GEANT 3 Step Settings

III. step size in chamber
IV. step size in DC cells
V. truncated tracks

TWIST Technical Note 85

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Abstract

The position of a pencil positron beam generated just outside the target was found to differ by tens of microns near the end of the half stack depending on the value of the parameter $STEmax$ in the entire chamber and on the step size inside the DC cells. This difference is systematic and increases with the starting angle of the positron helix. The kinetic energy of the beam was found to differ by less than $3keV$ as the step size is varied. Effects of track limit cuts were found to result in the rejection of up to few tracks in 10^3 for values of $STEmax$ below $200\mu m$.

1 Introduction

Effects of various GEANT 3 parameter settings are discussed in this note. The study is aimed at finding parameters that may cause sizable differences on the positron helix track, as well as determining whether such differences are systematic (energy and/or angle dependent).

In a previous note (tech note 84) effects of varying $STEmax$, the step size inside the target were investigated. In this note effects of varying the cluster separation (which is equivalent to varying the step size) in the drift cells are investigated, as well as effects of varying $STEmax$ inside the entire chamber (excluding the target).

Other parameters that may result in systematic biases were also investigated; these include tracks abandoned due to: getting stuck, exceeding a specified length limit, or exceeding the maximum number of allowed steps. All these cuts can potentially lead to systematic biases since the likelihood of them being encountered is higher for the longer high-angle high-energy tracks.

To investigate these effects, a pencil positron beam was tracked starting at a position of $(0, 0, 2)cm$ (right outside the target) and various distributions were plotted at $(0, 0, 51)cm$ (near the end of the half-stack). These distributions include the x and y position of the beam as well as its kinetic energy.

2 Effects of Step Size Variation in DC Cells

Only energy loss (including delta ray production and bremsstrahlung) was turned on and a million positron tracks were simulated at $\theta = 70°$ and KE $= 40MeV$ with the cluster separation set to values in the range [50,500]μm. Table 1 shows the means for various distributions after the beam traversed a distance of $51.0cm$ in z. Figures 1a and 1b show the change in beam position as the cluster separation is changed and the corresponding percentage change in CPU time. A difference of up to $40\mu m$ in beam position is seen as the cluster separation is varied from $500\mu m$ to $100\mu m$. A trend reversal is seen as the cluster separation is shrunk below $100\mu m$, likely due to single precision limitations in GEANT 3. Figure 2 shows the kinetic energy at $z = 51.0cm$ for cluster separations of $100\mu m$ (green) and $500\mu m$ (red). A slight difference in shape is seen, with the rising edge differing by less than $3keV$.

It is important to emphasize here that the cluster separation parameter is used as a way to limit the step size inside the drift cells only and not to study the drift gas cluster effects on timing. The latter study was done separately by comparing TDC distributions of real and GEANT data, and concluded that the cluster separation parameter should be set to $\sim 160\mu m$.

cluster separation(μm)	$\langle x \rangle (cm)$	$\langle y \rangle (cm)$	CPU(msec)	% CPU increase
500	-1.982	-0.7921	11.3	0%
300	-1.982	-0.7925	12.8	13.2%
200	-1.980	-0.7943	14.6	29.2%
100	-1.979	-0.7963	19.6	73.5%
50	-1.982	-0.7940	29.5	161%

Table 1: The first two columns are the mean x and y position of the positron beam at $z = 51.0cm$. The last two columns are the CPU time per event and the percentage increase in CPU time as the cluster separation is made smaller. The positron beam was simulated with a kinetic energy of $40MeV$ and a θ angle of $70°$.

A million positron tracks were then simulated at $\theta = 20°$ and KE $= 40MeV$ and the same exercise was repeated. Table 2 shows the means for various distributions after the beam traversed a distance of $51.0cm$ in z. Figures 1c and 1d show the change in beam position as $STEmax$ is changed and the corresponding percentage change in CPU time. No difference is seen in beam position to within the statistical accuracy of this simulation. Figure 3 shows the kinetic energy at $z = 51.0cm$ for cluster separations of $100\mu m$ (green) and $500\mu m$ (red). A slight difference in shape is seen, with the rising edge differing by less than $3keV$.

cluster separation (μm)	$\langle x \rangle (cm)$	$\langle y \rangle (cm)$	CPU(msec)	% CPU increase
500	0.8807	-0.2413	4.9	0%
300	0.8814	-0.2411	5.4	10.2%
200	0.8809	-0.2414	6.1	24.5%
100	0.8813	-0.2417	7.8	59.2%
50	0.8804	-0.2406	11.3	131%

Table 2: The first two columns are the mean x and y position of the positron beam at $z = 51.0cm$. The last two columns are the CPU time per event and the percentage increase in CPU time as the cluster separation is made smaller. The positron beam was simulated with a kinetic energy of $40MeV$ and a θ angle of $20°$.

3 Effects of $STEmax$

The same process was repeated, this time fixing the cluster separation at $500\mu m$ (so it won't be the step size limiting factor) and varying $STEmax$ in the entire chamber excluding the target, where $STEmax$ was fixed at $10\mu m$. Events were first simulated at $\theta = 70°$ and KE = $40MeV$ with $STEmax$ set to values in the range [100,500]μm. Table 3 shows the means for various distributions after the beam traversed a distance of $51.0cm$ in z. Figures 4a and 4b show the change in beam position as $STEmax$ is changed and the corresponding percentage change in CPU time. A trend similar to varying the step size in the DC cells is seen, with the beam position moving in the same direction as the step size is lowered, followed by a trend reversal. However, at $STEmax = 300\mu m$ the beam position moves by about $30\mu m$, as opposed to only a slight change (if any) in the previous case. This result is plausible, since the step size is now reduced in the entire chamber as opposed to only the DC cells. Below $STEmax = 300\mu m$ a trend reversal is seen as opposed to this trend reversal occurring below a step size of $100\mu m$ for the DC cells. This result is consistent with attributing the trend reversal to single precision limitations since a much larger number of steps occurs when the step size is reduced in the entire chamber.

A million positron tracks were then simulated at $\theta = 20°$ and KE = $40MeV$ and the same exercise was repeated. Table 4 shows the means for various distributions after the beam traversed a distance of $51.0cm$ in z. Figures 4c and 4d show the change in beam position as $STEmax$ is changed and the corresponding percentage change in CPU time.

4 Abandoned Tracks

Two cuts are imposed to abandon tracks that may loop for a long time, thereby waisting a large amount of CPU time. While these cuts are very useful, it is important that their effects are investigated to make sure that no significant systematic

$STEmax$ (μm)	$\langle x \rangle (cm)$	$\langle y \rangle (cm)$	CPU(msec)	% CPU increase
500	-1.982	-0.7911	35.7	0%
400	-1.980	-0.7908	41.7	16.5%
300	-1.982	-0.7937	48.5	35.9%
200	-1.982	-0.7908	71.7	101%
100	-1.986	-0.7900	120	237%

Table 3: The first two columns are the mean x and y position of the positron beam at $z = 51.0cm$. The last two columns are the CPU time per event and the percentage increase in CPU time as the cluster separation is made smaller. The positron beam was simulated with a kinetic energy of $40MeV$ and a θ angle of $70°$.

$STEmax$ μm	$\langle x \rangle (cm)$	$\langle y \rangle (cm)$	CPU(msec)	% CPU increase
500	0.8817	-0.2407	15.4	0%
400	0.8812	-0.2415	18.0	16.9%
300	0.8818	-0.2413	22.0	42.9%
200	0.8815	-0.2416	30.7	99.3%
100	0.8811	-0.2405	55.6	261%

Table 4: The first two columns are the mean x and y position of the positron beam at $z = 51.0cm$. The last two columns are the CPU time per event and the percentage increase in CPU time as the cluster separation is made smaller. The positron beam was simulated with a kinetic energy of $40MeV$ and a θ angle of $20°$.

biases are introduced.

One of these cuts limits the total number of steps that a track can have, while the other limits the total track length. Tracks that exceed a value determined by the MAX_STEP or the MAX_LENGTH parameters (both of which can be specified in the $MAXS$ ffcard) are abandoned. If set too tight these cuts can result in a systematic bias, since large-angle high-energy tracks are longer and result in a large number of steps. Additionally, the total number of steps depends on the step size parameters ($STEmax$ and cluster separation).

To investigate these effects tracks were simulated at KE = $40MeV$ at various values of $STEmax$ in the range [100,500]μm. Figures 5a and 5b show the results for a positron helix simulated at $\theta = 70°$ and $\theta = 20°$, respectively. Figures 5c and 5d are the same as 1a and 1b but on a log scale. The values for these cuts were $MAX\_STEP = 60000$ and $MAX\_LENGTH = 6000cm$.

5 Conclusions

The step size parameters in GEANT are meant to be used as a compromise between accuracy and speed. If no single precision limitations were present, one would expect to see differences on the positron helix track as the step size is reduced from a large value and would eventually reach a plateau as the step size is made small. However, no such plateau is observed, likely due to single precision limitations in GEANT 3.

When the step size parameter in the DC cells is reduced the mean position of the positron helix changes by up to $40\mu m$ as can be seen from figure 1a. At values below $100\mu m$ the trend reverses, likely due to accumulation of rounding errors. If one assumes that the helix position will continue to differ at the same rate down to $50\mu m$ and then reach a plateau if it wasn't for single precision limitations, the green curve of figure 1a will reach $-60\mu m$. Since the current value used for cluster separation in the DC cells is $160\mu m$, the overall difference in helix position between this value and a cluster separation of $50\mu m$ would be in the neighborhood of $20\mu m$. This would be an upper limit.

However, when the step size is varied in the entire chamber the biases are bigger. The helix position moves by $30\mu m$ as the step size is reduced from $400\mu m$ to $300\mu m$, and the trend reversal is encountered at a much bigger step size of around $300\mu m$ as a result of the higher accumulation rate of rounding errors. If we make the same assumption again, namely that if it wasn't for single precision limitations the helix position would have continued changing at the same rate down to a step size of $50\mu m$ before reaching a plateau, the overall change in helix position would be in the neighborhood of $100\mu m$.

Since changing the step size value results in a relatively large systematic bias, it is recommended that this study be pursued by testing the effects on the vertex momentum and angle of the decay positron, as well as the fitted Michel parameters if necessary.

Varying the step size parameter in either the DC cells or the entire chamber has a small effect on the kinetic energy of the positron beam changing it by less than $3keV$ as it is varied from $100\mu m$ to $500\mu m$.

Abandoned tracks due to getting stuck in GEANT are less than few parts in 10^4. Furthermore, the effect is similar for both $70°$ and $20°$ tracks. Tracks abandoned due to the total length limit cut are less than few parts in 10^5. Only tracks abandoned due to the number of steps cut show a systematic behavior, resulting in cutting few tracks in 10^3 at a step size of $100\mu m$ for the $70°$ tracks, but cutting no tracks at $20°$. It is therefore recommended that the number of steps cut be raised to avoid possible systematic biases.

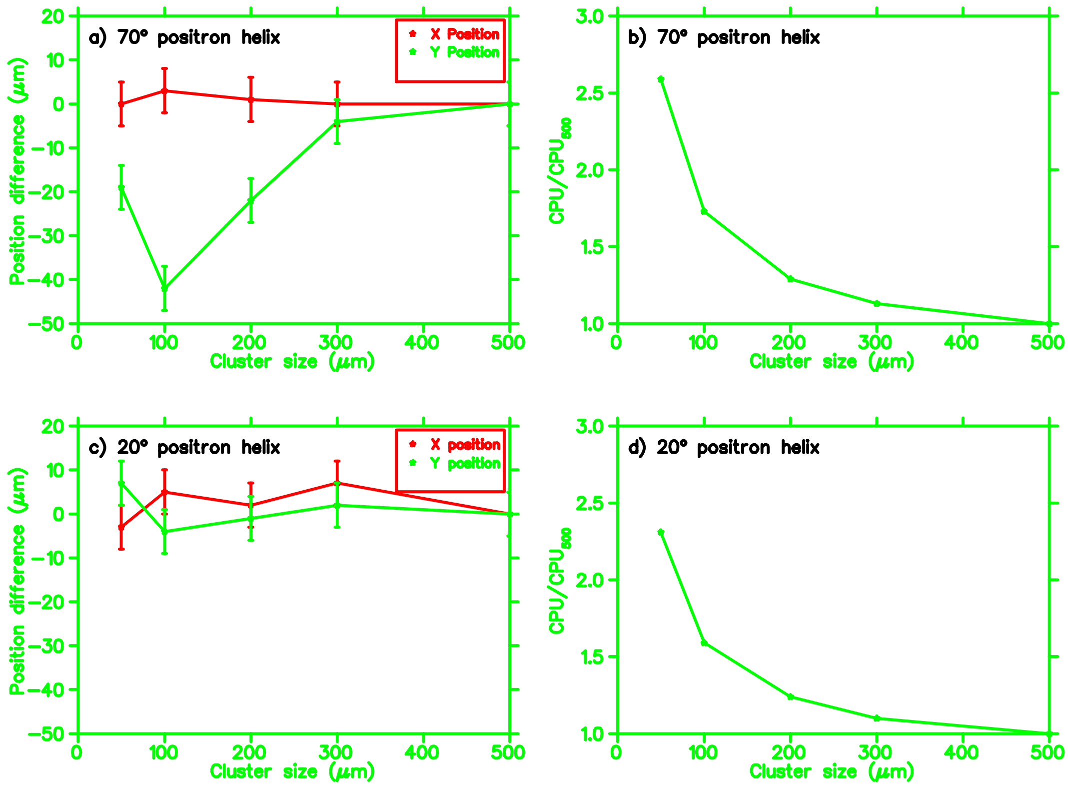

Figure 1: a) difference in $\langle x \rangle (cm)$ (red) position for various values of cluster separation and $\langle x \rangle (cm)$ at cluster separation $= 500\mu m$; the green curve is the same for y. The positron beam was generated with a kinetic energy of $40 MeV$ and a θ angle of $70°$. b) percentage CPU increase as the cluster separation is lowered from the $500\mu m$. c) difference in $\langle x \rangle (cm)$ (red) position for various values of cluster separation and $\langle x \rangle (cm)$ at cluster separation $= 500\mu m$; the green curve is the same for y. The positron beam was generated with a kinetic energy of $40 MeV$ and a θ angle of $20°$. d) percentage CPU increase as the cluster separation is lowered from $500\mu m$.

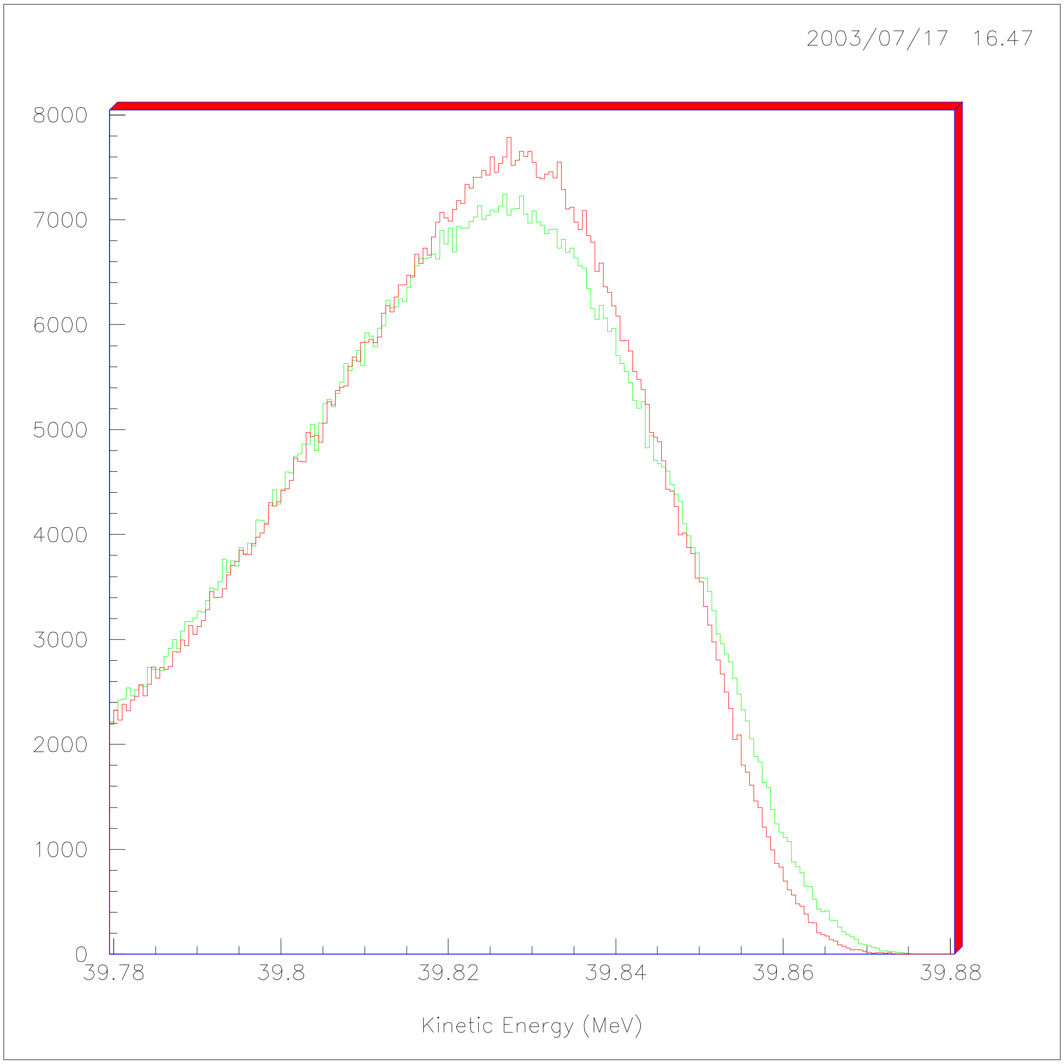

Figure 2: Kinetic energy of a pencil positron beam at $z = 51cm$ generated at $z = 2cm$ with a kinetic energy of $40MeV$ and an angle of $70°$. The cluster separation is $100\mu m$ for the green curve and $500\mu m$ for the red curve.

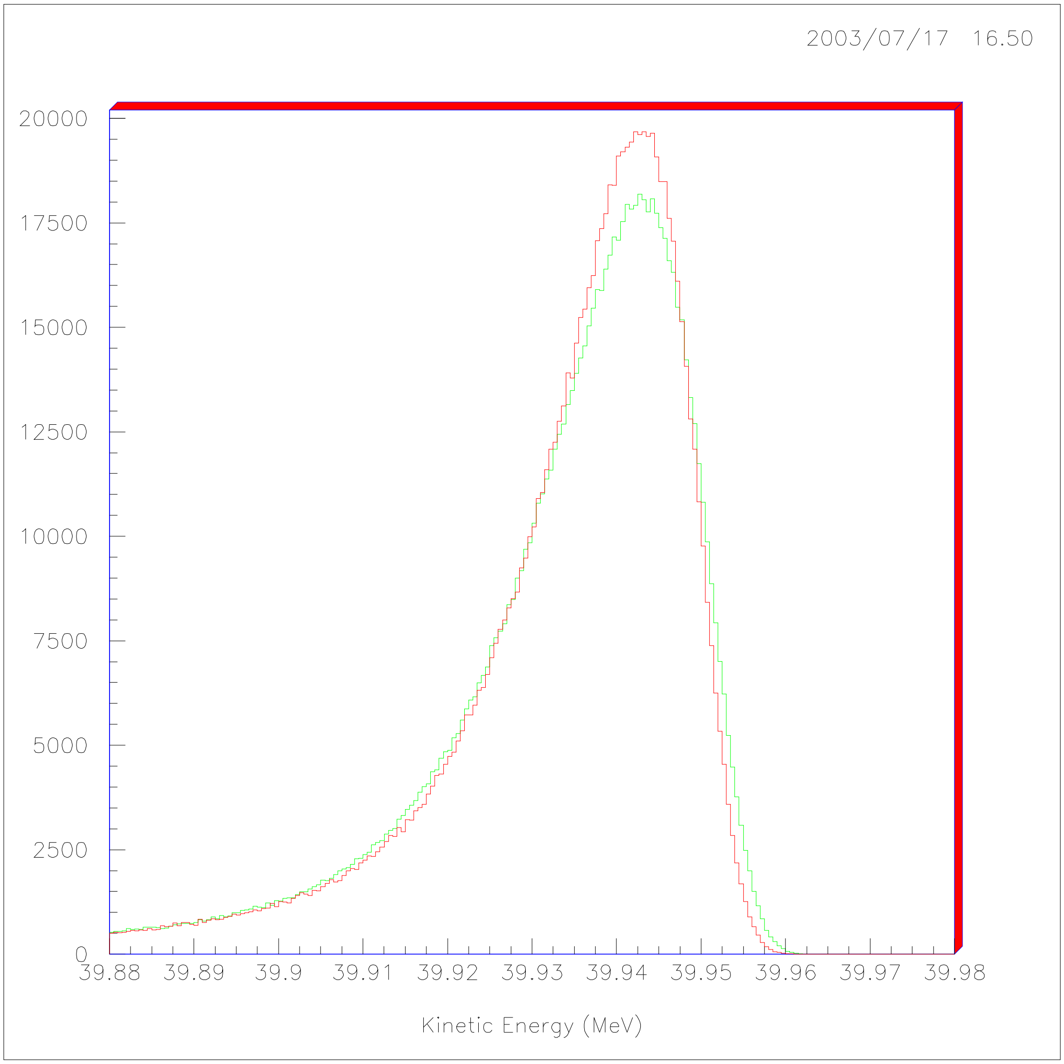

Figure 3: Kinetic energy of a pencil positron beam at $z = 51cm$ generated at $z = 2cm$ with a kinetic energy of $40MeV$ and an angle of $20°$. The cluster separation is $100\mu m$ for the green curve and $500\mu m$ for the red curve.

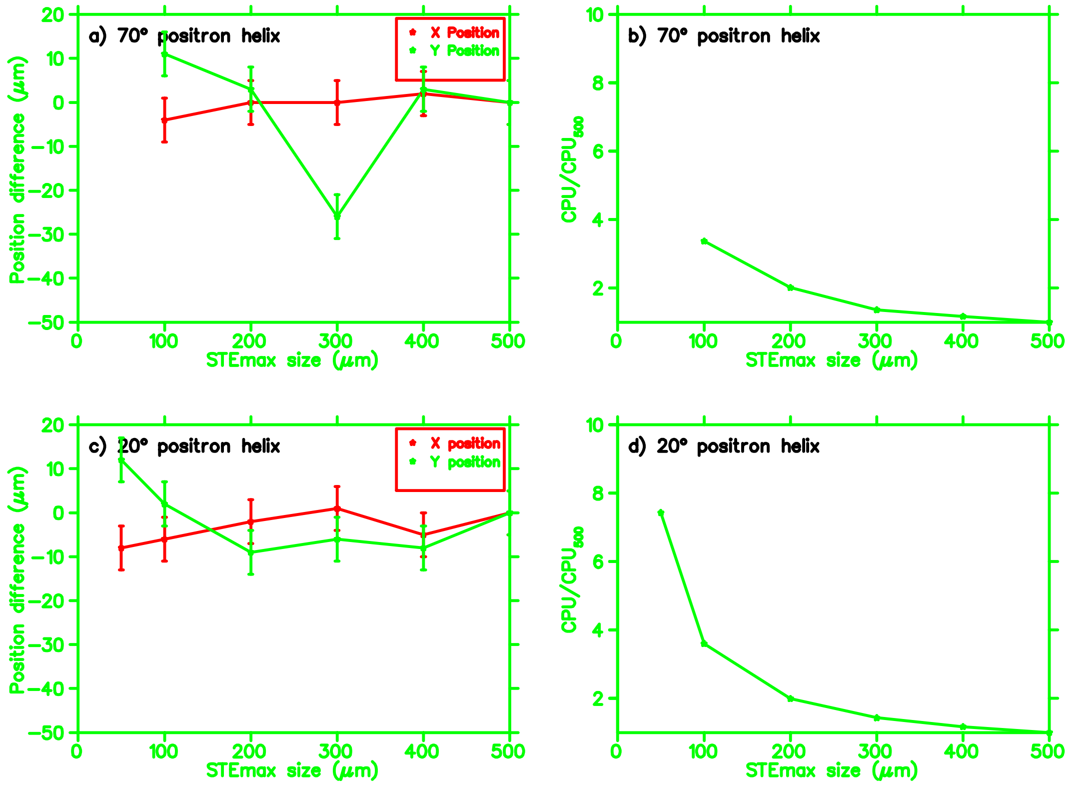

Figure 4: a) difference in $\langle x \rangle (cm)$ position (red) at various values of $STEmax$ and $\langle x \rangle (cm)$ at $STEmax = 500\mu m$; the green curve is the same for y. The positron beam was generated with a kinetic energy of $40MeV$ and a θ angle of $70°$. b) percentage CPU increase as $STEmax$ is lowered from $500\mu m$. c) difference in position (red) at various values of $STEmax$ and $\langle x \rangle (cm)$ at $STEmax = 500\mu m$; the green curve is the same for y. The positron beam was generated with a kinetic energy of $40MeV$ and a θ angle of $70°$. d) percentage CPU increase as $STEmax$ is lowered from $500\mu m$.

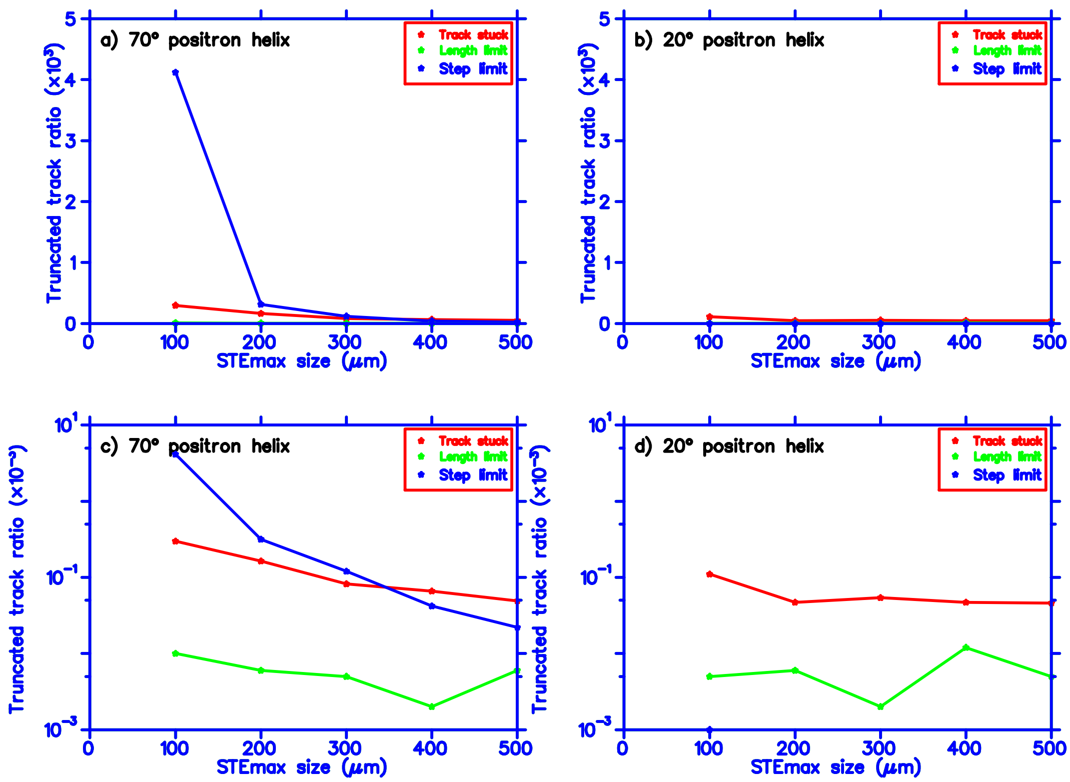

Figure 5: Abandoned tracks due to: 1) exceeding MAX_STEP, the maximum number of allowed steps parameter (blue); 2) exceeding MAX_LENGTH, the maximum allowed track length (green); and 3) getting stuck (red). Figure (a) is for positron helices generated at KE = $40 MeV$ and $\theta = 70°$, figure (b) is for positron helices generated at KE = $40 MeV$ and $\theta = 20°$, and figures (c) and (d) are the same as 1a and 1b but on a log scale.