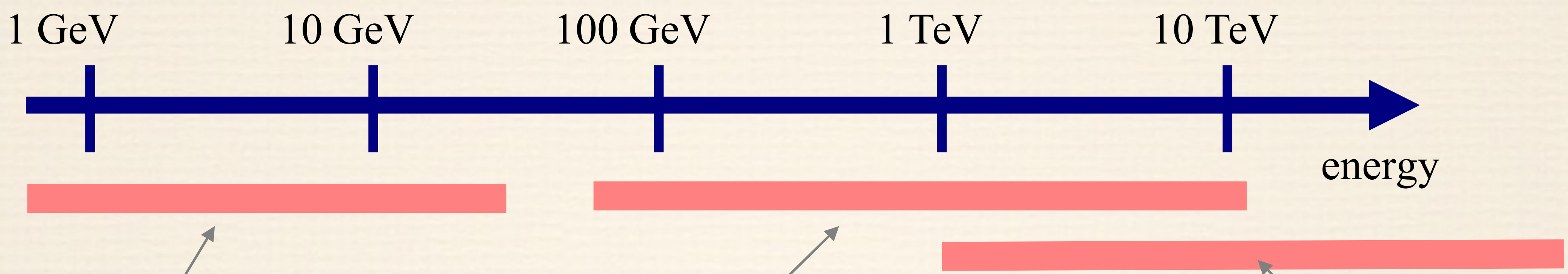
VERITAS
and
Its computational challenges

Udara Abeysekara
University of Utah

Gamma-Ray Instruments

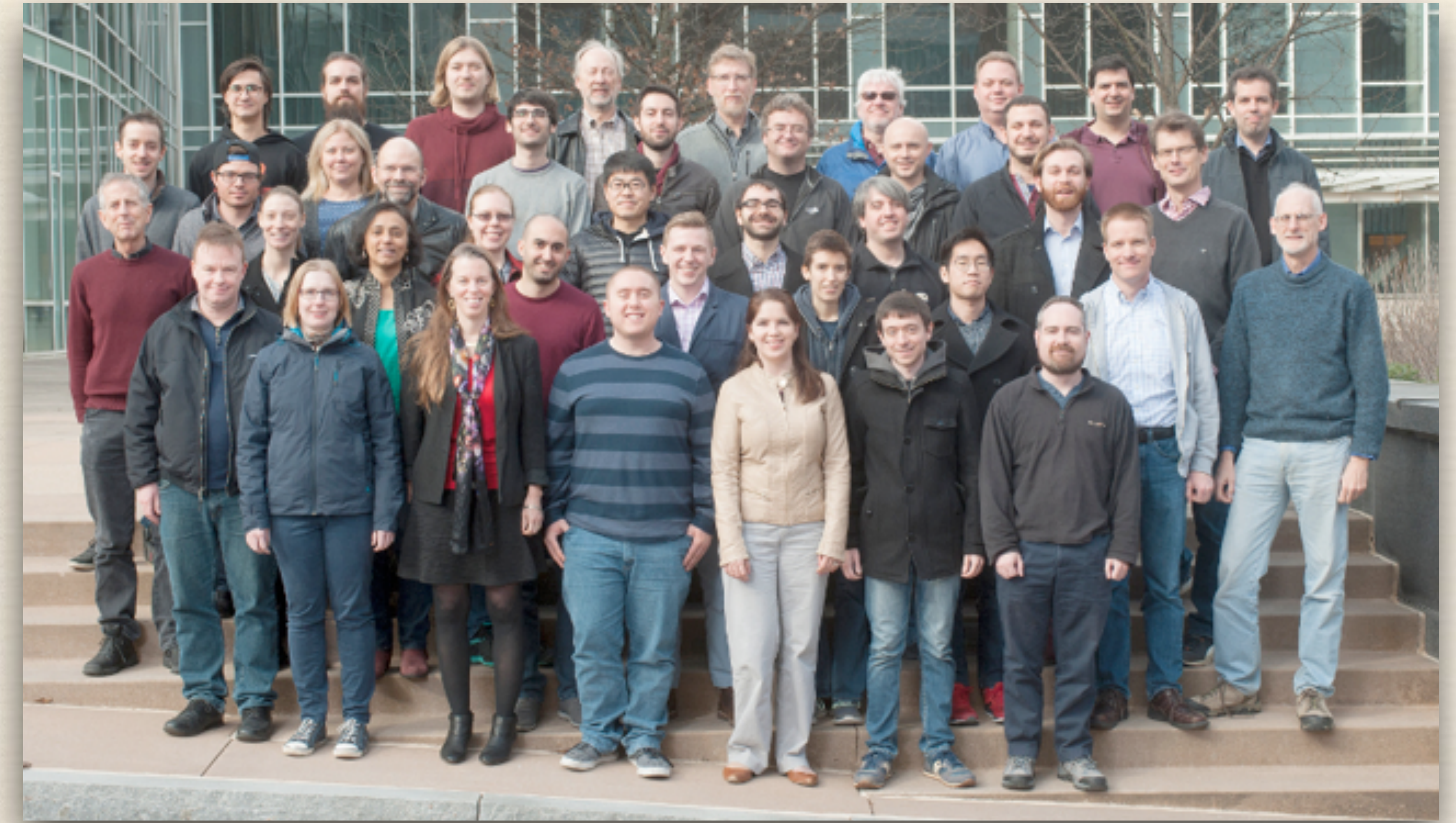


Satellites: Fermi-LAT

Cherenkov telescopes:
like VERITAS and CTA

Water Cherenkov detectors: HAWC

VERITAS Collaboration



Acknowledgments: This research is supported by grants from the U.S. Department of Energy Office of Science, the U.S. National Science Foundation and the Smithsonian Institution, by NSERC in Canada, and by the Science Foundation Ireland (SFI 10/RFP/AST2748). We acknowledge the excellent work of the technical support staff at the Fred Lawrence Whipple Observatory and at the collaborating institutions in the construction and operation of the instrument.

~100 members, 20 institutions
24 non-affiliated members
+35 associate members
Smithsonian Astrophysical Observatory
Adler Planetarium
Argonne National Lab
Barnard College / Columbia University
Bartol Research Institute / University of Delaware
Purdue University
University of California, Los Angeles
University of California, Santa Cruz
University of Chicago
University of Iowa
University of Minnesota
University of Utah
Washington University in St. Louis
McGill University, Montreal
University College Dublin
Cork Institute of Technology
Galway-Mayo Institute of Technology
National University of Ireland, Galway

NSF

U.S. DEPARTMENT OF ENERGY
Office of Science

VERITAS in a nutshell

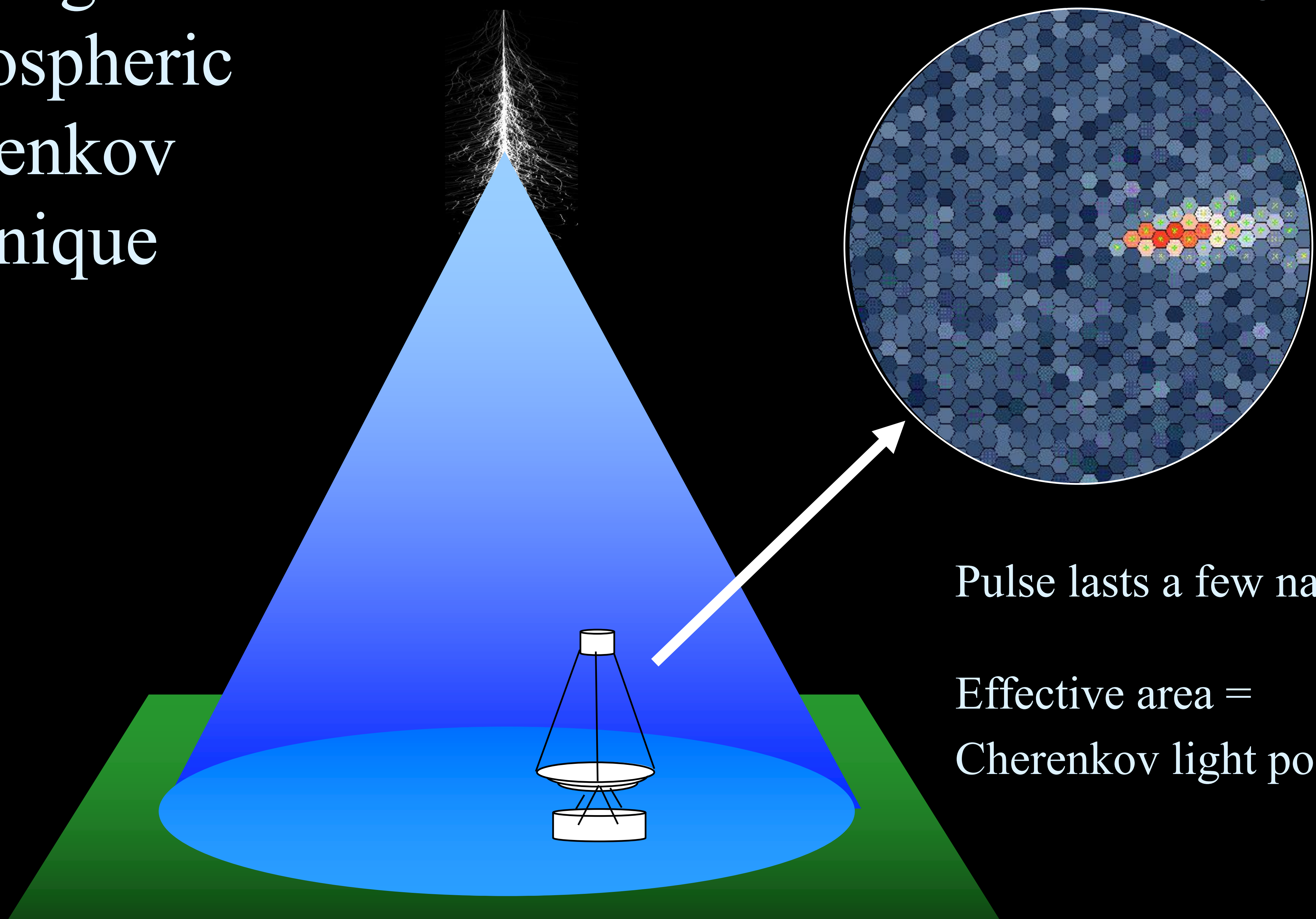
Relocated in Summer 2009

Camera resolution upgraded in Summer 2012

Four 12 m Cherenkov telescopes in southern Arizona
499 high efficiency PMTs per camera
3.5° field of view
Energy range from ~85 GeV to >10 TeV
Sensitivity of 1% Crab in < 24 hours
~1400 hours of observations per year (including observation under bright moon light)
Stable instrument performance over timescales of years

Imaging Atmospheric Cherenkov Technique

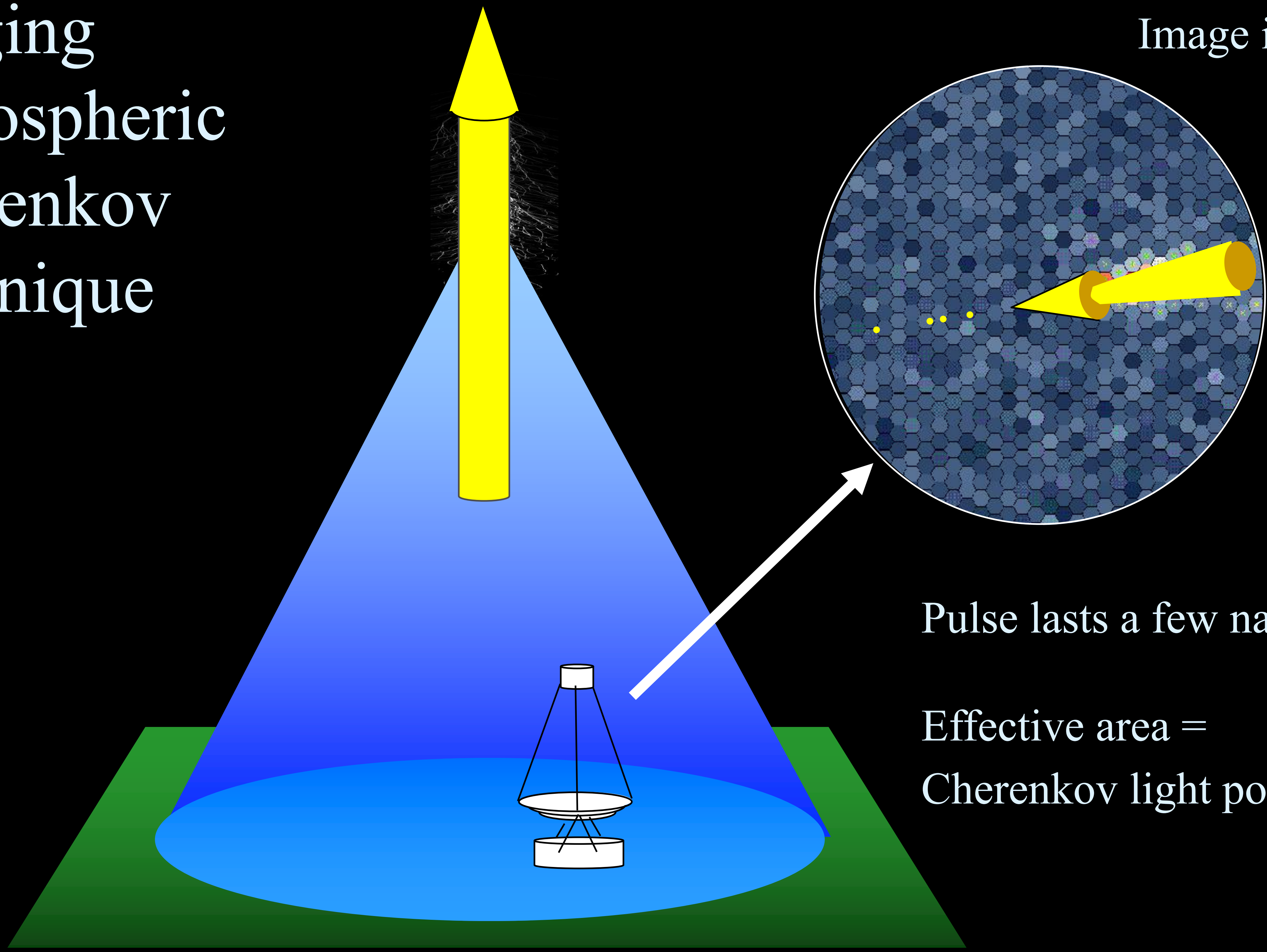
Image in camera



Pulse lasts a few nanoseconds

Effective area =
Cherenkov light pool~10^5 m^2

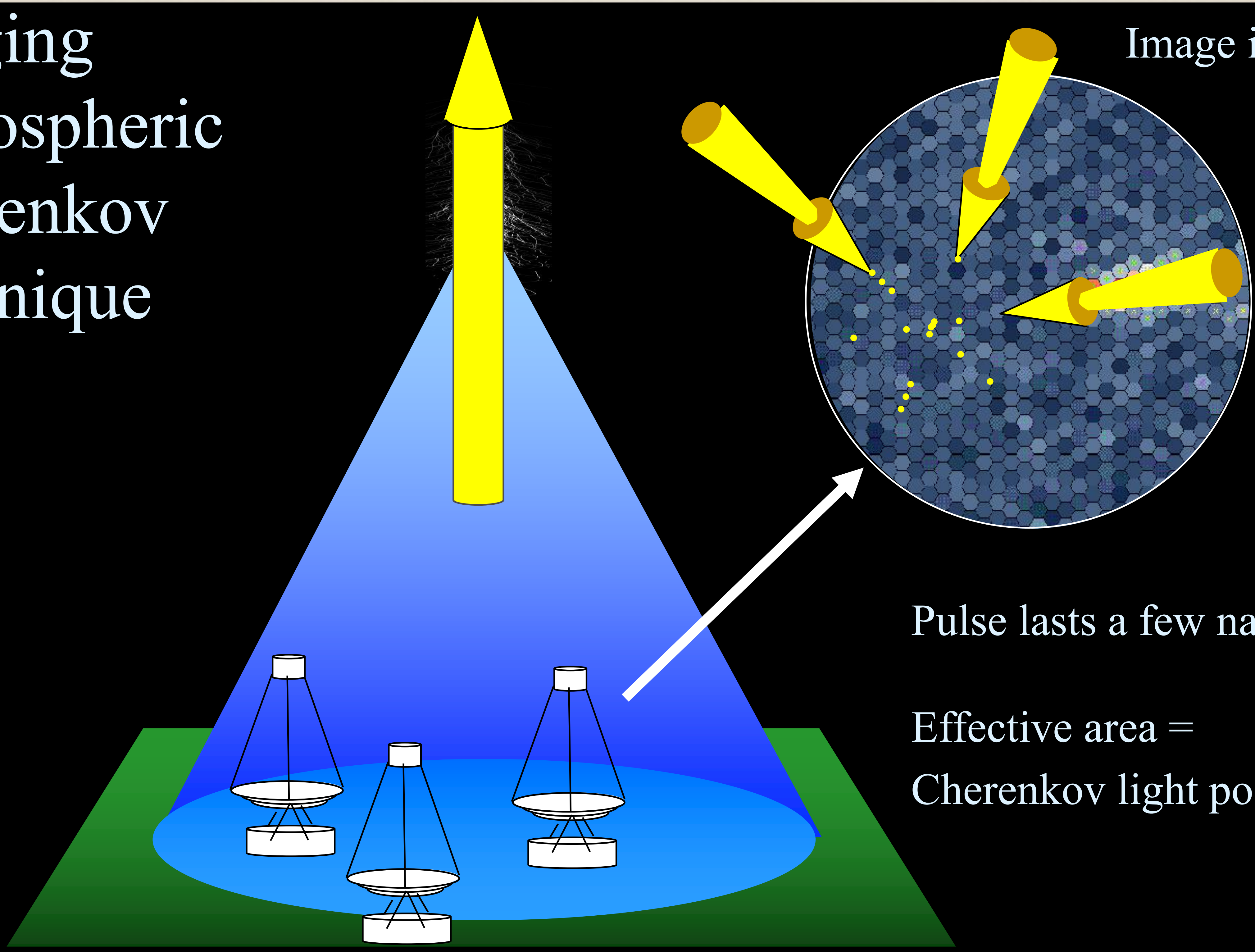
Imaging Atmospheric Cherenkov Technique



Pulse lasts a few nanoseconds

Effective area =
Cherenkov light pool~10^5 m^2

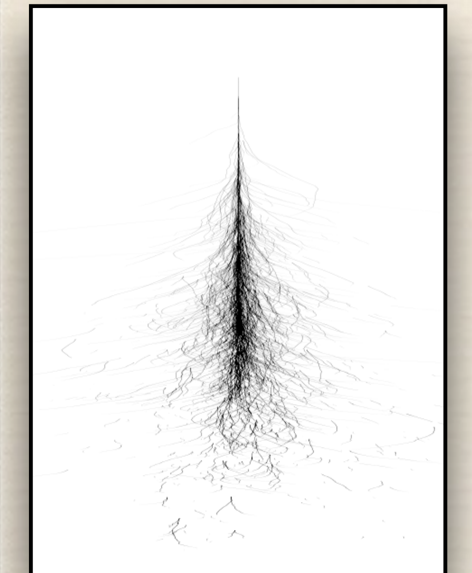
Imaging Atmospheric Cherenkov Technique

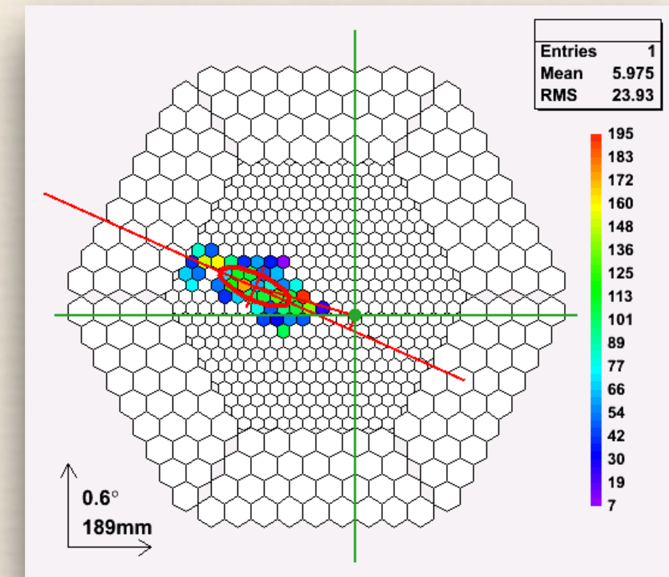


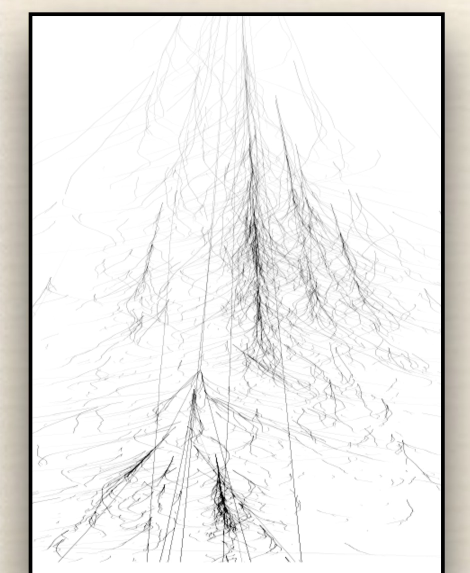
Pulse lasts a few nanoseconds

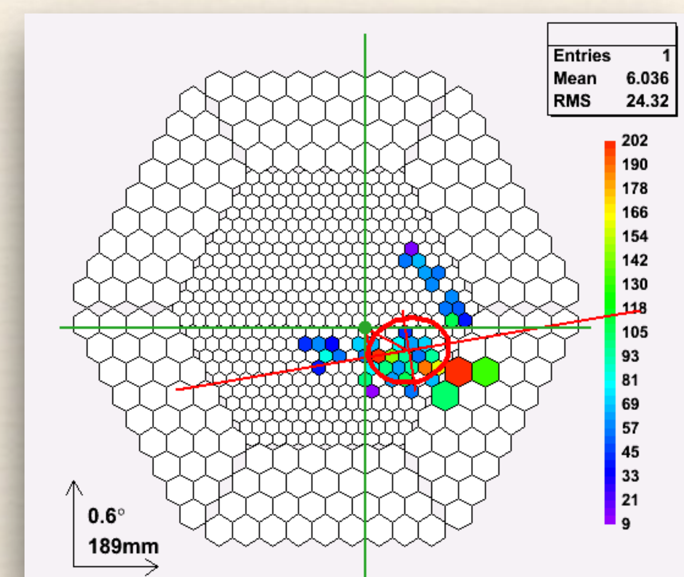
Effective area =
Cherenkov light pool~10^5 m^2

Background Rejection









<u>Main background:</u>

- Cosmic ray (hadron) showers
- 10^3...10^4 times more abundant than γ-ray showers
- How reject the background
  - Shower shape (hadrons are broader and longer)
  - Orientation of the image

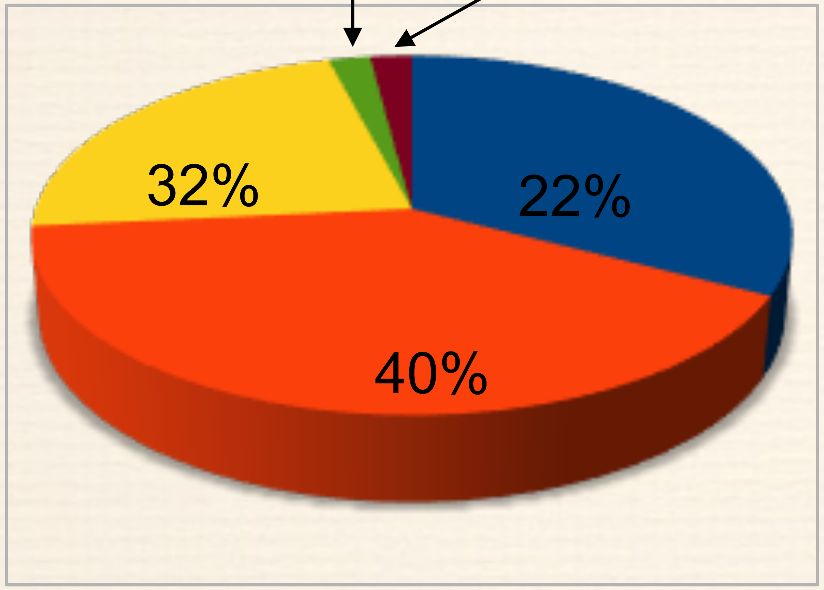
Background rejection efficiency depends on two factors

- Camera Resolution
- Investment in computing
  - Need to simulate every possible conditions
  - Consider all systemtaics

VERITS Science

- Galactic sources
  - Acceleration
  - SNRs and PWNe
  - Pulsars
  - Binary Systems
  - Galactic Center

- Calibration 2%
- GRBs 2%



- Dwarf Spheroidal Galaxies
  - Search for Dark Matter

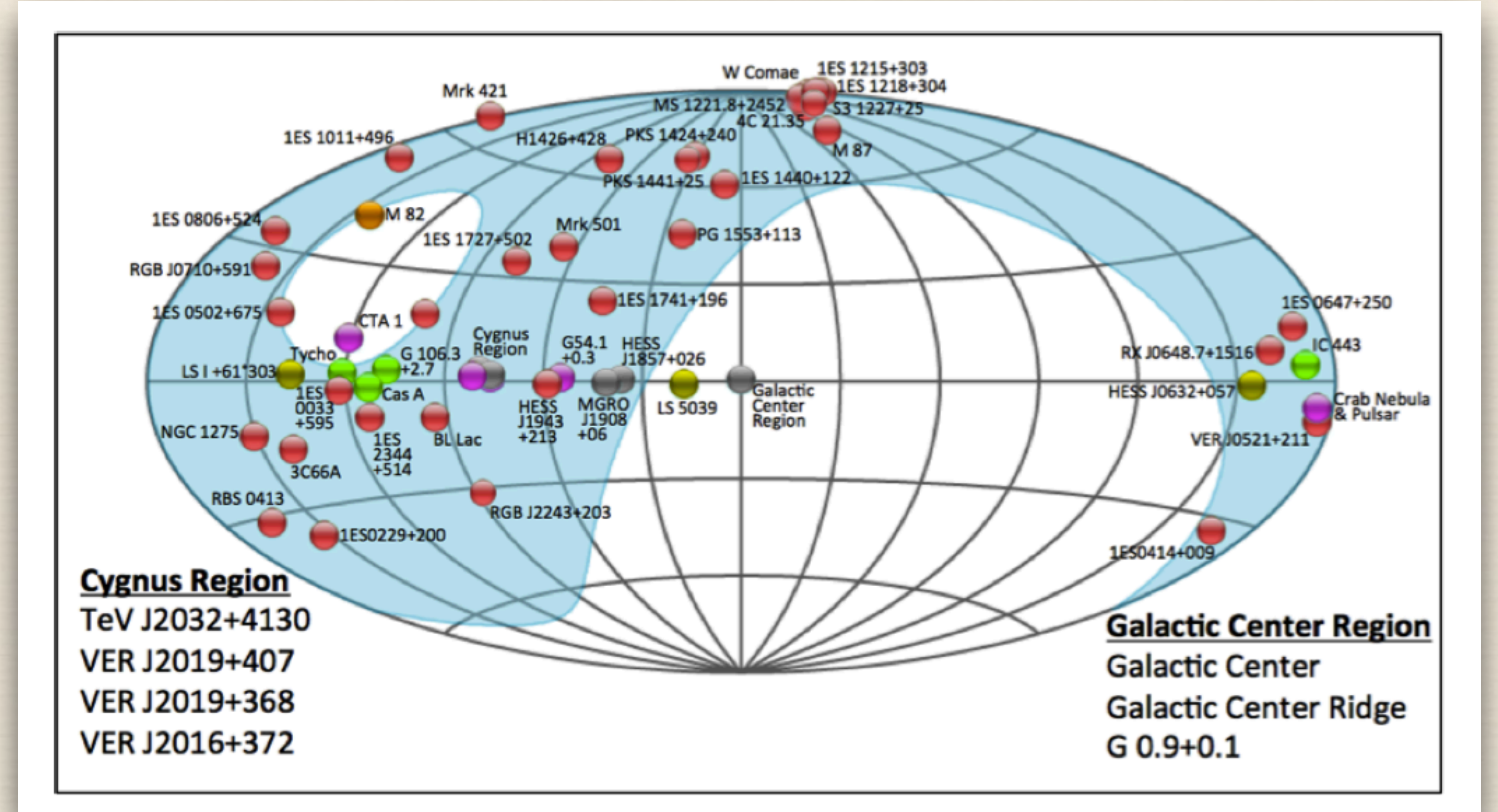
- Untargetted
  - Cosmic Ray Electrons
  - Primordial Black Holes

- Blazars and other AGN
  - Acceleration
  - EBL and IGMF
  - Flares (LIV)

Time Allocation

70% for "long term plan"
30% for proposals (time allocation committee) and director's discretionary time

VERITS Source Catalog

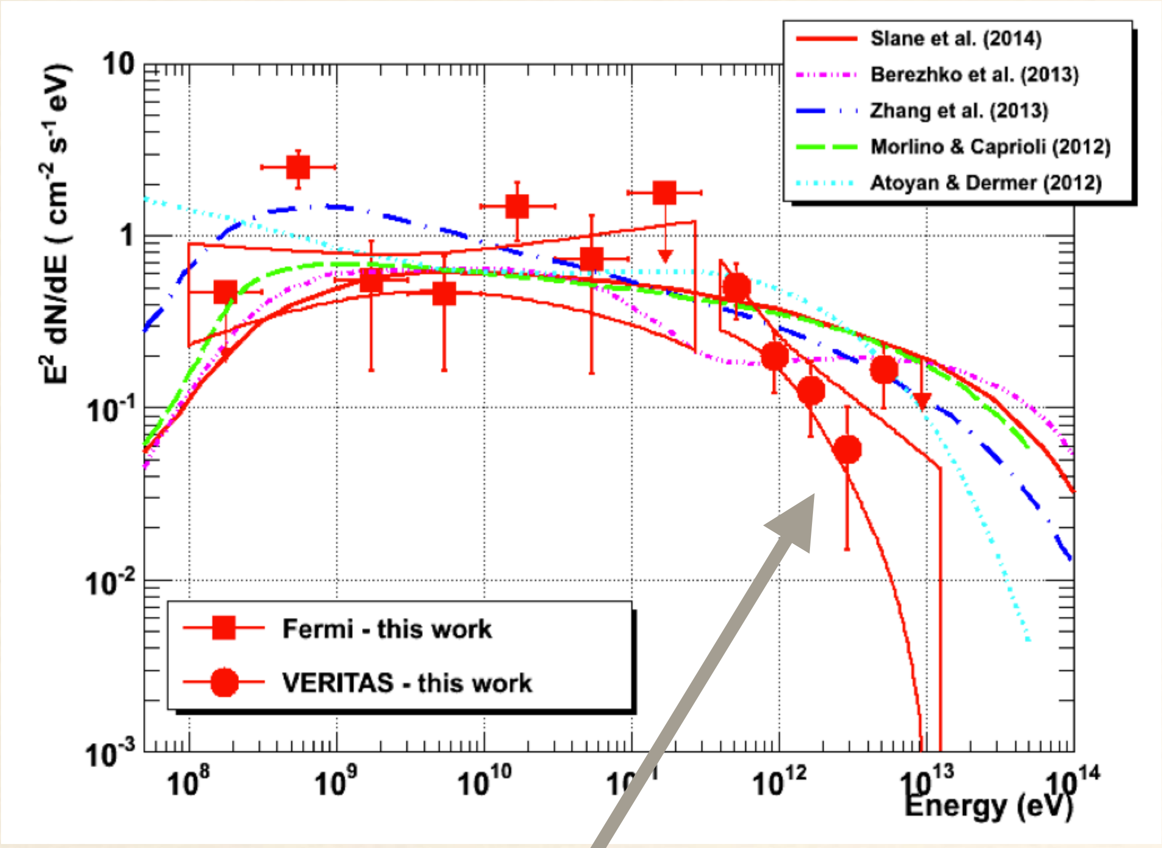


56 Sources 8 classes

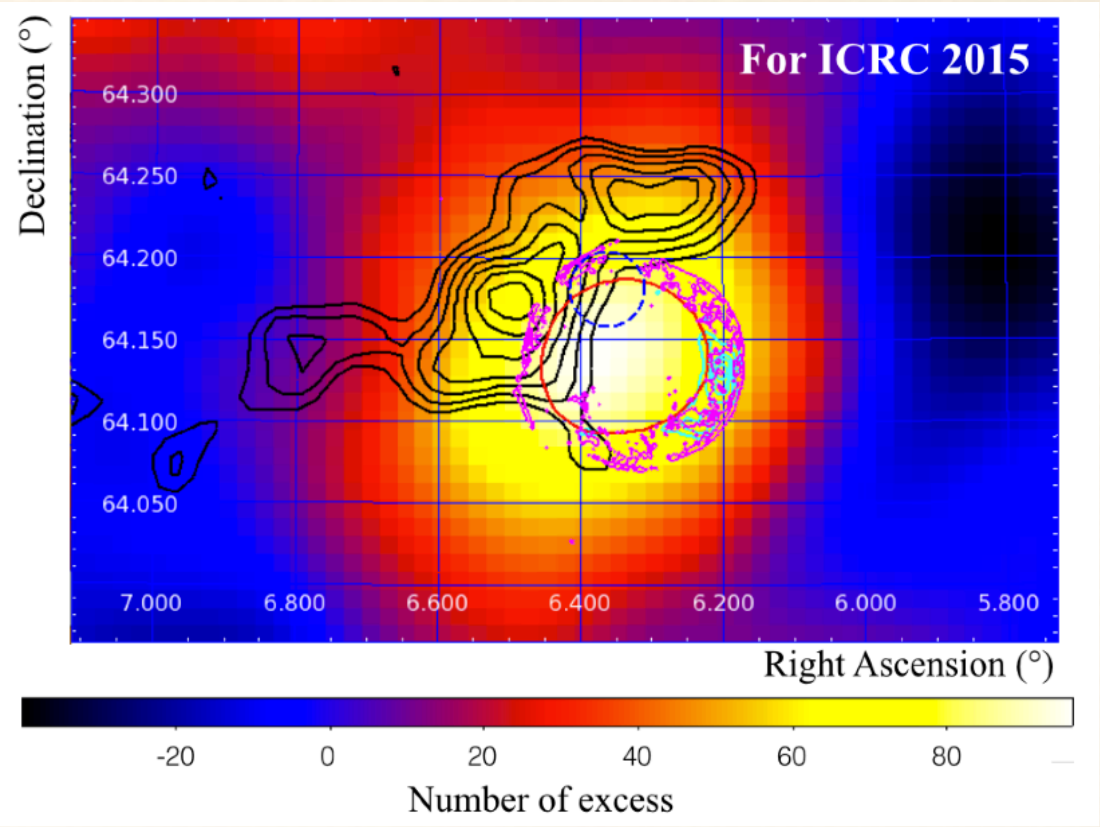
36 Extragalactic (64%) : 33 Blazars, 2 radio galaxies & a starburst galaxy (M82)

20 Galactic (36%) : Crab pulsar, 3 gamma-ray binaries, 7 pulsar wind nebulae, 3 SNRs, and 6 unidentified objects

Tycho: Historical 1A SNR



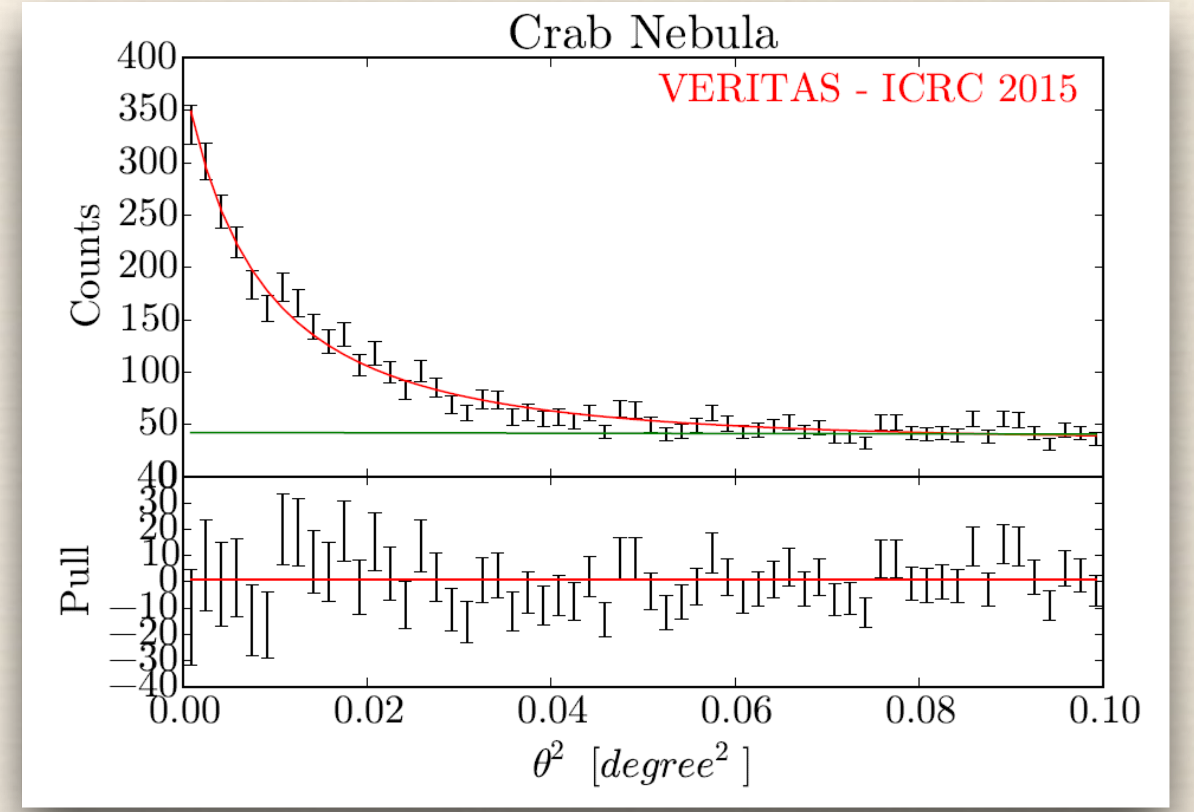
- Good candidate for hadronic emission scenarios
- Exploded in a clean environment
- Young and well-observed at other wavelengths



What is the maximum particle / gamma-ray energy?

Systematic uncertainties above 10 TeV complicate comparisons with models
Better simulations is the key to improve the systematic uncertainties

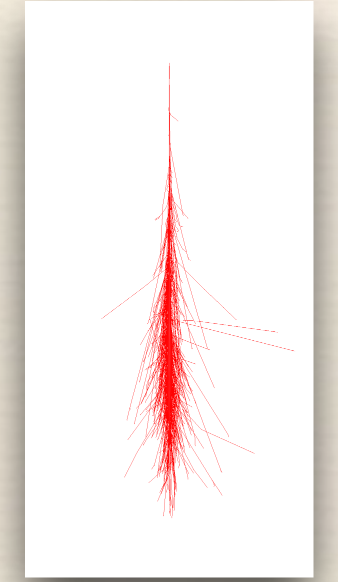
Gamma-ray extension of the Crab Pulsar Wind Nebula



- Size of emission region expected to be1 arc minute
- Results in slight enlargement of spatial gamma-ray excess
- Limited by simplifications in existing Monte Carlo simulations

Simulation Chain

Air Shower (particle physics) → Telescope Optics (ray tracing) → Camera Response (electronics)



New Monte Carlo Production

- More statistics above 10 TeV
- Includes saturation of signal chain
- Better description of trigger
- Better description of optics
- Simulation of night sky background photon fields

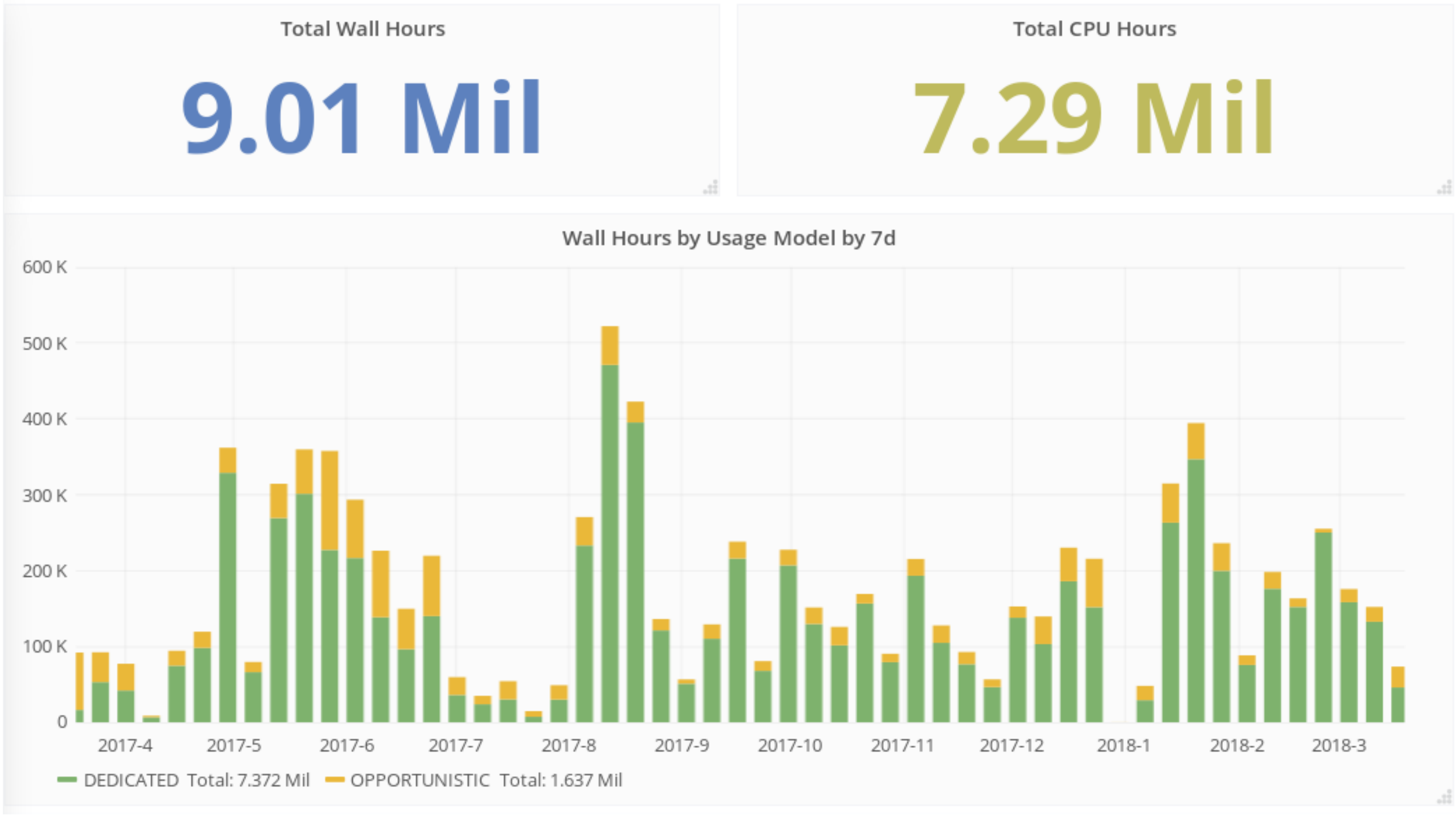
10^9 particle showers, $2 \cdot 10^7$ CPU hours, 400 TB

Need large scale computing infrastructure

Experience with OSG

- Continued great support (Thanks Mats Rynge and everyone else)
- Thanks for the additional computing resources at UoC after San Diego meeting → considerable speed-up of processing

Summary of last 365 days



Production Status: Shower Simulations

Zenith Angle	0	20	30	35	40	45	50	55	60	65	Total
Summer (Atm62)											
Simulated showers [1e6]	2	4.99	5	10	10	10	10	10	10	10	
Target [1e6]	4	10	10	20	20	20	20	20	20	20	
Completed	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	**50%**
Winter (Atm61)											
Simulated showers [1e6]	4	10	9	20	20	10	10	10	10	10	
Target [1e6]	4	10	10	20	20	20	20	20	20	20	
Completed	100%	100%	90%	100%	100%	50%	50%	50%	50%	50%	**72%**

Production of showers 60% complete (~1 year processing)

Optics and Camera Simulation

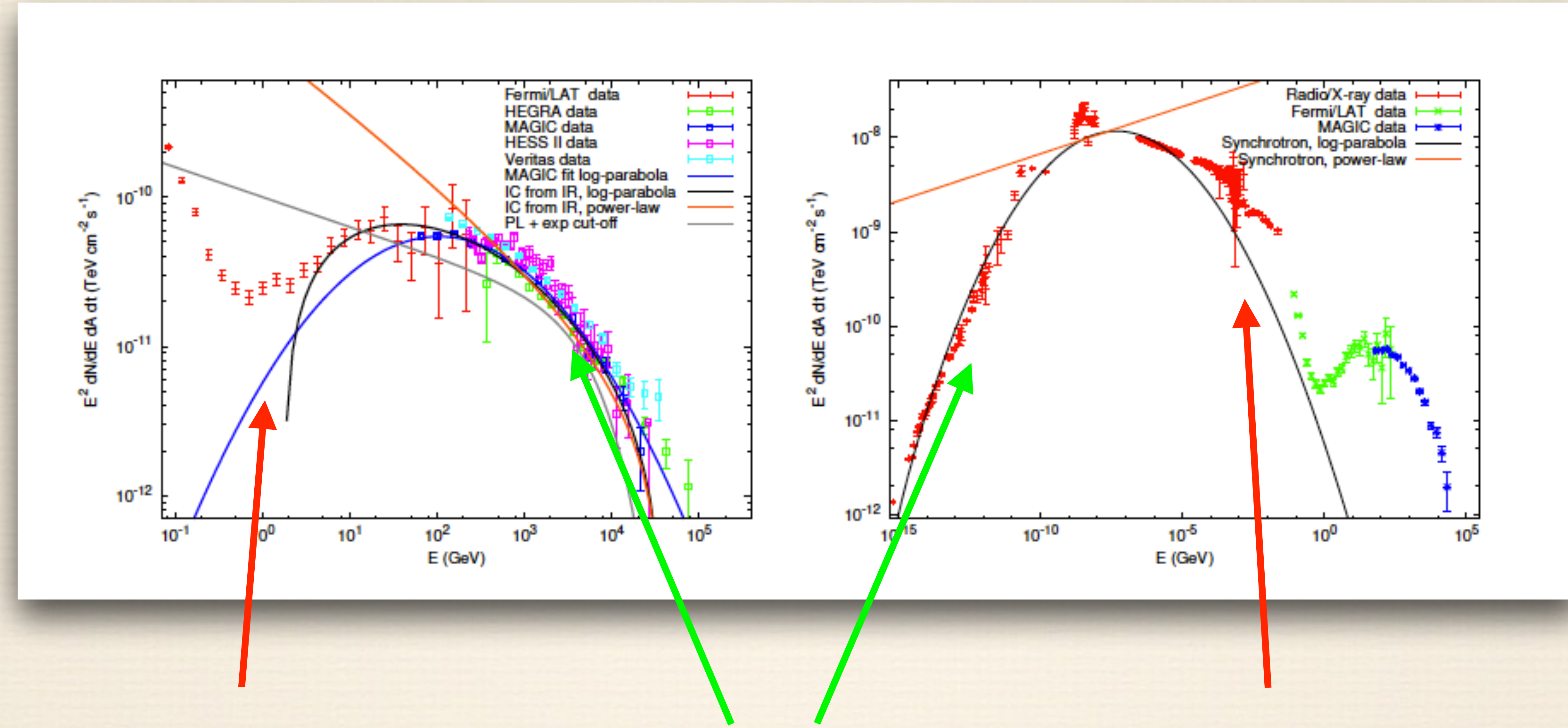
- Production completed with ¼ of final statistics
- Already used by VERITAS Collaboration in publications

VERITAS Simulation Production Overview

File Edit View Insert Format Data Tools Add-ons Help Last edit was 2 days ago

Zenith Angle	0	20	30	35	40	45	50	55	60	65
Wobble 0.5										
GrOptics	1.96	4.9	4	4.99	4.99	4.18	4.99	4.99	4.98	0
CARE Std	merged	merged	merged	merged	merged	merged	merged	merged	merged	merged
50 MHz	1.96 ok	4.9 ok	4 ok	4.97 i	4.99 i	4.18 i	4.99 i	4.99 i		
75 MHz	1.96 ok	4.9 ok	4 ok	4.97	4.99	4.18	4.99	4.99		
100 MHz	1.96 ok	4.9 ok	4 ok	4.97	4.99	4.18	4.99	4.99		
130 MHz	1.96 ok	4.9 ok	4 ok	4.97	4.99	4.18	4.99	4.99		
160 MHz	1.96 ok	4.9 ok	4 ok	4.97	4.99	4.18	4.99	4.99		
200 MHz	1.96 ok	4.9 ok	4 ok	4.97	4.99	4.18	4.99	4.99		
250 MHz	1.96 ok	4.9 ok	4 ok	4.97	4.99	4.18	4.99	4.99		
300 MHz	1.96 ok	4.9 ok	4 ok	4.97	4.99	4.18	4.99	4.99		
350 MHz	1.96 ok	4.9 ok	4 ok	4.97	4.99	4.18	4.99	4.99		
400 MHz	1.96 ok	4.9 ok	4 ok	4.97	4.99	4.18	4.99	4.99		
450 MHz	1.96 ok	4.9 ok	4 ok	4.97	4.99	4.18	4.99	4.99		
CARE RHV	merged	merged	merged	merged	merged	merged	merged	merged	merged	merged
150 MHz	1.96 ok	3.3 ok	2.8 ok	3.5 ok	4.99 ok	4.18 ok	4.99 ok	4.99 ok		
300 MHz	1.96 ok	3.3 ok	2.8 ok	3.5 ok	4.99 ok	4.18 ok	4.99 ok	4.99 ok		
450 MHz	1.96 ok	3.3 ok	2.8 ok	3.5 ok	4.99 ok	4.18 ok	4.99 ok	4.99 ok		
600 MHz	1.96 ok	3.3 ok	2.8 ok	3.5 ok	4.99 ok	4.18 ok	4.99 ok	4.99 ok		
750 MHz	1.96 ok	3.3 ok	2.8 ok	3.5 ok	4.99 ok	4.18 ok	4.99 ok	4.99 ok		
900 MHz	1.96 ok	3.3 ok	2.8 ok	3.5 ok	4.99 ok	4.18 ok	4.99 ok	4.99 ok		

The Latest computing challenge is Multiwavelength Astronomy



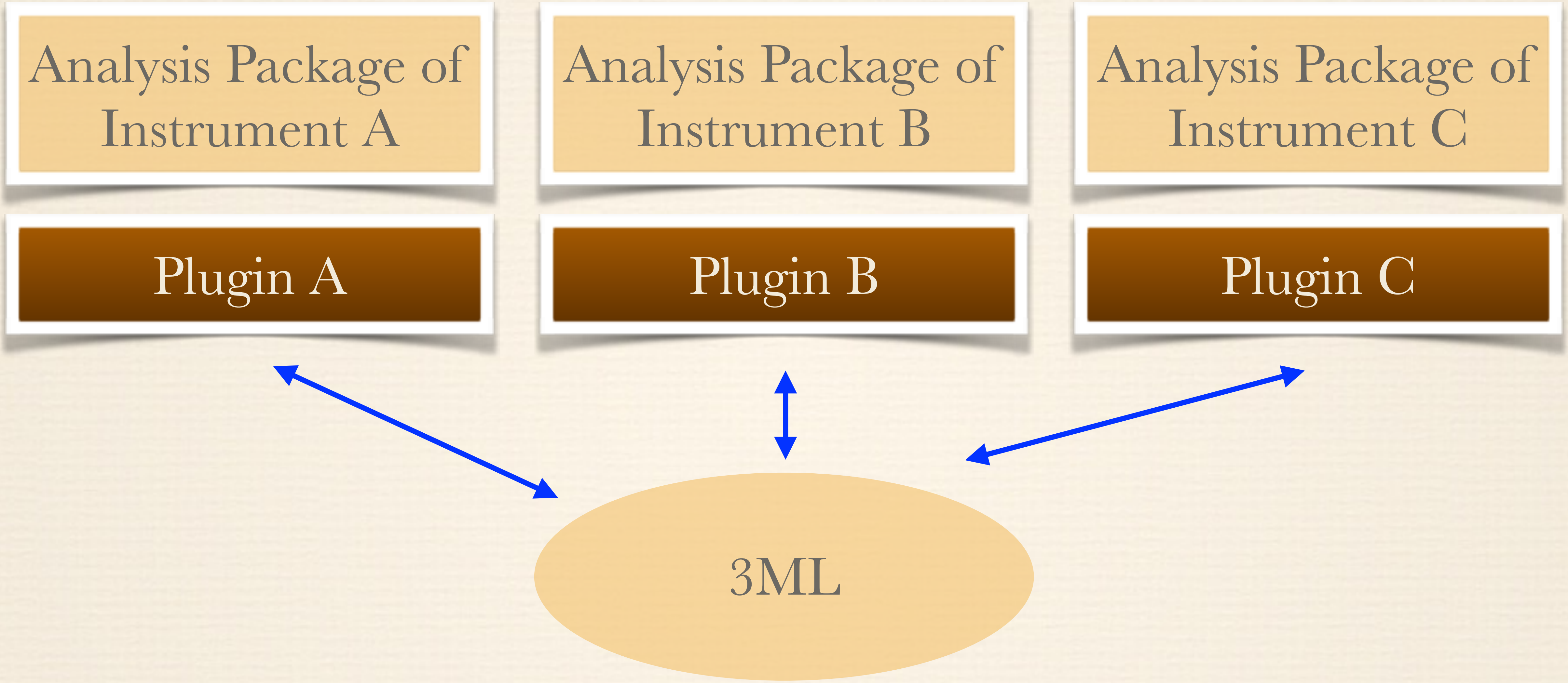
Bad Good Bad

We need a unified model that is able to explain the multiwavelength measurements starting from radio to gamma rays

Computational challenge in Multiwavelength Astronomy

- Each instrument has its own data analysis packages
- Own data formats
- Not designed to perform joint analysis

Multi Mission Maximum Likelihood Framework
3ML



- There are some libraries that more than one package uses
- However, they use different version configured differently
- Currently, the major challenge is running multiple versions in a single system

Summary

- VERITAS is one of the worlds best gamma-ray instruments.
- The instruments runs very smoothly.
- Moving into an era where systematics dominate.
- New Monte Carlo Simulations allow us to extract more science from our data.
  OSG is great.
- We will continue to use resources for at least two more years and probably beyond.