Search For $B \to VV$ Decays With CLEO II and II.V

Zhaohui Xu
CLEO/Vanderbilt

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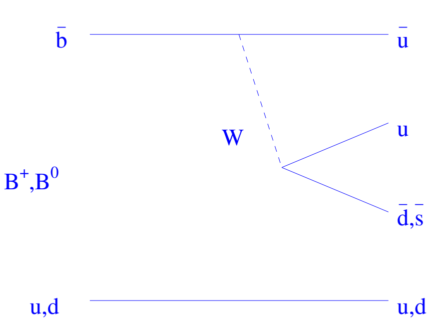
Outline:

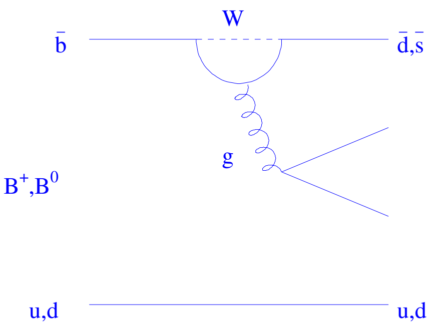
- Physics Motivation
- CESR - CLEO
- Analysis Strategy
- Preliminary Results

Physics Motivation

- Natural extension of $B \to \pi\pi, K\pi$ discovery
- Search for 7 rare $B \to VV$ decay channels:
  - $\rho^0\rho^0$
  - $K^{*0}\rho^0$
  - $K^{*0}K^{*0}$
  - $K^{*0}\overline{K^{*0}}$
  - $K^{*+}\rho^0$
  - $K^{*+}\overline{K^{*0}}$
  - $K^{*+}K^{*-}$
- Opportunity to see direct CP violation in the future.
- $K^{*0}K^{*0}$ mode is NOT expected to be seen because of the violation of rule $\Delta S = 1$

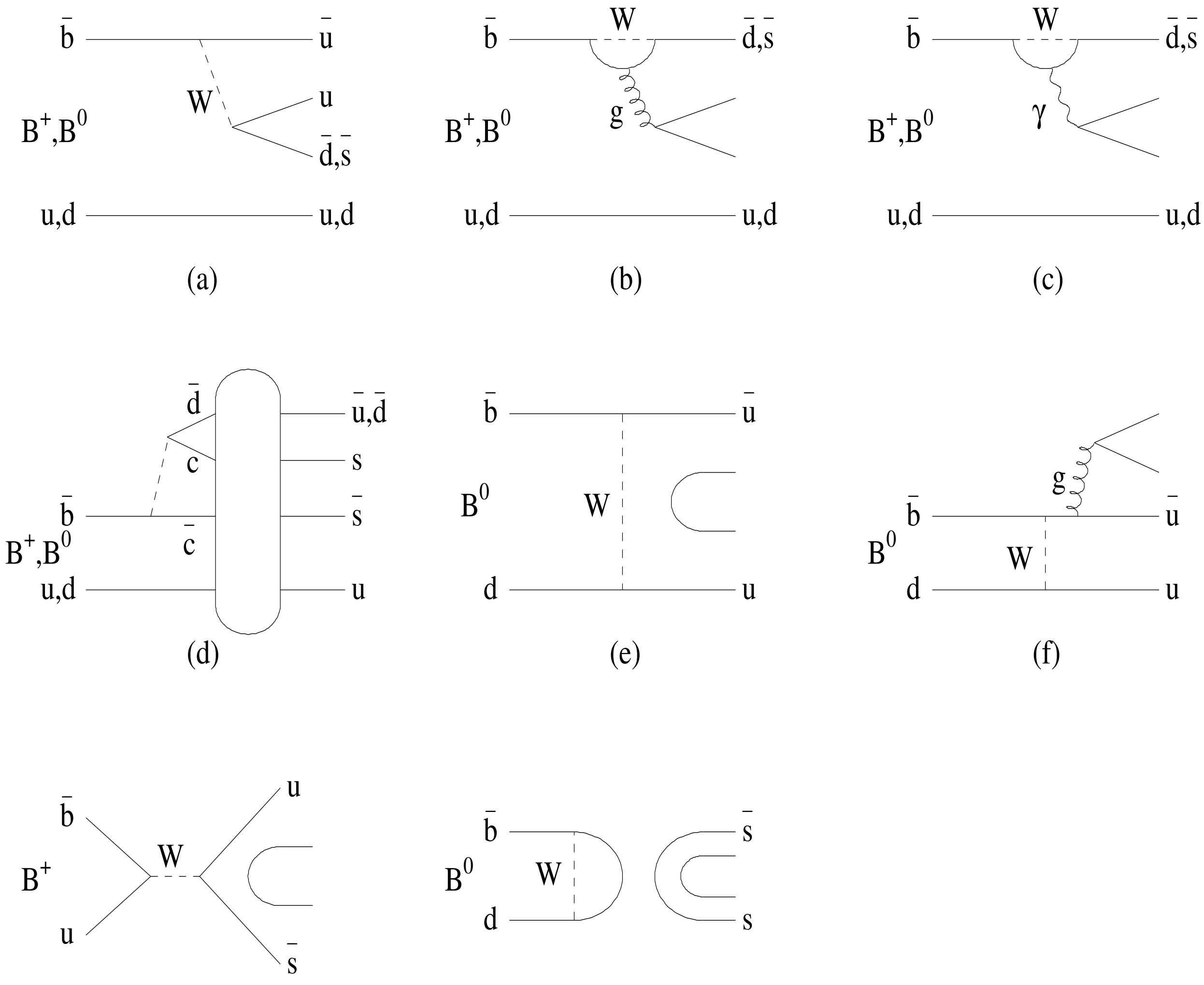


tree diagram



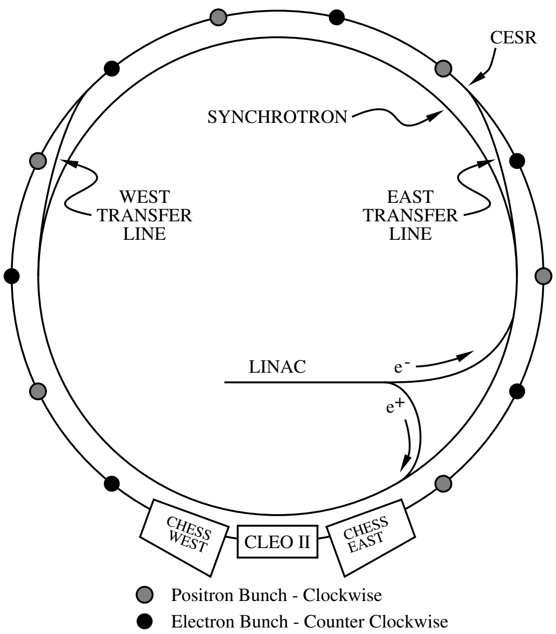
gluonic penguin

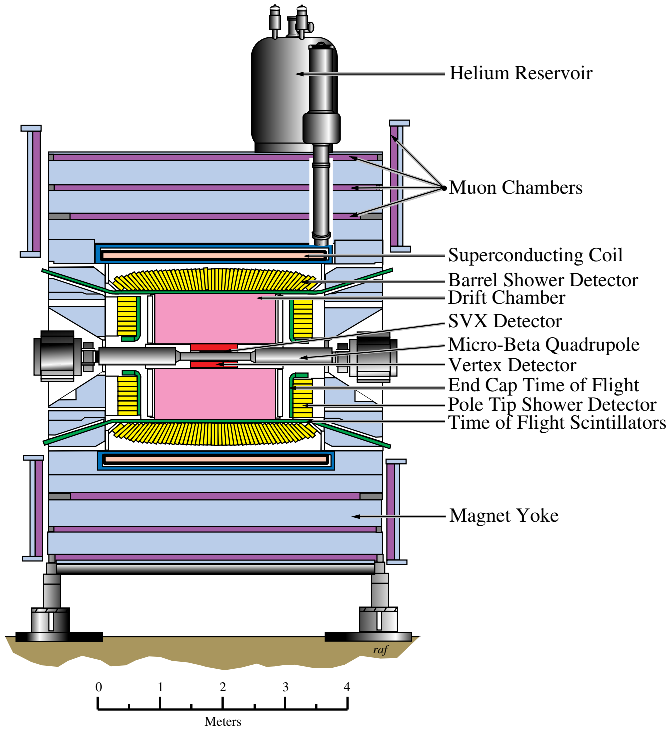
- Many possible decay mechanisms:



Feynman diagrams for $B \to VV$ decays: (a) tree diagram with internal W emission, (b) gluonic penguin, (c) electroweak penguin, (d) $b \to c$ tree diagram followed by final state interaction, (e) and (f) $b \to u$ W exchange, (g) annihilation, and (h) vertical W loop.

CESR and CLEO





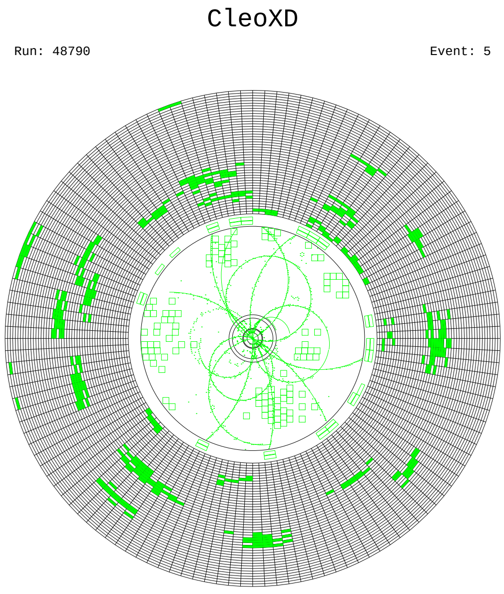
- Cornell Electron Storage Ring (CESR) operates mainly at 5.285 – 5.295GeV beam energy, on the $\Upsilon(4S)$ resonance. Data collected by CLEO detector.
- For backgrounds study, CLEO also collects data at energies just below the $\Upsilon(4S)$ resonance, where the "continuum" data of $e^+e^- \to q\bar{q}$ events are generated.

Analysis Strategy

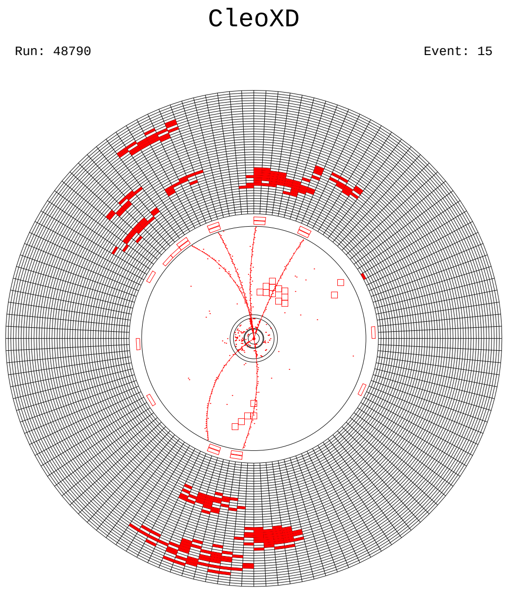
- On-resonance data: $9.1 fb^{-1}$, 9.7×10^6 $B\overline{B}$ events
- Off-resonance data: $4.6 fb^{-1}$, 15×10^6 continuum events
- 74×10^6 continuum MC and 35×10^6 $b \to c$ MC to simulate backgrounds
- Reconstruct vector meson through charged final states:
  - $\rho^0 \to \pi^+\pi^-$ $\quad \Delta M_\rho < 150\,\mathrm{MeV}/c^2$
  - $K^{*0} \to K^+\pi^-$ $\quad \Delta M_{K^*} < 50\,\mathrm{MeV}/c^2$
  - $K^{*+} \to K_S^0\pi^+$ $\quad \Delta M_{K^*} < 50\,\mathrm{MeV}/c^2$
  - $K_S^0 \to \pi^+\pi^-$ $\quad \Delta M_{K_S} < 10\,\mathrm{MeV}/c^2$
- The specific ionization, dE/dx, of charged tracks (π/K) are required to be within 3.0σ of their most probable values.
- Use event shape to discriminate isotropic $B\overline{B}$ events from jetty continuum events.
- Use beam constrained mass and beam energy to define signal events:
  - $M_B = \sqrt{E_{beam}^2 - (\sum \mathbf{p}_i)^2}$ $(\sigma = 2.5 \sim 3.0\,\mathrm{MeV}/c^2)$
  - $\Delta E = \sum E_i - E_{beam}$ $(\sigma = 15 \sim 20\,\mathrm{MeV})$
- Optimize cuts to maximize significance of a signal near observation threshold.

Event shape

At 5.29GeV beam energy, the B meson is produced almost at rest. The momentum distribution of the event is isotropic. For continuum events, the shape is "jet-like".



$e^+e^- \to \Upsilon(4S) \to B\bar{B}$

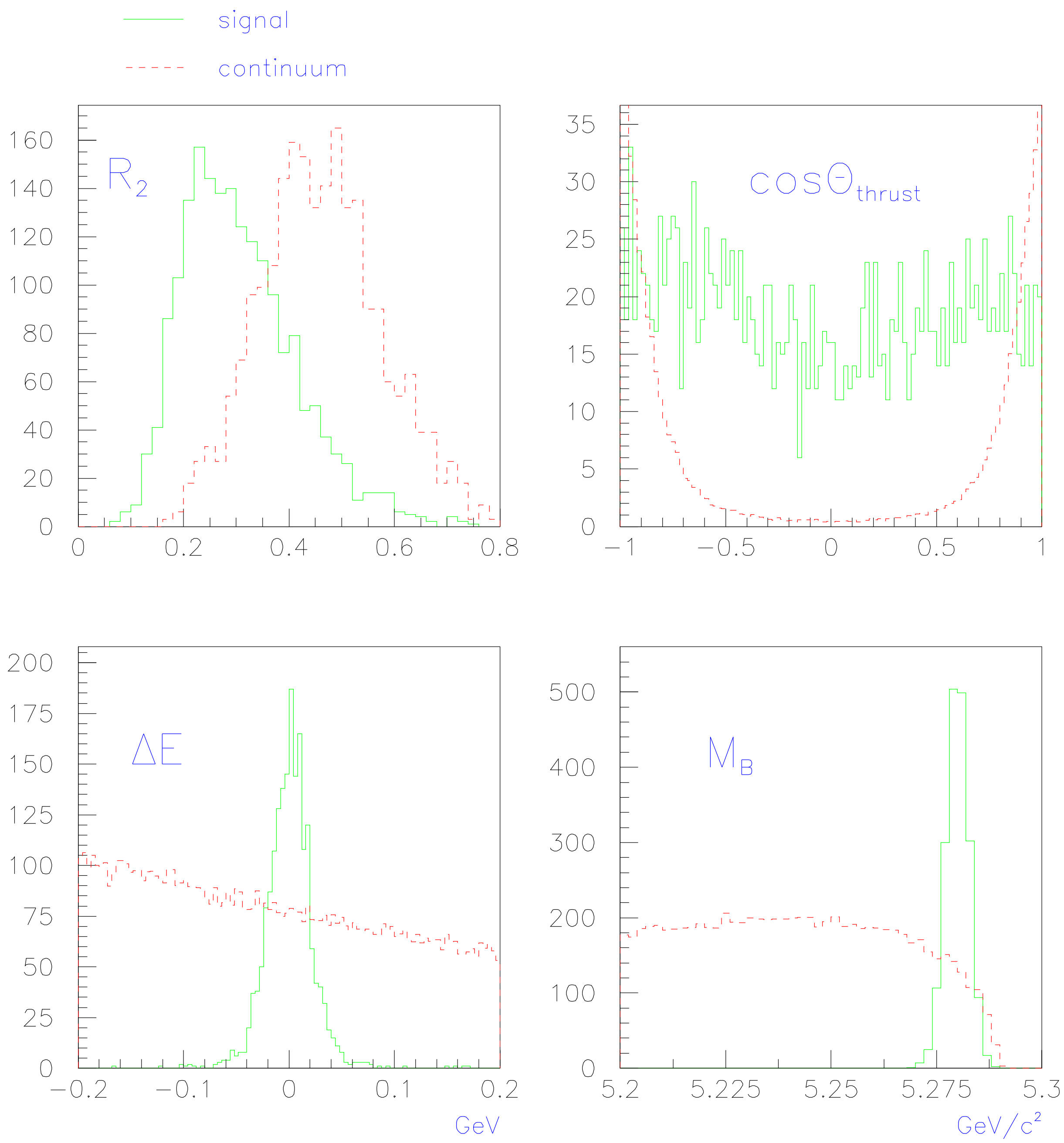


$e^+e^- \to q\bar{q} \to' hadron\ jets'$
(q=u,d,s,c)

Event-shape variables may be useful to suppress continuum:

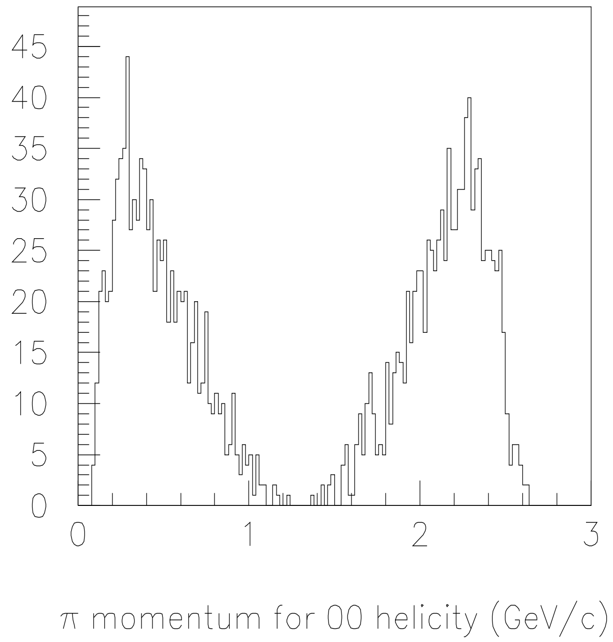
- R_2 – ratio of second to zeroth Fox-Wolfram moments
- $\cos\theta_{thrust}$ – angle between the thrust axes of the B candidate and the rest of the event

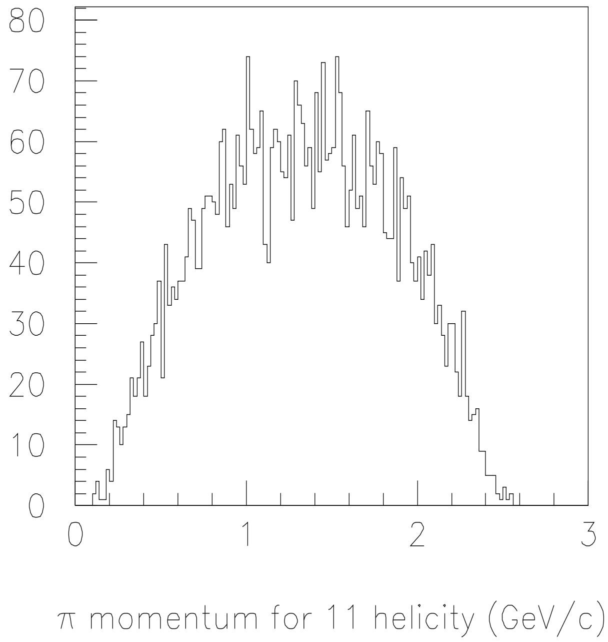
Signal and Backgrounds



Momentum distribution for 00 and 11 Helicity

These plots show the π^+ momentum spectrum from the $B^0 \to \rho^0\rho^0$ Monte Carlo for 00 and 11 helicities.





- The helicity 00 signal events have more low-momentum charged π and K tracks, for which the detector has lower acceptance. We expect lower signal efficiency for helicity 00 events.
- Separate analyses for pure helicity 00 and 11 of hypotheses. Results for any helicity distribution can be obtained by linear interpolation.

Cut Selection

Ignoring small differences due to statistics, we choose the following cuts:

Channel	R2	$\lvert\cos\theta_{tt}\rvert$	$\lvert\Delta E\rvert$	$\lvert\Delta M_B\rvert$
$\rho^0\rho^0$, $K^{*0}K^{*0}$, $K^{*0}\overline{K^{*0}}$, $K^{*0}\rho^0$, $K^{*+}\rho^0$, $K^{*+}\overline{K^{*0}}$	< 0.5	< 0.7	$< 40.0\,\mathrm{MeV}$	$< 5\,\mathrm{MeV}/c^2$
$K^{*+}K^{*-}$	< 0.5	< 0.9	$< 40.0\,\mathrm{MeV}$	$< 7\,\mathrm{MeV}/c^2$

- R_2 and $\cos\theta_{thrust}$ are the most effective event-shape cuts.
- The ΔE and B mass cuts are about 2σ.
- $K^{*+}K^{*-}$ is the cleanest channel due to the constraints for the two K_S^0. Accordingly, it has looser cuts.

Preliminary Results

Decay Mode	Helicity	Effi.	On4S Yield	Esti. Back.	90% U.L. on Yield	$\mathcal{BR}$
$\rho^0\rho^0$	00	13.4%	54	80.7	6.2	$< 4.8 \times 10^{-6}$
	11	16.9%				$< 3.8 \times 10^{-6}$
$K^{*0}\rho^0$	00	15.4%	123	130.2	16.0	$< 16.1 \times 10^{-6}$
	11	24.9%				$< 9.9 \times 10^{-6}$
$K^{*0}K^{*0}$	00	11.5%	22	16.7	13.5	$< 27.2 \times 10^{-6}$
	11	14.9%				$< 21.0 \times 10^{-6}$
$K^{*0}\overline{K^{*0}}$	00	12.5%	12	18.6	4.0	$< 7.4 \times 10^{-6}$
	11	14.8%				$< 6.3 \times 10^{-6}$
$K^{*+}\rho^0$	00	5.4%	12	9.2	9.1	$< 5.2 \times 10^{-5}$
	11	8.2%				$< 3.4 \times 10^{-5}$
$K^{*+}\overline{K^{*0}}$	00	5.0%	3	0.0	6.7	$< 6.2 \times 10^{-5}$
	11	7.2%				$< 4.3 \times 10^{-5}$
$K^{*+}K^{*-}$	00	3.2%	0	2.2	2.3	$< 6.7 \times 10^{-5}$
	11	4.8%				$< 4.4 \times 10^{-5}$

- Estimated background is the combination of off-resonance count and $b \to c$ MC count with normalization.
- No systematics has been assigned to the results.

Conclusion

Decay mode	Helicity	Preliminary $\mathcal{BR}$ (90% C.L.)	Theoretical Prediction [1, 2, 3, 4, 5, 6]
$\rho^0\rho^0$	00	$< 4.8 \times 10^{-6}$	$(0.54 \sim 1.6) \times 10^{-6}$
	11	$< 3.8 \times 10^{-6}$	
$K^{*0}\rho^0$	00	$< 16.1 \times 10^{-6}$	$(0.7 \sim 6.2) \times 10^{-6}$
	11	$< 9.9 \times 10^{-6}$	
$K^{*0}K^{*0}$	00	$< 27.2 \times 10^{-6}$	
	11	$< 21.0 \times 10^{-6}$	
$K^{*0}\overline{K^{*0}}$	00	$< 7.4 \times 10^{-6}$	0.96×10^{-6}
	11	$< 6.3 \times 10^{-6}$	
$K^{*+}\rho^0$	00	$< 5.2 \times 10^{-5}$	$(0.8 \sim 14) \times 10^{-6}$
	11	$< 3.4 \times 10^{-5}$	
$K^{*+}\overline{K^{*0}}$	00	$< 6.2 \times 10^{-5}$	$(1.0 \sim 1.8) \times 10^{-6}$
	11	$< 4.3 \times 10^{-5}$	
$K^{*+}K^{*-}$	00	$< 6.7 \times 10^{-5}$	
	11	$< 4.4 \times 10^{-5}$	

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