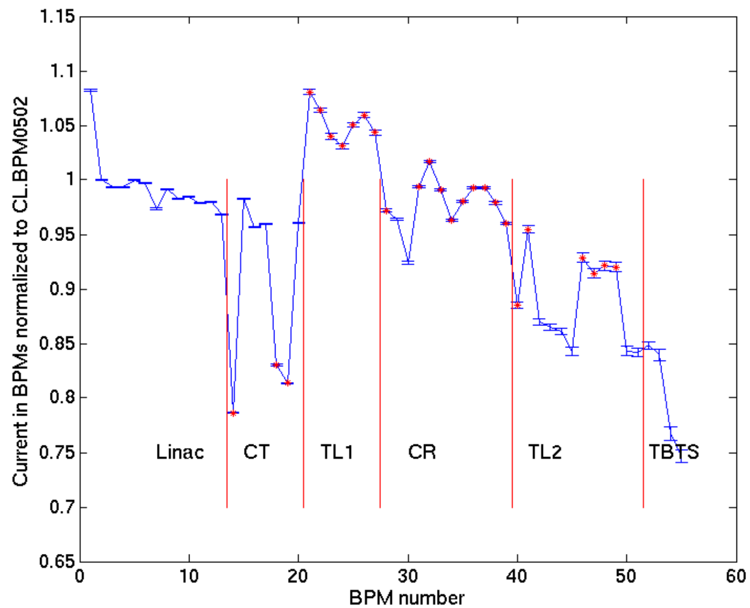
Operational issues with BPMs and BPIs

- **Known issues**
  - Inconsistency between BPMs and BPIs
  - Response of BPIs is non-linear along the pulse

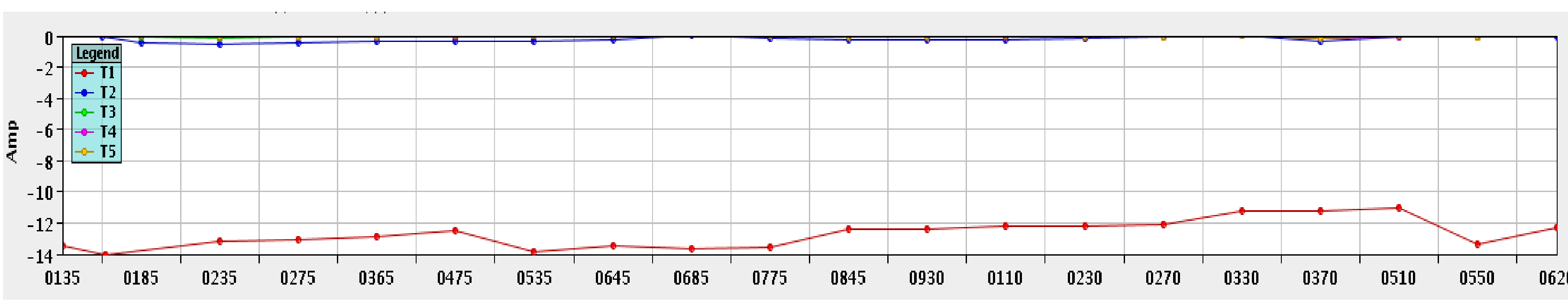
- **Note – BPIs in delay loop have different processing electronics**
  - Diagnostic data taken in December 2011 for delay loop BPIs only
  - Will focus on these monitors
  - However, conclusions may well be applicable to all BPIs – to be confirmed

Example – transmission along machine

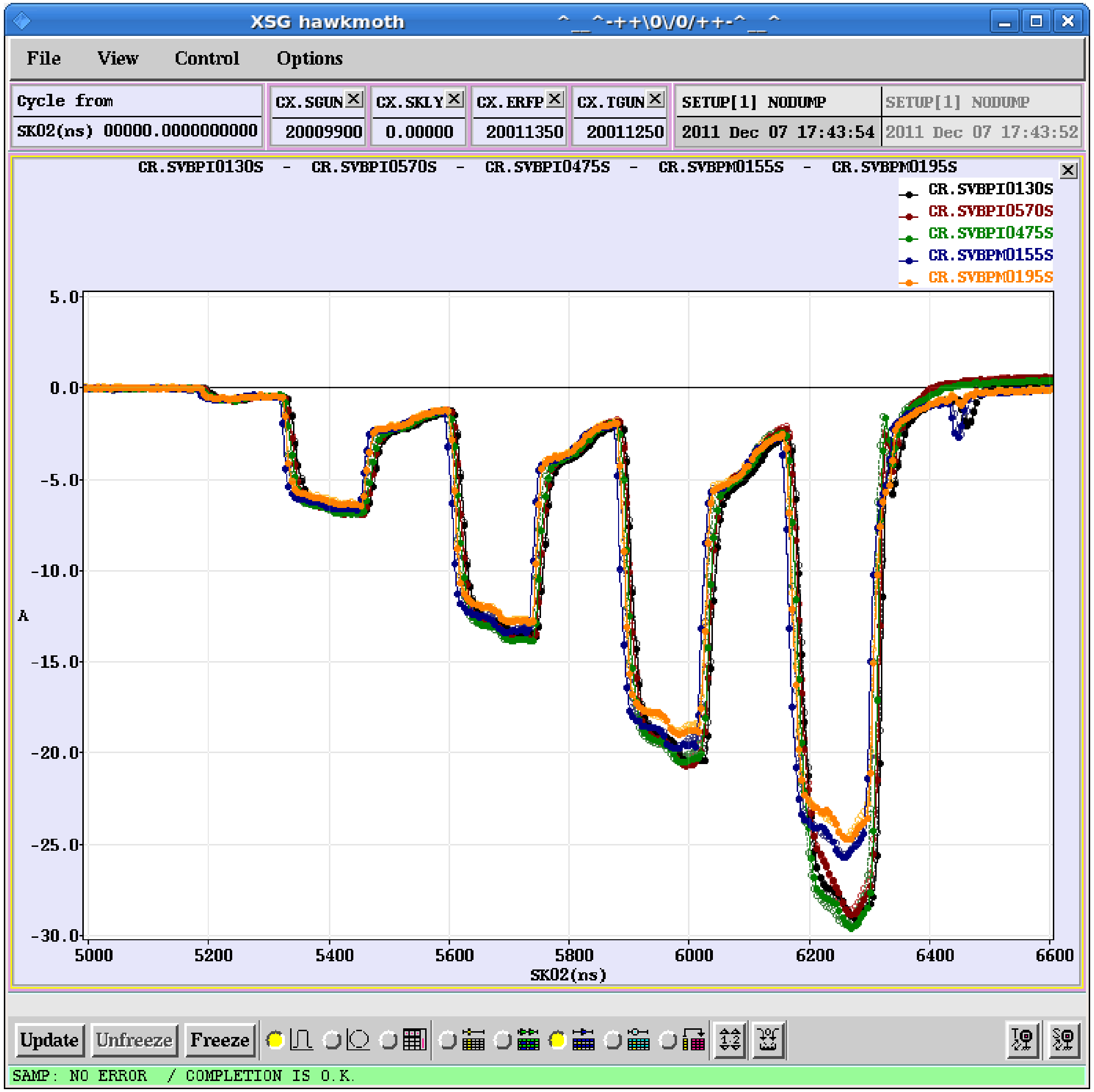
- **Tobias 2011, analysis of current losses**
  - Red asterisks mark BPIs, other monitors are BPMs



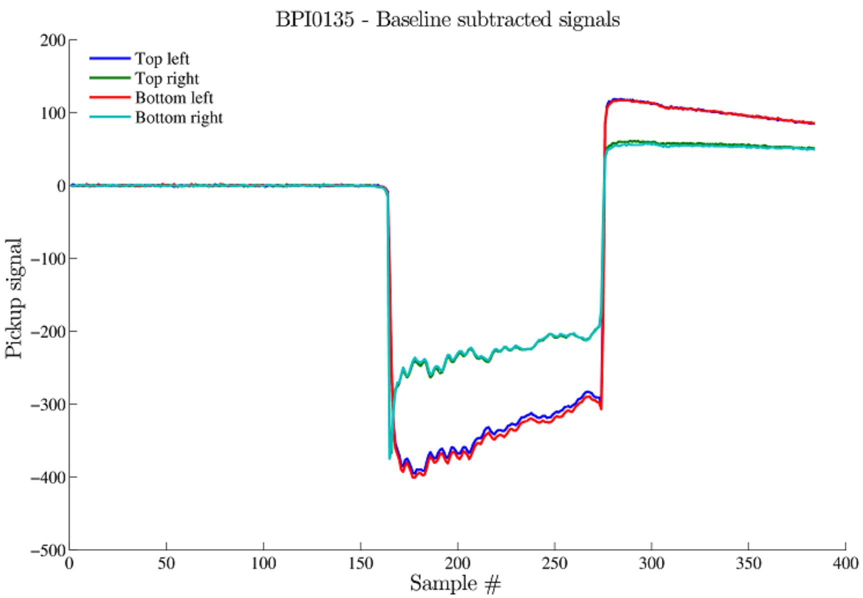
- **Typical transmission to TBTS**

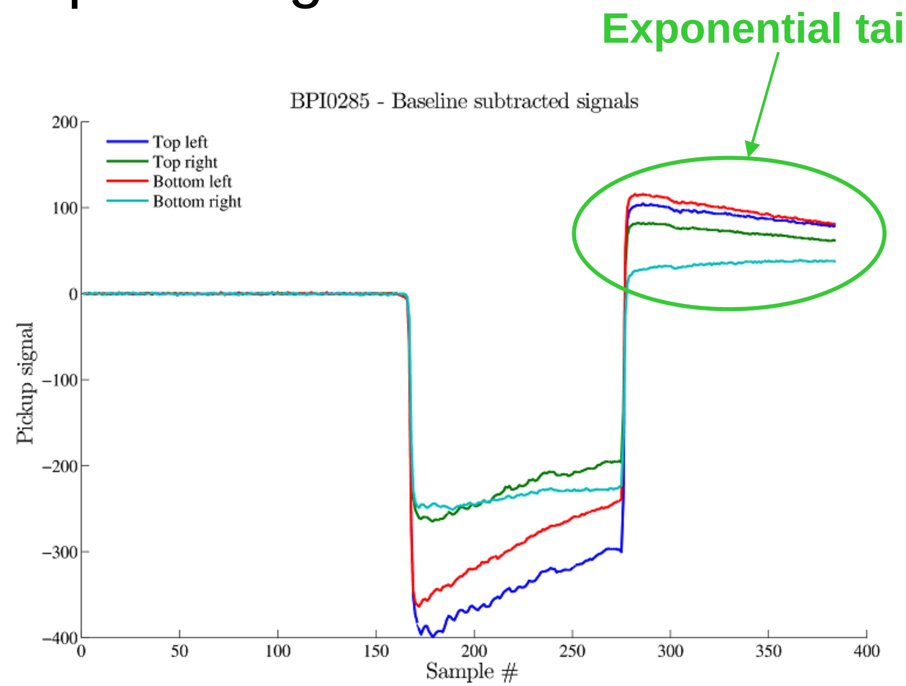


Example – non-linear BPIs vs. BPMs in combiner ring



Example delay loop BPI signals





- **Observation of delay loop signals December 2011**
  - Log raw electrode signals (decouple beam offset, current)
  - Droop on individual strip signals seen to be approximately exponential
  - Strips have *different time constants*
  - Time constants are *dependent on the signal level*

Offline BPI signal processing

- **Signal processing is as follows:**

$$\Sigma = V_{TL} + V_{TR} + V_{BL} + V_{BR}$$

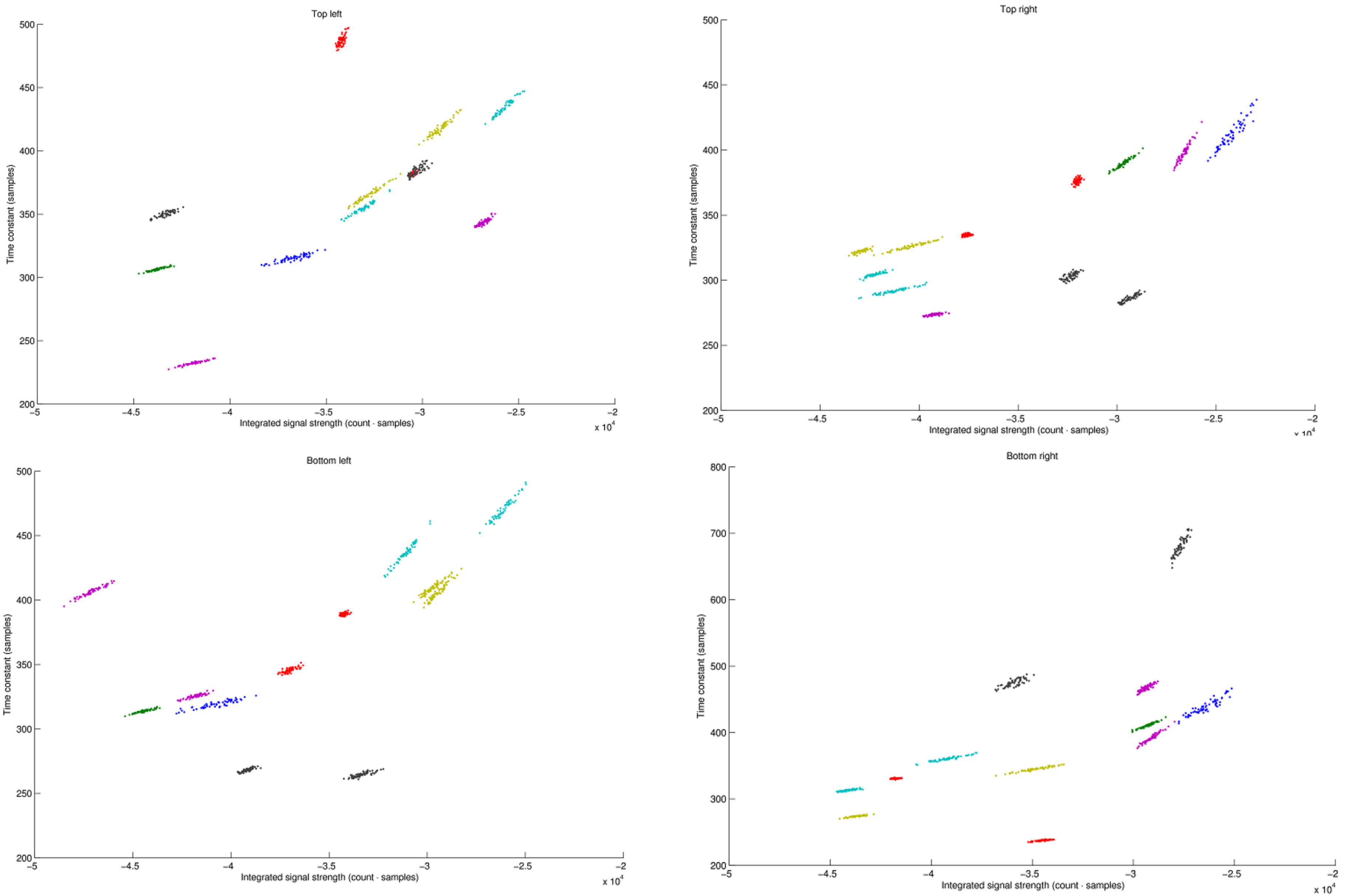
$$x = \frac{(V_{TL} + V_{BL}) - (V_{TR} + V_{BR})}{\Sigma}$$

$$y = \frac{(V_{TL} + V_{TR}) - (V_{BL} + V_{BR})}{\Sigma}$$

where the signals have had their pedestal subtracted

- **Summation over signals with differing time constants**
  - The droop on the current/position measurements is *not a pure exponential*
  - Any correction should be done on an individual electrode basis
- **Used least square fitting to measure decay time constants**
  - However, poor fits to signals with larger time constants due to limited range of exponential tail (see next plot)
  - No obvious parameterisation

Time constant vs. signal strength for all DL BPIs



Consistency between BPM and BPI current measurement

- **Not simply a calibration issue**
  - The delay loop BPIs give decaying sum signals
  - Similar non-linearity observed in BPIs elsewhere
  - Typically, signals are averaged over a window
  - Absolute recorded current dependent on window position and size

- **Ideally, would like to correct for non-linearity before calibration**

Droop correction by IIR filter

- **Can correct an exponential droop with an IIR filter:**

$$V'_n = V_n + \lambda \sum_{i=0}^{n-1} V_i$$

where V_n is the n^{th} sample and $\lambda = 1/\tau$ is the decay constant

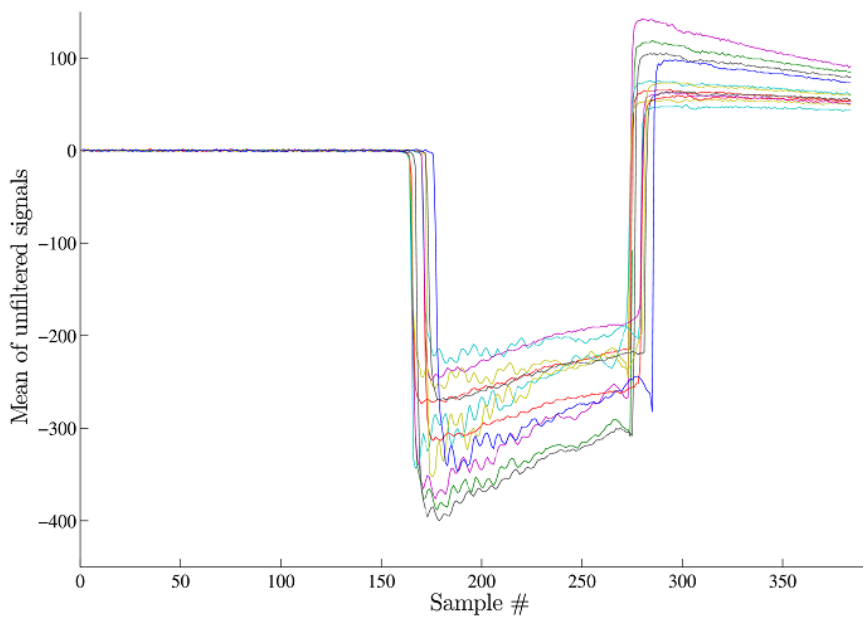
- **Pragmatic approach to filtering**
  - Least square fit to the signal exponential tail
  - Fit for each electrode on a pulse-to-pulse basis
  - Fast fitting by linearisation and direct calculation of time constant
  - For N samples of the exponential tail at times t_n, the least sq. estimate of τ is:

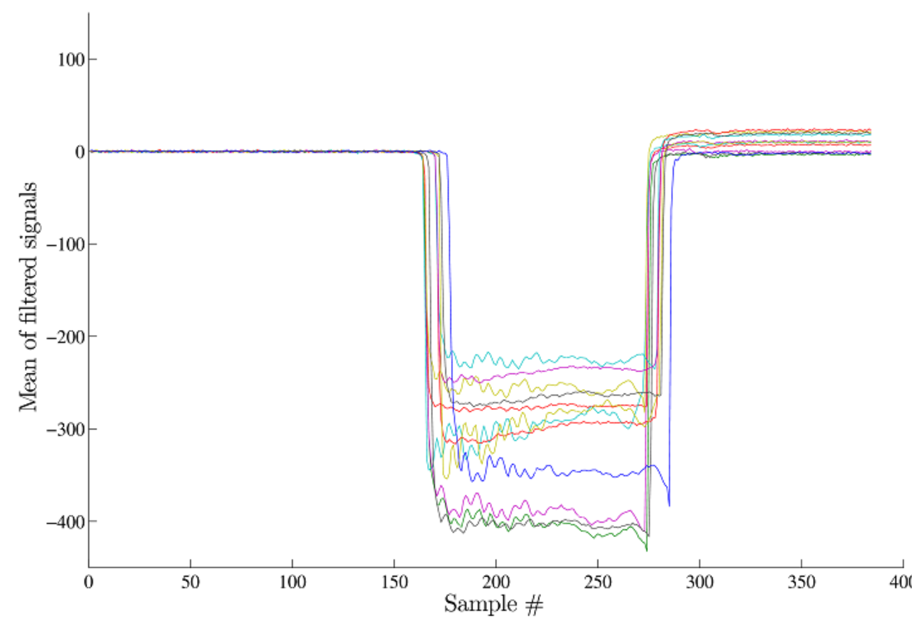
$$\tau = \frac{\mathsf{var}\left[t_n\right]}{\mathsf{cov}\left[\ln V(t_n),\ t_n\right]}$$

- **Algorithm is fast**
  - Would expect approximately double total signal processing latency

Offline processing using fast algorithm

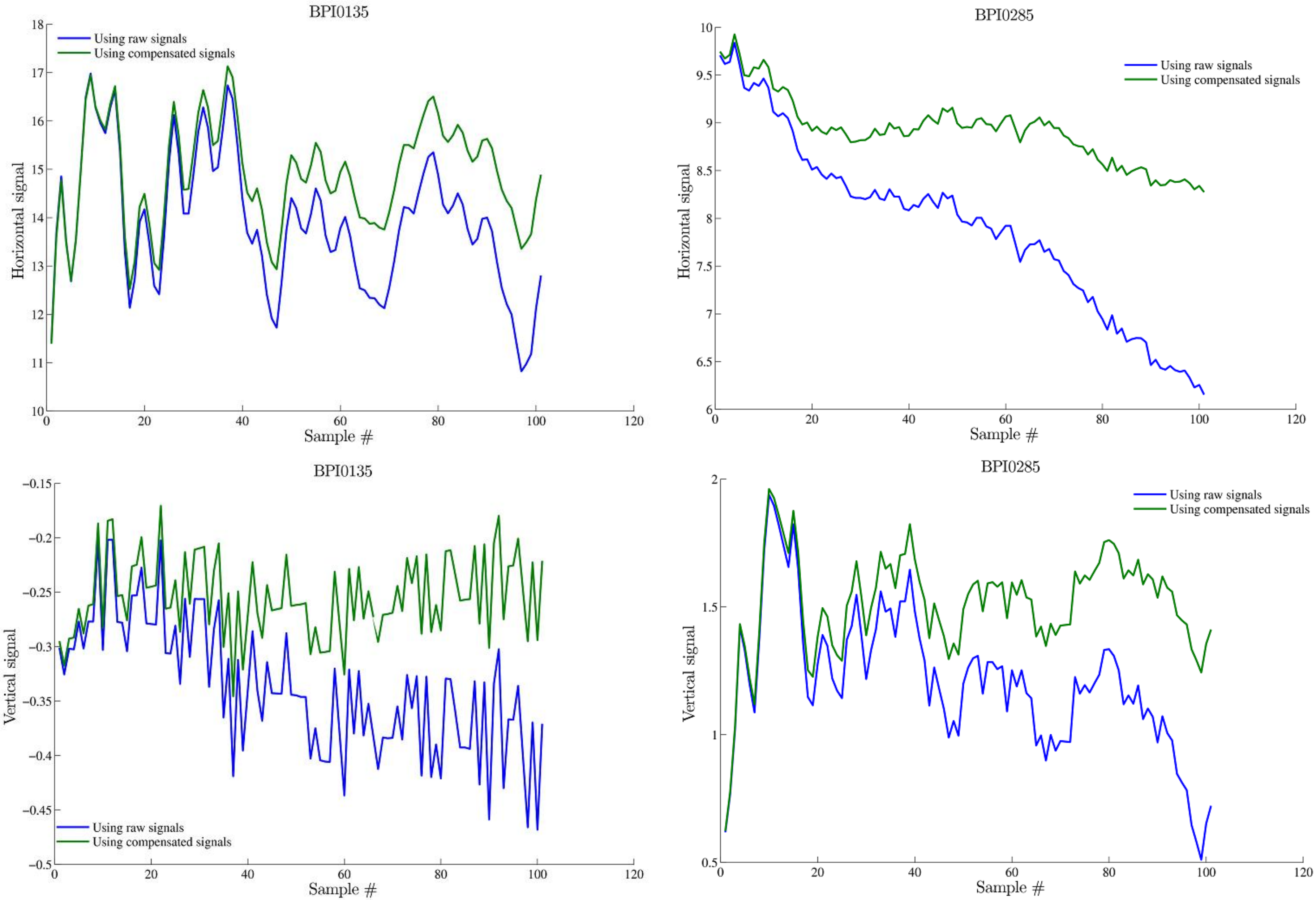
- **Top-left electrode signals for all DL BPIs, averaged over ~50 pulses:**





- **Smaller time constants are well corrected, larger time constant signals aren't**
  - Slowly decaying signals' tails do not go to zero
  - Again, due to insufficient length of exponential tail

Significant effect on position signals (well corrected signals)

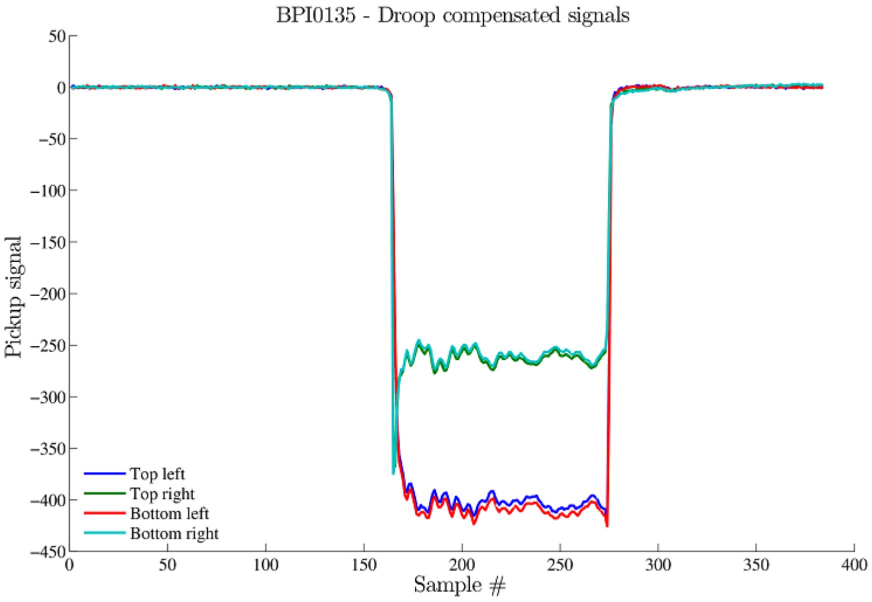


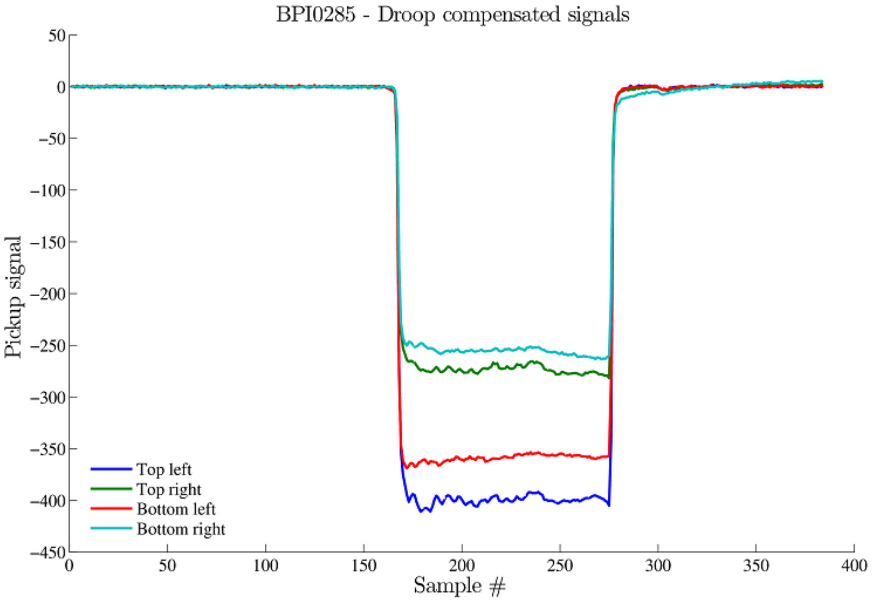
Conclusions and further work

- **BPI non-linearity has significant impact on measured current and position**
  - Desirable to correct this. IIR filter could potentially do so
- **Parameterisation of each electrode's response non-trivial**
  - Overcome by real-time fitting to exponential tail of signal
  - Currently, DL ADC gates do not sample enough tail for good correction
  - Shifting gate time to sample less baseline, more tail should work for DL
  - Extend gate length?
- **Must consider robustness if implementing in, for example, BPI driver**
  - Must work for different pulse lengths (pedestal subtraction, location of tail)
- **Check applicability to TL1/CR/TL2 BPIs**
  - Different processing electronics and higher beam current
  - Diagnostic data required to say more about these
- **Any changes to BPI processing should be followed by calibration**

END

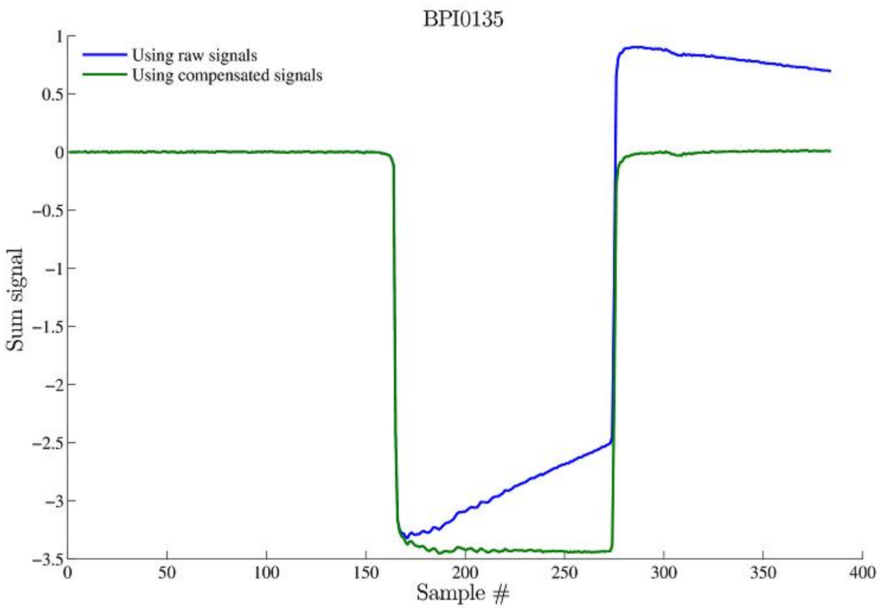
Example filtered signals

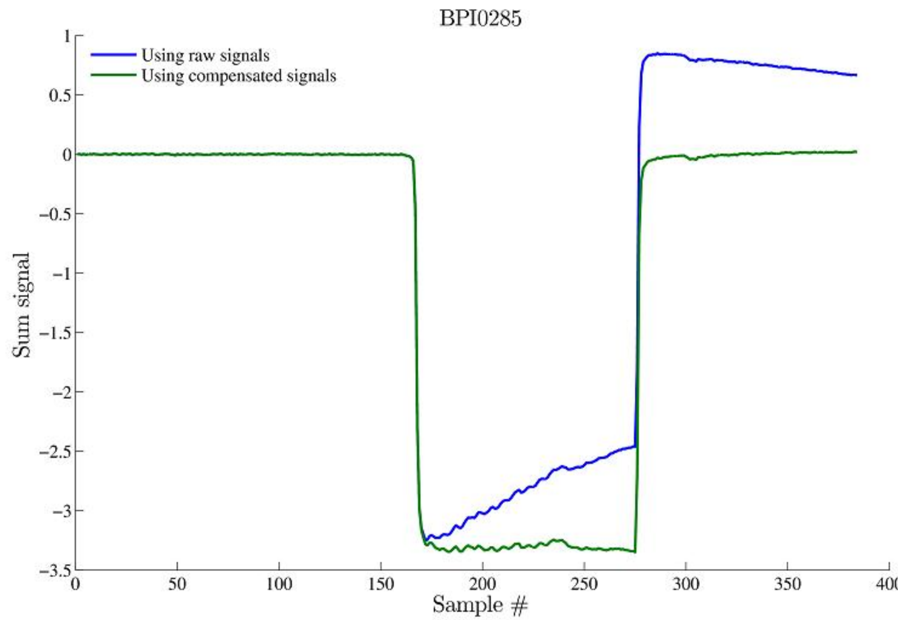




Effect on sum signals

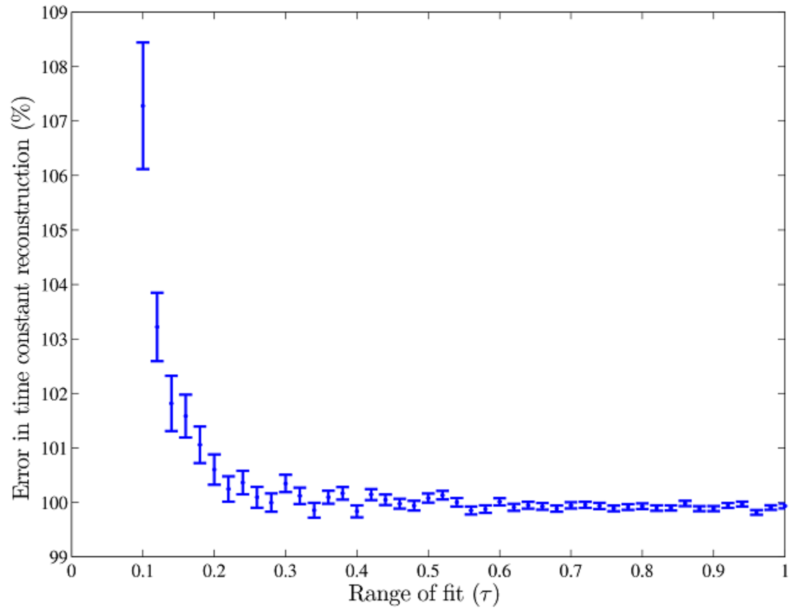
- **Note: calibrated empirically with respect to treated signals**





Monte Carlo exponential fits

- **Fast fit to simulated, noisy exponential**
  - RMS noise 2% of initial signal level
  - Vary range of simulated data used in fit from 10 – 100% of the time constant
  - Plot the fitted time constant as percentage of real value (with std. error)



- **Bad fit when droop is comparable to noise or any systematic 'overshoot'**
- **When fit range is small compared to time constant, fit tends to over-estimate**

Possible solutions

- **Range of tail is 10 – 30% of the various observed time constants**
  - Clearly too small a range for reliable time constant fitting
  - Contributing to (or explaining) the apparent nonlinearity in time constant vs. signal level

1. **Shift the gate timing to observe more tail**
   - Currently ~150 samples of baseline before signal which could be used
   - Gives tail range of 40 – 100% of time constant, and likely accurate fitting
   - Would this ruin pedestal subtraction? How does the current algorithm work?
2. **Extend the gate**
   - Could we do the same as we did for the CR and observe more tail?
3. **Parameterise…**

Possibility of parameterisation (for DL)

- **Much of the apparent nonlinearity (time constant vs. signal level) may be an artefact due to poor fits**
- **Observing longer tail *may* allow decent parameterisation**
- **Need to parameterise time constant vs. signal level by calibration**
- **In absence of variable high current supply, must be beam based:**
    - Short pulse would allow more tail to be observed
    - Generate two or three 1.5 GHz beams with different capture efficiencies
    - Inject satellites and inject mains into DL
    - Should give a good range of signal levels