HF Sourcing: Pedestal Oscillation Analysis

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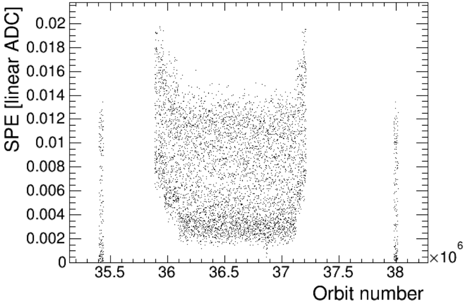
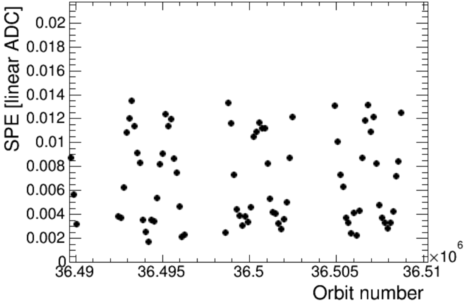
Issue: HF pedestal oscillating for some channels



- Plot from Viktor Khristenko
- Run: ???; Channel: HF(40, 23, 1)
- Full x-axis range shown

Issue: HF pedestal oscillating for some channels



- Same plot as last slide, but zoomed x-axis range
- Data broken into 0.35s chunks (expected)
- Oscillations are clear (not in all channels)

Goals

- Three (more?) main goals for this analysis:
    1. Identify oscillating channels
    2. Quantify oscillation
    3. See if oscillation varies with time
- Focus on Goal 1 (identification) for now

Method: overview

1. Viktor provides a `TGraph` (slide 2) for each channel in run
2. For each channel, break `TGraph` into 0.35s chunks
3. Convert each chunk's x-axis from OrN to time
   - Divide OrN by orbit frequency in Hz
4. Fit each chunk ($\approx$ 200) with a sinusoid
5. Use collection of fits to identify oscillating pedestals:
   - Oscillating channels have good fits & big amplitudes
   - Non-oscillating channels have bad fits & low amplitudes

Method: the fit

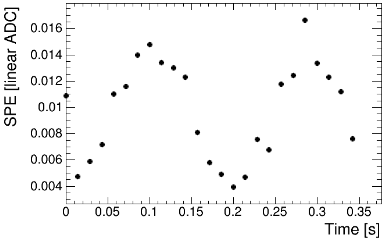
- Fit function with 4 degrees of freedom:

  $$f(t) = a_0 + a_1 \cdot \sin(2\pi \cdot (f \cdot x + \phi))$$

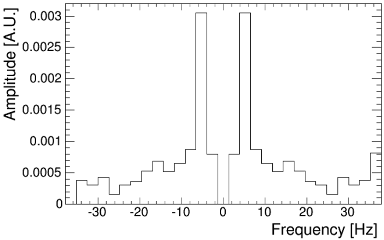
- Limits on parameters:
  - Let y_i be the SPE of the i-th point in the chunk
    - a_0 varies between 0 and $\left[2 \cdot \left(\frac{y_{\mathbf{max}} + y_{\mathbf{min}}}{2}\right)\right]$
    - a_1 varies between 0 and $\left[2 \cdot \left(\frac{y_{\mathbf{max}} - y_{\mathbf{min}}}{2}\right)\right]$
  - Let f_{FFT} be the frequency found by the peak of an FFT on the chunk
    - f varies between 0 and sampling frequency
    - f initially set to f_{FFT}
  - No restrictions on phase
    - ϕ varies between 0 and 1

Method: example on oscillating channel

Example 0.35*s* chunk input

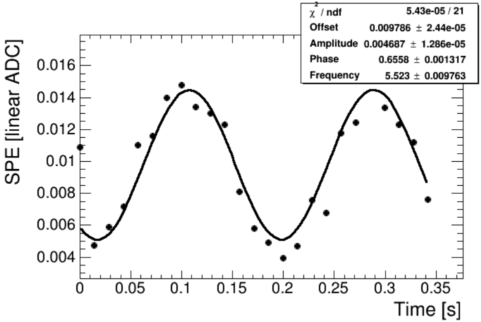


Example FFT output



- Channel = HF(40, 23, 1): oscillating
- FFT peaks around 5.2 Hz: f is within [2.6, 10.4] Hz in fit
- Fit on next slide

Method: example on oscillating channel



- Channel = HF(40, 23, 1): oscillating

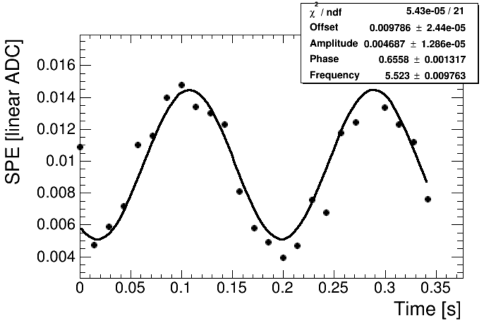
Method: define fit significance

- Define variable to quantify residuals of data w.r.t. fit
- Each point, i, in chunk has coordinate in time and SPE:
  - time value: t_i [s]
  - SPE value: y_i [linear ADC]
- Fit function, f, is defined for each t_i
- There are N points in a given chunk
- Define significance, σ, for a chunk as follows:

$$\sigma = \frac{1}{N} \cdot \sqrt{\sum_{i=1}^{i=N} [f(t_i) - y_i]^2}$$

  - σ small for oscillating distributions
  - σ large for non-oscillating distributions

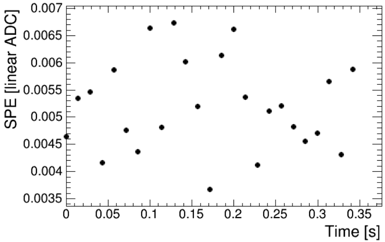
Method: example on oscillating channel



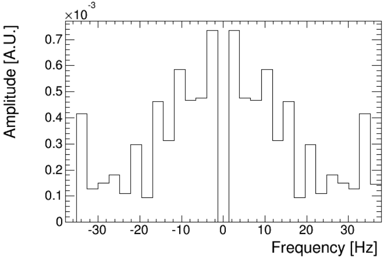
- Channel = HF(40, 23, 1): oscillating
- $\sigma = 9.2\text{e-}5$; a_1 (amplitude from fit) = 4.7e-3
- $\sigma / a_1 = 15.9$ (large)

Method: example on non-oscillating channel

Example 0.35*s* chunk input

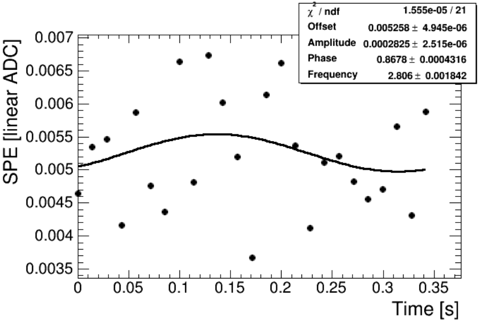


Example FFT output



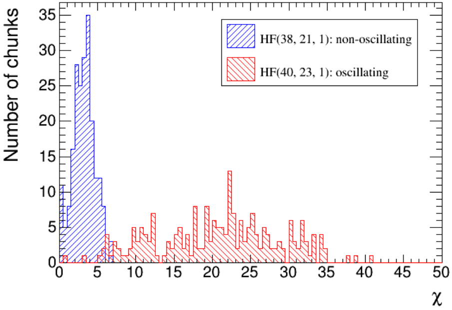
- Channel = HF(38, 21, 1): non-oscillating
- FFT peaks around 2.6 Hz: f is within [1.3, 5.2] Hz in fit
- Fit on next slide

Method: example on non-oscillating channel



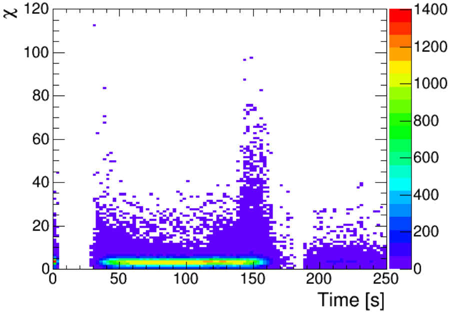
- Channel = HF(38, 21, 1): non-oscillating
- σ = 1.6e-4; a_1 (amplitude from fit) = 2.8e-4
- $\sigma / a_1 = 1.8$ (small)

Method: look at all 0.35s chunks for two channels



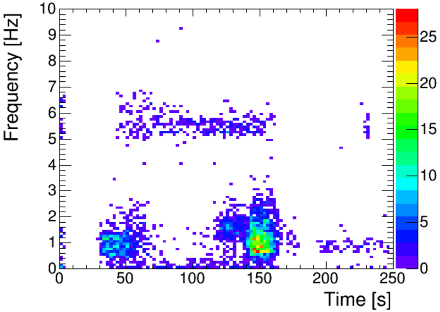
- Define $\chi = \sigma / a_1$: a good measure for "oscillating-ness"
- Naively look for chunks with $\chi > 10$
- Enough method: let's look at results

Results: χ vs. time for all chunks



- Plot is a 2D histogram
- One entry per chunk, per channel
- x-axis: time [seconds], y-axis: χ

Results: Freq. vs. time for chunks with $\chi > 10$

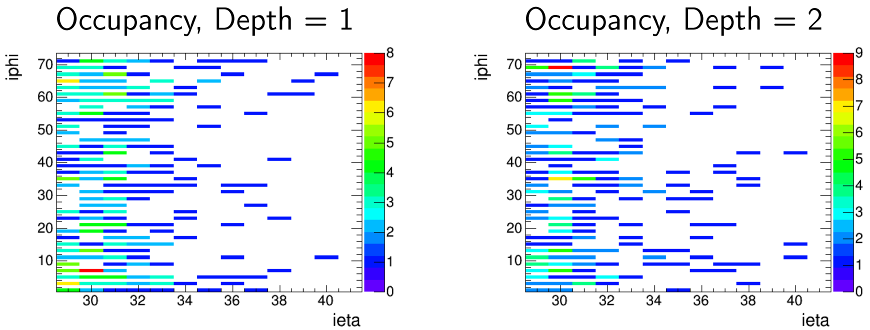


- Plot is a 2D histogram
- One entry per chunk, per channel, if chunk $\chi > 10$
- x-axis: time [seconds], y-axis: frequency from fit

Observations:

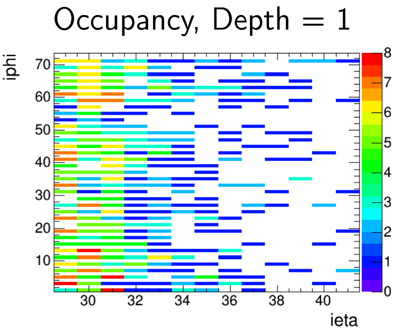
- Observations from the χ vs time plot:
  - Most chunks have $\chi < 10$ (non-oscillating)
  - There are spikes in χ at time $=$ 40s and 150s
- Observations from the frequency vs time plot:
  - Two frequencies of oscillation observed
  - Spikes in χ at time $=$ 40s and 150s are mostly 0-2 Hz
  - Roughly constant rate of 5-7 Hz chunks between time $=$ 40s and 150s
- Next:
  - Where (ieta, iphi, depth) are the 0-2 Hz chunks?
  - Where (ieta, iphi, depth) are the 5-7 Hz chunks?

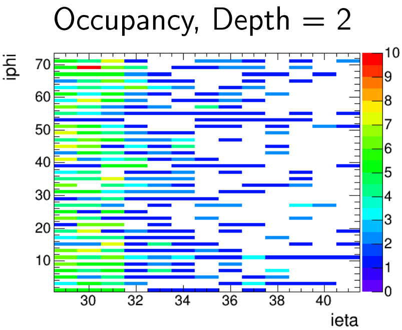
Results: Where are the 0-2 Hz chunks (30-60 s)?



- Plot is a 2D histogram
- One entry per chunk, per channel,
  if freq < 4 Hz, $\chi > 10$, and time ϵ [30, 60]
- x-axis: ieta, y-axis: iphi

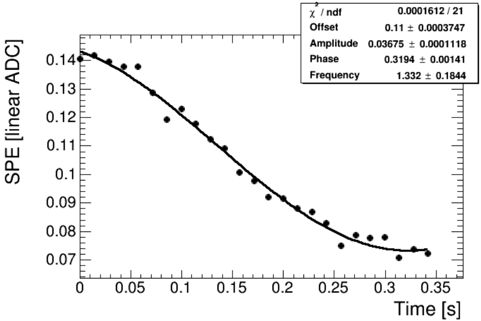
Results: Where are the 0-2 Hz chunks (140-160 s)?





- Plot is a 2D histogram
- One entry per chunk, per channel,
  if freq < 4 Hz, $\chi > 10$, and time ϵ [140, 160]
- *x*-axis: ieta, *y*-axis: iphi

Results: What does an 0-2 Hz chunk look like?

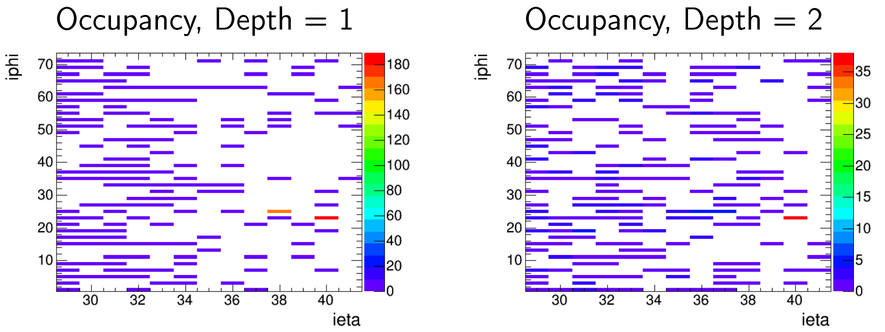


- Channel: HF(29, 5, 1)
- Time: 145s
- Frequency: 1.3 ± 0.2 Hz

Observations: 0-2 Hz chunks

- 0-2 Hz chunks more common at 140-160 than at 30-60 s
- No single channel contributing most of the 0-2 Hz chunks
- Low-ieta channels are far more likely to have 0-2 Hz chunks
- Side effect from sourcing?

Results: Where are the 5-7 Hz chunks?

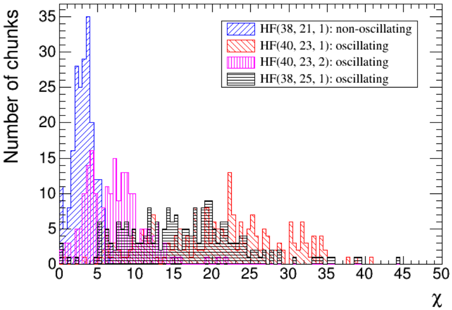


- Plot is a 2D histogram
- One entry per chunk, per channel, if freq $>$ 4 Hz and $\chi > 10$
- *x*-axis: ieta, *y*-axis: iphi

Observations:

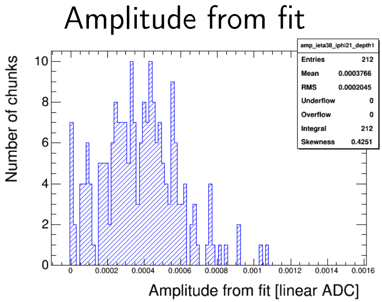
- 5-7 Hz chunks mostly come from three hot channels:
  - HF(40, 23, 1)
  - HF(40, 23, 2)
  - HF(38, 25, 1)
- Other channels contribute relatively few chunks per run
- Next:
  - More investigation into these oscillating channels
  - Compare against HF(38, 21, 1) (non-oscillating)

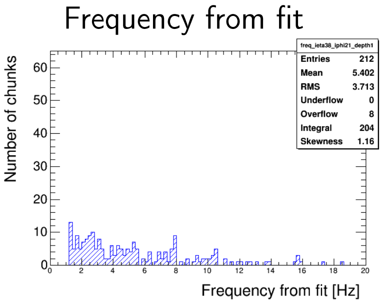
Results: $\langle\chi\rangle$ for 5-7 Hz hot channels



- HF(40, 23, 1): $\langle\chi\rangle = 21.2$
- HF(38, 25, 1): $\langle\chi\rangle = 17.2$
- HF(40, 23, 2): $\langle\chi\rangle = 7.2$

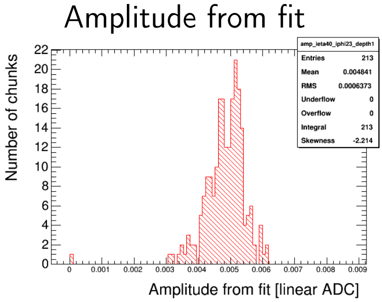
Results: Amplitude and Frequency HF(38, 21, 1)

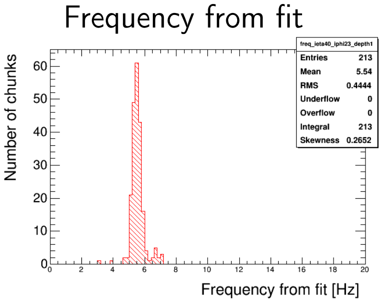




- Non-oscillating channel
- Avg. amplitude $= 0.00038 \pm 0.00020$

Results: Amplitude and Frequency HF(40, 23, 1)

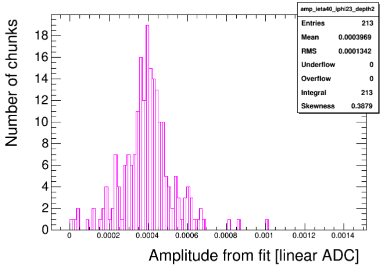




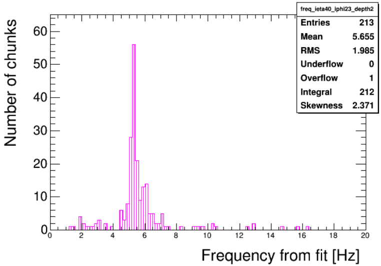
- Oscillating channel
- Avg. amplitude $= 0.00484 \pm 0.00064$
- Avg. frequency $= 5.54 \pm 0.44$

Results: Amplitude and Frequency HF(40, 23, 2)

Amplitude from fit

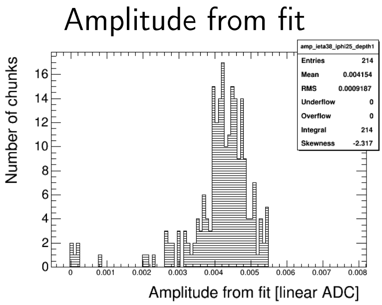


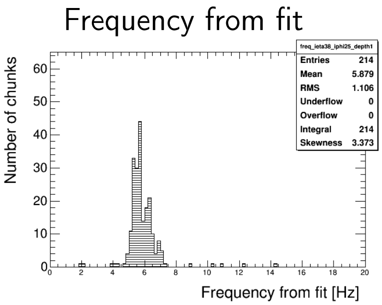
Frequency from fit



- Oscillating channel
- Avg. amplitude $= 0.00040 \pm 0.00013$
- Avg. frequency $= 5.65 \pm 1.99$

Results: Amplitude and Frequency HF(38, 25, 1)





- Oscillating channel
- Avg. amplitude $= 0.00415 \pm 0.00092$
- Avg. frequency $= 5.88 \pm 1.11$

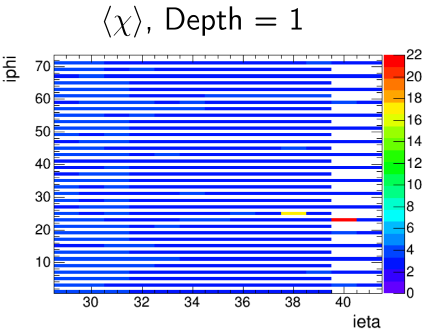
Results: Amplitude and Frequency observations

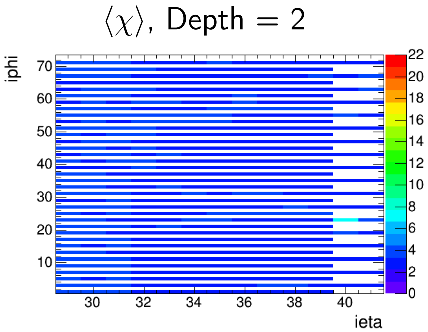
- Avg. amplitudes of oscillating channels vary by an order of magnitude:
  - Avg. amplitude $= 0.00484 \pm 0.00064$ in HF(40, 23, 1)
  - Avg. amplitude $= 0.00040 \pm 0.00013$ in HF(40, 23, 2)
  - Units are linear ADC (y-axis of Viktor's plots)

Conclusions

- Used χ to find oscillating channels
  - Variable determined from FFT + sine-wave fit
- Found two kinds of oscillations:
  - 0-2 Hz, spread in low-ieta channels at specific times
    - Related to movement of the source?
  - 5-7 Hz, mostly from three hot channels at all times:
    - HF(40, 23, 1)
    - HF(40, 23, 2)
    - HF(38, 25, 1)
- 5-7 Hz chunks have widely varying amplitudes:
  - Avg. amplitude $= 0.00484 \pm 0.00064$ in HF(40, 23, 1)
  - Avg. amplitude $= 0.00040 \pm 0.00013$ in HF(40, 23, 2)

Backup: Mean χ





- HF(40, 23, 1): $\langle \sigma / a_1 \rangle = 21.2$
- HF(38, 25, 1): $\langle \sigma / a_1 \rangle = 17.2$
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