

# Supplementary material for LHCb-PAPER-2020-042

The supplementary material for LHCb-PAPER-2020-042 provides additional details of the analysis. Fig. 1 and Table 1 present results of the BDT training. In Fig. 2 the results of a simulation study for background contamination to signal region are presented. Table 2 shows details of the tagging performance.

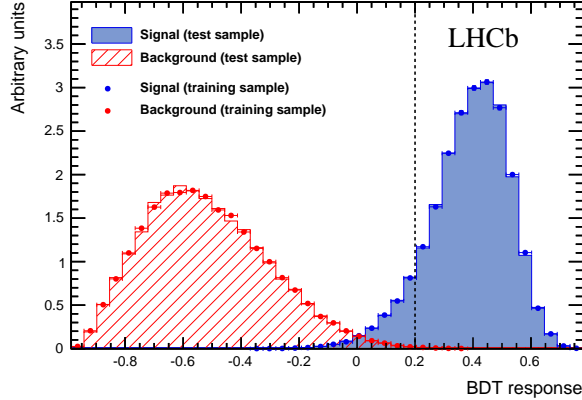


Figure 1: Distributions of the BDT variable for both training and test samples of  $B_s^0 \rightarrow J/\psi(e^+e^-)\phi$  signal and background events. The signal samples are from simulation (blue) and the background samples derived from the same-sign data combination (red). The black dotted line indicates the chosen minimum BDT requirement.

Table 1: Variables used in the BDT selection: the transverse momenta of the  $J/\psi$  and  $\phi$  candidates,  $p_T(J/\psi)$  and  $p_T(\phi)$ ; the vertex  $\chi^2$  of the  $B_s^0$  candidate,  $\chi_{\text{vtx}}^2(B_s^0)$ ; the  $\chi^2$  of  $B_s^0$  candidate kinematic fit with the  $J/\psi$  mass constrained to its PDG value,  $\chi_{\text{DTF}}^2(B_s^0)$ ; the electron and kaon identification probabilities as provided mainly from the RICH and calorimeter systems,  $\text{PIDE}(e^\pm)$  and  $\text{ProbNNK}(K^\pm)$ . The importance is evaluated as the total separation-gain that this variable had in the decision trees (weighted by the number of events) [1].

Variable	Importance
$\text{PIDE}(e^+)$	0.18
$\text{PIDE}(e^-)$	0.17
$\log(\text{ProbNNK})(K^+)$	0.14
$\log(\text{ProbNNK})(K^-)$	0.13
$p_T(J/\psi)$	0.11
$p_T(\phi)$	0.10
$\log(\chi_{\text{DTF}}^2)(B_s^0)$	0.09
$\chi_{\text{vtx}}^2(B_s^0)$	0.08

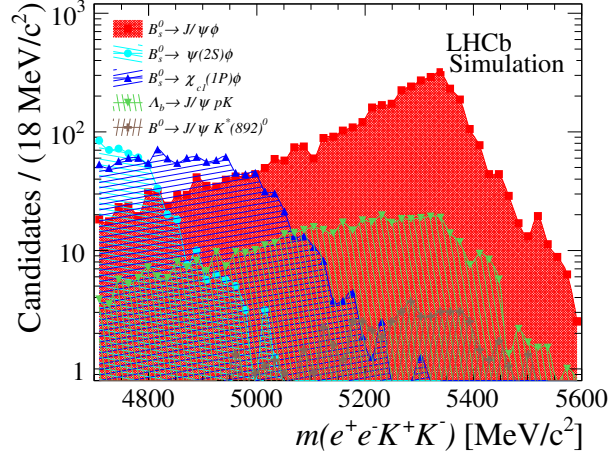


Figure 2: Distribution of the reconstructed mass of simulated  $B_s^0$  candidates. The red area shows the signal  $B_s^0 \rightarrow J/\psi\phi$  candidates. The green and brown areas correspond to candidates selected from  $\Lambda_b^0 \rightarrow J/\psi p K^-$  and  $B^0 \rightarrow J/\psi K^*(892)^0$  decays, respectively, that are mis-reconstructed as  $B_s^0 \rightarrow J/\psi\phi$  due to proton and pion misidentification as kaon or due to partially random combinations with other tracks. The light blue and blue areas show the partially reconstructed background contribution from  $B_s^0 \rightarrow \psi(2S)\phi$  and  $B_s^0 \rightarrow \chi_{c1}(1P)\phi$  decays, respectively.

Table 2: Tagging efficiency  $\varepsilon_{\text{tag}}$ , squared average tagging dilution  $\mathcal{D}^2$  and tagging power  $\varepsilon_{\text{eff}}$  of the  $B_s^0 \rightarrow J/\psi\phi$  signal candidates for the data sample in the three tagging categories. The column “Fraction” reports the fraction of events in each category out of the all tagged events.

Category	Fraction(%)	$\varepsilon_{\text{tag}}(\%)$	$\mathcal{D}^2$	$\varepsilon_{\text{eff}}(\%)$
OS-only	11.1	$10.72 \pm 0.73$	$0.1157 \pm 0.0105$	$1.24 \pm 0.09$
SSK-only	41.6	$40.20 \pm 1.14$	$0.0279 \pm 0.0013$	$1.12 \pm 0.04$
OS&SSK	25.5	$24.70 \pm 1.01$	$0.1097 \pm 0.0068$	$2.71 \pm 0.13$
Total	78.2	$75.62 \pm 1.69$	$0.0670 \pm 0.0028$	$5.07 \pm 0.16$

## References

- [1] H. Voss, A. Hoecker, J. Stelzer, and F. Tegenfeldt, *TMVA - Toolkit for Multivariate Data Analysis with ROOT*, PoS **ACAT** (2007) 040.