ILC Muon Detector Prototype Testing at Fermilab

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Outline

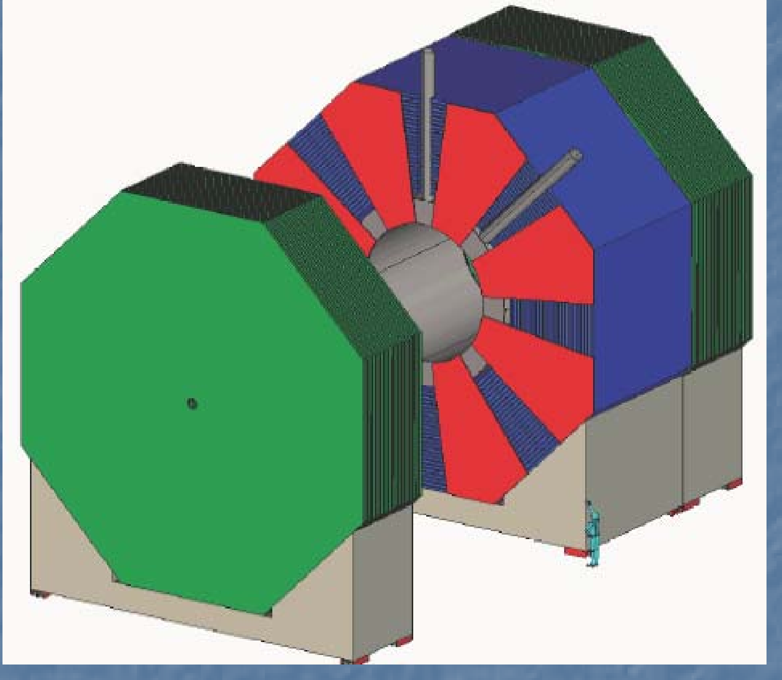
- Overview and Current Status
- Detector and Beam Setup
- Measurements and Test Results

Overview and Current Status

Participants and Responsibilities

- Collaboration: Fermilab, Indiana, Notre Dame, Wayne State, UCDavis
- FNAL: E. Fisk, C. Milstene. Project leadership, operation, software support
- IU: R. Abrams and R. Van Kooten. Testing, mounting frame
- UND: M. Wayne and M. McKenna. Assembly of prototypes
- WSU: P. Karchin, A. Gutierrez. Electronics support, PMT calibration
- UCD: M. Tripathi. Readout electronics (future)
- Further acknowledgements
  - Fermilab provided significant materials, lab space, shop services.
  - E. Ramberg provided test beam support

Proposed SiD Muon System/Tail Catcher



Starts outside of EM and Hadron calorimeters
(4.6 nuclear interaction lengths (L))
and 5T solenoid coil and cryostat(1.27L)
at radius 3.5 m.

Solenoid flux return ~ 230 cm thick in the barrel (14 L)
Flux return divided into 23 layers of 10 cm steel for
octagonal barrel. Central barrel 5.7 m long.

End caps: 23 layers of 10 cm thick steel octagons at
both ends of barrel.

Muon detectors inserted in the 4-5 cm gaps between
plates.

First barrel layer ~2.9m by 5.7 m,
last layer ~5.6m by 5.7m.

Total detector area ~8600 m^2 for 18 layers.

Measurement Objectives

- Performance Related
  - What is the single muon detection efficiency per layer?
  - What is the uniformity of the response across the detector?
  - How effective is the detector for use as a tail catcher?
- Design and Cost Related
  - Are dual readouts needed (cost effective)?
  - Refinements or modifications needed?
  - Obtain cost estimates, possible cost reductions
  - Provide basis for comparison with other techniques

Recent History/Current Status

- Proposal (T956) for beam testing approved 12/2005.
- Set up in MBTF in January
- Small data sample collected in February
- Shutdown from March-June
- Completed several weeks of running in June-September
- Currently Meson Building and MTBF is undergoing renovation and improvements to beam line (September-January 2007)
- Our equipment has been moved to Lab E/F
- Data analysis still in preliminary stage. MAPMT calibrations not done yet.

Summary of June-Sept Run

- June 22-29: Check out counters and electronics
- June 29-July 15: Taking data while trying to identify and fix “DAQ” problem
  - July 10: Identified bit 5 as problem
  - July 10: SW cut on pedestals to remove bad events
- July 15-Aug 13: Not running at MTEST
- Aug 13-31: Taking data
  - Aug 17: Found and fixed “DAQ” problem
  - Aug 31-Sep 3: Pauletta runs with Si PM
- Sep 11-16: Steady Data Taking

Presentations During 2005-2006

- Presented source tests of pre-prototype muon scintillation counter module at LCWS05 at Stanford, March, 2005
- Presented source tests and cosmic ray tests of first 2 prototype modules at ALCPG workshop at Snowmass, July, 2005
- Presented first beam tests of set of 4 prototype modules at ILCW06 at Bangalore, March, 2006
- Presented further beam test results of set of 4 prototype modules at VLCW06 at Vancouver, July, 2006
- Presentation at SiD Workshop, October, 2006

Near Term Objectives

- Continue to analyze present data (IU and FNAL). Need to automate the data processing.
- Calibrate MAPMTs to correct for gain variations (WSU responsible)
- Implement LED/PIN calibration and monitoring system (IU, WSU, FNAL)
- Replace Lecroy ADCs with version of Minerva front end digitizers and test at MTBF. (IU, FNAL, UCD)
- Possibly build additional prototypes with faster wavelength shifters, different scintillator extrusions (FNAL and UND).

Future Plans

- R&D and testing of ILC muon scintillation counters with Si PMs.
  - A supplementary proposal (IU, WSU, UND, UCD and NIU) has been submitted for this work.
  - Additional collaborators FNAL, CSU, INFN (Trieste and Frascati) to facilitate getting samples of Si PMs and to combine efforts
  - Try to get Si PMs from other sources
- This R&D also applies to calorimeters

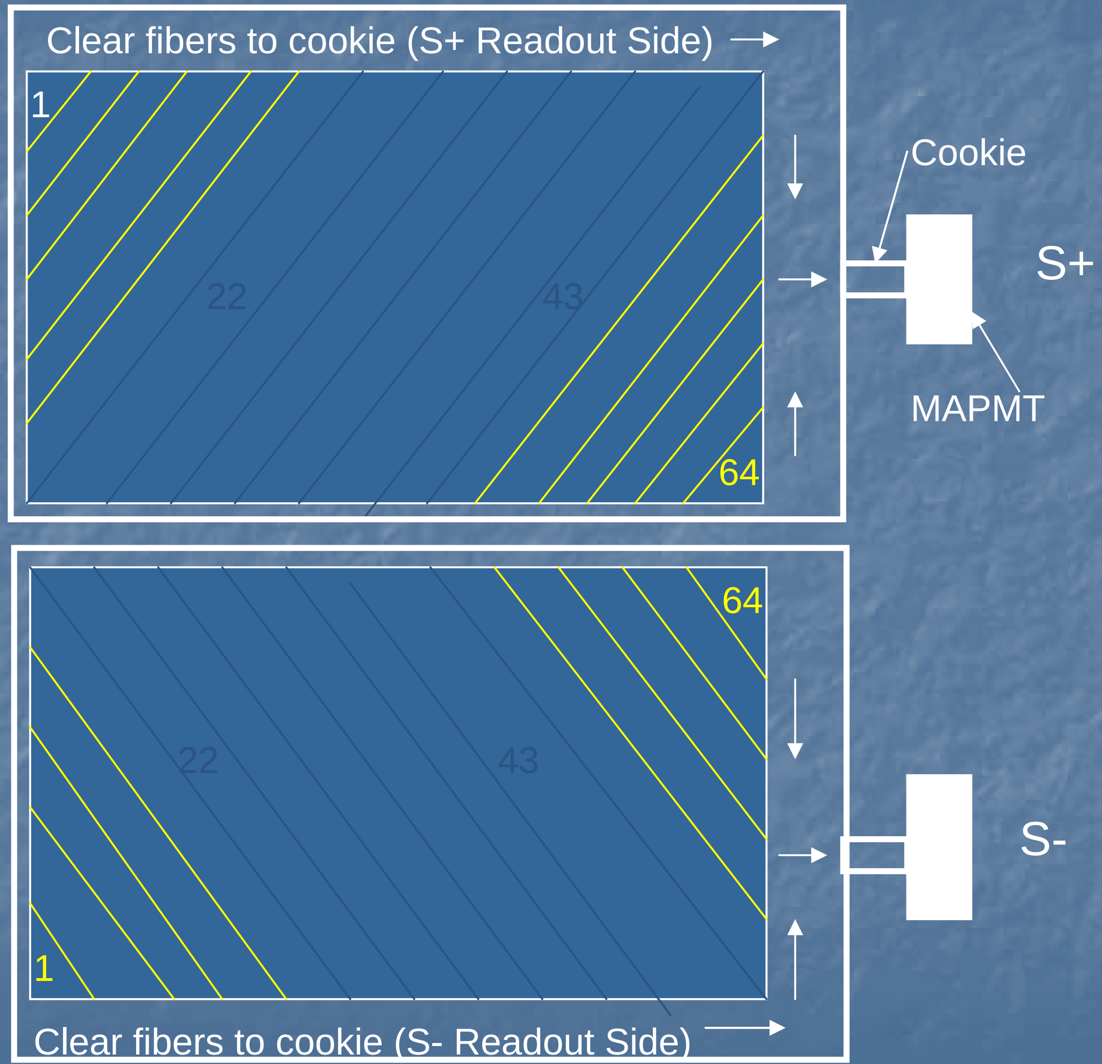
Detector and Beam Setup

Single Module Layouts

Construction:
64 scintillator strips
Per plane.
Each strip 4cm x 1cm
1 WL shifter fiber/strip

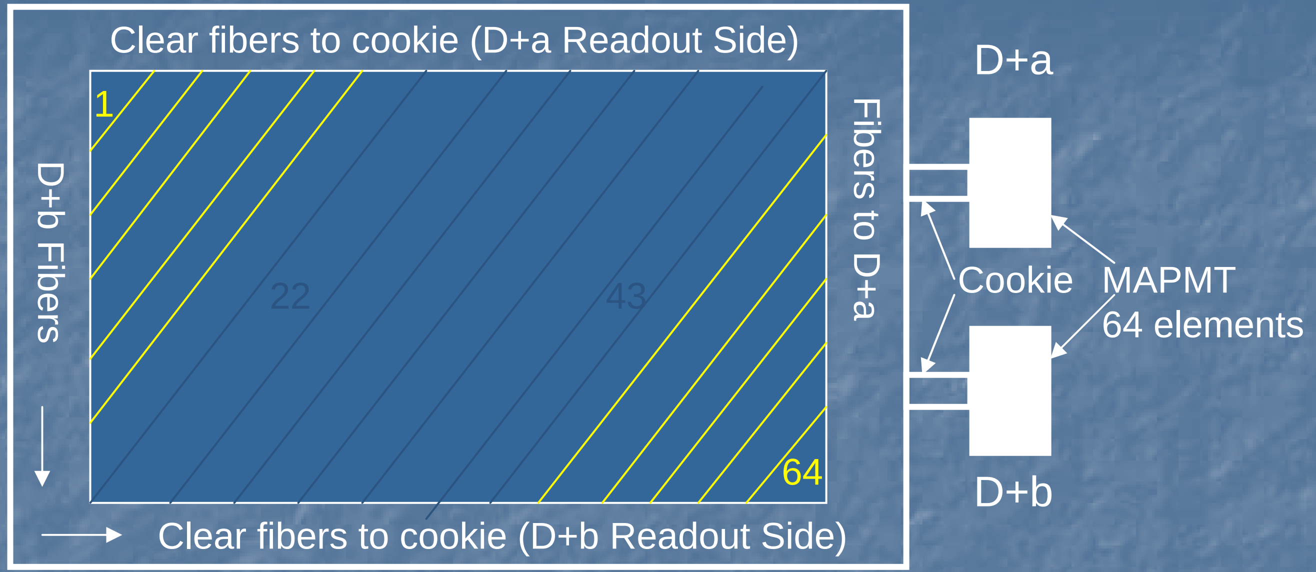
Prototype S+
Strips at +45º

Prototype S-
Strips at -45º

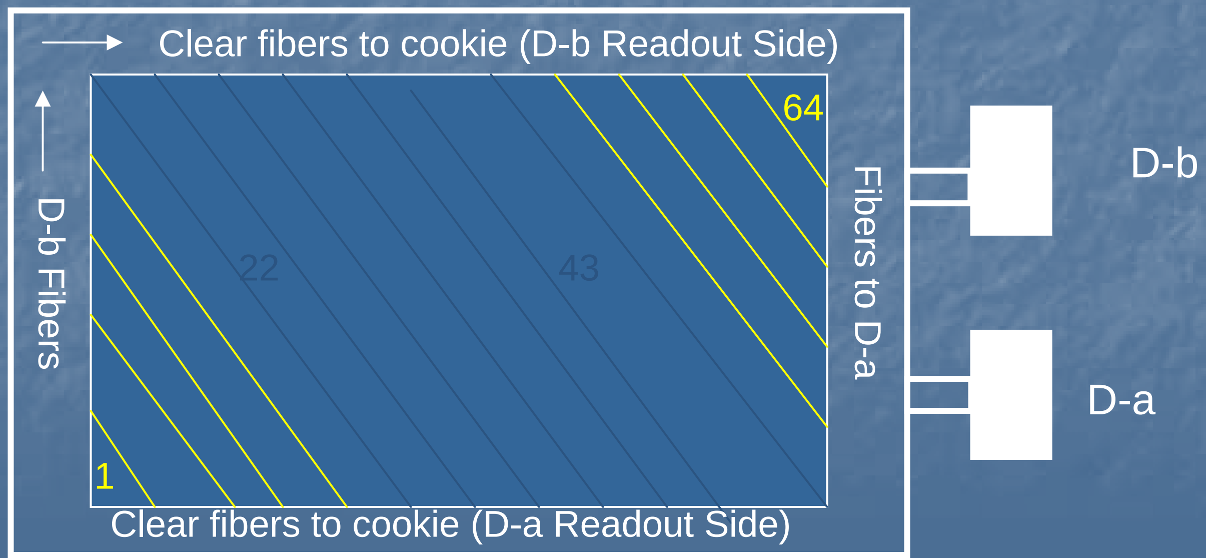


Dual Readout Prototype Modules

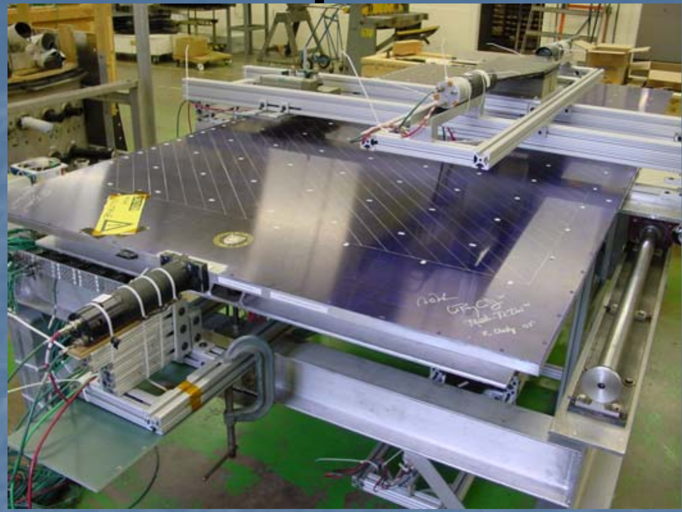
Prototype D+
Strips at +45º.
Fibers from far
End go to D+b



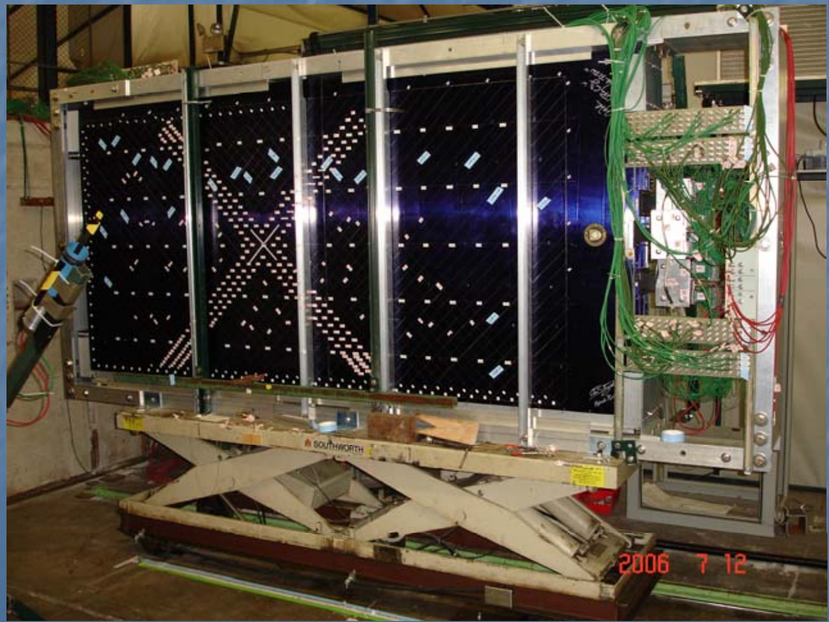
Prototype D-
Strips at -45º.
Fibers from far
End go to D-b



ILC MuonTest Setups



Pre-prototype
27 strips



Prototype test setup at
Fermilab Lab 6
Single channel PMT

Prototypes installed in
Fermilab Beam Test Facility
256 scintillator strips
384 PMT channels

Connections and Cabling

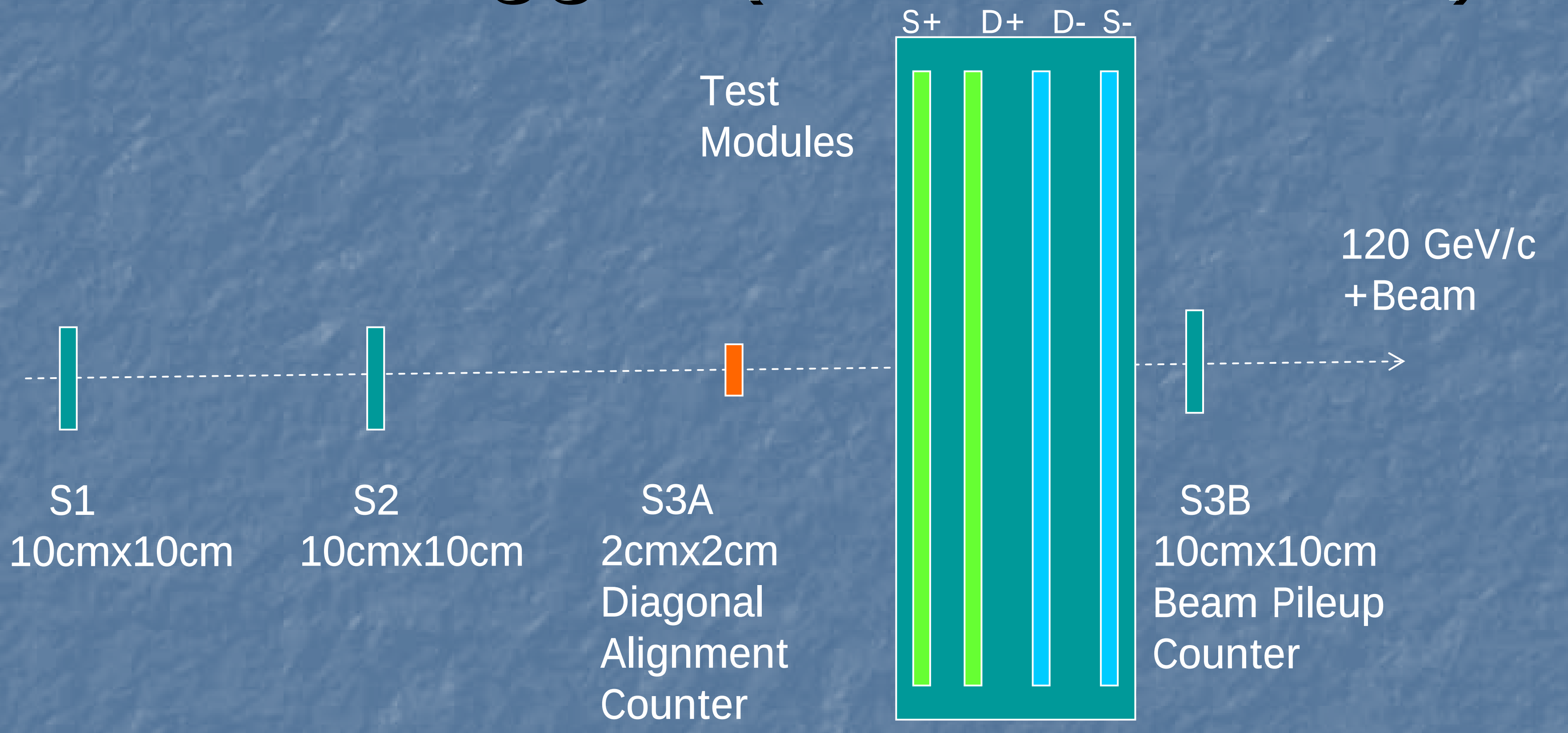
Monitoring and Positioning

Position monitoring with 2 commercial Laser levels. Horizontal line at beam height, and vertical line along beam line. Lines Intersect at beam Position.

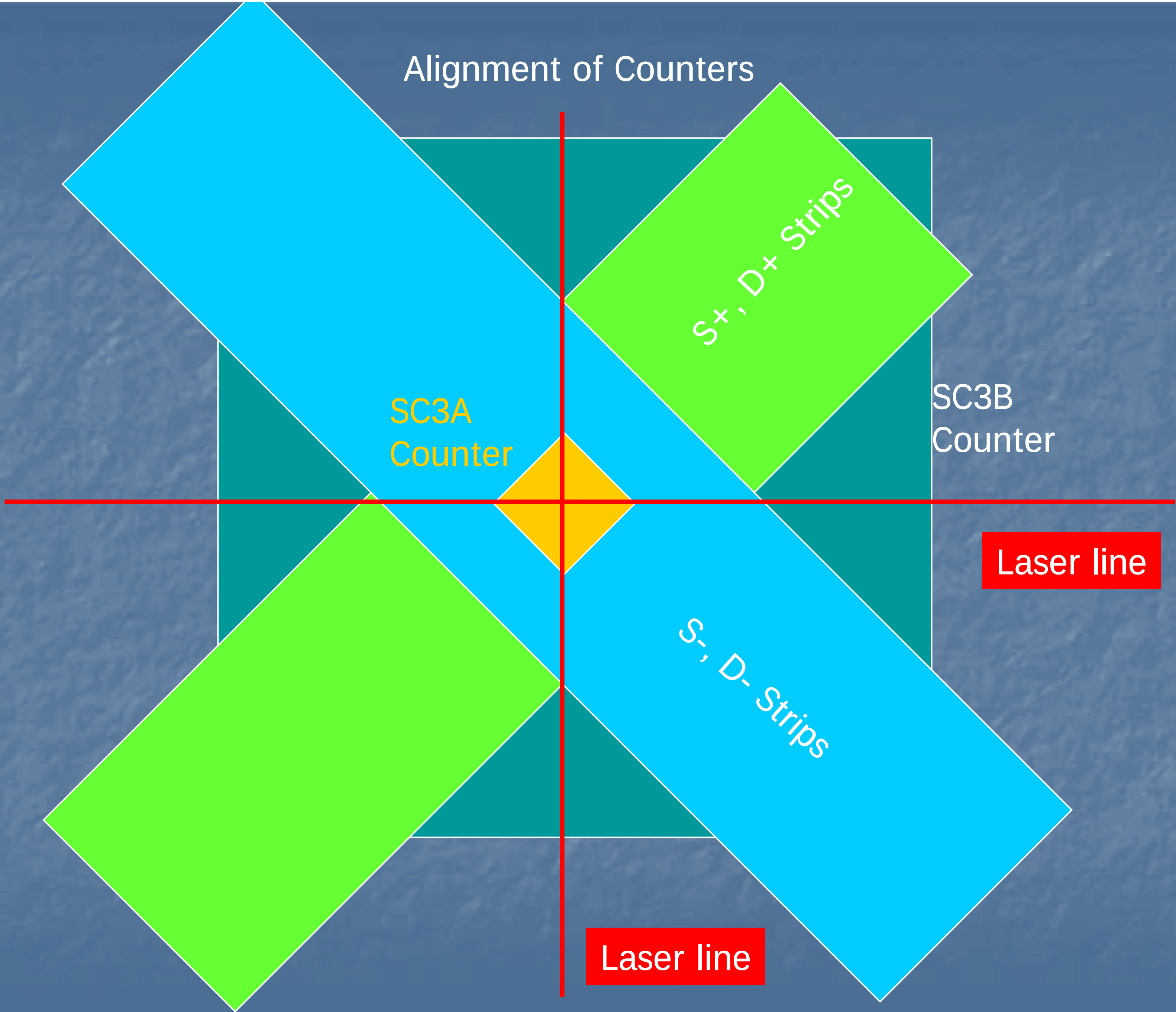
Video monitor and Motor controls for remote adjustment

96 inch horizontal motion along rail, Hydraulic scissors jack cart has 45 inch vertical travel.

Beam Trigger (S1.S2.S3A.SCB)



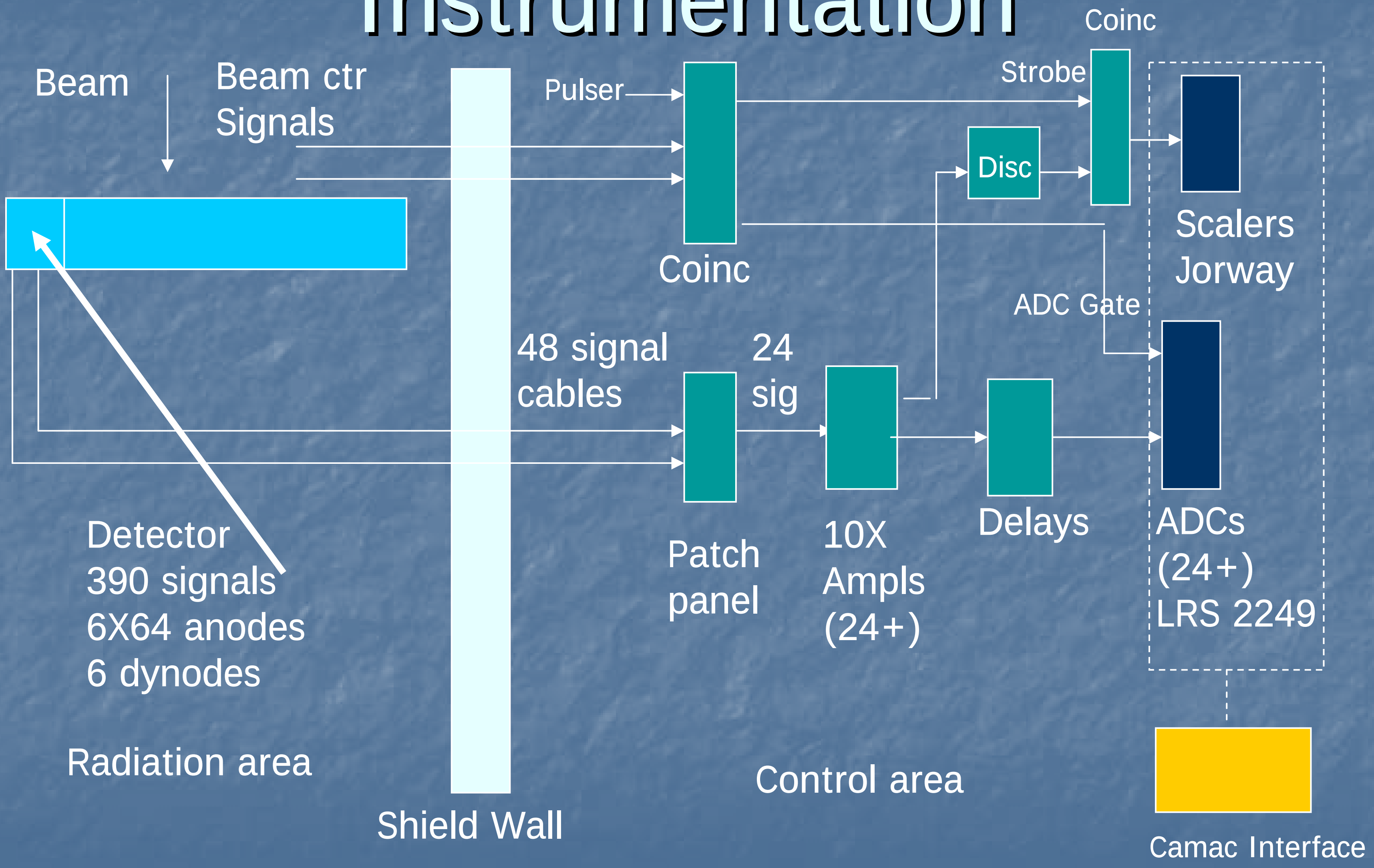
Alignment of Counters



Beam Operating conditions

- We trigger on beam signal, not on detector.
- As prime user we ran at low intensity, ~ 1000/sec during spill, two 1-sec spills/minute, 12 hours/day.
- As secondary user we operated at ~20,000/sec.
- DAQ limits data rate to ~50Hz
- Beam spot at +120 GeV/c ~ 1 cm FWHM
- We observed "bunching", or additional beam particles within 40ns to 800 ns after beam particle, 30% even at low rates ~ 1000/sec
- Additional beam particles within ADC gate ~10% of time, even at low rates

Instrumentation

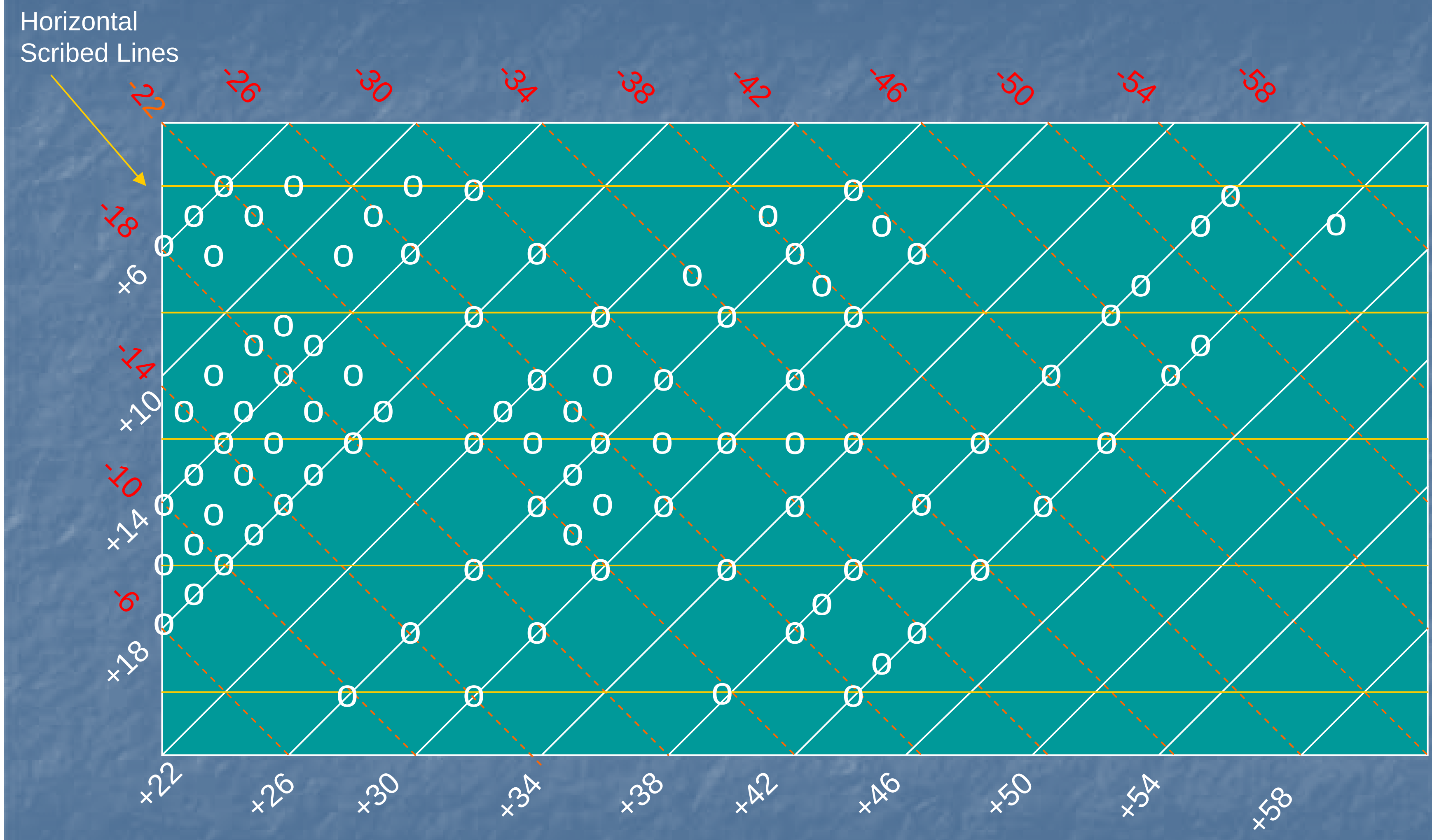


Measurements and Test Results

Measurement Procedures

- Position detector so that beam hits particular (+, -) pairs of counters.
- Measure:
  - multiple strips with beam at center or comparable points
  - at different positions along strips.
  - near boundaries between strips
- Also record coincidence rates of signals with CAMAC scalers.
- Typical data point 2000 to 5000 triggers

Schematic Measurement Grid

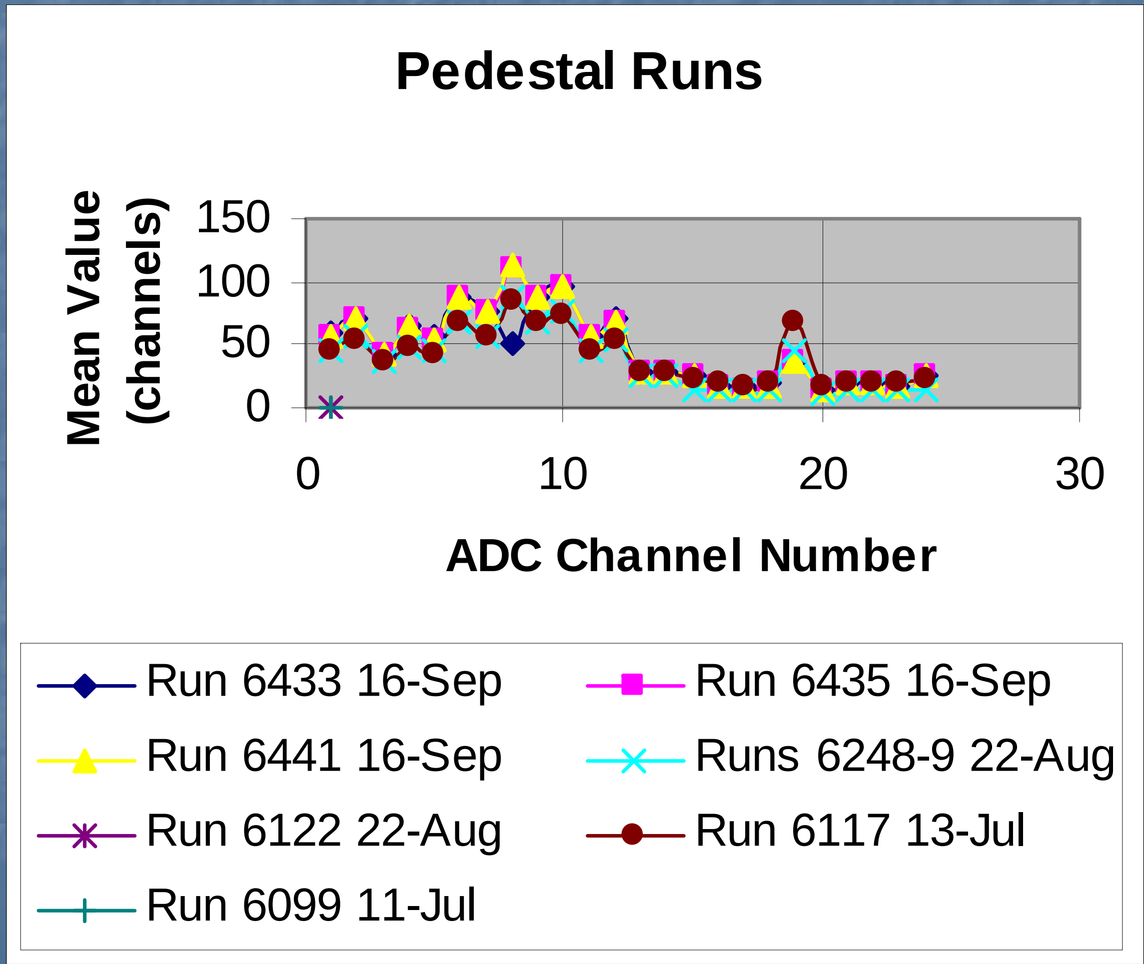


Circles show points that were measured. Numbers indicate strip numbers

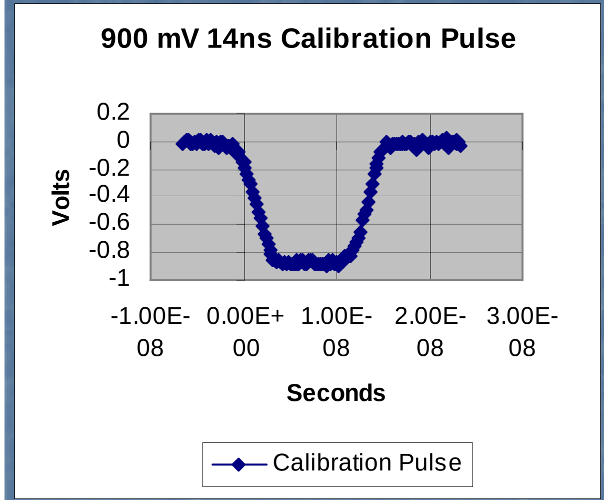
Variable Factors

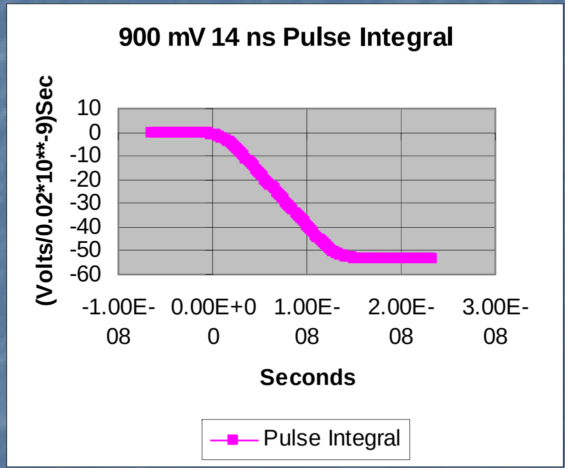
- Scintillator/WL shifter fiber lengths vary
  - Corner strips lengths vary
  - Attenuation along scintillator and fibers position dependent
- Clear fiber lengths vary strip-to-strip and Da vs Db differ
  - Lengths are known
- Consistency of joints between WL shifters and clear fibers
- Optical coupling between cookie and MAPMT
- ADC gain variations, both channel-to-channel and over time
  - Calibrations were run, signals from channels not hit by beam recorded
- MAPMT gain variations, both tube-to-tube, over time, per channel
  - LED monitoring strips

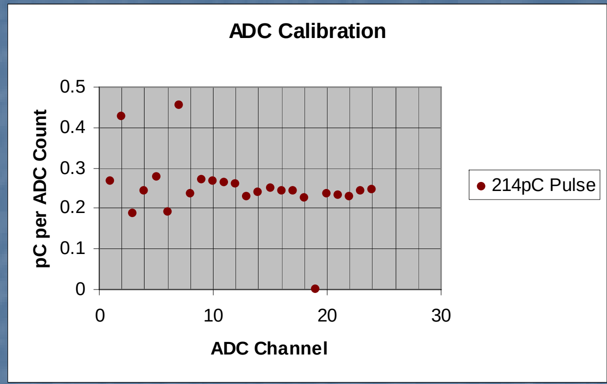
Results of Pedestal Runs



Calibration of ADCs

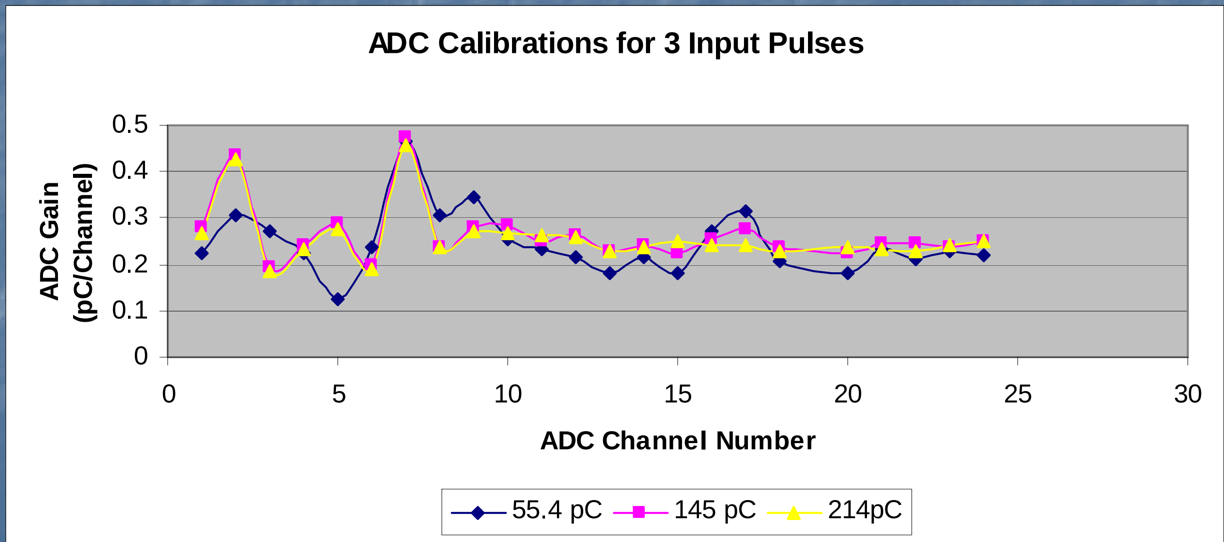




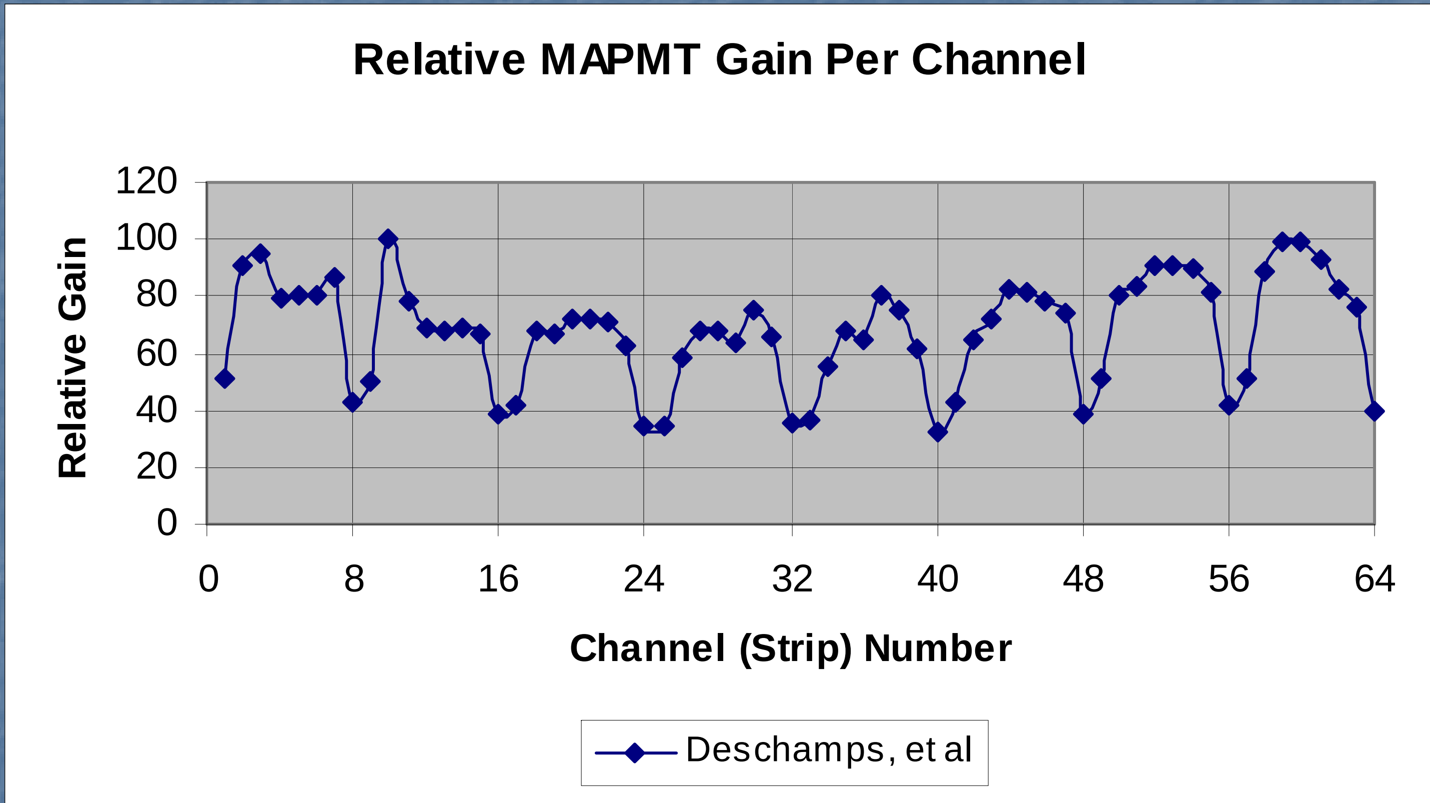


107.2 e-10 V-s
Q=214 pC

Additional Calibrations for 55.4 pC and 146pC

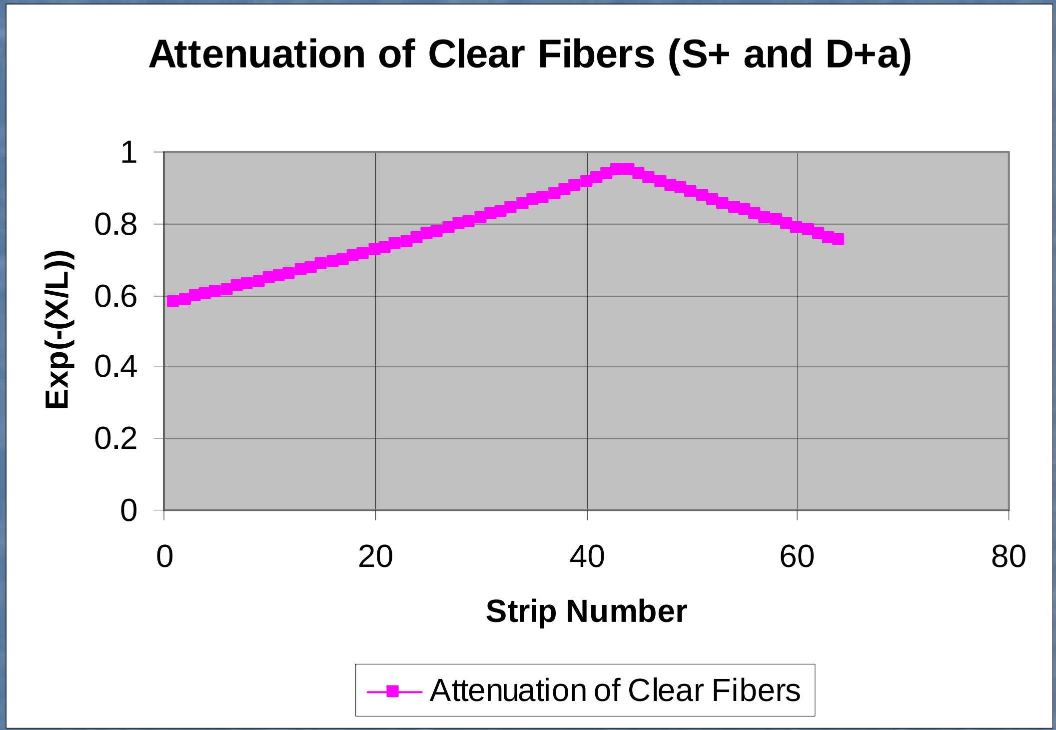


Effects of Variations of MAPMT Gain per Channel



Overall gain at 960V = 2.5 x 10**6 (Hamamatsu data sheet)

Effects of Varying Clear Fiber Lengths



For L = 5 m

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

11450 Total Events

S+ mean 439.2

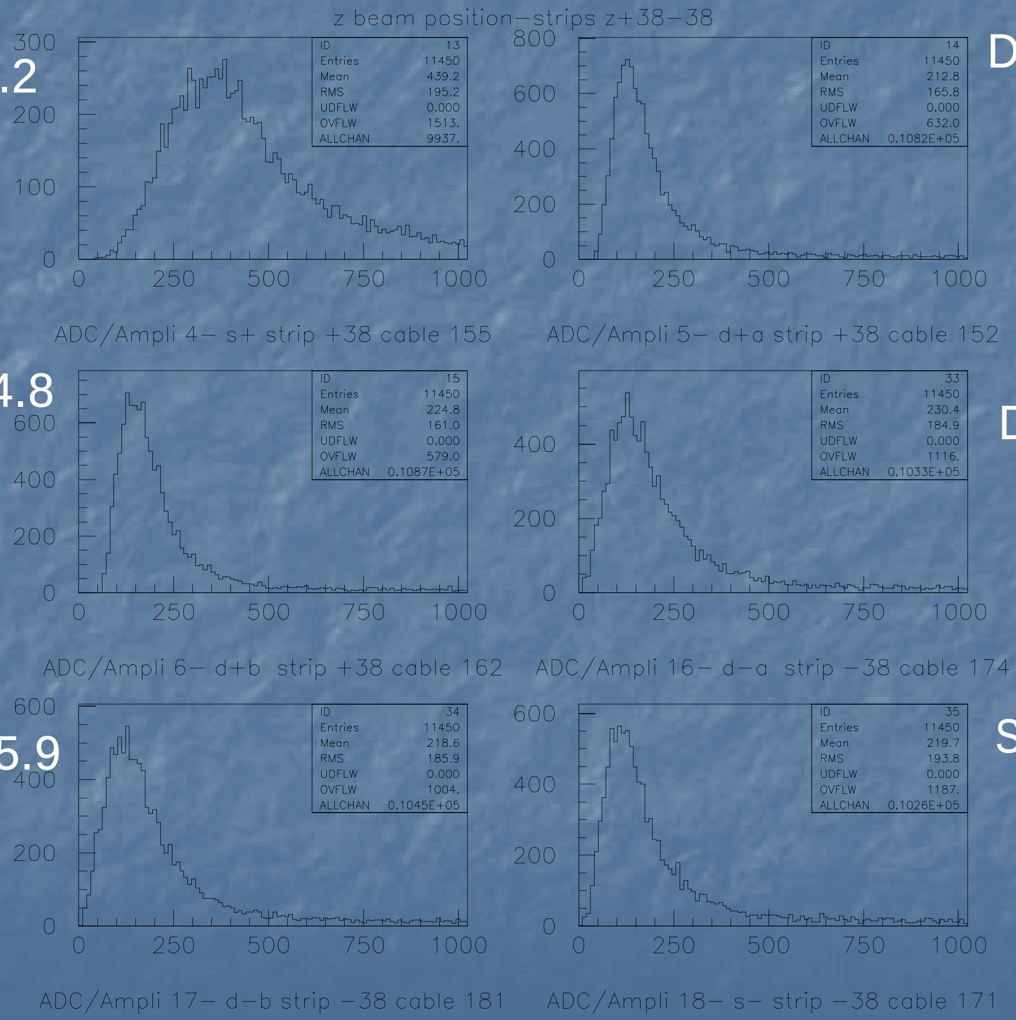
D+a mean 212.8

D+b mean 224.8

D-a mean 230.4

D-b mean 185.9

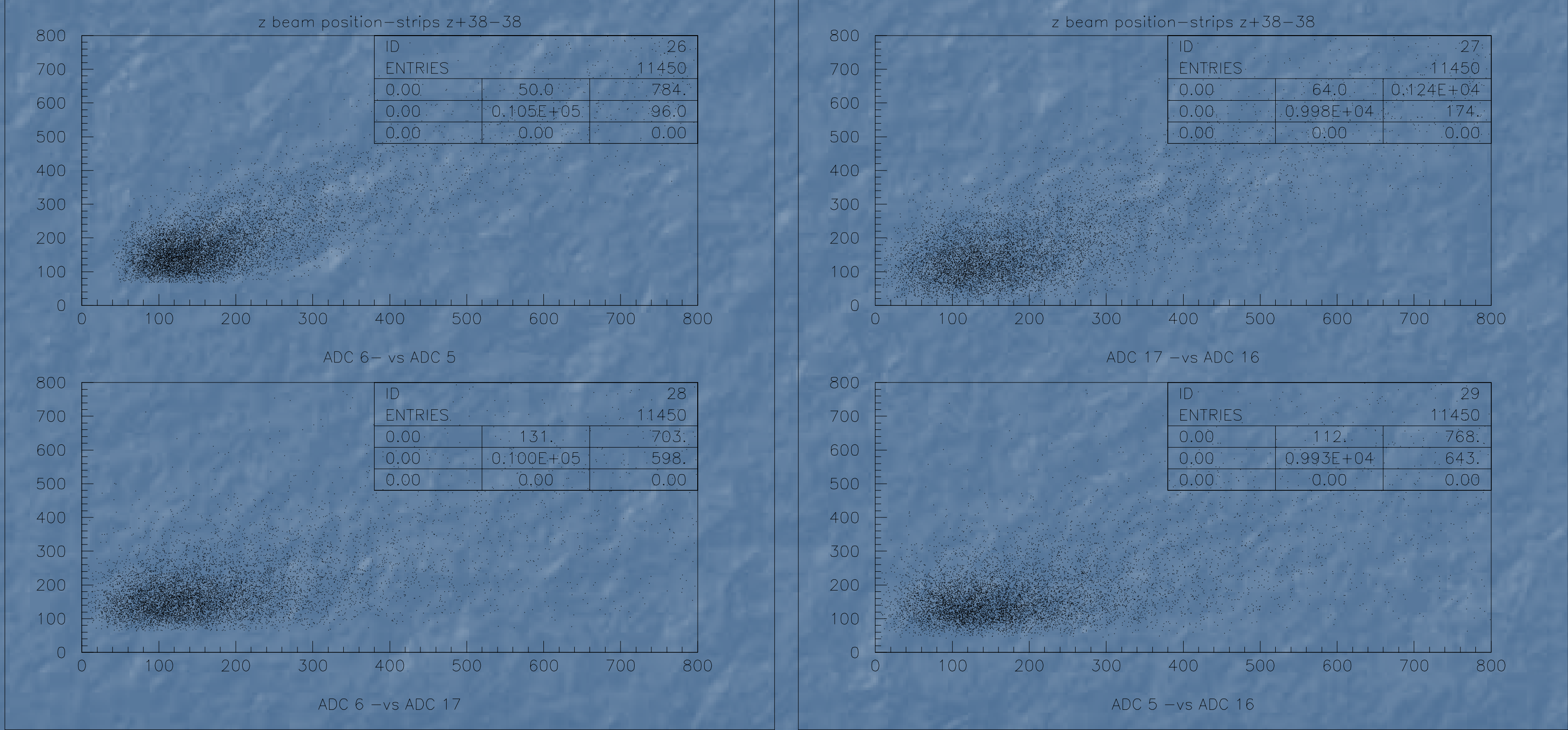
S- mean 219.7



Correlations Between Signals

D+b vs D+a

D-b vs D-a



D+b vs D-a

D+a vs D-b

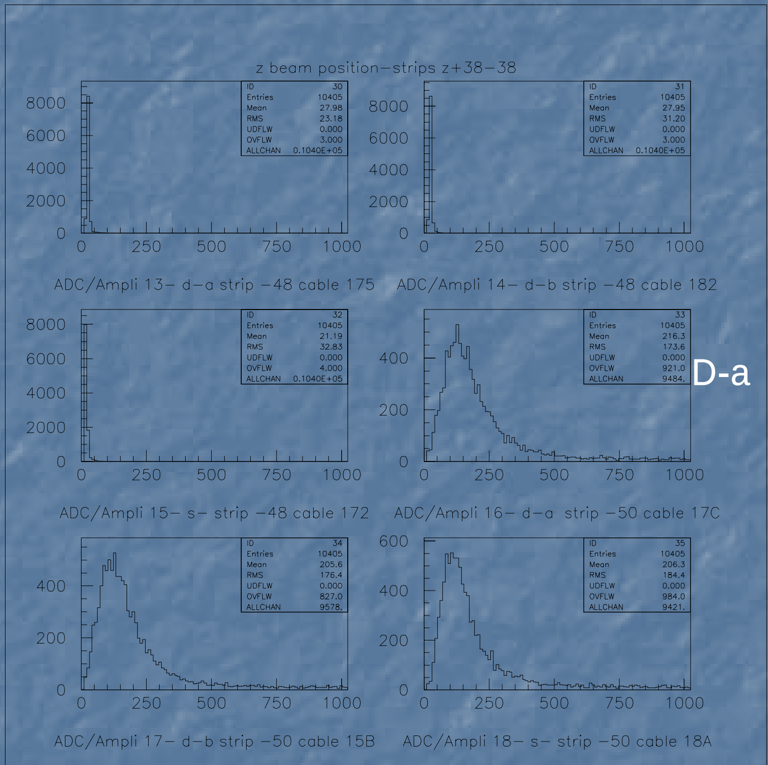
Multiple Beam Particle Events

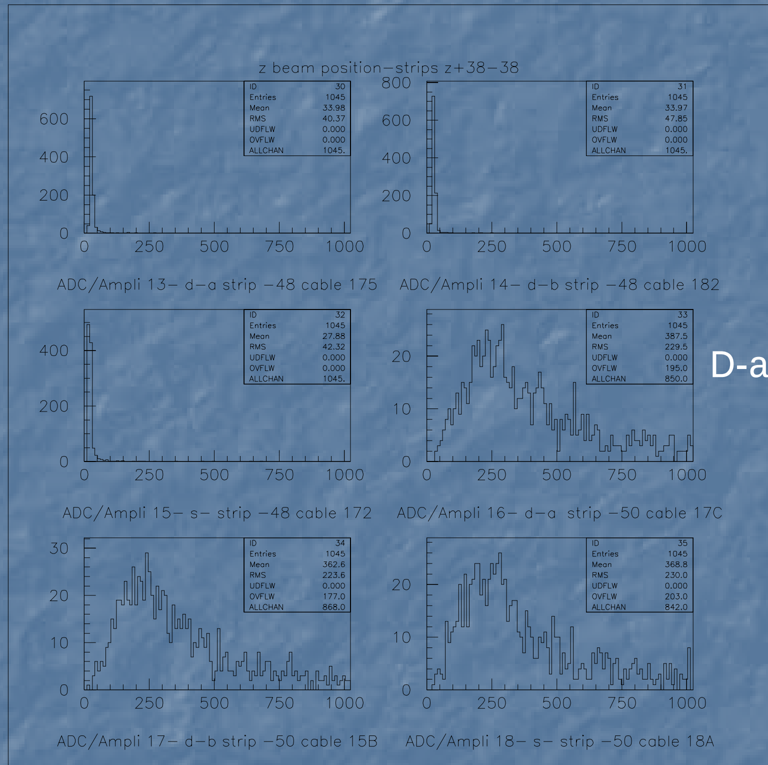
- Initially seen on scope
- Then counted using delayed gate in coincidence with beam signal.
- Finally put output of beam counter discriminator into an ADC channel
  - If 2 beam particles within ADC gate the charge measured is 2x the single signal charge, etc.
  - Can identify (and/or remove) multiple beam events from analysis by applying cut on “beam” ADC value.

Single and Double Beam Events from Run 6446

10405 Single Beam Particle Evts

1045 Double Beam Particle Evts





D-a Mean = 216.3

D-a Overflows =921 = 8.8%

D-a Mean = 387.5

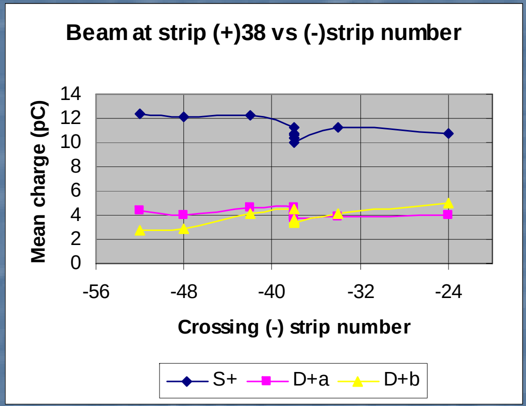
D-a Overflows = 195 = 19%

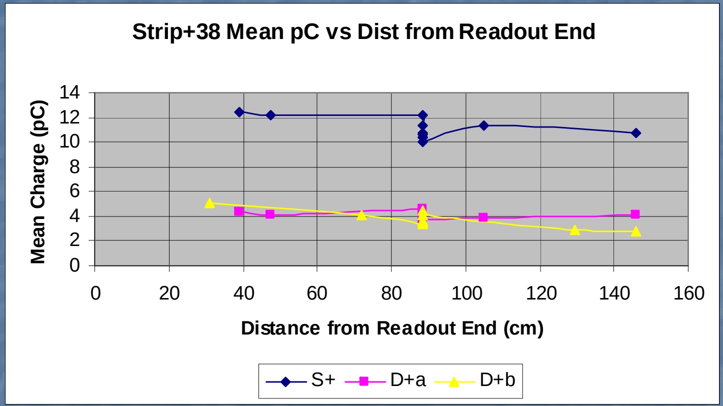
Observations from Single/Double Beam Events

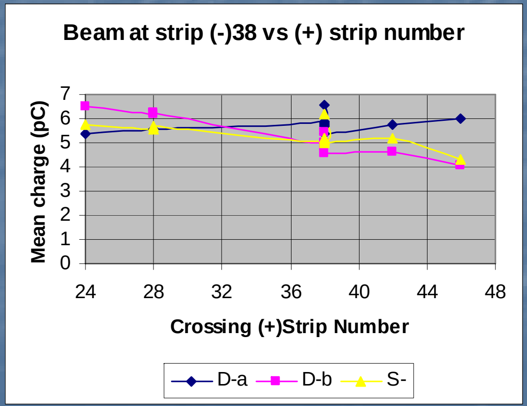
- Double beam events contribute more to high channel tail and overflows
- Mean is ~ 2X mean of single particles
- Provides basis for further study for tail catcher.
  - Implies need for larger dynamic range of signals in ADC to identify multiple particles compared to single muons.
  - Can remove 10X amplifiers to increase range of signals in ADCs

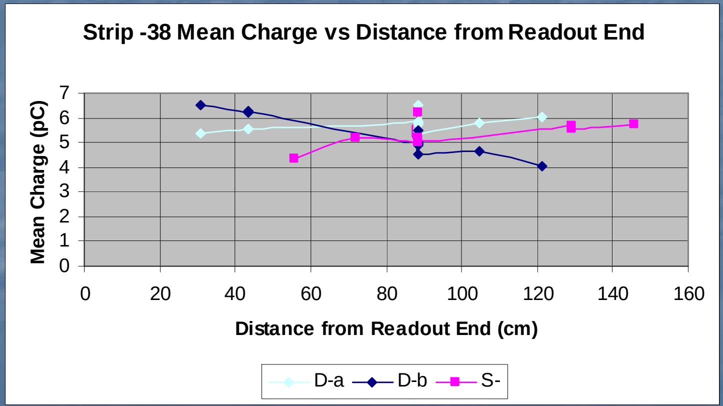
Responses along Strips 38

Double Beam Events Removed

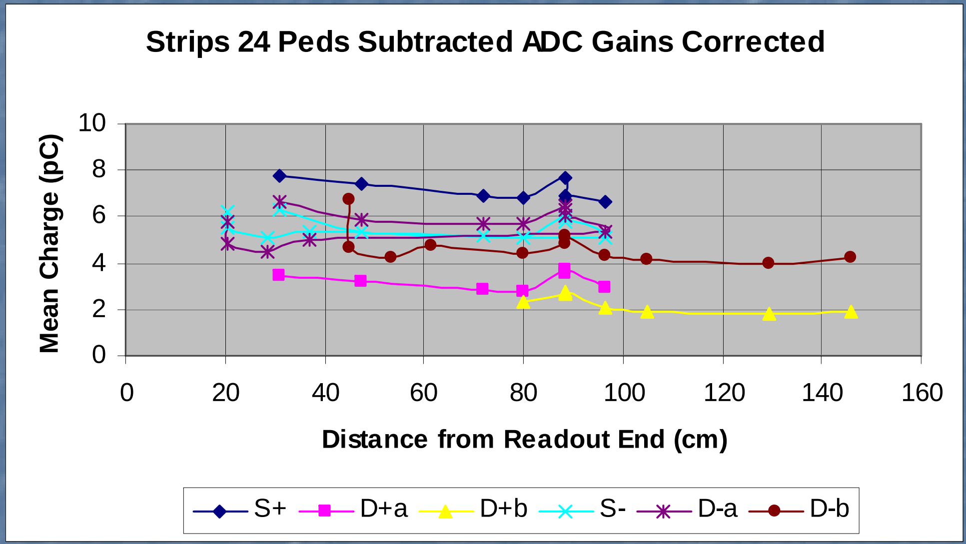






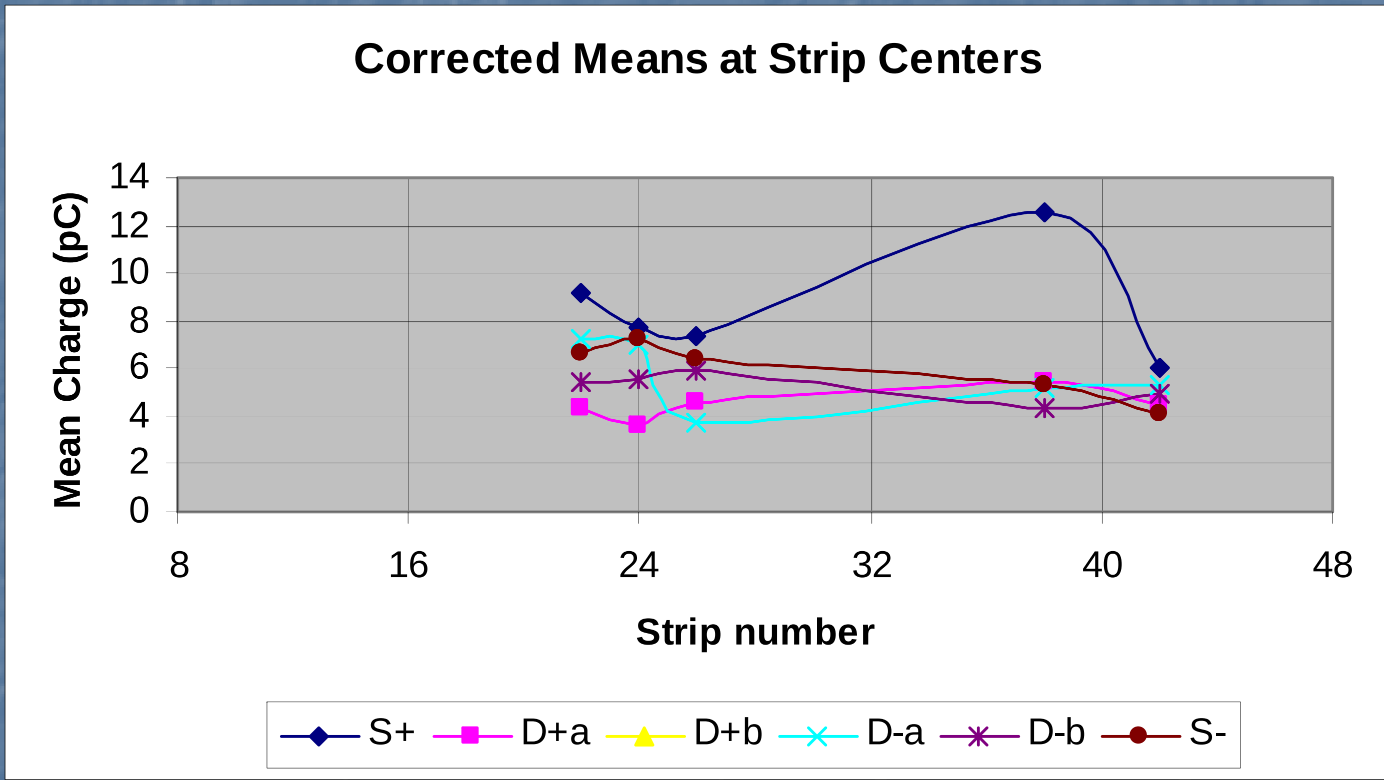


Responses Along Strips 24

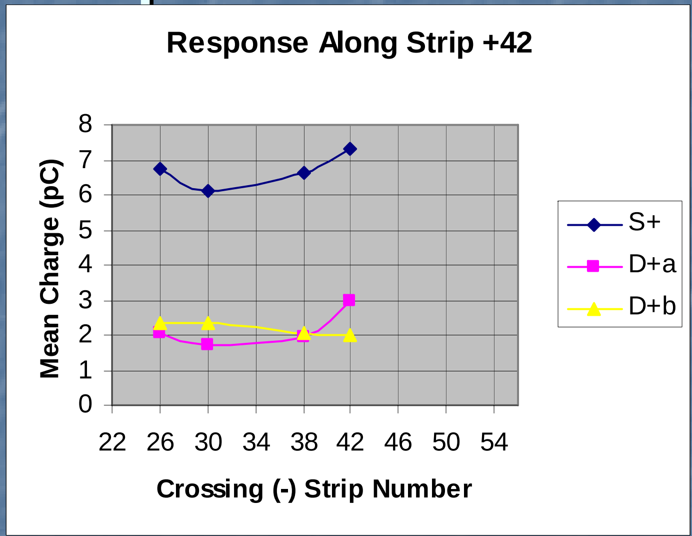


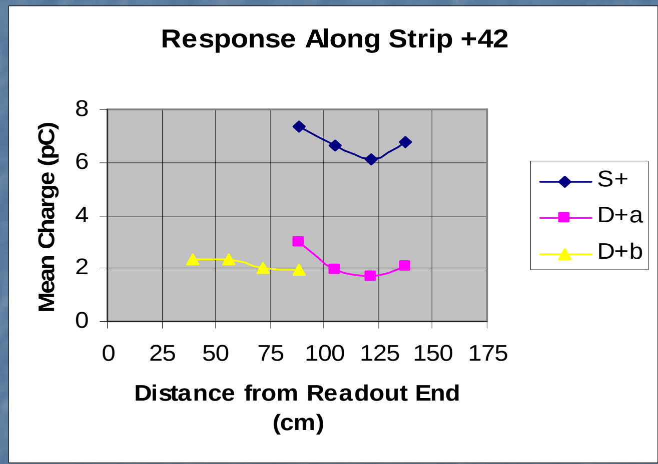
Double Beam Events Not Removed

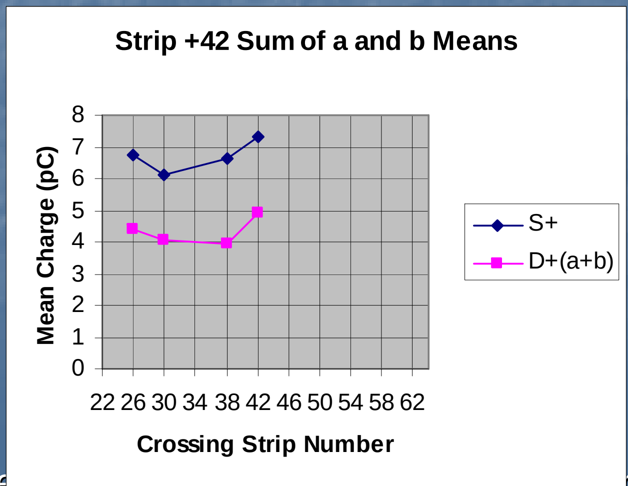
Preliminary Result: Response at Strip Centers



Preliminary Result:
Response at Points Along Strip +42







Photelectron Yields:

D+a or D+b separately: ~ 5 PEs
D+a and D+b combined: ~ 10 PEs
S+: ~14 PEs

Estimated PE Yields

- Using nominal gain of Hamamatsu 7546B: 2.5 x 10**6 at 960V, 2.5 pC <--> 6 PEs
- Then our yields are from 5-10 PEs for D+a and D+b to 16 PEs for D-a, D-b, and S-.
- S+ gain is probably higher than nominal
- Efficiency appears to be high – no sign of pedestal peaks in ADC distributions
- We'll have better estimates after calibrating the MAPMTs

"DAQ" Problem

- Resulted in badly structured ADC distributions and double peaked (split) pedestal distributions.
- Intermittant problem due to 5th bit failing to clear for beam and some cosmic ray triggers.
- Resulted in adding 16 counts to all signals and pedestals that did not have a value that used bit 5.
- Problem did not occur for pulser triggers.
- Able to filter out bad events by removing events with pedestal values in the spurious upper peak
- Found problem was due to a bad Jorway scaler in the CAMAC crate (8/17/06). Unit replaced – no more problems.

“DAQ” Problem: Run 6103

Raw Data, After Cut on ADC 19< 80