PSEC3 Ongoing Timing Calibration

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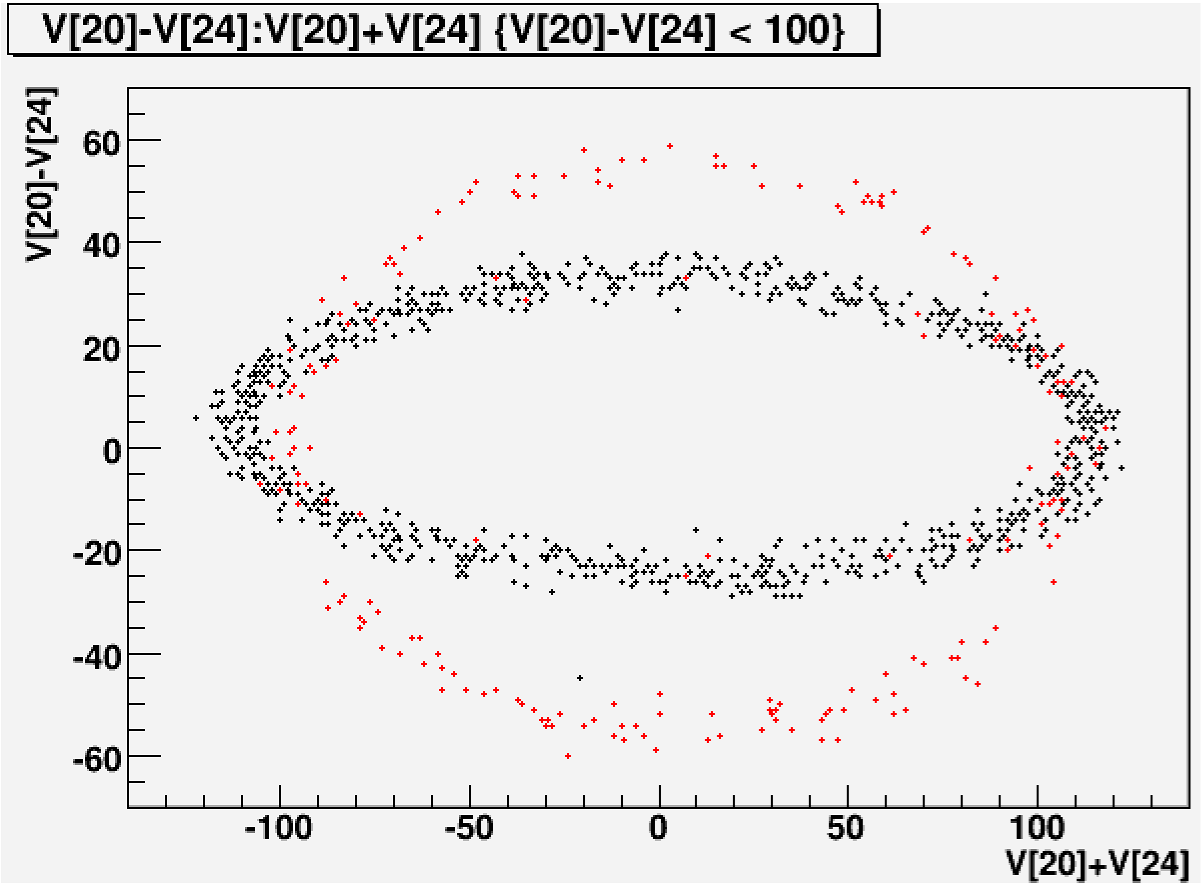
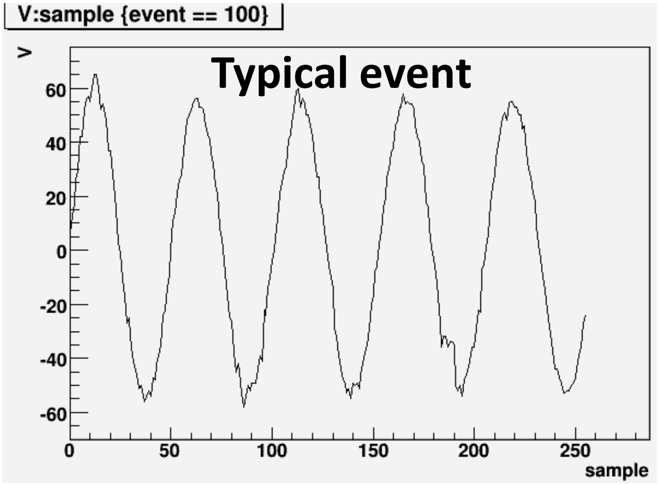
Data samples

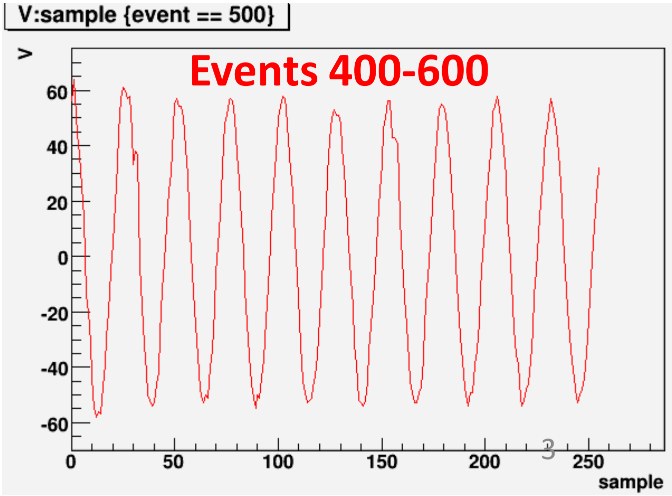
- Old PSEC3 data from Eric:
  - 10 GSa/s
  - CH3 (256 sample cells)
  - 100 events each of:
    - 40 MHz
    - 120 MHz
- **New PSEC3 data from Eric:**
  - **5 GSa/s**
  - **CH3 (256 sample cells)**
  - **1200 events of:**
    - **100 MHz**

Qualitative Features of New Data

- Sampling rate slipped in events **~400-600**:

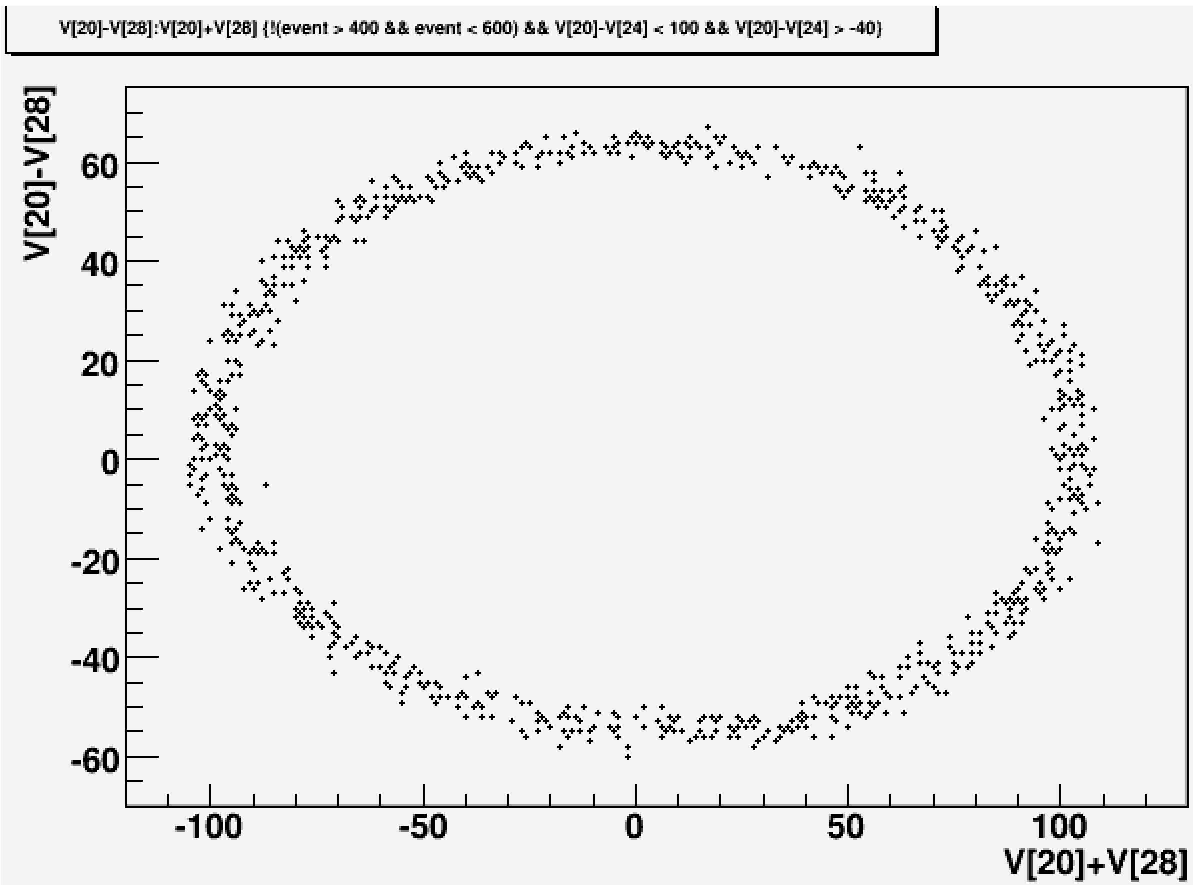


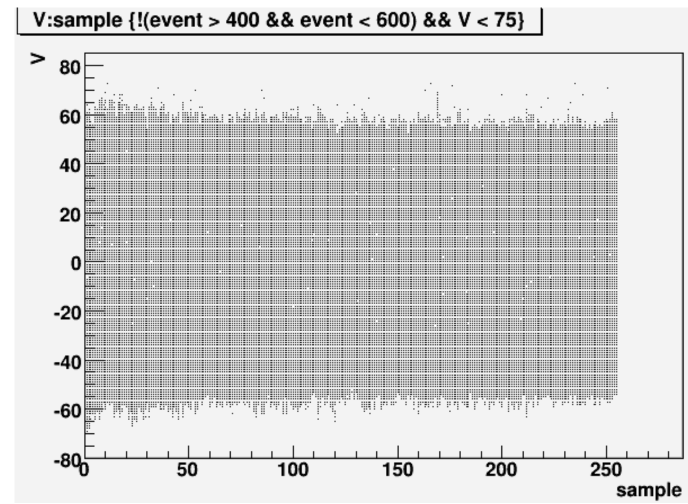




Qualitative Features of New Data

- Some gain variation between cells?
  - Manifests as rotation of ellipse.



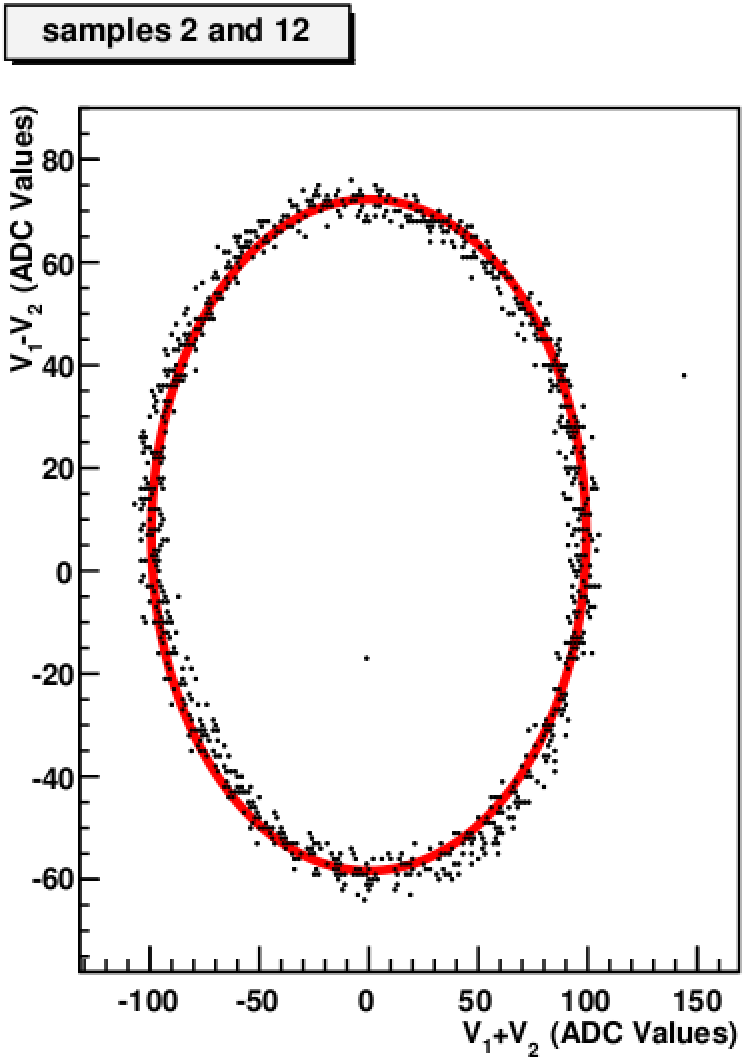


All waveforms except events 400-600

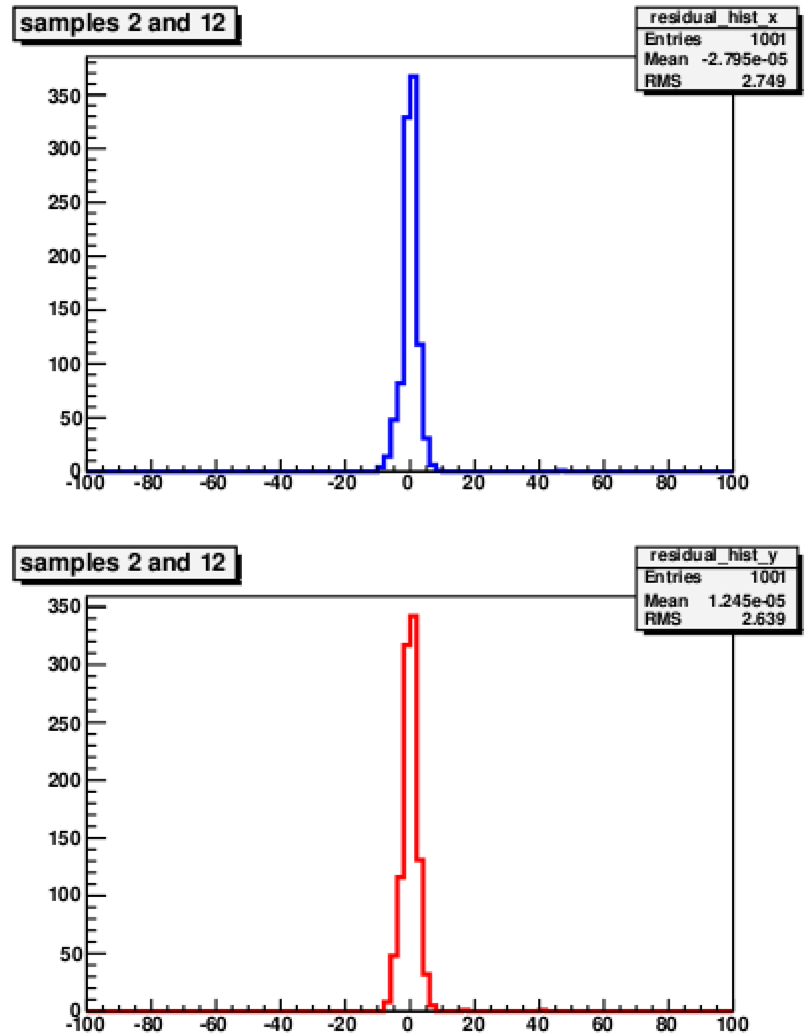
➔ If so, very small… not incorporating the effect into fit at this time.

Example Fit

Data and fit

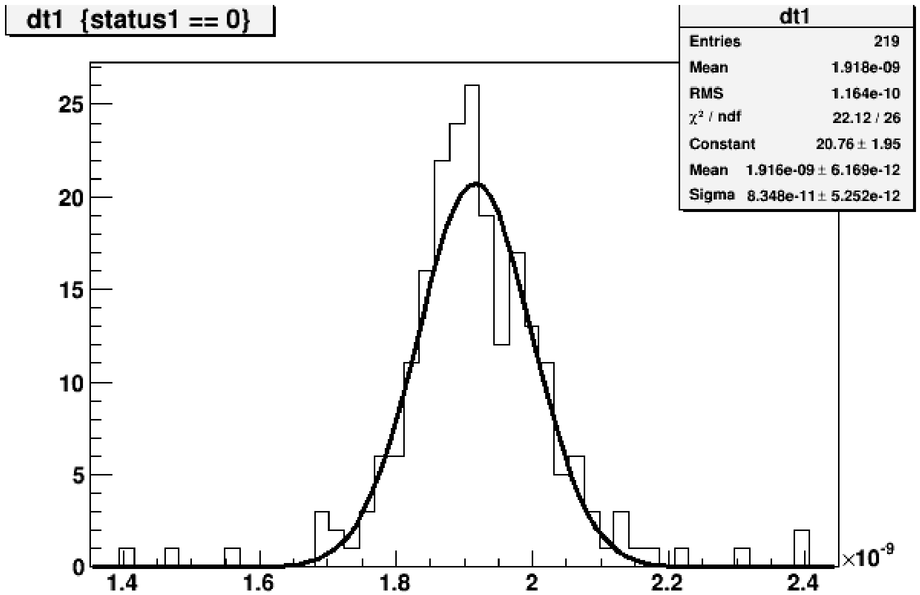


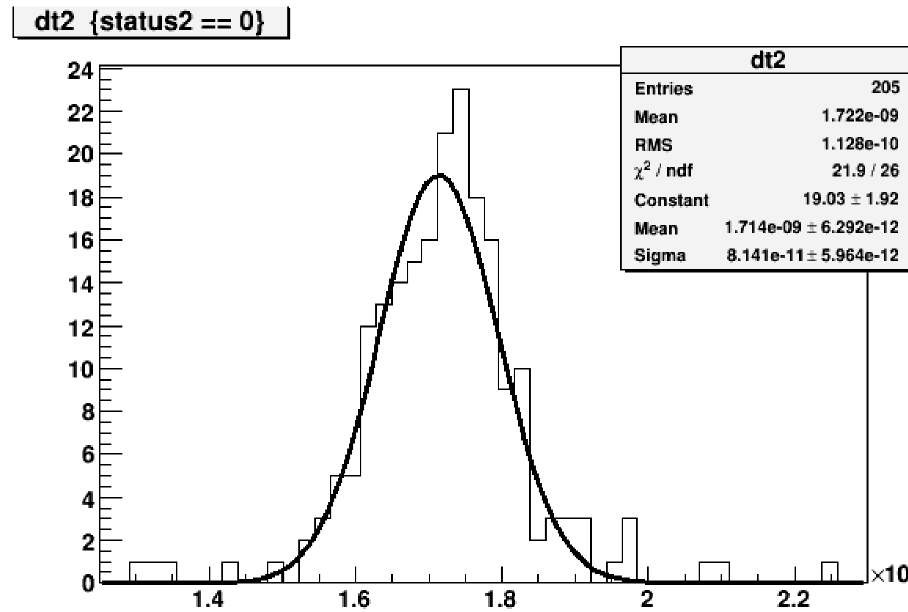
Residuals in x, y



➔ Improved first guess procedure, relatively robust.
Still some fit failures due to outliers… need to implement outlier removal.

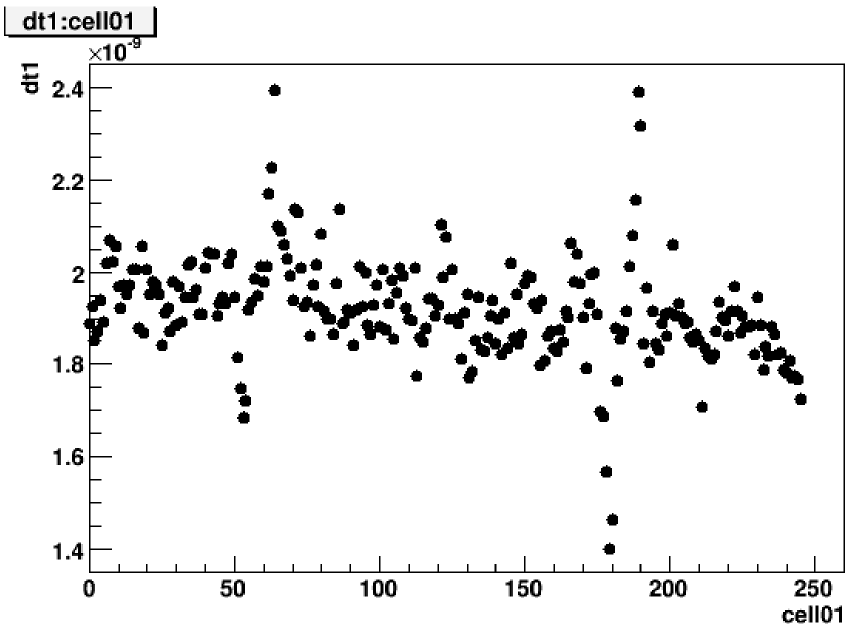
Distributions of $\Delta t_{i,i+10}$ and $\Delta t_{i,i+9}$

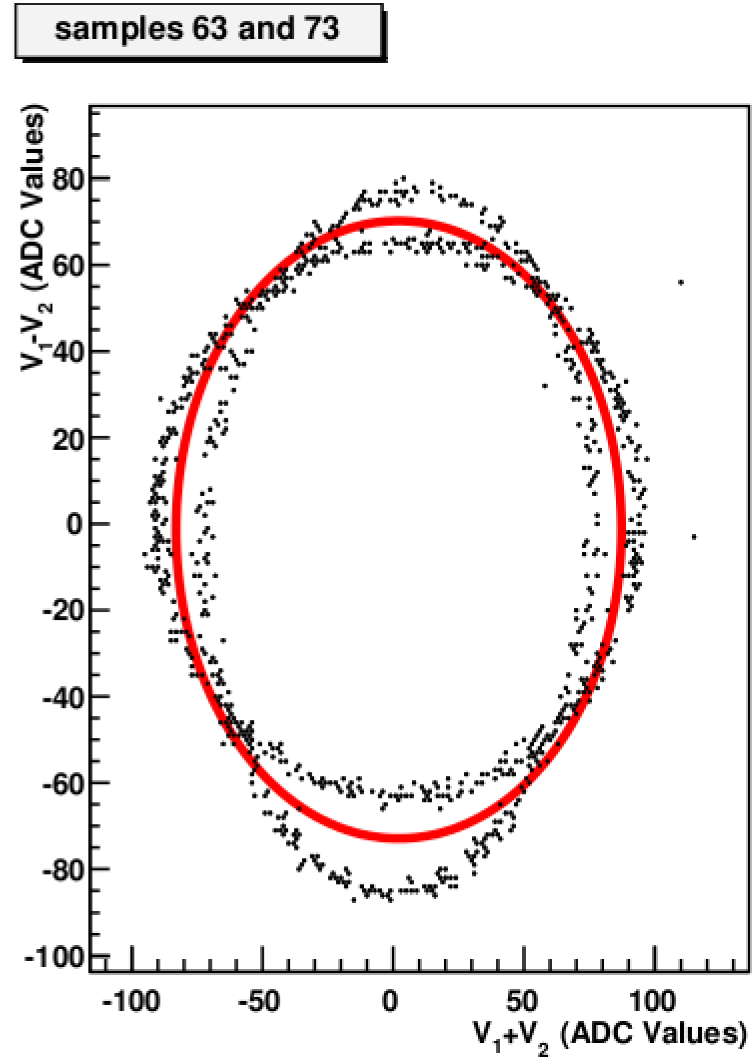




- Number of entries ≠ 256, (still) due to some failed / bad fits.
- Width of distributions (~5% of mean, compared to ~15% last time):
  - ➔ Previous calibration was definitely statistics limited.

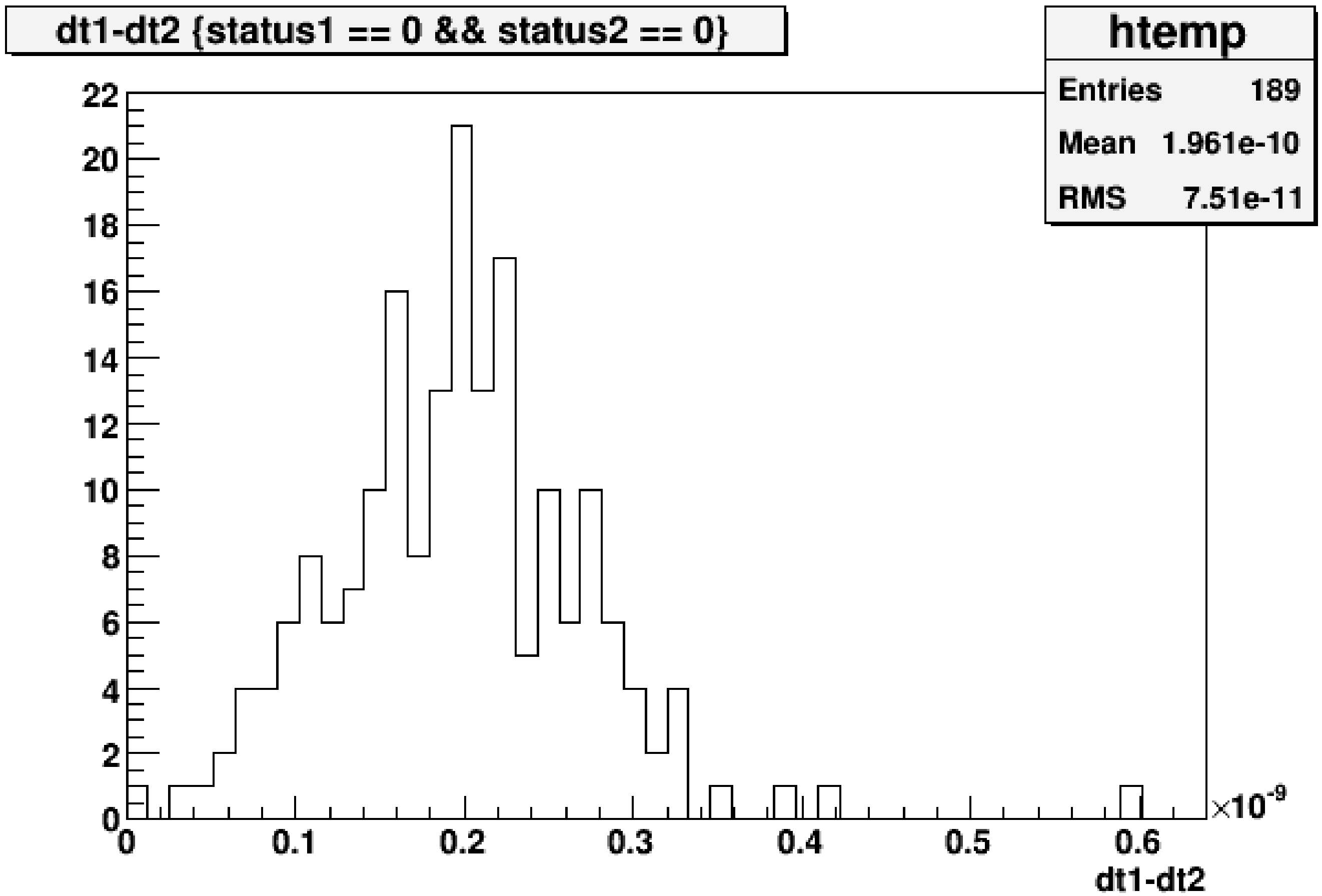
$\Delta t_{i,i+10}$ vs. Sample Cell





- Some structure overall with respect to sample cell.
- Corresponding fit shown at right.
  - Appears to have multiple sampling rates.

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



➔ Mean is reasonable for 5 GSa/s, no more negative time intervals.

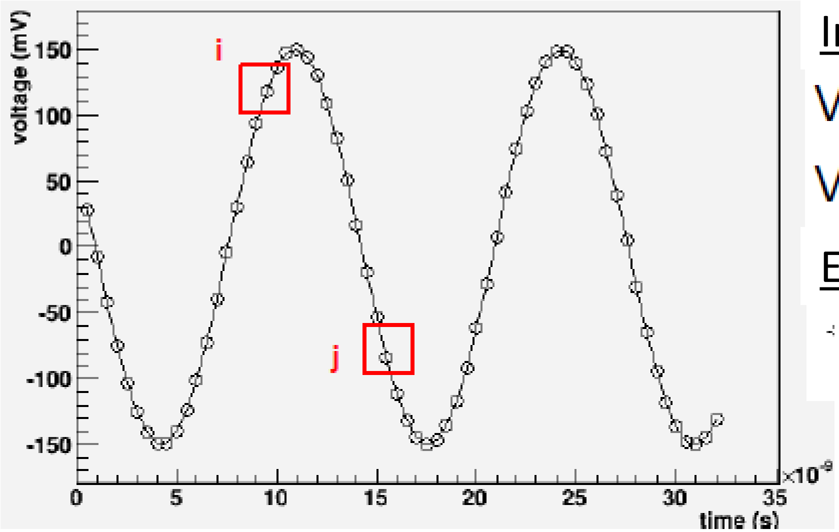
Still lots of potential improvements…

- 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.
- Apply Δt values from one dataset to another dataset (or compare from independent datasets).
  - 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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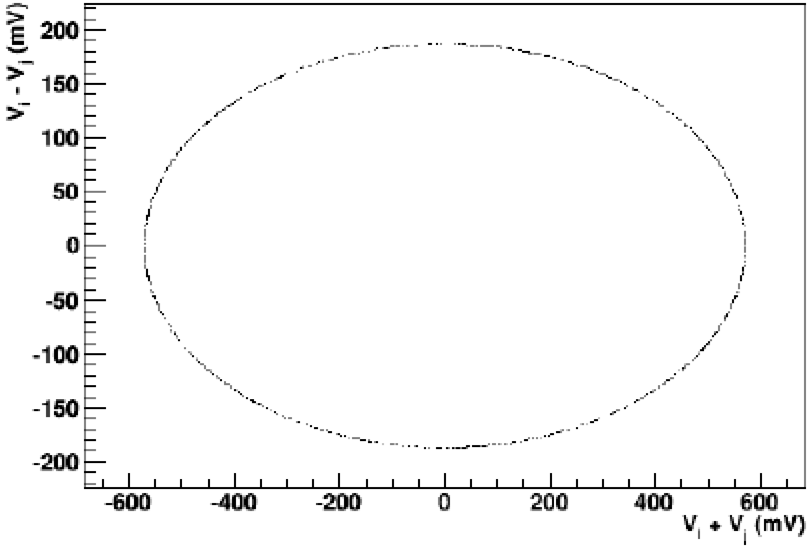

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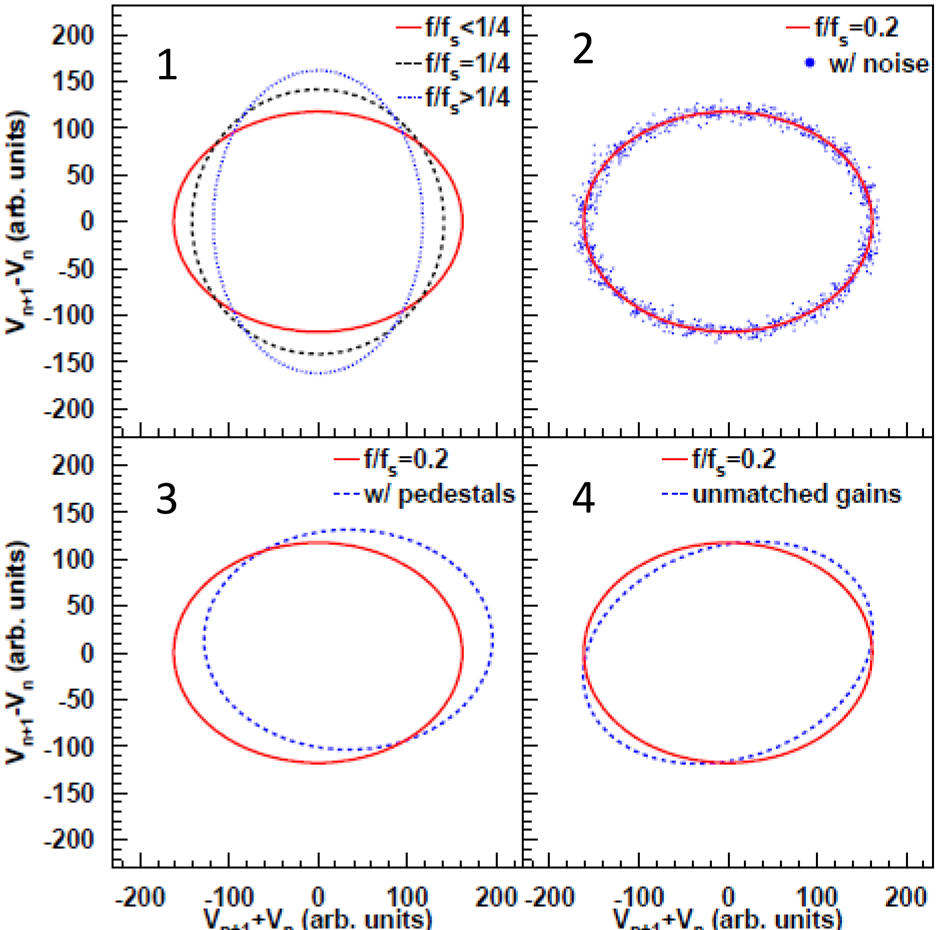
Timing Calibration w/ Correlations

- 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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