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Performance of the track matching

M. Needham
CERN *

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Abstract

The performance of the track matching algorithm in Brunel v31r8 is discussed. An event weighted efficiency of 82.3% is found for a ghost rate of 8.9%.

*Present Addresss: Laboratoire de Physique des Hautes Energies, Ecole Polytechnique Fédérale de Lausanne .

1 Introduction

The track matching algorithm at the time of the DC' 06 data challenge [1] is described in [2]. Since then there have been improvements in the inputs to the algorithm — the T seeds and the VELO tracks. This has led to a better track matching algorithm with a lower ghost rate and higher efficiency. The relevant changes to the T-seeds are as follows. First, the performance of the T-seeding has improved [3]. This led to an increase in the matching efficiency by around 1 % whilst reducing the ghost rate by 0.7 %. Second, the quality of the Kalman fit that is performed on seed tracks after the pattern recognition step has been improved [4].

The quality of the VELO tracks has also improved. The final step in the VELO pattern recognition is to fit a straight line to the VELO track candidate. To account for multiple scattering in this procedure hits further away from the interaction point are deweighted [5]. Consequently, the track parameters, determined by this procedure, are not optimal at the exit of the VELO where the matching is performed. By reducing this de-weighting parameter and performing the fit in the opposite sense a better estimate of the track parameters for the matching was obtained. This increased the efficiency of the track matching increased by ~ 1 % whilst reducing the ghost rate by 4 % [6]. Finally, a second pass VELO tracking algorithm, based on building spacepoints has been implemented [7]. This algorithm increases the efficiency of the VELO track finding by 1 %. In particular the performance for K_s decays products has been improved. The efficiency of the VELO tracking for tracks for tracks of this type is increased from ~ 84 % to 91 % [1].

In addition, the speed of the algorithm has been improved [6] by:

- Minimizing the number of track extrapolations.
- Caching selected VELO candidates.
- An improved selection procedure for the candidate matches.
- Using the information in the non-bend plane to make a fast pre-selection of good matches before making the full χ^2 calculation.

[1] This is still worse than the performance for tracks originating from the interaction point where an efficiency of ~ 95 % is obtained.

2 Performance

The performance of the algorithm has been studied using data generated for the DC' 06 production reconstructed with Brunel v31r8. The following data samples were used:

- A sample of 13000 $\mathrm{B_d} \rightarrow J/\psi(\mu^+\mu^-)\mathrm{K_S}(\pi^+\pi^-)$ events generated at the default LHCb luminosity of 2×10^{32} $\mathrm{cm^{-2}s^{-1}}$.
- A sample of 4000 $\mathrm{B_d} \rightarrow J/\psi(e^+e^-)K^*$ events generated at the default LHCb luminosity of 2×10^{32} $\mathrm{cm^{-2}s^{-1}}$.
- Samples of 500 inclusive b events generated at luminosities of 5, 8, 10, 2 0 $\times 10^{32}$ $\mathrm{cm^{-2}s^{-1}}$.

The majority of results were obtained with the first sample. From the context it should be clear when this is not the case. The definitions of efficiency and ghost rate are those given in [8]. The following efficiencies are determined with respect to those particles which are reconstructible as long tracks.

The performance of the algorithm depends on the value of the χ^2_{match} that is used. In Fig. 1 the efficiency versus the ghost rate is plotted for various values of this variable. From this plot it can be seen that a cut at $\chi^2_{\mathrm{match}} = 900$ is reasonable. Using this value an event-weighted efficiency of 82.3 % is obtained [2]. This is 3% higher than the corresponding DC 06 number [2].

The efficiency of the algorithm depends quite strongly on the track momenta. This can be seen in Fig. 2 where the efficiency is plotted as a function of the track momentum. For tracks with $p > 20$ GeV/c an efficiency of ~ 91 % is found. Below 20 GeV/c the efficiency falls rapidly. This reflects the fact that low momentum tracks are penalized in the matching procedure because the effect of multiple scattering is ignored. In Fig. 3 the dependence of the efficiency on the pseudorapidity of the track is shown. Within the LHCb acceptance the efficiency is largely flat. However, there are dips at $\eta \sim 3.7$ and $\eta \sim 4.3$. The latter is attributed to the material of the conical 25 mrad section of the beam pipe which lies within the acceptance of the detector. The origin of the former is not clear.

The efficiency for reconstructing tracks that originate from B decays has also been investigated. The results are summarized in Table 1. For the

[2] The corresponding track-weighted efficiency would be 80.6 %.

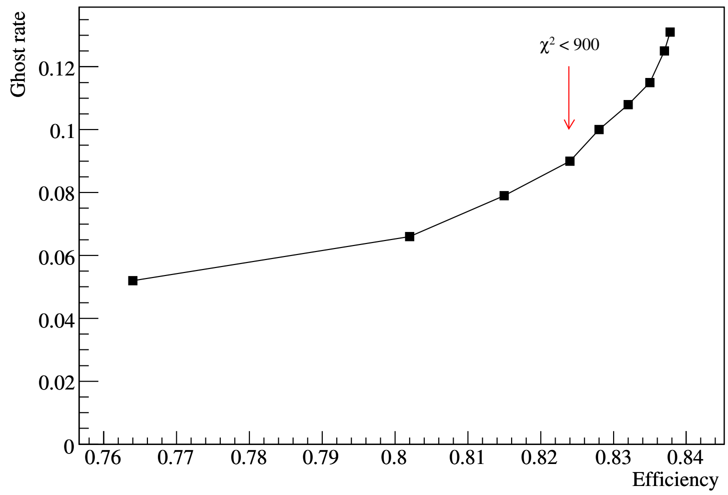

Figure 1: Track finding efficiency versus ghost rate for various cuts on the χ^2_{match}. The points from left to right correspond to cuts at 300, 500, 700, 900, 1100, 1300, 1500, 1800, 2000.

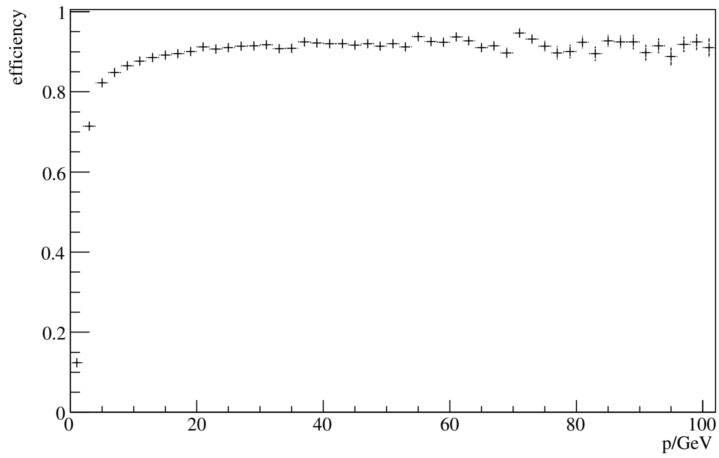

Figure 2: Track finding efficiency as a function of the track momentum.

case of muons from $\mathrm{B_d} \to J/\psi(\mu^+\mu^-)\mathrm{K_S}(\pi^+\pi^-)$ and electrons from $\mathrm{B_d} \to J/\psi(e^+e^-)K^*$ the performance is comparable to that of the inclusive track sample. The performance for pions from $\mathrm{B_d} \to J/\psi(\mu^+\mu^-)\mathrm{K_S}(\pi^+\pi^-)$ is worse. This is explained by the worse VELO tracking performance for tracks

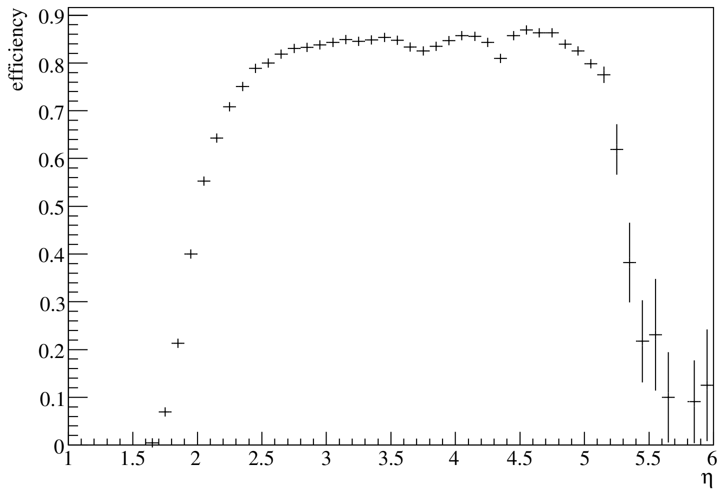

Figure 3: Track finding efficiency as a function of the track pseudorapidity η.

Track type	$\overline{p}$ (GeV)	Track efficiency (%)
$\mu^{\pm}$ from $\mathrm{B_d} \to J/\psi(\mu^+\mu^-)\mathrm{K_S}(\pi^+\pi^-)$	33	88.1 ± 0.3
$e^{\pm}$ from $\mathrm{B_d} \to J/\psi(e^+e^-)K^*$	23	84.3 ± 0.3
$\pi^{\pm}$ from $\mathrm{B_d} \to J/\psi(\mu^+\mu^-)\mathrm{K_S}(\pi^+\pi^-)$	12	76.7 ± 0.4

Table 1: Efficiencies for reconstructing tracks from specific B final states. The column labeled final state efficiency refers to the efficiency for reconstructing both tracks.

of this type discussed in Section 1.

An event-weighted ghost rate of 8.9 % is found[3] with the default value of the χ^2_{match} cut. This value is 4.8 % lower than corresponding DC'06 number. Since this value is stored in the **Track** class [9] it is possible to reduce the ghost rate at a later stage — though at the expense of some loss in efficiency.

In Fig. 4 the distributions for four different variables are compared for real and ghost tracks. The four variables are:

[3]The track-weighted ghost rate is 10.9 %.

- The weighted number of measurements on the track defined as:

$$n_{meas} = n_{VELO} + n_{TT} + n_{IT} + 0.5 \times n_{OT} \quad ,$$

  where the weight of 0.5 takes accounts of the fact that the OT gives on average twice as many measurements per track as the IT.

- The χ^2/ndof.

- The track pseudorapidity.

- The track's transverse momentum.

Compared to real tracks ghost tracks have less measurements and a worse χ^2/ndof. In addition, they tend to lie at high η and also around $\eta = 4.3$ [4]. Finally, it can be seen that ghost tracks have on average a lower p_T than real tracks. Either one or a combination of these variables could be used to reduce the ghost rate. Studies in this direction are ongoing [10, 11].

The origin of ghost tracks has been also studied using the tool described in [12]. The results are shown in Fig 5. It can be seen that the majority of ghost tracks are due to a 'random' combination of a VELO track with an unrelated T seed being chosen. The second largest source of ghosts is due to cases where either the T or VELO part of the track is classified as a ghost.

The performance as a function of the number of visible interactions as defined in [14] has also been investigated. Fig. 6 shows the dependence of the efficiency and ghost rate on this quantity. For each additional visible interaction in the detector the efficiency decreases by 2.5 % whilst the ghost rate increases by 4.2 %. This behaviour is similar to that found in the previous studies [2]. If only the number of visible interactions in the event spill effects the performance of the track reconstruction then efficiencies and ghost rates for an arbitrary luminosity can be derived directly from Fig. 6. Such a procedure is only valid if other effects, for example, the increased spillover at high luminosity can be neglected. The performance of the long tracking system for luminosities up to 2×10^{32} cm^{-2}s^{-1} has been also been studied directly. The results are summarized in Fig. 7. In this plot the efficiency and ghost rate as a function of luminosity are shown together with predictions made based on Fig. 6. The latter are referred to as the limited spillover efficiency and ghost-rate. As can be seen the efficiency of the algorithm is robust up to a luminosity of 5×10^{32} cm^{-2}s^{-1}. Above this the performance degrades

[4] This effect is also attributed to the 25 mrad cone of the beam pipe.

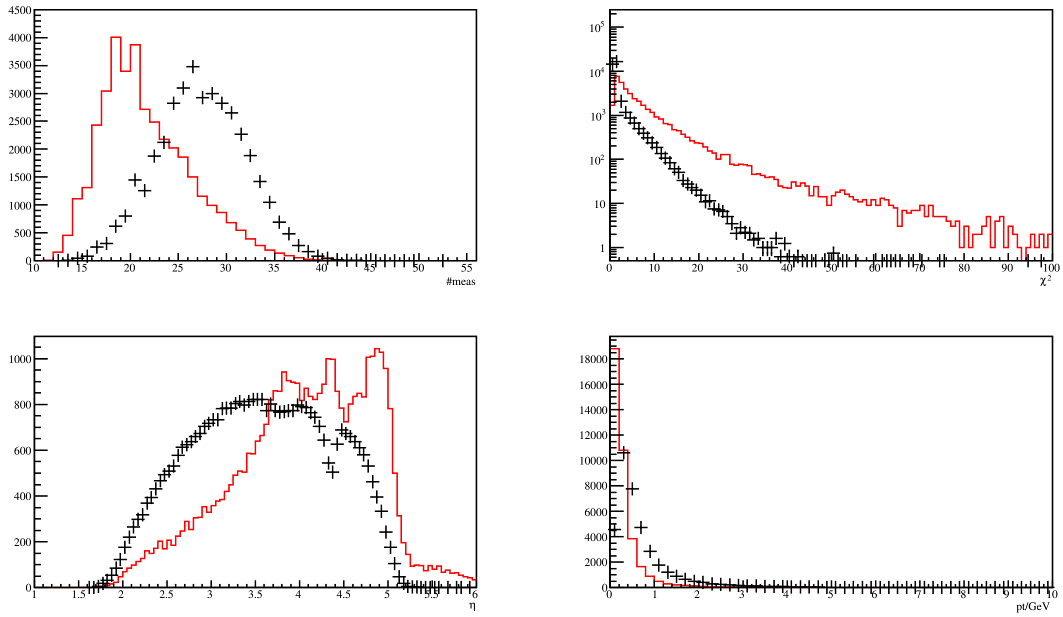

Figure 4: Comparison of the properties of real (points) and ghost tracks (line). The four variables considered are: number of measurements, χ^2/ndof, η, p_T.

linearly with increasing luminosity. The ghost-rate increases linearly with the luminosity. Above 5×10^{32} cm^{-2}s^{-1} the predicted values diverge from those found indicating that the effect of spillover is not small.

Finally, it should be noted that at a luminosity of 2×10^{32} cm^{-2}s^{-1} the algorithm takes 6 ms per event on a 64-bit 3 GHz Intel Xeon processor.

3 Summary

In this note the performance of the track matching has been updated. The improvements in the VELO tracking and T-seeding since DC' 06 has resulted in a noticeable improvement in performance. It should be noted that by fully implementing the program of work discussed in [2] it is expected that the performance of the algorithm can be further improved.

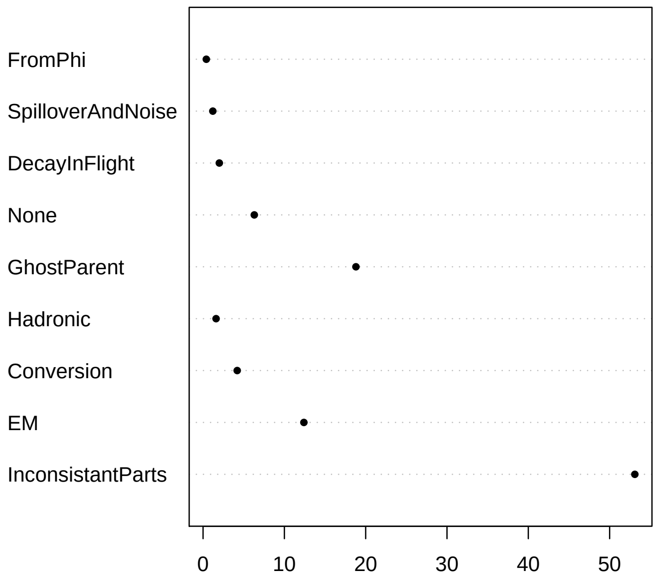

Figure 5: R dotchart [13] showing the composition of ghost tracks in %. The definitions of the ghost classes are given in [12].

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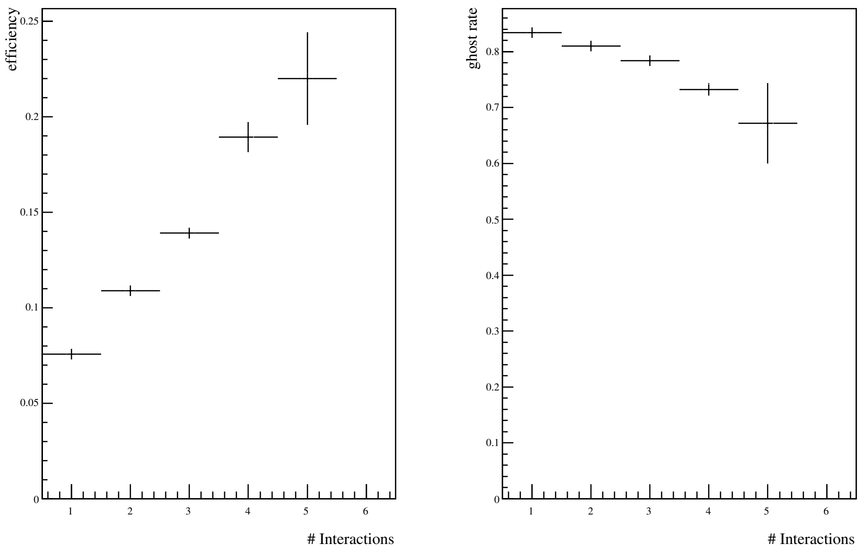

Figure 6: Efficiency (left) and ghost rate (right) versus the number of visible interactions.

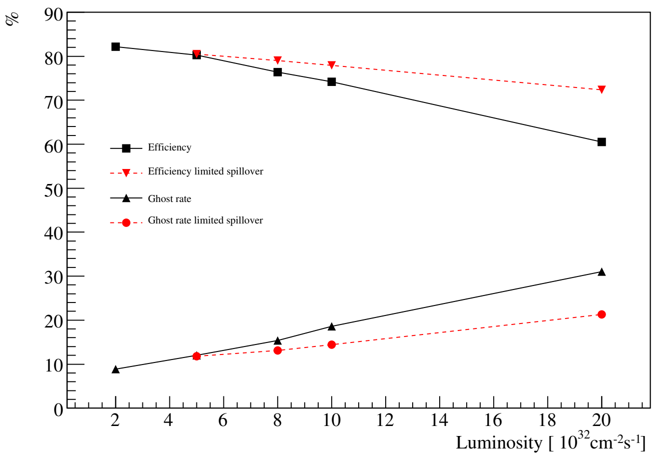

Figure 7: Track Matching performance versus luminosity.

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