TWIST
Technical Note 91
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Abstract

The properties of the beams employed in the TWIST fall of 2002 data aquisition period were studied in the summer/fall of 2003. The technique employed and the results are described. The use of these results in the generation of Monte Carlo data is described.

1 The Technique

The absence of a functioning TEC(time expansion chamber) led to the employment of a simple, effective, but time consuming technique for characterization of the beams used in fall 2002 data acquisition period. The apparatus consisted of a movable 2mm wide slit upstream of a XY pair of fast 96 wire chambers. The chambers were followed by a thin muon scintillator which in turn was followed by another scintillator to veto beam positrons. The phase space of the muon component of the beam was studied using this setup. The slit was first oriented vertically and could be moved horizontally to provide information on the dx distribution of the incoming beam. The slit was then removed and remounted, this time oriented horizontally and able to move vertically to provide information on the dy distribution of the beam. Finally the slit was removed and the muon x and y distributions were measured. The positron component of the beam was also studied in this mode by employing another chamber pair and a different scintillator arrangement as well as a modified trigger.

2 The Data

The first discovery re the properties of the fall 2002 beam was that there was a change in the beam tune part way through the running period. These two distinct periods were separated by a change in the way we monitor the beam, from relying on the DAC settings to relying on a new more modern current monitoring scheme. The assumed relationship between the magnet currents read prior to the monitoring change to those read following the change appears to have been incorrect for some magnets. This error resulted in significant changes in the settings of some of the magnets. The date of the monitoring change was October 23, 2002, hence the tunes are referred to as either preOct23 or as postOct23. The run number 10,000 corresponds closely with this date. There were several large data sets taken with surface muons before October 23, set A, rate studies, downstream materials studies, stopping position studies, etc. All of these studies had B2 set to 950 Gauss. There was also a data set taken with B2 at 960.2 Gauss, and part of a data set with B2 at 940.2 Gauss. Following October 23 there were several large data sets taken with surface muons with B2 at 950 Gauss, set B, more downstream materials studies, chamber voltage studies, solenoid field studies, etc. In addition there was part of a set taken with B2 at 940.2 Gauss and a full set taken with a cloud muon beam. (Very recently it has been discovered that there may have also been a change in the beam tune in early October of 2002, no data were taken to characterize this change so it will not be discussed further here.)

Data characterizing seven different tunes, the six listed above, the preOct23 surface muon tune with B2 at 940, 950 and 960 Gauss, the postOct23 surface muon tune with B2 at 940 and 950 Gauss and the postOct23 cloud muon tune, was taken. Since this apparatus was employed coincidentally to establish a new improved surface muon tune, a seventh set of characterization data (surface tune 03) was also acquired. In all cases the nominal central momentum of these beams was 29.6MeV/c. Data to characterize the positron component of each of these beams was also taken.

3 The Analysis

The required inputs to the analysis code (in part written by Ari Gross) are the slit position and the slit chamber distance. The code fills a histogram with hit positions on the chamber, either x or y, for the muon rays that pass through the slit. It also calculates, employing the above inputs, the angle of those rays and fills a histogram. The peaks in the two resulting histograms were fit with a Gaussian. The means and σ's of these fits provide a point in a table of dx vs x or dy vs y values. The procedure was repeated for each slit setting. While this procedure is straightforward in the central regions of the beam problems occasionally arose in the low statistics tails of the beam edges because the runs were not long enough. These low statistics data were so poor in some of the dy vs y studies that the results have been discarded. The x and y distributions were extracted from the hit position histograms for runs when the slit was not present. The positron component data has not yet been analyzed.

4 The Results

The beam tunes that have been characterized thus far are;
pre October 23rd, 2002 surface muons with B2 = 940, 950 and 960 Gauss
post October 23rd, 2002 surface muons with B2 = 940, 950 Gauss and cloud muons,
and the new improved surface muon tune (surface_tune_03.dat).

The results are presented below in figure form. They are available in table form for use in the GEANT generation of the incident muon beam, the technology of which is briefly described below. The following subsection titles are the file names of these tables that correspond to the beam tune figures presented in that subsection.

4.1 preOct23_950_mu.dat

The preOct23 surface muon tune with B2 at 950.2 Gauss was the "nominal" tune for data taken before the beam tune change. Fig. 1 and Fig. 2 show the x and y profiles of this beam tune. Fig. 1 indicates that 950.2 Gauss produces a beam spot slightly shifted to positive x, i.e. to the left in the beam coordinates.

Fig. 3 and Fig. 4 show the dx vs x and the dy vs y distributions respectively for the preOct23 surface muon 950.2 tune extracted from the data employing the movable slit. The error bars shown on all figures of this type are the σ's derived from fitting a Gaussian to the peaks in the position and angle distribution histograms filled during the analysis of the movable slit data.

4.2 preOct23_960_mu.dat

Fig. 5 and Fig. 6 show the x and y profiles respectively for both the 960(squares) and 950(X) Gauss tunes with the counts scaled to the highest count bin. Note that in Fig. 5 the 950 Gauss data has been shifted so that the left edge matches that of the 960 Gauss data. This figure shows that the 960 Gauss data is limited in extent by the edge of the chamber and/or the beam pipe. Fig. 6 shows that there is little difference in the y distribution due to this problem. The shifted 950 Gauss x distribution is used to represent the 960 Gauss x distribution in the preOct23_960_mu.dat file. The assumption underlying this use of the 950 tune, and all similar extensions of the profiles presented below, is that the beams were essentially identical when they exited the B2 dipole, except for a small change in position and angle produced by the different B2 settings. They will therefore be best represented by extrapolations back from the measuring point if the limitations due to the beam pipe and chamber (approximately the same size as the beam pipe) used in these studies are circumvented. These limitations were not present during the 2002 data accumulation. The beam pipe was considerably larger in 2002. In addition the focusing due to the solenoid fringe field would have helped to keep the entire beam within the beam pipe.

Fig. 7 and Fig. 8 show the dx vs x and the dy vs y distributions respectively for the preOct23 surface muon 960.2 tune extracted from the data employing the movable slit.

4.3 preOct23_940_mu.dat

Fig. 9 and Fig. 10 show the x and y profiles for the 940 Gauss tune. The shapes of these profiles closely resemble those of the 950 Gauss tune. In fact the negative side of the x profile has been "extended"(dark squares) to include points beyond the limit of the wire chamber. These extra points were extracted from a shifted and scaled version of the 950 x profile.

Fig. 11 and Fig. 12 show the dx vs x and the dy vs y distributions respectively for the preOct23 surface muon 940.2 tune. Again these distributions correspond closely to those of the 950 Gauss tune.

4.4 postOct23_940_mu.dat

Fig. 13 and Fig. 14 show the x and y profiles, respectively for the postOct23 surface muon 940.2 Gauss tune. Here the x profile has been extended(dark squares) using a shifted and scaled postOct23 950 x profile. Fig. 15 and Fig. 16 show the angular information data for this tune.

4.5 postOct23_950_mu.dat

The postOct23 surface muon tune with B2 at 950.2 Gauss was the "nominal" tune for data taken after the beam tune change. Fig. 17 and Fig. 18 show the x and y profiles, respectively for the postOct23 surface muon 950.2 Gauss tune. Here the x profile has been extended(dark squares) using a shifted and scaled postOct23 940 x profile. Fig. 19 and Fig. 20 show the angular information data for this tune.

A comparison of Fig. 1 and Fig. 17 shows that there was a substantial difference in the beam tunes employed before and after October 23/2002.

4.6 postOct23_cld_mu.dat

Fig. 21 and Fig. 22 show the x and y profiles, respectively for the postOct23 cloud muon beam tune. Here the x profile has been extended(dark squares) using a shifted and scaled postOct23 940 x profile while the y profile has been extended(dark squares) using a shifted(in two directions) and scaled postOct23 950 y profile. Fig. 23 and Fig. 24 show the angular information data for this tune.

4.7 surface_tune_03.dat

As stated above an improved tune was established and evaluated during the summer/fall of 2003. Fig. 25 and Fig. 26 show the x and y profiles, respectively for the new 2003 surface muon beam tune while Fig. 27 and Fig. 28 show the angular information data for this tune.

5 Discussion

There are several sources of uncertainty in these results.

First, there is the question of whether we are accurately reproducing the tunes used prior to October 23, 2002. These tunes have been studied using the DAC settings recorded in 2002 but whether the relation between those inputs and the currents in the magnets is the same as in 2002 is somewhat uncertain. The level of this uncertainty can be estimated by examining the relationship between the DAC settings and the corresponding NMR measured fields in the dipoles. An examination of a beam setting recorded on October 16, 2002 and one on August 8, 2003 shows that the B1 DAC/field ratio changed by about 0.5% while the B2 DAC/field ratio changed by about 0.2%. This difference, if it reflects the uncertainty for the quadrupole settings, means that for the pre October 23, 2002 tune results presented here, the DAC settings should be adequate.

Second, the slit motion was limited, so for beams that were off center, it was difficult/impossible to accumulate data at one or other of the extremes.

Third, there is the assumption that the various beams had essentially identical profiles when they exited the B2 dipole, except for a small change in position and angle produced by the different B2 settings. Both the 2002 beam pipe and the fringe field focusing are accounted for in the Monte Carlo so "actual" beam losses should be properly reproduced.

Forth, where the edges of the beam were "filled in" using scaled and shifted data from other tunes the angular information was, of course, not extracted for these regions. This forced the assumption that in the Monte Carlo the dx vs x and dy vs y information can be extrapolated to these extremes from the region in which it was extractable. Since the statistical significance of these regions is small and because there is no apriori reason to expect large deviations in the angular distributions this is probably a safe assumption.

Fifth, the data takers were often impatient so that in the low rate x or y regions of the beam insufficient statistics were accumulated to get a "good" measure of the angle. Again the statistical significance of these regions is small.

6 Use in GEANT

The GEANT code reads in the beam properties file as defined in the command file by a statement such as
setenv MU_BEAM $CAL_DB/preOct23_950_mu.dat
These files contain the numbers used in producing the figures shown here. The kinematics of an incident muon is then determined by first randomly selecting a position according to the beam profile read in and then generating the corresponding momentum component using a fit, similar to those shown as straight lines in the angular information figures. The angle that determines this momentum component is generated randomly according to a Gaussian distribution whose sigma is that shown on the corresponding figure shown here.

In order to trigger the reading of these files and the employment of above described position and momentum generation the e614.ffcards file must have IMSOR set to 4 for the particle in question.
C IMSOR = Use-Flag: any positive integer to use [1]
C =1 : uniform direction into rectangular aperture,
C gaussian beam spot from PGUN.
C =2 : gaussian distributed direction,
C gaussian beam spot from PGUN.
C =3 : direction in combo with vertex(not at focus),
C position and direction are correlated.
C =4 : read in beam properties and employ,
C requires z position of Particle Gun == z where the
C measurements were made (see PGUN card comments).

The Particle Gun z position must be set to the position at which these beam profiles and angular distributions were measured, -154.0 cm.
PGUN 65 2
0. 0. -154.0 0. 0. 0. 1.15 0.77 0. 0. 0. 29.6 1.007
0. 0. -134.0 0. 0. 0. 1.15 0.77 0. 0. 0. 29.6 1.007

Each of the beam properties files was tested using this .com and .ffcard setup. Some interesting histograms where generated during these test runs.

Fig. 29 shows the GEANT generated x and y profiles for preOct23_950_mu.dat tune. These profiles are to be compared to the input distributions seen in Fig. 1 and Fig. 2. Fig. 30 displays the shape of the target stopping distributions for the 950 and 960 Gauss tunes. It is interesting to note the shift upstream created by the fact that the 960 beam was entering at an angle.

Fig. 31 shows the position of the beam at the trigger scintillator as tracked by GEANT for the 940/950/960 tunes. A vertical shift in position is obvious. Fig. 32 shows the change in the target stopped muon spin distributions. The polarization is worse for the off center 960 Gauss tune.

Fig. 33 shows the GEANT generated x and y distributions for the postOct23 cloud muon beam. Fig. 34 shows the generated dx vs x and dy vs y distributions for this beam. These match the inputs shown in Fig. 21 through Fig. 24.

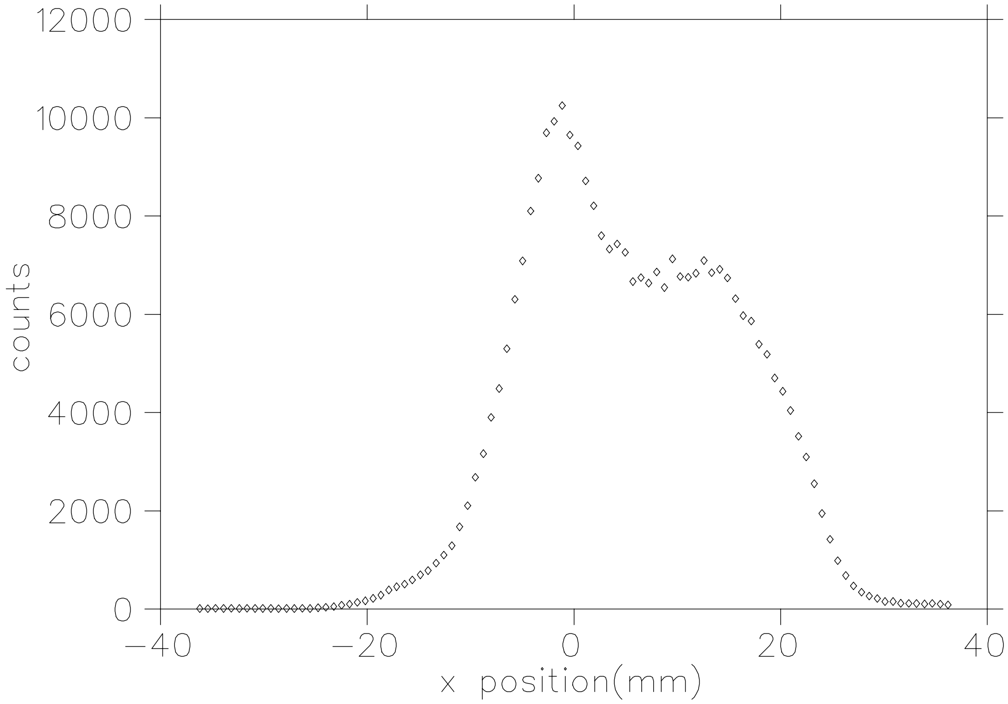

Figure 1: Pre Oct. 23/2002 surface muon x distribution(B2=950Gauss)

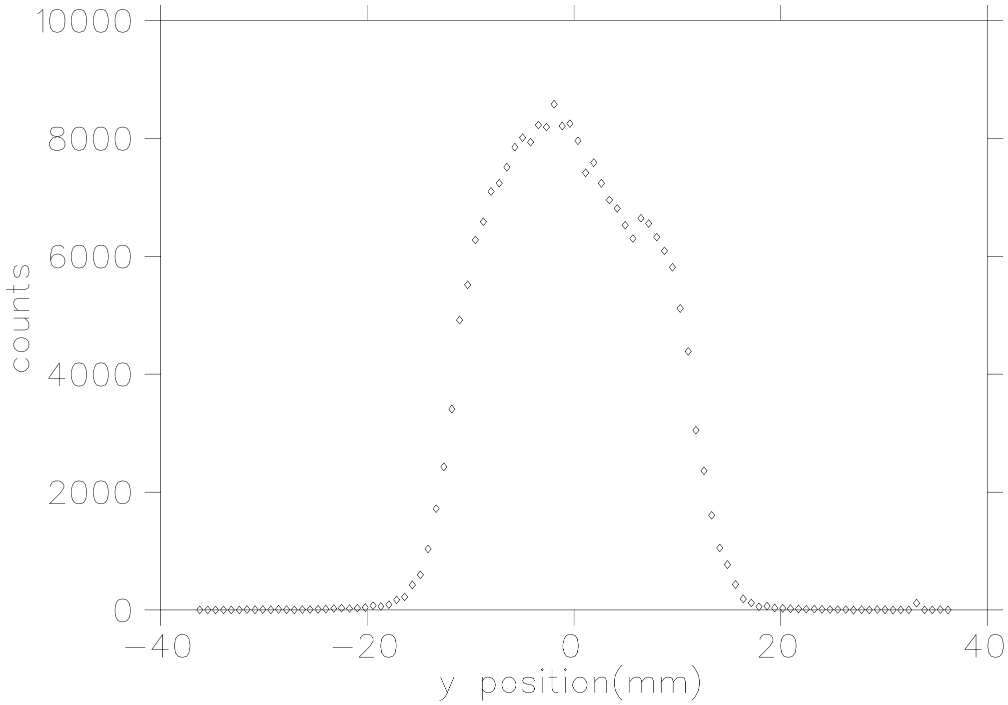

Figure 2: Pre Oct. 23/2002 surface muon y distribution(B2=950Gauss)

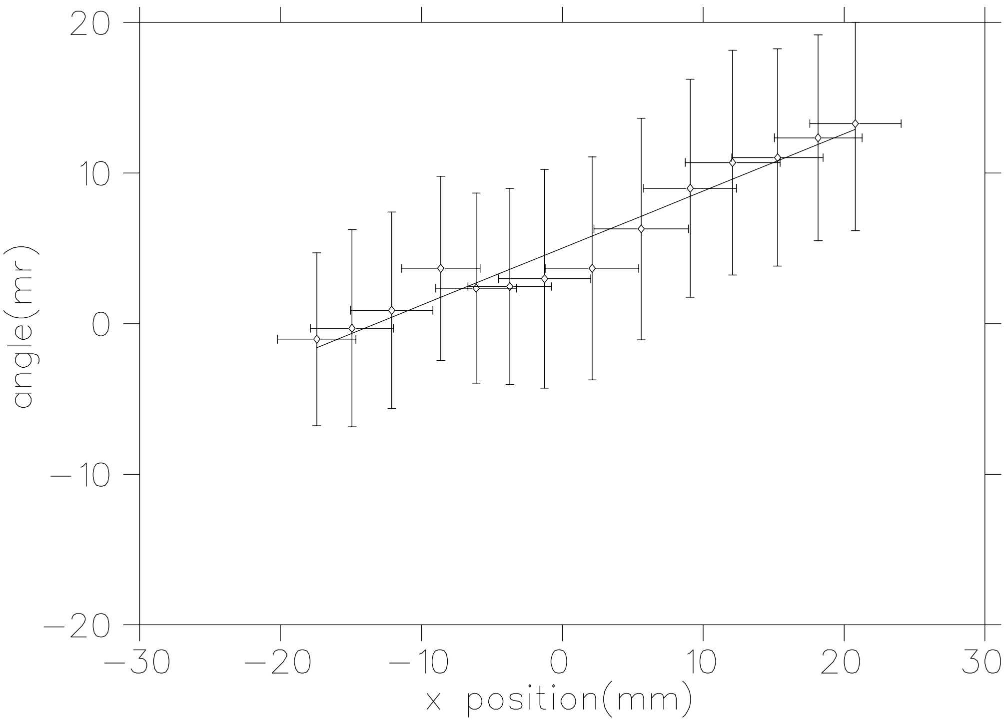

Figure 3: Pre Oct. 23/2002 surface muon dx vs x distribution(B2=950Gauss)

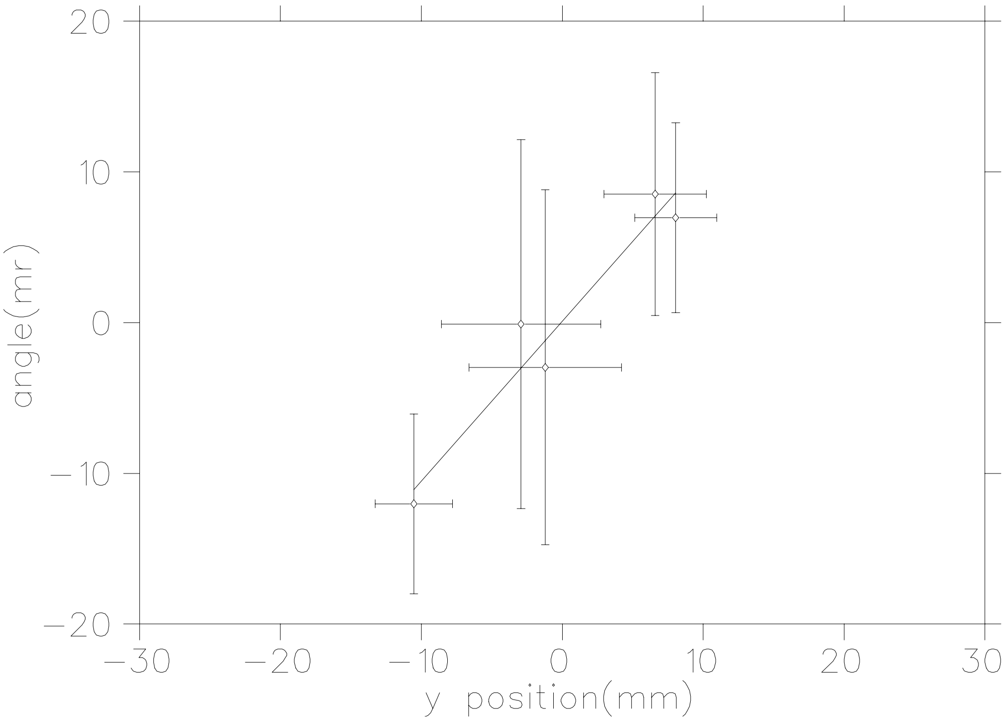

Figure 4: Pre Oct. 23/2002 surface muon dy vs y distribution(B2=950Gauss)

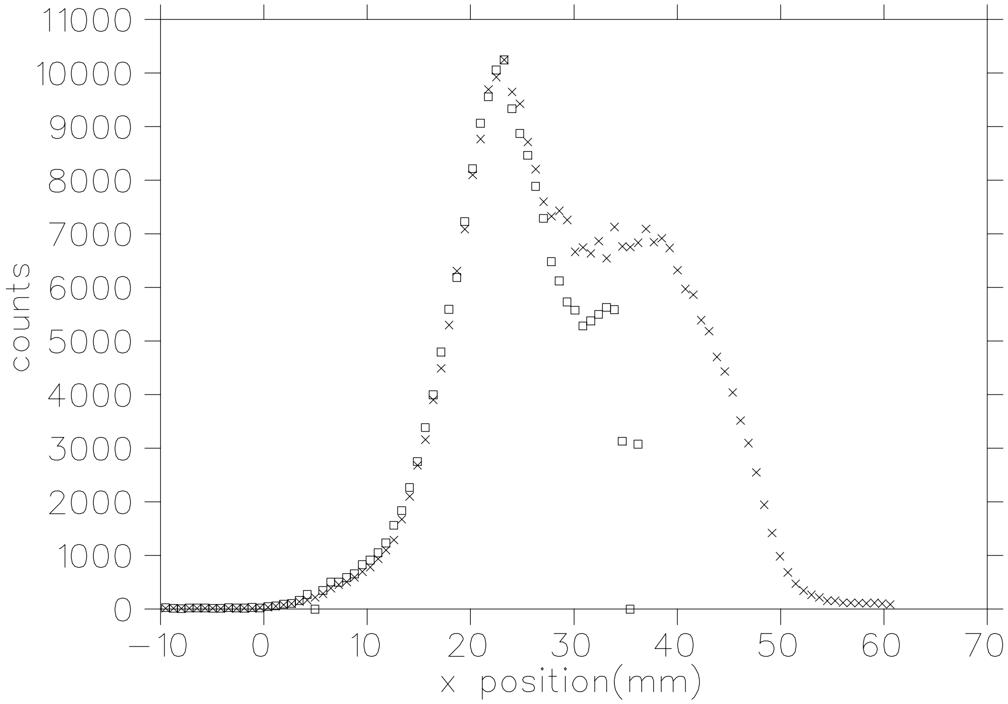

Figure 5: Pre Oct. 23/2002 surface muon x distribution(B2=960 & 950 Gauss see text)

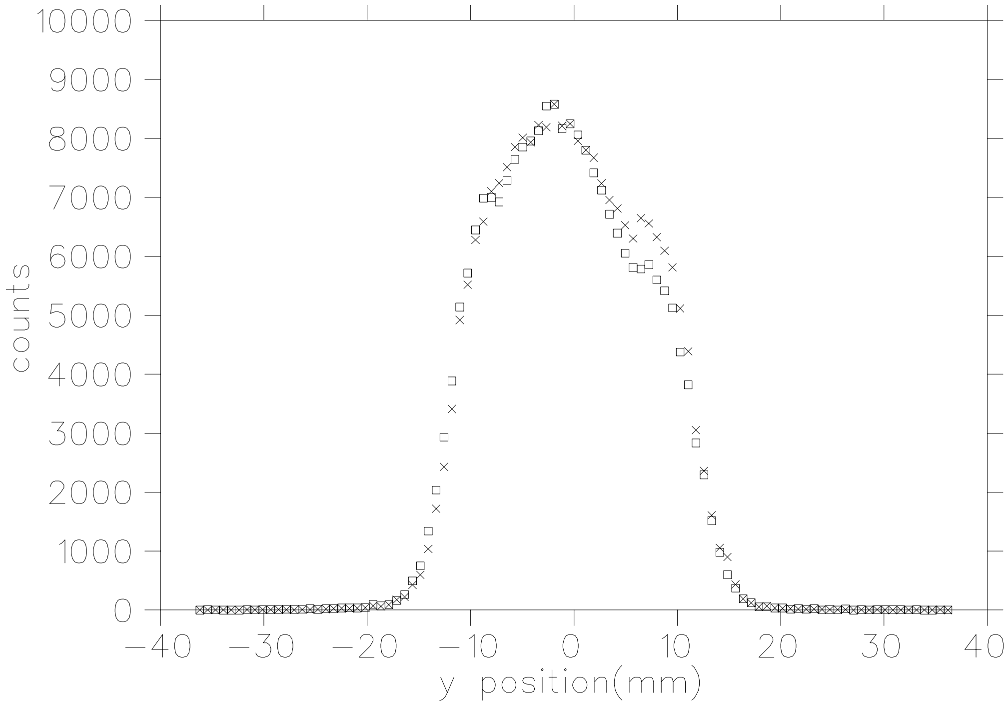

Figure 6: Pre Oct. 23/2002 surface muon y distribution(B2=960 & 950 Gauss see text)

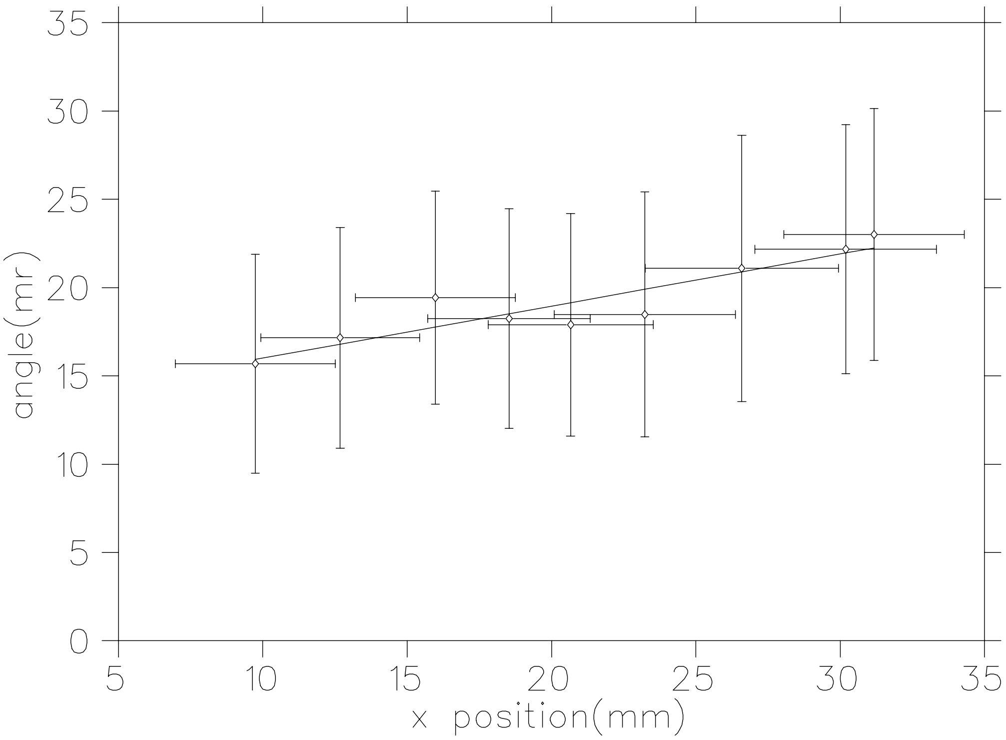

Figure 7: Pre Oct. 23/2002 surface muon dx vs x distribution(B2=960Gauss)

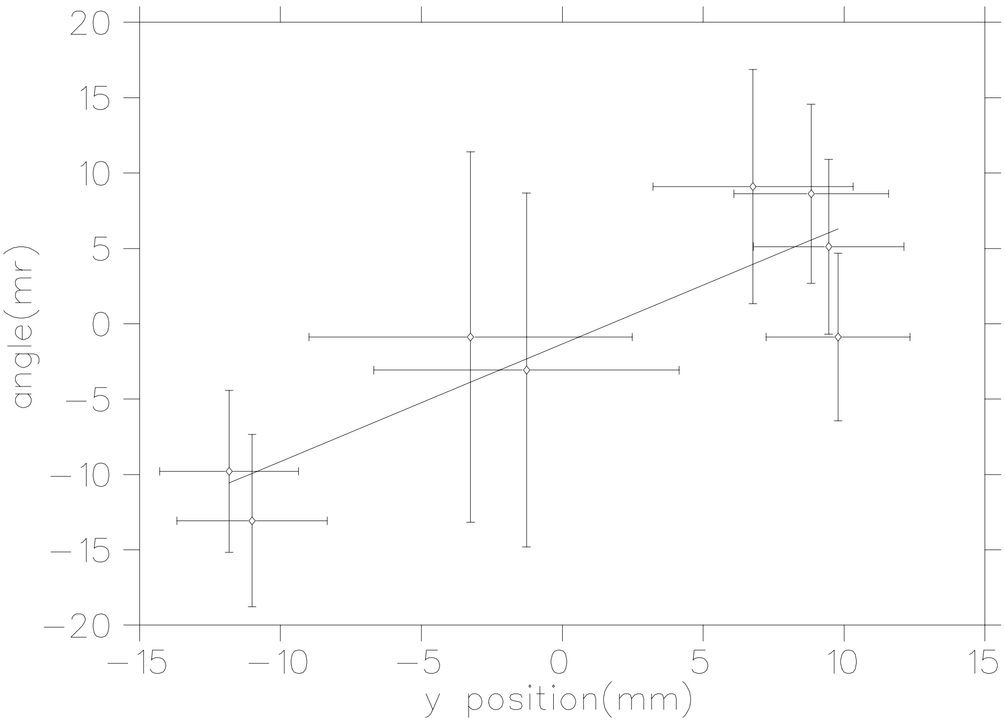

Figure 8: Pre Oct. 23/2002 surface muon dy vs y distribution(B2=960Gauss)

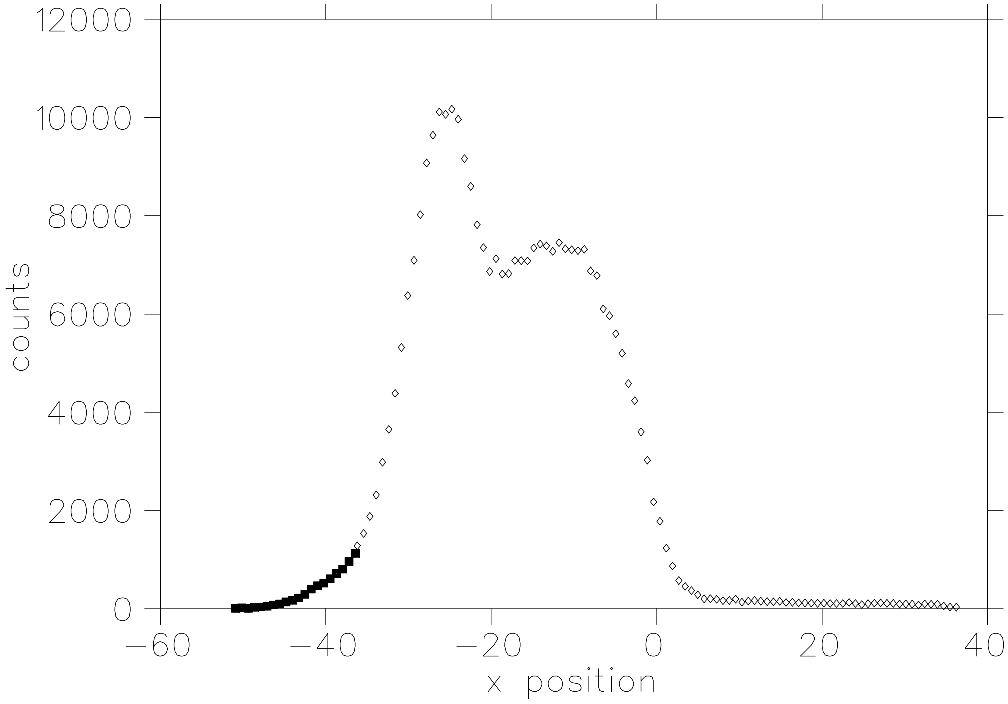

Figure 9: Pre Oct. 23/2002 surface muon x distribution(B2=940Gauss)

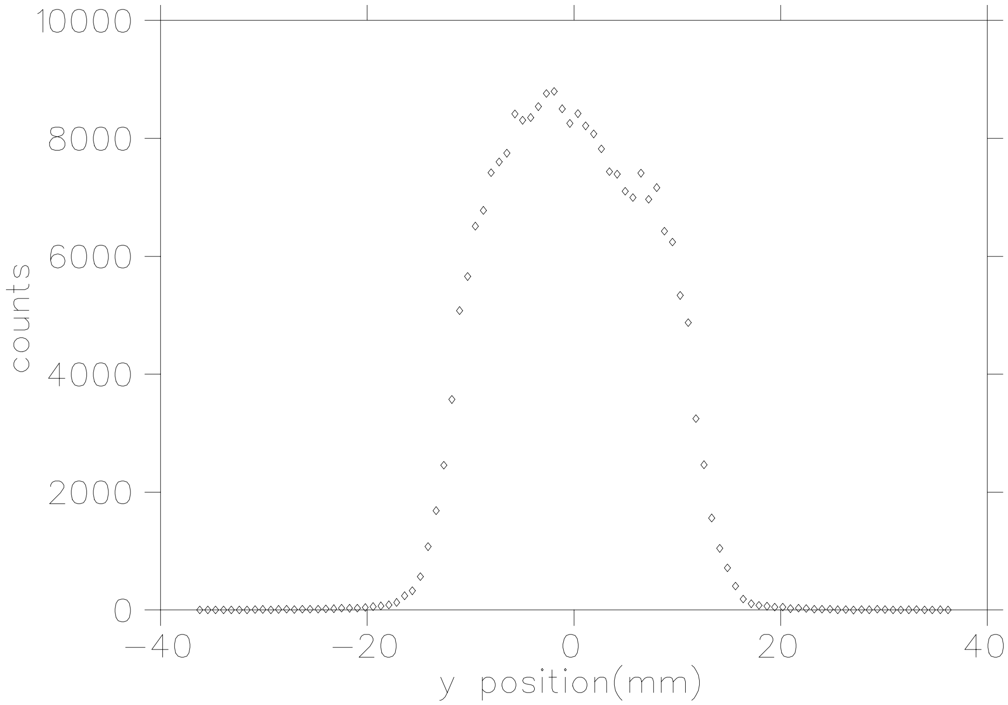

Figure 10: Pre Oct. 23/2002 surface muon y distribution(B2=940Gauss)

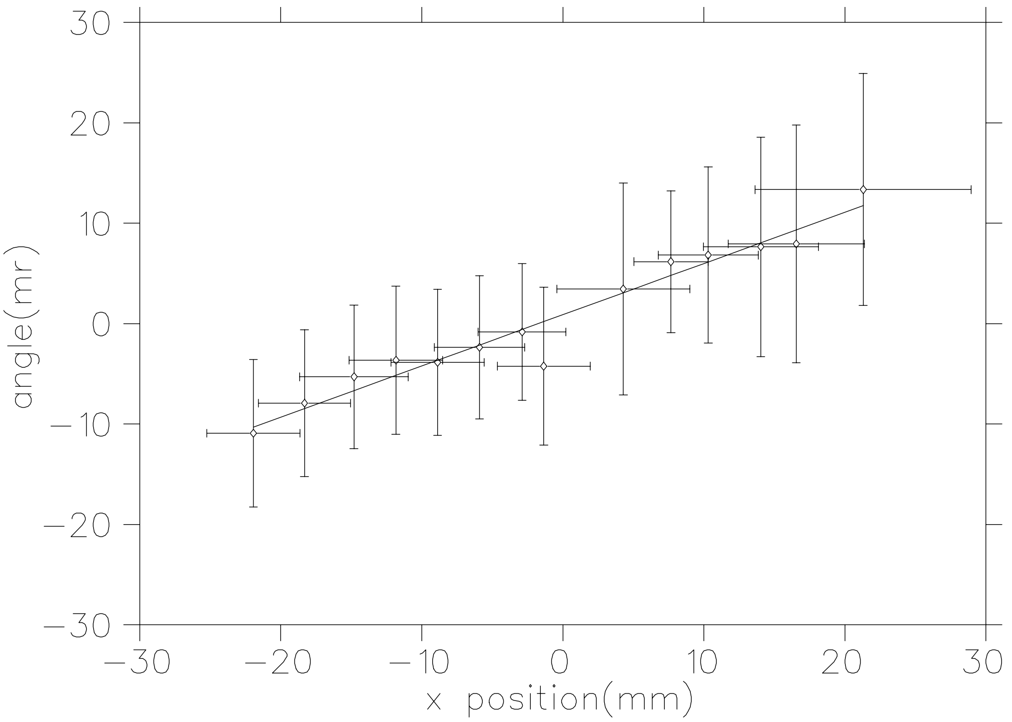

Figure 11: Pre Oct. 23/2002 surface muon dx vs x distribution(B2=940Gauss)

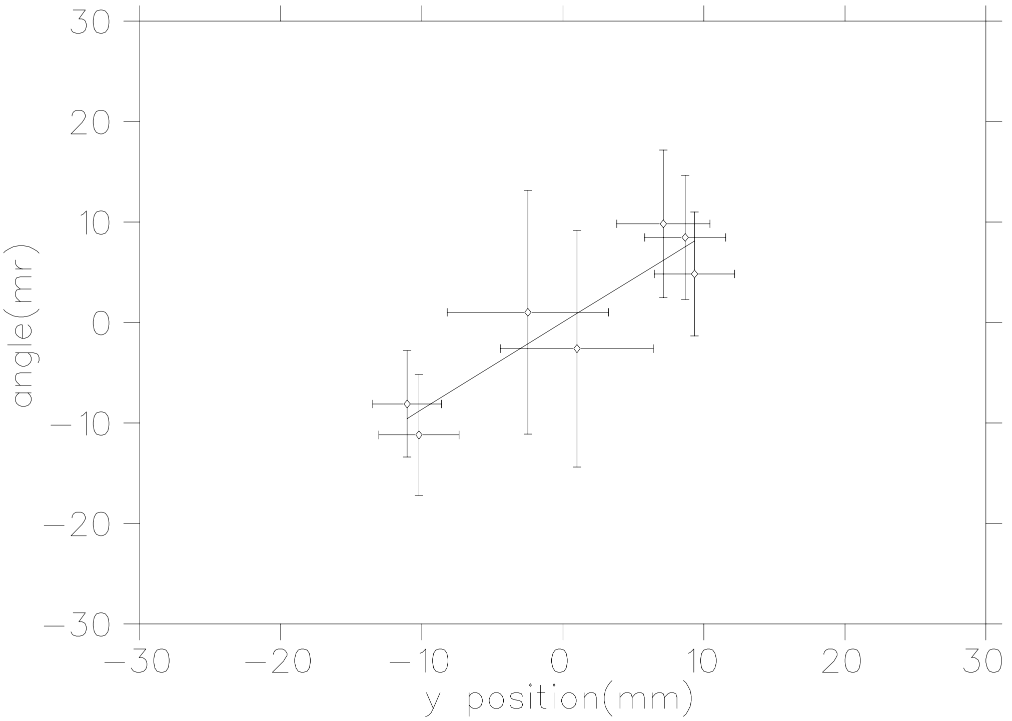

Figure 12: Pre Oct. 23/2002 surface muon dy vs y distribution(B2=940Gauss)

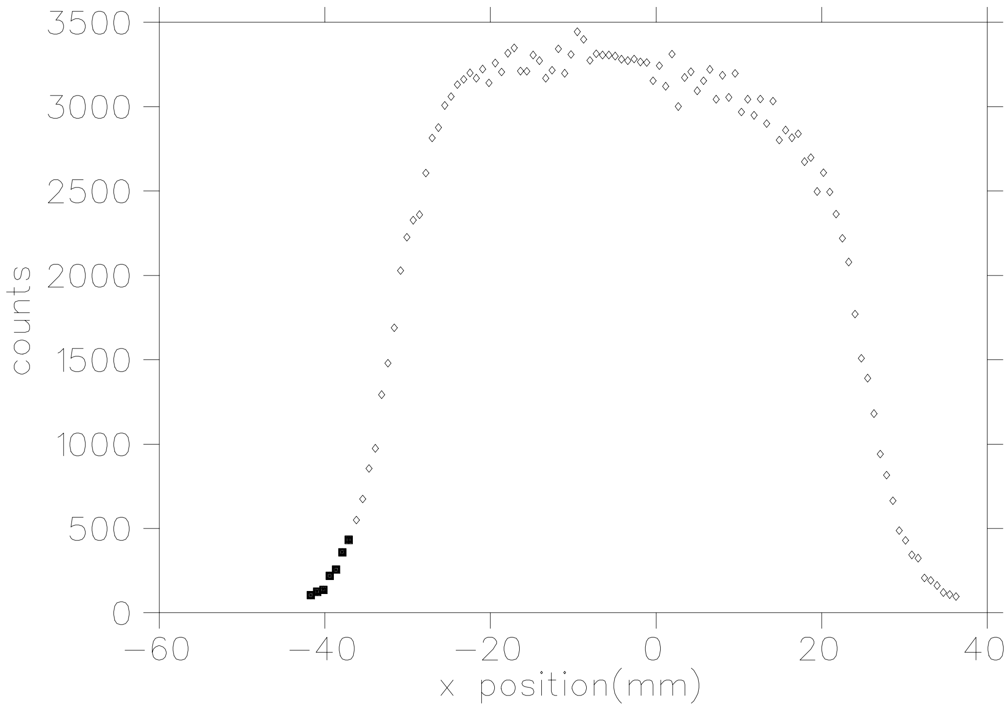

Figure 13: Post Oct. 23/2002 surface muon x distribution(B2=940Gauss)

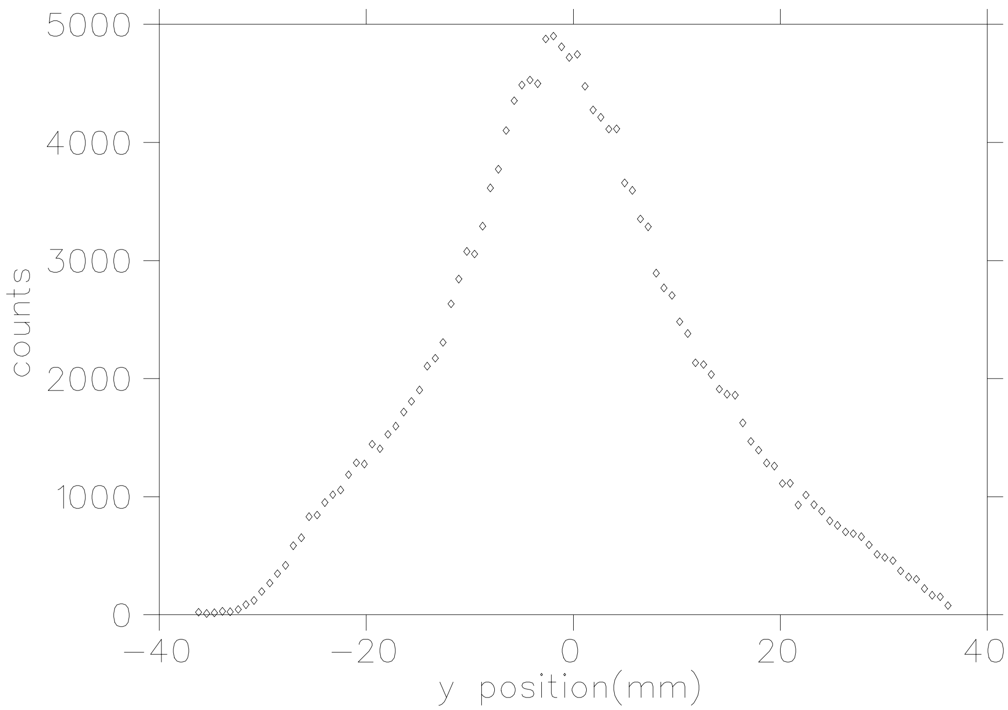

Figure 14: Post Oct. 23/2002 surface muon y distribution(B2=940Gauss)

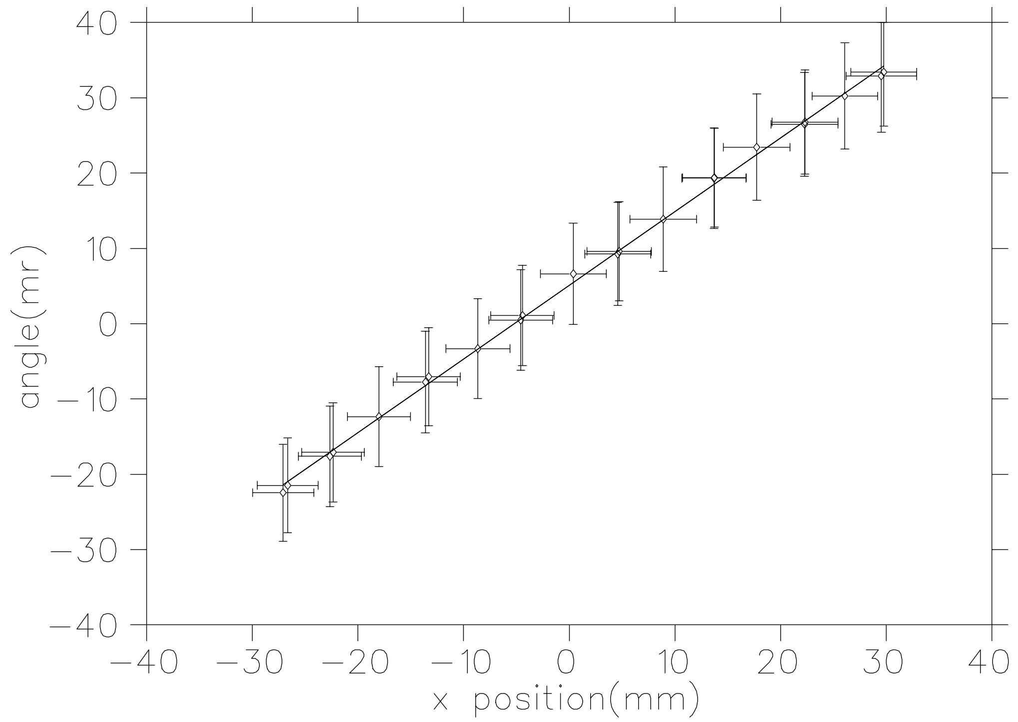

Figure 15: Post Oct. 23/2002 surface muon dx vs x distribution(B2=940Gauss)

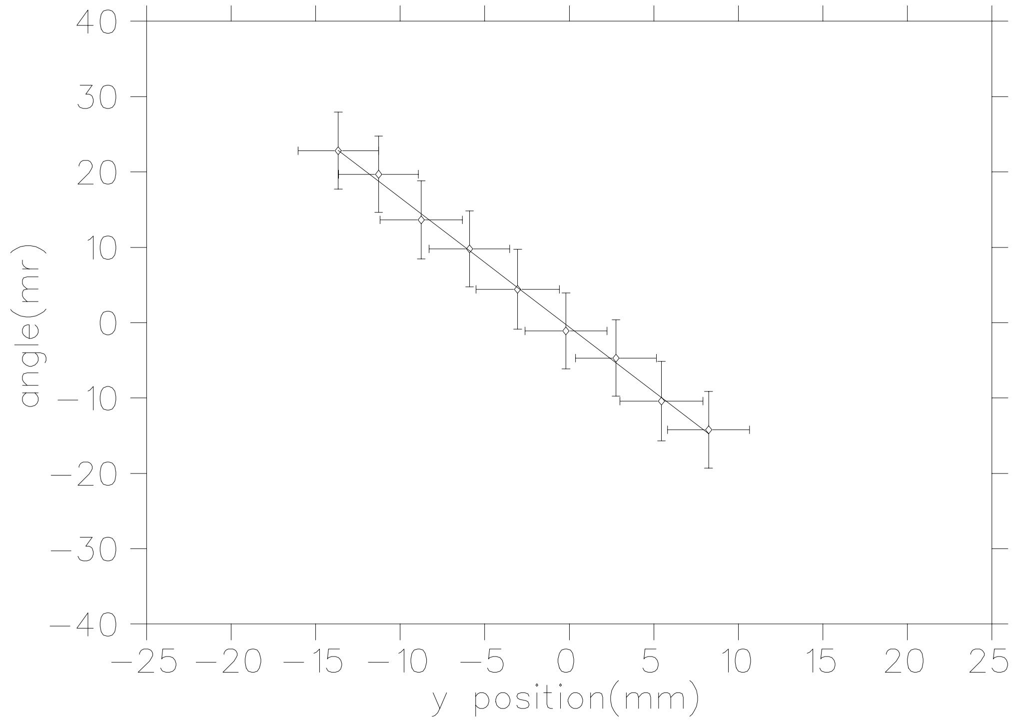

Figure 16: Post Oct. 23/2002 surface muon dy vs y distribution(B2=940Gauss)

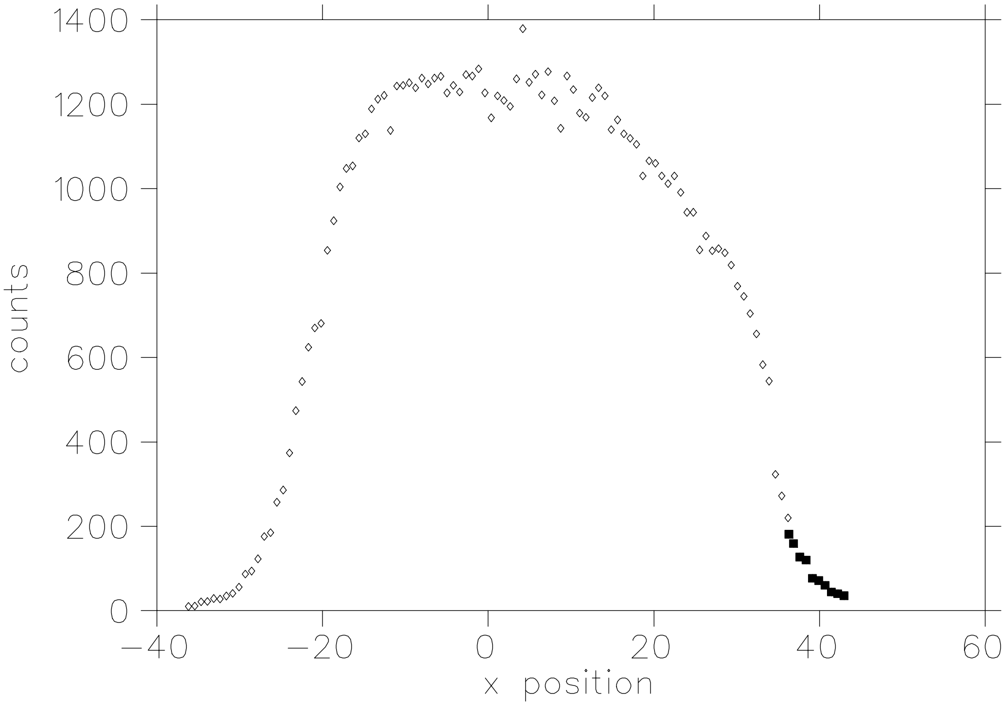

Figure 17: Post Oct. 23/2002 surface muon x distribution(B2=950Gauss)

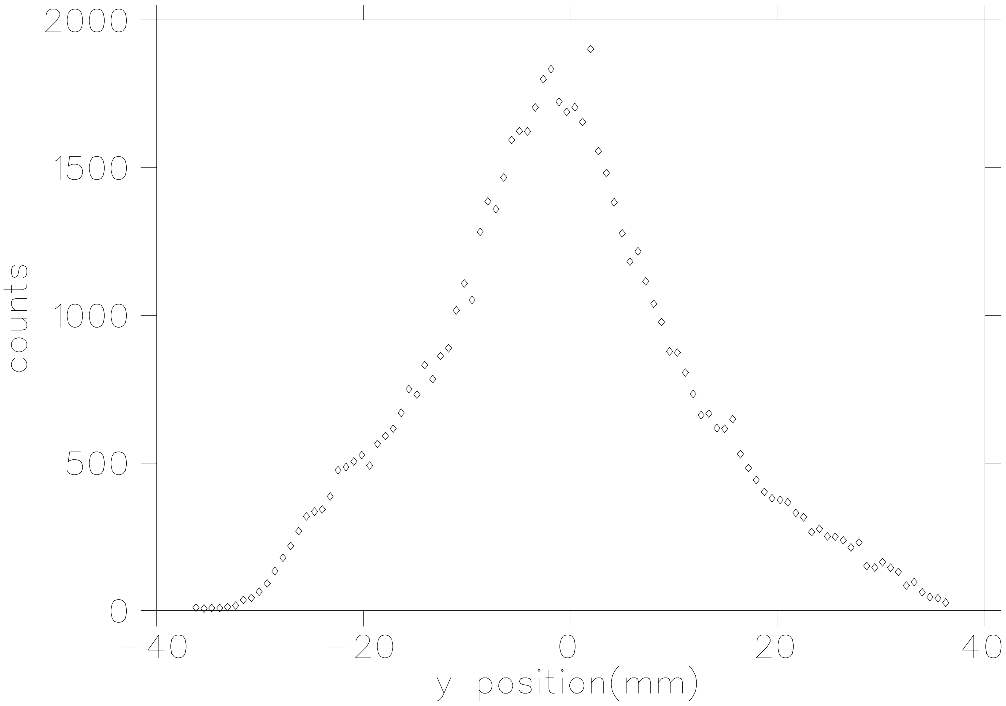

Figure 18: Post Oct. 23/2002 surface muon y distribution(B2=950Gauss)

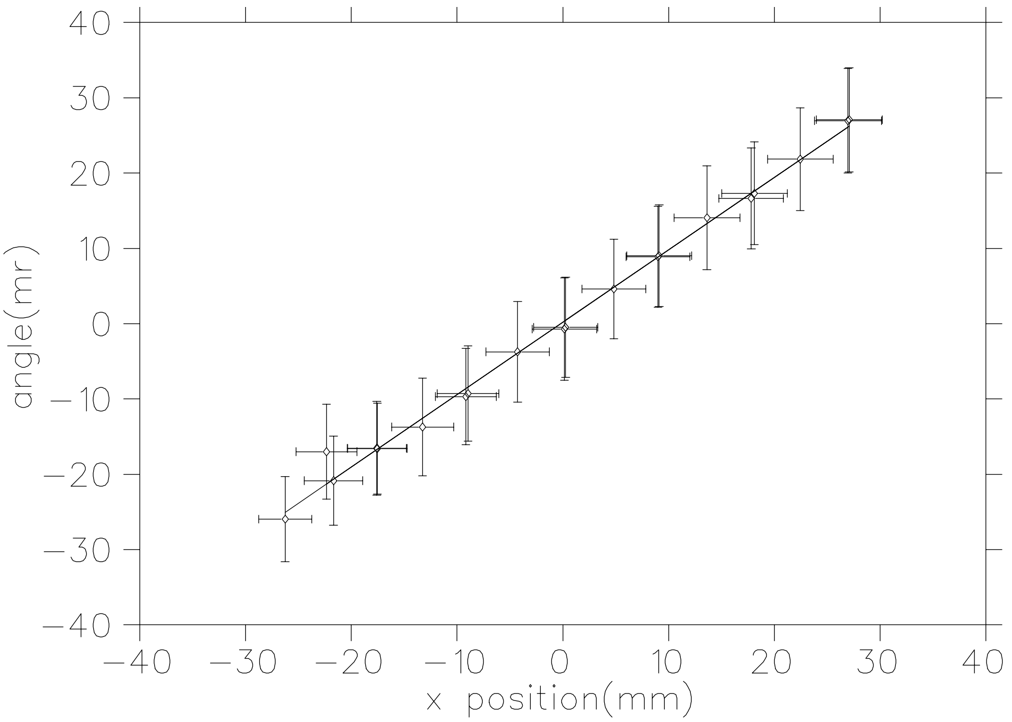

Figure 19: Post Oct. 23/2002 surface muon dx vs x distribution(B2=950Gauss)

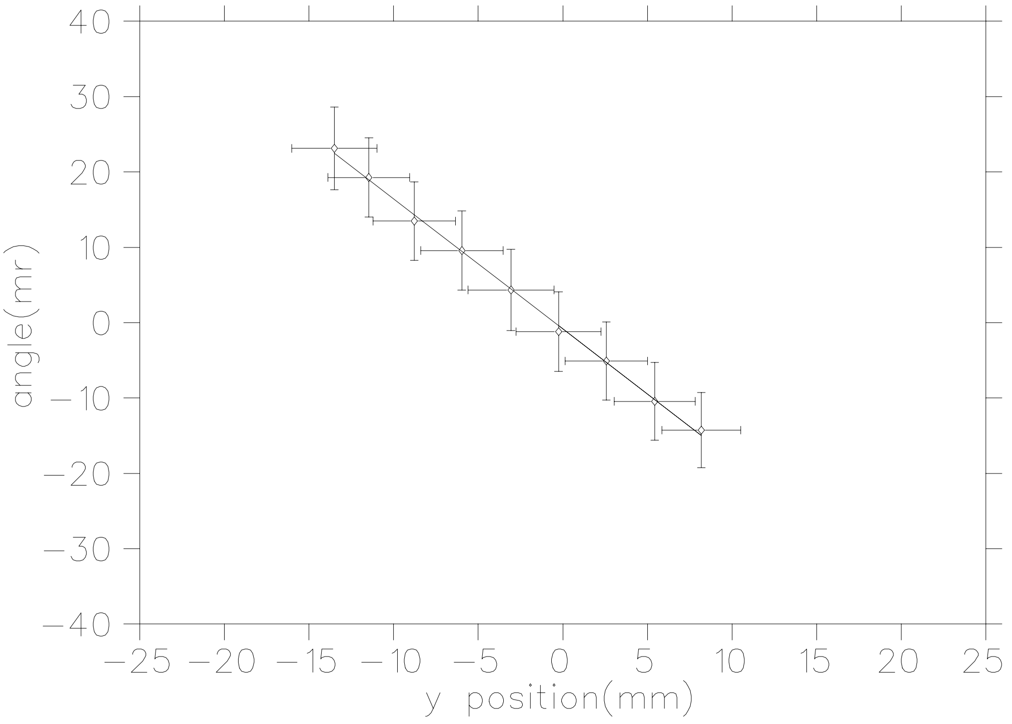

Figure 20: Post Oct. 23/2002 surface muon dy vs y distribution(B2=950Gauss)

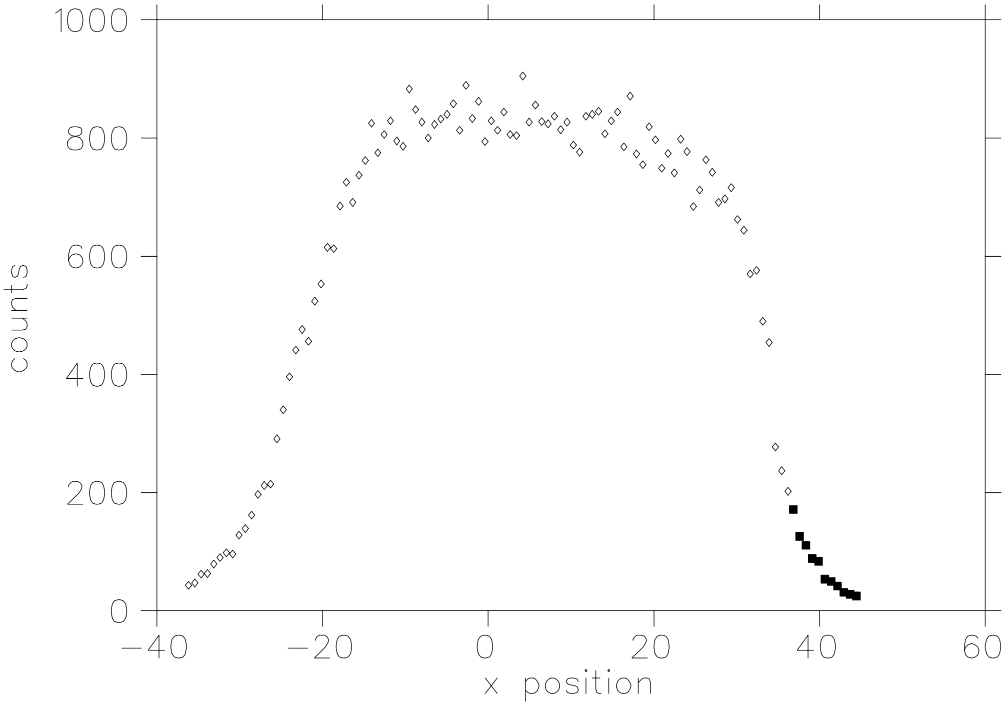

Figure 21: Post Oct. 23/2002 cloud muon x distribution

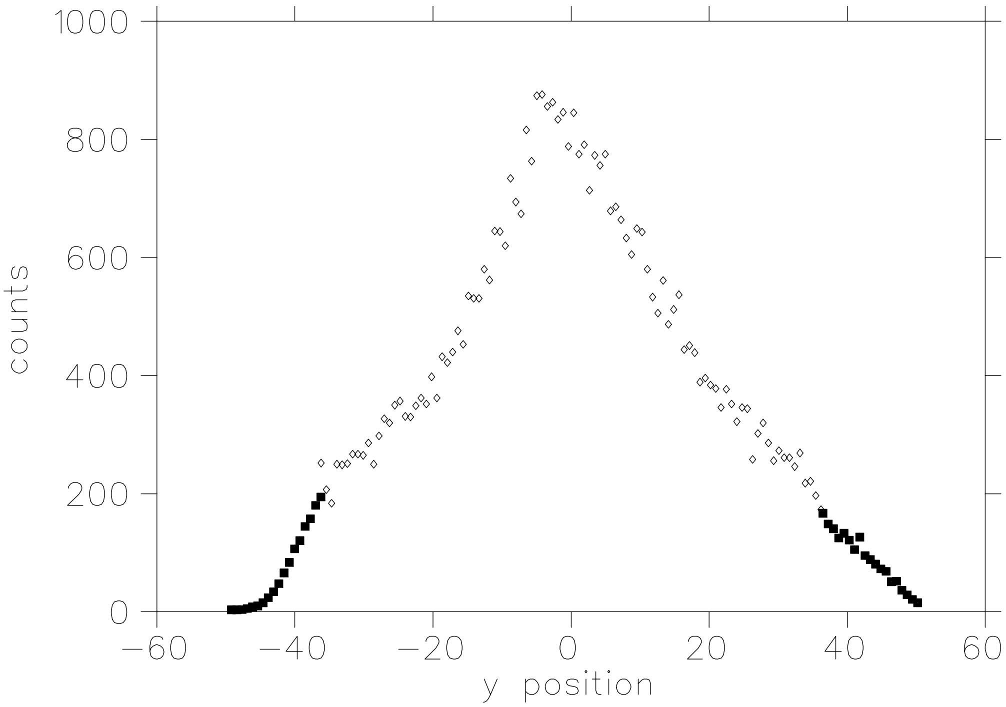

Figure 22: Post Oct. 23/2002 cloud muon y distribution

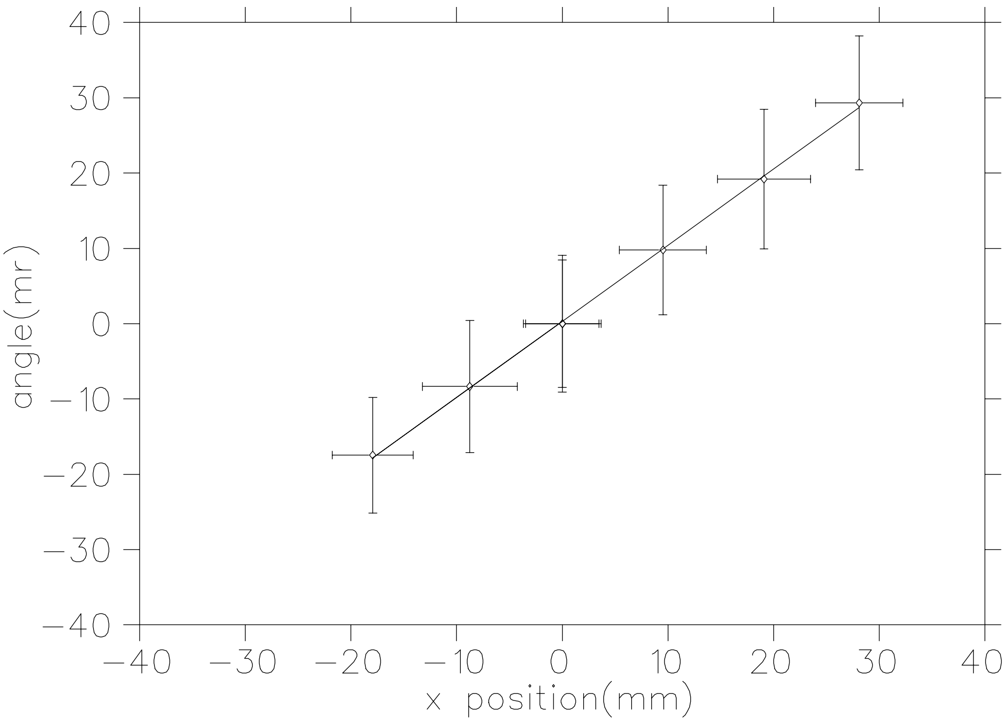

Figure 23: Post Oct. 23/2002 cloud muon dx vs x distribution

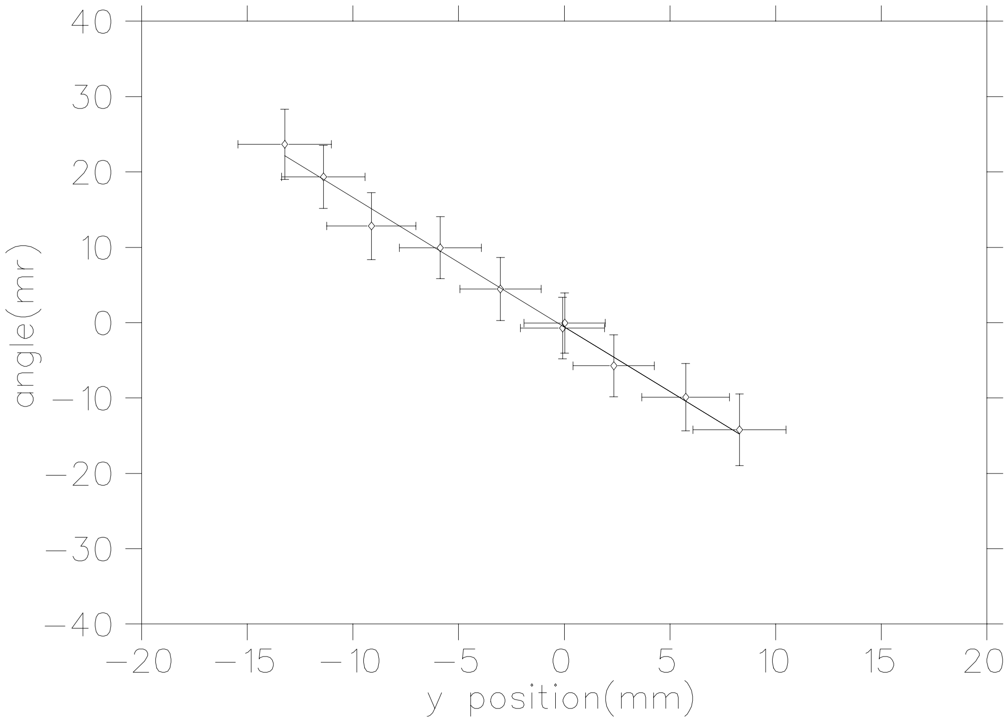

Figure 24: Post Oct. 23/2002 cloud muon dy vs y distribution

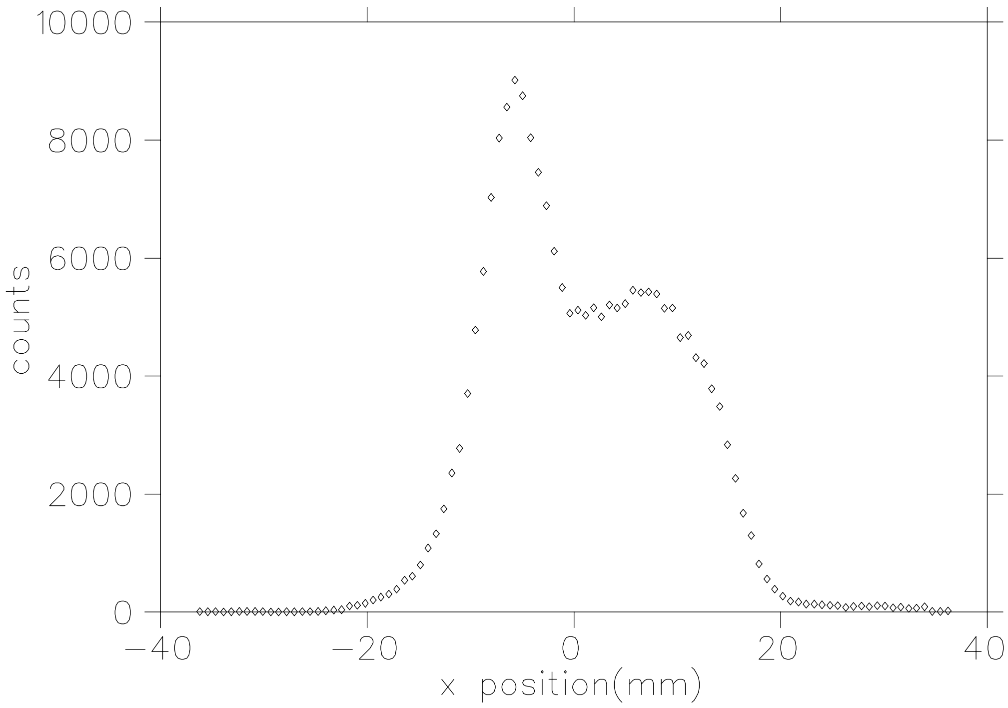

Figure 25: New 2003 surface muon tune x distribution

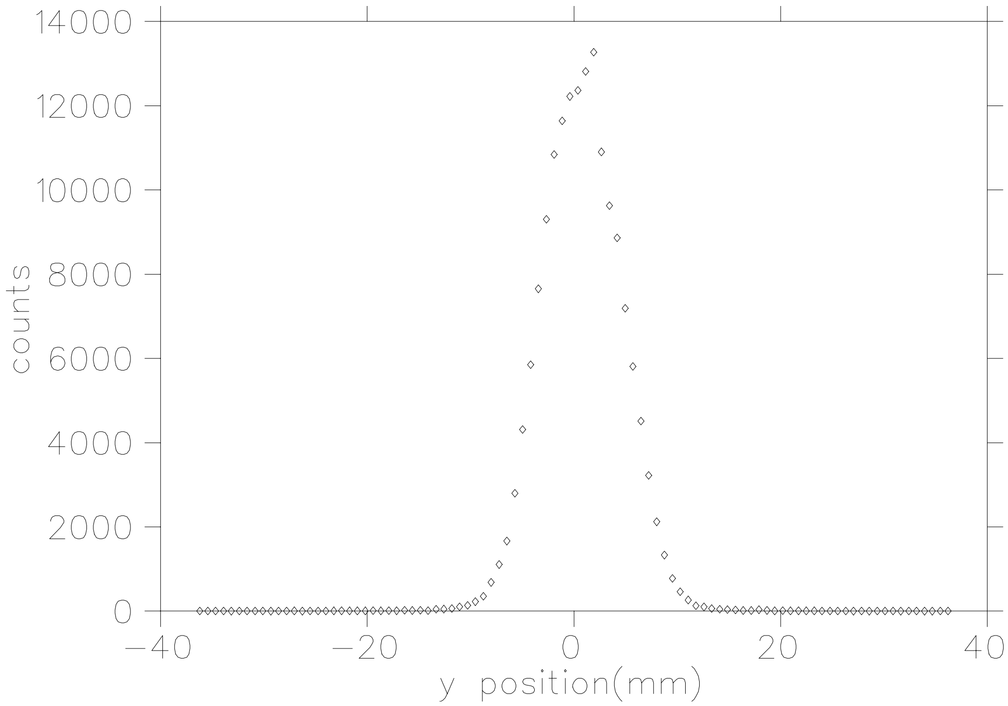

Figure 26: New 2003 surface muon tune y distribution

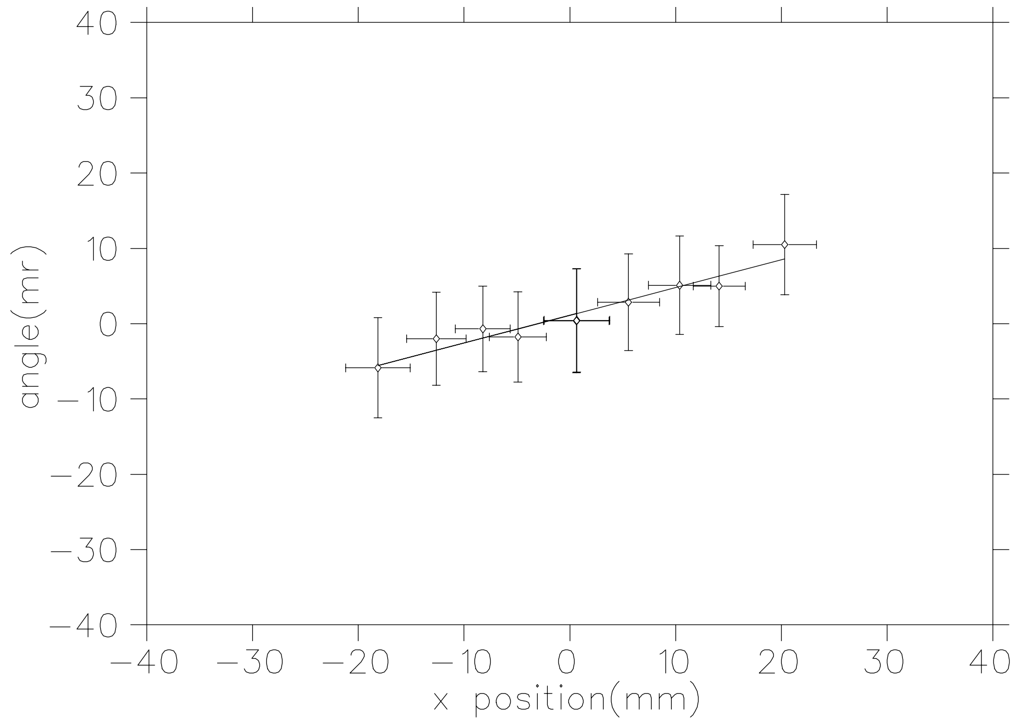

Figure 27: New 2003 surface muon tune dx vs x distribution

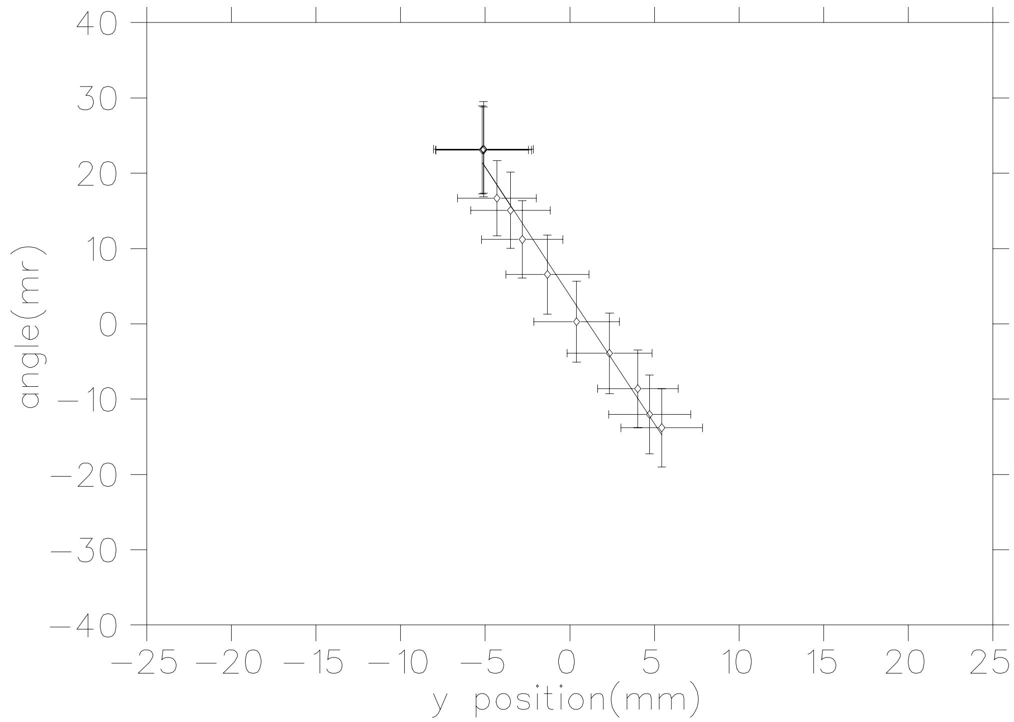

Figure 28: New 2003 surface muon tune dy vs y distribution

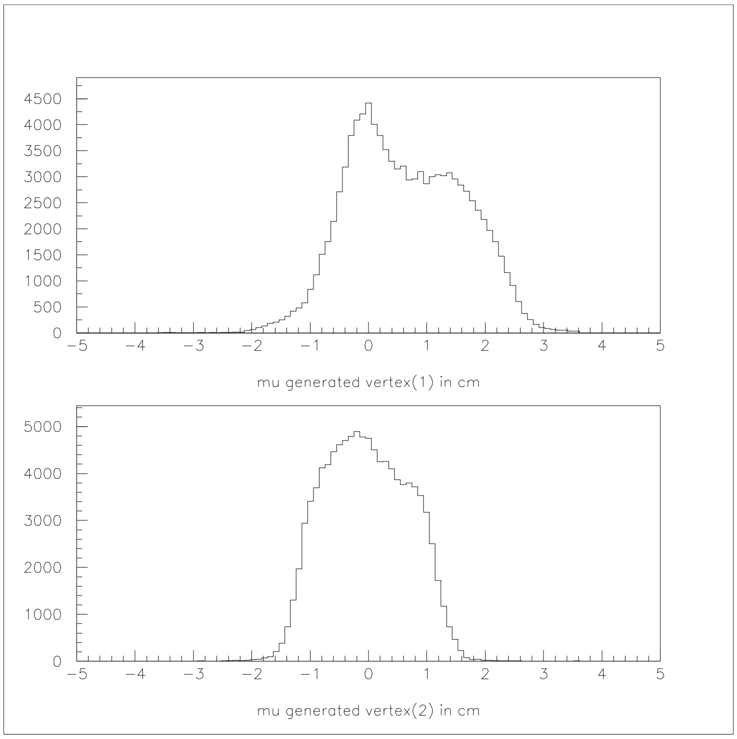

Figure 29: GEANT generated Pre Oct. 23/2002 surface muon x and y distributions(950Gauss)

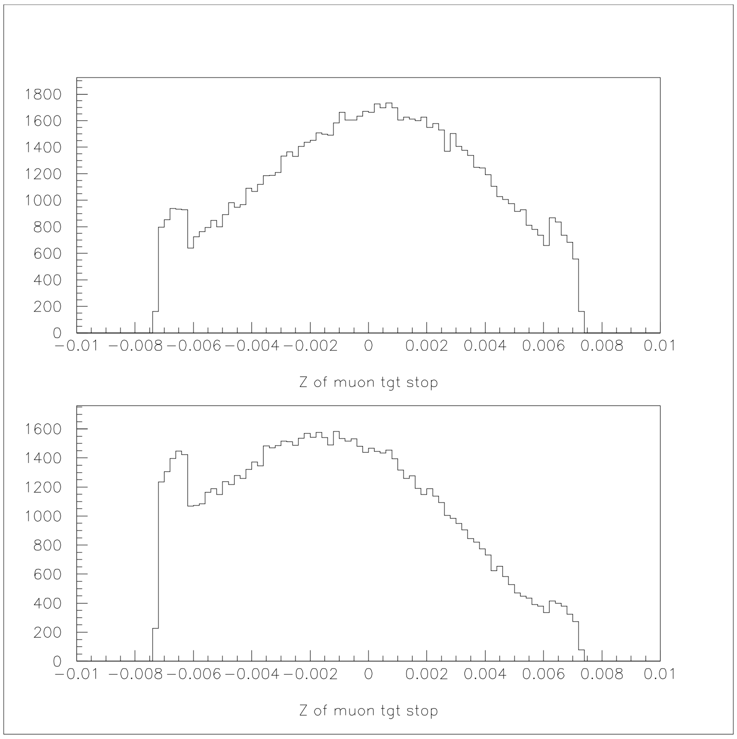

Figure 30: Target stop positions for Pre Oct. 23/2002 surface muon 950 and 960 Gauss tunes

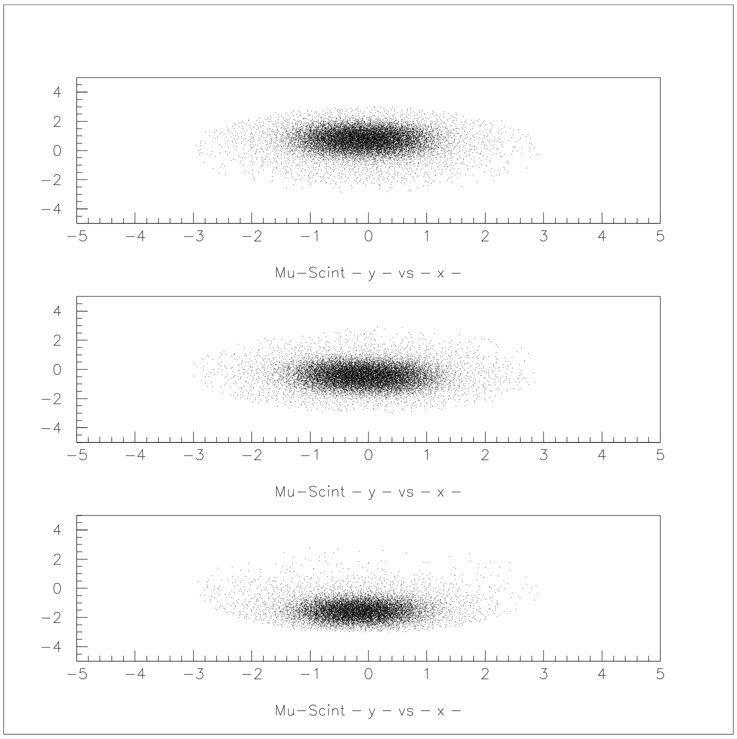

Figure 31: Pre Oct. 23/2002 surface muon distributions(940/950/960) at trigger scintillator.

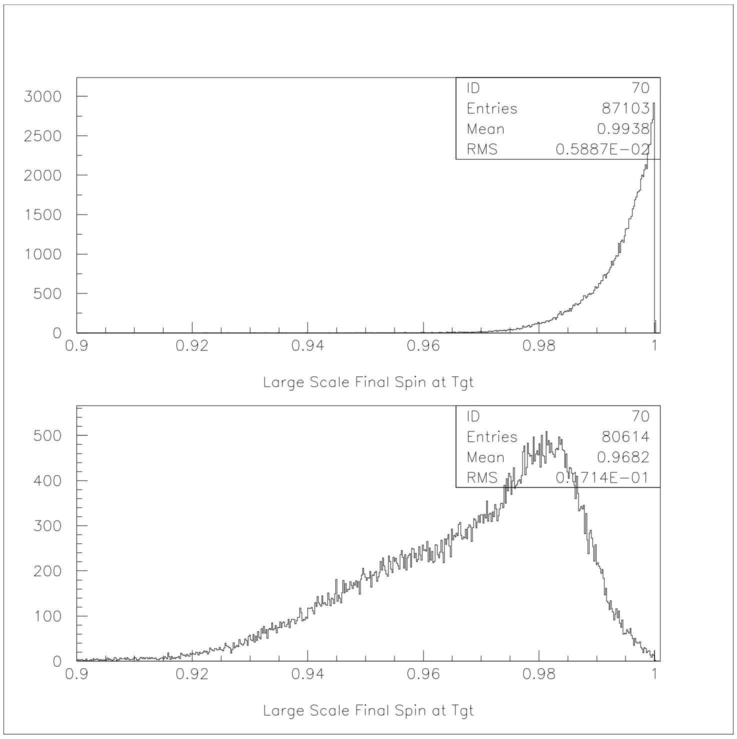

Figure 32: Target stopped Pre Oct. 23/2002 surface muon spin distributions(950/960)

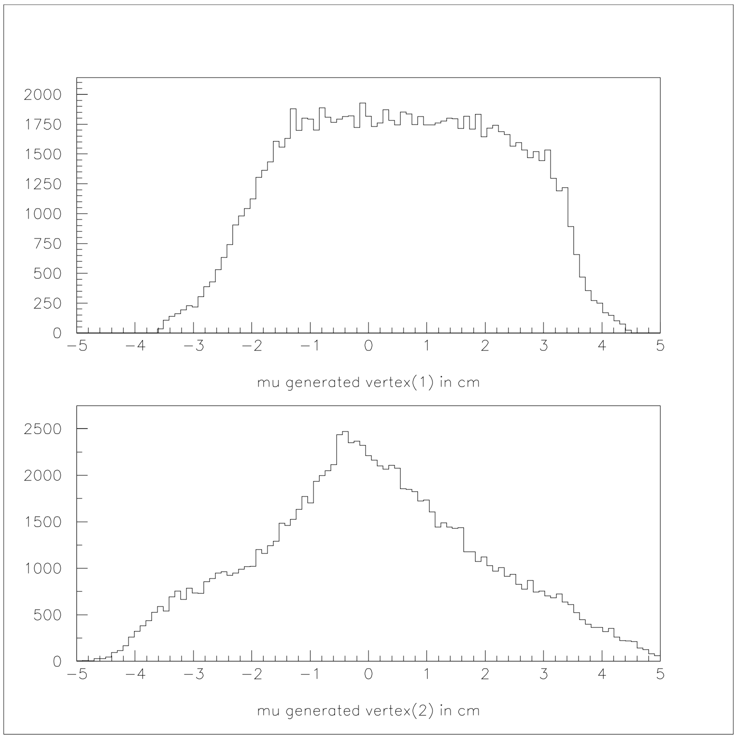

Figure 33: Post Oct. 23/2002 cloud muon x and y distributions

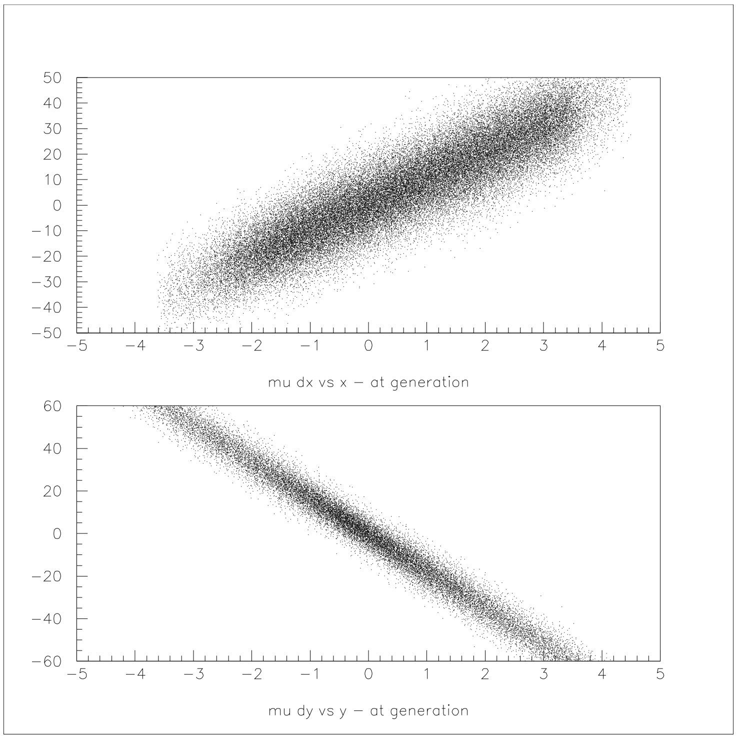

Figure 34: Post Oct. 23/2002 cloud muon dx vs x and dy vs y distributions