Charmless two-body decays

Ascelin Gordon, The University of Melbourne

representing the Belle Collaboration

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Outline

- Analysis Overview
- $B \to hh$ (10 modes)
  - $K^+\pi^-$, $K^+\pi^0$, $K^0\pi^+$, $K^0\pi^0$, $\pi^+\pi^-$, $\pi^+\pi^0$, $\pi^0\pi^0$, K^+K^-, $K^+\bar{K}^0$, $K^0\bar{K}^0$
  - BELLE-CONF-0219
- $B \to \rho\pi$ (3 modes)
  - $\rho^0\pi^+$, $\rho^\pm\pi^\mp$, $\rho^0\pi^0$
  - BELLE-CONF-0220
- $B^+ \to \rho^+\rho^0$ (1 mode)
  - BELLE-CONF-0255
- Conclusions

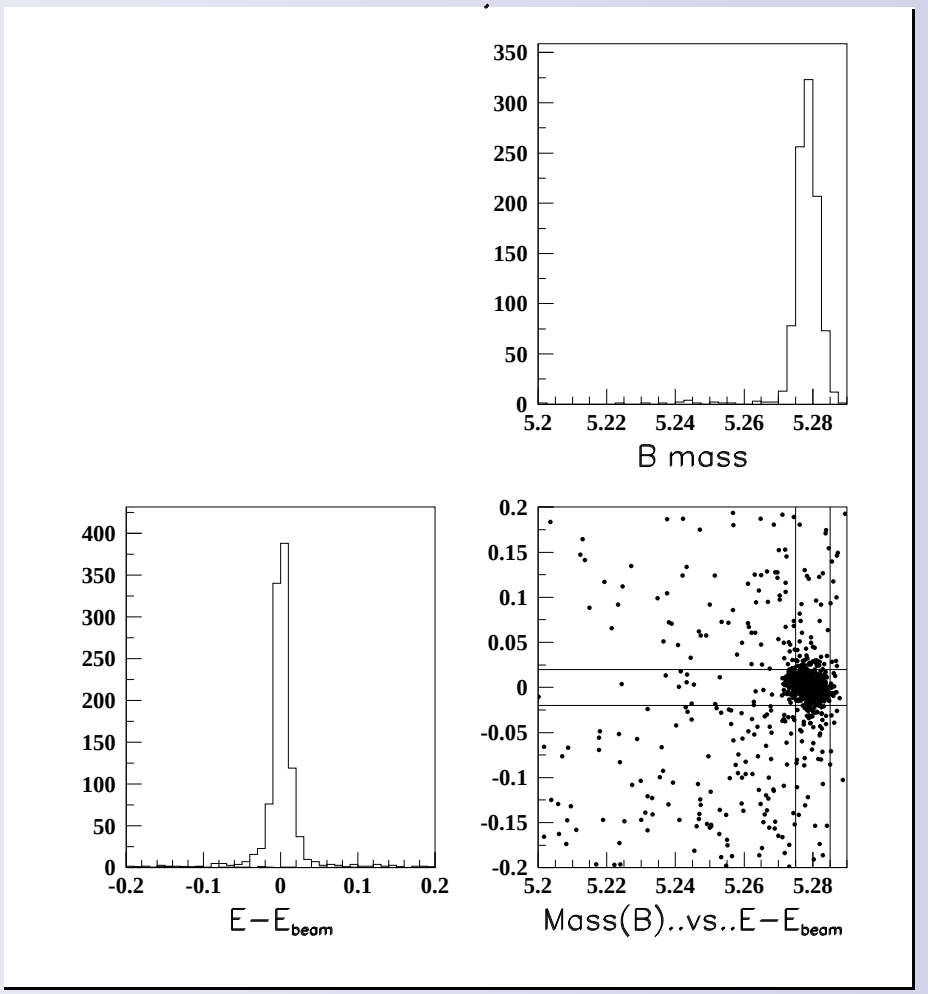
- $\rho^+\rho^0$ analysis done with a 43 fb^{-1} data set

- All other analyses done with a 29 fb^{-1} data set.

- A_{cp} measurement for hh modes presented separately.

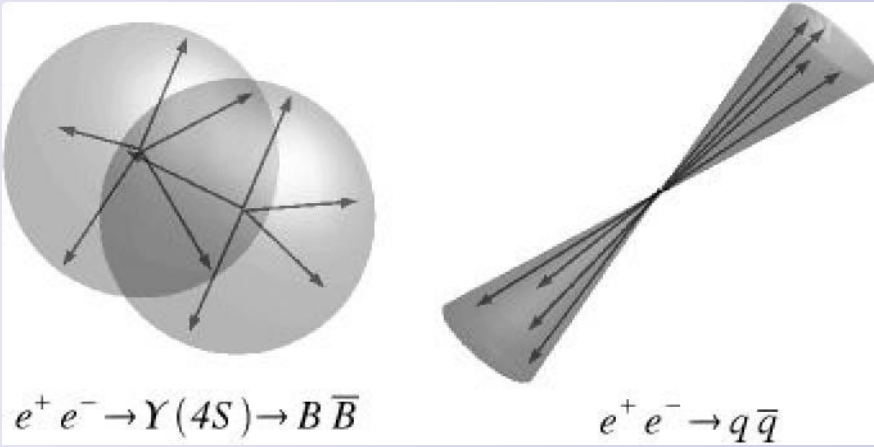
B meson reconstruction

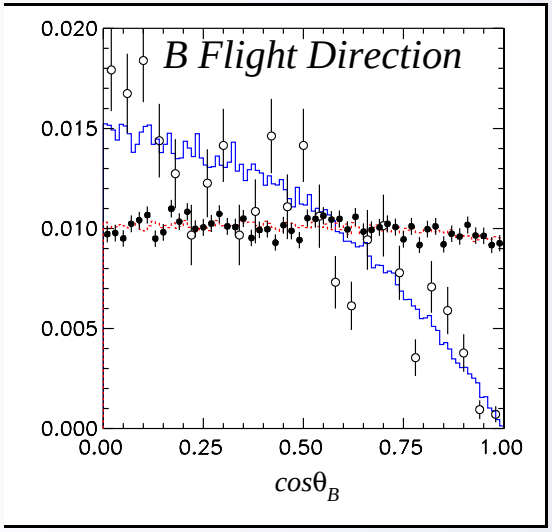
- B meson events are kinematically separated using the 2 variables
  - $\Delta E = E_B - E_{\text{beam}}$
  - $M_{bc} = \sqrt{E^2_{\text{beam}} - p^2_B}$
- M_{bc} dominated by beam energy spread
- Incorrect mass hypothesis or incorrectly reconstructed B's produce a shift in $\Delta E \rightarrow$ extra discrimination between modes.
- Use ΔE yield for BF calculation. M_{bc} for cross check.

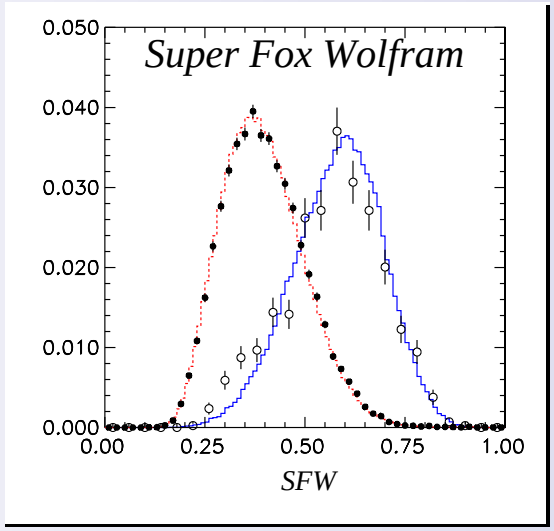


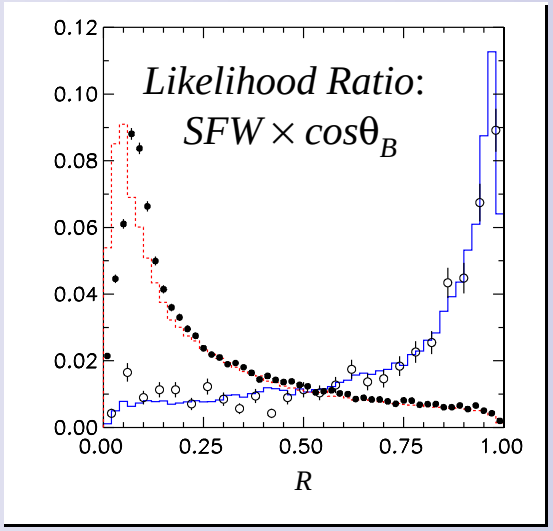
Continuum Suppression

- Separate spherical $B\overline{B}$ events from jet-like continuum events
- Likelihood ratio. Usually consists of:
  - Modified Fox-Wolfram moments into Fisher discriminant
  - B Flight Direction
- Thrust: Angle between thrust axis of B candidate and rest of event ($\rho\rho$ mode)
- Helicity of ρ ($\rho\pi$ mode) - follows a $\cos^2\theta$ for $B \to PV$ modes









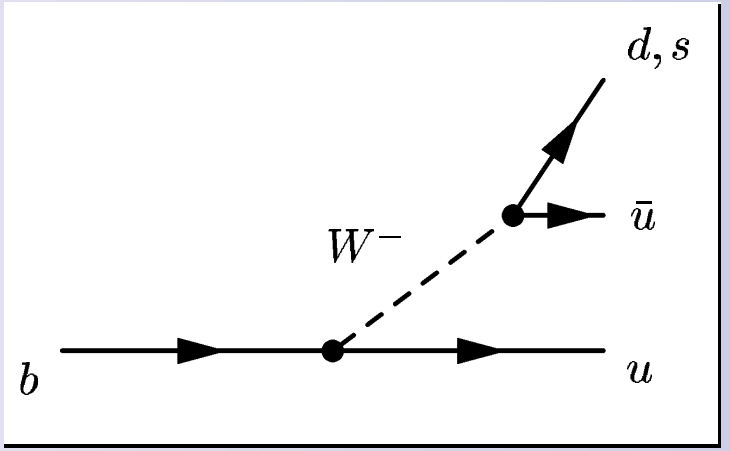
$B \to hh$ introduction

- These modes contain enough information to measure all CKM angles.
- Many of these modes are dominated by V_{ub} tree and gluonic penguin diagrams
- Tree-penguin interference $\to$ DCP violation

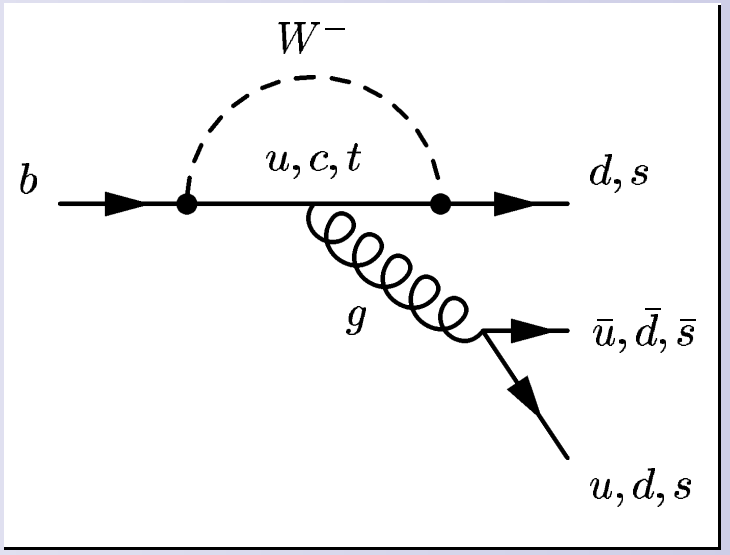
Features of the analysis

- Separate charged Ks and πs
  - High momentum PID using aerogel and dE/dx
  - Take account of cross-feeds in fitting.
- Reconstruct:
  - π^0 from $\pi^0 \to \gamma\gamma$
  - K^0 from $K_S \to \pi^+\pi^-$

Tree

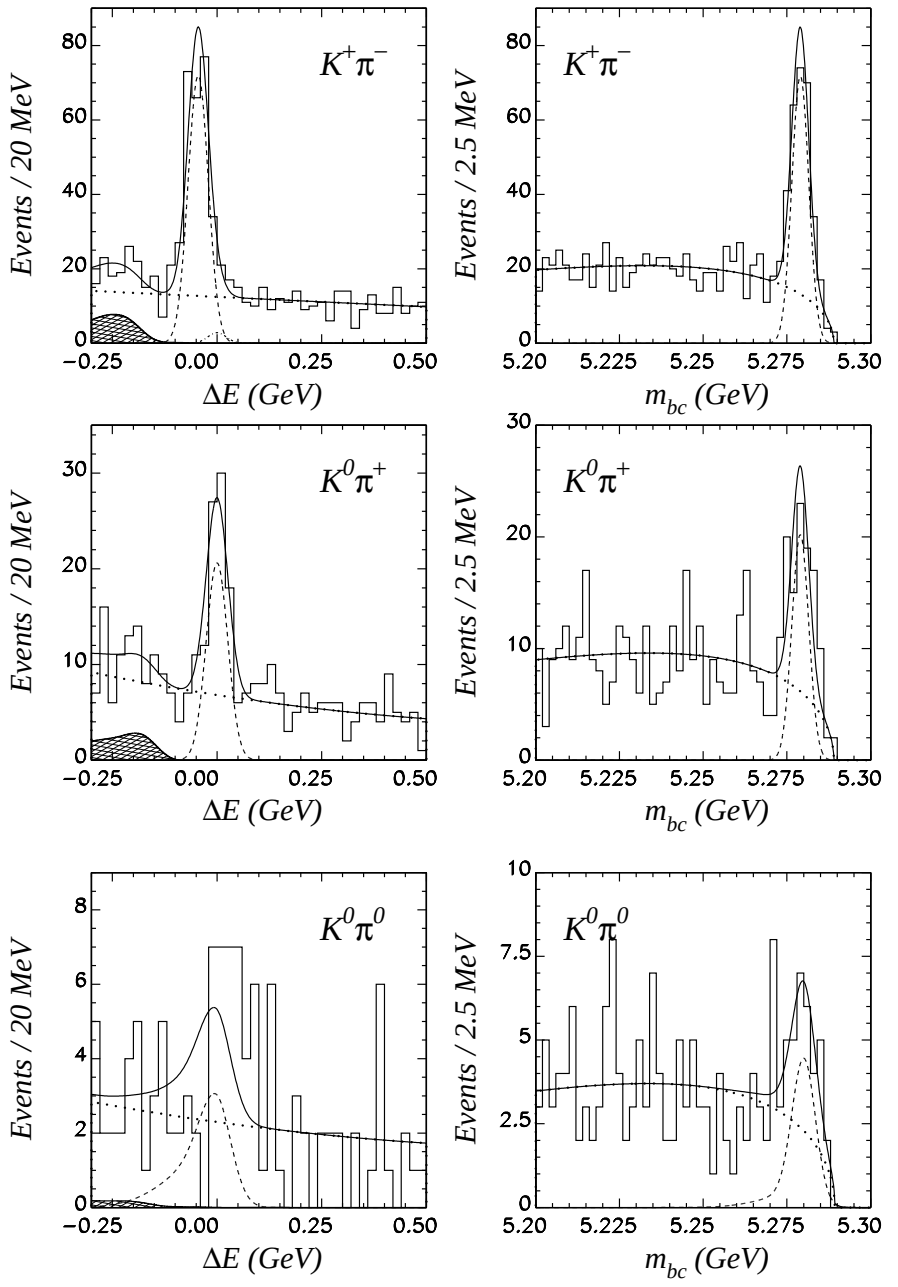


Penguin



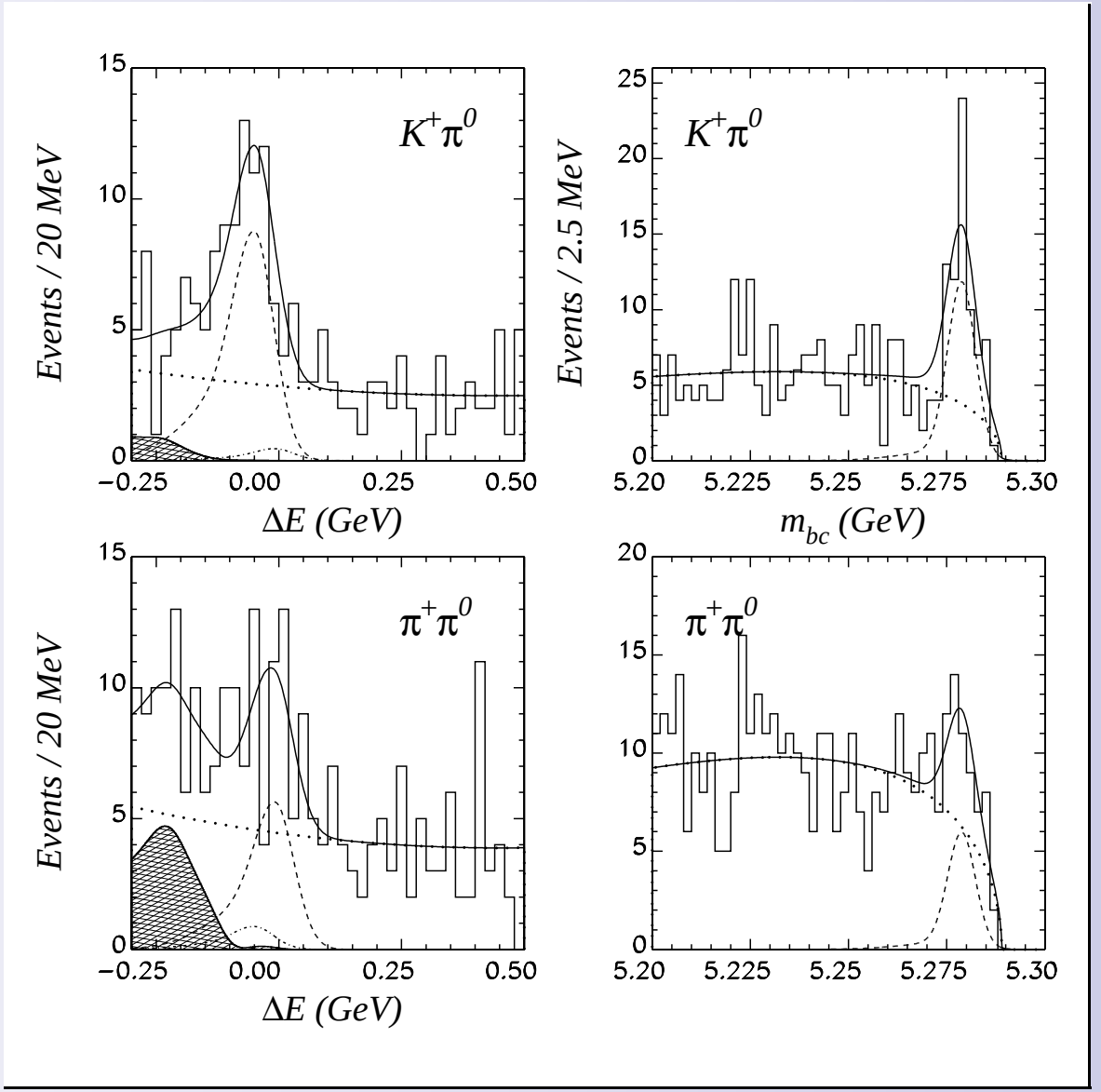
$B \to K\pi$

- π mass hypothesis used $\Rightarrow \Delta E$ shifted by -45 MeV for $K^{\pm}$
- Extract signal yields with maximum likelihood fit.
- 4 components in the ΔE fits:
  - signal
  - continuum
  - cross feeds from other hh modes
  - rare B background (hatched histograms)
- Normalization of all components left to float



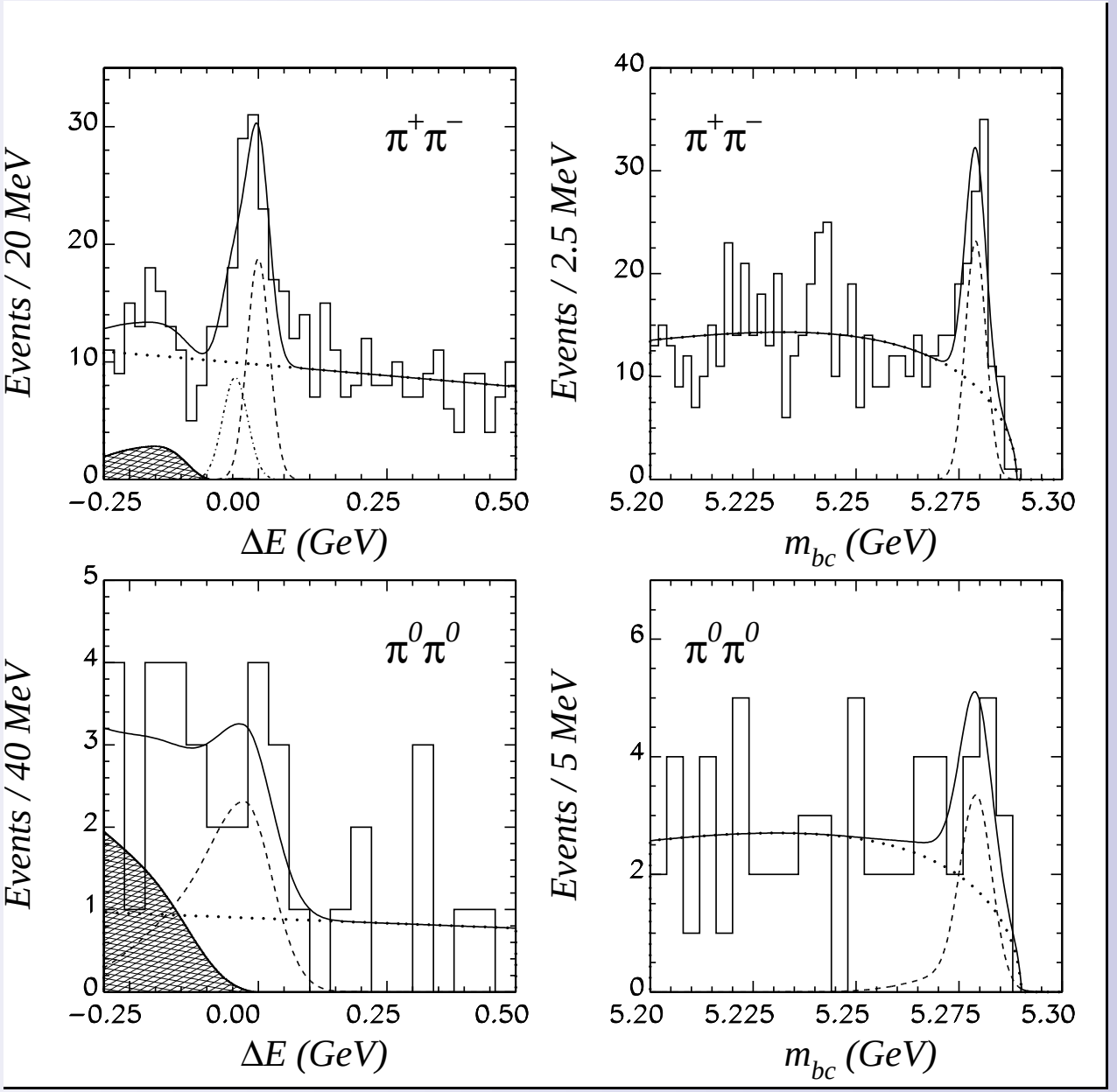
$B \to \pi\pi, K\pi$

- Simultaneous fit $K^+\pi^0$ and $\pi^+\pi^0$.
- Constrain cross feeds to what is expected from fake rates.
- $\pi^+\pi^0$: 3.5σ significance.



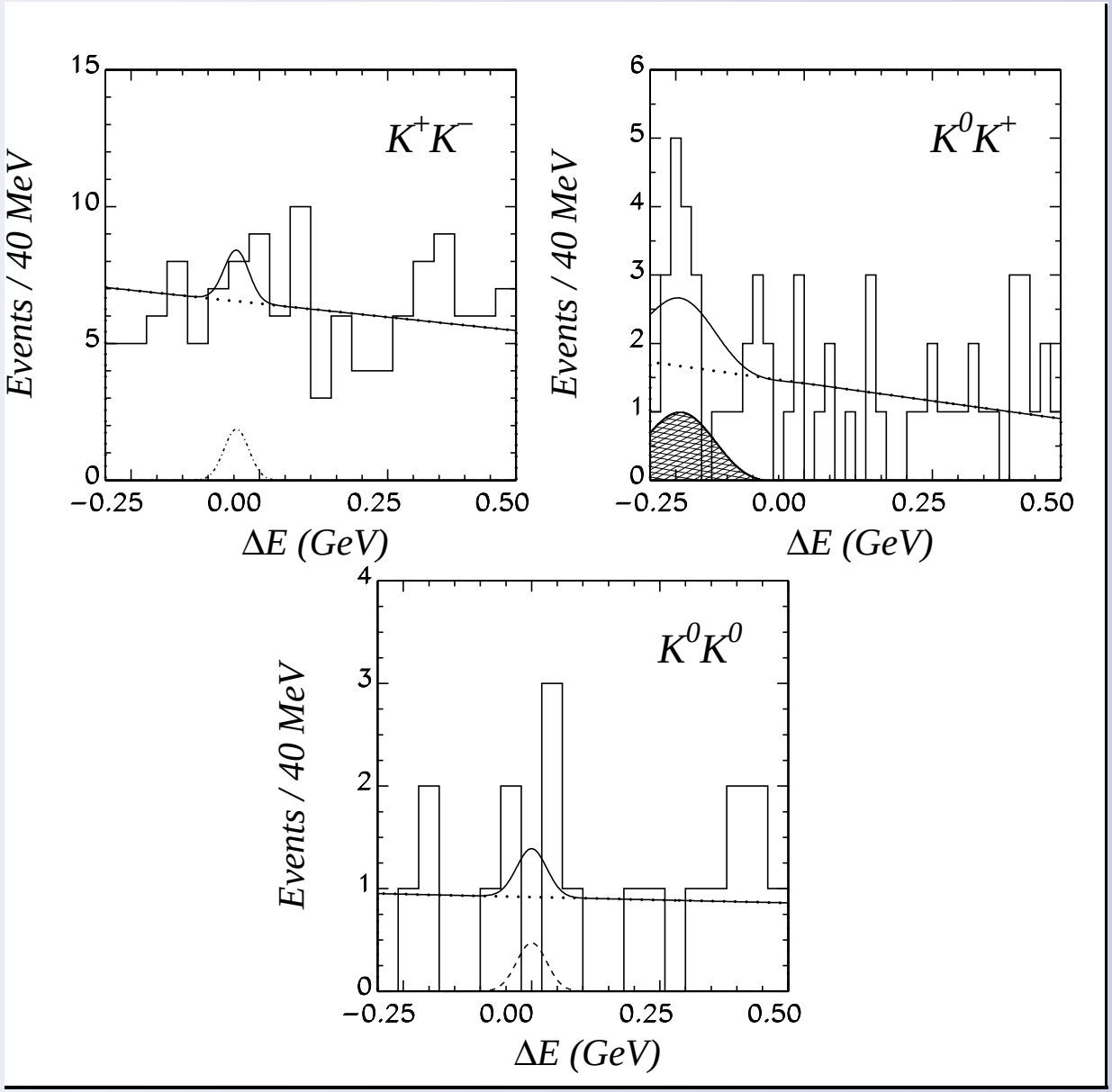
$B \to \pi\pi$

- Hint of $\pi^0\pi^0$ - 2.4σ significance.
- Provide upper limit.
- Last mode need for $B \to \pi\pi$ isospin analysis.



$B \to K\bar{K}$

- No signal for the $K\bar{K}$ modes has been observed.



Summary for $B \to hh$

mode	N_{sig}	Eff (%)	S(σ)	BF/UL$[10^{-6}]$
$K^+\pi^-$	218	31	16.4	$2.25 \pm 0.19 \pm 0.18$
$K^+\pi^0$	59	14	6.4	$1.30^{+0.25}_{-0.24} \pm 0.13$
$K^0\pi^+$	67	32	7.6	$1.94^{+0.31}_{-0.30} \pm 0.16$
$K^0\pi^0$	20	23	2.8	$0.80^{+0.33}_{-0.31} \pm 0.16$
$\pi^+\pi^-$	51	30	5.4	$0.54 \pm 0.12 \pm 0.05$
$\pi^+\pi^0$	37	16	3.5	$0.74^{+0.23}_{-0.22} \pm 0.09$
$\pi^0\pi^0$	13	13	2.4	< 0.64
K^+K^-	$0^{+3.2}_{-0}$	20	0	< 0.09
$K^+\bar{K}^0$	$0^{+2.0}_{-0}$	17	0	< 0.20
$K^0\bar{K}^0$	$0^{+2.9}_{-0.9}$	20	0	< 0.82

$B \to \rho\pi$

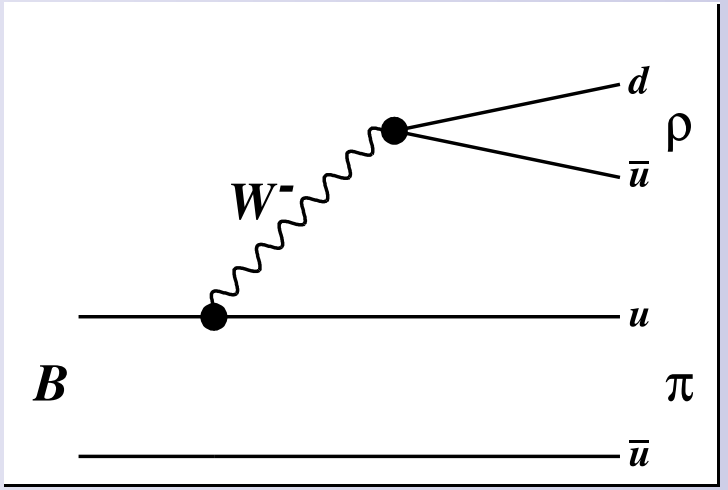
Motivation

- Probe CKM angles $\phi_2(\alpha)$ and $\phi_3(\gamma)$.
- Candidates for Direct and Indirect CP Violation measurements.
- Possibility of enhanced DCP through $\rho - \omega$ mixing.

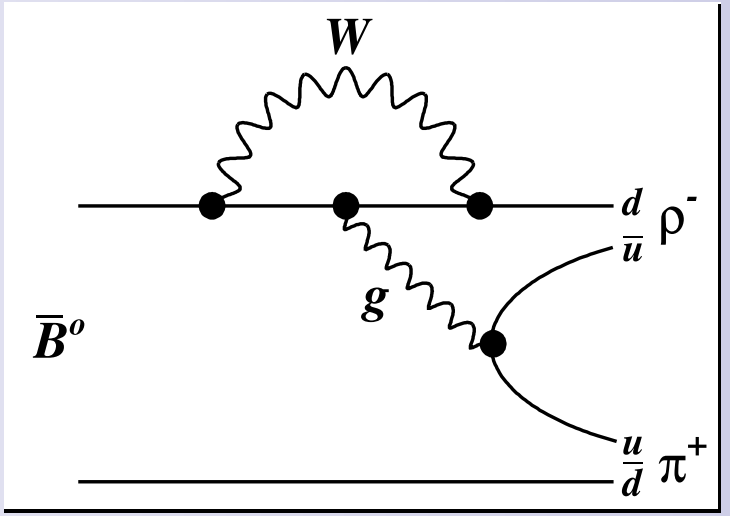
Features of the analysis

- PID on all charged tracks.
- e^- veto.
- veto B decays with D^0, J/ψ, $\psi(2S)$ into 2 charged hadrons.
- $0.6 < M(\pi\pi) < 0.95$ GeV$/c^2$.

Tree



Penguin

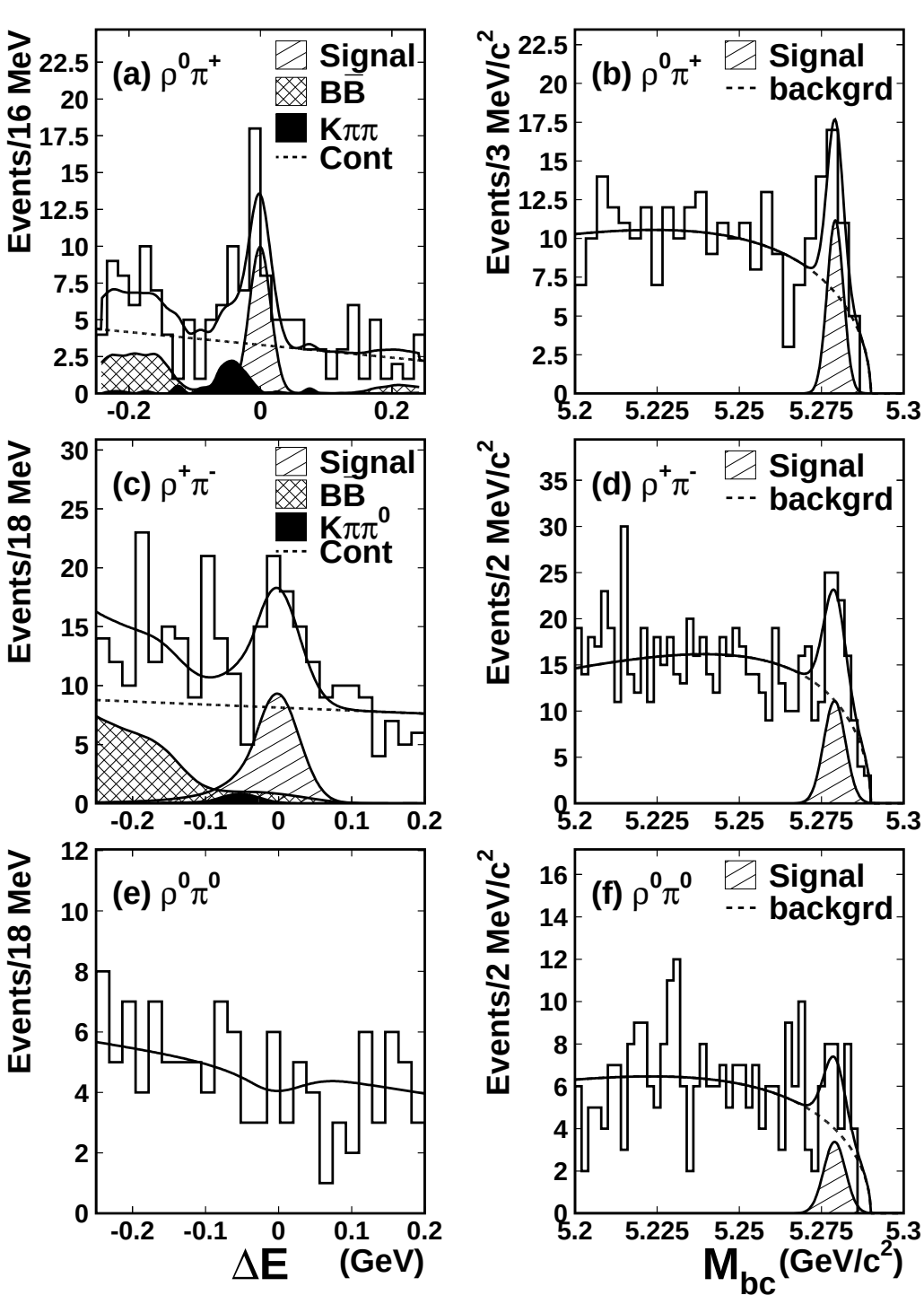


$B \to \rho\pi$

- Helicity requirement
  $|\cos\theta_h| > 0.3$

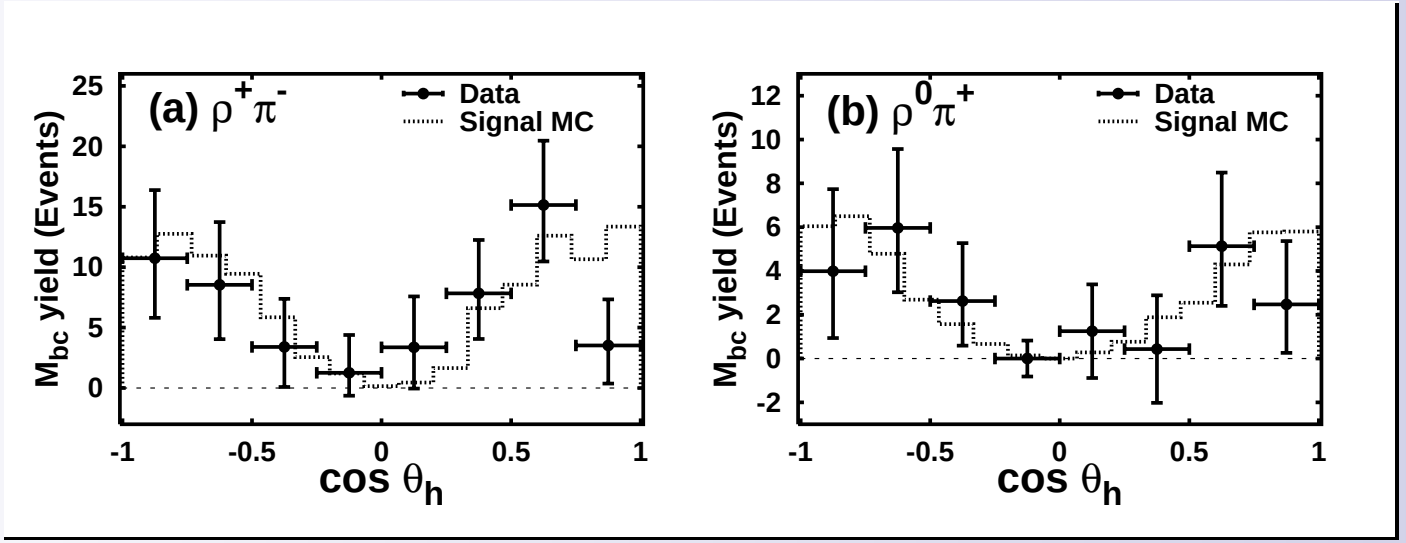
Backgrounds in fits

- Normalisation floated: signal, continuum, $\rho\rho$ components
- Normalisation fixed (scaled by luminosity): $K\pi\pi^{(0)}$ component, hh components.

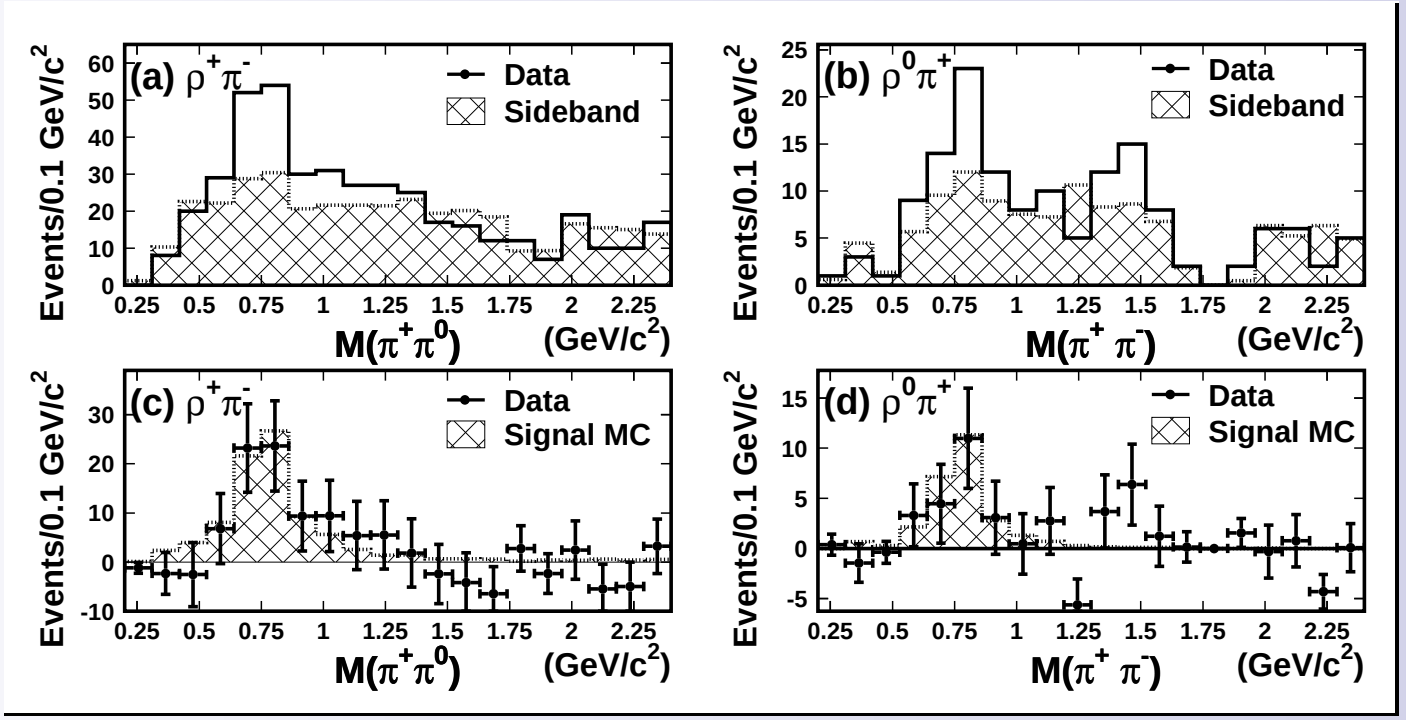


$B \to \rho\pi$

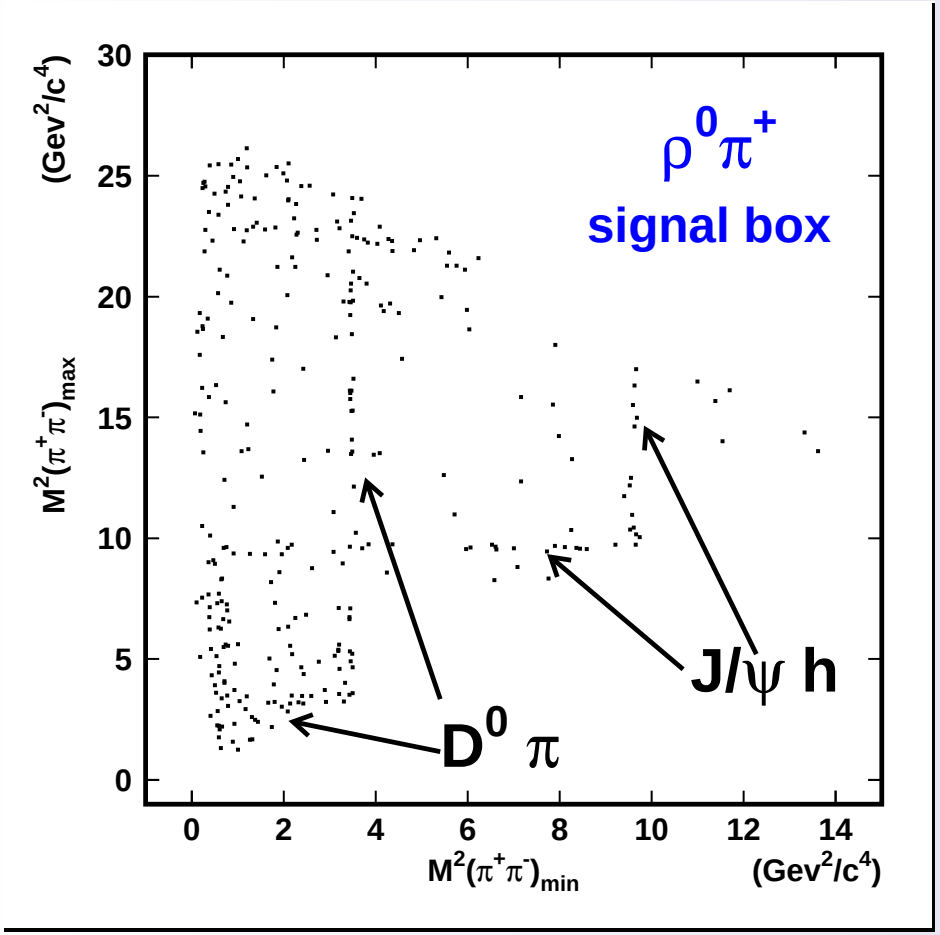
- Helicity:



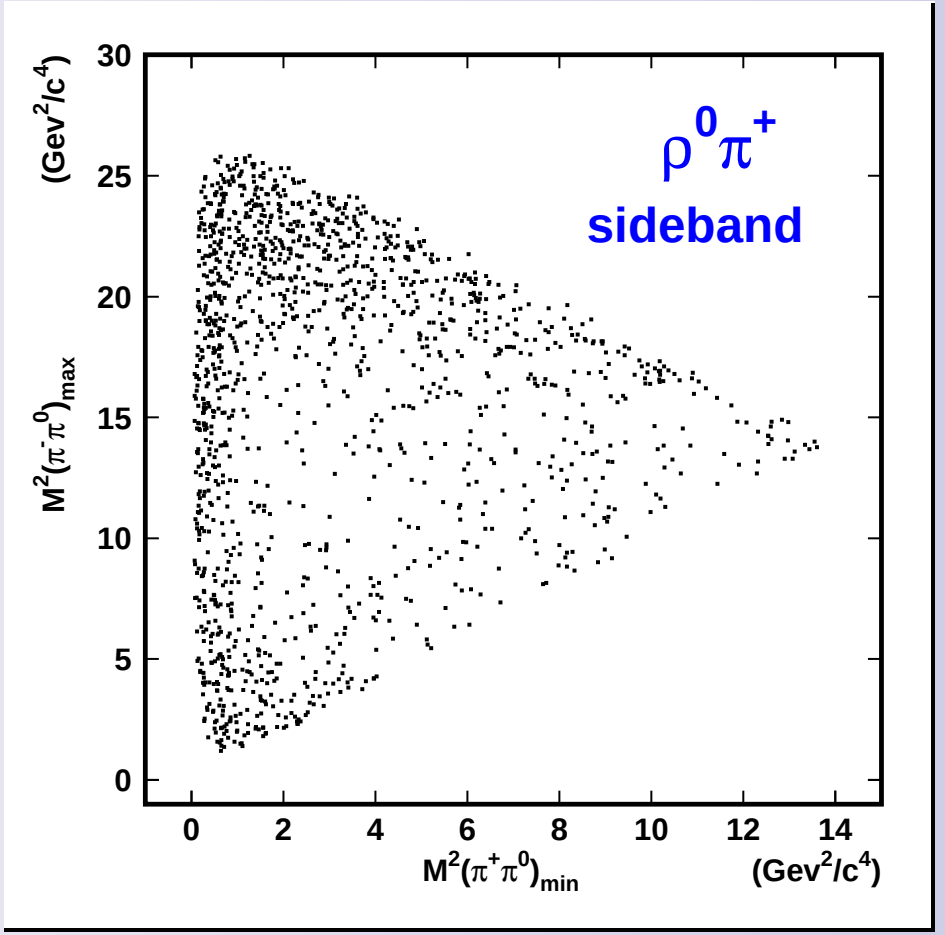
- M($\pi\pi$):



$B \to \pi^+\pi^-\pi^+$ Dalitz Plot



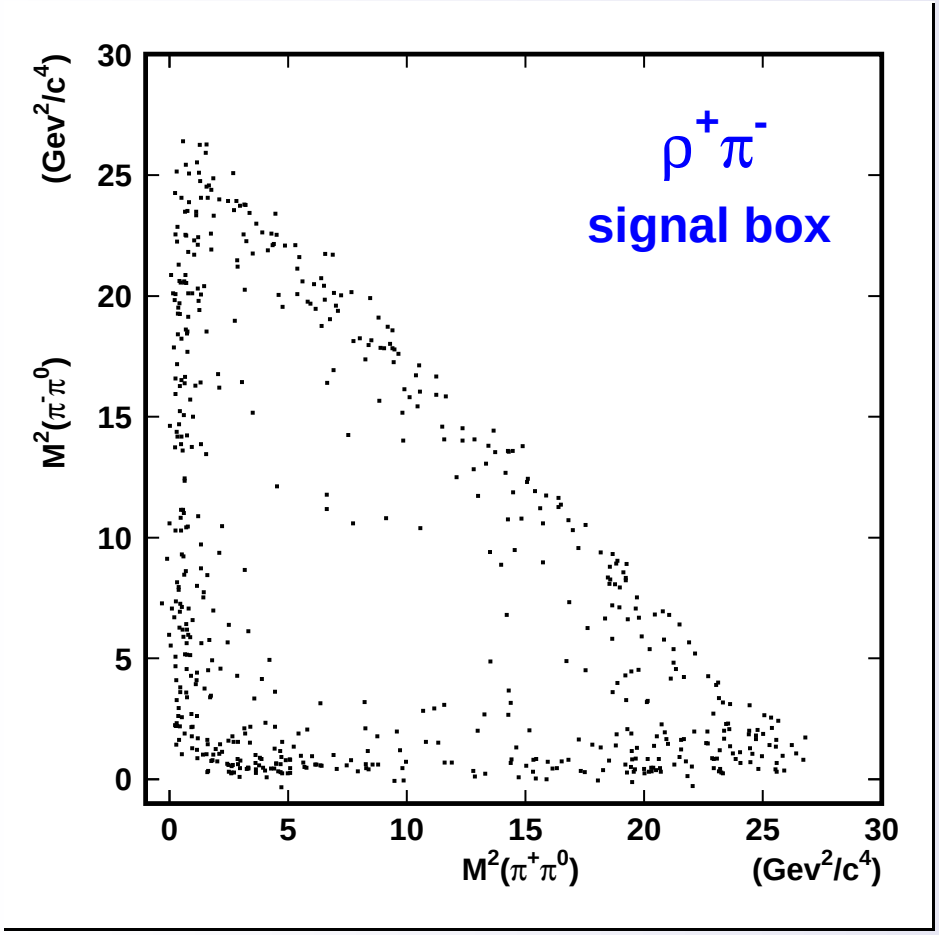
ΔE M_{bc} signal box



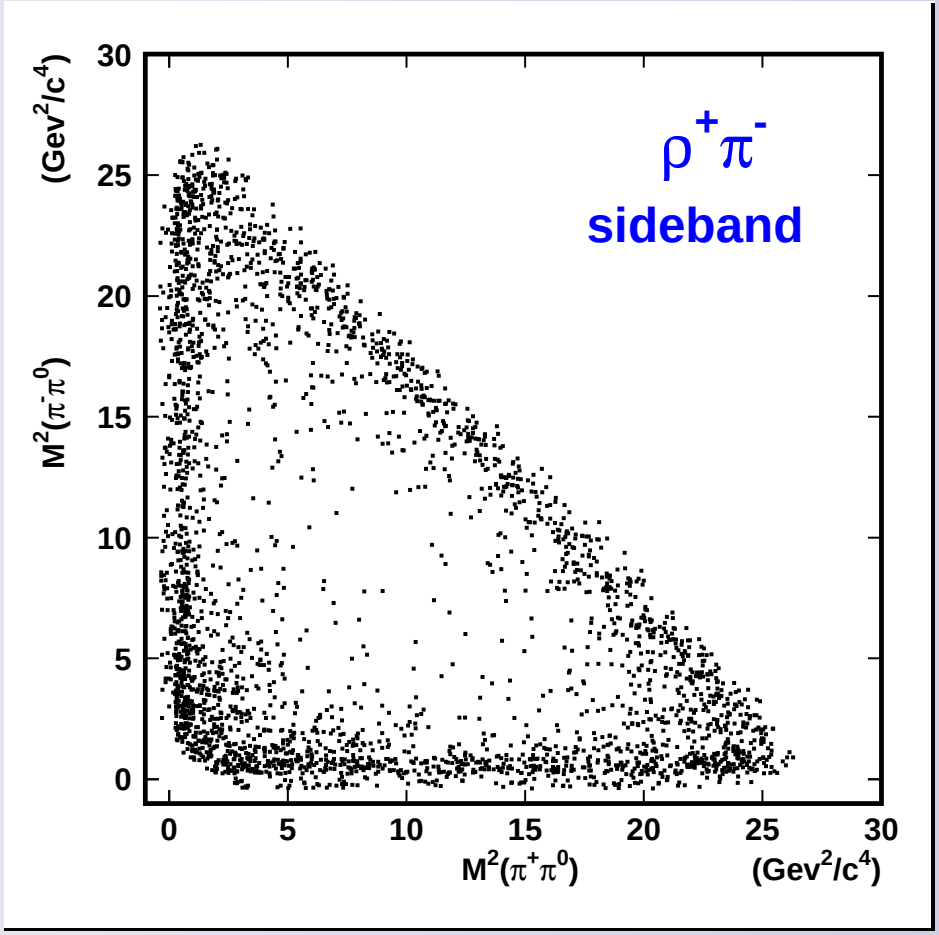
the M_{bc} sideband

- Regions around polluted by D^0 and J/ψ decays vetoed.
- No background subtraction done on signal plot

$B \to \pi^+\pi^-\pi^0$: Dalitz Plot



ΔE M_{bc} signal box



the M_{bc} sideband

- No background subtraction done on signal plot

$B \to \rho\pi$: Summary

mode	N_{sig}	Eff(%)	S(σ)	BF/UL$[10^{-6}]$
$\rho^0\pi^+$	24.3	9.6	4.4	$8.0^{+2.3+0.7}_{-2.0-0.7}$
$\rho^\pm\pi^\mp$	44.6	6.8	3.7	$20.8^{+6.0+2.8}_{-6.3-3.1}$
$\rho^0\pi^0$	-4.4	8.5	-	< 5.3

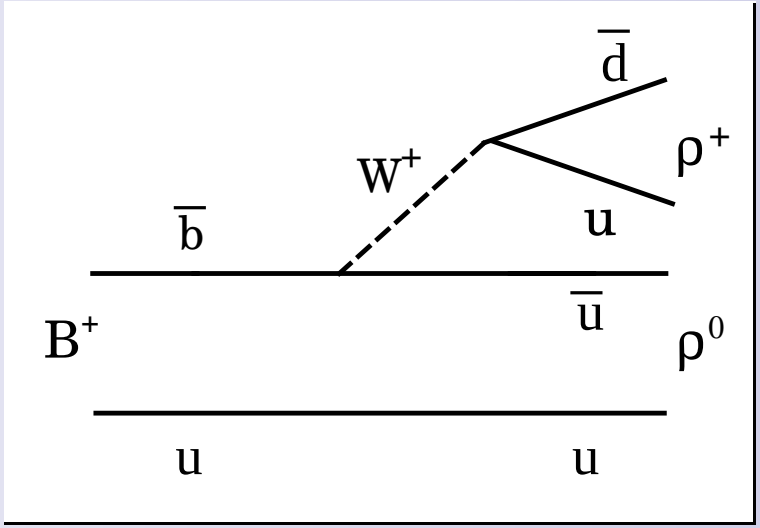
Experiment	$\mathcal{B}(B^0 \to \rho^\pm\pi^\mp)$ $[10^{-6}]$	$\mathcal{B}(B^+ \to \rho^0\pi^+)$ $[10^{-6}]$	R
Belle	$20.8^{+6.0+2.8}_{-6.3-3.1}$	$8.0^{+2.3+0.7}_{-2.0-0.7}$	2.6 ± 1.1
BaBar	$28.9 \pm 5.4 \pm 4.3$	$24 \pm 8 \pm 3$	1.2 ± 0.5
CLEO	$27.6^{+8.4}_{-7.4} \pm 4.2$	$10.4^{+3.3}_{-3.4} \pm 2.1$	2.7 ± 1.3

- The Ratio R is smaller then expected. (R is ~ 6 using tree level calculations).
- Nonresonant contribution not significant. We estimate $< 4\%$
- Time dependent CP studies underway for $B \to \rho^\pm\pi^\mp$

$B^+ \to \rho^+ \rho^0$

- BF's were expected to be small.
- Has only tree and electro-weak penguin contributions (gluonic penguins suppressed).
- Probe $\phi_2(\alpha)$.
- $B \to VV$ decay, polarizations of the ρ mesons can be either transverse or longitudinal.

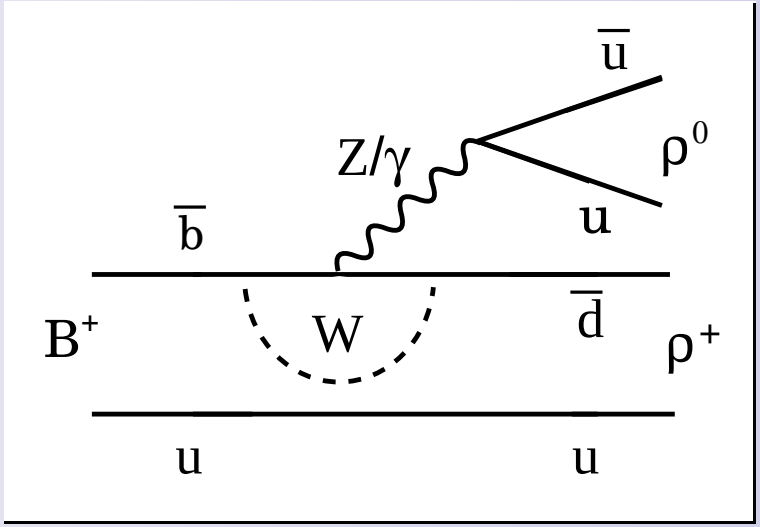
Tree



Features of the analysis

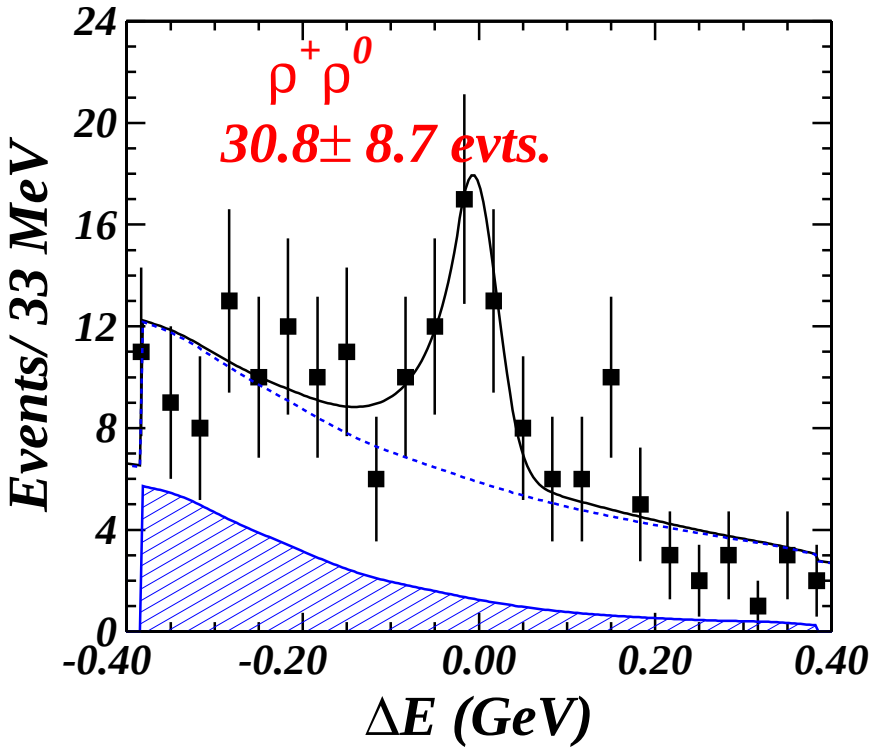
- PID on all charged tracks.
- e^- veto
- $0.6 < M(\pi\pi) < 0.95$ Gev$/c^2$ for both ρ^+ and ρ^0.
- Different MC reconstruction efficiency depending on polarizations of the ρs.

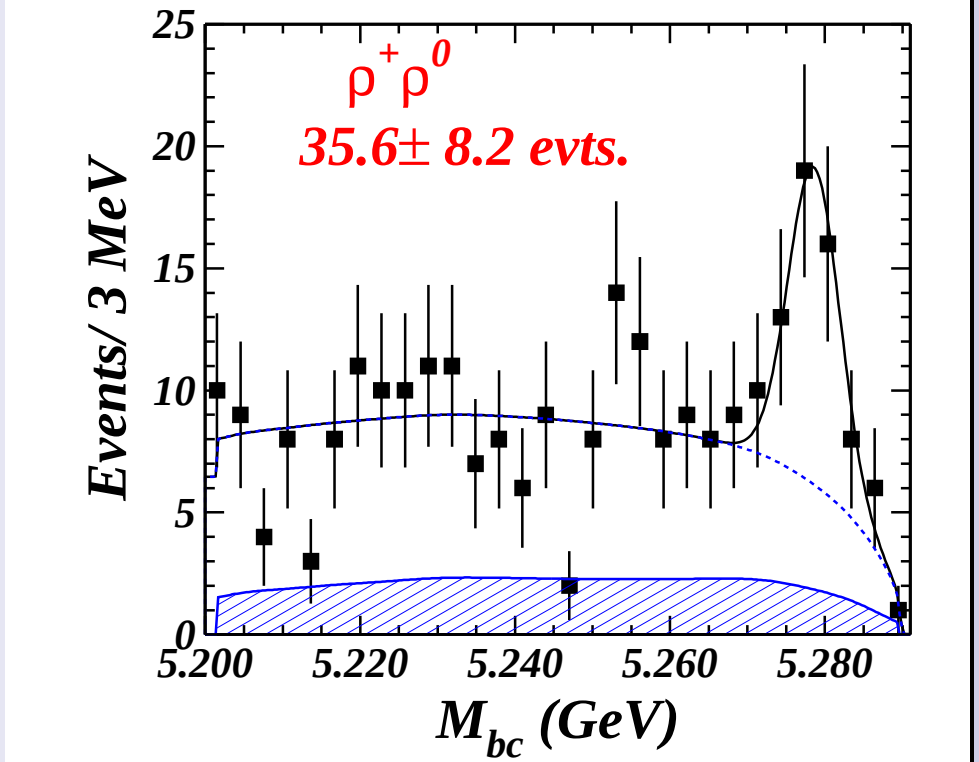
EW Penguin



$B^+ \to \rho^+\rho^0$

- This is the 1st example of a $b \to u$ vector-vector mode.
- Normalization of all components left to float in fit.
- $B\bar{B}$ contribution is consistent with MC expectation

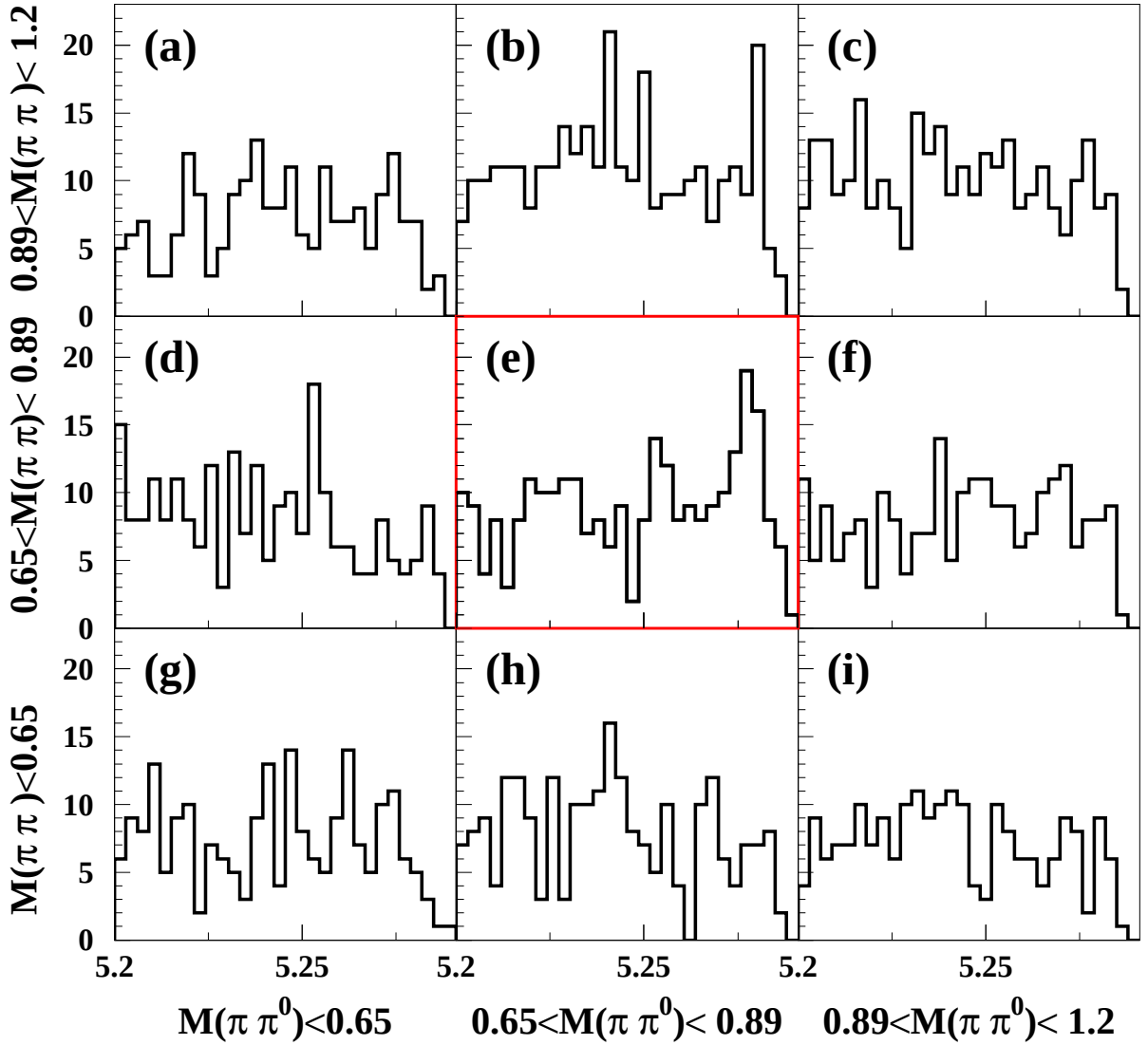




Hatched component is $B\bar{B}$ Background

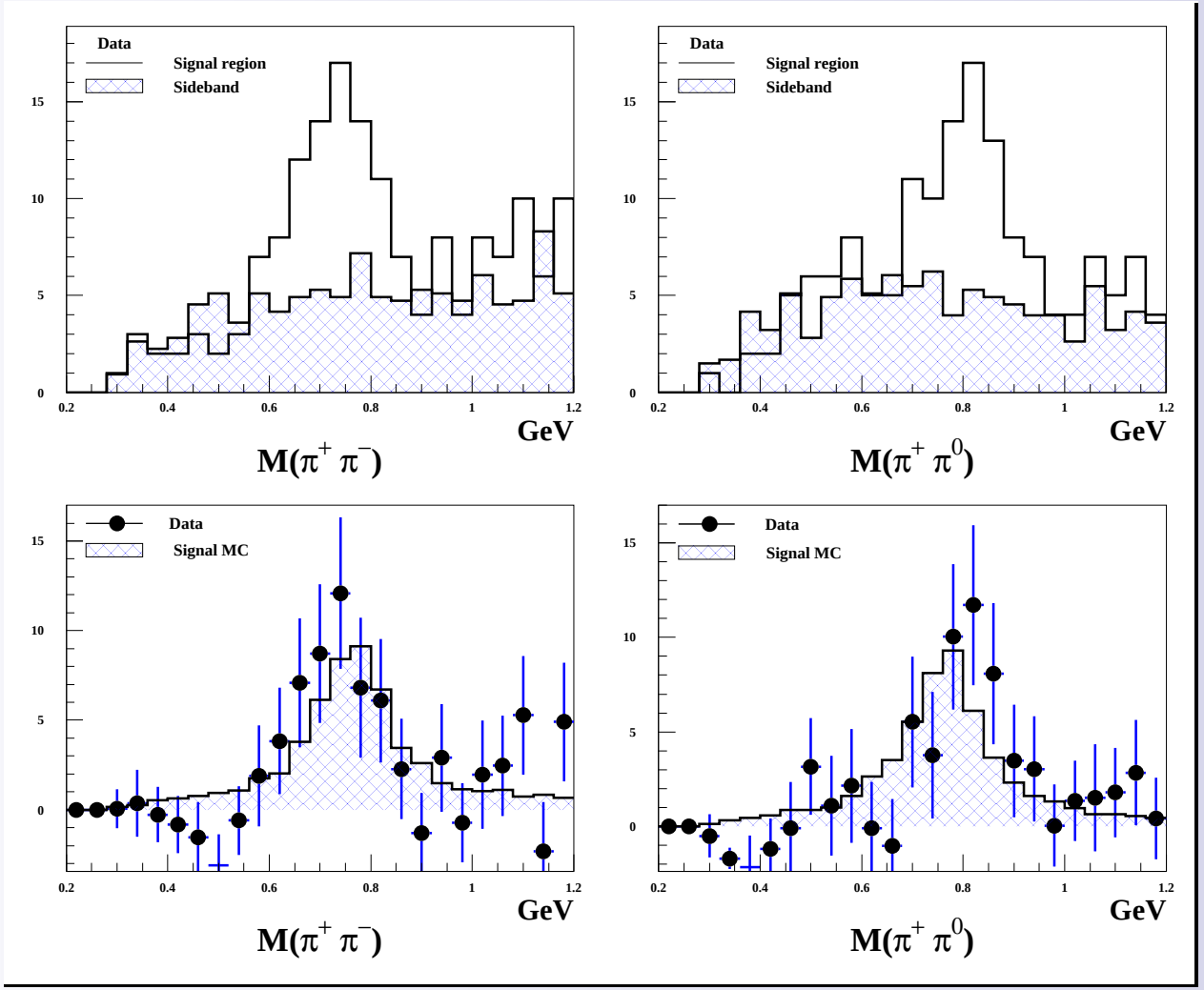
$B^+ \to \rho^+ \rho^0$

- Cross check of M_{bc} yields in both ρ^+ and ρ^0 sidebands.



$B^+ \to \rho^+ \rho^0$

- $\pi\pi$ invariant mass distributions

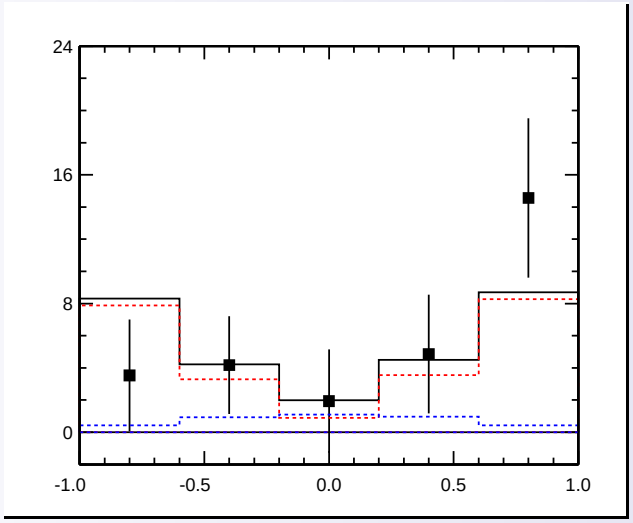


ρ^0 ρ^+

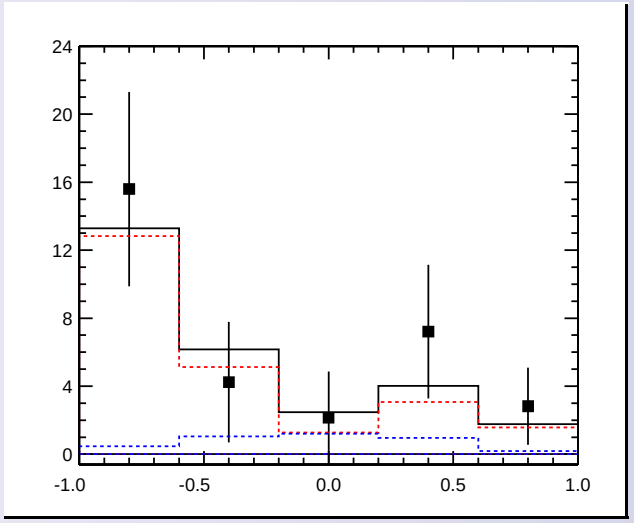
- Good agreement between Data and MC.

$B^+ \to \rho^+\rho^0$

Simultaneous fit to background subtracted $\cos\theta_h$ distributions



$\rho^0 \cos\theta_h$



$\rho^+ \cos\theta_h$

red is H_{00} component (longitudinal)
blue is H_{11} component (transverse)

- Fit data with both helicity components ($\epsilon_{00} = 1.8\%$, $\epsilon_{11} = 3.3\%$).
- Fit results: $H_{00} = 0.86 \pm 0.41$, $H_{11} = 0.14 \pm 0.23$

mode	N_{sig}	S(σ)	BF/UL$[10^{-6}]$
$\rho^+\rho^0$	31	4.2	$38.5 \pm 10.9^{+5.9+2.5^*}_{-5.4-7.5^*}$

Preliminary

* 3rd error is due to helicity mix uncertainty

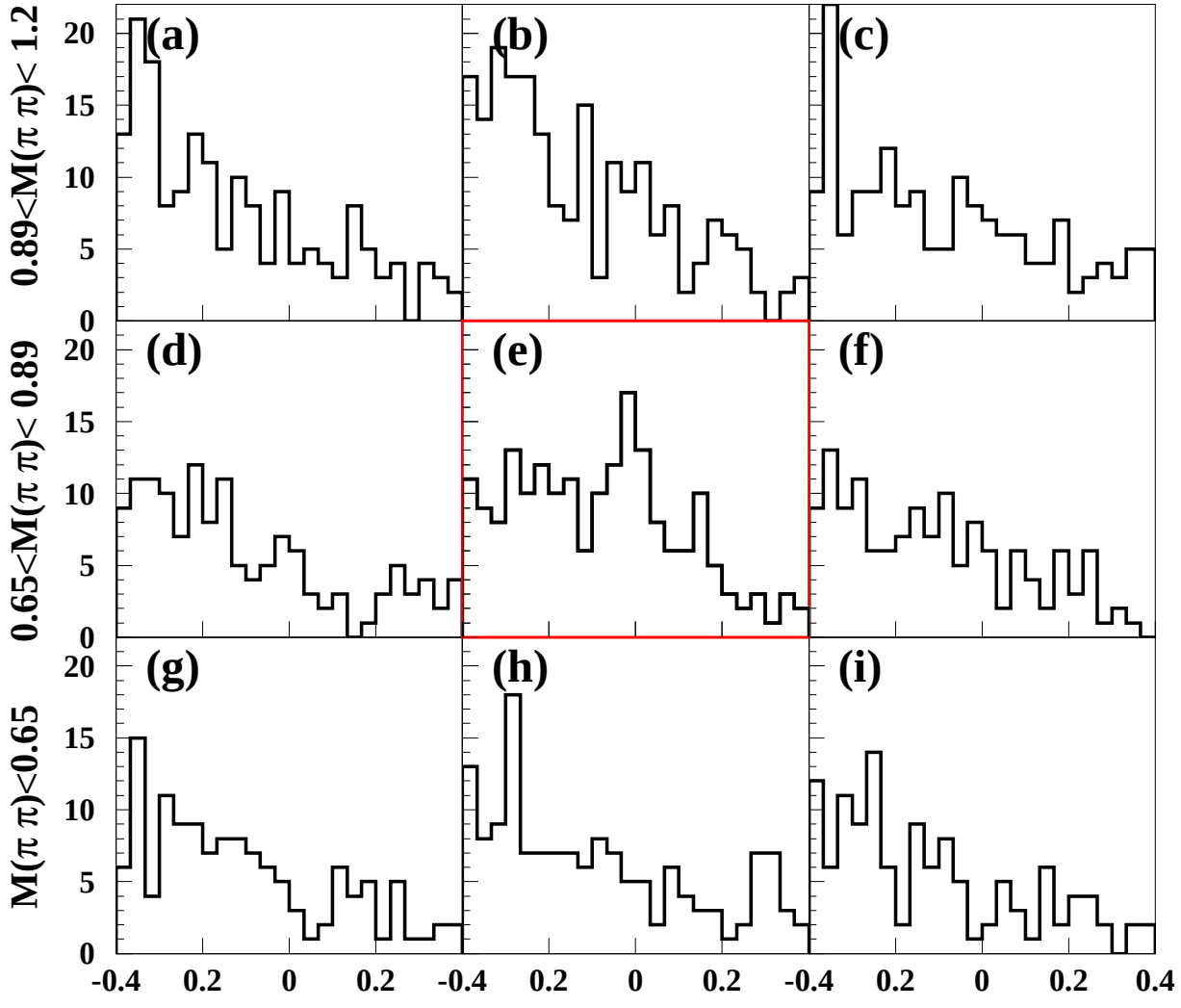
Conclusions

- Complete set of hh modes has been investigated. Significant signals in $K\pi$, $\pi^+\pi^-$ and $\pi^+\pi^0$ modes. Upper limits on $\pi^0\pi^0$, KK.
- We have a new measurement for $B^+ \to \rho^0\pi^+$, $B^\pm \to \rho^\pm\pi^\mp$ and upper limit for $B^0 \to \rho^0\pi^0$
- First observation: $B^+ \to \rho^+\rho^0$ 1st example of a $b \to u$ VV mode.

  BF = $(38.5 \pm 10.9^{+5.9+2.5}_{-5.4-7.5}) \times 10^{-6}$ (Preliminary)
- Will update with 90fb^{-1} of data that has now been taken.
- New prospects for observing CP violation with $\rho\pi$ and $\rho\rho$ modes.

$B^+ \to \rho^+ \rho^0$

- Cross check of ΔE yields in both ρ^+ and ρ^0 sidebands.



$B \to \rho\pi$ Systematic errors

Source			$\rho^0\pi^+$	$\rho^\pm\pi^\mp$
Fitting	ΔE	shape	+3.45% -3.33%	+4.86% -6.01%
	Continuum	slope	1.1%	+5.62% -5.90%
	$B\overline{B}$	area	-	6.2%
	$\rho\rho$	area	0.8%	+0.96% -2.31%
	hh	area	+0.17% -0.18%	-
	$K\pi\pi$	area	+1.33% -1.34%	2.42%
Other	Tracking		$3 \times 2\%$	$2 \times 2\%$
	PID		1.6%	0.4%
	π^0 reconstruction		-	8%
	Continuum Suppression		5.7%	3.8%
	Nonresonant contribution		3.2%	3.7%
Total			+8.53% -8.49%	+14.17% -14.86%

$B \to \rho\rho$ Systematic errors

Source	Error (%)
Tracking	6
PID	6
π^0 recon	7.7
Continuum Suppression	6
ΔE fit	+8.2 -5.4
$N_{B\bar{b}}$	1
Total	+15.35 -14.05