Double counting of tracks in the IDL : biases as seen in real data and Monte Carlo

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March 1996

Charged particles giving more than one S1 hits sometimes lead the IDL to count two tracks instead of one. Some golden events with a decay inside PC2 were thus rejected with the old trigger. Such events are studied both on real (P28b, no IDL) and simulation data. Good agreement between data and Monte Carlo is found. The study predicts an M1–M2 effect of approximately half the size of that observed in old trigger data and a shift of $\approx 1^0$ on the value of ϕ_{+-} as fitted in the sum of equal parts of M1 and M2 data. A cut (events where the IDL doublecounts a primary particle) is proposed to remove this bias from old trigger data. This cut is tested on $\pi^+\pi^-$ and semileptonic real data.

1 Introduction

It is known that charged particles sometimes either cross two adjacent S1 sectors and give light in both, or give rise to more than one S1 hits due to secondary particles from interactions in the PID or surrounding materials. The IDL track and primary definition (presence of hits in (DC6/5), (DC1/2) and (PC1/2)) can sometimes lead to double counting of such tracks. As presented by M. Dejardin and A. Cody at the begining of March, for decays inside the PCs this may lead to the existence of 5 or more IDL primaries, resulting in the rejection of the event by the IDL decision. However, if the decay is outside PC2, the double counting may lead to e.g. 3prim/5tracks, which are not rejected. Since the probability of double counting was shown to be asymetric for charge (different interactions) and curvature (imperfections in the relative alignment of DCs–PID), this would create a variation of normalization with radius and thus give rise to an M1–M2 discrepancy.

This effect has been studied using both MC and the real data of P28b, where the IDL was passive and its decision can be reproduced offline using the trigger simulation. This report demonstrates how the effect results in an M1–M2 difference and also to a residual in the sum of fields, as far as ϕ_{+-} is concerned. If one cuts offline all events where the IDL has counted two times any of the real primary particles ($K^{\pm}\pi^{\mp}$), then the different treatment inside/outside PCs is compensated for and the biases are removed. This is shown using the $\pi^+\pi^-$ and semileptonic data samples taken with the old trigger conditions (P25–P28a).

Throughout this report the trigger simulation is assumed to be perfect; any question about this is outside its scope.

2 Extra S1 hits and IDL tracks

We know from the offline pattern recognition through which S1 sector a charged particle goes and if this S1 has fired. We also have available the full hit map of S1's (from pattern units, as seen in EDL). This allows us to separate the events where any S1 has fired appart from those associated to tracks by the pattern. On both real data (figure 1) and Monte Carlo (figure 2) we have about 40% of events with such extra hits. In both cases this percentage is higher for K^- events. When comparing the two figures one should keep in mind that they are before any LUT correction and that any small difference in absolute levels is less important than the time– or radius–dependent shapes. In 25% of events one of the primaries ($K^{\pm}\pi^{\mp}$) gives at least one extra S1 hit.

If a particle fires two S1 sectors one next to the other, then there is a probability that the IDL starting from both sectors and using the same hits (or the ones from a real backscattered particle) will count the track two times. This results in the IDL counting one extra track in 8.5% of good events. This is almost equally due to all 4 tracks of the event. If the additional track is seen as primary, then an extra primary track will be taken into account for the IDL decision. Things get complicated since for decays inside the PCs, as the decay radius increases the probability to loose a real track in the IDL tracking also increases. In any case, events seen in the IDL as having more than 5 primaries are killed. The precentage of such events for

P28b real data are plotted in figure 3 as function of transverse decay radius. The same plot as function of decay time are shown in figure 4 for real data and 5 for MC.

Detailed studies and parametrisations of the extra S1 hits correlated to the real kaons/pions are going on by A. Cody and M. Carroll.

3 Relevance for the M1–M2 effect

Using the trigger simulation, one can cut given events and look at the M1–M2 difference on the real data of P28b. In all this study and for each cut normalization LUTs were done for each sample and used in the following way : M1 and M2 are corrected by their own separate LUTs and the M1+M2 sum is corrected by a single crossed LUT, as done in the physics analysis procedure. The results obtained for P28b are shown in table 1.

Trig. cut	M1	M2	Δ(M1–M2)
P28b trig	$45.43^0 \pm 1.73^0$	$42.77^0 \pm 1.68^0$	$2.66^0 \pm 2.41^0$
IDL=3	$49.13^0 \pm 1.87^0$	$41.54^0 \pm 1.92^0$	$7.59^0 \pm 2.68^0$
P27 trig	$49.29^0 \pm 1.97^0$	$41.92^0 \pm 1.96^0$	$7.37^0 \pm 2.79^0$

Table 1: P28b data : the ϕ_{+-} value for the two fields after LUT normalization for different simulated trigger cuts

We observe that the IDL is responsible for all of the M1–M2 difference we can introduce on the new trigger data. The IDL=3 rejects : i) events seen as 3 primary, 3 tracks ii) events seen to have more than 4 primaries, independent of number of total tracks. The last category can be further splitted : In some cases there are extra hits in the chambers, so the track follower will find more than four total tracks, and these events would be rejected by the CONFIG=3 decision. When the extra IDL track is using the same hits as the good one, then this extra track will be marked invalid by the track follower and the event would survive the CONFIG cut. The study has shown that both on MC and real data the M1–M2 effect arises from this last category of ghost IDL tracks, as demonstrated in table 2.

CONFIG=3	M1	M2	Δ(M1–M2)
fail	$45.41^0 \pm 1.74^0$	$42.87^0 \pm 1.77^0$	$2.54^0 \pm 2.46^0$
pass	$48.98^0 \pm 1.76^0$	$41.51^0 \pm 1.80^0$	$7.47^0 \pm 2.50^0$

Table 2: P28b data : rejecting events with more than four IDL primaries, separately depending on track follower output

4 The IDL ghost primaries effect on real data and MC

The advantage of tracking down a problem to a small percentage of events is that one can look for asymmetries in the fractions of rejected (K^0, $\overline{K^0}$, M1, M2) events, which increases the statistical significance given any number of total real or MC events. In figure 6 one can see (before the use of LUTs) the change in normalization as function of transverse decay radius for M1 and M2 separatelly on the real data of P28b, when we remove the last subcategory of events with ghost tracks in the IDL. Figure 7 shows the same for the flat $\pi^+\pi^-$ MC events. The agreement is remarkable, keeping in mind that the $1\tau_s$ cut we always do in both data and MC would have a different reflection inside 4cm (exp–flat).

Then we correct the M1 and M2 MC events with proper LUTs before and after the cut of the ghost IDL events, and we look for the shape introduced in the $A_\pm$ curves of the two fields by this cut. This corresponds to the M1–M2 difference of table 2. This is shown in figure 8, where we observe that the effect introduced in M1 is bigger than the one in M2. This difference could lead to a residual bias in the final results after combining M1 and M2 data in equal amounts. In figure 9 the same plots are shown for the P28b real data. The absolute levels are not important; the agreement of shapes is the interesting thing. The range of all plots in x and y is the same.

The two shapes are parametrised with polynomials as can be seen in figures 10 and 11 for the two fields. The average of the two curves can be assumed to describe the residual in the final result. This is parametrised in figure 12. Then, as a crosscheck, these parametrizations are used to describe a time dependent normalization in the fit of the $A_\pm$ curves of the old trigger (P25–P28a) data. This then removes half of the M1–M2 ϕ_{+-} difference and shifts the final result downwards by 1^0. The numbers are presented in table 3. The results obtained on P28b data are shown in table 4 for comparison.

Sample	As is	Using MC corr.
M1	2.325 ± 0.061	2.312 ± 0.067
	$51.13^0 \pm 1.20^0$	$47.59^0 \pm 1.24^0$
M2	2.097 ± 0.061	2.087 ± 0.062
	$38.87^0 \pm 1.37^0$	$41.42^0 \pm 1.37^0$
M1+M2	2.189 ± 0.046	2.205 ± 0.045
	$45.10^0 \pm 0.92^0$	$44.06^0 \pm 0.92^0$

Table 3: P25–P28a data (old trigger): results after LUTs, left as is, right using MC bias parametrizations

Sample	As is	IDL ghosts cut
M1+M2	2.173 ± 0.062	2.157 ± 0.063
	$44.25^0 \pm 1.23^0$	$45.37^0 \pm 1.26^0$

Table 4: P28b data (new trigger): results after LUTs, left as is, right cutting events where only the IDL sees more than 4 primaries (ghosts)

5 A cut to remove the bias

The use of parametrizations from MC poses the problem of how well this reproduces the interactions responsible for the extra S1 hits. We know that this (interactions in our low energy region) is the weakest part of our simulation. Moreover, as one can see from figure 9, in the real $\pi^+\pi^-$ data there is not enough statistics above $5\tau_s$ to define the level of the curves and thus no direct comparison to the MC (fig. 8) can be made in this region. Given these facts, it would be difficult to define the systematic error from such a correction.

On the other hand, if one is able to define a "symmetrization" cut which would make the selection of all events independent of the decay radius, then the problem is solved in principle. This restoration of equal treatment inside/outside PCs is already being used for other parts of the trigger (dE/dx AND logic, KK logic). Up to now no extra systematic error is taken into account for all such symmetrization operations.

For our particular case, and given the symmetry of the $\pi^+\pi^-$ final state, the problem arises from the different double counting probabilities of the primary $K^\pm$ and $\pi^\mp$ particles, which played a role in the IDL decision only in the presence of four real primary tracks (decay inside PCs). An obvious symmetrization cut is to remove all events where any of the two primary particles is doublecounted in the IDL. One has to prove the following for this cut :

- it does not change the results of P28b
- it removes on P28b the bias introduced by simulation of the IDL
- it has a similar behaviour on the old trigger data (P25–P28a)

The first two points are proven by comparing the results in table 5 to the ones in tables 1 and 2, in terms of M1–M2 difference. By comparing table 6 to 4 the same is seen for the overall M1+M2 result.

Applying the cut on P25–P28a data, the ϕ_{+-} difference is decreased by 5.6^0 and the average result is shifted downwards by 1.6^0, as can be seen in table 7.

cuts	M1	M2	Δ(M1–M2)
sym	$45.04^0 \pm 1.79^0$	$42.81^0 \pm 1.81^0$	$2.23^0 \pm 2.55^0$
IDL+sym	$45.04^0 \pm 1.82^0$	$43.03^0 \pm 1.83^0$	$2.01^0 \pm 2.56^0$

Table 5: P28b data : Effect of the symmetrization cut before and after simulation of the IDL more than 4 primaries cut

Sample	sym. cut	IDL(gt4prim)+ sym. cut
M1+M2	2.159 ± 0.063	2.147 ± 0.063
	$44.05^0 \pm 1.26^0$	$44.14^0 \pm 1.28^0$

Table 6: P28b data (new trigger): effect of the symmetrization cut on the physics results

Sample	As is	after sym. cut
M1	2.325 ± 0.061	2.324 ± 0.068
	$51.13^0 \pm 1.20^0$	$46.77^0 \pm 1.25^0$
M2	2.097 ± 0.061	2.091 ± 0.062
	$38.87^0 \pm 1.37^0$	$40.14^0 \pm 1.39^0$
M1+M2	2.189 ± 0.046	2.202 ± 0.046
	$45.10^0 \pm 0.92^0$	$43.53^0 \pm 0.93^0$

Table 7: P25–P28a data (old trigger): results after LUTs, left as is, right after the symmetrization cut

6 Effect of the cut on semileptonic data

The proposed symmetrization cut was also studied on old trigger semileptonic data. The advantage in this decay chanel is that statistics are almost equally distributed in the regions inside/outside PCs, so one can measure the normalization level in this two regions and actually measure a step at 12cm and its change after the cut. Moreover it is a different and asymmetric final state, so the efficiency of the cut (only on primaries) is tested in a more stringent environment. The disadvantage is that the total number of events is lower, so the M1–M2 difference in old data appears as a 3σ effect, compared to the 6.4σ in $\pi^+\pi^-$.

The study is done in the following way: the events are corrected for normalization with LUTs taken from $\pi^+\pi^-$ data as in the usual physics analysis. Then the A_2 asymmetry is constructed for M1, M2 and the sum of equal parts of M1+M2. A normalization residual is fitted inside and outside PC, under the assumption that $Re(\varepsilon_S) = Re(\varepsilon_L)$.

One can see the acceptance of the symmetrization cut on old data in figure 13 as a function of transverse decay radius. The small fraction of events rejected in small radius is because the IDL was active during data taking and thus most events with primaries doublecounting were rejected online. The variation of this acceptance from 0 to 12cm reflects the probability to loose a real decay track in the IDL counting as the decay point moves away from the origin, as already mentioned in section 2. It is obvious that this cut changes in a different way the normalization inside–outside the PCs. This is better demonstrated in figure 14. One can see the effect removed in M1, M2 (very small) and in the sum M1+M2.

The results for old trigger data are shown in table 8 before the cut and 9 after the cut. We observe that the M1 difference (inside–outside) PC is reduced to half by the cut, while in M2 no change is seen. For the sum of M1+M2 there is initially a difference (on the limit of statistics) and after the cut the values are in much better agreement.

For P28b data (tables 10 and 11) all values remain unchanged, as expected and as implicitly shown by the $\pi^+\pi^-$ results presented earlier. In conclusion, inspite of the inferior total precision, the results on semileptonics data confirm well the ones from $\pi^+\pi^-$.

Region	M1	M2	M1+M2
ins.PC	4.3 ± 2.7	-5.6 ± 2.8	-0.6 ± 1.9
outs.PC	-7.2 ± 2.5	-0.7 ± 2.5	-4.0 ± 1.8
All	-2.0 ± 1.8	-2.9 ± 1.9	-2.5 ± 1.3

Table 8: Old trigger semileptonic data: residual normalization after LUT correction for the two fields and their sum, iside and outside PC. All values are permille.

Region	M1	M2	M1+M2
ins.PC	6.4 ± 2.7	-5.9 ± 2.8	0.4 ± 2.0
outs.PC	0.4 ± 2.5	-1.0 ± 2.6	-0.3 ± 1.8
All	3.2 ± 1.9	-3.3 ± 1.9	0.0 ± 1.3

Table 9: Old trigger semileptonic data after symmetrization cut: residual normalization after LUT correction for the two fields and their sum, iside and outside PC. All values are permille.

7 Conclusions

We have seen that removing $\approx 5\%$ of events, where the IDL sees more than 4 primaries but the track follower sees no more than 4 total tracks, we introduce an asymmetric bias in M1 and

Region	M1	M2	M1+M2
ins.PC	-5.6 ± 3.4	-1.3 ± 3.4	-3.4 ± 2.4
outs.PC	4.5 ± 3.6	4.0 ± 3.6	4.3 ± 2.5
All	-0.8 ± 2.5	1.3 ± 2.5	0.3 ± 1.7

Table 10: P28b semileptonic data: residual normalization after LUT correction for the two fields and their sum, iside and outside PC. All values are permille.

Region	M1	M2	M1+M2
ins.PC	-5.7 ± 3.5	-0.6 ± 3.5	-3.2 ± 2.5
outs.PC	4.9 ± 3.7	4.0 ± 3.6	4.4 ± 2.6
All	-0.6 ± 2.5	1.6 ± 2.5	0.5 ± 1.8

Table 11: P28b semileptonic data after symmetrization cut: residual normalization after LUT correction for the two fields and their sum, iside and outside PC. All values are permille.

M2. The shape of this bias is in good agreement in MC and real data of P28b, where the IDL was not in the trigger decision.

As far as the M1–M2 ϕ_{+-} difference is concerned, making the cut on data of P28b we can introduce an additional ϕ_{+-} difference of 4.8^0 (total of $7.5^0 \pm 2.5^0$). When we parametrize the bias on MC and use this as correction we remove 6.1^0 from the M1–M2 difference seen in data of P25–P28a (total difference is $12.3^0 \pm 1.8^0$). On the same data, the symmetrization cut removes 5.6^0 from the M1–M2 difference. Allowing for statistical fluctuations, we can conclude that the IDL cut of events with more than 4 primaries is responsible for $\approx$ half of the M1–M2 effect observed in old trigger data. This part of the effect can be removed in the old data by removing all events where the IDL has doublecounted any of the primary particles.

As far as the final result is concerned (sum of equal parts of M1 and M2 data), on the P28b data simulating the IDL cut moves the phase up by 1.1^0, and on P25–P28a data correcting for the residual as parametrised in the MC moves the phase down by 1.0^0. The symmetrization cut moves ϕ_{+-} down by 1.6^0.

Furthermore, we have assumed that double counting of the decay pions has no effect on the results, due to the symmetry of the decay final state. It has been verified that cutting all events where the secondaries are doublecounted in the IDL moves the average ϕ_{+-} value furhther downwards by 0.13^0 for P28b and 0.22^0 for P25–P28a. It is not clear if this is due to a small remnant of the IDL effect after the symmetrization cut (primaries only) or a different effect due to the slight differences in momentum spectra of secondaries originating from other sources. The effect of cutting only events where the decay particles are doublecounted will be studied when P29 data become available (twice the statistics of P28b).

The symmetrization cut acts in the old trigger semileptonic data in a very similar way.

Here again the big statistics of P29 will help to check this agreement to a better precision.

disclaimer

All the above conclusions stand under the assumption that the IDL decision by the offline trigger simulation is properly reproducing the one taken by the hardware. No implicit or explicit claim in favour or against this assumption is made throughout this report.

8 Figures

Figures are grouped at the end of the report to facilitate reading

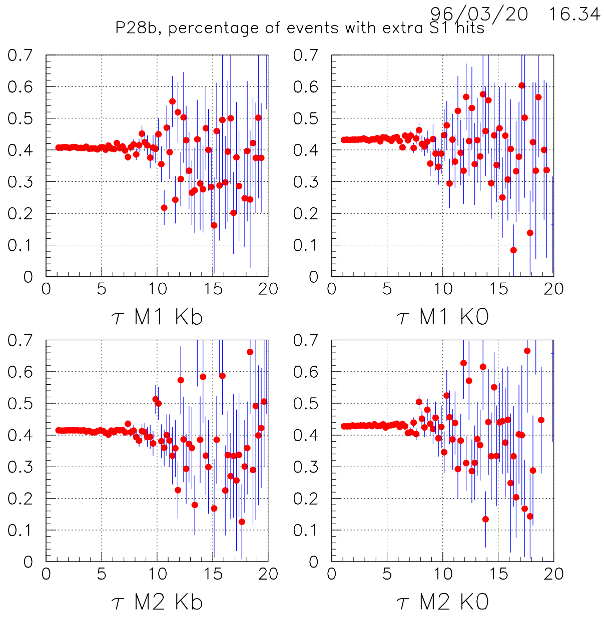

Figure 1: Percentage of events with any extra S1 hits in real data as function of lifetime

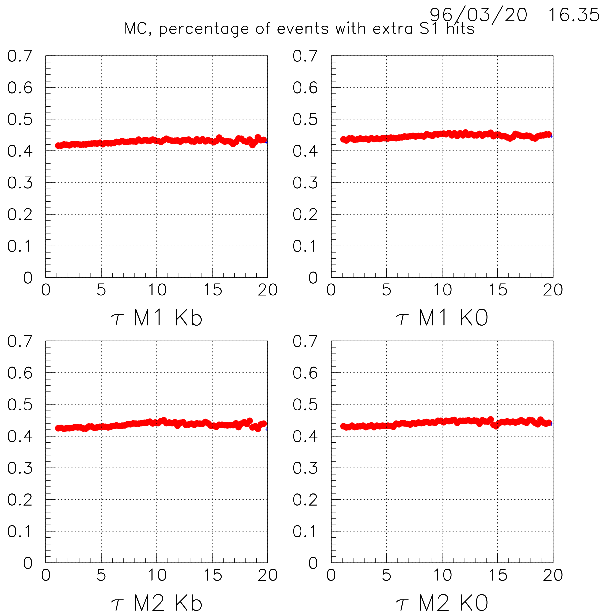

Figure 2: Percentage of events with any extra S1 hits in MC as function of lifetime

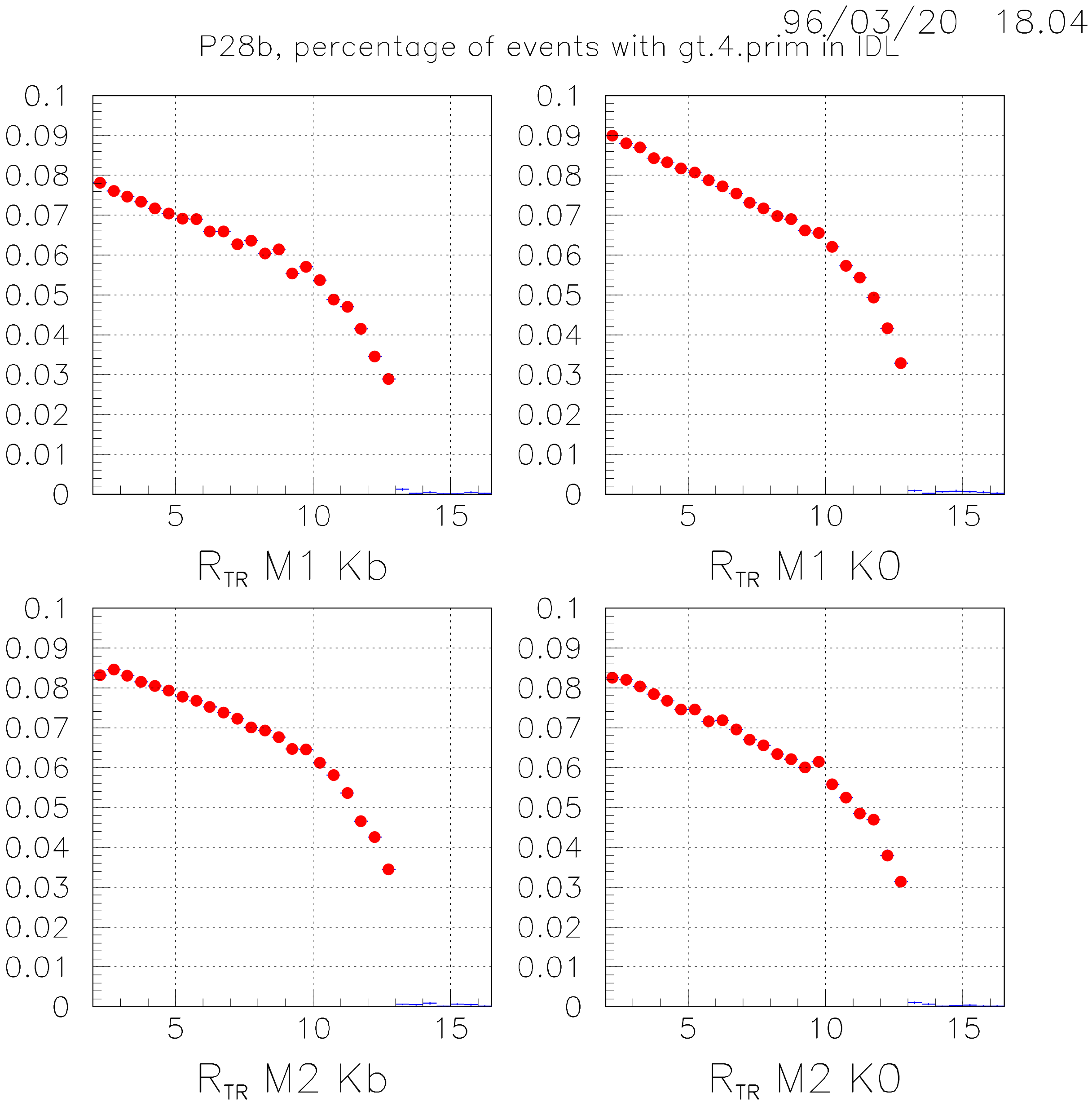

Figure 3: Percentage of events where the IDl finds more than 4 primaries in real data as function of transverse decay radius

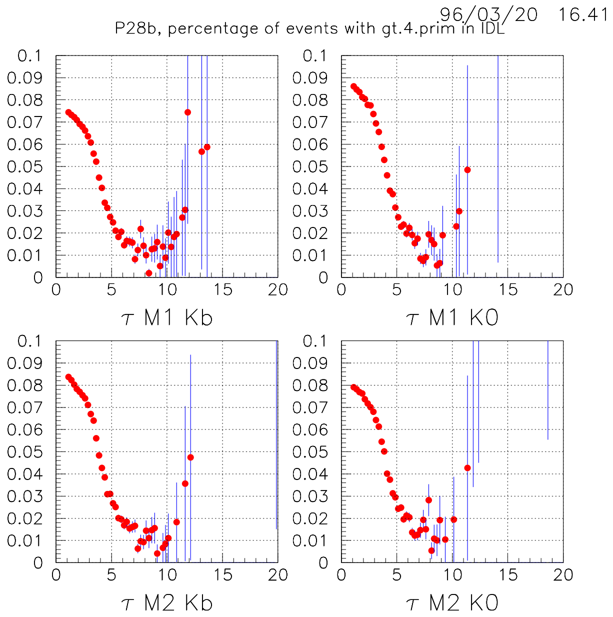

Figure 4: Percentage of events where the IDl finds more than 4 primaries in real data as function of lifetime

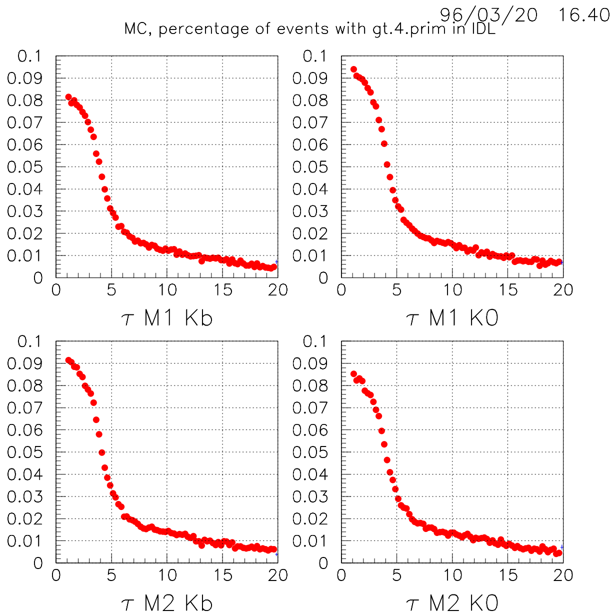

Figure 5: Percentage of events where the IDl finds more than 4 primaries in MC as function of lifetime

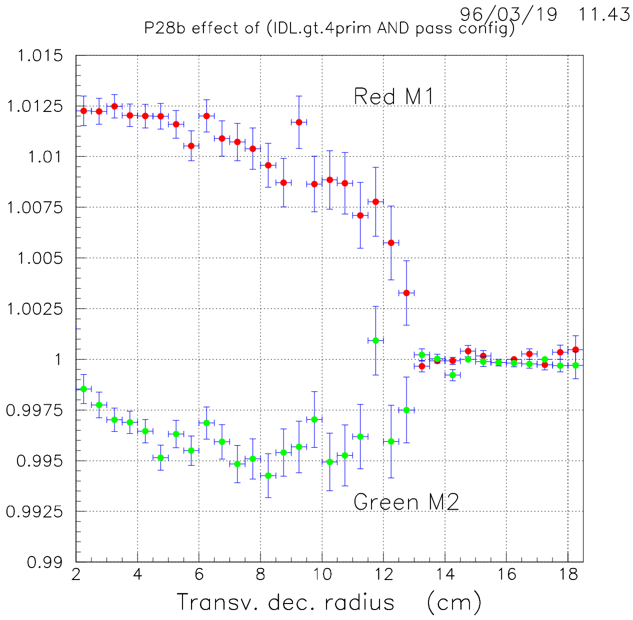

Figure 6: Normalization bias in M1 and M2 introduced by cutting events with IDL ghost tracks in real data as function of transverse decay radius

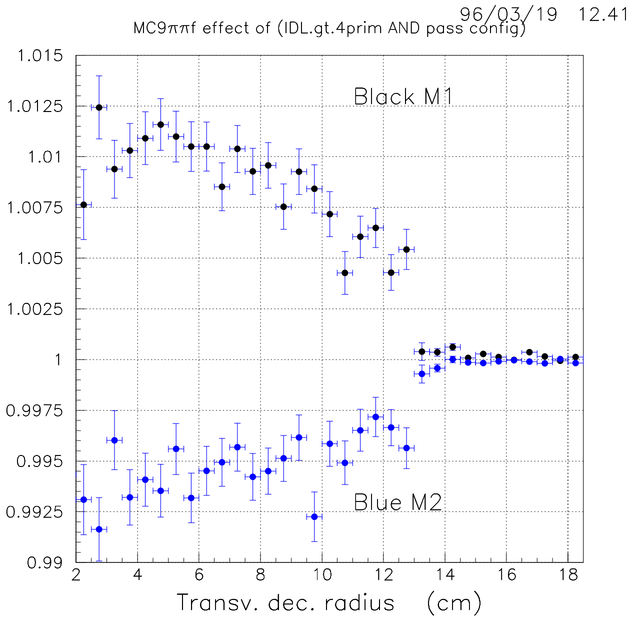

Figure 7: Normalization bias in M1 and M2 introduced by cutting events with IDL ghost tracks in MC as function of transverse decay radius

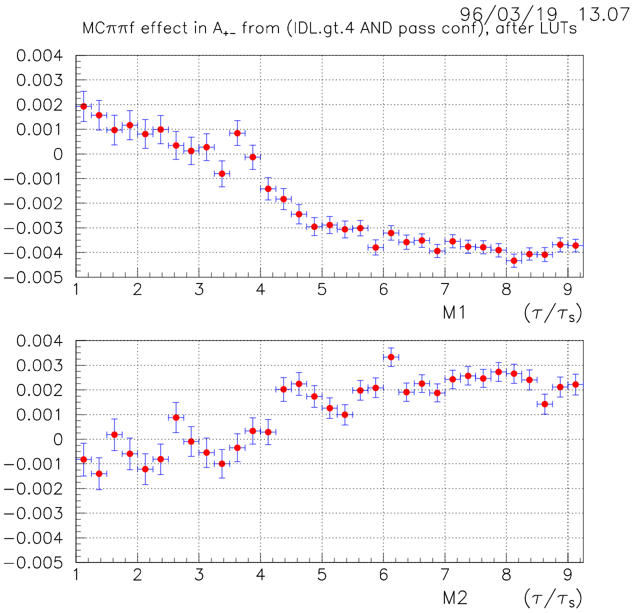

Figure 8: The shape of the bias introduced in the $A_{\pm}$ curve of the two fields by cutting events with IDL ghost tracks in MC

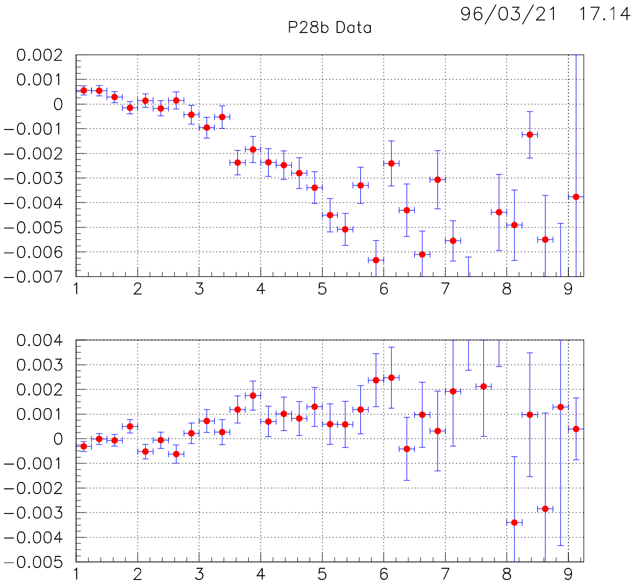

Figure 9: The shape of the bias introduced in the $A_{\pm}$ curve of the two fields by cutting events with IDL ghost tracks in P28b data

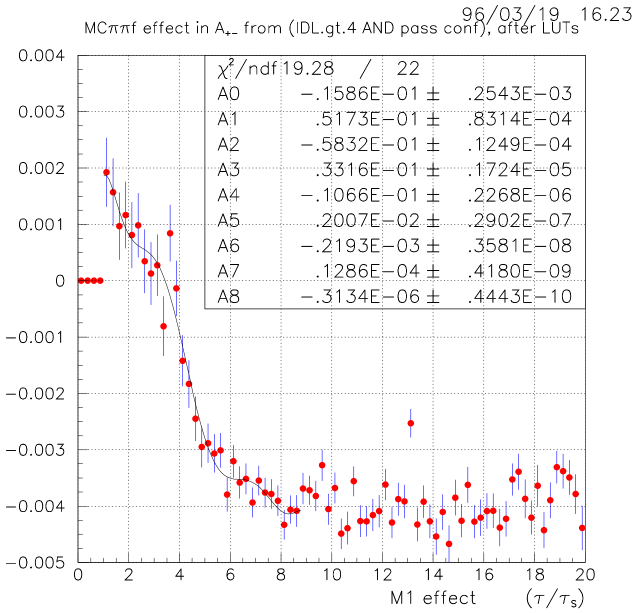

Figure 10: Parametrization of the bias introduced in the $A_{\pm}$ curve of M1 by cutting events with IDL ghost tracks in MC

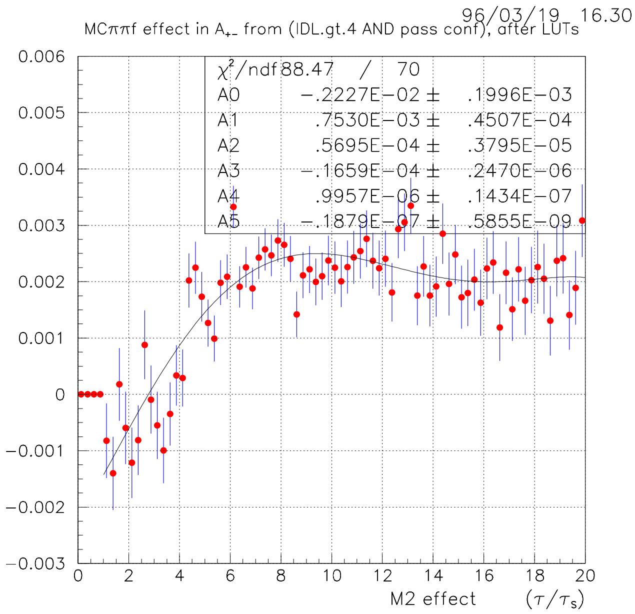

Figure 11: Parametrization of the bias introduced in the $A_{\pm}$ curve of M2 by cutting events with IDL ghost tracks in MC

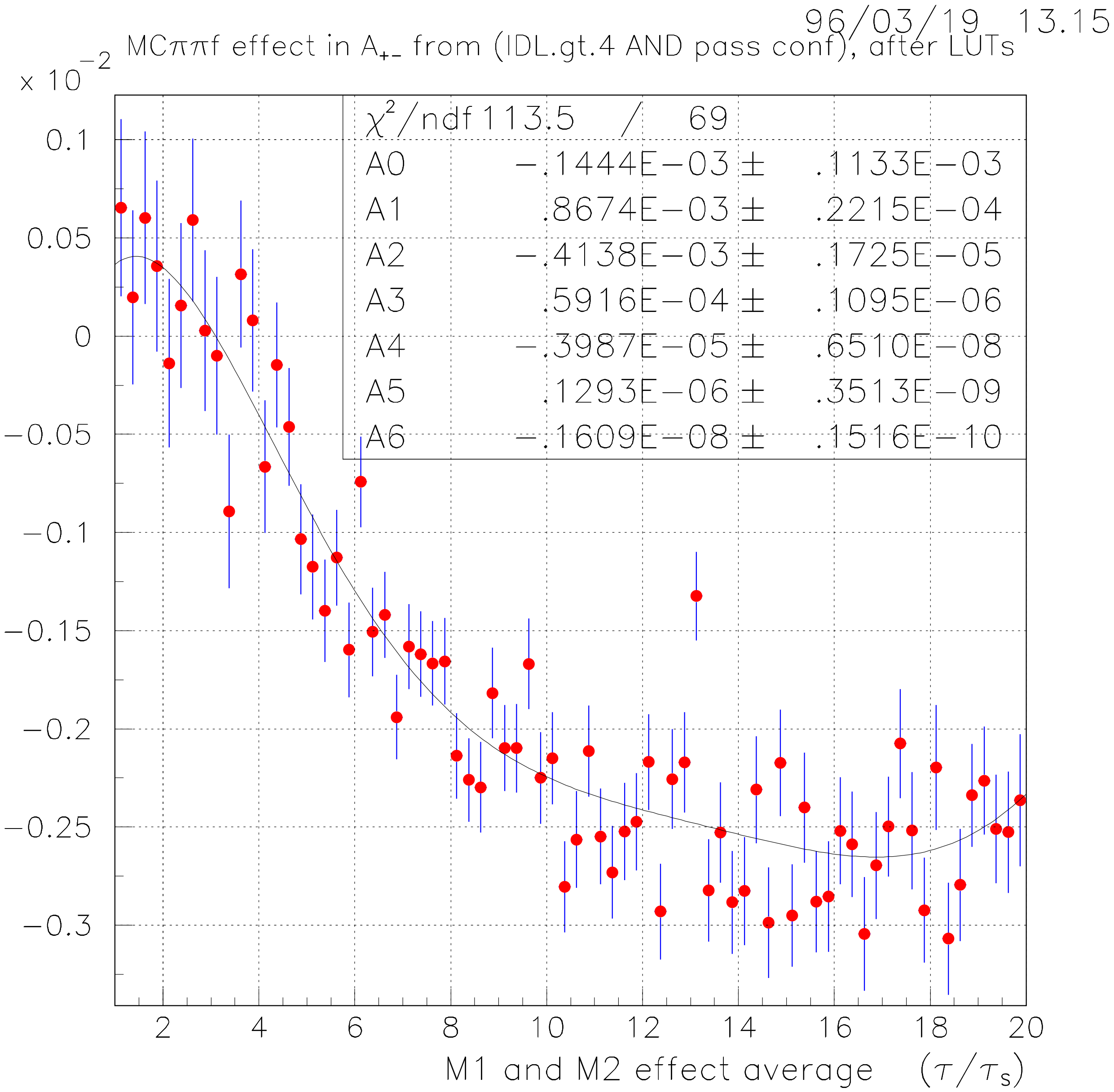

Figure 12: Parametrization of the bias introduced in the $A_{\pm}$ curve of the sum of equal parts of M1 and M2 events (residual) by cutting events with IDL ghost tracks in MC

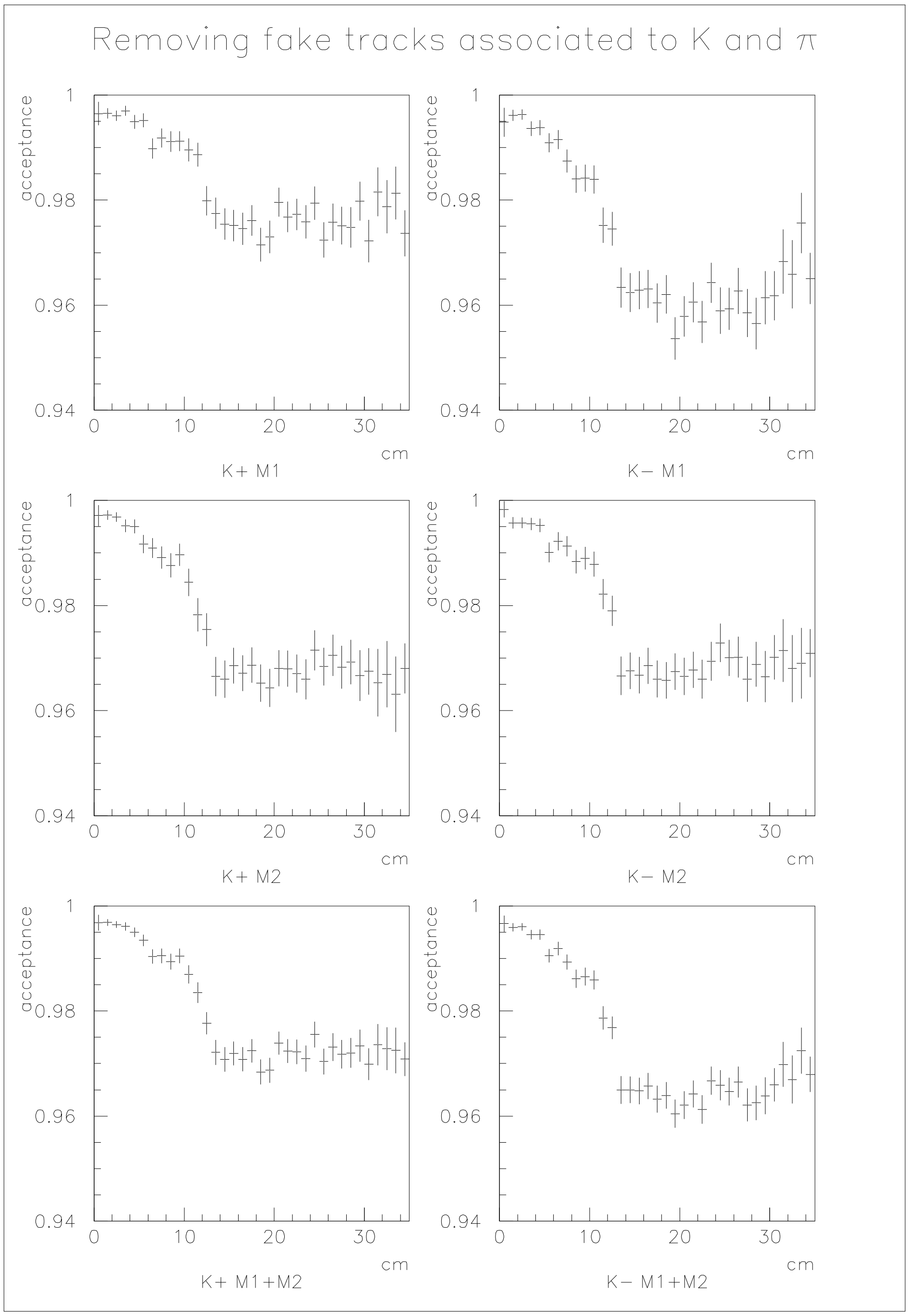

Figure 13: Acceptance of the symmetrization cut on old trigger semileptonic data

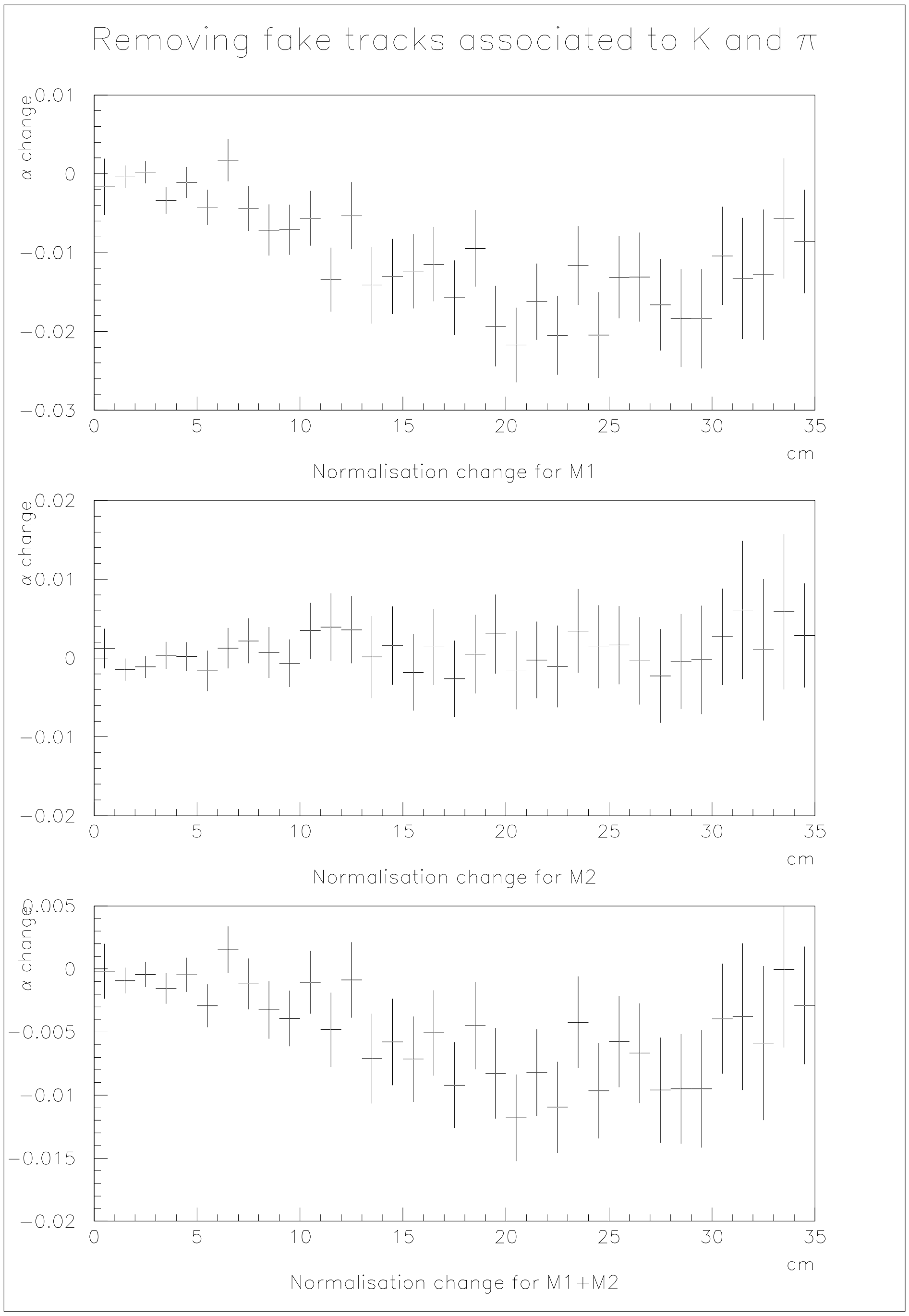

Figure 14: Effects removed by the symmetrization cut on old trigger semileptonic data