Latest

Development of the LED optical calibration devices mounted on the PSUP

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We give a short summary of the spectroscopical and electronical characteristics of the LED calibration device followed by a discussion about the deployment of the LEDs on the PSUP.

1 Motivation

Various calibration devices are being designed and installed in SNO. These devices will calibrate the energy, timing, attenuation coefficients, scattering properties, and background properties of the detector. We propose an additional device based on a fast-pulsing blue LED to assist primarily in the time and geometric calibration of the detector. The electronic design is adapted from one originated at LBNL for the AMANDA project. Below, we present the results from our investigations of the light output and timing behavior of the LEDs.

Mounting DAQ controlled LEDs on the PSUP presents us with the opportunity to independently establish the time-pedestals for the TDC measurements. The positions of the LEDs can be determined accurately ($\leq$ 1 cm) by mounting the devices onto spare mounting holes on the PSUP hubs (see [Les90a],[Les90b]). The PSUP hubs are the most stable and accurate location for establishing geometric parameters of the PMT array. The pathlength and phase for each PMT-LED combination can be calculated from the surveyed hub locations and from the engineering file of PMT locations. Effects of optical pathlength through the acrylic vessel and different media (water or air) can be included. The arrival time for each PMT illuminated by an LED can be compared to the uncorrected time spectra for each hit PMT.

The certainty of LED locations provides an important and unique determination of the time information obtained from the laserball. The PSUP-LEDs timing information is independent of the systematic effects introduced by the additional uncertainties inherent with laserball position or AV position. By calibrating a subset of PMTs with the LED system we can in turn use this calibration to reconstruct the position of luminous sources (laserball, sonoball, etc.) independent of these sources, the calibration source deployment devices, and the position of the AV relative to the PSUP. Once the laserballs position is confirmed we can use it to establish the time pedestals for the complete PMT array.

Using the narrow beam of the LEDs we can investigate scattering and reflection properties of the acrylic and water media and serve as an important method of confirm the properties extracted from other sources with independent experimental uncertainties. The LEDs permit the determination of the AV position relative to the PSUP during the operation of the detector without introducing additional sources or changing the operational parameters of the detector. The cone nature of the LEDs may permit additional investigations of event vertex determination effects associated with Cerenkov light cones.

2 Electronical characteristics

For the test measurements two types of circuits were used: one was free-running which was used for the spectroscopy measurements and the second one with a trigger output signal. This trigger output was basically a scope trigger. The self-triggering device had a frequency of 10.68kHz.

The devices being provided for SNO will be triggerable. That is, SNO electronics can control the frequency (up to 1kHz) of the light output. All LEDs mounted on the PSUP will be controlled by the DAQ and SNO electronics.

The required inputs for the PLEDs (*PSUP* mounted *LEDs*) are:

- 3 conductors, 1 coax cable;
- +5V power input; +0 ... 44V steering voltage; ground;
- required trigger input signal: TTL input, min. duration 100ns, ≤1kHz, ≤5ns rise time

To determine the shape of the light pulse emitted from the pulsing LED two 1"-PMTs in a distance of about 0.5m in front of the LED were setted up in a dark box. One of both was covered to allow the measurement of the time distribution of the LED light pulse. The cover was a thin plastic sheet to attenuate the amount of visible light on that specific PMT.
The time resolution of the PMTs for the uncovered and covered case were estimated in separate measurements. Therefore, we can unfold the duration of the light pulse from the measured time distribution (shown in fig. 1) where a covered and a uncovered PMT are used.

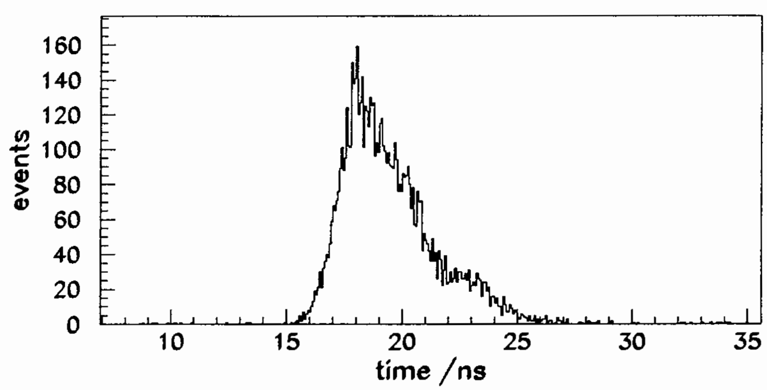

Fig. 1: *Time distribution using the setup with a covered and a uncovered PMT*

The light pulse emitted from the LED looks like:

- rise time of light signal: $\leq 2ns$,
- duration of light pulse: $\sim 7 \ldots 10ns$;

3 Light spectroscopy

Wavelength Scanning the light spectrum as a function of wavelength a non-pulsed LED circuit was used. In fig. 2 the calibrated intensity spectrum is shown, smoothed with FFT and reduced by straight line background subtraction. The average wavelength is 480nm. There was no evidence of the 380nm emission [Mor95].

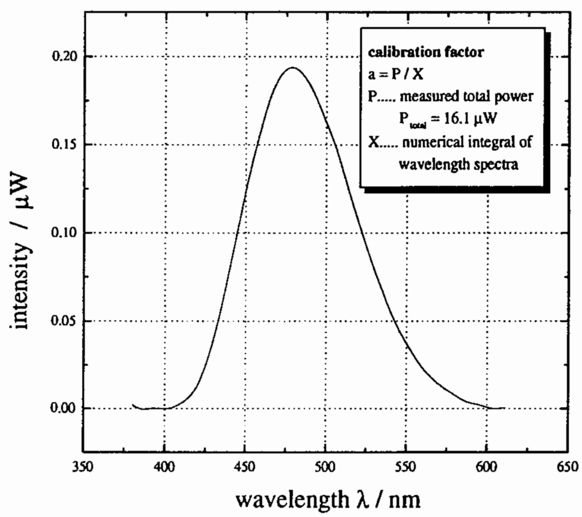

Fig. 2: *Calibrated light spectra for U=50V steering voltage using a non-pulsed circuit*

Intensity The intensity of the light pulse is measured as a function of the steering voltage using a power meter *xxx* where λ is corrected to 480nm. For this measurement the test device provided with a trigger output signal (5V TTL output at 10.68kHz) is used. The result is listed in tab. 1.

From LED specification [Ame97] NLPB-LEDs produces typical 1200μW of luminars power at a peak wavelength of 480nm or $2.89 \cdot 10^{15}$ photons/sec. For the device tested we recorded a duty factor of $7.47 \cdot 10^{-5}$ ($\sim 7ns$ every

93.65 μs) which results in $2.1 \cdot 10^7$ photons/pulse or $2.2 \cdot 10^{11}$ photons/sec. This would be for $U = 4V$ by $I_R = 50\mu A$. Tab. 1 summarizes the power depending on different steering voltage and its converted number of photons per trigger pulse.

$U_{steer.}/V$	power/nW	photons/sec.	photons/pulse
0	0.17	$4.1 \cdot 10^8$	$3.8 \cdot 10^4$
4	0.25	$6.0 \cdot 10^8$	$5.6 \cdot 10^4$
5	0.43	$1.1 \cdot 10^9$	$9.7 \cdot 10^4$
6	0.71	$1.7 \cdot 10^9$	$1.6 \cdot 10^5$
7	1.43	$3.5 \cdot 10^9$	$3.3 \cdot 10^5$
10	6.51	$1.6 \cdot 10^{10}$	$1.5 \cdot 10^6$
15	16.83	$4.0 \cdot 10^{10}$	$3.7 \cdot 10^6$

Tab. 1: *Average power and number of photons depending of the steering voltage (without background subtraction)*

Due to the high number of emitted photons from the LED we propose to use neutral density filters to reduce the amount of light emission. The characteristics of the tested filters are given in tab. 2. The attenuation factor $f_{atten} = \frac{P_0 - P_{backgr}}{P_{filt} - P_{backgr}}$ for each filter is calcualted for the measured average power at $U_{steer.} = 10V$.

filter id	optical density	red. factor f_{atten}
acrylic window	-	1.8
03FNG240	0.04	5.2
03FNG299	0.50	7.1
03FNG257	1.00	24.4
03FNG265	2.00	158.0
03FNG269	3.00	~ 1000

Tab. 2: *Characteristics of several test filters.*

The LED device will hold an optical filter 03FNG269 with a diameter of 2.54cm and a thickness of 0.3cm in front of the diode behind an acrylic window.

Angular distribution The LED is a blue GaN diode with a diameter of 3mm (NLPB300 series) or 5mm (NLPB500 series). The angular distribution of the directivity types for 15°, 30° and 45° are shown in fig. 3a,b for both series (taken from [Ame97]). Using a LED of the directivity of 15° the limits of the light cone could be confirmed at MiniSNO by illuminating only one PMT.

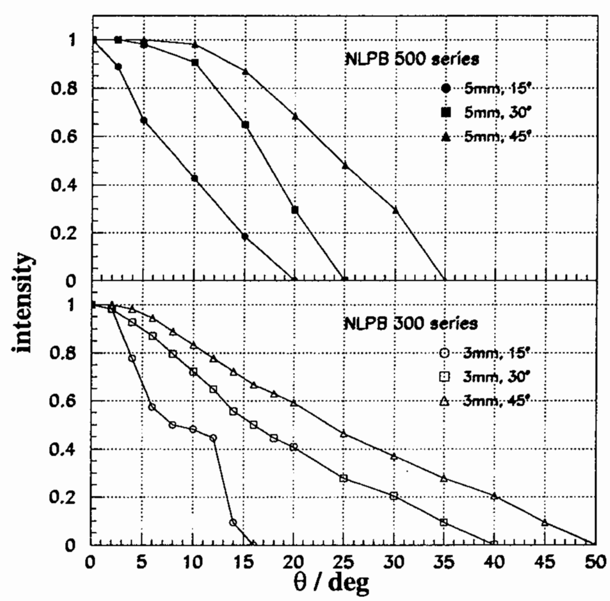

Fig. 3: *Angular distribution of the emitted light for serie NLPB500(above) and NLPB300(below)*

4 Mounting Positions for the PLEDs

The requirements for the PMT timing of the laserball reconstruction impose conditions on the placement of the PLEDs. Discussed below is a suggested arrangement of LEDs, summarized in tab. 3.

LED id.	hub id	layer	α_{open}	x_{PLED}	y_{PLED}	z_{PLED}
1-L312	H25	3	45°	714.6	188.6	384.0
2-L611	H55	6	15°	-41.4	-737.9	-384.0
3-L622	H71	6	15°	717.0	11.82	-423.7
4-L633	H35	6	15°	-125.3	700.4	-432.9
5-L635	H45	6	30°	-704.9	97.3	-432.9
6-L911	H79 to H87	9	45°	-41.4	-13.5	-831.8

Tab. 3: *LED position on the PMT support structure*

The LED mounted on PSUP layer 9 (near south pole hub) is carrying a wide angle LED (45°) which allows to cover the complete φ-range in a ϑ-range of about $0 \ldots 0.6$. The wide angle LED on layer 6 provides an overlap for the ϑ-range of layer 9 and provides an additional wide field of PMT subsets. This LED on layer 6 is distributing light within a cone of 45°. To avoid a focused spot location in a selected φ-area on the PMT array we will mount additional 15°-LEDs on the layer 6 (see LED id. in tab. 3). The wide angle LED on layer 3 with a cone of 45° generates a large spot and provides a subset of calibration points on the lower hemisphere. This is neccessary to reach a good resolution in fitting the laserball position with a subset of calibrated PMTs.

To show the complete PMT array including both hemisspheres in one plot we choose the Lambert projection. It transforms the polar angle ϑ in a radius of a circle with the maximum radius of $r_{max} = 2.0$ by

$$r = 2 \cdot sin(\frac{\pi}{2} - \frac{\vartheta}{2}),$$

the azimuth angle φ is kept. This transformation is an equal-area projection of spherical data onto a plane. The north pole data points populate the maximum radius of the circle and the south pole data are projected onto the center point. Data points around the equator appear at the radius $r = 1.0$. The orientation of the x and y axis going with φ is unchanged. Fig. 4 shows the LED spots in the Lambert projection.

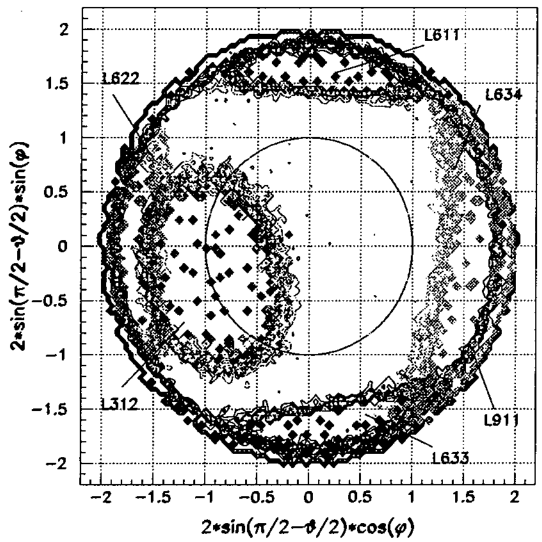

Fig. 4: *Lambert projection of the PLED spot positions; the individual spots are labelled with the LED id of tab. 3, the circle at the radius $r = 1.$ represents the equator, the north pole is projected onto the raduis $r = 2.$, the south pole transforms to the center point*

After time calibration of this PMT subsets we could illuminate the entire PMT array using the laserball. The calibrated PMT array serves now as provider for the estimation of the laserball position. With choosing the deployment of the PLEDs in the suggested setup (as summarized in tab. 3) we compare in fig. 5 the quality of the position reconstruction.

For that, we simulated 1000 laserball events in the center of the acrylic vessel with 4000 photons per event using SNOMAN 3.01 and fitted its position with the standard time fitter. Fig. 5 shows the fitter shift $|\vec{r}_{dev}| = |\vec{r}_{fit} - \vec{r}_{ev}|$ comparing the fit result for the entire PMT array with the result using the PMT subset array calibrated by the PLEDs. The dotted line shaped distribution shows the fitter shift for a PMT subset in which the PLED spots arranged on the upper hemisphere are only used. Fig. 6 shows the $(x_{fit} - x_{ev})$ and the $(z_{fit} - z_{ev})$ distribution comparing these three cases.

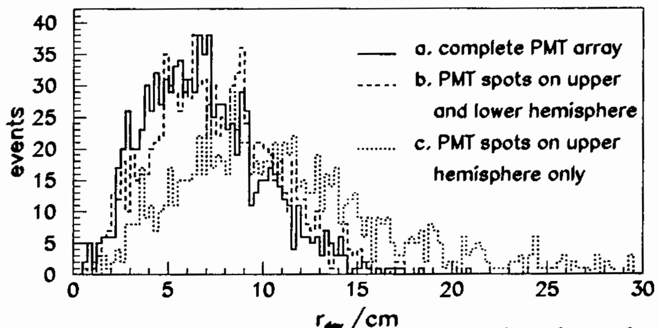

Fig. 5: *Criterion for the PLEDs arrangement to localize the laserball position: Fitter shift $|\vec{r}_{dev}| = |\vec{r}_{fit} - \vec{r}_{ev}|$ comparing the cases of fitting PMT sets: a. using the whole PMT array, b. using the PMT subset shown in table above, c. using PMT subset arranged only on upper hemisphere;*

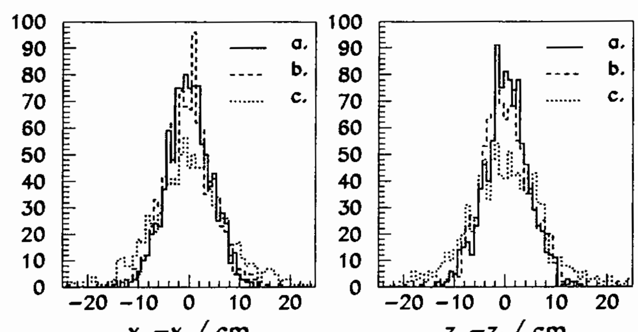

Fig. 6: $(x_{fit} - x_{ev})$ *and* $(z_{fit} - z_{ev})$ *distribution comparing the cases of fitting PMT sets: a. using the whole PMT array, b. using the PMT subset shown in table above, c. using PMT subset arranged only on upper hemisphere;*

Simulation with SNOMAN shows that the position of the laserball located at the center point can be estimated with a resolution of $\sigma_z = 4.7\ cm$ and $\sigma_x = 4.7\ cm$ in water-filled scenario using the time fitter and the selected PMT array.

References

[Ame97] Nichia America Coorp. Identification for Product types. (for blue and blue-green LEDs), 1997.

[Les90a] K.T Lesko, et al. Sudbury Neutrino Observatory. LBL technical drawings 23H8606B, 23H8646A, 23H8636B, LBNL, 1990.

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[Mor95] H. Morkov, S.N. Mohammad. High-Luminosity Blue and Blue-Green Gallium Nitride Light-Emitting Diodes. *Science*, Vol.267:p.51–55, 1995.