BB vertex resolution: The vertex resolution from BigBite Analytical Model.

TO SEE THE VERTEX RESOLUTION OF BIGBITE SINCE IT SELF TIMING IS NOT ALWAYS THE CASE.

Using the comparison to the LHRS, we can see the BigBite resolution from the dummy target at 15 cm and 4 cm. (2014,2015 run)

Cut: [DBB.evtypebits&(1<<3) && DBB.edtpl==0 && exL.ok==1 && abs(exL.dp)<0.045 && abs(exL.th)<0.060 && abs(exL.ph)<0.030 && (L.prl1.e/1100.+L.prl2.e/850.)/(exL.p) >=0.6 && L.tr.n ==1&& L.s2.trpad[0]>-1 && abs(L.s2.y_t[L.s2.trpad[0]])<0.5 && abs(DBB.l1a[0]-345)<235 && BB.tr.n==1]

All the cut in LHRS except vertex cut. And require single track in BigBite.
First, let see what we have after electron selection event with single track in BigBite.

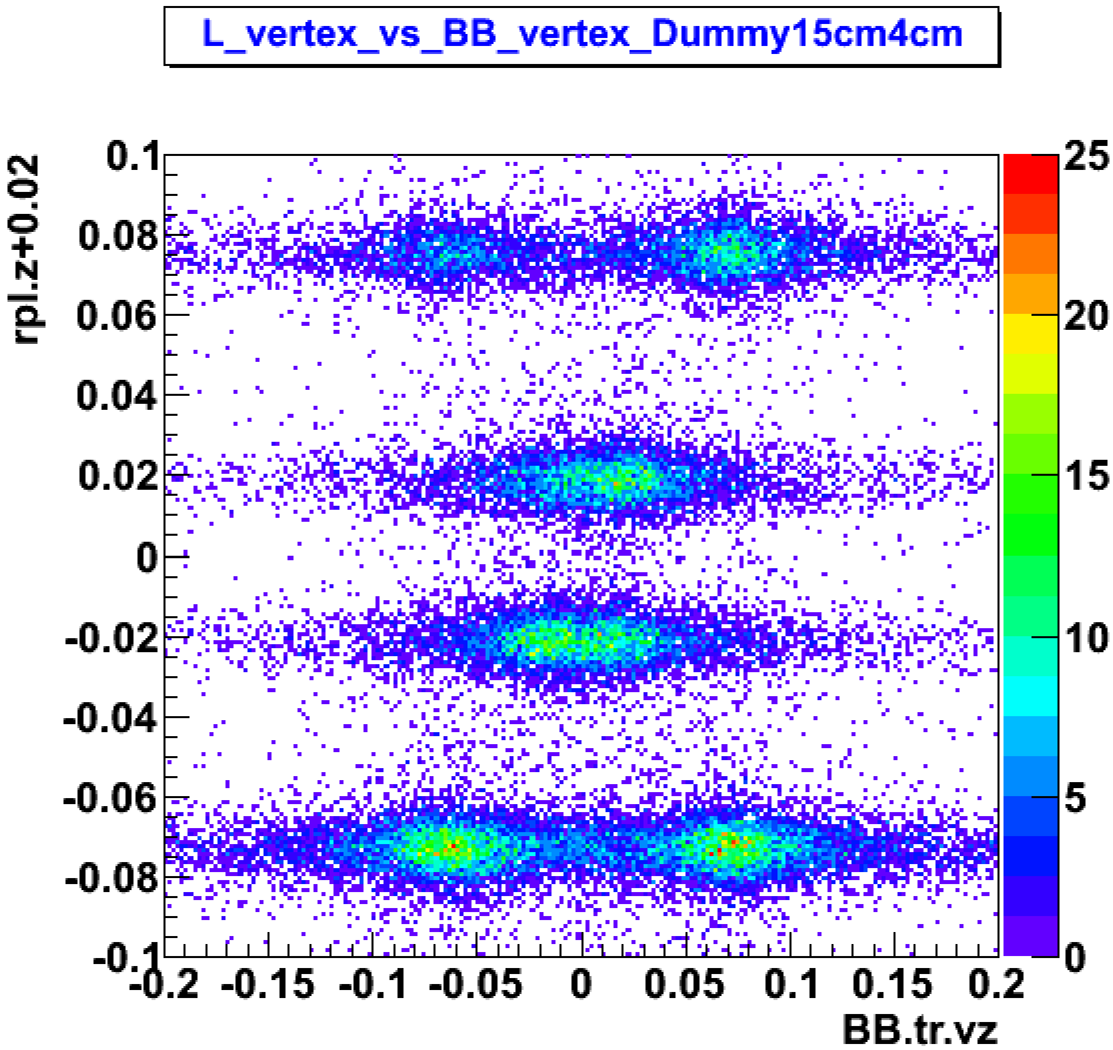

Figure 1: LHRS vertex (y) vs BigBite vertex (x).

The 15 cm dummy target shows up at +/- 0.075 m and the 4 cm dummy at +/- 0.02m for the LHRS vertex reconstruction. Ideally, the LHRS and BB vertex should show along x = y line with resolution

difference. However, we do see that when LHRS vertex is "positive", there are some data in BigBite vertex is "negative". I believe that the miss-match should be the accidental data.
To prove this I use the timing information from the BigBite.

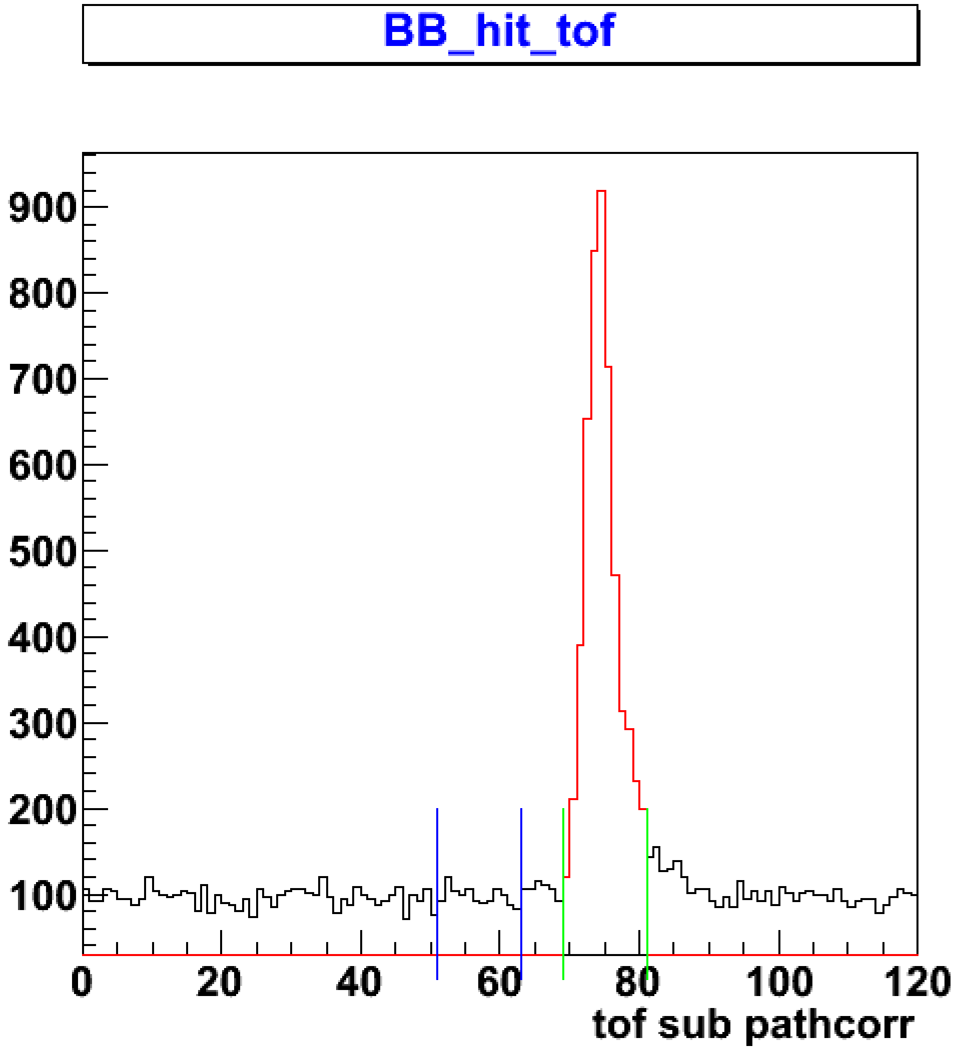

Figure 2: BigBite time – pathlengh correction (repected to L1A)

Here I make a cut about 75+/-6 ns, which show up in red + green line. The integral is 5457 (69 to 81) events with the background estimate (in blue window) is 1242 (51 to 63). The signal with background subtraction is 4215 and signal : bg = 4.39.

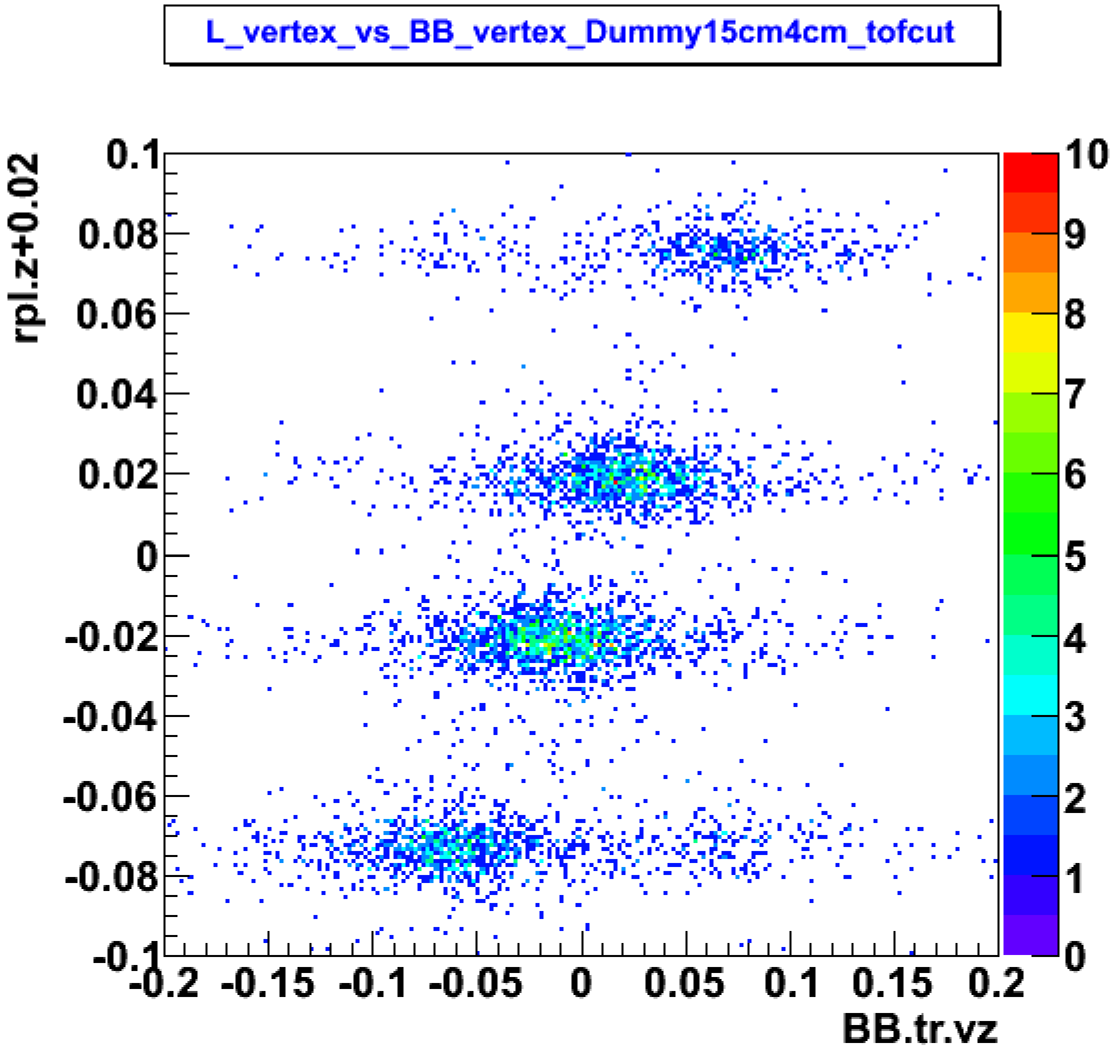

Figure 3: LHRS vertex (y) vs BigBite vertex (x) with the cut on BB TOF (in red of figure 2).

With this tightly cut on TOF, the plot of the LHRS vertex vs BigBite vertex shows up mainly along the x = y with some miss-match vertex reconstruction as the background.

Inversely, we want to use the vertex cut to improve the signal to background in BB TOF. If we consider the vertex difference "LHRS -BB vertex" in the same TOF cut, we have the majority of the data along about "zero".

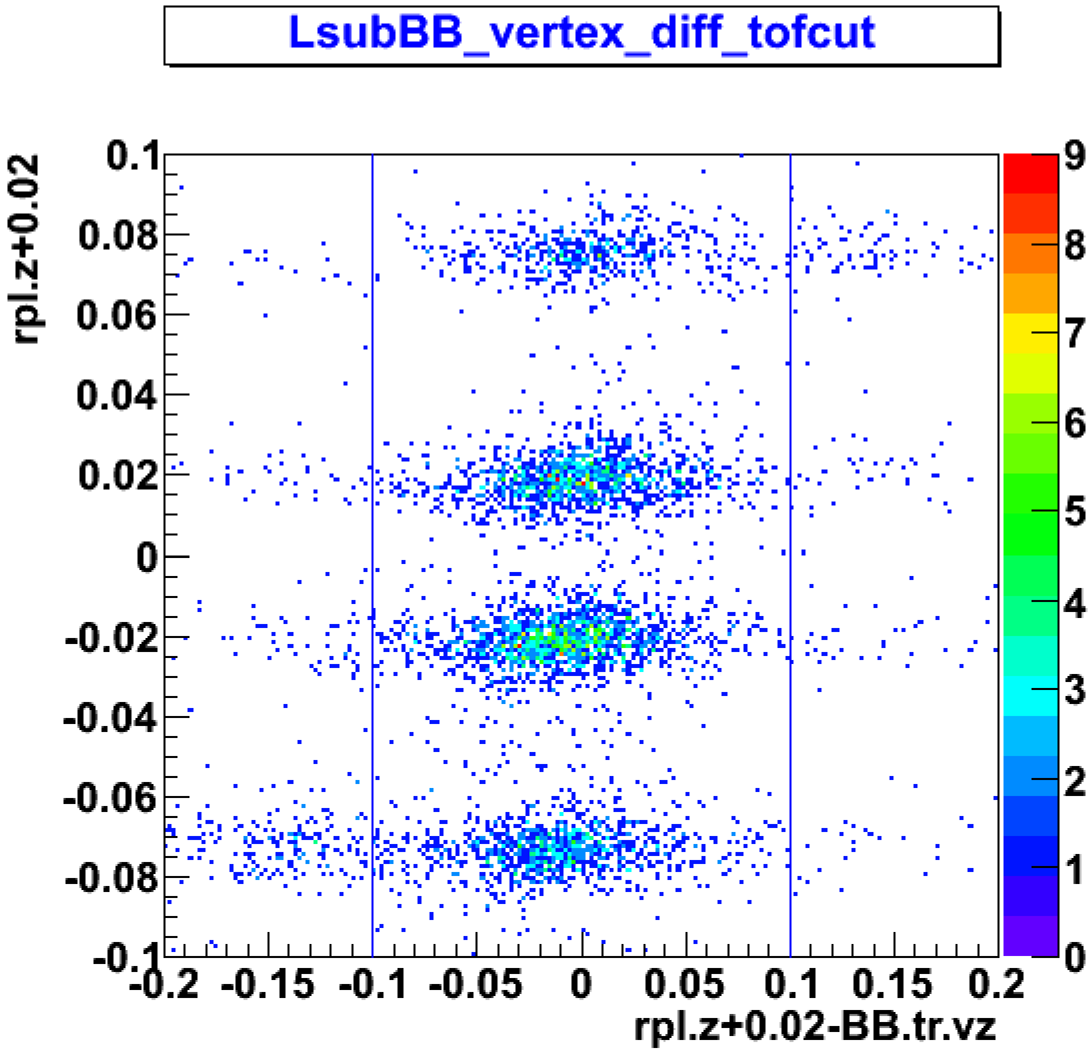

Figure 4: LHRS vertex (y) vs LHRS-BB vertex (x) with the cut on BB Tof (in red of figure 2).

I make the (very) lose cut at +/- 0.1 m which shows up in blue lines. Then reversely looking back at the BB TOF.

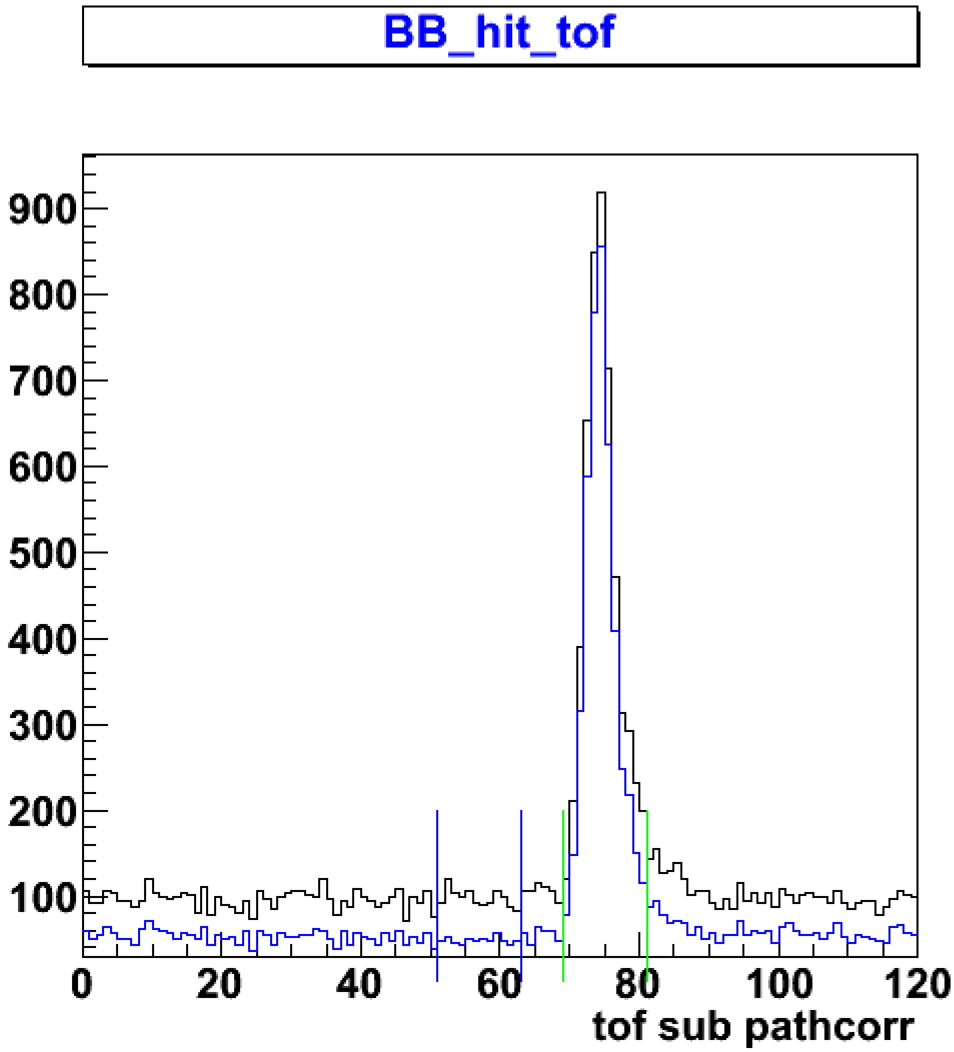

Figure 5: BigBite time – pathlengh correction (repected to L1A). The black line is the same as figure 2. The blue line is with the cut on the vertex difference very losely at +/- 0.1. The signal to background is calculated using the same interval.

After the vertex diffence cut, the integral is 4576 (69 to 81)
events with the background estimate (in blue window) is 618 (51 to 63)
. The signal with background subtraction is 3958 and signal : bg = 7.40. The vertex difference cut does improve the signal to background (comparing to the 4.39 ratio).

Finally with both cut on the vertex difference and the BB tof cut, here is what the LHRS vs BB vertex look like.

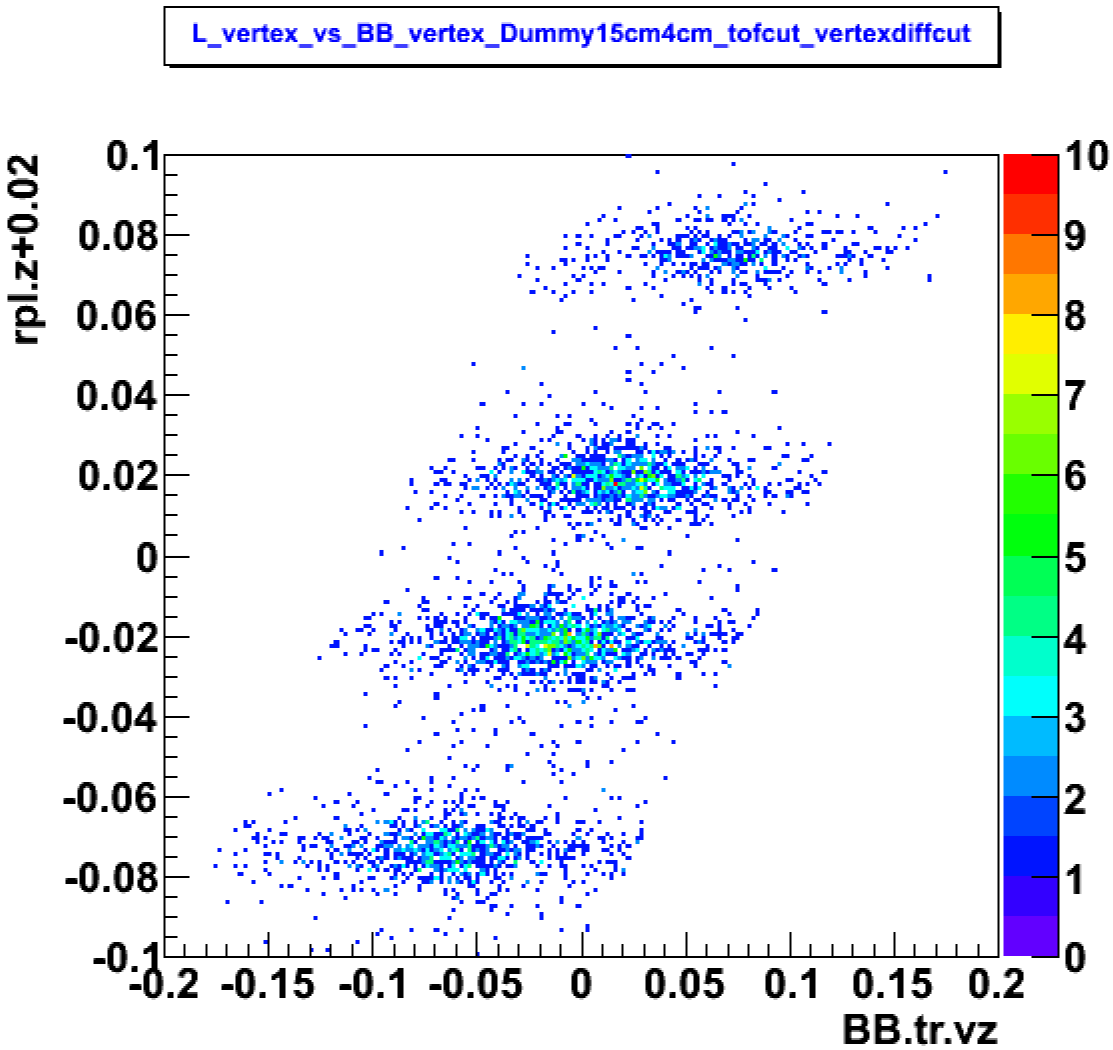

Figure 6: LHRS vertex (y) vs BigBite vertex (x) with the cut on BB TOF (in red of figure 2) and the LHRS-BB vertex cut (in blue of figure 4).

In term of resolution. Let consider the data in piece.

<table>
<tr>
<td>

Figure 7.1 : The BigBite vertex reconstruction with the requirement of the LHRS vertex at +7.5 cm.
Consider LHRS vertex is at +7.5 cm.
The BigBite vertex contain the accidental portion (negative peak). The red line shows when the data actually within the BB TOF (figure 2). The BigBite vertex resolution (sigma) is 3.1 cm.

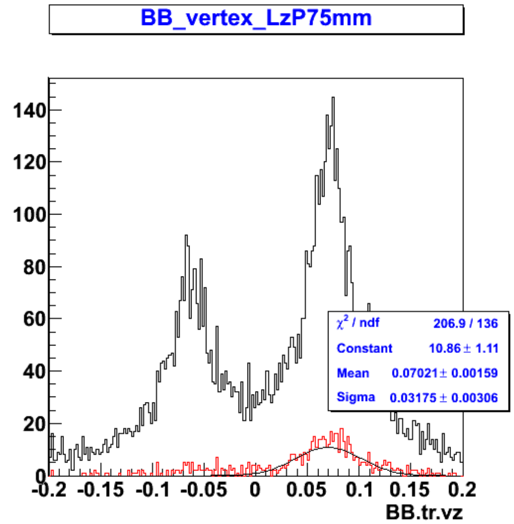

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Figure 7.2 : The BigBite vertex reconstruction with the requirement of the LHRS vertex at -7.5 cm.

Consider LHRS vertex is at -7.5 cm.
The BigBite vertex contain the accidental portion (now positive peak). The red line shows when the data actually within the BB TOF (figure 2). The BigBite vertex resolution (sigma) is 3.4 cm.

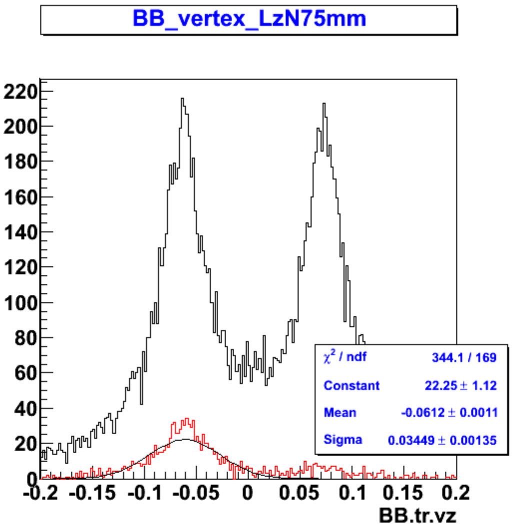

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Figure 7.3 : The BigBite vertex reconstruction with the requirement of the LHRS vertex at +2.0 cm.

Consider LHRS vertex is at +2.0 cm.
The BigBite vertex contain the accidental portion (negative peak) which in this case cannot be separate from the actual signal. The red line shows when the data actually within the BB TOF (figure 2). The BigBite vertex resolution (sigma) is 3.2cm about 1.9 cm.

</td>
<td>

Figure 7.4 : The BigBite vertex reconstruction with the requirement of the LHRS vertex at -2.0 cm.

Consider LHRS vertex is at -2.0 cm.
The BigBite vertex contain the accidental portion (now positive peak) which in this case cannot be separate from the actual signal. The red line shows when the data actually within the BB TOF (figure 2). The BigBite vertex resolution (sigma) is 3.1 cm at -1.2 cm.

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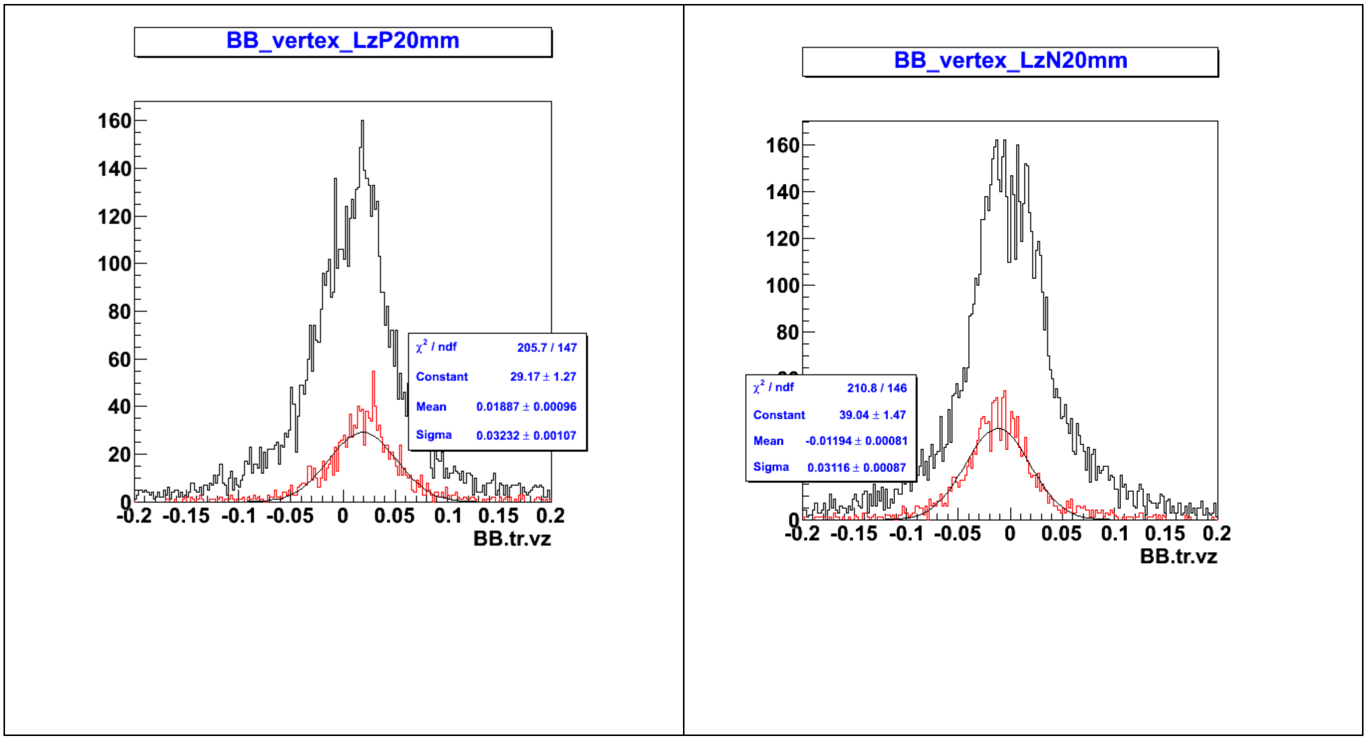
</table>



BB_vertex_LzP20mm
χ2 / ndf 205.7 / 147
Constant 29.17 ± 1.27
Mean 0.01887 ± 0.00096
Sigma 0.03232 ± 0.00107
BB.tr.vz
BB_vertex_LzN20mm
χ2 / ndf 210.8 / 146
Constant 39.04 ± 1.47
Mean -0.01194 ± 0.00081
Sigma 0.03116 ± 0.00087
BB.tr.vz

Production BigBite vertex Resolution

Combine data for the following list1:
{2939 2940 2941 2942 2943 2944 2945 2946 2947 2985
2986 2987 2988 2989 2994 2995 2996 2997 2998 2999
3000 3001 3002 3004 3005 3006 3007 3008 3009 3010
3011 3012 3014 3015 3016 3017 3018 3019 3020 3021 }
and list2:
{3022 3025 3026 3027 3028 3029 3031 3033 3034 3035
3036 3037 3038 3039 3040 3043 3044 3045 3046 3047
3048 3049 3050 3051 3053 3054 3055 3056 3058 3059
3061 3062 3063 3064 3065 3066 3067 3068 3069 3070 }

Cut: [DBB.evtypebits&(1<<3) && DBB.edtpl==0 && exL.ok==1 && abs(exL.dp)<0.045 && abs(exL.th)<0.060 && abs(exL.ph)<0.030 && (L.prl1.e/1100.+L.prl2.e/850.)/(exL.p) >=0.6 && L.tr.n ==1&& L.s2.trpad[0]>-1 && abs(L.s2.y_t[L.s2.trpad[0]])<0.5 && abs(DBB.l1a[0]-345)<235 && BB.tr.n==1]

All the cut in LHRS except vertex cut. And require single track in BigBite.
&& pick only the PartHit on E (high momentum portion) proton with graphic cut to select only proton.

This is because the background is much lower in the high momentum proton and makes it easily to see the BB TOF peak.

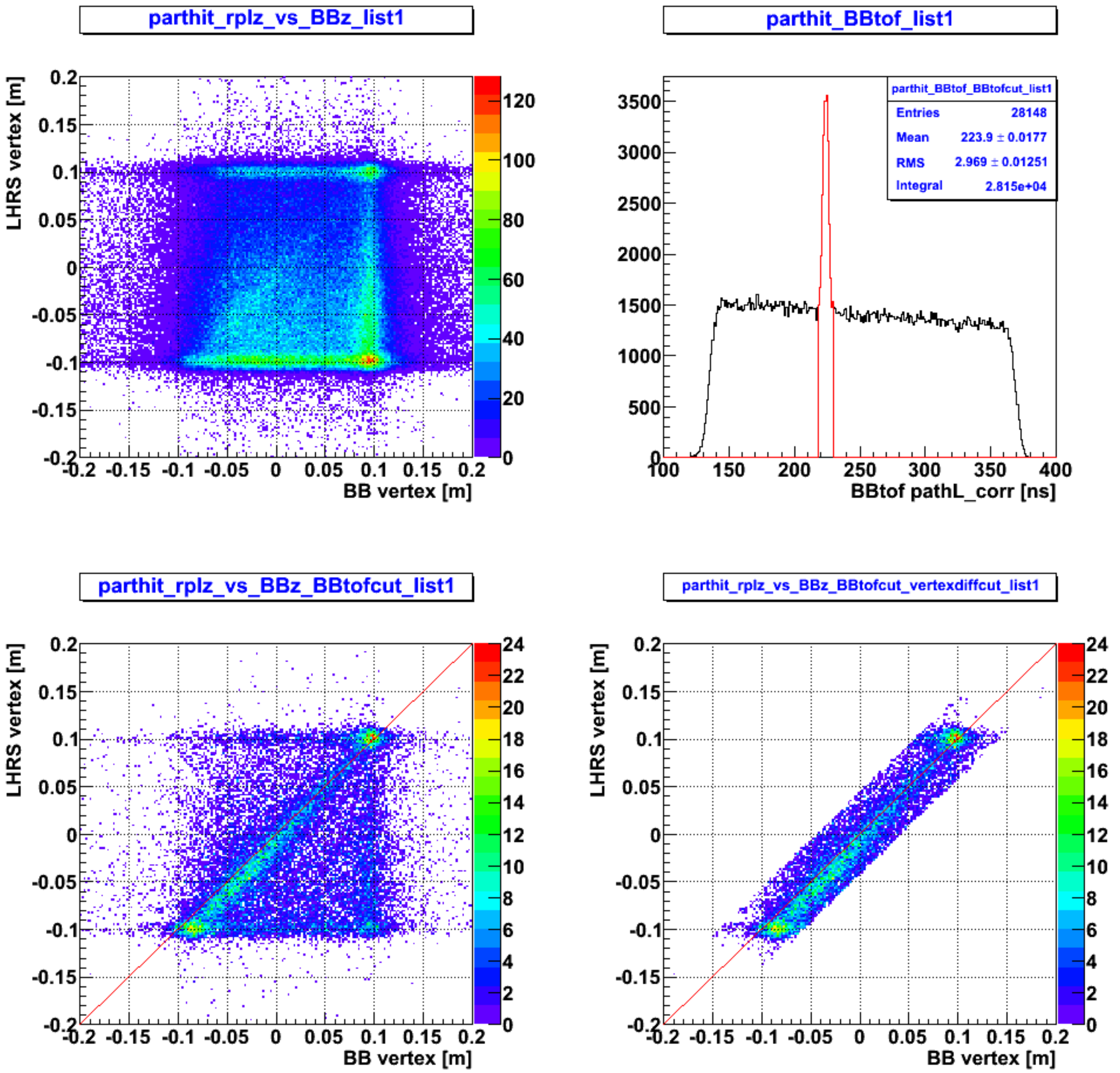


Figure (parthit)

1. Top Left : First look at the LHRS and BB vertex correlation.
2. Top Right : Then, look at the BB TOF and make a cut on the peak about 3*sigma. (224+/-6 ns)
3. Bottom Left : Then check LHRS and BB vertex correlation with BB TOF cut.
4. Bottom Right: Decide cut at |LHRS-BB vertex| <= 0.043 [m] (3 sigma) on the correlation between LHRS and BB vertex.

From figure I, there are some faint strip around x=y but the non-correlation at y = +/- 0.1 is much stronger. With the BB TOF cut in figure III, the correlation between LHRS and BB vertex become stronger almost along the x = y. In figure IV, it is easier to see that the correlation of LHRS-BB vertex is not exactly x = y.
With the new fitting on the main strip, the adjustment of the new BB vertex is

BB_vertex_new = 1.10742*BB_vertex_old – 0.00540.

The correlation between LHRS and BB vertex is now along x=y

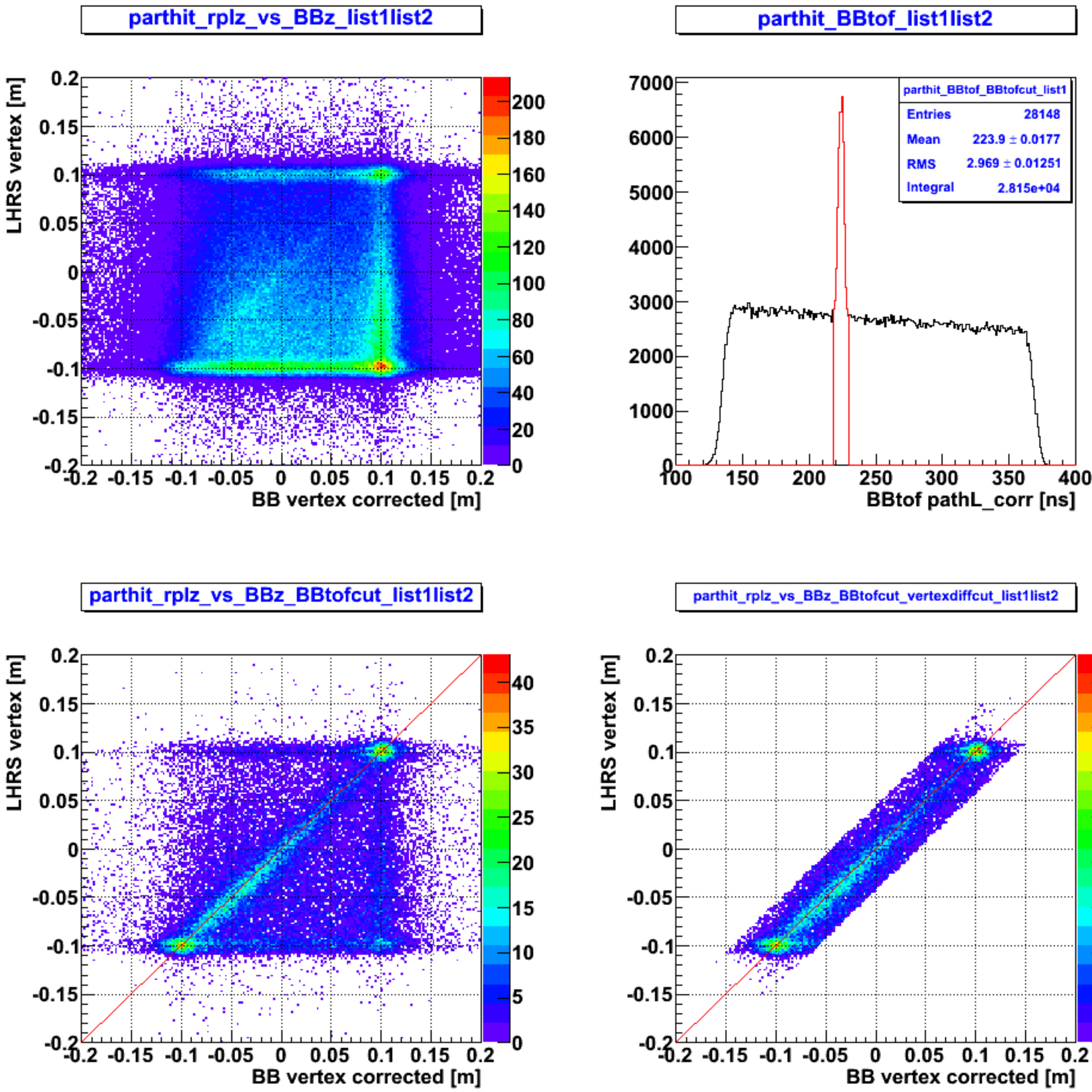


Figure (parthit)

5. Top Left : First look at the LHRS and BB vertex correlation.
6. Top Right : Then, look at the BB TOF and make a cut on the peak about 3*sigma. (224+/-6 ns)
7. Bottom Left : Then check LHRS and BB vertex correlation with BB TOF cut.
8. Bottom Right: Decide cut at |LHRS-BB vertex| <= 0.043 [m] (3 sigma) on the correlation between LHRS and BB vertex.

With the new BigBite vertex, we have also the new resolution on the vertex difference (Figure 2).

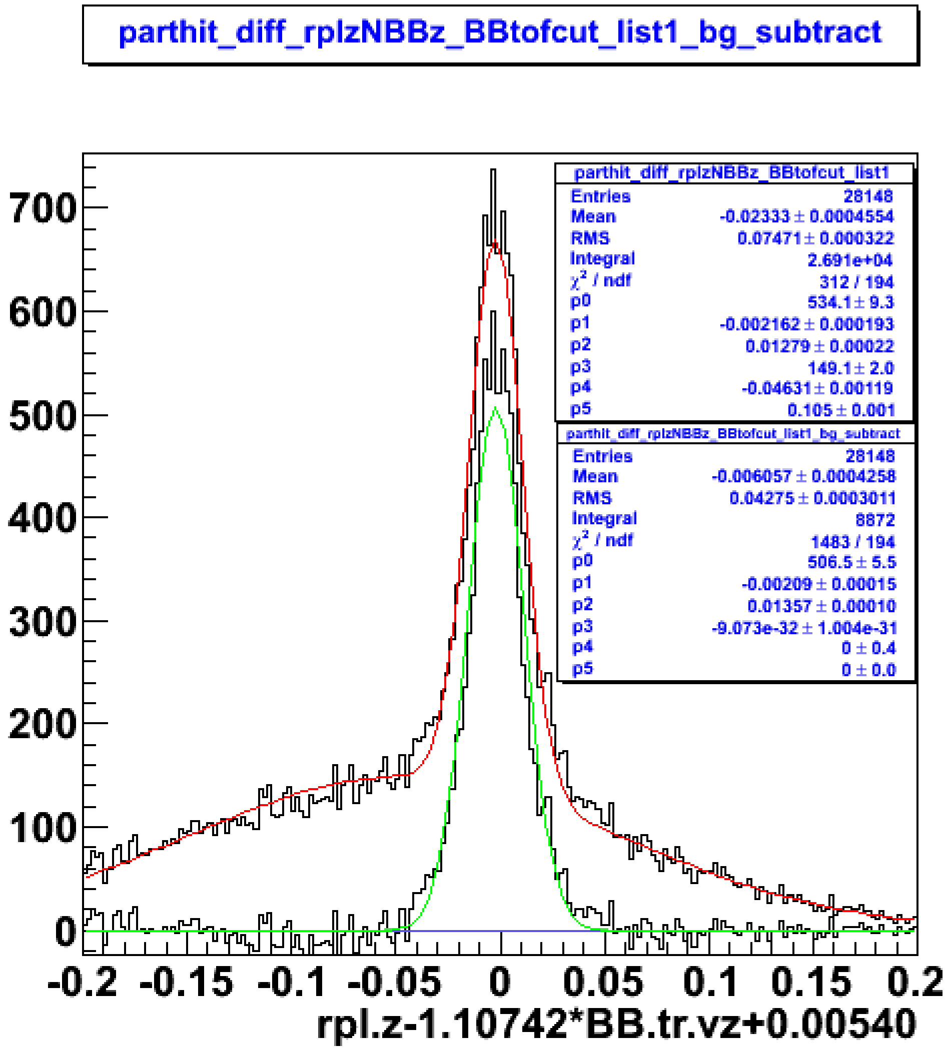


Figure (parthit)

IX. LHRS-BigBite vertex new** difference (x) with the cut on BB TOF 224+/- 6 ns. The histogram with TOF cut is fitted with the red line as a function of a Gaussian peak (p1,p2 = mean,sigma) and Gaussian background (p4,p5 = mean,sigma). The distribution with background subtraction is fitted with the green line as a function of a Gaussian peak on the flat background.

The vertex difference has the resolution of 1.28-1.35 cm (depend on the fit on top of bg or without bg). This mean we can make more refine cut at +/- 2.6 cm (for 2 sigma) or at +/- 4 cm (for 3 sigma).

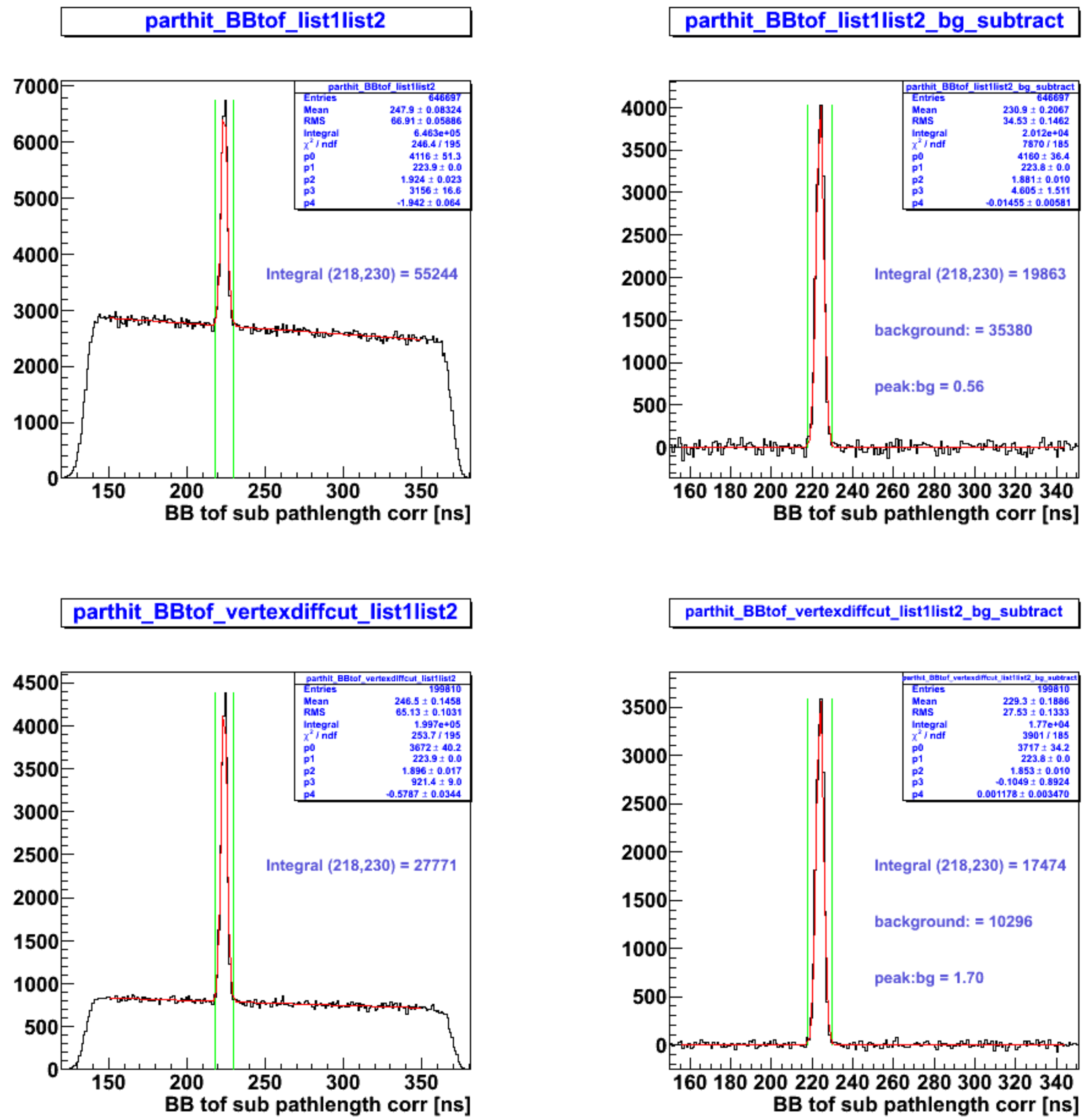


Figure (parthit)

X. Top Left: BB TOF with original cut.
XI. Top Right: BB TOF with background subtracted.
XII. Bottom Left: BB TOF with additional vertex cut at +/- 0.043 m.
XIII. Bottom Right: BB TOF with additional vertex cut and background subtracted.

The fit is Gaussian on the linear background. (p0,p1,p2) = Gaussian(constant,mean,sigma) and (p3,p4) = background pol1(x0,slop).

The integral of the interval +/- 3*sigma we get the ratio peak (bg_subtracted) : background to be 0.56, 1.70, without vertex cut and with the vertex cut respectively. The improvement is 3 time better.

There are some reduction of the signal. This is note here to be further investigated whether it is within the background uncertainty.

Now consider the fullhit proton where the data are in both dE & E trigger plane.
Proton selection using two graphic cuts on E vs p and dE vs p.

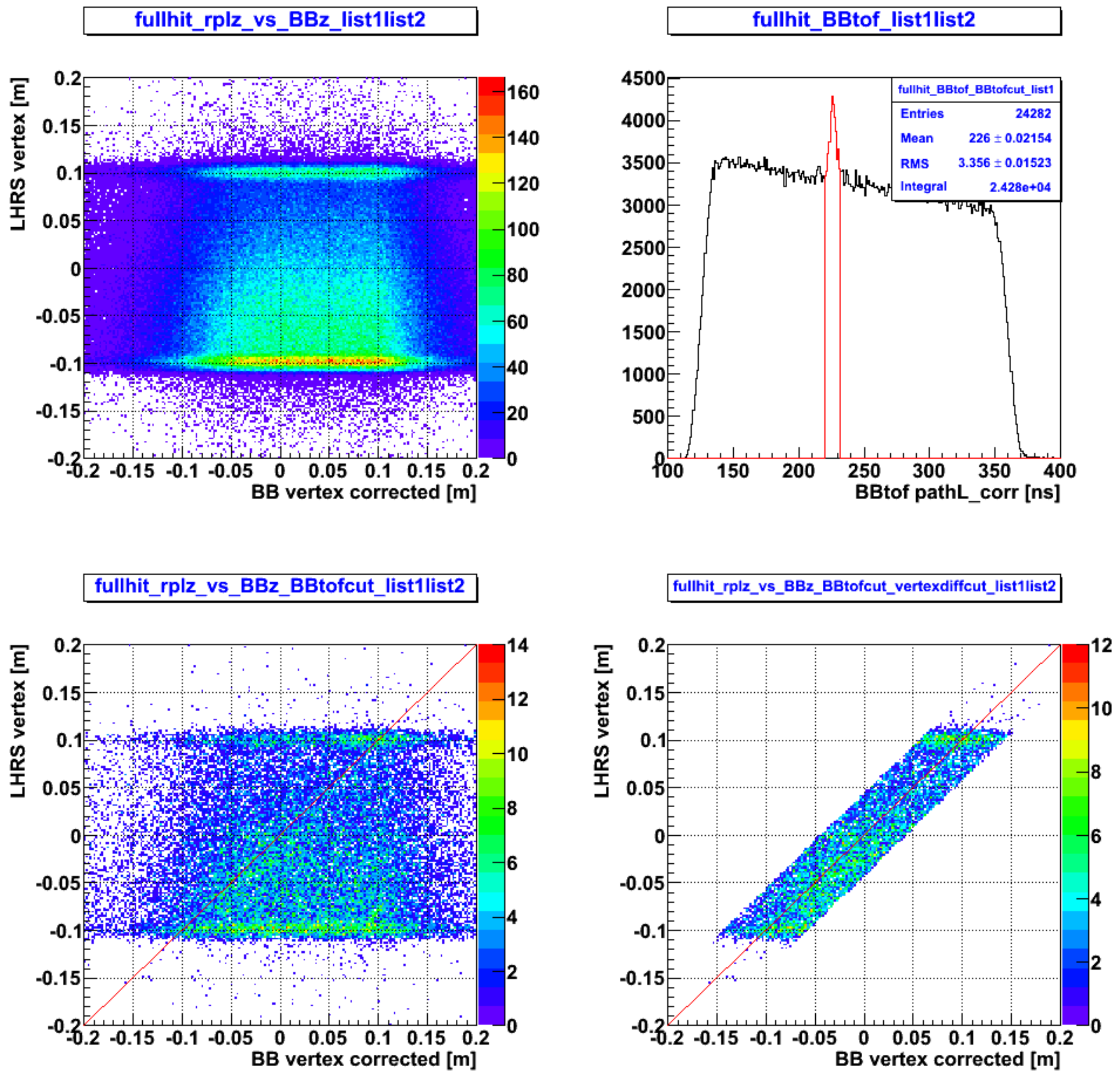


Figure (fullhit)

1. Top Left : First look at the LHRS and BB vertex correlation.
2. Top Right : Then, look at the BB TOF and make a cut on the peak about 3*sigma. (226+/-6 ns)
3. Bottom Left : Then check LHRS and BB vertex correlation with BB TOF cut.
4. Bottom Right: Decide cut at |LHRS-BB vertex| <= 0.043 [m] (3 sigma) on the correlation between LHRS and BB vertex.

This section of data mostly contain the low momentum proton (up to 550~600 MeV/c). And it contain very highly background which clearly shown in figure 2. Using the same BB TOF cut, the correlation strip is not show up from the background.

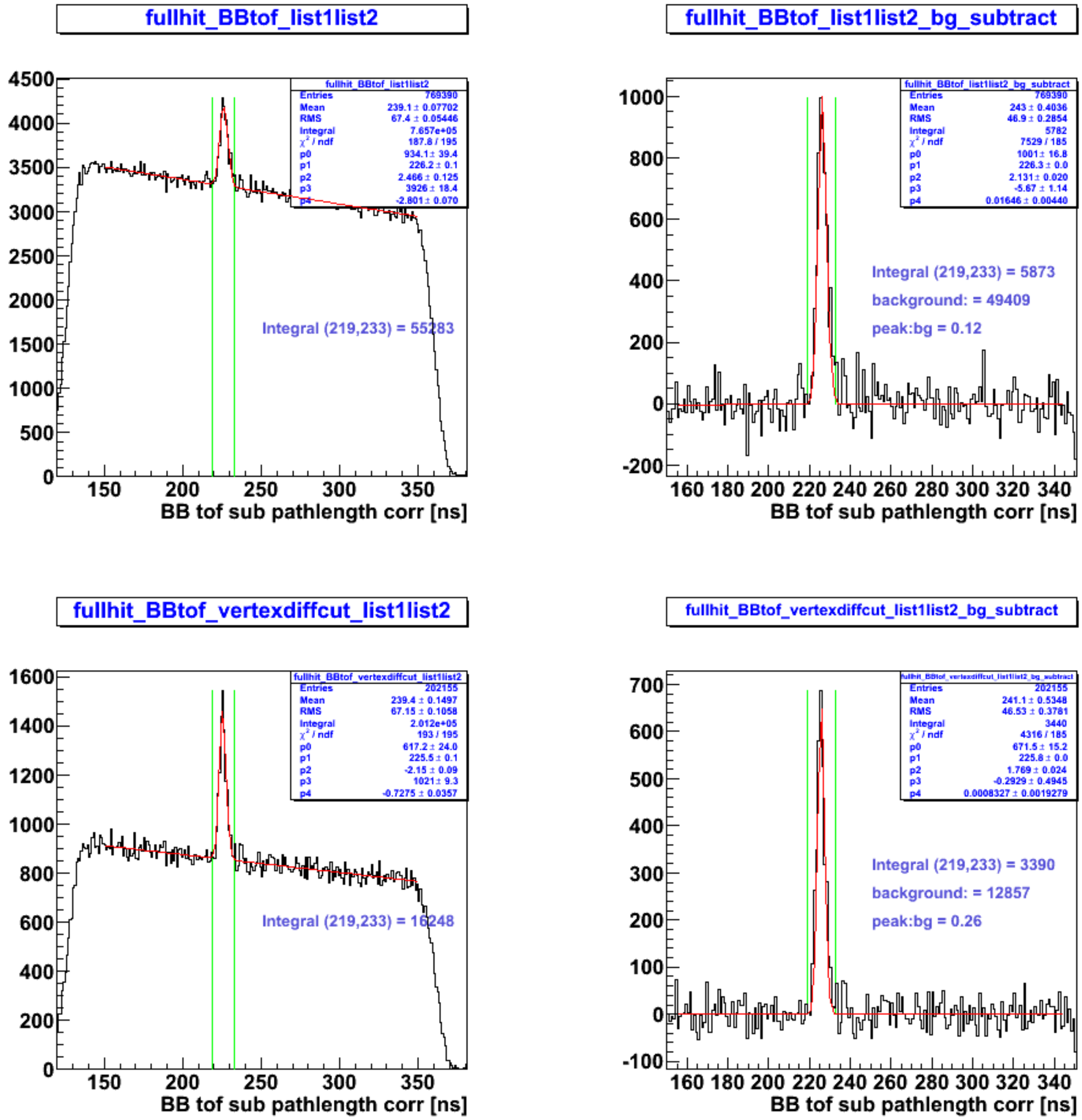


Figure (fullhit)

5. Top Left: BB TOF with original cut.
6. Top Right: BB TOF with background subtracted.
7. Bottom Left: BB TOF with additional vertex cut at +/- 0.043 m.
8. Bottom Right: BB TOF with additional vertex cut and background subtracted.

with the LHRS-BB vertex cut we do see the improvement of the signal to background , from 0.12 to 0.26 -> ~ 2 times, even though we cannot see the strong correlation between the vertexes.

End Cap Cut

In reality, we don't want the contribution from the end cap of the target. So, I impose the cut also on the end cap for both LHRS and BB vertex. |LHRS vertex|<0.08 && |BB vertex| < 0.08.

PartHit (high momentum portion)

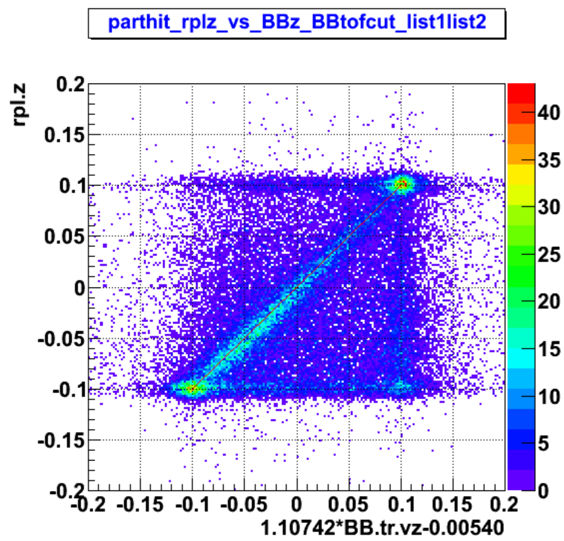


Figure 9.1: LHRS vertex vs BB corrected vertex in the BB TOF cut.
Without vertex End cap cut.
Make an easy spot at the end cap correlation at +/- 0.1 m.

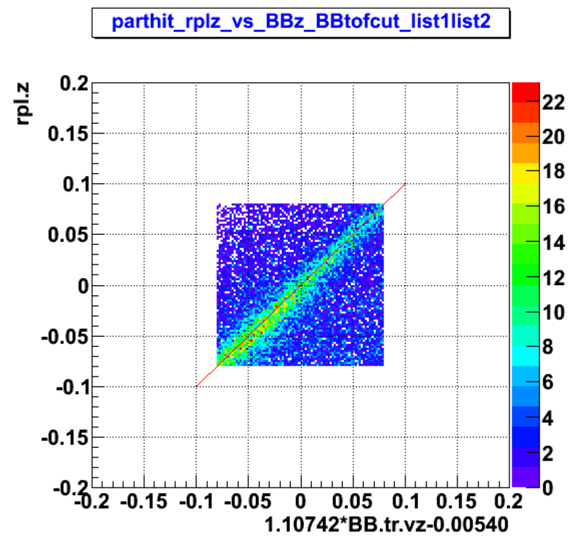


Figure 9.2: LHRS vertex vs BB corrected vertex in the BB TOF cut.
Considering data with the vertex End cap cut at +/- 0.08 for both LHRS and BigBite vertexes.

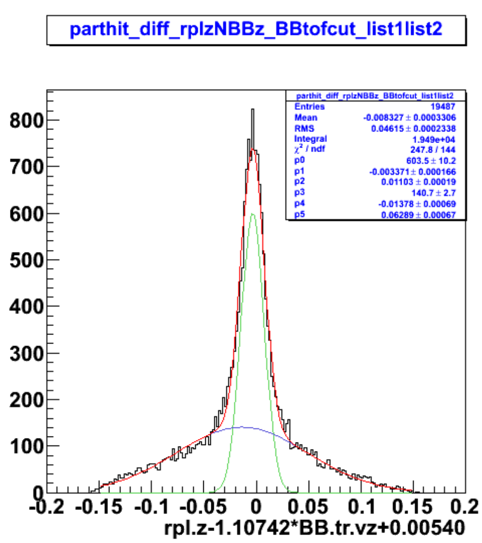


Figure 9.3: vertex difference resolution fitting with background estimate to be the Gaussian

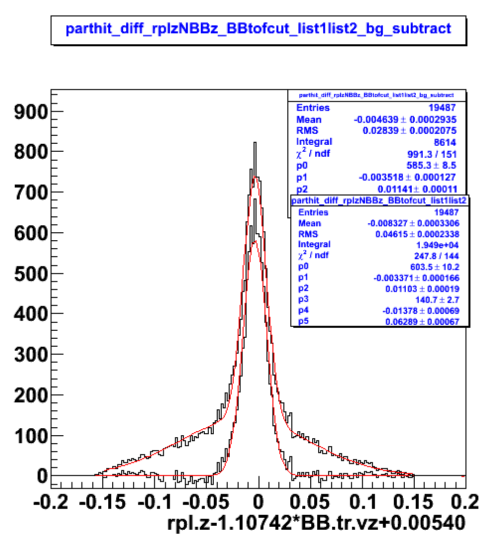


Figure 9.4: fitting vertex differenece with background subtracted.

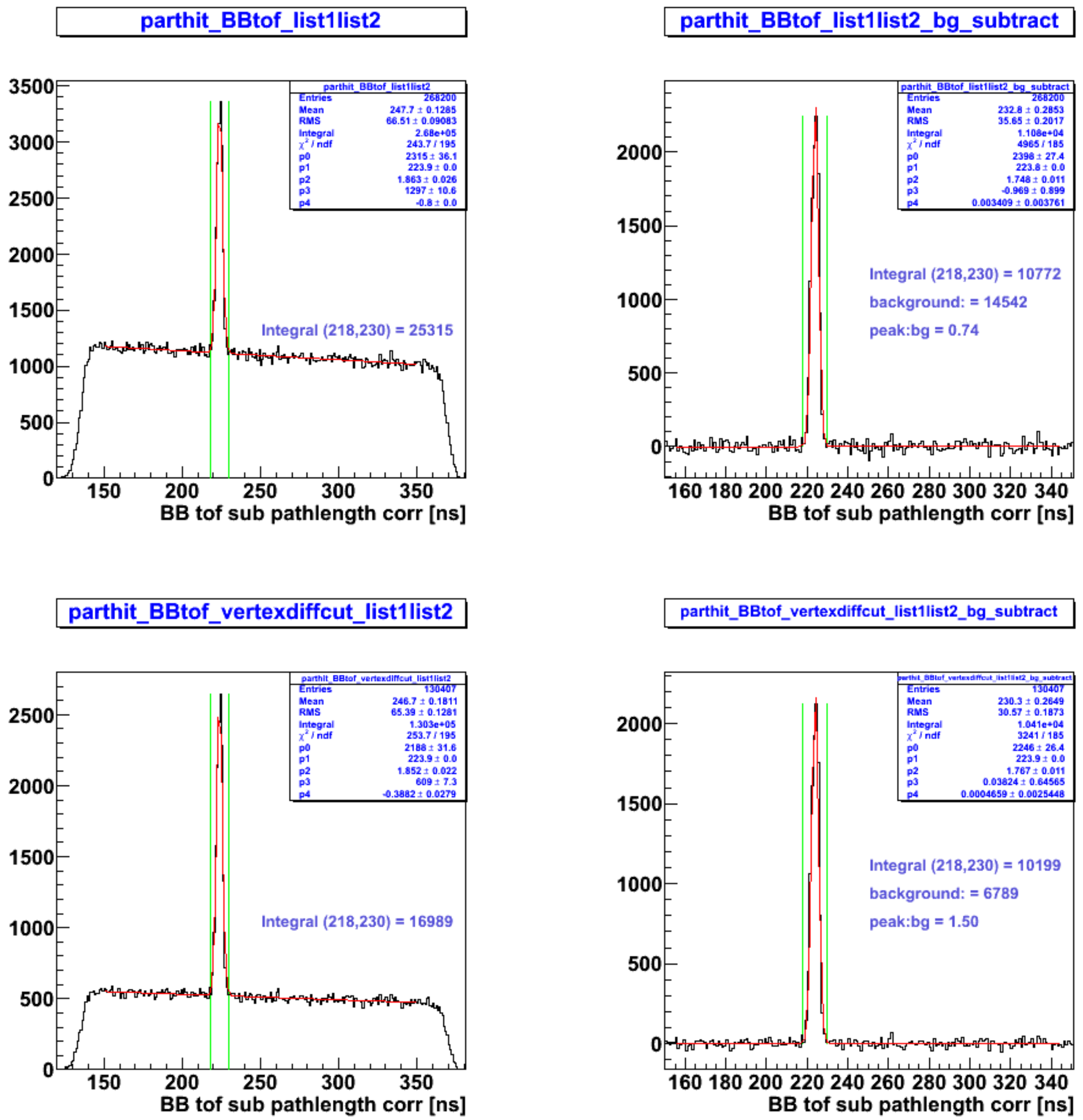


Figure 10.1: Top Left: BB TOF with LHRS-BB End caps cut
10.2: Top Right: BB TOF with LHRS-BB End caps cut and background subtracted Figure
10.3: Bottom Left: BB TOF with LHRS-BB End caps cut and the |LHRS-BB vertex|<0.043 m
10.4: Bottom Right: BB TOF with LHRS-BB End caps cut and the |LHRS-BB vertex|<0.043 m and background subtracted

From here the signal above background is almost constant. The ratio of signal- background to background improve from 0.74 to 1.50 which is ~ 2 times better.

From 10.1
Signal with background: S = 25315+/- 159.1 (using error of 1/sqrt(n))
Background function = (1297 +/-10.6) -0.8* BBtof
Background under the peak (from 218 to 230) = 15448.8 +/- 127.2

Signal – bg = 9866.2 +/- 203.7

From 10.3

Signal with background: S = 16989+/- 130.3 (using error of 1/sqrt(n))
Background function = (609 +/-7.3) –(0.388 +/- 0.028)* BBtof
Background under the peak (from 218 to 230) = 7252.1 +/- (87.6) +/- 4.0

Signal – bg = 9736.9 +/- 158.7

Signal –bg seem to be within the uncertainty of background estimation and the 1/sqrt(n) sample

From 10.5

Signal with background: S = 13527+/-116.3

Background function = (386 +/- 5.8) – (0.254 +/- 0.022) BBtof

Background under the peak = 4596.7 +/- 69.6+/-3.1

Signal – bg = 8930.3 +/-

With now 2* sigma of the vertex difference resolution:

The plots of tof are:

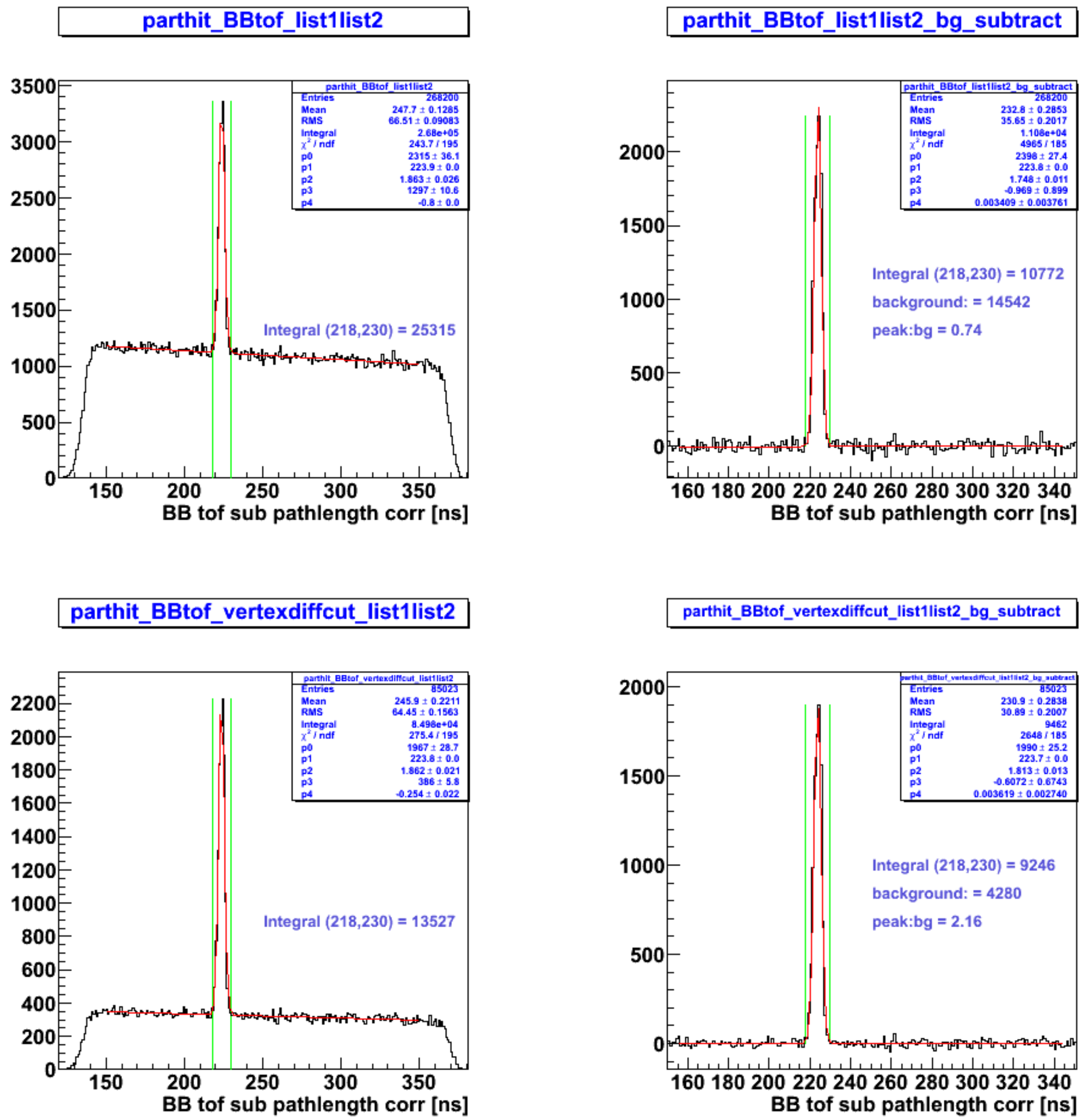


Figure 10.1: Top Left: BB TOF with LHRS-BB End caps cut
10.2: Top Right: BB TOF with LHRS-BB End caps cut and background subtracted Figure
10.5: Bottom Left: BB TOF with LHRS-BB End caps cut and the |LHRS-BB vertex|<0.0256 m
10.6: Bottom Right: BB TOF with LHRS-BB End caps cut and the |LHRS-BB vertex|<0.0256 m and background subtracted