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Research Article

SU(3) Symmetry Breaking Decays of Charmonia

Khadija Saeed[1*], Aneela Amin[1], Farzana Younas[1], Amir Khalid[1], Muhammad Qamar Saeed[2], and Ghalib ul Islam[3]

[1]Centre for High Energy Physics (CHEP) University of the Punjab, Lahore, 54590, Pakistan
[2]Government Dyal Sing College Lahore, Pakistan
[3]Department of Physics, The University of Lahore, Pakistan

Abstract: SU (3) symmetry breaking in several Charmonia decays was studied using the data from world's leading High Energy Physics laboratories. The charm factory BESIII was the main source of information. Branching fraction with different number of events of J/ψ, ψ (2S) → $\Lambda\bar{\Lambda}$, ΣΣ, Ξ $\bar{\Xi}$ were computed. The total number of events for J/ψ from 1.32×10^6 to 1310.6×10^6 and that of ψ (2S) from 3.96×10^{106} to 448.1×10^{106} were studied. The corresponding branching fractions and value of decay constant α for above mentioned channels became more precise with increase of the number of events. The results of their comparison have been elaborated and are compiled in tabular form. All the data is collected year wise from the date of arise of this phenomenon (1984) to present. It has been observed from the study that with the passage of time and increased number of events gives more precise values of branching fraction and decay constant α.

1. INTRODUCTION

After the discovery of J/ψ and other Charmonia states, different experiments have been conducted to study different Baryonic decay channels. Baryon anti baryon channel has attracted the interest of both theoretical and experimental experts as it provides a test of predictive power of QCD. Also at low and intermediate energy states, the decays of J/ψ are used to study the strong interactions [1]. The observations of two body intermediate states are common in J/ψ Baryonic decays. The nature of J/ψ, in case of flavor symmetry breaking can be seen by comparing the decay rates of baryonic states with theoretical models [1]. In this work we have collected information about three baryon anti baryon channels i.e., J/ψ→$\Lambda\bar{\Lambda}$, ΣΣ, Ξ $\bar{\Xi}$ from different laboratories. It is shown that number of data samples have been increased for both J/ψ and ψ(2S) from 1.32×10^6 to 1310.6×10^6 and 3.96×10^6 to 448.1×10^6 respectively. The corresponding branching fractions and α value are also tabulated. The comparison shows that the values of branching fraction and α-decay became more precise with the increase in number of events.

2. SU(3) SYMMETRY BREAKING IN BARYON- ANTI BARYON CHANNEL

The decay which are allowed by SU(3) symmetry breaking are

$$J/\Psi \rightarrow B_1\overline{B_1}\ ,B_8\overline{B_8}\ ,B_{10}\ \overline{B_{10}} \qquad [1]$$

SU(3) symmetry can be broken in several ways,
SU(3) symmetry breaking is observed in octet rather than singlet state, e.g; in one photon process

$$c\bar{c} \rightarrow \gamma 1 \otimes 8 \rightarrow Bi\ Bj \qquad [2]$$

Where, i≠j. This decay process is only possible when octet component contribute in direct product $8\otimes\overline{10}$. In Baryonic decay one of the three gluons is replaced by photon present in electromagnetic decay.

$$J/\Psi \rightarrow \gamma \rightarrow B_{10}\ \overline{B_{10}} \qquad [3]$$

$$c\bar{c} \rightarrow gg\,\gamma \rightarrow B_{10}\ \overline{B_{10}} \qquad [4]$$

Equation (3) ref. [2] and equation (4) ref. [3] are representation of direct electromagnetic decay. The difference in the masses of strange and light quarks

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* Corresponding Author: Khadija Saeed <rikza.saeed03@gmail.com>

is another mechanism for the SU (3) symmetry breaking. The difference in coupling α and β may cause the occurring of decay chain.

$$c\bar{c} \rightarrow (\mu\bar{\mu} + d\bar{d} + s\bar{s})1 \rightarrow \alpha(\mu\bar{\mu} + d\bar{d})1 \oplus 8 + \beta(s\bar{s})1 \oplus 8 \rightarrow B_{10}\bar{B}_8 \quad [5]$$

The intermediate states q are responsible for the third mechanism of SU (3) symmetry breaking [4].There are three parts of effective lagrangian of SU(3) parameterization; One is SU(3) symmetric. Second shows the effect of SU(3) breaking. Third include the effects of iso-spin breaking [1]. For octet baryon there are two types of invariant coupling of SU(3) , symmetric part and the anti symmetric one. Effective Lagrangian is

$L_{int1} = a\,tr(\bar{B}B)$

$L_{int2} = \varepsilon\,tr(T^3{}_3\bar{B}B)$

$L_{int3} = \varepsilon\,tr(T^3{}_3[\bar{B}B])$

$L_{int4} = a\gamma 1\ tr(Q[\bar{B}B])$

$L_{int5} = a\gamma 2\ tr(Q[\bar{B}B])$

Here Q represents the electric charge matrix and SU(3) breaking effects are represented by $T^3{}_3$. More parameters are introduced by two types of SU(3) combination in case of $J/\psi \rightarrow B_8\bar{B}_8$ as compared to $J/\psi \rightarrow V_9\bar{P}_8$ [1].

3. EXPERIMENTAL SETUP AT BESIII

The charmonium factory Beijing Electron Spectrometer (BES) was established in 1989. BESII was the upgraded version of BES, established in 1996. BEPCII and BESIII, upgradation of BESII, was established in 2003. BEPC achieved maximum luminosity of $10^{31}cm^{-2}s^{-1}$ before shutting down. It was a single storage ring made to operate in single bunch mode. BEPCII is a single mode double ring collider achieving a luminosity of $\sim 1 \times 10^{33}cm^{-2}s^{-1}$ which is 100 times larger than BEPC and center of mass energy up to 2×1.89 GeV. BEPCII is used to operate in τ charm region and also used as high flux synchrotron radiation light source. The advanced design of BESIII has ability to take full advantage of high luminosity provided by BEPCII [5].The conventional 0.4 T magnet of original BES detector has been replaced by 1 T Supper Conducting Solenoid Material (SCSM) in BESIII. SCSM is present outside the Electromagnetic Calorimeter having length 3.52 m and radius 1.482 m.

Beryllium Beam Pipe are surrounded by Multilayer Drift Chamber (MDC) and MDC is surrounded by two layers of time of flight TOF system. After TOF system the electromagnetic calorimeter EMC is located. Resistive plates chamber (RPCs) are mounted above SSM, layers of these plates form Muon Identifier (MU). Spectrometer covers a solid angle 4Ω/4π = 0.93 and a polar angle of 210 < θ < 1590 range [5].

Main Drift Chamber (MDC) is used to detect particles of relatively low momentum with good dE/dx and momentum resolution. Its outer radius is 810 mm and inner radius is 56 mm. In order to avoid multiple scattering a mixture of He − C_3H_8 60:40 is used in MDC. It is also used to reduce the background events. At the outer shell of MDC the Time of Fight (TOF) is present. It consists of two layers of staggered scintillating bars. 88 scintillation bars of 5 cm thickness are present in each layer. Time resolution of this TOF system is ∼ 100 ps. The solid angle range of its endcaps is 0.85<cos θ <0.95 and that of barrel TOF is cos θ <0.95 [5].

Electromagnetic Calorimeter (EMC) is located outside the TOF system. It is composed of 6240 CSI(T1) crystals. It is used to trigger signal and to measure the photons of energy above 20 MeV and momentum above 200 MeV. The length of the crystal is 28 cm and its inner radius is 94 cm. The angular coverage of its two endcaps is 21.3 < θ <34.5 and 145.4< θ <158.7 (0.85< | cos θ| <0.95) and that of barrel EMC is 144.7< θ <33.5 (| cos θ| <0.83). The main function of Muon Identifier is to identify and separate the muons from hadrons and other charge particles by detecting the hit pattern of muons. For this purpose muon identifier consist of 9 layers of RPCs and 9 layers of steel plates having thickness of 41 cm. The muon identifier is effective for 0.4 GeV/c momentum of muons [5]. The comparison of BESII and BESIII detector is shown in Table 1.

Table 1. Comparison between different parameters of BESII and BESIII

Parameters	Sub system	BESIII	BESII
MDC	Single wire σrϕ(μm)	130	250
	σp/p(1GeV/c)	0.5 percent	2.4 percent
	σ(dE/dx)	6 percent	8.5 percent
EMC	σE /E(1GeV)	2.5 percent	20 percent
	Position resolution (1 GeV)	0.6 cm	3 cm
TOF	στ (ps) Barral	100	180
	στ (ps) End cap	110	350
	No. of layers barral/endcaps	9/8	3
Muon	Cut of momentum MeV/c	0.4	0.5
	Solenoid magnet field T	1.0	0.4
	4Ω/4π	93 percent	83 percent

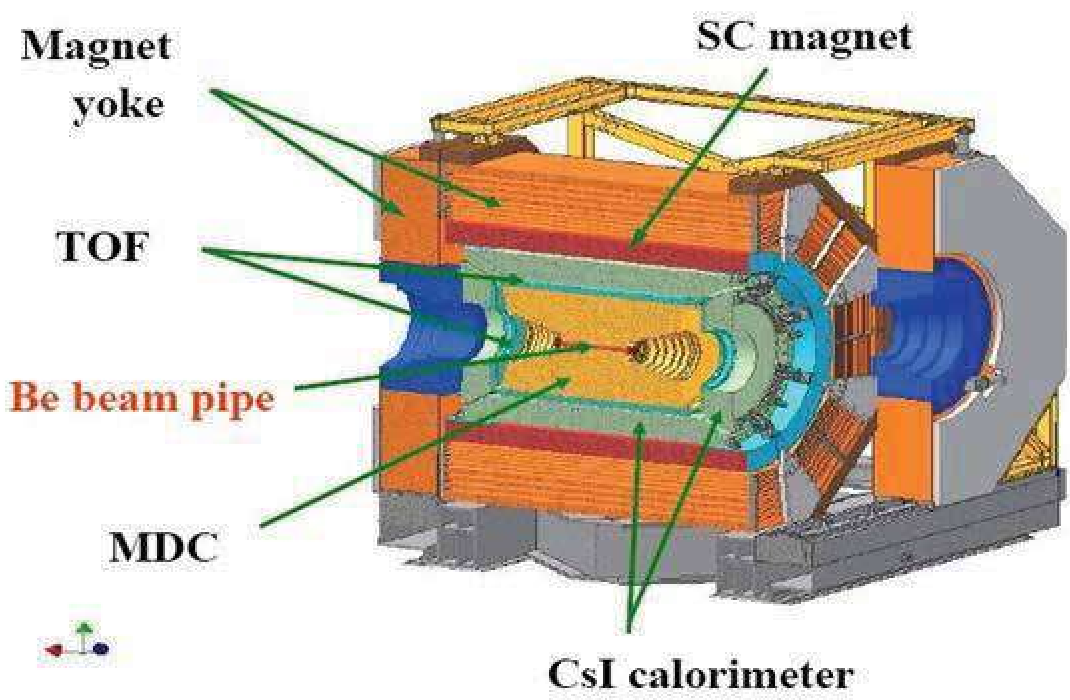

Fig. 1. Schematic diagram showing BESIII detector

4. OBSERVATION OF SU (3) SYMMETRY BREAKING DECAYS OF CHARMONIA

4.1 Observation of $\Lambda\bar{\Lambda}$ Channel

The study of Charmonia decays into baryon anti baryon is a field of interest for physicists as it provides a lot of information about the properties of baryon anti-baryon pairs. Annihilation of $c\bar{c}$ quark pair is responsible for the production of J/ψ, ψ(2S) charmonia states [6]. For the channel $e^+e^- \rightarrow \psi \rightarrow B\bar{B}$, the angular distribution is given by,

$$\text{Angular distribution} = \frac{dN}{dcos\theta}(1 + \alpha cos^2\theta) \quad [6]$$

Here θ is the angle between the beam direction and the outgoing baryon and α is the constant providing the known decay modes of $J/\psi \rightarrow B\bar{B}$ have been computed using first order PQCD [7]. The MC observation of J/ψ → $\Lambda\bar{\Lambda}$ is studied using Monte Carlo event generator KKMC [8], where the known decay modes of J/ψ are generated using EVTGEN [9]. In MDC charge tracks are reconstructed using track induce signals. Tracks at10 cm distance from interaction point in perpendicular direction of beam, and 20 cm along the direction of beam are selected. The angular distribution of these tracks must be | cos θ < 0.93| in MDC. As $\Lambda \to p\,\pi^-$ and $\bar{\Lambda} \to \bar{p}\,\pi^+$ so events having four charge tracks with zero net charge should be selected. Hence all the events with positive and negative charges are considered and only those events are selected in which at least one ($p\pi^-$) ($p\pi^+$) tracks are present. For events containing more than one ($p\,\pi^-$)($p\,\pi^+$) tracks, the one having least value of $(M_{p\pi^-} - M_{\Lambda})^2 + (M_{\bar{p}\pi+} + M_{\bar{\Lambda}})^2$ is selected. If the momentum of any candidate event is less than 0.3 GeV, it is rejected, as detection efficiencies of MC and data sample are different [6]. Photon candidate events are reconstructed by the energy cluster depositing at EMC. The events to be selected as photons must have a minimum energy of 25 MeV in barrel region | cos θ < 0.80| and a minimum of 50 MeV in end cap region (0.86| <cos θ| <0.92). To avoid showers from other charged tracks a candidate photon must be 10 cm away from its nearest pion or proton and 300 away from anti proton track. A 4C kinematics fit

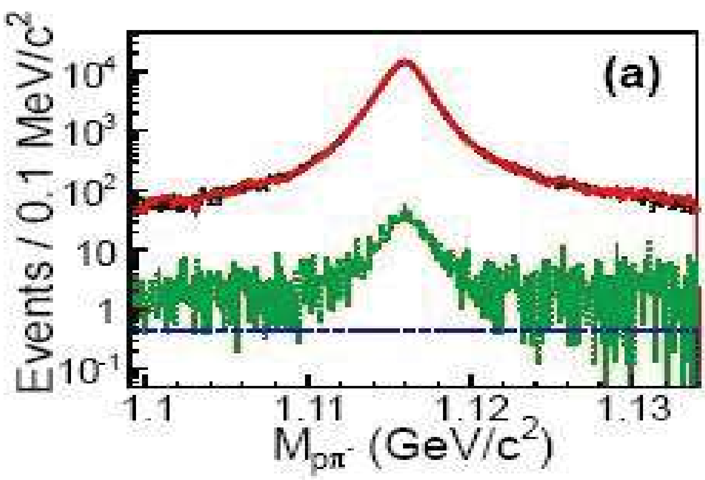

Fig. 2. The distribution of $M_{p\pi^-}$ for J/ψ → $\Lambda\bar{\Lambda}$. Real data is represented by dots with error bars, and the red solid curve shows the fit results, background estimated by MC samples are represented by green histograms and the remaining background are represented by blue dotted line.

Table 2. Observation of decay channel J/ψ → $\Lambda\bar{\Lambda}$

Decay Channel	No. of Events × 10^6	Branching Fraction (Br)	α	Laboratories	Year
J/ψ → $\Lambda\bar{\Lambda}$ [9]	1.32	(1.58±0.08±0.19)x10^{-3}	0.72±0.36	MarkII	1984
J/ψ → $\Lambda\bar{\Lambda}$ [10]	7.8	(1.08±0.06±0.24)x 10^{-3}	1.52±0.33±0.13	BES	1998
J/ψ → $\Lambda\bar{\Lambda}$ [11]	386	(2.00+0.33-0.29 ±0.34±0.08)x 10^{-3}	(-0.63±0.46±0.27)	Belle	2005
J/ψ → $\Lambda\bar{\Lambda}$ [12]	58	(2.03±0.03±0.15)x 10^{-3}	0.65±0.11±0.03	BESII	2005
J/ψ → $\Lambda\bar{\Lambda}$ [13]	386	(2.00+0.34-0.29 ±0.34±0.08)x 10^{-3}	-0.44±0.51±0.31	Belle	2006
J/ψ → $\Lambda\bar{\Lambda}$ [14]		(1.92±0.21)x 10^{-3}		BABAR	2007
J/ψ → $\Lambda\bar{\Lambda}$ [15]	58	(2.03±0.03±0.11)x 10^{-3}	0.65±0.11±0.03	BESIII	2008
J/ψ → $\Lambda\bar{\Lambda}$ [2]		(1.92±0.21)x 10^{-3}		BESIII	2009
J/ψ → $\Lambda\bar{\Lambda}$ [6]	1310.6	(19.43±0.03±0.33) x10^{-4}	0.469±0.026±0.008	BESIII	2017

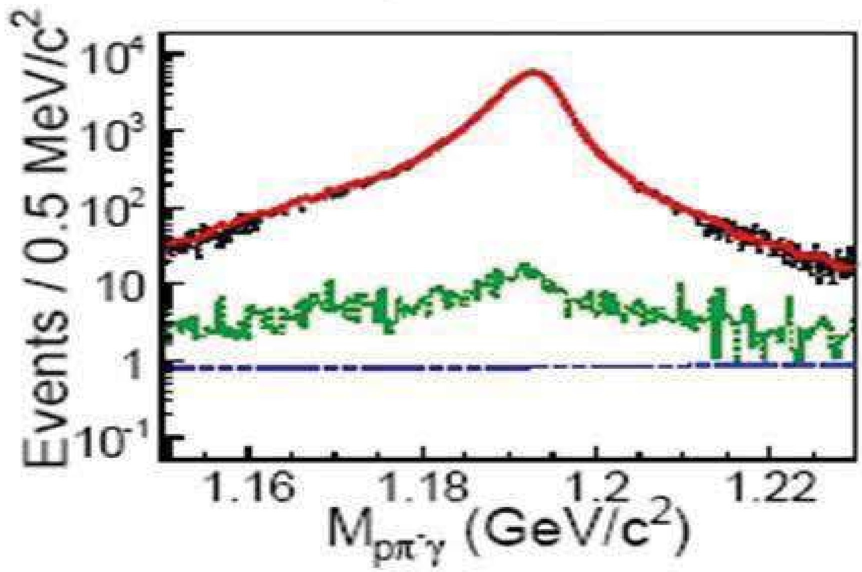

Fig. 3. The distribution of Mγpπ- for J/ψ → Σ0 $\bar{\Sigma}$ [0]. Real data is represented by dots with error bars and red solid curve shows the fit results , background estimated by MC samples are represented by green histograms and the remaining background are represented by blue

Table 3. Observation of decay channel ψ (2S) →$\Lambda\bar{\Lambda}$

Decay Channel	No. of Events × 10^6	Branching Fraction (Br)	α	Laboratories	Year
ψ(2S) →$\Lambda\bar{\Lambda}$ [16]	3.95	(18.1±2.0±2.7)x 10^{-5}	0.67±0.21	BES	2001
ψ(2S) →$\Lambda\bar{\Lambda}$ [17]	3.08	(3.28±0.23±0.25) × 10^{-3}	< 2.0 90%CL	CLEO	2005
ψ(2S) →$\Lambda\bar{\Lambda}$ [18]	14	(3.39±0.20±0.32) × 10^{-4}		BESIII	2007
ψ(2S) →$\Lambda\bar{\Lambda}$ [14]		(6.0±1.5) × 10^{-4}		BABAR	2007
ψ(2S) →$\Lambda\bar{\Lambda}$ [6]	1310.6	(3.97±0.02±0.12) × 10^{-4}	0.82±0.08±0.02	BESIII	2017

for energy momentum conservation is also applied to select photon candidate, and photon candidate having minimum χ^2 is selected [6].

The invariant mass of $\Lambda\bar{\Lambda}$ must lie in the range [3.05, 3.15] (GeV) in order to suppress backgrounds. The dominant background remaining after event selection in analysis of J/ψ → $\Lambda\bar{\Lambda}$ are J/ψ → $\Lambda\bar{\Sigma}^0$ + c.c, J/ψ → $\gamma\eta_c$, ($\eta_c \to \Lambda\bar{\Lambda}$) and J/ψ → γ Ks Ks. The backgrounds containing $\Lambda\bar{\Lambda}$ are expected to produce peak around Λ region in the invariant mass distribution of $M_{p\pi-}$ with low background. Signal yields are determined by performing the likely hood fits. The difference in mass resolution of MC and data samples is described by fitting with Gaussian function. The branching fraction is given by the formula,

$$B(J/\psi \to B\bar{B}) = \frac{N_{obs}}{N_{\psi}\,{}_{,}\varepsilon B_i} \qquad [7]$$

Here signal events minus peaking background is equalto, detection efficiency is represented by ε. The observation of $\Lambda\bar{\Lambda}$ channel in different labs is presented in tables below. Table 2 shows that the branching fraction and value of α for J/ψ → $\Lambda\bar{\Lambda}$ was first observed in Mark II in 1984, using 1.32×10^6 events and the resulting branching fraction and α values are (1.58 ± 0.08 ± 0.19) × 10^{-3} and 0.72 ± 0.36. After that in 1998 BES shows the results for the study of same channel using 7.8×10^6 events and the observed branching fraction and α values are (1.08 ± 0.06 ± 0.24) × 10^{-3} and (0.52 ± 0.33 ± 0.13).

Table 4. Observation of Decay channel $J/\psi \to \Sigma\bar{\Sigma}$

Decay Channel	No. of Events × 10^6	Branching Fraction (Br)	α	Laboratories	year
$\psi \to \Sigma^0\bar{\Sigma}^0$ [9]	1.32	$(1.58 \pm 0.16 \pm 2.5) \times 10^{-3}$	0.7 ± 1.1	MarkII	1984
$\psi \to \Sigma(1385)\bar{\Sigma}^+(1385)$[9]	1.32	$(0.86 \pm 0.18 \pm 0.22) \times 10^{-3}$		MarkII	1984
$\psi \to \Sigma^+(1385)\bar{\Sigma}^-(1385)$ [9]	1.32	$(1.03 \pm 0.24 \pm 0.25) \times 10^{-3}$		MarkII	1984
$\psi \to \Sigma^+(1385)\bar{\Sigma}^-$ [9]	1.32	$(0.31 \pm 0.11 \pm 0.11) \times 10^{-3}$		MarkII	1984
$J/\psi \to \Sigma^0\bar{\Sigma}^0$ [12]	58	$(1.33 \pm 0.04 \pm 0.11) \times 10^{-3}$	$-0.24 \pm 0.19 \pm 0.07$	BESII	2005
$J/\psi \to \Sigma^0\bar{\Sigma}^0$ [20]	58	$(1.33 \pm 0.04 \pm 0.11) \times 10^{-3}$	$-0.24 \pm 0.19 \pm 0.07$	BESII	2006
$J/\psi \to \Sigma^0\bar{\Sigma}^0$ [18]	14	$(2.35 \pm 0.36 \pm 0.32) \times 10^{-3}$		BESIII	2007
$J/\psi \to \Sigma^0\bar{\Sigma}^0$ [14]		$(1.16 \pm 0.26) \times 10^{-3}$		BABAR	2007
$J/\psi \to \Sigma^0\bar{\Sigma}^0$ [21]	58	$(1.40 \pm 0.03 \pm 0.07) \times 10^{-3}$	-0.22 ± 0.17	BESIII	2008
$J/\psi \to \Sigma^+\bar{\Sigma}^-$ [15]	58	$(1.50 \pm 0.10 \pm 0.22) \times 10^{-3}$		BESIII	2008
$J/\psi \to \Sigma^+\bar{\Sigma}^-$[22]		$(1.5 \pm 0.24) \times 10^{-3}$		BESIII	2009
$J/\psi \to \Sigma^0\bar{\Sigma}^0$ [2]		$(1.29 \pm 0.09) \times 10^{-5}$		BESIII	2009
$J/\psi \to \Sigma^0\bar{\Lambda} + \bar{\Sigma}^0\Lambda$ [2]		<0.15		BESIII	2009
$J/\psi \to \Lambda\bar{\Sigma}^0$ + *c.c* [23]	225	$(1.37 \pm 0.12 \pm 0.11) \times 10^{-5}$		BESIII	2012
$J/\psi \to \Lambda\bar{\Sigma}^0$ + *c.c* [23]	225	$(1.46 \pm 0.12 \pm 0.11) \times 10^{-5}$		BESIII	2012
$J/\psi \to \Sigma^0(1385)\bar{\Sigma}^0(1385)$ [27]	1310.6	$(10.71 \pm 0.09) \times 10^{-5}$	-0.64 ± 0.03	BESIII	2016
$J/\psi \to \Sigma^0\bar{\Sigma}^0$ [5]	1310.6	$(11.64 \pm 0.04 \pm 0.23) \times 10^{-4}$	$-(0.449 \pm 0.026)$	BESIII	2017

Table 5. Observation of Decay channel $\psi(2S) \to \Sigma\bar{\Sigma}$

Decay Channel	No. of Events ×10^6	Branching Fraction (Br)	α	Labs	year
$\psi(2S) \to \Sigma(1385)\bar{\Sigma}^+$[9]	1.32	$(0.31 \pm 0.11 \pm 0.11) \times 10^{-3}$		Mark II	1984
$\psi(2S) \to \Sigma^0\bar{\Sigma}^0$[16]	3.95	$(1.2 \pm 4 \pm 4) \times 10^{-3}$		BESII	2001
$\psi(2S) \to \Sigma^+\bar{\Sigma}^-$[16]	3.95	$(11 \pm 3 \pm 3) \times 10^{-5}$		BESII	2001
$\psi(2S) \to \Sigma^+\bar{\Sigma}^+$[17]	3.08	$(2.57 \pm 0.44 \pm 0.88) \times 10^{-4}$		CLEO	2005
$\psi(2S) \to \Sigma^0\bar{\Sigma}^0$[17]	3.08	$(2.63 \pm 0.35 \pm 0.21) \times 10^{-4}$		CLEO	2005
$\psi(3686) \to \Sigma^0(1385)\bar{\Sigma}^0(1385)$ [24]	1310.6	$(0.78 \pm 0.06) \times 10^{-4}$	0.59 ± 0.25	BESIII	2016
$\psi(3686) \to \Sigma^0\bar{\Sigma}^0$[6]	1310.6	$(2.44 \pm 0.03 \pm 0.11) \times 10^{-4}$	$0.71 \pm 0.11 \pm 0.04$	BESIII	2017

In 2005 BES has been improved to BESII, with this up gradation data events have been increased to 58×10^6 and the corresponding branching fraction and α also improved and became more precise, and there values are mentioned in the Table 2.

After 2007, BESII was again upgraded to BESIII, Its design and manufacturing parameters are improved in BESIII and are discussed in Table 1. As a result of this the branching fraction and α values are improved to be $(2.03 \pm 0.03 \pm 0.11) \times 10^{-3}$ and $(0.65 \pm 0.11 \pm 0.03)$. Now in 2017 data events of BESIII are recorded to be 1310.6×10^6, with this increase in data samples the branching fraction and α value are measured more precisely. Similarly this channel has also been studied in other laboratories

Table 6. Observation of Decay Channel J/ψ→ $\Sigma\bar{\Sigma}$

Decay Channel	No. of Events	Branching Fraction	Laboratories	year
$\psi \rightarrow \Xi^-\bar{\Xi}^+$ [9]	1.32×10^6	$(1.14\pm0.08\pm0.20)\times10^{-3}$	MarkII	1984
$J/\psi \rightarrow \Xi^0\bar{\Xi}^0$ [15]	58×10^6	$(1.20\pm0.12\pm0.21)\times10^{-3}$	BESII	2008
$J/\psi \rightarrow \Xi^0\bar{\Xi}^0$ [2]		$(1.2\pm0.24)\times10^{-3}$	BESIII	2009
$J/\psi \rightarrow \Xi^-\bar{\Xi}^+$ [2]		$(0.9\pm0.2)\times10^{-3}$	BESIII	2009
$J/\psi \rightarrow \Xi^0\bar{\Xi}^0$ [24]	1310.6×10^6	$(11.65\pm0.04)\times10^{-4}$	BESIII	2016

Table 7. Observation of Decay Channel ψ(2S)→ $\Sigma\bar{\Sigma}$

Decay Channel	No. of Events	Branching Fraction	Laboratories	Year
$\psi(2S) \rightarrow \Xi^-\bar{\Xi}^+$ [16]	3.95×10^6	$(9.4\pm2.7\pm1.5)\times10^{-5}$	BESII	2001
$\psi(2S) \rightarrow \Xi^{*0}\bar{\Xi}^{*0}$ [16]	3.95×10^6	$(<8.1)\text{x}10^{-5}$	BESII	2001
$\psi \rightarrow \Xi^-\bar{\Xi}^+$ [17]	3.08×10^6	$(2.38\pm0.30\pm0.12)\times10^{-4}$	CLEO	2005
$\psi \rightarrow \Xi^0\bar{\Xi}^0$ [17]	3.08×10^6	$(2.75\pm0.64\pm0.61)\times10^{-4}$	CLEO	2005
$\psi \rightarrow \Xi^0$ (1530) $\bar{\Xi}^0$(1530) [17]	3.08×10^6	$0.72\pm0.10(<3.2)\times10^{-4}$	CLEO	2005
$\psi \rightarrow \Xi^-\bar{\Xi}^+$ [18]	14×10^6	$(3.03\pm0.40\pm0.32)\times10^{-3}$	BESII	2007
$\psi(3686) \rightarrow \Xi^{*0}\bar{\Xi}^{*0}$ [24]	1310.6×10^6	$(2.73\pm0.03)\times10^{-4}$	BESIII	2016

i.e. Belle and BABAR; their details are also mentioned in Table 2. Resonances of J/ψ i.e ψ(2S) →$\Lambda\bar{\Lambda}$ was observed at BES in 2001 3.95×10^6 events and observed branching fraction and α-values are $(18.1 \pm 2.0 \pm 2.7) \times 10^{-5}$ and (0.67 ± 0.21). Later in 2007 the similar decay channel were studied at BESIII, its branching fraction is shown in Table 3. In 2017 using a huge data sample of 1310.6×10^6 at BESIII the currently measured branching fraction and α values are $(3.97 \pm 0.02 \pm 0.12) \times 10^{-4}$ and $(0.82 \pm 0.08 \pm 0.02)$, respectively.

4.2 Observation of $\Sigma\,\bar{\Sigma}$ Channel

In the analysis of $J/\psi \rightarrow \Sigma^0\bar{\Sigma}^0$ process the candidate events for Σ^0 can be reconstructed using decay $\Sigma^0 \rightarrow p^-\pi^-\gamma$ and candidate events for $\bar{\Sigma}^0$ are obtained using decay $\rightarrow \bar{p}\pi^+\gamma$ [5]. The events have at least two charge tracks in the range $|\cos\theta| < 0.93$ are selected in MDC. For particle identfication two parameters dE/dx and TOF are used. Energy deposits in EMC are used to identify photons. The minimum energy required for end cap showers ($0.86< |\cos\theta| <0.92$) is 50 MeV and for barrel showers ($|\cos\theta| <0.80$) is 25 MeV. Pairs of photons having invariant mass in the range 0.115 GeV/c^2<$M_{\gamma\gamma}$< 0.115 GeV/c^2 are reconstructed to obtain candidate events of π^0. By applying all the fitting requirements on γγ mass distribution the invariant mass distribution for π^0 is determined to be 4.2 MeV/c^2 [22]. In this case background comes from both ηc and J/ψ decay channels. For $J/\psi\rightarrow\Sigma^0\bar{\Sigma}^0$ the dominant backgrounds are $J/\psi \rightarrow \gamma\eta_c$ with $\eta_c \rightarrow \Lambda\,\bar{\Sigma}^0$, $J/\psi \rightarrow \Sigma^0\bar{\Sigma}^0$ and $J/\psi\rightarrow \Lambda\ \Sigma^{0+}$c.c. The background containing Σ^0 are expected to have a peak at invariant mass distribution of $\gamma\ p\pi^-$ and can be estimated with the help of MC sample [5].

Fig. 3 shows the invariant mass distribution $M_{p\pi}$, clear peak of Σ^0 are seen with low background. Signal yield is determined using maximum likelihood fits. In the fit, to resolve the difference between mass resolution of MC samples and data, MC simulation fitted with Gaussian function is used [5]. The observation of $\Sigma\,\bar{\Sigma}$ channel in different laboratories in previous years is listed in Tables 4 and 5. The channel $J/\psi \rightarrow \Sigma^0\bar{\Sigma}^0$, $\Sigma^+(1385)\ \overline{\Sigma^-(1385)}$, $\Sigma^+(1385)\ \bar{\Sigma}^-$, has been studied in MarkII in 1984 with 1.32×10^6 events, and their measured branching fraction has also been listed in the Table 4. The channel $J/\psi \rightarrow \Sigma^0\bar{\Sigma}^0$ has been studied in three laboratories BESII, BESIII and BABAR from the year 2005 to 2017, and number of events in these labs has drastically increased. As a result of this branching fraction changed from (1.33 ± 0.04 ± 0.11) × 10^{-3} to (11.64 ± 0.04 ± 0.23) × 10^{-4} and corresponding α values have changed from (-0.24 ± 0.19 ± 0.07) to -(0.449 ± 0.026). BESII studied two channels ψ(2S)→ $\Sigma^+\overline{\Sigma^-}$, $\Sigma^0\overline{\Sigma^0}$ with number of events 3.95×10^6 in 2001 at that time measured branching fraction of these two channels is listed in Table 5, which was improved in 2005-06. Recently in 2016-17 ψ(2S) → $\Sigma^0\overline{\Sigma^0}$ channel has been studied in BESIII with events 1310.6×10^6. The channels ψ(2S) → $\Sigma^+\overline{\Sigma^-}$ and ψ(2S) → $\Sigma^-\overline{\Sigma^+}$ has still not been measured in BESIII, the more precise branching fraction can be calculated using increased data samples of BESIII.

4.3 Observation of $\Xi\overline{\Xi}$ Channel

Large samples of BESIII detector are also used to study J/ψ, ψ(3686) → Ξ $\overline{\Xi}$. One Baryon tag technique is used to study this process in order to avoid systematic uncertainties and to achieve higher efficiency. Remaining Candidate events for Ξ $\overline{\Xi}$ are reconstructed from $\Lambda\pi^0$ decays and Λ further decays to pπ− and $\pi^0 \to \gamma\gamma$. So in process there are $p\pi^-$ and $\bar{p}\pi^+$ charged tracks and two neutral track γγ. Photon tracks are reconstructed in EMC showers. To increase the energy resolution and reconstruction efficiency the energy depositing near TOF counter is also included. Photon candidates having energy of 50MeV in EMC cap region 0.86<|cosθ|<0.92 and energy of 25MeV in EMC barrel region |cosθ|<0.8 are required. Events containing more than one γ tracks are selected by applying1c kinematic fit in order to reconstruct π^0 candidate events [24]. Ξ^0 charge tracks are reconstructed by applying vertex fit at $p\pi^-$ within range of MDC covering angle cosθ<0.93 where polar angle with respect to beam is represented by θ. Events having χ^2<500 are considered. Flight time predicts by the final state particles is used to apply secondary vertex fit on those reconstructed tracks. Candidate events $p\pi^-$ with invariant mass closed to that of Λ are selected.

Candidates are reconstructed using recoiling mass against Σ^0[24]. $\pi^0\Lambda P^2_{\pi0\Lambda}$

$$M^{recoil}_{\pi^0\Lambda} = \sqrt{(E_{CM} - E_{\pi^0\Lambda})2 - P^2_{\pi^0\Lambda}} \quad [8]$$

Whereand $E_{\pi^0\Lambda}$ are momentum and energy of $\Lambda\pi^0$ events respectively. MC samples of J/ψ events are used to the background channels. Background channel of J/ψ → Ξ $\overline{\Xi}$ channel are mainly J/ψ → $\Xi^-\overline{\Xi^+}$, $\gamma\eta_c$ ($\gamma\Xi^0\overline{\Xi^0}$, $\gamma\Xi^0\overline{\Xi^0}$), Σ^0(1385) and $\Xi^0\overline{\Xi^0}$. Peaking background for ψ(1385) → Σ^0 Σ^0 is from Σ^0 Σ^0 [24]. The branching fraction can be calculated using:

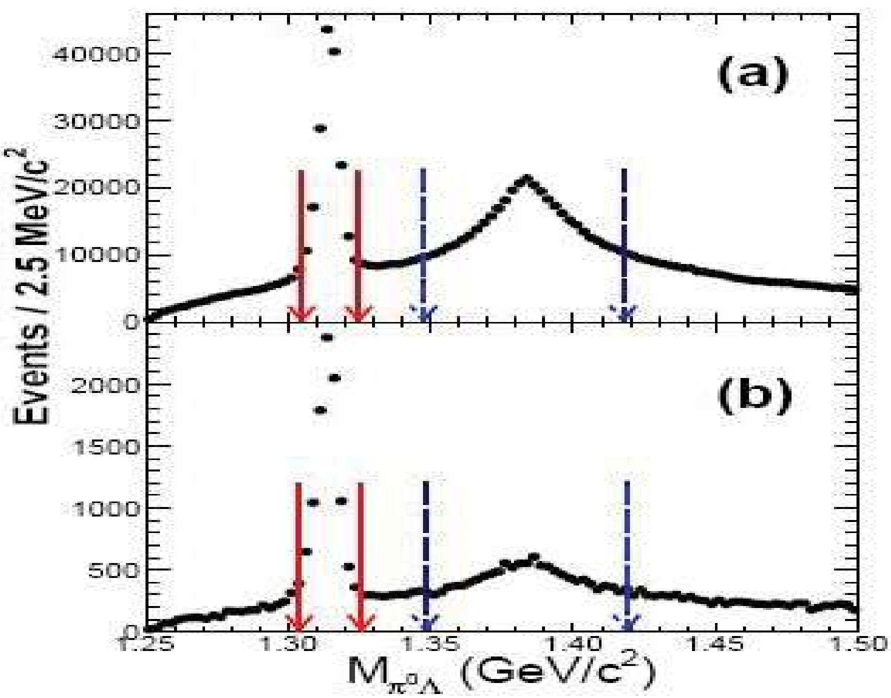

Fig. 4. (a) Shows scatter plot for M($\bar{p}\pi^+\pi^+$) and M($p\pi^-\pi^-$). **(b)** shows the invariant mass distribution of $p\pi^-$ and $\bar{p}\pi^+$

$$B[\psi \to X\bar{X}] = \frac{N_{obs}}{N_{\psi,\varepsilon} B(X \to \Lambda\pi^0) . B(\Lambda \to P\pi^0) . B(\pi^0 \to \gamma\gamma)}$$

This channel has only been studied in BES laboratory. At first in 2008 at BESII with 58×10^6 J/ψ events the corresponding Branching fraction is $(1.20\pm0.12\pm0.21)\times10^{-3}$. After upgradation of BESII to BESIII it has been observed in 2009 and 2016. In 2016 the $(11.65\pm0.04)\times10^{-4}$ branching fraction was measured with events (1310.6×10^6). Data of channel $J/\psi \to \Xi\bar{\Xi}$ has been collected from year 2001 to 2016 and summarized in Table 6. From these channels BESII lab studied two channels $J/\psi \to \Xi^0\bar{\Xi}^0$, $J/\psi \to \Sigma\bar{\Sigma}$ with events (3.95×10^6) during 2007. The same channel was again studied with 14×10^6 and the measured branching fraction was $(3.03\pm0.40\pm0.32)\times10^{-3}$, which is more precise. The channel $\psi(3686) \to \Xi^0\bar{\Xi}^0$ has been observed with 1310.6×10^6 events in BESIII and its branching fraction is $(2.73\pm0.03)\times10^{-4}$ as shown in Table 7. Other channels like $J/\psi \to \Xi^-\bar{\Xi}^+, \Xi^0\bar{\Xi}^0$, $J/\psi \to \Sigma^0(1530)\,\bar{\Sigma}^0(1530)$ should be studied with the present data of BESIII, precision in branching fraction can be more enhanced.

5. SUMMARY

SU(3) symmetry breaking has been observed in J/ψ, ψ(2S) → $B\overline{B_1}$, $B\overline{B_8}$, $B\overline{B_{10}}$. We collected data samples from various laboratories having different number of events. From the processing of these data events branching fraction and decay constant (α) values have been studied. The sources of information are High Energy Physics laboratories like MarkI, MarkII, Belle, Cleo and BESIII. In these labs the data events for J/ψ and ψ(2*S*) varying from1.32×10^6 to 1310.6×10^6 and 3.96×10^6 to1310.6×10^6 respectively have been reported from 1984 to date ,the corresponding branching fraction and values of α have also been given. The study shows that for J/ψ, ψ(2S) → $\Lambda\bar{\Lambda}$ the values of decay constant(α) varied from 0.72 to 0.82 and corresponding branching fraction changes from 1.58×10^{-3} to 3.97×10^{-4}. Also for J/ψ, ψ(2S) → $\Sigma\bar{\Sigma}$ the value of α varied from 0.7 to 0.71 and corresponding branching fraction changes form 1.58×10^{-3} to 2.44×10^{-4}. Similarly for $J/\psi \to \Xi\bar{\Xi}$ branching fraction varied from 1.14×10^{-3} to 2.44×10^{-4}.

In this work we have considered only three channels J/ψ, ψ(2S) → $\Lambda\bar{\Lambda}$, $\Sigma\bar{\Sigma}$, $\Xi\bar{\Xi}$ which shows SU(3) symmetry breaking. The comparison shows the dependence of branching fraction on number of events. The increased number of data samples provides highly precise results. The data is shown in tabulated form which shows the trends in improvement of values of branching fraction and α with increased data events. We can conclude that the improved number of events provides more precise branching fraction and α value. These more precise results will enhance d the understanding of dynamics of J/ψ and ψ(2S).

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