FIRST RESULTS FROM NICHE AND THE NICHE-TALE HYBRID DETECTOR

DOUGLAS R BERGMAN

JOHN F KRIZMANIC, K NAKAI, Y OMURA, Y TSUNESADA

FOR THE TELESCOPE ARRAY COLLABORATION

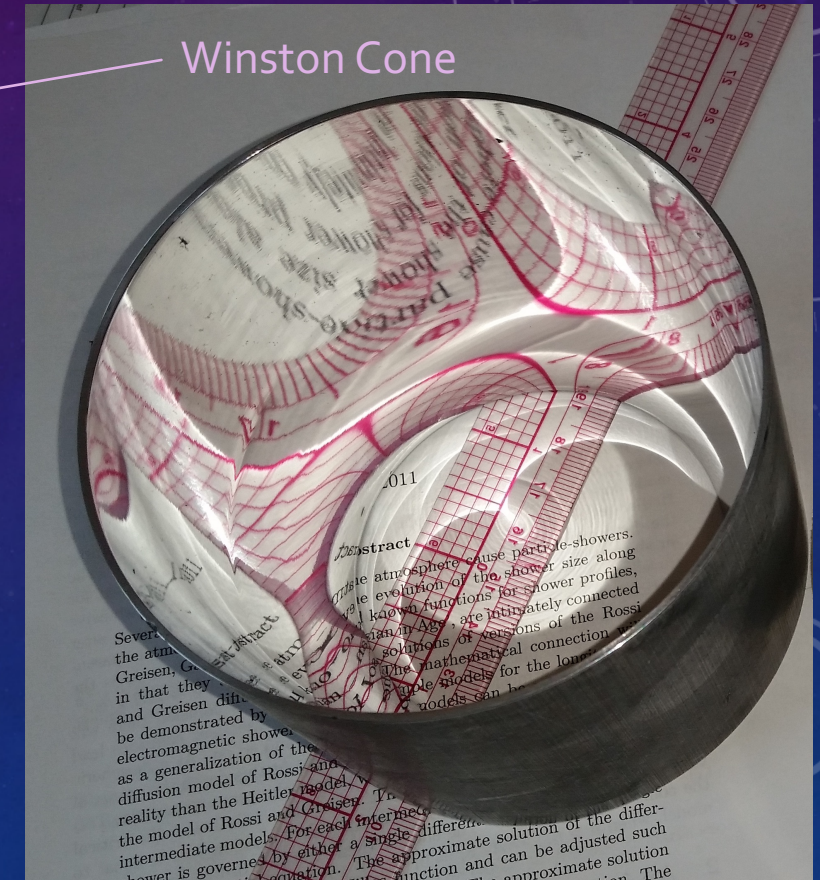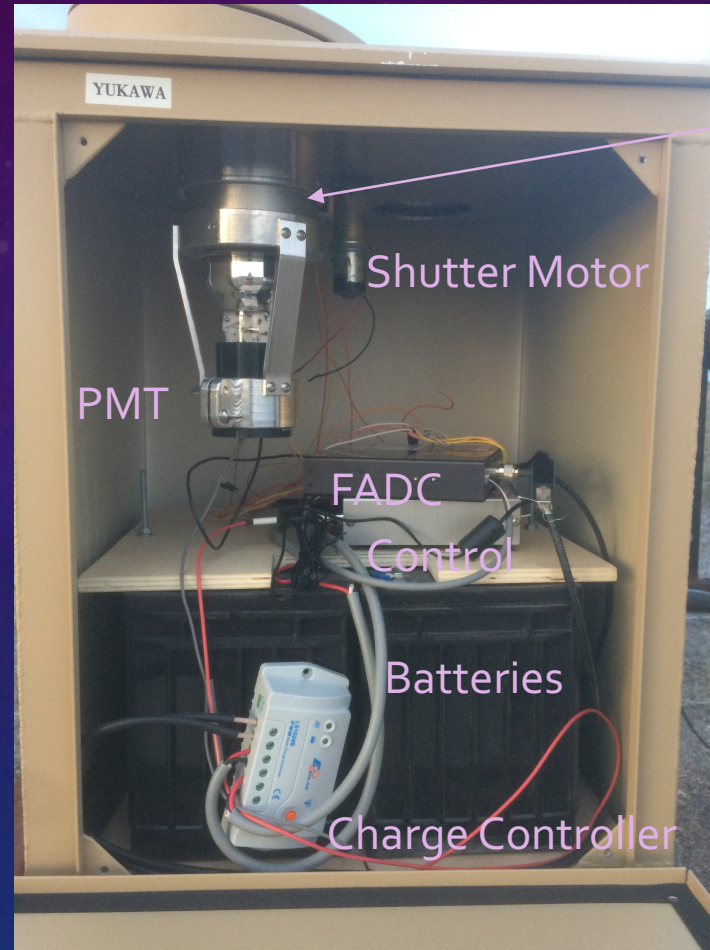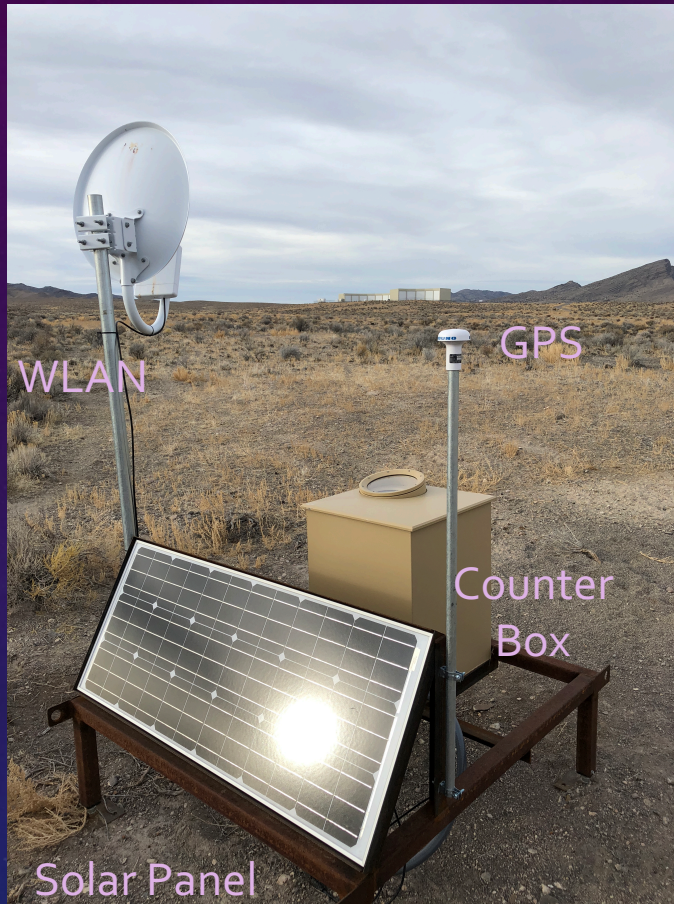36TH INTERNATIONAL COSMIC RAY CONFERENCE

26 JUNE 2019

NICHE LAYOUT

TALE FD

noether

einstein

rossi

newton

dirac

rutherford

bardeen

curie

yukawa

feynman

rubin

meitner

bell

NICHE LAYOUT

NICHE COUNTERS

WLAN

GPS

Counter Box

Solar Panel

YUKAWA

Shutter Motor

PMT

FADC Control

Batteries

Charge Controller

Winston Cone

CHERENKOV PHENOMENOLOGY

Lorenz, NIM **A433**, 24 (1999)

Illuminated radial "footprint" of a straight track ($\beta = 1$).

Patterson & Hillas , JPG **9**, 1433 (1983)
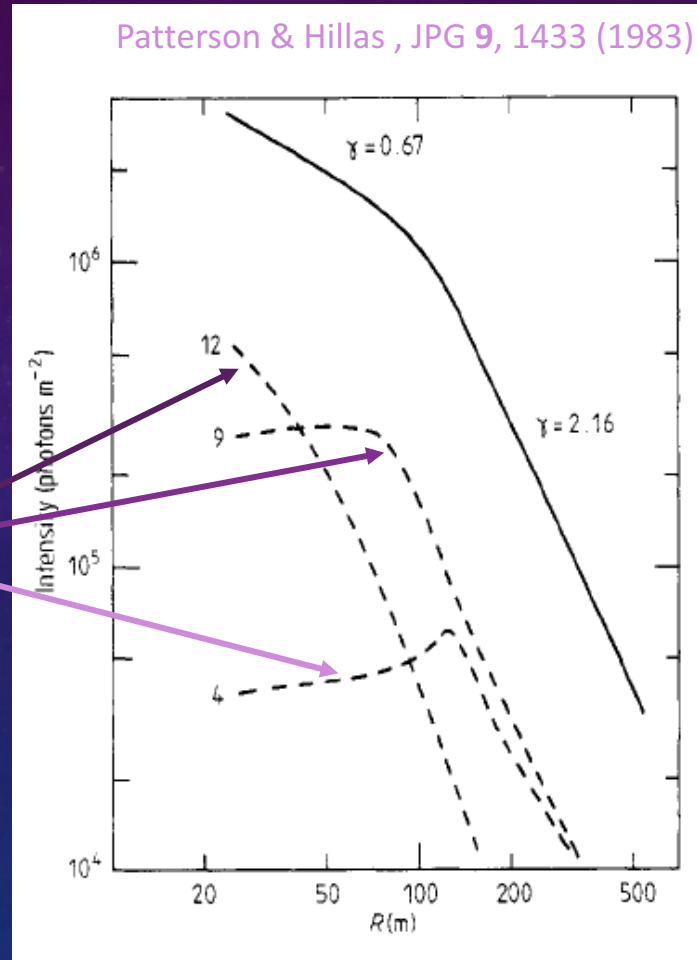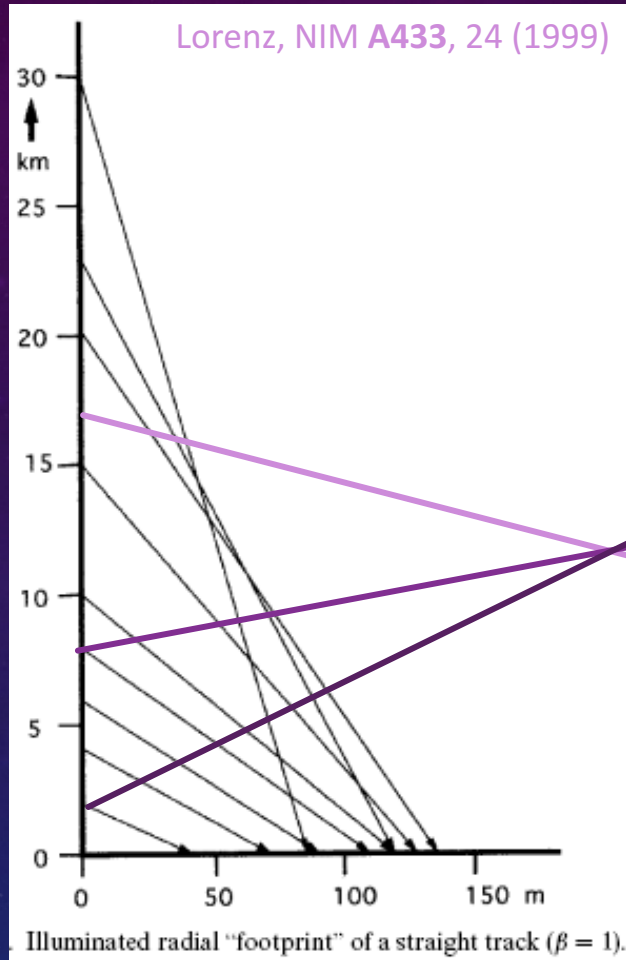
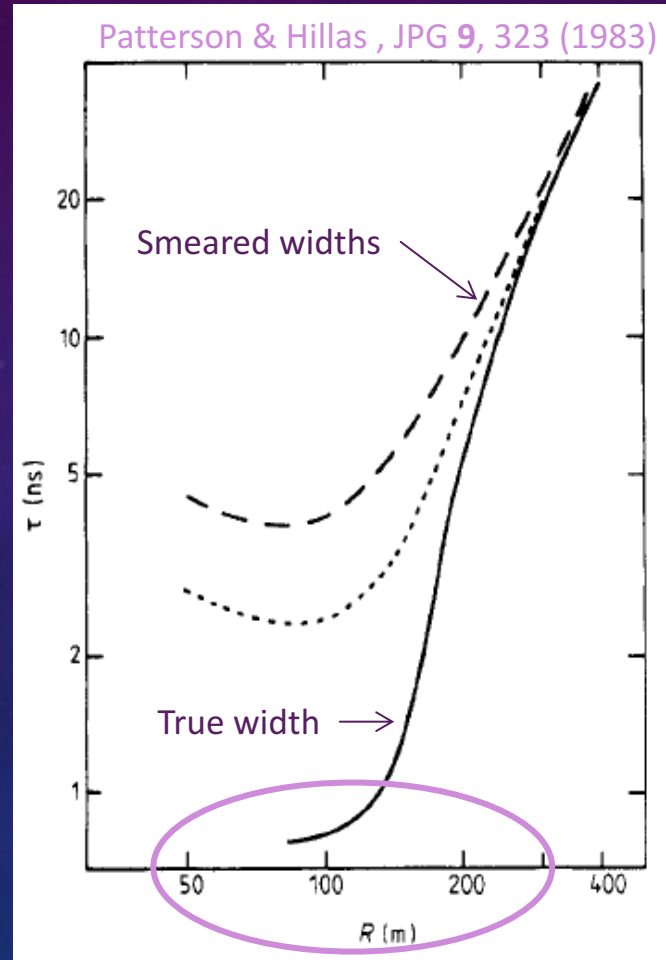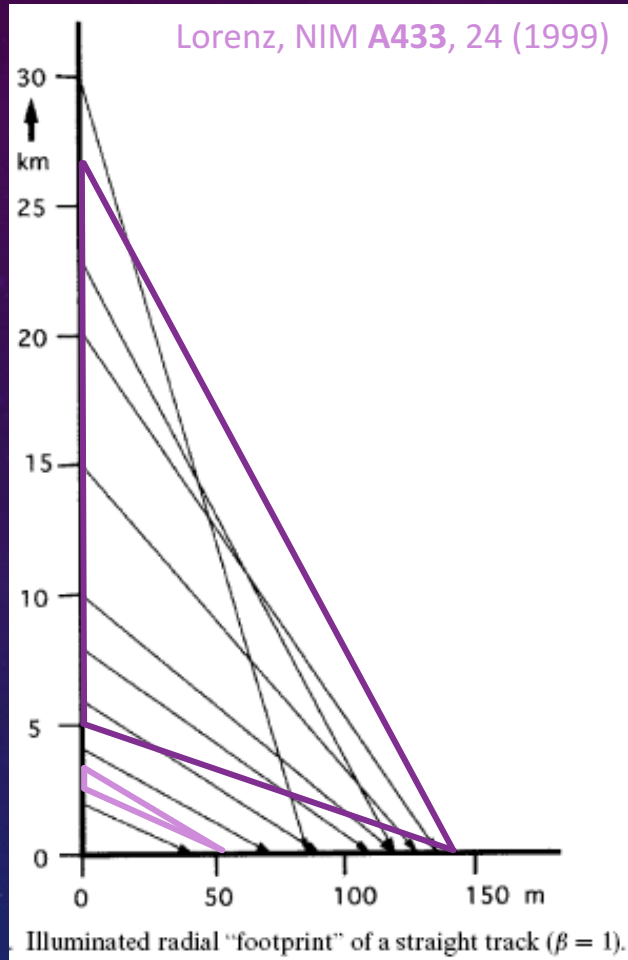Traditionally one measures the Cherenkov Lateral Distribution.

$R > 120$ m: Energy

$R < 120$ m: X_{Max}

This requires measurements within 120 m of the shower core.

Requires large number of Cherenkov detectors for > 1 km^2 sr.

CHERENKOV PHENOMENOLOGY

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Patterson & Hillas , JPG **9**, 323 (1983)

Smeared widths

True width

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
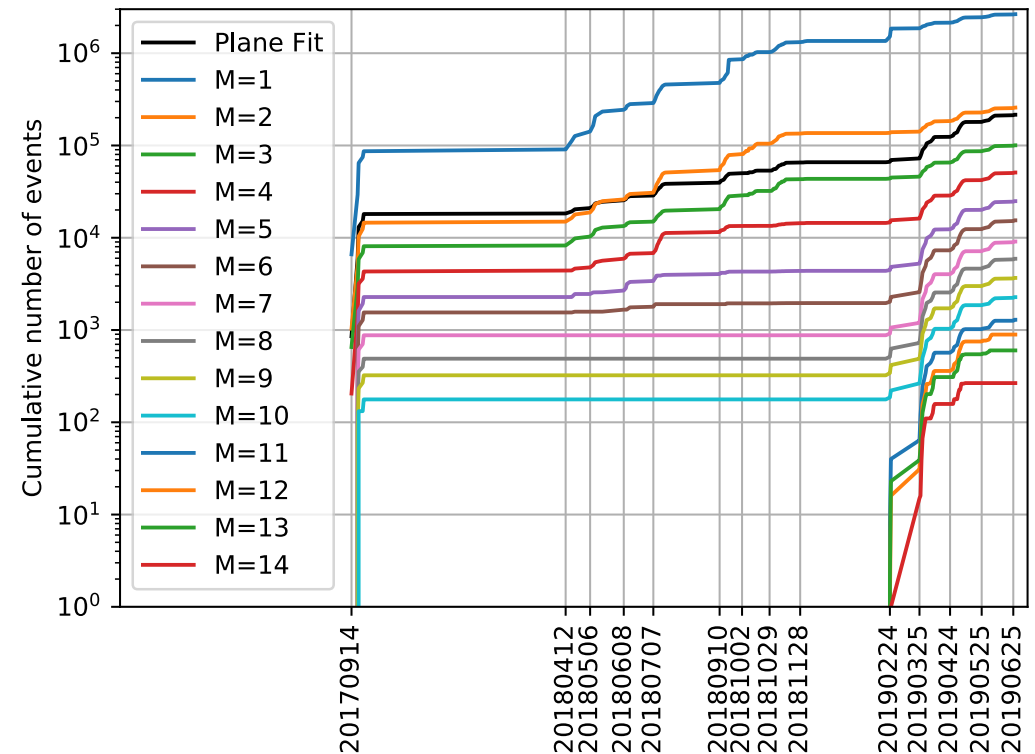
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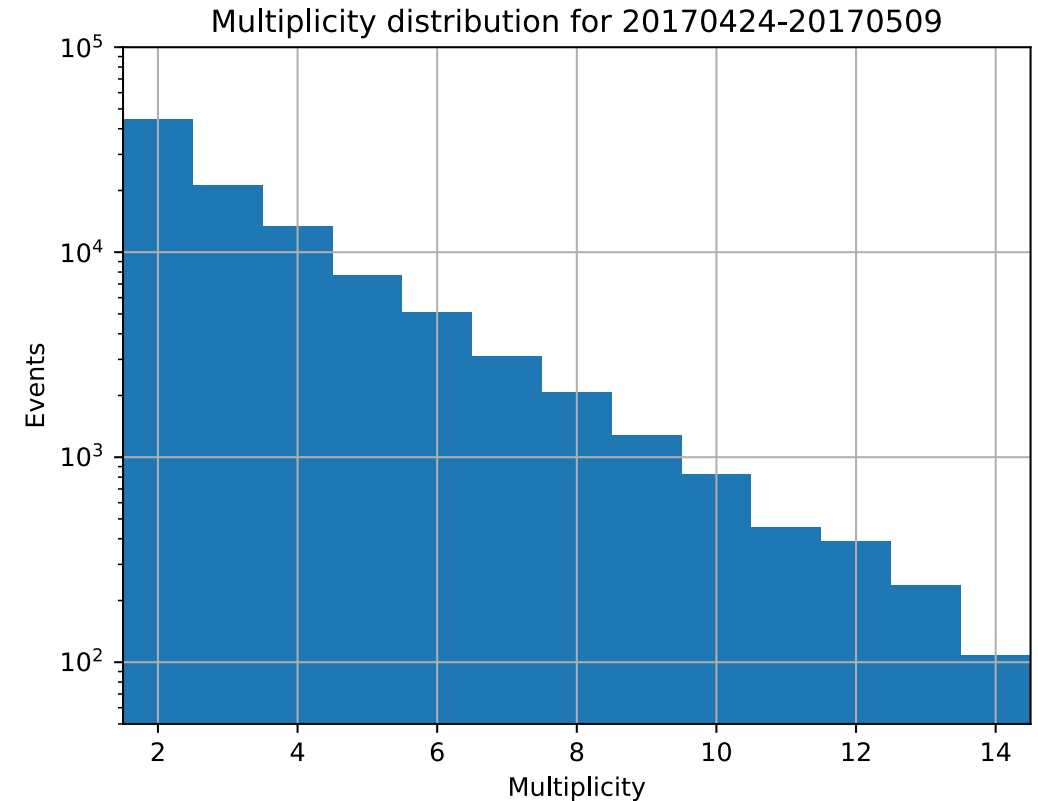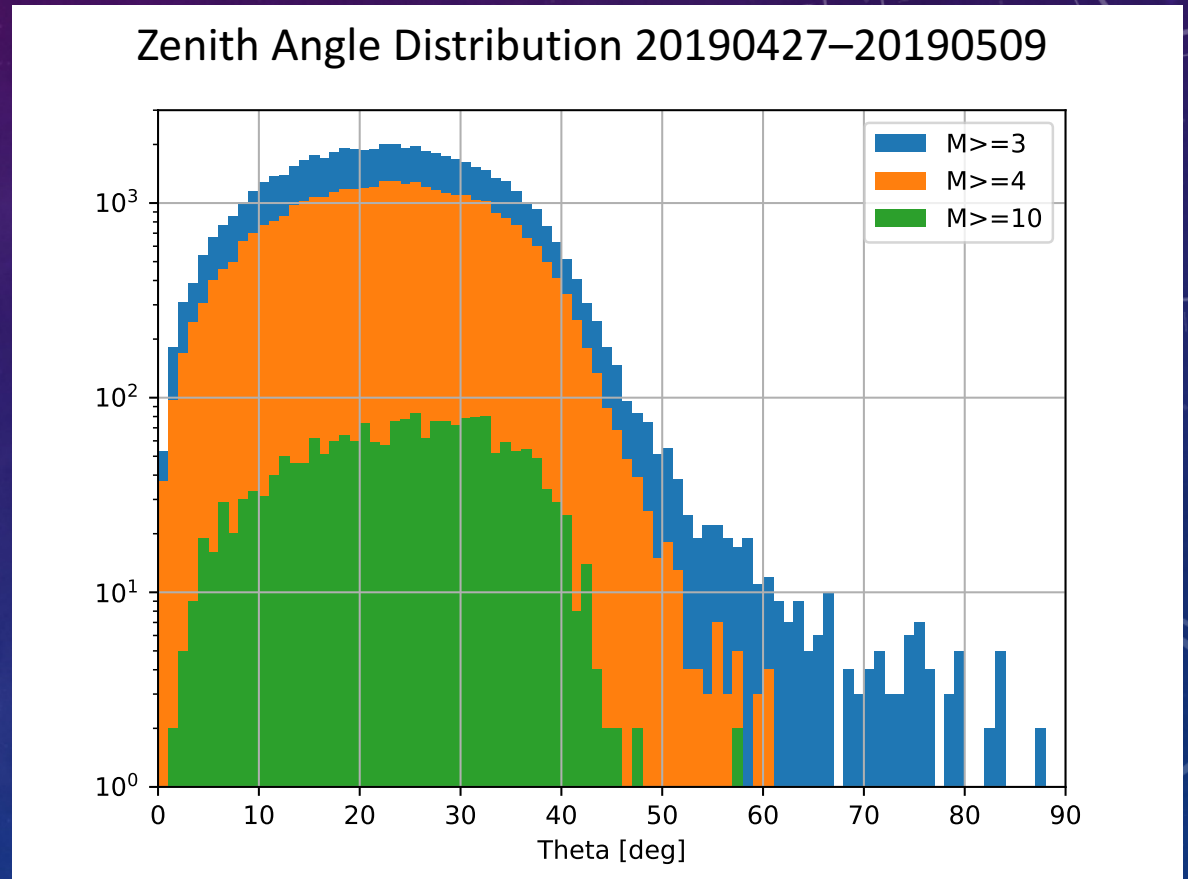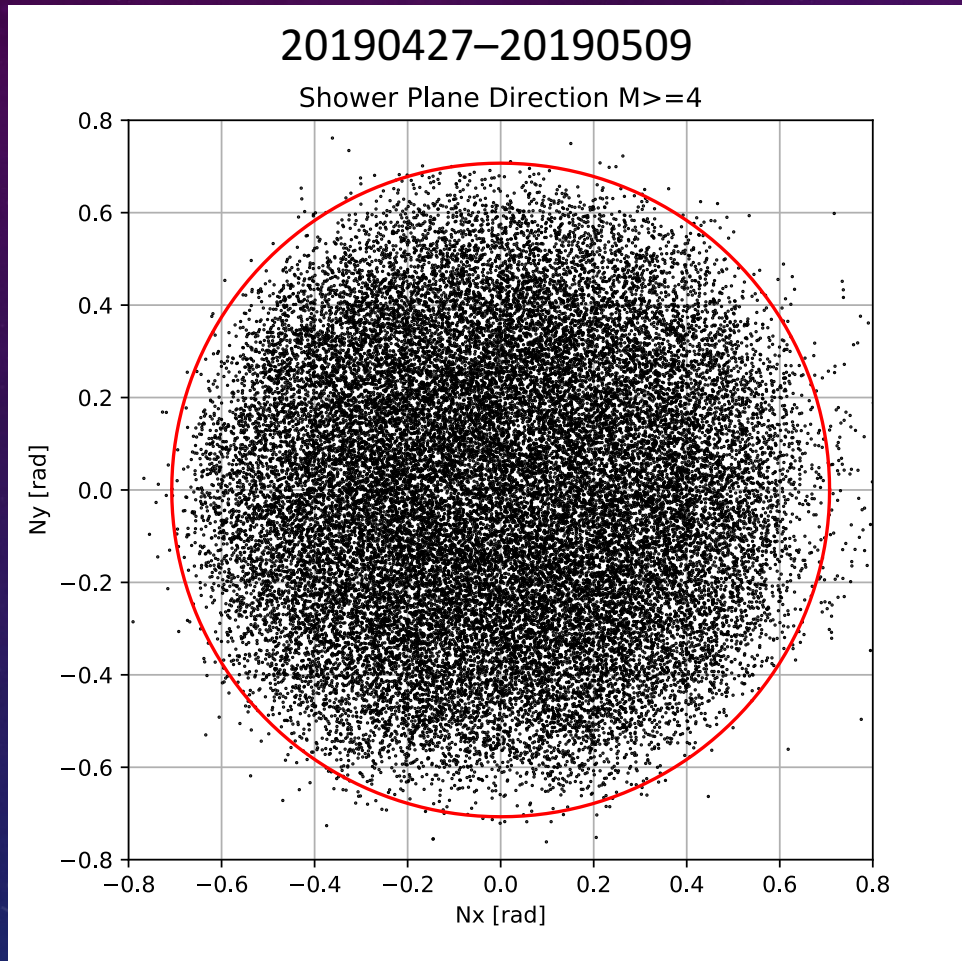
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- With current thresholds (7σ) see 0.35 Hz of triggers *per counter*, 0.4 Hz of events with a plane fit.
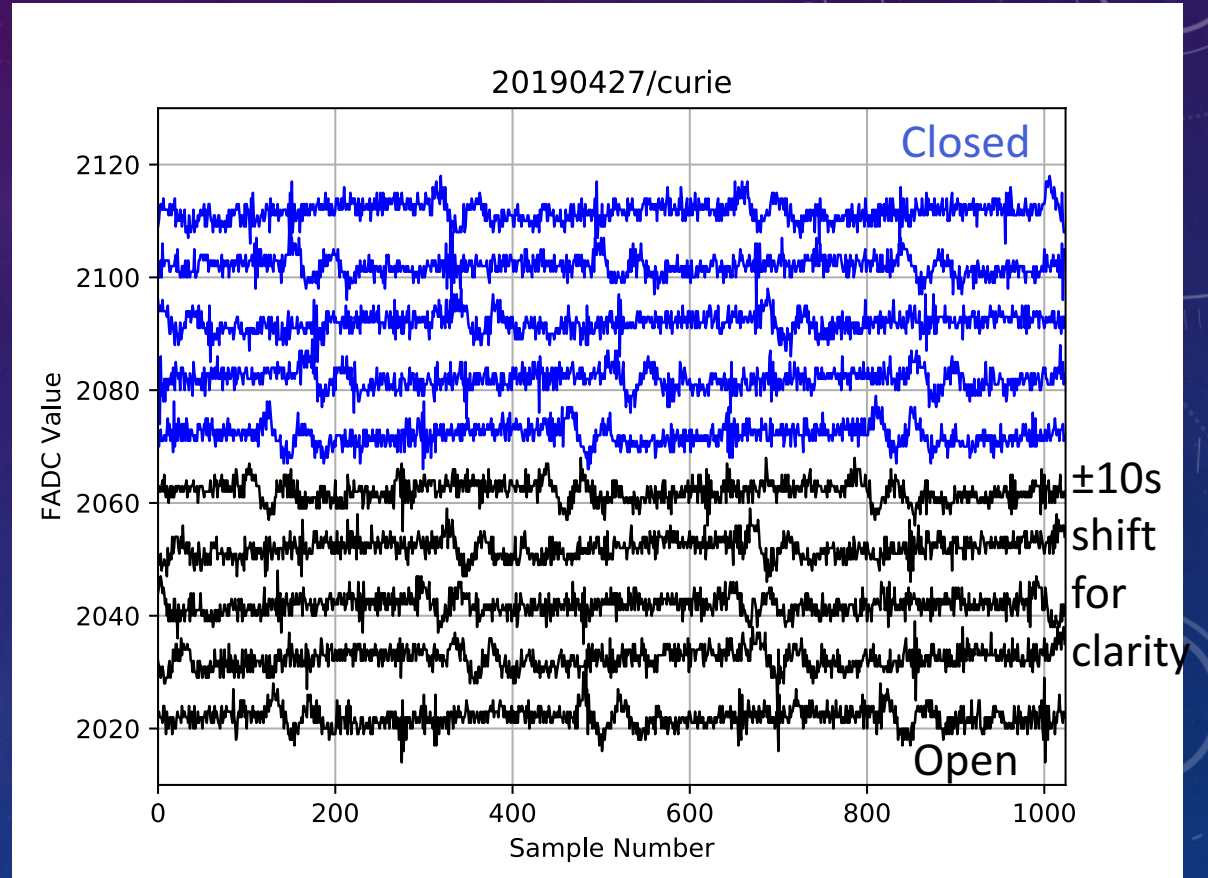
    See also Omura #379

Multiplicity distribution for 20170424-20170509

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

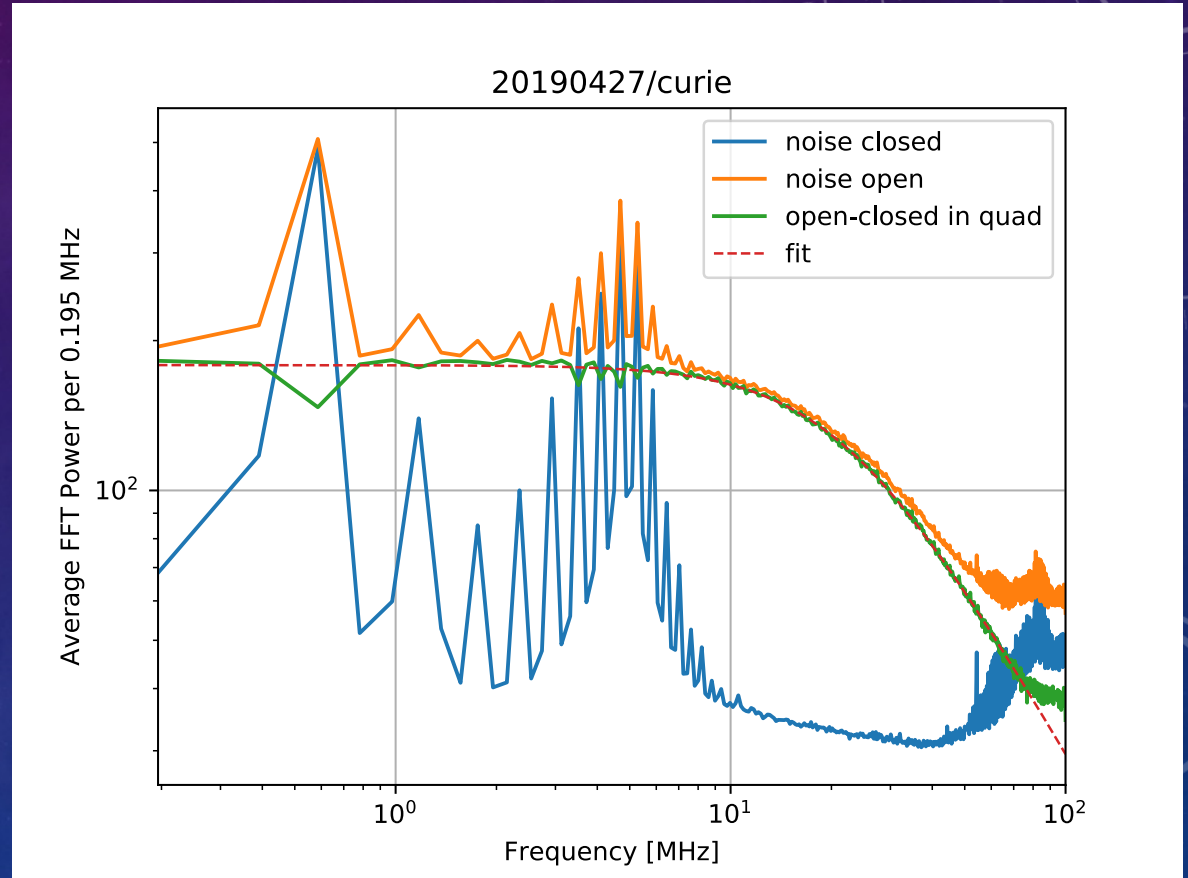- There is a clear signal from the data acquisition system

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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

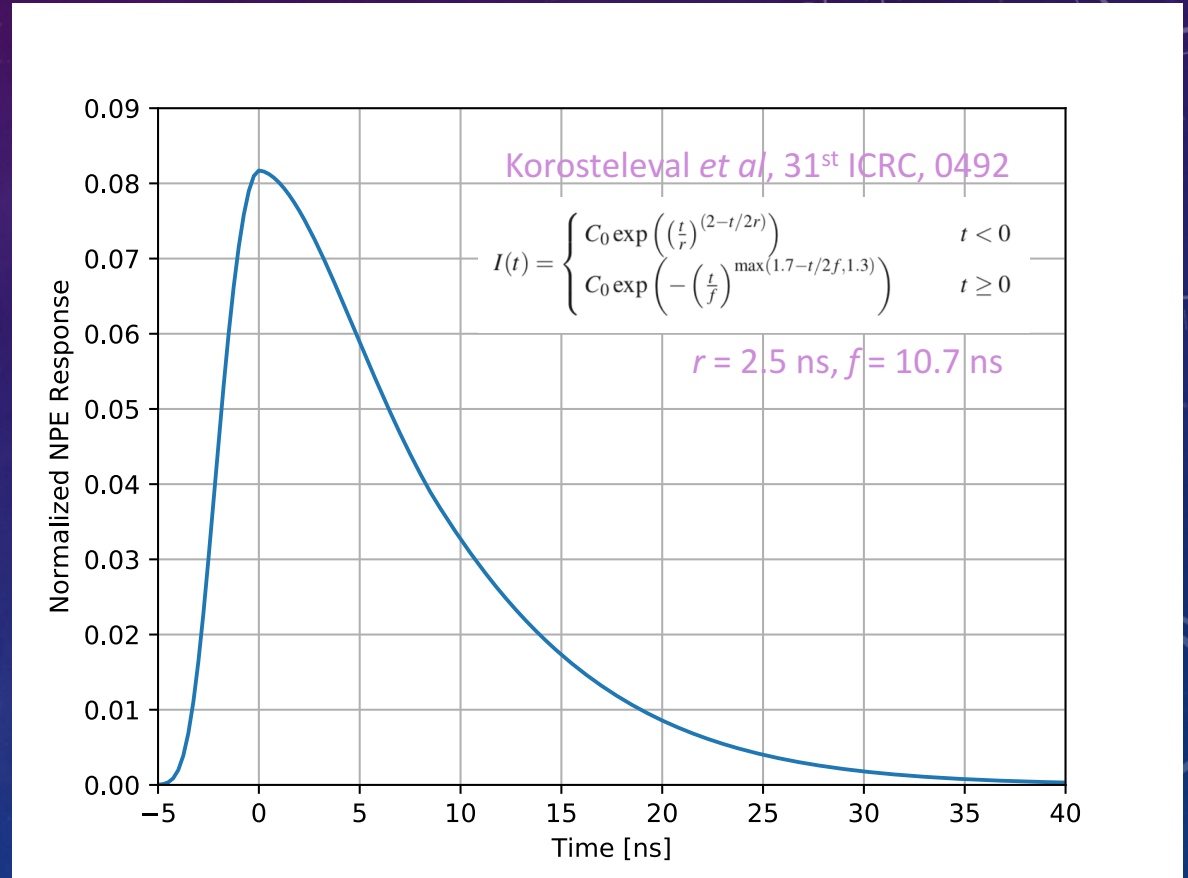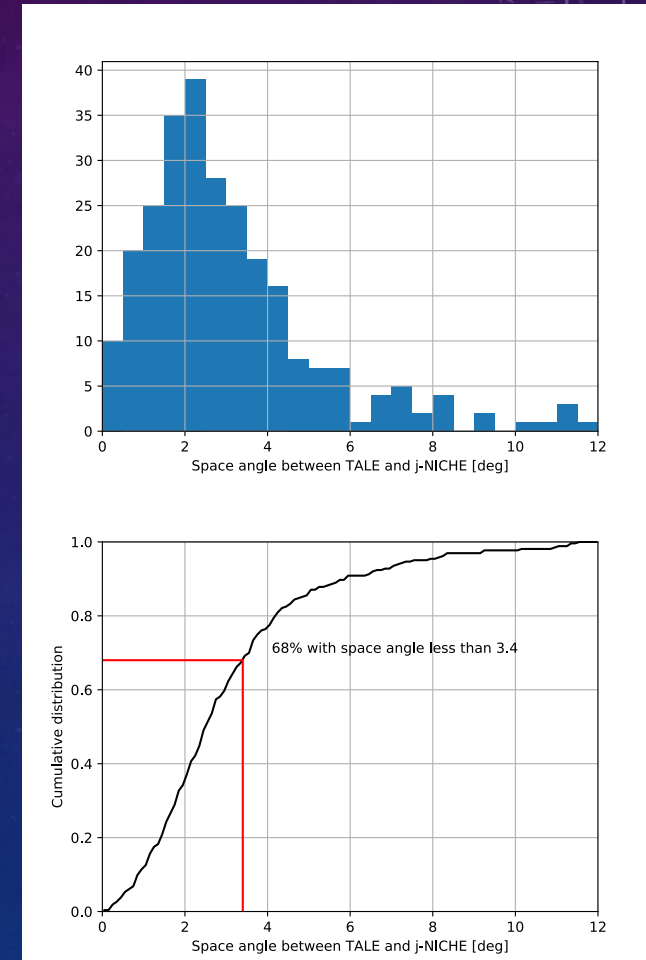 - Looks like low pass filter (from impulse response of PMT)

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- Need 72 NPE/ns with this response to get same low-pass filter behavior (some clouds?)

Korosteleval *et al*, 31st ICRC, 0492

$$I(t) = \begin{cases} C_0 \exp\left(\left(\frac{t}{r}\right)^{(2-t/2r)}\right) & t < 0 \\ C_0 \exp\left(-\left(\frac{t}{f}\right)^{\max(1.7-t/2f,1.3)}\right) & t \geq 0 \end{cases}$$
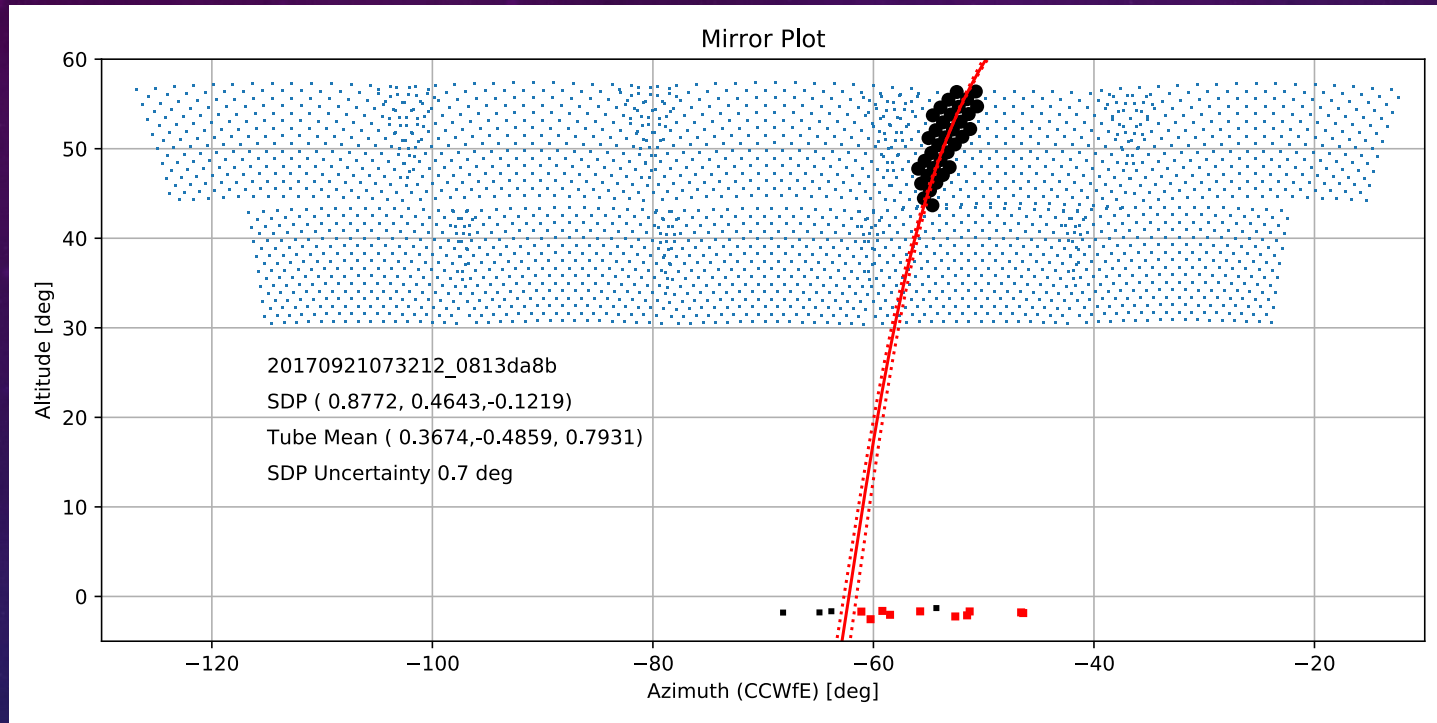
$r = 2.5$ ns, $f = 10.7$ ns
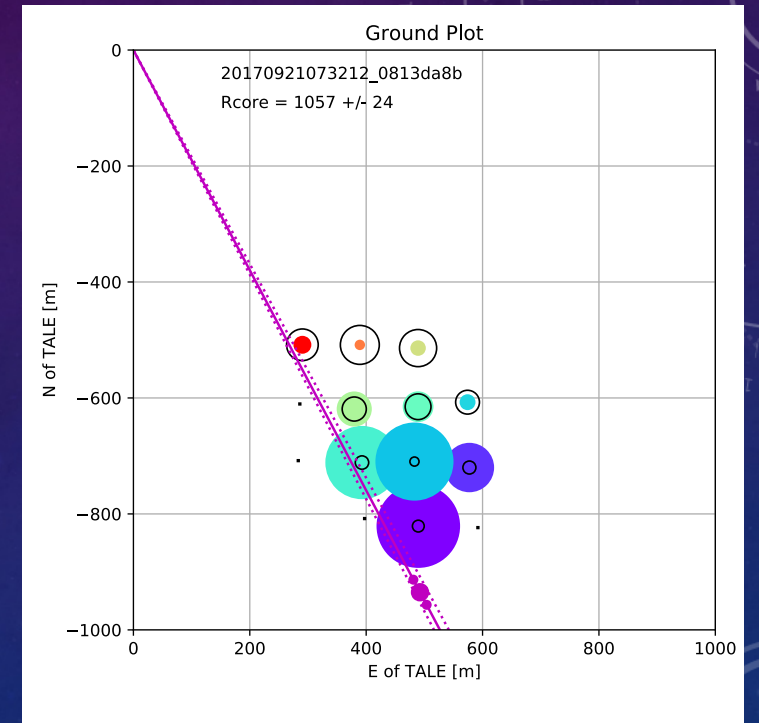
NICHE-TALE HYBRID

- 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"

HYBRID EVENT EXAMPLE

Mirror Plot

20170921073212_0813da8b
SDP (0.8772, 0.4643,-0.1219)
Tube Mean (0.3674,-0.4859, 0.7931)
SDP Uncertainty 0.7 deg

TALE view of shower along with shower-detector plane (and uncertainty). NICHE counters shown as red squares.

Ground Plot

20170921073212_0813da8b
Rcore = 1057 +/- 24

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.
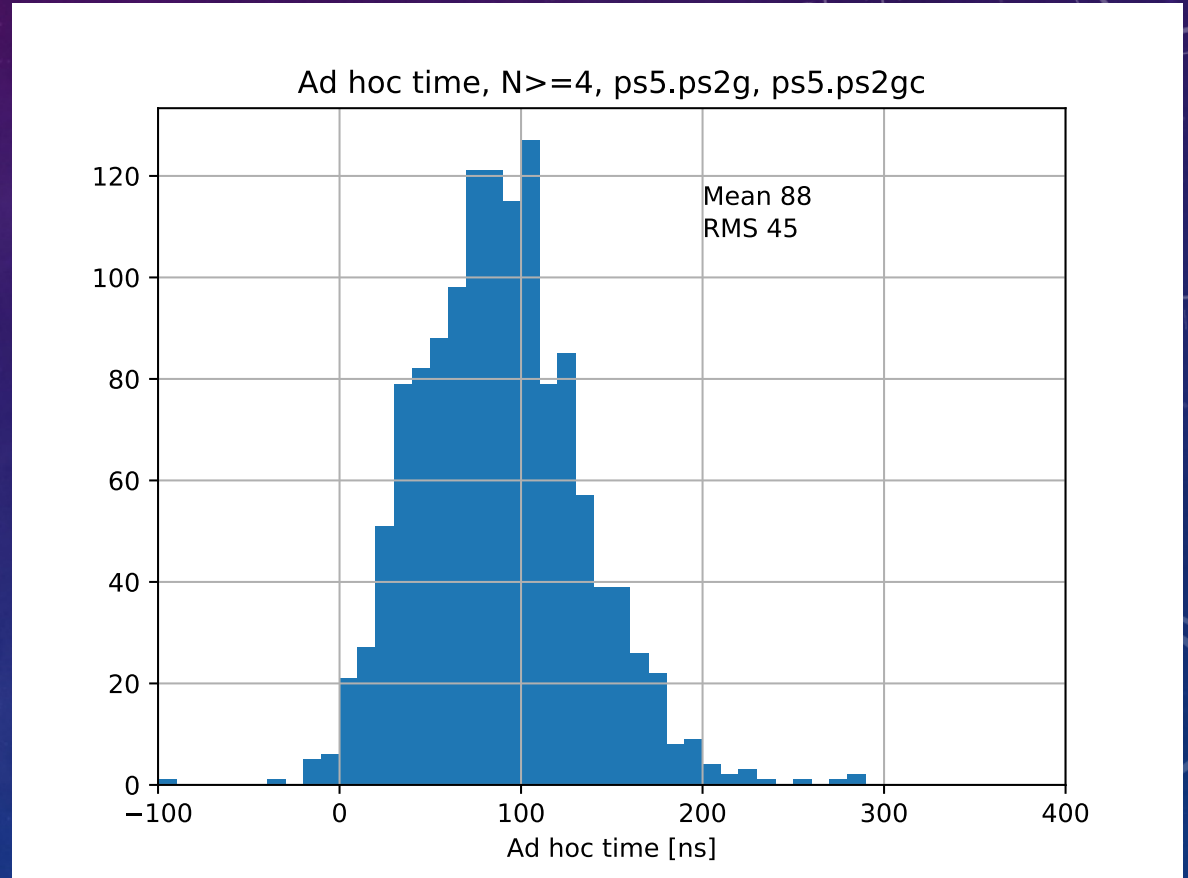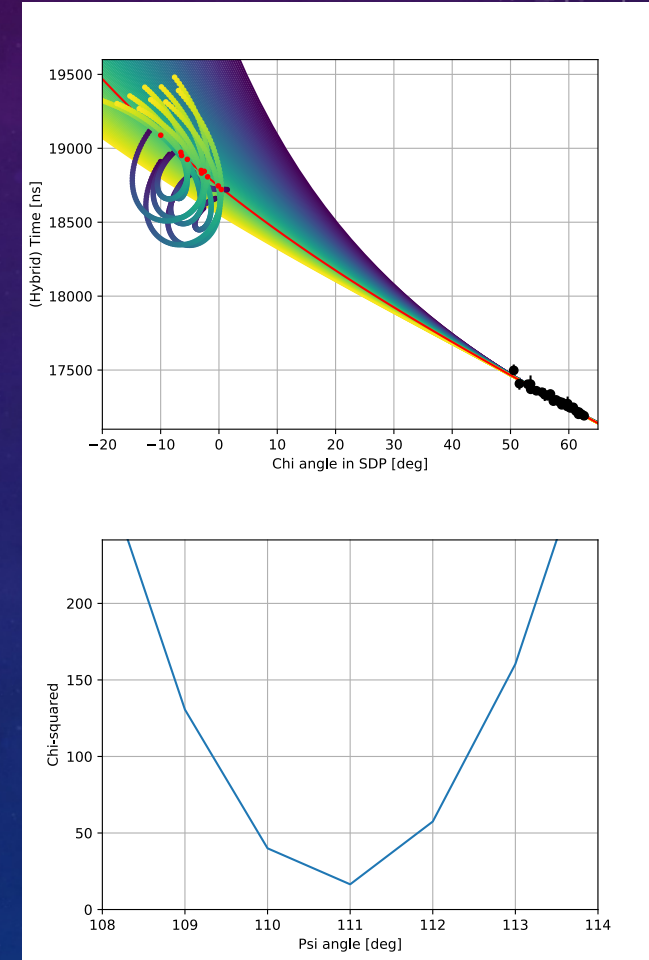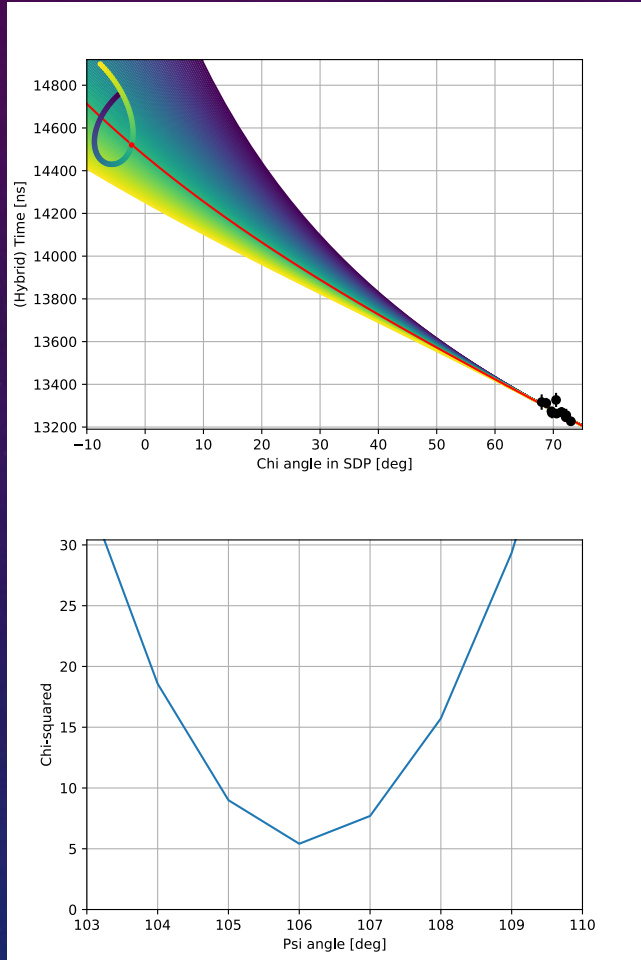
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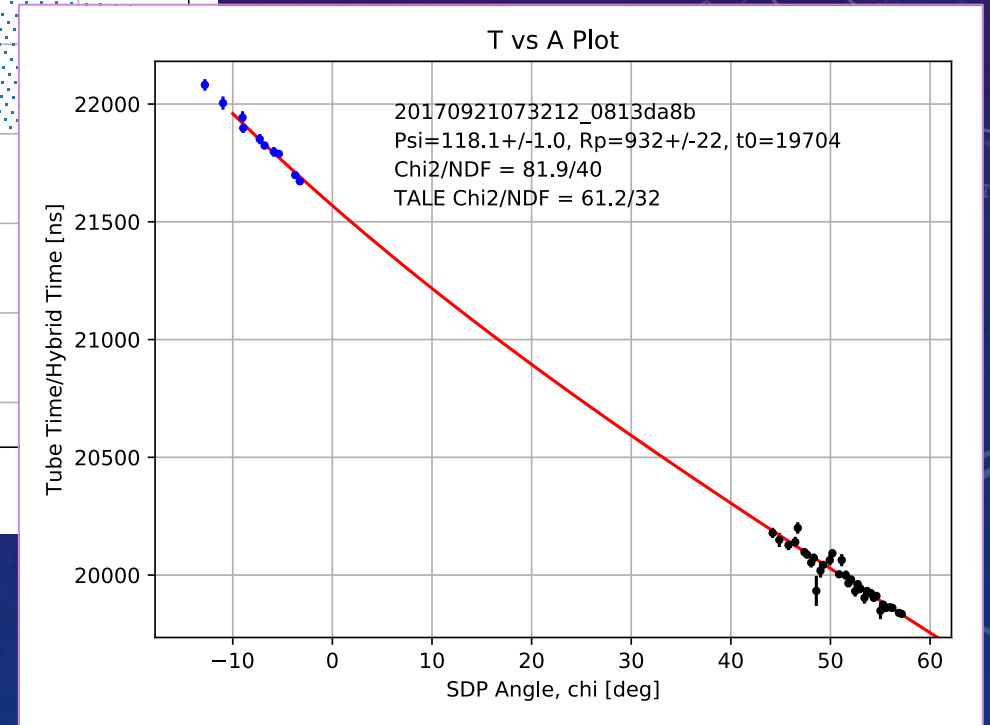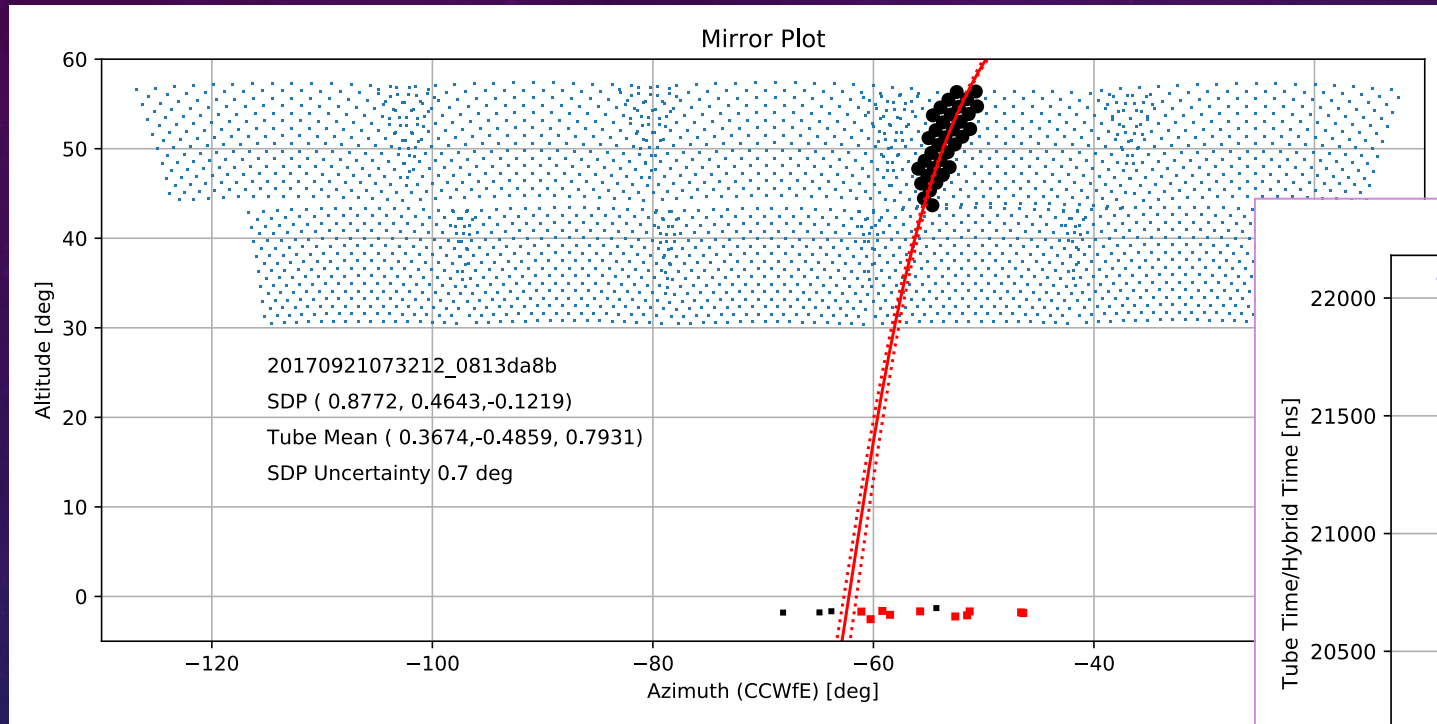
The NICHE counter times allow one to fit the time-vs-angle over a *much* larger angular range to determine the geometry. This validates the TALE PCGF geometry to 1˚.

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
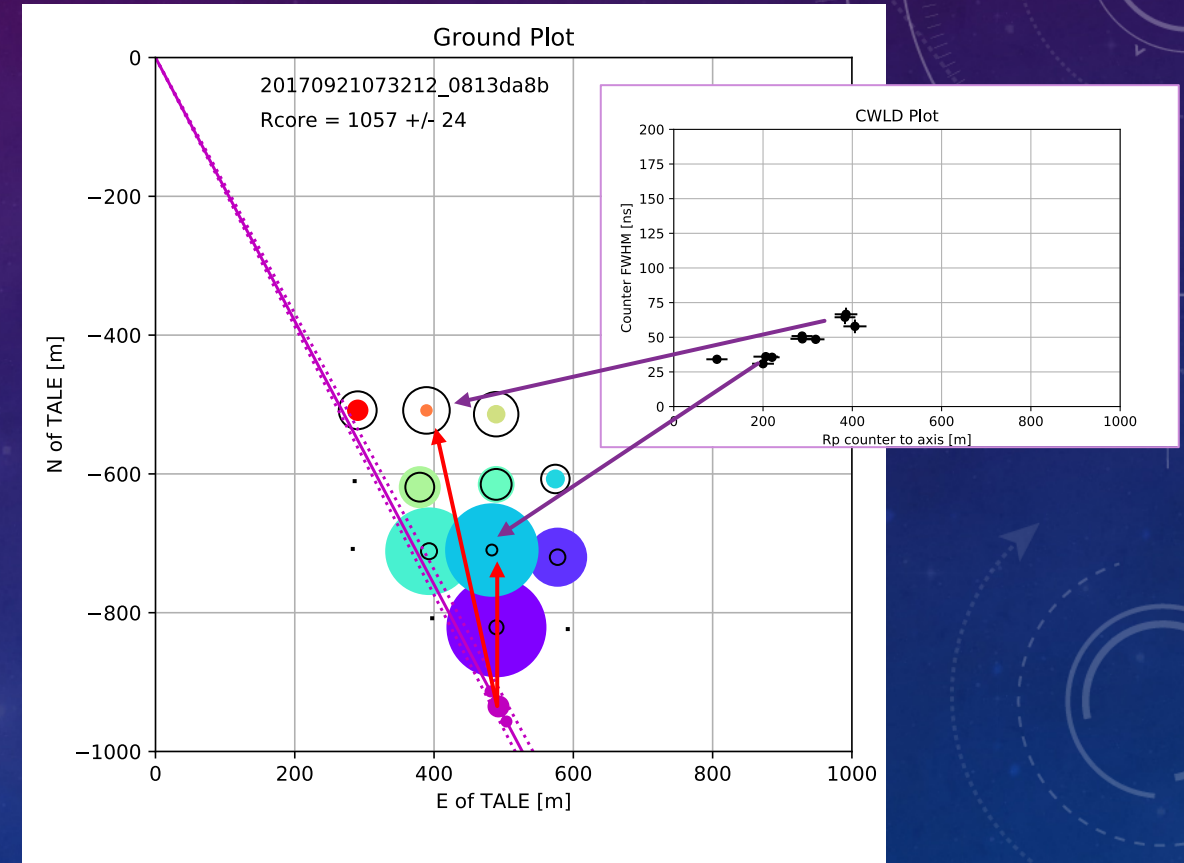

Ad hoc time, N>=4, ps5.ps2g, ps5.ps2gc

Mean 88
RMS 45

NICHE-TALE HYBRID

NICHE-TALE WIDTH VS DISTANCE

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

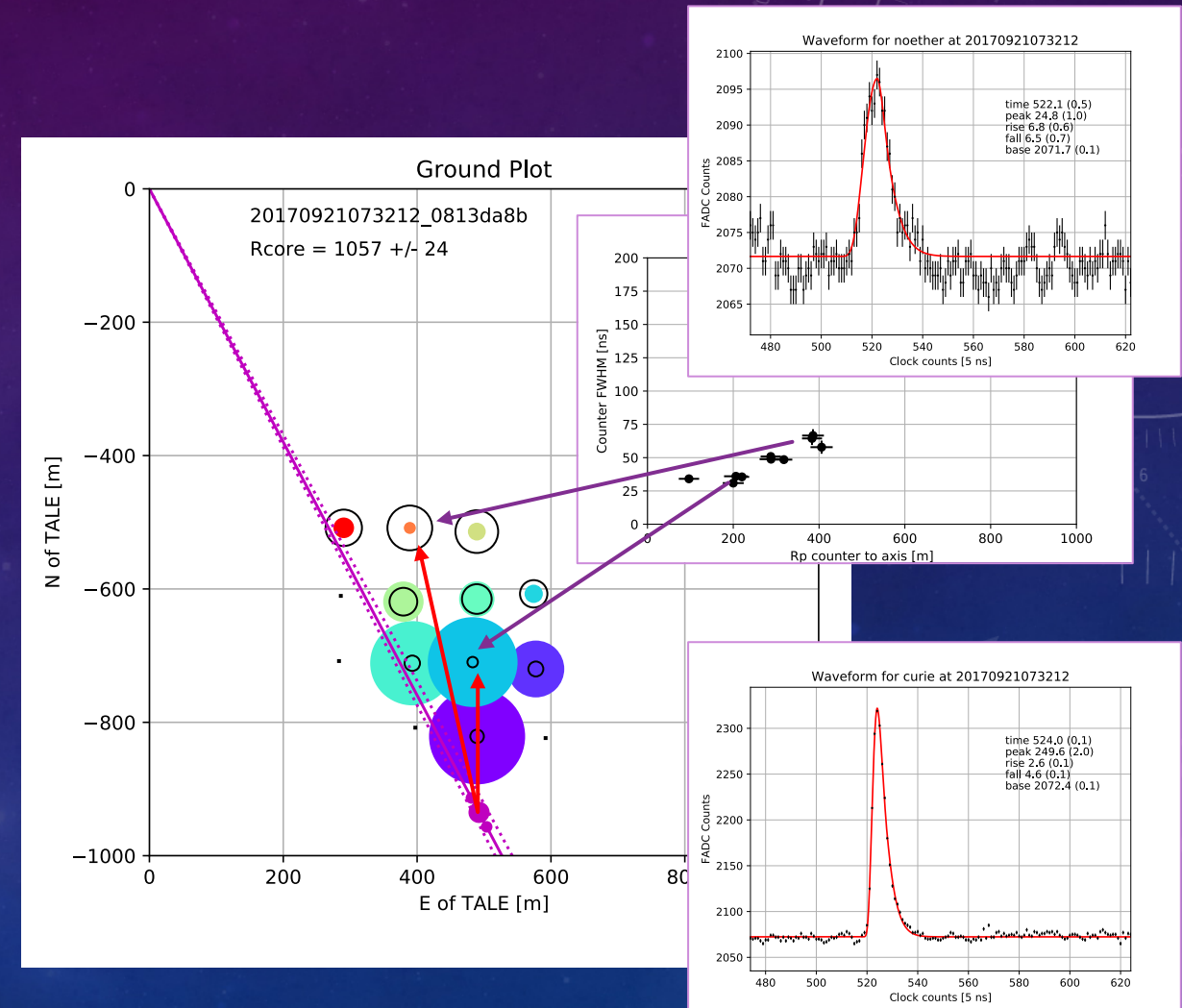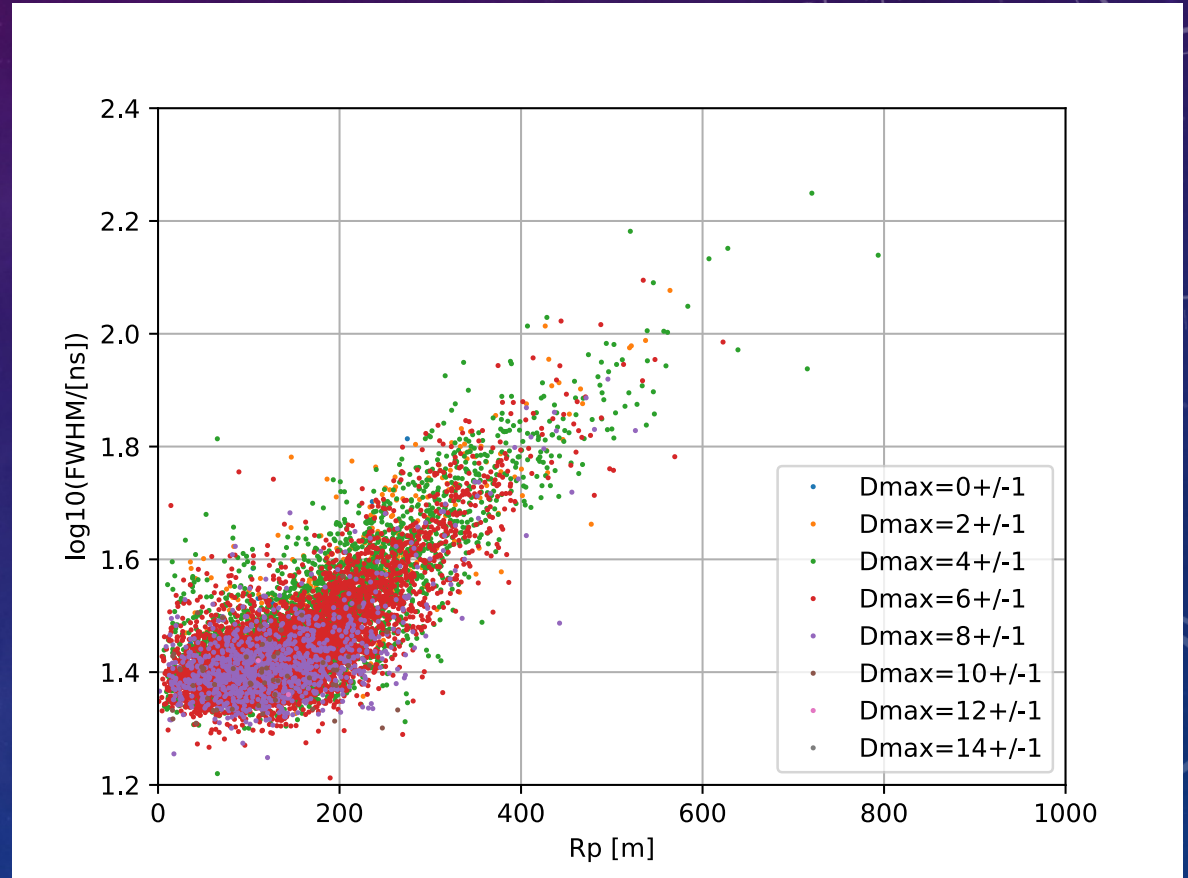- The shape of the CWLD depends on how far the X_{max} point along the shower is from the counter, D_{max}

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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
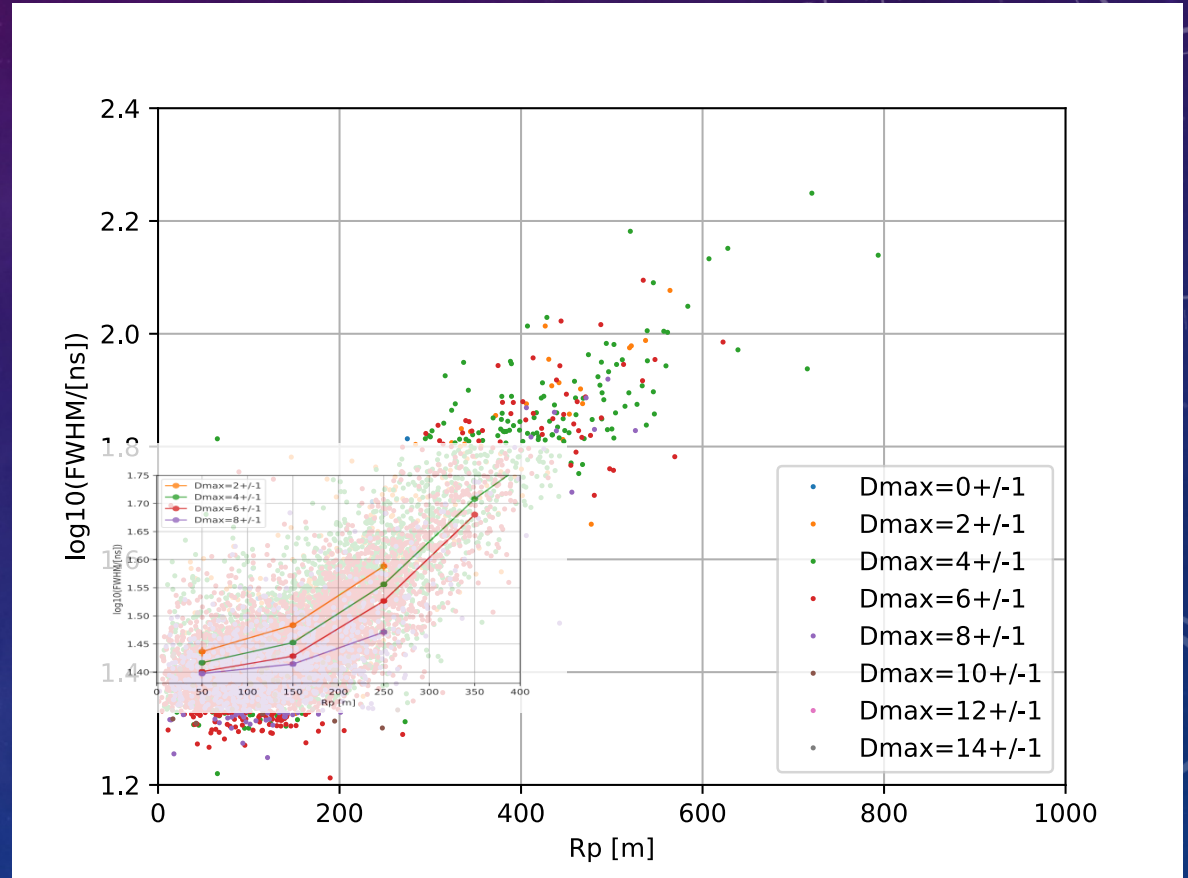 - The R_P uncertainty smears right/left on the plot

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- Take FWHM averages, keeping only bins with more than 40 events
- Smaller D_{max} correlates with larger FWHM
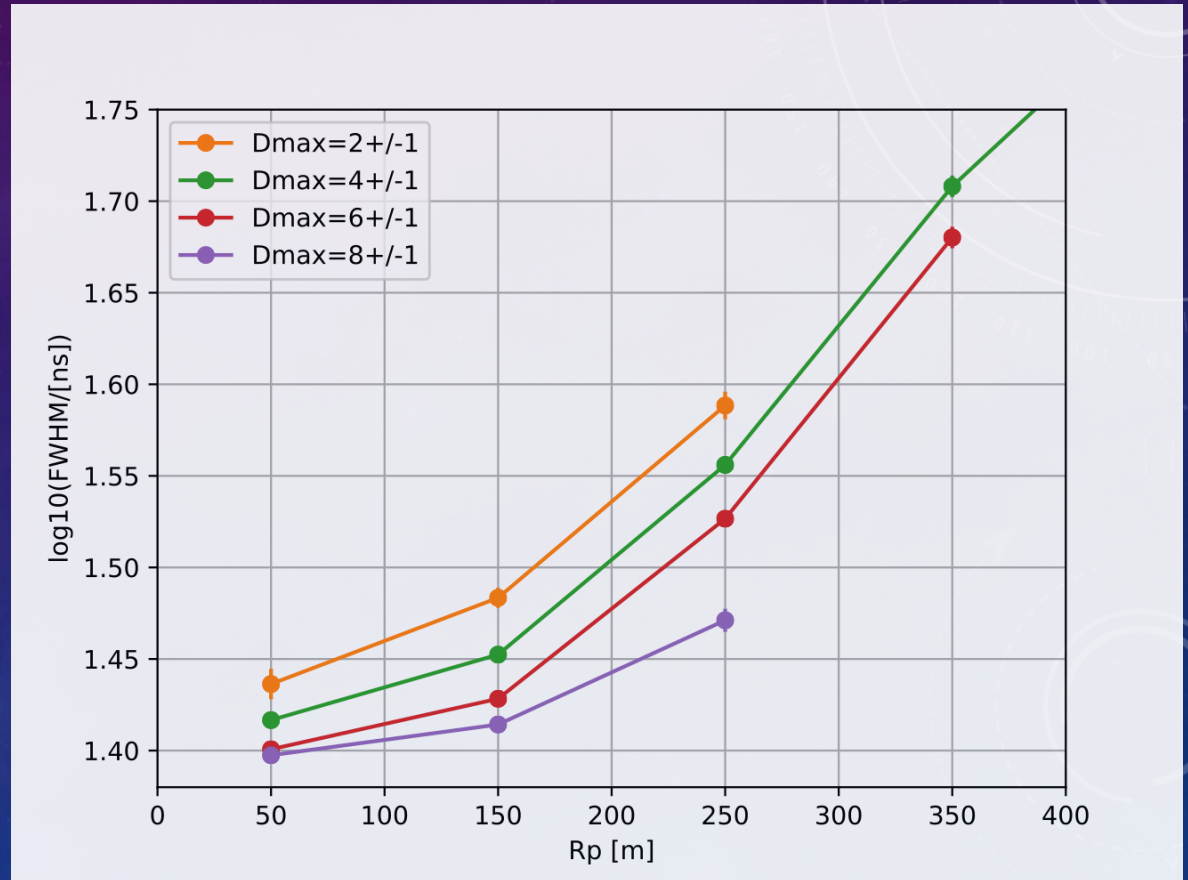
CONCLUSION

- 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