First Results from VERITAS

David Hanna
McGill University
Montreal, Canada

Outline of Presentation

- collaboration
- description of the detector
  - telescopes
  - readout
  - trigger
  - construction timeline
- 2006-2007 observations
  - Crab
  - Mrk431, Mrk501
  - LSI+61 303
  - 1ES 1218
  - M87
- near-term plans
  - key science projects

VERITAS Collaboration
Four Countries, Six Funding Agencies, Twenty Institutions, Eighty members

- Smithsonian Astrophysical Observatory *
- Adler Planetarium
- Purdue University *
- Barnard College, NY
- Iowa State University *
- DePauw University, IN
- Washington University, St. Louis *
- Grinnell College, IA
- University of Chicago *
- University of California, Santa Cruz
- University of Utah *
- University of Massachussetts
- University of California, Los Angeles *
- Cork Institute of Technology
- McGill University, Montreal *
- Galway-Mayo Institute of Technology
- National University of Ireland, Dublin *
- National University of Ireland, Galway
- University of Leeds *
- Argonne National Lab
- Associate Members

Project office: F.L. Whipple Observatory, SAO

Funding from NSF/DOE/Smithsonian/PPARC/SFI/NSERC

VERITAS

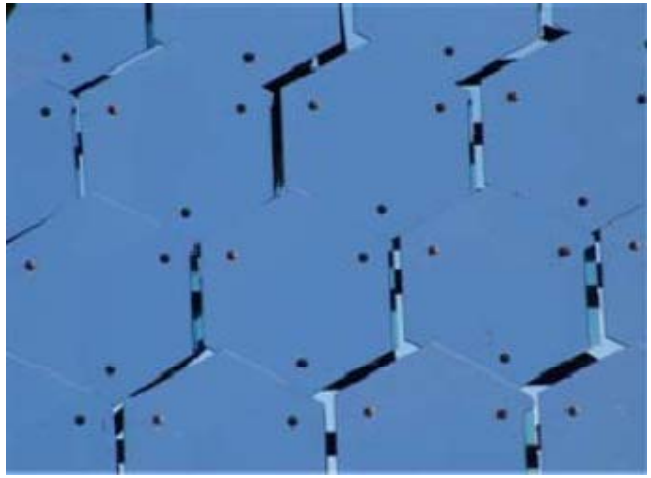
Very Energetic Radiation Imaging Telescope Array System

four 12 m telescopes located at
Whipple Observatory Base Camp

Amado, Arizona

31º 40′ N, 110º 57′ W, 1268 masl

Each Telescope



Reflector
- 349 hexagonal facets
- spherical – 24 m radius
- Davies-Cotton mounting
- 12 m diameter
- 12 m focal length
- 110 m² area

Camera
- 499 29mm PMTs
- 0.15⁰ separation
- 3.5⁰ field-of-view

Trigger and Readout

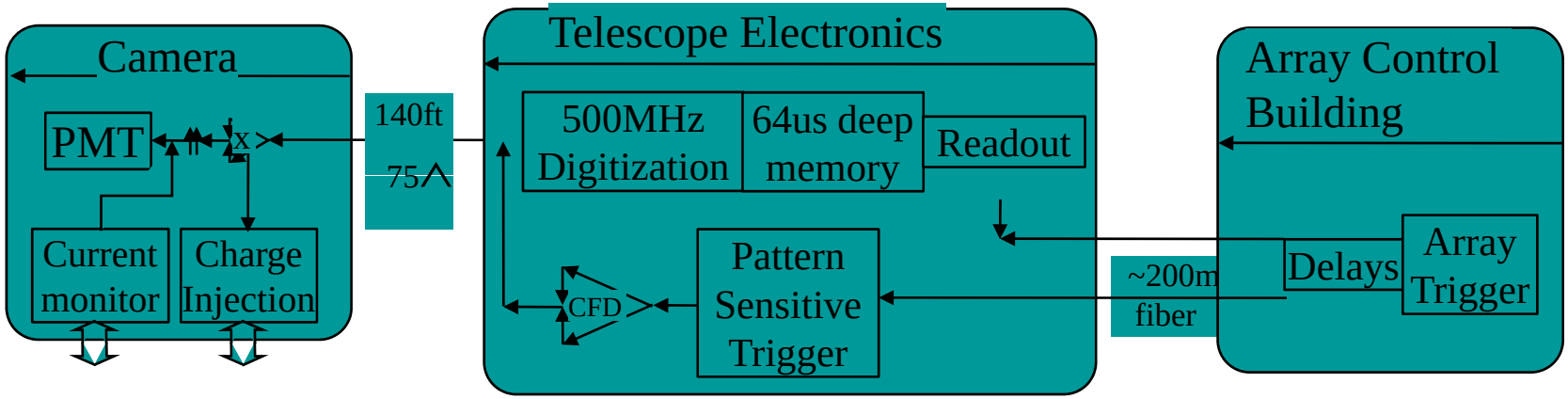
-three-level trigger

1. constant fraction discriminator on each PMT

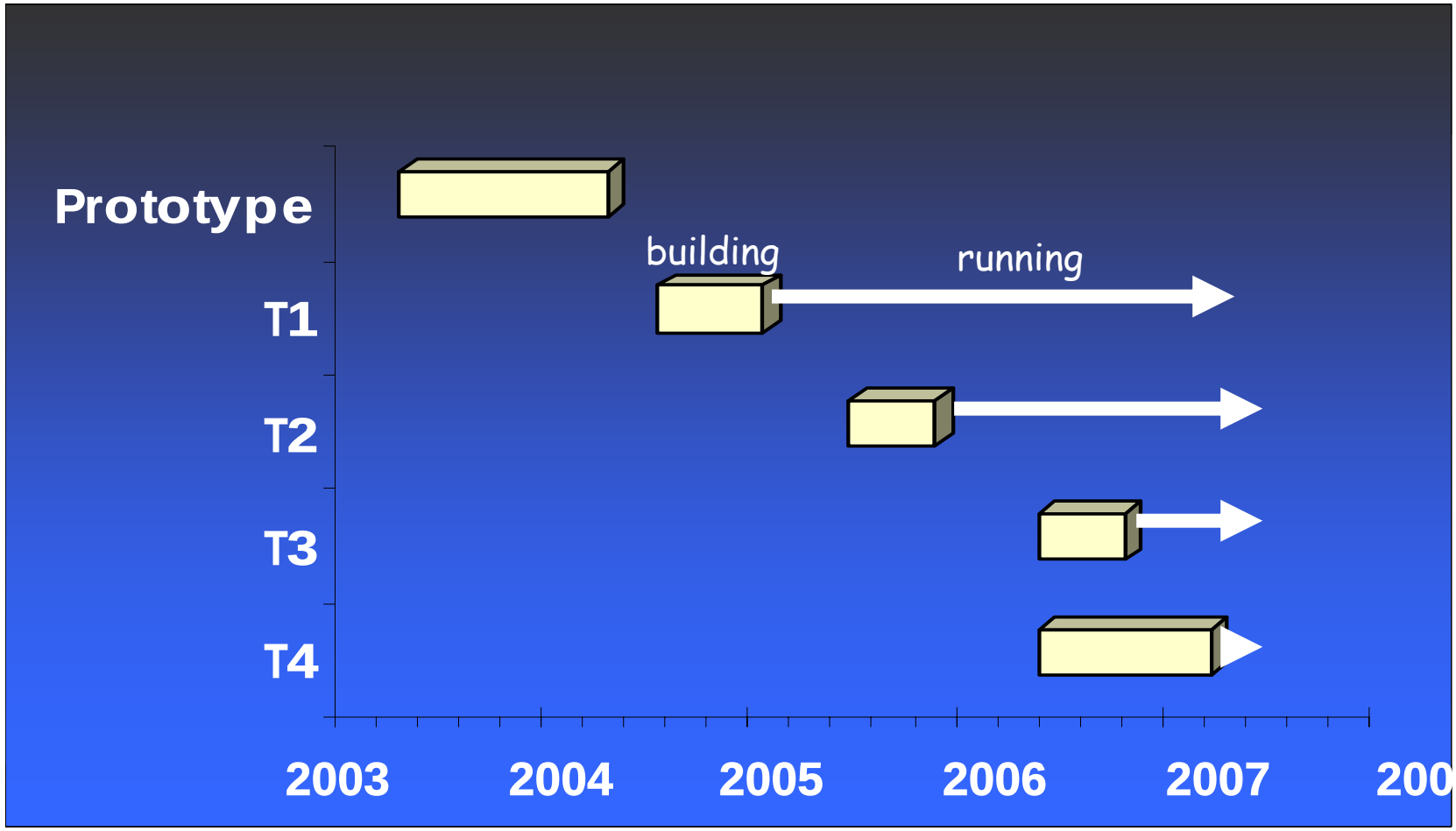
2. pattern trigger on every telescope
(require hits on adjacent PMTs – typically 3)

3. array trigger (require 2 or more telescopes)

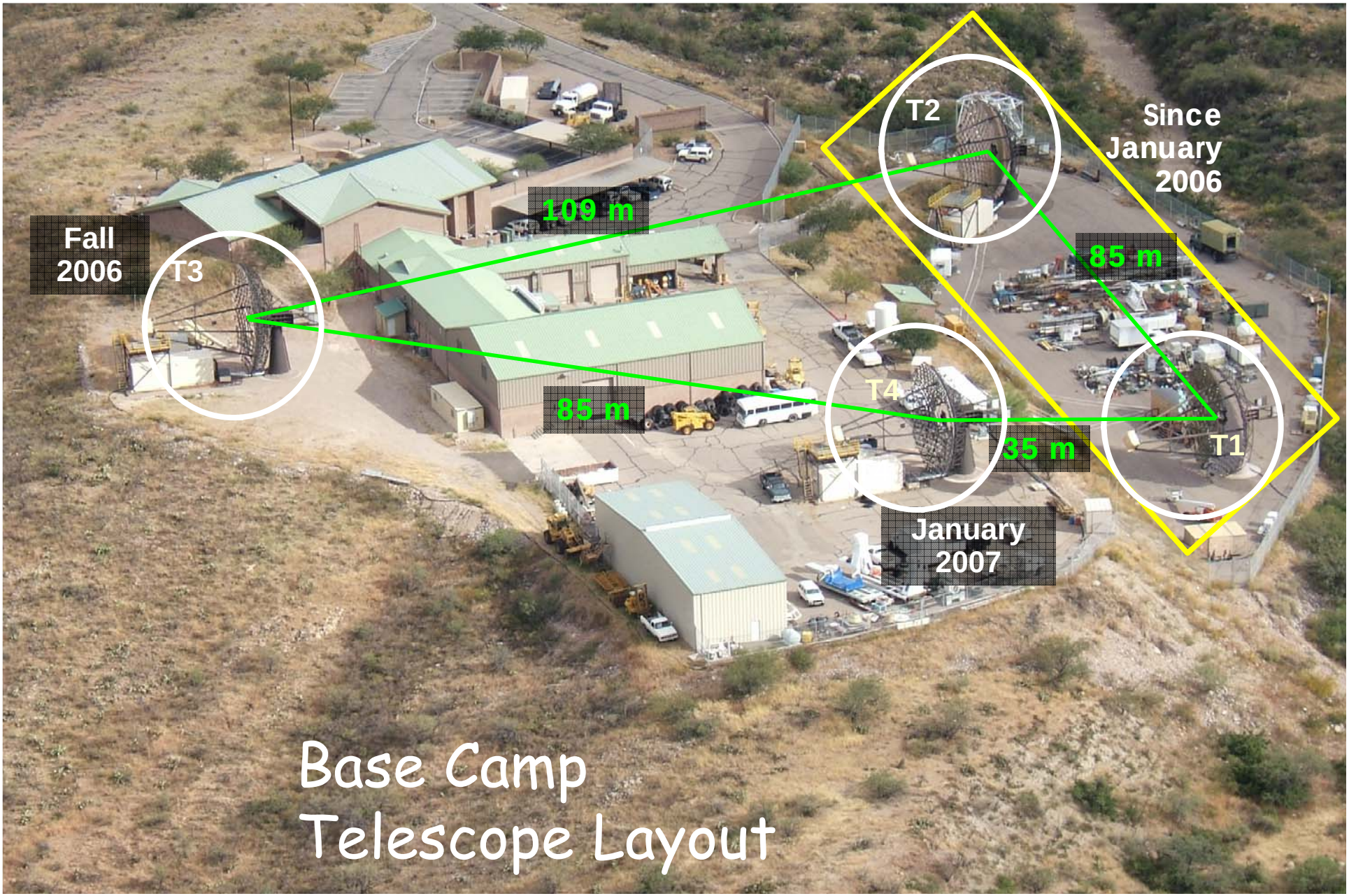
- 500 Mega-sample/s Flash ADC on every channel



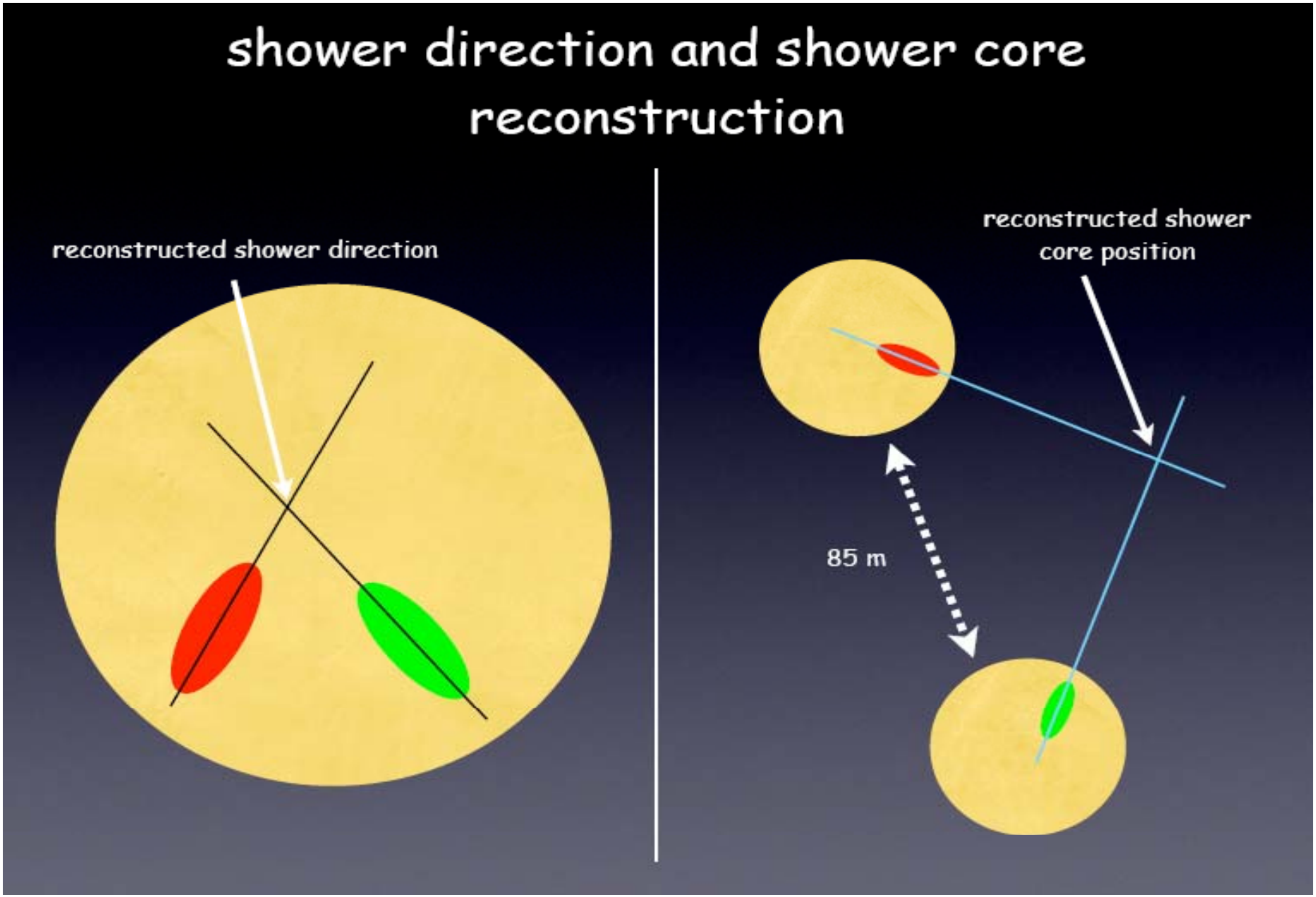
VERITAS Construction History



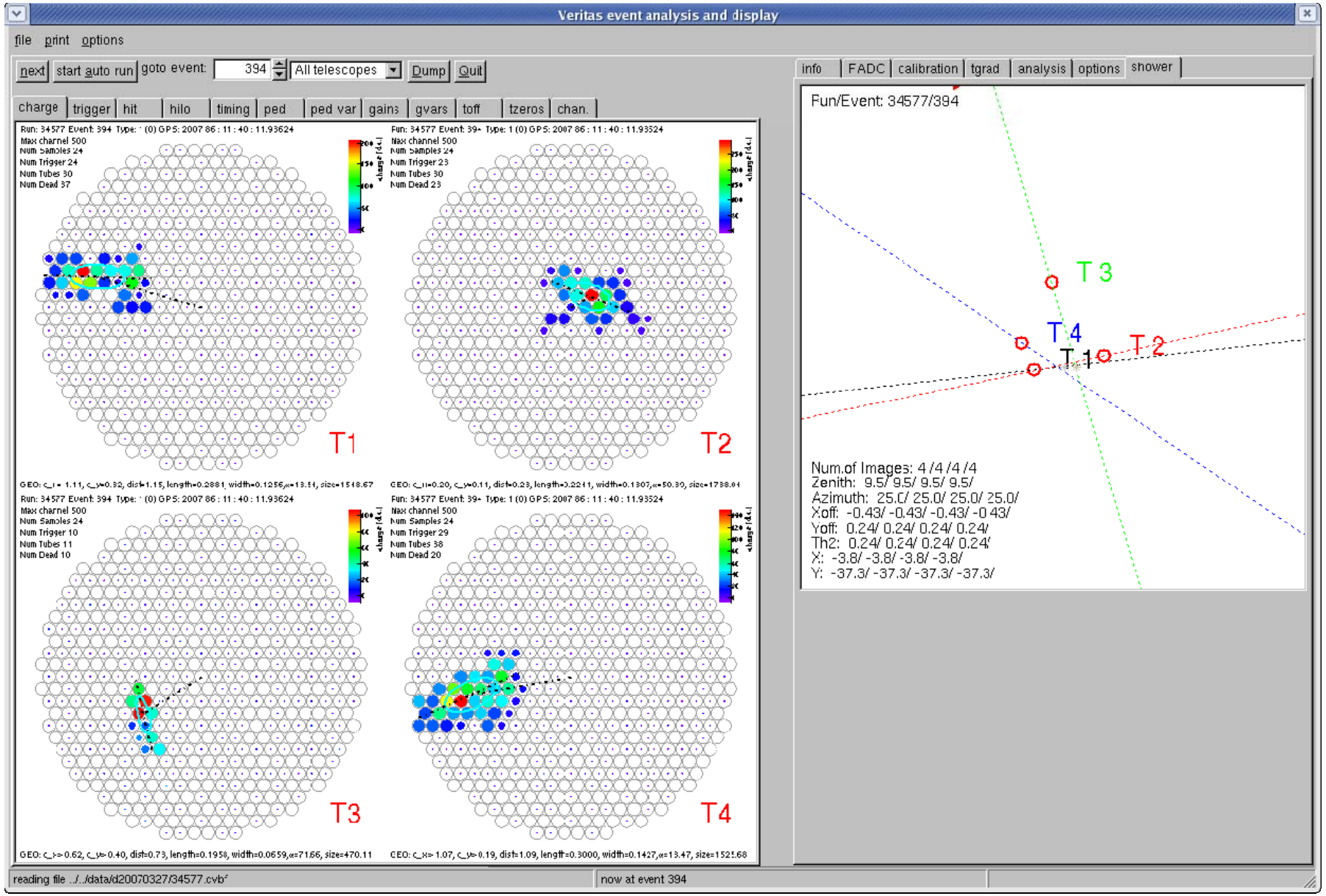
Observations done with various combinations as they became possible


T2
Since
January
2006
109 m
Fall
2006
T3
85 m
T4
85 m
35 m
T1
January
2007
Base Camp
Telescope Layout

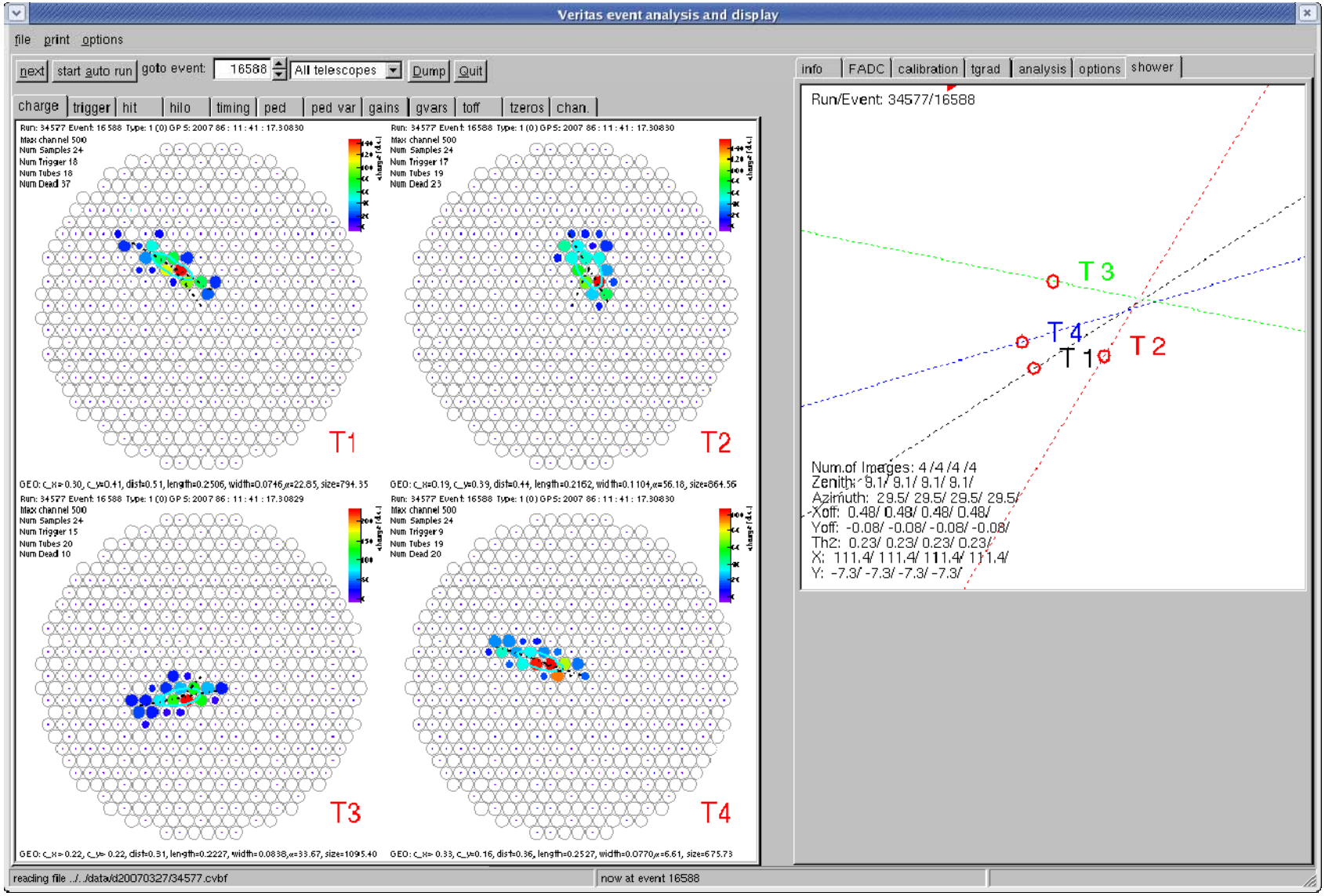
shower direction and shower core reconstruction



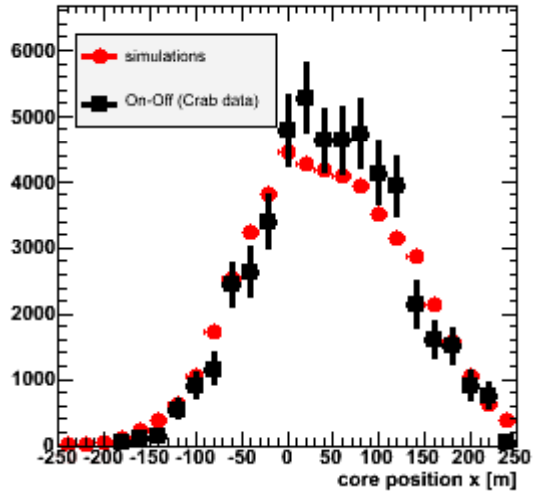
Four-telescope event inside the array

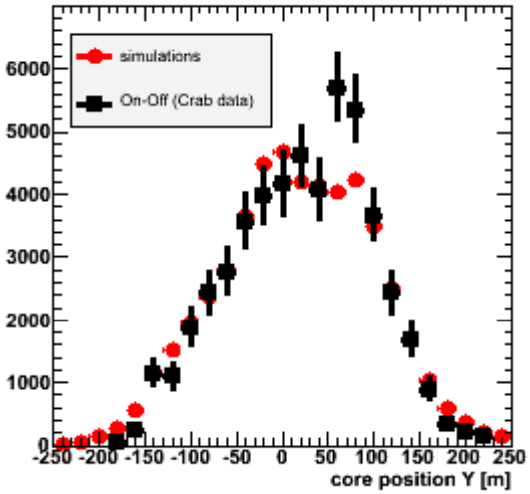


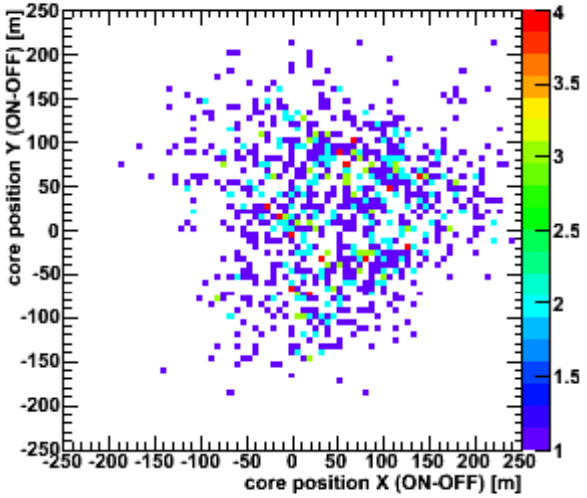
Four-telescope event outside the array

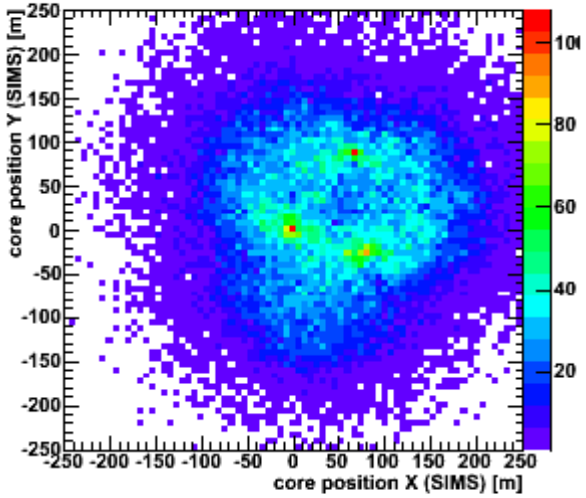


Core Reconstruction- 3 telescopes

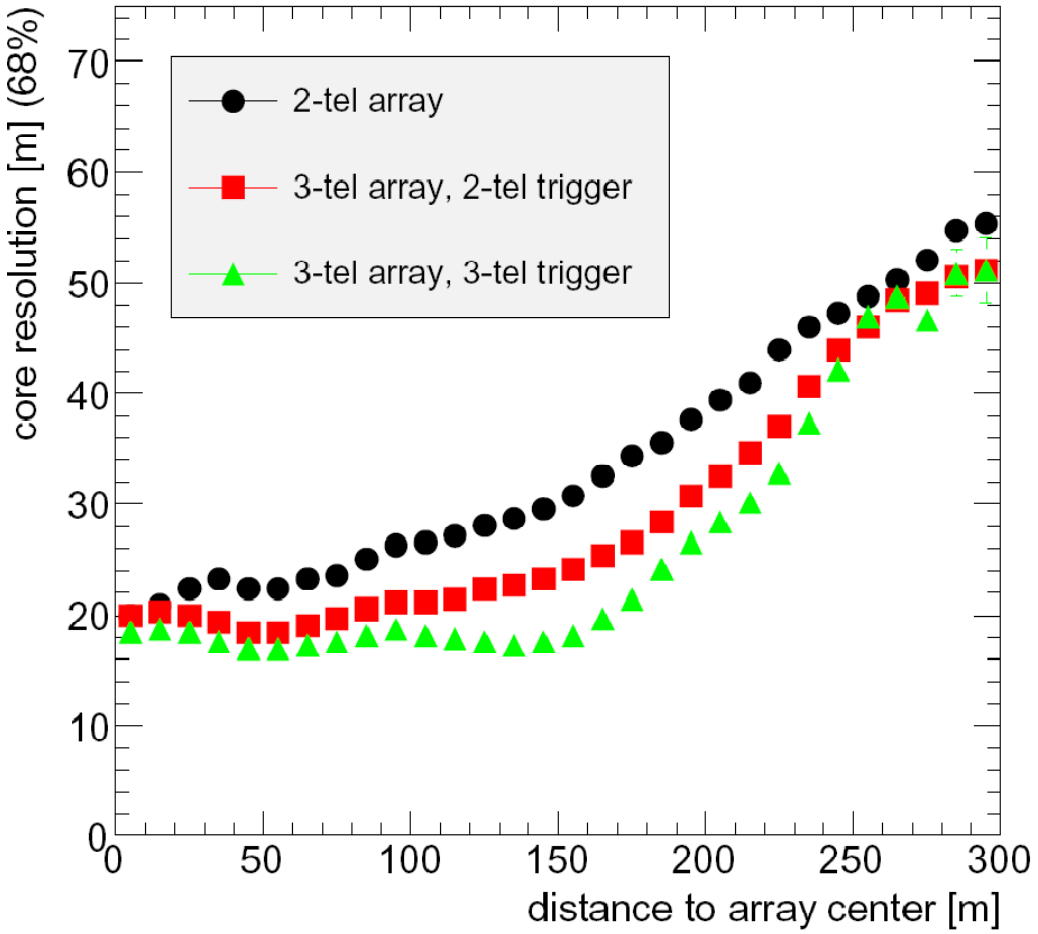




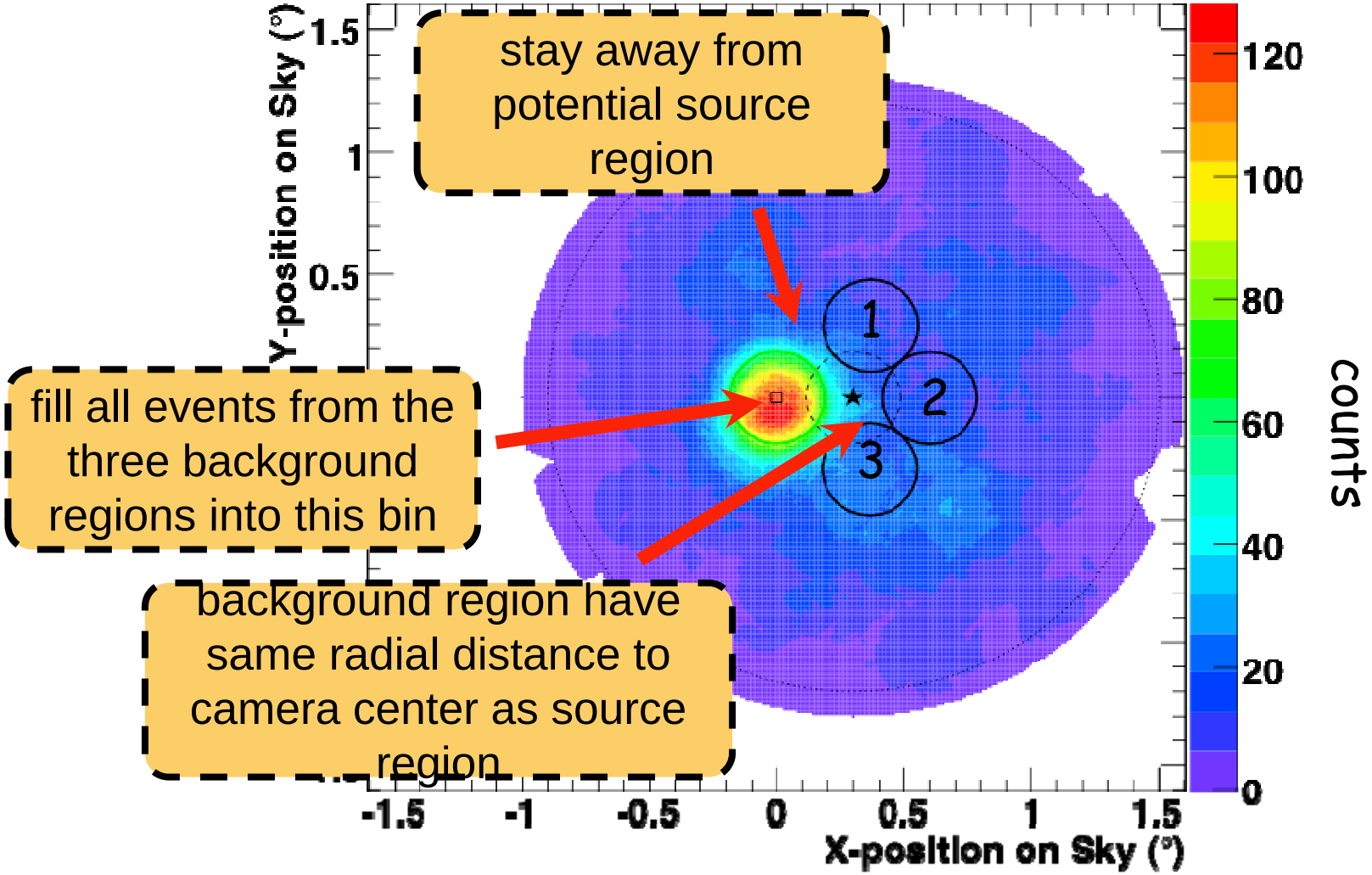




Core Resolution: 68% Containment

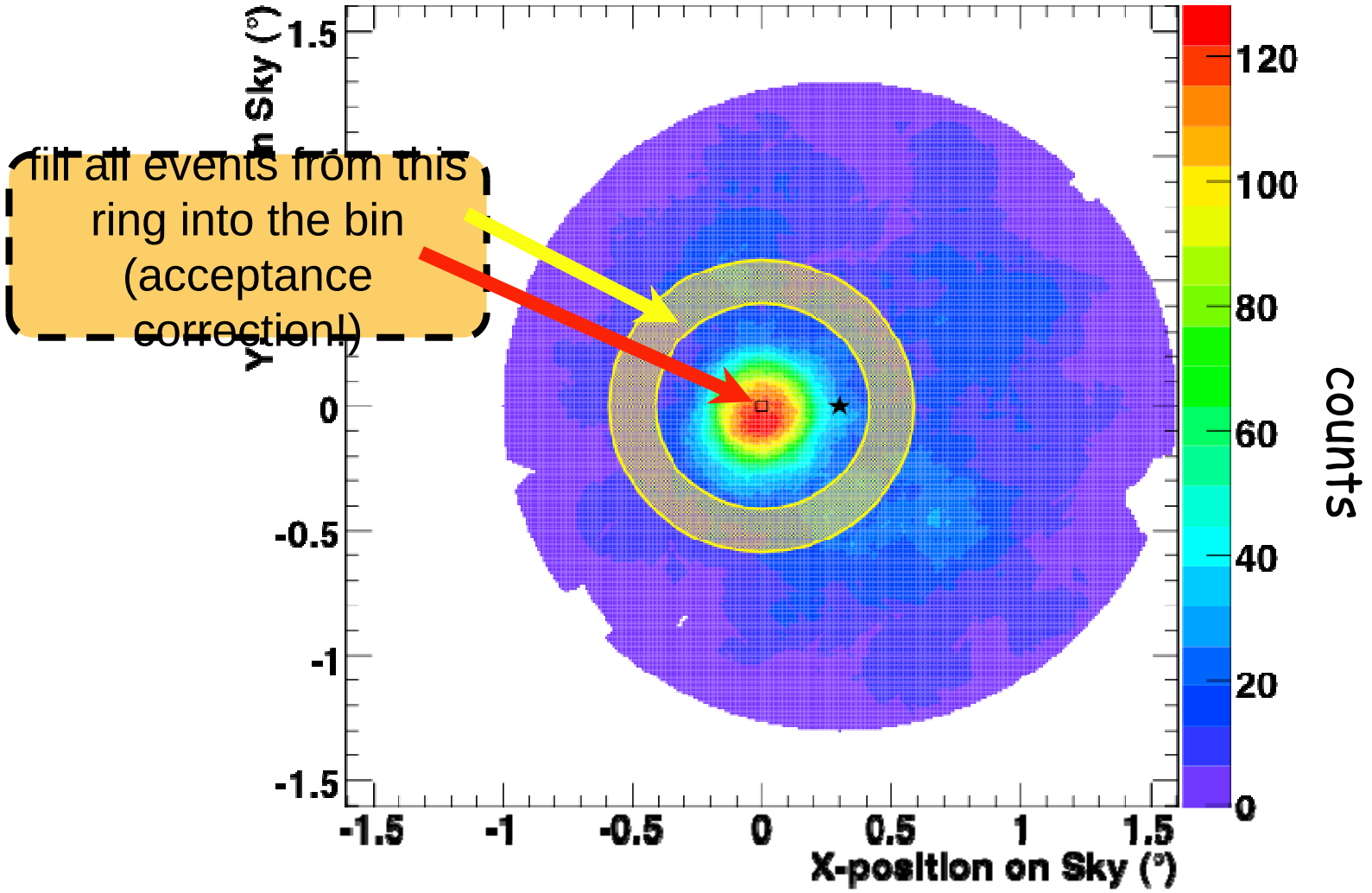


reflected region model



Crab run 31965, wobble offset 0.3°

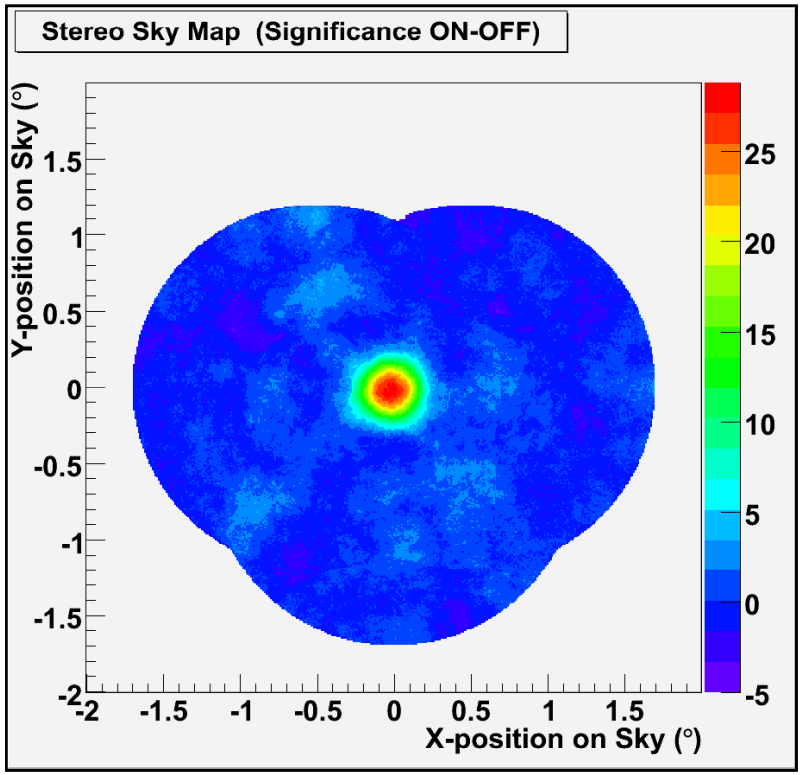
ring background model

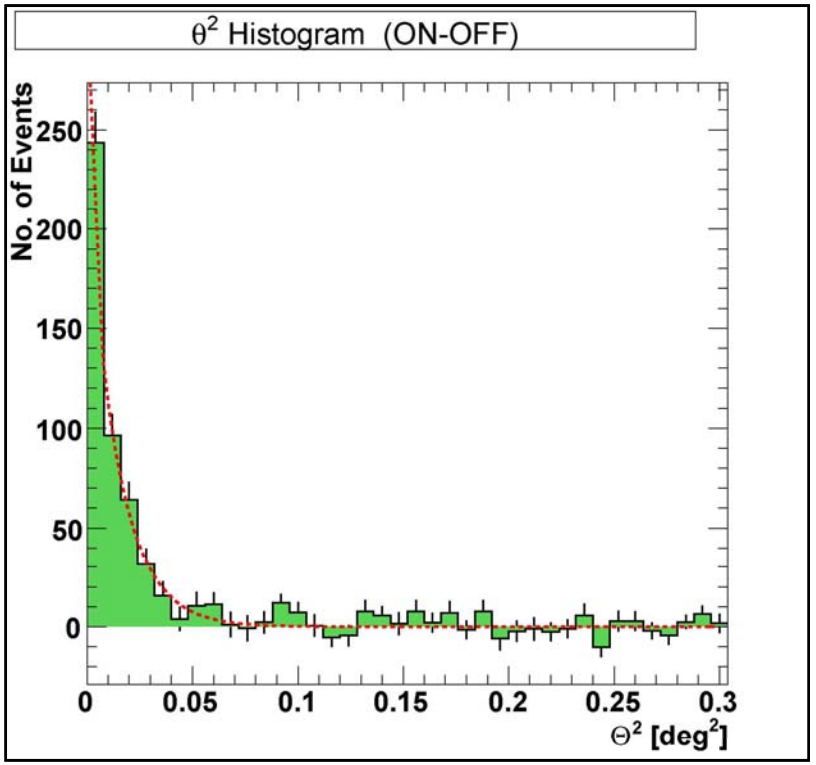


Crab run 31965, wobble offset 0.3°

Crab Nebula (test pattern)

January 2007
three-telescope data
wobble
76º elevation
28.1 σ





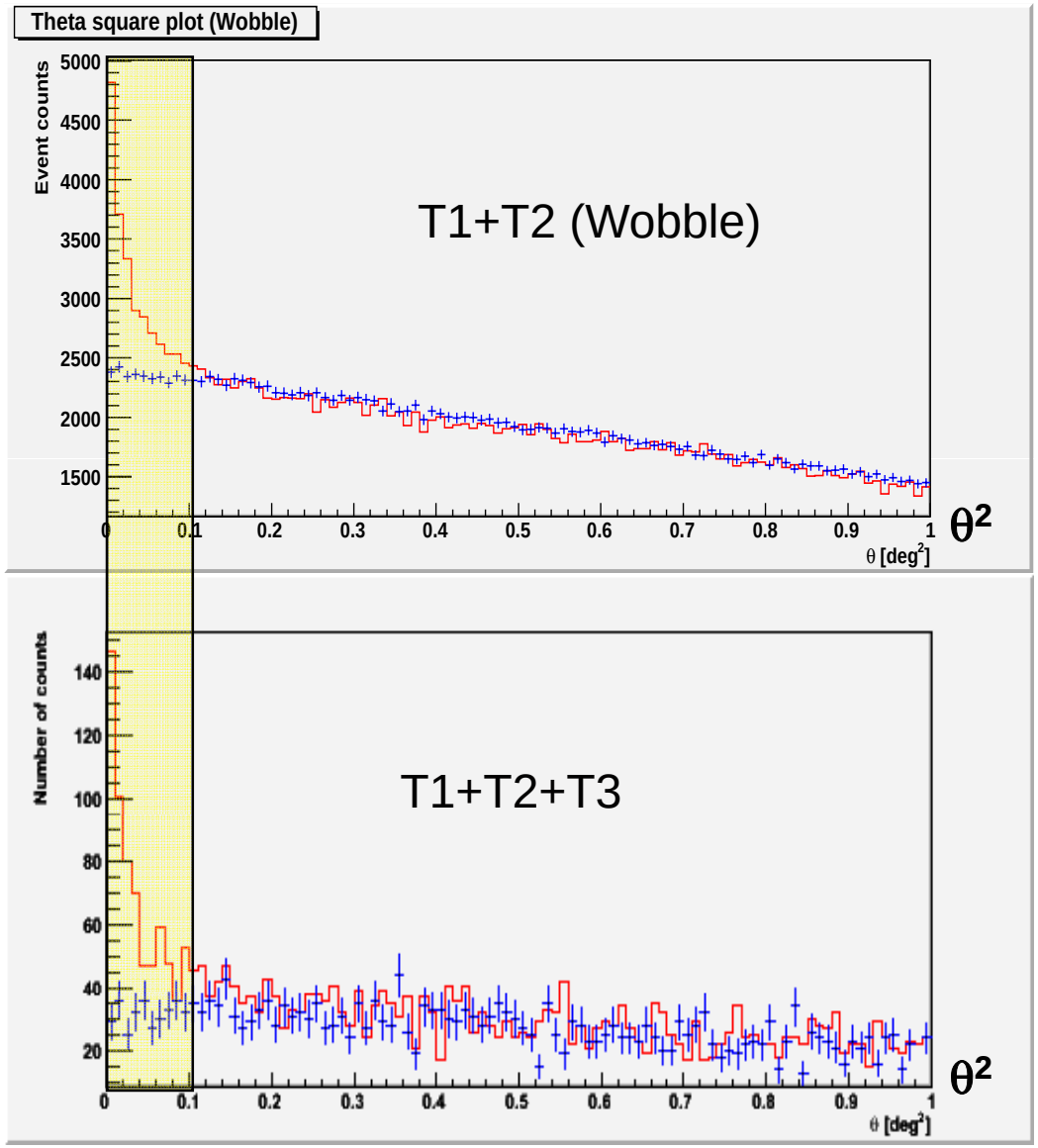
θ^2 distributions:

measure the arrival direction of the candidate gamma ray

subtract the coordinates of the source being tracked

square the result → θ^2

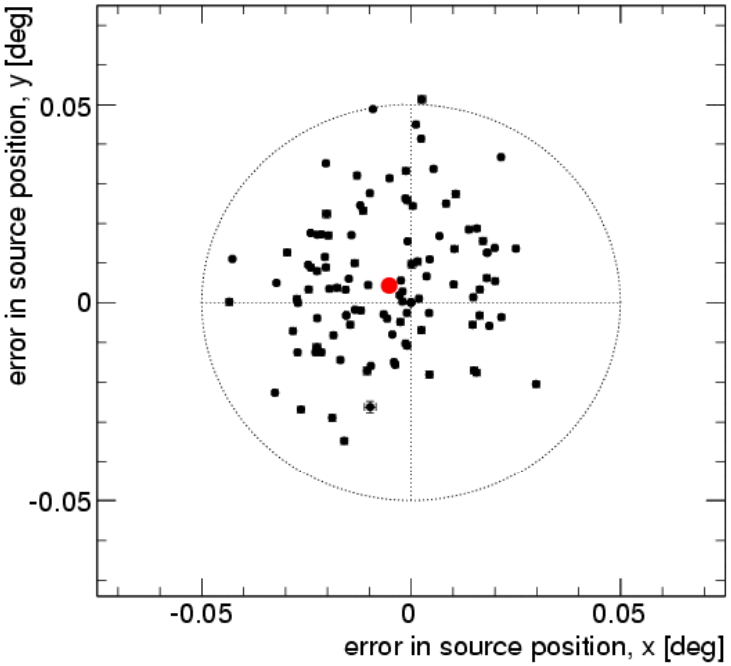
cut and subtract background from the background regions to get signal



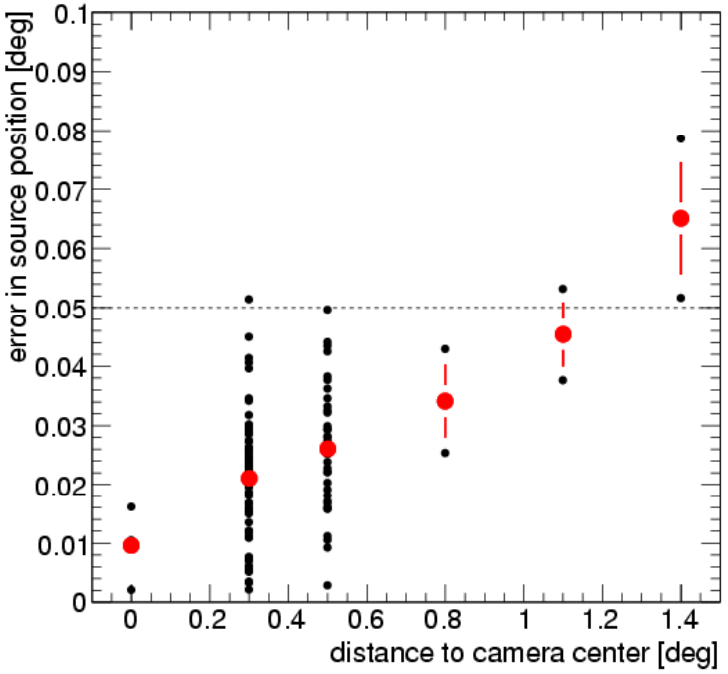
Crab data

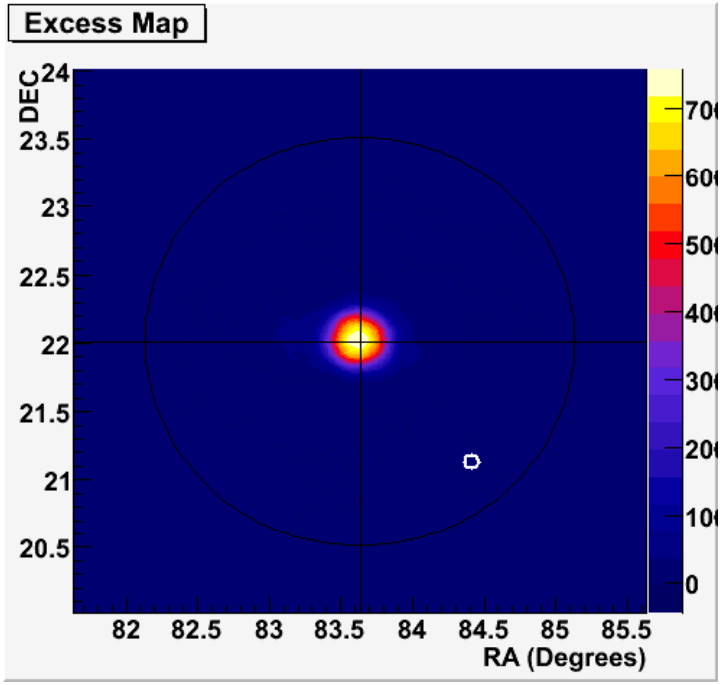
Pointing Accuracy from Crab Nebula runs

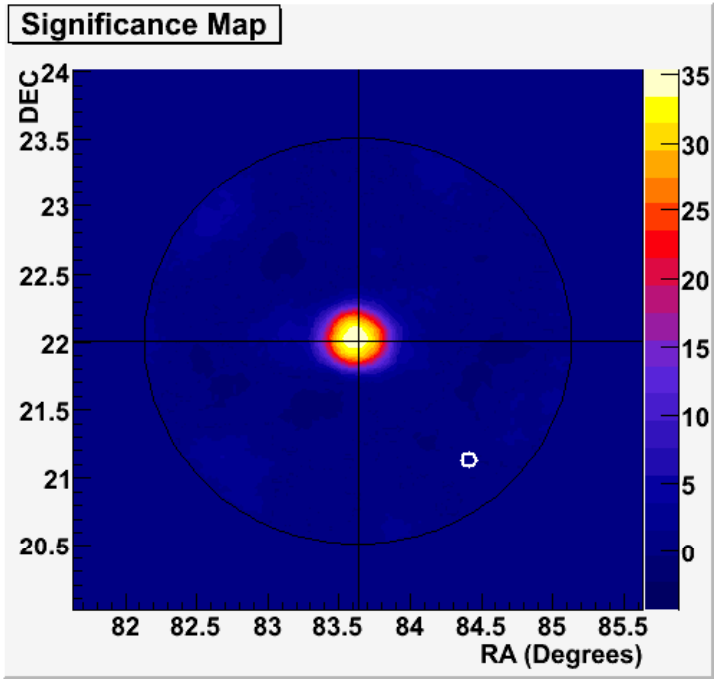
scatter to be reduced with pointing monitors being installed on all telescopes



accuracy degrades as off-axis distance increases

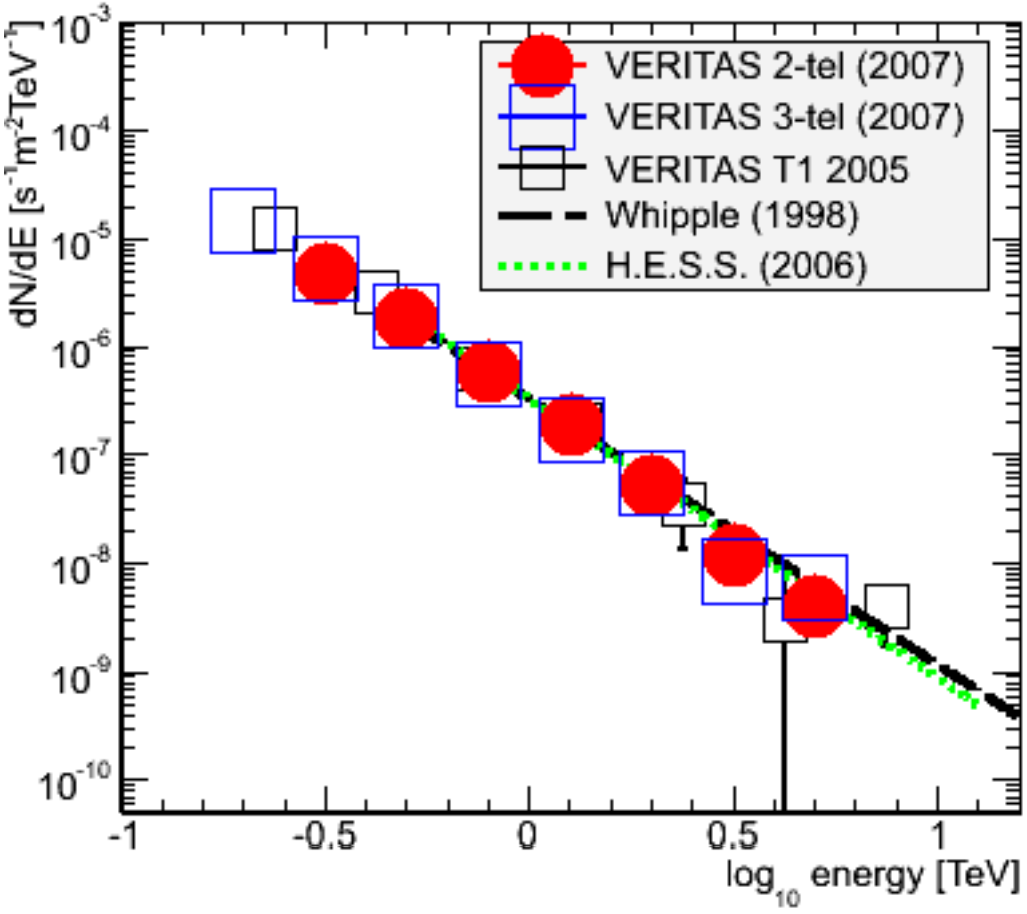




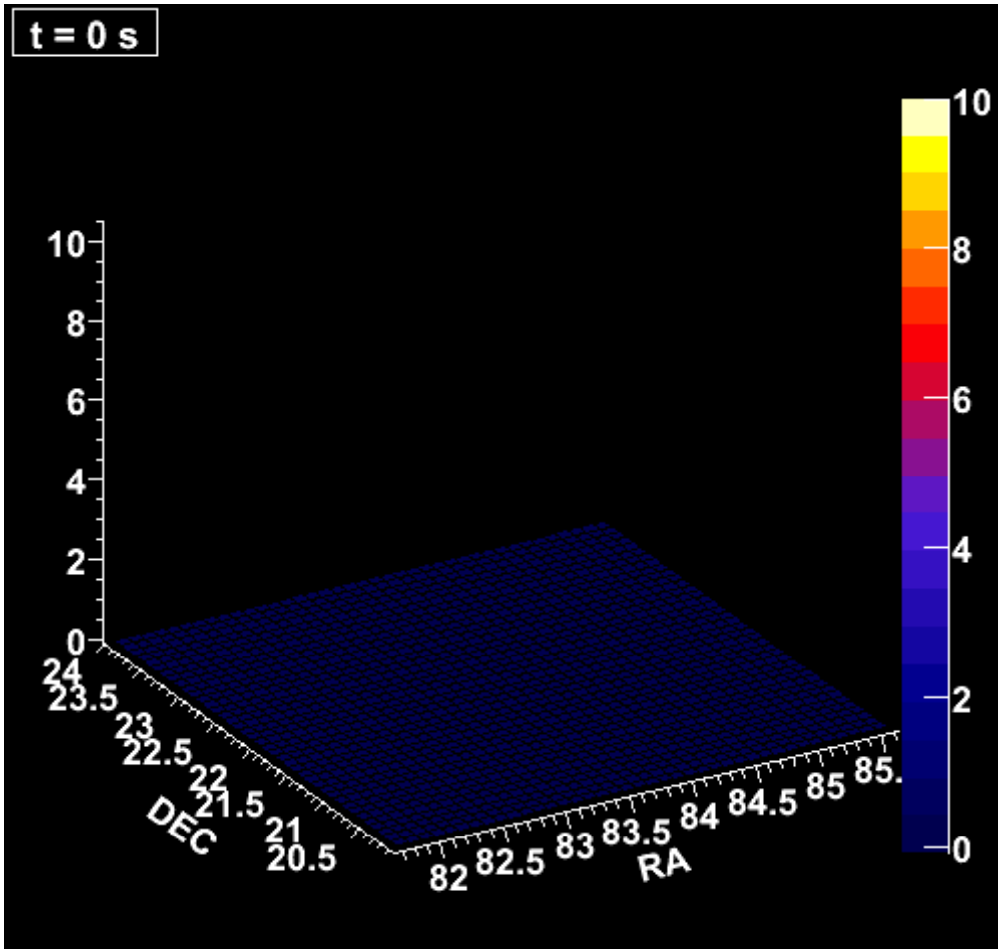


Crab Nebula

30 σ/√hour



Growth of Crab Signal



VERITAS Performance

effective area: 10^4 – 10^5 m^2

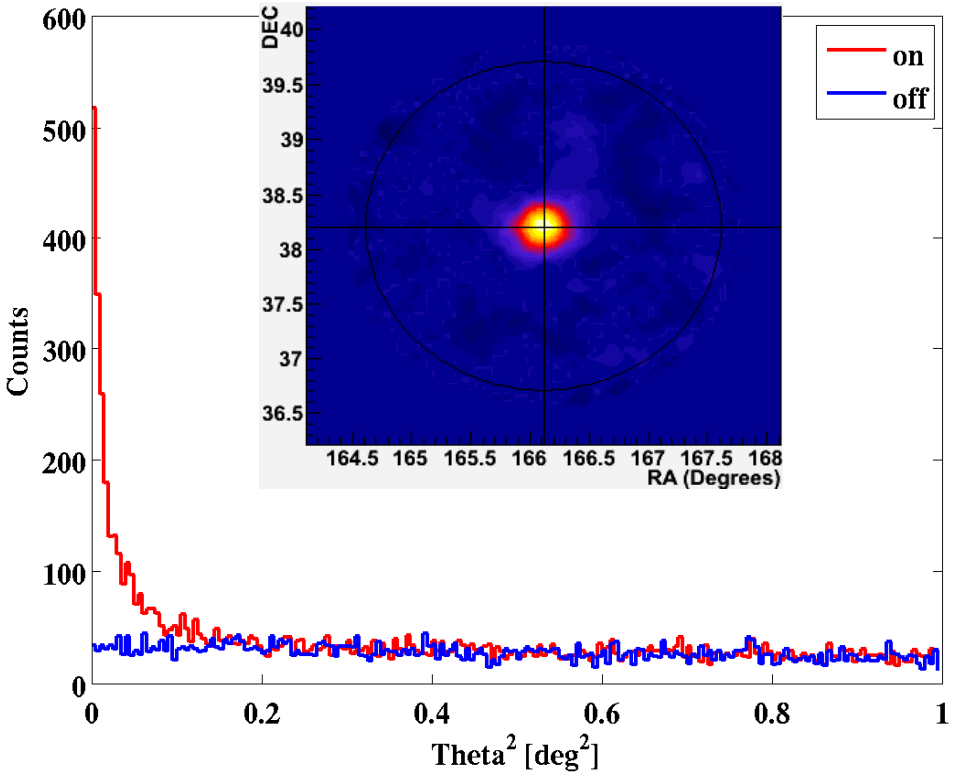
energy range: 80 GeV – 30 TeV

sensitivity: 10% of Crab Nebula Flux in under one hour (5σ)

angular resolution: ~ 0.1^o - 0.2^o (68% containment – E dependent)

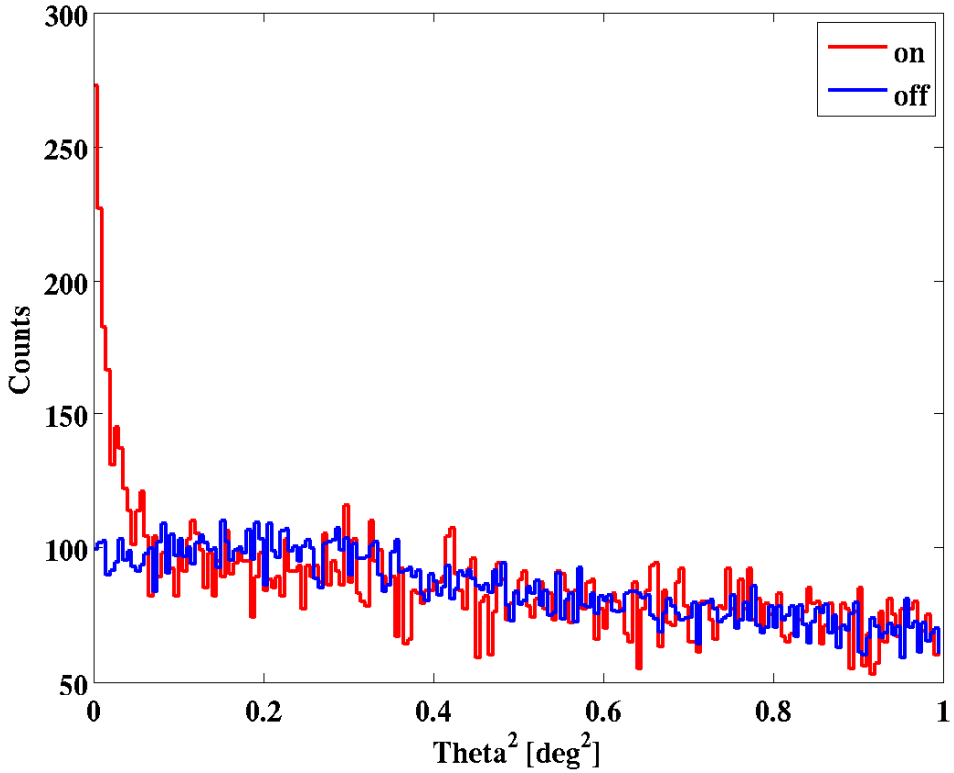
energy resolution: ~ 15%

AGN Observations:
Markarian 421 and Markarian 501
Two telescopes: Spring, 2006



Mrk421: 7.2 hours
5.6 γ/minute

active state



Mrk501: 11.4 hours
0.8 γ/minute

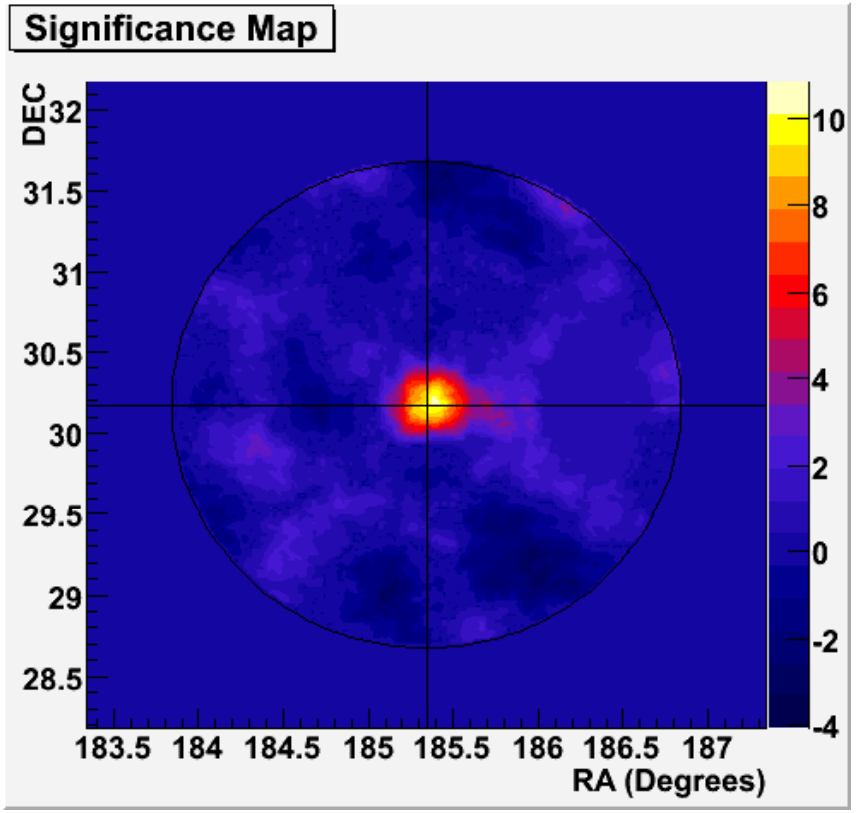
good sensitivity to MrK501
in its quiescent state

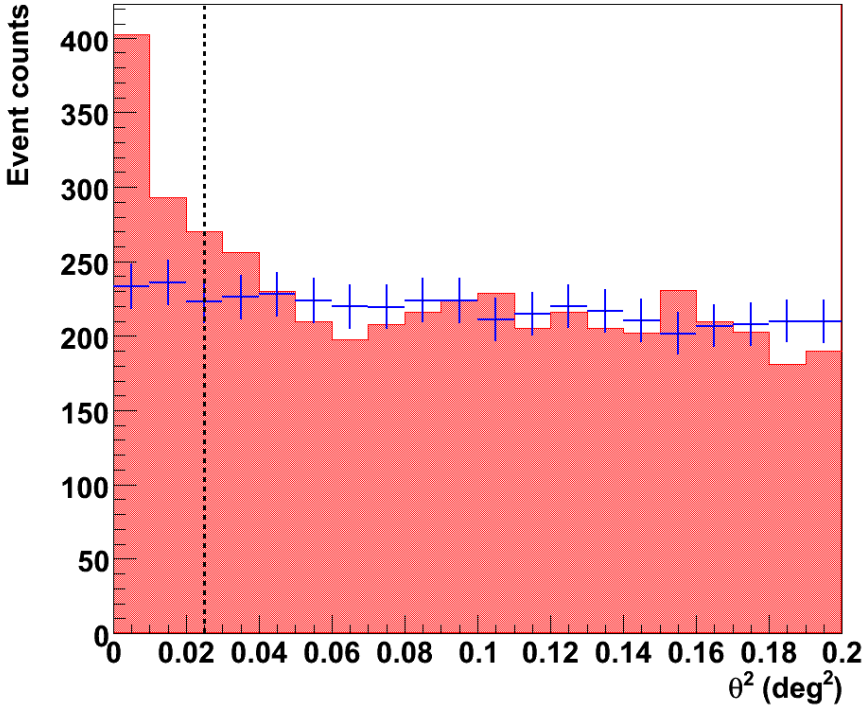
1ES1218+30.4

2nd furthest VHE blazar (z = 0.182)

detected by MAGIC

E > 120 GeV
8.2 hours
6.4 σ



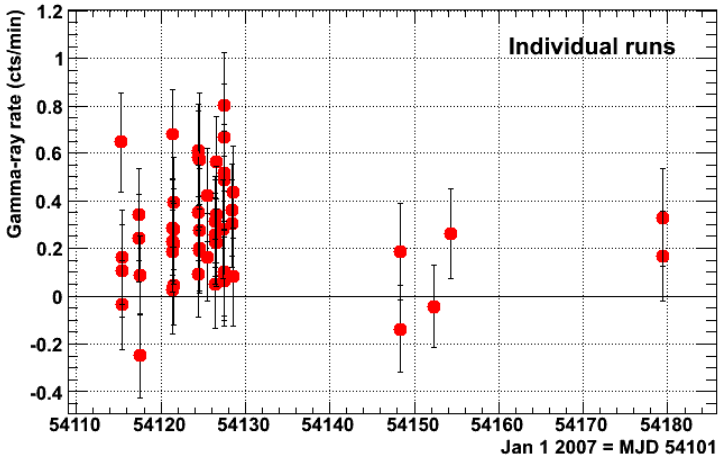


VERITAS detection:

observations Dec 06 – Mar 07
2 or 3 telescopes
0.5º wobble
17.4 hours after quality cuts
10.2 σ
0.3 +/- 0.05 γ/minute

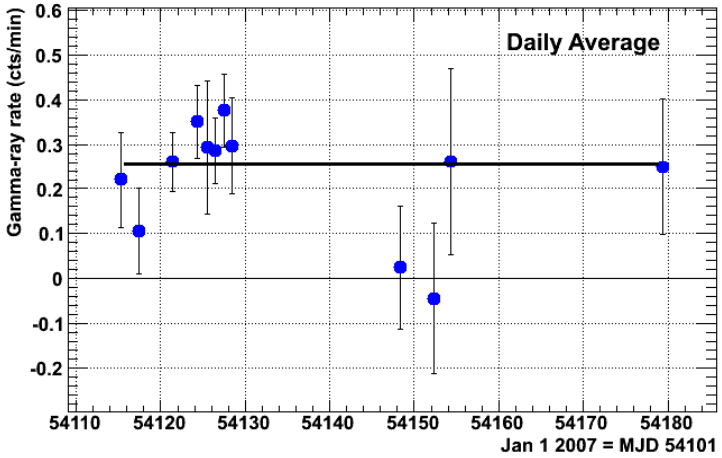
1ES1218+30.4

VERITAS light curve: no evidence for time variability
but statistics are limited



counts per minute
averaged over the run

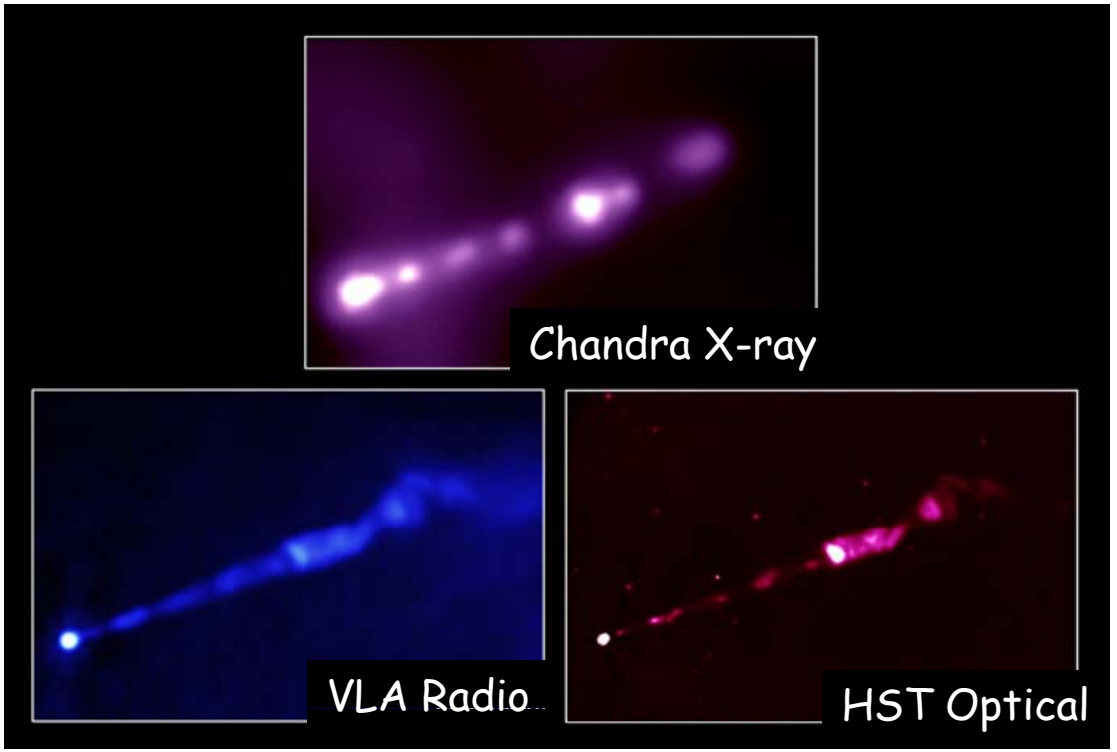
(not corrected for elevation angle)



counts per minute
daily average

statistical errors only

M87



- giant (elliptical) radio galaxy
- only non-blazar extragalactic VHE source
- 16 Mpc distant – near centre of Virgo cluster
  - -also called Virgo A
  - - powerful radio source
- core has an AGN with $3.2 \times 10^9 M_\odot$ black hole
- like a BL Lac, but jet does not point at us
  - - jet seen in radio, optical and X-rays with similar morphologies
  - - probably synchrotron radiation -> IC can give VHE γ
  - - HST says jet angle is $<19^o$ (superluminal motion)
- previous detections:
  - HEGRA 4.1 σ (1998-1999)
  - HESS 13 σ (2003-2006) variable on different time scales

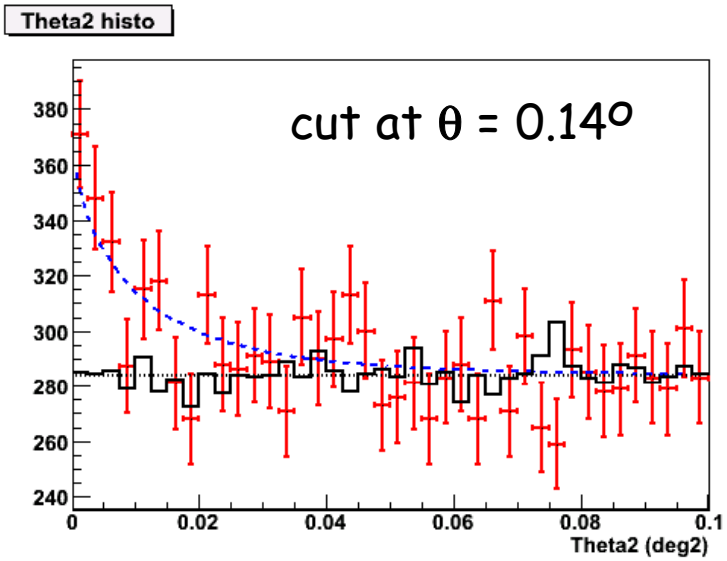
VERITAS observations of M87

51 hours, Feb – Apr 2007
(90% pass quality cuts)

55º – 71º elevation

wobble mode 0.5º

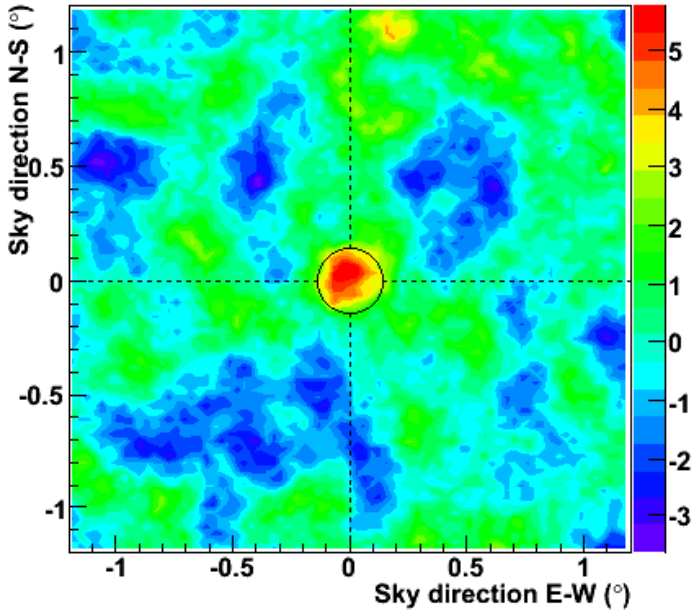
3 telescopes



263 events above background → 5.1 σ

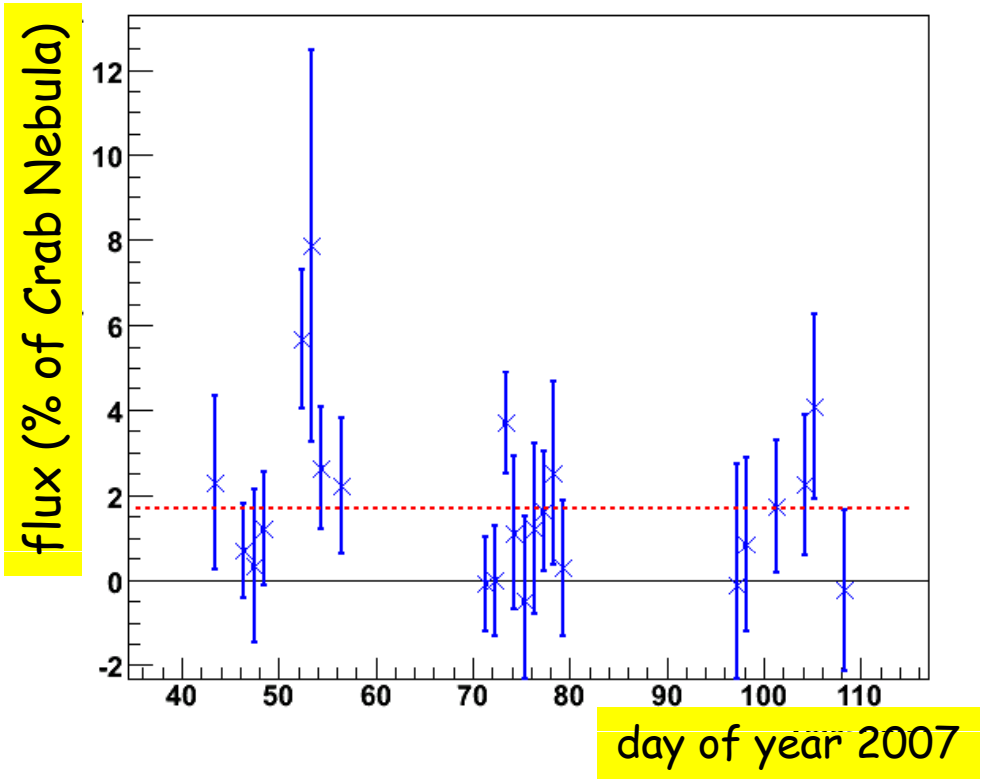
threshold energy = 250 GeV

point-like: < 2.3 arc-min radius (ie PSF)



M87 light curve

no statistically significant variability observed



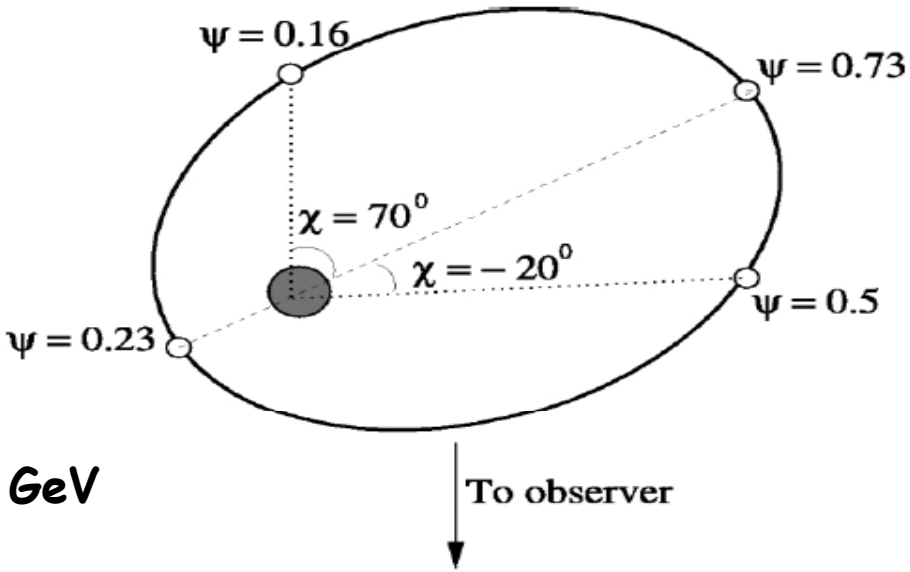
NB: HESS detected day-scale variability during M87 *high state* in 2005

LSI+61 303

- high mass X-ray binary (HMXB)
- one of three detected in TeV γ rays
(HESS detected PSR B1259-63 and LS5039)
- massive Be star with dense circumstellar disk
- orbiting a neutron star or black hole
- period = 26.5 days (very similar to lunar cycle – see later)
- close orbit only a few stellar radii separation
- phases (radio defines phase = 0)

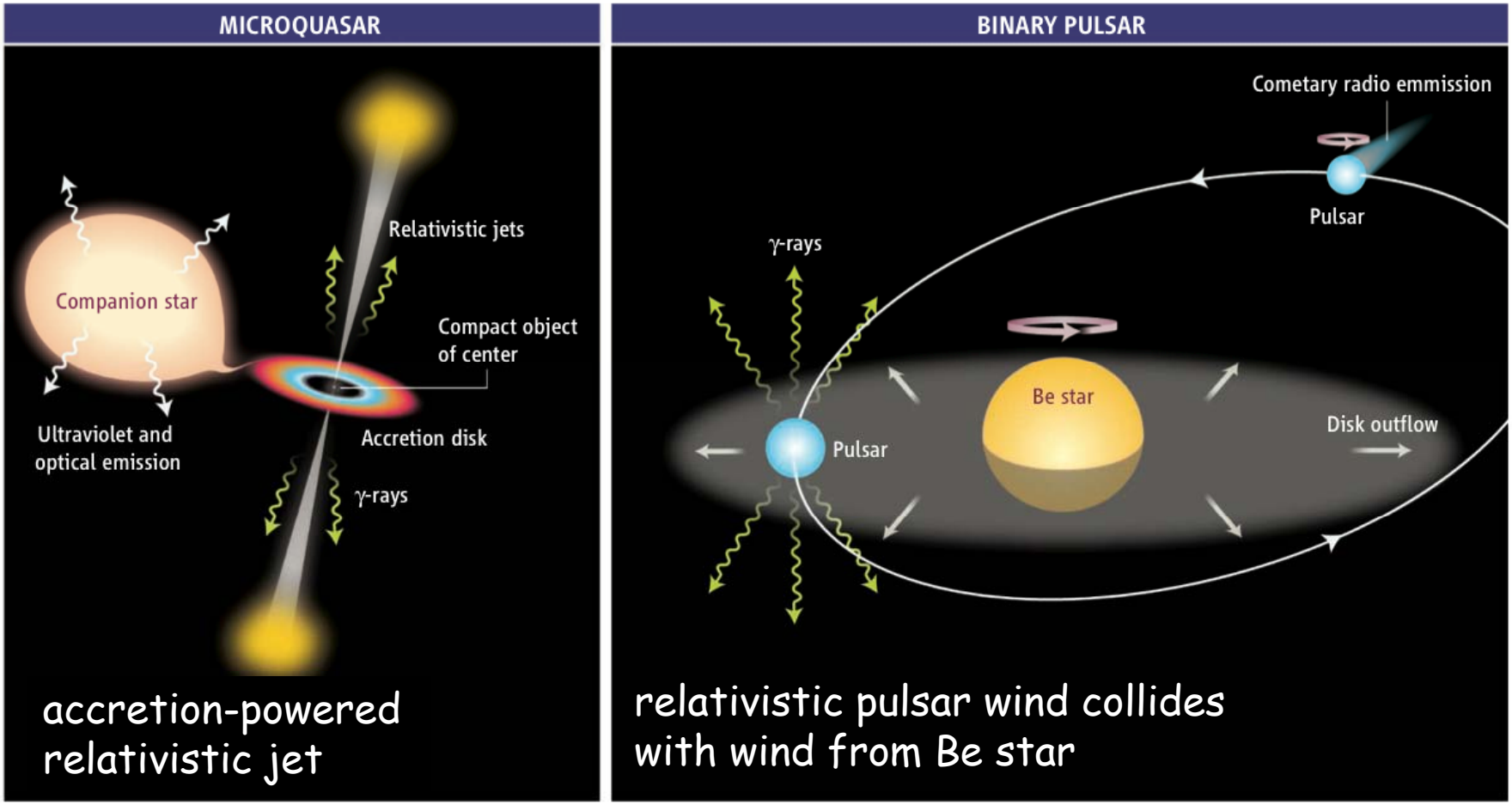
- periastron	0.23
- apastron	0.73
- inferior conjunction	0.26
- superior conjunction	0.16

- phase-dependent variable emission seen at all wavelengths



MAGIC detection: 54 h, 9.0σ, E>200 GeV

LSI+61 303 model classes



particle acceleration in both models - VHE γ rays produced by

- inverse-Compton scattering with electrons and stellar photons

and/or

- hadronic production of π^0s from proton collisions

VERITAS observations of LSI +61 303

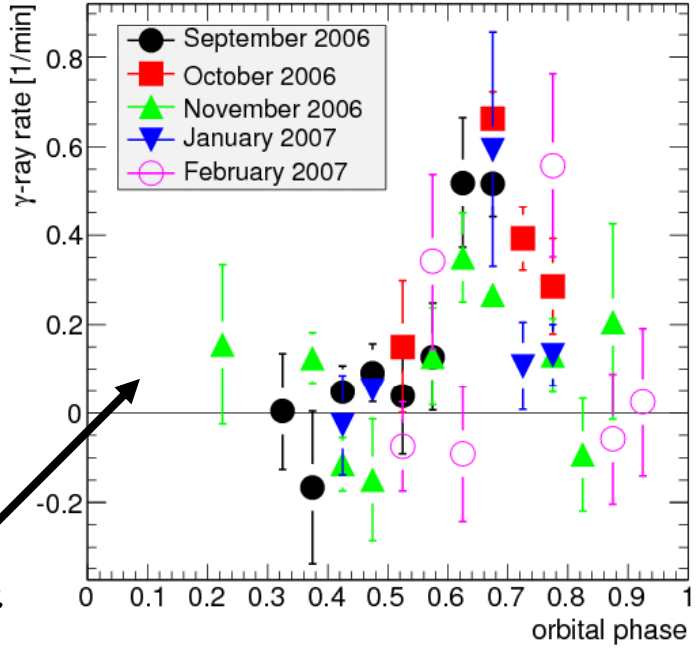
Sep - Nov 2006 2 telescopes 32 hours 0.3º wobble

sensitivity: 5 σ in 3.3 h for 10% of a Crab-like source at 70º

Jan – Feb 2007 3 telescopes 12 hours 0.5º wobble

sensitivity: 5 σ in 1.2 h for 10% of a Crab-like source at 70º

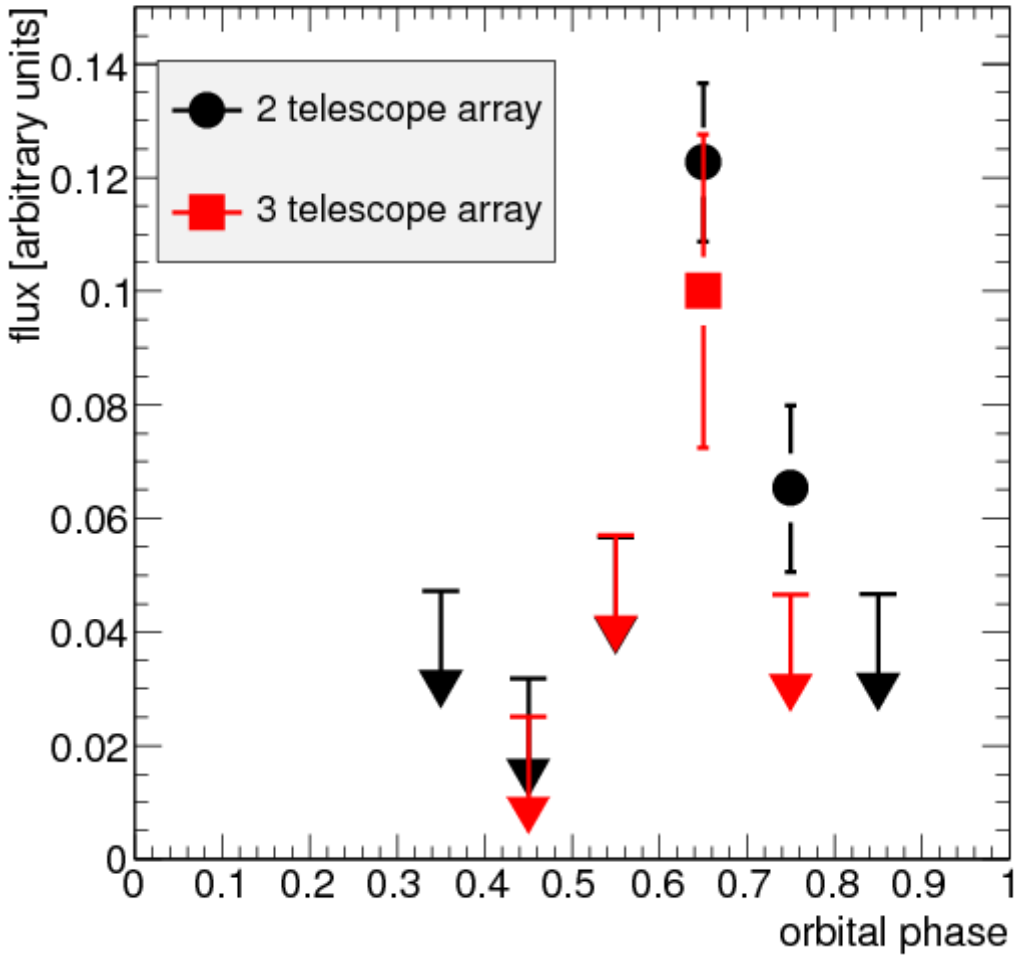
raw rates vs phase



no data while moon is up

no detection in February but limited observing/statistics

Combined Data

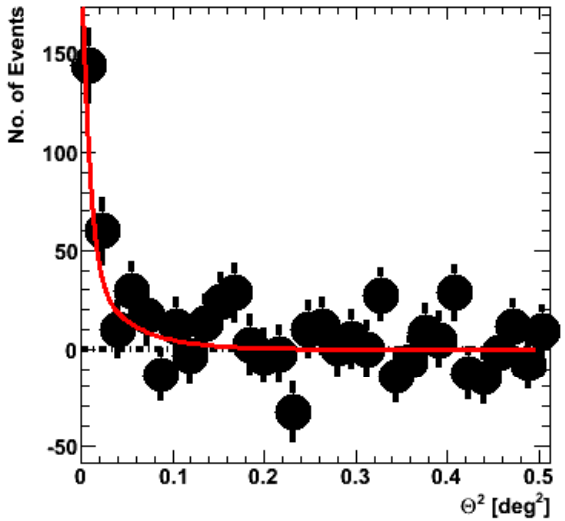


Flux < 3% of Crab in low-flux phase bins,

Flux > 10% of Crab in high-flux phase bin

Period of 26.49 days has 99.94% probability

LSI +61 303

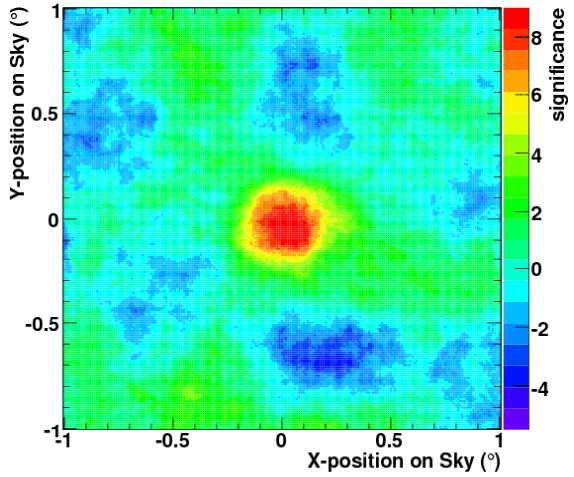


Can we resolve the source?

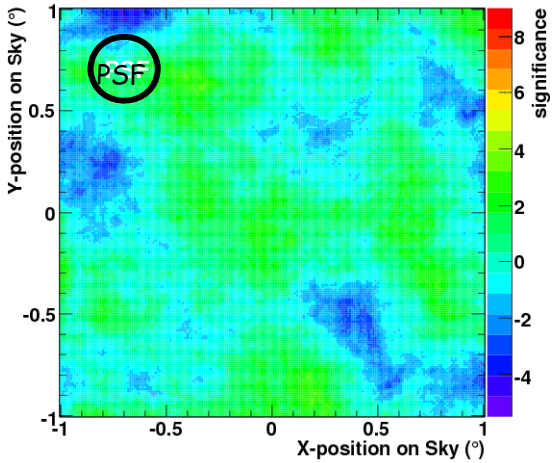
θ^2 distribution for high-flux phase bin (0.6 – 0.7) is well fit by Monte Carlo assuming a point source

2D sky maps are consistent with point-spread function

2-telescope data



$0.5 < \psi < 0.8$ (25 h)



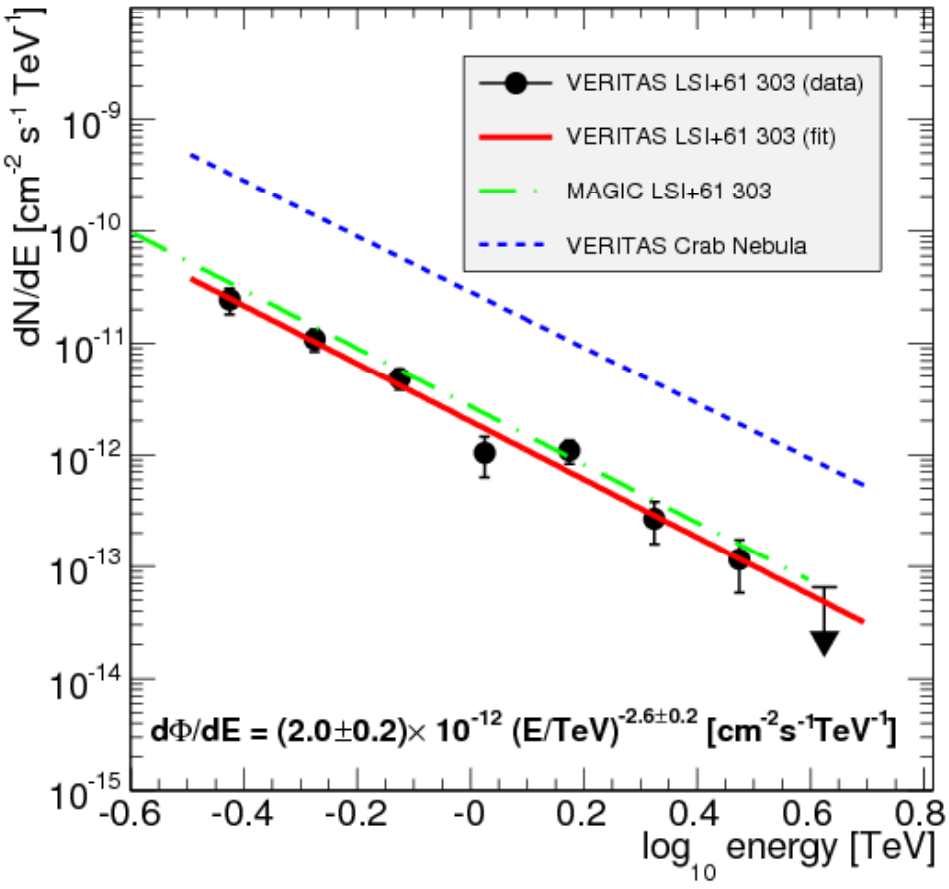
$0.8 < \psi < 0.5$ (19 h)

LSI +61 303

preliminary energy spectrum

Crab-like but 10%

consistent with MAGIC



More Results

results on other topics/sources will be given at the

International Cosmic Ray Conference

Merida, Mexico

July 3 – 11, 2007

Future Plans

near term (first two years):

4 key science projects (50%)

- sky survey (Cygnus) 130 hours/year
- active galactic nuclei 110
- supernova remnants 100
- dark matter 60

proposed observations (40%)

- time allocation committee

director's discretionary time (10%)

- targets of opportunity
- engineering

longer term:

stay at present site to at least end of 2010