Measuring the Higgs-Charm Coupling with Heavy Quarkonia

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Bodwin, Petriello, Stoynev, Velasco, PRD88, 053003 (2013) Bodwin, Chung, Ee, Lee, Petriello, PRD90, 113010 (2014) Bodwin, Chung, Ee, Lee, arXiv:1603.06793 [hep-ph]

Higgs coupling to charm quark

- Higgs coupling to first- and second-generation quarks are yet to be measured.

- Higgs-charm coupling $g_{Hc\bar{c}}$ may deviate significantly from the SM values in new physics theories; yet the coupling is only weakly constrained by Higgs production rates.

- $H \to J/\psi + \gamma$ is sensitive to the Higgs-charm coupling through H decay into $c\bar{c}$.

Direct process

- H decays into $c\bar{c}$, which emits a photon and forms a J/ψ
- Amplitude proportional to $g_{Hc\bar{c}}$
- Known for many years
- Decay width too small to be observed at LHC
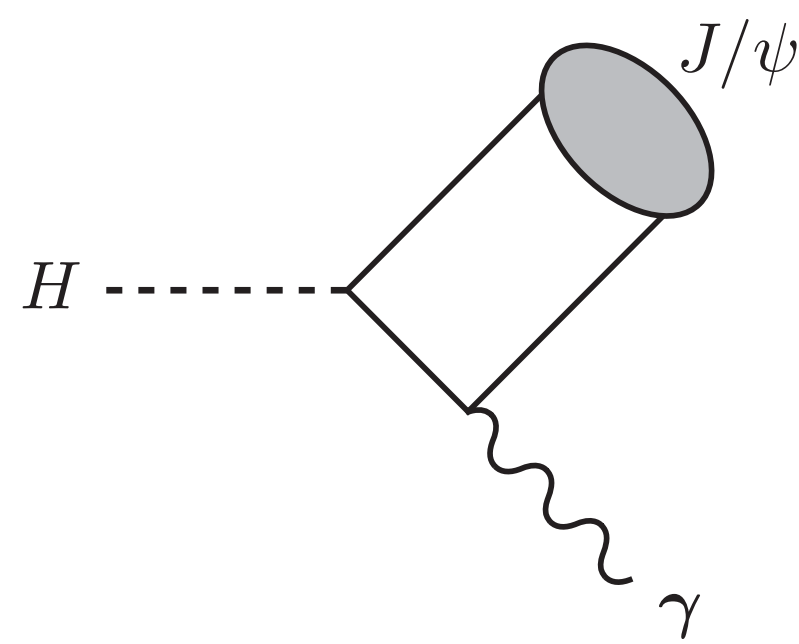
Keung, PRD27, 2762 (1983)

Newly identified indirect process

- H decays into two photons, one of which decays into J/ψ
- Dependence on $g_{Hc\bar{c}}$ is negligible
- An order of magnitude larger than the direct amplitude
- Interferes destructively with the direct amplitude
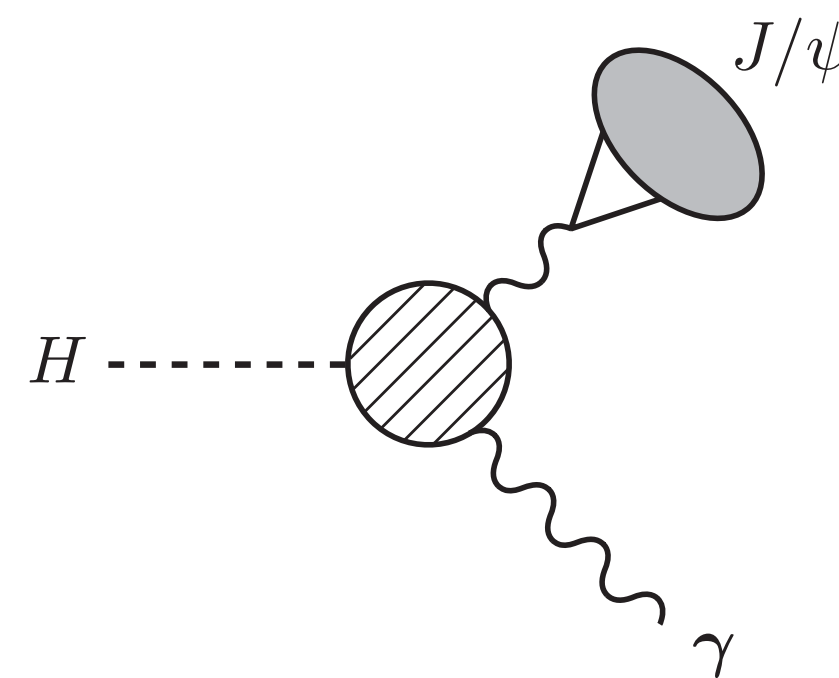
Results

$$\Gamma(H \to V + \gamma) = |\alpha_V - \beta_V \kappa_Q|^2 \times 10^{-10} \text{ GeV}$$
$$g_{HQ\bar{Q}} = \kappa_Q (g_{HQ\bar{Q}})_{\text{SM}}$$

V	α_V	β_V
J/ψ	11.71 ± 0.16	$(0.627^{+0.092}_{-0.094}) + (0.118^{+0.054}_{-0.054})i$
$\Upsilon(1S)$	3.283 ± 0.035	$(2.908^{+0.122}_{-0.124}) + (0.391^{+0.092}_{-0.092})i$
$\Upsilon(2S)$	2.155 ± 0.028	$(2.036^{+0.087}_{-0.089}) + (0.293^{+0.069}_{-0.069})i$
$\Upsilon(3S)$	1.803 ± 0.023	$(1.749^{+0.077}_{-0.078}) + (0.264^{+0.062}_{-0.062})i$

Bodwin, Chung, Ee, Lee, arXiv:1603.06793 [hep-ph]

- Indirect process calculated from $H \to \gamma\gamma^*$ followed by $\gamma^* \to J/\psi$.
- $H \to \gamma\gamma^*$ can be approximated by $H \to \gamma\gamma$. $\gamma^* \to J/\psi$ can be extracted from J/ψ leptonic decay.
- Direct process includes relativistic corrections of order v^2 and NLL resummed to all orders.
- Nonperturbative matrix elements are extracted from J/ψ leptonic decay.
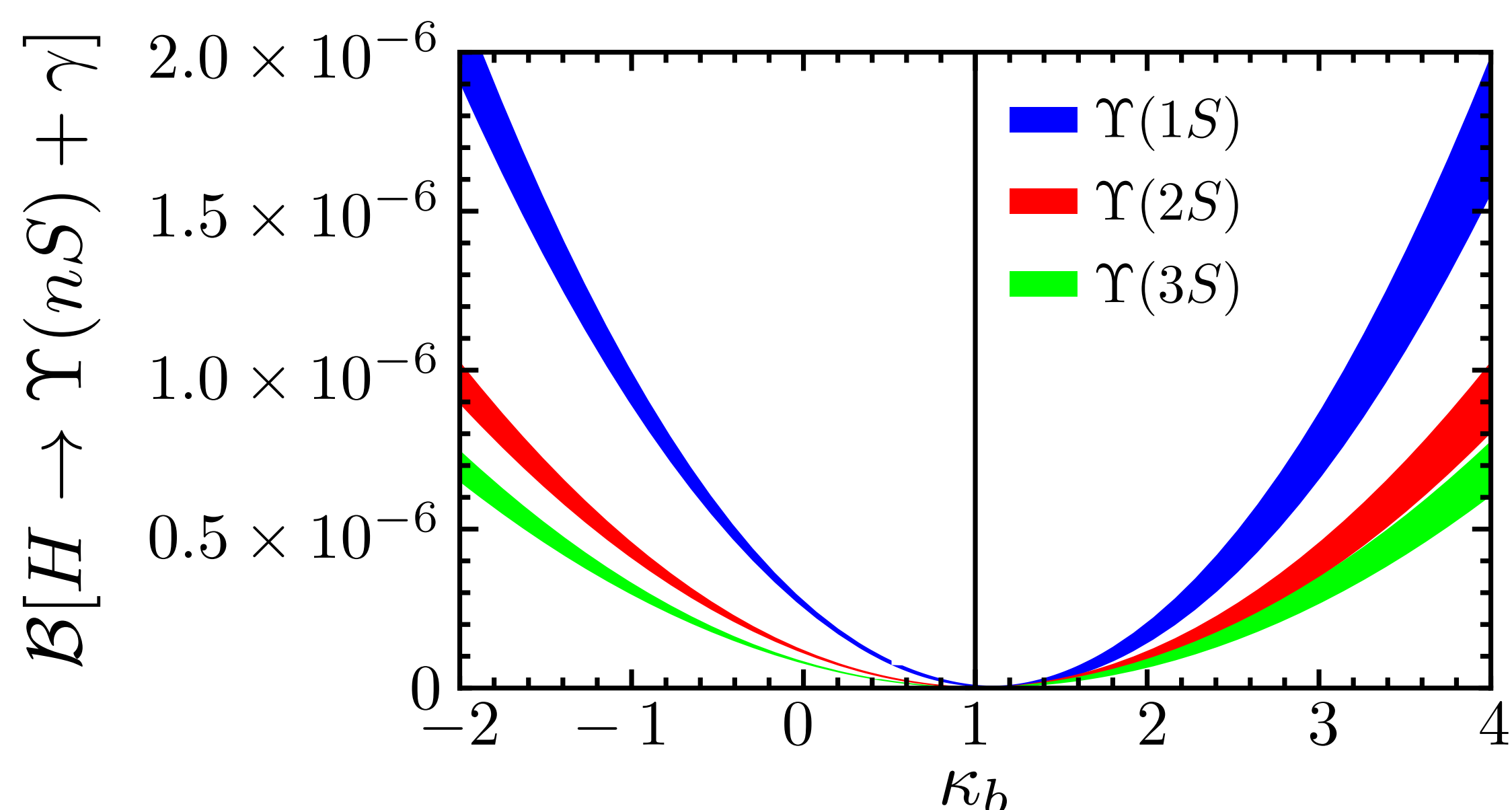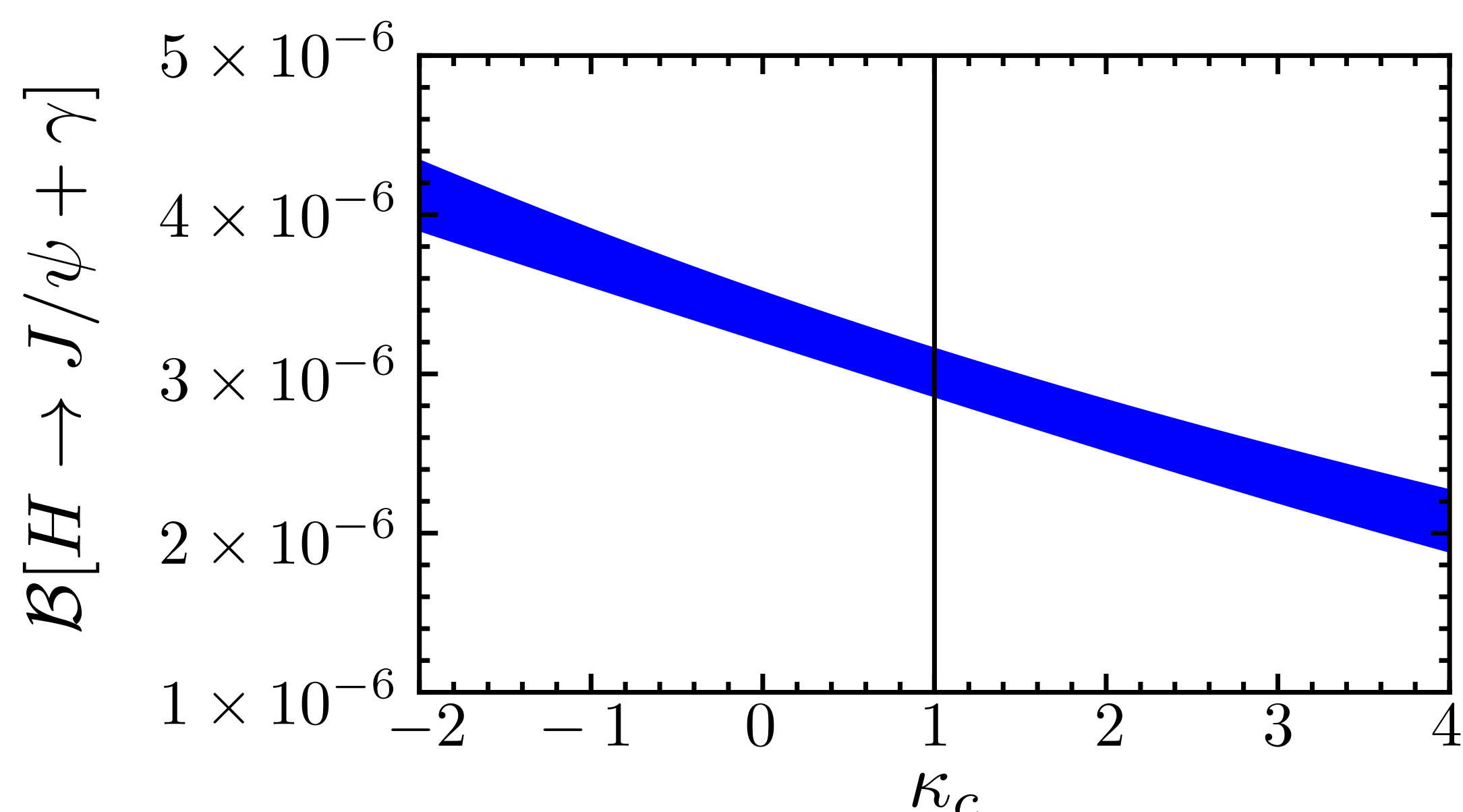
- $B_{H \to J/\psi + \gamma} \times B_{J/\psi \to \ell^+\ell^-}$ comparable to background from $B_{H \to \ell^+\ell^- + \gamma}$.

Firan and Stroynowski, PRD76, 057301 (2007)

- We expect about 100 ATLAS+CMS e^+e^- and $\mu^+\mu^-$ final state events at HL-LHC

- $H \to \Upsilon(nS) + \gamma$ may help determine the phase of the Higgs-bottom coupling