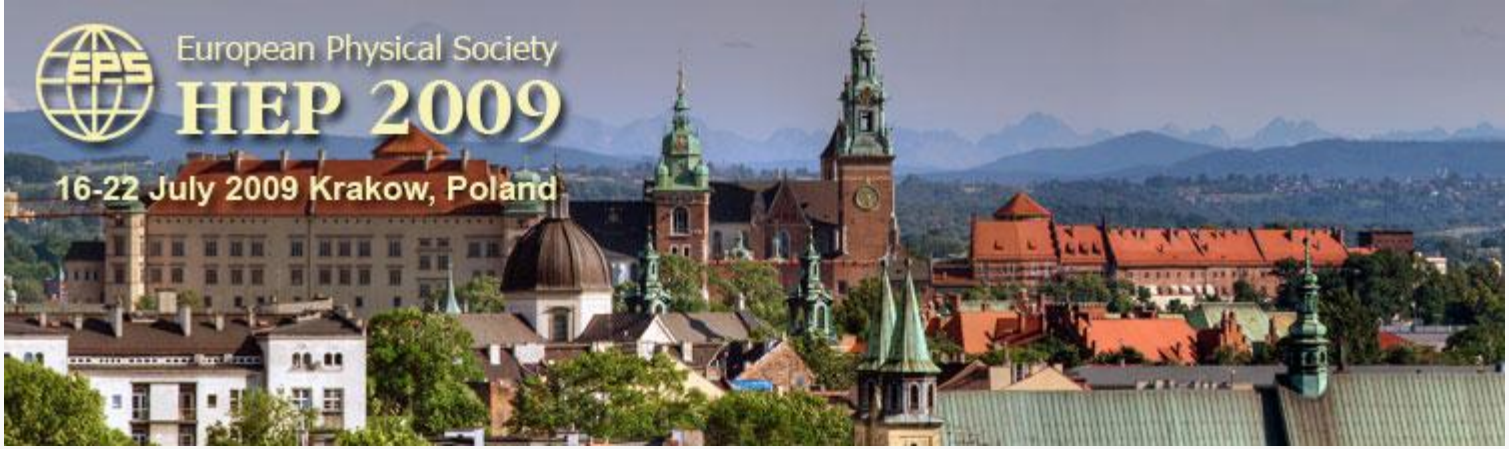


Light particle searches at Belle

16th July 2009

Chao Liu
University of Science and Technology of China
(Belle Collaboration)

Contents

- Search for the X(1812)
  - $B^{\pm} \rightarrow K^{\pm}\omega\varphi$
- Search for a light pseudo-scalar particle
  - $B \rightarrow K^{*0}X^0$, $X^0(214) \rightarrow \mu^+\mu^-$
  - $B \rightarrow \rho^0 X^0$, $X^0(214) \rightarrow \mu^+\mu^-$
- Summary

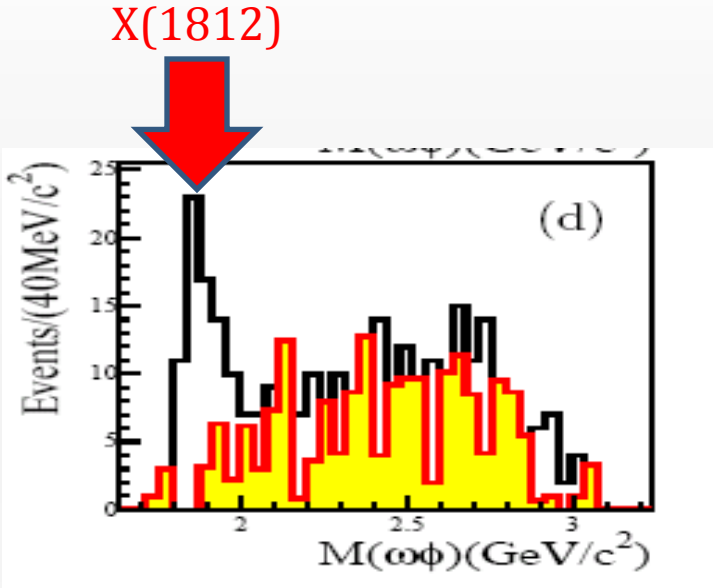
Part I

Search for the X(1812) in $B^{\pm} \rightarrow K^{\pm}\omega\varphi$

Near-threshold enhancement

- BES found a near-threshold enhancement from the decay channel J/psi → γωφ :

  M.Ablikim, PRL 96,162002(2006)



$$B(J/\psi \to \gamma X)\cdot B(X \to \omega\phi)$$

$$= (2.61 \pm 2.07(stat) \pm 0.58(syst)) \times 10^{-4}$$

$$M = 1812^{+19}_{-26}(stat) \pm 0.58(syst) MeV/c^2$$

$$\Gamma = 105 \pm 20(stat) \pm 25(syst) MeV/c^2$$

Speculation

- Tetraquark state: PRD 74,054017(2006)
- Hybrid K.T.Chao,hep-ph/0602194
- Glueball P.Bicudo, S.R.Cotanch, F.J.Llanes-Estrada and D.G.Robertson, Eur.Phys.J.C 52,363 (2007)
- an effect due to intermediate meson rescatterings Q.Zhao and B.S.Zou, PRD 74,114025 (2006)
- a threshold cusp attracting a resonance D.V.Bugg, J.Phys. G 35,075005 (2008)

Purpose

- Confirm whether X(1812) can be found in other decay channels.
- Measurement of the $B^{\pm} \rightarrow K^{\pm}\omega\varphi$ three-body decay is helpful for investigating decay mechanisms.
  - via a b → s penguin with ssbar and uubar popping.
  - A similar decay mode $B^{\pm} \rightarrow K^{\pm}\varphi\varphi$, has a rather large branching ratio B.Aubert, PRL,97,261803(2006)

Event Selection

$\varphi \rightarrow K^+K^-$

$B \rightarrow K\omega\varphi$ ⇒

$\omega \rightarrow \pi^+\pi^-\pi^0$

- π^0: $0.1193 < M_{\gamma\gamma} < 0.1477\ GeV/c^2$,

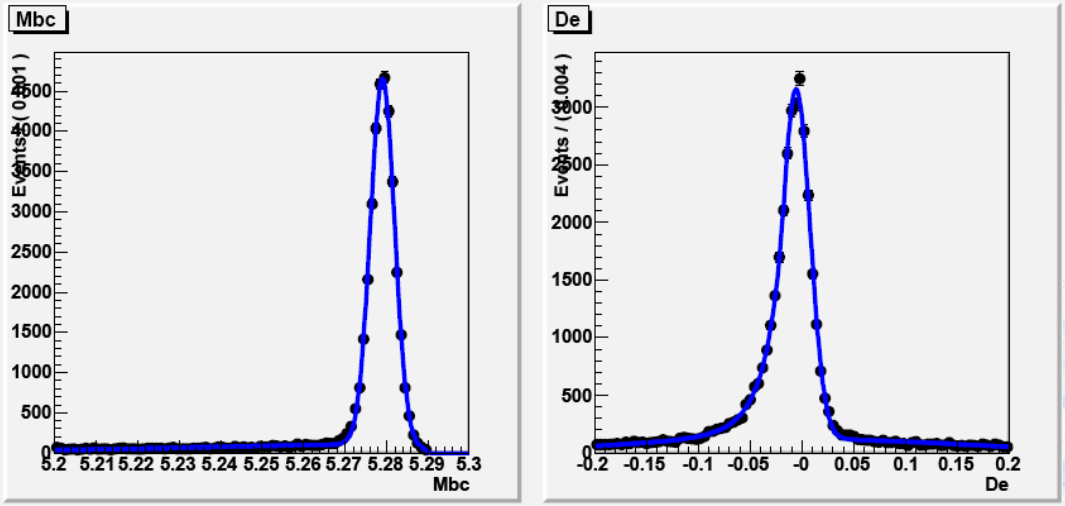
  $|P_{\pi 0}|_{lab} > 0.38\ GeV/c$
- ω: $|M_{\pi^+\pi^-\pi 0} - M_{\omega}| < 0.03\ GeV/c^2$
- φ: $|M_{K^+K^-} - M_{\varphi}| < 0.02\ GeV/c^2$,

  $|P_K|_{CM} < 1.5 Gev/c$

Kinematic variables, ΔE and M_{bc}

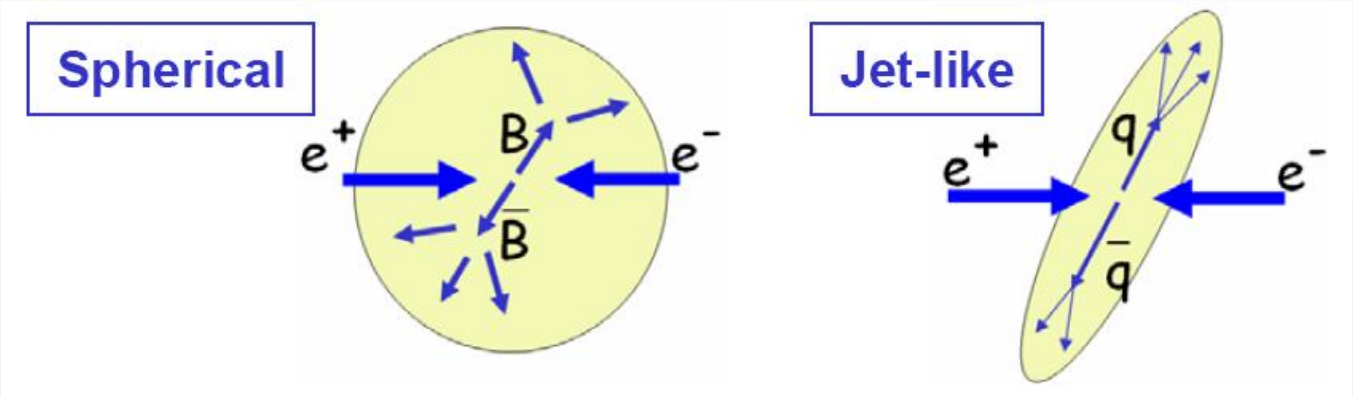
- Kinematic variables, ΔE and M_{bc}
  - $\Delta E = E_B^* - E_{beam}^*$
  - $(M_{bc})^2 = (M_{ES})^2 = (E_{beam}^*)^2 - |p_B^*|^2$

    E_{beam}^* : beam energy, p_B^* and E_B^* : momentum and energy of B candidate
  - $-0.2\ \text{GeV} < \Delta E < 0.2\ \text{GeV}$, $5.20\ \text{GeV}/c^2 < M_{bc} < 5.29\ \text{GeV}/c^2$

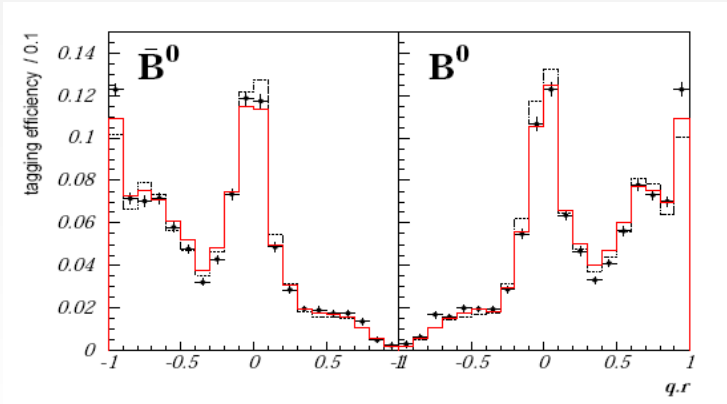


Continuum Suppression

- Continuum suppression with event topology variables

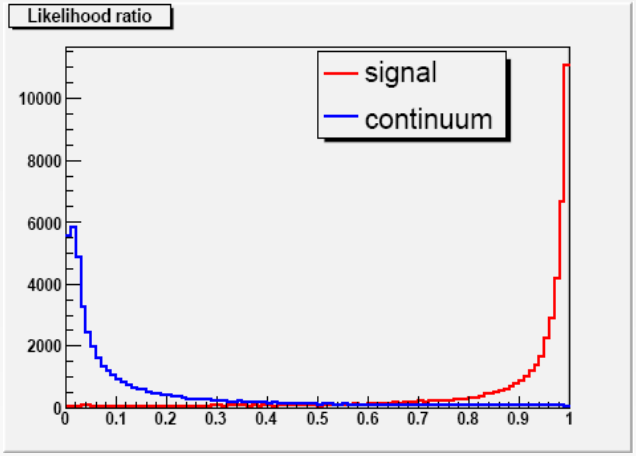


- Belle b-flavor tagging algorithm
  - flavor of the tagged meson q (± 1).
  - flavor tagging quality factor r ($0 \sim 1$).

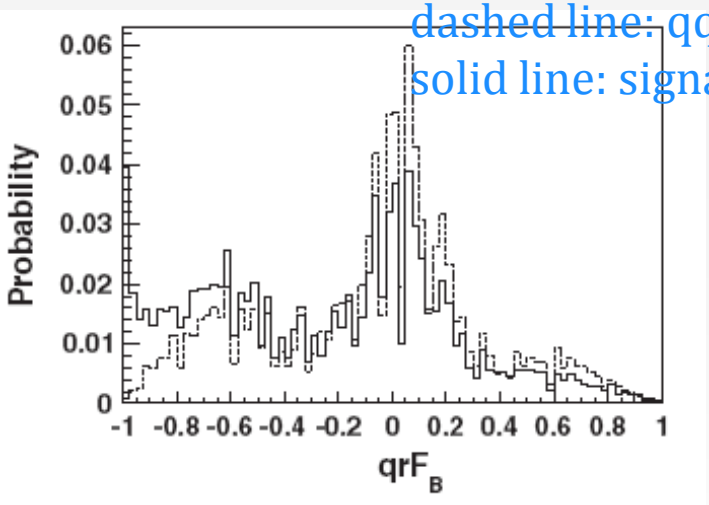


Background Study

- Combine events topology variables into a fisher discriminate



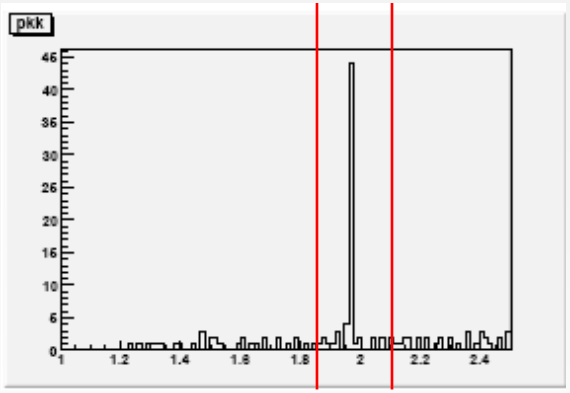
- Further suppression is achieved using b-flavor tagging information.

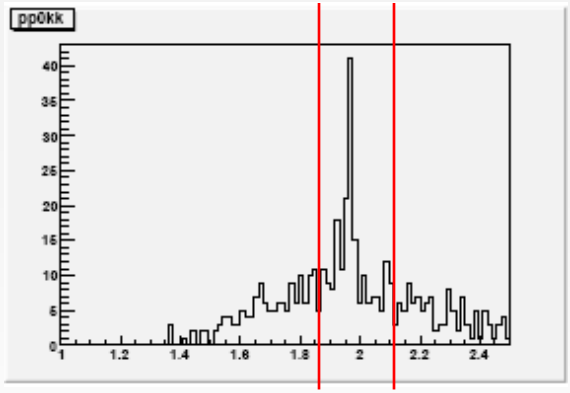


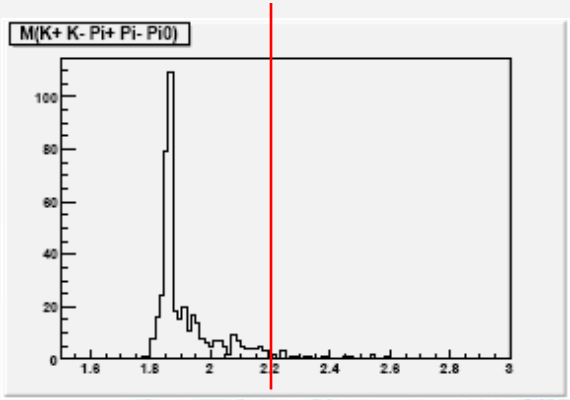
preserve 57.9% signal
reject 98.6% continuum background

BBbar Background

- Charmed B (b→c) decay
  - $|M_{\pi K^+K^-} - M_{D_s}| > 0.15 GeV/c^2$
  - $|M_{\pi^0 \pi K^+K^-} - M_{D_s}| > 0.15 GeV/c^2$
  - $M_{\pi^+\pi^-\pi^0 K^+K^-} > 2.2 GeV/c^2$



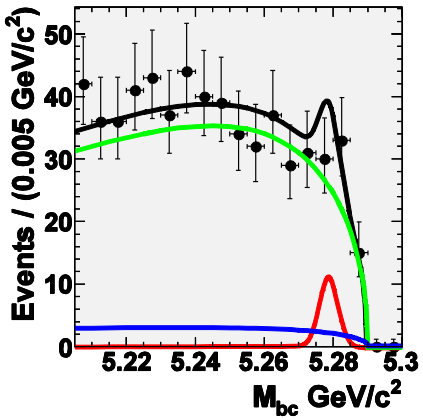


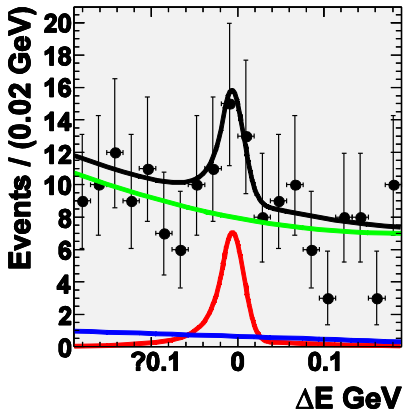


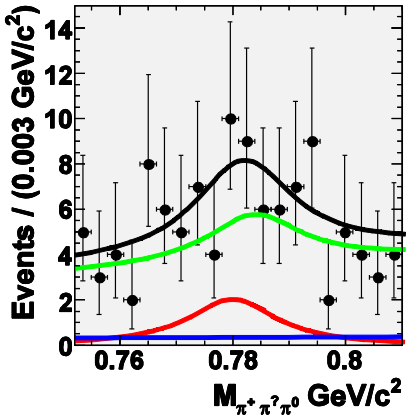
- Charmless B decay is negligible

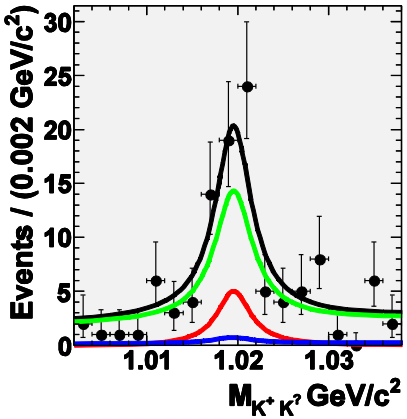
Result

4D extended unbinned ML fit is performed 605fb^{-1}









signal
qqbar
BBbar
total

signal region:

-0.15 GeV<ΔE<0.05 GeV

5.27 GeV/c^2 <M_{bc} <5.29 GeV/c^2

- signal yield : $22.1^{+8.3}_{-7.2}$
- branch ratio of $B^{\pm} \rightarrow K^{\pm}\omega\varphi$:

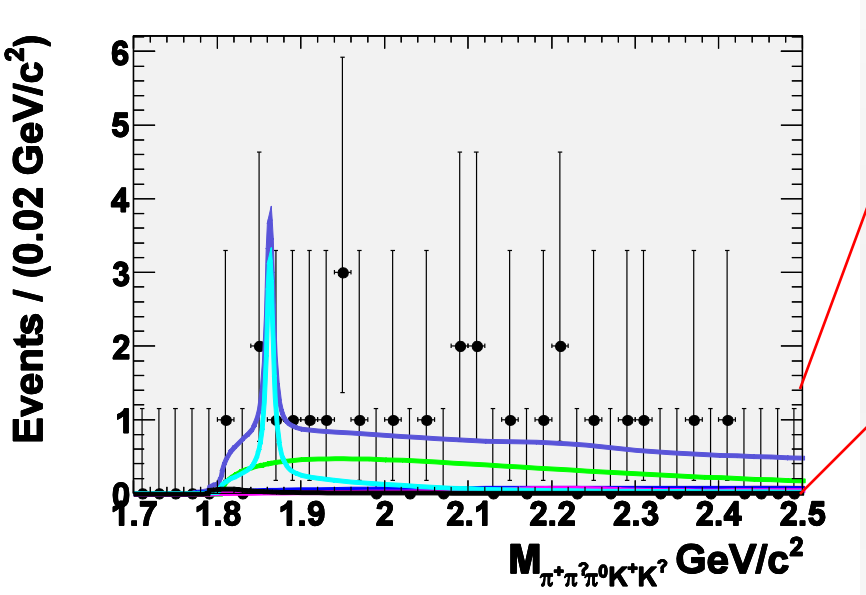
$$(1.15^{+0.43+0.14}_{-0.38-0.13}) \times 10^{-6} (2.8\sigma)$$

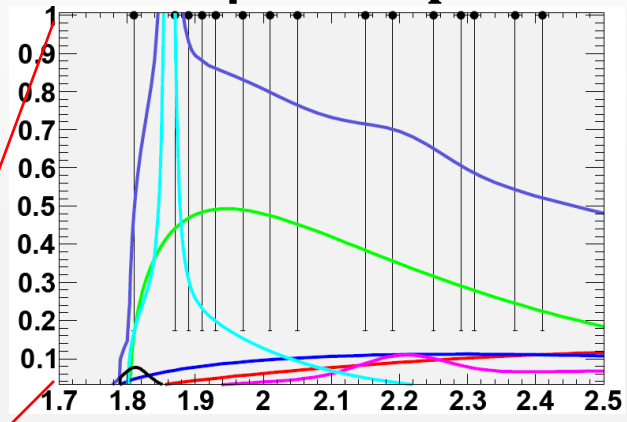
$$Br(B^{\pm} \rightarrow K^{\pm}\omega\varphi) < 1.9 \times 10^{-6}$$

@90%C.L

Result

NO significant signal is observed in ωφ mass spectrum





B→Kωφ
X
qqbar
BBbar
D^0
D_s
total

Do not use D^0 and D_s mass veto to exclude D^0 and D_s background

X(1812) yield : $0.2^{+2.4}_{-1.5}$

Systematic error: +34.4%
-27.1%

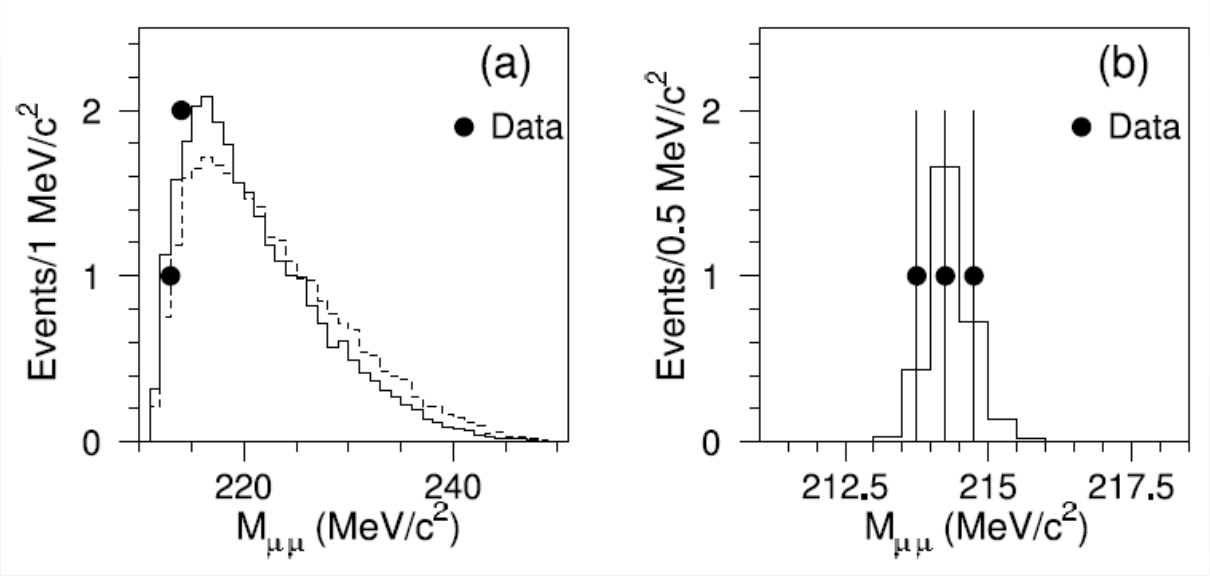
$$Br(B^{\pm} \to K^{\pm} X, X \to \omega\varphi) < 3.2 \times 10^{-7}$$

@90%C.L

Part II

Search for a light pseudo-scalar particle $X^0(214) \rightarrow \mu^+\mu^-$

HyperCP Exotic Events



- Observation of 3 events for $\Sigma^+ \rightarrow p\,\mu^+\mu^-$ decays
  H.K.Park et al. (HyperCP Collaboration), PRL 94, 021801 (2005)
  - Property of $X^0(214)$
    - mass : 214.3 ±0.5 MeV/c^2
    - Pseudo-scalar or axial-vector
  - Possible interpretations
    - Sgoldstino (pseudo-scalar)
      D.S.Gorbunov and V.A.Rubakov, PRD 73, 035002 (2006)
    - Low mass Higgs
      X.-G.He, J.Tandean and G.Valencia, PRL 98, 081802 (2007)

Possible Decay Modes for Further Search at B-Factory

- Possible decay modes for further search as sgoldstino in GMSB (Gauge Mediated SUSY Breaking)
  - Pseudo-scalar B and D meson decays to pseudo-scalar meson and X^0
    - $D \rightarrow \pi \pi X^0$, $X^0 \rightarrow \mu^+\mu^-, \gamma\gamma$
    - $B \rightarrow K \pi X^0$, $X^0 \rightarrow \mu^+\mu^-, \gamma\gamma$
  - Pseudo-scalar B and D meson decays to vector meson and X^0

    S.V.Demidov and D.S.Gorbunov, JETP Letters, 2006, vol. 84, No. 9, pp479-484
    - $B(D \rightarrow \rho X^0, X^0 \rightarrow \mu^+\mu^-) = 10^{-9} \sim 10^{-6}$
    - **$B(B \rightarrow K^* X^0, X^0 \rightarrow \mu^+\mu^-) = 10^{-9} \sim 10^{-6}$**
    - **$B(B \rightarrow \rho X^0, X^0 \rightarrow \mu^+\mu^-) = 10^{-9} \sim 10^{-6}$**

- The listed channels above are possible for low mass Higgs search in NMSSM (Next-to-Minimal SUSY SM)

PRELIMINARY

Event selection and Signal efficiency

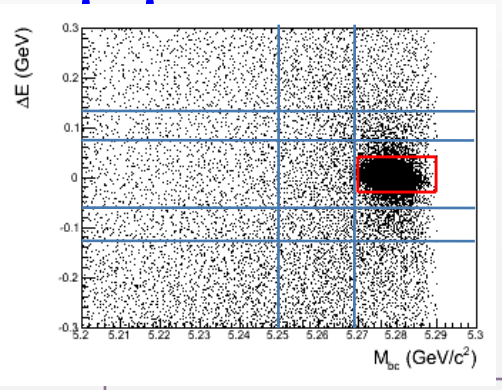
$B \rightarrow K^{*0}X^0$, $K^{*0} \rightarrow K^+\pi^-$, $X^0 \rightarrow \mu^+\mu^-$

$B \rightarrow \rho^0 X^0$, $\rho^0 \rightarrow \pi^+\pi^-$, $X^0 \rightarrow \mu^+\mu^-$

- Invariant masses of K^{*0} and ρ^0 :

  central value of the fitted $\pm 1.5\Gamma$ and $\pm 1\Gamma$, respectively

- Kinematic variables, ΔE and M_{bc}, cut applied



Decay mode	Dimuon mass resolution [keV/c^2]	Signal efficiency (ε)
$B \rightarrow K^{*0}X^0$	427 ± 14	$(26.3 \pm 0.1)\%$
$B \rightarrow \rho^0 X^0$	428 ± 15	$(23.5 \pm 0.1)\%$

- X^0 window defined with dimuon mass resolution

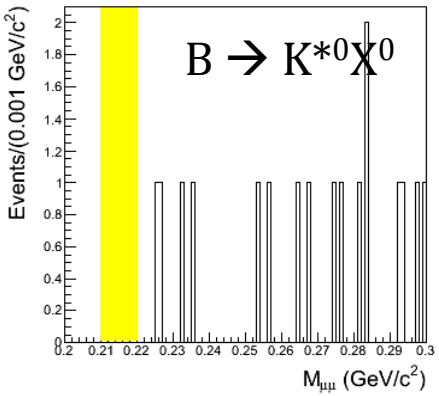
  $214.3 \pm 3 \times$ (0.5 (HyperCP) + resol. (Belle)) [MeV/c^2]

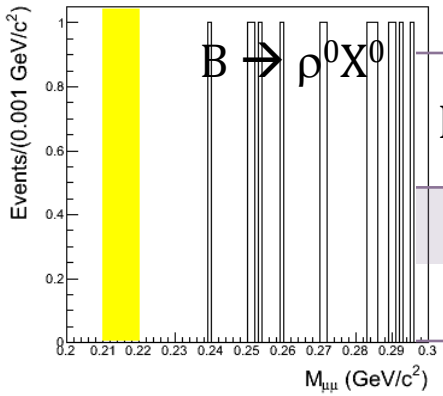
  $211.5\ \text{MeV}/c^2 < M_{\mu^+\mu^-} < 217.1\ \text{MeV}/c^2$

PRELIMINARY

Background Study

- Counting method
  - Use MC samples of continuum and BB-bar which are larger than data sample

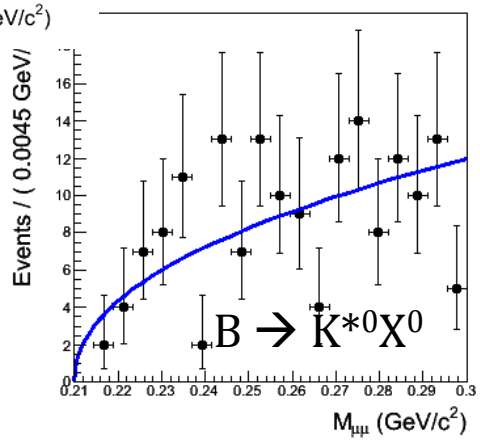


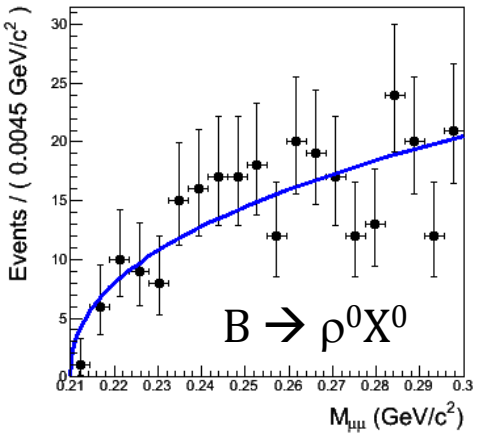


- Shaded region is X^0 window

Decay mode	Fitting the sidebands	Counting
$B \rightarrow K^{*0}X^0$	$0.13^{+0.04}_{-0.03}$	0
$B \rightarrow \rho^0 X^0$	$0.11^{+0.03}_{-0.02}$	0

- Fitting method
  - Fit MC data in sideband region (sideband is defined as $5\sigma \sim 10\sigma$ in ΔE-M_{bc})

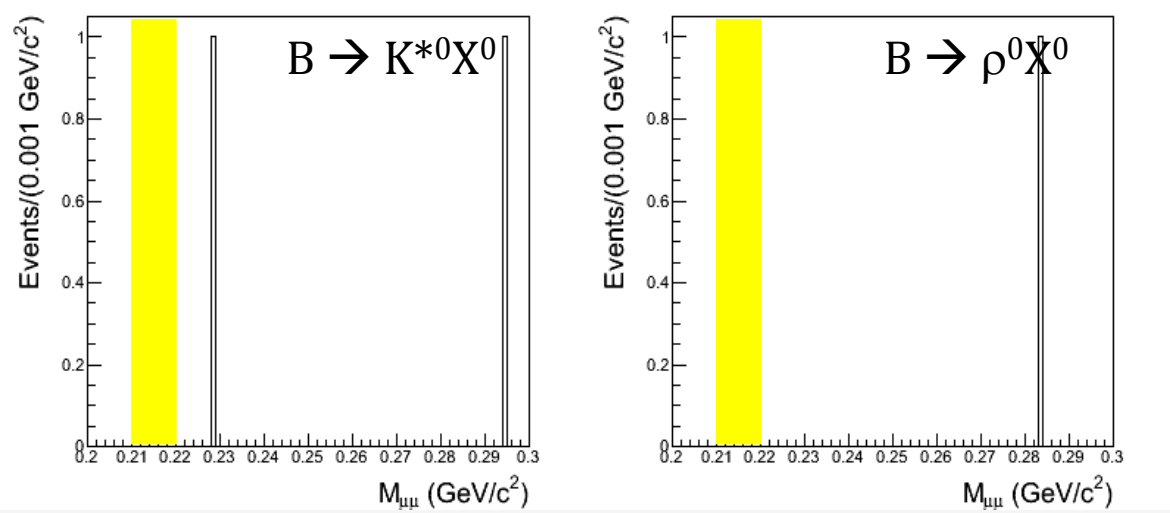




PRELIMINARY

Systematic and Upper limit

- **No event** is observed in the signal region for each mode with 657M BB-bar data



- The upper limits @ 90% C.L. are calculated **NEW RESULTS**
  - **$B(B^0 \to K^{*0} X^0, K^{*0} \to K^+ \pi^-$ and $X^0 \to \mu^+ \mu^-) < 2.0 \times 10^{-8}$**
  - **$B(B^0 \to \rho^0 X^0, \rho^0 \to \pi^- \pi^+$ and $X^0 \to \mu^+ \mu^-) < 1.5 \times 10^{-8}$**
- Our result rules out most of allowed BR for sgoldstino interpretation (will study U.L. as function of lifetime)

Expected BR as sgoldstino

Branching ratios of decays $P_{B,D} \longrightarrow VP(P \longrightarrow \mu^+\mu^-)$ in the models I, II, and III. Branching ratios of decays $P_{B,D} \longrightarrow VP(P \longrightarrow \gamma\gamma)$ are given by the same numbers multiplied by $\Gamma(P \longrightarrow \gamma\gamma)/\Gamma(P \longrightarrow \mu^+\mu^-)$

Decay	h_{jl}	$A_0^{(P_{B,D},\,V)}$	$\mathrm{Br}_{(\text{model I})}$	$\mathrm{Br}_{(\text{model II})}$	$\mathrm{Br}_{(\text{model III})}$
$B_s \longrightarrow \phi P(P \longrightarrow \mu^+\mu^-)$	$h_{23}^{(D)}$	0.42 [18]	6.5×10^{-9}	8.8×10^{-6}	8.7×10^{-6}
$B_s \longrightarrow K^{*0}P(P \longrightarrow \mu^+\mu^-)$	$h_{13}^{(D)}$	0.37 [18]	5.3×10^{-9}	7.2×10^{-6}	2.3×10^{-7}
$B_c^+ \longrightarrow D^{*+}P(P \longrightarrow \mu^+\mu^-)$	$h_{13}^{(D)}$	0.14 [19]	3.2×10^{-10}	4.4×10^{-7}	1.4×10^{-8}
$B_c^+ \longrightarrow D_s^{*+}P(P \longrightarrow \mu^+\mu^-)$	$h_{23}^{(D)}$	0.14[a]	3.0×10^{-10}	4.0×10^{-7}	4.0×10^{-7}
$B_c^+ \longrightarrow B^{*+}P(P \longrightarrow \mu^+\mu^-)$	$h_{12}^{(U)}$	0.23 [20]	4.1×10^{-10}	4.4×10^{-8}	8.2×10^{-7}
$B^+ \longrightarrow K^{*+}P(P \longrightarrow \mu^+\mu^-)$	$h_{23}^{(D)}$	0.31 [17]	3.8×10^{-9}	5.2×10^{-6}	5.1×10^{-6}
$B^0 \longrightarrow K^{*0}P(P \longrightarrow \mu^+\mu^-)$			3.5×10^{-9}	4.8×10^{-6}	4.7×10^{-6}
$B^0 \longrightarrow \rho P(P \longrightarrow \mu^+\mu^-)$	$h_{13}^{(D)}$	0.28 [17]	3.1×10^{-9}	4.2×10^{-6}	1.4×10^{-7}
$B^+ \longrightarrow \rho^+P(P \longrightarrow \mu^+\mu^-)$			3.3×10^{-9}	4.6×10^{-6}	1.3×10^{-7}
$D^0 \longrightarrow \rho P(P \longrightarrow \mu^+\mu^-)$	$h_{12}^{(U)}$	0.64 [17]	1.4×10^{-9}	1.5×10^{-7}	2.8×10^{-6}
$D^+ \longrightarrow \rho^+P(P \longrightarrow \mu^+\mu^-)$			3.5×10^{-9}	3.7×10^{-7}	7.0×10^{-6}

[a] We did not find any estimate of this form factor in literature and use this value as an order-of-magnitude estimate, which is sufficient for our study.

S.V.Demidov and D.S.Gorbunov, JETP Letters, 2006, vol. 84, No. 9, pp479-484

Summary

- Search for the X(1812) in $B^{\pm} \rightarrow K^{\pm}\omega\varphi$
  - No significant signal is observed in $\omega\varphi$ mass spectrum
  - The obtained upper limits @ 90% C.L. are as follows :
    - $Br(B^{\pm} \rightarrow K^{\pm}\omega\varphi) < 1.9 \times 10^{-6}$
    - $Br(B^{\pm} \rightarrow K^{\pm}X(1812), X(1812) \rightarrow \omega\varphi) < 3.2 \times 10^{-7}$
- Search for a light pseudo-scalar particle X(214)
  - No event is observed in B decays
  - The obtained upper limits @ 90% C.L. are as follows :
    - $B(B^0 \rightarrow K^{*0} X^0, K^{*0} \rightarrow K^+\pi^-$ and $X^0 \rightarrow \mu^+\mu^-) < 2.0 \times 10^{-8}$
    - $B(B^0 \rightarrow \rho^0 X^0, \rho^0 \rightarrow \pi^-\pi^+$ and $X^0 \rightarrow \mu^+\mu^-) < 1.5 \times 10^{-8}$

THANK YOU