BEACH 2010

The IX International Conference on Hyperons, Charm, and Beauty Hadrons

HADRONIC *B* DECAYS AT BELLE

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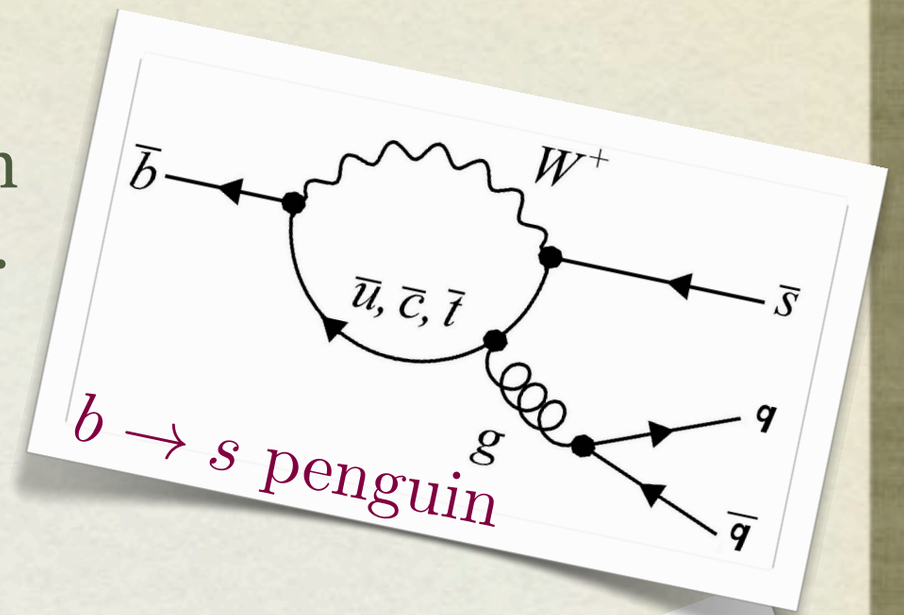
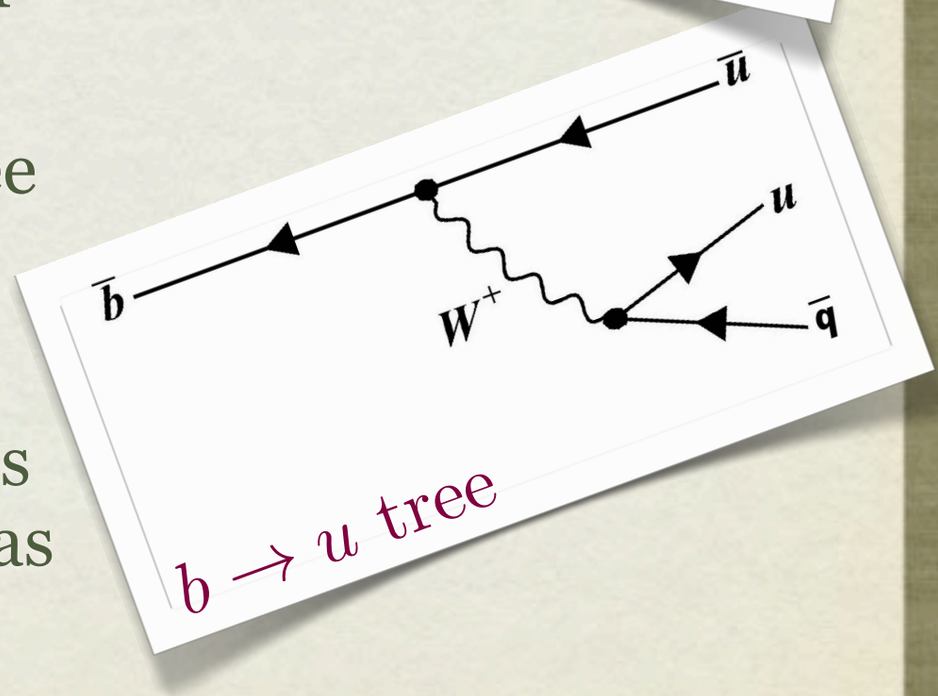
OUTLINE

- Introduction & Motivation
- Inclusive $B \to X_s \eta$
- $B \to VV$: $\rho^0 K^{*0}$ & $K^{*0} K^{*0}$
- Summary

INTRODUCTION & MOTIVATION

- The charmless hadronic B decays provide rich final states: an excellent tool to probe the SM.
- Dominated by $b \to s(d)$ penguin diagrams & $b \to u$ tree amplitudes:
  - Loop processes are ideal places to look for new physics / new particles.
  - Interference between those penguin & tree amplitudes is one of the key element to *CP* (and phase) analyses.
- The global picture of experimental data helps developing theoretical models or tools such as QCDF/pQCD/SCET approaches.





THE KEKB FACTORY

↑ Mt. Tsukuba

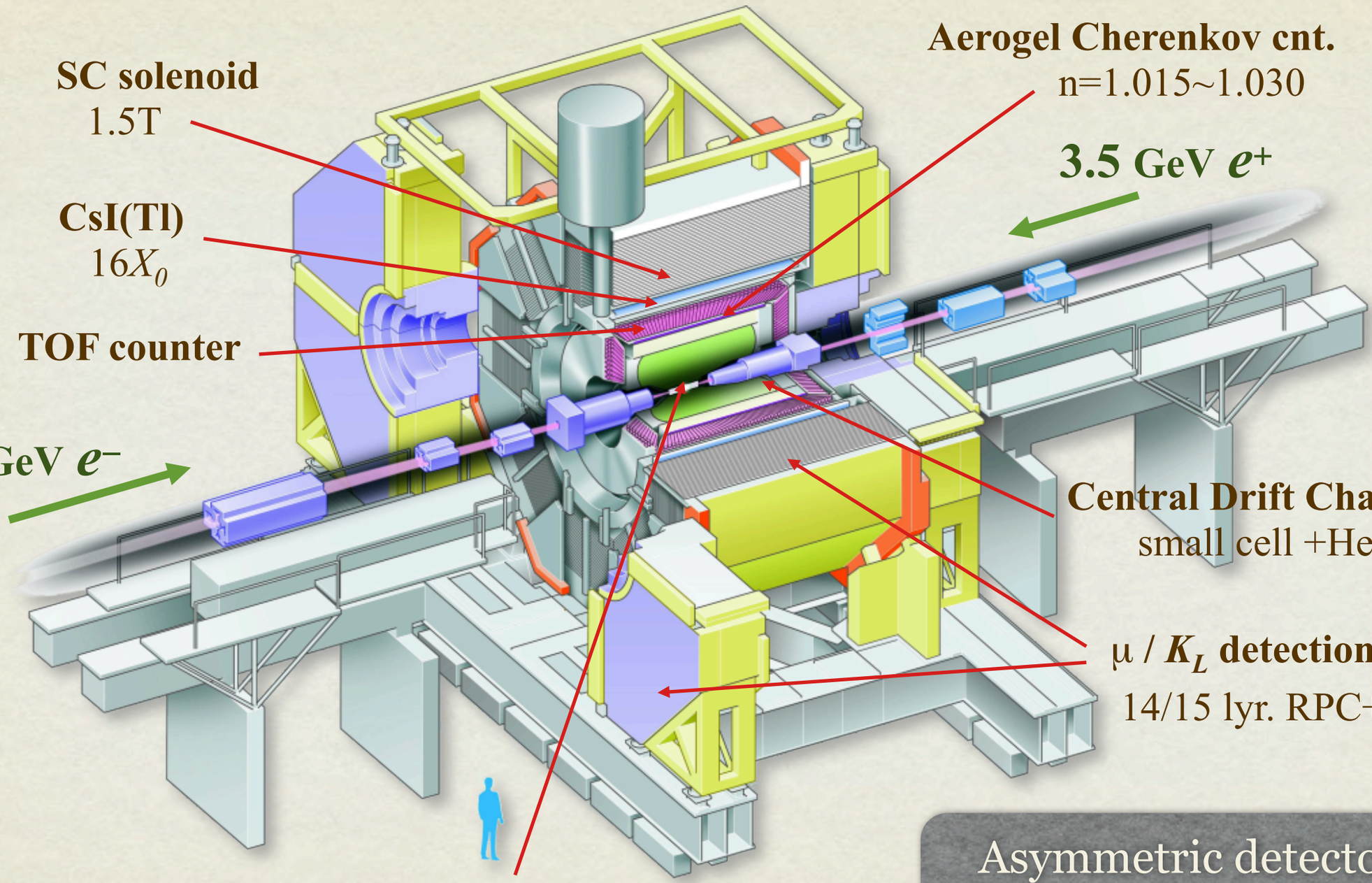
↙ Tsukuba Experimental Hall

↖ KEKB Storage Ring

Dorm & Restaurant →

e+e- linac →

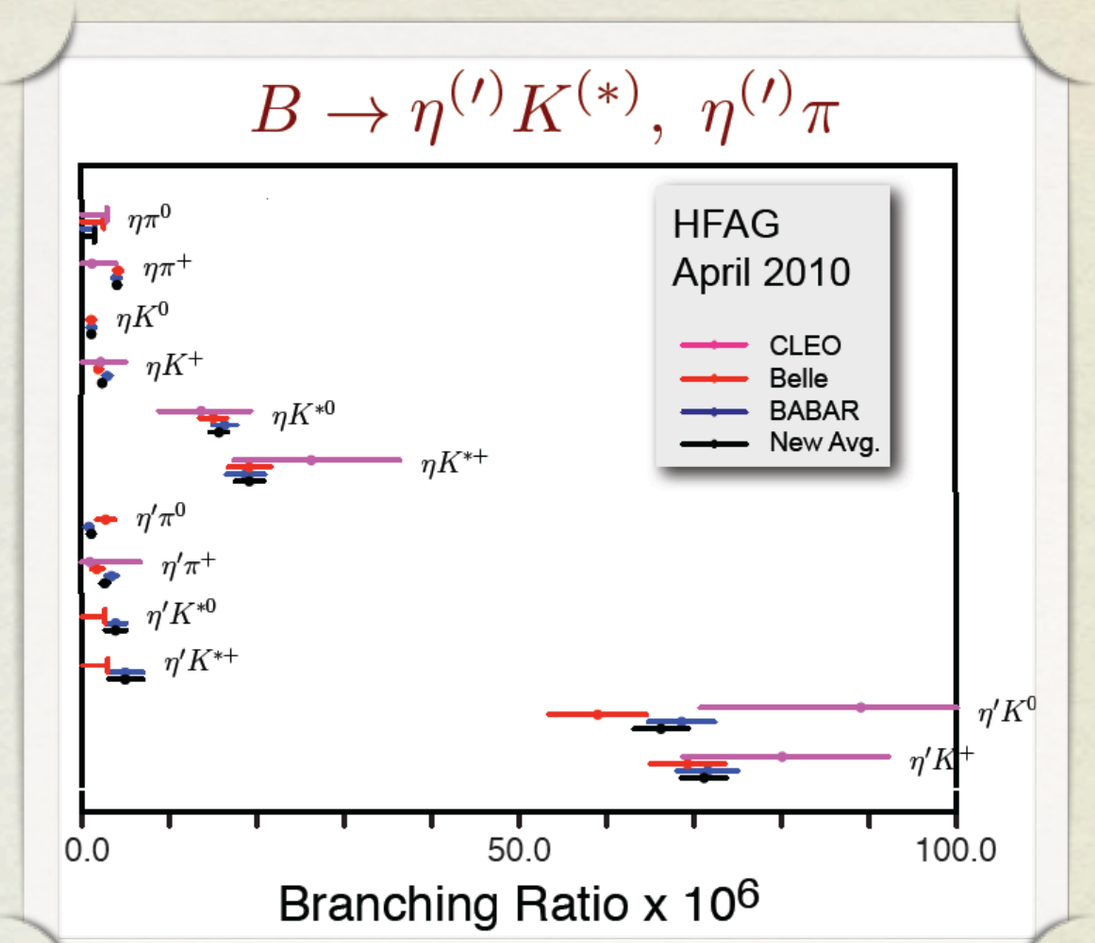
THE BELLE DETECTOR



Asymmetric detector for *CP* violation studies.

INCLUSIVE $B \to X_s \eta^{(\prime)}$

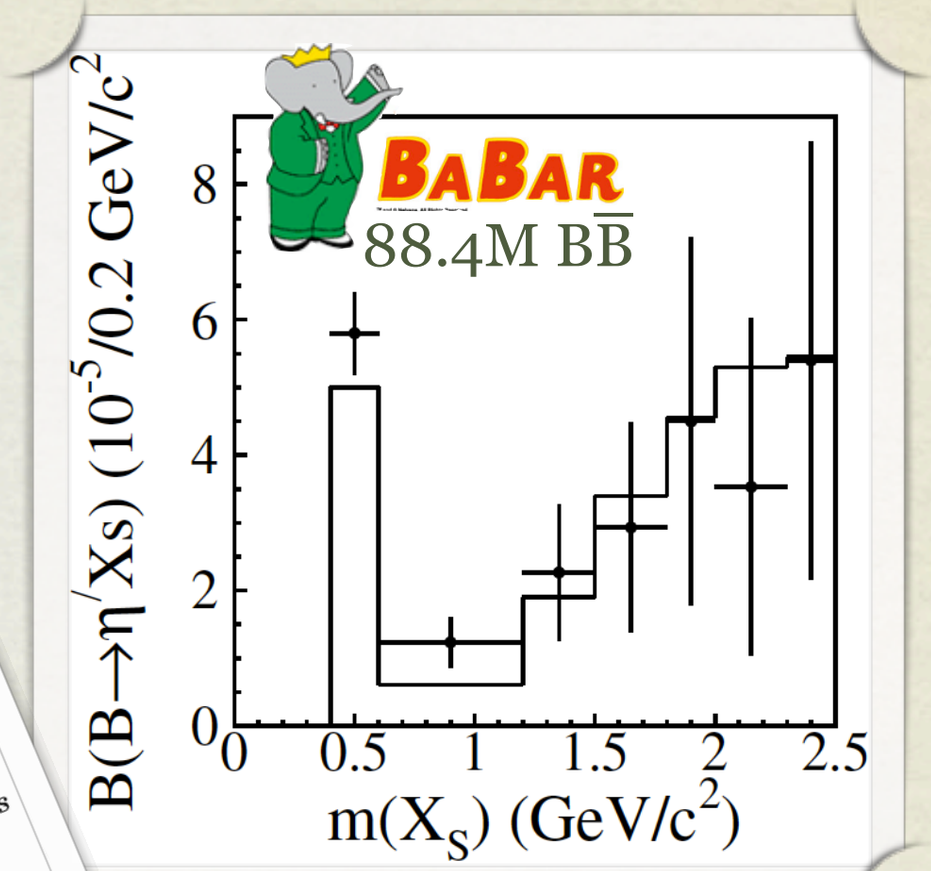
- $B \to X_s\, \eta^{(\prime)}$ decay proceeds with $b \to s$ penguin process: provide the sensitivity for New Physics beyond the SM.
- Involving η/η': probing the interference effects between the underlying pseudo-scalar octet and singlet components.
- The picture for exclusive modes are relatively well understood, but less clear for the inclusive (X_s) decays.



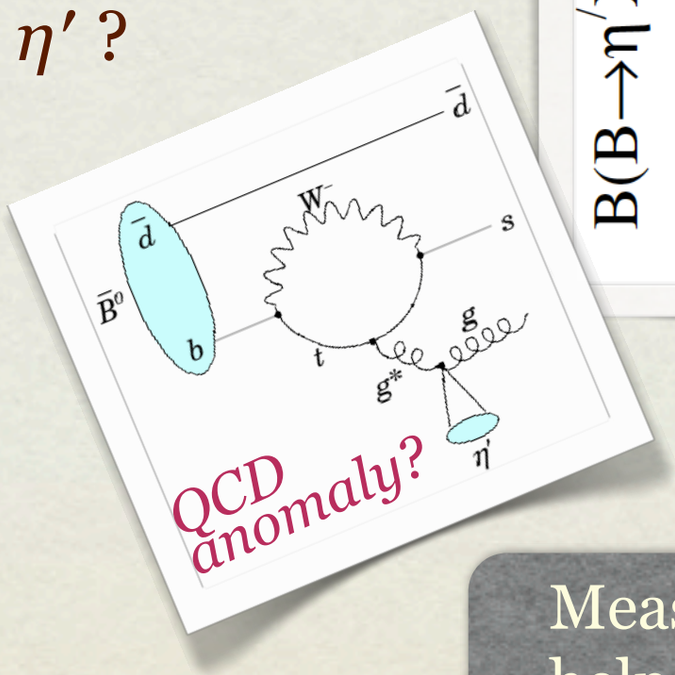
Exclusive Decays:
$\mathcal{B}(\eta' K, \eta K^*) > \mathcal{B}(\eta' K^*, \eta K)$

LEARNED FROM $X_s\eta'$

- Key features:
  #1: Unexpected large branching fractions.
  #2: Large X_s mass.
- Possible explanations:
  - QCD anomaly mechanism - couples two gluons to the singlet η' ?
  - Intrinsic charm component of the η' ?
  - Large contributions from non-perturbative charming penguin ?



PRL 93, 061801 (2004)



Measuring $B \to X_s\eta$ decay may help to clarify the picture!

EVENT RECONSTRUCTION

- A semi-inclusive method is introduced in the reconstruction:

$B^+ \to K^+(\pi^0)\eta$ $B^0 \to K^0_S(\pi^0)\eta$

$B^+ \to K^0_S\pi^+(\pi^0)\eta$ $B^0 \to K^+\pi^-(\pi^0)\eta$

$B^+ \to K^+\pi^+\pi^-(\pi^0)\eta$ $B^0 \to K^0_S\pi^+\pi^-(\pi^0)\eta$

$B^+ \to K^0_S\pi^+\pi^-\pi^+(\pi^0)\eta$ $B^0 \to K^+\pi^-\pi^+\pi^-(\pi^0)\eta$

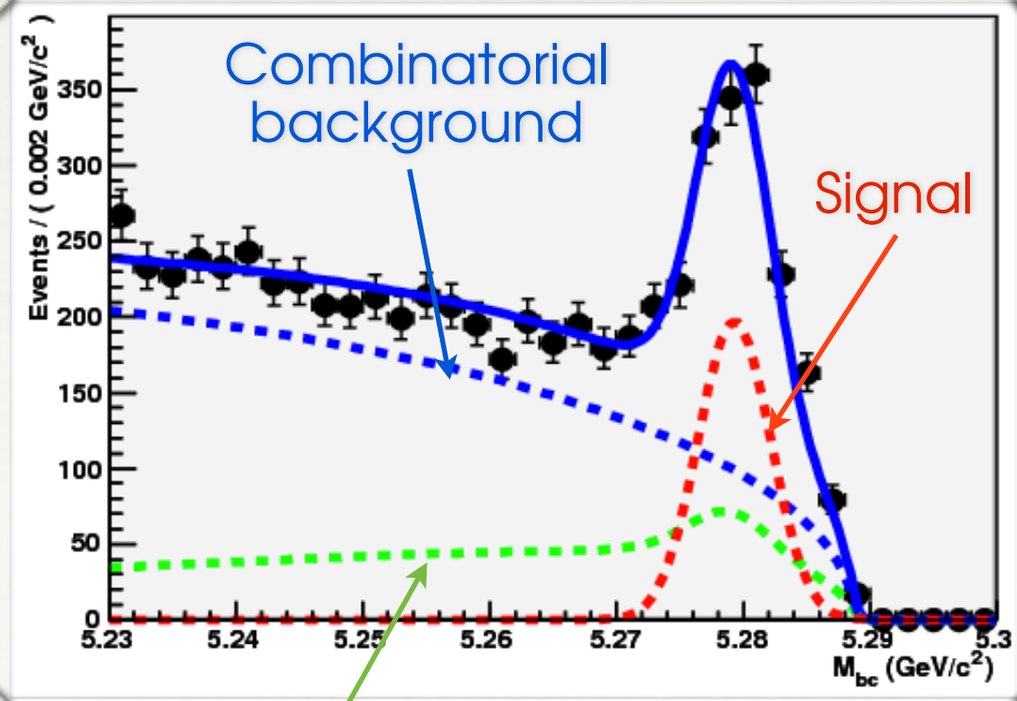
$B^+ \to K^+\pi^+\pi^-\pi^+\pi^-\eta$ $B^0 \to K^0_S\pi^+\pi^-\pi^+\pi^-\eta$

with $\eta \to \gamma\gamma$ (18 channels in total).

- Charm (D^0, D^+, η_c) / η' veto is applied - further reduce the contributions from other B decays.

Belle
657M

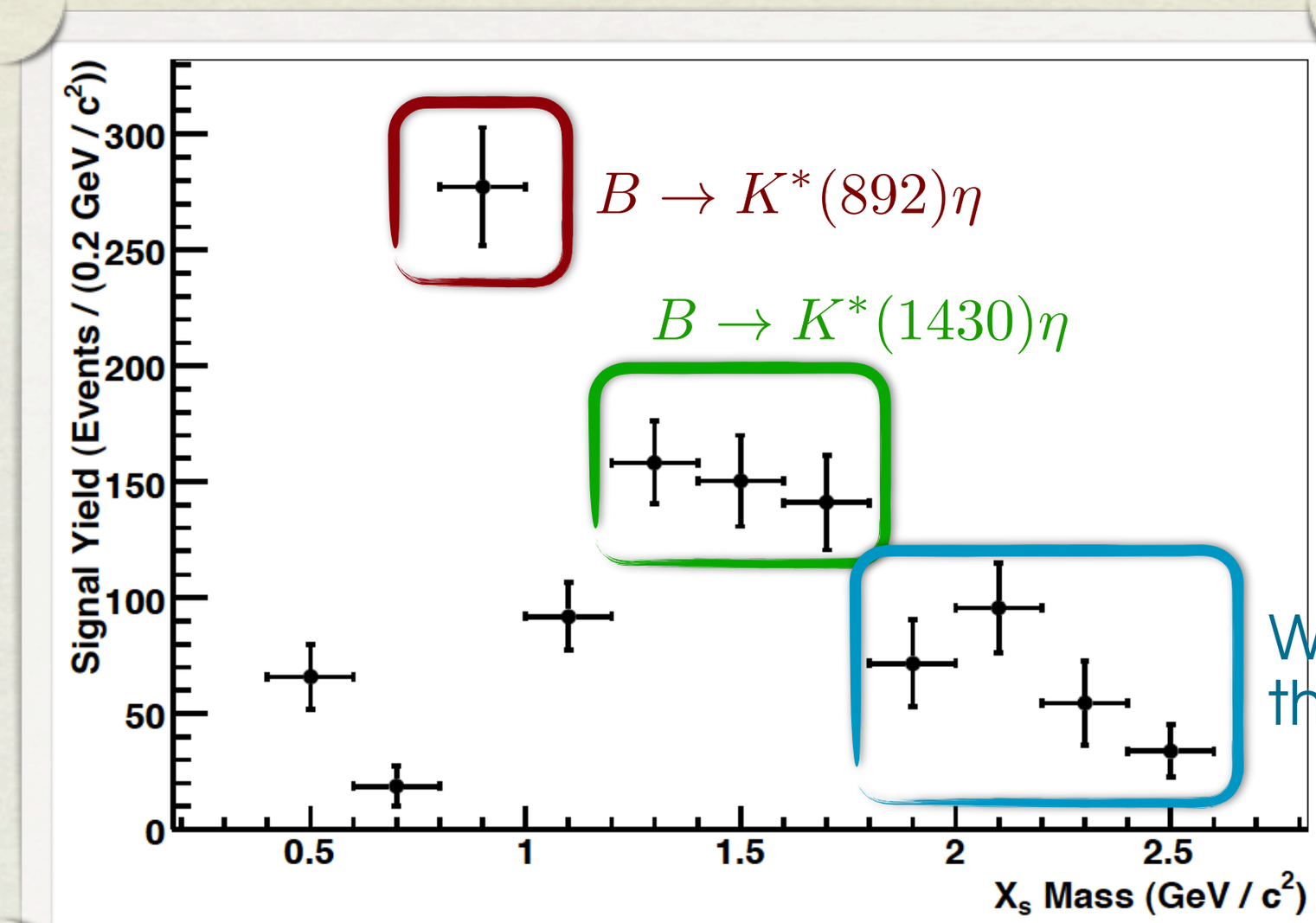
arXiv: 0910.4751



$$N(B \to X_s\eta) = 749 \pm 48 \pm 7$$

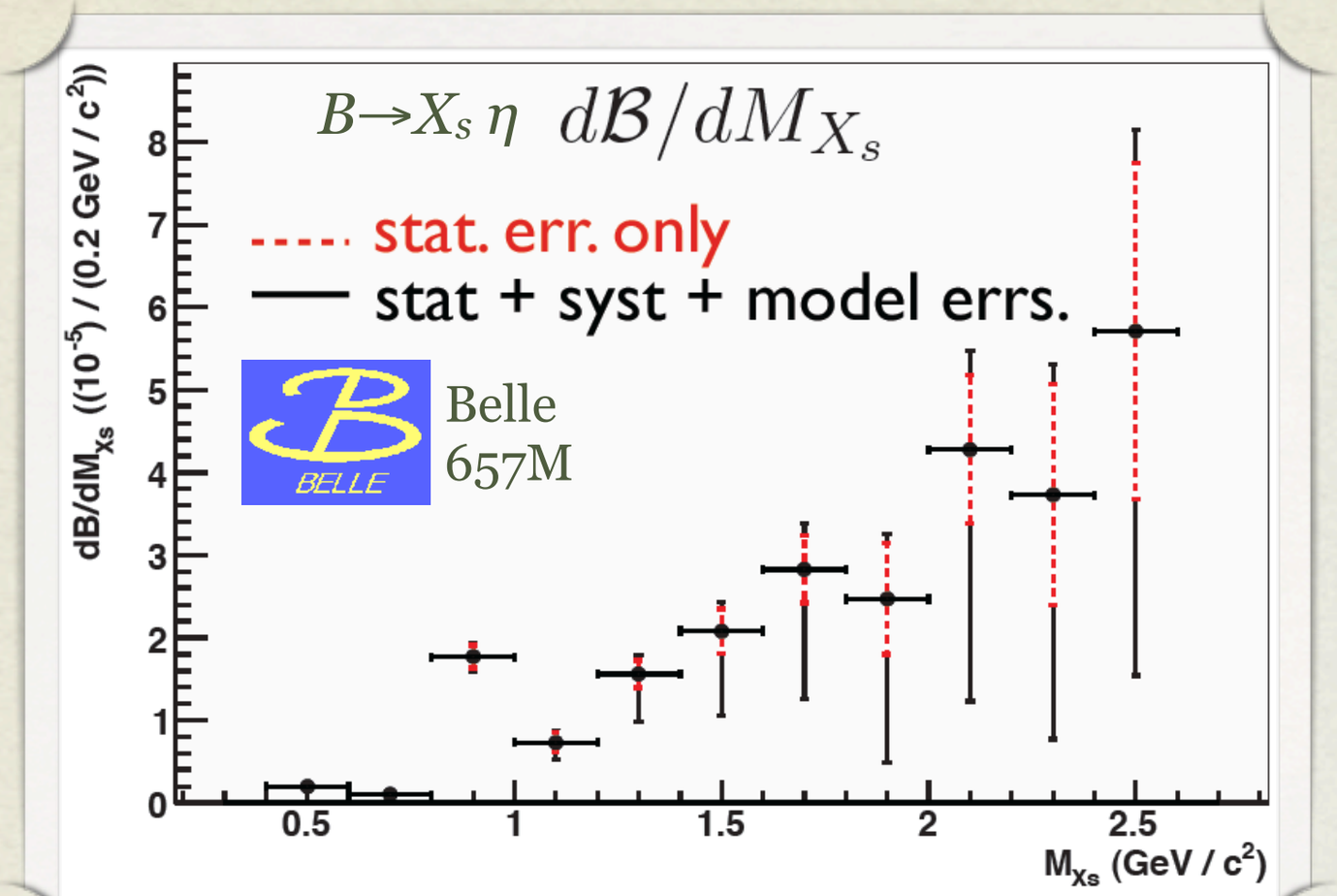
$$(1.0 < M_{X_s} < 2.6\ \mathrm{GeV}/c^2)$$

$X_s\eta$ SIGNAL YIELDS



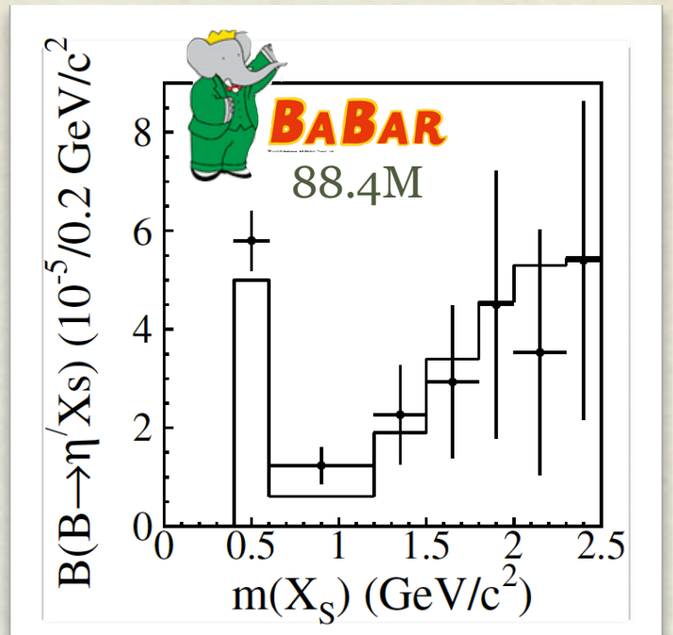
Signal yields are extracted by fitting the $M_{\rm bc}$ in bins of $M(X_s)$.

$X_s\eta$ BRANCHING FRACTIONS



Partial BF in $0.4<M(X_s)<2.6$ GeV/c^2:

$$\mathcal{B}(B \to X_s\eta) = (25.5 \pm 2.7 \pm 1.6^{+3.8}_{-14.1}) \times 10^{-5}$$



$B\to X_s\,\eta'$ from BaBar

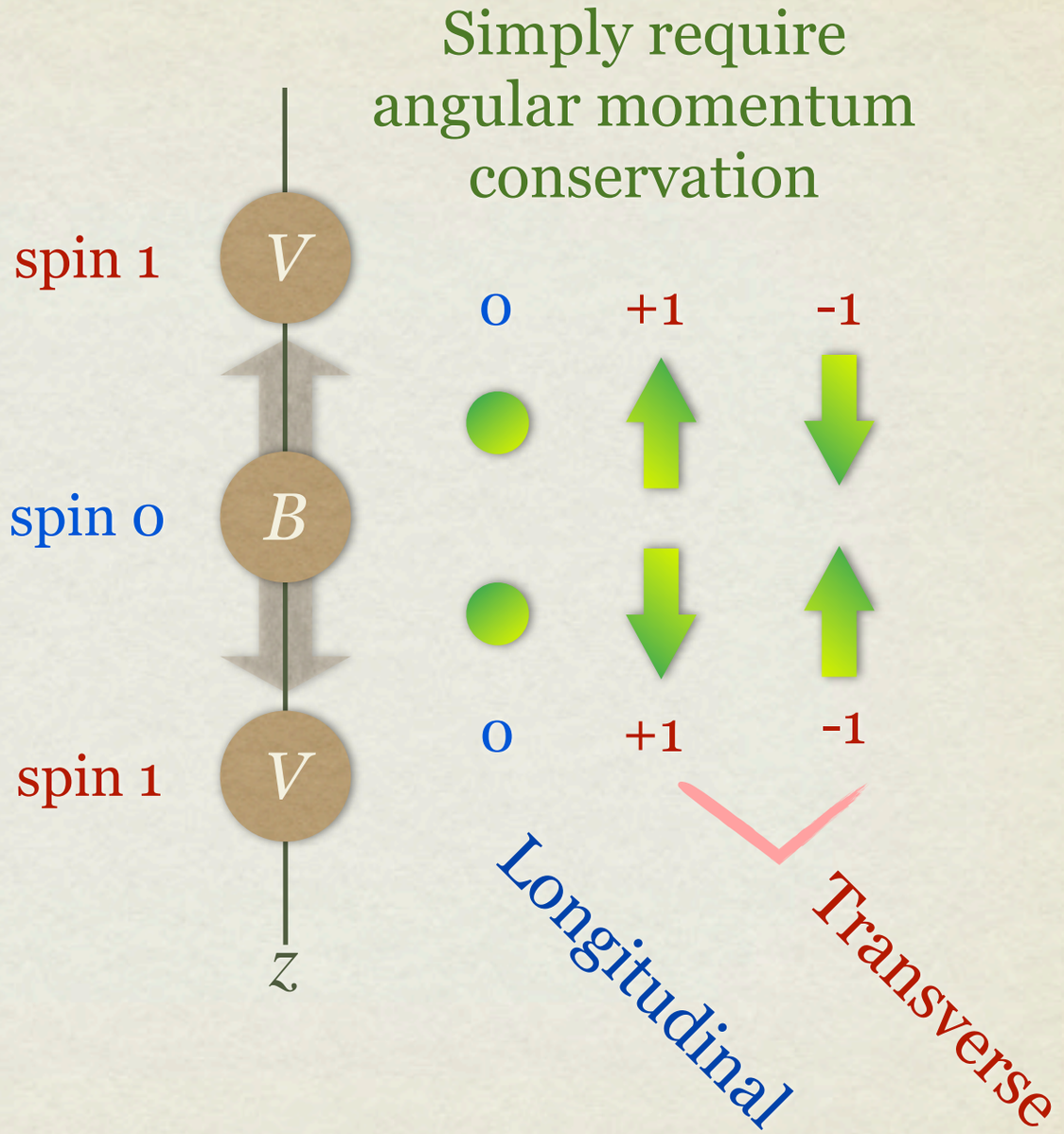
Large signals for $M(X_s)>2$ GeV for both η/η' channels: "large $\eta' gg$ coupling" hypothesis is disfavored.

$B \to VV$: INTRODUCTION

- A typical $B \to VV$ decay has three possible helicity states.
- Many measurable parameters in a single decay: BF/CP/Polarization - useful for theoretical studies.
- The naive SM prediction: Polarization should be dominated by the longitudinal component:

$$f_L \propto 1 - \mathcal{O}(\frac{M_V}{M_B})^2 \approx 95\%$$

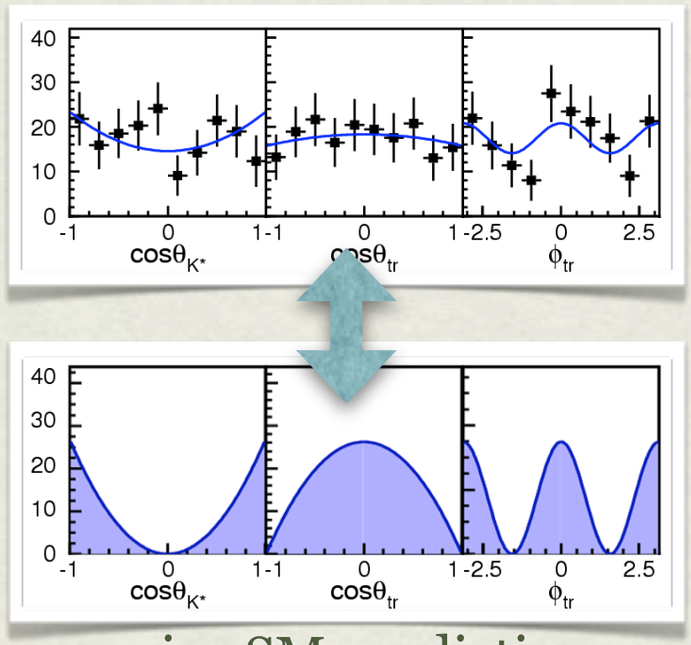
However, it's not the case in experimental data!



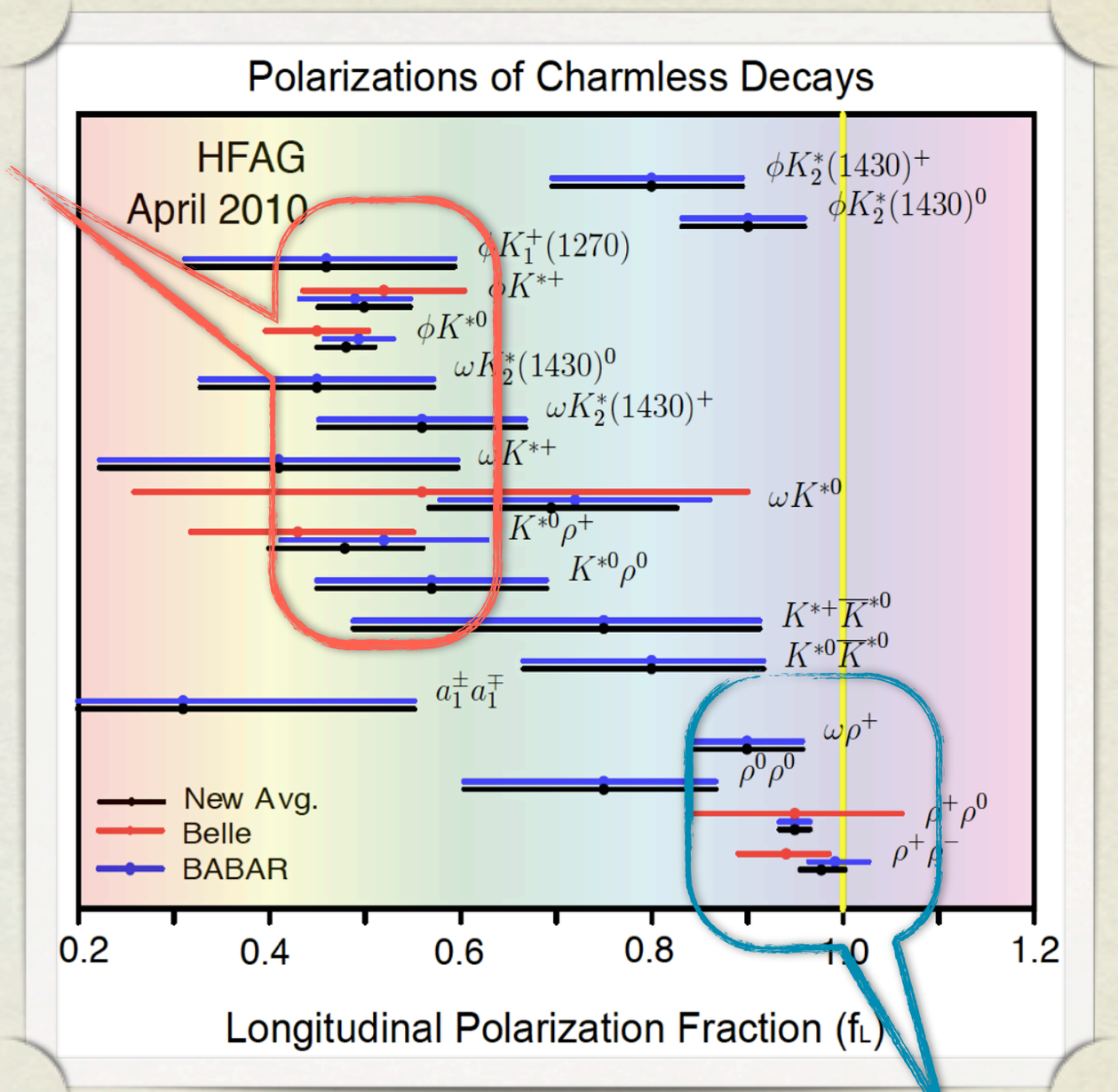
$B \to VV$: THE f_L PUZZLE

Penguin dominated modes are mostly puzzling!

e.g. Belle φK^* data
PRL 94, 221804 (2005)



naive SM prediction



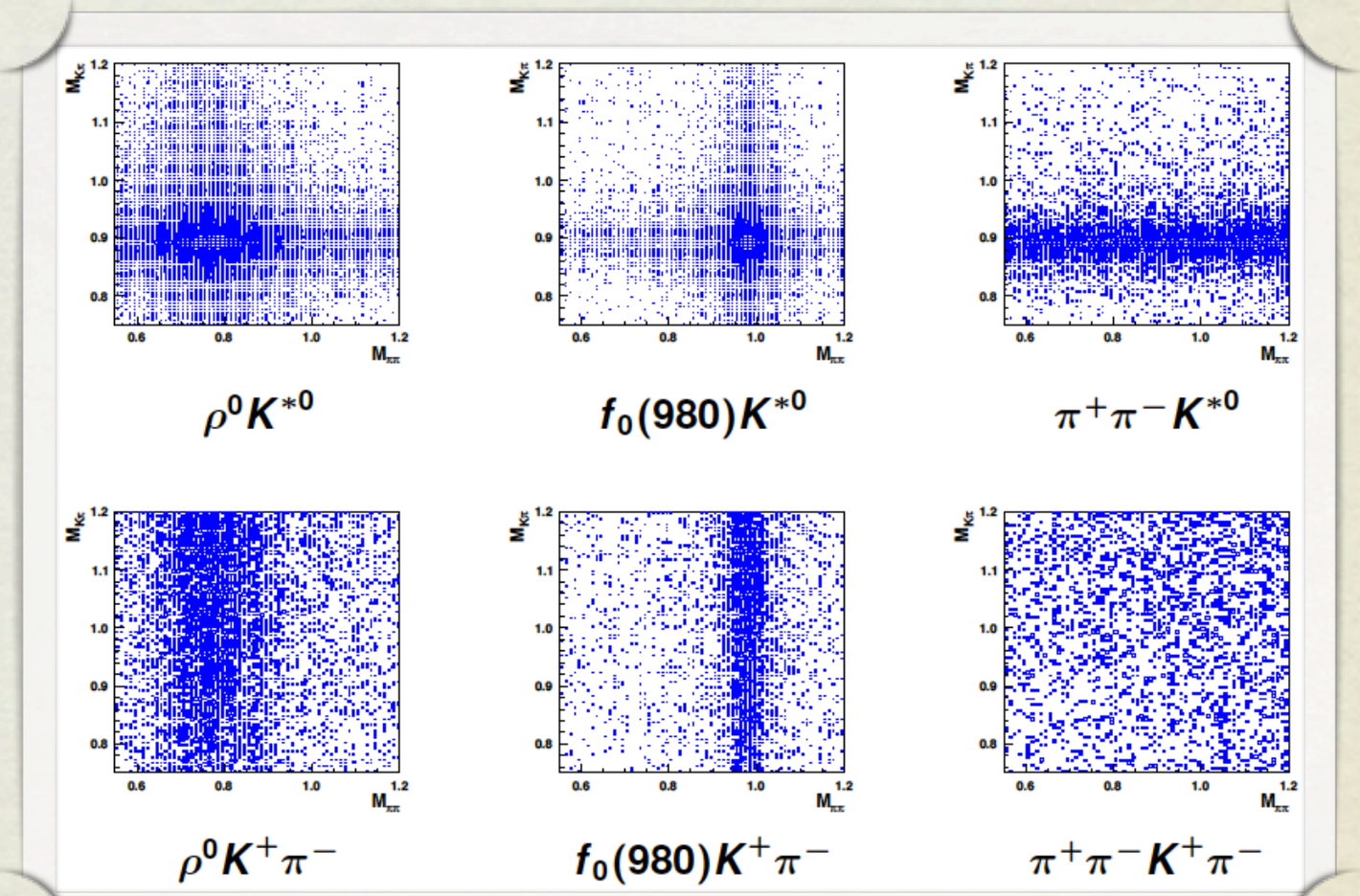
More measurements in penguin modes (e.g. ρK^*, K^*K^*) may help to understand the global picture!

Tree decays are generally okay.

RECENT BELLE *VV* RESULT: $B \to \rho^0 K^{*0}$

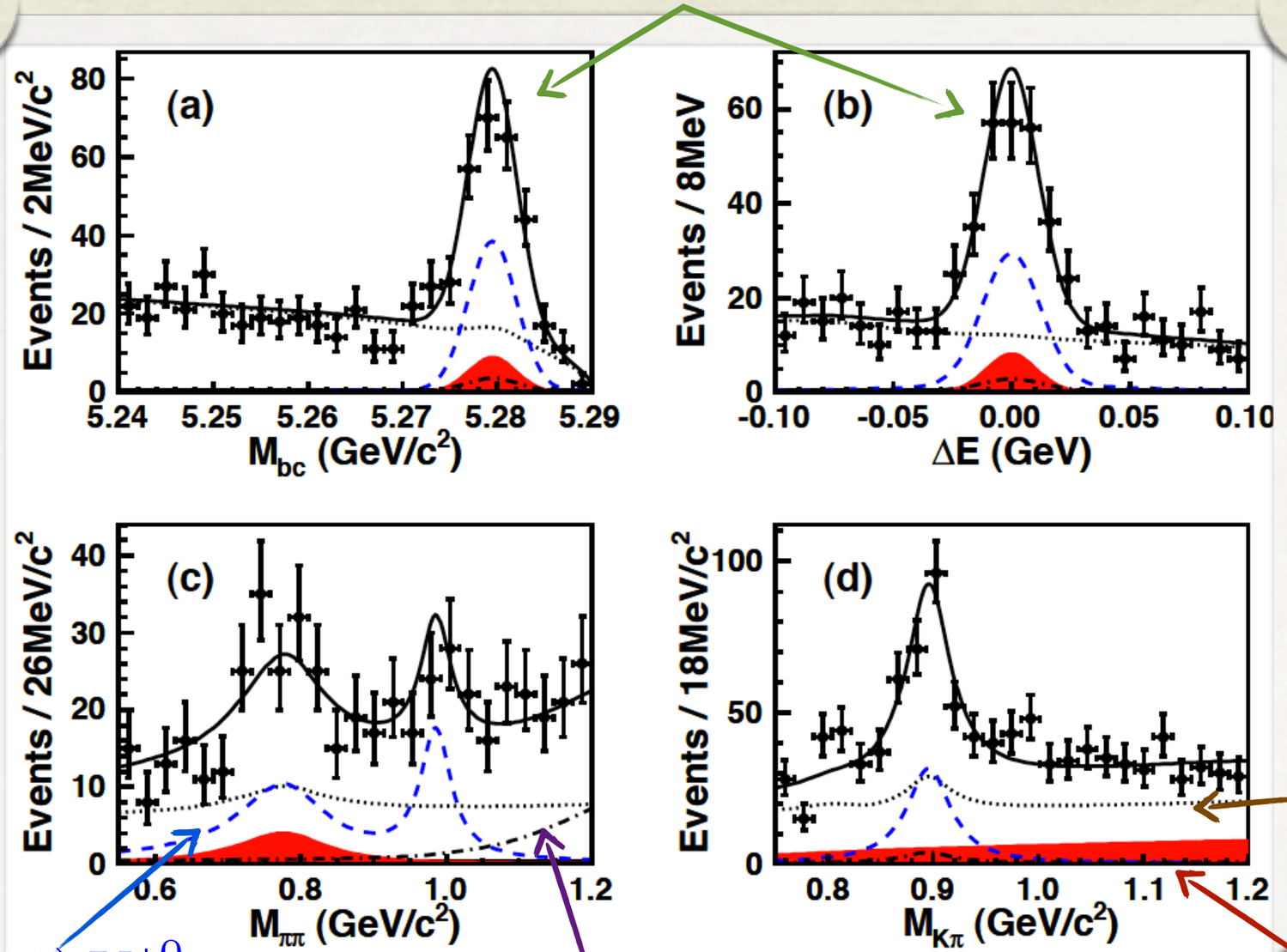
- Dominated by $b \to s$ penguin amplitude.
- Reconstruction with $\rho^0 \to \pi^+\pi^-$ & $K^{*0} \to K^+\pi^-$: the final state is shared by more then one decay channels:
- Use ΔE and $M_{\rm bc}$ to identify B mesons; consider $M(\pi^+\pi^-)$ and $M(K^+\pi^-)$ to distinguish different channels.
- Reject $D^{*\pm}X/D^{\pm}X/D^0X$ events actively.

Put them all together:
a 4D unbinned ML fit is introduced to the analysis!



RECENT BELLE *VV* RESULT: $B \to \rho^0 K^{*0}$

Very clear *B*-meson peak!



Belle
657M

PRD 80:051103 (2009)

$\rho^0 K^{*0} + f_0(980) K^{*0}$

other feed-down modes
e.g. $f_2(1270) K^{*0}$

background sum

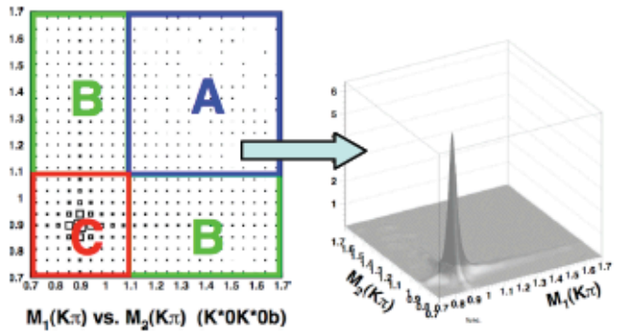
$\rho^0 K^+ \pi^-$

RECENT BELLE *VV* RESULT: $B \to \rho^0 K^{*0}$

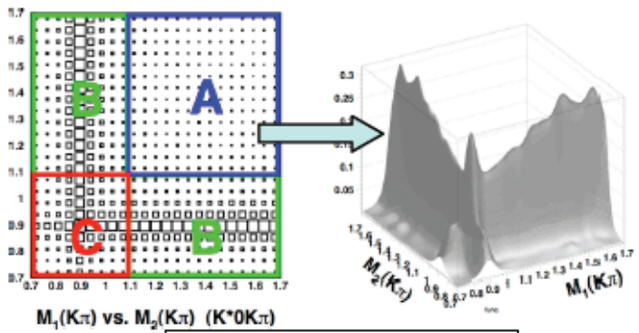
Mode	Yields	Sig.(σ)	BF (10^{-6})	U.L.(10^{-6})	
$\rho^0 K^{*0}$	$77.6\ ^{+28.6}_{-27.9}$	2.7	$2.1\ ^{+0.8\ +0.9}_{-0.7\ -0.5}$	<3.4	Not seen!?
$f_0(980)K^{*0}$	$51.2\ ^{+20.4}_{-19.3}$	2.5	$1.4\ ^{+0.6\ +0.6}_{-0.5\ -0.4}$	<2.2	
$\rho^0 K^+\pi^-$	$207.8\ ^{+39.8}_{-39.2}$	5.0	$2.8 \pm 0.5 \pm 0.5$	-	First Observation!
$f_0(980)K^+\pi^-$	$106.9\ ^{+31.6}_{-29.9}$	3.5	$1.4 \pm 0.4\ ^{+0.3}_{-0.4}$	<2.1	
$\pi^+\pi^- K^{*0}$	$200.7\ ^{+46.7}_{-44.9}$	4.5	$4.5\ ^{+1.1\ +0.9}_{-1.0\ -1.6}$	-	
$\pi^+\pi^- K^+\pi^-$	$-5.4\ ^{+54.9}_{-44.9}$	0.0	$-0.1\ ^{+1.2\ +1.4}_{-1.1\ -0.8}$	<2.1	

- Only partial phase spaces are covered for the non-resonant decays: $0.55 < M(\pi\pi) < 1.2$ GeV and $0.75 < M(K\pi) < 1.2$ GeV
- f_L ($\rho^0 K^{*0}$) is assumed to be 0.5 for the central value, 0 or 1 are used in systematic uncertainty estimation.

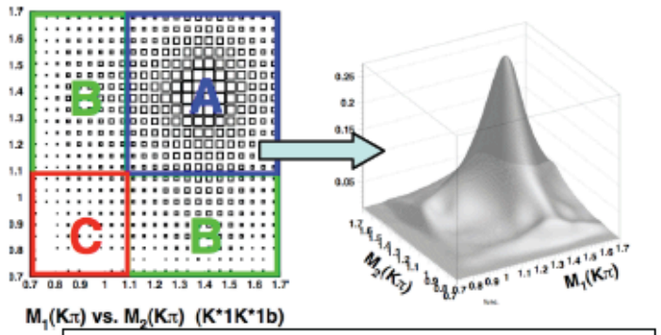
RECENT BELLE *VV* RESULT: $B \to K^{*0}\overline{K}^{*0}$



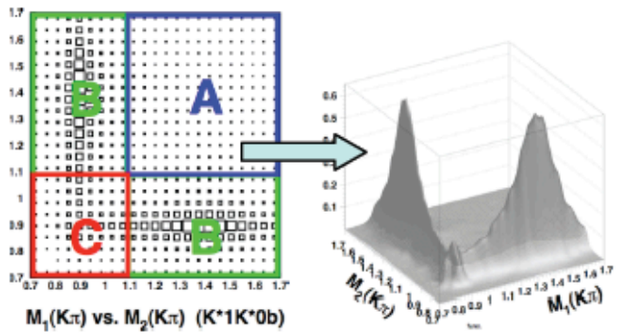
$B \to K^{*0}\overline{K}^{*0}$ (MC)



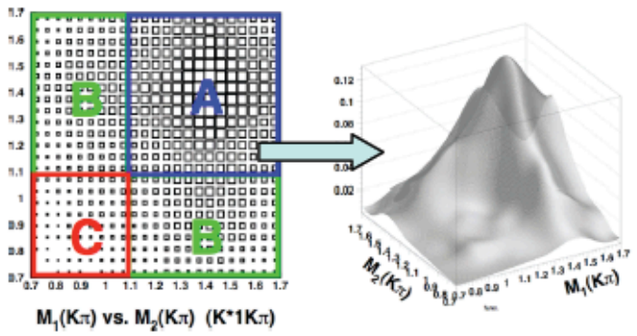
$B \to K^{*0}K\pi$ (MC)



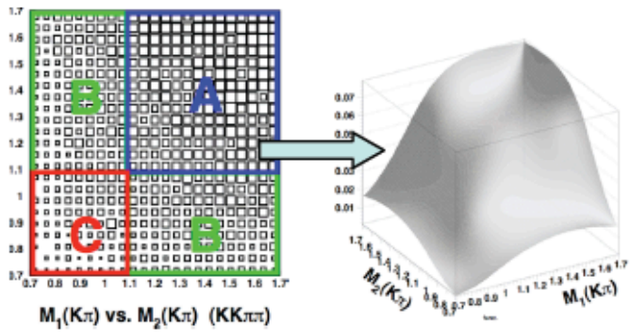
$B \to K_0^*(1430)\overline{K}_0^*(1430)$ (MC)



$B \to K_0^*(1430)\overline{K}^{*0}$ (MC)



$B \to K_0^*(1430)K\pi$ (MC)

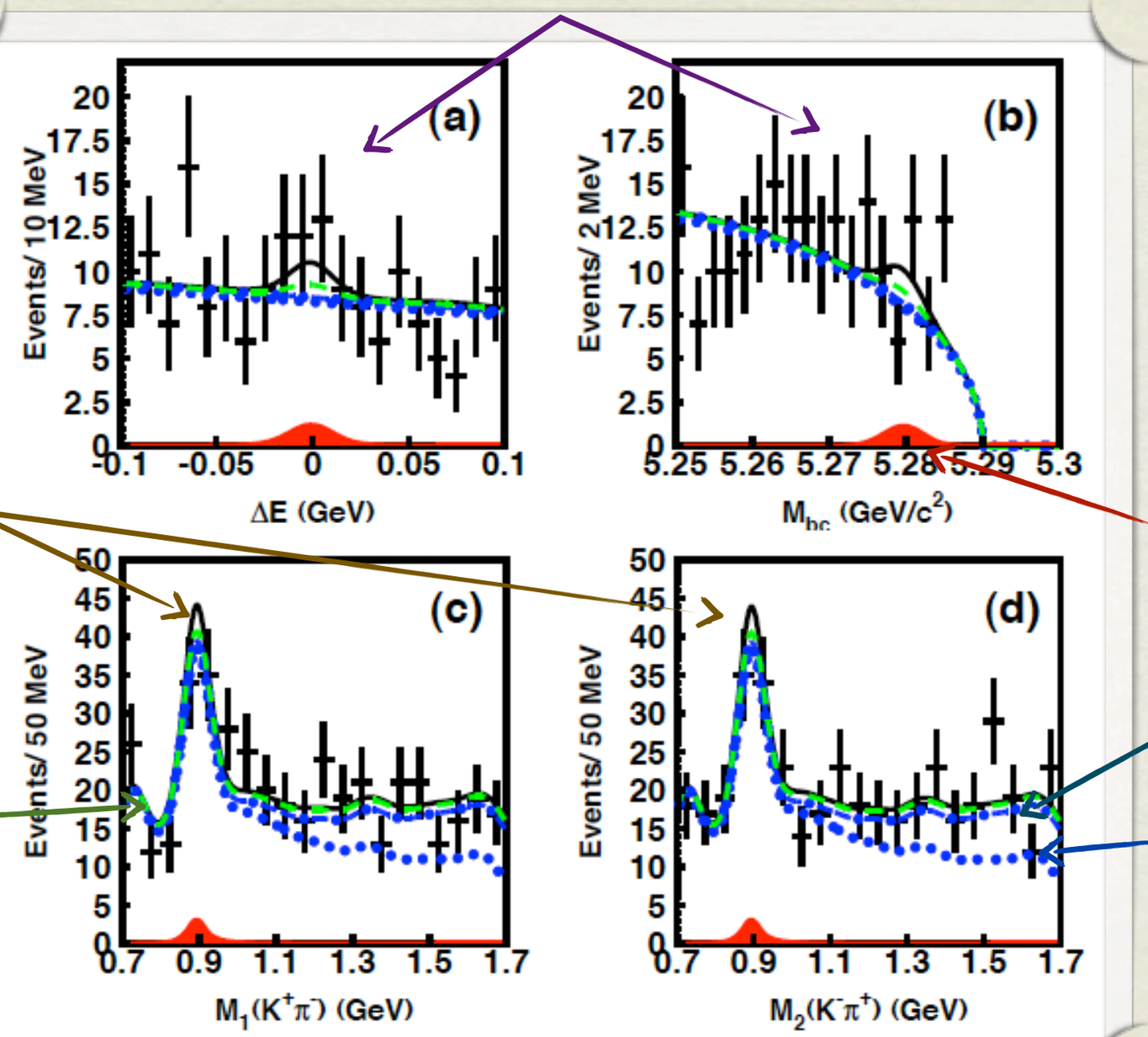


non-resonant $B \to K^+K^-\pi^+\pi^-$ (MC)

- Dominated by $b \to d$ penguin amplitude.
- A similar issue for $B \to K^{*0}\overline{K}^{*0} \to KK\pi\pi$: we need to include two $M(K\pi)$ in the fitting in order to distinguish different decay channels.

RECENT BELLE *VV* RESULT: $B \to K^{*0}\overline{K}^{*0}$

No significant *B* signals…



Belle
657M

PRD 81:071101 (2010)

$K^{*0}\overline{K}^{*0}$

Clear K^* peak!

Background from b→c processes

Other charmless *B* decays

Continuum background

RECENT BELLE *VV* RESULT: $B \to K^{*0}\overline{K}^{*0}$

Mode	Yields	Sig.(σ)	BF (10^{-6})	U.L.(10^{-6})
$K^{*0}\overline{K}^{*0}$	$7.7\ ^{+9.7}_{-8.5}\ ^{+2.8}_{-2.2}$	0.9	$0.26\ ^{+0.33}_{-0.29}\ ^{+0.10}_{-0.08}$	<0.8
$K^{*0}\overline{K}^{-}\pi^{+}$	$18\ ^{+48}_{-45}\ ^{+42}_{-41}$	0.3	$2.1\ ^{+5.6}_{-5.3}\ ^{+4.9}_{-4.8}$	<14
$K^{*0}(1430)\overline{K}^{*0}(1430)$	$79\ ^{+71}_{-70}\ ^{+56}_{-57}$	0.8	$3.2 \pm 2.9 \pm 2.3$	<8.3
$K^{*0}(1430)\overline{K}^{*0}$	$20 \pm 31\ ^{+40}_{-43}$	0.4	$0.7 \pm 1.1\ ^{+1.4}_{-1.5}$	<3.3
$K^{*0}(1430)K^{-}\pi^{+}$	$-223\ ^{+172}_{-171}\ ^{+160}_{-169}$	-	-	<32
$K^{+}\pi^{-}K^{-}\pi^{+}$	$158\ ^{+121}_{-118}\ ^{+104}_{-105}$	1.0	$29 \pm 22 \pm 19$	<72

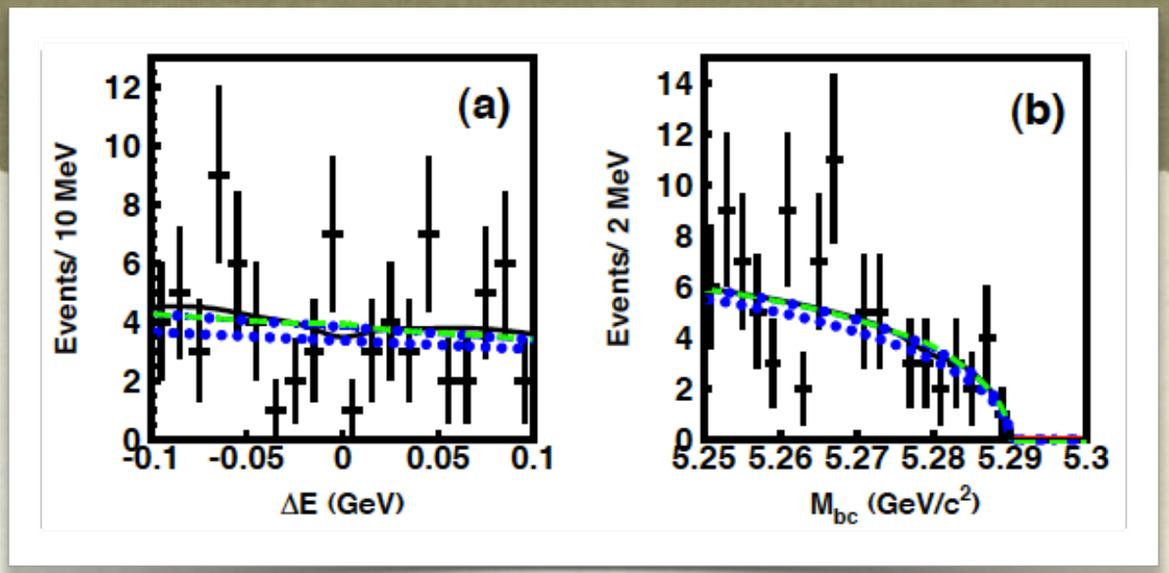
Not seen!

Large central value with large error.

- Only partial phase spaces are covered: 0.7 GeV < $M(K\pi)$ <1.7 GeV.
- f_L ($K^{*0}\overline{K}^{*0}$) is assumed to be 1.0 in the efficiency estimation.

RECENT BELLE *VV* RESULT: $B \to K^{*0} K^{*0}$

- Look for forbidden decays — a "wrong" charge combination: $B \to K^{*0} K^{*0} \to K^+\pi^- K^+\pi^-$.



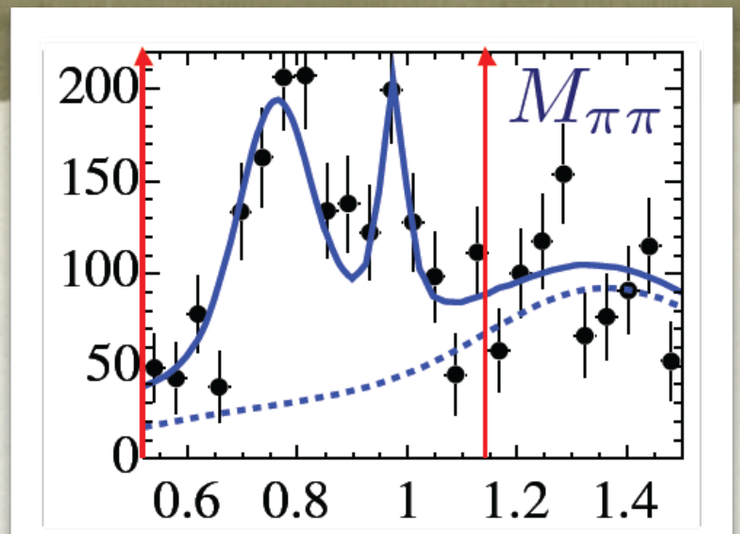
Mode	Yields	Sig.(σ)	BF (10^{-6})	U.L.(10^{-6})
$K^{*0}K^{*0}$	$-3.7 \pm 3.3\ ^{+2.5}_{-2.7}$	-	-	<0.2
$K^{*0}K^+\pi^-$	$0.5 \pm 32.3\ ^{+44}_{-40}$	0.0	$0.04 \pm 2.55\ ^{+3.43}_{-3.16}$	<7.6
$K^{*0}(1430)K^{*0}(1430)$	$-28 \pm 16\ ^{+88}_{-21}$	-	-	<4.7
$K^{*0}(1430)K^{*0}$	$8.0 \pm 18.7\ ^{+24}_{-30}$	0.3	$0.24 \pm 0.55\ ^{+0.71}_{-0.90}$	<1.7
$K^+\pi^-K^+\pi^-$	$11 \pm 28\ ^{+31}_{-102}$	0.3	$0.8 \pm 2.2\ ^{+2.4}_{-7.8}$	<6.0

As expected by theory: no clear hint of signal.

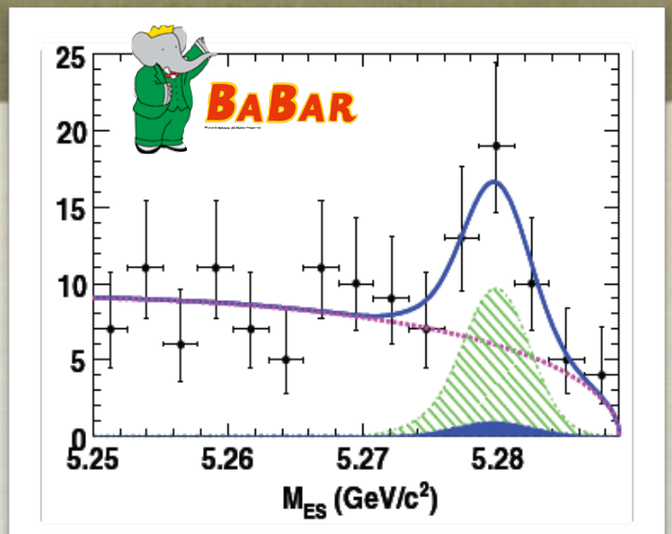
A COMPARISON WITH BABAR

These two *VV* channels has been measured by BaBar already…

PRL 97, 201801 (2006) $\rho^0 K^{*0}$



PRL 100, 081801 (2008) $K^{*0}\overline{K}^{*0}$



- $B \to \rho^0 K^{*0}$

Experiment	N(*BB*)	Yields	Sig.(σ)	BF (10^{-6})	f_L
Belle	657M	$77.6\ ^{+28.6}_{-27.9}$	2.7	$2.1\ ^{+0.8}_{-0.7}\ ^{+0.9}_{-0.5}$ (<3.4)	*not measured*
BaBar	232M	185±30	5.3	5.6±0.9 ±1.3 !?	0.57±0.09±0.08

- $B \to K^{*0}\overline{K}^{*0}$

Experiment	N(*BB*)	Yields	Sig.(σ)	BF (10^{-6})	f_L
Belle	657M	$7.7\ ^{+9.7}_{-8.5}\ ^{+2.8}_{-2.2}$	0.9	$0.26\ ^{+0.33}_{-0.29}\ ^{+0.10}_{-0.08}$ (<0.8)	*not measured*
BaBar	383M	$33.5\ ^{+9.1}_{-8.1}$	6.0	$1.28\ ^{+3.5}_{-3.0}$ ±0.11 !?	$0.80\ ^{+0.10}_{-0.12}$ ±0.12

SUMMARY

- We present two recent measurements with 657M B-meson pairs recorded by the Belle detector:
  - $B \to X_s \eta$ measurement is carried out with a semi-inclusive method. A large branching fraction is found for $M(X_s) > 2$ GeV/c^2, following the same track in the η' channel.
  - Two penguin dominated $B \to VV$ channels and the associated decays are studied; the three body $B \to \rho^0 K^+ \pi^-$ decay is observed for the first time. Some differences are found by comparing Belle/BaBar results — a further investigation is needed.

Stay tuned, more interesting results are coming in the near future.