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American Linear Collider Physics Group

Victoria Linear Collider Workshop

Muon Detector MAPMT Tests - Calibration R&D

Scintillator Based Muon System R&D for a Linear Collider

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Motivation

economy of MAPMT's makes possible the large channel count needed for a fine-grained scintillator detector

<1000 channel readout needed for a prototype system

develop expertise to specify a larger system

General Considerations

1 pC charge = gain of ~ 6 x 10^6

1 pC in a 5 ns pulse into a 50 ohm load = 10 mV amplitude

advanced testing and characterization of M-16 and M-64 phototubes by MINOS collaboration, HERA-B RICH, CDF calorimeter

Status of PMT work at WSU

- PMT's purchased with FY 2004 DOE funds

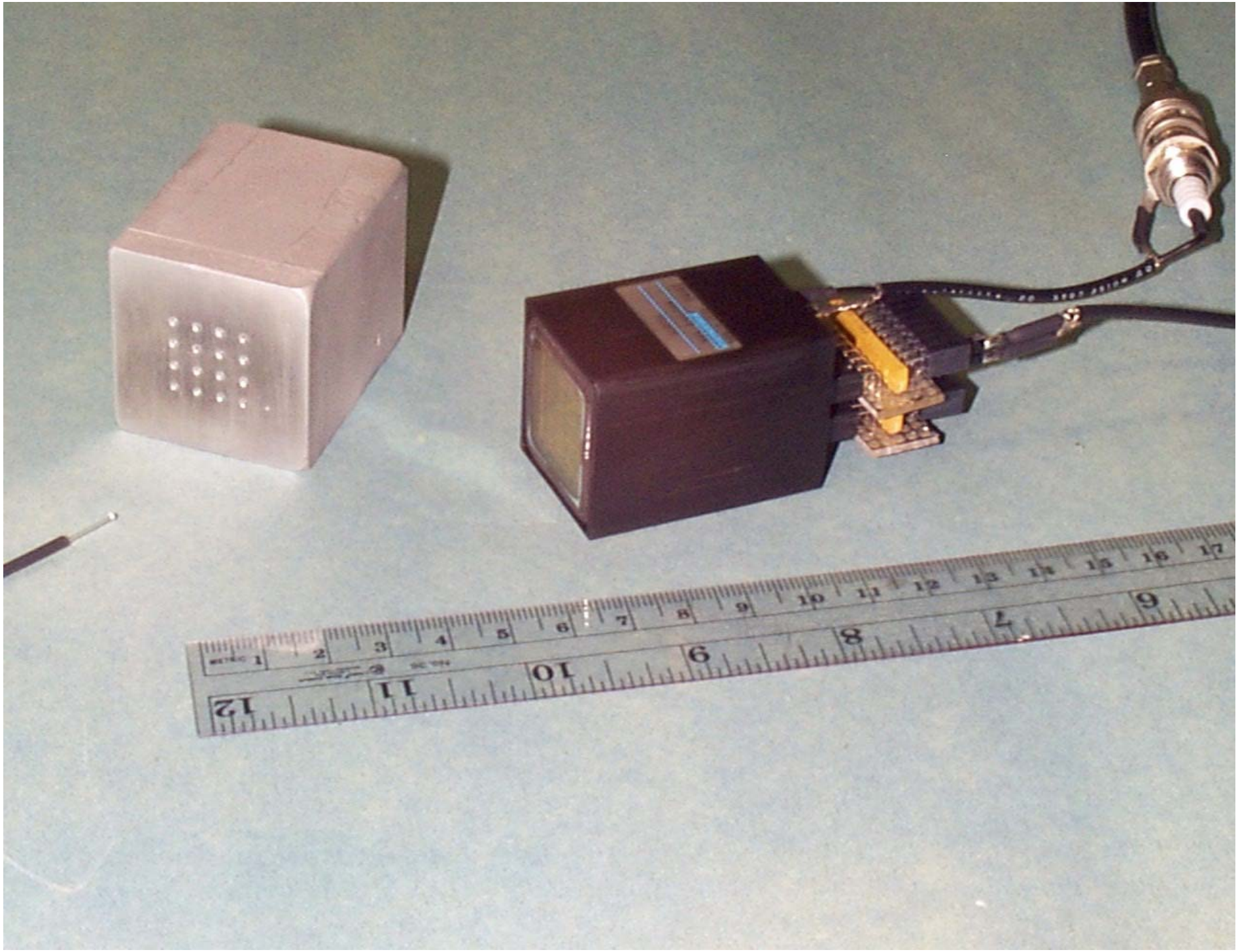
(3) H7546B: 64-channel, includes base, $1750 each
(2) H8711: 16-channel, includes base, $1369 each

- fiber guides and connector assemblies for 16-channel tubes fabricated

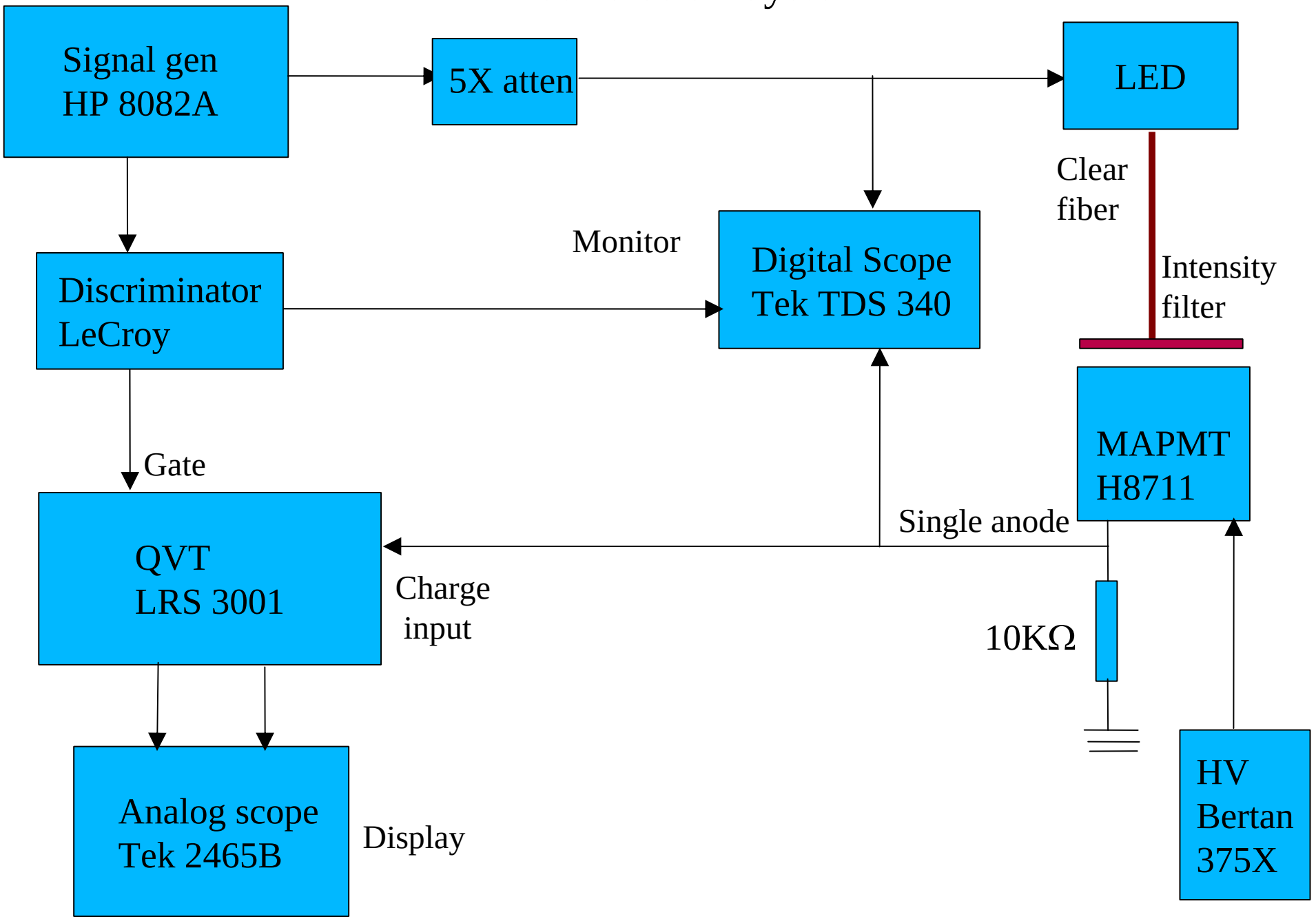
- single photon calibration of 16-ch tube with pulsed light emitting diode (LED)

- gain versus HV measured for 16-ch tube

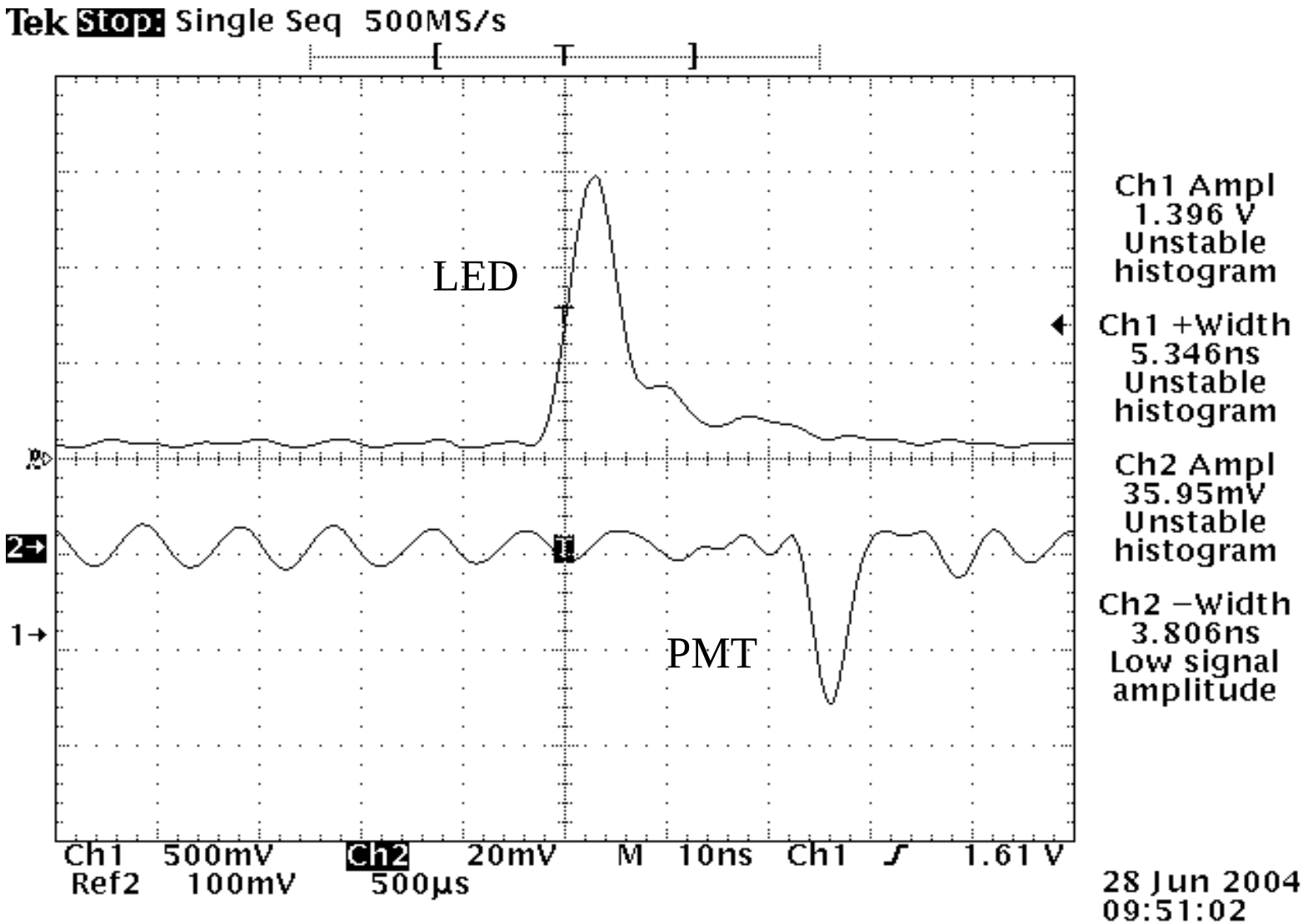
- test station commissioned at Fermilab



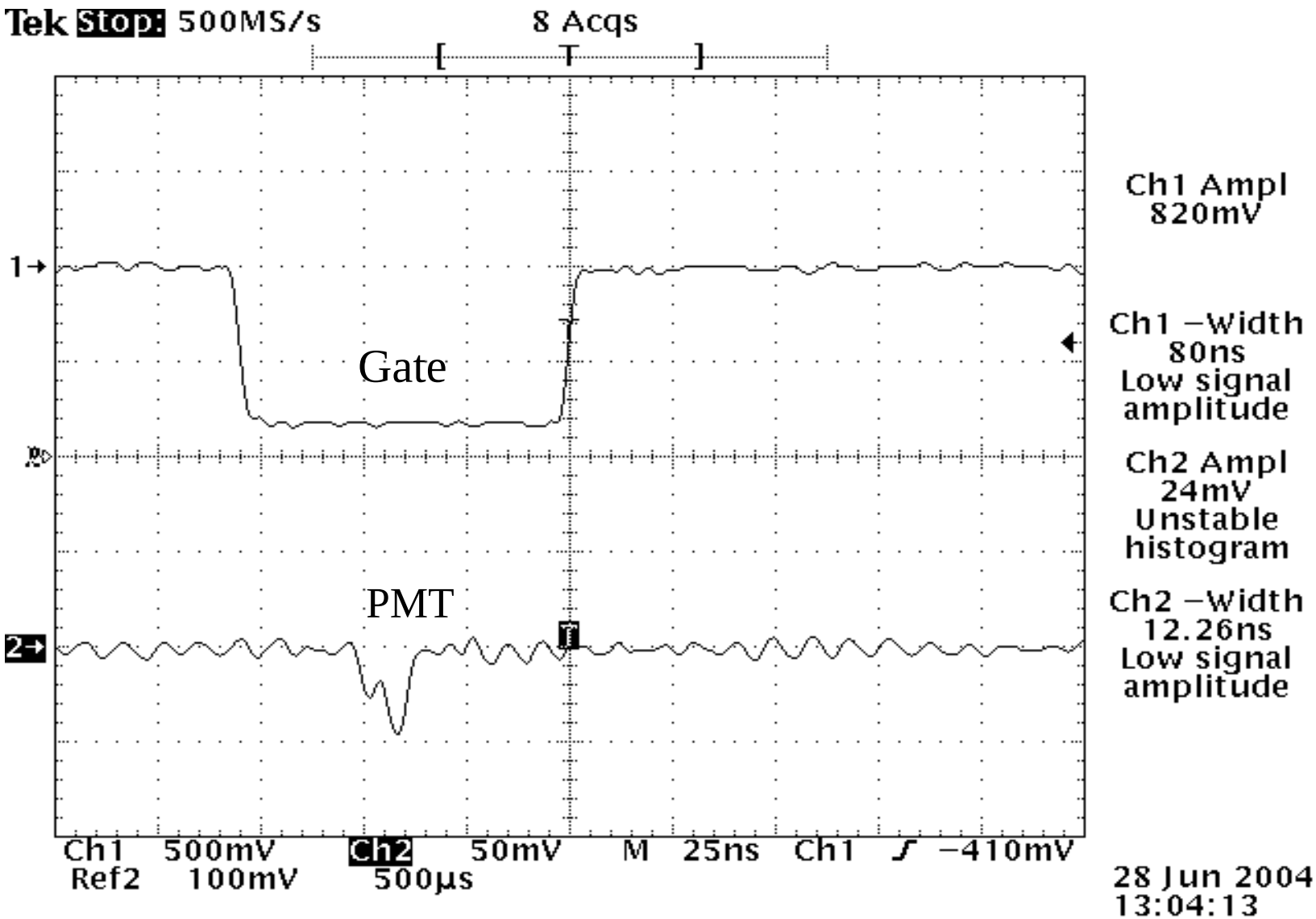
MAPMT Calibration System

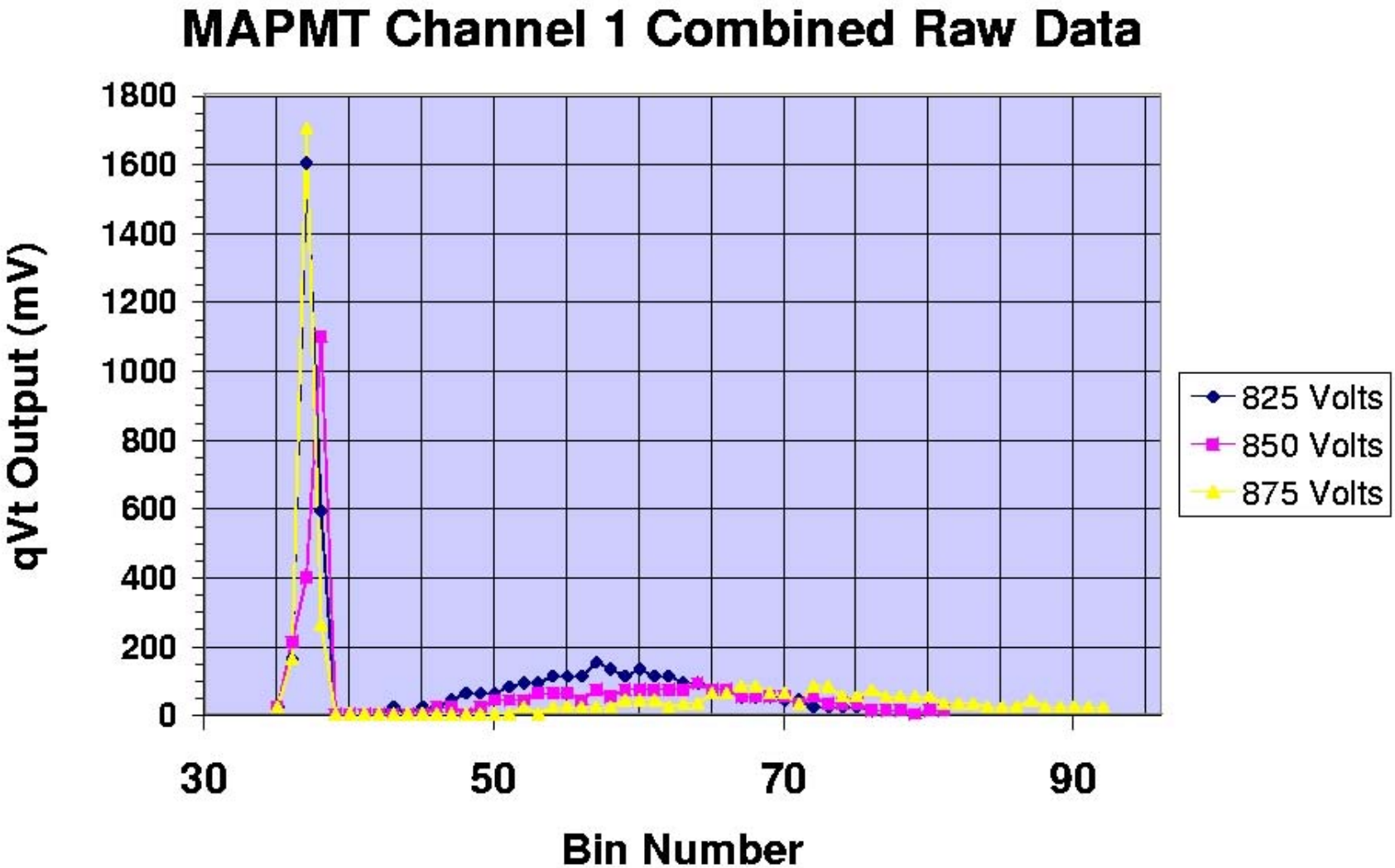


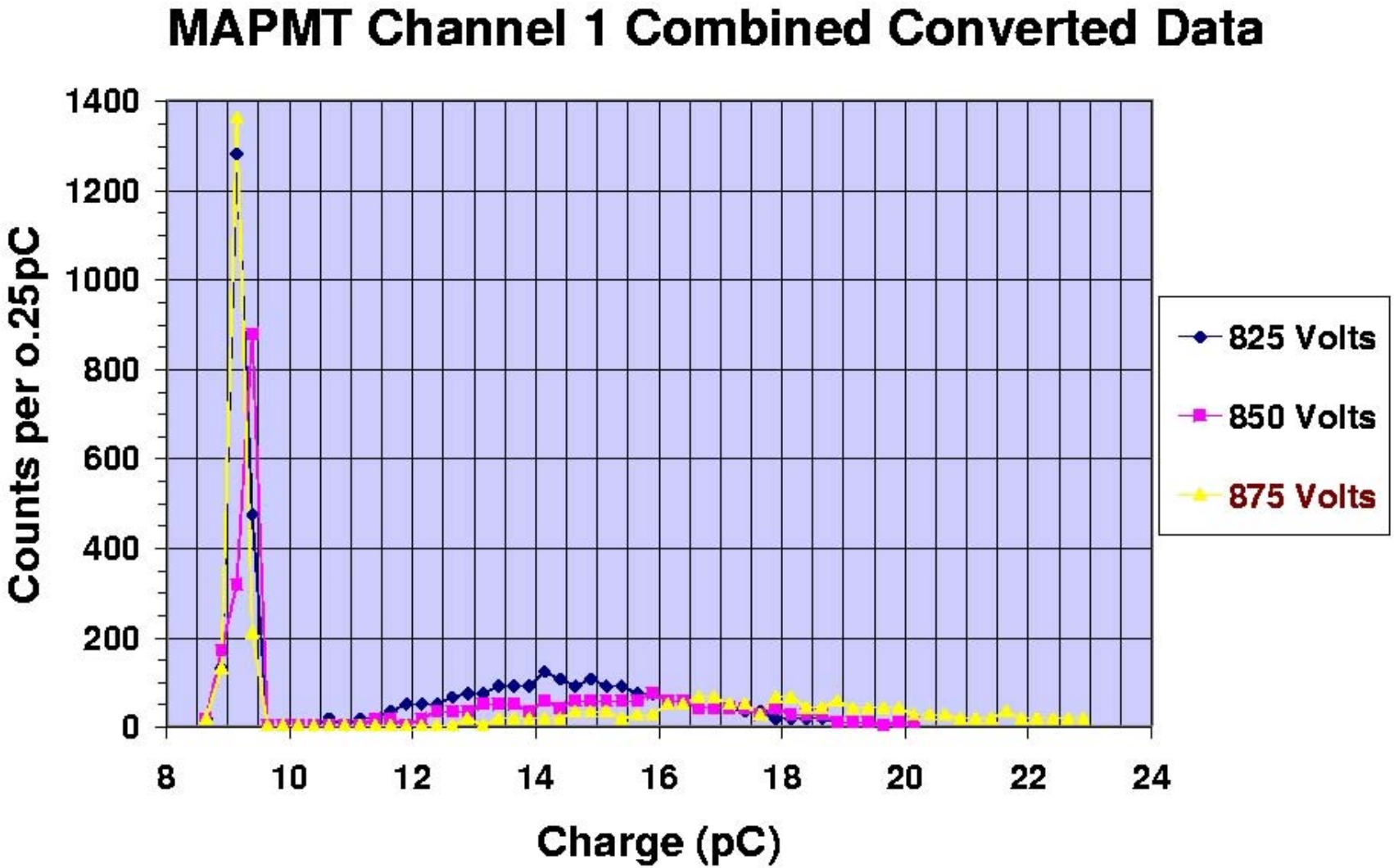
LED and PMT Anode Single Sample Waveforms

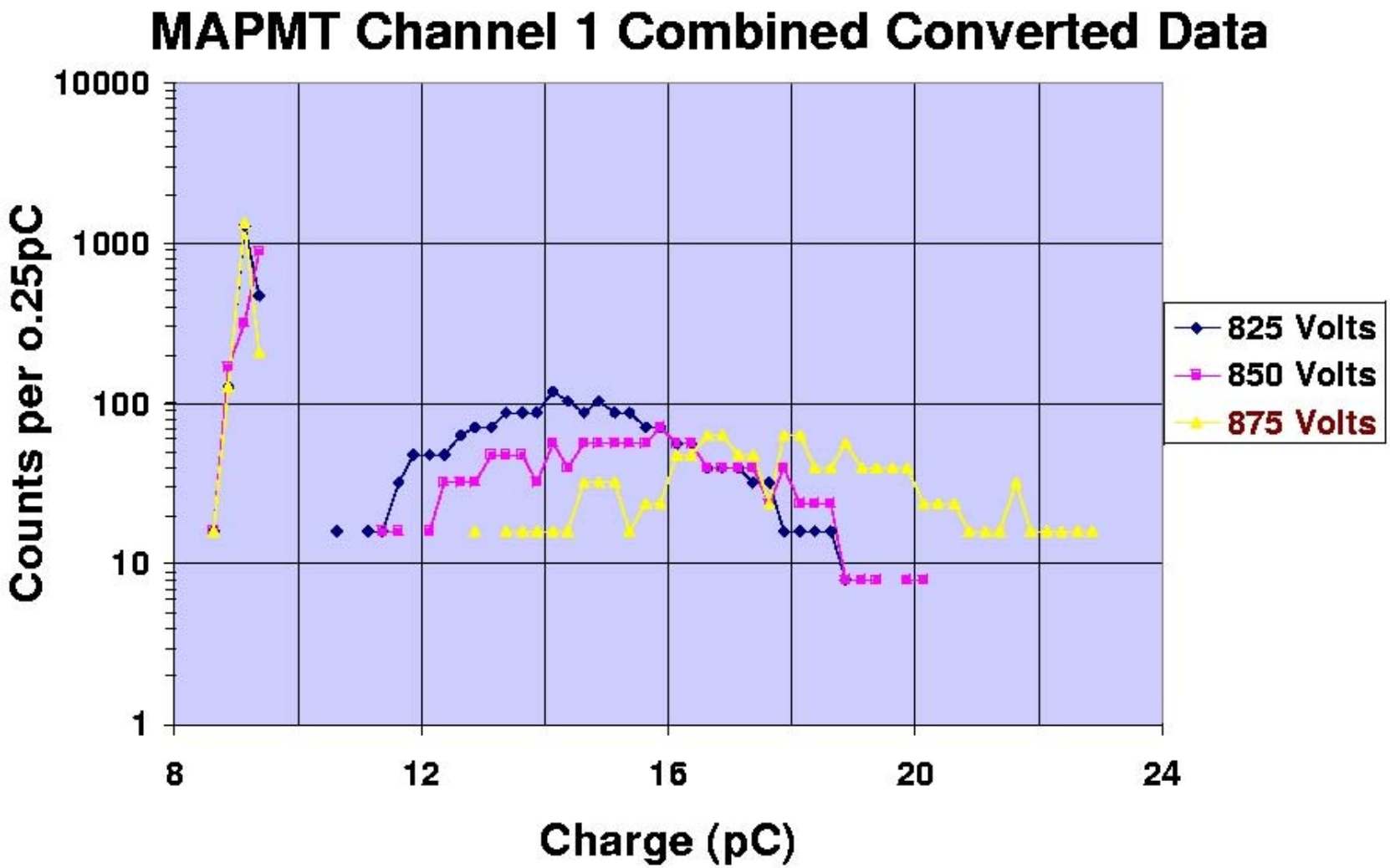


QVT Gate and PMT Anode Single Sample Waveforms




MAPMT Channel 1 Combined Raw Data
qVt Output (mV)
1800
1600
1400
1200
1000
800
600
400
200
0
30
50
70
90
Bin Number
825 Volts
850 Volts
875 Volts


MAPMT Channel 1 Combined Converted Data
Counts per o.25pC
1400
1200
1000
800
600
400
200
0
8
10
12
14
16
18
20
22
24
Charge (pC)
825 Volts
850 Volts
875 Volts


MAPMT Channel 1 Combined Converted Data
Counts per o.25pC
10000
1000
100
10
1
8
12
16
20
24
Charge (pC)
825 Volts
850 Volts
875 Volts

Data Analysis

- assume that shape of charge distribution is dominated by Poisson fluctuations at the photocathode

- fluctuations at each dynode stage smear the distribution for $N_{pe} > 0$

- determine $\langle N_{pe} \rangle$ and <Gain> from charge distribution

Method 1: Zero Counting

Prob(0) = sum(pedestal) / sum(ped+signal)

$$\langle N_{pe} \rangle = -\ln \text{Prob}(0)$$

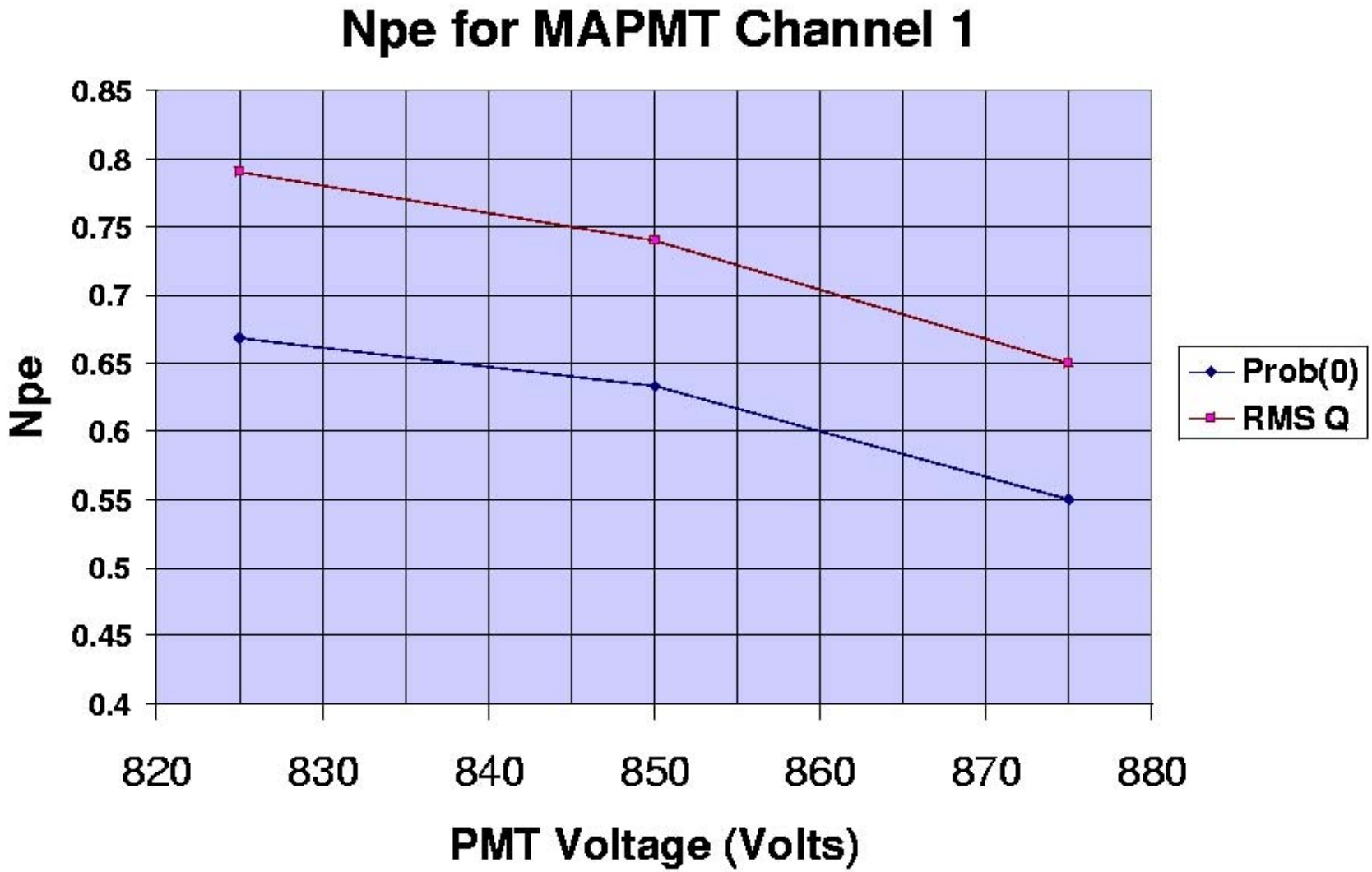
$$\langle \text{Gain} \rangle = \langle G \rangle = \frac{\langle Q \rangle}{\langle N_{pe} \rangle e}$$

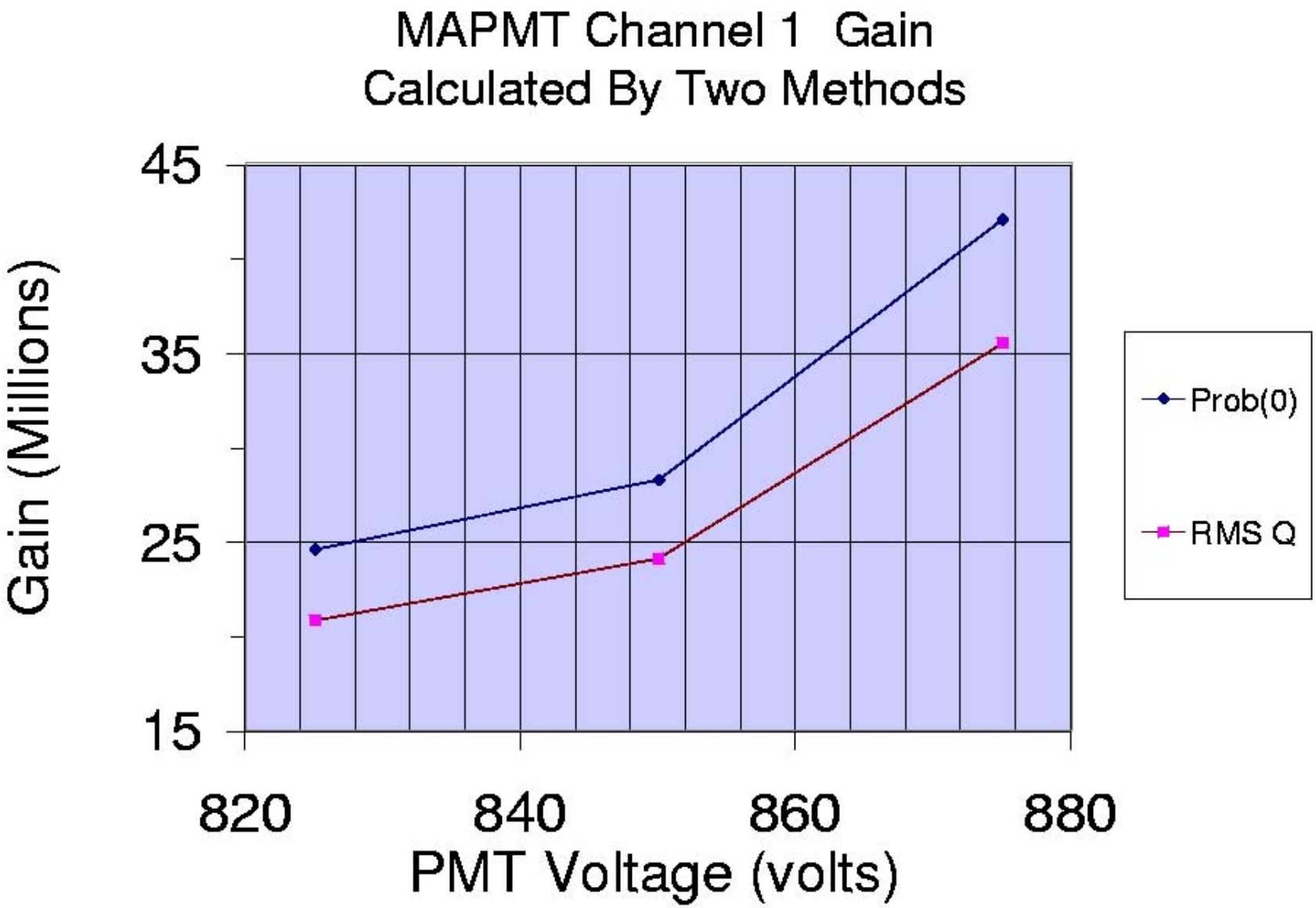
Method 2: Variance of Charge

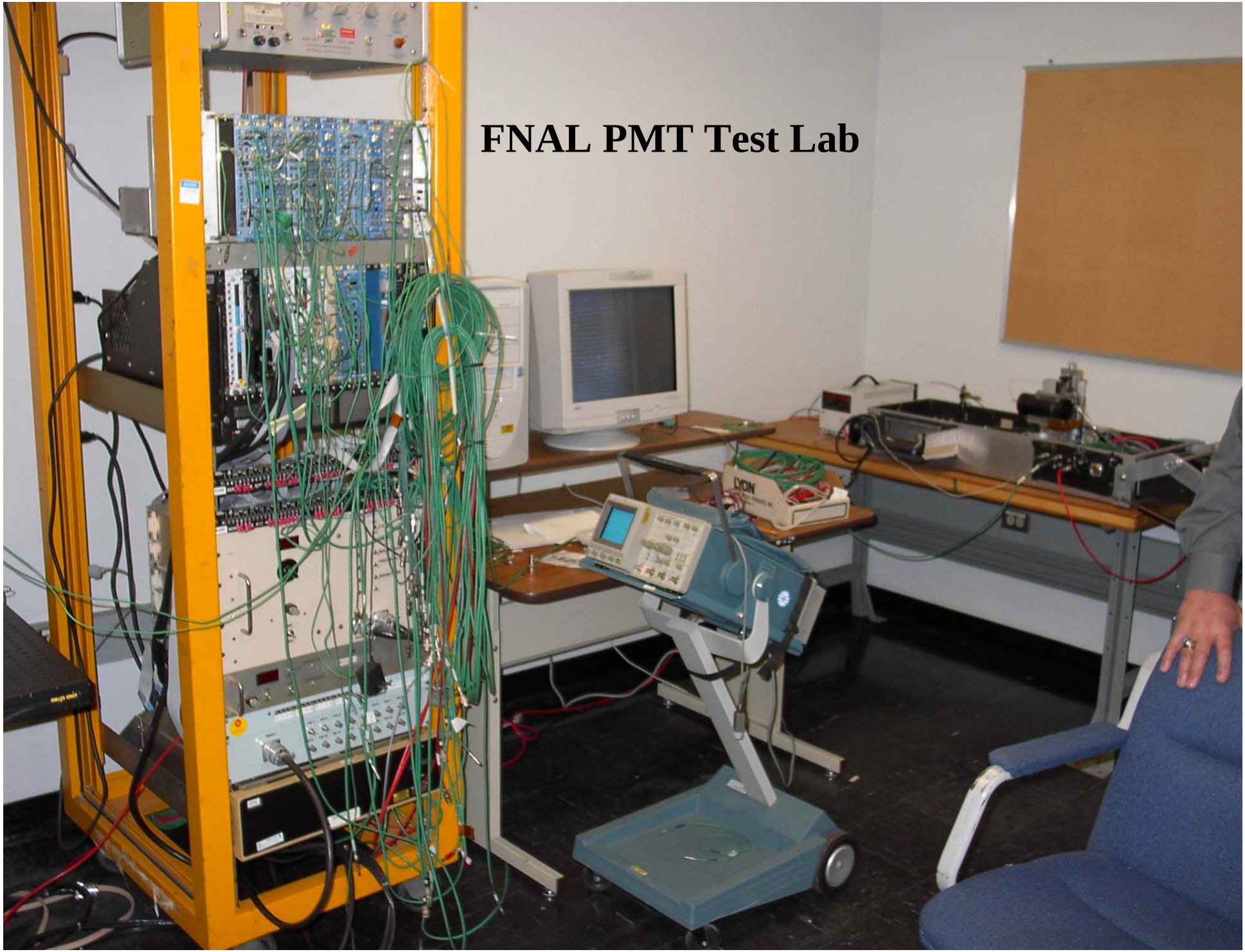
$$\sigma^2 = \langle (Q - \langle Q \rangle)^2 \rangle$$

$$\langle G \rangle = \frac{\sigma^2}{\langle Q \rangle e}$$

$$\langle N_{pe} \rangle = \frac{\langle Q \rangle}{\langle G \rangle e}$$


Npe for MAPMT Channel 1
Npe
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
820
830
840
850
860
870
880
PMT Voltage (Volts)
Prob(0)
RMS Q


MAPMT Channel 1 Gain
Calculated By Two Methods
Gain (Millions)
45
35
25
15
820
840
860
880
PMT Voltage (volts)
Prob(0)
RMS Q


FNAL PMT Test Lab

Prototype Scintillator Bars at FNAL
Note groove and TiO2 coating

Conclusions

- Operation of 16-channel MAPMT is established for single photo-electrons
- Photo-electron yield and single-channel PMT gain are measured using a simple analysis technique
- In-situ LED calibration of a scintillator/fiber/PMT system is promising

Future Plans

- Measure PMT response for larger numbers of p.e., compare with factory gain measurements for all channels
- Calibrate using fully digital readout
- instrument scintillator bar prototypes