PXD Response to Gated Mode

Belle II PXD Workshop, 2019

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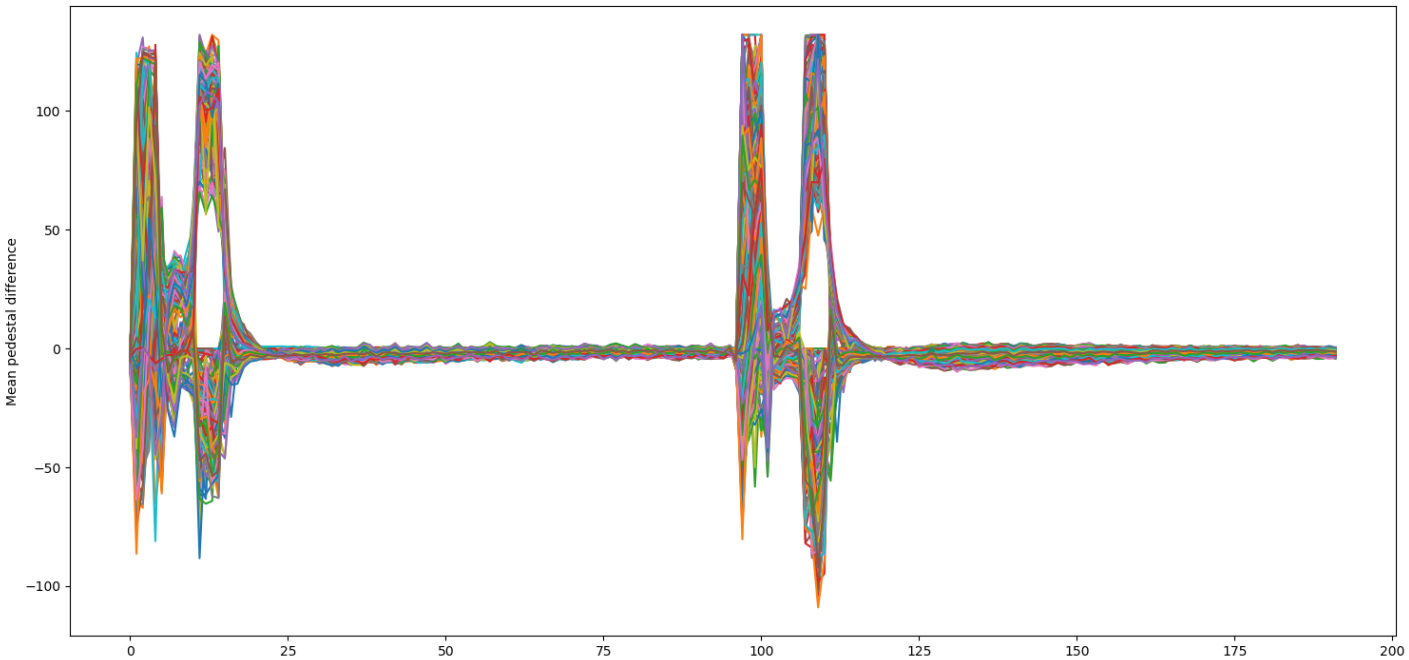
Display of 2 Gated Modes for the First 256 of 1024 Drain Lines

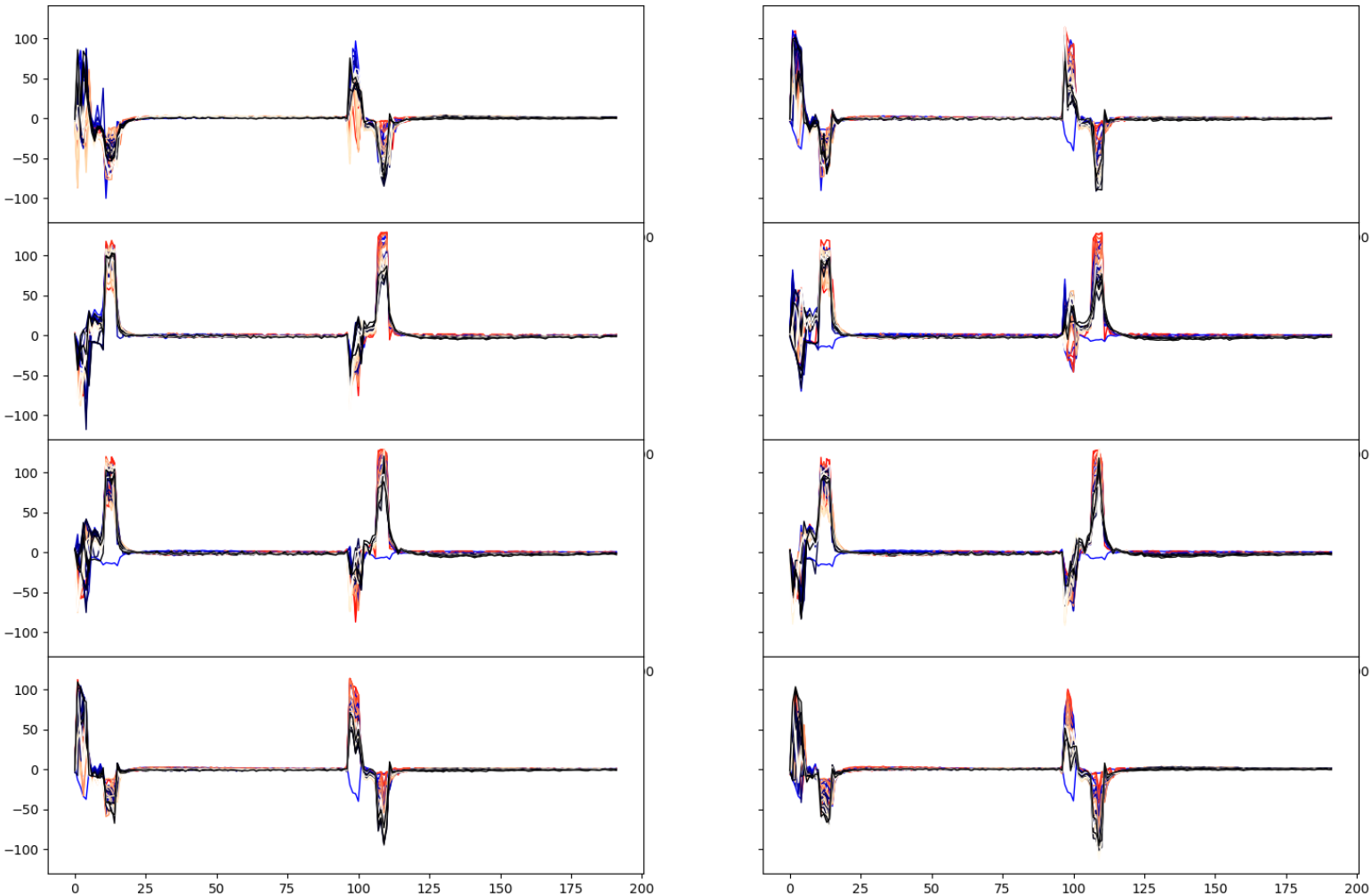
H1011 with clear on 15 V and Common Mode



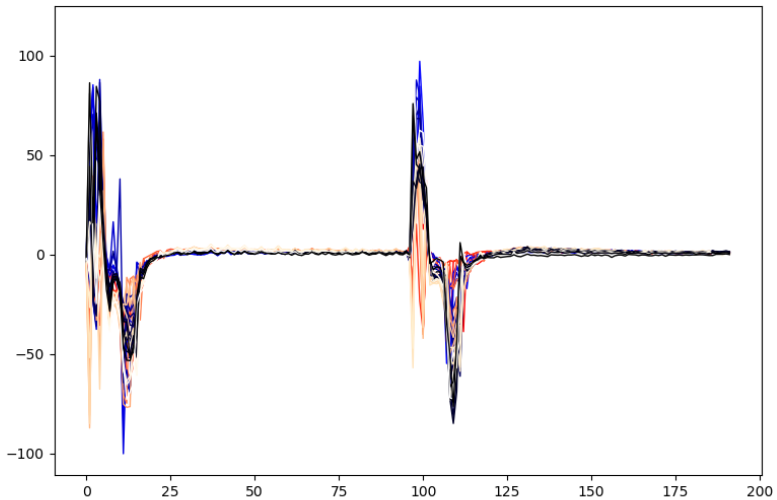
- Drain lines continuously counted starting at 0:
  1st DCD 0-255, 2st DCD 256-511, 3rd DCD 512-767, 4th DCD 768 -1023
- Dead drain lines: 11th to 16th drain line of each DCD:
  10...15, 266...271, 522...527, 778...783

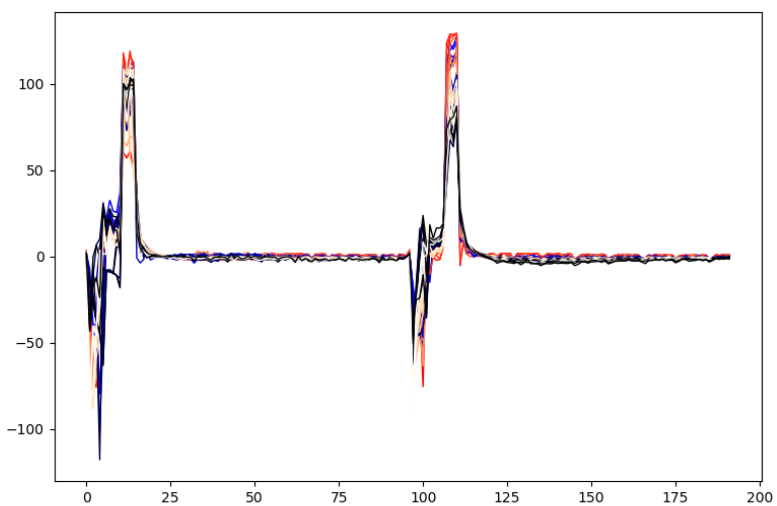
Distribute the Drain Lines in 8 Figures

Every 8th Drain Line in One Plot



GM Response Function





Description of the GM response:

- When there is no effect from GM
- Prediction of the actual GM response

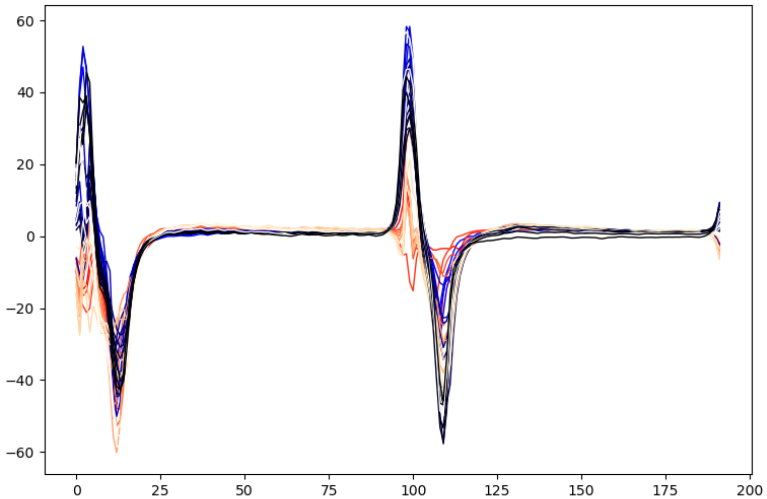
Treated as a time-signal:

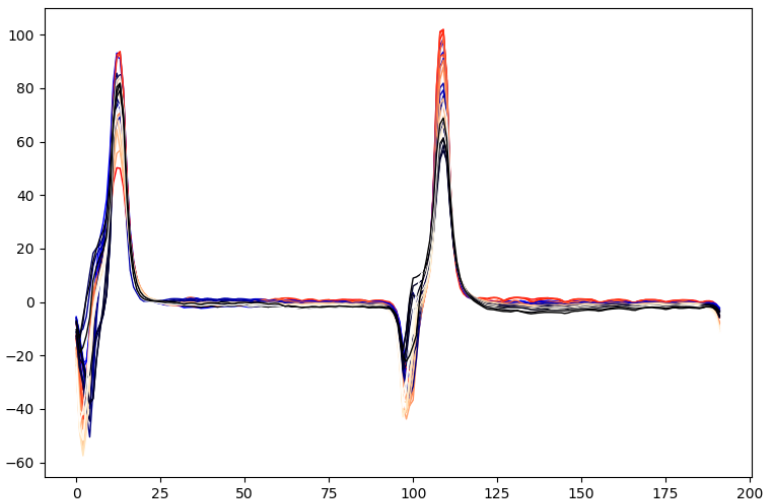
- Very noisy signal $\mathbf{I}(t)$
- Split signal into:

  filtered signal + noise

$$\mathbf{I}(t) = S(t) + N(t)$$

Getting the filtered Signal with a Software Low-Pass Filter





- Switching to FFT $\mathcal{F}$:

$$\mathcal{F}\left[\mathbf{I}\right](\omega) = \underbrace{f(\omega) \cdot \mathcal{F}\left[\mathbf{I}\right](\omega)}_{\mathcal{F}[S](\omega)} + \underbrace{(1 - f(\omega)) \cdot \mathcal{F}\left[\mathbf{I}\right](\omega)}_{\mathcal{F}[N](\omega)}$$

- Applying the Low-Pass Filter:

$$f(\omega) = \frac{1}{1 + \mathrm{i} \cdot \frac{\omega}{\omega_0}}$$

$$\omega_0 = 0.25 \cdot \omega_{\mathrm{max}}$$

- Retrieve filtered Signal and Noise:

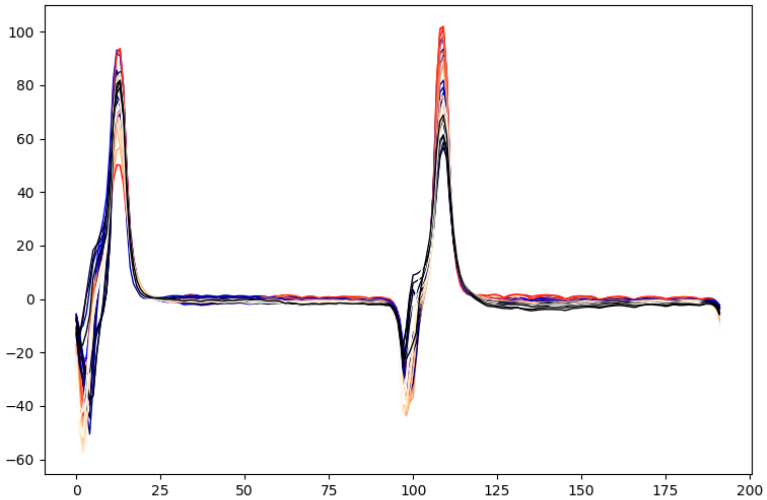
$$S(t) = \mathcal{F}^{-1}[\mathcal{F}[S]](t)$$

$$N(t) = \mathcal{F}^{-1}[\mathcal{F}[N]](t)$$

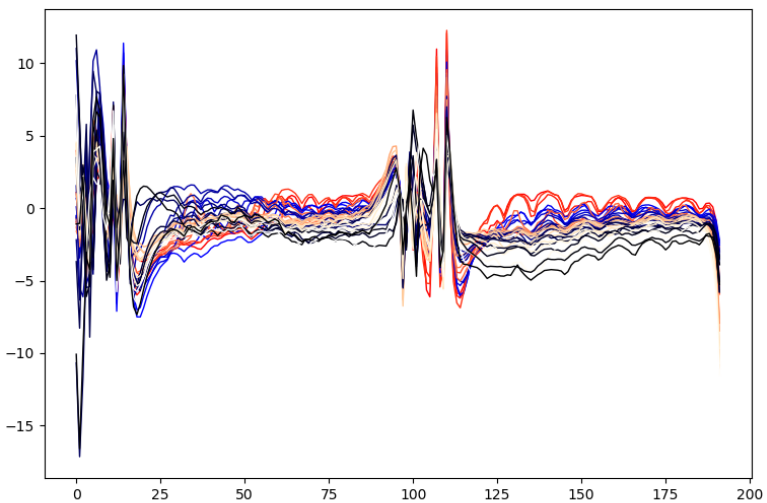
- Filtered Signal shown on the right

Describing the filtered Signal with 2×2 Cauchy distribution

Signal:



Fit residuals:



- Splitting according to the 2 GMs:

$$S(t) \rightarrow \begin{cases} S_1 & 0 \leq t < 0.25 \cdot t_{\text{max}} \\ S_2 & 0.25 \cdot t_{\text{max}} \leq t < 0.75 \cdot t_{\text{max}} \\ S_{\text{rest}} & \text{else} \end{cases}$$

- Using a Cauchy distribution

$$\mathcal{C}\left(A, t, t_0, \Delta t\right) = \frac{A}{1 + \left(\frac{t - t_0}{\Delta t}\right)^2}$$

- Each $S_i(t)$ fitted with 2 distributions:

$$S_i(t) = \mathcal{C}\left(A_1, t, t_1, \Delta t_1\right) + \mathcal{C}\left(A_2, t, t_2, \Delta t_2\right)$$

- Sensitivity to initial fit values
  - If initial values too far off $\rightarrow$ Fit fails

$\Rightarrow$ Provides good results but not very robust

Main GM Response Function

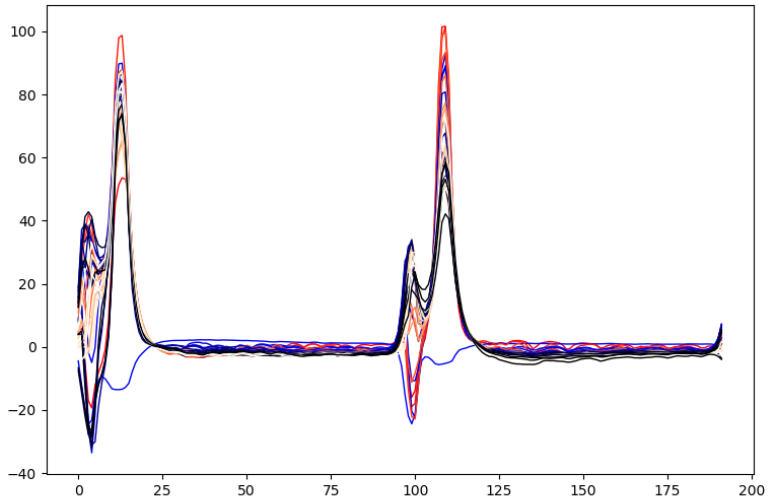
- The main GM response is in good agreement with two Cauchy functions
- Results shown for the first DCD of H1011
  - The remaining DCD are also in good agreement with two Cauchy functions
  - An identical behavior if the drain lines are shifted by -2 mod 8 for each DCD

e.g. comparing the 3rd drain line of the 1st DCD with the 1st of the 2nd DCD and so forth

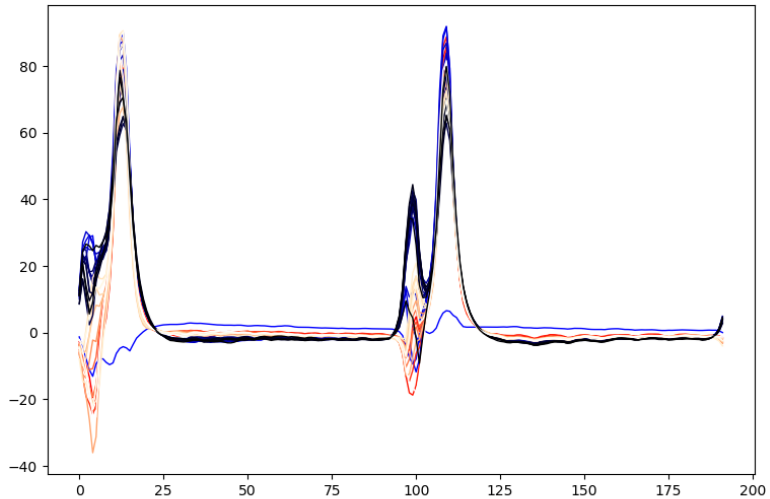
- A similar behavior is also achieved for H1021

Origin Same-Sign Peaks

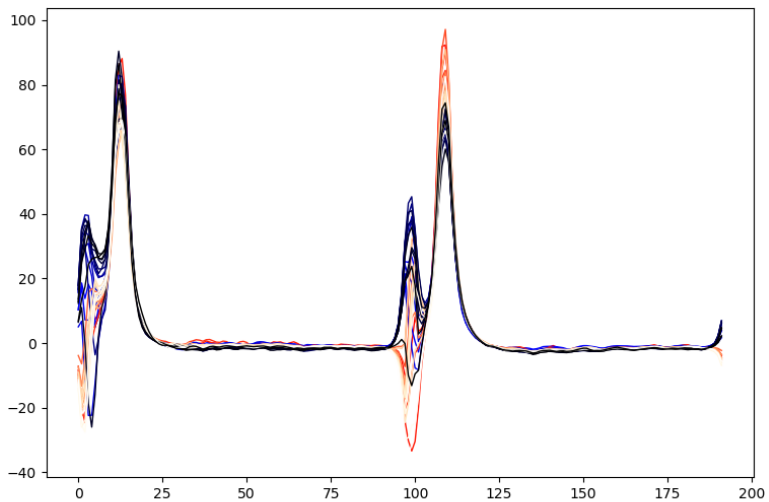
Channel: $5, 13, 21, \ldots, 253$



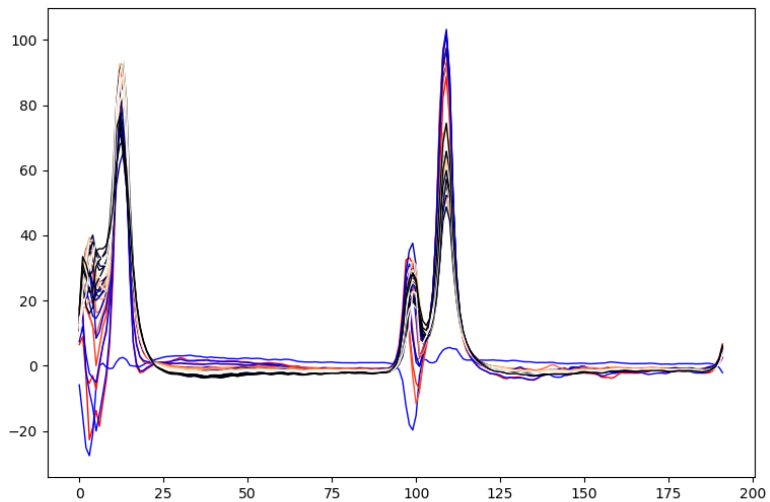
Channel: $259, 267, 275, \ldots, 507$



Channel: $513, 521, 529, \ldots, 761$



Channel: $775, 783, 791, \ldots, 1023$

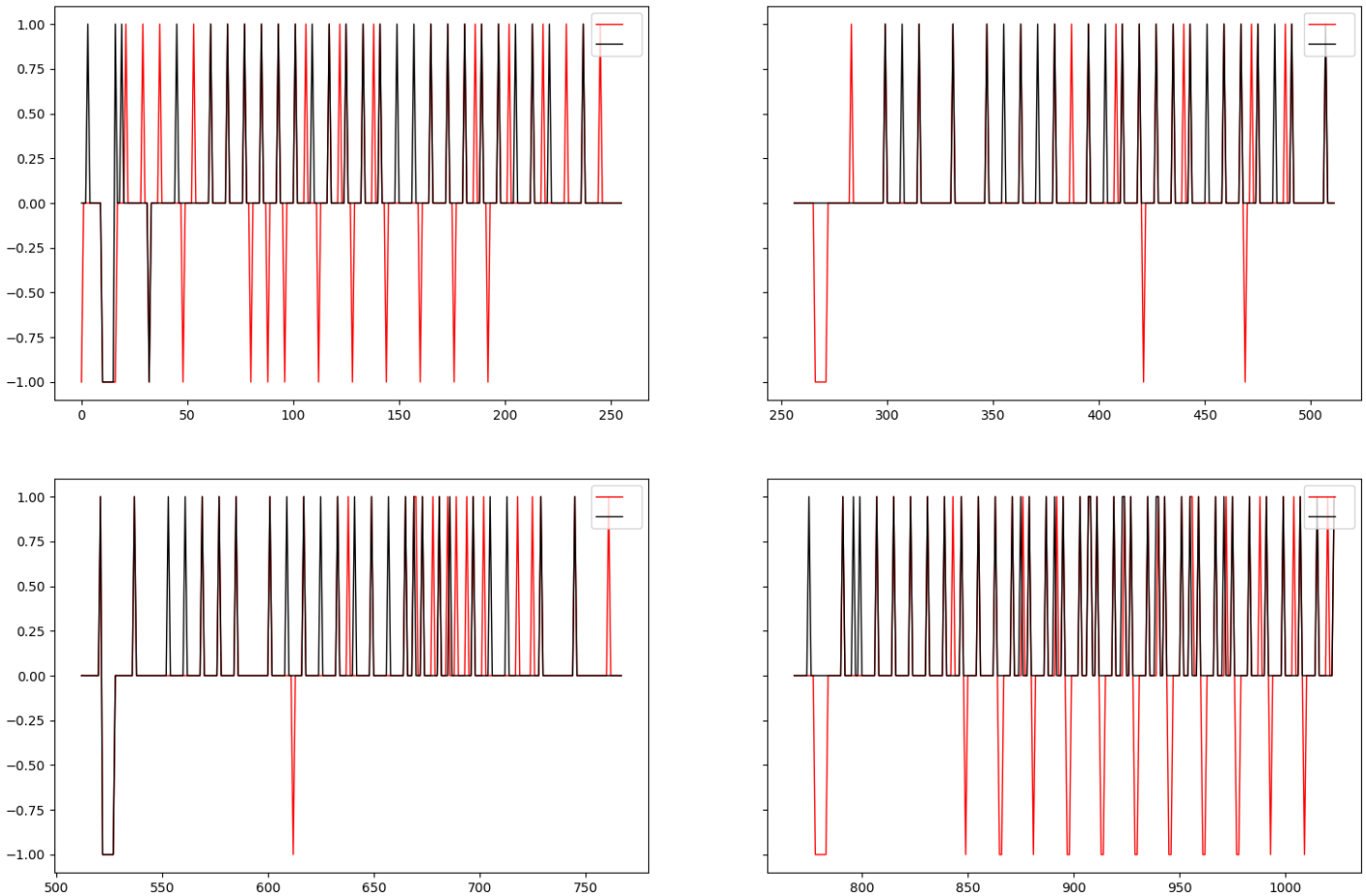


Origin of the Same-Sign Peaks

There are 2 effects:

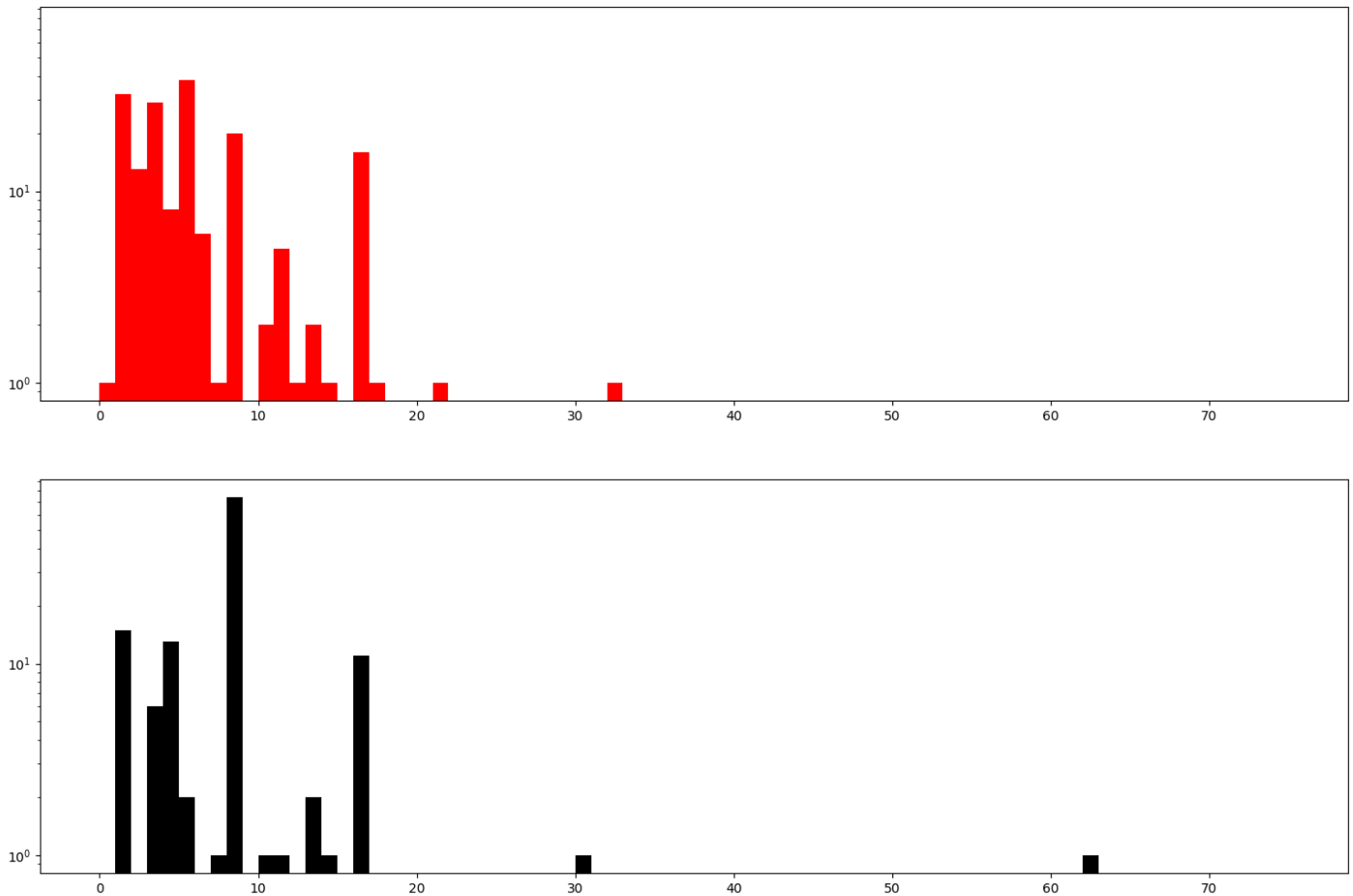
1. The Fit cannot find a good resonance $\rightarrow$ artificial same-sign peaks
   - There is no clear resonance in the channel
   - No clear resonance at the first line
2. There are actual tow resonances with Same-Sign Peaks
   - Why does this appear?
   - At which channels does this appear?

Channel with Same-Sign Peaks

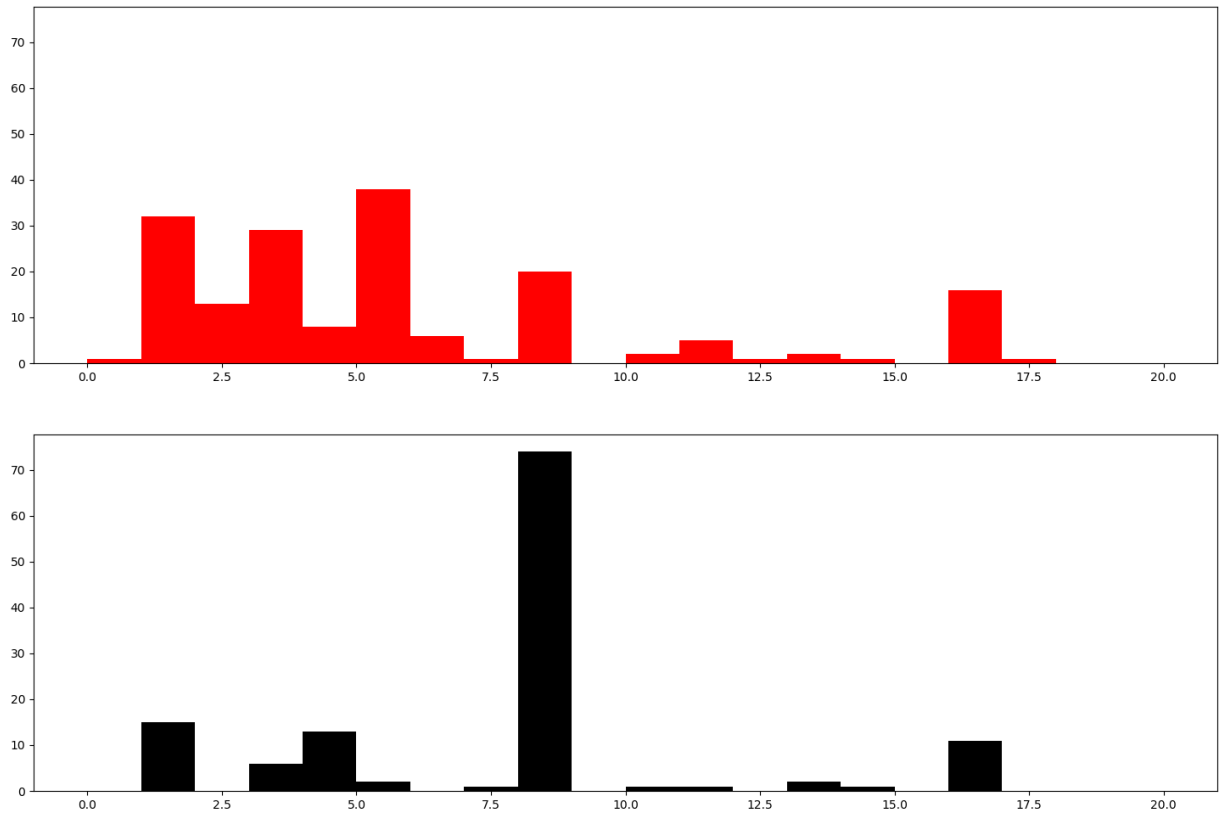


- Red peaks for first gated mode, **black** peaks for second gated mode
- $+1$: both peaks positive, -1 both peaks negative

Distance to Neighboring Channels with Same-Sign Peaks

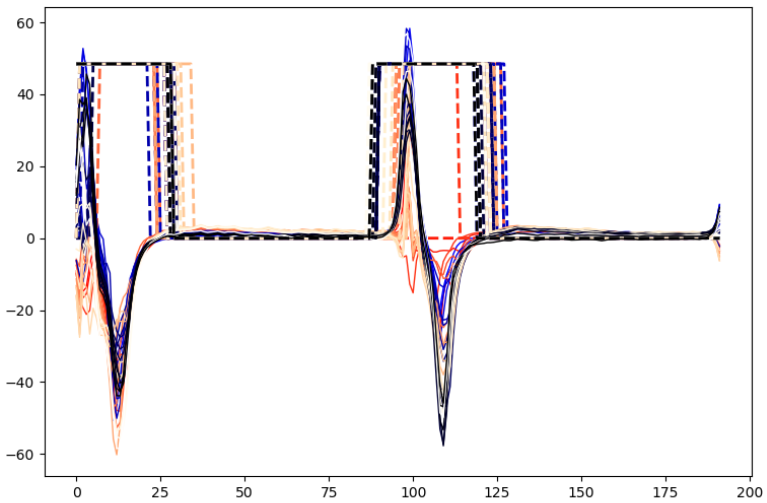


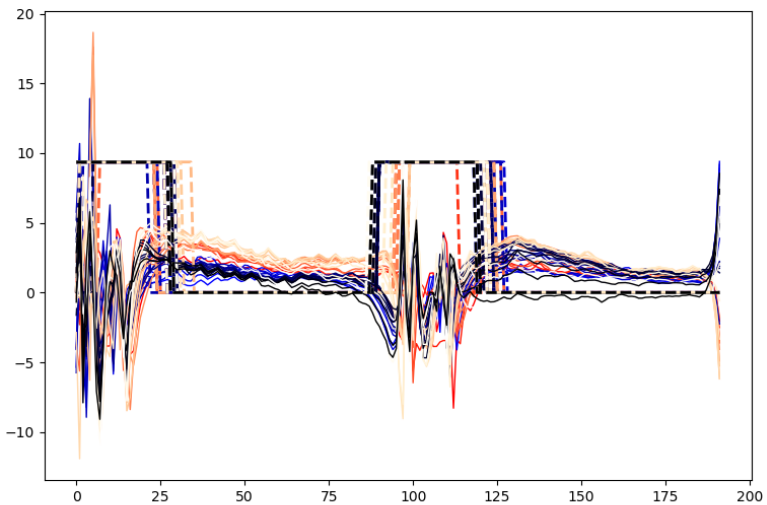
Distance to Neighboring Channels with Same-Sign Peaks (Detail)



- In principle: every 8th channel $\rightarrow$ every 2nd column in every 4th row
- Further studies with different GM start positions

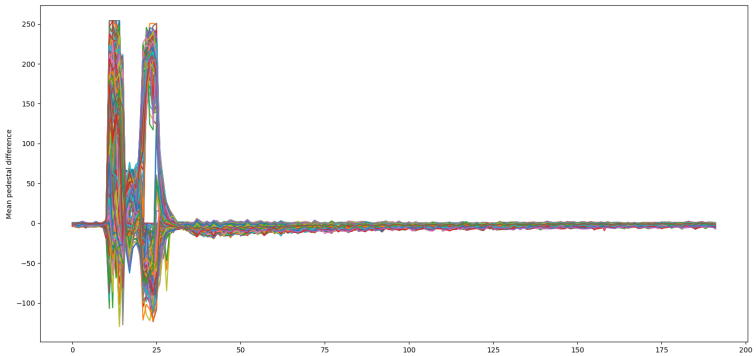
Post-Gated Mode Response

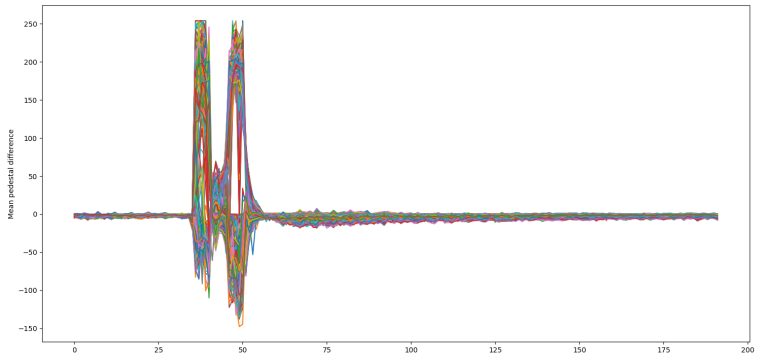


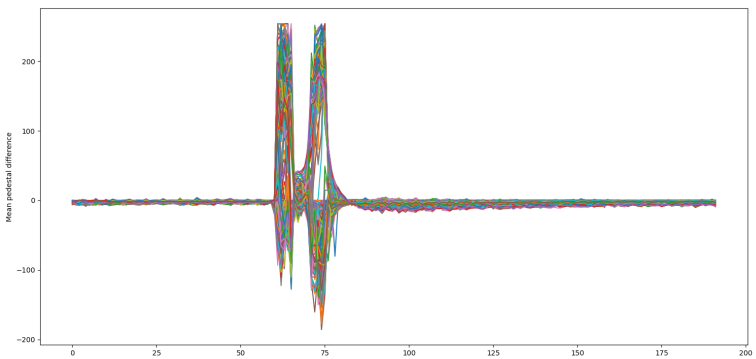


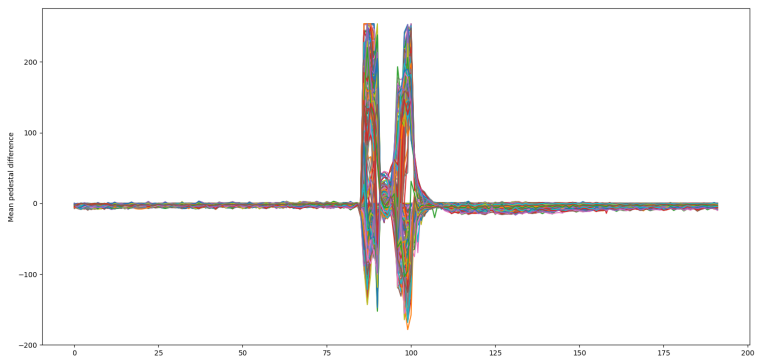
- Behavior after the gate mode
  - How long are the effects visible?
  - Are these effects predictable?
- Occasional 'bump' after signal
  - Disentangle temporal from spacial effects
  - 'Individual' description for each pixel
- GM sweep:
  - Measurements with different GM start positions
  - Extraction of the signal description of the individual pixel

Gated Mode Position



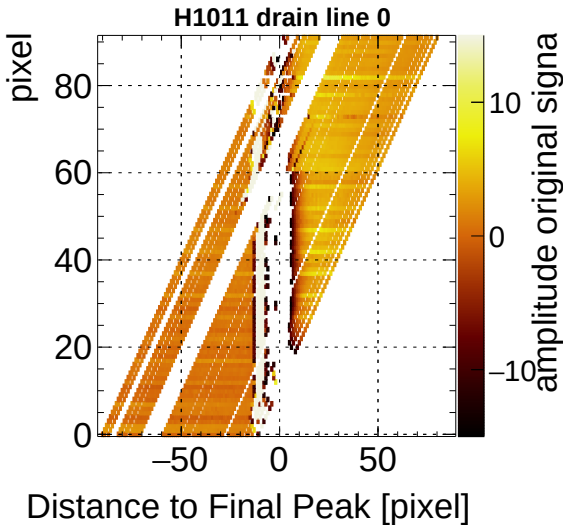


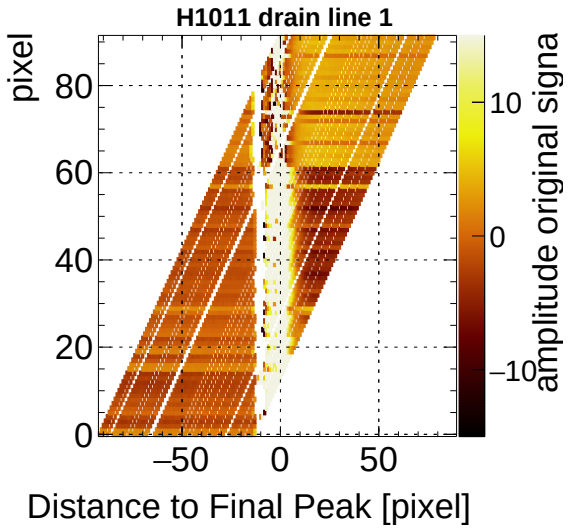


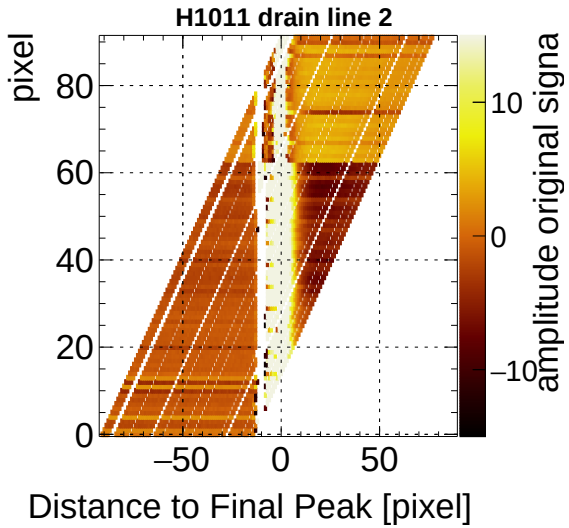


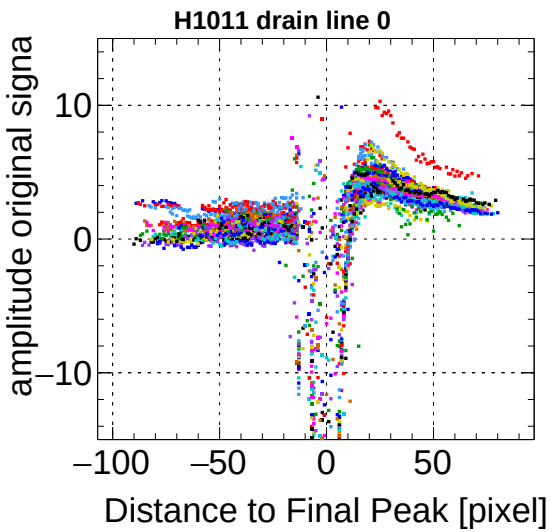
- 192 GM measurements shifted by one line
- Problems in the measurements after 95th shift $\rightarrow$ use only the first 95 for the start
- Try to separate spacial from temporal effects

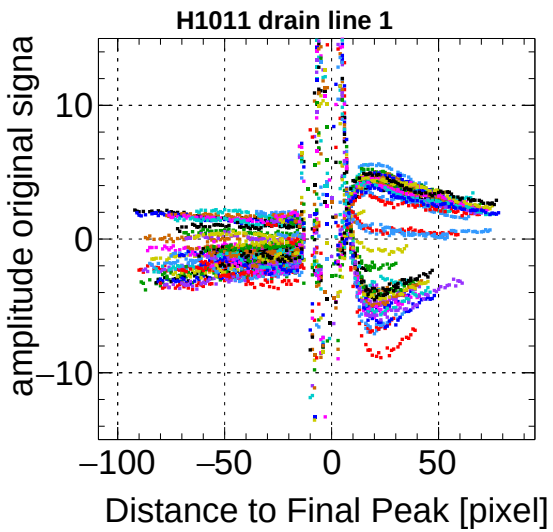
Distance to GM Resonance (H1011)

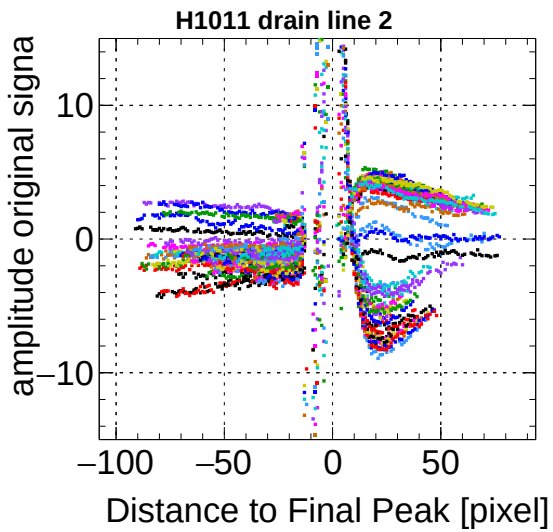




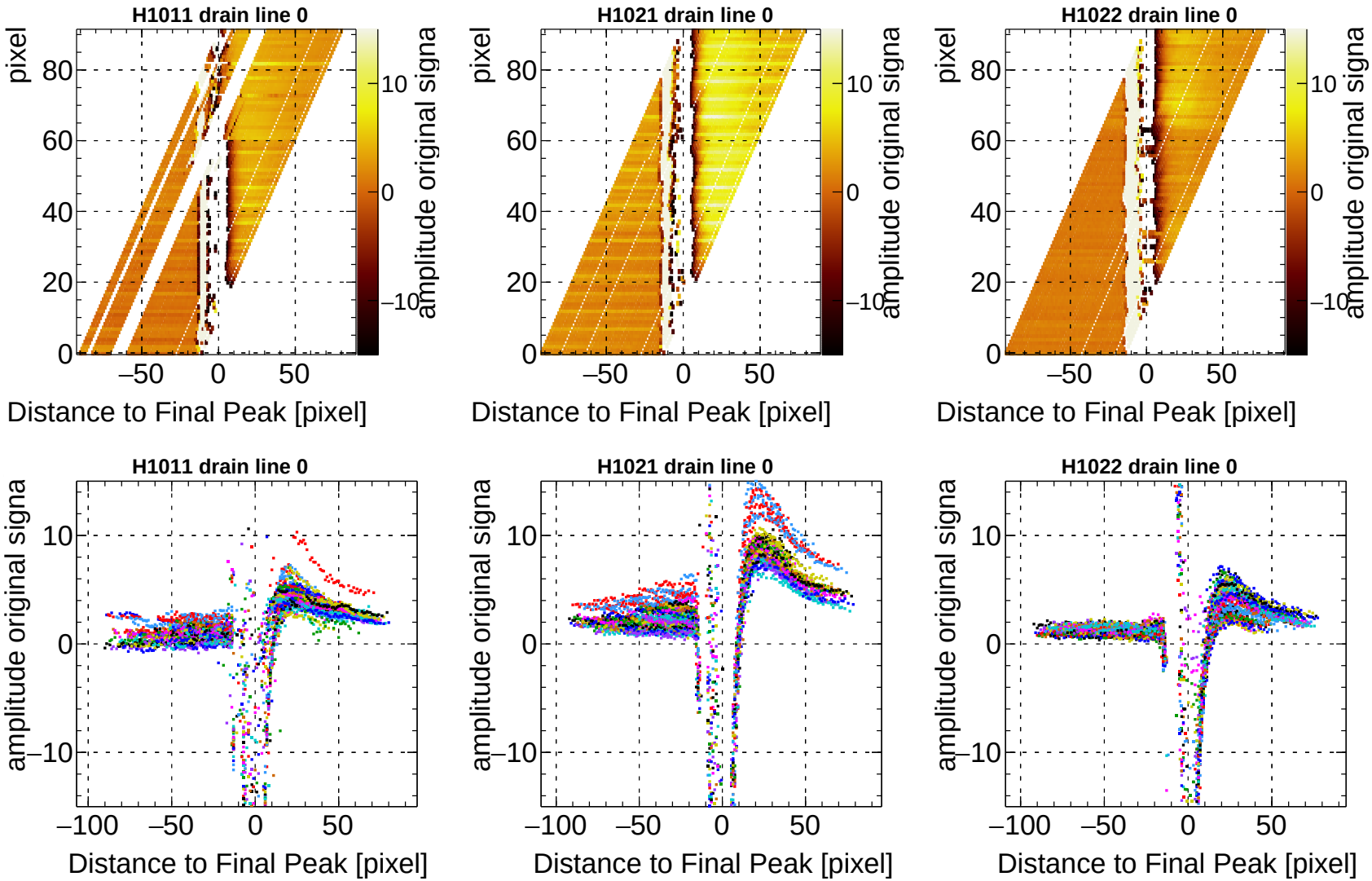




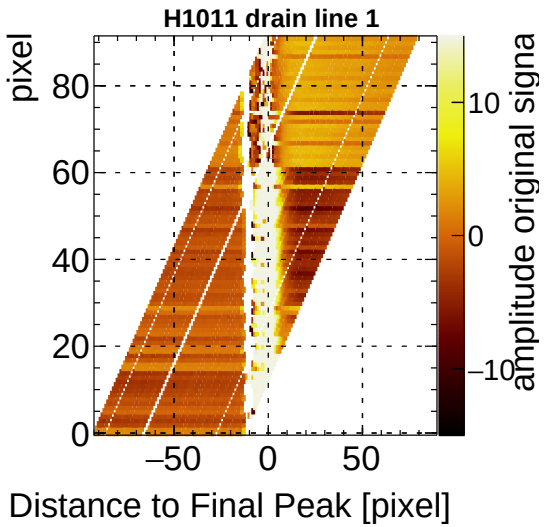


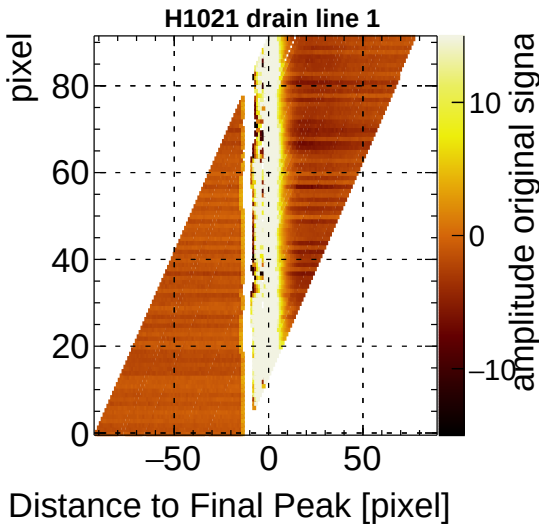


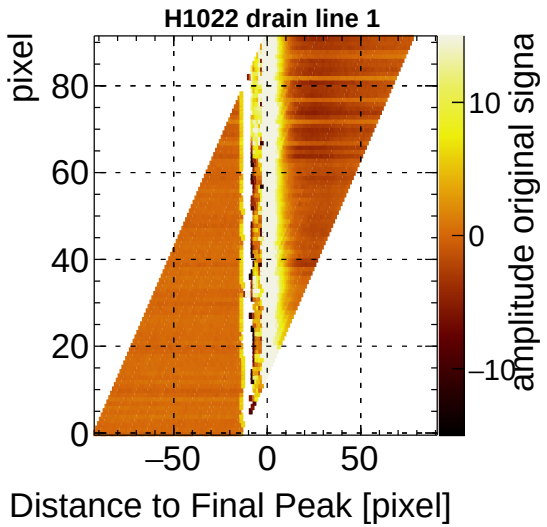
Distance to GM Resonance (Drain Line 0)

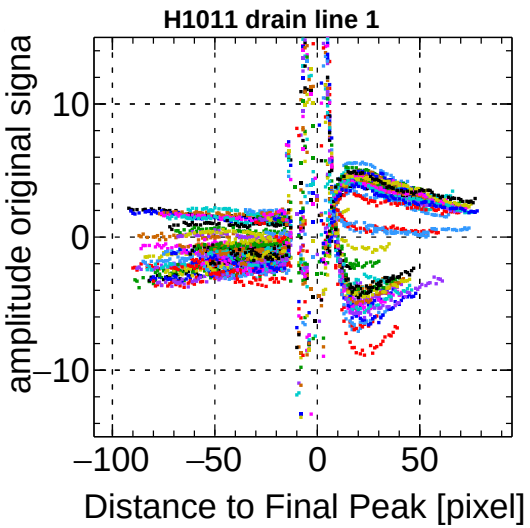


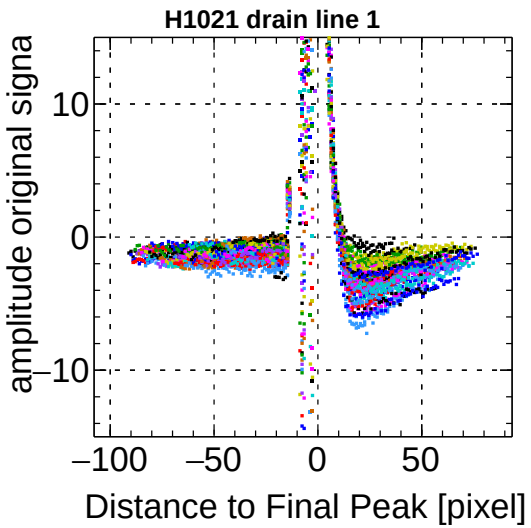
Distance to GM Resonance (Drain Line 1)

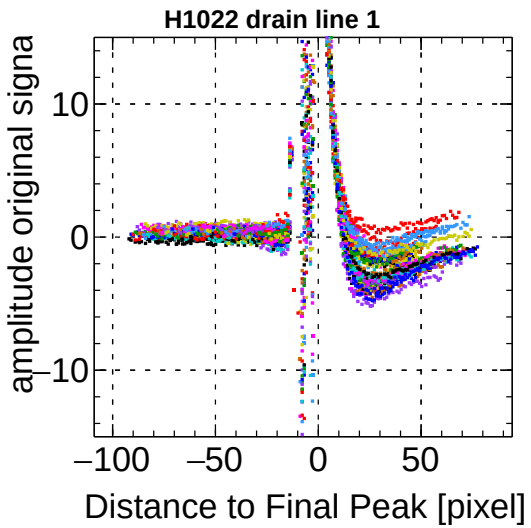












Prediction of Post-Gated Mode Response

- **The Good News:**
  - A clear pattern is visible $\rightarrow$ in principle, it is deterministic, no chaotic fluctuations
  - The pattern is generated via multiple measurements $\rightarrow$ The pattern reproducible

  $\Rightarrow$ It is predictable

- **The Challenge:**
  - Large variety of patterns $\rightarrow$ In the worst chase, each pixel has its own pattern
  - Requirement of some time to disentangle

Outlook

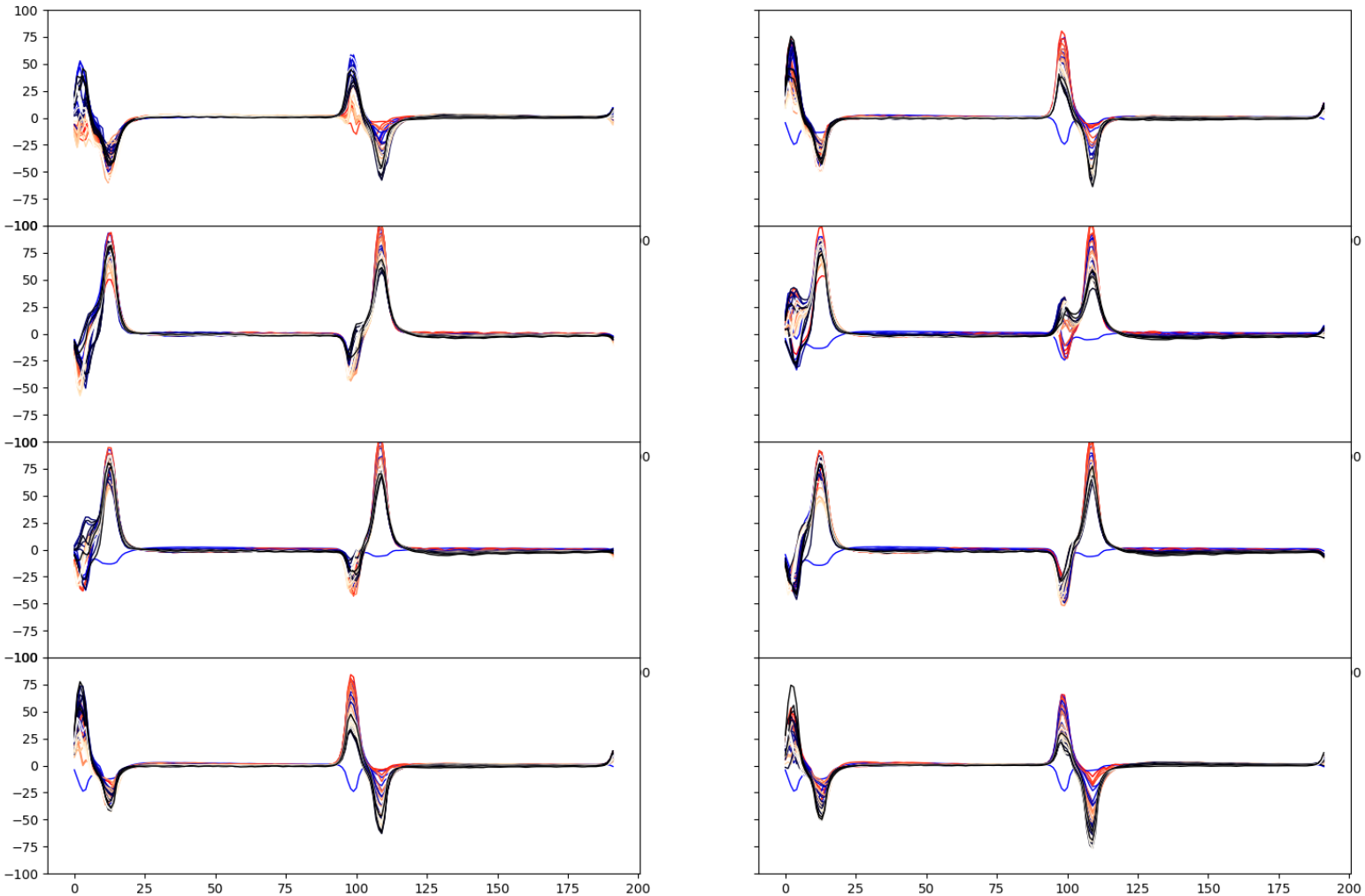
- **Analysis:**
  - Finding the post-gated mode response function for the individual pixel
    - Applying the low-pas filter on the time signal of each pixel
    - Goal: 'common' function with 'individual' parameters
  - Studying the 'common' pixel behavior:
    - Which pixel has the same post-gated mode response patter
    - Origin of same-signed peak structure
- **Measurement:**
  - Repeat the GM sweep with earlier stating and later ending point of the GM position
  - Different length of the GM
  - Continuous GM operation

Conclusion

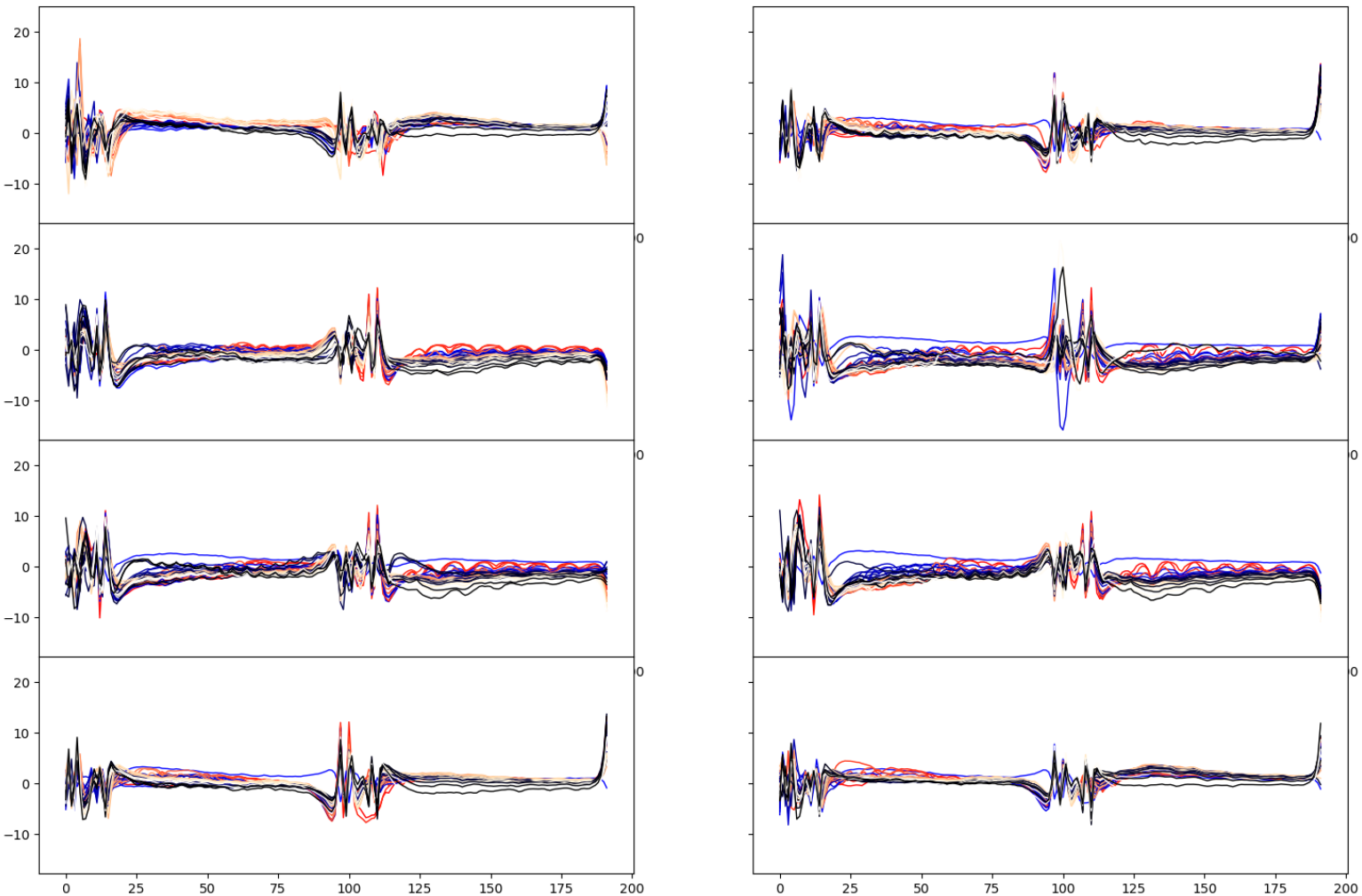
- The main response during gated mode can be well described by 2 Cauchy functions
- The post-gated mode response can be predicted in the future
- Pattern of 'common' behavior quite complex

Backup Slides

Complete Actual Signal

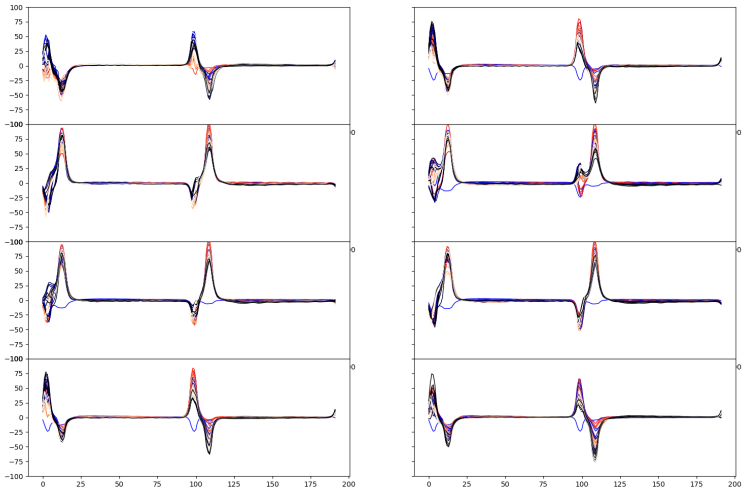


Complete Residuals with Peakfinder

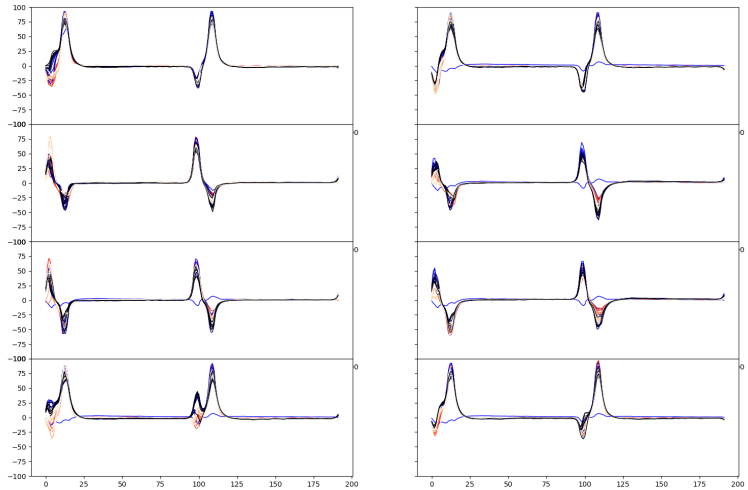


H1011 DCD Comparison

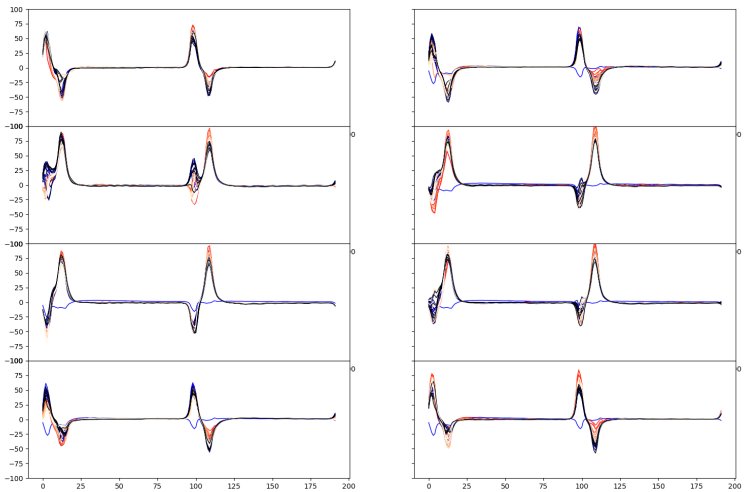
channel 0 to 255



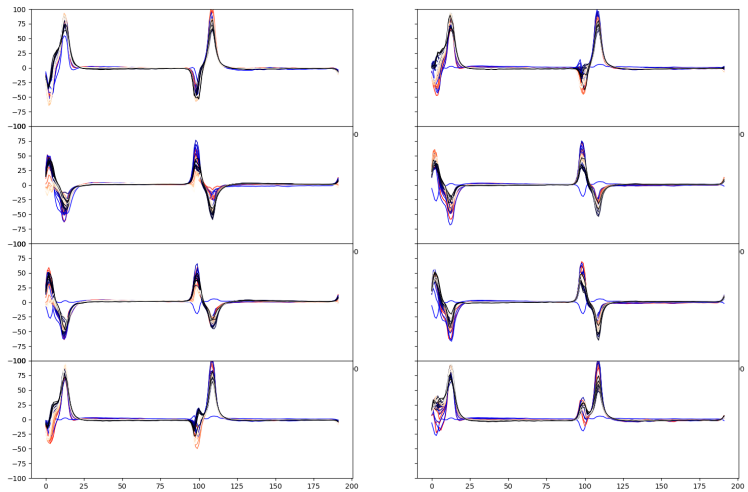
channel 256 to 511



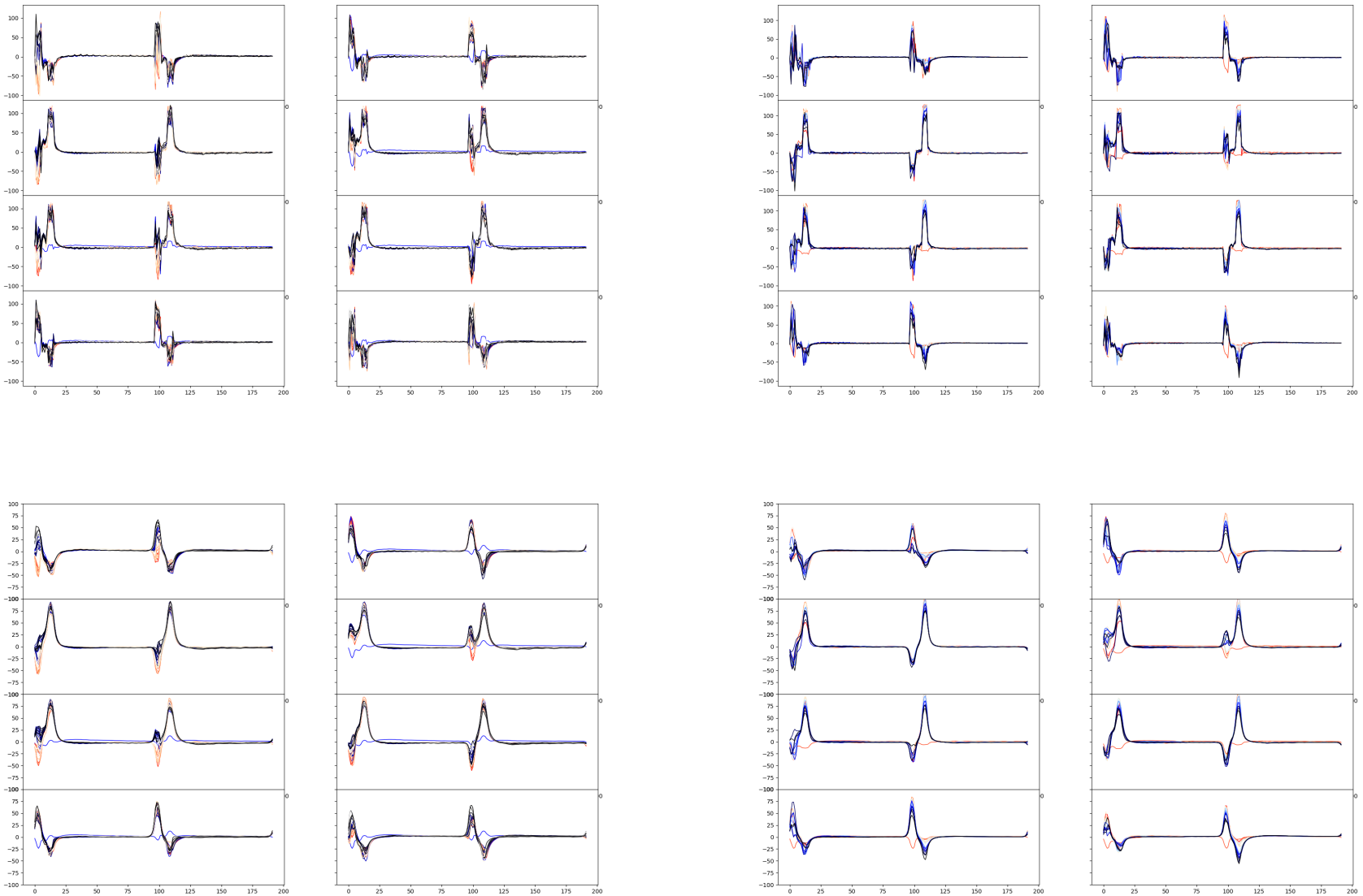
channel 512 to 767



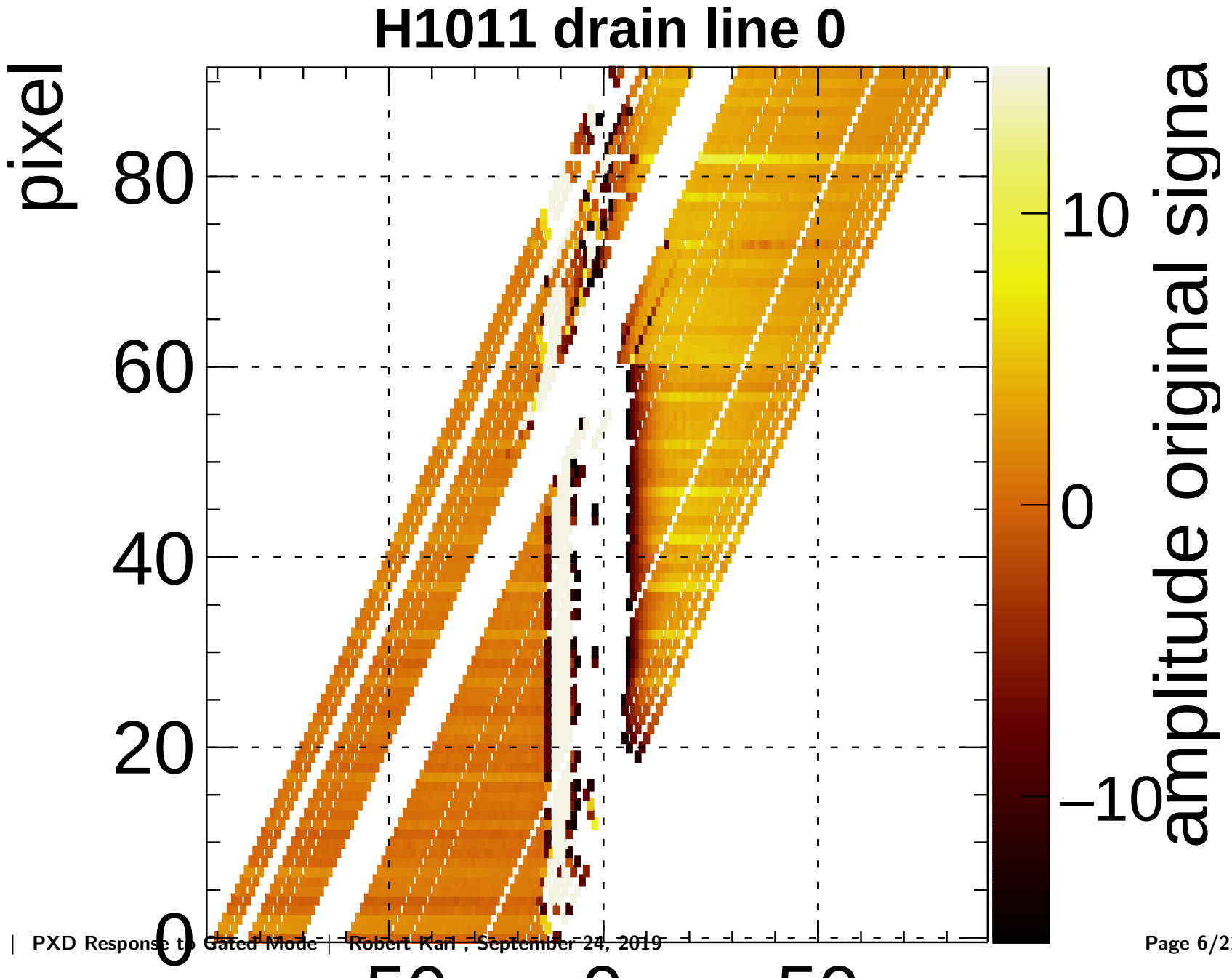
channel 768 to 1023



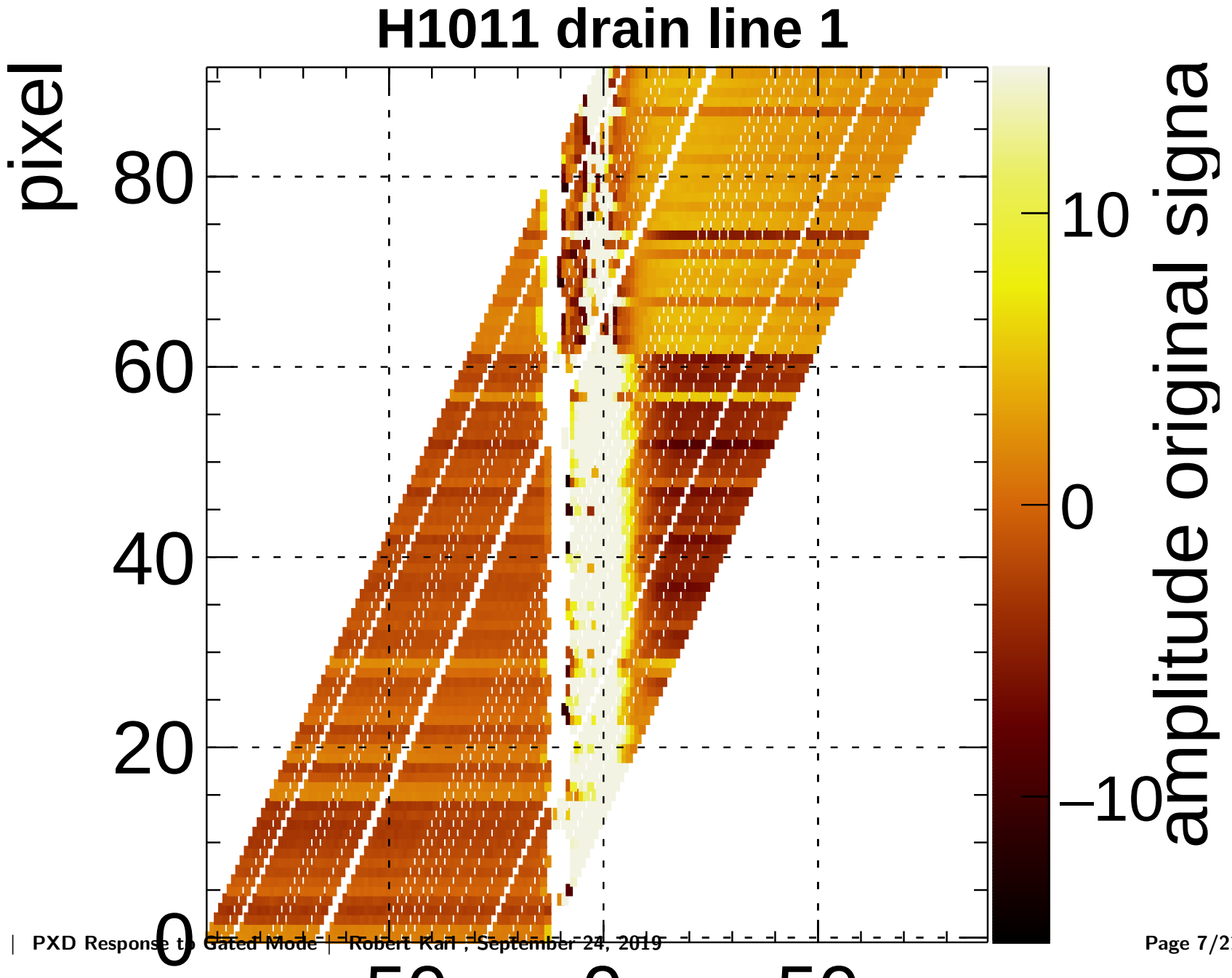
Comparison H1021(*left*) and H1011(*right*)

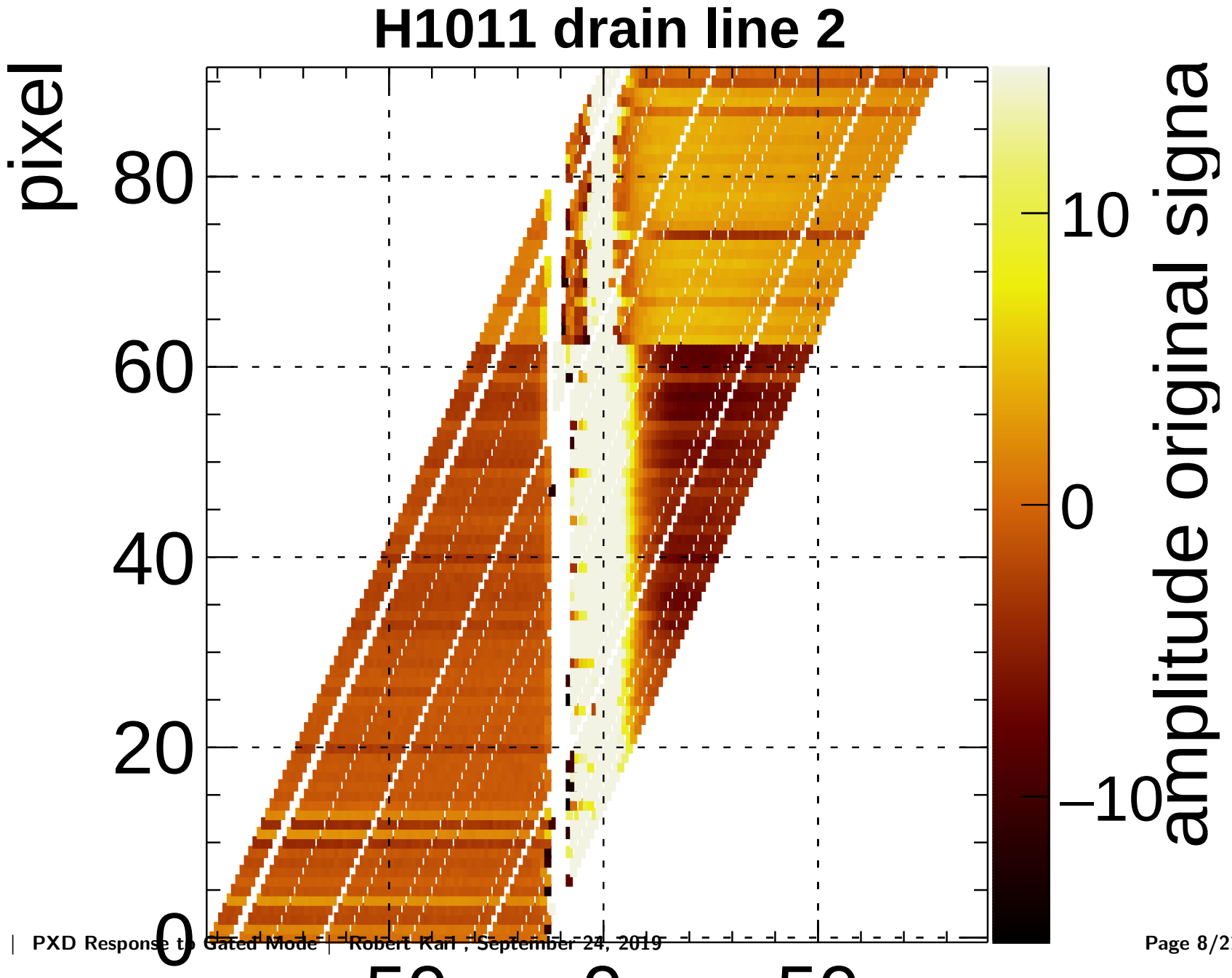


Dist

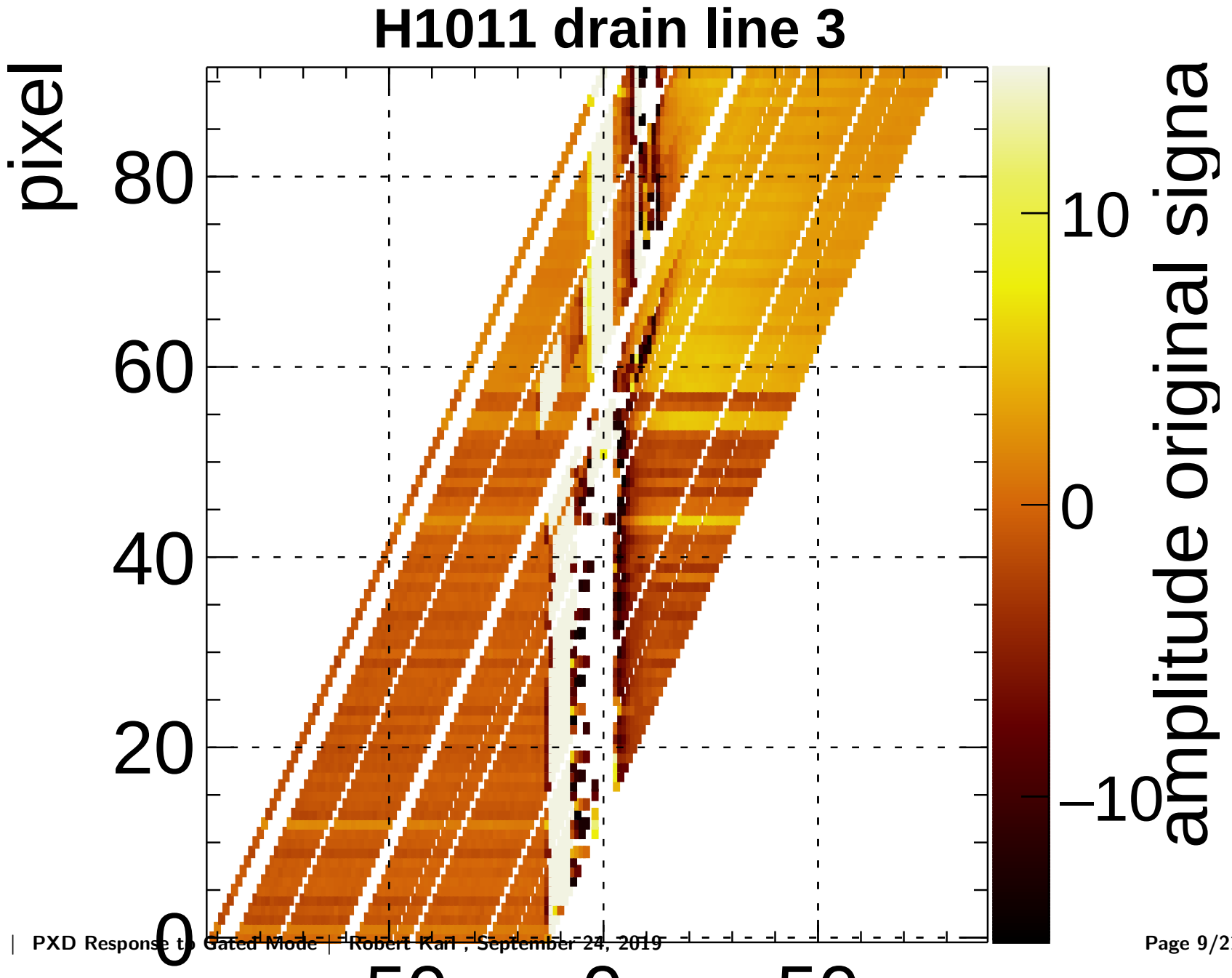

H1011 drain line 0
pixel
0
20
40
60
80
10
0
−10
amplitude original signa

Dist

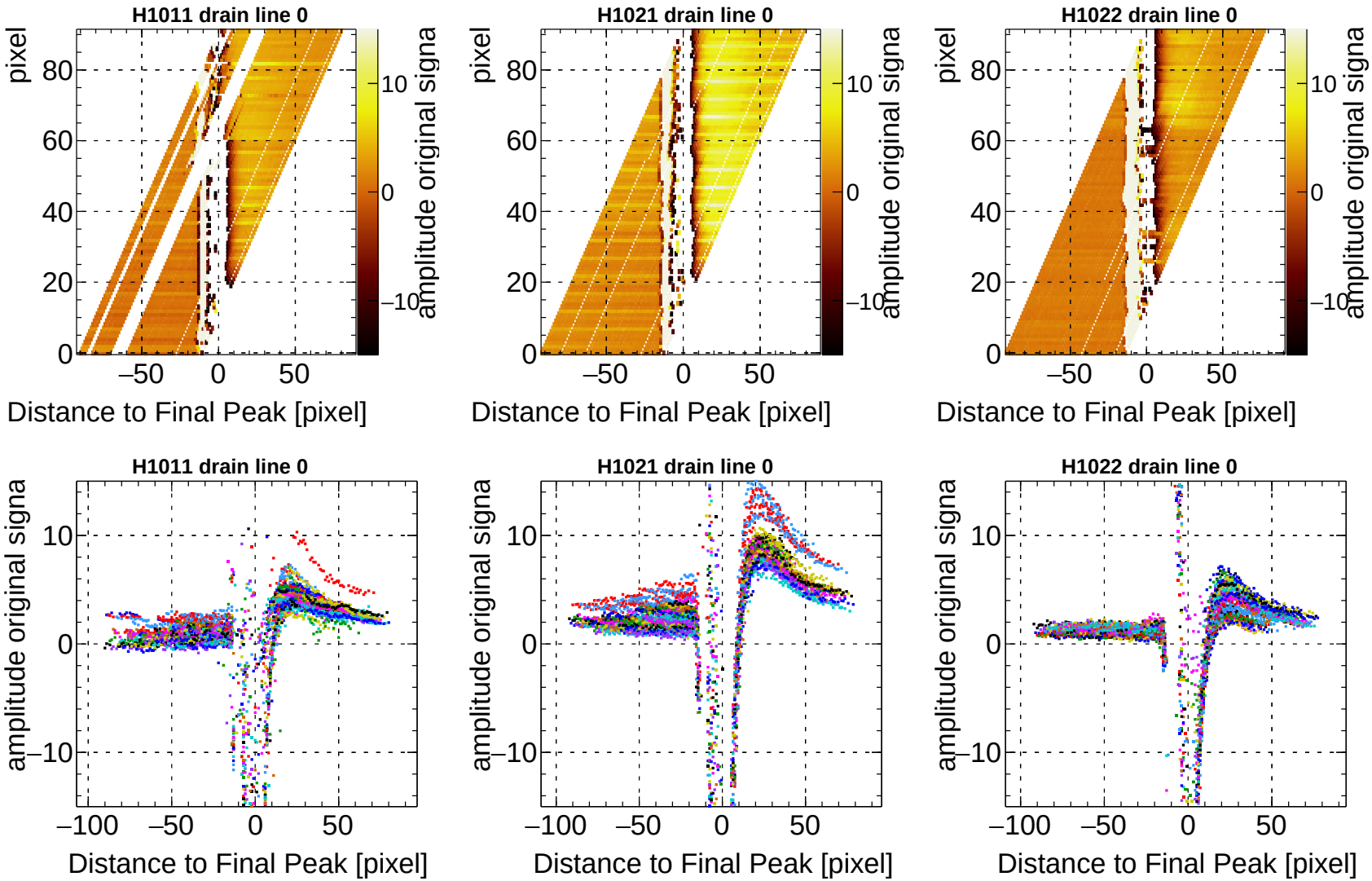

H1011 drain line 1
pixel
0
20
40
60
80
10
0
−10
amplitude original signa


H1011 drain line 2
pixel
0
20
40
60
80
amplitude original signa
10
0
−10

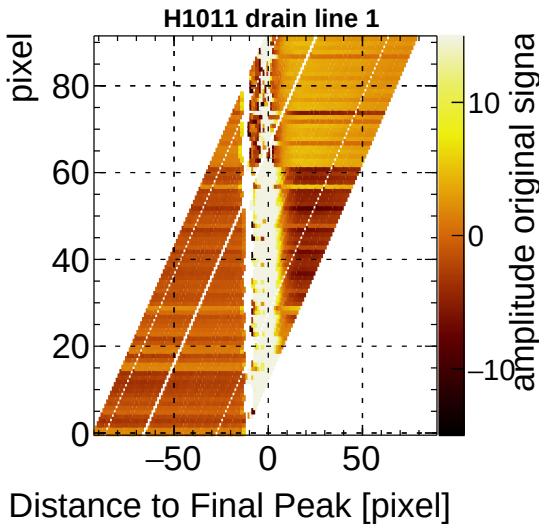
Dist

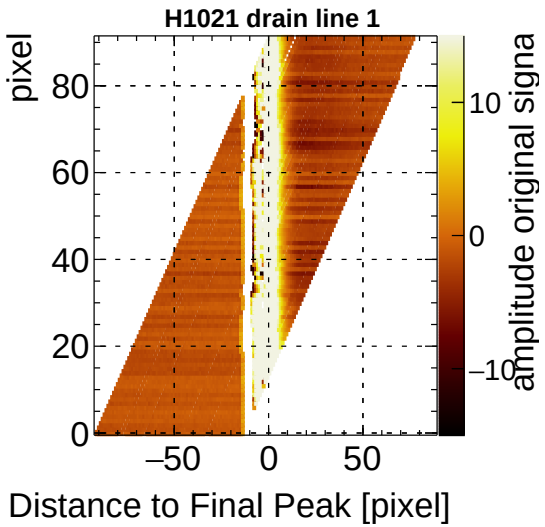

H1011 drain line 3
pixel
0
20
40
60
80
amplitude original signa
10
0
−10

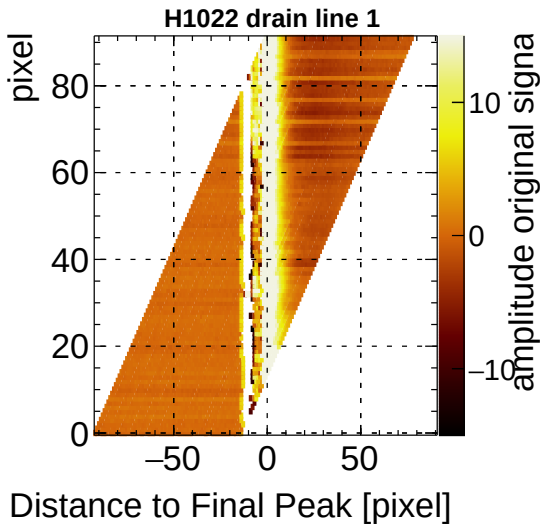
Distance to GM Resonance (Original Signal)

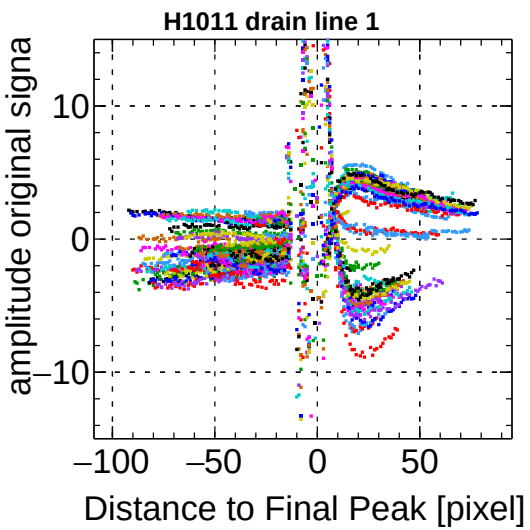


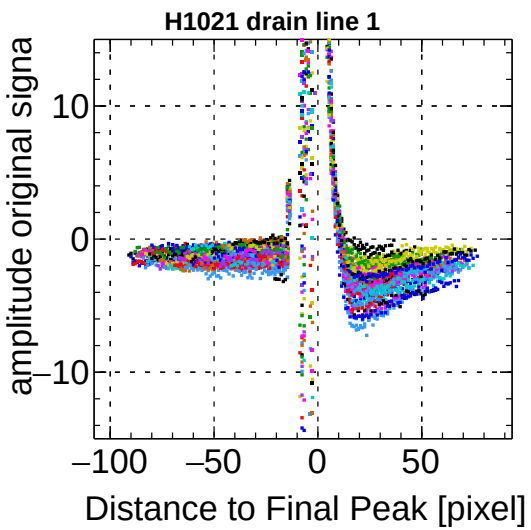
Distance to GM Resonance (Original Signal)

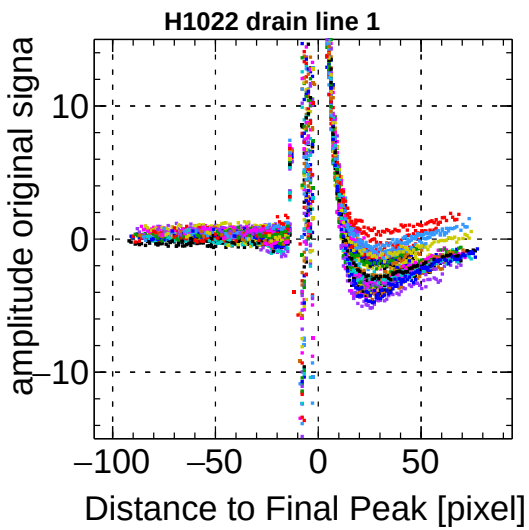




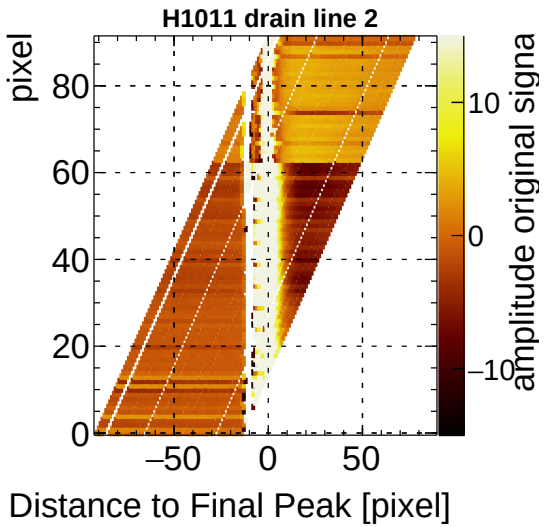


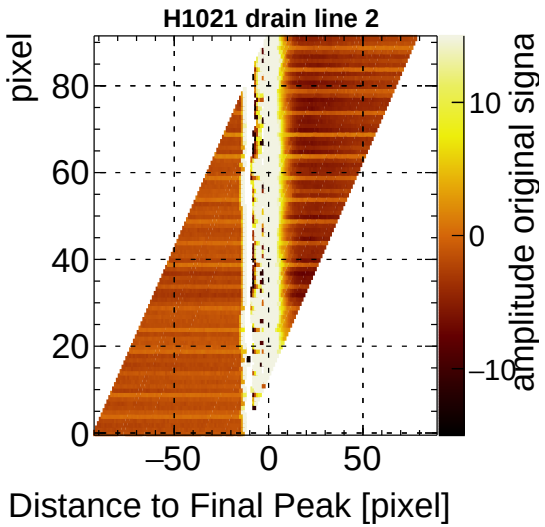


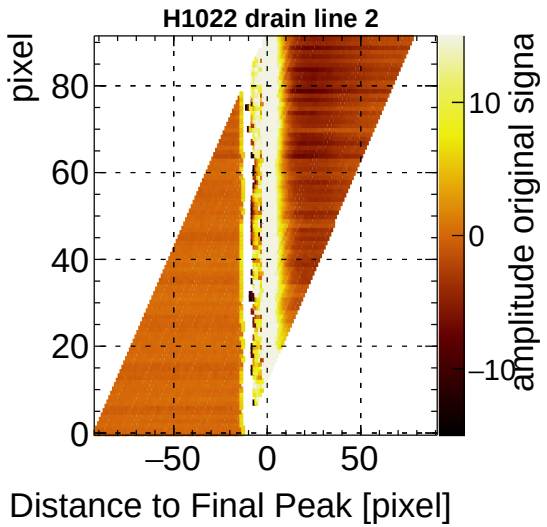


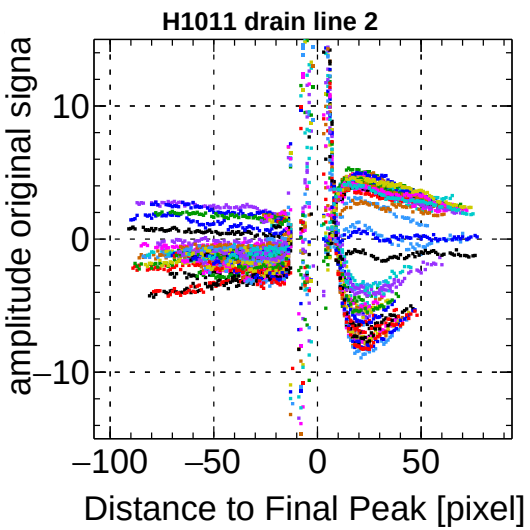


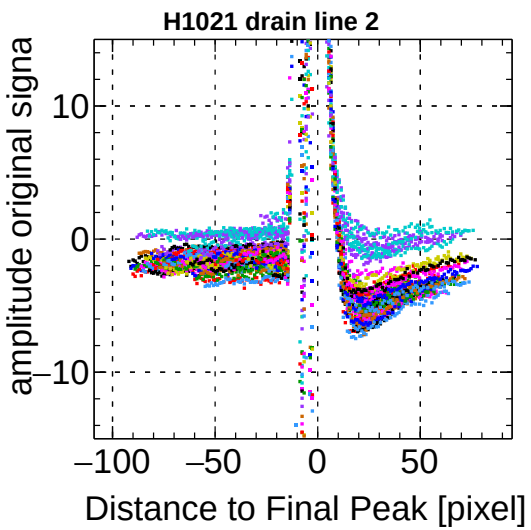
Distance to GM Resonance (Original Signal)

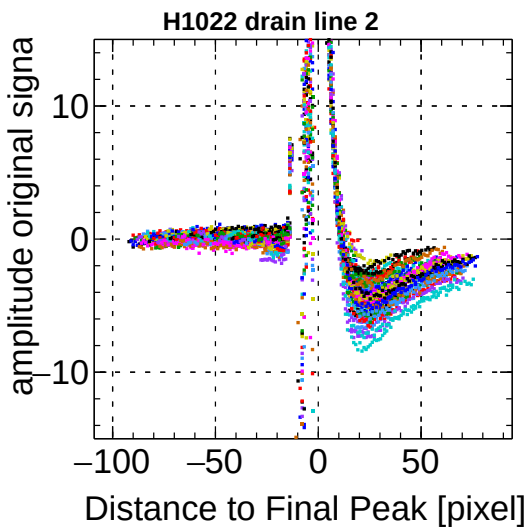




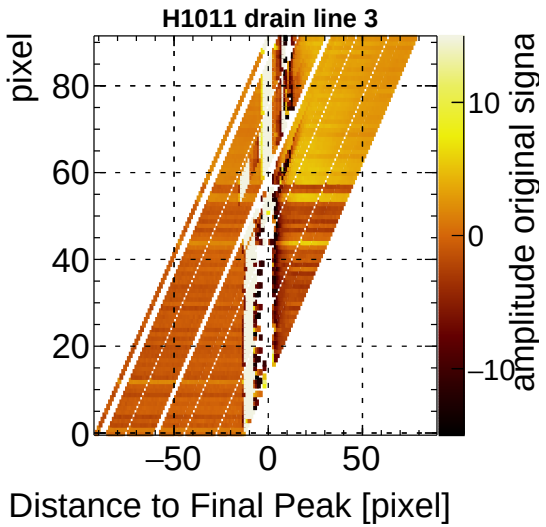


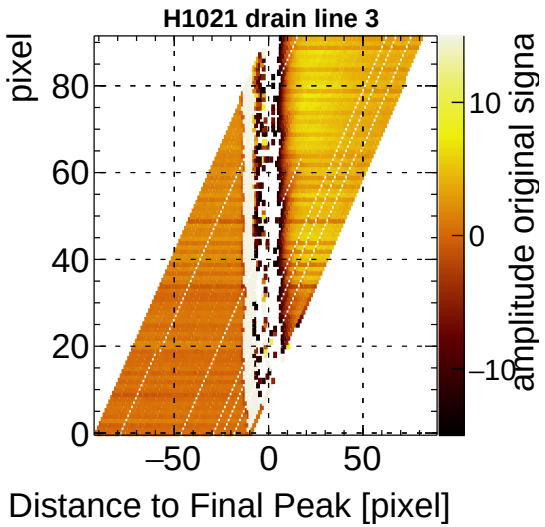


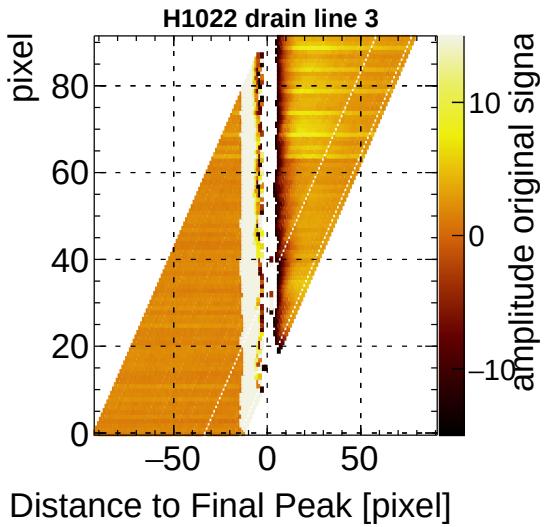


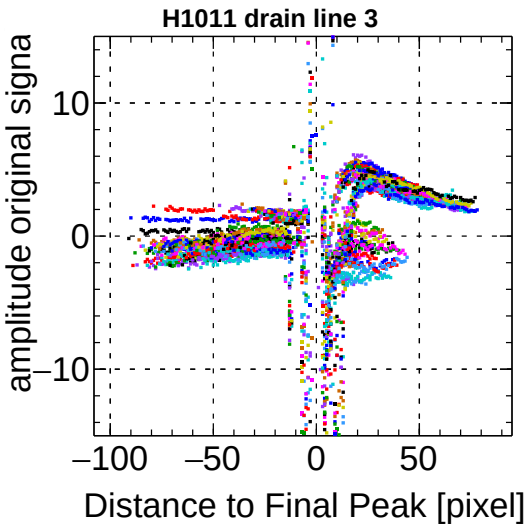


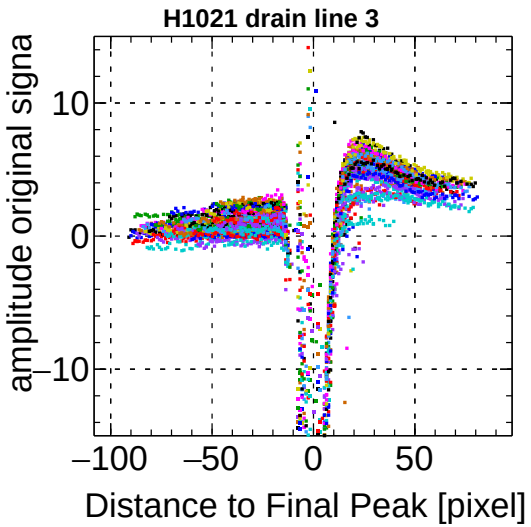
Distance to GM Resonance (Original Signal)

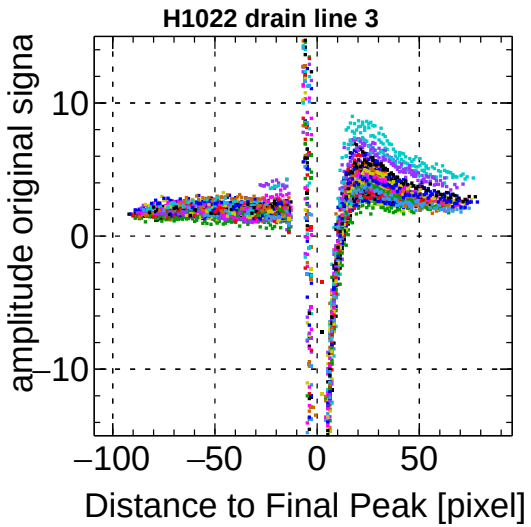




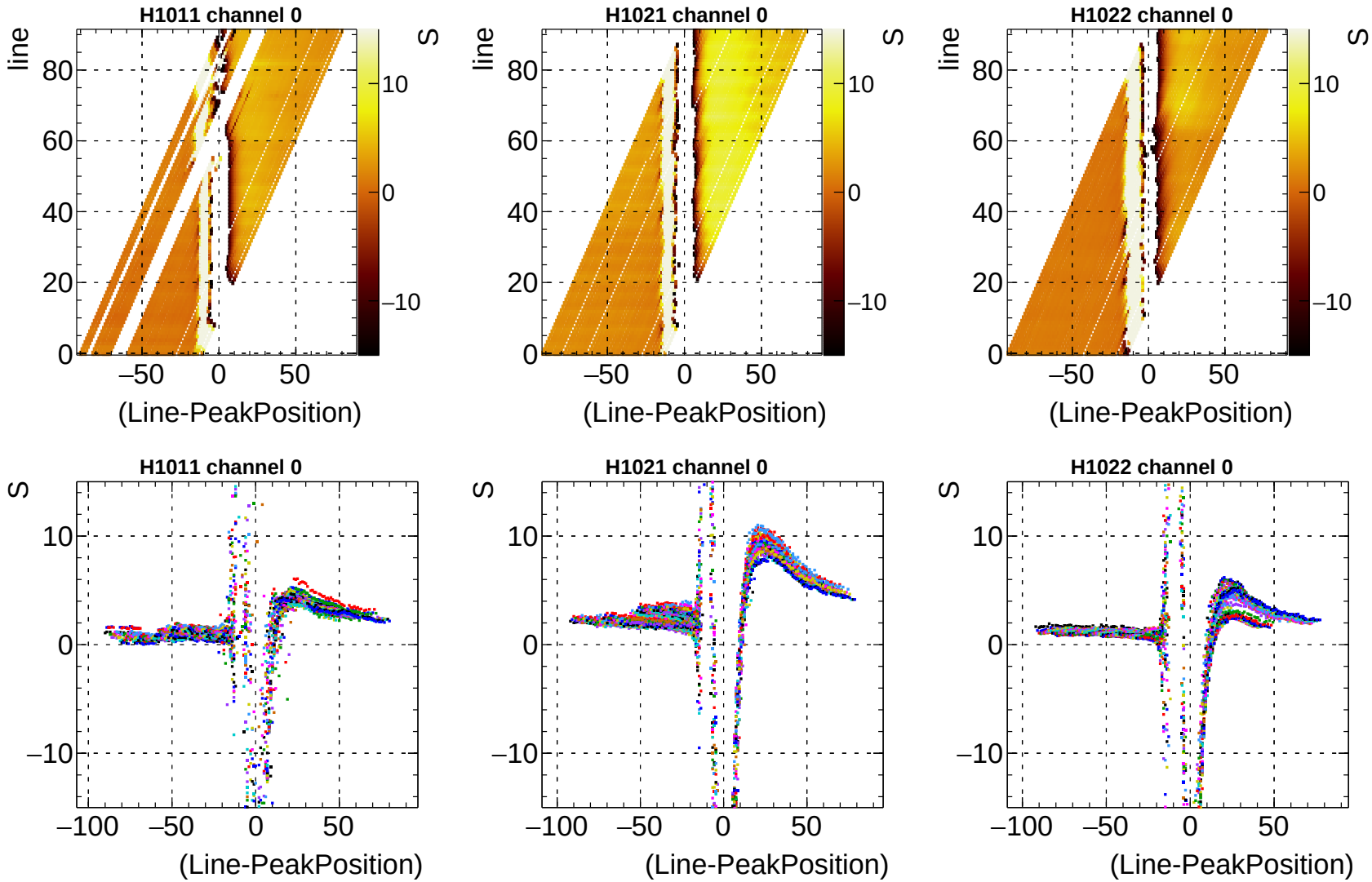




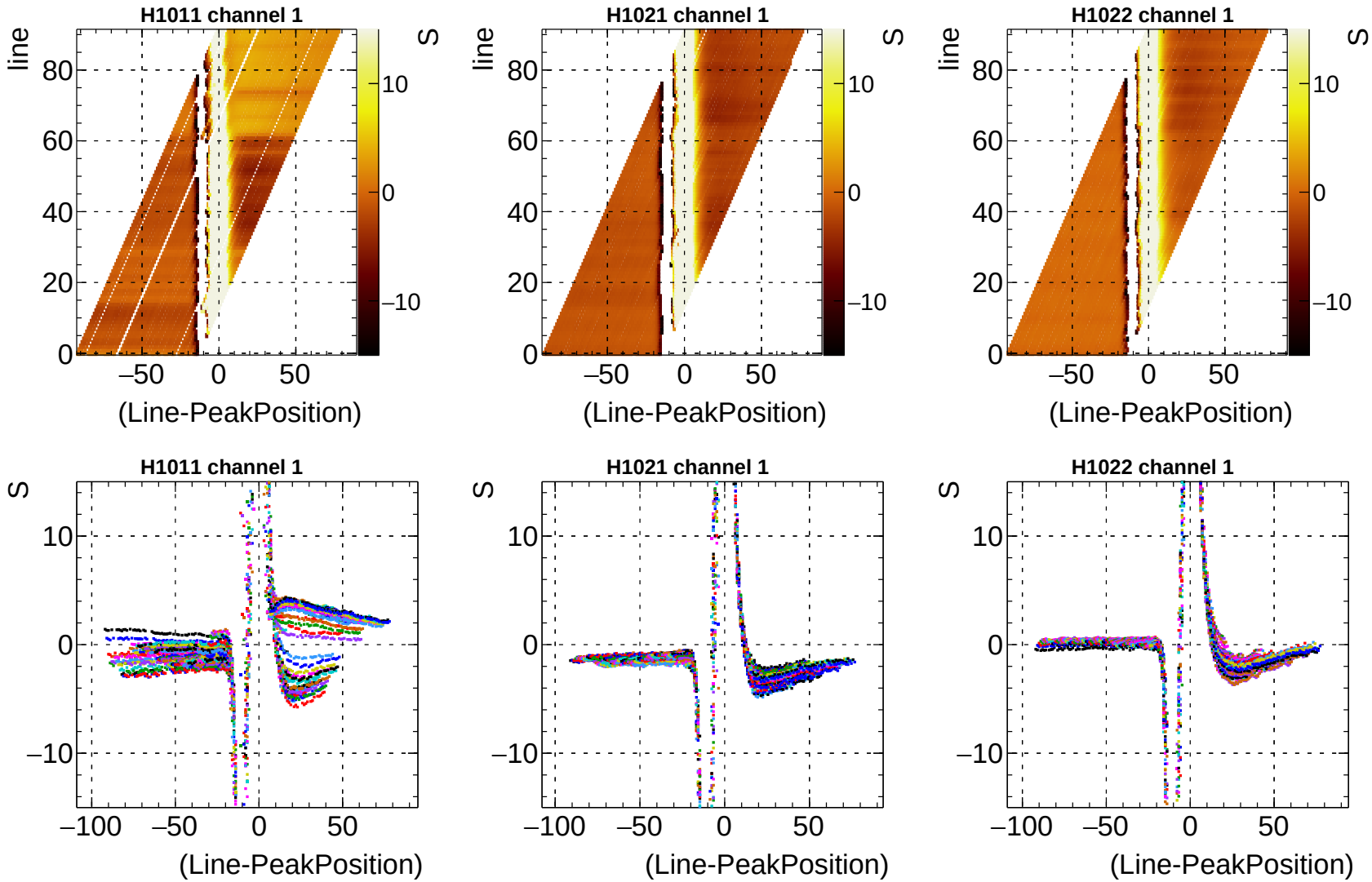




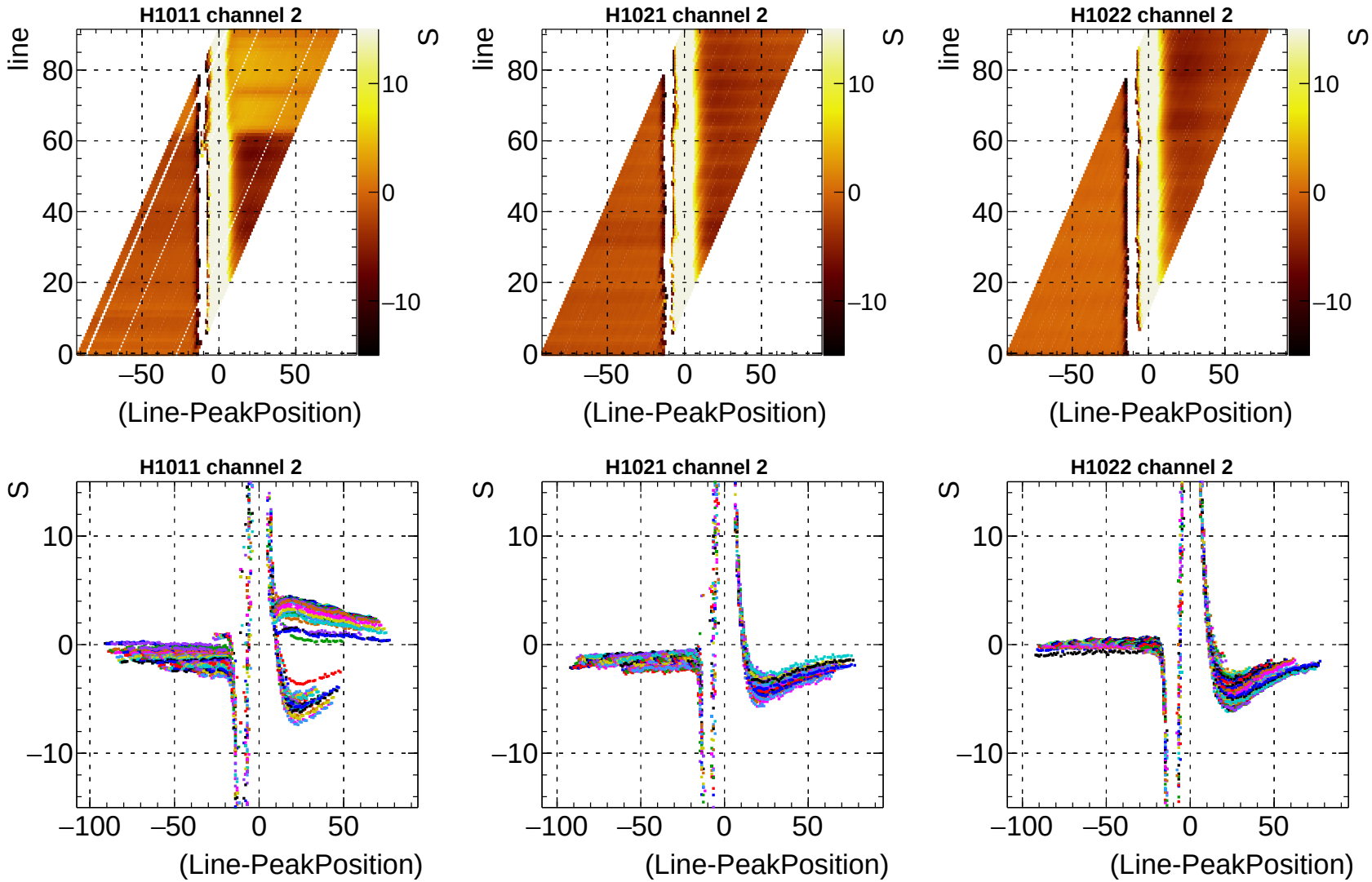
Distance to GM Resonance (Filtered Signal)



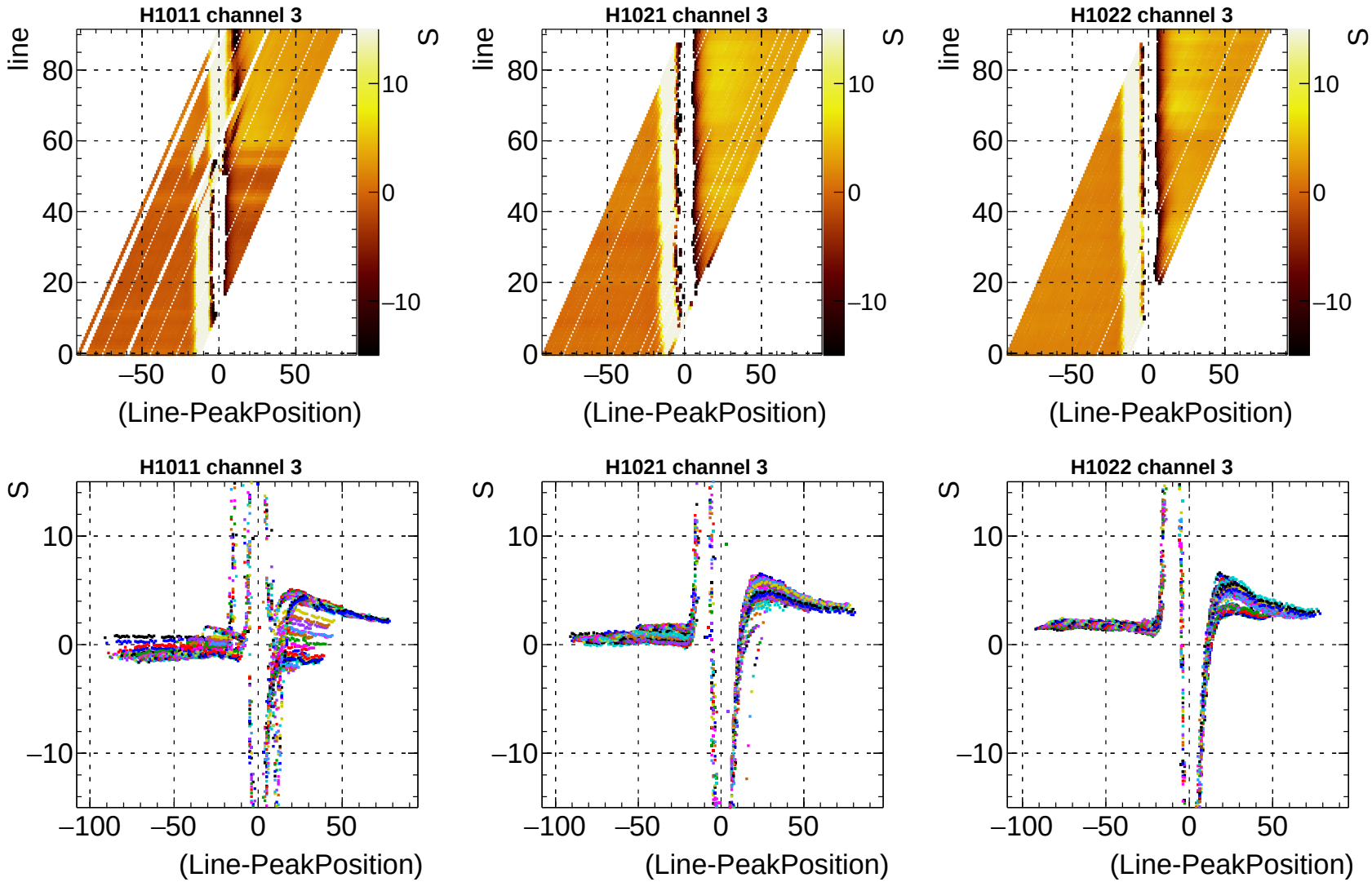
Distance to GM Resonance (Filtered Signal)



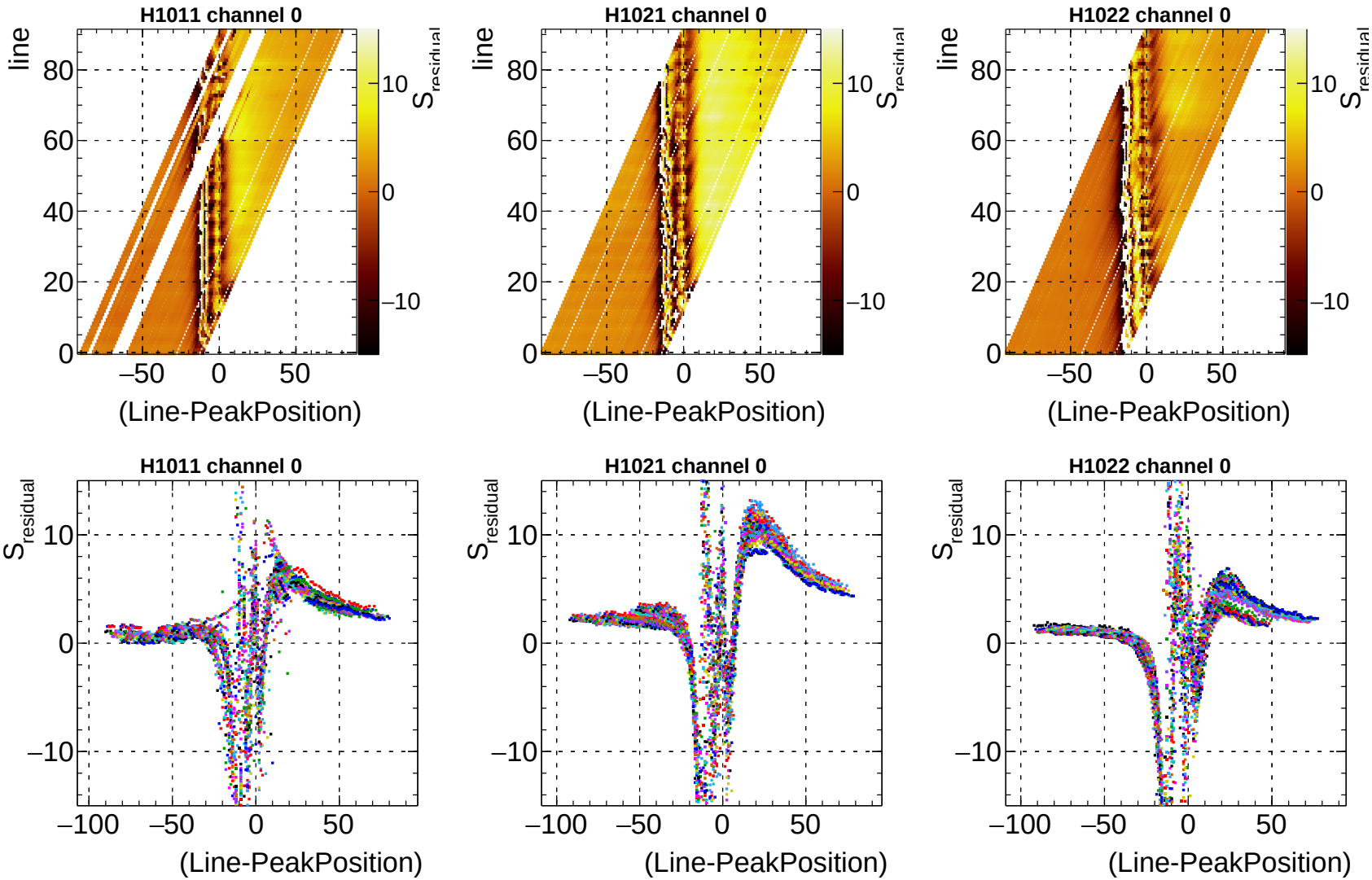
Distance to GM Resonance (Filtered Signal)



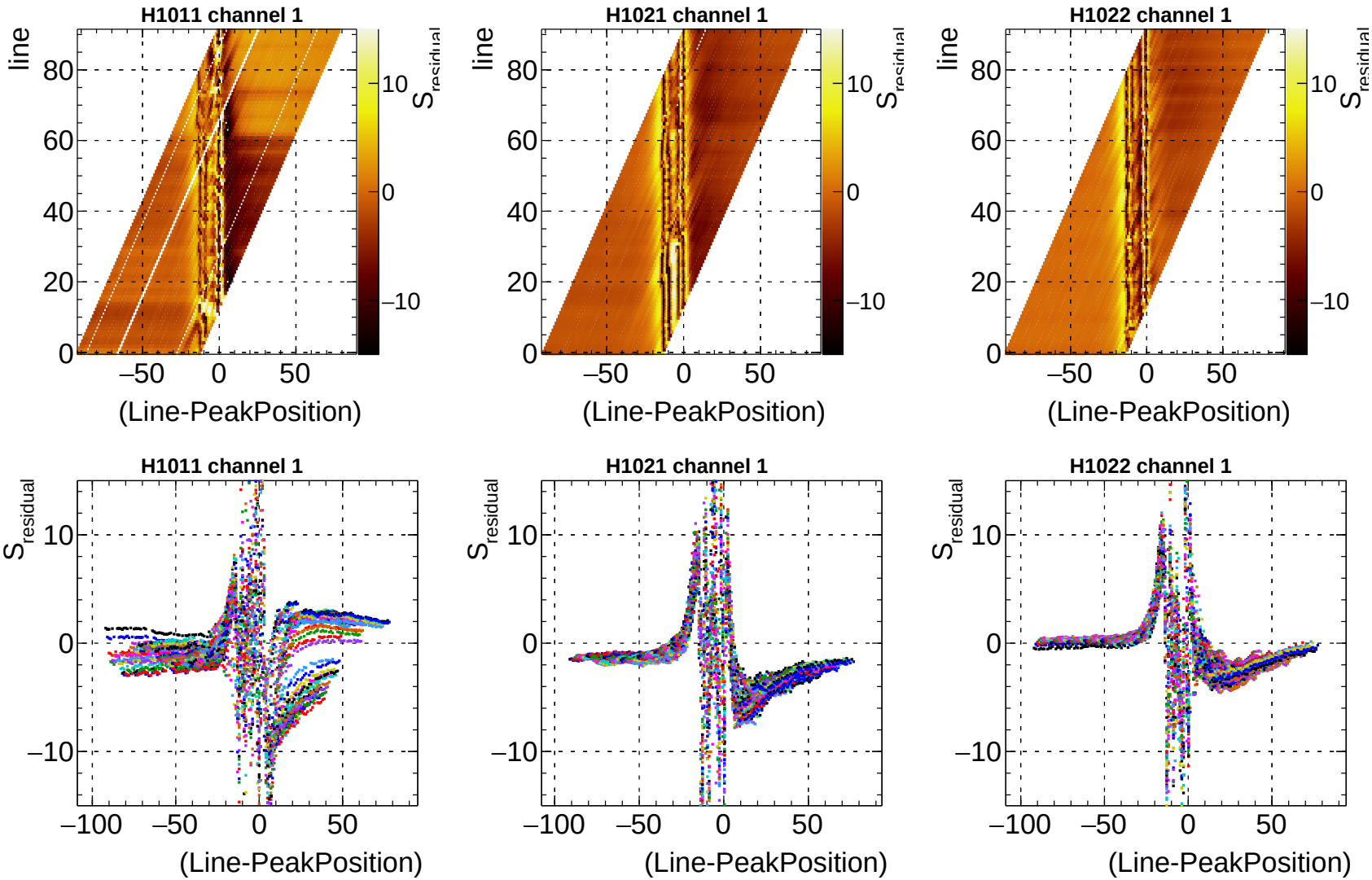
Distance to GM Resonance (Filtered Signal)



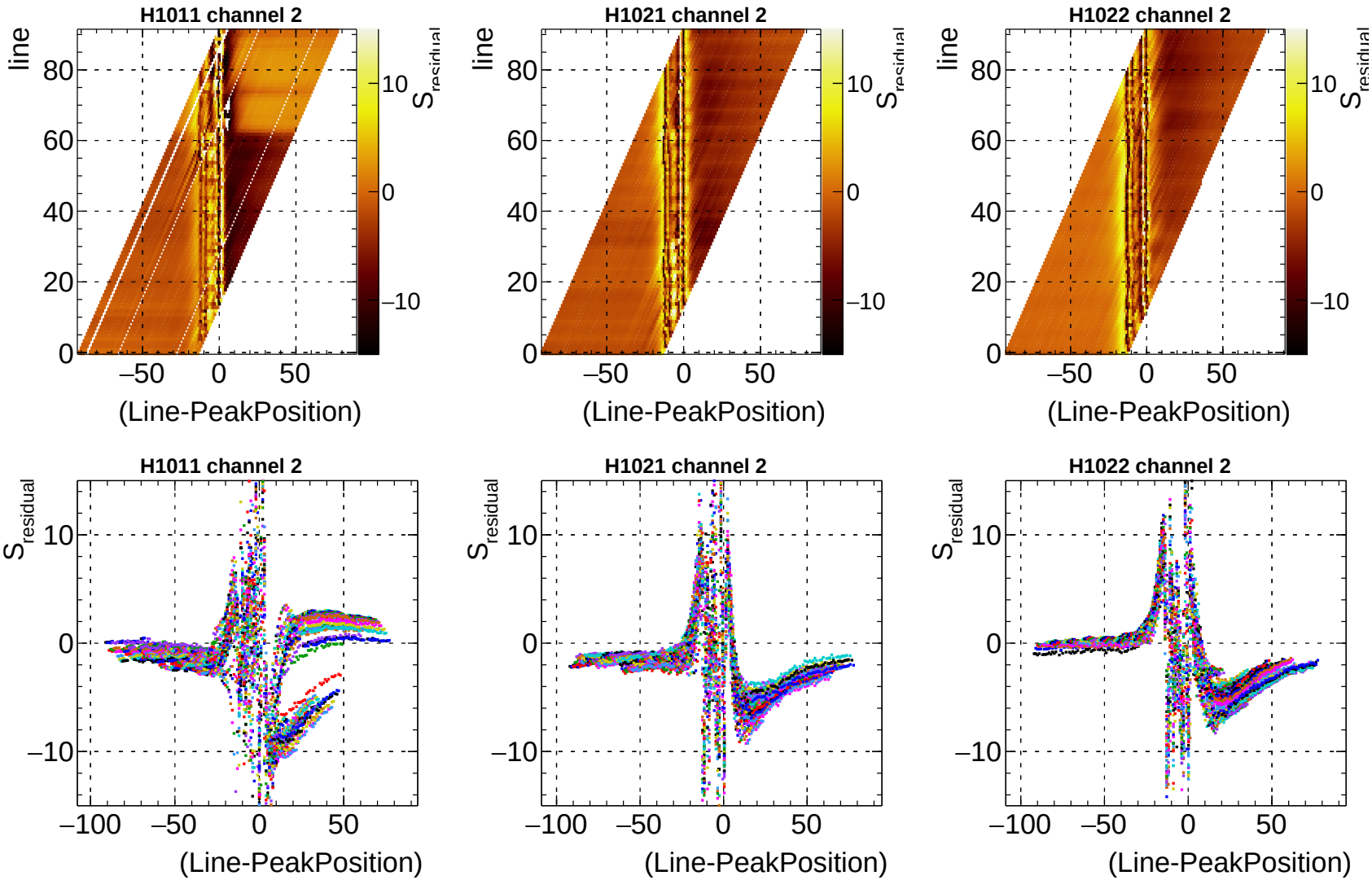
Distance to GM Resonance (Fit Residuals)



Distance to GM Resonance (Fit Residuals)



Distance to GM Resonance (Fit Residuals)



Distance to GM Resonance (Fit Residuals)