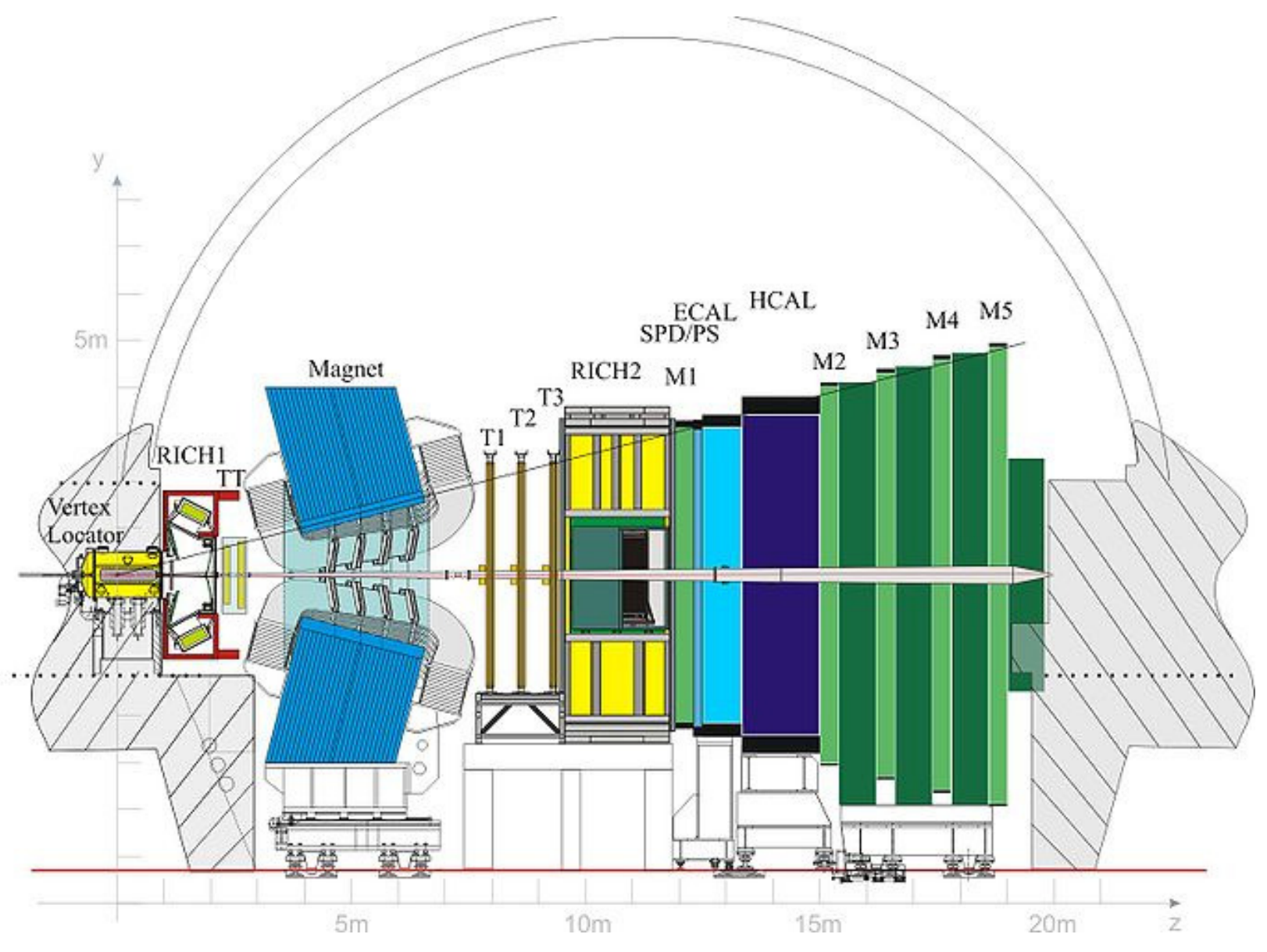
Optimization and Calibration of Flavour Tagging Algorithms for the LHCb experiment

ANTONIO FALABELLA
UNIVERSITÀ DI FERRARA-INFN BOLOGNA
LHCC 2013 CERN

LHCB

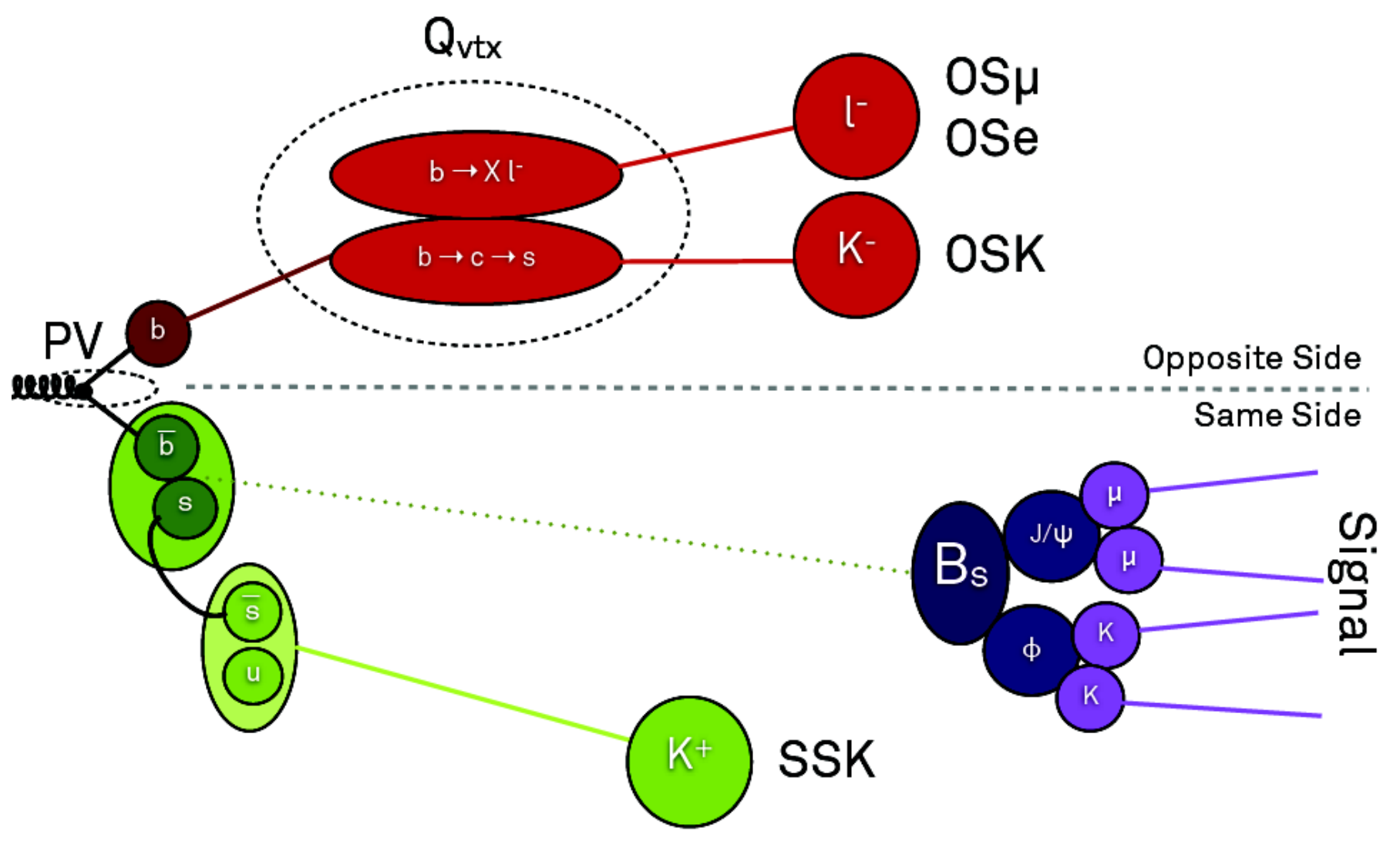


Purposes: Precision studies of B-meson and D-meson decays (CP violation, rare decays)
Features: Efficient trigger and selection. Very good vertexing and tracking. Very good mass resolution and PID (Particle IDentification - RICH: $\pi/K/p/$, MUON μ, ECAL e/γ)

FLAVOUR TAGGING

Identification of the initial flavour of reconstructed B^0 and B^0_s mesons. Fundamental for measurements of oscillation and time-dependent CP asymmetries.
Same side algorithms- SS: Assert the flavour exploiting the fragmentation chain of the b that produce the signal B-meson

- ◇ **Pion**, for $B_{u/d}$(**SS**π)
- ◇ **Kaon**, for B_s(**SSK**)



Opposite side algorithms - OS: Assert the flavour exploiting the decay products of the opposite B

- ◇ μ, e from semileptonic decays of the B (**OS**μ **e OSe**)
- ◇ Kaon from the decay chain $b \to c \to s$ (**OSK**)
- ◇ Inclusive reconstruction of the opposite B vertex (**Q****VTX**)

Each algorithm provide a tagging decision $d = +1/-1$ for the B containing a $\bar{b}/b$ and an estimated probability for the decision of being wrong (η).

Performances
Mistag: Fraction of events with a wrong tagging decision

$$\omega = W/(R+W)$$

Tagging efficiency: Fraction of events with a tagging decision

$$\epsilon_{tag} = (R+W)/(R+W+U)$$

Tagging power:
Effective statistical reduction factor of the sample size

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

R, W, U=right, wrong, untagged events
The flavour tagging algorithms have been developed on MC data [1] and optimized on real data.

CONTROL CHANNELS

The mistag probability is measured directly on flavour-specific control channels:

- ◇ $B^+ \to J/\Psi K^+$ $(SS\pi, OS)$
- ◇ $B^0 \to J/\Psi K^{*0}$ $(SS\pi, OS)$
- ◇ $B^0_d \to D^{*-}\mu^+\nu_\mu$ $(SS\pi, OS)$
- ◇ $B^0_s \to D^-_s\pi^+$ (SSK, OS)

Charged channels: comparison between the charge of the signal B and the tag decision.

Neutral channels: fit of the time-dependent measured mixing asymmetry:

$$A^{meas}_{mix}(t) \propto D_{tag}D_tA_{mix} = (1-2\omega)e^{-\frac{1}{2}(\Delta m_{d/s}\sigma_t)^2}cos(\Delta m_{d/s}t)$$

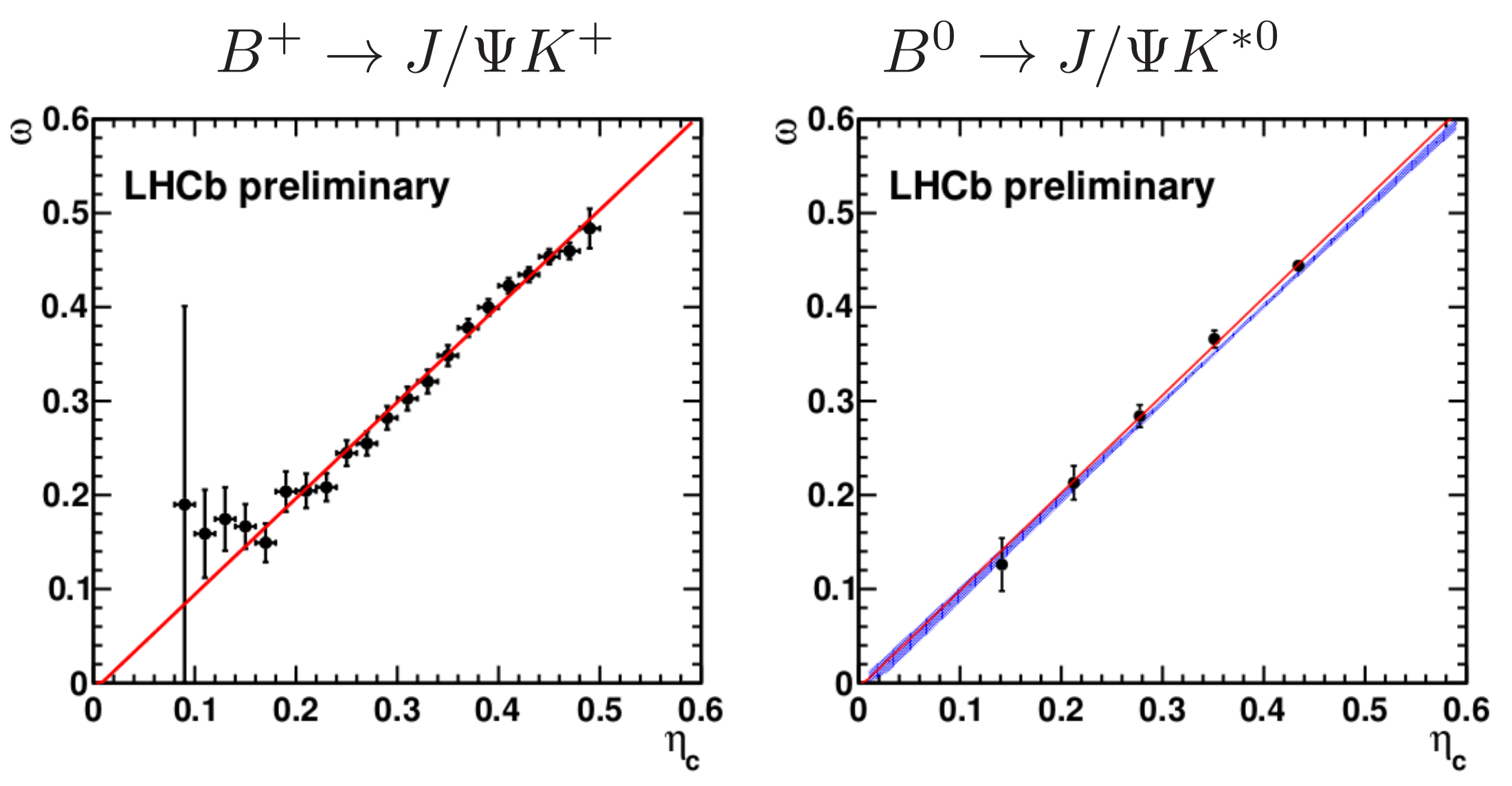
Where D_{tag}, D_t are the dilution factors due to tagging and decay time resolution.
For B^0_s channels the correct estimation of ω require a good knowledge of D_t.

CALIBRATION

The probability of the decision to be wrong (η) is estimated with NNet-based algorithm which uses several geometric and kinematic properties of the tagger particle and is trained on MC to identify the correct decision.
To use η on data as a faithful mistag estimation it is calibrated using control channels ($B^+ \to J/\Psi K^+$, $B^0 \to J/\Psi K^{*0}$) assuming a linear dependency:

$$\omega(\eta) = p_0 + p_1(\eta - <\eta>)$$

The results are consistent among the different control channels.



Systematic uncertainties:

- ◇ **Run**: split the data sample by run period and magnet polarity
- ◇ **Signal** B **flavour**: different tagging performances on B and $\overline{B}$
- ◇ **Fit model** : different assumptions on the signal and background probability distributions for η

	p_0	p_1	η_c
$B^+ \to J/\Psi K^+$ OS [2]	$0.392 \pm 0.002 \pm 0.009$	$1.035 \pm 0.021 \pm 0.012$	0.391
$B^0_s \to D^-_s\pi^+$ SSK [4]	$0.349 \pm 0.015 \pm 0.012$	$1.00 \pm 0.30 \pm 0.02$	0.350

OS TAGGERS PERFORMANCES

OS taggers
The performances of each tagger are calculated summing the calibrated event-by-event tagging power. When more than one tagger gives a decision the combination is computed.
The combination is recalibrated due to correlation among taggers.
In the table are reported the OS tagging algorithms performances [2]

$B^+ \to J/\psi K^+$ ($1.0fb^{-1}$ LHCb 2011 data sample)			
	$\epsilon_{tag}(\%)$	$\omega(\%)$	$\epsilon_{eff}(\%)$
μ	5.20 ± 0.04	30.8 ± 0.4	0.77 ± 0.04
e	2.46 ± 0.03	30.9 ± 0.6	0.36 ± 0.03
K	17.67 ± 0.08	39.33 ± 0.24	0.81 ± 0.04
$Q_{\rm vtx}$	18.46 ± 0.08	40.31 ± 0.24	0.70 ± 0.04
OS	33.2 ± 0.09	36.7 ± 0.2	2.35 ± 0.06

The optimized performances of the OS taggers in the neutral channels are calculated with $0.37fb^{-1}$ data sample collected in 2011 by LHCb [3]

- ◇ $B^0 \to J/\psi K^{*0}$: $(2.09 \pm 0.09 \pm 0.24)\%$
- ◇ $B^0 \to D^{*-}\mu^+\nu_\mu$: $(2.53 \pm 0.10 \pm 0.27)\%$

SS-KAON TAGGER PERFORMANCES

The SS-Kaon algorithm has been optimized in the $B^0_s \to D^-_s\pi^+$ decay.
The performance is reported in the table [4].

$B^0_s \to D^-_s\pi^+$ ($1.0fb^{-1}$ LHCb 2011 data sample)			
	$\epsilon_{tag}(\%)$	$\omega(\%)$	$\epsilon_{eff}(\%)$
SSK	16.3 ± 0.4	34.8 ± 2.1	1.5 ± 0.4

and the combination of the OS and SS-Kaon algorithms

$B^0_s \to D^-_s\pi^+$ ($1.0fb^{-1}$ LHCb 2011 data sample)			
	$\epsilon_{tag}(\%)$	$\omega(\%)$	$\epsilon_{eff}(\%)$
$SSK + OS$	49.1 ± 0.3	36.1 ± 1.4	3.8 ± 0.4

PHYSICS RESULTS

The optimized and calibrated results with $1fb^{-1}$ of data taken in 2011 have been used for some of the most relevant CP violation measurement and asymmetry studies

- ◇ The measurement of the CP-violating phase ϕ_s in $B^0_s \to J/\Psi K^+K^-$ and $B^0_s \to J/\Psi\pi^+\pi^-$ decays [5]

  $\epsilon_{eff} = (3.13 \pm 0.12 \pm 0.20)\%$ (SSK + OS) (preliminary)

- ◇ The measurements of $B^0_{s/d} - \overline{B}^0_{s/d}$ oscillation frequencies $\Delta m_{s/d}$ [6] [7].

  $\epsilon_{eff} = (3.5 \pm 0.5)\%$ (SSK + OS) for Δm_s

- ◇ The measurement of time dependent CP-violation in $B^0_s \to D^\mp_s K^\pm$ [8]

  $\epsilon_{eff} = 1.9\%$ (OS)

- ◇ and in charmless two-body B decays [9]

  $\epsilon_{eff} = 2.3 \pm 0.1\%$ (OS)

REFERENCES

[1] M.Calvi, et al.,"Flavour Tagging Algorithms and Performances in LHCb", CERN-LHCB-2007-058
[2] LHCb Collaboration "Opposite-side flavour tagging of B mesons at the LHCb Performance of flavour tagging algorithms optimised for the analysis $B^0 \to J/\Psi\phi$", LHCB-CONF-2012-026
[3] LHCb Collaboration "Opposite-side flavour tagging of B mesons at the LHCb experiment", Eur. Phys. J. C (2012) 72:2022, arXiv:1202.4979
[4] LHCb Collaboration "Optimization and calibration of the same-side kaon tagging algorithm using B^0_s hadronic decays in 2011 data", LHCB-CONF-2012-033
[5] LHCb Collaboration, "Measurement of CP -violation and the B^0_s decay width difference with $B^0_s \to J/\Psi K^+K^-$ and $B^0_s \to J/\Psi\pi^+\pi^-$ decays", LHCB-PAPER-2013-002
[6] LHCb Collaboration, "Measurement of the $B^0_s - \overline{B^0_s}$ oscillation frequency Δm_s in $B^0_s \to D^+_s\pi^-$", LHCB-PAPER-2013-006-001
[7] LHCb Collaboration, "Measurement of the $B^0 - \overline{B^0}$ oscillation frequency Δm_d with the decays $B^0 \to D\pi^+$ and $B^0 \to J/\Psi K^{*0}$", LHCB-PAPER-2012-032, arXiv:1210.6750
[8] LHCb Collaboration, "Measurement of time-dependent CP-violation observables in $B^0_s \to D^\mp_s K^\pm$", LHCB-CONF-2012-009
[9] LHCb Collaboration, "Measurement of time-dependent CP violation in charmless two-body B decays", LHCB-CONF-2012-007