1. Motivation

In the Standard Model CP violation is described by a phase in the CKM matrix. One of the manifestations of this complex phase is a phase shift direct and mixing-mediated $B_s$ decays producing a common final state. In the case of $B_s \to J/\psi K^*$ this phase shift is predicted to be small: $\phi_s \approx 0.038 - 0.0018 \text{ rad}$. New physics can enhance $\phi_s$ whilst satisfying all existing constraints.

2. CP violation in $B_s$ system

To distinguish between different CP violating effects three categories are defined:

- **CP violation in decay**: decay amplitudes of $B$-meson and anti-$B$-meson are different
- **CP violation in mixing**: asymmetry in the particle antiparticle oscillations (CP eigenstates are not equivalent to the mass eigenstates)
- **in the $B_s \to J/\psi K^*$ channel the CP violation occurs in interference of mixing and decay:**

3. Used data and candidate selection

- 2011 data, 4.9 fb$^{-1}$ of 7 TeV proton-proton collisions
- single and di-muon triggers based on the identification of $J/\psi \to \mu^+\mu^-$ decays with threshold as low as 4 GeV

Offline candidate reconstruction:

- oppositely-charged muon pair
- [n] dependent mass cuts (retains 99.8% of signal)
- vertex: $\chi^2/\text{ndf} < 10$
- oppositely-charged track pair (not muons)
- $p_T(K) > 1 \text{ GeV}$
- $|m[KK] - m_{(\bar{B}_s)}| < 11 \text{ MeV}$

4. Flavour tagging

- inclusion of the $B_s$ meson flavor at production enhances the fit sensitivity to $\Phi_s$
- initial flavour of (neutral) $B_s$ can be inferred using the other $B$-meson, typically produced in the event (Opposite-Side Tagging)
- calibration by decays of $B^+ \to J/\psi K^+$ from the entire 2011 run period (same data quality selections)

Momentum tagging:

- use semi-leptonic decay of the $B$-meson
- combined and segment-tagged muons are used
- momentum-weighted charge of muon and tracks around
- diluted through $b \to c \to \mu$, but even so it has good separation power

5. Lifetime

- $\phi_s$ constrained to $> 0$ in

6. Fitting model

An unbinned maximum likelihood fit was performed, using these per-candidate variables:

- $B_s$ mass and proper decay time $t$
- their uncertainties
- mass and lifetime of final-state particles in transversity basis $Q(\Phi_s, \Phi_s, \psi)$
- $B_s$ momentum $p_1$
- $B_s$ tag probability and tagging method

Fit determines 9 physics variables that describe $B_s \to J/\psi K^*$ and S-wave ($B_s \to J/\psi K^*(0)$ or $f_0$) component: $\Delta \Phi_s, \Delta \Gamma_s, |\epsilon(0)|, |\epsilon(0)|, |\epsilon(0)|, \delta_1, \delta_2$

7. Systematic uncertainties

- Effect of radiative recombination (reduced to signal MC)
- Uncertainty in the relative fraction of $B_s$ background contamination from $B_s \to J/\psi K^*$ and $B_s \to J/\psi K$ decay (matched reconstructed at $B_s \to J/\psi K$)
- Uncertainty in the $\Phi_s$ and $\Delta \Phi_s$ resolution
- $\Phi_s$-dependent $\Delta \Phi_s$ and $\Delta \Gamma_s$

8. Systematic uncertainties

9. Results

Since the PDF describing the $B_s \to J/\psi K^*$ decay is invariant under the transformations $(\Phi_s, \Delta \Phi_s, \delta_1, \delta_2) \to (\pi - \Phi_s, -\Delta \Phi_s, \pi - \delta_1, 2\pi - \delta_2)$, we consider only solutions with positive $\Delta \Phi_s$ (according to other experiments).

- $22.670 \pm 150 \text{ signal} B_s$ from fit
- $\phi_s$ and other parameters are consistent with the Standard Model prediction
- S-wave amplitude is consistent with 0

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