# APEX High Rate VDC Analysis

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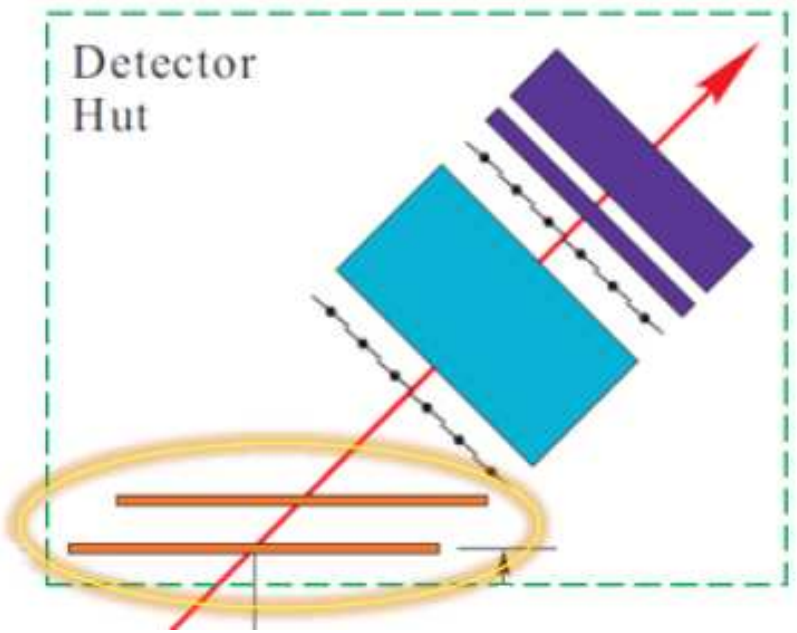
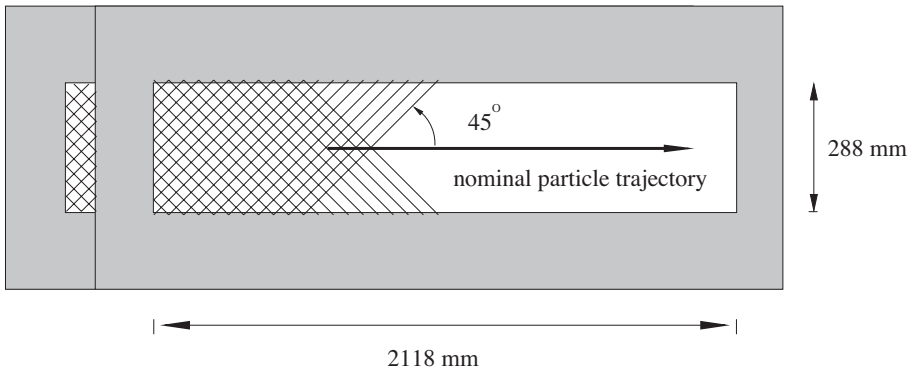
# Outline

- HRS VDCs
- APEX Calibration
- High Rate Tracking Performance

# HRS Vertical Drift Chambers



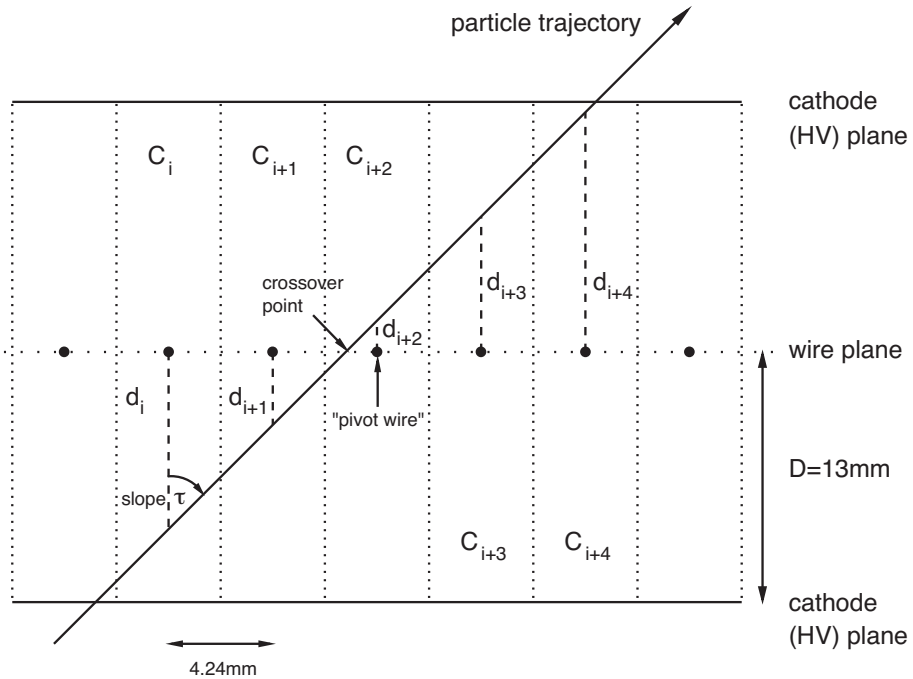



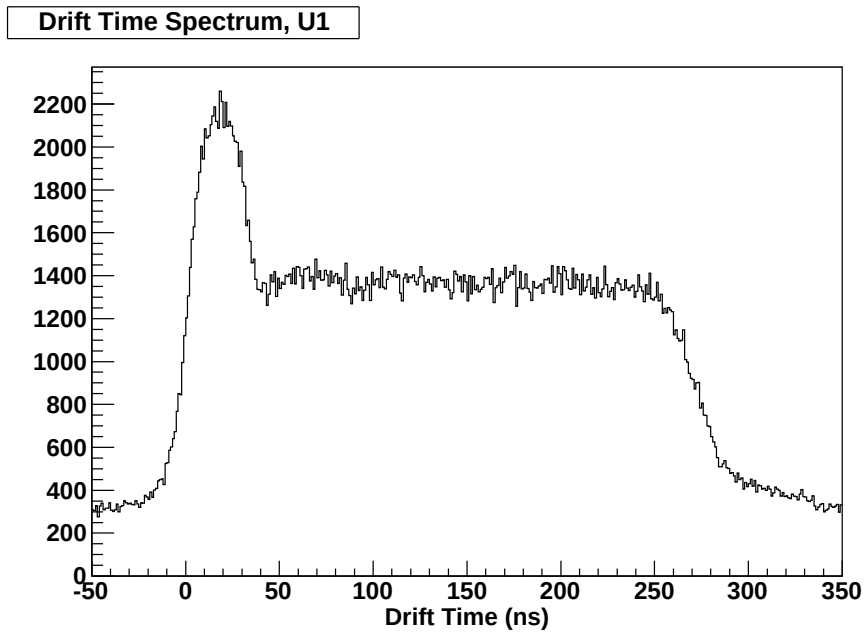

## Nominal Characteristics

| | |
|---|---|
| U/V angle | $\pm 45^\circ$ |
| Sense wires/plane | 368 |
| Wire Spacing | 4.24 mm |
| Pos. Res | $\sim 100\ \mu$m |
| Ang. Res | $\sim 0.5$ mrad |

# Basic VDC Operation

- Tracks enter nominally 45°, produce signals on 3-7 wires
- Drift time patterns among several wires matched to construct “cluster”
- 2 U-plane and 2 V-plane clusters fit to recreate full 3D track



# PAC Concerns

- Requested for test run by PAC:
  *Prove that the vertical drift chambers (VDCs) can operate at a rate higher that 20 kHz/wire (that, according to the TAC report, is the maximum Hall A has operated till now).*

- VDCs had not been run at such high rate (for extended period of time)
- Required to go to $\sim 5$ MHz ($75$ kHz/wire)
- Requires hardware modifications to run efficiently without severe aging

# VDC Modifications

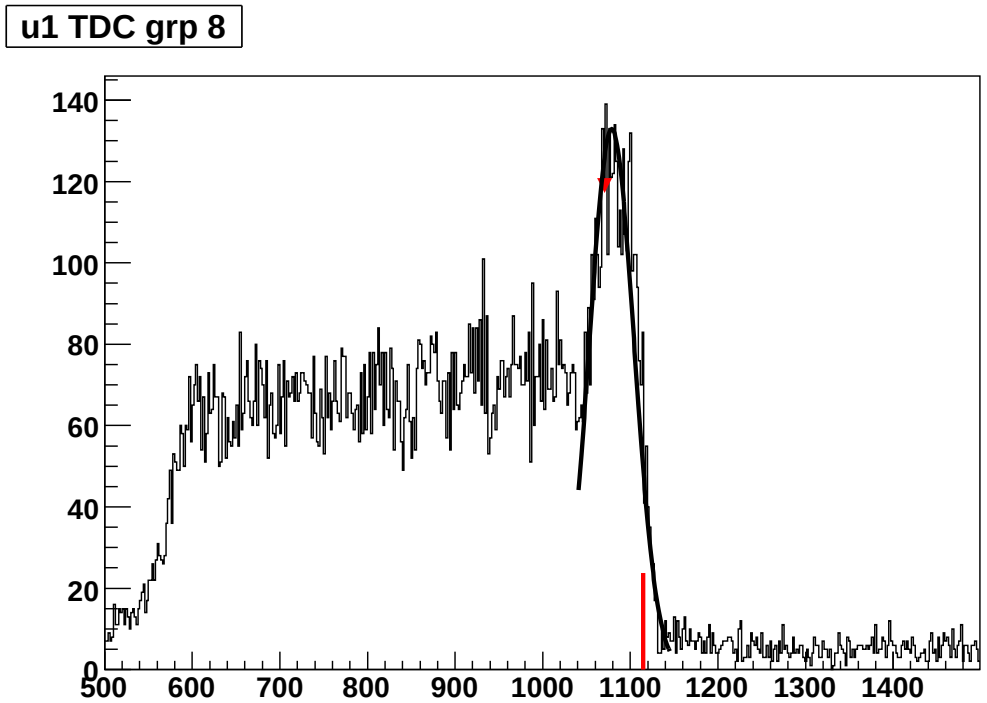
Modifications for performance up to 5 $\mathrm{MHz}$ (full experiment luminosity).

| | Standard | APEX High Rate |
|---|---|---|
| HV | $-4.0\ \mathrm{kV}$ | $-3.5\ \mathrm{kV}$ |
| Disc. | LeCroy ($I_{\mathrm{th}} = 8\ \mu\mathrm{A}$) | JLab Custom ($I_{\mathrm{th}} = 1\ \mu\mathrm{A}$) |
| Gas | 60-40 Ar/$\mathrm{CH_2}$ | 60-40 Ar/$\mathrm{CH_2}$ |
| Max Rate | 500 $\mathrm{kHz}$ | 5 $\mathrm{MHz}$ |
| Gain | $20 \times 10^3$ | $25 \times 10^3$ |

- Max VDC current draw $I/\mathrm{wire}/\mathrm{cm}\ \sim 5\ \mathrm{nA}$
- For APEX, $Q_{\mathrm{VDC}} < 0.1\ \mathrm{C}$ (no serious aging)

# Timing Offset Calibration

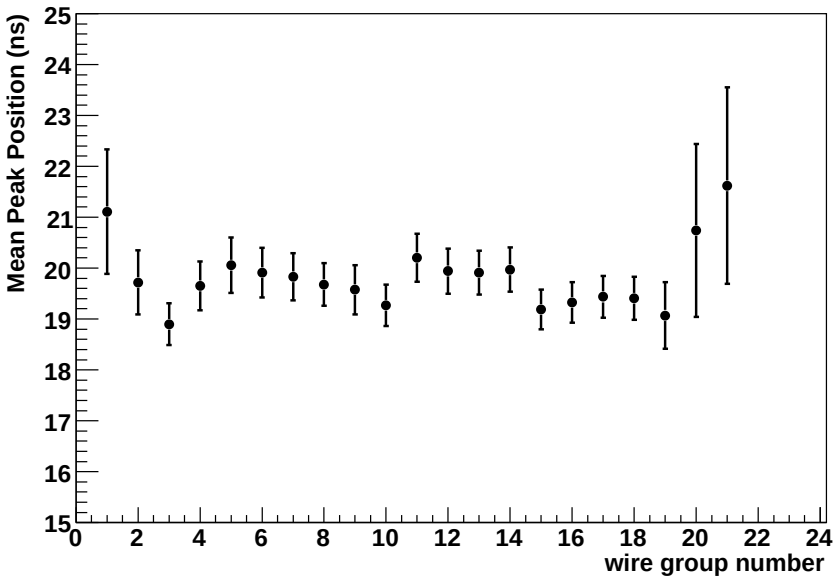
- VDC requires software offsets for drift time
- Calibrated in groups of 16 wires (discriminator inputs)

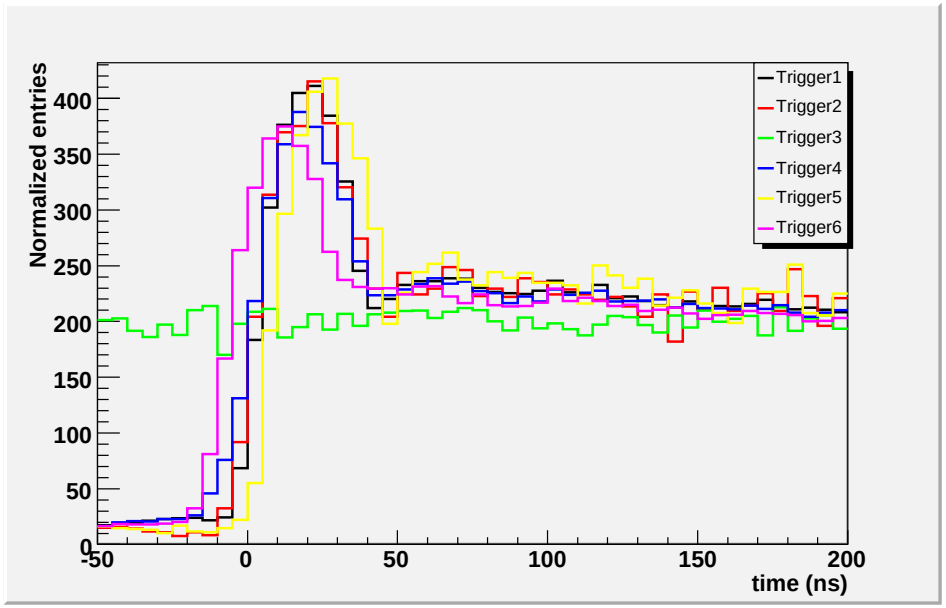



- Calibration done by fitting time dist. peak and fixed at 1.4 $\sigma$ earlier from peak (arbitrary)

# Timing Offset Calibration Results

- Calibration is done to $\sim$ ns level
- Offsets may be different for different triggers
  - Minimized in hardware to $\sim$ 10 ns level, fully corrected in software



# Drift Time-to-Distance

- Drift time-to-distance conversion follows form:
- Theta dependence:

$$\begin{aligned} v_2 t < 0 \quad &: d = \quad v_2 t \\ 0 < v_2 t < a_1 \quad &: d = \quad v_1 t = v_2 t \left(1 + \frac{a_2}{a_1}\right) \\ a_1 < v_2 t \quad &: d = \quad v_2 t + a_2 \end{aligned}$$

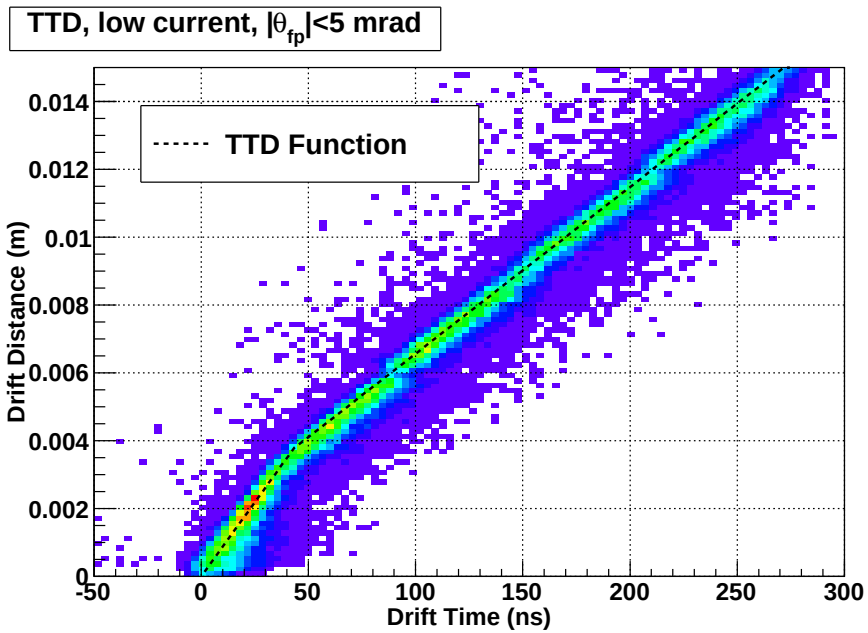
- $a_1$ and $a_2$ carry $\tan\theta = \frac{\Delta z}{\Delta r}$ dependence ($r = u$ or $v$)

$$\begin{aligned} a_1 &= \sum_{i=0}^{3} a_{1,i} \tan^i \theta \\ a_2 &= \sum_{i=0}^{3} a_{2,i} \tan^i \theta \end{aligned}$$

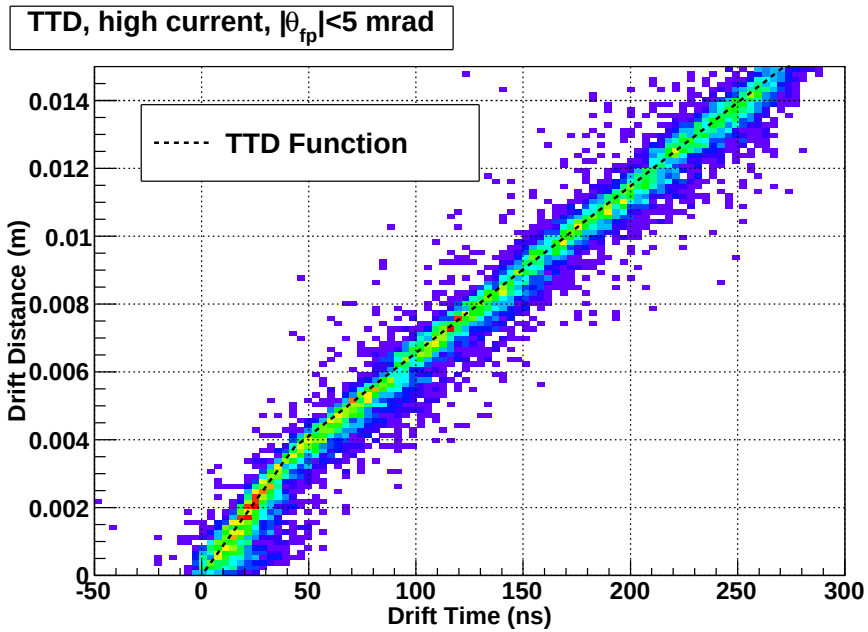
# TTD Calibration

- No serious differences between high and low rate data
- Restricting to slice in incident angle θ:

Low Rate, 0.4 MHz

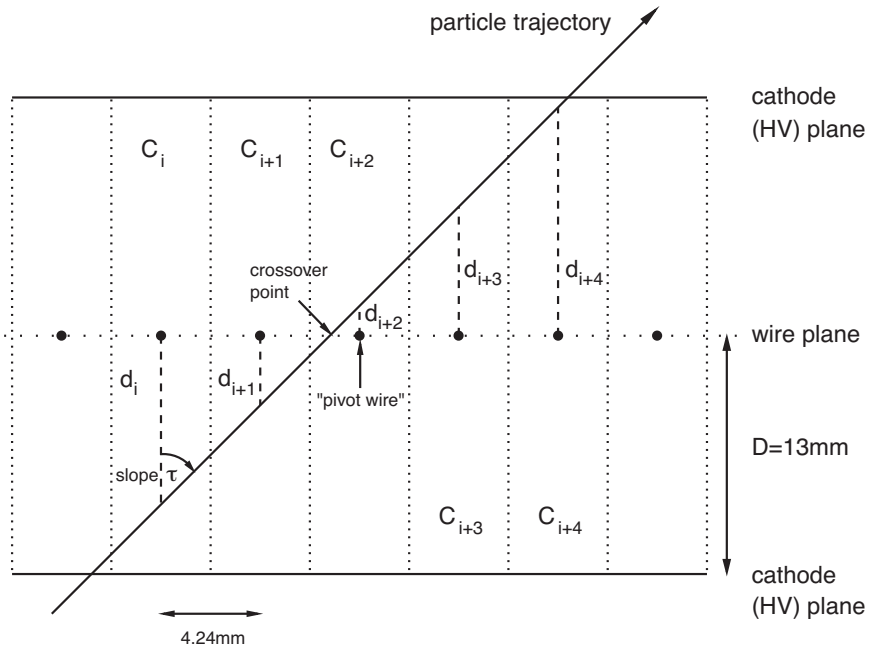


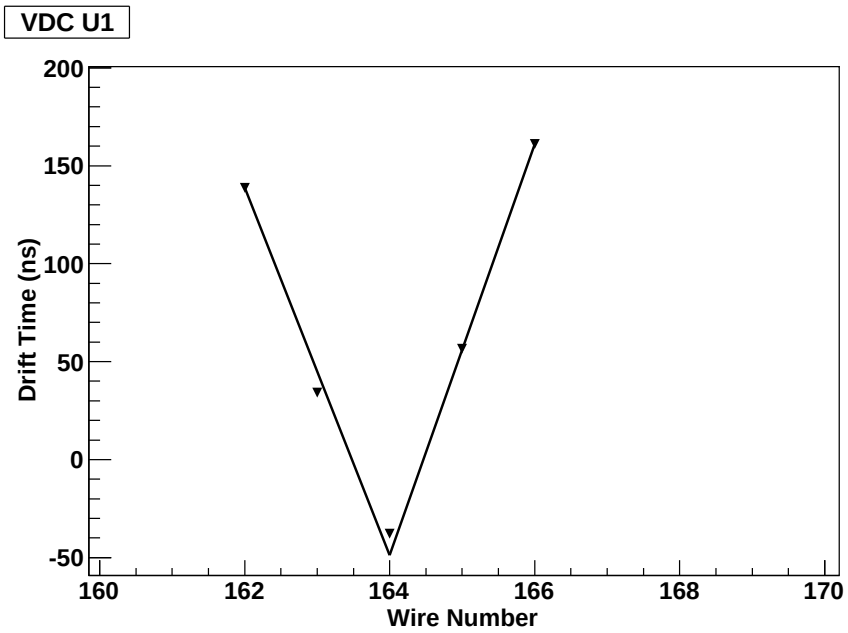

High Rate, 4.6 MHz




- Small recalibrations for θ dependence are necessary

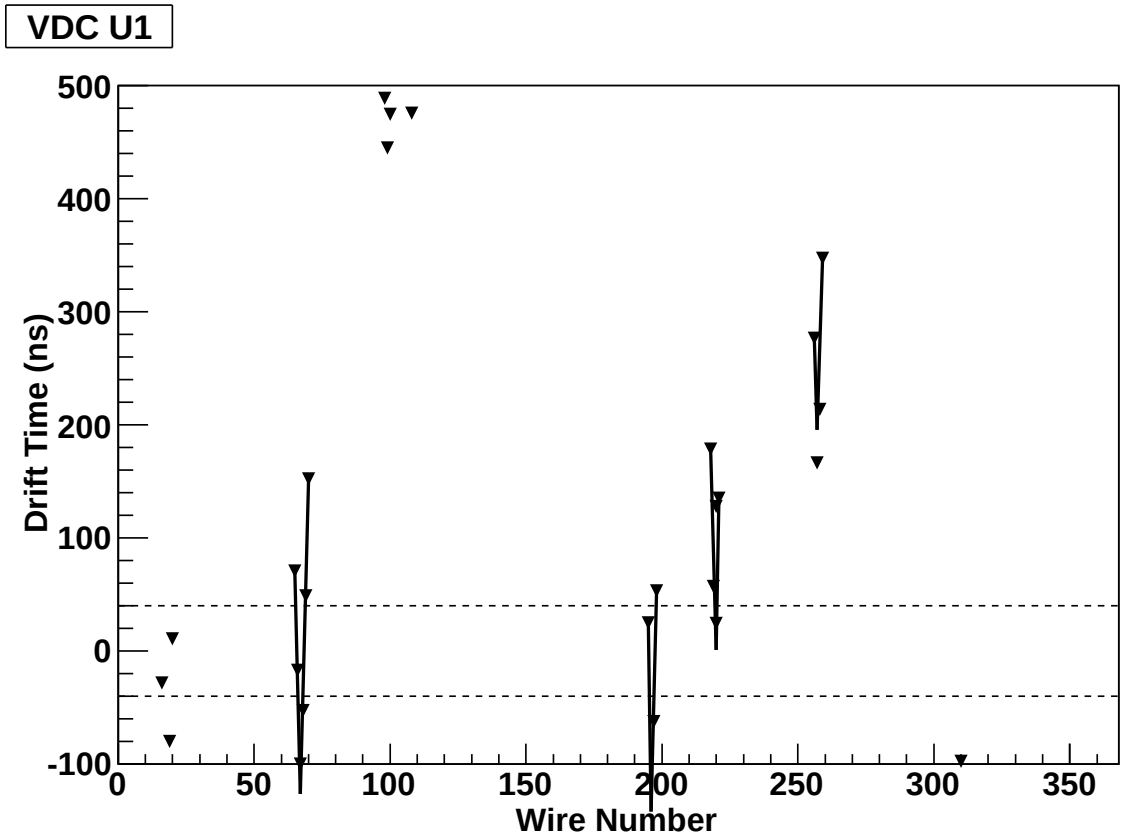
# Tracking Algorithm - Clustering




- Algorithm scans for 'V' shaped clusters in time
- Hits in each cluster must be within reasonable time constraints
- Allow for gaps of 1 wire, must have $3 \leq$ wires in cluster $\leq 7$
- Time of the cluster is offset, calculated through fit based on time-to-drift distance mapping
  - Time resolution from fit on $\sigma_t \approx 15$ ns

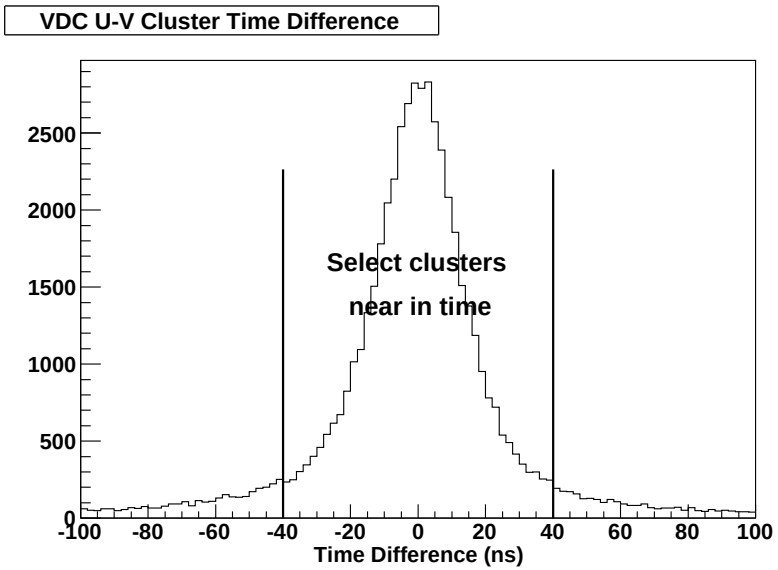
# Advanced Scanning

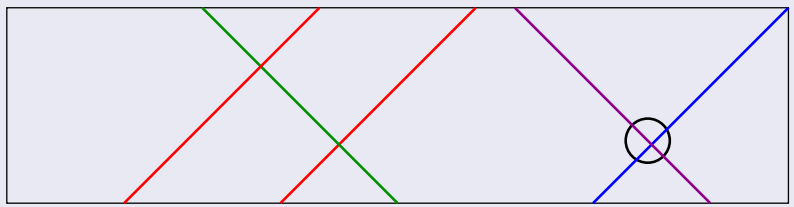



- Multihit TDC information used since rates are high
- Earliest hits used to fit clusters
- Several passes over data taken to maximize clusters found when separated in time, but not space

# Tracking Algorithm - UV Association

- Cut on U cluster - V cluster time difference, $\pm 40$ ns
- Cluster positions must be in chamber active area



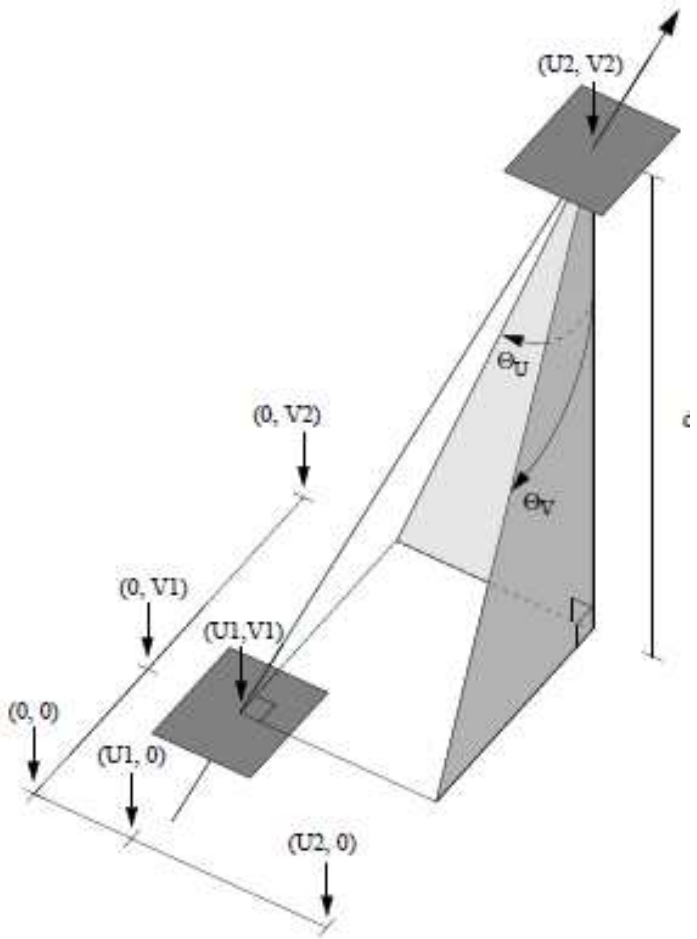



Ambiguity prevents unique association between U-V clusters

- If ambiguity in UV association, end tracking

# Tracking Algorithm - Track Fitting

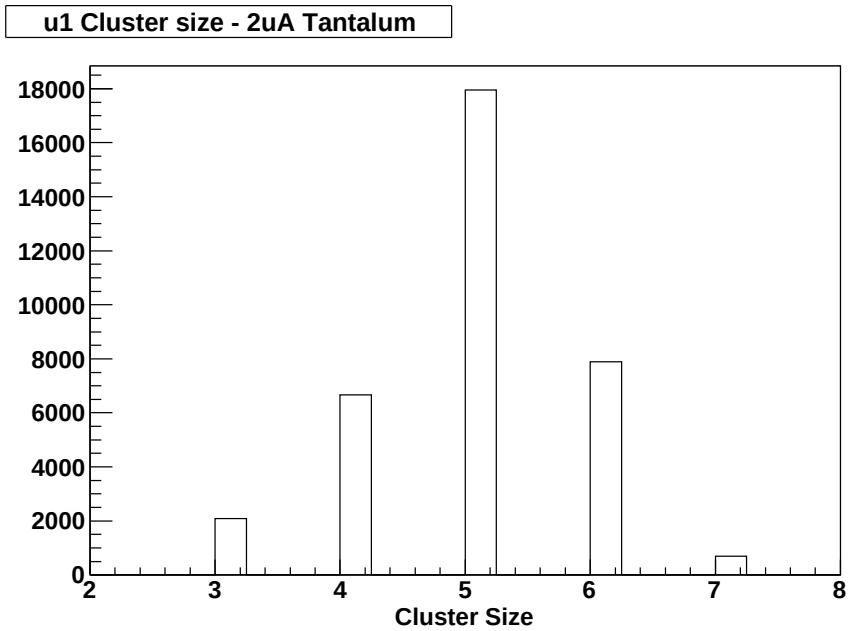
- All chamber 1 - chamber 2 UV clusters built
- Sort by $\chi^2$ based on angular information from drift time fit
- Accept as many $\chi^2$ clusters until maximum found



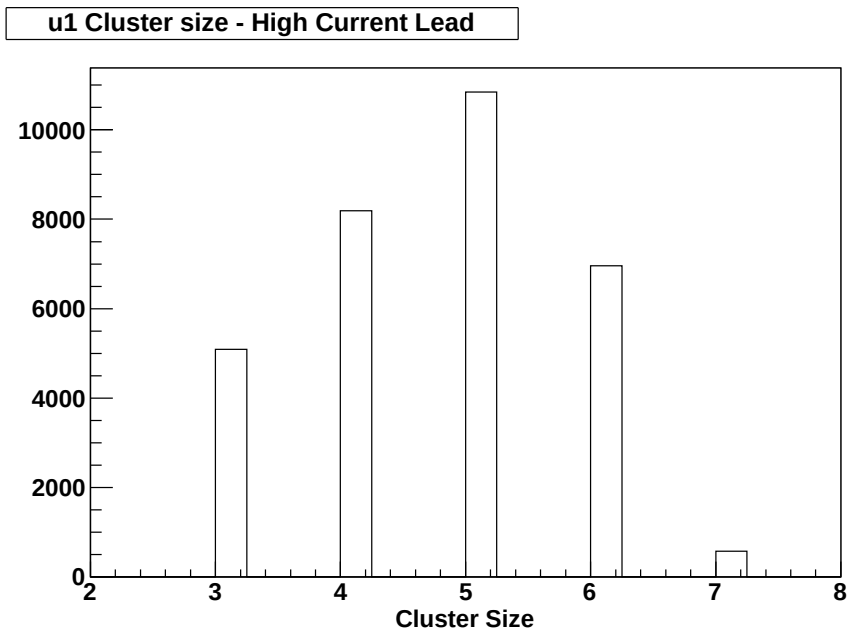
# Tracking Efficiency

- Tracking efficiency found in left arm for:
  - Left arm s2m scintillator trigger
  - High preshower+shower calorimeter signal ($e^-$)

Low rate, 0.3 MHz



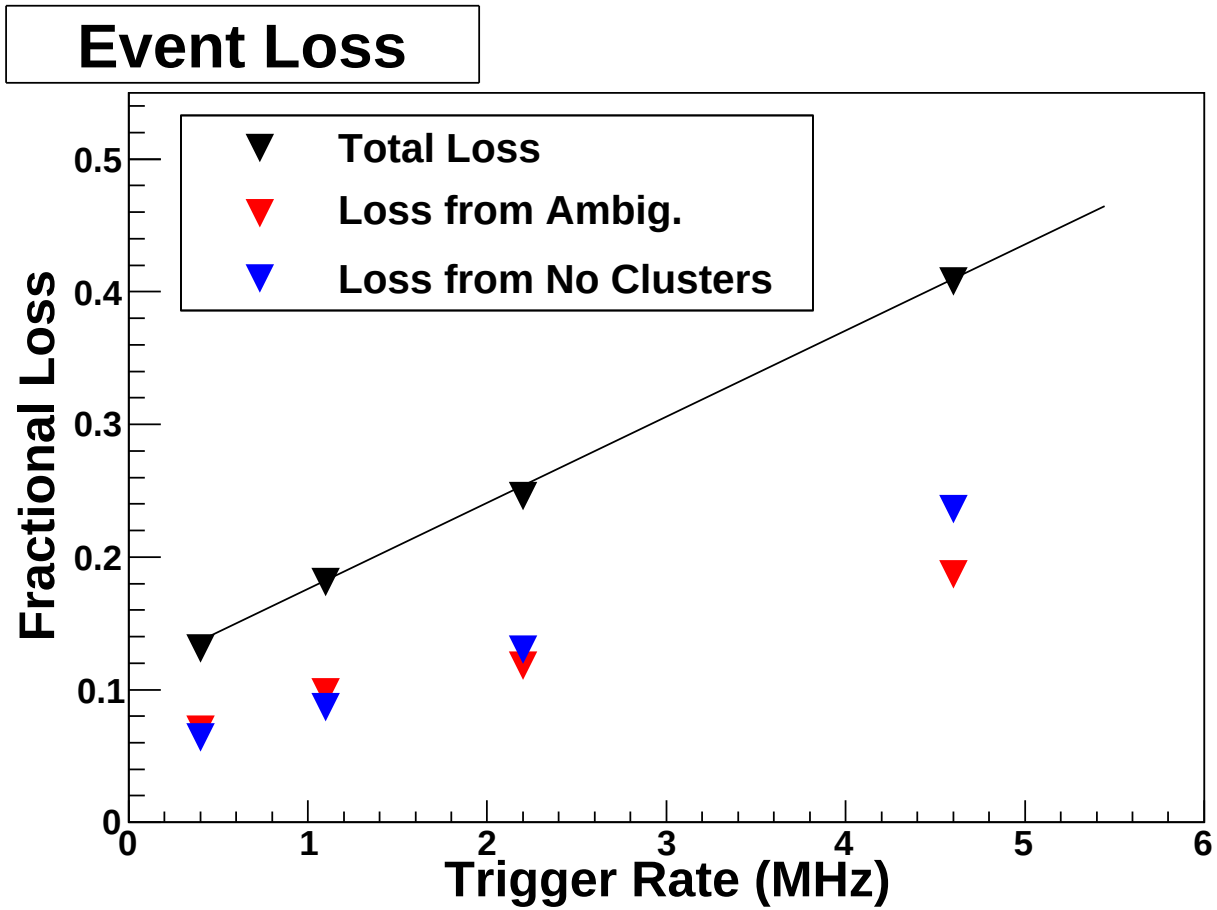

Highest rate, 5 MHz




- Average wires in clusters become smaller at high rate due to efficiency

# Tracking Efficiency

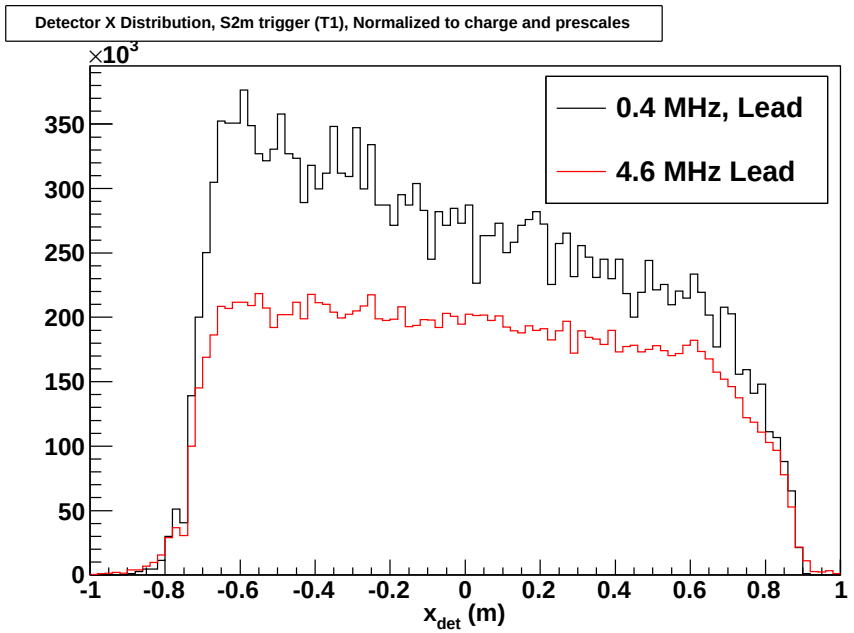
- Losses come from:
  - UV association ambiguity
  - No clusters found (bad timing structure, overlapping, hit inefficiency)



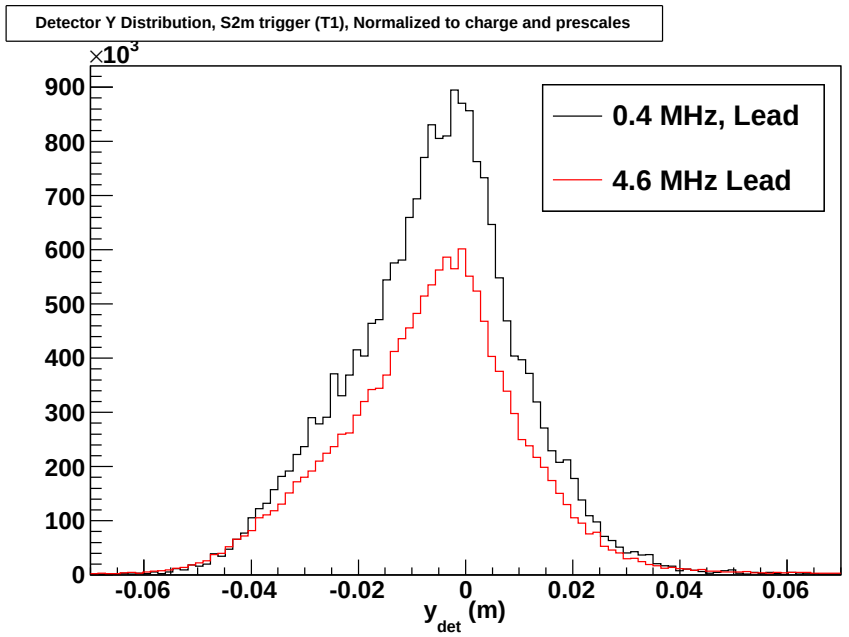
# Event distribution

- Event distribution has small distortions due to non-uniform efficiency

$X_{det}$




$Y_{det}$



# Efficiency Improvements

Tracking Work To Do:

- UV ambiguity may be broken through use of other detectors, $\chi^2$ fitting, geometry considerations, event distribution considerations
- Some clusters from “no cluster” events may be recovered through better cluster searching code
- Efficiency improvents to 75% (from 60%) with improved analysis as estimate

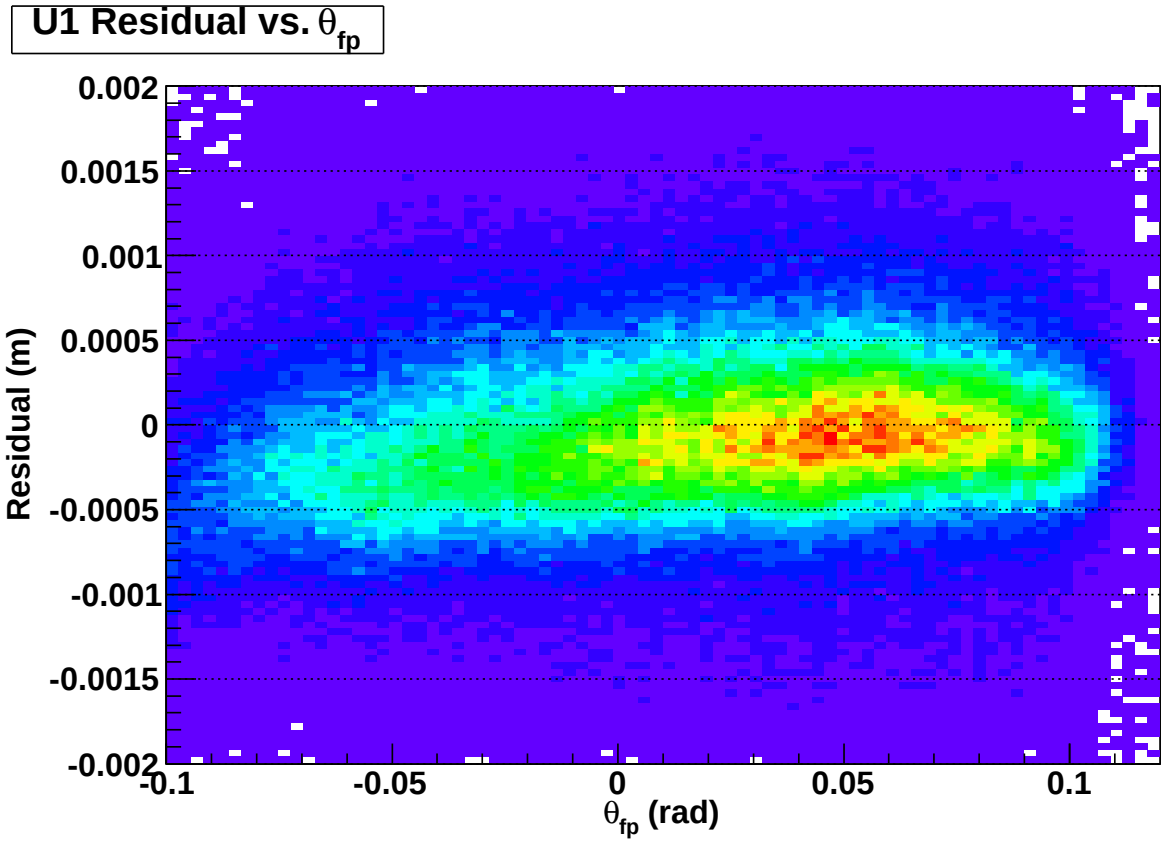
# Conclusion

- HRS VDC provide high resolution, hit based tracking
- PAC condition met: VDCs were able to perform tracking at high rates with appropriate hardware modifications
- Tracking efficiency is about 60% at 5 $\mathrm{MHz}$ trigger, optimization of beam current must be performed

# BACKUP SLIDES

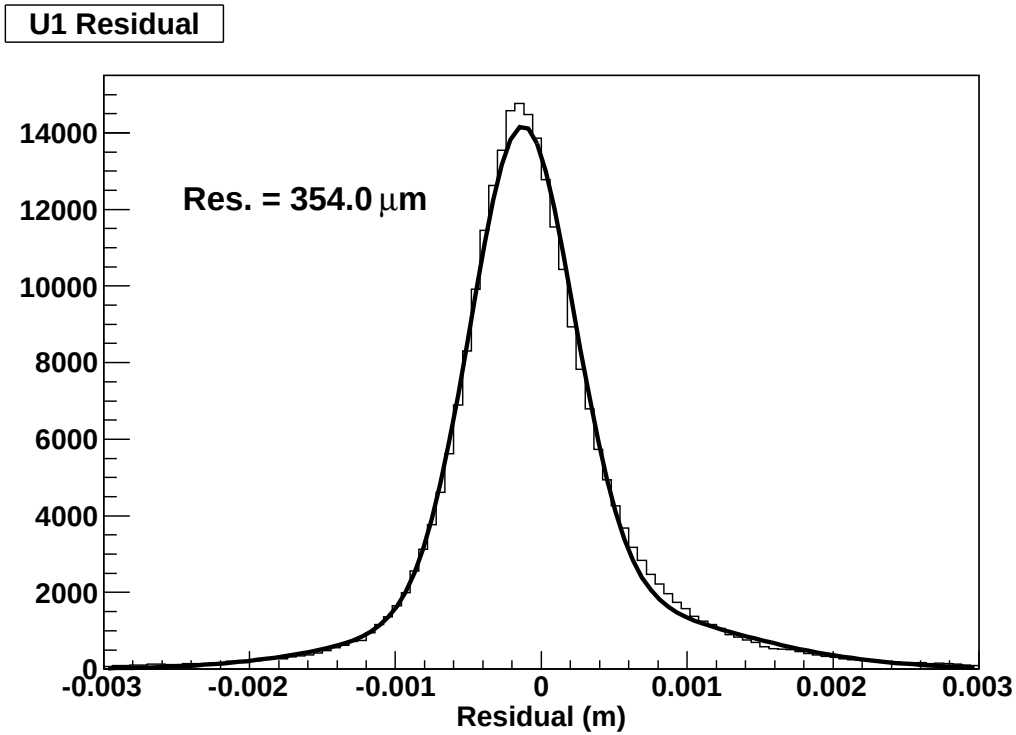
# TTD Calibration

- Requires some $\theta$ dependence re-fitting
- Discrepancies are in the tail on the level of 20 $\mu$m



# Tracking Resolutions

- Track resolutions found through residuals of full $\chi^2$ fit




- Second, broader Gaussian distribution appears for high rate data
- Average width of central peak goes from 320 $\mu$m to 360 $\mu$m between low and high rate data
- Corresponds to 100 $\mu$m, 0.3 mrad detector resolution

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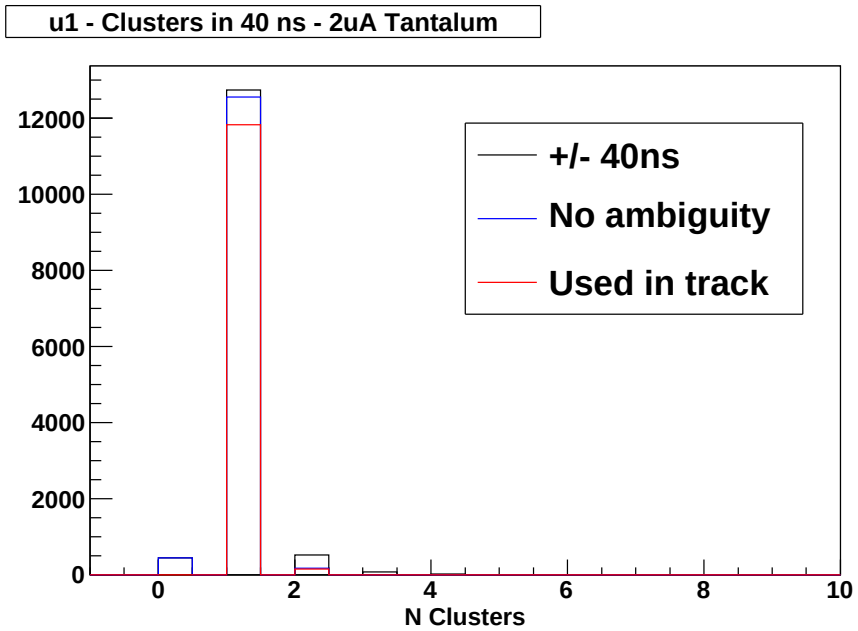
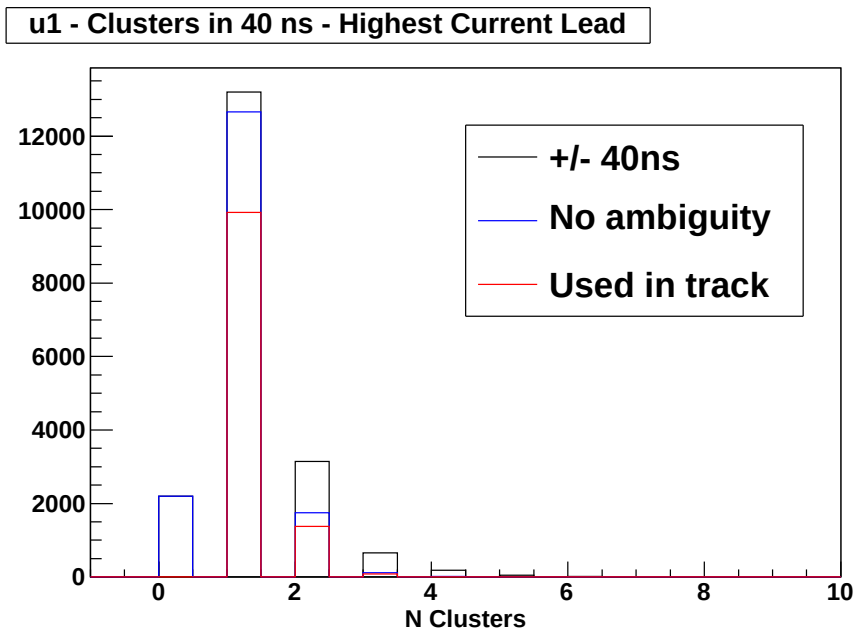



Highest rate, 5 MHz

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