Light readout system for the Liquid Argon TPC of the DUNE ND

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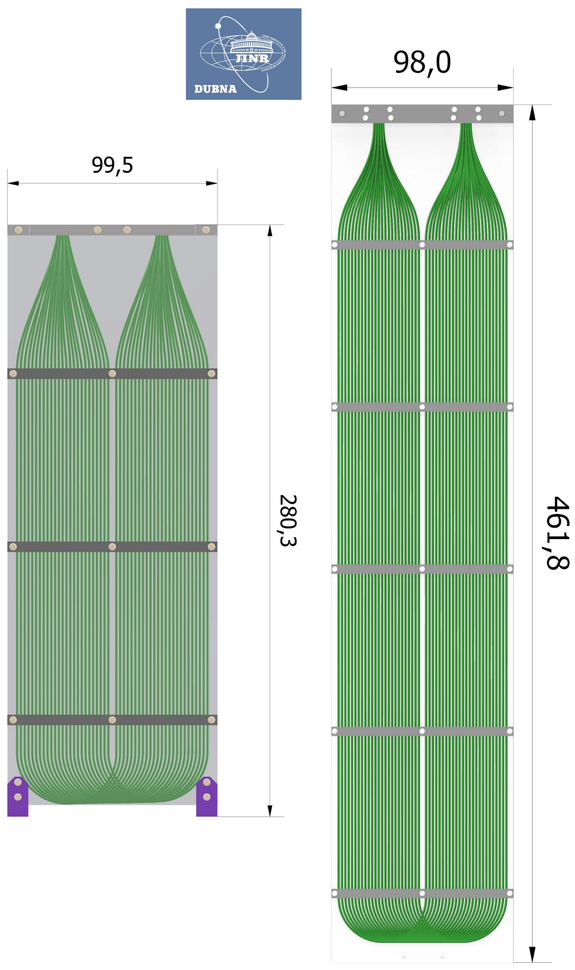
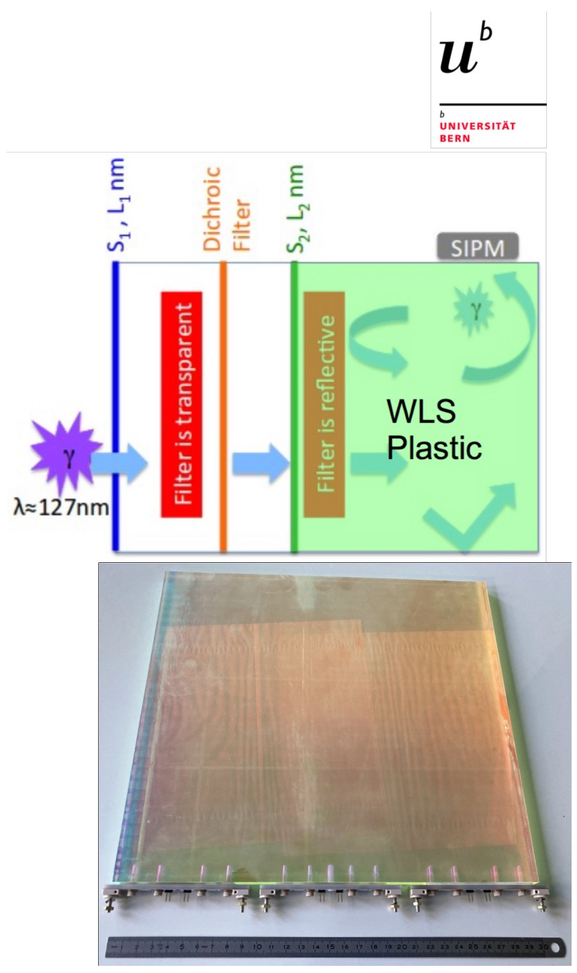
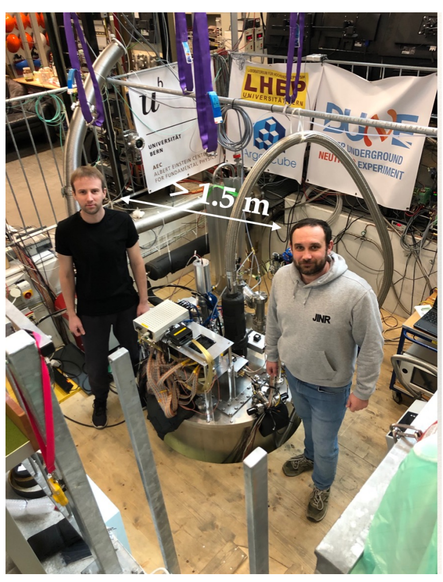
Abstract: A modular liquid-argon (LAr) TPC with pixelated charge readout is considered as a part of the near detector for the DUNE experiment. Such the TPC is developing by ArgonCube collaboration. To provide a trigger for the neutrino event the LAr scintillation light detection is proposed. The light is a vacuum ultraviolet with 128 nm wavelength, thus, it is a challenge to register it. The main requirements imposed on the light detection system are: a good performance at cryogenic temperatures, nonconductive materials, compact dimensions, detection efficiency at a level of percent. A light collection module (LCM) as a one candidate for the system is developed at JINR (Dubna, Russia). Second candidate is ArCLight which was developed at University of Bern. Also, a full readout chain for the Light Readout System (LRS) is being developed at JINR that contains the front-end electronics, SiPMs power supply, ADC, cold PCB.
The ArgonCube 2x2 program is currently ongoing to verify the performances of the subsystems of the TPC including LRS. So far, 3 TPC modules have been tested in the Bern University cryogenic laboratory using cosmic muons. These studies have shown a good performance of the LRS subsystem. Further tests at Fermilab of all 4 TPC modules (2x2 setup) are going to verify the LRS performance using neutrino beam.

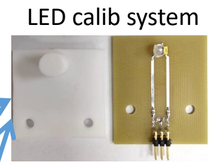
Light detectors concept

Light Collection Module construction is based on the ribbon of wavelength shifting fibers with a coating of tetraphenyl butadiene (TPB). ArCLight construction is based on the WLS plastic covered with a TPB coated dichroic filter on the one side. The purpose of the TPB is to re-emit the scintillation light of the liquid argon to the blue light which is trapped and shifted to the green light by the WLS-dopant. SiPM light readout is utilized on both detectors.



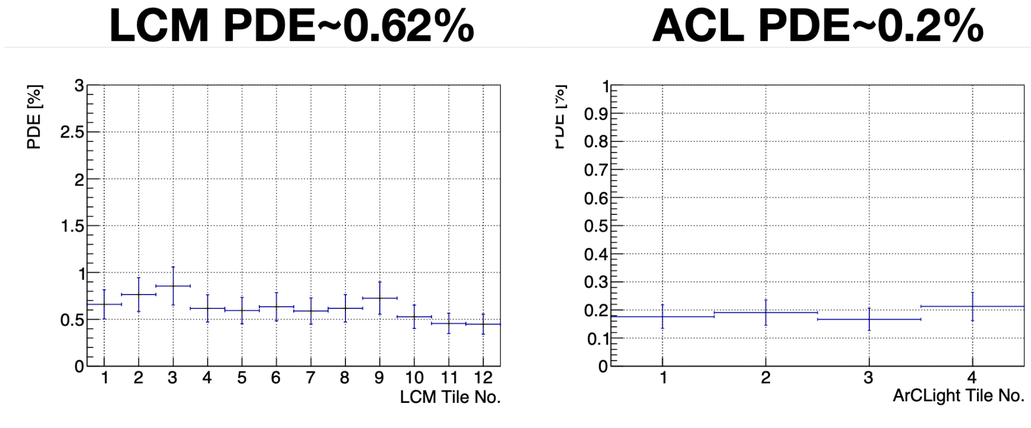






The calibration system prototype of the LRS uses LEDs (4 LEDs per TPC). It allows for conducting time calibration of the LRS and SiPM gain calibration.

LRS have to provide the photon detection efficiency at a level of ½ percent. Obtained results of TPC prototypes tests at Bern showed required PDE.

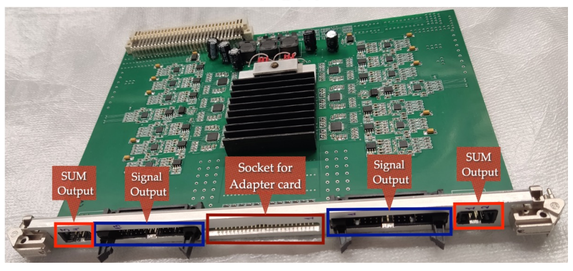


LRS electronics

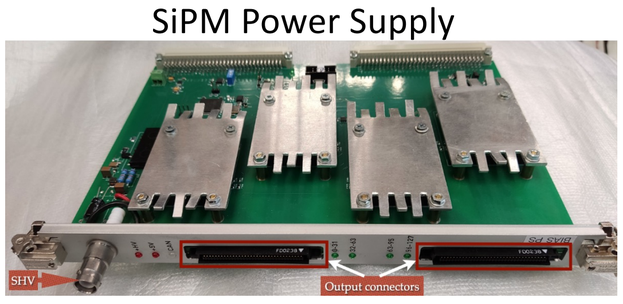
The set of electronics has been designing for the light readout system, including the SiPM PS, SiPM PS control, Variable Gain Amplifier (VGA), VGA control unit, and cold preamplifiers PCB. SiPM PS is based on HV DAC (up to 200V) and contains 128 individually controlled channels. VGA contains 24 ch of variable amplifiers together with 4 ch of sum signals of a group of 6 signal channels. Cold PCB with preamplifiers, called E-PCB, is developed to transmit the signals to the long coaxial cable lines outside the cryostat.

LRS uses 64 ch AFI ADC developed at JINR with 14-bit resolution, 62.5 MS/s. White rabbit synchronization client is implemented in ADC. ADC allows to digitizing of up to 2048 samples.

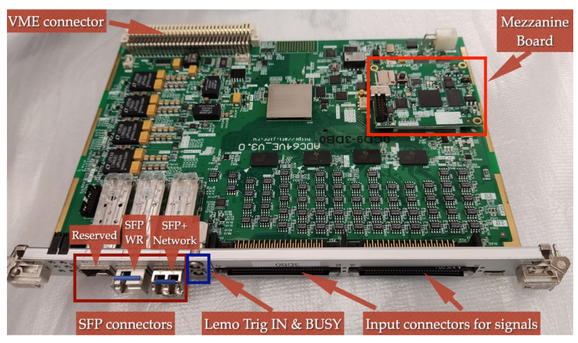
VGA



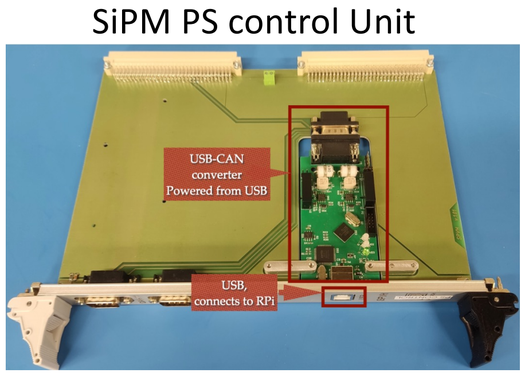
SiPM Power Supply



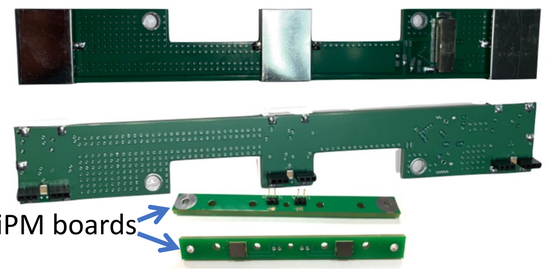
ADC board



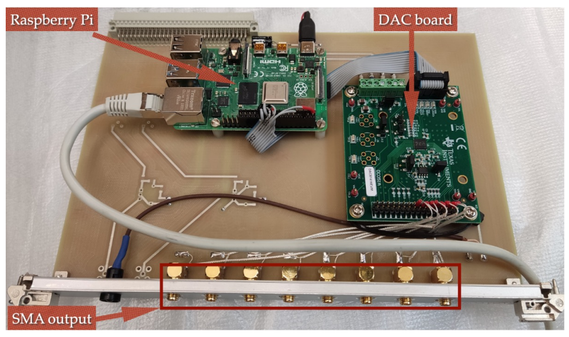
SiPM PS control Unit



E-PCB



VGA control unit



There is a requirement for the LRS to have a time resolution at a level of a 10 ns. Carried-out tests at Bern University show that the time resolution of the LRS is at level ~ 1 ns (see plot below).