TWIST Geant 2.0 Results for Various Energy Positrons Produced at Large Angles

Date: February 11, 2002

# 1 Motivation

Monte Carlo studies using the TWIST Geant version 2.0, available in October 2001 were conducted in order to study positrons that the code does not track until the end of their interactions and thus Geant does not output any hits for the TWIST analysis code for these positrons. For example, if the track of a positron comes off at large angles, Geant will give up on tracking this particle since the particle track begins looping, however, while doing this it is not moving very far in the z direction, thus creating a very long track. In the experiment however, these positrons may get hard scattered and traverse the rest of the detector, looking like a different type of event. Understanding the energy and angular dependence of such events is important in the long term for TWIST so that we can either alter the Geant code or be able to correct for this effect in our analysis, if we determine that these type of events are important.

# 2 Introduction

For this study we were interested in positron events in which Geant would for some reason stop tracking and abort the positron. This currently happens due to 3 different reasons which were studies in detail. One is a limit on the time-of-flight of the particle, another is the track length that the particle is traveling becomes too long, and the third is the step limit imposed on the particle is reached.

# 3 TWIST Geant

## 3.1 Particle generation and ffcards flags

For the current study, positrons were generated by the particle gun in a stopping distribution determined by Peter Gumplinger. The origin of the positrons used was (x,y,z)=(-0.00055,-0.00094,0.00058)(ie: generated in the target). The sigma of the distribution used was (0.63,0.63,0.0040). (units are cm).

Peter implemented a flag called CONE into geant. This flag allows the user to generate particles isotropically in a cone distribution. The flag requires 3 numbers, eg: CONE 1. -80. 6. The first number tells whether the cone flag is on or off, the second number is the theta angle (away from the z-axis) in which to generate the cone of particles, and the third number gives the angle span over which to generate the cone (ie: in this example the cone spans from $\theta$=77 to $\theta$=83 degrees).

The criteria used for aborting tracks due to the track length and step limit cuttoff were set in the ffcards file to be 30000 for the maximum number of steps for a track and the maximum path length was set to 1200 cm.

## 3.2 Changes in gustep to histogram aborted events

Variables were implemented in gustep to become set once a positron was going to be discarded due to a time-of-flight, track too long or step limit cutoff. Histograms were filled for each of the three different events in order to determine the frequency of each event and at which z position these events were occurring.

Conditions were also programmed into gustep so we could determine how many of the initial positrons entered the 'TSCV' thick ring scintillator, how many of the initial positrons entered the 'MSCV' muon scintillator and how many of the initial positrons go out the side of 'HCTR' where all the chambers are located (active detector 'mother' volume), along with the positions of the events (x,y and z) and $cos(\theta)$ distribution.

# 4 Geant runs

## 4.1 physics off

Sets of Geant runs were conducted with all physics processes off and no energy loss to test the coding changes made in gustep as well as to have a sample to compare with for the runs where the physics processes will be turned on.

Runs were conducted for 10000 positrons each at energies of 10, 20, 30, 40, 50 and 53 MeV/c at four separate range of angles:

1. CONE 1 -75. 6.
2. CONE 1 -80. 6.
3. CONE 1 -84. 6.
4. CONE 1 -87. 6.

Given in Table 1 are the number of positron tracks aborted due to the three different cutoff conditions. No positrons are ever lost to the time-of-flight cutoff. At low momentum we see some tracks lost to the step limit condition and a few more lost to the track too long condition. As the momentum increases many more positrons are lost to the track too long condition. At 50 MeV/c

| Energy (MeV/c) | Cone Angle | Step Limit | Time-of-Flight | Track Too Long |
|---|---|---|---|---|
| 10 | 75 | 0 | 0 | 0 |
| | 80 | 0 | 0 | 0 |
| | 84 | 0 | 0 | 0 |
| | 87 | 165 | 0 | 627 |
| 20 | 75 | 0 | 0 | 0 |
| | 80 | 0 | 0 | 0 |
| | 84 | 0 | 0 | 0 |
| | 87 | 166 | 0 | 4653 |
| 30 | 75 | 0 | 0 | 0 |
| | 80 | 0 | 0 | 0 |
| | 84 | 0 | 0 | 0 |
| | 87 | 164 | 0 | 4710 |
| 40 | 75 | 0 | 0 | 0 |
| | 80 | 0 | 0 | 0 |
| | 84 | 0 | 0 | 0 |
| | 87 | 165 | 0 | 4789 |
| 50 | 75 | 0 | 0 | 0 |
| | 80 | 0 | 0 | 33 |
| | 84 | 0 | 0 | 21 |
| | 87 | 162 | 0 | 4863 |
| 53 | 75 | 0 | 0 | 0 |
| | 80 | 0 | 0 | 0 |
| | 84 | 0 | 0 | 33 |
| | 87 | 149 | 0 | 4405 |

Table 1: The number of positrons out of 10000 initially generated which are lost due to a step limit, time-of-flight or track too long cutoffs in Geant for various initial energies and cone angles at which they were generated.

positrons in the cone of 80 and 84 degrees start to get cut by this condition as well. Notice that the number of positrons aborted at 53 MeV/c is lower than the number at 50 MeV/c. This is expected since the radial dimensions of our detector are just right to allow positrons of 53 MeV/c transverse momentum to be contained in a field of 2.2 Tesla. For larger momentum, the positrons leave the active volume of the detector and are not tracked past this point in Geant, thus they cannot be lost due to a step limit or track too long cutoff. Preliminary runs of 60, 70 and 80 MeV/c positrons were conducted and this hypothesis was verified.

Figures 1 to 8 show Geant simulation results for physics processes turned off at positron energies of 10 and 53 MeV/c for cone angles of 75 and 87 degrees. The set of eight plots shown per geant run depict the following; the radius ($\sqrt{(}x^2 + y^2)$) of the positrons leaving the mother detector volume (HCTR) and the x vs y scatter plots of where these positrons leave HCTR, scatterplots showing the x vs y positions of positrons entering TSCV, the thick ring scintillator and positions of the positrons entering the muon scintillator (MSCV). Also shown are the z position of any positron that gets aborted due to the above mentioned cutoffs, the radius of positrons entering TSCV and $cos(\theta)$ of positrons entering the muon scintillator and $cos(\theta)$ of positrons entering TSCV.

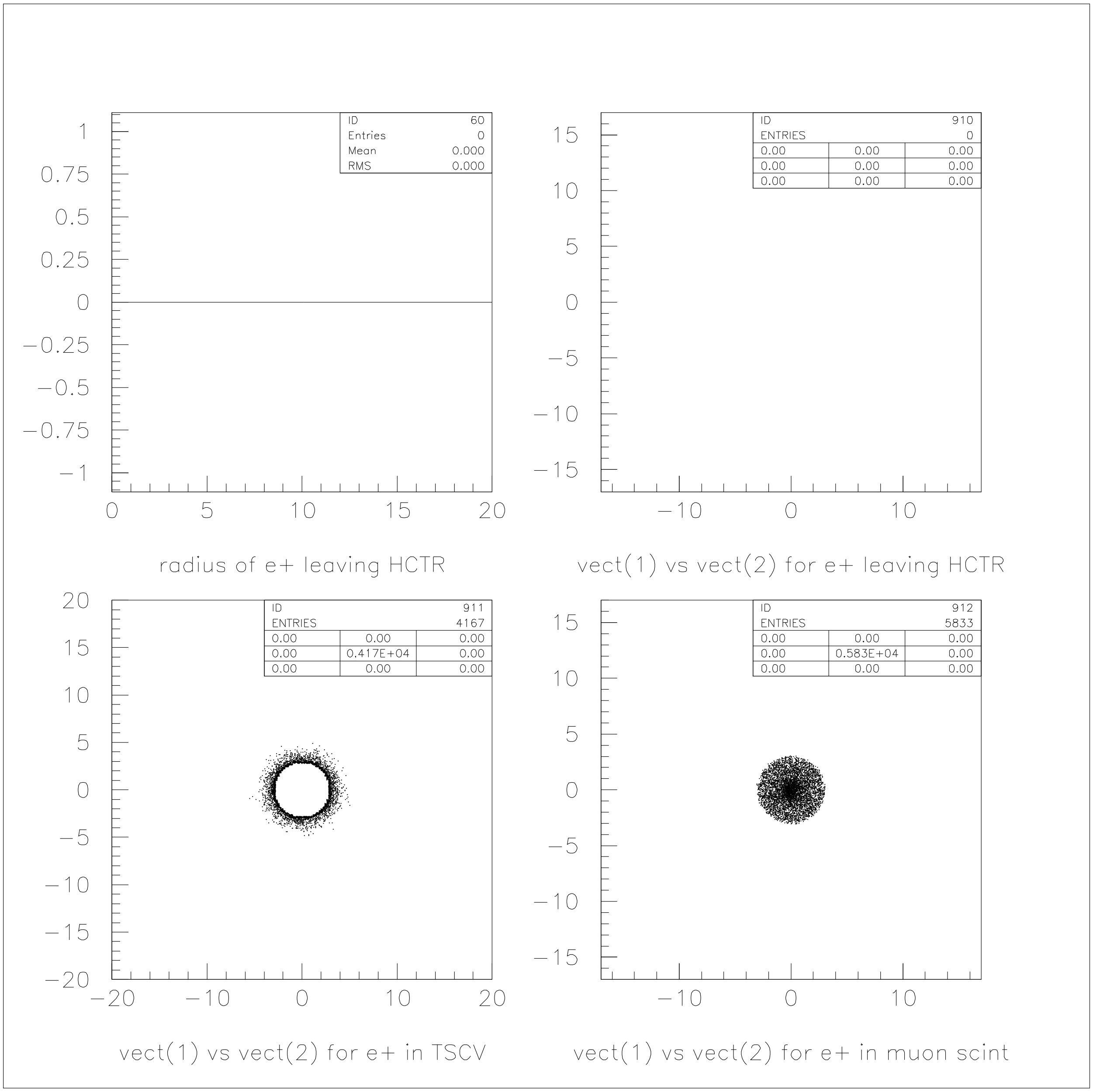


Figure 1: Geant results for 10 MeV/c positrons generated in a cone centered at 75 degrees. Shown are results for the x(vect(1)) and y(vect(2)) positions of positrons leaving the mother detector volume (HCTR), positrons entering the (TSCV) thick ring scintillator and positrons which enter the (MSCV) muon scintillator.

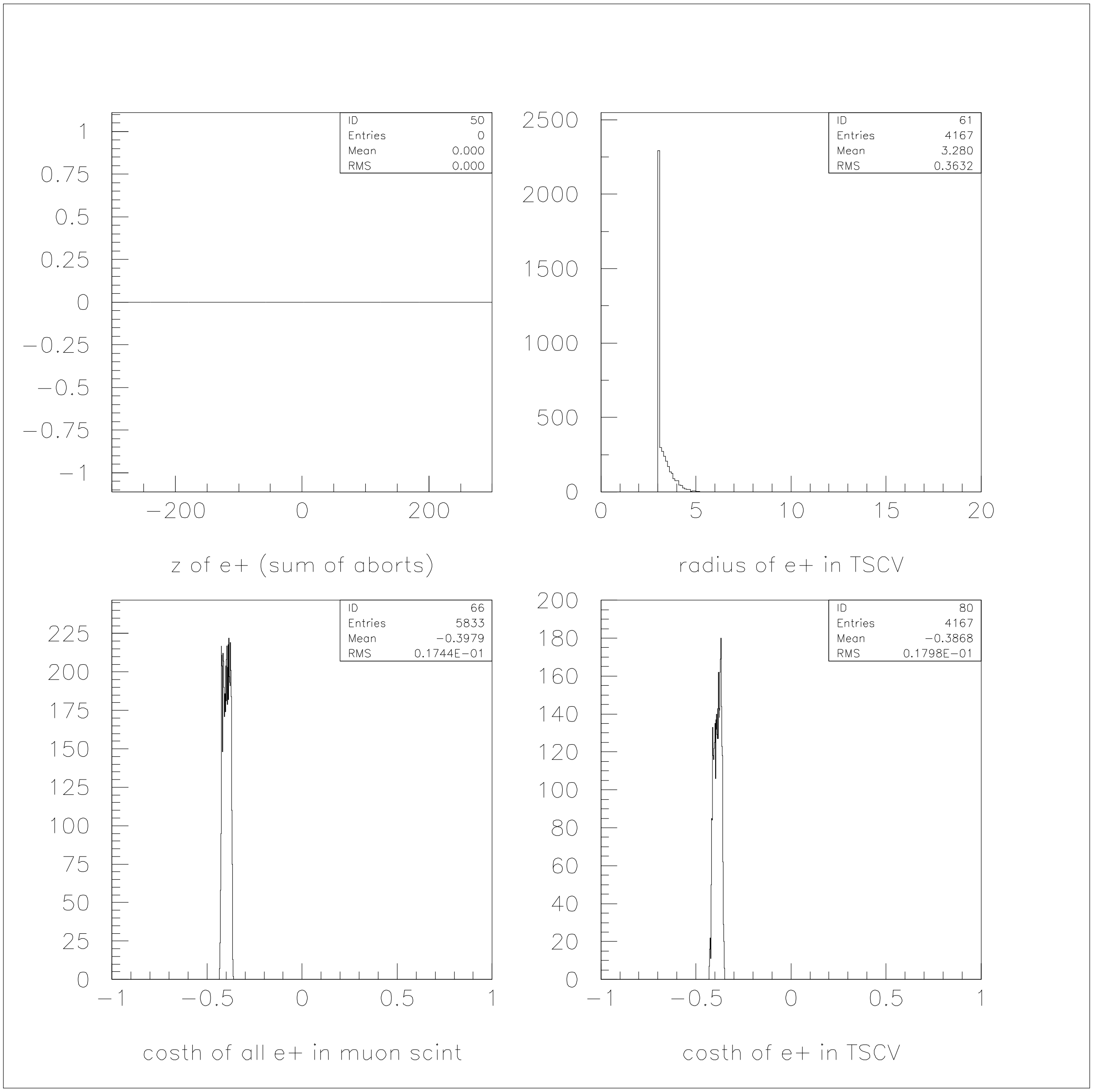


Figure 2: Geant results for 10 MeV/c positrons generated in a cone centered at 75 degrees. Shown is the z position of any aborted positron tracks, the radius ($\sqrt{(x^2 + y^2)}$) of positrons which enter the thick ring scintillator, the $cos(\theta)$ of positrons which enter the muon scintillator and the $cos(\theta)$ of positrons which enter the thick ring scintillator.

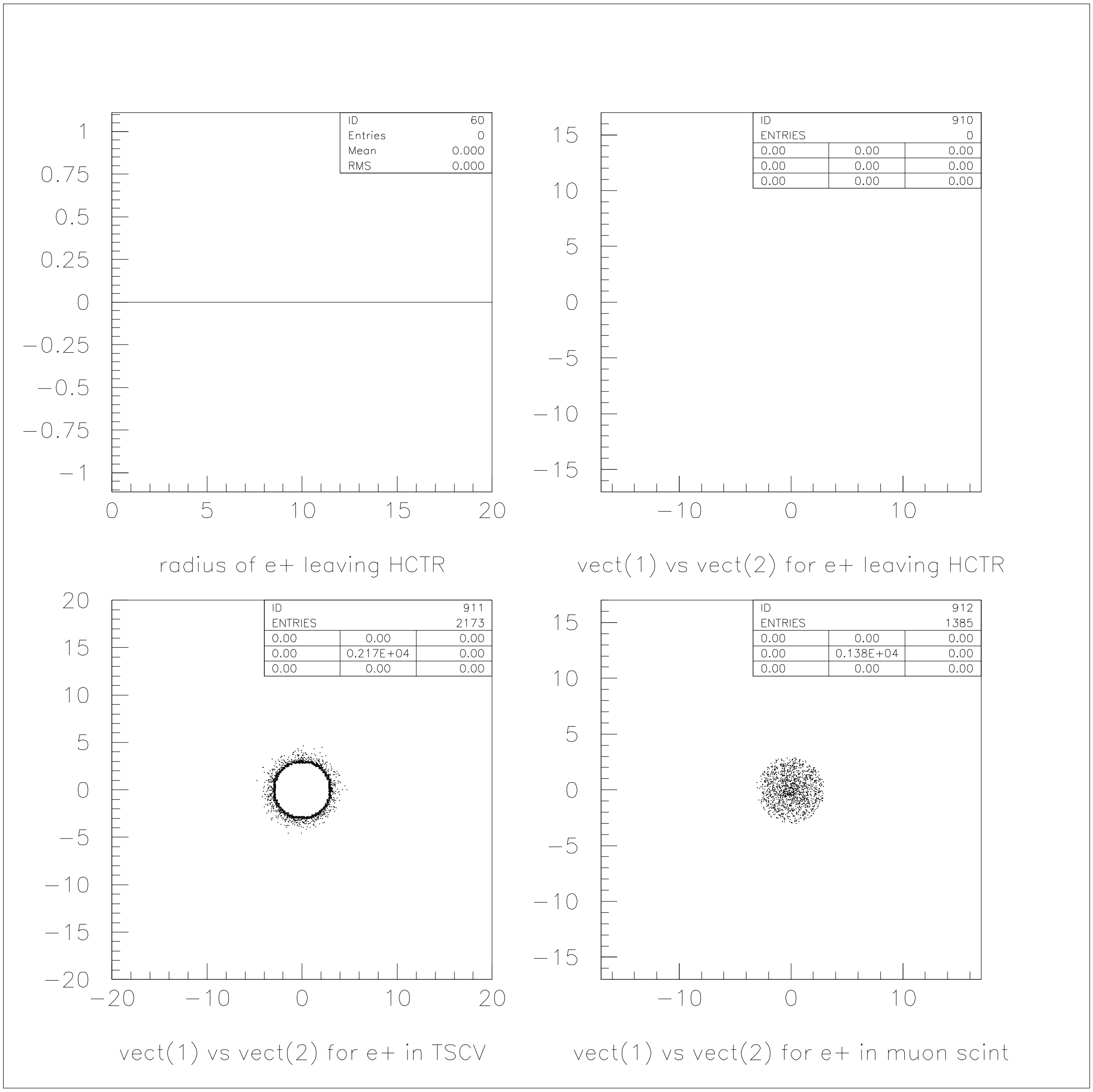


Figure 3: Geant results for 10 MeV/c positrons generated in a cone centered at 87 degrees. Shown are results for the x(vect(1)) and y(vect(2)) positions of positrons leaving the mother detector volume (HCTR), positrons entering the (TSCV) thick ring scintillator and positrons which enter the (MSCV) muon scintillator.

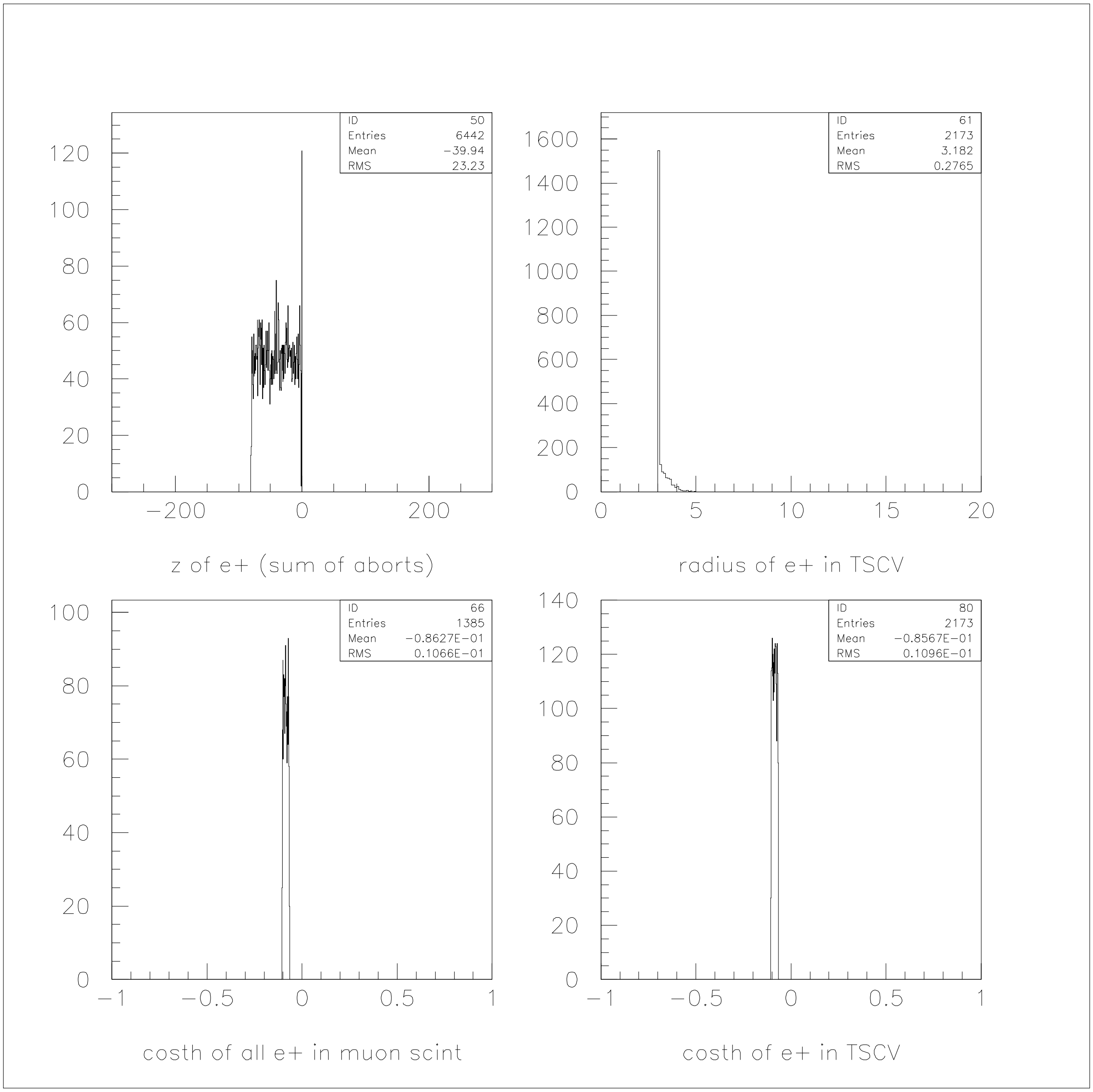


Figure 4: Geant results for 10 MeV/c positrons generated in a cone centered at 87 degrees. Shown is the z position of any aborted positron tracks, the radius ($\sqrt{(x^2+y^2)}$) of positrons which enter the thick ring scintillator, the $cos(\theta)$ of positrons which enter the muon scintillator and the $cos(\theta)$ of positrons which enter the thick ring scintillator.

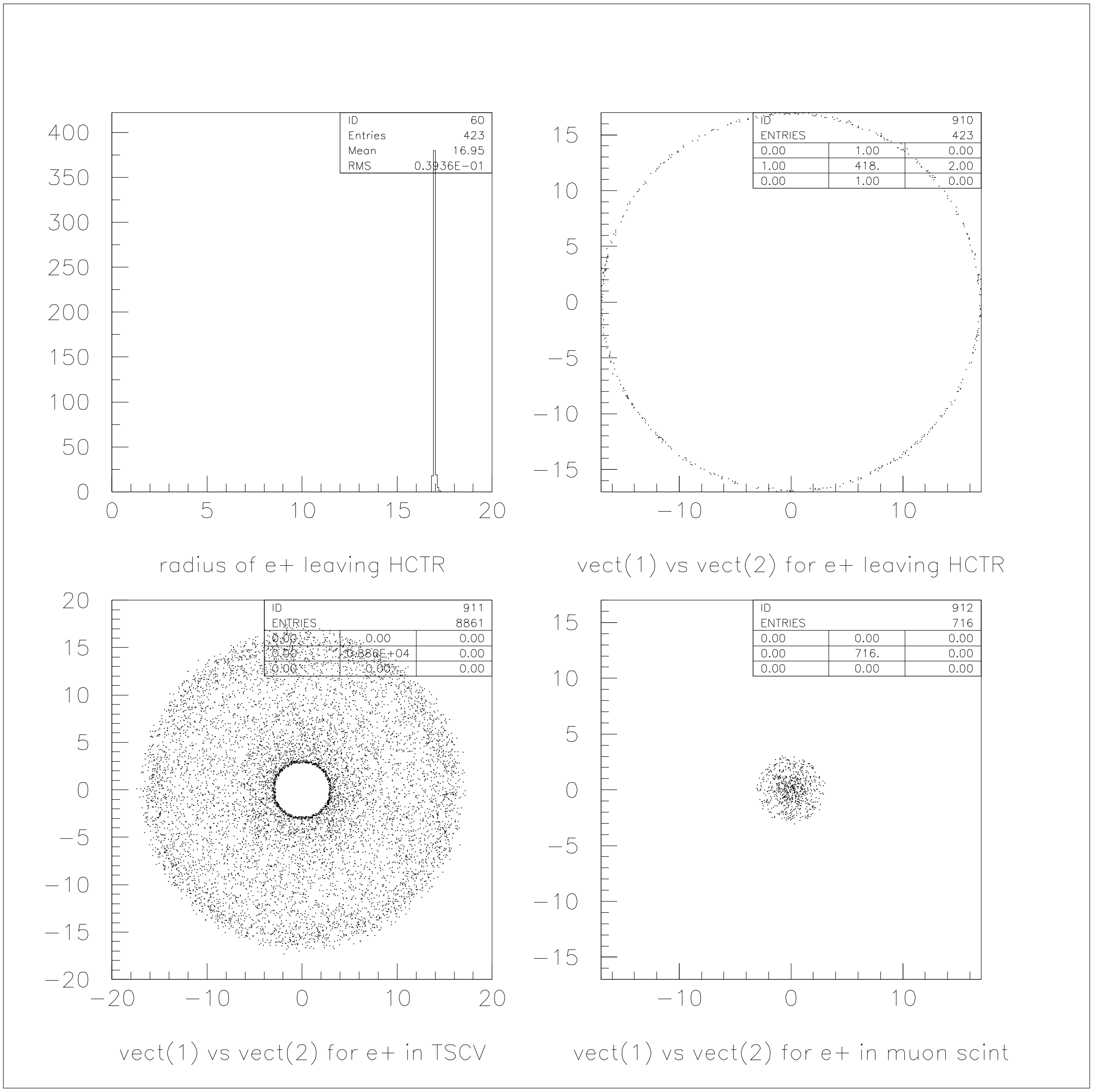


Figure 5: Geant results for 53 MeV/c positrons generated in a cone centered at 75 degrees. Shown are results for the x(vect(1)) and y(vect(2)) positions of positrons leaving the mother detector volume (HCTR), positrons entering the (TSCV) thick ring scintillator and positrons which enter the (MSCV) muon scintillator.

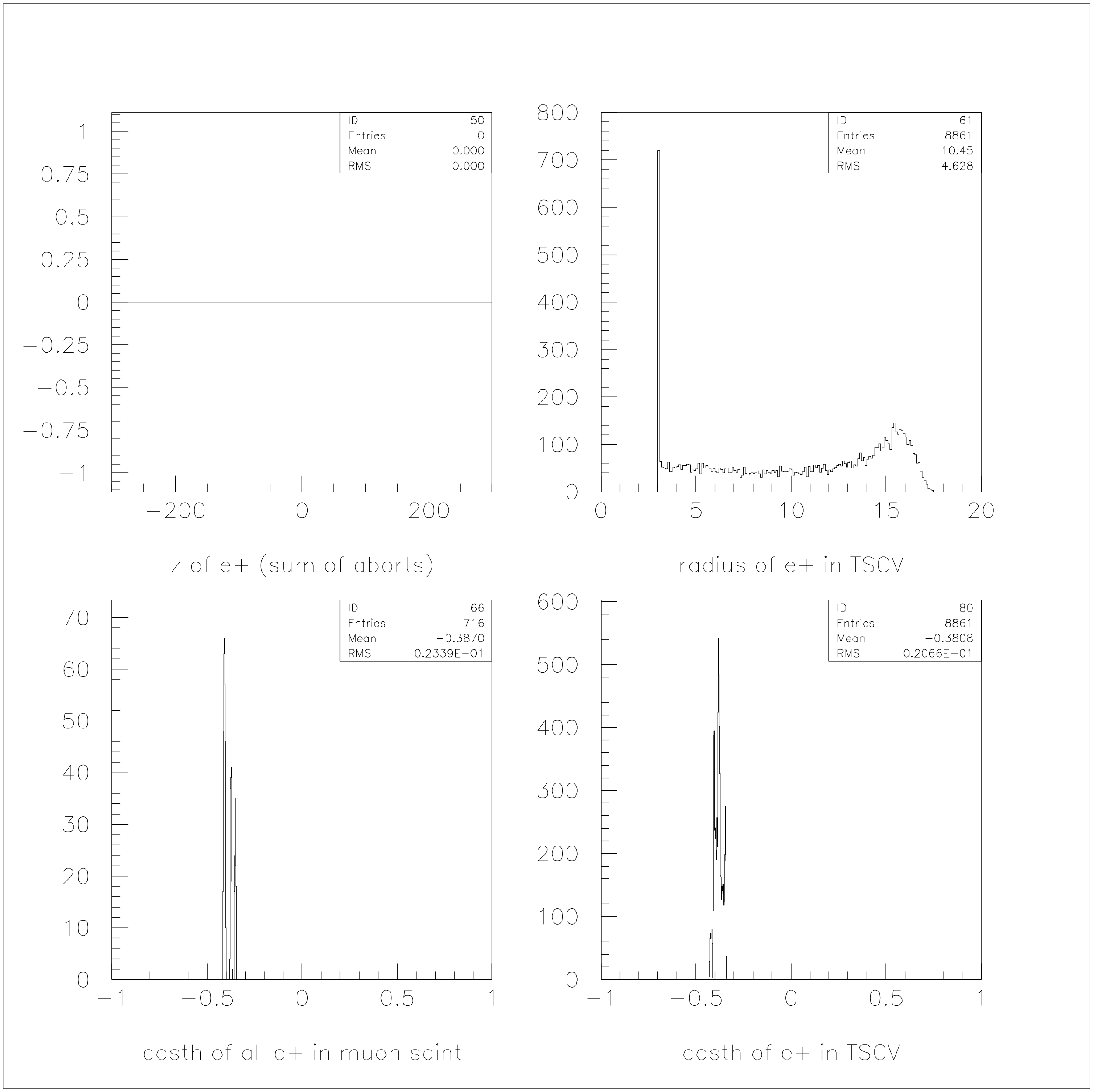


Figure 6: Geant results for 53 MeV/c positrons generated in a cone centered at 75 degrees. Shown is the z position of any aborted positron tracks, the radius ($\sqrt{(}x^2 + y^2)$) of positrons which enter the thick ring scintillator, the $cos(\theta)$ of positrons which enter the muon scintillator and the $cos(\theta)$ of positrons which enter the thick ring scintillator.

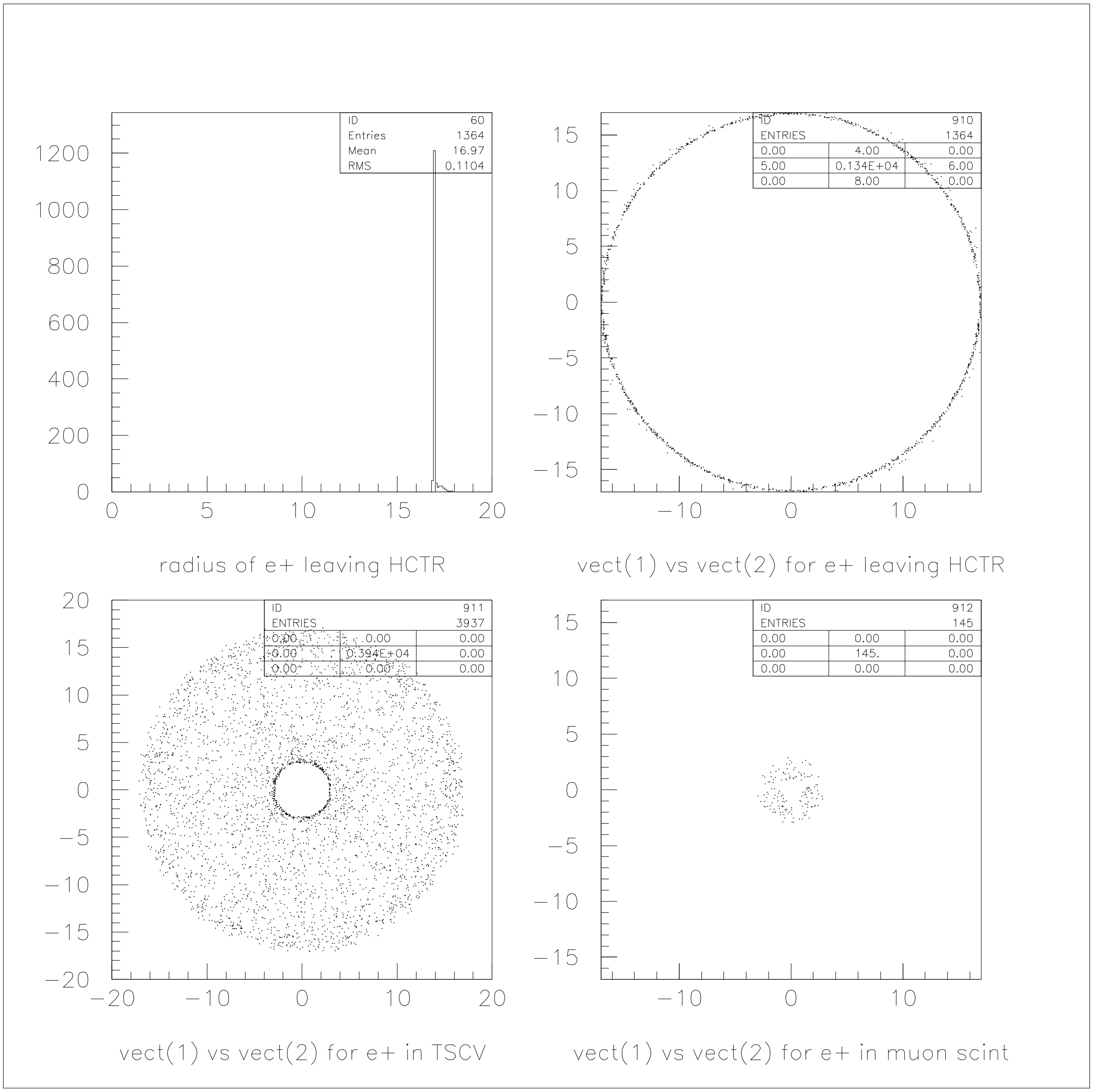


Figure 7: Geant results for 53 MeV/c positrons generated in a cone centered at 87 degrees. Shown are results for the x(vect(1)) and y(vect(2)) positions of positrons leaving the mother detector volume (HCTR), positrons entering the (TSCV) thick ring scintillator and positrons which enter the (MSCV) muon scintillator.

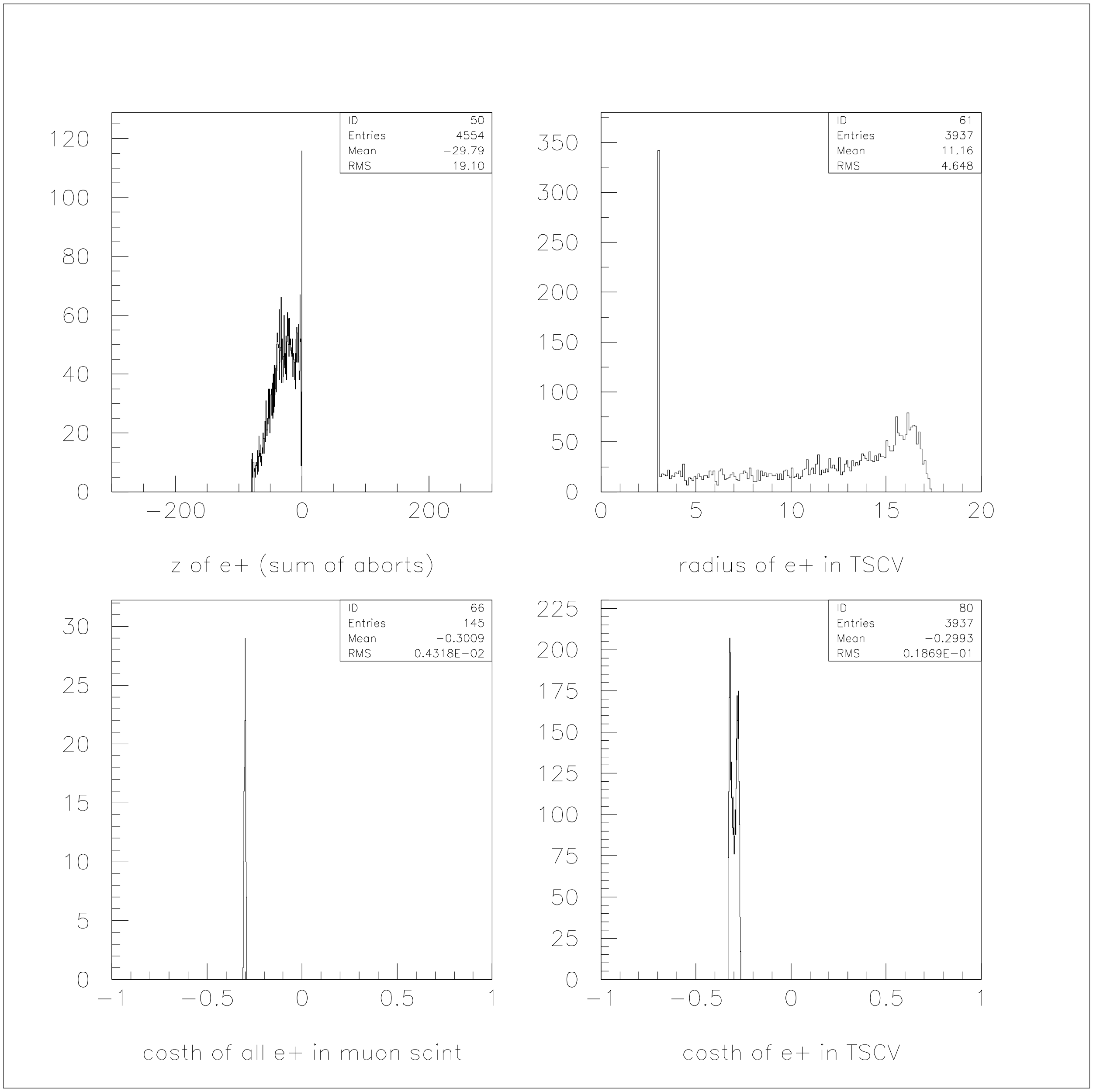


Figure 8: Geant results for 53 MeV/c positrons generated in a cone centered at 87 degrees. Shown is the z position of any aborted positron tracks, the radius ($\sqrt{(x^2+y^2)}$) of positrons which enter the thick ring scintillator, the $cos(\theta)$ of positrons which enter the muon scintillator and the $cos(\theta)$ of positrons which enter the thick ring scintillator.

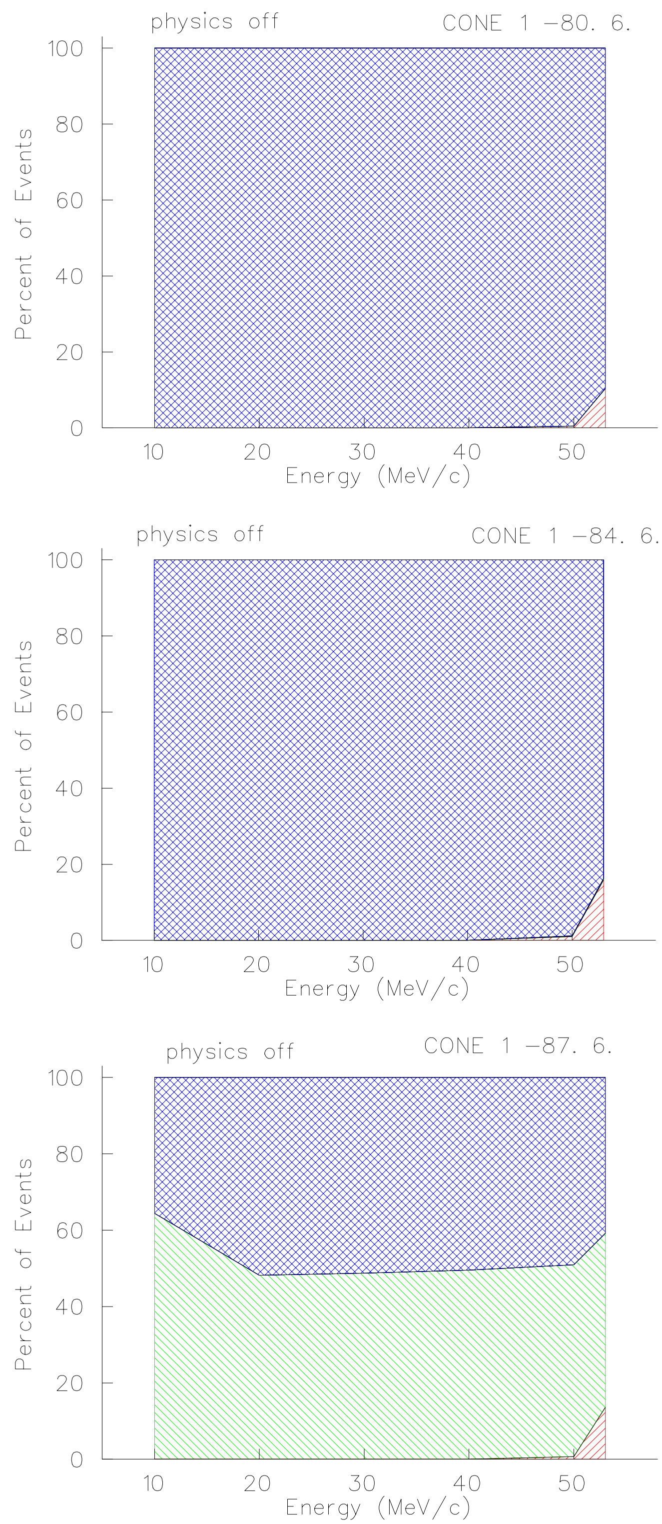


Figure 9: Geant results showing the number of positrons tracks that survive without being aborted (hashed blue), the number of positron tracks that leave (HCTR) the mother detector volume (hashed red) and the number of positrons aborted due to the 3 restrictions + the number of positrons that leave HCTR (solid upper green line). (note: green area represent positrons that were aborted).

At low momentum (10 MeV/c), the positrons have their radius fully contained inside HCTR, thus none leave HCTR. For larger momentum, many more positrons go out the side of HCTR before they can be cut by the track too long or step limit cutoff. The spike which occurs at the minimum possible radius for the 'radius of e+ in TSCV' seems to be due to positrons which spiral into the hole of the T0 counter, yet due to the counters finite thickness, spiral back out of the hole in T0.

Many debugging tests were conducted to try to understand why $cos(\theta)$ of the positrons that enter the T0 counter (TSCV) have values around -0.3, when the field is uniform and all physics has been turned off. It was initially believed that the angle of the positron with respect to the z-axis should not change. The Runge Kuta method employed by Geant was tested and found to not be introducing any rounding errors that would change $cos(\theta)$. The change in $cos(\theta)$ is real and comes about because the positron tightly spirals in the end region of the detector where the B-field is changing a little bit. This seems to be implying that many tight spirals turn the positron momentum vector more forward in this region.

Figure 9 depicts the percentage of positrons which get cut due to all three cutoff restrictions in Geant for 10 to 53 MeV/c positrons for three different generated cone angles. The number of positrons that survive without getting aborted is shown by the hashed blue area. The number of positrons that are aborted is depicted by the hashed green area and the number of positrons that leave the mother dectector volume (HCTR) is depicted by the hashed red area.

## 4.2 physics on

Sets of Geant runs were also conducted with physics processes on. These processes include positron annihilation, Bremsstrahlung, energy loss and Coulomb scattering (note: delta rays were not generated in these runs). Runs were conducted for 10000 positrons each at energies of 10, 20, 30, 40, 50 and 53 MeV/c at four separate range of angles:

1. CONE 1 -75. 6.
2. CONE 1 -80. 6.
3. CONE 1 -84. 6.
4. CONE 1 -87. 6.

Given in Table 2 are the number of positron tracks aborted due to the three different cutoff conditions for Geant runs with the above physics processes turned on. Again we see that no positrons are ever lost due to the time-of-flight limitation. We also notice barely any positrons being lost to the step limit restriction. Not only are the positrons just being lost because their tracks are too long but we see now because the positrons are undergoing physical interaction they

| Energy (MeV/c) | Cone Angle | Step Limit | Time-of-Flight | Track Too Long |
|---|---|---|---|---|
| 10 | 75 | 0 | 0 | 129 |
| | 80 | 0 | 0 | 563 |
| | 84 | 0 | 0 | 1024 |
| | 87 | 0 | 0 | 1153 |
| 20 | 75 | 0 | 0 | 20 |
| | 80 | 0 | 0 | 245 |
| | 84 | 0 | 0 | 1324 |
| | 87 | 0 | 0 | 2174 |
| 30 | 75 | 0 | 0 | 7 |
| | 80 | 0 | 0 | 75 |
| | 84 | 1 | 0 | 1156 |
| | 87 | 3 | 0 | 2824 |
| 40 | 75 | 0 | 0 | 3 |
| | 80 | 0 | 0 | 29 |
| | 84 | 2 | 0 | 1014 |
| | 87 | 2 | 0 | 3264 |
| 50 | 75 | 0 | 0 | 2 |
| | 80 | 0 | 0 | 17 |
| | 84 | 1 | 0 | 981 |
| | 87 | 3 | 0 | 3724 |
| 53 | 75 | 0 | 0 | 2 |
| | 80 | 0 | 0 | 11 |
| | 84 | 0 | 0 | 853 |
| | 87 | 5 | 0 | 3542 |

Table 2: The number of positrons out of 10000 initially generated which are lost due to a step limit, time-of-flight or track too long cutoffs in Geant for various initial energies and cone angles at which they were generated. Physics processes have been turned on in Geant however no delta rays were generated.

are lost at 75 and 80 degrees compared to virtually no loses at these angles when physics was turned off. We again witness the trend that the loses tend to increase with increasing momentum until we reach approximately 50 MeV/c and then they decrease (see discussion above in physics off section).

Shown in figures 10 through 17 are some Geant simulation results for physics processes turned on at positron energies of 10 and 53 MeV/c for cone angles of 75 and 87 degrees. The plots are similar to those shown for the geant runs with physics processes turned off. Again at low momentum we see that the positrons have their radius fully contained inside HCTR and thus none are leaving the mother volume. As the momentum is increased, more positrons make it out the side of HCTR. We again see the spike occurring at the minimum possible radius for the T0 counter. Besides noticing that at all angles tested we are getting aborted positrons, we notice a difference in the $cos(\theta)$ distributions. They are wider than those seen previously, which is to be expected as the particles are now undergoing interactions, however even at the smallest momentum studied we start to see the development of a secondary peak in the distributions for both the positrons that enter the muon scintillator and those that enter the T0 counter. This secondary peak for low momentum positrons becomes more pronounced as the cone angle is increased. For larger momentum positrons the secondary peak appears in the $cos(\theta)$ distribution for a high cone angle but with lower intensity in comparison to the main peak than that seen at low momentum. The z position of aborted positrons seems to have developed a second peak as well. The source of this peak had not yet been studied but will be in the future.

Figure 18 is similar to figure 9, depicting the percentage of positrons which get cut due either a track too long or step limit cutoff using Geant in which physics was turned on. The differences are that positrons now are being aborted right from 10 MeV/c upward for all cone angles tested (green area). Thus the number of positrons that survive these restrictions in geant (blue area) are lower that we have seen with physics processes off for cone angles of 80 and 84 degrees. However, once we reach cone angles of 87 degrees the number of positrons aborted is smaller. The number of positrons that leave the mother volume is also smaller (red area).

## 4.3 delta rays on

A set of Geant runs was also done with all the above physics processes on (ie: e+ annihilation, Bremsstrahlung, energy loss and Coulomb scattering) as well as delta rays being generated. Only one set of runs was done for 10000 positrons at 53 MeV/c for the above 4 different cones.

Given in Table 3 are the number of positron tracks aborted due to the three different cutoff conditions with physics processes turned on and delta rays turned on. Again we notice no positrons are ever lost due to the time-of-flight condition. In comparing these results with delta rays to those with no delta rays (see Table 2) we see the same number of events are lost due to the step limit cutoff. The number of events lost to the track too long condition are very similar with and without delta ray production. The number of events aborted when delta ray production is included in the Geant simulation are slightly larger than when no delta ray production is turned on when considering the statistical error on the counts.

| Energy (MeV/c) | Cone Angle | Step Limit | Time-of-Flight | Track Too Long |
|---|---|---|---|---|
| 53 | 75 | 0 | 0 | 6 |
| | 80 | 0 | 0 | 12 |
| | 84 | 0 | 0 | 893 |
| | 87 | 5 | 0 | 3728 |

Table 3: The number of positrons out of 10000 initially generated at 53 MeV/c which are lost due to a step limit, time-of-flight or track too long cutoffs in Geant. Note physics processes are on as well as delta ray production.

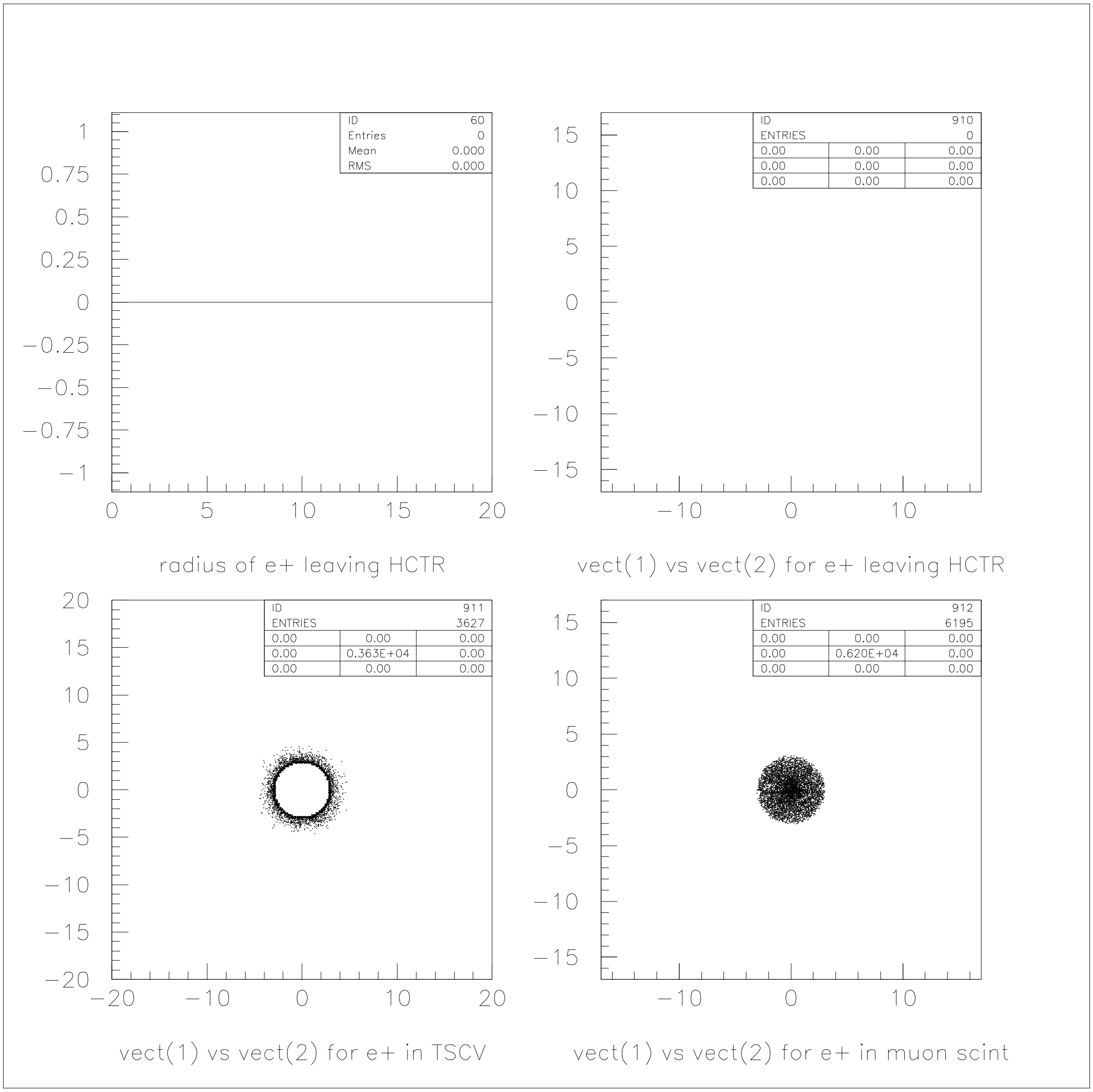


Figure 10: Geant results for 10 MeV/c positrons generated in a cone centered at 75 degrees. Shown are results for the x(vect(1)) and y(vect(2)) positions of positrons leaving the mother detector volume (HCTR), positrons entering the (TSCV) thick ring scintillator and positrons which enter the (MSCV) muon scintillator.

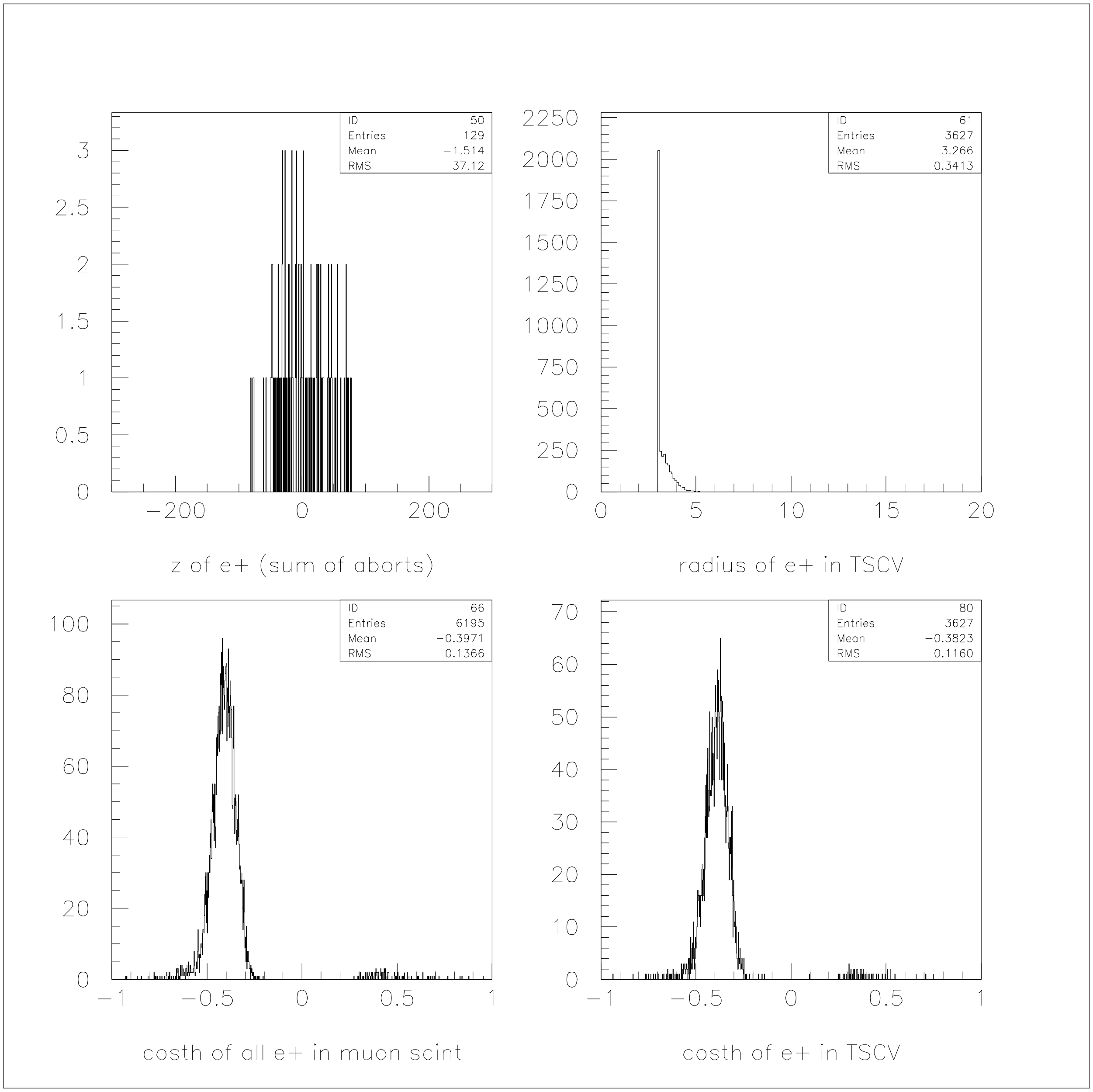


Figure 11: Geant results for 10 MeV/c positrons generated in a cone centered at 75 degrees. Shown is the z position of any aborted positron tracks, the radius ($\sqrt{(x^2+y^2)}$) of positrons which enter the thick ring scintillator, the $cos(\theta)$ of positrons which enter the muon scintillator and the $cos(\theta)$ of positrons which enter the thick ring scintillator.

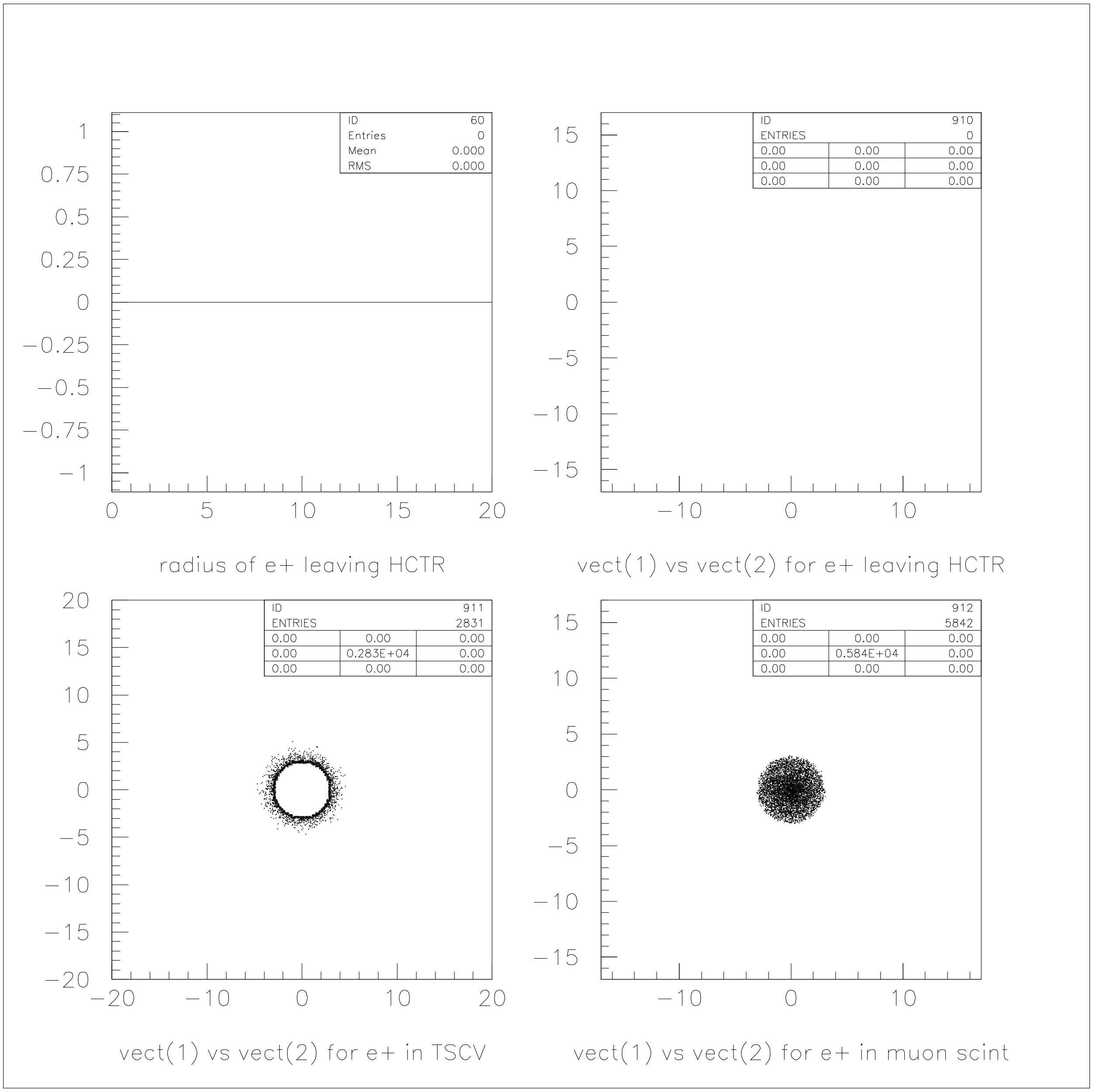


Figure 12: Geant results for 10 MeV/c positrons generated in a cone centered at 87 degrees. Shown are results for the x(vect(1)) and y(vect(2)) positions of positrons leaving the mother detector volume (HCTR), positrons entering the (TSCV) thick ring scintillator and positrons which enter the (MSCV) muon scintillator.

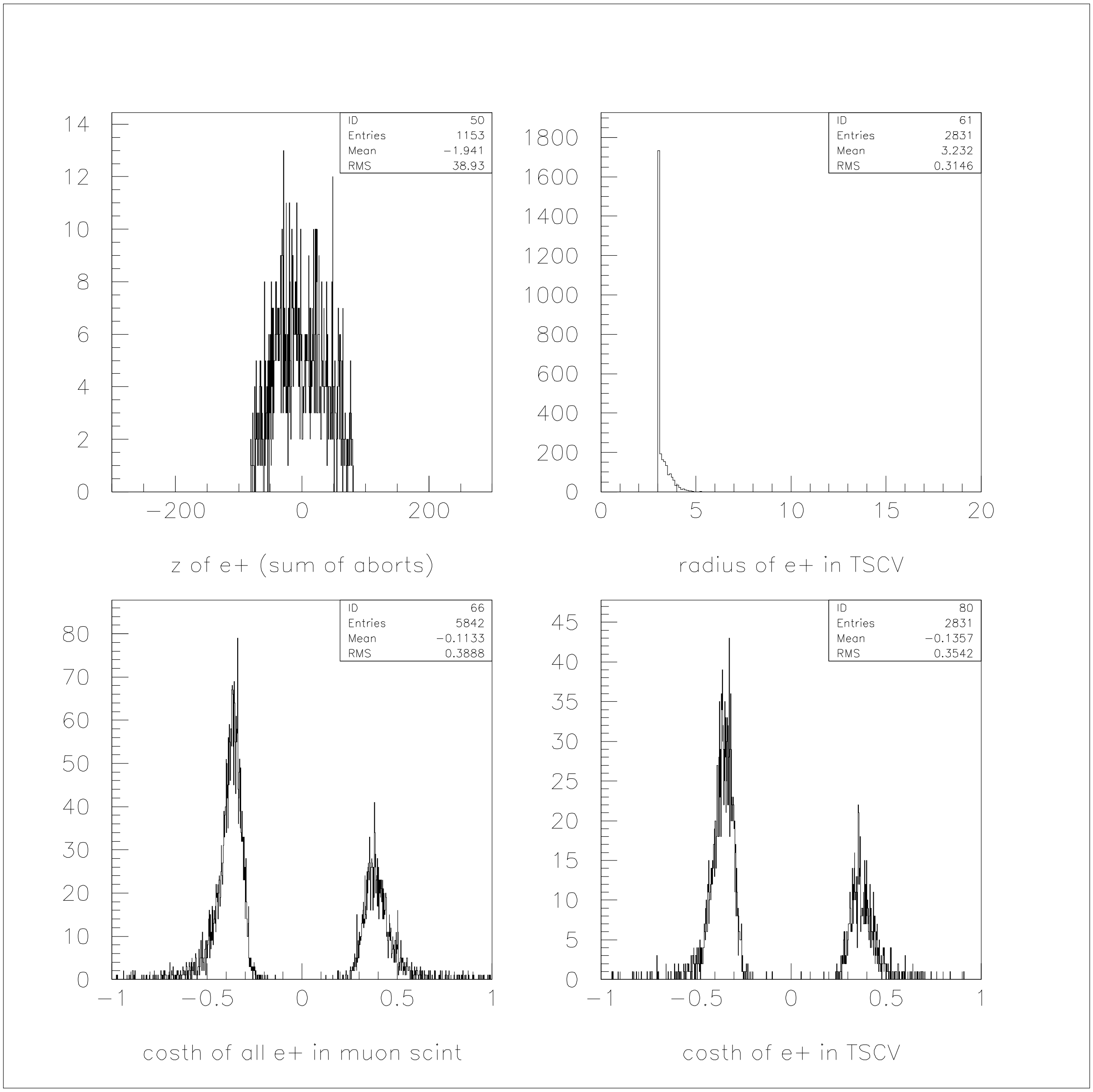


Figure 13: Geant results for 10 MeV/c positrons generated in a cone centered at 87 degrees. Shown is the z position of any aborted positron tracks, the radius ($\sqrt{(x^2+y^2)}$) of positrons which enter the thick ring scintillator, the $cos(\theta)$ of positrons which enter the muon scintillator and the $cos(\theta)$ of positrons which enter the thick ring scintillator.

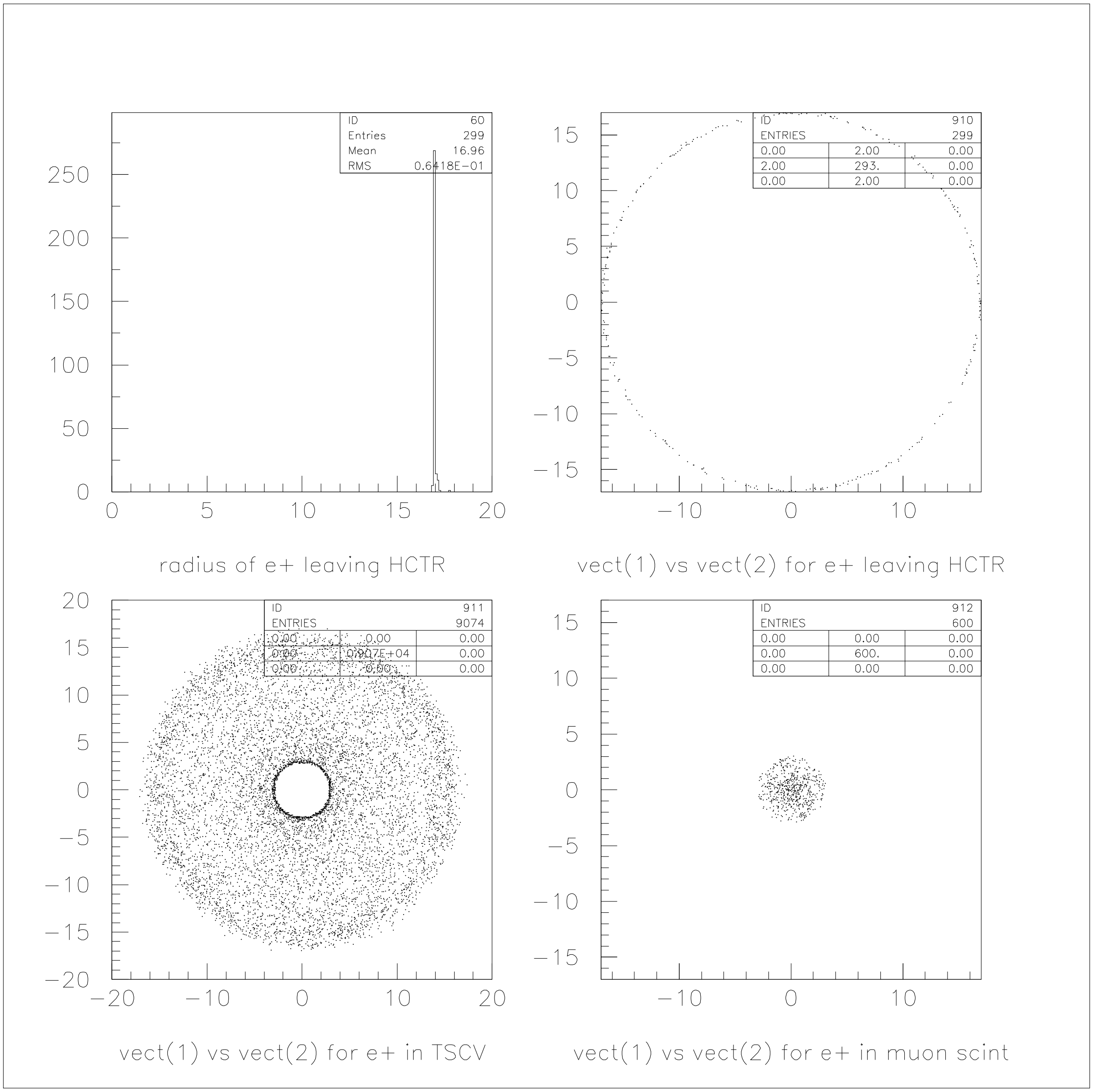


Figure 14: Geant results for 53 MeV/c positrons generated in a cone centered at 75 degrees. Shown are results for the x(vect(1)) and y(vect(2)) positions of positrons leaving the mother detector volume (HCTR), positrons entering the (TSCV) thick ring scintillator and positrons which enter the (MSCV) muon scintillator.

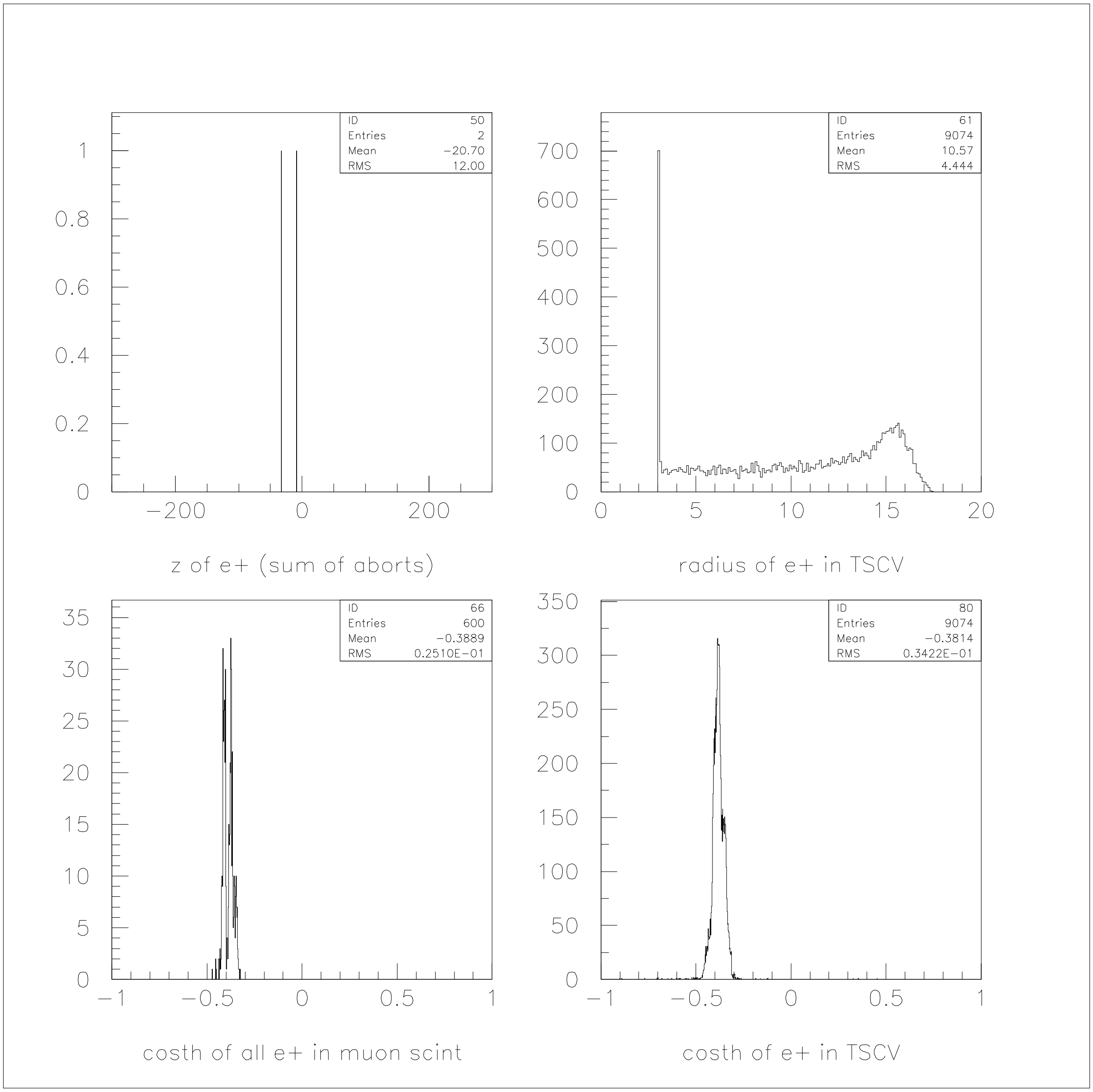


Figure 15: Geant results for 53 MeV/c positrons generated in a cone centered at 75 degrees. Shown is the z position of any aborted positron tracks, the radius ($\sqrt{(x^2 + y^2)}$) of positrons which enter the thick ring scintillator, the $cos(\theta)$ of positrons which enter the muon scintillator and the $cos(\theta)$ of positrons which enter the thick ring scintillator.

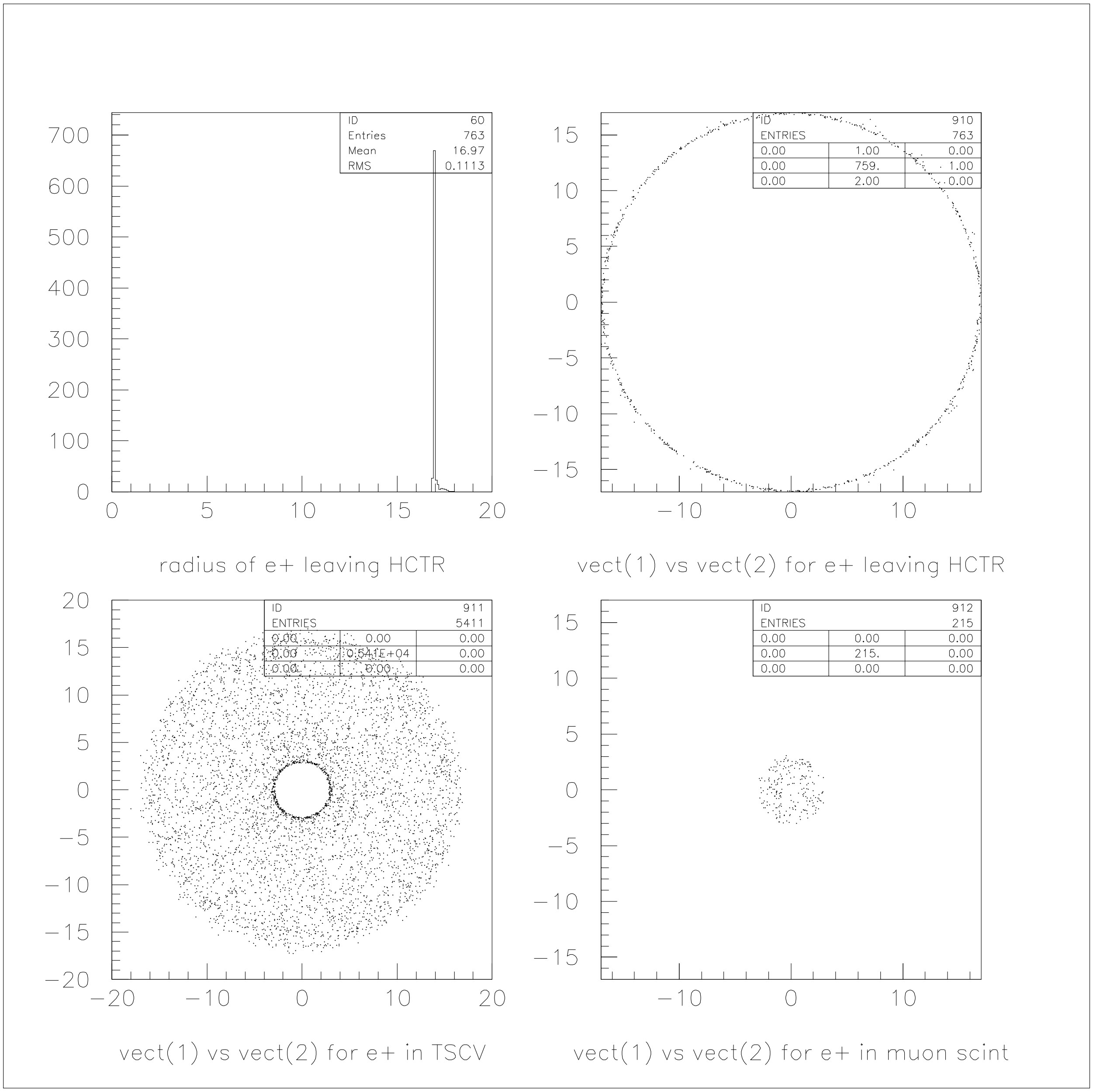


Figure 16: Geant results for 53 MeV/c positrons generated in a cone centered at 87 degrees. Shown are results for the x(vect(1)) and y(vect(2)) positions of positrons leaving the mother detector volume (HCTR), positrons entering the (TSCV) thick ring scintillator and positrons which enter the (MSCV) muon scintillator.

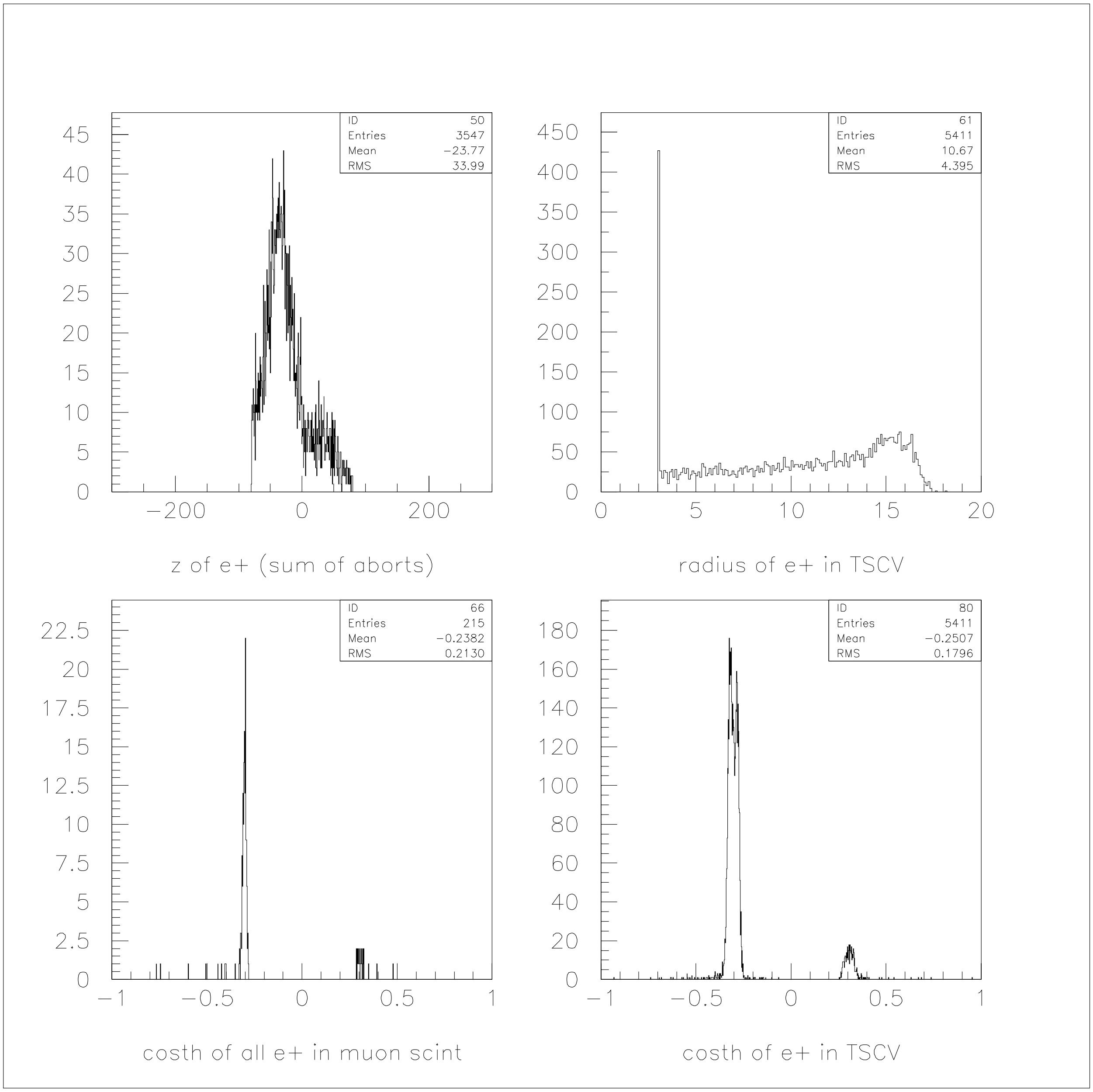


Figure 17: Geant results for 53 MeV/c positrons generated in a cone centered at 87 degrees. Shown is the z position of any aborted positron tracks, the radius ($\sqrt{(x^2+y^2)}$) of positrons which enter the thick ring scintillator, the $cos(\theta)$ of positrons which enter the muon scintillator and the $cos(\theta)$ of positrons which enter the thick ring scintillator.

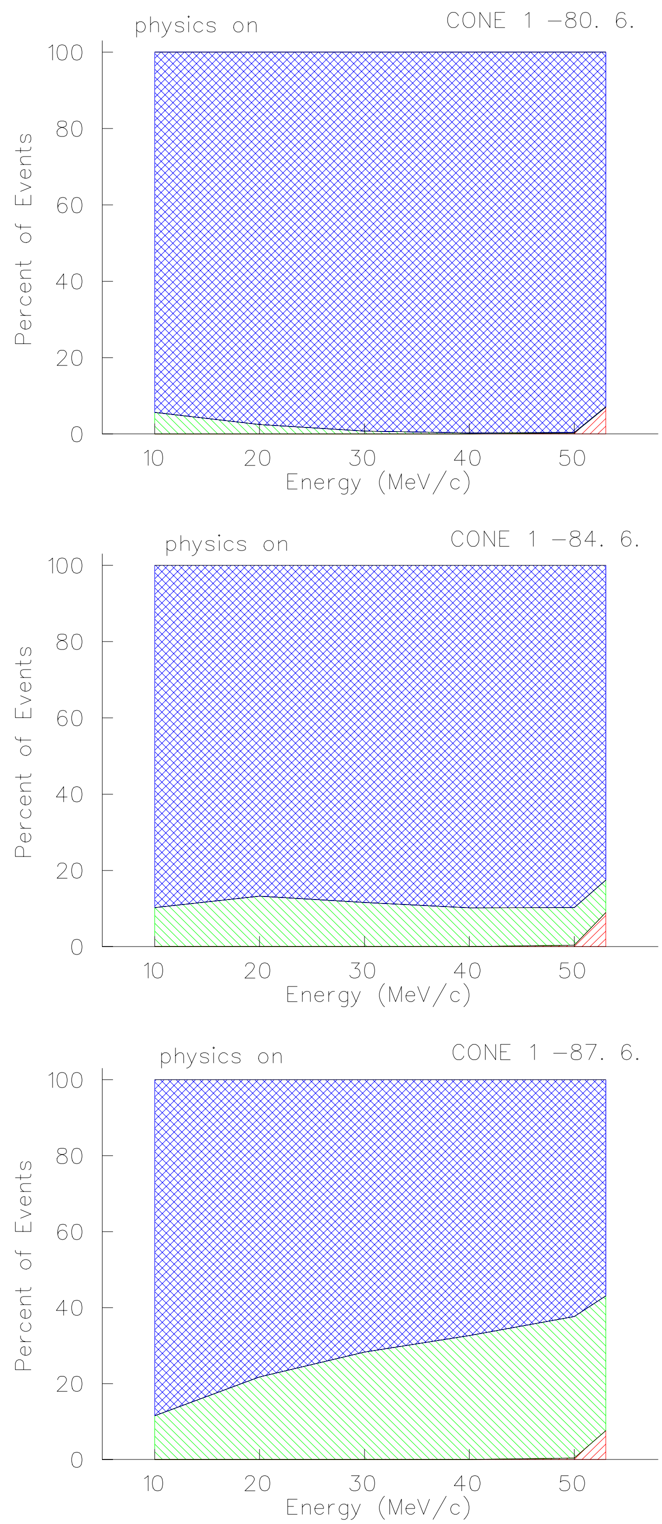


Figure 18: Geant results showing the number of positrons tracks that survive without being aborted (hashed blue), the number of positron tracks that leave (HCTR) the mother detector volume (hashed red) and the number of positrons aborted due to the 3 restrictions + the number of positrons that leave HCTR (solid upper green line). (note: green area represent positrons that were aborted).

Shown in figures 19 through 22 are Geant simulation results for physics processes turned on including delta ray production for 53 MeV/c positrons at cone angles of 75 and 87 degrees. For 53 MeV/c positrons at a cone angle of 75 degrees we see a slight different in the number of positrons which make it into the muon scintillator (less make it when delta rays are included in Geant). This discrepancy does not exist between delta rays on and off for the cone angle of 87 degrees. Again the number of positron tracks aborted when including delta ray production is slightly higher than when it is not turned on in the Geant simulation.

# 5 Summary

Studies have been conducted with the TWIST Geant in which 10 to 53 MeV/c positrons were generated in an isotropic cone distribution at various angles to test how many positrons would not be tracked until the end of their interactions. The two restrictions which caused this to happen are a track length restriction which is enforced as well as a step limit imposed on the particles. The time-of-flight cutoff did not seem to restrict any positron tracks for the current studies.

Three different physics cases were studied, one with no physics processes implemented, one with various physics processes turned on but no delta rays production and the last case allowed delta ray production to occur. The difference between physics off and physics on in the simulations was in the number of positron which stop being tracked increased at smaller angles (75 and 80 degrees) when physics processes are turned on. A secondary peak in the $cos(\theta)$ distributions of the positrons entering the muon scintillator and those entering the T0 counter appeared when physics processes were turned on. The source of this peak will require further investigation in the coming weeks. The difference between no delta rays turned on and delta rays turned on was very minimal and shows up in the number of positrons that make it to the muon scintillator as well as how many positrons tracks are aborted.

General trends were observed for all 3 different cases. These include that at low momentum we see that all the positrons have their radius fully contained inside HCTR, the mother detector volume. As the momentum is increased, more positrons make it out the side of HCTR. As well a spike in the distribution of positrons making it into the T0 counter was seen at the smallest possible radius. The trend that the number of aborted positrons tended to increase up to momentum of 50 MeV/c and then started to decrease around 53 MeV/c was also noticed.

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Thanks to Peter Gumplinger for questions answered, mysteries solved and Geant support.

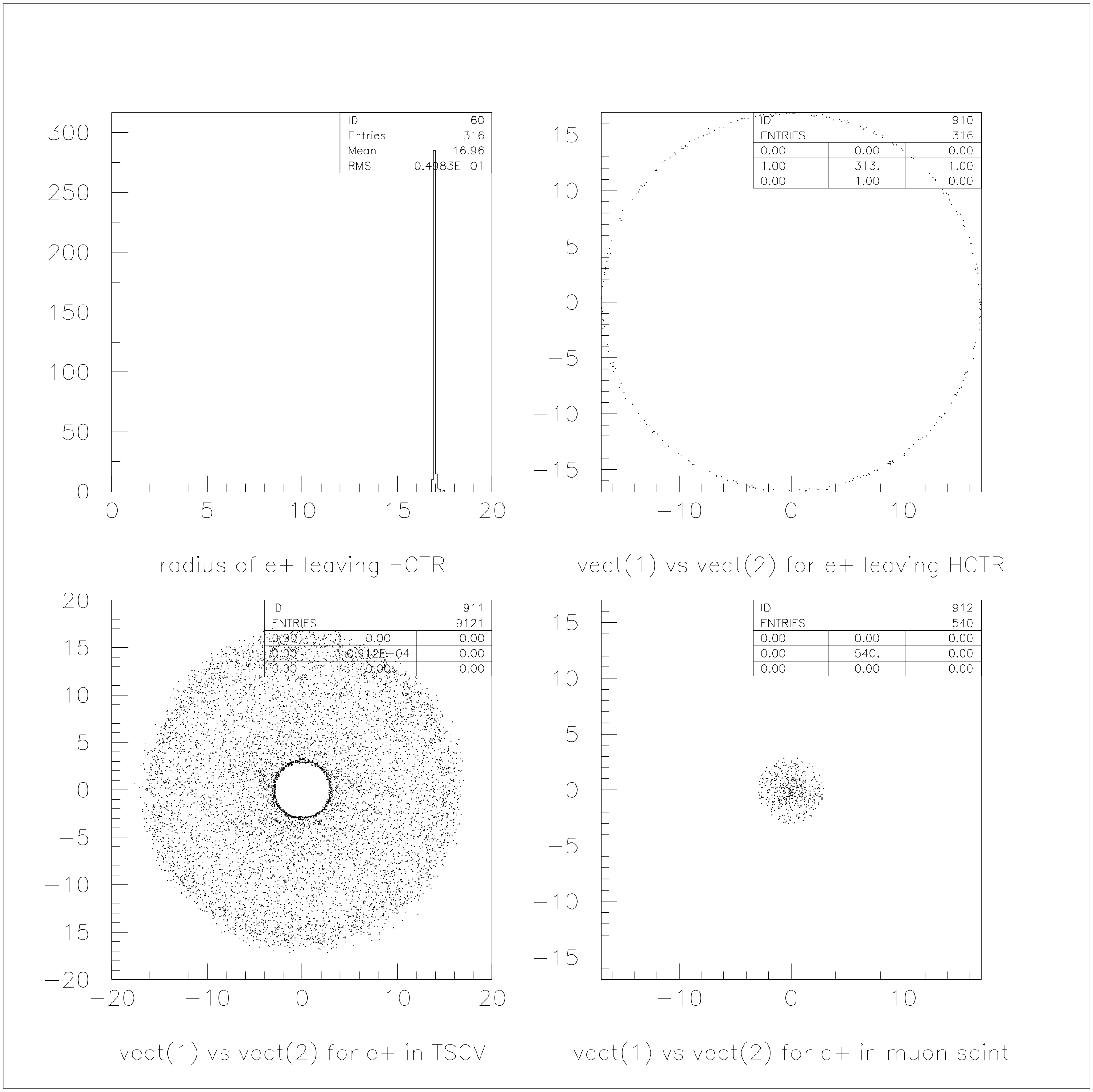


Figure 19: Geant results for 53 MeV/c positrons generated in a cone centered at 75 degrees. Shown are results for the x(vect(1)) and y(vect(2)) positions of positrons leaving the mother detector volume (HCTR), positrons entering the (TSCV) thick ring scintillator and positrons which enter the (MSCV) muon scintillator.(delta rays on)

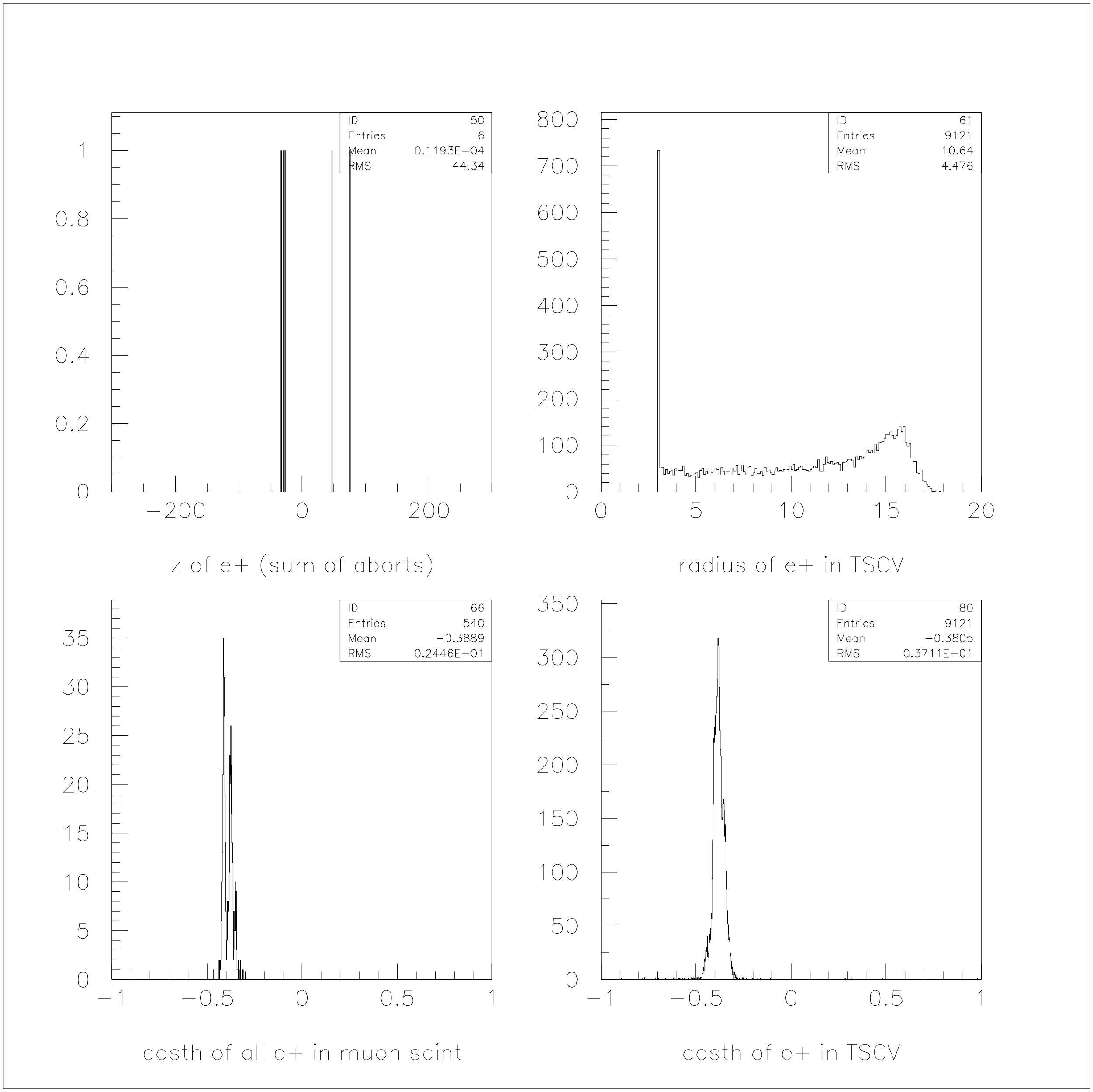


Figure 20: Geant results for 53 MeV/c positrons generated in a cone centered at 75 degrees. Shown is the z position of any aborted positron tracks, the radius ($\sqrt(x^2 + y^2)$) of positrons which enter the thick ring scintillator, the $cos(\theta)$ of positrons which enter the muon scintillator and the $cos(\theta)$ of positrons which enter the thick ring scintillator. (delta rays on)

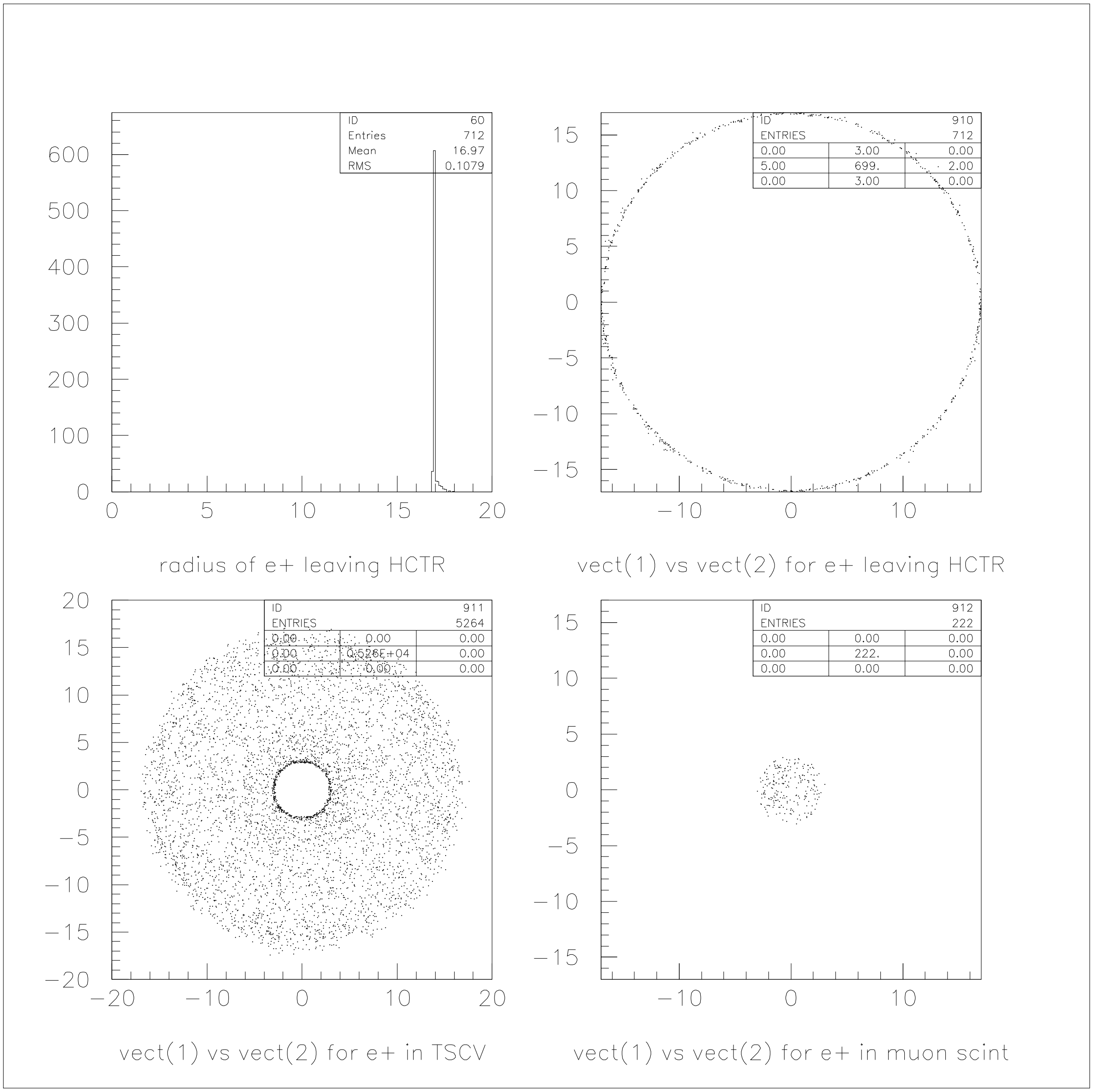


Figure 21: Geant results for 53 MeV/c positrons generated in a cone centered at 87 degrees. Shown are results for the x(vect(1)) and y(vect(2)) positions of positrons leaving the mother detector volume (HCTR), positrons entering the (TSCV) thick ring scintillator and positrons which enter the (MSCV) muon scintillator. (delta rays on)

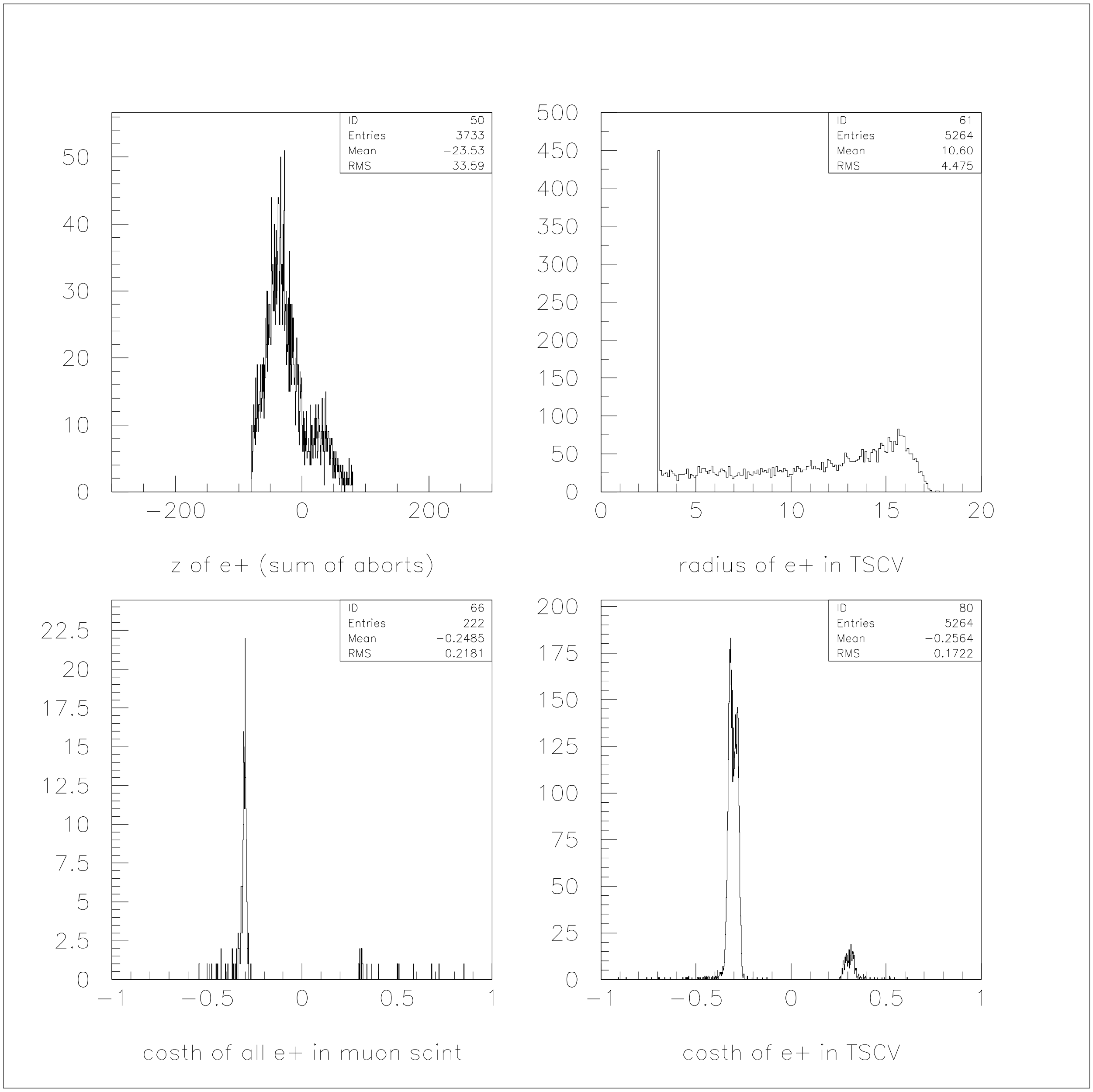


Figure 22: Geant results for 53 MeV/c positrons generated in a cone centered at 87 degrees. Shown is the z position of any aborted positron tracks, the radius ($\sqrt{(}x^2 + y^2)$) of positrons which enter the thick ring scintillator, the $cos(\theta)$ of positrons which enter the muon scintillator and the $cos(\theta)$ of positrons which enter the thick ring scintillator. (delta rays on)