Snowmass2021 - Letter of Interest

Feasibility study of CP-violating Phase ϕ_s measurement via $B_s \to J/\Psi\phi$ channel at CEPC

Thematic Areas: (check all that apply □/■)

□ (EF01) EW Physics: Higgs Boson properties and couplings
□ (EF02) EW Physics: Higgs Boson as a portal to new physics
■ (EF03) EW Physics: Heavy flavor and top quark physics
□ (EF04) EW Precision Physics and constraining new physics
□ (EF05) QCD and strong interactions: Precision QCD
□ (EF06) QCD and strong interactions: Hadronic structure and forward QCD
□ (EF07) QCD and strong interactions: Heavy Ions
□ (EF08) BSM: Model specific explorations
□ (EF09) BSM: More general explorations
□ (EF10) BSM: Dark Matter at colliders
□ (Other) [Please specify frontier/topical group]

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Abstract: The time-dependent CP-violation asymmetry in $B_s \to J/\Psi\phi$ decays can be measured on the Circular Electron-Positron Collider (CEPC), who is a Higgs factory but also a Z factory. In the Z factory mode of the CEPC, hundreds of billions $b\bar{b}$ pairs are produced. In addition to the abundance of $b\bar{b}$ pairs, the clean environment of the e^+e^- collision makes CEPC a competitive experiment to study the flavor physics. In this study, precision of measuring the CP-violating parameters will be explored. The key constraining components, acceptance and reconstruction efficiency, flavor tagging power, and decay time resolution will be explored through reliable approaches such as full simulation.

1 Introduction

The CKM quark mixing matrix provides a single phase resulting the CP violation in the Standard Model[1]. In the procedure of B mesons decay to final state particles, they can oscillation into $\bar{B}$. Thus there is a time-dependent CP-violating asymmetry between the decay time distribution of B and $\bar{B}$ mesons. In the $B_s \to J/\Psi\phi$ decay channel, the time dependent asymmetry can be determined by the heavy and light B_s eigenstates decay time difference $\Delta\Gamma_s$ and CP-violation phase ϕ_s, where $\phi_s = -arg(-V_{ts}V_{tb}^*/V_{cs}V_{cb}^*)$[2]. In the Standard Model, the ϕ_s is predicted to be small. In some new physics model, the ϕ_s is predicted to be large and thus the measurement is sensitive to Beyond Standard Model physics[3]. The ϕ_s has been measured on CDF, D$\emptyset$, LHCb, ATLAS and CMS experiments. The low statics makes it hard to draw firm conclusion. In the CEPC, the b decays from Z bosons are abundant and the environment is clean. The measurement of ϕ_s on CEPC is interesting and the feasibility study is worth doing[4].

2 Method

The estimation of $\sigma(\phi_s)$ can be obtained by scaling the LHCb measurement, where $\sigma(\phi_s) \propto 1/\sqrt{N_{\text{eff}}}$.

- $N_{\text{eff}} \propto N_{b\bar{b}}$
- $N_{\text{eff}} \propto$ Efficiency
- $N_{\text{eff}} \propto$ Tagging power
- $\sigma_{\phi_s} \propto 1/e^{-\frac{1}{2}\Delta m_s^2 \sigma_t^2}$

2.1 $N_{b\bar{b}}$

It is natural that the N_{eff} is proportional to the $N_{b\bar{b}}$. At lhcb:

- Luminosity at HL-LHC: 300 fb^{-1}.
- $b\bar{b}$ cross-section at LHCb at 13 TeV: 144μb
- Total statics: 43.2×10^{12}

While at CEPC:

- Z production at Z pole: 10^{12} Z
- $b\bar{b}$ branching fraction: 15.2%
- Total statics: 0.152×10^{12}

2.2 Efficiency

A full simulation is needed to see the impact on the efficiency. A simulation package is under development. The package takes all the final state Monte-Carlo particles, according the user-defined particle identification rate and momentum resolution to produce reconstructed particles. The momentum of reconstructed particles are smeared and the id of them are randomly given according to the user-defined particle identification rate.

2.3 Flavor tagging power

The flavor tagging algorithm should be developed. The algorithm should benefit from the energetic b jet of cepc.

2.4 Time resolution

The time resolution can be studies through full detector simulation.

References:
[1] CP Violation in the Renormalizable Theory of Weak Interaction
[2] Unitary Symmetry and Leptonic Decays; CP Violation in Cascade Decays of B Mesons; CP Violation in B Meson Decays; Notes on the Observability of CP Violations in B Decays; CP Violation in Heavy Flavor Decays: Predictions and Search Strategies
[3] New Physics in B0(s) —> J/psi phi: A General Analysis
[4] https://indico.cern.ch/event/838862/contributions/3755970