APEX Software

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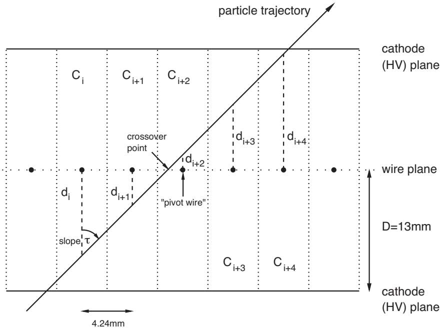
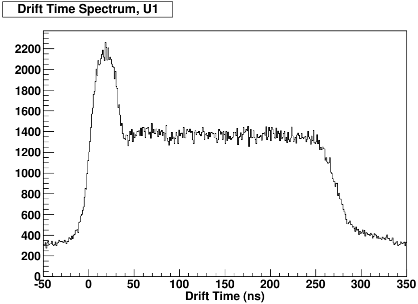
Outline

- HRS VDCs and APEX
- High Rate Tracking Performance
- Optics Going Forward

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





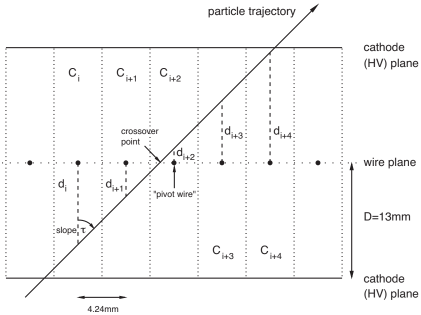
VDC Modifications

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 $\mathrm{Ar/CH_2}$	60-40 $\mathrm{Ar/CH_2}$
Max Rate	$500\ \mathrm{kHz}$	$5\ \mathrm{MHz}$
Gain	20×10^3	25×10^3

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

Tracking Algorithm - Clustering



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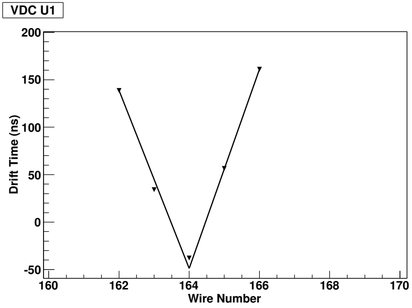
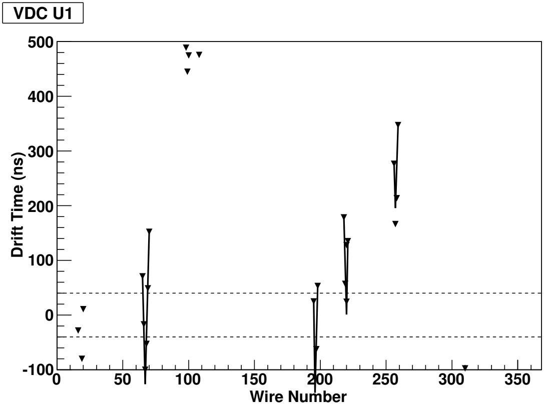


- Algorithm scans for 'V' shaped clusters in time
- Hits in each cluster must be within reasonable time constraints
- Allow for gaps of 1 wire, must have 3 $\leq$ wires in cluster $\leq$ 7
- Time of the cluster is offset, calculated through fit based on time-to-drift distance mapping
  - Time resolution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

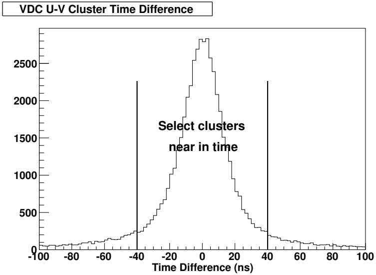
Advanced Scanning

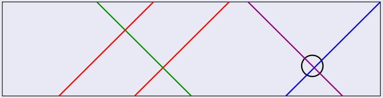


- Multihit TDC information used since rates are high
- Earliest hits used to fit clusters
- Several passes over data taken to maximize clusters found when separated in time, but not space

Tracking Algorithm - UV Association

- Cut on U cluster, V cluster time difference w/ trigger, $\pm 40\ \mathrm{ns}$
- Cluster positions must be in chamber active area



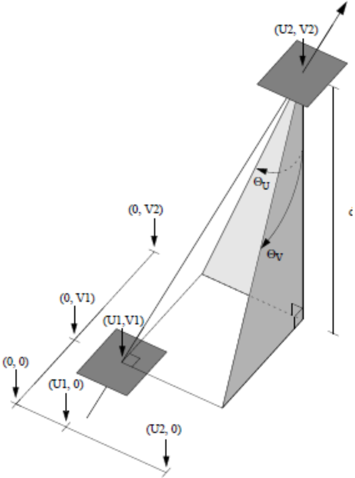


Ambiguity prevents unique association between U-V clusters

- If ambiguity in UV association, no tracks are returned

Tracking Algorithm - Track Fitting

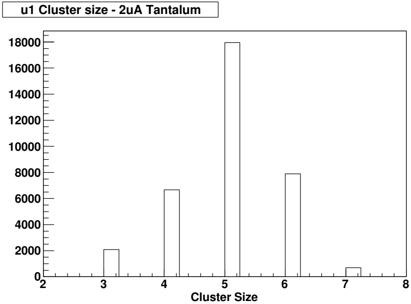
- All chamber 1 - chamber 2 UV cluste built
- Sort by χ^2 based on angular information from drift time fit
- Accept as many χ^2 clusters until maximum found



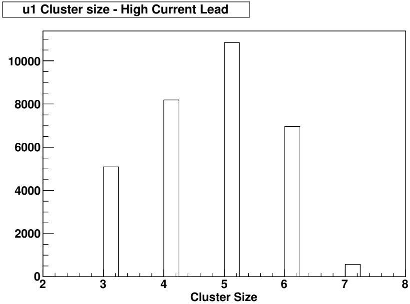
Tracking Efficiency

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

Low rate, 0.3 MHz



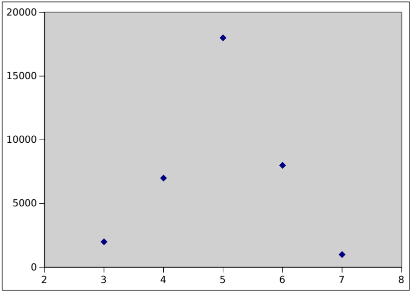
Highest rate, 5 MHz

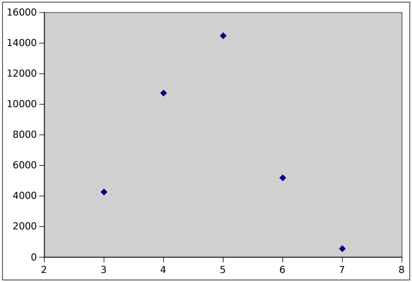


- Average wires in clusters become smaller at high rate due to efficiency

Tracking Efficiency

- Can take low rate as base and calculate how it shifts for hit inefficiencies





- Have $\sim$ 92% hit efficiency
- Expect 2% loss of tracking efficiency with hits < 3

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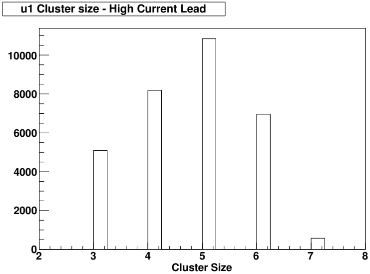

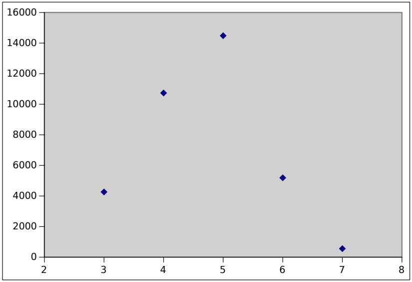

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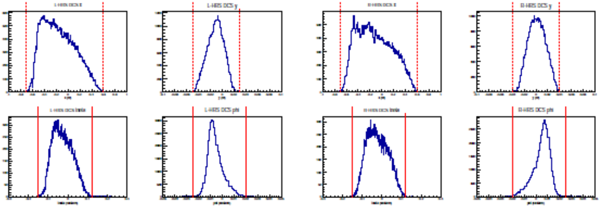
Tracking Efficiency - II

- From Eric's thesis:

Left-HRS	Right-HRS
-0.7 m $< x <$ 0.6 m	-0.7 m $< x <$ 0.6 m
-0.05 m $< y <$ 0.03 m	-0.04 m $< y <$ 0.04 m
-150 mrad $< \theta <$ 120 mrad	-150 mrad $< \theta <$ 120 mrad
-25 mrad $< \phi <$ 25 mrad	-20 mrad $< \phi <$ 25 mrad

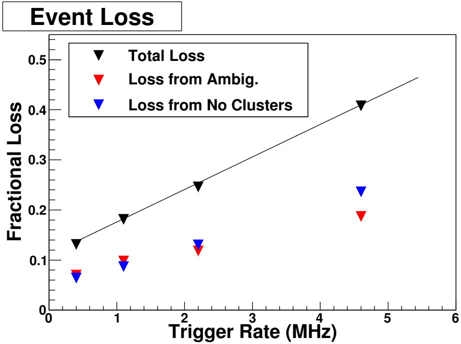


(A) (B)

- Required coincident event and then frequency of how often a track was found in an arm
- 99.0% for LHRS, 98.2% for RHRS
- Close enough with simple cluster argument?

Tracking Efficiency - Losses

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



- Loss goes up to 40% for highest current running

Efficiency Improvements

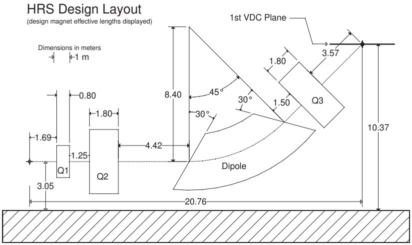
Tracking Work To Do:

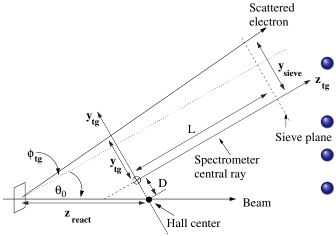
- UV ambiguity may be broken through use of other detectors, χ^2 fitting, geometry considerations, event distribution considerations
- Some clusters from "no cluster" events may be recovered through better cluster searching code
- Try to understand how spurious clusters are generated - G4 simulation?

Overview and Strategy

- APEX has unique optics requirements
  - FOM is driven by *scattering angle* resolution rather than momentum resolution
  - Septum needed to go from 6° to 12.5°
- Requires careful examination of HRS tune to optimize
- John LeRose is gone so we have to think through much of this ourselves
- Have produced 2nd order transport matrices for ideal case as starting test ground
- Confirmation in existing ray tracing required for final result

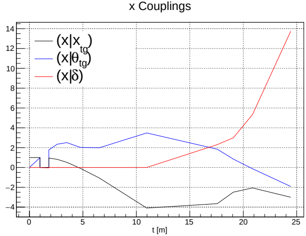
Optics Overview

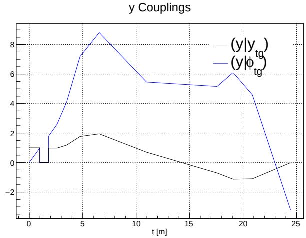




- Using idealized representation of HRS first and second order elements can be calculated
- Excellent primer for framework
- http://cds.cern.ch/record/283218/files/SLAC-75.pdf
- http://github.com/seamusriordan/hrstrans

APEX Tune - Simple Optimization Attempt





- Using first order code allows for rapid calculation of acceptance and matrix elements
- A fitter is used which
    - Preserve acceptance for target length (as seen at 6°)
    - Produce first order reconstruction matrix by inverting transport
    - Minimize reconstruction elements of $\phi_{\rm tg}$ with VDC spatial/angular resolutions
- Immediately drove $(y|y_{\rm tg})$ coupling to zero and increased $(y|\phi)$
- About the same acceptance - but serious losses in momentum and vertex resolution ($>$ factors 2?)

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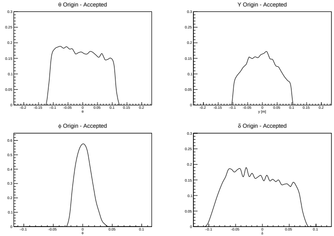

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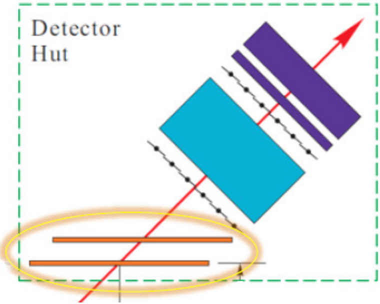
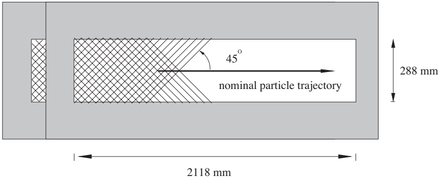
Summary and Work To Do

- Tracking generation for trying to match all clusters is about 60% at 5 MHz trigger, can this be understood?
- John LeRose's files were recovered and are available - I have access to SNAKE and the files used for standard tune, PREX, and have been using them
- Need to include our new septum, produce full polynomial transport, verify acceptance and reconstruction
- I believe this is a project which we can handle on our own and this is at a point where a grad students could get involved

BACKUP SLIDES

HRS Vertical Drift Chambers





Nominal Characteristics

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

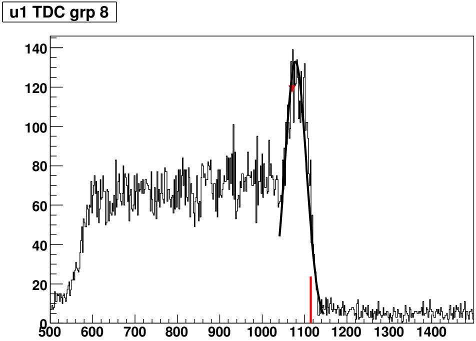
Pre-test run PAC Requirements

- 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 $\sim 5\ \mathrm{MHz}$ ($75\ \mathrm{kHz/wire}$)
- Requires hardware modifications to run efficiently without severe aging

Timing Offset Calibration

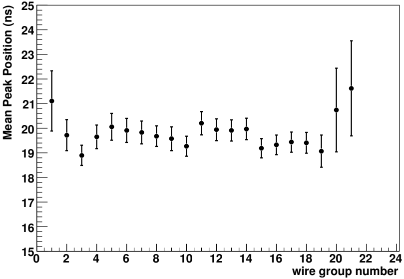
- VDC requires software offsets for drift time
- Calibrated in groups of 16 wires (discriminator inputs)

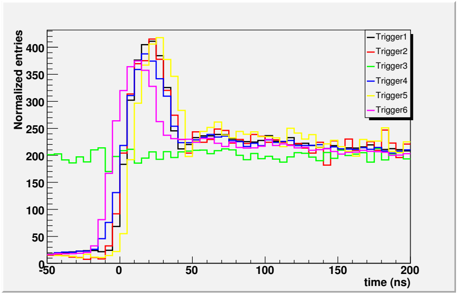


- Calibration done by fitting time dist. peak and fixed at 1.4 σ earlier from peak (arbitrary)

Timing Offset Calibration Results

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





Drift Time-to-Distance

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

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

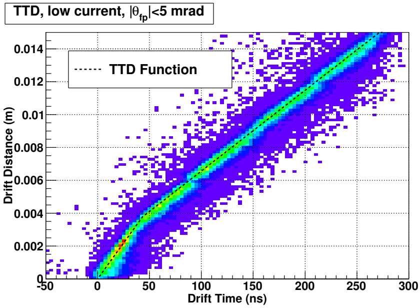
- a_1 and a_2 carry $\tan\theta = \frac{\Delta z}{\Delta r}$ dependence ($r = u$ or v)

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

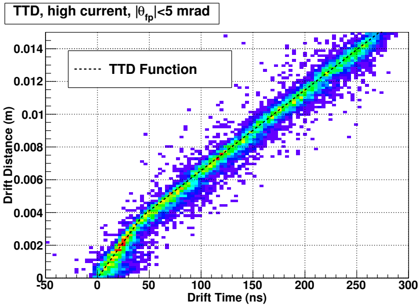
TTD Calibration

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

Low Rate, 0.4 MHz



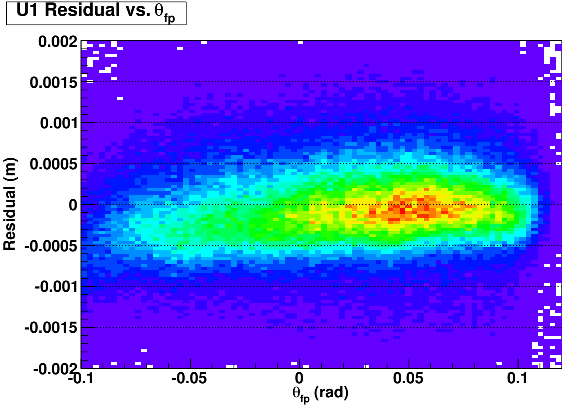
High Rate, 4.6 MHz



- Small recalibrations for θ dependence are necessary

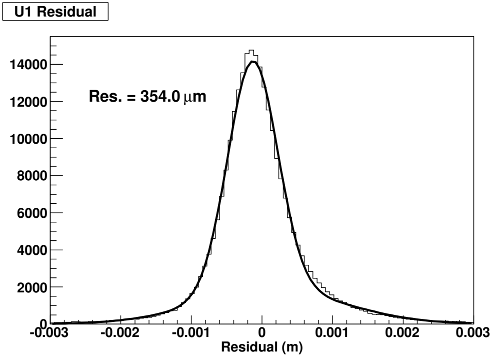
TTD Calibration

- Requires some θ dependence re-fitting
- Discrepancies are in the tail on the level of 20 $\mu\mathrm{m}$



Tracking Resolutions

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



- Second, broader Gaussian distribution appears at high rate
- Should be fitting to students t distribution with mult scatt
- Corresponds to 100 $\mu\mathrm{m}$, 0.3 mrad detector resolution

Tracking Efficiency

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  - Left arm s2m scintillator trigger
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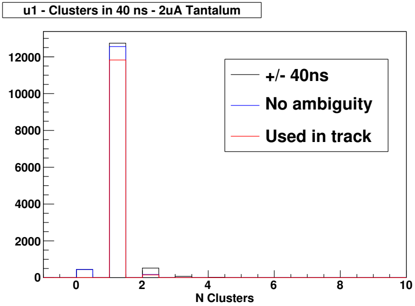
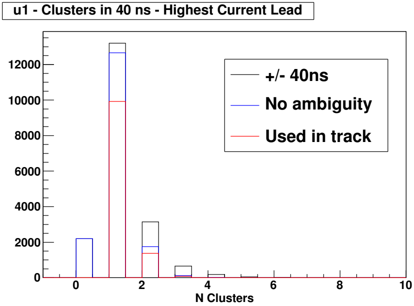
Low rate, 0.3 MHz



Highest rate, 5 MHz

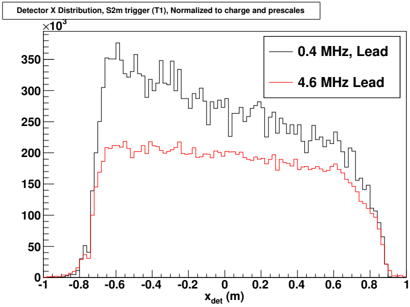


- Average wires in clusters become smaller at high rate due to efficiency

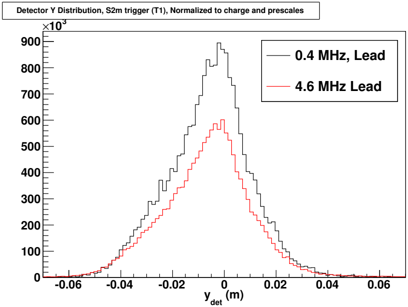
Event distribution

- Event distribution has small distortions due to non-uniform efficiency
- How does this affect the acceptance?

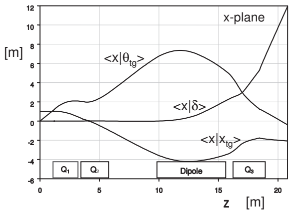
X_{det}

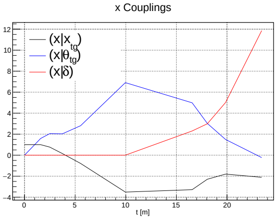


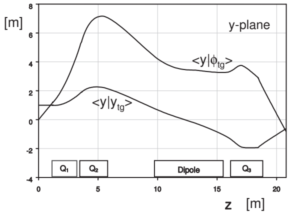
Y_{det}

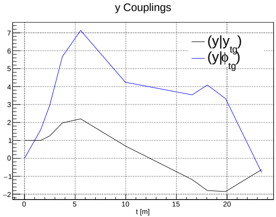


Standard Tune Comparison







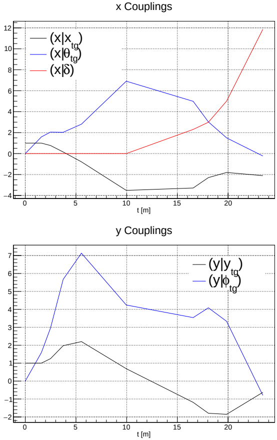


- Framework does a reasonably good job of recreating first order elements
- Acceptance $\sim$ 6 msr using simple aperture cuts

APEX Tune

- APEX test run ran with special tune which nominally reproduces standard tune optics and acceptance but with pure $(y|\phi)$ coupling

Standard Optics



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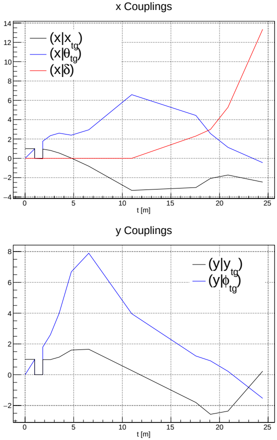
APEX Test Run Configuration



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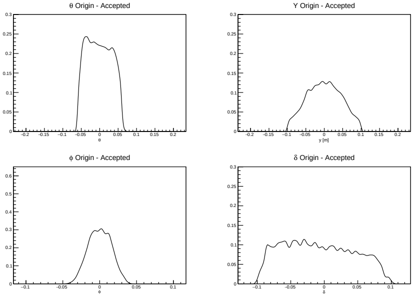

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