The Light detection system of the ICARUS T600 detector at the Short Baseline Neutrino (SBN) Experiment

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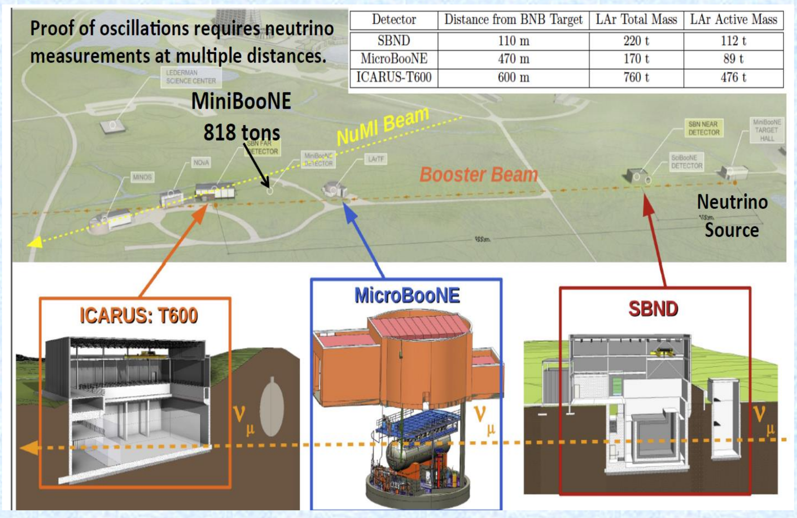
SBN - Short Baseline Neutrino Experiment

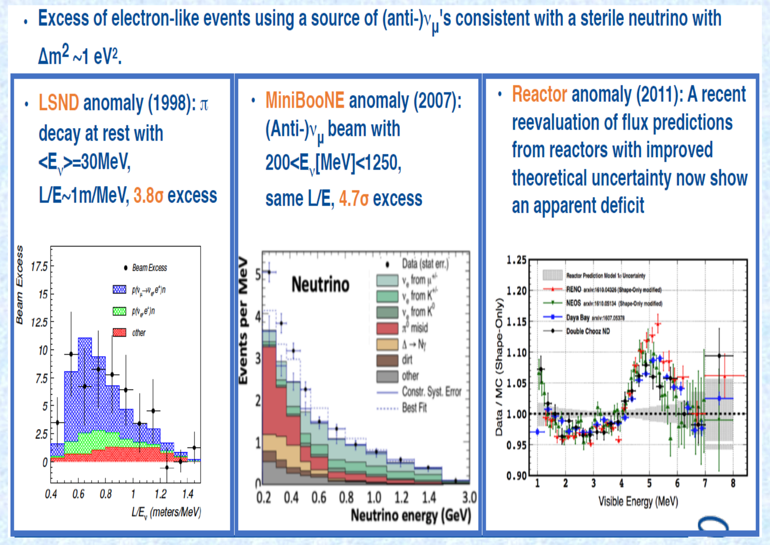


SBN Program

- *Short Baseline experimental anomalies have been reported over the last 20 years*
- *Common interpretation is as evidence for one or more additional, mostly "sterile" neutrino.*
- *The Short Baseline Neutrino Program is composed of three LArTPC detectors with the goal of definitively addressing the hints of eV-scale sterile neutrinos.*

Physics motivation of SBN :

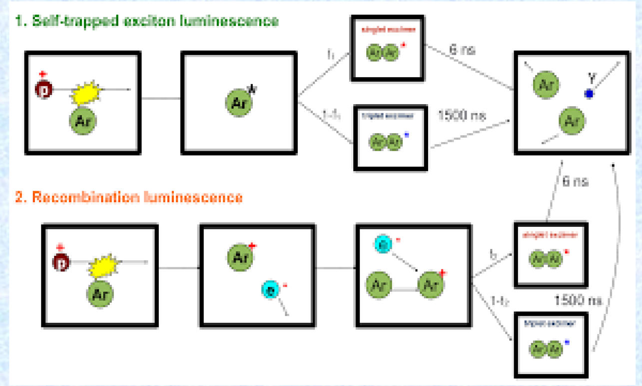
- *Resolve the low-energy excess anomaly*
- *Search for νe appearance and νμ disappearance*
- *Multiple detectors at different baselines are key for reducing systematic uncertainties with same target and same beam.*
- *Preparation for future long-baseline neutrino experiment*
- *Further R&D of LArTPC technology*



Excess of events from three different experiments

New Light Detection system

- *Scintillation light emission in LAr is due to the radiative decay of excimer molecules Ar^*_2 produced by ionizing particles, releasing monochromatic VUV photons (λ ≈ 128 nm) in transitions from the lowest excited molecular state to the dissociative ground state, A fast (τ ≈ 6 ns decay time) and a slow (τ ≈ 1.5 μs) components are emitted.*
- *The light detection system will be contributing to identify neutrino interactions occurring in the neutrino beam spill gate and rejecting the expected cosmic background*
- *This requires high light detection granularity, good timing resolution, sensitivity down to low threshold*



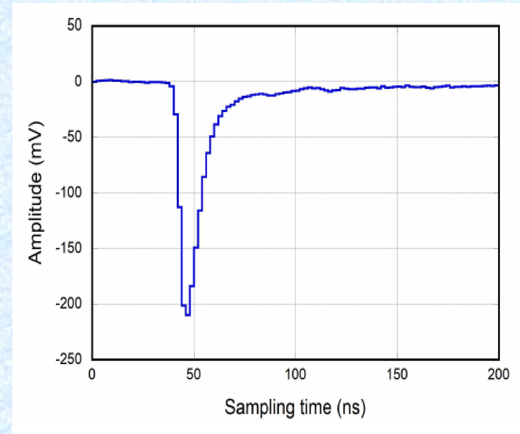
Scintillation mechanism in LAr

R5912-MOD PMT

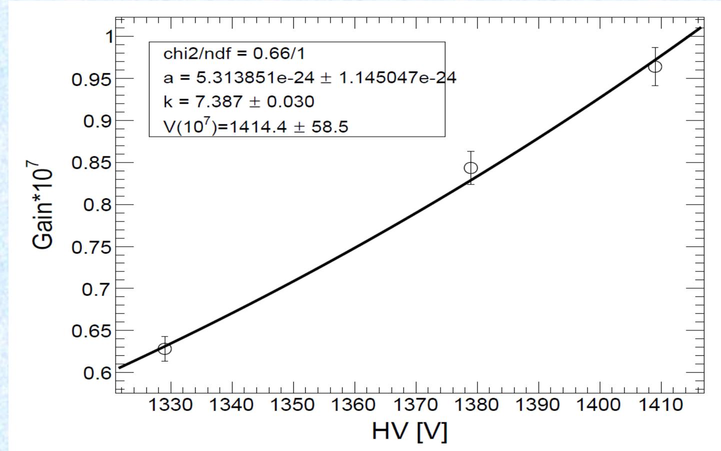
- *The large area (8 inch) R5912-MOD Hamamatsu PMTs coated with TPB were considered.*
- *Very good timing resolution (~ns)*
- *Sensitivity to ionizing interactions in LAr down to 100 MeV with good quantum efficiency*
- *High gain (10^7) and low dark rate at cryogenic condition*

Characterization and performance of the PMTs

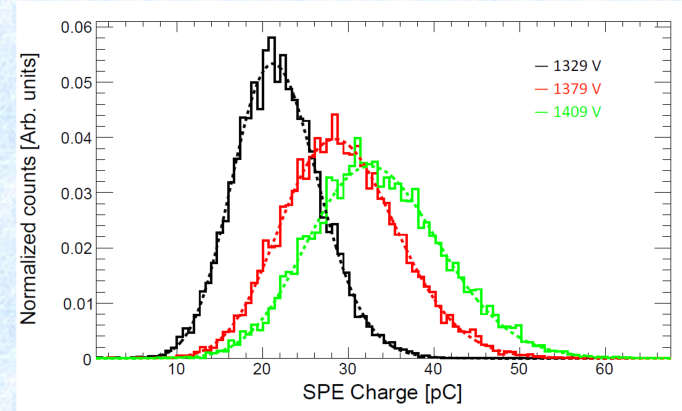
- *The full light detection system was tested at Fermilab after installation in order to check the functioning of all the PMT channels, evaluate their performance before cooling down.*
- *An example of PMT signal shape recorded in combination with a Laser light pulse is shown.*
- *The PMT signal analysis was mainly focused on the gain calibration and dark count rate.*
- *The distribution of the applied voltage needed to obtain a gain of G = 10^7 for all 351 working PMTs is shown below*



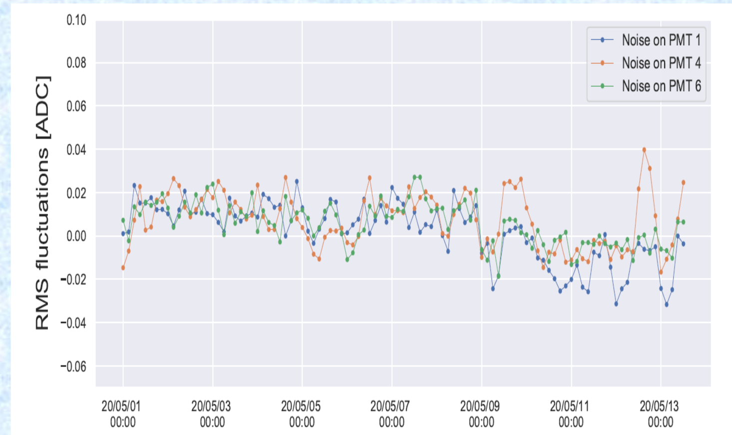
PMT signal shape



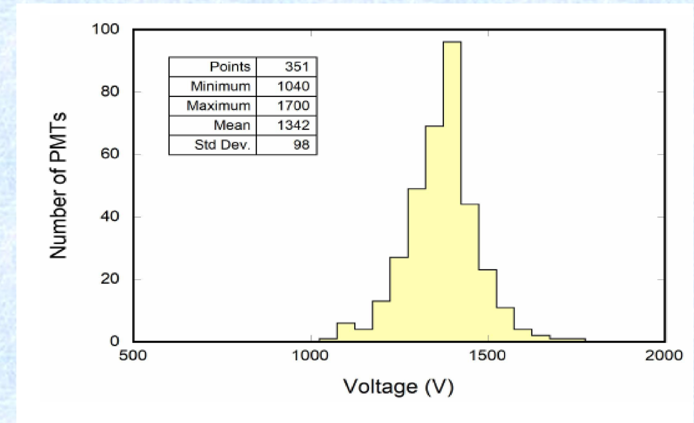
Gain at three different voltages



Single PE charge spectra at three different voltages



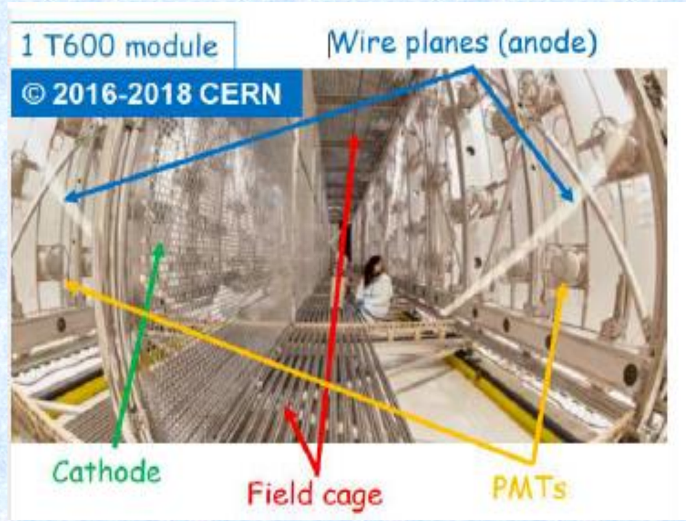
RMS fluctuation for different PMTs in LAr



Voltage distribution to attain 10^7 gain

ICARUS-T600 Detector

- *First large-scale LAr-TPC in a neutrino beam*
- *Two identical module: each module size : 19.6 (L) x 3.6(W) x 3.9(H) m3 ; total LAr mass ~760 tons, active LAr mass 476 tons.*
- *Drift distance 1.5m, drift field 500V/cm → drift time ~ 1ms*
- *3 signal wire planes (2 Induction+Collection) with wire readout*



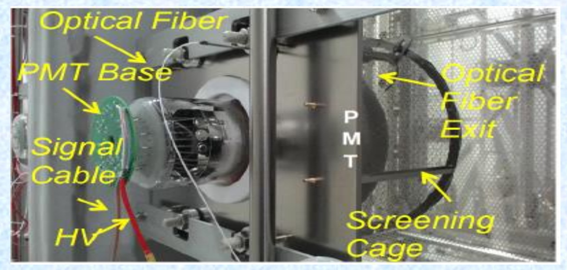
ICARUS Detector at SBN

- *ICARUS at FNAL is facing a more challenging experimental condition (surface) than underground condition at LNGS*
- *Large (11 kHz) of cosmic ray events will be occurring continuously during the readout time window of T600 at SBN*
- *To overcome the new experimental challenge, T600 underwent an intensive overhauling at CERN*
- *One of the significant upgrade is on light detection system (PMTs)*

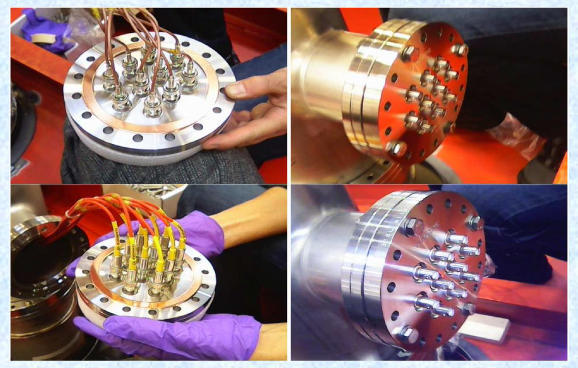
Deployment and installation of the PMTs

- *Total of 360 PMTs deployed in groups of 90 devices behind each wire chambers.*
- *PMTs are located in the 30 cm space behind the wire planes, 10 unit for each frame sector.*
- *The sensitivity to vacuum-ultra-violet (VUV) photons was achieved by depositing a layer of a proper wavelength shifter on the PMT windows (220ug/cm²)*

Configuration of PMTs installed behind the wire plane



Complete assembly of the PMT inside the cryostat



Assembly of the PMT flanges with signal and HV cables

- *For each group of 10 PMTs mounted in the same frame sector, two bundles of 10 signal cables and 10 power supply cables are deployed along the mechanical structure up to the frame top*
- *The top edge of each chimney hosts a set of feedthrough flanges for the interconnection of various elements of the detector (PMT signal and power supply, optical fibers and sensors)*
- *PMT electronics is designed to allow continuous read-out, digitization and independent waveform recording of signals coming from the 360 PMTs using 24 V1730B digitizer*
- *Installation and testing of all the components of the light collection system completed Dec 2019.*

Conclusions

- *The new scintillation light detection system for the ICARUST600 LAr-TPC realized for its operation at Fermilab in the context of the SBN program, includes the use of 360 large area PMTs mounted behind the wire planes and a fast-laser calibration system*
- *The high performance of this detection system in terms of sensitivity, granularity and time resolution, will permit ICARUS to cope with the large cosmic ray background by identifying the events associated with the neutrino beam*
- *Installation and testing of all the components completed.*
- *Commissioning of the detector components started after cool-down*

Acknowledgement .

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