LHCb Collaboration

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Upgrade of the Muon System background parameterization

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Abstract

An upgrade of the LHCb Muon System parameterized background package is presented. The upgrade is in 2 parts. Firstly, the parameterization and generation of background tracks has been adapted to the new muon chamber geometry description, and secondly, additional tracks are generated due to interactions in previous bunch crossings. The additional tracks allow spill-over and dead-time to be simulated.

1 Introduction

The LHCb mainstream simulation uses high energy thresholds in the simulation of particle interactions in the Muon Filter, the beampipe and its shielding. This is necessary to reduce computing time. However, the thresholds suppress the low energy component of the particles which traverse the chambers of the Muon system. The low energy component is therefore parameterised and added to the mainstream events.

The original parameterization is described in [**?**]. The parameterization is in terms of single and double hit tracks reflecting the simple 2 layer description of each muon station used at that time. A single hit track is a track which traverses only one of the 2 layers and is, in general, of low momentum. Double hit tracks traverse both layers and have a harder momentum spectrum.

In the new and more realistic description of the muon system [**?**], each muon station is comprised of many smaller chambers and the material composition of each chamber is accurately described. Region 3 and 4 of stations 4 and 5 are implemented with 2-gap Resistive Plate Chambers (RPC). The rest of the system is implemented with 4-gap Multi-Wire Proportional Chambers (MWPC). As a result, the original parameterization, in terms of single and double hit tracks, is no longer suitable. This note describes the new parameterization.

In addition, the material and dimensions of the beam-pipe have been changed [**?**]...,neccessatating a new param.

The material within each chamber...good sim of secondary ints. new beam-pipe, new M5 shielding. but most importantly, old simple single and double hit tracksare no longer appropriate...

now we have a new muon system description with many chambers with either 2 or 4 gaps. a new parameterization is required. this note describes the new param and its performance. other changes have been made to the muon system description since time of old param - new beam-pipe, new M5 shielding.

large tof of some hits (n-gamma processes). therefore interactions in clock cycles before the present can introduce bkg in the present (spill-over) and in the few immediately before, which introduce innefficiency due to channel dead-time. in old param only bkg due to same interaction considered in the upgrade tracks are generated in the previous ints also...

2 Data

- changes in database since last version

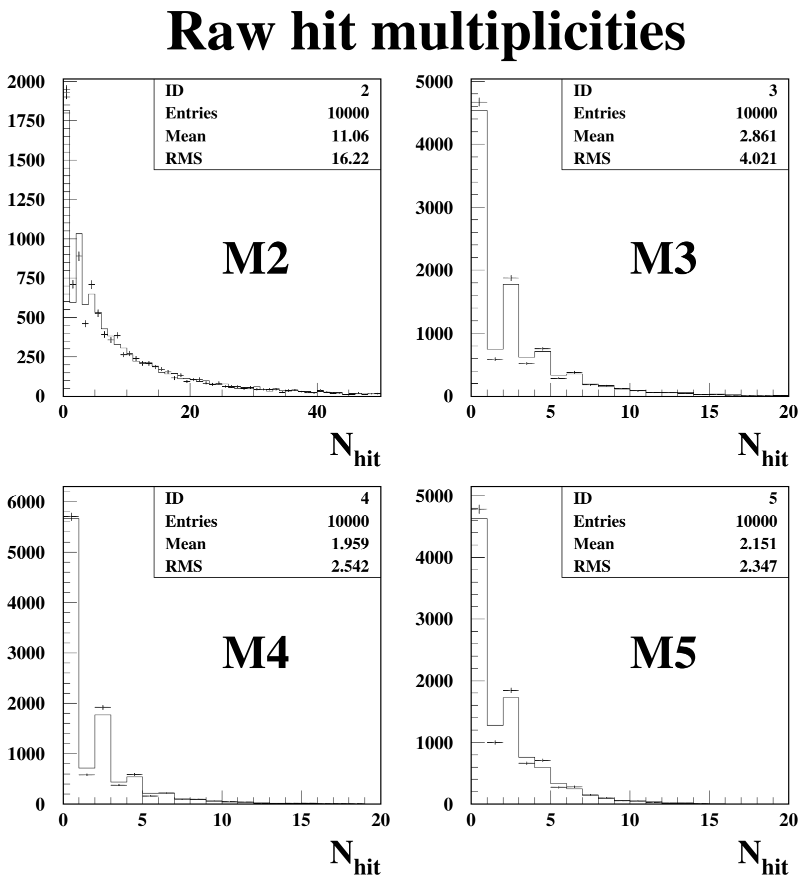

Figure 1: The total Raw hit multiplicity distributions in muon stations M2 to M5. The histograms correspond to the GCALOR simulation, N_{hit}^{LT}, and the points with error bars correspond to the mainstream simulation plus the parameterized background, N_{hit}.

3 New background track parameterization

- form of parameterization has not changed
    - new definitions of single and double hit tracks (0.5 count)
    - new background track generation procedure
    - problems expected

3.1 Comparison of GCALOR and the parameterized background

To check the quality of the parameterization, the Low Threshold (GCALOR) data was compared to the High Threshold (Mainstream) data plus the parameterized background.

Figure 1 shows the total Raw hit multiplicity distributions in stations M2 to M5, and table 1 summarises the mean values. The agreement is good indicating that the parameterization effectively simulates the total number of Raw hits in an event.

Figures 2 and 3 show the Double-hit track and Single-hit track multiplicity distributions. The agreement is in general good. The only significant discrepancies are in the Single-hit distributions for stations M3, M4 and M5. In some events, no Single-hit background tracks are generated when in fact 1 should be generated. This is due to a technical flaw in the software im-

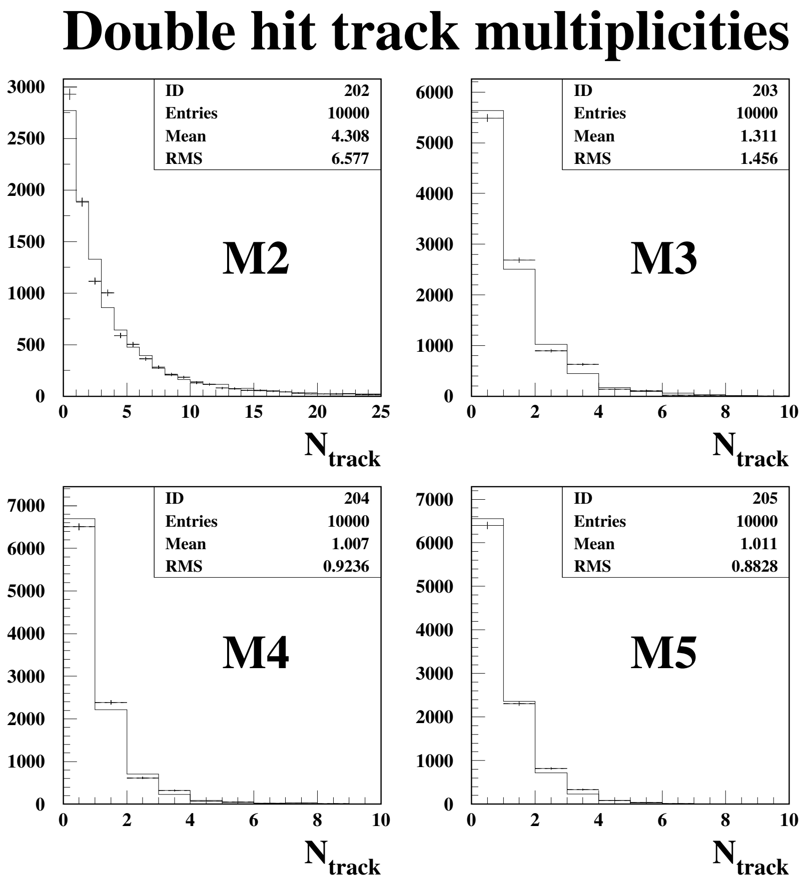

Figure 2: The total Double-hit track multiplicity distributions in muon stations M2 to M5. The histograms correspond to the GCALOR simulation, N_{DH}^{LT}, and the points with error bars correspond to the mainstream simulation plus the parameterized background, N_{DH}.

plementation of the parameterization : if the total number of Single-hit tracks in the mainstream event is half-integer, the number is forced to be integer by randomly adding or subtracting 0.5, both with equal probability. This feature could be corrected, but... This effect is less significant in the total Raw hit distribution due to the dominanace of double hit tracks.

Figure 4 shows the pad hit multiplicity distributions. Discrepancies are seen in each station. The main reason for the discrepancies is that in the 4-gap chambers, Single-hit background tracks are generated independently in each of the 2 gaps within each layer. No tracks are generated crossing both gaps. This underestimates the correlation in space between hits caused by “Single-hit” tracks resulting in an excess of generated hits. Table 1 shows the average number of pad hits in the low threshold data and in the mainstream plus background data. The discrepancy is less than 20% in each station. In fact...

Figures 5 and 6 show the radial distributions of Double-hit tracks at the station centres and Single-hit tracks at the gap centres respectively. The normalization differences evident for muon stations 4 and 5 in figure 6 are due to the discrepancies in the Single-hit track multiplicities observed in figure 3. Figures 7 and 8 show the Time of flight distributions. reduction in out of time

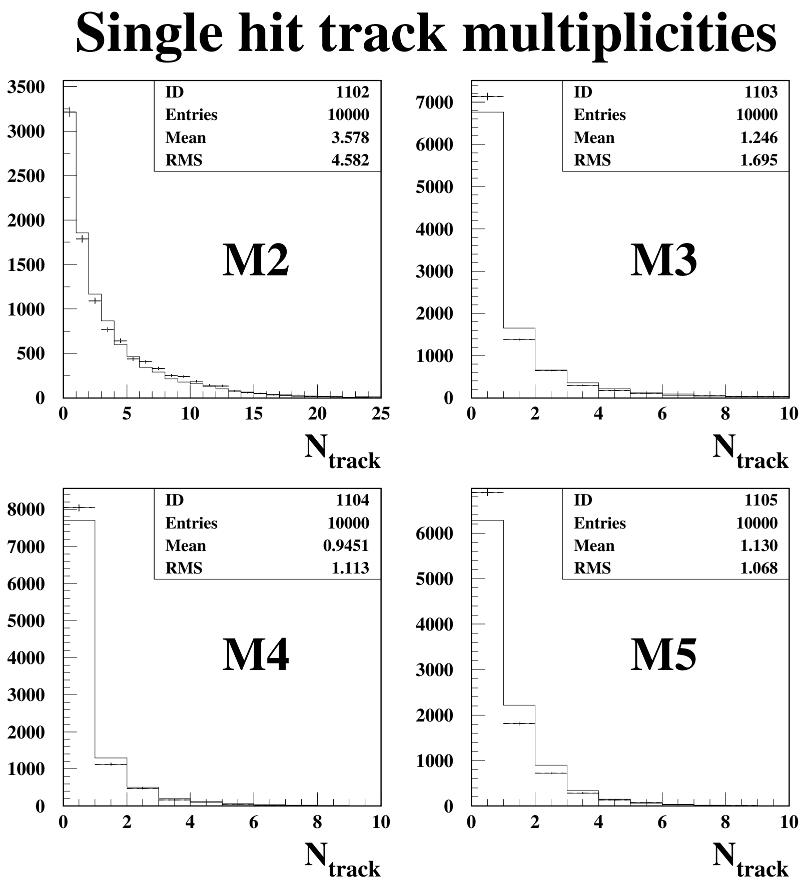

Figure 3: The total Single-hit track multiplicity distributions in muon stations M2 to M5. The histograms correspond to the GCALOR simulation, N_{SH}^{LT}, and the points with error bars correspond to the mainstream simulation plus the parameterized background, N_{SH}.

Muon Station	$\langle N_{hit}^{HT} \rangle$	$\langle N_{hit}^{LT} \rangle$	$\langle N_{hit}^{PB} \rangle$	$\langle N_{pad}^{LT} \rangle$	$\langle N_{pad}^{PB} \rangle$
2	9.08	11.06	11.08	14.01	14.62
3	1.21	2.86	2.84	3.48	4.02
4	0.84	1.96	1.96	1.57	1.51
5	0.75	2.15	2.17	1.23	1.17

Table 1: Average numbers of hits, N_{hit}, and pads fired, N_{pad}, per minimum bias event, for High Threshold data (HT), Low Threshold data (LT), and High Threshold data plus Parameterized Background (PB).

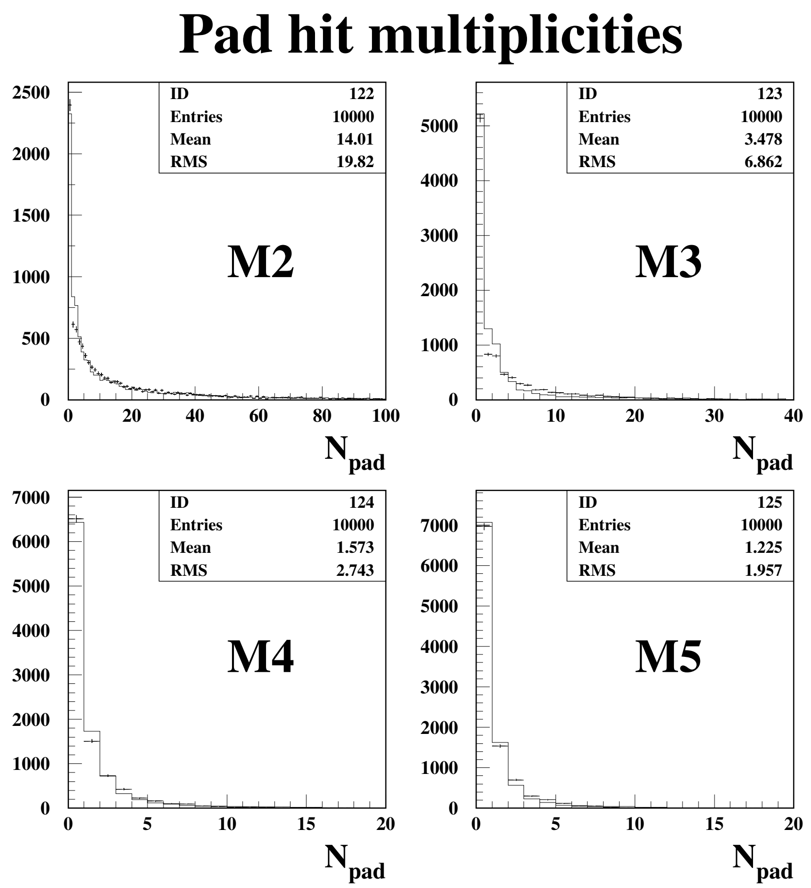

Figure 4: The total Pad hit multiplicity distributions in muon stations M2 to M5. The histograms correspond to the GCALOR simulation, and the points with error bars correspond to the mainstream simulation plus the parameterized background.

Muon Station	Logical pad hit rate (hits in 20ns time window)	Fraction of logical pad hit rate due to :	
		present interaction	all previous ints.
1	136.5	0.96	0.04
2	14.01	0.84	0.16
3	3.48	0.78	0.22
4	1.58	0.66	0.34
5	1.23	0.36	0.64

Table 2: The mean fraction of the logical pad hit rate (pads hit per event) within a 20 ns time window in each station, due to tracks originating from the present interaction and all interactions before the present. The numbers correspond to an average luminosity of $2{\times}10^{32} cm^{-2} s^{-1}$.

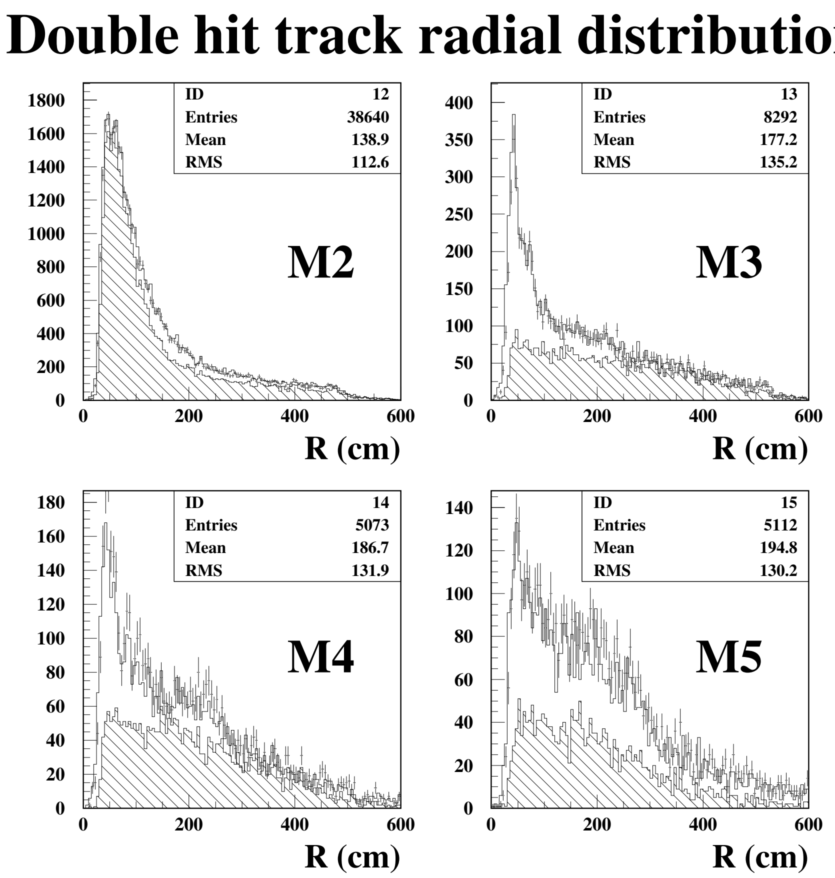

Figure 5: The Radial distributions of Double-hit tracks in muon stations M2 to M5. The histograms correspond to the GCALOR simulation, and the points with error bars correspond to the mainstream simulation plus the parameterized background.

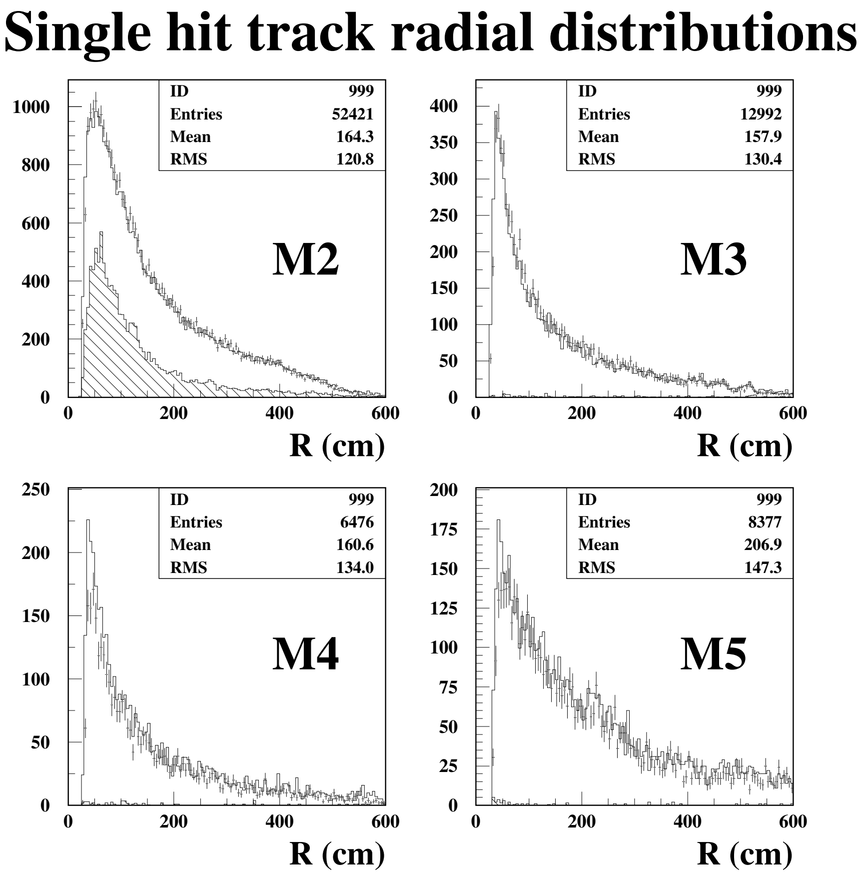

Figure 6: The Radial distributions of Single-hit tracks in muon stations M2 to M5. The histograms correspond to the GCALOR simulation, and the points with error bars correspond to the mainstream simulation plus the parameterized background.

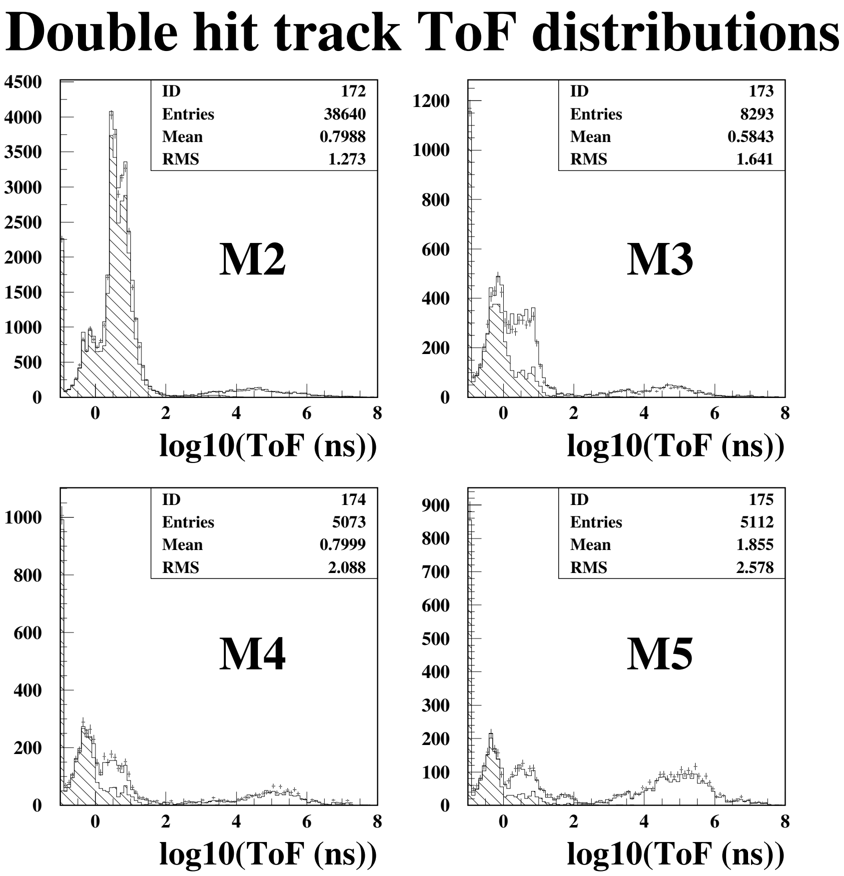

Figure 7: The Time of Flight distributions of Double-hit tracks in muon stations M2 to M5. The histograms correspond to the GCALOR simulation, and the points with error bars correspond to the mainstream simulation plus the parameterized background.

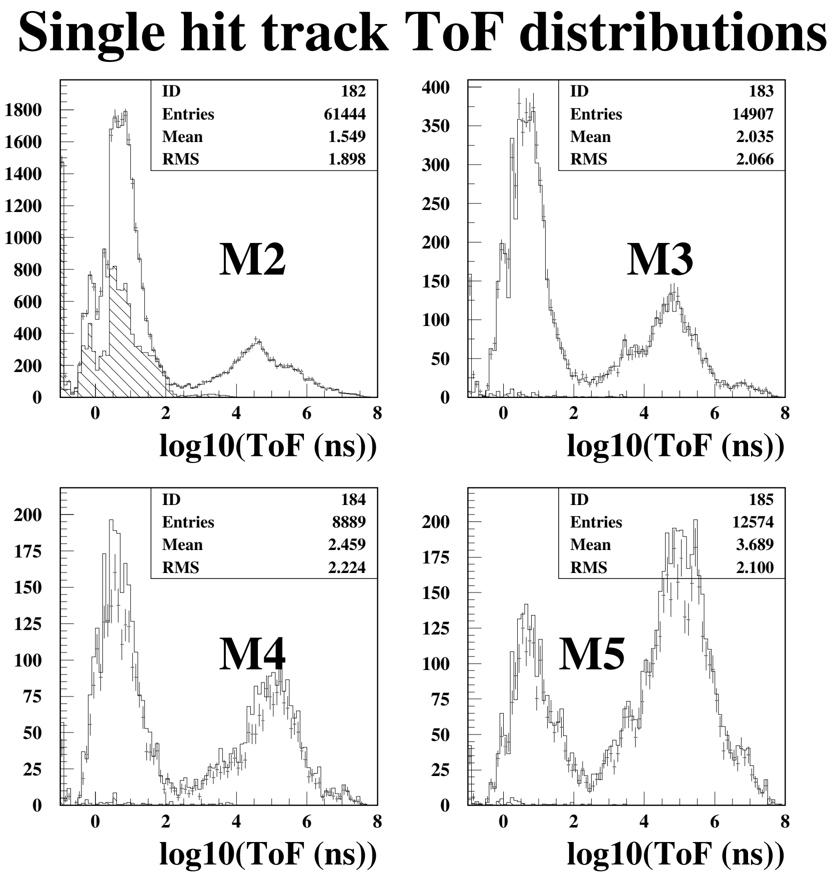

Figure 8: The Time of Flight distributions of Single-hit tracks in muon stations M2 to M5. The histograms correspond to the GCALOR simulation, and the points with error bars correspond to the mainstream simulation plus the parameterized background.

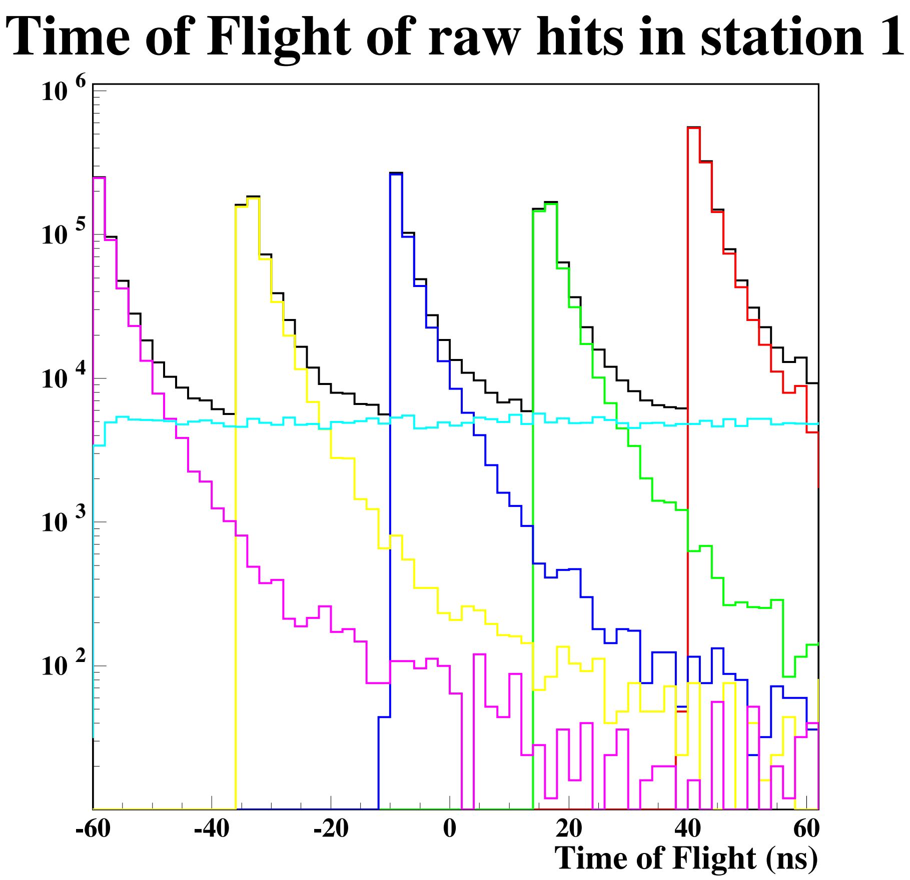

Figure 9: .

4 Simulation of spill-over and dead-time

figure 8 shows that many tracks/hits arrive very late, especially in station 5. such tracks from interactions in previous clock cycles/bunch crossings produce background in later signal interactions... it is therefore important to accurately simulate hits due to interactions in previous bunch crossings. hits in previous bunch crossings can also introduce dead-time...

the simulation of dead-time requires an accurate simulation of the time spectrum of hits preceeding the signal interaction. Therefore the tof spectrum of hits in N previous bunch crossings is correctly simulated, where N=(deadtime+25)/25ns. All previous bunches will not produce deadtime in the present interaction, but they will produce spill-over into the present interaction and the previous N.

The LHC nominal bunch rate is 40 MHz, but only 75% cross at LHCb. The mean bunch crossing rate at LHCb is therefore 30 MHz. To evaluate the number of interactions in each of the previous N clock cycles, we first of all assume, conservatively, that each cycle has a bunch crossing. so the bunch crossing rate is 40 MHz at the time of the interaction and immediately before. 40MHz bunch rate, pp inelastic cross section of 55mb and luminosity of $2*10^{3}2$ implies an average of 0.53 interactions per bunch crossing. the luminosity is generated instantaneously as proposed by ? and ?. that is, with a 7 hour fill time and 10 hour beam decay constant.

- generation of number of interactions in previous clock cycles
- generation of hit multiplicities/correlations

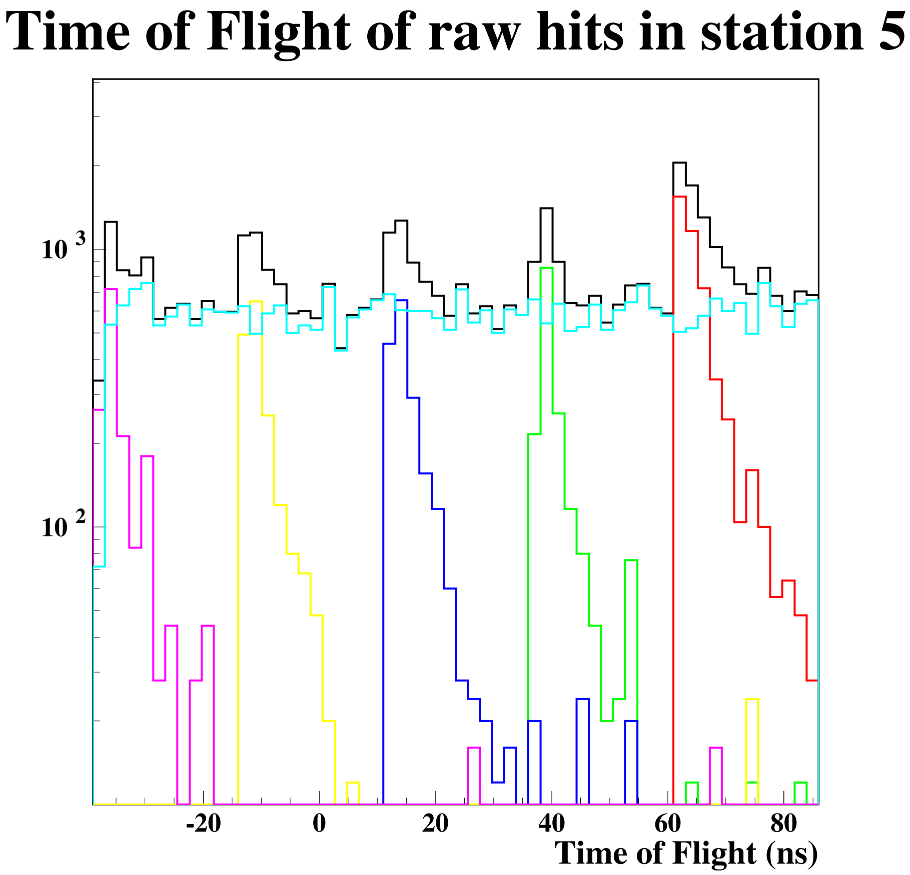
Time of Flight of raw hits in station 5
10 3
10 2
-20
0
20
40
60
80
Time of Flight (ns)

Figure 10: .

tof distributions for M1 to M5 with deadtime=90 and indicating each clock-cycle. what fraction of raw hit rate in each region of each station is due to spill-over? these will go up linearly with luminosity.

fraction of channels dead for all of 20ns time window as a function of deadtime.

- dead-channel multiplicity v dead-time
- spill-over multiplicity v luminosity

5 Particle rates

6 Implementation

7 Conclusion

Acknowledgements

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