Geiger Mode APD status and Development Planning

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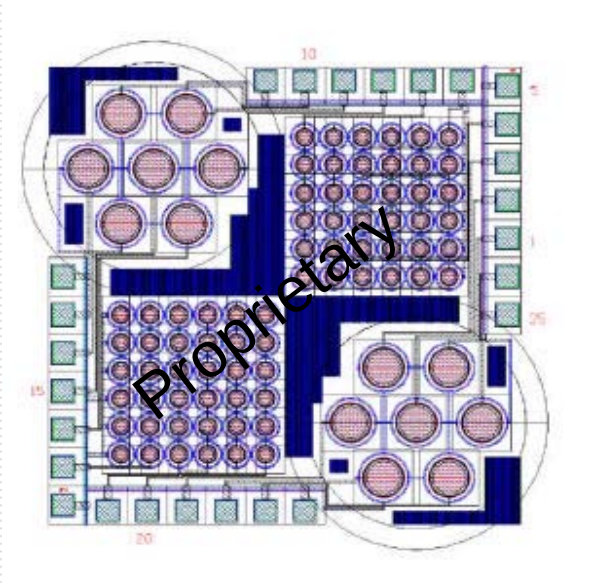
Overview

- aPeak GPDs
- SBIR Phase I Results Summary
- Plans for Phase II
- Conclusions

aPeak GPDs

- aPeak GPD pixels are similar to SiPMT pixels, optimized to binary WLS fiber readout
  - 7 150-micron diameter pixels
  - Active quenching to minimize pixel dead time
  - Low bias (~-13.6V)
  - 350 – 400 kHz DCR



Advantages:

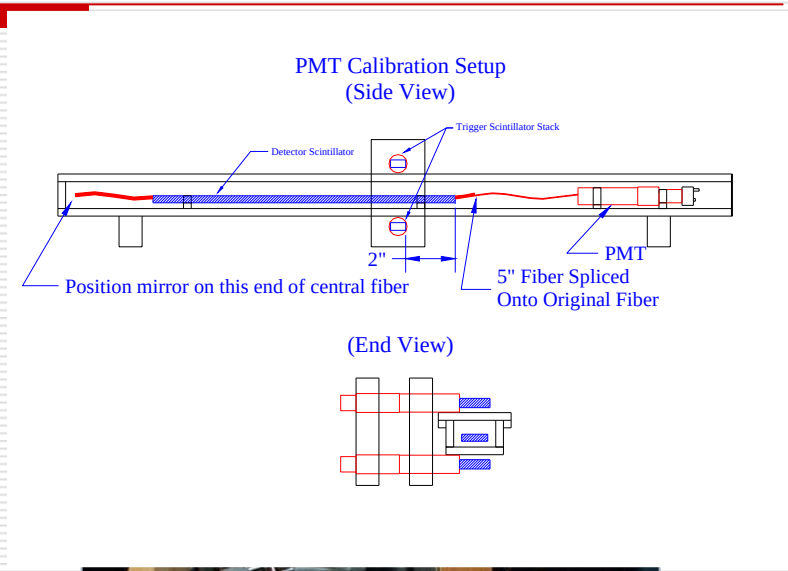
- Minimal readout electronics
- Minimal physical plant requirements
  - Low operating voltage
  - High gain (typically $>10^8$)
  - Potential for integrated active quenching and TTL readout
- Potential for low cost and high reliability
  - CMOS technology should result in high yields
  - Minimal (no?) cooling requirements

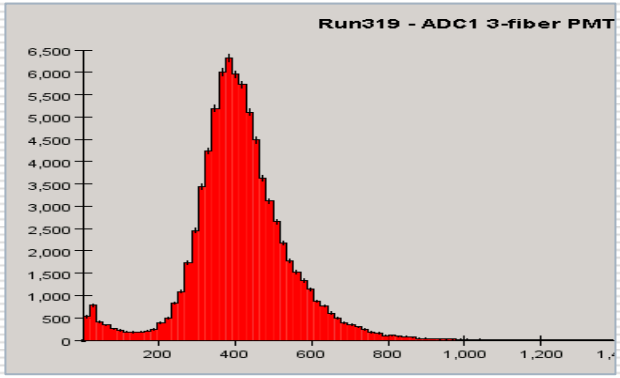
SBIR Phase I

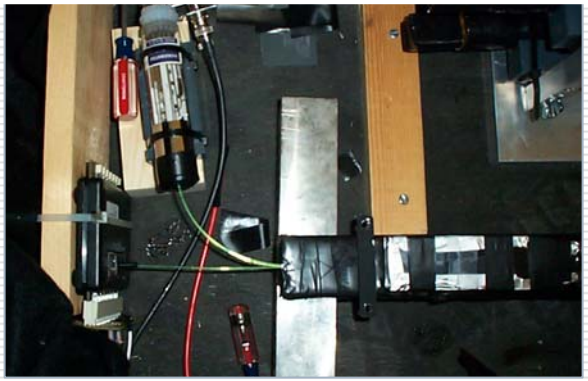
- 7-pixel array optimized for MINOS style SiFi readout produced
- Measurements of detection efficiency and DCR made at CSU

CSU Test Bed

- Consists of MINOS-style scintillator bar with 4 embedded Y-11 fibers
- GPD reads one fiber, other 3 go to calibration PMT
- Approx. 3 photons/track

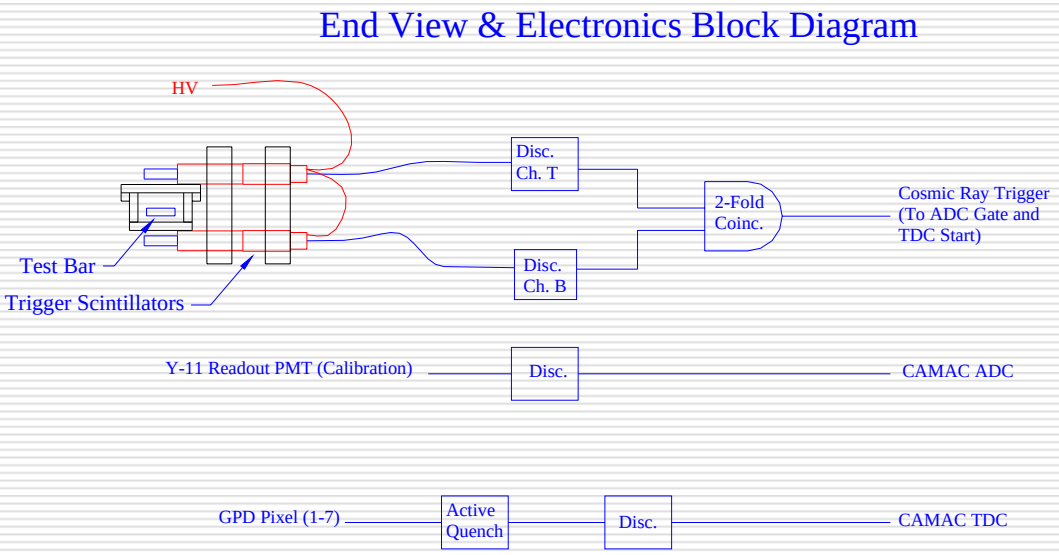






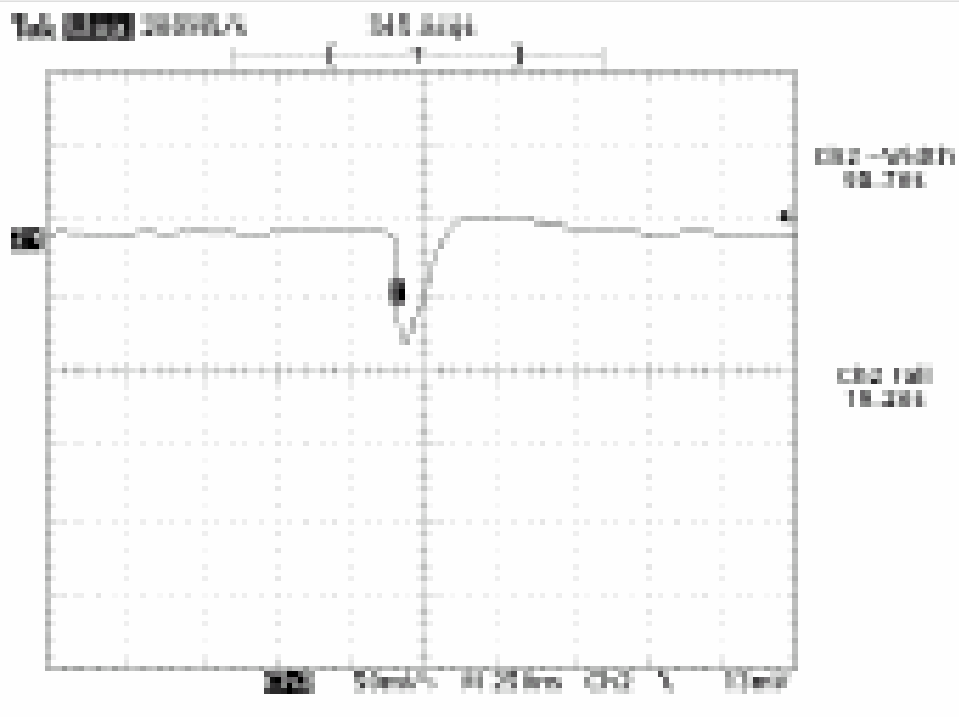
Phase I Electronics Setup

- Phase I electronics based on LabVIEW readout of CAMAC electronics
- Limited to ~10 Hz data collection rate
- Significant contribution to timing width from leading edge dciscrimination



Signal Characteristics

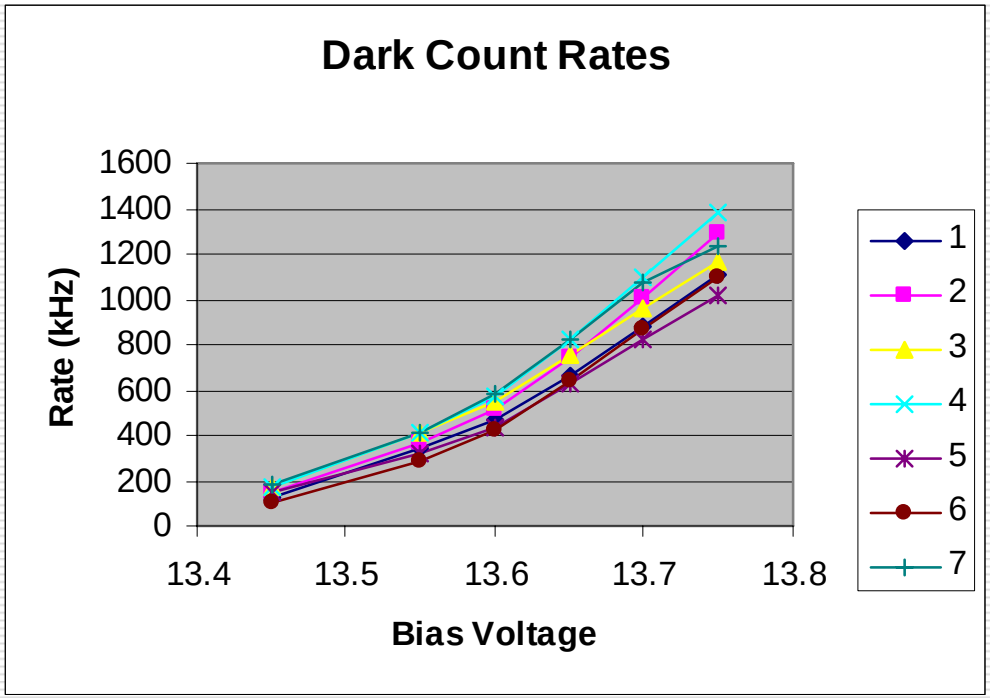
- GPD signal shape and amplitude determined by active quenching circuit
- Amplitude 300 - 500 mV
- Rise time ~30 ns; 200 ns wide; 50 mV overshoot ~500 ns long



250 ns/division, 50 ohm load

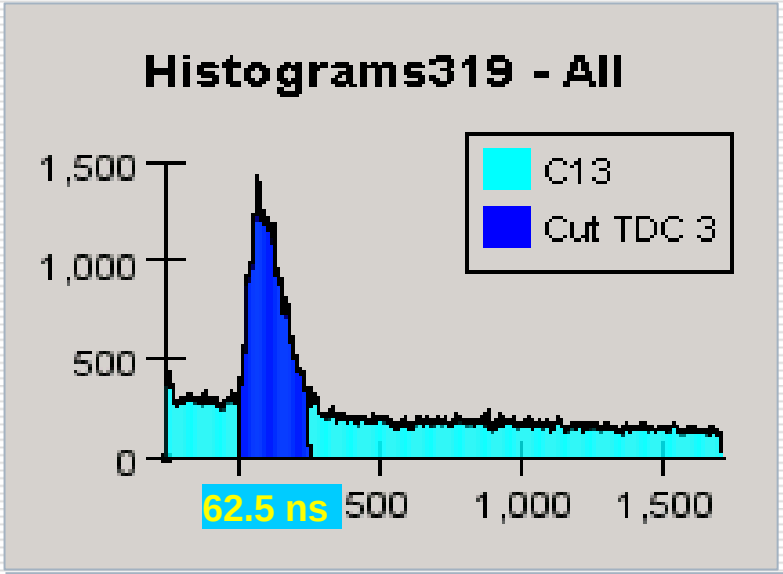
Dark count rate

- DCR varies strongly with bias voltage
- DCR also decreases with junction temperature– dependence still to be measured
- Background estimated from DCR measured before/after each run



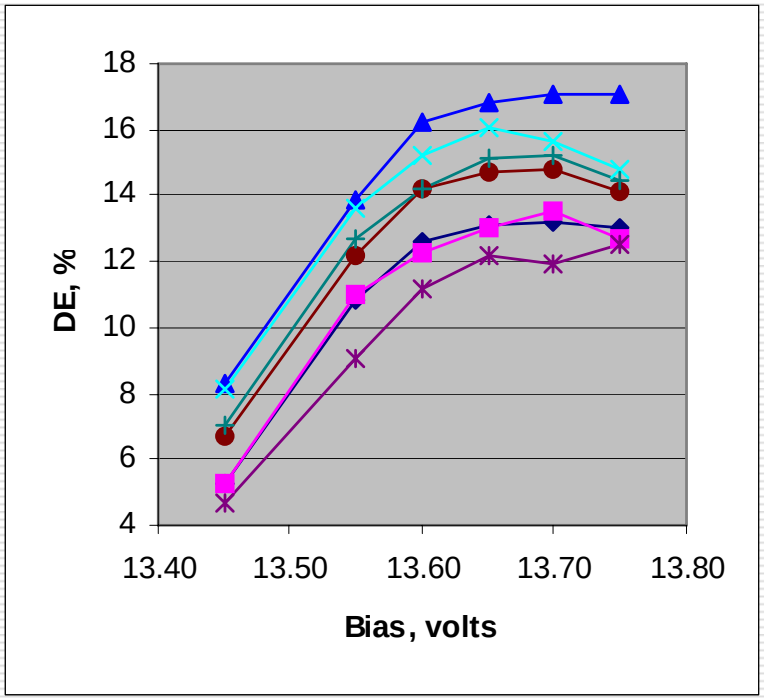
Signal Time Distribution

- Signals arrive in an approximately 62.5 ns time window
- Background subtraction for DE calculations uses a random 62.5 ns window
- Apparent slope in background is an artifact due to masking of late events by single-hit TDC.

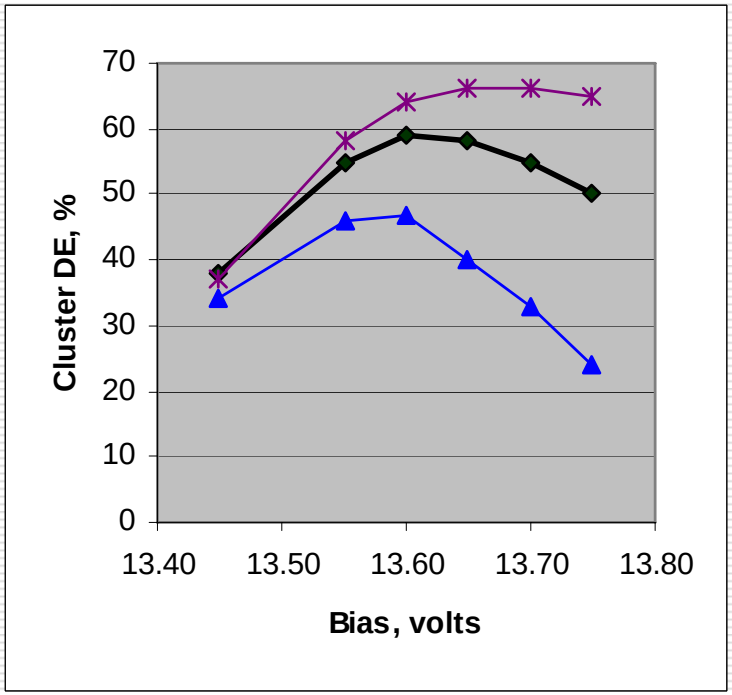


- Single pixel TDC distribution (ped/overflow removed)
- 120,000 triggers in 48 hours
- ~80,000 “good event” (3-fiber signal > 3 cts)
- Bias voltage -13.75 V

Measured Detection Efficiency



Single-pixel DE
~2.5 to 3 photons/pixel/event



Combined cluster efficiency
Middle– Best estimate
Top- No background subtraction
Bottom- no hit number weighting

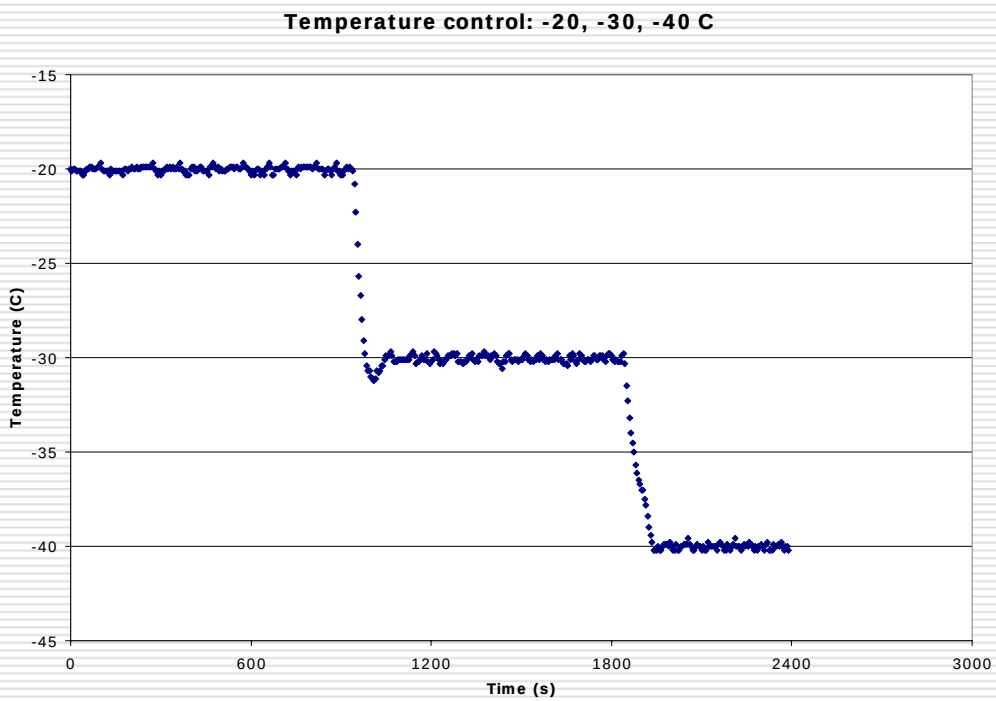
Main lessons from Phase I

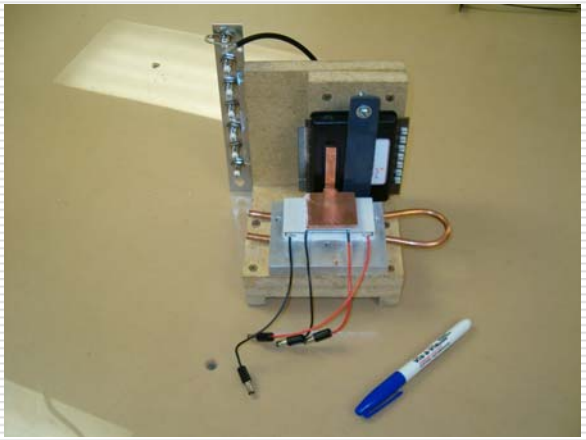
- ~60% detection efficiency is not sufficient. Our Phase I experience has pointed the way to improvements---
  - Reduce DCR (Cooling?)
  - Improve active quenching circuit (AQC) (reduce 62.5 ns collection time)
  - Improve photon collection (bigger pixels, improved photocathode surface)
  - Better fiber coupling

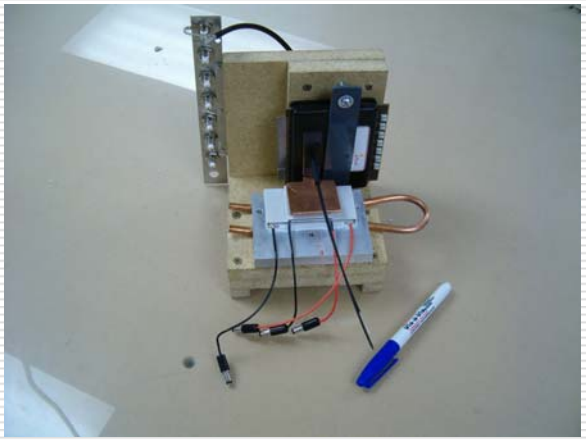
Phase II Plans

- aPeak was awarded an approximately $750K phase-II SBIR for GPD development in July 2004.
  - CSU awarded sub-contract of $167K for testing services
- 3 main development stages seen:
  - Produce next-generation GPD run implementing planned improvements from Phase I arrays (Spring 2005)
  - Produce 8-fiber readout chip with improved fiber coupling system (Summer 2005)
  - Produce 64-fiber GPD arrays to mate with ILC muon system prototype (Winter/Spring '05-'06)

Labview-controlled Peltier-junction chiller

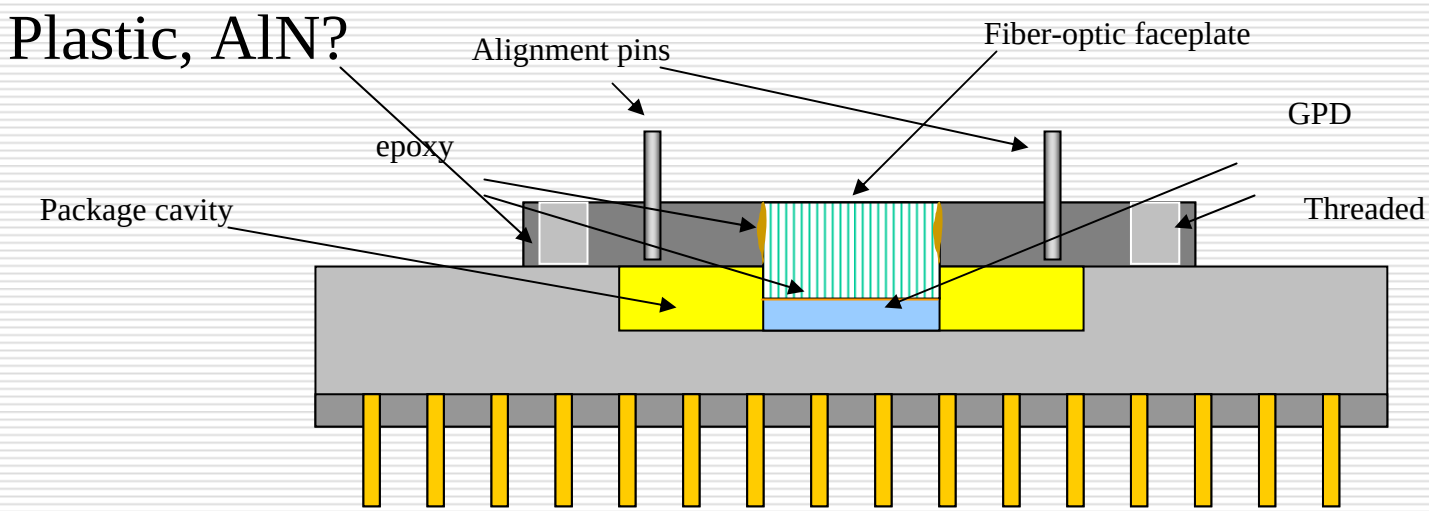






This work funded by LCDRD grant

New Fiber Mounting Scheme



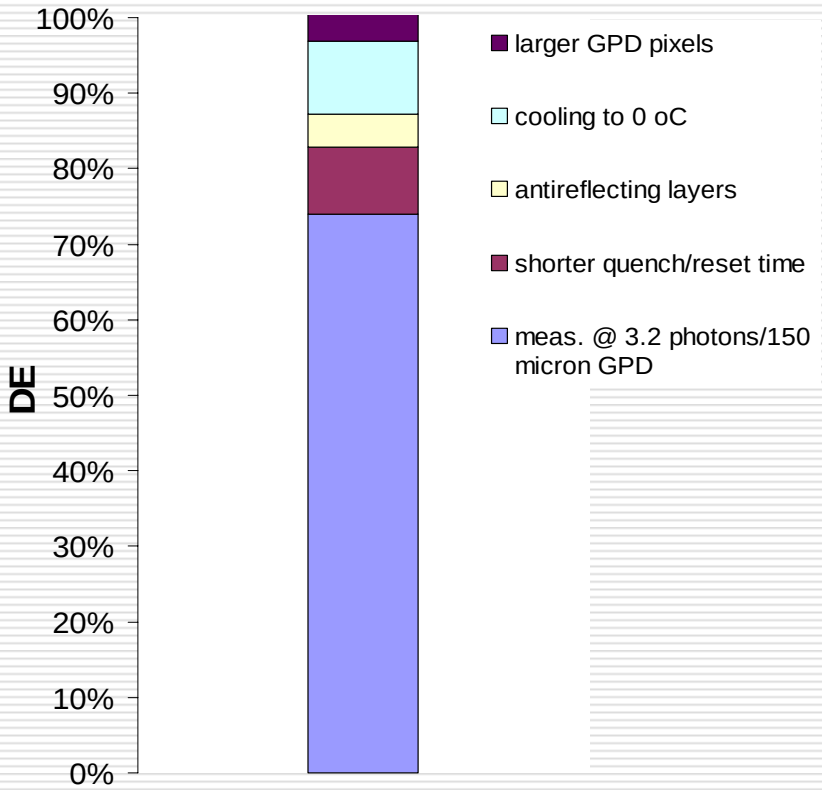
Optical interface

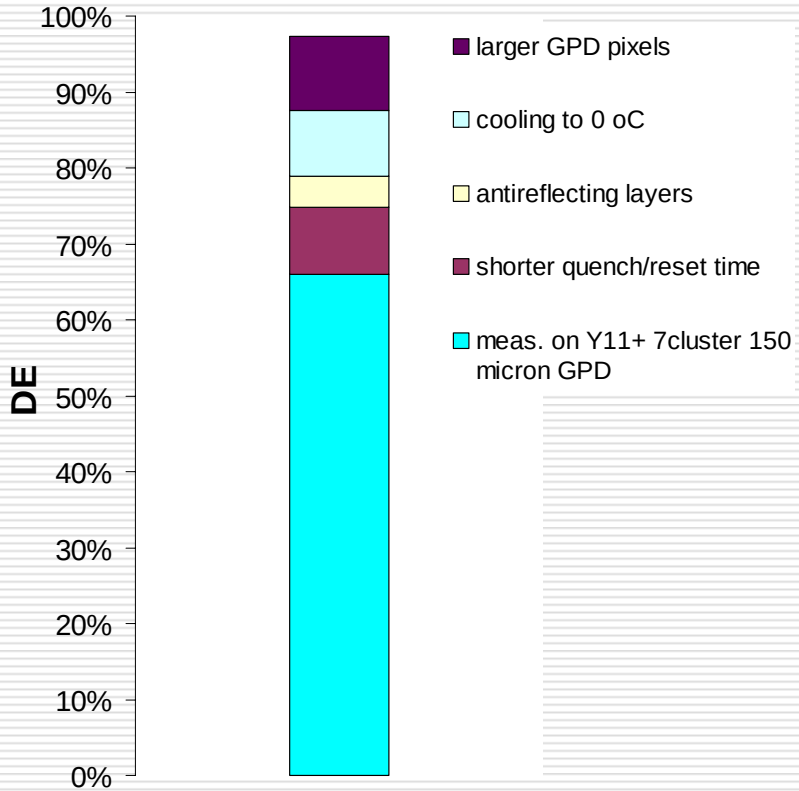
Improvements to generation 2 pixel array/electronics

- Pixel size increased to 170 micron diameter
- New anti-reflective SiO_2 coating on GPD surface
- New AQC (10 ns risetime, ~50 ns reset time, -1.5V signal into 50 Ω load)
- Cooling junction (to -20°C?)
- Improved fiber mounting technique
- AQC will allow for testing ganged readout of all 7 pixels in a cluster or individual pixel readout

- Sum of improvements are expected to yield detection efficiencies >90% per track

aPeak expectations for DE improvement





Bench test @ 10kHz MINOS style μ setup @ 0.06 Hz

Short-term Status

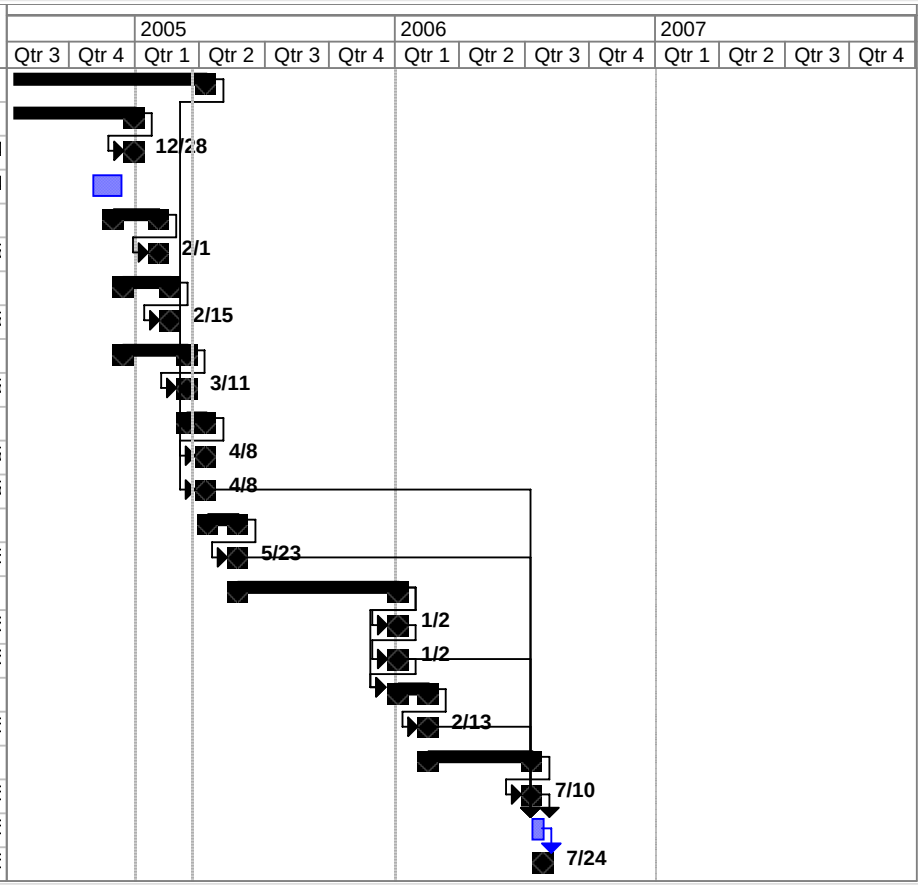
- Peltier junction cooler ready at CSU
  - Testing with Phase I GPDs to begin this week
- New Generation-2 GPD array and AQC expected at CSU before April 1
- Preliminary DE measurements expected 6 weeks after delivery

Plans for Generation 3 GPDs

- Generation 3 “Muon system test” GPDs will include:
  - 64 1-mm diameter fibers per chip (8 X 8 array)
  - “ganged” readout of all 7 pixels
  - Integrated signal conditioning– NIM logic level readout
  - Packaging to include cooling as required
- Readout will initially be via gated 64-channel CAMAC hit register (LabVIEW driven, slow data collection rate)
  - Other readout options may be implemented as needed for testing in muon system

Schedule for Phase II

ID	Task Name	Duration	Start	Finish
1	**WP Phase 1: New test bed for GPD testing**	**193 days?**	**Wed 7/14/04**	**Fri 4/8/05**
2	**Develop readout electronics**	**120 days**	**Wed 7/14/04**	**Tue 12/28/04**
6	Readout electronics ready	0 days	Tue 12/28/04	Tue 12/28/04
7	Procure scintillator bar	30 days	Mon 11/1/04	Fri 12/10/04
8	**Procure Calibrated PMT**	**45 days**	**Wed 12/1/04**	**Tue 2/1/05**
11	Calibration PMT Ready	0 days	Tue 2/1/05	Tue 2/1/05
12	**New Dark Box**	**47 days?**	**Mon 12/13/04**	**Tue 2/15/05**
16	Dark Box Ready	0 days	Tue 2/15/05	Tue 2/15/05
17	**Fiber Coupling Technique**	**65 days**	**Mon 12/13/04**	**Fri 3/11/05**
21	Fiber Coupling System Ready	0 days	Fri 3/11/05	Fri 3/11/05
22	**Certify test bed**	**20 days**	**Mon 3/14/05**	**Fri 4/8/05**
26	Test bed commissioned	0 days	Fri 4/8/05	Fri 4/8/05
27	GPD Test bed ready for use	0 days	Fri 4/8/05	Fri 4/8/05
28	**Test GPD module prototype at CSU**	**31 days?**	**Mon 4/11/05**	**Mon 5/23/05**
33	Test module prototype tested	0 days	Mon 5/23/05	Mon 5/23/05
34	**LCD Prototype detector simulator setup**	**160 days**	**Mon 5/23/05**	**Mon 1/2/06**
40	LCD Detector simulator ready	0 days	Mon 1/2/06	Mon 1/2/06
41	Third Generation 64-cluster GPD module at CSU	0 days	Mon 1/2/06	Mon 1/2/06
42	**Testing of Third Generation Module at CSU**	**30 days**	**Tue 1/3/06**	**Mon 2/13/06**
46	Third Generation modules tested	0 days	Mon 2/13/06	Mon 2/13/06
47	**Test modules in LCD Muon System Prototype**	**105 days**	**Tue 2/14/06**	**Mon 7/10/06**
55	LCD Muon System Testing completed	0 days	Mon 7/10/06	Mon 7/10/06
56	Final Report for aPeak	10 days	Tue 7/11/06	Mon 7/24/06
57	PROJECT COMPLETE	0 days	Mon 7/24/06	Mon 7/24/06



Summary

- Phase I GPD array testing lessons are being implemented in new Phase II devices
- New results should be coming shortly
- We expect to have GPD arrays for testing in a muon system in Feb. 06.
- We need to integrate further with the muon system to ensure compatibility with their test bed.