Measurement of the weak phase ϕ_s from $B_s^0 \to J/\psi\phi$ decays.

Vasilis Syropoulos

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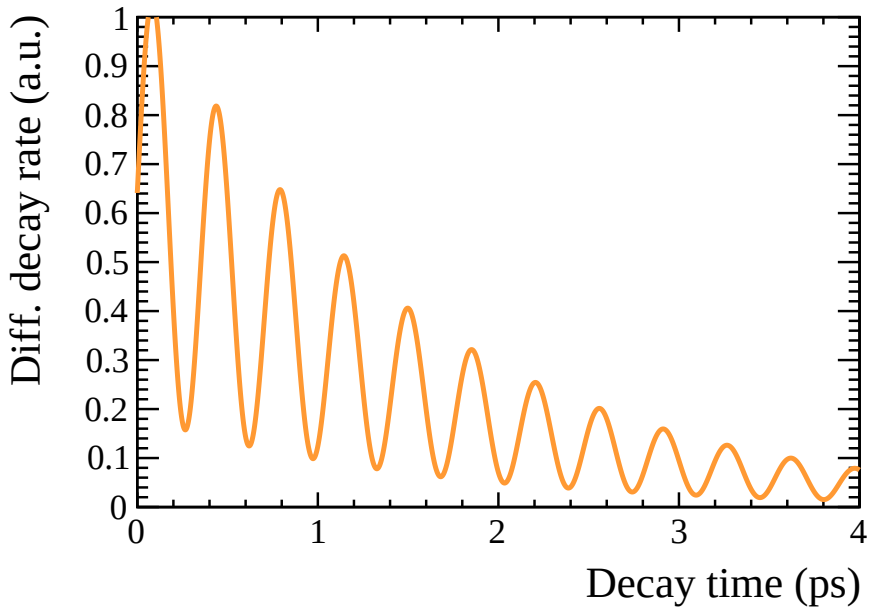
10 May 2014

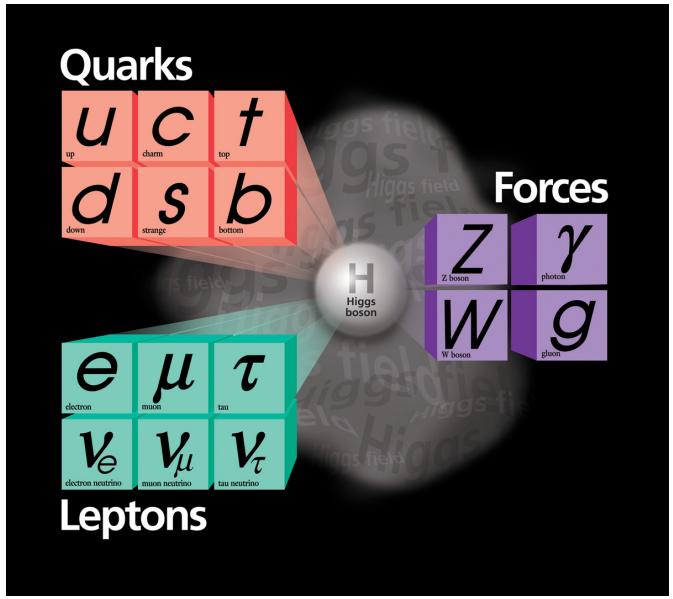
Outline

ϕ_s from decay time oscillations.



Standard Model

- Is it the complete story?
  - Direct searches: ATLAS, CMS... .
  - Indirect searches: LHCb, Belle... .
- Rare decays.
- Non SM CP-Violation. $\leftarrow$ **this talk**.



[Dave Goldberg]

"CP-violating effects in the time-dependent angular distribution of $B_s^0 \to J/\psi\phi$ play a key role for the search of new physics."

[R.Fleischer: PhysRevD.79.014005]

The power of indirect searches

- 1970: Existence of c quark in $K_L \to \mu^+\mu^-$. [Phys.Rev.D2,1285,1970]
- 1987: Top quark mass from B^0 oscillations. [Phys.Lett.B192:245,1987]

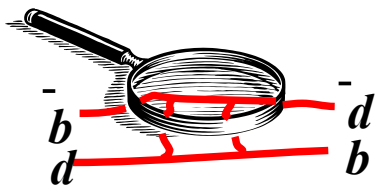
DESY 87-029
April 1987

OBSERVATION OF B^0-$\bar{B}^0$ MIXING

The ARGUS Collaboration

In summary, the combined evidence of the investigation of B^0 meson pairs, lepton pairs and B^0 meson-lepton events on the $\Upsilon(4S)$ leads to the conclusion that B^0-$\bar{B}^0$ mixing has been observed and is substantial.

Parameters	Comments
$r > 0.09$ 90%CL	This experiment
$x > 0.44$	This experiment
$B^{\frac{1}{2}} f_B \approx f_\pi < 160$ MeV	B meson ($\approx$ pion) decay constant
$m_b < 5 GeV/c^2$	b-quark mass
$\tau_b < 1.4 \cdot 10^{-12}$s	B meson lifetime
$\|V_{td}\| < 0.018$	Kobayashi-Maskawa matrix element
$\eta_{QCD} < 0.86$	QCD correction factor [17]
$m_t > 50 GeV/c^2$	t quark mass



[Niels Tuning]

Weak Interactions with Lepton-Hadron Symmetry*

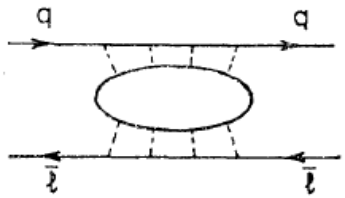
S. L. Glashow, J. Iliopoulos, and L. Maiani†
Lyman Laboratory of Physics, Harvard University, Cambridge, Massachusetts 02139
(Received 5 March 1970)

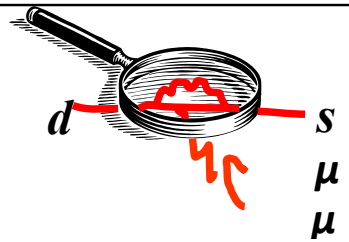
We propose a model of weak interactions in which the currents are constructed out of four basic quark fields and interact with a charged massive vector boson. We show, to all orders in perturbation theory, that the leading divergences do not violate any strong-interaction symmetry and the next to the leading divergences respect all observed weak-interaction selection rules. The model features a remarkable symmetry between leptons and quarks. The extension of our model to a complete Yang-Milis theory is discussed.

splitting, beginning at order $G(G\Lambda^2)$, as well as contributions to such unobserved decay modes as $K_2 \to \mu^+ + \mu^-$, $K^+ \to \pi^+ + l + \bar{l}$, etc., involving neutral lepton

We wish to propose a simple model in which the divergences are properly ordered. Our model is founded in a quark model, but one involving four, not three, fundamental fermions; the weak interactions are medi-

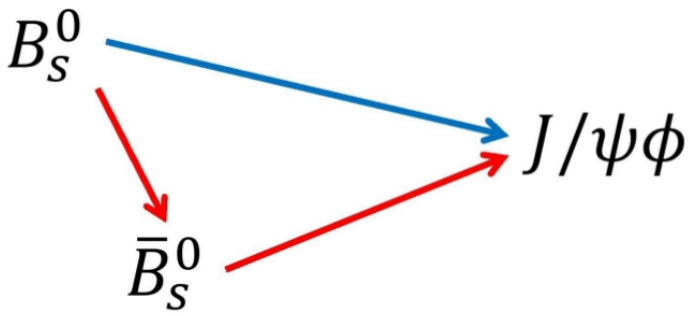
new quantum number $\mathcal{C}$ for charm.

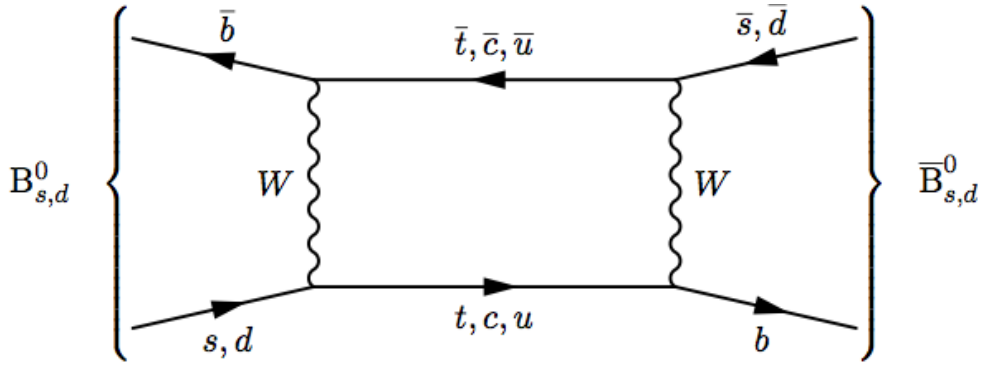




The power of indirect searches

- Oscillations: $B^0_{(s)} \leftrightarrow \bar{B}^0_{(s)}$.
- ϕ_s from $B^0_s/\bar{B}^0_s \rightarrow J/\psi(\rightarrow \mu\mu)\phi(\rightarrow KK)$.





Relative phase difference $\rightarrow$ access ϕ_s

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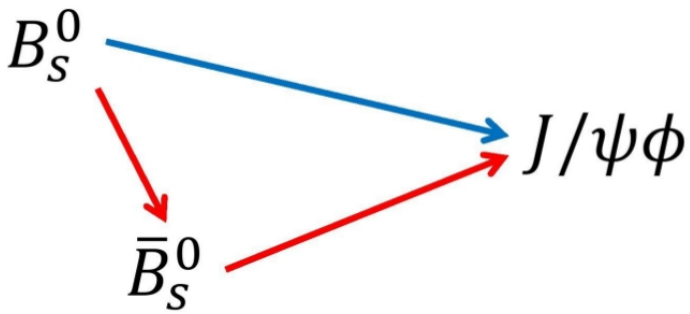

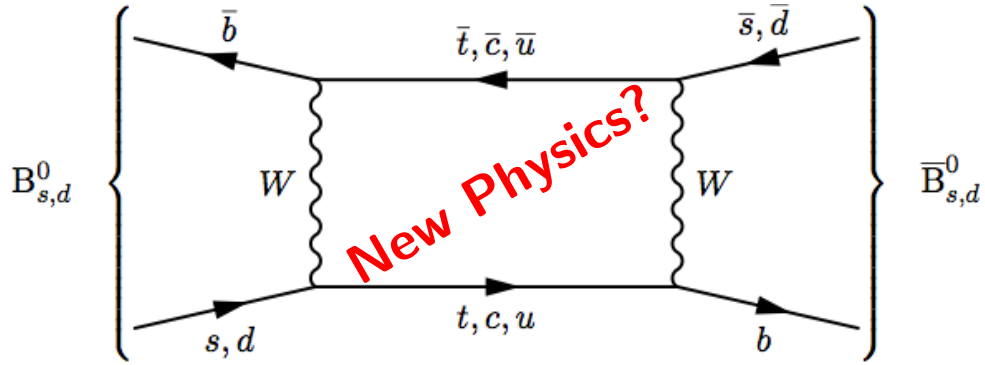

Relative phase difference $\to$ access ϕ_s

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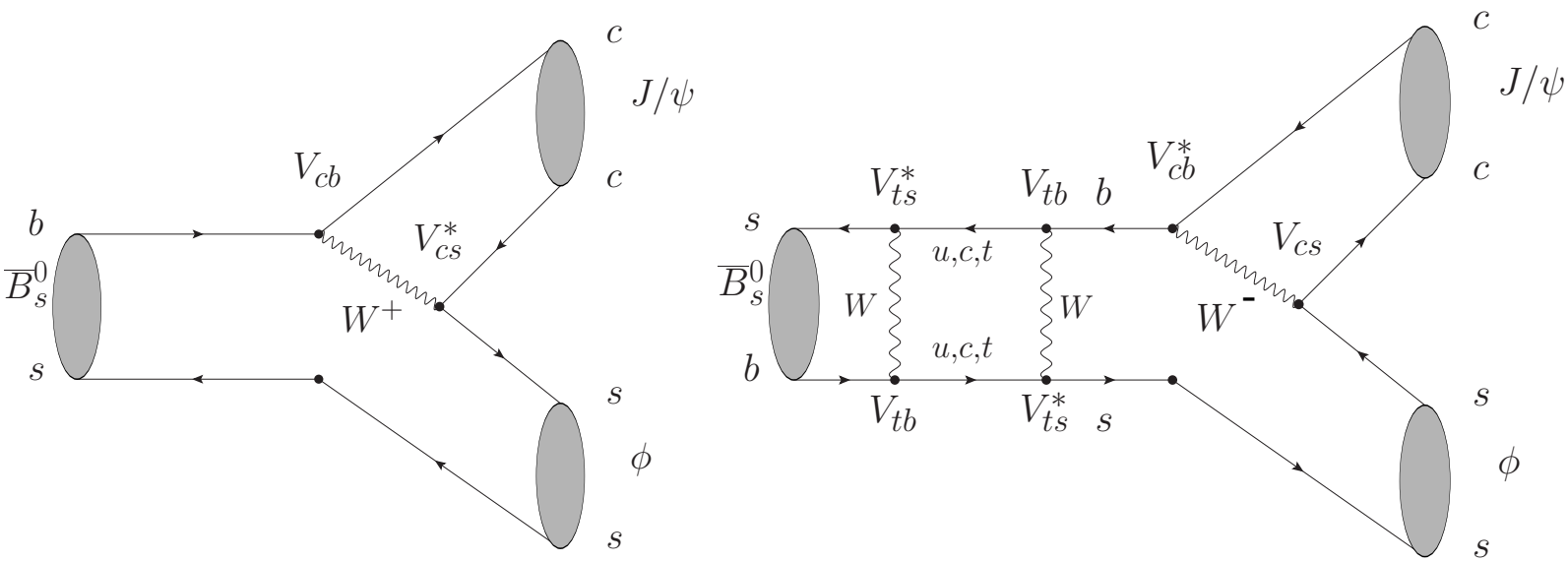
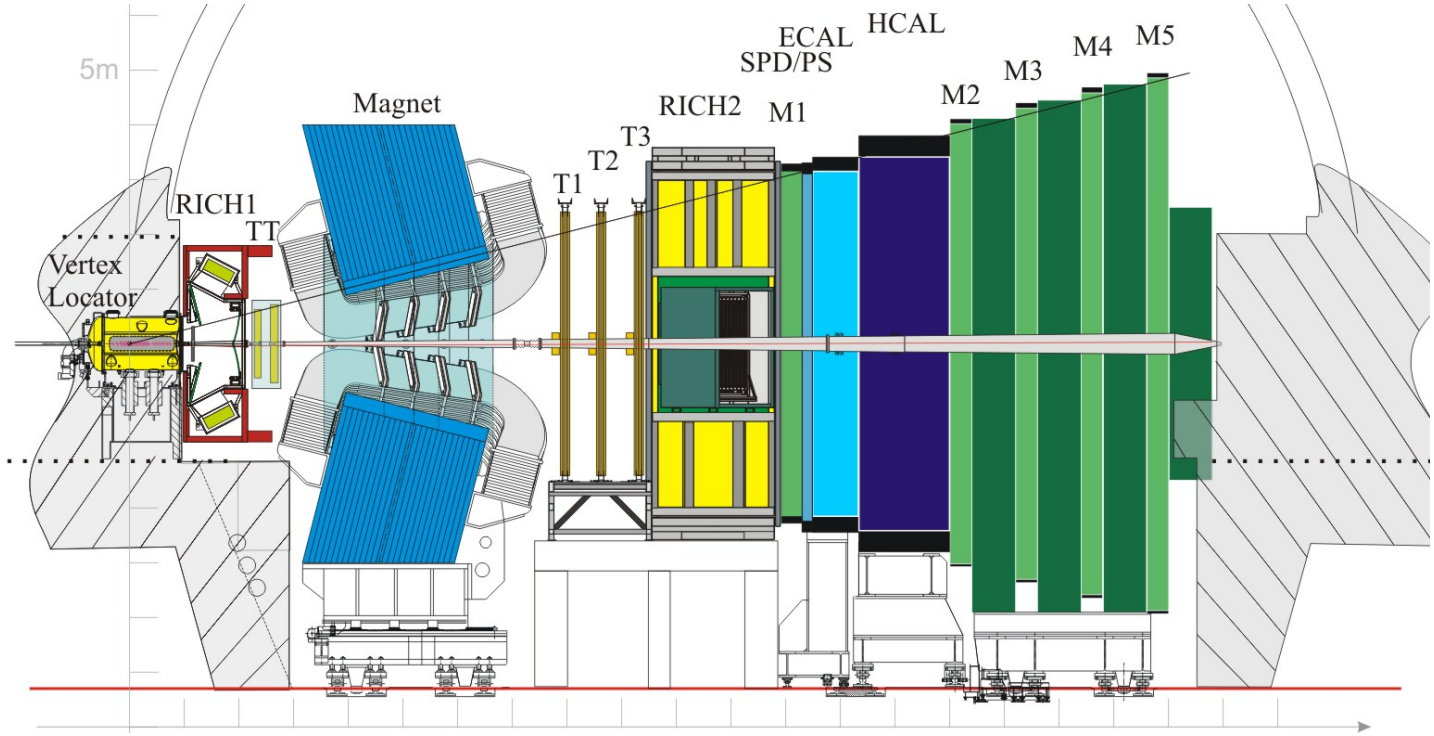


Assuming tree decays only:

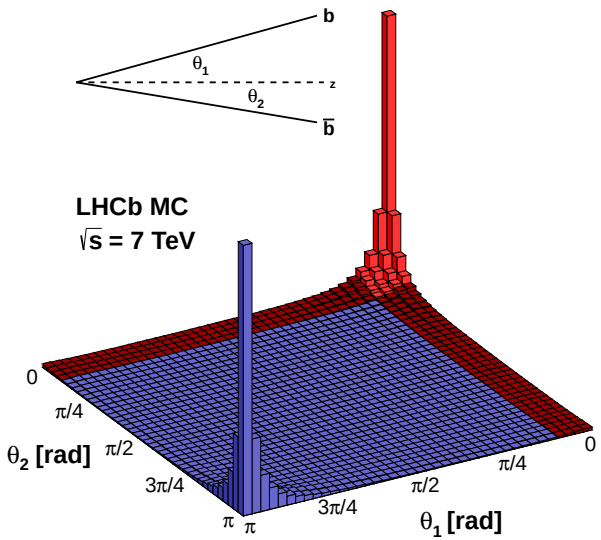
$$\phi_s^{SM} \simeq -2\beta_s = -0.0364 \pm 0.0016 \text{ [Phys. Rev. D84 (2011)033005]},$$
$$\beta_s \equiv \arg\left[-\left(V_{ts}V_{tb}^*/V_{cs}V_{cb}^*\right)\right].$$

Unknown processes: $\phi_s = \phi_s^{SM} + \Delta^{NP}$

LHCb detector

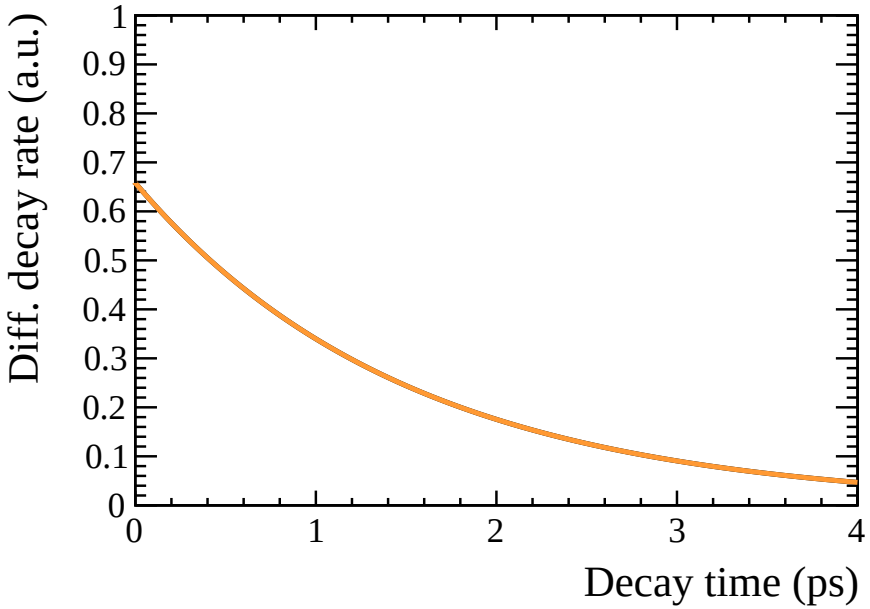


- Designed for displaced vertices, like the B_s^0 .
- Movable VErtex LOcator (8mm from the z).
- 5% of 4π solid angle, 25% of $b\bar{b}$ production.
- Excellent vertex and momentum resolution.
- Particle identification.



CP-Violation and ϕ_s

"CP-violating effects in the time-dependent angular distribution...." [R.Fleischer]



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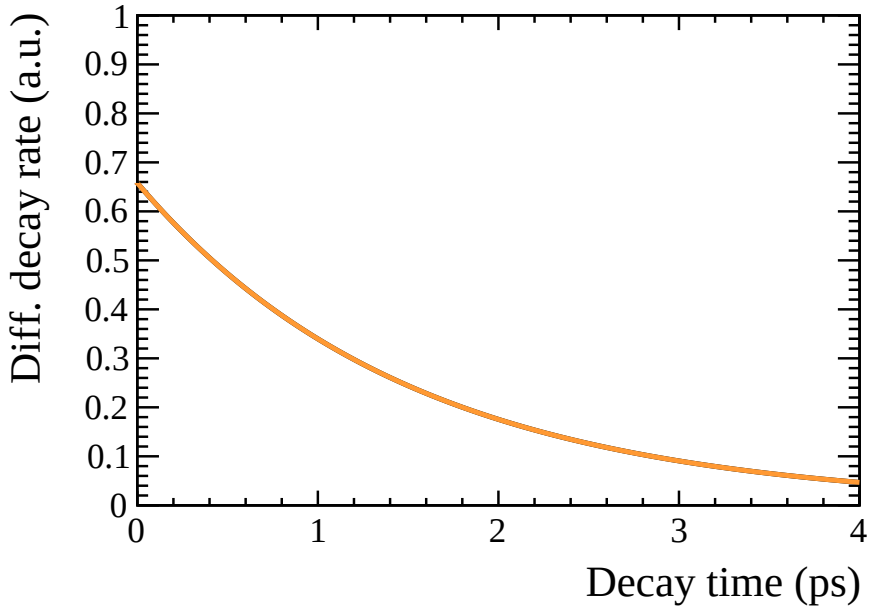
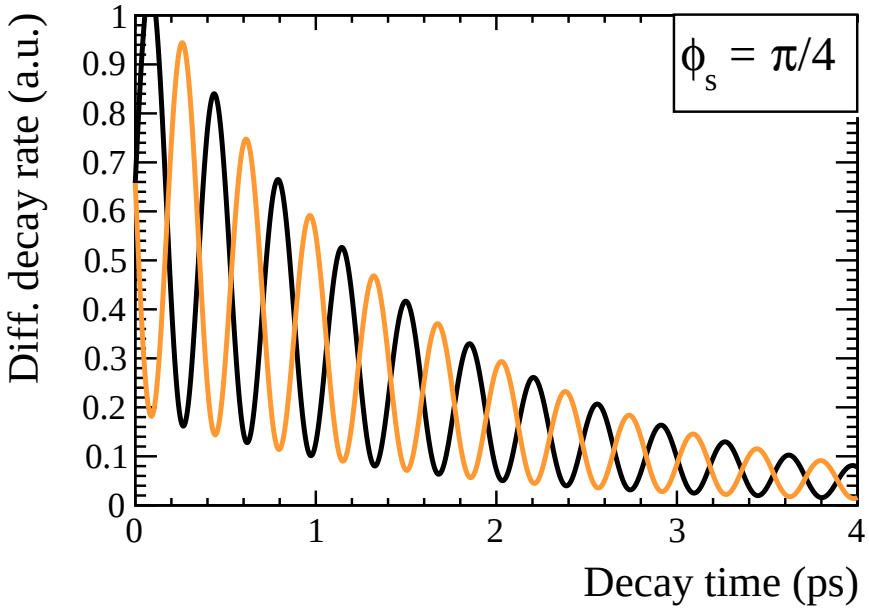
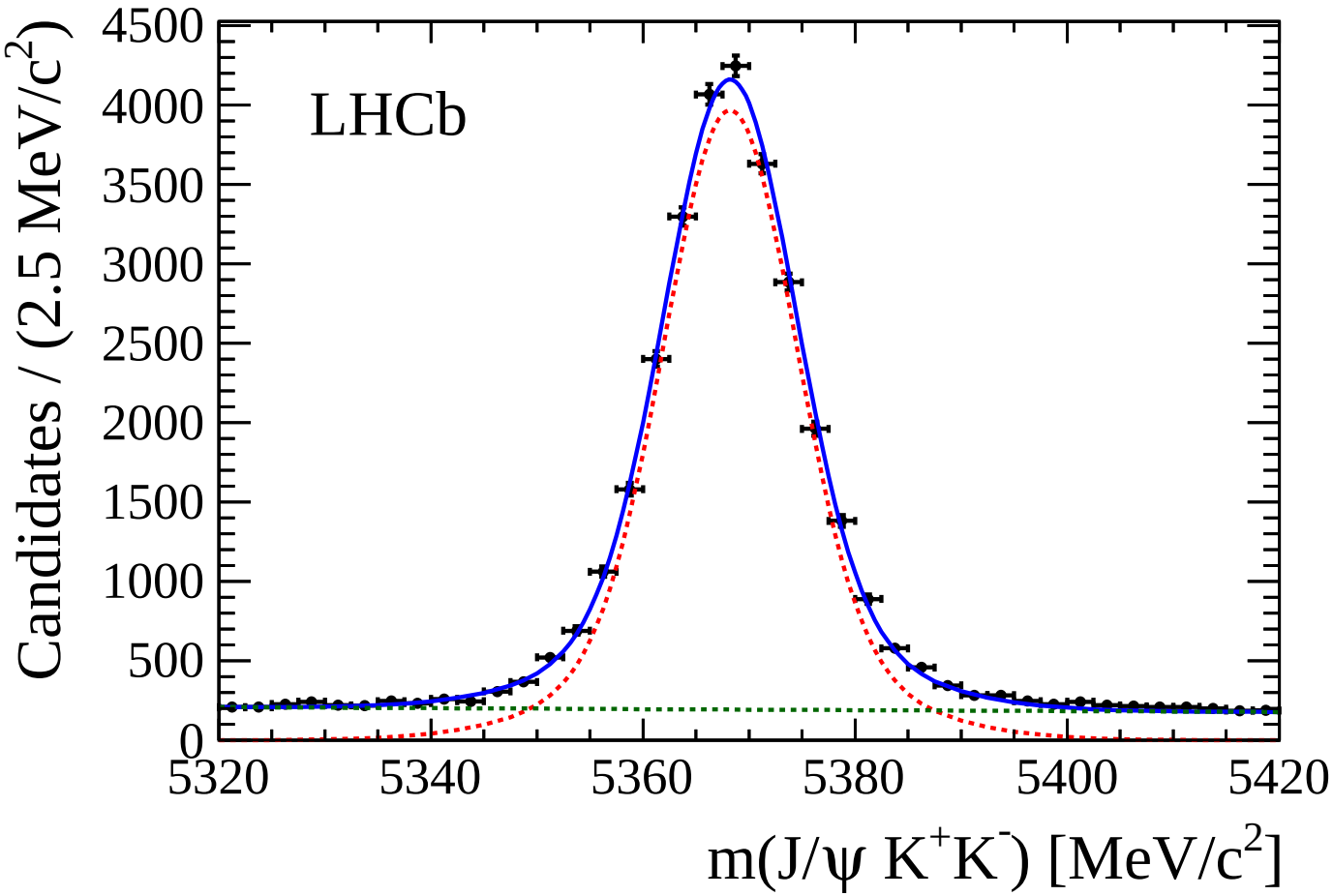




$$h_k(t) \propto e^{-\Gamma t}\left\{\mathbf{a_k}\cosh\frac{\Delta\Gamma\cdot t}{2} + \mathbf{b_k}\sinh\frac{\Delta\Gamma\cdot t}{2} + \mathbf{c_k}\cos(\mathbf{\Delta m}\cdot t) + \mathbf{d_k}\sin(\mathbf{\Delta m}\cdot t)\right\}$$

ϕ_s is the amplitude of the decay time pdf oscillations. Γ, $\Delta\Gamma$?

CP-Violation and ϕ_s



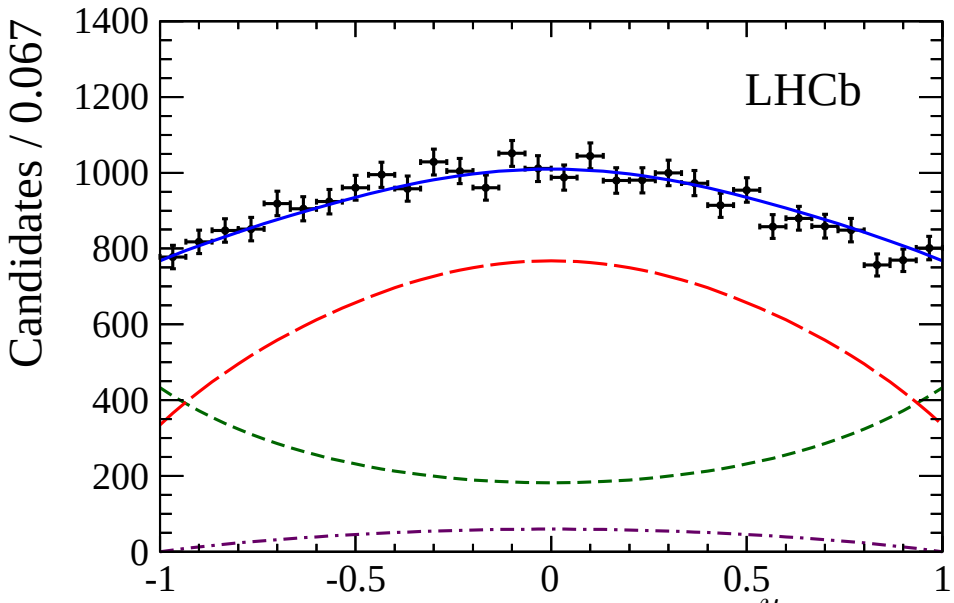
[PhysRevD.87.112010]

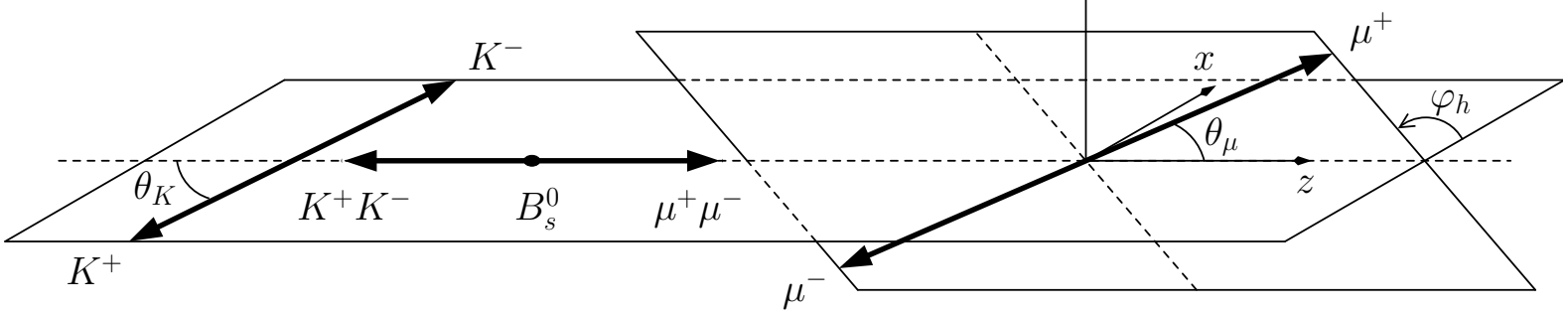
- Very clean signal.
- Around 27k candidates with the 1fb^{-1} of 2011 run.

CP-Violation and ϕ_s

We gain sensitivity to ϕ_s from:

- Angular analysis $(\theta_\mu, \theta_K, \phi_h)$: $J/\psi\phi$ is a CP-odd/even mixture.
- Flavor tagging: $J/\psi\phi$ came from either $B_s^0/\bar{B}_s^0$.





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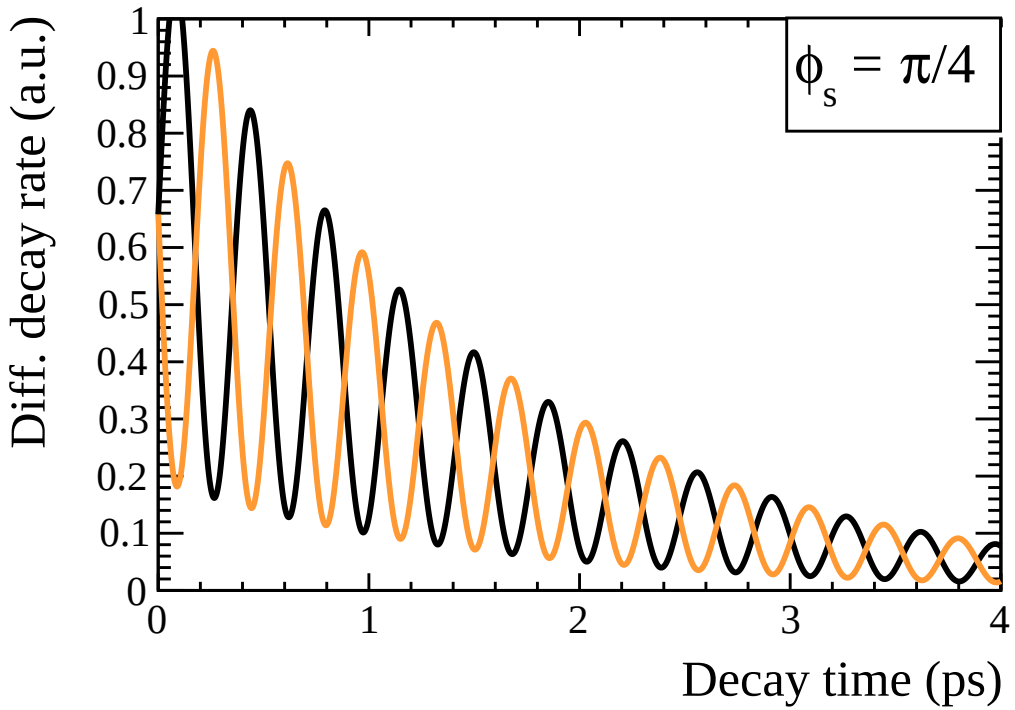

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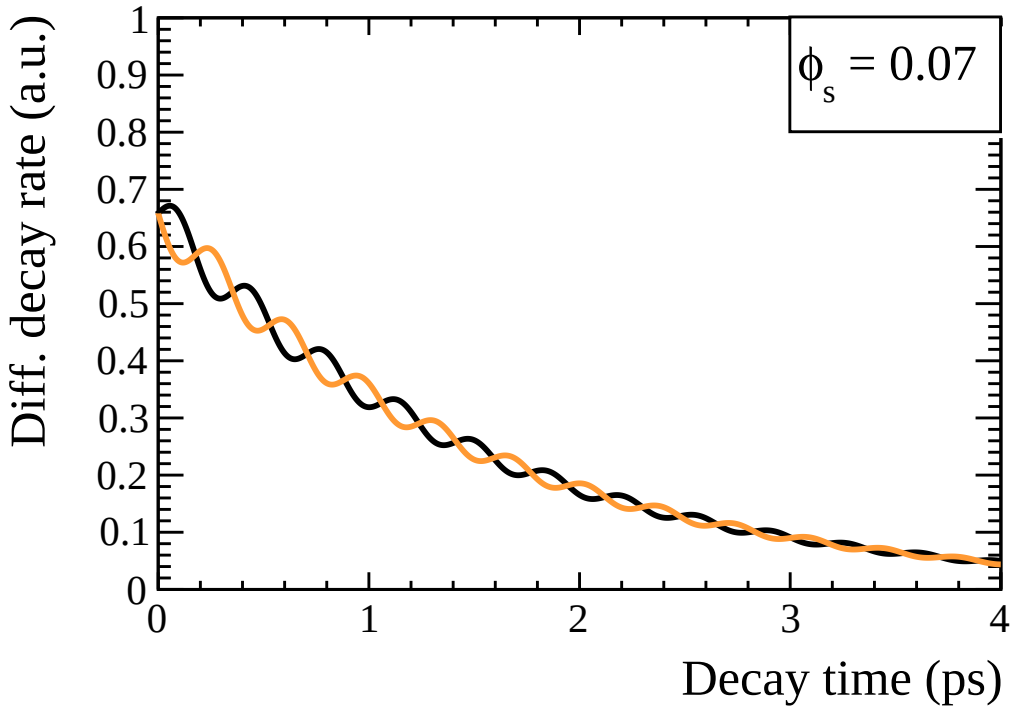

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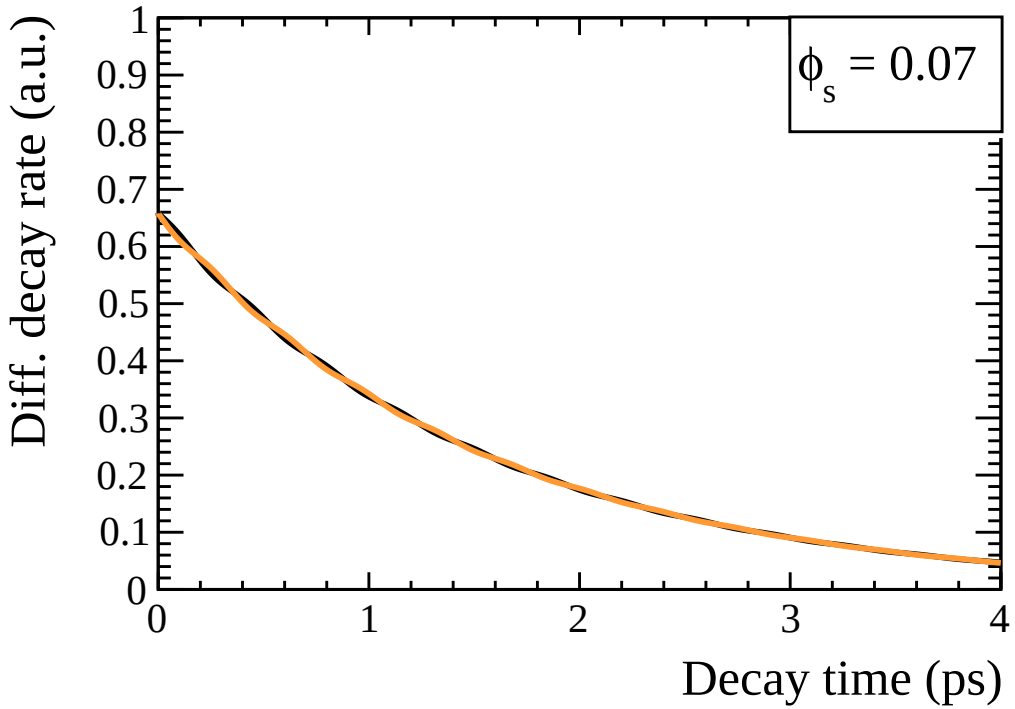

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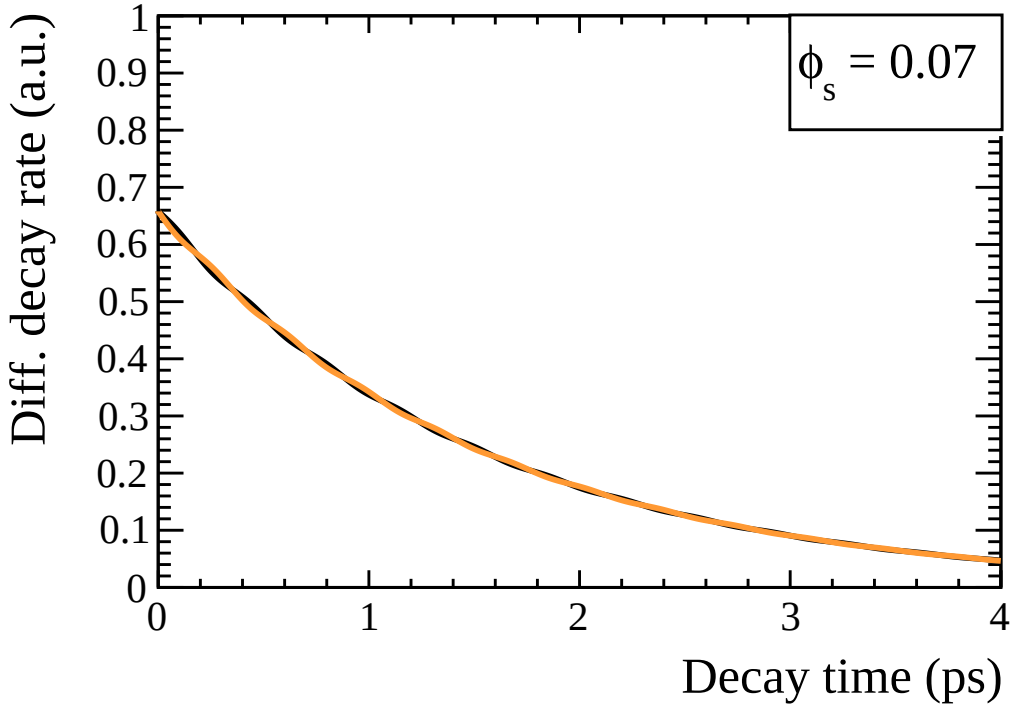
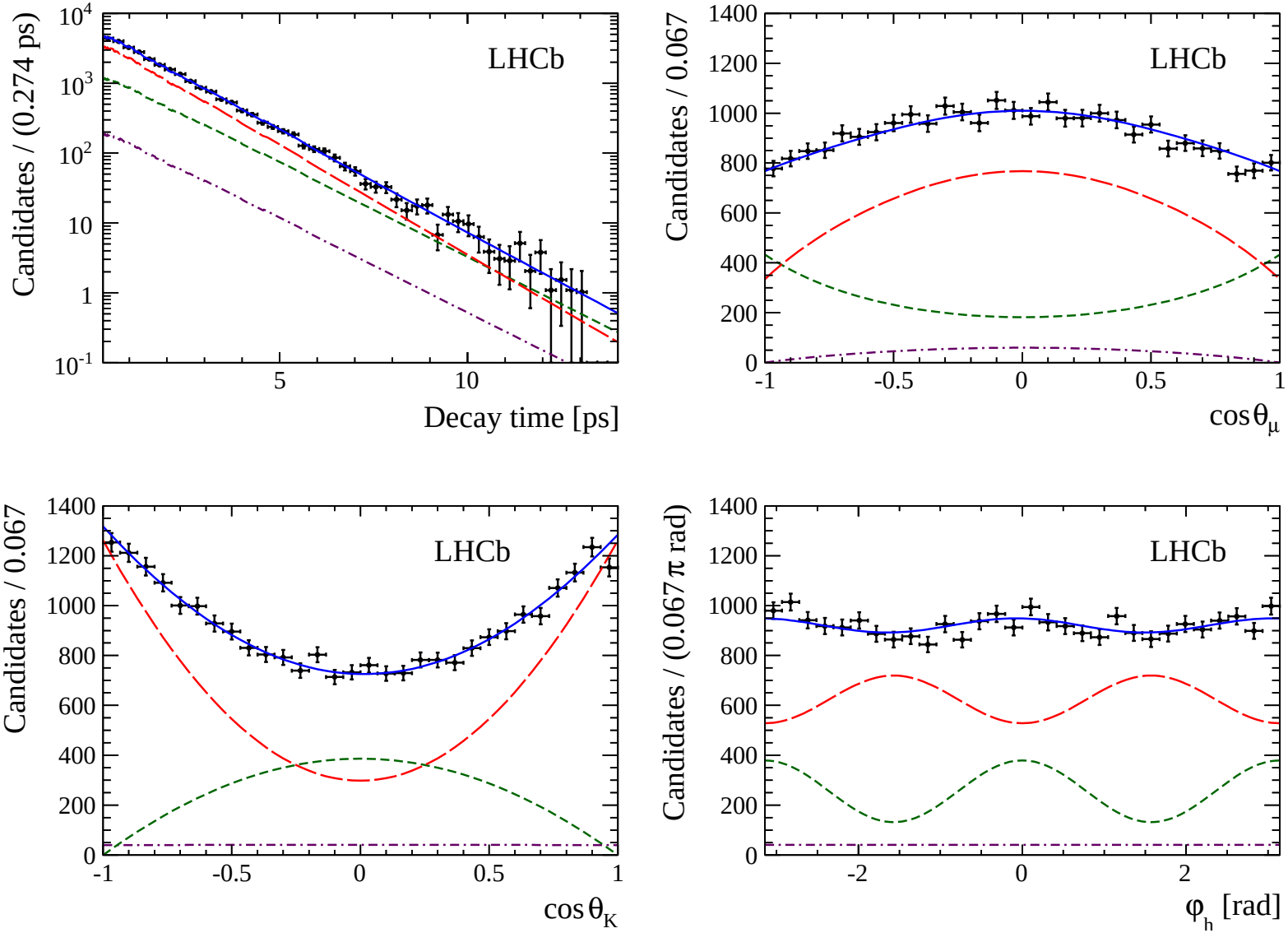


We take good control of:

Time and angular resolution, time and angular acceptances, mass model, peaking backgrounds, reflections, s-wave contributions, data stability between runs, factorization of acceptances and observables, S-P waves coupling, sFit technique. ...

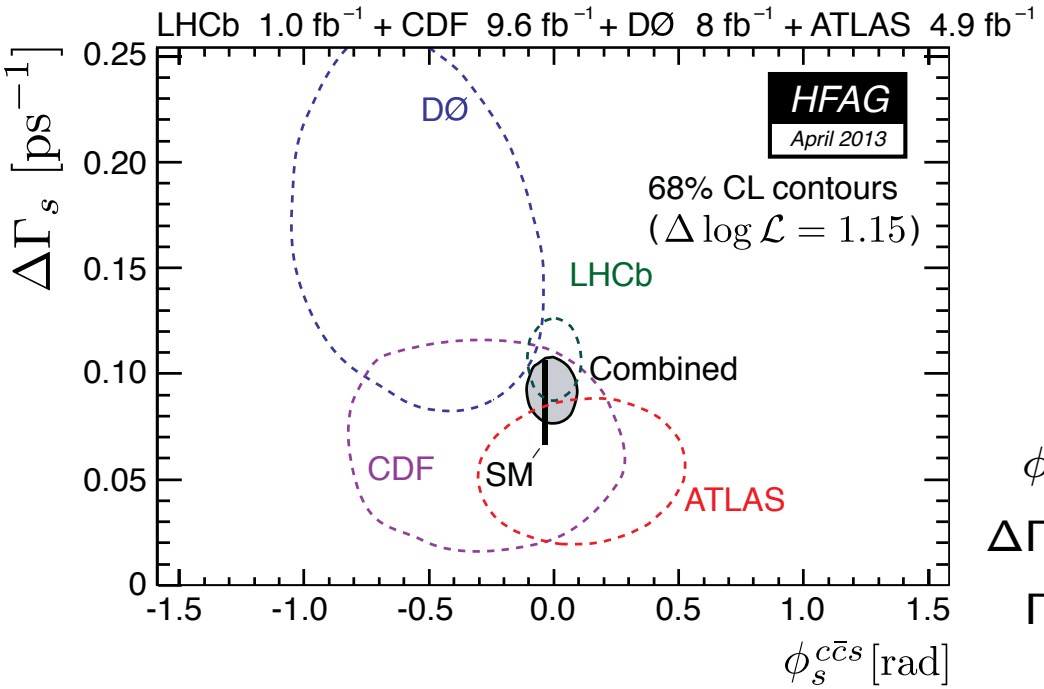
Results

[PhysRevD.87.112010]



Unbinned simultaneous min. log likelihood fit of 5 observables

Results



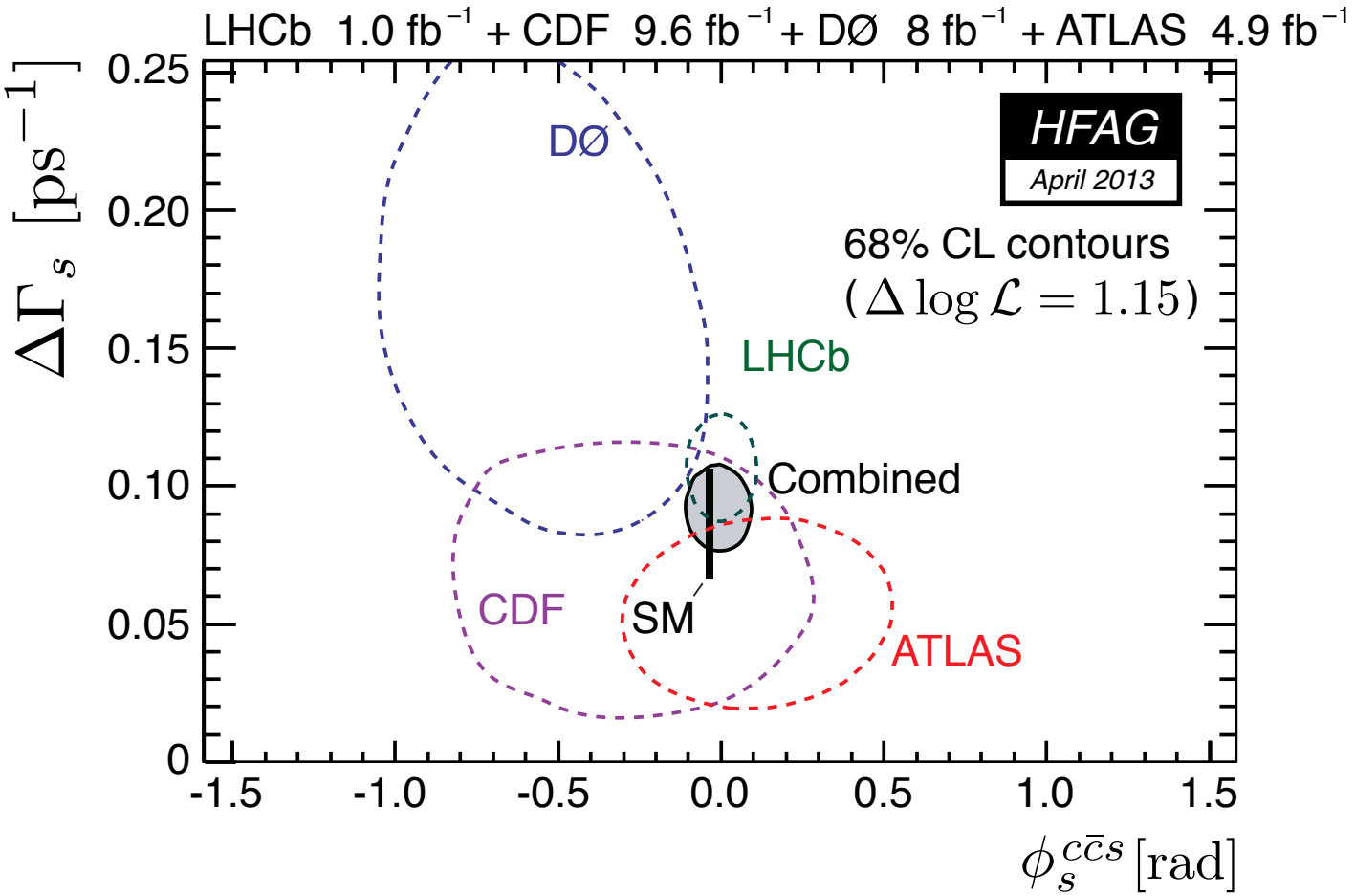
- Most precise ϕ_s measurement.
- Determination of the $\Delta\Gamma_s$ sign.
- No sign of NP yet.

$$\phi_s = 0.07 \pm 0.09(\text{stat}) \pm 0.01(\text{syst}) \text{ rad}$$
$$\Delta\Gamma_s = 0.100 \pm 0.016(\text{stat}) \pm 0.003(\text{syst}) \text{ ps}^{-1}$$
$$\Gamma_s = 0.663 \pm 0.005(\text{stat}) \pm 0.006(\text{syst}) \text{ ps}^{-1}$$

Near future:

- Combine with $B_s^0 \to J/\psi\pi^+\pi^-$.
- Sub-leading penguin contributions to $B_s^0 \to J/\psi\phi$.
- 2fb^{-1} more analyzed: ~ 2 improvement on $\sigma(\phi_s)$.
- Run II: Factor ~ 3 in total.

Questions



Thank you for your attention!

Back up (New Physics)

1. Buras: arxiv:0909.1333v2 [hep-ph]

ABGPS

DNA Tests of Flavour Models

0909.1333

	AC	RVV2	AKM	δLL	FBMSSM	LHT	RS	4G
$D^0 - \bar{D}^0$	★★★	★	★	★	★	★★★	?	★★
ϵ_K	★	★★★	★★★	★	★	★★	★★★	★★
$S_{\psi\phi}$	★★★	★★★	★★★	★	★	★★★	★★★	★★★
$S_{\phi K_S}$	★★★	★★	★	★★★	★★★	★	?	★★
$A_{\rm CP}(B \to X_s\gamma)$	★	★	★	★★★	★★★	★	?	★
$A_{7,8}(B \to K^*\mu^+\mu^-)$	★	★	★	★★★	★★★	★★	?	★★
$A_9(B \to K^*\mu^+\mu^-)$	★	★	★	★	★	★	?	★★
$B \to K^{(*)}\nu\bar{\nu}$	★	★	★	★	★	★	★	★
$B_s \to \mu^+\mu^-$	★★★	★★★	★★★	★★★	★★★	★	★	★★★
$K^+ \to \pi^+\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★	★★★
$K_L \to \pi^0\nu\bar{\nu}$	★	★	★	★	★	★★★	★★★	★★★
$\mu \to e\gamma$	★★★	★★★	★★★	★★★	★★★	★★★	★★★	★★★
$\tau \to \mu\gamma$	★★★	★★★	★	★★★	★★★	★★★	★★★	★★★
$\mu + N \to e + N$	★★★	★★★	★★★	★★★	★★★	★★★	★★★	★★★
d_n	★★★	★★★	★★★	★★	★★★	★	★★★	★
d_e	★★★	★★★	★★	★	★★★	★	★★★	★
$(g-2)_\mu$	★★★	★★★	★★	★★★	★★★	★	?	★

2. Chiang et al.: arXiv:0910.2929 [hep-ph]