CALIBRATION STUDIES OF THE 2nd GENERATION DETECTORS OF THE *HKS* (E01 – 011)

This **Review** contains results of the systematic studies which were performed on the two types of the detectors of the ***HKS Detector Package***, namely:

- **SCINTILLATION WALLS**, to be used for the particles Time-of-Flights, type 1X and 2X,
- **AEROGEL ČERENKOV COUNTER**, for the Kaons recognition and suppression of the e^+ and π^+ in the Trigger.

Work on the calibration studies was performed in Bld. 90 of the Jlab, during the period of July 2 – August 1, 2004. Collaborators – who were involved – are the following:

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CALIBRATION of the PLASTIC WALLS of the *1X* type

(Jlab, Bld. 90; July 2 – July 28, 2004)

To study response (pulse height, shape of the pulse, position dependence) of the *PMT*s coupled to the plastic walls on each end, we applied a small ^{60}Co source method. A source was positioned at the near end (10 cm from the junction of the scintillator and light pipe), and in the middle of the bar, respectively. **Results are summarized in the Table!**

NOTE: To simulate real signal path of the experiment, we took a delay of 1100 ns for the analog signal (the ADC signal path). Therefore, we studied response for the so called "direct out" (shortly-delayed) to correspond to the signal to be used for the discriminators (trigger), and of the delayed signal.

UNITS: Pulse height **in mV;** Decay time **in ns;** Voltage **in volts**.

Counter Number	LEFT END		Mid. pos. P.h./ Decay Time	**High volt.**	RIGHT END		Mid. pos. P.h./ Decay time	**High volt.**	Counter Number
	P.h.dir / Decay time	P.h.del / Decay time			P.h.dir / Decay time	P.h.del / Decay time			
1X1L	50/40	10/220	45/40	**1550**	55/40	10/200	50/40	**1540**	**1X1R**
1X2L	50/40	10/220	45/40	**1480**	50/40	10/200	45/40	**1410**	**1X2R**
1X3L	50/40	10/200	45/40	**1480**	55/40	10/200	45/40	**1480**	**1X3R**
1X4L	50/40	10/220	45/40	**1500**	50/40	10/200	45/40	**1490**	**1X4R**
1X5L	50/40	10/200	45/40	**1490**	50/40	10/200	45/40	**1440**	**1X5R**
1X6L	50/40	10/200	45/40	**1440**	50/40	10/200	45/40	**1440**	**1X6R**
1X7L	50/40	10/200	45/40	**1490**	50/40	10/200	45/40	**1410**	**1X7R**
1X8L	50/40	10/200	45/40	**1500**	50/40	10/200	45/40	**1530**	**1X8R**
1X9L	50/40	10/200	45/40	**1470**	50/40	10/200	45/40	**1410**	**1X9R**
1X10L	50/40	10/200	45/40	**1490**	50/40	10/200	45/40	**1440**	**1X10R**
1X11L	50/40	10/200	45/40	**1520**	50/40	10/200	45/40	**1360**	**1X11R**
1X12L	50/40	10/200	45/40	**1430**	50/40	10/200	45/40	**1490**	**1X12R**
1X13L	50/40	10/200	45/40	**1490**	50/40	10/200	45/40	**1440**	**1X13R**
1X14L	50/40	10/200	45/40	**1510**	50/40	10/200	45/40	**1470**	**1X14R**
1X15L	50/40	10/200	45/40	**1470**	50/40	10/200	45/40	**1490**	**1X15R**
1X16L	50/40	10/200	45/40	**1500**	50/40	10/200	45/40	**1450**	**1X16R**
1X17L	50/40	10/200	45/40	**1540**	50/40	10/200	45/40	**1450**	**1X17R**

THRESHOLD DETERMINATION: ^{60}Co deposits of around 1 MeV_{ee} in the thickness of 2 cm of the plastic scintillator. **Therefore, 50 mV of the ^{60}Co (~ 1 MeV_{ee}) is the threshold. High voltage in accord with it may be regarded as the minimal (conservative) voltage applied to the PMTs**. Minimum ionizing particles (pions, kaons, muons) should deposit around ΔE = 2.1 MeV/cm x 2 cm = 4.2 MeV.

CALIBRATION of the PLASTIC WALLS of the *2X* type

(Jlab, Bld. 90; July 2 – July 29, 2004)

To study response (pulse height, shape of the pulse, position dependence) of the *PMT*s coupled to the plastic walls on each end, we applied a small ^{60}Co source method. A source was positioned at the near end (10 cm from the junction of the scintillator and light pipe), and in the middle of the bar, respectively. On few walls light leaks were found and removed. **Results are summarized in the Table!**

NOTE: To simulate real signal path of the experiment, we took a delay of 1100 ns for the analog signal (the ADC signal path). Therefore, we studied response for the so called "direct out" (shortly-delayed) to correspond to the signal to be used for the discriminators (trigger), and of the delayed signal.

UNITS: Pulse height **in mV;** Decay time **in ns;** Voltage **in volts**.

Counter Number	**LEFT END** P.h.dir / Decay time	P.h.del / Decay time	Mid. pos. P.h./ Decay Time	**High volt.**	**RIGHT END** P.h.dir / Decay time	P.h.del / Decay time	Mid. pos. P.h./ Decay Time	**High volt.**	Counter Number
2X1L	50/40	10/220	45/40	**1570**	55/40	10/200	50/40	**1550**	**2X1R**
2X2L	50/40	10/220	45/40	**1480**	50/40	10/200	45/40	**1580**	**2X2R**
2X3L	50/40	10/200	45/40	**1380**	55/40	10/200	45/40	**1590**	**2X3R**
2X4L	50/40	10/220	45/40	**1420**	50/40	10/200	45/40	**1585**	**2X4R**
2X5L	50/40	10/200	45/40	**1600**	50/40	10/200	45/40	**1530**	**2X5R**
2X6L	50/40	10/200	45/40	**1480**	50/40	10/200	45/40	**1500**	**2X6R**
2X7L	50/40	10/200	45/40	**1600**	50/40	10/200	45/40	**1470**	**2X7R**
2X8L	50/40	10/200	45/40	**1460**	50/40	10/200	45/40	**1540**	**2X8R**
2X9L	50/40	10/200	45/40	**1550**	50/40	10/200	45/40	**1520**	**2X9R**
2X10L	50/40	10/200	45/40	**1530**	50/40	10/200	45/40	**1480**	**2X10R**
2X11L	50/40	10/200	45/40	**1490**	50/40	10/200	45/40	**1510**	**2X11R**
2X12L	50/40	10/200	45/40	**1530**	50/40	10/200	45/40	**1510**	**2X12R**
2X13L	50/40	10/200	45/40	**1530**	50/40	10/200	45/40	**1430**	**2X13R**
2X14L	50/40	10/200	45/40	**1540**	50/40	10/200	45/40	**1500**	**2X14R**
2X15L	50/40	10/200	45/40	**1490**	50/40	10/200	45/40	**1530**	**2X15R**
2X16L	50/40	10/200	45/40	**1420**	50/40	10/200	45/40	**1540**	**2X16R**
2X17L	50/40	10/200	45/40	**1540**	50/40	10/200	45/40	**1500**	**2X17R**
2X18L	50/40	10/200	45/40	**1500**	50/40	10/200	45/40	**1540**	**2X18R**

THRESHOLD DETERMINATION: ^{60}Co deposits of around 1 MeV_{ee} in the thickness of 2 cm of the plastic scintillator. **Therefore, 50 mV of the ^{60}Co (~ 1 MeV_{ee}) is the threshold. High voltage in accord with it may be regarded as the minimal (conservative) voltage applied to the PMTs**. Minimum ionizing particles (pions, kaons, muons) should deposit around ΔE = 2.1 MeV/cm x 2 cm = 4.2 MeV.

PULSE HEIGHT LINEARITY of the *1X* type PLASTIC WALL

(Jlab, Bld. 90; July 2 – July 30, 2004)

To examine pulse height response linearity with respect to the high voltage which may be applied on the PMT, a small ^{60}Co source was positioned close to one end (10 cm), in the middle of the bar, and at the other side (10 cm from the other end of the bar).
One bar (one PMT side) was examined for each family!

Results are summarized in the Table!

NOTE: To simulate signal path of the real experiment, we took a delay of 1100 ns for the analog signal (the ADC signal path). Therefore, we studied response for the so called "direct out" (non-delayed) corresponding to the signal to be used for the discriminators (trigger), and of the delayed signal.

1X8L side of the 1X type bar was examined

UNITS: Voltage **in volts**; Pulse height **in mV;** *Decay time* **in ns**

High Voltage	**^{60}Co close (10 cm)**		**^{60}Co in the middle**		**^{60}Co at the other end**	
	P.h. dir./ *Decay time*	P.h. del./ *Decay time*	P.h. dir./ Decay time	P.h. del./ *Decay time*	P.h. dir./ *Decay time*	P.h. del./ *Decay time*
1300	20/30	3/100	16/30	2.5/100	15/30	2/100
1350	27/30	4/100	23/30	3.5/100	22/30	3/100
1400	36/30	6/100	32/30	5/100	30/30	4.5/100
1450	50/40	8/150	44/40	7/150	40/40	6/150
1500	70/40	12/200	61/40	9/200	56/40	8/200
1550	100/40	15/200	82/40	12/200	75/40	11/200
1600	125/40	20/200	110/40	16/200	100/40	15/200
1650	170/40	25/200	150/40	20/200	140/40	19/200
1700	220/40	32/200	190/40	28/200	180/40	25/200
1750	280/40	40/200	250/40	35/200	235/40	32/200
1800	360/40	55/200	310/40	45/200	305/40	41/200

Variation in pulse height, by looking ratio of the closer end against other end of the bar, with respect to the same tube, for the typically operating voltage region of (1400 – 1600) V, has the value (calculated form the Table):

$$\textbf{(Pulse height dir.)}_{\textbf{close}} \textbf{ / (Pulse height dir.)}_{\textbf{other end}} \textbf{ = 1.256 } \pm \textbf{ 0.126}$$

(Overall error of 10 % was assumed, due to the analog read-out!)

PULSE HEIGHT LINEARITY of the *2X* type PLASTIC WALL

(Jlab, Bld. 90; July 2 – July 30, 2004)

To examine pulse height response linearity with respect to the high voltage which may be applied on the PMT, a small ^{60}Co source was positioned close to one end (10 cm), in the middle of the bar, and at the other side (10 cm from the other end of the bar).
One bar (one PMT side) was examined for each family!

Results are summarized in the Table!

NOTE: To simulate real signal path of the experiment, we took a delay of 1100 ns for the analog signal (the ADC signal path). Therefore, we studied response for the so called "direct out" (non-delayed) corresponding to the signal to be used for the discriminators (trigger), and of the delayed signal.

2X11L side of the 2X type bar was examined

UNITS: Voltage **in volts**; Pulse height **in mV;** *Decay time* **in ns**

High Voltage	**^{60}Co close (10 cm)**		**^{60}Co in the middle**		**^{60}Co at the other end**	
	P.h. dir./ *Decay time*	P.h. del./ *Decay time*	P.h. dir./ Decay time	P.h. del./ *Decay time*	P.h. dir./ *Decay time*	P.h. del./ *Decay time*
1300	20/30	3/100	18/30	3/100	16/30	2.5/100
1350	28/30	4.5/100	25/30	4/100	22/30	3.6/100
1400	38/30	6/100	33/30	6/100	30/30	5/100
1450	55/40	8/150	46/40	8/150	42/40	6.4/150
1500	72/40	11/200	64/40	11/200	58/40	9/200
1550	100/40	15/200	85/40	14/200	80/40	13/200
1600	130/40	20/200	112/40	19/200	105/40	16/200
1650	170/40	26/200	145/40	25/200	140/40	23/200
1700	220/40	33/200	200/40	31/200	180/40	28/200
1750	300/40	42/200	260/40	40/200	230/40	36/200
1800	380/40	55/200	310/40	50/200	295/40	42/200

Variation in pulse height, by looking ratio of the closer end against other end of the bar, with respect to the same tube, for the typically operating voltage region of (1400 – 1600) V, has the value (calculated form the Table):

$$\textbf{(Pulse height dir.)}_{\textbf{close}} \textbf{ / (Pulse height dir.)}_{\textbf{other end}} \textbf{ = 1.262 } \pm \textbf{ 0.126}$$

(Overall error of 10 % assumed, due to the analog read-out!)

SINGLE PHOTOELECTRON (*S.ph.e.*) and COSMICS STUDIES of the ČERENKOV AEROGEL (*BOX 1*)

(Jlab, Bld. 90; July 6 – August 1, 2004)

I. The Aerogel tiles were carefully inserted in the all 7 segments of the Box, and Box mechanically and optically entirely closed. Test of the light leaks of the *Photonis XP4572* were done, and proper connections to the DAQ were provided.

II. To make *Single Photoelectron Calibration*, we examined each segment of the Aerogel Čerenkov counter. We looked at pulse height response by **the self–trigger**: one PMT (one side of the Segment) was triggered by the other PMT (opposite side) and vice versa. **Results are summarized in the Table**, for the voltage region of 1100 V up to 1700 V!

III. To see **ADC spectra and pedestals** in them, we made studies by the self-trigger mode for each segment, acquiring data by the DAQ. The last raw of the Table contains **proper voltage settings** used to see **the pedestal and associated single photoelectron peak** of each tube, for each segment! Data were recorded for each tube and segment, respectively.

UNITS: Voltage **in volts**; Pulse height **in mV**
Decay time **in ns;** Each cell in the Table indicates values of the **(Pulse height)/(Decay time)** of the pulses corresponding to the S.Ph.e., as they being looked at by the Oscilloscope.

High voltage	**Segment1**		**Segment2**		**Segment3**		**Segment4**		**Segment5**		**Segment6**		**Segment7**	
	A11	**A12**	**B11**	**B12**	**C11**	**C12**	**D11**	**D12**	**E11**	**E12**	**F11**	**F12**	**G11**	**G12**
+1100	No sig	1/30	2/30	1/30	1/30	1/30	1/30	1/30	1/30	1/30	1/30	1/30	No bases: test was not done! However, by one good base, we tested both PMTs, found them O.K.	
+1200	10/40	2/30	6/30	2/30	10/40	8/30	5/30	4/30	10/40	6/30	2/30	2/30		
+1300	15/40	10/40	11/40	6/40	15/40	20/40	10/40	15/40	20/40	20/40	8/40	20/40		
+1400	30/40	25/30	30/40	15/40	25/40	45/40	25/40	25/40	50/40	35/40	20/40	40/40		
+1500	50/40	40/40	50/40	30/40	55/40	70/40	50/40	45/40	90/40	55/40	40/40	75/40		
+1600	100/40	70/40	80/40	60/40	70/40	150/40	80/40	80/40	100/40	90/40	70/40	120/40		
+1700	150/40	160/40	110/40	150/40	110/40	200/40	120/40	150/40	150/40	200/40	110/40	220/40		
H.volt. S.Ph.e. & Cosmics Studies	1710	1730	1690	1760	1690	1620	1680	1670	1550	1630	1730	1610	1700 (?)	1750 (?)

IV. Cosmics data taking were obtained by the trigger of the **Telescope counters**: one scintillator bar (1X16) at the top of the segment, and two others (1X3 and 1X4) below the segment; those two were orthogonally positioned each other. By the 2–fold coincidence (top and bottom counters), we took long runs (typically day and night) for each segment. Cosmics data on the Aerogel are available on the disc (hallc16.jlab.org; for details contact **T. Miyoshi**)!

V. By the Gaussian fit of the pedestal, *S.ph.e.* peak, and distribution (peak) of the Čerenkov light produced by muons in the 5 cm thick Aerogel radiator, the ***number of photoelectrons*** $N_{ph.e.}$ may be estimated, as follows:

$$N_{ph.e.} = \frac{n - n_1}{n_2 - n_1}$$

where:

$\mathbf{n_1}$ = channel number of centroid of the pedestal peak in the *ADC* spectrum

$\mathbf{n_2}$ = channel number of centroid of the *Single photoelectron peak* in the *ADC* spectrum of the PMT

n = channel number of the of the centroid of the Čerenkov light distribution (peak) in the *ADC* spectrum.

• We determined – just to get insight what $N_{ph.e.}$ should be – number of photoelectrons for the single **E11** tube of the Aerogel Box 1 (Segment 5), by analyzing data of the Cosmics Run 1481 (July 31 – August 1, 2004). The following result was obtained:

$n_1 = 155$
$n_2 = 185$
$n = 552$

$N_{ph.e.}$ (E11) = 13.23 photoelectrons

This result seems to be O.K., 13 to 14 photoelectrons! Sum of the two PMTs of one segment should be as doubled as the single value, i.e. 26 – 28.

We recall the number of roughly **19 photoelectrons observed for pions with 1.2 GeV/c momentum**, as obtained by **the test KEK PS-T500** (*Jlab E01–011, Second Readiness Review*, May 13, 2003, p.33).

• Gaussian fits through the spectrum of each PMT of the Aerogel Box 1 should be done in the next few days, in order to figure out precise number of $N_{ph.e.}$