

# Coherent Noise and TP Generation

Q: At what point does coherent noise become a problem? Will we need special handling?

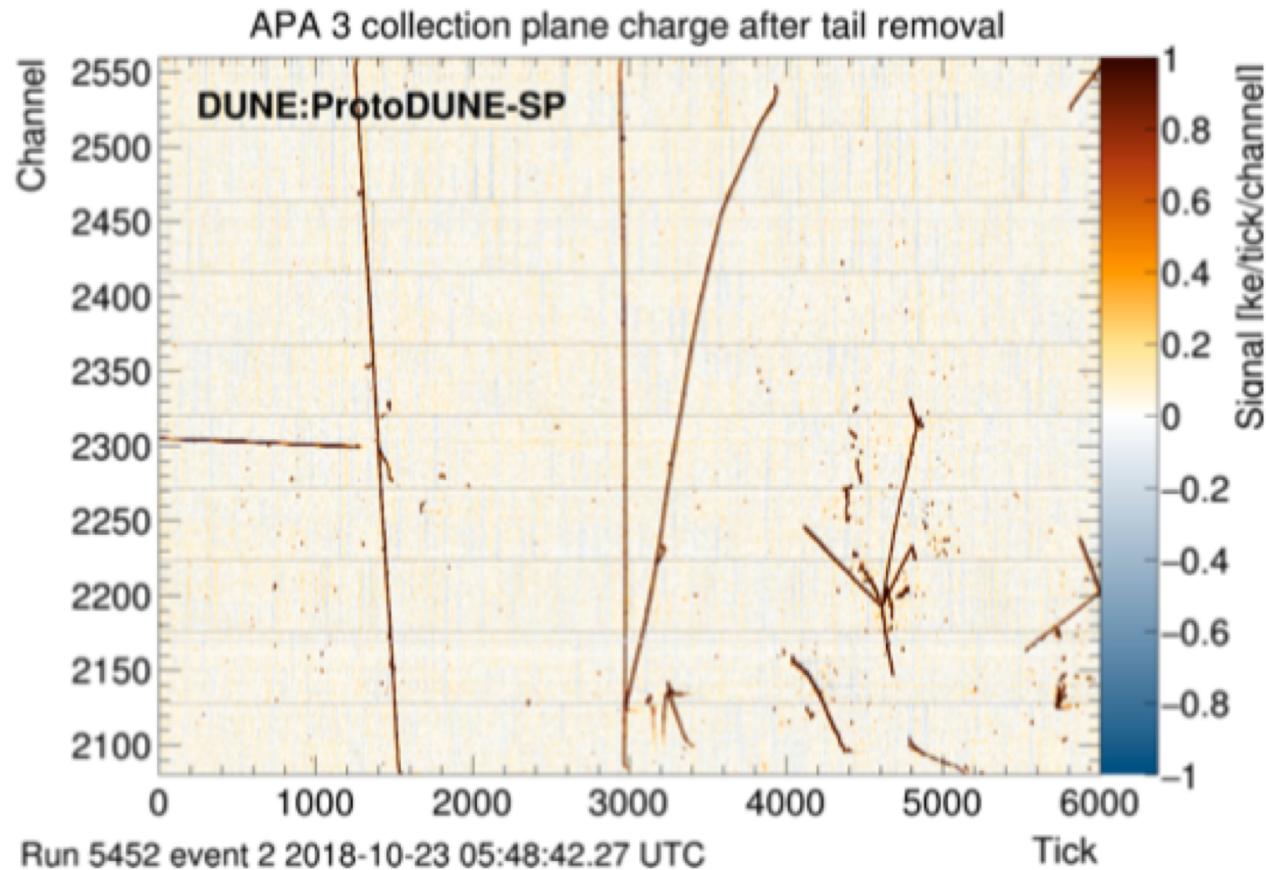
(“Coherent” is often take to mean BOTH that the noise is correlated across channels AND that it is narrow-band or even monochromatic).

Two impacts:

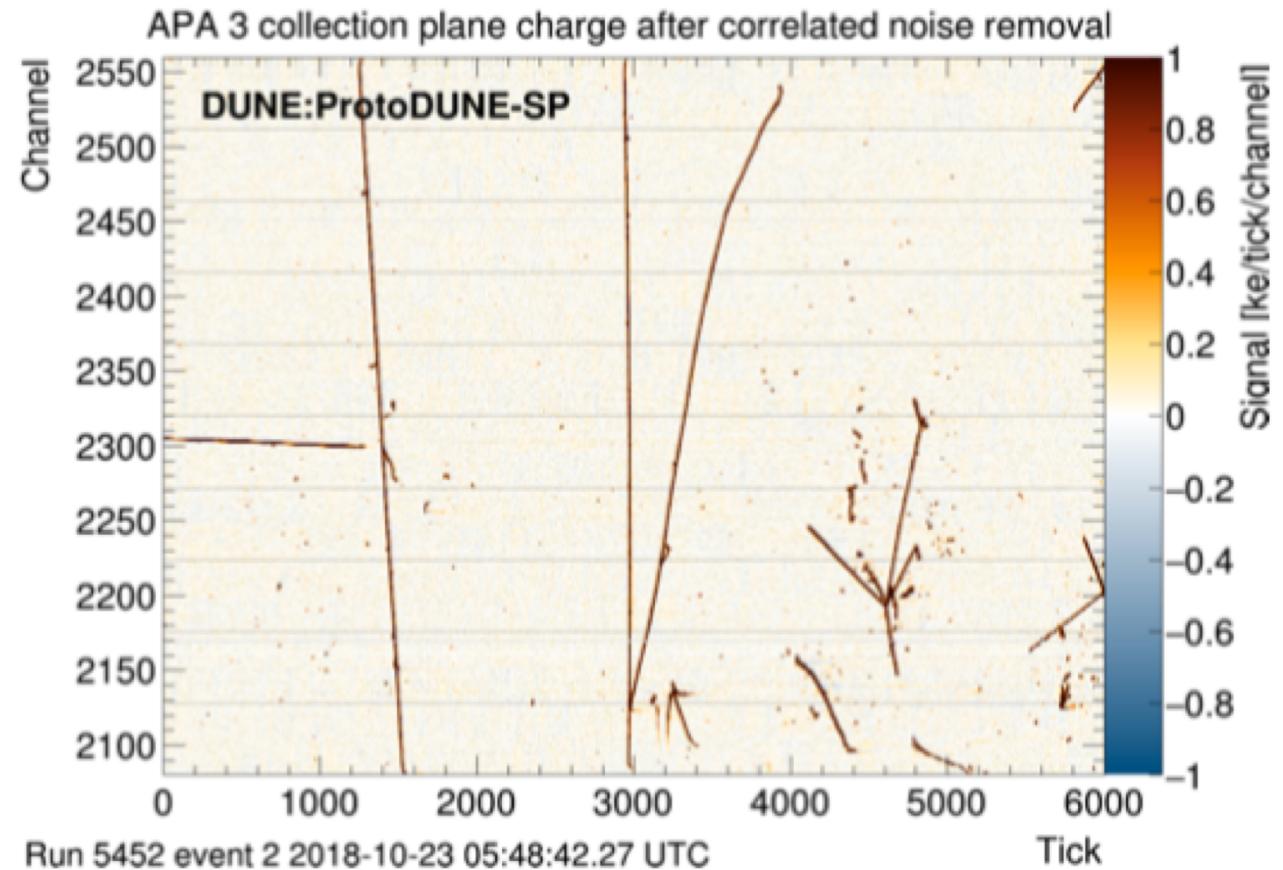
1. Increase in TP rate compared to “standard” broad-band noise (today)
2. Increase in Trigger Activity rate compared to pile-up and other backgrounds (another time)

*Note: None of this is a substitute for a full simulation-based or data-driven study, using a noise model like that described by Pierre, Babak, etc.*

# Coherent Noise and TP Generation



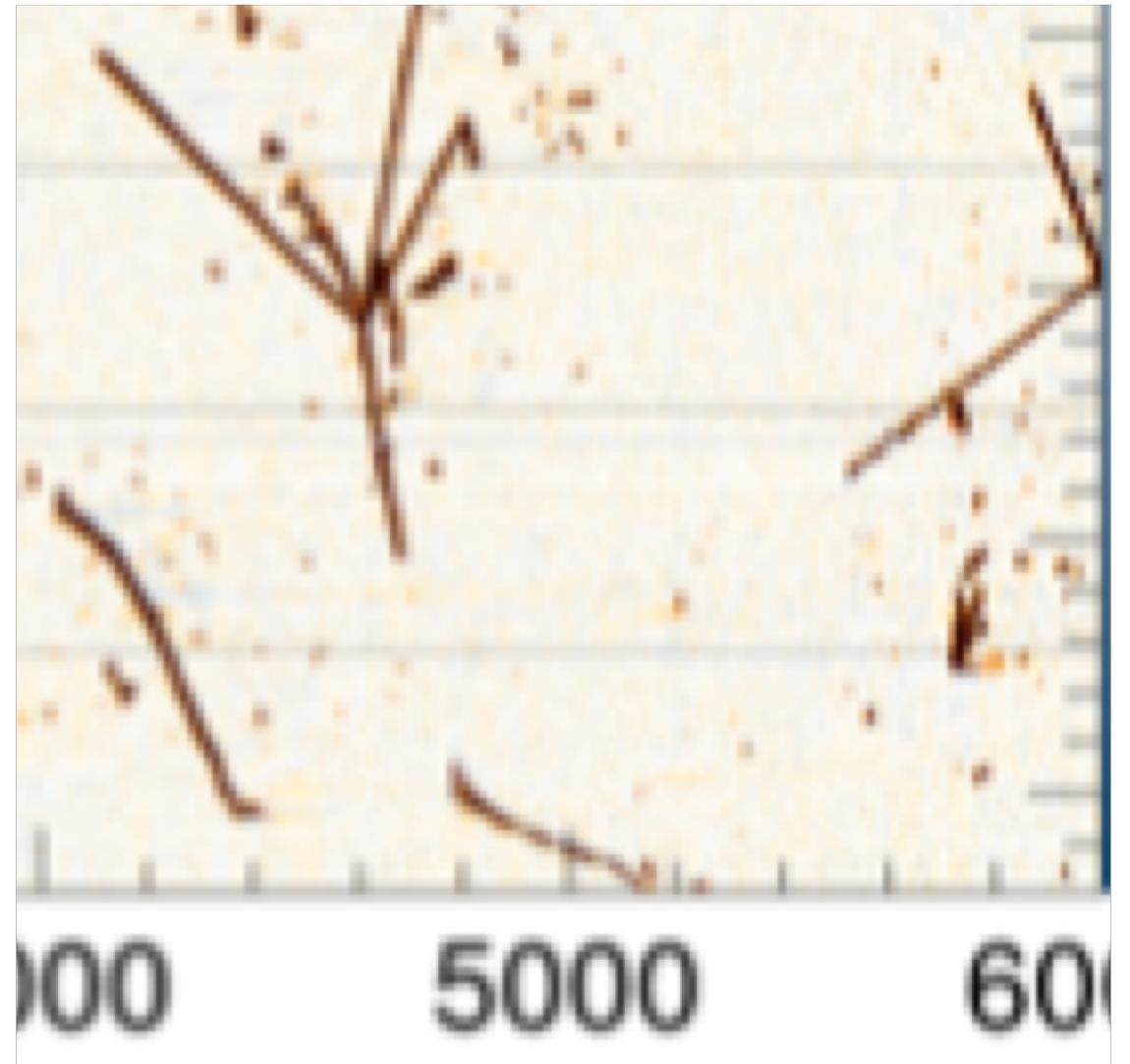
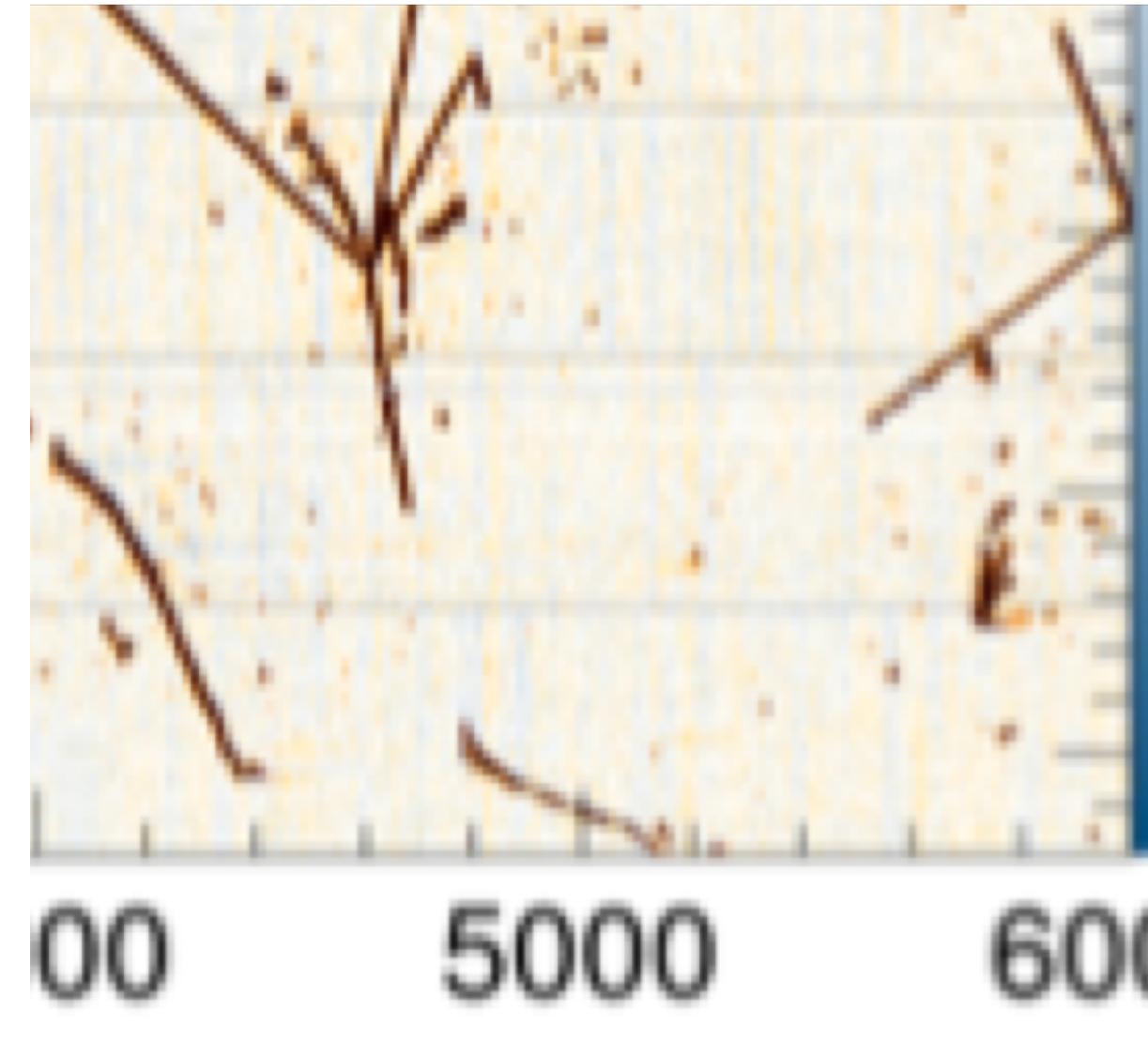
(c) After tail removal.



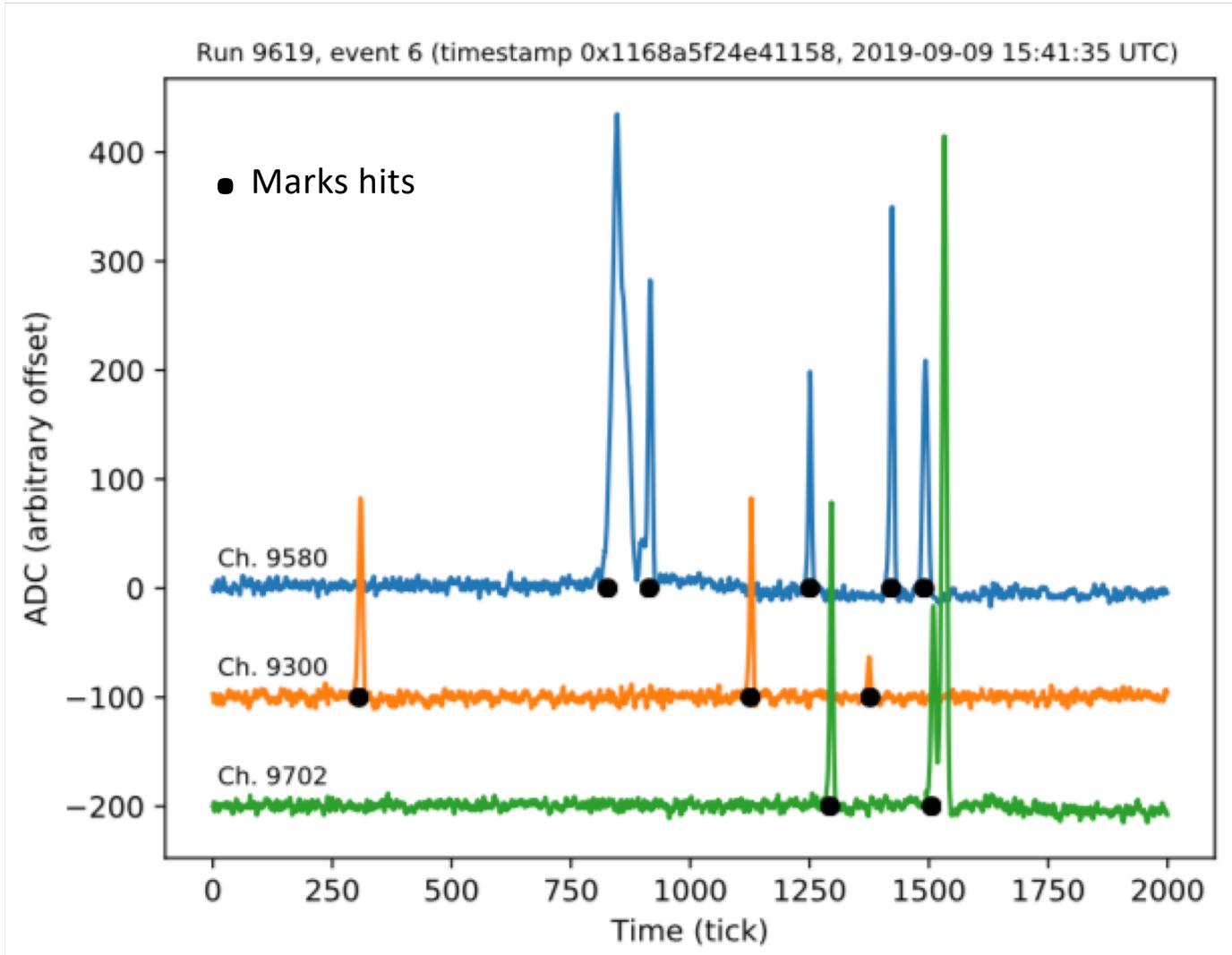
(d) After correlated noise removal.

Relative “easy” to remove coherent noise offline...but what are impacts on hit-finding?

# Coherent Noise and TP Generation

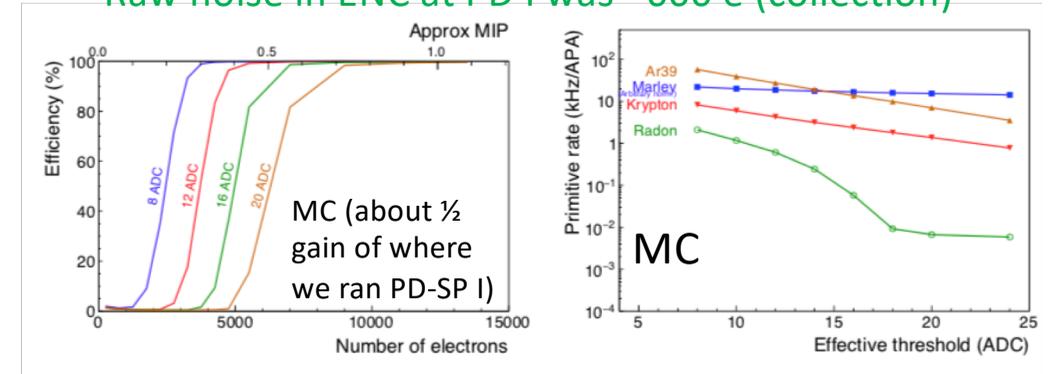


# Trigger Primitives at ProtoDUNE

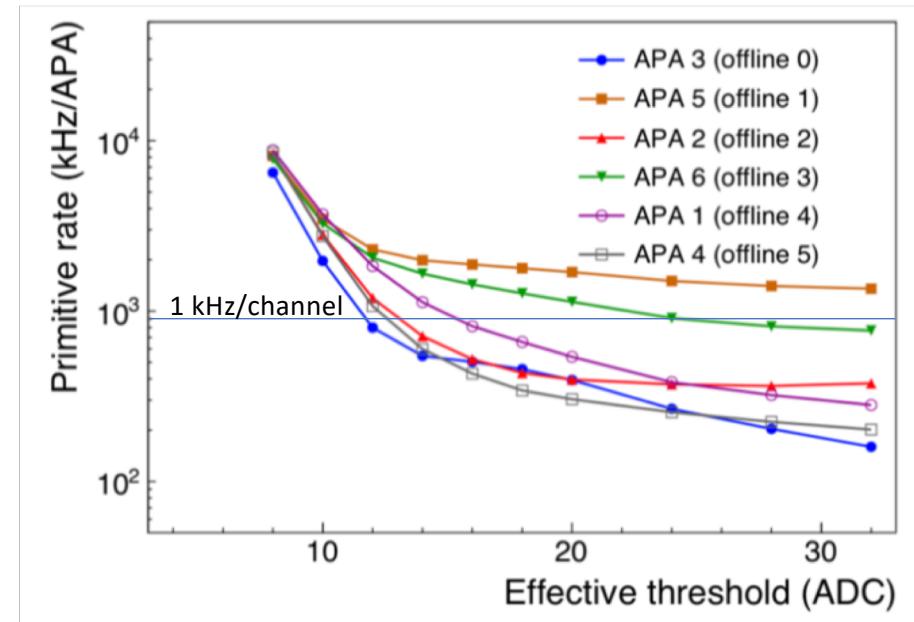


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Raw noise in ENC at PD I was  $\sim 600$  e (collection)



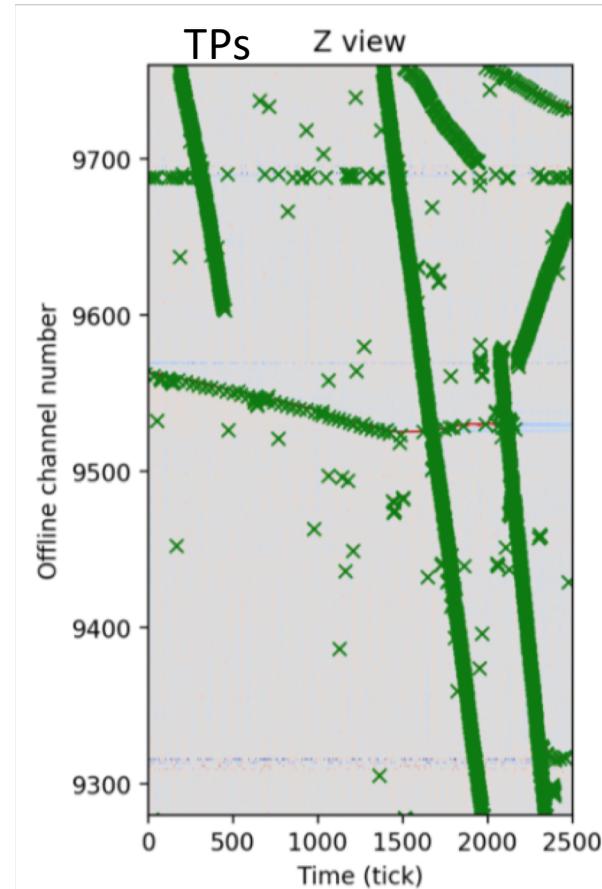
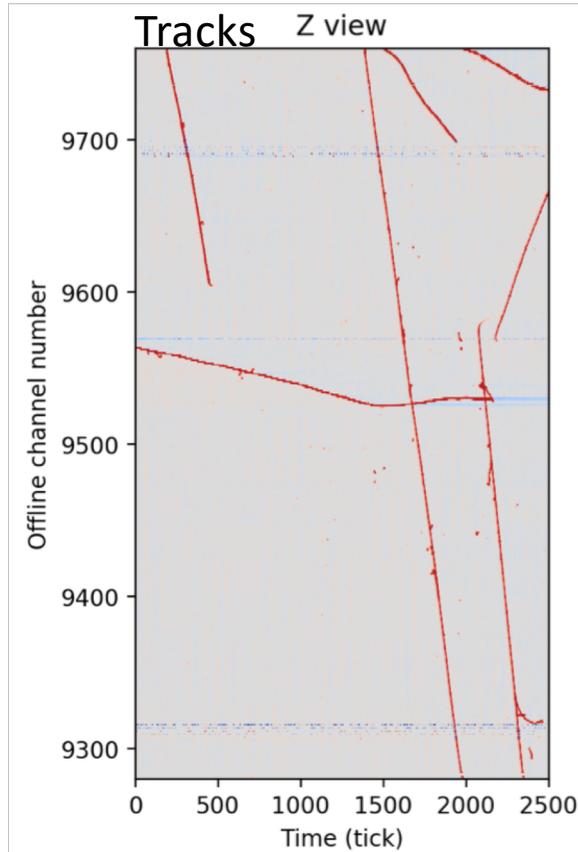
Raw noise RMS in PD I was 3-4 ADC above pedestal



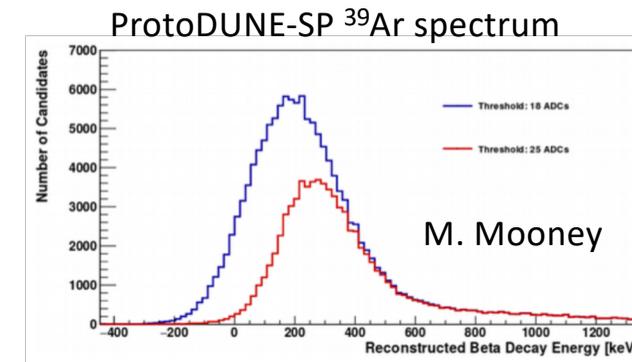
# Trigger Primitives (TPs)

Hit finding

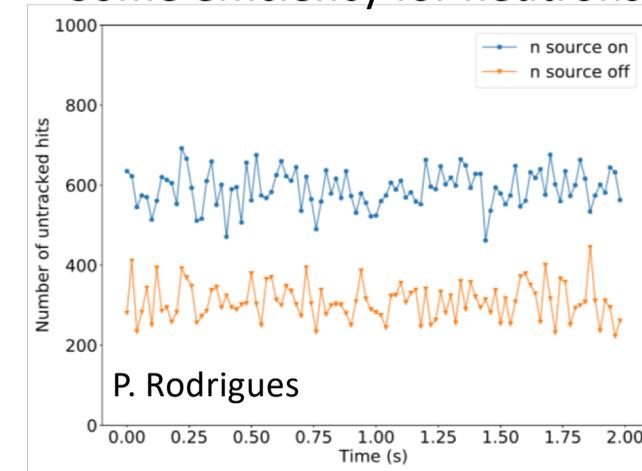
Run 11044, event 5 (timestamp 0x11955baa4c000a0, 2020-03-09 17:22:51 UTC)



TP threshold was around 1/4 MIP-equivalent, or around 250 keV<sub>ME</sub> (per wire)



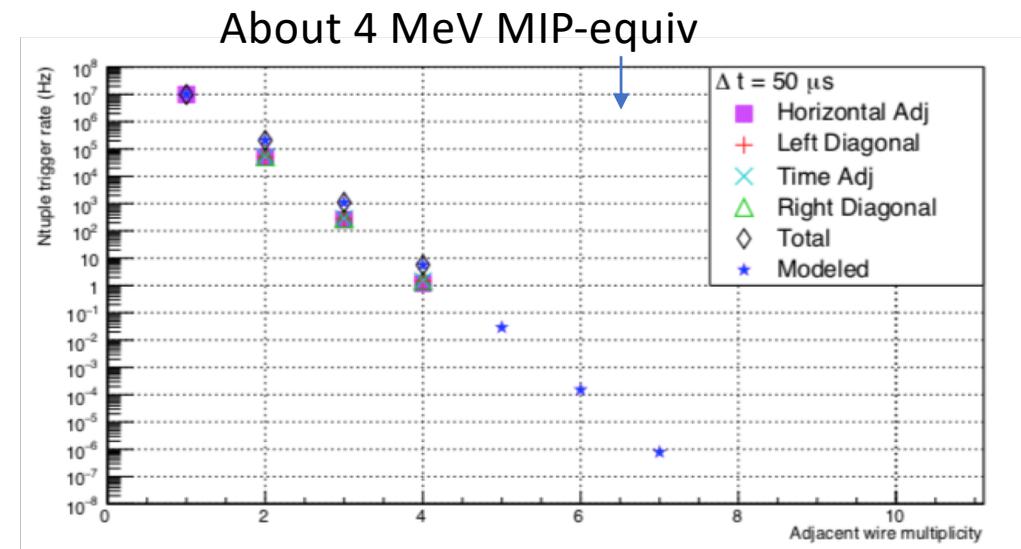
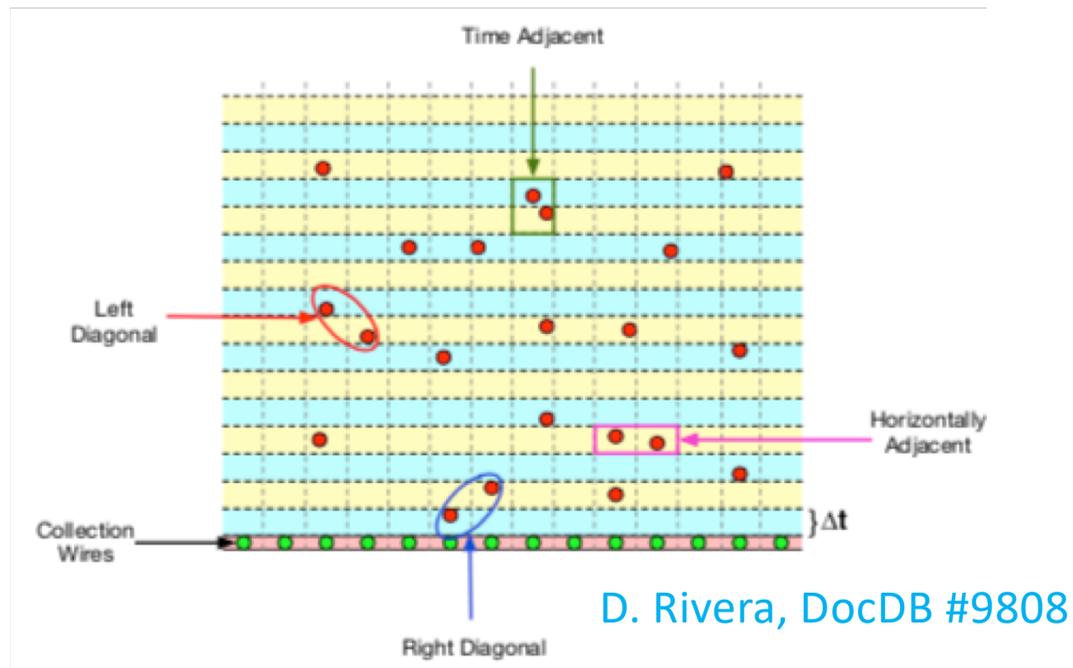
Some efficiency for neutrons



P. Rodrigues

# At What Point Would Noise Dominate TP Rate?

- For thresholds we've been imagining for DUNE, we sit inside the  $^{39}\text{Ar}$  spectrum
- Rates of TPs from  $^{39}\text{Ar}$  are therefore some large fraction of  $10^7$  Hz/10 ktonne
- Which is about 90 Hz per collection wire
- These rates can still lead to "trigger activity" via pileup (if *uncorrelated!*):



**Uncorrelated TP rates  $<$   $^{39}\text{Ar}$  TP rate cannot be a problem**

## At What Point Would Noise Dominate TP Rate?

If we assume that the noise is effectively white and thus for any given sample it is normally distributed about the baseline it is a pretty straightforward calculation:

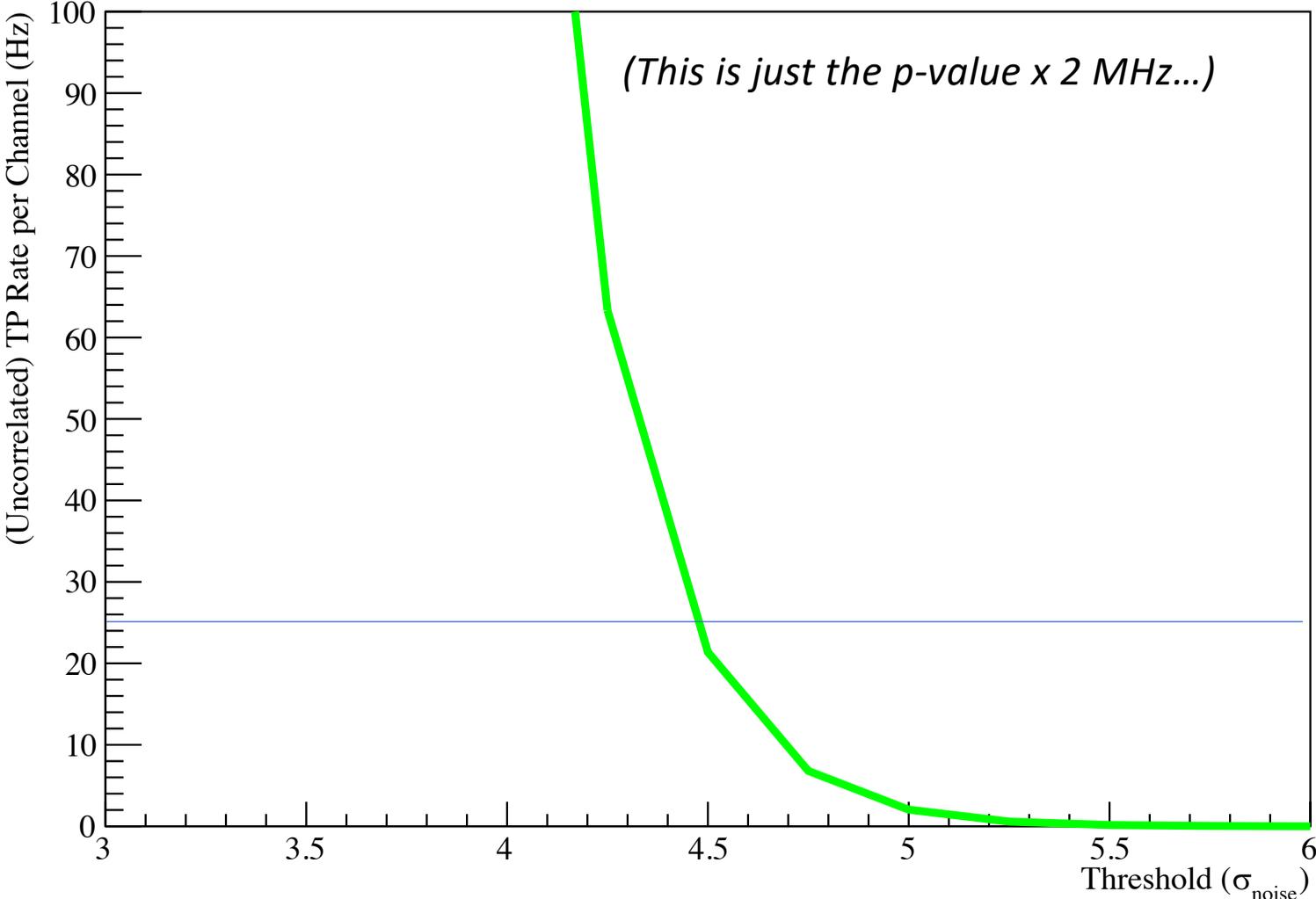
$$R_{\text{TP}} = S \times \int_{\text{thresh}}^{\infty} \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(\frac{-(x-x_0)^2}{2\sigma^2}\right) dx$$

Where  $S$  is the sampling rate ( $\sim 2$  MHz) and  $\sigma$  is the rms of the (assumed normal!) noise. (It isn't and can't be white noise, but...).

If we set a threshold for a hit that is in units of  $\sigma_{\text{noise}}$  then we can show something identical of filtering up to the white noise assumption above...

# At What Point Would Noise Dominate TP Rate?

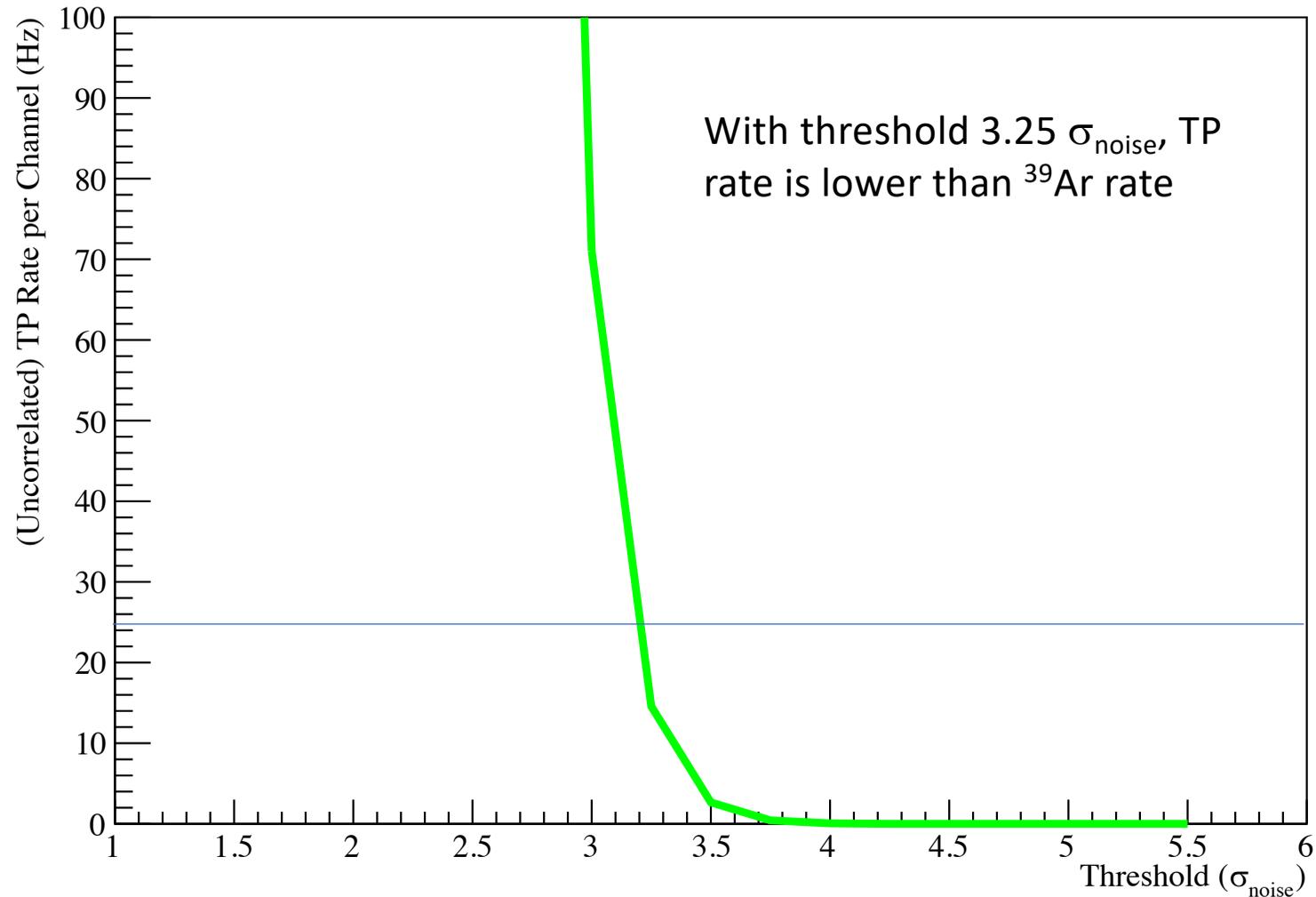
This assumes a single fluctuation generates a TP and no correlations sample-to-sample (ie, white noise)



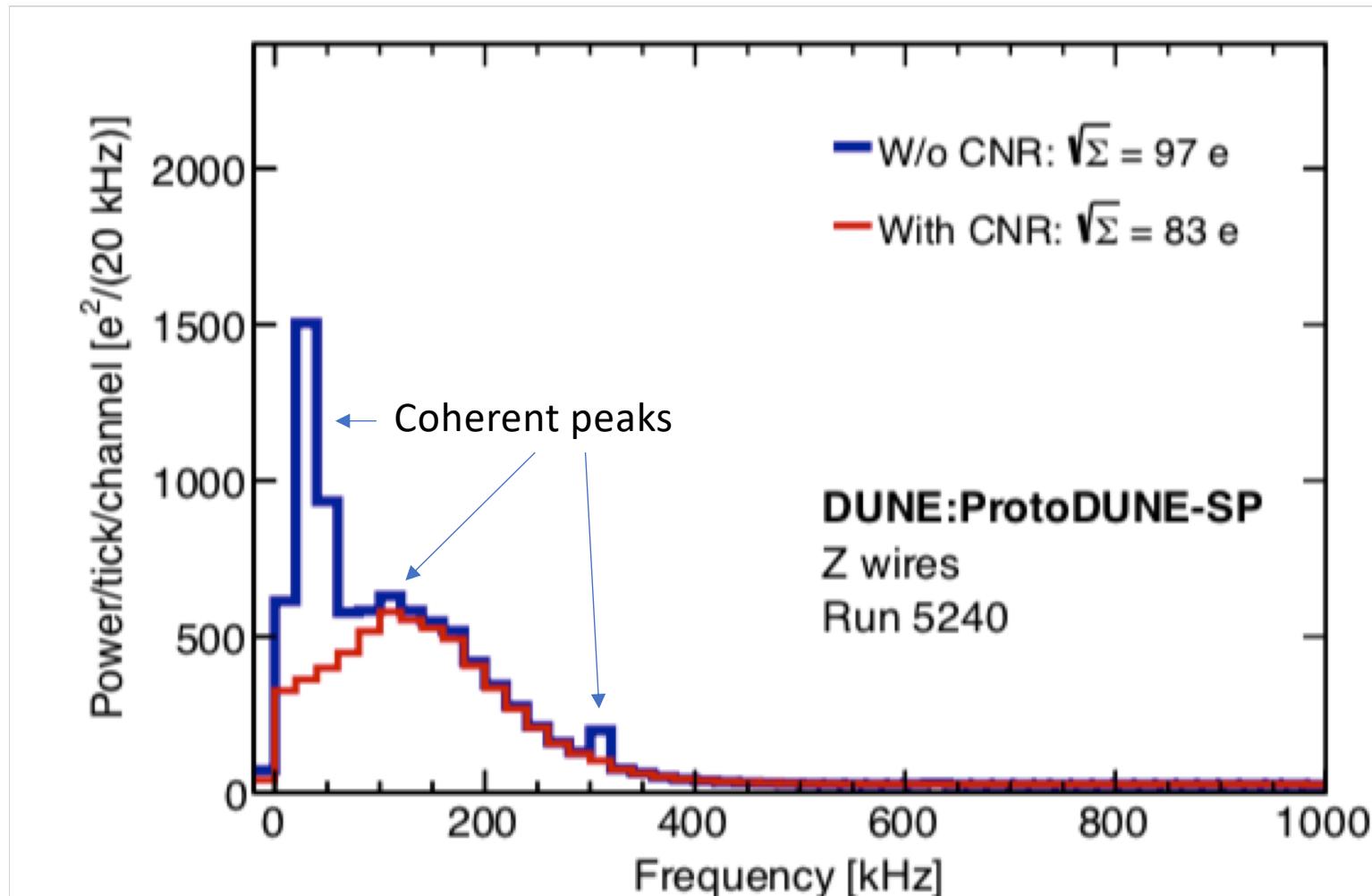
# At What Point Would Noise Dominate TP Rate?

Actual TP algorithm requires 2 samples above threshold

Including two-sample requirement (coincidence in 1  $\mu$ s of two fluctuations):



# What is the impact of coherent noise?



Going to look first at impact of monochromatic noise on uncorrelated TPs

## At What Point Would Coherent Noise Dominate TP Rate?

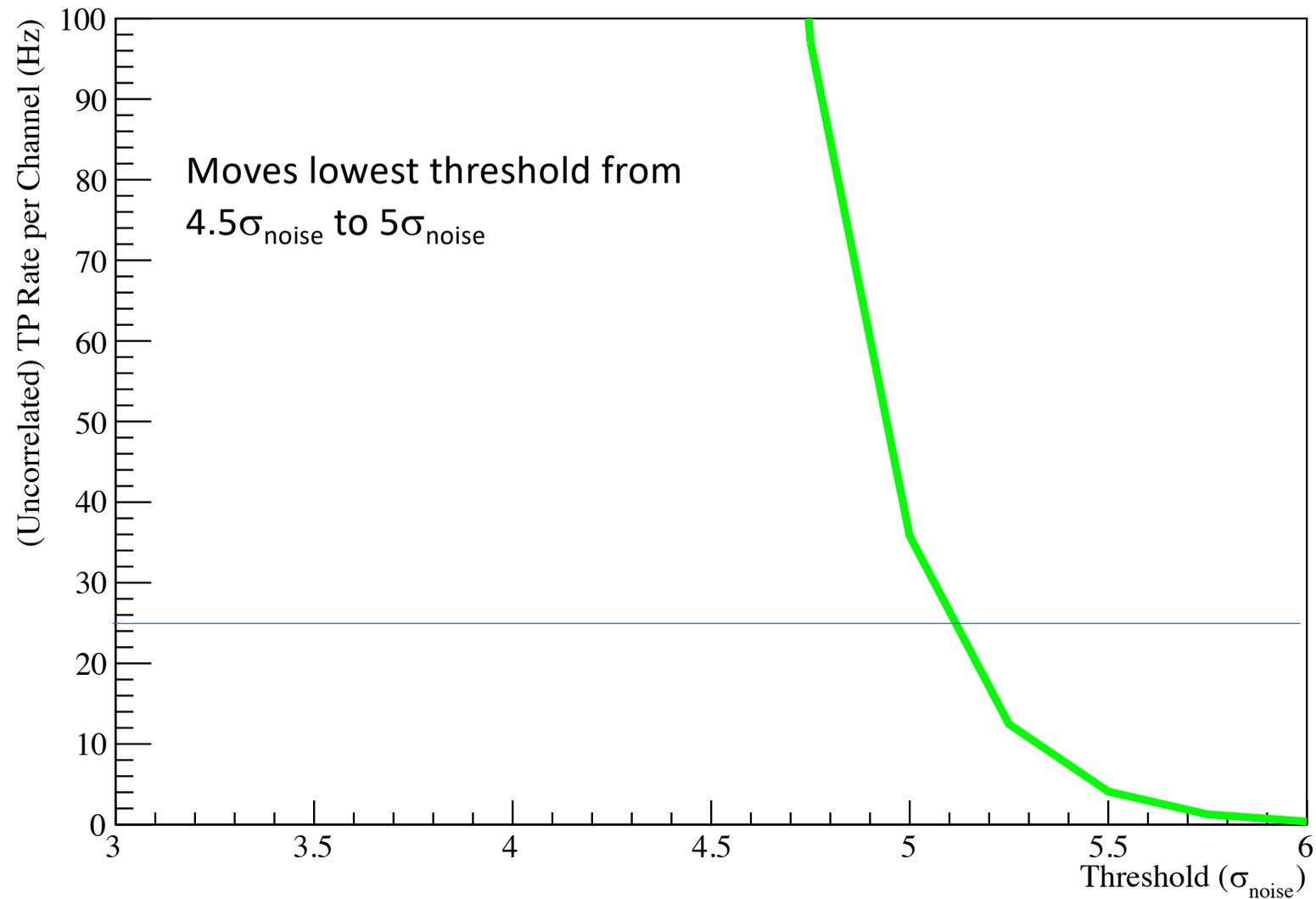
If we assume coherent noise is effectively monochromatic, then addition of this just shifts the baseline from which “normal” fluctuations happen, so we integrate over 1 cycle for each frequency

$$R_{\text{TP}} = S \times f \int_0^{1/f} \int_{\text{thresh}}^{\infty} \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(\frac{-(x - A \sin(2\pi ft))^2}{2\sigma^2}\right) dx dt$$

S is again sampling rate; f is frequency of monochromatic noise; sigma is the “normal” noise rms; A is the amplitude (in, e.g., ADC counts) of the monochromatic noise.

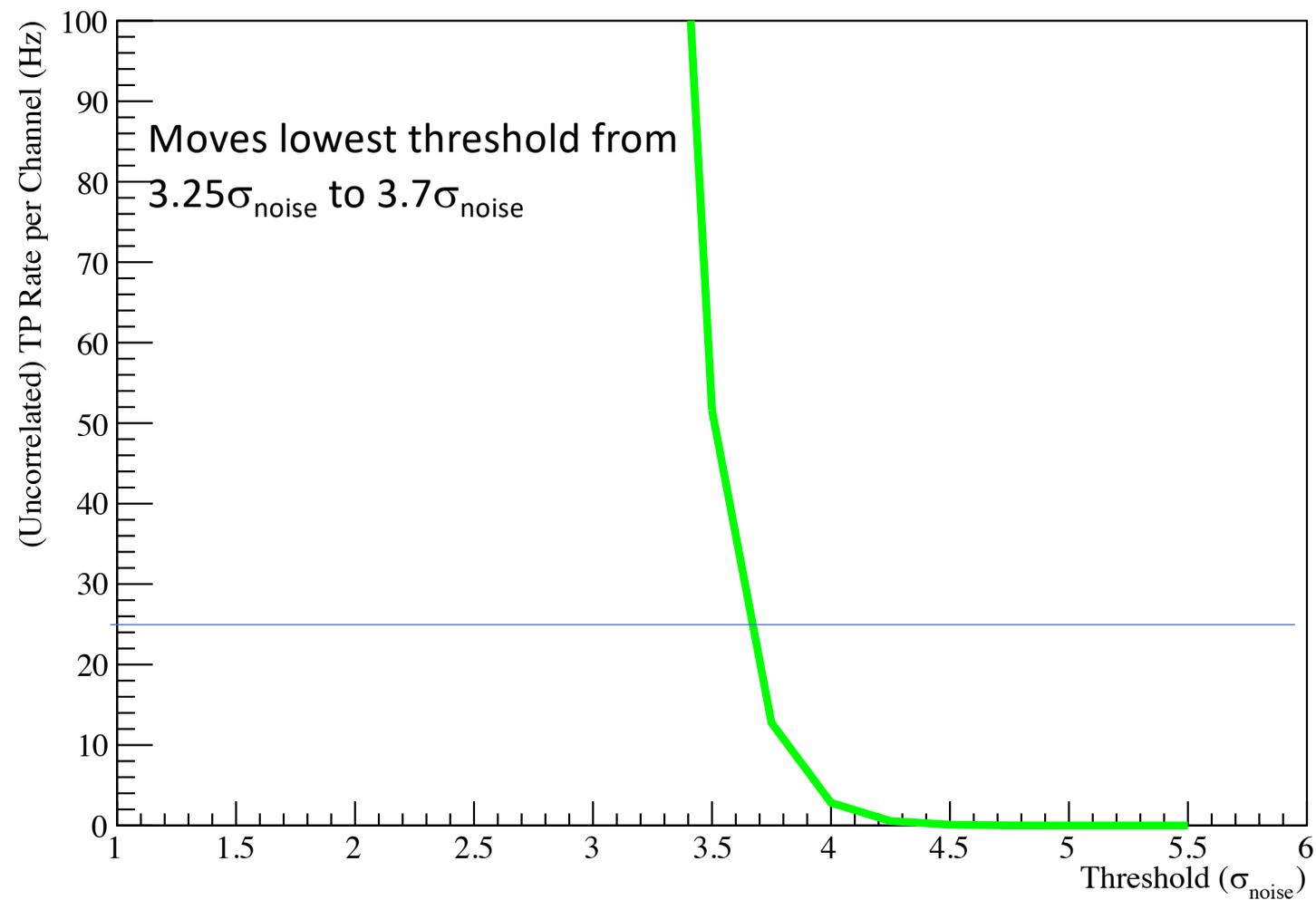
# At What Point Would Coherent Noise Dominate TP Rate?

Single-point fluctuation on top of 50 kHz coherent/monochromatic noise with amplitude =  $1 \sigma_{\text{noise}}$



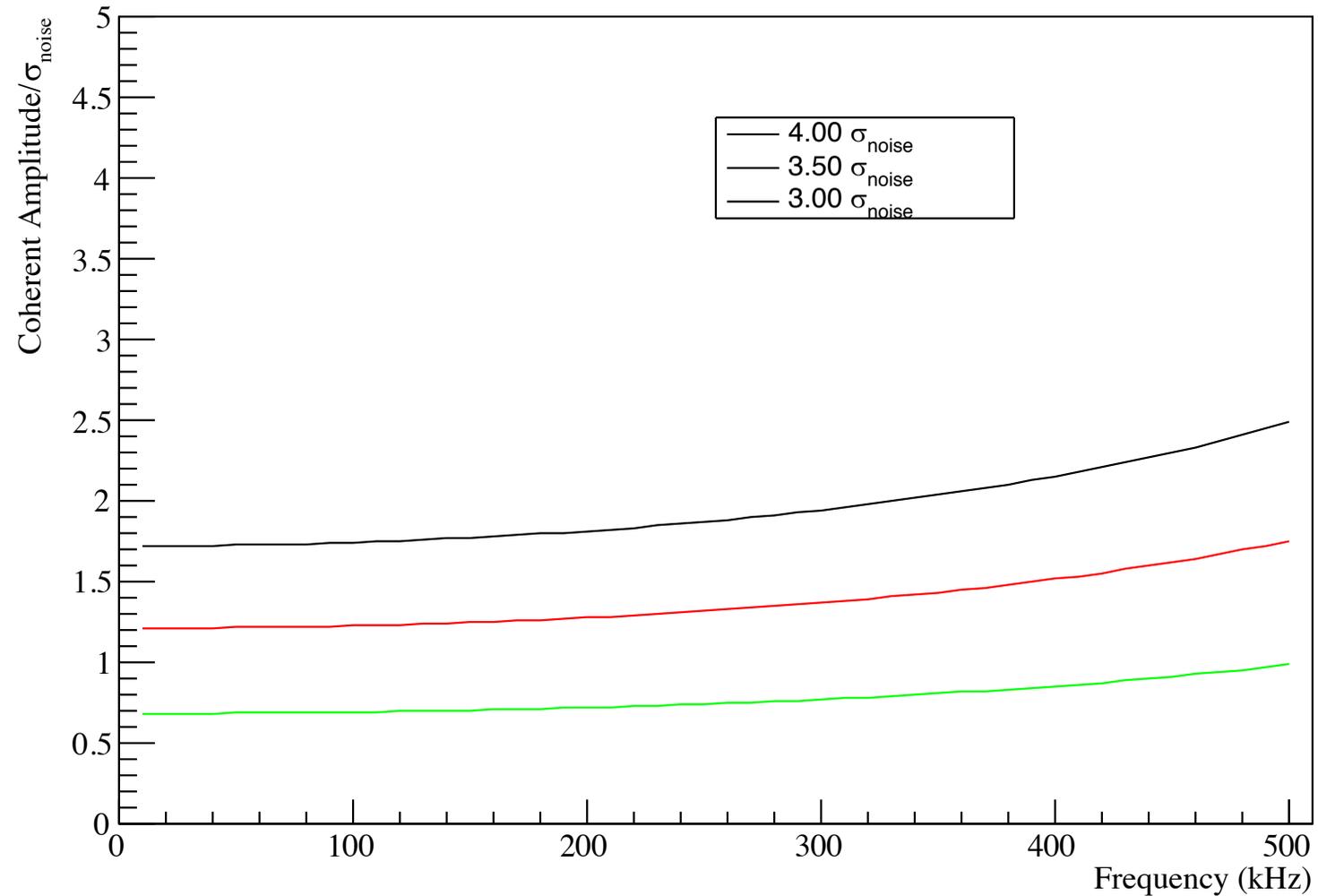
# At What Point Would Coherent Noise Dominate TP Rate?

Two-point fluctuation on top of 50 kHz coherent noise with amplitude = 1  $\sigma_{\text{noise}}$



# At What Point Would Noise Dominate TP Rate?

Size of coherent amplitude in units of  $\sigma_{\text{noise}}$  as a function of frequency for various thresholds

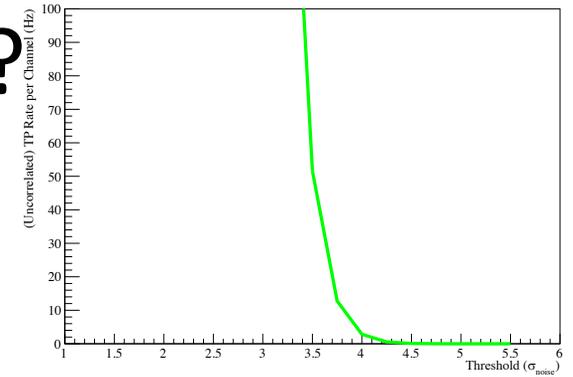


# Intermediate Summary

With extremely simplifying assumptions:

- when amplitude of coherent noise is equal to rms of “random” noise, TP rate from just noise is = to  $^{39}\text{Ar}$  TP rate at a threshold of  $\sim 3.7\sigma_{\text{noise}}$
- TP rate from noise equals  $^{39}\text{Ar}$  rate for amplitudes of coherent noise that are between  $0.5$  and  $2\sigma_{\text{noise}}$  depending on (reasonable) threshold and frequency

# What About Actual Coherent Noise?



- Noise is coherent across FEMBs (128 channels)
- There is no clustering approach to trigger activity that uses more channels than that---only a small fraction of these have to have hits to look like TA
- If we do not use ROI readout, trigger rate is limited to  $< 0.1$  Hz
- So probably we would need thresholds higher than 5 sigma on each channel
- For ROIs in time and space we can go up to about 30 kHz, which gives us some breathing room (but how dumb would it be to have 30 kHz of noise TAs?)
- Need to repeat calculation above including correlated-coincidences (baseline shifts are correlated; the rest of the noise is not)