

Measurement of Born cross sections and effective form factors of $e^+e^- \rightarrow \Omega^-\bar{\Omega}^+$ from $\sqrt{s} = 3.7$ to 4.7 GeV



The BESIII collaboration

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ABSTRACT: Using e^+e^- collision data corresponding to an integrated luminosity of 22.7 fb^{-1} , collected at center-of-mass energies between 3.7 and 4.7 GeV with the BESIII detector at the BEPCII storage ring, we measure the energy-dependent Born cross sections of $e^+e^- \rightarrow \Omega^-\bar{\Omega}^+$ and the effective form factors of the Ω^- baryon. The analysis employs a single baryon tagging method, and the results are consistent with theoretical predictions, providing critical constraints on the electromagnetic structure of the Ω^- hyperon. No significant signal of charmonium or charmonium-like states decaying to $\Omega^-\bar{\Omega}^+$ is observed in the investigated energy range.

KEYWORDS: e^+e^- Experiments, QCD

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Contents

1	Introduction	1
2	Detector and data sets	2
3	Event selection and signal determination	3
4	Measurement of BCS and EFF	4
5	Systematic uncertainty	8
6	Summary	8
	The BESIII collaboration	13

1 Introduction

Over the past two decades, many vector states have been observed at center-of-mass (c.m.) energies between 3.7 and 4.7 GeV by various e^+e^- colliders. Four charmonium states ($\psi(3770)$, $\psi(4040)$, $\psi(4160)$, and $\psi(4415)$) have been observed in the inclusive hadronic cross section line shape [1, 2]. Several charmonium-like vector states, such as $Y(4230)$, $Y(4260)$, $Y(4360)$, and $Y(4660)$, have been observed by the BaBar [3–6], Belle [7–10], CLEO [11, 12], and BESIII [13–17] experiments. Many theoretical models have been proposed to understand the underlying structure of these Y states, interpreting them as hybrid charmonia [18], tetraquarks [19], or hadronic molecules [20]. However, none of them has been able to describe all the experimental observations. Up to now, no evidence of their decays into light-quark baryon-antibaryon pairs has been found. As an example, BESIII recently searched for charmonium-like vector states in the processes $e^+e^- \rightarrow \Xi^-\bar{\Xi}^+$ and $e^+e^- \rightarrow \Lambda\bar{\Lambda}$ [21, 22]. In addition, BESIII reported a large number of precision measurements of the cross sections of SU(3) baryon-antibaryon pairs [23] and some experimental results regarding the production of $\Omega^-\bar{\Omega}^+$ pairs [1].

The electromagnetic structure of the Ω^- hyperon, consisting of three valence strange quarks, remains poorly understood due to limited experimental measurements. As a baryon with a spin-parity of $3/2^+$, its structure is characterized by its electric charge (G_{E0}), magnetic dipole (G_{M1}), electric quadrupole (G_{E2}), and magnetic octupole (G_{M3}) form factors [24, 25]. Precision measurements of the Ω^- electromagnetic form factors in the space-like region ($q^2 < 0$) are challenging due to the difficulty in creating suitable strange baryon targets which can be scattered by electron beams. Currently, the primary method of measuring the electromagnetic form factors of hadrons is through the cross section measurement in e^+e^- annihilation, which offers information of time-like momentum transfer ($q^2 > 0$). Due to limited statistical precision, most experiments have only been able to measure a combination of the electromagnetic form factors, known as the effective form factor (EFF) [22]. The form factors

of SU(3) baryons can be obtained from the production cross sections of $e^+e^- \rightarrow \gamma^* \rightarrow B\bar{B}$. Recent measurements reported the Ω^- electromagnetic form factors at a c.m. energy (\sqrt{s}) of approximately 3.7 GeV ($q^2 = s = 14.2 \text{ GeV}^2$) using the data from the BESIII and CLEO-c detectors [26–28]. These data provide valuable information about the time-like form factors in the large q^2 region and offer a unique opportunity to test their behaviour under extreme conditions. A recent calculation of the EFF for the Ω^- hyperon was performed using the covariant spectator quark model [29]. However, the accuracy of the description of the EFF is limited due to insufficient data. More data at larger momentum transfer are therefore highly desirable. The measurements would provide better constraints on the shape of the form factors at large q^2 and enhance the significance of time-like measurements in calibrating different theoretical models.

In this article, we present a measurement of the Born cross sections (BCSs) of $e^+e^- \rightarrow \Omega^-\bar{\Omega}^+$ and the EFFs for Ω^- using data corresponding to a total integrated luminosity of 22.7 fb^{-1} , collected at c.m. energies between 3.7 and 4.7 GeV with the BESIII detector [30] at the Beijing Electron Positron Collider (BEPCII) [31]. Through the analysis of the cross-section line shape measured by the single baryon tag method, we can search for charmonium-like vector states in their baryonic decay modes. In addition, the EFFs obtained will provide essential information to understand the structure of Ω^- hyperons.

2 Detector and data sets

The BESIII detector [30] records symmetric e^+e^- collisions provided by the BEPCII storage ring [31] in the c.m. energy range from 2.0 to 4.95 GeV, with a peak luminosity of $1 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$ achieved at $\sqrt{s} = 3.77 \text{ GeV}$. BESIII has collected large data samples in this energy region [32–34].

Its cylindrical core consists of a helium-based multilayer drift chamber (MDC), a plastic scintillator time-of-flight system (TOF), and a CsI (TI) electromagnetic calorimeter (EMC), which are all enclosed in a superconducting solenoidal magnet that provides a 1.0 T magnetic field. The solenoid is supported by an octagonal flux-return yoke with resistive plate counter muon identifier modules interleaved with steel. The acceptance of charged particles and photons is 93% over 4π solid angle. The charged-particle momentum resolution at 1.0 GeV/ c is 0.5%, and the specific ionization energy loss (dE/dx) resolution is 6% for electrons from Bhabha scattering. The EMC measures photon energies with a resolution of 2.5% (5%) at 1 GeV in the barrel (end cap) region. The time resolution in the TOF barrel region is 68 ps, while that in the end cap region was 110 ps. The end cap TOF system was upgraded in 2015 using multigap resistive plate chamber technology, providing a time resolution of 60 ps, which benefits 66.6% of the data used in this analysis [35–37].

GEANT4-based [38, 39] Monte Carlo (MC) simulations are used to evaluate the detection efficiency and estimate the physics backgrounds. The simulations include the geometric and material description of the BESIII detectors [40], the detector response and digitization models, as well as the tracking of the detector’s running conditions and performance. The simulations model the beam energy spread and initial state radiation (ISR) in the e^+e^- annihilations with the KKMC generator [41]. The two signal processes, $e^+e^- \rightarrow \Omega^-\bar{\Omega}^+$, $\Omega^- \rightarrow \Lambda K^-$, $\Lambda \rightarrow p\pi^-$, $\bar{\Omega}^+ \rightarrow$ anything and $e^+e^- \rightarrow \Omega^-\bar{\Omega}^+$, $\bar{\Omega}^+ \rightarrow \bar{\Lambda}K^+$, $\bar{\Lambda} \rightarrow \bar{p}\pi^+$, $\Omega^- \rightarrow$

anything, are generated to evaluate the detection efficiency. For each signal process, 100,000 events are simulated with the joint angular distribution of the decay sequence from ref. [42] at each of the thirty-four c.m. energies. The decay of the Ω^- hyperon are generated by EVTGEN [43, 44], with branching fractions set to the world average values from the Particle Data Group (PDG) [1]. In addition, large simulated generic MC samples are generated for background study [45].

3 Event selection and signal determination

A single baryon tag method is used to select the $e^+e^- \rightarrow \Omega^- \bar{\Omega}^+$ candidate events, i.e. only one baryon of the $\Omega^- \bar{\Omega}^+$ pair is reconstructed in each event, where the Ω^- or $\bar{\Omega}^+$ is reconstructed with $\Omega^- \rightarrow K^- \Lambda$, $\Lambda \rightarrow p\pi^-$ or $\bar{\Omega}^+ \rightarrow K^+ \bar{\Lambda}$, $\bar{\Lambda} \rightarrow \bar{p}\pi^+$, and the Ω^- or $\bar{\Omega}^+$ on the recoil side is inferred from the recoil mass of the reconstructed particles. The following event selections are described for $\Omega^- \rightarrow K^- \Lambda$ ($\Lambda \rightarrow p\pi^-$), as an example; the same selections are also applied for the $\bar{\Omega}^+$ selection.

All charged tracks detected in the MDC must satisfy $|\cos\theta| < 0.93$, where θ is the polar angle of the charged track with respect to the z -axis, which is the symmetry axis of the MDC. Particle identification (PID) for charged tracks combines measurements of the dE/dx in the MDC and the flight time in the TOF to form likelihoods $\mathcal{L}(h)$ ($h = p, K, \pi$) for each hadron h hypothesis. Each charged track is then assigned to the particle type with the greatest likelihood. Events with at least one charged proton, kaon, and pion candidate are kept for further analysis.

Each Λ candidate is reconstructed with two oppositely charged $p\pi^-$ tracks, identified using PID algorithm. They are constrained to originate from a common vertex, and a loose requirement on the invariant mass of $p\pi^-$ is applied as $1.09 < M(p\pi^-) < 1.14 \text{ GeV}/c^2$ to suppress background events. The Ω^- candidates are then reconstructed from all pairs of the selected $K^- \Lambda$ candidates, which are constrained to originate from a common vertex. A secondary vertex fit [46] is performed to ensure the Ω^- candidates originate from the interaction point.

To further suppress background, the decay lengths of Λ and Ω^- candidates, i.e. the distance between the average position of the e^+e^- collisions and the decay vertex of Λ and Ω^- , are required to be greater than twice the vertex resolution. The χ^2 values of the vertex fit for Λ and Ω^- are both required to be less than 100 for further analysis. If there is more than one Ω^- or $\bar{\Omega}^+$ candidate satisfying all above requirements in the event, the one with the minimum χ^2 is retained for further study.

To improve the mass resolution, we exploit the correlation between $M(K^- \Lambda)$ and $M(p\pi^-)$ by using the variable $M^{\text{cor}}(K^- \Lambda) = M(K^- \Lambda) - M(p\pi^-) + m(\Lambda)$ instead of $M(K^- \Lambda)$, where $M(K^- \Lambda)$ is the invariant mass of the $K^- \Lambda$ combination and $m(\Lambda)$ is the known mass of the Λ from the PDG [1]. Similarly, for the recoil mass, we use $RM^{\text{cor}}(K^- \Lambda) = RM(K^- \Lambda) + M(K^- \Lambda) - m(\Omega^-)$ instead of $RM(K^- \Lambda)$, where $m(\Omega^-)$ is the known mass of the Ω^- from the PDG [1]. Figure 1 shows the distribution of $RM^{\text{cor}}(K^- \Lambda)$ versus $M^{\text{cor}}(K^- \Lambda)$ for all data samples having passed all above requirements and with a requirement of $M(p\pi^-)$ in the Λ signal region of $[1.111, 1.121] \text{ GeV}/c^2$, corresponding to three times the $p\pi^-$ mass resolution to the nominal Λ mass [1]. A clear enhancement around the nominal Ω^- mass is observed.

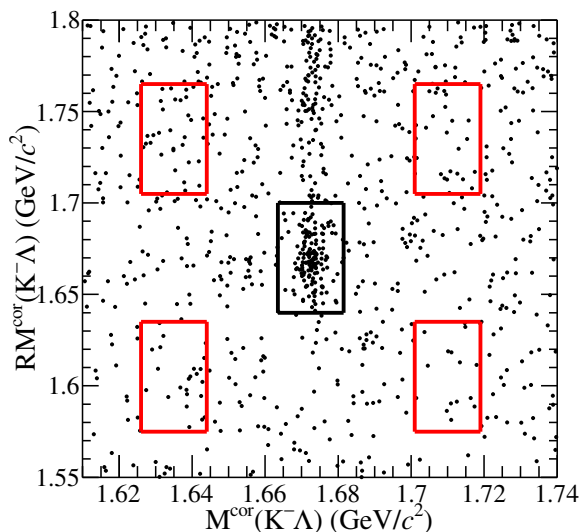


Figure 1. Distribution of $RM^{\text{cor}}(K^-\Lambda)$ versus $M^{\text{cor}}(K^-\Lambda)$ of the accepted candidates from all thirty-four c.m. energies, where the black box shows the signal region, and the red boxes denote the selected sideband regions.

After applying the above criteria, the survived background events are mainly from non- Ω processes, such as $e^+e^- \rightarrow \Lambda\bar{\Lambda}\phi$ with $\phi \rightarrow K^-K^+$. The enhancement above the signal region in $RM^{\text{cor}}(K^-\Lambda)$ distribution is due to the process $e^+e^- \rightarrow \gamma_{ISR}\psi(3773)$ with $\psi(3773) \rightarrow \Omega^-\bar{\Omega}^+$. The contribution of this background in signal region is negligible according to simulation. The background contribution in the signal region is estimated by four sideband regions, each with the same area as the signal region. The Ω^- signal and the sideband regions are shown in figure 1. The signal region is chosen as $[1.6635, 1.6815]$ GeV/c^2 for $M^{\text{cor}}(K^-\Lambda)$ corresponding to three times the mass resolution in the tag side and $[1.64, 1.70]$ GeV/c^2 for $RM^{\text{cor}}(K^-\Lambda)$ in the recoil side. The sideband regions are chosen as $[1.626, 1.644]$ and $[1.701, 1.719]$ GeV/c^2 for $M^{\text{cor}}(K^-\Lambda)$ and $[1.575, 1.635]$ GeV/c^2 and $[1.705, 1.765]$ GeV/c^2 for $RM^{\text{cor}}(K^-\Lambda)$. The net signal yield (N^{sig}) at each c.m. energy is obtained by subtracting the normalized total number of events in the sideband regions ($\frac{1}{4}N^{\text{bkg}}$) from the number of events in the signal region (N^{obs}) using the formula $N^{\text{sig}} = N^{\text{obs}} - \frac{1}{4}N^{\text{bkg}}$. Table 1 lists the signal yield at each c.m. energy, where the negative values of N^{sig} have been set to zero to prevent an unphysical number of signal events. For c.m. energy points where $S(\sigma) < 3\sigma$, we calculate the 90% confidence level upper limit (N^{UL}) using the TRolke package [47], after incorporating systematic uncertainties. The signal significance $S(\sigma)$ is defined as $N^{\text{sig}}/\sqrt{N^{\text{obs}}}$ and is expressed in units of standard deviations (σ), which correspond to the probability (p-value) that the observed signal arises from a background fluctuation.

4 Measurement of BCS and EFF

The BCS of the $e^+e^- \rightarrow \Omega^-\bar{\Omega}^+$ process at each c.m. energy is calculated by

$$\sigma^{\text{B}}(e^+e^- \rightarrow \Omega^-\bar{\Omega}^+) = \frac{N^{\text{sig}}}{\mathcal{L}(1+\delta)\frac{1}{|1-\Pi|^2}\mathcal{B}(\Omega^- \rightarrow K^-\Lambda)\mathcal{B}(\Lambda \rightarrow p\pi^-)\epsilon}, \quad (4.1)$$

where N^{sig} is the net signal yield, \mathcal{L} is the integrated luminosity, ϵ is the detection efficiency, $(1 + \delta)$ is the ISR correction factor, and $(1/|1 - \Pi|^2)$ is the vacuum polarization (VP) correction factor [48]. The values of $\mathcal{B}(\Omega^- \rightarrow K^- \Lambda) = (67.8 \pm 0.7)\%$ and $\mathcal{B}(\Lambda \rightarrow p \pi^-) = (63.9 \pm 0.5)\%$ are from the PDG [1]. An iterative procedure is adopted to obtain a stable product of $(1 + \delta)\epsilon$ [21, 26]. The values of $(1 + \delta)\epsilon$ after the third iteration are convergent and used to calculate the BCSs.

Assuming that the one-photon exchange $e^+e^- \rightarrow \gamma^* \rightarrow \Omega^- \bar{\Omega}^+$ is the dominant process, the EFF $|G_{\text{eff}}(s)|$ for baryons with spin-parity $3/2^+$ is defined by a combination of the four form factors: G_{E0} , G_{M1} , G_{E2} , and G_{M3} [26]. It is written as

$$|G_{\text{eff}}(s)| = \sqrt{\frac{2 \times \frac{s}{4m^2} |G_M^*(s)|^2 + |G_E^*(s)|^2}{2 \times \frac{s}{4m^2} + 1}}, \quad (4.2)$$

where s is the square of the c.m. energy, and m is the Ω^- baryon mass. $|G_E^*(s)|$ and $|G_M^*(s)|$ are defined as

$$|G_E^*(s)|^2 = 2|G_{E0}|^2 + \frac{8}{9} \left(\frac{s}{4m^2} \right)^2 |G_{E2}|^2, \quad (4.3)$$

$$|G_M^*(s)|^2 = \frac{10}{9} |G_{M1}|^2 + \frac{32}{5} \left(\frac{s}{4m^2} \right)^2 |G_{M3}|^2. \quad (4.4)$$

The relationship between the BCS and $G_{\text{eff}}(s)$ of the $e^+e^- \rightarrow \Omega^- \bar{\Omega}^+$ process is defined as

$$\sigma^{\text{B}}(s) = \frac{4\pi\alpha^2\mathcal{C}\beta}{3s} \left[|G_M^*(s)|^2 + \frac{2m^2}{s} |G_E^*(s)|^2 \right], \quad (4.5)$$

where α is the fine structure constant, the variable $\beta = \sqrt{1 - \frac{4m^2}{s}}$ is the velocity of Ω^- , and the Coulomb factor \mathcal{C} parameterizes the electromagnetic interaction between the outgoing baryon and the anti-baryon [49].

$G_{\text{eff}}(s)$ is then determined from the BCSs by

$$|G_{\text{eff}}(s)| = \sqrt{\frac{3s\sigma^{\text{B}}}{4\pi\alpha^2\mathcal{C}\beta \left(1 + \frac{2m^2}{s} \right)}}. \quad (4.6)$$

The measured BCSs and EFFs at the thirty-four c.m. energies are listed in table 1. The upper limits are determined with the profile likelihood method after incorporating the systematic uncertainties [47]. Figure 2 shows the obtained BCSs at different c.m. energies, together with the CLEO-c measurements. There is a small enhancement around 4.22 GeV, where many charmonium-like states, such as $Y(4230)$, were observed in other processes [8, 16]. The measured BCS at $\sqrt{s} = 4.17$ GeV agrees with the CLEO-c result, while being about 3σ higher at 3.77 GeV. Based on the current data, we attempt to fit the energy-dependent cross section incorporating continuum and resonant components but do not obtain statistically significant results (e.g., the signal for the $Y(4230)$ has a significance of less than 2σ). The continuum process is parameterized by a perturbative QCD (pQCD)-driven energy power function [26], while resonances such as the $Y(4230)$ and $\psi(3770)$ are modeled with coherent

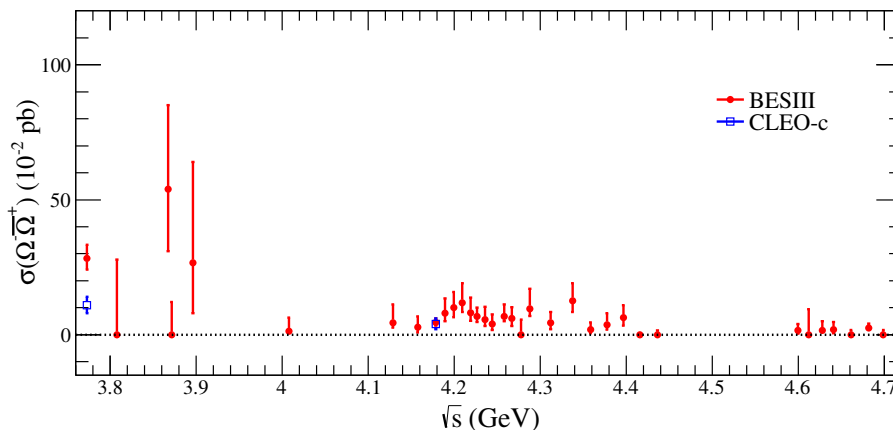


Figure 2. The measured $e^+e^- \rightarrow \Omega^-\bar{\Omega}^+$ BCSs from 3.7 GeV to 4.7 GeV, where the uncertainties are statistical. The red and blue points with error bars are the results obtained in this work and by CLEO-c [27], respectively.

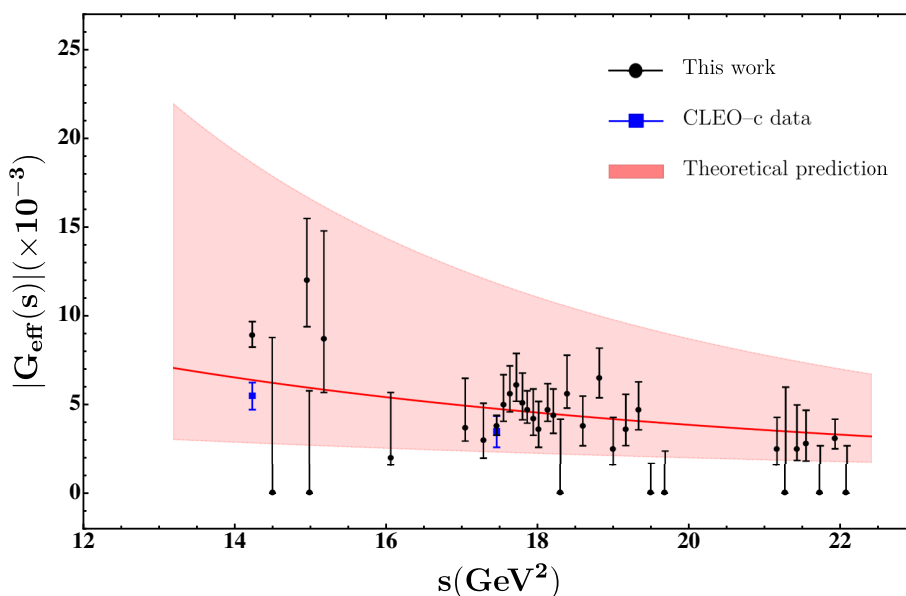


Figure 3. Comparison of the measured EFFs and the theoretical prediction. The black points with error bars are the results of this work. The blue points with error bars are the CLEO-c measurements [27], where G_{E0} is assumed to be zero. The red band indicates the theoretical prediction, in which the red line denotes the predicted central value and its boundaries marks the upper and lower limits of the theoretical error [29].

Breit-Wigner amplitudes [16]. Due to the limited statistics and the fact that a reliable analysis would require a more complete theoretical framework (e.g., one that accounts for coupled-channel effects), we refrain from reporting specific resonance parameters. We provide the BCSs as essential inputs for future high-statistics experiments, which will allow for a conclusive analysis of the possible resonant structure using advanced formalisms. Figure 3 shows the EFFs determined in this work, in comparison with the CLEO-c measurements [27] and the theoretical predictions using the covariant spectator quark model [29]. The measured EFFs are consistent with the theoretical prediction within an uncertainty of 1.0σ .

\sqrt{s} (GeV)	\mathcal{L} (pb $^{-1}$)	$N^{\text{sig}} (N^{\text{UL}})$	$1/ 1 - \Pi ^2$	D (10^{-2})	σ^{B} (fb)	$ G_{\text{eff}}(s) $ (10^{-3})	$S(\sigma)$
3.7730	2931.8	$50.5^{+9.0}_{-7.3}$	1.073	13.1	$282.9^{+50.4}_{-40.9} \pm 17.5$	$8.9^{+0.8}_{-0.6} \pm 0.3$	6.2
3.8076	50.5	$0.0^{+0.9}_{-0.0} (< 2.0)$	1.071	13.8	$0.0^{+278.7}_{-0.0} \pm 0.0 (< 619.3)$	$0.0^{+8.8}_{-0.0} \pm 0.0 (< 13.0)$...
3.8674	108.9	$4.0^{+2.3}_{-1.7} (< 8.3)$	1.056	14.9	$539.6^{+310.3}_{-229.3} \pm 33.5 (< 1119.7)$	$12.0^{+3.5}_{-2.6} \pm 0.4 (< 18.0)$	2.0
3.8713	110.3	$0.0^{+0.9}_{-0.0} (< 2.0)$	1.055	14.8	$0.0^{+121.0}_{-0.0} \pm 0.0 (< 268.8)$	$0.0^{+5.8}_{-0.0} \pm 0.0 (< 8.7)$...
3.8962	52.6	$1.0^{+1.4}_{-0.7} (< 3.7)$	1.050	15.7	$267.0^{+373.7}_{-186.9} \pm 16.6 (< 987.7)$	$8.7^{+6.1}_{-3.0} \pm 0.3 (< 17.0)$	1.0
4.0076	482.0	$0.5^{+1.9}_{-0.2} (< 3.7)$	1.036	17.5	$13.2^{+50.3}_{-5.3} \pm 0.8 (< 97.9)$	$2.0^{+3.7}_{-0.4} \pm 0.1 (< 5.3)$	0.5
4.1285	401.5	$1.5^{+2.3}_{-0.6} (< 5.3)$	1.058	18.4	$44.3^{+67.9}_{-17.7} \pm 2.7 (< 156.5)$	$3.7^{+2.8}_{-0.7} \pm 0.1 (< 6.9)$	1.1
4.1574	408.7	$1.0^{+1.4}_{-0.7} (< 3.7)$	1.060	18.6	$28.7^{+40.1}_{-20.1} \pm 1.8 (< 106.0)$	$3.0^{+2.1}_{-1.0} \pm 0.1 (< 5.7)$	1.0
4.1784	3189.0	$13.0^{+4.2}_{-3.5}$	1.062	19.3	$46.0^{+14.9}_{-12.4} \pm 2.9$	$3.8^{+0.6}_{-0.5} \pm 0.1$	3.4
4.1891	526.7	$3.8^{+2.6}_{-1.4} (< 8.3)$	1.066	19.5	$80.1^{+54.8}_{-29.5} \pm 5.0 (< 175.1)$	$5.0^{+1.7}_{-0.9} \pm 0.2 (< 7.4)$	1.9
4.1992	526.0	$4.8^{+2.8}_{-1.7} (< 9.7)$	1.068	19.7	$100.3^{+58.5}_{-35.5} \pm 6.2 (< 202.7)$	$5.6^{+1.6}_{-1.0} \pm 0.2 (< 8.0)$	2.1
4.2094	517.1	$5.5^{+3.3}_{-1.6} (< 11.1)$	1.068	19.3	$119.1^{+71.5}_{-34.7} \pm 7.4 (< 240.4)$	$6.1^{+1.8}_{-0.9} \pm 0.2 (< 8.7)$	2.2
4.2189	514.6	$3.8^{+2.6}_{-1.4} (< 8.3)$	1.067	19.5	$82.0^{+56.1}_{-30.2} \pm 5.1 (< 179.1)$	$5.1^{+1.7}_{-0.9} \pm 0.2 (< 7.5)$	1.9
4.2263	1056.4	$6.8^{+3.2}_{-2.1} (< 12.4)$	1.067	20.4	$68.4^{+32.2}_{-21.1} \pm 4.2 (< 124.7)$	$4.7^{+1.7}_{-0.7} \pm 0.1 (< 6.3)$	2.6
4.2358	530.3	$2.8^{+2.3}_{-1.2} (< 6.9)$	1.064	20.2	$56.6^{+46.5}_{-24.2} \pm 3.5 (< 139.4)$	$4.2^{+1.7}_{-0.9} \pm 0.1 (< 6.7)$	1.6
4.2440	538.1	$2.0^{+1.8}_{-1.1} (< 5.3)$	1.065	20.3	$39.7^{+35.8}_{-21.9} \pm 2.5 (< 105.3)$	$3.6^{+1.6}_{-1.0} \pm 0.1 (< 5.8)$	1.4
4.2580	828.4	$5.3^{+3.5}_{-1.4} (< 11.1)$	1.059	20.5	$68.0^{+44.9}_{-18.0} \pm 4.2 (< 142.5)$	$4.7^{+1.5}_{-0.9} \pm 0.1 (< 6.8)$	2.2
4.2668	531.1	$3.0^{+2.1}_{-1.4} (< 6.9)$	1.058	20.4	$60.4^{+42.3}_{-28.2} \pm 3.7 (< 138.9)$	$4.4^{+1.5}_{-1.0} \pm 0.1 (< 6.7)$	1.7
4.2778	175.7	$0.0^{+0.9}_{-0.0} (< 2.0)$	1.057	20.2	$0.0^{+55.5}_{-0.0} \pm 0.0 (< 123.3)$	$0.0^{+4.2}_{-0.0} \pm 0.0 (< 6.3)$...
4.2879	502.4	$4.8^{+3.3}_{-1.2} (< 9.7)$	1.056	19.3	$96.7^{+74.2}_{-27.0} \pm 6.0 (< 218.1)$	$5.6^{+2.2}_{-0.8} \pm 0.2 (< 8.4)$	1.9
4.3121	501.2	$2.0^{+1.8}_{-1.1} (< 5.3)$	1.055	19.6	$44.6^{+40.2}_{-24.6} \pm 2.8 (< 118.3)$	$3.8^{+1.7}_{-1.1} \pm 0.1 (< 6.2)$	1.4
4.3374	505.0	$5.8^{+3.0}_{-1.9} (< 11.1)$	1.051	20.0	$125.9^{+65.1}_{-41.2} \pm 7.8 (< 241.0)$	$6.5^{+1.7}_{-1.1} \pm 0.2 (< 9.0)$	2.4
4.3583	544.0	$1.0^{+1.4}_{-0.7} (< 3.7)$	1.052	21.3	$18.9^{+26.5}_{-13.2} \pm 1.2 (< 69.9)$	$2.5^{+1.8}_{-0.9} \pm 0.1 (< 4.8)$	1.0
4.3774	522.7	$1.8^{+2.0}_{-0.9} (< 5.3)$	1.052	20.1	$37.5^{+41.7}_{-18.8} \pm 2.3 (< 110.5)$	$3.6^{+2.0}_{-0.9} \pm 0.1 (< 6.1)$	1.3
4.3965	507.8	$3.0^{+2.1}_{-1.1} (< 6.9)$	1.052	20.2	$64.3^{+45.0}_{-30.0} \pm 4.0 (< 147.9)$	$4.7^{+1.6}_{-1.1} \pm 0.1 (< 7.1)$	1.7
4.4156	1043.9	$0.0^{+0.9}_{-0.0} (< 2.0)$	1.055	21.6	$0.0^{+8.7}_{-0.0} \pm 0.0 (< 19.4)$	$0.0^{+1.7}_{-0.0} \pm 0.0 (< 2.6)$...
4.4362	569.9	$0.0^{+0.9}_{-0.0} (< 2.0)$	1.059	20.4	$0.0^{+16.9}_{-0.0} \pm 0.0 (< 37.4)$	$0.0^{+2.4}_{-0.0} \pm 0.0 (< 3.6)$...
4.5995	586.9	$1.0^{+1.4}_{-0.7} (< 3.7)$	1.059	22.4	$16.6^{+23.2}_{-11.6} \pm 1.0 (< 61.4)$	$2.5^{+1.8}_{-0.9} \pm 0.1 (< 4.8)$	1.0
4.6119	103.8	$0.0^{+0.9}_{-0.0} (< 2.0)$	1.059	20.1	$0.0^{+94.3}_{-0.0} \pm 0.0 (< 209.5)$	$0.0^{+6.0}_{-0.0} \pm 0.0 (< 8.9)$...
4.6280	521.5	$0.8^{+1.6}_{-0.4} (< 3.7)$	1.058	20.1	$16.6^{+33.3}_{-8.3} \pm 1.0 (< 76.9)$	$2.5^{+2.5}_{-0.6} \pm 0.1 (< 5.4)$	0.8
4.6409	552.4	$1.0^{+1.4}_{-0.7} (< 3.7)$	1.058	20.1	$19.6^{+27.5}_{-13.7} \pm 1.2 (< 72.6)$	$2.8^{+1.9}_{-1.0} \pm 0.1 (< 5.3)$	1.0
4.6612	529.6	$0.0^{+0.9}_{-0.0} (< 2.0)$	1.058	20.1	$0.0^{+18.4}_{-0.0} \pm 0.0 (< 40.9)$	$0.0^{+2.7}_{-0.0} \pm 0.0 (< 4.0)$...
4.6819	1669.3	$3.8^{+2.6}_{-1.4} (< 8.3)$	1.058	20.0	$24.8^{+17.0}_{-9.1} \pm 1.5 (< 54.2)$	$3.1^{+1.1}_{-0.6} \pm 0.1 (< 4.6)$	1.9
4.6988	536.5	$0.0^{+0.9}_{-0.0} (< 2.0)$	1.058	20.0	$0.0^{+18.3}_{-0.0} \pm 0.0 (< 40.7)$	$0.0^{+2.7}_{-0.0} \pm 0.0 (< 4.0)$...

Table 1. The numerical results for $e^+e^- \rightarrow \Omega^-\bar{\Omega}^+$ at each c.m. energy. Here, \mathcal{L} is the integrated luminosity [50, 51], $N^{\text{sig}} (N^{\text{UL}})$ denotes the number (upper limit) of the signal events in the signal region, $1/|1 - \Pi|^2$ is the VP correction factor, $1 + \delta$ is the ISR correction factor, ϵ is the signal efficiency ($D = (1 + \delta)\epsilon$) and σ^{B} and $|G_{\text{eff}}(s)|$ are the measured BCS and EFF, respectively. For the BCS and EFF, the first uncertainties are statistical and the second are systematic. For N^{sig} , σ^{B} , and $|G_{\text{eff}}(s)|$, the numbers in brackets correspond to the upper limits at the 90% confidence level. The $S(\sigma)$ is the signal significance estimated by $N^{\text{sig}}/\sqrt{N^{\text{obs}}}$.

5 Systematic uncertainty

The systematic uncertainties in the BCS measurement mainly come from the luminosity measurement, branching fractions of the $\Omega^- \rightarrow K^- \Lambda$ and $\Lambda \rightarrow p\pi^-$ decays, Ω^- reconstruction efficiency, MC generator, mass windows of the Λ and Ω^- selections, choice of the sideband regions and $(1 + \delta)\epsilon$ estimation. All sources of systematic uncertainties are discussed in detail below.

The integrated luminosity is measured using Bhabha events with an uncertainty of 1.0% [52]. The uncertainties of the branching fractions of $\Omega^- \rightarrow K^- \Lambda$ and $\Lambda \rightarrow p\pi^-$ are taken from the PDG [1]. The systematic uncertainty due to the Ω reconstruction efficiency, including the tracking and PID efficiencies of charged tracks and the efficiency of the Λ reconstruction, is estimated by the control sample $\psi' \rightarrow \Omega^- \bar{\Omega}^+$ with the same method as described in ref. [21]. We consider the systematic uncertainties of the decay parameters (α_Ω and α_Λ) in the angular distribution function and the helicity parameters from the analysis of $\psi' \rightarrow \Omega^- \bar{\Omega}^+$ events [42] as the systematic uncertainty for the MC generator.

The uncertainties of the $M(p\pi^-)$ and $M^{\text{cor}}(K^- \Lambda)$ mass windows are estimated by varying their sizes by $\pm 1\sigma$. The systematic uncertainty of the $RM^{\text{cor}}(K^- \Lambda)$ mass window is estimated by varying it by $\pm 0.01 \text{ GeV}/c^2$. The larger deviation in each case is taken as the uncertainty. To estimate the uncertainty from the sideband positions, we double the relative distance between the signal and sideband regions. After adjusting the box window, we compare the signal yield from data and the efficiency from MC simulation; the relative difference between the signal yield ratio from data and the efficiency ratio from MC is taken as the systematic uncertainty [53, 54]. The $(1 + \delta)\epsilon$ systematic uncertainty depends on two different sources. The input line-shape of the cross section is iterated until the final cross section becomes stable, and the largest variation in $(1 + \delta)\epsilon$ (1.8%) during the last two iterations is taken as the systematic uncertainty. The ISR factor and the signal efficiency are dependent on the fit to the line shape of the cross section. The systematic uncertainty is evaluated by varying the fitted line-shape parameters by $+1\sigma$ of statistical uncertainty in the input cross-section model. The resulting largest difference of $(1 + \delta)\epsilon$ (2.0%) is assigned as the systematic uncertainty.

All systematic uncertainties discussed above are summarized in table 2. Assuming all sources are independent, the total systematic uncertainty in the BCS measurement is determined to be 6.9% by adding them in quadrature.

6 Summary

In summary, using 22.7 fb^{-1} of e^+e^- collision data collected at thirty-four c.m. energies from 3.7 GeV to 4.7 GeV with the BESIII detector, the BCSs of the process $e^+e^- \rightarrow \Omega^- \bar{\Omega}^+$ and the EFFs of Ω^- are determined by the single baryon tag method. Clear $e^+e^- \rightarrow \Omega^- \bar{\Omega}^+$ signals are observed at $\sqrt{s} = 3.77$ and 4.17 GeV. From the \sqrt{s} -dependent BCS, no significant resonance contribution is observed. A hint of enhancement around 4.2 GeV is observed, but we can't draw clear conclusion due to large uncertainty. More data is needed to confirm the structure in this region. The experimental measurements of the EFFs are consistent with the theoretical calculation. These results obtained provide important information to understand the production mechanism of $\Omega^- \bar{\Omega}^+$ pair and the inner structure of the Ω^- baryons, which are crucial to constrain the theoretical predictions [29, 55].

Source	Uncertainty
Luminosity	1.0
$\mathcal{B}(\Omega^- \rightarrow K^- \Lambda)$	0.7
$\mathcal{B}(\Lambda \rightarrow p\pi^-)$	0.5
Ω^- reconstruction	0.7
MC generator	2.2
$M(p\pi^-)$ mass window	2.6
$M^{\text{cor}}(K^- \Lambda)$ mass window	2.6
$RM^{\text{cor}}(K^- \Lambda)$ mass window	3.5
Position of the sidebands	2.7
$(1 + \delta)\epsilon$	2.7
Sum in quadrature	6.9

Table 2. Systematic uncertainties in the BCS measurement for all data samples (in %). The uncertainties are the same for the thirty-four c.m. energy points.

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Data Availability Statement. This article has no associated data or the data will not be deposited.

Code Availability Statement. This article has no associated code or the code will not be deposited.

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























































































































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