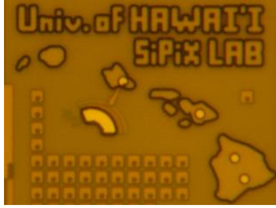


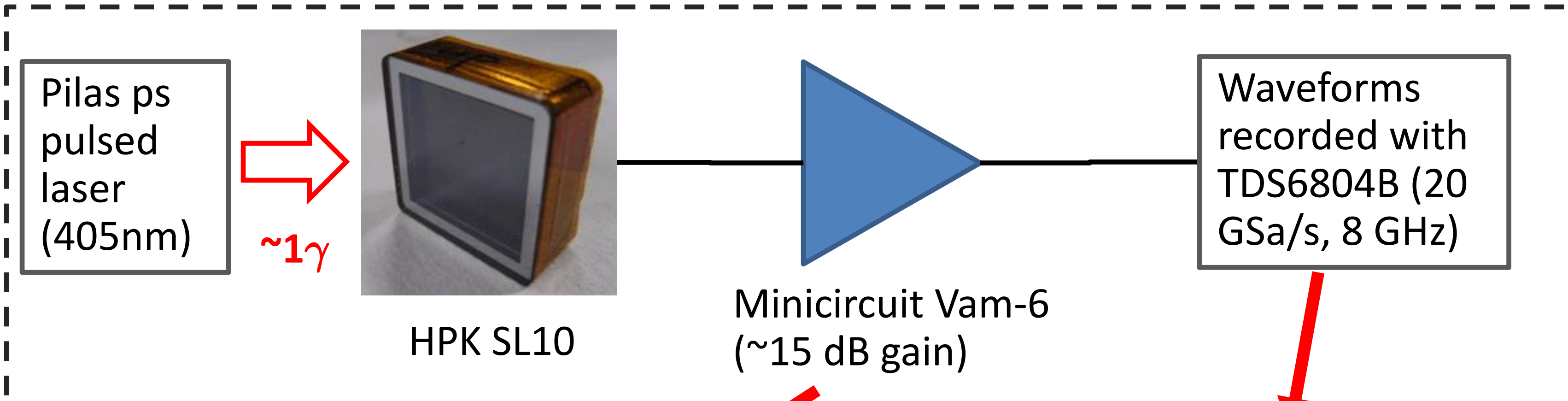
Hawaii Activities

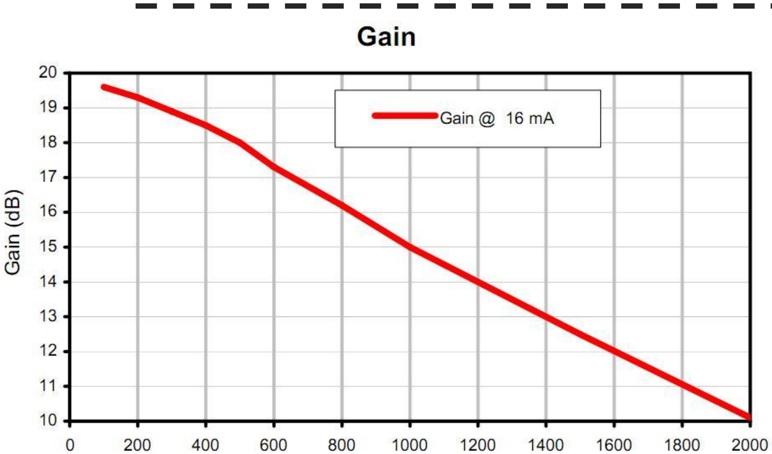
- Bandwidth/sampling analysis of fast PMT pulses
- Test structures for 3rd ASIC submission

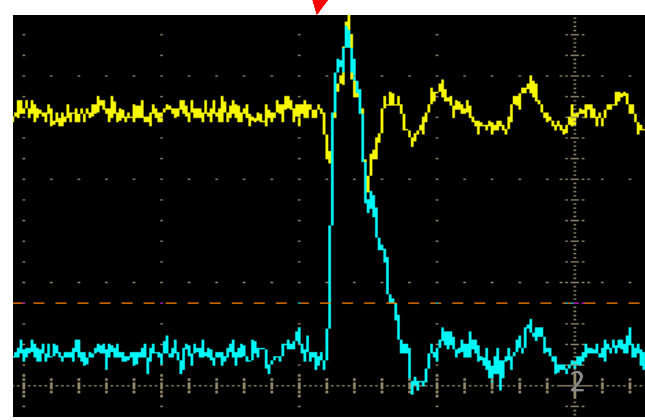
Juaquin Anderson
Matt Andrew
Tom Browder
Michael Cooney
Xin Gao
James Kennedy
Luca Macchiarulo
Kurtis Nishimura
Louis Ridley
Jamal Rorie
Larry Ruckman
Gary Varner

Analysis of Fast PMT Pulses

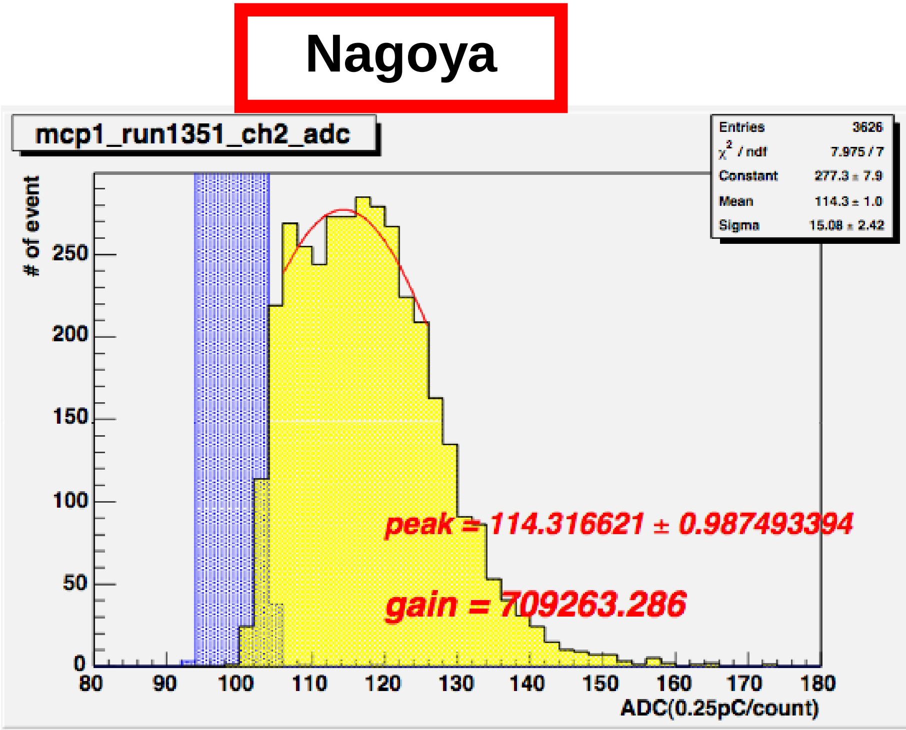
- Single photon test waveforms have been previously shown from the Hamamatsu SL10.
- Setup:

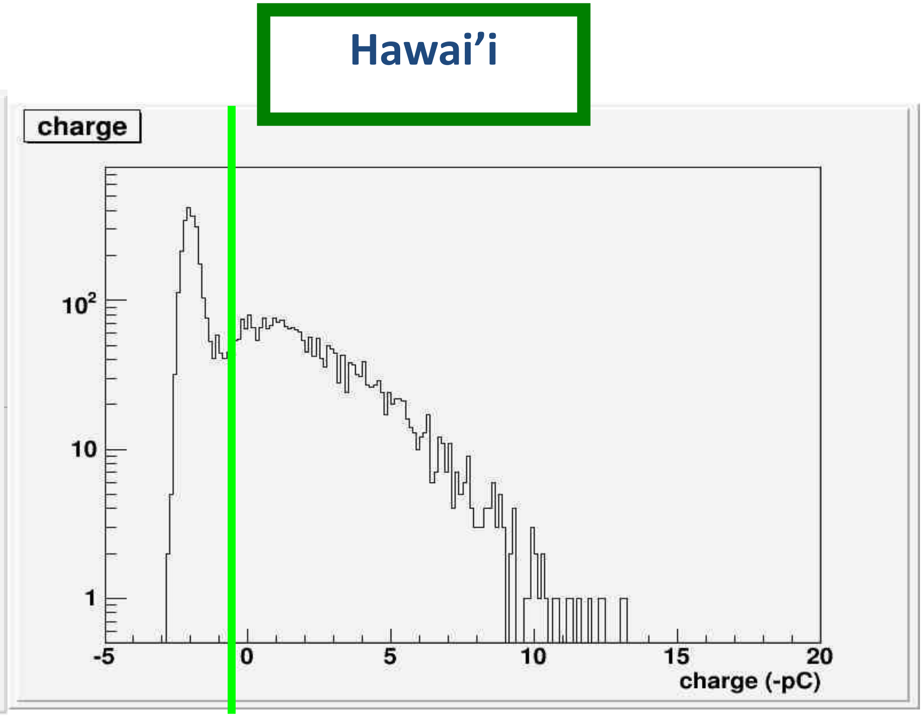






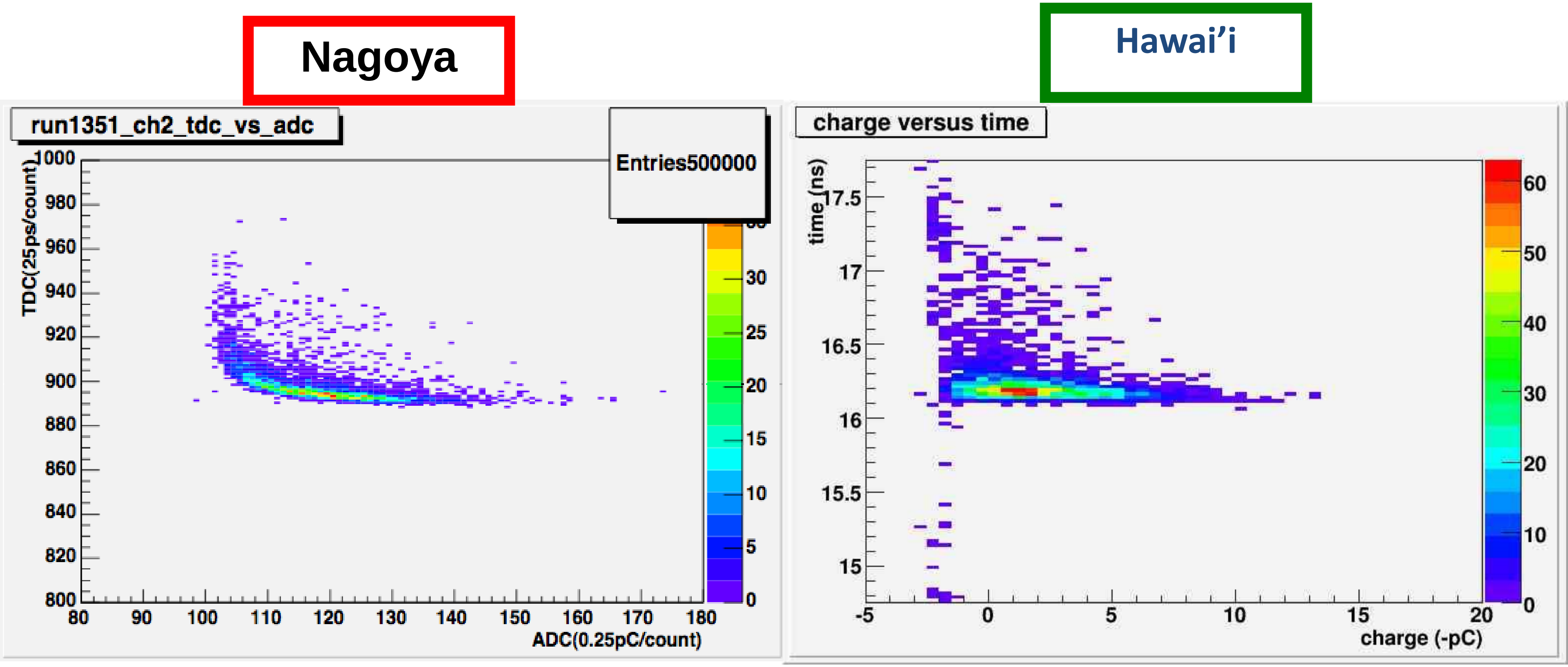
ADC Distributions





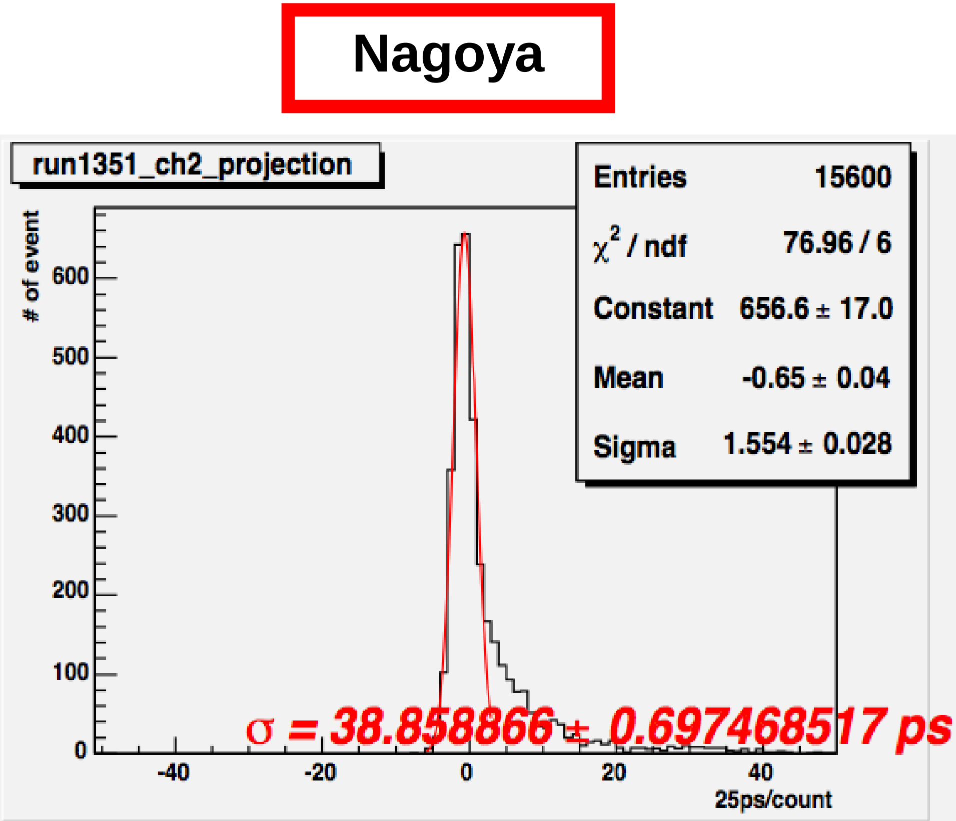
- Nagoya: larger gain for the external amplifier
- Hawai'i: recorded every waveform (even if no signal)

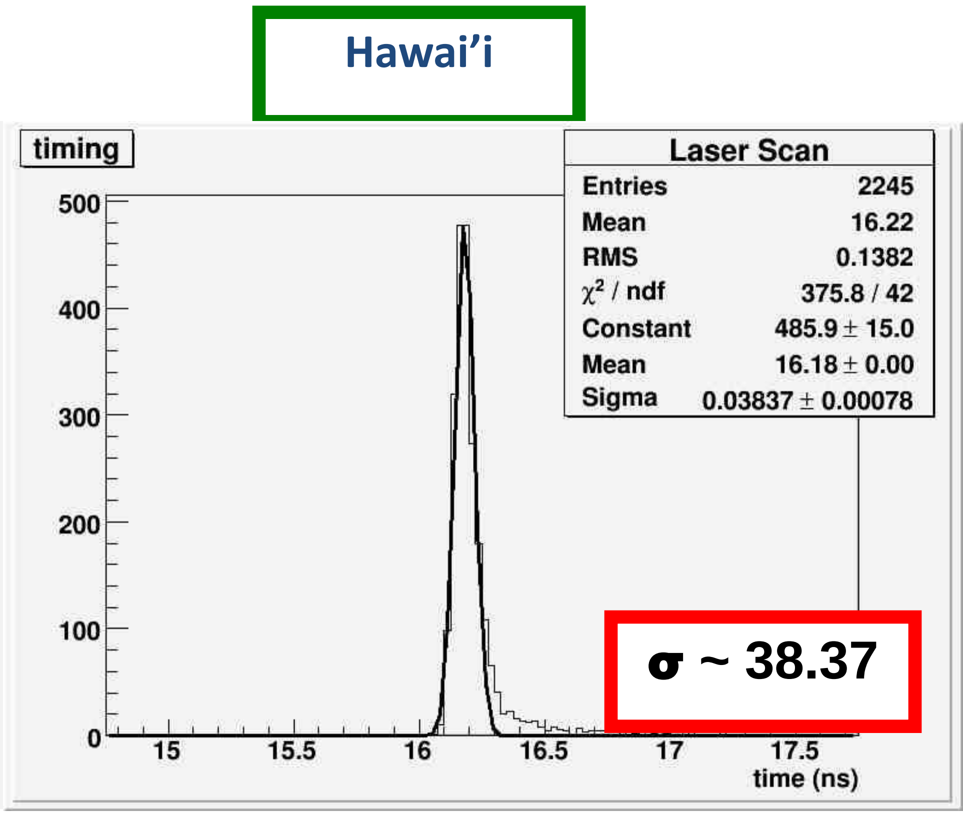
ADC vs TDC Distributions



- Nagoya: time-walk correction performed
  - time is measured by CFD
- Hawai'i: no time-walk correction performed
  - time is measured by interpolating the leading edge threshold crossing using waveform data
  - Threshold set to 50% of the peak voltage for each event

TDC Distributions (Single Photon Timing)



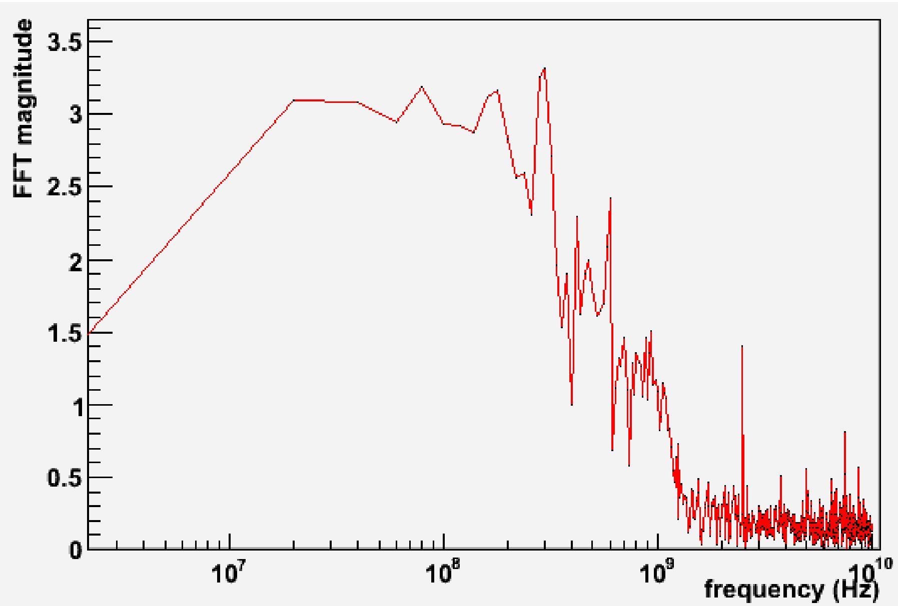


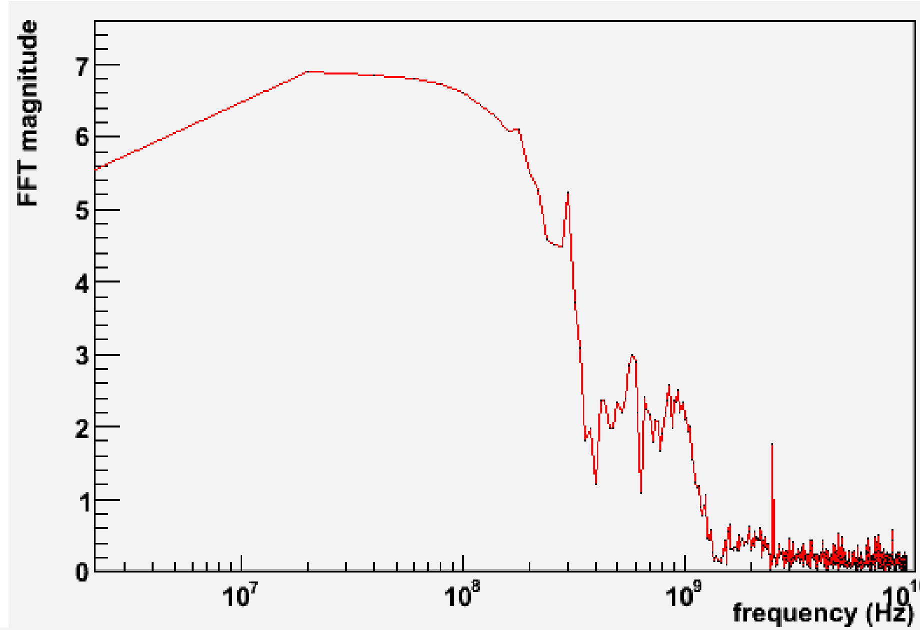
- Nagoya & Hawai'i measurement agree with each other
- Hawai'i has less of a tail in distribution
  - Less overall TDC RMS

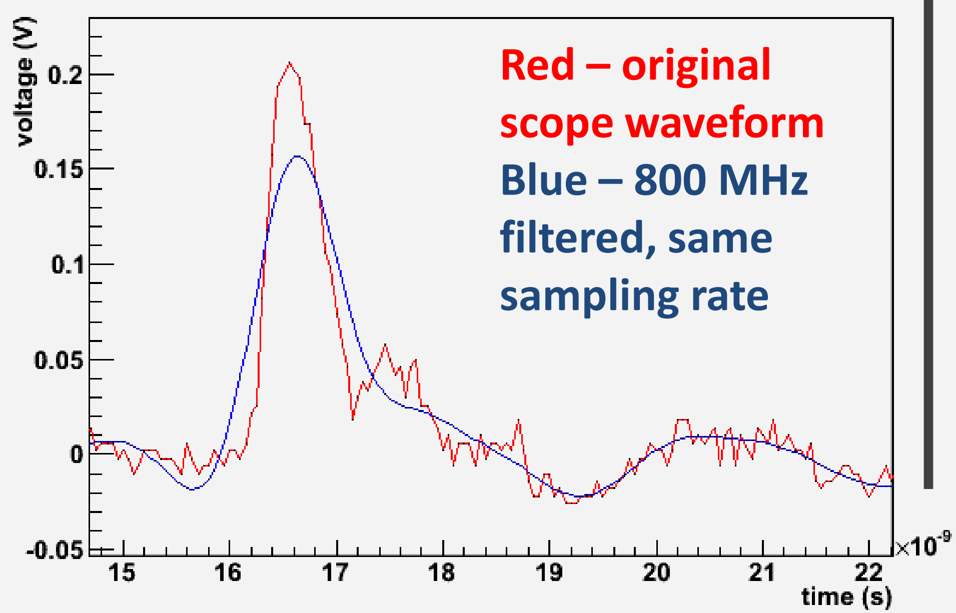
Updated Analysis

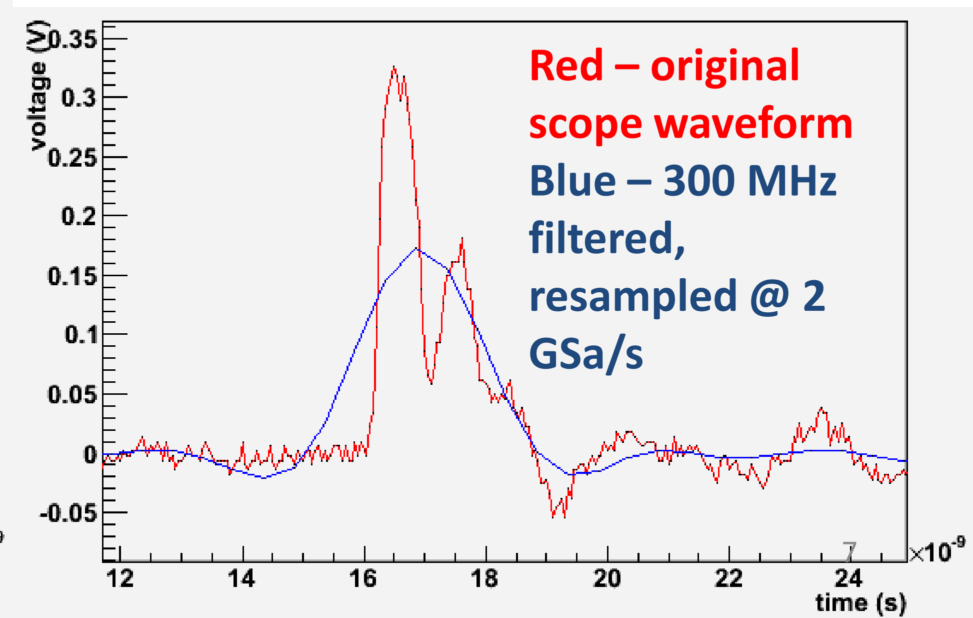
- Previous analysis used waveforms "as-is" from the scope.
- What happens if we have lower bandwidth and/or a lower sampling rate.
  - To test, for example, expected performance from a waveform digitizing ASIC.
- New analysis steps:
  1. Take FFT of the raw scope waveform
  2. Apply low pass filter with varying 3dB points to simulate bandwidth limitations.
     - In this analysis, we use a 4^{th} order Butterworth filter, but we can explore others, for example simulated frequency response of a waveform digitizing ASIC.
  3. Transform back to the time domain
  4. Downsample to simulate lower sampling rate.
     - We take every N^{th} point, with initial offset randomly chosen from 0 to N-1. We can make this more sophisticated as well, but interesting to start.
  5. Perform timing measurement similar to before.
     - We find the time to reach 30% of the measured peak voltage.

Sample Spectra, Waveforms



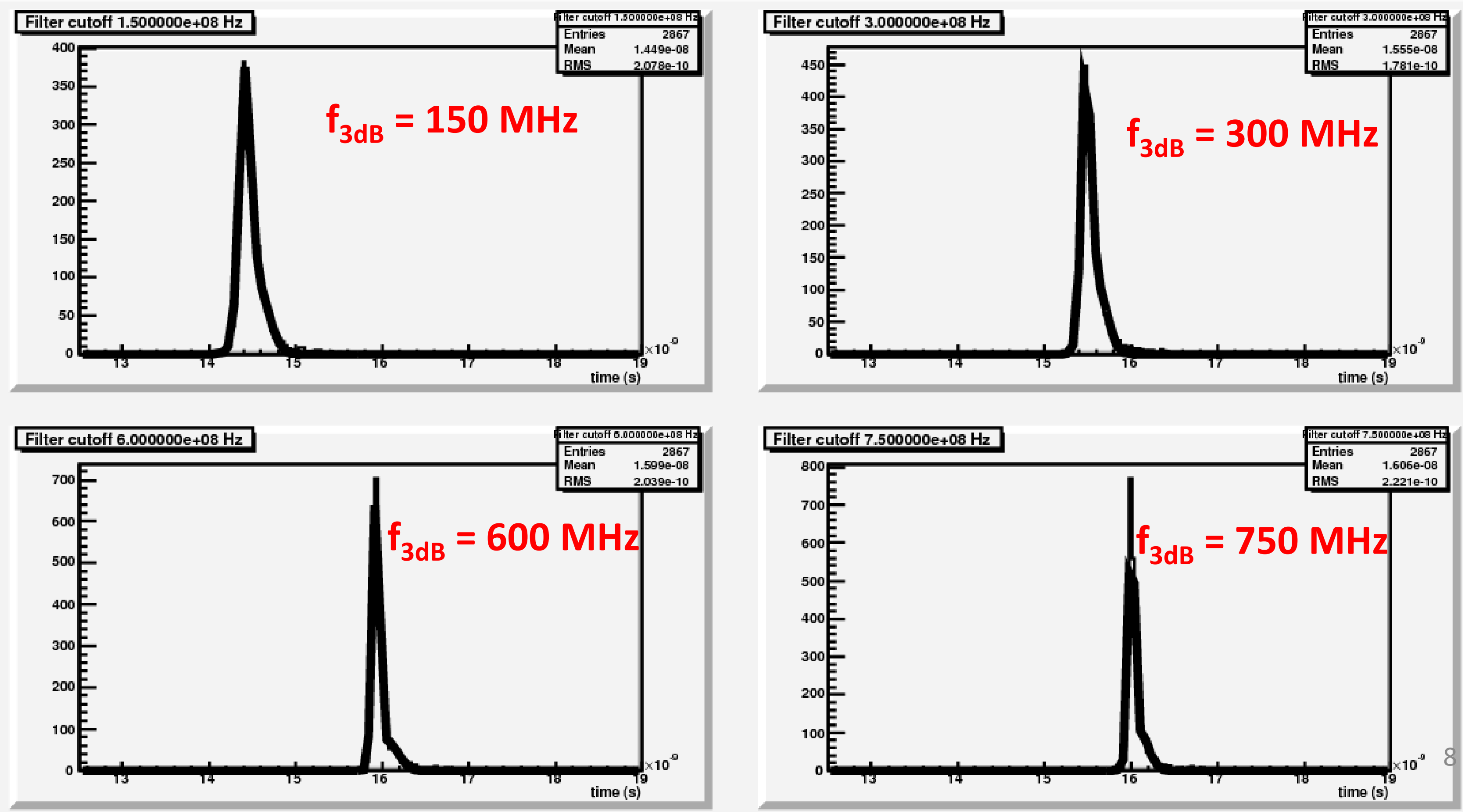


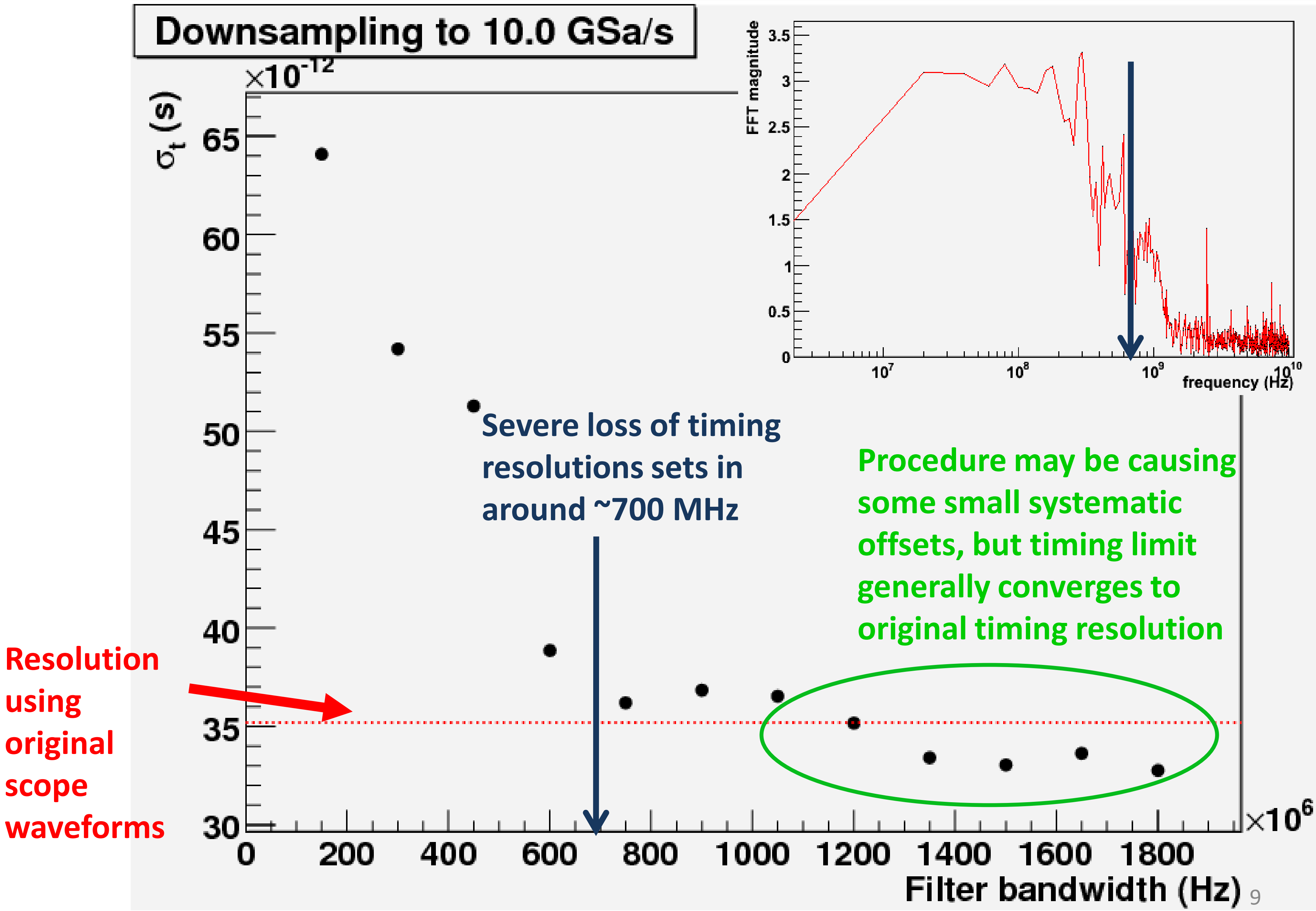


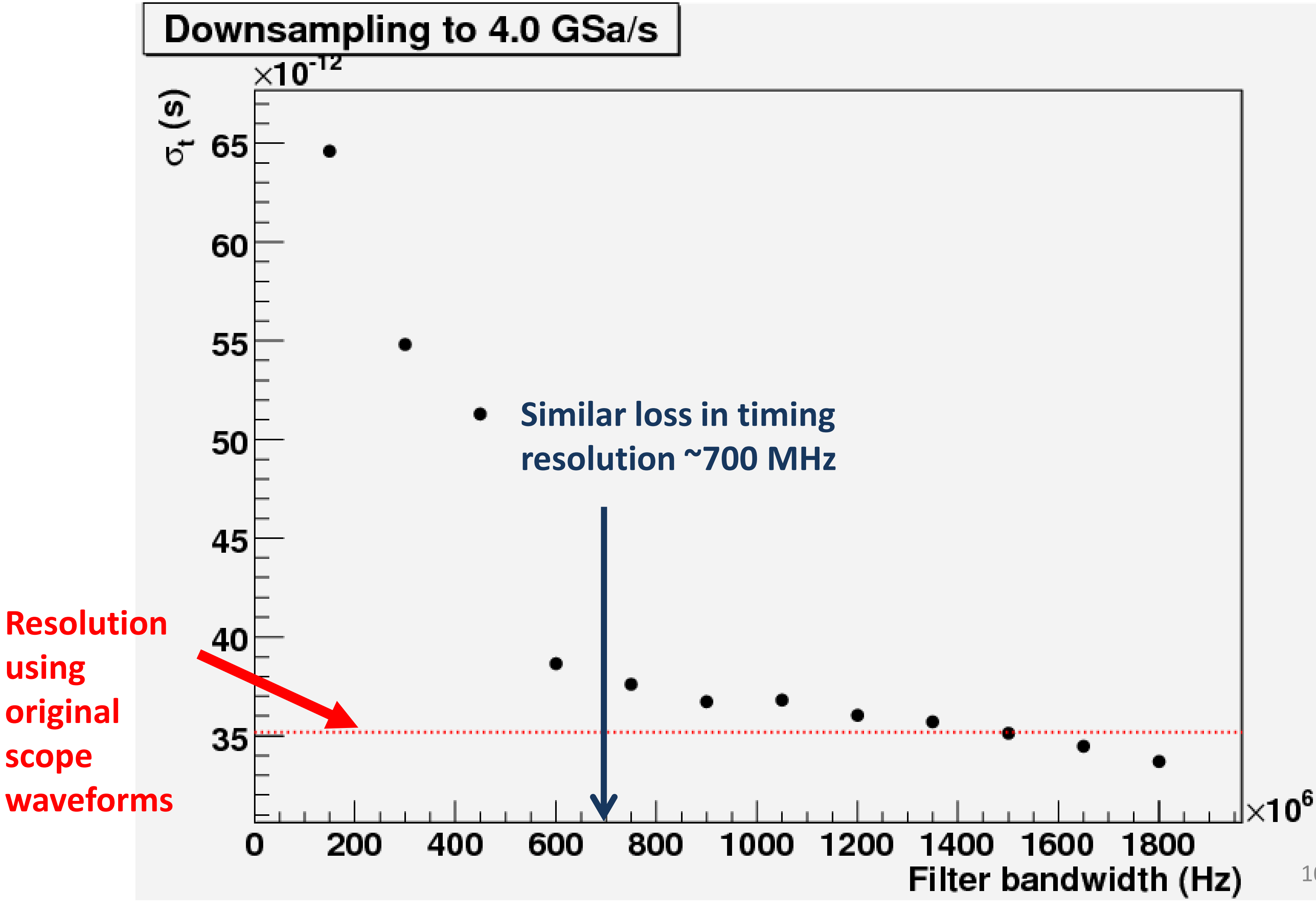


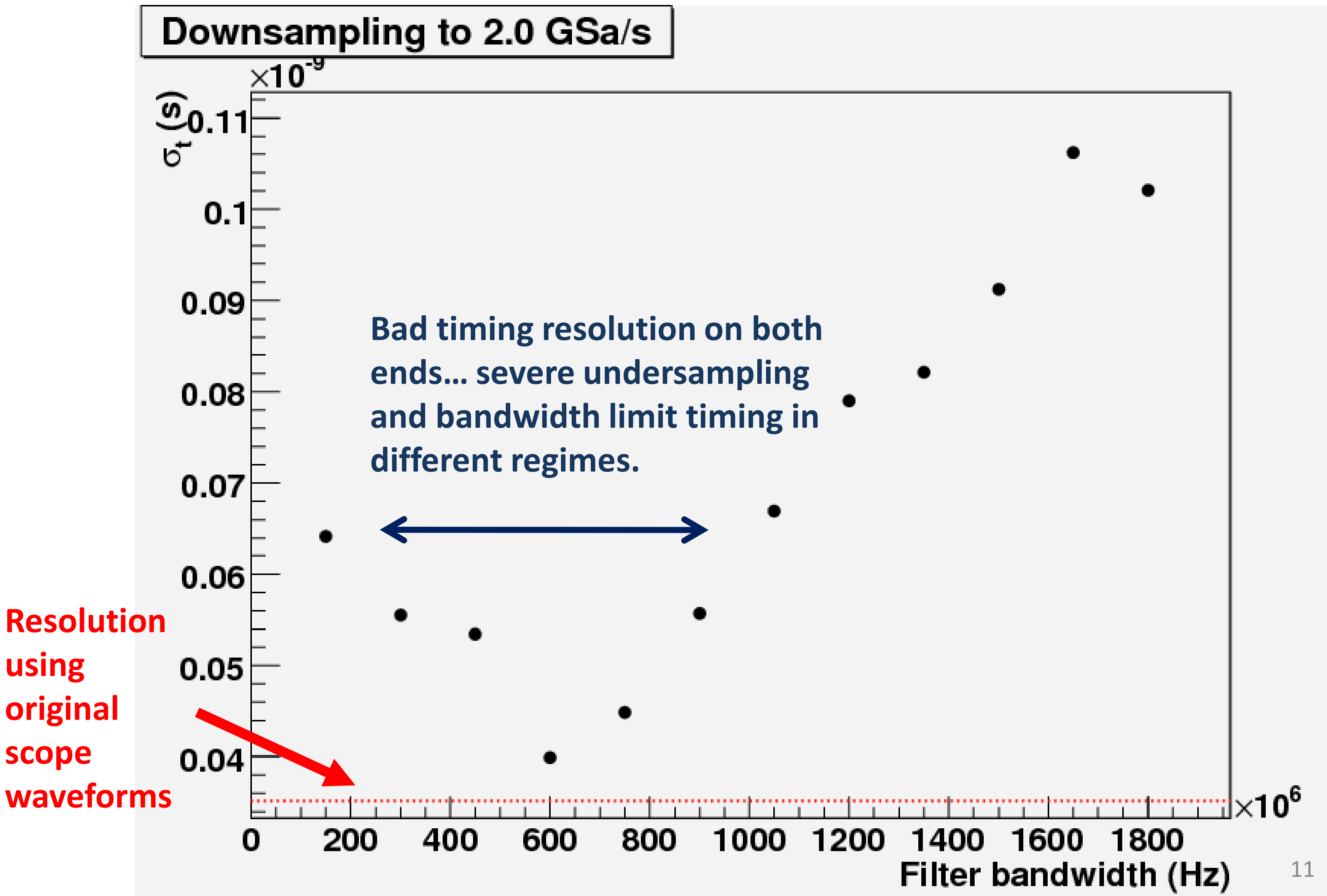
Single Photon Timing Resolutions

- Double Gaussian fits to the distribution of calculated times (using 30% of peak voltage method)
- Time resolution is σ of the narrow Gaussian.
- Example fits @ 10 GSa/s downsampling:




Downsampling to 10.0 GSa/s
×10^-12
σt (s)
65
60
55
50
45
40
35
30
0
200
400
600
800
1000
1200
1400
1600
1800
×10^6
Filter bandwidth (Hz)
FFT magnitude
frequency (Hz)
Severe loss of timing resolutions sets in around ~700 MHz
Procedure may be causing some small systematic offsets, but timing limit generally converges to original timing resolution
Resolution using original scope waveforms


Downsampling to 4.0 GSa/s
×10^-12
σt (s)
65
60
55
50
45
40
35
0
200
400
600
800
1000
1200
1400
1600
1800
×10^6
Filter bandwidth (Hz)
Similar loss in timing resolution ~700 MHz
Resolution using original scope waveforms


Downsampling to 2.0 GSa/s
×10^-9
σ_t (s)
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0
200
400
600
800
1000
1200
1400
1600
1800
×10^6
Filter bandwidth (Hz)
Bad timing resolution on both ends… severe undersampling and bandwidth limit timing in different regimes.
Resolution using original scope waveforms

Analysis Summary & Future Work

- Preliminary analysis results indicate for a fast PMT (in this case the HPK SL10, single photon σ_t ~35 ps), the important part of the signal for timing is all $\lesssim$ 700 MHz.
  - (Provided that the sampling rate is adequate.)
- This type of analysis could be useful to determine optimal or adequate bandwidths and/or sampling rates.
- As needed, can implement:
  - More realistic responses
  - More sophisticated downsampling estimates

Hawaii Contributions for 3rd ASIC Submission

- Test structures planned for inclusion in the next ASIC submission:
  - Matt Andrew: Ring oscillator, high speed flip flop
  - Wei Cai: Charge sensitive amplifier
  - Mike Cooney: High speed LVDS transceiver
  - Kurtis Nishimura: Analog switch into waveform sampling array (high bandwidth)
  - Larry Ruckman: Analog switch for sampling cell ➔ storage cell
- Design review: tentatively April 28th.