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Update on the Dynamic Beta Effect at CESR with CLEO

Abstract

This CBN/CBX is an update to CBN 96-17/CBX 96-94. A different set of test data was processed with improved alignment of the CLEO SVX. This leads to an improved resolution on the luminous region, and continued observation of the dynamic beta effect. The resolution, as measured by the height of the luminous region, and the length of the bunch are no longer seen to depend on the bunch current. Dave Sagan and Dave Rubin have studied the CESR lattice and made a measurement of the horizontal β at zero bunch current, and included the theoretical dynamic effects caused by the parasitic crossings. These lead to an improved comparison with theory. Studies of the vertical shape of the luminous region reveal that the resolution depends at least on the number of tracks used to find the primary vertex and that vertices made from only two tracks are primarily responsible for the non-Gaussian tails. Toy Monte Carlo studies indicate that the procedure used in CBN 96-17/CBX 96-94 of using a single Gaussian to measure the resolution of one distribution with a small underlying width smeared by many different resolutions gives the correct unfolding of the underlying width of another distribution with a wide underlying width smeared by the same resolutions. Also double Gaussian fits are used. They give much improved fits, and little change is seen from the standard result. The analysis is repeated requiring more than two tracks in the vertices and little change is seen indicating that the effect of the non-Gaussian tails is negligible.

1 New Data Set

The data set used is the mini-PASS2 November data set of 4SJ data collected in June 1996. The differences from the previous data set include the first round of internal alignment of the SVX and some improvements in XDUET. No SVTF processed data was used. Thanks to Andy Folland who processed by hand three runs that I took during a machine study in early July. These were at low beam current and are used to make the low bunch current point that appears in the following plots. Unfortunately the two highest bunch current data points disappear as the beam(bunch) current never got above 300(8.3)mA in June. Thus this data set covers the range of beam(bunch) currents from 120(3.3) to 300(8.3)mA, with the lowest bin from 120(3.3)-180(5.0)mA and the 12 other bins being 10(0.28)mA wide. The average beam(bunch) current is 238(6.6)mA. A total of 77327 events give a good primary vertex.

Figures 1 through 3 shows the distributions of the primary vertex found. The width of the vertical distribution is $(117.93 \pm 0.51)\mu$m, which is much improved over the 165μm found in the

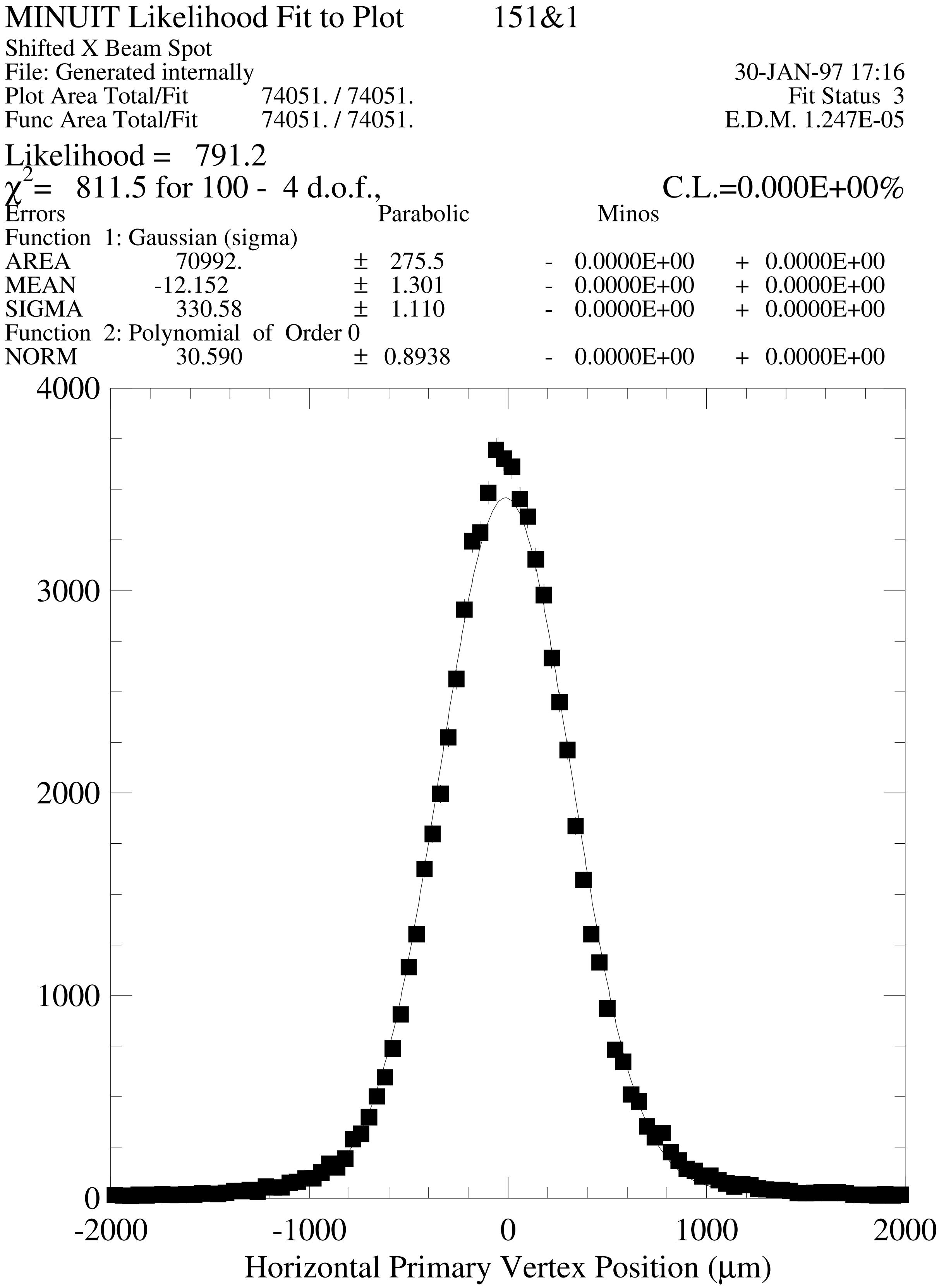

Figure 1: The horizontal primary vertex distribution.

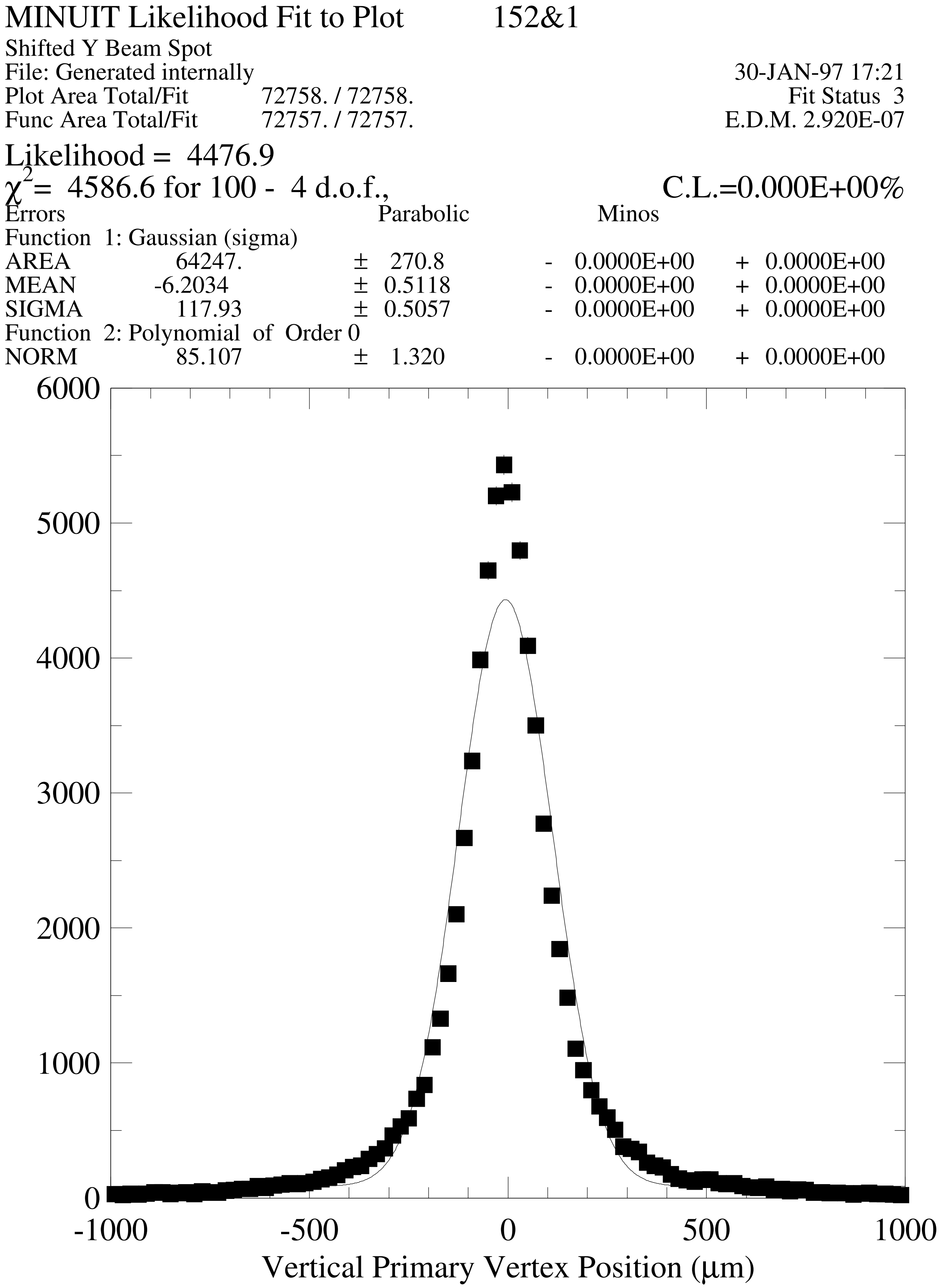

Figure 2: The vertical primary vertex distribution.

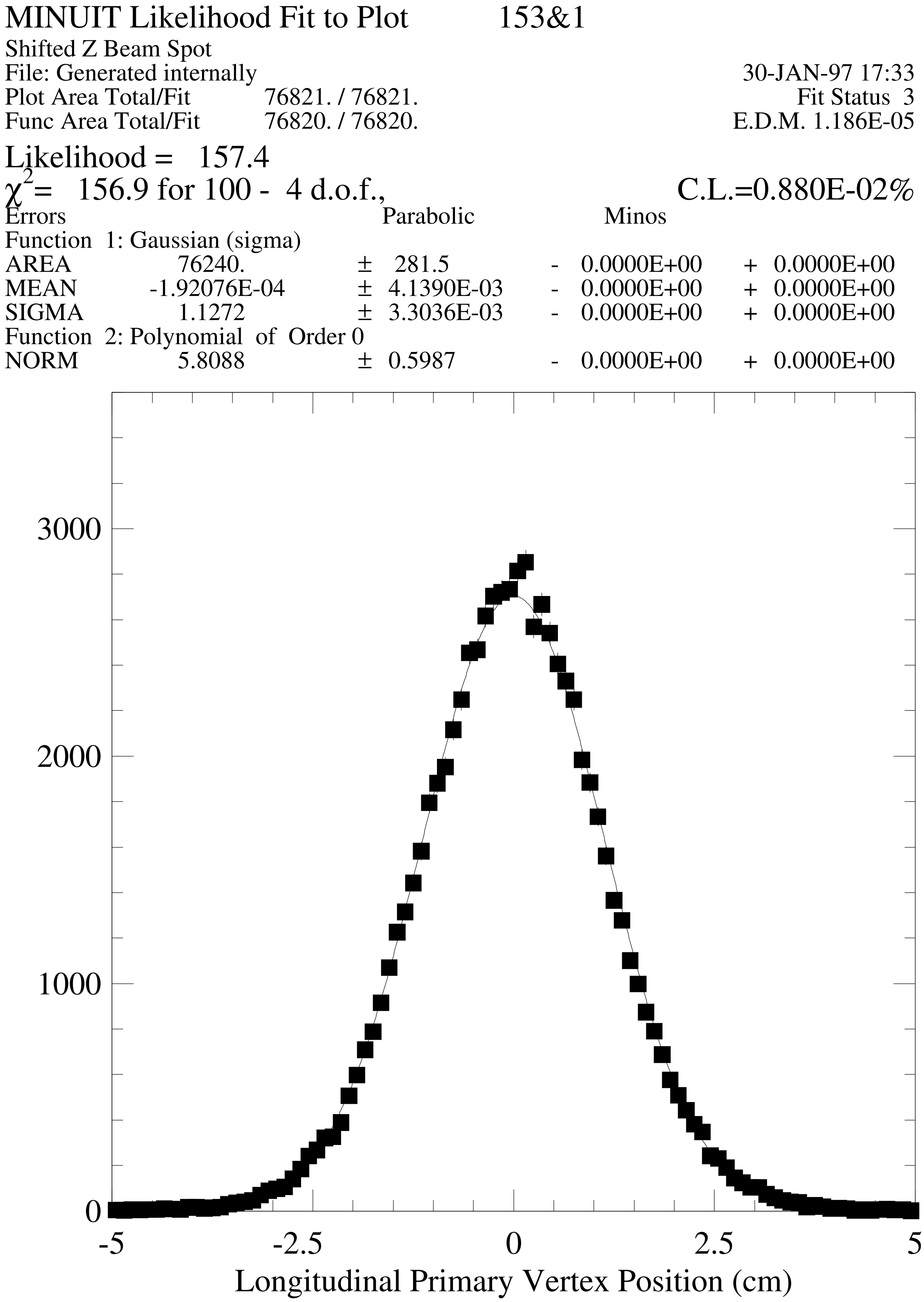

Figure 3: The longitudinal primary vertex distribution.

last study, but still worse than the $80-90\mu$m expected from the Monte Carlo. This indicates that there remain misalignments at the 80μm level.

Using this vertical width as the resolution I extract an underlying horizontal width of $\sigma_{x\mathcal{L}} = (308.9 \pm 1.7)\mu$m. Using a horizontal emittance of $\epsilon_x = 2.05 \times 10^{-7}$m-rad^2 I extract a horizontal beta of $\beta_x = 0.965$m and β_x/β_{x0} of 0.753 ± 0.038 with $\beta_{x0} = (1.38 \pm 0.07)$m which is the value indicated by measurements by Dave Sagan based on the observed phase shifts of single bunches.

In the longitudinal direction the width of (1.1272 ± 0.0033)cm agrees with the expectation. Figure 4 shows the result of fitting the primary vertex longitudinal distribution to the hourglass shape. The fit gives a bunch length (1.786 ± 0.018)cm, while I expect 1.87cm. This also gives an indirect measure of the vertical beta, $\beta_y = (1.93 \pm 0.11)$cm which agrees well with the expectation of 1.9cm.

Figures 5 and 6 show the Gaussian widths versus bunch current for the primary vertex distribution in horizontal and vertical direction respectively. They are a classic case of good news and bad news. The good news is that there is no longer dependence of the resolution on the bunch current. If I fit the distribution of Figure 6 to a line I get a slope within one standard deviation of zero. I use a constant resolution of $(117.93 \pm 0.51)\mu$m from Figure 2. The bad news is that the decrease of the horizontal bunch width with increasing bunch current is no longer clearly evident in Figure 5. When I fit that distribution to a line I get a slope of $(-5.4 \pm 1.6)\mu$m/mA which is significant and has the expected sign.

I forge ahead using the resolution given above and the emittance from Figure 2 of CBN 96-17/CBX 96-94 to extract the horizontal β as a function of bunch current. The results are show in Figure 7. The agreement between data and theory remains remarkable.

The theory prediction also includes the results of Dave Rubin's work on the dynamic focusing effect caused by the parasitic crossings[1]. This causes the theoretical β/β_0 dependence on the bunch current to be steeper than that found in CBN 96-17/CBX 96-94 and the effect of just the parasitic crossings is shown in Figure 8. I use the fitted second order polynomial displayed in Figure 8 as a parameterization of this effect.

Figure 9 shows the extraction of the bunch length versus the beam current. For this extraction I fixed the horizontal beta to the values found in Figure 7 and the vertical beta to 1.9cm. There is no longer a trend for the bunch length to get smaller with increasing bunch current. Only the point at the highest bunch current is significantly bigger than the others. This may be an indication of the longitudinal instability which struck especially hard during June of 1996.

2 Resolution Studies

One problem evident in the original CBX is the quality of the fits as remains visible in Figure 2. This is due to the shape of the presumed resolution not being Gaussian. I studied this by breaking up the data by the number of tracks used to find the primary vertex. Figures 10-13 show the vertical primary vertex distribution using 2-5 or more tracks respectively. These distributions are fit to a Gaussian plus a flat background. The fits are of better quality than the fit to the overall distribution, but remain poor. The width of the Gaussian, the assumed resolution, has a strong dependence on the number of tracks used to find the vertex and is shown in Figure 14. Also note that the 2 track distribution of Figure 10 has the largest tails that are

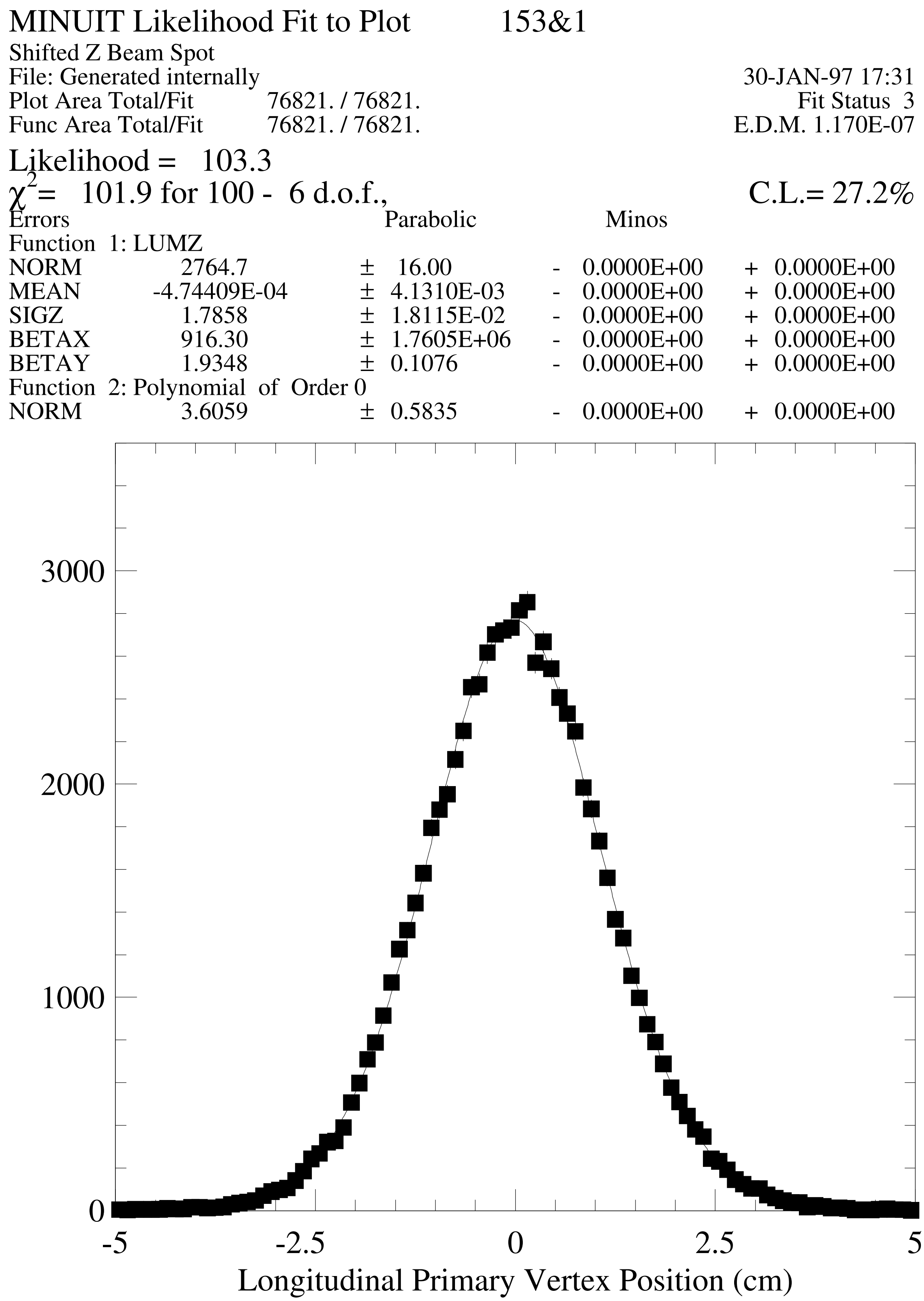

Figure 4: The longitudinal primary vertex distribution with a fit to the expected hourglass shape.

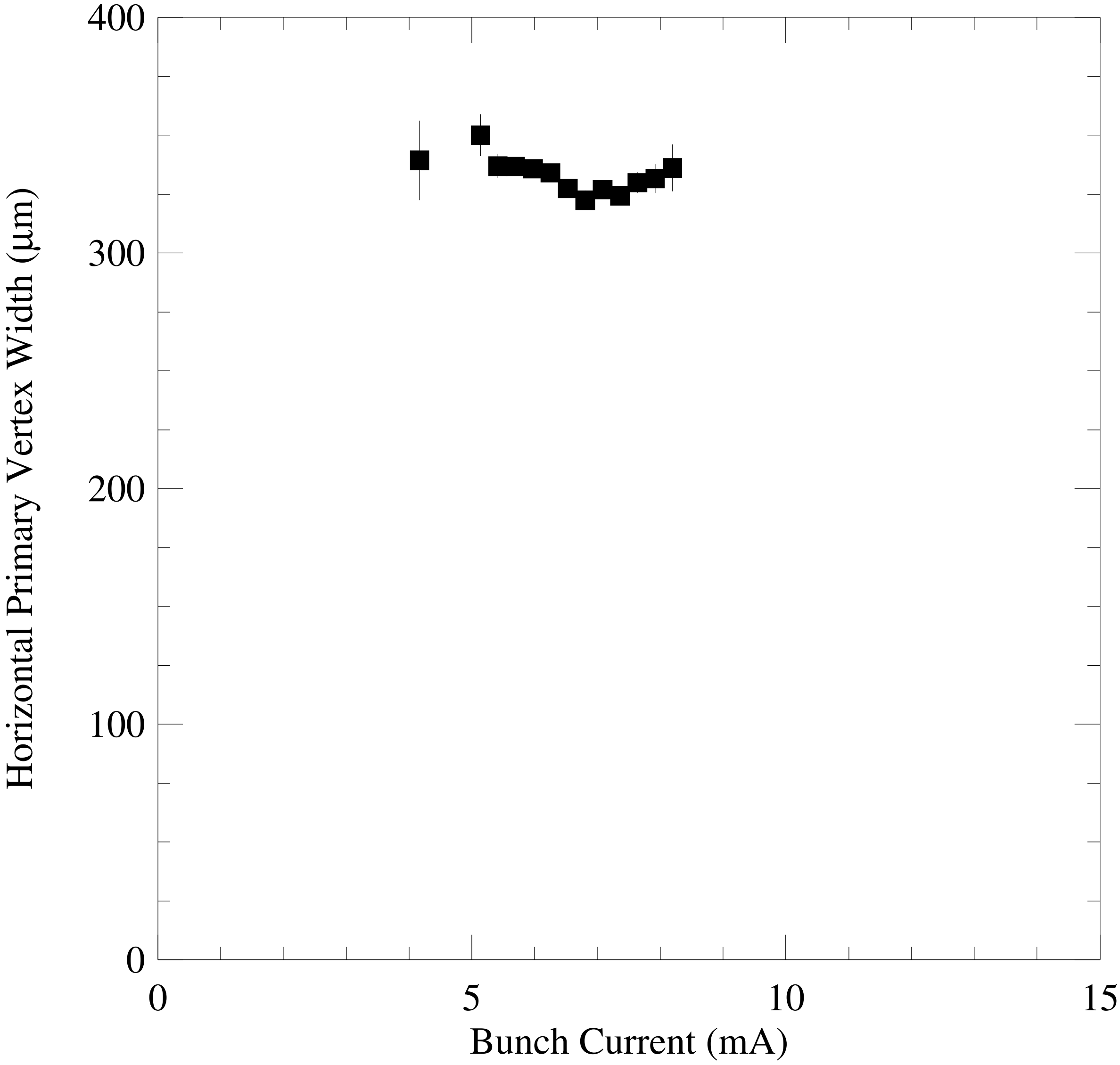

Figure 5: The width of the fits to the horizontal primary vertex distribution versus the bunch current.

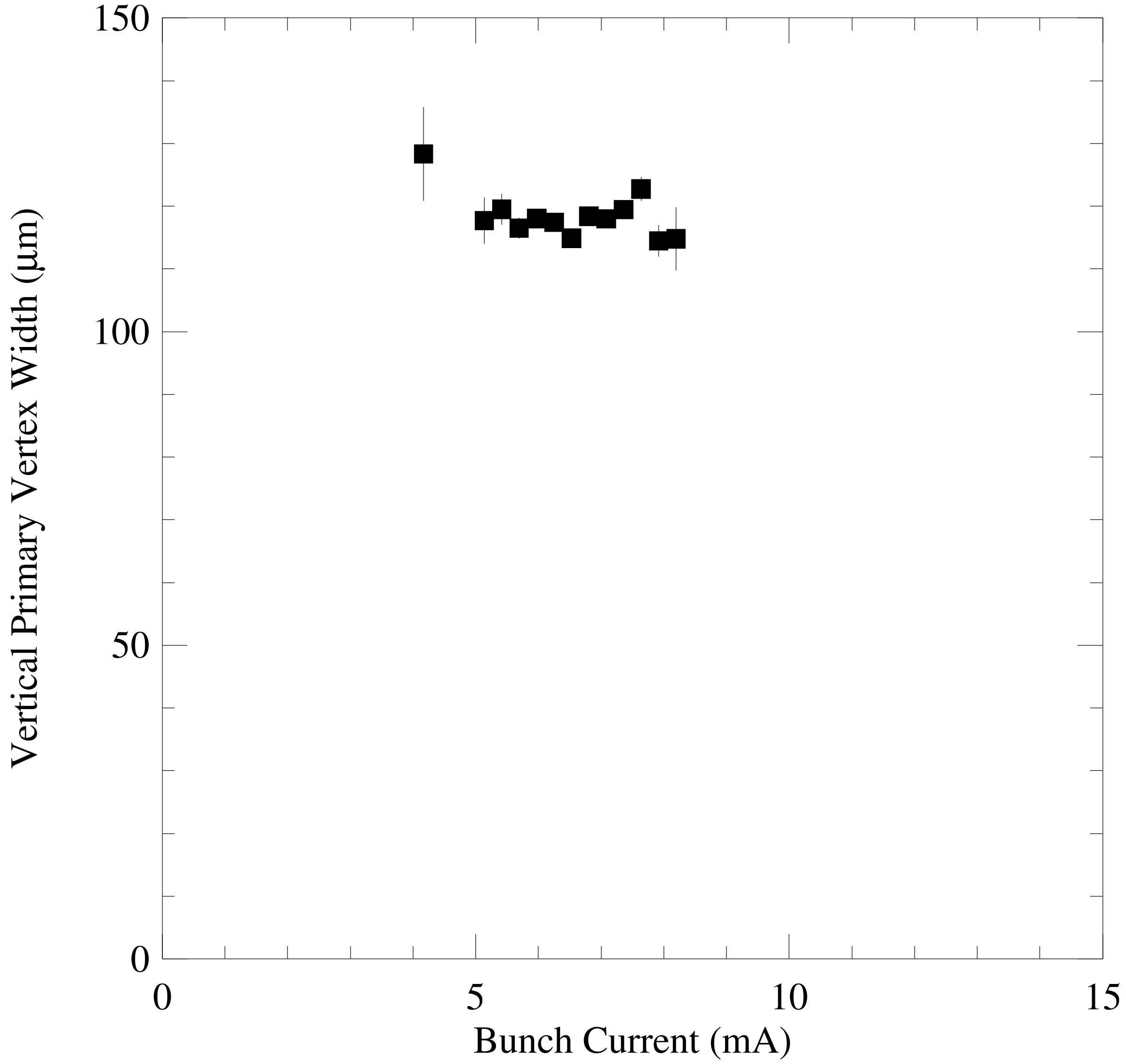

Figure 6: The width of the fits to the vertical vertex distribution versus the bunch current.

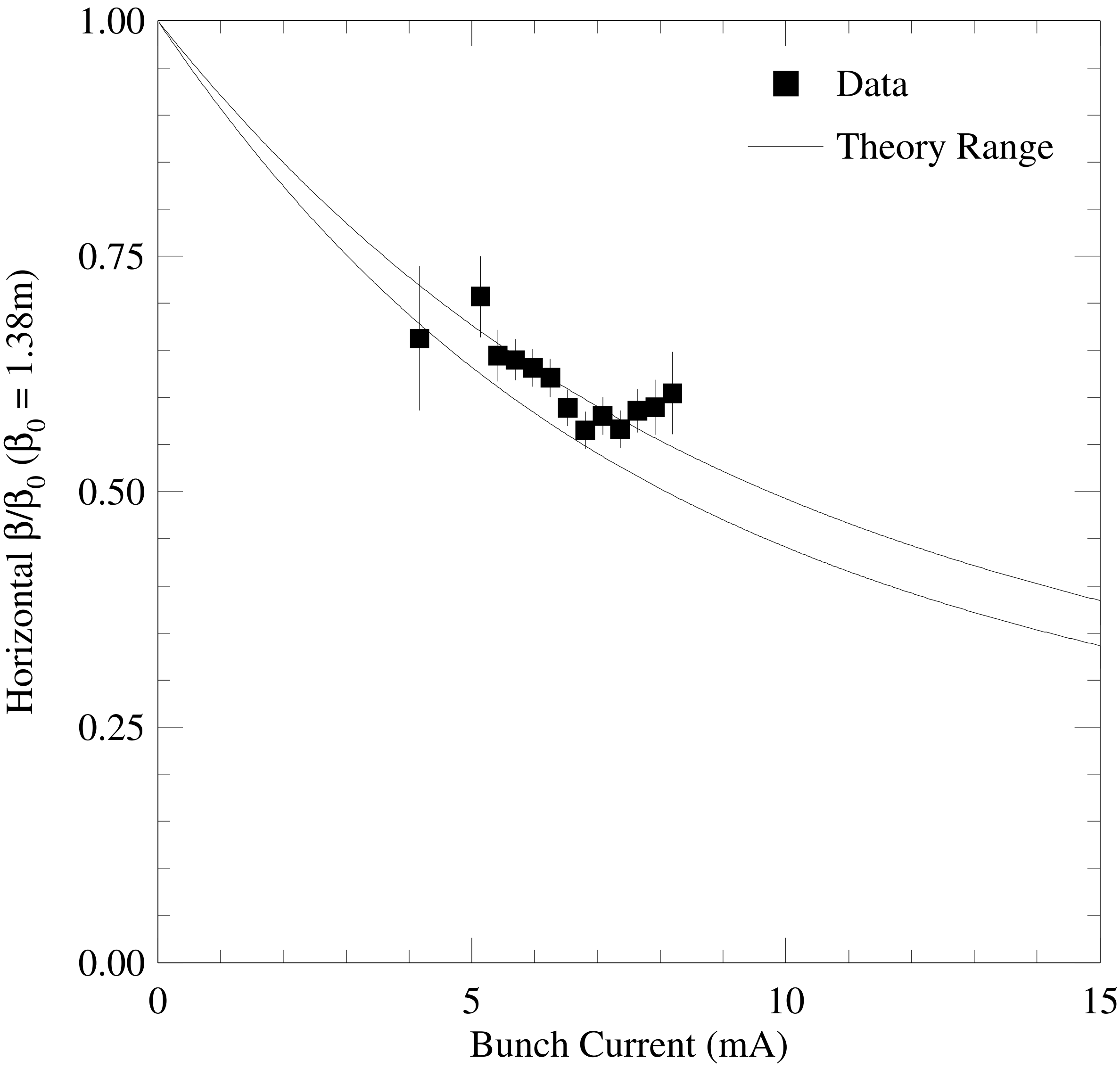

Figure 7: The horizontal beta as function of bunch current. Note that the error on β_{x0} of 5% of its value is not included in the error bars on the data.

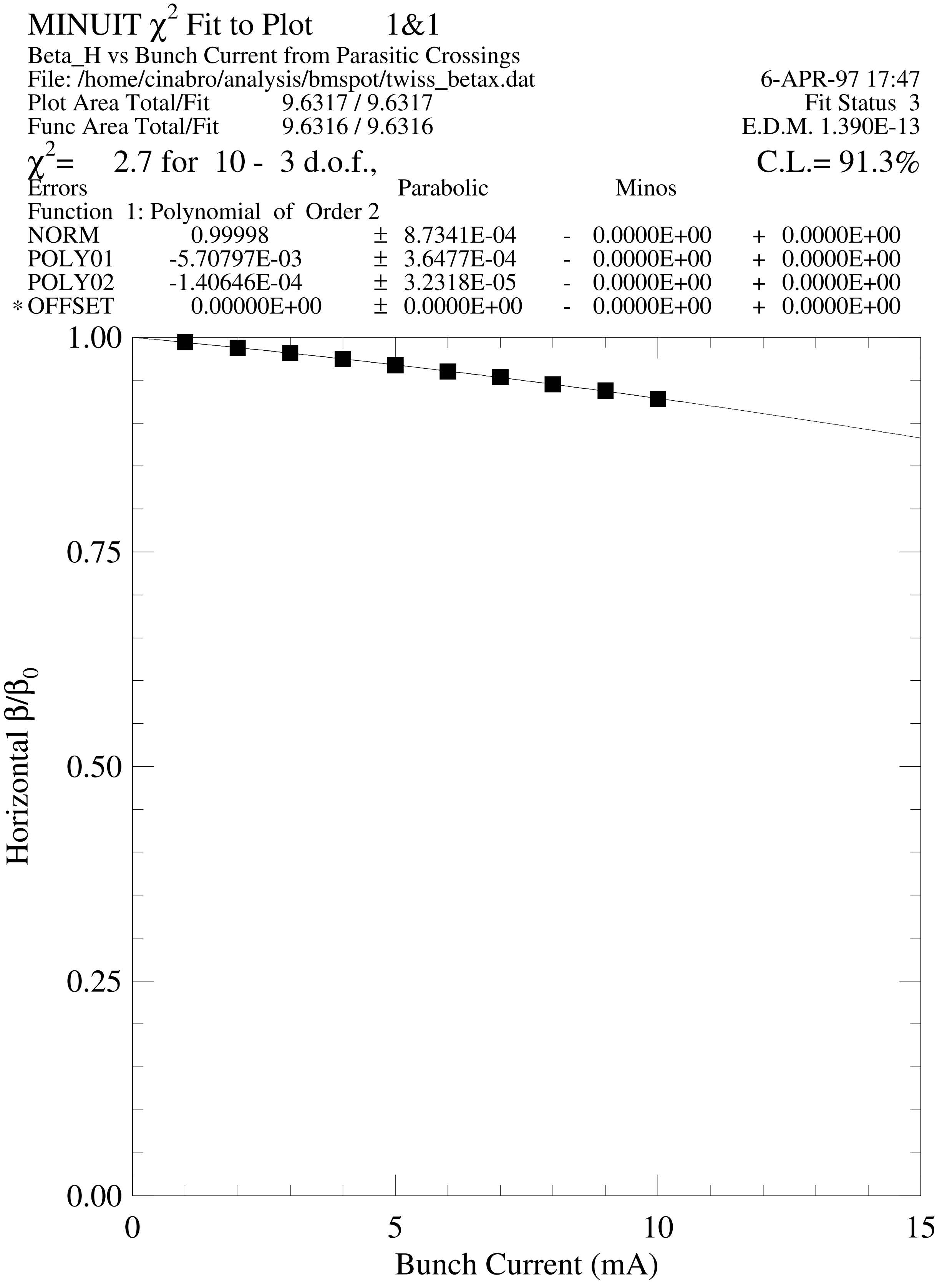

Figure 8: The dynamic effect on the horizontal beta caused by only the parasitic crossings.

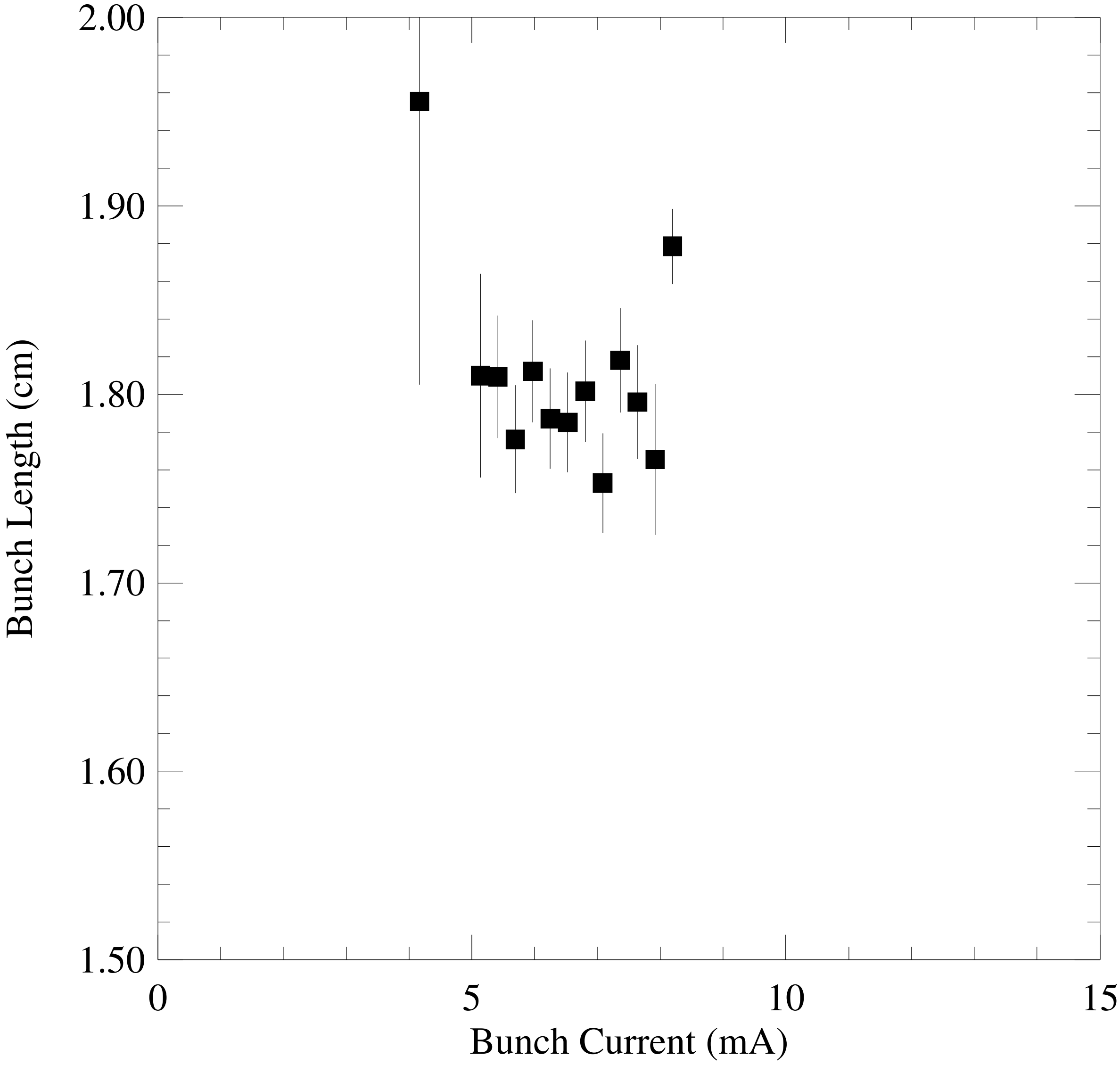

Figure 9: The extracted bunch length versus the bunch current.

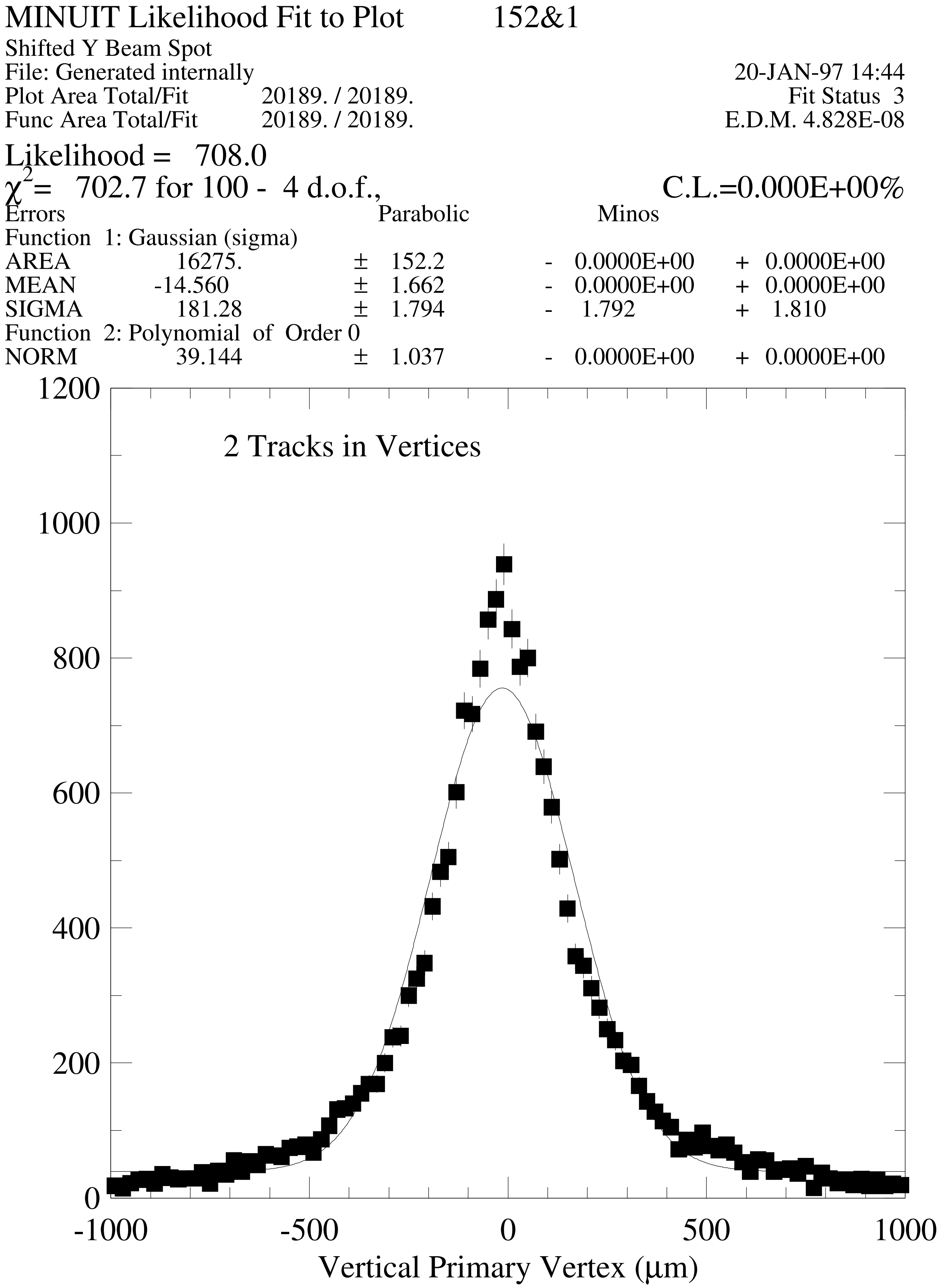

Figure 10: The vertical primary vertex distribution for vertices with two tracks.

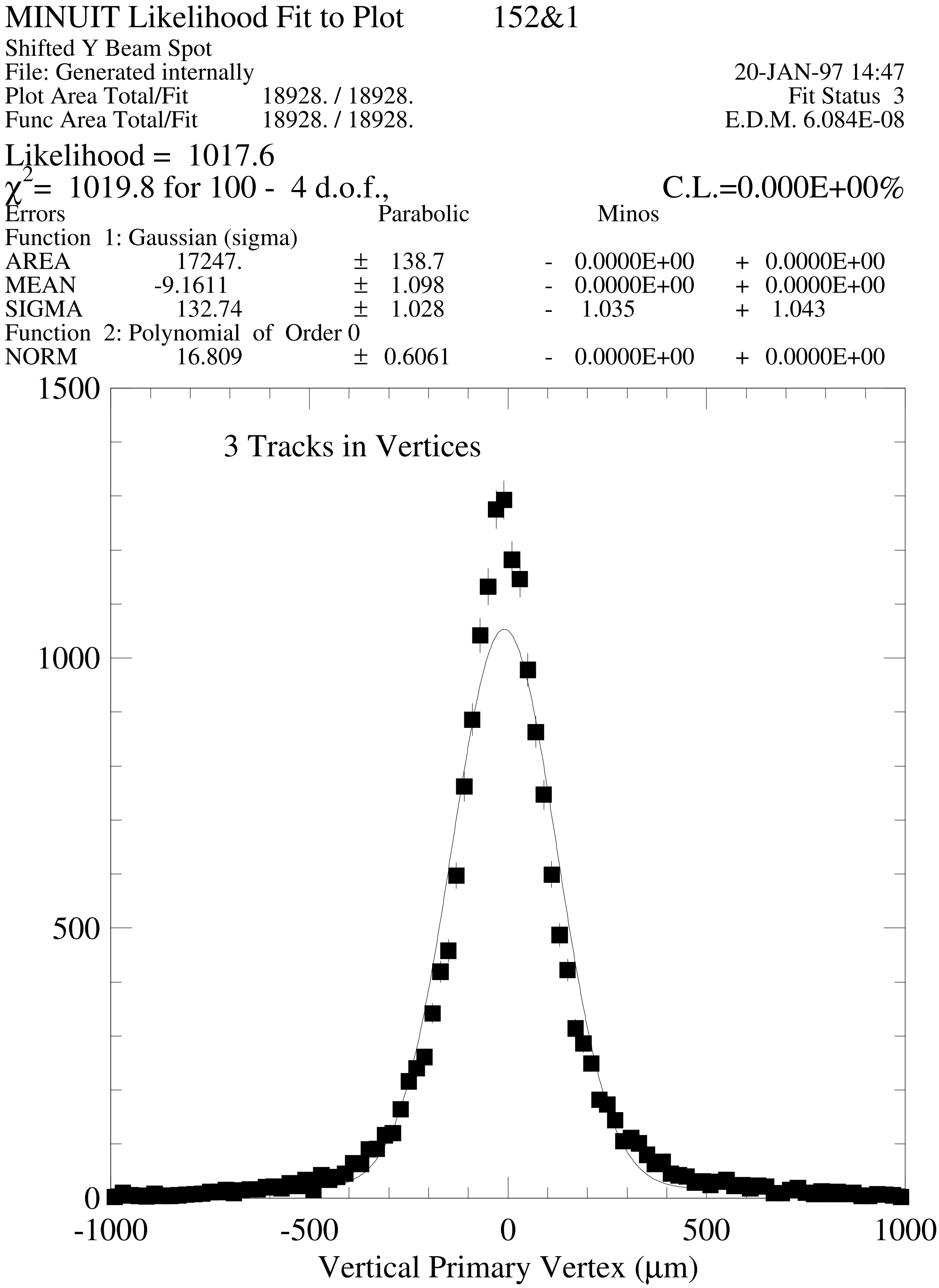

Figure 11: The vertical primary vertex distribution for vertices with three tracks.

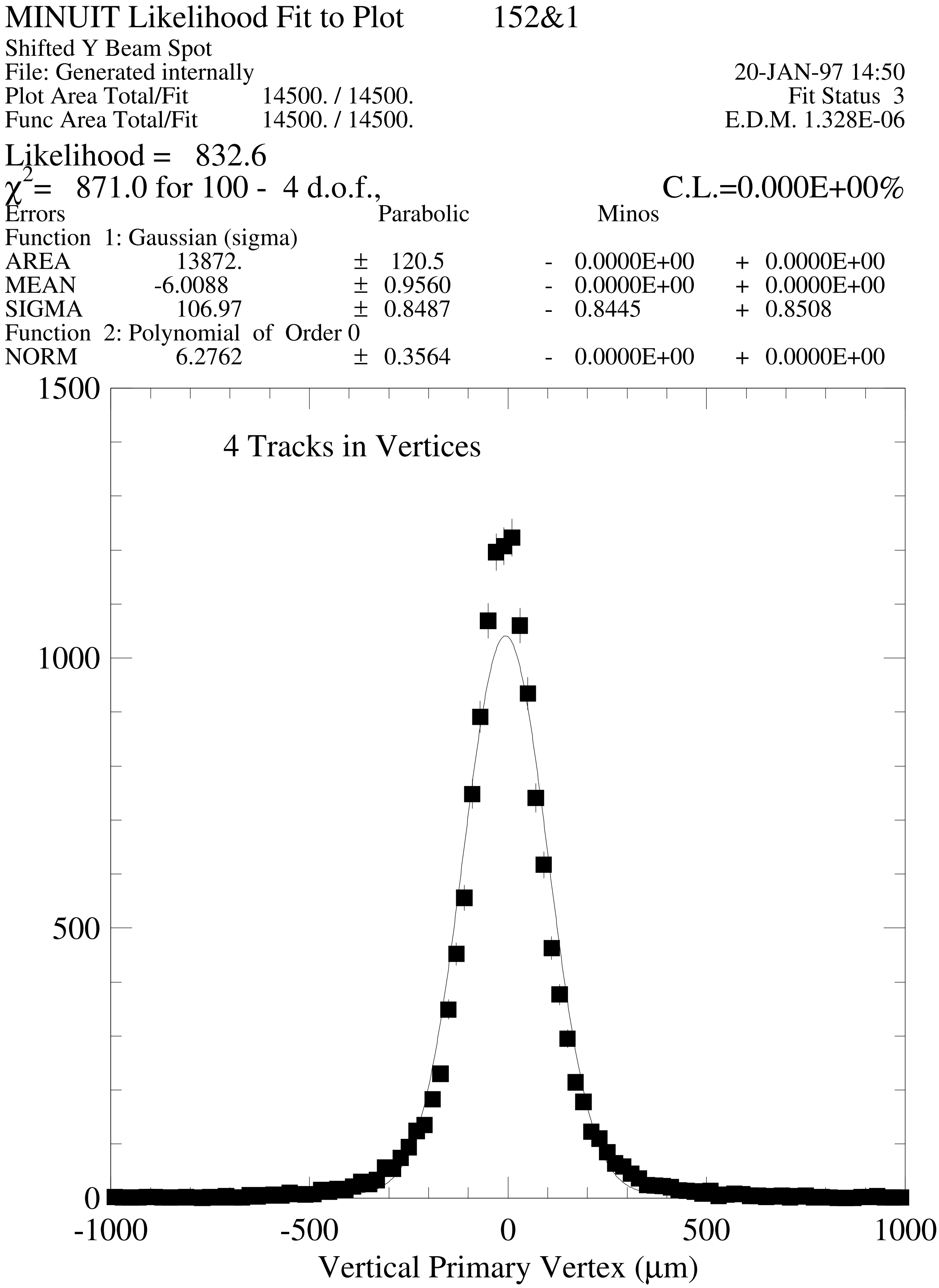

Figure 12: The vertical primary vertex distribution for vertices with four tracks.

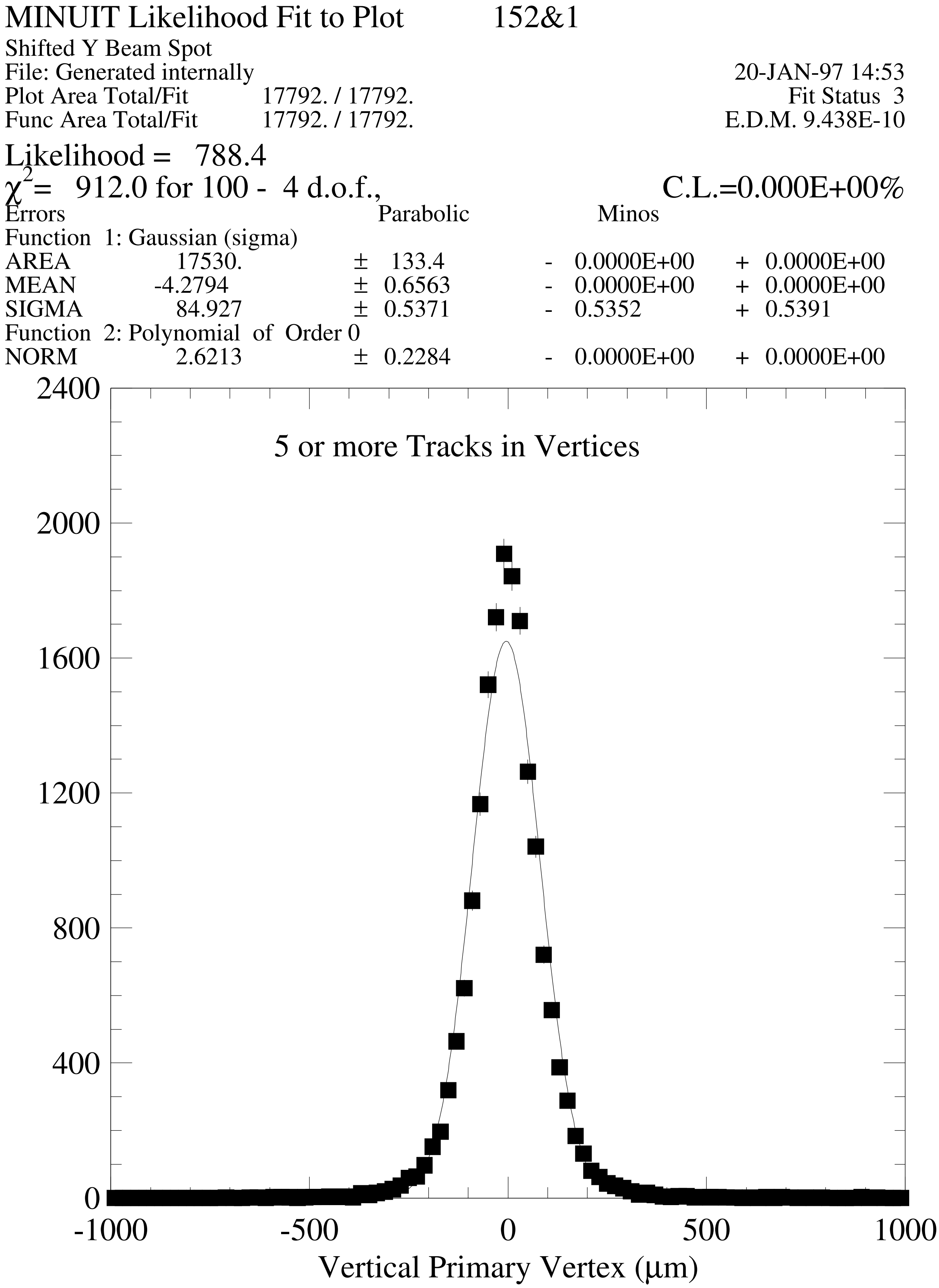

Figure 13: The vertical primary vertex distribution for vertices with five or more tracks.

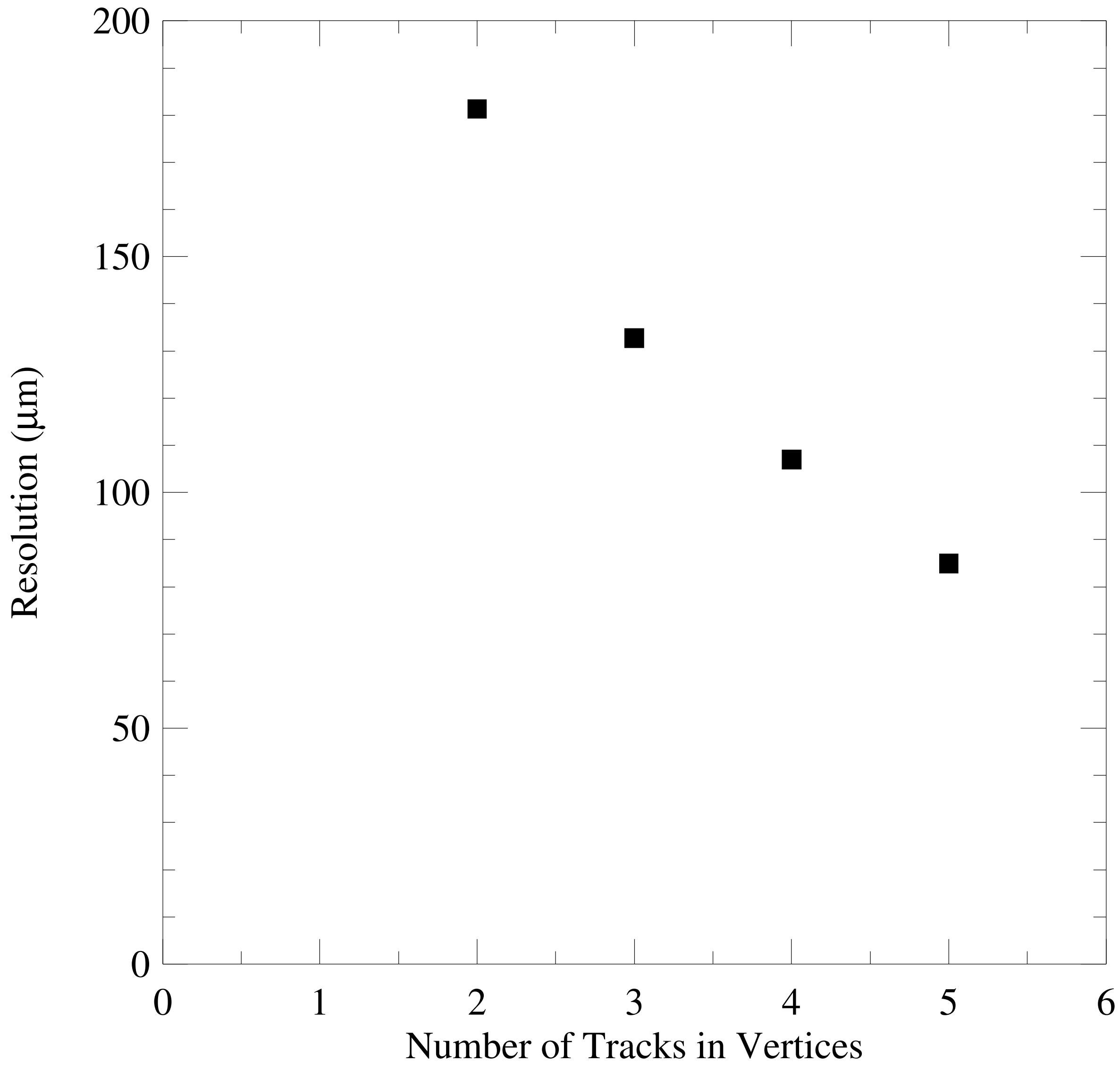

Figure 14: The width of the vertical primary vertex distribution versus the number of tracks used to find the vertices. Note that five means five or more tracks.

only marginally related to the primary vertex. This is not a surprise as the vertex determined with only two tracks is often a secondary vertex. Table 1 summarizes the results of this study

Table 1: Summary of the dependence of the primary vertex resolution on the number of tracks used to find the vertices.

Number of Tracks	Fraction of Vertices	Resolution
2	31%	181μm
3	26%	132μm
4	19%	107μm
5 or more	24%	85μm

which shows that the primary vertex distribution is made up of multiple distributions each with a different resolution. Certainly there are more hidden variables on which the resolution depends.

I tested whether the procedure of using a single Gaussian fit to a distribution with a narrow underlying width smeared with multiple resolutions as the resolution to extract the underlying width of a distribution smeared in the same way but having a wide underlying width worked. I generated underlying Gaussian distributions with widths of 10 and 300μm. I smeared them using the fractions and Gaussian widths found in the primary vertex data versus the number of tracks in the vertices given in Table 1. Figures 15 and 16 show one such toy Monte Carlo experiment with 10,000 events. The measured resolution from Figure 15 is $137.22 \pm 0.97\mu$m. Also note the poor quality of the fit. The shape of the toy Monte Carlo "data" in Figure 15 as compared to the fitted Gaussian is similar to the real data in Figure 2. The measured width of the wide distribution in Figure 16 is $330.2 \pm 2.3\mu$m. The extracted underlying width of the wide distribution is $300.3 \pm 2.6\mu$m, exactly agreeing with the input value of 300μm. Figure 17 shows the distribution of extracted underlying widths of the wide distribution from 100 such toy Monte Carlo experiments. I conclude that the single Gaussian procedure works very well, and the poor fits are not a problem.

Dave Cassel was not convinced by the toy Monte Carlo study above which showed that the poor fits did not matter. He suggested that I try a better shape to fit the data. I tried a number of things, but one of the simplest that gave much improved fit qualities over the single Gaussian was a double Gaussian. Figures 19 and 18 show the vertical and horizontal ditributions of the primary vertex fit to the double Gaussian. These should be compared with Figures 1 and 2 respectively. I extract an underlying horizontal width of $\sigma_{x\mathcal{L}} = (315 \pm 16)\mu$m which agrees with the value of 309 from the single Gaussian fit. Figure 20 compares the extracted underlying horizontal width of the luminous region versus bunch current for the single Gaussian and double Gaussian methods. There is only a small effect from the improved fits, and I continue to use the single Gaussian fits in the analysis.

I worried that the non-Gaussian tails would be a bigger problem. To test this I repeated the entire procedure requiring that each primary vertex be found with 3 or more tracks and accepting good runs with more than 700 events passing all the cuts. The resolution improves to $(105.17 \pm 0.46)\mu$m by not including the 2 track vertices. The extracted underlying horizontal width of the luminous region versus bunch current is shown in Figure 21 comparing the standard

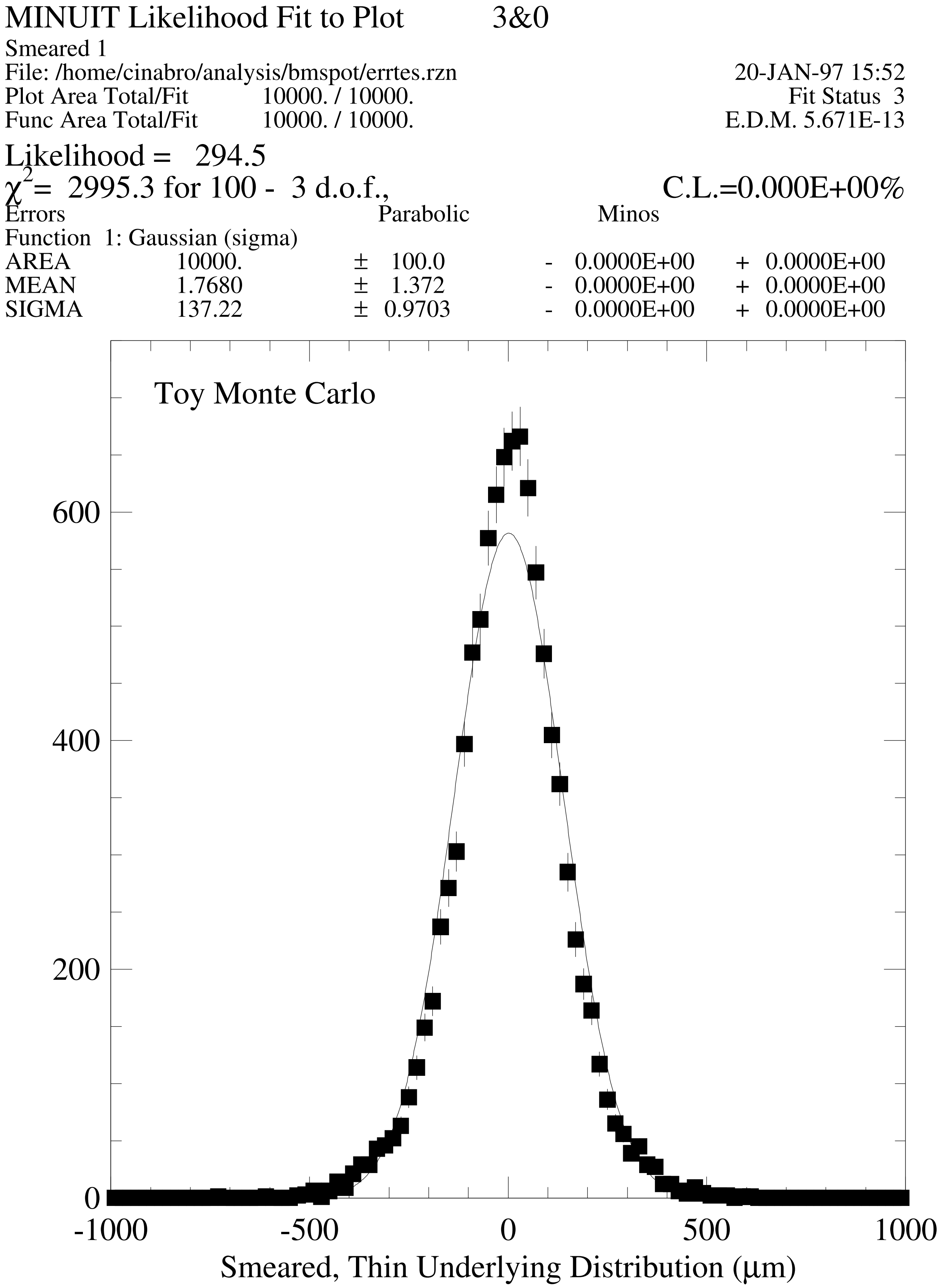

Figure 15: The distribution of the toy Monte Carlo with underlying width of 10μm and smeared using the fractions and resolutions given in Table 1.

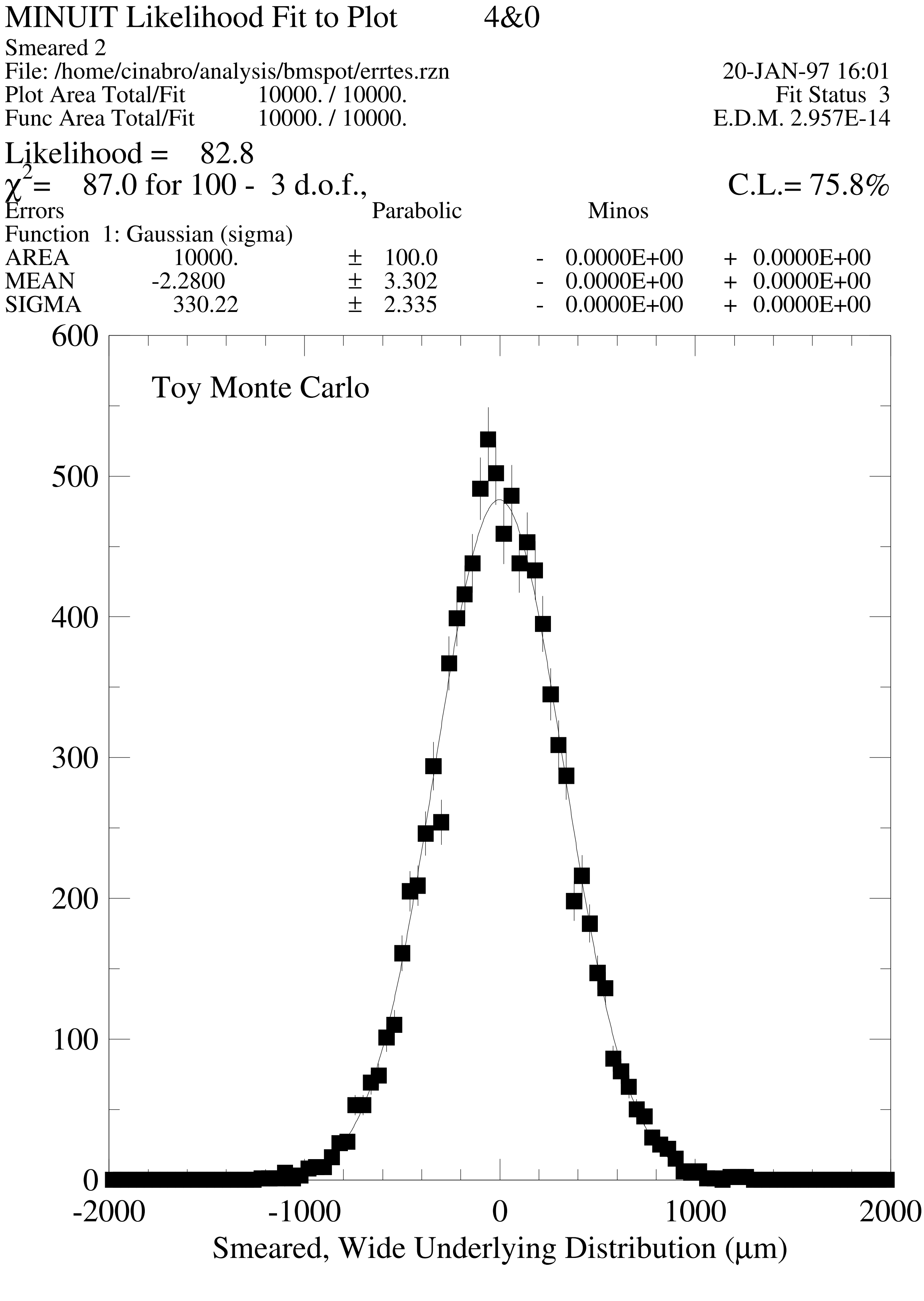

Figure 16: The distribution of the toy Monte Carlo with underlying width of 300μm and smeared using the fractions and resolutions given in Table 1.

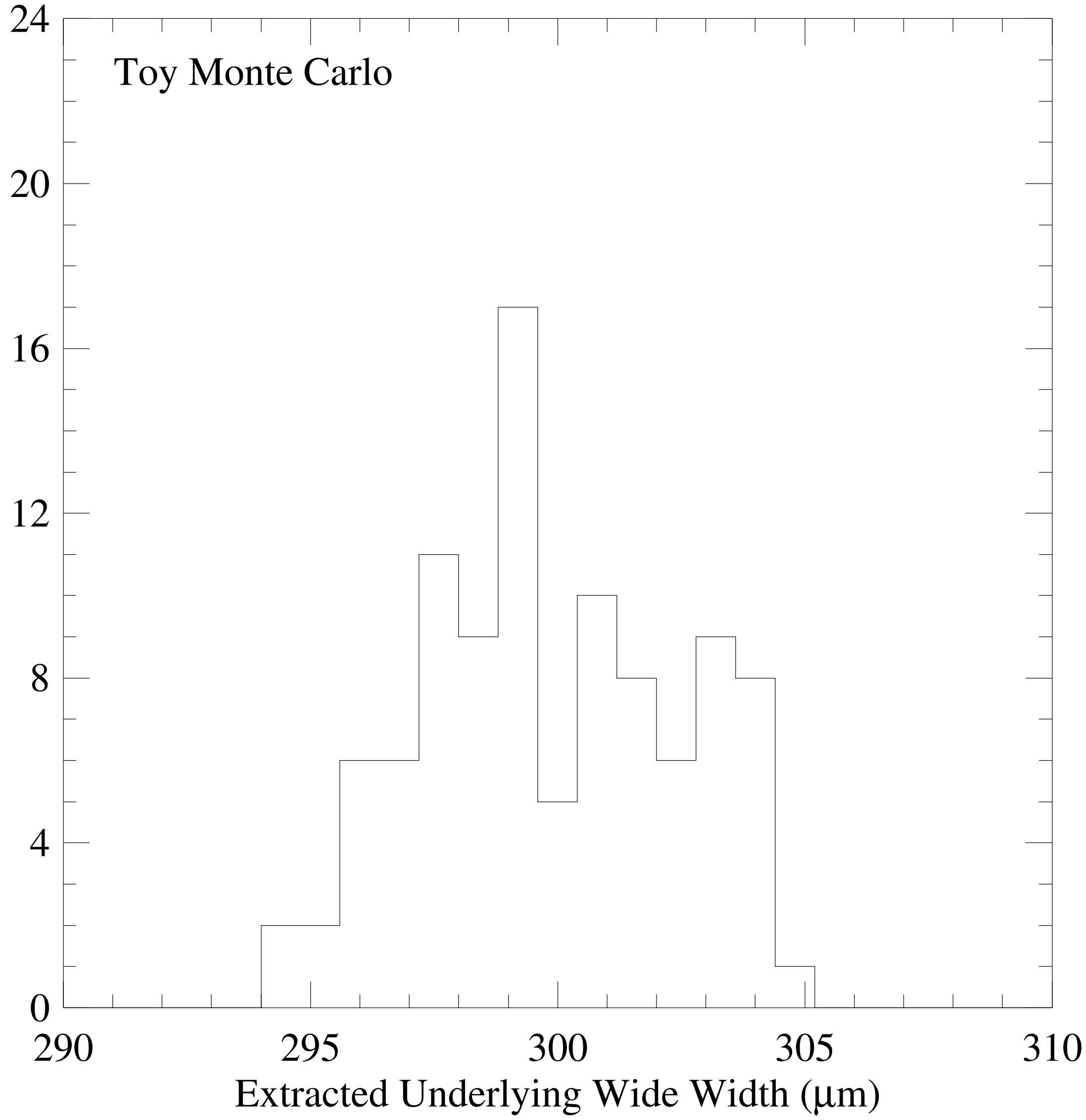

Figure 17: The extracted underlying width of the wide distribution for 100 such toy Monte Carlo experiments as described in the text. The generated underlying width was 300μm.

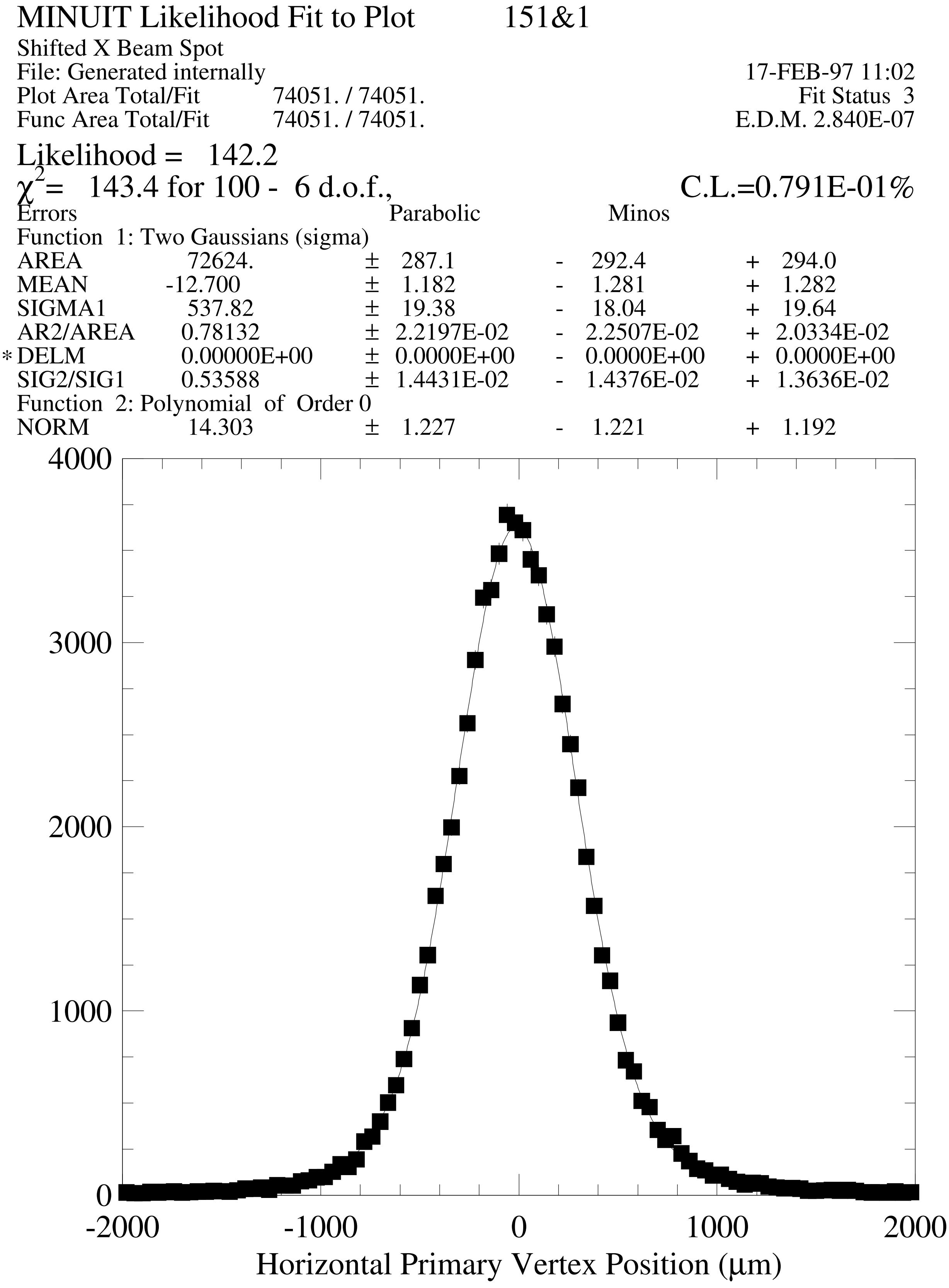

Figure 18: The horizontal primary vertex distribution fit to a double Gaussian.

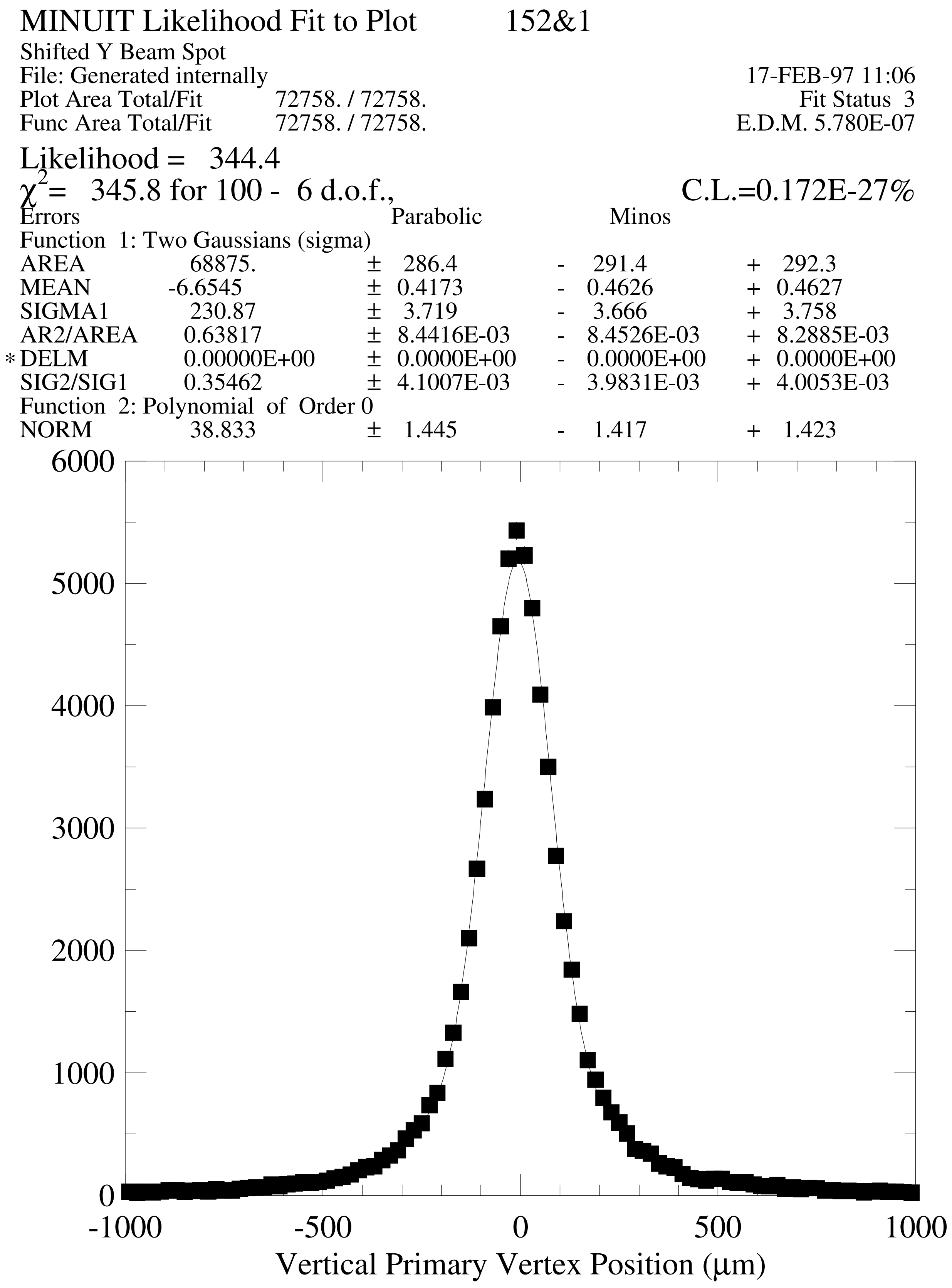

Figure 19: The vertical primary vertex distribution fit to a double Gaussian.

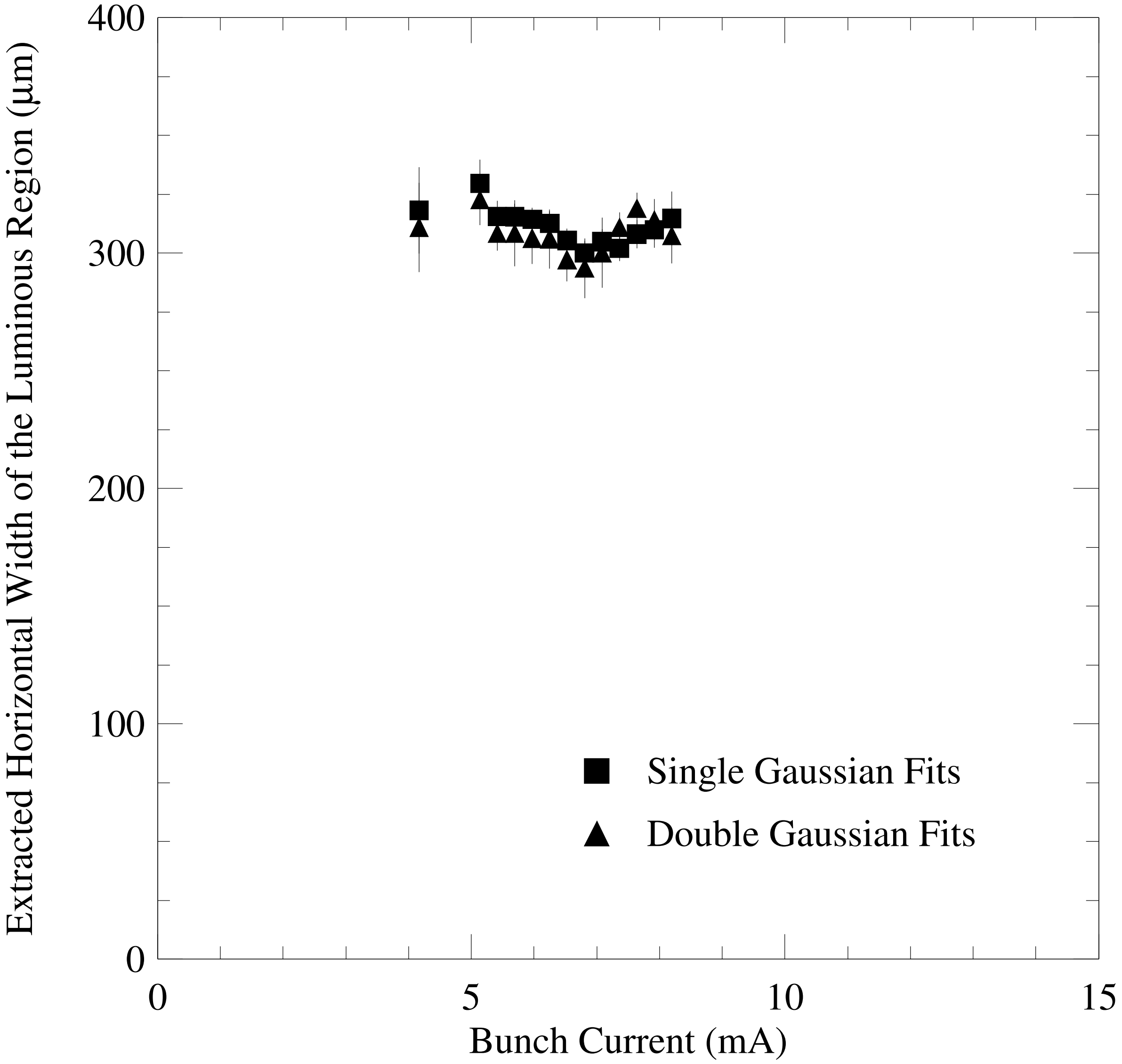

Figure 20: The extracted underlying horizontal width of the luminous region comparing the standard procedure of single Gaussian fits with double Gaussian fits.

procedure with this test. There is only a small effect from the non-Gaussian tails, and I continue to use the two track vertices in the analysis.

3 Conclusion

Despite not looking as beautiful as it did in CBN 96-17/CBX 96-94 we have still unambiguously observed the dynamic beta effect. We see both a shift down in β_x from the measured value at 0 bunch current and a significant negative slope on the observed values of β_x as the bunch current increases. There remains good agreement between the data and the theoretical expectation even as we have included the smaller theoretical effect of the parasitic crossings.

References

[1] D. Rubin, CBN 96-2 explains the general effects of parasitic crossings. The specific result for the lattice and bunch train structure in use in June 1996 comes from a private communication from Dave Rubin.

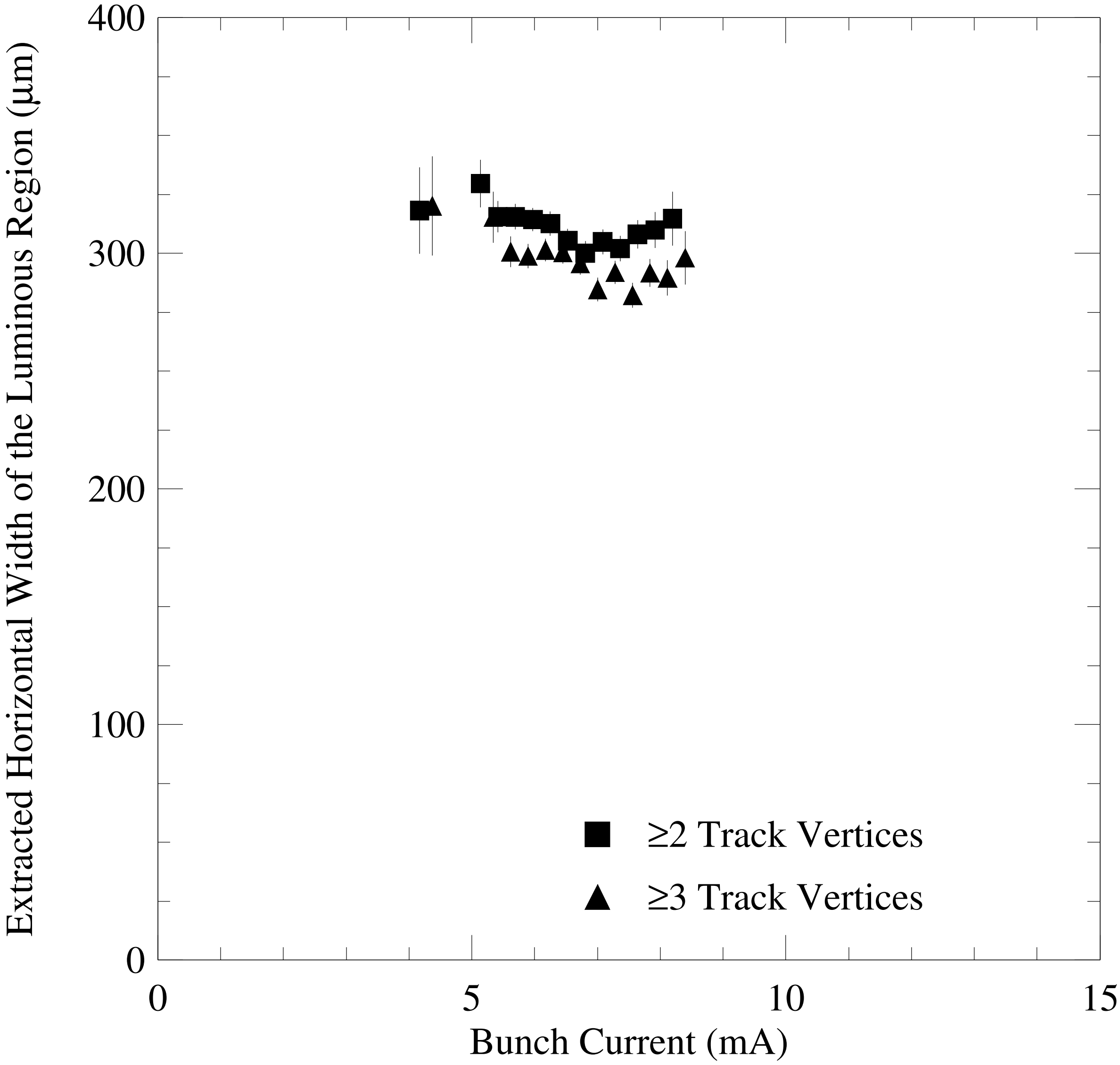

Figure 21: The extracted underlying horizontal width of the luminous region comparing the standard procedure which includes vertices with 2 tracks with the test procedure which does not include 2 track vertices.