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Recent results on charmless B and B_s decays from Belle

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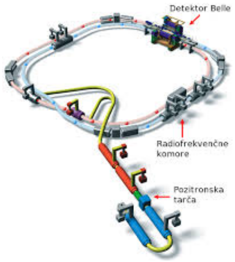
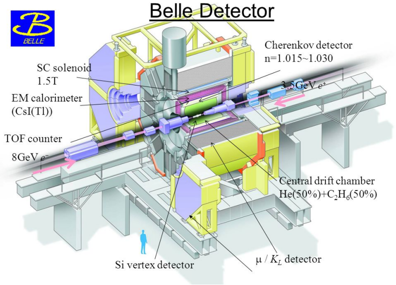
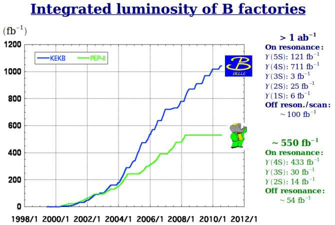
Outline

- Results on B_s decays
  - $B_s \to K^0 \bar{K}^0$
- Results on B decays
  - $B^0 \to \eta\eta$

Belle Experiment at KEKB, Japan

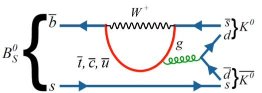






- KEKB is an asymmetric energy electron positron collider, with electrons having energy 8 GeV and positrons 3.5 GeV.
- At the interaction point of the beams the Belle detector is located.
- The center-of-mass (CM) energy of the electron positron system is 10.58 GeV which coincides with the mass of the $\Upsilon(4S)$ resonance. About 121.4 fb^-1 data were also collected at $\Upsilon(5S)$ resonance.
- Due to the energy asymmetry of the beams the B meson pairs are created with a Lorentz boost $(\beta\gamma)$ of 0.425 which is important for time dependent CP violation study.
- The results presented are based on the data collected by the Belle detector

$B_s \to K^0 \bar{K}^0$ analysis



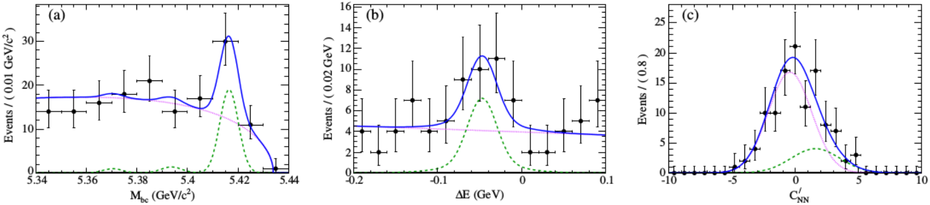
- Proceeds mainly through $b \to s$ penguin decay: highly sensitive to new physics.
- Predicted BF is $(1.6 - 2.7) \times 10^{-5}$ [JHEP 0612, 027 (2006)]
- Non Standard Model particles such as Z' may contribute to the process and enhance the BF upto 3.0×10^{-5} [$Q.Chang, X.Q.Li$ and $Y.D.Yang, J.Phys.G41, 105002(2014)$]
- Study of direct CP asymmetry A_{cp} is very promising observable to search for the new physics in this decay mode. A_{cp} is not more than 1% in SM, but can be as large as 10% in the presence of SUSY, while the branching ratio remain unaffected.

  [$A.Hayakawa, Y.Shimizu, M.Tanimoto, K.Yamamoto, PTEP2014, no.2, 023B04(2014); S.Baek, D.London, J.MatiasandJ.Virto, JHEP0612, 019(2006)$]

- This analysis is done based on the $121.4 fb^{-1}$ of Belle data collected at $\Upsilon(5S)$ resonance.
- Previously this decay mode was searched by Belle with $23.6 fb^{-1}$ of data and set an upper limit of $B(B_s \to K^0 \bar{K}^0) < 6.6 \times 10^{-5}$ at 90 % CL.[PhysRevD 82,072007 (2010)]
- K^0 mesons are reconstructed only via the decay $K_s^0 \to \pi^+ \pi^-$.
- Multivariate analyzer (Neural Network) is used to reduce the Continuum background.
- Distinguish signals from Background using event shape variables.
- 3D fit is performed to extract the signal yield
- Fit Models are studied from MC simulations, peak positions and resolutions are then calibrated using high statistics control sample.

Fit Results

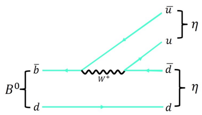
$$M_{bc} = \sqrt{(E_{beam})^2 - (P_{recon})^2},\ \Delta E = E_{recon}^{B_s^0} - E_{beam}, C'_{NN} = ln[\frac{C_{NN} - C_{NN}^{min}}{C_{NN}^{max} - C_{NN}}]$$

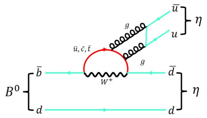


- The three peaks in M_{bc} arise from $\Upsilon(5S) \rightarrow B_s^0 \bar{B}_s^0, (B_s \bar{B}_s^* + B_s^* \bar{B}_s), B_s^* \bar{B}_s^*$
- The latter two channels dominate with production fractions of $(7.3 \pm 1.4)\%$ and $(87.0 \pm 1.7)\%$, respectively. These fractions are fixed in the fit which are obtained from [PRD 87, 031101(R) (2013)]

- We observe $29.0^{+8.5}_{-7.6}$ signal events with a significance of 5.1 σ including the systematic uncertainty.
- The measured branching fraction is
  $B(B_s^0 \to K^0 \bar{K}^0) = \frac{Y_s}{2N_{B_s^0 \bar{B}_s^0} . (0.50) . B^2_{K^0} . \epsilon}$
  $B(B_s \to K^0 \bar{K}^0) = [19.6^{+5.8}_{-5.1}(stat) \pm 1.0(syst) \pm 2.0(N_{B_s^0 \bar{B}_s^0})] \times 10^{-6}$
- $N_{B_s^0 \bar{B}_s^0} = (6.53 \pm 0.66) \times 10^6$ $B_s^0 \bar{B}_s^0$ pairs [$PRD92, 072013(2015)$],
  $\epsilon = (46.3 \pm 0.1)\%$ is the signal efficiency.
- This measurement is in good agreement with the Standard Model expectations and is the first observation of a charmless two-body B_s decays involving only neutral hadrons.

$B \to \eta\eta$ Analysis



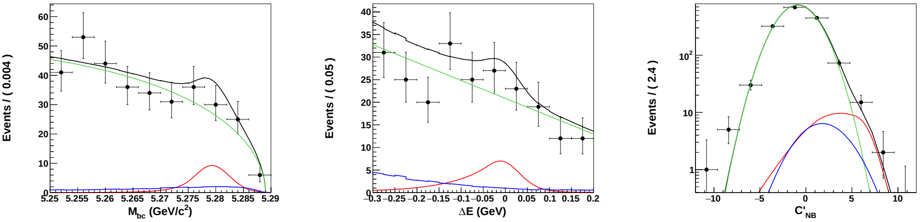


- Mainly proceeds via $b \to u$ Cabibbo & color suppressed *tree* diagram, and via a $b \to d$ *penguin* diagram.
- Can be used in flavor SU(3) based calculations of $|S_{ccs} - S_f|$ where $f = \eta' K, \phi K$. This $sin2\phi_1$ deviation bound may be improved by more precise measurements of the branching fraction of this mode. [PhysRevD.80.114008]
- Expected branching fraction: $0.32^{+0.15}_{-0.07} \times 10^{-6}$ [PhysRevD.80.114008]
- Latest result on $B \to \eta\eta$ decay
    - Belle: $B(B \to \eta\eta) < 2.0 \times 10^{-6}$ at 90% CL (152 M $B\bar{B}$).[PhysRevD 71, 091106(R) (2005)]
    - BaBar: $B(B \to \eta\eta) < 1.0 \times 10^{-6}$ at 90% CL (467 M $B\bar{B}$). [PhysRevD 80, 112002 (2009)]

$B \to \eta\eta$ selection and fit

- η mesons are reconstructed via the modes
  - $\eta \to \gamma\gamma$,$\eta \to \gamma\gamma$
  - $\eta \to \gamma\gamma$,$\eta \to \pi^+\pi^-\pi^0$
  - $\eta \to \pi^+\pi^-\pi^0$, $\eta \to \pi^+\pi^-\pi^0$
- Neural Network (NeruoBayes) is used for continuum $e^+e^- \to q\bar{q}$ background suppression.
- 3D simultaneous fit to three sub decay modes.
  - beam constrained mass, $M_{bc} = \sqrt{(E_{beam})^2 - (P_{recon})^2}$
  - energy difference, $\Delta E = E_{recon}^{B_s^0} - E_{beam}$
  - continuum suppression, $C'_{NN} = ln[\frac{C_{NN} - C_{NN}^{min}}{C_{NN}^{max} - C_{NN}}]$
- Three components included in the fit
  - Signal
  - 1 floating background: $q\bar{q}$
  - 3 fixed background: $B\bar{B}(b \to c)$, rare$B\bar{B}(b \to u, d, s)$, $B \to \pi^0\eta$

$B \to \eta\eta$ fit result (Preliminary)



- Extracted $B(B \to \eta\eta) = (7.6^{2.7+1.4}_{-2.3-1.5}) \times 10^{-7}$ at 3.3σ.
  - First evidence for the decay $BB \to \eta\eta$.

Summary

- We have presented results for $B_s \to K^0 \bar{K}^0$ and $B \to \eta\eta$
- First observation of $B_s \to K^0 \bar{K}^0$ at 5.1 σ at Belle
  - The measured branching fraction is $B(B_s \to K^0 \bar{K}^0) = [19.6^{+5.8}_{-5.1}(stat) \pm 1.0(syst) \pm 2.0(N_{B_s^0 \bar{B_s^0}})] \times 10^{-6}$
- First evidence of $B \to \eta\eta$ decay at 3.3 σ
  - The measured branching fraction is $B(B \to \eta\eta) = (7.6^{2.7+1.4}_{-2.3-1.5}) \times 10^{-7}$
  - 90% CL upper limit on the branching fraction is $B(B \to \eta\eta) < 11.6 \times 10^{-7}$

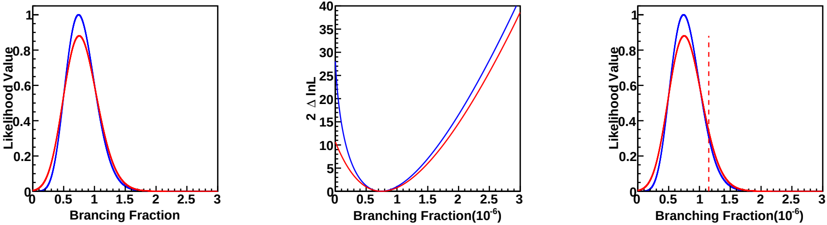
Thanks.

Back Up

- Summary of Box open

Sub-decay mode	$B^0 \to \eta_{\gamma\gamma}\eta_{\gamma\gamma}$	$B^0 \to \eta_{\gamma\gamma}\eta_{3\pi}$	$B^0 \to \eta_{3\pi}\eta_{3\pi}$
Yields :			
Signal	$23.6^{+8.1}_{-6.9}$	$9.2^{+3.2}_{-2.7}$	$2.7^{+0.9}_{-0.8}$
Continuum	$3860.5^{+63.1}_{-62.4}$	$3779.7^{+62.0}_{-61.5}$	$621.4^{+25.4}_{-24.8}$
Charmed B (fixed)	5.9	5.9	2.2
rare B (fixed)	27.4	17.8	4.5
$B^0 -> \eta\pi^0$ (fixed)	1.4	0.1	-
Efficiency :			
$\epsilon_{rec}(\%)$	26.3	17.8	8.9
$\prod \mathcal{B}(\%)$	15.5	8.9	5.1
Combined results:			
$\mathcal{B}(\times 10^{-7})$		$7.6^{+2.7+1.4}_{-2.3-1.5}$	
$\mathcal{B}$ significance $\mathcal{S}(\sigma)$		3.3	
$\mathcal{B}(\times 10^{-7})$ Upper limit(C.L 90%)		11.5	

- $B(B \to \eta\eta) = \frac{N_sig}{N_{B\bar{B}} \times \epsilon \times \Sigma B}$



- with the $+16.8 and -17.8$ systematics which affect signal yields
  - significance=3.26
  - Upper Limit $< 1.15 \times 10^{-6} (90\% CL)$

Systematic Uncertainty

TABLE I. Systematic uncertainties on $\mathcal{B}(B_s^0 \to K^0 \bar{K}^0)$. Those listed in the upper section are associated with fitting for the signal yields and are included in the signal significance.

Source	Uncertainty (%)
PDF parametrization	0.2
Calibration factor	$^{+0.9}_{-0.8}$
$f_{B_s^{(*)}\bar{B}_s^{(*)}}$	$^{+1.2}_{-1.1}$
Fit bias	$^{+0.0}_{-2.6}$
$K_S^0 \to \pi^+\pi^-$ reconstruction	4.0
$C_{\rm NN}$ selection	0.9
MC sample size	0.2
$\mathcal{B}(K_S^0 \to \pi^+\pi^-)$	0.1
Total (without $N_{B_s^0\bar{B}_s^0}$)	$^{+4.4}_{-5.1}$
$N_{B_s^0\bar{B}_s^0}$	10.1