Measurement of ϕ_s using $B_s^0 \to J/\psi\pi^+\pi^-$

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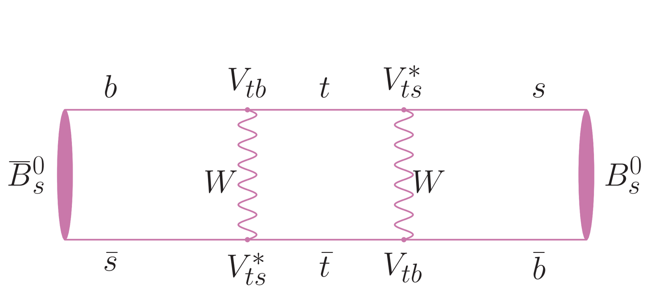
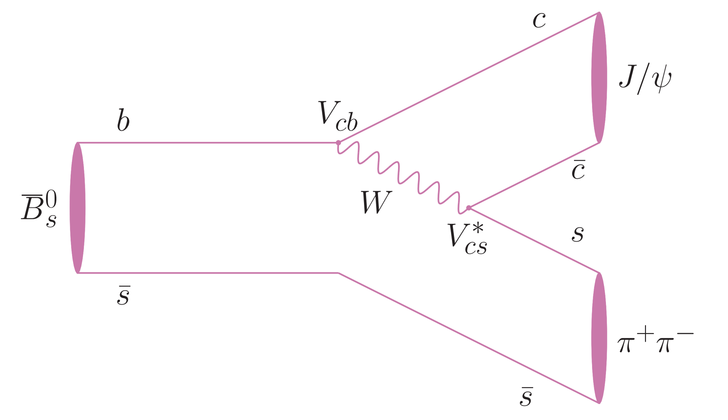
1. $\mathcal{CP}$ violating phase ϕ_s in $B_s^0 \to J/\psi\pi^+\pi^-$



Mixing: $\phi_{\rm M} = 2\arg(V_{tb}V_{ts}^*)$

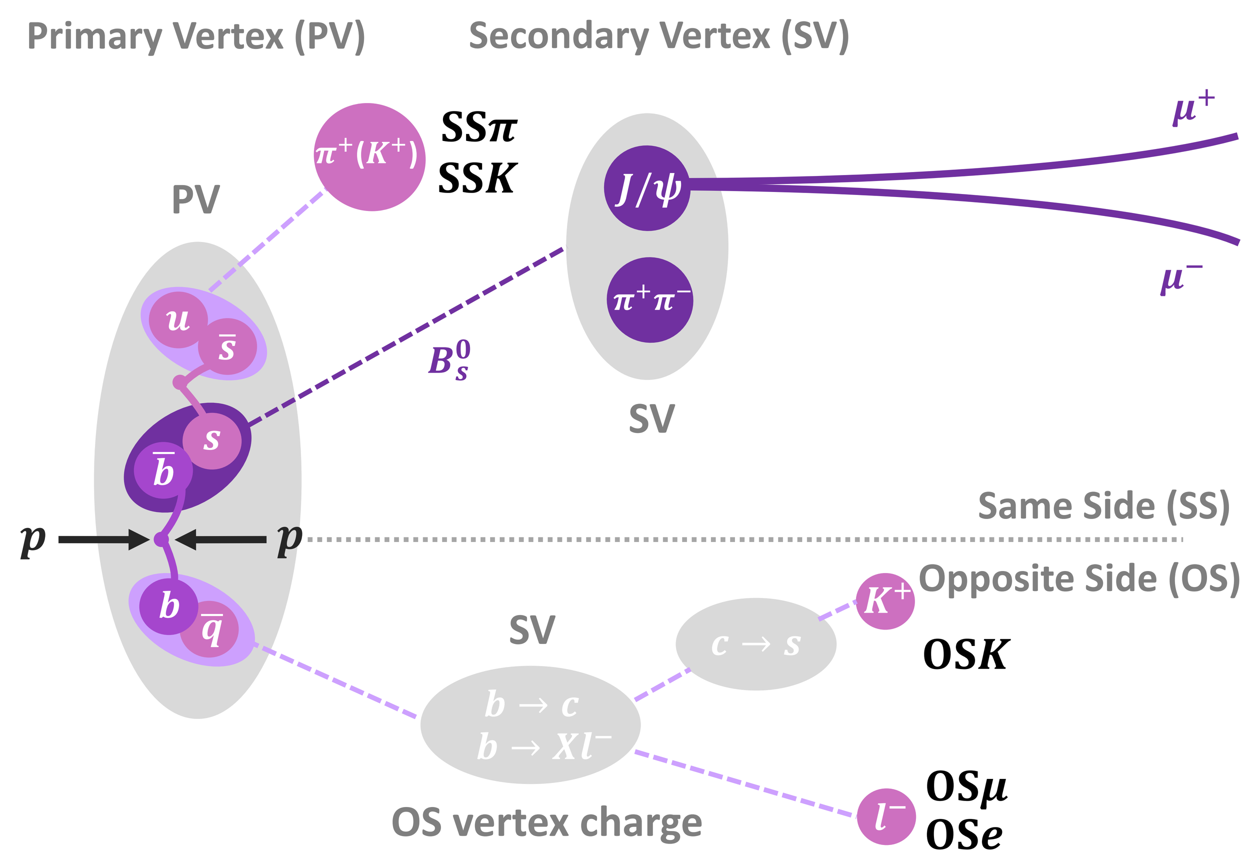


Decay: $\phi_{\rm D} = \arg(V_{cb}V_{cs}^*)$

$$\phi_s = \phi_{\rm M} - 2\phi_{\rm D} \Rightarrow \phi_s \overset{\rm SM}{=} -2\arg\left(-\frac{V_{cb}V_{cs}^*}{V_{tb}V_{ts}^*}\right) = -2\beta_s = -37.6^{+0.8}_{-0.7}\ \text{mrad}^{[1]}$$

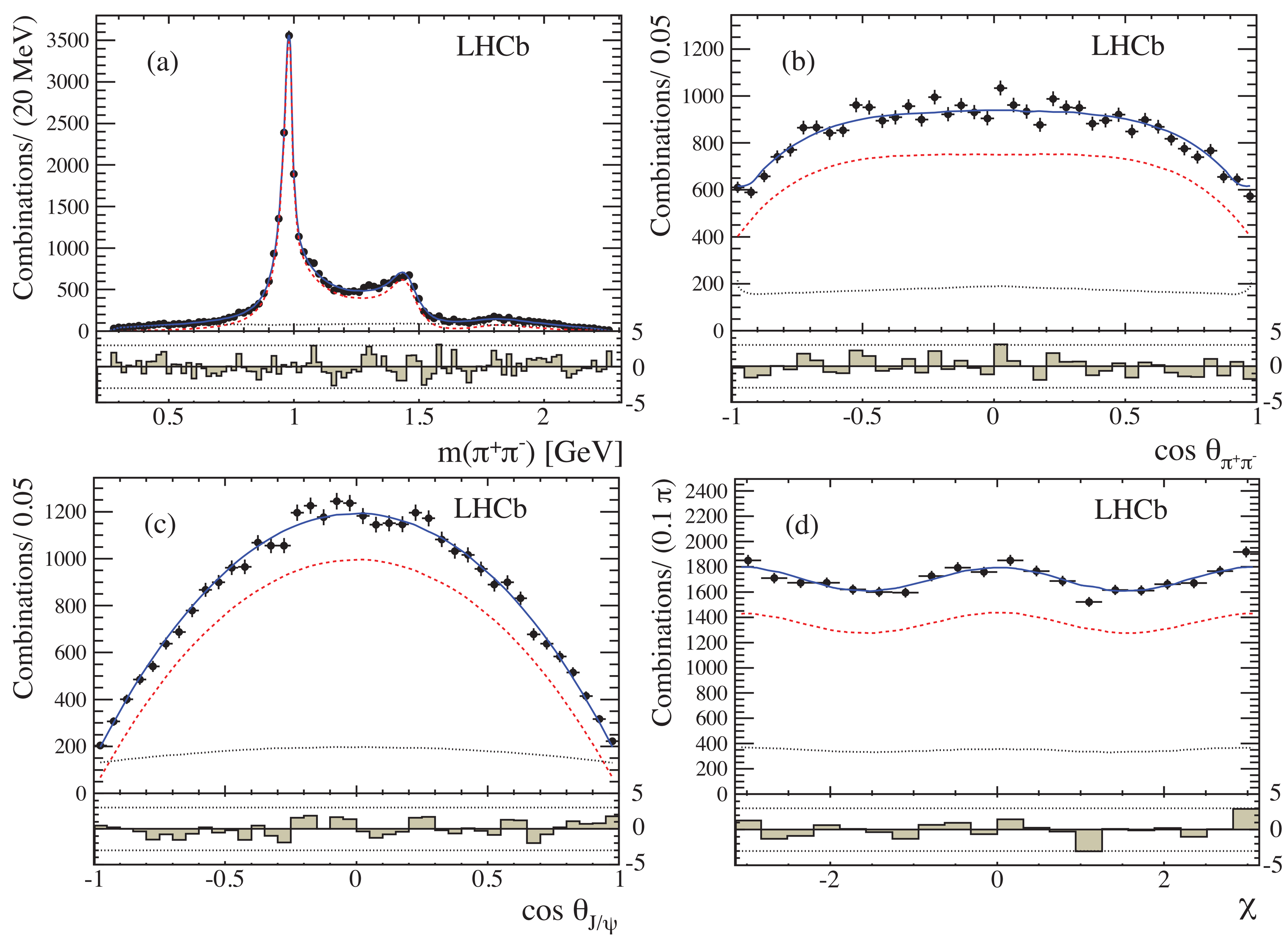
- The phase ϕ_s is predicted very **precisely** in the Standard Model (SM).
- ϕ_s is a **probe** for **New Physics** (NP) if new particles contribute to the box diagrams.
- The $B_s^0 \to J/\psi\pi^+\pi^-$ decay is dominated by the $\mathcal{CP}$**-odd component** which contributes >97.7% at 95% C.L.[2]. This allows to determine the decay width of the heavy B_s^0 mass eigenstate, $\Gamma_{\rm H}$.

2. Flavour tagging



- It is essential to determine the **initial flavour** of each B_s^0 meson
  - Final states of B_s^0 **self conjugated**
  - B_s^0 flavour can **oscillate** with time
- The flavour tagging algorithms provide: **decision** on the flavour of B candidates (tag) and calibrated **mistag probability** of B candidates

3. LHCb Run-I results of ϕ_s with $B_s^0 \to J/\psi\pi^+\pi^-$



Fit projections of $m(\pi^+\pi^-)$ and helicity angles[3].
Red: signal candidates; Black: background component; Blue : total fits.

- **Time-dependent amplitude** analysis using **3 fb^{-1}** Run-I data :

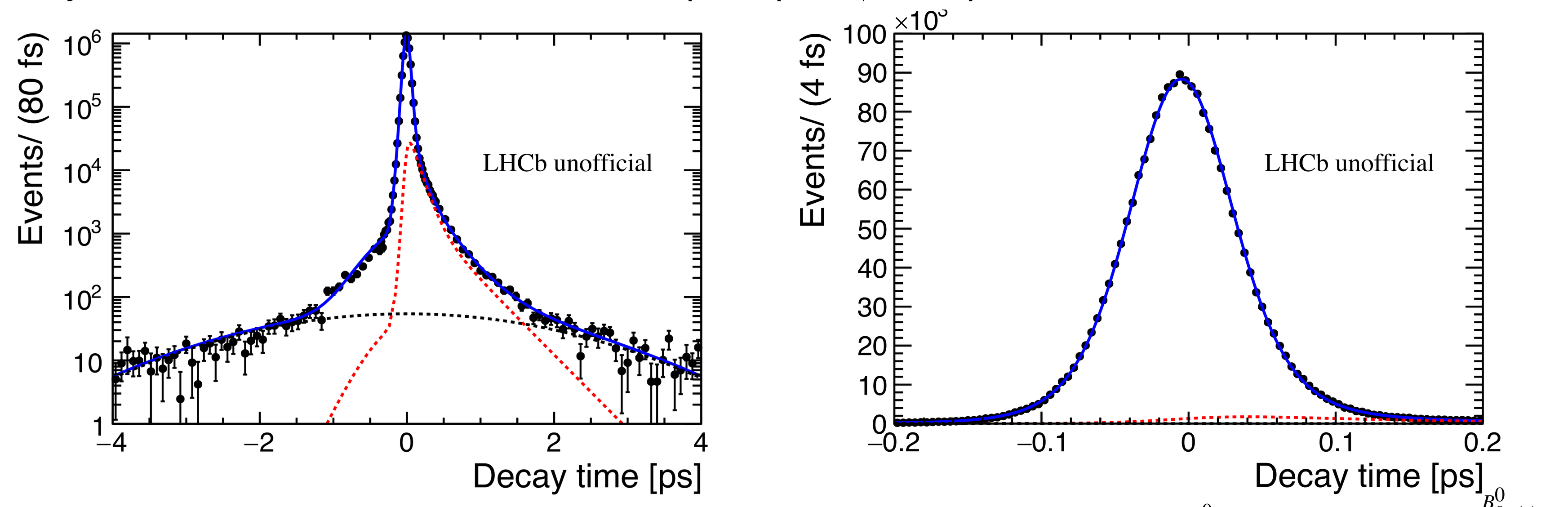
$$\phi_s = 70 \pm 68 \pm 8\ \text{mrad}$$

- Combined result including $B_s^0 \to J/\psi\phi(1020)$[4] and $B_s^0 \to J/\psi K^+K^-$[5] measurements:

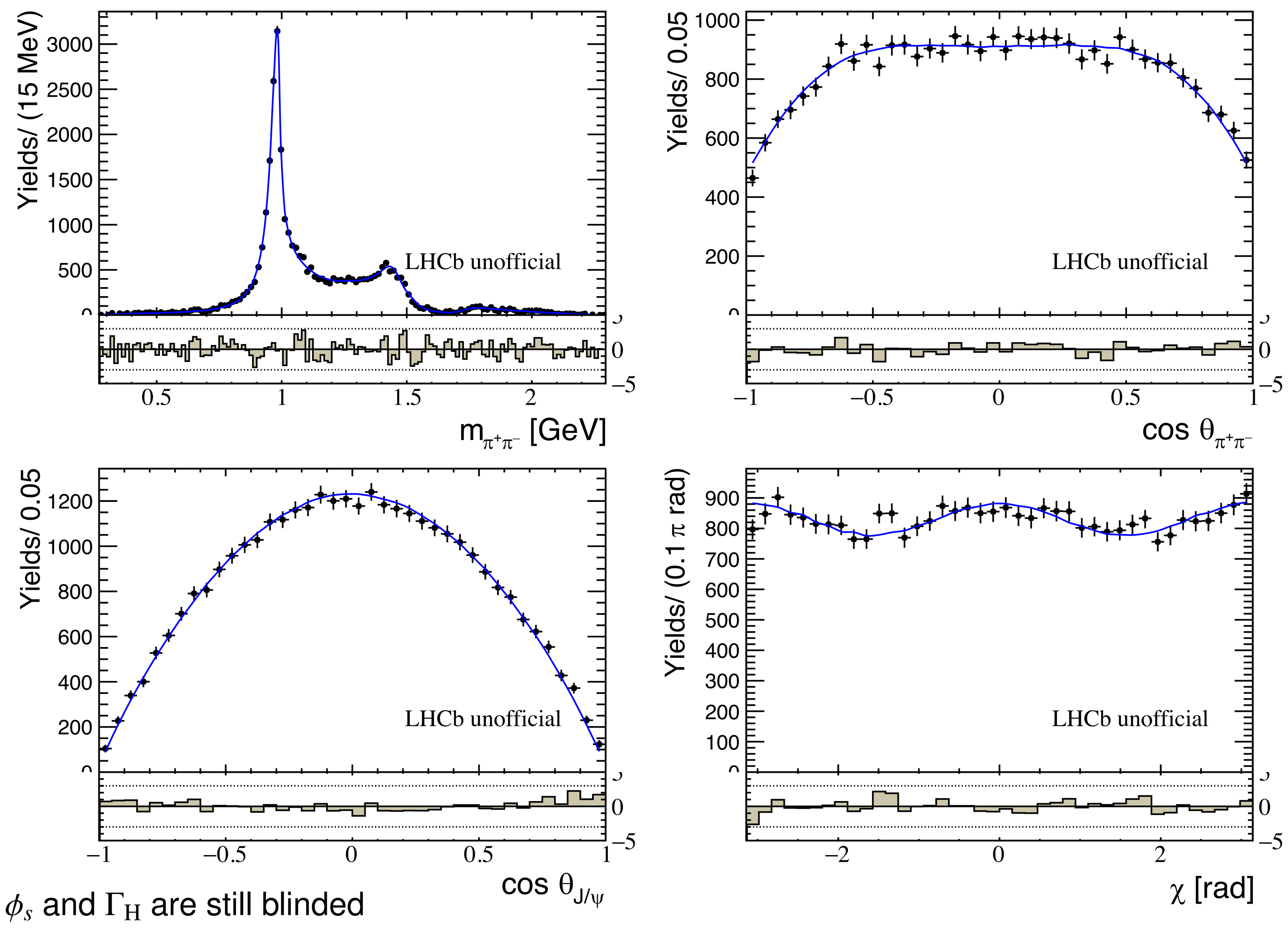
$$\phi_s = 1 \pm 37\ \text{mrad}$$

4. Measurement of ϕ_s with $B_s^0 \to J/\psi\pi^+\pi^-$ using Run-II data

- **Time-dependent amplitude**[6] analysis using **1.9 fb^{-1}** data collected by LHCb during 2015 and 2016 .
- Detection effect modelling:
  - Decay time resolution is determined with prompt J/ψ samples : 40.9 fs

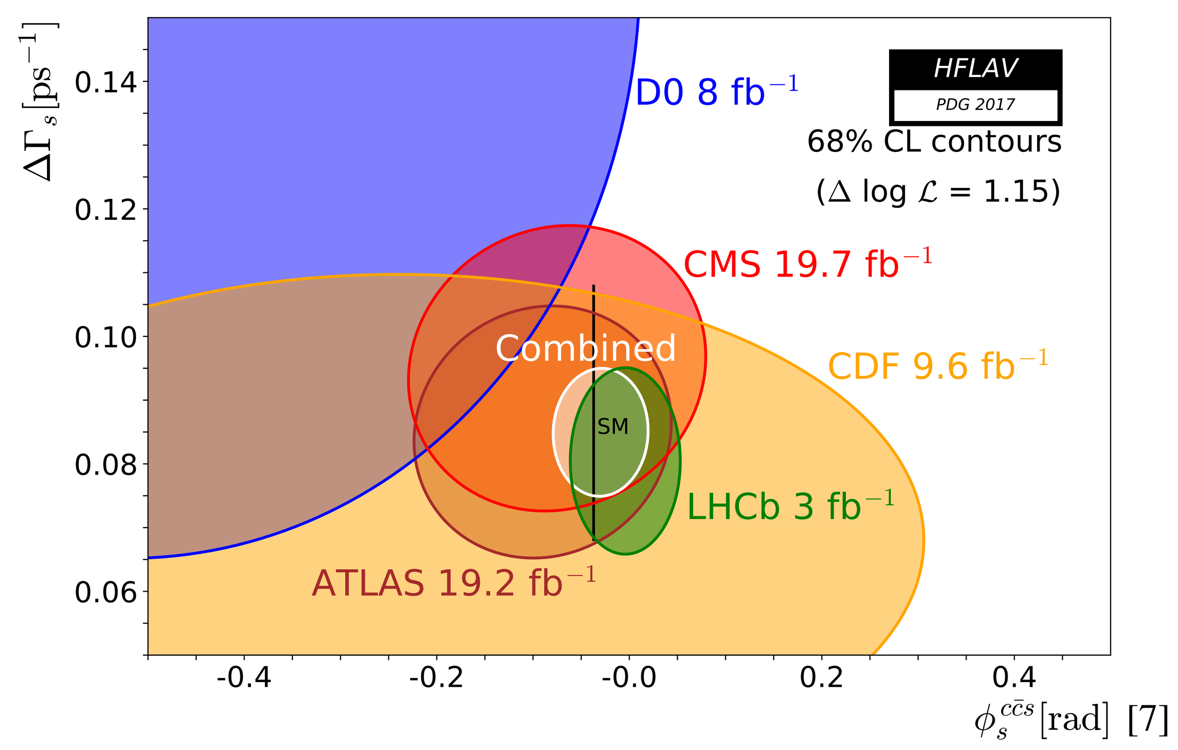


  - Decay time acceptance is estimated with $B^0 \to J/\psi K^{*0}$ sample using $\epsilon_{\rm data}^{B_s^0}(t) = \epsilon_{\rm data}^{B^0}(t) \times \frac{\epsilon_{\rm MC}^{B_s^0}(t)}{\epsilon_{\rm MC}^{B^0}(t)}$
  - Flavour tagging power: 4.37±0.46 %
  - Angular and $m_{\pi^+\pi^-}$ efficiencies vary by about ± 10%
- Preliminary results: fit projections of $m(\pi^+\pi^-)$ and helicity angles



  - ϕ_s and $\Gamma_{\rm H}$ are still blinded
  - Expected **precision** to be improved by 8%

5. Prospects



- Current combined result is **compatible** with SM predictions, but there's still room for NP.
- LHCb sensitivity with phase-2 upgrade expected to be < **3 mrad**.
- Measurement of ϕ_s using $B_s^0 \to J/\psi K^+K^-$ with Run-II data is also ongoing.

Stay tuned for more Run-II results!

Reference

[1] J. Charles et al., *Current status of the Standard Model CKM fit and constraints on $\Delta F = 2$ New Physics*, Phys. Rev. D91 (2015) 073007.

[2] LHCb collaboration, R. Aaij et al., *Measurement of resonant and CP components in $\bar{B}_s^0 \to J/\psi\pi^+\pi^-$ decays*, Phys. Rev. D89 (2014) 092006.

[3] LHCb collaboration, R. Aaij et al., *Measurement of the CP-violating phase ϕ_s in $\bar{B}_s^0 \to J/\psi\pi^+\pi^-$*, Phys. Lett. B736 (2014) 386.

[4] 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 (2015) 041801.

[5] LHCb collaboration, R. Aaij et al., *Resonances and CP violation in B_s^0 and $\bar{B}_s^0 \to J/\psi K^+K^-$ decays in the mass region above $\phi(1020)$*, JHEP 08 (2017) 037.

[6] L. Zhang and S. Stone, *Time-dependent Dalitz-plot formalism for $\bar{B}_q^0 \to J/\psi h^+h^-$*, Phys. Lett. B719 (2013) 383.

[7] Heavy Flavor Averaging Group, Y. Amhis et al., *Averages of b-hadron, c-hadron, τ-lepton properties as of summer 2016*, arXiv:1612.07233.

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