Summary of Results and Conclusions

The investigation carried out in this thesis is based on 711 $fb^{-1}$ of Belle data containing 771.6 Million $B\bar{B}$ events collected with the Belle detector at the KEKB $e^+e^-$ asymmetric-energy collider, situated at Tsukuba, Japan. This data sample was collected by operating collider at the $\Upsilon(4S)$ resonance, which is at threshold of $B\bar{B}$ mass. As soon as $\Upsilon(4S)$ resonance is produced in $e^+e^-$ collision, it decays to pair of $B$-meson ($B$-meson pair is produced at rest). In this Chapter, we summarize and discuss the results which are obtained from the study of $B \rightarrow X(3872)K\pi$ decay modes undertaken in this work. The $X(3872)$ is electrically neutral particle, which is discovered by the Belle Collaboration in 2003 and rapidly confirmed by other experiments, still its nature has remained unsettled. Being neutral, it is challenging to distinguish the $X(3872)$ from an ordinary charmonium resonances. In this investigation, production of $X(3872)$ and $\psi'$ in three body decay of $B$-meson, namely $B^0 \rightarrow X(3872)K^+\pi^-$, $B^0 \rightarrow \psi'K^+\pi^-$, $B^+ \rightarrow X(3872)K_S^0\pi^+$, $B^+ \rightarrow \psi'K_S^0\pi^+$, $B^+ \rightarrow X(3872)K^+\pi^0$ and $B^+ \rightarrow \psi'K^+\pi^0$, have been studied. This is the first time the decay of $B$-mesons to three body decay having $X(3872)$ has been studied in such detail and results have been published [130]. We could only perform preliminary study for $B^+ \rightarrow \psi'K^+\pi^0$ and $B^+ \rightarrow X(3872)K^+\pi^0$ decay modes, because of high background and low sensitivity to signal with the current statistics.

Decays of $B$ mesons to three body final states having charmonium in final states
(ψ′) are expected to occur predominantly via the color-suppressed spectator diagrams and are also Cabibbo-favored ones at tree level. With the analysis of full Belle experimental data, we have performed a search for X(3872) in the three body decay of B-mesons and present the first observation of $B^0 \to X(3872)K^+\pi^-$ decay, first evidence for $B^+ \to X(3872)K_S^0\pi^+$ decay. However no observation/evidence for $B^+ \to X(3872)K^+\pi^0$ decay mode has been found. In addition to the above study, we have also searched for any new resonant structures in the observed decay mode $B^0 \to X(3872)K^+\pi^-$ by studying background subtracted mass distributions of $M_{X(3872)K}$, $M_{X(3872)\pi}$ and $M_{K\pi}$.

7.1 Search for $B^0 \to X(3872)K^+\pi^-$ and $B^+ \to X(3872)K^+_S\pi^+$ Decay Modes

The procedure carried out for the search of $B^0 \to X(3872)K^+\pi^-$ and $B^+ \to X(3872)K^+_S\pi^+$ decay modes can be summarized as follows:

- Monte Carlo Study: A Monte Carlo simulation study is performed to estimate reconstruction efficiency for branching fraction calculations using 2 Million signal events for each decay mode. Using this MC study, it is found that we can extract signal yield by using two dimensional extended unbinned maximum likelihood fitting of $\Delta E$ and $M_{J/\psi\pi\pi}$ variables.

- Background Study: To understand nature of backgrounds and types of backgrounds, officially generated $J/\psi$ inclusive MC sample (all decay modes of type $B \to J/\psi X$, where $X$ can be any particle) has been used. This sample is two order magnitude higher than the luminosity of final data set accumulated by Belle detector. Based upon this study, we found that due to mis-reconstruction and cross-feed from few decay modes (having similar kinematics) some events (not coming from signal) can peak in the signal region of one dimension, while being flat in the other dimension. We identify those decay modes and parametrize them in our signal extraction procedure. Rest of the backgrounds have no
structure and hence are flat in both dimensions. Non-$J/\psi$ backgrounds are also checked using $J/\psi$ mass sidebands distributions and no peaking structure is seen in the signal region.

- Verification of Signal Extraction strategy: Based upon background study, we perform fit modeling using 2D extended UML fitting and verify branching fractions of known decay modes based upon signal yield and efficiency from MC. It has been found to be consistent with the generated branching fractions.

- Calibration Decay Mode Study: In order to calibrate the detector resolution and to verify our background understanding in the experimental data for our search decay modes, we use $B^0 \rightarrow \psi' K^+ \pi^-$ and $B^+ \rightarrow \psi' K_S^0 \pi^+$ decay modes as our calibration decay modes, as these modes have been well studied. This study provides confidence and reliability to our signal extraction procedure.

- Fudge Factor Estimation: The difference between Monte Carlo simulation and experimental data is called Fudge Factors which is estimated using calibration decay mode. Difference due to different decay dynamics and kinematics of $\psi' \rightarrow J/\psi \pi^+ \pi^-$ and $X(3872) \rightarrow J/\psi p^0 (\rightarrow \pi^+ \pi^-)$ is also taken into account.

- Background Modeling and Fit Validation: The 2D fitter is used to extract signal yield. Fit bias in extraction of signal yield is verified using toy MC study and GSIM study. We did not observe any significant bias, hence it provides confidence in our fitter and technique of analysis. However, as a conservative, we added the insignificant bias to our source of systematics uncertainty.

- Signal Extraction Method: After validating our reconstruction procedure, selections and fitter, same strategy is adopted to extract signal events from experimental data. We find statistical significance of $7\sigma$ and $3.7\sigma$ for extracted signal yield for the $B^0 \rightarrow X(3872)K^+ \pi^-$ and $B^+ \rightarrow X(3872)K^0 \pi^+$ decay modes respectively. These are used to estimate product of branching fractions $\mathcal{B}(B^0 \rightarrow X(3872)K^+ \pi^-) \times \mathcal{B}(X(3872) \rightarrow J/\psi \pi^+ \pi^-)$ and $\mathcal{B}(B^+ \rightarrow X(3872)K^0 \pi^+) \times \mathcal{B}(X(3872) \rightarrow J/\psi \pi^+ \pi^-)$. 
CHAPTER 7. SUMMARY OF RESULTS AND CONCLUSIONS

• Efficiency Correction and Systematic Uncertainty Study: As we know the method used to estimate reconstruction efficiency and procedure used to extract signal yield has some limitation due to uncontrollable factors, so these uncertainties are estimated in order to provide the most correct and best measurement as one can think of. So we correct the reconstruction efficiency (which is estimated from signal MC) because of small difference in the signal detection efficiency between signal MC events and experimental data. This is due to lepton, kaon and pion identification differences and also because of difference in charged tracks identification e.g. kaon, pion, leptons etc. In our case, we try to include all major sources of systematic uncertainties which can affect our signal yield and hence branching fraction measurements.

To be conservative in our announcement of observation/evidence, we include systematic uncertainty in our estimation of statistical significance (only those systematic uncertainties are included which affects signal yield).

7.2 Preliminary Study of $B^+ \rightarrow X(3872)K^+\pi^0$ Decay Mode

The very preliminary study of $B^+ \rightarrow X(3872)K^+\pi^0$ decay mode is also performed in the present investigation. Because of large multiple $B$ candidates during reconstruction of events, more self cross feed, wide range of $\Delta E$ and $M_{J/\psi\pi\pi}$, it becomes difficult to handle backgrounds in this decay mode at the same footing as that of previous decay modes. Because of this we could not get statistically significant yield to claim any evidence or observation for this decay mode and could set only upper limit at 90% C.L. The $B^+ \rightarrow \psi'K^+\pi^0$ decay mode is used as calibration decay mode for above study and is analysed with the full experimental data of Belle.
7.3 Results for $B^0 \rightarrow X(3872)K^+\pi^-$, $B^+ \rightarrow X(3872)K_S^0\pi^+$ and $B^+ \rightarrow X(3872)K^+\pi^0$ Decay Modes

The $B \rightarrow \psi' K \pi$ decay modes are Cabibbo-favored and color-suppressed one at tree level. The branching fraction for this decay mode $\mathcal{B}(B^0 \rightarrow \psi' K^+\pi^-)$ is measured to be $(5.79 \pm 0.14{\text{(stat.)}} \pm 0.31{\text{(syst.)}}) \times 10^{-4}$, which agrees well with the world average value, $(5.8 \pm 0.4) \times 10^{-4}$ [1]. We have observed $B^0 \rightarrow X(3872)K^+\pi^-$ decay mode for the first time in world with a statistical significance of 7$\sigma$. The product of branching fractions $\mathcal{B}(B^0 \rightarrow X(3872)K^+\pi^-) \times \mathcal{B}(X(3872) \rightarrow J/\psi\pi^+\pi^-)$ is estimated to be $(7.91 \pm 1.29{\text{(stat.)}})^{+0.43}_{-0.42}{\text{(syst.)}} \times 10^{-6}$.

Branching fractions for $B^+ \rightarrow \psi' K^0\pi^+$ decay mode is measured as $(6.00 \pm 0.28{\text{(stat.)}} \pm 0.35{\text{(syst.)}}) \times 10^{-4}$, which is also consistent with the PDG value as $(5.88 \pm 0.34) \times 10^{-4}$.

With the present study, we find first evidence of $B^+ \rightarrow X(3872)K^0\pi^+$ decay mode with statistical significance of 3.7$\sigma$. The product of branching fractions $\mathcal{B}(B^+ \rightarrow X(3872)K^0\pi^+) \times \mathcal{B}(X(3872) \rightarrow J/\psi\pi^+\pi^-)$ is estimated as $(10.64 \pm 3.04{\text{(stat.)}})^{+0.81}_{-0.86}{\text{(syst.)}} \times 10^{-6}$.

The branching fraction $\mathcal{B}(B^+ \rightarrow \psi' K^+\pi^0)$ obtained from the 2D fitting of experimental data comes out to be $(3.56 \pm 0.24{\text{(stat.)}}) \times 10^{-4}$. Upper limit (@ 90% C.L) for the product of branching fractions is $\mathcal{B}(B^+ \rightarrow X(3872)K^+\pi^0) \times \mathcal{B}(X(3872) \rightarrow J/\psi\pi^+\pi^-) < 11.2 \times 10^{-6}$.

The results for the decay modes studied in this investigation can be summarized in Table 7.1 and Table 7.2.

7.4 Search for Resonances/New Particles in Background Subtracted Mass Distributions

In order to understand the production mechanism of three body decay $B^0 \rightarrow X(3872)K^+\pi^-$, the background subtracted $M_{X(3872)K}$, $M_{X(3872)\pi}$ and $M_{K\pi}$ distributions are investigated for $B^0 \rightarrow X(3872)K^+\pi^-$ decay mode. Also one can investigate the pro-
CHAPTER 7. SUMMARY OF RESULTS AND CONCLUSIONS

Table 7.1: Signal yield (Y) from the fit, weighted efficiency (ε) after PID correction and measured branching fractions for $B^0 \to \psi' K^+ \pi^-$, $B^+ \to \psi' K^0_S \pi^+$ and $B^+ \to \psi' K^+ \pi^0$ decay modes. The first (second) uncertainty represents a statistical (systematic) contribution.

<table>
<thead>
<tr>
<th>Decay Mode</th>
<th>Yield (Y)</th>
<th>ε (%)</th>
<th>$\mathcal{B}(B \to \psi' K\pi)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B^0 \to \psi' K^+ \pi^-$</td>
<td>2599 ± 61</td>
<td>14.14</td>
<td>$(5.79 \pm 0.14 \pm 0.31) \times 10^{-4}$</td>
</tr>
<tr>
<td>$B^+ \to \psi' K^0_S \pi^+$</td>
<td>629 ± 30</td>
<td>9.55</td>
<td>$(6.00 \pm 0.28 \pm 0.35) \times 10^{-4}$</td>
</tr>
<tr>
<td>$\uparrow B^+ \to \psi' K^+ \pi^0$</td>
<td>692 ± 47</td>
<td>6.13</td>
<td>$(3.56 \pm 0.24$ (stat.)$) \times 10^{-4}$</td>
</tr>
</tbody>
</table>

† It is to be noted that for $B^+ \to \psi' K^+ \pi^0$ decay mode, results are without any PID correction and without any systematic uncertainty study. These results are only preliminary one.

Table 7.2: Signal yield (Y) from the fit, weighted efficiency (ε) after PID correction, significance (Σ) and measured branching fractions for $B^0 \to X(3872) K^+ \pi^-$, $B^+ \to X(3872) K^0_S \pi^+$ and $B^+ \to X(3872) K^+ \pi^0$ decay modes. The first (second) uncertainty represents a statistical (systematic) contribution.

<table>
<thead>
<tr>
<th>Decay Mode</th>
<th>Yield (Y)</th>
<th>ε (%)</th>
<th>$\Sigma$ (σ)</th>
<th>$\mathcal{B}(B \to X(3872)K\pi) \times \mathcal{B}(X(3872) \to J/\psi \pi^+ \pi^-)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B^0 \to X(3872) K^+ \pi^-$</td>
<td>116 ± 19</td>
<td>15.99</td>
<td>7.0</td>
<td>$(7.91 \pm 1.29^{+0.43}_{-0.42}) \times 10^{-6}$</td>
</tr>
<tr>
<td>$B^+ \to X(3872) K^0_S \pi^+$</td>
<td>35 ± 10</td>
<td>10.31</td>
<td>3.7</td>
<td>$(10.64 \pm 3.04^{+0.81}_{-0.86}) \times 10^{-6}$</td>
</tr>
<tr>
<td>$\uparrow B^+ \to X(3872) K^+ \pi^0$</td>
<td>39 ± 17</td>
<td>6.38</td>
<td>–</td>
<td>&lt; $11.2 \times 10^{-6}$ ($@90%$ C.L.)</td>
</tr>
</tbody>
</table>

‡ It is to be noted that for $B^+ \to X(3872) K^+ \pi^0$ decay mode, results are without any PID correction and without any systematic uncertainty study. These results are only preliminary one.
7.4. SEARCH FOR RESONANCES/NEW PARTICLES IN BACKGROUND SUBTRACTED MASS DISTRIBUTIONS

Production of new particle/resonance with these distributions. This study is motivated from the fact that Belle Collaboration found a clear peak in mass distribution of $M_{\psi'\pi^\pm}$ [131], which they named it as $Z(4430)^\pm$. Almost 7 years later, LHCb reports a more detailed measurement of the $Z(4430)^\pm$ that confirms that it is unambiguously a particle, and a long-sought exotic hadron [132]. And also to check the production mechanism of $(K\pi)$ in $B^0 \to X(3872)K^+\pi^-$ decay mode, because it was found that for ordinary charmonium states like $\psi'$ and $\chi_{c1}$ [133] mass regions, resonant $(K^*(892)^0 \to K^+\pi^-)$ contribution is more as compared to non-resonant ($(K\pi)_{NR}$) one. To get background subtracted mass distributions for $M_{X(3872)K}$, $M_{X(3872)\pi}$ and $M_{K\pi}$, the 2D extended UML fitting is performed in each bin of $M_{X(3872)K}$, $M_{X(3872)\pi}$ and $M_{K\pi}$, respectively to the $\Delta E$ and $M_{J/\psi\pi\pi}$ variables. This will return us signal yield and custom error for each distribution of $M_{X(3872)K}$, $M_{X(3872)\pi}$ and $M_{K\pi}$. These distributions are without any backgrounds and hence called background subtracted distribution. We didn’t observe any obvious pattern in $M_{X(3872)K}$ and $M_{X(3872)\pi}$ background subtracted distributions as shown in Figure 5.4. However a clear peak is observed in background subtracted $M_{K\pi}$ distribution. Further to get different components of $(K\pi)$ system, it is necessary to perform the fitting of $M_{K\pi}$ background subtracted distribution. So binned minimum $\chi^2$ fitting is performed to extract the $(K\pi)$ resonant and non-resonant contributions. This total procedure is called background subtracted binned fit study. This study can be summarized as follows:

- Monte Carlo Study: A Monte Carlo study is performed to get reconstruction efficiency. We perform 2D extended UML fitting in each bin of $M_{K\pi}$ mass for each generated signal MC sample and get only signal $M_{K\pi}$ distribution for each signal MC sample. From this signal yield, we estimate the reconstruction efficiency for different $K\pi$ components.

- Background Study and Verification of Strategy: Official generated $J/\psi$ inclusive MC sample includes $B^0 \to \psi'K^*(892)^0$ decay mode, but there is no $B^0 \to X(3872)K^+\pi^-$ decay mode included. So we embed signal events for both $\psi'$ and $X(3872)$ mass regions to do background subtracted binned fit study.
CHAPTER 7. SUMMARY OF RESULTS AND CONCLUSIONS

Furthermore, the whole $J/\psi$ inclusive MC sample is divided into 100 parts (equivalent to the luminosity we have for our experimental data) and embedded signal events into each part. After that we perform fitting of background subtracted $M_{K\pi}$ distribution using binned minimum $\chi^2$ method and study its pull distribution. From pull distribution no significant bias has been observed, so this provides us confidence in the fitter as well as in the strategy adopted for $K\pi$ component study. Insignificant bias has been added to systematic uncertainty study.

- Calibration Decay Mode Study: Further verification is done with the calibrated $B^0 \rightarrow \psi' K^+\pi^-$ decay mode. For this decay mode, we assume $K^*(892)^0$, $K^*_2(1430)^0$, and non-resonant $(K^+\pi^-)$ as major contribution in whole $(K\pi)$ system. From the fitting of background subtracted $M_{K\pi}$ distribution, we get ratio of $K^*(892)^0$ to the whole $(K\pi)$ system contribution. This ratio is found to be consistent with PDG value [128]. For concerned decay mode $B^0 \rightarrow X(3872)K^+\pi^-$, the decay mode $B^0 \rightarrow X(3872)K^*_2(1430)^0$ is kinematically suppressed. So, we consider here rest two components of $(K\pi)$ system.

- Fudge Factor Estimation: The Fudge Factors, differences between Monte Carlo and experimental data for mean and width parameters (which is fixed in each bin) are estimated using calibration decay mode.

- Modeling and Fit Validation: We have used binned minimum $\chi^2$ fit for signal extraction. Fit bias in the extraction of signal yield is estimated from toy MC study and from GSIM study. No significant bias has been observed, which gives us surety about our fitter and signal extraction procedure.

- Signal Extraction Method: After validating our reconstruction procedure with signal MC and calibration decay mode, we apply same strategy to extract signal events for concerned decay mode with full experimental data set.

- Efficiency Correction and Systematic Uncertainty Study: As explained in previous decay modes, it is required to correct efficiency obtained from signal MC.
7.5. RESULTS FROM RESONANCE STUDY

This is also called particle identification (PID) correction. The estimated systematic uncertainty is calculated with the knowledge of all sources of systematic uncertainties.

Another important conclusion from the above study is about ratios of branching fractions. We obtain the ratio of branching fractions for $\psi'$ mass region given below:

$$\frac{B(B^0 \to \psi'K^*(892)^0) \times B(K^*(892)^0 \to K^+\pi^-)}{B(B^0 \to \psi'K^+\pi^-)} = 0.68 \pm 0.01\text{(stat.)} \pm 0.01\text{(syst.)}.$$  \hspace{1cm} (7.1)

while this ratio in case of $X(3872)$ mass region is:

$$\frac{B(B^0 \to X(3872)K^*(892)^0) \times B(K^*(892)^0 \to K^+\pi^-)}{B(B^0 \to X(3872)K^+\pi^-)} = 0.34 \pm 0.09\text{(stat.)} \pm 0.02\text{(syst.)}. \hspace{1cm} (7.2)$$

From above two ratios, we observe that in the $\psi'$ mass region, the contribution $B^0 \to \psi'K^*(892)^0$ decay mode dominates as compared to $B^0 \to \psi'(K^+\pi^-)_{NR}$ one. However, for $X(3872)$ mass region, the $B^0 \to X(3872)K^*(892)^0$ is not dominating which is in contrast with other charmonium states like $\psi'$ mass region. This result also didn’t match with $\chi_{c1}$ charmonium state [133], which has same $J^{PC}$ as that of $X(3872)$ i.e. $1^{++}$. But with more knowledge about quark content of $X(3872)$, one may clearly observe this difference.

7.5 Results from Resonance Study

For $B^0 \to X(3872)K^+\pi^-$ decay mode, we search for any resonant structure from background subtracted distributions of $M_{X(3872)K}$, $M_{X(3872)\pi}$ and $M_{K\pi}$. It has been observed that there is no clear peak in $M_{X(3872)K}$ and $M_{X(3872)\pi}$ distributions. But peak is observed at background subtracted $M_{K\pi}$ distribution. Further binned minimum $\chi^2$ fit is performed to get different ($K\pi$) components. From this study, it was found that for $X(3872)$ mass region, ratio of branching fractions i.e.

$$\frac{B(B^0 \to X(3872)K^*(892)^0) \times B(K^*(892)^0 \to K^+\pi^-)}{B(B^0 \to X(3872)K^+\pi^-)}$$

is $0.34 \pm 0.09\text{(stat.)} \pm 0.02\text{(syst.)}$, which is in contrast with the same ratio for ordinary charmonium states like $\psi'$ mass region (where
CHAPTER 7. SUMMARY OF RESULTS AND CONCLUSIONS

this ratio is $0.68 \pm 0.01(\text{stat.}) \pm 0.01(\text{syst.})$. This property indicates that $X(3872)$ is not behaving like ordinary charmonium state. These ratios of branching fractions are summarized in Table 7.3.

Table 7.3: Ratio of Branching fractions and its estimated value. The first (second) uncertainty represents a statistical (systematic) contribution.

<table>
<thead>
<tr>
<th>Ratio of Branching fractions</th>
<th>Estimated Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{B(B^0 \to \psi'K^<em>(892)^0) \times B(K^</em>(892)^0 \to K^+\pi^-)}{B(B^0 \to \psi K^+\pi^-)}$</td>
<td>$0.68 \pm 0.01(\text{stat.}) \pm 0.01(\text{syst.})$</td>
</tr>
<tr>
<td>$\frac{B(B^0 \to X(3872)K^<em>(892)^0) \times B(K^</em>(892)^0 \to K^+\pi^-)}{B(B^0 \to X(3872)K^+\pi^-)}$</td>
<td>$0.34 \pm 0.09(\text{stat.}) \pm 0.02(\text{syst.})$</td>
</tr>
</tbody>
</table>

Branching fractions for $B^0 \to \psi'K^*(892)^0$ decay mode is measured to be $(5.88 \pm 0.18(\text{stat.}) \pm 0.31(\text{syst.})) \times 10^{-4}$, which is also consistent with PDG value which is $(6.0 \pm 0.4) \times 10^{-4}$. The product of branching fractions $B(B^0 \to X(3872)K^*(892)^0) \times (X(3872) \to J/\psi\pi^+\pi^-)$ is found to be $(3.99 \pm 1.48(\text{stat.}) \pm 0.28(\text{syst.})) \times 10^{-6}$. This signal yield has statistical significance of 3σ. Results for above described decay modes are summarized in Table 7.4.

Table 7.4: Signal yield ($Y$) from the fit, efficiency ($\epsilon$) after PID correction, significance ($\Sigma$) and measured branching fractions for $B^0 \to \psi'K^*(892)^0$ and $B^0 \to X(3872)K^*(892)^0$ decay modes. The first (second) uncertainty represents a statistical (systematic) contribution.

<table>
<thead>
<tr>
<th>Decay Mode</th>
<th>Yield ($Y$)</th>
<th>$\epsilon$ (%)</th>
<th>$\Sigma$ ($\sigma$)</th>
<th>$B$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B(B^0 \to \psi'K^*(892)^0)$</td>
<td>$1708 \pm 52$</td>
<td>13.74</td>
<td>$&gt;30$</td>
<td>$(5.88 \pm 0.18 \pm 0.31) \times 10^{-4}$</td>
</tr>
<tr>
<td>$B(B^0 \to X(3872)K^*(892)^0)$</td>
<td>$38 \pm 14$</td>
<td>15.38</td>
<td>3.0</td>
<td>$(3.99 \pm 1.48 \pm 0.28) \times 10^{-6}$</td>
</tr>
<tr>
<td>$B(X(3872) \to J/\psi\pi^+\pi^-)$</td>
<td>$190$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7.6 Discussions and Future Scenario

In the present investigation, we have observed \( B^0 \to X(3872)K^+\pi^- \) decay mode with full Belle data set collected with Belle detector at \( e^+e^- \) asymmetric collider (KEK B-factory). The product of branching fractions for this decay mode has also been measured.

Investigation has also been performed with the background subtracted mass distributions of \( (X(3872)K) \), \( (X(3872)\pi) \) and \( (K\pi) \) systems for the search of any resonance/new particle. We didn’t observe any new resonance/new particle in \( (X(3872)K) \) and \( (X(3872)\pi) \) mass distributions. However in \( (K\pi) \) mass distribution, we found that resonant \( K^*(892)^0 \) component is small as compared to non-resonant \( ((K\pi)_{NR}) \) component, which doesn’t match with the normal charmonium states property (where \( K^*(892)^0 \) is dominating).

The first evidence for the decay mode \( B^+ \to X(3872)K^0_S\pi^+ \) is also seen and measurement on its product of branching fractions is performed. However, the significance of \( B^+ \to X(3872)K^+\pi^0 \) is not sufficient enough for any clear evidence and hence only upper limit is set. Search for \( X(3872) \) in the decay mode \( B^+ \to X(3872)K^+\pi^0 \) decay mode is constrained due to procedure adopted and due to limited statistics. We can access this decay mode with more precision in future with more experimental data available from Belle II at super-KEKB Factory.

With the present analysis of Belle data and latest results from other experiments, the \( X(3872) \) has come out to be more interesting and wonderful state. One can clearly see that there is a difference in the production of the normal charmonium state \( B \to \psi' K\pi \) and “exotic” state \( B \to X(3872)K\pi \). This different behaviour of \( X(3872) \) is also seen if we compare this state with other charmonium states like \( \psi' \), \( \chi_{c1} \). This suggests that \( X(3872) \) does not have normal charmonium content and it might be a molecular state of \( D^0 \bar{D}^{0*} \) with an admixture of \( c\bar{c} \). This hypothesis is seen to be consistent with other searches such as \( X(3872) \) or \( \chi_{c1}(2P) \) in \( B \to \chi_{c1}\pi^+\pi^- K \).
decay [133] and results from the study of radiative decay of $X(3872)$. However, coming to this conclusion is still not very comfortable and one needs more statistics to really pinpoint the structure of $X(3872)$. But one thing is sure, $X(3872)$ is really a special state and this may be inherited by it due to its proximity to the $D^0\bar{D}^{0*}$ mass.