Executive Summary : Double-layered Water Cherenkov Detector for the Southern Wide-field Gamma-ray Observatory (SWGO)

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The Southern Wide-field-of-view Gamma-ray Observatory (SWGO) will use the well-established and cost-effective technique of detecting Cherenkov light produced in water-filled detection units for TeV gamma-ray astronomy. Instrumenting at a High altitude (> 4.4 km) with a high fill factor ($> 80\%$) will allow SWGO to be complementary in the same energy range as Imaging Atmospheric Cherenkov Telescopes (IACTs). Several detector designs and technologies are currently being considered. Here we leverage aspect ratio and material reflectivity to develop a double-layered Water Cherenkov Detector (DLWCD) design; as a potential detector unit for SWGO, comprising two isolated chambers where the lower chamber in conjunction with the upper chamber enables an effective method for gamma/hadron separation in addition to improved energy and angular resolution.

1 Unit Design

Cylindrical DLWCD designs comprising an upper chamber ($\pi \times 1.91^2 \times 2.5\ m^3$) with a combination of reflective (white) and non reflective (black) walls and bases and an entirely white lower chamber ($\pi \times 1.91^2 \times 0.5\ m^3$). The upper chamber comprises an 8" PMT facing upwards, and the lower chamber comprises an 8" PMT facing downwards.

2 Particle Detection Efficiency and Energy Resolution

The DLWCD design, with white walls and a black top, has improved particle detection efficiency over contemporary designs in operation. A deeper chamber would ensure cascade production and subsequent detection of Cherenkov photons, while a narrower chamber with reflective walls improves sensitivity to lower energy γs. Reflective walls improve particle detection efficiency over non-reflective walls. The lower PMT can extend the dynamic range when the upper PMT saturates.

3 Angular Resolution

Angular resolution for 1 - 100 TeV vertical γ-ray's simulated with shower core at the center of an array of DLWCD's show that with appropriate likelihood function, material combinations should not affect angular resolution as late photons have minimal effect. The 68% containment is $\sim 0.03^{\circ}$ at 10 TeV γ energy.

4 Gamma/Hadron Separation

A maximum log-likelihood method comprising charge in the two chambers is implemented to discriminate between γs and hadrons. While there is no significant difference in the γ - hadron separation power with different material combinations, with the combination of reflective material, lower energy threshold can be achieved due to an increased particle detection efficiency.

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