The development of the HAWC γ-ray observatory in Mexico

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Wide FOV Southern TeV Observatory,
Puebla, 11 November 2016

The HAWC Collaboration

High Altitude Water Cherenkov Gamma-Ray Observatory

Mexico		**United States**	
Instituto Nacional de Astrofísica, Óptica y Electrónica	(INAOE)	University of Maryland	(UMD)
Universidad Nacional Autónoma de México		Los Alamos National Laboratory	(LANL)
Instituto de Astronomía UNAM	(IA-UNAM)	Colorado State University	(CSU)
Instituto de Ciencias Nucleares UNAM	(ICN-UNAM)	George Mason University	(GMU)
Instituto de Física UNAM	(IF-UNAM)	Georgia Institute of Technology	(GATECH)
Instituto de Geofísica UNAM	(IG-UNAM)	Michigan State University	(MSU)
Benemérita Universidad Autónoma de Puebla	(BUAP)	Michigan Technological University	(MTU)
Instituto Politécnico Nacional		Pennsylvania State University	(PSU)
Centro de Investigación y Estudios Avanzados	(CINVESTAV)	NASA GSFC	
Centro de Investigación en Cómputo - IPN	(CIC-IPN)	University of California Santa Cruz	(UCSC)
Universidad Autónoma de Chiapas	(UNACH)	University of California Irvine	(UCI)
Universidad Autónoma del Estado de Hidalgo	(UAEH)	University of New Hampshire	(UNH)
Universidad de Guadalajara	(UdG)	University of New Mexico	(UNM)
Universidad Michoacana de San Nicolás de Hidalgo	(UMSNH)	University of Rochester	(UR)
Universidad Politécnica de Pachuca	(UPP)	University of Utah	(UU)
		University of Wisconsin	(UW)

Instituto Nacional de Astrofísica Óptica y Electrónica

Reunión de la colaboración HAWC

Complejo Cultural Universitario BUAP del 27 al 29 de octubre de 2014

WCO before HAWC

Haverah Park	Water Cherenkov	England	1967 - 1987	Very high energy cosmic rays
Pierre Auger observatory	WČ & fluorescence (hybrid)	Argentina	2004 -	Ultra high energy CRs
Cygnus array	Scintillator & WČ	New Mexico (2100m)	1986 -	CRs (and γ-rays)
Tibet γ-AS	Scintillation counters	Yangbajing, Tibet (4300m)	1990 -	CRs (and γ-rays)
Milagro	γ-WČO	New Mexico (2600m)	1999 - 2008	γ-rays

Before Milagro

November 21, 1984

Dr. Louis Rosen
MP Division
Los Alamos National Laboratory
Los Alamos, NM 87545

Dear Louis:

This is to support very strongly the proposal by Darragh Nagle to search for gamma-ray showers in the energy range of 10^{14} eV coming from stellar sources.

This seems to me an extremely interesting problem. How do these binary stars make gamma rays of such enormous energy? Los Alamos is particularly qualified to investigate this problem, (a) because of the high altitude of the Laboratory, and (b) because you have great experience in making veto counters to exclude the presence of muons in the shower. I don't believe any other laboratory is similarly qualified. Darragh seems to have analyzed the experiment very well.

It seems to me fully justified to spend money of MP Division for this purpose even if the project is not a nuclear physics problem. It is such a spectacular phenomenon, and it could be most important for astrophysics. The money requirement is moderate, and the results could be spectacular.

With best regards,

Yours sincerely,

Hans

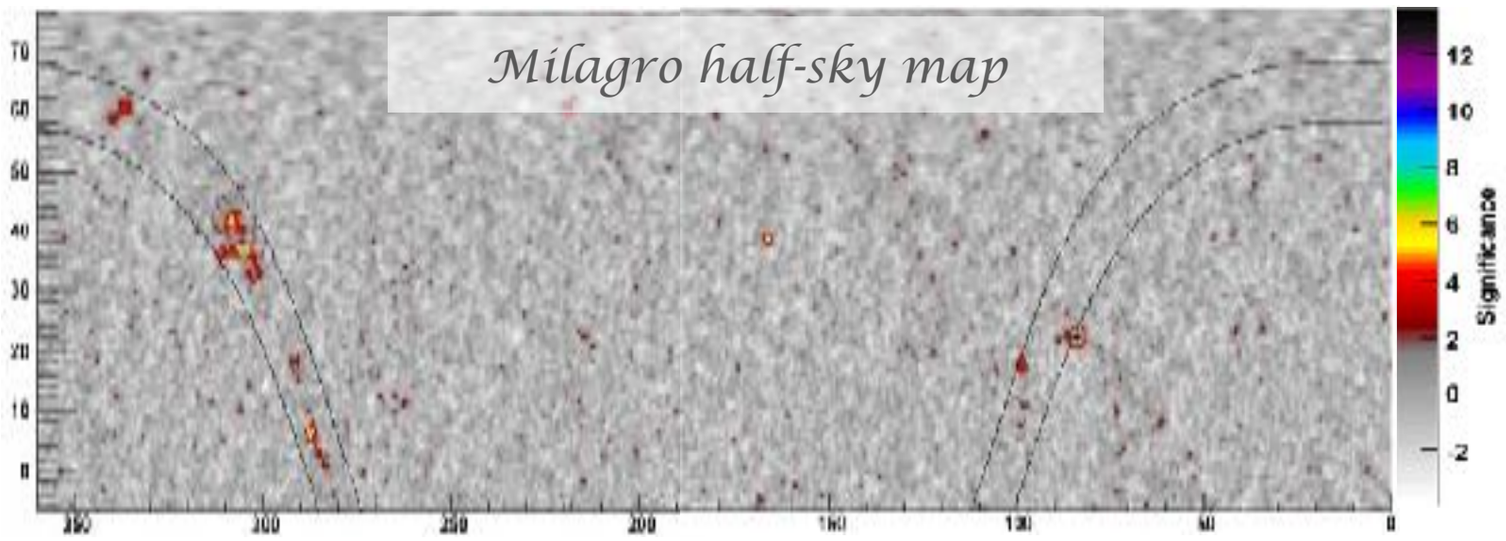
Hans A. Bethe

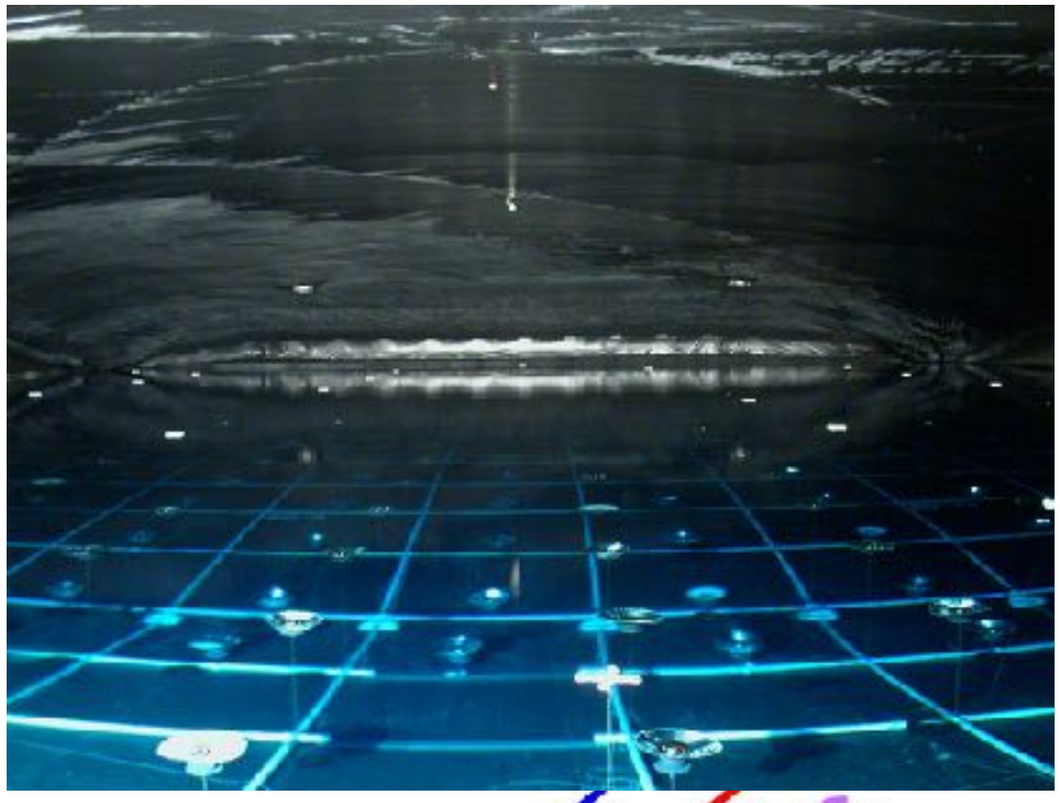
HAB:vhr

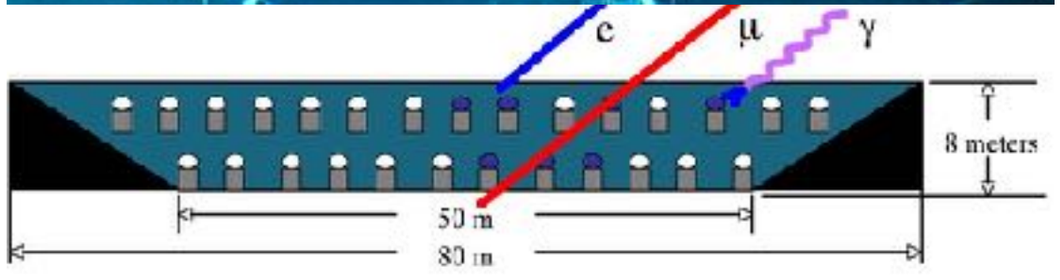
cc: Darragh Nagle

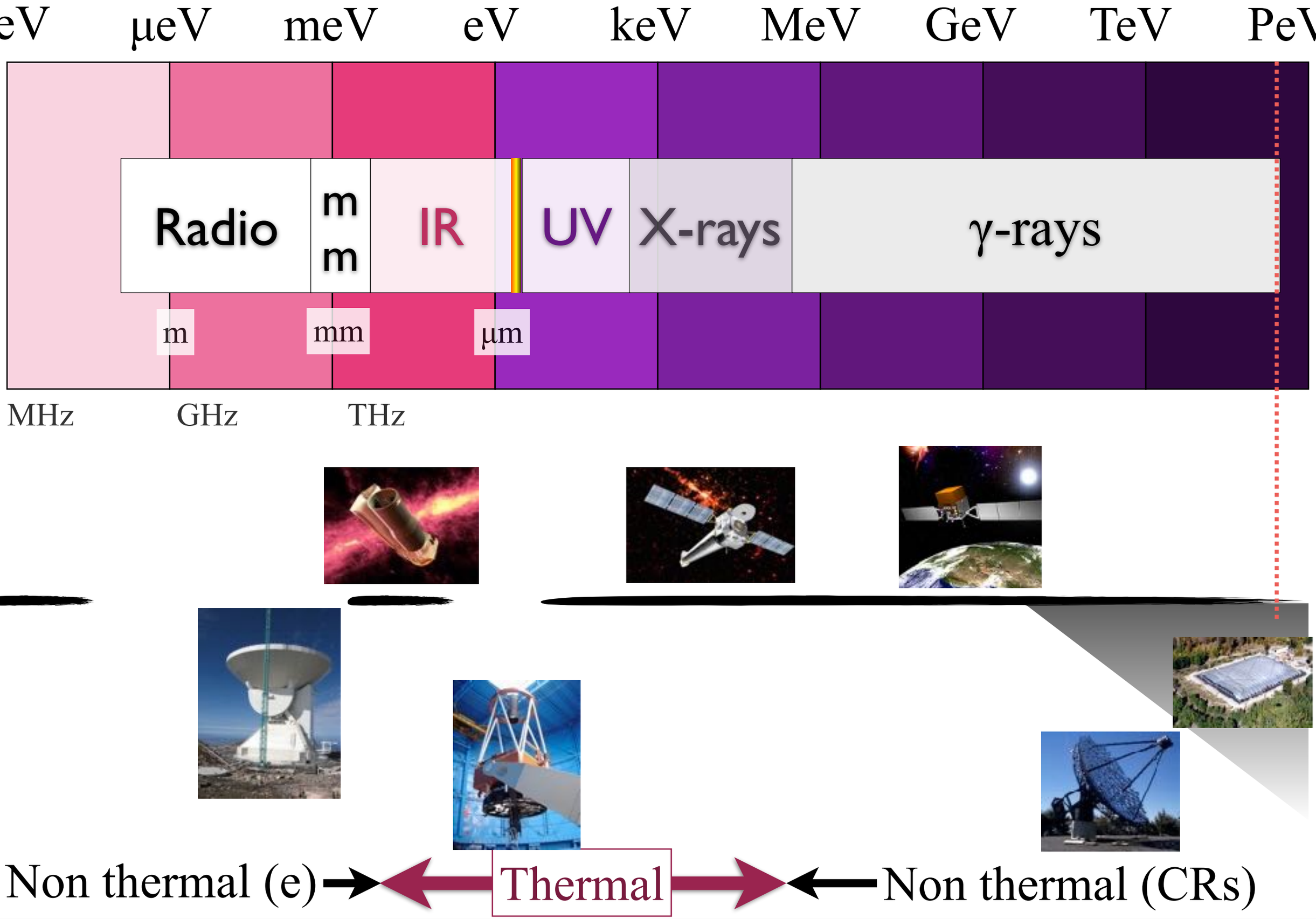
NOV 30 1984

The Milagro γ-ray observatory








neV
μeV
meV
eV
keV
MeV
GeV
TeV
PeV
Radio
m
m
IR
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X-rays
γ-rays
m
mm
μm
MHz
GHz
THz
Non thermal (e)
Thermal
Non thermal (CRs)

Sr

<u>Pair production telescopes</u>

0.1 - 100 GeV
Space based: small effective area
Background free
Large f.o.v. and high duty cycle

All sky survey & monitoring
Transients (AGN, GRB)
Diffuse emission

<u>Extensive air-shower arrays</u>

100 GeV - 100 TeV
Good background rejection
Large f.o.v. and high duty cycle

Partial sky survey & monitoring
Extended sources
Transients (AGN, GRB)
Highest energies

FoV

Deg

E

<u>Atmospheric Cherenkov Telescopes</u>

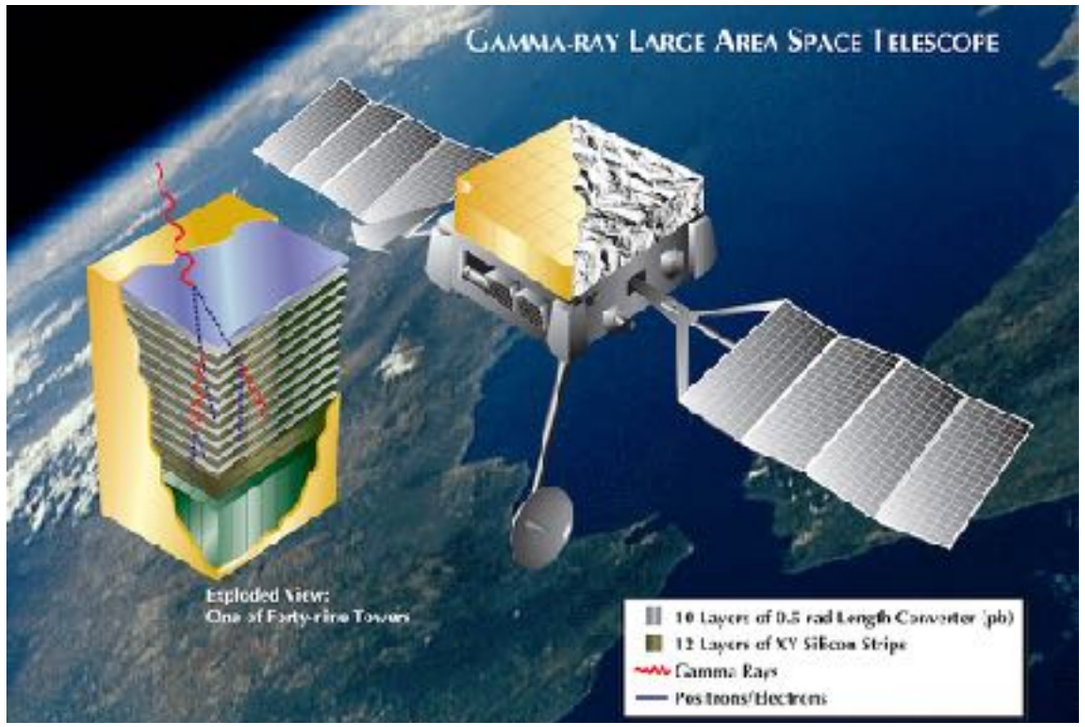
50 GeV - 100 TeV
Large effective area
Excellent background rejection
Small f.o.v. and low duty cycle

Detailed study of known sources
Deep surveys of limited regions
High resolution spectra

GeV

TeV

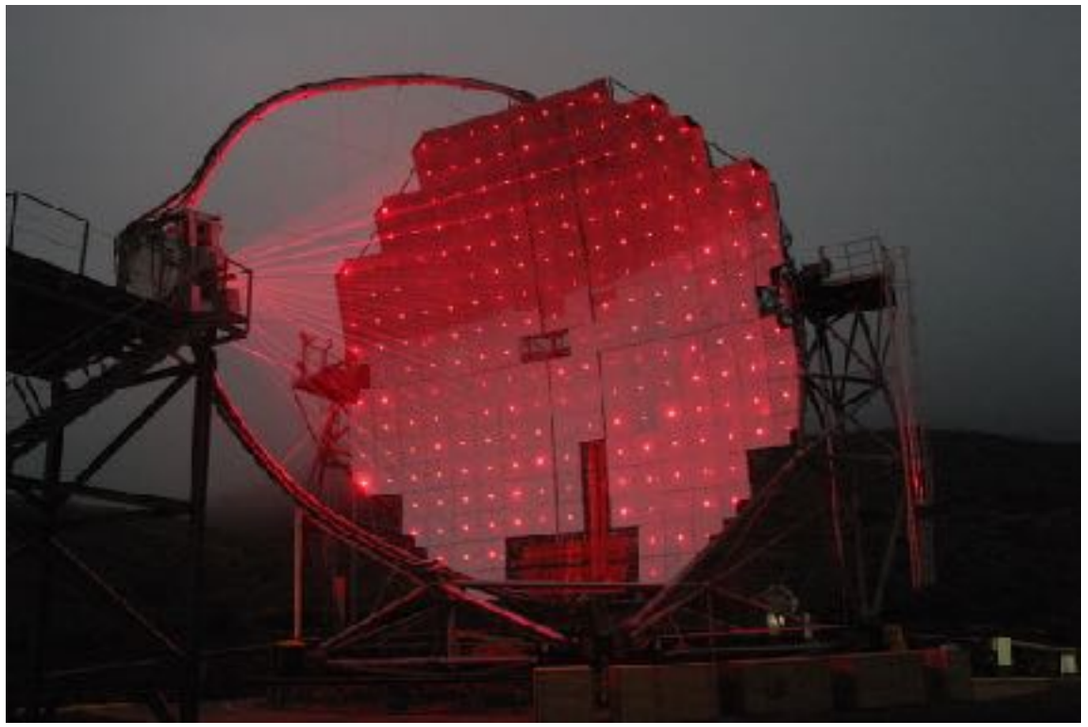
Sr



FoV

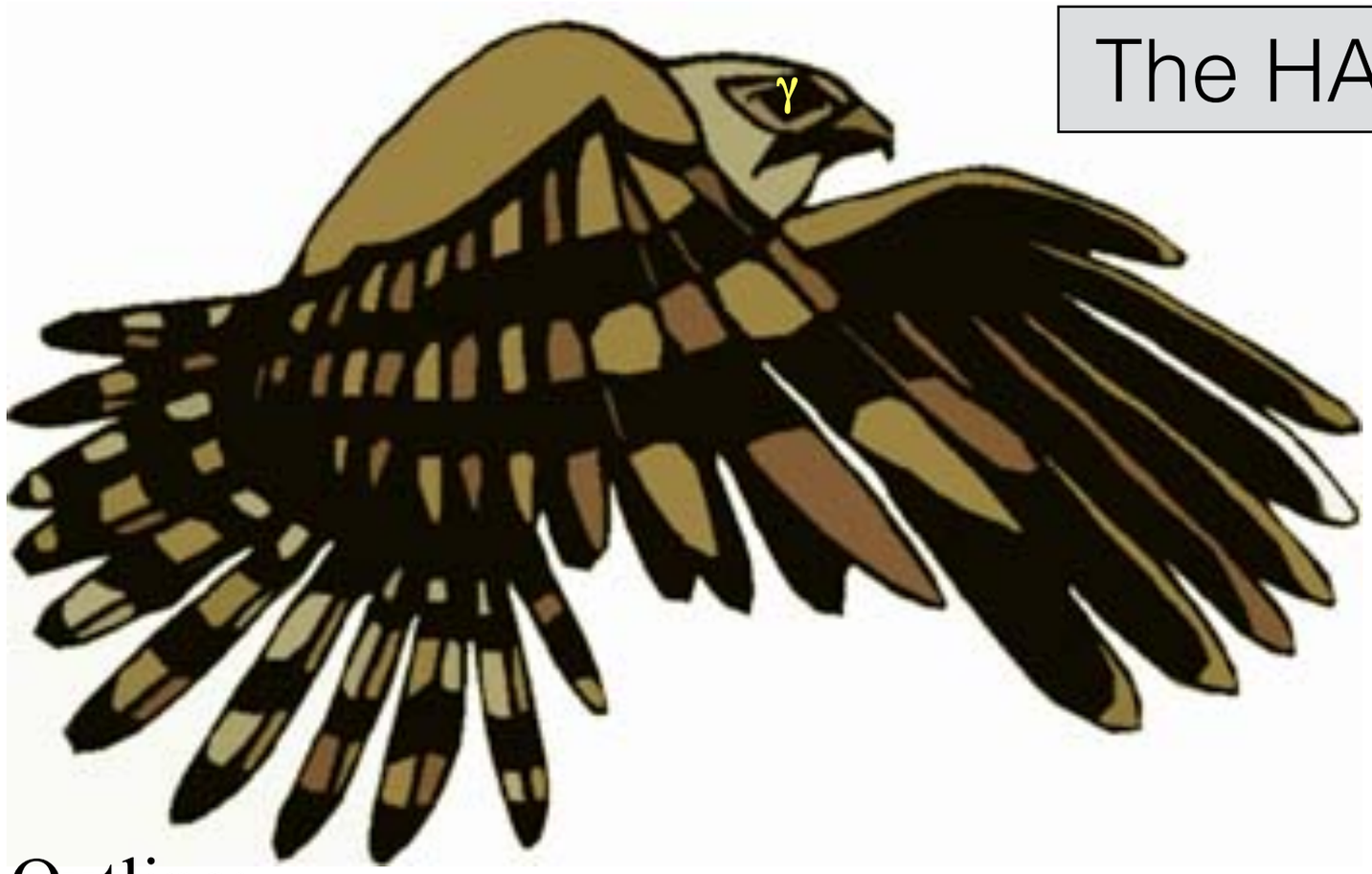
Deg

E



GeV

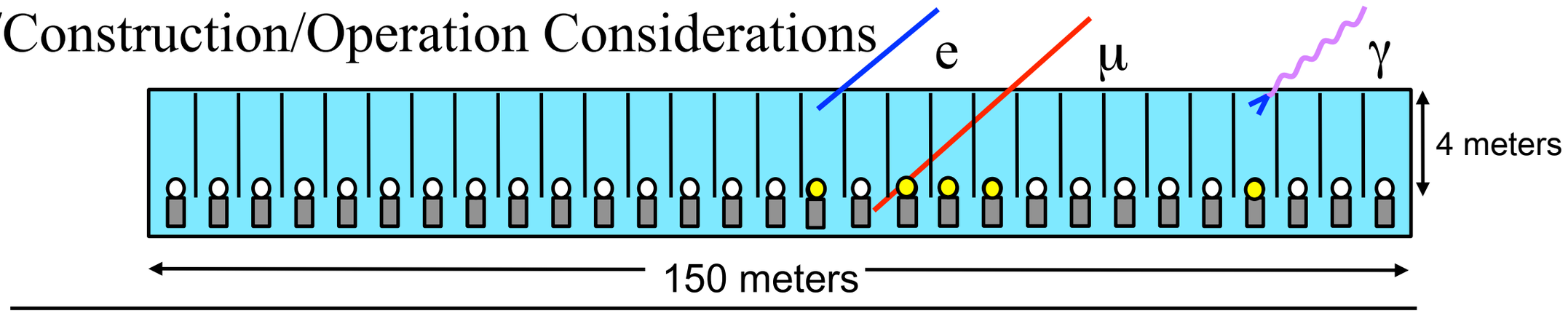
TeV

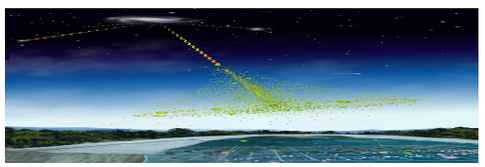


High **A**ltitude **W**ater **C**herenkov experiment

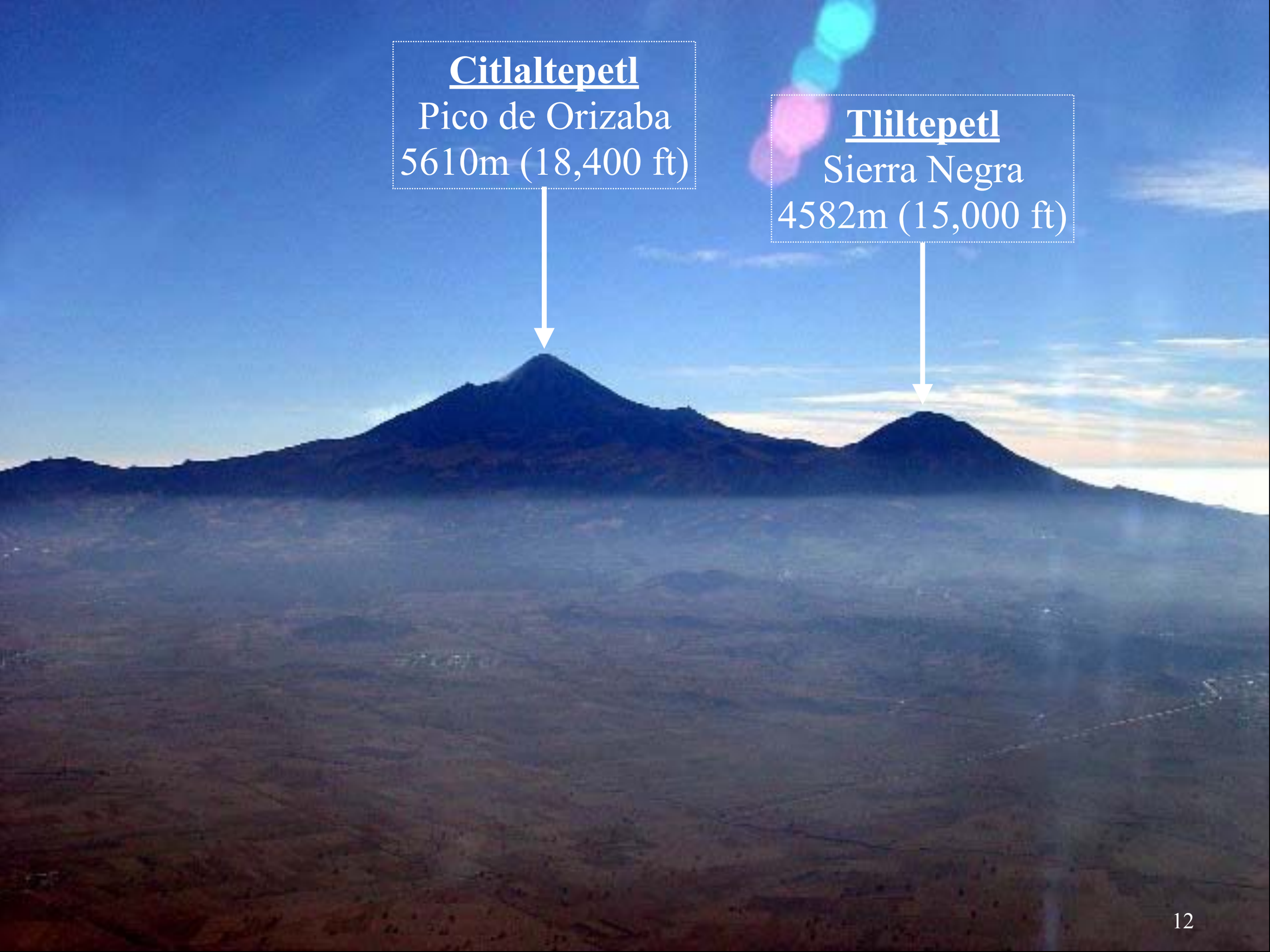
Outline:

- What is HAWC
- Design Parameters
- Sensitivity
- Design/Construction/Operation Considerations





Taller de Astrofísica de Altas Energías (TAAE)


Citlaltepetl
Pico de Orizaba
5610m (18,400 ft)
Tliltepetl
Sierra Negra
4582m (15,000 ft)

Gran Telescopio Milimétrico Alfonso Serrano

- The Large Millimeter Telescope Alfonso Serrano (LMT/GTM).

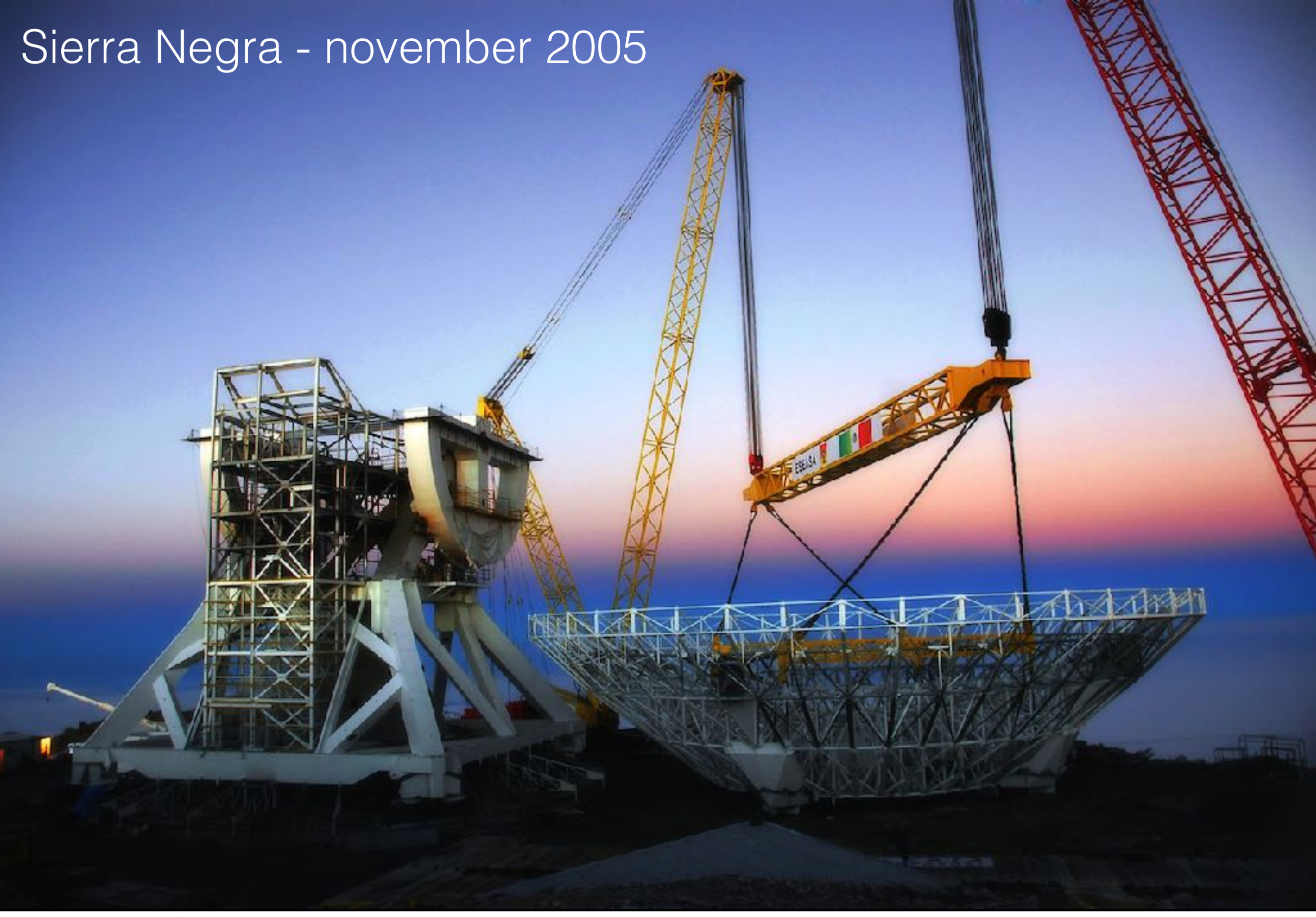
- Twenty year collaboration between INAOE and UMASS, Amherst, to build and operate the largest single dish mm telescope in the world.

- A 50m diameter antenna for observations in the 0.8-4.0mm band.

- Installed at Sierra Negra top at an altitude of 4593m. Infrastructure developed since 1998.

- Operational since May 2013 with a functional aperture of 32m.

Sierra Negra - november 2005



Ideal location

Latitude: +18º59’ 41

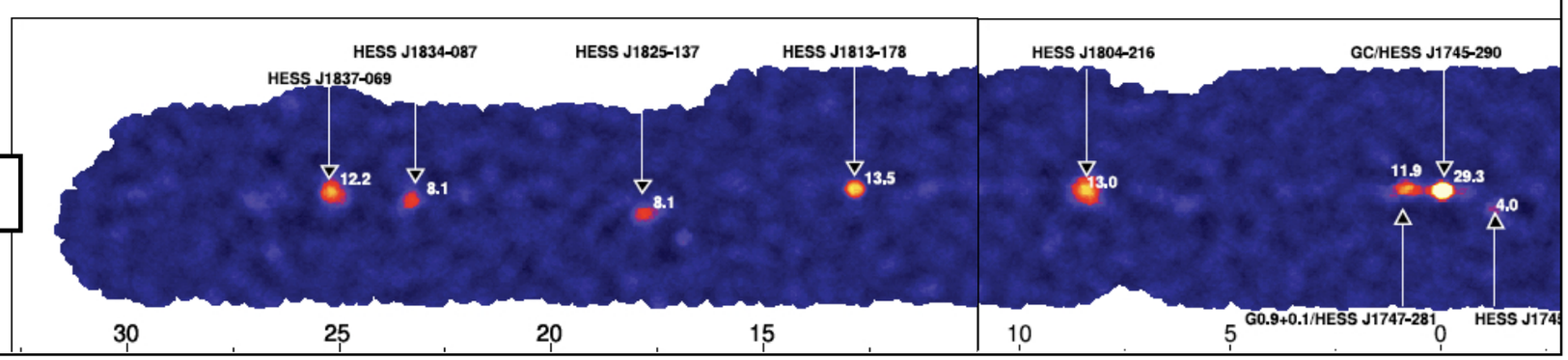
- Crab culminates at 3º from zenith
- Cygnus culminates at 20º
- 4 (5) Galactic plane HESS sources within 36º (41º)
- Galactic centre culminates at 48º

Longitude: 97º18’ 28”W

- Synchronous with US, Mexican and Latin American observatories
- eventual overlap with HAWC-South (GC)?

- increased sky coverage
  - 15% more sky compared to New Mexico

$\Omega_{survey} = 4\pi \cos(lat) \sin(\theta_{max})$



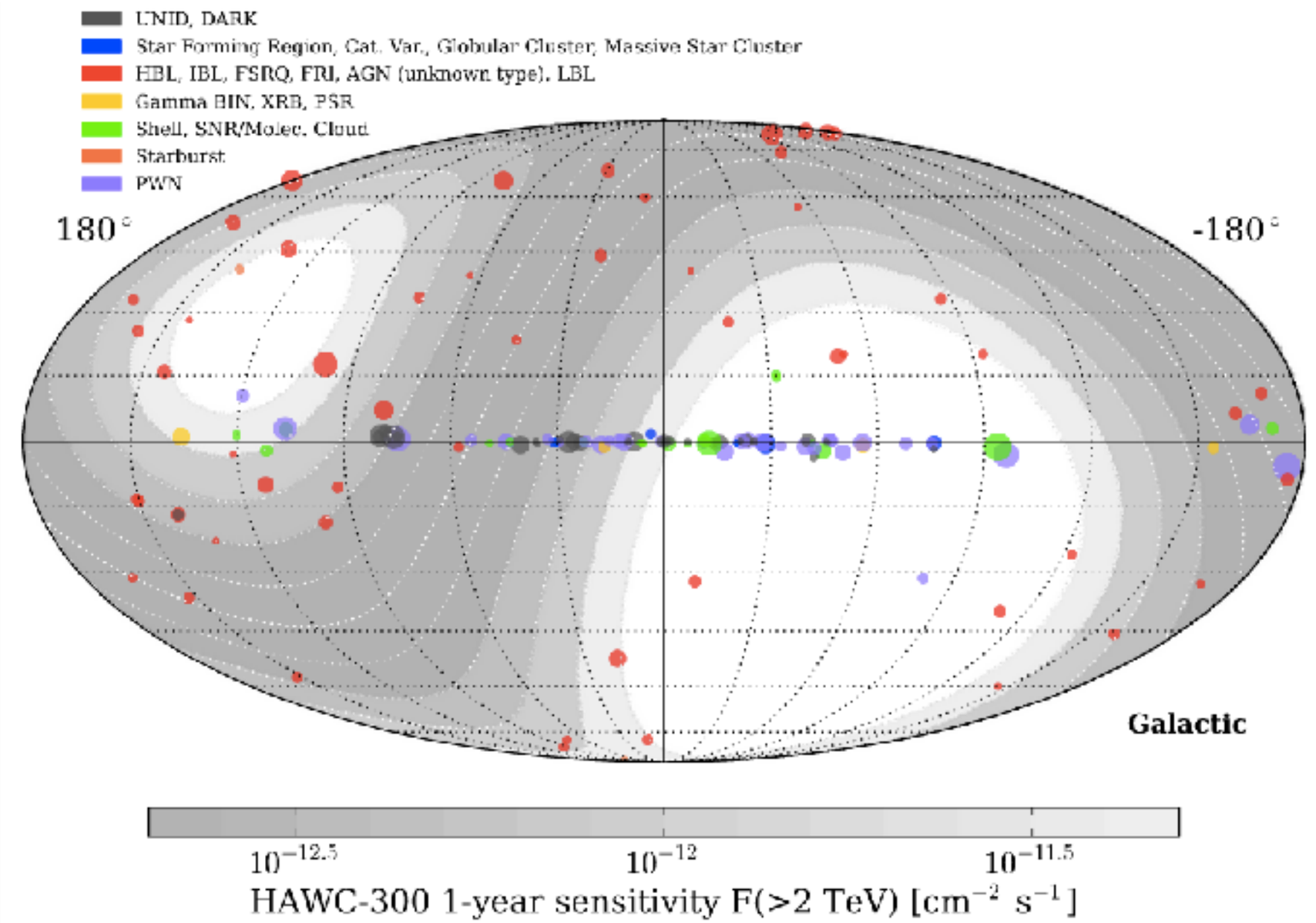
Sensitivity & Field of View

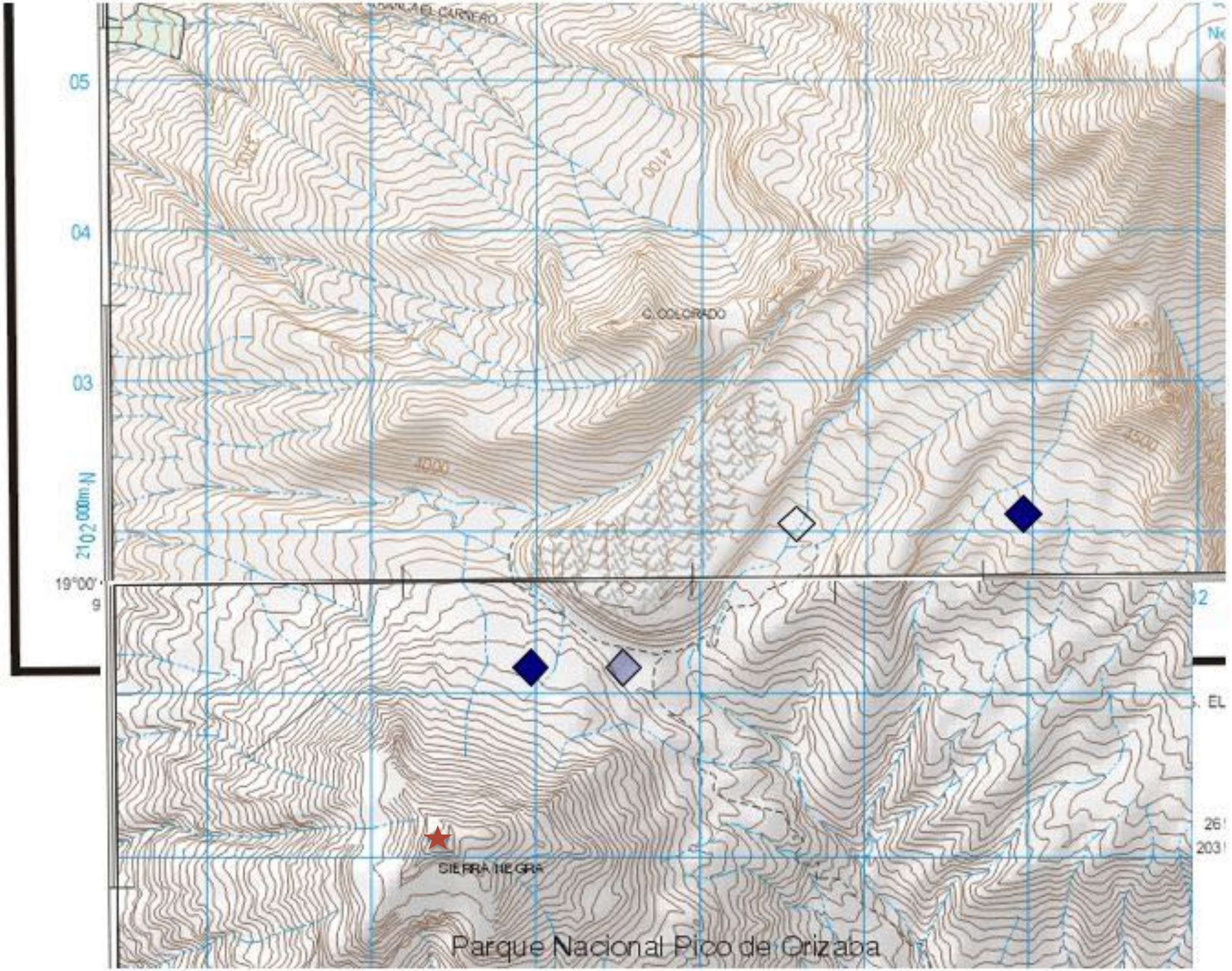
FOV = 1.8 Sr

HAWC scans 2/3 of the celestial sphere every sidereal day to a depth of 1 Crab:

➡ transient events

➡ extended diffuse sources

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EL CARRIZO
C. COLORADO
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4000
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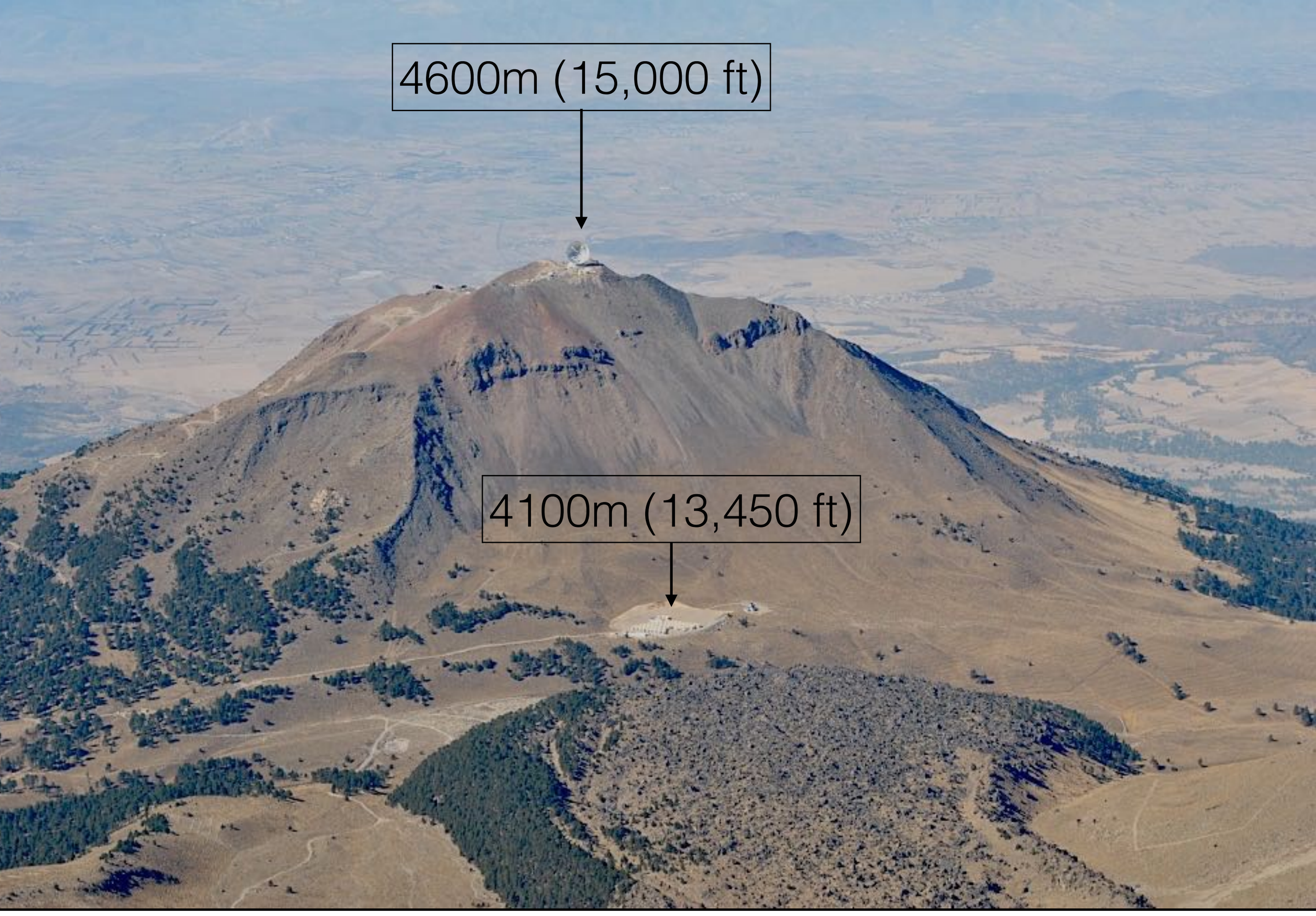
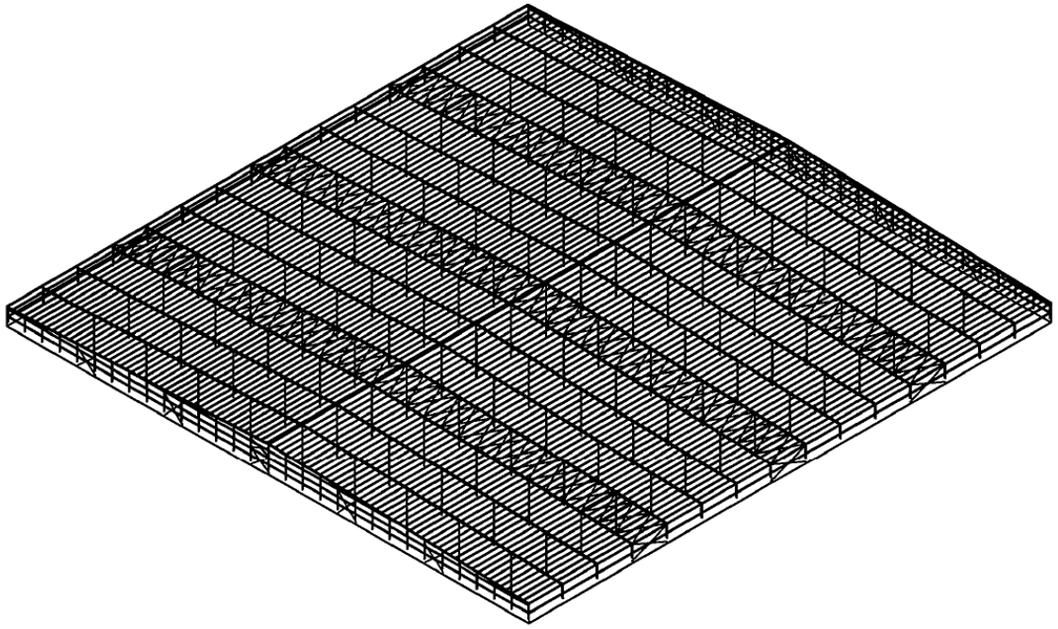
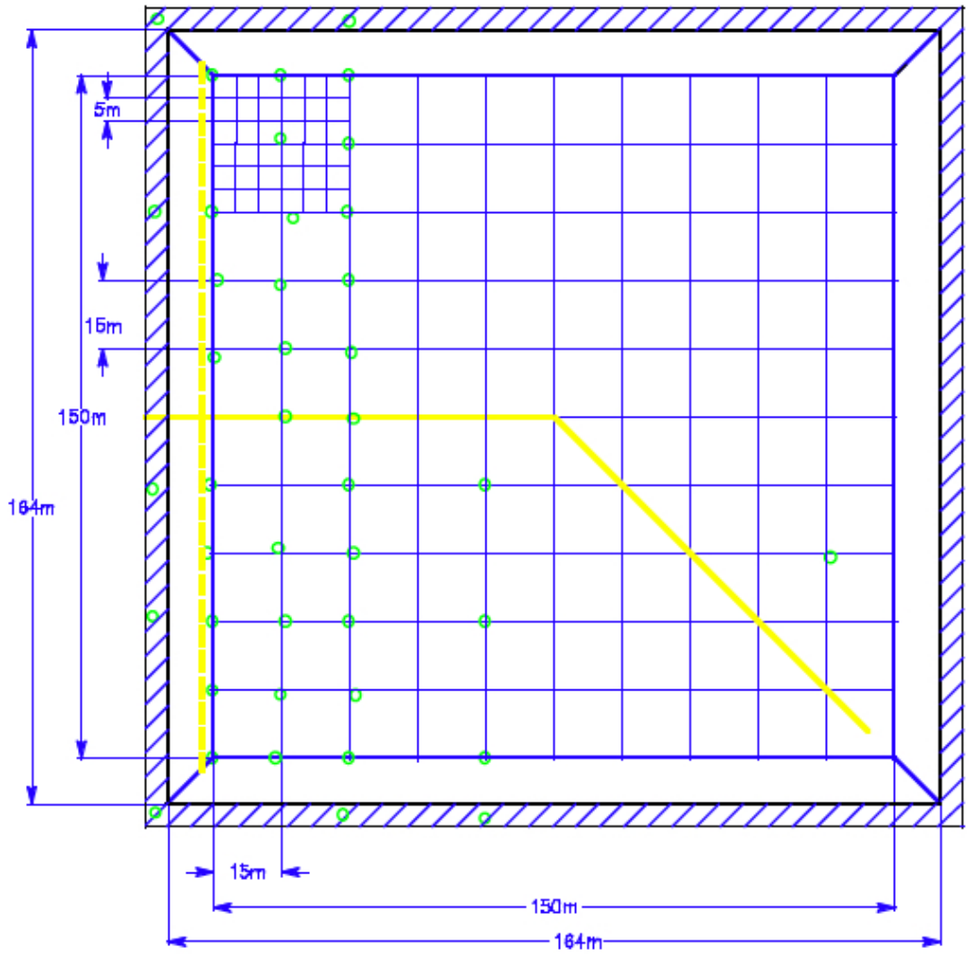
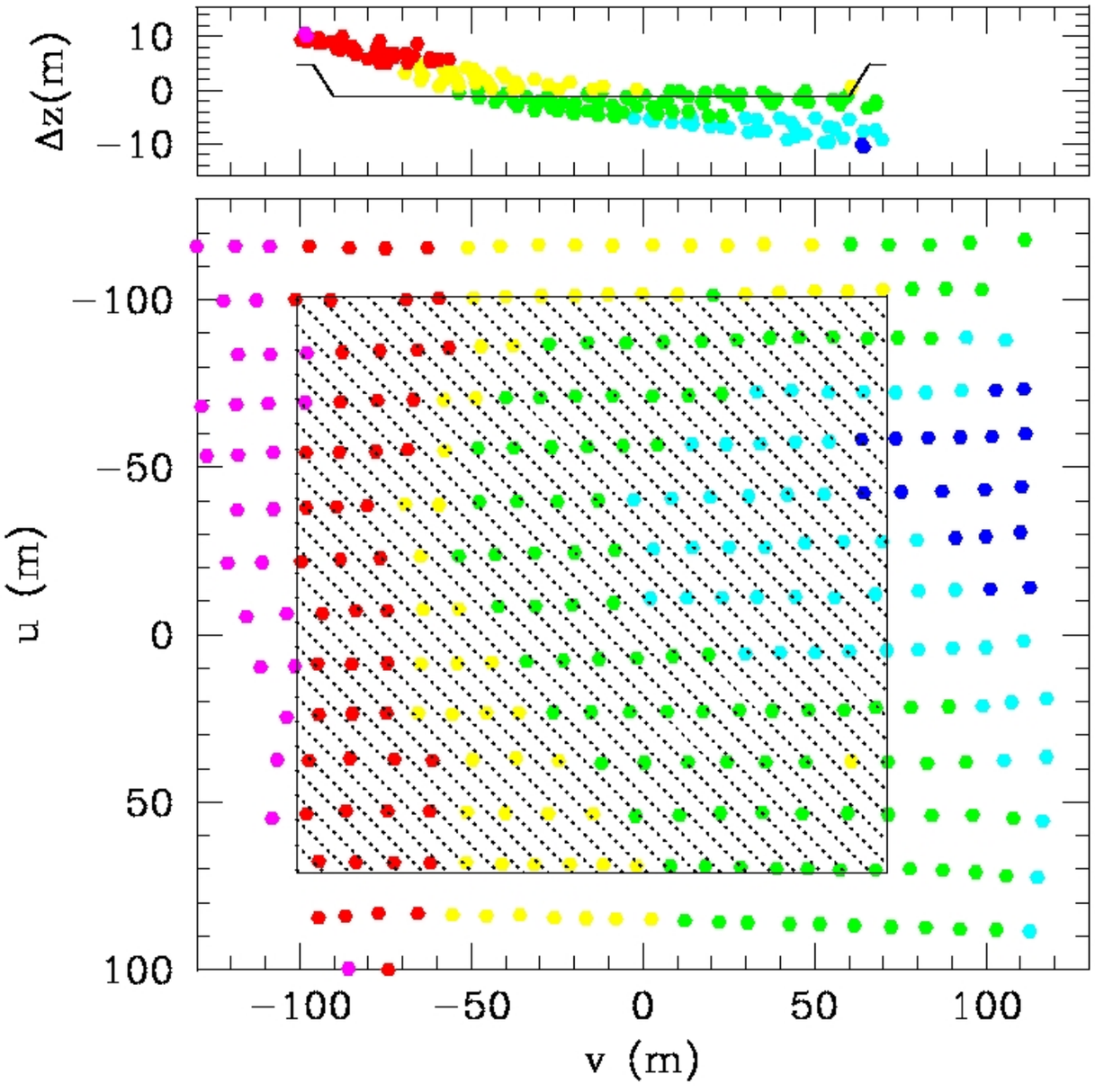
SIERRA NEGRA
Parque Nacional Pico de Orizaba


4600m (15,000 ft)
4100m (13,450 ft)

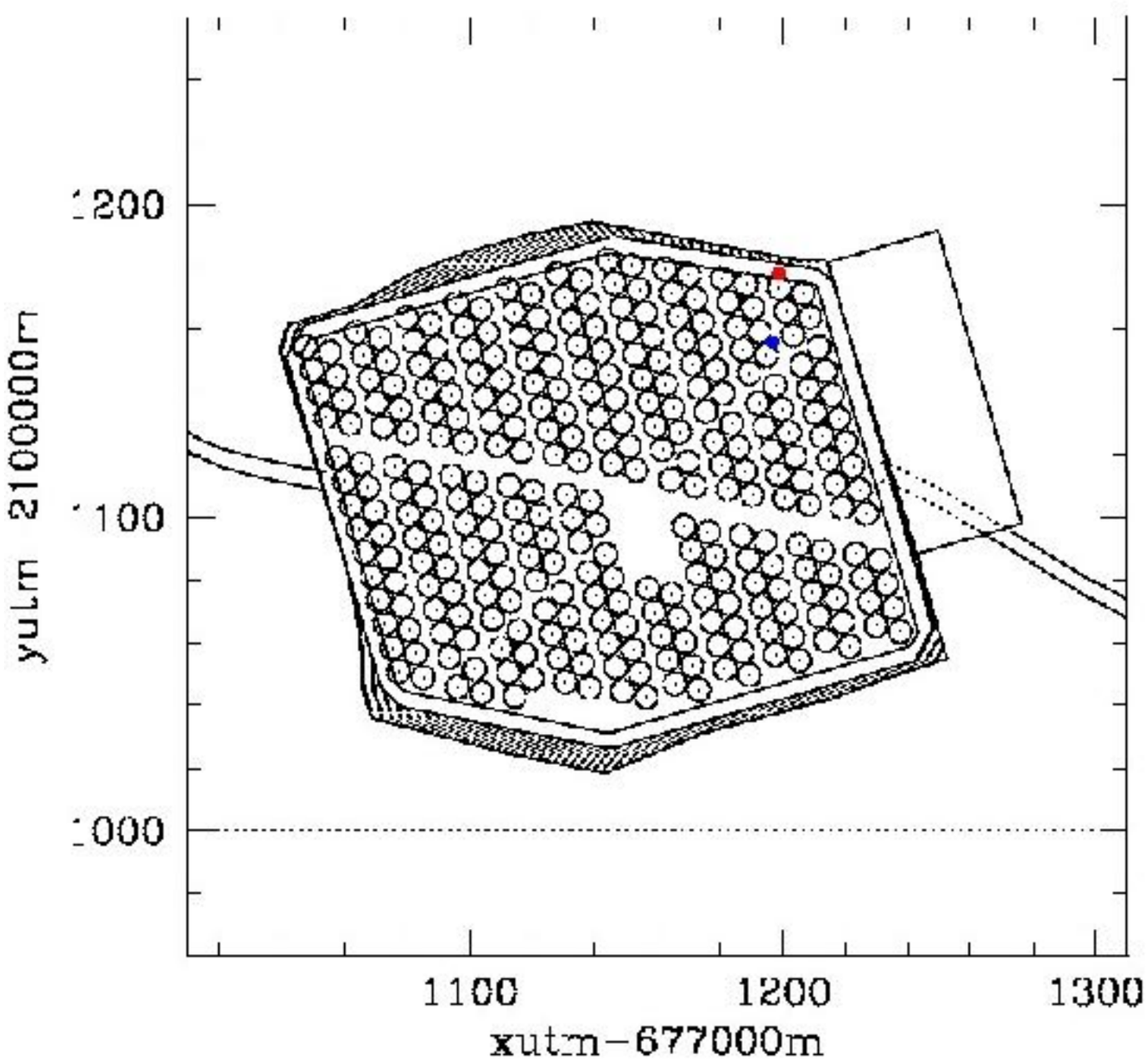
HAWC v.0




5m
15m
150m
164m
15m
150m
164m


Δz(m)
10
0
−10
−100
−50
0
50
100
u (m)
−100
−50
0
50
100
v (m)

HAWC design



Array of 300 individual WCDs with 3+1 PMTs each = 1,200 PMTs.

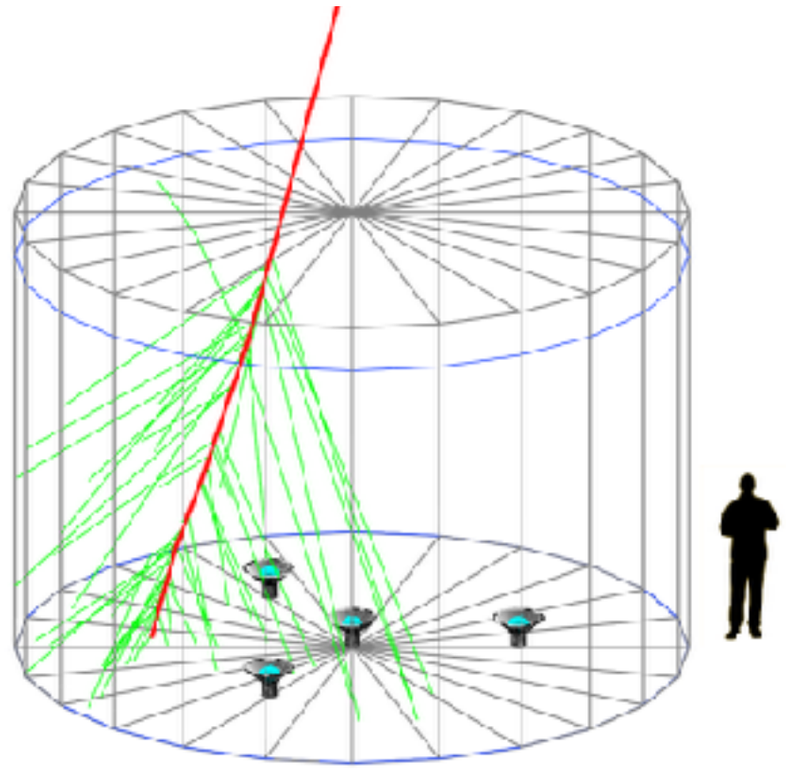
HAWC covers 22,500 m^2, of which 12,000 m^2 are detector area.

Modular design:

- ➡ Better environmentally
- ➡ Project phases: engineering, data, early science operations

Water Cherenkov Detectors

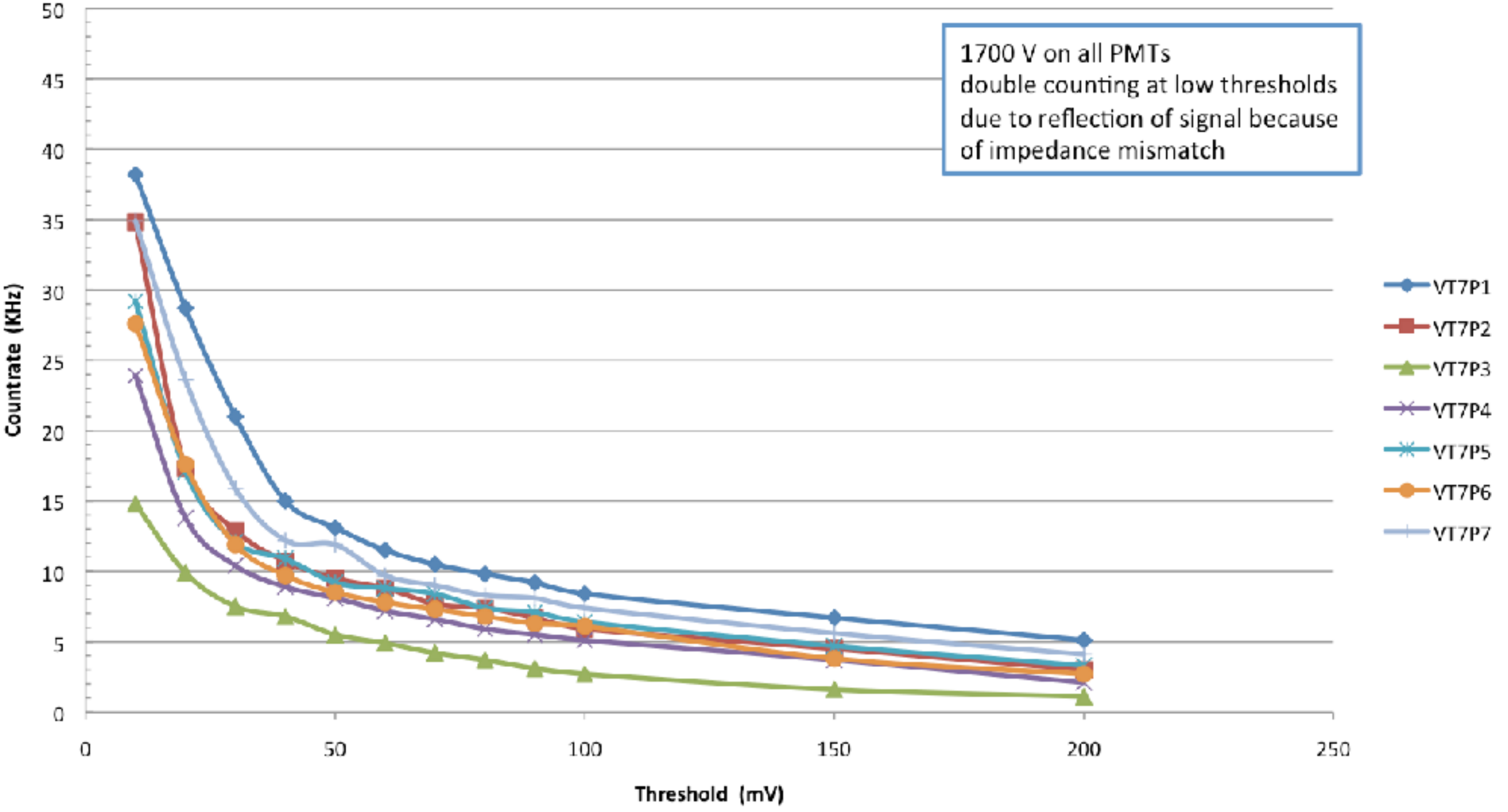
- Metal tank with plastic bladder.
- Each individual WCD holds 180,000 liters of purified water.
- 3+1 PMTs at the bottom of each WCD.

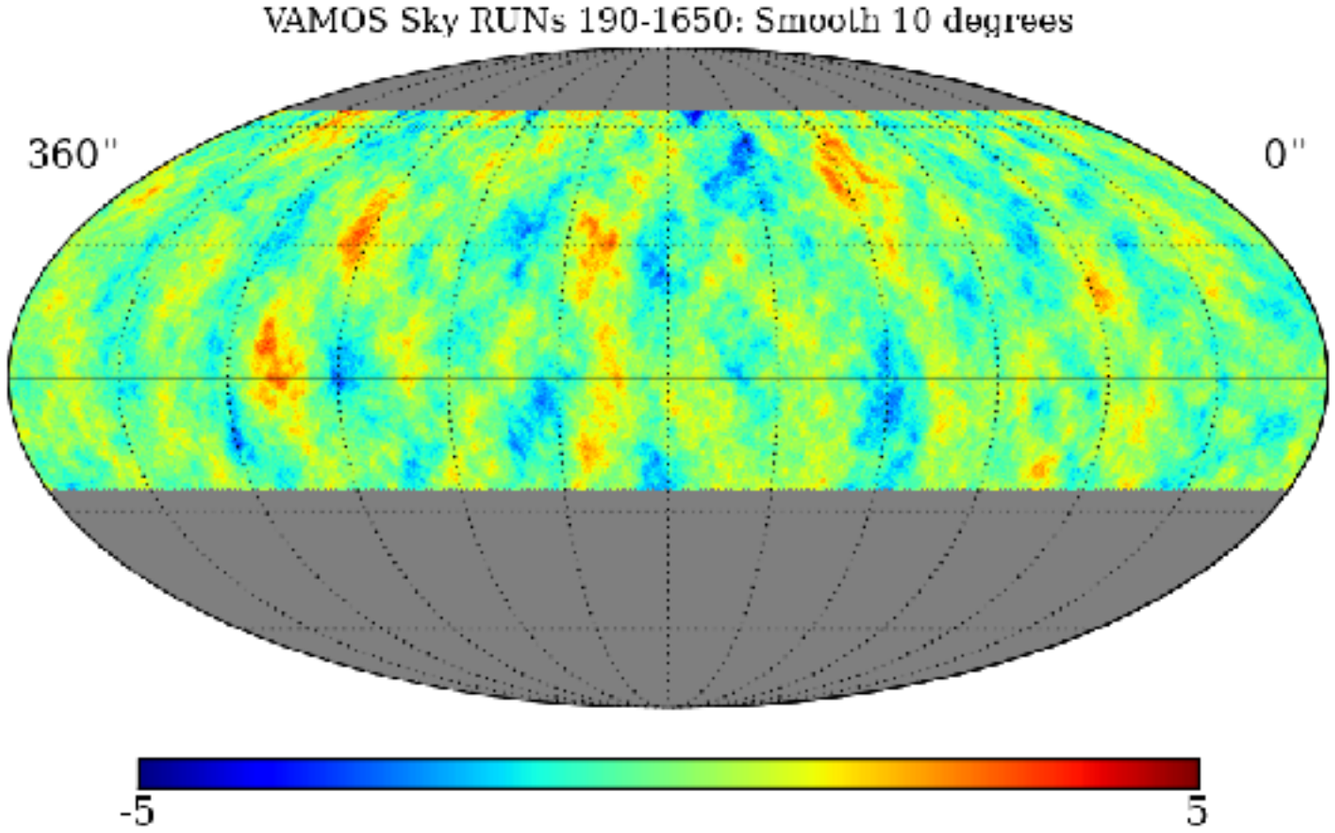


July 2009

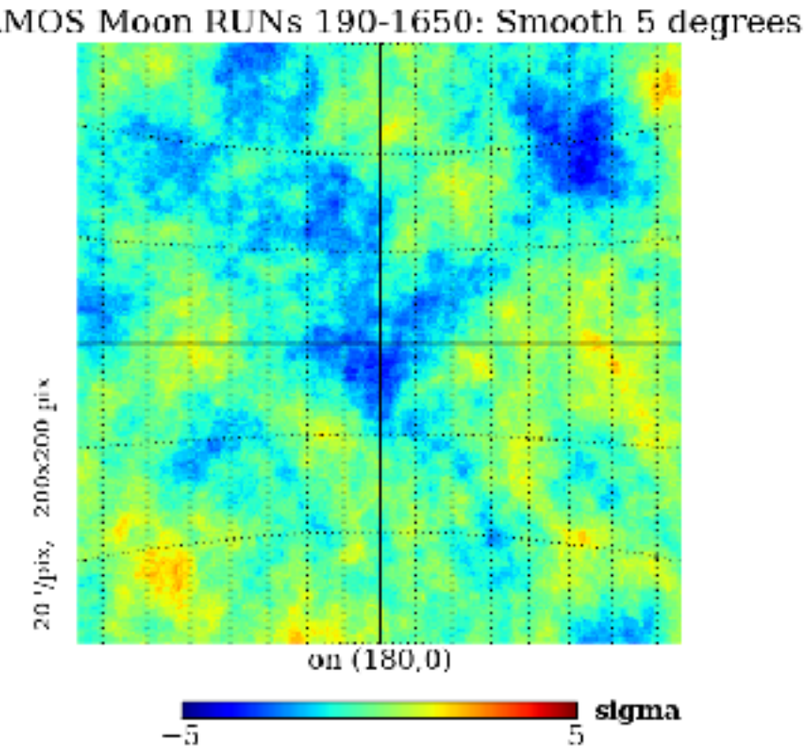
VAMOS (2010 - 2011)

Vamos Tank 7 first data 30 April 2011

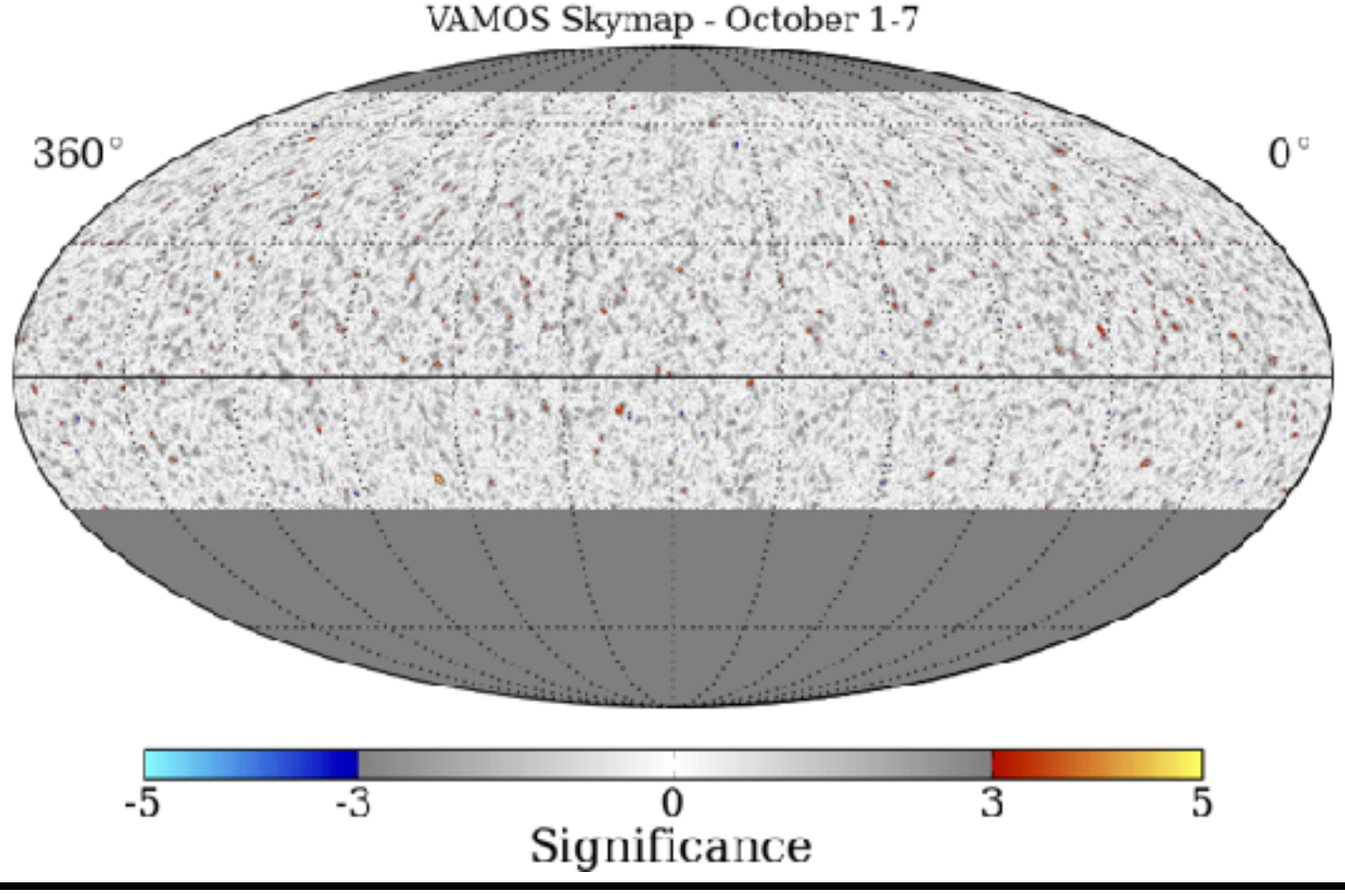




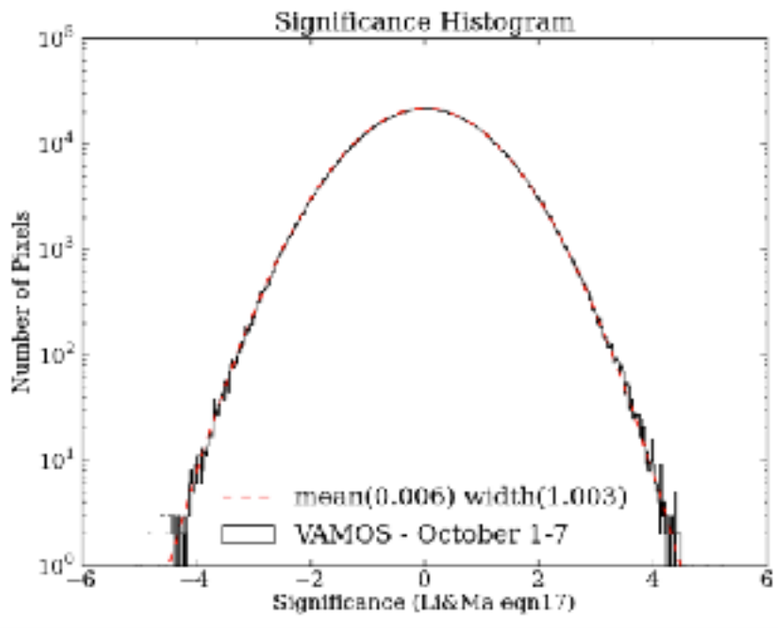
RC



Abeysekara et al.
(Astrop. Phys 62, 125, 2015;
arxiv 1408.3477)



γ




August 2011


April 2012


Mon Apr 22 00:02:58 GMT 2013


10/10/2012
2003
2012
N
Image © 2013 DigitalGlobe
125 m
Google earth
Imagery Date: 10/10/2012 18°59'41.26" N 97°18'26.99" W elev 4098 m eye alt 4.73 km

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15 April 2013 Last updated at 06:22 GMT

574 Share

Hawc gamma-ray telescope captures its first image

By Jason Palmer
BBC News, Denver

The Hawc facility is able to spot the highest-energy light ever seen on Earth - possibly the highest we will ever see

A new set of "eyes" to capture the Universe's highest-energy particles and light has snapped its first image.

The High-Altitude Water Cherenkov Observatory or Hawc, high on a Mexican plain, now holds the record for the highest-energy light it can

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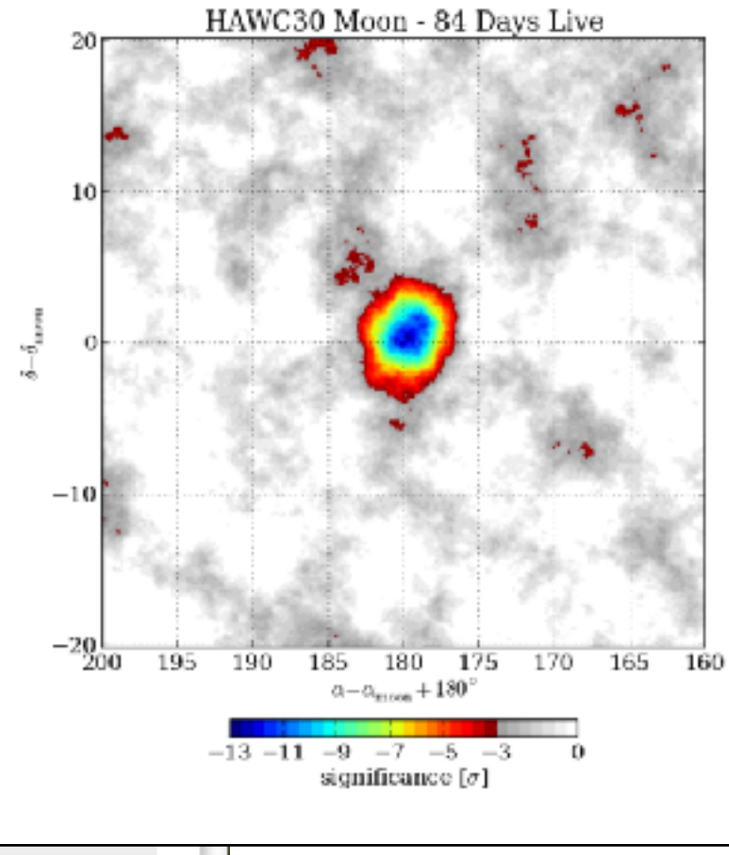
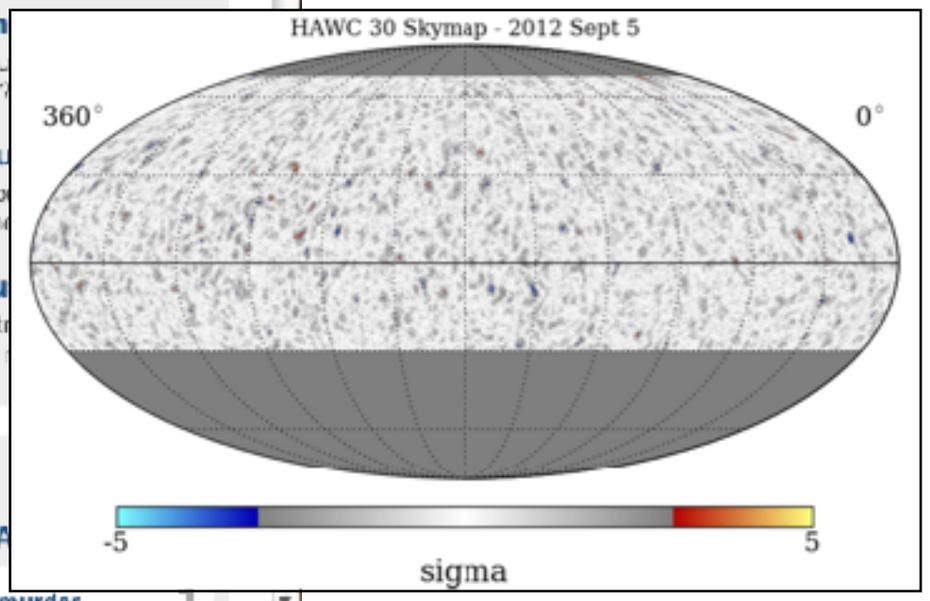




HAWC-100
Sept 2013

HAWC-100
Sept 2013

HAWC Utility Building

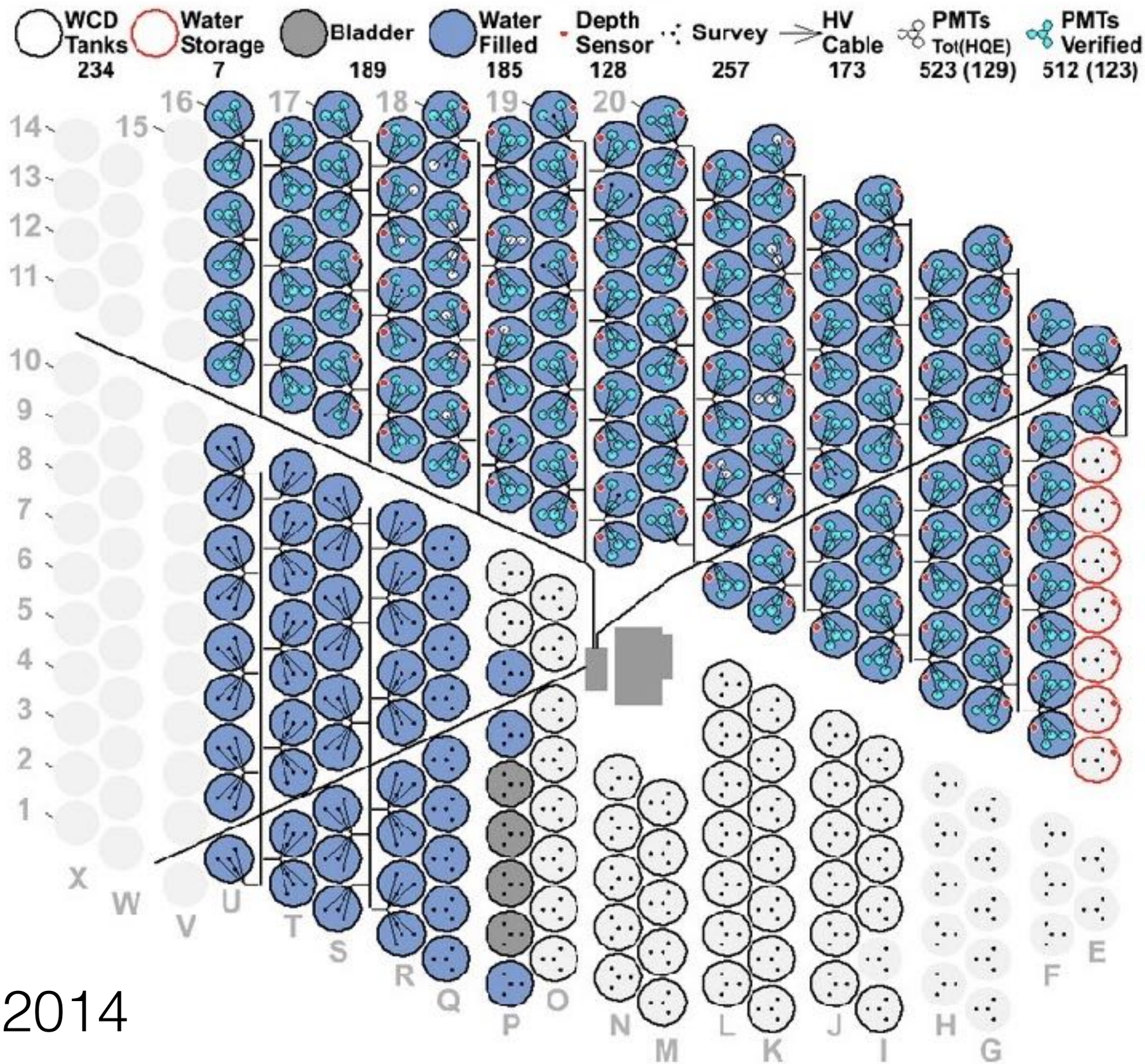
- Water filtration
- Bladder testing

Counting house

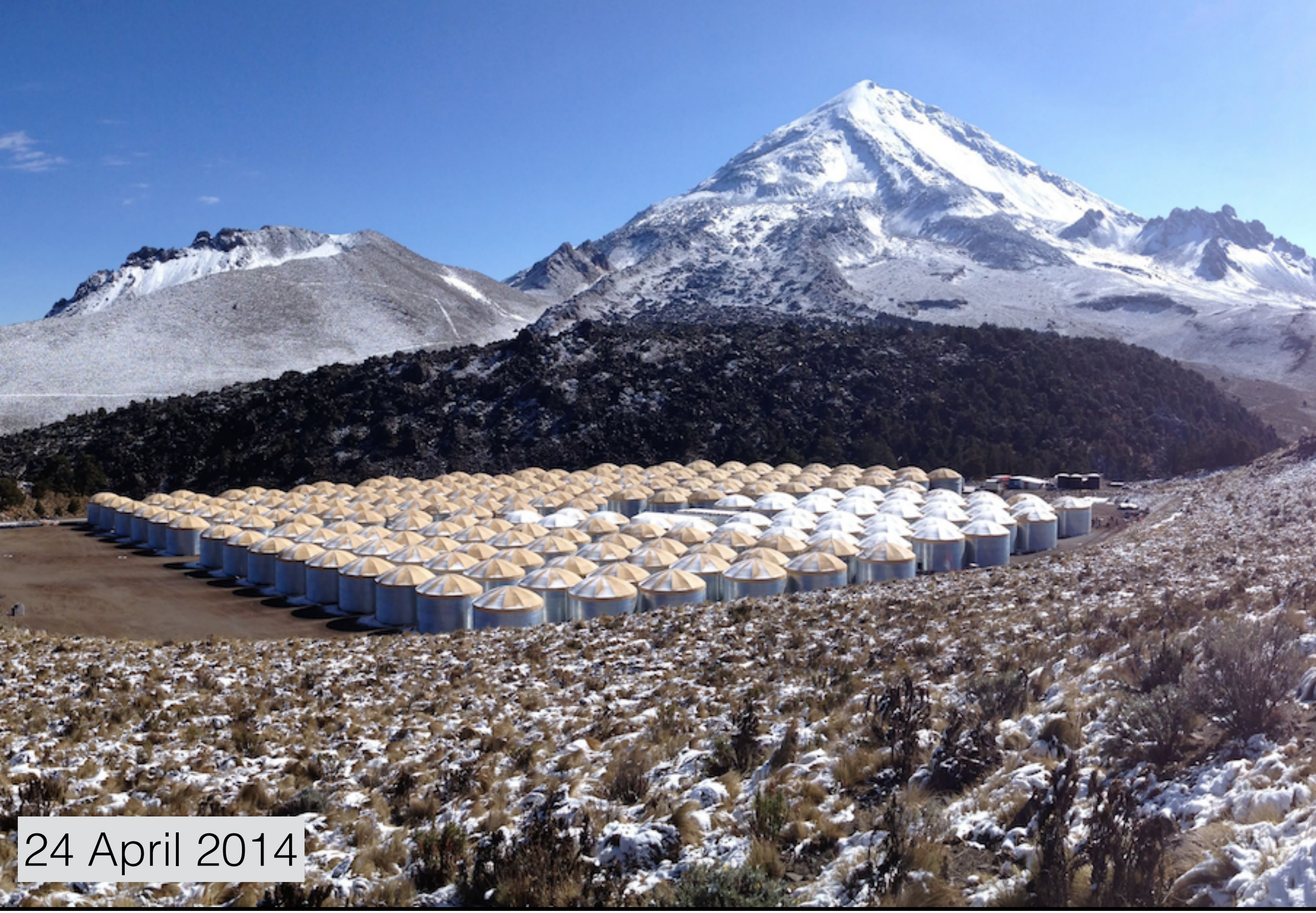
- DAQ & laser calibration
- system

HAWC Utility Building

- Water filtration
- Bladder testing

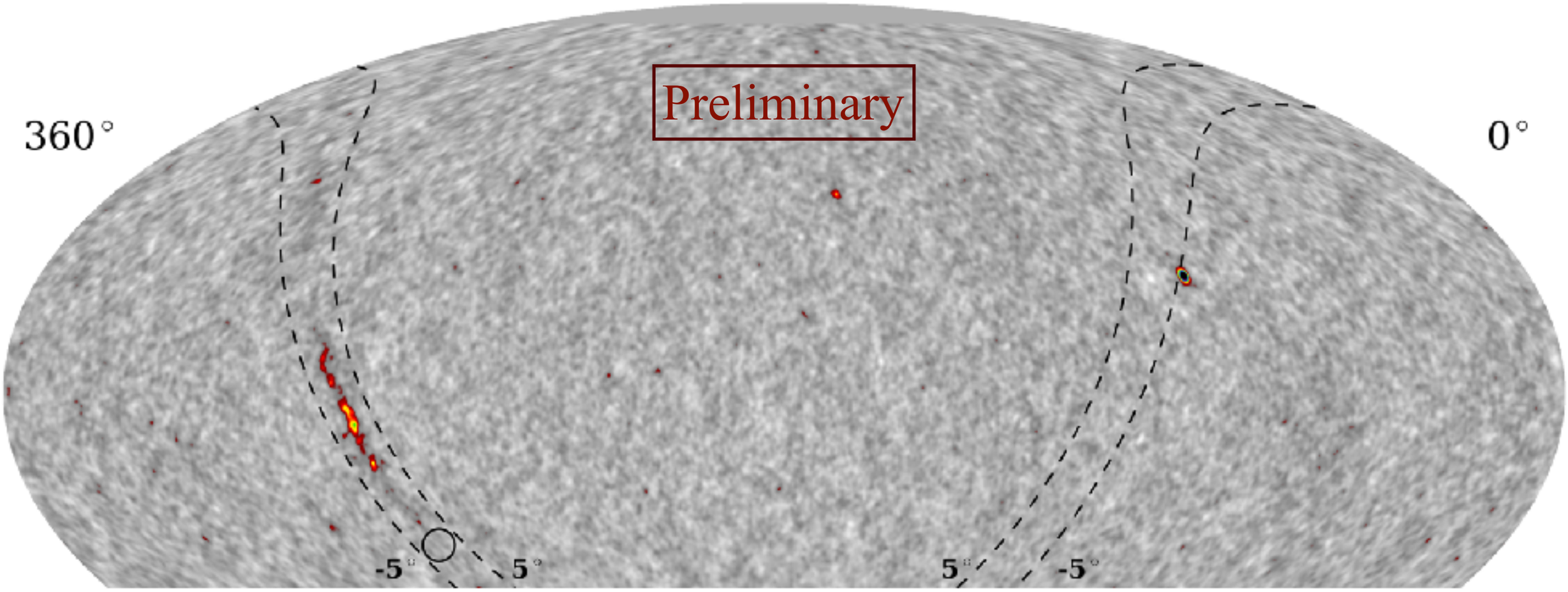


11 April 2014

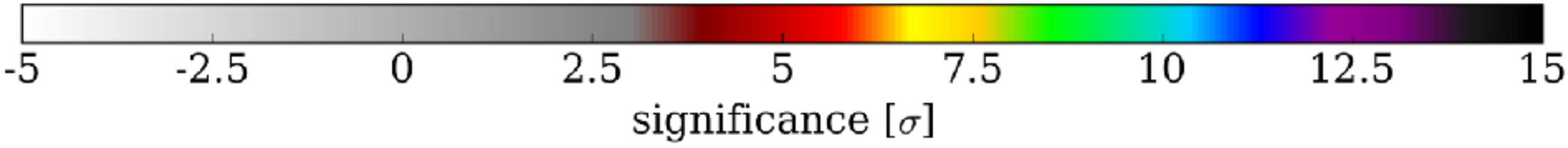


24 April 2014

HAWC-111 γ-ray skymap

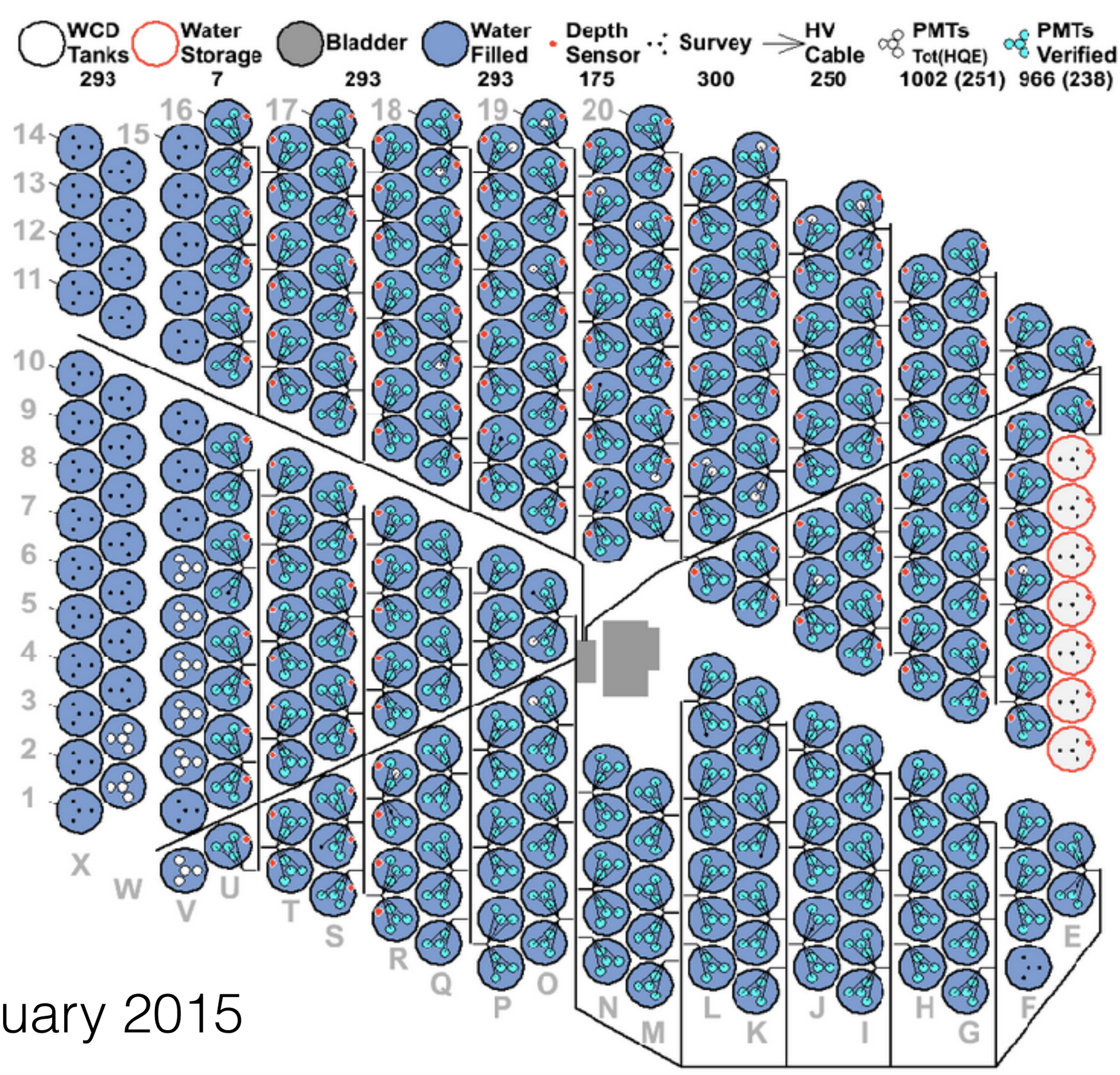


HAWC-111 - August 2013 to June 2014

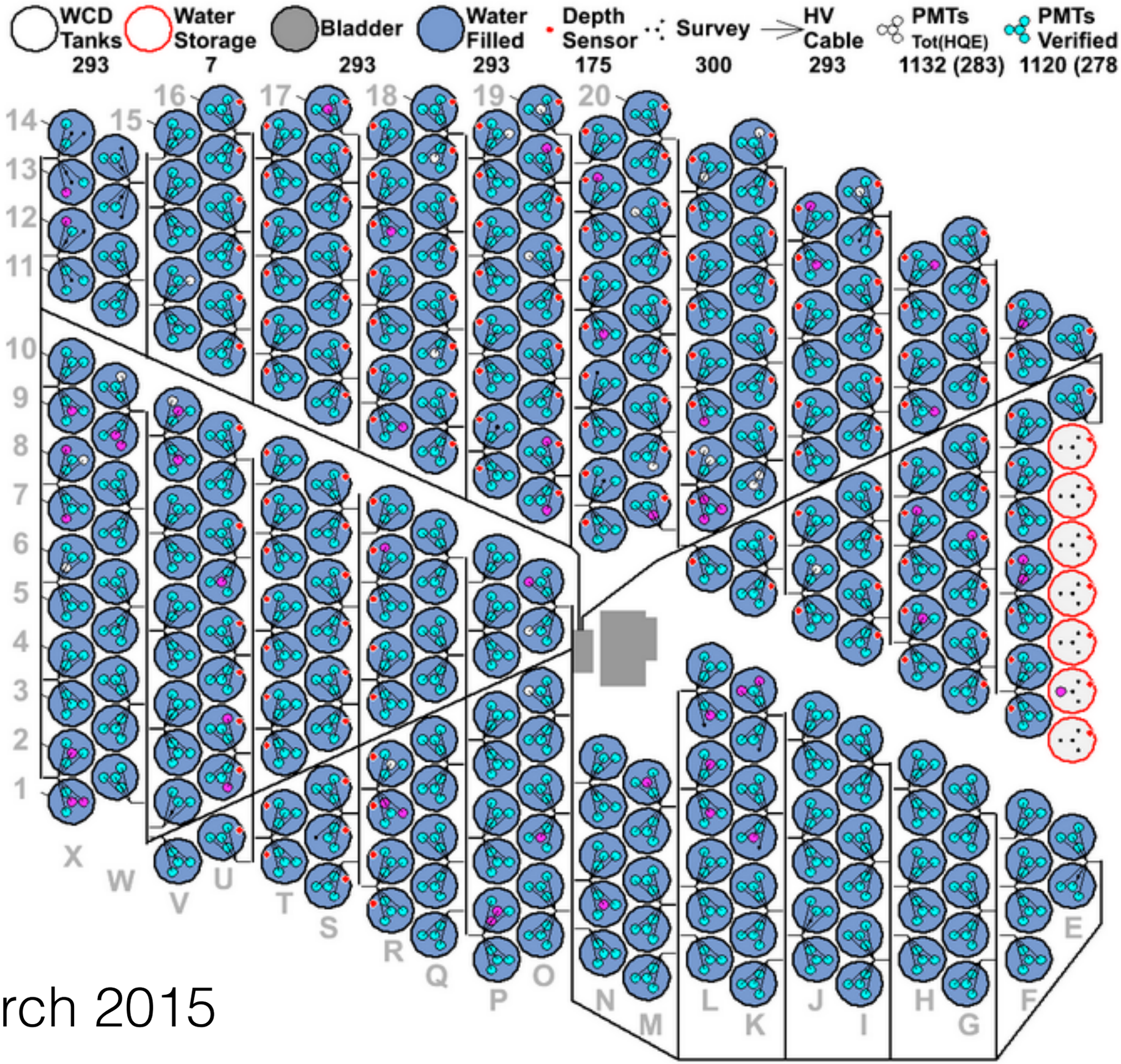


15 diciembre 2014
X01 => HAWC 300

February 2012 to December 2015



19 January 2015



19 March 2015

The HAWC timeline

Jan 2006	HAWC proposed to MX institutions by Milagro	
Jul 2007	HAWC collaboration formed	
May 2009	HAWC environmental permits cleared	
2010-2011	LMT road, electricity and optical fiber extended to	
Feb 2011	Start of project funding (DoE)	
Sep 2011	VAMOS test array deployed and verified	
Dic 2011	HAWC platform prepared	
March 2012	Start of array installation	
Sep 2012	HAWC 30 deployed and verified - start of data	
Aug 2013	Start of science operations with HAWC 111	
Jan 2015	HAWC 300 tank installation complete	
March 2015	HAWC inauguration	
March 2025	End of operation phase in site permit	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