Scintillator/WLS Fiber Readout with Geiger-mode APD Arrays

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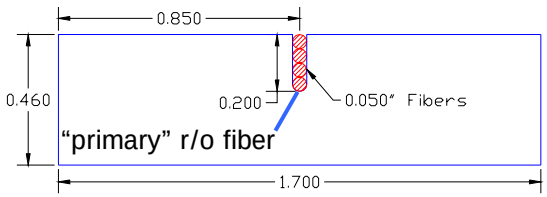
Overview

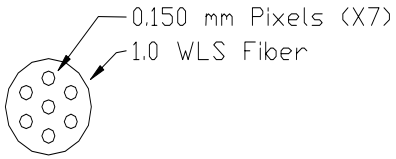
- Recap report at SLAC ALCPG meeting, Jan. 2004
- Results from 7-pixel cluster measurements (SBIR Phase I)
- SBIR Phase II: 2-year work plan

ALCPG – SLAC, Jan. 2004

- 4 x 1mm WLS (Y-11) fiber readout of 12 mm x 43 mm x 400 mm scintillator w/ cosmics
  - *Primary* WLS r/o fiber ~50% of total 4-fiber yield; ~110 γ/event
  - Primary spliced to clear fiber glued to single 150 μm GPD
  - ~4 photons/event onto pixel
  - Measured Detection Efficiency (DE) = 0.21 $\pm$ 0.05 (stat)
  - Expect ~0.24 from 550 nm LED measurements



- First 7-pixel cluster received 12/18/03

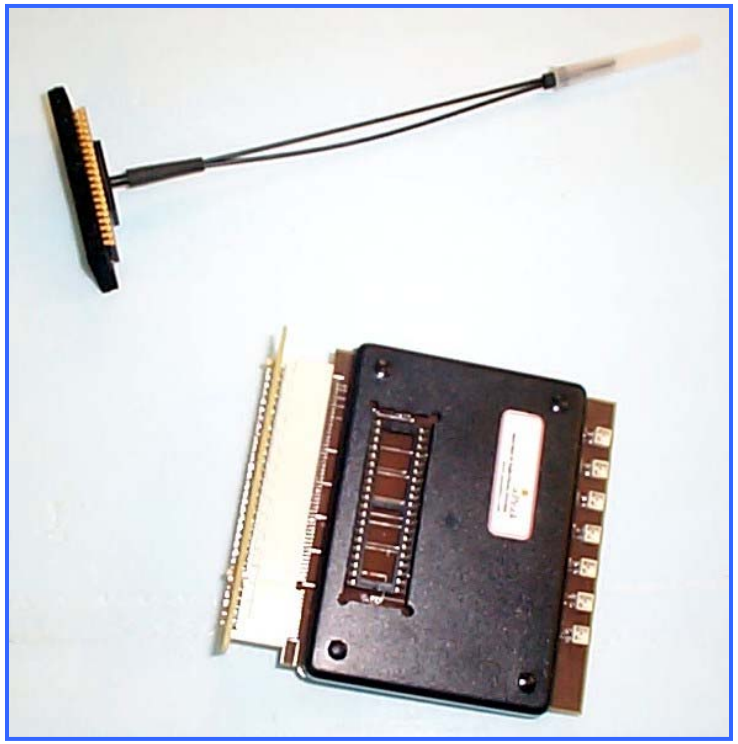


- LCRD Proposal – Comprehensive 3-year R&D plan - requested $65k in Year 1 (submitted also to DoE Advanced Detector program)

SBIR phase I – CSU Goals

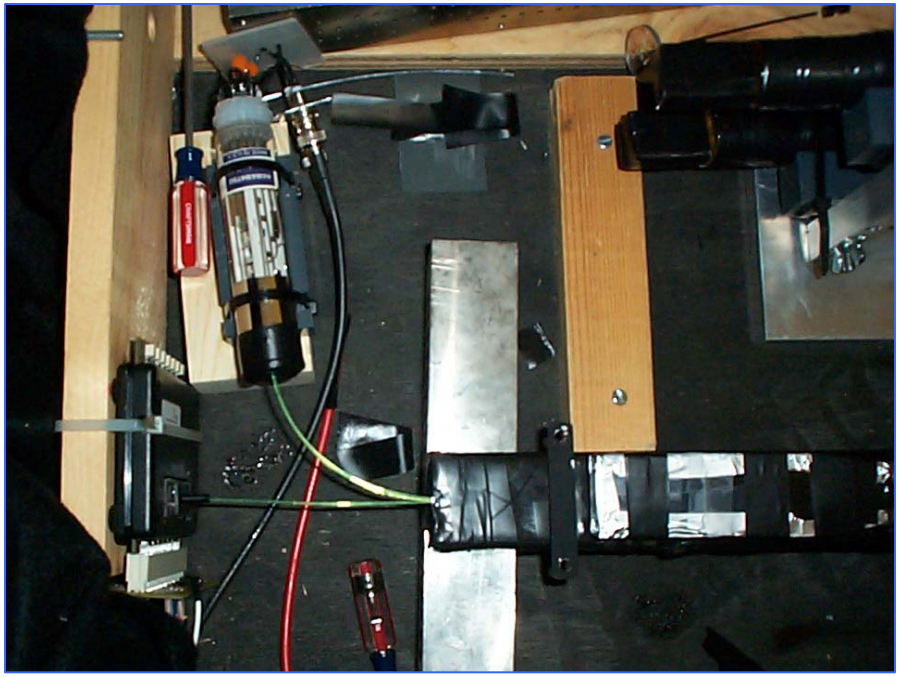
- Measure 7-pixel cluster detection efficiency for minions in scintillator bar
- Investigate timing characteristics of GPDs, and techniques for minimizing the impact of dark counts using pixel coincidences
- This talk: Measurements and analysis from spring 2004

7-pixel layout GPD



GPD Scintillator/Fiber Test Bed

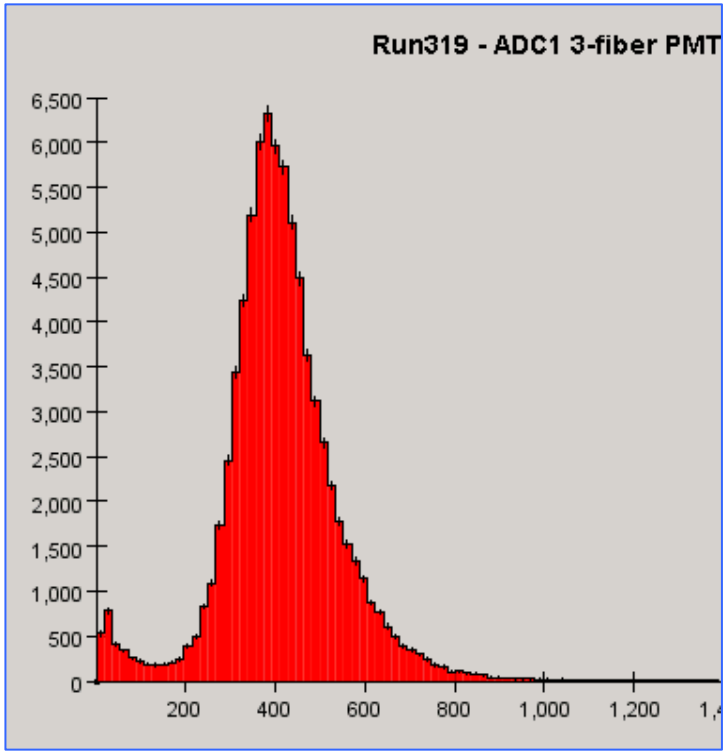
- P*rimary* WLS fiber is attached to the GPD array mounted on the left-hand side; mirror at opposite end
- Remaining three fibers are attached to the face of a PMT (Hamamatsu R2658)
- DAQ (LabView s/w)
  - GPD Time: Single-hit TDC (LRS 2228) r/o of each GPD in cluster + hod. scint.
  - PMT Charge: ADC (LRS 2249) 3-fiber PMT and both hod. scint.
  - Event time



The hodoscope has been moved to the side for this photograph, it is visible in the top right.

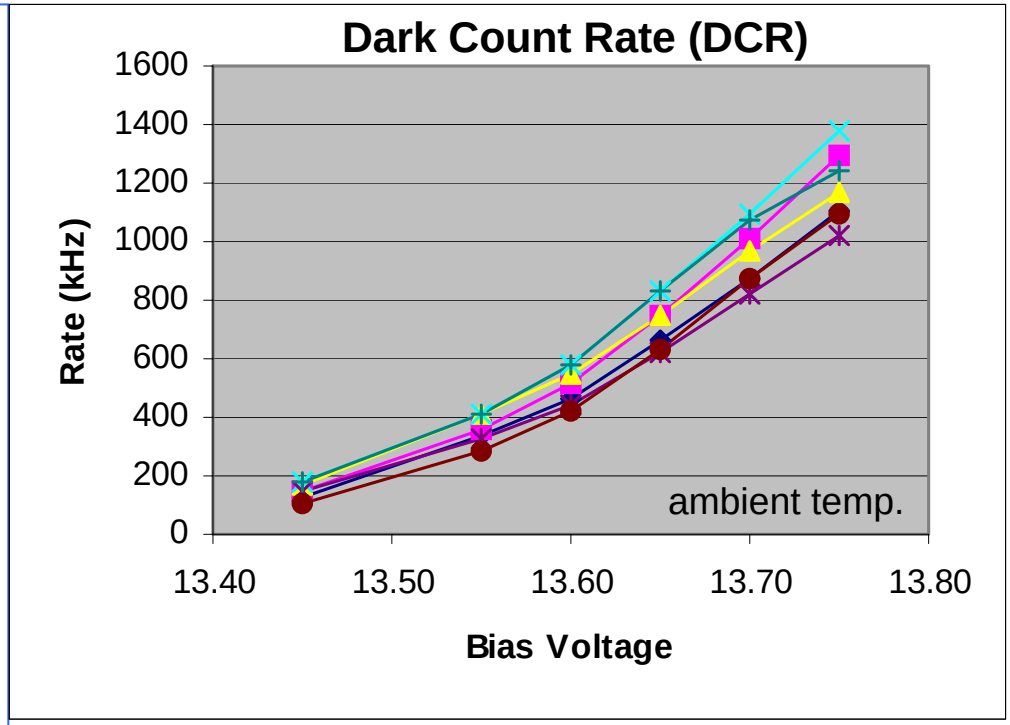
3-fiber PMT Charge distribution

- Integrated charge for 3-fiber PMT (< 3 ADC counts removed)
- Single photon response ~ 7 ADC cts
- Peak corresponds to ~ 60 photons (no mirrors on the fibers)



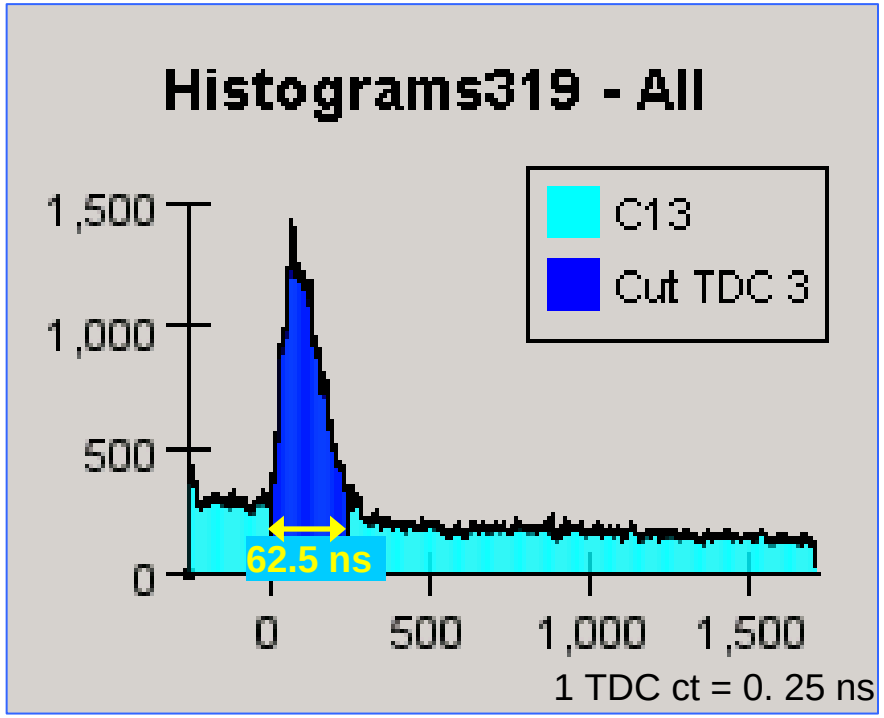
GPD signal characteristics

- GPD + active quenching circuit (AQC)
- Operating voltage: -13.4 V to -13.8 V
- Amplitude 300 - 500 mV
- Rise time ~30 ns; 200 ns wide; 50 mV overshoot
- AQC not optimized; new version available, σ < 1 ns claimed by aPeak
- Background estimated from DCR measured before/after each run



* High DCR pixels can be identified optically – over-biasing (25%) produces photon emission proportional to DCR. Can be mechanically removed from array readout on-chip.

GPD Time distribution



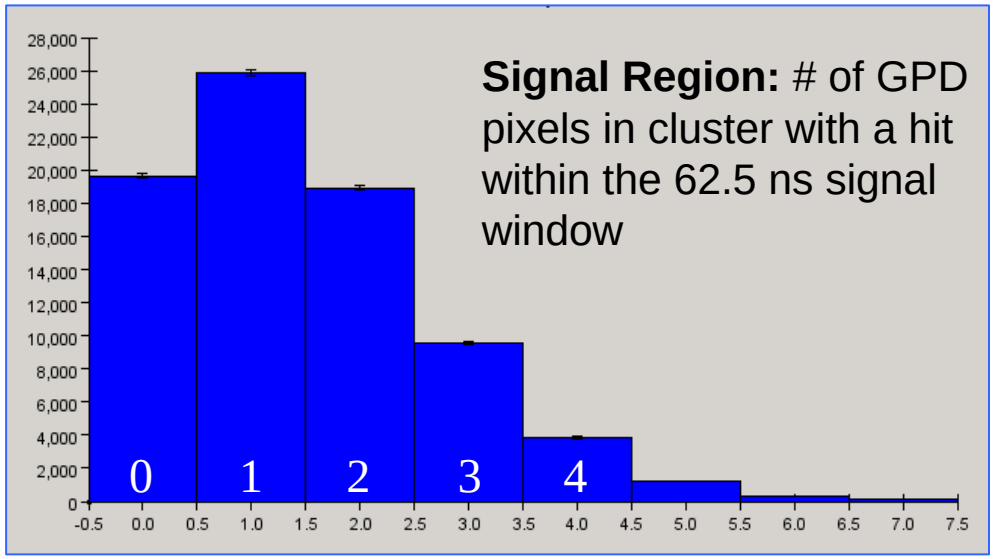
- Single pixel TDC distribution (ped/overflow removed)
- 120,000 triggers in 48 hours
- ~80,000 "good event" (3-fiber signal > 3 cts)
- Bias voltage -13.75 V

- Channel-by-channel background subtraction is calculated for each pixel using the measured DCR scaled to the signal window length

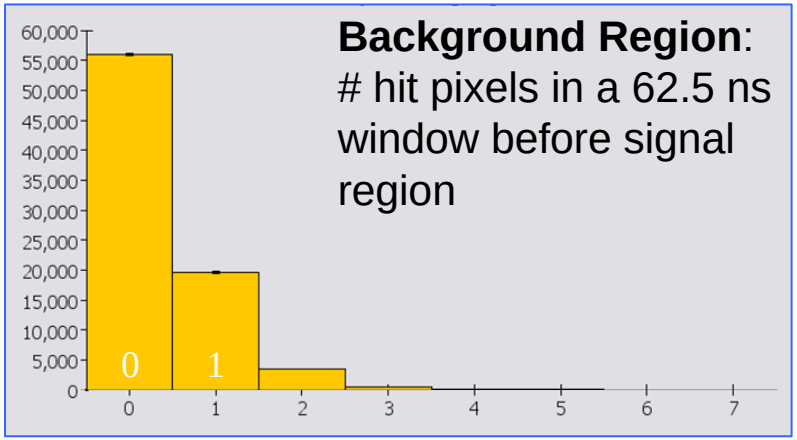
- The apparent slope of the background is an artifact of the single-hit capability of the TDC – a hit recorded early in the trigger window shadows hits that come later

  - this introduces a DCR dependence in the detection efficiency calculation (verified by toy Monte Carlo simulation)

Pixel hit distribution



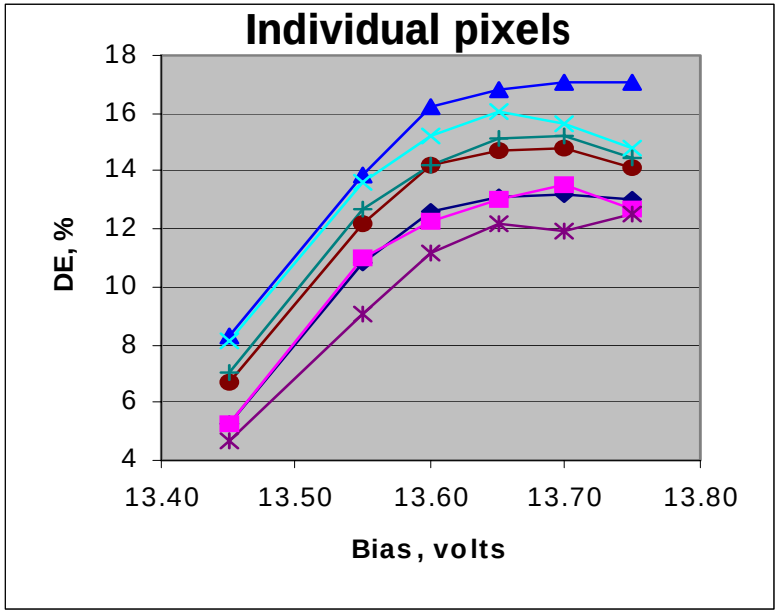
Signal Region: # of GPD pixels in cluster with a hit within the 62.5 ns signal window

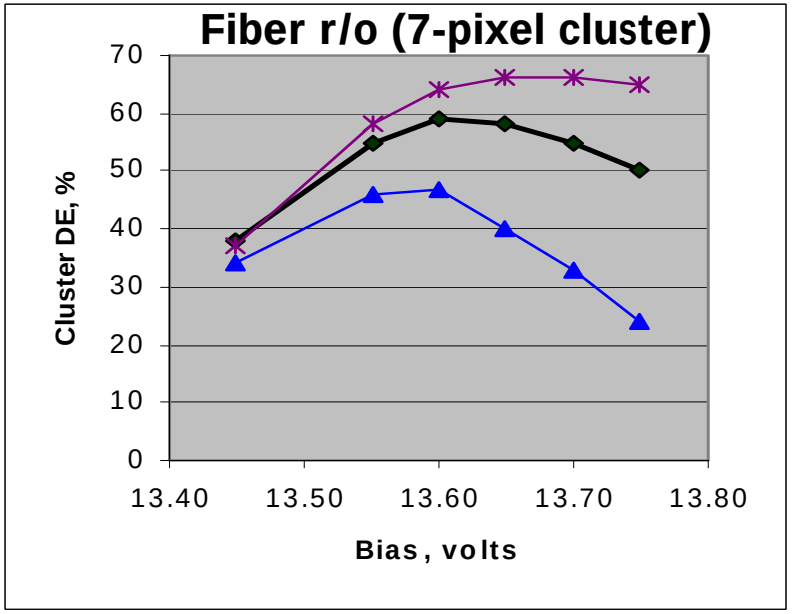


Background Region: # hit pixels in a 62.5 ns window before signal region

- Used to calculate cluster Detection Efficiency
  - need only that any one of the pixels has a true signal hit
  - use measured DCR to correct for background
  - DCR-dependent uncertainty
- Pixel crosstalk "low" – under study
  - Could increase pixel packing fraction

Detection Efficiency





- *cf* fall '03 single pixel value (21±5) %
- Could be fiber coupling/alignment
- Difficult to calculate effect of large DCR

Curves:

- middle – best estimate
- top – calculated from single pixels if no noise/correlation
- bottom – overestimation of background correction (to exaggerate effect of DCR)

LCD R&D Funding

- LCDRD request:
  - approx. $70k/year x 3 years
  - Develop devices/readout system compatible with LCD muon system prototype
- Awarded $15k – very useful
  - Allowed hire of technician this summer (just graduated student – Tom Toppel)
  - Update ancient DAQ (Mac -> PC; LabView v2.5 -> 7!)
  - Construction of an chamber for controlled GPD cooling
  - Additional analysis of existing GPDs
- **Many of other LCRD tasks will be addressed by the aPeak SBIR**

aPeak SBIR Phase II Goals

1. Increase the detection efficiency (to > 95% for "MINOS bars") by:
    - Decreasing the reset time;
    - Setting the optimal operation temperature; and
    - Improving the optical coupling to the scintillation fiber.
2. Develop GPD arrays architecture for dual tracking and calorimetry operation
3. Improve the timing performance
4. Develop compact and improved interface electronics (active quenching circuitry and drivers) with:
    - Integrated bias control to compensate for process variations
    - Additional amplification stage with improved stability
    - Signal multiplexing in cluster.
5. Identify failure mechanisms and extract lifetime
6. Develop 64 channel GPDs to readout 1.2 mm diameter WLS fiber bundles in scintillator strip configuration.
    - Demonstrate performance on CSU setup
    - Validate performance and functionality in beamline at Fermilab.
7. Performance versus Cost Analysis

Deliverable: Ten 64 channel GPDs (incl. AQC and driver electronics) to read out 640 WLS fibers.

SBIR Phase II : Performance Schedule - aPeak

	design review
	progress review
	task begin/end

TASK	Task Begin/End (quarter)								Milestone	Level of Effort (%)
Detection Efficiency Enhancement									Detection efficiency >95%	11.8
Improvement of the timing performance									Reset time 700 psec	5.4
Develop Compact Interface Electronics									AQC schematic selected	15.7
Develop GPD Array Architecture for dual tracking and calorimetric operation									Demonstrate separation of single photon events	5.4
Develop and refine the fuse technique for array repair and configuration									Hardware and procedure to repair and configure arrays	2.0
Develop 64 channel GPDs to readout WLS fiber bundles in scintillator strip, MINOS style configuration									(1) 64-channel MCM design validated, (2) 64-channel monolithical module developed, qualified and delivered to CSU	19.7
Identify failure mechanisms and extract reliability lifetime									(1) Burn-in procedures developed	4.9
Prototype fabrication line									(1) Equipment setup (2) Operation protocol in place	4.9

SBIR Phase II: Performance Schedule - CSU

	design review
	progress review
	task begin/end

TASK	Task Begin/End (quarter)								Milestone	Level of Effort (%)
Build and test experimental muon setup									Setup fully tested and calibrated	4.7
Y11-GPD interface development									(1) Interface module fully qualified (2) Procedures documented	3.2
2nd-generation GPD module qualification									(1) Data acquisition completed and validated (2) GPD tested and feedack provided to aPeak	3.4
Muon system hardware, interface and plant engineering									(1) Optical interface built (2)Cooling system operational	5.9
3rd generation GPDmodule qualification									Test bed completed and performance documented	7.9
Muon system test in beam line									(1) Muon system mounted to LCD (2) Data acquired and analyzed	5.0

Summary

- First demonstration of fiber readout with GPD cluster
- Configuration far from optimized
  - High dark count rate complicates extraction of DE
  - Crosstalk seems okay – increase packing fraction?
- Will construct cooling system with LCD R&D funds
- Two-year SBIR Phase II directed significantly by LCD muon readout specs
  - Funds this fall