PHOKHARA in BELLE experiment

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Outline

- The issue which I raised in the last meeting
- Current situation MC vs data
- Further discussions
- Summary

Introduction

In my talk in the first WG meeting last October, my slide says An example is the process

$$e^+e^- \to \gamma\gamma J/\psi\pi^+\pi^-$$

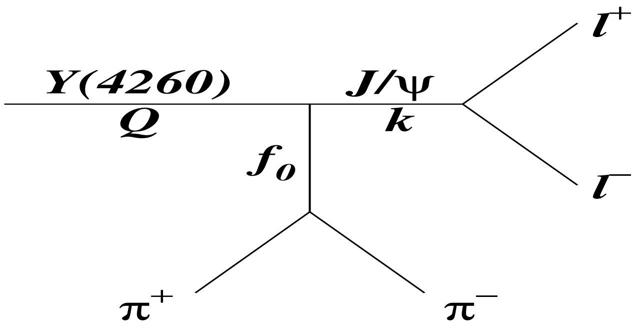
On B factories, this process is to measure the braching fractions of many charmonium states to $\pi^+\pi^- J/\psi$ by ISR process. These branching fractions are predicted by potential model.

It is also the final state in which Y(4260) has been found.

In this process, we either need to output the polarization of J/ψ, or alternatively, (and better off) we may write J/ψ to $\mu^+\mu^-$ and e^+e^- into the program, since experiments usually tag J/ψ by their decays into $\mu^+\mu^-$ and e^+e^-.

In some experiments, like BELLE and BES, the simulation software has no place for the polarization of the vector mesons. To get better simulation, one needs to write their decays explicitly into the Monte Carlo.

From data, it indicates that the $\pi^+\pi^-$ are in S wave. As a first order of approximation, we may consider the coupling of virtual photon to $\pi^+\pi^- J/\psi$ and then $J/\psi \to \mu^+\mu^-$ as



$$\langle \pi^+\pi^-\mu^+\mu^- | H^\mu | 0 \rangle \sim T(Q^2)(g^{\mu\nu} - \frac{Q^\mu Q^\nu}{Q^2}) T(k^2) \Gamma^\nu (J/\psi \to \mu^+\mu^-) \quad (1$$

In this final state, there are both mesons and fermions. How do we implement it in PHOKHARA?

The progress since then

After a week of work with Henryk at Frascati, soon after I went back to my home institute, the PHOKHARA with this final state became available. The MC is consistent with experimental data very well.

The progress since then

Due to that the BELLE paper has not been released (it will come to online in a few days) I cannot show the distributions of recoiled mass and anglular distributions of the hadron system, but these two distributions show good consistence between experimental data and MC by PHOKHARA.

The consistence between data and MC on these two distributions are viewed as a proof that the selected events are indeed from radiative return process.

The progress since then

The invariant mass of $\pi^+\pi^-$ shows that in different interval (of the invariant mass of $\pi^+\pi^- J/\psi$), the distribution of $\pi^+\pi^-$ invariant mass varies. (Sorry that I cannot show the figures)

It indicates a factor $1 - m^2_{\pi^+\pi^-}/(\Lambda m^2_\pi)$ is needed. In chiral lagrangian, $\Lambda = 2$, for $\psi(2S)$, empirically $\Lambda = 4$.BES Collaboration, J.Z.Bai et al., Phys.Rev.D 62, 032002 (2000).

The progress since then

Such distribution is what I said in the last meeting :

For many, if not most of the final states, the coupling of the hadronic current to the virtual photon is not well known to our present theoretical knowledge.

In the actual experiments, one needs to try different couplings, or more often, different combinations of couplings and compare the Monte Carlo with the experimental data, to yield the best simulation.

Further discussions

What is Y(4260)?

In the process $e^+e^- \to \gamma_{ISR}\pi^+\pi^- J/\psi$, BaBar observed an accumulation of events at 4.26GeV in the invariant mass spectrum of $\pi^+\pi^- J/\psi$. In a subsequent search for this state in the process $e^+e^- \to \gamma_{ISR}\pi^+\pi^-\psi(2S)$, BaBar observed a different structure at $m = 4324 \pm 24 MeV/c^2$ with a width 172 ± 33 MeV, that is neither consistent with $Y(4260) \to \pi^+\pi^-\psi(2S)$ peak nor $\psi(4415) \to \pi^+\pi^-\psi(2S)$.

This new structure add to the confusion in the charmonium spectrpscopy in the 3.8 GeV to 4.5GeV mass region, where thre are more candidates $J^{PC} = 1^{--}$ vectors states than predicted by potential models.

Is Y(4260) a single resonance, or is it due to interference of two, or several charmonium resonances?

Further discussions

For the interpretation of Y(4260), PHOKHARA could be important for simulating these resonances and their interference.

For narrow resonances, we need to sum up the terms

$$(\frac{\alpha}{\pi}(\log\frac{s}{m_e^2} - 1))^N \tag{2}$$

This is not only to simulate the observed peaks due to interfence of different resonances. We also use the events

$$e^+e^- \to \psi(2S) \to \pi^+\pi^- J/\psi$$

as a control sample to check the event selection, and correct the acceptances obtained from MC.

More need by BELLE

My colleague in BELLE Pasha Pakhlov (ITEP) wants to raise these needs

He said that

phokhara is a good generator, but it has not enough flexibility to incorporate the new two body processes in ee annihilation with radiative corrections. If the developers are really interested it would be nice if they introduce the generation of the processes like:

$e^+e^- \to D^{(*)}D^{(*)}$

$e^+e^- \to$ double charmonium

$e^+e^- \to$ charmed baryons?

etc ...

Certainly the QCD part for this processes is unknown, but the simple model can be introduced with a possibility for users to change the model.

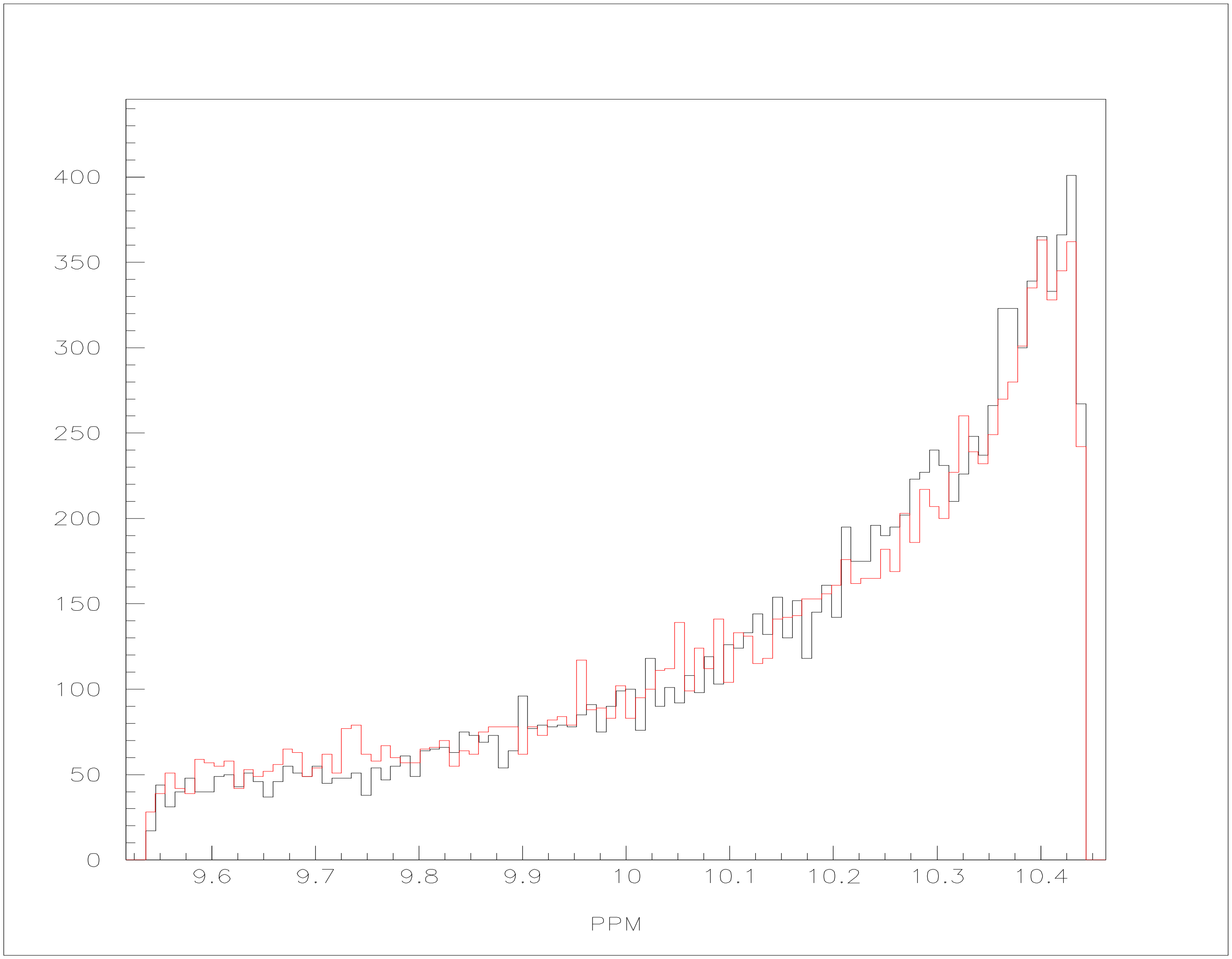
BABAYAGA with 3-body final state

Recently I have tried to put $\pi^+\pi^-\pi^0$ final state into BABAYAGA. This is for use in BELLE and BES-3.

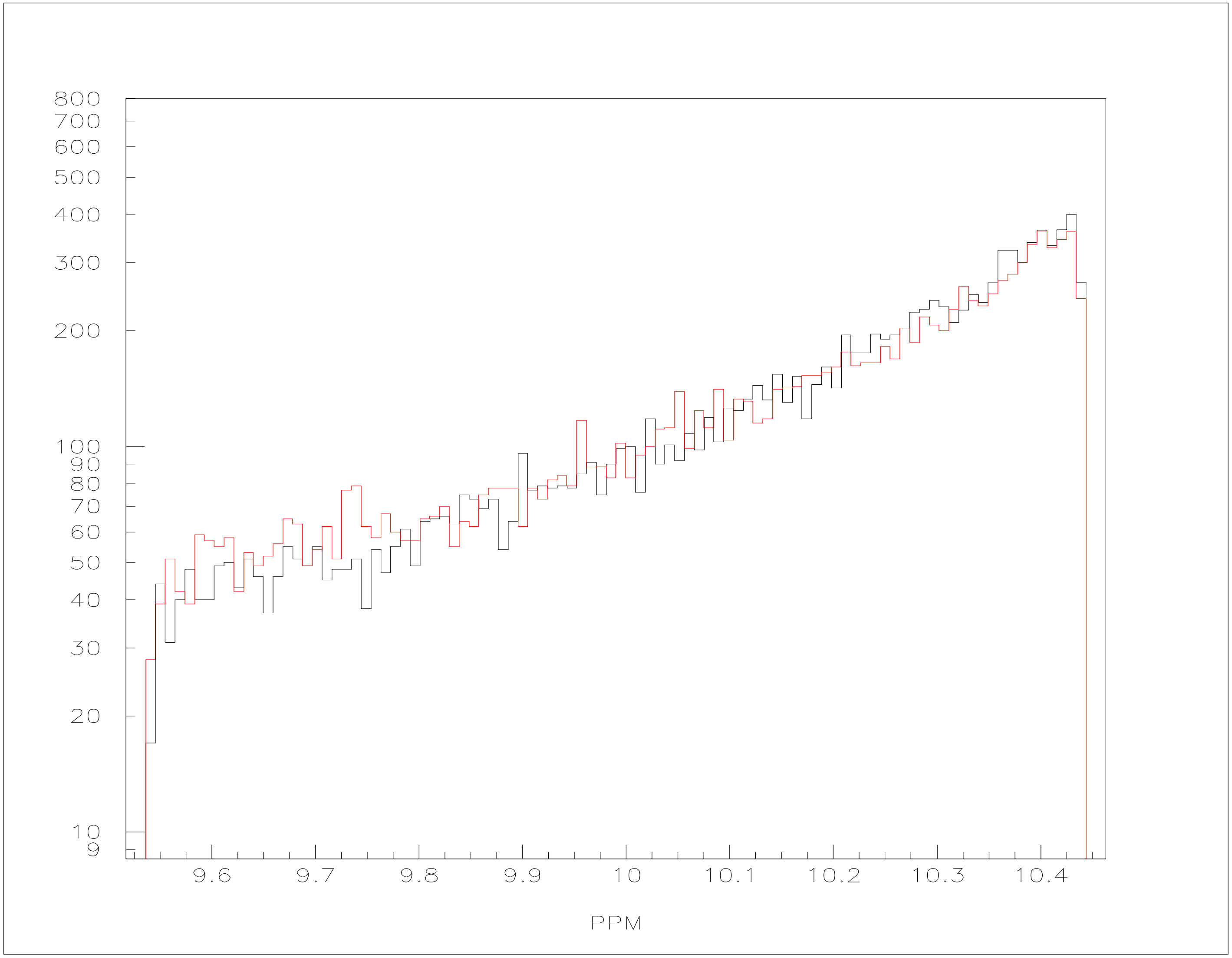
I just use $e^+e^- \to \pi^+\pi^-\pi^0$ Born order cross section to replace the angular distribution of 2-body final state in BABAYAGA.

The invariant mass spectrum thus produced does not agree with PHOKHARA satisfactorily.

BABAYAGA with 3-body final state



BABAYAGA with 3-body final state



BABAYAGA with 3-body final state

For such comparison, I put the form factors in both programs to be $\frac{1}{q^2}$, and compare the invariant mass of $\pi^+\pi^-\pi^0$ within $91 GeV^2$ and $109 GeV^2$.

Some thing more complicated to be done in multi-body final state?

Summary

PHOKHARA has been used successively by BELLE in radiative return measuement.

PHOKHARA could be an important tool in the understanding of what Y(4260) is.

For this purpose, it must be used on the charmonium resonaces.