The ongoing experimental studies of the combined charge conjugation parity (CP) symmetry violation in particle decays aim to find effects that are not expected in the Standard Model (SM), such that new dynamics is revealed. The existence of CP violation in kaon and beauty meson decays is well established [1–3]. The first observation of the CP violation for charm mesons was reported this year by the LHCb experiment [4] and in the bottom baryon sector evidence is mounting [5]. All reported this year by the LHCb experiment [4] and in the strange baryon sector was obtained by comparing the ΞΛ decay chains of unpolarized Ξ baryons with strange quark(s) (hyperons). Hyperon decays offer promising possibilities for such searches as they are sensitive to sources of CP violation that neutral kaon decays are not [6]. A signal of CP violation can be a direct comparison of the baryon and antibaryon decay properties and a sensitive test of CP symmetry in the strange baryon sector. We show that all involved decay parameters can be determined separately in vector and (pseudo)scalar charmonia decays into ΞΛ due to the spin correlations between the weak decay chains. Contrary to the recently measured $e^+e^− → J/ψ → ΛΛ$ process, the transverse polarization of the cascade is not needed and has almost no impact on the uncertainties of the decay parameters.

In Ref. [18] we have extended the formalism to describe processes which include decay chains of multi-strange hyperons like the $e^+e^− → ΞΞ$ reaction with the $Ξ → Λπ$, $Λ → pπ^−$ and $Ξ^− → Λπ^−$ as $α_Λ$ and $α_Ξ$, respectively. In the CP symmetry conserving limit the parameters $α$ and $ϕ$ for the charge conjugated decay mode have the same absolute values but opposite signs e.g. $α_Λ = −α_Ξ$. The best limit for CP violation in the strange baryon sector was obtained by comparing the $Ξ^−$ and $Ξ^+$ decay chains of unpolarized Ξ baryons at the HyperCP (ES71) experiment [8] by determining the asymmetry $A_{ΞΛ} = (α_Λα_Ξ − α_Ξα_Λ)/(α_Λα_Ξ + α_Ξα_Λ)$. The result, $A_{ΞΛ} = (0.0 ± 5.1 ± 4.7) × 10^{−4}$, is consistent with the SM predictions: $|A_{ΞΛ}| ≤ 5 × 10^{−5}$ [9]. However, a preliminary HyperCP result presented at the BEACH 2008 Conference suggests a large value of the asymmetry $A_{ΞΛ} = (−6.0 ± 2.1 ± 2.0) × 10^{−4}$ [10].

With a well-defined initial state charmonium decay into a strange baryon-antibaryon pair offers an ideal system to test fundamental symmetries. Vector charmonia $J/ψ$ and $ψ'$ can be directly produced in an electron-positron collider with large yields and have relatively large branching fractions into a hyperon-antihyperon pair, see Table I. With the world’s largest sample of $10^{10}$ $J/ψ$ collected at BESIII [11, 15] detailed studies of the hyperon-antihyperon systems are possible. The potential impact of such measurements was shown in the recent analysis using a data set of $4.2 × 10^6 e^+e^− → J/ψ → ΛΛ$ events reconstructed via $Λ → pπ^−$ and $c.c.$ decay chain and has lead e.g. to the major revision of the $α_Λ$ value [16]. The determination of the asymmetry parameters was possible only due to the transverse polarization and the spin correlations of the $Λ$ and $Λ$. In the analysis the complete multi-dimensional information of the final state particles was used in an unbinned maximum log likelihood fit to the fully differential angular expressions from Ref. [17]. The method allows for a direct comparison of the decay parameters of the charge conjugate decay modes and a test of the CP symmetry.
where a set of four Pauli matrices $\sigma^B_{\mu}$ in the rest frame of a baryon $B(B')$ is used and $C_{\mu\nu}$ is $4 \times 4$ real matrix representing polarizations and spin correlations for the baryons.

Consider the $e^+e^- \rightarrow B\bar{B}$ reaction represented in Fig. 1, where the electron and positron beams are unpolarized. The spin matrices $\sigma^B_{\mu}$ and $\sigma^\bar{B}_{\nu}$ are given in the helicity frames of the baryon $B$ and antibaryon $\bar{B}$, respectively. The axes of the coordinate systems are denoted $\hat{x}_1,\hat{y}_1,\hat{z}_1$ and $\hat{x}_2,\hat{y}_2,\hat{z}_2$. The baryons and antibaryon can have aligned or opposite helicities. Due to the parity conservation only two transitions are independent and the $C_{\mu\nu}$ matrix can be parameterized by: $\alpha_\psi$—baryon angular distribution parameter, $-1 \leq \alpha_\psi \leq 1$, and $\Delta \Phi$—relative phase between the two transitions. The elements of the $C_{\mu\nu}$ matrix are functions of the scattering angle $\theta$ of the $B$ baryon [18]:

$$
\begin{pmatrix}
1 + \alpha_\psi \cos^2\theta & 0 & \beta_\psi \sin2\theta & 0 \\
0 & \sin^2\theta & 0 & \gamma_\psi \sin2\theta \\
-\beta_\psi \sin2\theta & 0 & \alpha_\psi \sin^2\theta & 0 \\
0 & -\gamma_\psi \sin2\theta & 0 & -\alpha_\psi - \cos^2\theta
\end{pmatrix},
$$

(2)

where $\beta_\psi$ and $\gamma_\psi$ (real parameters) are defined as: $\gamma_\psi + i\beta_\psi = \frac{1}{2} \sqrt{1 - 4 \alpha_\psi^2 \exp(i\Delta \Phi)}$. The polarization vector of $B(\bar{B})$ can have only $\hat{y}_1(\hat{y}_2)$ component and the value is $\beta_\psi \sin 2\theta / (1 + \alpha_\psi \cos^2\theta)$ i.e. the polarization is zero if $\beta_\psi = 0$. In the limit of large c.m. energies $\alpha_\psi = 1$ implying $\beta_\psi = \gamma_\psi = 0$ [21] and diagonal $C_{\mu\nu}$. For the $BB$ decay of a (pseudo)scalar charmonium (like $\eta_c$ or $\chi_{c0}$) the initial state is spin singlet and the spin orientations of the baryon and antibaryon are opposite. Therefore $C_{\mu\nu}$ is diag(1,−1,1,1), where the signs are stipulated by the relative orientation of the axes of the $B$ and $\bar{B}$ helicity frames shown in Fig. 1. The direction of the $\hat{z}$ axis is arbitrary.

In a weak hadronic decay $D$ of a spin one-half baryon to a spin one-half baryon and a pseudoscalar meson: $B_A \rightarrow B_B + P$, the initial and final states can be represented by linear combinations of the Pauli density matrices $\sigma^B_{\mu}$ and $\sigma^{B'}_{\nu}$, defined in the helicity frame of $B_A$ and $B_B$, respectively. It is enough to know how each base spin matrix transforms under a decay process. One can therefore represent the weak decay by a decay matrix $a^D_{\mu\nu}$ which transforms the base matrices [18]:

$$
\sigma^B_{\mu} \rightarrow \sum_{\mu' = 0}^3 a^B_{\mu\mu'} \sigma^{B'}_{\mu'}. \quad (3)
$$

The decay matrix depends on two decay parameters: $-1 \leq \alpha_D \leq 1$ and $-\pi \leq \phi_D < \pi$ according to the Par-
The joint angular distribution Eq. (5) is a function of \( \Xi \) are four parameters to describe the angular distribution. The vector \( \xi \) is the same) with the \( \Xi \) decay chains is obtained by the application of Eq. (1), antihyperon pair production process including the weak decay is described by the 4 decay matrix \( a_\mu \equiv a_{\mu \nu}(\theta, \varphi; \alpha D, \phi D) \) depend on the kinematic variables \( \theta \) and \( \varphi \), the spherical coordinates of the \( B_B \) momentum in the \( B_A \) helicity frame, and on the decay parameters \( \alpha D \) and \( \phi D \). The explicit form of the \( a_{\mu \nu} \) is given in Ref. [18], where a two angle helicity rotation matrix convention is used. If the polarization of the baryon \( B_B \) is not measured the decay is described by the \( a_{\mu \nu} \) elements of the decay matrix and only the \( \alpha D \) parameter is involved. This is normally the case for \( \Lambda \rightarrow p\pi^- \) since the proton polarization determination would require a dedicated detection system. A complete joint angular distribution of a hyperon-antihyperon pair production process including the weak decay chains is obtained by the application of Eq. (1), the decay matrices transformations Eq.(3) and by taking trace of the final proton-antiproton density matrix. For the process \( e^+e^- \rightarrow \Lambda \bar{\Lambda} \) with \( \Lambda \rightarrow p\pi^- + c.c. \) the joint angular distribution is [18]:

\[
W^{\Lambda \bar{\Lambda}}(\xi; \omega) = \sum_{\mu,\nu}^3 C_{\mu \nu} a_{\mu \nu}^\Lambda a_{\mu \nu}^{\bar{\Lambda}} ,
\]

where the production reaction is described by the corresponding \( C_{\mu \nu} \equiv C_{\mu \nu}(\theta; \varphi; \Delta \Phi) \) matrix, \( a_{\mu \nu}^{\Lambda} \equiv a_{\mu \nu}(\theta, \varphi; \alpha \Lambda, \phi \Lambda) \) and \( a_{\mu \nu}^{\bar{\Lambda}} \equiv a_{\mu \nu}(\theta, \varphi; \alpha \bar{\Lambda}, \phi \bar{\Lambda}) \). The vector \( \xi \equiv (\theta, \varphi, \theta, \varphi) \) represents a complete set of the kinematic variables describing a single event configuration in the five dimensional phase space. There are four parameters to describe the angular distribution \( \omega \equiv (\alpha \Lambda, \Delta \Phi, \alpha \bar{\Lambda}, \phi \bar{\Lambda}) \). The asymptotic case \( \Lambda \rightarrow p\pi^- \) since the proton polarization determination would require a dedicated detection system. A complete joint angular distribution of a hyperon-antihyperon pair production process including the weak decay chains is obtained by the application of Eq. (1), the decay matrices transformations Eq.(3) and by taking trace of the final proton-antiproton density matrix. For the process \( e^+e^- \rightarrow \Xi \Xi^+ \) reaction the formalism for the \( \Xi \Xi^0 \Xi^0 \) is the same with the \( \Xi^+ \rightarrow \Lambda \pi^- \), \( \Lambda \rightarrow p\pi^- + c.c. \) decay sequences the joint angular distribution is [18]:

\[
W^{\Xi \Xi}(\xi; \omega) = \sum_{\mu,\nu}^3 C_{\mu \nu} \sum_{\mu',\nu'}^3 a_{\mu' \nu'}^\xi a_{\mu' \nu'}^{\bar{\xi}} a_{\mu' \nu'}^{\Lambda} a_{\mu' \nu'}^{\bar{\Lambda}} ,
\]

where \( a_{\mu' \nu'}(\theta, \varphi; \alpha \Xi, \phi \Xi) \), \( a_{\mu' \nu'}^\xi \equiv a_{\mu' \nu'}(\theta, \varphi; \alpha \bar{\Xi}, \phi \bar{\Xi}) \). For \( \Xi(\bar{\Xi}) \) all elements of the decay matrix are used and dependence on the \( \phi \Xi(\phi \bar{\Xi}) \) should be included. The joint angular distribution Eq. (5) is a function of nine helicity angles: \( \xi \equiv (\theta, \varphi, \theta, \varphi, \theta, \varphi, \theta, \varphi, \theta, \varphi) \) and depends on eight global parameters: \( \omega \equiv (\alpha \psi, \Delta \Phi, \alpha \Xi, \phi \Xi, \alpha \bar{\Xi}, \phi \bar{\Xi}, \alpha \Lambda, \phi \bar{\Lambda}) \). Since all decays of the sequences are two body with constant c.m. momenta the kinematic weight of states in phase space expressed by the sets of helicity angles \( \xi \) is given by the isotropic distributions. The angular distributions (4) and (5) can be rewritten as:

\[
\sum_{k=1}^m g_k(\omega) \cdot h_k(\xi),
\]

where the functions \( g_k \) and \( h_k \) depend only on \( \omega \) and \( \xi \), respectively. The angular distribution in Eq. (5) requires \( m = 72 \) unique functions \( g_k(\omega) \) of the global parameters, while Eq. (4) only \( m = 7 \). For \( \Delta \Phi = 0 \) the number of such terms reduces to \( m = 56 \), and \( m = 5 \), respectively. The asymptotic case \( \alpha = 1 \) and the (pseudo)scalar charmonium decay still require 20 terms for \( \Xi \Xi \) while only 2 terms for the \( \Lambda \Lambda \) final state. This suggests the structure of the \( \Xi \Xi \) pair joint decay products distribution is rich enough to determine all involved decay parameters separately. For example, in all cases the six pair-wise products of the \( \alpha \Xi, \alpha \bar{\Xi}, \alpha \Lambda, \alpha \bar{\Lambda} \) are present.

Before introducing a rigorous method to analyze the exclusive joint angular distributions we make a comment on the inclusive measurement. If in \( e^+e^- \rightarrow \Xi^- \Xi^+ \) decay products are measured the corresponding angular distribution is obtained by integrating \( W^{\Xi \Xi} \) over the \( \varphi \bar{\psi}, \varphi \Lambda, \cos \theta \bar{\psi} \) and \( \cos \theta \Lambda \) variables. The integral is \( 16\pi^2(C_{00}T_0 + C_{20}T_2) \) where \( T_0 \) and \( T_2 \) are:

\[
T_0 = 1 + \alpha \epsilon \alpha \Lambda \cos \theta \Lambda ,
\]

\[
T_2 = \sin \varphi \epsilon \sin \theta \epsilon (\alpha \Xi + \alpha \Lambda \cos \theta \Lambda)
\]

\[
+ \alpha \epsilon \sin \theta \Lambda (\cos \varphi \epsilon \cos \theta \bar{\psi} - \beta \bar{\lambda} \sin \varphi \epsilon)
\]

\[
+ \cos \varphi \epsilon (\beta \bar{\lambda} \cos \varphi \epsilon + \gamma \bar{\lambda} \sin \varphi \epsilon)) .
\]

If \( \beta \bar{\psi} = 0 \) (no polarization) only \( T_0 \) contributes implying \( \alpha \Xi \) and \( \alpha \Lambda \) cannot be determined separately as the distribution is given by the product \( \alpha \Xi \alpha \Lambda \).

In general the importance of the individual parameters \( \omega_k \) in the joint angular distributions Eqs. (4) and (5) and their correlations are best studied using properties of the corresponding likelihood function. In the ideal case when the response function is diagonal the likelihood function can be written as:

\[
\mathcal{L}(\omega) = \prod_{i=1}^N P(\xi_i, \omega) = \prod_{i=1}^N \frac{1}{N} \mathcal{W}(\xi_i, \omega) ,
\]

where \( N \) is the number of events in the final selection and \( \xi_i \) is the full set of kinematic variables describing \( i \) th event. The asymptotic expression of the inverse covariance matrix element between parameters \( \omega_k \) and \( \omega_l \) from the vector parameter \( \omega \) is given by [7]:

\[
V_{kl}^{-1} = E \left( -\frac{\partial^2 \mathcal{L}}{\partial \omega_k \partial \omega_l} \right) ,
\]
where $E(h)$ denotes the expectation value of a random variable $h(\xi)$. Eq. (9) can be reduced to:

$$V_{kl}^{-1} = N \int \frac{1}{P} \frac{\partial P}{\partial \omega_k} \frac{\partial P}{\partial \omega_l} d\xi. \quad (10)$$

The above integral involves inverse of the angular distribution $W$ and has to be evaluated numerically. We use the weighted Monte Carlo method to calculate the integrals. The calculated values are then used to construct the matrix, which is inverted to get the covariances for the parameters. If two or more parameters are fully correlated and their values cannot be determined separately the matrix is singular. We report the resulting uncertainties multiplied by $\sqrt{N}$, and call such quantity sensitivity.

We start by verifying the method using the $e^+e^- \rightarrow J/\psi \rightarrow \Lambda\Lambda$ reaction. Here all parameters, including the phase $\Delta \Phi = 0.740 \pm 0.010 \pm 0.008$, are known [16] and we can cross-check our estimates of the uncertainties shown in the first row of Table III. To compare with the BESIII statistical uncertainties (in parentheses) we set $N$ to 0.42 $\times 10^6$: $\sigma(\alpha_{\Lambda}) = 0.010(0.010)$, $\sigma(\alpha_{e}) = 0.005(0.006)$ and $\sigma(\Delta \Phi) = 0.012(0.010)$. The agreement is satisfactory because no efficiency variation is included in our calculations. In particular, the $\Lambda$ emission angle is limited to the range $|\cos \theta| < 0.85$ in BESIII. Our correlation coefficient between $\alpha_{\Lambda}$ and $\alpha_{\bar{\Lambda}}$ is 0.87 to be compared to 0.82 from the BESIII fit.

To study the angular distribution for the $e^+e^- \rightarrow \Xi^0\Xi^0$ reaction we fix the decay parameters of the $\Lambda$ and $\bar{\Xi}$ to the central values listed in Table II. For the production process the main unknown parameter is the phase $\Delta \Phi$ and therefore we use the extreme cases: $\Delta \Phi = 0$ and $\pi/2$. In Table III we report the sensitivities in the $J/\psi \rightarrow \Xi^-\Xi^+$ decay. Correlations between parameters are given in Table IV. The results practically do not change between the two $\Delta \Phi$ cases. The results for other decays: $\psi' \rightarrow \Xi^-\Xi^+$ and $J/\psi, \psi' \rightarrow \Xi^0\Xi^0$ are similar. In the table the results for the $e^+e^- \rightarrow \Xi^-\Xi^-$ asymptotic case with $\alpha_{e} = 1$ and for a scalar charmonium decay to $\Xi \Xi$ are also shown. We conclude that contrary to $e^+e^- \rightarrow \Lambda\bar{\Lambda}$ the polarization in the production process plays practically no role. We find that the weak decay phases $\alpha_{\Xi}$ and $\alpha_{\bar{\Xi}}$ are not correlated with each other and with any other parameter. Also, the use of parameter input values for $\Xi^-$ or $\Xi^0$ from Table II have only minor effect on the sensitivities.

For $e^+e^- \rightarrow J/\psi \rightarrow \Xi^-\Xi^+$ we also consider single tag measurement and determine correlation coefficient $\rho(\alpha_{\Xi}, \alpha_{\Lambda})$ between $\alpha_{\Xi}$ and $\alpha_{\Lambda}$. It is equal to one for $\Delta \Phi = 0$ and the dependence on $\Delta \Phi$ is well represented by the relation $\rho(\alpha_{\Xi}, \alpha_{\Lambda}) = (1 - p) \cos(\Delta \Phi) + p$, where $p = 0.91$. Sensitivity for the product $\alpha_{\Xi}\alpha_{\Lambda}$ is 1.7, nearly independent on the $\Delta \Phi$ value. The best sensitivity for $\phi_{\Xi}$, with $\Delta \Phi = \pi/2$ is 12.4 i.e. at least two times worse than in the exclusive measurement, while for $\Delta \Phi < 0.2$ the sensitivity for $\phi_{\Xi}$ can be approximately described by $12.5 \cot(\Delta \Phi)$.

An exclusive experiment allows to determine both the average values and differences of the decay parameters for the charge conjugated modes, which e.g. for the $\phi_{\Xi}$ parameter are defined as:

$$\langle \phi_{\Xi} \rangle \equiv \frac{\phi_{\Xi} + \phi_{\bar{\Xi}}}{2} \quad \text{and} \quad \Delta \phi_{\Xi} \equiv \frac{\phi_{\Xi} - \phi_{\bar{\Xi}}}{2}. \quad (11)$$

The CP asymmetry $A_{\Xi}$ is defined as:

$$A_{\Xi} \equiv \frac{\alpha_{\Xi} + \alpha_{\bar{\Xi}}}{D_{\Xi}} - \frac{\alpha_{\Xi} - \alpha_{\bar{\Xi}}}{D_{\Xi}} \quad (12)$$

and $B_{\Xi}$ as:

$$B_{\Xi} \equiv \frac{\beta_{\Xi} + \beta_{\bar{\Xi}}}{5} \approx -\frac{\alpha_{\Xi} \Delta \phi_{\Xi}}{1 - \langle \alpha_{\Xi} \rangle^2} + \frac{\Delta \phi_{\Xi}}{\tan(\phi_{\Xi})}. \quad (13)$$

where the approximate form includes only linear terms in $\Delta \alpha_{\Xi}$ and $\Delta \phi_{\Xi}$. Since the phase $\langle \phi_{\Xi} \rangle$ is small, the last term in Eq. (13) dominates and $B_{\Xi} \approx \Delta \phi_{\Xi} / \langle \phi_{\Xi} \rangle$. The sensitivities for the $A_{\Xi}$, $A_{\Lambda}$, $A_{\Xi\Xi}$ and $B_{\Xi}$ asymmetries are given in Table III. The sensitivity for $A_{\Xi}$ is 2.5 times better in $J/\psi \rightarrow \Xi^-\Xi^+$ than in $J/\psi \rightarrow \Lambda\bar{\Lambda}$. The statistical uncertainty for the $A_{\Xi\Xi}$ asymmetry from the dedicated HyperCP experiment could be surpassed at STCF in a run at the $J/\psi$ c.m. energy with more than $10^{12}$ events. The SM predictions for the $A_{\Xi}$ and $A_{\Xi\Xi}$ asymmetries are $-3 \times 10^{-5} \leq A_{\Xi} \leq 4 \times 10^{-5}$ and $-2 \times 10^{-5} \leq A_{\Xi\Xi} \leq 1 \times 10^{-5}$ [9].

A prerequisite for a complementary CP test using $B_{\Xi}$ asymmetry, advocated in Ref. [6] as the most sensitive probe, is $\langle \phi_{\Xi} \rangle \neq 0$. Assuming $\langle \phi_{\Xi} \rangle = 0.037$, according to the Table II value for $\Xi^-$, the five sigma significance requires $3.1 \times 10^5$ exclusive $\Xi^-\Xi^+$ events. To reach the statistical uncertainty of 0.011, as in the HyperCP experiment [22] requires $1.4 \times 10^5$ $J/\psi \rightarrow \Xi^-\Xi^+$ events, while the single cascade HyperCP result is based on $114 \times 10^6$ events. The present PDG precision of $\phi_{\Xi\Xi}$ can be achieved with just $3 \times 10^5 \Xi^0\Xi^0$ events. The SM estimate for $B_{\Xi}$ is $8.4 \times 10^{-3}$, an order of magnitude larger compared to the $A$ asymmetries [6, 23], while the sensitivities for $B_{\Xi}$ in Table III are 20–30 times worse. However, it should be stressed that the SM predictions for all asymmetries need to be updated in view of the recent and forthcoming BESIII results on hyperon decay parameters. Our analysis shows that a wide range of CP precision tests can be conducted in a single measurement. Thus, the spin entangled cascade-anticascade system is a promising probe for testing fundamental symmetries in the strange baryon sector.

P.A. work was supported by The Knut and Alice Wallenberg Foundation (Sweden) under Contract No. 2016.0157 (PI K. Schöning).

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\[ J/\psi \rightarrow \Lambda \bar{\Lambda} \]
\[ J/\psi \rightarrow \Xi^- \Xi^+ \ (\Delta \Phi = 0) \]
\[ J/\psi \rightarrow \Xi^- \Xi^+ \ (\Delta \Phi = \pi/2) \]
\[ J/\psi \rightarrow \Xi^- \Xi^+ \ (\Delta \Phi = \pi/2) \]
\[ e^+e^- \rightarrow \Xi^- \Xi^+ \ (\alpha_\psi = 1) \]
\[ J/\psi \rightarrow \Xi^- \bar{\Xi}^+ \]

| TABLE III. Sensitivities (standard errors multiplied by \(\sqrt{N}\)) for the extracted parameters. Errors for the parameters of the charge conjugated decay modes are the same. The input values of the parameters are from Tables I and II. |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| \(\alpha_\Xi\)  | \(\alpha_\bar{\Xi}\) | \(\alpha_\Lambda\) | \(\alpha_\bar{\Lambda}\) | \(\Delta \Phi\) | \(\langle \alpha_\Xi \rangle\) | \(\langle \alpha_\Lambda \rangle\) | \(\langle \alpha_\bar{\Xi} \rangle\) |
| +0.03 | +0.37 | +0.11 | −0.03 | \(\Delta \Phi = 0\) | 0.10 | 0.30 | 0.10 |
| +0.01 | +0.11 | +0.37 | +0.03 | \(\Delta \Phi = \pi/2\) | 0.09 | 0.30 | 0.10 |
| +0.31 | +0.07 | +0.43 | −0.12 | \(\Delta \Phi = \pi/2\) | 0.09 | 0.30 | 0.10 |
| +0.07 | +0.31 | +0.39 | +0.12 | \(\alpha_\psi = 1\) | 0.09 | 0.30 | 0.10 |
| −0.04 | +0.04 | 1 | 1 | \(\Delta \Phi = \pi/2\) | 0.09 | 0.30 | 0.10 |

| TABLE IV. Correlation matrix for the parameters in the \(e^+e^- \rightarrow J/\psi \rightarrow \Xi^- \Xi^+\) process. \(\Delta \Phi = 0\) case (above the diagonal) and \(\Delta \Phi = \pi/2\) case (below the diagonal). Only correlation coefficients with the absolute value greater than 0.01 are shown. |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| \(\alpha_\Xi\)  | \(\alpha_\bar{\Xi}\) | \(\alpha_\Lambda\) | \(\alpha_\bar{\Lambda}\) | \(\alpha_\psi\) | \(\alpha_\Xi\) | \(\alpha_\bar{\Xi}\) | \(\alpha_\Lambda\) |
| +0.03 | +0.37 | +0.11 | −0.03 | 1 | 0 | 0 | 0 |
| +0.01 | +0.11 | +0.37 | +0.03 | 0.01 | 1 | 0 | 0 |
| +0.31 | +0.07 | +0.43 | −0.12 | 0.31 | 0.07 | 1 | 0 |
| +0.07 | +0.31 | +0.39 | +0.12 | 0.07 | 0.31 | 0.39 | 1 |
| −0.04 | +0.04 | 1 | 1 | 1 | 1 | 1 | 1 |

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