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Charm physics prospects at the Belle II experiment

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Summary. — Belle II is a major upgrade of the Belle experiment and will operate at the B-factory SuperKEKB in Japan. Here we discuss the expected sensitivity of Belle II for D^0 - $\bar{D}^0$ mixing and CP violation measurements in the charm sector, which will benefit from a factor 50 increase in statistics and an improved vertex detection. The impact on the determination of CKM parameters from the measurements of purely leptonic D mesons decays is discussed. A novel method of flavour tagging to substantially increase the sample of D^0 and $\bar{D}^0$ is also presented.

1. – The Belle II experiment

Belle II is a major upgrade of the Belle experiment and will operate at the B-factory SuperKEKB, located at the KEK laboratory in Tsukuba, Japan. Although Belle II has been designed to perform precise measurements in the b-quark sector, it will also be an ideal laboratory to study the properties of the charm quark. The data taking will start in 2018 and Belle II is expected to collect within the next decade a data sample of more than 10^{10} $c\bar{c}$ events with a total integrated luminosity of about $50\,\text{ab}^{-1}$ [1].

Belle II will have a six-layer silicon vertex detector, whose innermost layer will be 2 times closer to the interaction point respect to Belle. From Monte Carlo (MC) simulations it has been shown that Belle II will have a proper time resolution σ_t about half with respect to BaBar [2] (for $D^0 \to h^- h^+$, where $h = \pi, K$, Belle II will have $\sigma_t = 14\,\text{ps}$).

2. – Impact on D^0 - $\bar{D}^0$ mixing and CP violation measurements

One of the main goal of the Belle II charm physics program is to improve the measurements of D^0 - $\bar{D}^0$ mixing and the search for the CP violation (CPV).

The time-dependent analysis of the so-called "wrong sign" decay $D^0 \to K^+\pi^-$ is sensitive to both the mixing parameters ($x' = x\cos\delta_{K\pi} + y\sin\delta_{K\pi}$, $y' = y\cos\delta_{K\pi} - x\sin\delta_{K\pi}$, where $x = \Delta m/\Gamma$, $y = \Delta\Gamma/2\Gamma$ and $\delta_{K\pi}$ is the strong phase) and the CP-violating parameters ($|q/p|$ and $\phi = \arg(q/p)$). An ensemble of toy MC experiments, including the smearing of the decay times by the 14 ps expected proper time resolution, has been generated to test the sensitivity of Belle II with the full data set [2]. The preliminary estimates of the expected sensitivity with $50\,\mathrm{ab}^{-1}$ of data are $\sigma_{x'} = 0.15\%$, $\sigma_{y'} = 0.10\%$, $\sigma_{|q/p|} = 0.05\%$ and $\sigma_{\phi} = 5.7°$. These results are a significant improvement with respect to the Belle and BaBar achievements.

Belle II will have an excellent efficiency for reconstructing multi-body final states with tiny and well-controlled detector-based asymmetries. Thus, the experiment is ideal for searching for time-integrated CPV in several final states. The expected precision of Belle II for the measurement of CP asymmetry $A_{CP} = [\Gamma(D \to X) - \Gamma(\bar{D} \to \bar{X})]/[\Gamma(D \to X) + \Gamma(\bar{D} \to \bar{X})]$ is obtained by properly scaling the Belle uncertainty with the integrated luminosity [2]. For most of the decay modes considered the scaled uncertainty on A_{CP} is less than 0.1%. Two processes are specially interesting to study at Belle II: $D^0 \to K^0_S K^0_S$, where we expect $\sigma_{A_{CP}} = 0.2\%$ (A_{CP} is enhanced up to 1% in the Standard Model (SM) predictions [3]) and $D^+ \to \pi^+\pi^0$, where we expect $\sigma_{A_{CP}} = 0.4\%$ (the SM predicts $A_{CP} = 0$ [4], so CPV could be enhanced by New Physics contributions).

3. – Impact on purely leptonic decays

The clean environment of a B-factory and the knowledge of the center-of-mass energy will allow Belle II to measure precisely the branching fractions of the leptonic decays $D^-_q \to l^-\bar{\nu}_l$ (with $q = d, s$) and to extract the quantities $f_{D_q}|V_{cq}|$ (where f_{D_q} are the decay constants and V_{cq} are the CKM matrix elements). By using the f_{D_q} values computed with lattice QCD techniques, Belle II will significantly improve the Belle measurement of $|V_{cs}|$ (that is the world's most precise determination so far) and will measure $|V_{cd}|$ with less than 2% uncertainty [2].

The same method used for the measurement of leptonic D decays will allow Belle II to improve the search for the invisibles decays of D^0 mesons (*e.g.*, $D^0 \to \nu\bar{\nu}$).

4. – The ROE method for the flavour tagging of D^0 and $\bar{D}^0$

A new flavour tagging method, called "ROE method", has been developed in order to determine the flavour of D^0 and $\bar{D}^0$ at the production time in a $c\bar{c}$ event [2]. This method, which is complementary to the one using the pion charge in the $D^{*+} \to D^0\pi^+$ decay, exploits events where a signal D^0 is reconstructed and only one $K^{\pm}$ is identified in the rest of the event (ROE). In such case the charge of the kaon tags the flavour of the neutral D meson ($K^+ \leftrightarrow D^0$; $K^- \leftrightarrow \bar{D}^0$). The expected performances of the method are: tagging efficiency $\epsilon \sim 27\%$, mistagging fraction $\omega \sim 13\%$ and effective tagging efficiency $Q = \epsilon(1-2\omega) \sim 20\%$. When comparing such performance with the D^{*+} tagging method, which yelds $Q \sim 80\%$, it should be taken into account that only 25% of the D^0 mesons comes from a D^{*+} decay in a $c\bar{c}$ event at the B-factories.

It has been estimated that, by combining the results obtained using the D^{*+} tag and the ROE method, a 15% reduction of the statistical uncertainty on $A_{CP}(D^0 \to K^-\pi^+)$ can be achieved.

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