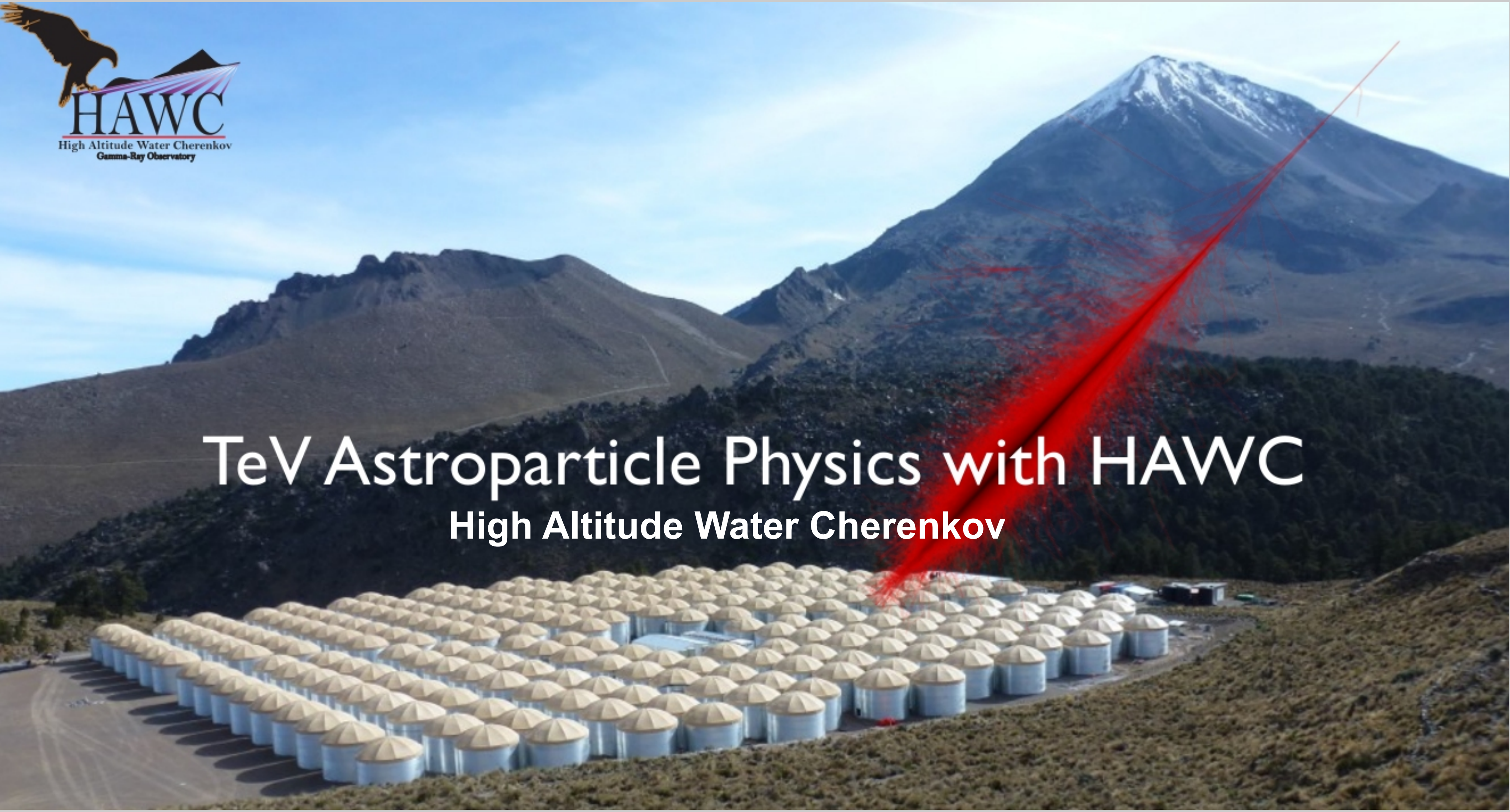


TeV Astroparticle Physics with HAWC

High Altitude Water Cherenkov

Luis Carrasco, INAOE


HAWC
High Altitude Water Cherenkov
Colorado State University
Georgia Institute of Technology
George Mason University
Los Alamos National Laboratory
Michigan State University
Michigan Technological University
University of New Hampshire
Pennsylvania State University
University of Alabama
University of California, Irvine
University of California, Santa Cruz
University of Maryland
University of New Mexico
University of Wisconsin-Madison
University of Utah
Centro de Investigacion en Computacion, Instituto Politecnico Nacional
Centro de Investigacion y de Estudios Avanzados del IPN
Benemérita Universidad Autónoma de Puebla
Universidad Nacional Autónoma de México:
Instituto de Astronomía
Instituto de Ciencias Nucleares
Instituto de Física
Instituto de Geofísica
Instituto Nacional de Astrofísica, Óptica y Electrónica
Universidad Autónoma del Estado de Hidalgo
Universidad Michoacana de San Nicolás de Hidalgo
Universidad Autónoma de Chiapas
Universidad Politecnica de Pachuca
Universidad de Guadalajara
HAWC Collaboration Meeting, February 25-27, 2014
Universidad Autónoma del Estado de Hidalgo
Pachuca, Hidalgo
~100 members
15 U.S. institutions
13 Mexican institutions

<u>Important Dates</u>

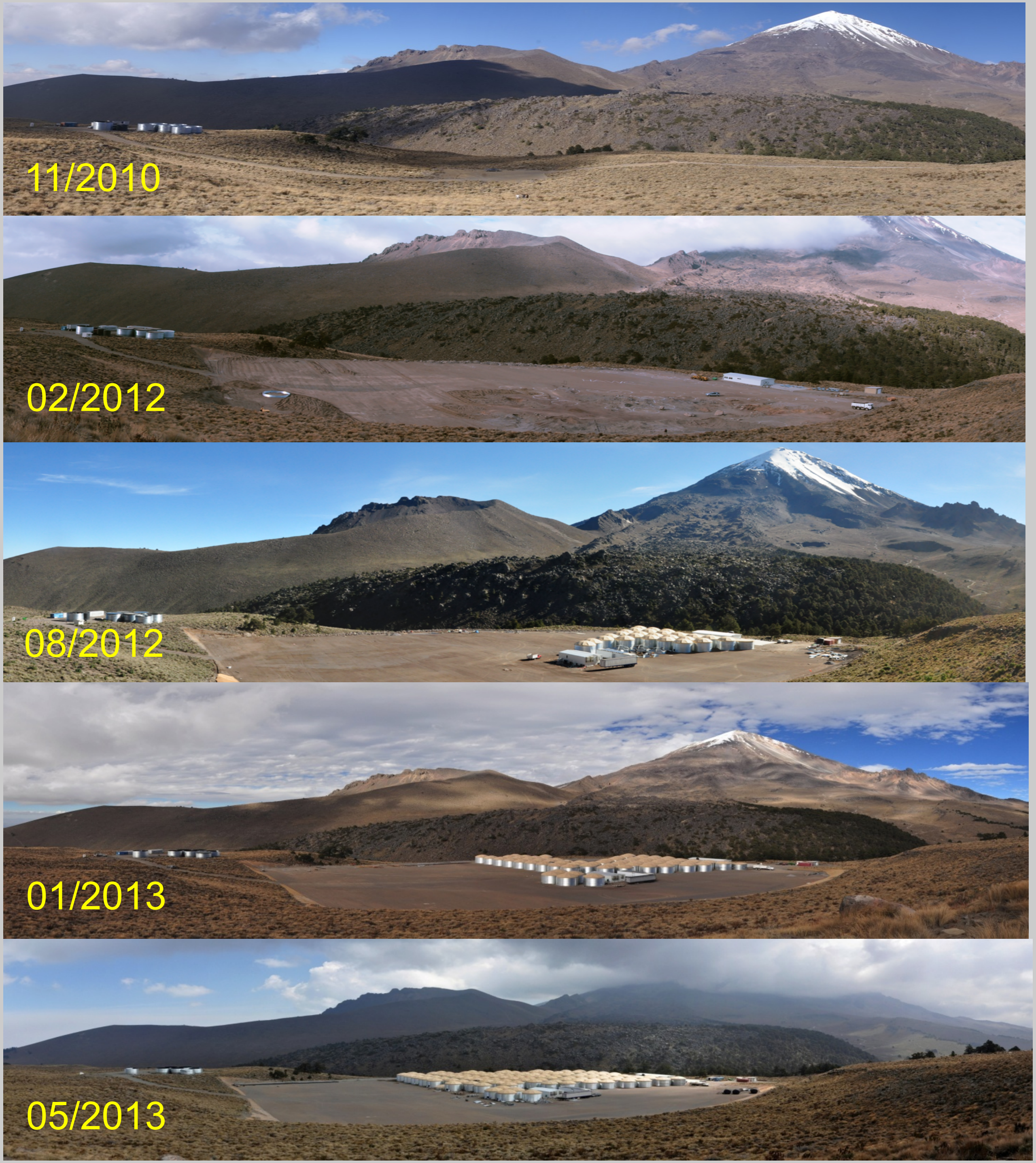
2007 Cosmic Ray Conference in Mérida Mex.

Milagro collaboration was looking for a **higher site** with **infrastructure** and **physic community**

$13M project funding began Feb 2011

Operations with 100 water Cherenkov detectors in Aug 2013

Observatory complete in Aug 2014

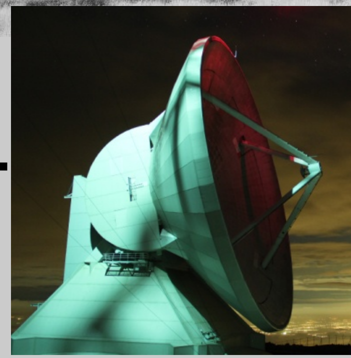



250th WCD tank constructed May 15, 2014

Observatories

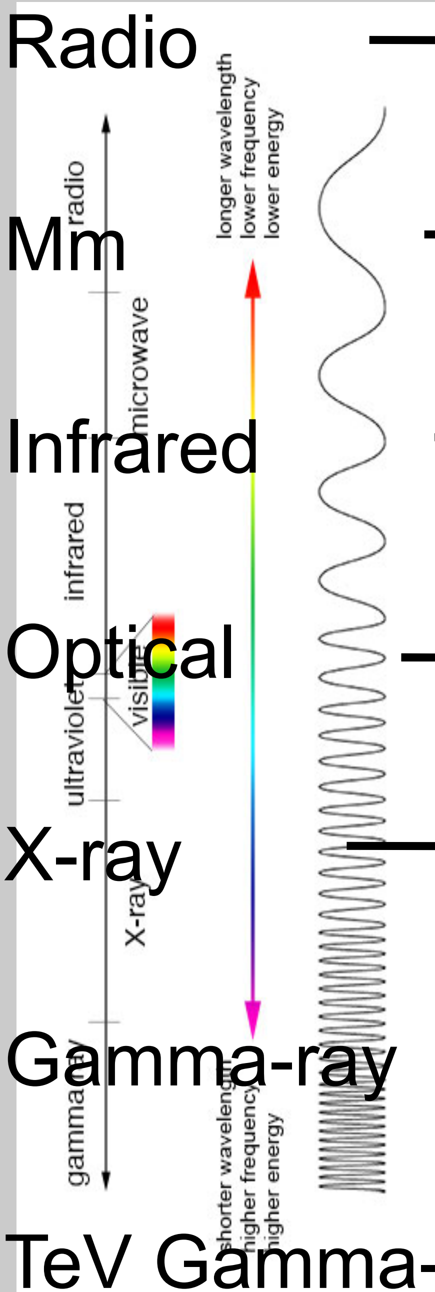
Non Thermal (e.g. synchrotron)

Radio



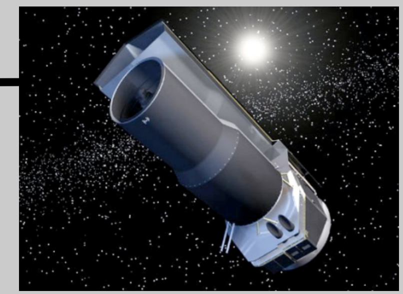
Thermal, T~ 10 K

Mm



T~ 50 K

Infrared



T~ 6000 K

Optical

X-ray

T~ 1000000 K

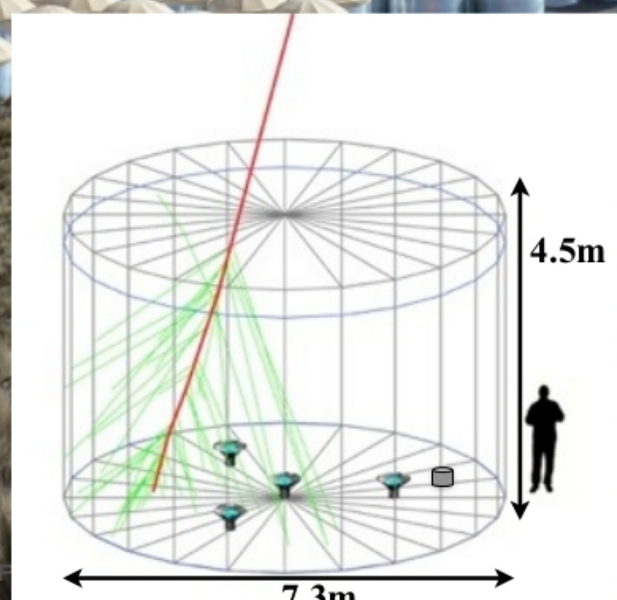
Gamma-ray

Non Thermal (synchrotron, Inverse Compton)

TeV Gamma-ray

High Altitude Water Cherenkov Gamma-ray Observatory

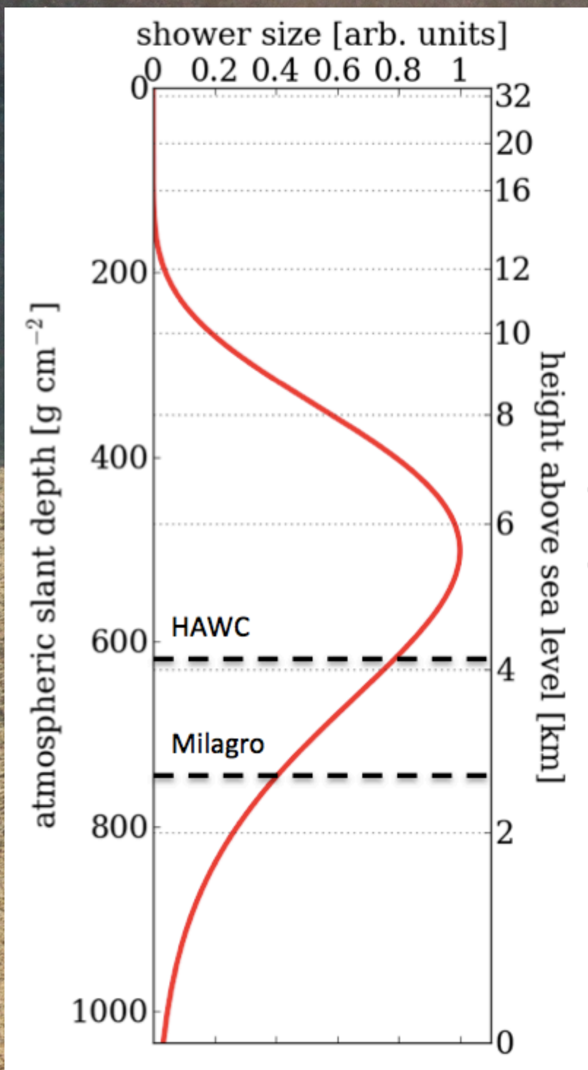
- High altitude (4100 m) site at Sierra Negra, Mexico.
- Second generation of technique developed for the Milagro gamma-ray observatory (2000-2008).
- Large tanks of water covering 22,000 m^2 area.
- Each contains 3 8" PMTs and 1 central 10" PMT.
- Sensitive from 100 GeV to 100 TeV.
- Angular resolution 1.0 – 0.1 degrees.
- 2sr instantaneous field of view.
- >90% duty cycle.
- Overall 15x improvement in sensitivity over Milagro.
- See the Crab at over 5σ every day.
- ***Strengths:***
  - ***Extreme high-energy reach.***
  - ***Wide field-of-view: ideal for transients and extended objects.***



How can HAWC be so much more sensitive than Milagro with the same number of PMTs?

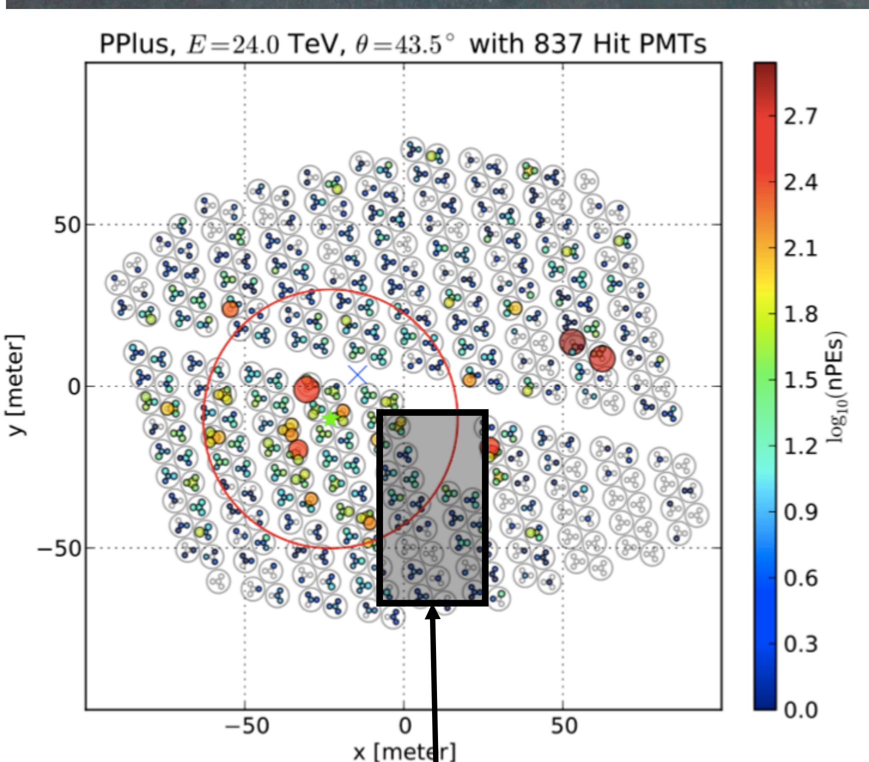
High Altitude = Better Statistics

>5x # of detectable shower particles relative to Milagro



Hadron rejection area and shower sampling

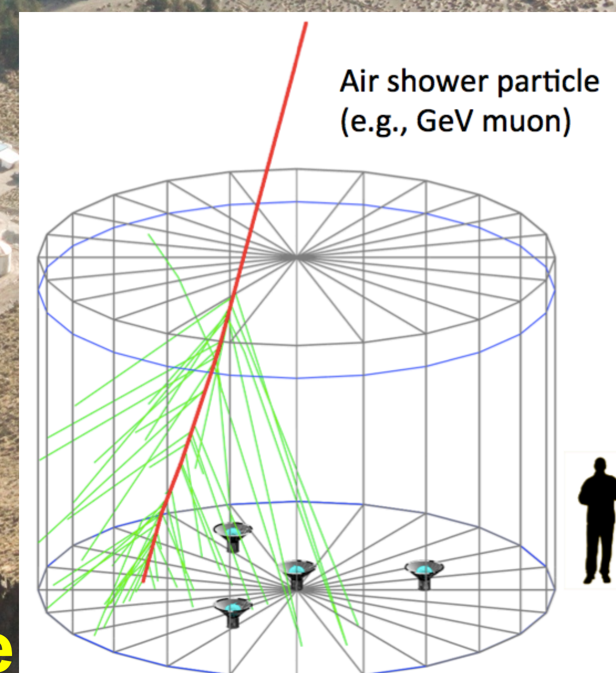
10x Larger particle detection area (~22,000m^2)



Milagro bottom layer size

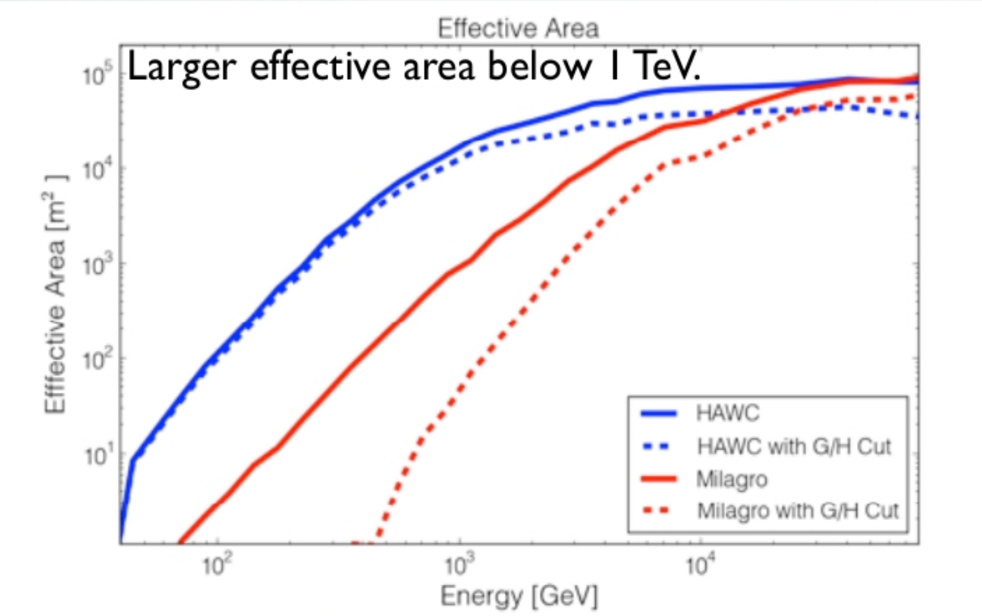
Improved Angular & Energy Resolution

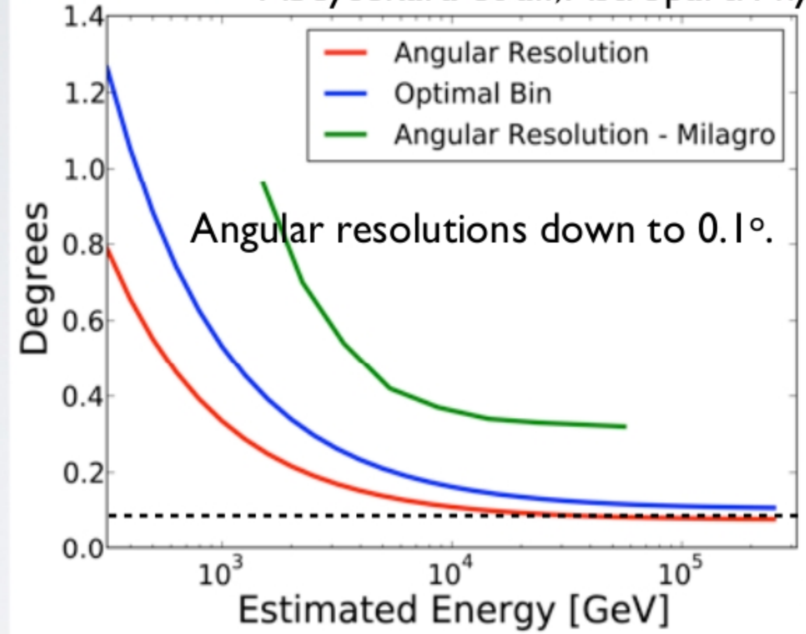
Optical isolation of detector elements

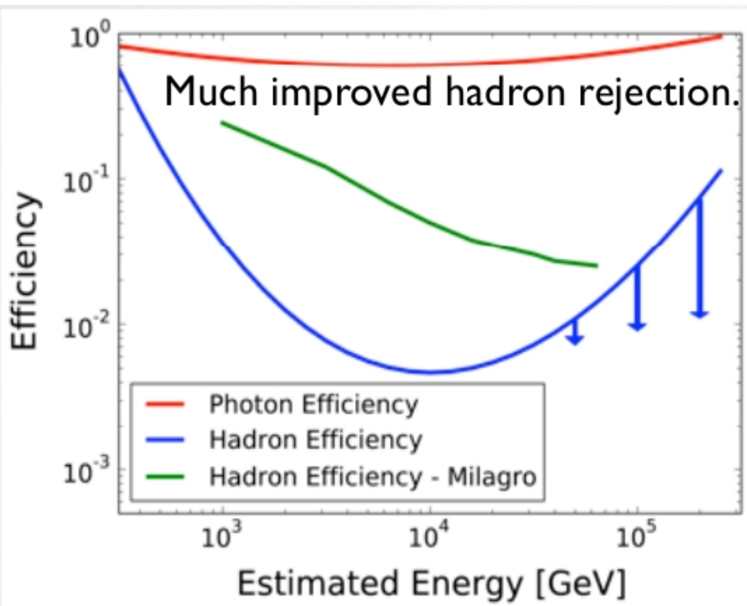


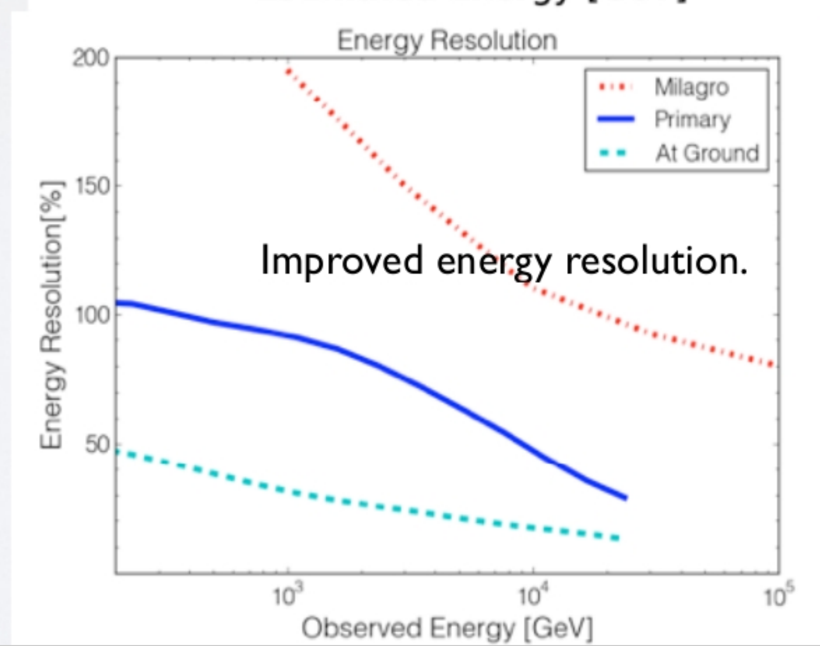
HAWC Performance

Abeysekara et al., Astropart. Phy. (2013)

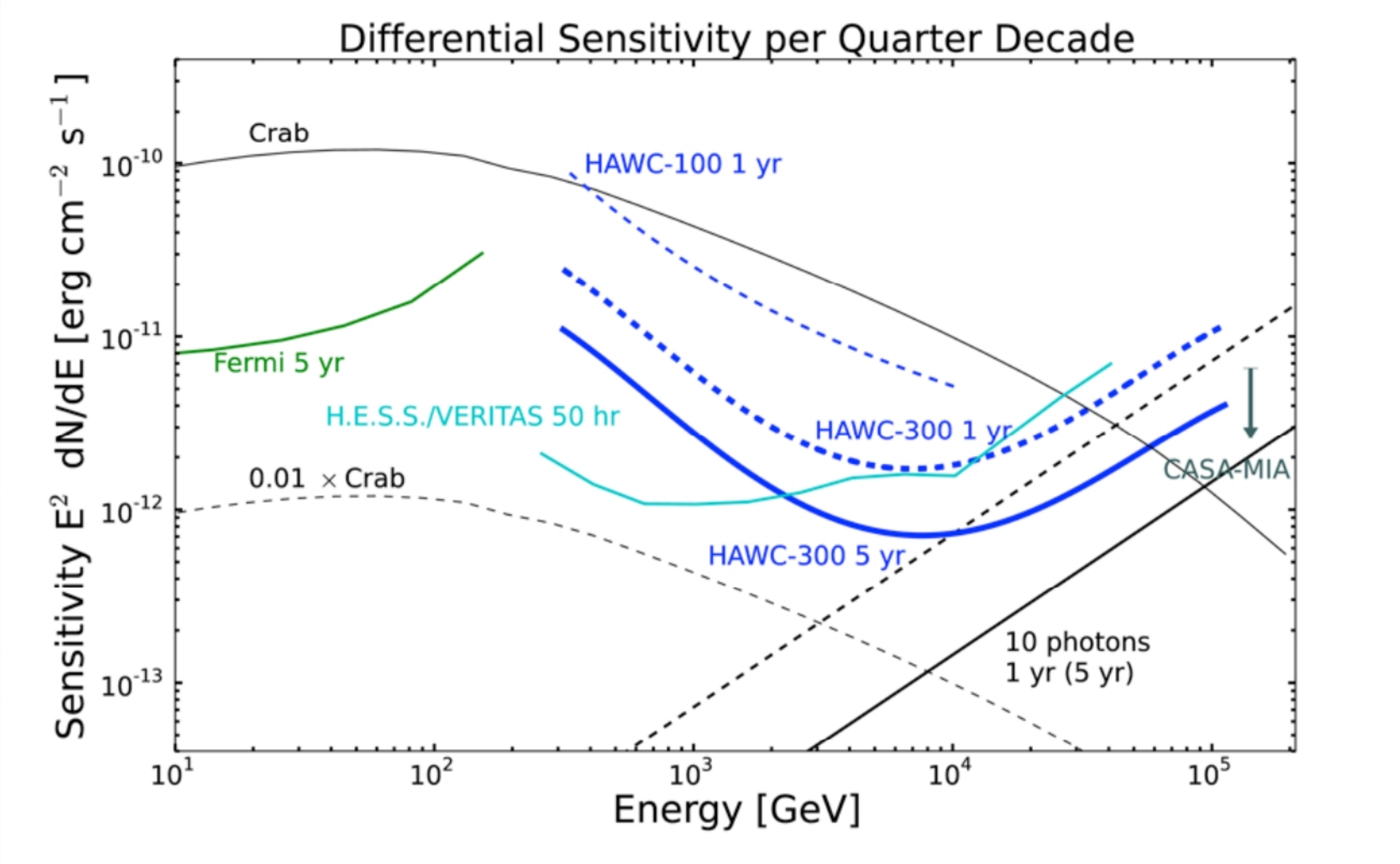




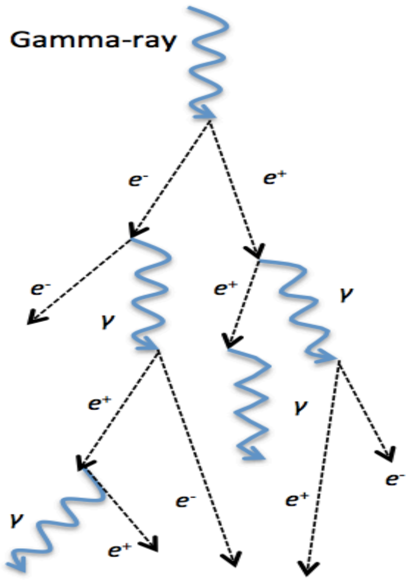


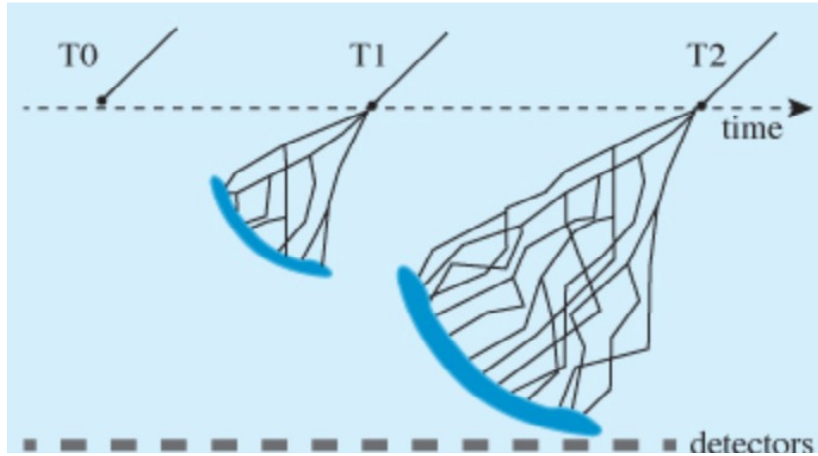


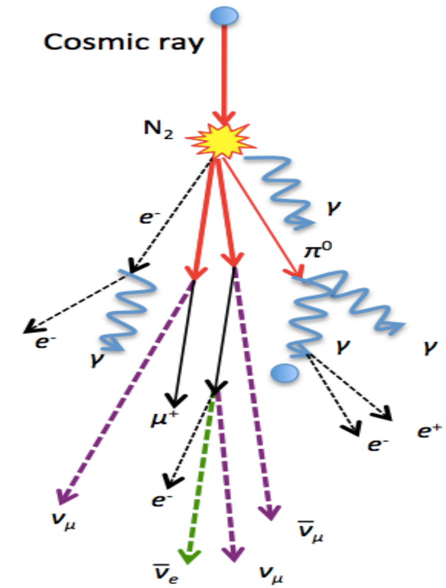
HAWC Performance

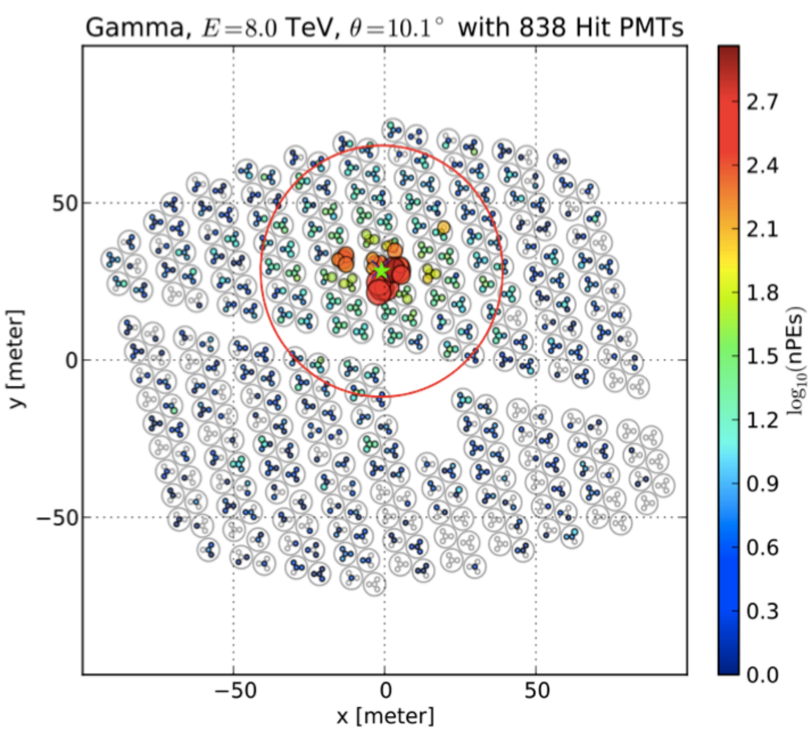


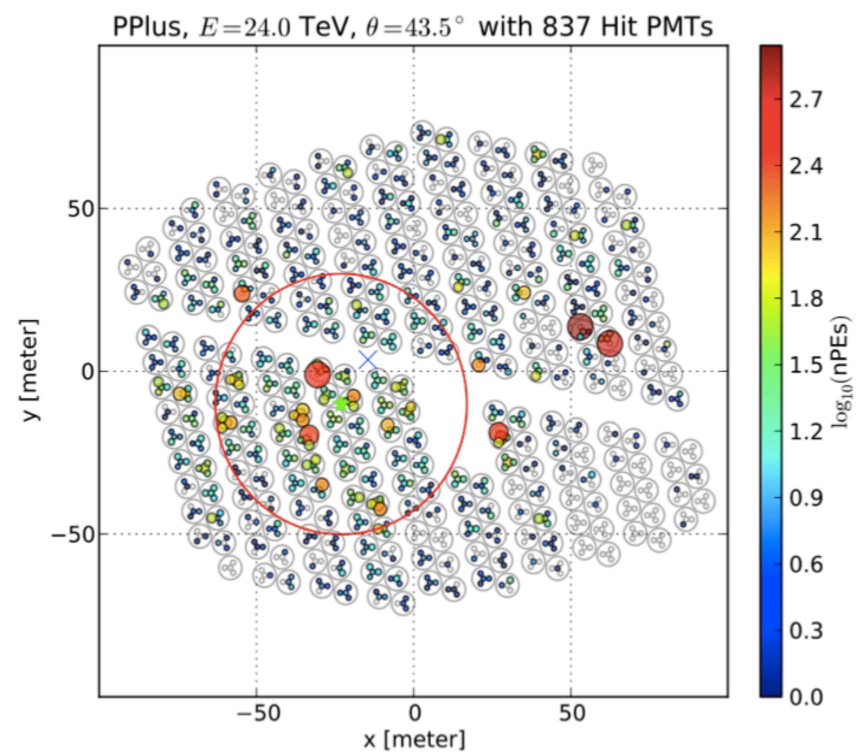
Gamma/Hadron Separation



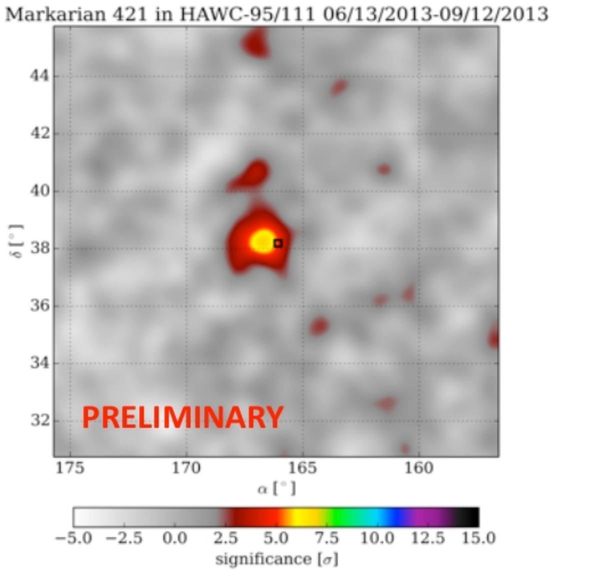


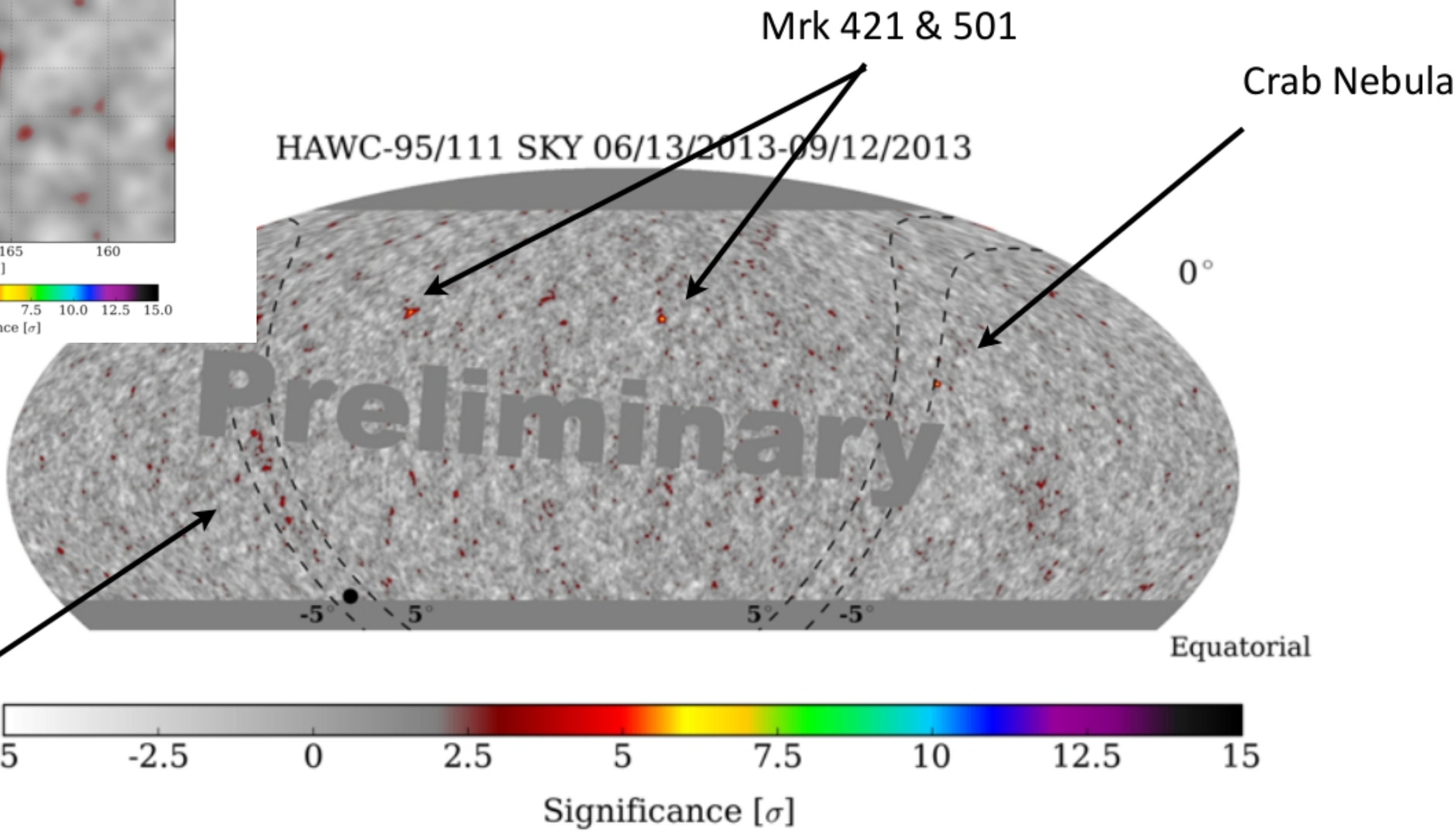






All-Sky Map





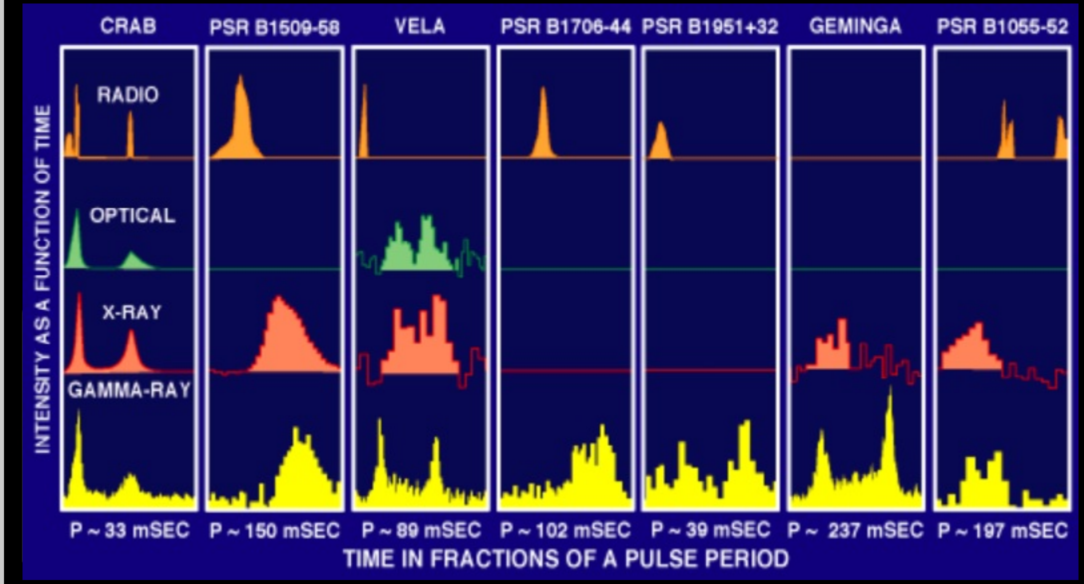
Caveats:

Absolute pointing uncertainties.
Very preliminary calibration.
Subset of the data reconstructed "online".
Many small analysis issues TBD yet.

- Clear association with sources in the plane with 3 months of partially completed detector.
- Hot spots near many known TeVCat sources.
- Very Exciting!!

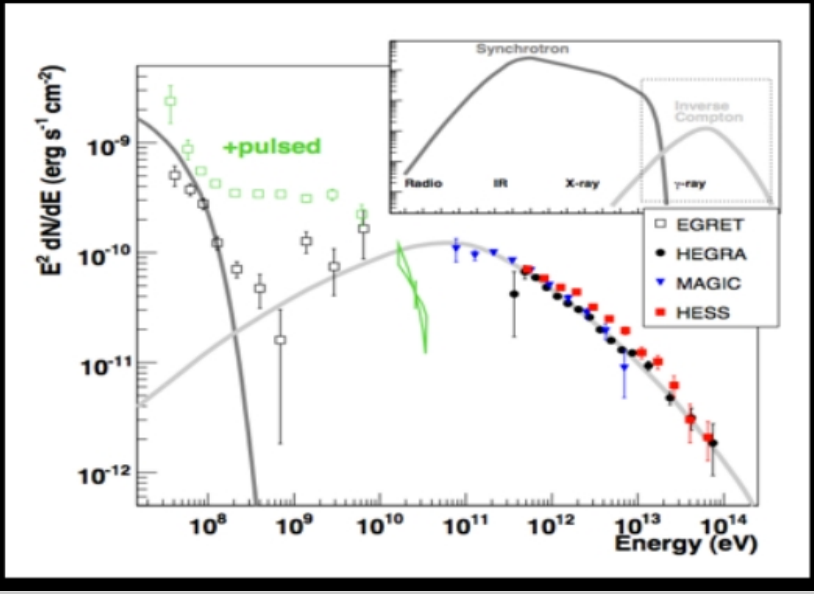
Astronomical Targets

Pulsar Wind Nebulae



Most common Galactic TeV sources.
Many of them are extended.
Complex background for searches of more exotic gamma-ray production (e.g. dark matter).
Crab flares hard to understand
- Continues to TeV Inverse Compton emission?
- Flares in other PWN?

Potential sources of Cosmic Rays

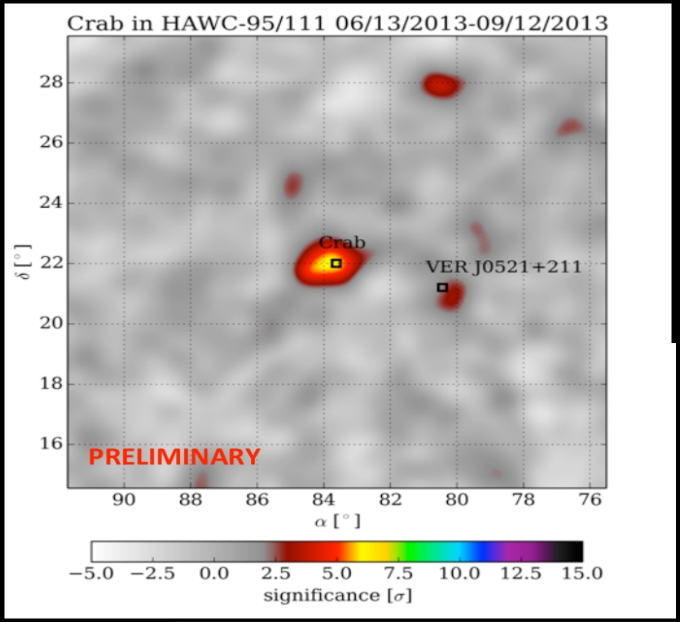


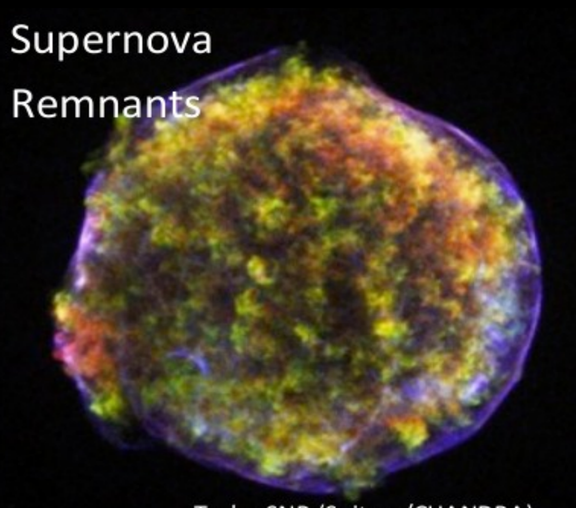
Chandra Image of the Crab PWN

Astronomical Targets

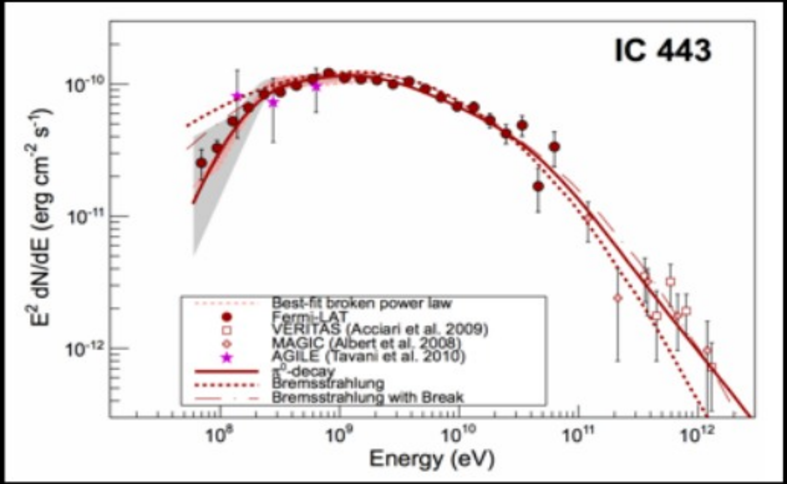
Supernova Remnants

Strong evidence for cosmic ray acceleration (e.g. Araya & Cui 2010 in Cassiopeia A)
- Association of HE emission with dense molecular clouds
- Observation of characteristic pion emission
How high does the emission go? Flux implied by Milagro in IC443 is 10x larger than the extrapolation of the VERITAS spectrum



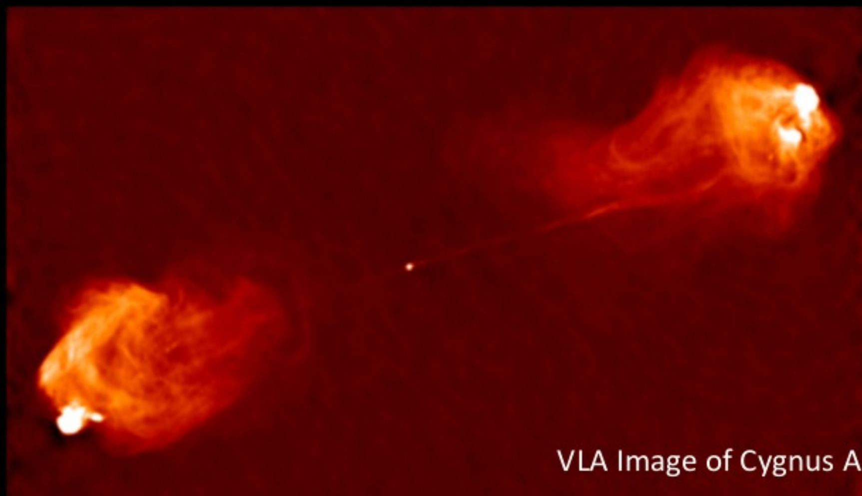


Tycho SNR (Spitzer/CHANDRA)

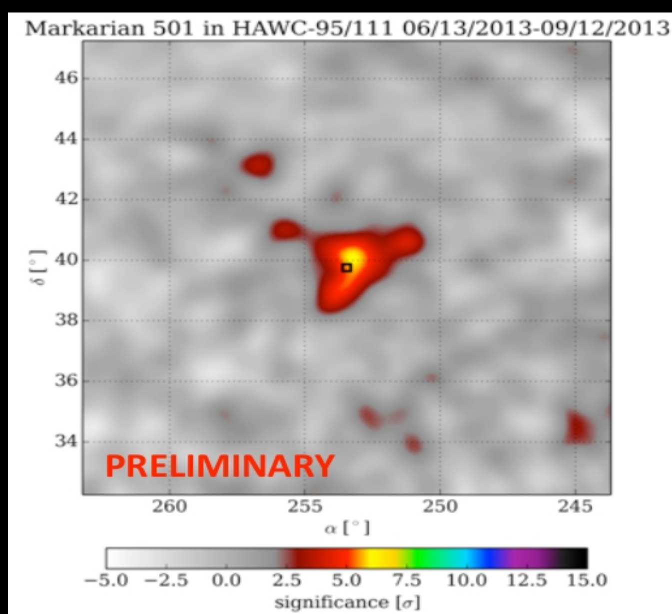


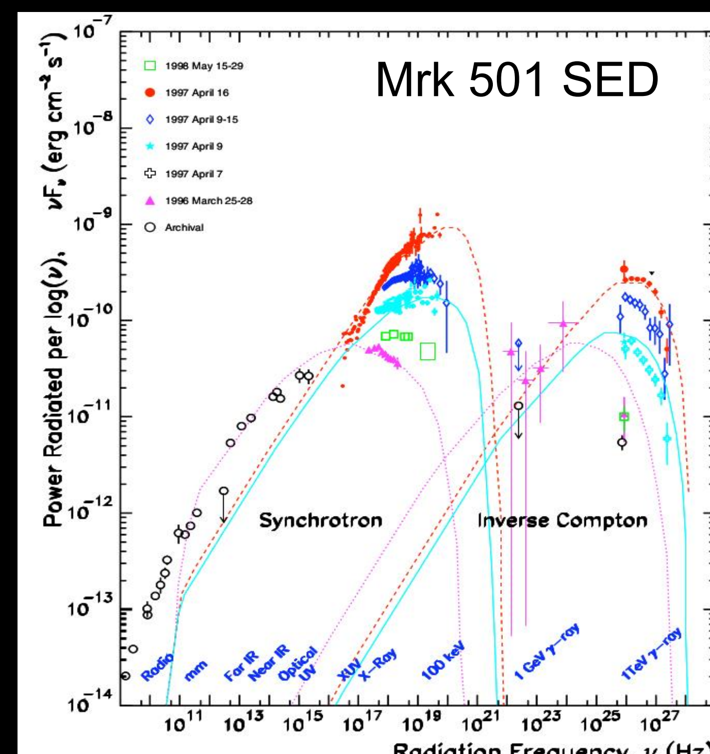
Astronomical Targets

Active Galactic Nuclei



- Origin of the strong flares seen in TeV
- Unbiased TeV survey will find more flares
- Understand the correlation between Synchrotron and Inverse Compton emission
- Studies of the Extragalactic Background Radiation (EBL)





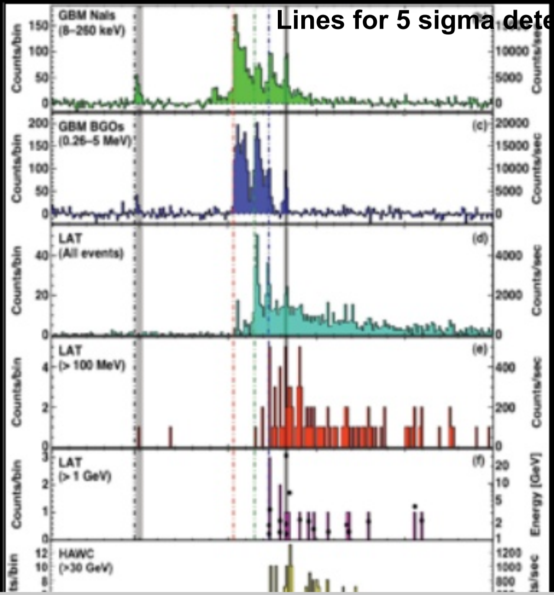
Astronomical Targets

Gamma-Ray Bursts

Origin of the TeV emission in GRBs, neutron star-neutron star or neutron star-black hole mergers, millisecond magnetars and the core collapse of massive stars.

Studies of the EBL with GRB

Two detection methods, the main DAQ will acquire and reconstruct data on a shower by shower basis. The scaler system will search for a statistical excess on the combined rate of all PMTs.

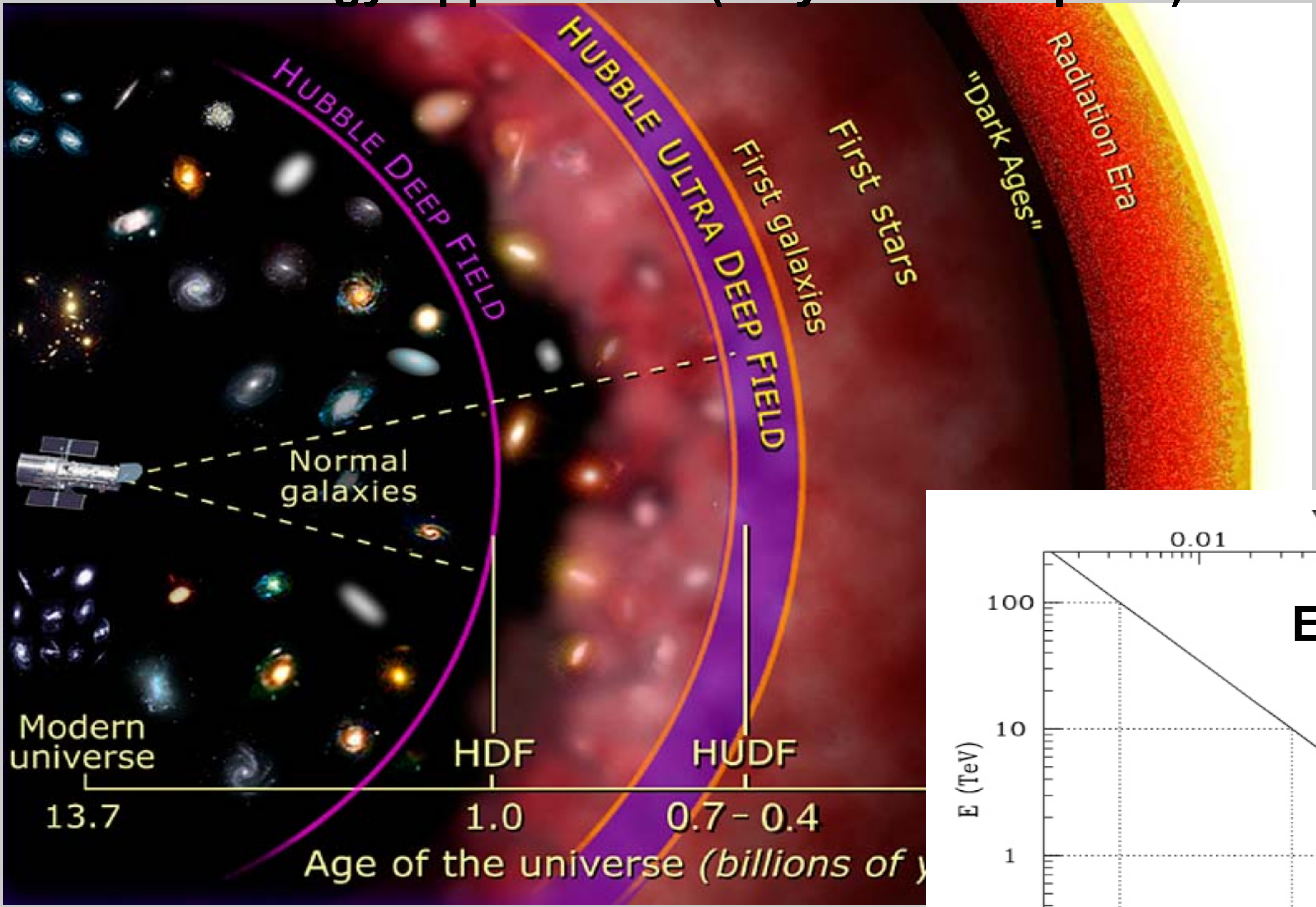


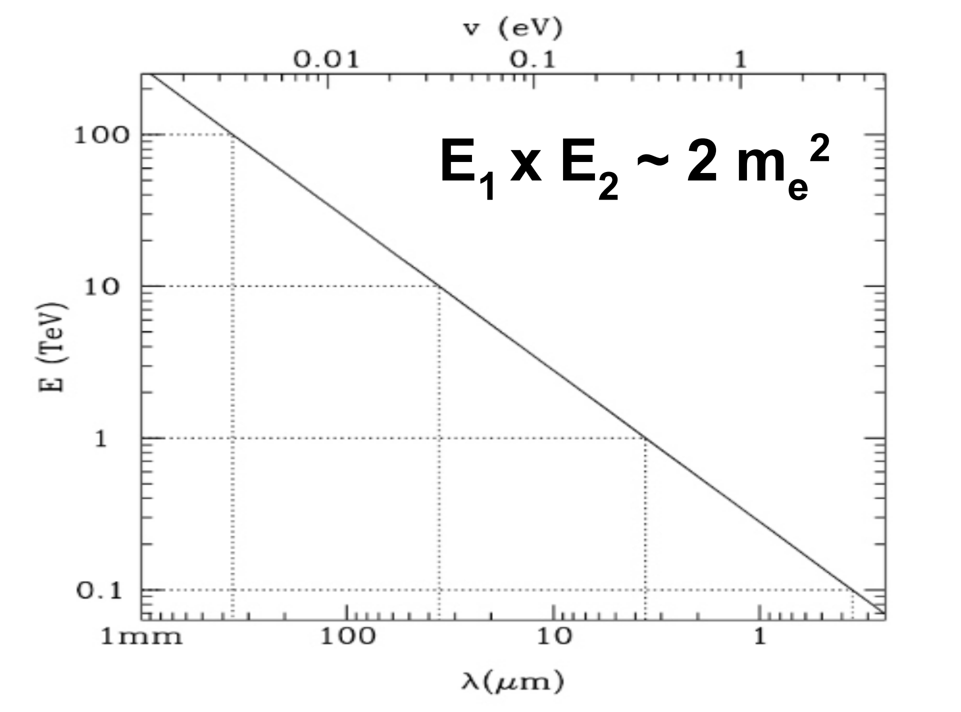
Continuation of Fermi-LAT "rising" GeV component.

Ground-based (cheap) trigger for IACTs.

Extragalactic Background Light (EBL)

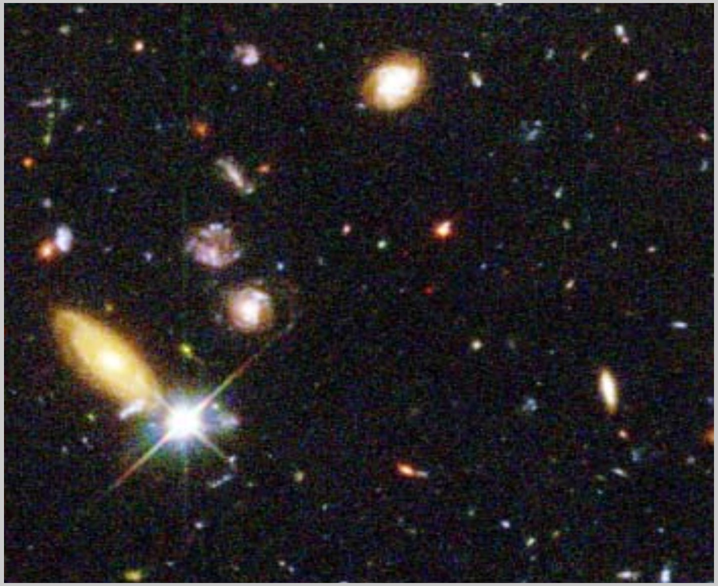
Intrinsic spectral energy distribution of extragalactic sources
Cosmology Applications (Lilly & Madau plots)



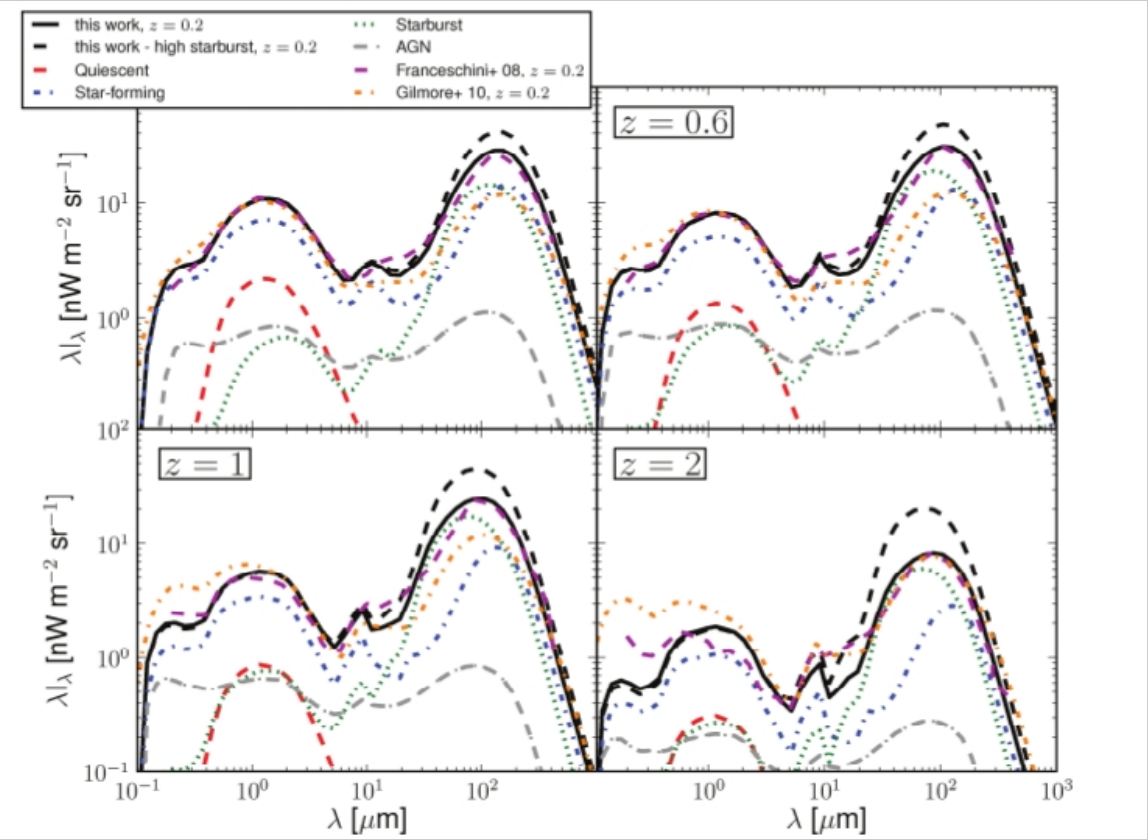


$$\gamma\gamma \rightarrow e^+e^-$$

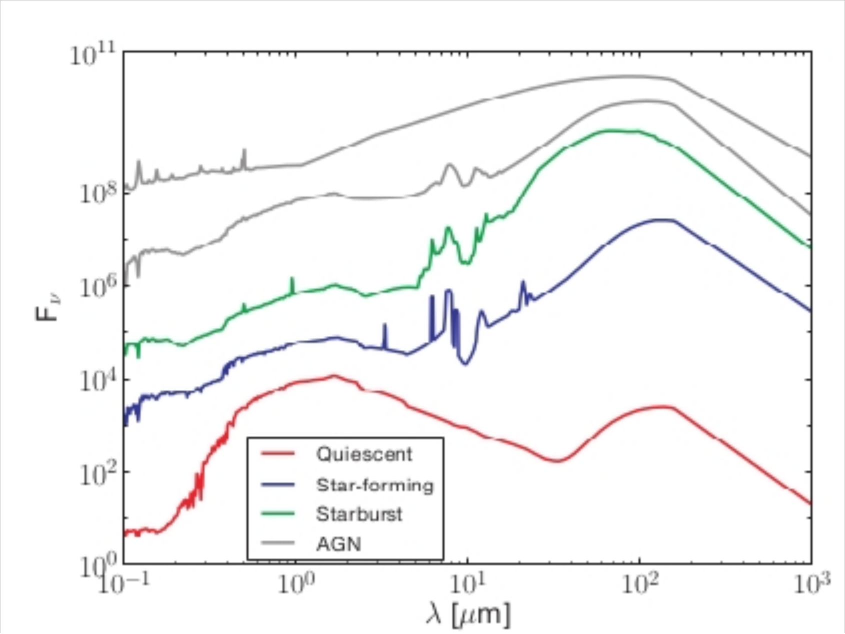
Creating your own EBL model



2.- Adding the SEDs you get the evolution of the EBL as a function of redshift



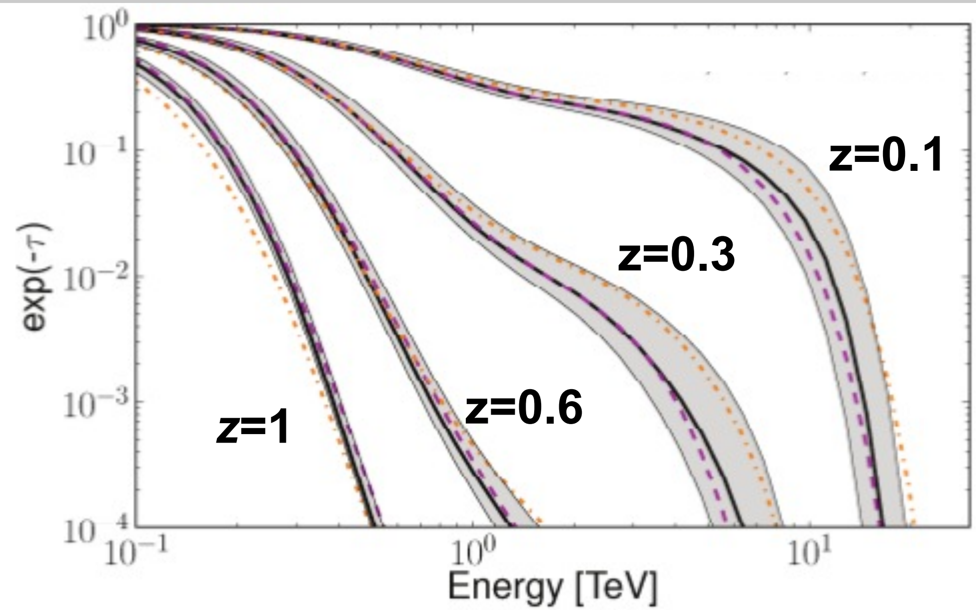
1.- Assign a redshift and a SED to each galaxy

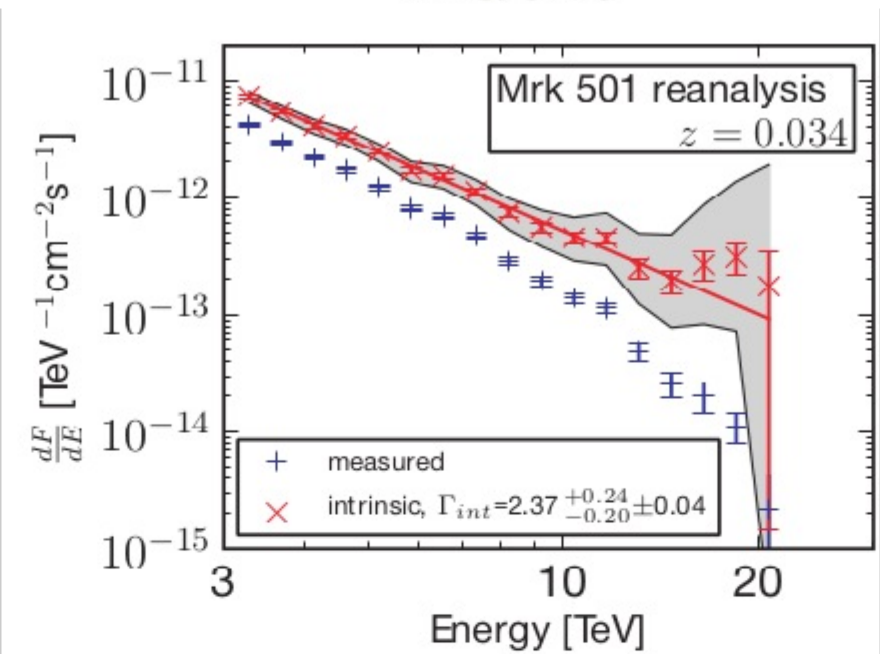


3.- Sum all the contributions to get the integrated EBL at *z=0*

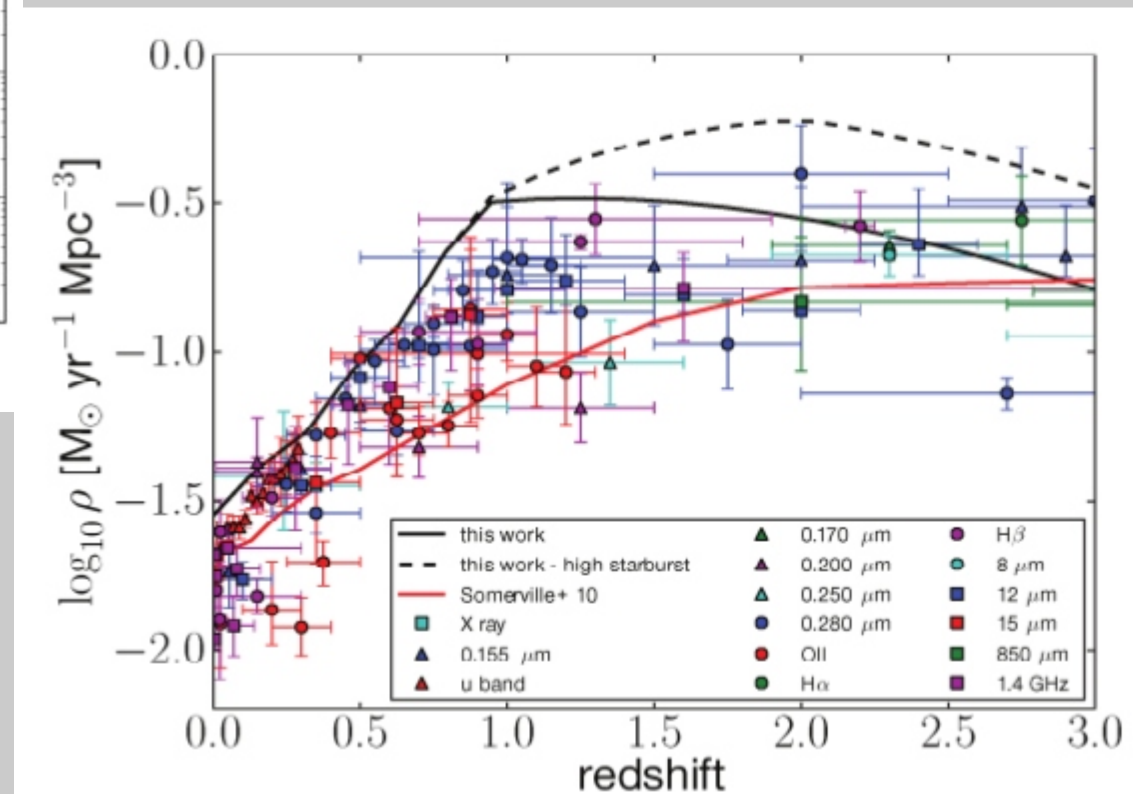
e.g. Domínguez et al. 2011, MNRAS, 410, 2556

Outputs of the EBL models





Cosmological applications: Evolution of the Star Formation Rate Density



e.g. Domínguez et al. 2011, MNRAS, 410, 2556

Conclusions

HAWC is a large-field-of-view, high duty-cycle multi-purpose instrument with high discovery potential (survey the sky with ~50 mCrab sensitivity over 8sr of sky at ~1 TeV)

High Altitude Water Cherenkov
Gamma-Ray Observatory

Data collection with full array starts this year,
but rigth now, Terabytes of data ready to be analyzed

Physics include

Origin, evolution, and acceleration of cosmic rays

Study known sources: Supernova remnants, pulsar wind nebulae, binary systems, gamma ray bursts, active galactic nuclei

Analysis of Solar Forbush after coronal mass ejection

Extragalactic Background Radiation

Discover unknown sources and structures

Dark matter, exotic physics (e.g. Lorentz violation)

Great oportunities for Msc and PhD Students

- Astronomy and particle physics
- Software development and data analysis
- Electronics