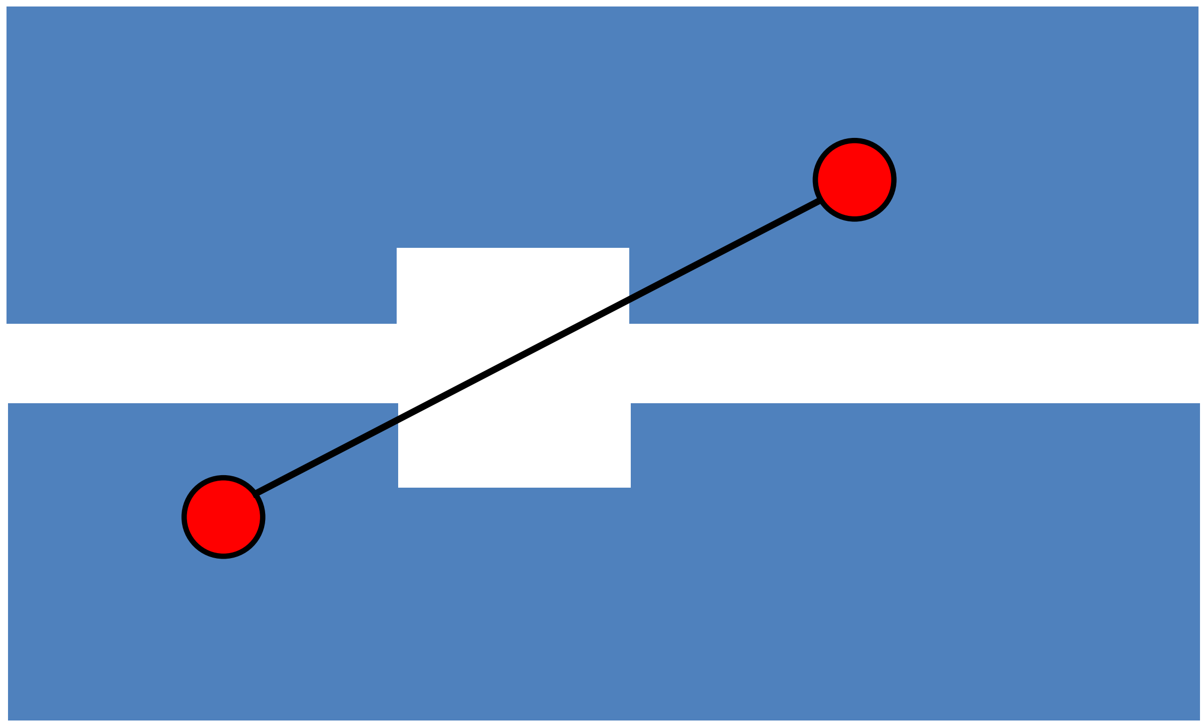
Positron Trigger

Monte Carlo Update

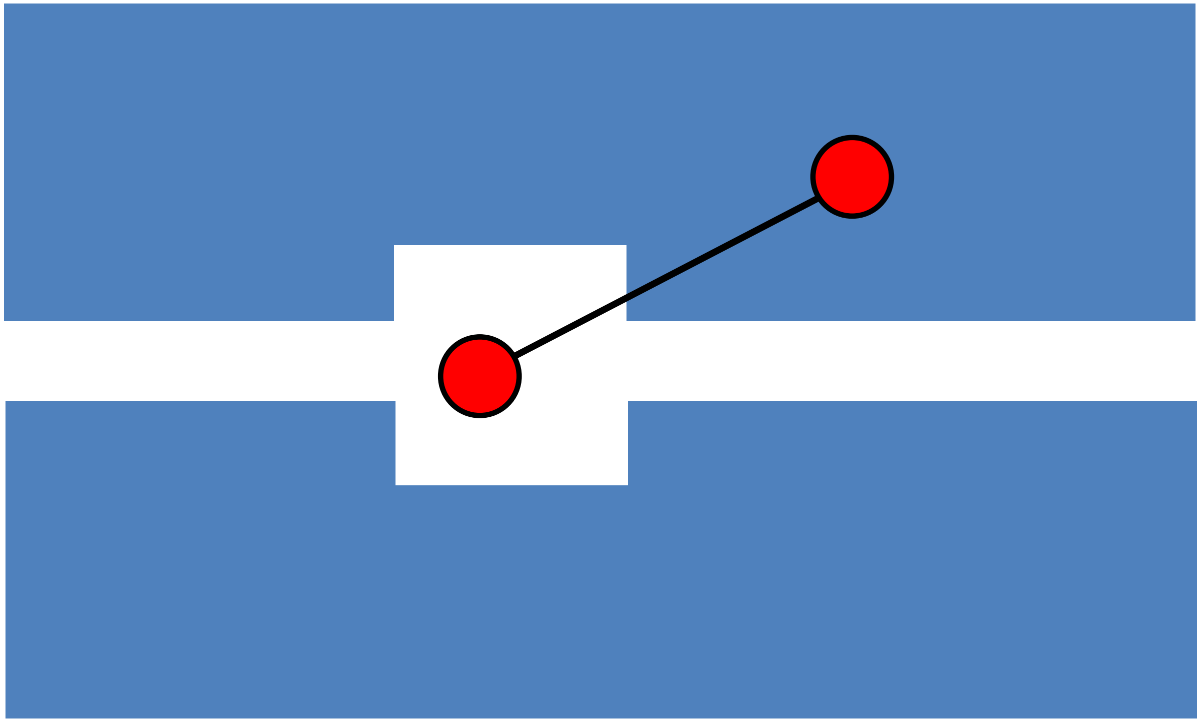
Introduction

- The HPS experiment has thus far employed a pair trigger for the purpose of selecting trident-like events.
    - The pair trigger takes two calorimeter clusters and, using a number of cuts, selects those most likely to be tridents.



Introduction

- It turns out that for many tridents, the electron in the pair is lost to the beam hole and, further, wide-angle bremsstrahlung rates are very high.
  - Many lost electrons are good, high-energy particles.
  - Wide-angle bremsstrahlung can often cause a pair trigger.



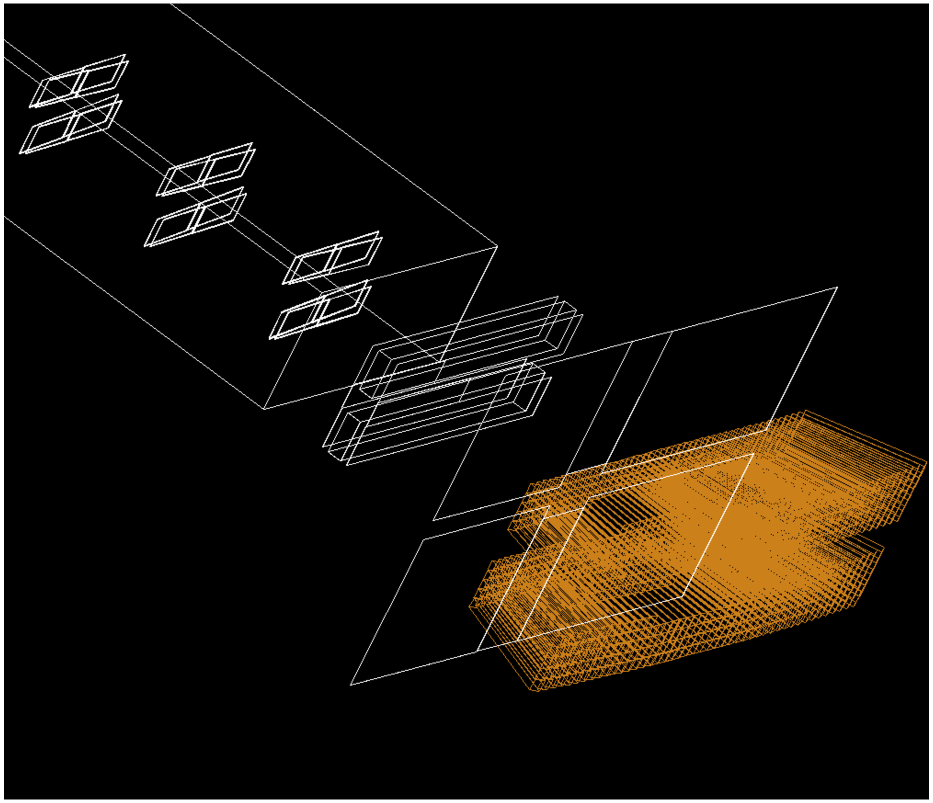
Introduction

- A possible solution to this is positrons. Positrons rarely appear outside of tridents, and are produced relatively rarely.
  - A positron trigger should be able to select events where the electron is lost, increasing trident rates in readout.
  - A positron trigger should be more pure and have fewer WAB events.

- A singles triggers won't work!
  - Rates are extremely high, even when limited to just the positron side of the detector.
  - There is not a reliable way to differentiate a positron from other particles using only the calorimeter.
  - The SVT can not perform reconstruction quickly enough to be used for triggering purposes.

Introduction

- Proposed solution: Add a hodoscope in between the calorimeter and SVT.
  - The hodoscope can detect when a charged particle passes through, removing photon contamination.
  - Rates can be controlled by establishing a coincidence between the hodoscope and the calorimeter face.
  - This will reduce rates enough to trigger on single clusters on the positron side of the calorimeter.



Particle Selection

- Before considering a positron trigger, it is first necessary to characterize the positrons.
  - Where do they end up?
  - What backgrounds are there?
  - What rates could be expected?

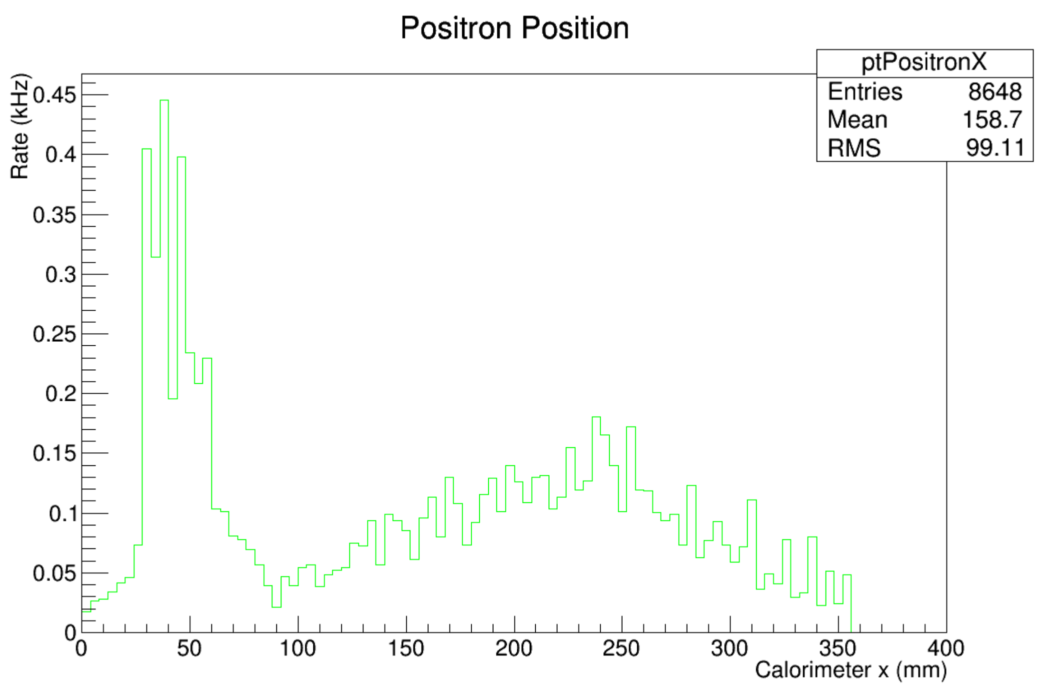
- To do this, SVT data is used to select particles and map their positions on the calorimeter. Several classes of particle are defined.
  - Clustered Particles
    - Have a GBL track and cluster.
    - Have a cluster/track matching goodness of $n_\sigma < 3$.
    - Have a track fit goodness of $\chi^2/n_{\mathrm{DF}} < 5$.
    - Have a charge of $q < 0$ (electrons) or $q > 0$ (positrons).

Particle Selection

- Particle classes [continued]:
  - Clusterless Particles:
    - Have a GBL track.
    - Have a track fit goodness of $\chi^2/n_{\mathrm{DF}} < 5$.
    - Have a charge of $q < 0$ (electrons) or $q > 0$ (positrons).
    - Have either no cluster, or cluster/track matching goodness $n_\sigma > 5$.
  - Ambiguous Particles
    - Have a GBL track and a cluster.
    - Have a track fit goodness of $\chi^2/n_{\mathrm{DF}} < 5$.
    - Have a charge of $q < 0$ (electrons) or $q > 0$ (positrons).
    - Have a cluster/track matching goodness $3 < n_\sigma < 5$.

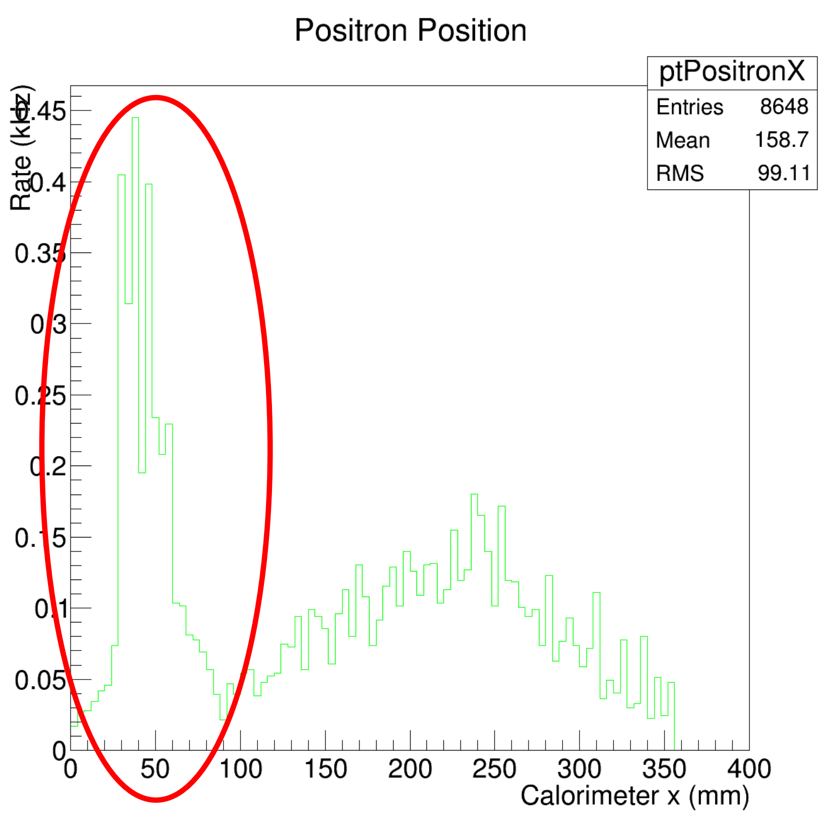
Positron Positioning and Rates

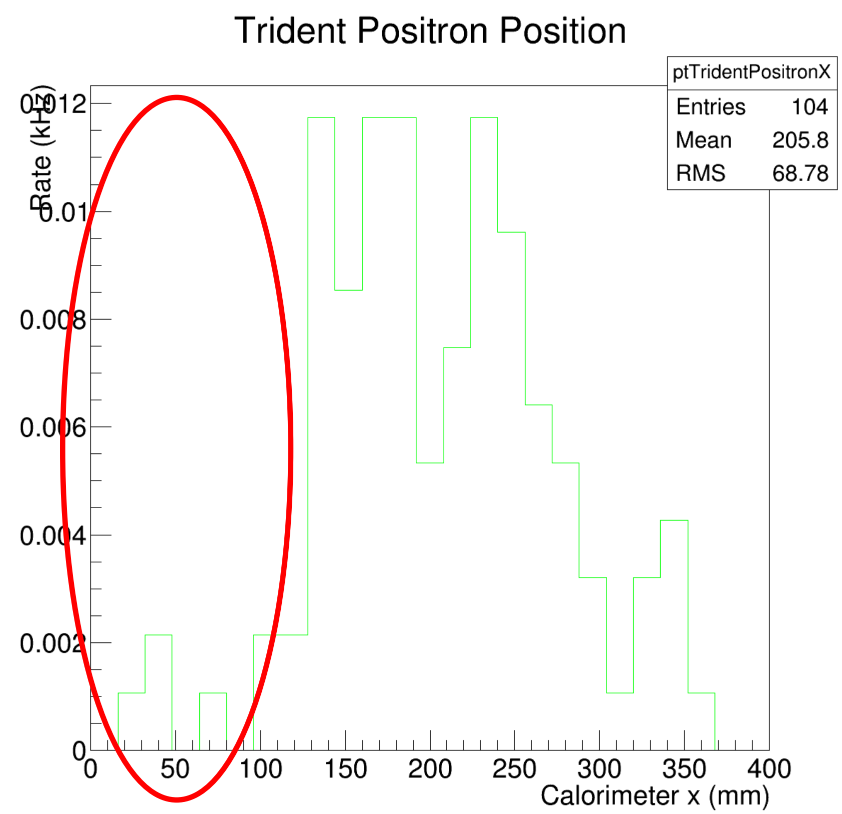
- We first consider the positron spatial distribution.
  - Only clustered positrons are considered.
  - We want to have a coincidence between the hodoscope and calorimeter, so we will need a positron cluster.
- The x-distribution on the calorimeter face for these particles is plotted.



Positron Positioning and Rates

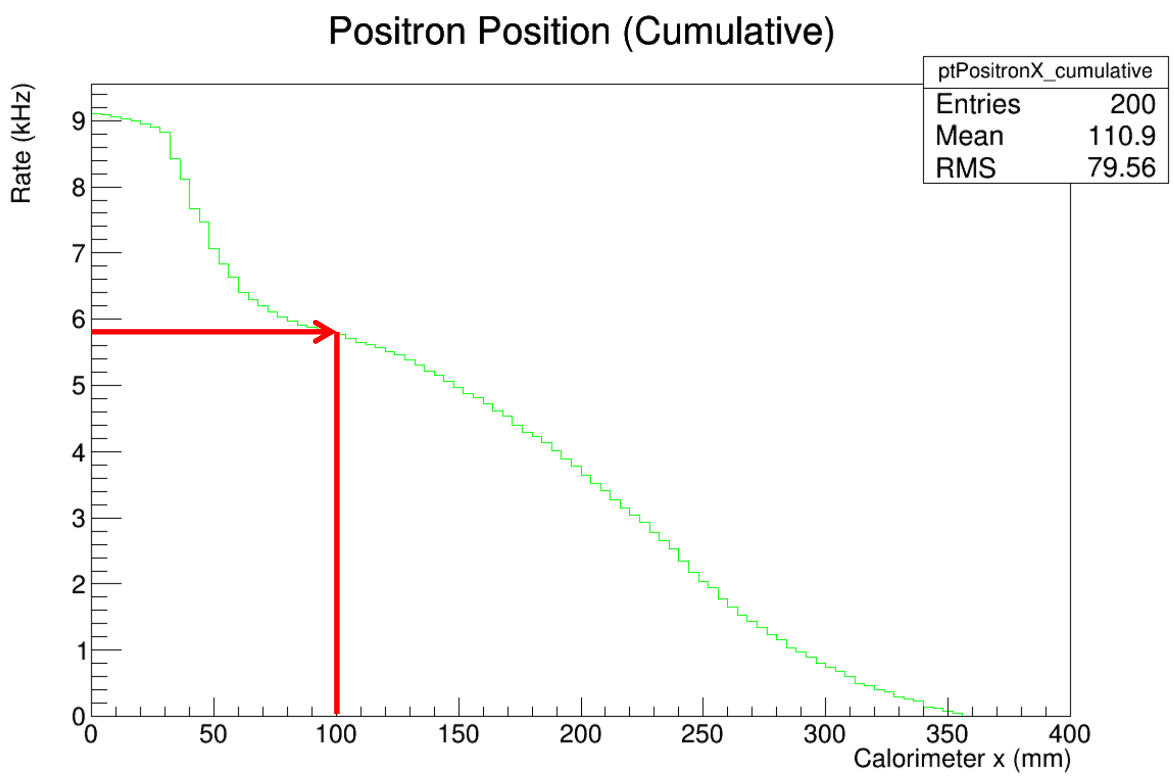
- First thing to note: the large peak at 50 mm is almost certainly not a real positron peak. Note that it is almost entirely absent from tridents.
- Real positrons appear to largely start at about 100 mm.





Positron Positioning and Rates

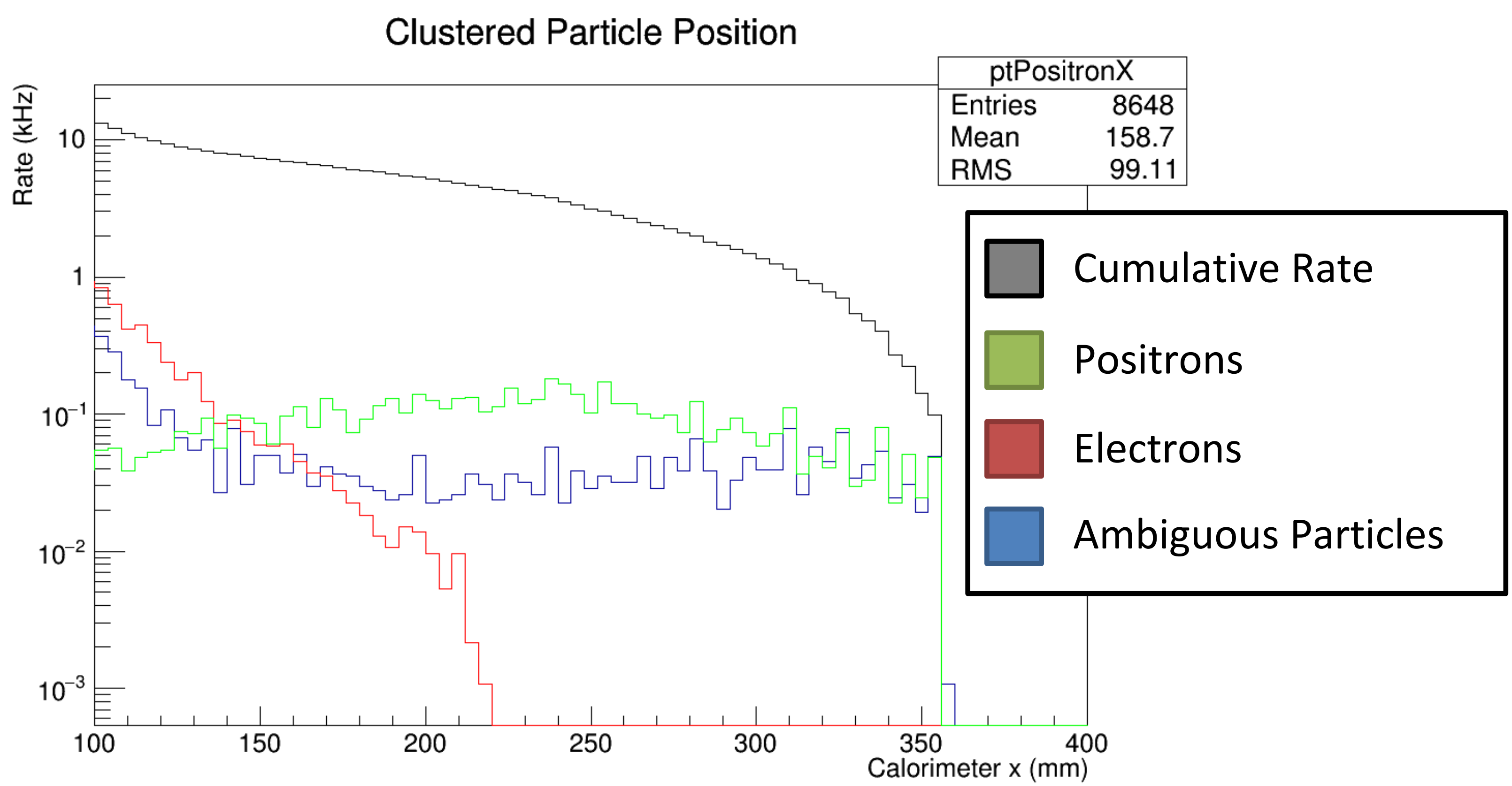
- It seems (real) positrons begin to appear roughly around 100 mm.
- A cumulative positron rate can be estimated using the previous plot.



- Rates for (real) positrons at $x > 100$ mm appear to be roughly 6 kHz.

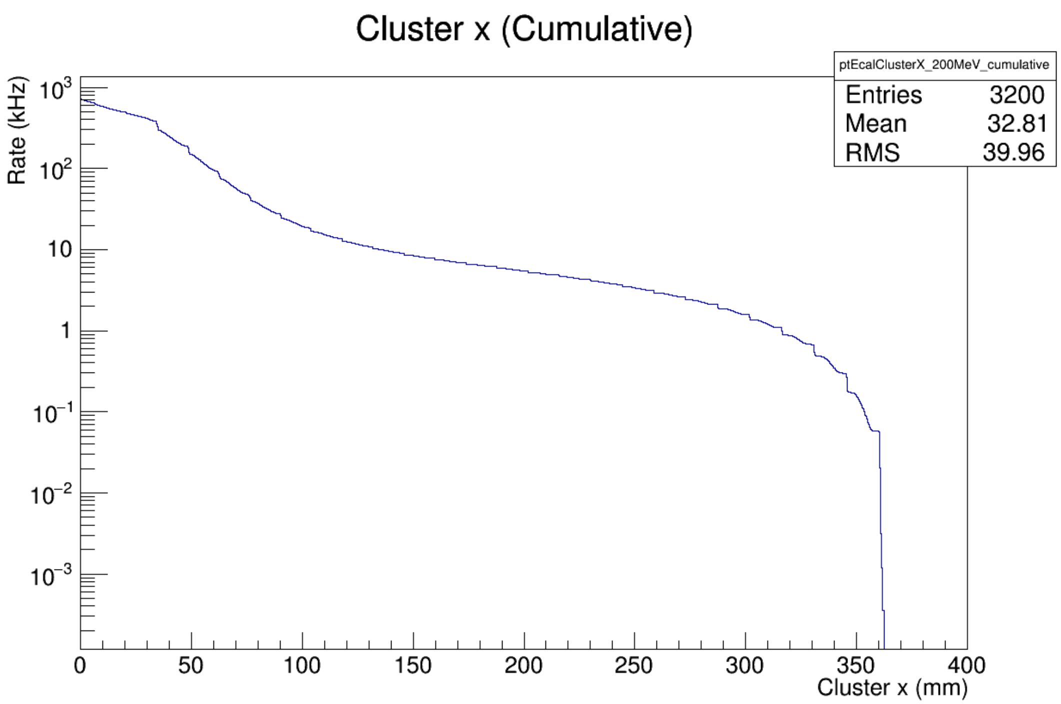
Positron Positioning and Rates

- Of course, positrons are not the only charged particles. Accidentals need to be considered as well.
  - Consider the rates when including electrons and ambiguous particles.



Positron Positioning and Rates

- With all charged particles, we would expect a rate of roughly 16 kHz.
  - This is manageable!
  - It is also a major improvement over the raw calorimeter cluster rates.



- All cluster rates for the same region are order 50 kHz!

Positron Positioning and Rates

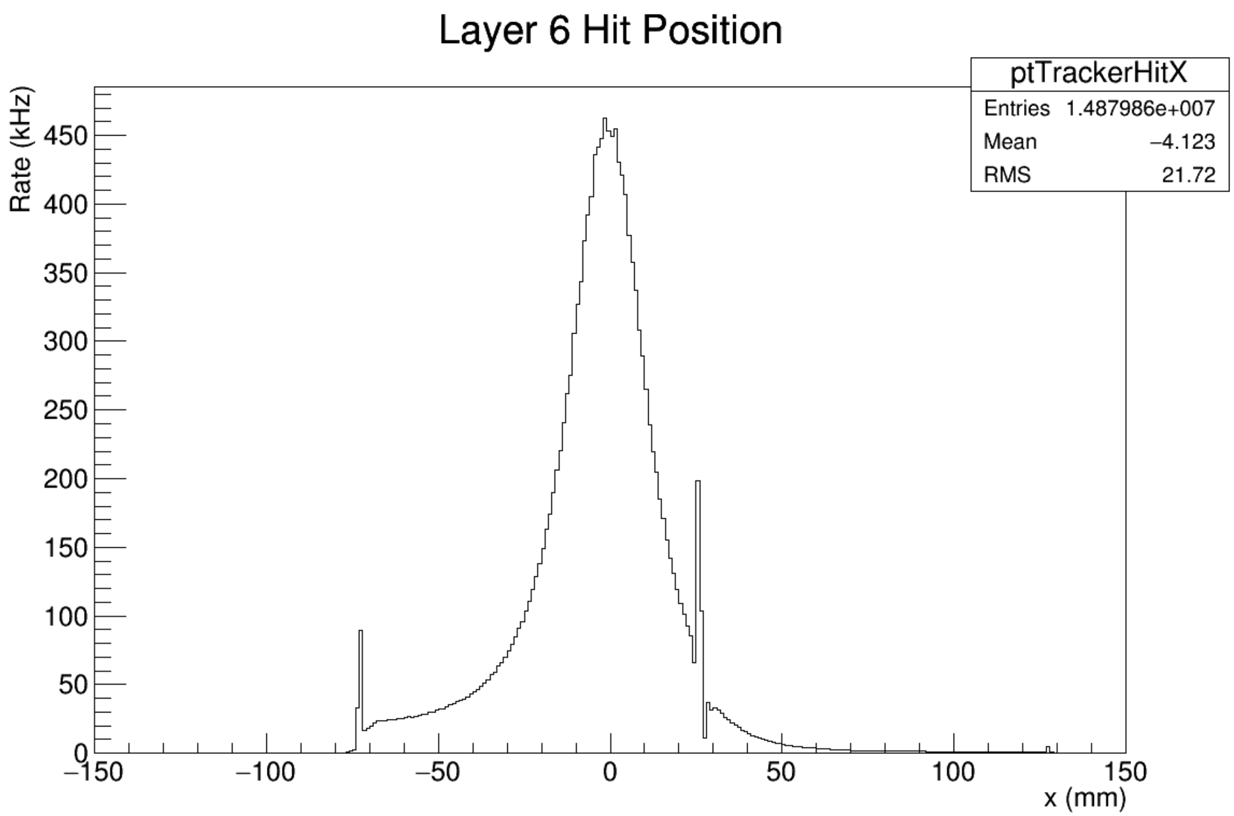
- Tracks are a good way to estimate the total *analyzable* positron rate, but are not good for estimating the total rates a hodoscope would actually see.
  - Many particles may be produced in the SVT and not hit enough layers to produce tracks.

- The SVT layer 6 can serve as a useful stand-in for the hodoscope.
  - It is located not too far from the expected hodoscope position.
  - It only detects charged particles.
  - Most particles that would hit the hodoscope will also probably pass through the SVT.

- The rate of hits on layer 6 is then measured and a projected rate calculated.

Positron Positioning and Rates

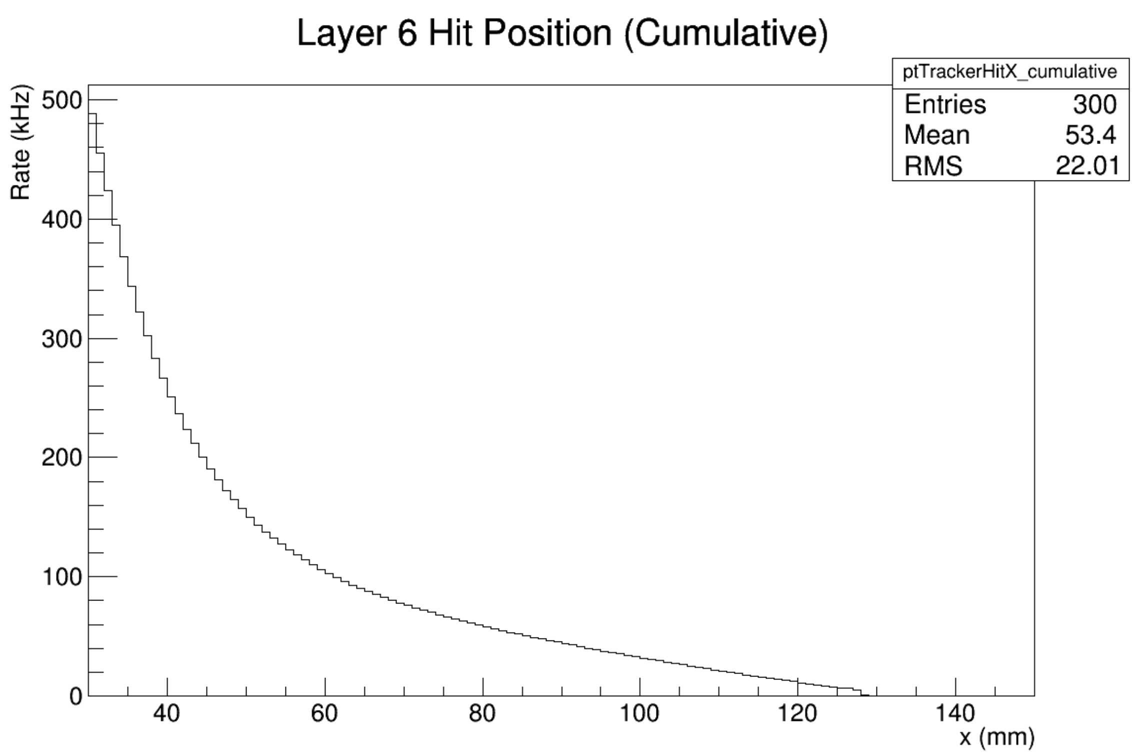
- Consider the results from the 2015 data run:



- Rates ultimate get quite high, but remain fairly low in the positron region.

Positron Positioning and Rates

- Viewed cumulatively, from the positron side of the detector:

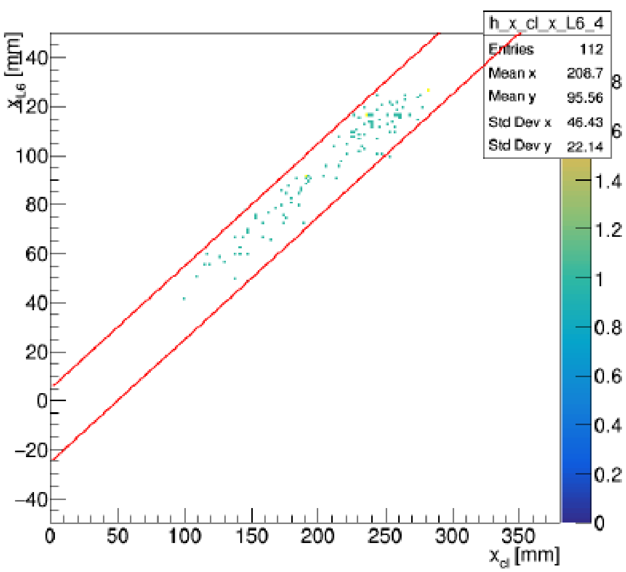


- For the region of layer 6 that corresponds roughly to the positron region of the calorimeter, rates of around 150 kHz are expected.

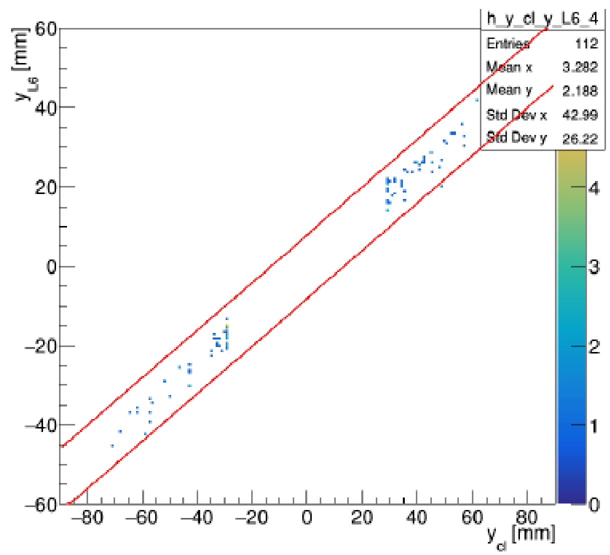
Positron Positioning and Rates

- Rafo also performed a simple study to simulate a hodoscope trigger rate.
  - Layer 6 was used in place of a hodoscope.
  - A spatial coincidence was established between the layer 6 hit position and calorimeter cluster position.

X coorelation

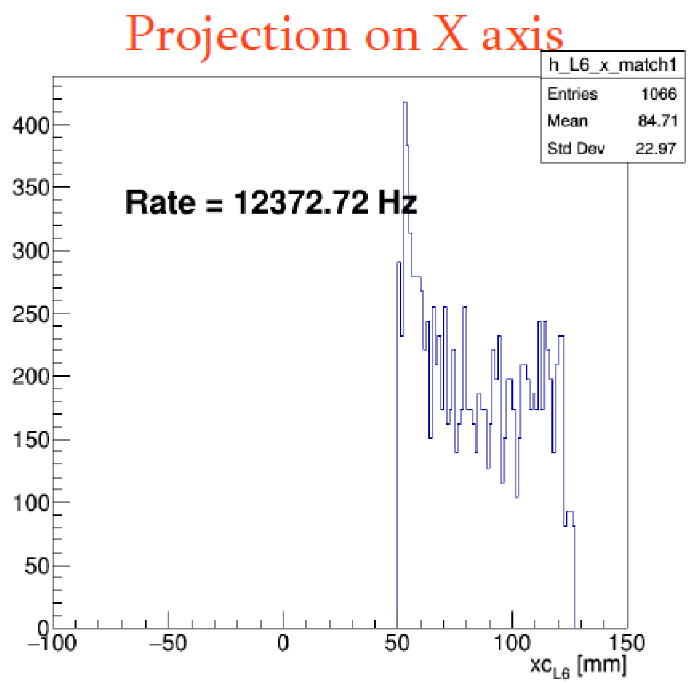


Y coorelation



Positron Positioning and Rates

- Using these relations and performing the matching, he estimates a trigger rate of roughly 12 kHz.
  - This is consistent with the above predictions of 16 kHz, with some pruning due to the hit relations.



- Full Cuts:
  - $38\ \mathrm{ns} < t_{\mathrm{cl}} < 48\ \mathrm{ns}$
  - $x_{\mathrm{ecal}} > 100\ \mathrm{mm}$
  - $x_{\mathrm{L6}} > 50\ \mathrm{mm}$
  - Apply hit position relations.

Trident Rate Gain

- 150 kHz is tenable, and the positron trigger feasible.
- The question remains, however: Is the positron trigger useful?
- It is important to test how many new trident events we expect to gain from introducing a positron trigger.
- It also important to see that we are able to select tridents when one particle (the electron) does not possess an associated cluster.

Trident Rate Gain

- Consider a traditional two-cluster trident selection cuts.
  - Select a particle pair.
  - Both particles should have tracks.
  - Both particles should have clusters.
  - Require track $\chi^2/n_{\mathrm{DF}} < 5$ for both tracks.
  - Require $n_\sigma < 3$ for both track/cluster pairs.
  - Select only one track if more than one is matched to a single cluster.
  - One cluster must have $y > 0$ and one must have $y < 0$.
  - Cluster time difference Δt must be within some threshold.

- Several of these cuts can not be applied as-is to a pair where one track lacks a cluster. Can we work around this?

Trident Rate Gain

- Consider each of the no-longer valid cuts.
  - Both particles should have clusters.
    - Now, only the positron must have a cluster.
  - Require $n_\sigma < 3$ for both track/cluster pairs.
    - Retain this rule for the positron. It is not applicable for the electron.
  - Select only one track if more than one is matched to a single cluster.
    - Duplicate tracks can be eliminated looking for tracks that share more than three tracker hits in common. In this case, keep only the track with the best χ^2/n_{DF}.
  - One cluster must have $y > 0$ and one must have $y < 0$.
    - Track position can be extrapolated to the calorimeter to determine y instead of using cluster position.

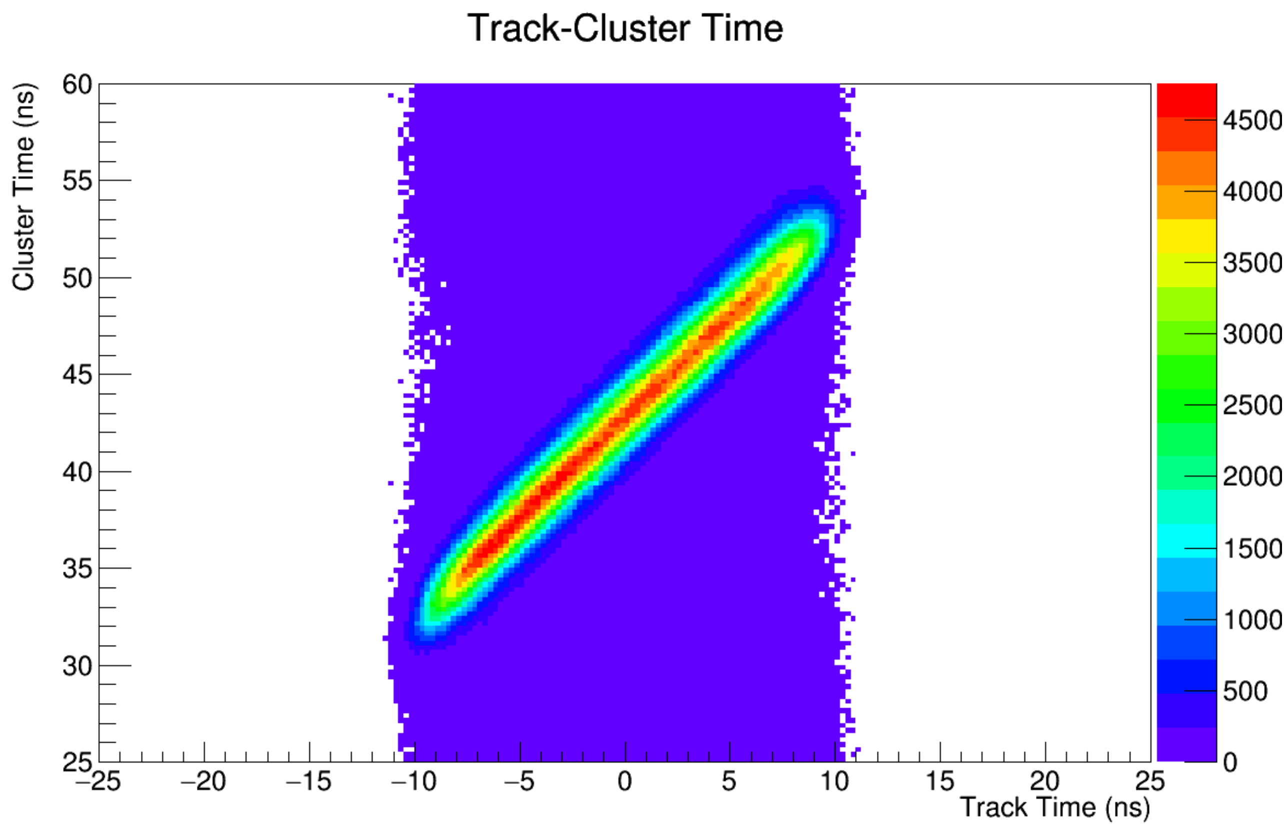
Trident Rate Gain

- Most of these changes are fairly straightforward. The biggest concern is the time cut.
    - The time coincidence cut cleans a lot of background out of regular trident selection.
    - Tracks have a time-of-flight corrected average time based on their tracker hits.
    - It needs to be shown that this can work in conjunction with a cluster time to replicate the time coincidence cut.

- To begin the process of checking this, clustered tracks are considered.
    - The time of the cluster is plotted versus the time of the track to establish a relation between the two.

Trident Rate Gain

- There is, fortunately, a clear relation between the two times.



- A new time coincidence cut of $\Delta t = (t_{e^+} - t_{e^-} + 43)$ is defined.

Trident Rate Gain

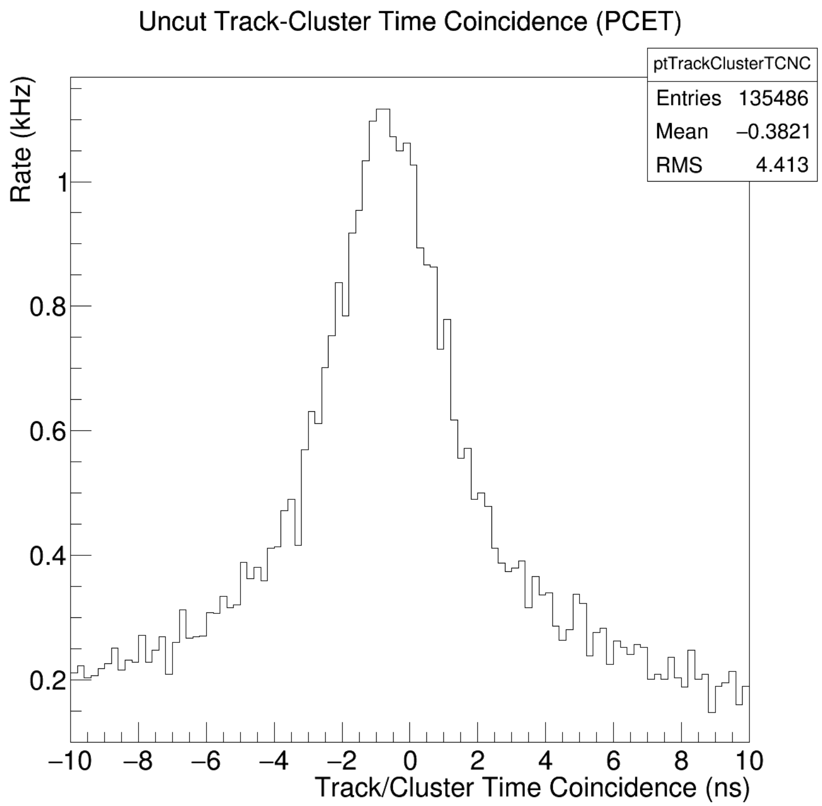
- We may now compare the time coincidence distributions for particle pairs.

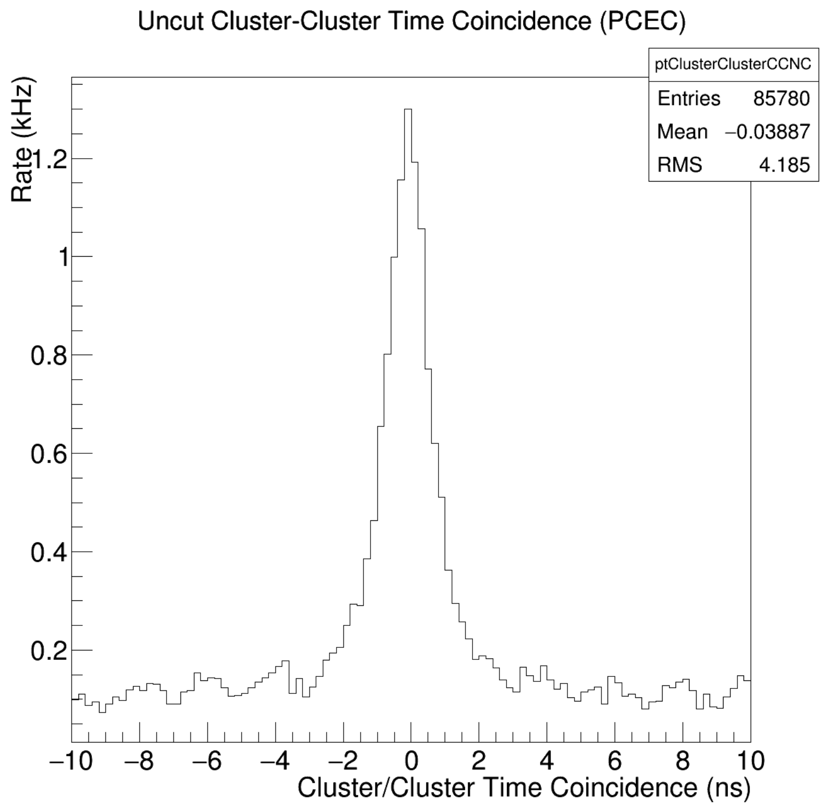
- We consider several sets of distributions.
    - Clustered e^+/e^- pairs with no other cuts.
    - A clustered e^+ and a clustered or unclustered e^- with no other cuts.
    - Clustered e^+/e^- pairs with all (new) non-temporal trident cuts.
    - A clustered e^+ and a clustered or unclustered e^- with all (new) non-temporal trident cuts.

- This allows both the old and new distributions to be compared.
    - With particles clustered, the old cluster time difference will be plotted.
    - For the case of one particle clustered, the new track/cluster time difference will be plotted.

Trident Rate Gain

- We may now compare the time coincidence distributions for particle pairs.

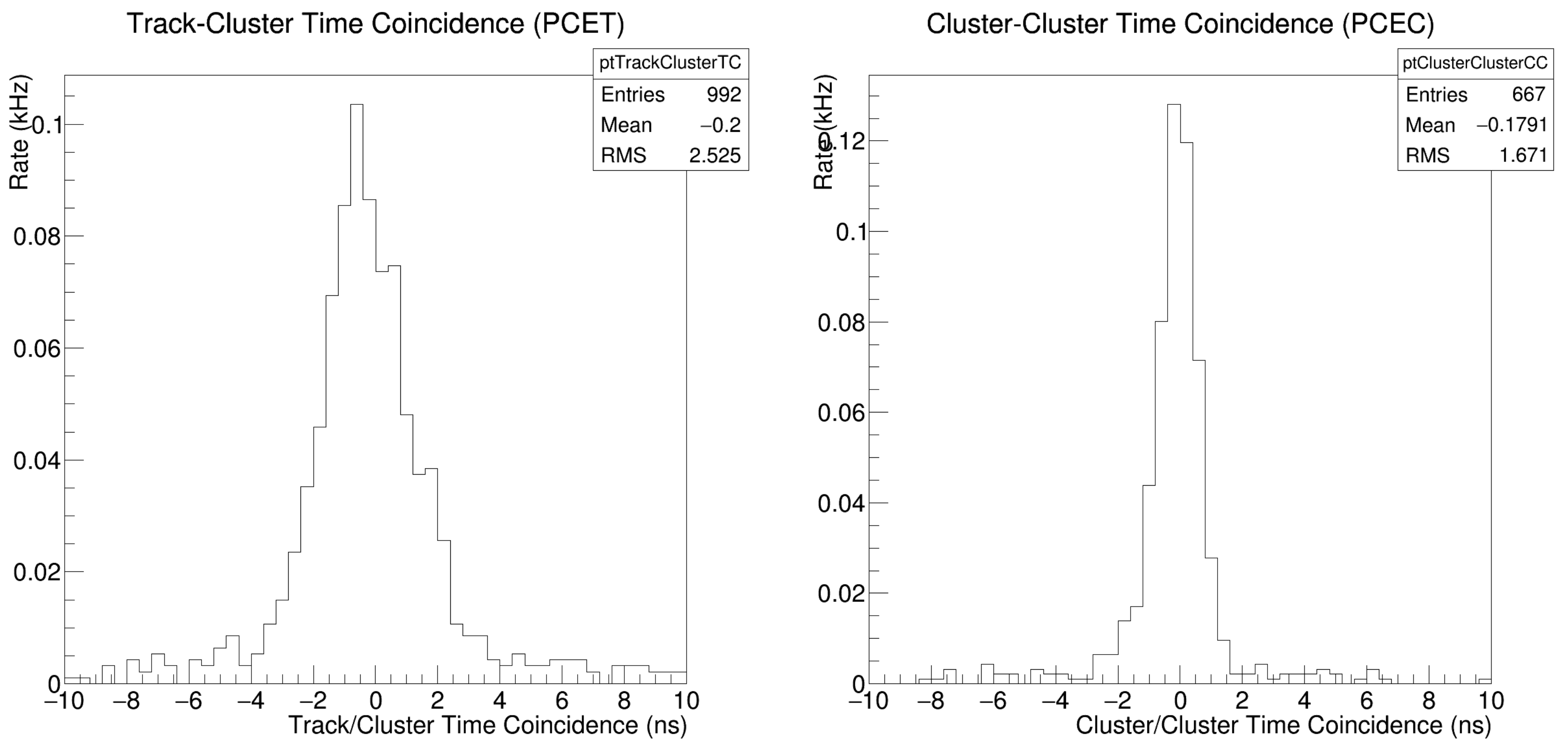




- There is much more background noise in the track/cluster distribution and a wider peak for the no additional cuts pairs.

Trident Rate Gain

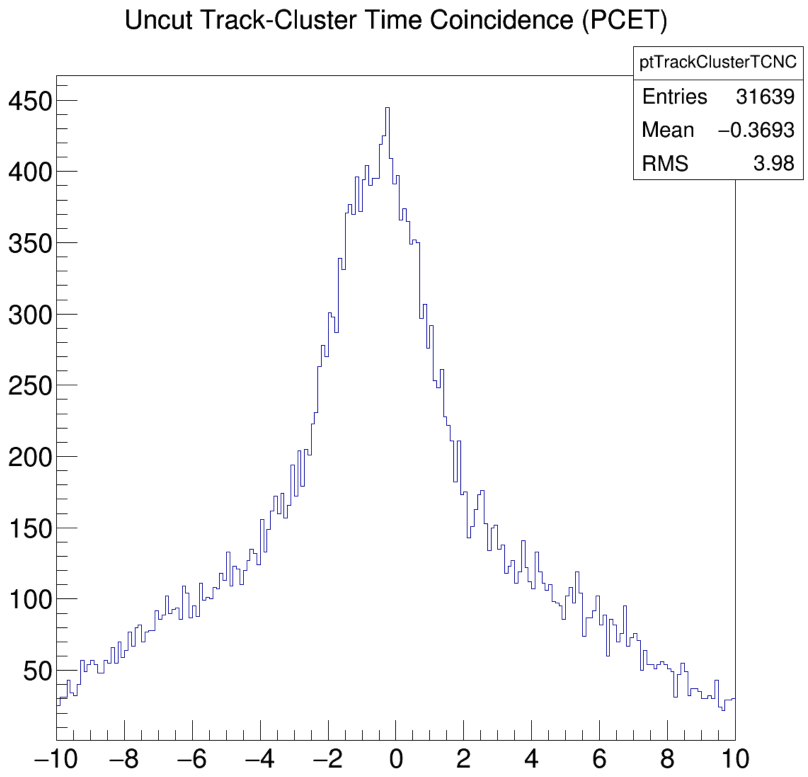
- We may now compare the time coincidence distributions for particle pairs.

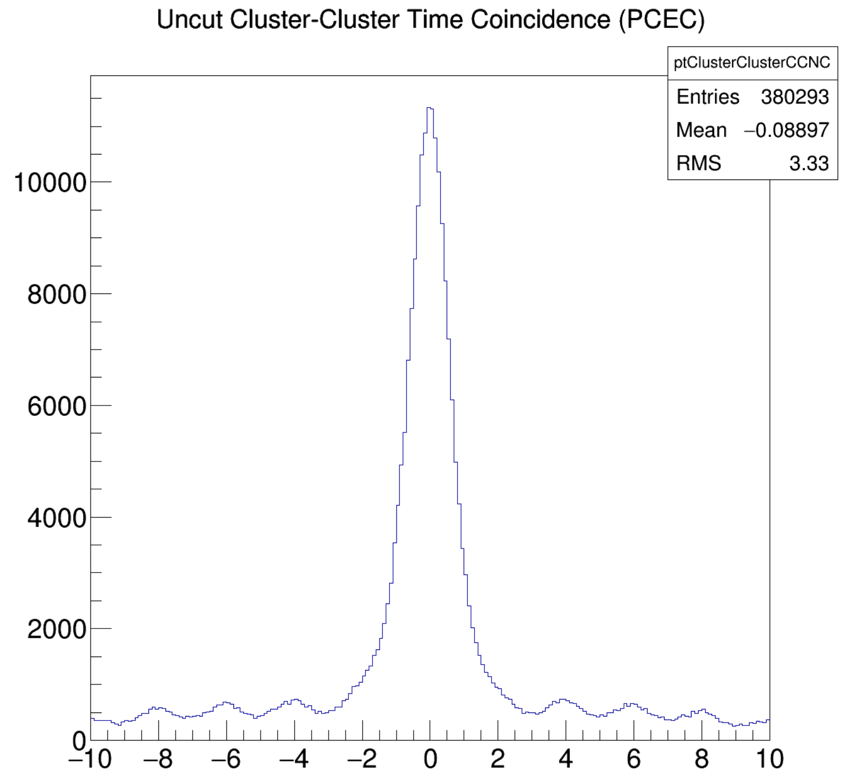


- Applying the trident cuts cleans up the distribution considerably, though the time resolution remains wider in the track/cluster case.

Trident Rate Gain

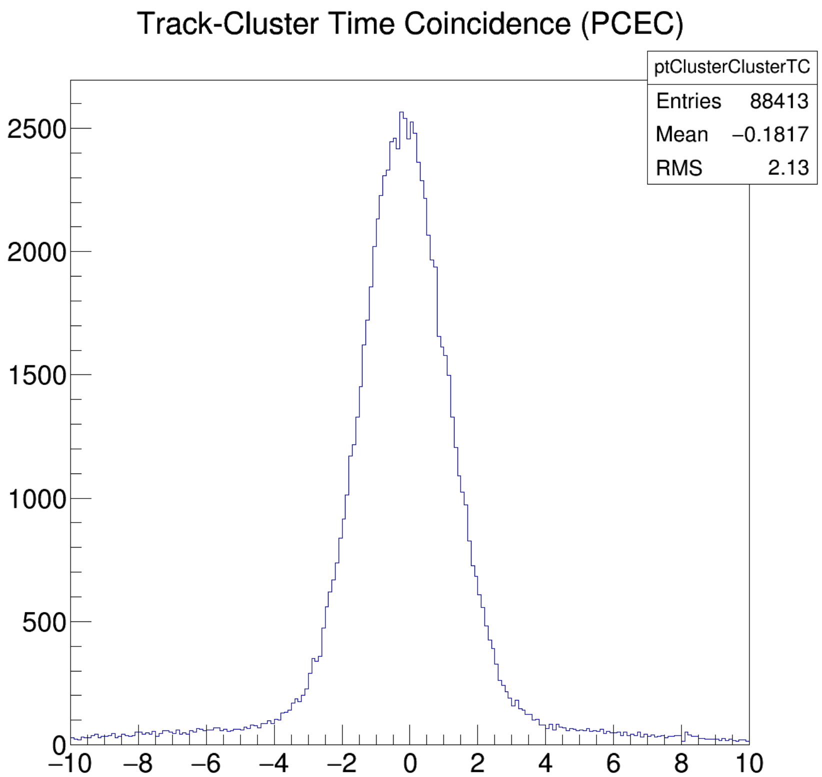
- Note that this same behavior is seen when using a production run, but is clearer. Consider the uncut plots below, for run 5772:

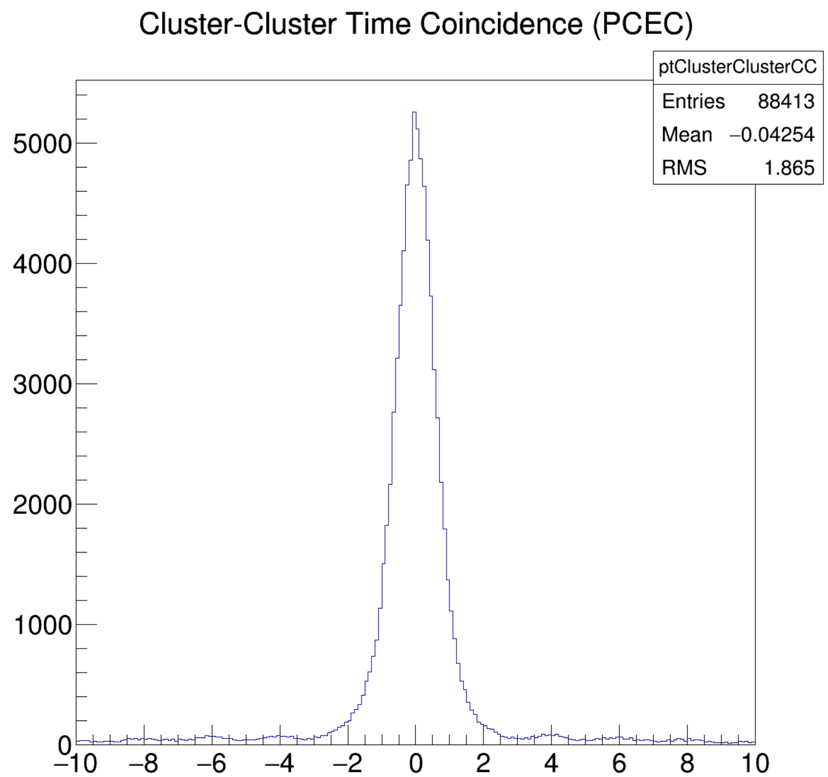




Trident Rate Gain

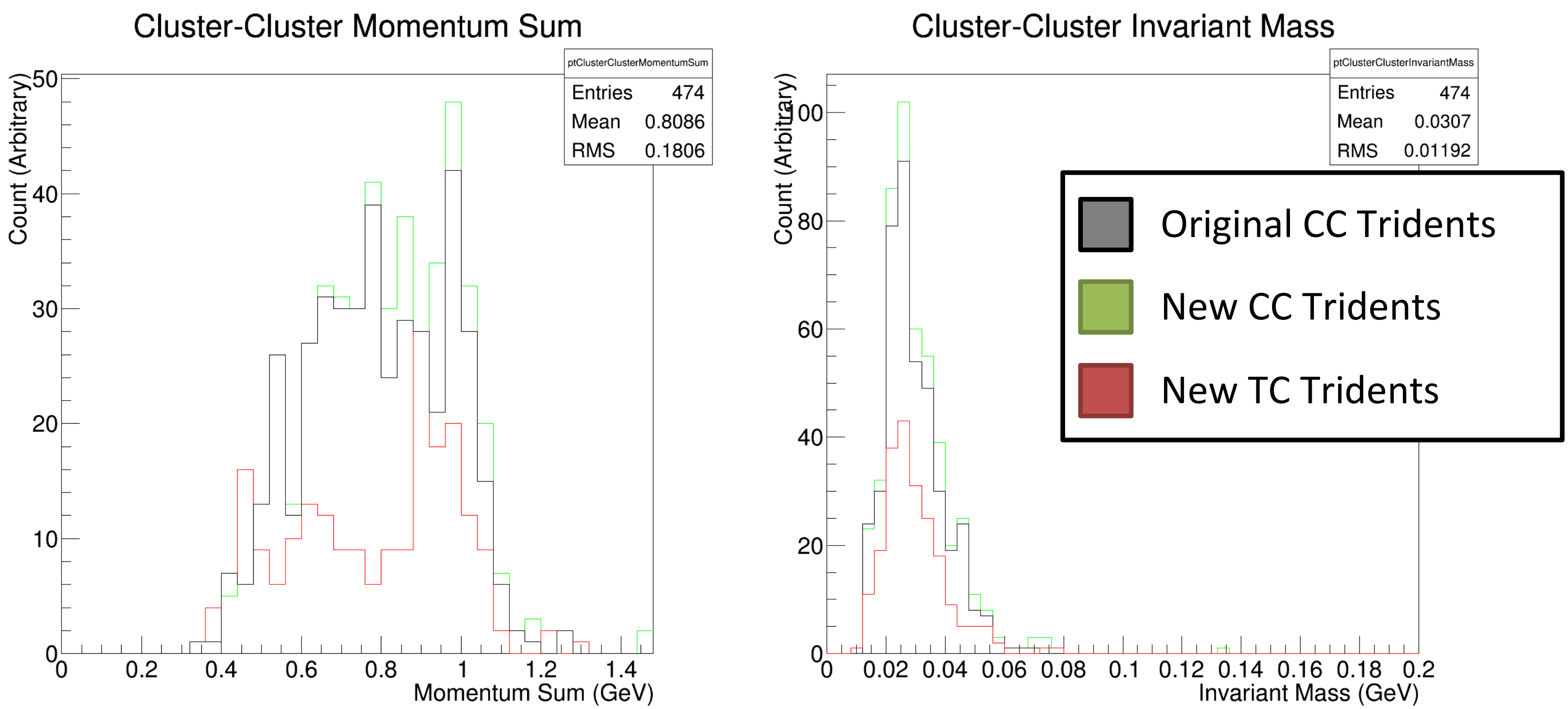
- The same plots, but with trident cuts:





Trident Rate Gain

- It seems that the time coincidence cut is viable, if not as accurate. As a final test, consider a comparison of the full trident selection.



- We observe a considerable gain in rates, measured to be roughly 50%.

Monte Carlo Analysis

- There are some questions which are difficult to answer from data.
  - What is the risk of back-scatter from the calorimeter onto the hodoscope?
  - What is the spatial relation between a particle position on the hodoscope, versus the calorimeter face?
  - What is the expected trigger rate of a positron trigger for 4.4 GeV?
  - How should the hodoscope be pixelated?

- For these, it is useful to employ Monte Carlo data.
  - A large set of Monte Carlo was generated for 2.3 GeV.
  - Hodoscope is represented with inert material (EJ-204 scintillator; same as CLAS12 forward tagger.)
  - Scoring planes are used at both sides of the hodoscope and the calorimeter face to register particles.

Monte Carlo Analysis

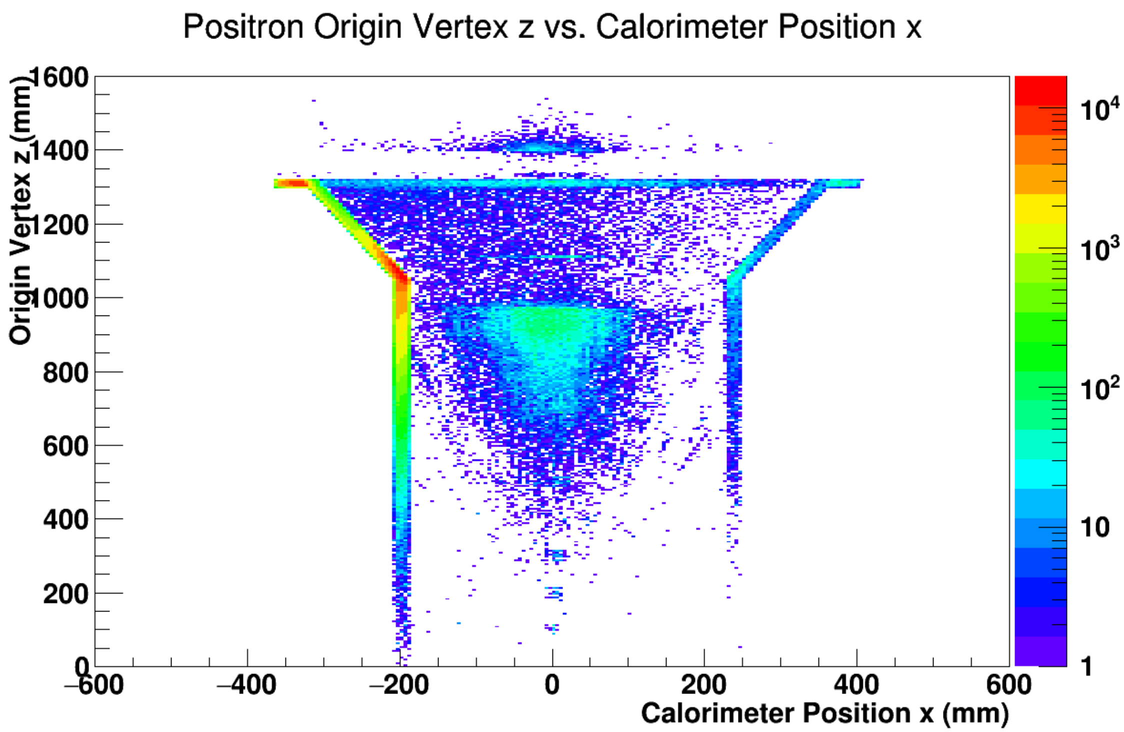
- We begin by exploring back-scattering.
  - A back-scattered particle is defined as any particle with a production vertex at $z > 1100$ (the hodoscope position) which passes through the rear hodoscope scoring plane.

- It is found that back-scatter accounts for only about 5% of particles on the hodoscope.
  - Virtually all back-scatter is extremely low energy as well.

- It appears that back-scatter is not a serious concern for a hodoscope at z = 1100 mm.

Monte Carlo Analysis

- Next, we explore potential backgrounds.
  - Two primary sources of background were discovered:
    - The vacuum box on the electron side
    - Wide-angle bremsstrahlung interacting with the mid-SVT region.



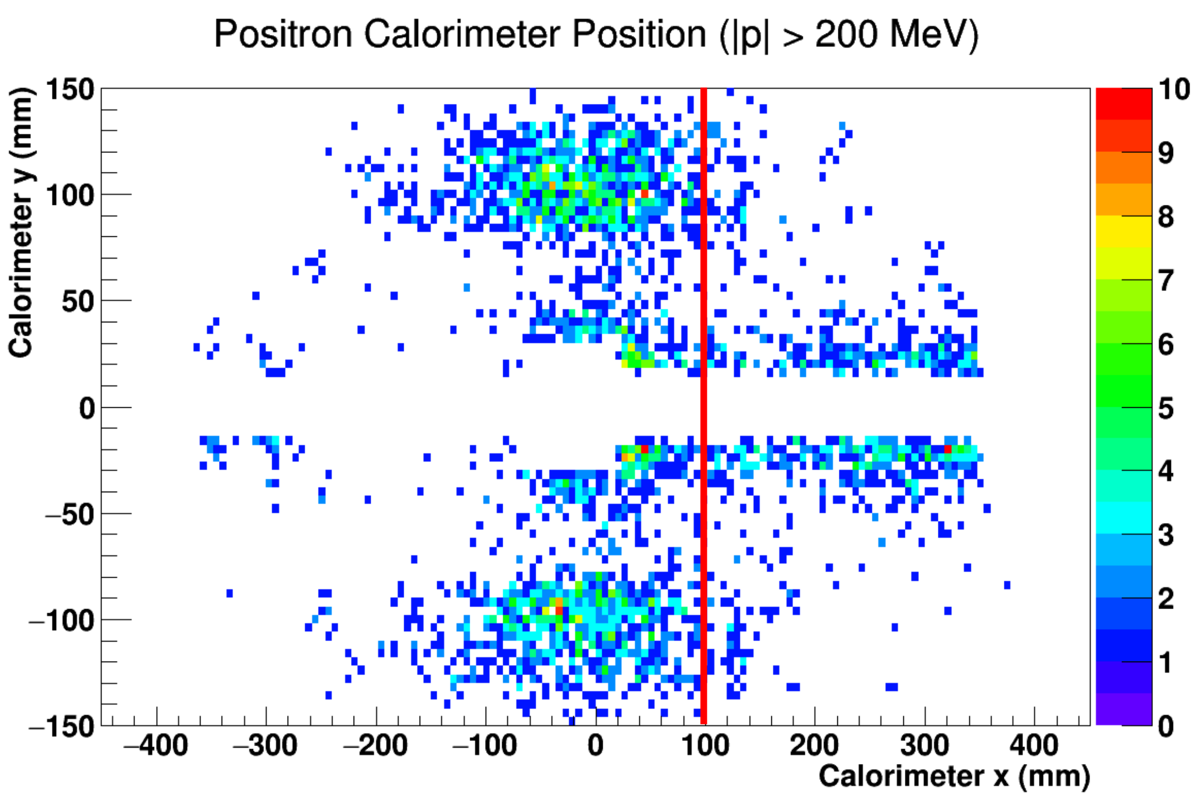
Monte Carlo Analysis

- The vacuum box produces a large number of very-low energy (sub-10 MeV) particles on the electron side of the detector.
  - These are easily controlled.
  - The hodoscope simply does need to extend into this region for proper positron trident acceptance.

- The central SVT structure interaction produces a cluster of positrons above and below the beam gap.

Monte Carlo Analysis

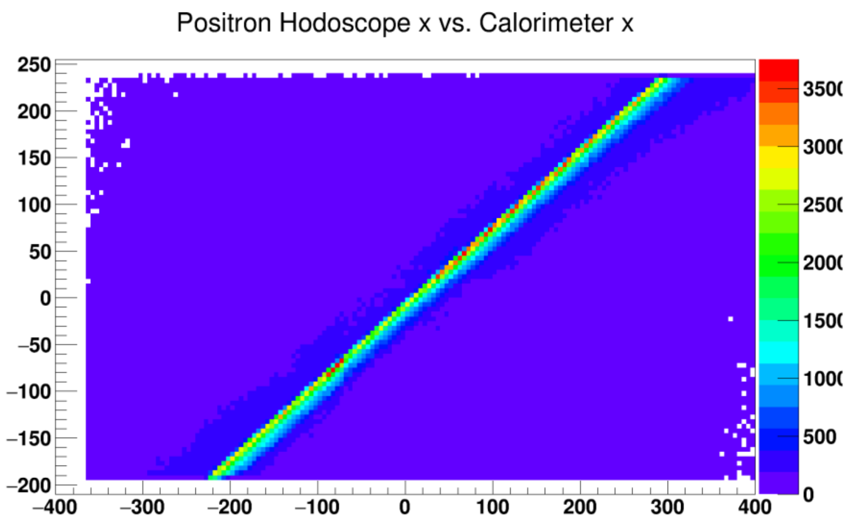
- Many of these WAB positrons are high-energy.

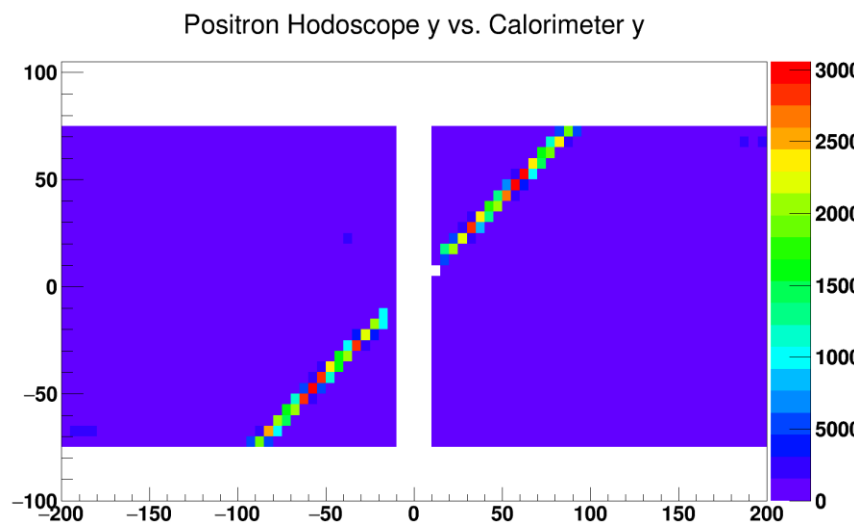


- However, they are almost exclusively below the 100 mm target range, and most are too high to hit the hodoscope at 1100 mm.

Monte Carlo Analysis

- We can also compare the hodoscope positron position to the calorimeter face positron position to investigate the possibility of a coincidence cut.

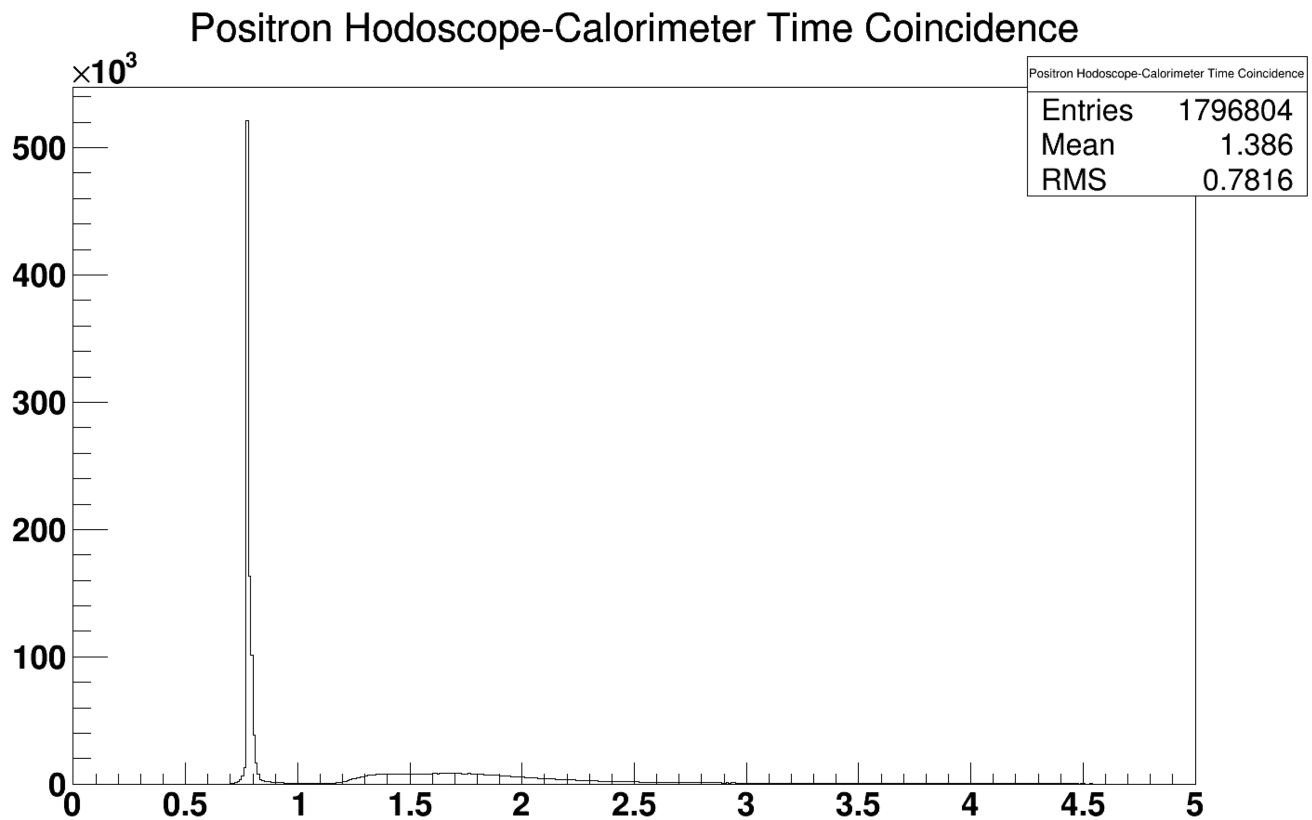




- It appears that there is a fairly strong relation between hodoscope and calorimeter position.
- This supports what Rafo found with L6.

Monte Carlo Analysis

- We see a similar result with time coincidence between the hodoscope and calorimeter. (Note: Usefulness here will depend on hodoscope/calorimeter timing resolution; probably not useful at trigger level.)



Monte Carlo Analysis

- Thus, it appears that:
    - Back-scatter is a very small percentage of hodoscope events, and very low energy. It is not likely to either overwhelm proper event selection or to greatly increase rates.
    - Notable backgrounds exist, but their positioning means they are unlikely to cause significant issues.
    - It is probable that a coincidence relation can be safely defined between the hodoscope and calorimeter.

- There is more to be done:
    - Hodoscope pixilation needs to be investigated.
    - Rates need to be calculated and compared with data.
    - Positron trigger needs to be fully simulated without using truth data.

Conclusion

- A positron trigger appears very feasible.
    - Positrons exist in a region where they are relatively dominant.
    - There appears to be a strong relation between positron position on a hodoscope and positron position on the calorimeter face. This allows for a spatial coincidence cut.
    - The same is true for hodoscope versus calorimeter time.
    - Rate estimates for total charged particles are tolerable for readout.

- Positron trigger data is useful.
    - Trident data can be successfully reconstructed from data using a track/cluster pair for the positron and just a track for the electron.
    - All trident cuts can be replicated without requiring two clusters.
    - It is estimated that using electrons lost to the beam gap will increase trident rates to at least 150% - possibly more.