Measurement of the *CP* Violating Phase φ_s in $B_s^0 \to J/\psi\, h^+h^-$ Decays at LHCb

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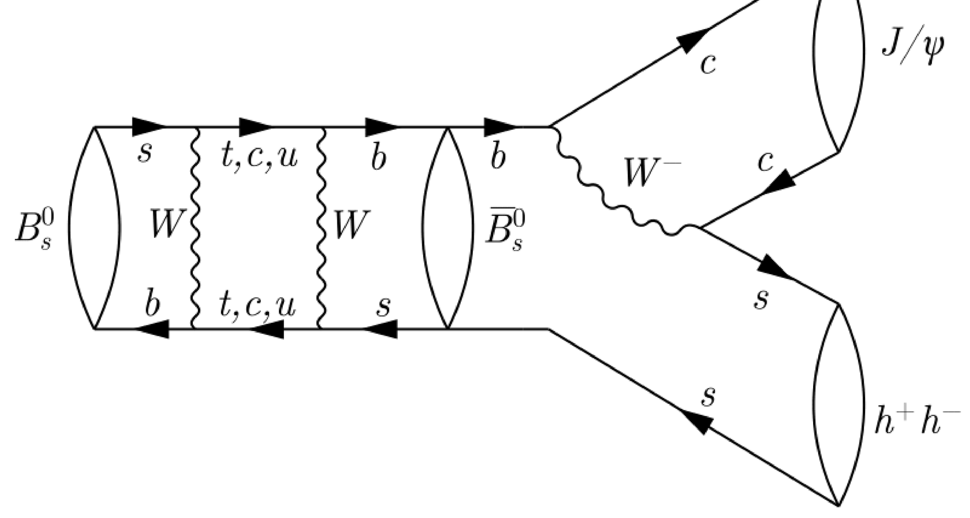
CP Violating Phase φ_s

The decays $B_s^0 \to J/\psi K^+K^-$ and $B_s^0 \to J/\psi\pi^+\pi^-$ can proceed via the same decay diagram. Being a neutral particle, the B_s^0 meson can **oscillate** into its anti-particle.

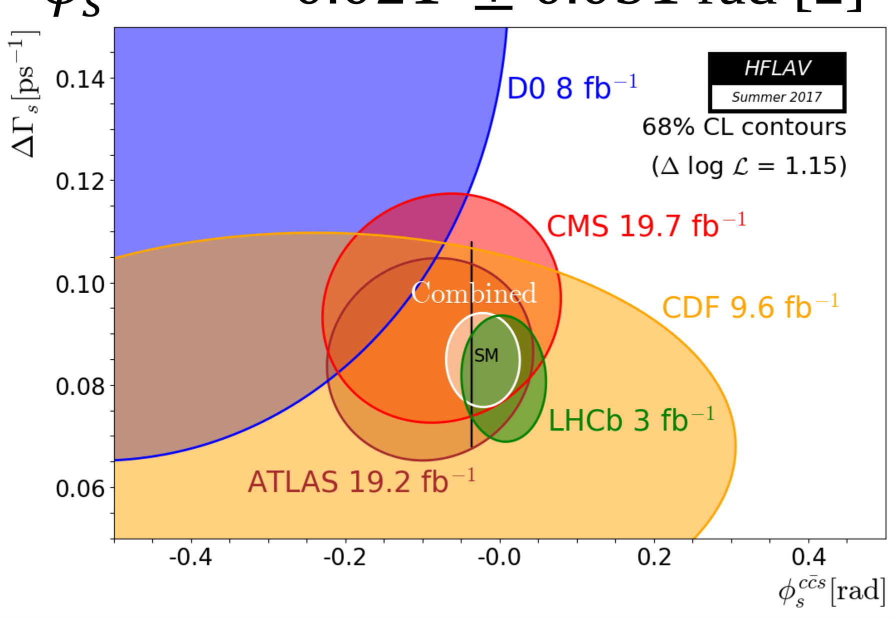


Interference between direct decay and via oscillation gives rise to the CP violating phase φ_s, which is precisely predicted by the Standard Model:

$$\varphi_s^{SM} \approx -2\beta_s \equiv -2\arg\left(-\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right) = -0.037 \pm 0.001 \text{ rad [1]}$$

However this value could be significantly affected by **New Physics**, which makes it experimentally very interesting. The current World Average is in agreement with the Standard Model and is dominated by LHCb:

$$\varphi_s^{WA} = -0.021 \pm 0.031 \text{ rad [2]}$$



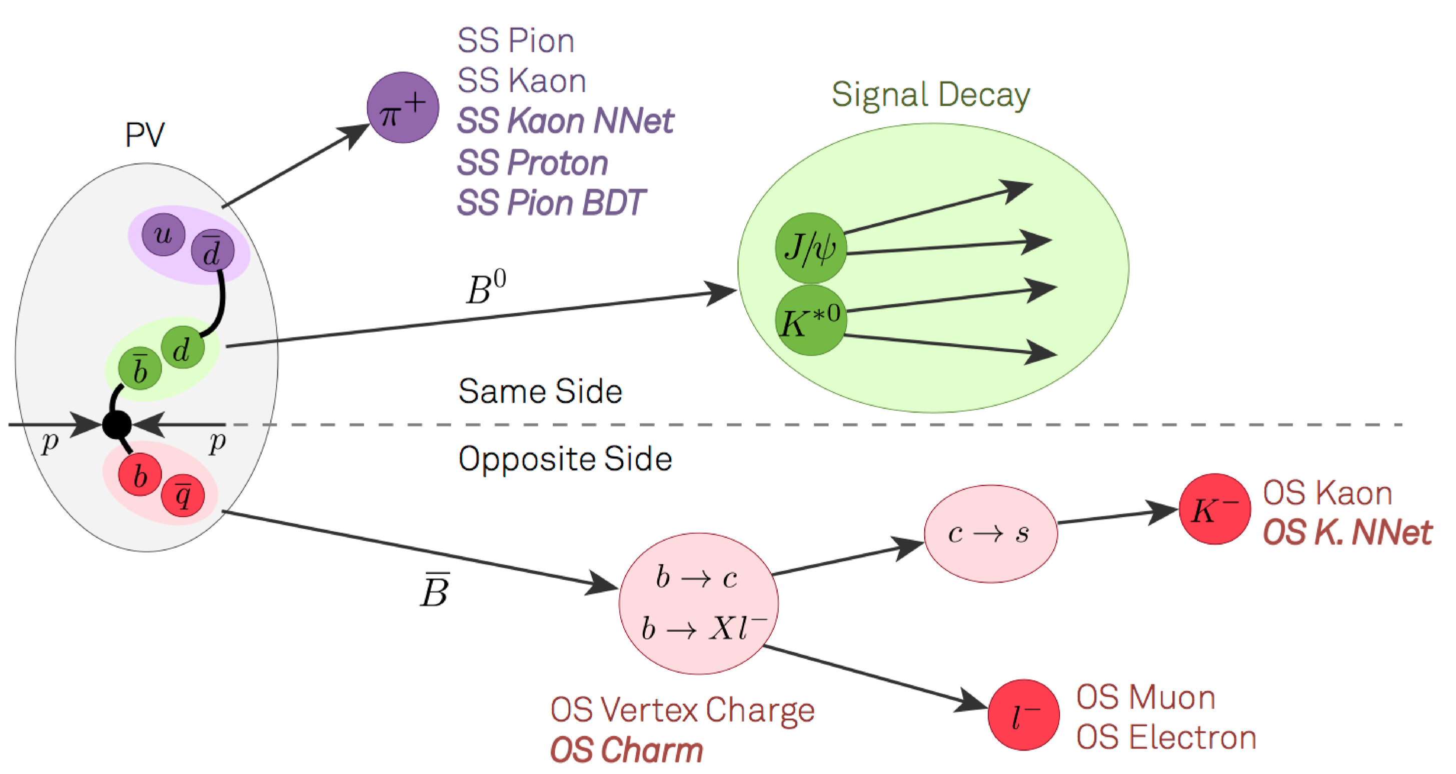
$B_s^0 \to J/\psi\, h^+h^-$ Run 1 Analyses

Time-dependent amplitude analysis of **3 fb^{-1}** of Run 1 data using $B_s^0 \to J/\psi\, K^+K^-$ [3, 4] and $B_s^0 \to J/\psi\pi^+\pi^-$ [5] leads to a combined result of:

$$\varphi_s = 0.001 \pm 0.037 \text{ rad}$$

Flavour tagging, **decay time resolution**, **decay time acceptance** and **angular acceptance** are essential ingredients for this precise result.

Flavour Tagging



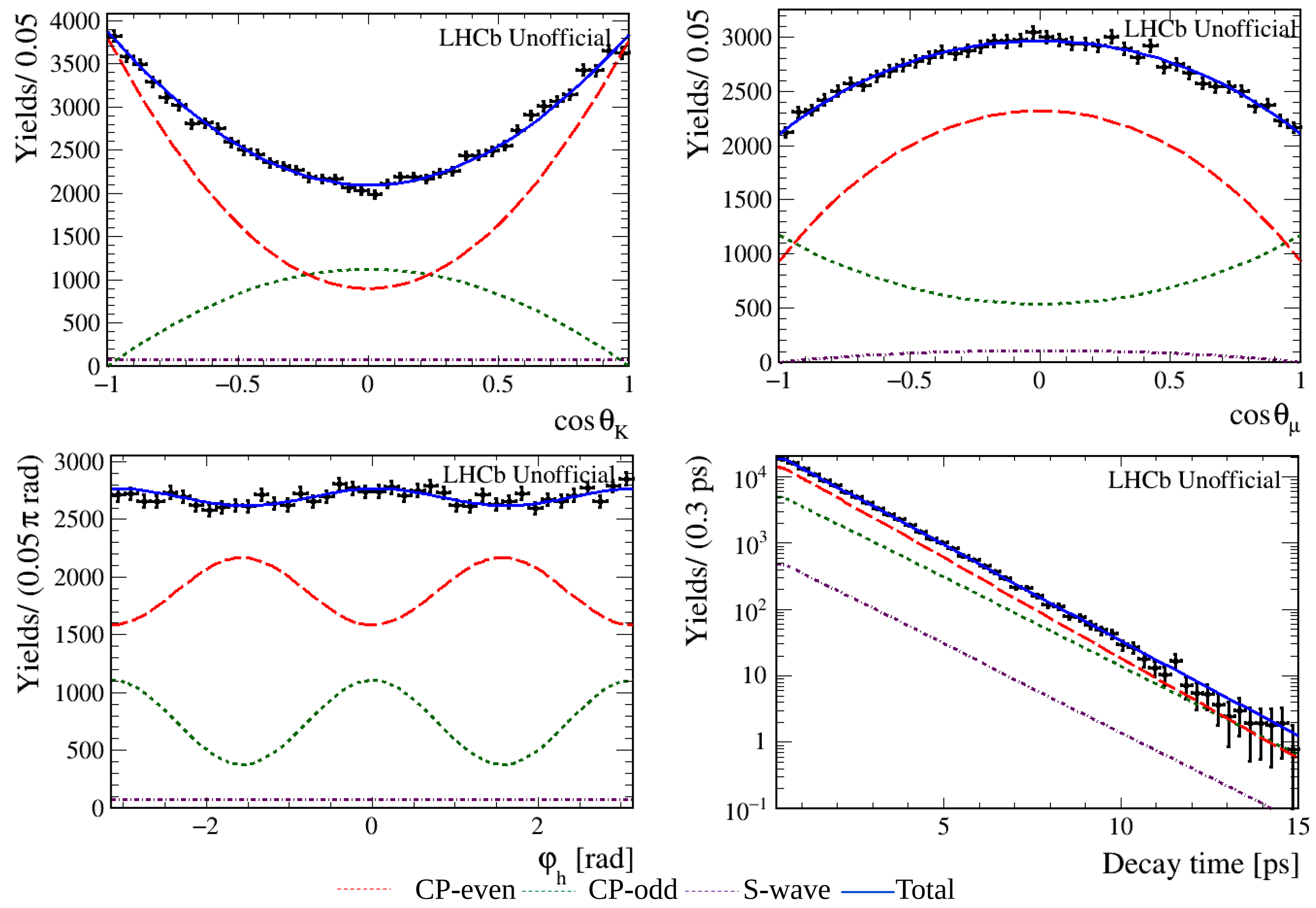
To determine φ_s it is crucial to properly **tag** the b quark flavour at production. The OS and SS taggers are exploited to determine the **effective tagging efficiency**:

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

Analysis of **1.9 fb^{-1}** 2015 and 2016 data determines the effective tagging efficiency to be roughly 5% for both $B_s^0 \to J/\psi K^+K^-$ and $B_s^0 \to J/\psi\pi^+\pi^-$.

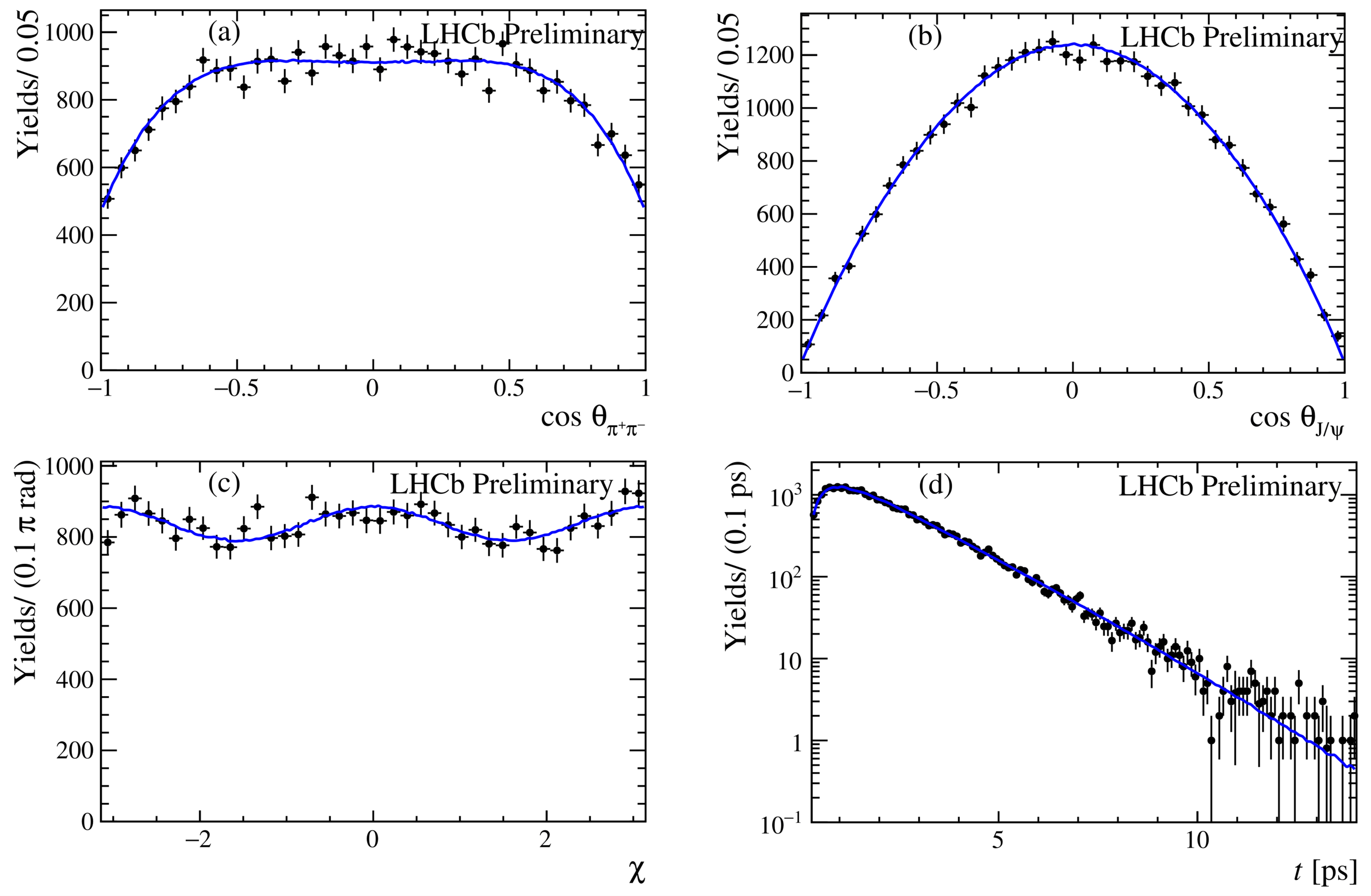
$B_s^0 \to J/\psi\, K^+K^-$ 2015 and 2016 Analysis

Determination of $\boldsymbol{\varphi_s}$, $\boldsymbol{\Gamma_s}$, the average width in the B_s^0 system, and $\boldsymbol{\Delta\Gamma_s}$, the decay width difference of the light (L) and heavy (H) B_s^0 mass eigenstates. A **multidimensional fit** is performed to the decay time and the three helicity angles to **disentangle** the *CP*-even and *CP*-odd components.



$B_s^0 \to J/\psi\, \pi^+\pi^-$ 2015 and 2016 Analysis

Access to $\boldsymbol{\varphi_s}$ and $\boldsymbol{\Gamma_H}$, the decay width of the heavy B_s^0 mass eigenstate, by fitting **simultaneously** the *CP*-even and *CP*-odd decay amplitudes to decay time, the three helicity angles and $m(\pi^+\pi^-)$. [6]



Expected Precision

- $B_s^0 \to J/\psi\, K^+K^-$ statistical uncertainty $\sigma_{stat} \sim \mathbf{0.041}$ rad and including Run 1 $\sigma_{stat} \sim 0.030$ rad
- $B_s^0 \to J/\psi\pi^+\pi^-$ statistical uncertainty $\sigma_{stat} \sim \mathbf{0.060}$ rad and including Run 1 $\sigma_{stat} \sim 0.044$ rad [6]
- LHCb sensitivity is expected to reach < **0.003** rad with Phase-II Upgrade [7]

References

[1] J. Charles *et al.*, Current status of the Standard Model CKM fit and constraints on $\Delta F = 2$ New Physics, *Phys. Rev.* **D 91**, p. 073007 (2015)
[2] Y. Amhis *et al.*, Averages of *b*-hadron, *c*-hadron, and τ-lepton properties as of summer 2016 (2016), *Eur. Phys. J.* **C77** (2017)
[3] The LHCb Collaboration, R. Aaij *et al.*, Precision measurement of *CP* violation in $B_s^0 \to J/\psi\, K^+K^-$ decays, *Phys. Rev. Lett.* **114**, p. 041801 (2015)
[4] The LHCb Collaboration, R. Aaij *et al.*, Resonances and *CP* violation in $\boldsymbol{B_s^0}$ and $\overline{B_s^0} \to J/\psi\, K^+K^-$ decays in the mass region above the $\boldsymbol{\varphi(1020)}$, *JHEP 08* 037 (2017)
[5] The LHCb Collaboration, R. Aaij *et al.*, Measurement of the *CP*-violating phase φ_s in $\overline{B_s^0} \to J/\psi\pi^+\pi^-$ decays, *Phys. Lett.* **B736** 186 (2014)
[6] LHCb-PAPER-2019-003, *in preparation*
[7] The LHCb Collaboration, R. Aaij *et al.*, Physics case for an LHCb Upgrade II, CERN-LHCC-2018-027 (2018)