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Update on B and $\mathbf{V}_{tb}$ determination

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Abstract

We update our determination of B, branching ratio of top decaying to bottom, using the full `RUN 1B` statistics ($\sim$ 90 pb^{-1}) of $W+ \geq 3$ jets events. We also present a determination of B using the entire `1B` dilepton sample. The two measurements are then combined to obtain a single value for B. In the end we set the lower limit B>0.61 (95 %), which translates into V$_{tb}$ >0.78 (if we assume 3 generation unitarity) and V$_{tb}$ >0.038 (if we drop the unitarity requirement).

Introduction

In a previous note [1] we obtained a determination of the branching fraction of top decaying to W and b using a $W+$ jets sample in which the top content was enhanced by cutting on kinematical variables. This approach was taken in an attempt to gain in statistics by including also untagged events in our sample and proved satisfactory. The increase in background due to the release of the tagging requirements was limited by the kinematical cuts. The amount of background in our sample was calculated using the data themselves by extrapolating from the background dominated region into the signal region. In sec. 2 we update our previous results using the entire `RUN 1B` sample which amounts at about 90 pb^{-1}.

The same technique was used to determine B in the dilepton sample. The statistics in this case is very limited even if this sample is expected to be much cleaner. In this case too, the full `RUN 1B` data have been used. This is described in sec. 3.

The two top samples mentioned above are orthogonal by construction. This allows us to easily merge the two analysis and obtain a single determination of B. This combined analysis which yields to our final result for B, is illustrated in sec. 4.

Finally, in sec. 5 we use this result to obtain a lower limit on V$_{tb}$.

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1 Data samples

This $W+$ jets analysis starts by selecting a $W+\geq 3$ jets sample according to the cuts listed in [1]. After this selection we are left with 214 events (98 electrons and 116 muons). We enhance the top content of this sample by cutting on the relative likelihood, L_{rel}, of the event. The sample obtained in this way, which we will call *Sample I*, is the one we use for our main determination of B. This result will be double-checked on a subsample of sample I in which we also apply a $\cos(\theta^{\star})$ cut (*Sample II*). This sample has less background but has smaller statistics, thus providing less significant limits. In addition the $\cos(\theta^{\star})$ cut is very sensitive to the details of the Monte Carlo and gives a larger systematic error on the acceptances.

The number of events in the two samples are shown in table 1 and 2. In this tables the number of events with 0, 1 or 2 b-tags are also shown. We recall that for this analysis only `SECVTX` tags are considered.

tags	no. events
0	53
1	10
2	5
total	68

Table 1: Sample I

tags	no. events
0	17
1	3
2	4
total	24

Table 2: Sample II

The dileptons analysis uses the standard dilepton cuts (see, for example, [2]). The total number of events and the total number of tags (`SECVTX` only) are shown in table 3. The $\mu\mu\gamma$ event is not removed from our sample.

tags	events
0	5
1	2
2	0
total	7

Table 3: Dilepton sample

2 $W+$ jets analysis

We determine B by fitting our data with a model that describes the number of (tagged and untagged) events in the sample in terms of the acceptances of our cuts, the tagging efficiency and an extimate of the expected background.

The quantities we need have been discussed in [1]. Here we only note a few differences. We have removed an additional 5 % systematical error we assigned to the tagging efficiency and we use primarly method II to determine the background in the 1 and 2 tag bins and method I (with top contribution subtracted) only as a double-check.

The final numbers are shown in tables 4 and 5.

quantity	sample I
ε	$0.56 \pm 0.01(stat)$
$\varepsilon_{s.f.}$	$0.95 \pm 0.07(stat+sys)$
r_1	$0.81 \pm 0.04(stat) \pm 0.07(sys)$
r_2	$1.07 \pm 0.05(stat) \pm 0.05(sys)$
f_1	$0.77 \pm 0.01(stat) \pm 0.03(sys)$
f_2	$0.28 \pm 0.005(stat) \pm 0.08(sys)$
b_{non-W}	$0.90 \pm 0.36(stat+sys)$
b_{SVX-}	$0.81 \pm 0.03(stat) \pm 0.16(sys)$
$b_{Wbb,Wcc}$	$0.80 \pm 0.36(stat+sys)$
b_{double}	$0.06 \pm 0.04(stat+sys)$

Table 4: Summary of fit parameters for sample I

quantity	sample II
ε	$0.57 \pm 0.01(stat)$
$\varepsilon_{s.f.}$	$0.95 \pm 0.07(stat+sys)$
r_1	$0.63 \pm 0.04(stat) \pm 0.08(sys)$
r_2	$1.31 \pm 0.08(stat) \pm 0.11(sys)$
f_1	$0.80 \pm 0.02(stat) \pm 0.03(sys)$
f_2	$0.23 \pm 0.01(stat) \pm 0.06(sys)$
b_{non-W}	$0.51 \pm 0.25(stat+sys)$
b_{SVX-}	$0.33 \pm 0.02(stat) \pm 0.07(sys)$
$b_{Wbb,Wcc}$	$0.22 \pm 0.11(stat+sys)$
b_{double}	$0.02 \pm 0.02(stat+sys)$

Table 5: Summary of fit parameters for sample II

In table 6 we report for convenience a summary of the way in which all systematical errors have been determined.

2.1 Fit results

The results of the fit are shown in table 7. The results between the fits done using method I and method II background calculations are quite consistent. We will use method II background in the following.

The predictions of the fit are in good agreement with the number of events observed in each sample, as shown in table 8. In the same table we show the results when B is set to a value of 1. The agreement, within errors, is good.

In fig. 1 we show the likelihood function for this fit. Using the method described in our previous note we can determine from these fits a lower limit on B. The 90 and 95 % C.L. limits on B are shown in table 9.

quantity	sys. error
$\varepsilon_{s.f.}$	see CDF 2989
r_1	E_T scale (± 10 %) $\oplus$ ISR on/off
r_2	E_T scale (± 10 %) $\oplus$ ISR on/off
f_1	E_T scale (± 10 %) $\oplus$ Q^2 variation
f_2	E_T scale (± 10 %)
$b_{1,o}$	$\sim$ 30–50 %
$b_{1,f}$	assume 15 % (positive), 20 % (negative)
b_2	method II calculation

Table 6: Summary of systematical uncertainties assigned to fit parameters

B	sample I (meth. I bkg)	sample I (meth. II bkg)
stat	$1.39^{+0.40}_{-0.37}$	$1.40^{+0.43}_{-0.39}$
stat + sys	$1.42^{+0.41}_{-0.39}$	$1.45^{+0.44}_{-0.42}$

Table 7: Fit results using the $W+$ jets sample (sample I). Results are shown for both cases when only stat. errors and stat. plus syst. error are used in the fit

tags	0	1	2
data	53	10	5
fit	51.46	10.39	4.92
fit (B=1)	53.54	12.07	3.21

Table 8: Fit prediction compared with observed number of events (sample I)

CL	Sample I
90 %	B $>$ 0.67
95 %	B $>$ 0.61
CL	Sample II
90 %	B $>$ 0.66
95 %	B $>$ 0.59

Table 9: Lower limits on B

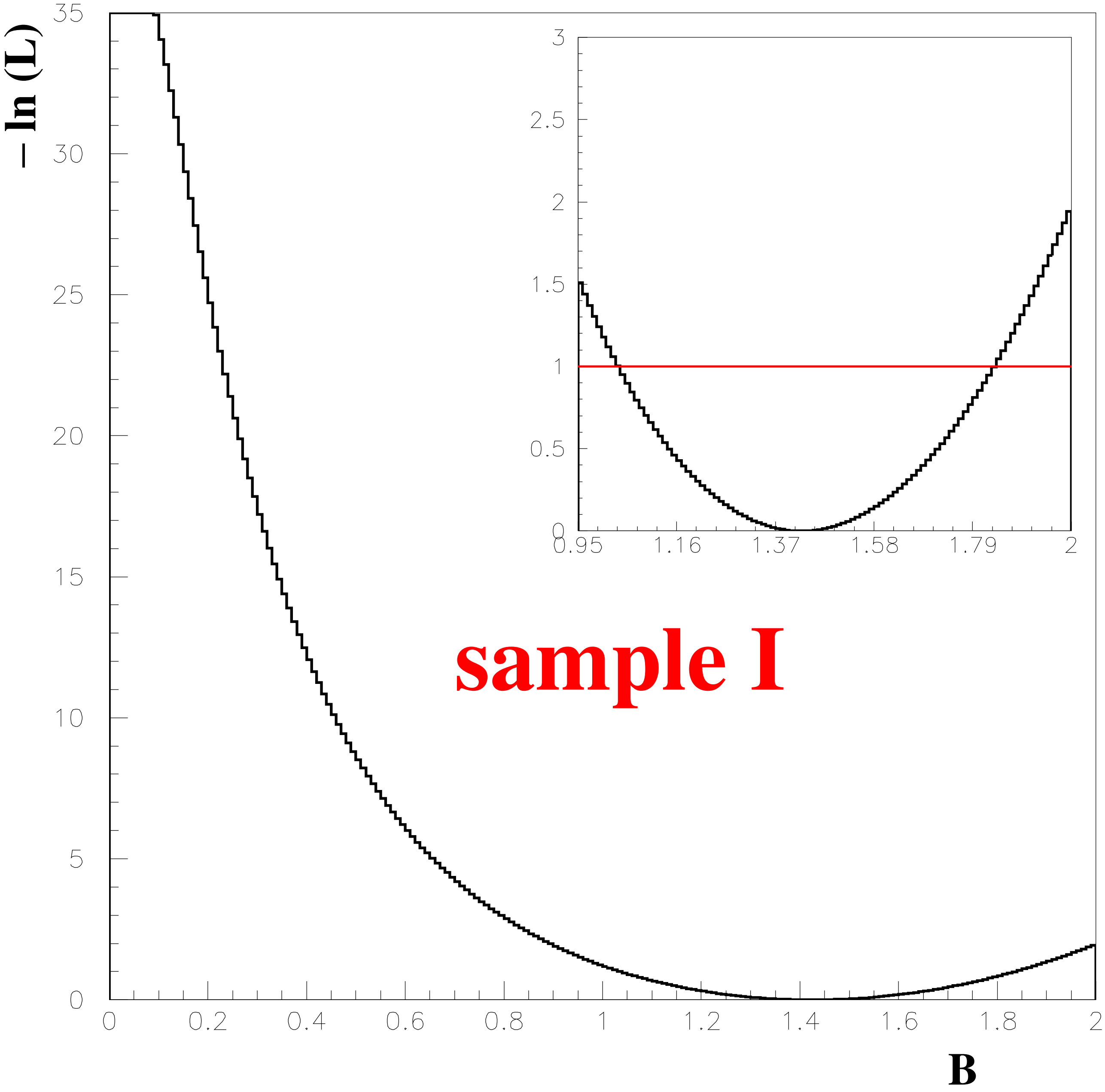

Figure 1: Plot showing the negative logarithm of the likelihood function $\mathcal{L}$ as a function of parameter B for sample I. The inset histogram is a blow-up of the minimum region.

3 Dilepton analysis

The technique we use in this case is similar to the one we use for the $W+$ jets case. Also in this case we fit the number of events observed in the three rows of table 3. The tagging efficiency and the acceptances for this analysis are determined on the same MC as in the $W+$ jets case (PYTHIA $\mathrm{M}_{top} = 170$ GeV/c^2).

The background before tagging is taken from note [2] and scaled by. The background after tagging is calculated by applying to our sample the positive SECVTX fake parametrization: the top contribution is subtracted after the calculation. The double tagged background is assumed to be ~ 10 times smaller than the single tagged background (as in the $W+$ jets case) and a large error is assigned to it (100 %).

A list with all the values assigned to the parameters relevant to this analysis is shown in table 10 and a summary of the way we assigned a systematical error is given in table 11.

quantity	DIL sample
ε	$0.55 \pm 0.02(stat)$
$\varepsilon_{s.f.}$	$0.95 \pm 0.07(stat+sys)$
r_1	$0.77 \pm 0.08(stat) \pm 0.12(sys)$
r_2	$0.77 \pm 0.08(stat) \pm 0.04(sys)$
b_{before}	$1.77 \pm 0.40(stat+sys)$
b_{after}	$0.08 \pm 0.03(stat) \pm 0.02(sys)$
b_{double}	$0.01 \pm 0.01(stat+sys)$

Table 10: Summary of dilepton parameters

quantity	sys. error
$\varepsilon_{s.f.}$	see CDF 2989
r_1	$\mathrm{E_T}$ scale (± 10 %) $\oplus$ ISR on/off
r_2	$\mathrm{E_T}$ scale (± 10 %) $\oplus$ ISR on/off
b_{before}	see CDF 3203
b_{SVX+}	assume 15 %
b_2	100 %

Table 11: Summary of systematical uncertainties assigned to fit parameters

3.1 Fit results

The results of the fit are shown in table 12.

The predictions of the fit are in good agreement with the number of events observed in each sample, as shown in table 13.

In fig. 2 we show the likelihood function for this fit.

Using the method described in our previous note we can determine from this fit a lower limit on B. The results are shown in table 14.

B	DIL sample
stat	$0.72^{+0.65}_{-0.41}$
stat + sys	$0.72^{+0.66}_{-0.41}$

Table 12: Fit results using the dilepton sample. Results are shown for both cases when only statistical errors and statistical plus systematical error are used in the fit.

tags	0	1	2
data	5	2	0
fit	5.43	1.45	0.24
fit (B=1)	4.84	1.67	0.43

Table 13: Fit prediction compared with observed number of events (dilepton sample)

CL	DIL sample
90 %	B > 0.28
95 %	B > 0.20

Table 14: Lower limits on B

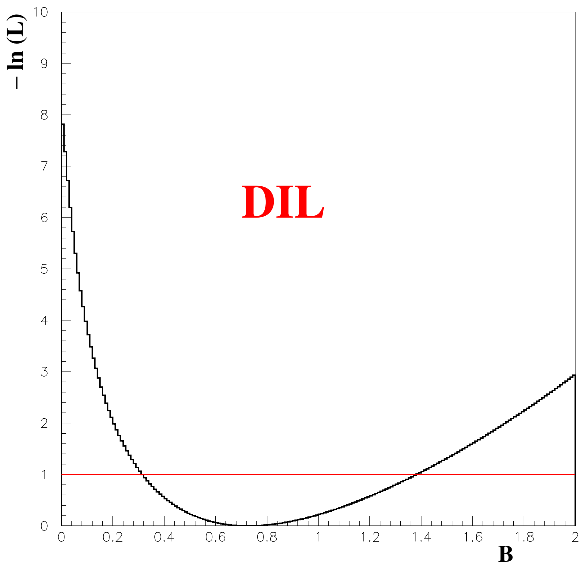

Figure 2: Plot showing the negative logarithm of the likelihood function $\mathcal{L}$ as a function of parameter B for the dilepton case.

4 Combined analysis

The two samples we have used in the two previous sections are not correlated so we can easily combine them to gain in statistical power. We write a single likelihood function that includes terms from both the single likelihood previously used and we do a minimization.

The results of the fit are presented in table 15.

B	sample I + DIL
stat	$1.23^{+0.37}_{-0.31}$
stat + sys	$1.25^{+0.38}_{-0.33}$
B	sample II + DIL
stat	$1.19^{+0.47}_{-0.43}$
stat + sys	$1.44^{+0.47}_{-0.44}$

Table 15: Fit results combining the $W+$ jets and dilepton results

The predictions of the fit are in good agreement with the number of events observed in each sample, as shown in table 16 for sample I. Again, in the same table we show the results when B is set to a value of 1. The agreement, within errors, is good.

tags	0	1	2
data	53	10	5
fit	52.16	11.23	4.18
fit (B=1)	53.57	12.08	3.19
data	5	2	0
fit	4.38	1.74	0.63
fit (B=1)	4.81	1.68	0.44

Table 16: Fit prediction compared with observed number of events. The upper block refer to the $W+$ jets sample I and the lower one to the dilepton sample.

The likelihood distribution for the combined sample I and dilepton fit is shown in fig. 3. From these fits we obtain the lower limits on B reported in table 17.

CL	Sample I + DIL
90 %	B > 0.67
95 %	B > 0.61
CL	Sample II + DIL
90 %	B > 0.66
95 %	B > 0.60

Table 17: Lower limits on B.

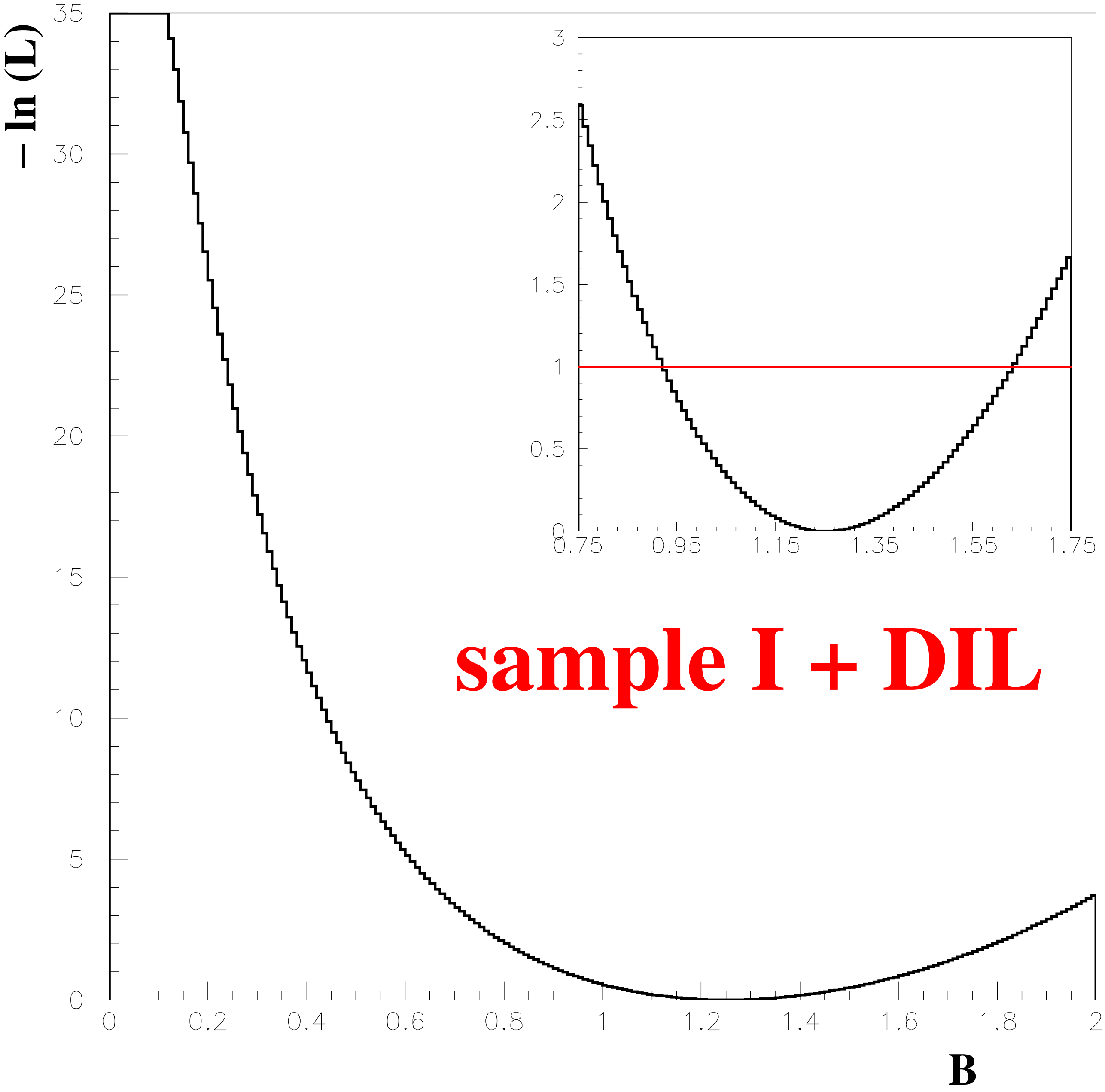

Figure 3: Plot showing the negative logarithm of the likelihood function $\mathcal{L}$ as a function of parameter B for the combined sample I and dilepton fit. The inset histogram is a blow-up of the minimum region.

As it can be seen from table 15, the statistical uncertainty accounts for most of the error on B. Nevertheless to check the effect of systematic errors on our result we have decided to perform an initial fit using only the statistical errors, then move each parameter up and down by an amount equivalent to the size of the corresponding systematic error and then refit. The net effect on the lower limit on B is shown in table 18.

quantity	-1σ	central value (stat. error only)	$+1\sigma$
ε	0.64		0.63
$\varepsilon_{s.f.}$	0.65		0.62
r_1	0.63		0.64
r_2	0.64		0.63
f_1	0.66		0.60
f_2	0.64		0.62
b_{non-W}	0.64	⋮	0.63
b_{fake}	0.64	0.64	0.63
b_{double}	0.64	⋮	0.63
ε_{dil}	0.64		0.63
$r_{1,dil}$	0.63		0.64
$r_{2,dil}$	0.64		0.63
b_{before}	0.63		0.64
b_{after}	0.64		0.63
b_{double}	0.76		0.64

Table 18: Lower limits (all at the 95 % CL) on B obtained by scaling each fit parameter up and down of one (systematical) sigma. The central value for the variations is obtained by using only statistical errors in the fit.

As a further consistency check we have compared the rL shape observed in the data with a weighted average of the rL shapes taken from Top Monte Carlo and Vecbos. The percentage of top and background have been derived from the results of our likelihood fit to B. The comparison is shown in fig. 4. Within the statistics, our results are a good description of the shape of the data.

5 Determination of V$_{tb}$

The lower limit on B can be converted in a limit on V_{tb}, the Cabibbo-Kobayashi-Maskawa matrix element linking *top* with *beauty*. We will use the limit obtained when combining the $W+$ jets sample with the dilepton sample.

As shown in [1] one can obtain two different set of limits on V_{tb} depending upon the assumptions made [3]. Assuming 3 generation unitarity $B = |V_{tb}|^2$ we deduce the limits on V_{tb} (see table 19).

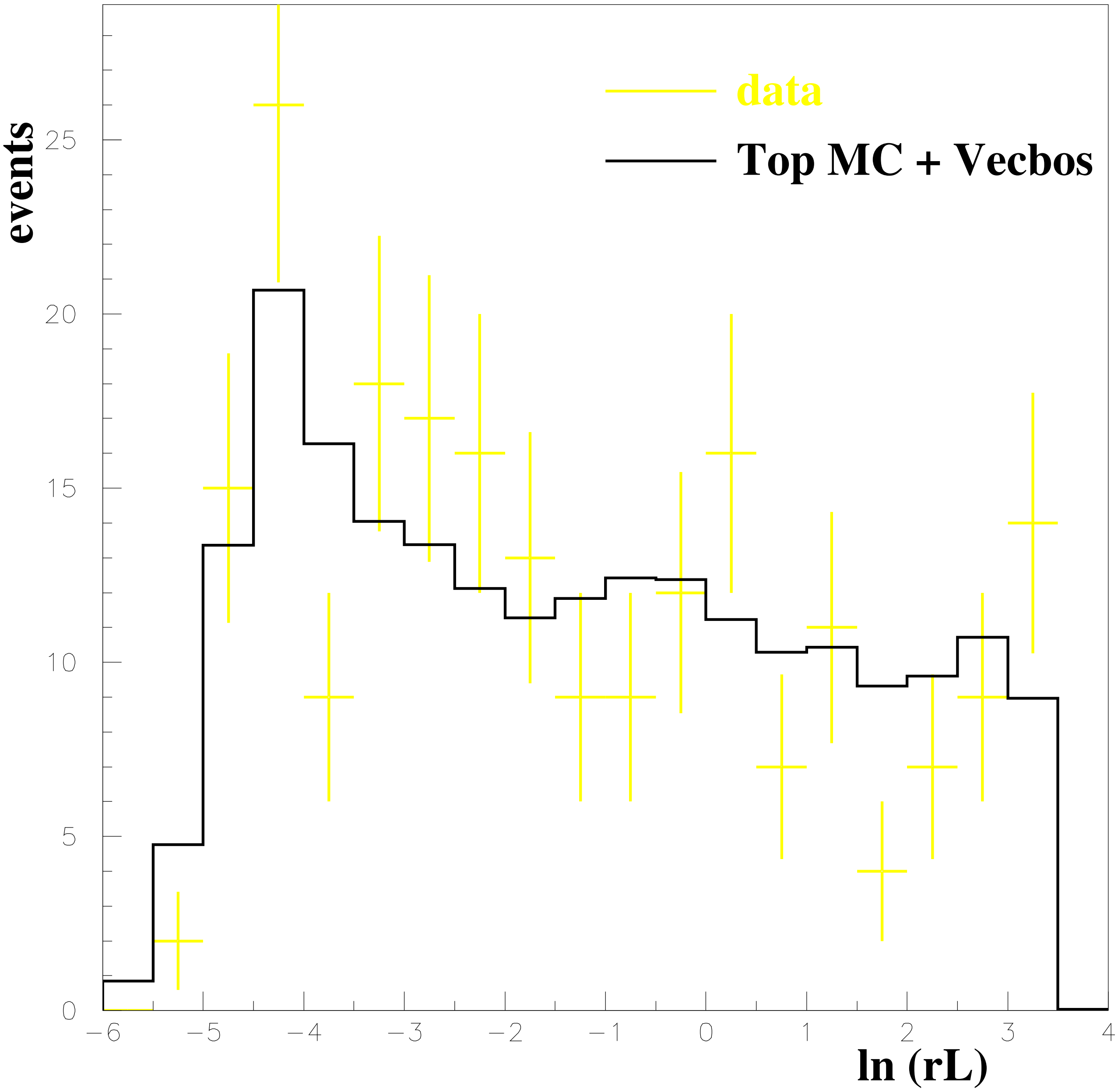

Figure 4: Histogram showing the relative likelihood shape observed in the data (points with errors). Superimposed we show the sum of the rL shapes of Top MC and Vecbos weighted with the results of our fit to B.

If one now releases the requirement of 3 generation unitarity, B is related to the CKM

	sample I + DIL	sample II + DIL
90 % CL	$V_{tb} > 0.82$	$V_{tb} > 0.81$
95 % CL	$V_{tb} > 0.78$	$V_{tb} > 0.77$

Table 19: Limits on V_{tb} assuming unitarity.

elements by the following relation:

$$B = \frac{|V_{tb}|^2}{|V_{tb}|^2 + |V_{td}|^2 + |V_{ts}|^2}$$

where $0.004 \leq |V_{td}| \leq 0.015$ and $0.03 \leq |V_{ts}| \leq 0.048$. Taking the lower values for $|V_{td}|$ and $|V_{ts}|$ we obtain our 90 and 95 % CL on $|V_{tb}|$ (see table 20).

	sample I + DIL	sample II + DIL
90 % CL	$V_{tb} > 0.043$	$V_{tb} > 0.042$
95 % CL	$V_{tb} > 0.038$	$V_{tb} > 0.037$

Table 20: Limits on V_{tb} after releasing unitarity constraint.

References

[1] F. Bedeschi *et al.*, CDF 3369.

[2] J. Konisberg *et al.*, CDF 3203.

[3] T. J. LeCompte, R. M. Roser, CDF 3056.