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Optimisation and calibration of the LHCb opposite side flavour tagging

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Introduction

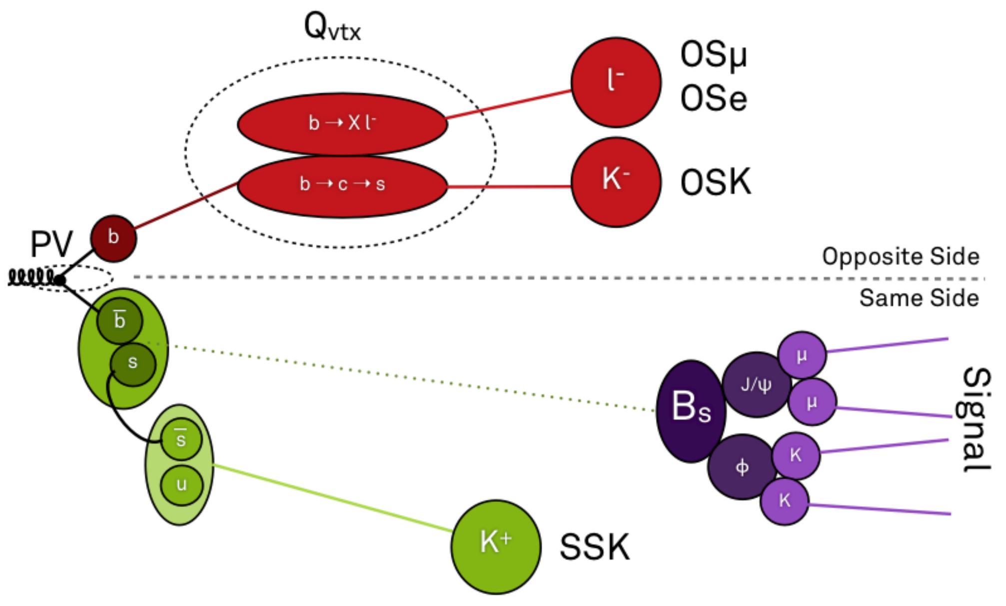
The identification of the flavour of reconstructed B^0 and B_s mesons at production is crucial for the measurements of oscillations and time-dependent CP asymmetries.

This process is known as **Flavour Tagging** (FT).

Flavour Tagging

Two independent algorithms provide informations to tag the initial flavour of the *B* candidate

- **Same side tagger** (SS)
  from the fragmentation of the *b* quark producing the signal *B*-meson a correlated particle is produced
  - Pion, for $B_{u/d}$ (SSπ)
  - Kaon, for B_s (SSK)
- **Opposite side tagger** (OS)
  The non-signal *b* quark of the $b\bar{b}$-pair is exploited
  - overall charge of the secondary vertex (Q_{vtx})
  - lepton from semi-leptonic *B* decays (OSμ and OSe)
  - kaon from the $b \to c \to s$ decay chain (OSK)



Performance of tagging algorithms:

- **mistag**: fraction of events with a wrong tagging decision

$$\omega = \frac{W}{R+W}$$

- **tagging efficiency**: fraction of events with a tagging decision

$$\epsilon_{\text{tag}} = \frac{R+W}{R+W+U}$$

- **tagging power**: effective tagging efficiency indicates the statistical precision of the sample

$$\epsilon_{\text{eff}} = \epsilon_{\text{tag}}(1-2\omega)^2$$

where *R*,*W*,*U* are the number of correctly tagged, incorrectly tagged, and untagged events. The tagging algorithms were developed and studied using simulated events [1].

Control channels

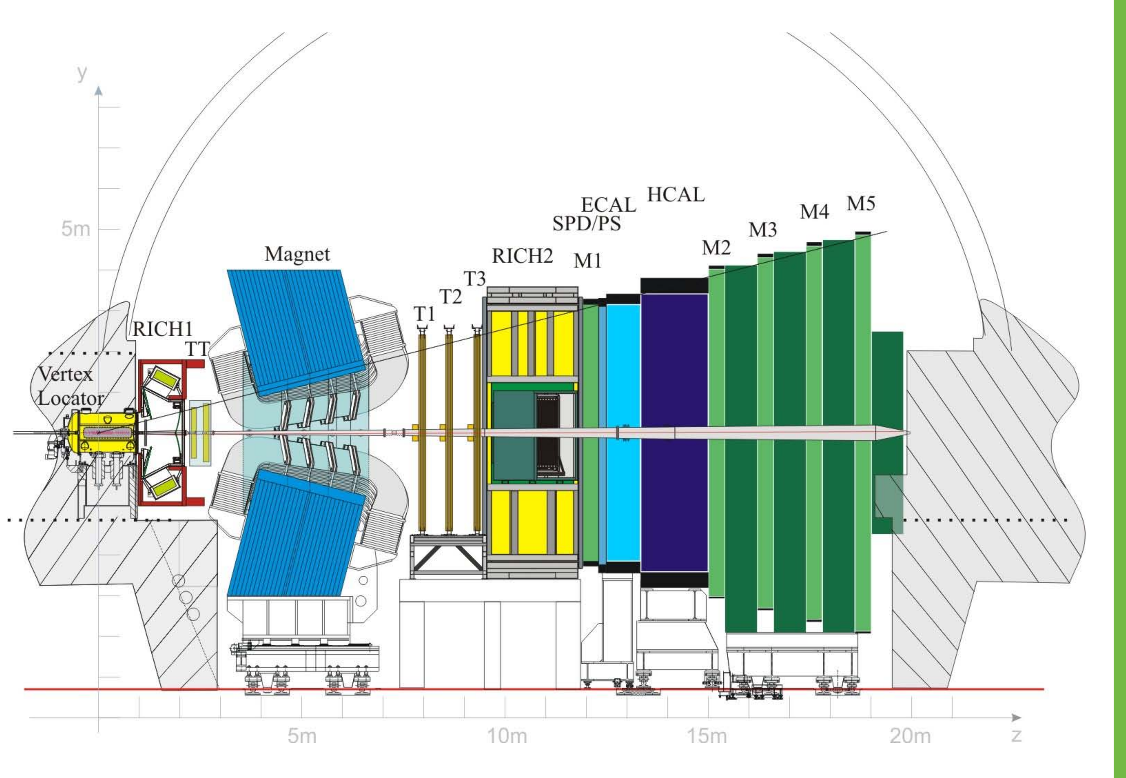
The mistag probability can be measured in data using flavour-specific decay channels, e.g.:

- $B^+ \to J/\psi K^+$
- $B^0 \to J/\psi K^{*0}$
- $B^0 \to D^{*-}\mu^+\nu_\mu$

In a charged channel, it is possible to compare the tag decision with the charge of the signal to determine if the decision is wrong.

In a neutral channel, the mistag probability can be extracted from the time-dependent mixing asymmetry

$$\mathcal{A}_{\text{mix}}(t) = (1-2\omega)\cos(\Delta m_d t)$$



Calibration of mistag probabilities

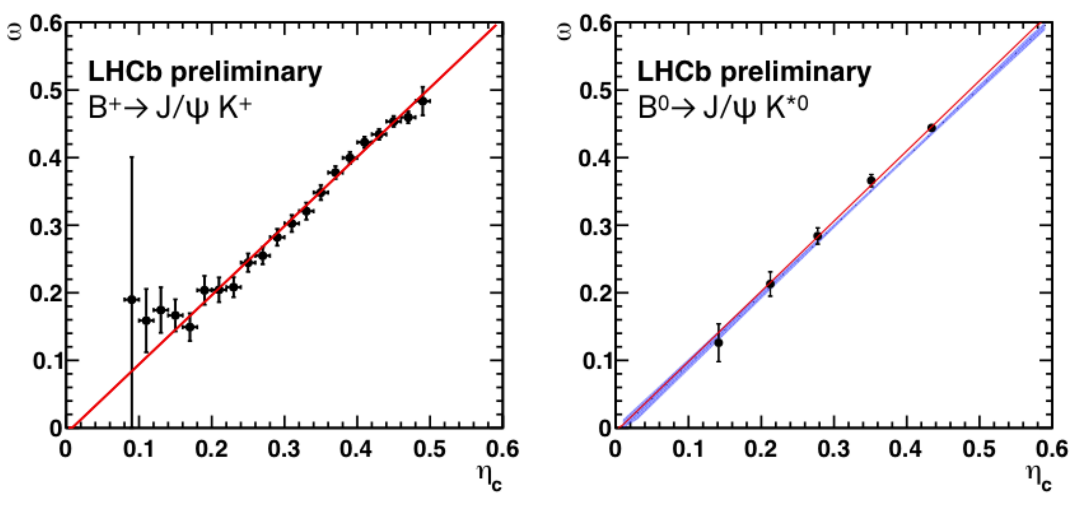
For each tagger, the per event probability η of the tag decision to be wrong is estimated by a neural net (NN) using properties of the tagger and the event itself.

To calibrate the neural net output, the true mistag ω is extracted from the self-tagged control channel $B^+ \to J/\psi K^+$. A linear dependence $\omega(\eta)$ is assumed to calibrate the predicted mistag probability:

$$\omega(\eta) = p_0 + p_1(\eta - \langle\eta\rangle)$$

where p_0 and p_1 are free parameters, and $\langle\eta\rangle$ is the mean calculated mistag. Afterwards, the calibration can be validated using another control channel.

The calibration results [5] for 1 fb⁻¹ of data recorded in 2011 are:



In the right plot the calibration obtained from the $B^+ \to J/\psi K^+$ sample is superimposed as the blue area. [5]

	p_0	p_1	$\langle\eta_c\rangle$
$B^+ \to J/\psi K^+$	0.392±0.002	1.035±0.021	0.391

all uncertainties are statistical only

The calibration is consistent among the different channels. The main systematic uncertainties are:

- Run period
  Split the data sample according to run periods and to the magnet polarity; check for detector asymmetries
- Signal *B* flavour
  Due to possibly different particle/anti-particle interactions, the data sample is split according to the signal flavour
- Fit model assumptions
  Different distributions of the mistag probability in the fit model are investigated
- Distribution of mistag in different channels
  Different distributions of the mistag probability amoung the control channels as well as the p_T distributions and the dependence of the mean mistag on this p_T are studied

The largest systematic uncertainty originates from the dependence on the signal flavour.

	δp_0	δp_1
Total	±0.005	±0.012

Opposite side tagging performance

The OS tagging performance can be computed on different ways:

- Dividing the sample in bins of η_c, where η_c is the calibrated mistag. Then fit for each sub-sample to estimate the tagging power. Since the sub-samples are disjoint, the OS tagging power is the sum of the single bins.
- Using the event-by-event mistag by summing the mistag on all signal events.

For the three control channels the performances for 0.37 fb⁻¹ of data recorded in the first half of 2011 are:

$B^+ \to J/\psi K^+$

Taggers	ε_{tag} [%]	ω [%]	$\varepsilon_{\text{tag}}(1-2\omega)^2$ [%]
μ	4.8±0.1	29.9±0.7	0.77±0.07
e	2.2±0.1	33.2±1.1	0.25±0.04
K	11.6±0.1	38.3±0.5	0.63±0.06
Q_{vtx}	15.1±0.1	40.0±0.4	0.60±0.06
OS sum of η_c bins	27.3±0.2	36.2±0.5	2.07±0.11
OS event-by-event	27.3±0.1	36.1±0.3	2.10±0.08

$B^0 \to J/\psi K^{*0}$

Taggers	ε_{tag} [%]	ω [%]	$\varepsilon_{\text{tag}}(1-2\omega)^2$ [%]
μ	4.8±0.1	34.3±1.9	0.48±0.12
e	2.2±0.1	32.4±2.8	0.27±0.10
K	11.4±0.2	39.6±1.2	0.49±0.13
Q_{vtx}	14.9±0.2	41.7±1.1	0.41±0.11
OS sum of η_c bins	27.1±0.3	38.0±0.9	1.57±0.22
OS event-by-event	27.3±0.3	36.2±0.3	2.09±0.09

$B^0 \to D^{*-}\mu^+\nu_\mu$

Taggers	ε_{tag} [%]	ω [%]	$\varepsilon_{\text{tag}}(1-2\omega)^2$ [%]
μ	6.08±0.04	33.3±0.4	0.68±0.04
e	2.49±0.02	34.3±0.7	0.25±0.02
K	13.36±0.05	38.3±0.3	0.74±0.04
Q_{vtx}	16.53±0.06	41.5±0.3	0.48±0.03
OS sum of η_c bins	30.48±0.08	37.0±0.3	2.06±0.06
OS event-by-event	30.1±0.1	35.5±0.3	2.53±0.10

all uncertainties are statistical only

The differences in the efficiencies are mainly due to different p_T spectra. Moreover, different trigger requirements can effect ε_{tag} and ω.

Conclusion

The optimisation and calibration of the flavour tagging is performed on the first 0.37 fb⁻¹ collected in 2011. By using the calibrated OS taggers the tagging power was $\varepsilon_{\text{tag}}(1-2\omega)^2$ finally determined on an event-by-event basis to be:

- **(2.10±0.08±0.24)%** in $B^+ \to J/\psi K^+$
- **(2.09±0.09±0.24)%** in $B^0 \to J/\psi K^{*0}$
- **(2.53±0.10±0.27)%** in $B^0 \to D^{*-}\mu^+\nu_\mu$

On the full dataset of 2011 of 1 fb⁻¹ the tagging power is:

- **(2.29±0.07±0.26)%**

for the channel $B_s \to J/\psi\phi$, and

- **2.1%**

for the channel $B_s \to J/\psi f_0(980)$, which are both used for measurements of the CP violating phase ϕ_s [3,5].

Moreover, some other time dependent measurements in the CP field have already be done using this flavour tagging [4,6].

(first uncertainty is statistical, the second is systematic)

References

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[4] LHCb Collaboration, "Measurement of ϕ_s in $B_s \to J/\psi\pi^+\pi^-$ decays", LHCB-PAPER-2012-006, for submission to PLB

[5] LHCb Collaboration, "Tagged time-dependent angular analysis of $B_s \to J/\psi\phi$ decays at LHCb", LHCB-CONF-2012-002

[6] LHCb Collaboration, "Measurement of time-dependent CP violation in charmless two-body B decays", LHCB-CONF-2012-007