VERITAS

Gamma-ray Astronomy at the Highest Energies

David Hanna
McGill University

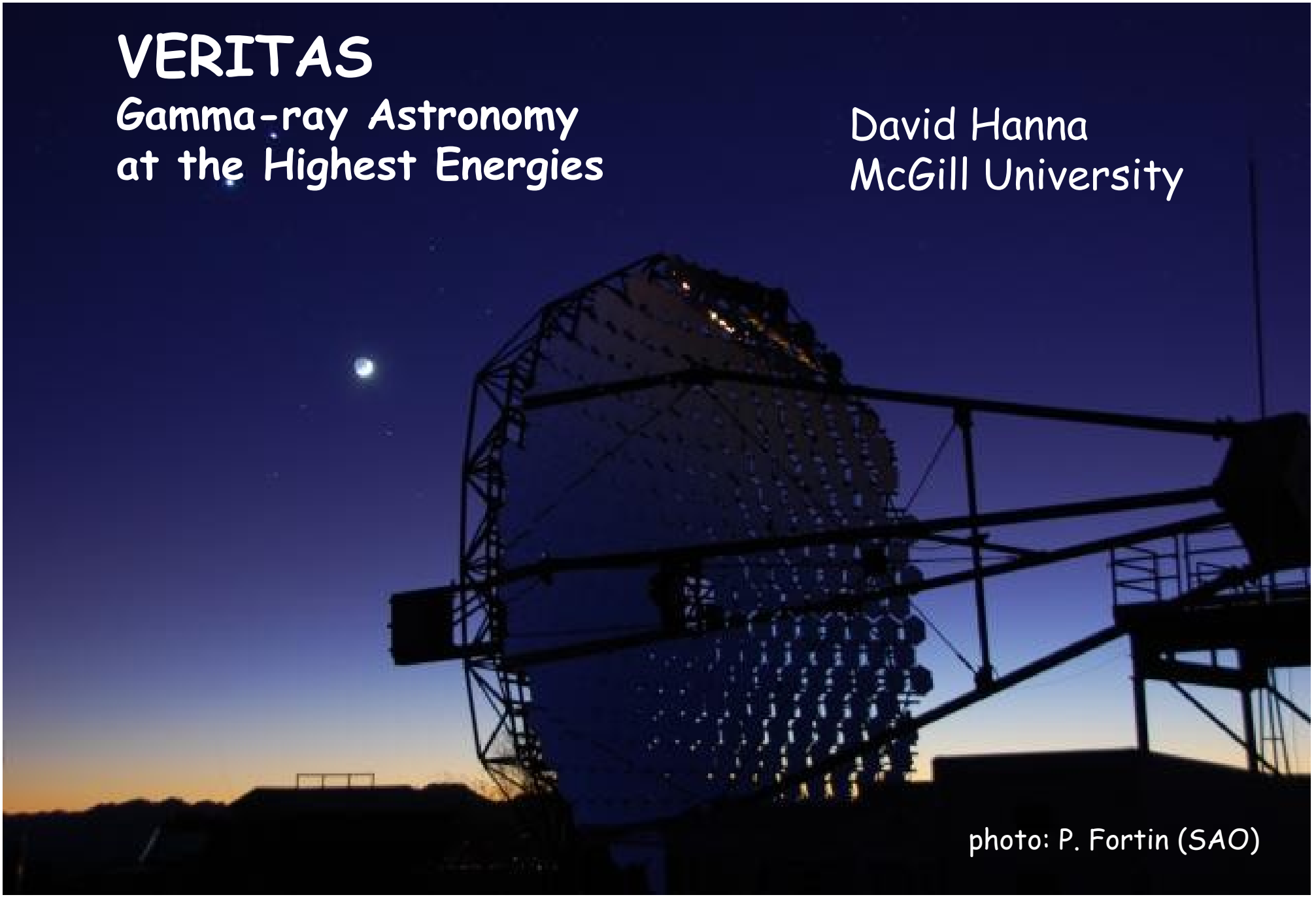


photo: P. Fortin (SAO)

Outline of Presentation

- introduction to VERITAS
  - science motivations
  - historical and technical developments
- present status and recent results
- near-term future
- longer-term opportunities

Science Topics

Galactic sources

- Supernova Remnants (SNRs)
  - source of cosmic rays (with $E < 10^{15}$ eV)?
- Pulsar Wind Nebulae (PWNe)
- Binary Systems
- Primordial Black Holes (PBH)

Dwarf Spheroidal Galaxies

- clean targets for WIMP annihilation searches

Active Galactic Nuclei (AGNs)

- how do they work?
  - -what is accelerated? protons or electrons?
    (implications for Auger, IceCube, Antares)
- located at cosmological distances
  - fast flares probe quantum gravity
  - spectral distortions probe extragalactic radiation

Cherenkov Astronomy

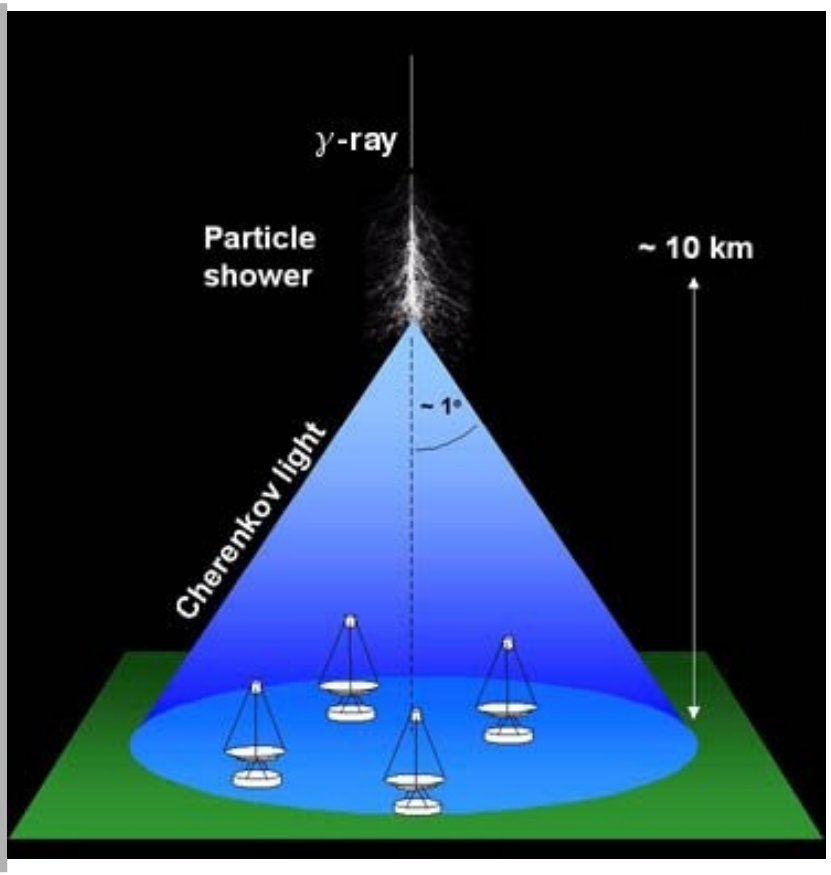
the shower achieves maximum development at about 10-12 km altitude

Cherenkov light spreads out and produces a large 'foot-print' (~ 100,000 m²)

a detector anywhere in the light pool can potentially detect the shower

the detector has enormous effective area - good for fighting the E^{-2} spectra drop-off

light all arrives in ~5 ns so fast detectors and tight coincidences can beat the random light from stars (night-sky background)



VERITAS

four 12-m atmospheric Cherenkov telescopes

1.3 km altitude in southern Arizona

Construction 2003-2007

Full operation from September 2007

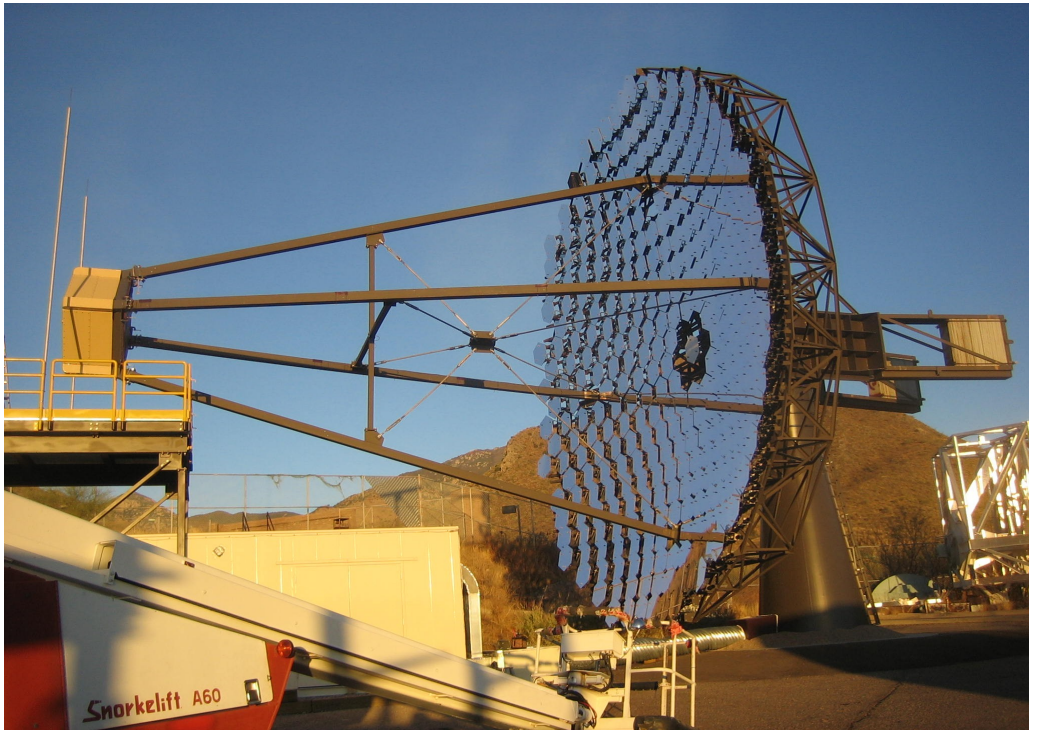
~ 100 collaborators at 21 institutions

- 15 – USA
- 4 – Ireland
- 1 – UK
- 1 - Canada

Nominal cost - $20M

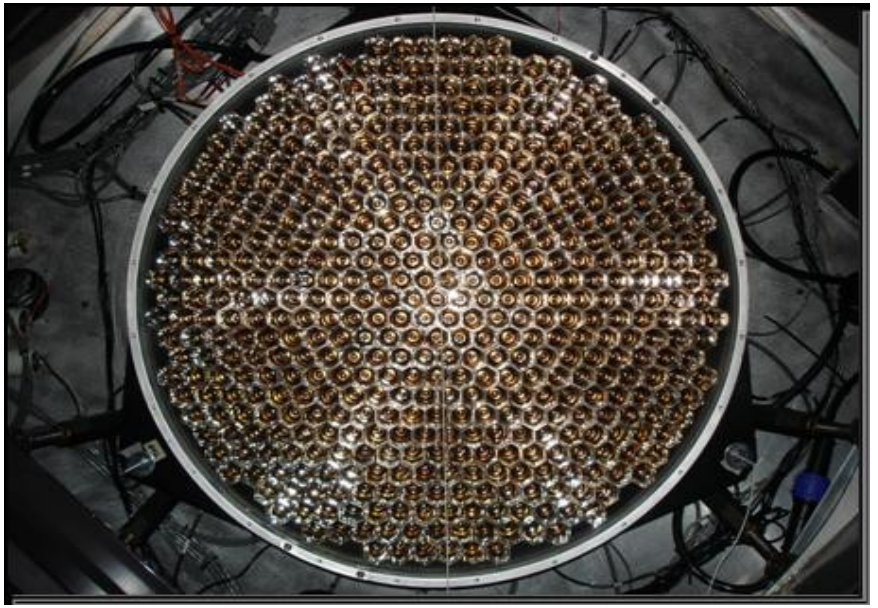
VERITAS: some details

the array comprises four 12 m diameter telescopes



each has 350 mirror facets made from glass surfaced with anodized aluminum

they are mounted on a steel frame to make a Davies-Cotton reflector with a 12 m focal length and a point-spread function with a width of 0.07 °



A 'camera' at the focal point is made from 499 30-mm PMTs which are read out by 500 MHz FADCS

VERITAS and McGill

- joined the collaboration 2002
  - last of the seven core institutions
  - outcome of experience with STACEE project

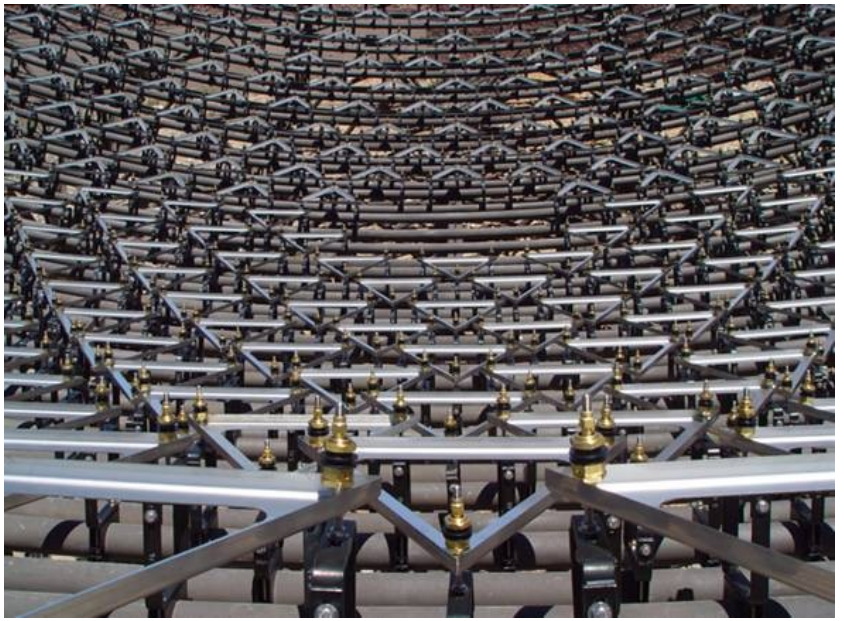
- contributed to building of prototype (2003)
  - mirror mounts
  - night-sky-background measurement device
  - laser calibration system
  - digital delay system for 3rd-level trigger

- contributed to building of the final detector (2004-2007)
  - mirror mounts (NSERC major equipment grant $210k)
  - digital delays

- improvements and upgrades since first-light (2007)
  - mirror alignment device
  - UV-LED calibration flashers
  - UV filters for observing under moonlight

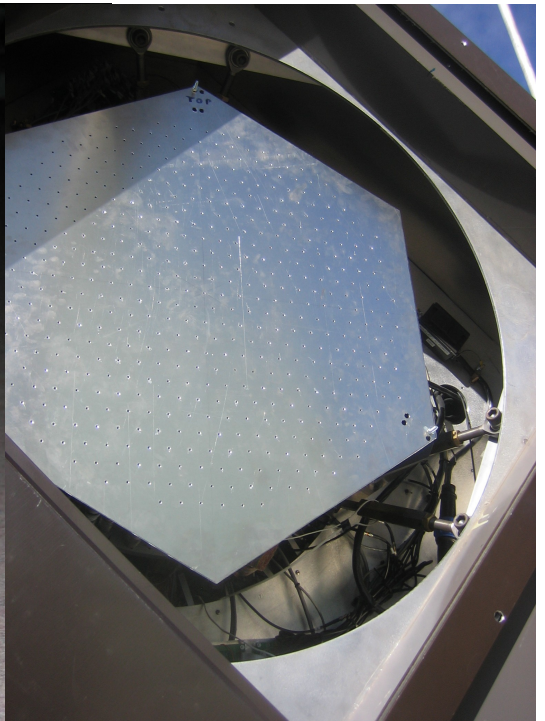
- personnel

McGill Contributions to VERITAS



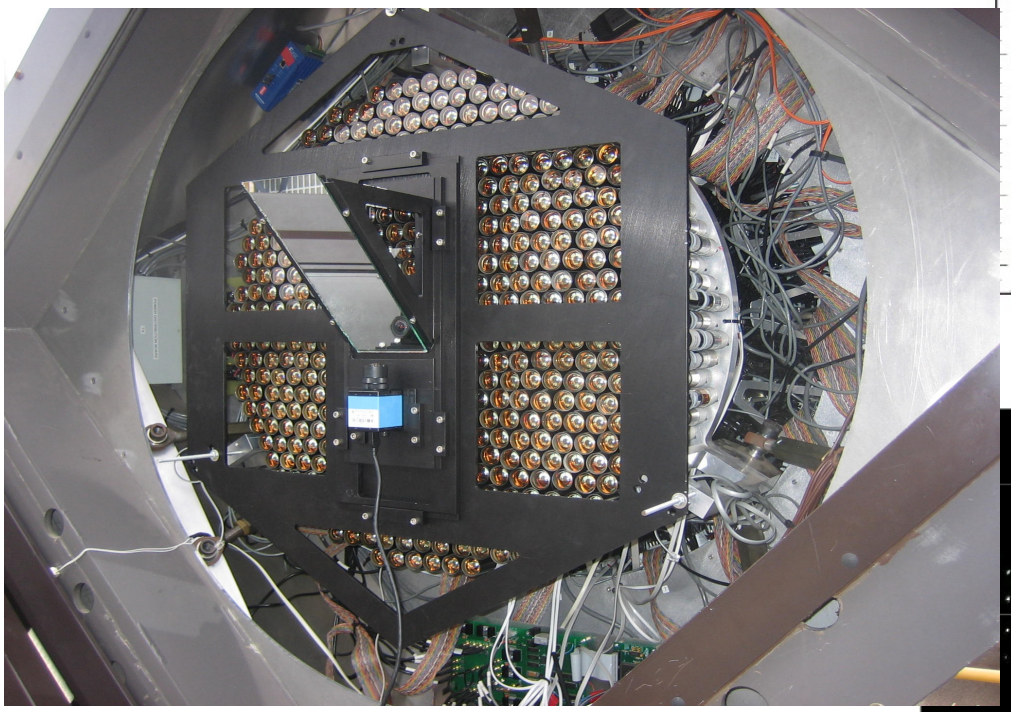
Mirror Mounts

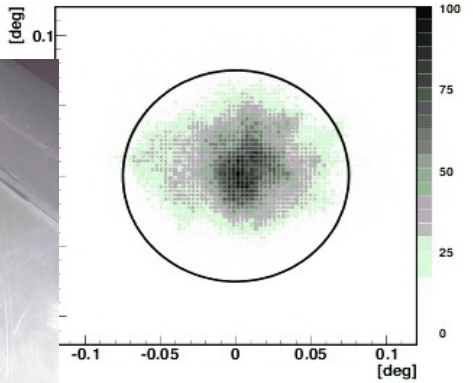
Trigger Electronics



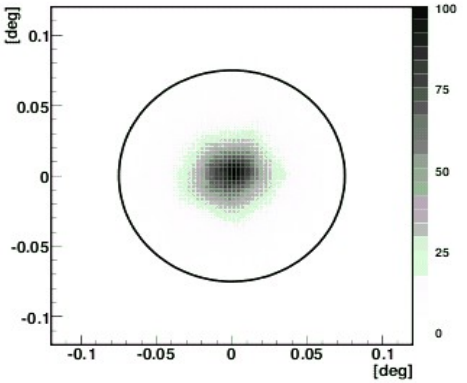
UV-LED Calibration System

McGill Contributions to VERITAS

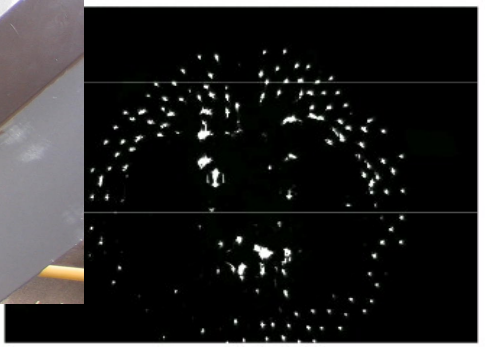




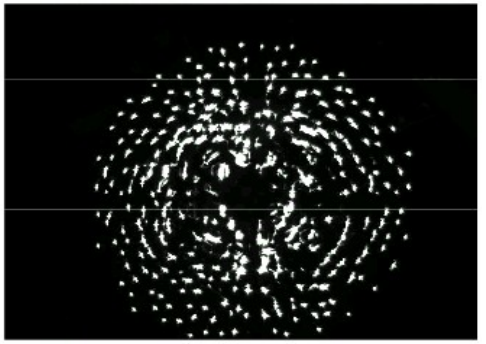
(a) PSF image before



(b) PSF image after



(c) Reflector image before



(d) Reflector image after

Mirror Alignment Tool

McGill Contributions to VERITAS

UV filters
- allow running under moonlight
- allow observations of bright fields

McGill Contributions to VERITAS

People!

VERITAS is ~2x smaller collaboration than HESS or MAGIC

McGill is one of the larger teams

Excellent opportunities for HQP training

- no lack of good students

- healthy flow into and out of traditional HEP as well as high-tech industry

Faculty

D Hanna
K Ragan

Post-doctoral

J Kildea	(2003 - 06)	McGill medical physics
G Maier	(2006 - 09)	DESY Zeuthen
P Cogan	(2007 - 08)	Amdocs Dublin
G Tesic	(2009 - 12)	Penn State
D Staszak	(2010 -)	
J-F Rajotte	(2012 -)	

PhD

L Valcarcel	(2003 - 08)	SES Tech - Montreal
R Guenette	(2006 – 10)	Oxford (STFC Rutherford Fellow)
A McCann	(2006 - 11)	Chicago (Kavli Fellow)
M McCutcheon	(2006 - 12)	NuVu Cameras - Montreal
S Archambault	(2011 -)	
S Griffin	(2011 -)	
J Tyler	(2012 -)	

MSc

JP Gagnon	(2003 - 04)	Telops Quebec City
A MacLeod	(2005 – 08)	NRCan
M Bautista	(2007 - 09)	ETS Montreal
S Griffin	(2009 - 11)	McGill
J Tyler	(2009 - 12)	McGill
T Lin	(2014 -)	

NSERC Support

Project Grants

2004/05	120k
2005/06	170k
2006/07	225k
2007/08	265k
2008/09	265k
2009/10	265k
2010/11	277k
2011/12	277k
2012/13	277k
2013/14	270k
2014/15	270k
2015/16	270k

Equipment Grants

2004/05	105k
2005/06	105k

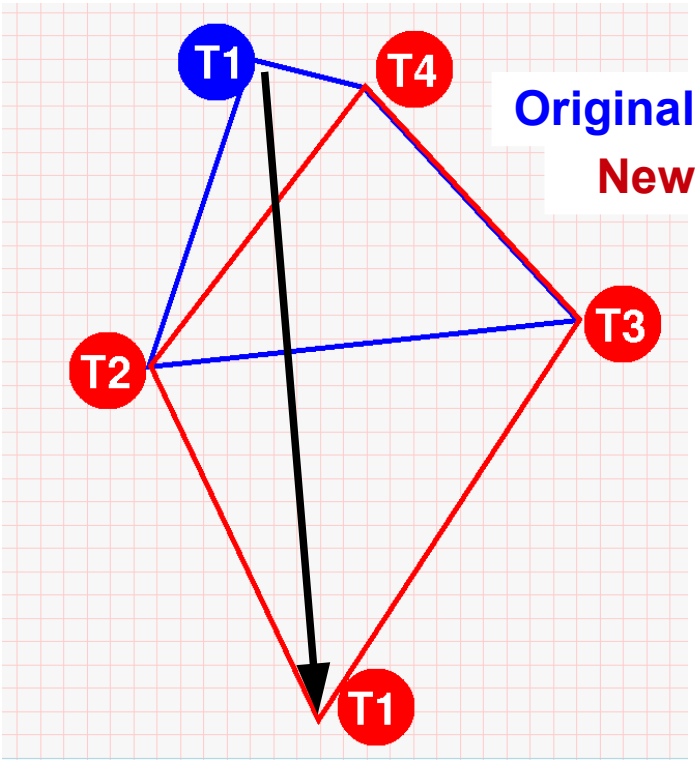
Recent Developments

Relocation of Telescope 1

- for historical reasons the array did not have an optimal configuration

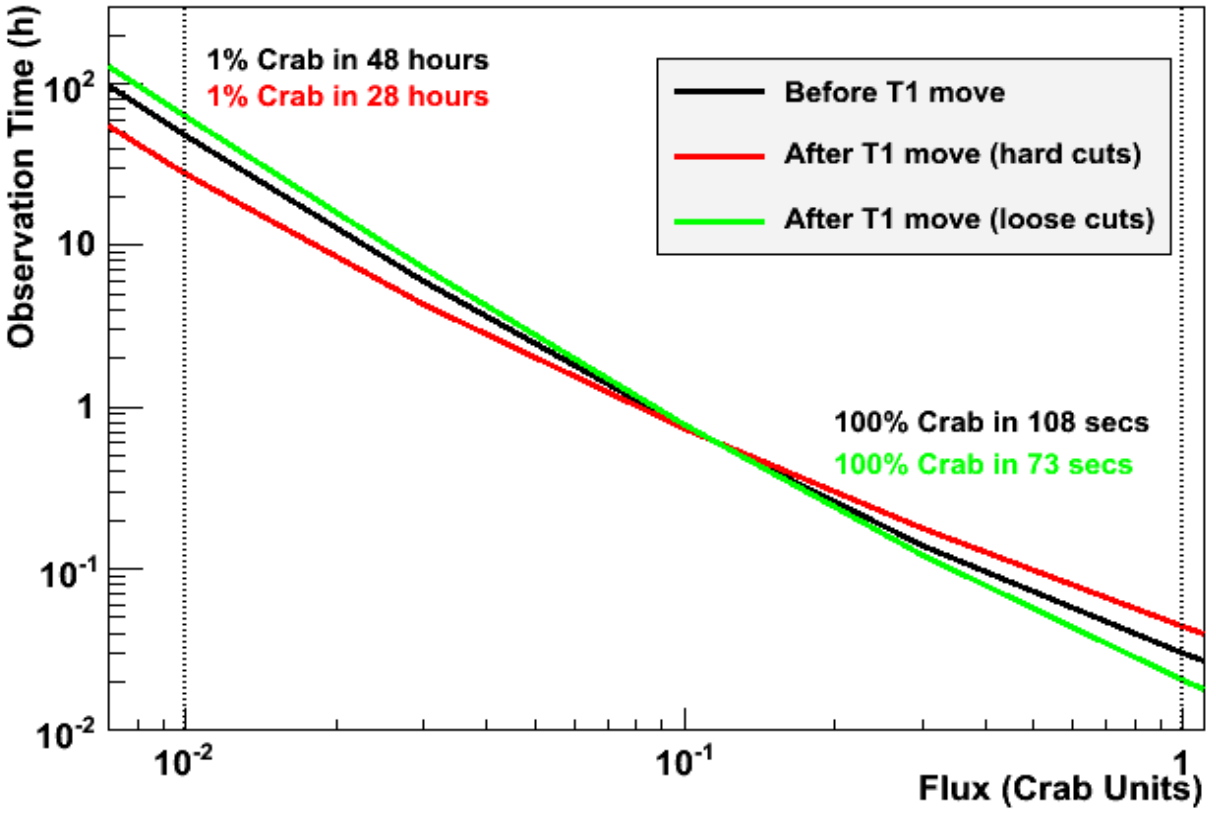
- during the summer of 2009 we relocated T1 to improve baselines and muon rejection

VERITAS is the most sensitive VHE detector in the world!



Original Layout

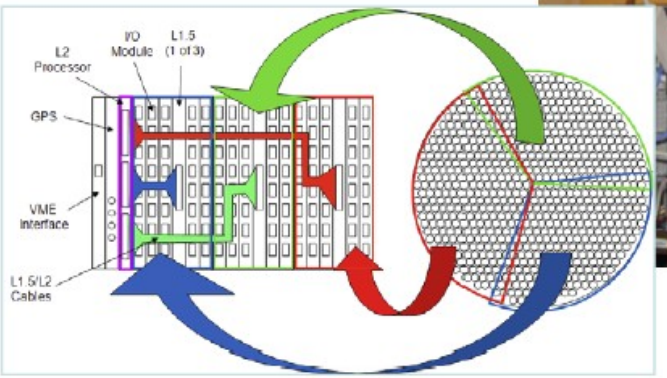
New Layout

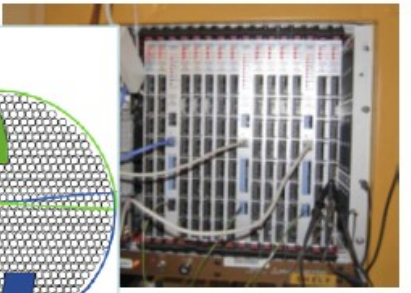


VERITAS Trigger & Camera Upgrade

Trigger upgrade (2009-2011):

- Camera trigger processing done by special (L1.5) FPGA-trigger cards.
- L2 processor combines L1.5 signals.
- Installed Summer 2011.

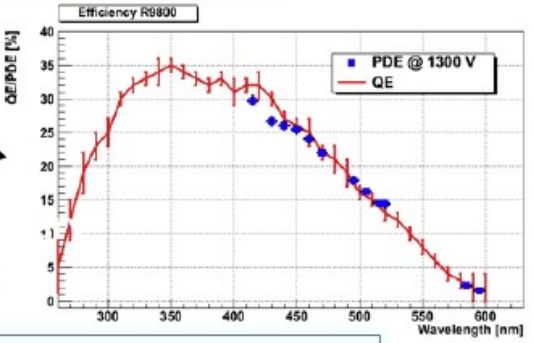




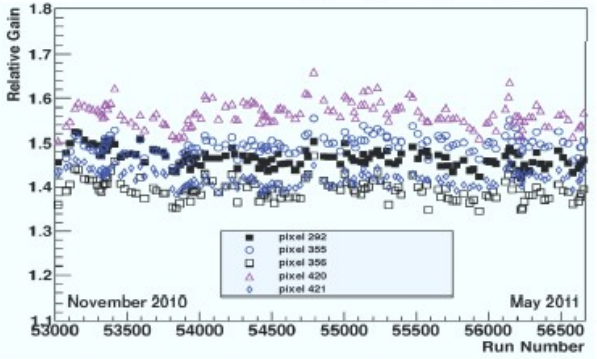
Camera upgrade (2010-2012):

- Replace all pixels with HQE PMTs (Hamamatsu R9800 SBA); new mount tube and pre-amp.
- Improved sensitivity and lower E threshold (120 GeV→ 80 GeV) .
- Installed Summer 2012.

Measured QE/PDE (50% increase)



PMT stability (*in situ*)

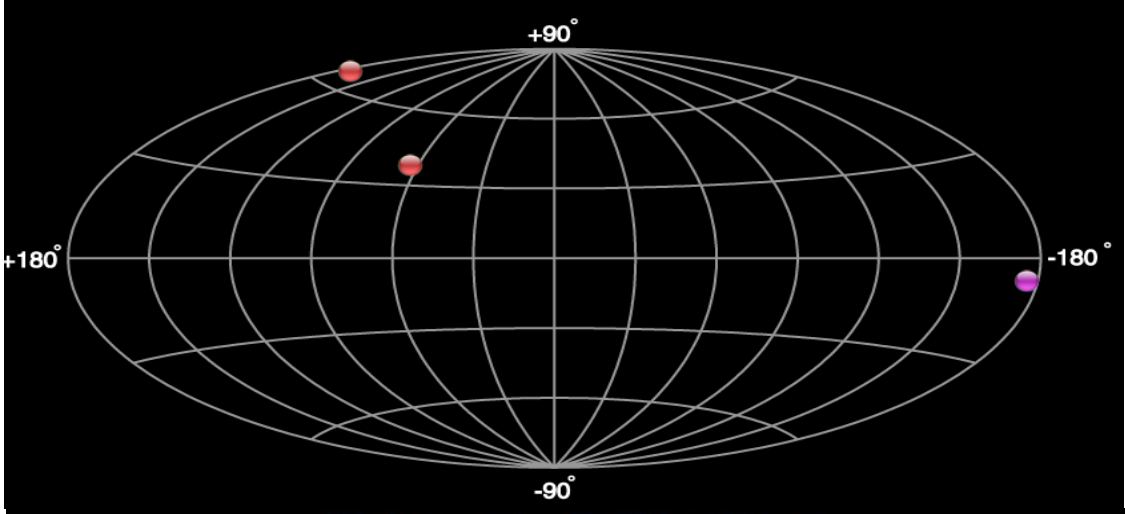


Evolution of TeV catalog

(see tevcat.uchicago.edu
Scott Wakely, Deirdre Horan)

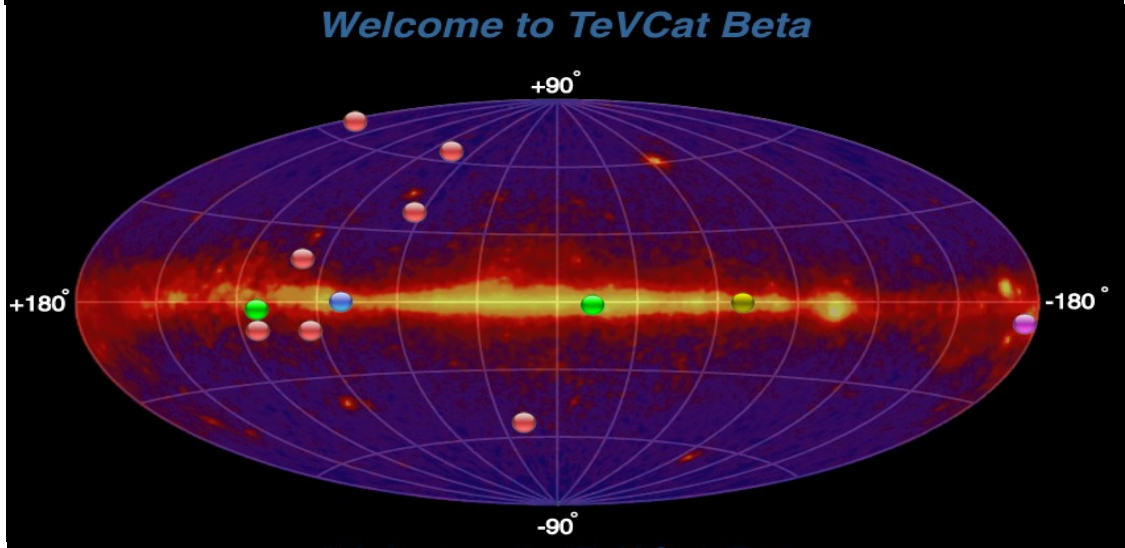
1996

3 sources



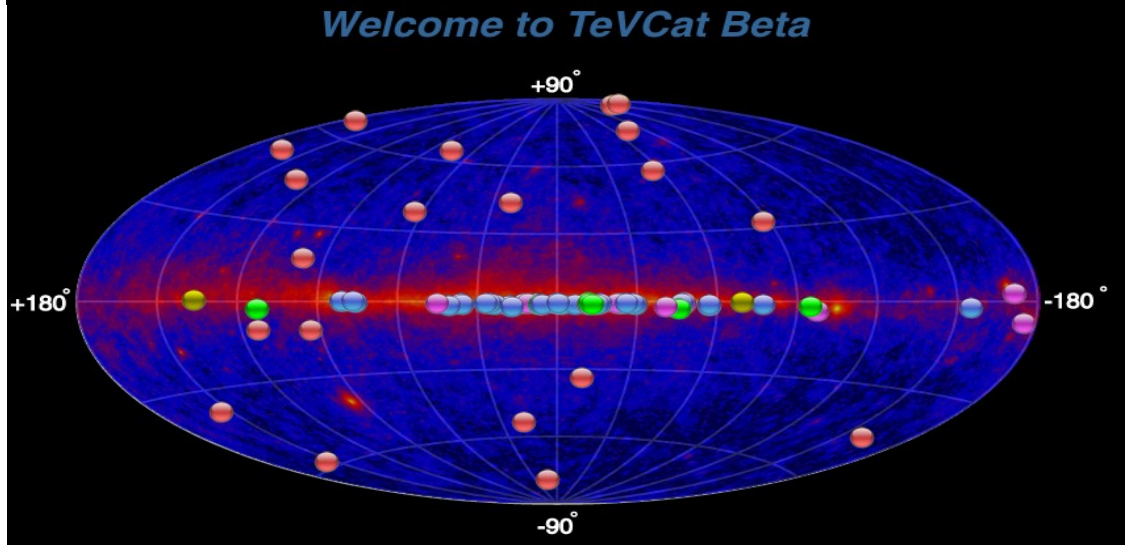
2002

12 sources
(galactic continuum
sky map from EGRET)



2008

72 sources
(galactic continuum
sky map from Fermi)

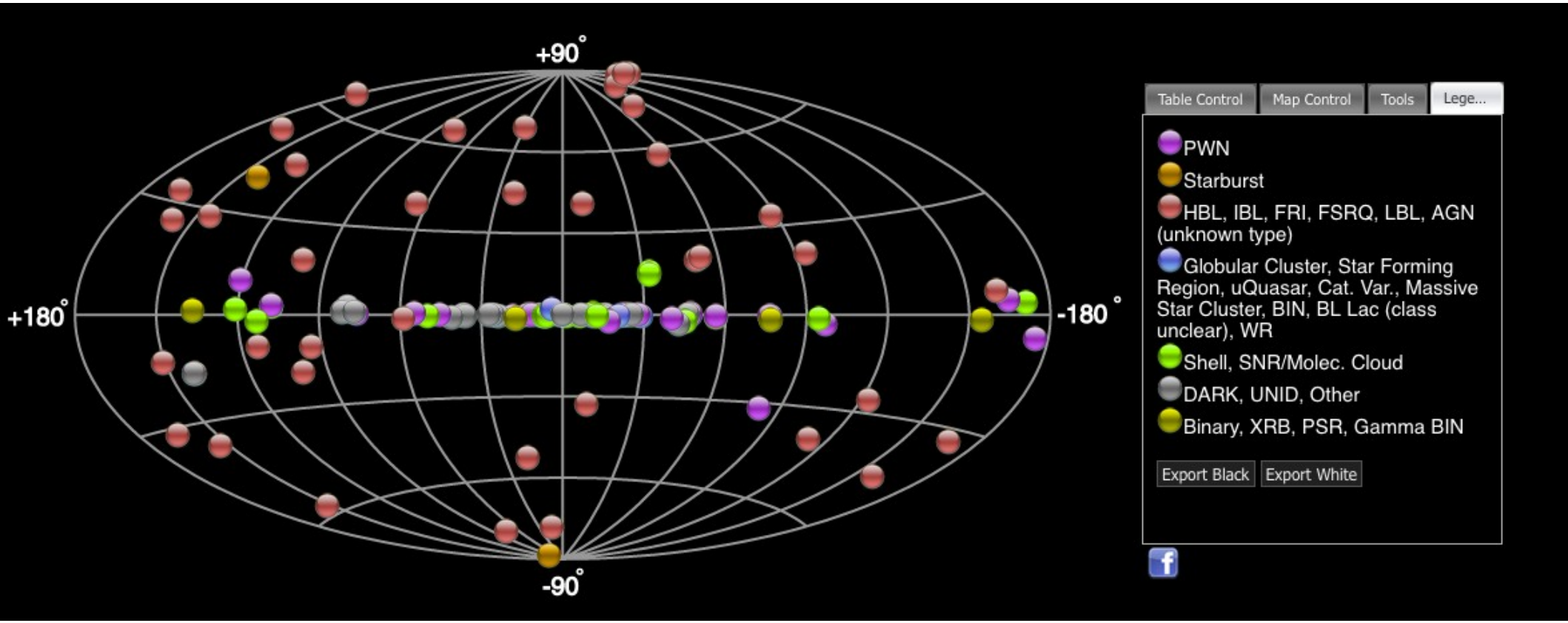


Evolution of TeV catalog

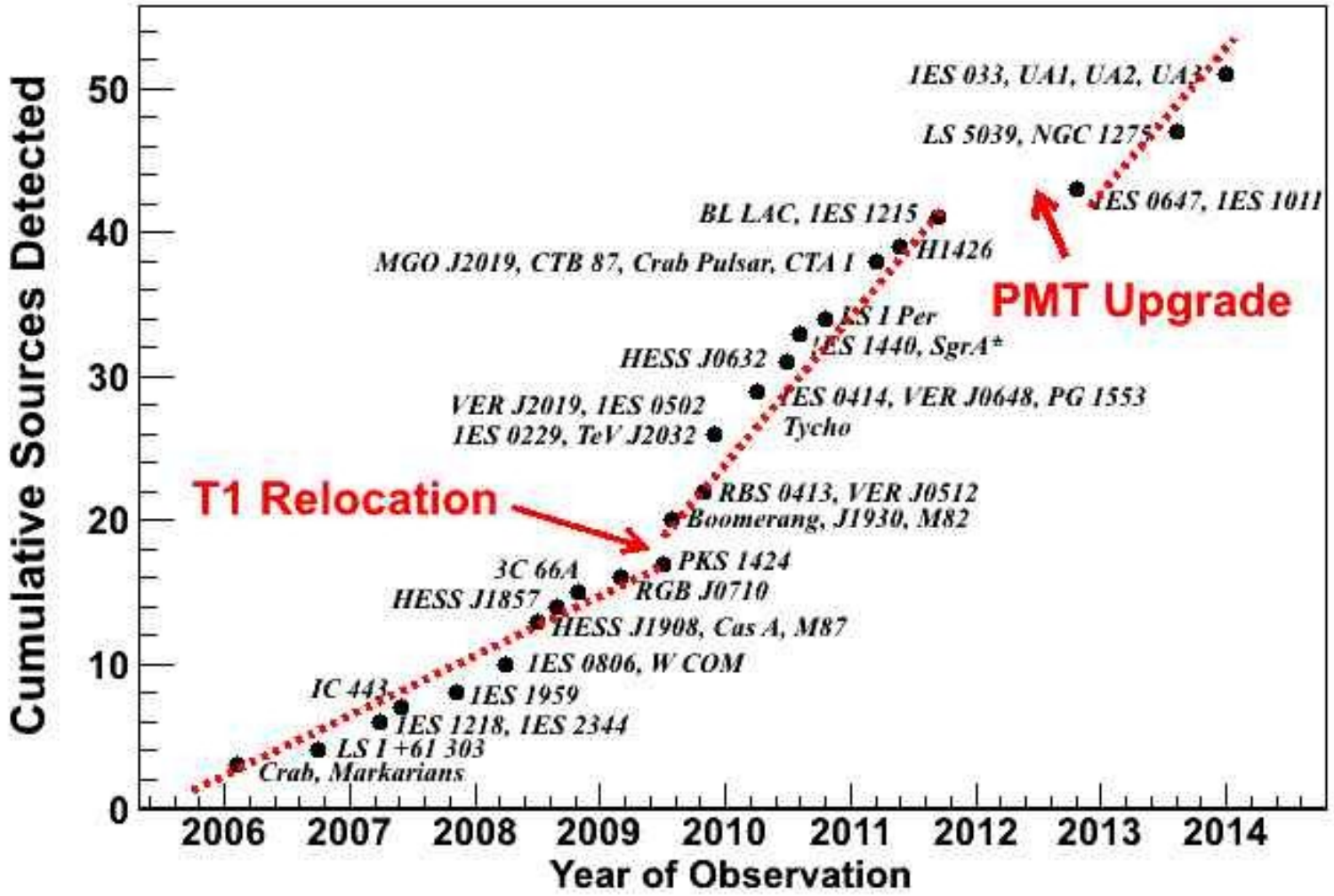
(see tevcat.uchicago.edu
Scott Wakely, Deirdre Horan)

2013 (September)

145 sources

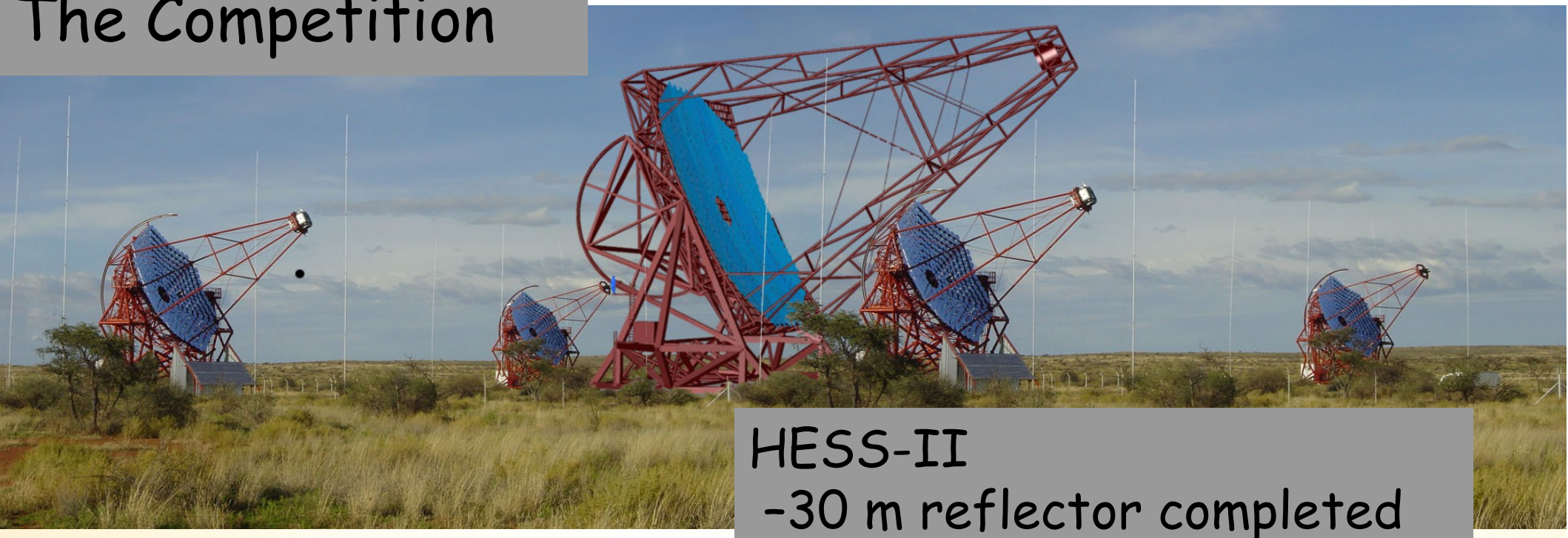


Kifune Plot - VERITAS

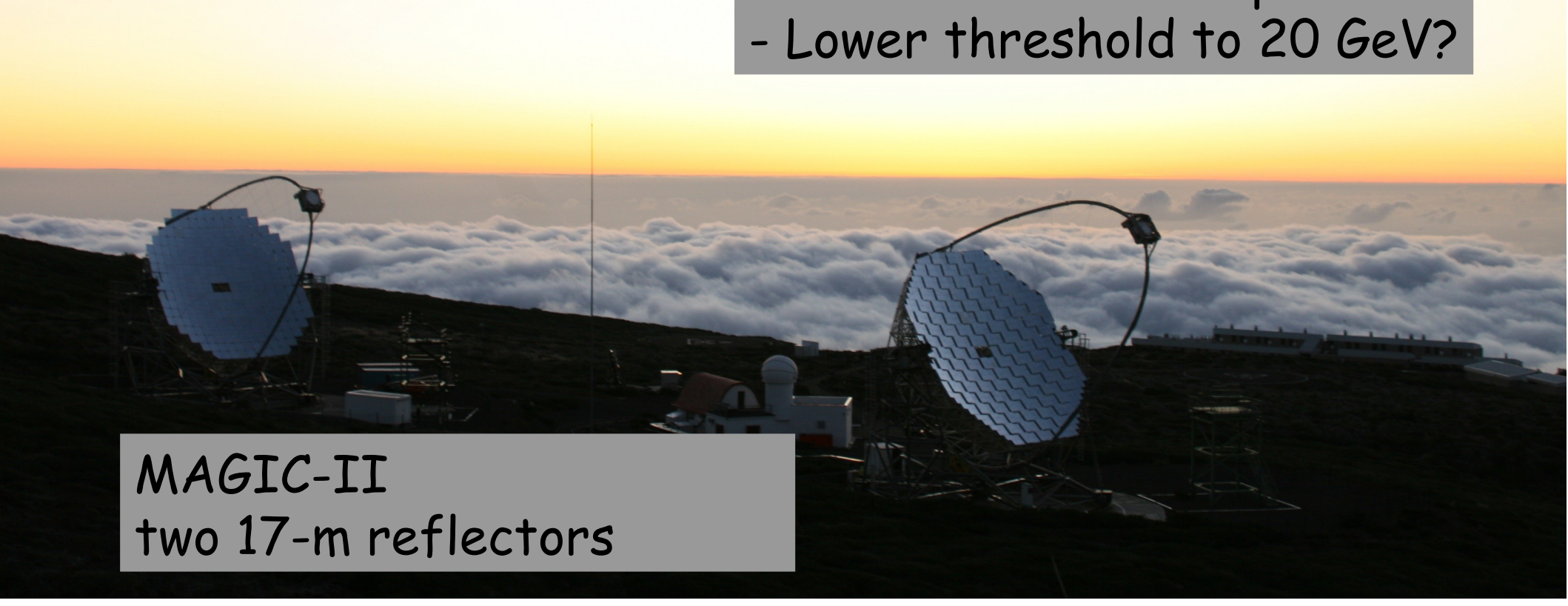


Andy Smith (Utah)

The Competition



HESS-II
-30 m reflector completed
- Lower threshold to 20 GeV?



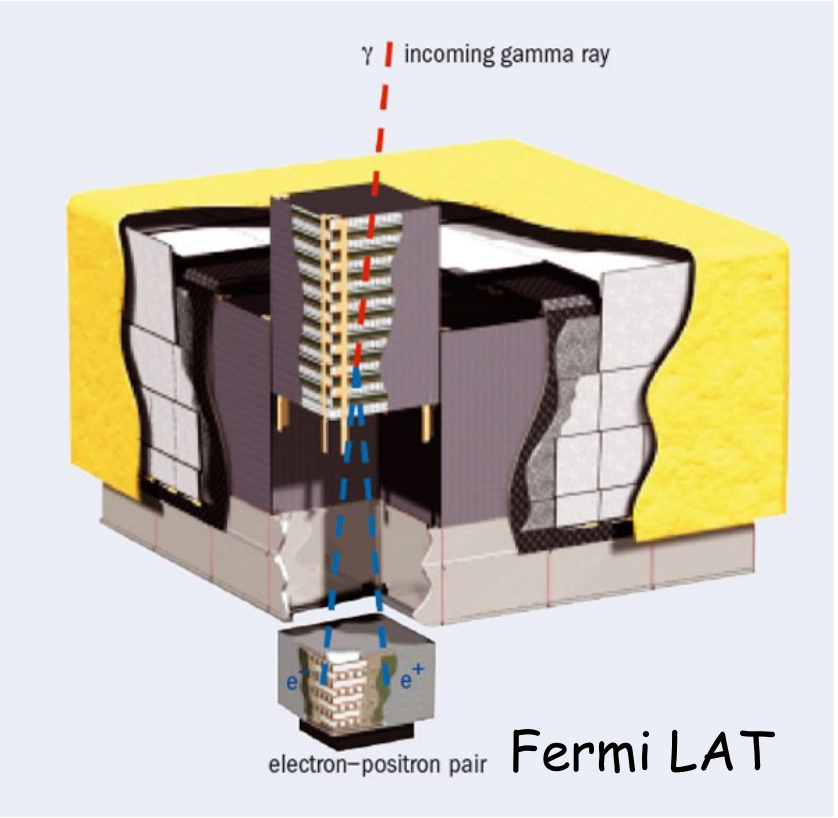
MAGIC-II
two 17-m reflectors

Space-borne instruments - FERMI

- great signal-to-noise (anti-coincidence detector to veto charged particles)

- excellent duty factor – always on

- superb acceptance – Fermi scans the entire sky in 3 orbits



But

- limited collection area (order 1 m^2) - need long integration times for faint sources (poor sensitivity to transients)

- limited angular resolution (especially at low energies) due to multiple scattering of e+e-
  - some sources are not matched with known objects (UFOs)

Fermi was launched in 2008 - will operate until at least 2018(?)

- it is an excellent complement to VERITAS (multiwavelength campaigns, pathfinder, transient alert)

HAWC (High Altitude Water Cherenkov observatory)

- a new pathfinder at TeV energies

new detector in Mexico
(Sierra Negra 4100 m)

signal comes from shower particles generating Cherenkov light in 300 large water tanks

large field-of-view (15% of sky)

no pointing

100% duty cycle

complete in 2014

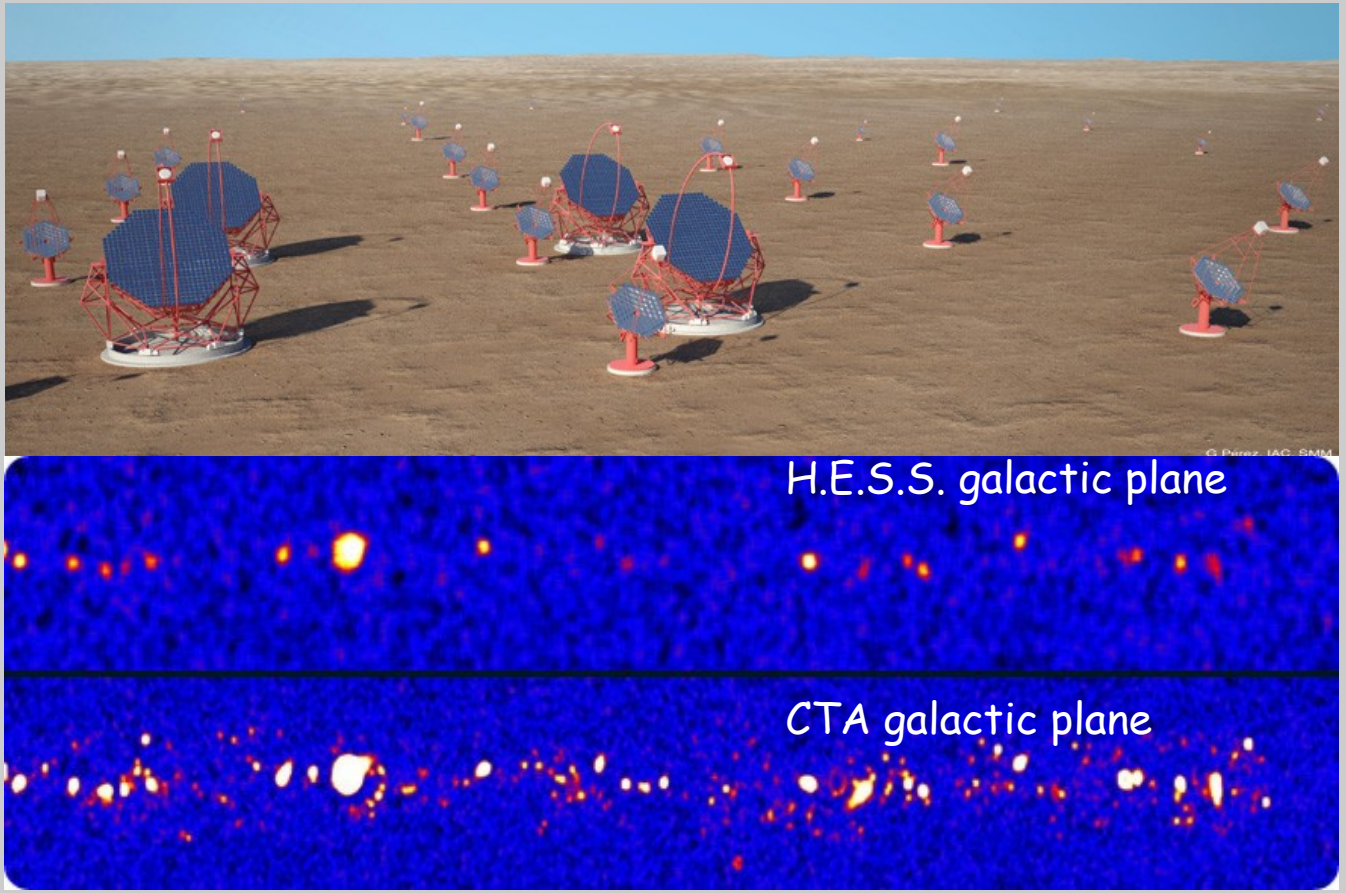
less sensitivity than VERITAS but good for unbiased surveys and as a pathfinder

CTA – the (far ?) future

- VHE gamma-ray astronomy has a well-defined and promising near-term future with VERITAS, MAGIC and H.E.S.S.

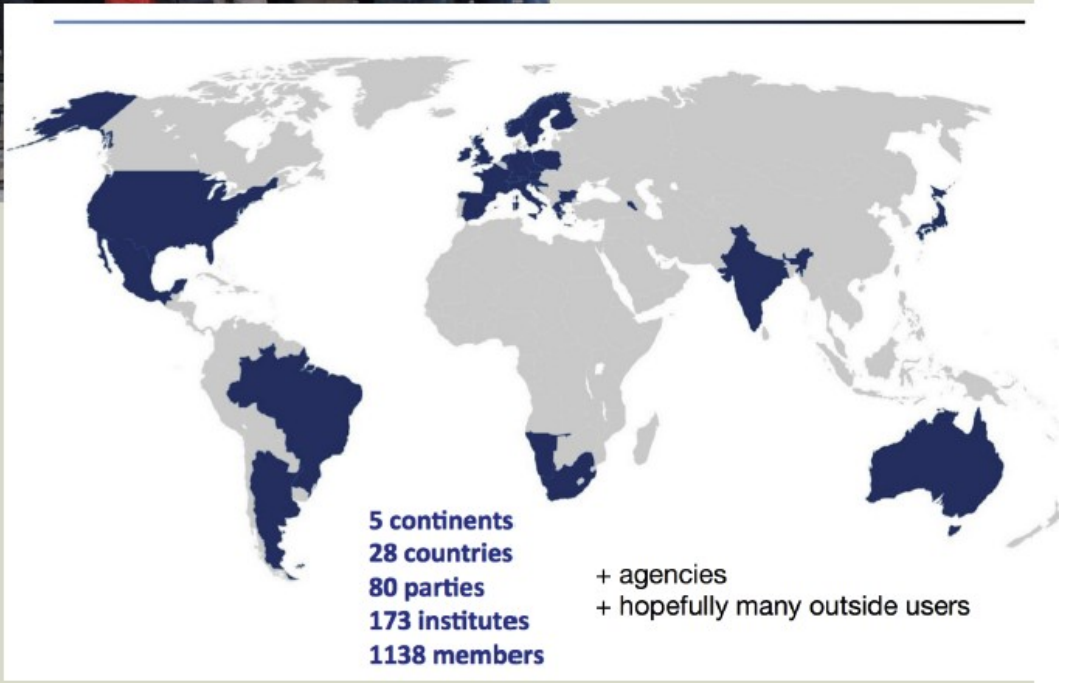
- the next-generation instrument is already in the design phase

- Cherenkov Telescope Array (CTA)



see www.cta-observatory.org for details

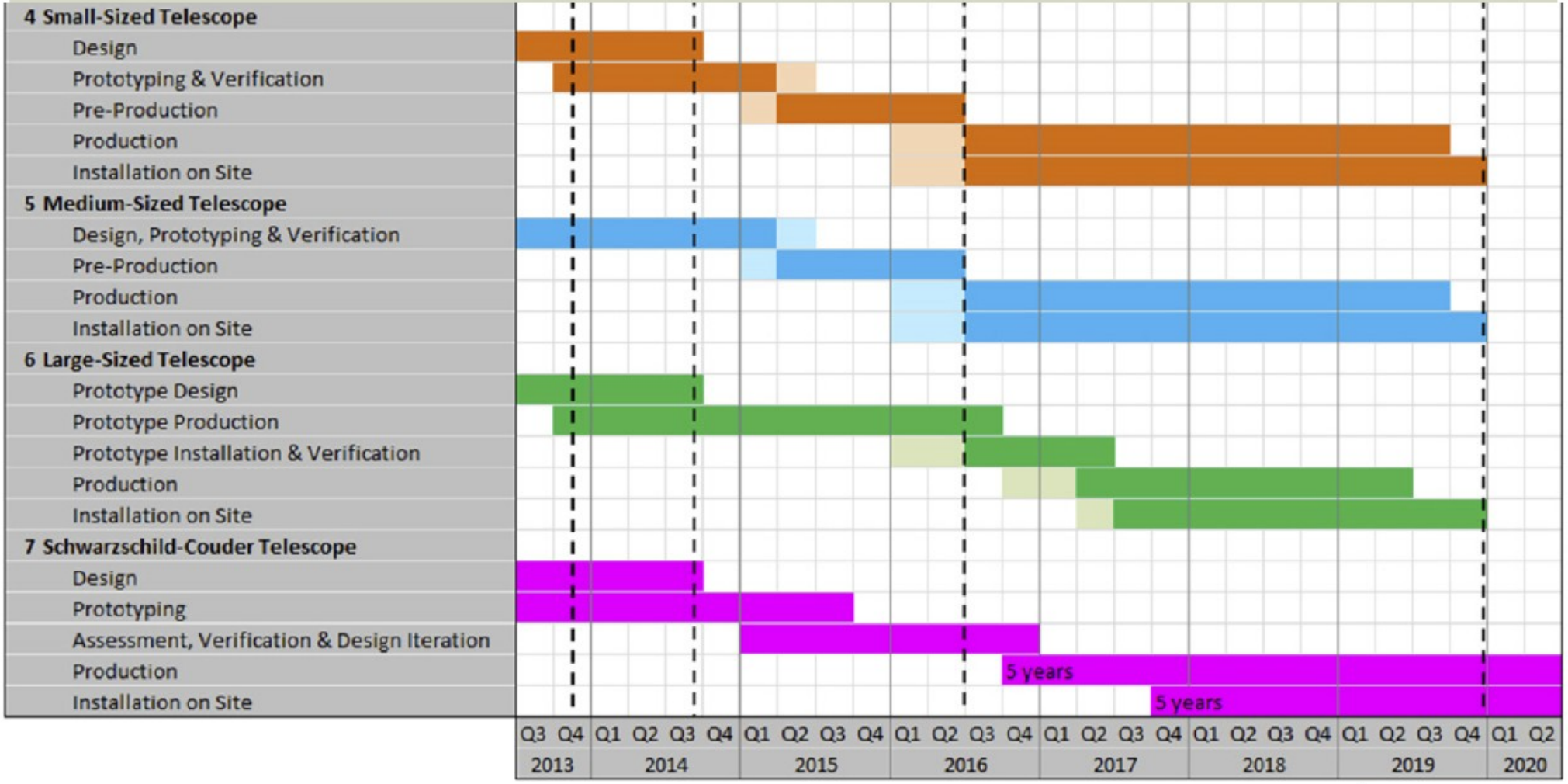
A COLLABORATION THAT GROWS



- HESS+MAGIC+VERITAS collaborations + Europe + world interest (Japan, Argentina)
- US AGIS (Advanced Gamma-ray Imaging System) converged to CTA
- Regular meetings since 2007.

CANDIDATE SITES

TELESCOPES (PRELIMINARY)



2019

The near-term future at McGill

- VERITAS will run for at least the next five years
  - stable, well-understood instrument
  - operations and maintenance - no upgrades
  - less focus on 'low-hanging fruit'
  - deeper observations
  - more time on dark-matter candidates (legacy observations)
  - systematic studies of binaries
  - HAWC and FERMI can serve as pathfinders

- McGill Team will continue its role
  - excellent opportunities for students and postdocs
  - less development needed - frees up time for other projects

    DH intends to reduce time to 50% and spend the rest on the CHIME experiment

    KR intends to spend 90% on VERITAS for the next three years