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

Analysis of 9/06 MTest Data

Calibration of Multi-Anode PMT Channels

Bench Testing and Measurements of SiPMs

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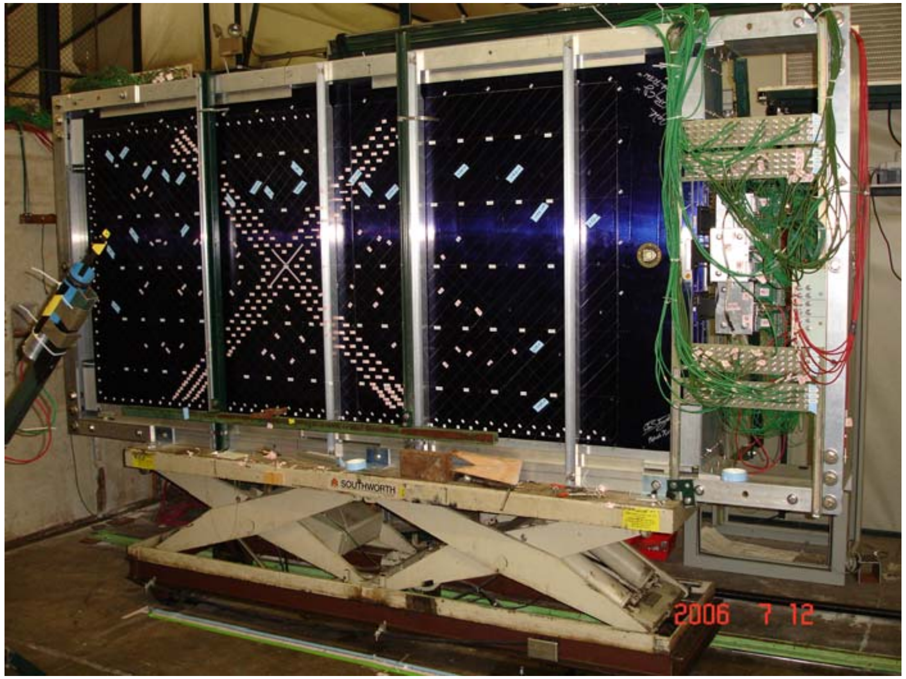
ILC MuonTest Setup



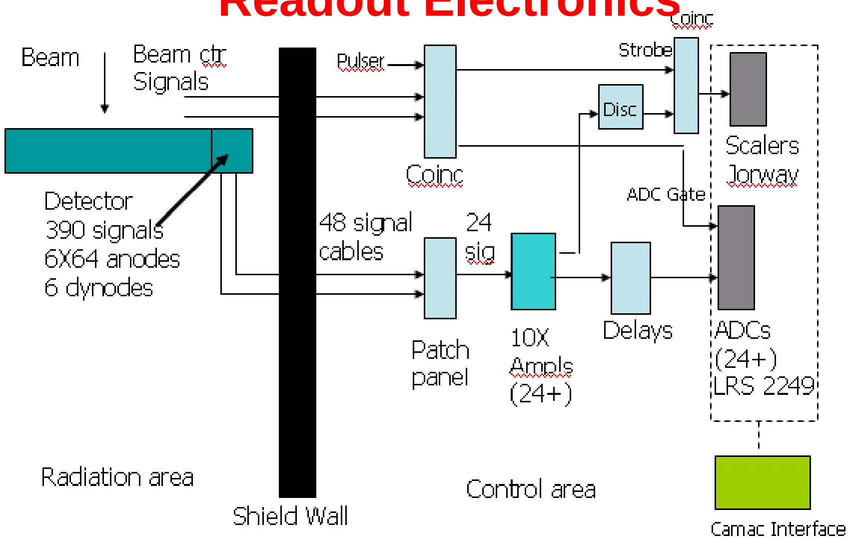
Scintillator-strip planes installed in Fermilab Beam Test Facility

Planes: 1.25m X 2.5m

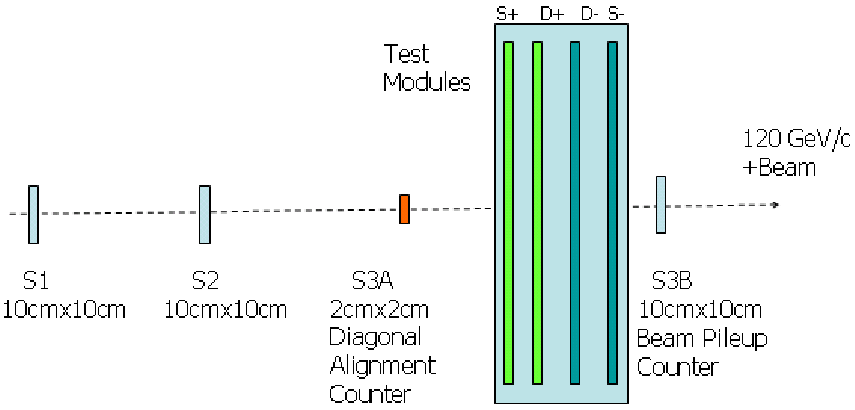
256 scintillator strips: 4.1cm (W) X 1cm (T) X 1.8m (L). Two planes have single- ended readout and 2 planes have both ends of strips readout.

Read out by 384 PMT channels

Readout Electronics



Beam Trigger (S1.S2.S3A.S3B)



Beam Operating conditions

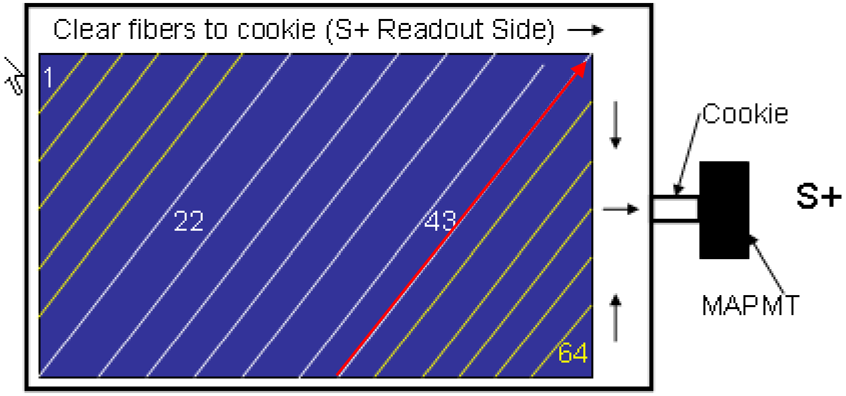
- DAQ triggered on beam; no strips in the trigger.
- When prime user, we had low intensity, ~ 1000p/sec during spill, two 1-sec spills/minute, 12 hours/day.
- When secondary user we operated up to ~20K p/sec.
- DAQ data rate limited < 50Hz. (CAMAC readout)
- Beam spot at +120 GeV/c ~ 1 cm FWHM.
- Additional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

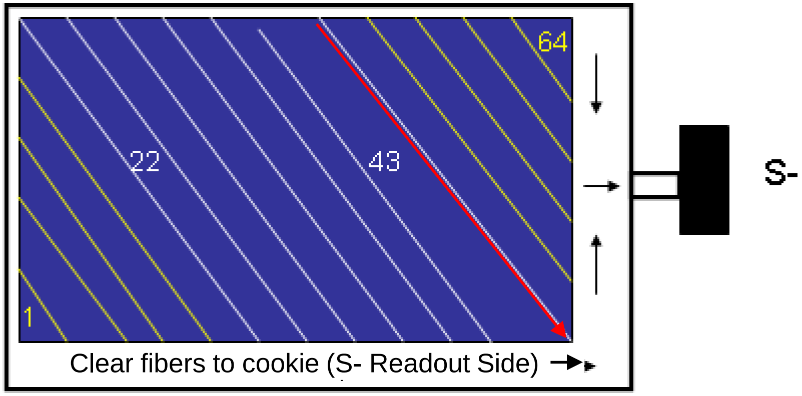
Beam Test Objectives

- 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.

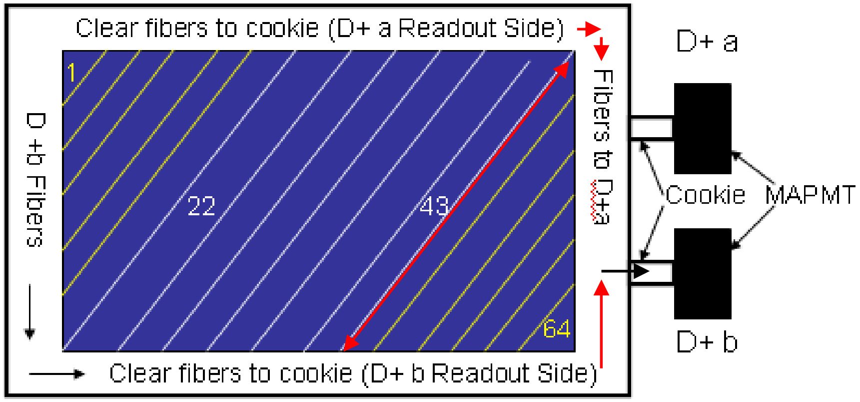
Four Detector planes

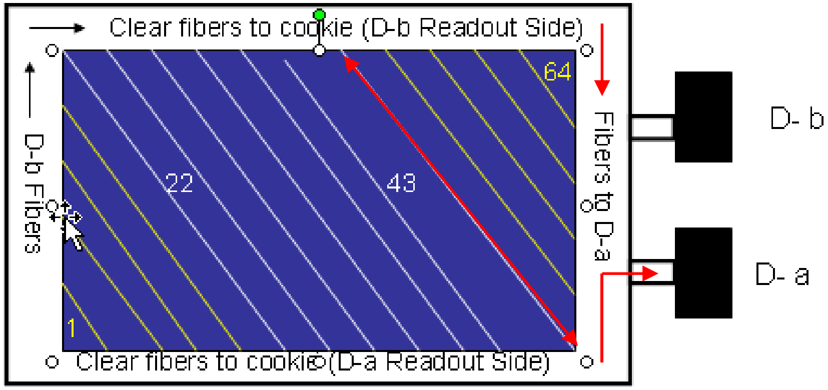
Single ended readout





Dual readout





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

11450 Total Events

S+ mean 439.2

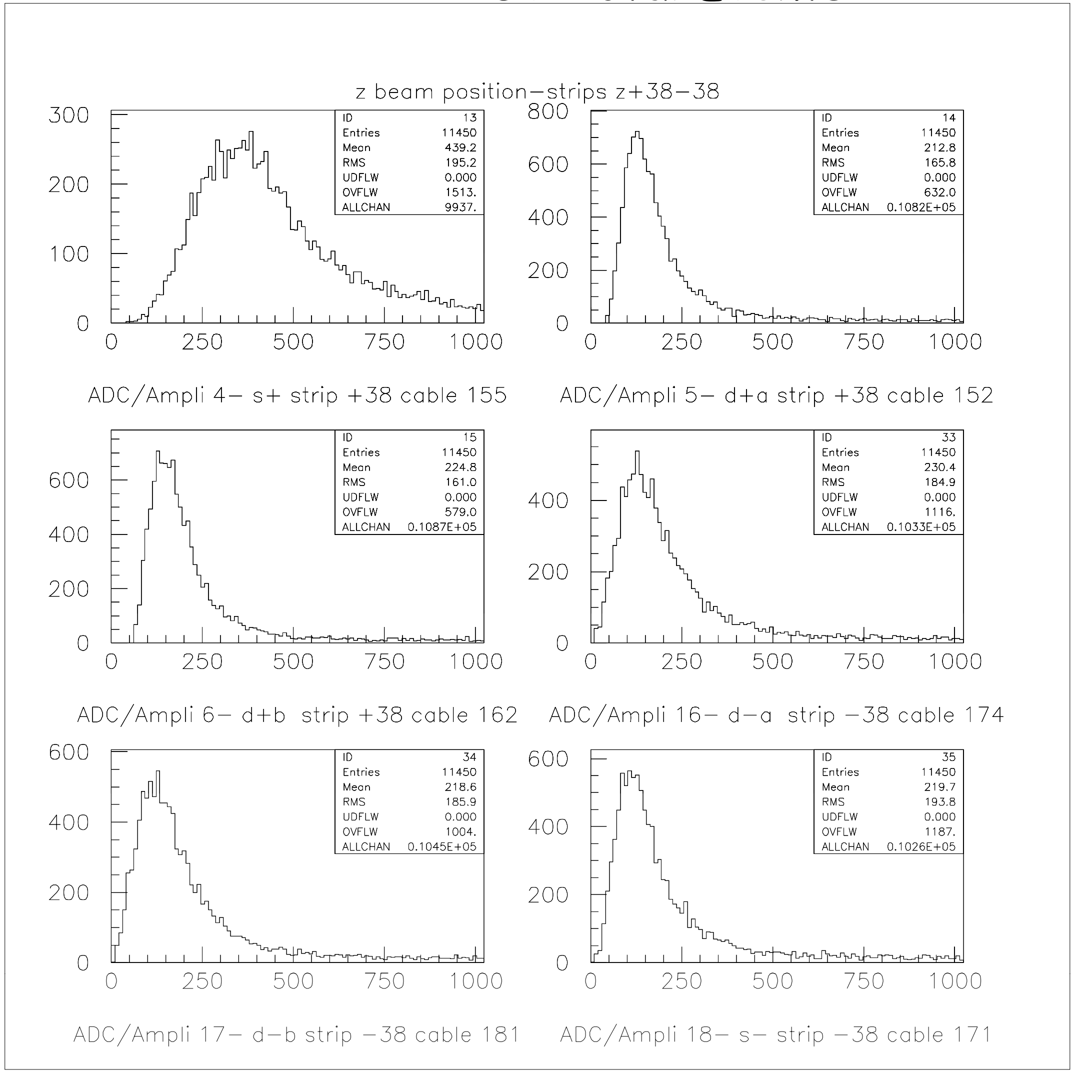
D+a mean 212.8

D+b mean 224.8

D-a mean 230.4

D-b mean 185.9

S- mean 219.7

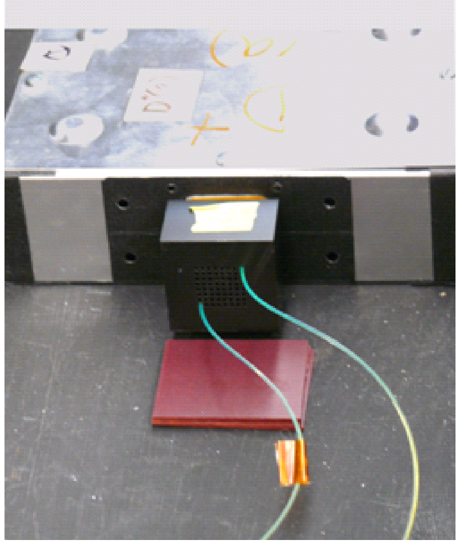


Calibration of MAPMTs (H7546B)

(A. Dyshkant NIU)

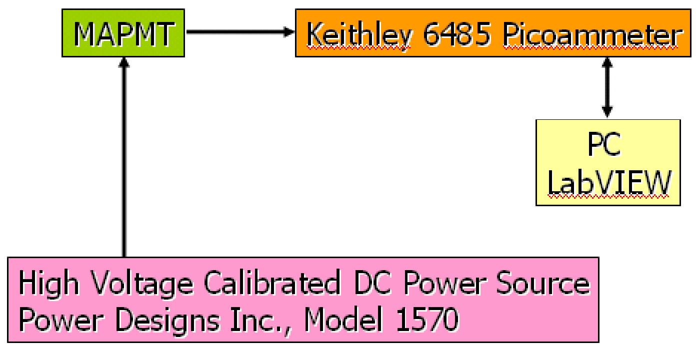
- Use scintillator irradiated by Sr^{90} to supply light to two 1m long 1.2mm dia. WLS fibers. Reference fiber always illuminates same pixel; the other fiber is moved from pixel-to-pixel via a precisely machined block that is aligned and in contact with face of the MAPMT.
- The PMT, source, etc. is maintained 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.

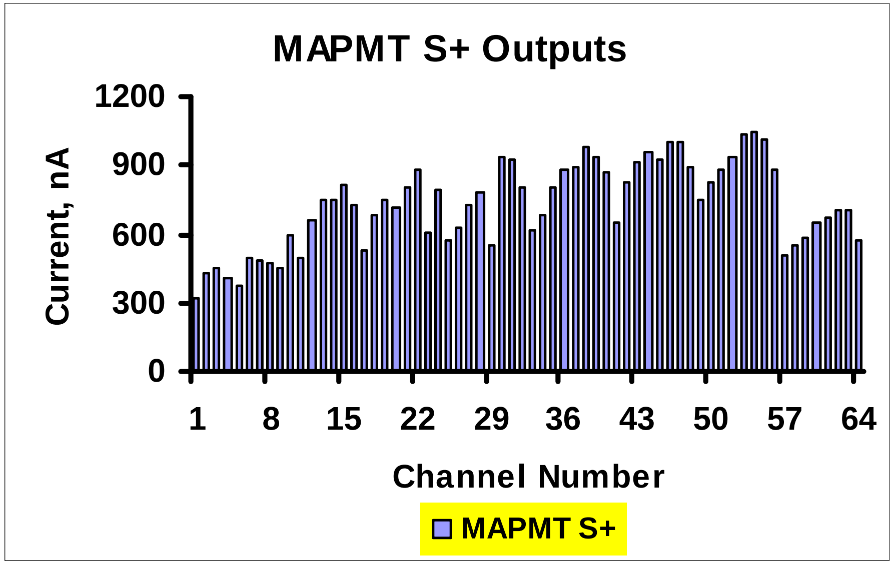
Boxed MAPMT with interface and fibers connected

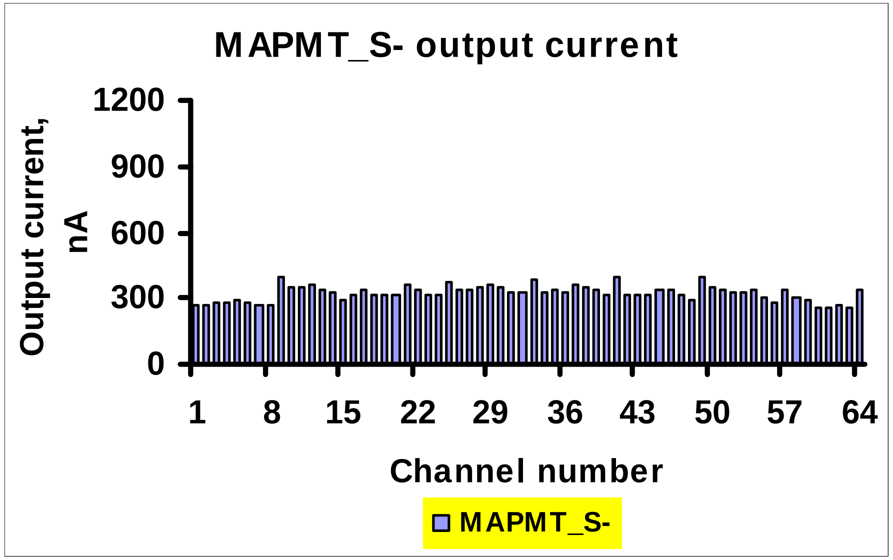


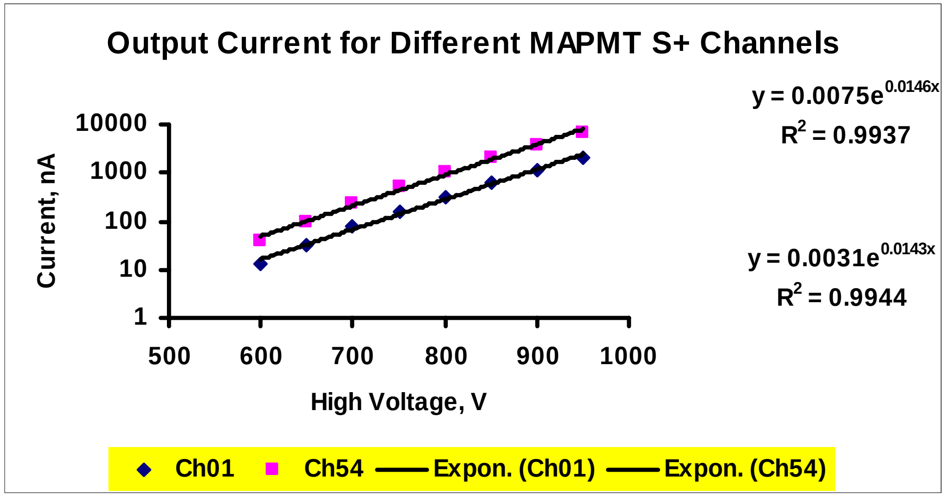
Labeled WLS fiber is a reference always positioned At channel number 57 in each MAPMT.
Control measurements were performed using the second fiber by repeating the measurement in channel number 64.

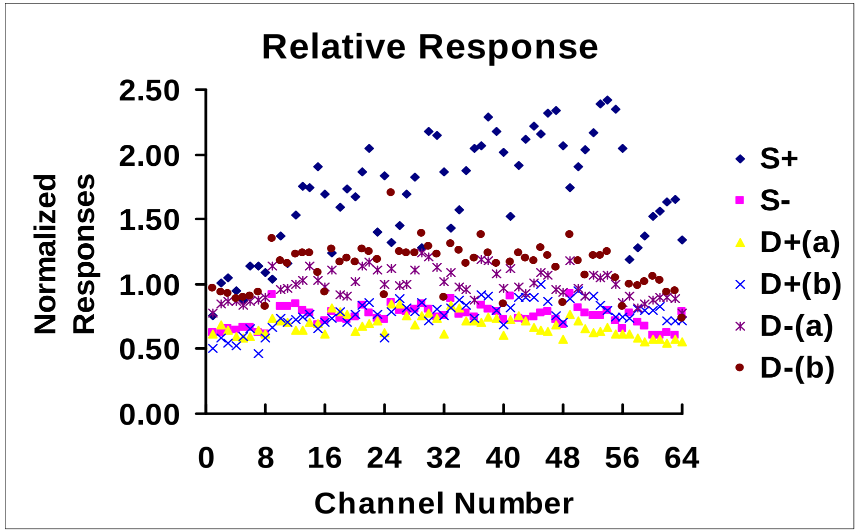
Measurement Setup




MAPMT S+ Outputs
Current, nA
1200
900
600
300
0
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-


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

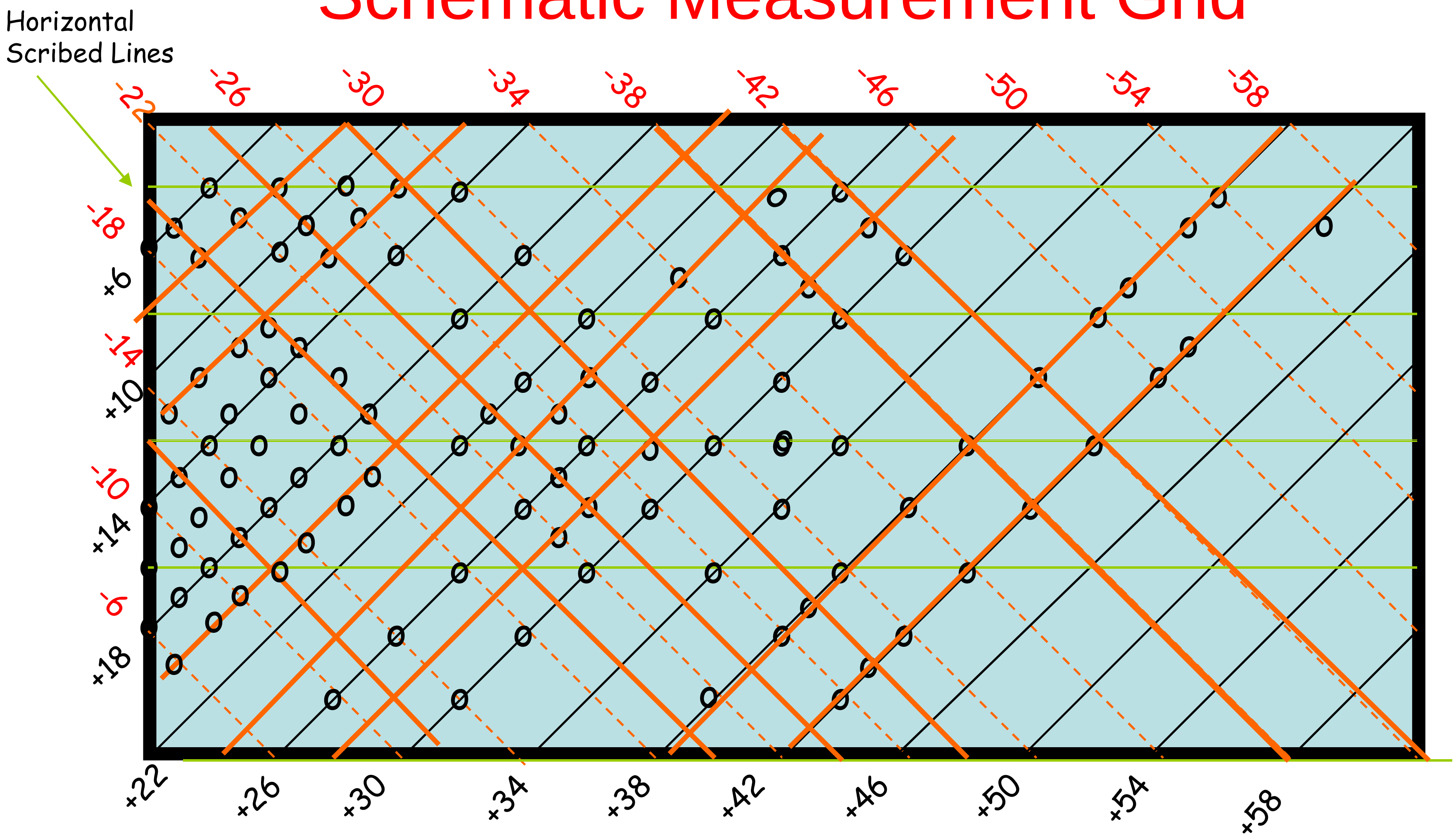
MAPMT Normalization Results

- 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.

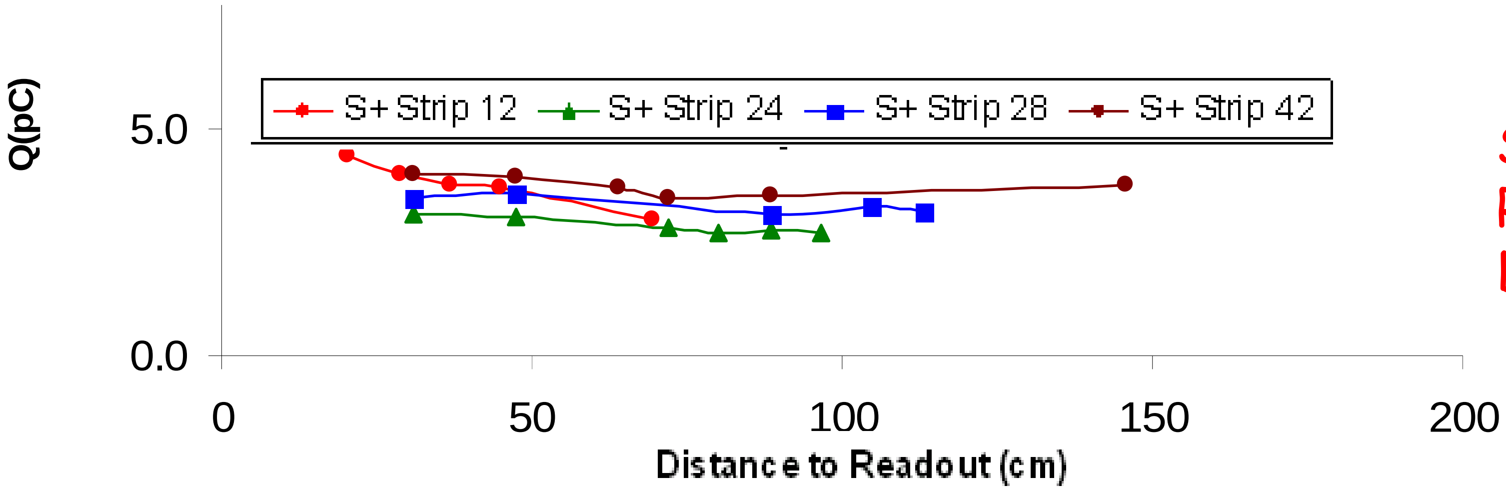
Back toTest Beam Data Analysis

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

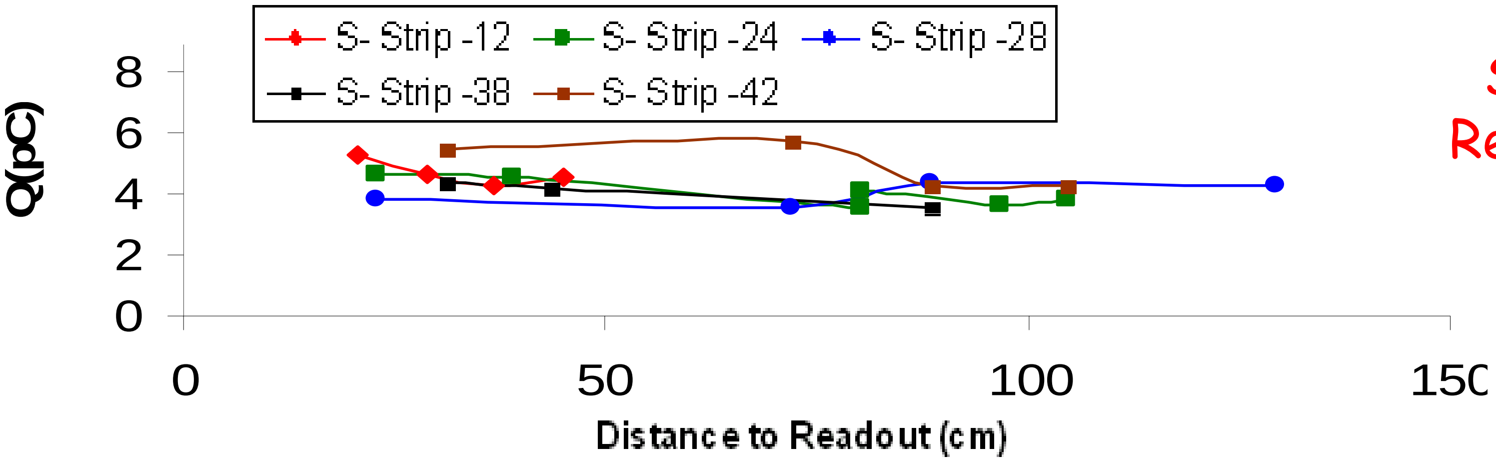
Schematic Measurement Grid



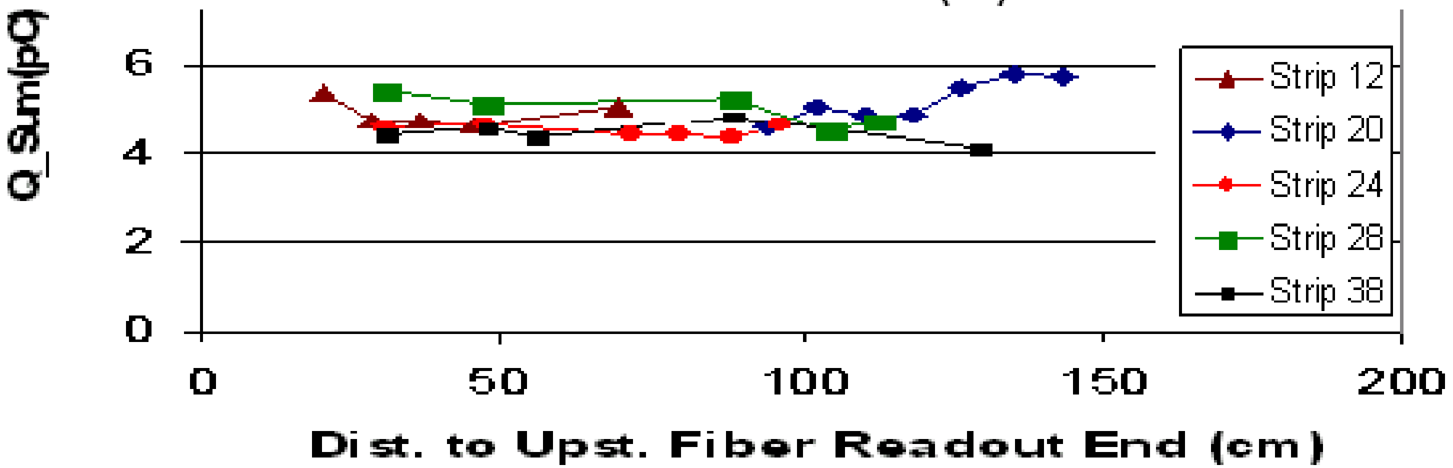
Circles show points that were measured. Numbers indicate strip numbers



S^+ Strips: Response vs. Distance



S^- Strips: Response vs. Distance



D+ Strips: Readout Both Ends of the Fibers

Preliminary Conclusions

- S+ & S- strips yield ~ 3 – 4 pC

- Adding integrated charge from each end of the D+ fibers yields ~ 5 pC.

- Clearly see greater light yield if signals from both ends of the fiber are added.

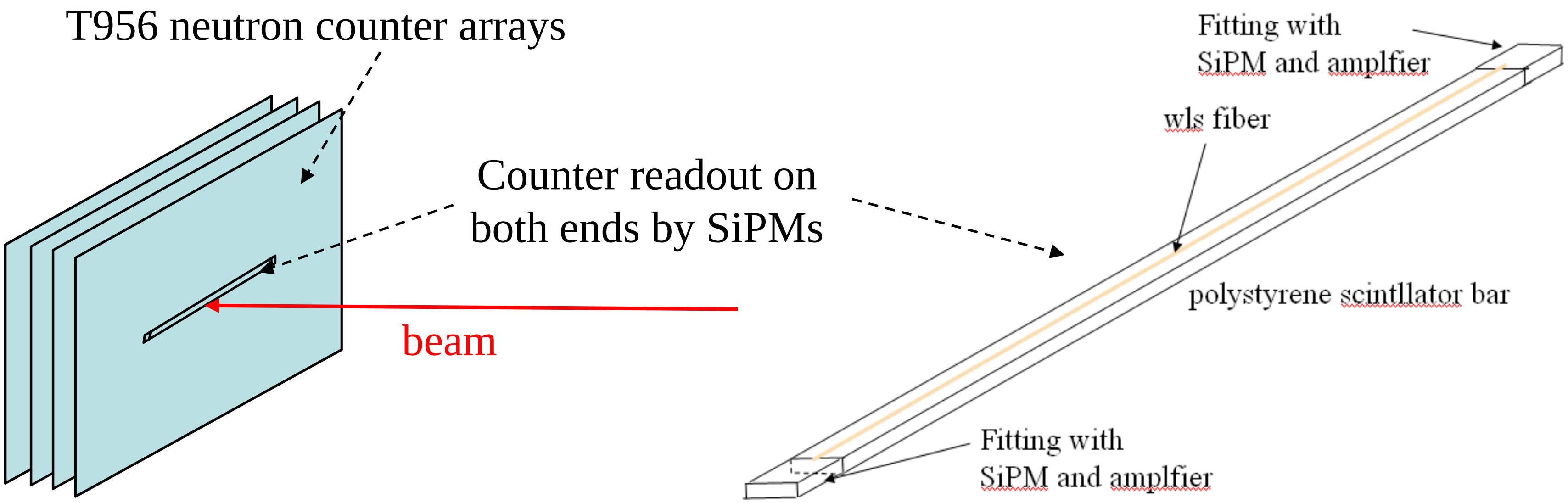
- Not much attenuation over 1.8m of WLS fiber as anticipated.

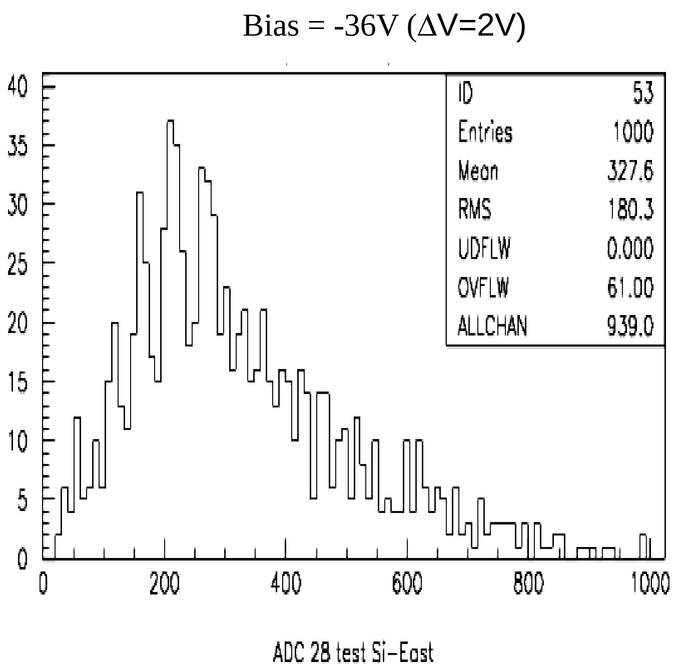
So far, so good. (Haven't looked at D-)

Future Muon/Tail-Catcher Program

- We will continue calibration studies of MAPMT gain. Preliminary results from Wayne State are cooking and look promising.
- SiPMs are our future interest. Their deployment would eliminate clear fiber and possibly WLS fiber costs.
- Bench Tests of Russian, IRST, MPPC and other avalanche photo-diodes have started at Fermilab and are ongoing at NIU and Trieste/Udine.
- Electronics development in concert with DHCal are in the planning stages.

Preliminary study if Scint. Strip viewed by IRST SiPM





Data with 120 Gev p - beam

$$N_{p.e.} \approx 6.5\,p.e.$$

$$\varepsilon = 99\%$$

$$N_{d.c.} \approx 1.5MHz$$

$$G \approx 1.6 \times 10^{6}$$

Characterization of SiPMs at Fnal & Udine

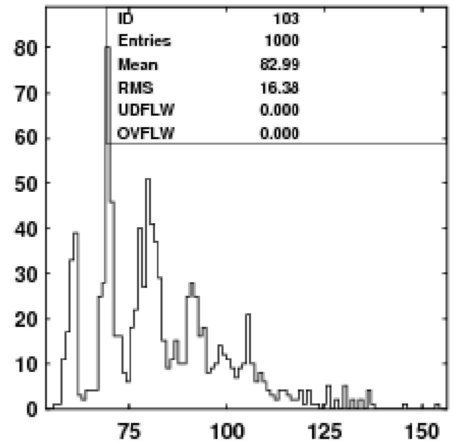
(A. Driutti, D. Cauz and G.Pauletta)

Visual inspectons (SiDet) and dynamic tests at lab 6 prior to use of SiPMs in Test Beam yielded results compatible with IRST measurements:

V_B = 34.1 V

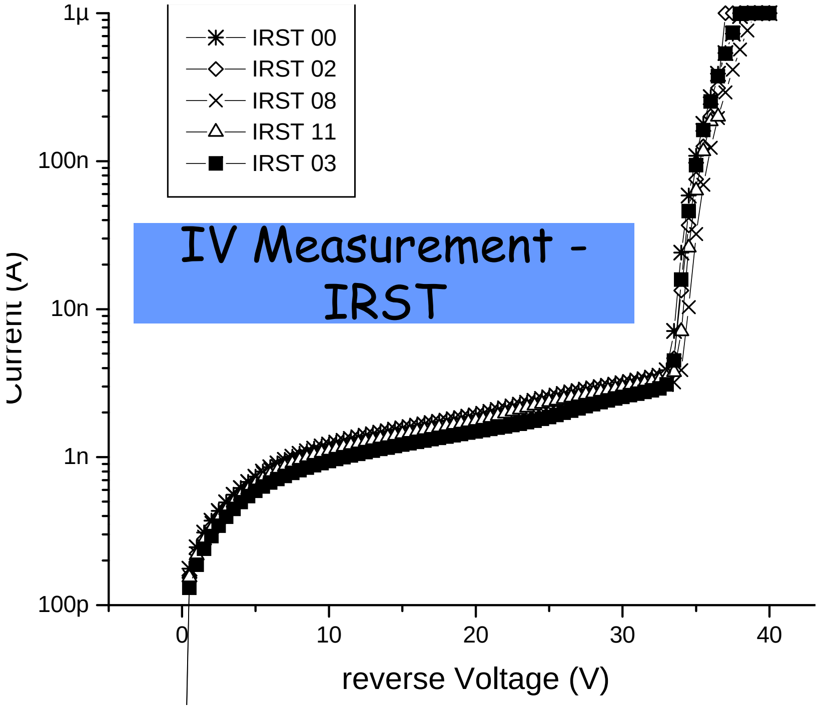
Gains between ~1 and 2 x 10^6

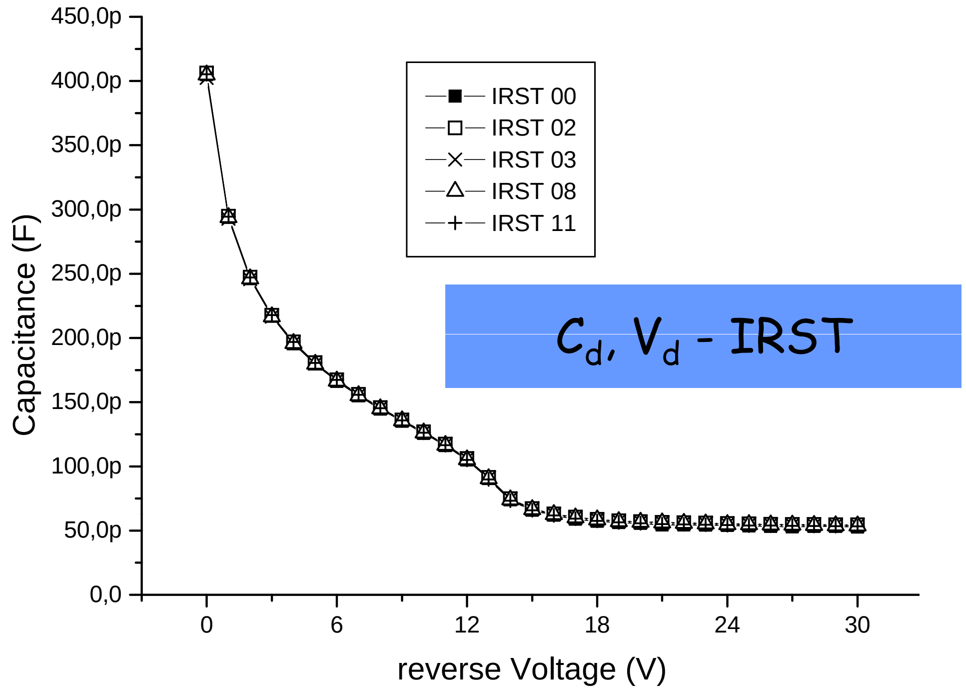
Dark counts between 9.6 and 3 MHz



IRSTSiPM illuminated by fast led

Detailed characterization of the same devices is now in progress at Udine





This work is part of the INFN – supported FACTOR project

The project focuses on two complementary objectives:

1. *Development of SiPMs;*
2. *Study of future applications:*

So far as SiPM development is concerned,

The main objectives connected to SiPM performance improvement are:

- Maximizing the Photon Detection Efficiency (Optimization of the ARC and of the doping profiles; optimization of the Sensitive-to-Total Area ratio:

- Reduction of the dark count (process optimization, gettering)

Applications being studied are:

a. Fiber calorimetry, readout of wls fibers in large area scintillators
b. Detection of UHECR
c. FEL

Characterization of Silicon Photodetectors (Avalanche Photodiodes in Geiger Mode)

S. Cihangir, G. Mavromanolakis, A. Para.
N.Saoulidou

Detector Samples

Existing
Hamamatsu (100, 50 and 25 μ micropixels)
IRST (several designs)
CPTA
Mehti
Dubna (two designs)
Forthcoming
SensL
Others?

Factors Affecting Response of a Silicon Photodetector

- Bias voltage (or rather overvoltage, $\Delta V = V - V_{brkd}$)
- Temperature
- Time structure of the light input
- Amplitude of the light input
- Details of the detector construction (geometrical fill factor, cross-talk suppresion)
- Others?

Goals

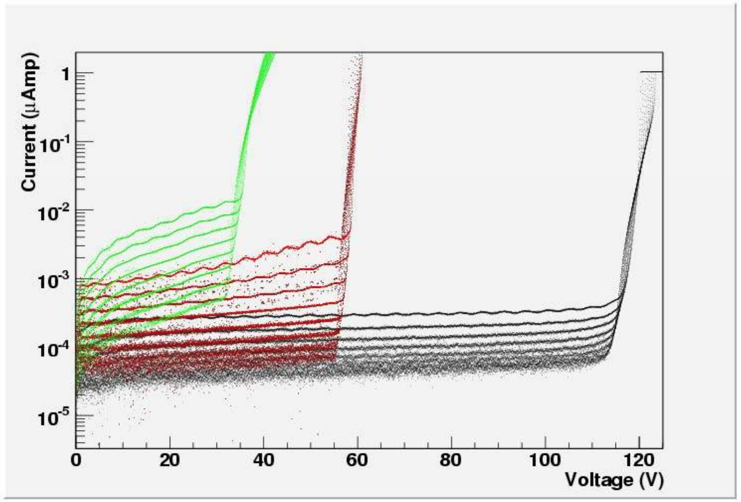
- Develop a complete characteristics of the detector response. Identify relevant variables.
  - For example: is $G(T,V) = G(\Delta V)$, with $V_{brkd} = V_{brkd}(T)$?
- Try to relate some of the characteristics to the detector design and construction
  - For example inter- and intra micro-pixel response uniformity
- Develop algorithm for readout strategy and calibration procedure (integration time, cross-talk, after-pulses, etc..)

Step 1: Database of Static Characteristics

- Develop a procedure for imaging of the detector samples (SiDET facility)
- Develop an automated procedure for static characterization (breakdown voltage, resistance) as a function of the operating temperature
  - Keithley 2400 source-meter
  - Dark box
  - Peltier cold plate
  - Labview controls/readout
- Create a database of the samples, enter the static and image data

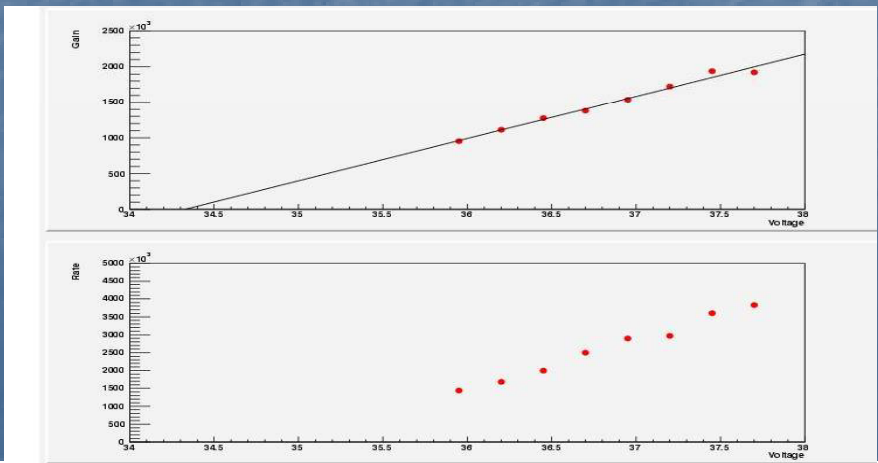
e.g.
I-V Characteristics at Different Temperatures

- Different detectors have quite different operating point
- Dark current and the operating point depend on temperature



Step 2: 'Dark Measurements' (no external light signal)

- Readout strategy:
  - Trans-conductance amplifier (MITEQ amplifiers: AU-2A-0159, AU-4A-0150, AM-4A-000110)
  - Controlled temperature:
    - Peltier creates too much of a noise
    - Chiller-based setup under construction
  - Tektronix 3000 series digital scope (5 GHz)
  - LabView DAQ and analysis program
  - Root-based analysis environment
- Dynamical characteristics of the detectors (Later: as a function of the operating temperature).
  - Rate (as a function of threshold, voltage and temperature)
  - Gain = (Charge of a single avalanche)/e (as a function of threshold, voltage and temperature)



e.g. Gain and Rate as a Function of Voltage at room temperature

Step 3: Characterization of the Detector Response to a Calibrated Light Pulse

- Light source (under construction):
  - Short pulse duration (<1 nsec)
  - Absolute light calibration (modified scheme of P. Gorodetzky)
  - Variable light intensity (0.1 – 1000 photons)
- Readout and analysis scheme (as before)
- As a function of voltage and temperature:
  - PDE
  - Linearity of the 'prompt' response (~5 nsec gate)
  - The rate, time and amplitude distribution of 'follow-up' pulses (as a function of the light intensity)

Step 4: Microscopic Studies of the Photodetector (Planned)

- Focused (calibrated) light source, 2-3 μ spot size (Selcuk C.)
- Microstage (<1 μ stepping accuracy)
- Dark box containing the detector, focusing lenses and the stage
- Readout as before
- Spatial characteristics of the photodetector, intra and inter-micro pixel variation of:
  - Gain
  - PDE
  - Afterpulses
  - Cross-talk

Plans for the future are summarized in the:

Roadmap for ILC Detector R&D Test Beams

World Wide ILC Detector R&D Community

June 1, 2007

They are summarized in the follwing transaparencies

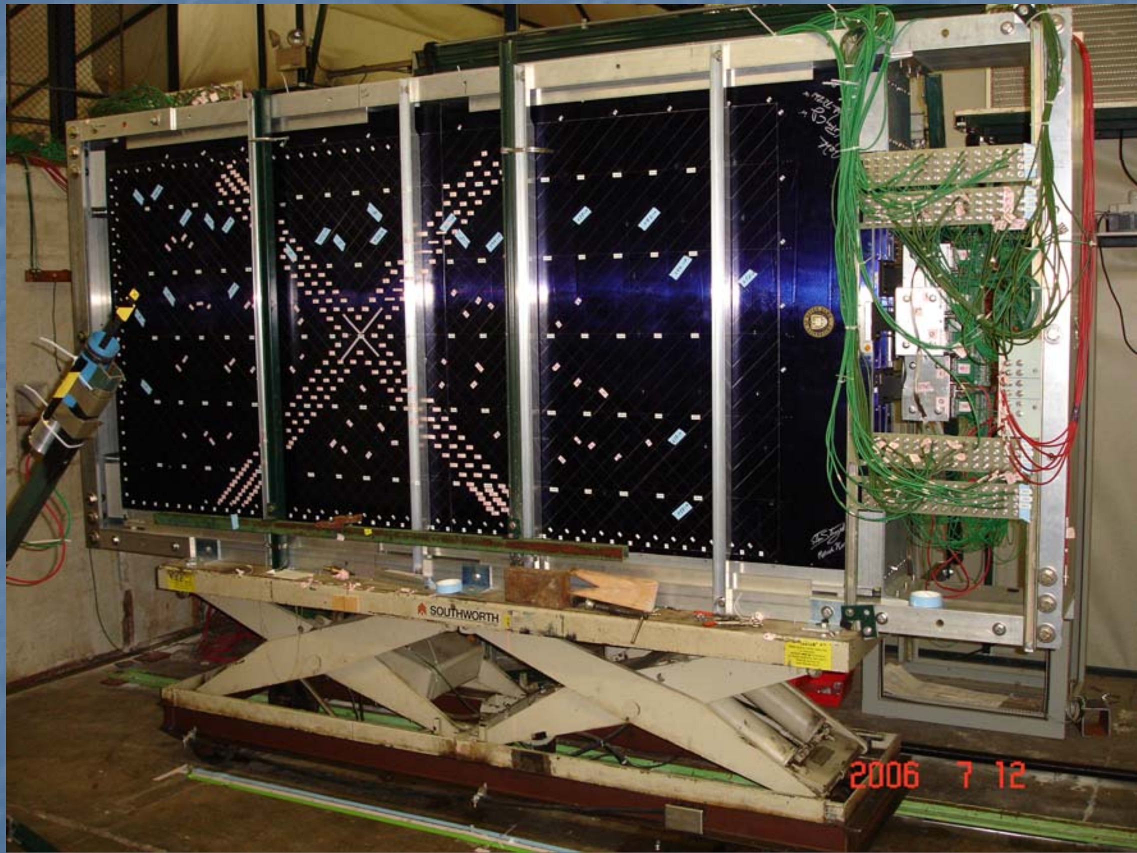
SiD Muon/Tail-catcher Test Beam Needs/Expectations

Fermilab
MTest

LC Muon
Test Set-up

July – Sept.
2006

Fermilab
Indiana U.
INFN – Ts/Udine
No. Illinois U.
Notre Dame
Wayne State



Future Activities at MTest

- Continuation of scintillator-based muon & calorimetry beam testing.
- Development of detectors using multi-pixel photon counters (arrays of APDs).
- Exposure of detectors to hadrons, electrons and muons to understand both mip's, EM showers and hadron showers.
- Tests of custom electronics and DAQ.

Schedule & Beam Conditions

- Start with prototype strips and FE electronics/DAQ and existing strip-scint. planes. 2007? => 2008
- Add new strip-scintillator plane(s) 100 – 200 strips and prototype electronics: 500 channels – 2008. Many more scint pixels & electronics channels for tail-catcher.
- New electronics on existing planes(?).
- Run on protons, pions, muons as available.
- Beam rates available now are OK.
- High-rate tests wanted at some point.

Other Possible Activities

- Tests of RPCs with a variety of beam particles. Tested elsewhere first.
- Need to test at high beam rates.
- Upstream PWCs useful for measurement of performance near/at detector boundaries.
- Anticipate a progression of tests as instrumentation and DAQ proceeds from prototypes to production stages.