Photosensors for the SCT design: the MAPMT option

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- Georgia Tech.: Nepomuk Otte
- Barnard/Columbia: Andrea Egan, Manel Errando, Reshmi Mukherjee

What's on the market for a compact SCT design?

- MAPMT (this talk)
  - H8500/H10966B
  - R8900
- SiPM (Nepomuk's talk)
  - MPPC

MAPMT (H10966B)

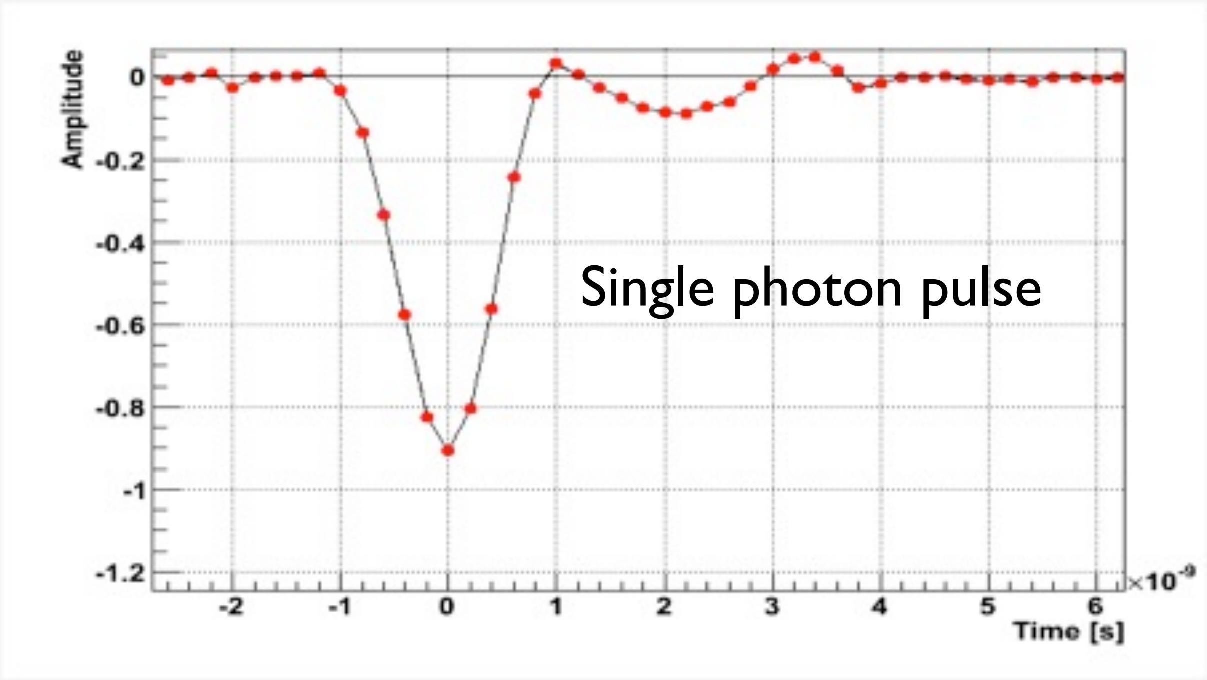
MAPMT (R8900)

MPPC (S10984)

	R8900	H8500/H10966B
Single p.e. response	can resolve single p.e. peak ☺	single p.e. peak sometimes hard to resolve ☹
Gain uniformity	RMS/mean ~ 11%	RMS/mean ~ 16%
Quantum Efficiency	~35% ☺	~35% ☺
Collection Efficiency	~80% ☺	~70% ☹
Dead space	~20% ☹	~10% ☺
Price	~60$/pixel ☹	~30$/pixel ☺

Hamamatsu H10966B (aka H8500D-103 MOD8)

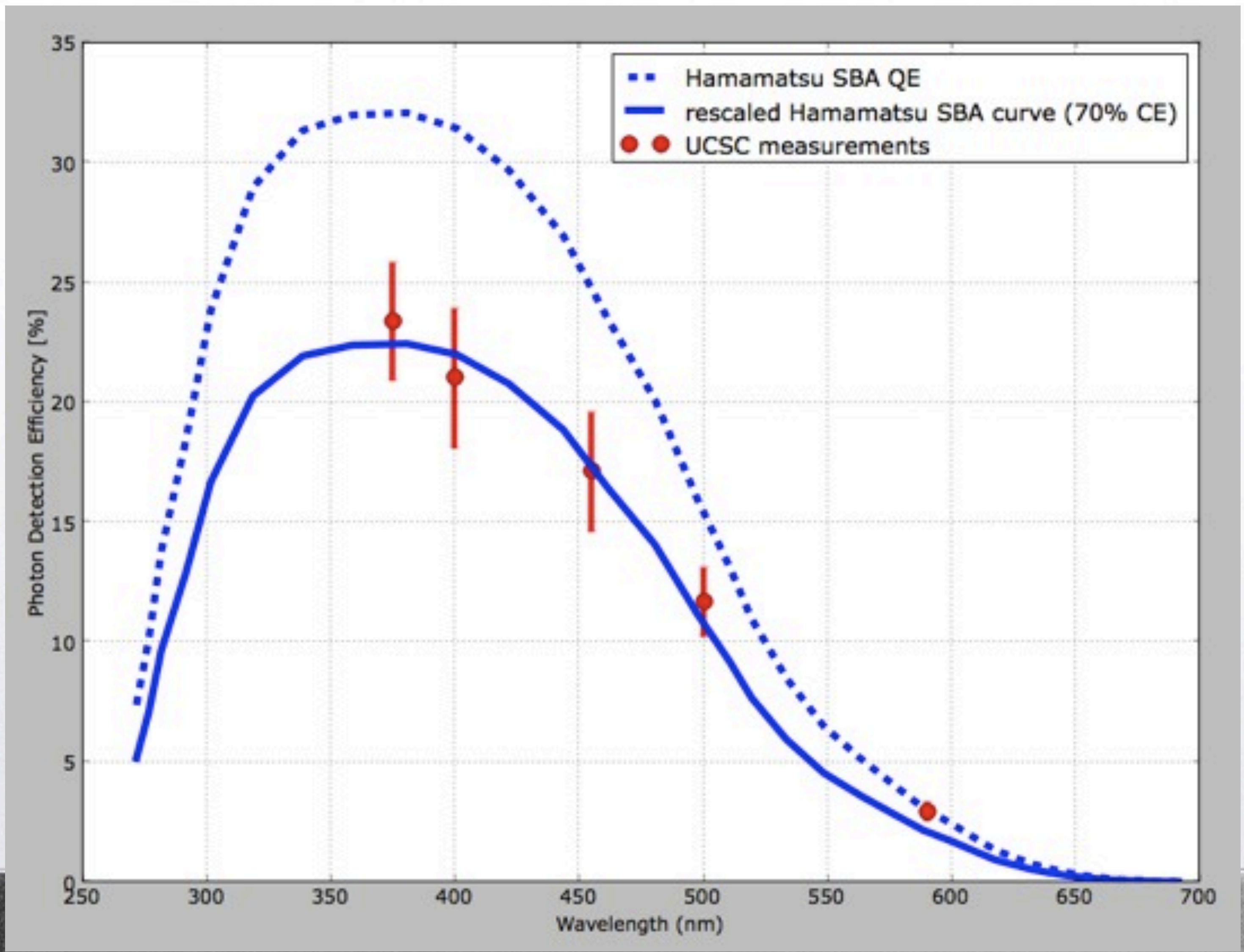
- Physical size: 52x52 mm^2
- Active area: 49x49 mm^2 (dead area ~ 11%)
- 64 pixels (8x8)
- Pixel size: 6.125x6.125 mm^2 (~0.067 deg / pixel)
- Available with SBA & UV glass
- 8 dynode stages

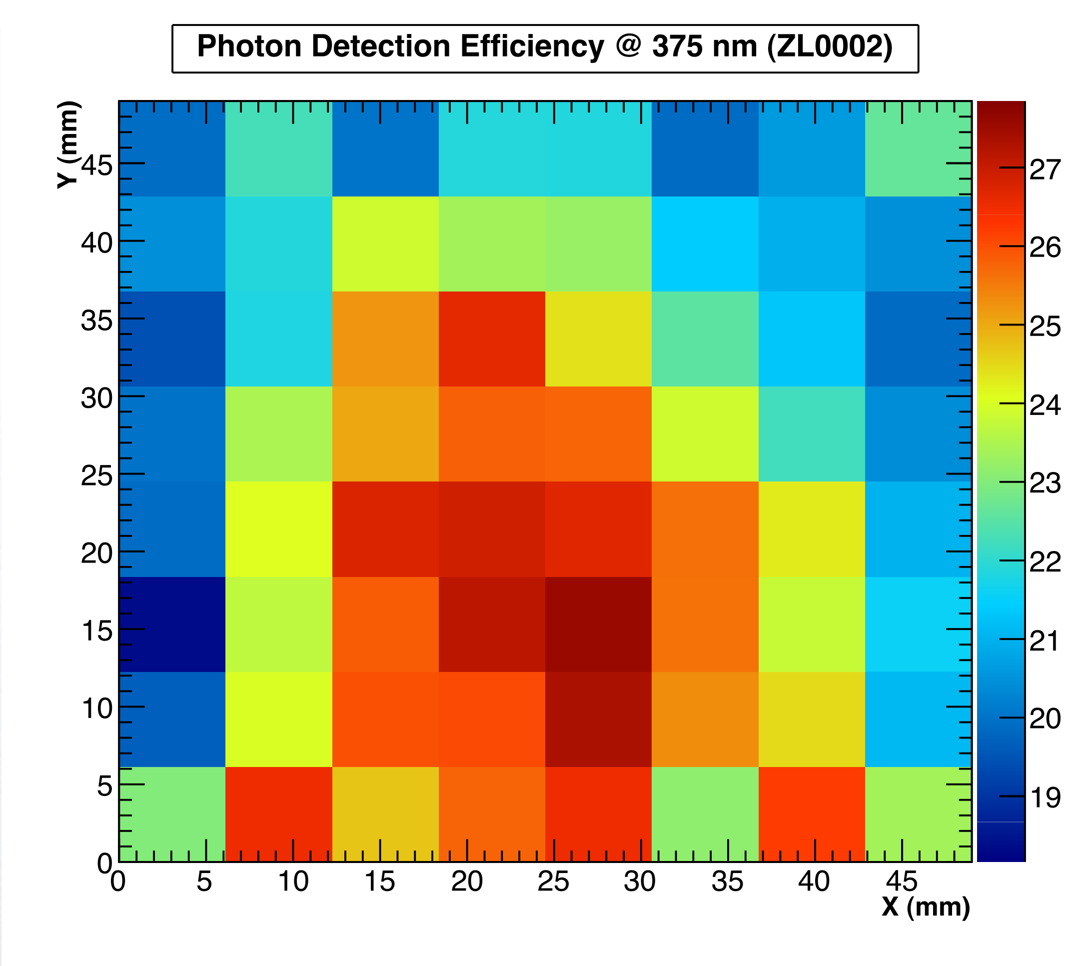


- Fast response:
  - 0.4ns rise, 4ns transit time, 0.4ns transit time spread
  - important to take advantage of isosynchronous design of SCT

Photon Detection Efficiency

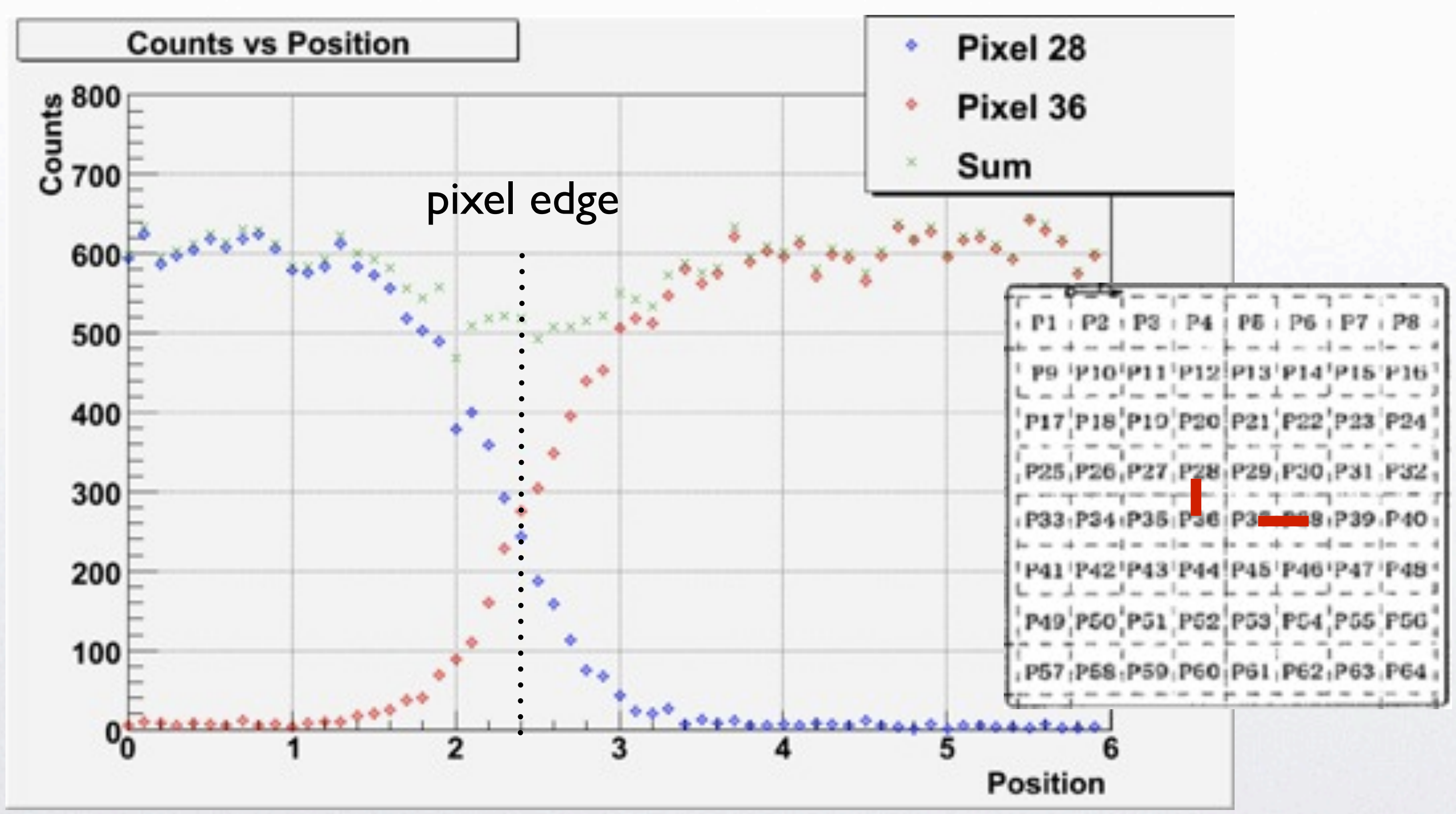
- Specs for SBA QE is 32% min at peak (~35% average advertised by Hamamatsu). UCSC PDE measurements at 375 nm is ~23.5% on average => ~70% collection efficiency
- Hamamatsu working on a redesign of the focusing electrode structure to improve CE (2 years timescale?)
- Highest PDE values in central pixels of the tube

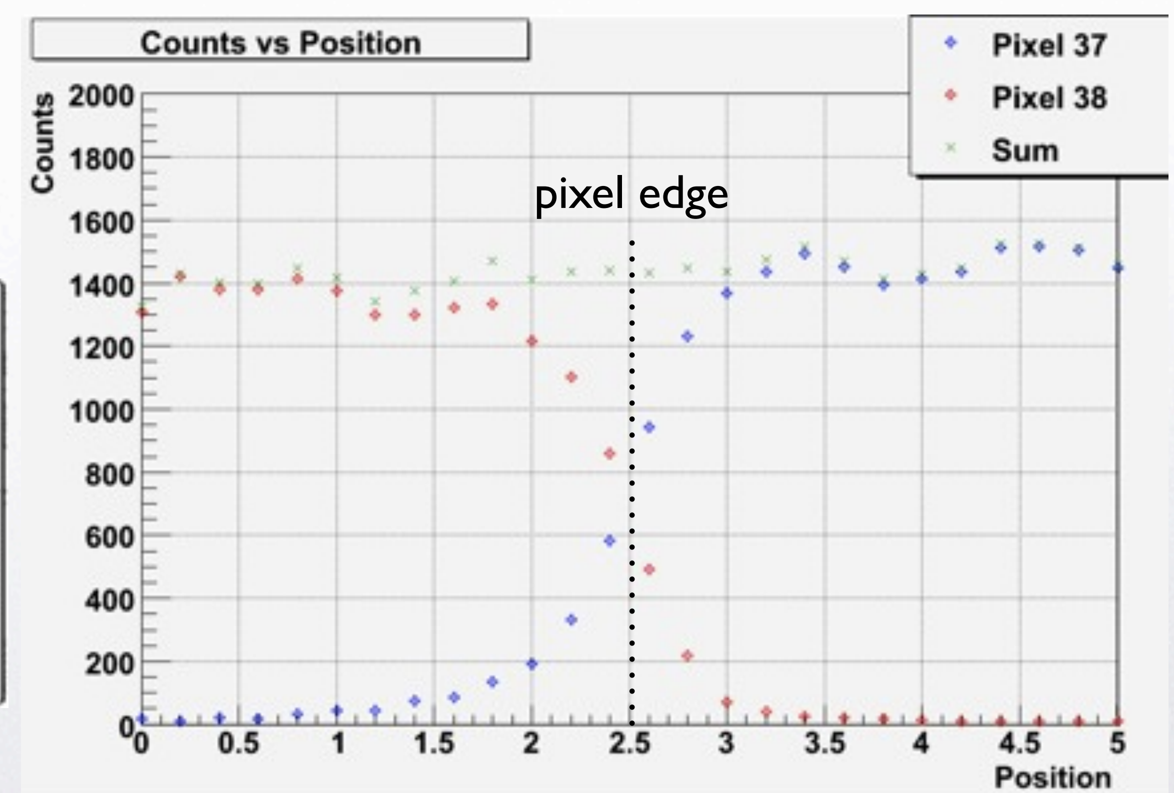




Dead Space

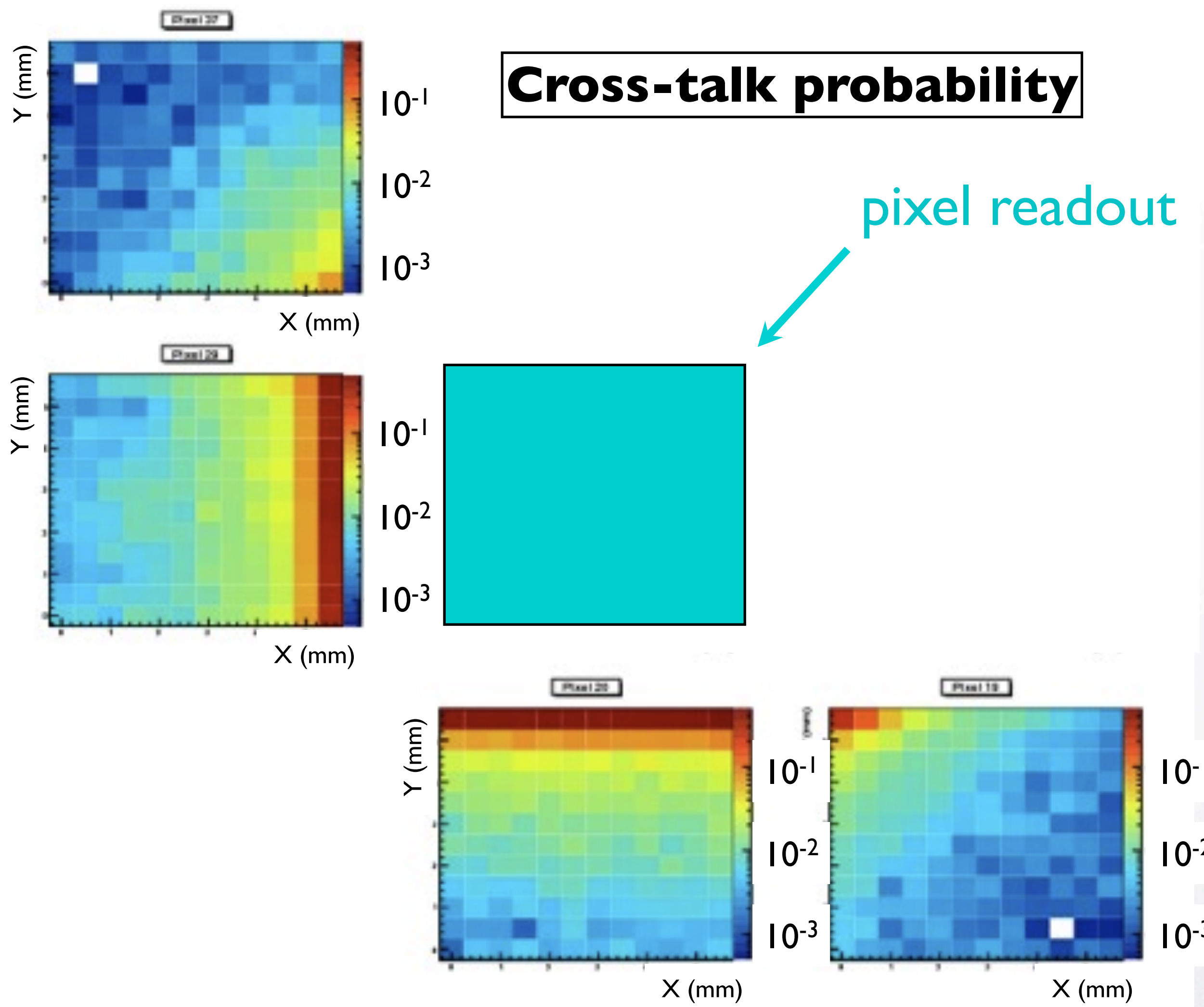
- Edge ~11% dead area
  - ~1.5mm dead band in between MAPMTs
- Inner pixel boundaries ~4% loss
  - measurement: neighbor pixels readout simultaneously while fiber is moved with a motion controller
  - vertical boundaries: 15-20% loss in ~1.5mm wide area for vertical boundaries
  - horizontal boundaries: no loss





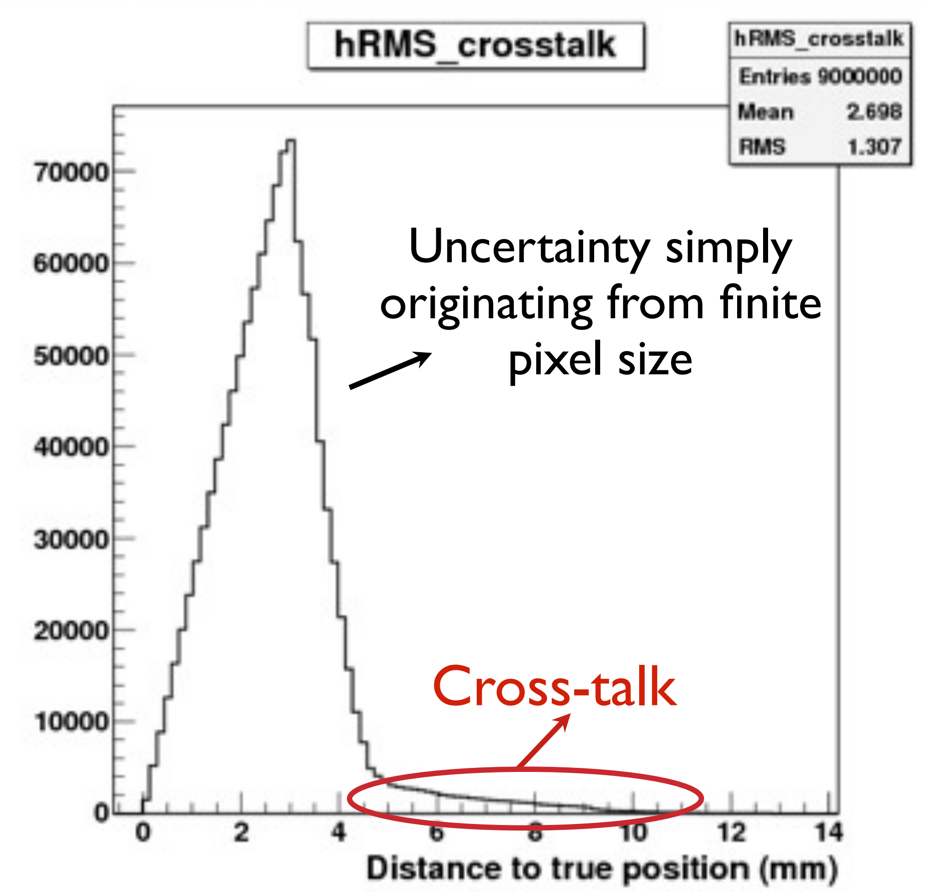
Cross-Talk

- Cross-talk in center of the pixel ~ 1% (less than optical cross-talk) but strongly non-uniform



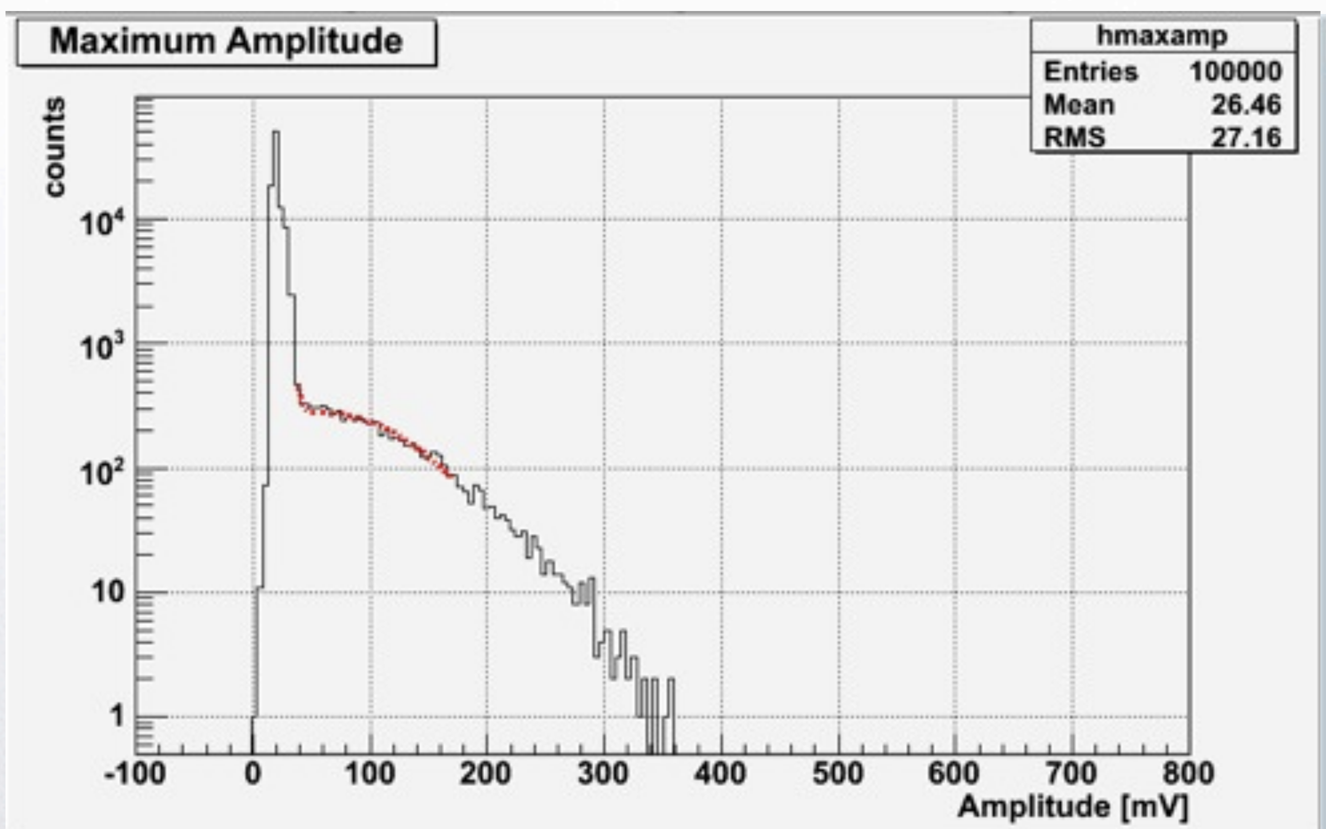
Optical cross-talk measurement in the center pixel when fiber is positioned where cross-talk values are plotted

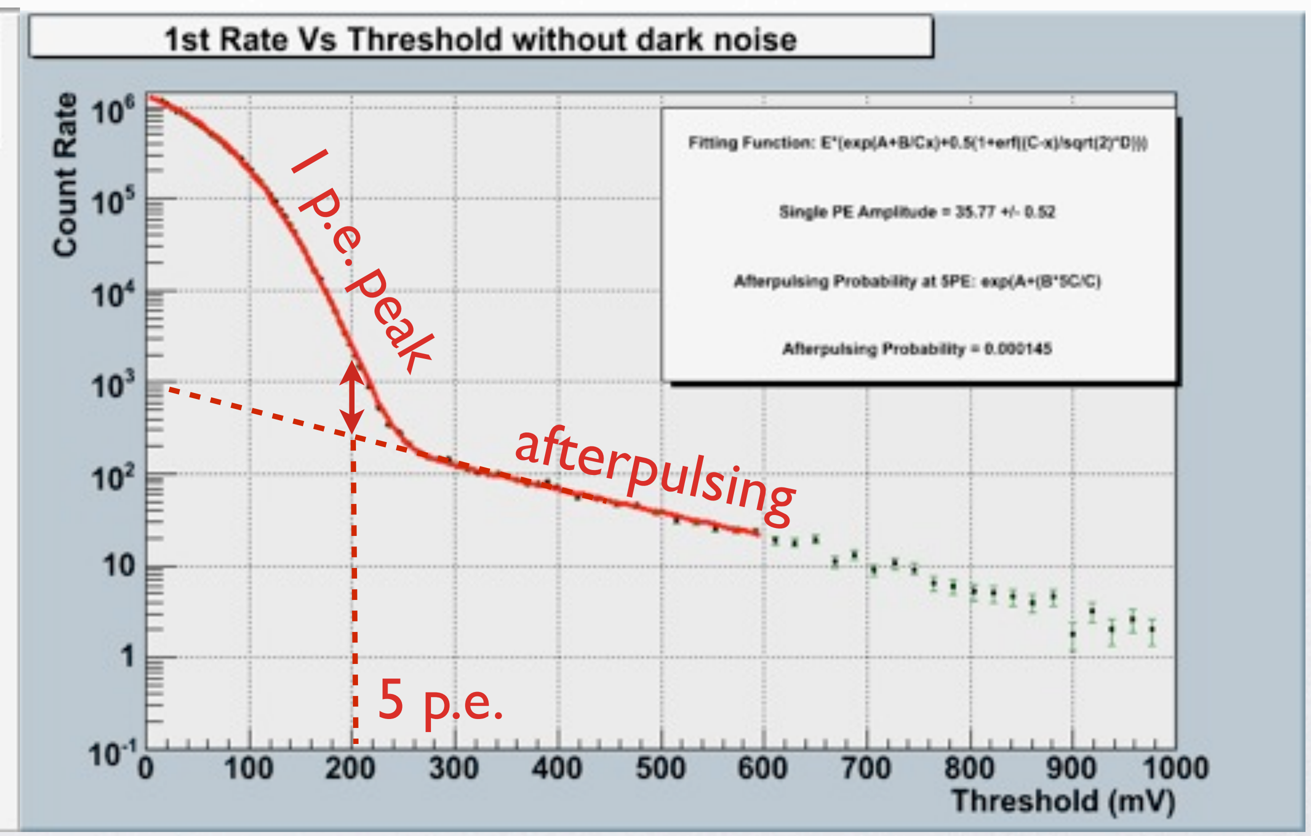
- Cross-talk introduces higher uncertainty in photon impact point in the focal plane.
- ~15% increase in the mean uncertainty (2.3mm => 2.7mm; 1.5' => 1.8')



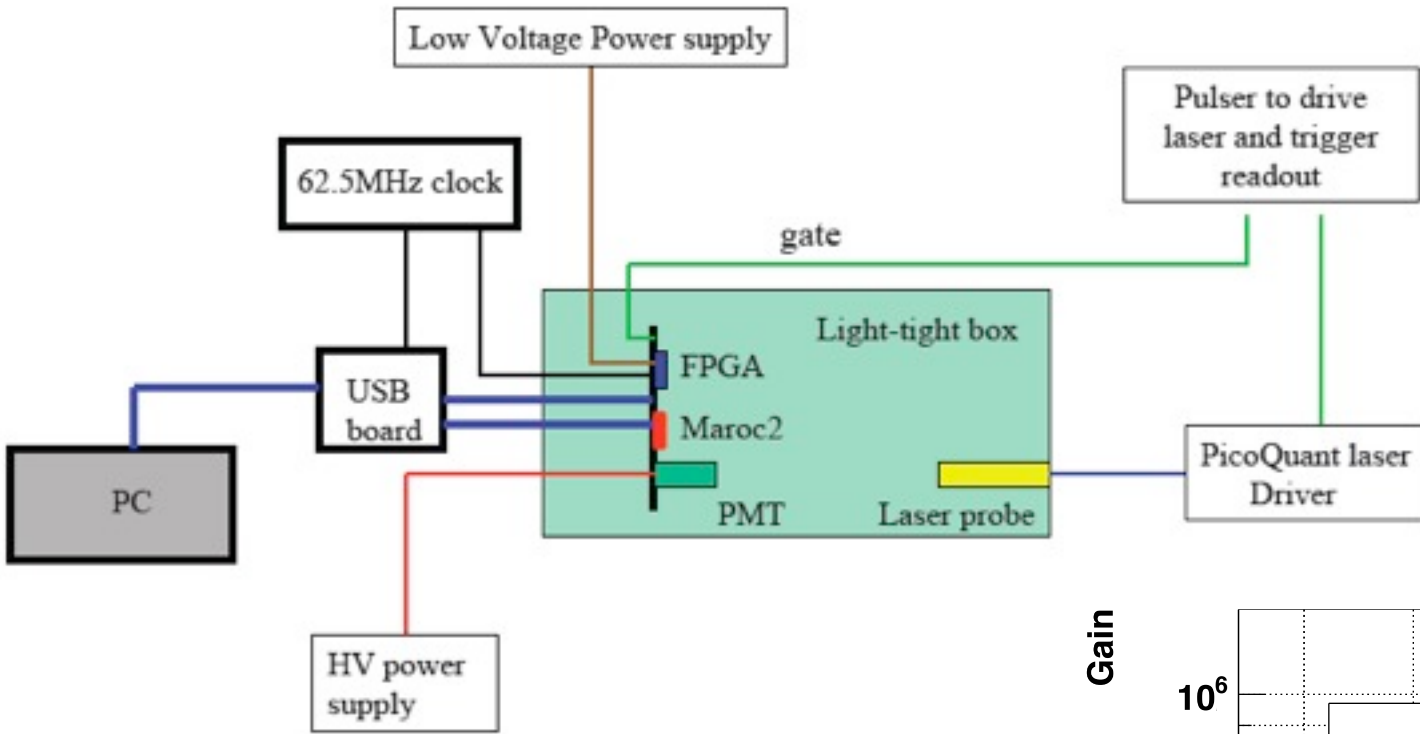
Single p.e. response vs afterpulsing

- I p.e. peak can be difficult to resolve and very broad. Issue for gain calibration?
- Low afterpulsing (<0.1%) but >5p.e. noise will mostly come from tail of I p.e. distribution
- Single p.e. amplitude distribution tightens with increased HV. Need to compromise with issues occuring at high gain operation (see next slide)
- impact on trigger/analysis?

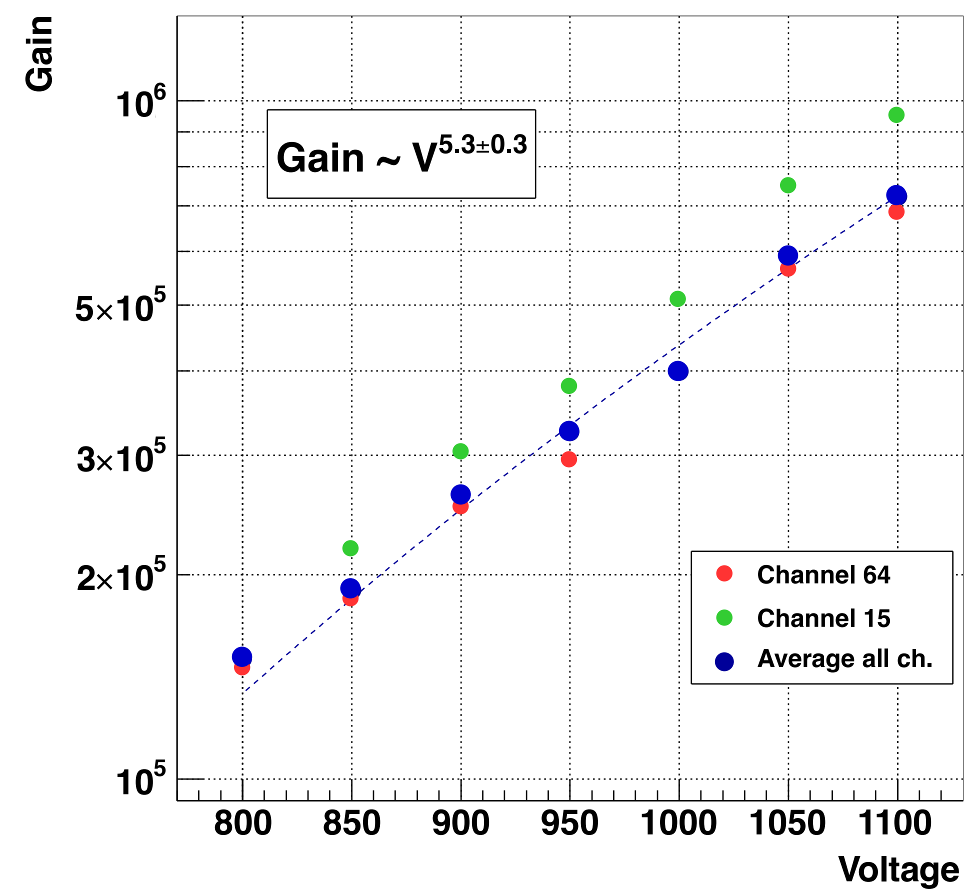




Barnard/Columbia Experimental setup

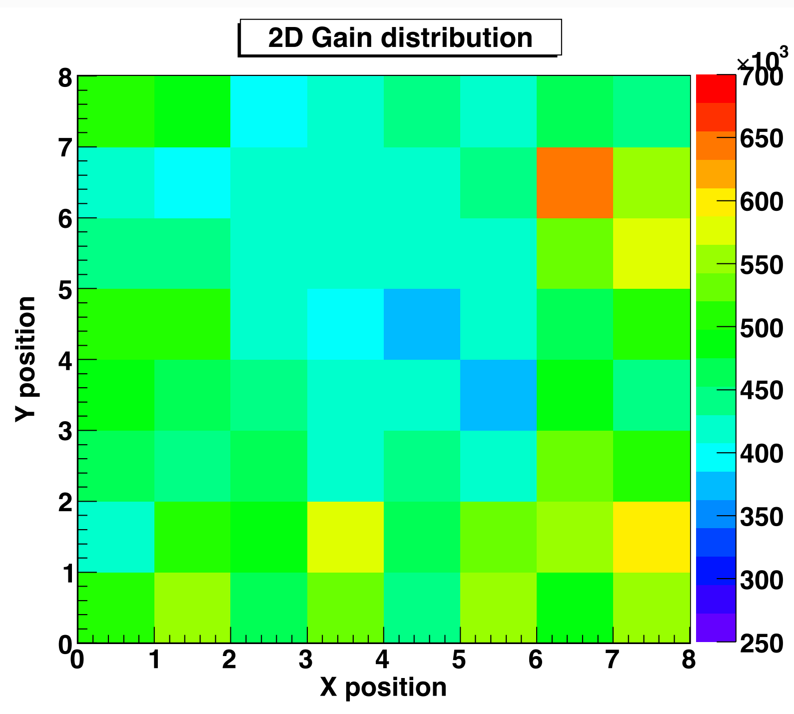


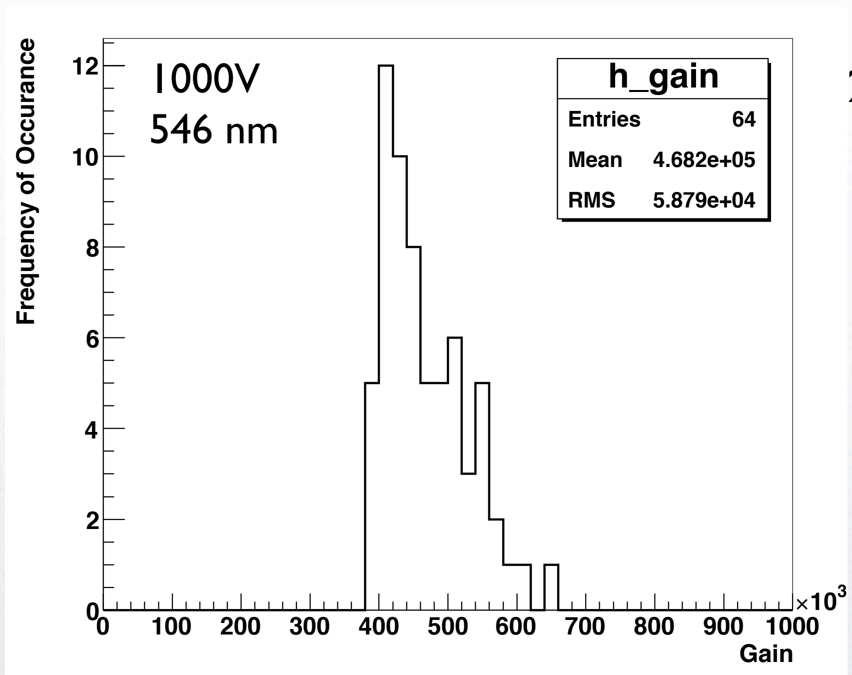
- Light source: Pulsed laser @ 456nm, pulse width <1ns.
- 64-channel readout board borrowed from DoubleChooz neutrino experiment.
- Triggered by an external pulse generator that provides a synchronized readout gate.
- Gain measured from photostatistics at light level ~20 phe



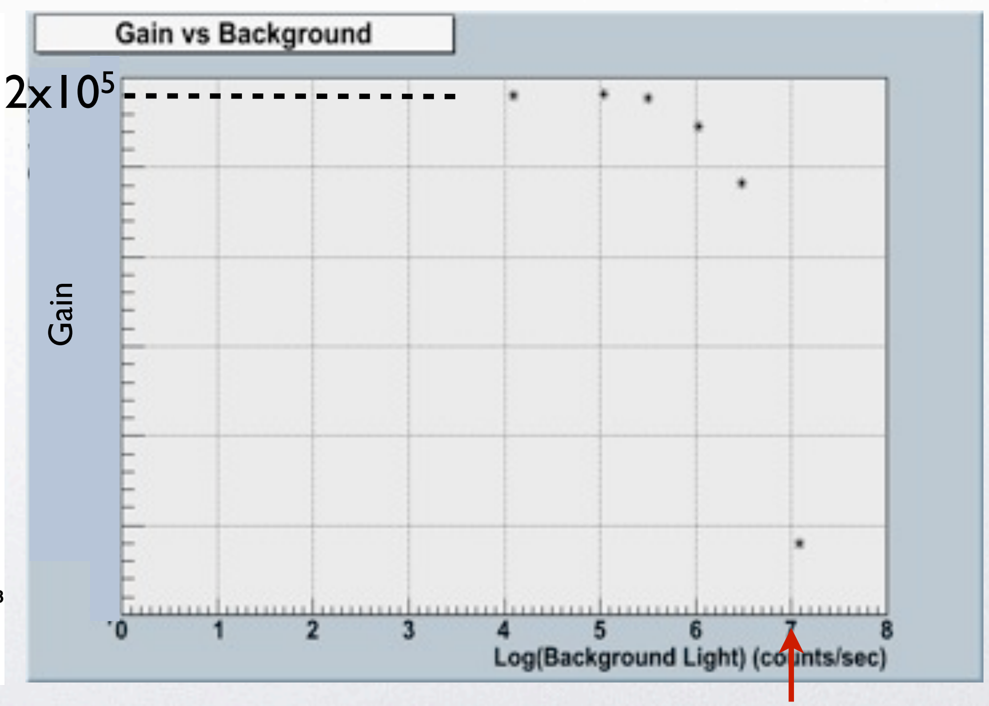
Gain

- Gain non-uniformity:
  - RMS/mean ~ 13% (photostatistics, Barnard) - 16% (single p.e., UCSC) => impact at trigger level
  - HV not adjustable at pixel level but 2 gain path available in TARGET board (20% difference in gain) => after gain correction, RMS/mean improves to ~ 9% (UCSC)
- Which gain to operate at?
  - Low: aging (~1 C/yr at gain~2×10^5, assuming similar aging as VERITAS tubes), shut down of 64 pixels due to bright star (might be ok, need to check), gain sag at high NSB level (due to maximum anode current rating)
  - High: resolve single p.e. peak, higher collection efficiency (K-Dy1 voltage)





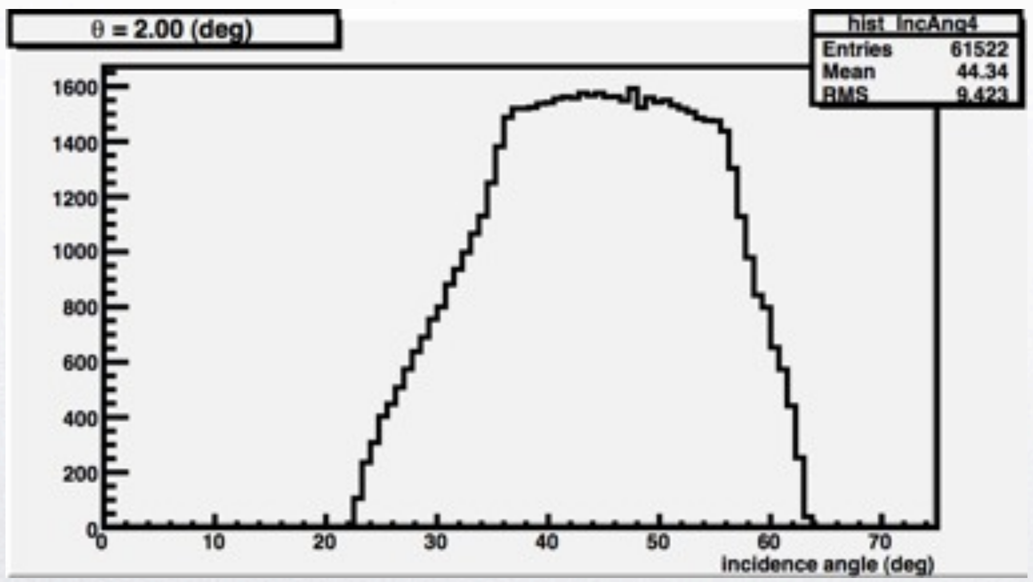
Photostatistics gain (Barnard/Columbia)



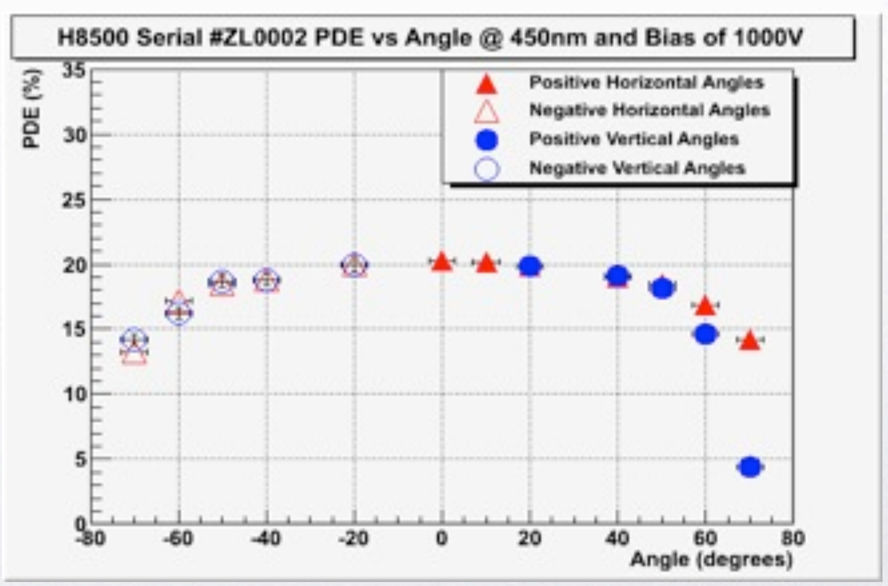
Level for SCT: ~10 MHz (p.e./sec/pixel)

Upcoming measurements...

- Barnard/Columbia:
  - characterize cross-talk between channels
  - try resolve single p.e. and compare gains with photostats method
- UCSC:
  - Aging
  - Response vs polarization
  - Response vs incidence angle, up to 65deg (crucial for SCT design)



Incidence angle distribution on surface of MAPMT (using Akira's ROBAST ray tracing code)



Previous measurements at UCSC. We now have an improved setup with better control on the input light level vs incidence angle

backups

❖ Improving single p.e. resolution by operating at higher gain