Sensitivity to Energy Thresholds in GEANT 3

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Monte Carlo sets were generated and analyzed to investigate the effects of GEANT 3 photon and electron energy thresholds. Effects on the statistical error as a result of using the same set of muon decay spectrum in the base set and the test set were investigated, as well as effects of doubling the statistics in the base set only. Effects of increasing the fiducial volume on the statistical error and on the χ^2 distribution were also examined.

1 Intorduction

GEANT 3 allows the user to specify energy thresholds for both electrons and photons. Above the specified energy threshold, GEANT explicitly generates secondary particles and tracks them through the detector. When this happens, extra hits are generated which may possibly confuse the analysis code at the level of pattern recognition (classification and first guess) or at the level of the helix fit. Below the specified energy threshold, the secodary particles are not explicitly generated, and the energy loss effects on the primary particle are calculated as a continous process.

This note investigates a possible systematic bias that may result from these energy thresholds. Altough a systematic bias would indicate GEANT's limited accuracy in handling energy loss and/or secondary particle production, the analysis code can potentially reduce or enhance such differences. The systematic effect is therefore a combination of both.

2 Effects of lowering the γ energy threshold

2.1 The statistically independent case

A Monte Carlo set (gen68/anal1) of 2000 runs (2×10^8 events) was generated with a γ energy threshold of 10 keV. This set was fitted against a base set (gen70/anal5) of 4000 runs (4×10^8 events) which uses a 500 keV energy threshold and a different muon decay spectrum, making the two sets statistically independent.

Figure 1 shows a comparison of the event types histogram at the low and high γ thresholds. Figure 2 shows a comparison of the 1-dimensional normalized momentum and $\cos(\theta)$ histograms for the two cases. Figure 3 shows the difference between the normalized histograms of figure 2.

2.1.1 Fitting results

a) Fiducial volume $20.00 < p < 50.00$ and $0.54 < cos(\theta) < 0.80$

Data: spectrumStat(fiducial_bins=1560, fiducial_entries=1.84823e+07, min_bin_entries=5289)
Base: spectrumStat(fiducial_bins=1560, fiducial_entries=3.28436e+07, min_bin_entries=9337)
chi2=1483.18
ndf=1556
confLevel=0.905637
rho = 0.003367 +/- 0.002004
eta = 0.210693 +/- 0.109377
xi = 0.002562 +/- 0.002323
delta = -0.000162 +/- 0.001285

b) Fiducial volume $15.00 < p < 50.00$ and $0.42 < cos(\theta) < 0.90$

Data: spectrumStat(fiducial_bins=3360, fiducial_entries=3.62361e+07, min_bin_entries=3092)
Base: spectrumStat(fiducial_bins=3360, fiducial_entries=6.43909e+07, min_bin_entries=5474)
chi2=3168.15
ndf=3356
confLevel=0.99007
rho = 0.000033 +/- 0.001079
eta = 0.010483 +/- 0.049293
xi = 0.000286 +/- 0.001391
delta = -0.001252 +/- 0.000850

2.2 The statistically semi-dependent case

The same set (gen68/anal1) was then fitted against a base set (gen77/anal1) of 2000 runs (2×10^8 events) generated with a 500 keV γ threshold and the same set of muon decay spectrum. This introduces some statistical correlations between the two sets, and the two sets are referred to as statistically semi-dependent.

2.2.1 Fitting results

a) Fiducial volume $20.00 < p < 50.00$ and $0.54 < cos(\theta) < 0.80$

Data: spectrumStat(fiducial_bins=1560, fiducial_entries=1.84823e+07, min_bin_entries=5289)
Base: spectrumStat(fiducial_bins=1560, fiducial_entries=1.66513e+07, min_bin_entries=4675)
chi2=1491.83
ndf=1556
confLevel=0.87587
rho = 0.004538 +/- 0.001944
eta = 0.271603 +/- 0.106055
xi = 0.026213 +/- 0.002225

delta = -0.000210 +/- 0.001219

b) Fiducial volume $15.00 < p < 50.00$ and $0.42 < cos(\theta) < 0.90$

Data: spectrumStat(fiducial_bins=3360, fiducial_entries=3.62361e+07, min_bin_entries=3092)
Base: spectrumStat(fiducial_bins=3360, fiducial_entries=3.26529e+07, min_bin_entries=2793)
chi2=3298.09
ndf=3356
confLevel=0.759733
rho = 0.001654 +/- 0.001047
eta = 0.077964 +/- 0.047862
xi = 0.024618 +/- 0.001341
delta = -0.001163 +/- 0.000807

2.3 Doubling statistics in the base set only

The same set (gen68/anal1) was then fitted against half the runs in the statistically independent set, gen70/anal5 (2000 runs or 2×10^8 events), to investigate the effects of doubling the statistics in the base set only.

2.3.1 Fitting results

a) Fiducial volume $20.00 < p < 50.00$ and $0.54 < cos(\theta) < 0.80$

Data: spectrumStat(fiducial_bins=1560, fiducial_entries=1.84823e+07, min_bin_entries=5289)
Base: spectrumStat(fiducial_bins=1560, fiducial_entries=1.63759e+07, min_bin_entries=4650)
chi2=1453.25
ndf=1556
confLevel=0.969402
rho = 0.003326 +/- 0.002131
eta = 0.209932 +/- 0.116307
xi = 0.002291 +/- 0.002472
delta = 0.000264 +/- 0.001368

b) Fiducial volume $15.00 < p < 50.00$ and $0.42 < cos(\theta) < 0.90$

Data: spectrumStat(fiducial_bins=3360, fiducial_entries=3.62361e+07, min_bin_entries=3092)
Base: spectrumStat(fiducial_bins=3360, fiducial_entries=3.2112e+07, min_bin_entries=2719)
chi2=3137.68
ndf=3356

confLevel=0.996703
rho = -0.000173 +/- 0.001149
eta = 0.002810 +/- 0.052494
xi = 0.000368 +/- 0.001481
delta = -0.001169 +/- 0.000905

2.4 summary

Table 1 shows a summary of the results for the small fiducial region and table 2 for the large fiducial region.

	$rho \pm \Delta\rho$	$\delta \pm \Delta\delta$	χ^2
Independent case	3.3 ± 2.1	0.3 ± 1.4	0.93
Semi-dependent case	4.5 ± 1.9	-0.2 ± 1.2	0.95
Doubled stats in base set	3.4 ± 2.0	-0.2 ± 1.3	0.95

Table 1: Small fiducial region.

	$rho \pm \Delta\rho$	$\delta \pm \Delta\delta$	χ^2
Independent case	-0.2 ± 1.1	-1.2 ± 0.9	0.93
Semi-dependent case	1.7 ± 1.0	-1.2 ± 0.8	0.98
Doubled stats in base set	0.03 ± 1.0	-1.3 ± 0.9	0.94

Table 2: Large fiducial region.

3 Effects of lowering the e energy threshold

3.1 The statistically independent case

A Monte Carlo set (gen69/anal1) of 2000 runs (2×10^8 events) was generated with a γ energy threshold of 10 keV. This set was fitted against a base set of 4000 runs (4×10^8 events) which uses a 20 keV e threshold and a different muon decay spectrum.

Figure 4 shows a comparison of the event types histogram at the low and high e thresholds. Figure 5 shows a comparison of the 1-dimensional normalized momentum and $\cos(\theta)$ histograms for the two cases. Figure 6 shows the difference between the normalized histograms of figure 5.

a) Fiducial volume $20.00 < p < 50.00$ and $0.54 < cos(\theta) < 0.80$

Data: spectrumStat(fiducial_bins=1560, fiducial_entries=1.80995e+07, min_bin_entries=4987)
Base: spectrumStat(fiducial_bins=1560, fiducial_entries=3.28436e+07, min_bin_entries=9337)
chi2=1577.39
ndf=1556
confLevel=0.346931
rho = -0.001550 +/- 0.002022
eta = -0.079070 +/- 0.110339
xi = -0.001160 +/- 0.002343
delta = -0.000789 +/- 0.001300

b) Fiducial volume $15.00 < p < 50.00$ and $0.42 < cos(\theta) < 0.90$

Data: spectrumStat(fiducial_bins=3360, fiducial_entries=3.54822e+07, min_bin_entries=3027)
Base: spectrumStat(fiducial_bins=3360, fiducial_entries=6.43909e+07, min_bin_entries=5474)
chi2=3347.98
ndf=3356
confLevel=0.541463
rho = -0.001107 +/- 0.001086
eta = -0.020215 +/- 0.049654
xi = -0.000140 +/- 0.001401
delta = -0.000927 +/- 0.000857

3.2 The statistically semi-dependent case

The same set (gen69/anal1) was then fitted against a base set (gen77/anal1) of 2000 runs (2×10^8 events) generated with the same set of muon decay spectrum.

3.3 Fitting results

a) Fiducial volume $20.00 < p < 50.00$ and $0.54 < cos(\theta) < 0.80$

Data: spectrumStat(fiducial_bins=1560, fiducial_entries=1.80995e+07, min_bin_entries=4987)
Base: spectrumStat(fiducial_bins=1560, fiducial_entries=1.66513e+07, min_bin_entries=4675)
chi2=1532.88
ndf=1556
confLevel=0.657145
rho = 0.000390 +/- 0.001958
eta = 0.027423 +/- 0.106828
xi = 0.023164 +/- 0.002241
delta = -0.000718 +/- 0.001231

b) Fiducial volume $15.00 < p < 50.00$ and $0.42 < cos(\theta) < 0.90$
Data: spectrumStat(fiducial_bins=3360, fiducial_entries=3.54822e+07, min_bin_entries=3027)
Base: spectrumStat(fiducial_bins=3360, fiducial_entries=3.26529e+07, min_bin_entries=2793)
chi2=3325.04
ndf=3356
confLevel=0.647085
rho = 0.000659 +/- 0.001053
eta = 0.050389 +/- 0.048112
xi = 0.024236 +/- 0.001348
delta = -0.000895 +/- 0.000811

4 Conclusions

Increasing the fiducial volume from the range $20.00 < p < 50.00$ and $0.54 < cos(\theta) < 0.80$ to the range $15.00 < p < 50.00$ and $0.42 < cos(\theta) < 0.90$ showed no deterioration of the χ^2. For the γ threshold study, the χ^2 per degree of freedom decreased from 0.95 to 0.94 as the fiducial volume was increased, and decreased from 1.01 to 1.0 for the e threshold study (using number from the statistically independent case). The statistical error on ρ decreased by about a factor of 2 in both cases, and the error on δ decreased by a factor of about 1.5.

Fitting semi-dependent sets (by using the same muon decay spectrum) results in reducing the statistical error by less than 10%, with essentially no effect on the χ^2 distribution (0.95 vs 0.93 for the small fiducial volume, and 0.98 vs 0.93 for the large fiducial volume).

Doubling the statistics in the base set only results in decreasing the statistical error by about 6% with the value of χ^2 decreasing from 0.95 to 0.93 for the small fiducial volume, and from 0.94 to 0.93 for the large fiducial region.

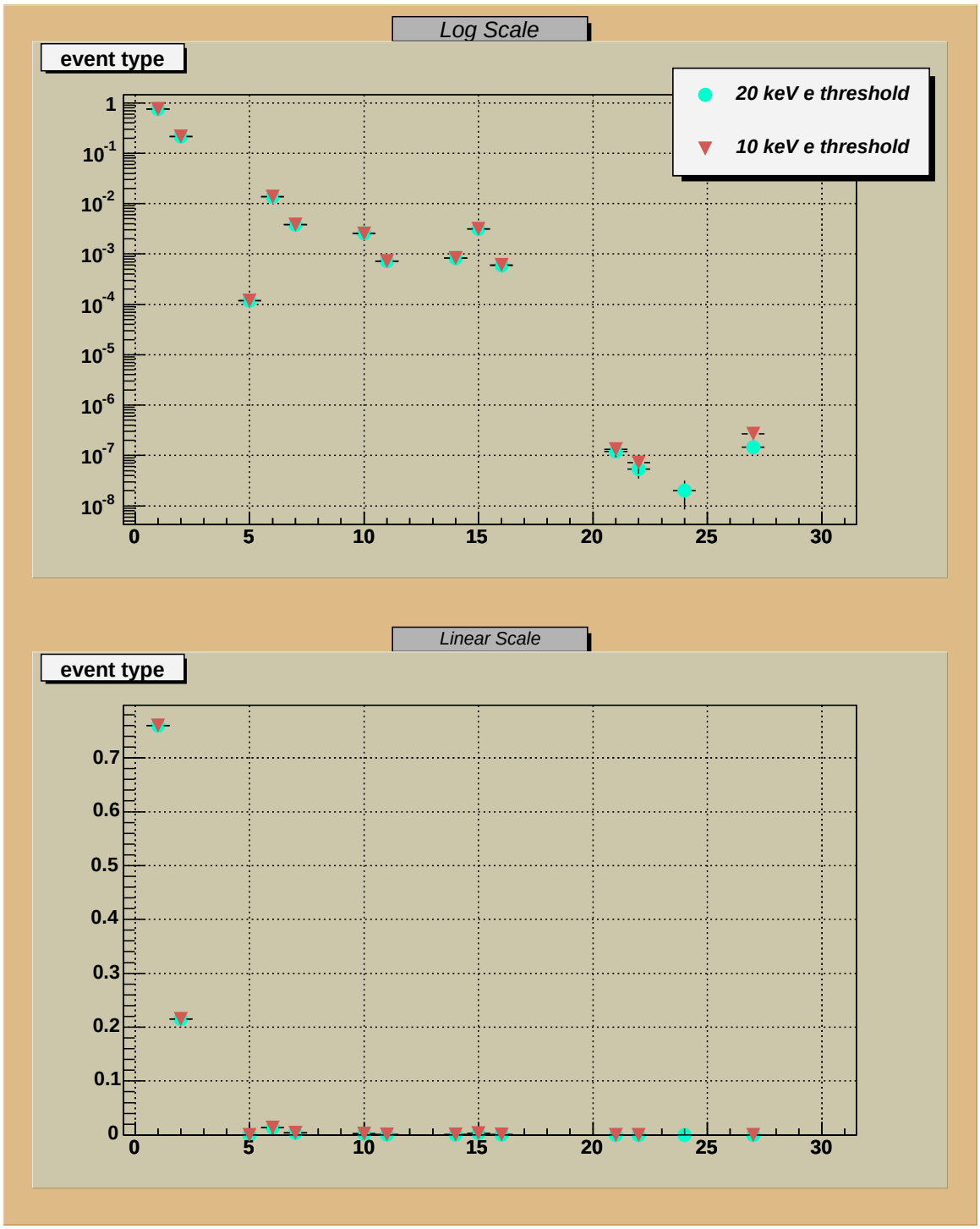

Figure 1: Event types plotted on a log scale (top) and linear scale (bottom) for a 20 and a 10 keV e threshold.

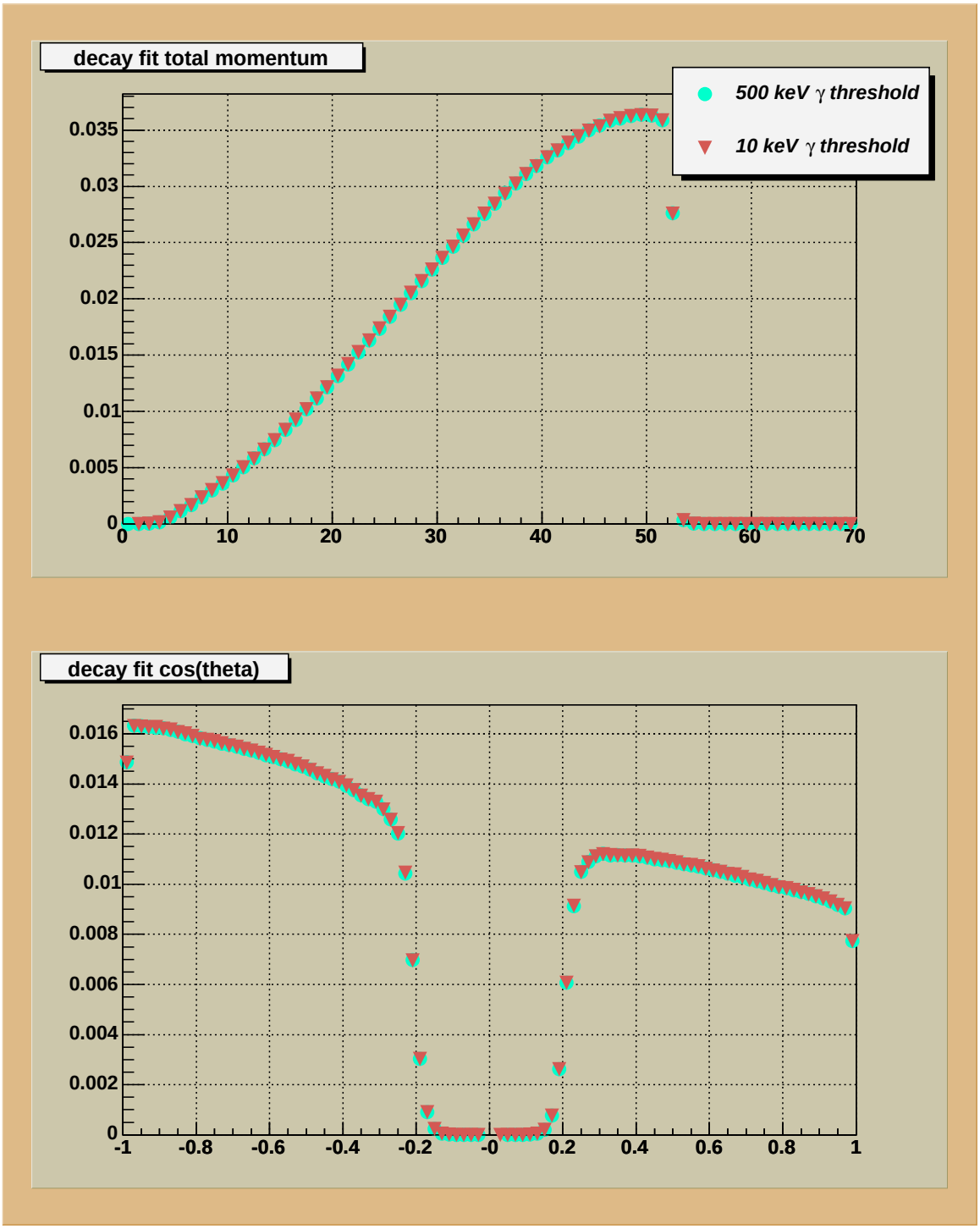

Figure 2: Momentum (top) and $\cos(\theta)$ (bottom) distributions for for a 20 and a 10 keV e threshold.

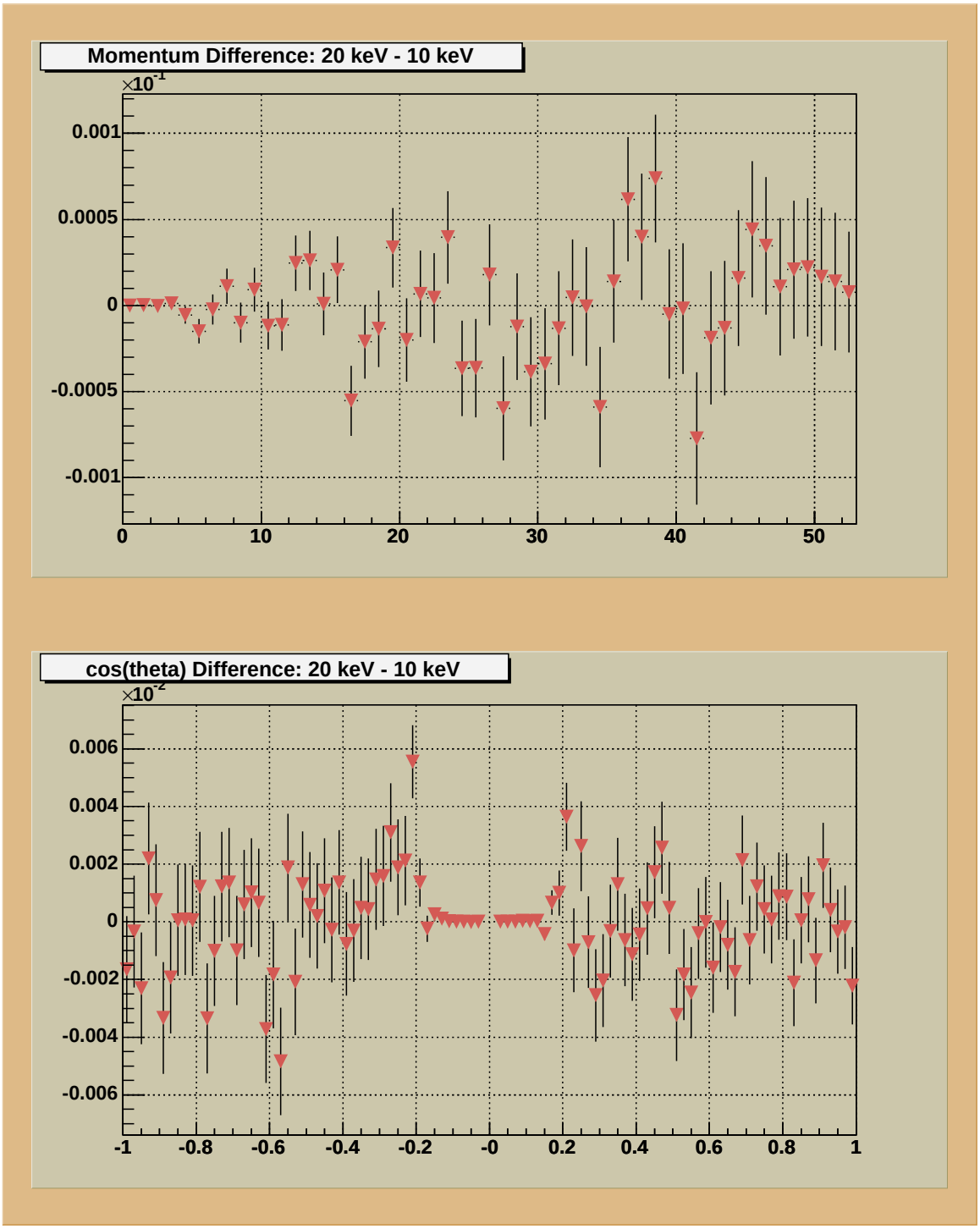

Figure 3: Momentum difference (top) and cos(θ) difference (bottom) for a 20 and a 10 keV e threshold.

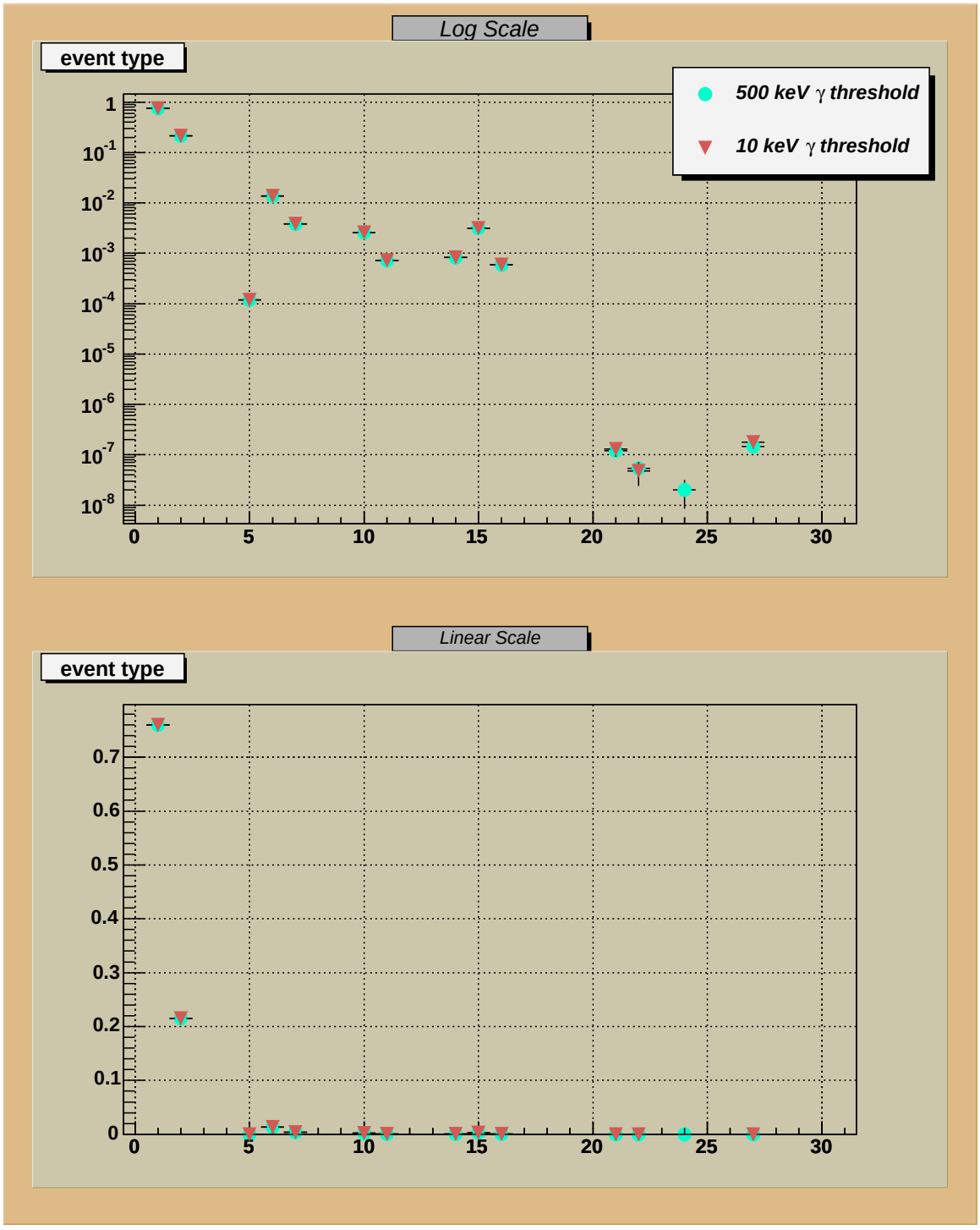

Figure 4: Event types plotted on a log scale (top) and linear scale (bottom) for a 500 and a 10 keV γ threshold.

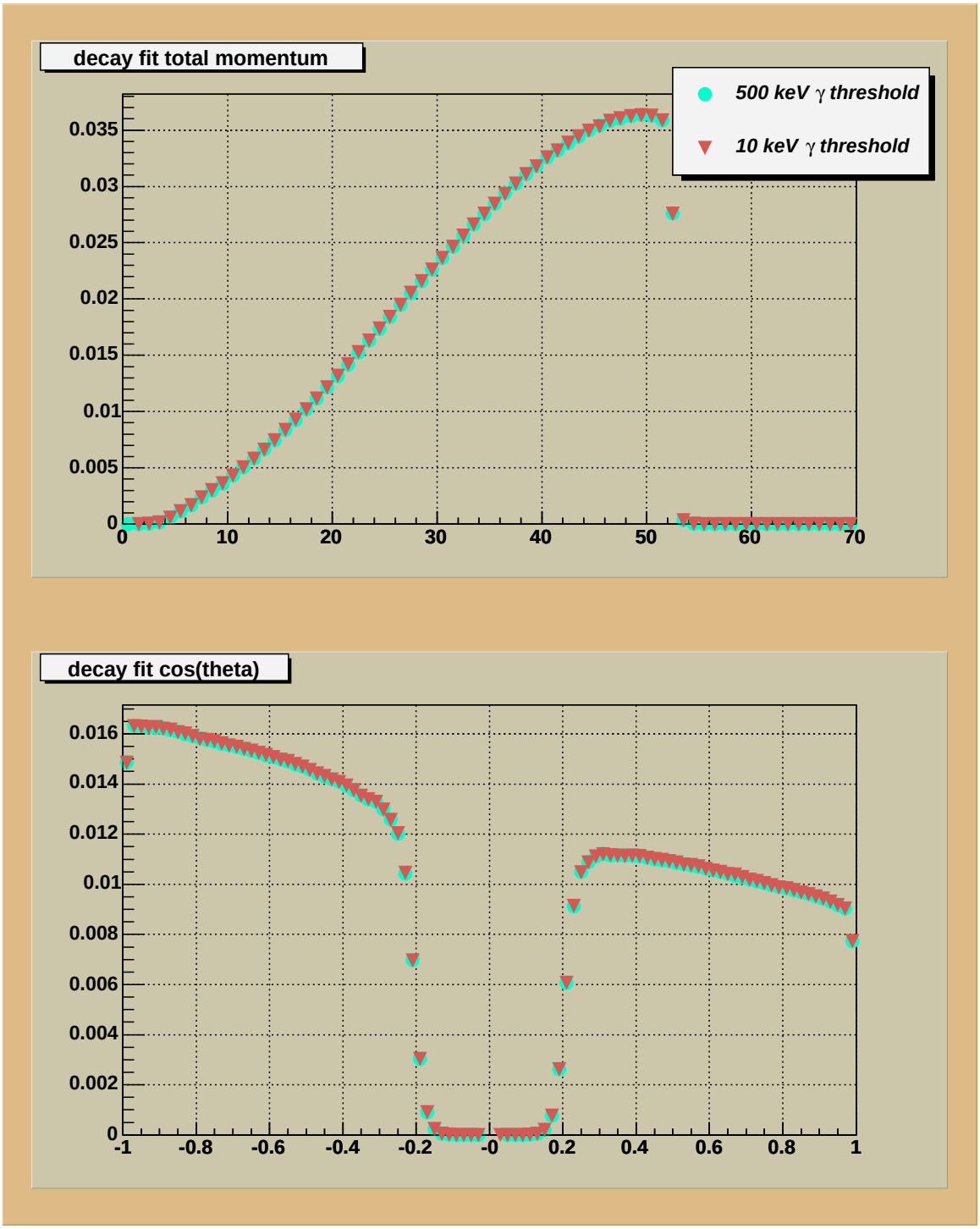

Figure 5: Momentum (top) and cos(θ) (bottom) distributions for for a 500 and a 10 keV γ threshold.

Figure 6: Momentum difference (top) and cos(θ) difference (bottom) for a 500 and a 10 keV γ threshold.