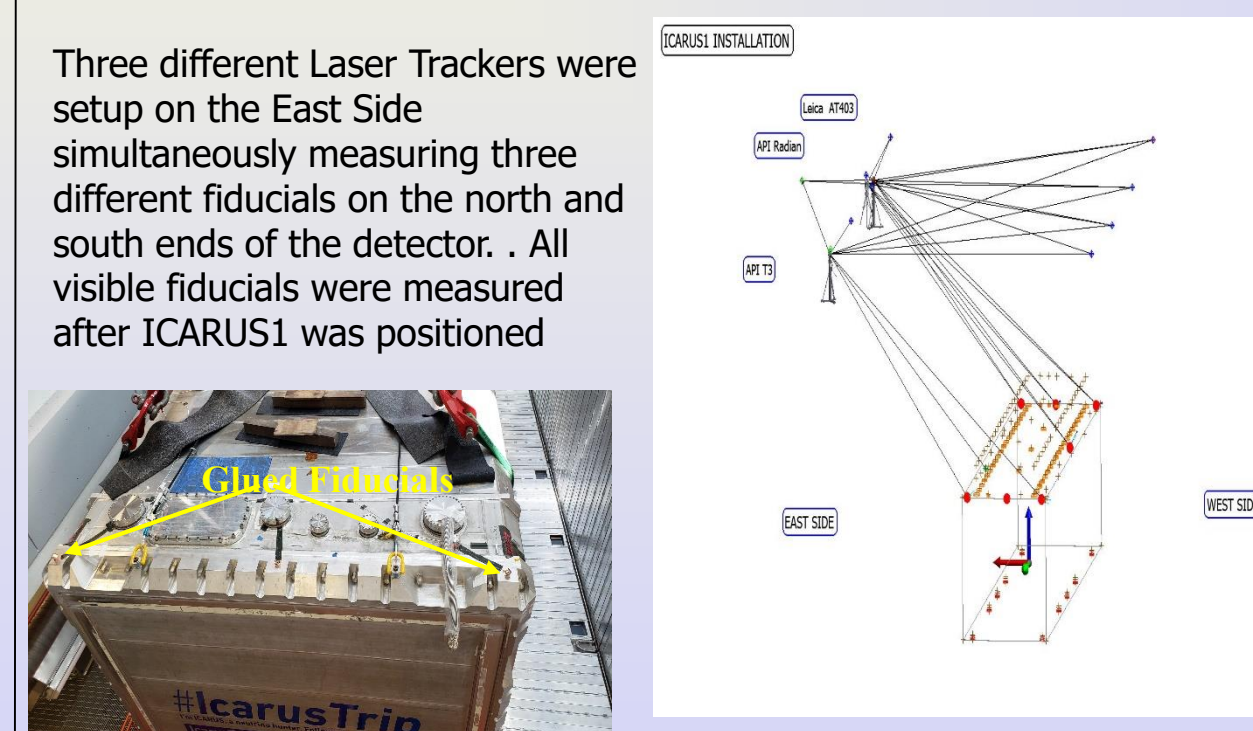
Tied all the top Flange and glued fiducial measurements and the bottom Cold Feet measurements to 6 CERN fiducials

Pre-Installed Locations of ICARUS Detectors



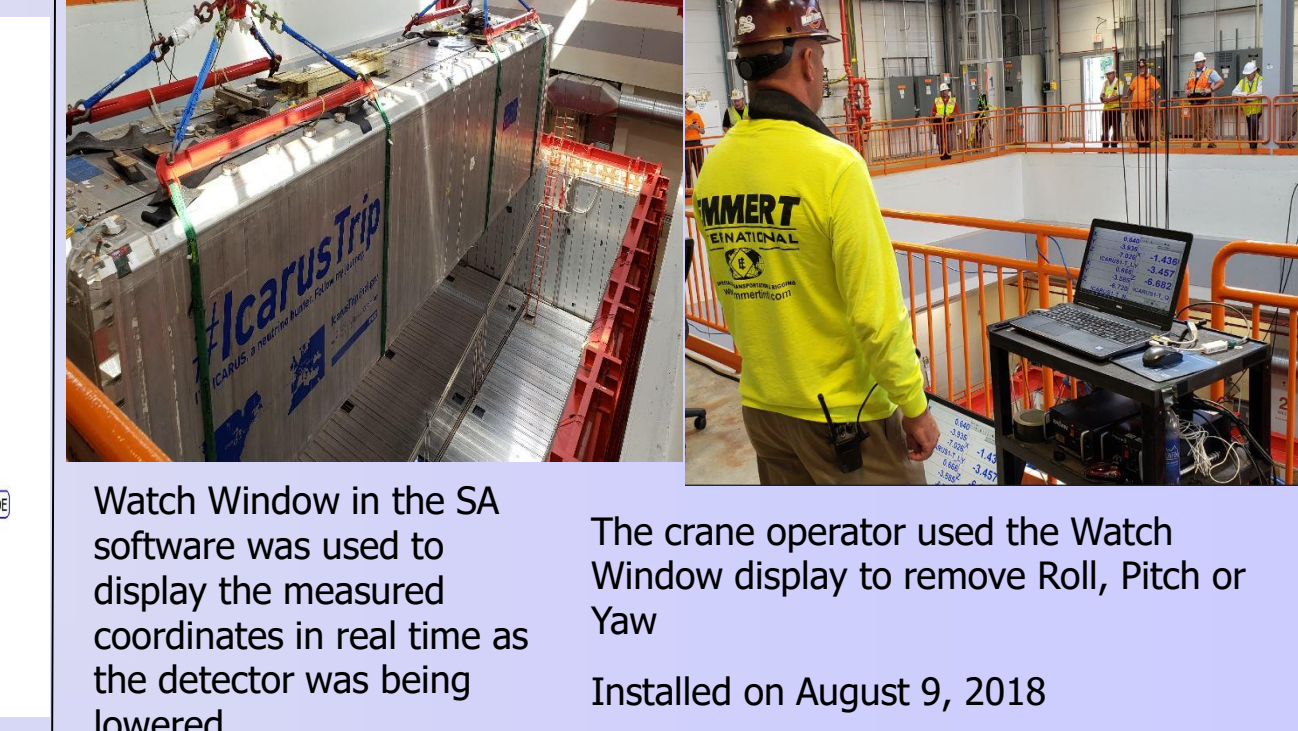
Pre-Installed Locations of ICARUS1 and ICARUS2 Detectors inside the Warm Vessel were determined by transforming the measured detectors in the parking lots into the Cold Feet centers measured inside the Warm Vessel, in the SBN-FD Building Coordinate System

Installation of ICARUS1 Detector



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

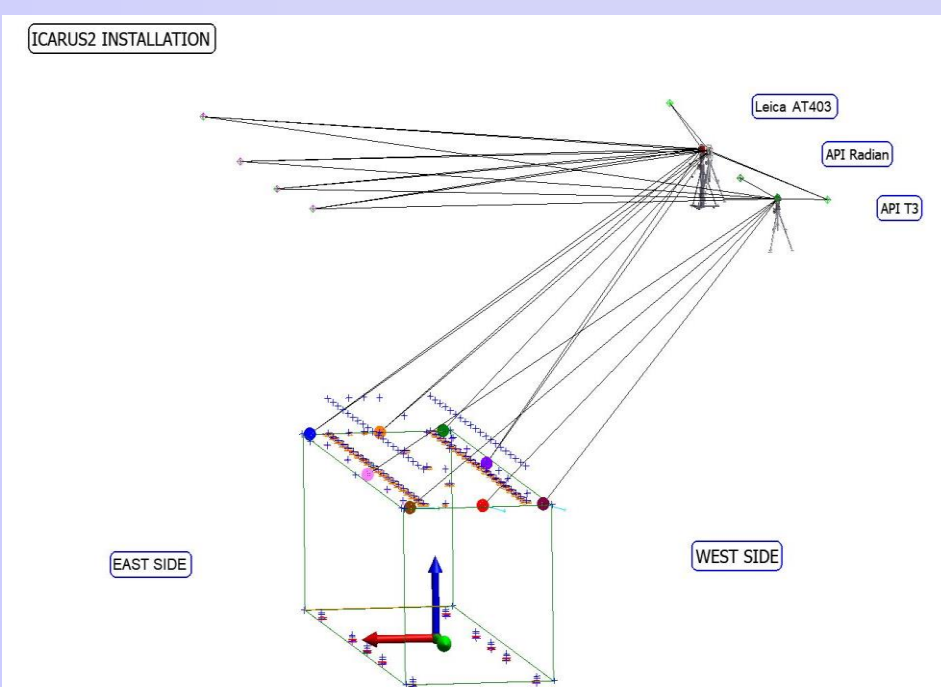
Installation of ICARUS1 Detector



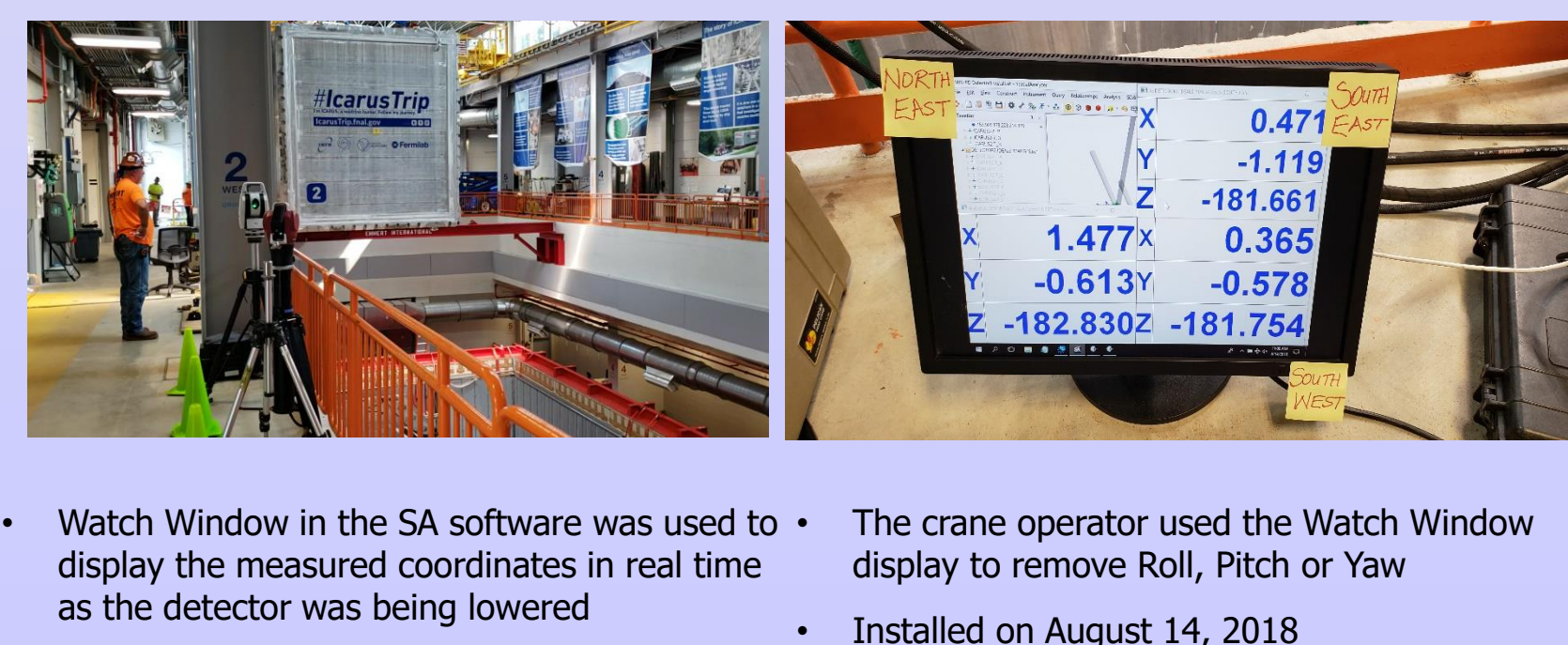
Watch Window in the SA software was used to display the measured coordinates in real time as the detector was being lowered. The crane operator used the Watch Window display to remove Roll, Pitch or Yaw. Installed on August 9, 2018

Installation of the ICARUS2 Detector

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 ICARUS2 Detector



- 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

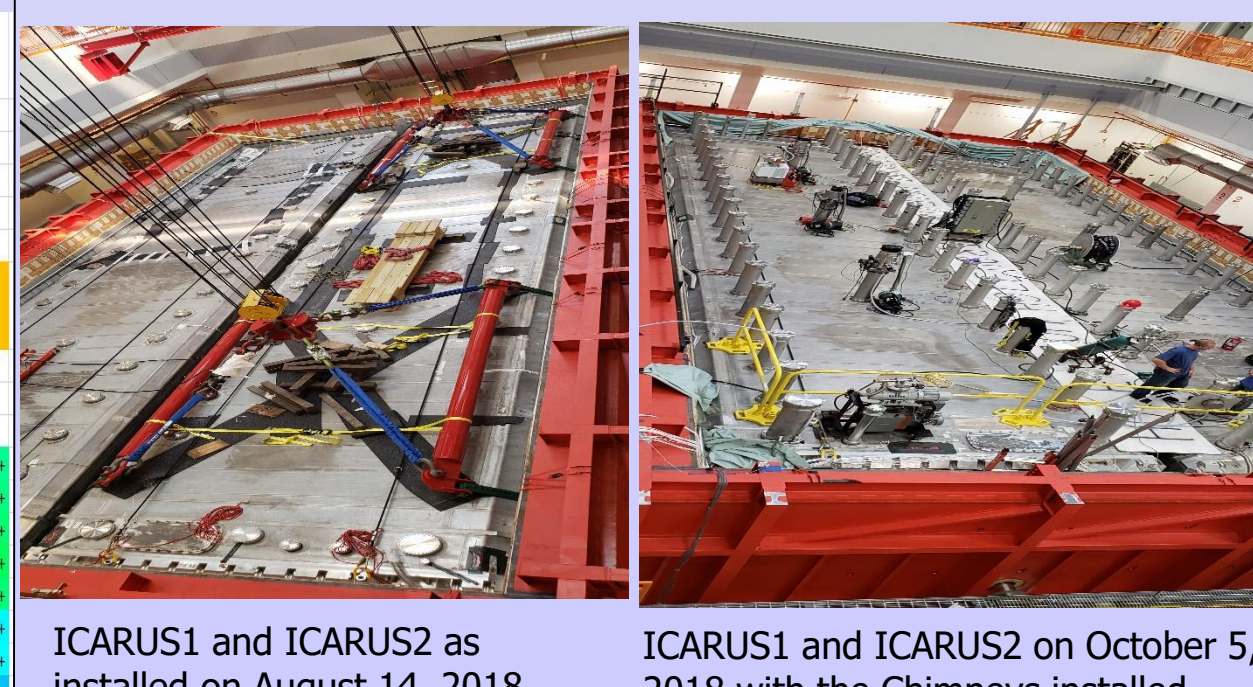
ICARUS Detectors Installed

All Vectors Summary: Vector Group											
BDD_CALCS-ICARUS1 INSTALLED - ICARUS1 Pre-Installed											
Statistic	dx	dy	dz	Mag	dx	dy	dz	Mag	dx	dy	dz
Min	-3.6	-5.7	-1.8	3.2	-3.6	-5.7	-1.8	3.2	-3.6	-5.7	-1.8
Max	-1.1	3.0	2.8	6.5	-1.1	3.0	2.8	6.5	-1.1	3.0	2.8
Average	-2.3	-2.5	-0.4	5.1	-2.3	-2.5	-0.4	5.1	-2.3	-2.5	-0.4

All Vectors Summary: Vector Group											
BDD_CALCS-ICARUS2 INSTALLED - ICARUS2 Pre-Installed											
Statistic	dx	dy	dz	Mag	dx	dy	dz	Mag	dx	dy	dz
Min	-1.8	-3.6	1.9	2.2	-1.8	-3.6	1.9	2.2	-1.8	-3.6	1.9
Max	0.6	1.3	7.8	7.9	0.6	1.3	7.8	7.9	0.6	1.3	7.8
Average	-2.9	-5.5	0.8	4.4	-2.9	-5.5	0.8	4.4	-2.9	-5.5	0.8

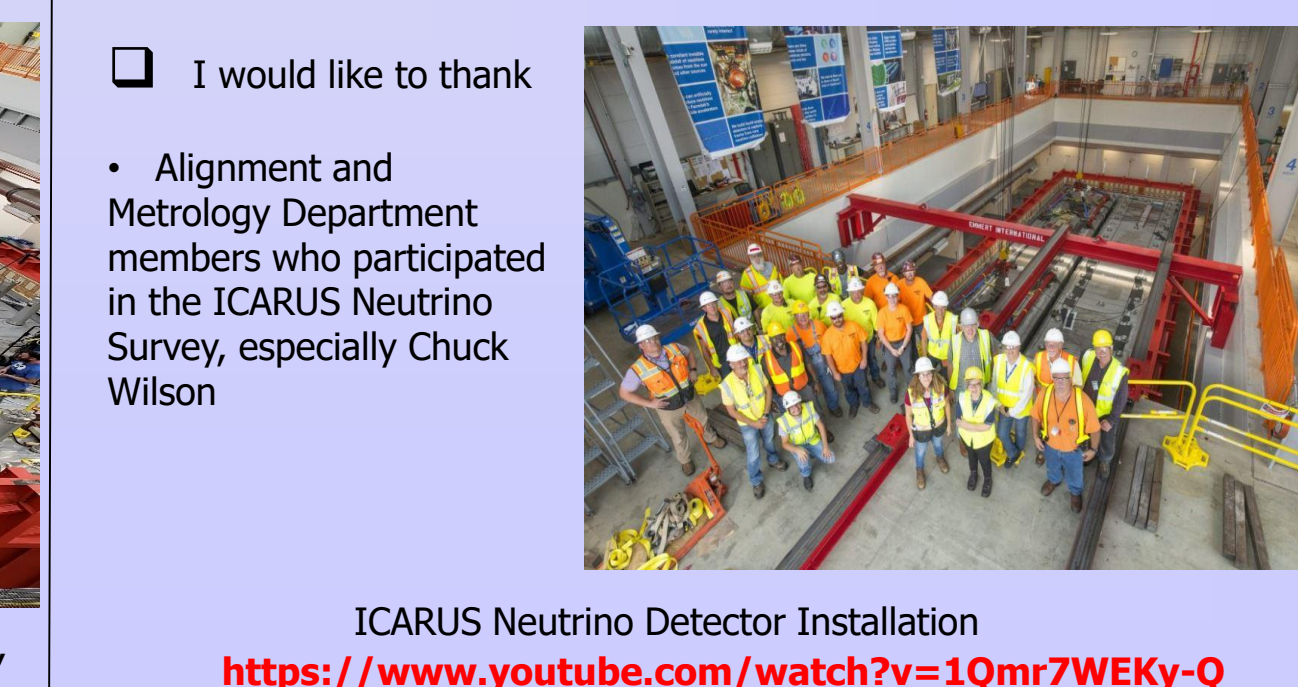
Vector Group												
BDD_CALCS-ICARUS1 INSTALLED - ICARUS1 Pre-Installed												
Name	Begin	End	dx	dy	dz	Mag	Name	Begin	End	dx	dy	dz
ICARUS1-T-P	3876.6	24292.8	5400.8	-3882.2	24294.7	5409.2	ICARUS1-T-N	3908.7	4530.0	5473.9	3909.1	4526.5
ICARUS1-T-R	3815.9	24328.7	5405.4	-3943.2	24328.8	5406.4	ICARUS1-T-M	2071.9	4542.1	5480.1	2081.1	4539.9
ICARUS1-T-C	3796.6	13519.9	5478.7	-3799.4	13519.9	5481.0	ICARUS1-T-L	3485.4	4541.9	5471.1	3489.8	4539.2
ICARUS1-T-M	1936.0	4527.7	5463.7	-1937.7	4520.0	5460.2	ICARUS1-T-H	3814.3	15481.1	5471.5	3818.9	15407.8
ICARUS1-T-L	3853.6	4504.4	5464.0	-3856.1	4498.7	5462.1	ICARUS1-T-P	2884.2	24007.7	5462.2	2822.2	24006.4
ICARUS1-T-N	-278.7	4509.8	5465.1	-279.8	4504.2	5463.7	ICARUS1-T-R	3871.1	24219.9	5478.9	3854.4	24301.1

ICARUS1 and ICARUS2 Detector Installed



ICARUS1 and ICARUS2 as installed on August 14, 2018

Acknowledgment



- I would like to thank
- Alignment and Metrology Department members who participated in the ICARUS Neutrino Survey, especially Chuck Wilson

ICARUS Neutrino Detector Installation <https://www.youtube.com/watch?v=1Qmr7WEky-Q>