APEX High Rate VDC Analysis

Seamus Riordan
University of Massachusetts, Amherst
sriordan@physics.umass.edu

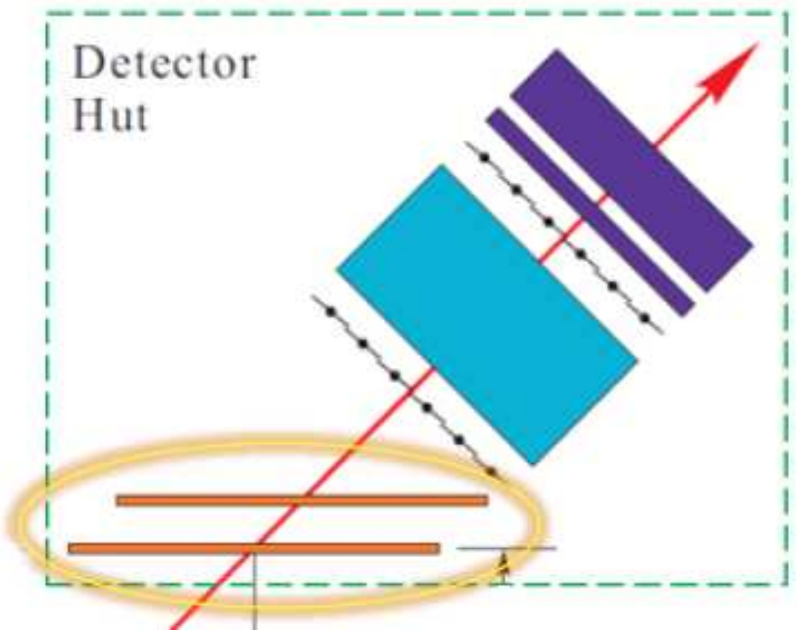
Mathew Graham, SLAC
Ole Hansen, Jefferson Lab
Mike Paolone, University of South Carolina

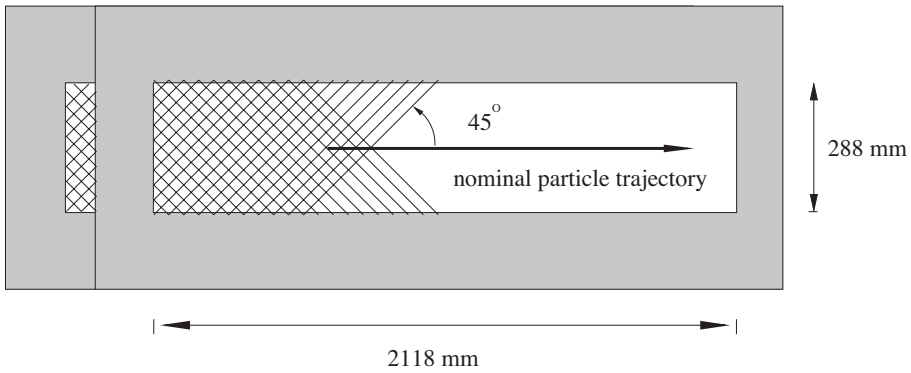
December 8, 2010

Outline

- HRS VDCs
- APEX Calibration
- High Rate Tracking Performance

HRS Vertical Drift Chambers



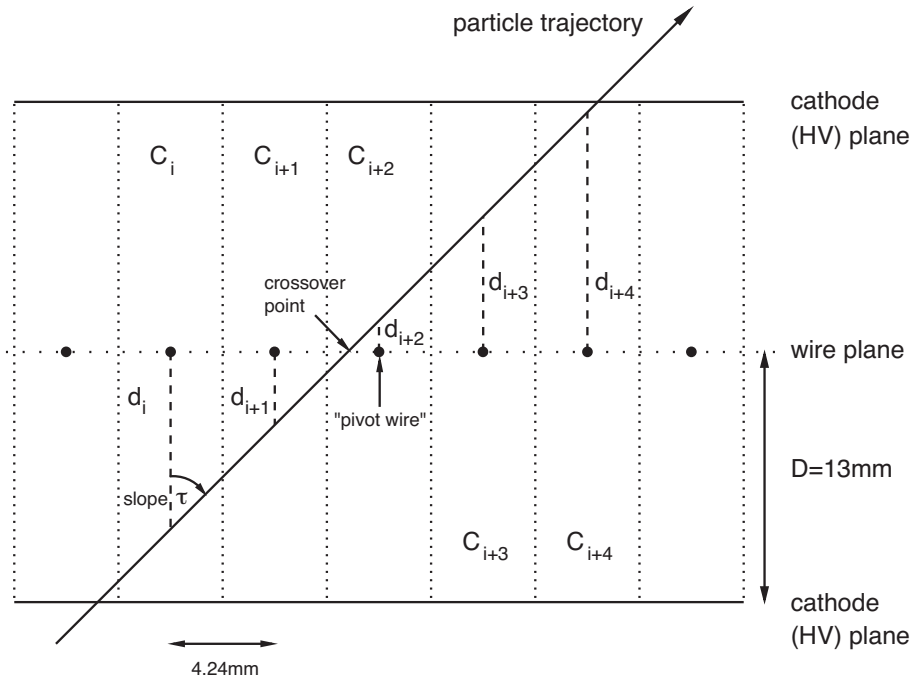


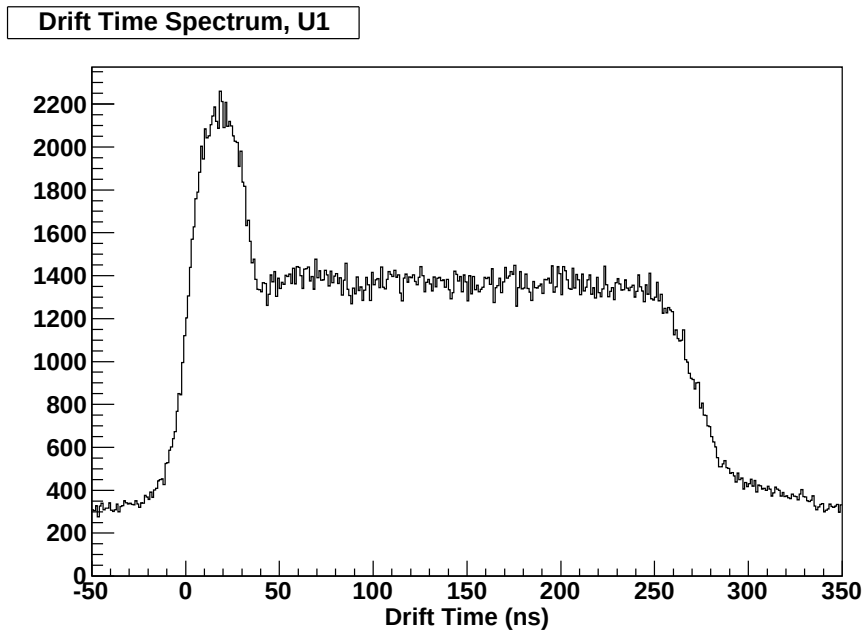
Nominal Characteristics

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





APEX 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 ~ 5 MHz (75 kHz/wire)
- Requires hardware modifications to run efficiently without severe aging

VDC Modifications

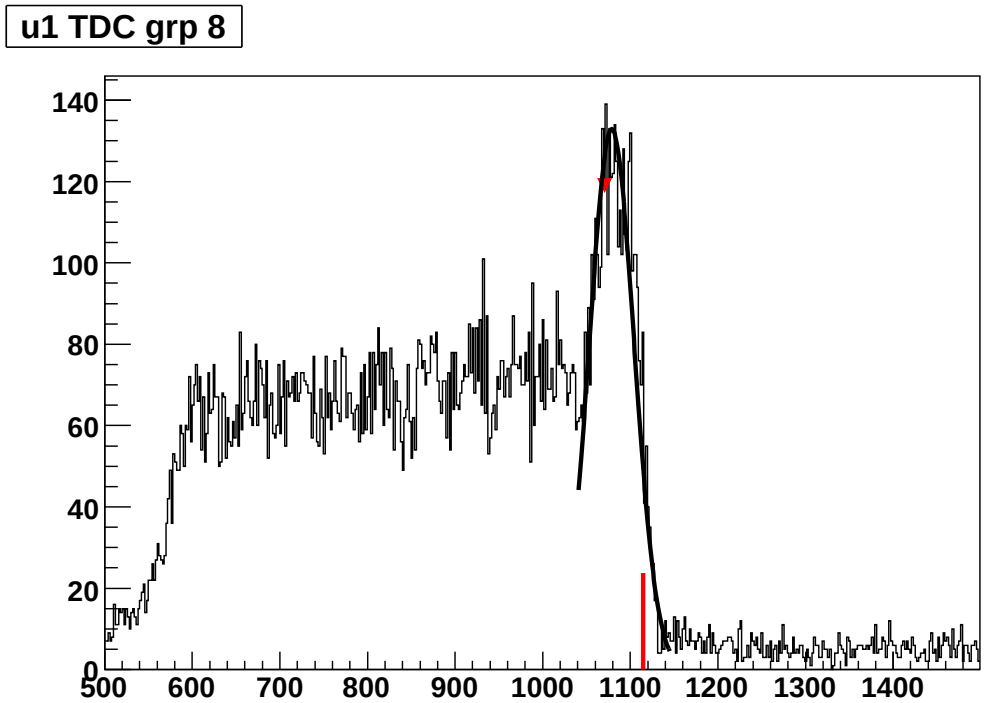
Modifications for performance up to 5 MHz (full experiment luminosity).

	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 kHz	5 MHz
Gain	20×10^3	2.5×10^3

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

Timing Offset Calibration

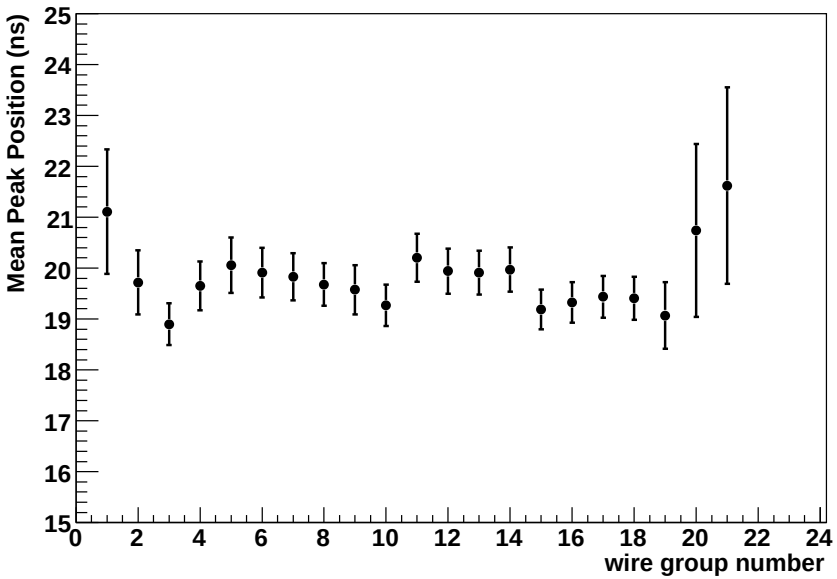
- VDC requires software offsets for drift time
- Calibrated in groups of 16 wires (discriminator inputs)

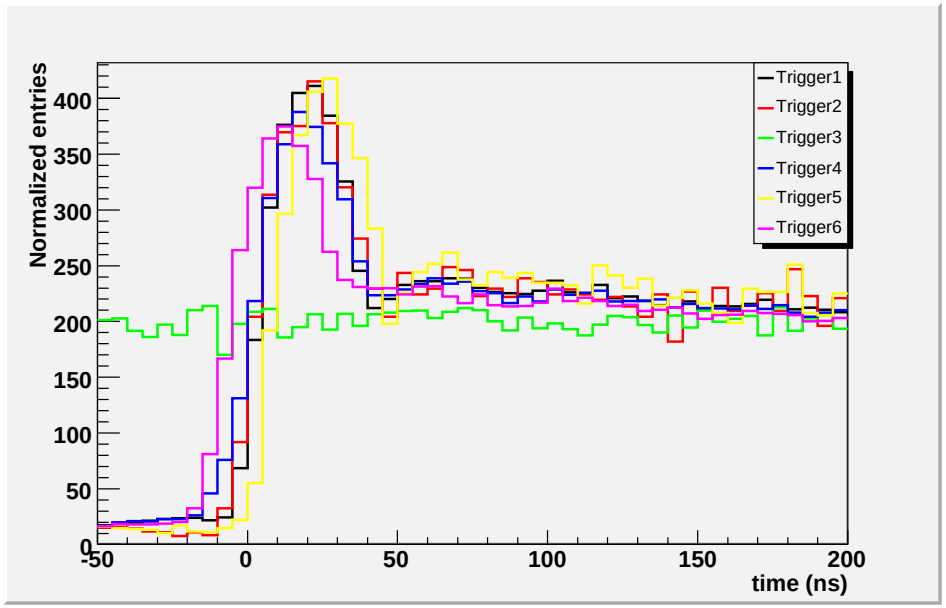


- Calibration done by fitting time dist. peak and fixed at 1.4 σ earlier from peak (arbitrary)

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:

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

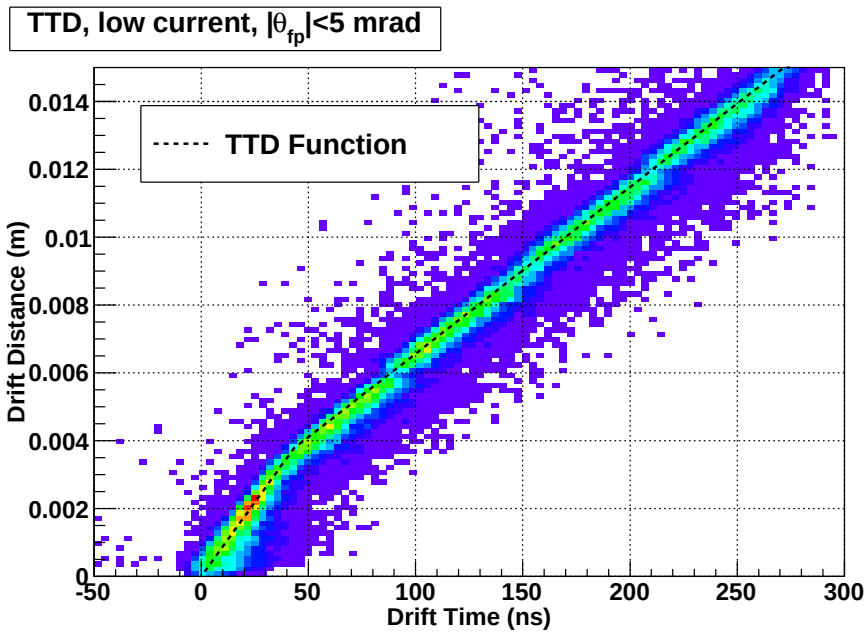
- a_1 and a_2 carry $\tan\theta = \frac{\Delta z}{\Delta r}$ dependence ($r = u$ or v)

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

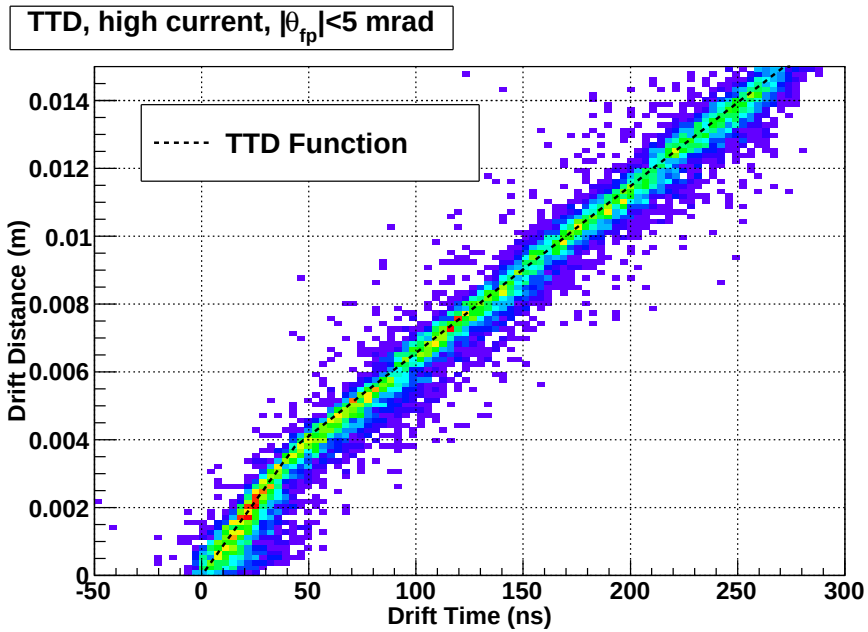
TTD Calibration

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

Low Rate, 0.4 MHz



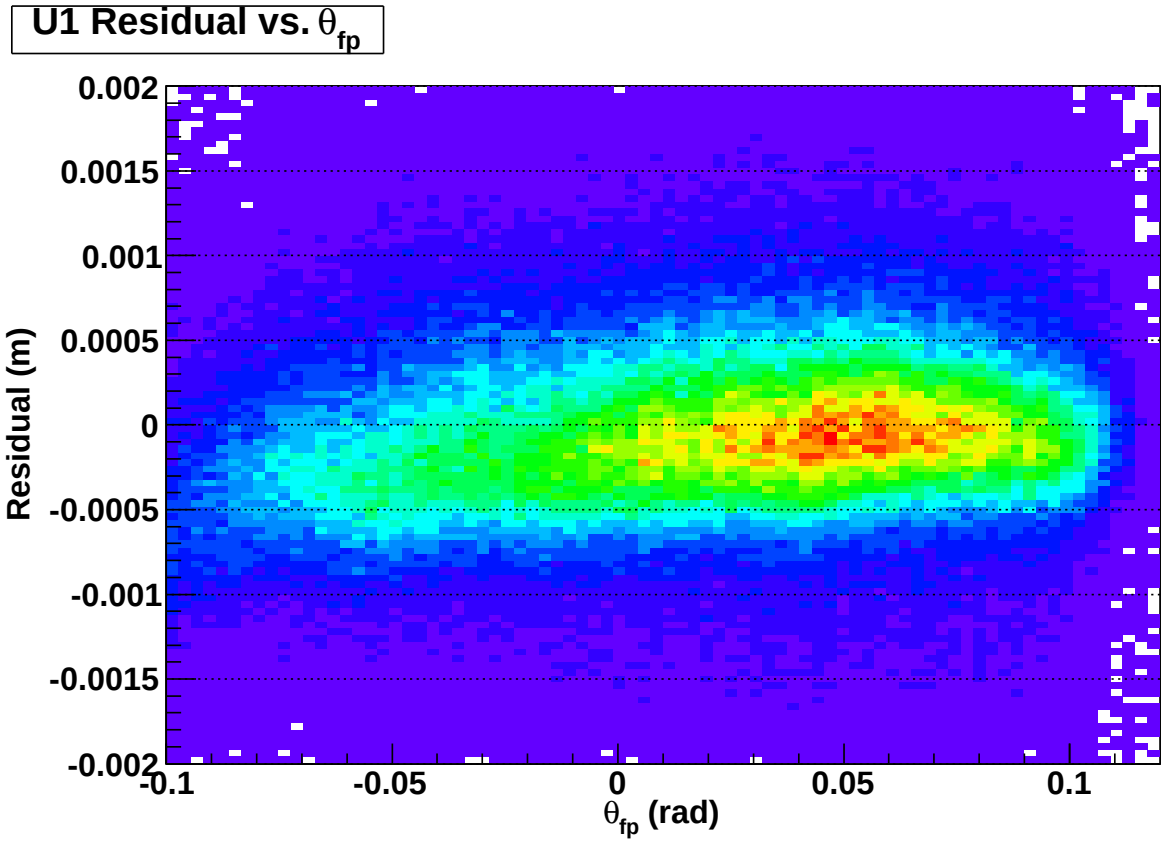
High Rate, 4.6 MHz



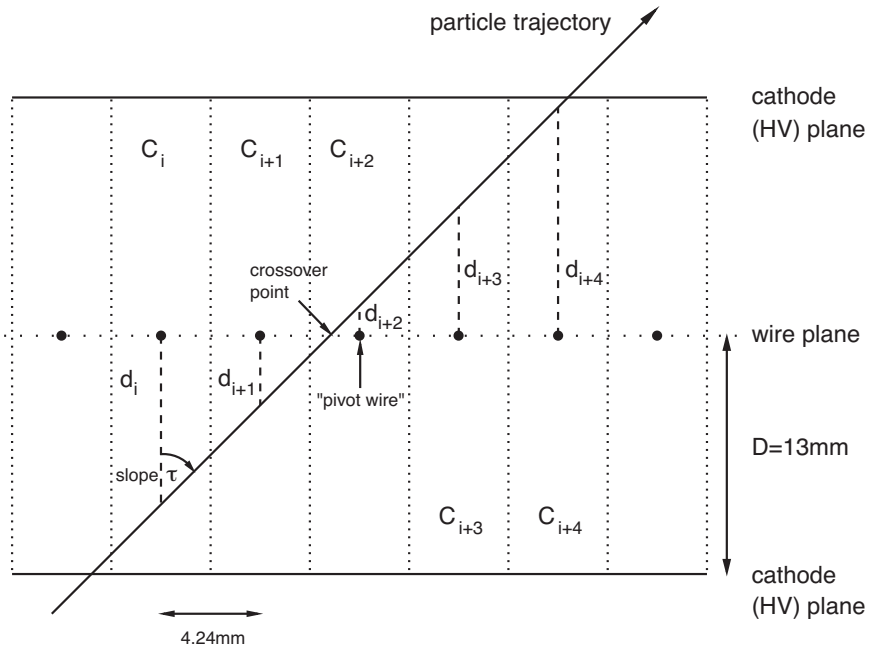
- Small recalibrations for θ dependence are necessary

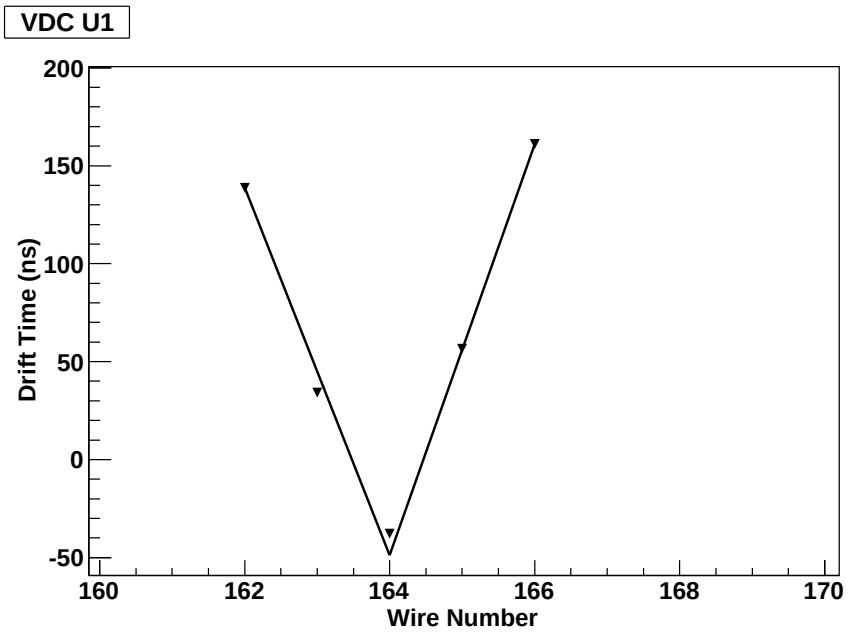
TTD Calibration

- Requires some θ dependence re-fitting
- Discrepancies are in the tail on the level of 20 μm



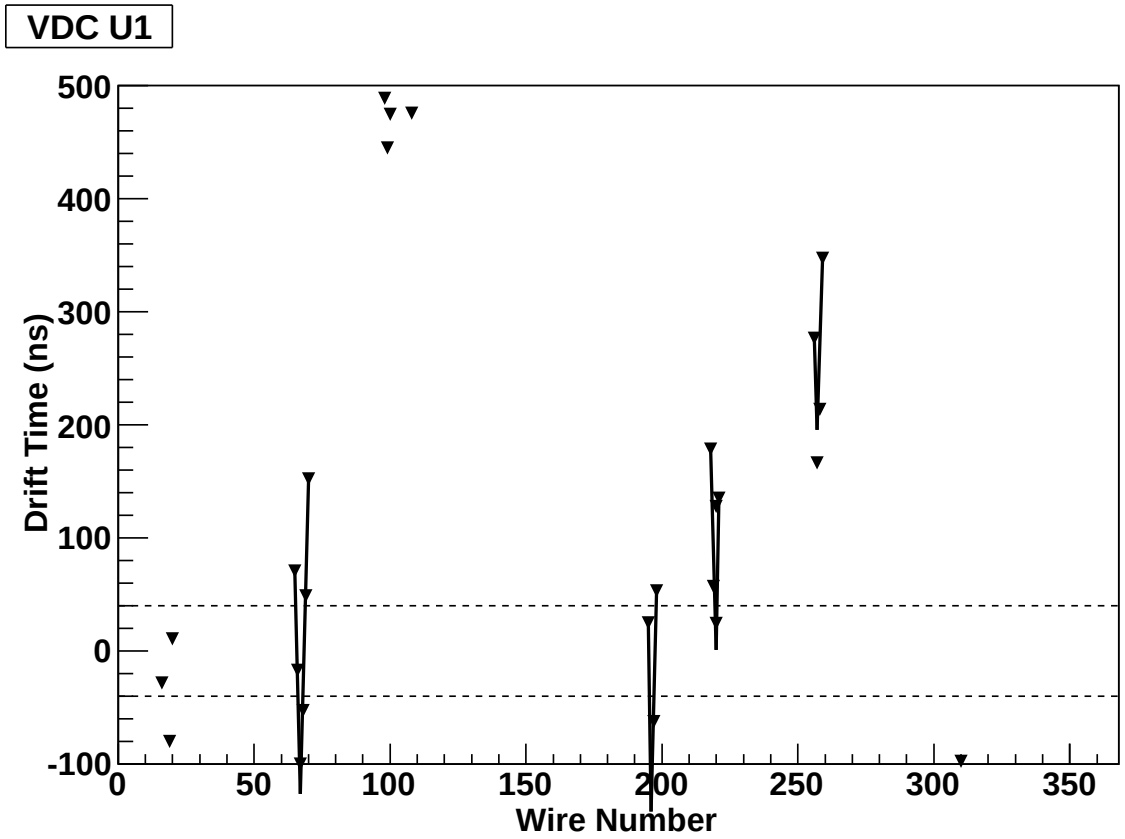
Tracking Algorithm - Clustering





- 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 ≤ 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

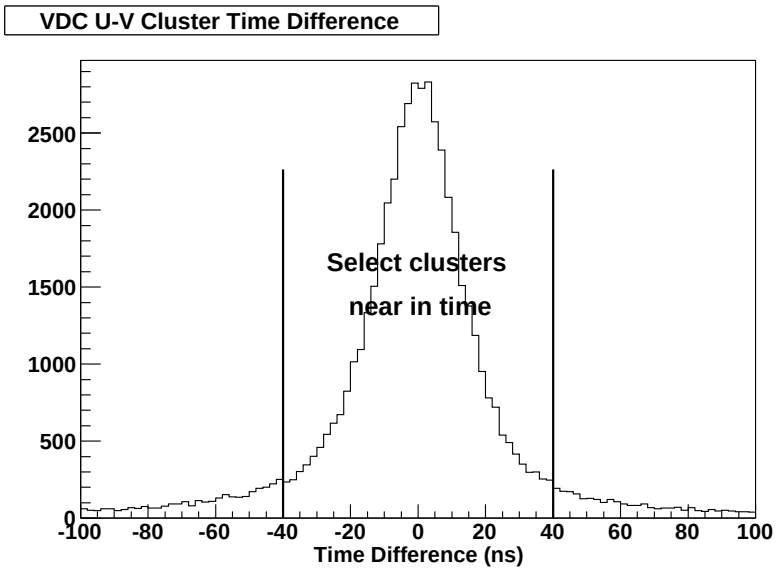
Advanced Scanning

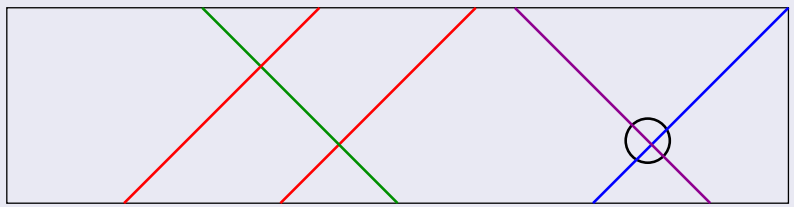


- Multihit TDC information used since rates are high
- Earliest hits used to fit clusters
- Several passes over data taken to maximize clusters found when separated in time, but not space

Tracking Algorithm - UV Association

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



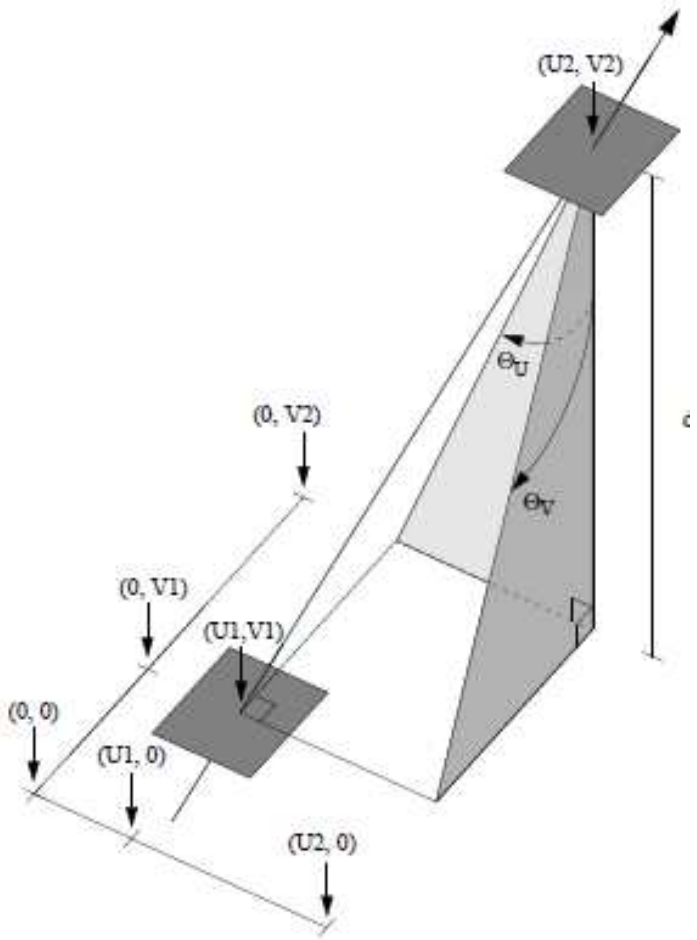


Ambiguity prevents unique association between U-V clusters

- If ambiguity in UV association, end tracking

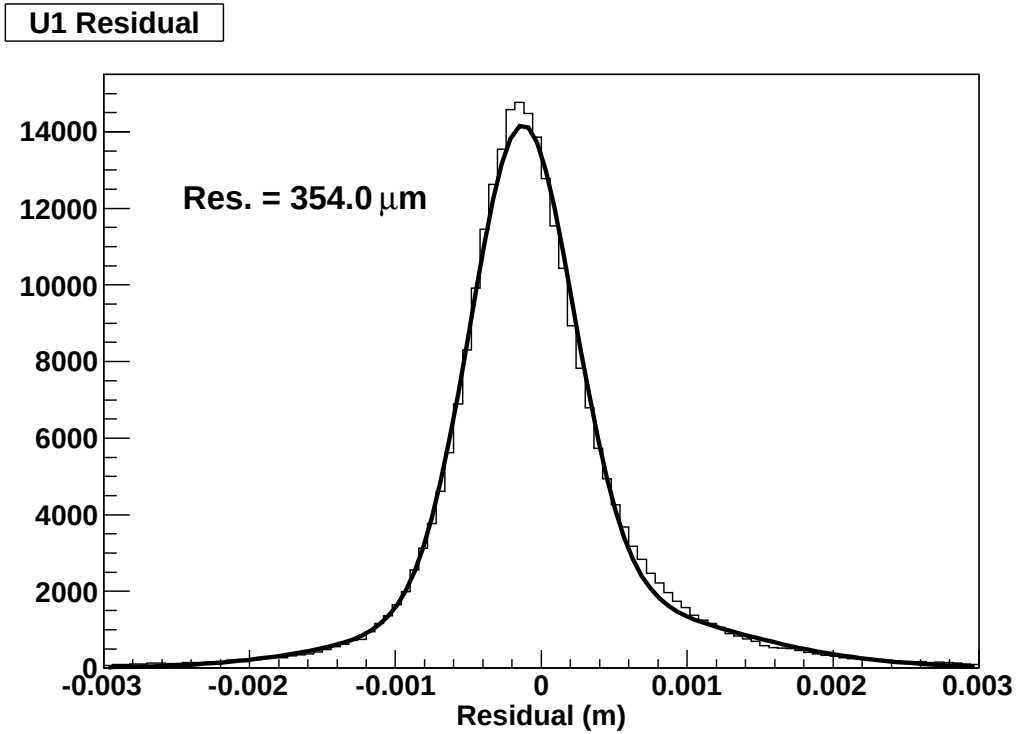
Tracking Algorithm - Track Fitting

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



Tracking Resolutions

- Track resolutions found through residuals of full χ^2 fit

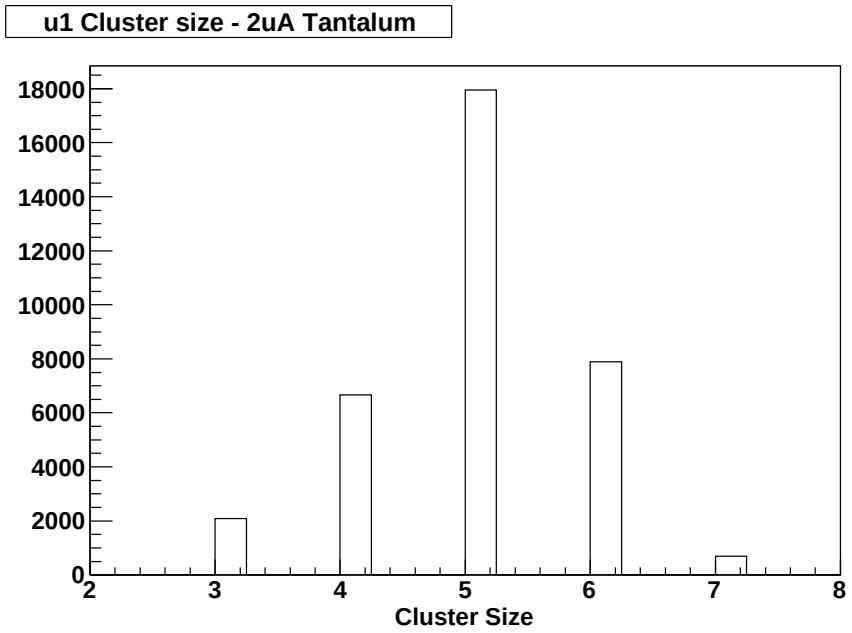


- Second, broader Gaussian distribution appears for high rate data
- Average width of central peak goes from 320 μm to 360 μm between low and high rate data

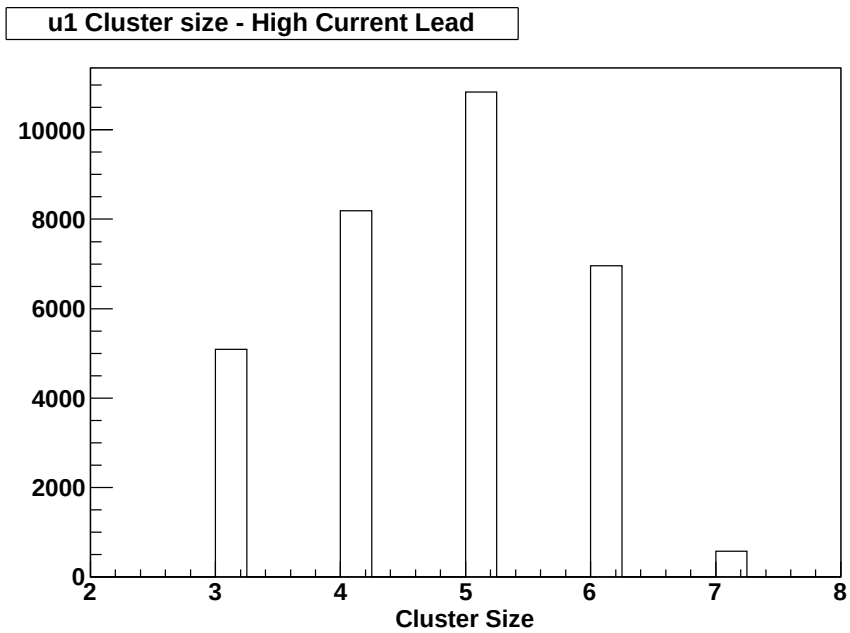
Tracking Efficiency

- 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

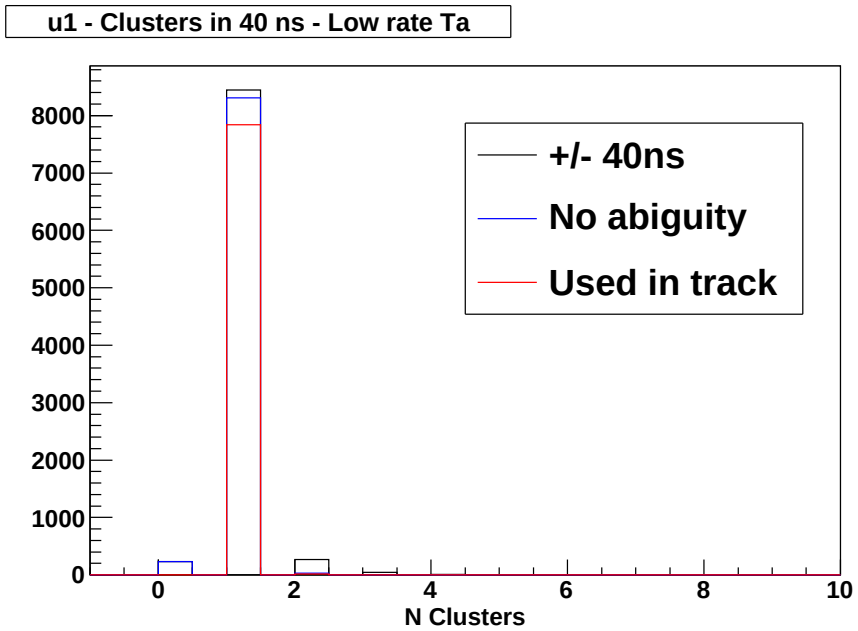


- Average wires in clusters become smaller at high rate due to efficiency

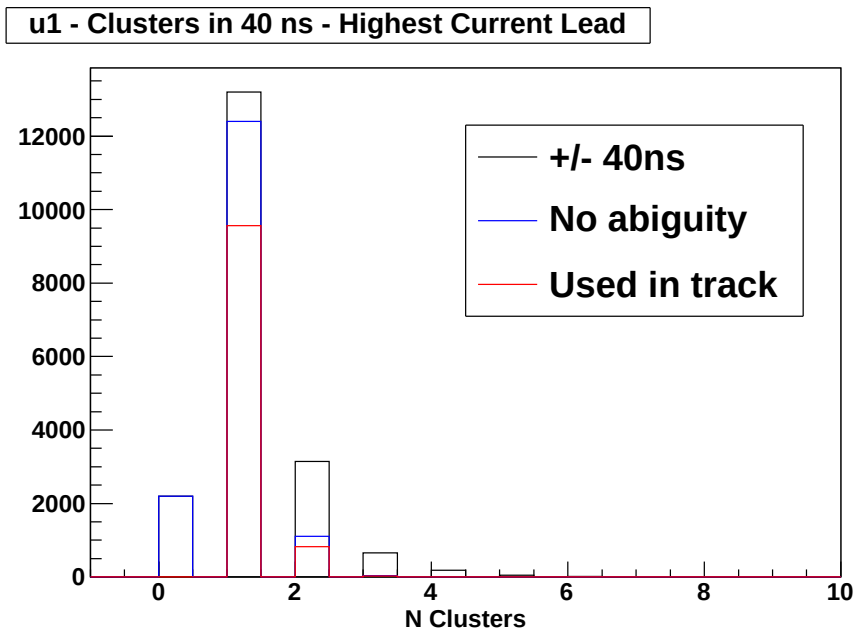
Tracking Efficiency

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

Low rate, 0.3 MHz



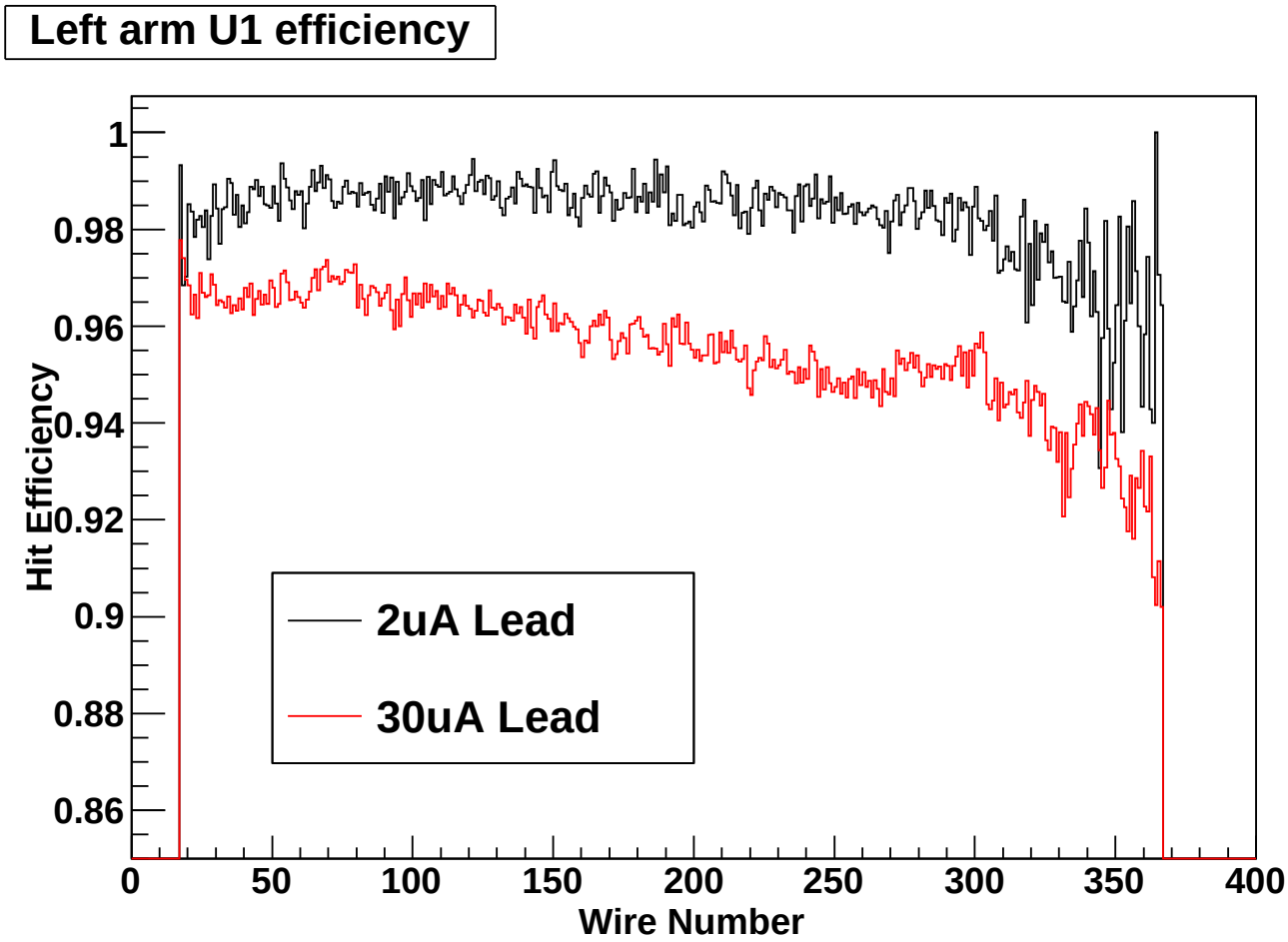
Highest rate, 5 MHz



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

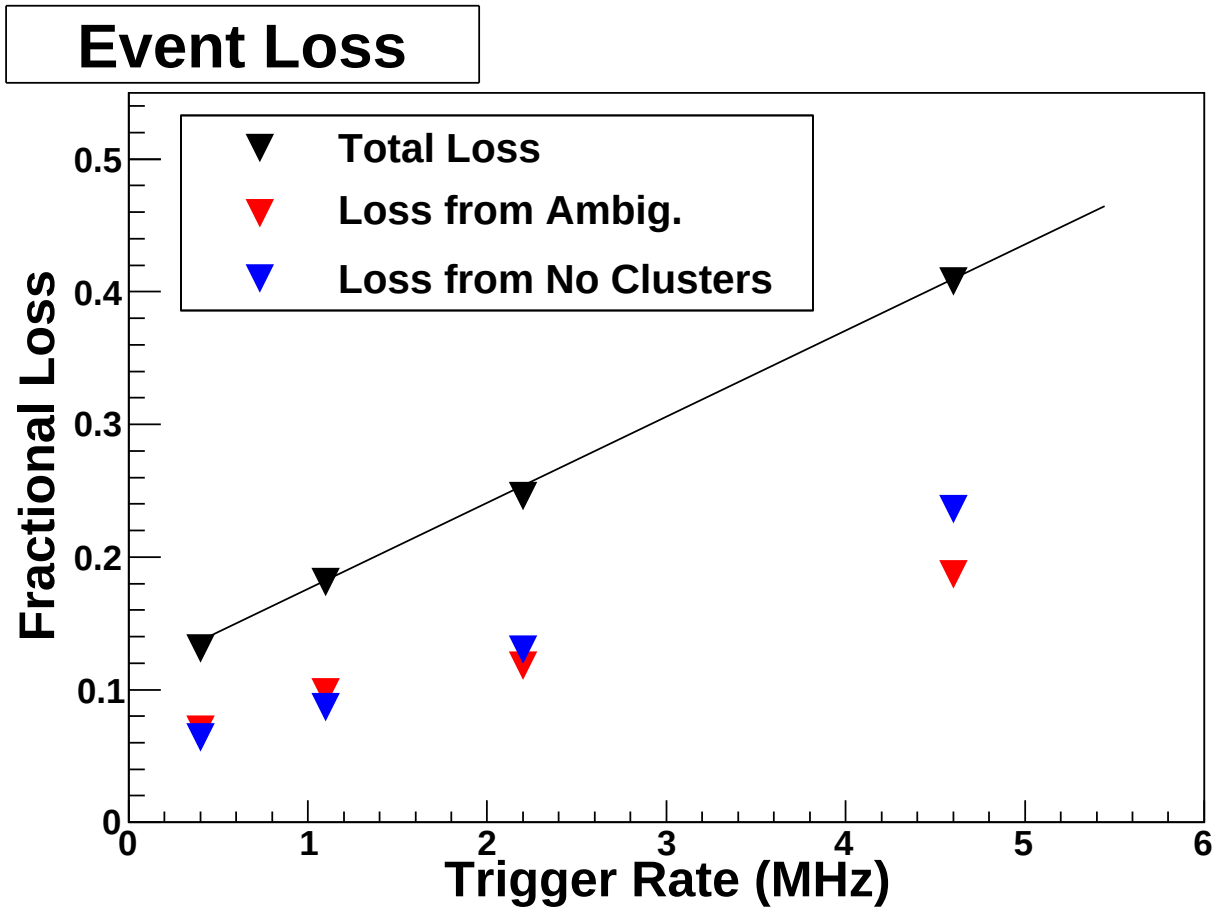
Hit Efficiency

- Hit efficiency drops at higher rate
- Non-uniform due to non-uniform event distribution



Tracking Efficiency

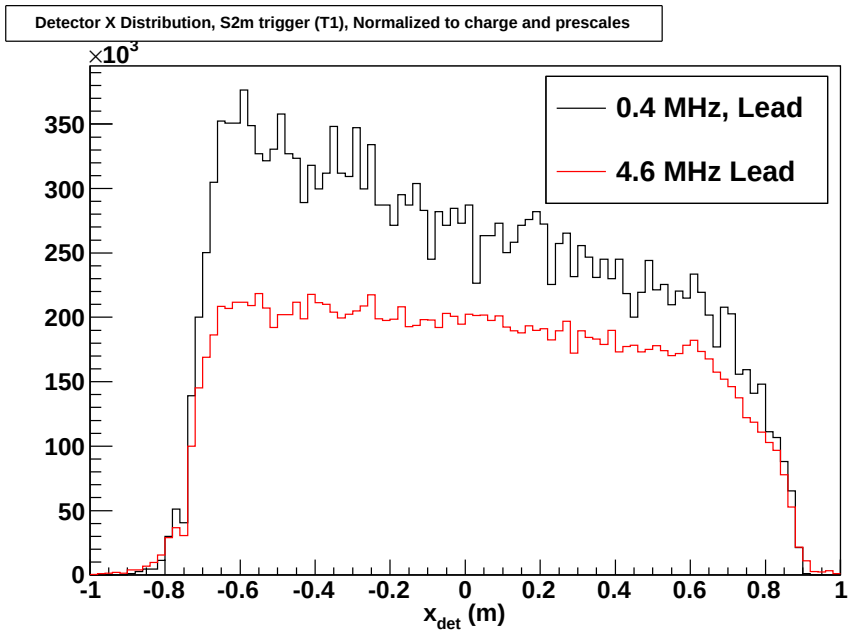
- Losses come from:
  - UV association ambiguity
  - No clusters found (bad timing structure, overlapping, hit inefficiency)



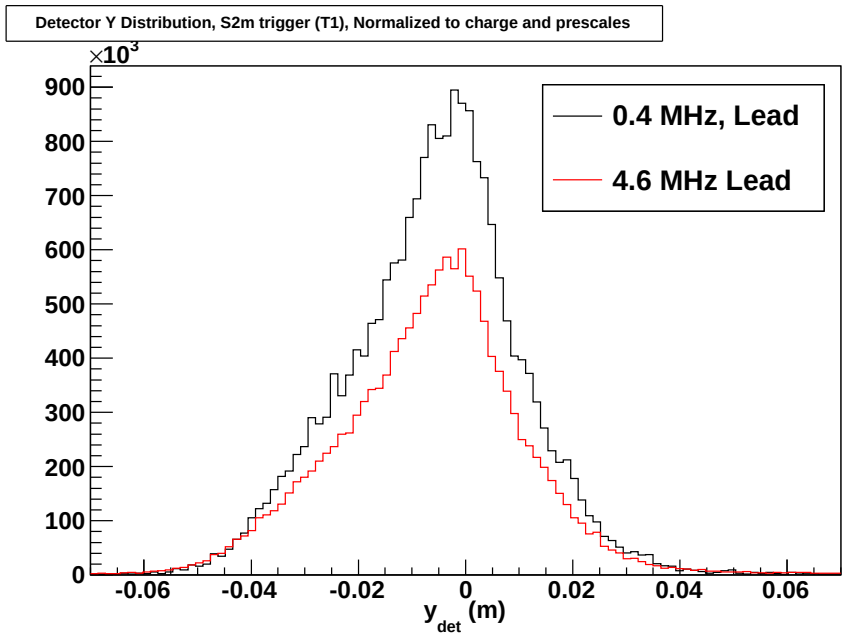
Event distribution

- 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, χ^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 MHz trigger, optimization of beam current must be performed

BACKUP SLIDES