LC Scintillator-based Muon/Tail-catcher R&D

Analysis of 9/06 MTest Data Using Measured MAPMT Channel Response

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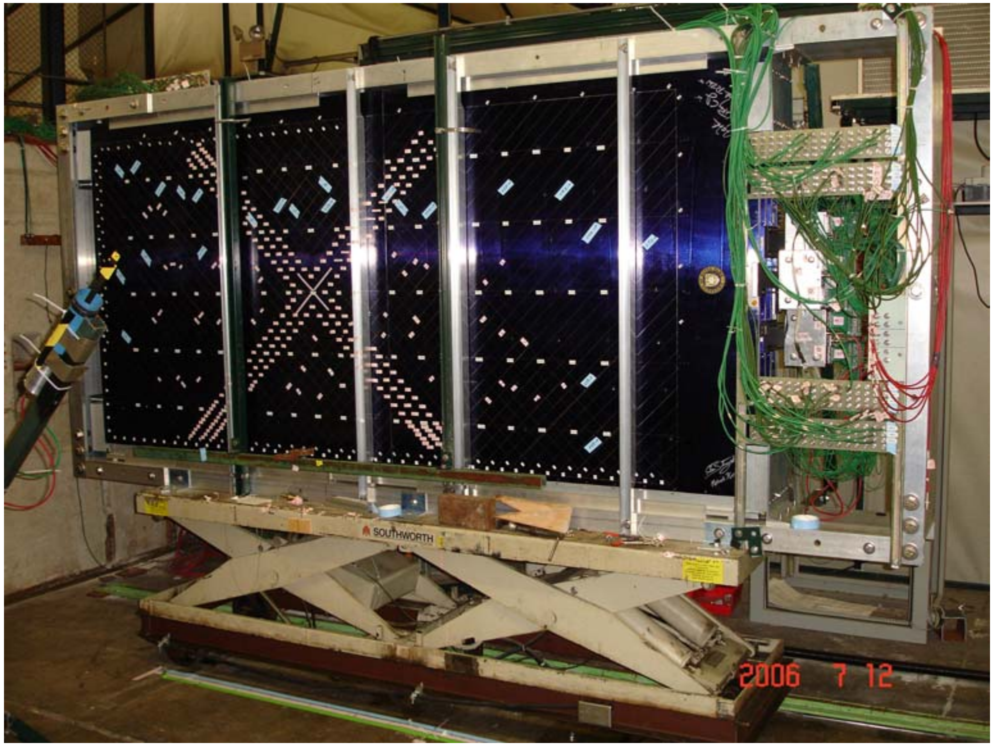
Outline

- MTest beam results from September '06 run.
- "Calibration" of Multi-anode PMT Channels
- Comparison of Single/Double ended Readout
- Can we do/learn more?
- Future Plans

ILC MuonTest Setup



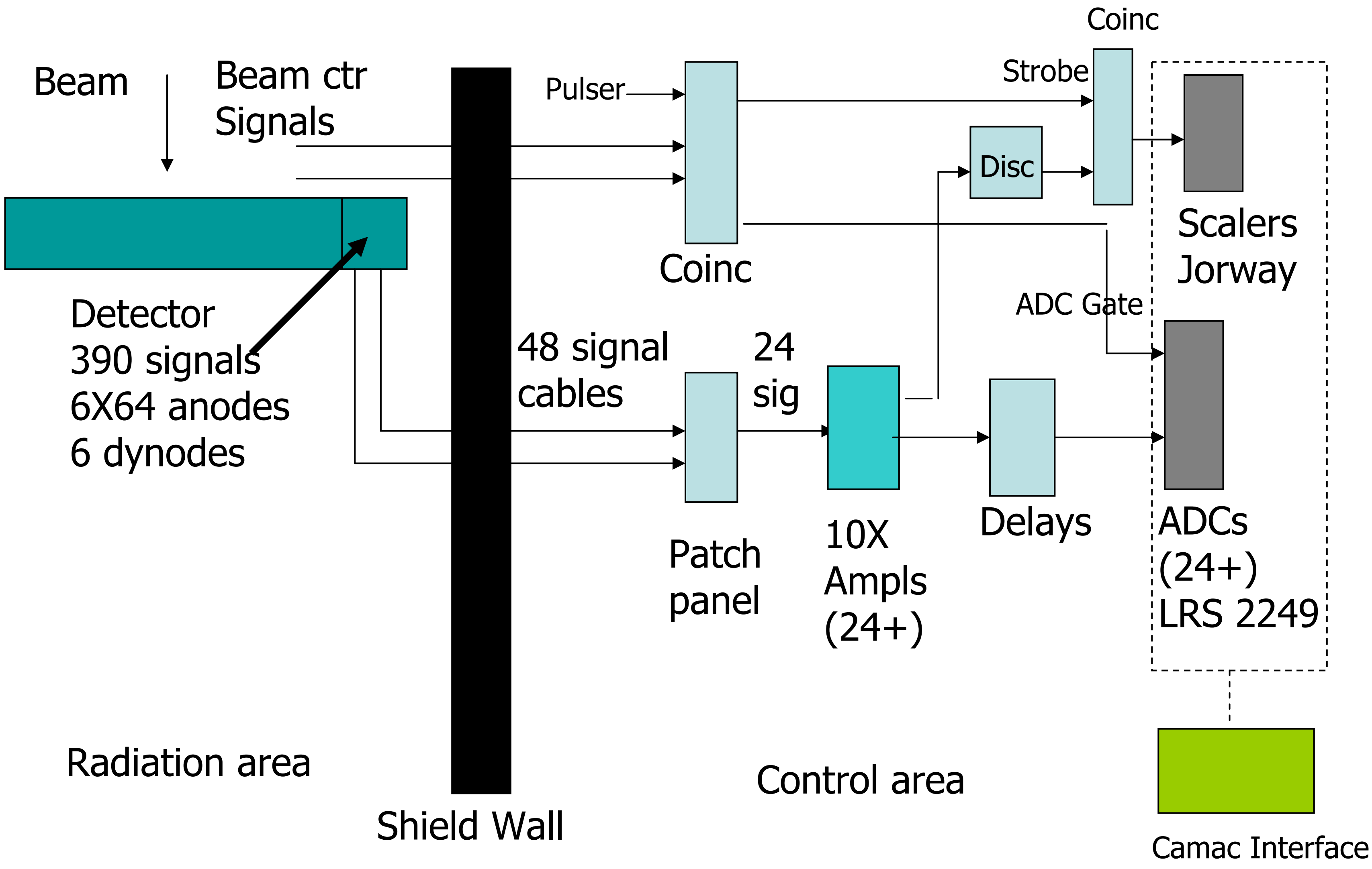
Scintillator-strip planes installed in Fermilab Beam Test Facility

Planes: 1.25m X 2.5m

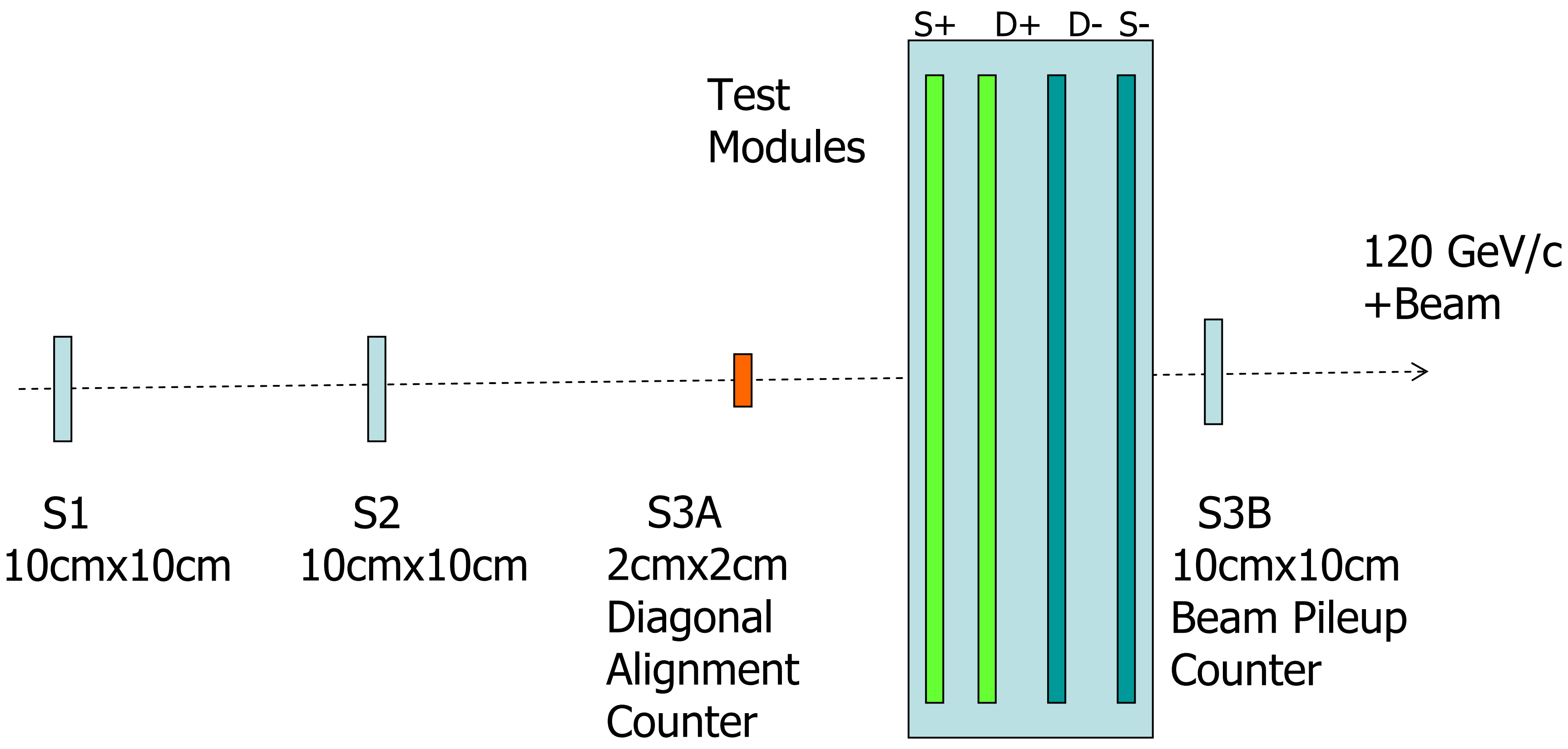
256 scintillator strips:
 strips: 4.1cm (W) X 1cm (T) X 1.8m (L). Two planes have single-ended readout and 2 planes have both ends of strips readout.

384 PMT channels

Instrumentation



Beam Trigger (S1.S2.S3A.S3B)



Beam Operating conditions

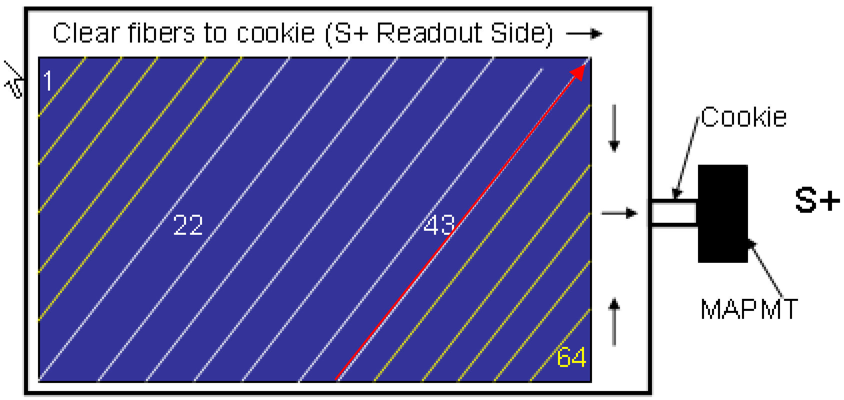
- DAQ triggered on beam; no strips in the trigger.
- When prime user, we had low intensity, ~ 1000p/sec during spill, two 1-sec spills/minute, 12 hours/day.
- When secondary user we operated up to ~20K p/sec.
- DAQ data rate limited < 50Hz. (CAMAC readout)
- Beam spot at +120 GeV/c ~ 1 cm FWHM.
- Additional beam particles within ADC gate (170ns) ~10% of time, even at low rates.
- Offline veto of multiple beam particles using beam counter.

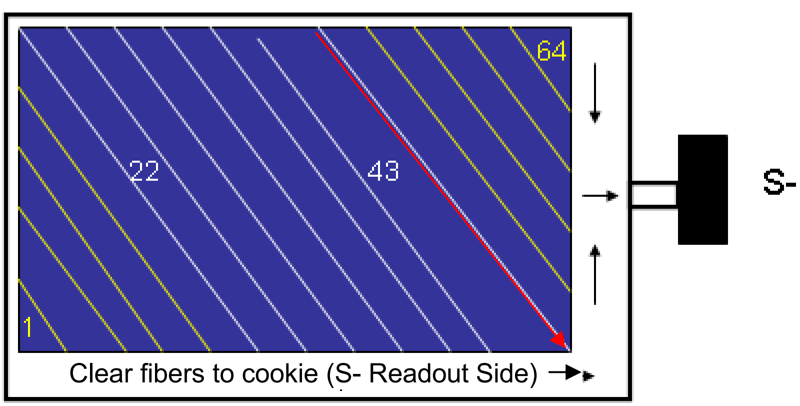
Beam Test Objectives

- Pulse height characteristics
- Measurement of integrated dE/dx charge => $N_{p.e.}$
- Strip longitudinal position response.
- Strip-to-strip response.
- Read out two ends or only one end?
- SiPM confirmation data w/similar strips.

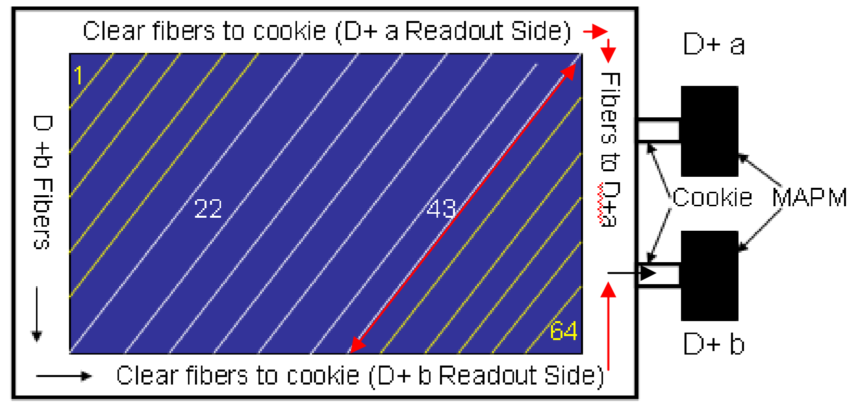
Four Detector planes

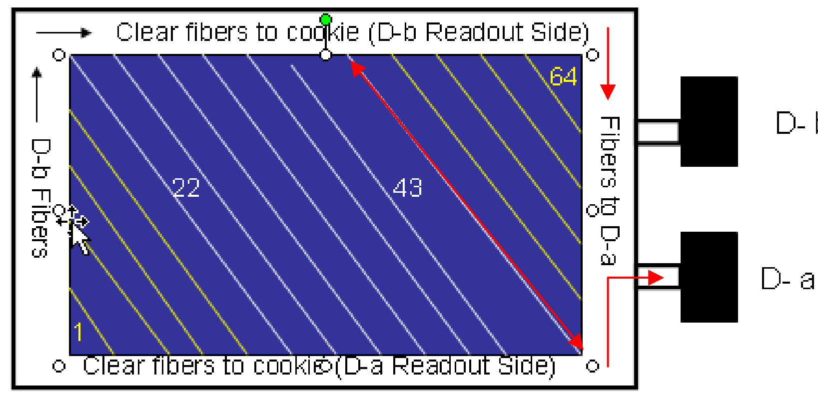
Single ended readout





Dual readout





Distributions from Composite Run 6446 at (+38, -38)

11450 Total Events

S+ mean 439.2

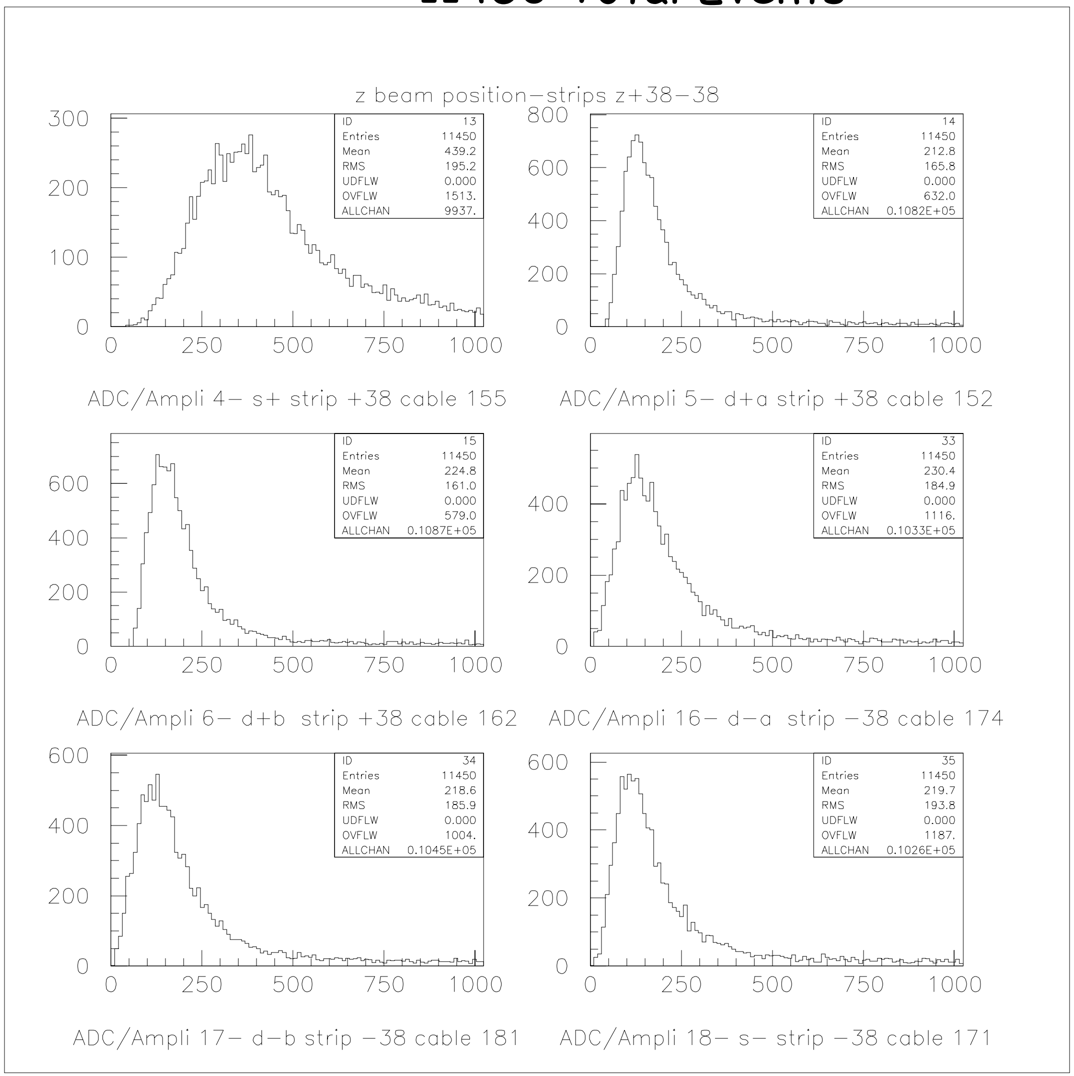
D+a mean 212.8

D+b mean 224.8

D-a mean 230.4

D-b mean 185.9

S- mean 219.7

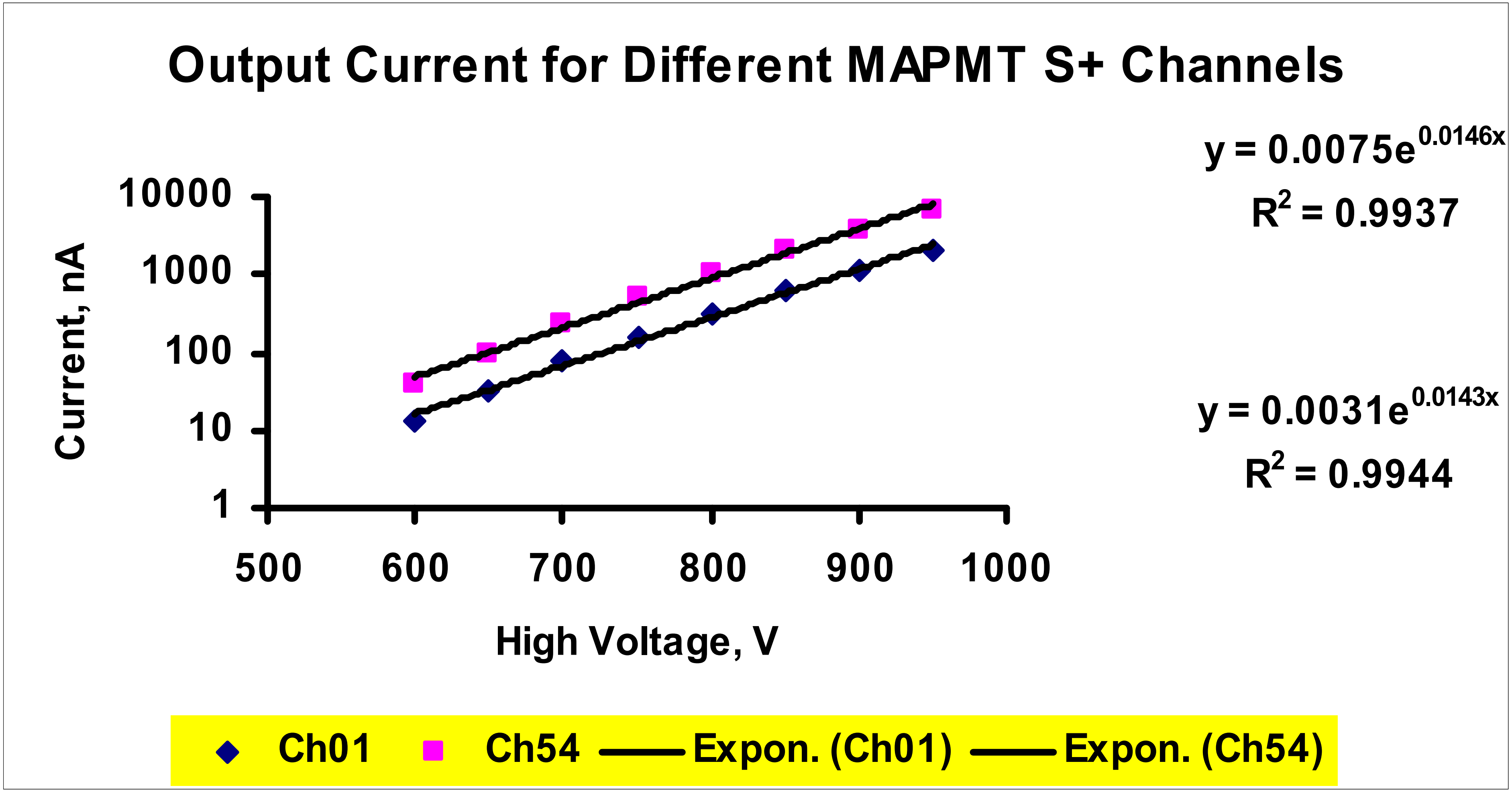


Observation: No events near Q = 0

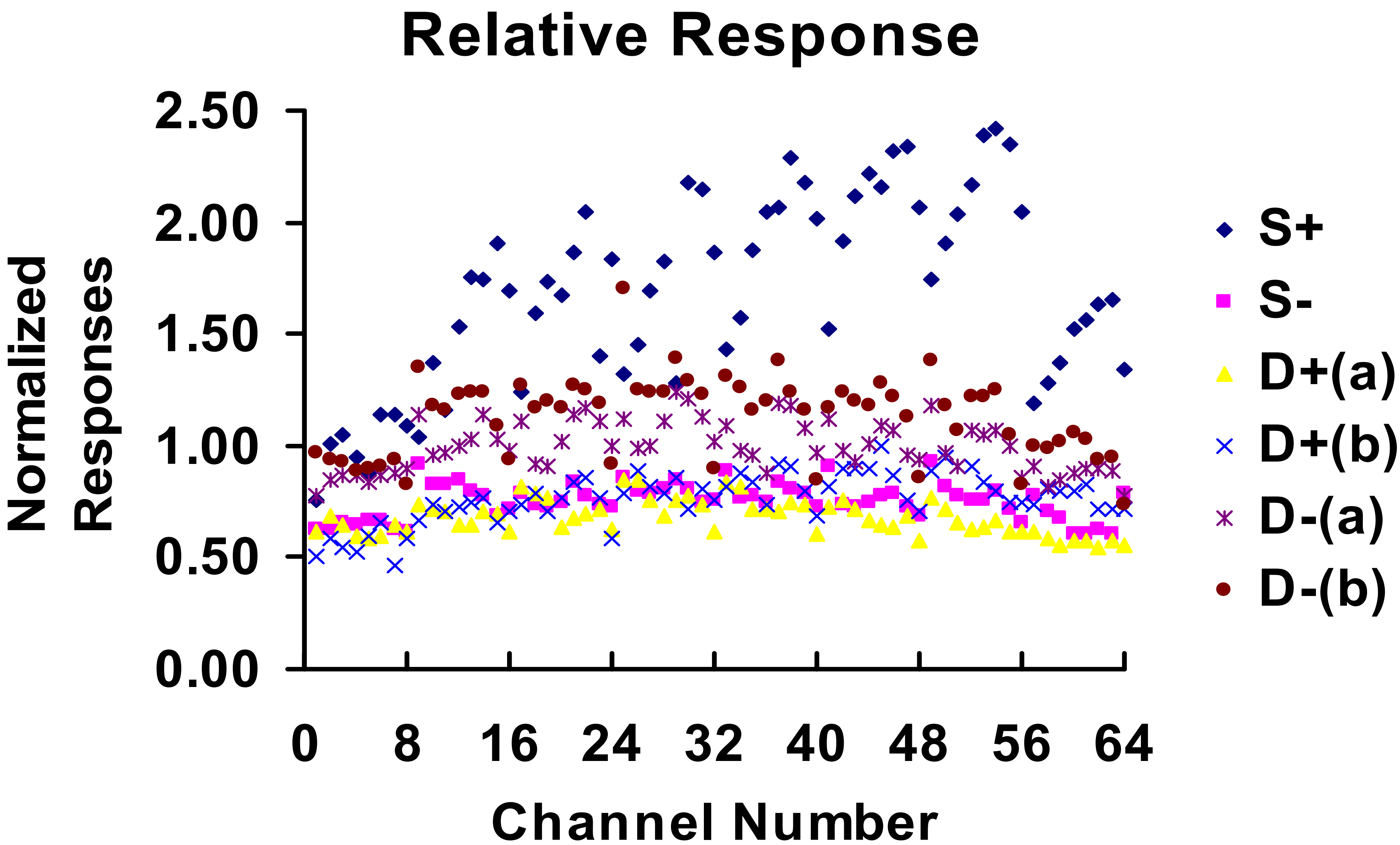
11,450 events - With pedestals subtracted there appear to be no events with pulse height near zero. If this is the case, then we can get an estimate of the number of photo-electrons.

Suppose there is one p.e. then $P(0) < P(1) = 1/11450$

$P(0) = \exp(-\mu) < 8.7\ E\text{-}05 \Rightarrow \mu > 9$



Output Current for Different MAPMT S+ Channels
y = 0.0075e^0.0146x
R^2 = 0.9937
y = 0.0031e^0.0143x
R^2 = 0.9944
Current, nA
10000
1000
100
10
1
500
600
700
800
900
1000
High Voltage, V
Ch01
Ch54
Expon. (Ch01)
Expon. (Ch54)


Relative Response
2.50
2.00
1.50
1.00
0.50
0.00
Normalized Responses
0
8
16
24
32
40
48
56
64
Channel Number
S+
S-
D+(a)
D+(b)
D-(a)
D-(b)

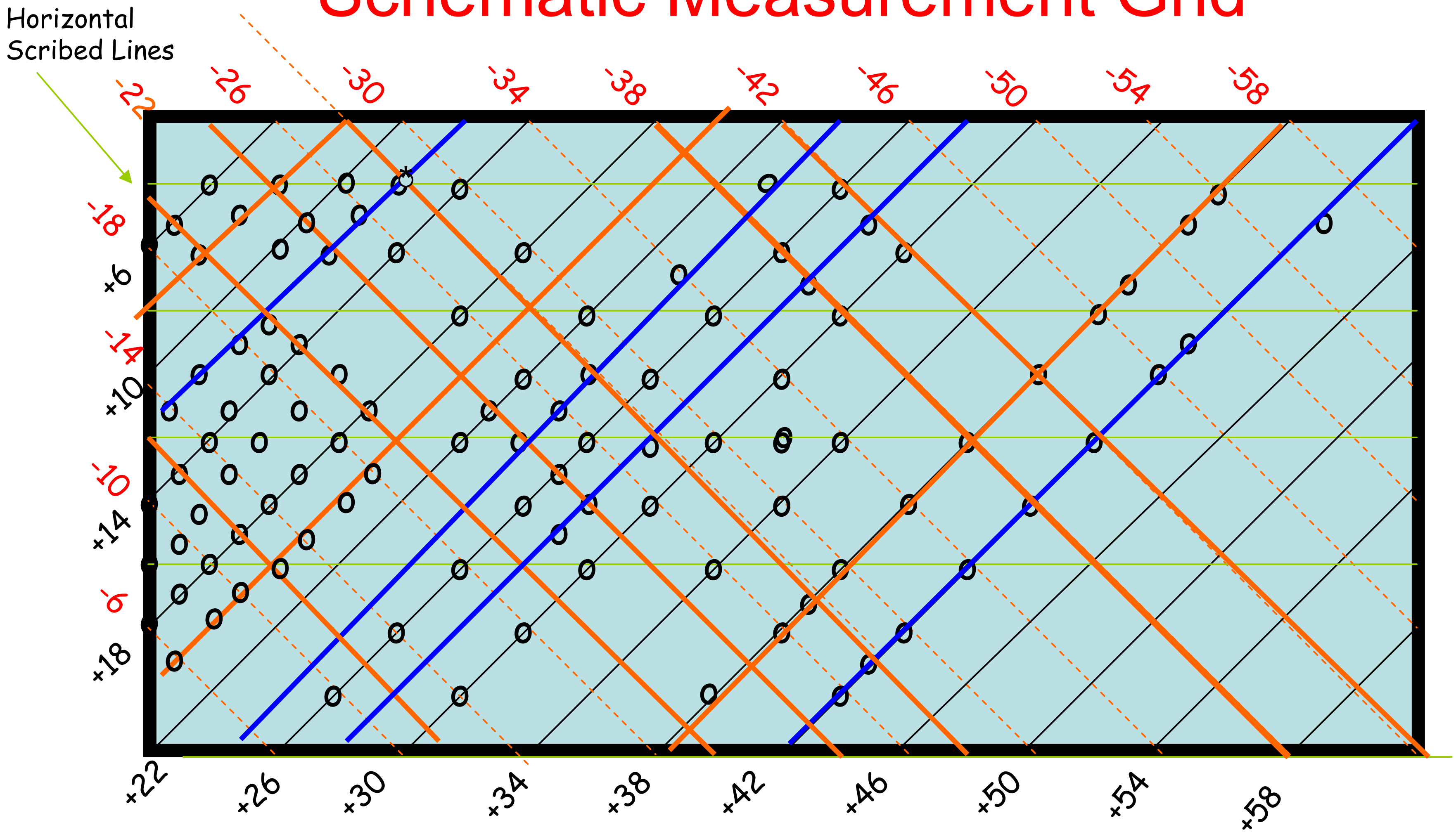
MAPMT Normalization Results

- Response of MAPMT to a standard light input varies as indicated from beam and radioactive source measurements.
- S+ tube has the largest variation and largest average response.
- Avg. response for a given tube at fixed voltage varies from tube to tube as anticipated. Calibration necessary.
- The response of a given channel to HV varies as a power law as is expected from 0.7 – 1.0 KV.
- No saturation is observed over the nominal operating ranges. Cross-talk averages ~ 3.9% (1%) near(diag) chns.
- This method of measuring relative response of individual channels of 6 H7546B MAPMTs provides a manageable calibration method.
- A second standard calibration technique of measuring the mean/σ is also being done to compare test-beam results. (P. Karchin Talk)

Back toTest Beam Data Analysis

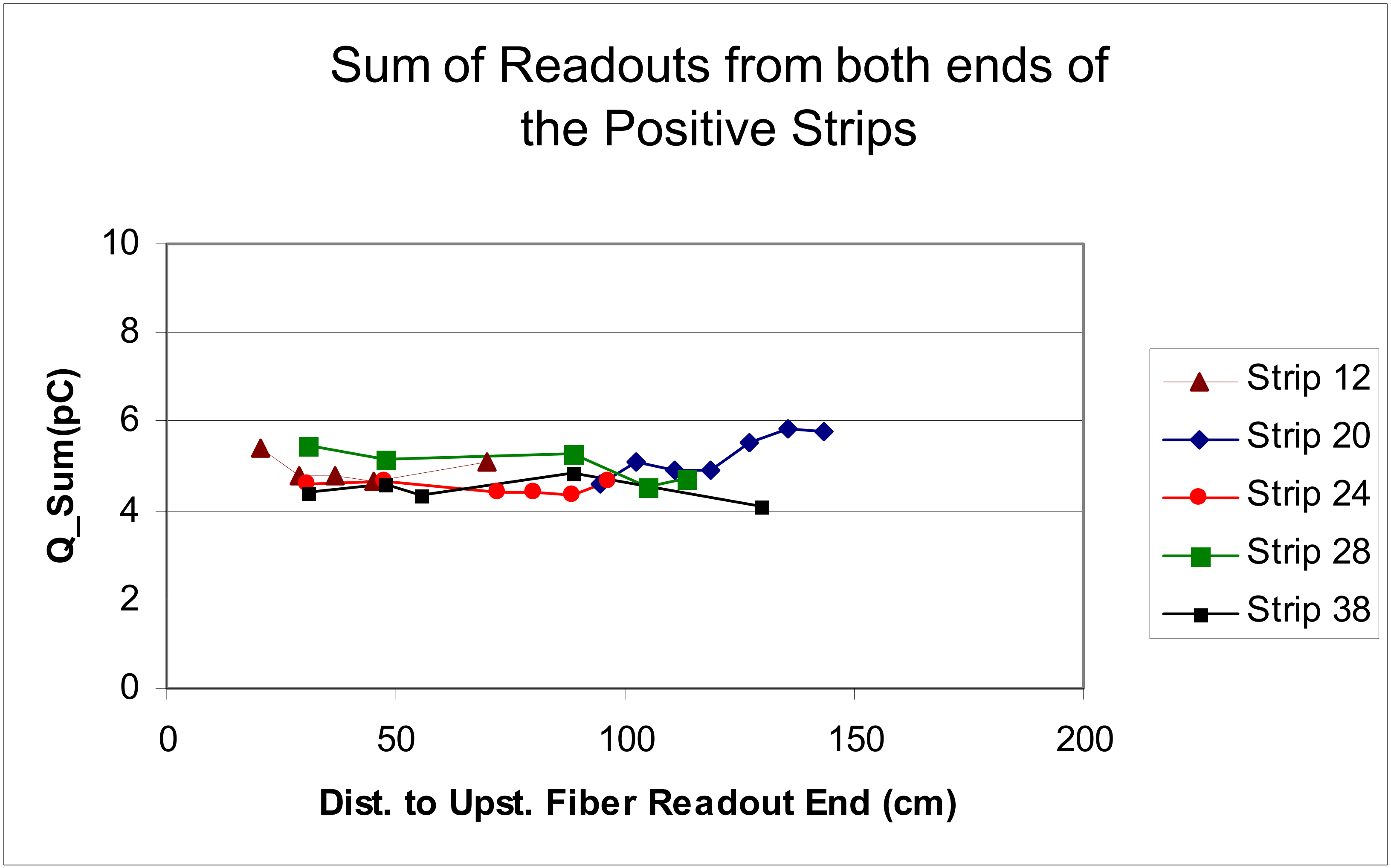
- X10 Amplifier Gain checked.
- Pedestal subtraction done.
- LeCroy 2249a ADC calibration done.
- WLS/Clear fiber splice transmission measured in some cases.
- Relative response of MAPMT channel measurements used.
- Attenuation of light pulses in WLS/Clear fiber not yet included.

Schematic Measurement Grid



Circles show points that were measured. Numbers indicate strip numbers

D+ Strips: Readout Both Ends of the Fibers



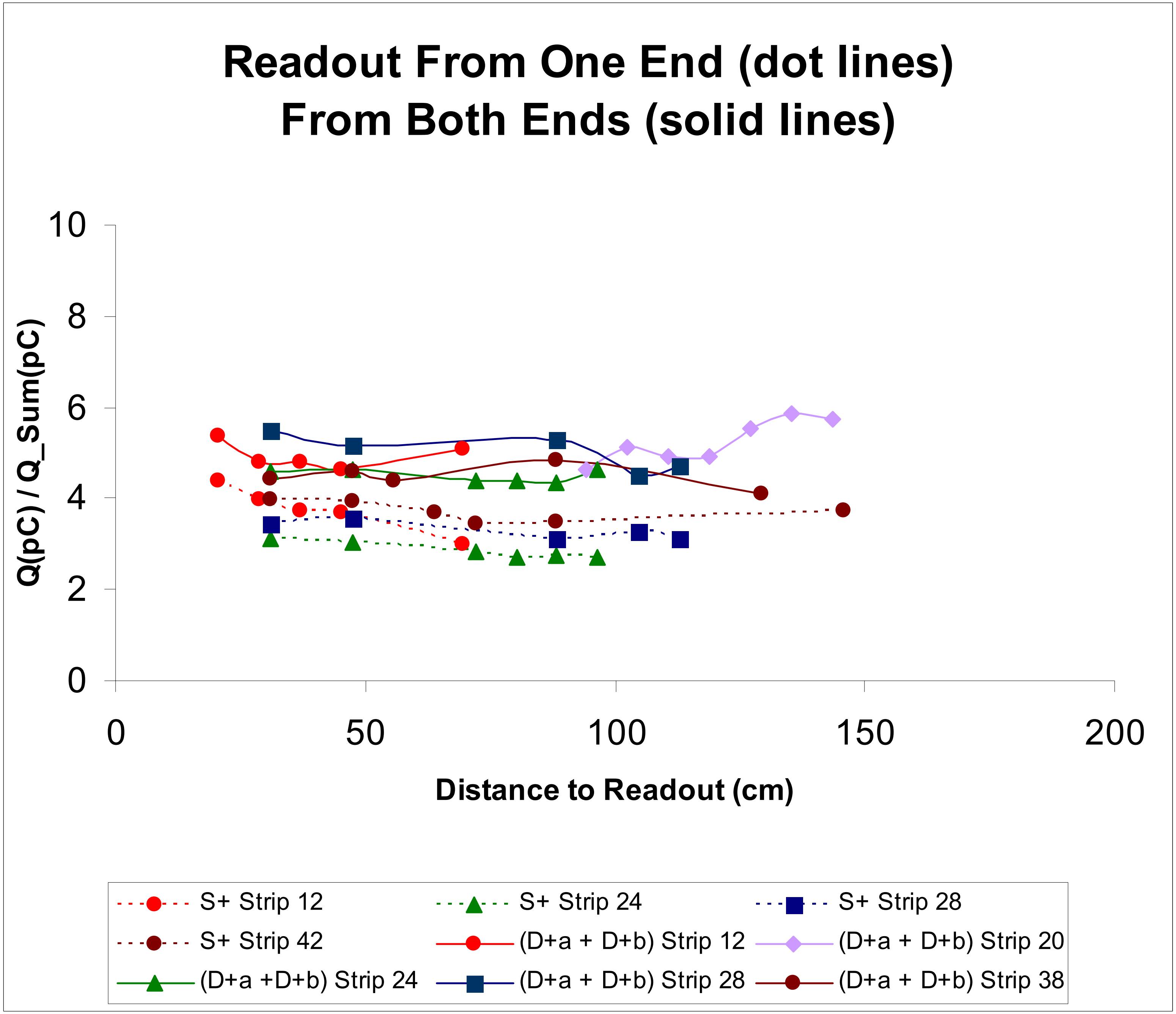
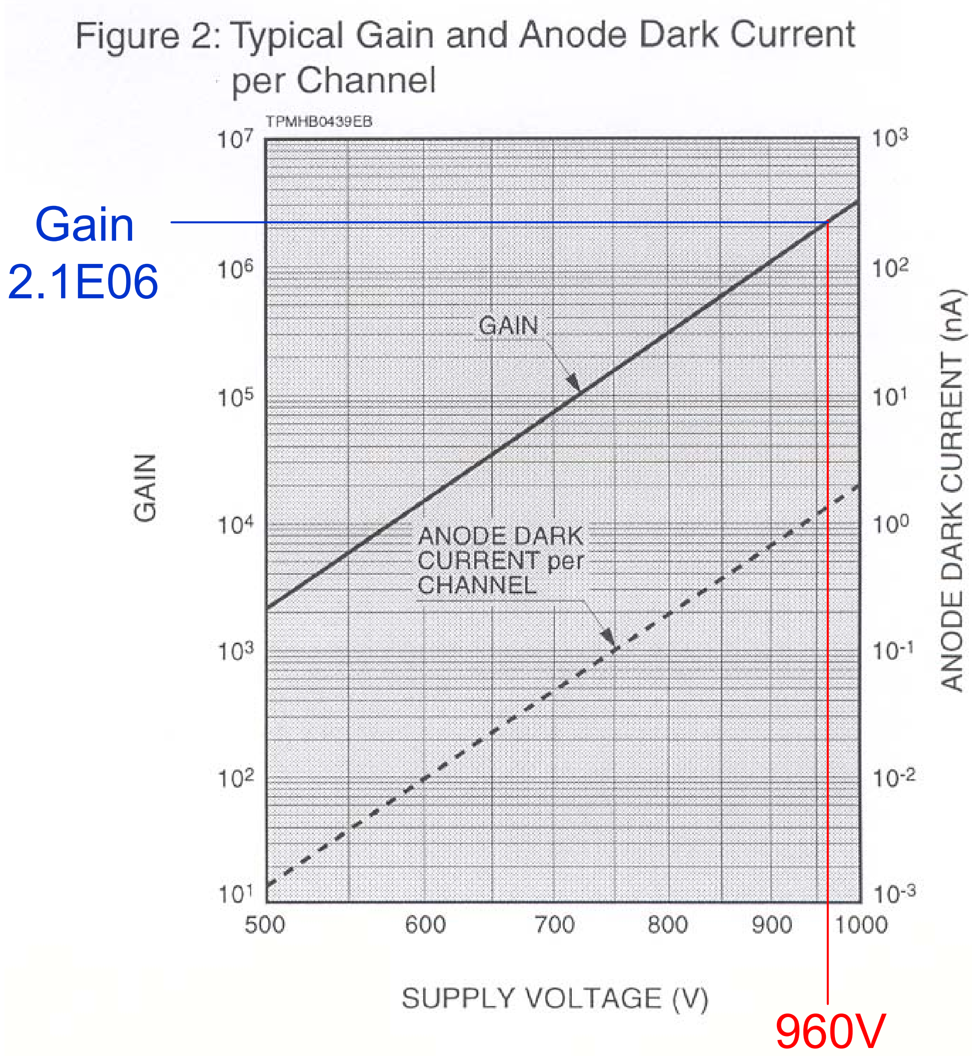

Readout From One End (dot lines)
From Both Ends (solid lines)
Q(pC) / Q_Sum(pC)
0
2
4
6
8
10
0
50
100
150
200
Distance to Readout (cm)
S+ Strip 12
S+ Strip 24
S+ Strip 28
S+ Strip 42
(D+a + D+b) Strip 12
(D+a + D+b) Strip 20
(D+a +D+b) Strip 24
(D+a + D+b) Strip 28
(D+a + D+b) Strip 38

Photo-electron Yield Estimate



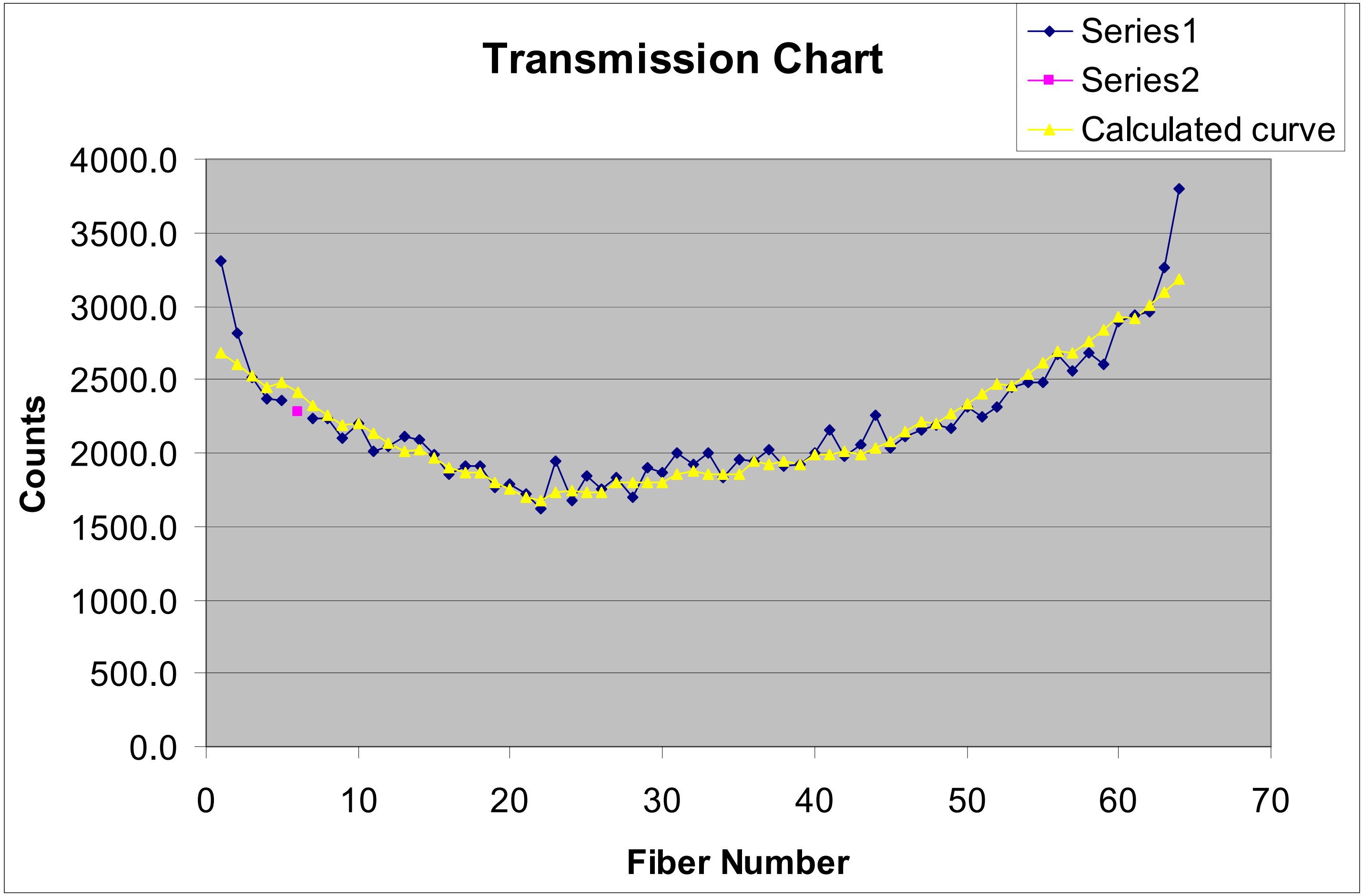
3.2 pC = 20 X 10⁶ e's

Nom. Gain = 2.1 X 10⁶

Nom. p.e.s ?? 9

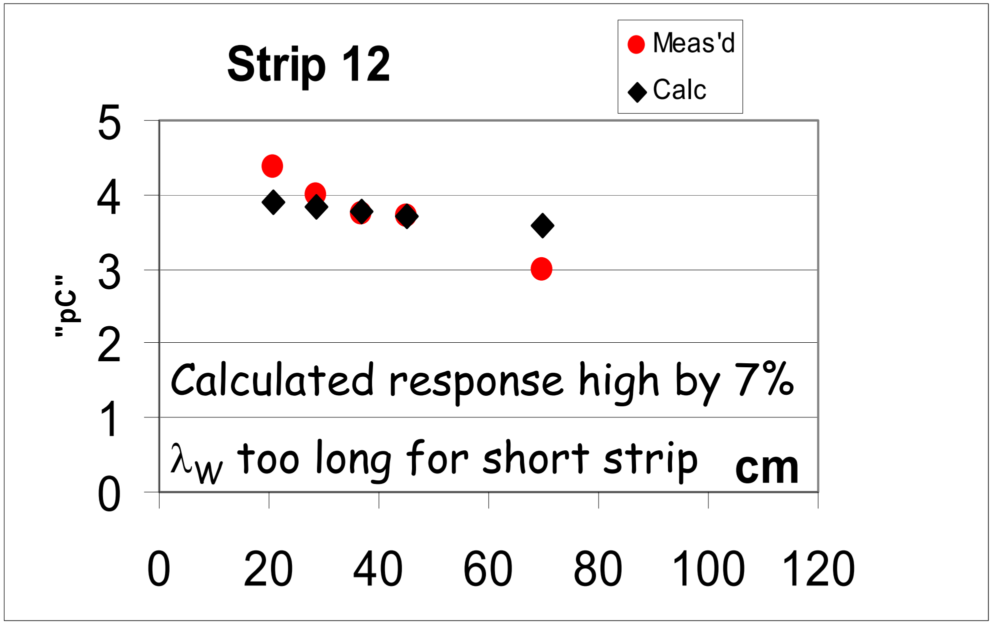
Hamamatsu H7546B
64 channel MAPMT

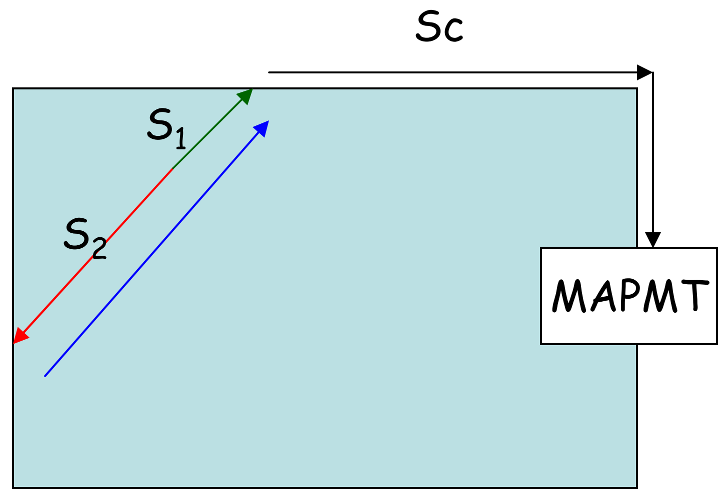
Can we do more?



$I = I_o[\exp(-L_W/\lambda_W) * \exp(-L_C/\lambda_C)]$ 64 fibers

Find : $\lambda_W = 2.76m$, $\lambda_C = 7.25m$





$I = \{\exp(-S_1/\lambda_W)$

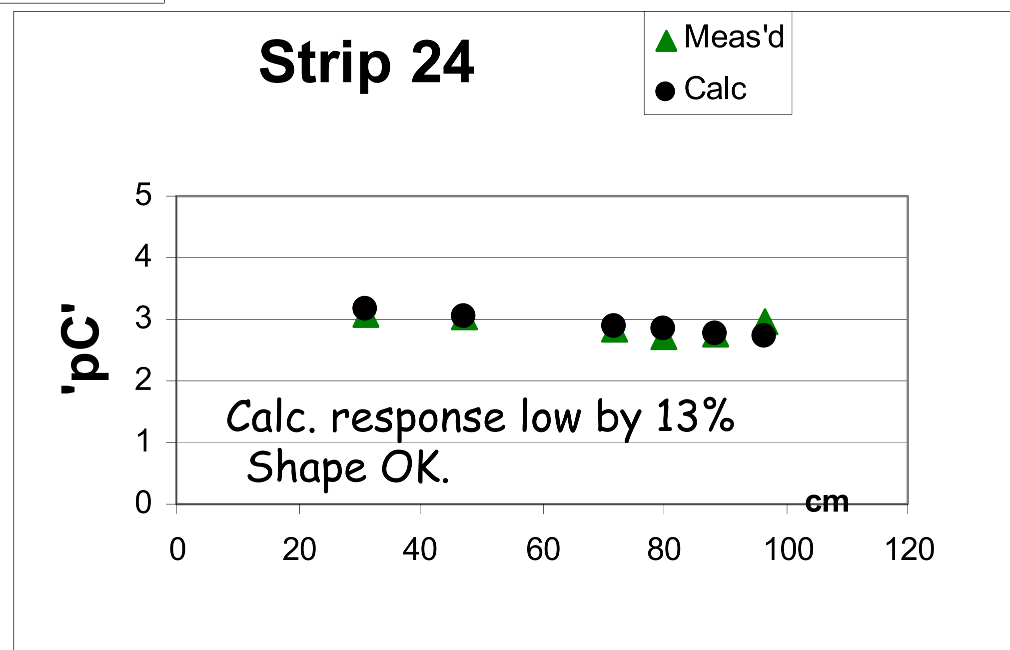
$+[\exp(-S_2/\lambda_W)*R*\exp-(S_1+S_2)/\lambda_W\}*$

$T*\exp(-S_C/\lambda_C)$ $T = 1,$

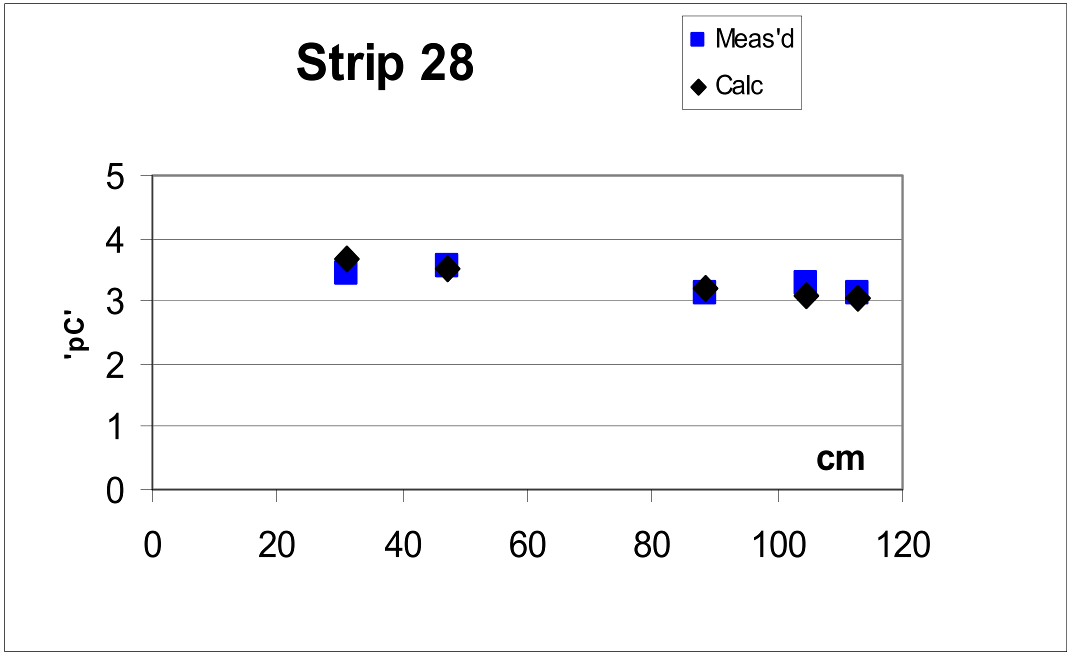
$\lambda_W = 2.76m,\ \lambda_C = 7.25m,\ R = 0.6$

Not an absolute prediction.

Calculated/Meas'd Attenuation



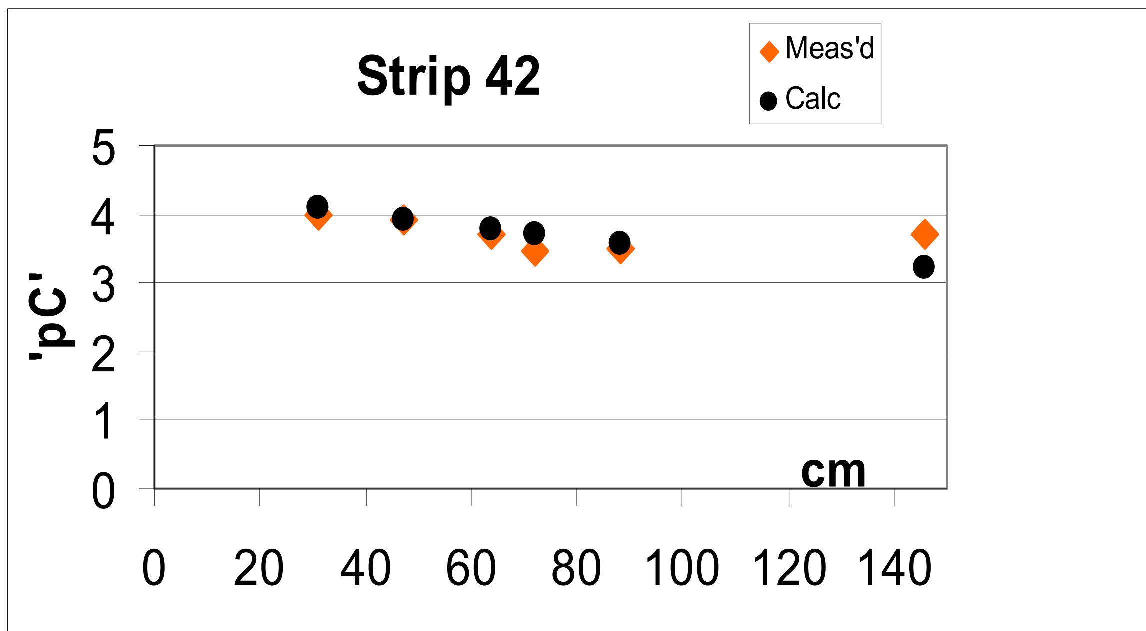
Calculations for 1.7m long strips



Attenuation length reasonable. (slope)

Avg. calculated response OK for both of these strips, compared to 12 & 24. No D analysis.

Still early, but OK?



Lessons Learned

- From pulse height spectra and no zeros, $N_{pe} > 9$ Correct?
- $Q = N_{pe} \times 1.6 \times 10^{-19} \times$ Gain $\times$ (1 - Attenuation) for G of 2M at 960V (Hamamatsu data sheet), $N_{pe} \sim 9$ OK.
- Gain measurement techniques developed and used.
- Double/Single readout => 4.8pC/3.2pC; ~50% more signal for readout at both ends. (Needs further confirmation)
- Attenuation length ~ few meters. Looks OK, but more quantitative studies would be good (non-trivial?).
- MAPMTs work well, but miles of clear fiber and loss of light thru splices may be possible to eliminate with SiPMs or MPPC, Geiger mode APDs. Begin testing of SiPMs.
- Better Readout/DAQ system needed for more systematic studies.

Status & Plans

- Finish analysis of existing MTest data.
- Procure SiPMs and begin to do beam tests after bench tests. Need FE electronics and DAQ software. (In collaboration with other ILC projects)
- We need to test some 3.5m strips with single and double ended readout. Start with existing extrusions, then consider alternative.
- Construct a new (1.25 m X 2.5 m) plane with SiPMs, FE electronics and DAQ.
- This is not an easy menu. We will need additional collaborators.

Backup Transparencies

Calibration of MAPMTs (H7546B)

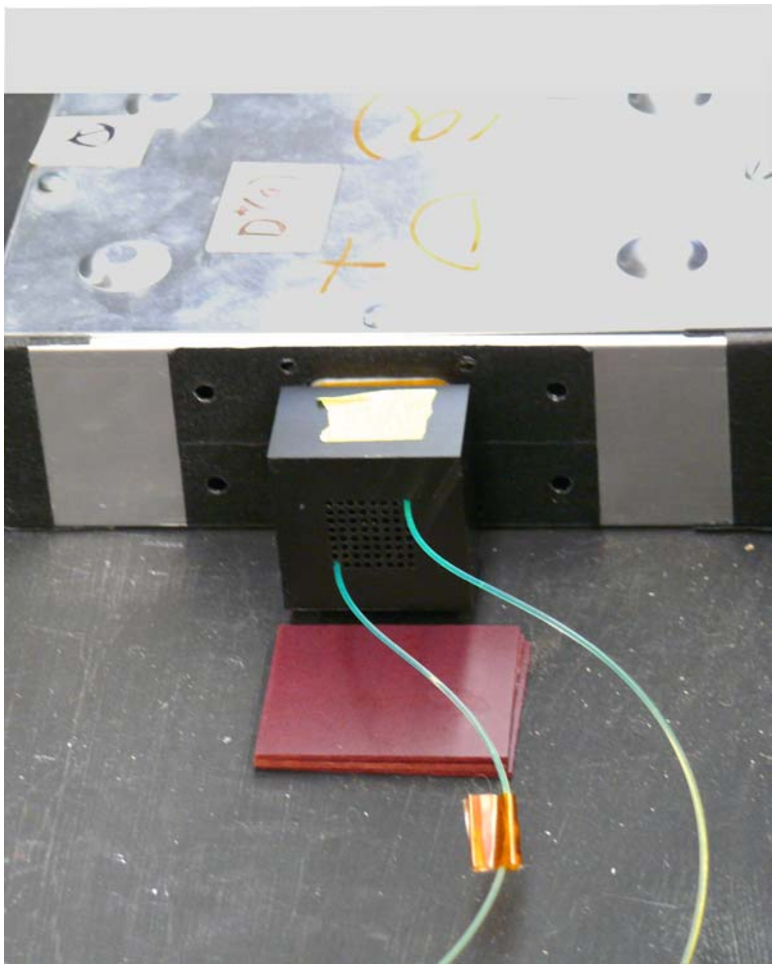
(A. Dyshkant NIU)

- Use a radioactive source Sr^{90} to supply light to two 1m long 1.2mm dia. WLS fibers. One fiber is used as a standard "candle"; the other is moved from pixel-to-pixel via a precisely machined block that is aligned and in contact with face of the MAPMT.
- The PMT, source, etc. is maintained in a dark box at constant voltage for all channels.
- The rms current from each PMT channel is recorded using a pA meter as the fiber is cycled through all 64 channels of the MAPMT.

Current Measurement Problems

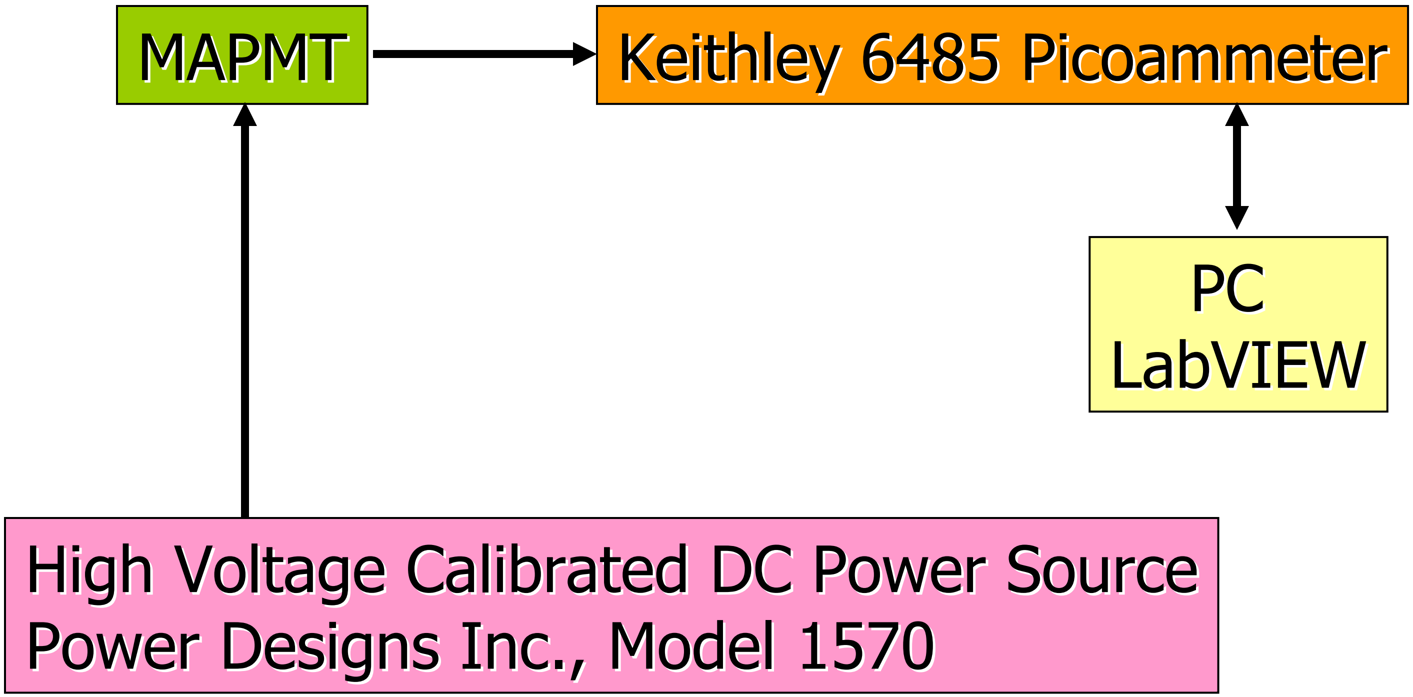
- What is the MAPMT dark current level?
- What is the HV?
- Can the custom made source of light saturate a MAPMT?
- How was the fiber connected?
- How was the interface alignment checked/verified?
- What is a gain? What is a response?
- Do different channels have a different slope in response dependence of voltage?
- How large is cross talk between neighboring channels?
- Can the double reference method help keep track of reproducibility and repeatability of the measurements?

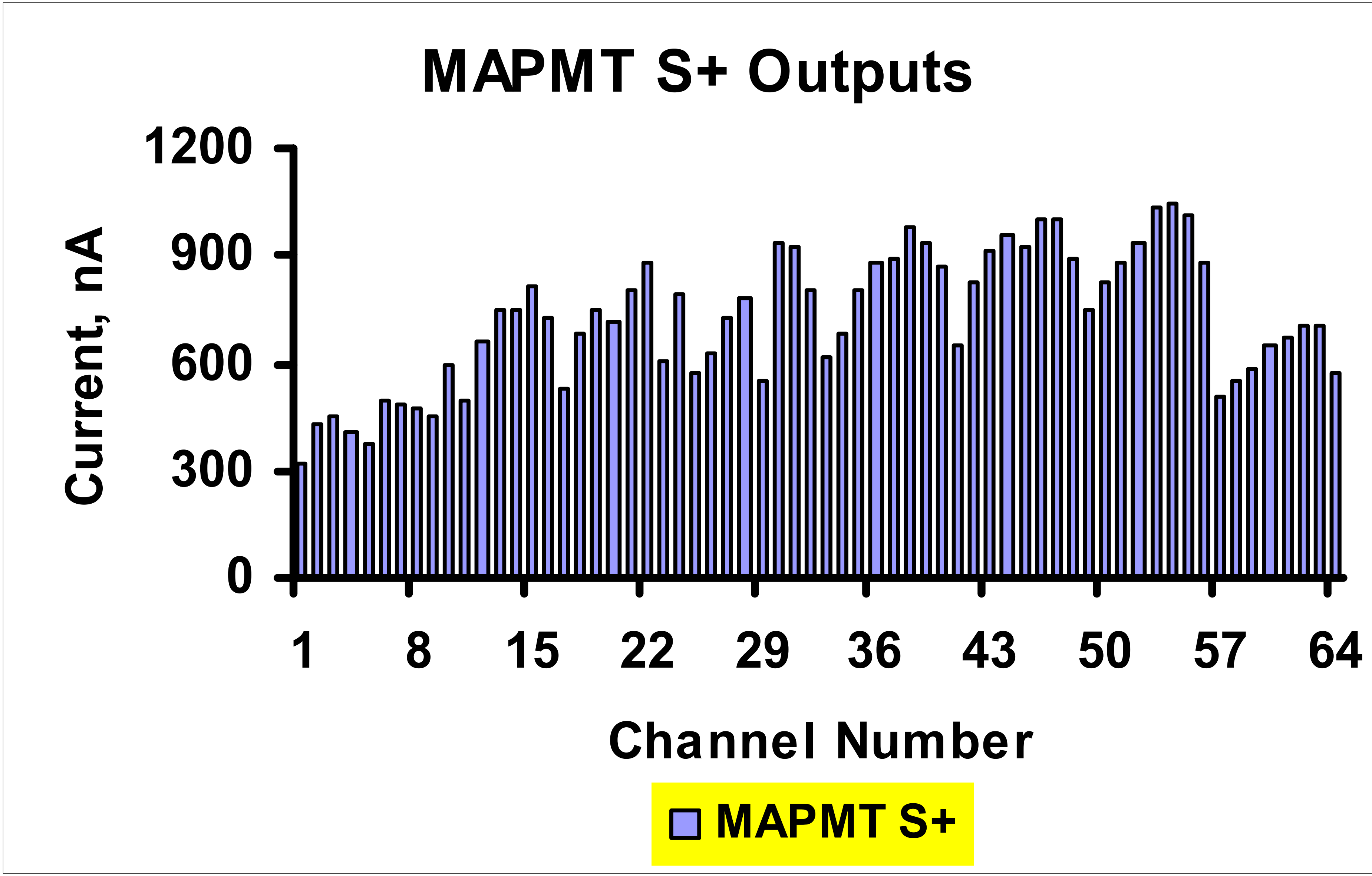
Boxed MAPMT with Interface and WLS Fibers Connected

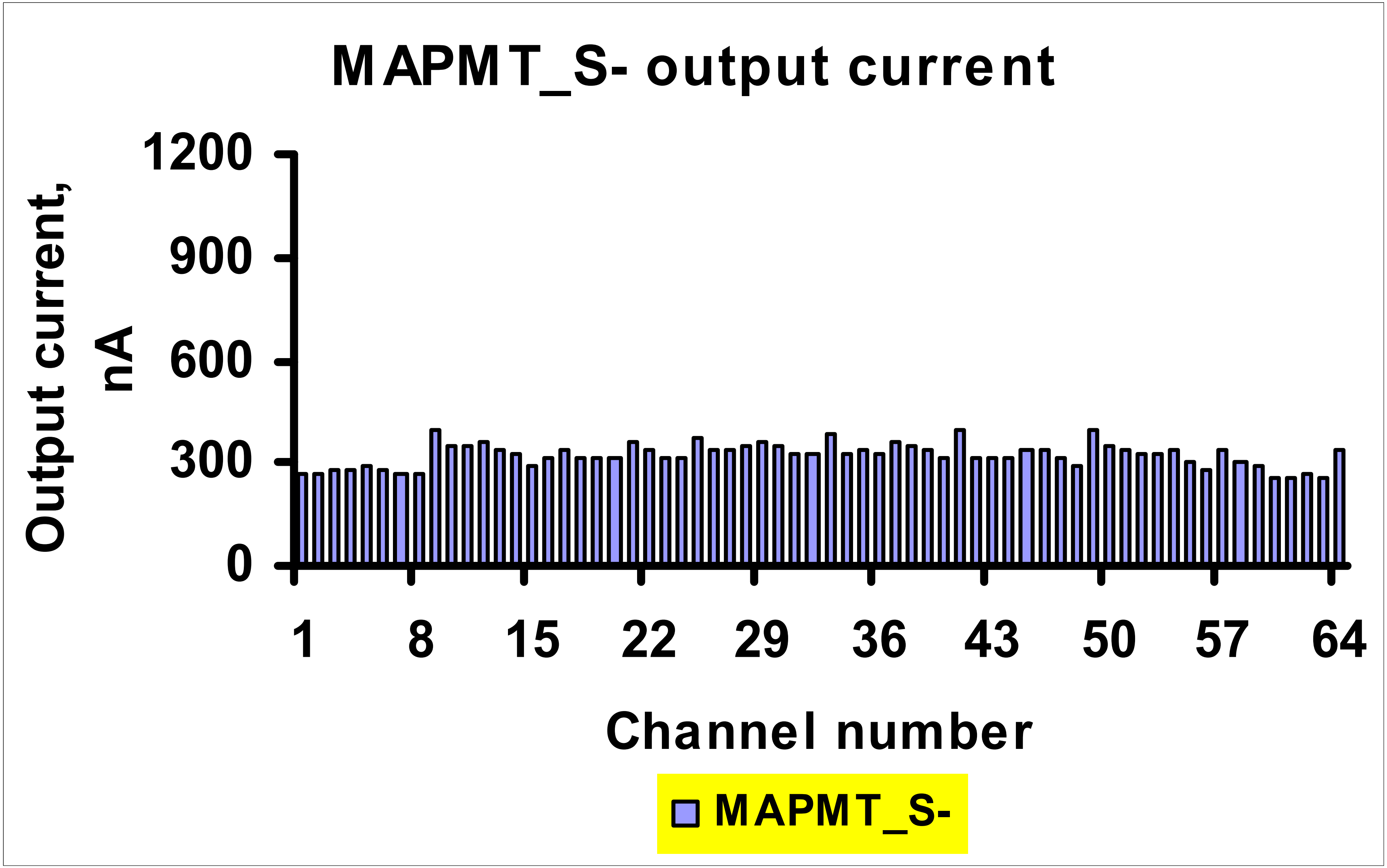


Labeled WLS fiber is a reference always positioned At channel number 57 in each MAPMT.
Control measurements were performed using the second fiber by repeating the measurement in channel number 64.

Measurement Setup




MAPMT S+ Outputs
1200
900
600
300
0
Current, nA
1
8
15
22
29
36
43
50
57
64
Channel Number
MAPMT S+



MAPMT_S- output current
Output current, nA
1200
900
600
300
0
1
8
15
22
29
36
43
50
57
64
Channel number
MAPMT_S-