The High Altitude Water Cherenkov Gamma Ray Observatory

Current Status and Future Prospects

Tom Weisgarber

10 June 2014

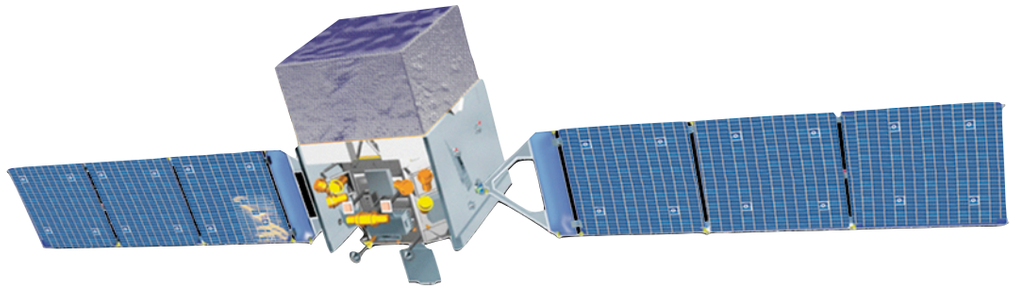
Outline

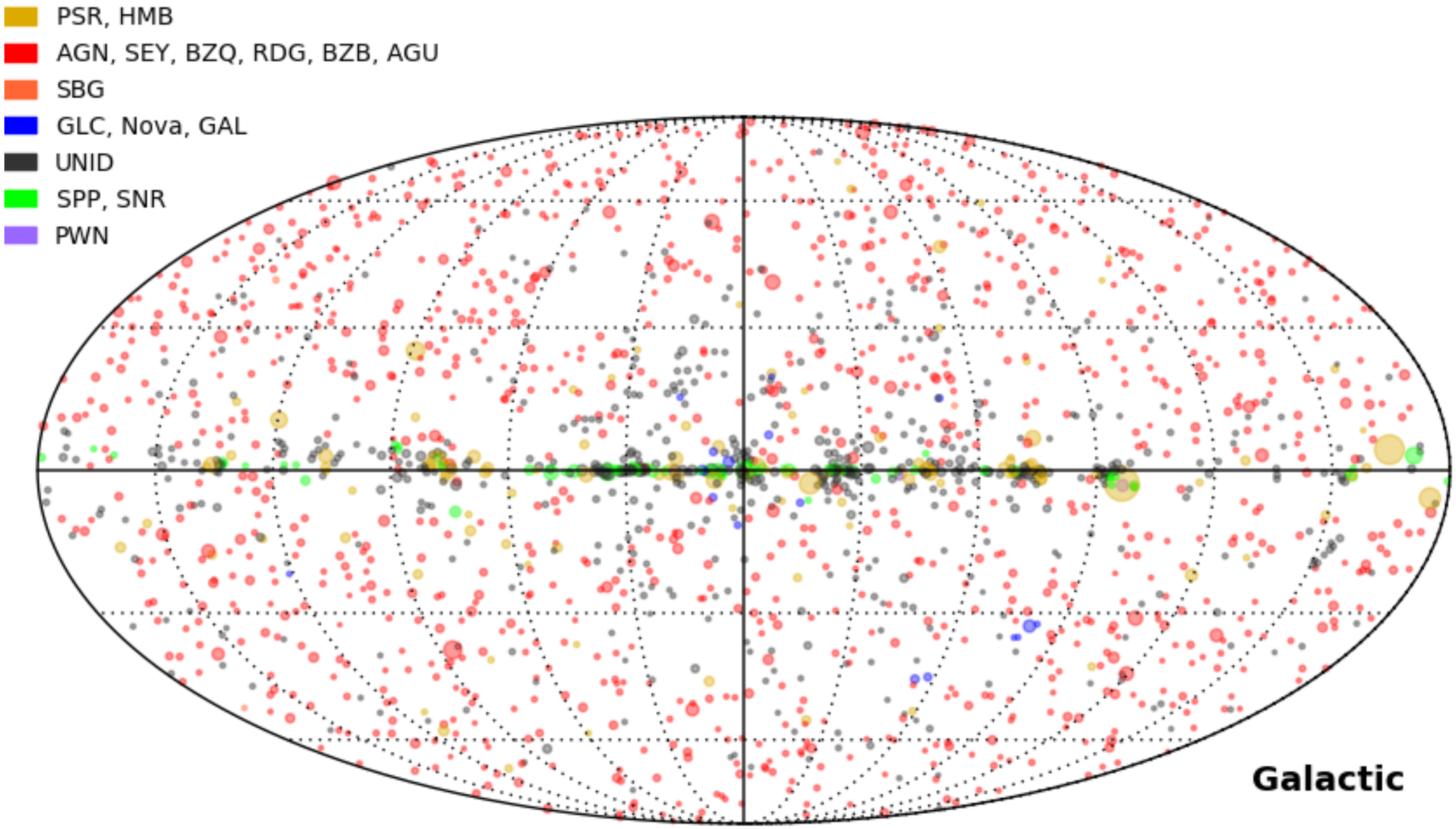
Outline

- The case for TeV astronomy
- HAWC detector
  - design
  - construction
- Preliminary results
- Outlook

The Case for TeV Astronomy

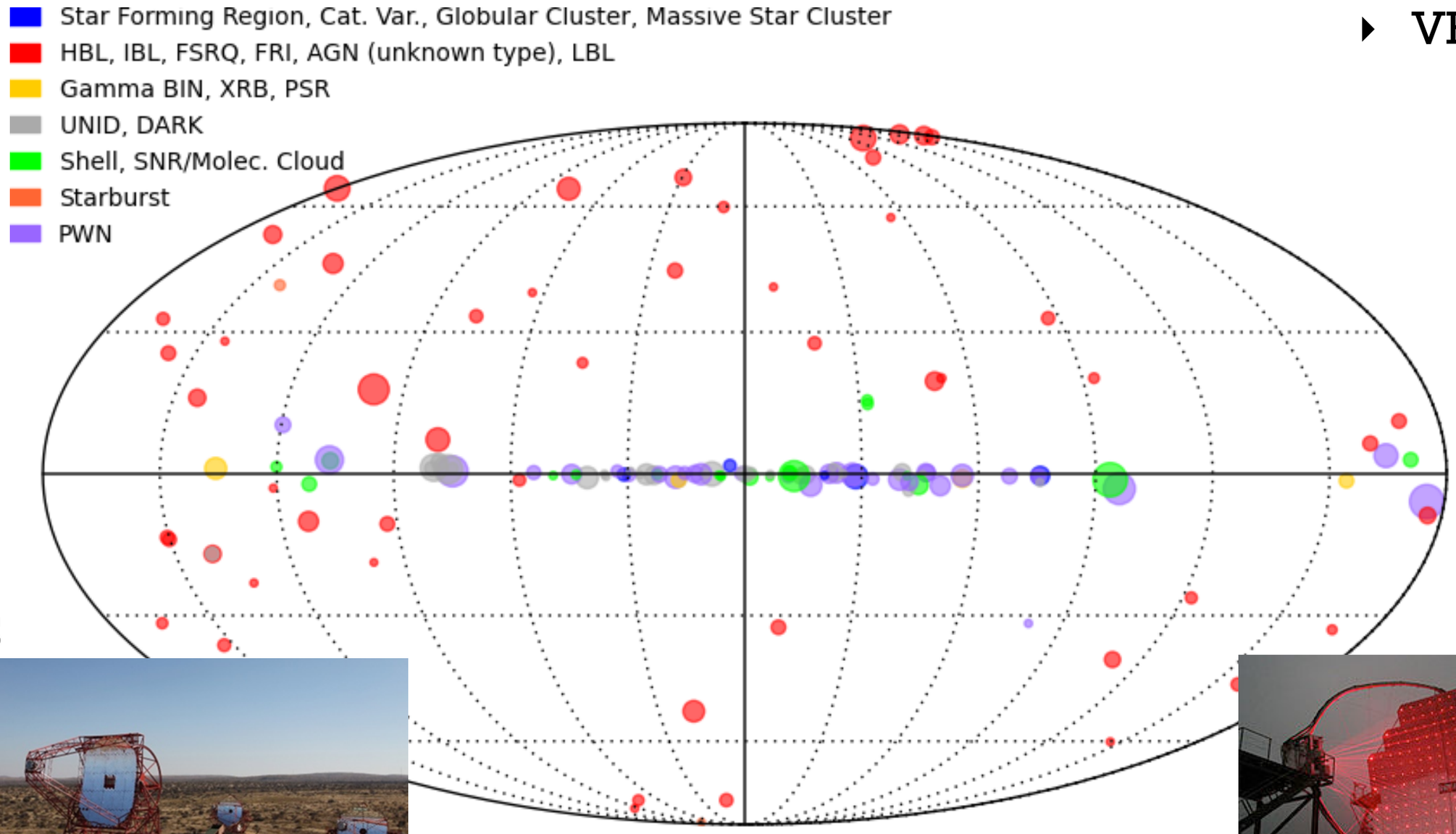
- Fermi
  - 1,873 sources in the 2FGL catalog
  - energy range: ~100 MeV to ~300 GeV



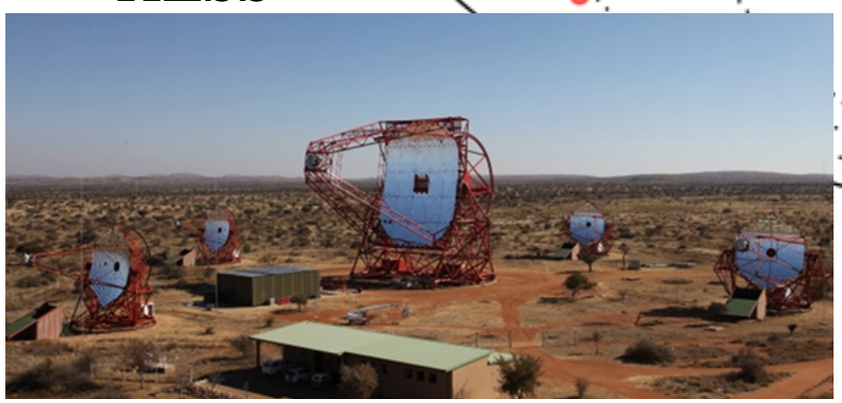


The Case for TeV Astronomy

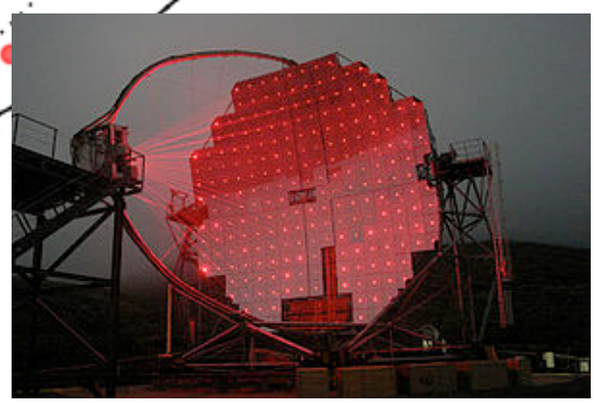
- IACTs
  - ~100 GeV to 10's of TeV
  - ~150 sources
  - sparse (biased?) sky map



- VERITAS
- HESS

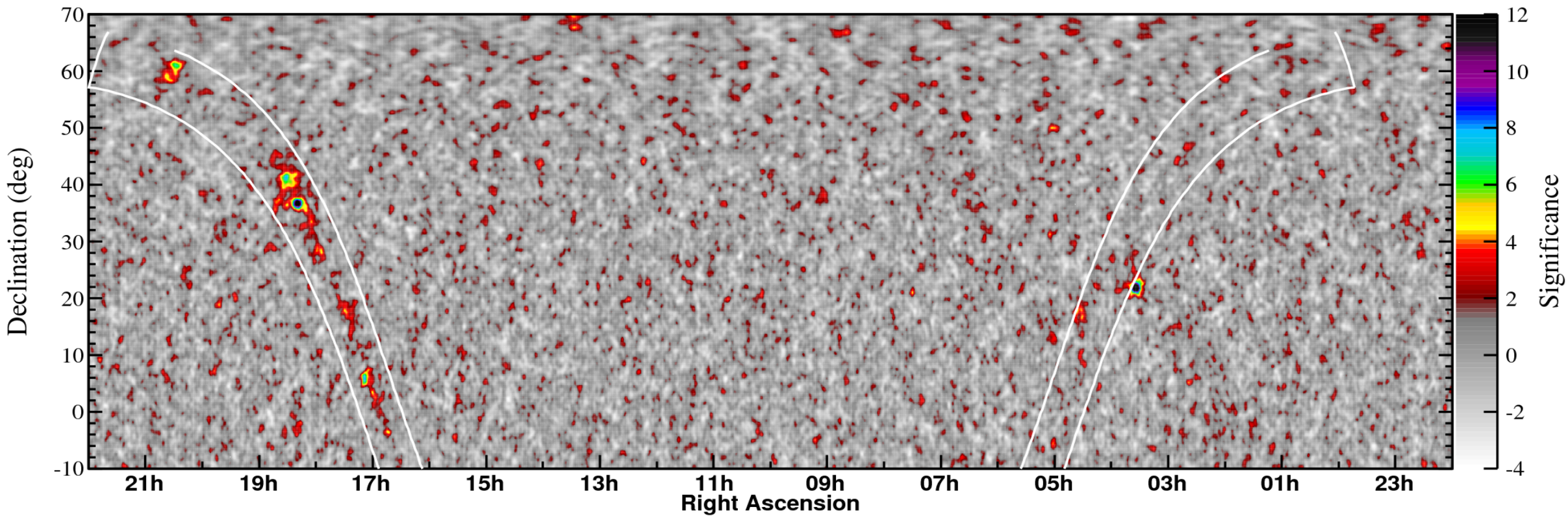


- MAGIC



The Case for TeV Astronomy

- Milagro
  - sensitivity from 100 GeV - 100 TeV
  - ~10 sources, mostly Galactic (but hints of many more!)
  - unbiased sky coverage between -10° and 70° dec.
  - extended sources (challenging for IACTs)
  - predecessor to HAWC



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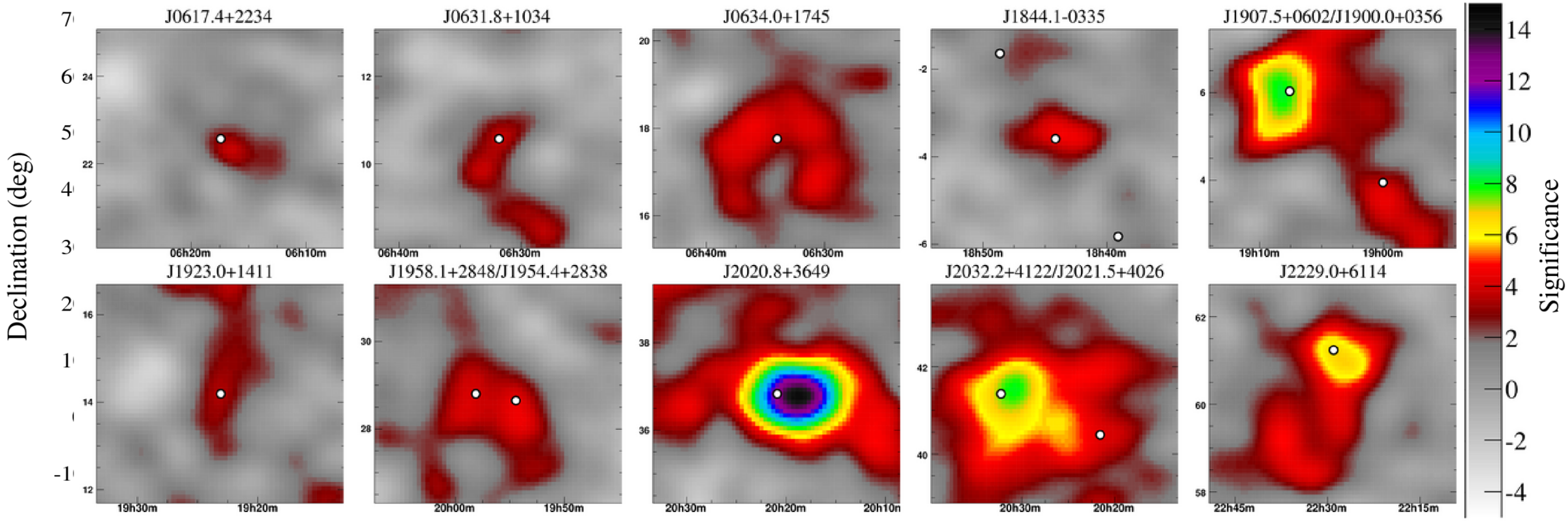
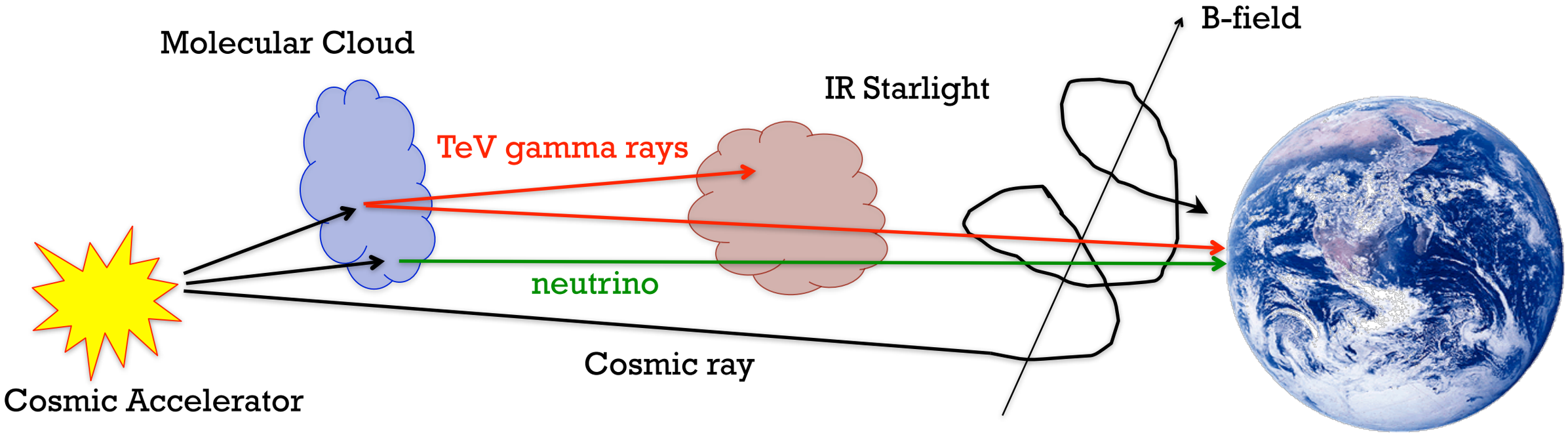
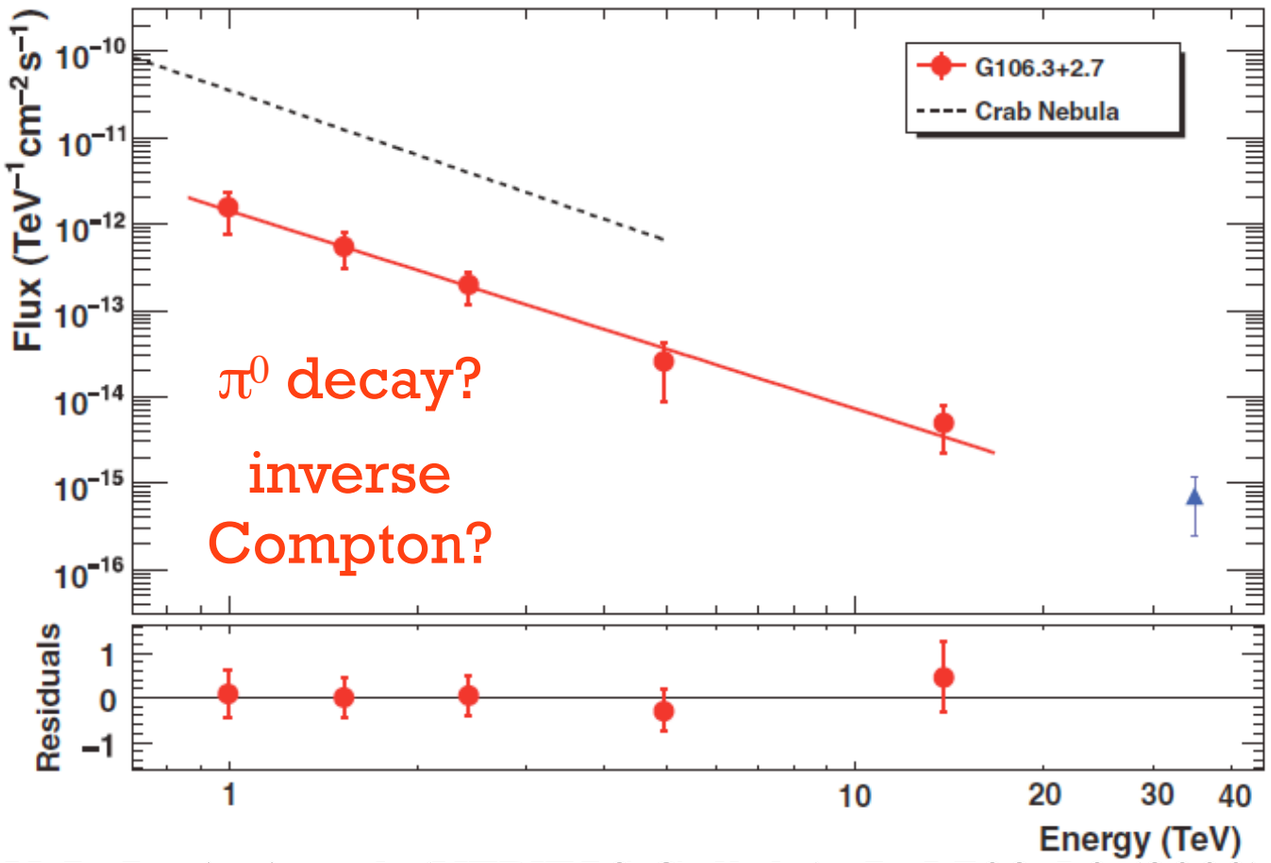


Abdo et al. (Milagro Collaboration), ApJ 700, L127 (2009)

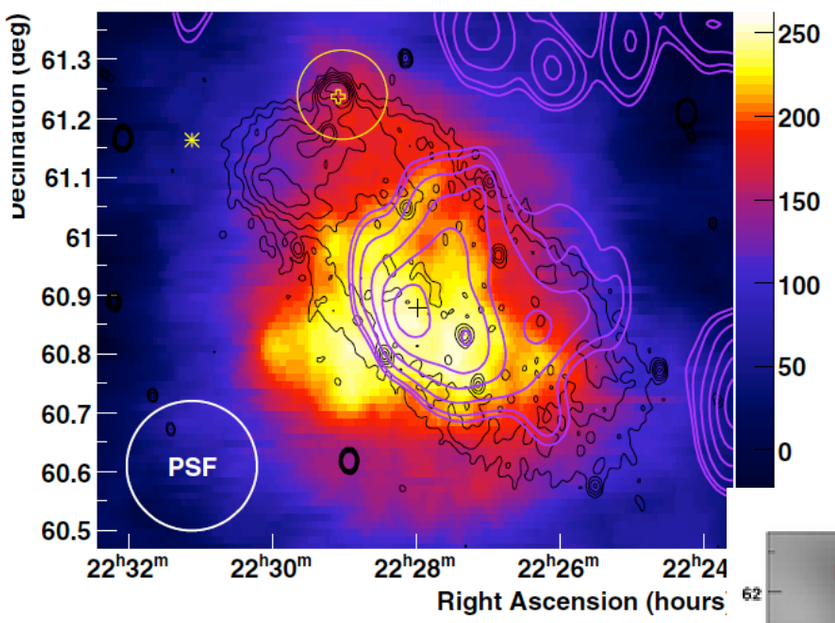
The Case for TeV Astronomy

- What are the sources of Galactic cosmic rays? Are SNRs the accelerators?

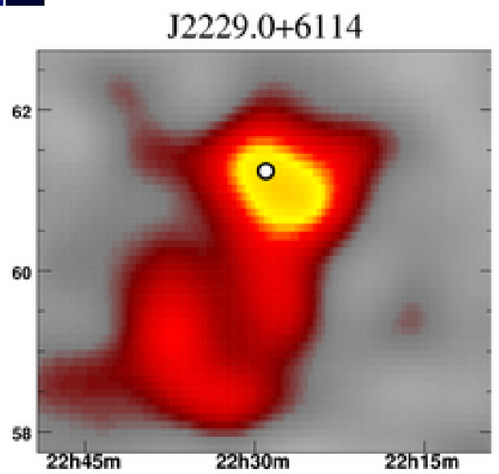




V. A. Acciari et al. (VERITAS Collab.), ApJ 703, L6 (2009)

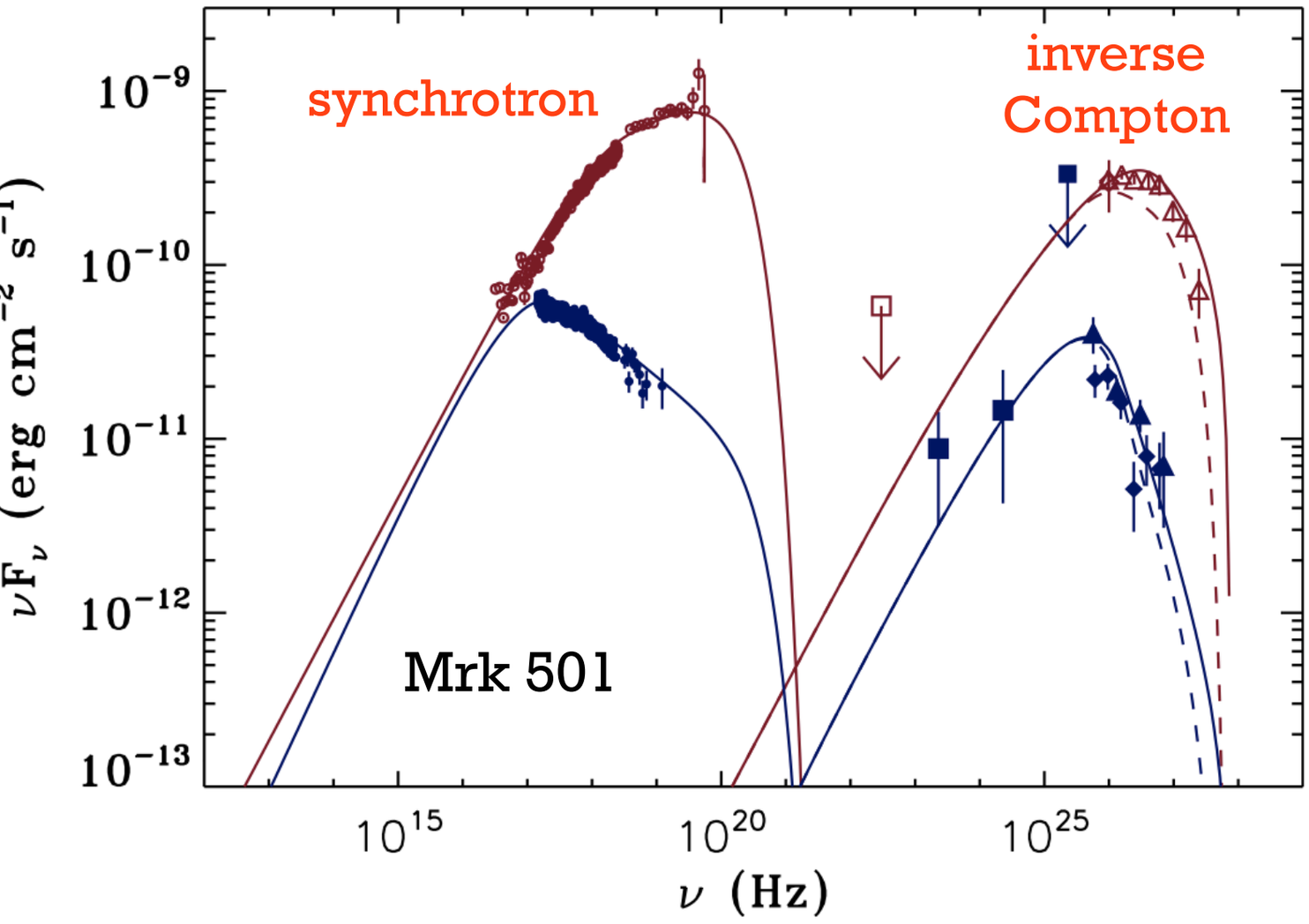


SNR G106.3+2.7

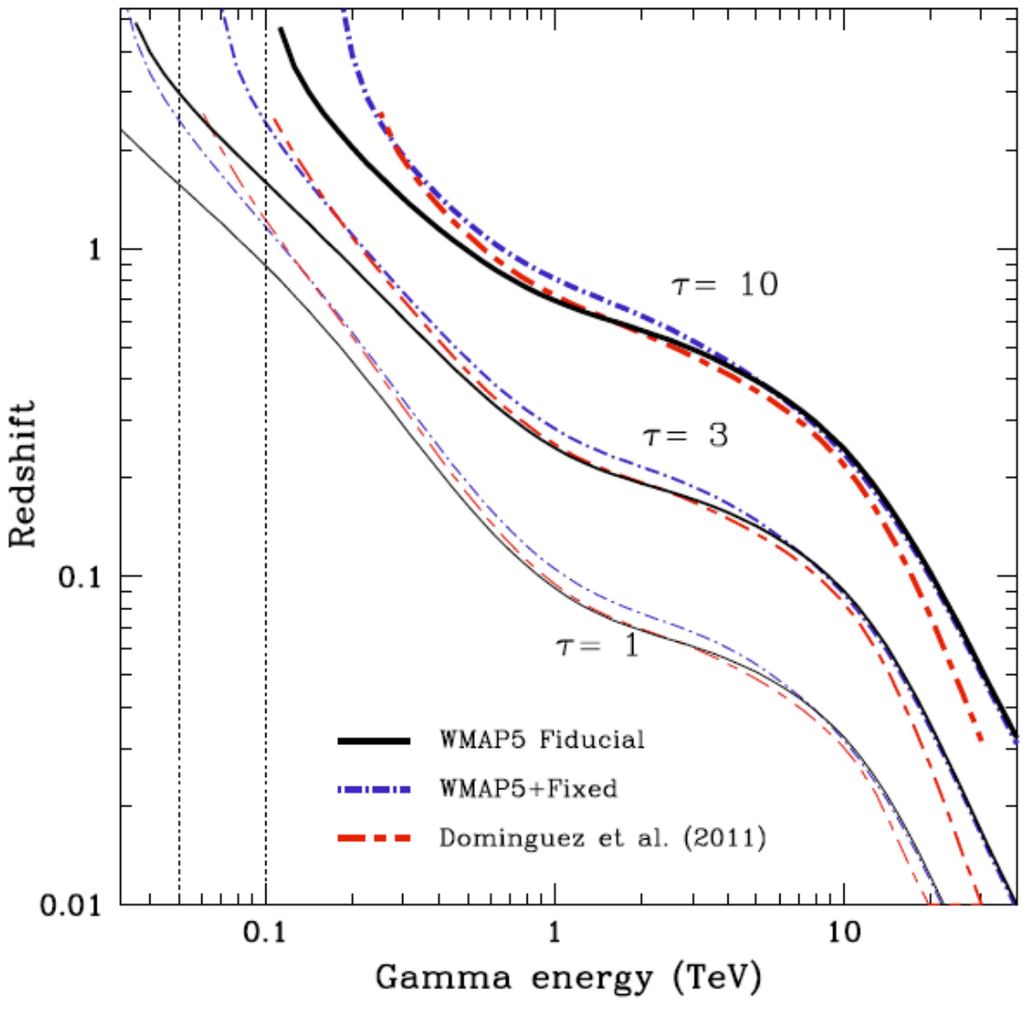


The Case for TeV Astronomy

- How do blazars operate? What causes flares?
- Can blazars and/or AGNs accelerate cosmic rays?



V. A. Acciari et al. (VERITAS Collab.), ApJ 729, 2 (2011)



Gilmore et al., MNRAS 424, 3189 (2012)

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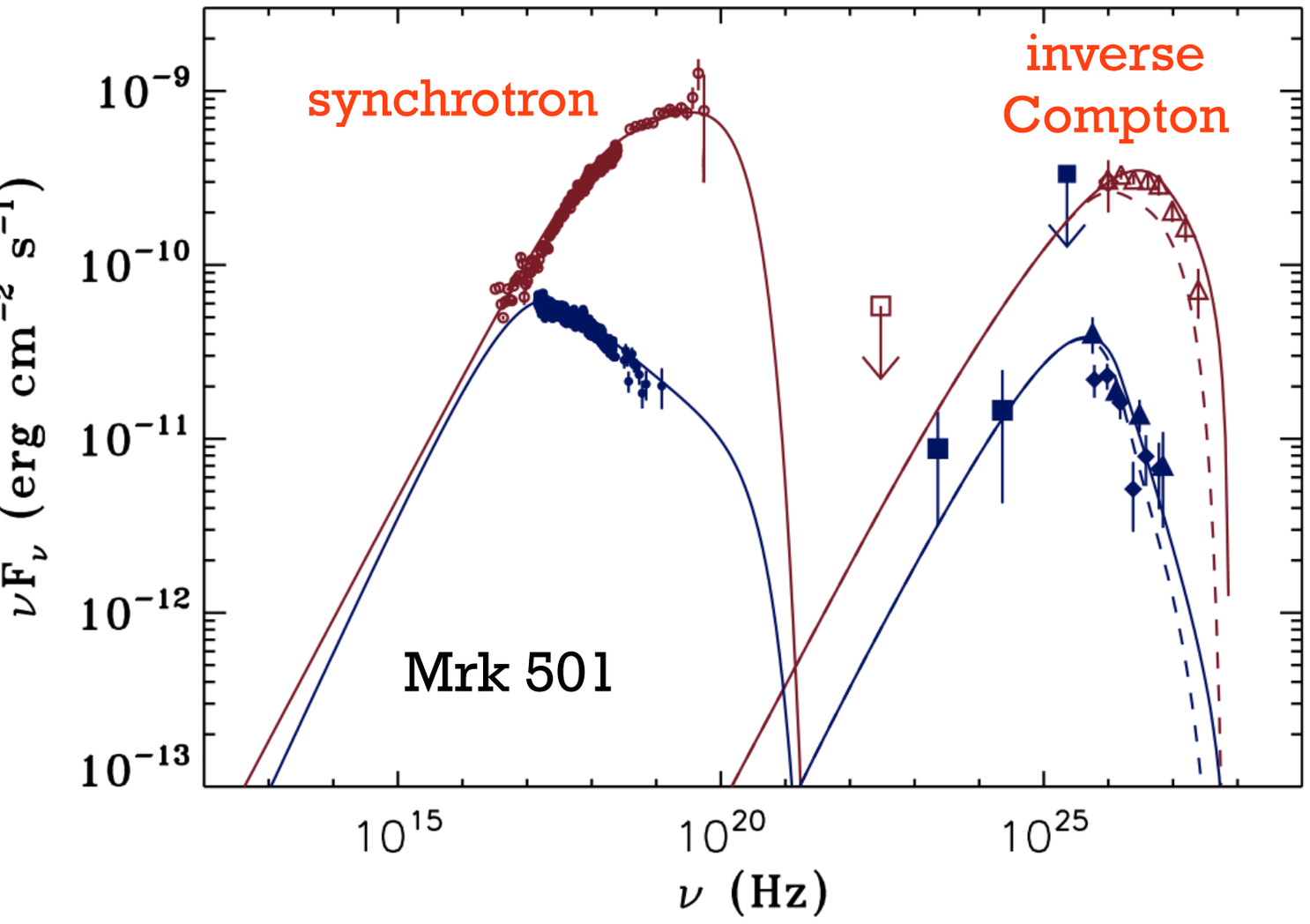

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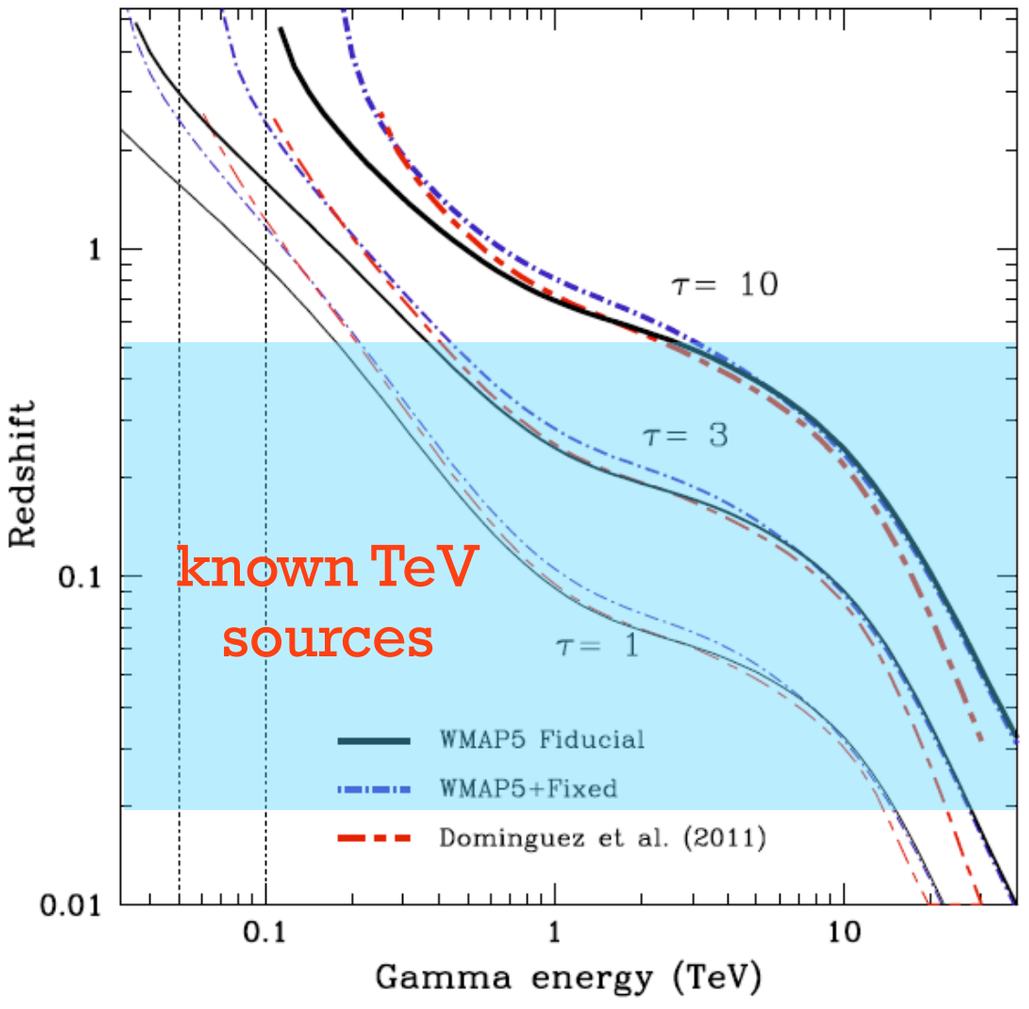

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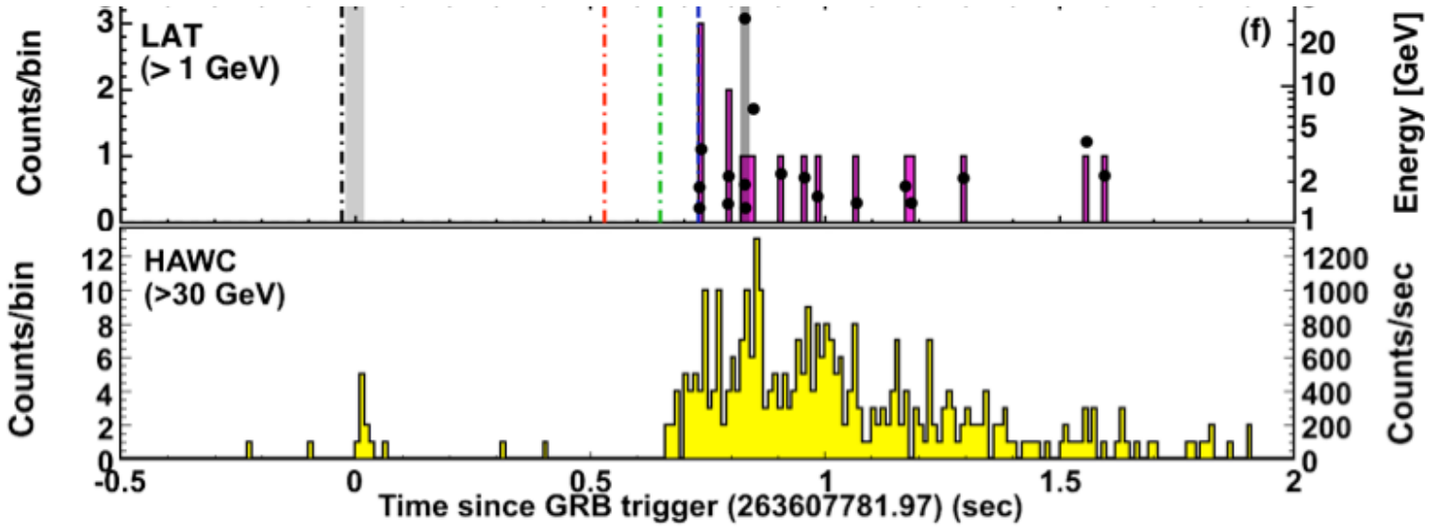
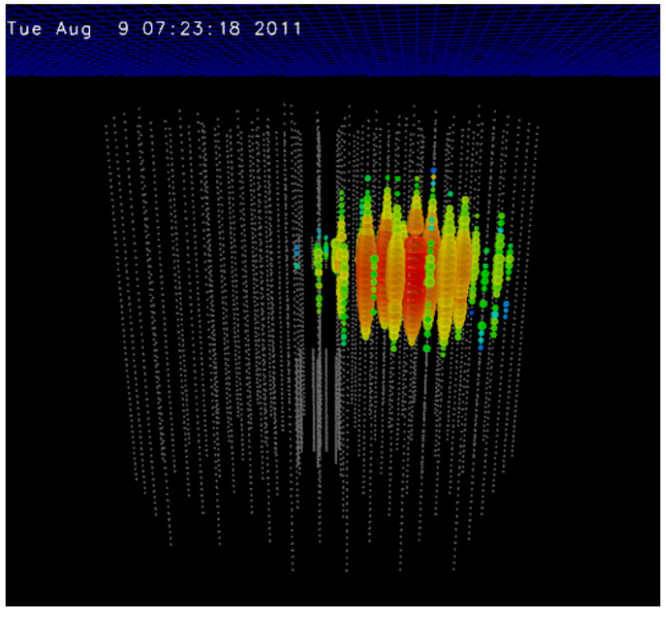
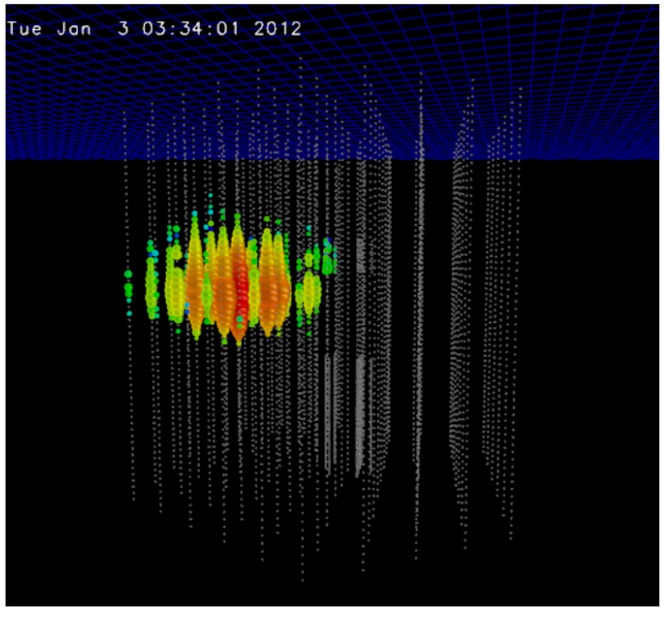
The Case for TeV Astronomy

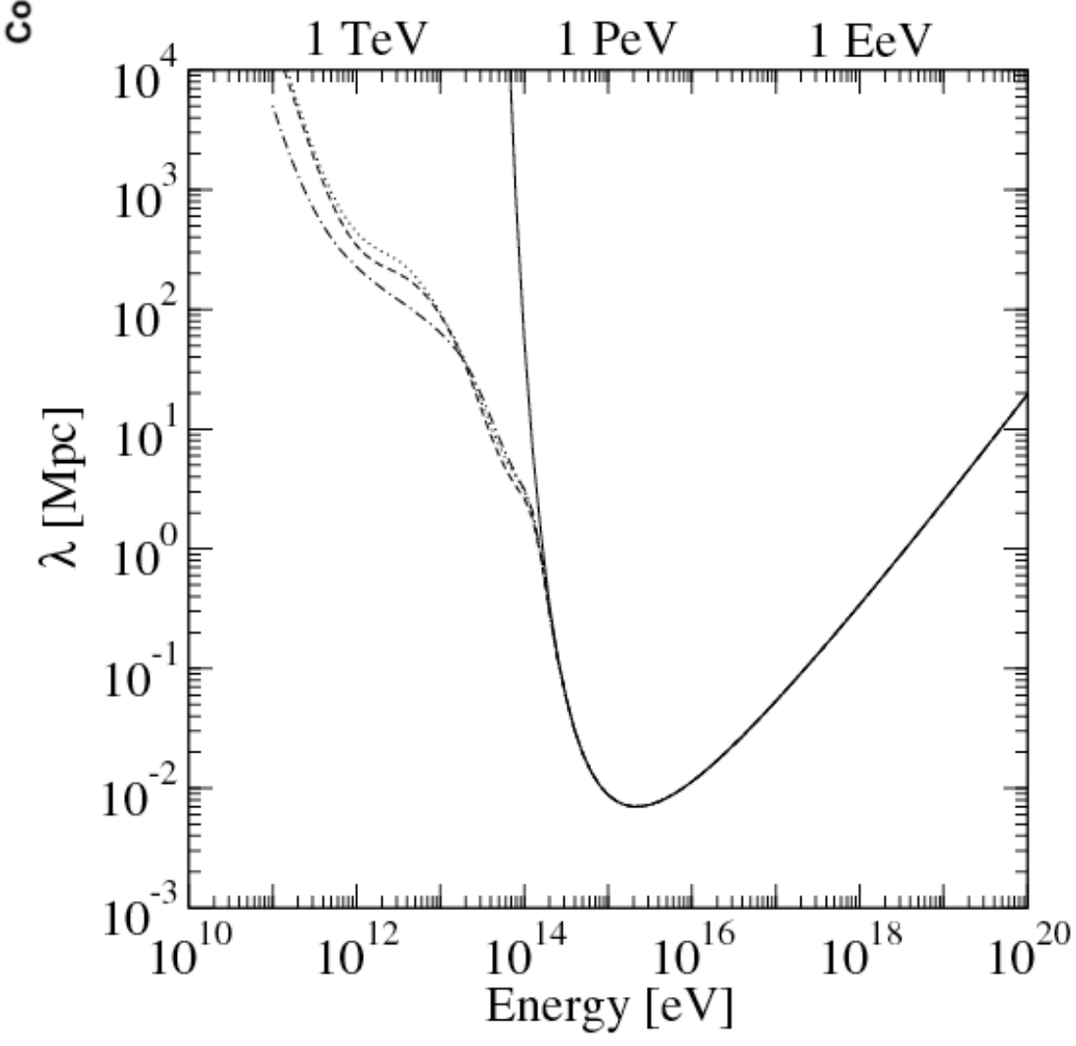
- What is the mechanism of GRBs? How high do their spectra extend?



- For gamma rays, TeV is the energy frontier

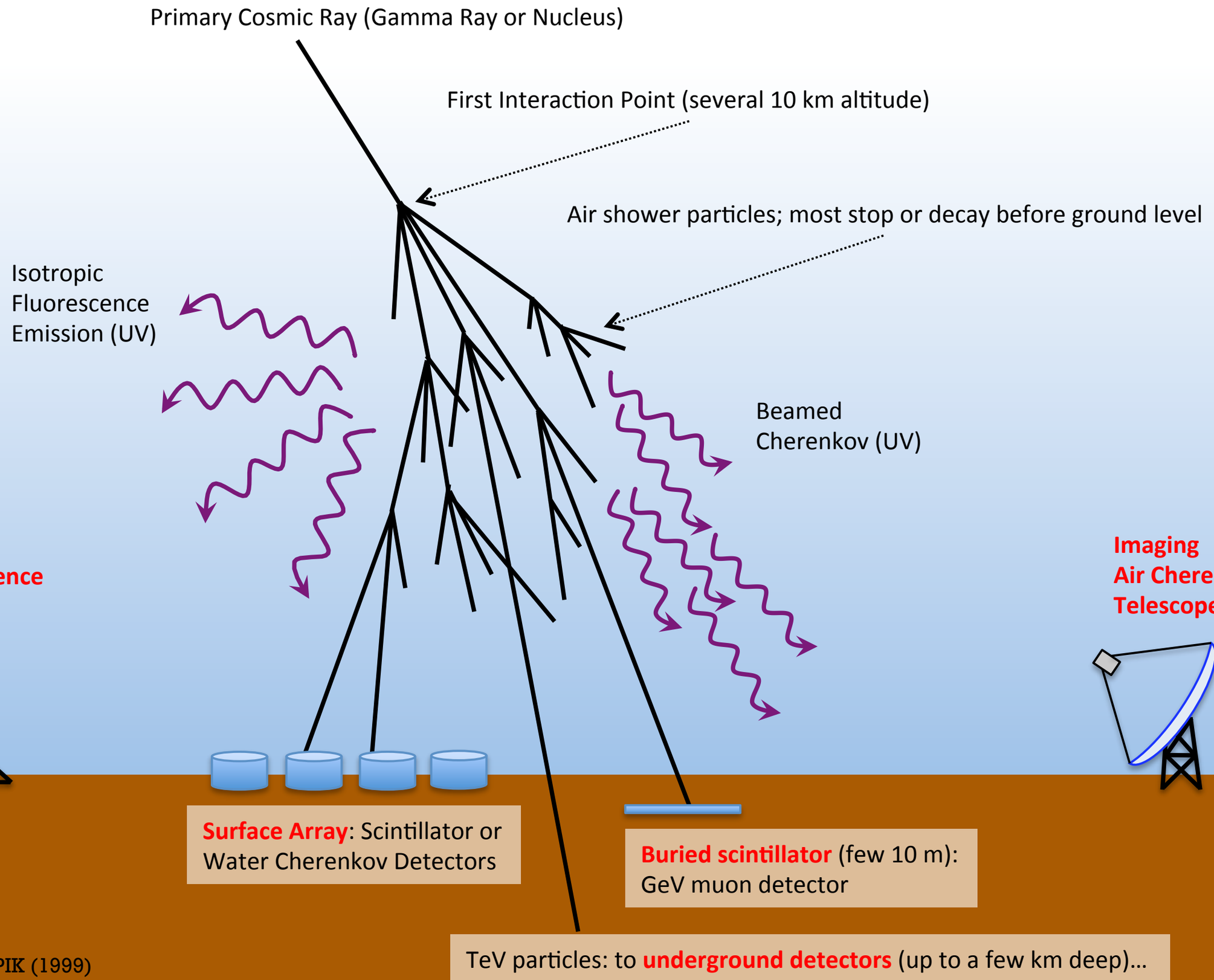






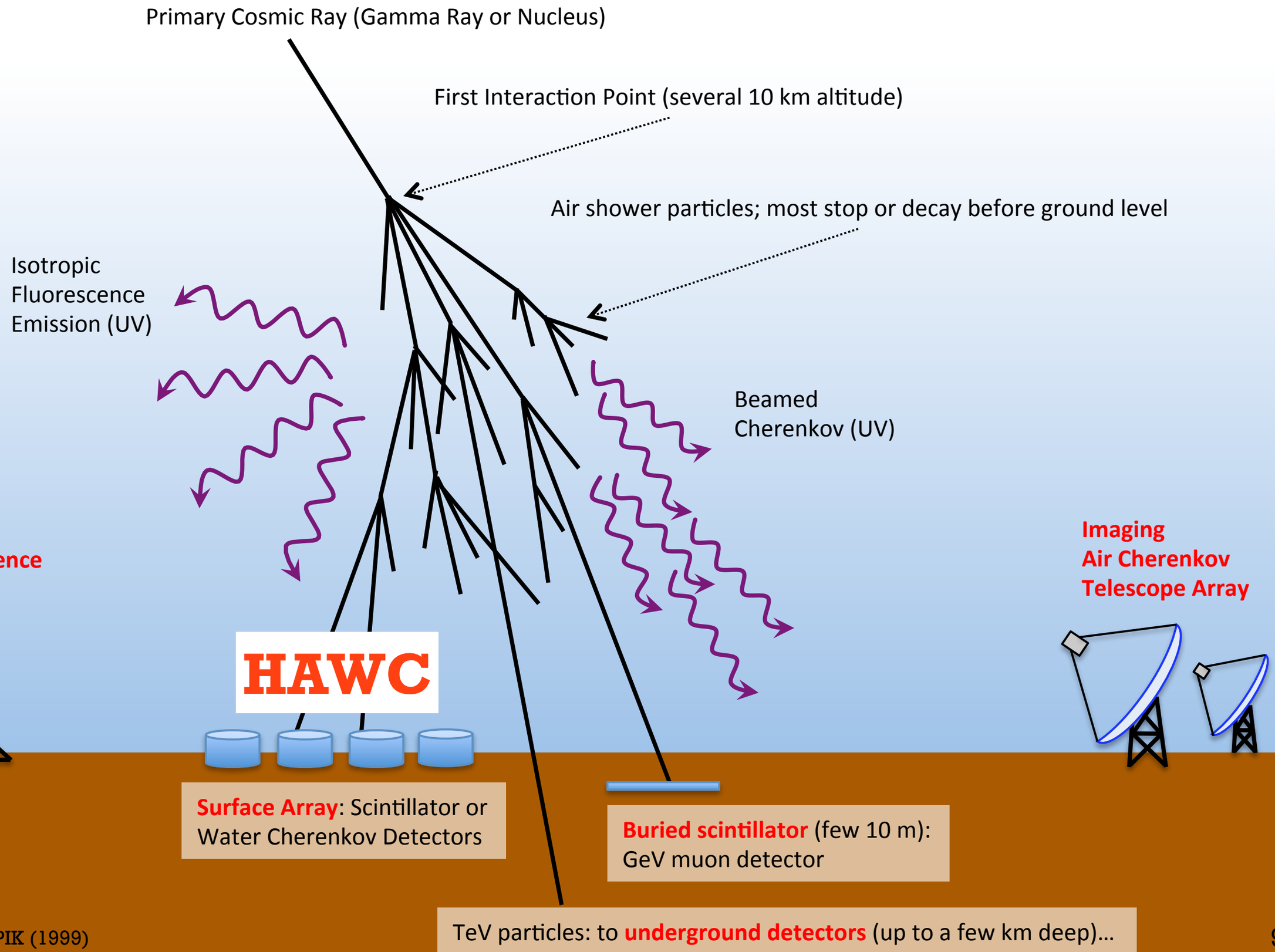
- All of these topics benefit from a multimessenger approach

HAWC Detector Design



credit: Bernlöhr, MPIK (1999)

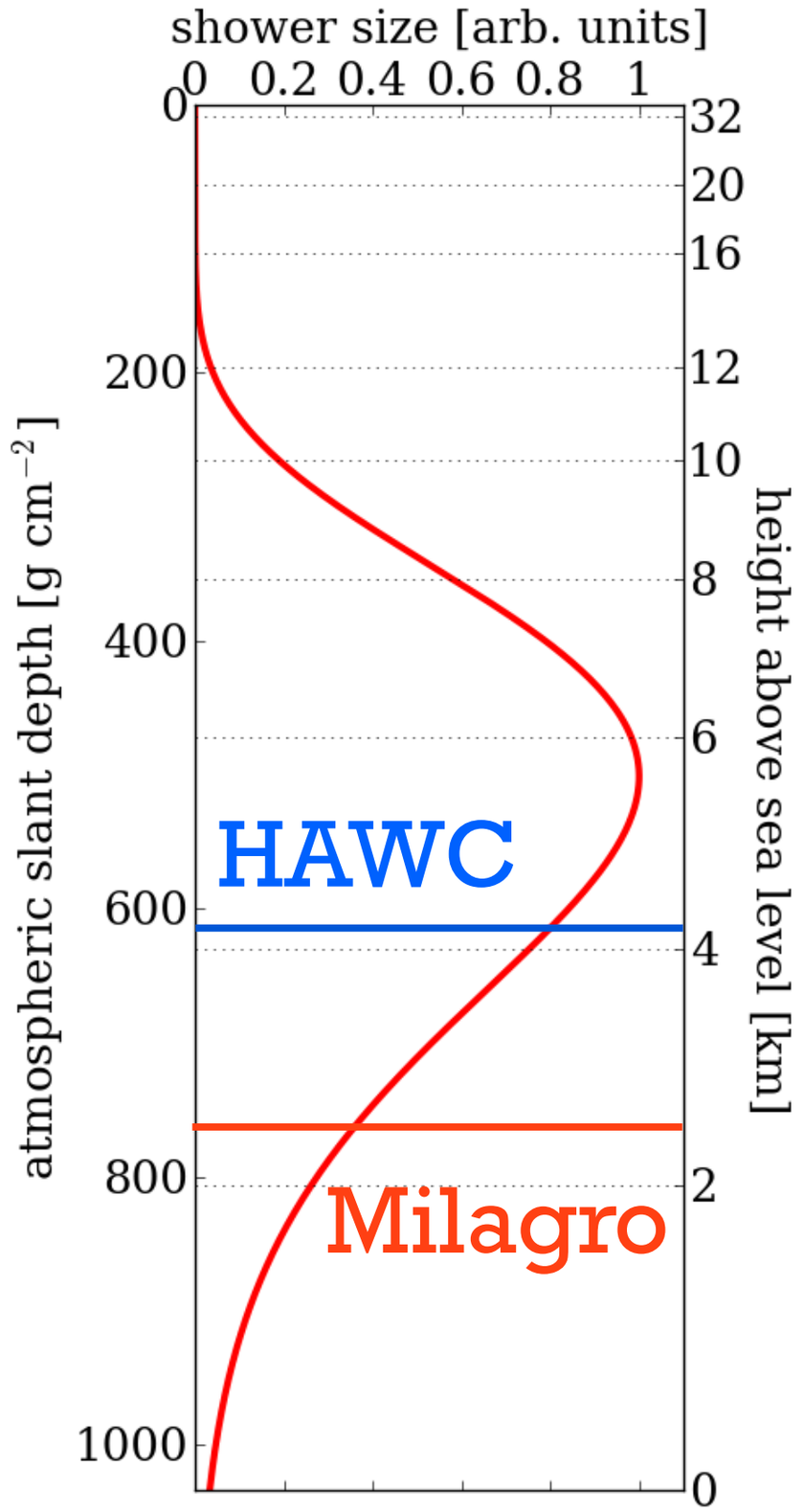
HAWC Detector Design

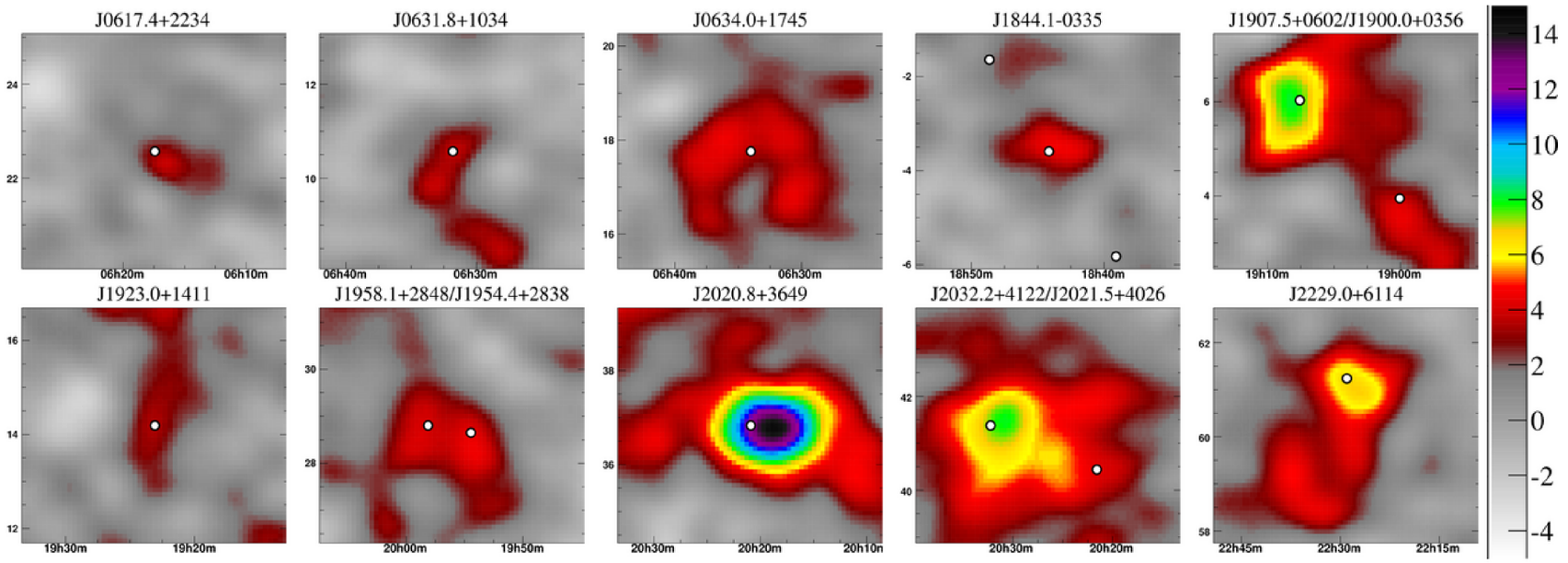


credit: Bernlöhr, MPIK (1999)

HAWC Detector Design

- Improvements over Milagro
  - move to higher altitude
  - increase optical isolation
  - increase instrumented volume
- Net result is a factor of ~15 improvement in sensitivity
- Potentially many sources just below Milagro's detection threshold





HAWC Detector Design

- HAWC facts
  - collaboration between US and Mexican institutions
  - ~100+ members
  - sited in the state of Puebla, MX, near Pico de Orizaba
- 19o N latitude
- 4100 m a.s.l.
- 300 water tanks
- 2 sr instantaneous field of view

HAWC Detector Design

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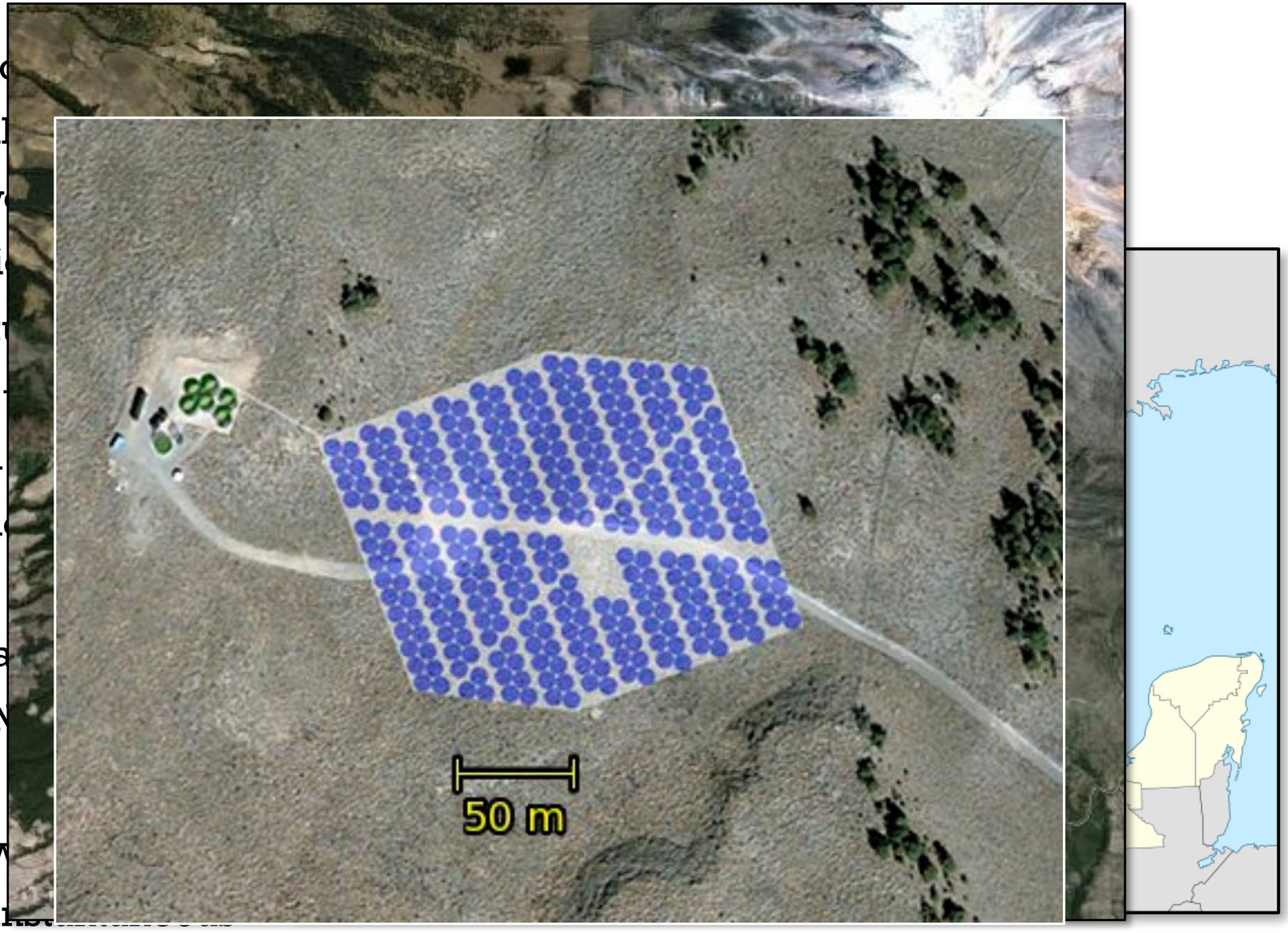

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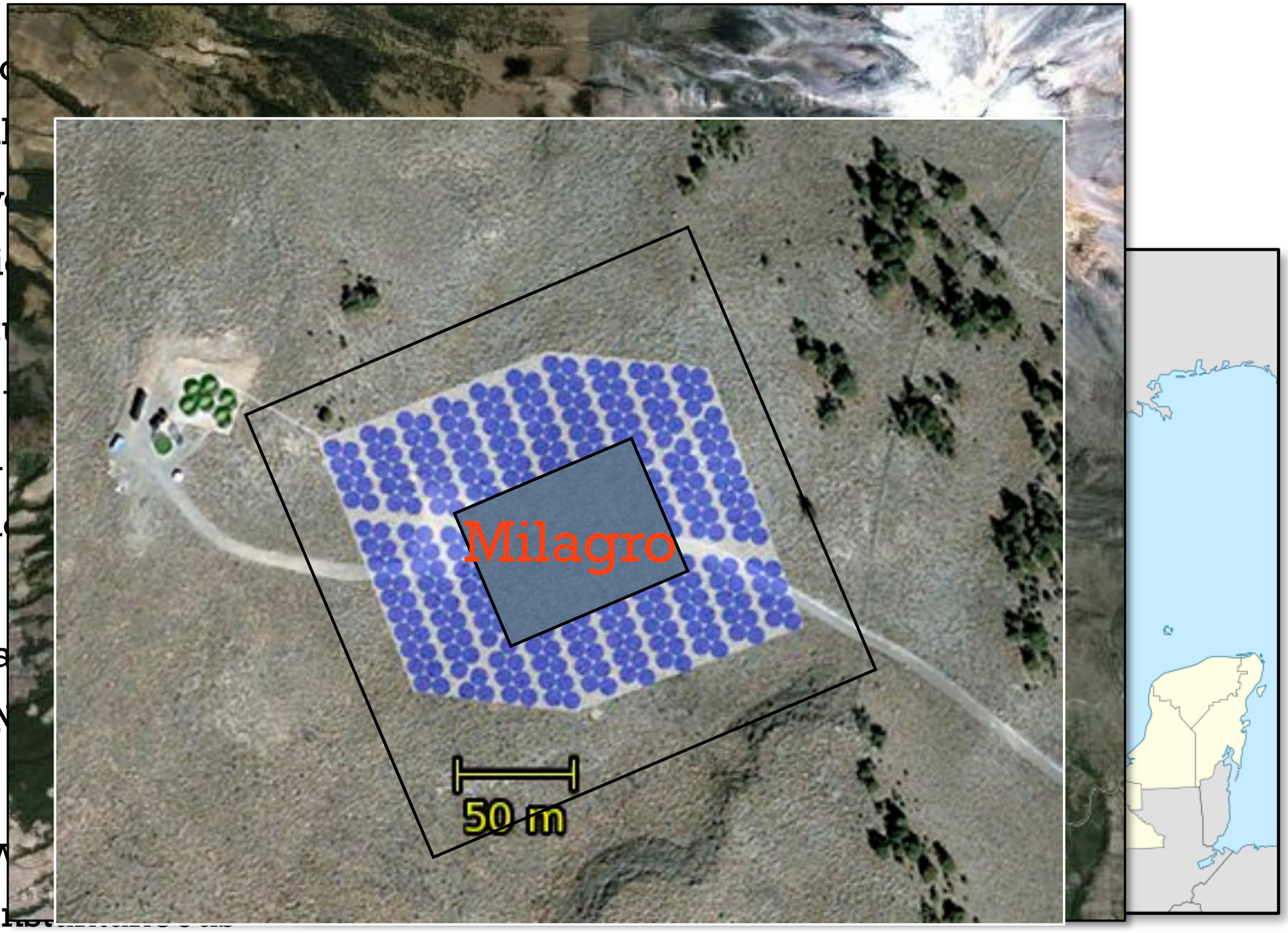


HAWC Collaboration

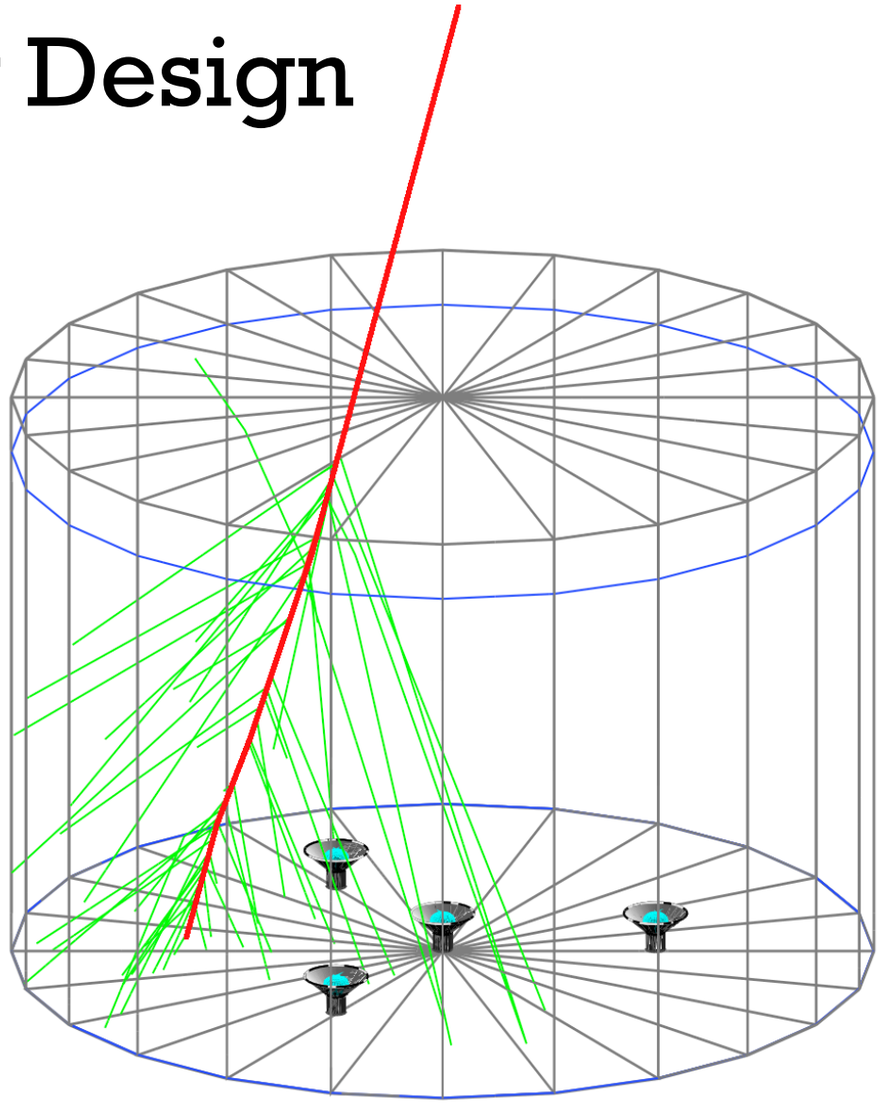
Los Alamos National Laboratory
University of Maryland
University of Utah
University of New Mexico
Michigan State University
Pennsylvania State University
NASA/Goddard Space Flight Center
University of New Hampshire
Georgia Tech
George Mason University
University of California, Irvine
Colorado State University
Michigan Technological University
University of Alabama
University of Wisconsin - Madison

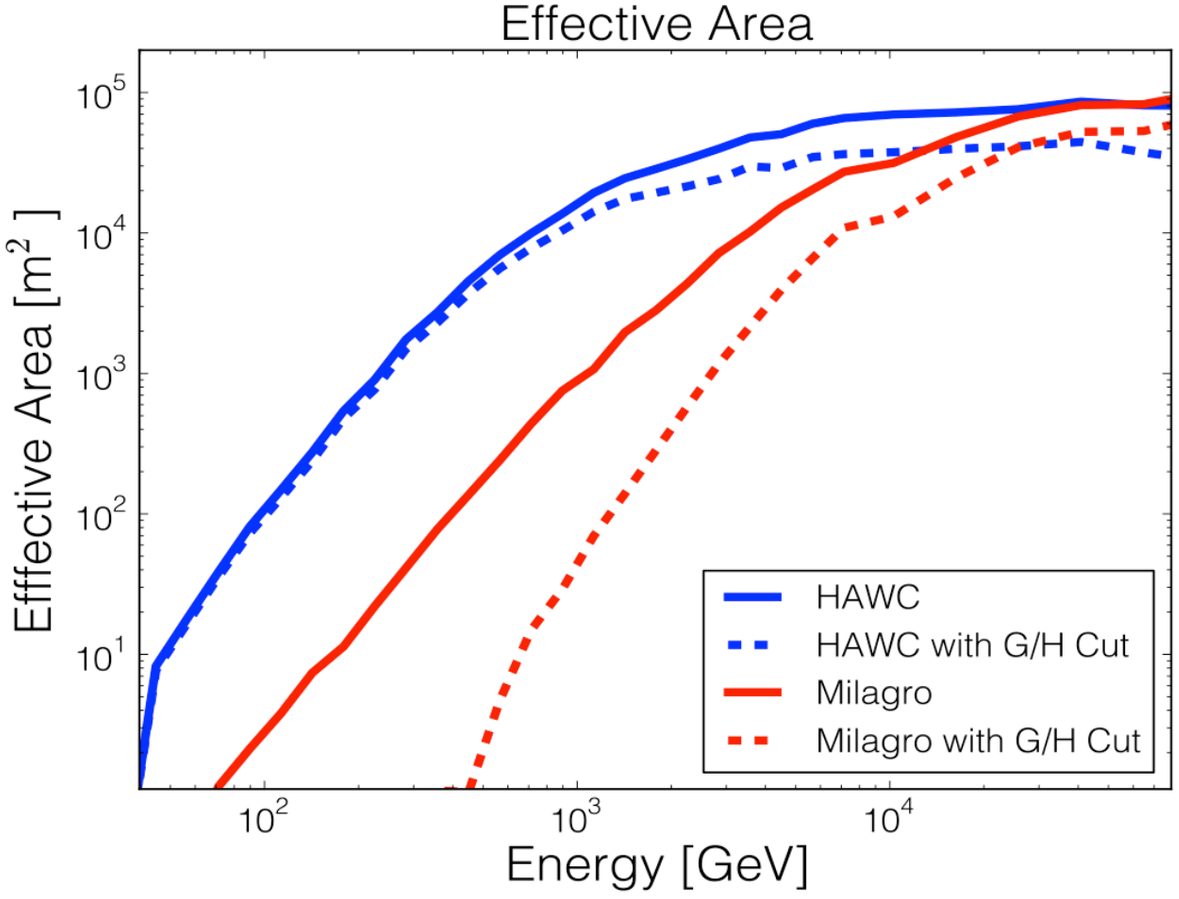
Instituto Nacional de Astrofisica Óptica y Electrónica (INAOE)
Universidad Nacional Autónoma de México (UNAM)
- Instituto de Astronomia
- Instituto de Fisica
- Instituto de Ciencias Nucleares
- Instituto de Geofisica

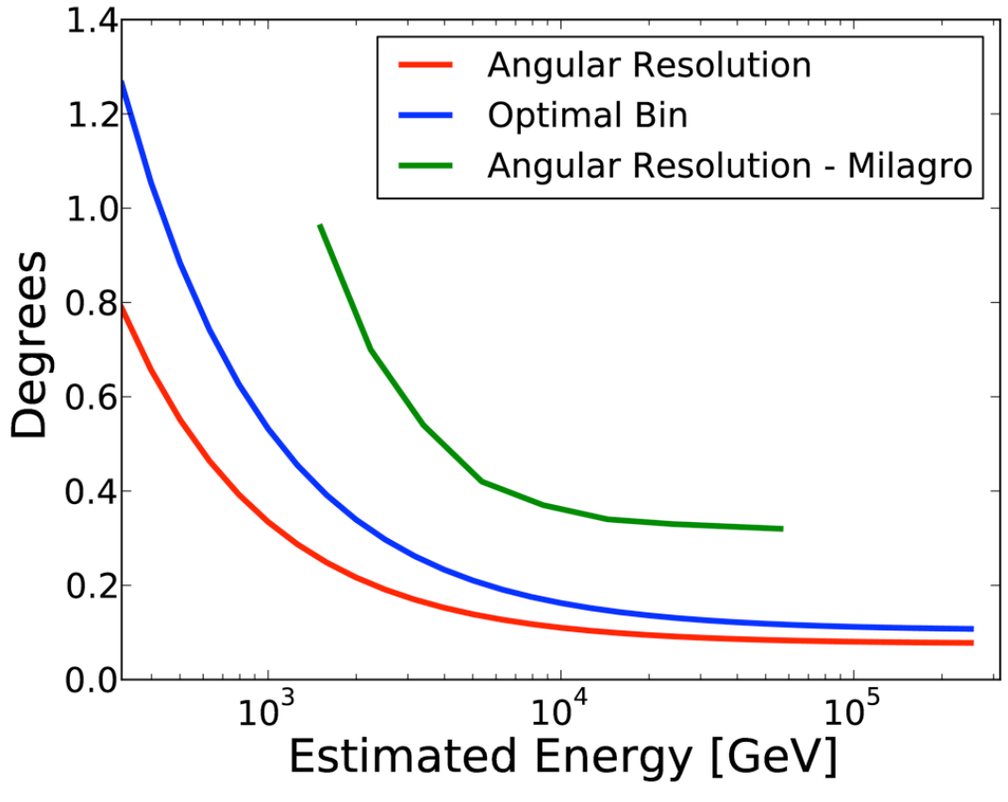
Universidad Autónoma de Chiapas
Universidad de Guadalajara
Benemérita Universidad Autónoma de Puebla
Universidad Michoacana de San Nicolás de Hidalgo
CINVESTAV
Universidad de Guanajuato
UGTO-IF
Universidad Autonoma del Estado de Hidalgo
Instituto Politecnico Nacional

HAWC Detector Design

- Cherenkov radiation from air shower particles measured by 4 upward-facing PMTs
- PMT timing and charge information used to reconstruct direction of primary particle
- Effective area substantially increased below 1 TeV







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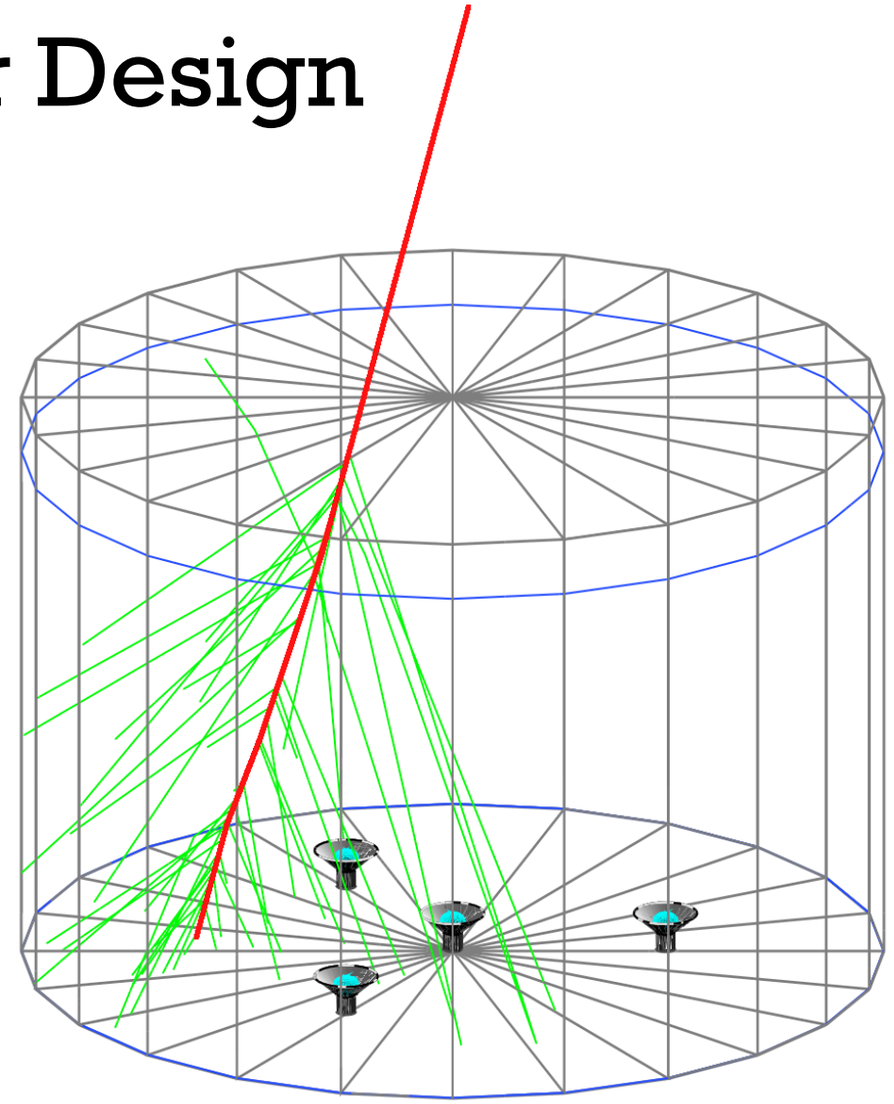

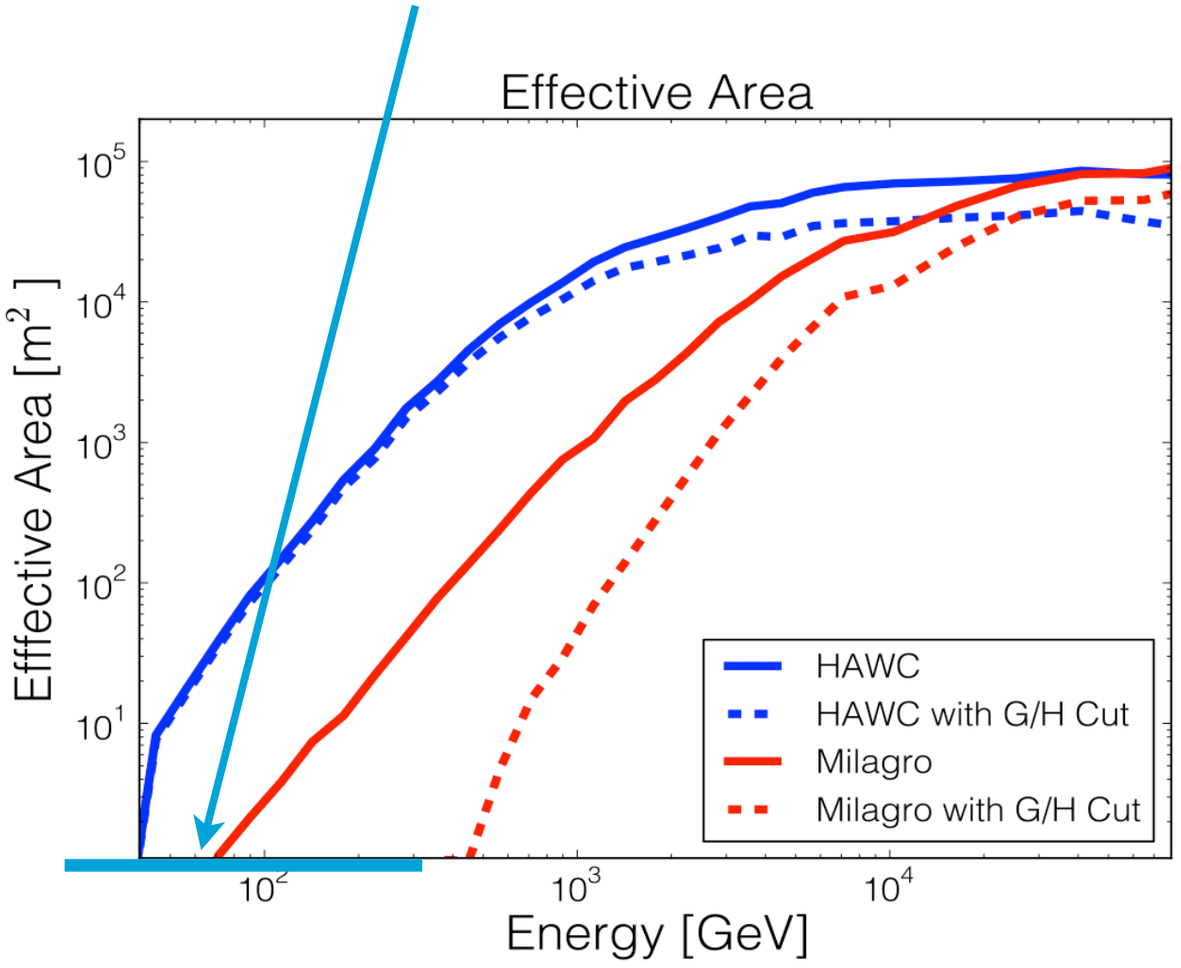

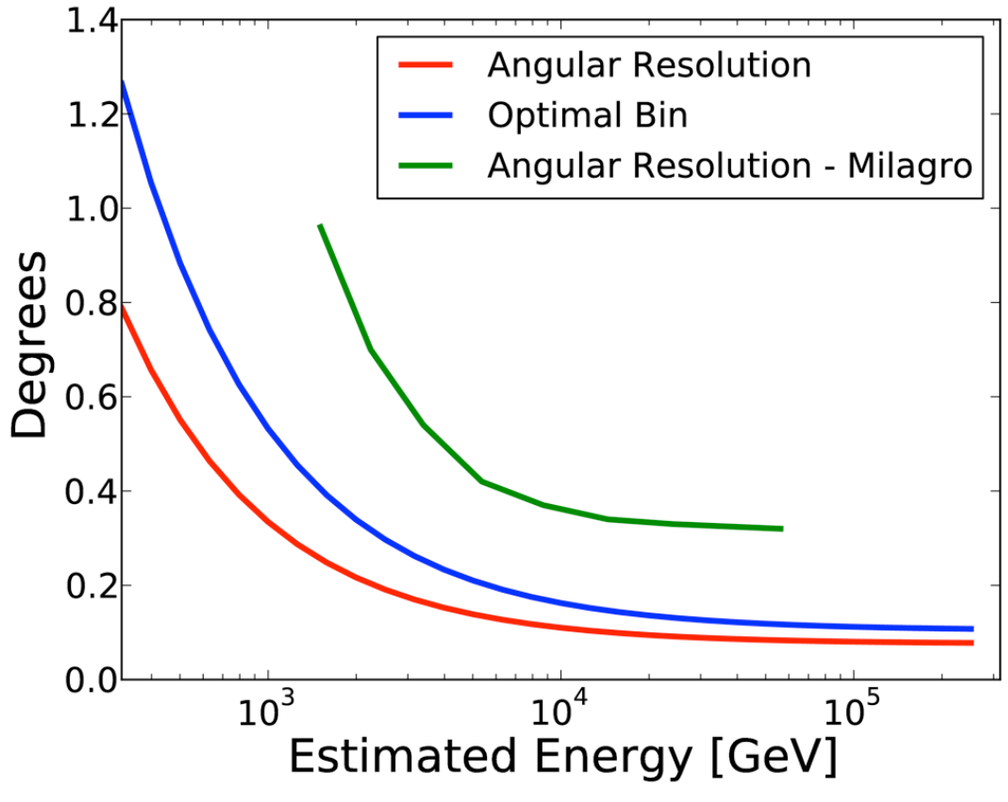

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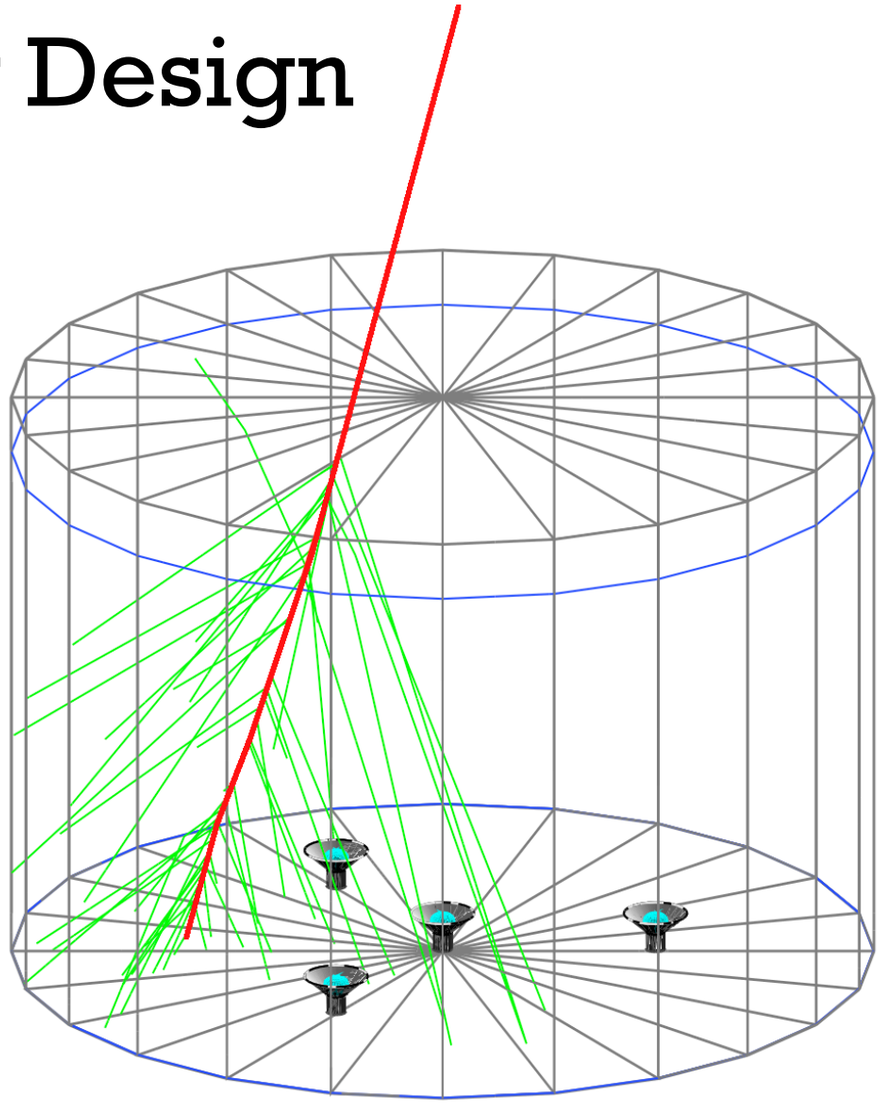
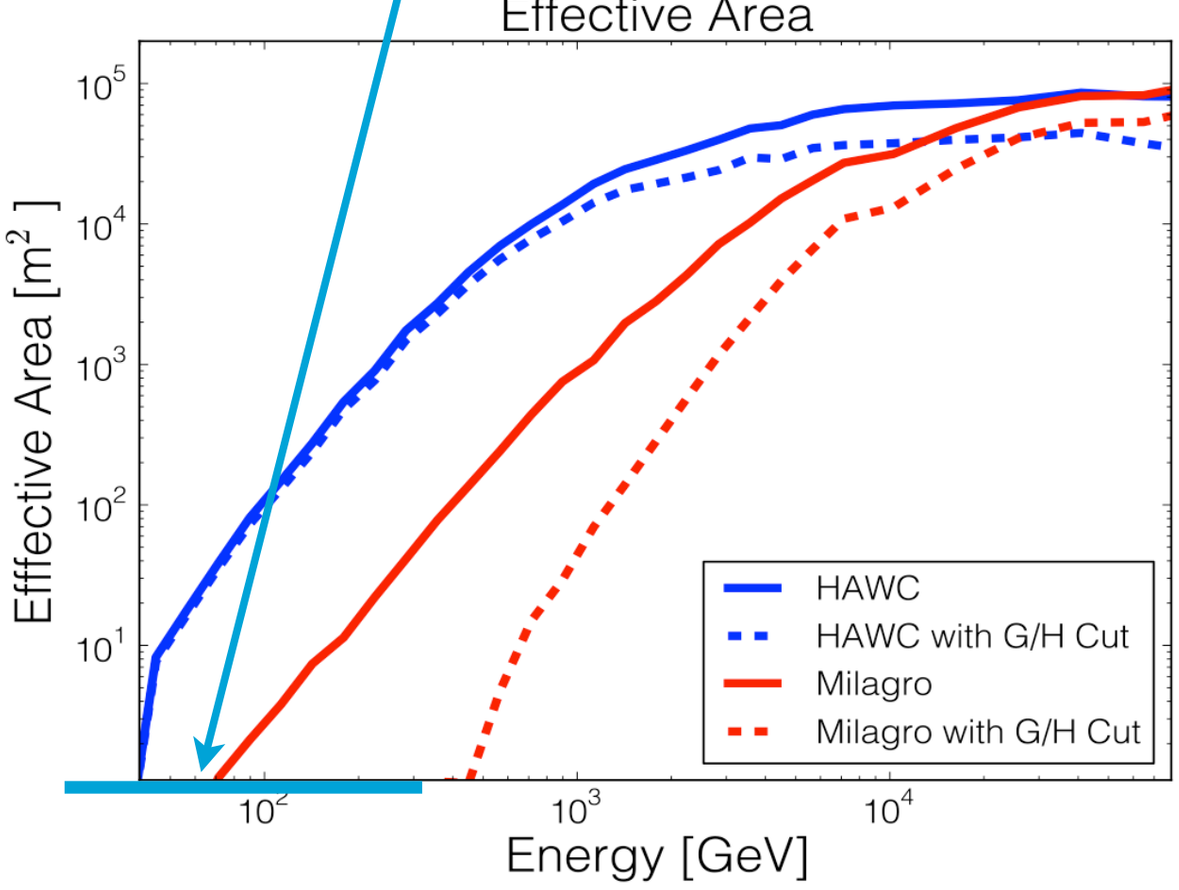
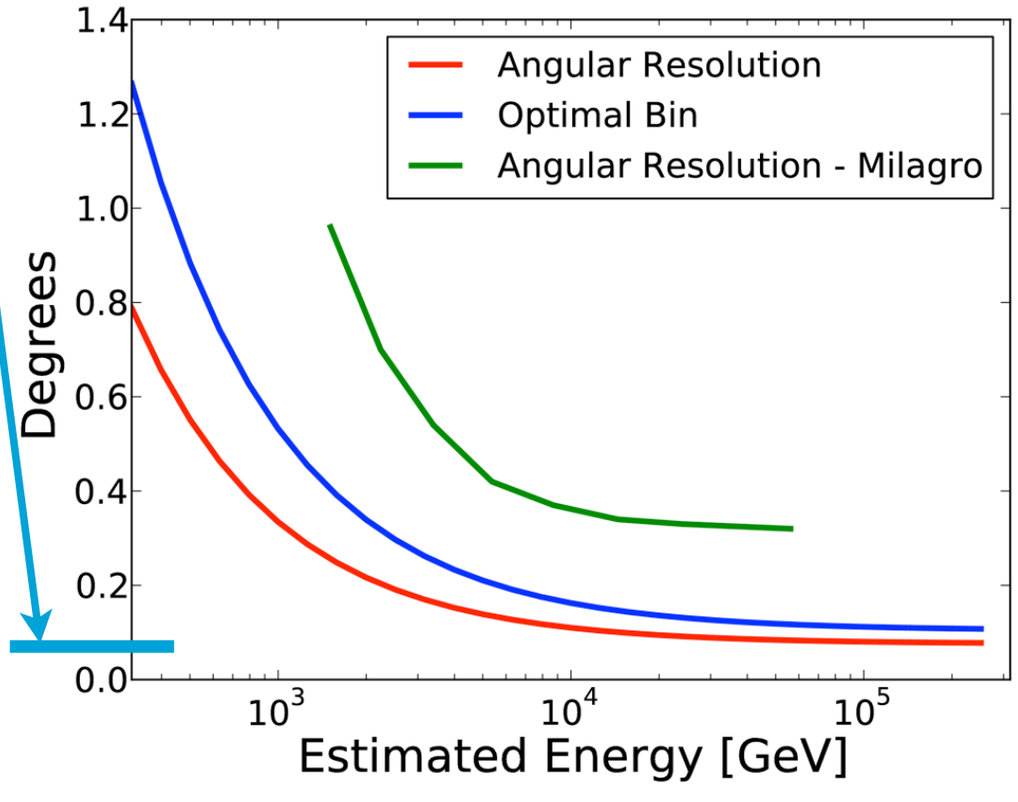


Fermi LAT Effective Area



Fermi LAT PSF



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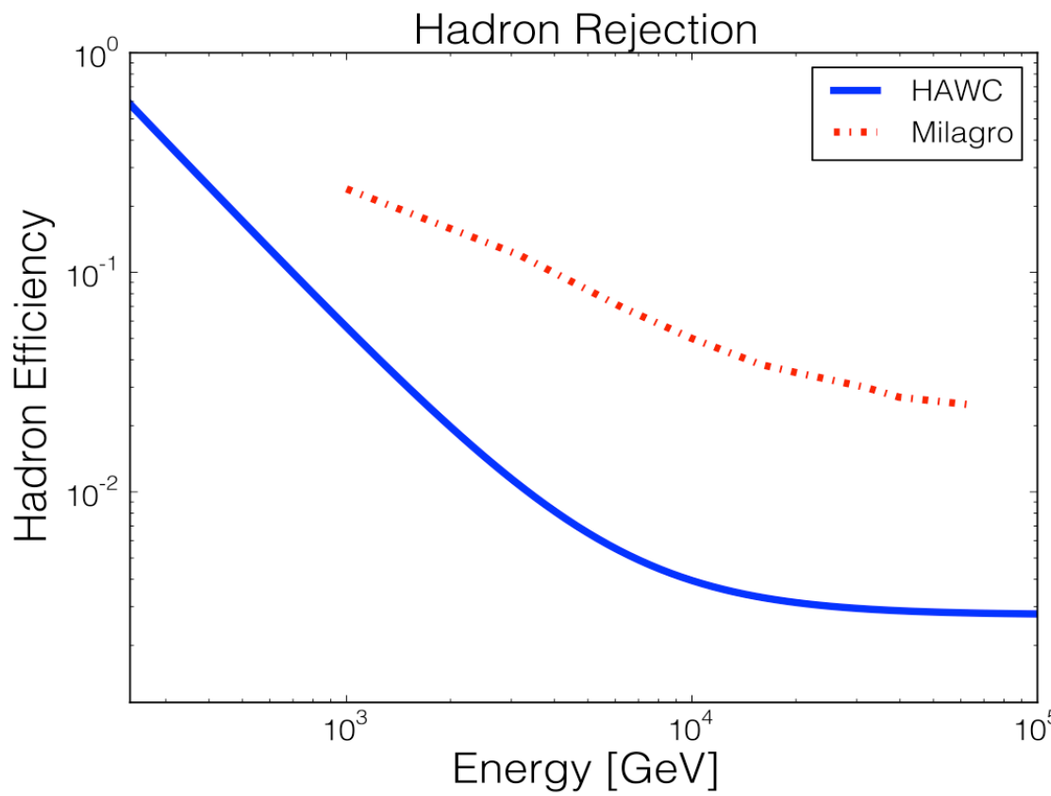

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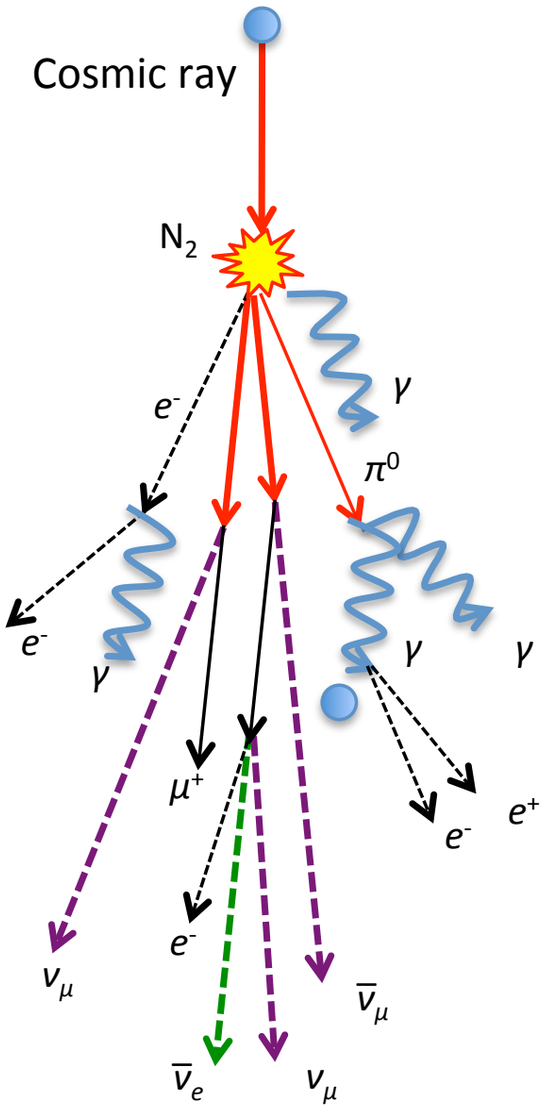

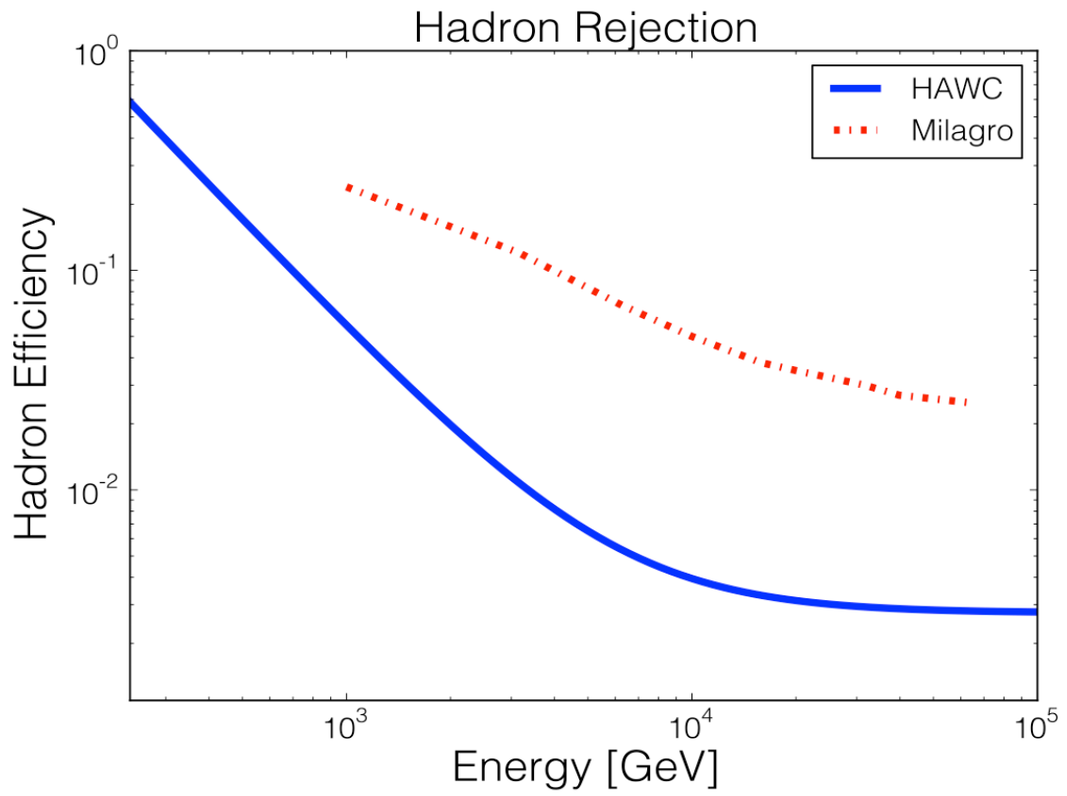

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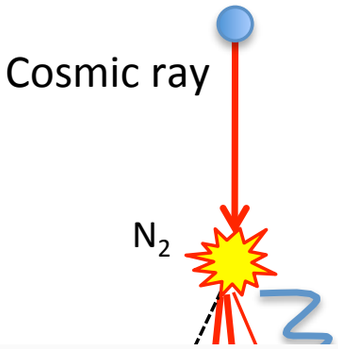

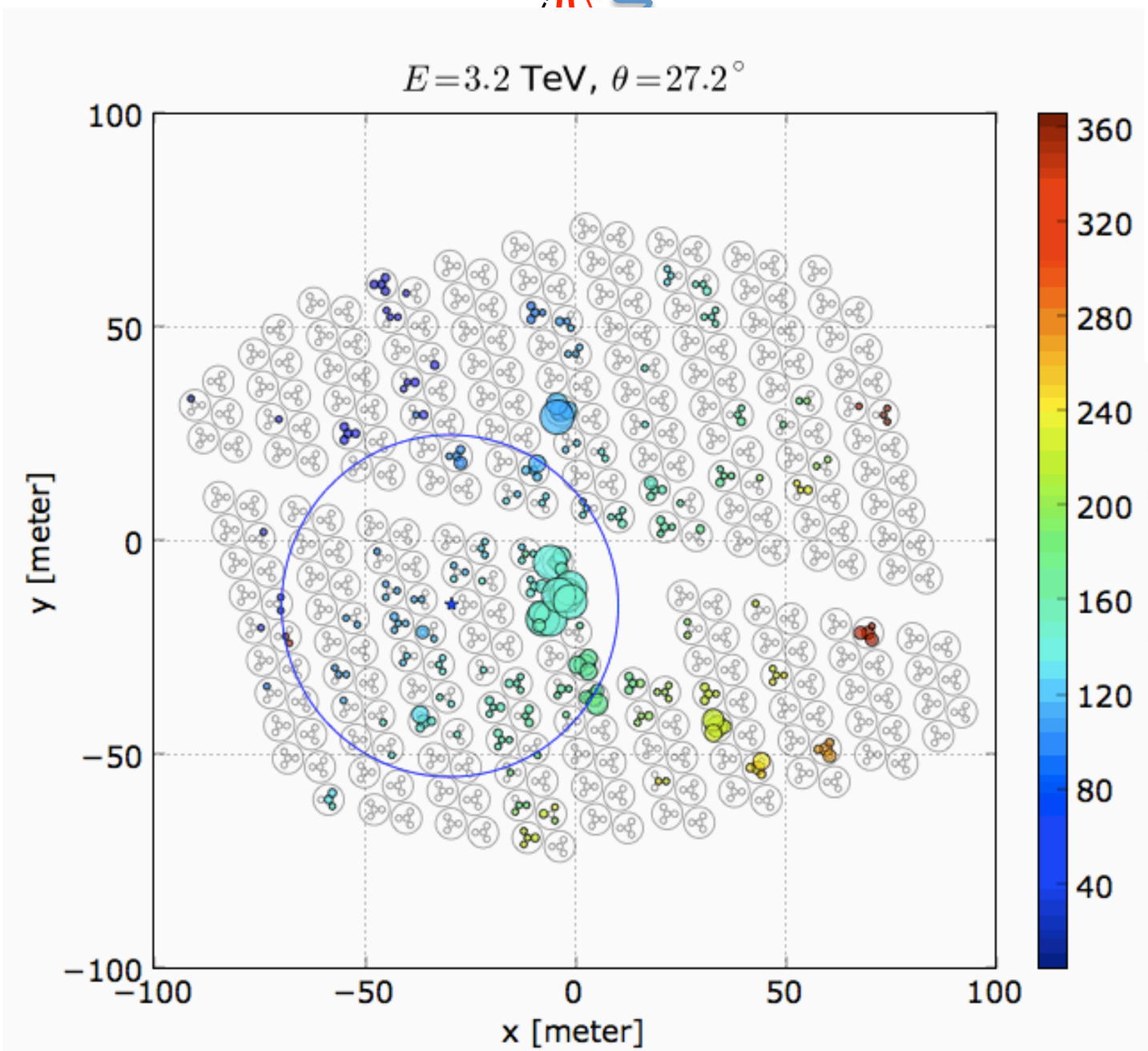

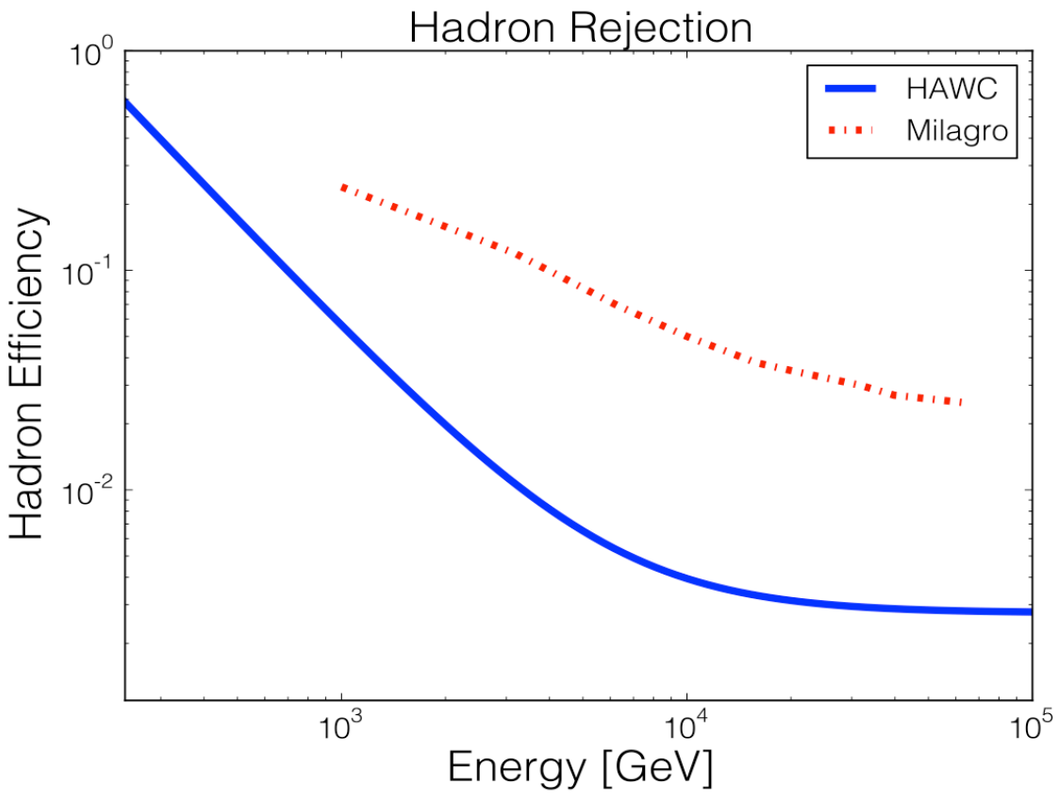

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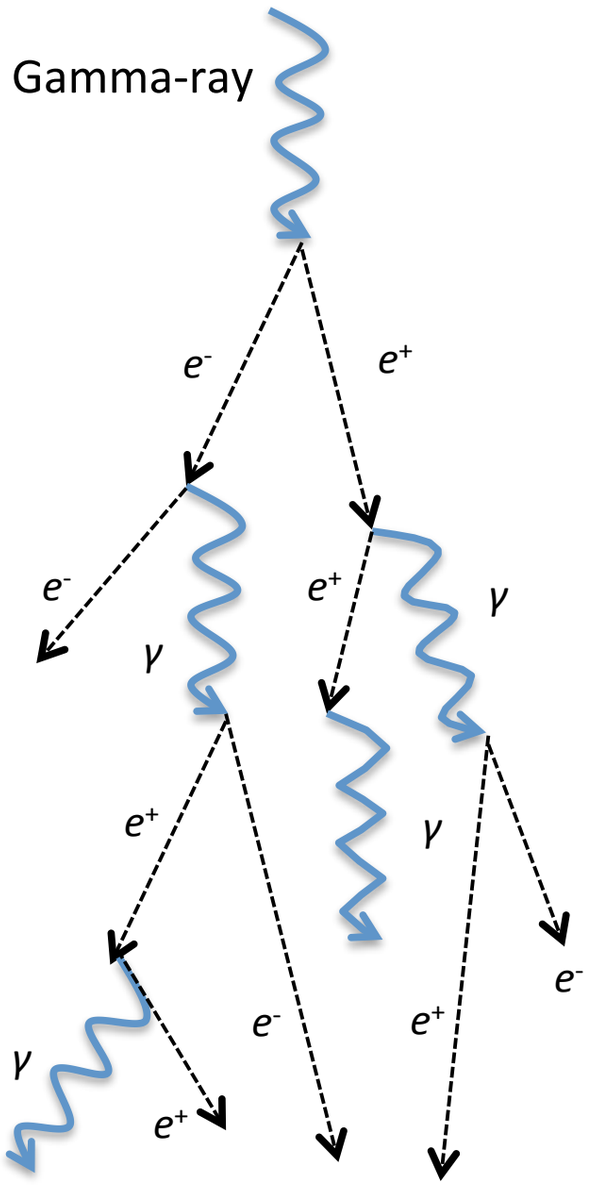

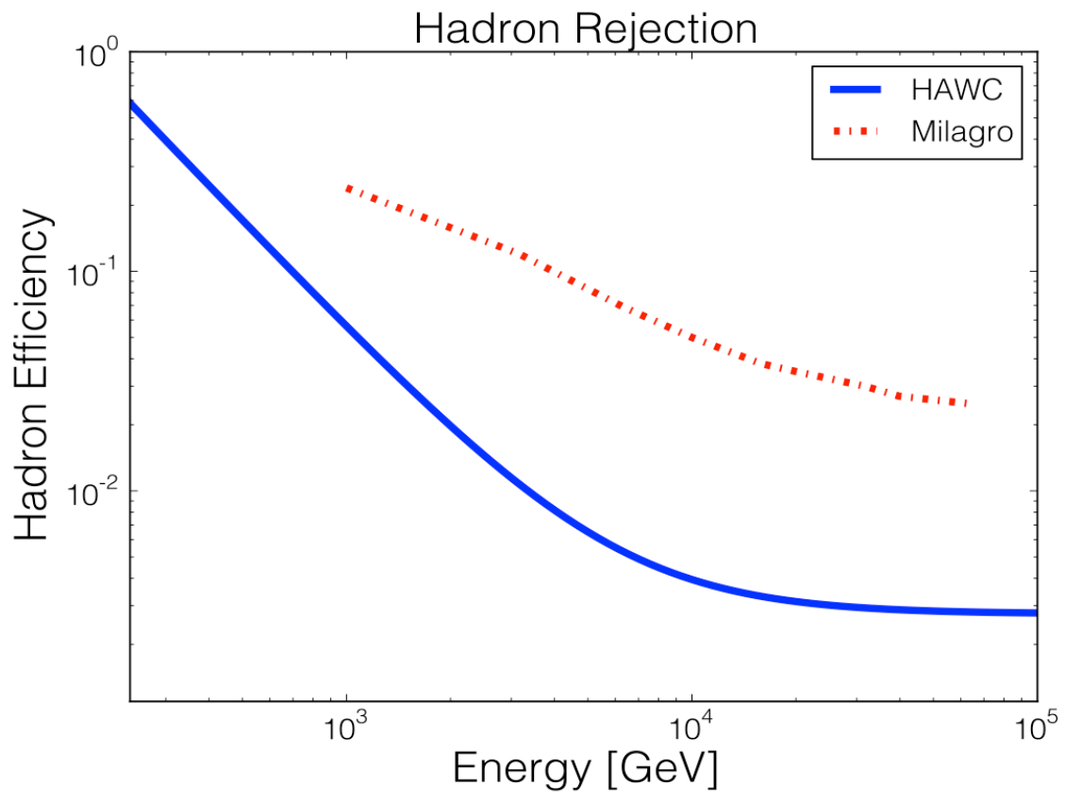

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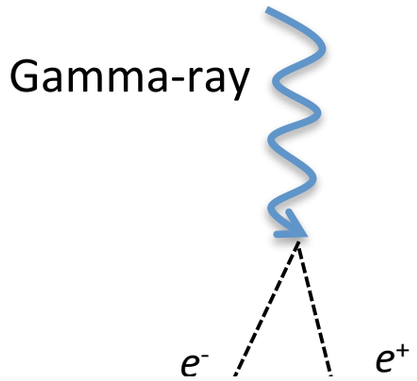

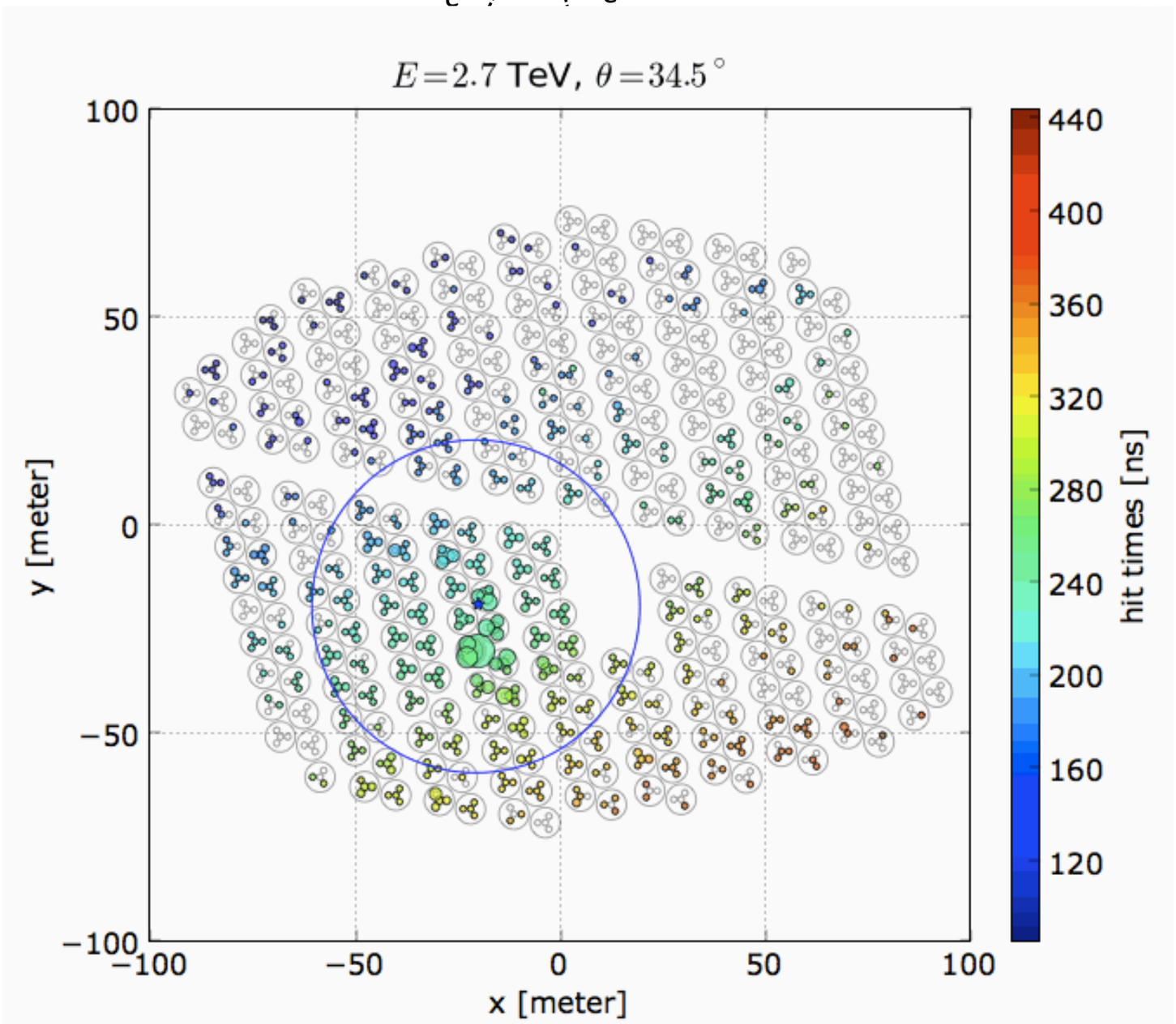

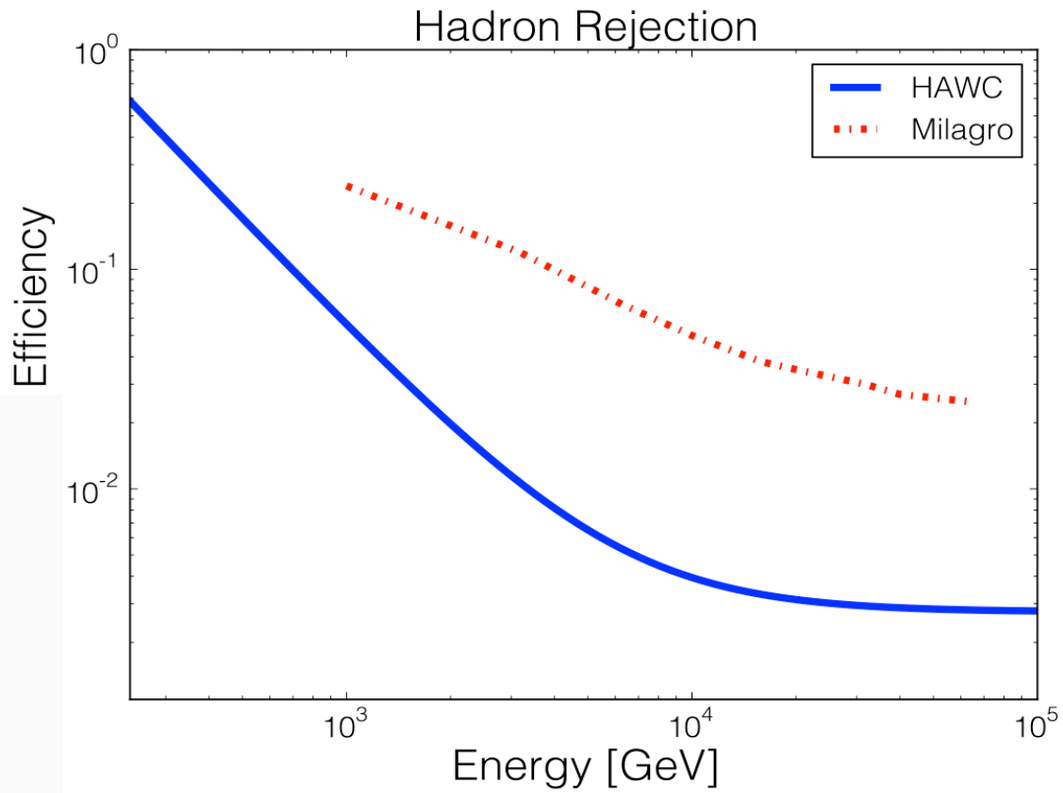

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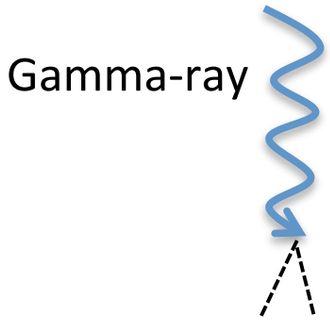
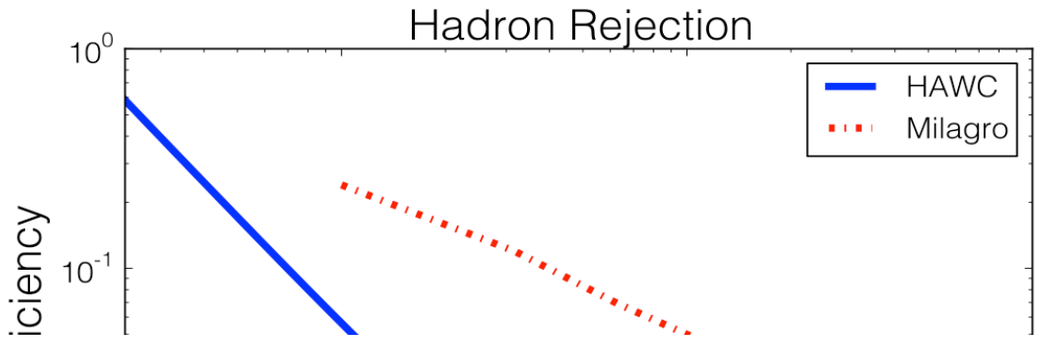
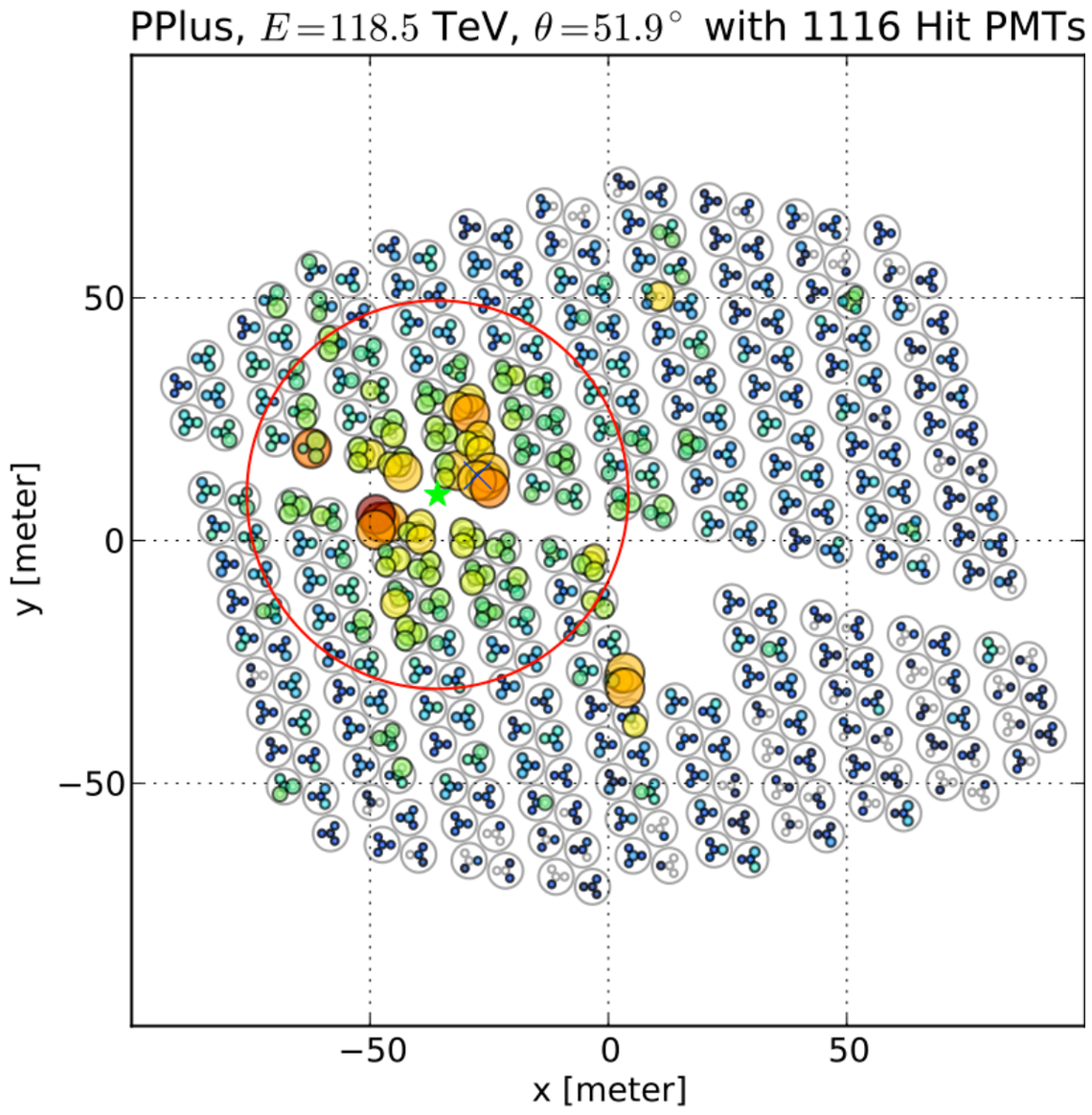
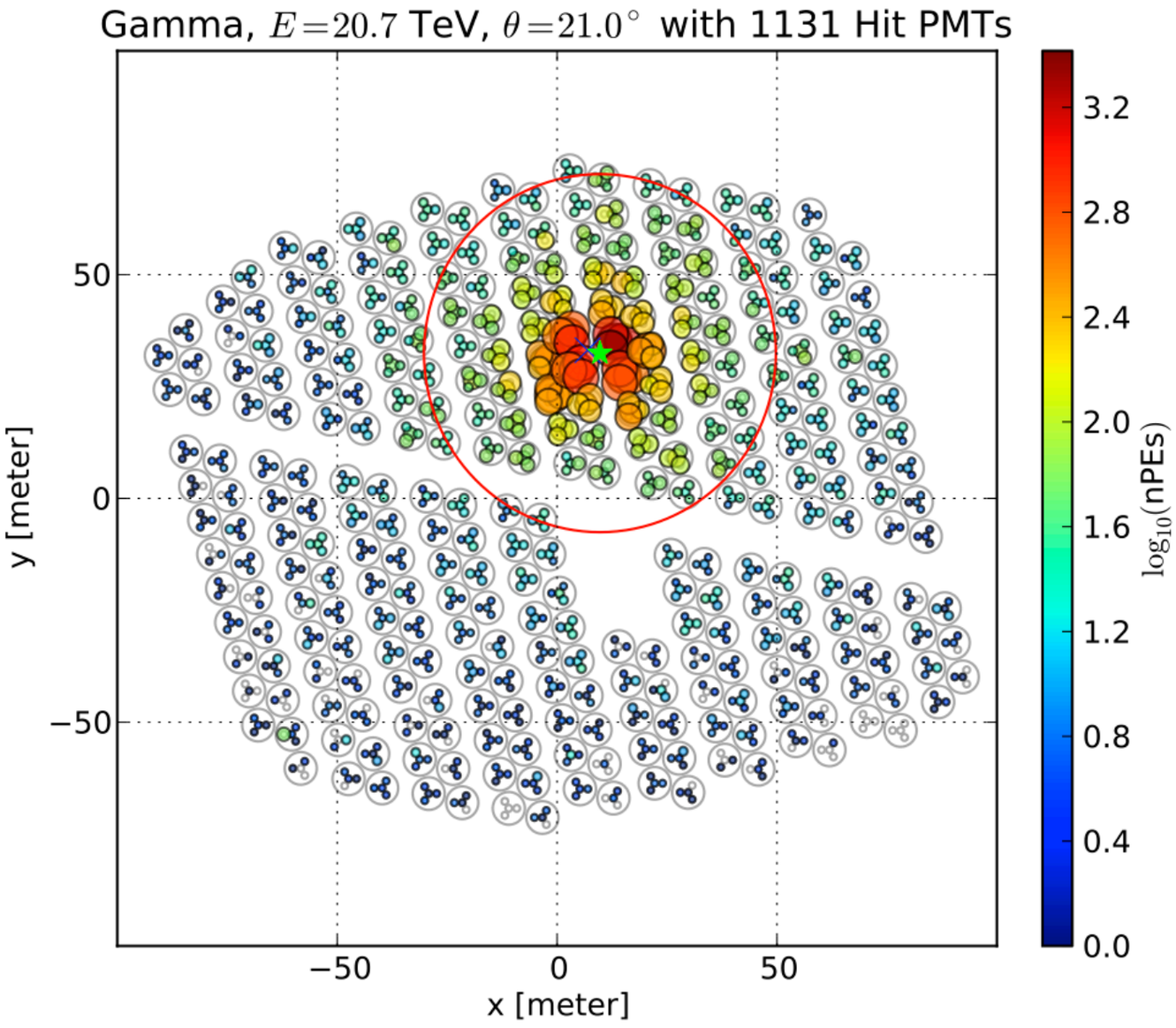




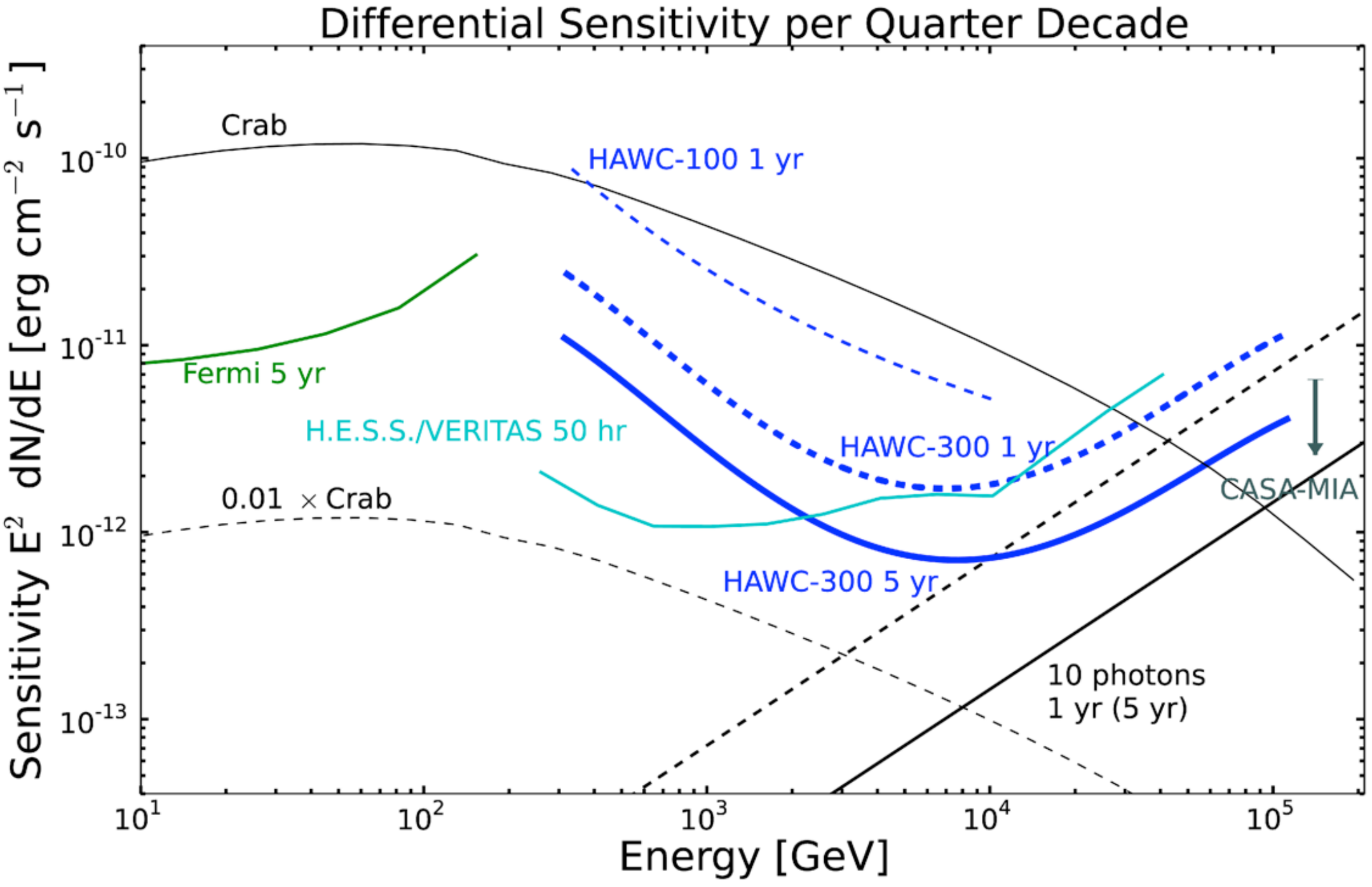




x [meter]

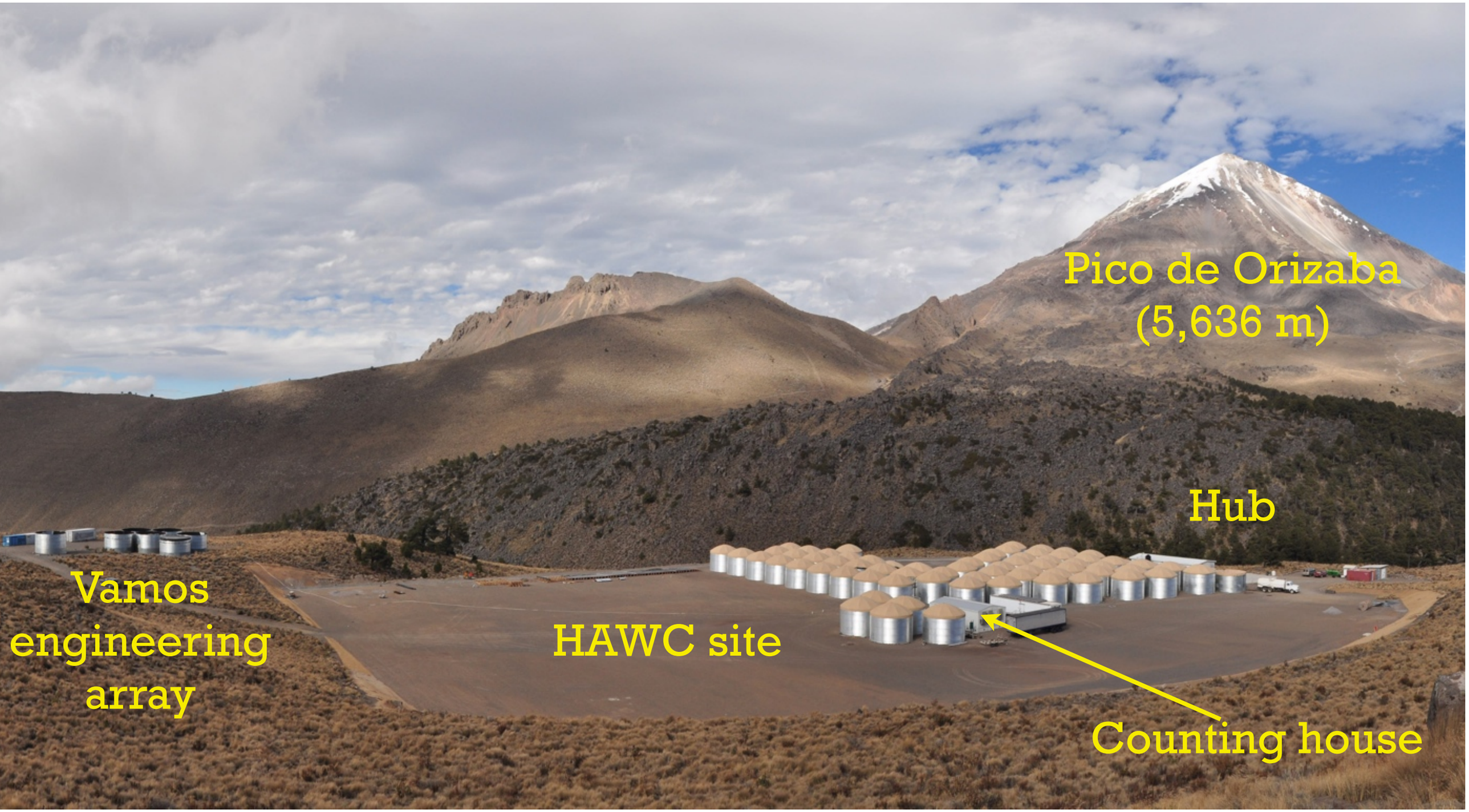
HAWC Detector Design

- For the full array, the sensitivity to all sources will be comparable to a single 50-hour pointed observation by an existing IACT



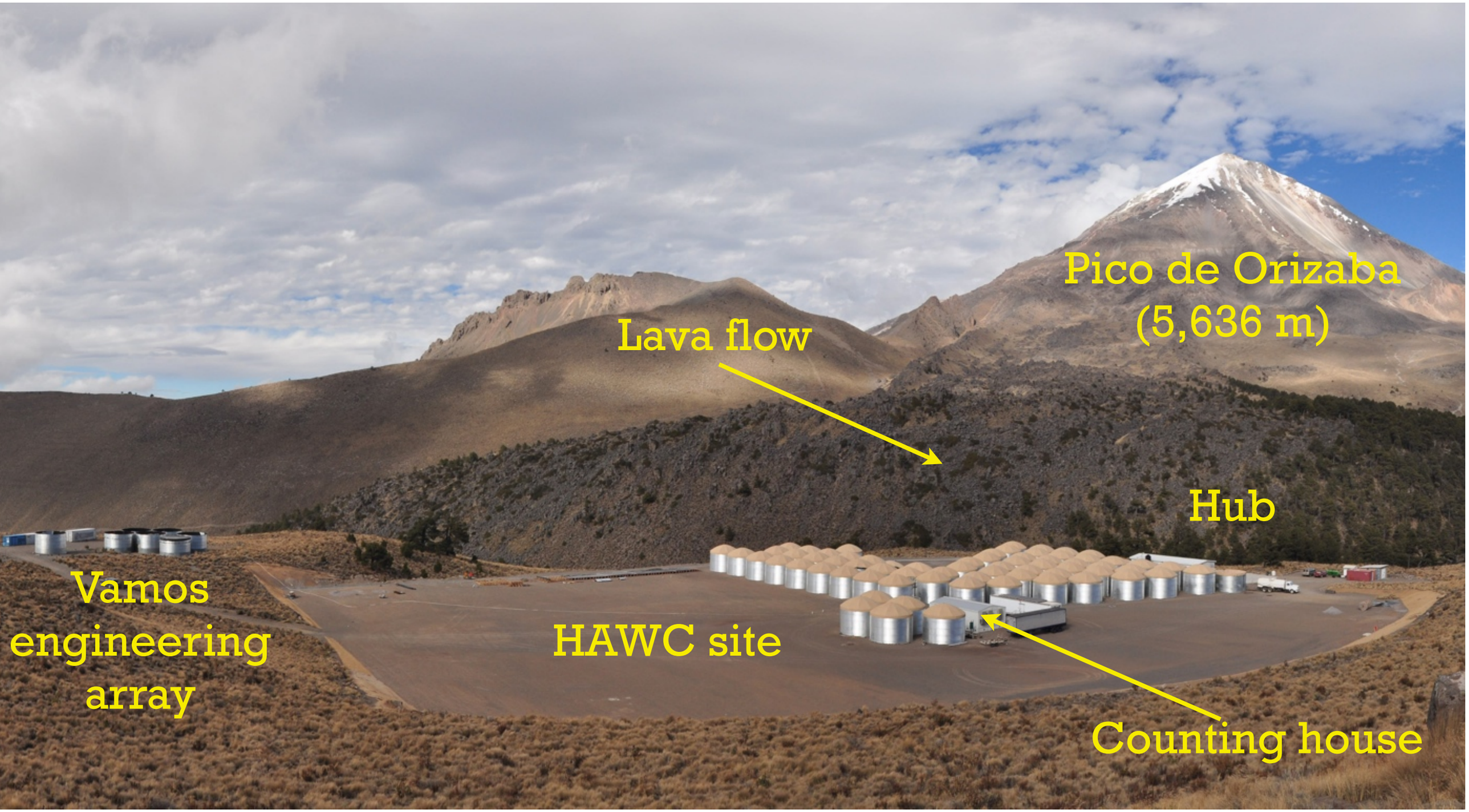
HAWC Detector Construction

Site ~1 year ago:



HAWC Detector Construction

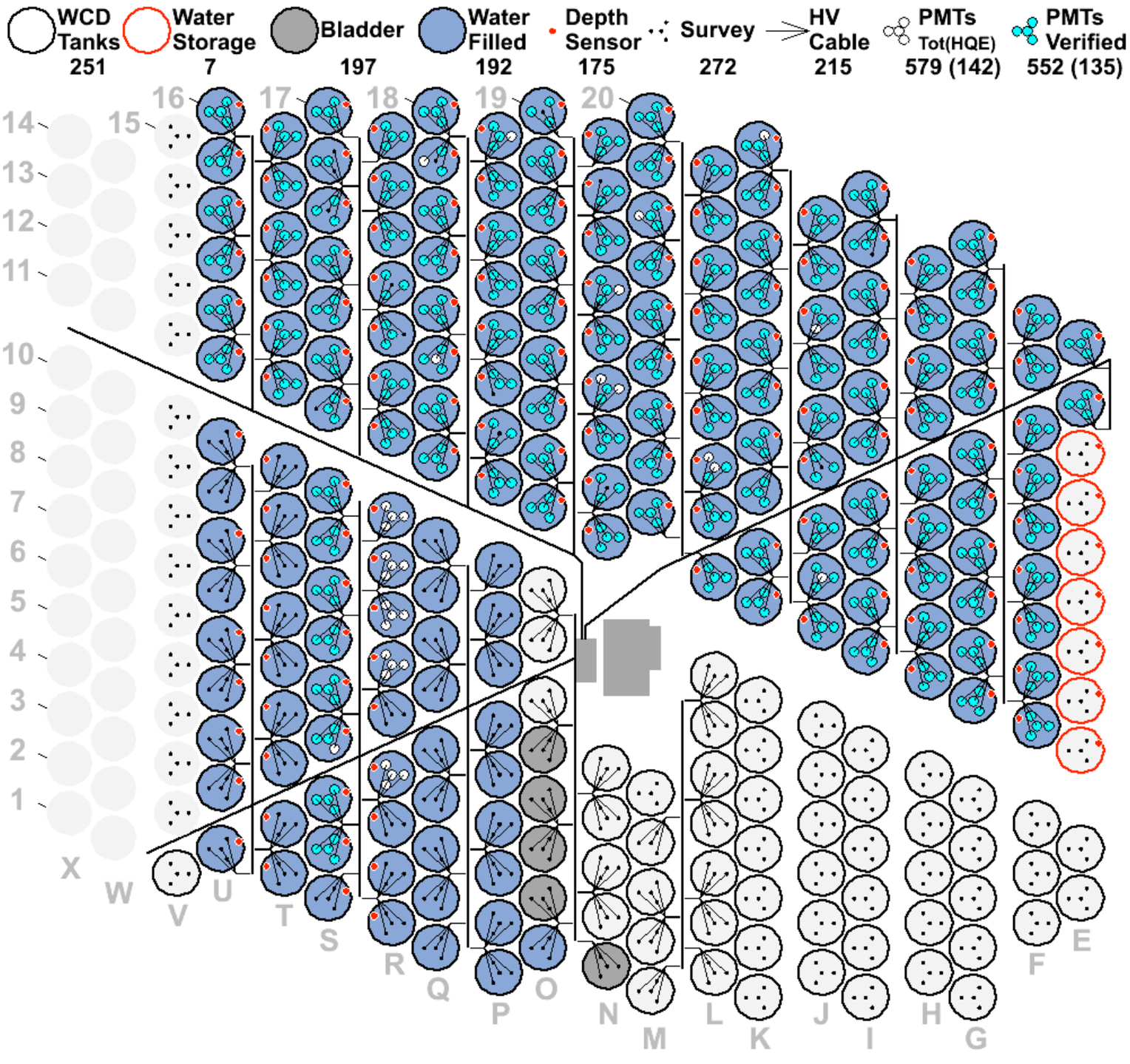
Site ~1 year ago:



HAWC Detector Construction

HAWC Detector Construction

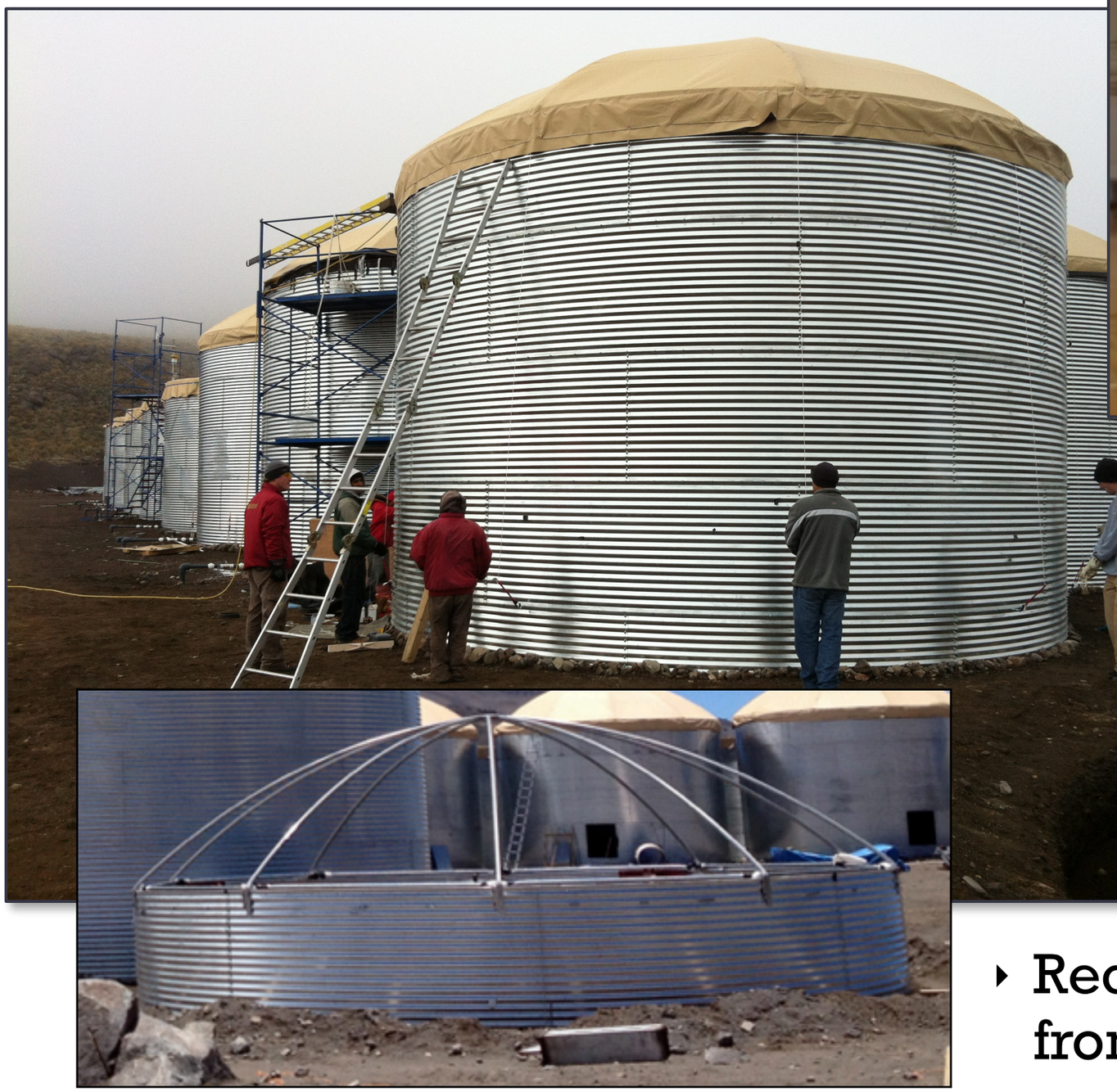
- current status of HAWC tanks
- completion scheduled before the end of this year!



HAWC Site

HAWC Construction

- Light-tight bladders fabricated at CSU

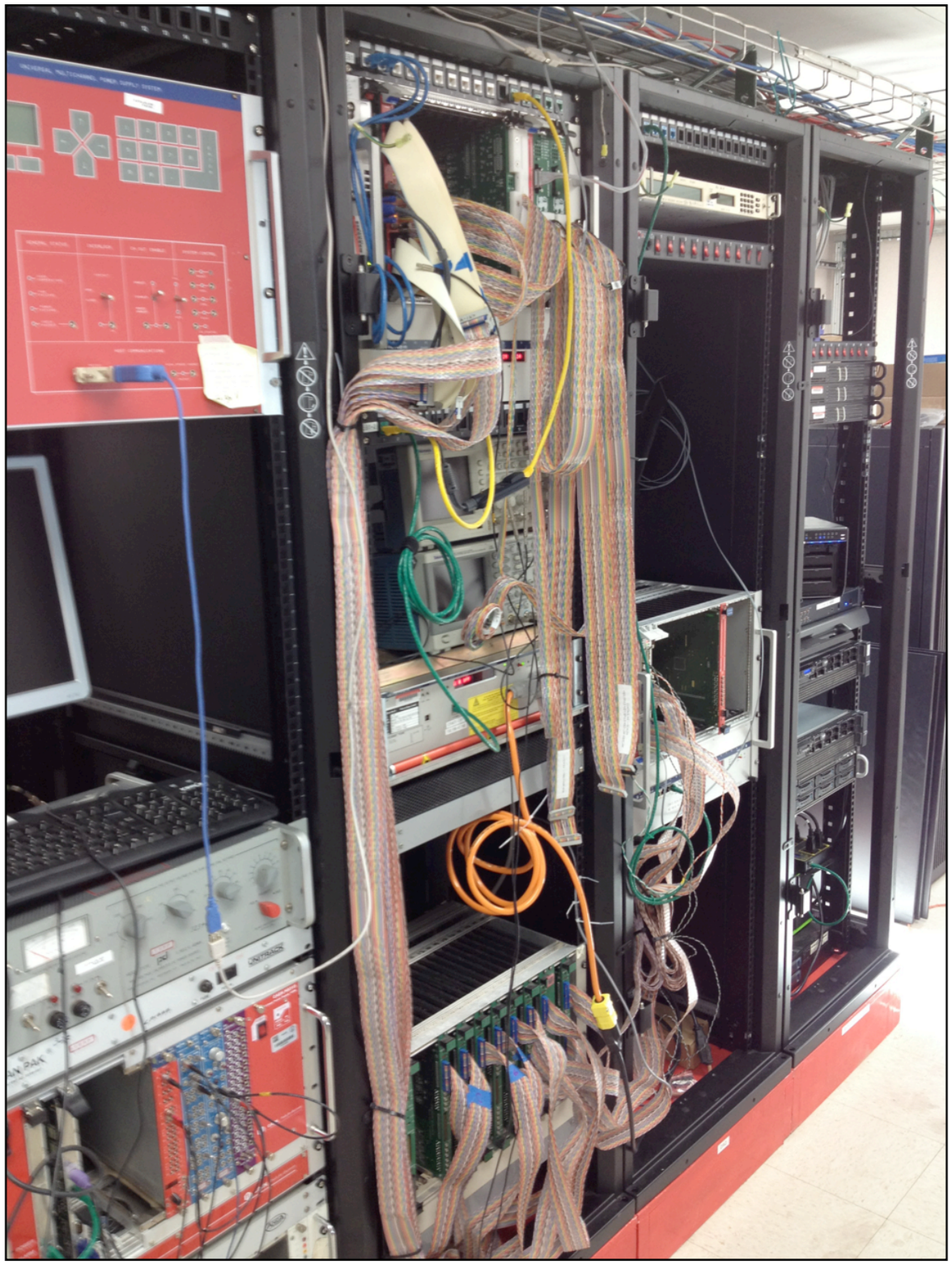


- Recycle PMTs from Milagro

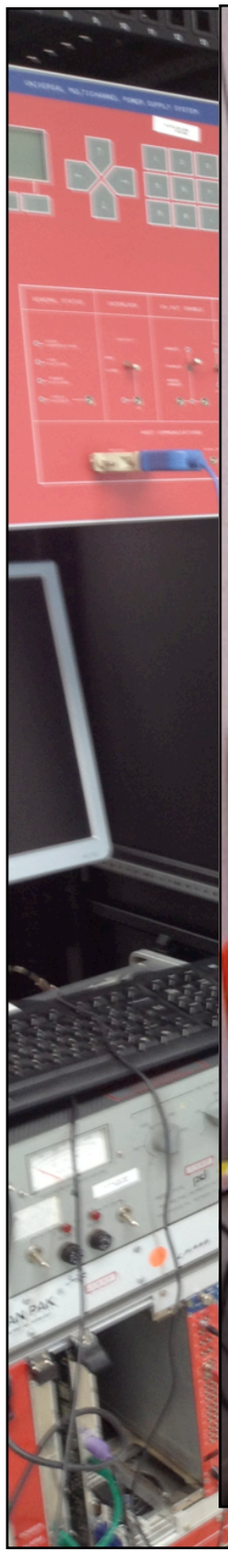
HAWC Construction

- PMTs are wet deployed

HAWC Construction

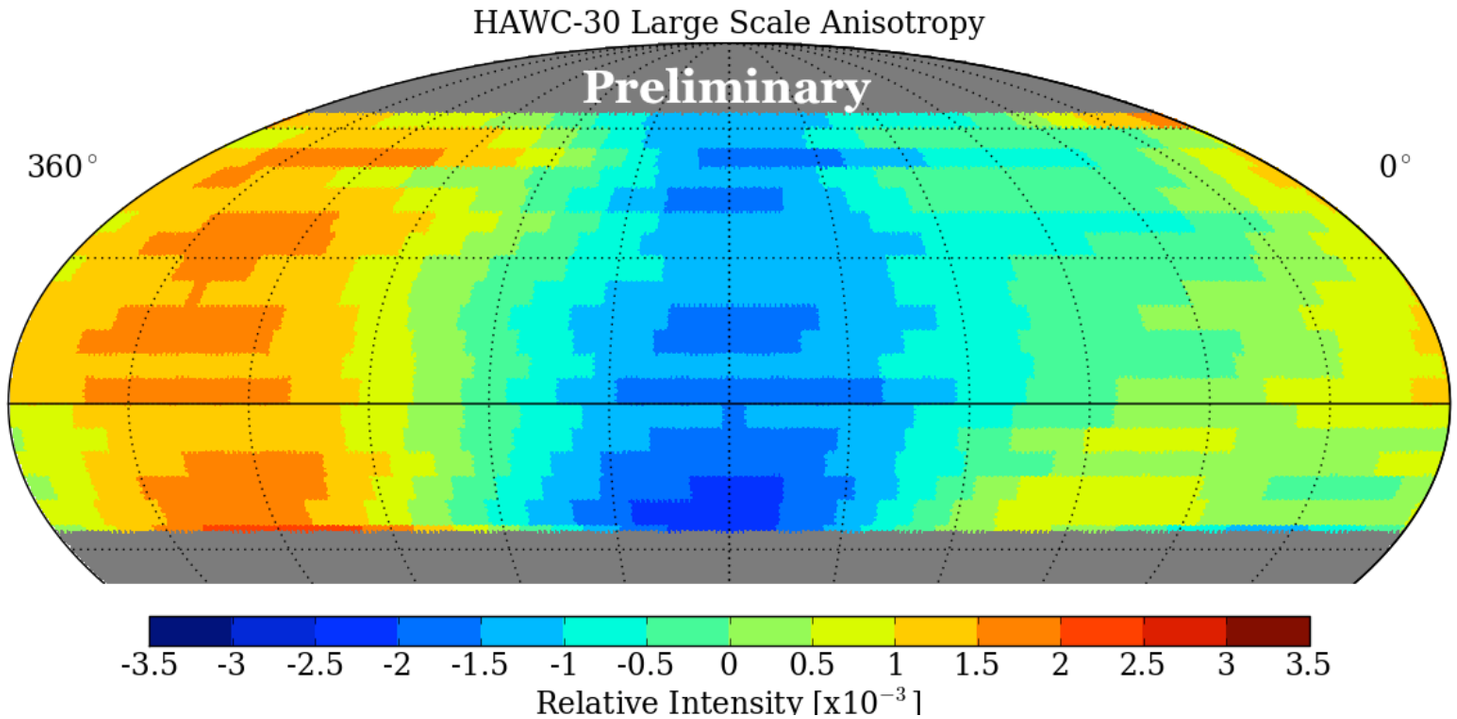


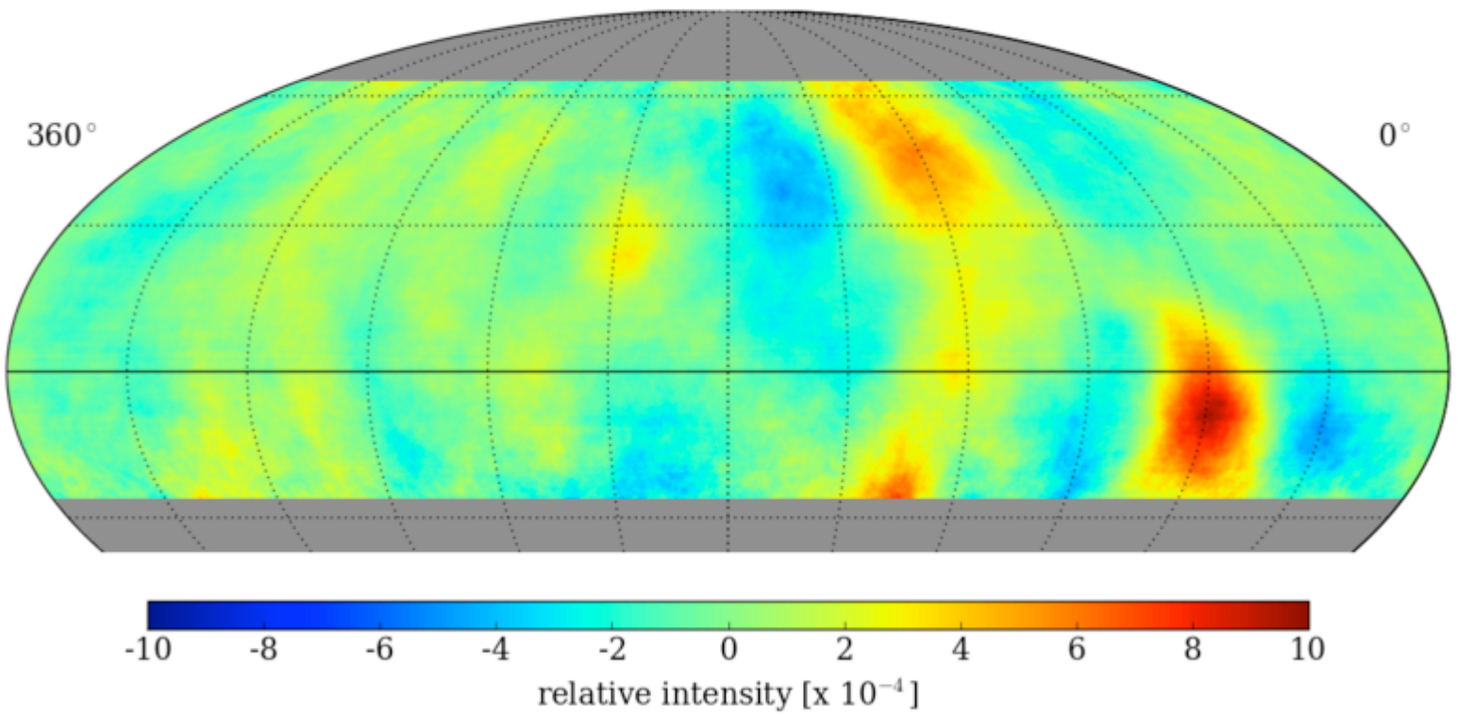
HAWC Construction

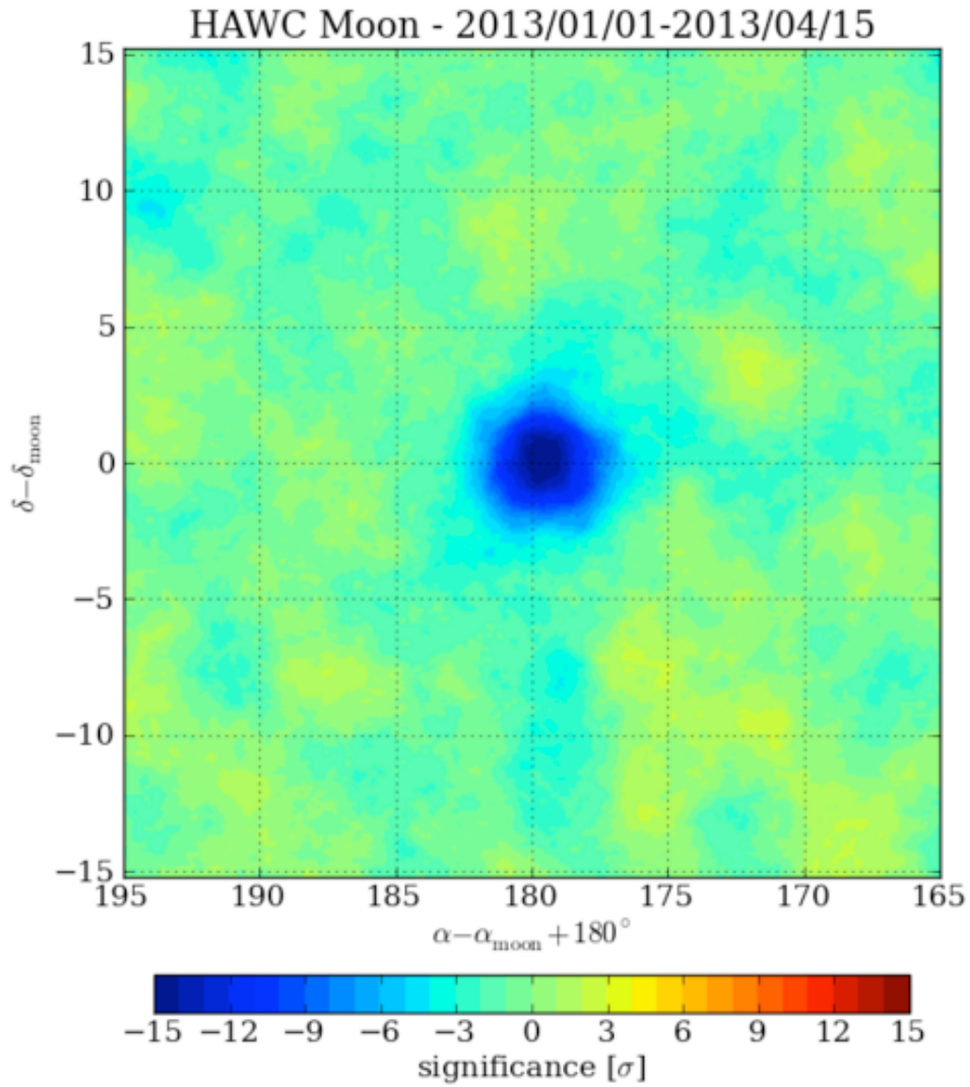


Preliminary Results

- verification of cosmic-ray moon shadow
- cosmic-ray anisotropy (large and small scales)

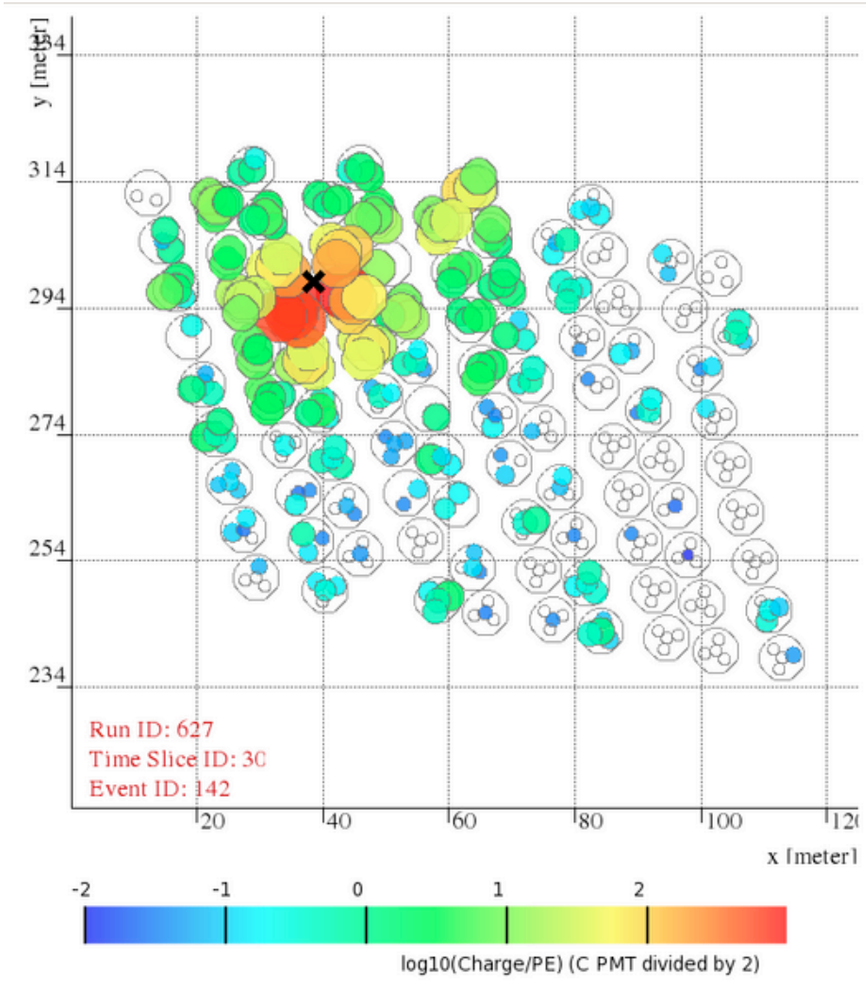


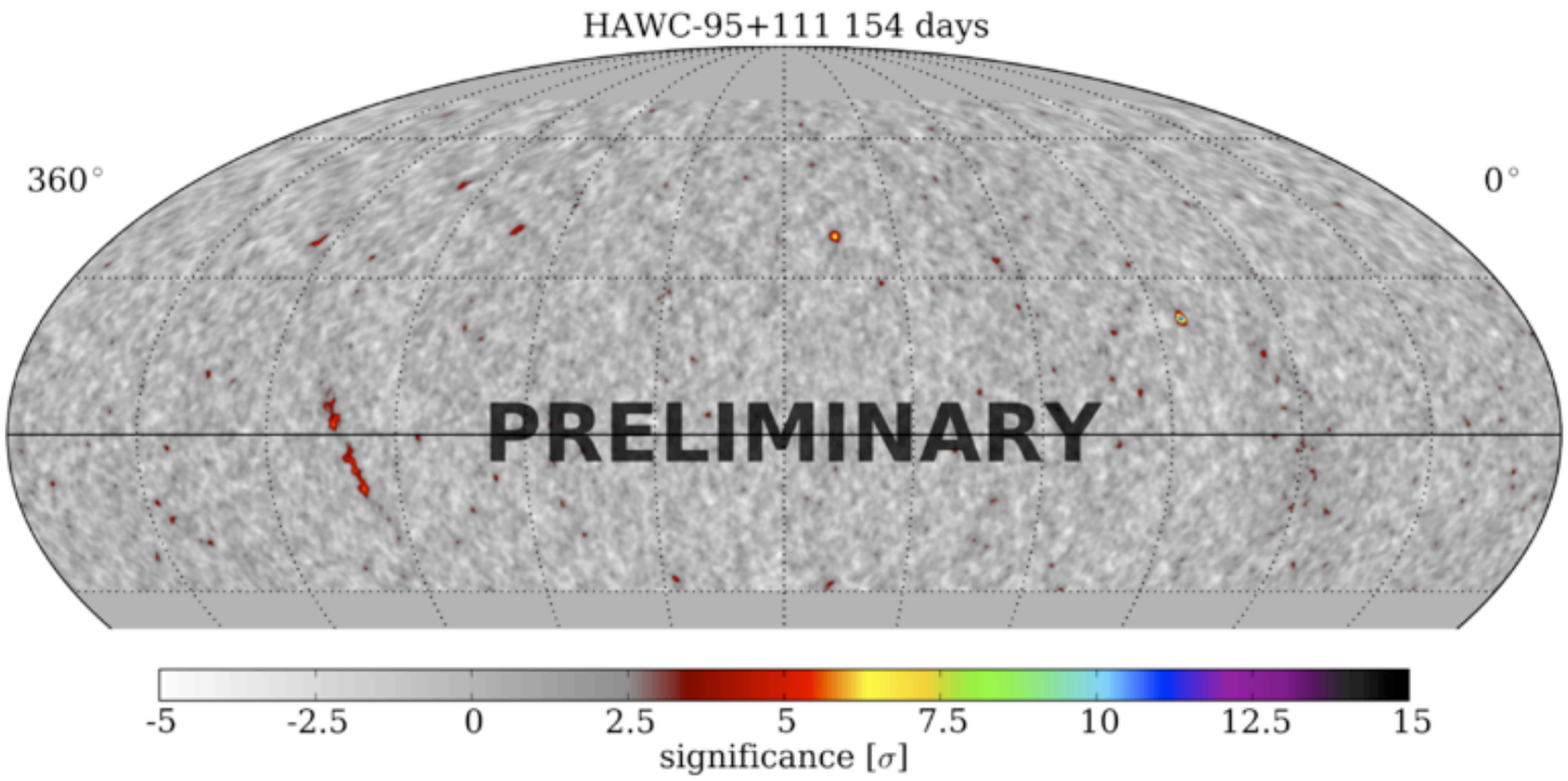




Preliminary Results

- no longer just a cosmic-ray detector; we see gammas too!





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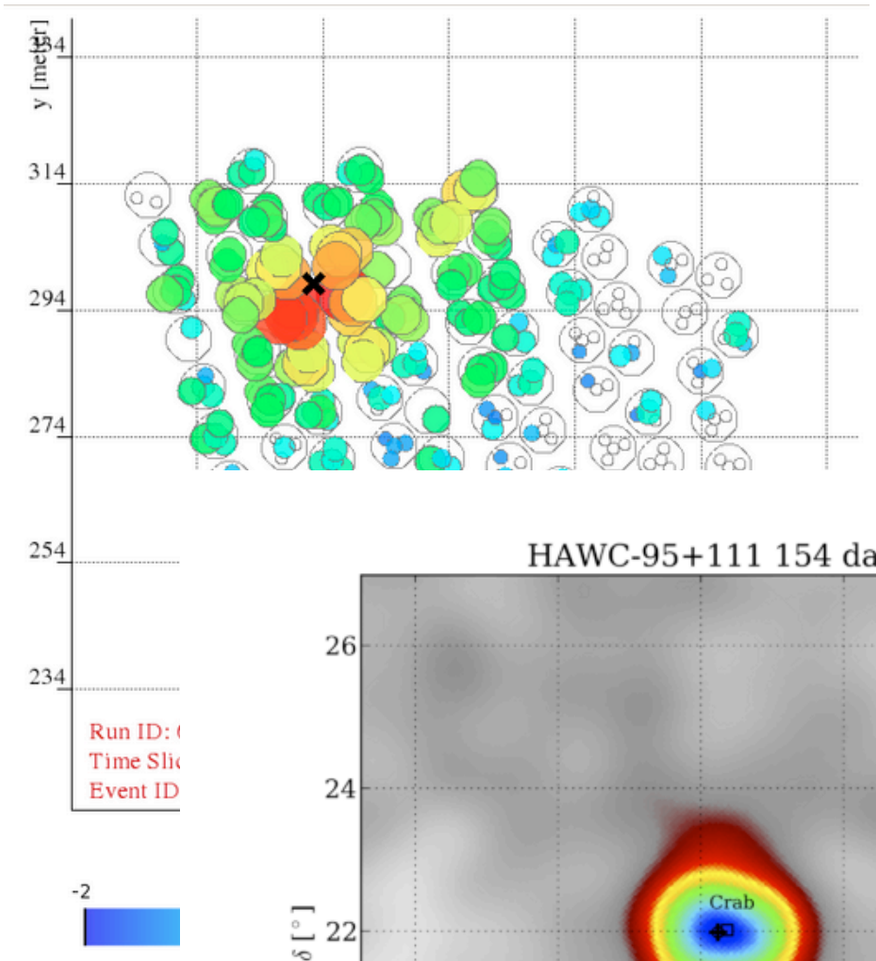

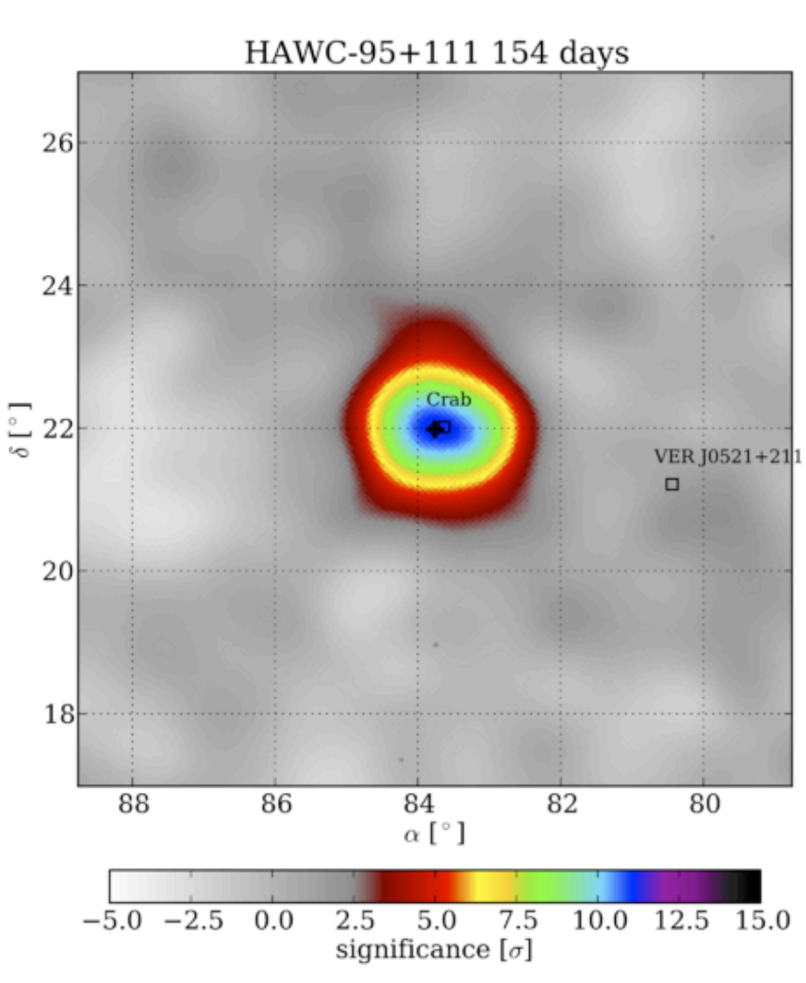

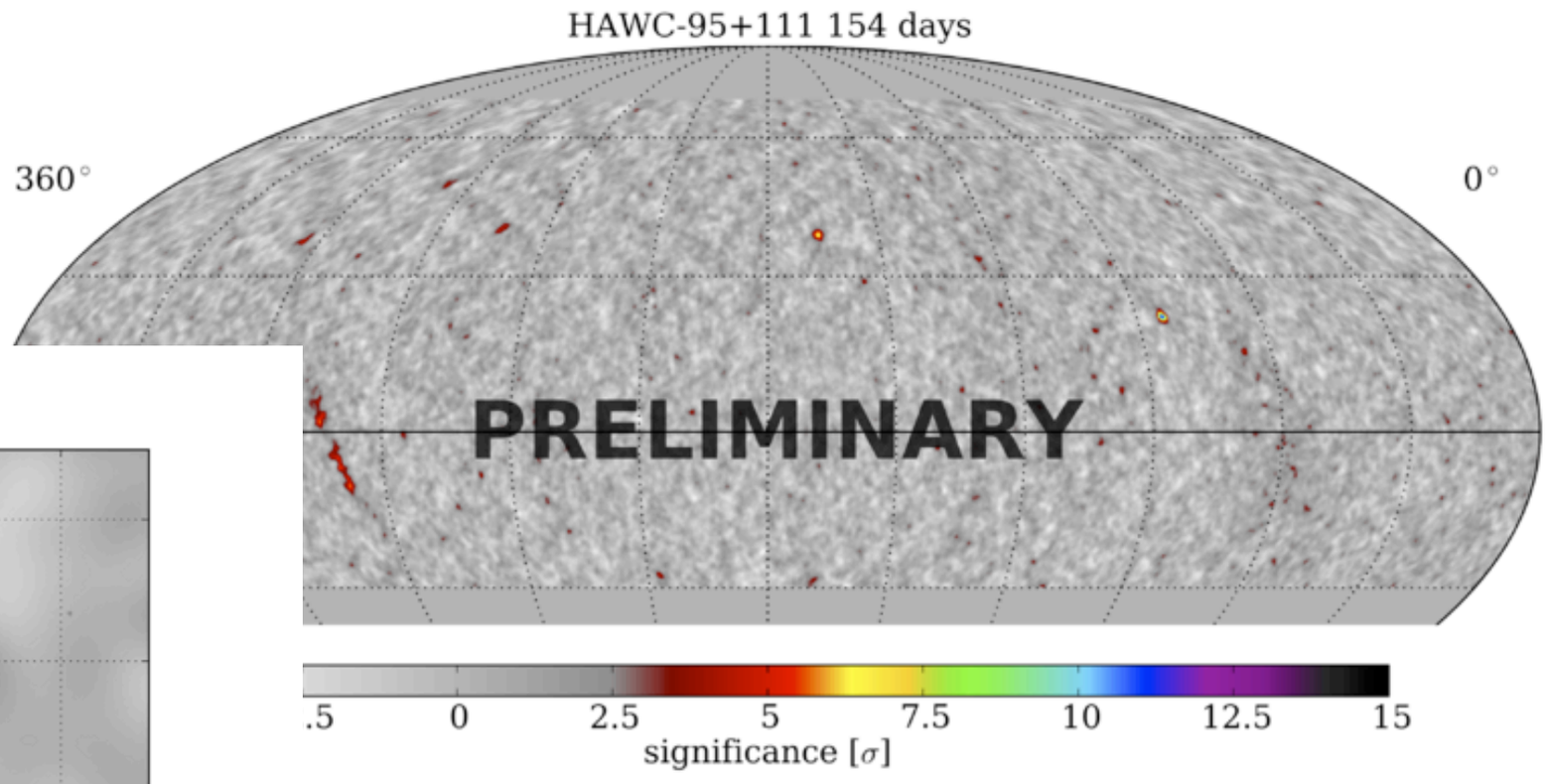

Preliminary Results

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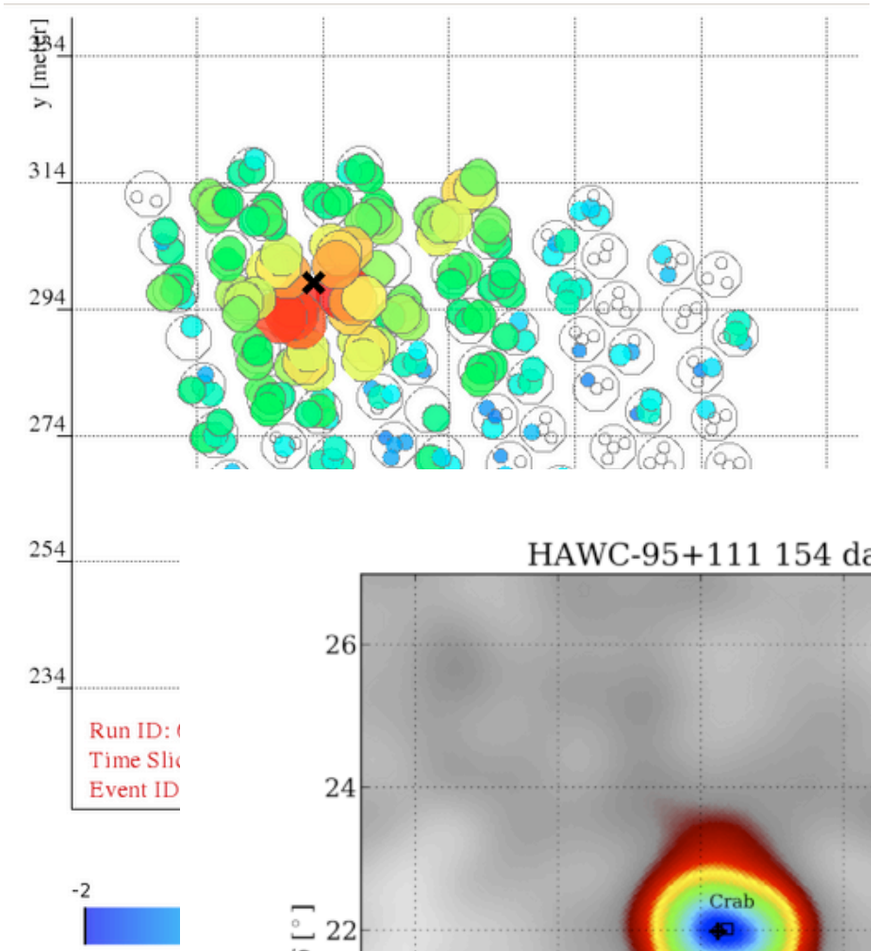
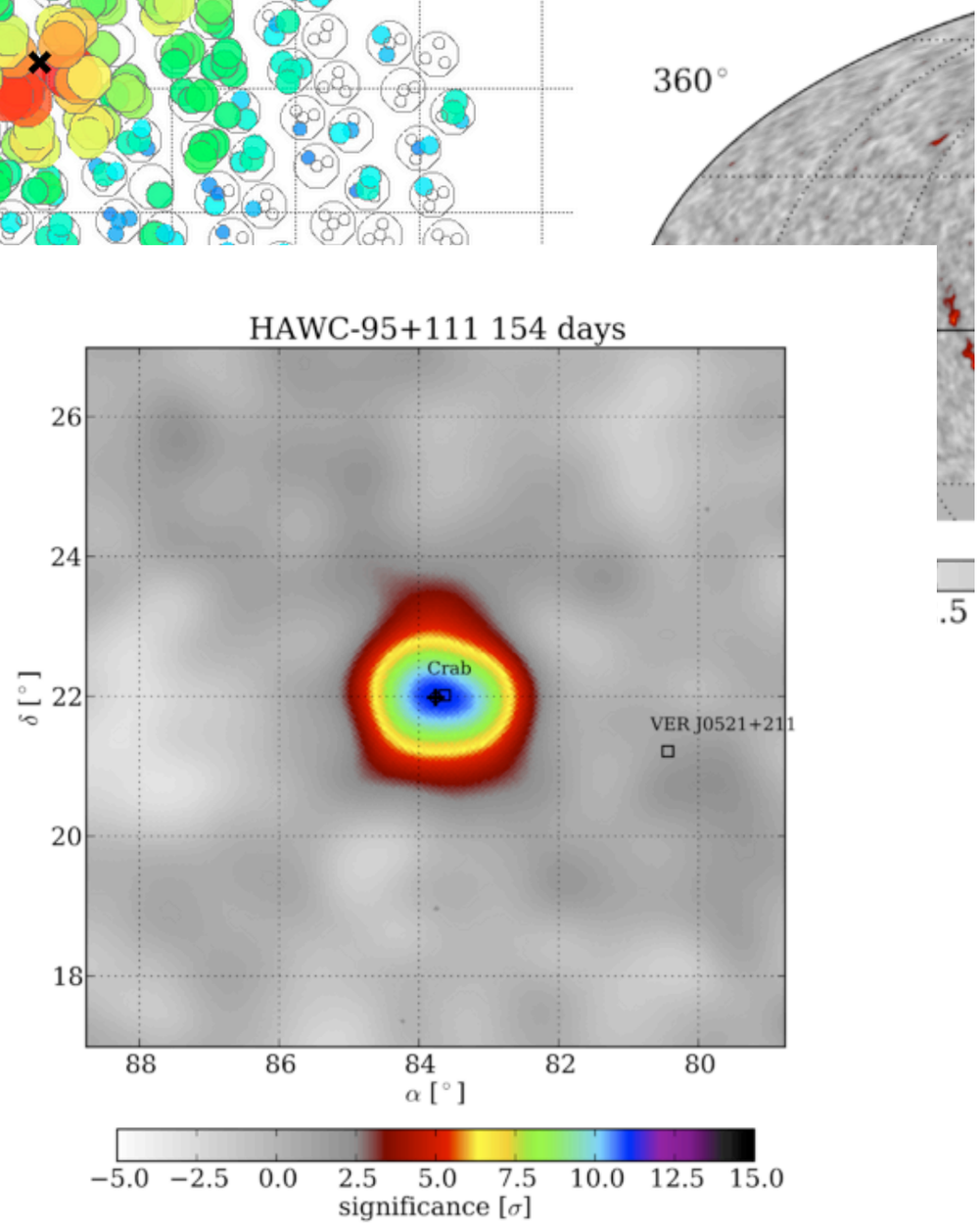
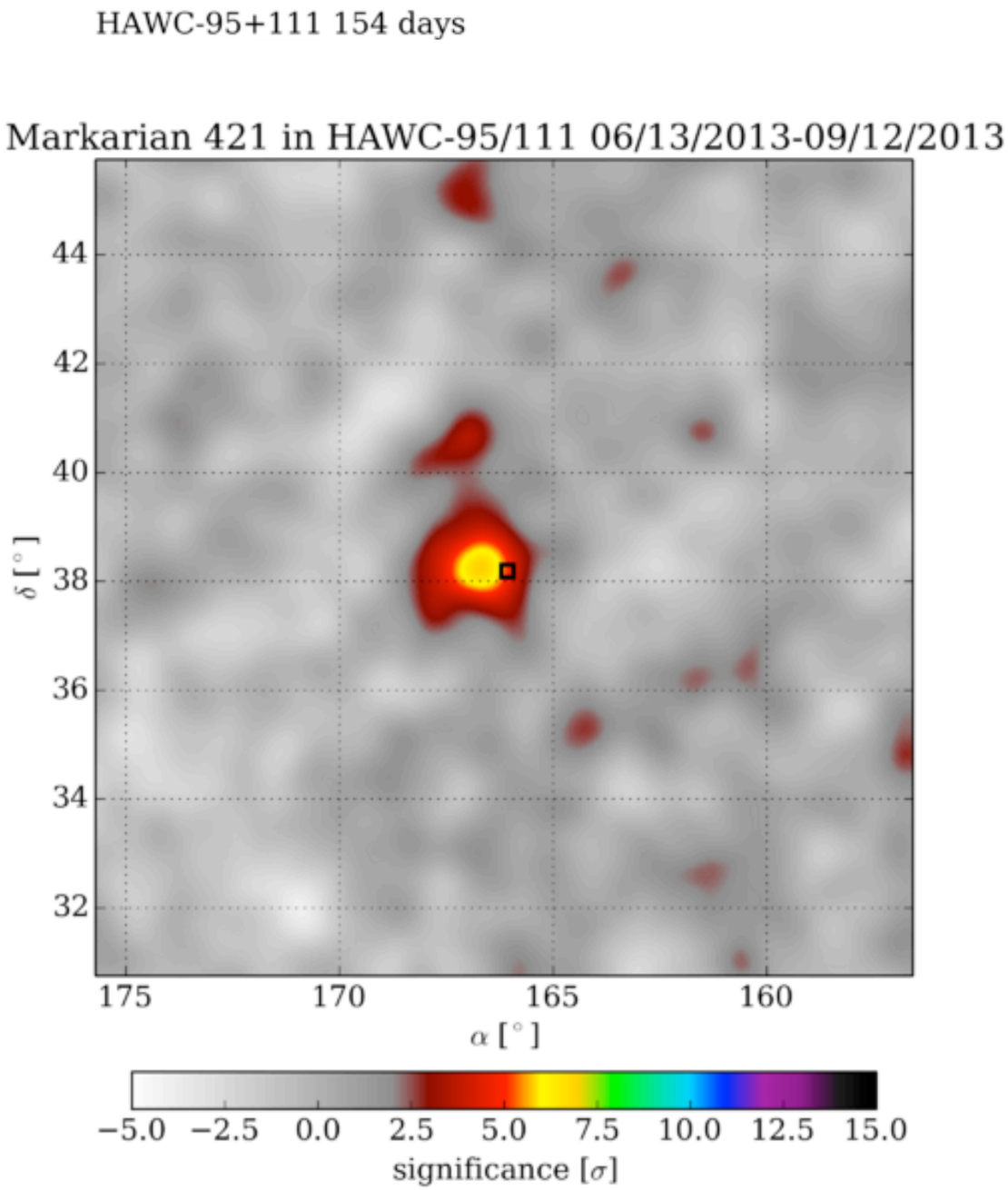


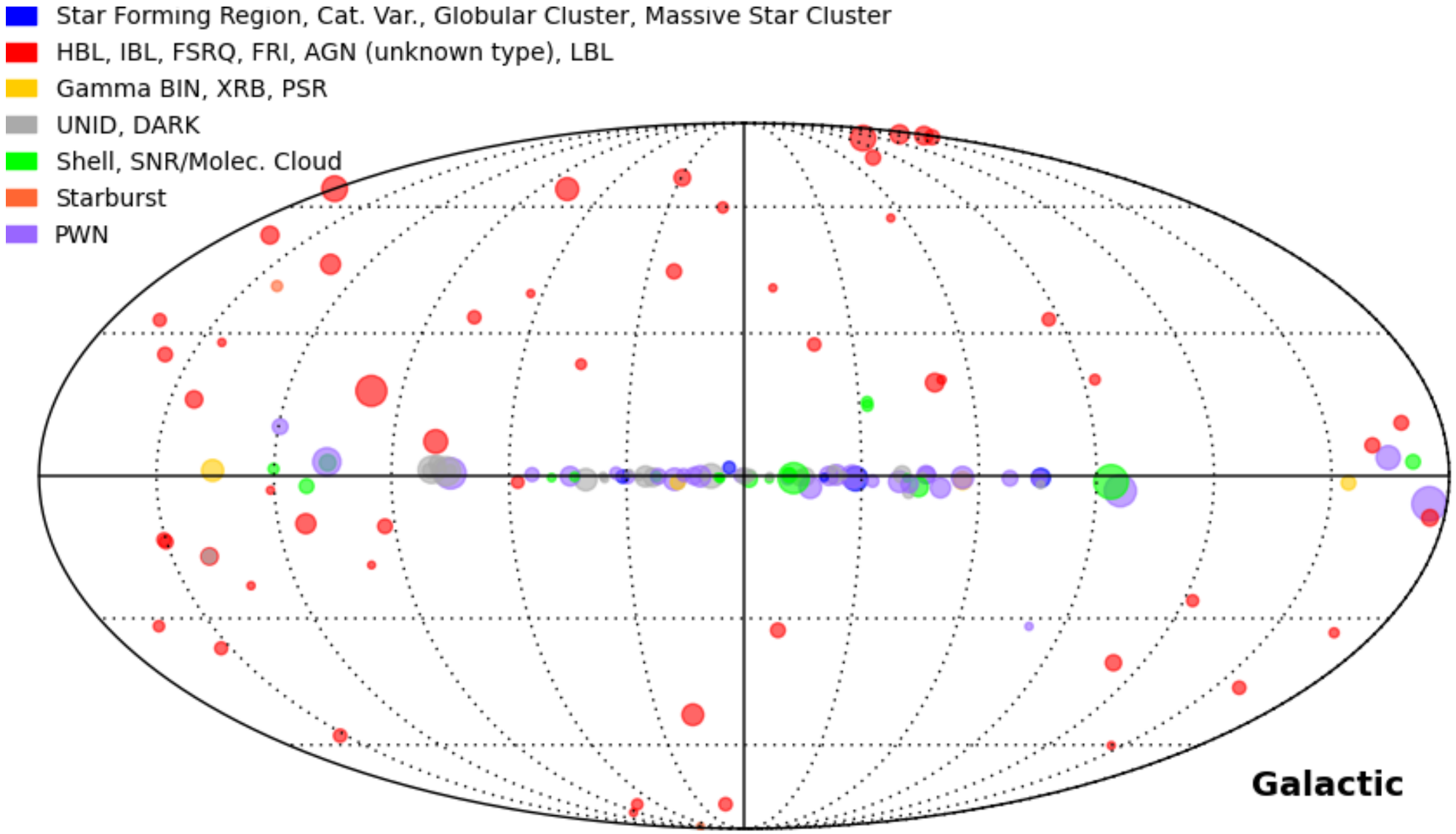




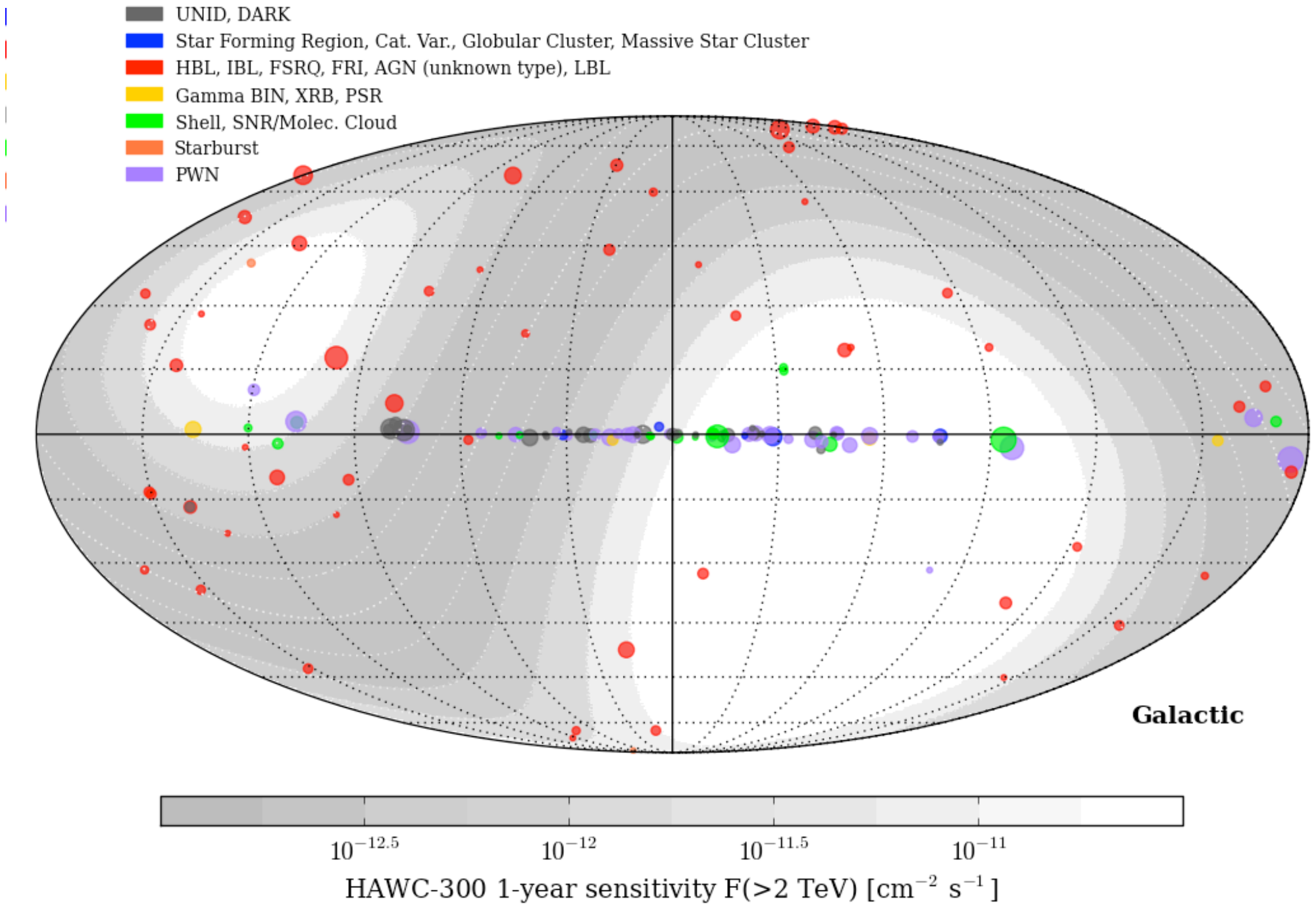
Outlook

- Now is HAWC's time to shine!
- Galactic science
  - SNRs, pulsars, other point and extended sources
  - Galactic diffuse
- Extragalactic science
  - blazars
    - identify TeV flares and issue alerts to the community
  - GRBs
- Fundamental physics
  - dark matter
  - Lorentz invariance violation
  - primordial black holes
  - intergalactic magnetic fields
- The great unknown…

Outlook


Star Forming Region, Cat. Var., Globular Cluster, Massive Star Cluster
HBL, IBL, FSRQ, FRI, AGN (unknown type), LBL
Gamma BIN, XRB, PSR
UNID, DARK
Shell, SNR/Molec. Cloud
Starburst
PWN
Galactic

Outlook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Galactic
$10^{-12.5}$
10^{-12}
$10^{-11.5}$
10^{-11}
HAWC-300 1-year sensitivity F(>2 TeV) [cm^{-2} s^{-1}]