LC Muon/Tail-catcher R&D: RPC and Scintillator-based Detector R&D: Status & Plans

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Outline

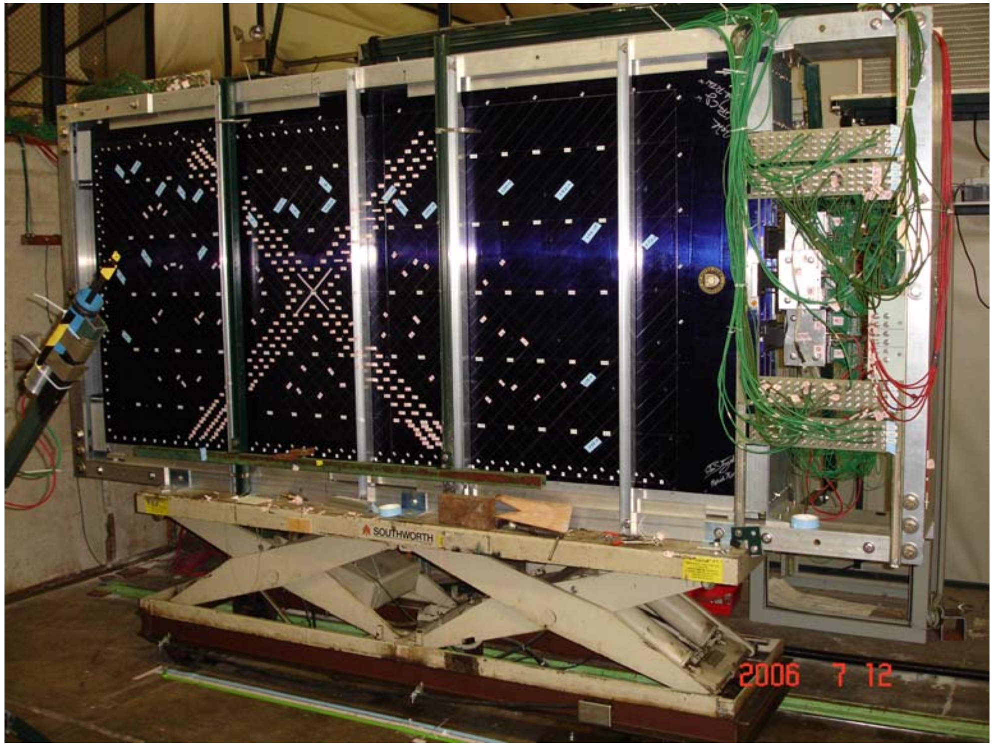
Status:

- MTest Data w/Calibrated MAPMTs
- IRST SiPM Beam test
- RPC collaboration with IHEP/Beijing

Plans:

- SiPMs: Future Scint R&D Program
  - * BenchTesting SiPMs from: IRST, SensL, Hamamatsu, SensL, Radiation Mon. Devices, …
  - * Beam/Source Testing w/NIM Amp/Disc => Interface board (from MINERvA)
  - * Long Scintillator/WLS Strip Tests
- RPCs: 4 IHEP 0.5m X 0.5m arriving soon for tests at SLAC; avalanche mode operation.

ILC MuonTest Setup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Scintillator-strip planes, 1.25m X 2.5m tested Fermilab MTest Facility

4 X 64 scintillator strips: 4.1cm (W) X 1cm (T) X 1.8m (L). Single and Double ended read-out measurements

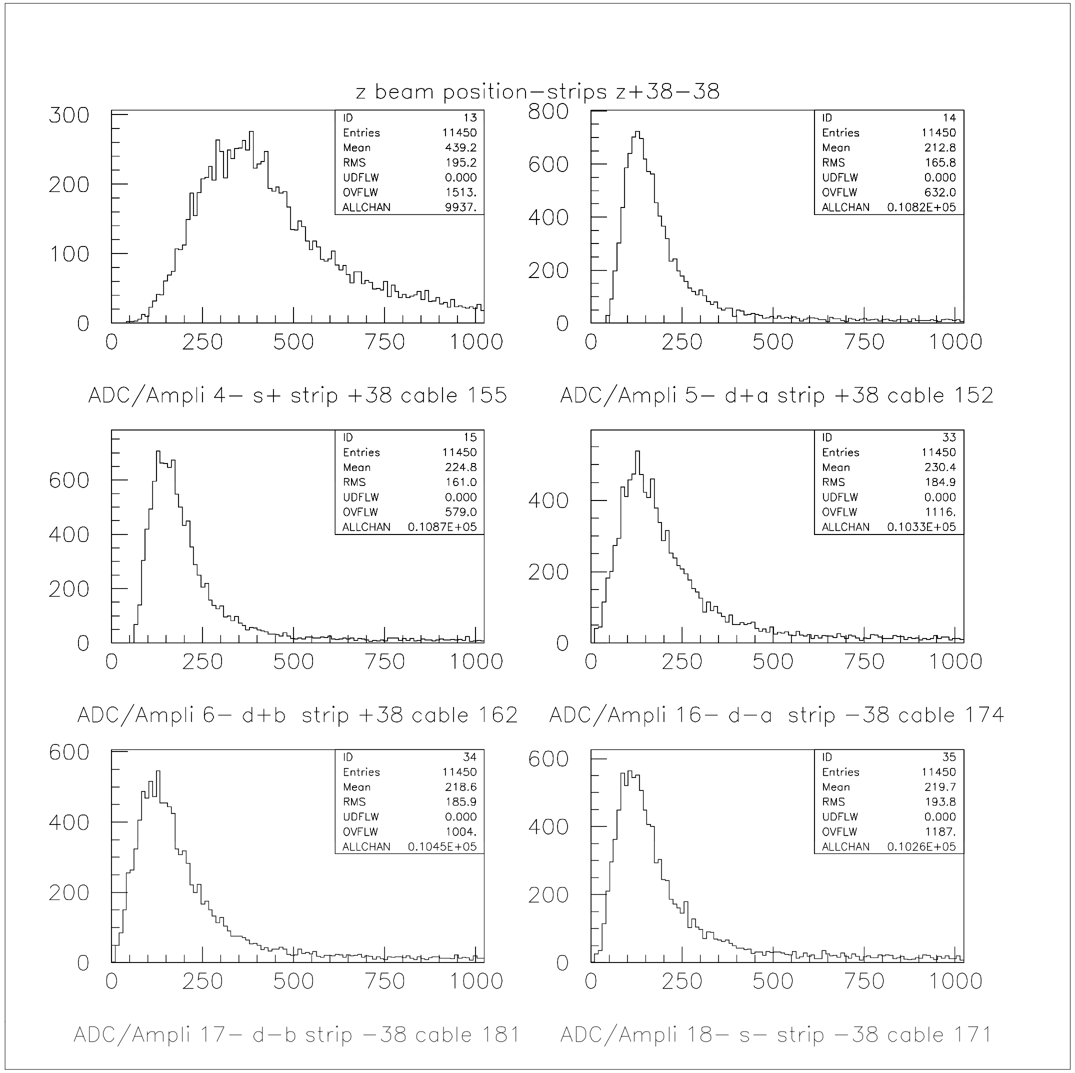
384 PMT channels

Scintillator MTest Objectives

- Scintllator/WLS pulse characteristics
- Integrated dE/dx Q meas. => $N_{p.e.}$
- Longitudinal beam position response.
- Read out two ends or one end?
- SiPM data with 1.7 m long strips.

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

No zeros!
All charged
Tracks show
Q > 0

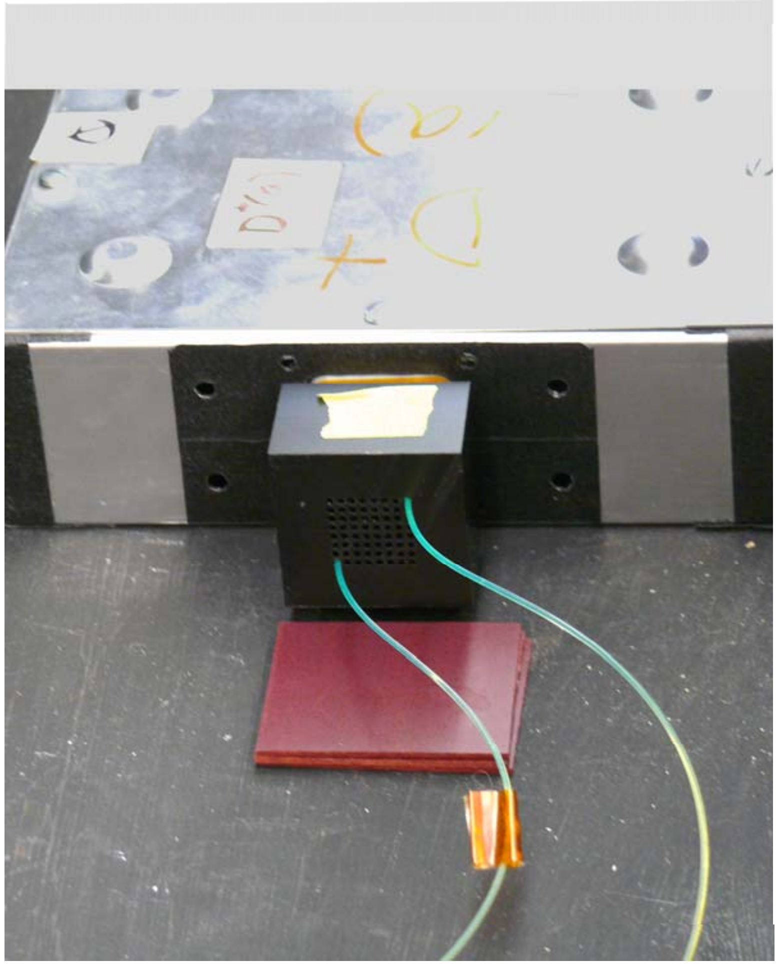
Note: gain
variation =>
calibration

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.

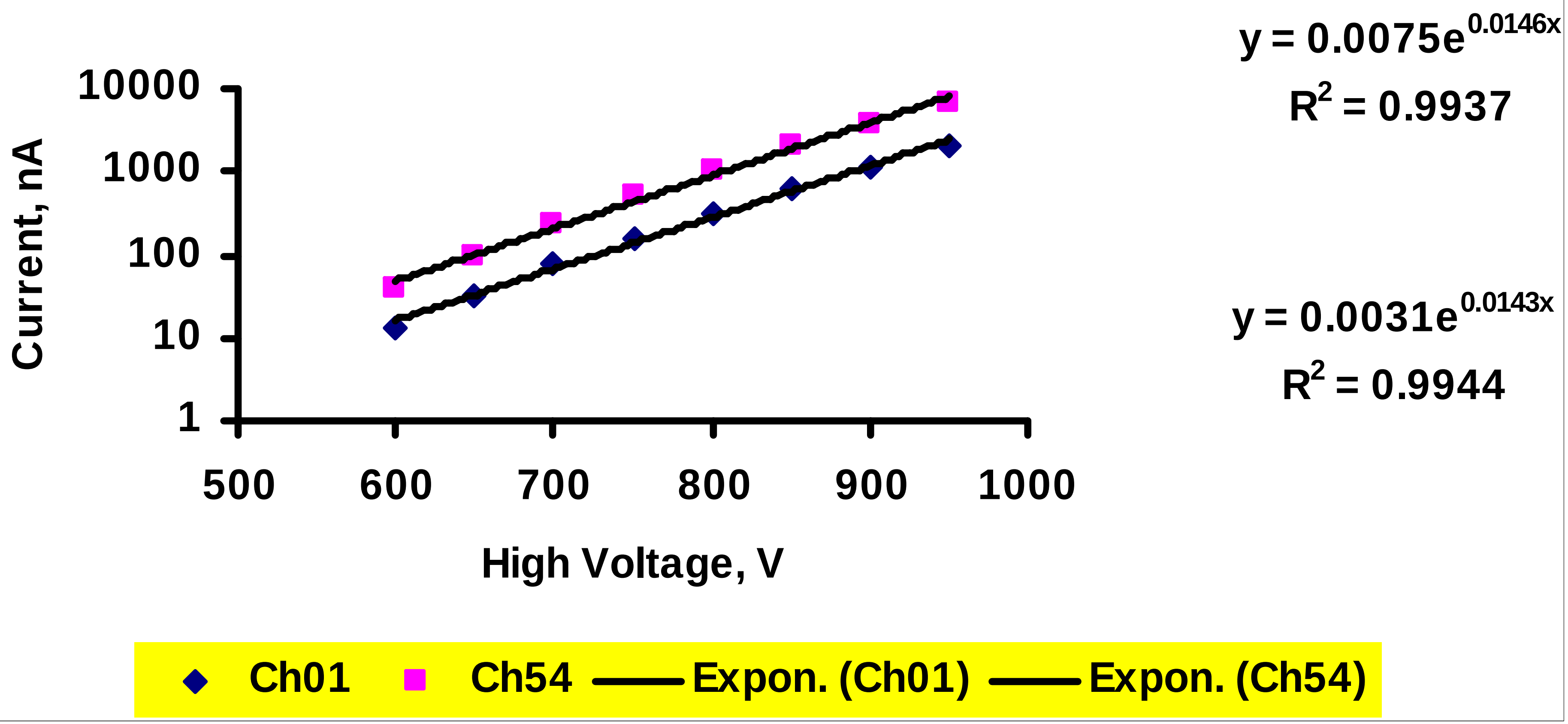
Boxed MAPMT with Interface and WLS Fibers Connected

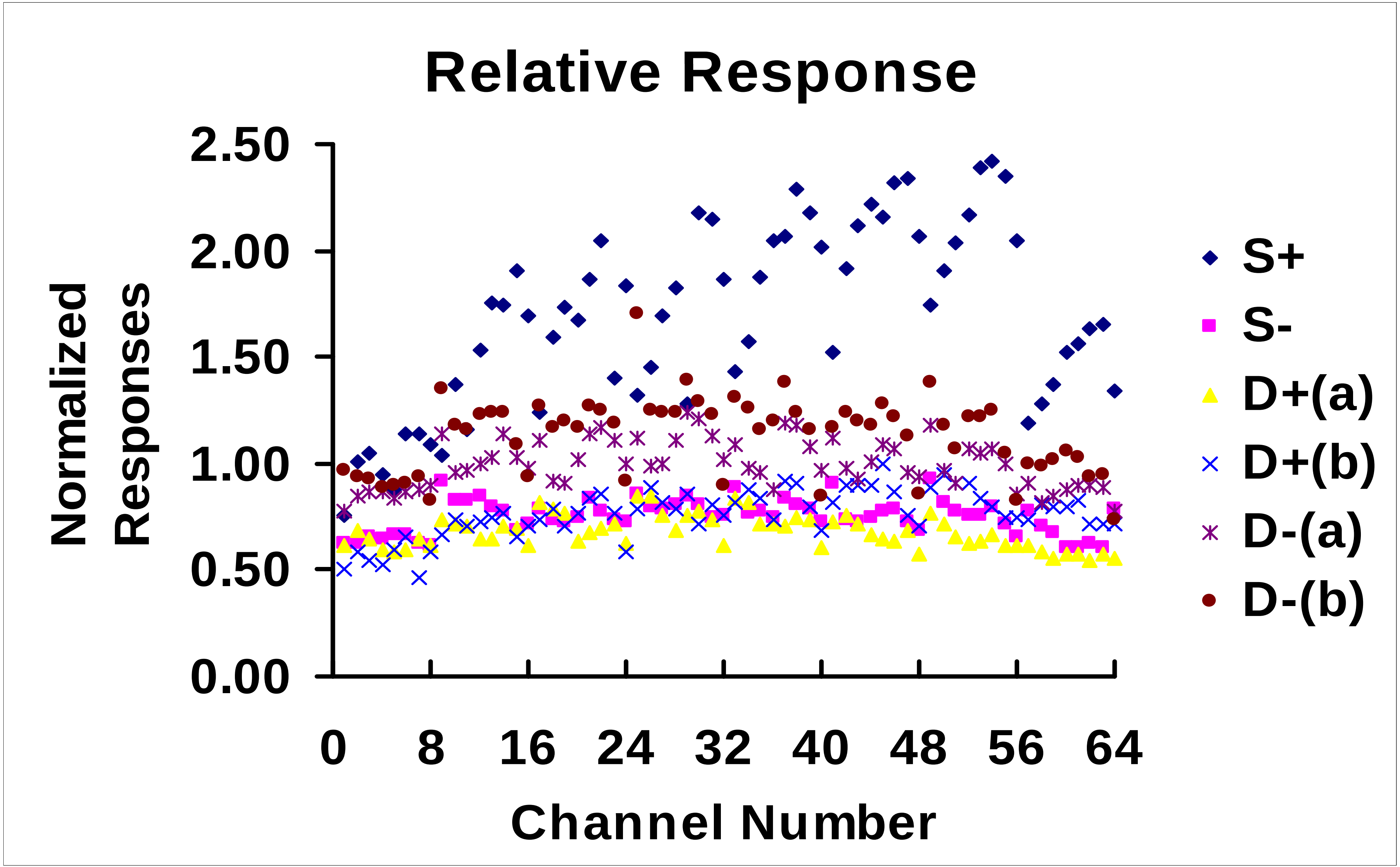


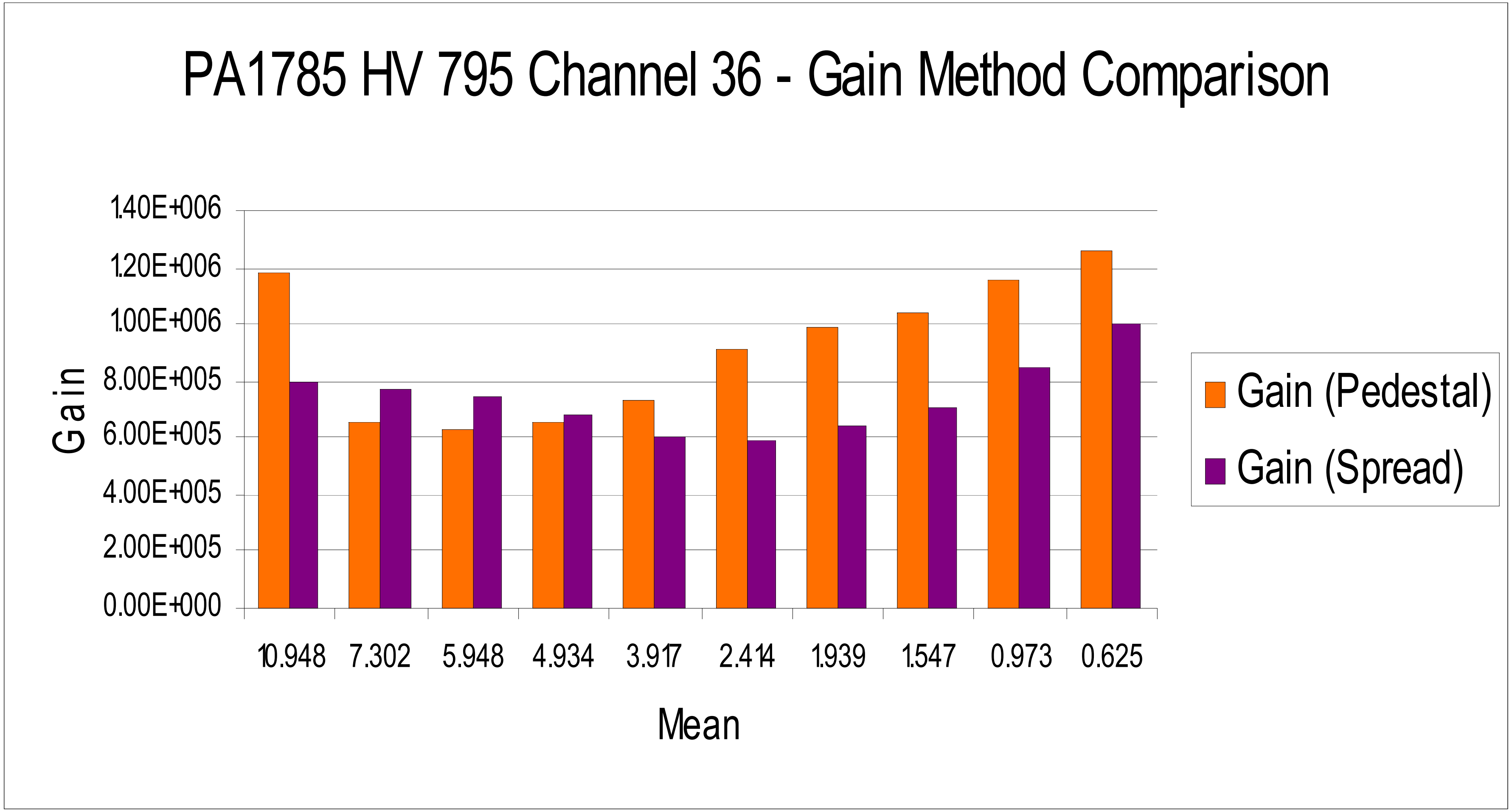
Labeled WLS fiber is a reference always positioned At channel number 57 in each MAPMT.

Control measurements were performed using the second fiber by repeating the measurement in channel number 64.

Output Current for Different MAPMT S+ Channels

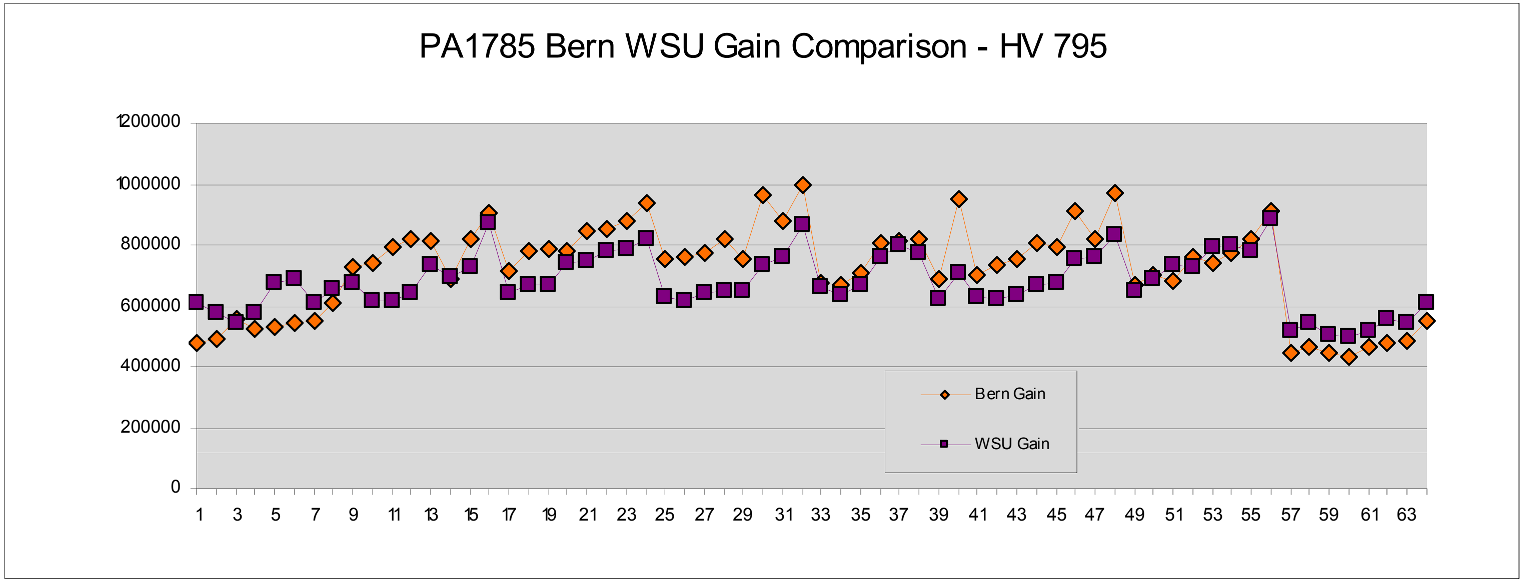


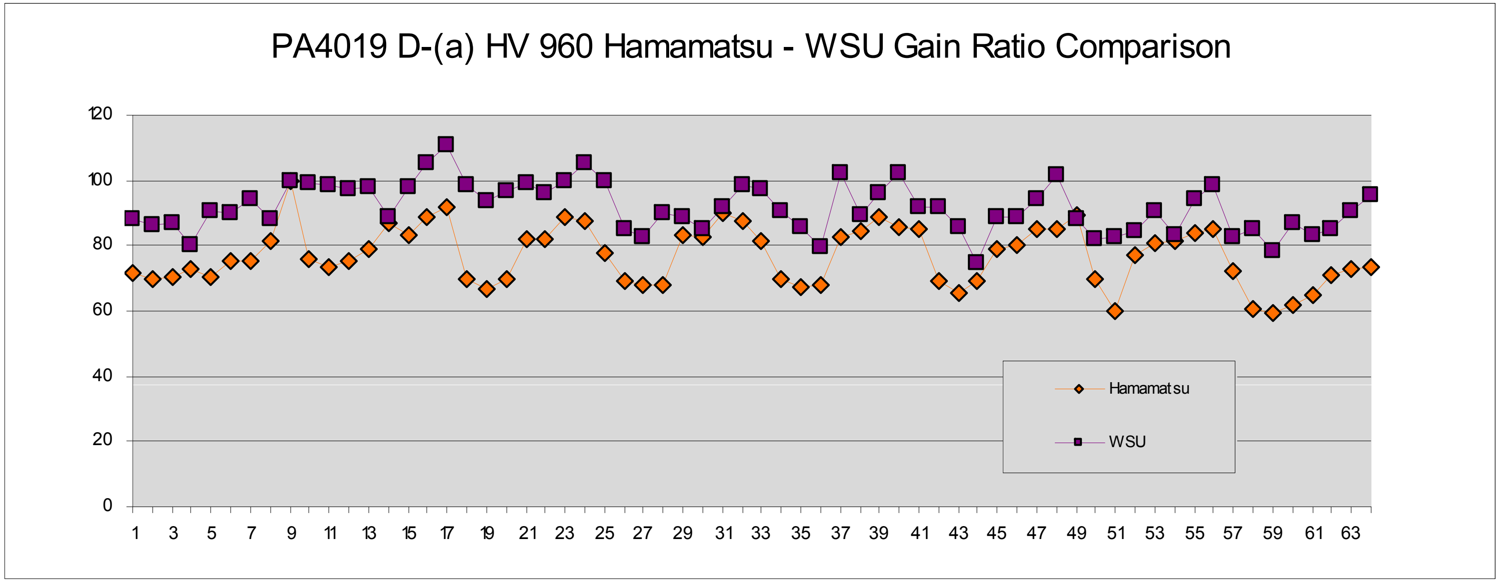

Relative Response
Normalized Responses
2.50
2.00
1.50
1.00
0.50
0.00
0
8
16
24
32
40
48
56
64
Channel Number
S+
S-
D+(a)
D+(b)
D-(a)
D-(b)



Bern Gain 8.07 E+005

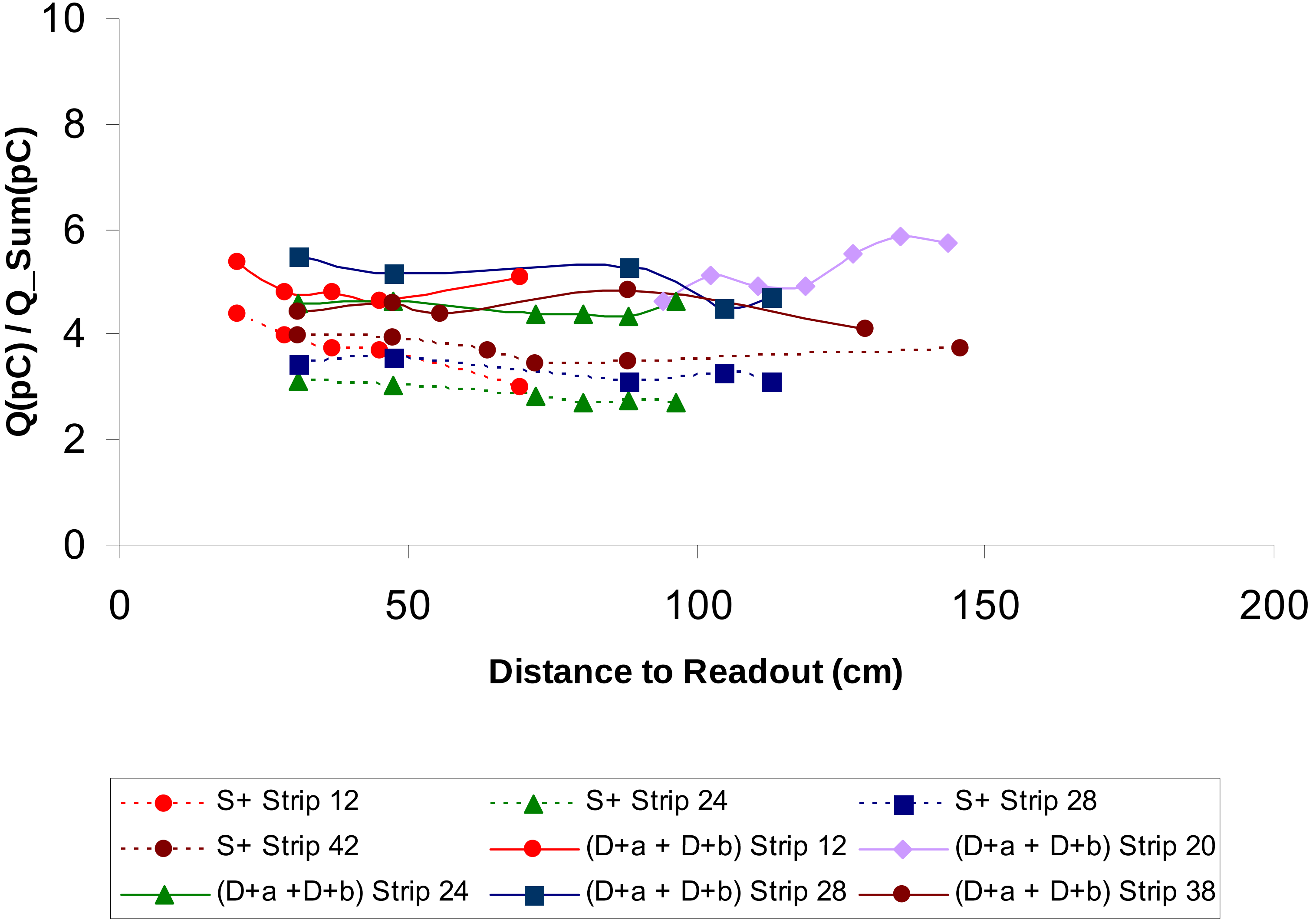
P. Karchin et al, Wayne State


PA1785 Bern WSU Gain Comparison - HV 795


PA4019 D-(a) HV 960 Hamamatsu - WSU Gain Ratio Comparison

P. Karchin et al, Wayne State

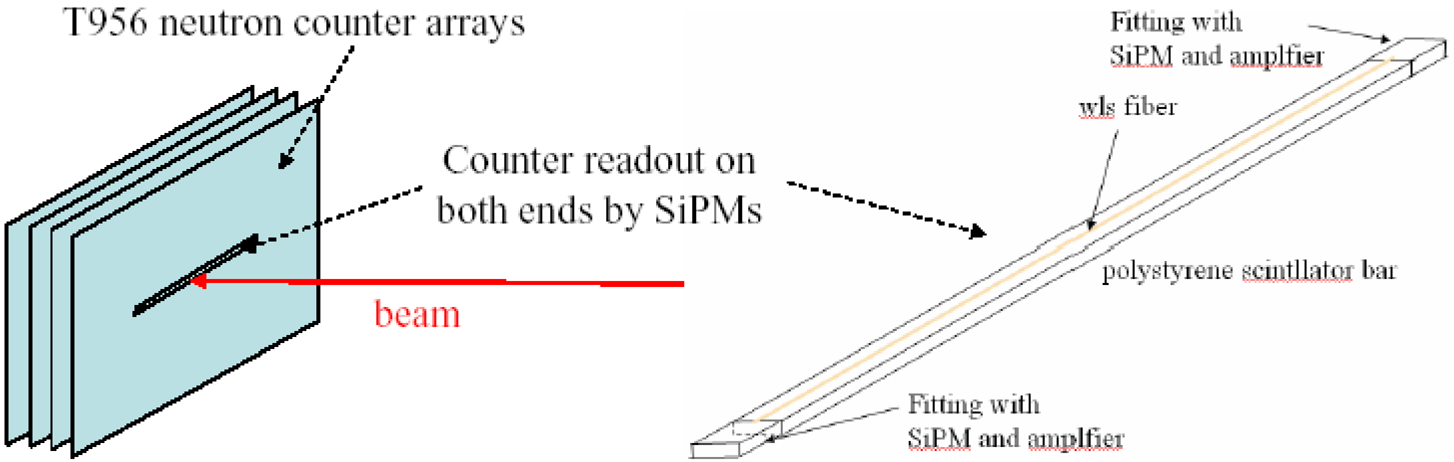
Readout From One End (dot lines)
From Both Ends (solid lines)



Signal Yield Conclusions

- S strips yield ~ 3 – 4 pC.
- Adding integrated charge from each end of the D fibers yields ~ 5 pC.
- Clearly ~50% more light yield if signals from both ends of the fiber are added.
- Not much attenuation over 1.8m of WLS fiber as anticipated.

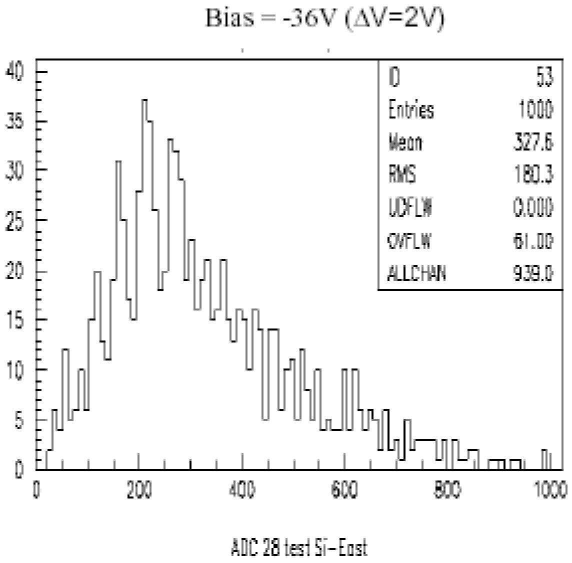
Preliminary study if Scint. Strip viewed by IRST SiPM



T956 neutron counter arrays

Counter readout on both ends by SiPMs

beam



Data with 120 Gev p - beam

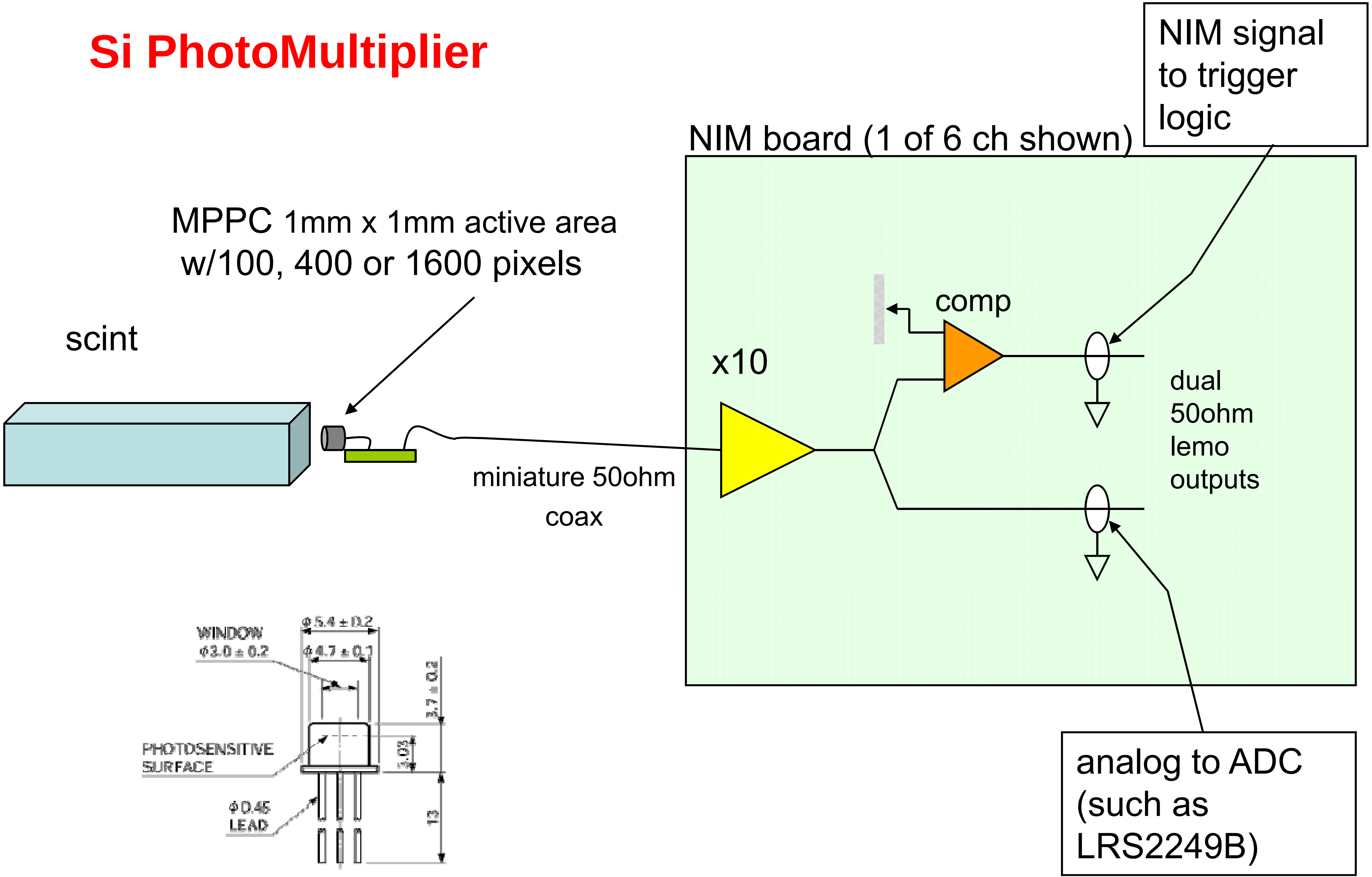
$$N_{p.e.} \approx 6.5\,p.e.$$

$$\varepsilon = 99\%$$

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

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

Si PhotoMultiplier



NIM signal to trigger logic

NIM board (1 of 6 ch shown)

MPPC 1mm x 1mm active area w/100, 400 or 1600 pixels

scint

comp

x10

dual 50ohm lemo outputs

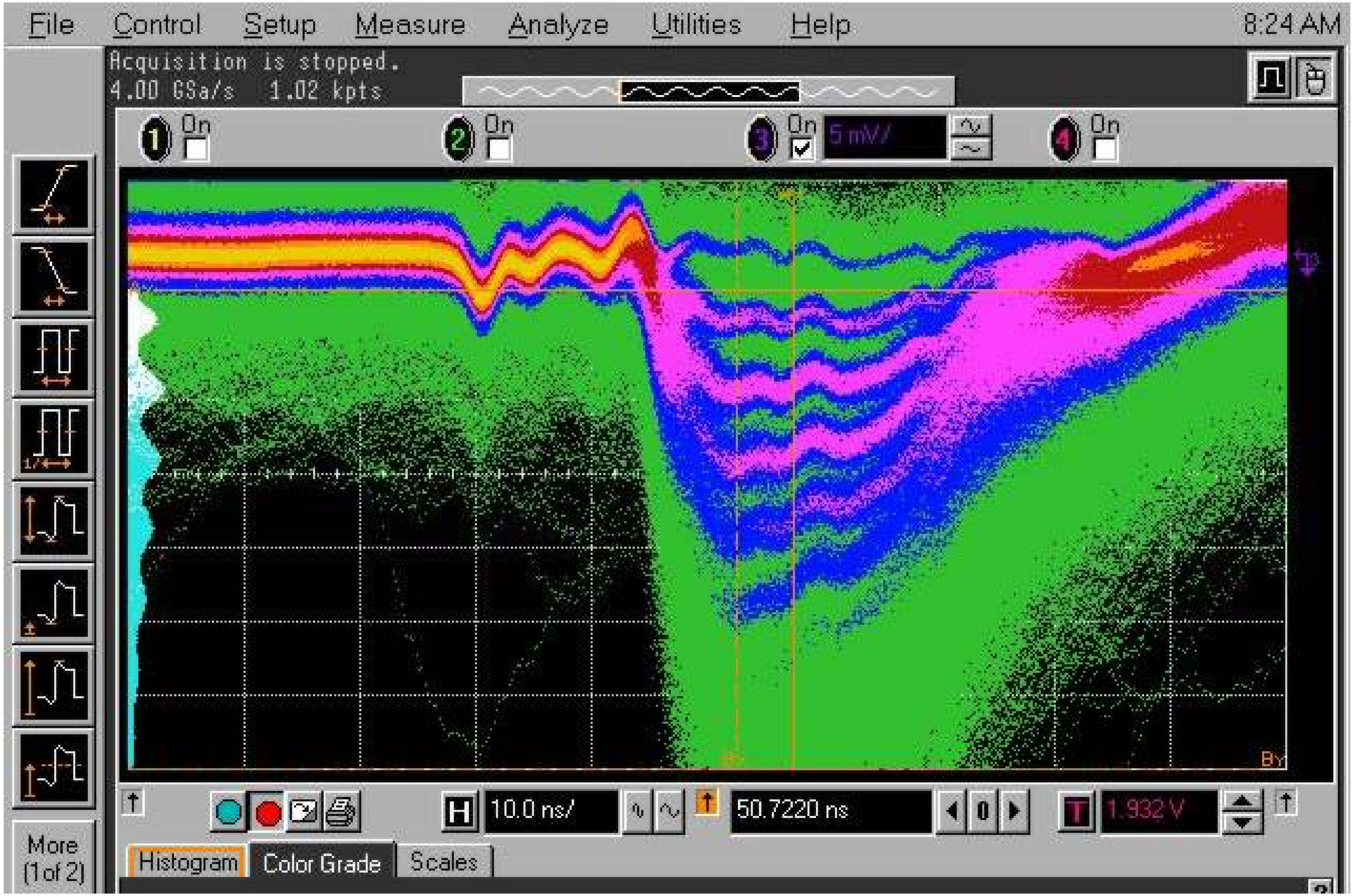
miniature 50ohm coax

analog to ADC (such as LRS2249B)

HPK MPPC

Paul Rubinov

Saved: 09 JAN 2008 08:24:39



Acquisition is stopped.
4.00 GSa/s 1.02 kpts

3 On ☑ 5 mV/

H 10.0 ns/

50.7220 ns

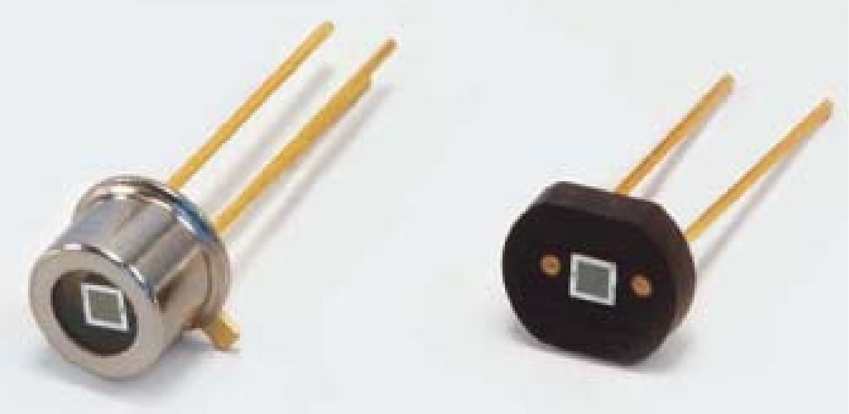
T 1.932 V

Vert = 5mv/div : Horiz = 10ns/div

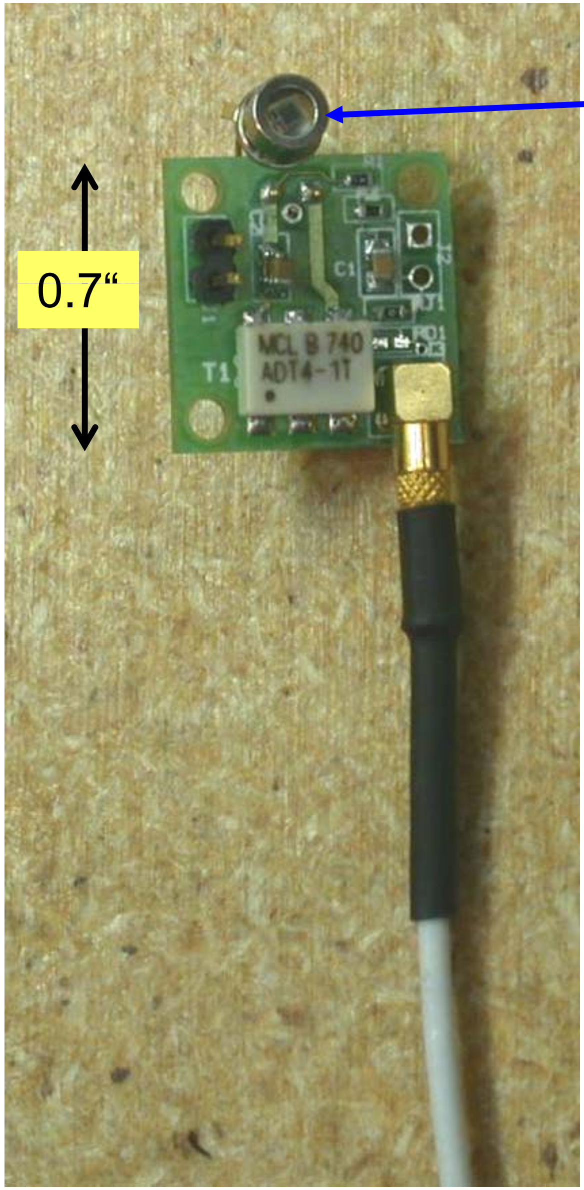
Paul Rubinov

Performance

- 5mv/pe at nominal bias voltage for 100 pixel Hamamatsu MPPC

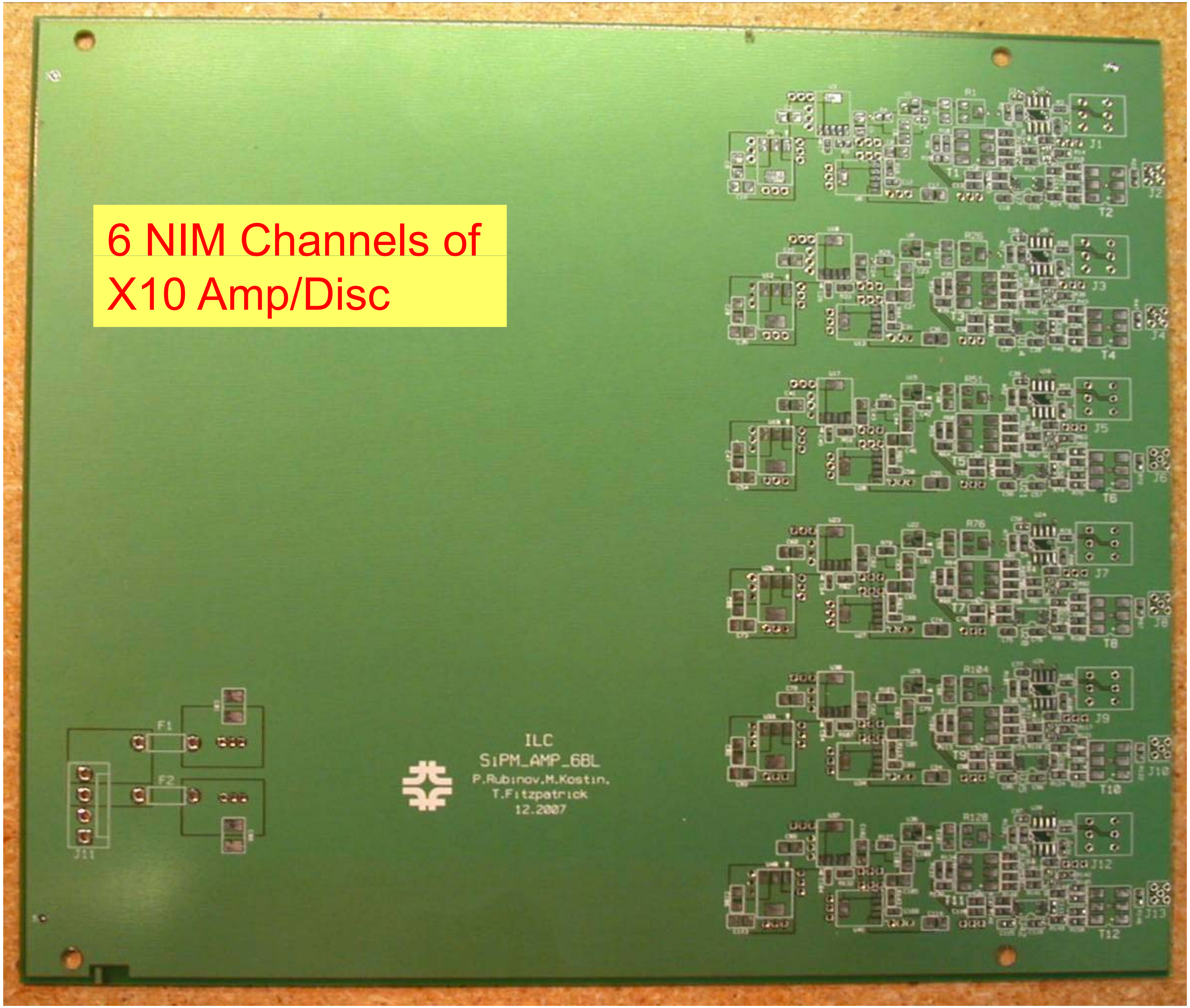


- 2ns risetime
- ~1mv RMS noise



Hamamatsu MPPC
100 pixels 100µ X 100µ

Transformer Coupled
Filter



6 NIM Channels of
X10 Amp/Disc

Facts about SiPM amp

- Designed for simple “play”
  - small SiPM interface board with filter and transformer couples signal to miniature coax
  - NIM format amplifier board contains 6 chan

  Each ch:
  - SiPM signal input on miniature coax (MMCX)
  - fast x10 transformer coupled amplifier,
    LEMO output (50ohm)
  - high speed comparator, NIM level output

Goals for SiPM amp board

- Demonstrate system usable for small scale test beam/cosmic test
- Define bandwidth/noise requirements
- Demonstrate advantages and drawbacks of transformer coupling
- Enable use of existing CAMAC DAQ systems with adequate performance

Cost to produce

All stock, off the shelf components

- $20 parts/channel
- $20 misc/channel (NIM mecanics)
- $20 PCB/channel
- $30 assembly labor (1 hr/ch tech time)

Total for assembled/tested board ~$600

Characterization of Silicon Photodetectors (Avalanche Photodiodes in Geiger Mode)

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

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..)

Detectors

- Existing

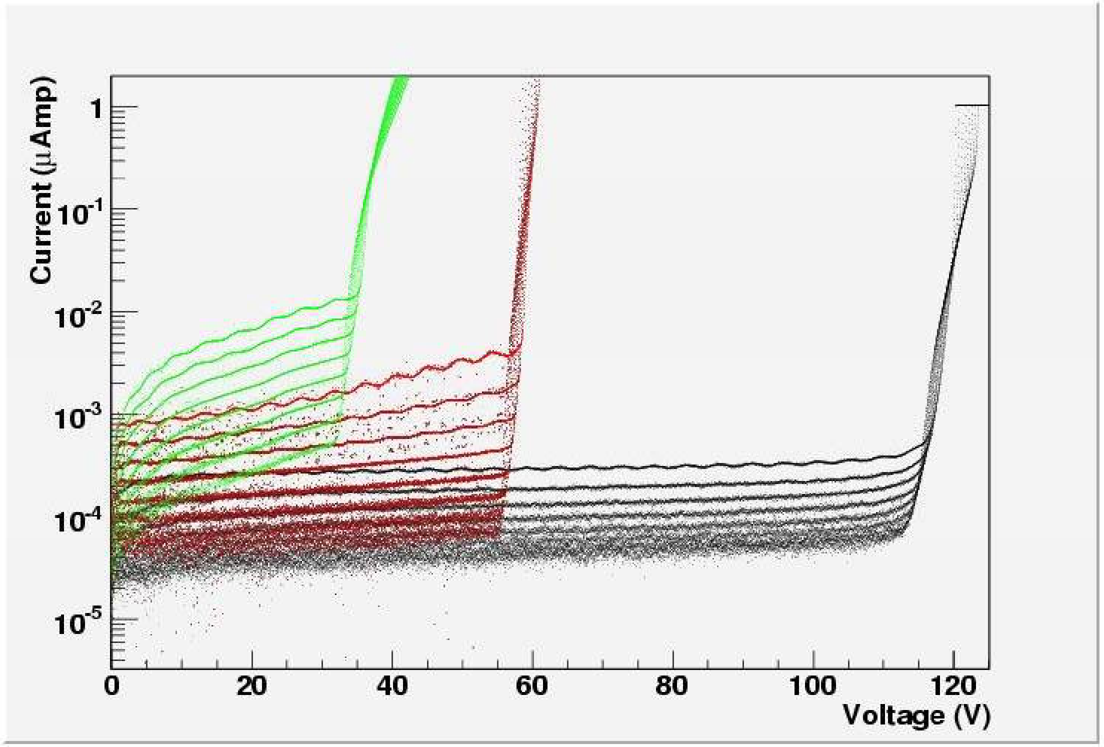
Hamamatsu (100, 50, 25 μpixels)	Japanese
IRST (several designs)	Italian
CPTA	Russian
Mehti	Russian
Dubna (two designs)	Russian

- Forthcoming

SensL	Irish
Radiation Monitoring Devices	USA

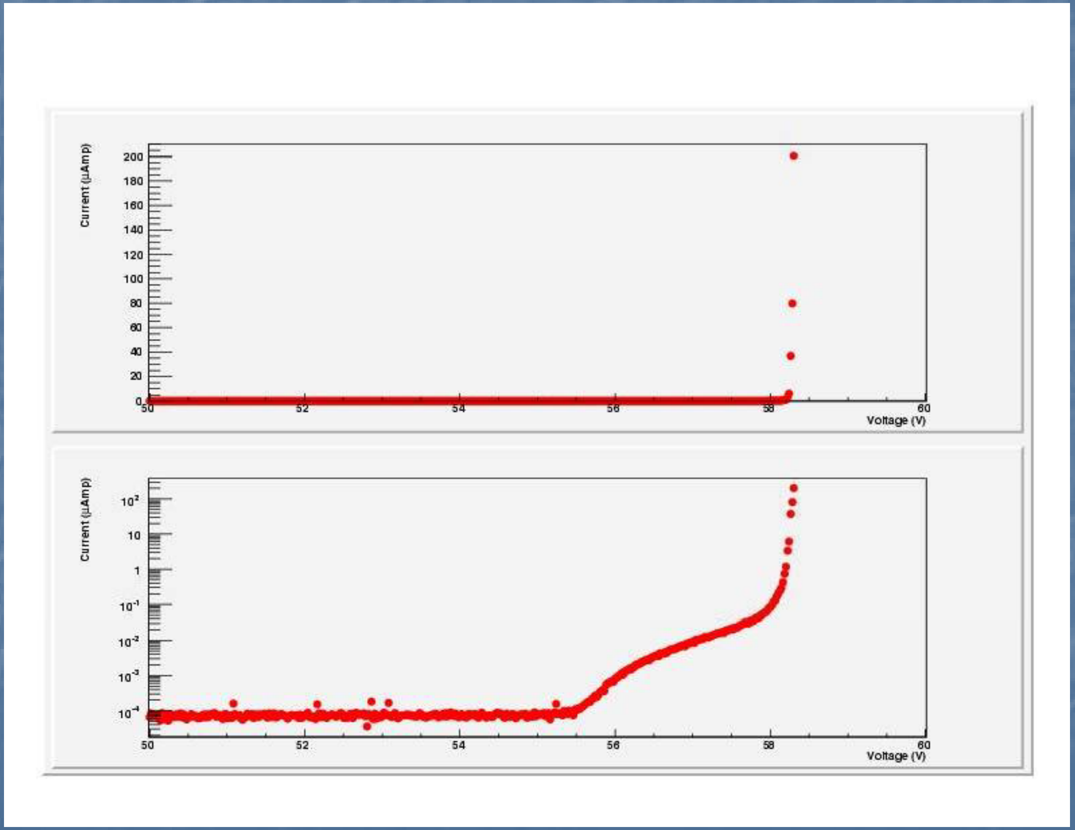
CMOS + active quenching = low cost + no after pulse

I-V Characteristics at Different Temperatures



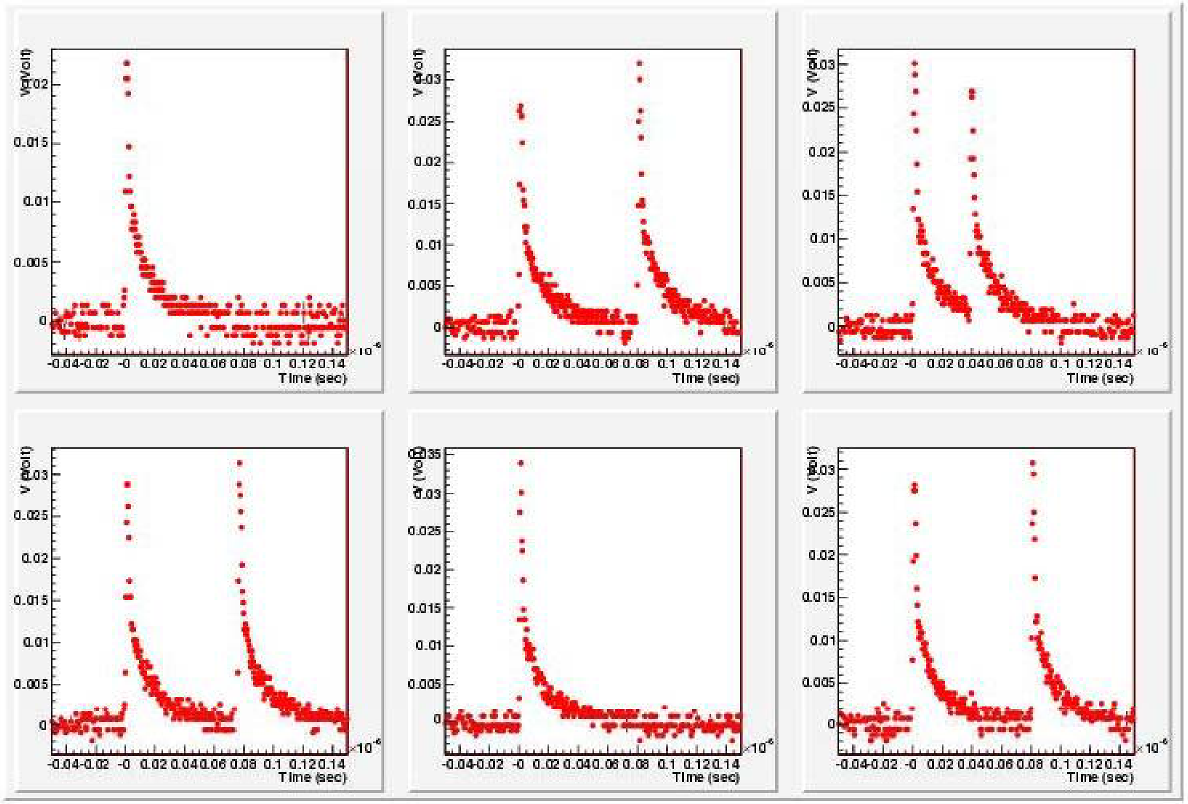
- Different detectors have quite different operating point
- Dark current and the operating point depend on temperature

Breakdown Voltage: a Knee on the I-V plot?



- Linear or logarithmic plot (derivative)?
- What is the shoulder on the IV log plot?
- Different pixels break-down at different voltages??
- Is it related to the resolution/width of the single electron peak??

Examples of Real Pulses



- Afterpulses and/or cross-talk
- ~ 5-10% (depending on voltage)
- Time constant of tens of nanoseconds

Pros & Cons: SiPM vs X Muon System

- No Clear Fiber Cost ++
- SiPMs instead of MAPMTs Cost ++
- Calibration by counting p.e. peaks
- SiPMs are noisier, but …
- SiPMs are smaller – easier to engineer?
- Power supplies of 70V vs 1.1kV (noise specs?) Cost +
- SiPMs may have better QE*geometrical acceptance.

Significant bench and beam tests to qualify a potentially superior and less expensive detector technology, and make **SiD** a true **Silicon Detector**.

RPC Plans - from ALCPG07

- Obtain larger IHEP RPCs
  - IHEP building 4 .5 by .5 m RPCs for shipment to SLAC within this week
  - Bulk Resistance ~10^{12} Ω-cm (Daya Bay)
    - Belle (glass 10^{12} Ω-cm) limited to .2-.4 Hz/cm^2
    - BaBar (Bakelite 10^{11} Ω-cm) ~10 Hz/cm^2
    - CMS,Atlas (Bakelite 10^{9-10} Ω-cm) 100-1000 Hz/cm^2
  - Needed rate capability set by machine backgrounds
  - Estimates
    - 0.01 hit/cm^2 per train (change from ~2 10^{-4}) N. Mokhov (further reduction of muon spoilers would increase)
    - 0.4 hits/cm^2 per train in the endcaps T. Maruyama
  - Avalanche mode operation 1/5 to 1/10 current of streamer- OK for 1--2 Hz/cm^2
  - Fine for barrel, marginal for endcap

KPIX/RPC

- Goal -establish KPIX as RPC DAQ option
- Design and build KPIX (64 ch) interface board
  - In progress *(D. Freytag and R. Herbst)*
- Test with IHEP & BaBar RPCs this spring

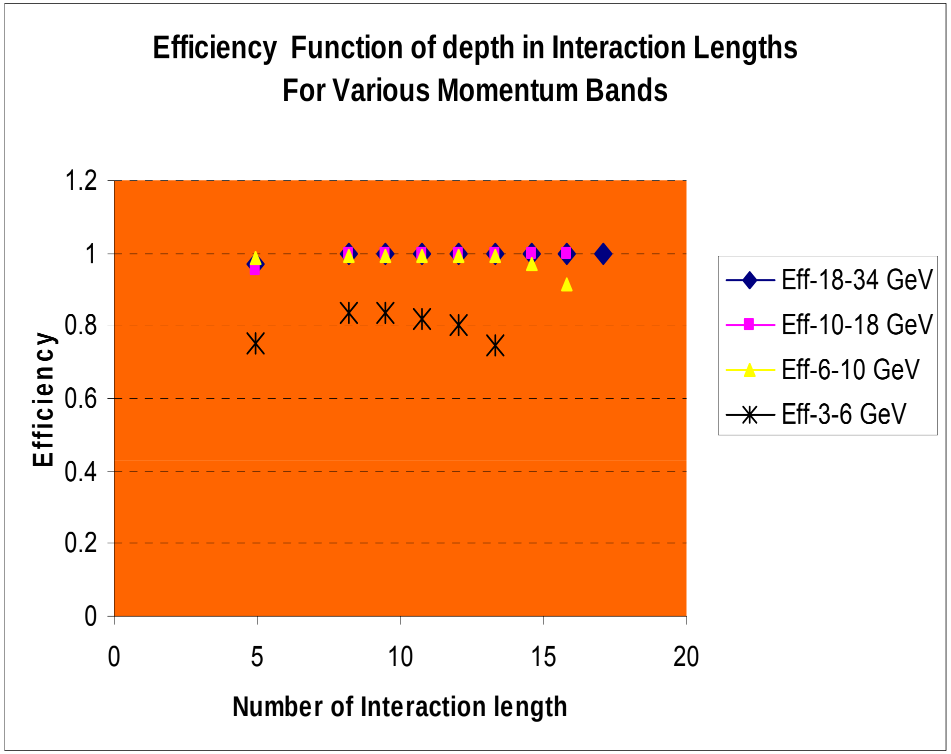
- Study
  - Signal termination/coupling vs signal time constant, gain
    - KPIX designed for 2μsec, RPC strip output ~300 nsec)
    - May need KPIX with shorter shaping time.
  - Robustness
    - (against sparks, large signals)
  - Gain
    - Streamer/avalanche mode

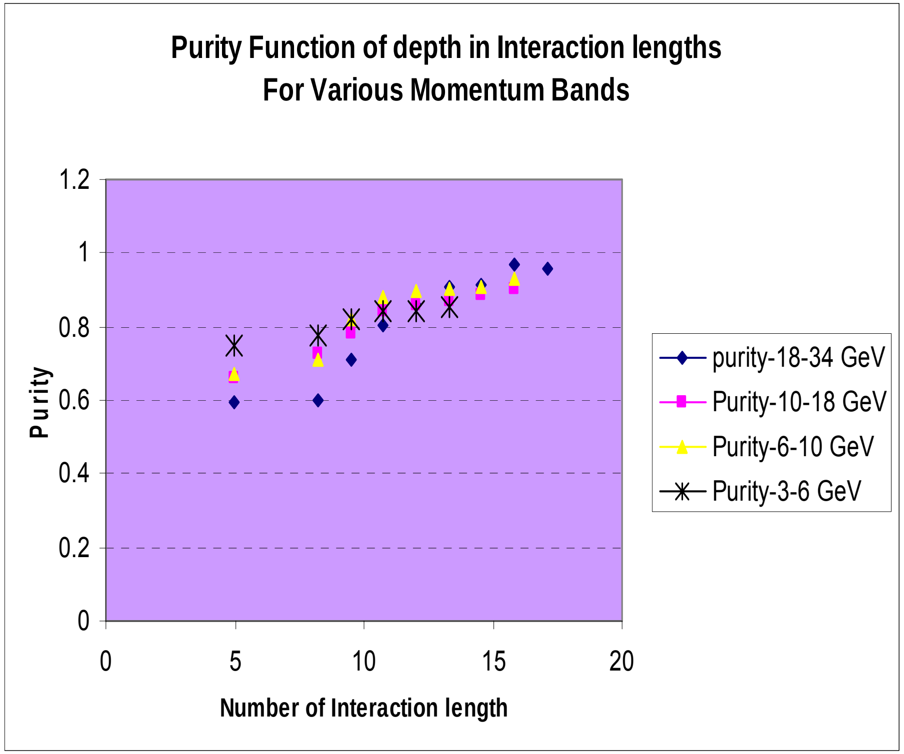
Other RPC Studies (3)

- Measure sensitivity of IHEP RPCs to input humidity
- Measure sensitivity of IHEP RPCs to gas pollutants (HF)
  - Lu has shown that IHEP RPCS are more sensitive to HF pollutants than previous (Italian Bakelite + linseed oil) RPCs
- Use HF from BaBar chambers for an accelerated aging study of the IHEP RPCs
- Cosmic ray tests (08)
  - Establish efficiency and hit multiplicity
- Need beam tests (09-12)?

Muon Efficiency & Purity Function of Depth For Various Momentum Bands

Starting at the End of HCAL ending at the End of MUDET





C. Milstene

Handles to Increase Muon Purity

- The Hadron Calorimeter starts after 0.87 λ and ends up at 4.95 λ. The bulk of the hadrons tend to interact in the first 2/3 of their length.
- The Muons above 3 GeV are going through the whole Hadron Calorimeter; tleaving a regular repetitive signal of 1 to 2 hits per layer.

1. A cut requiring *activity in the last 5 layers of the HCal*

   gets rid of the bulk of the hadrons and is very powerful in obtaining high purity muons. Most of the hadrons have *Interacted* before going through 2/3 of HCal and *the hadron showers are short* whereas the *regularity and penetration of Muons* indicates a probable muon.
2. Another cut to separate muons from hadrons is to require the layer with the minimum number of hits to have between 1 and 2 hits. A scan of the track in regions of low dE/dx in HCal, on the path of a Hadron that has interacted, can give zero hits and allow to check the muon out of high activity regions.

Muon System Technology Choice

RPC R&D, etc

Test Chinese RPCs; learn:

- Baseline Design
- Reliability
- Rate Capability
- Required Services
- Prototype Modules for ILC
- Signal collection scheme
- Electronics scheme
- Installation Scheme
- Cost Estimate (reviewed)
- Manpower for above

Scint-based w/ SiPMs

- Procure SiPMs
- Bench Tests for noise, gain, QE*Acceptance, ..
- Coupling WLS light to SiPM
- X10 Ampl FE package
- Sig. Concentrator/Cable
- Strip tests /source, beam
- Test beam setup
- Cost estimate
- Manpower for above

Generic Detector R&D?

Summary

- Muon System studies are severely manpower limited
- New people can make major contributions
- NEED
  - Fast MC study of the effect of hadronic mis-id rates in the benchmark processes
  - Optimization of the number of layers and segmentation
- Well defined, short term projects for those wishing to learn LC -SIMulation packages
- Contact
  - Gene – hefisk@fnal.gov
  - Henry - hrb@slac.stanford.edu

SiD Muon Technology Choice

- New baseline
  - 10 layers
  - Double layer
  - 3-5 cm segmentation
- Criteria
  - Reliability
  - Rate capability
  - Required services
  - Ease of installation
  - Cost

- Cost Estimate
  - ASAP
  - Potential future savings
  - 10 year operating costs

Plans - from ALCPG07

- Obtain larger IHEP RPCs
  - IHEP building 4 .5 by .5 m RPCs for shipment to SLAC within a month
  - Bulk Resistance ~$10^{12}\,\Omega$ /cm^2
  - Rate capability set by machine backgrounds
    - 0.01 hit/cm^2 per train (change from ~2 10^{-4}) N. Mokhov
    - 0.4 hits/cm^2 per train in the endcaps T. Maruyama
  - Belle glass RPCS limited to .2-.4 Hz/cm^2
  - Avalanche mode operation 1/5 to 1/10 current of streamer- OK for 1--2 Hz/cm2
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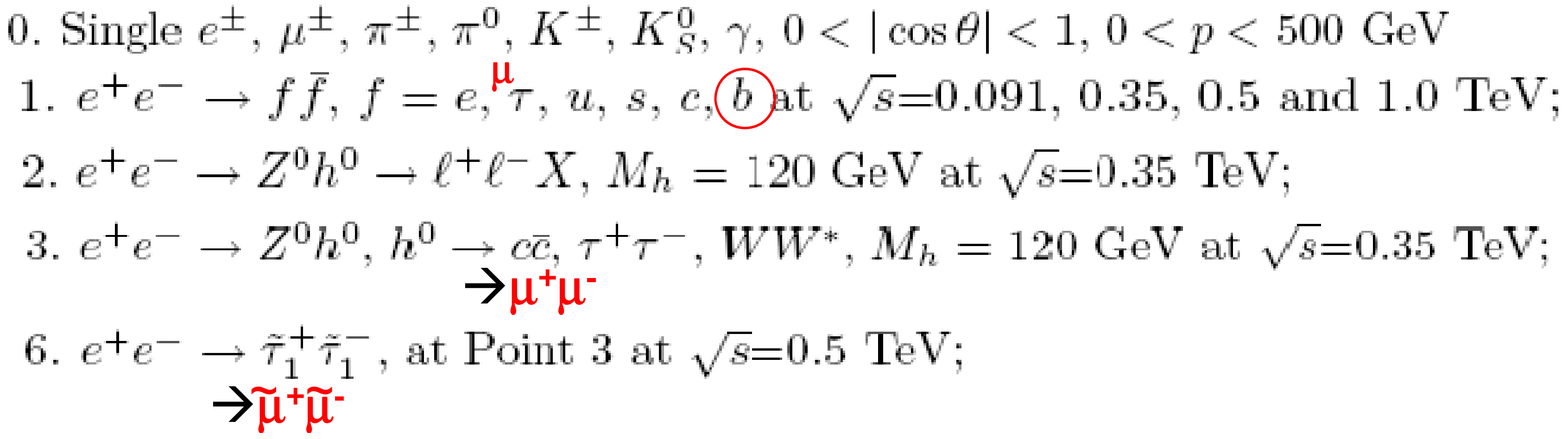
Backup Slides

Benchmarking processes - Muon

reduced list from Snowmass 2005 report hep-ex/0603010

- Muons
  - efficiency vs purity (hadronic misidentification rates)



0. Single $e^\pm$, $\mu^\pm$, $\pi^\pm$, π^0, $K^\pm$, K^0_S, γ, $0 < |\cos\theta| < 1$, $0 < p < 500$ GeV

1. $e^+e^- \to f\bar{f}$, $f = e, \overset{\mu}{} \tau, u, s, c, \textcircled{b}$ at $\sqrt{s}$=0.091, 0.35, 0.5 and 1.0 TeV;

2. $e^+e^- \to Z^0h^0 \to \ell^+\ell^- X$, $M_h = 120$ GeV at $\sqrt{s}$=0.35 TeV;

3. $e^+e^- \to Z^0h^0$, $h^0 \to c\bar{c}, \tau^+\tau^-, WW^*$, $M_h = 120$ GeV at $\sqrt{s}$=0.35 TeV;

$\to \mu^+\mu^-$

6. $e^+e^- \to \tilde{\tau}_1^+\tilde{\tau}_1^-$, at Point 3 at $\sqrt{s}$=0.5 TeV;

$\to \tilde{\mu}^+\tilde{\mu}^-$

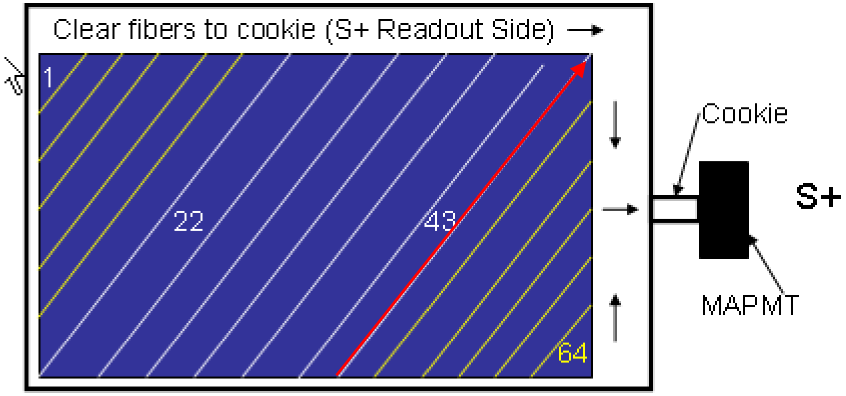
  - No serious study of how good the muon ID should be
    - Keep efficiency high (obvious)
    - Acceptable hadronic fake rate ?
  - Need simple fast MC analyses utilizing Tim’s data set of SM processes and ZH signals

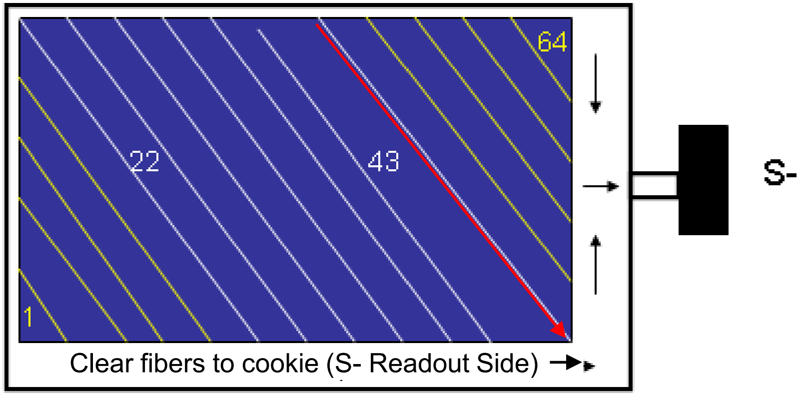
Beam Operating conditions

- 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.

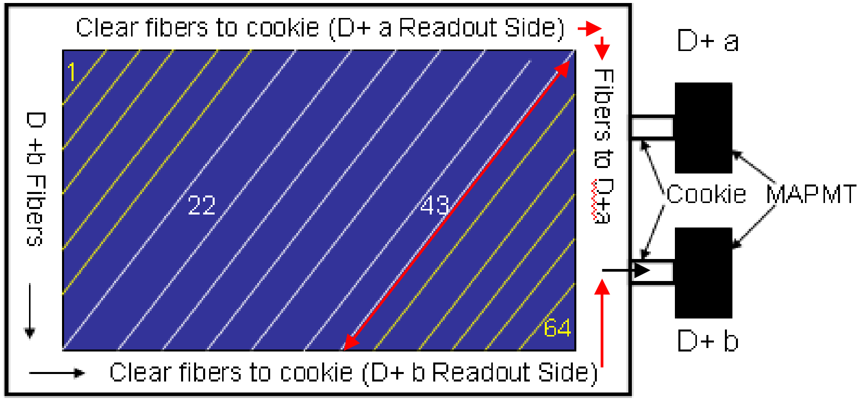
Four Detector planes

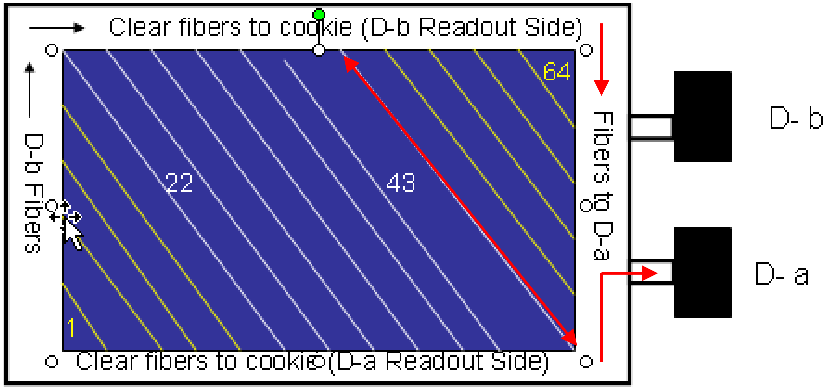
Single ended readout

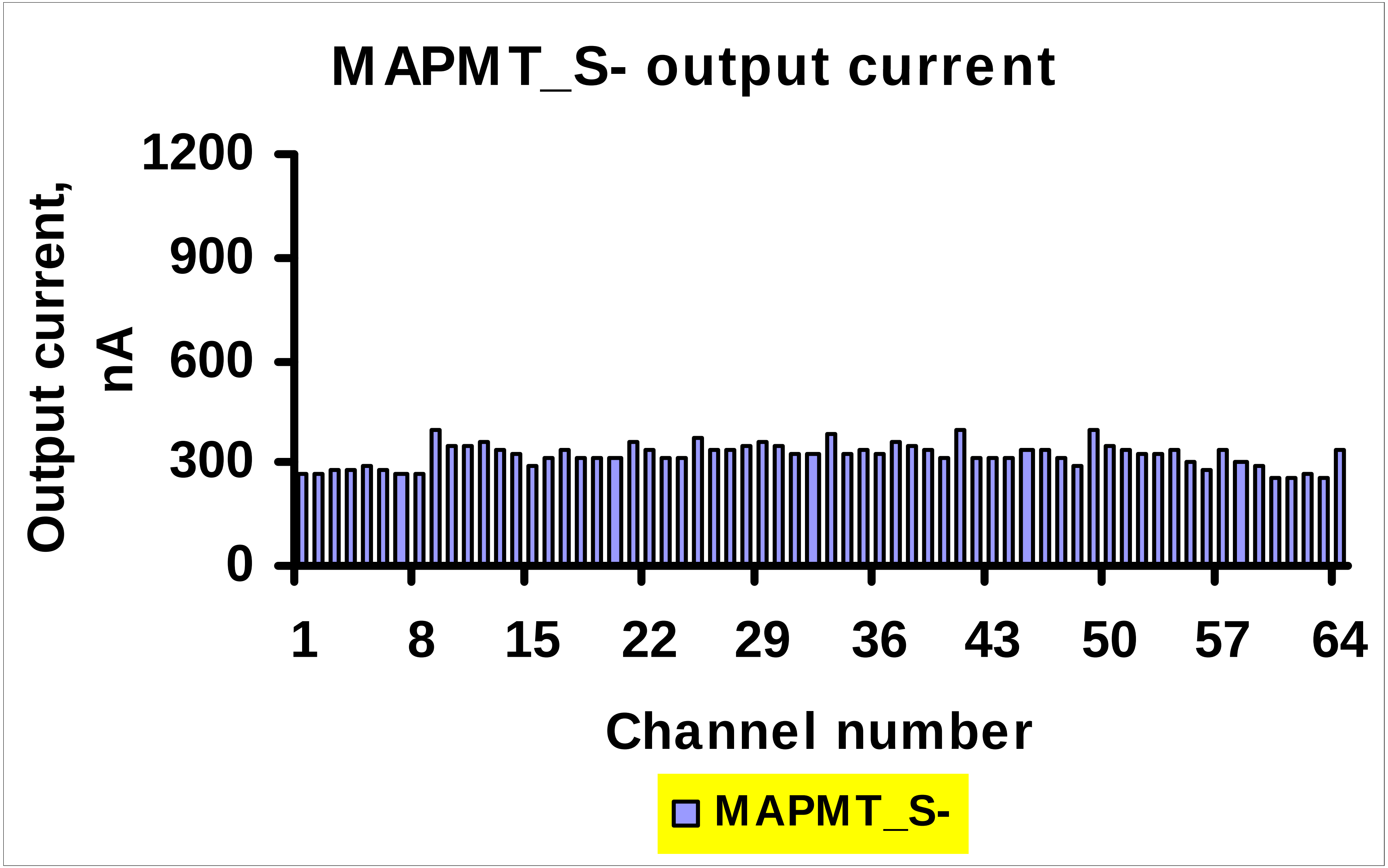


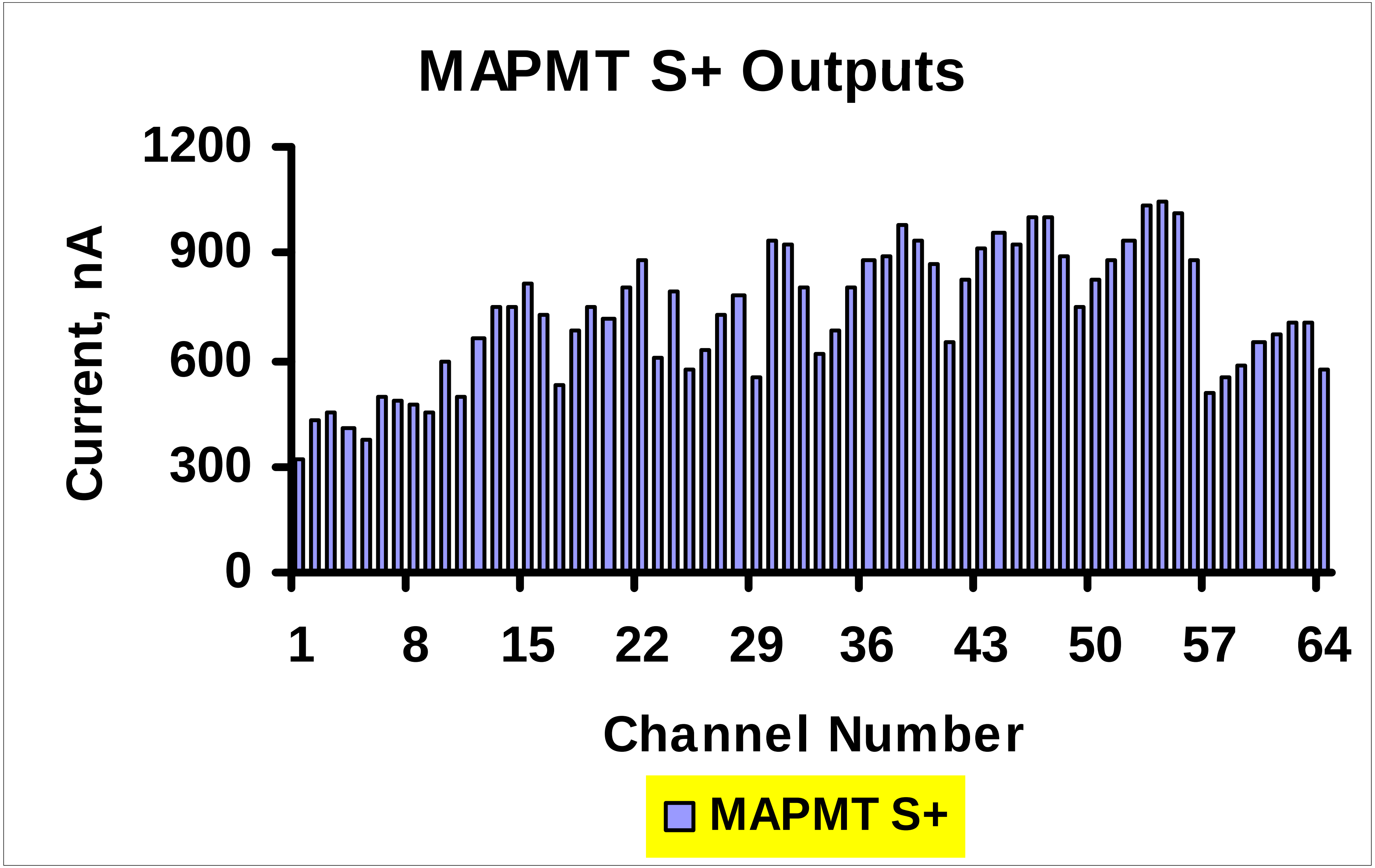


Dual readout






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-



S. Dychkant - N.I.U.

Instrumentation