FIRST RESULTS FROM NICHE AND THE NICHE-TALE HYBRID DETECTOR

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NICHE LAYOUT
NICHE COUNTERS

Solar Panel

GPS

Counter Box

WLAN

PMT

FADC

Shutter Motor

Batteries

Charge Controller

Winston Cone
Traditionally one measures the Cherenkov Lateral Distribution.

\[ R > 120 \text{ m}: \text{Energy} \]

\[ R < 120 \text{ m}: X_{\text{Max}} \]

This requires measurements within 120 m of the shower core.

Requires large number of Cherenkov detectors for > 1 km\(^2\) sr.
At sufficiently high energies, larger detector spacings can be used to measure the time-width at a given $R$.

At small $R$: dominated by light from lowest portion of shower.

At large $R$: get large part of shower. Many paths, wide time. The deeper the shower the wider the time. We want to demonstrate this with hybrid NICHE/TALE data.
NICHE STATUS

- Ten counters deployed by September 2017
- Base antenna for remote operation April 2018
- Final four counters deployed September 2018
- PMT Recommissioning February 2018

See also Omura #379
NICHE STATUS

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- Base antenna for remote operation April 2018
- Final four counters deployed September 2018
- PMT Recommissioning February 2018
- With current thresholds ($7\sigma$) see 0.35 Hz of triggers per counter, 0.4 Hz of events with a plane fit.

See also Omura #379
NICHE STATUS

20190427–20190509
Shower Plane Direction M>=4

Zenith Angle Distribution 20190427–20190509
NIGHT-SKY BACKGROUND

- Started taking shutter-closed and shutter open noise runs at the beginning of each night from 2018 October
- 4096 external triggers of each type
- There is a clear signal from the data acquisition system

[Graph showing data acquisition with closed and open shutters]
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- 4096 external triggers of each type
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- Average together the 4096 Fourier Transforms (FFTs) of each type (closed/open)
- Take difference in quadrature of open average FFT and closed average FFT
  - Most of the DAQ noise is removed
  - Looks like low pass filter (from impulse response of PMT)
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- Need 72 NPE/\text{ns} with this response to get same low-pass filter behavior (some clouds?)

\[ I(t) = \begin{cases} \frac{C_0 \exp\left(-\frac{t^2}{2\sigma^2}\right)}{\sqrt{2\pi \sigma^2}} & t < 0 \\ C_0 \exp\left(-\frac{t^2}{2\sigma^2}\right) \left(1+\frac{17.1+t}{1.3}\right) & t \geq 0 \end{cases} \]

\( r = 2.5 \text{ ns}, f = 10.7 \text{ ns} \)

Korosteleval et al., 31st ICRC, 0492
NICHE-TALE HYBRID

- Find matches in range 10–20 µs between NICHE events and TALE FD events.
- TALE performs a Profile-Constrained Geometry Fit (PCGF) for Cherenkov dominated events
  - Gives very precise measurement (<1°) determination of shower angle within the shower-detector plane
- Comparison between NICHE plane direction and TALE PCGF geometry directions shows agreement within 3.4°
  - This is dominated by NICHE assumption of a Cherenkov “plane”
TALE view of shower along with shower-detector plane (and uncertainty). NICHE counters shown as red squares.

NICHE counter locations, signal size (filled circles), relative time (color) and width (open circles). Intersection of TALE SDP with ground shown and core position shown in purple.
The NICHE counter times allow one to fit the time-vs-angle over a much larger angular range to determine the geometry. This validates the TALE PCGF geometry to 1°.
NICHE-TALE HYBRID

• Using one floating time offset (the ad hoc time) can use $M \geq 4$ plane fit events, to do hybrid timing fits.
• Find an ad hoc time distribution with a mean of 88 ns and a width of 45 ns.
• Note that TALE time sampling cadence is 100 ns.
• Can now use the mean ad hoc time as input and do tightly constrained hybrid timing fits even with singleton NICHE events.
NICHE-TALE HYBRID

[Graphs showing data analysis results]
NICHE-TALE WIDTH VS DISTANCE

• NICHE Waveforms get wider (larger FWHM) as they get farther from the shower axis: Cherenkov Width Lateral Distribution (CWLD)

• The shape of the CWLD depends on how far the $X_{\text{max}}$ point along the shower is from the counter, $D_{\text{max}}$
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NICHE-TALE WIDTH VS DISTANCE

• Using NICHE/TALE coincident events can look at Width vs $R_p$
  • Core position is uncertain from TALE to 50–100 m (thus $R_p$ is uncertain)
    • Take only bright and long events (250 photons/tube and longer than 6°)
  • Plot FWHM from NICHE, 10–1000 ns, that have good waveform fit
• Color by distance (from NICHE counter) to shower maximum
  • The $R_p$ uncertainty smears right/left on the plot
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- Take FWHM averages, keeping only bins with more than 40 events
- Smaller $D_{\text{max}}$ correlates with larger FWHM
CONCLUSION

• 14-detector NICHE array deployed in the TALE field-of-view
• Data-commissioning underway (and photometric calibration)
• Establishing night-sky noise baseline
• Observed coincidences with TALE-Cherenkov, imaging/non-imaging Cherenkov hybrid events
• Have observed the change in the CWLD with the distance to the shower maximum