# Status and plans of the WA104 (NP01) Experiment

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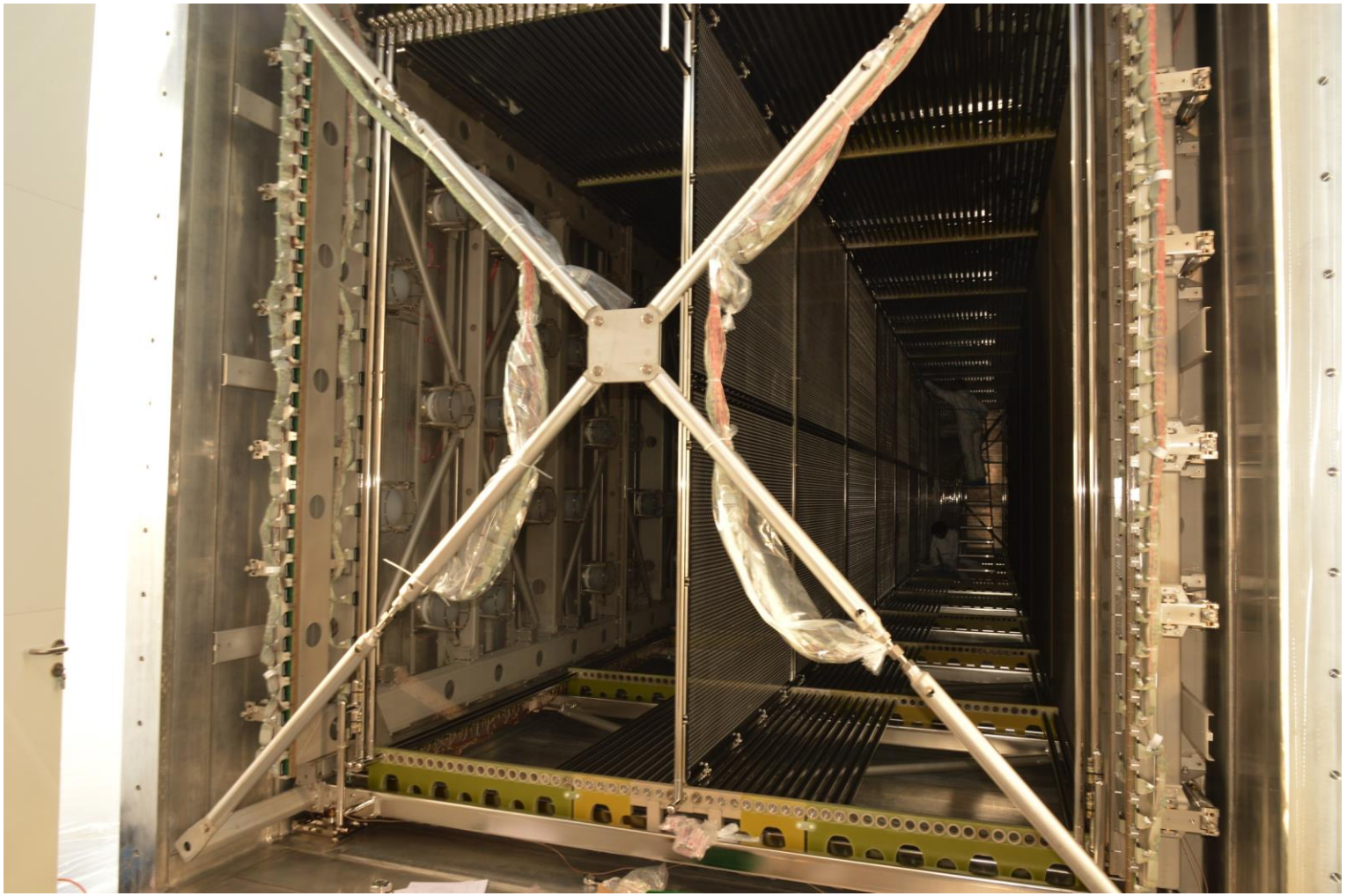
# Present status

- The first T300 detector has been moved in the new cold vessel on December 20, 2016. It has been aligned and the feet are bolted to the vessel in the final position.
  - All the PMTs are installed, cabled including optical fibers, and tested.
  - The cathode has been flattened.
  - New readout cables for the wires have been installed and connected.
- The second T300 detector was taken into the clean room on January 12, 2017.
  - The same activities as those of the first detector, have been performed for the second one:
    - new PMTs were installed and tested;
    - the cathode has been dismounted, flattened, cleaned and re-installed;
    - new readout cables have been installed.
  - All the operations have been completed by March 24, 2017.
  - The second detector was moved in the second new cold vessel the 28$^{th}$ of March; it was then precisely aligned and bolted in the final position. The cold vessel was finally closed on March 31.
- **The two detectors are now ready for transport to Fermilab.**

# Cathode flattening and new wires cabling

- The planarity of the cathode panels has been taken to ±2 mm (was ±25 mm).
- New internal cables for the wires readout have been installed.



# The new light detection system

- The improved T600 light detection system is devoted to:
  - The generation of a light based trigger signal;
  - The identification of the time of occurrence (t0) of each interaction with high precision.
- The realization of a new scintillation light detection system is fundamental to reject the expected huge cosmic background due to the T600 shallow depths operations. A sensitivity below 100 MeV of deposited energy and a time resolution of about one nanosecond is required.
- The new light detection system consists of 90 PMTs 8" HAMAMATSU R5912-MOD for TPC, installed behind each wire chamber.
- The chosen PMT model has an 8 in. diameter window made of borosilicate glass, 10 dynodes and a bialkali photo-cathode (K2CsSb) with platinum undercoating, to restore the photo-cathode conductivity at low temperature.

# Completion of the light collection system

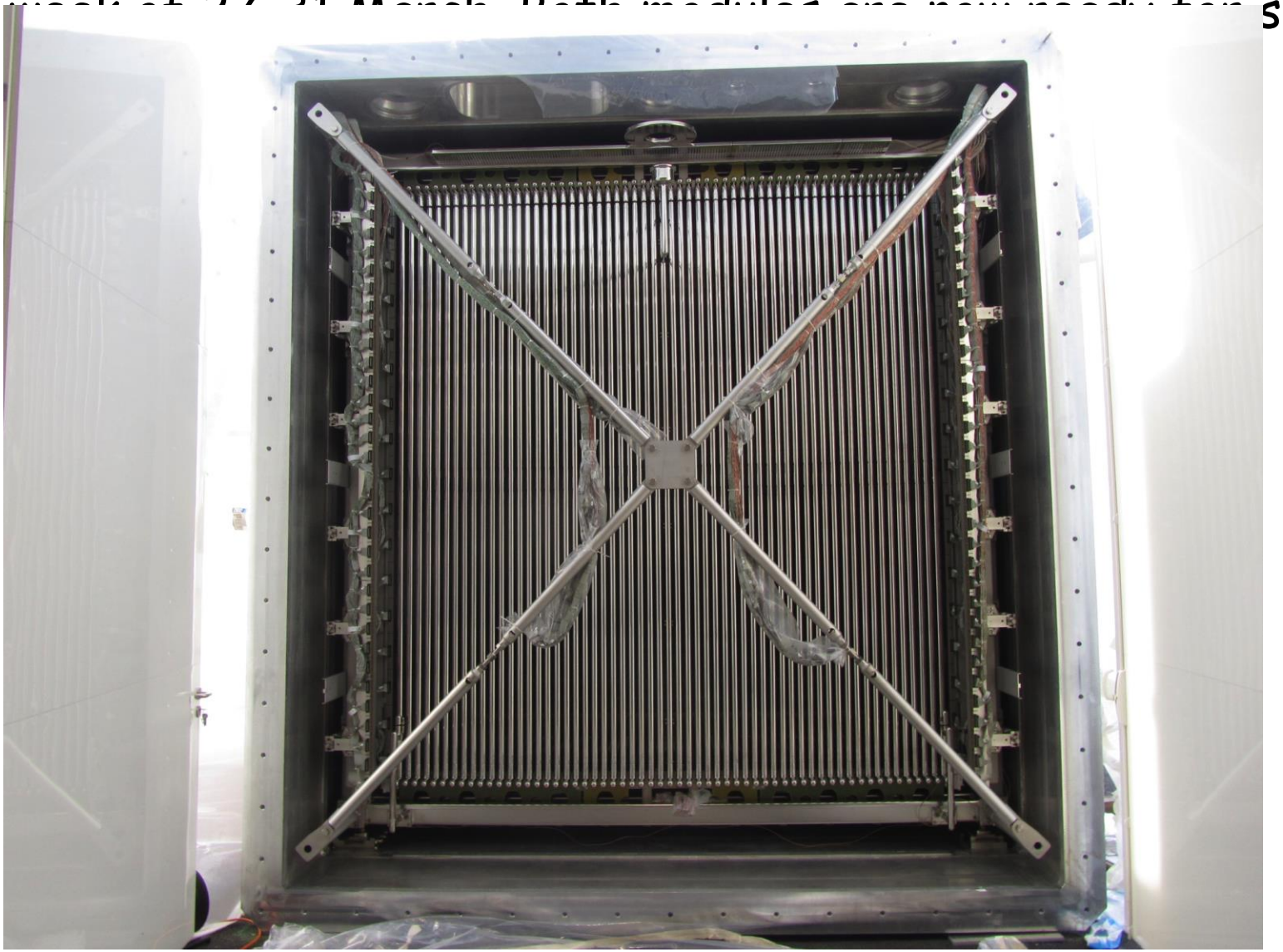
- A complete set of 400 PMTs, was procured from Hamamatsu. Each unit was tested before the installation in the T600, to verify its compliance with the required functioning specifications.
- 360 samples were selected for the installation. The units were made sensitive to ultraviolet photons ($\lambda$=128 nm) by coating a uniform thickness of about 200 g/cm2 of Tetra-Phenyl Butadiene (TPB) on the sensitive surface of each device.
- A new mechanical structure was adopted for the final installation in the TPC. This supports the PMTs in the correct position and orientation and holds up a 50 $\mu$m optical fiber in front of each device allowing the time equalization by means of an external laser.

# Second T600 module insertion in the cold vessel

- The second T600 module was inserted and sealed in its cryostat on the week of 27-31 March.

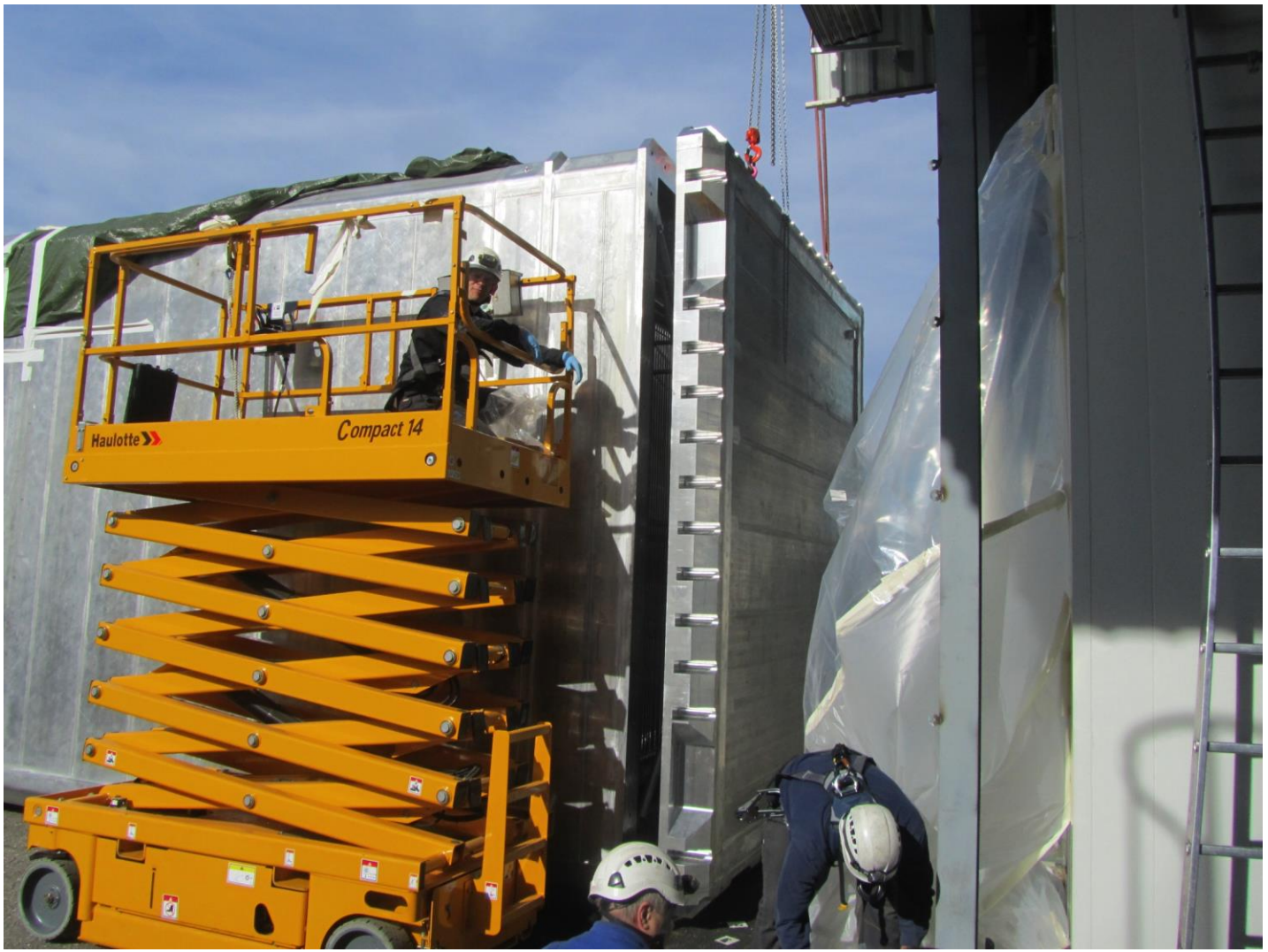
# T600 modules ready for shipment

- The second T600 module was inserted and sealed in its cryostat on the week of 27-31 March. Both modules are now ready for shipment.



# Second T600 module: closing the cold vessel

- Friday, March 31, 2017



# T600 modules: status and transport

- Both modules of the T600 detector are ready for transport to FNAL.
- Both cold vessels were tested under vacuum for vacuum tightness and for mechanical stability. Both vessels have been qualified for He leak tightness < 10-8 mbar lt s-1. Mechanical behavior under vacuum loading confirms to calculations.
  - Overall deformation for both cryostats under vacuum is measured in the order of 10 mm (calculated: 11 mm).
- CERN is evaluating offers from companies concerning the transport of the two modules to FNAL. Open items being discussed are:
  - The actual ocean route (East Coast port, Great Lakes, …)
  - Lashing procedures for the security of the two modules on the ocean freighter, where it is not possible to put limits on maximal velocities/accelerations experienced by the detectors.
- Ongoing discussion with Insurance company, in order to settle on a contract covering minor damages to the detectors, to be repaired:
  - Back at CERN, if damage takes place in Europe;
  - At FNAL, with CERN personnel, after construction of a new clean room, if damage takes place during/after ocean travel.
- Target date for shipment: week after Easter (April 17-21).
- CERN, FNAL, INFN press office to provide media coverage of trip.

# Installation activities at FNAL

- The building that will host the T600 at Fermilab is now ready for the detector installation.
- The installation will start at the beginning of May 2017 with the assembly of the warm vessel and will proceed until around the end of 2017.
- The installation and commissioning procedure and the relative sharing of responsibilities among CERN, INFN and Fermilab + US groups has been extensively discussed starting from February 2016.
- An addendum to the CERN-INFN MoU, signed at the end of 2017, covers the remaining activities for the detector implementation at Fermilab, including, but not limited to:
  - assembly and installation at FNAL;
  - procurement of new readout electronics for the wire chambers;
  - procurement of readout electronics for the new light collection system;
  - procurement of the calibration system for the new light collection system;
  - transports.
- High level agreements between CERN and DOE and between MIUR(INFN) and DOE are being perfected to provide the necessary formal support to the SBN and LBN technical and scientific activities. Addenda to these documents define the US contribution to the detector installation, commissioning and operation.

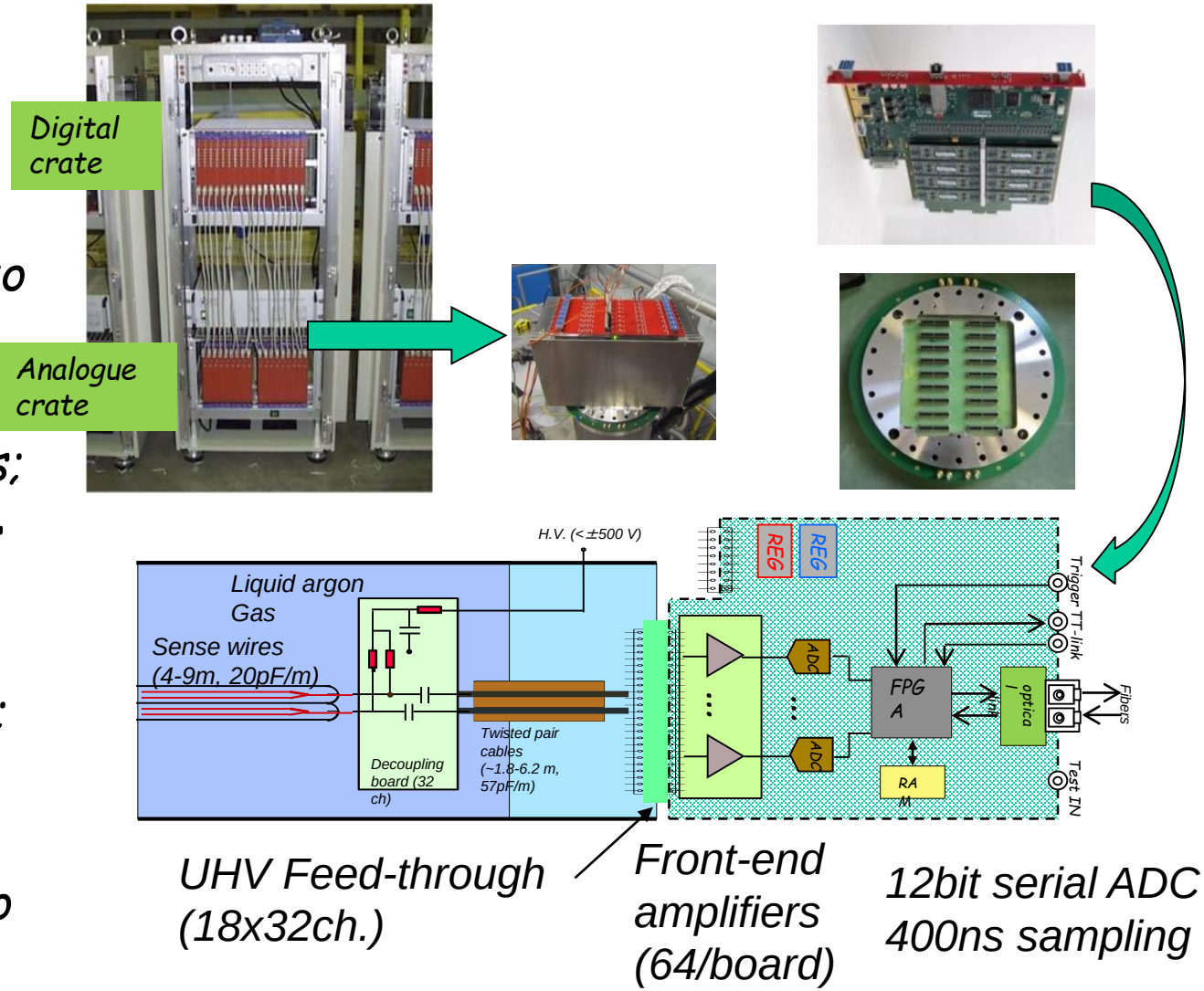
# Warm vessel structure

- The structure was realized in Europe. The floor and the sides are now at Fermilab where they will be assembled starting from the beginning of May 2017. The roof is at CERN for the preassembly of the thermal insulation.

# The new TPC read-out electronics

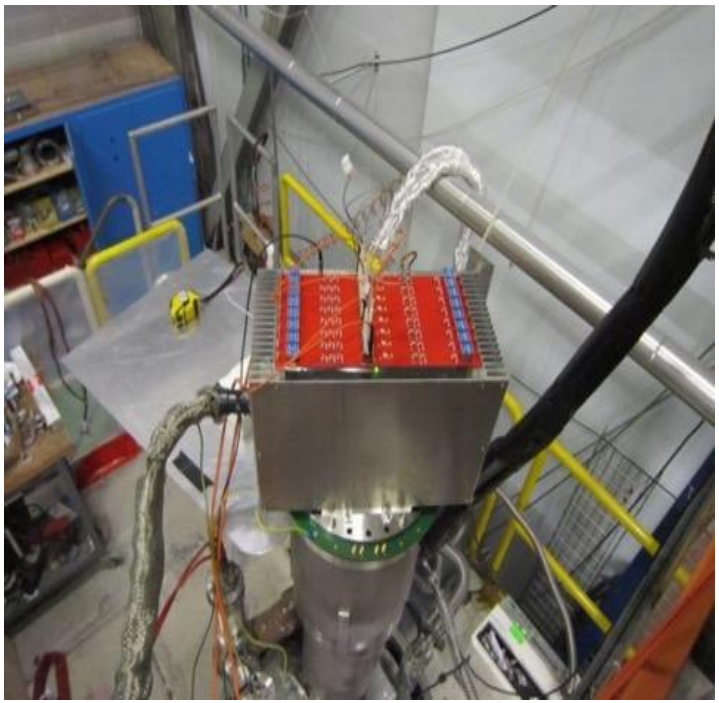
- *The old TPC read-out electronics was conceived in 1998, and even if well suited for ICARUS-T600, has some limitations. Improvements concern:*

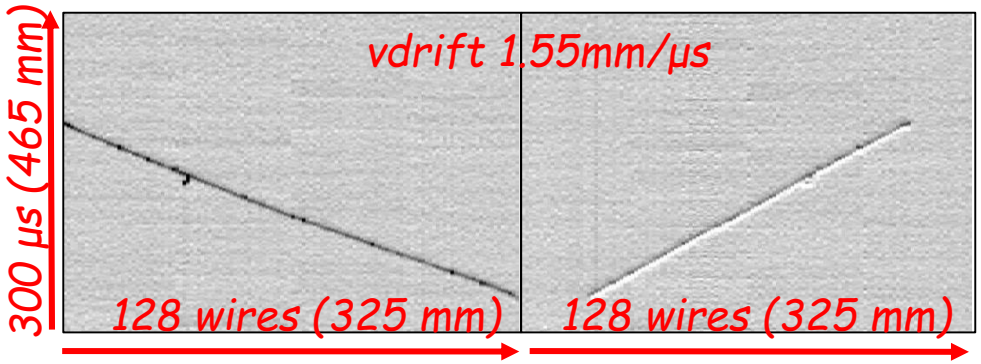
  - *Shorter shaping time ~ 1.5 μs of the analogue signals to match electron transit time in wire plane spacing and to avoid undershoot in Induction signals;*
  - *Adoption of serial ADCs;*
  - *Adoption of a serial bus architecture with optical links (Gbit/s) to increase the bandwidth;*
  - *Use of the signal feedthrough flange as electronics backplane to simplify cabling layout.*

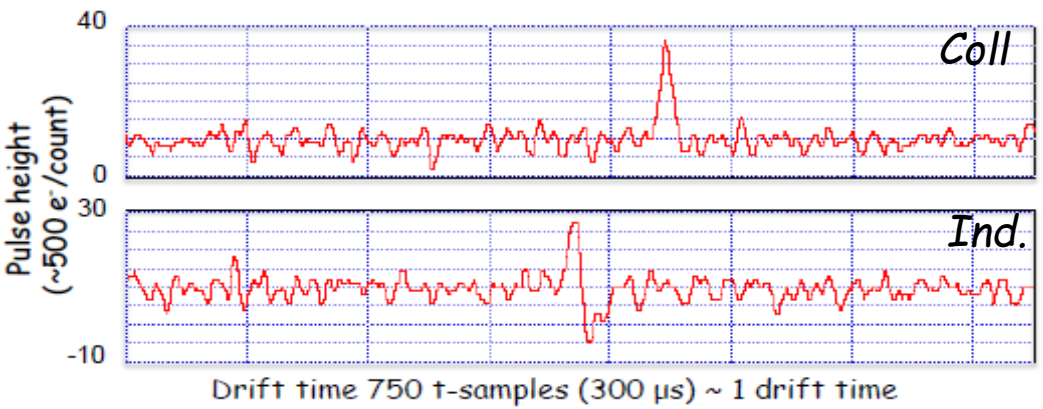


# Test facility in CERN (50 liter LAr -TPC)

- *The full electronics chain has been tested collecting cosmics with the 50 liters ICARUS Chamber: 2 wire planes (Ind. + Coll.) 128 wires each, 2.5 mm wire pitch, 4 mm plane spacing, E=500V/cm;*
  - *1 crate mounted on the flange, houses 9 boards, 64 channels each, to serve 576 chs*
  - *Cable length as in ICARUS Coll. plane, ~ 2.5 m;*



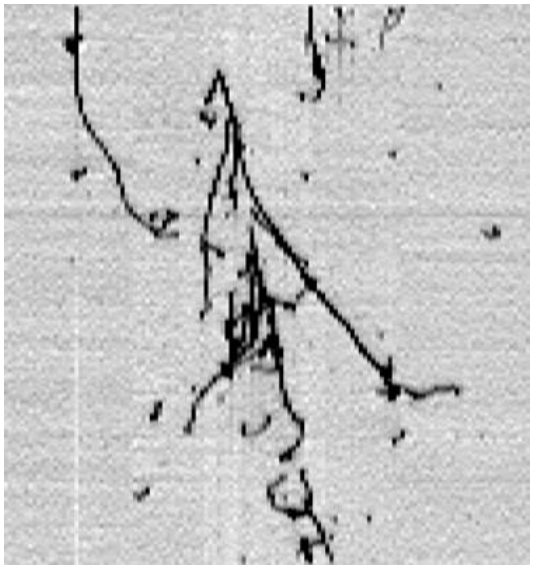



*Single m.i.p. track event:*

- *Same ~2ADC # (~1000 $e^-$) noise for both Collection & Induction;*
- *Unipolar Coll. signal: ~25 ADC #;*
- *Symmetric bipolar Ind. signal with slightly reduced amplitude as expected.*

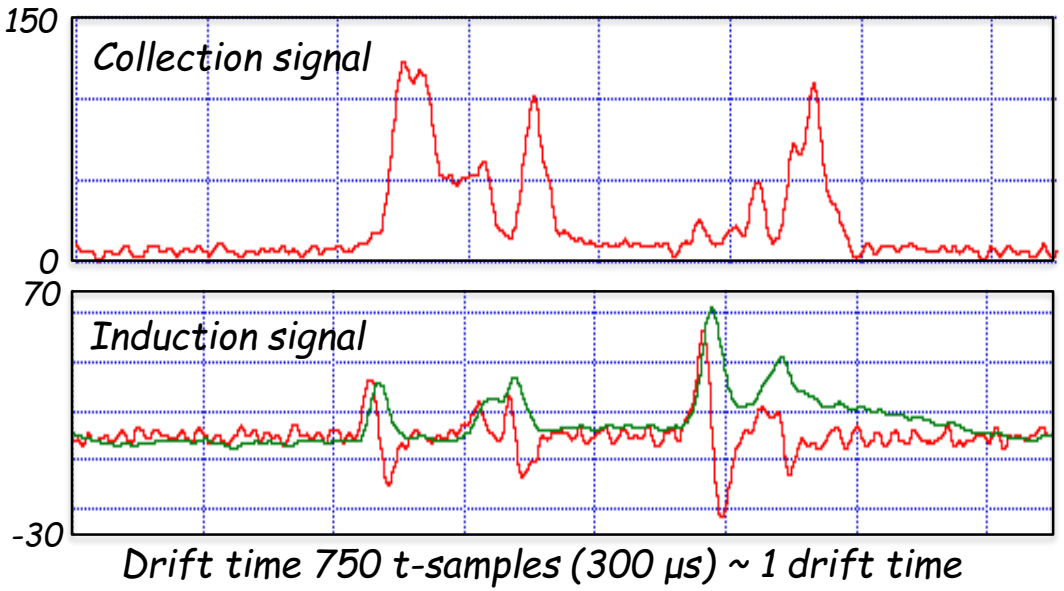
# Induction and Collection signals from the new electronics



300 μs (465 mm)
Drift velocity 1.55mm/μs

128 Collection wires (325 mm)

128 Induction wires (325 mm)



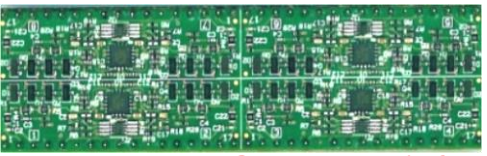

Pulse height
(~500 el/count)

Drift time 750 t-samples (300 μs) ~ 1 drift time

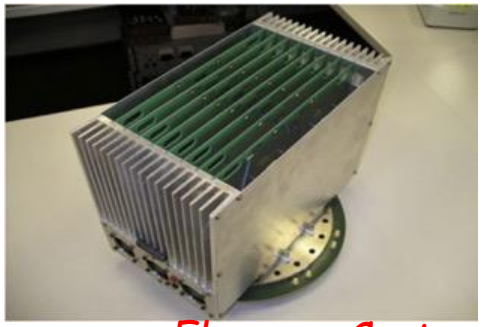
- *Clean images also for* complex shower events both in Collection and Induction views;
- The optimized preamp architecture results in:
  - no signal undershoot even *for* large signals;
  - a very stable baseline;
  - *unprecedented image sharpness and* better hit position separation due to faster shaping peak time.
- *On Induction plane, energy information easily recoverable with dedicated algorithms (e.g. running sum, green curve) allowing for a better event reconstruction.*

# Planning for electronics delivery

A2795



Pre-Amplifier



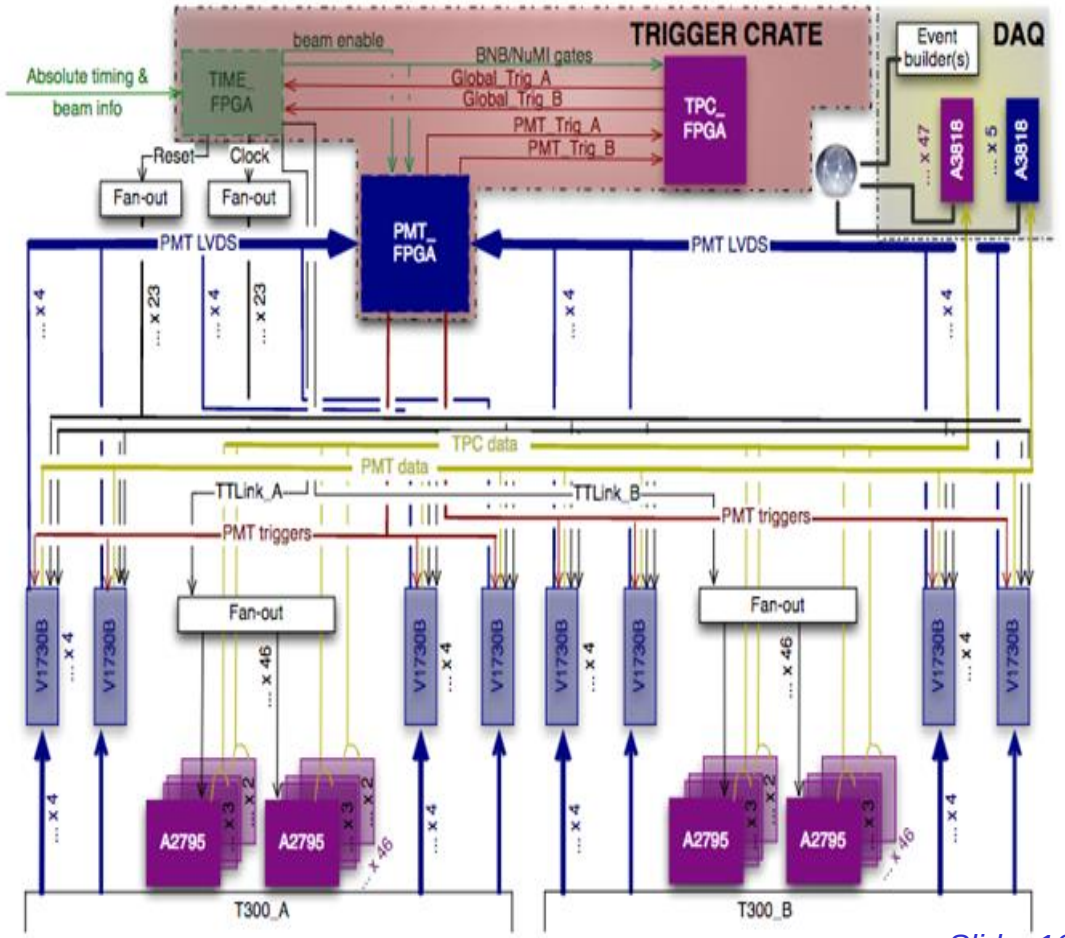
Flange + Crate


Power Supply

- A2795 board delivery: Tendering procedure finished.
  - 1st May 2017 after a ~30 board pre-series, 100 A2795 will be delivered;
  - Supplier production rate: 100 boards/month; boards for a full T300 will be delivered by August.
  - Supplier can produce the full system by January 2018.
- Pre-Amplifier status: 6000 ch's produced/tested in Padova. Full production completed by January 2018.
- Flanges status: Four prototypes realized, according to the INFN proprietary technique, tested and ordered. Full delivery by end 2017.
- Crates and backplane status: Four prototypes fully designed, developed, and tested. Full production expected in few months.
- Power Supply status: Power supply completely custom made in Padova for optimal noise performance (linear PS technique). Full delivery expected by January 2018.

# DAQ and trigger systems

- *ICARUS-T600Trigger/ DAQ at FNAL rely on architecture deployed at LNGS for data taking with CNGS beam.*
- *The system will consist of waveform recording of signals from TPCs and PMTs, triggered by scintillation light in coincidence with beam extraction; the additional feature of triggering directly on charge collected on TPC wires will also be maintained.*
- *TPC signals are readout by 24 PCs, each hosting 2 CAEN A3818,>80 MB/s bandwidth) serving 512 chs each; 3 PCs will handle data from PMTs/ CRT.*
- *A simplified synchronization & trigger distribution system has been setup to allow for testing readout of multiple TPC front-end units and PMT data merging.*
- *An ArtDAQ demonstrator setup for one crate has already with a 50 l LAr-TPC at CERN, with cosmics data taking runs.The setup will be fully equipped with boards as soon as they will be delivered.*

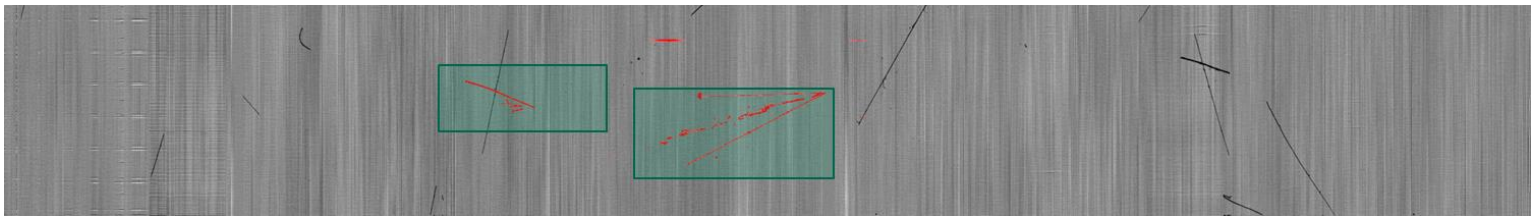


# Ongoing activities at CERN

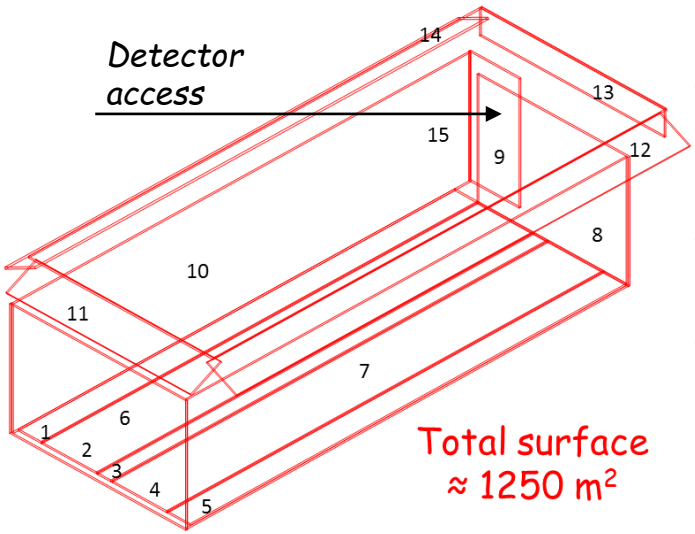
- There are several activities that will continue to take place at CERN during the next months:
  - survey and qualification of the components of the cryogenics and purification systems (proximity cryogenics) whose installation at Fermilab is foreseen to start in September 2017;
  - pre-assembly of the warm vessel roof prior to transport to Fermilab;
  - realization of the Cosmic Rays Tagger top (bottom and sides are under the responsibility of US institutions);
  - preparation for commissioning and data taking.

# Event finding at shallow depth and Cosmic Ray Tagger

- *Several uncorrelated cosmic rays (CR) will occur in the T600 per triggering event within the 1 ms drift window readout: ~ 12 muon tracks per drift in each T300 were measured in Pavia test run on surface (2001).*

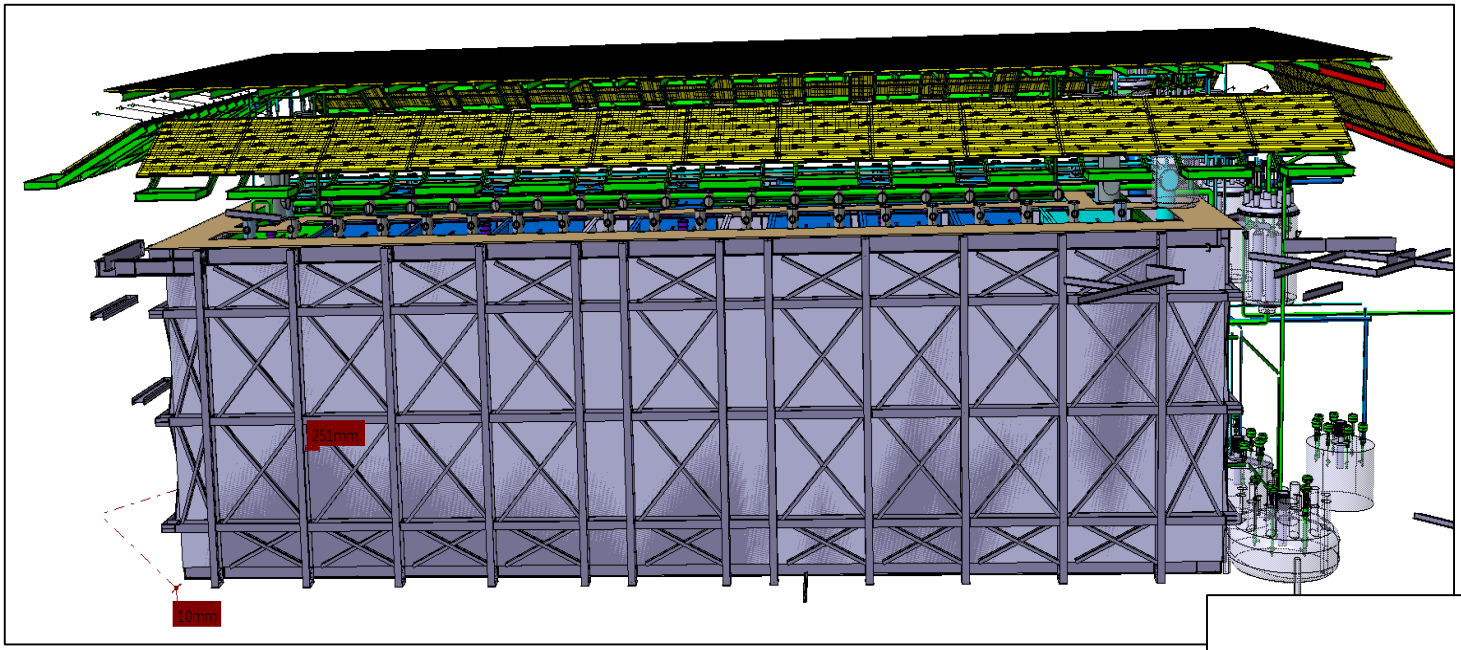


- *The reconstruction of true 3D position of the triggering event, requires to associate precisely the timing of the each track in the TPC image by*
  - *Exploiting the PMT ~1 ns time resolutions*
  - *Recognizing incoming cosmic particles by an external CRT system.*




- *A cosmic ray tagger (CRT), made of scintillating bars will surround the T600. Bars equipped with optical fibers driving light to SiPMs for readout.*
- *CERN and INFN will be responsible for the Top CRT modules, the FNAL Icarus group will design its mechanical supports.*
- *FNAL is recovering modules previously used by MINOS (sides) and Double Chooz (bottom).*

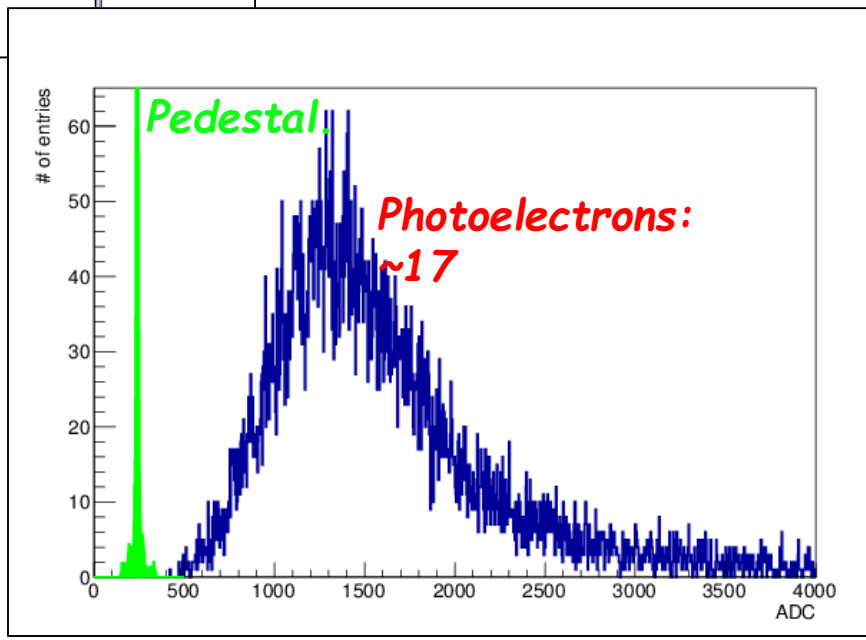
# Top CRT Design



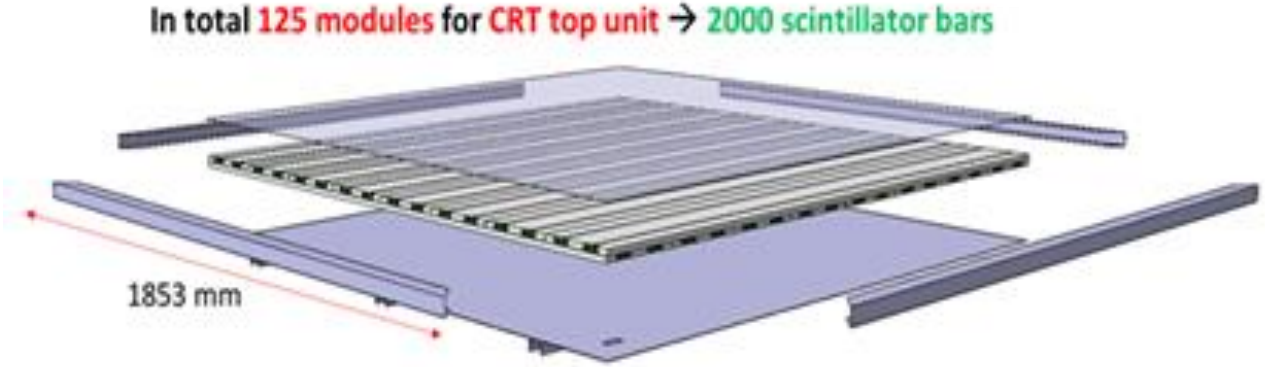

84 + 38 modules.
Each module has 8(X) + 8(Y) bars for 2D localization.
Around 2000 in total.

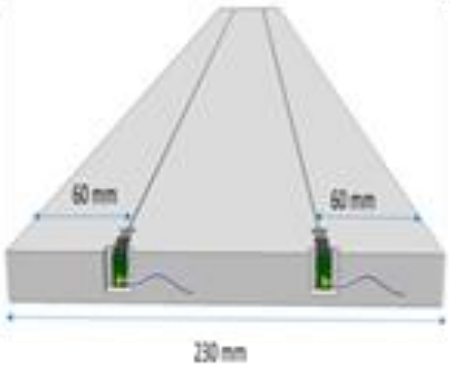
Module design optimization ongoing.

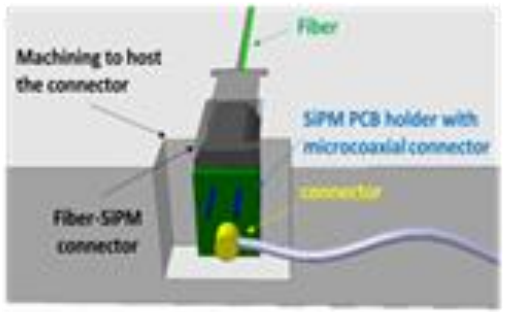
- Various scintillation bars tested at CERN with cosmic rays (doped polystyrene and PVT)
- Scintillator bars readout by two multiclad WLS fibers, diameter 1 mm, connected to SiPM's with an active area of 1.3 × 1.3 $mm^2$.
- The readout will be performed with the same electronic boards used for the CRT of the near detector (SBND) .
- Photoelectron distribution (see e.g. picture on the right) is made with 1 cm thick bars.
- Tagging efficiency of the TOP section: 80%



# Top CRT Design

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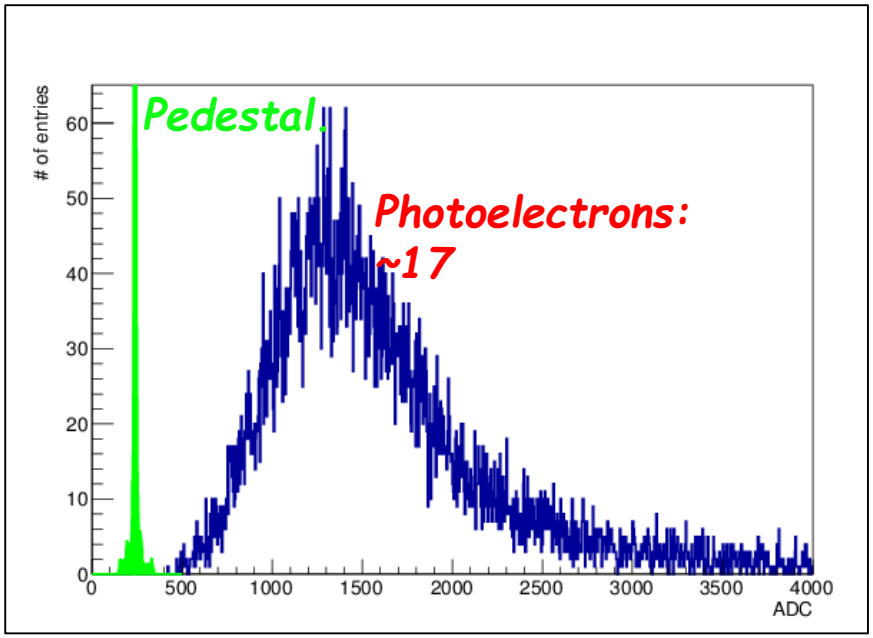

# Conclusions

- All the overhauling operations on the T600 detector have been completed by end of March, 2017.
- The two detector modules are now ready for the transport to Fermilab, which is foreseen to take place before and of April, 2017.
- The detector installation at Fermilab will start at the beginning of May, 2017 and will last until around the end of 2017.
- All installation and commissioning operations are covered by agreements already signed (CERN and INFN) or close to finalization (CERN and DOE , MIUR and DOE).
- Remaining activities at CERN will proceed according to the existing MoUs.
- Detector commissioning is planned for the beginning of 2018.