The VERITAS Upgrade: Performance and Status

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(for the VERITAS Collaboration)

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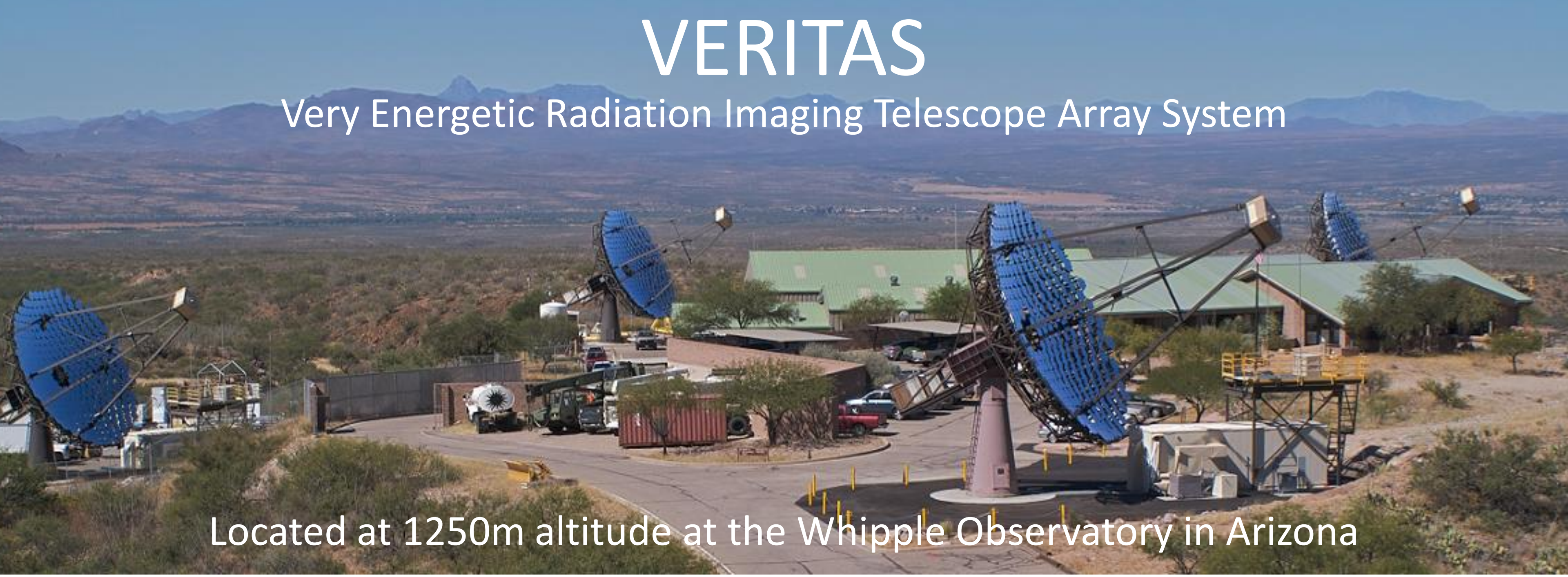
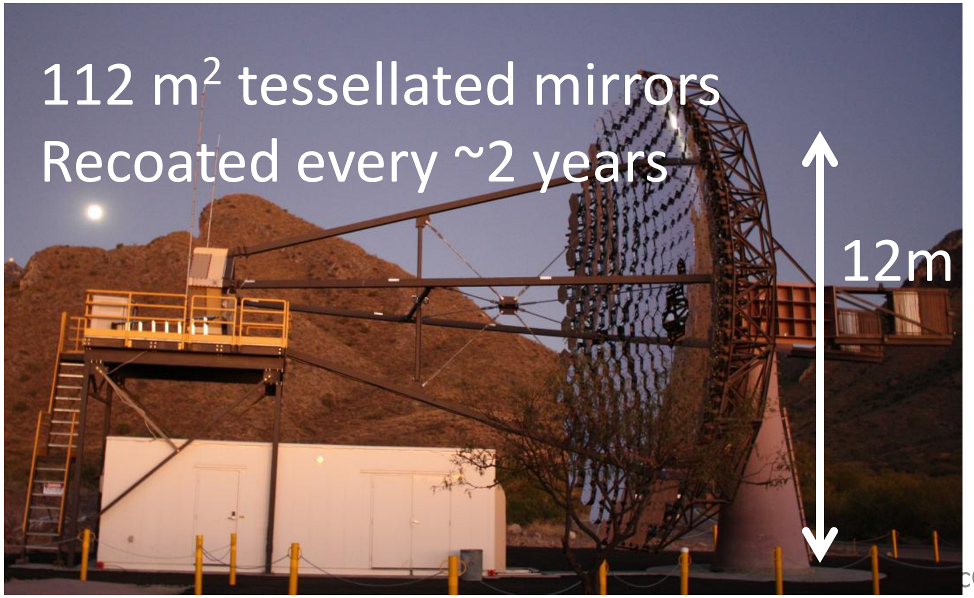
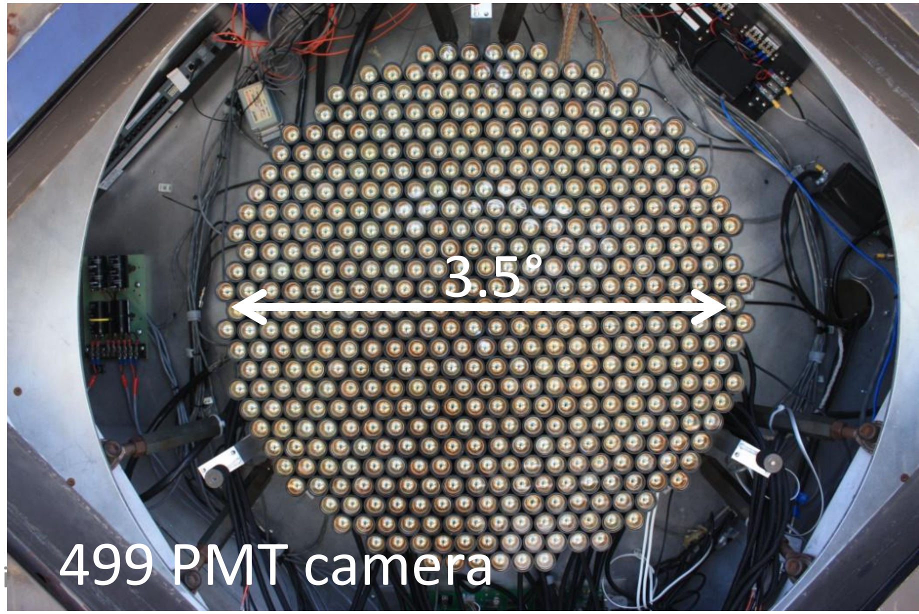
McGill



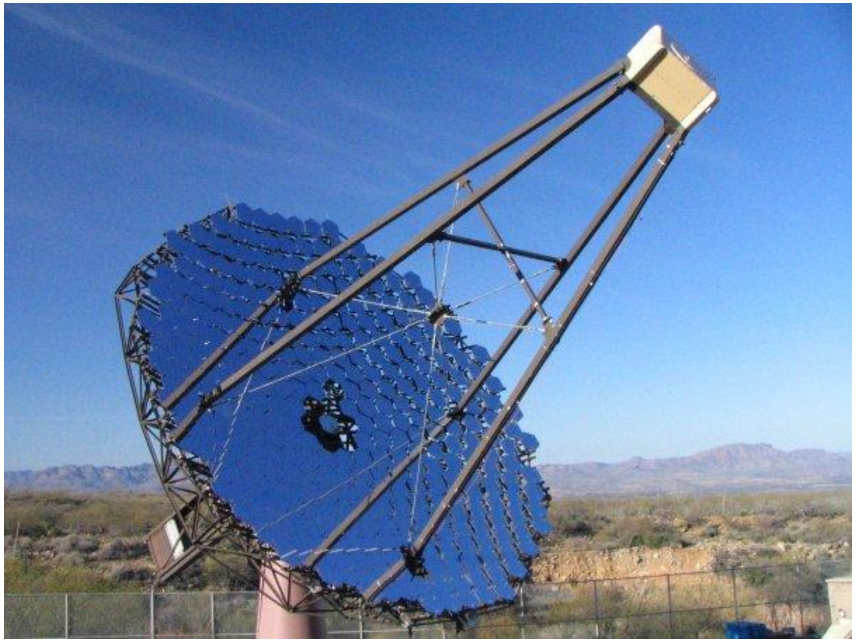
~100 collaborators: 21 institutions in the US, Canada, Ireland, the UK and Germany





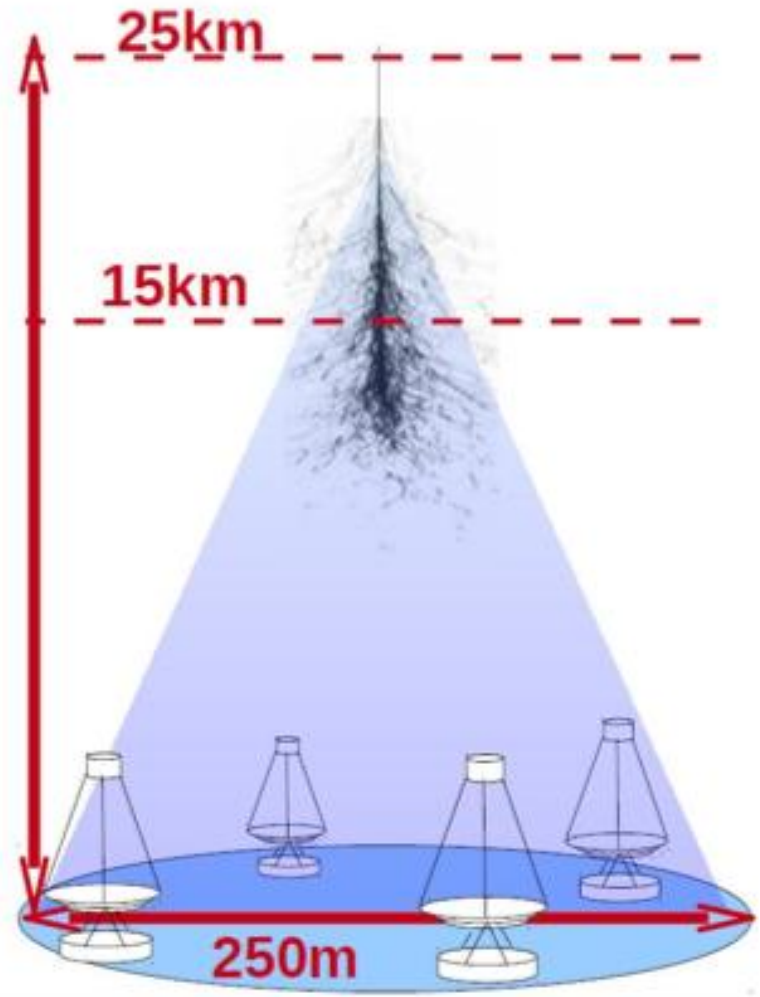
VERITAS Technical Performance

- Energy range:
  - ~60 GeV (post upgrade; depends on analysis cuts) to 30 TeV
- Energy Resolution:
  - ~15% above 300 GeV
- Angular resolution:
  - r_{68} ~ 0.1° @ 1 TeV
  - r_{68} ~ 0.4° @ 200 GeV
- Systematic errors:
  - Flux: 20%
  - Spectral index: ~0.2



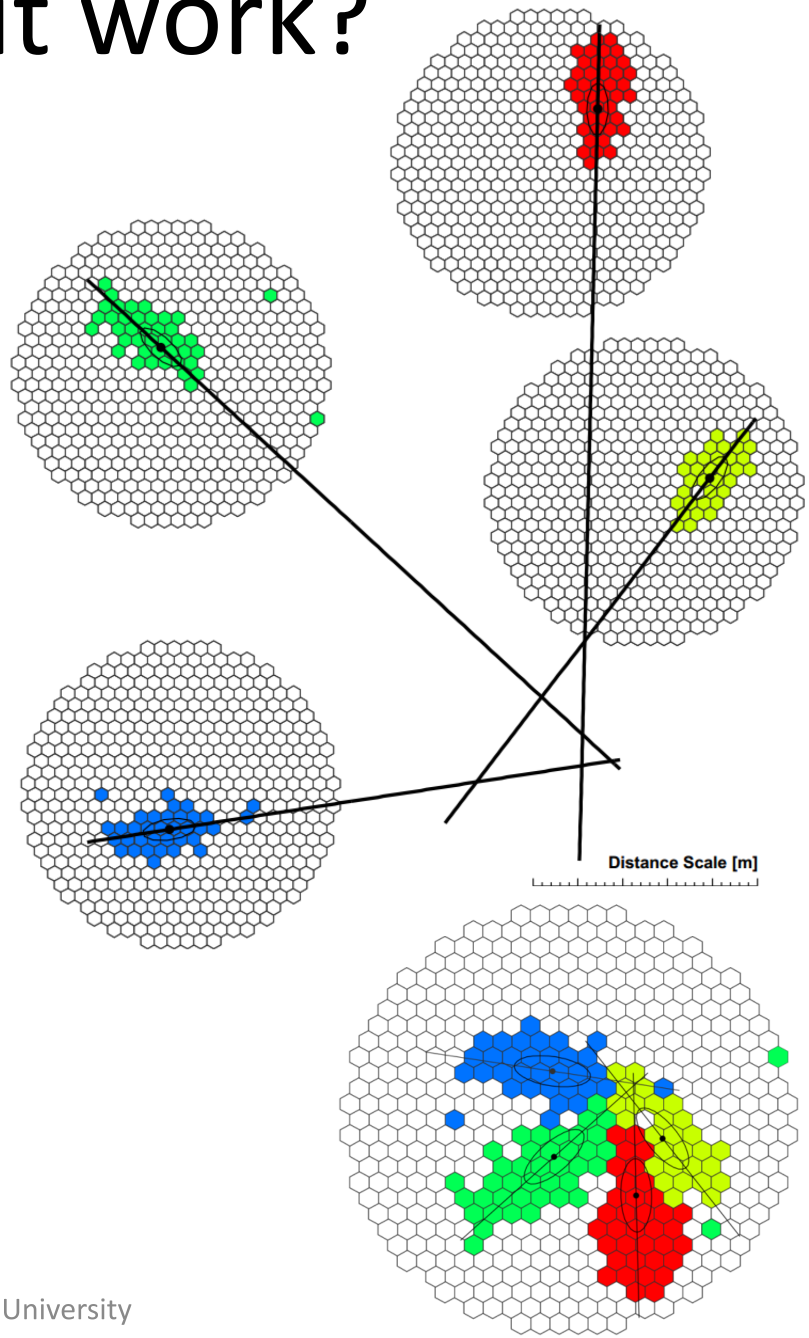
Imaging Atmospheric Cherenkov Technique

- VHE gamma rays pair produce in the upper atmosphere, starting an air shower.
- Secondary particles in the shower are highly energetic and have speeds > c/n .
- Cherenkov radiation is emitted creating a pool of light on the ground ~10^5 m^2
- Allows us to use the whole atmosphere as the detection medium.
- By placing telescopes in the pool, we can image the shower.



How does it work?

- Image shape → particle **type**
  - γ-ray like, hadrons, muons
- Image axis → γ-ray **orientation**
- Intensity → γ-ray **energy**
- Spectral reconstruction comes from comparing data to simulations.
- Stereoscopic view of a shower greatly improves:
  - angular & energy resolution
  - γ / hadron separation (background rejection)
  - **sensitivity**



VERITAS

- Since full array operations began in 2007, VERITAS has undergone a number of upgrades
- Improved mirror alignment → better optical PSF
- Telescope relocation (2009)
- Communications upgrade to fiber optics (2010)
  - 1 G b/s → 2 Gb/s with LACP (full redundancy)
- Telescope-level trigger upgrade (2011)
- Camera upgrade (2012)

T1 Relocation (2009)

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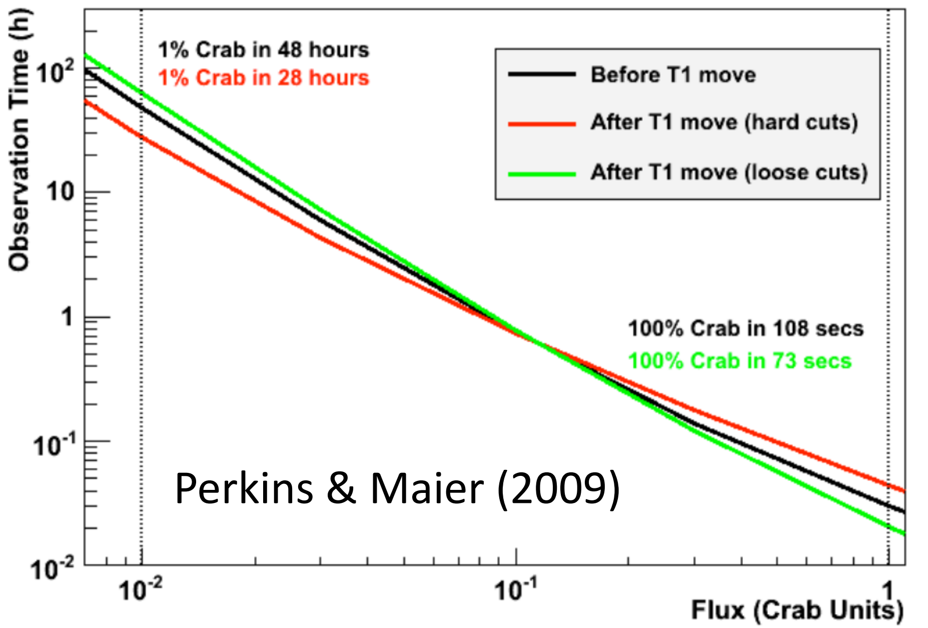
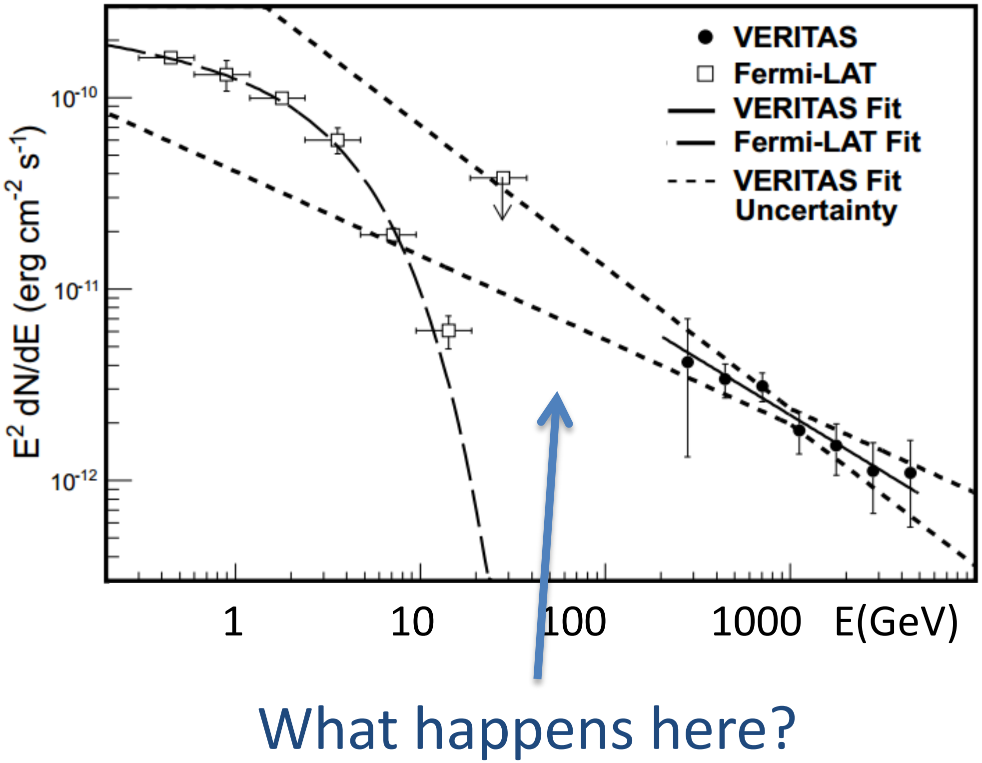
- Telescope moved to make array more symmetric
- 30% improved sensitivity
- 25% improved effective area
- Improved angular resolution



Trigger & Camera Upgrade (Motivation)

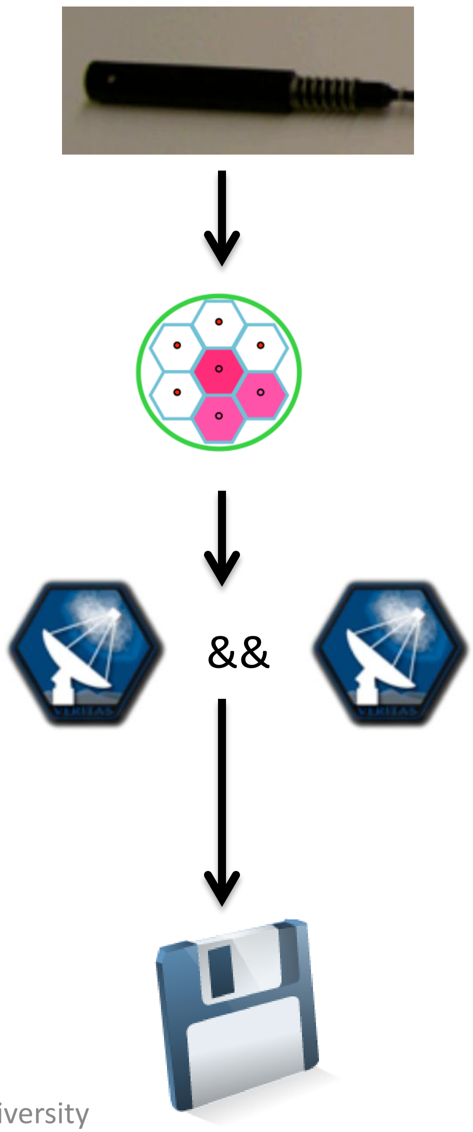
- Higher rates
  - Spend less time on any given target
  - Look at more objects → more potential for science
- Lower energy threshold
  - More potential sources
  - Close gap with *Fermi*
  - Can probe lower DM masses → increases overall DM sensitivity

LSI +61 303 (x-ray binary)
Aliu et al. (2013)



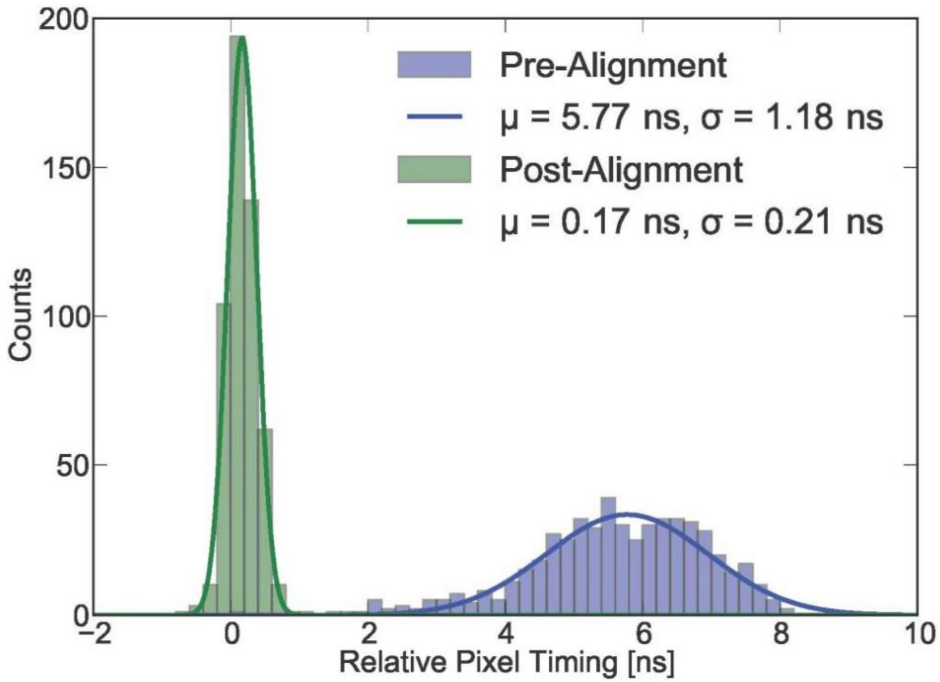
The VERITAS Trigger

- **L1**: CFD on individual PMTs
  - ~ 5 photoelectrons
  - ~few MHz
- **L2**: Pattern trigger
  - 3-fold coincidence within ~5 ns
  - 5-10 kHz
- **L3**: Array-level trigger
  - >= 2 telescopes within 50 ns
  - 400-500 Hz
- **Save**
  - 500MS/s 8-bit FADCs
  - Data rate: 25 GB/hour



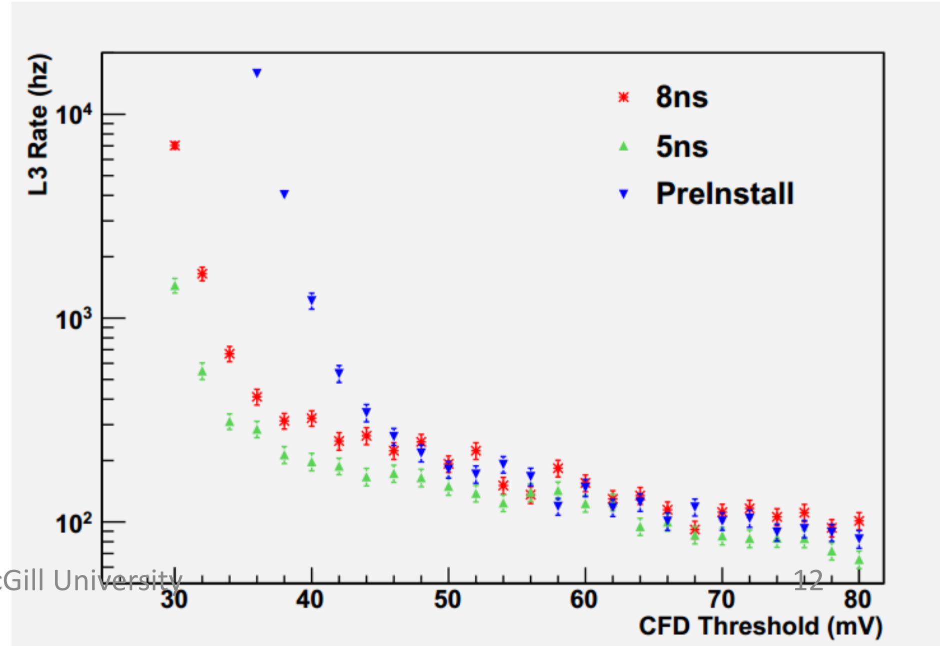
2011 Trigger Upgrade: L2 FPGA-based pattern trigger

- Pixel-to pixel timing now +/- 1 ns

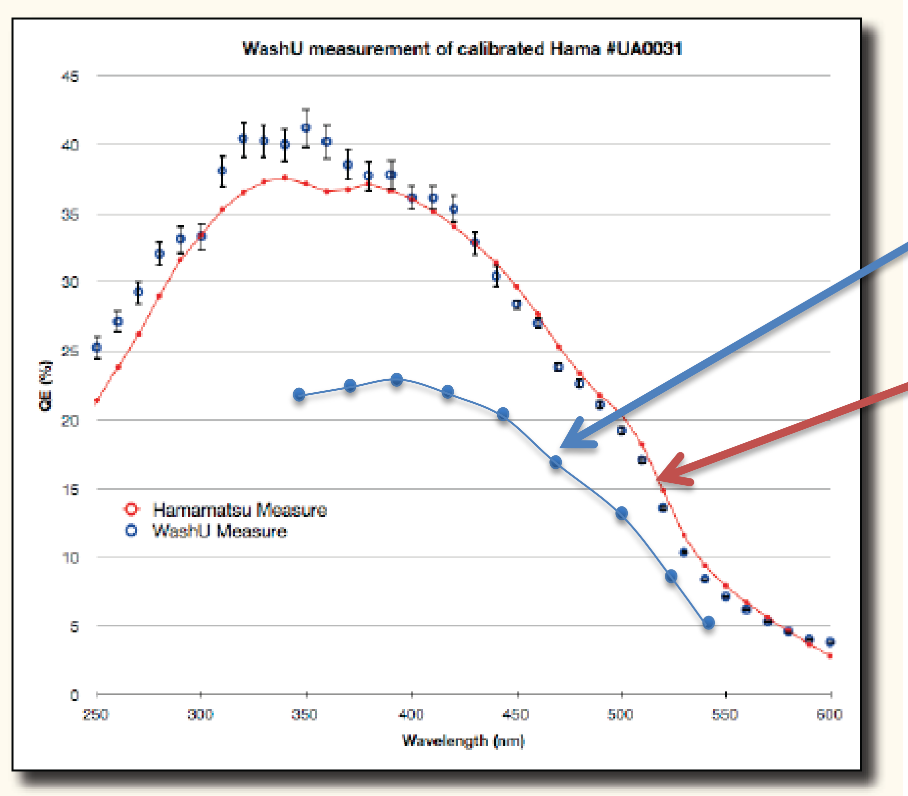


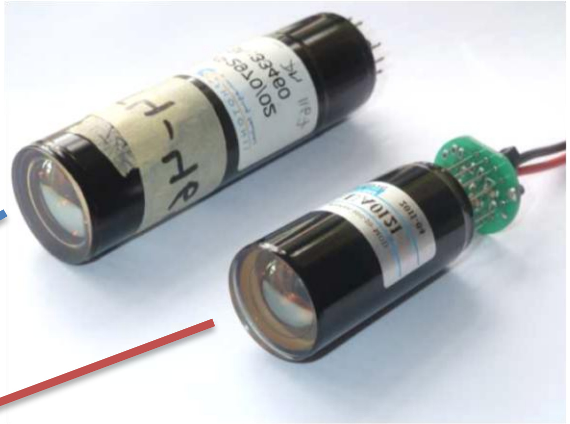
Zitzer (2013)

- Narrower coincidence window (8 → 5 ns)
- Lower CFD threshold for the same trigger rate means that we can trigger on lower energy showers.



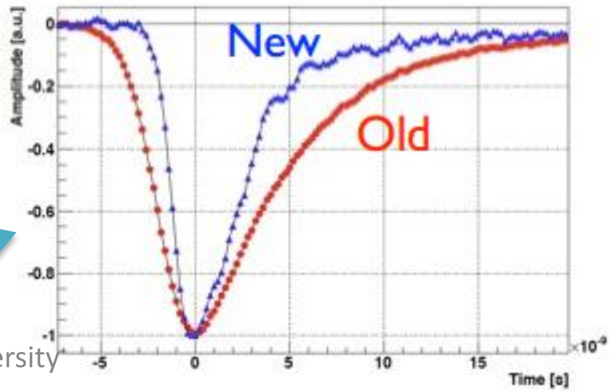
2012 Camera Upgrade





Old: Photonis XP2970

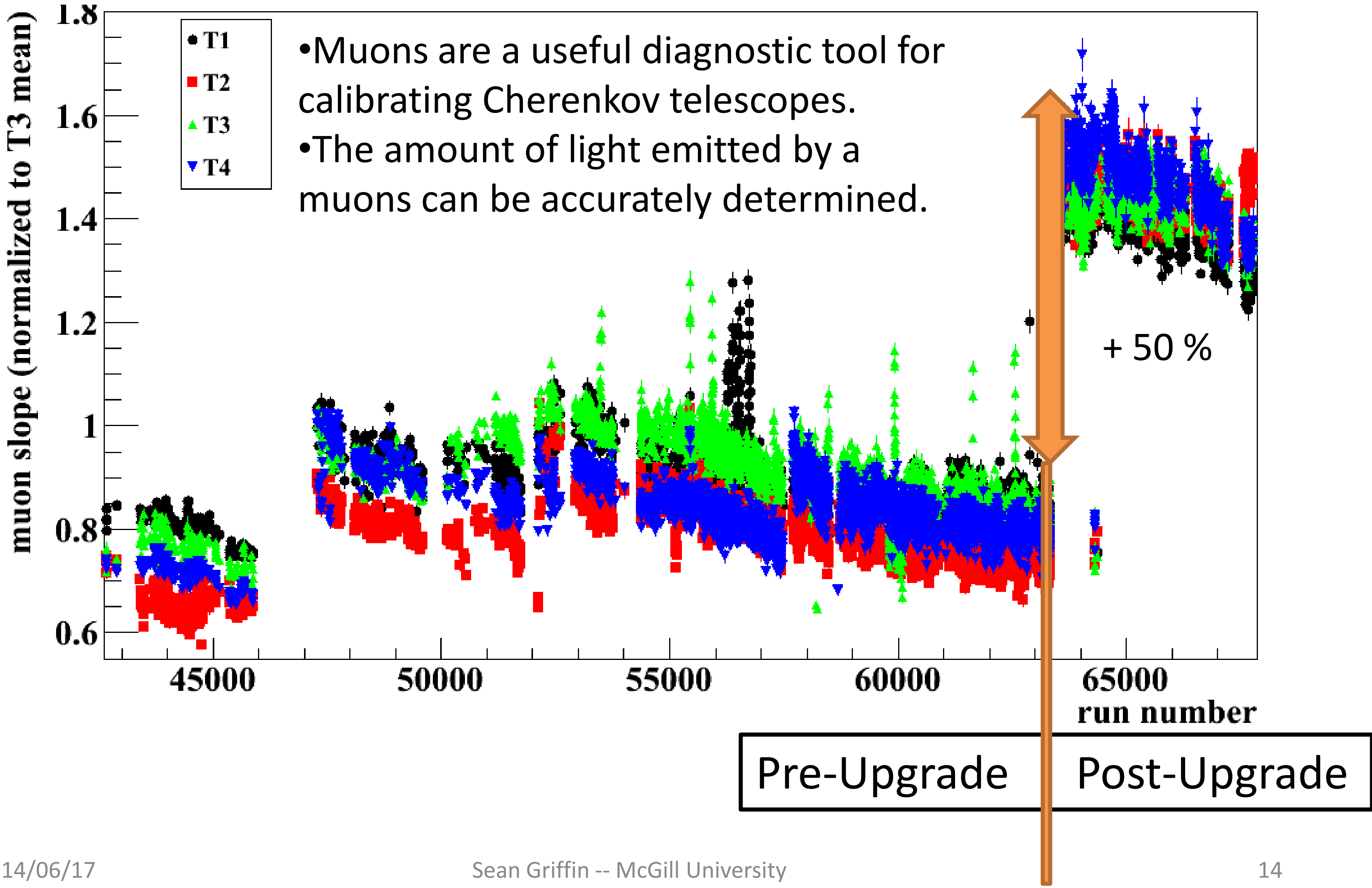
New: Hamamatsu R10560



Pulses ~40% more narrow

Less noise in signal region

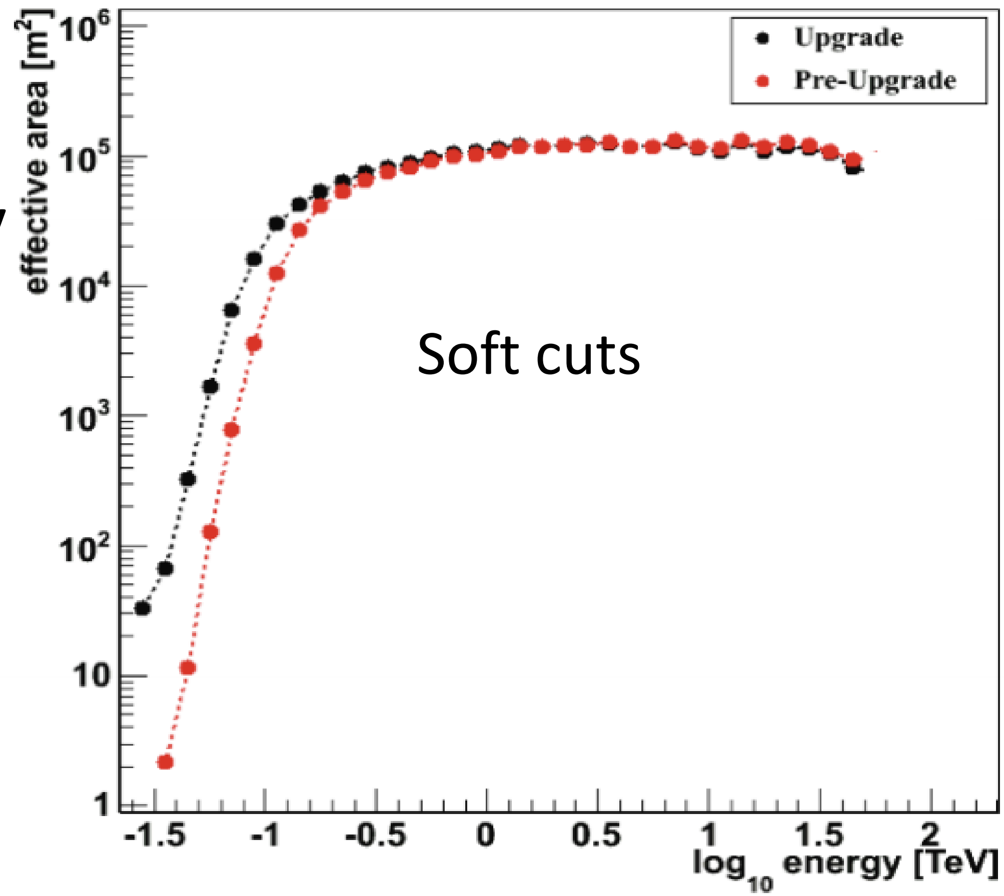
Muon Light Yields



- Muons are a useful diagnostic tool for calibrating Cherenkov telescopes.
- The amount of light emitted by a muons can be accurately determined.

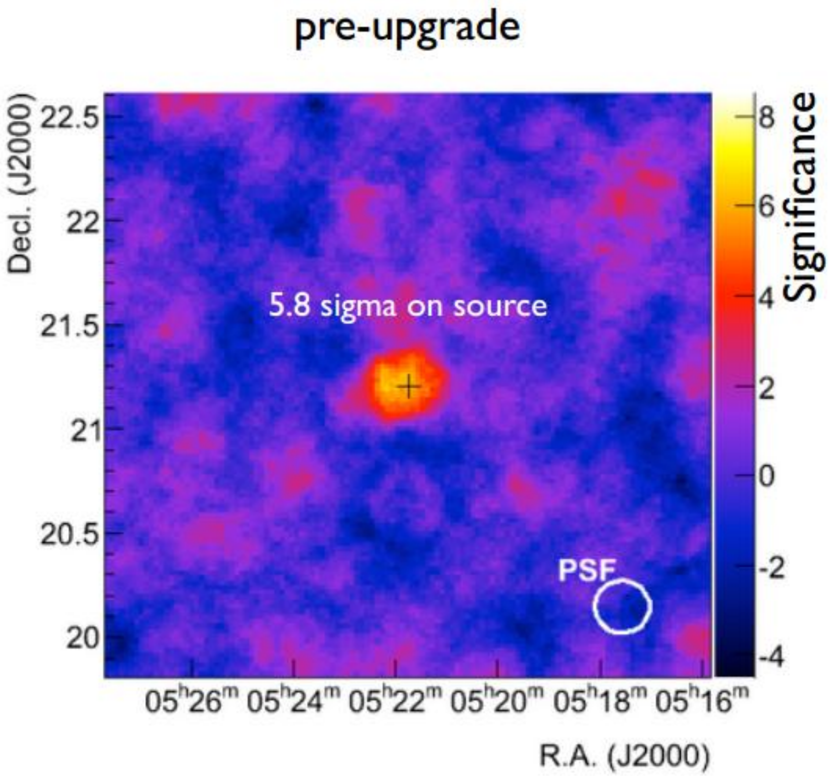
PMT & Trigger Upgrade

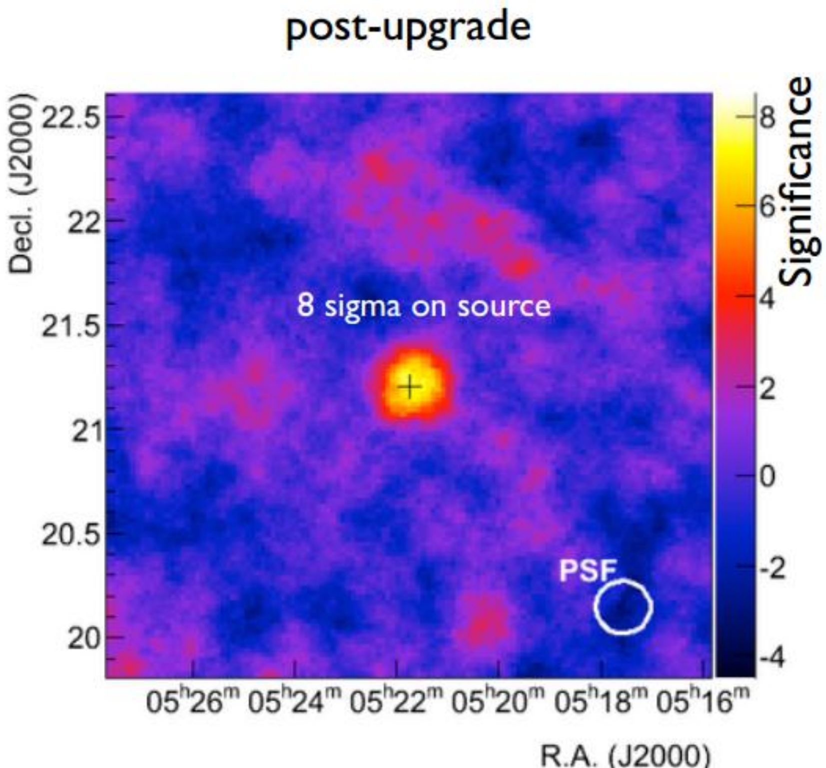
30% decrease in energy threshold for soft and standard analysis cuts



Sensitivity Boost

VER J0521+211
1 hour exposure
5.8 sigma → 8 sigma





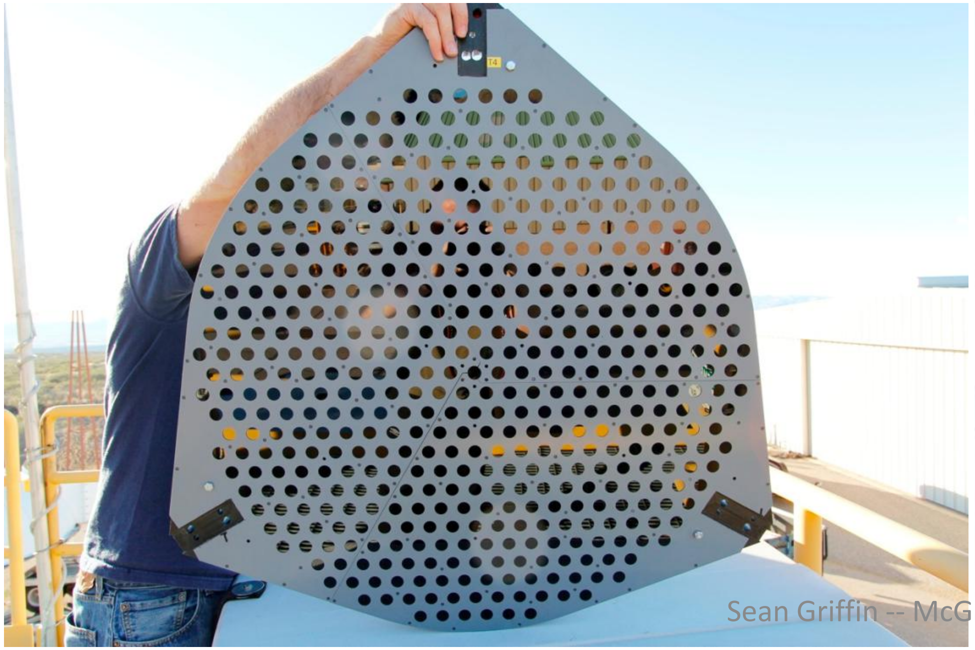
Rajotte (2013)

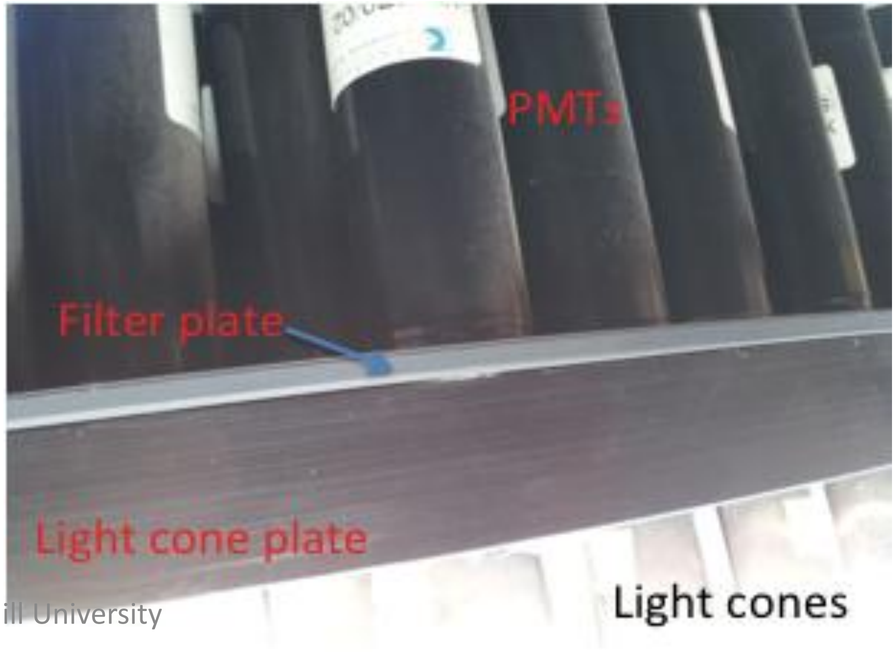
EXTRA

Bright Moonlight Program

- Main motivation: To increase the duty cycle of VERITAS
- Observing under moderate moonlight (35-65% illuminated) possible by reducing HV on PMTs.
  - 81% HV → 30% nominal gain
  - Energy threshold ~200 GeV
- Observing under bright moonlight (even full moon) made possible by using UV filters.
  - Energy threshold strongly dependent on moon illumination and angle (350-500 GeV)
- Extra ~250 hours of observing a year → 20% increase in exposure above 1 TeV

The Filters





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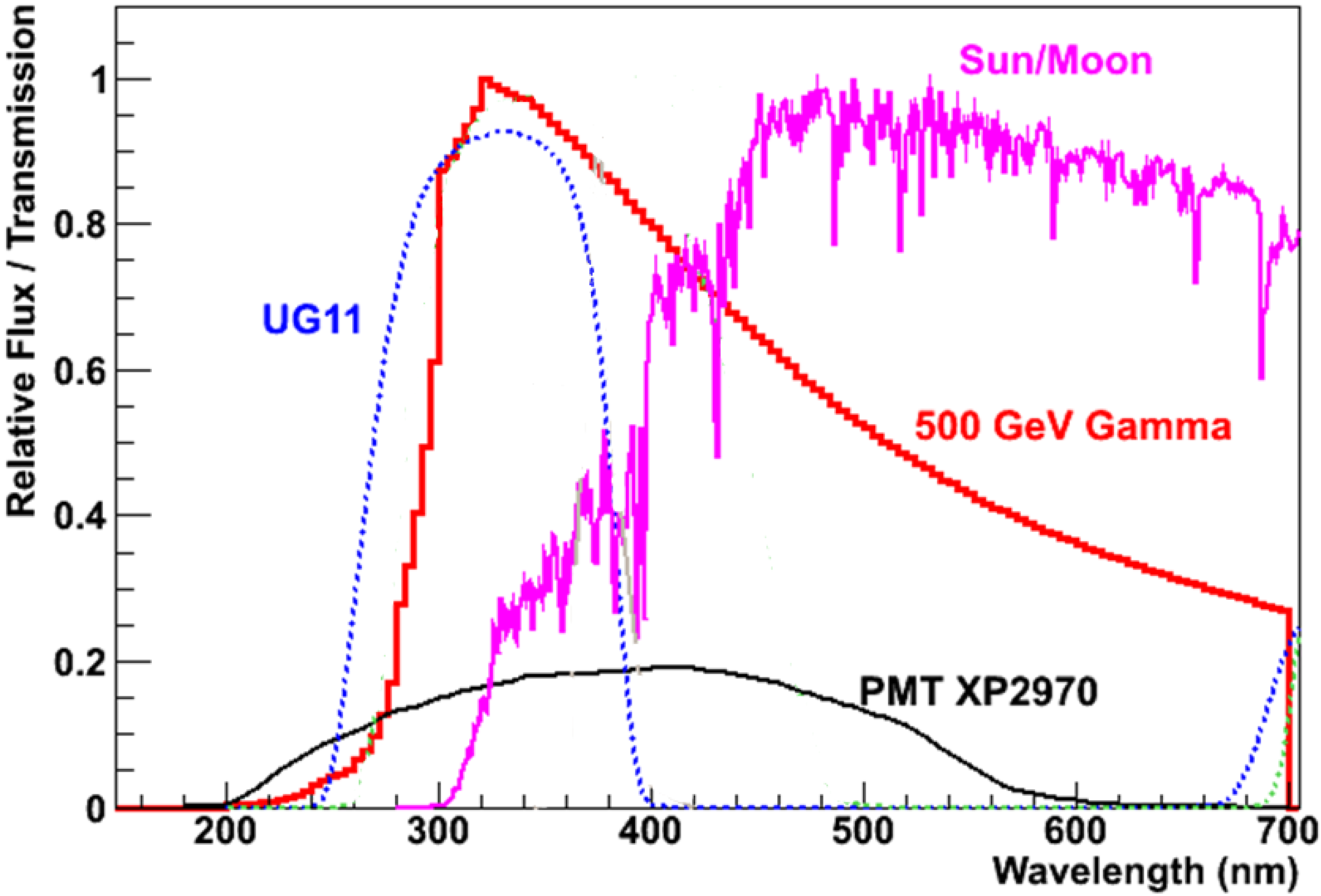
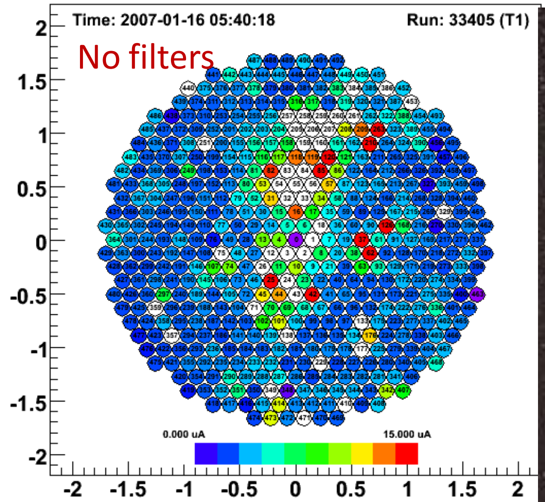
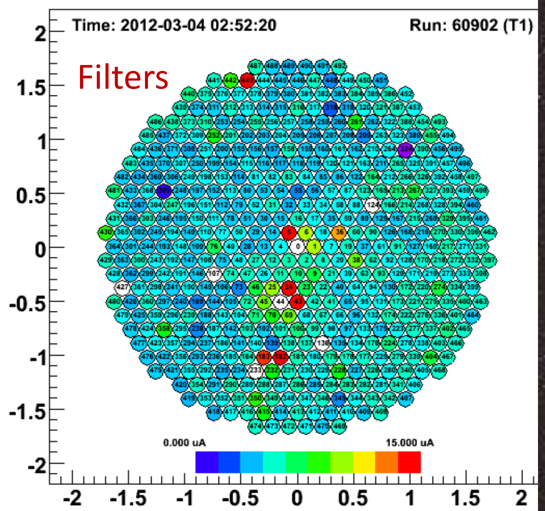


Cut out **~80%** of moonlight; Reduce Cherenkov light by **2/3**

Bright Moonlight Program

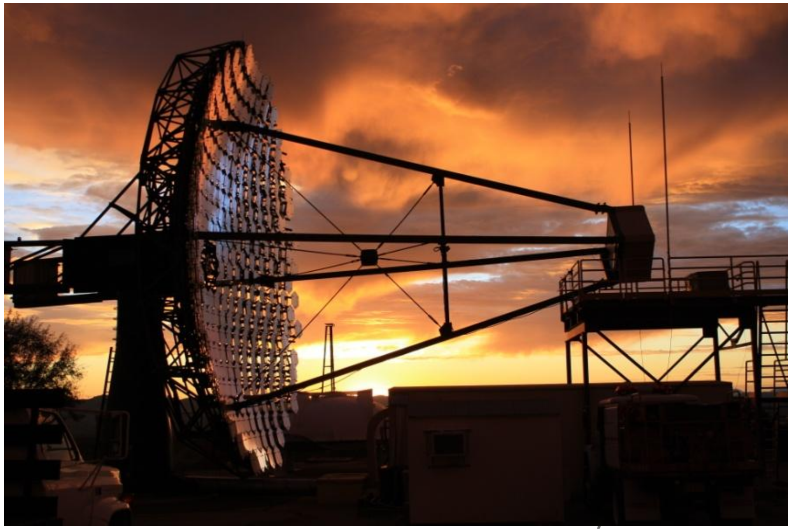
- Useful for monitoring sources for flares
  - We have detected a flaring blazar because of this; paper in preparation
- Increased exposure during periods of activity
  - No longer need to stop observing an active target because the moon is too bright.
- Also able to observe objects that are optically bright or targets that are close to the moon.
  - Electron / positron moon shadow, Orion Nebula, Crab occultation





Conclusions

- VERITAS has undergone several upgrades since 2009:
  - Higher sensitivity (factor of 2 for soft spectrum)
  - Lower energy threshold
  - Better angular resolution
- New bright moonlight program
  - Increases exposure above 1 TeV by ~20%
  - Starting to yield science results -- stay tuned!



References

- Aliu et al. (2013), ApJ, 779:88 (http://arxiv.org/abs/1310.7913)
- Perkins & Maier [VERITAS Collaboration] (2013), 2009 Fermi Symposium (http://arxiv.org/abs/0912.3841)
- Rajotte [VERITAS Collaboration] (2013), Proc. RICH 2013
- Zitzer [VERITAS Collaboration] (2013), Proc. 33rd ICRC (http://arxiv.org/abs/1307.8360)