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New flavour tagging algorithms at the LHCb experiment

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Summary. — Measurements of flavour oscillations and time-dependent CP asymmetries of neutral B mesons require the identification of the flavour of the meson at production. The flavour tagging technique allows to perform such identification by means of two kind of algorithms: Opposite Side and Same Side algorithms. The details of the new Same Side taggers, recently developed, and their performances are shown.

1. – Introduction

At the LHCb experiment, the measurement of time-dependent CP asymmetries and flavour oscillations covers a very important role in the research of physics beyond the Standard Model. Two important time-dependent measurements performed by LHCb exploited the flavour tagging algorithms: the measurement of $\sin(2\beta)$ [1] and the measurement of ϕ_s [2-4]. The identification of the flavour of the neutral B meson at production is necessary and it is performed thanks to the flavour tagging algorithms. The Opposite Side (OS) taggers exploit the main b-b quark production mechanism in pp collisions: the production flavour of the signal B is opposite to that of the other B hadron in the event, thus the decay products of the other B hadron can be used for flavour tagging. The Same Side (SS) taggers exploit the charge correlation between the B candidate and the particle (pion, proton, kaon) created in association with the b quark hadronization. The aim of these algorithms is to provide both a tagging decision for the initial B flavour and an estimation of the probability for the decision to be wrong (ω). The performance of each algorithm can be evaluated through the following formulas:

$$\varepsilon_{tag} = \frac{R+W}{R+W+U}, \qquad \omega = \frac{W}{R+W}, \qquad \varepsilon_{eff} = \frac{\varepsilon_{tag}}{R+W} \sum_{i=1}^{R+W} (1-2\omega)^2, \tag{1}$$

where U, R, W are the number of untagged, rightly and wrongly tagged candidates [5].

Table I. – *Performances of the SS taggers.*

Decay channel	Tagger	$\varepsilon_{\rm tag}$ [%]	$\varepsilon_{\rm eff}$ [%]
$B_s \to D_s^- \pi^+$	SSK NN	60.38 ± 0.16	1.80 ± 0.19
$B_d \to D^- \pi^+$	SSπ	71.96 ± 0.22	1.69 ± 0.10
	SSp	38.56 ± 0.15	0.53 ± 0.05
	SS(π+p)	79.40 ± 0.23	2.11 ± 0.11

2. – New Same Side taggers

The new SS taggers exploit a kaon, a pion or a proton as charge correlated particle. These taggers have been developed by means a Multi-Variate Analysis (MVA) which, combining kinematic and geometric variables, is able to select the best tagging candidate. To improve the MVA performances, a set of preselection cuts is applied to reduce the multiplicity of possible candidates. For each tagger the calibration of the mistag probability is checked in an independent data sample. The sample is divided in categories of the predicted mistag (η) and for each one the real mistag fraction is evaluated by resolving the $B^0_{(s)}$-$\bar{B}^0_{(s)}$ flavour oscillation via a fit to the decay time distribution.

2˙1. *Same Side kaon.* – The new SS kaon has been developed using two Neural Networks (SSK NN) [6]. It has been optimized with $B_s \to D_s^- \pi^+$ decays from the Run I data and simulations. The two NN are both trained on simulated events, the first one (NN1) to recognize the kaon produced in the b quark hadronization and the second one (NN2), calibrated on data, to combine the tracks selected by NN1 and assign a tagging decision and a mistag probability.

2˙2. *Same Side pion & proton.* – The new SS pion has been developed using a Boost Decision Tree (SSπ BDT) to improve the performances of the existing SSπ cut-based. The optimization has been performed on $B_d \to D^- \pi^+$ decays. On the same decay channel it has been developed for the first time also a SS proton tagger, based on a BDT. In the BDT training only B candidates with a decay time shorter than 2.2 ps have been used, in order to reduce the fraction of oscillated events. In case of multiple candidates, the one with the highest BDT value is chosen as best candidate. The mistag associated to the tagging decision has been evaluated from a time-dependent fit to the flavour oscillations of the full event sample. The SSπ and SSp responses can be combined in a single SS tagger to enhance the tagging performances.

The performances achieved by all these taggers are reported in table I.

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