

# Status of ICARUS

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*on Behalf of the ICARUS Collaboration*

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# Outline

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- ICARUS Collaboration
- Current technical status of the experiment
  - Status of Installation
  - Cryogenic Commissioning
  - Activities during the cryogenic commissioning
- Ongoing activities
  - Plans of the laboratory to return to normal activity
  - Activities on the detector
- Future plans
- Summary and Outlook



# ICARUS Collaboration in SBN

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# Technical status -1

*June 2019*

- ✓ TT-Link and wire bias cables have been installed. Connections to the minicrates will be done after the cryogenic commissioning to minimize risk of damage during the cryo pre-commissioning and commissioning.
- ✓ All Signal and HV cables for the PMTs have been installed and connected together with the optical fibers for calibration.
- ✓ The PMTs readout electronics and power supplies are installed, connected and ready to operate.
- ✓ The laser calibration system is installed and ready to operate.
- ✓ Optical fiber bundles for communication and DAQ are installed. Final connections to the minicrates to be done.
- ✓ Servers for DAQ and networking both for the TPC and the PMTs are operational.







# Technical status -2

December 2019

- ✓ HV Power Supply for the drift installed and connected.
- ✓ Readout for the North side and 1/3 of the West side of the CRT installed and operational.
- ✓ Slow controls for the internal cryogenics are operational. Slow controls for the PMTs are being tested, the ones for wires readout are under advanced development.
- ✓ DAQ for the wires readout, PMTs and CRT is operational and was used to collect noise data during the cryogenic commissioning.
- ✓ Data handling functional and continuously updated.
- ✓ The trigger logic is continuously developed. Plans for the final implementation are being developed.
- ✓ Control room in ROC West operational (not used at the moment).

*In brown are the common activities  
between ICARUS and SBND*

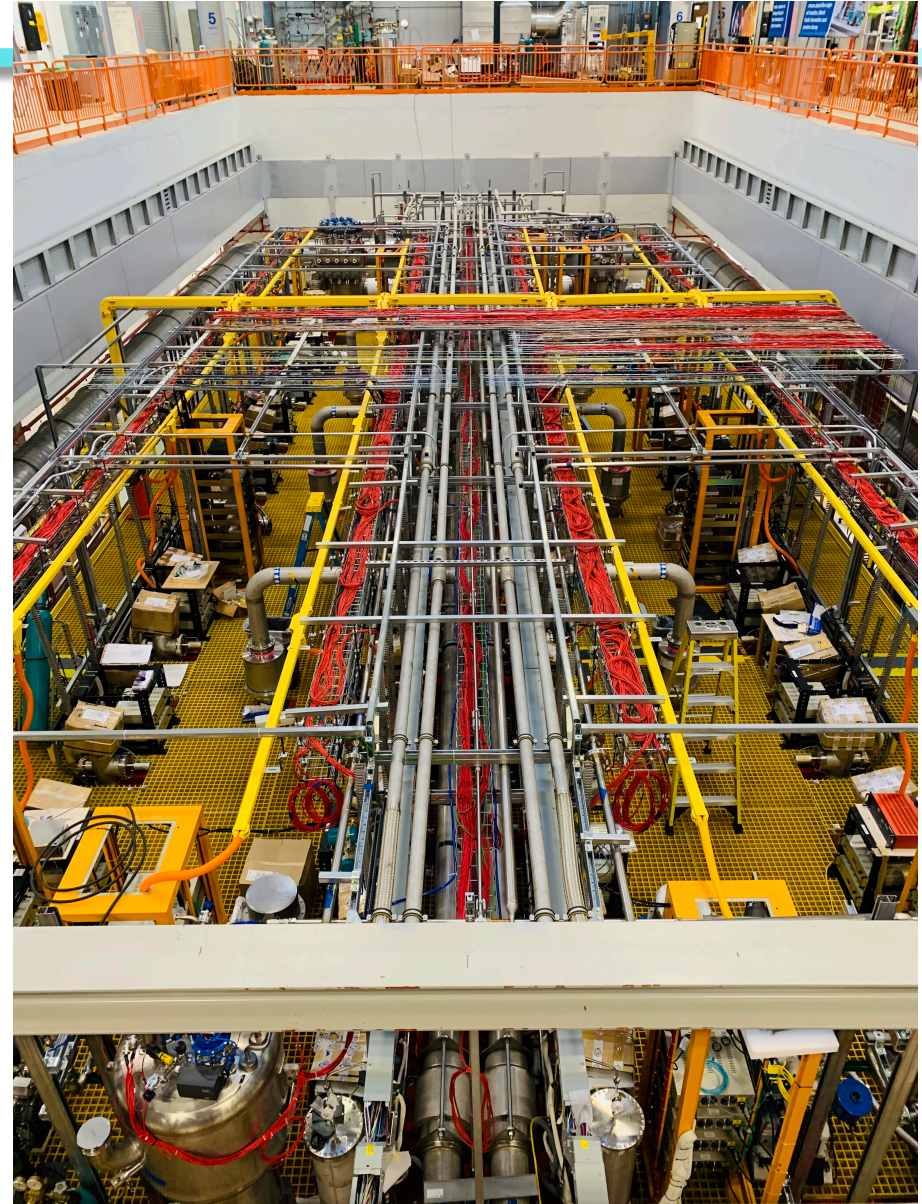




# Technical status - 3

- ✓ Power distribution on top the the detector and on the mezzanine operational.
- ✓ ODH system operational.
- ✓ Cryogenic commissioning is complete, with some minor issues being addressed.
- ✓ 24/7 shifts are active since February 14.  
Moved to remote shifts on March 17.

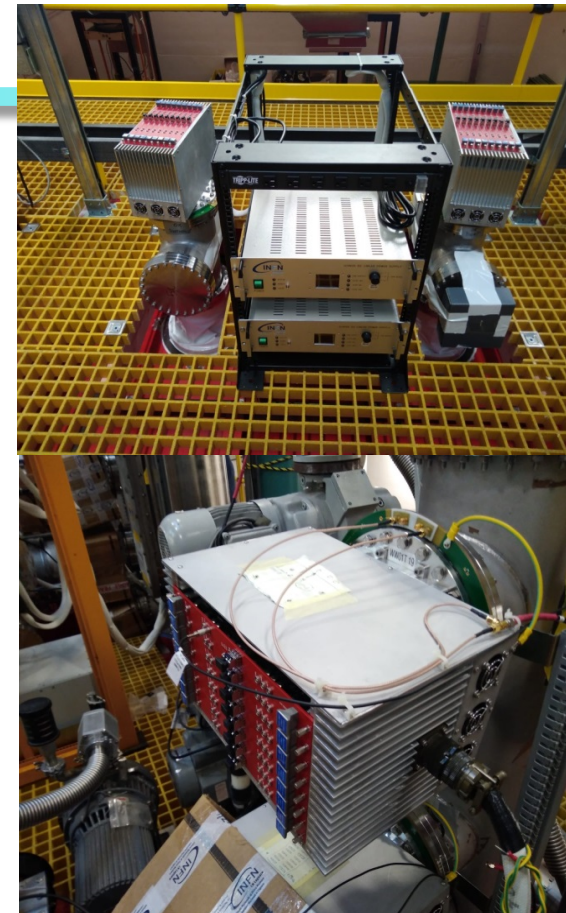
December 2019





# Status of the TPC electronics installation

- The installation of all 96 flanges with DBBs, Mini-crates, and 856 A2795 CAEN boards equipped with pre-Amps has been completed. Several VST have been performed that allowed to fix some noisy boards.
- All 96 power supplies have been installed, properly connected with prepared cables to Mini-crates: turned on, they behave as expected at nominal potential.
- The 6 Bertan HV power supplies for the wire polarization have been installed and tested, the corresponding cables deployed. The plug-in on the flanges will be realized by a more flexible 30 cm extension cable mechanically constrained to the mini-crate's wall by nylon clips, which will guarantee a reduced stress to the surface mounted SMA connectors in the flanges. Few initial tests at 10 V have been successfully performed.
- TT-Link (LVTTTL signals) originated by SPEXI from central trigger crate, will be distributed to all 96 Mini-crates by some 6+2 spare fan-out units (1 input, 26 outputs) prepared by CSU team. All TT-Link cables have been deployed, connected to TT-Link fan-out modules.  
Extensive tests on TT-Link distribution by their fan-outs showed no problem on the signal propagation to mini-crates, as checked with oscilloscope and with VSTs





# Cryogenic commissioning

- The cryogenic commissioning of the ICARUS detectors started on February 13, 2020 by breaking the vacuum in the two main cold vessels with ultra-purified argon gas.
- Cool down started on February 14 by injecting liquid nitrogen in the cold shields. It took about 4 days to bring the temperature on the wire chamber below 100 K. The cooling process was continuous and the maximum temperature gradient on the wire chambers was about 35 K.
- On February 19, the gas recirculation units were put into operation to purify the argon gas before the start of the liquid filling.
- The continuous filling with ultra-purified liquid argon started on February 24. The filling was interrupted around 50%, to regenerate the filling filter. The filling was stopped again when the liquid reached the -6cm probes (6 cm below the nominal level) to perform the final pressure test of the two cold vessels. After the test, the gas recirculation units were put into operation (3 out of 4).
- The filling was completed on April 19.
- On April 21 the liquid recirculation was started. The recirculation rates are 1.85 m<sup>3</sup>/hr in the West module and 2.25 m<sup>3</sup>/hr in the East module.



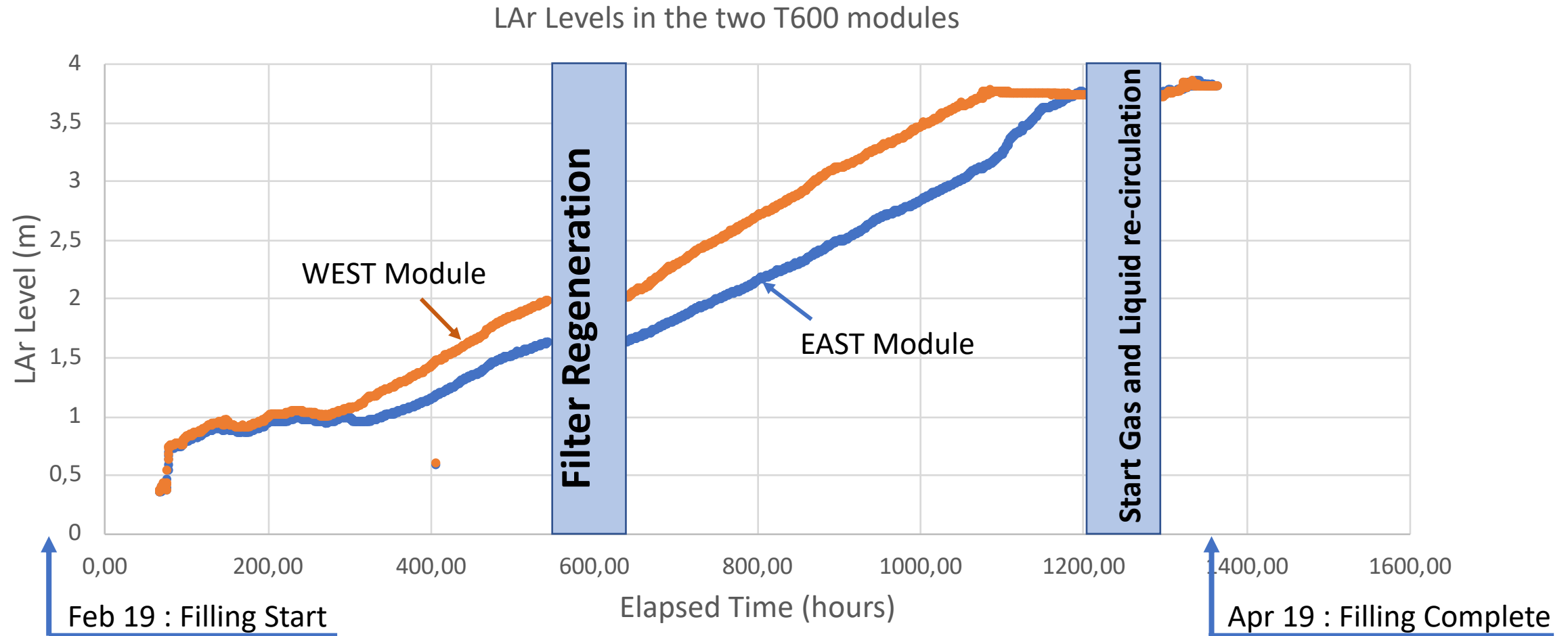
# Cryogenic commissioning cont.

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- The cryogenic stabilization phase was completed around the end of May.
  - One of the gas recirculation units on the East module is not working continuously: a solution is being implemented, possibly by mid July.
  - Pressure and temperatures in the two modules are stable.
  - No cold spots are observed on the external surface of the Warm Vessel.
  - Thermal losses through the thermal insulation are being evaluated.
- At the start of the cryogenic commissioning, all activities in the detector building not related to cryogenics have been suspended and the building was put in a higher safety condition, with strong limitations to the presence of people onsite. At the end of the liquid argon filling, after the final pressure test, the standard ODH safety conditions have been restored and regular activities on top of the detector could be re-started.
- The cryogenic commissioning has been conducted as a common effort of the CERN and Fermilab cryogenic teams. The commissioning was started with the CERN team onsite and then continued with the CERN team supporting remotely the activity of the local Fermilab team. Meetings have been held almost daily, including weekends, since the beginning of March.
- **The successful commissioning was made possible, in these quite difficult circumstances, by the dedication of these teams and by the months of careful preparation that preceded the start of the commissioning.**



# Level of the liquid argon during the filling





## 24/7 Shifts

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- On February 14, 2020, 24/7 shifts have been started from members of the ICARUS Collaboration.
- Shift started in the main Fermilab Control Room (ROC West) and then moved to remote around March 17, few days before Fermilab entered in the safe lockdown mode in response to the stay-at-home order for COVID-19 spread containment issued by Illinois Governor.
  - A considerable effort was made, by several people, to prepare in a very short time the Control Room first and then the technical infrastructure for remote shifts.
  - Several members of the Collaboration are now setup to take shifts remotely.
- June 14, 2020, a total of 52 shift-weeks (3 shift week per solar week) have been covered by Collaboration members. Shift-weeks (Sunday to Saturday) have been assigned randomly to Collaboration groups, they then have decided whose individuals from that group were going to cover the shifts. In agreement with the rules voted by the IB, a new organization of the shifts is going to be implemented, starting from July, that uses the software developed by NOvA.

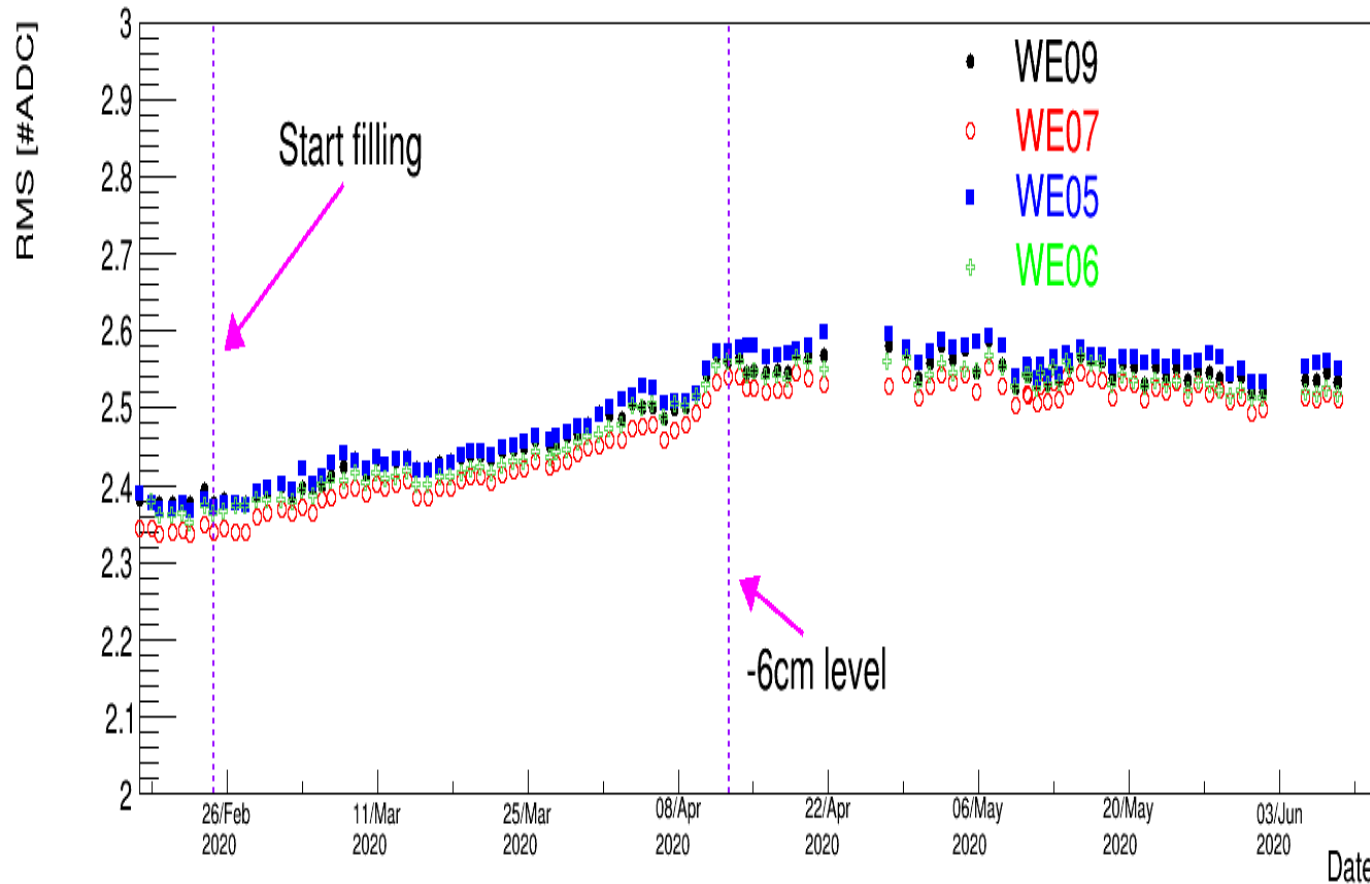




# Collaboration activities during the Cryogenic Commissioning

- During the Cryogenic Commissioning, there have been several activities both related to monitoring the status of the detectors (wire chambers, wires readout electronics, PMTs, CRT) and to developments for the following detector commissioning phases.
- Noise data have been continuously taken of wire readout electronics, PMTs and CRT. Effects on the noise from the activation of the cryogenic plant have been continuously monitored. Functionality and stress tests of DAQ have been conducted with several useful results.
- The slow controls for several subsystems are being developed continuously developed. They will be implemented progressively as the subsystems are being commissioned.
- The trigger system is also continuously developed.
- Data analysis and event reconstruction software development (common SBN WG)
- During this period of confinement, the activities of all Working Groups proceeded regularly at least those that could be handled by working from home or in the local laboratories. Working group meetings have been hold regularly and the general Technical Working Group Meetings have been intensified (from one meeting/week to 2 or 3 meetings/week).

# Level of the liquid argon during the filling



A gradual increase of the intrinsic noise in  $\pm 60^\circ$  TPC Coll. and Ind.2 wires with the LAr level corresponding to  $\sim 35$  pf increase of the wire capacitance is observed, in agreement with the expectations.



# Situation at Fermilab and plans for returning to full operation

- During the first two months after the stay-at-home order from Illinois Governor, Fermilab remained in safe lockdown mode. This means that presence onsite was limited to personnel required for essential services. All experiments were put in safe mode. Construction taking place outdoors continued. ICARUS cryogenic commissioning was allowed to continue, with presence onsite limited to one or two persons for the acceptance of the argon daily deliveries and for periodic walkthroughs of the detector installation.
- Starting from mid May the presence onsite has incremented at a rate of 65 persons per week. At the moment, a total of 5 persons (2 physicists/engineers and 3 technicians) have been added to the essential personnel list for operations on ICARUS.
- Starting from the first of June, Illinois has entered phase 3 of Recover from CODIV restrictions. The plan developed by the Laboratory and approved by DoE, foresees an incremental presence onsite of 100 persons per week, starting from people that cannot work or cannot work effectively from home. Return to work is, for the moment, on voluntary basis. Return to full occupancy is expected to take 14 weeks (mid September), pending possible change of conditions at the local or national level.
- A dedicated team has developed a set of rules to be followed for working onsite: people entering the laboratory are screened for high body temperature and have to answer some questions about possible exposure to the virus; face masks have to be worn inside buildings and also outdoors when social distancing cannot be guaranteed; all workplans have to be reviewed for possible COVID exposure and dedicated Hazard Analyses have to be performed when needed. Work will be slower. All personnel is requested to take a COVID-19 training course prior to be allowed into the Lab.
- At present, operation of the beams is planned for late October / early November.



# Ongoing activities

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- The detector is now available for installations and commissioning activities.
- In addition to the standard procedures to define and analyze the work plans, new rules and protocols have been introduced to minimize the spread of COVID-19
- Carrie McGivern, our Experiment Liaison Officer, is holding a weekly meeting (Thursday at 10 AM – Fermilab time) to analyze and organize all activities taking place at the detector building.
- Starting from the end of the cryogenic commissioning four activities have taken place:
  - Building to Detector Ground short search (ground short resolved; activity completed);
  - PMTs partial activation (8 PMTs per module);
  - Installation of the HV system for the drift and related Operational Readiness Review;
  - Installation of 50 ohm terminators to ground on the wire bias connectors.



# Near term planning

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- Next week, the minicrates of the horizontal wires will be connected to the DAQ servers and to the trigger distributors (TT-Link connections).
- If all conditions are met, the HV on the cathodes will be raised to about half the nominal Voltage (-40 kV).
- With all the wires shorted to ground, the first induction plane will work in collection mode. Several tests and verifications will be possible;
  - HV stability;
  - Tracks readout with random triggers;
  - Coincidence of light signals (with limited scope);
  - Noise levels.
  - Some indications on LAr purity.



# Long term planning

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- It is clear that, in the present situation, uncertainties dominate all possible planning. Limited access to the lab for onsite personnel and extremely limited possibility to travel from outside the Lab require to postpone most of the activities that were originally planned to take place at the end of the cryogenic commissioning.
- The additional constraints for limiting the COVID-19 spread, with social distancing and limited presence of people working in the same area, make work planning more complicated and the execution of the work intrinsically slower. Given the limited experience of activities in the new conditions, the estimate of the incremental time needed to perform a given task cannot be precise.
- The activities that have to take place to be ready for data taking with the beam in the nominal experimental conditions are:
  - Completion of cabling of wires chambers electronics;
  - Commissioning of wires bias;
  - Installation and commissioning of the trigger system;
  - Calibration of both PMTs and wires readout;
  - Commissioning of slow controls;
  - Installation and commissioning of the remaining parts of the side CRT;



## Long term planning (cont.)

- Installation and commissioning of services on top of the detector (ventilation, fire protection system, ODH sensors);
- Delivery onsite, installation and commissioning of the top CRT;
- Installation of the overburden.
- Most of these activities require the presence onsite of experts that are not resident in the Fermilab area.
- In the previous plan all these activities were supposed to take place between the beginning of May and the end of October.
- If we assume that the possibility to travel will be restored during the months of August and September and that some of the installation activities (side CRT and services) can take place during the summer with a longer duration, due to the additional constraints, we can anticipate a minimum delay of about 3.5 months with respect to the original planning.
- In this scenario we should be ready for data taking around mid February 2021.



# Summary and Outlook

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- The cryogenic commissioning of the ICARUS Detector was completed successfully during the month of May.
  - One gas recirculation unit is not fully operational, but both modules are stable and the liquid recirculation is active since April 21.
- During the cryogenic commissioning the wires electronics, the PMTs and the CRT have been continuously monitored to detect effects due to the operation of the cryogenic systems.
  - DAQ and data managing systems have been debugged and stress tested extensively.
- Several activities are ongoing to prepare to the first, partial, detector activation.
- Remaining installation and commissioning activities are delayed, due to travel and onsite presence constraints consequent to COVID-19 outbreak
- In the scenario in which travel to Fermilab will be restored during the month of September, a minimum delay of 3.5 months is anticipated with respect to the previous planning for readiness for data taking with the neutrino beams.





## PAC Q&A (Jun 30, 2020)

- **[\*] Report on the ICARUS Experiment** Charge: We ask the committee to review the status of the recommendations made at the January 2020 meeting and of the preparatory work towards the SBN operations.
- Recommendation:
- If the presented schedule is maintained, ICARUS will be operating and acquiring neutrino data without the near detector for a while. The PAC would like to hear what are the science goals that the collaboration plans to accomplish with this data and to specify the related computing needs.
- Answer:
- *In consideration of the current circumstances, I will discuss this subject verbally during the meeting. It is not yet known if the present schedule can be maintained as there are still uncertainties about the possibility to resume travel from Europe to the US in September. In any case case the collaboration has maintained the original goals and plans as described in the 2015 proposal. It must be remarked that the event rate of ICARUS because of the longer distance is 7 times smaller than the one of SBND and therefore more time is required to reach comparable statistics in the two measurements.*