UPGRADE PLANS FOR VERITAS

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OUTLINE

- VHE (Very High Energy) Astrophysics ($E > 10^{11}$ eV)
- Atmospheric Cherenkov Technique
- Introduction to VERITAS
- VERITAS Upgrade
    - FPGA Pattern Trigger
    - Higher Quantum Efficiency (QE) PMTs
- Upgrade schedule

VHE Astrophysics in 2011

- Over 100 Sources now!
  - Only a handful a decade ago
- Most detections from Atmospheric Cherenkov Telescopes
  - VERITAS, HESS, MAGIC
- Source types:
  - Galactic (PWN/SNR, Binaries, 1 Pulsar)
  - Extragalactic (Mostly Blazars)
  - Unidentified
- Constraining Limits indirect of Dark Matter annihilation, EBL absorption

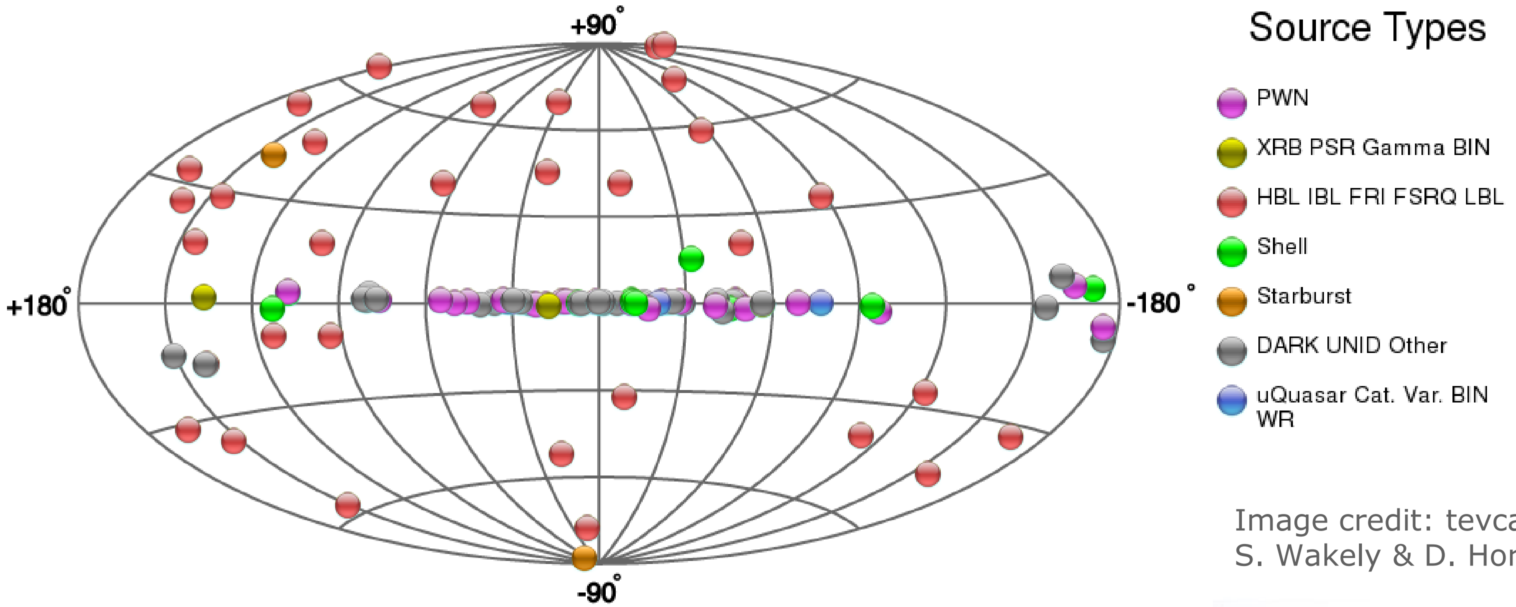


Image credit: tevcat.uchicago.edu
S. Wakely & D. Horan

Atmospheric Cherenkov Technique

- Primaries (Gammas + Cosmic rays) create showers of secondary particles
- Creates shower in upper atmosphere
- Secondary pairs emit Cherenkov radiation
- Large light pool area: $A_{eff} \sim 10^5 m^2$
- Shower imaged in multi-PMT Cameras at telescope focus

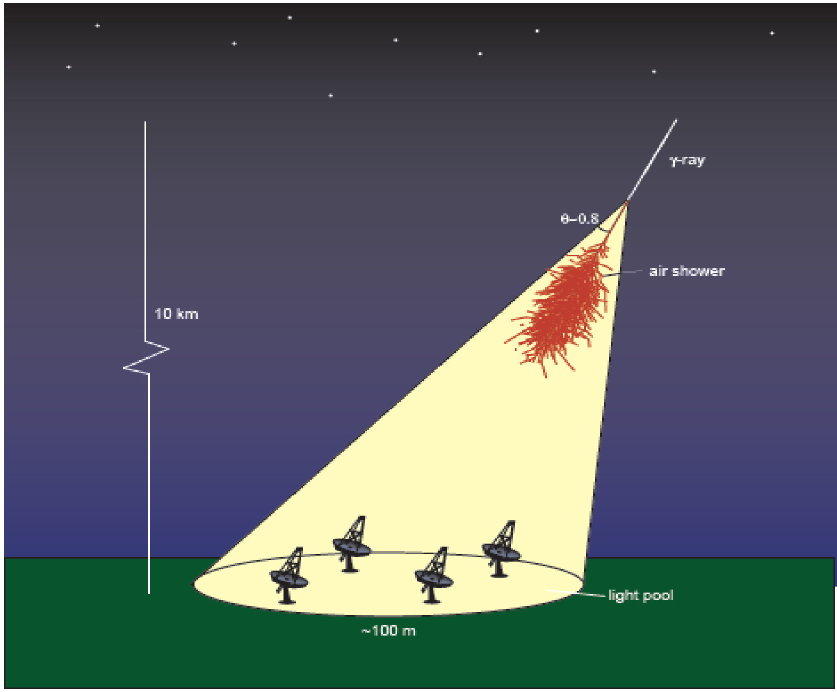


Image credit: Bethany Theiling

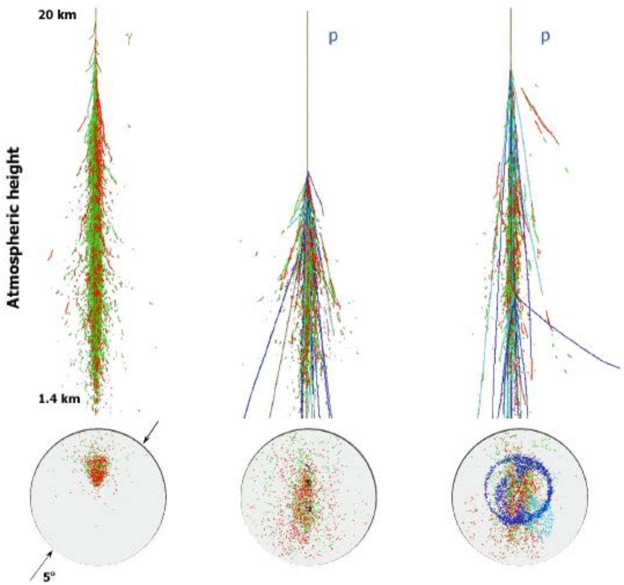


Image credit: Glenn Sembroski

- Images of gammas are different from those of charged cosmic rays

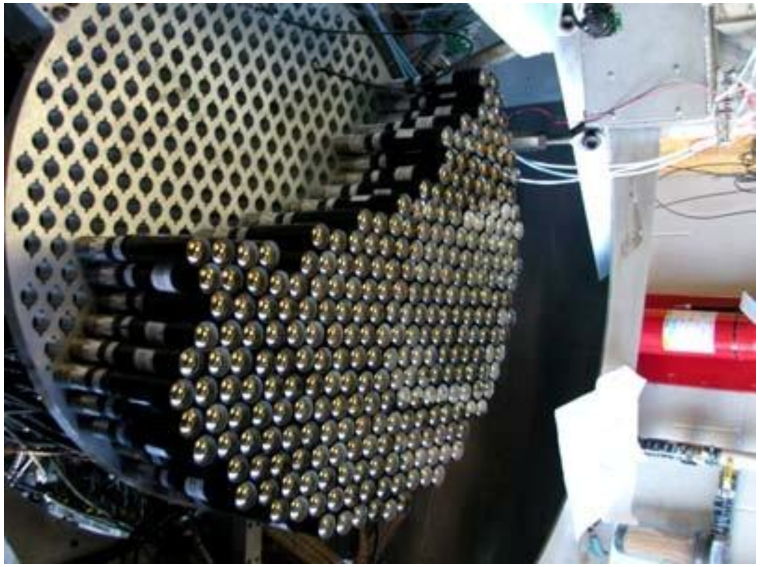
VERITAS

- Very Energetic Radiation Imaging Telescope Array System
- Four Telescope array located south of Tucson AZ
- Full array operations since Fall 2007
- ~1200 hrs observation/year, 200 hrs/year in low moonlight
- International Collaboration (US, Canadian, Irish, UK, German)
    - ~95 Collaborators at 20 institutions

Hardware and Performance

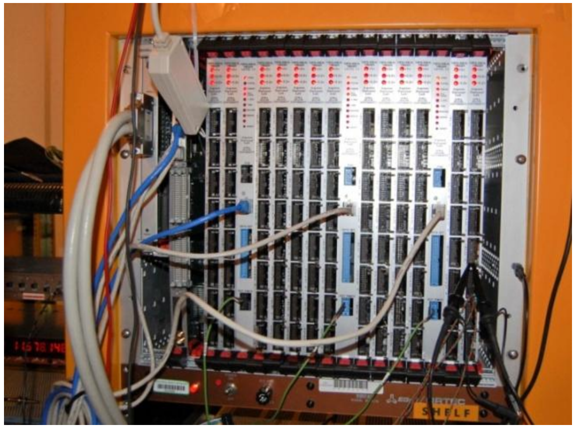
- Existing Hardware:
  - 350 mirrors/telescope, $110 m^2$ area
  - 499 PMT Camera
  - 500 Ms/s FADC channel on each pixel
  - Three level trigger system:
    - CFD on each pixel (L1, ~MHz/pixel)
    - Pattern Trigger (L2, ~kHz/telescope)
    - Array Trigger (L3, ~200 Hz for array)

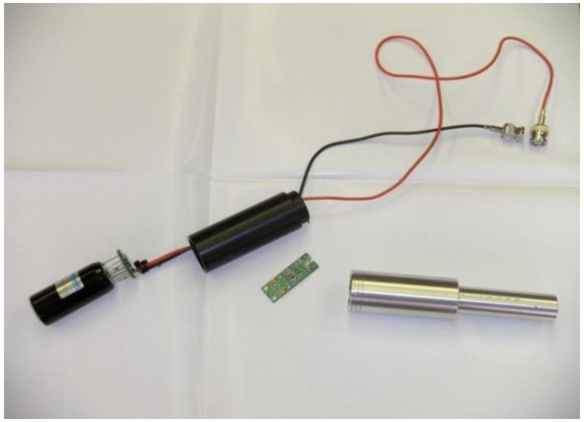
- Performance:
  - Energy Range: 100 GeV to 30 TeV
  - Energy Resolution: 15-25%
  - Angular Resolution: $R_{68\%} < 0.1°$
  - Pointing Accuracy: Error < 50 arcsec
  - 3.5° Field of View
  - Sensitivity: 1% Crab Flux in ~25 hrs



2009-2012 VERITAS Upgrade

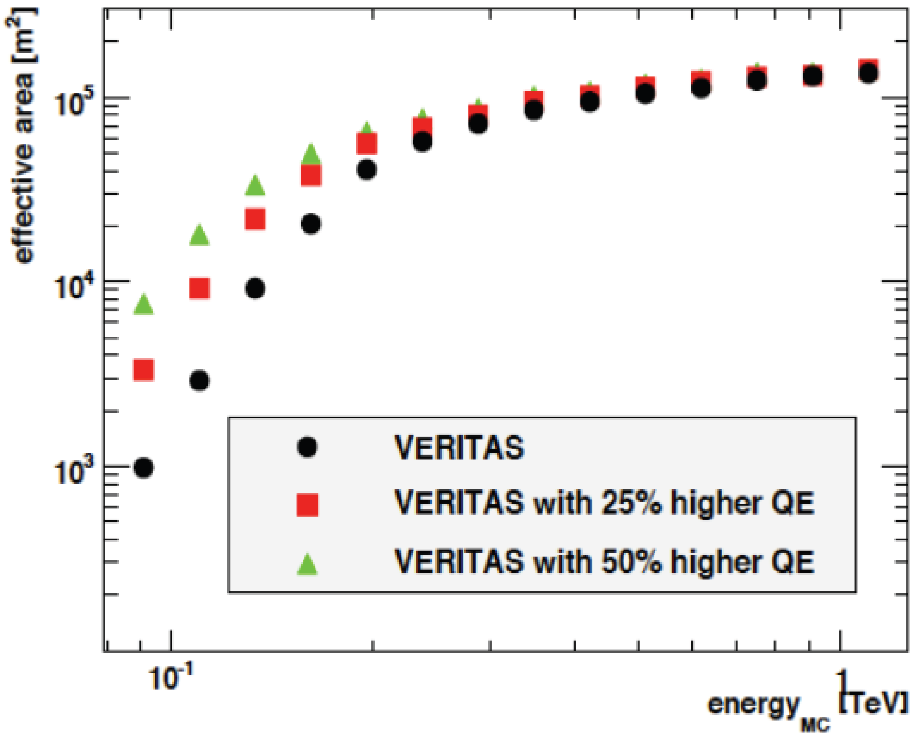
- Move of Telescope 1 (Complete)
  - Optimal baseline between telescopes
  - 1% Crab Sensitivity in ~25hrs down from ~48hrs
- Higher QE PMT Cameras
  - Super – Bialkali (SBA) photo cathodes
  - ~40% increase in photon collection efficiency
  - Reduce Trigger and detection threshold
- Optical Monitor/Intensity Interferometer
- Communication (Fiber Optic) Network Upgrade
- FPGA – Based Pattern L2 Trigger
  - Faster, drop in replacement of existing trigger
  - Narrow coincidence gate from 8-9ns to 3ns
  - Better timing alignment between pixels
  - Designed to reduce night sky coincidence rate
  - Hardware for future Topological trigger – Reduce Cosmic rays
  - Added flexibility during Observing/Calibration

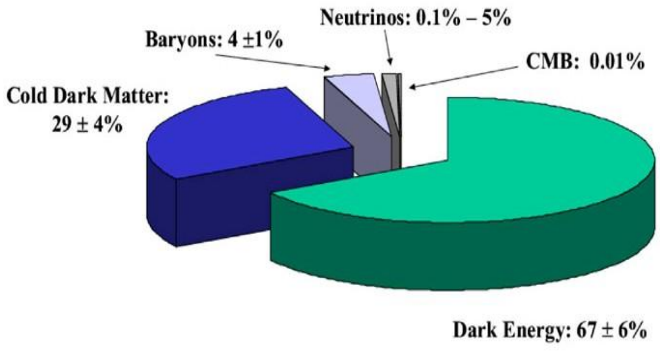


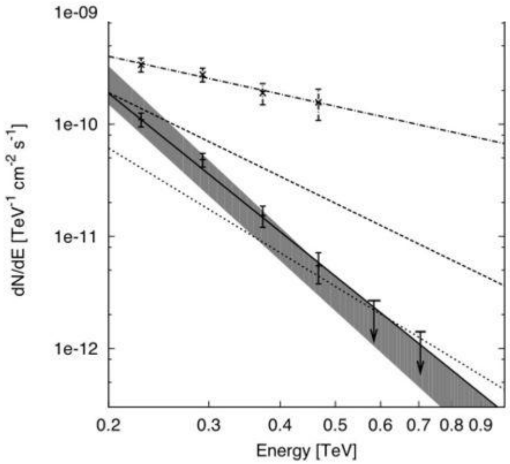


Upgrade Benefits

- Increased Sensitivity
  - Effectively more observing time
  - 1% Crab source in 16-20hrs
  - ~25 hrs currently
- Lower detector threshold
  - 60-70 GeV post-upgrade
  - NSB events dominate at low E
  - Physics motivations:
    - Tighter DM limits at low E
    - EBL Blazars density and evolution
    - Pulsar spectral cutoff ~GeV

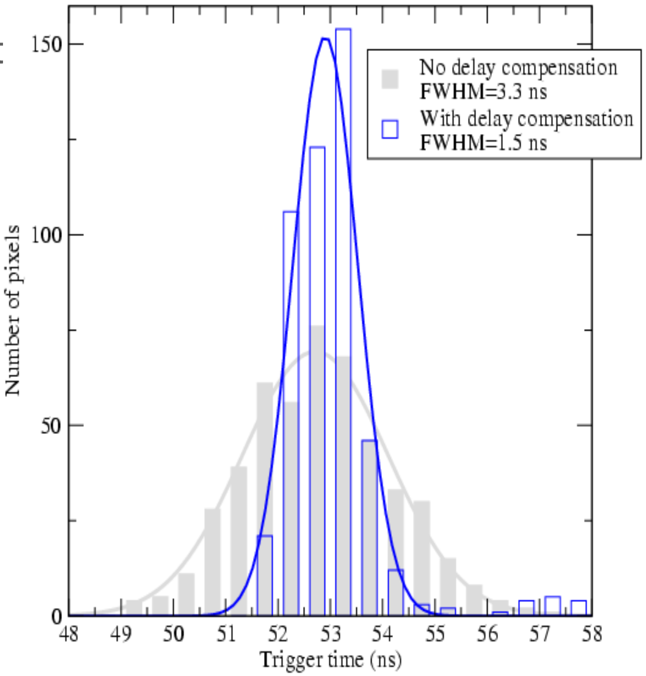




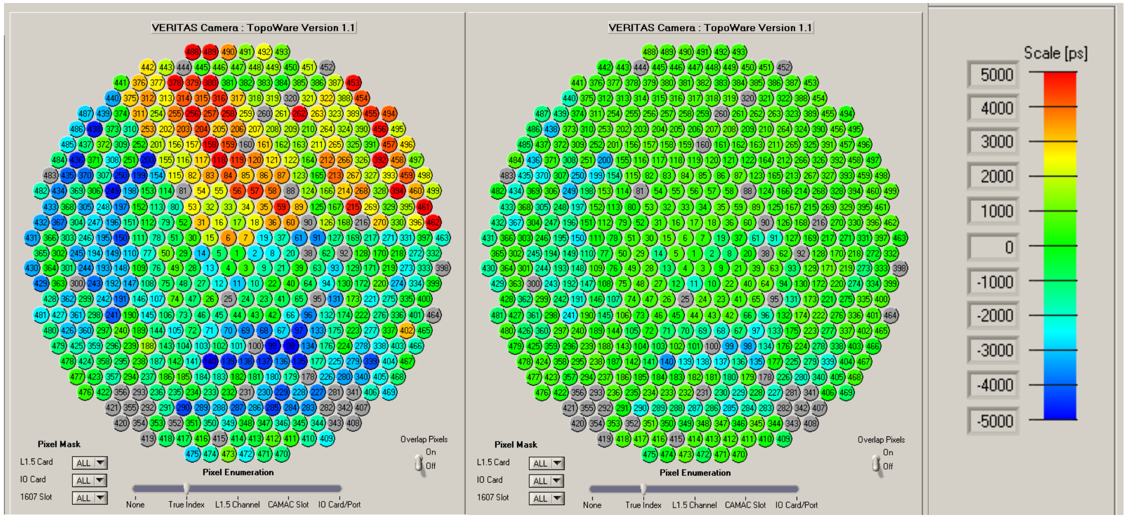


L2 - Pixel Time Alignment

- Pixels can be aligned for timing differences
  - Correct for path lengths in trigger, PMT transit times, et
- FPGA's programmed with a delay setting for each pixel
  - Built-in TDC measures relative time of arrival
- Night sky background has random coincidence
  - Showers have a shorter temporal structure



Before Alignment After Alignment

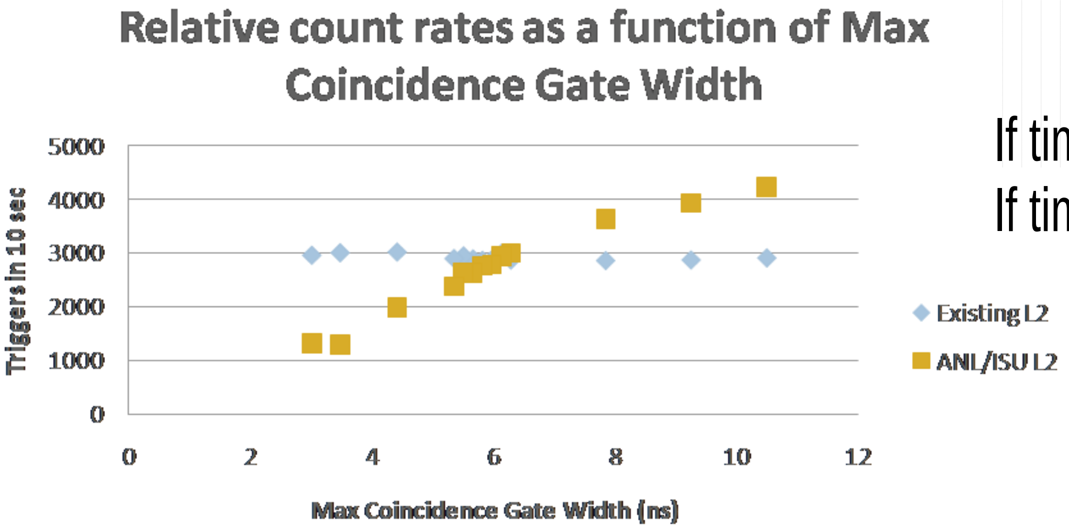


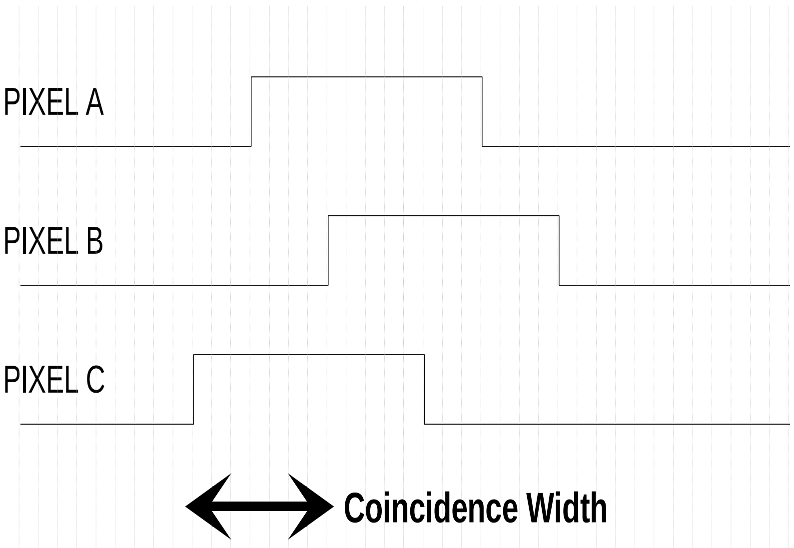
FWHM of signal dist.
Reduced to 1.5ns from 3.3ns

Gray pixels not time aligned:
Bad pixel or new SBA PMT

L2 - Reduction of NSB

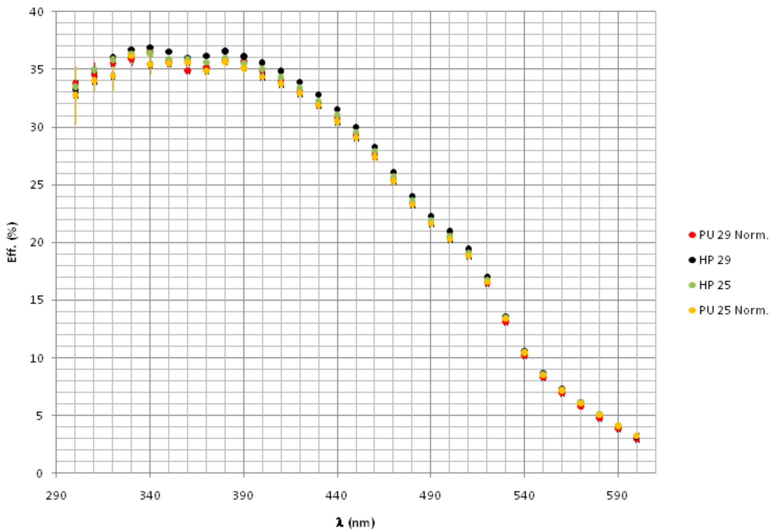
- NSB reduction requires leading edges closely time aligned
- Trigger is programmable to require leading edges down to 3ns
- Existing L2 equivalent is 6ns
- Optimize Coincidence gate to minimize NSB





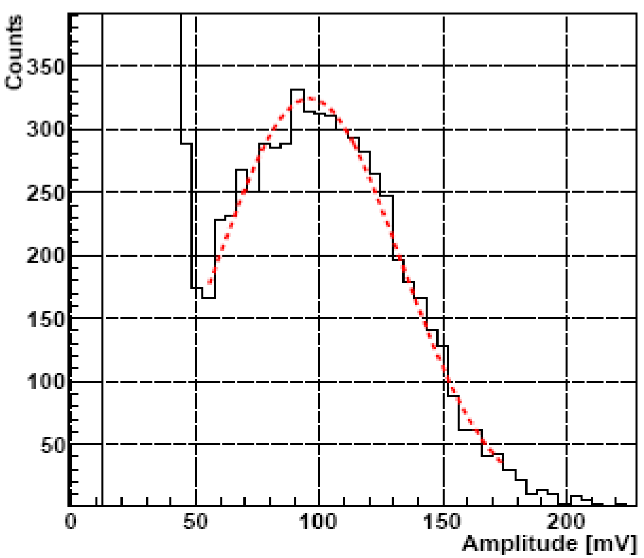
If time between edges > setting, no trigger
If time between edges <= setting, trigger

PMT Upgrade

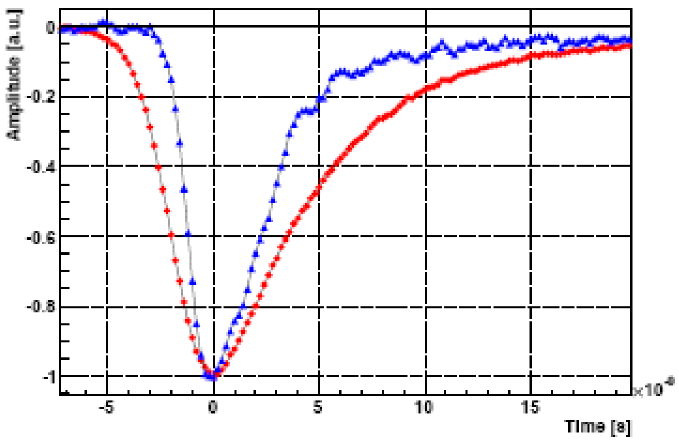


- Currently using Photonis XP2970
    - 15-20% QE
- Hammamatsu R10560-100-20mod
- SBA, 1 inch diameter
    - ~40% QE (plot on left)
- UV glass entrance window
- Eight stages

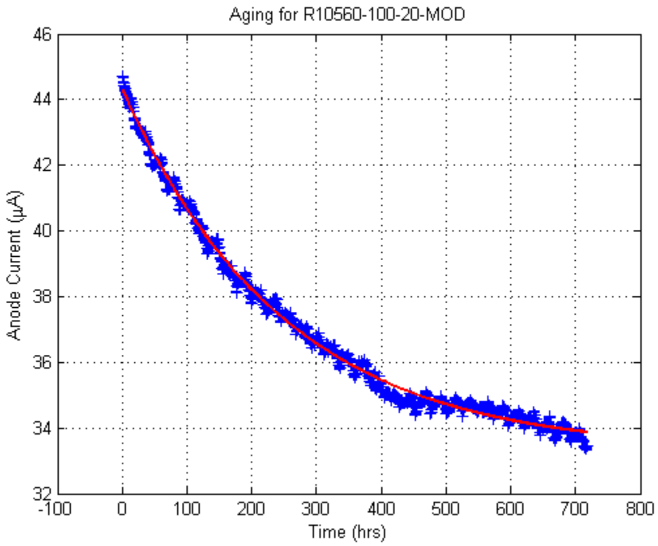
- Single Photoelectron peak (right)
- Separated from pedestal
- Gain @ HV of 1100V is $2x10^5$



Other PMT Measurements



- Pulse shape
  - Blue is Hammamatsu R10560
  - Red is Photonis XP2970
  - Peaks normalized to each other
- Narrow peak aids discrimination of Cherenkov Pulses



- Aging – PMT in dark box with HV on
  - High Current over long period
    - Normal operations ~ 3μA
  - Anode Current ~ Gain
  - Exponential decay
  - Gain eventually becomes constant
  - Estimate of ~30% gain drop over four years post-upgrade

Upgrade Schedule

- Upgrade fully funded
  - Funded by NSF MRI-R2 Grant
  - On Time, under budget
- Move of T1 accomplished in 2009
- Fall 2010:
  - ANL L2 in operation in parasitic mode in T3
  - Two clusters of seven R10560 PMTs in T3 camera
- Currently:
  - PMT Testing @ Purdue, UCSC
  - Pixel/Preamp building @ Delaware
  - L2 optimizing, debugging @ ANL, Iowa State
- Full install of new pattern trigger systems in 2011
- Camera upgrade over 2012