# CF2 – Facilities

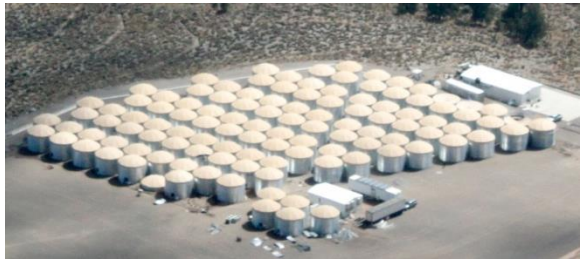
## Veritas Upgrade, CTA, HAWC, IceCube – Deepcore, PINGU

*K. Byrum*
*High Energy Physics (HEP) Division*
*Argonne National Laboratory*

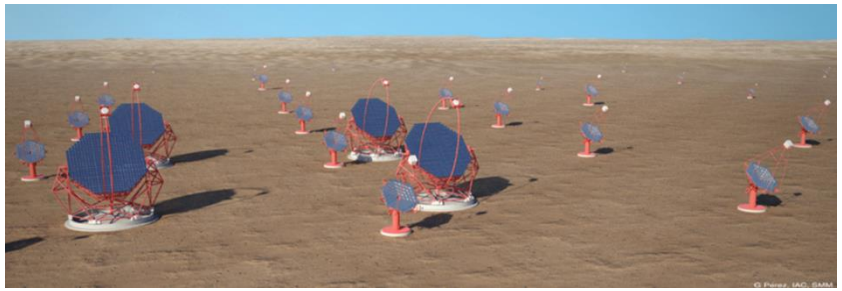
Snowmass on the Mississippi
Aug 3 2013

# Facilities: Gamma-Ray Detectors

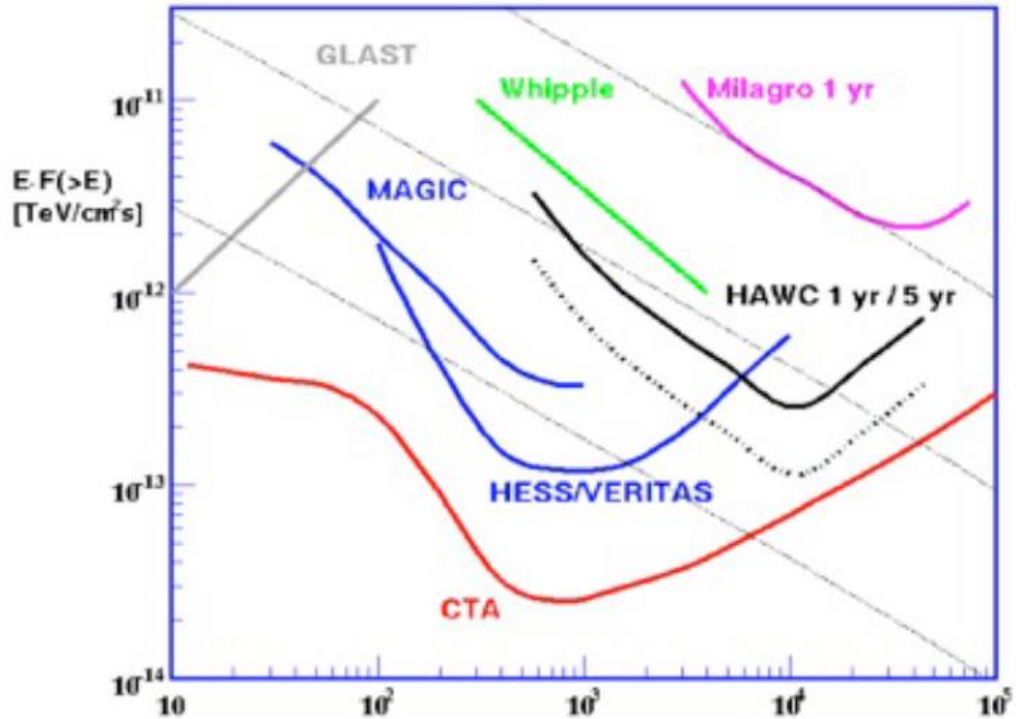
VERITAS Upgrade
First Light Fall 2012



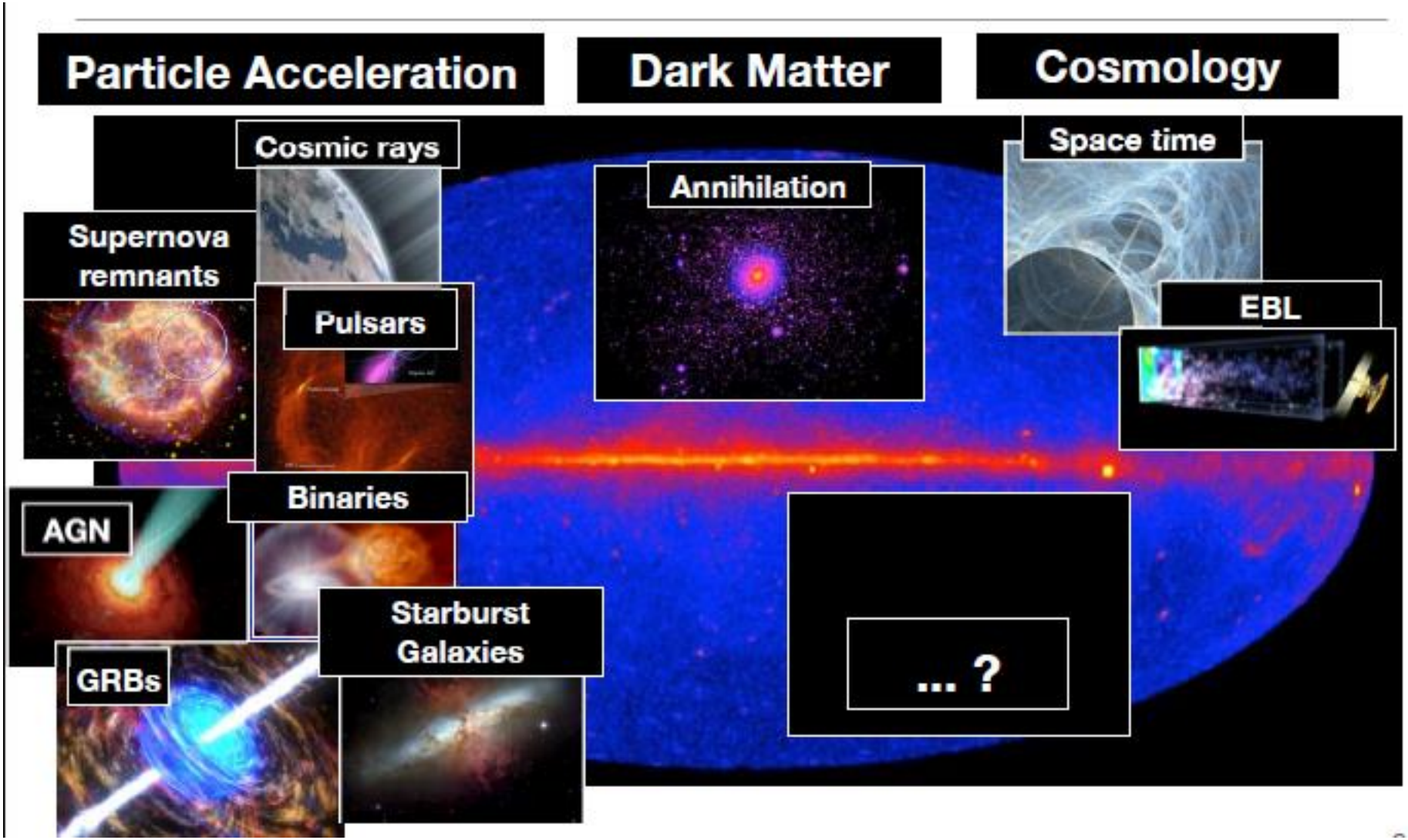
HAWC 300: First Light Aug 2014
HAWC 100 – Aug 2013



CTA: First Light - completed array in 2019
First Science 2016



# Gamma Ray Science:
# Astrophysics, Astronomy, Cosmology, Fundamental Physics



# VERITAS Contributions to CF6
# Cosmic rays, Gamma-rays and Neutrinos

**Jamie Holder**

**Bartol Research Institute/Department of Physics and Astronomy**

**University of Delaware**

Snowmass on the Mississippi
Minneapolis, August 2013

# VERITAS @ Mt Hopkins, AZ USA

**Support from:**

U.S. DOE
U.S. NSF
Smithsonian
STFC (U.K.)
NSERC (Canada)
SFI (Ireland)

**U.S.**

Adler Planetarium
Argonne Nat. Lab
Barnard College
Columbia Univ.
DePauw Univ.
Grinnell College
Iowa St. Univ.
Purdue Univ.
SAO
UCLA
UCSC
U. of Chicago
U. of Delaware
U. of Iowa
U. of Minnesota
U. Of Utah
Washington U.

**Canada**

McGill Univ.

**U.K.**

Leeds Univ.

**Ireland**

Cork Inst. Tech.
N.U.I. Galway
Galway-Mayo Inst.
Univ. College Dublin

**Non-Affiliated Members**

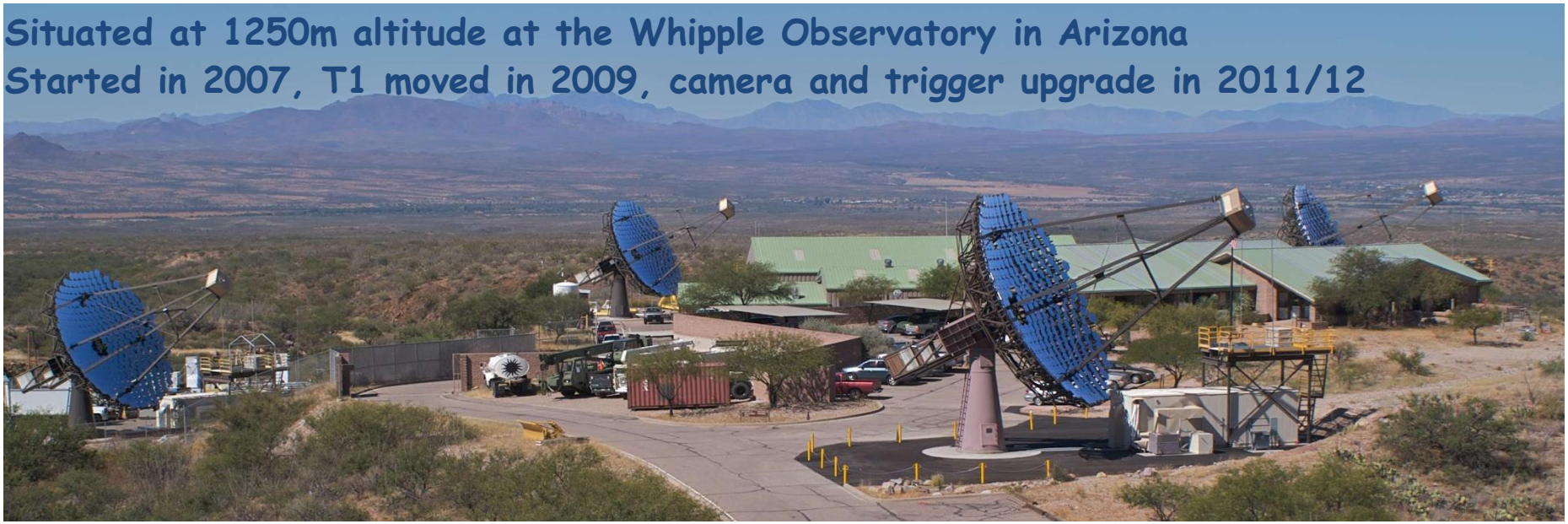
Anderson Univ.
Cal Poly, SLO
De Pauw U.
DESY/Potsdam
Georgia Tech
Grinnell College
Penn State

**MWL Partnerships:**
**36 Associate Members**
**(IceCube, Fermi, Swift, etc.)**
**MOU's with Fermi-LAT, IceCube**

**New: VERITAS-Fermi GI Program (2013)**

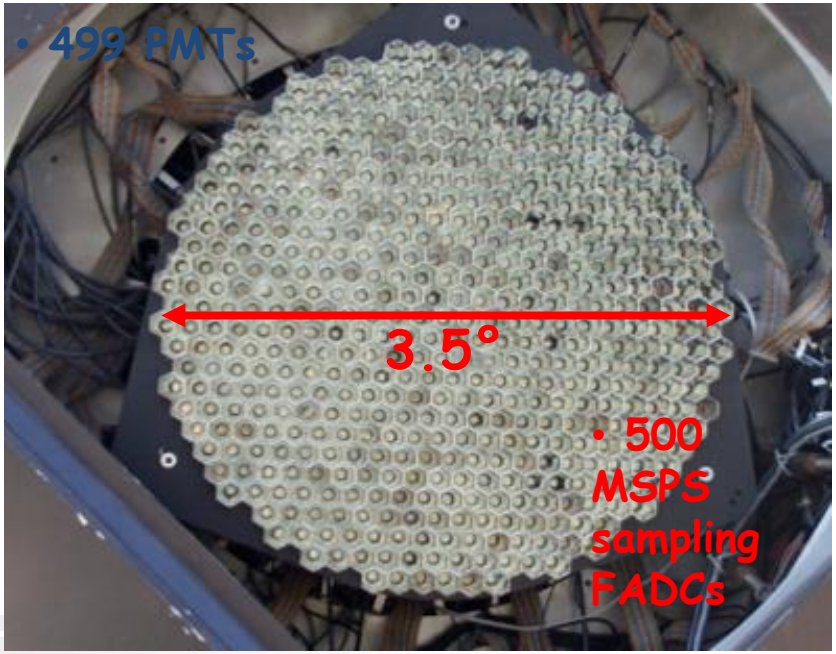
# VERITAS

- Situated at 1250m altitude at the Whipple Observatory in Arizona
- Started in 2007, T1 moved in 2009, camera and trigger upgrade in 2011/12



- 12m tessellated mirrors

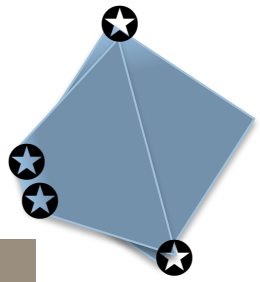
- 499 PMTs




- 500 MSPS sampling FADCs

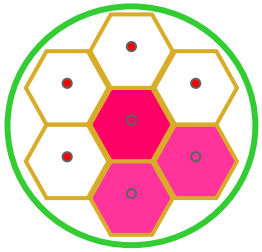
# 2009-2012 VERITAS Upgrade
## Four components:

☆ Rearrange Telescopes to Better Geometry (summer 2009)
*(SAO, U. Utah + collaboration)*

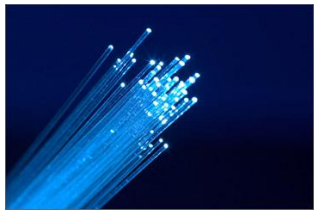


☆ Higher sensitivity Photomultiplier Tubes (summer 2012)
*(Purdue, U Delaware, U. Utah, Wash U, UCSC)*

☆ Faster Pattern (Level 2) Trigger (fall 2011)
*(Iowa State U, Argonne NL)*

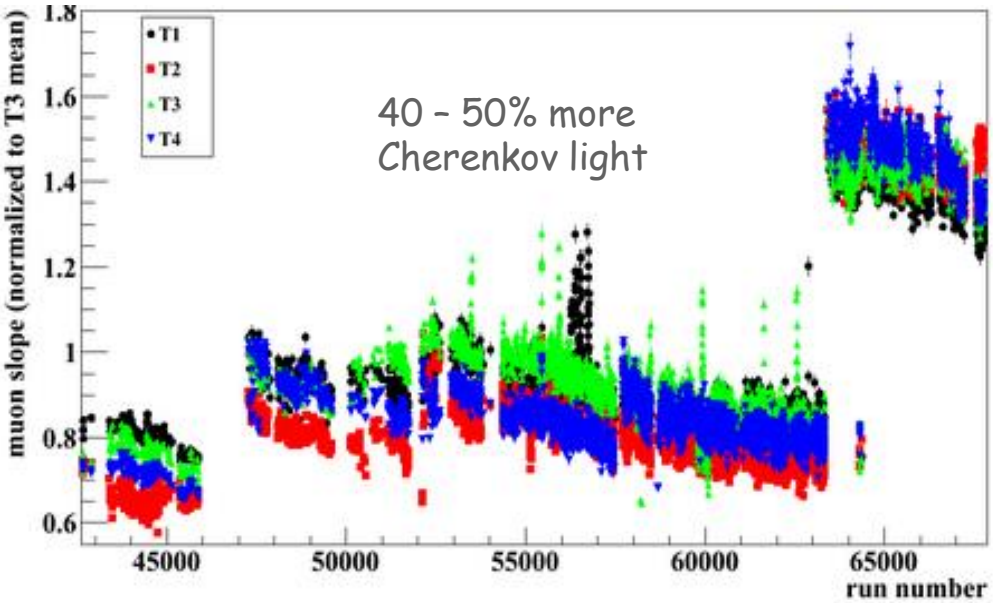


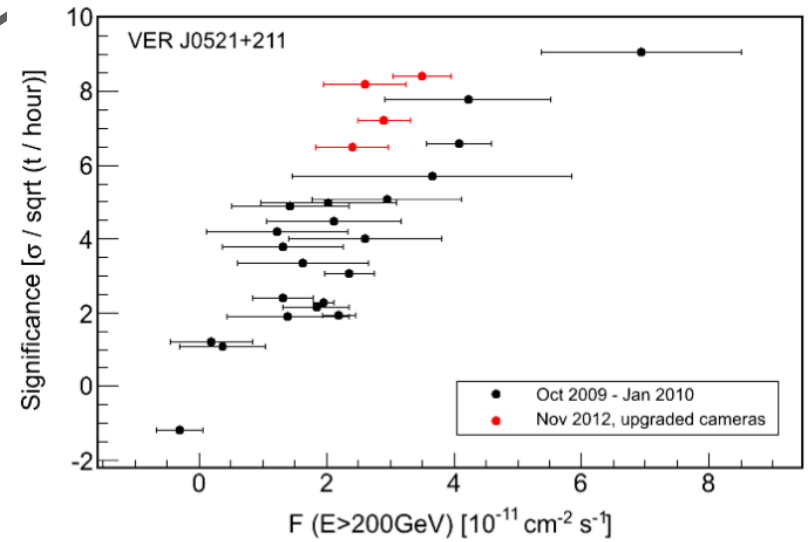
☆ Communication (Fiber Optic) Network Upgrade (summer 2012)
*(SAO, U. Utah)*



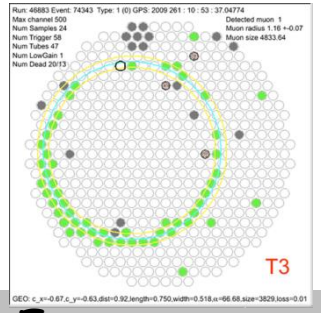
Endorsed by PASAG, a Sub-Panel of HEPAP
Funded by 2.2 M$ NSF MRI-R2 , University of Utah
*Main cost is the new photomultiplier tubes (1.2 M$)*

# VERITAS Upgrade

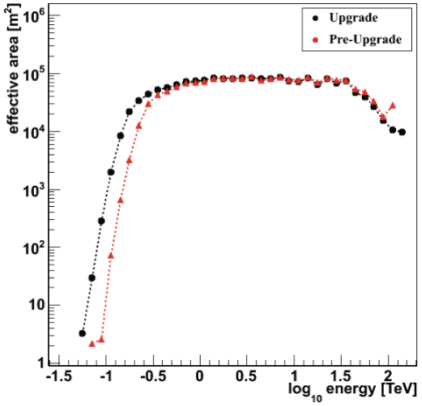



Detect soft spectrum sources twice as fast as in 2009




Muon Ring light intensity
Standard calibration
Light source




Energy threshold
~30% reduction
95 GeV -> 60 GeV

- Energy range: ~100 GeV - 30 TeV
- Sensitivity: 1% Crab in ~25h
  - 1 Crab in a few seconds
- Energy resolution: 15-25%
- Angular resolution: R_68% < 0.1 deg

# HAWC & Beyond: Continuous, Wide Field of View Observations of the Very High Energy Sky

Brenda Dingus, LANL
HAWC US Spokesperson
29 July 2013

# The HAWC Collaboration

**Los Alamos National Laboratory:** **Brenda Dingus (US spokesperson)**, : Gus Sinnis, John Pretz, Patrick Younk, Gerd Kunde, Pat Harding
**University of Maryland**: Jordan Goodman, Andrew Smith, Jim Braun, David Berley, Brian Baughman, Josh Wood
**University of Wisconsin:** Stefan Westerhoff, Segev BenZvi, Mike Duvernois, Zig Hampel-Arias, Dan Fiorino, Ian Wisher, Asif Imran, Tom Weisgarber
**University of Utah:** Dave Kieda, Wayne Springer, Ahron Barber
**Univ. of California, Irvine:** Gaurang Yodh, Peter Karn
**Michigan State University:** Jim Linnemann, Kirsten Tollefson, Dan Edmunds, Udara Abeysekara, Tilan Ukwatta
**George Mason University:** Robert Ellsworth
**Colorado State University:** Miguel Mostafa, Dave Warner, Megan Longo, Paco Salesa Grues, Michael Gussert
**University of New Hampshire:** James Ryan
**Pennsylvania State University**: Tyce DeYoung, Dmitry Zaborov, Kathryne Sparks
**University of Alabama:** Patrick Toale
**University of New Mexico:** John Matthews, Robert Lauer
**Michigan Technical University:** Petra Hüntemeyer, Emanuele Bonamente, Nathan Kelley-Hoskins, Michelle Hui, Hugo Ayala, Hao Zhou
**NASA/Goddard Space Flight Center:** Julie McEnery, Elizabeth Hays, Vlasios Vasileiou
**Georgia Institute of Technology:** Ignacio Taboada, Andreas Tep[illegible] Lennarz
[illegible] **Staff:** Michael Schneider, Scott Delay

**Instituto Nacional de Astrofísica Óptica y Electrónica (INAOE)**: **Alberto Carramiñana (Mexico Spokesperson)**, Eduardo Mendoza, Luis Carrasco, William Wall, Daniel Rosa, Ibrahim Torres, Sergey Silich, Jason Walters
**Universidad Nacional Autónoma de México (UNAM): Instituto de Astronomía**; Maria Magdalena Gonzalez, Marco Martos, Sergio Mendoza, Dany Page, William Lee, Hector Hernández, Deborah Dultzin, Erika Benitez **Instituto de Física:** Rubén Alfaro Molina, Varlen Grabski, Andres Sandoval Espinosa, Ernesto Belmont Moreno, Saul Aguilar Slazar **Institudo de Ciencias Nucleares;** Lukas Nellen, Gustaov Medina Tanco, Jaun Carlos D'Olivo **Institudo de Geofísica:** José Valdés Galicia, Alejandro Lara, Rogelio Caballero
**Benemérita Universidad Autónoma de Puebla:** Humberto Salazar Ibarguen, Arturo Fernández, Caupatitzio Ramirez, Oscar Martínez, Eduardo Moreno Barbosa, Lorenzo Diaz, Alfonso Rosado
**Universidad Autónoma de Chiapas**: Cesar Álvarez Ochoa, Eli Santos Rodriguez, Roberto Arceo Reyes, Jorge Jara Jiménez
**Universidad de Guadalajara**: Eduardo de la Fuente, Enrique Velazquez
**Universidad Michoacana de San Nicolás de Hidalgo**: Luis Villaseñor, Umberto Cotti, Juan Carlos Arteaga Velazquez, Pedro A. Miranda-Romagnoli, Roberto Noriega Papaqui, Eucario Gonzalo
**Centrode Investigacion y de Estudios Avanzados:** Arnulfo Zepeda
**Universidad de Guanajuato:** David Delepine, Gerardo Moreno, Edgar Casimiro Linares, Marco Reyes, Luis Ureña, Mauro Napsuciale, Victor Migenes
**CIC Instituto Politécnico Nacional:** Jesus Martinez

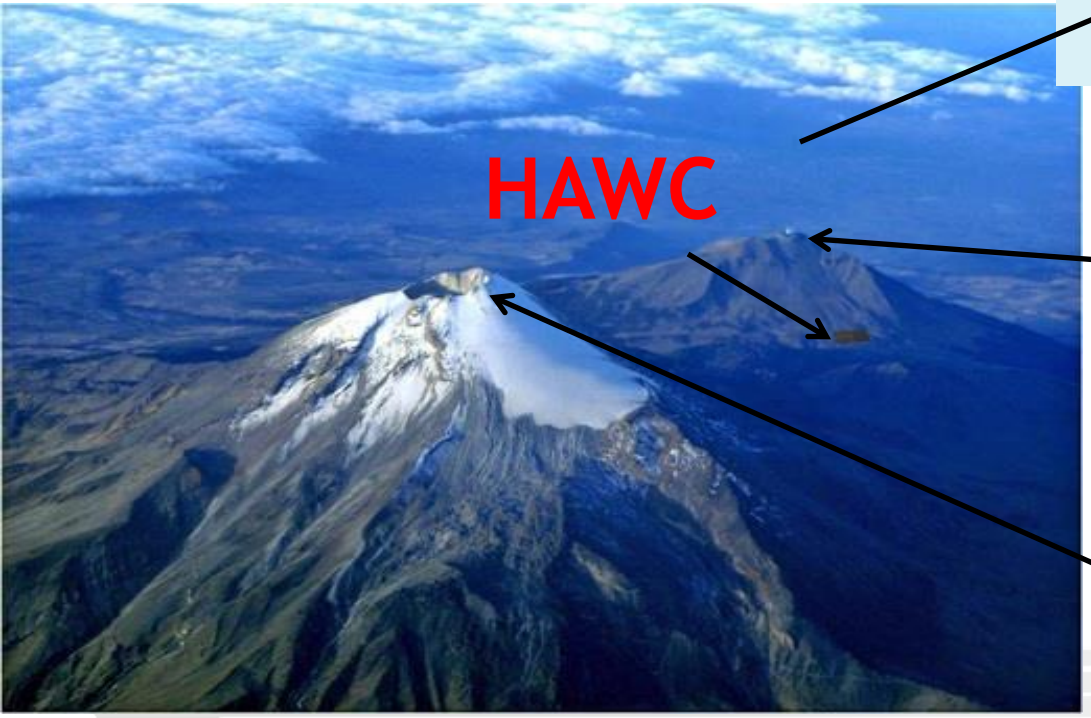
USA:
16 institutions,
57 people

Mexico:
15 institutions,
54 people

# HAWC Site Location in Mexico

## Sierra Negra volcano near Puebla, Mexico

- High Altitude Site of 4100 m with temperate climate and existing infrastructure
- 17 R.L. of atmospheric overburden vs 27 R.L. at sea level
- Latitude of 19 deg N

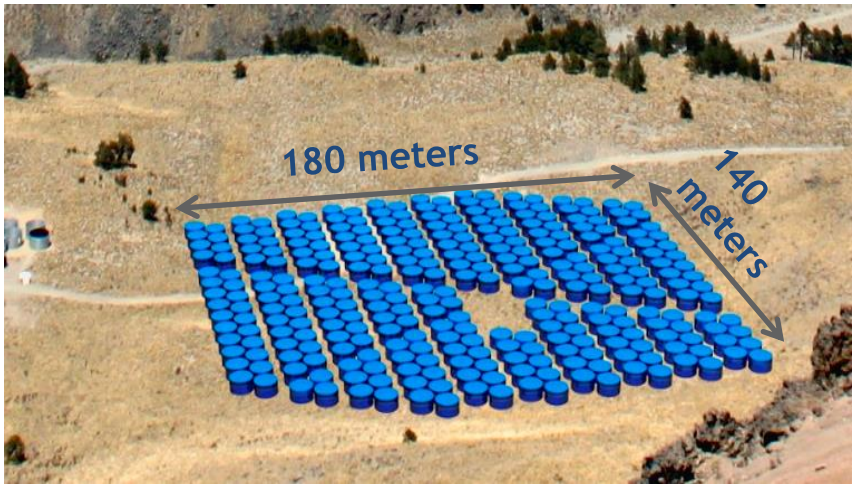


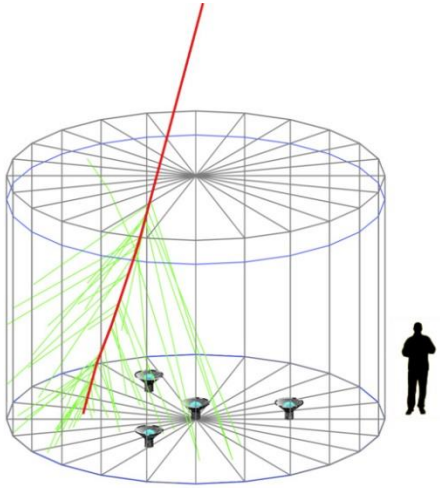

Large Millimeter Telescope (50m dia. dish)

Pico de Orizaba 5600 m (18,500')

# HAWC Design

300 close packed water tanks (7.3m dia x 4.5 m deep of 200,000 liters) each with 4 upward facing photomultiplier tubes at the bottom



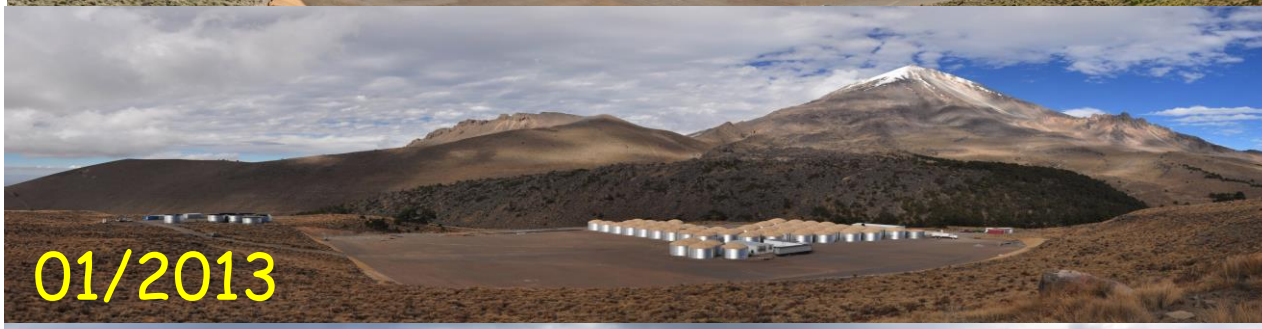


Important Dates

12M USD project funding began Feb 2011

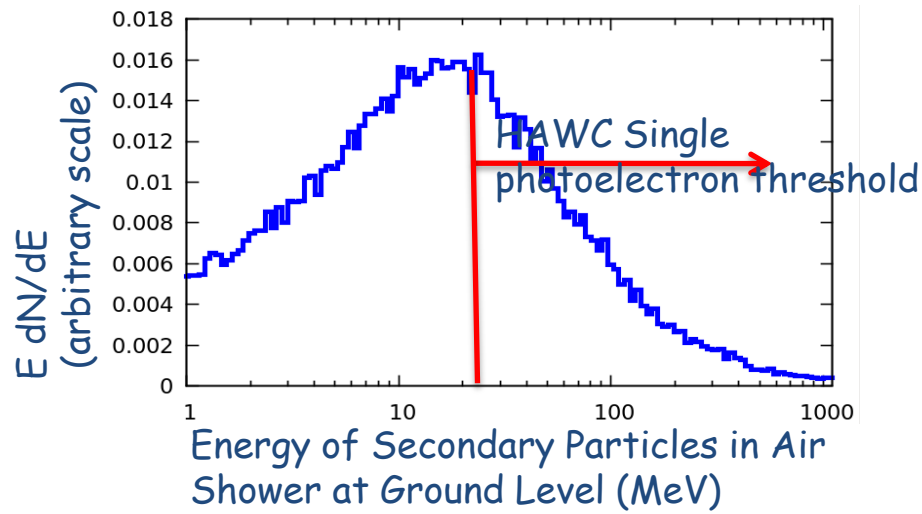
Operations with 100 water Cherenkov detectors in Aug 2013

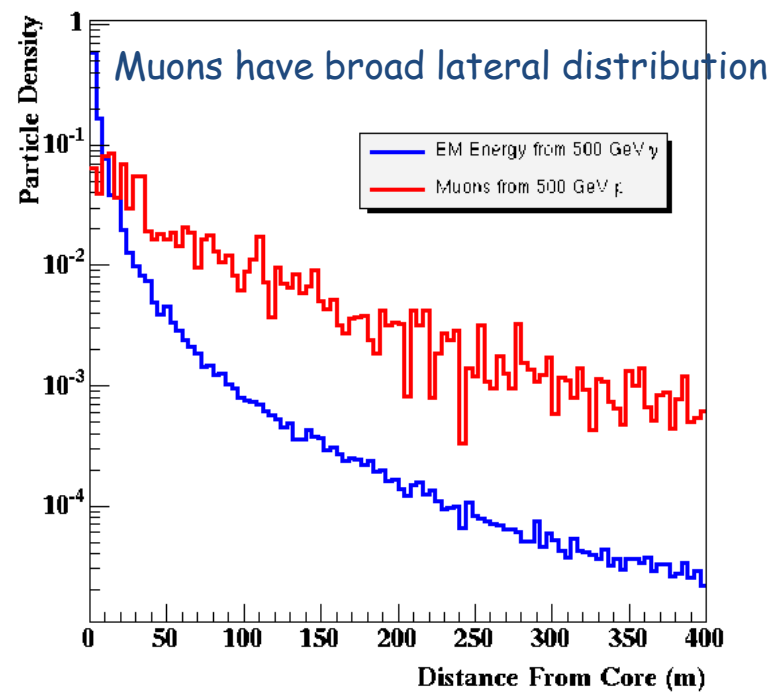
Observatory complete in Aug 2014



# Beyond HAWC: Increase Sensitivity

- Increase photodetection efficiency for lower energies
  - Winston Cones
  - Large Area Photodetectors
  - Liquid Scintillator
- Larger Area Array
  - Sensitivity proportional to Area, NOT sqrt(Area) due to background rejection

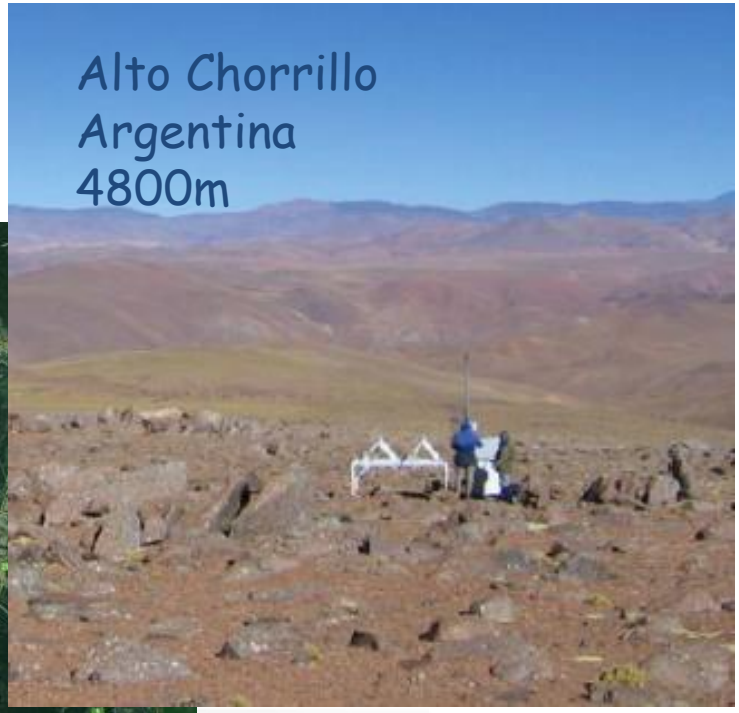



| | HAWC 150m x 150m | HAWC(100k m^2) 300m x 300m |
|---|---|---|
| Deep Survey Sensitivity (4 years) | 20mCrab | 4-5mCrab |
| Instantaneous sensitivity ($\sigma/\sqrt{hr}$) ~ | ~3 | 12-15 |

# Beyond HAWC: Southern Site

- Discovering rare transient events requires full sky coverage
  - GRB finder for Advanced LIGO, which will detect all neutron binary coalescence with z<0.5
  - AGN flares & GRBs as distant probes of high energy physics (e.g. Lorentz invariance and axions)
- Galactic Center
- TeV Source finder for CTA south



# CTA

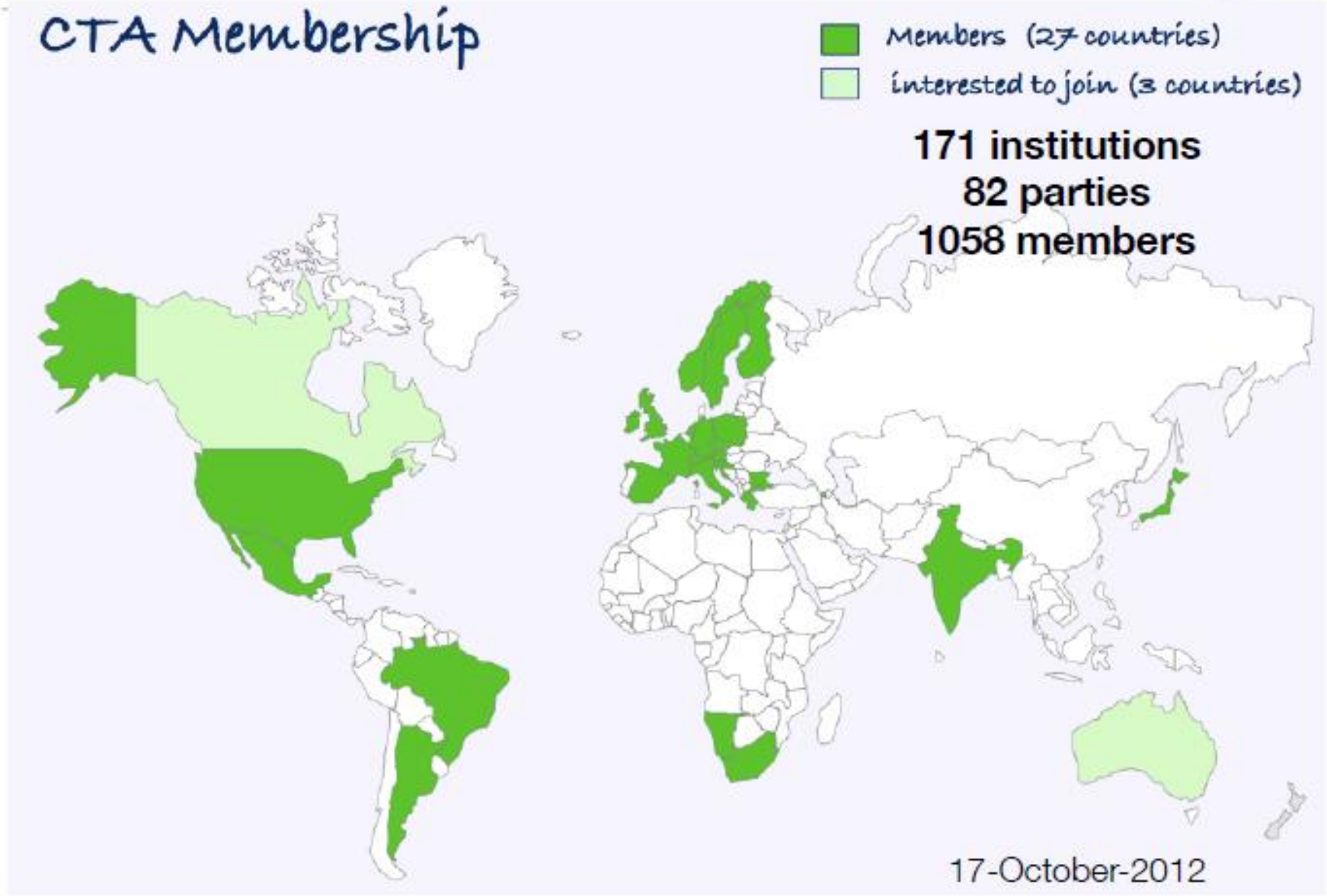
The Cherenkov Telescope Array

(Stefan Funk for the CTA Consortium)

cta
cherenkov telescope array

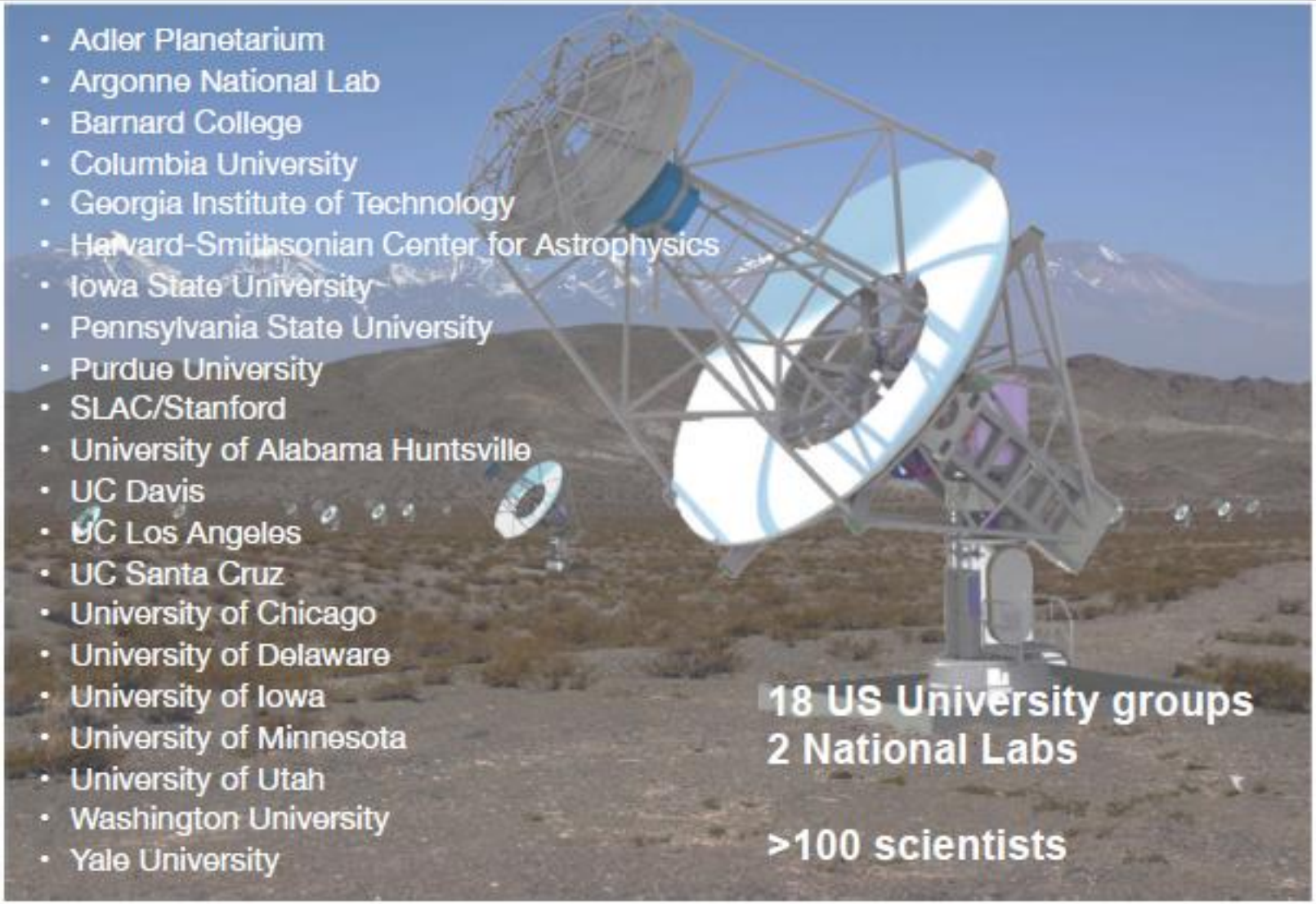
KIPAC KAVLI INSTITUTE FOR PARTICLE ASTROPHYSICS AND COSMOLOGY

# CTA is a world-wide Consortium:



# The US groups

- Adler Planetarium
- Argonne National Lab
- Barnard College
- Columbia University
- Georgia Institute of Technology
- Harvard-Smithsonian Center for Astrophysics
- Iowa State University
- Pennsylvania State University
- Purdue University
- SLAC/Stanford
- University of Alabama Huntsville
- UC Davis
- UC Los Angeles
- UC Santa Cruz
- University of Chicago
- University of Delaware
- University of Iowa
- University of Minnesota
- University of Utah
- Washington University
- Yale University



**18 US University groups**
**2 National Labs**

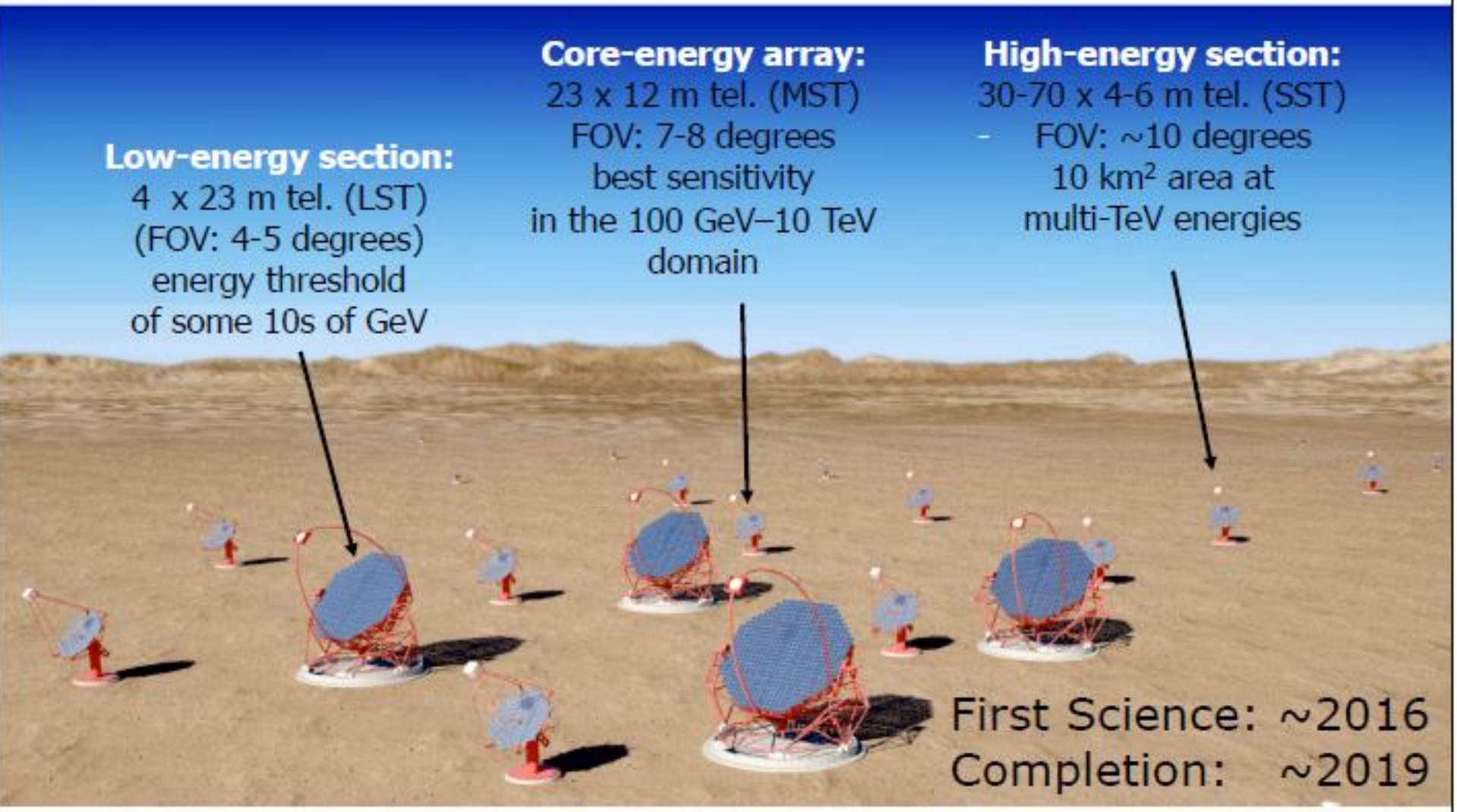
**>100 scientists**

# What one can (hopefully) afford ...

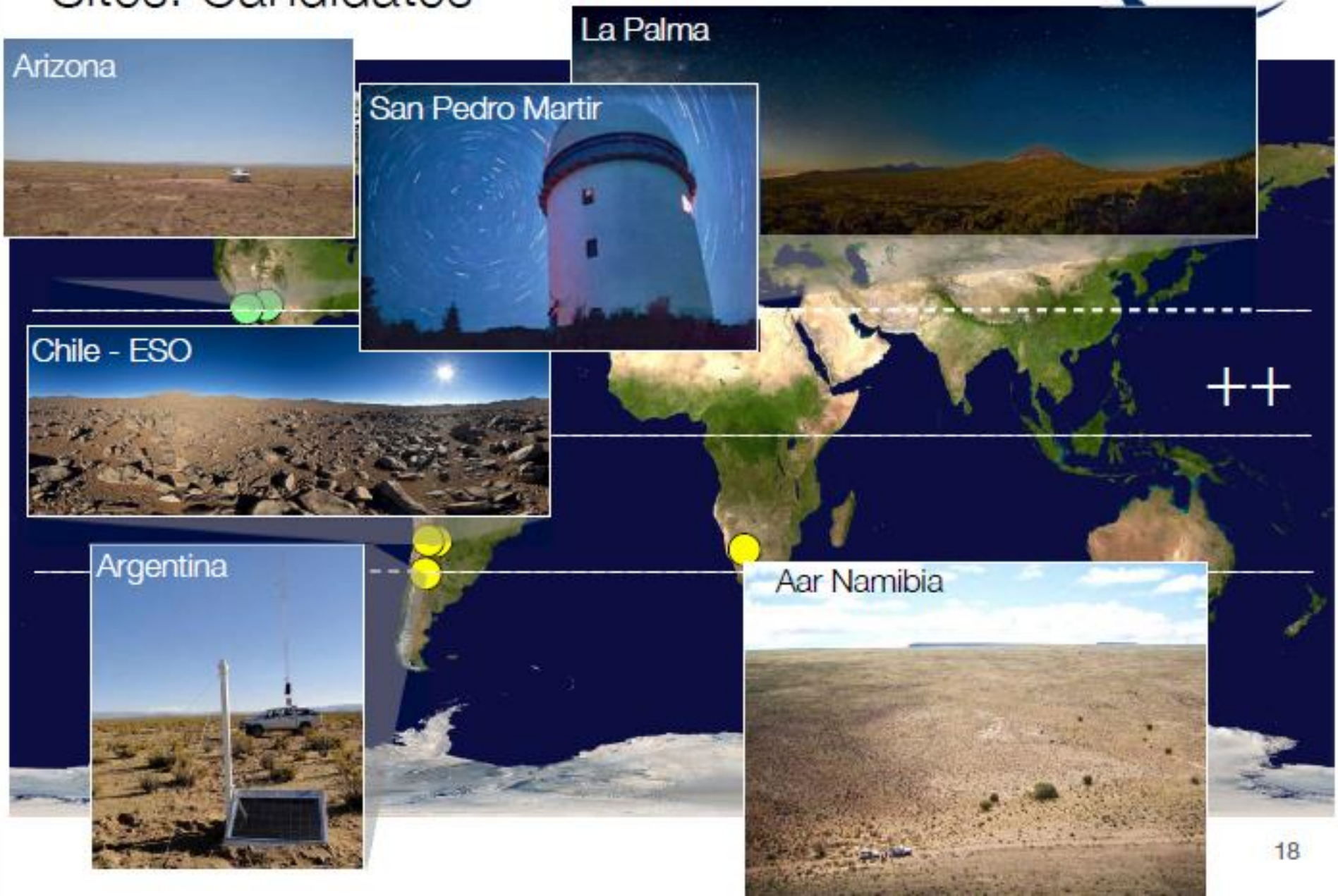
Key design goals:

- 10-fold increased sensitivity at TeV energies
- 10-fold increased effective energy coverage
- Larger field of view for surveys
- Improved angular resolution
- Full sky coverage: an array in each hemisphere

# The baseline ...

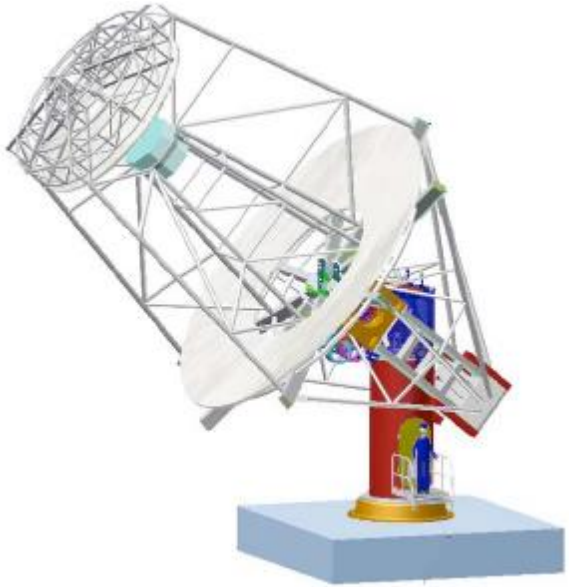


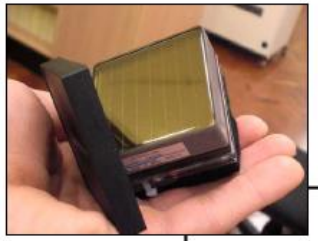
# Sites: Candidates



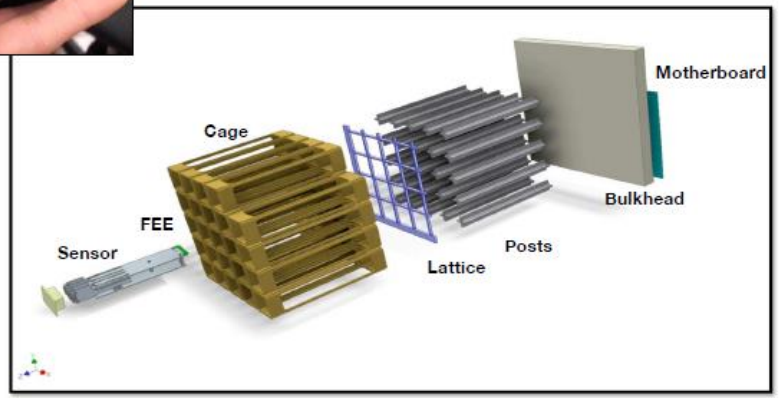
# US Contribution

- Focus on the mid-sized telescopes
  - The sweet-spot of the technique
- Start from suggested contribution from Astro2010
  - Double the number of mid-sized telescopes over baseline array
  - "Enhanced" telescope design
  - Secondary mirror allows for very small optical PSF across the whole field of view



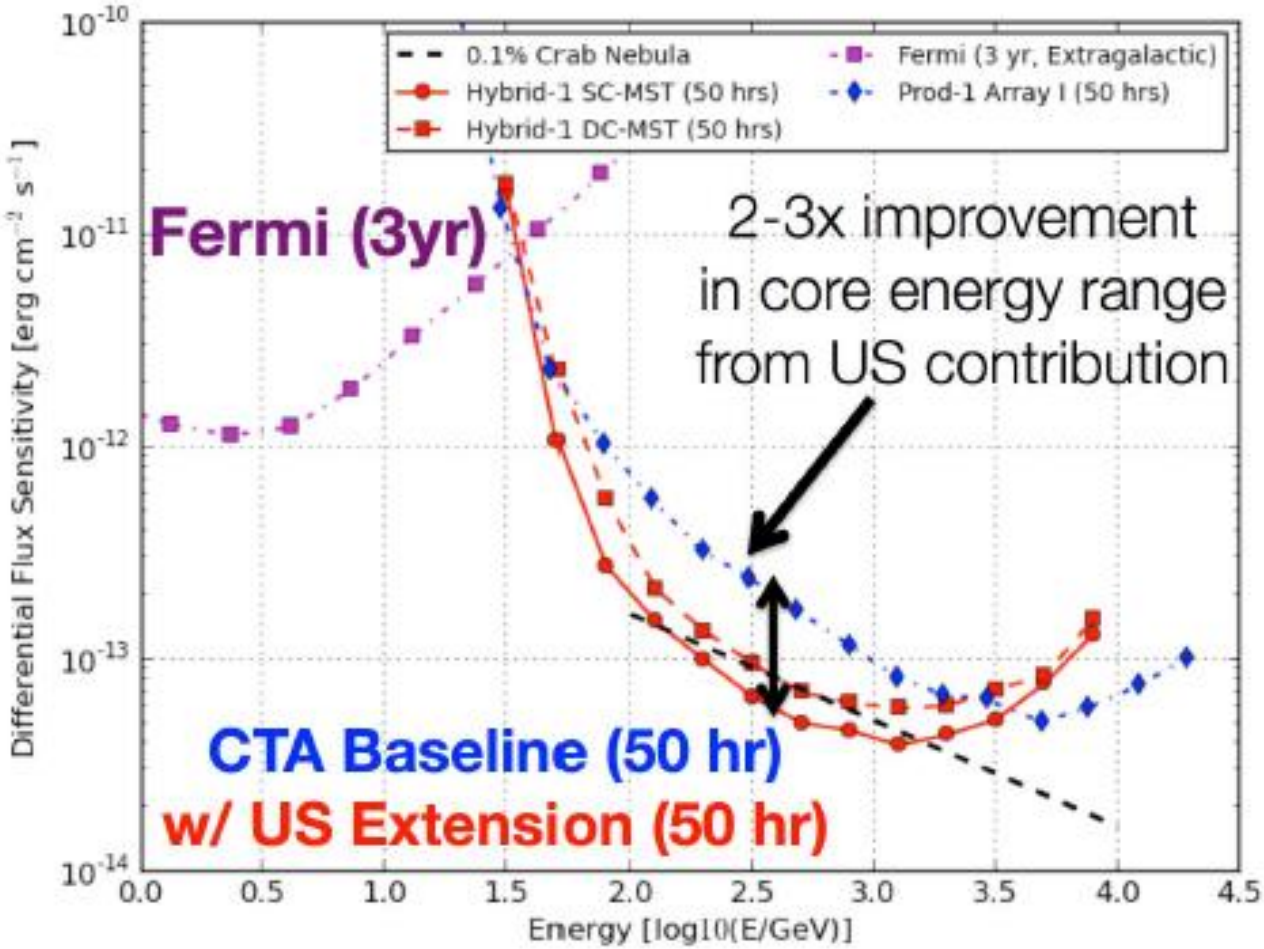


- Compare e.g. US camera to HESS-II camera:
  - Number of pixels: times 4 (~11500 vs ~2900)
  - Field of view: ~700% (solid angle)
  - Linear Size: ~40%
  - Mass: ~10%
  - Power consumption: ~25%




Highly Pixelated Camera
- SiPM sensors
- ASICs

# Results in enhanced sensitivity




CTA Baseline (Prod-1): See K. Bernlohr et al. 2012, arXiv:1210.3503
w/ US Extension (Hybrid-1): See T. Jogler et al. 2012, arXiv: 1211.3181

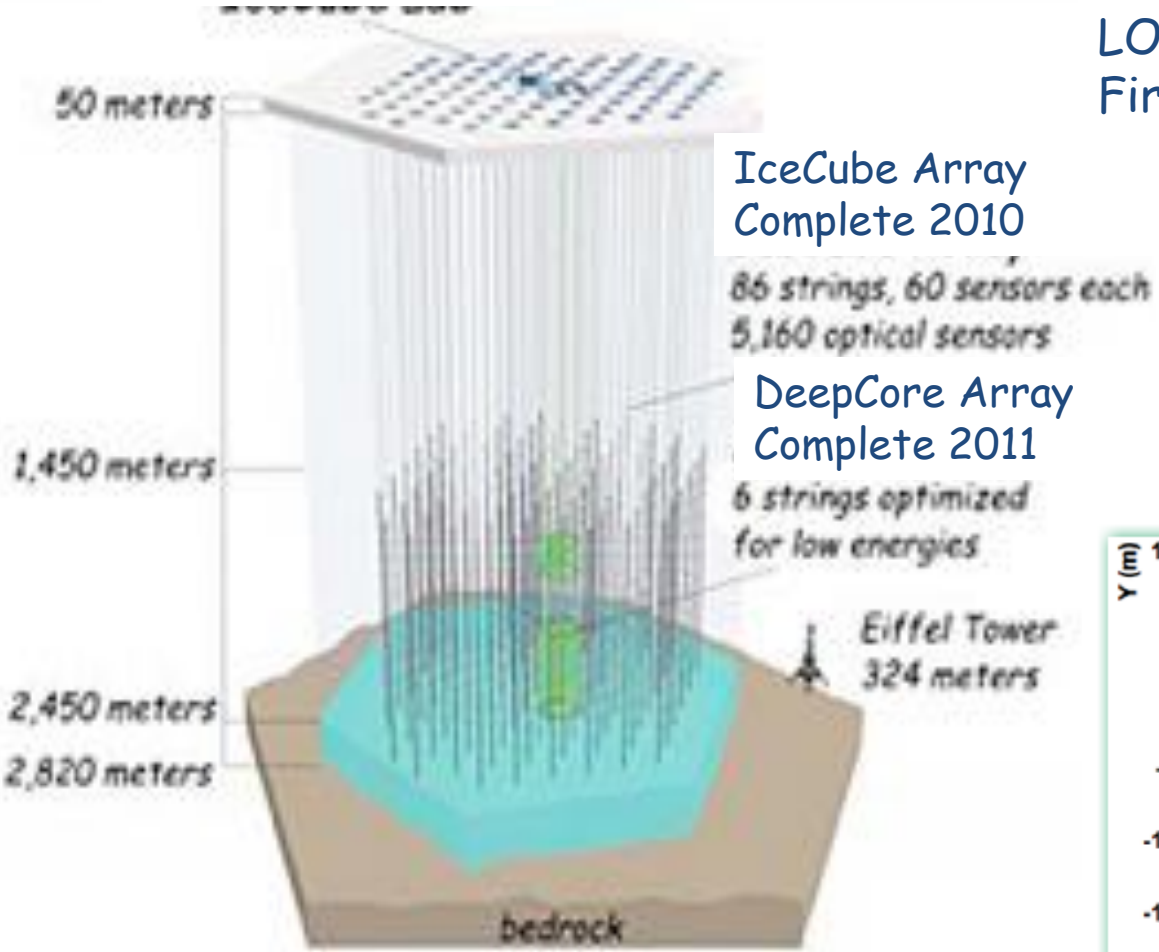
# Timelines

**NSF MRI and CTA-US timeline**

| | |
|---|---|
| 2012-2013 | SCT prototype design |
| 2013-2014 | SCT prototype construction |
| 2014-2015 | SCT prototype commissioning & operation |
| 2016 | CTA-US "CTA Extension" construction proposal |

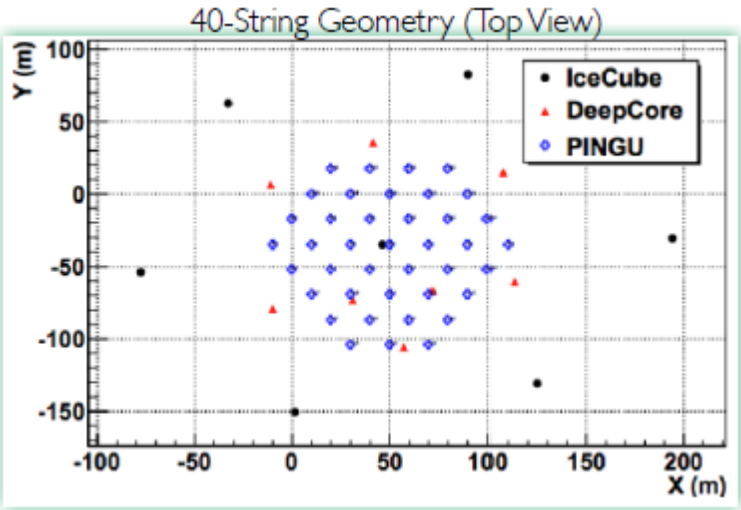
# Facilities: Neutrino Detectors

## IceCube Lab

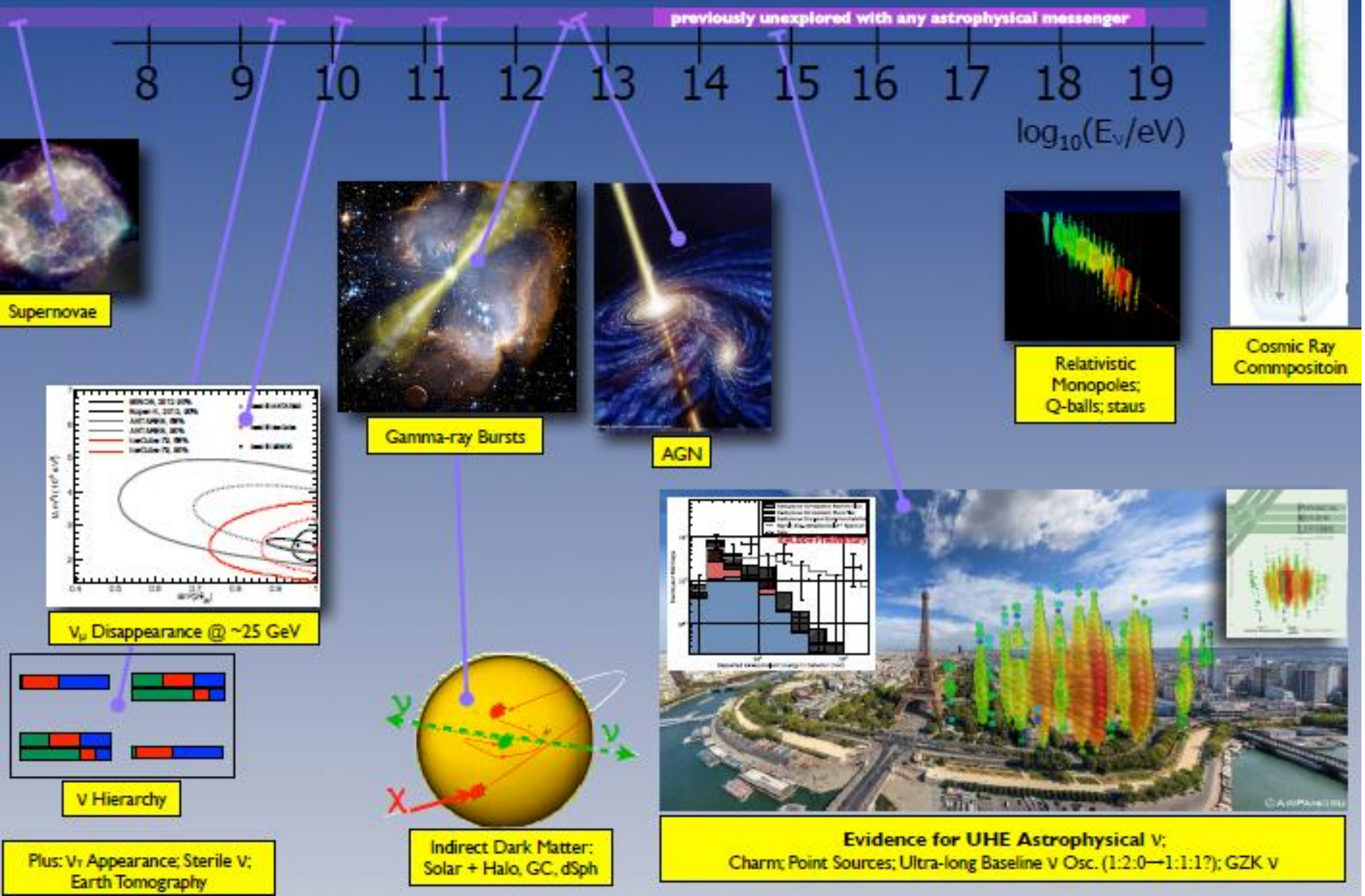



## PINGU – Precision IceCube

Next Generation Upgrade
LOI – next month;
First Light 2019



# Science Reach of IceCube/DeepCore/PINGU



# Searches for Neutrinos from WIMP Dark Matter

Doug Cowen, Penn State

- Potential Sources
- The IceCube Neutrino Detector
- Results from IceCube
- Future Prospects

July 29 - August 6 · Snowmass on the Mississippi · U. Minnesota, Minneapolis, MN

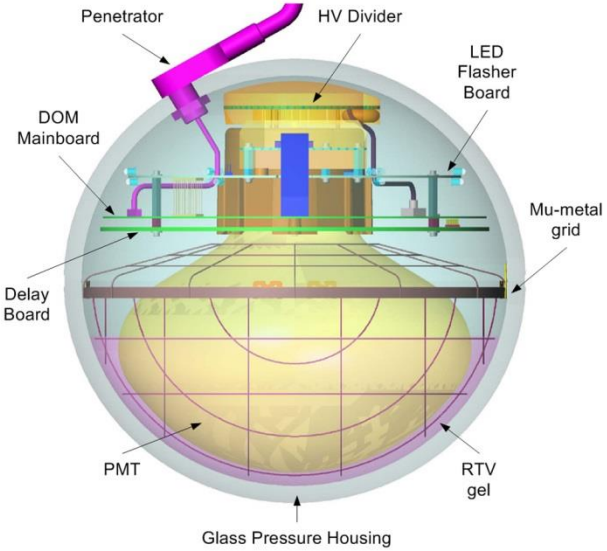
# The IceCube Collaboration

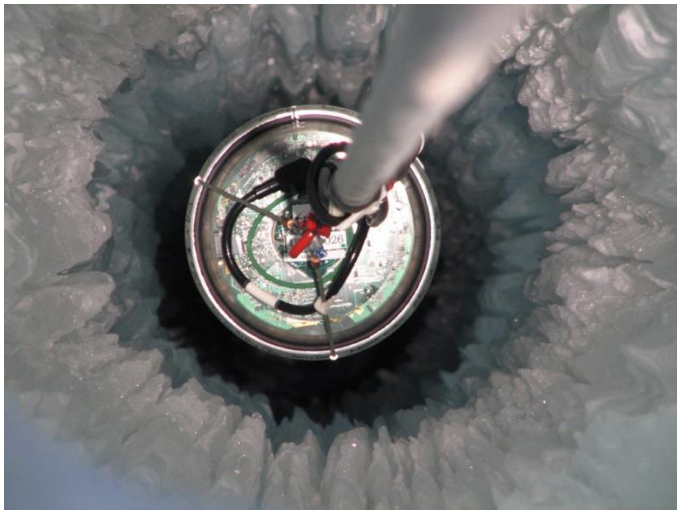
International Funding Agencies

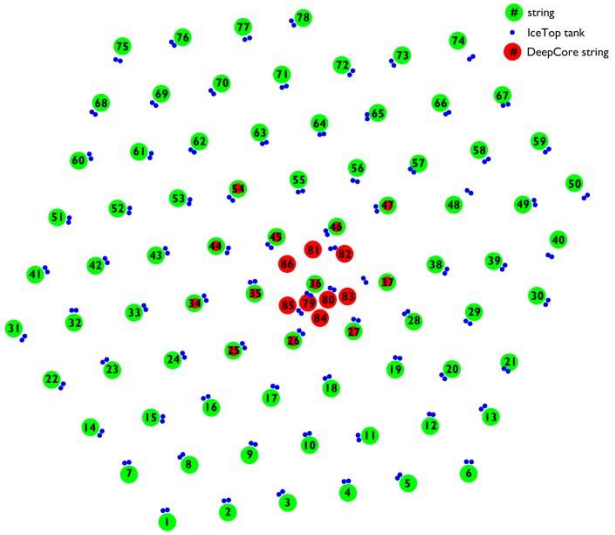
Fonds de la Recherche Scientifique (FRS-FNRS)
Fonds Wetenschappelijk Onderzoek-Vlaanderen (FWO-Vlaanderen)
Federal Ministry of Education & Research (BMBF)
German Research Foundation (DFG)
Deutsches Elektronen-Synchrotron (DESY)
Knut and Alice Wallenberg Foundation
Swedish Polar Research Secretariat
The Swedish Research Council (VR)
University of Wisconsin Alumni Research Foundation (WARF)
US National Science Foundation (NSF)


IceCube includes about 250 researchers from 39 institutions around the world. Prof. Francis Halzen, University of Wisconsin – Madison is the principal investigator and Prof. Olga Botner from Uppsala University serves as the collaboration spokesperson.

# Digital Optical Modules

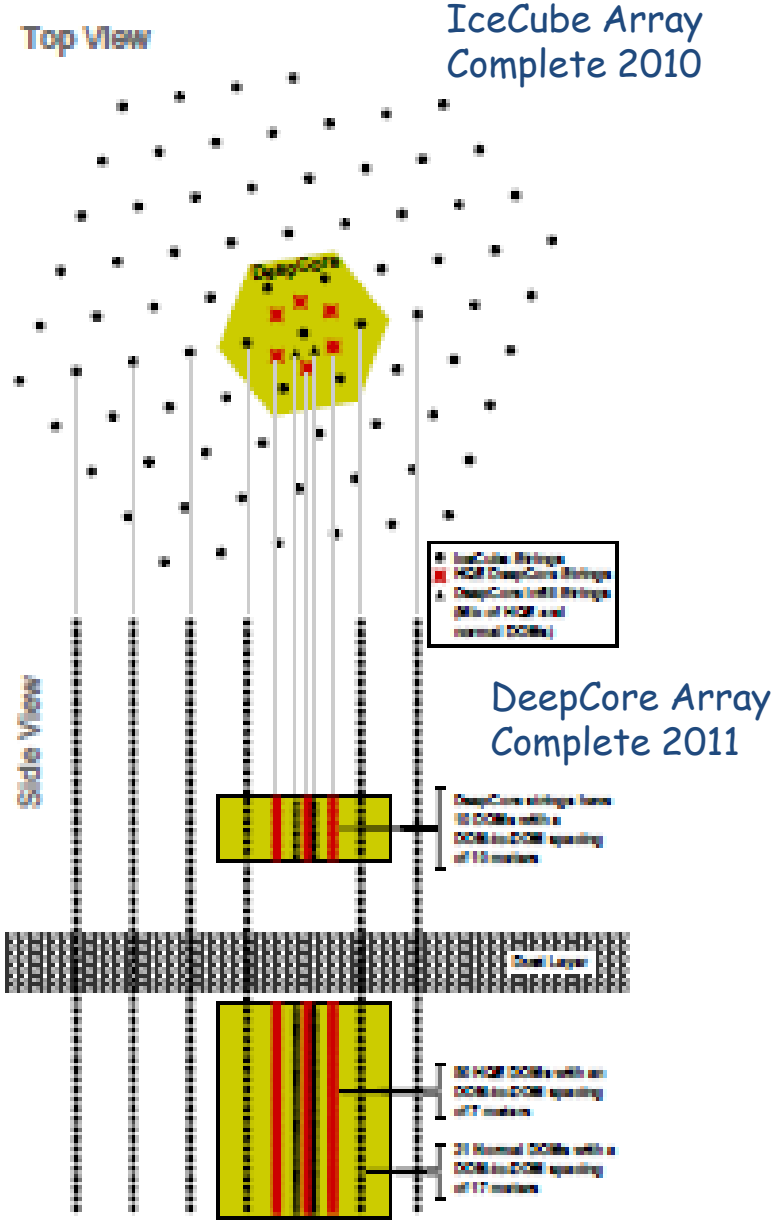






# The IceCube Detector

- First operating km-scale neutrino detector
  - ~5000 10" PMTs
  - 78 strings: 125 m horiz., 17 m vert.
- Originally optimized for TeV-PeV energies
  - now also sensitive to ~10 GeV scale with DeepCore in-fill
    - 8 in-fill strings mostly 72 m & 7 m
- Sensitive to $M_\chi$ from below ~50 GeV to above ~100 TeV
- Physics-quality data taken with partially completed detector
  - IC-22, IC-40, IC-59, IC-79
    - IC-79 volume is about 1 $km^3$



# PINGU & WIMPs

- PINGU: Precision IceCube Next Generation Upgrade
  - New IceCube in-fill array, to be proposed in fall 2013
  - Main physics goal: neutrino mass hierarchy with atmospheric neutrinos
    - see talk by T. DeYoung
      - 11:00 Weds., Anderson 250
  - But also has sensitivity to WIMPs, especially at lower WIMP masses

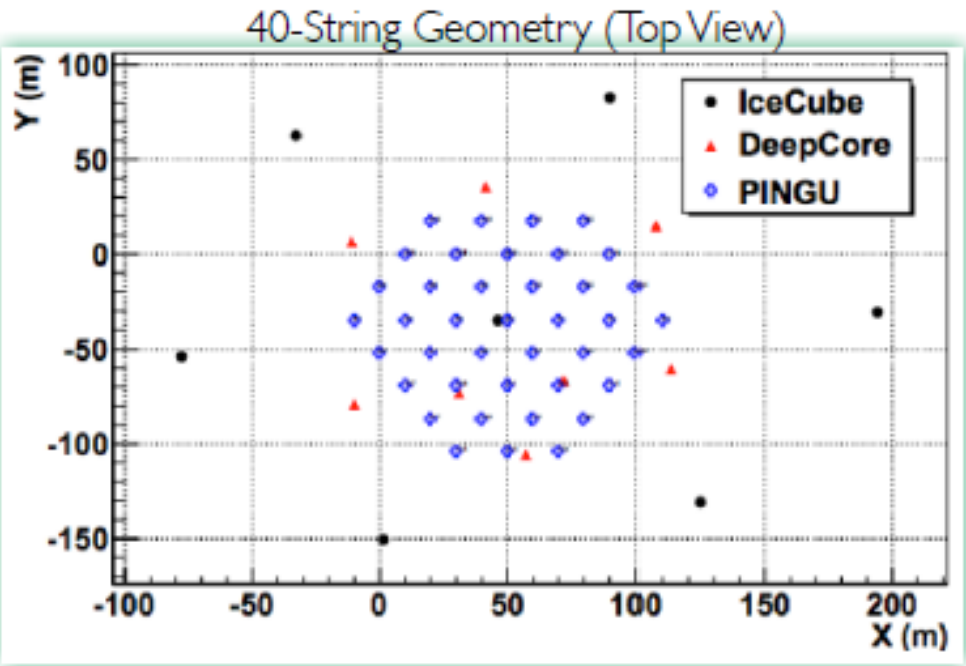
© [2011] The Pygos Group

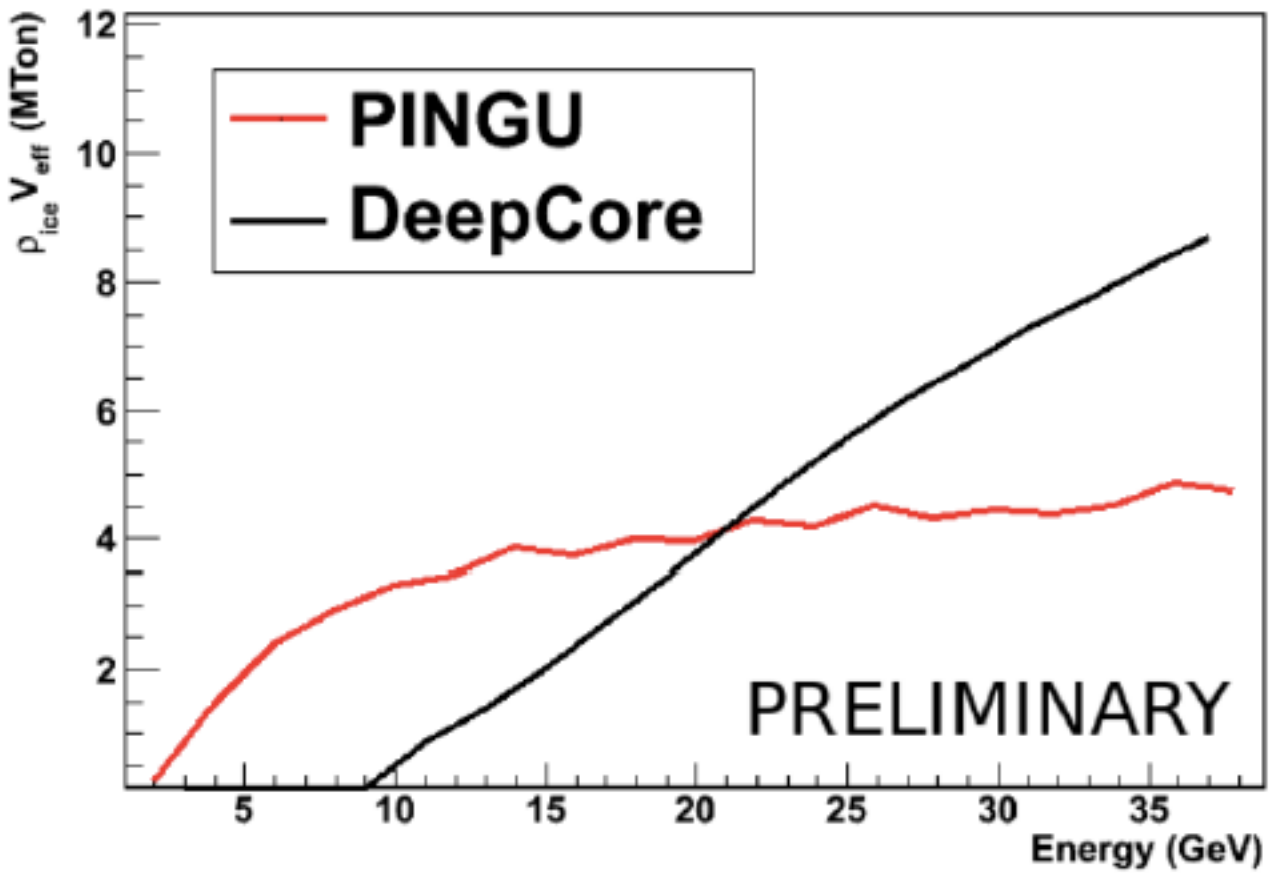
# The PINGU Collaboration

Plus: U. Erlangen, U. Manchester, NBI Copenhagen, Sungkyunkwan U., U. Tokyo, U. Toronto

# PINGU Detector

- Further increase sensor density relative to DeepCore
  - Baseline geometry has ~40 additional strings @ 60 DOMs
    - IceCube-based technology plus R&D modules
    - Include new low-E calibration devices
    - Geometry optimization underway
  - Aims:
    - Physics program at $E_{thr}$ ~ few GeV
      - Neutrino mass hierarchy
      - Low mass WIMPs ($M_\chi$~10-100 GeV)
    - R&D: Cherenkov ring segment reco.?



# PINGU Fiducial Volume

- Below $E_\nu \sim 20$ GeV, PINGU provides gain in fiducial mass relative to the existing low $E_\nu$ in-fill, DeepCore