VERITAS Status and Plans

IPP Long-range Town-hall Meeting
University of Alberta 2015/06/114

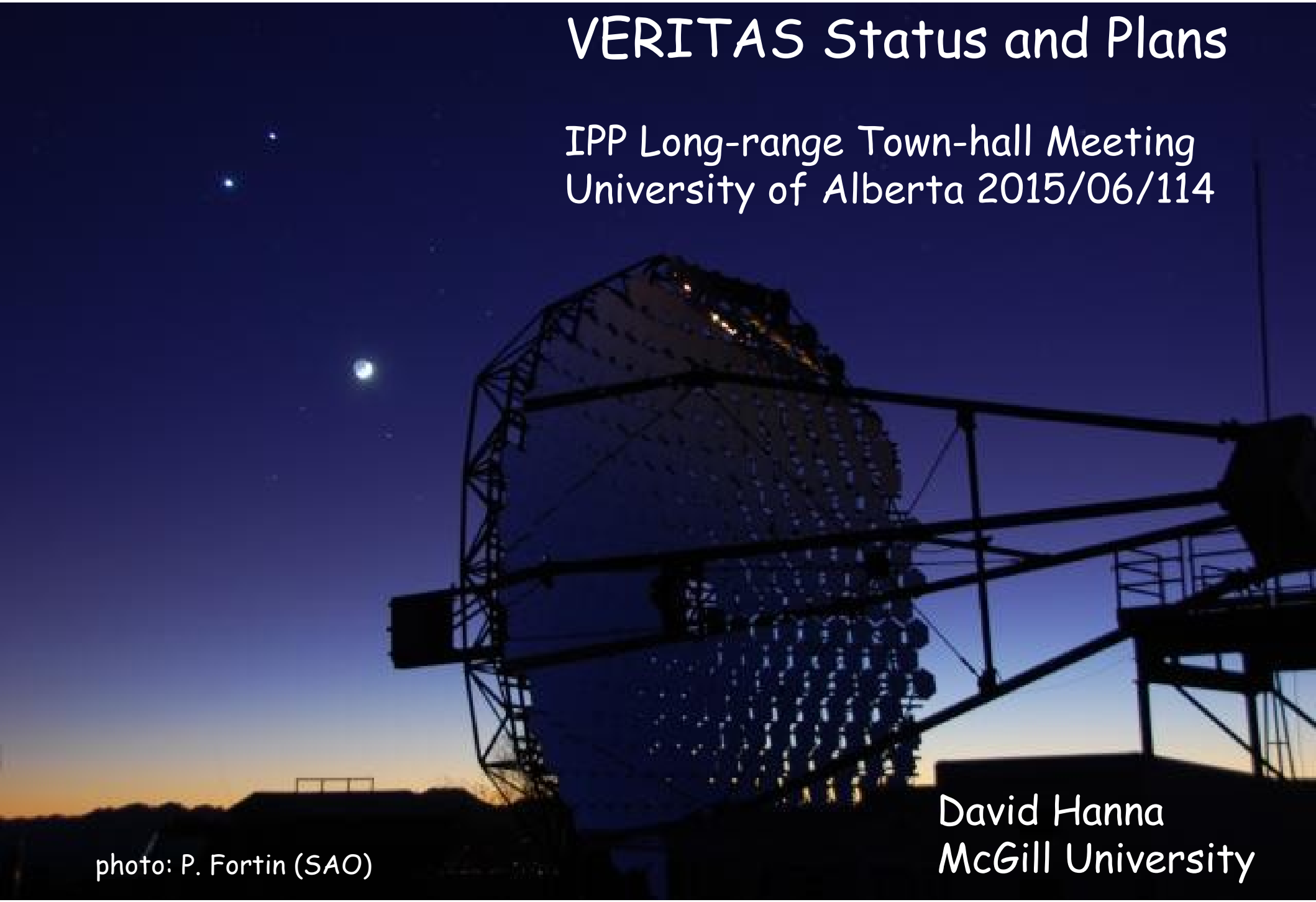


photo: P. Fortin (SAO)

David Hanna
McGill University

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)
- Cosmic-ray electrons (dark matter or pulsars?)

Dwarf Spheroidal Galaxies

- clean targets for WIMP annihilation searches
- more candidates being discovered thanks to SDSS

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

VERITAS

four 12-m atmospheric Cherenkov telescopes

1.3 km altitude in southern Arizona

Construction 2003-2007

Full operation from September 2007

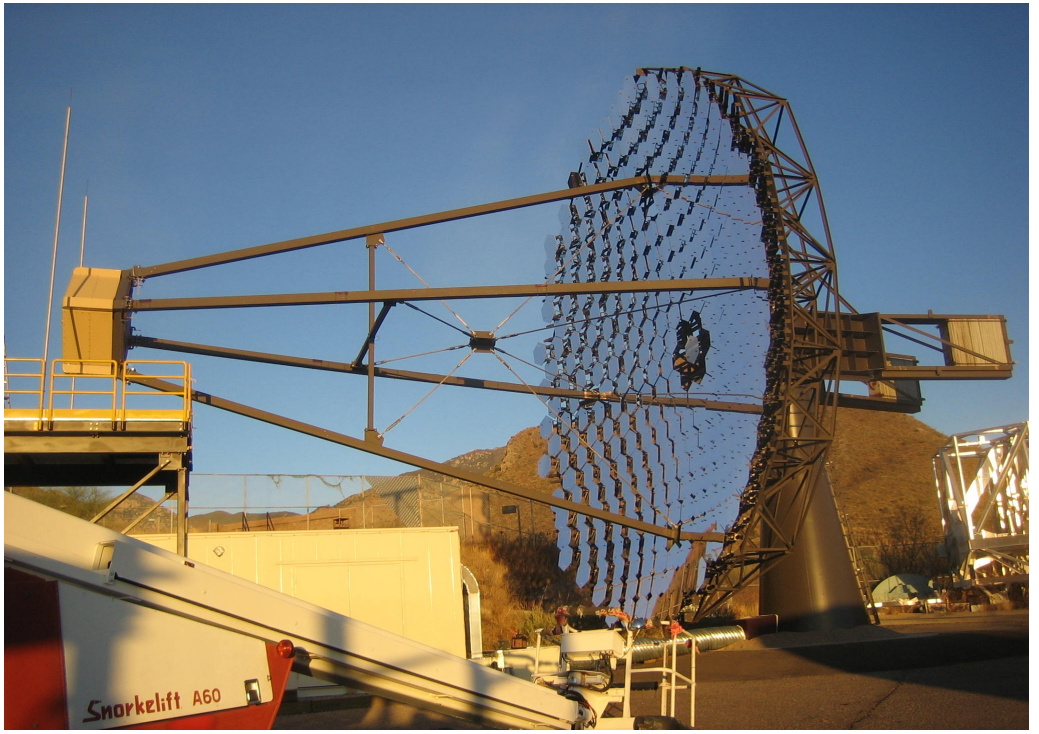
~ 100 collaborators at 22 institutions

- 15 – USA
- 4 – Ireland
- 2 - Germany
- 1 - Canada

Nominal cost - $20M

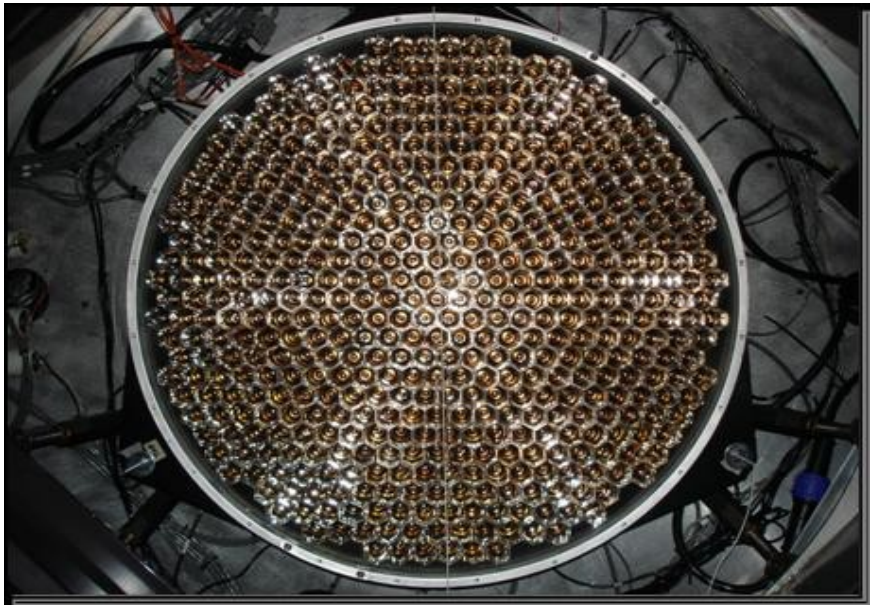
VERITAS: some details

the array comprises four 12 m diameter telescopes



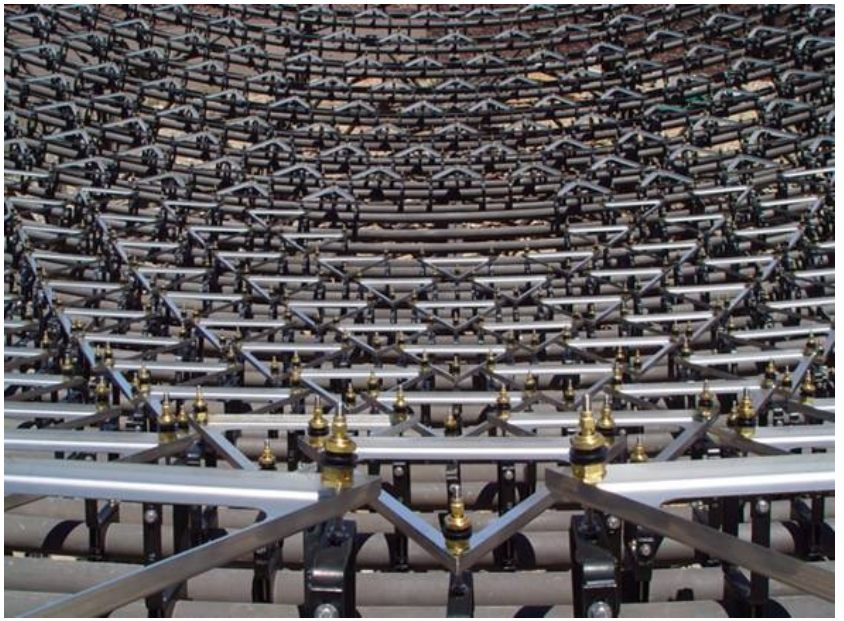
each has 350 mirror facets made from glass surfaced with anodized aluminum

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 °



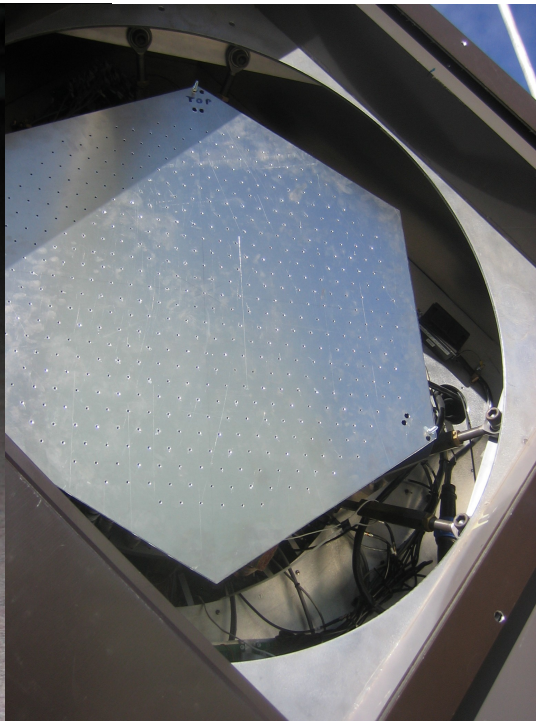
A 'camera' at the focal point is made from 499 30-mm PMTs which are read out by 500 MHz FADCS

McGill Contributions to VERITAS



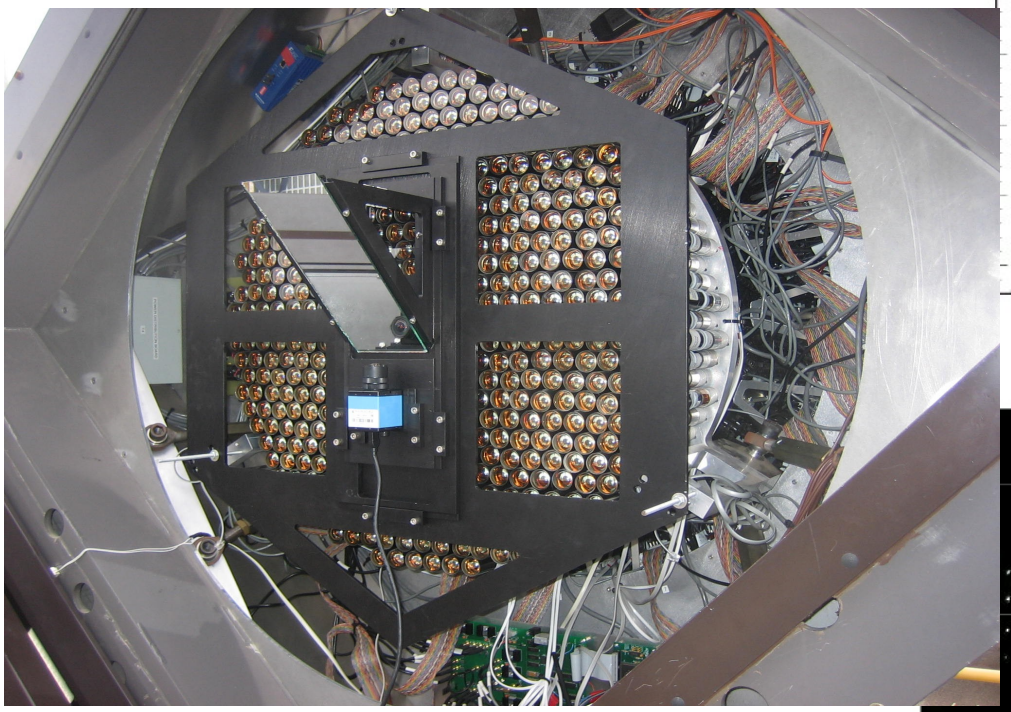
Mirror Mounts

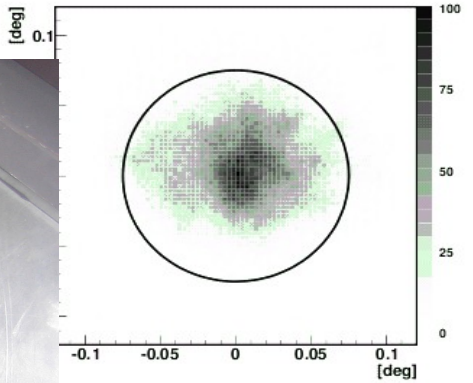
Trigger Electronics



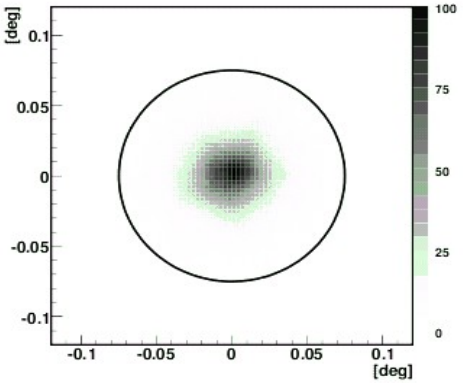
UV-LED Calibration System

McGill Contributions to VERITAS

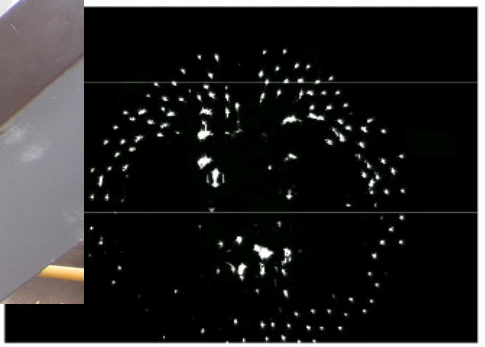




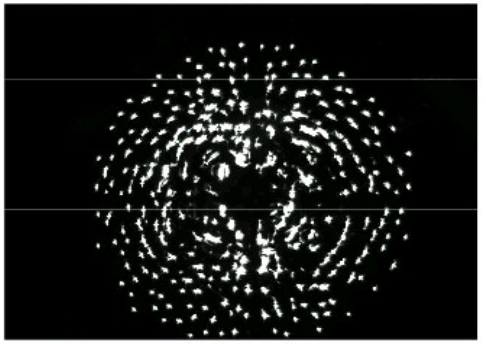
(a) PSF image before



(b) PSF image after



(c) Reflector image before

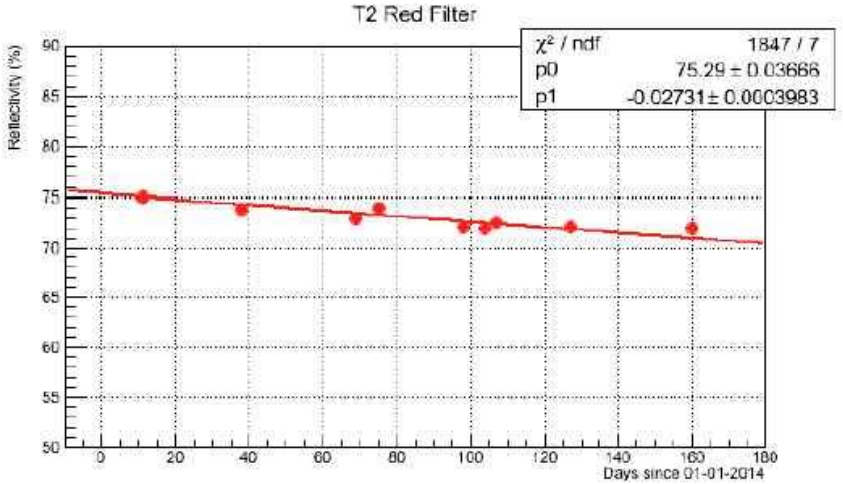


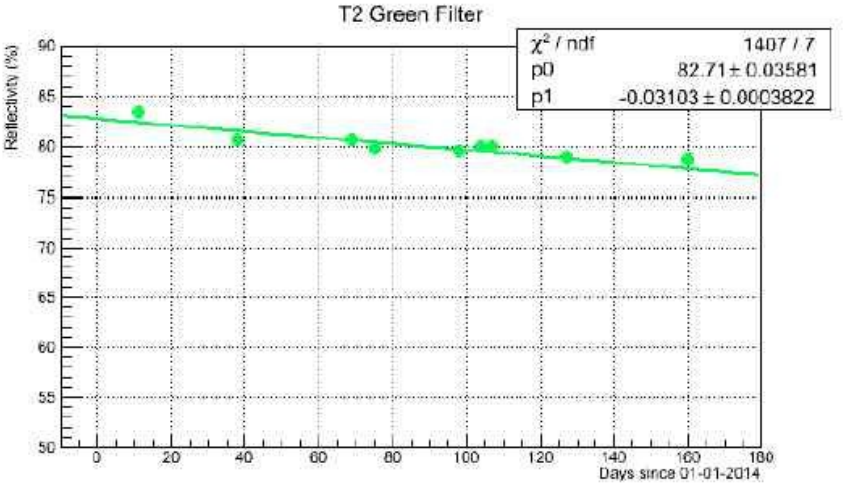
(d) Reflector image after

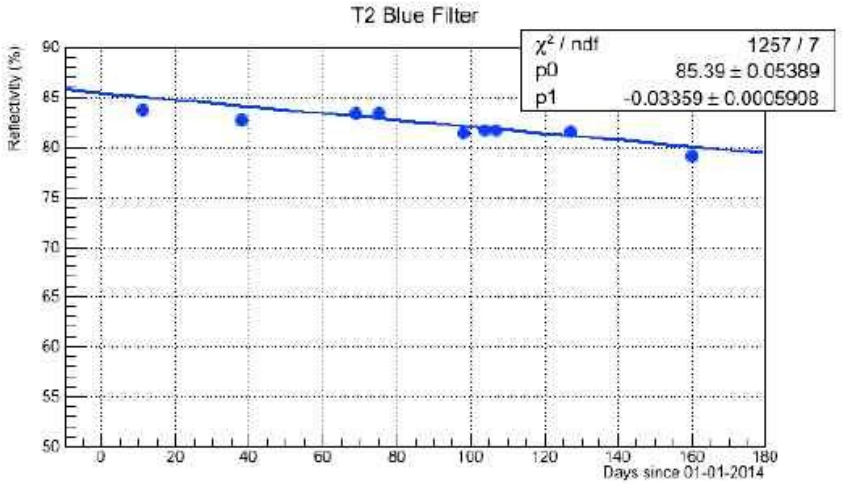
Mirror Alignment Tool

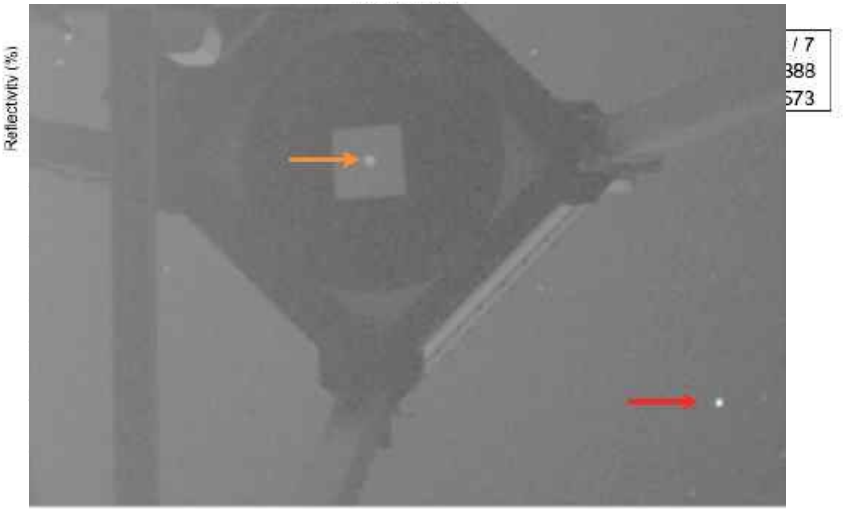
McGill Contributions to VERITAS

Mirror Reflectivity Measurement









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

Faculty

D Hanna	
K Ragan	

Post-doctoral

J Kildea	(2003 - 06)
G Maier	(2006 - 09)
P Cogan	(2007 - 08)
G Tesic	(2009 - 12)
D Staszak	(2010 - 15)
J-F Rajotte	(2012 - 14)
B Zitzer	(2015 -)

PhD

L Valcarcel	(2003 - 08)
R Guenette	(2006 – 10)
A McCann	(2006 - 11)
M McCutcheon	(2006 - 12)
S Griffin	(2011 - 15)
S Archambault	(2011 - 15)
J Tyler	(2012 -)

MSc

JP Gagnon	(2003 - 04)
A MacLeod	(2005 – 08)
M Bautista	(2007 - 09)
S Griffin	(2009 - 11)
J Tyler	(2009 - 12)
T Lin	(2014 -)
E Bourbeau	(2015 -)

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

2012 Upgrade

- replaced all PMTs with Hamamatsu Super-Bialkali (QE ~ 35%)

- factor 1.5 in effective mirror area

- installed flexible, faster FPGA-based second-level trigger

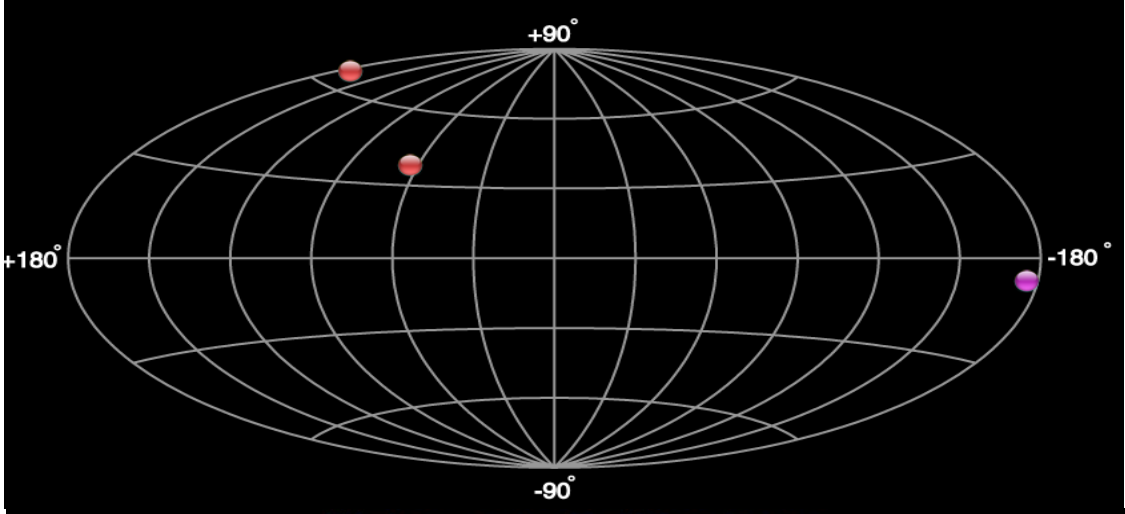
VERITAS is the most sensitive
VHE detector in the world

Evolution of TeV catalog

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

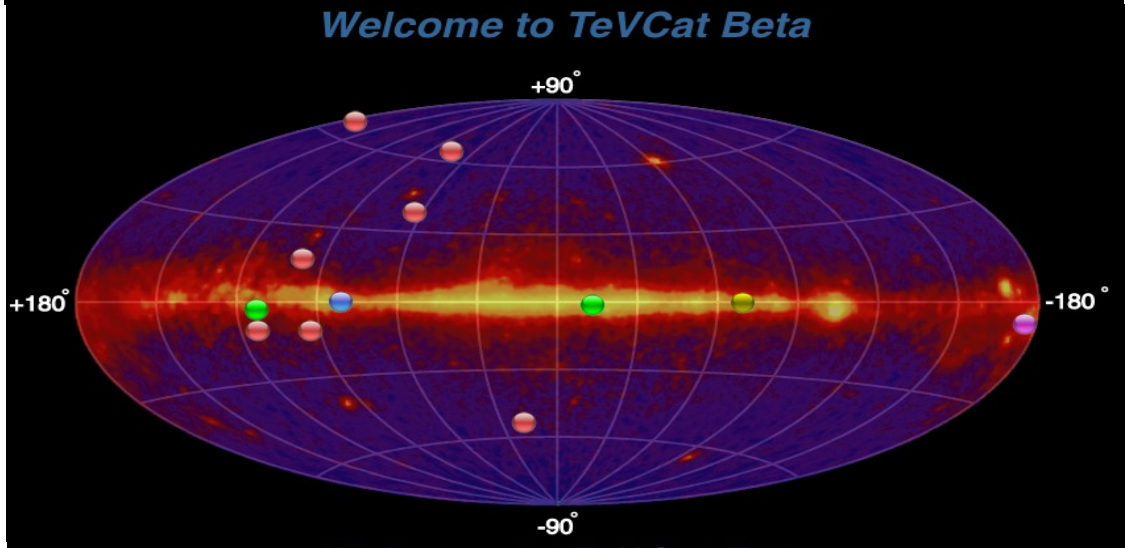
1996

3 sources



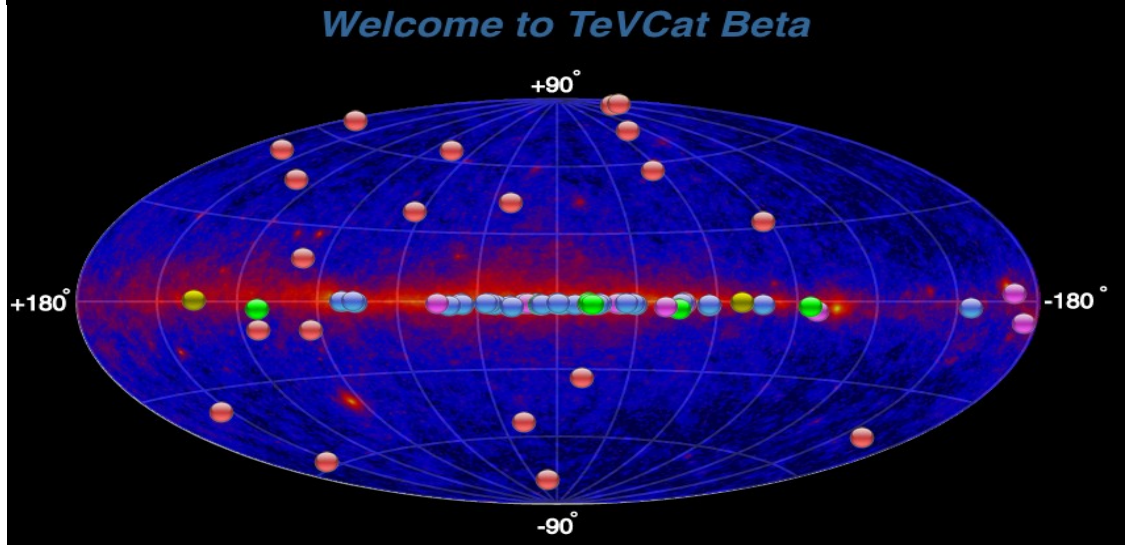
2002

12 sources
(galactic continuum
sky map from EGRET)



2008

72 sources
(galactic continuum
sky map from Fermi)

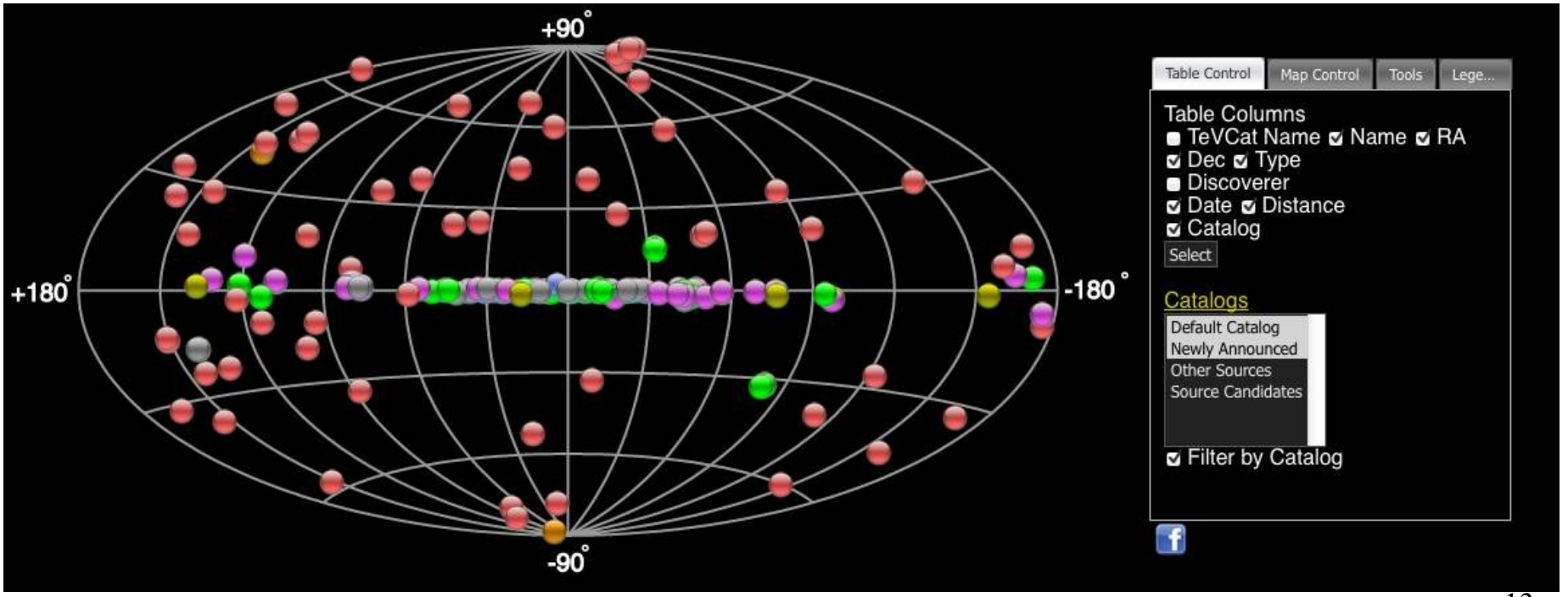


Evolution of TeV catalog

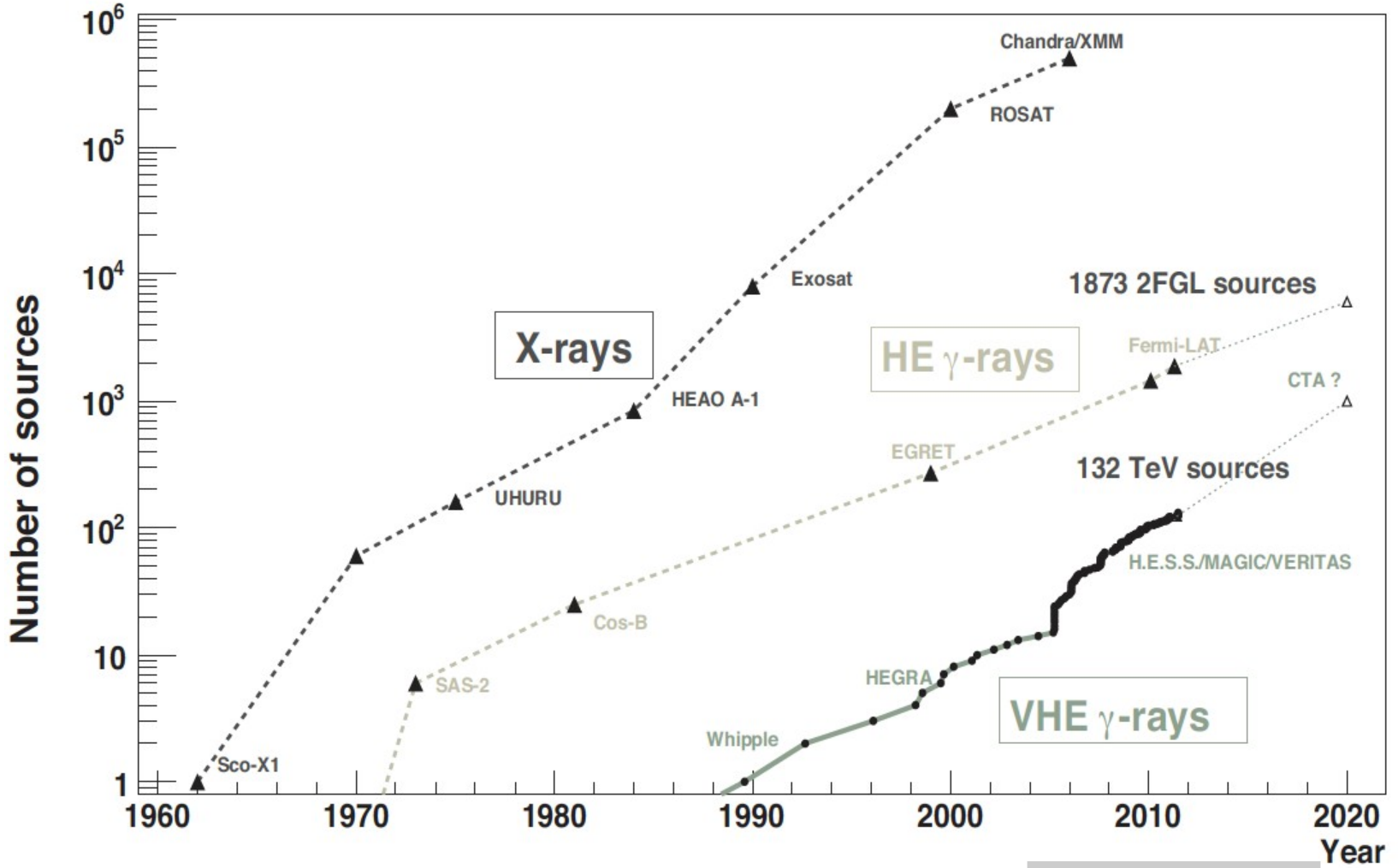
(see tevcat.uchicago.edu
Scott Wakely, Deirdre Horan)

2015 (February)

156 sources

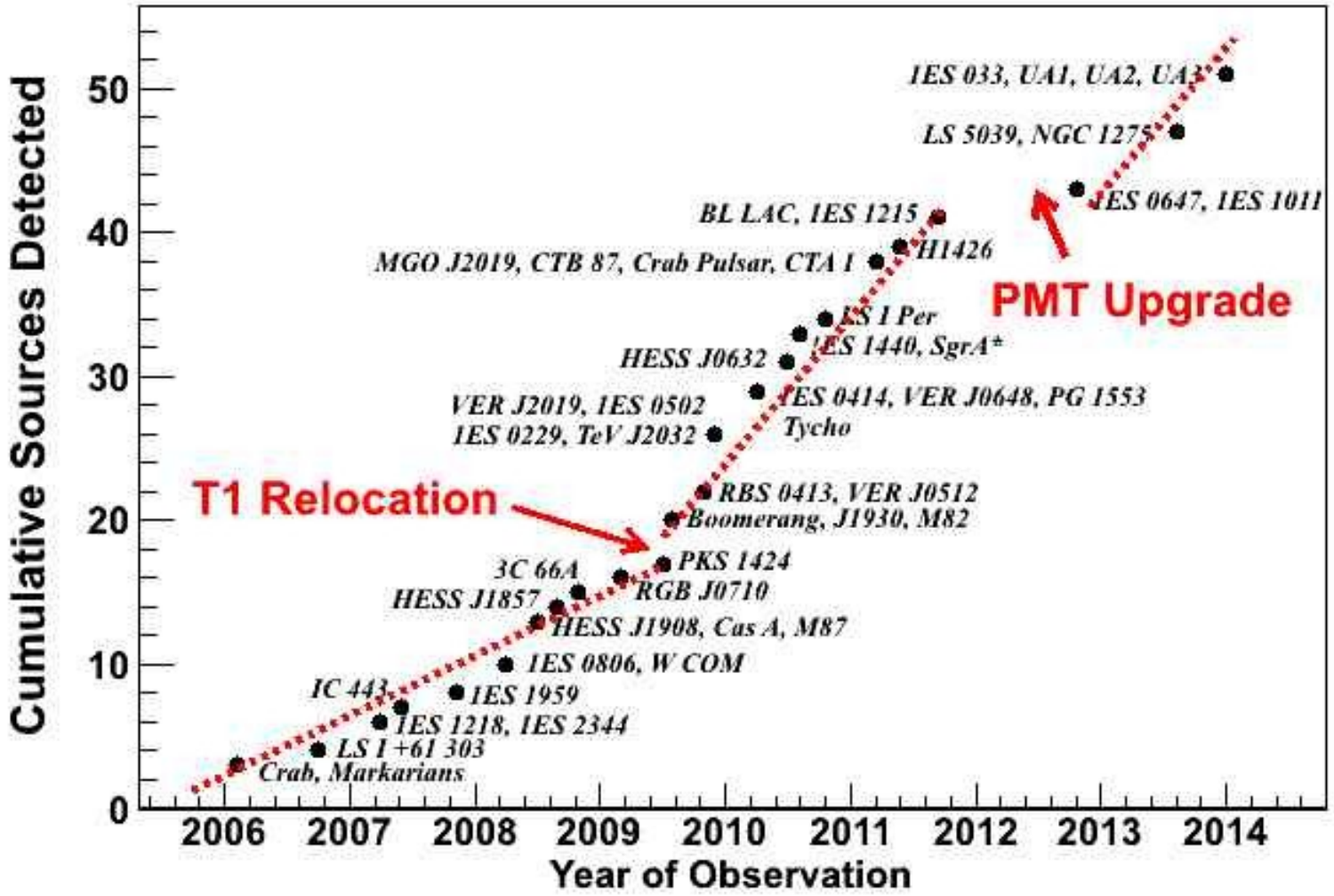


Kifune Plot



S. Funk (SLAC)

Kifune Plot - VERITAS



Andy Smith (Utah)

Detection of Crab Pulsar above 100 GeV

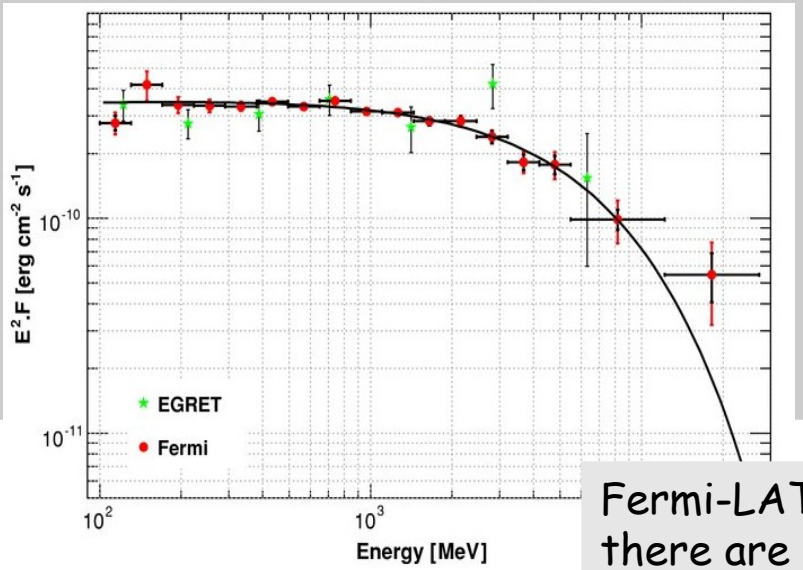
Crab Pulsar

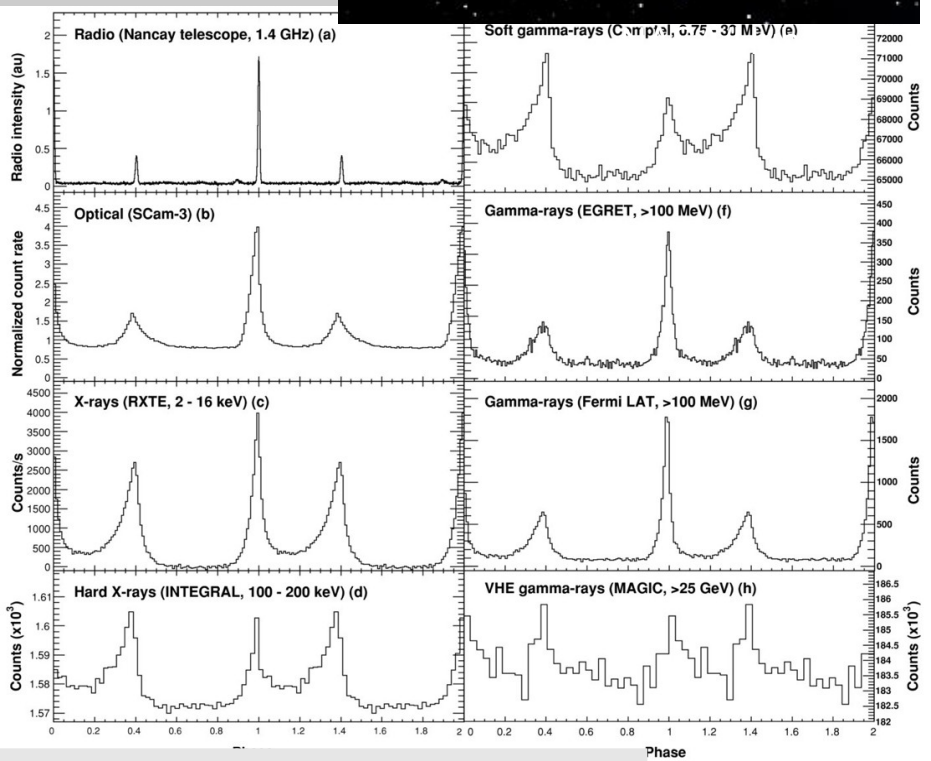
remnant of supernova in 1054

seen at all wavelengths

most energetic pulsar
4.6×10^{38} erg s^{-1}

one of the brightest in gamma rays





Fermi-LAT energy spectrum suggests that there are few gamma rays above ~ 10 GeV

(all Fermi-detected pulsars exhibit this feature)

VERITAS

Detection of Crab Pulsar above 100 GeV

VERITAS data:

2007-2009	45 hours
2010	62

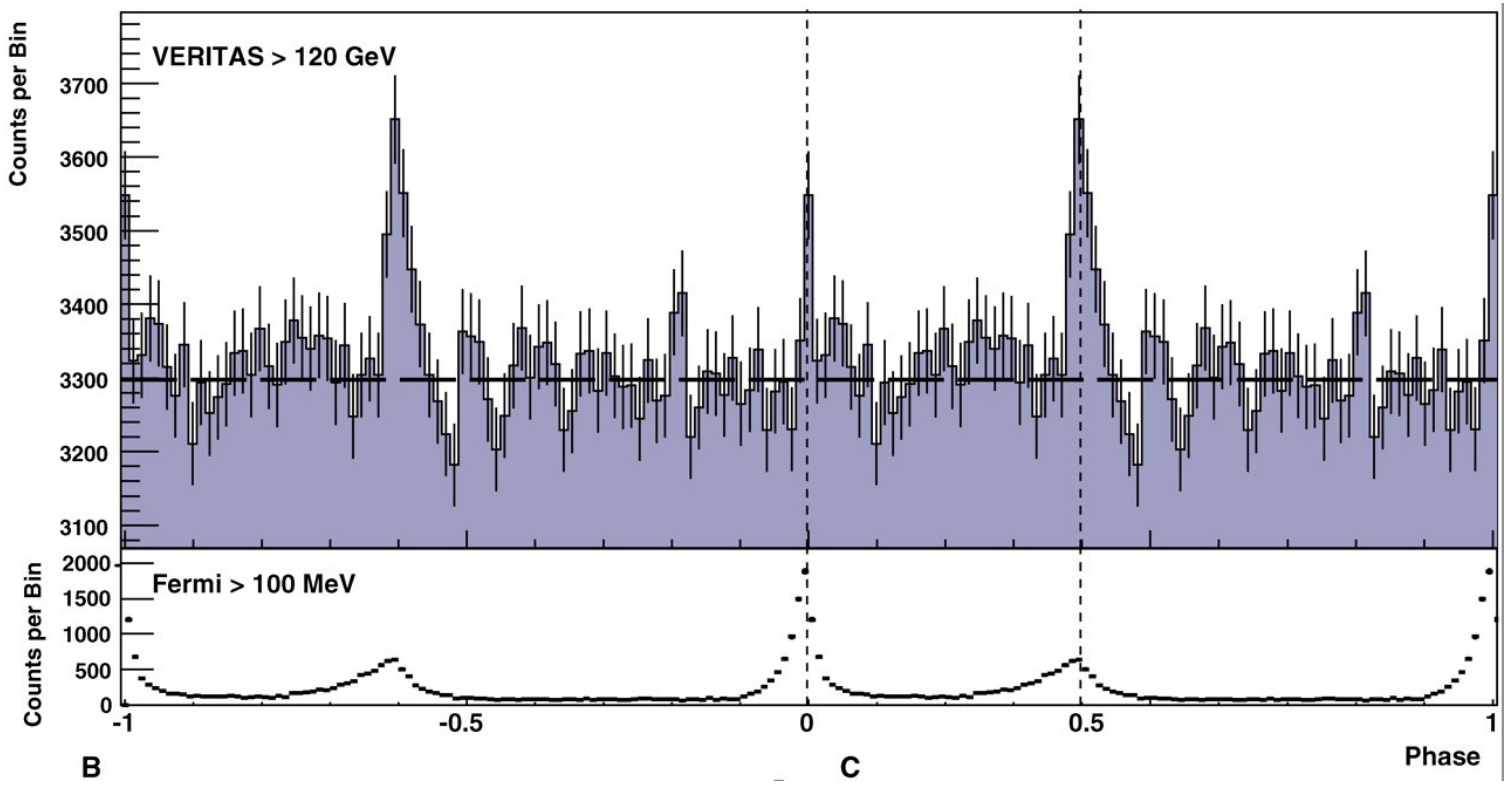
4 telescopes
zenith angle < 25 ^{o}

VERITAS analysis:

two independent analysis packages

analysis optimized for weak, soft source
- few-percent Crab flux
- power-law with index -4

analysis threshold: 120 GeV

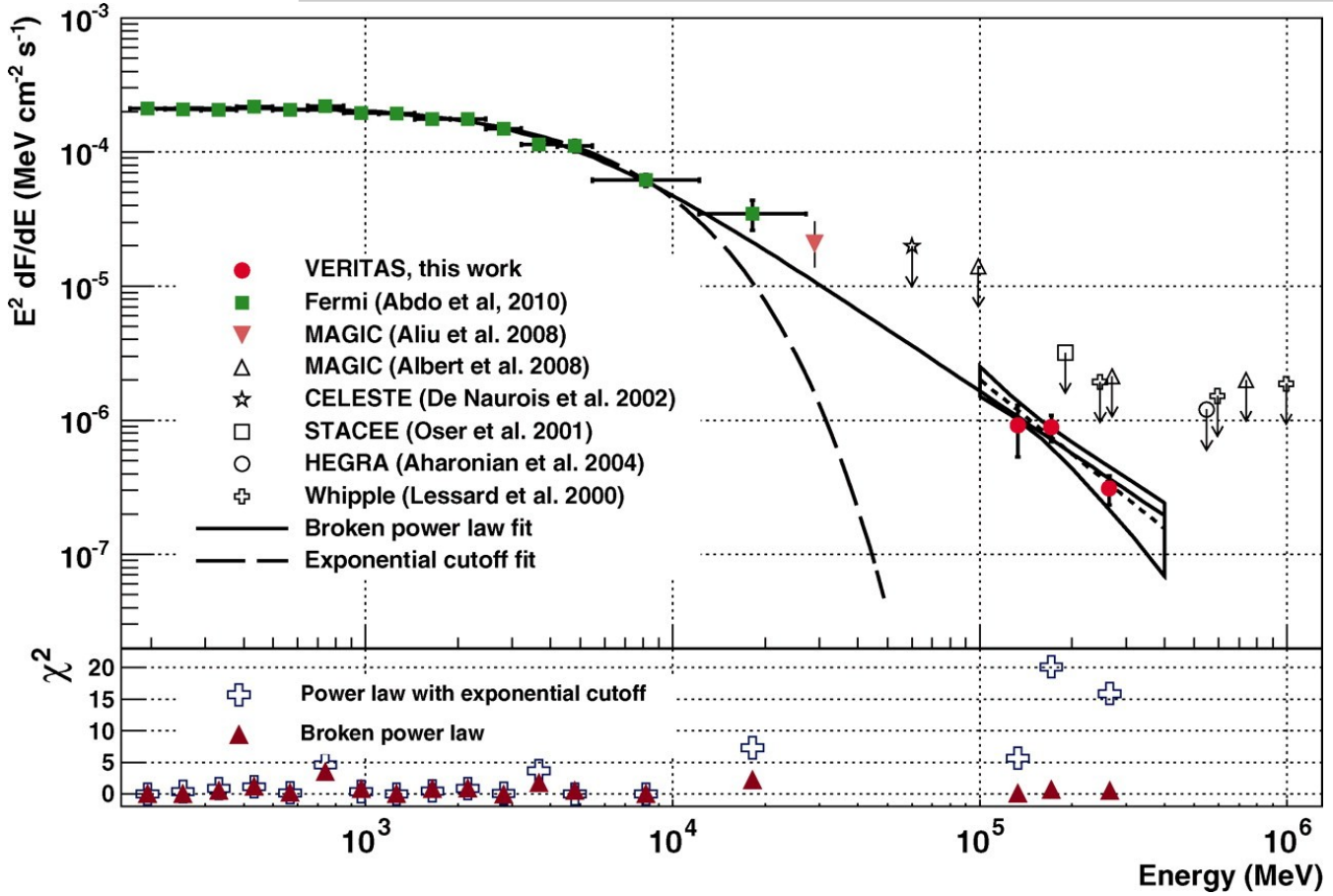


significance ~ 6σ

VERITAS

Detection of Crab Pulsar above 100 GeV

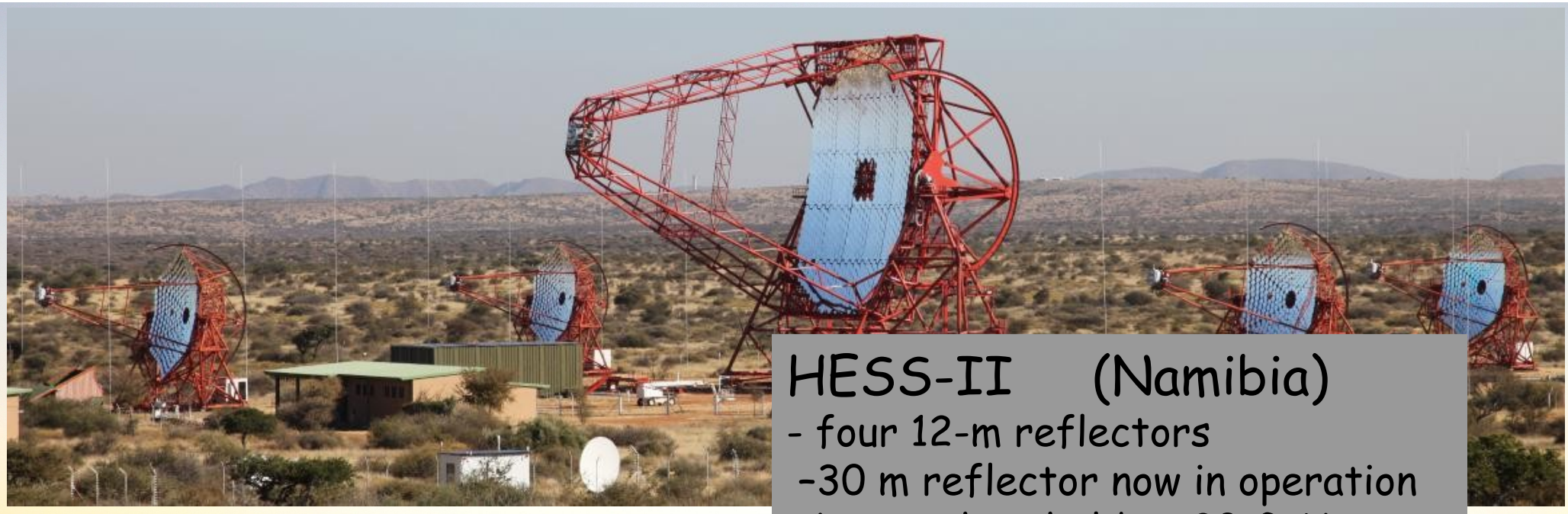
Science
Vol. 334 pp. 69-72



energy spectrum (combine P1 and P2)

- no exponential cutoff – power law with Γ = -3.8 +/- 0.5 +/- 0.3
- non-zero flux above 100 GeV (1% of Nebula at 150 GeV)
- curvature radiation cannot be the dominant mechanism
- the paradigm is shifting – stay tuned

The Competition



HESS-II (Namibia)
- four 12-m reflectors
 -30 m reflector now in operation
- Lower threshold to 20 GeV?

MAGIC-II (Canaries)
two 17-m reflectors

Fermi Space Telescope

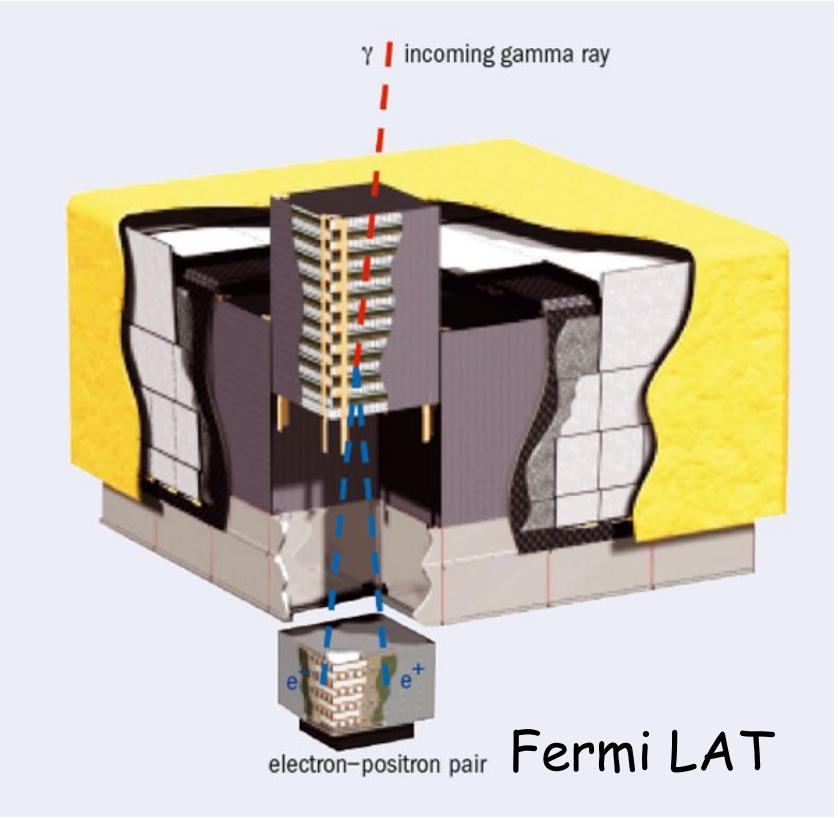
- on orbit since 2008

- still running perfectly
(lifetime is dollar limited)

- 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



Fermi LAT

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-

- useful to VERITAS as a pathfinder
  - flares
  - hard-spectrum sources

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

recently (2015) completed and now fully operational

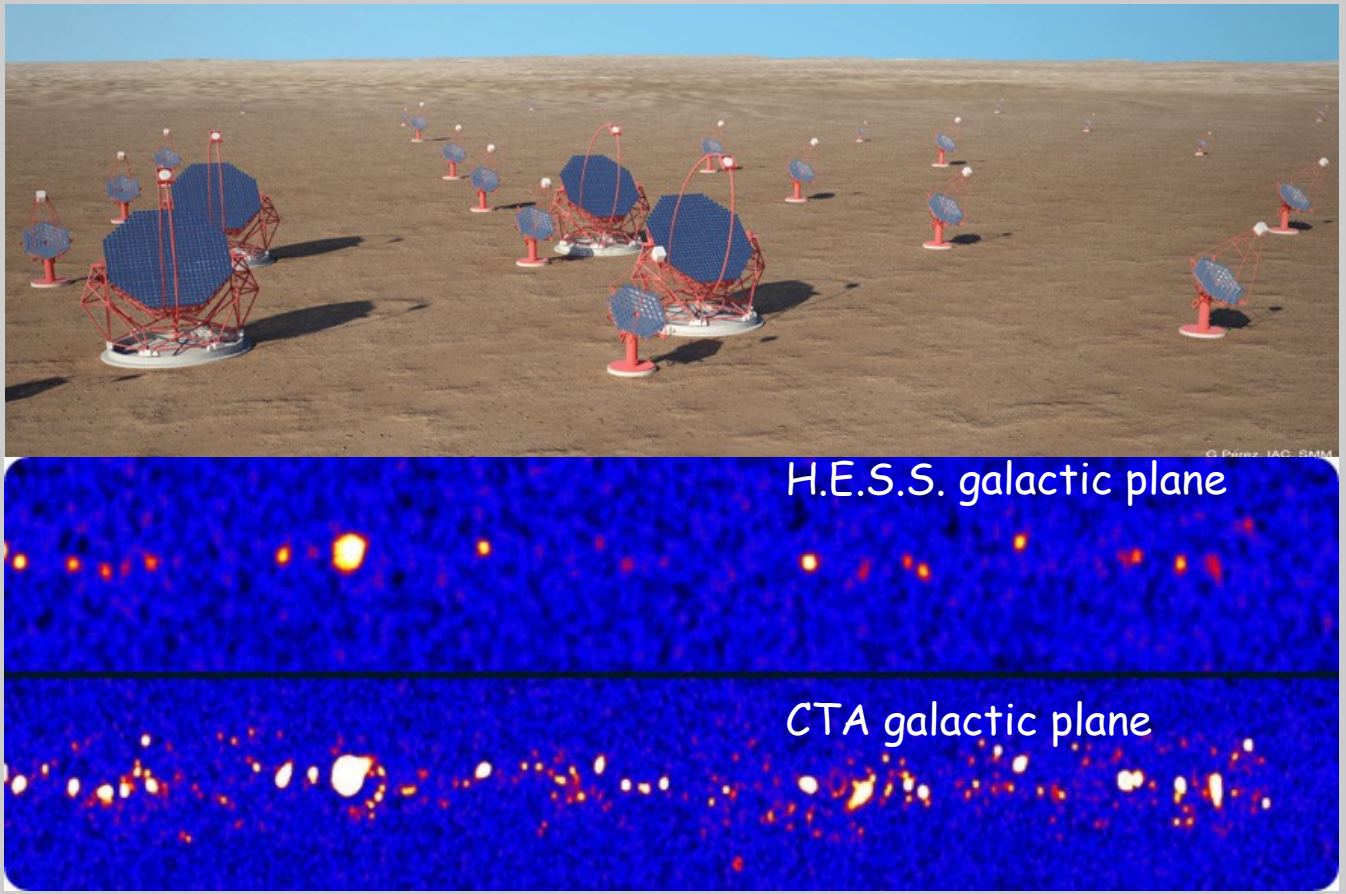
less sensitivity than VERITAS but good for unbiased surveys and as a pathfinder

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

Future Plans

- application to NSERC for three-year project grant 2016-19

- continued exploitation of VERITAS for the next three years

    - Fermi and HAWC will strengthen search and measurement programs

    - VERITAS is mature and understood - more difficult and longer-term studies can be carried out
        - CR electrons
        - LIV with Crab pulsar

- ramp-down after three years

    - migration of groups and funding to CTA
    (DOE already leaving gamma-rays, NSF and SAO still on board but resources need to be shifted)

- McGill group has no plans to join CTA

Summary:

- VERITAS is going strong
  - a good investment of time and resources
  - excellent HQP opportunities
- Canadian contributions are significant and recognized
- near-term future (3 years): continued success
- longer term prospects
  - ramp-down VERITAS and engage in new projects
  - finish in-progress analyses and theses