

Development of an Argon Light Source as a Calibration and Quality Control Device for Liquid Argon Light Detectors



M. Tosun^{1,2,3}, B. Bilki^{1,3,4}, F. Boran^{1,5}, F. Dolek^{1,5}, and K. K. Sahbaz^{1,2,3}

¹ Beykent University, Istanbul, Turkey

² Ankara University, Ankara, Turkey

³ Turkish Accelerator and Radiation Laboratory, Ankara Turkey

⁴ University of Iowa, Iowa City, USA

⁵ Cukurova University, Adana, Turkey



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Motivation

The majority of future large-scale neutrino and dark matter experiments are based on liquid argon detectors.

Since liquid argon is also a very effective scintillator, these experiments also have light detection systems.

127 nm wavelength of the liquid argon scintillation leads to the development of specialized light detectors, mostly based on wavelength shifters, and recently photodetectors sensitive to deeper UV.

The effective calibration and quality control of these newly developed detectors is still a persisting problem.

In order to respond to this need, we developed an argon light source which is based on plasma generation and light transfer across a MgF_2 window.

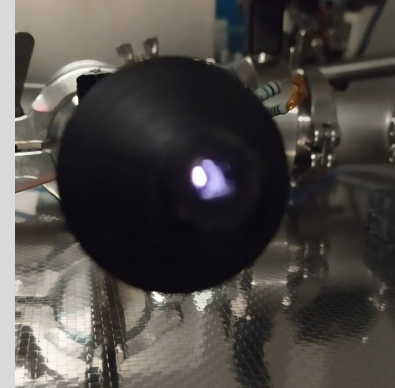
Argon Light Source

Needs to be:

- Small
- Portable
- Practical
- Relatively consistent in performance

The light source was made using

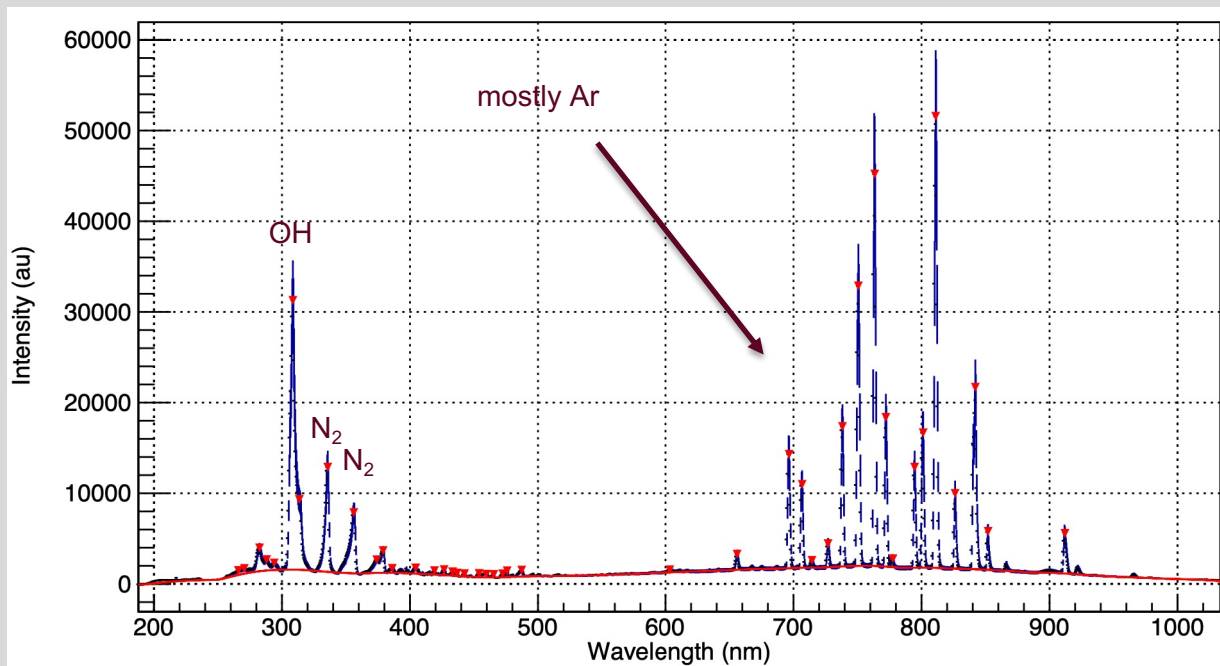
- Polyoxymethylene body
- 1 mm thick, 6 mm diameter MgF_2 window
- Titanium electrodes with 2 mm separation



Vacuum compatible epoxy was used at the connections and in flange construction.

Measurement of Emission Spectra

The emission spectra under various conditions were measured with Ocean Flame-S-XR1-ES spectrometer in 200 – 1000 nm range. Argon and impurity peaks are identified and the intensity integrals are calculated.

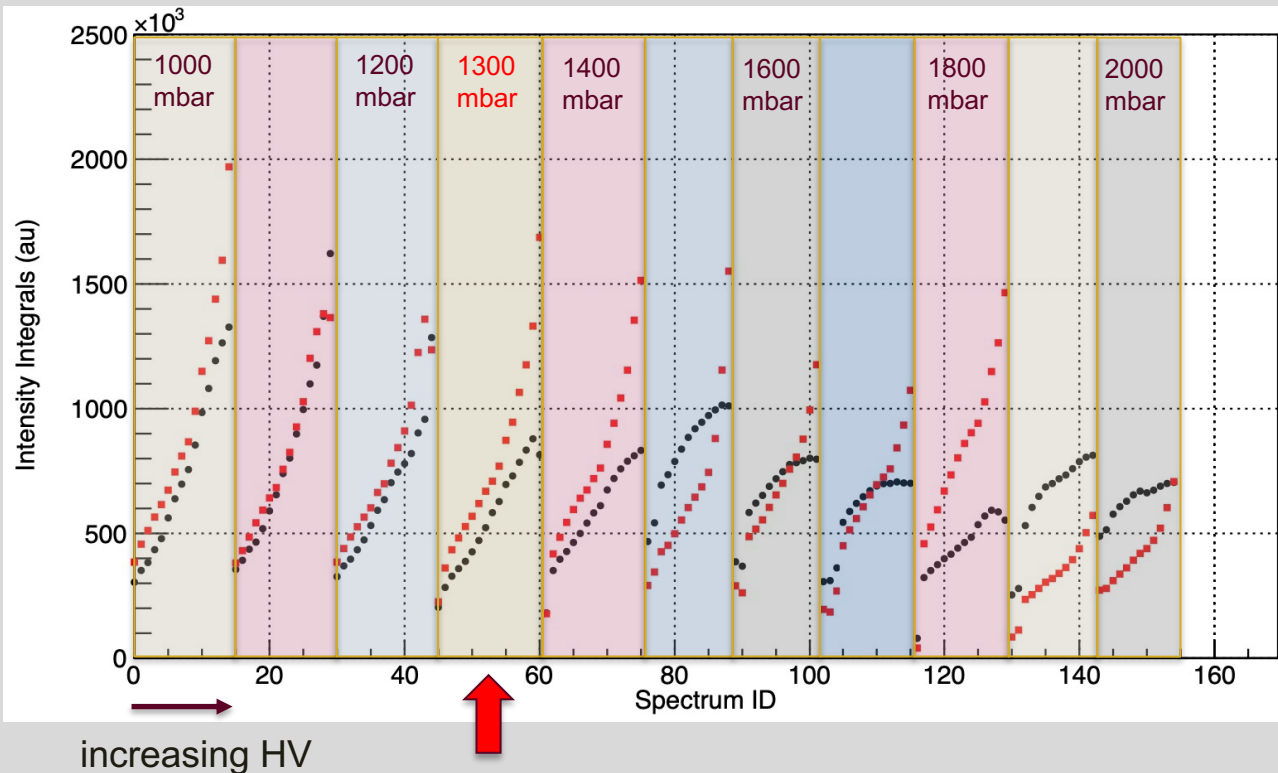


The light source was flushed with argon twice before measurements.

The gas contamination certified by the producer was 0.1 – 1 ppm.

Optimization for Maximum Argon Light

The light source was operated at 1000 – 2000 mbar range and at voltages in steps of 100 V from 2600 V down to the point the light is lost (1200 – 1300 V). Intensity integrals for the combined Argon emissions and the impurity emissions are compared.



Argon emissions
Impurity emissions

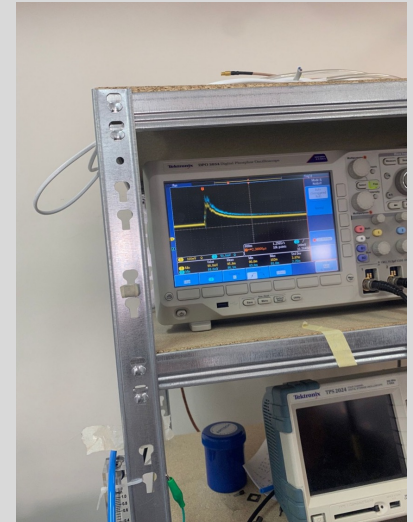
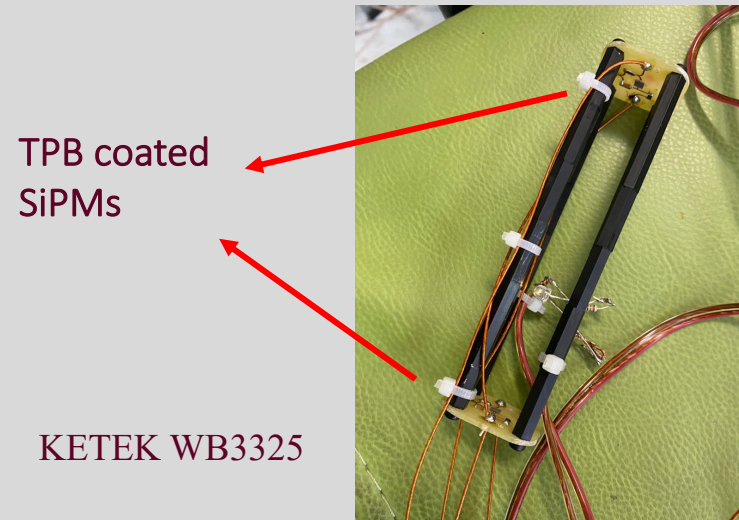
1300 mbar 2600 V
was chosen as the
default operating
point.

127-nm Sensitive Optical Detectors

In order to validate the performance of the light source, we needed optical detectors sensitive to the 127 nm light.

The simplest solution is coating SiPM windows with TPB (tetraphenyl butadiene). We dissolved TPB in toluene and applied on the SiPM windows with airbrush. In order to validate the sensitivity of the TPB coated SiPMs to 127 nm light, we constructed a small liquid argon chamber.

Tests of the SiPM assembly in liquid nitrogen



Liquid Argon Tests of the Optical Detectors

camera

We liquified high purity argon gas in a liquid nitrogen bath.

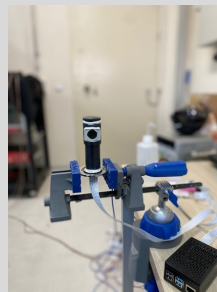
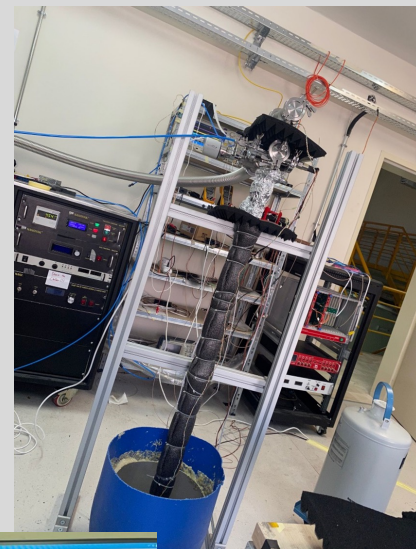
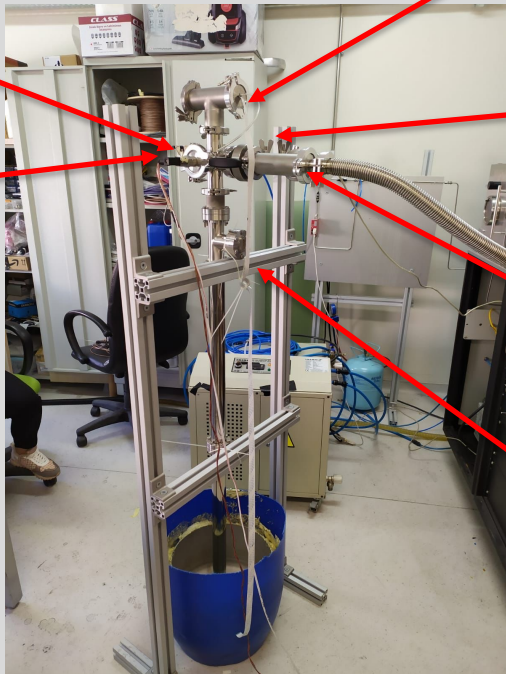
safety valve

pressure transmitter

gas inlet

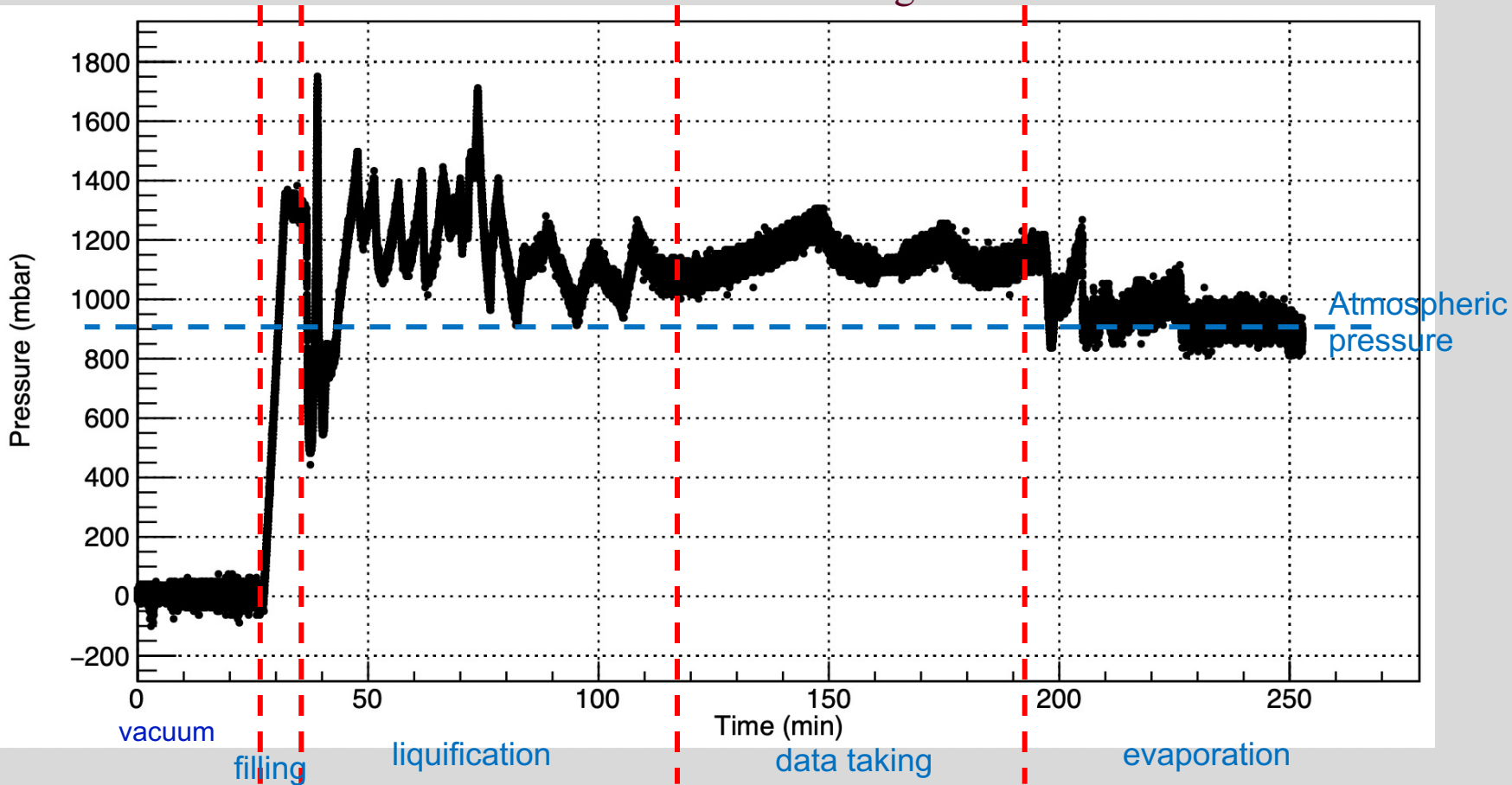
vacuum connection

Signal/HV/pt1000 feedthrough



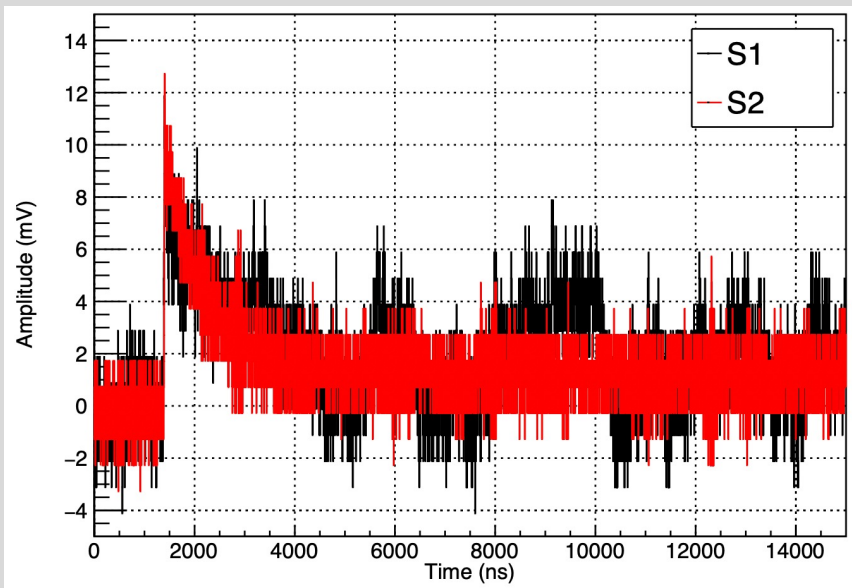
Liquid Argon Tests - Operations

The initial vacuum was 8×10^{-6} mbar.
The operation was smooth and the purity allowed
data taking for ~60 minutes.

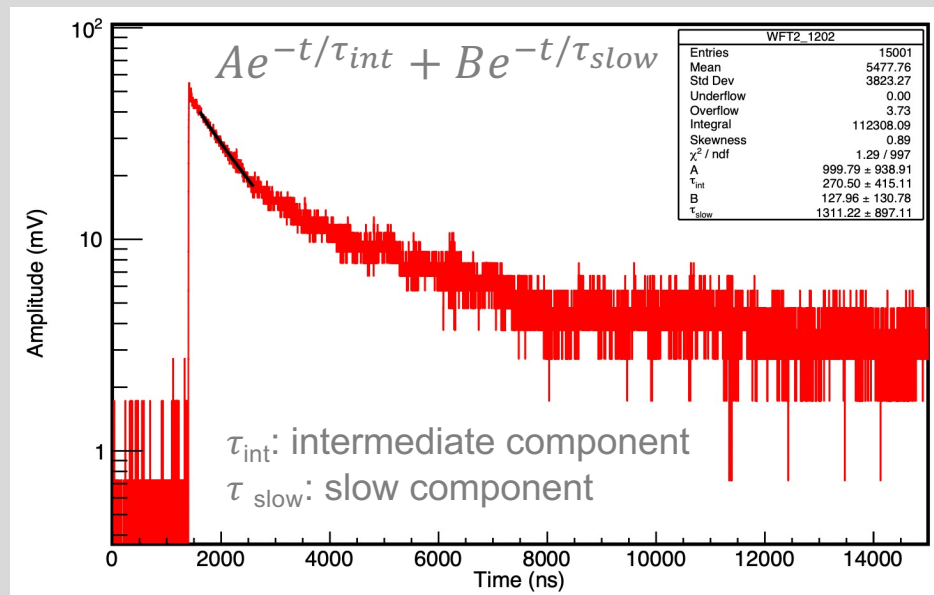


Liquid Argon Tests - Results

TPB coated SiPMs can be used to validate the light source performance.



An event display of the two SiPM signals (S1 and S2).



Quick inspection of the scintillation time constants (no deconvolution) with a partial fit. $\tau_{int} = 270$ ns and $\tau_{slow} = 1.3 \mu\text{s}$. Compatible with the CERN 50 liter TPC measurements ($\tau_{int} = 510$ ns and $\tau_{slow} = 1.5 \mu\text{s}$)*.

* B. Bilki, "Study of Light Production With A Fifty Liter Liquid Argon TPC", *Technology And Instrumentation In Particle Physics 2021 (TIIPP2021)*, <https://indico.cern.ch/event/981823/contributions/4293603/>

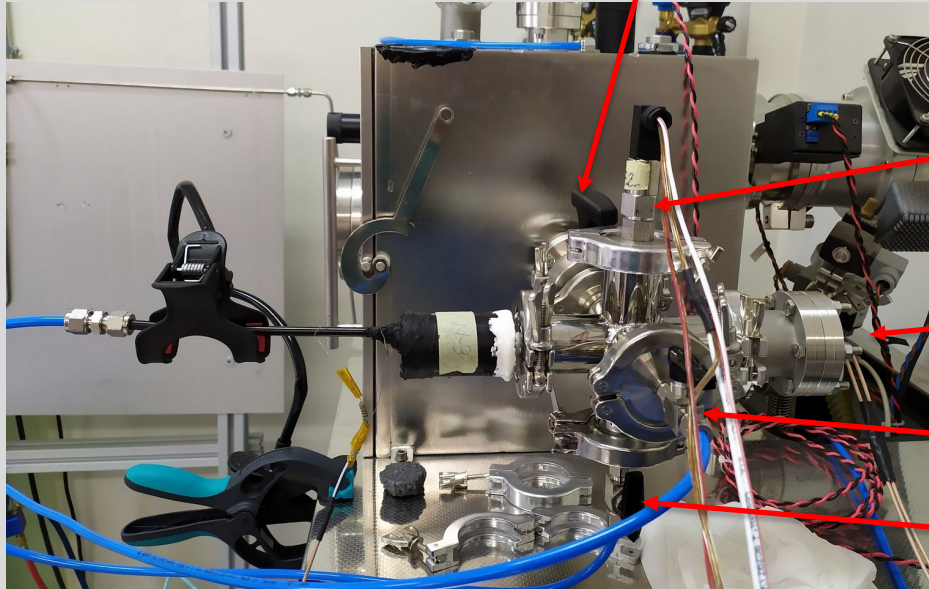
Light Source Tests - Operations

The light source performance was tested at 1300 mbar pressure with an HV of 2600 V.

The SiPM across the light source was with/without TPB coating.

The SiPM compartment was under vacuum.

vacuum connection



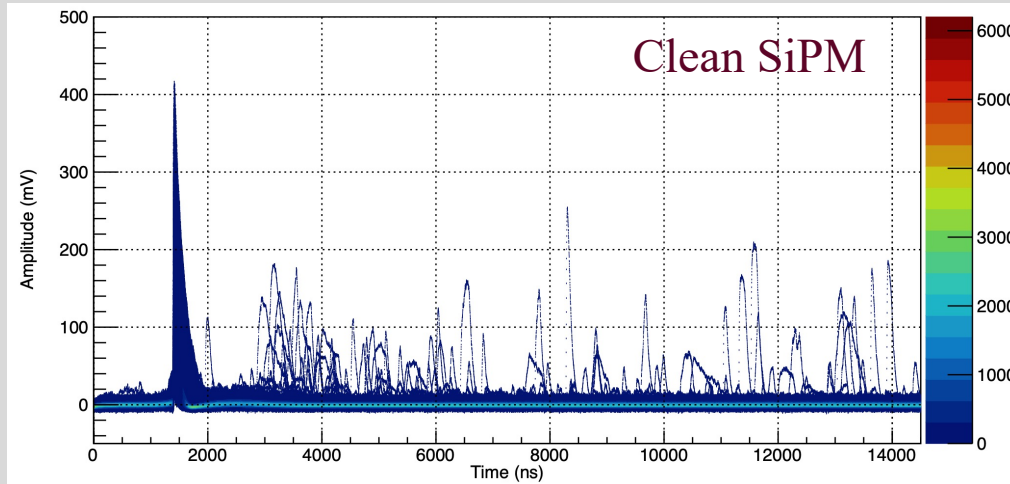
pressure transmitter

SiPM +
feedthrough flange

light source
gas valve

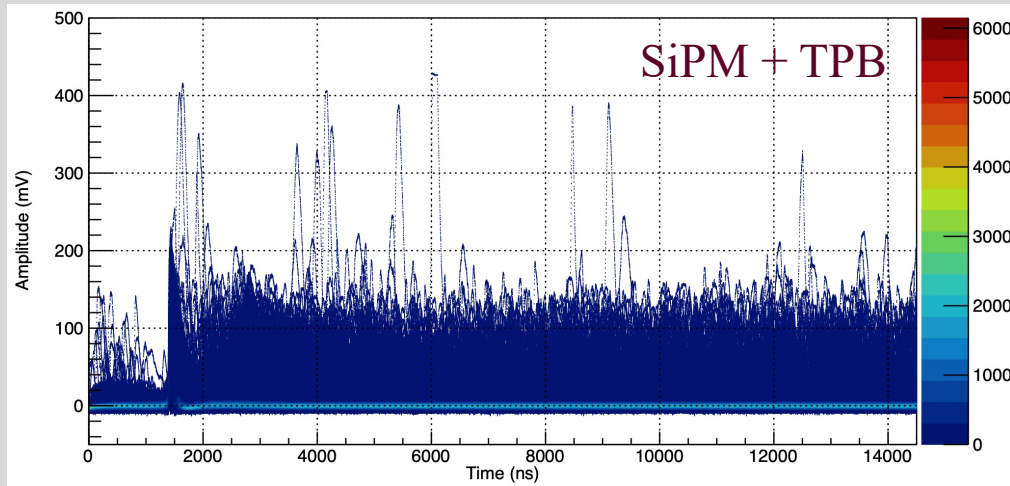
gas inlet

Light Source Tests – Overlaid Waveforms



Measurements were performed with the SiPM compartment under vacuum.

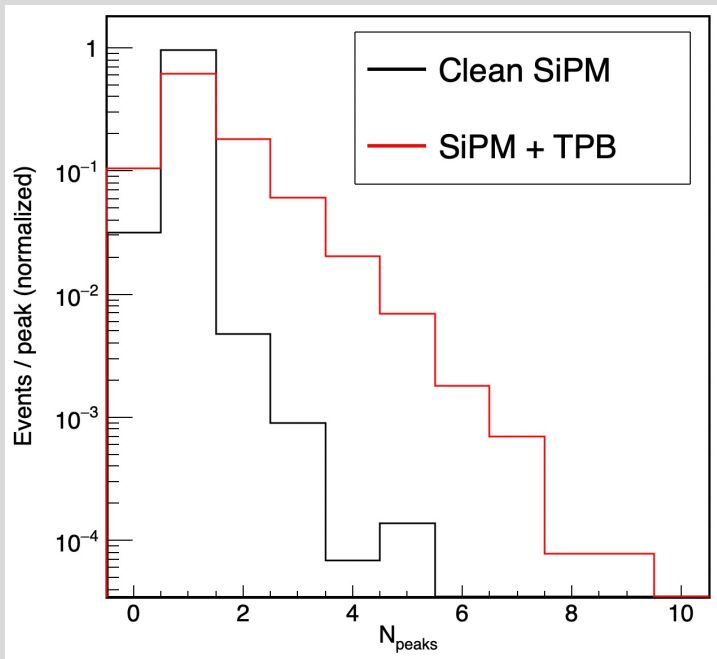
The continuum emission causes a shift in the baseline as well as overshoots and fluctuations, therefore a more careful baseline subtraction might be needed.



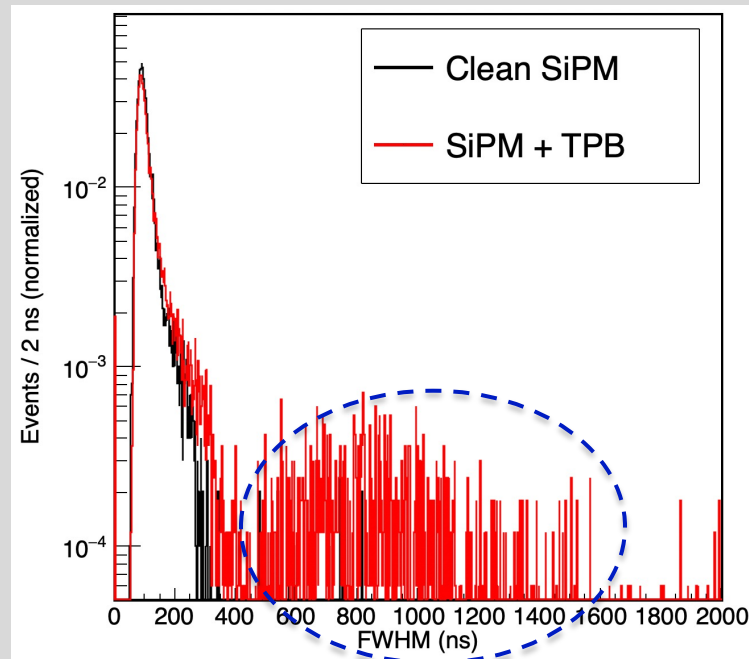
Heavily populated waveforms were recorded with the TPB coated SiPM compared to the clean SiPM.

Light Source Tests – Pulse Shapes

Number of peaks above 30 mV in the 15 μ s window.



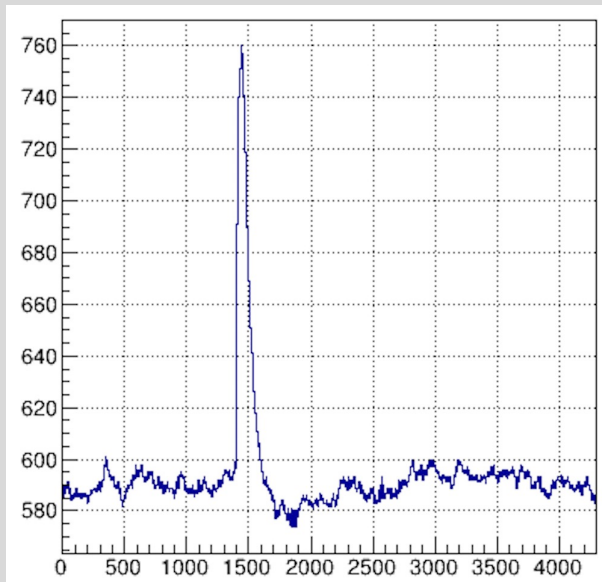
Full width at half maximum for the pulses with peak amplitudes above 30 mV.



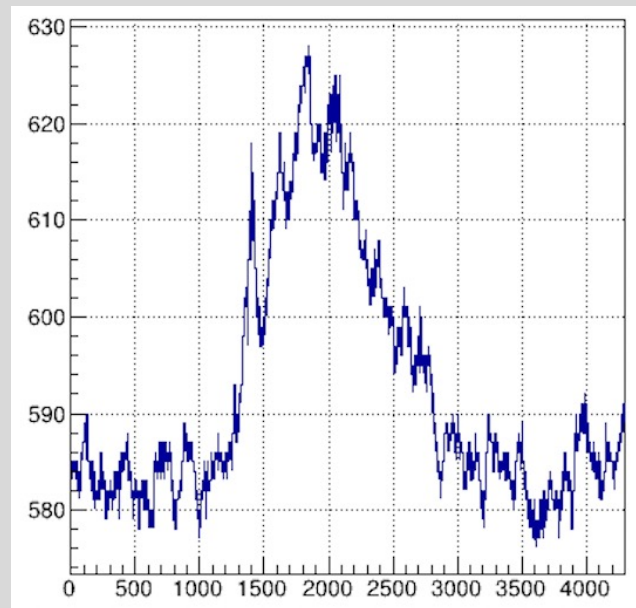
There is a small excess beyond ~ 500 ns in the SiPM+TPB configuration. The excess also disappears when the SiPM compartment is vented. This is attributed to the 127 nm light.

Light Source Tests – Sample Pulses

Sample pulse shape with $\text{FWHM} < 500$ ns.



Sample pulse shape with $\text{FWHM} > 500$ ns.



The 127-nm light seems to be coming in bursts.
Finer timing analysis is needed. The calculated rate of such pulse trains is ~ 15 Hz.

Summary

We developed an argon light source for the calibration and quality control of liquid argon light detectors.

127-nm light sensitive optical media was made with TPB coated SiPMs.

Initial tests indicate that 127 nm light is produced at around 15 Hz rate as a train of consecutive pulses.

The signal timing and baseline fluctuations need more detailed investigation.

Plans include tests with a more realistic liquid argon light detector e.g. TPB coated quartz plate read out from the edge.