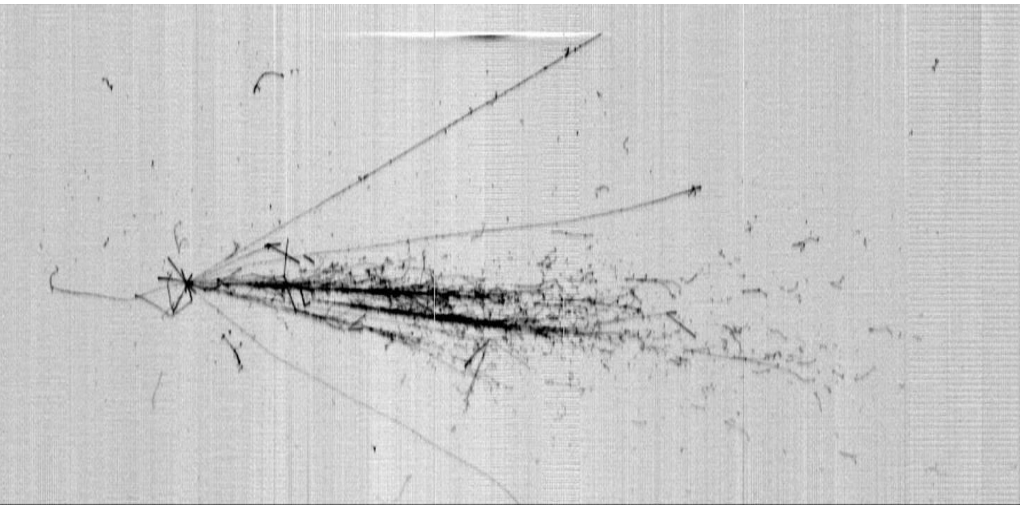
The Upgrading of the ICARUS T600 Detector



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on behalf of the

ICARUS/WA104 Collaboration

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The ICARUS/WA104 Collaboration

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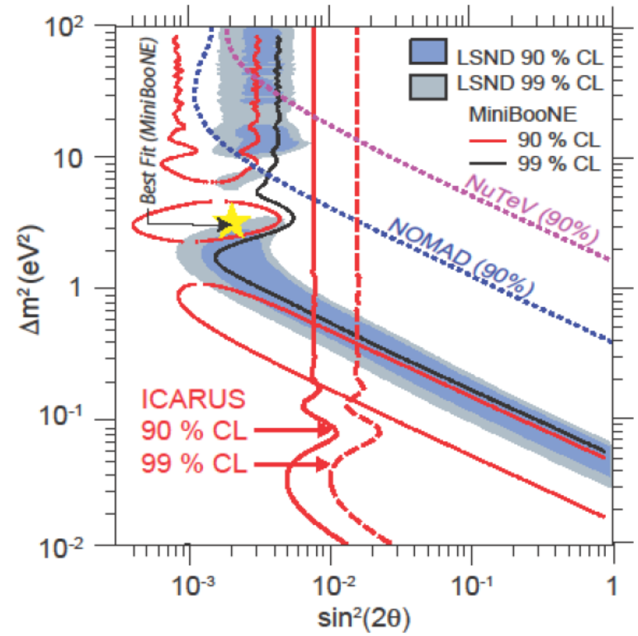
ICARUS T600: a summary

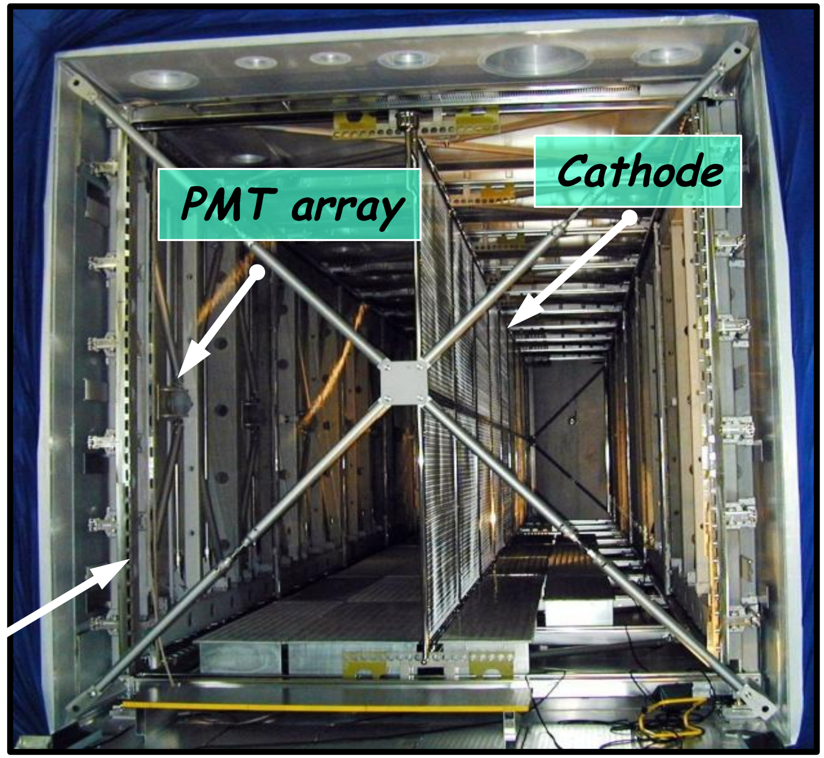
- ICARUS T600 detector concluded in 2013 a successful three-year-long run at LNGS taking data both with CNGS ν beam and cosmic rays. *Several relevant physics and technical results were achieved (see F. Varanini talk):*
  - Excellent tracking device homogeneous calorimeter with remarkable particle-identification capability, exploiting the measurement of dE/dx vs. range;
  - Reconstruction of ν interaction vertex and measurement of e.m. showers by primary e's and invariant mass of γ pairs, allowing the backgr. rejection in $\nu_\mu - \nu_e$ study to unprecedented level.
  - A sensitive search for LSND-like anomaly with CNGS beam, constraining the allowed region to a narrow region at $\Delta m_s^2 < 1\ eV^2$.



- ICARUS will be exposed to the ~0.8 GeV FNAL Booster Neutrino Beam at 600 m from target for a conclusive study of $\nu_\mu - \nu_e$ in LSND-like transitions.
- Sterile ν oscillations are searched for by comparing the spectra measured by ICARUS T600 (600 m) and by SBND (110 m), MicroBooNE (470 m).
- Before being deployed at FNAL, for the last two years, the apparatus underwent an intensive overhauling process at CERN.

T600 Overhauling at CERN (WA104)

- To face the new experimental situation at FNAL with respect to the LNGS run (shallow depth data taking with higher beam rate), the T600 detector needs important upgrades. The whole apparatus underwent an intensive overhauling process at CERN, before being shipped to FNAL.
- In 2015, T600 detector was moved to CERN for overhauling in the framework of CERN Neutrino Platform (WA104 project).
- The aim of these activities was to introduce technology developments *while maintaining the already achieved performance*:
  - New cold vessels, with a purely passive insulation, renovated cryogenic and LAr purification equipment;
  - Improvement of the cathode planarity;
  - Upgrade of the light collection system with high granularity/sensitivity and time resolution with ~1 ns precision;
  - New faster, higher performance read-out electronics.



3 Wire Planes: Induction1, Induction2 and Collection

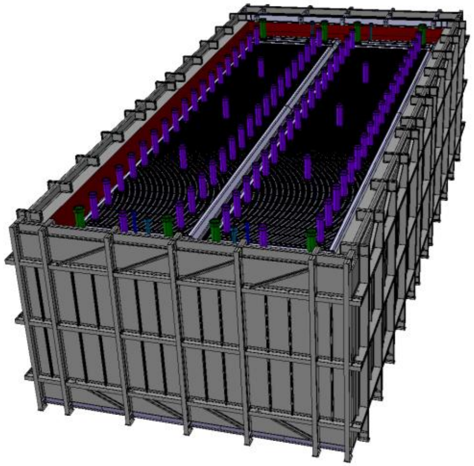
Cryogenic Upgrades

- Purely passive insulation chosen for the installation, coupled to standard two-phase N_2 cooling shield, redesigned and tested at CERN.
- New cold vessels, made of extruded aluminum profiles welded together at CERN.

Leak tightness verified to <10^{-7} mbar l/s
Structural test on the vessel by pumping down to 20 mbar. All measurements agree with calculation: 11 mm max. deformation.

WARM VESSEL

Expected heat loss through the insulation: ≈ 6.6 kW (~10 W/m^2)



- Warm vessel produced in Europe and sent to FNAL for installation.

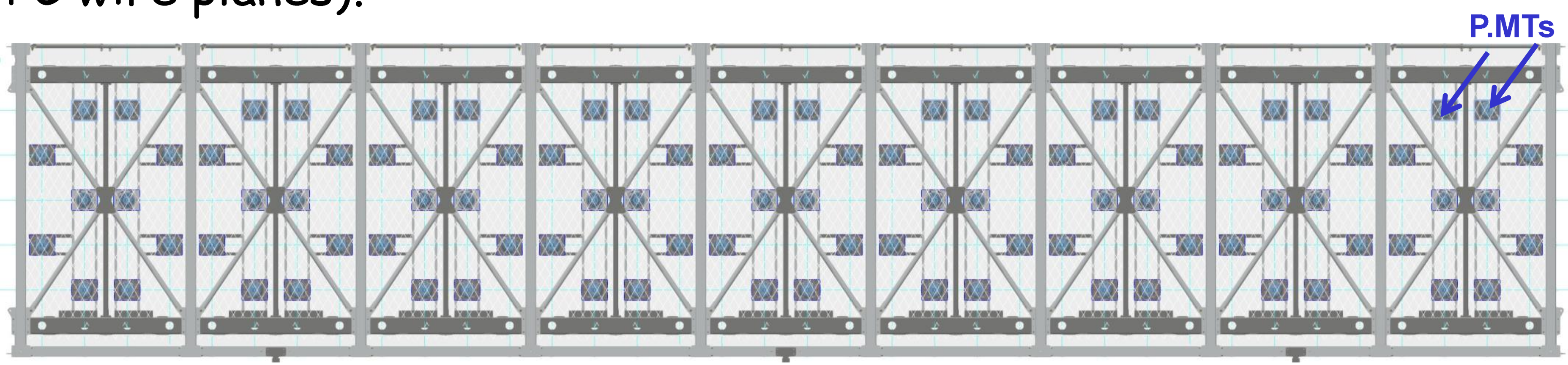
Cathode Flattening

- Each module houses two TPCs separated by a common cathode made of punched stainless-steel sheets with 58% transparency to produce ~500 V/cm electric drift field.
- Its non-perfect planarity (up to ~25 mm) resulted in % field distortions which affects e-drift velocity for particles travelling close to the cathode.
- As a result a small under-estimation of muon momentum measurement via multiple Coulomb scattering (MCS) was detected at p >3 GeV/c, (details by F. Varanini at this conference).
- Cathode panels underwent thermal treatment reducing the non-planarity to within few mm.

These interventions extend the muon momentum measurement by MCS well above the range required by the next short/long base-line ν exper.

Upgrade of the light collection system

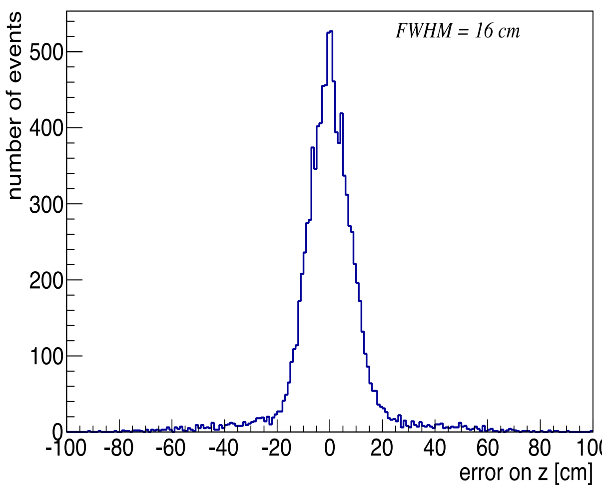
- The T600 light detection system is devoted to:
  - Generate a light based trigger signal;
  - Identify the time of occurrence (t_0) of each interaction.
- The realization of a new scintillation light detection system is fundamental to reject the expected huge cosmic background due to the T600 shallow depths operations. A particle detection below 100 MeV of deposited energy and a time resolution of ~1 ns are required.
- The system consists of 90 PMT 8" HAMAMATSU R5912-MOD for TPC, coated with TPB wavelength shifter and installed behind each wire planes (360 PMTs in the whole T600 for a total coverage of 5% of the TPC wire planes).



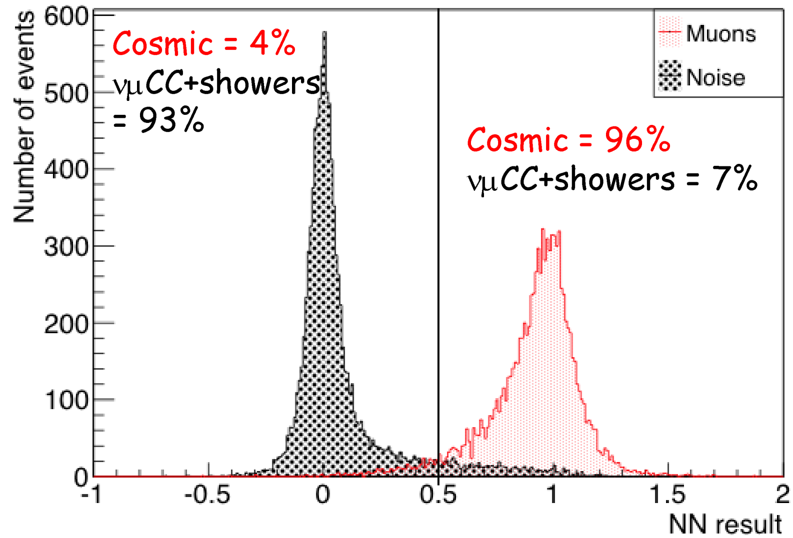
Z axis (beam direction)

Upgrade of the light collection system

- PMT number/ layout have been defined by M. C. studies aiming at:
  - maximizing spatial localization capability;
  - performing μ-tracks /e.m. showers separation, with a neural network approach, to help reducing cosmic backgrounds.



95 % of events localized along the beam direction within 30 cm using only PMT signals with fast component >10 phe thr.

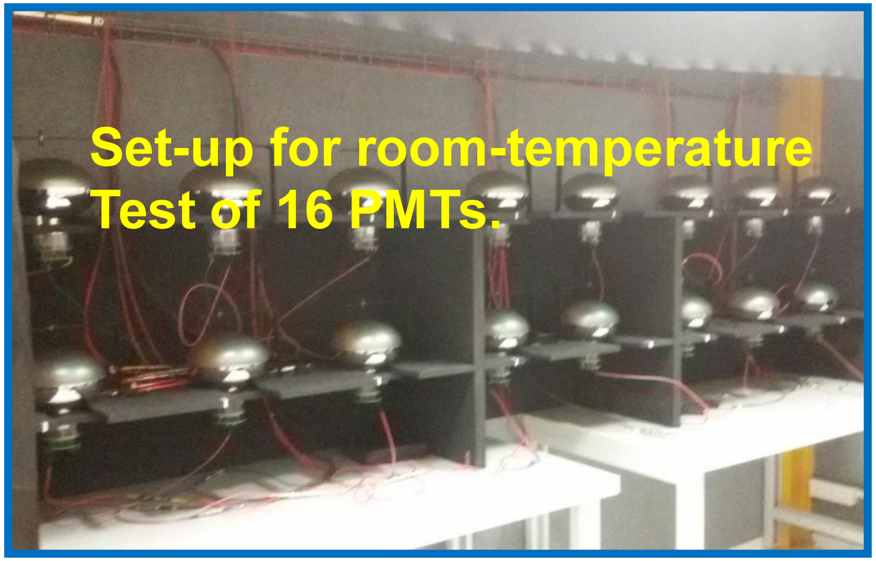


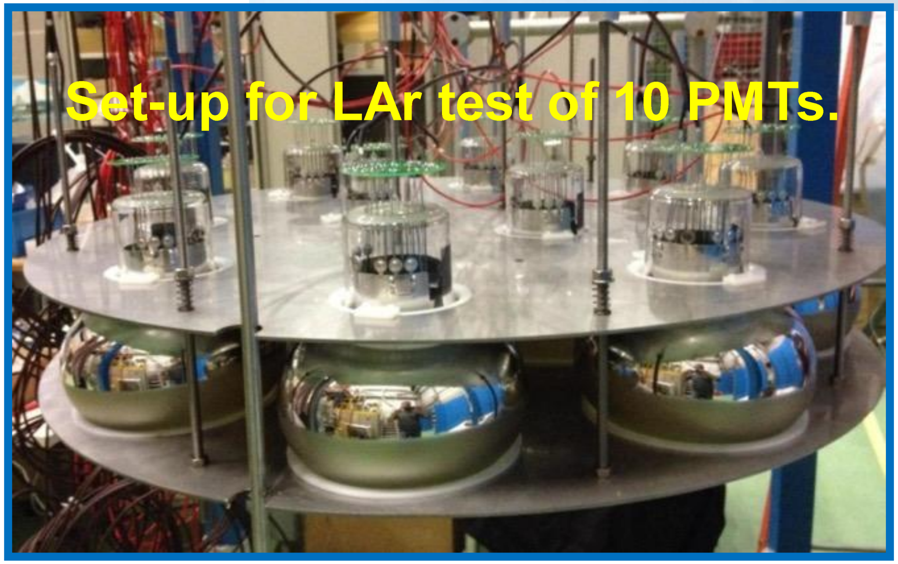
The combined use of different Neural Networks can provide a clear cosmic μ 's identification.

- An event localization better than 0.5 m and an initial classification of different topologies (μ-tracks/e.m. showers) can be obtained exploiting the arrival time of prompt photons and the light intensity.

Upgrade of the light collection system

- Test carried out at CERN in dedicated areas where a dark-room and a cryogenic facility were arranged.
- 400 PMTs were tested at room temperature and directly in a LAr bath to evaluate the parameter variation at cryogenic temperature.

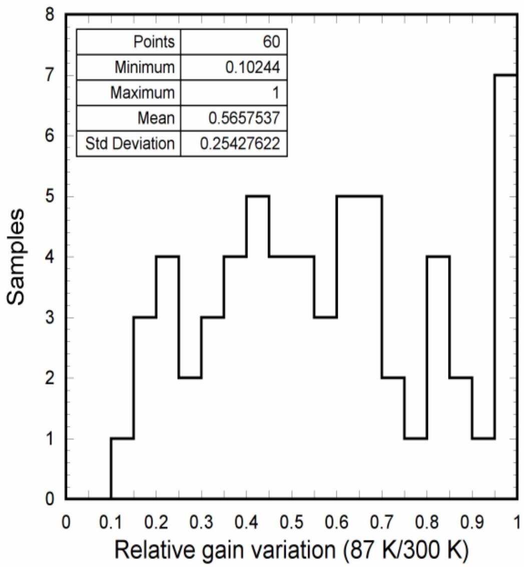


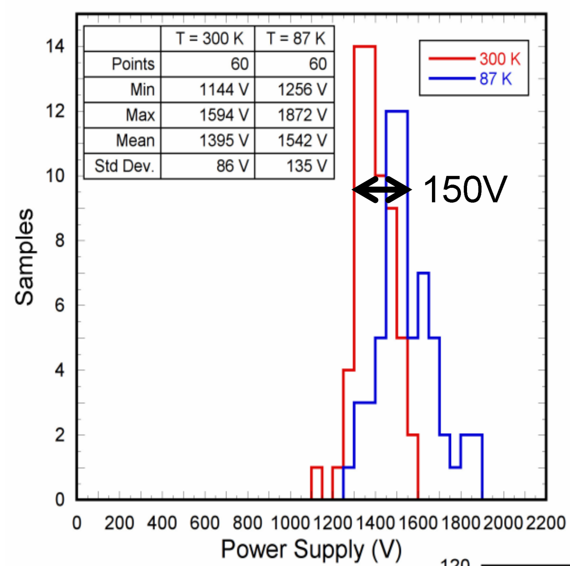


- Test carried out by illumination of the PMT surface by means of a LASER diode (405 nm) and optical fibers. A standard electronic chain (PRE+AMPL+MCA) was adopted.

PMT test results

Measurements include: signal characteristics, gain variation, saturation effects, photocathode uniformity, timing characteristics…

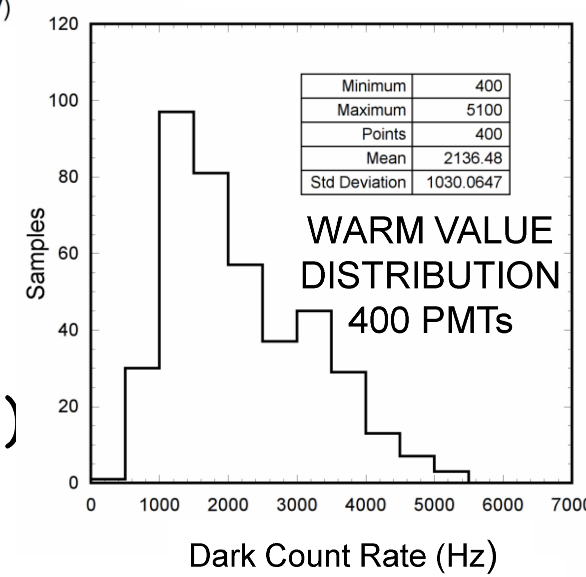


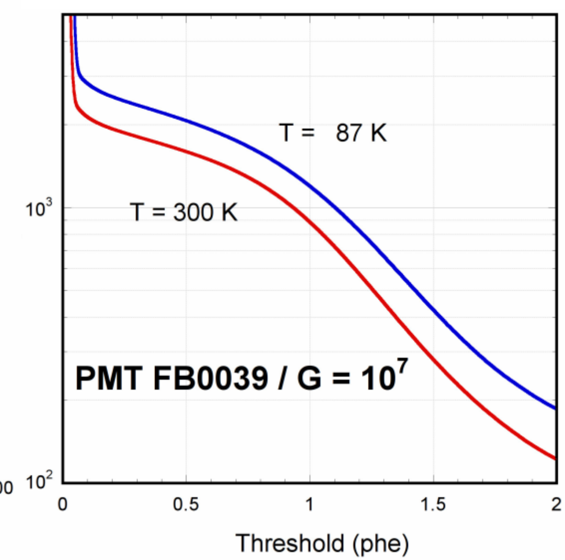


A gain variation was experienced for almost all the 60 units at 87K, with a mean reduction of ~50%. An increase of the HV supply (150V) is enough to restore the nominal value.

Dark count rate is also affected by the temperature, with a factor 2 increase at 87K with respect to the nominal values at room temperature (well known effect in literature though not yet completely explained)

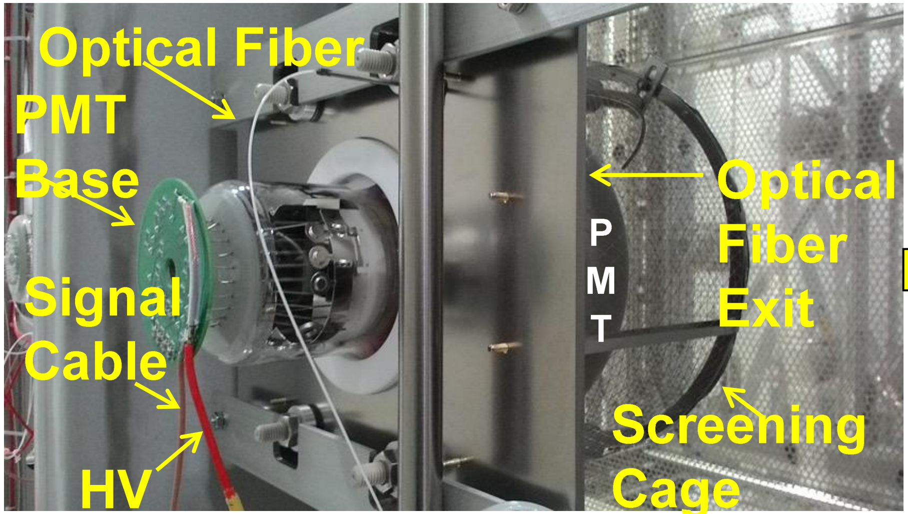
All the tested PMTs were rated for installation in the T600





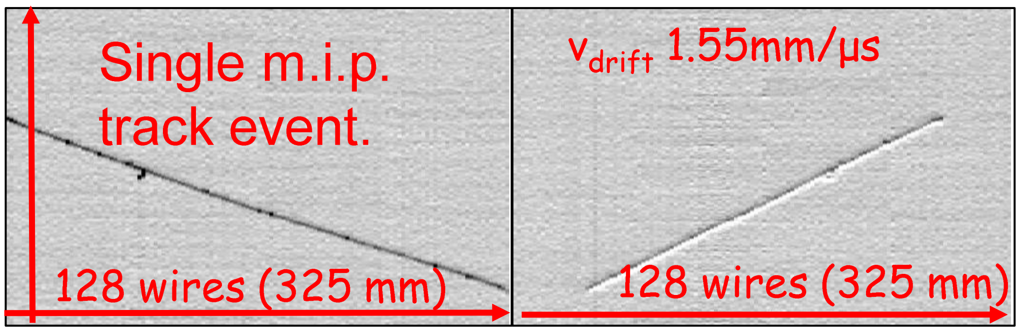
PMT installation

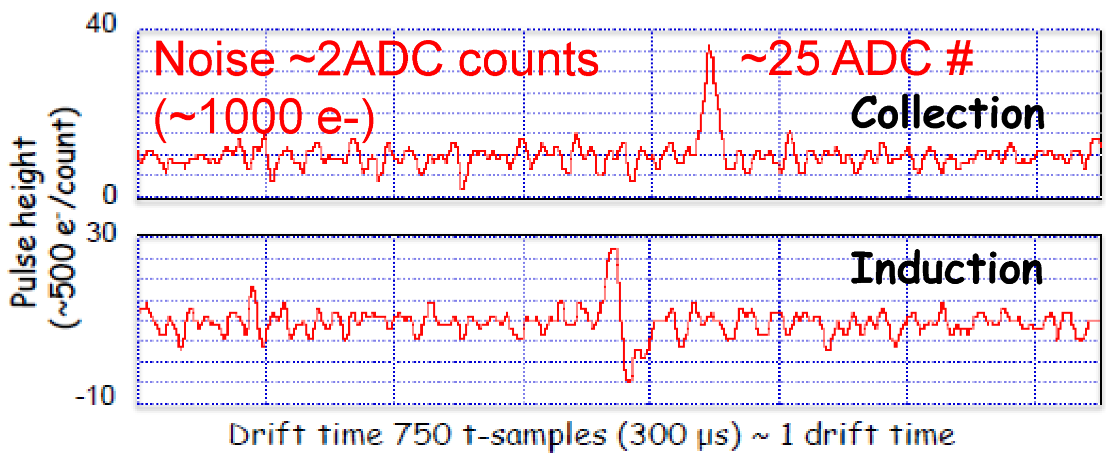
- Before installation all PMTs were coated by evaporation with ~200μg/cm^2 of Tetra-Phenyl-Butadiene (TPB) to detect the λ=128nm scintillation.
- New mechanical supports for the PMT installation were designed. Each device is inserted into a wire screening cage to prevent the induction of PMT pulses on the facing collection wire planes. An optical fiber for timing calibration is also installed

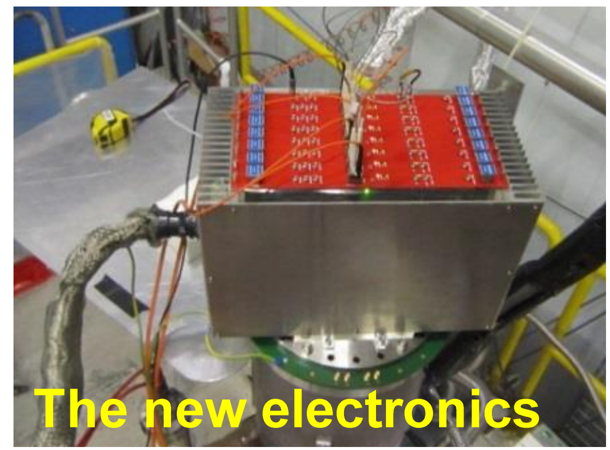


New TPC wire read-out electronics

- Adoption of serial ADCs (12 bits, one per channel), very compact, allowing for hosting both analogue and digital electronics directly on the proprietary flanges (~54000 channels total).
- Throughput of read-out of the whole detector improved up to 10 Hz.
- Synchronous sampling of all channels (400 ns sampling time) of the whole detector: relevant to slightly improve the μ momentum measurement by MCS, Δp/p from 15% to 12%.

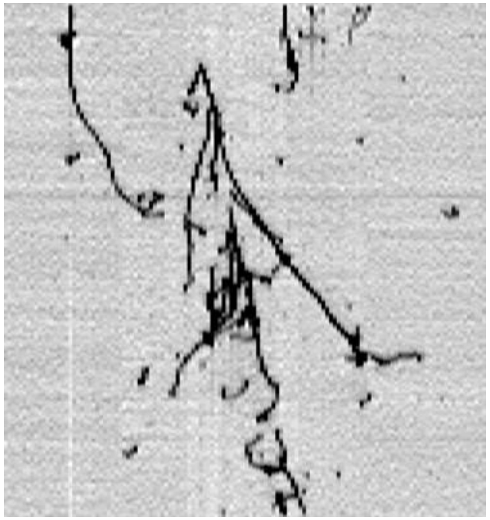




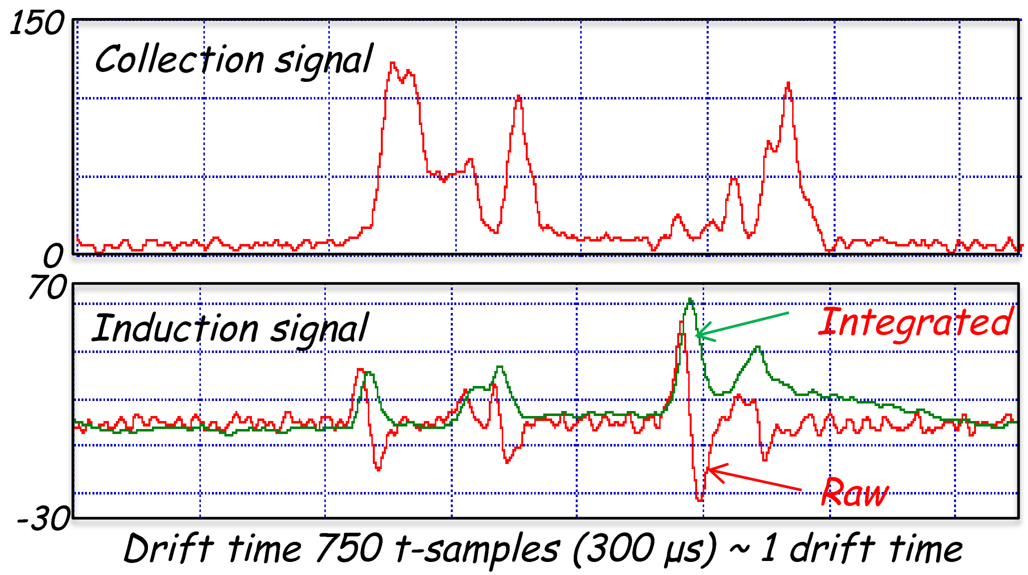


FOR MORE DETAILS SEE:
Guang Meng "The new front end and DAQ of the ICARUS detector" poster presentation at this conference

Induction and Collection signals from the new electronics




128 Collection wires (325 mm) 128 Induction wires (325 mm)



- Clean images also for complex shower events both in Collection and Induction views;
- The optimized preamp architecture with shorter shaping time (~1.5μs) 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 allowing for a better event reconstruction.

Conclusions

- The ICARUS T600 detector remains to date the only large volume LAr-TPC having successfully operated, for a three years in Gran Sasso underground laboratory collecting both CNGS neutrinos and cosmic rays.
- The detector will be exposed to the Booster Neutrino Beam at FNAL, within the SBN program, aiming at a definite answer to sterile ν hypothesis.
- To face the new experimental situation at FNAL with respect to the LNGS run, the whole apparatus underwent important upgrades.
- The overhauling of the internal parts of the apparatus has been completed in time for T600 to leave for FNAL.
- A strong effort is being carried on by INFN, CERN and FNAL to prepare the installation and commissioning of ICARUS in the far position on the BNB, to start data taking in 2018.

icarustrip.fnal.gov

Thank you!