What is the accuracy & precision of a single PDV velocity extraction?

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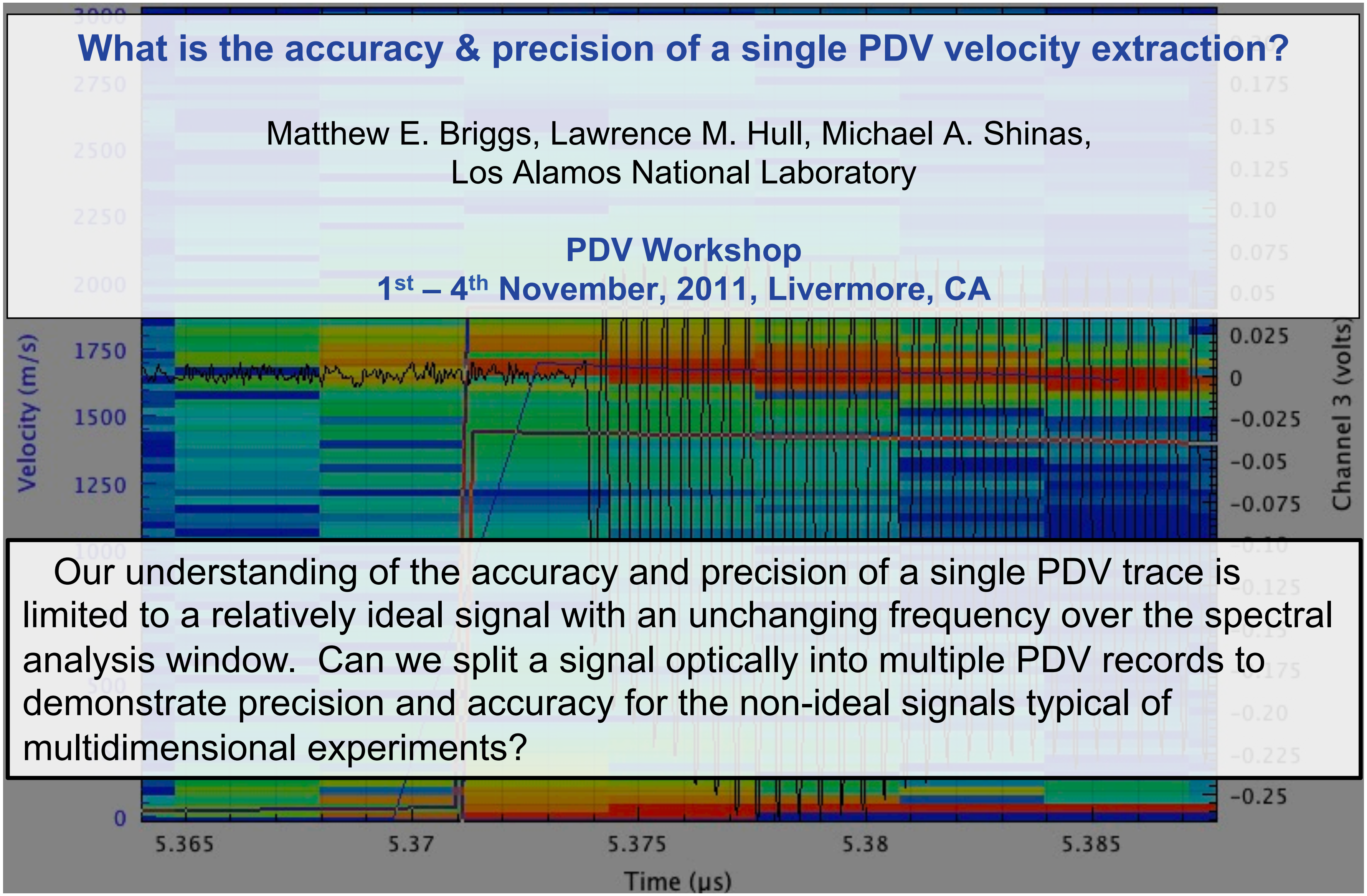

Our understanding of the accuracy and precision of a single PDV trace is limited to a relatively ideal signal with an unchanging frequency over the spectral analysis window. Can we split a signal optically into multiple PDV records to demonstrate precision and accuracy for the non-ideal signals typical of multidimensional experiments?

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Results so far give a limit on how good PDV can be. Do we need to know the actual errors?

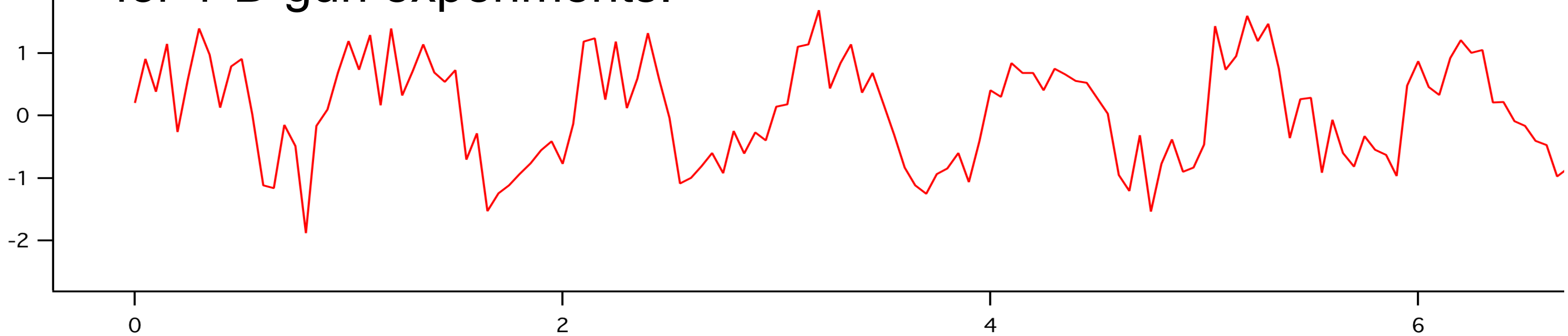
- Analytic treatment by Dolan ("Accuracy and precision in photonic Doppler velocimetry," RSI 81, 2010) provides an excellent discussion of errors and their origin, and gives a limit on how *good* the precision & accuracy can be. Assumes constant frequency and considers only noise for signal degradation.
- Experiments by Jensen et al. ("Accuracy limits and window corrections for photon Doppler velocimetry," JAP 101, 2007) demonstrate 0.1% accuracy & precision under experimental conditions similar to Dolan's assumptions of near-ideal signals.
- Are there other treatments of this topic?

If we need to know the error, rather than a limit, we have the following concerns

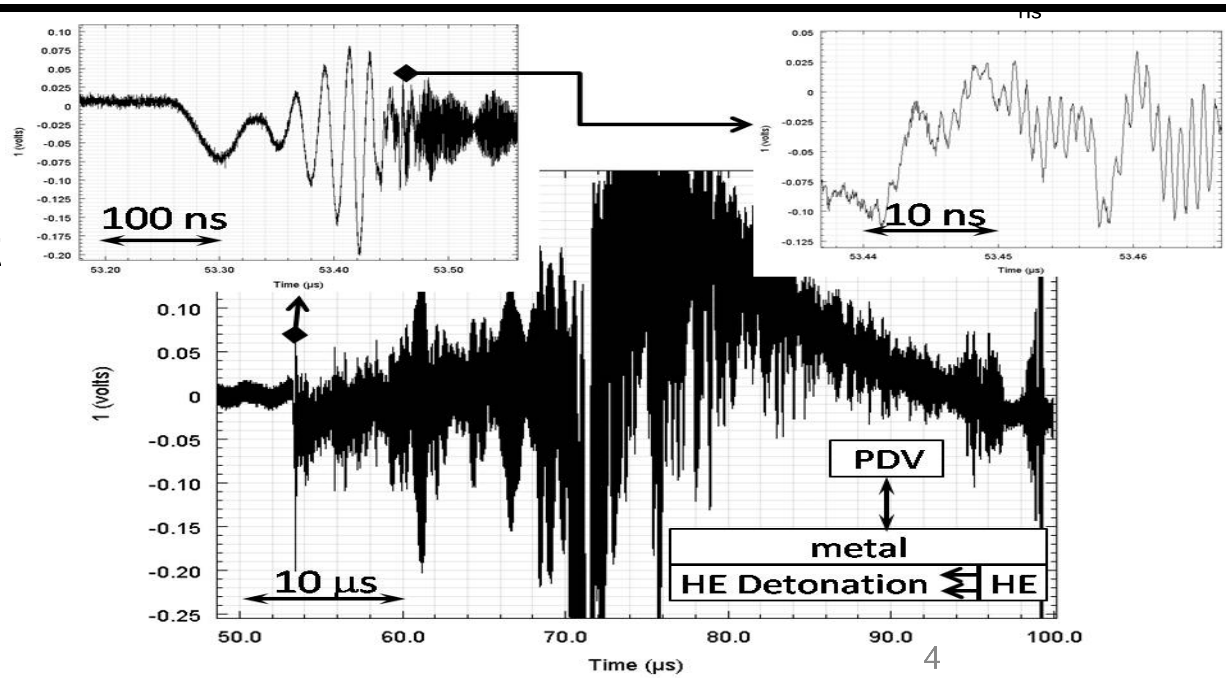
- We only understand the precision & accuracy for the case of constant frequency. We do not know how to quantify the effects of non-constant velocity.
  - Dolan has reported in a private communication that constant acceleration degrades only precision, not accuracy, and that jerk (non-constant acceleration) does cause accuracy errors, but not yet quantified.
- Dolan showed that the accuracy can be about 5x worse for ideal signals than suggested by the width of a Gaussian fit.
- The effects of time dependent offsets, amplitude and frequency, and the effects of non-linearity in the detection have not been quantified.

Above concerns arise frequently: the signal is often far from ideal, and velocity not constant.

A near ideal signal: only degradation is random noise. Typical only for 1-D gun experiments.



Signals from high-explosive driven experiments show in addition time-dependent offsets, amplitudes and frequency. What effects do these have on precision & accuracy?



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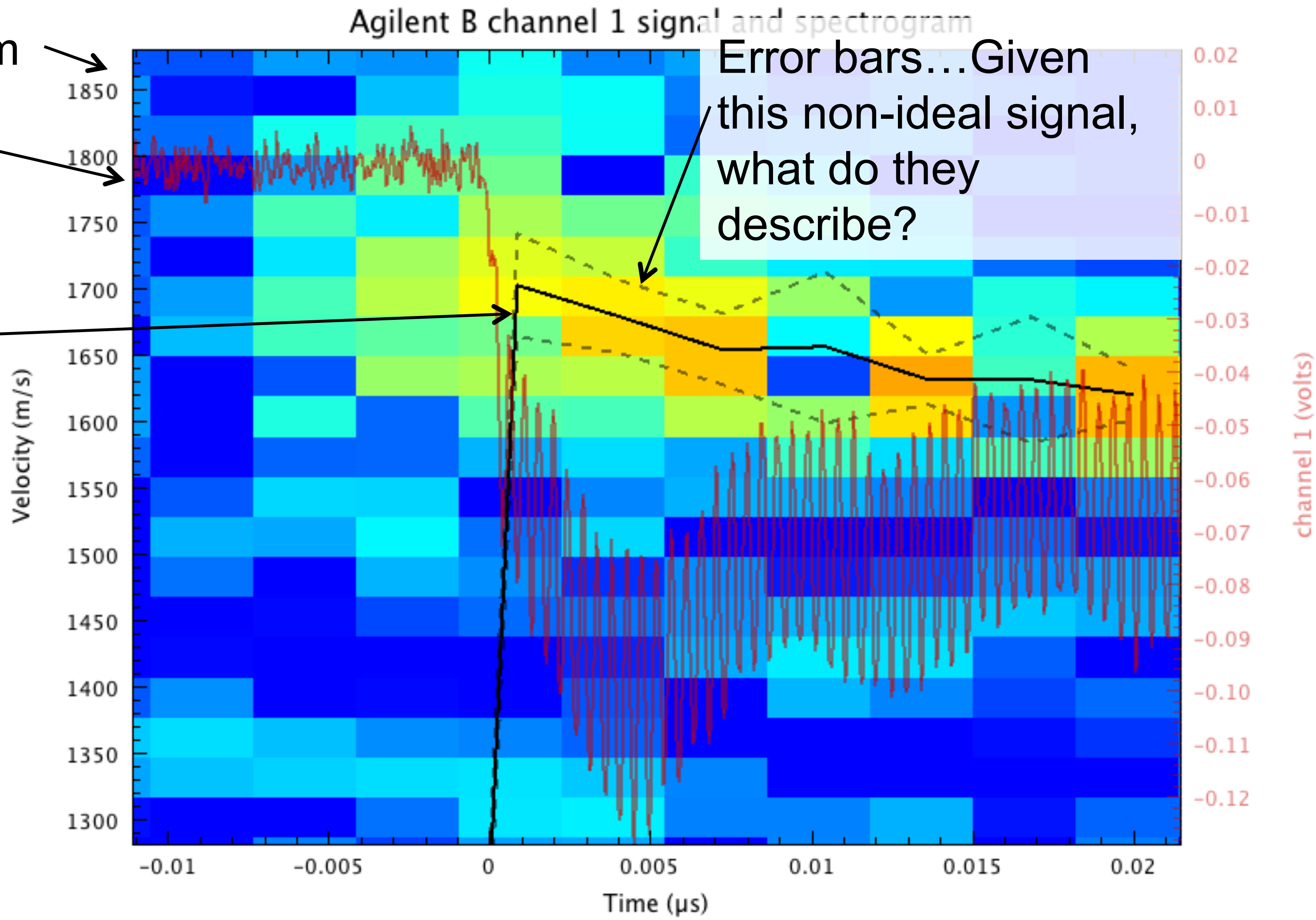
Typically one uses error estimates from the results of fitting a peak to each time slice

Spectrogram

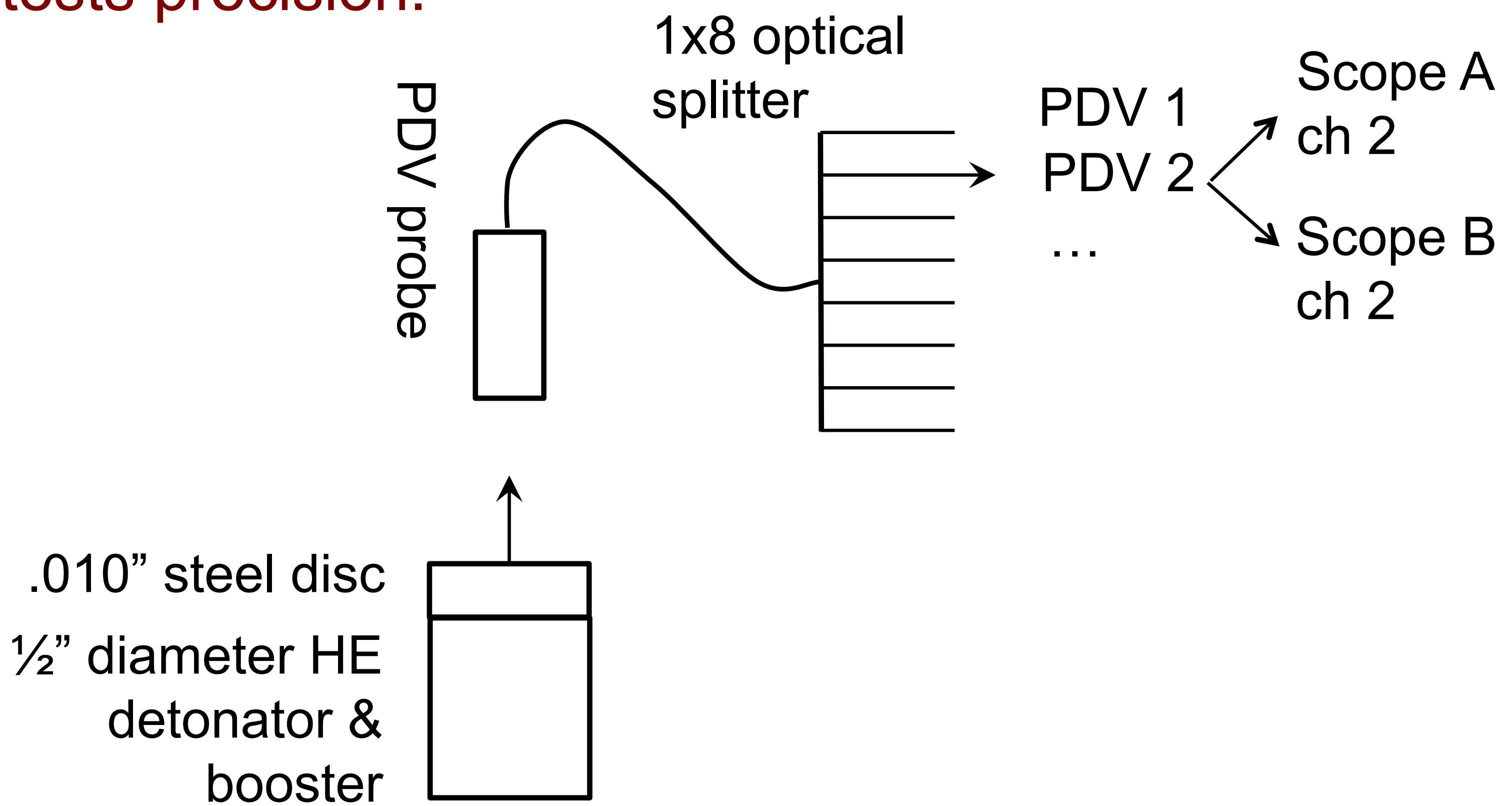
Oscilloscope record (2nd y axis)

Velocity calculated from spectrogram

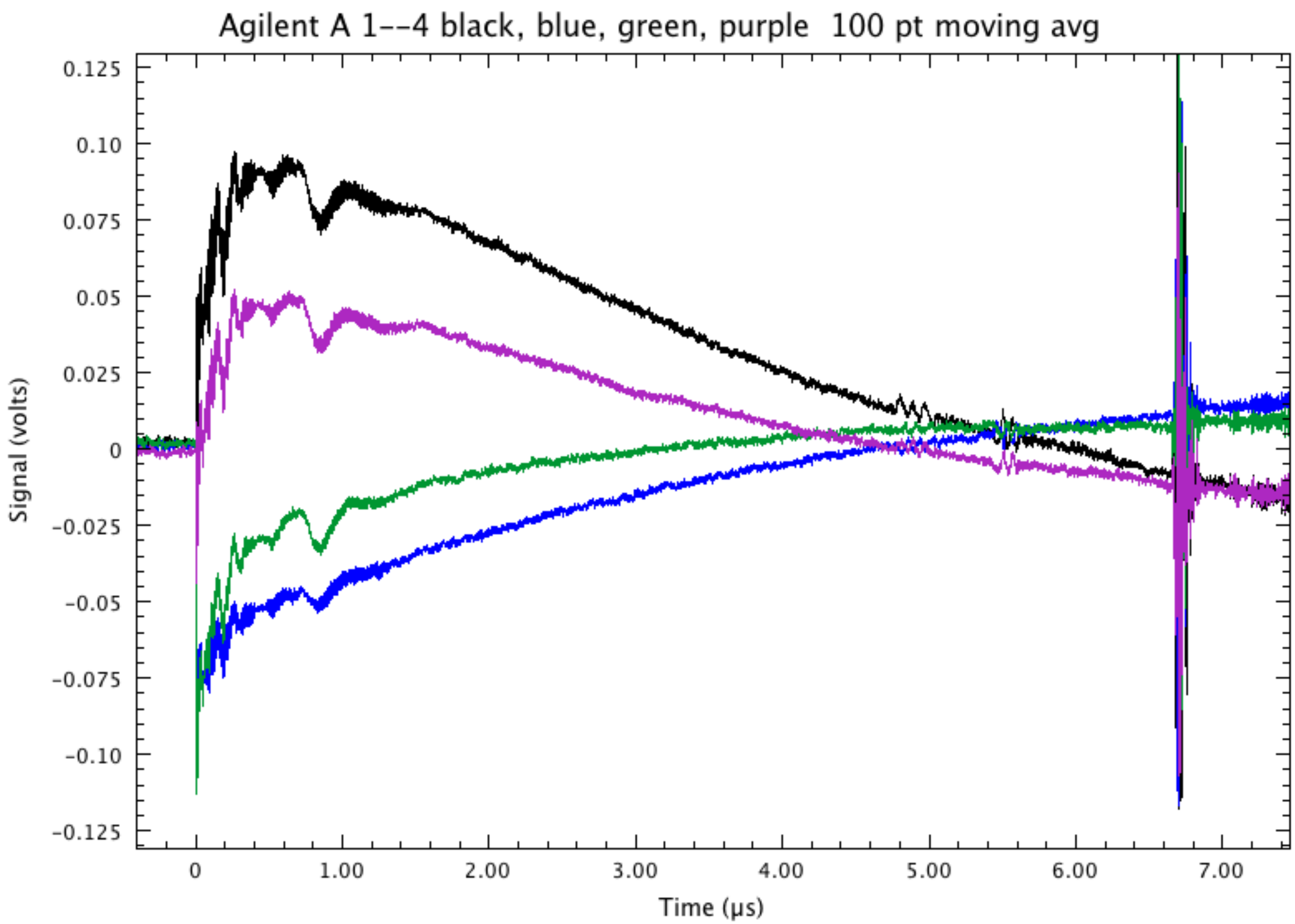


Can we group these problems together and demonstrate the final precision & accuracy with an experiment?

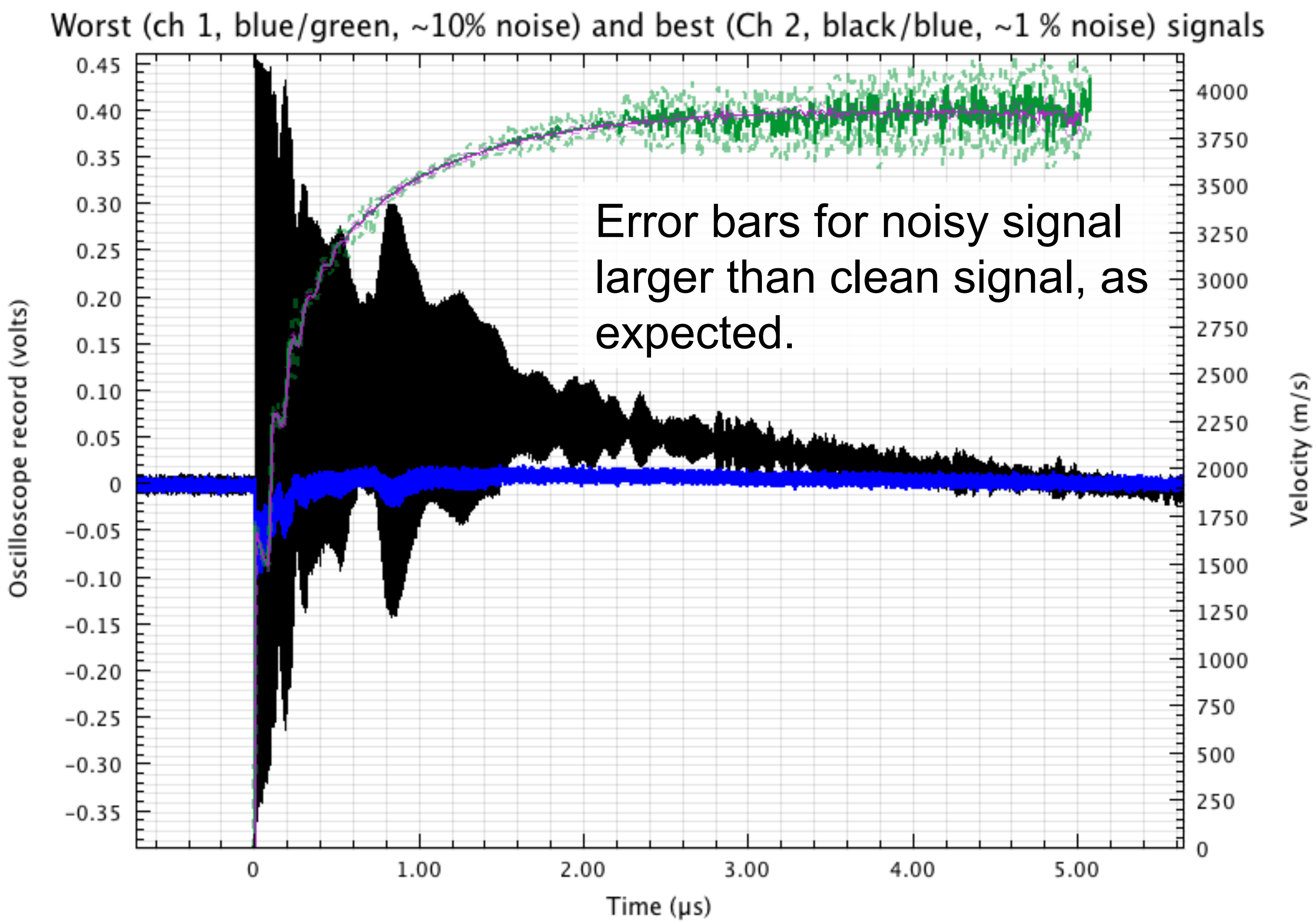
We split 1 probe optically 8 ways, sent them to 8 PDV channels, recording each on 2 independent scope channels. We do not know the velocity independently, so this only tests precision.



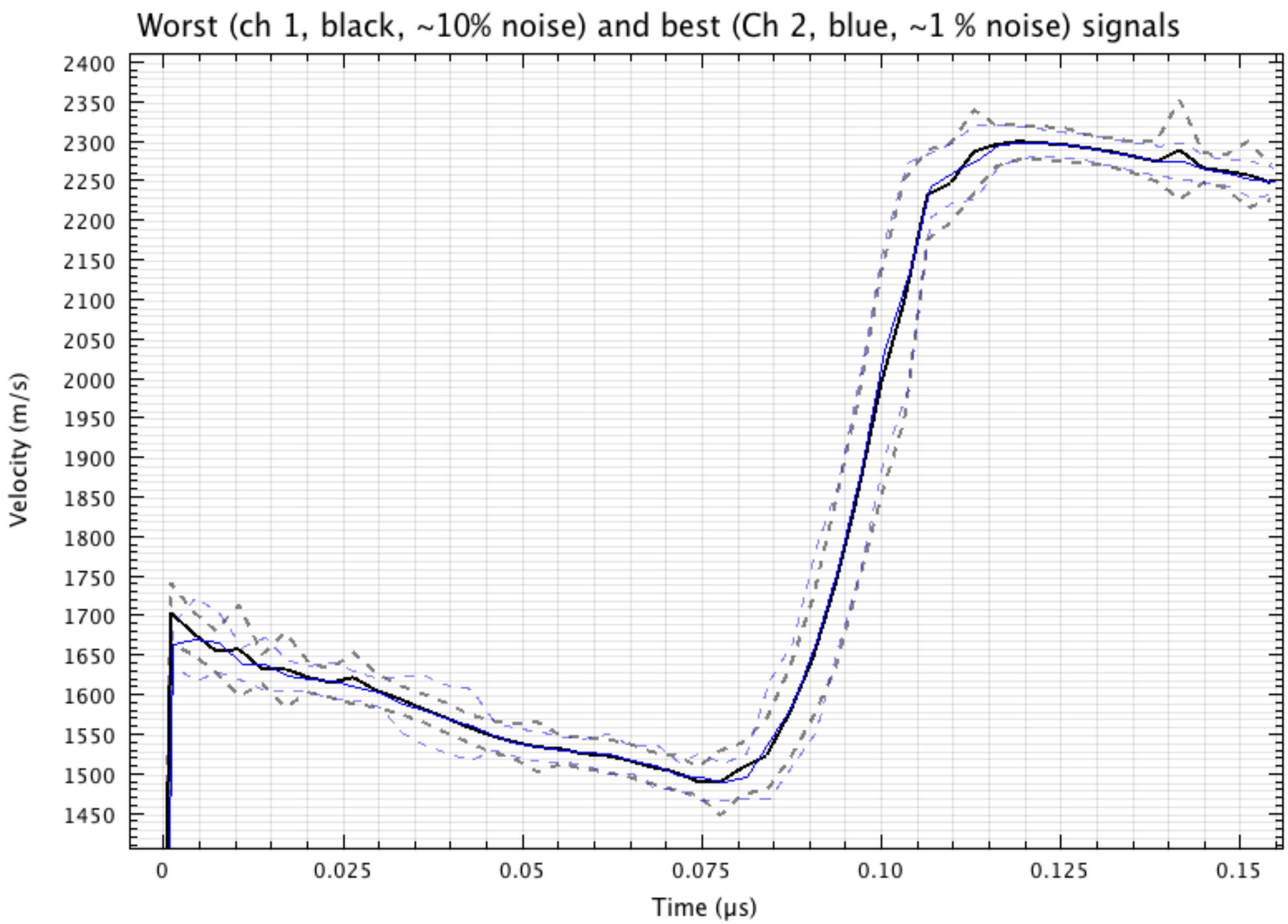
4 records from one oscilloscope, low-pass filter. They jump off to different offsets? Why?



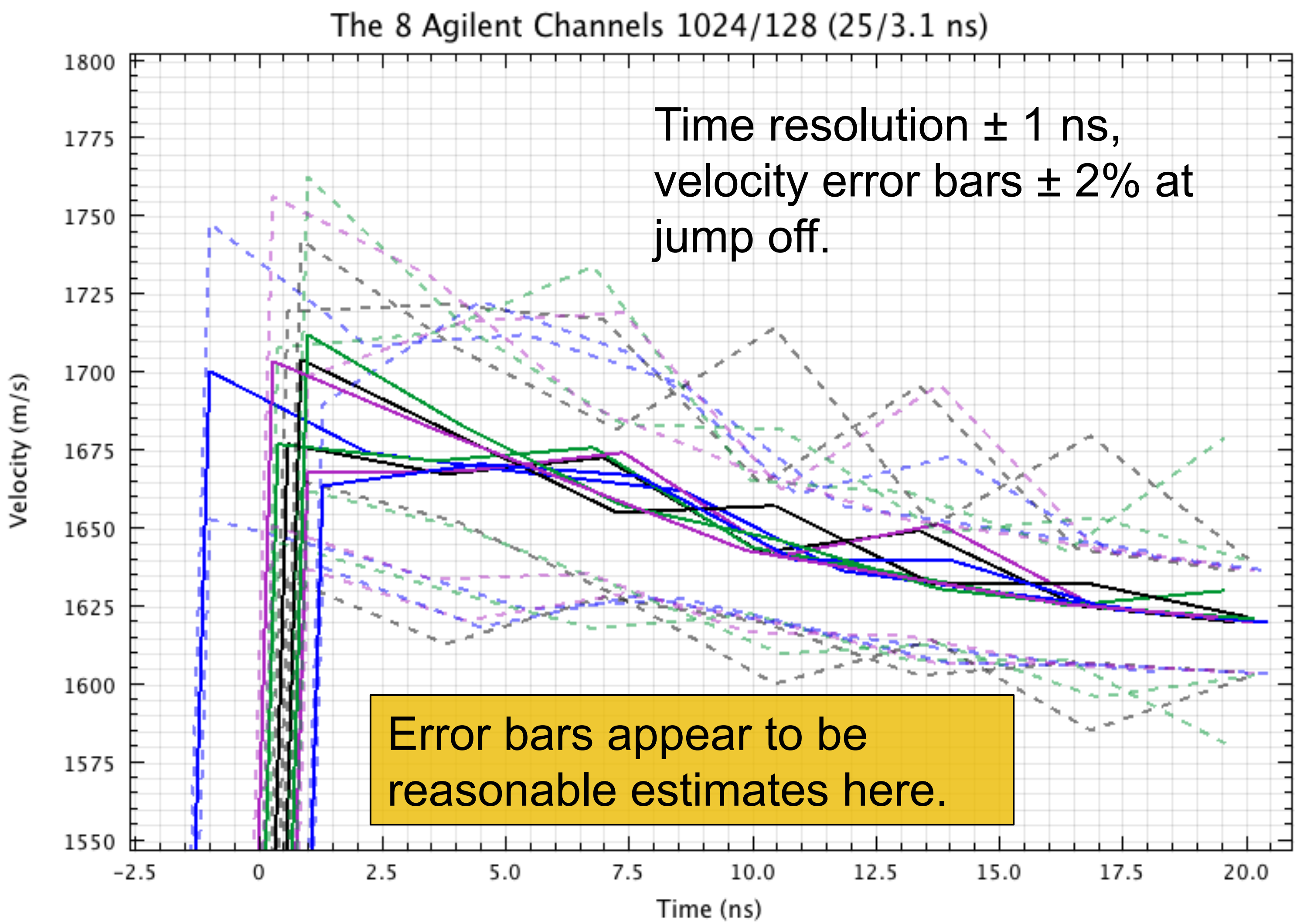
We had one signal with larger noise, 10% compared to 1% for the rest…



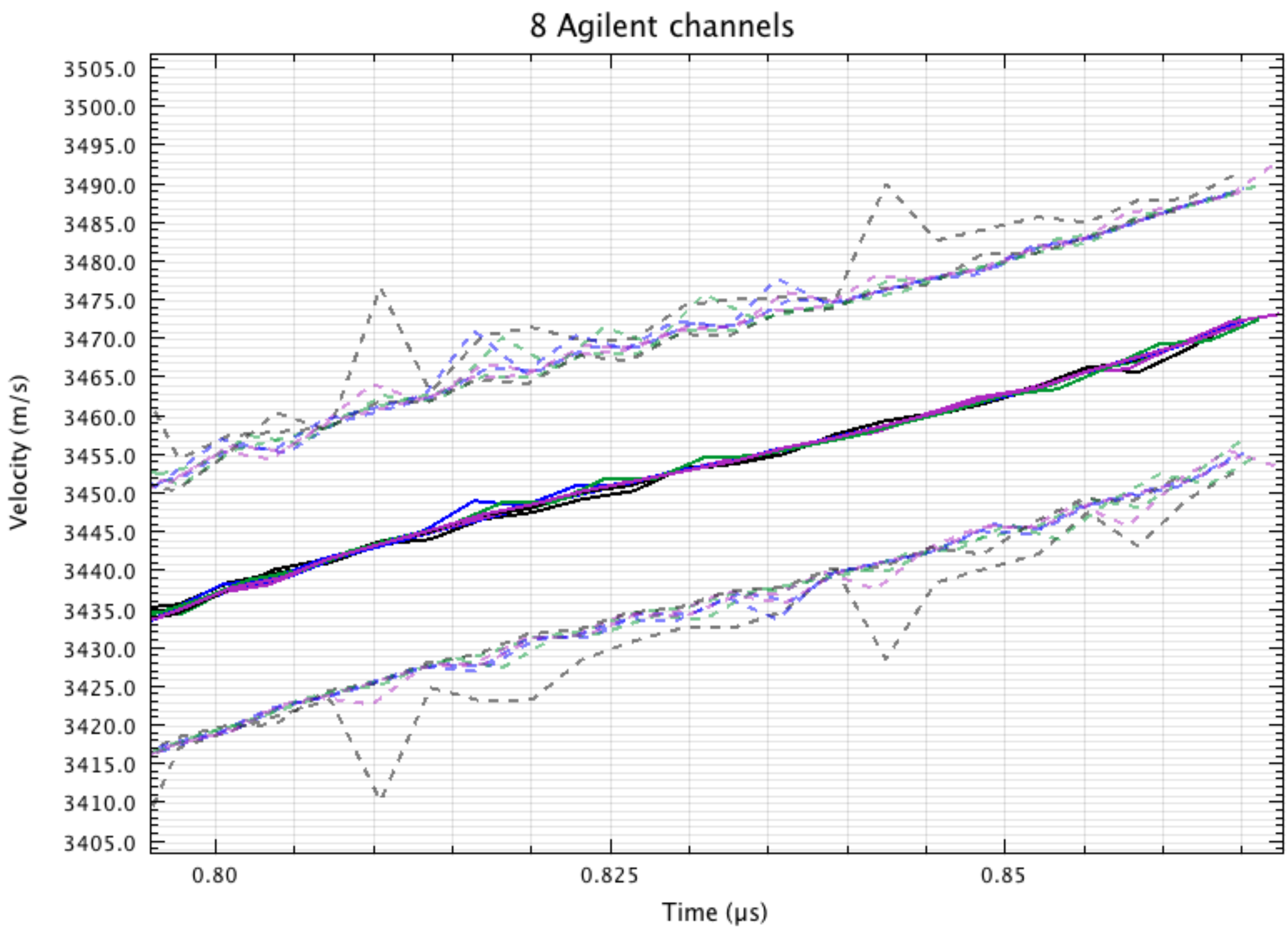
But at early times, the error bars show little difference…window width effect?



8 Channels at jump-off all lie inside each others error bars, except SOM of ch 3 (bin size effect)



During slow velocity ramps, the precision is <0.1 % …are the error bars too large here?



Summary

- Our understanding of precision and accuracy in PDV is limits on how good it could be, not what the actual error bars are.
- We split a single PDV probe signal optically 8x and measured the fringes with 8 PDV channels sharing a common laser.
- We did not know the velocity, so could not check accuracy.
- The results suggest that the error bars calculated from the standard statistical results of fitting a Gaussian or calculating a centroid range from reasonable to overly conservative estimates of the precision for the type of velocity trace studied.