Optimization and calibration of the flavour tagging using 2010 data

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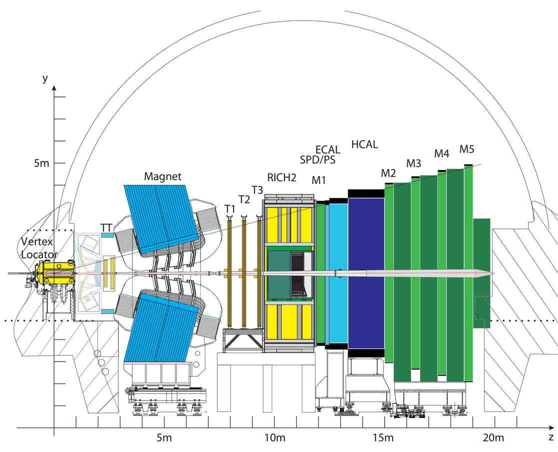
Introduction

Most of the measurements of flavour or CP asymmetries needs to identify the initial flavour of b hadron: whether the meson contained a b or a $\bar{b}$ quark. It is the flavour tagging.

The LHCb detector

- Study CP violation and rare decays in the beauty sector.
- Forward spectrometer characterized by excellent tracking, vertexing, and particle identification system.
- Nominal luminosity ($2.10^{32}\,\mathrm{cm}^{-2}.\mathrm{s}^{-1}$) tuned to obtain few interactions per bunch crossing

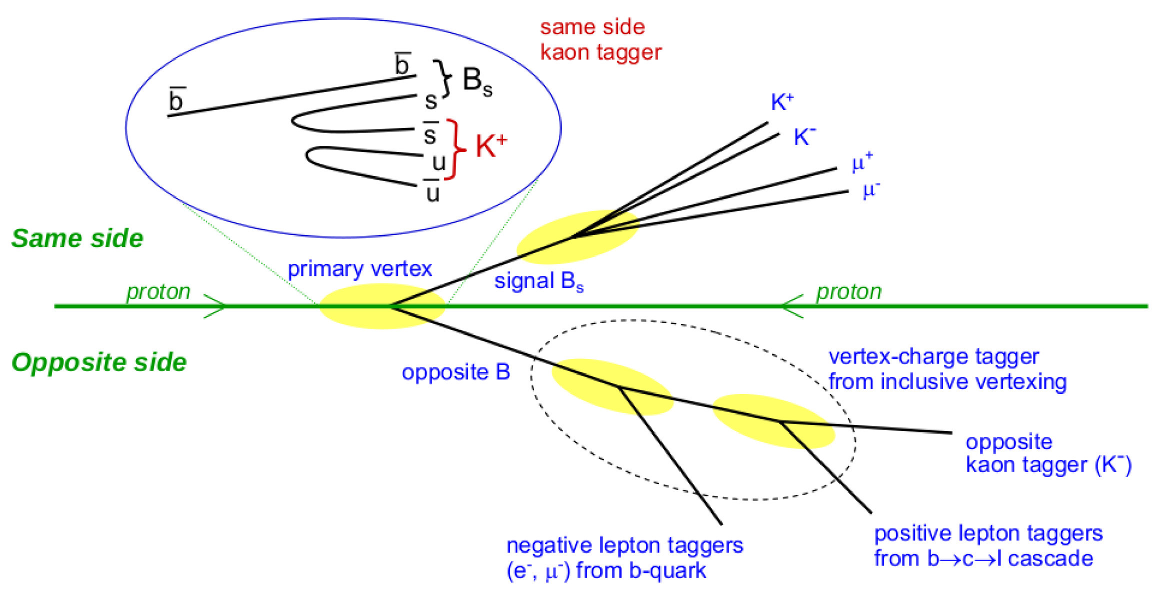


→ Favourable environment for flavour tagging

Flavour tagging algorithm

Two sources of information available to tag the initial flavour of a B candidate:

- Same side (SS): The accompanying quark of the signal B produce a pion for B^+, B^0, and kaon for B^0_s,
- Opposite side (OS): b quarks are produced by pair → Exploitation of the decay chain of the non signal b quark : muon, electron, kaon, vertex charge.



As the tagging algorithm is not perfect, the performances are quantified:

- Mistag: fraction of wrong tagged events: $\omega = \frac{W}{R+W}$,
- Tagging efficiency: fraction of events with a tagging decision: $\epsilon_{\mathrm{tag}} = \frac{R+W}{R+W+U}$,
- Tagging power, or effective tagging efficiency: $\epsilon_{\mathrm{eff}} = \epsilon_{\mathrm{tag}}\,(1 - 2\,\omega)^2$

where R, W, U are respectively the number of correctly tagged, incorrectly tagged, and untagged events.

Flavour tagging algorithm was developed and studied on Monte Carlo [1]:

- Selection of the taggers: based on the properties of the b hadrons decays (large IP and p_T, ...)
- For each tagger, the probability of the tag decision to be correct is estimated by means of a **neural network** trained on MC events,
- If more than one tagger available per event, the final decision is a combination between all available decisions weighted by their probabilities to be correct.

Optimization and Calibration on data

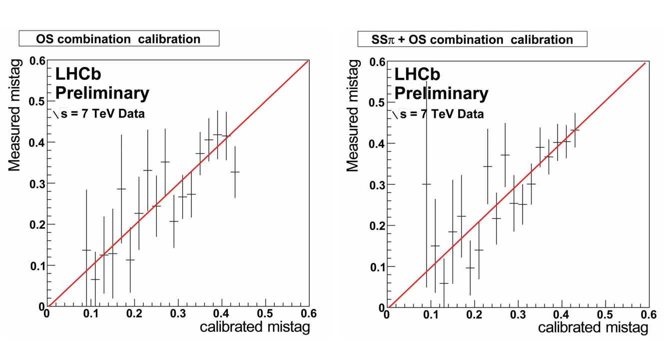
Optimization of the taggers' selection: cuts are tuned to maximize ϵ_{eff}, using $B^+ \to J/\psi K^+$ and $B^0 \to D^{*-}\mu^+\nu_\mu$ channels.

Each tagger and their combination have a mistag probability (η) calculated event by event, which is compared with the measured mistag (ω). A correction function is applied: $\omega = p_0 + p_1(\eta - <\eta>)$, with p_0, p_1 free parameters, and $<\eta>$ the mean calculated mistag.

The calibration procedure [2]:

- uses the self tagged channel $B^+ \to J/\psi K^+$,
- is applied to single taggers and combinations,
- extracts the p_0, p_1 values with an unbinned maximum likelihood fit performed to the mass, the tagging decision and the mistag probability (η),
- compares the measured mistag with the calibrated mistag probability (in $B^+ \to J/\psi K^+$ and $B^0 \to J/\psi K^{*0}$).

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

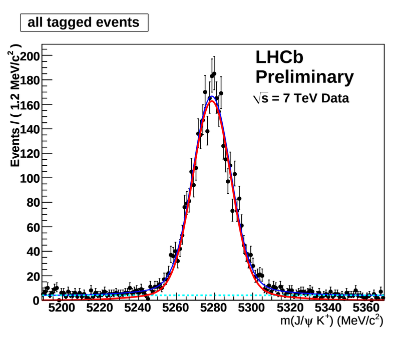


The present precision of the calibration parameters is limited by the statistics: ±0.012 on the mean mistag value and ±0.12 on the scale.

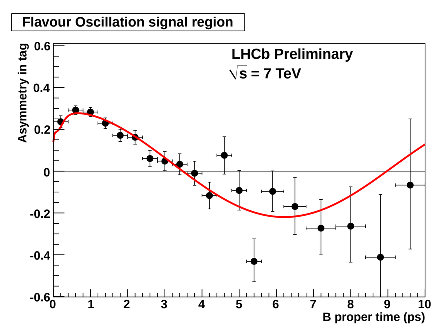
Flavour tagging performances

Analysis of the flavour specific channels: $B^+ \to J/\psi K^+$, $B^0 \to D^{*-}\mu^+\nu_\mu$, $B^0 \to J/\psi K^{*0}$:

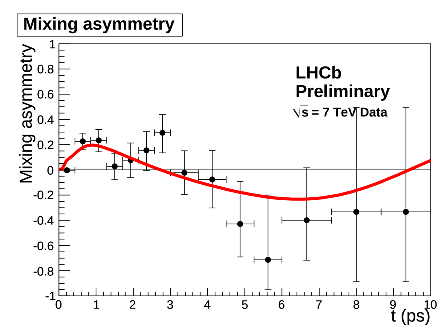
- $B^+ \to J/\psi K^+$: By counting the number of signal events which charge agrees with the flavour tagging decision, the number of correctly or wrongly tagged signal events is determined.
- $B^0 \to D^{*-}\mu^+\nu_\mu$ and $B^0 \to J/\psi K^{*0}$: Neutral channels oscillate. We study the B^0 flavour oscillations as a function of proper time. The time dependent asymmetry for signal is diluted by a function of the mistag: $\mathcal{A}(t) = (1 - 2\omega)\cos(\Delta m_d t)$, with Δm_d the B^0 oscillation frequency.



$B^+ \to J/\psi K^+$: Mass fit



$B^0 \to D^{*-}\mu^+\nu_\mu$: Flavour asymmetry fit



$B^0 \to J/\psi K^{*0}$: Flavour asymmetry fit

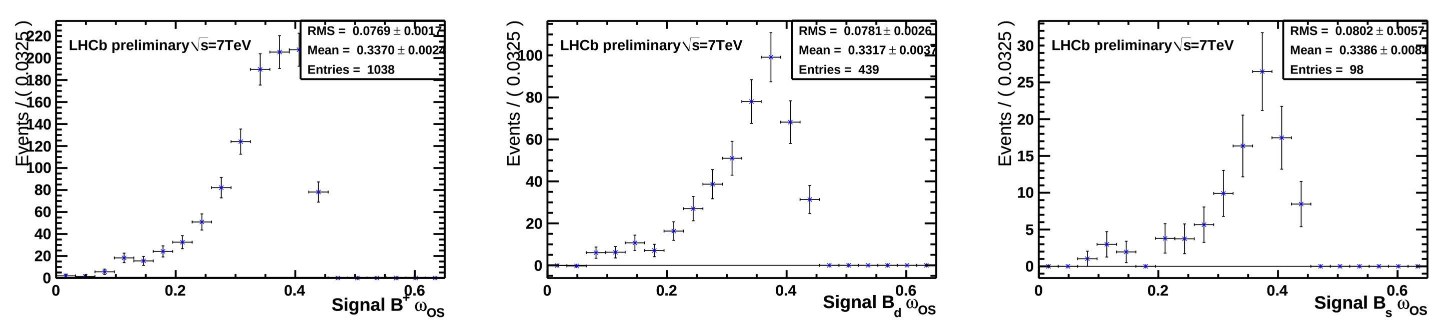
After optimization and calibration, the flavour tagging performances are extracted from the previous fits [3].

	$\varepsilon_{\mathrm{tag}}$(%)	ω(%)	$\varepsilon_{\mathrm{eff}}$(%)
$B^+ \to J/\psi K^+$			
OS	15.4±0.3	32.2±1.2	1.97±0.31
SSπ+OS	23.0±0.5	33.9±1.1	2.38±0.33
$B^0 \to D^{*-}\mu^+\nu_\mu$			
OS	18.3±0.2	33.6±0.8	1.97±0.18
SS-π+OS	28.9±0.2	34.2±0.8	2.87± 0.32
$B^0 \to J/\psi K^{*0}$			
OS	15.8±0.7	30.0±6.6	2.52±0.82
SSπ+OS	26.1±0.9	33.6±5.1	2.82±0.87

Exportation of the tagging performances

Exporting the tagging performances (ω) from a control channel to a different one is possible if selection, trigger, p_T spectra and running conditions are very similar.

For one of the LHCb key goals, the CP violating phase ϕ_s, previous studies on MC have shown we can safely use the performances measured in $B^+ \to J/\psi K^+$ and $B^0 \to J/\psi K^{*0}$ in the $B^0_s \to J/\psi\phi$ channel.



In 2010 data, the calibrated mistag distributions of signal events for $B^+ \to J/\psi K^+$ (left), $B^0 \to J/\psi K^{*0}$ (middle) and $B^0_s \to J/\psi\phi$ (right) confirm that.

Conclusion

Optimization and calibration of flavour tagging algorithm have been done using all the 2010 LHCb data.
Measurement of the B^0 and B^0_s oscillation frequencies and the CP asymmetry parameter $-\sin(2\beta)$ with the β CKM angle have already been done [4, 5, 6] with this FT.
Other measurements as the CP violating phase ϕ_s are expected very soon.

References

[1] M. Calvi, et al., "Flavour tagging algorithms and performances in LHCb", LHCb-2007-058.

[2] M. Calvi, et al., "Calibration of flavour tagging with $B^+ \to J/\psi K^+$ and $B^0 \to J/\psi K^{*0}$ control channels at LHCb", LHCb-2009-020.

[3] LHCb collaboration, "Optimization and calibration of flavour tagging", LHCb-CONF-2011-003.

[4] LHCb collaboration, "Measurement of Δm_d in the decay $B^0 \to D^-(K^+\pi^-\pi^-)\pi^+$", LHCb-CONF-2011-010.

[5] LHCb collaboration, "Measurement of Δm_s in the decay $B^0_s \to D_s(K^+K^-\pi^-)\pi^+$", LHCb-CONF-2011-005.

[6] LHCb collaboration, "Search for CP violation in $B^0 \to J/\psi K^0_S$ decays with first LHCb data", LHCb-CONF-2011-004.