Performance of the VERITAS experiment

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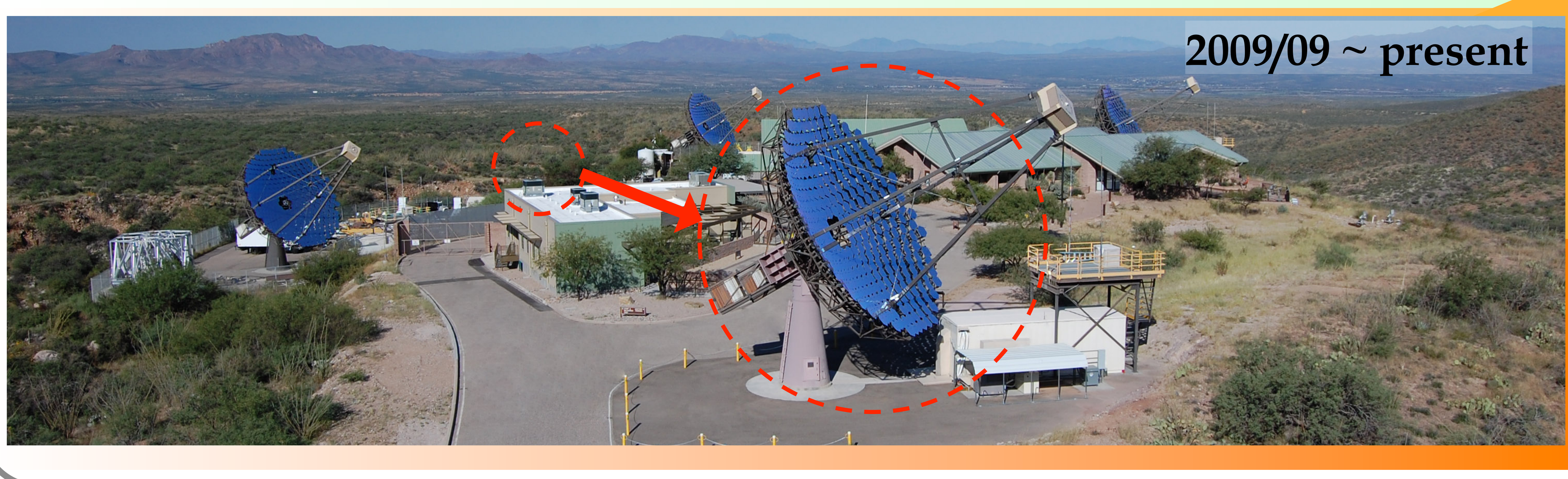
VERITAS Operation and Upgrades



V4

2007/09 ~ 2008/08

VERITAS [1] is an array of four imaging atmospheric Cherenkov telescopes located at the Fred Lawrence Whipple Observatory in south Arizona (30° 40'N 110° 57', 1268 m a.s.l.) designed to study astrophysical source of gamma-ray emission [2]

- ◉ Energy range : ~ 85 GeV up to > 30 TeV
- ◉ Field of view : 3.5°

V5

2008/09 ~ 2012/08 (Period after the relocation of telescope 1)

Relocation of telescope 1 was motivated to make the array more symmetric, increasing the sensitivity by augmenting the stereo observation of the air showers [3]

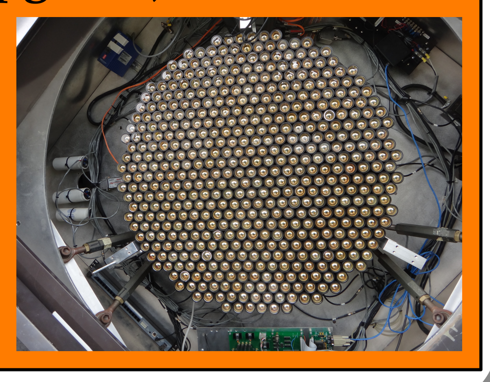
- ◉ Improvement on background rejection and angular resolution → Increased sensitivity

V6

2012/09 ~ Present (Period after the camera upgrade)

The camera upgrade replaced the PMTs with high quantum efficiency PMTs [4]

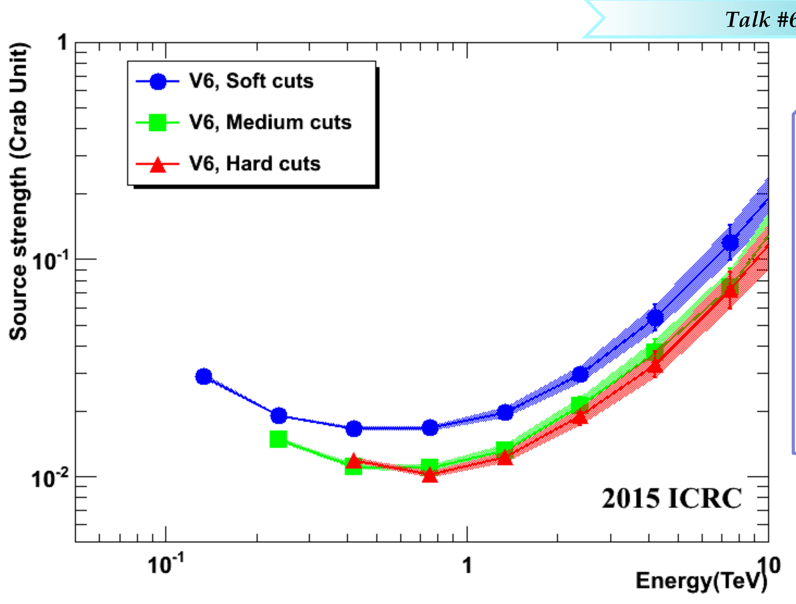
- ◉ Increase the Cherenkov photon collection efficiency
  - Better morphological separation between gamma-ray and hadronic induced air showers → Increased sensitivity
  - Lower energy threshold values

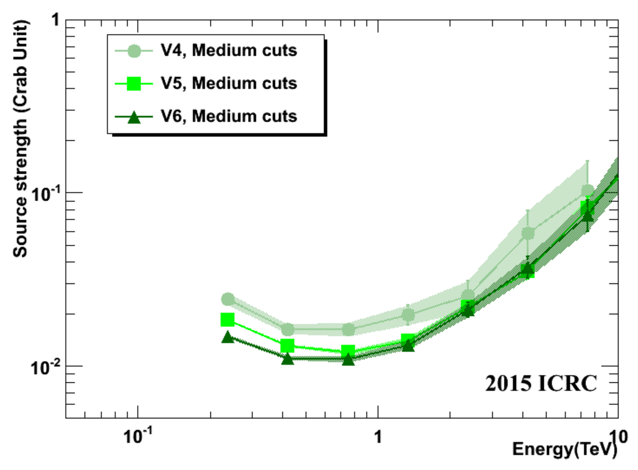


Sensitivity of VERITAS for standard operation

Sensitivity for high elevation observation

Talk #676 on VERITAS performance for moonlight operation





Differential sensitivity

Calculated with Crab Nebular data taken at high elevation to estimate the weakest source that can be detected at 5σ significance within 50 hours of observing time in each energy bin. Li & Ma's likelihood ratio method [5] was used.
Standard VERITAS analysis [6] was done using box cuts optimized differently with Hillas parameters [7].

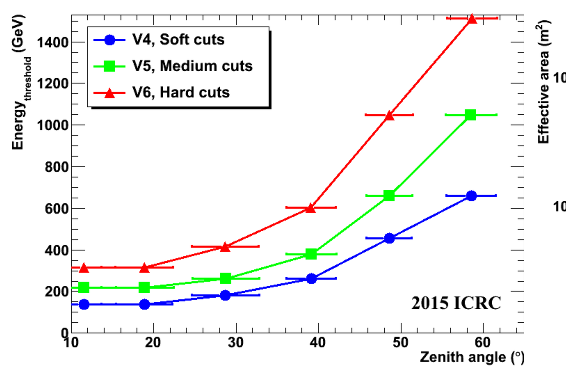
Soft cuts
Optimized for sources with index of -3.5 to -4.0, with low energy threshold values

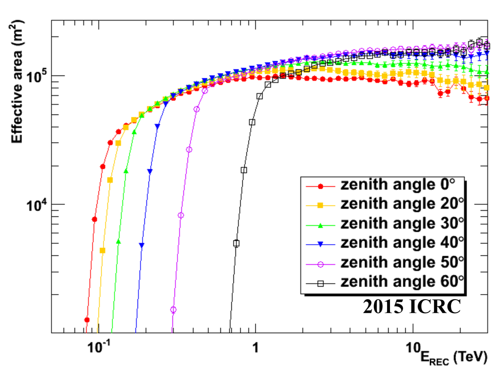
Medium cuts
Optimized for sources with index of -2.5 to -3.0, 2-10% of the Crab Nebular strength

Hard cuts
Optimized for sources weaker than 2% of the Crab Nebular strength

Clear improvements in sensitivity for all of the cuts with VERITAS upgrades

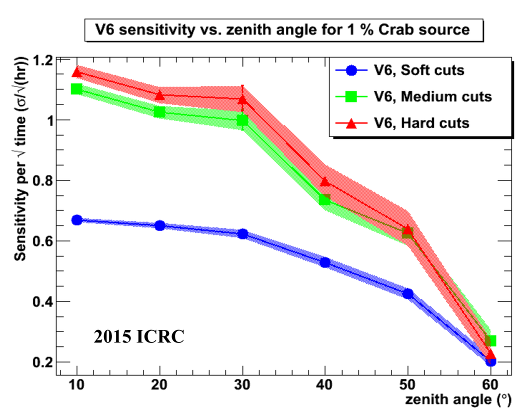
Zenith angle dependency

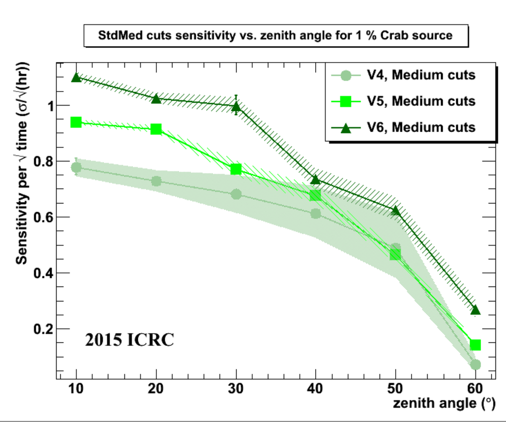




Zenith angle dependent performance

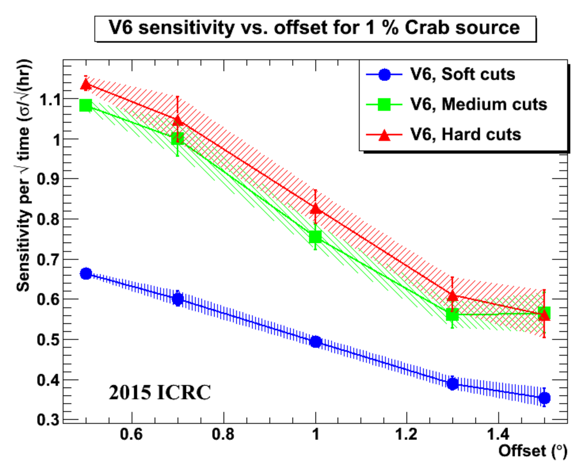
As zenith angle of observation increases, the energy threshold value and effective area increase. Studies of high energy gamma-ray emission from a relatively bright source with a hard index can benefit from large zenith angle observations. Generally other reconstruction methods, such as the displacement method are used for the analysis of large zenith angle data to improve the quality of shower reconstruction [8].

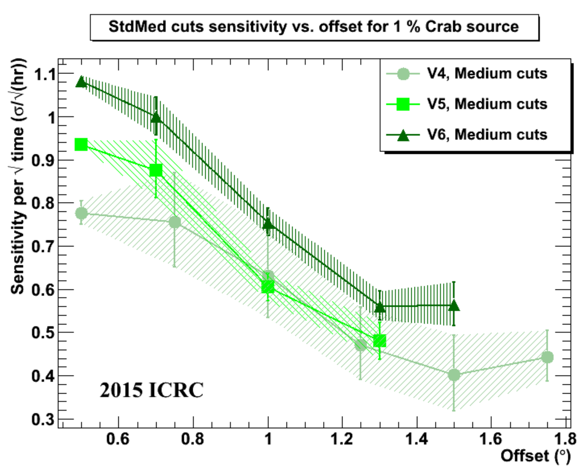




Offset dependency

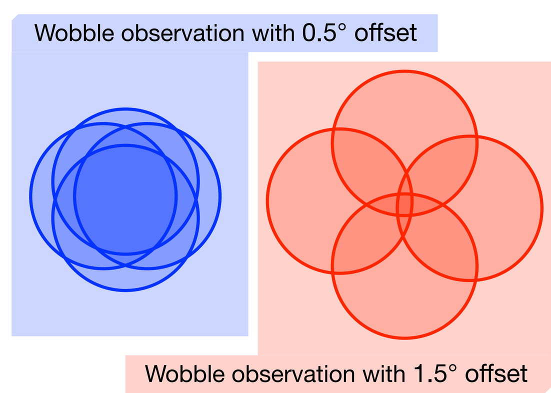
Talk #1172 on likelihood method for detecting very extended source with VERITAS



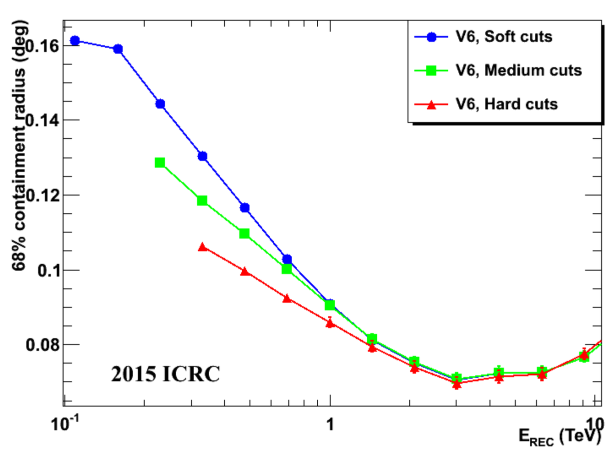


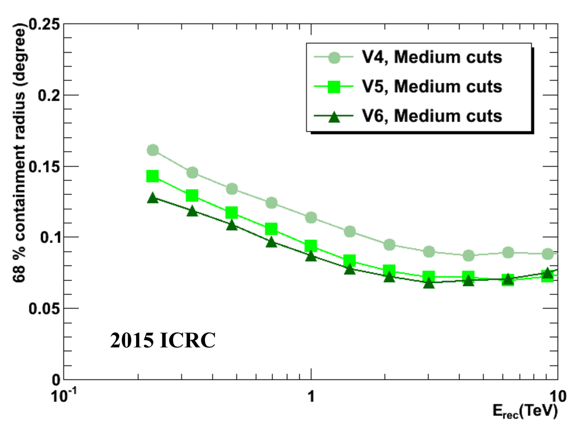
Offset dependent performance

Standard VERITAS observations are carried out with the wobble mode method. For a point source observation, a 0.5° offset is used. However, observations with larger offsets are necessary for studies of extended sources.
While sky coverage increases as observing offset increases, the sensitivity and point spread function degrades. Studying how the performance of the array changes with offset is essential to developing an optimal observing strategy, particularly when dealing with extended regions of gamma-ray emission or multiple sources in the same field of view.



Angular resolution



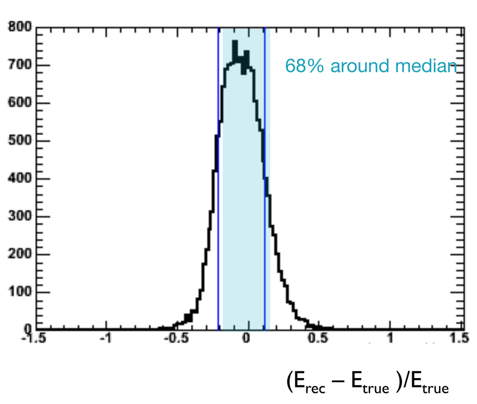


Angular resolution

Angular resolution is calculated to get a radius containing 68% of the gamma-ray events with Monte Carlo simulation.

Further improvements of angular resolution are possible via tighter event selection cuts, tighter telescope multiplicity requirements or several advanced analysis method.

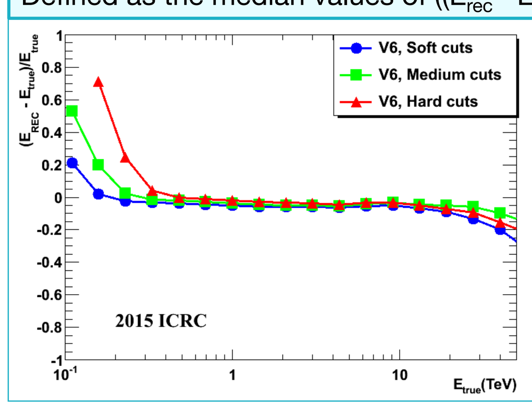
Energy bias & resolution

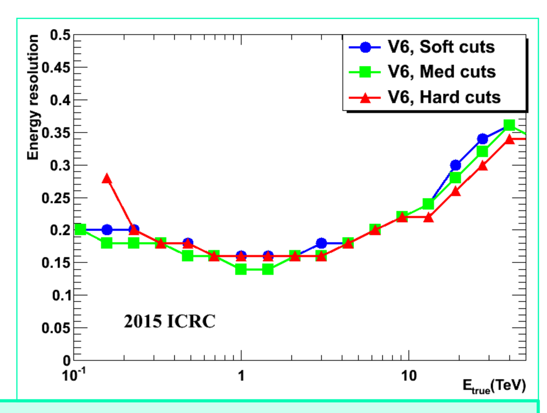


Energy estimation

Standard analyses for VERITAS use look-up tables derived from simulated events to reconstruct energy based on the strength of the signal and the distance of the air shower.
Difference between true energy and reconstructed energy of a gamma-ray event is studies to estimate the accuracy of the energy reconstruction.

Energy bias
Defined as the median values of $((E_{rec} - E_{true})/E_{true})$

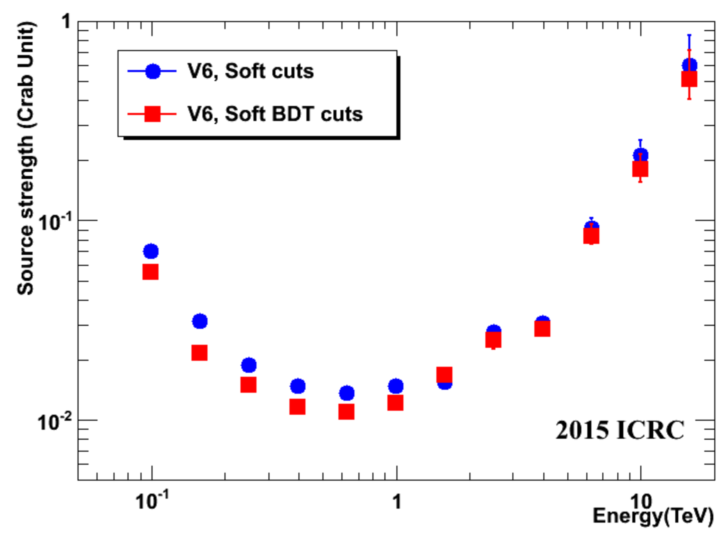




Energy resolution
Defined as 68% containment width around median values of $((E_{rec} - E_{true})/E_{true})$

Performance with advanced analysis

**Poster 3 GA board #81 On Monte Carlo template-based analysis applied to the VERITAS*



Advanced analysis for VERITAS

Performance of VERITAS array can be improved with better event reconstruction methods and with more sophisticated background rejection methods.
Among several methods under development for VERITAS (e.g. template-based analysis* [9]), we will show the results from a boosted decision tree (BDT) method [10] as an example.

Boosted Decision Tree method

BDTs are trained on simulated gamma rays and real background events as a function of energy and elevation, and they incorporate the standard Hillas parameters.
Although the BDT method performs best compared to box cuts on soft spectrum sources, improvements are also observed for sources with hard spectra.

- ◉ 10-25 % decrease in observation time required for detection of weak source with 1% C.U. strength and Crab Nebula-like spectrum

References

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[3] J. S. Perkins at al. Fermi Symposium proceeding, 2009
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[10] A. Hoecker et al., Arxiv:physics/0703039, 2007

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