PSEC3 Ongoing Timing Calibration

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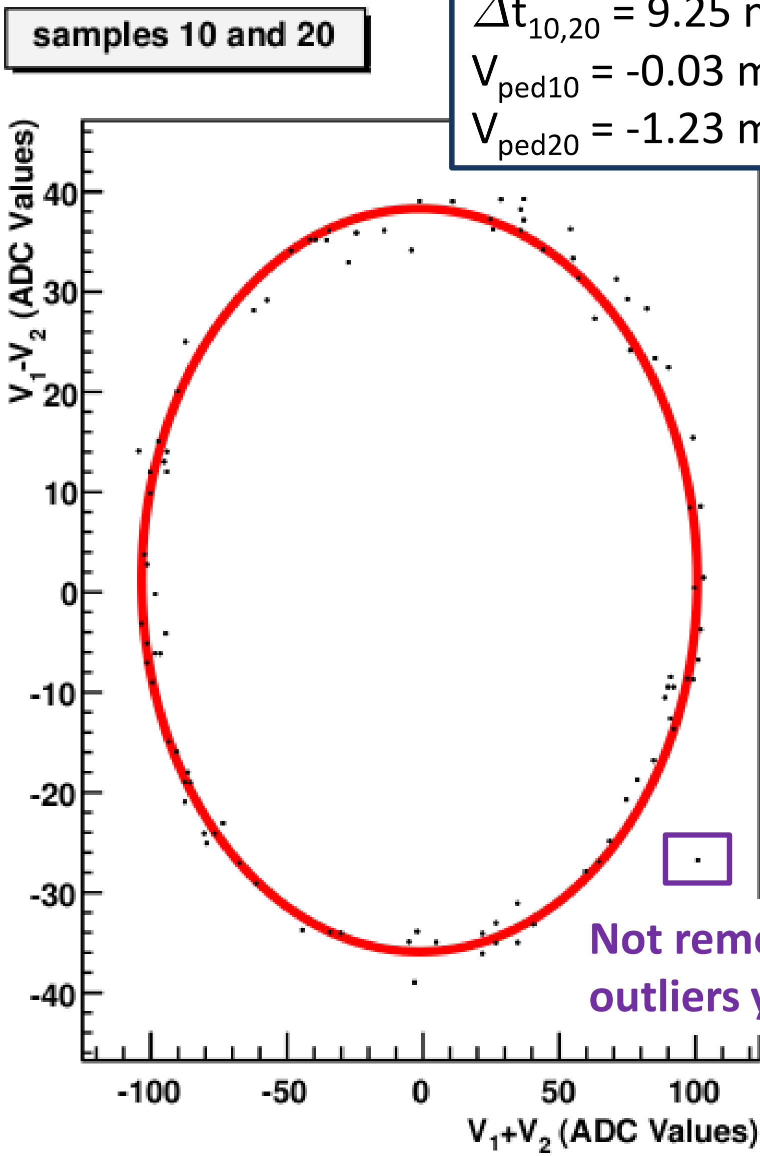
Data samples

- PSEC3 data from Eric:
  - 10 GSa/s
  - CH3 (256 sample cells)
  - 100 events each of:
    - 40 MHz
    - 120 MHz
- Fits ellipses to correlated voltage pairs:
  - $\Delta t_{i,i+10}$ fitted from V[i+10] – V[i] vs. V[i+10] + V[i]
  - $\Delta t_{i+1,i+10}$ fitted from V[i+10] – V[i+1] vs. V[i+10] + V[i+1]
  - **First stab at $\Delta t_{i,i+1} = \Delta t_{i,i+10} - \Delta t_{i+1,i+10}$**
  - *The gap of 10 samples is to deal with the high sampling rate. It is, for now, arbitrary… should study what works best.*

Example Fit

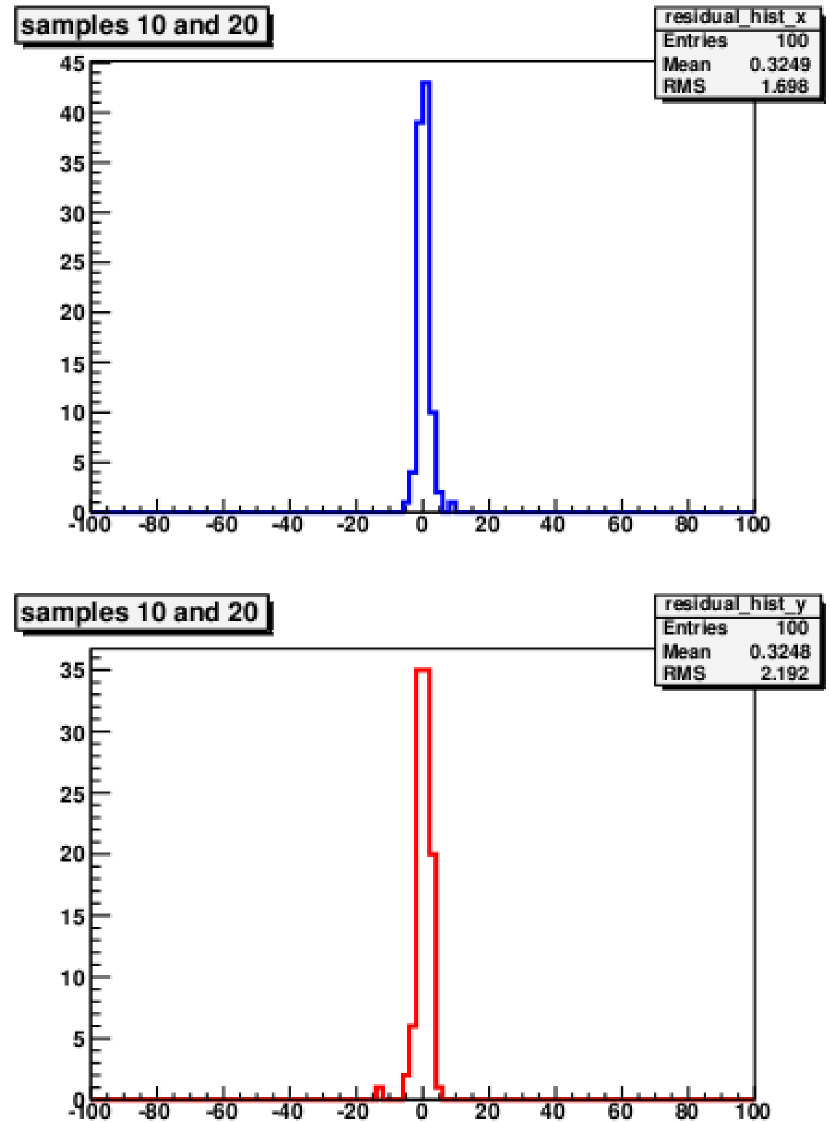
Data and fit

A = 54.30 mV
$\Delta t_{10,20}$ = 9.25 ns
V_{ped10} = -0.03 mV
V_{ped20} = -1.23 mV

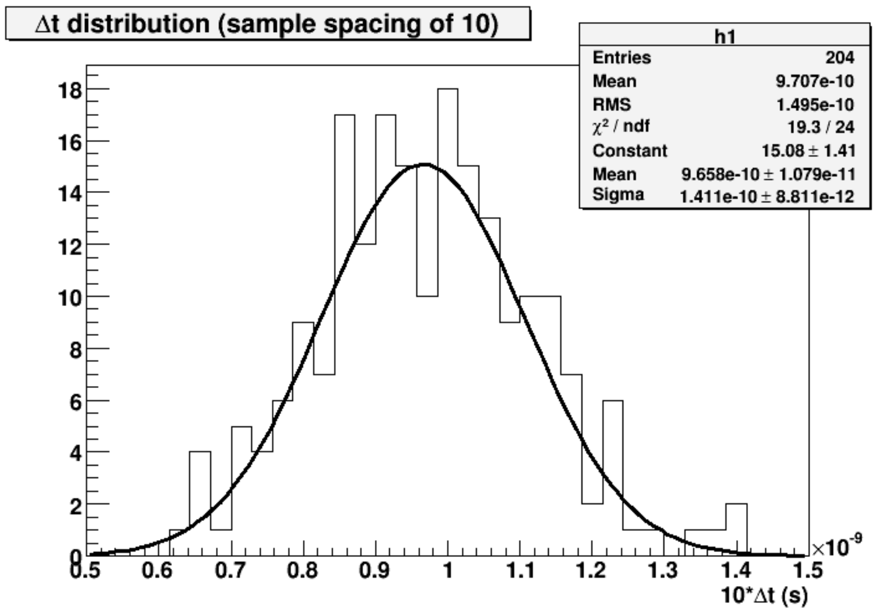


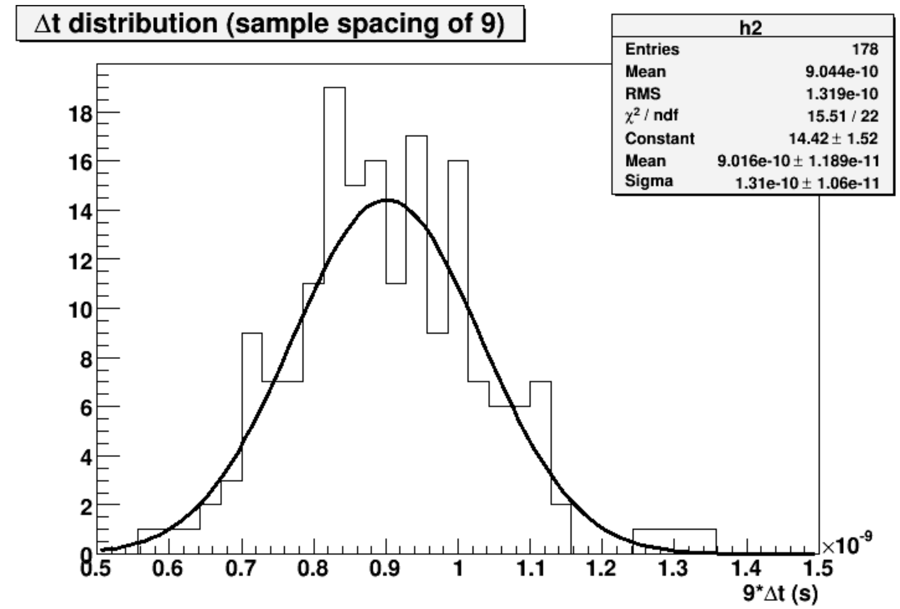
Not removing outliers yet…

Residuals in x, y



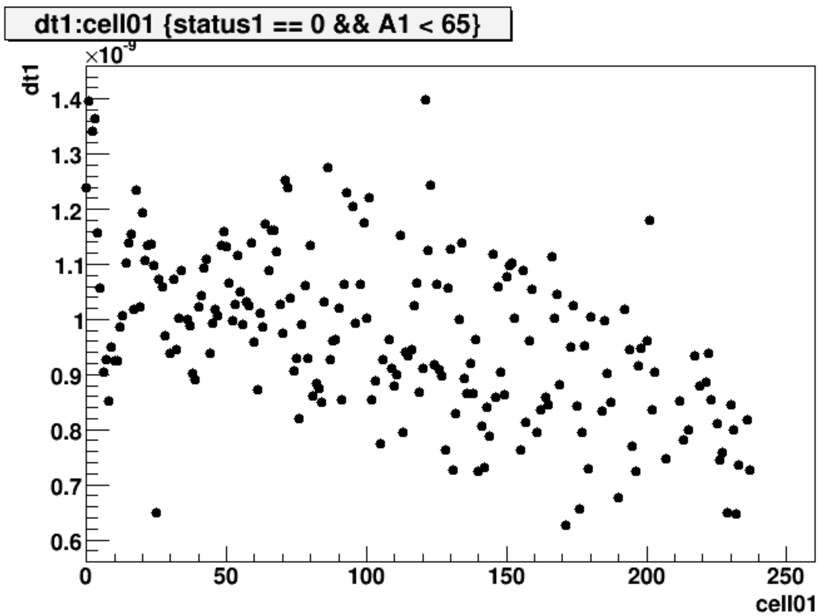
Distributions of $\Delta t_{i,i+10}$ and $\Delta t_{i,i+9}$

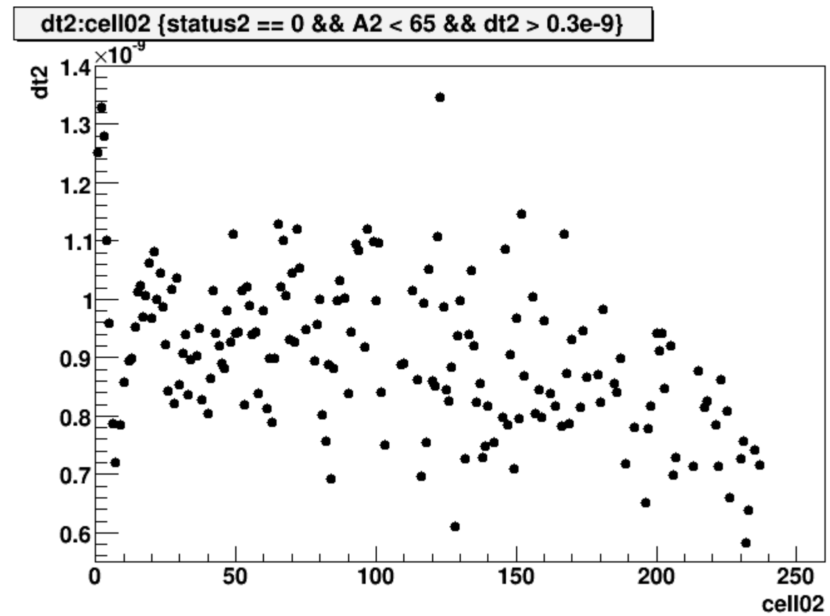




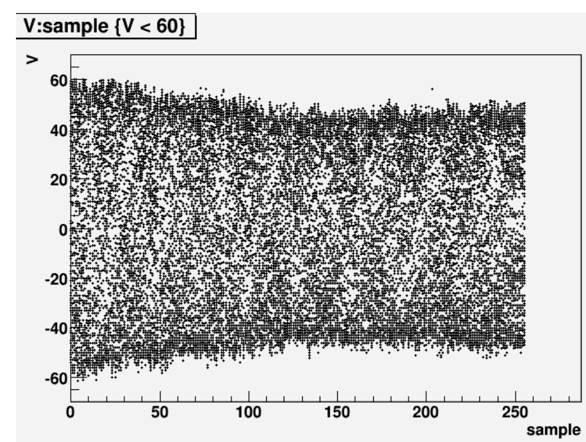
- Number of entries ≠ 256 due to some failed / bad fits.
- Width of distributions (~15% of mean) potentially reflects:
  - Natural variation in Δt values.
  - Resolution (or artifacts) of this procedure.
  - ➔ Not yet clear which dominates… more statistics could help.

$\Delta t_{i,i+10}$ and $\Delta t_{i,i+9}$ vs. Sample Cell

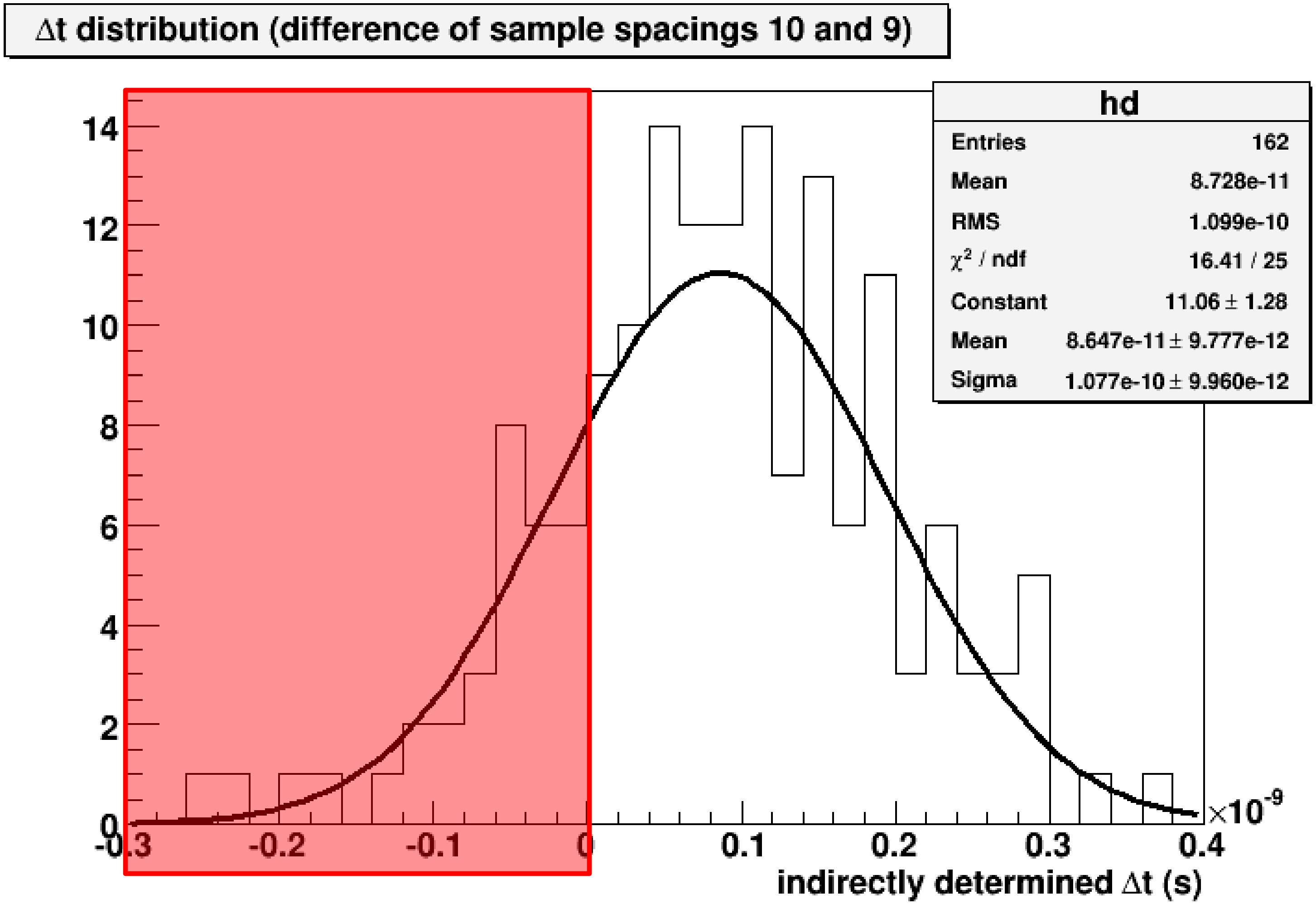




- Definite structure with respect to sample cell.
  - Is this due to a genuine timing difference or an artifact?
  - Maybe due to visible gain difference as a function of sample cell? (Right: all 100 waveforms for 120 MHz data plotted on top of one another)

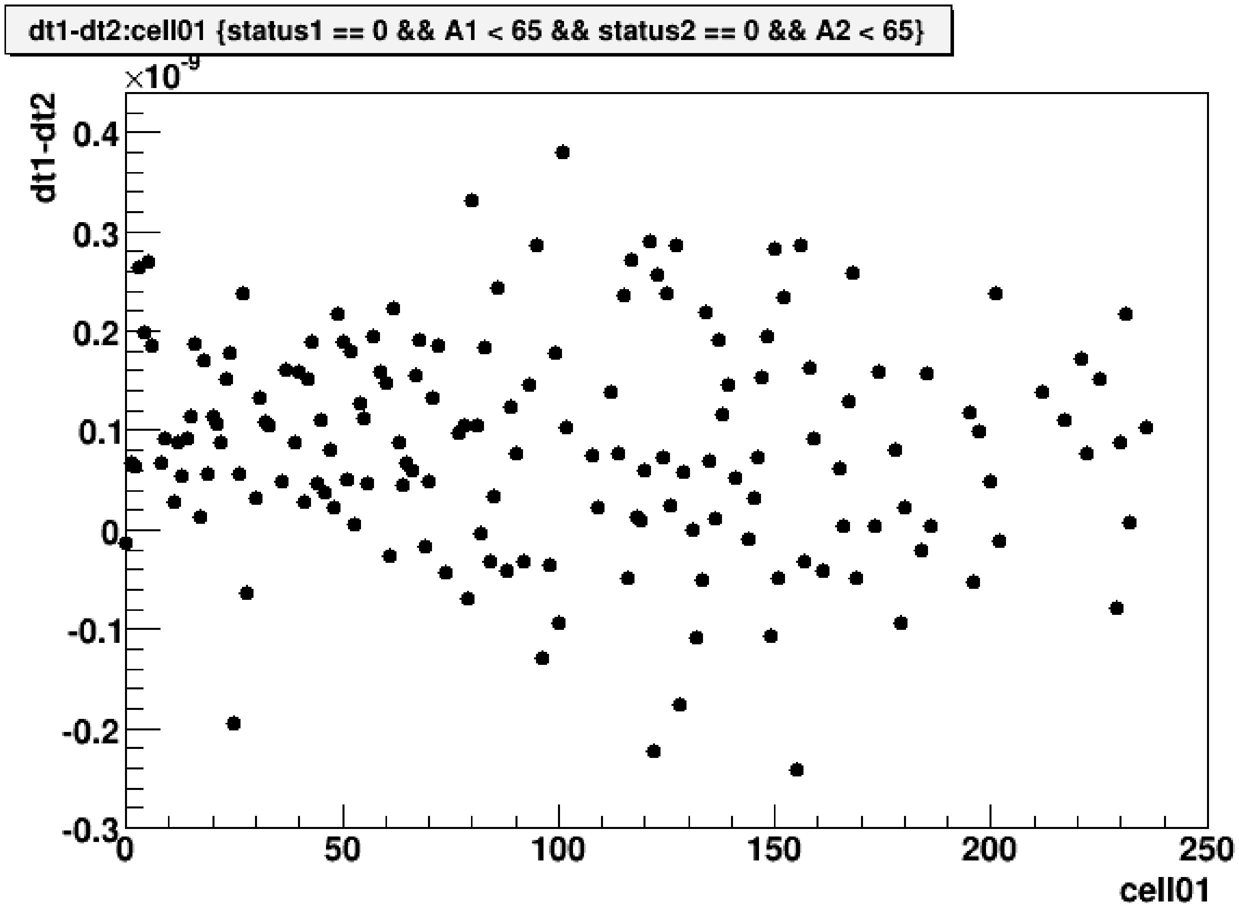


Derived Distribution of $\Delta t_{i,i+1}$



➔ Mean is reasonable for 10 GSa/s, but procedure is obviously not perfect… **negative Δt is unphysical**.

Distribution of $\Delta t_{i,i+1}$ vs. Sample Cell



- No obvious(?) pattern.

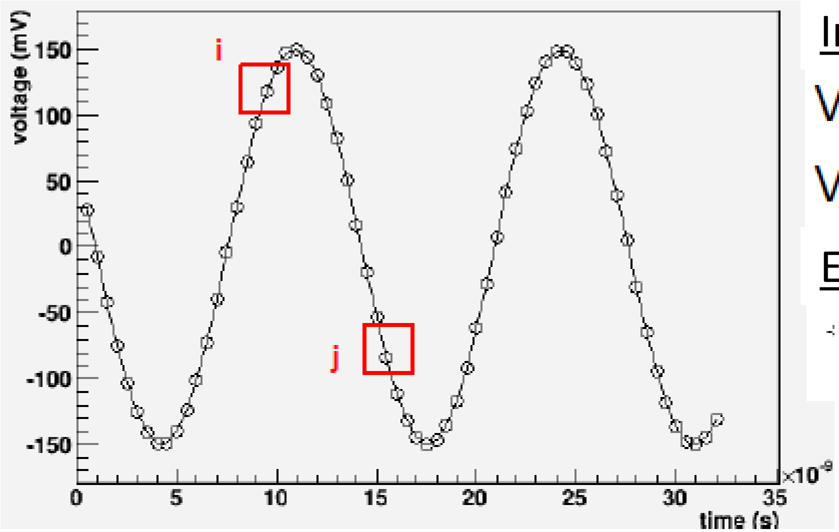
Lots left to do / potential improvements…

- Better combinations of $\Delta t_{i,j}$ values to get $\Delta t_{i,i+1}$.
  - Can utilize significant overconstraints of system by fitting for many (or all) feasible i,j pairs.
- Increase fit robustness:
  - Add outlier rejection.
  - Recover failed or bad fits.
- Increase statistics.
- Increase input frequency(?)
  - May be bandwidth limited.
- Apply Δt values from 120 MHz data to 40 MHz data:
  - Ellipse fits with Δt values fixed, fit for f_{input}.
  - Sine wave fits to 40 MHz data.
- Modify fitter to get meaningful errors.
- More next week…

BACKUP

Timing Calibration w/ Correlations

- Plot correlations between pairs of samples:
  - To determine Δt_{ij}, plot $V_i - V_j$ versus $V_i + V_j$



Input signals given by:

$V_i = A \sin(\omega t_i + \phi)$

$V_j = A \sin(\omega t_j + \phi)$

Effectively rotate by 45°:

- $x := V_i + V_j$
- $y := V_i - V_j$

$$\rightarrow \frac{x^2}{4A^2\cos^2(\omega\delta t/2)} + \frac{y^2}{4A^2\sin^2(\omega\delta t/2)} = 1$$

i and j can be adjacent (or not), but should not be > 1 period apart.

*Method and results from Andres-Romero Wolf and myself, with data from LAB3. Planning as TIPP submission(?)

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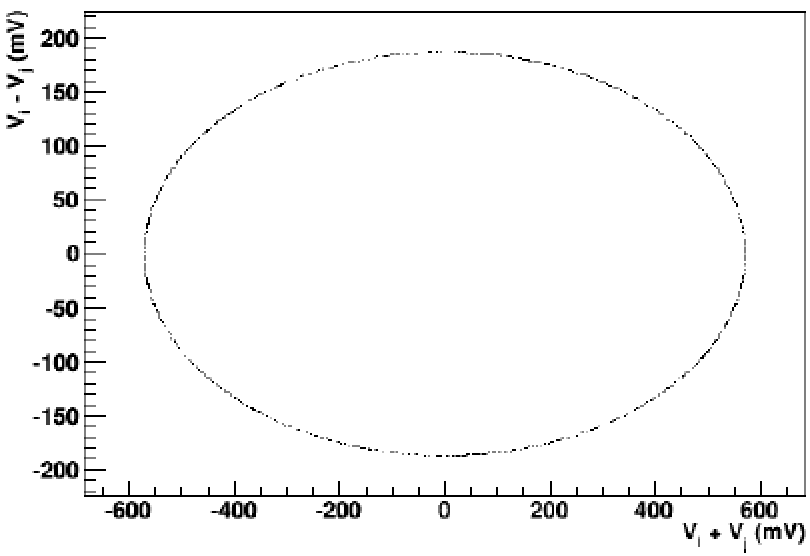

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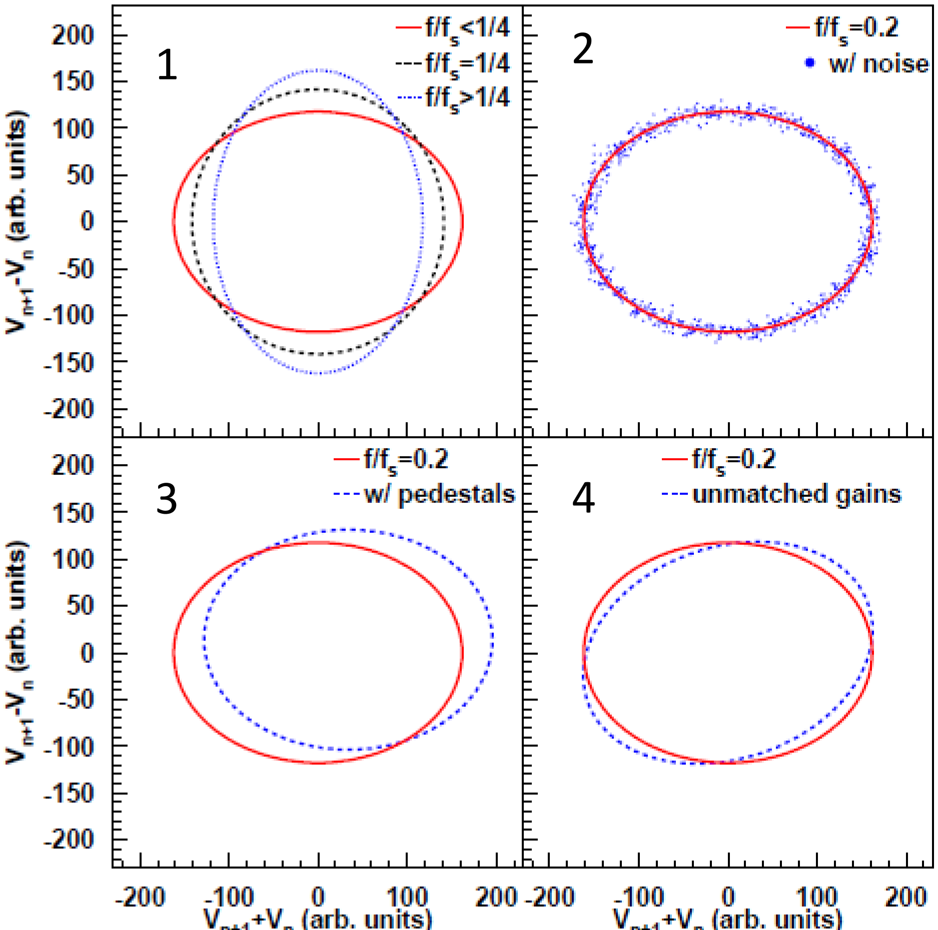
Timing Calibration w/ Correlations

- Ellipse features:



1) Different Δt (for known sampling frequency) give different major/minor radii.
2) Noise makes ellipse "fuzzy"
3) Nonzero pedestals shift origin
4) Difference in gain between two cells causes a rotation.

➔ We have written an ellipse fitter to perform this method.
➔ Even without fitting, it provides nice qualitative check on results.

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