CEBAF Tech Notes

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☐ Accelerator Physics	☐ DC Power	■ Linac
■ Arc	■ Diagnostics	☐ Magnets
☐ Beam Dynamics	☐ Environment, QA	☐ Nuclear Physics
☐ Beam Transport	☐ Experimental Equipment	☐ RF
☐ BSY	☐ Extraction	☐ Safety and Health Physics
☐ Civil Construction	■ Failure Mode/Tests	☐ Schedule
■ Commissioning	■ Front End	☐ SRF
■ Controls	■ Injector	■ Test Results
☐ Cost	☐ Installation	☐ Vacuum
☐ Cryogenics	☐ Integration	☐ Other

ABSTRACT

We describe the Beam Loss Monitor Calibration methods and procedures and give the results of the initial set-up runs.

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BEAM LOSS MONITOR SENSOR CALIBRATION SYSTEM

Andrew Policastro, John Perry

I. Introduction

A. System Description

The Beam Loss Monitor System is the last resort of the Machine Protection System. Vacuum line burn through is estimated at 50 to 100 microseconds. The design goal of the Machine Protection System is 45 microseconds. At full energy there will be 21 microseconds of beam stored in the accelerator. Ten microseconds is needed for FSD logic, 10 microseconds is needed for BLM logic and 4 microseconds is needed for signal transmission. The BLM's work by detecting the radiation shower that comes from a stray beam interacting with surrounding matter.

B. Assembly Description

The beam loss monitor sensor is housed in a 8 inch long plastic pipe with a 1.5 inch I.D. The main components are the photomultiplier tube (PMT), photomultiplier tube socket, green LED, male safe high voltage connector, and signal connector (figure 1). The beam loss monitor sensor uses a Hamamatsu 931B photomultiplier tube as it's radiation detector. The 931B was chosen for it's reliability, response time, sensitivity and cost. The 931B has a spectral response of 300 to 650 nm. The PMT output current is connected to a signal conditioner where the logarithm of the current is converted to voltage.

C. Purpose

The purpose of the beam loss monitor sensor calibration system is to establish a traceable path to a well defined reference. This will allow us to detect substantial changes in system response before they become a problem. Possible problems that could affect the sensors are radiation damage, aging of components, and injury to components during handling.

D. Method

The PMT with the least noise will be the master PMT and used only as a reference against the best LED's. The other four PMT's and LED's will form a master calibration matrix. This 4 x 4 matrix will be tested periodically to maintain the confidence of the matrix and the working PMT's and LED's of the BLM system (figure 2). The results of the testing will help select low noise and high gain sensors for critical areas of the accelerator.

II. Screening the Sensor Elements

A. PMT Noise Screening

We tested 96 BLM sensors for PMT noise level, PMT response and LED output. The most important criteria for the testing was PMT noise. Noise level was tested by pulse height analysis (PHA) on the pulse height analyzer in the block house. All the PMT's were tested at 500 and 600 cathode voltage for 5 minutes. The number of pulses and the maximum pulse height were recorded. All the PHA's were tested after being darkened for a minimum of 12 hours.

The procedure for the PHA noise testing was to connect the BLM head to the pulse height analyzer and to the high voltage power supply. 500 volts was applied first for 5 minutes and the results were recorded. Then the voltage was increased to 600 volts and the noise spectrum was again recorded. The high voltage was turned off and the noise spectrum was recorded and downloaded to a floppy disk. Fig. 3 is the noise spectrum for PMT #88,a new and unused tube. At 500 volts there were 4 pulses with a max. pulse at 349 mv. At 600 volts there were 2 pulses with a max. pulse at 123 mv. Fig. 4 is the noise spectrum for PMT #121, a tube that was located at the 45 MeV spectrometer dump during accelerator testing. At 500 volts there were 22 pulses with a max. pulse at 425 mv. At 600 volts there were 183 pulses with a max. pulse at 915 mv. We found no correlation between new PMT's and PMT's that were in the tunnel and noise levels.

B. PMT Gain Screening

PMT response was measured by the output voltage of the BLM sensor while the test pulse was on. The test pulse refers to turning on the LED. The procedure for PMT response (gain) was to test all the PMT's with one LED. The assembly chosen was head #21. Each LED is installed into a head and not moved again. Every PMT was placed in head #21 and tested at 0 to 700 cathode voltage in 100 volt steps. We periodically checked previously tested PMT's to be sure the LED did not change in output during the screening test. The PMT response was taken on a Tektronix 2430A digital oscilloscope set to measure mean voltage. The response was recorded and the cathode voltage was increased. Fig. 5 is the PMT gain plotted against the cathode voltage.

During the testing the response remained steady for some voltages and PMT's, but not for all. Some of the response voltages decreased on the scope as the readings were being taken. When this occurred the maximum voltage was recorded and the test continued. We discussed this voltage decay and decided to test for this phenomenon.

Voltage decay was tested on three PMT's from 200 to 700 cathode voltage. The cathode voltage was applied and the gain was recorded, then at ten minute intervals up to thirty minutes the gain was recorded. The voltage was then increased by 100 volts and the testing continued. The result was 4 readings: initial, 10 min., 20 min., 30 min. Like before the voltage decay occurred. The decay averaged 400 mv from the initial to the 30 minute reading. The 10 and 30 minute readings were the same. The voltage decay occurred during the first 10 minutes of applied cathode voltage. This 400 mv decrease was up to a 38 percent decrease at 300 cathode volts and up to a 10 percent decrease at 700 cathode volts. It was observed that most of this decay occurred in the first minute, and there wasn't any change in gain after 5 minutes of applied cathode voltage.

We decided not to re-run all the tests, assuming the immediate readings would be proportional to the standardized readings. There would not have been enough time to complete the screening if we had not continued with the available data.

There is some evidence that the above assumption is not altogether valid: the actual calibration procedures will be done with an appropriate delay to allow the PMT response to stabilize.

The PHA and gain data were sorted first on PHA at 600 Volts and secondly on gain at 500 Volts. The five best PMT's were selected and removed from the group.

C. LED Screening

LED output was tested by the output voltage of the BLM sensor while the test pulse was on. The procedure for the LED output was to test all the LED's against one PMT. PMT #80 was chosen for it's low noise and gain. PMT #80 was placed in every head and the output voltage was recorded after a five minute cool down from ambient light exposure. This exposure could not be prevented. We periodically checked previously tested LED's to be sure the response of PMT #80 did not change during the screening test. The results are plotted in Fig. 6. The 4 LED's with extremely low outputs were replaced, retested and returned to the group. At this point John suggested I also retest the 2 LED's with the largest outputs. His concern was that the black interior finish of the heads might be irregular. We found that few of the heads had the flat black paint applied to the interior of the head as was specified in their manufacture. Magenta paint covered the outside of the head assemblies and most of their interiors.

We tested 4 head assemblies for LED output while rotating the heads 360 degrees at 90 degree intervals. The data showed a maximum delta of 5 percent. We tested 4 assemblies with interiors painted flat black. The data showed a maximum delta of 1.4 percent. We did not feel that the possible degradation of our selection criteria was serious enough to warrant re-running all our tests. In any case, there was no time to re-run the tests. All future testing had flat black paint applied to the interior of the head assembly. The four best LED's were selected and removed from the group.

III. Initial Reference Matrix

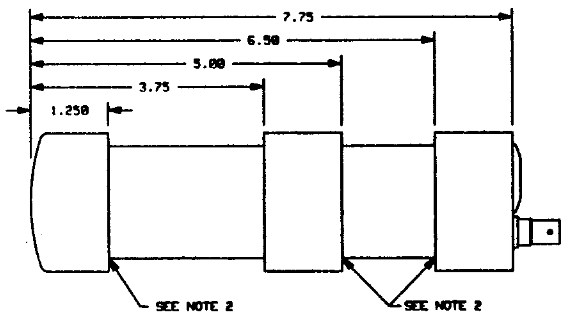
The best PMT is set aside as the master reference. The four other PMT's selected and the four LED's selected by the testing formed a reference 4 X 4 matrix. Each reference PMT and reference LED were tested against each other. The 4 x 4 matrix testing had a 10 minute time frame to allow for stabilization. The first four by four matrix was corrupt because one of the LED's was not cut off to specified length. The second four by four matrix was tested and the results are in Fig. 7. The matrix was tested three times and the percent changes, point by point, from the initial matrix are shown. The average change over the three tests was 1.3 percent.

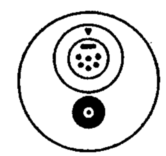
IV. Observations

The PHA results did not show the expected result of increased noise at the higher applied cathode voltage. Because of the results, PHA at 600 volts was chosen as the noise criteria.

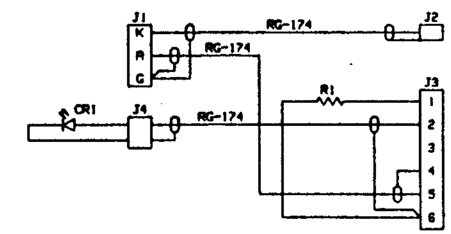
During the gain testing the PMT's were all exposed to ambient light because only one head assembly was used. The voltage decay that was observed can be explained by the ambient light exposure. The ambient light is an abnormal condition for a PMT even when there is no applied cathode voltage. Hamamatsu uses a 30 minute cool down period from ambient light for their PMT specifications. We found that a 5 minute cool down period achieved the same results as a thirty minute cool down period. We used a 10 minute cool down period for the 4 by 4 matrix.

The PMT gain was reduced approximately 5 percent when the interior of the assemblies were painted flat black (Rustoleum No. 2178). Two assemblies interiors were painted flat white (Rustoleum No. 2190). The PMT gain with white interiors was increased up to 50 percent or a minimum of 1.0 volt with the signal conditioning.

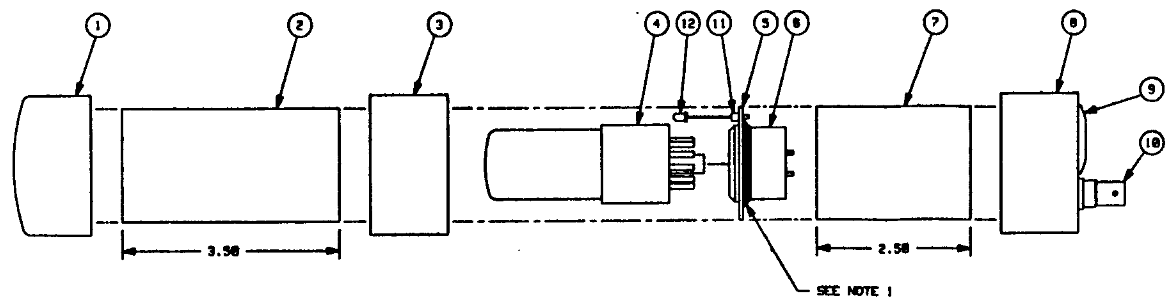




BLM PHOTOMULTIPLIER TUBE ASSEMBLY



WIRING DIAGRAM



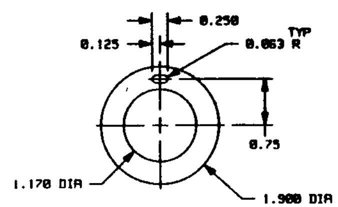
BLM PHOTOMULTIPLIER TUBE ASSEMBLY DETAIL

ASSEBLY NOTES:

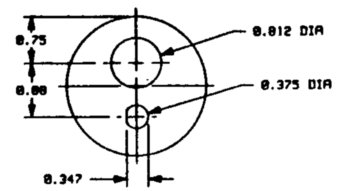
1. MOUNT ITEM 6 TO ITEM 5 USING RTV SILICONE RUBBER
2. AFTER ASSEMBLY, FILLET OF RTV SILICONE RUBBER IS REQUIRED AT HOUSING JOINTS REFERENCING THIS NOTE
3. ITEMS 1,3,7 & 8 ARE TO BE PAINTED BLACK, ITEM 2 IS TO BE PAINTED MAGENTA

1	13		RESISTOR,	VARIOUS	R1
1	12		LED, GREEN	VARIOUS	CR1
1	11	AUGAT 8059-4G4	TRANSISTOR SOCKET (MODIFIED)	VARIOUS	J4
1	10	KINGS 1704-1	BULKHEAD RECEPTACLE	VARIOUS	J2
1	9	SWITCHCRAFT B(6)MAu	6 PIN AUDIO CONNECTOR	VARIOUS	J3
1	8	—	MODIFIED 1 1/2" NPS PIPE CAP	SCH 40 ABS	
1	7	—	1 1/2" NPS PIPE	SCH 40 ABS	
1	6	HAMAMATSU E717-35	PHOTOMULTIPLIER TUBE SOCKET	VARIOUS	J1
1	5	—	SOCKET ADAPTER PLATE	.063 THK FIBERGLASS	
1	4	HAMAMATSU 931B	PHOTOMULTIPLIER TUBE	VARIOUS	
1	3	—	1 1/2" NPS PIPE COUPLING	SCH 40 ABS	
1	2	—	1 1/2" NPS PIPE	SCH 40 ABS	
1	1	—	1 1/2" NPS PIPE CAP	SCH 40 ABS	
-	-	—	PHOTOMULTIPLIER TUBE ASSEMBLY	—	

PARTS LIST



ITEM 5



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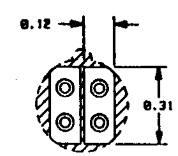


ITEM 11

SCALE: 1/4" = 1"

NOTE: REMOVE MATERIAL INDICATED BY CROSS-HATCH

CEBAF The Continuous Electron Beam Accelerator Facility

/JOBS/C368/c368a1

DRAWN D. WILLIAMS 02/25/92

APPROVED/ORIGINATOR E. WOODWORTH

BEAM DIAGNOSTICS
BEAM LOSS MONITOR
PHOTOMULTIPLIER TUBE - VERSION A
ASSEMBLY

SIZE D DWG. NO. B0070D01 REV. —

SCALE 1" = 1" SHEET 1 OF 1

DO NOT SCALE DRAWING

Figure 1

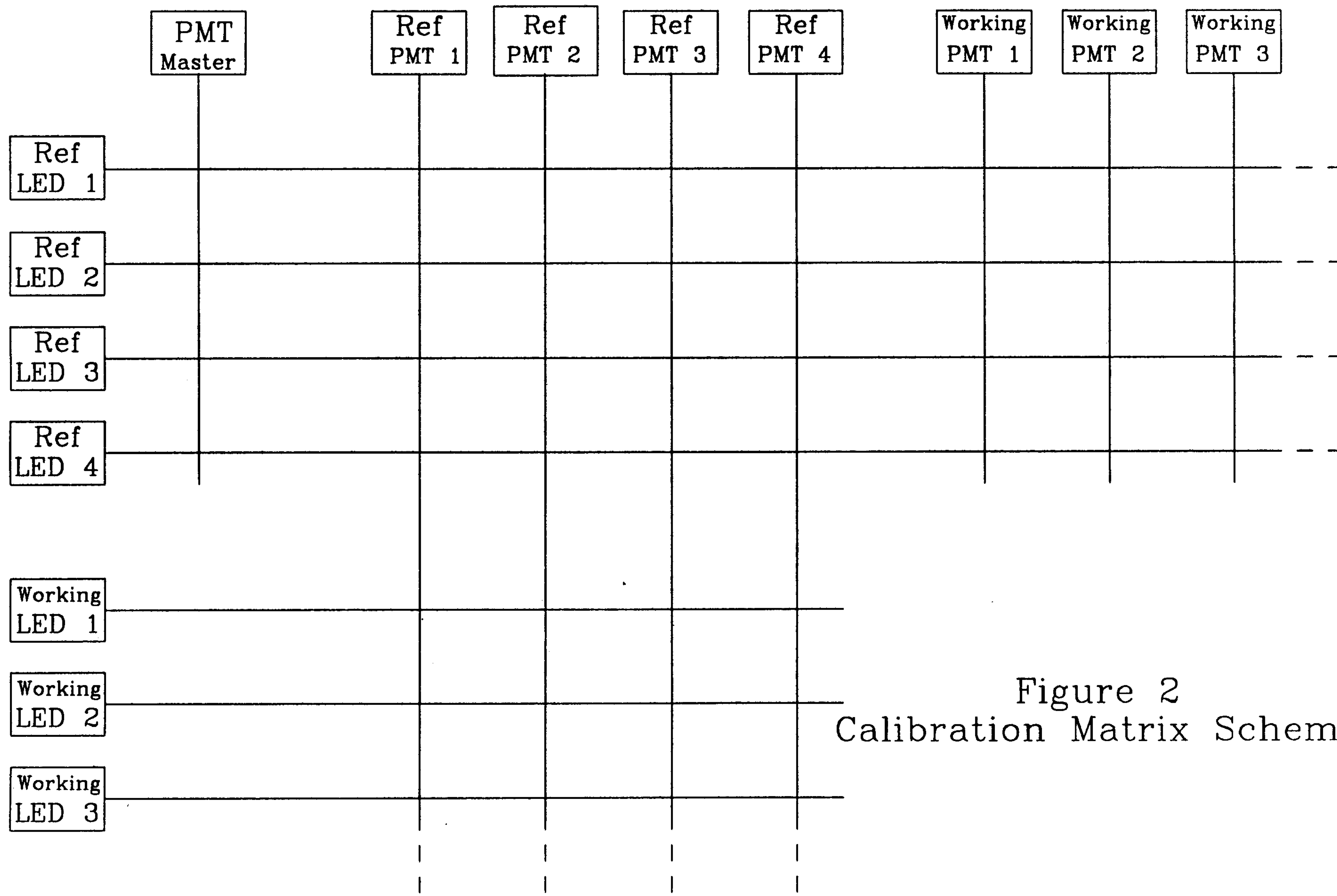


Figure 2
Calibration Matrix Scheme

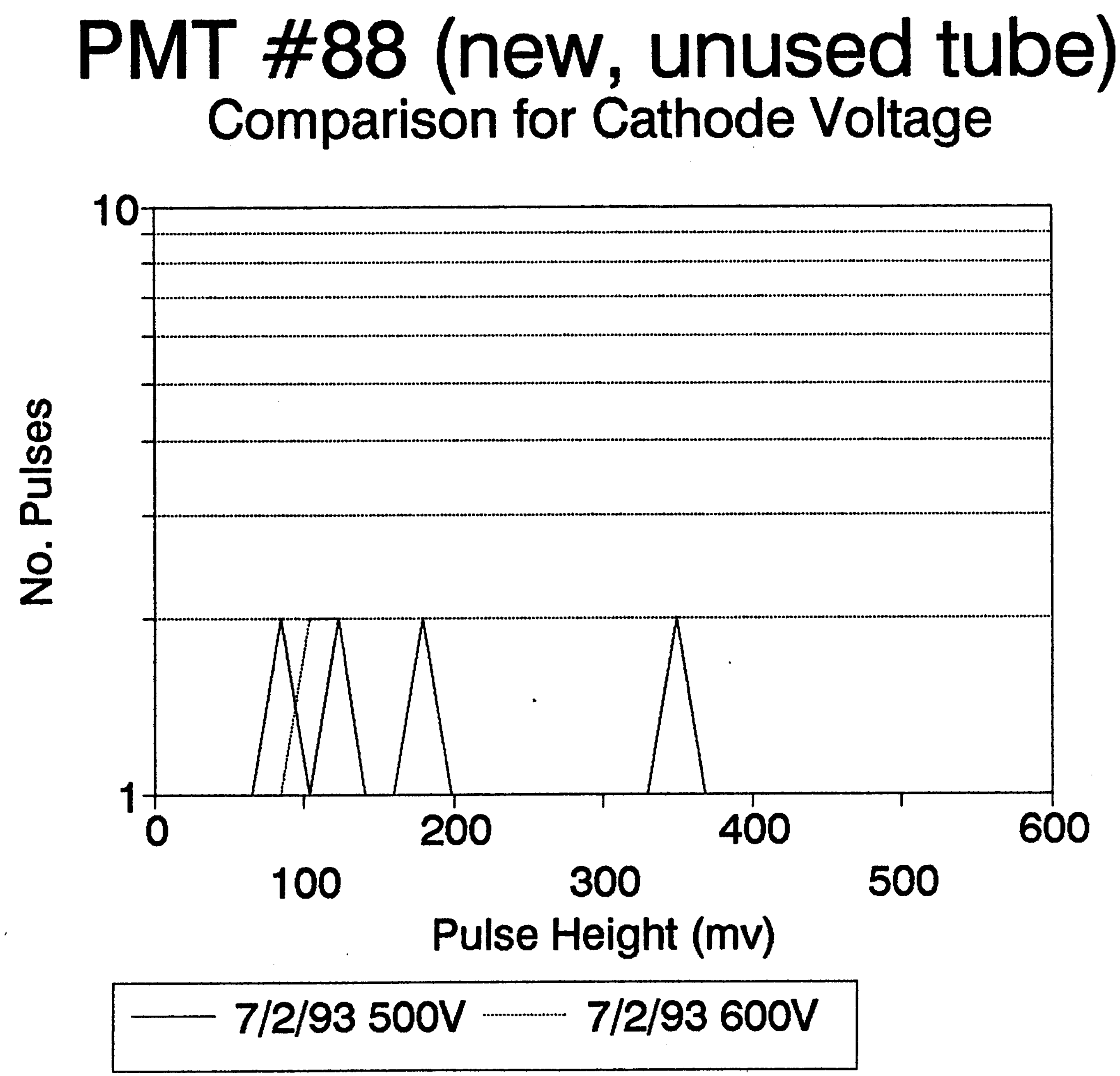
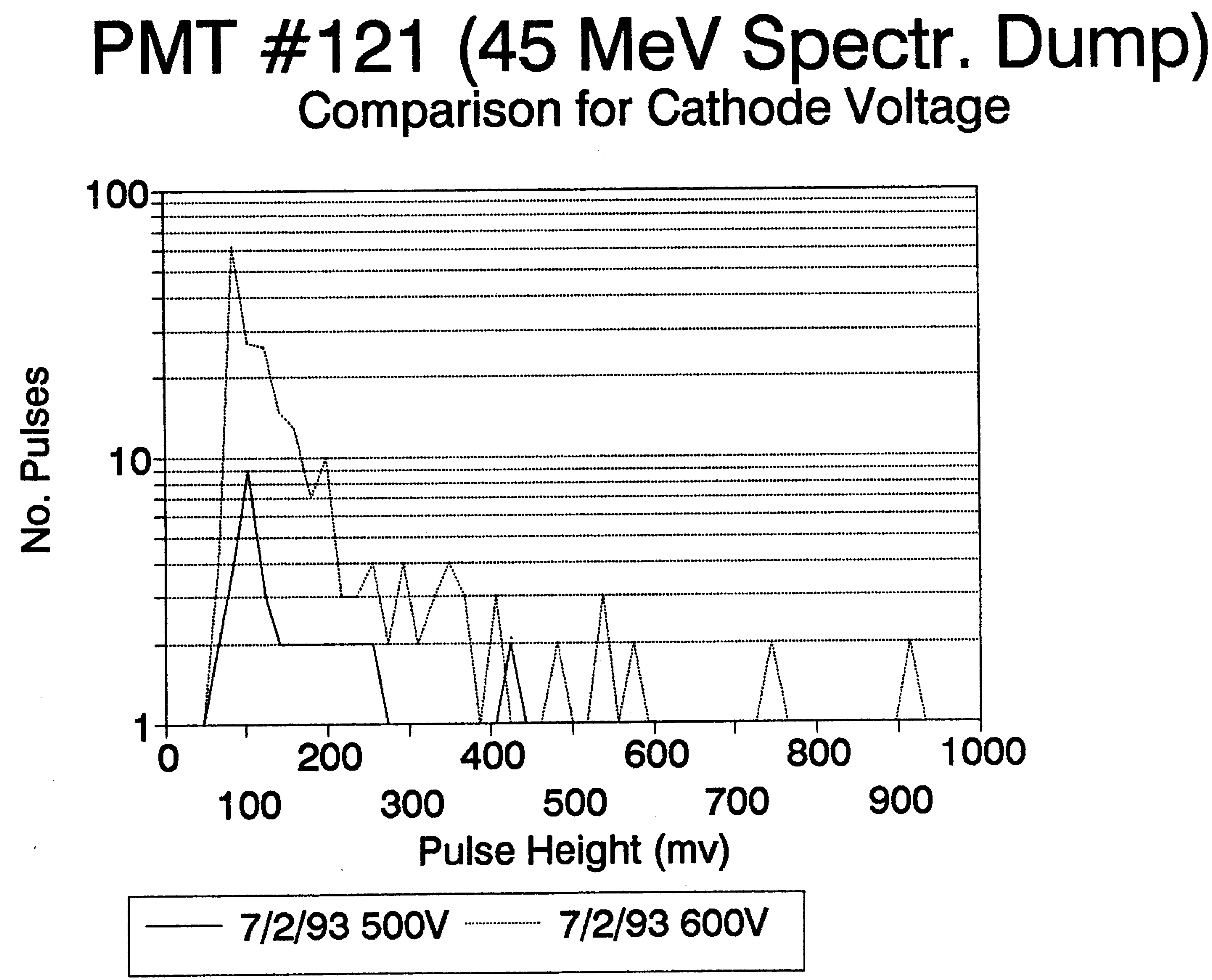

PMT #88 (new, unused tube)
Comparison for Cathode Voltage
No. Pulses
10
1
0
100
200
300
400
500
600
Pulse Height (mv)
7/2/93 500V
7/2/93 600V

Figure 3



PMT #121 (45 MeV Spectr. Dump)
Comparison for Cathode Voltage
No. Pulses
100
10
1
0
100
200
300
400
500
600
700
800
900
1000
Pulse Height (mv)
7/2/93 500V
7/2/93 600V

Figure 4

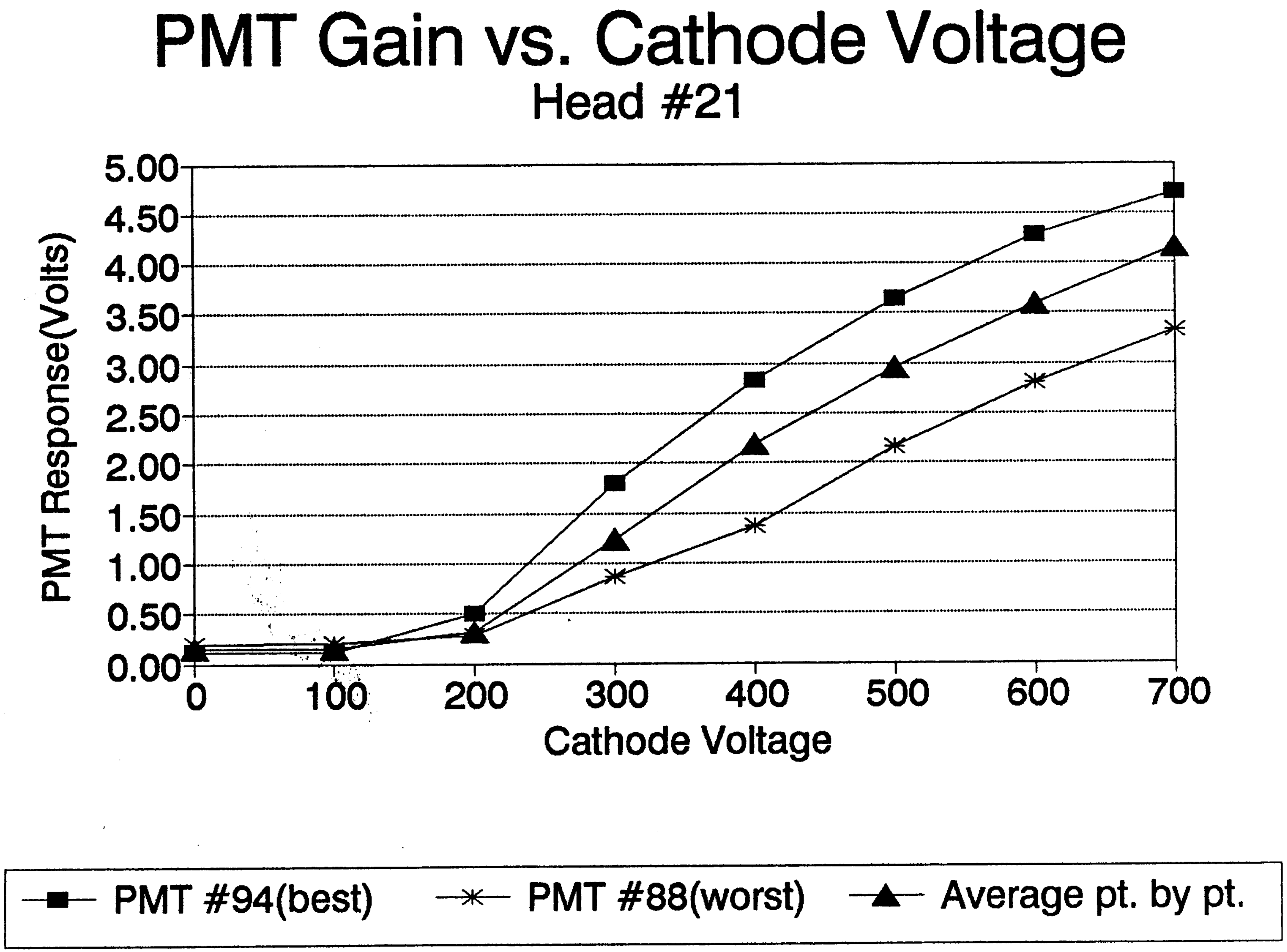

PMT Gain vs. Cathode Voltage
Head #21
PMT Response(Volts)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
100
200
300
400
500
600
700
Cathode Voltage
PMT #94(best)
PMT #88(worst)
Average pt. by pt.

Figure 5

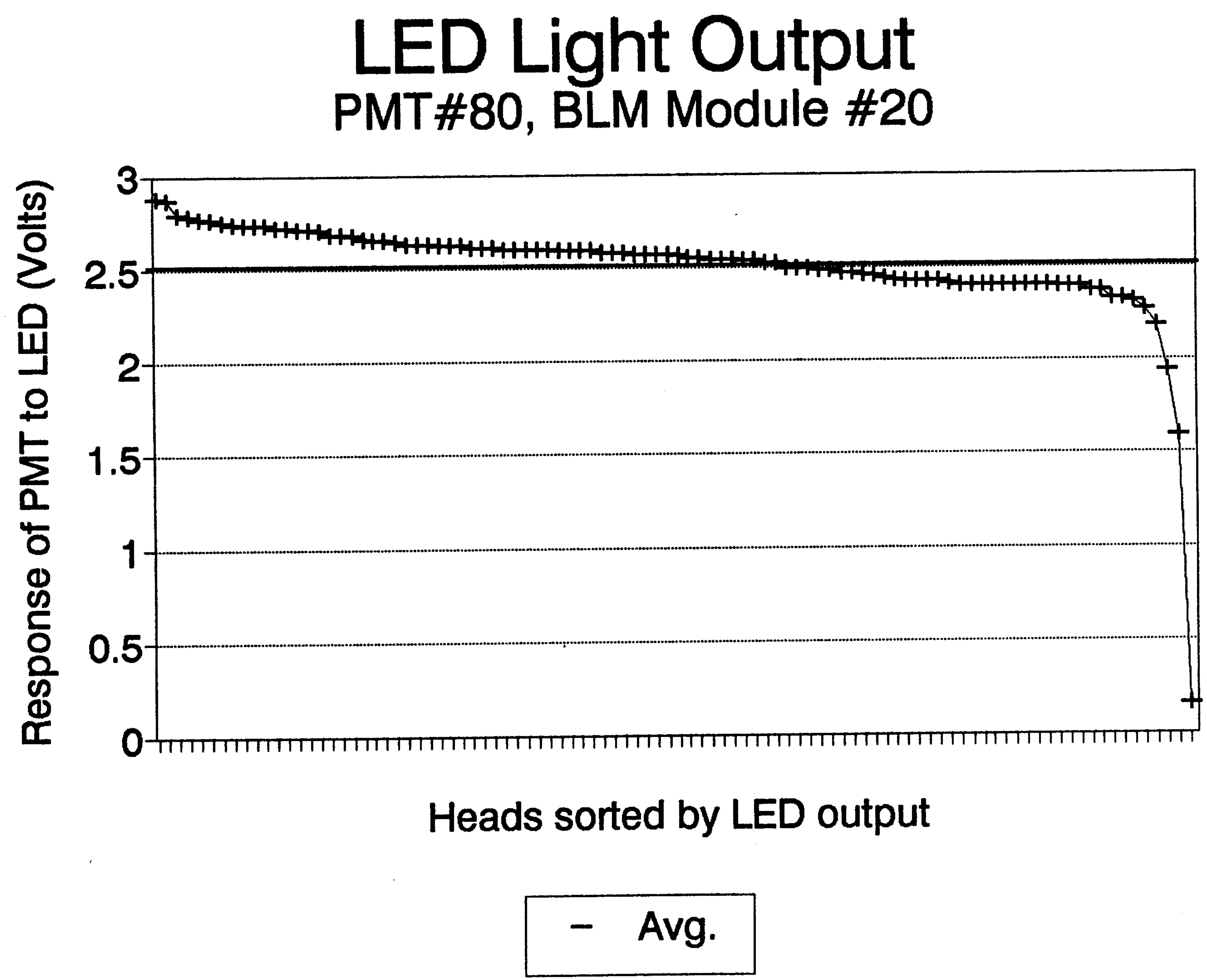

LED Light Output
PMT#80, BLM Module #20
Response of PMT to LED (Volts)
3
2.5
2
1.5
1
0.5
0
Heads sorted by LED output
Avg.

Figure 6

MASTER REFERENCE FOUR BY FOUR MATRIX

BLM MODULE #20 — OUTPUT IS IN VOLTS

AVG.= 2.519375 — STD.= 0.313953

REFERENCE LED'S	REFERENCE PMT'S 88	8	60	59	8/12/93	11:00
79	1.86	2.7	2.5	2.46		
90	2.17	2.91	2.75	2.62		
93	2.21	2.91	2.73	2.71		
117	1.97	2.71	2.54	2.56		

AVG. = 2.53 — STD.= 0.304587

REFERENCE LED'S	REFERENCE PMT'S 88	8	60	59	8/12/93	3:00	PERCENT CHANGE	
79	1.97	2.68	2.52	2.48	5.583756	-0.74627	0.793651	0.806452
90	2.17	2.95	2.75	2.66	0	1.355932	0	1.503759
93	2.19	2.93	2.73	2.68	-0.91324	0.682594	0	-1.1194
117	1.97	2.7	2.54	2.56	0	-0.37037	0	0

AVG. = 2.5225 — STD.= 0.292313

REFERENCE LED'S	REFERENCE PMT'S 88	8	60	59	8/13/93	11:00	PERCENT CHANGE	
79	1.95	2.64	2.54	2.52	4.615385	-2.27273	1.574803	2.380952
90	2.13	2.89	2.68	2.7	-1.87793	-0.69204	-2.61194	2.962963
93	2.23	2.93	2.73	2.64	0.896861	0.682594	0	-2.65152
117	2.02	2.7	2.5	2.56	2.475248	-0.37037	-1.6	0

Figure 7

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