NICHE: Air-Cherenkov light observation at the TA site

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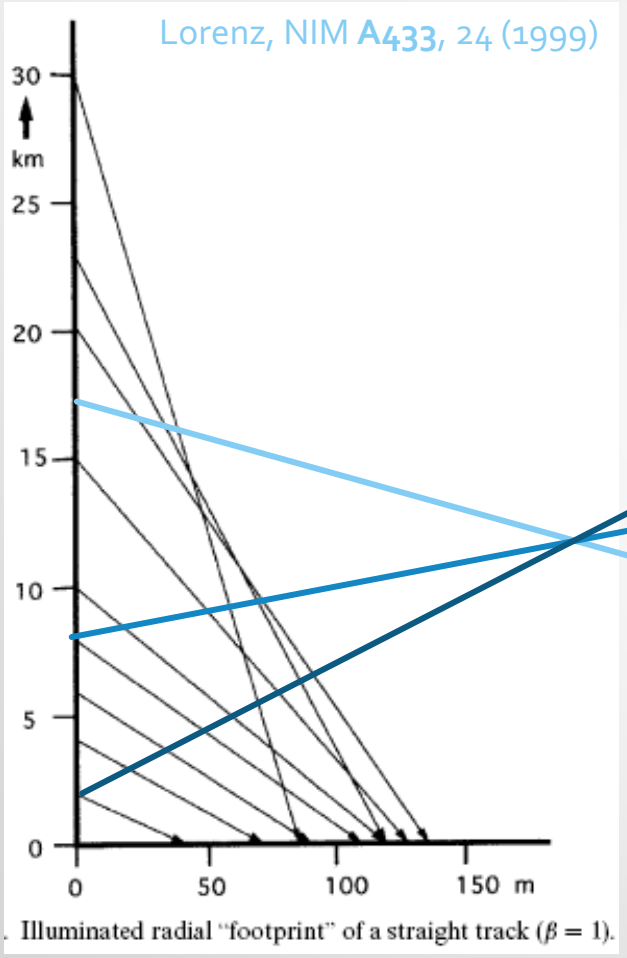
The NICHE Idea

- Use non-imaging light collectors with fine time resolution to extend the range of TA/TALE to below 10^{15} eV using air-Cherenkov
- Hybrid imaging/non-imaging air-Cherenkov measurements with TALE-Cherenkov
- 14 counter array with 100-m spacing at 800 m from TALE FD site
  - Yoshiki Tsunesada, ¥18.8M *Kakenhi* grant for young scientists
  - 10 counters deployed in Sept. 2017, 4 more in Sept. 2018

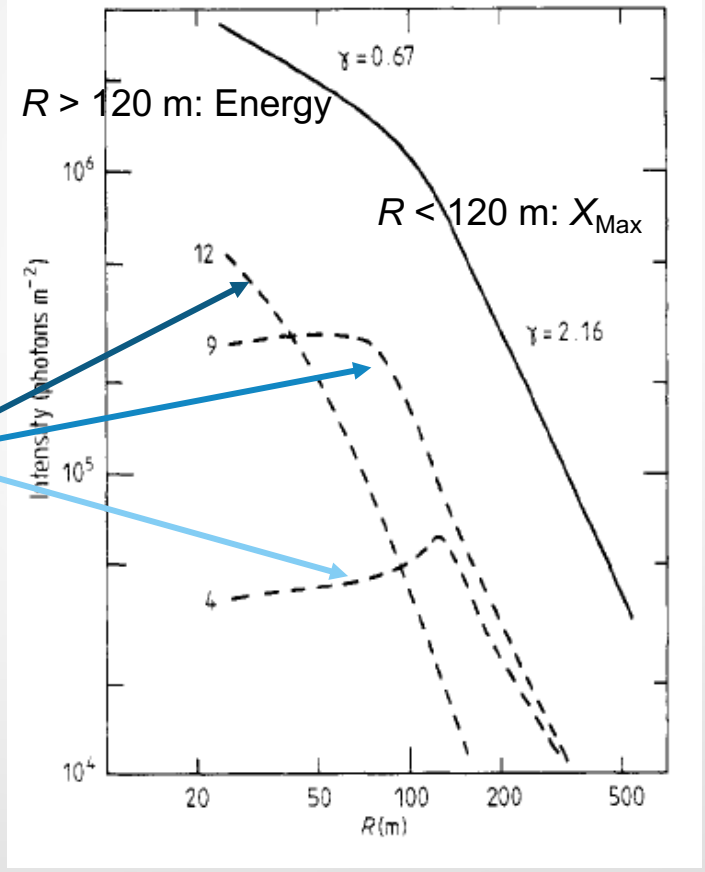
Cherenkov Phenomenology

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



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

Patterson & Hillas , JPG **9**, 1433 (1983)



R > 120 m: Energy

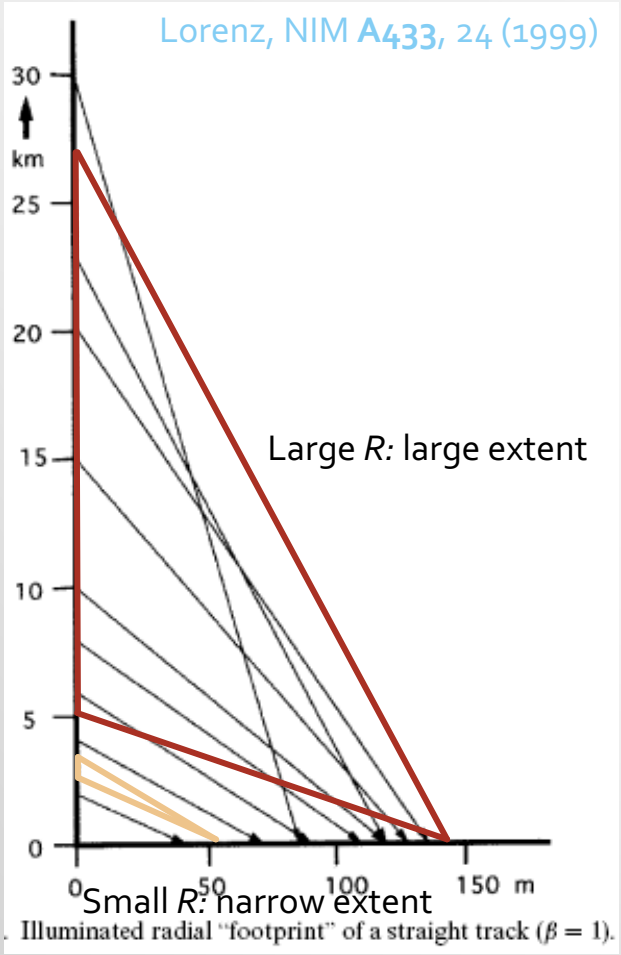
R < 120 m: X_{Max}

Traditionally one measures the Cherenkov Lateral Distribution.

Requires measurements within 120 m of the shower core.

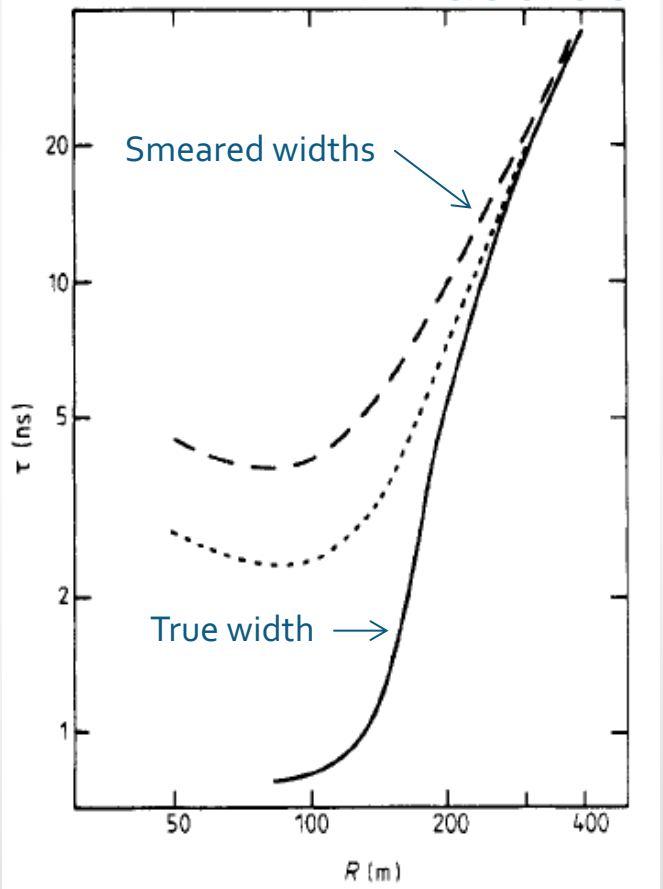
Cherenkov Phenomenology

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



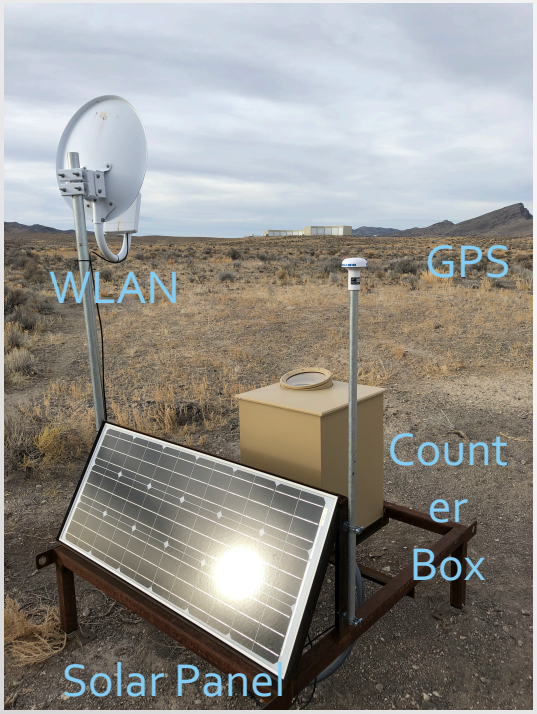
Illuminated radial "footprint" of a straight track ($\beta = 1$).

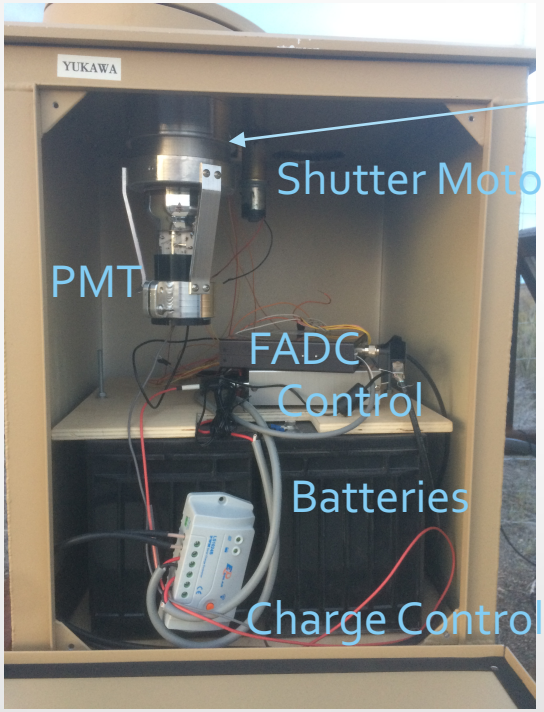
Patterson & Hillas , JPG **9**, 323 (1983)

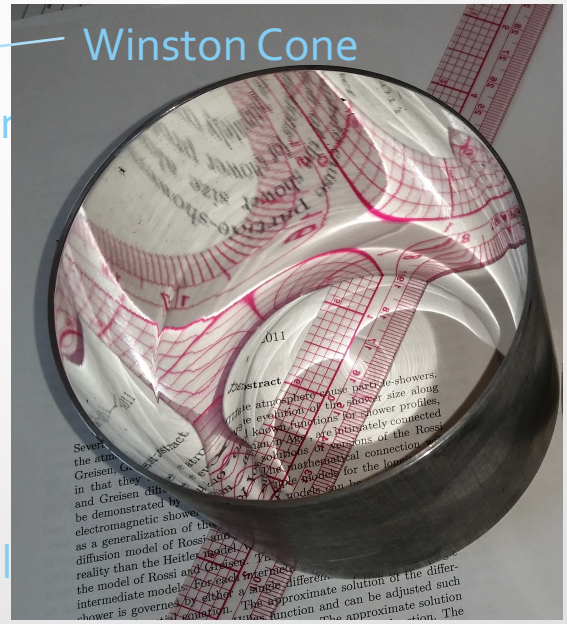


At sufficiently high energies, larger detector spacings can be used to measure the time-width at a given *R*.

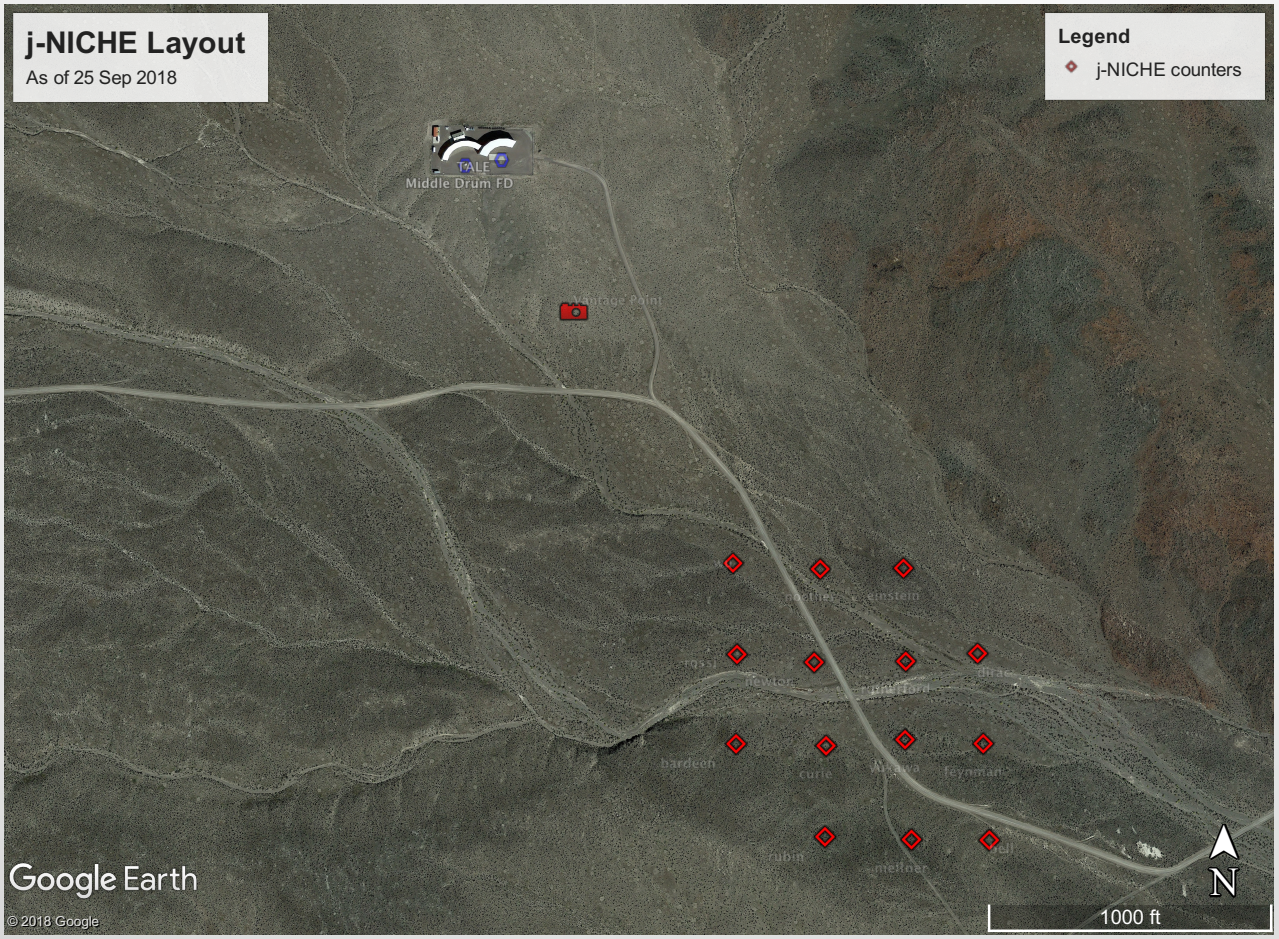
NICHE Counters



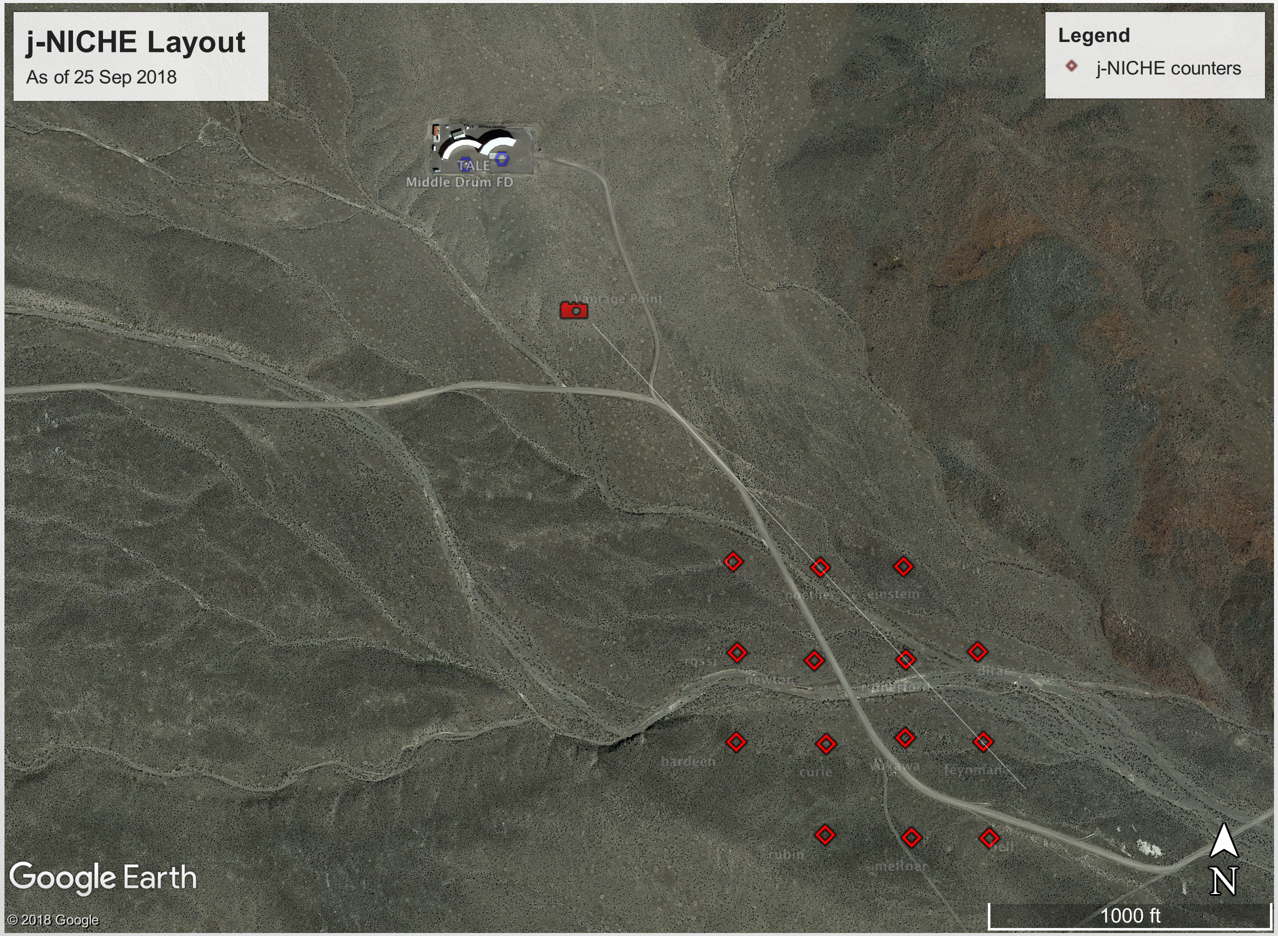




NICHE Array


j-NICHE Layout
As of 25 Sep 2018
Legend
j-NICHE counters
TALE
Middle Drum FD
Vintage Point
bardeen
curie
feynman
rubin
Google Earth
© 2018 Google
N
1000 ft

NICHE Array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NICHE Array

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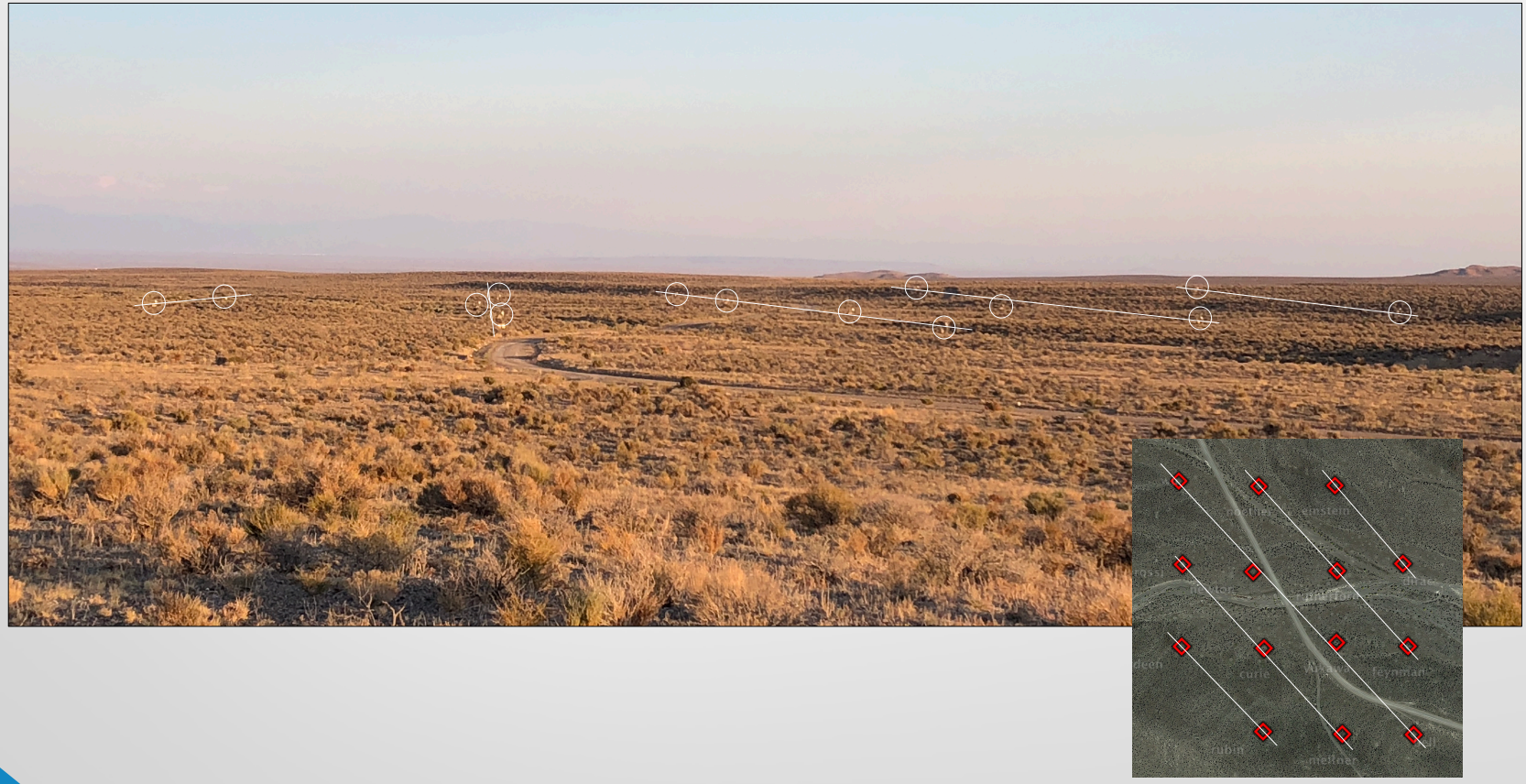
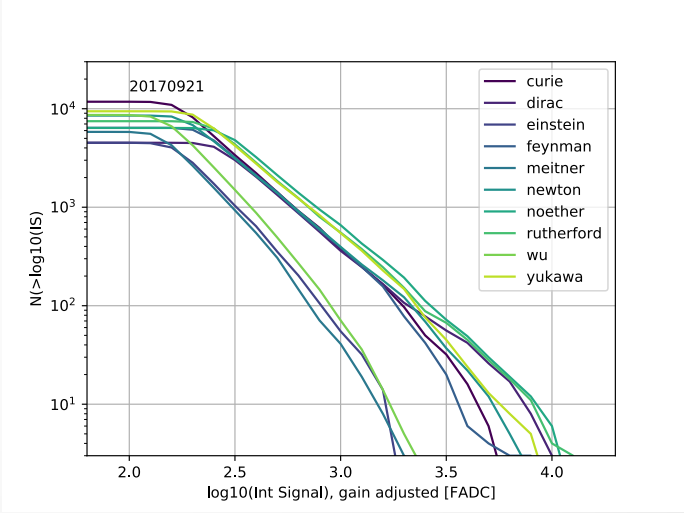
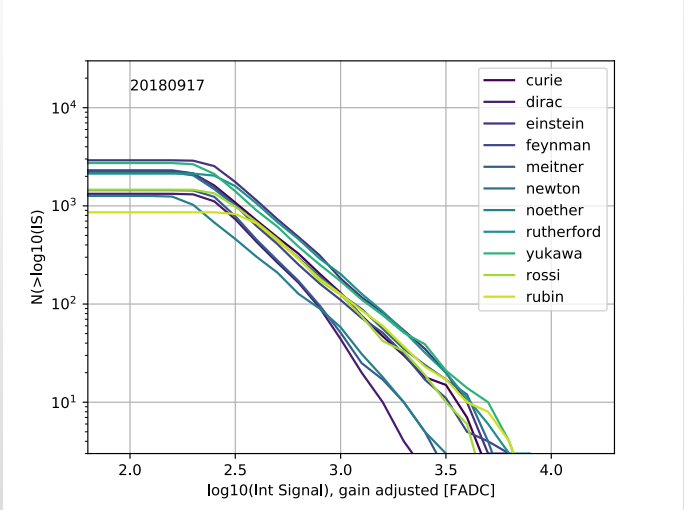


NICHE Running Status

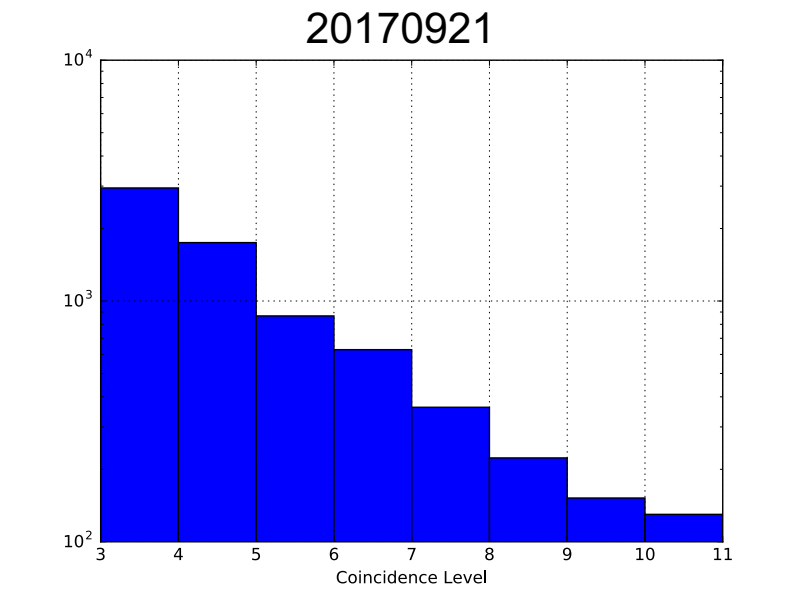
- 1350 counter-hours
- 936,000 counter-triggers
- 160 hours with 8–10 detectors from 20 Sept 2017
- 20 hours with 12-14 detectors from 10 Sept 2018





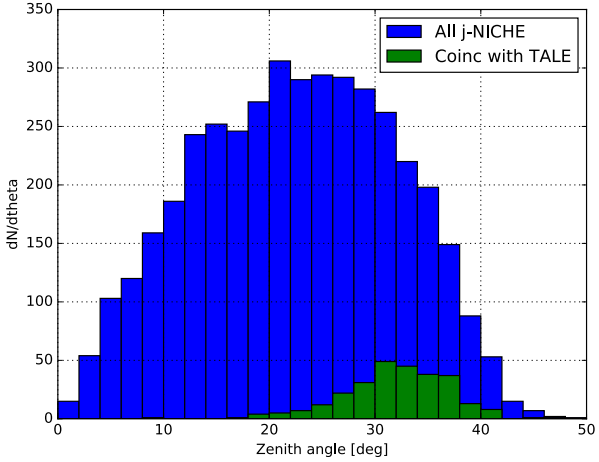
NICHE Events

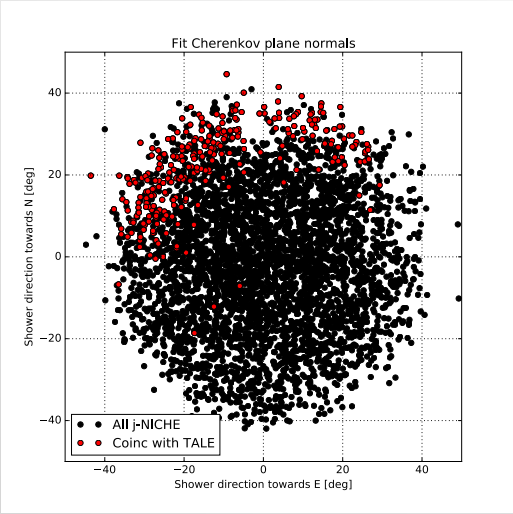
- Look for coincidences within NICHE
- Take all within 100 μs windows
  - Essentially no background
- Fit arrival times to a plane

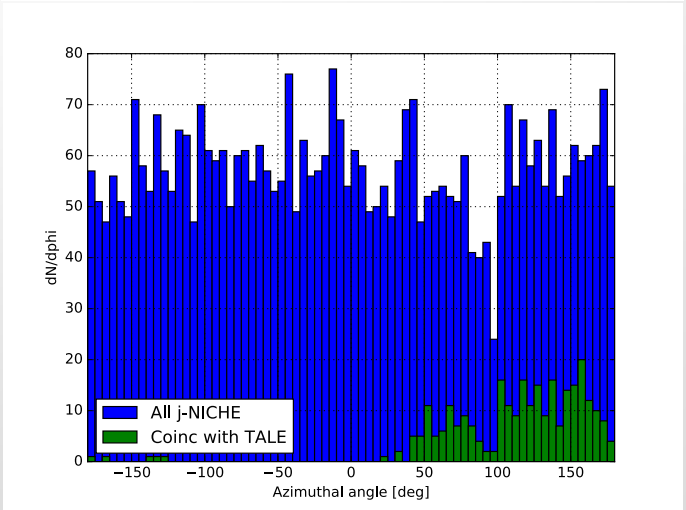


NICHE Events

- Look for coincidences within NICHE
- Take all within 100 μs windows
  - Essentially no background
- Fit arrival times to a plane
- Also look for coincidence with TALE-FD

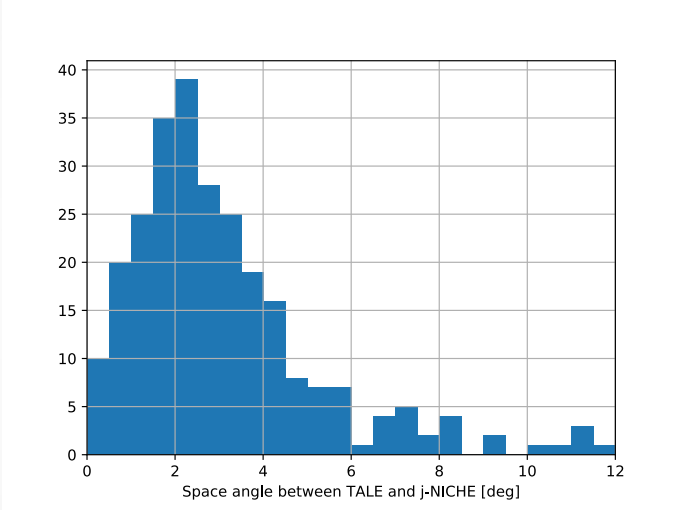


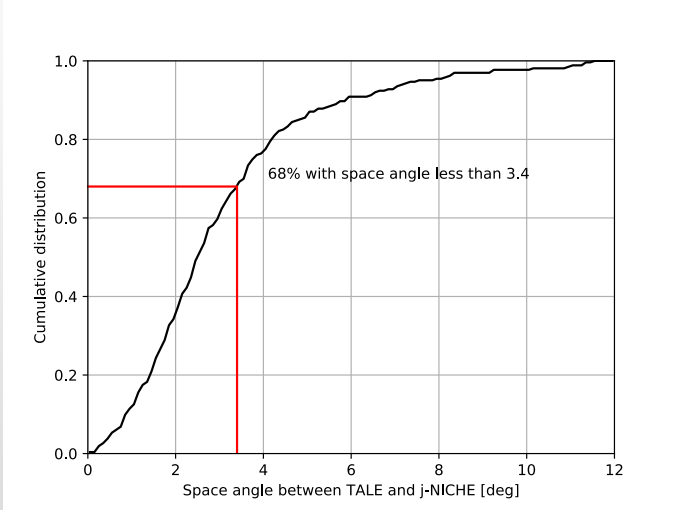




Verify TALE-FD PCGF Fit Angle

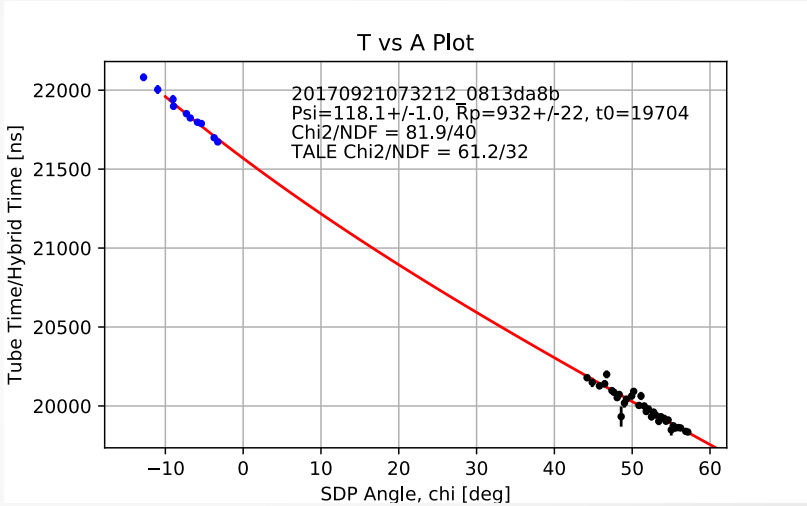
- NICHE-TALE coincidences are all within 10–20 μs (before hybrid timing correction)
- Can easily compare NICHE Cherenkov-plane fit to the TALE PCGF fit for the directino of the shower
- Find agreement within 3.4˚
  - This is a verification of TALE to this accuracy, not the accuracy of the TALE reconstruction

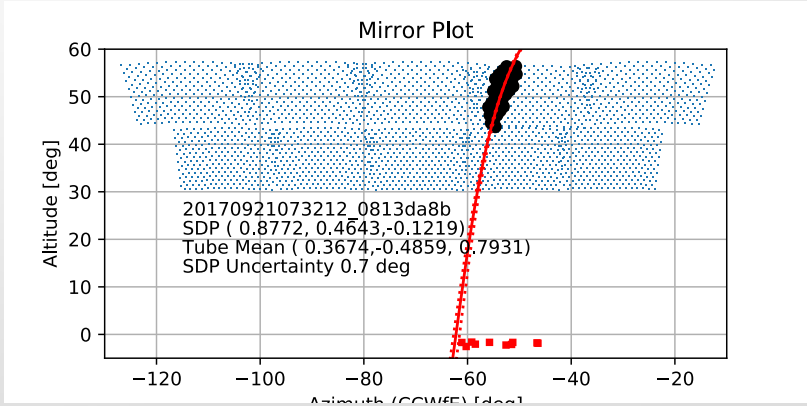


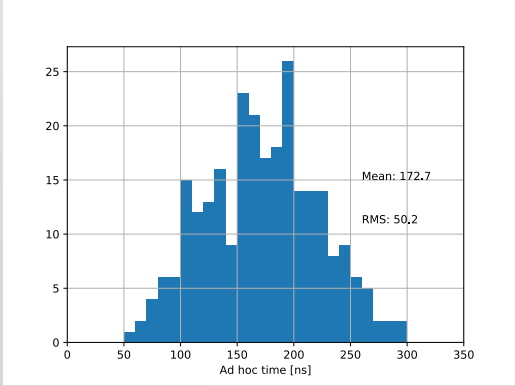


NICHE-TALE Hybrid Timing Fits

- Project NICHE Counters onto shower axis, then correct for time-of-flight from there to TALE
- Then count NICHE as extra hits on for Time vs Angle fit
  - Very large lever arm
- Can put in *one* ad-hoc time correction for all counters
  - 173±50 ns (over all events)







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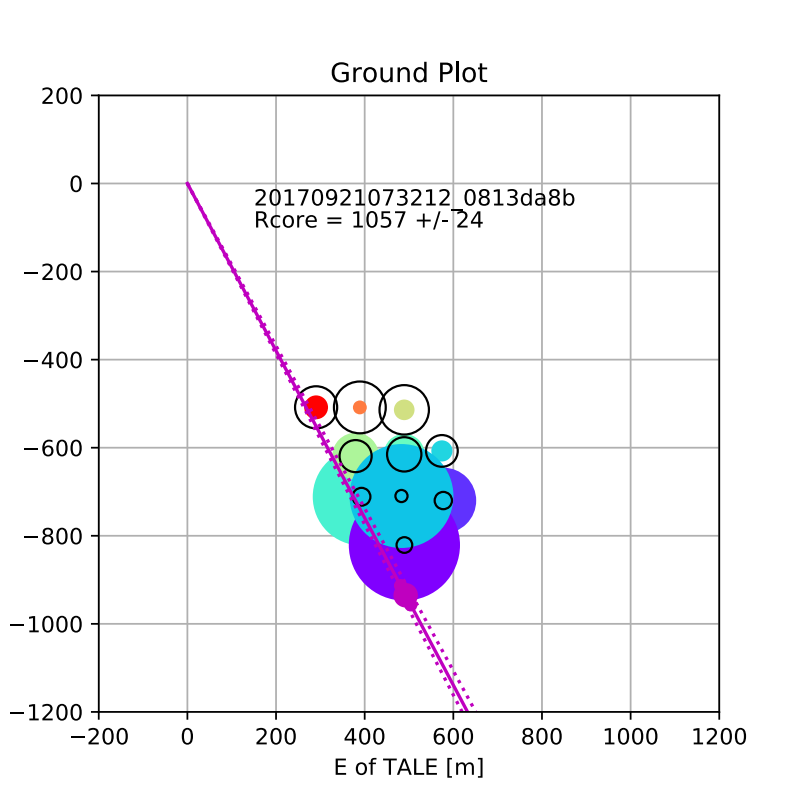
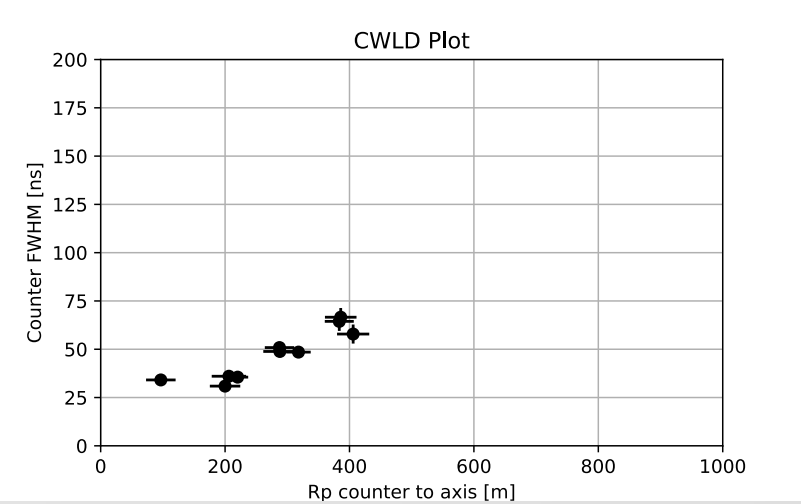


Width grows with distance!

Core position still has some uncertainty



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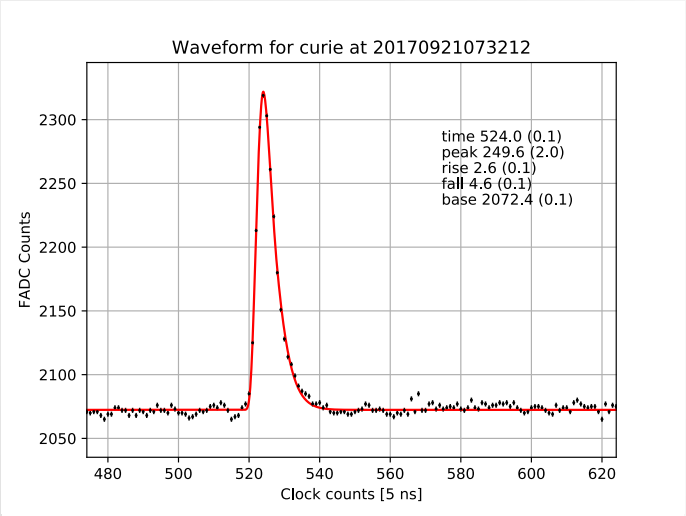
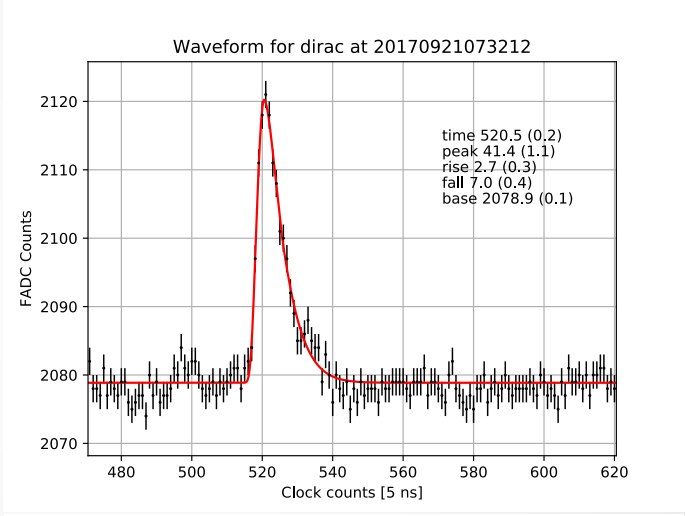
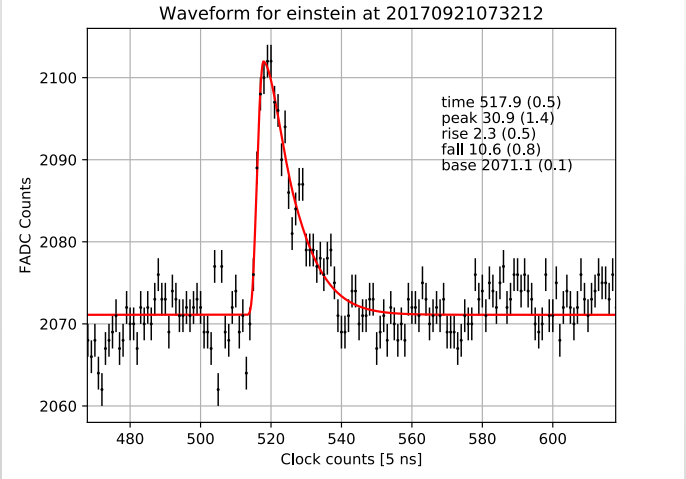
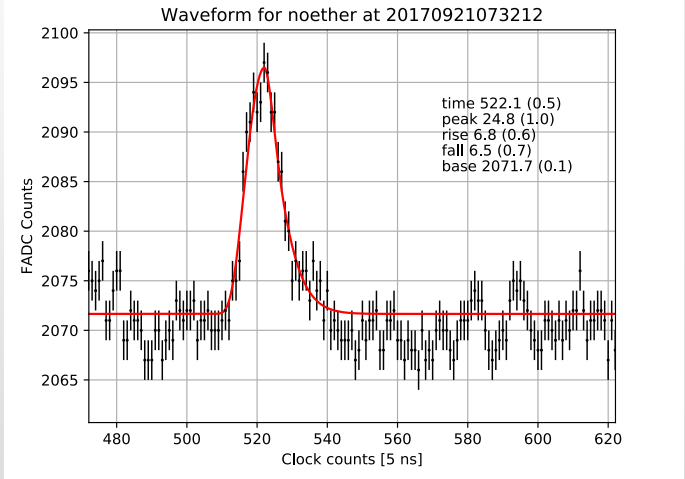


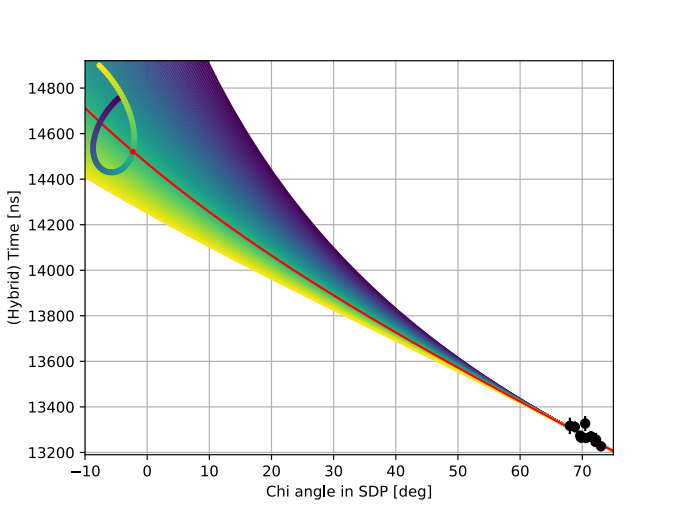


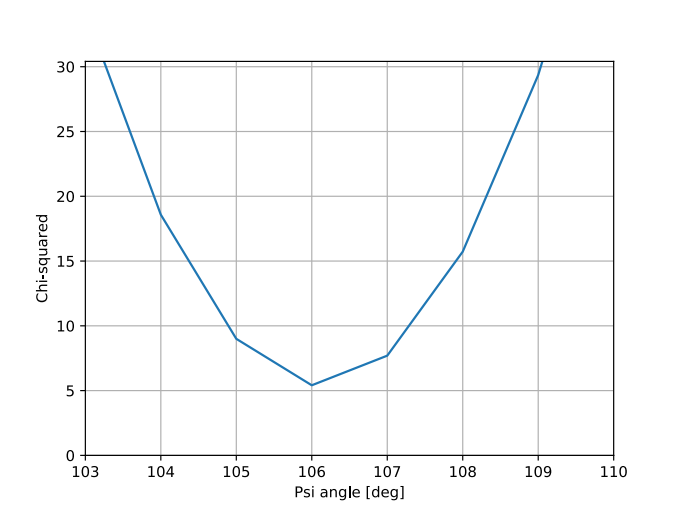


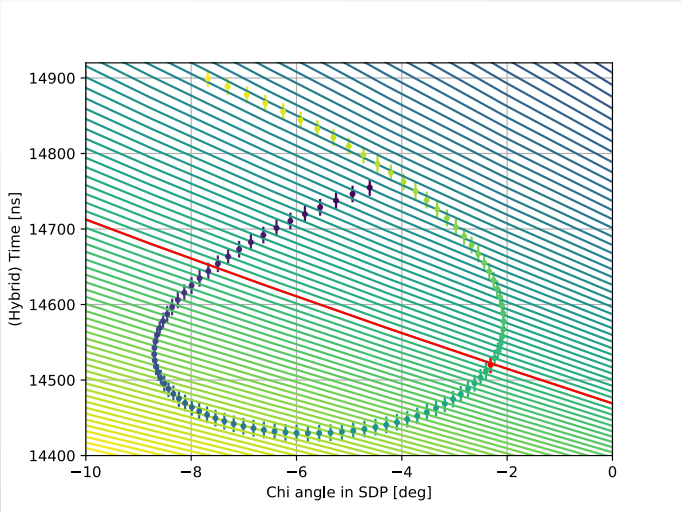


NICHE-TALE Hybrid Timing Fits

- Fixing offset time to 173 ns, can do hybrid with single NICHE counters







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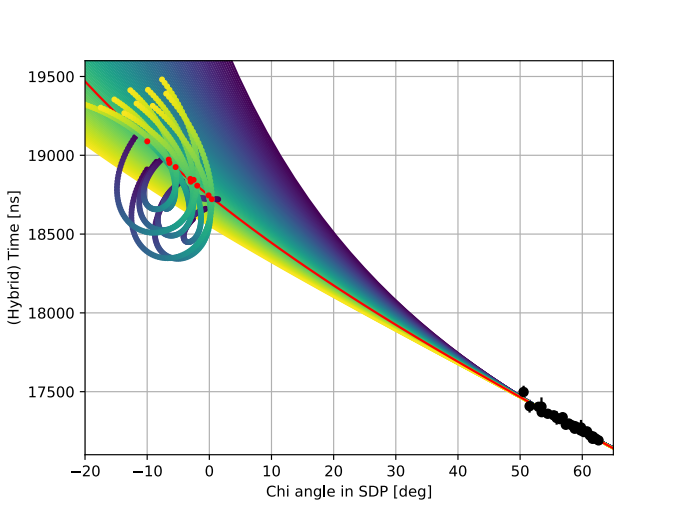
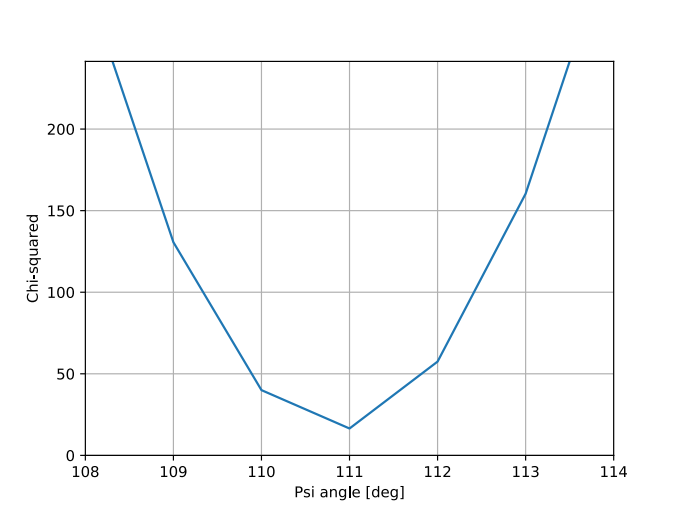
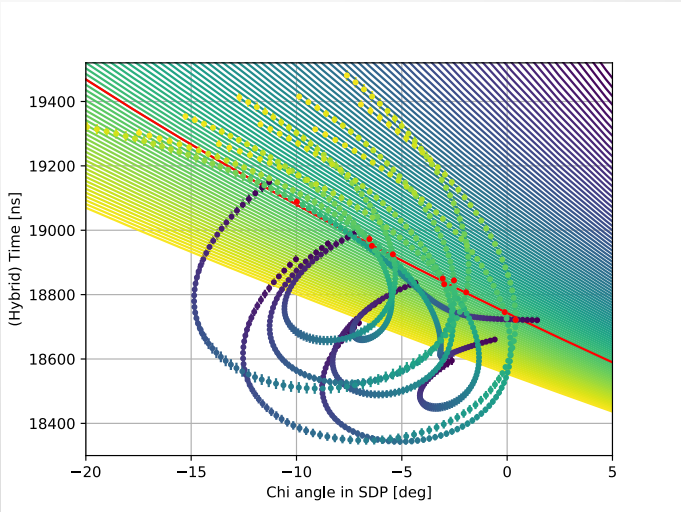
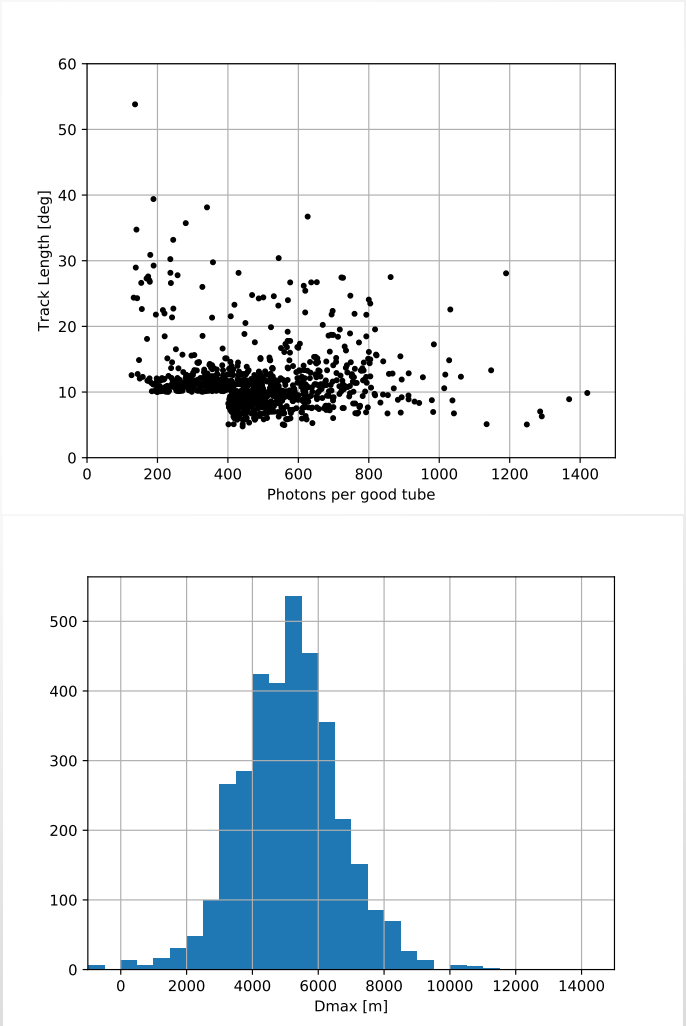






FWHM vs R_P vs D_{max}, Data Only

- Using just NICHE and TALE data, can show that how the NICHE FWHM depends on R_P is sensitive to how far away shower max is (D_{max})
- Note that the core is not that certain (despite <1˚ resolution on in-plane angle)
  - Select TALE events that are not too short and not too dim
- Get D_{max} from TALE's X_{max}
  - Divide range up into 10 bins with equal number of events



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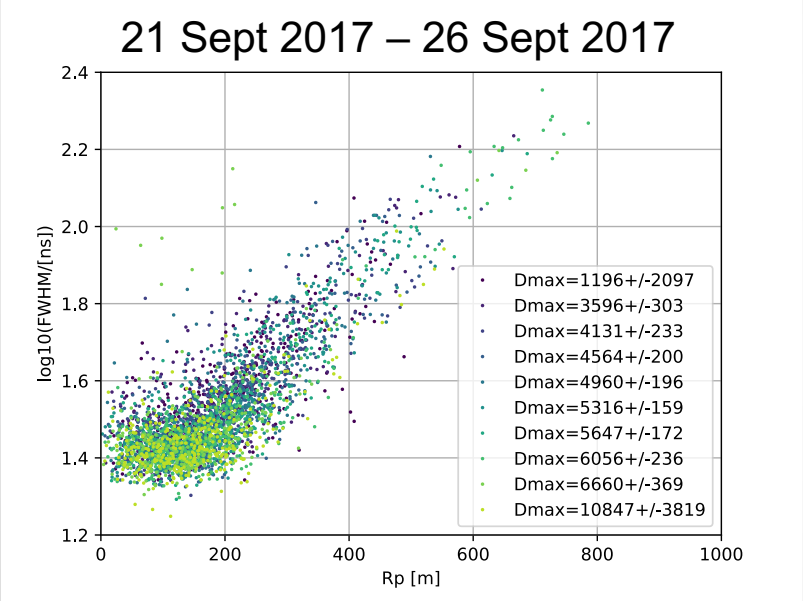

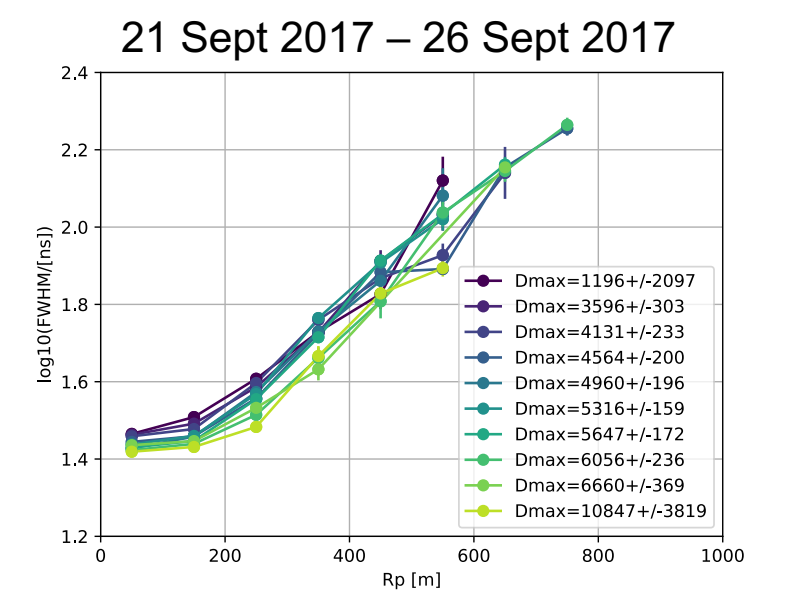

- Each D_{max} bin has a color/profile histogram
- Far away (large D_{max}) showers only start growing above impulse response for R_P > 200 m
- Close showers (small D_{max}) affect even R_P < 100 m (because of R_P uncertainty)
- Clear progression with increasing D_{max}!

Conclusion

- NICHE array is up and running
- 10 counter array running since last year, 4 more counters deployed last month
- We're seeing appropriate coincidences within NICHE and with TALE
- Have verified TALE's PCGF geometry at the 3˚ level
- Have performed hybrid fits between NICHE and TALE
- Have observed the dependence of the FWHM of the Cherenkov signal with the distance of the shower maximum from the array