Study of B-> K h h Decays at Belle

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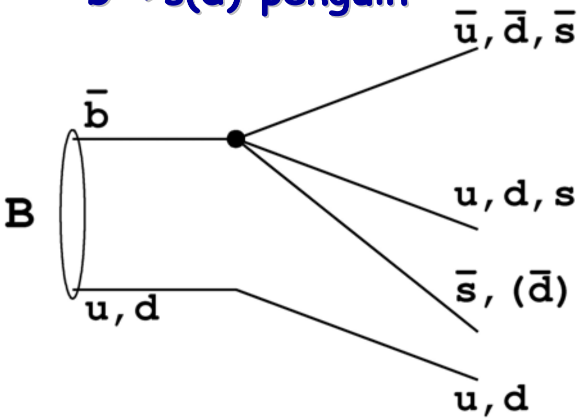
- Three-Body Charmless Decays
- Dalitz Analysis Results
- Search for DCPV in $B^{\pm} \to K^{\pm}\pi^{+}\pi^{-}$
- Summary

4th International Workshop on CKM Unitarity Triangle 2006 Nagoya

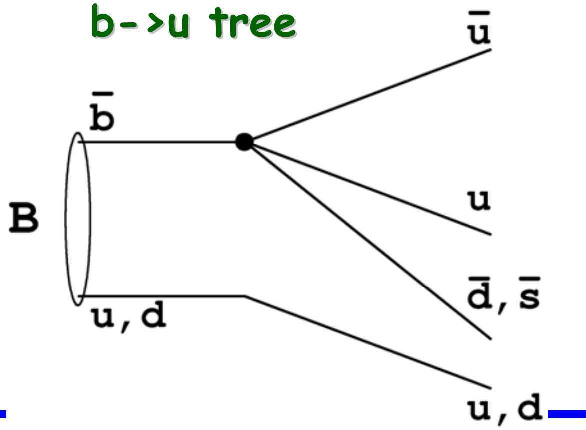
Classification

The dominant contributions to various 3-body final states:

b->s(d) penguin



b->u tree

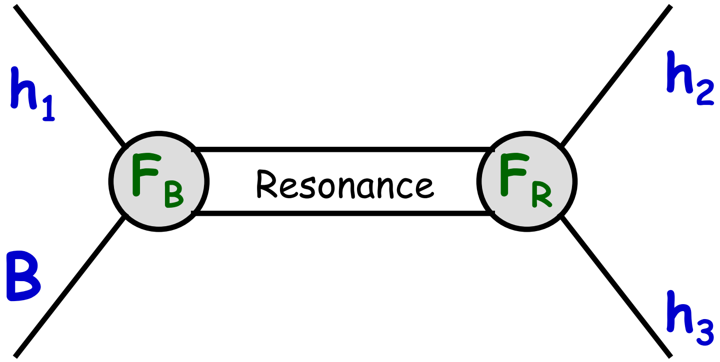


b->s penguin transition contributes only to final states with odd number of kaons (s-quarks): $K\pi\pi$, KKK

b->u tree and b->d penguin transitions contribute mainly to final states with even number of kaons (s-quarks): $\pi\pi\pi$, $KK\pi$. Contribution to states with odd number of kaons is Cabibbo suppressed

"*wrong flavor*" finals states such as $K^+K^+\pi^-$ and $K^-\pi^+\pi^+$ are expected to be exceedingly small (10^{-11}) in the SM
-> good place to search for NP

Dalitz Analysis Basics



In multi-body decays additional degrees of freedom appears. In the simplest case of the three-body $B \to h_1 h_2 h_3$ decay, where h_i are all spin-0 particles there are two additional degrees of freedom:

$s_{ij} = m^2(h_i h_j)$ – three combinations

From energy-momentum conservation:

$$s_{12} + s_{13} + s_{23} = M_B^2 + m_1^2 + m_2^2 + m_3^2$$

In the general case there is a set of intermediate resonances possible ...

Dalitz Analysis Basics

$$M(h_1h_2h_3) = \sum a_j A^j e^{i\delta_j}$$

$$A_J = F_B F^{(J)}_R BW_J T_J$$

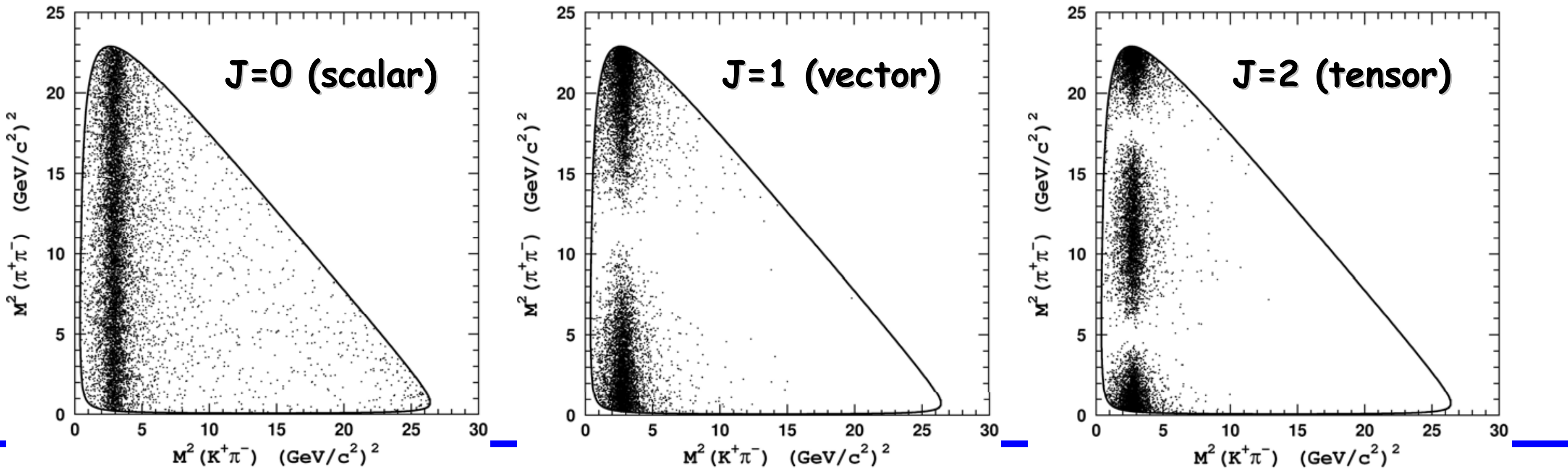
- BW_J - Breit-Wigner function
- $\Gamma^J_R(s)$ - s-dependent width
- T_J - Angular correlations of the decay products

$$BW^J = \frac{1}{M^2_R - s - iM_R\Gamma^{(J)}_R(s)}$$

$$\Gamma^{(J)}_R(s) = \Gamma_R F^2_R \frac{M_R}{s^{1/2}}\left(\frac{p_s}{p_0}\right)^{2J+1}$$

$$\frac{d\Gamma}{ds_1 ds_2} \sim |M|^2$$

Simplest case of a single quasi-two-body channel



$B^{+(0)} \to K^{+(0)}\pi^+\pi^-$

Large background from other B decays
⇨ impose 2-body vetoes:

- $B^- \to D^0(K^-\pi^+)\pi^-$: $|M(K^+\pi^-)-M_D| > 100$ MeV
- $B^- \to J/\Psi(\mu^+\mu^-)K^-$: $|M^*(\pi^+\pi^-)-M_{J/\psi}| > 70$ MeV
- $B^- \to \Psi'(\mu^+\mu^-)K^-$: $|M^*(\pi^+\pi^-)-M_{\psi'}| > 50$ MeV
- $B^- \to D^0(\pi^+\pi^-)K^-$: $|M(\pi^+\pi^-)-M_D| > 15$ MeV

Miss-ID D-veto:

- $|M(h^+h^-)-M_D|>15$ MeV

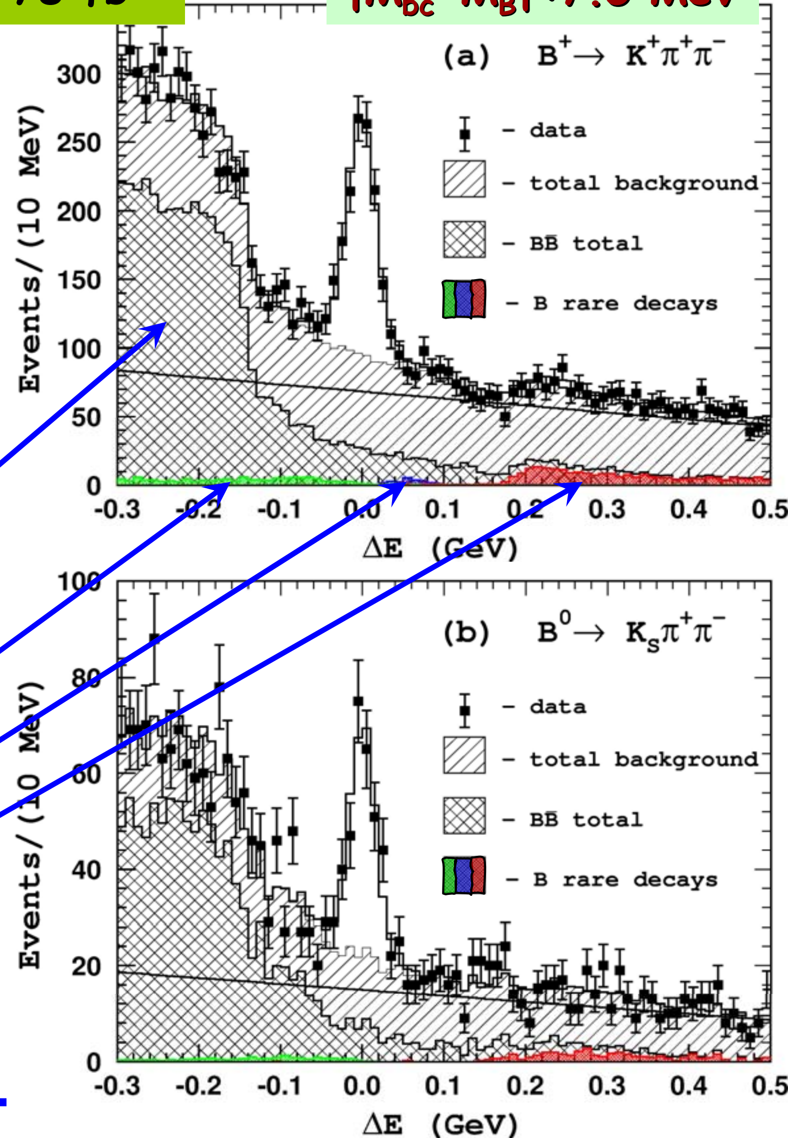
Remaining non-peaking BB background is well described by MC simulation

- $B^- \to D(K^-\pi^+\pi^0)\pi^-$
- $B^- \to D(K^-\mu^+\nu)\pi^-$
- $B^- \to D^*(K^-\mu^+\nu(\pi^0 \text{ or } \gamma))\pi^-$

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

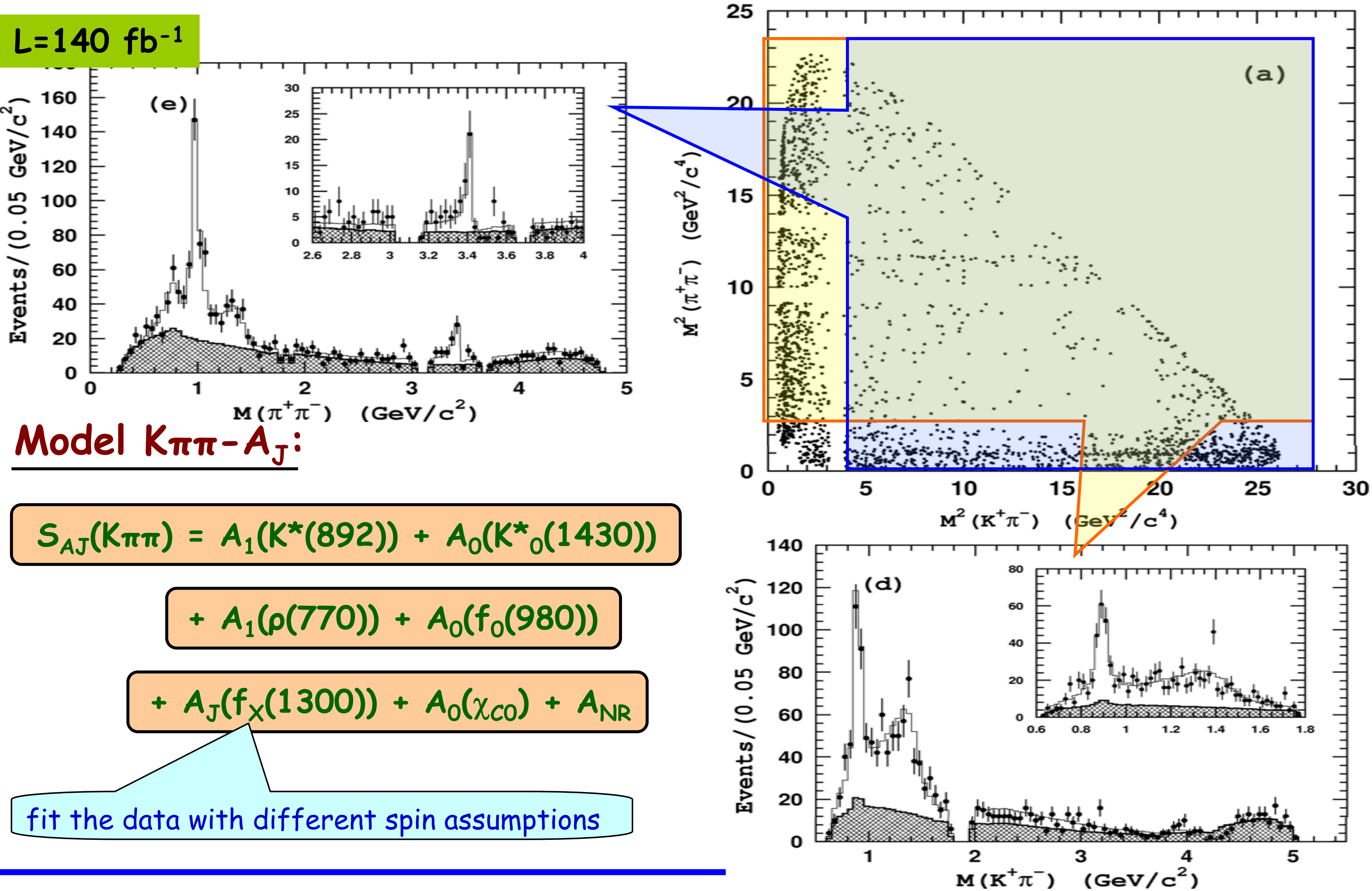
L=78 fb^{-1}

$|M_{bc}-M_B|<7.5$ MeV



$B^+ \to K^+\pi^+\pi^-$: Fitting The Signal

L=140 fb^{-1}



Model $K\pi\pi - A_J$:

$S_{AJ}(K\pi\pi) = A_1(K^*(892)) + A_0(K^*_0(1430))$

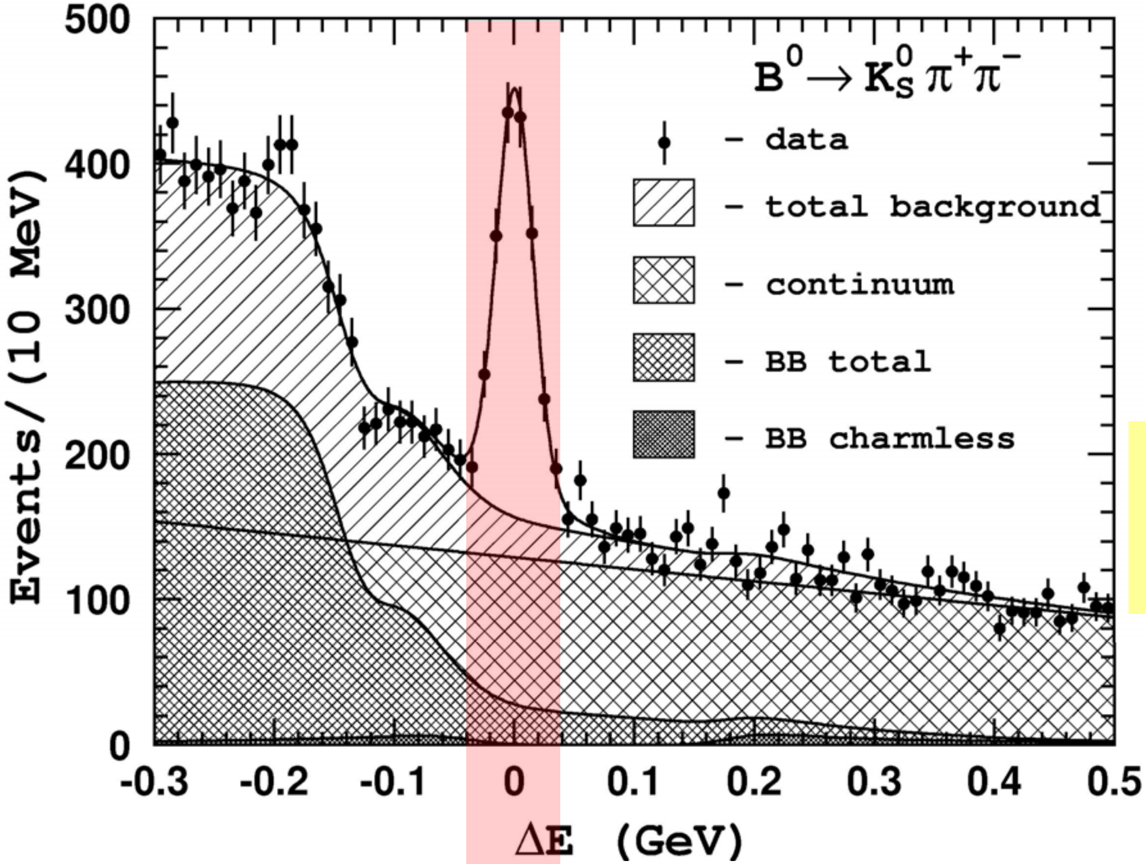
$+ A_1(\rho(770)) + A_0(f_0(980))$

$+ A_J(f_X(1300)) + A_0(\chi_{c0}) + A_{NR}$

fit the data with different spin assumptions

$B^0 \to K_S\pi^+\pi^-$: Signal Yield

L = 353 fb^{-1}



Use the same model to fit the signal as for the $B^+ \to K^+\pi^+\pi^-$ decay:

$$M \sim A(K^*(892)\pi) + A(K^*_0(1430)\pi) + A(\rho(770)K) + A(f_0(980)K) + A(f_X(1300)K) + A(\chi_{c0}K) + A_{NR}$$

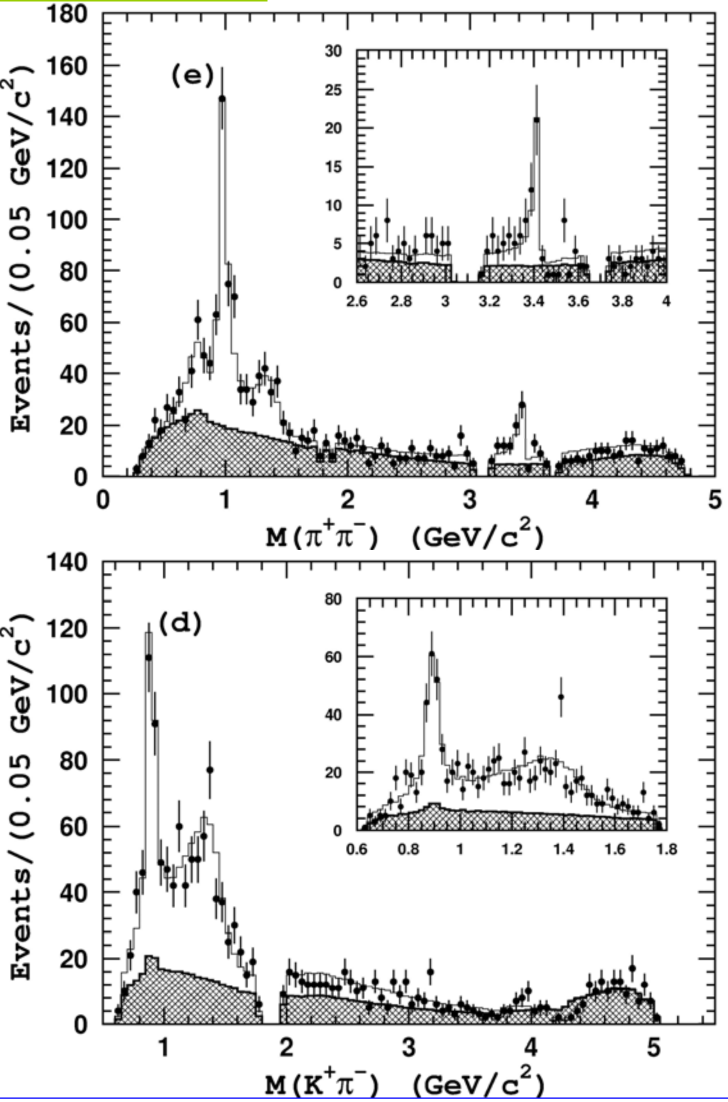
$N_{sig}(K_S\pi^+\pi^-) = 1246 \pm 63$

S/B~1

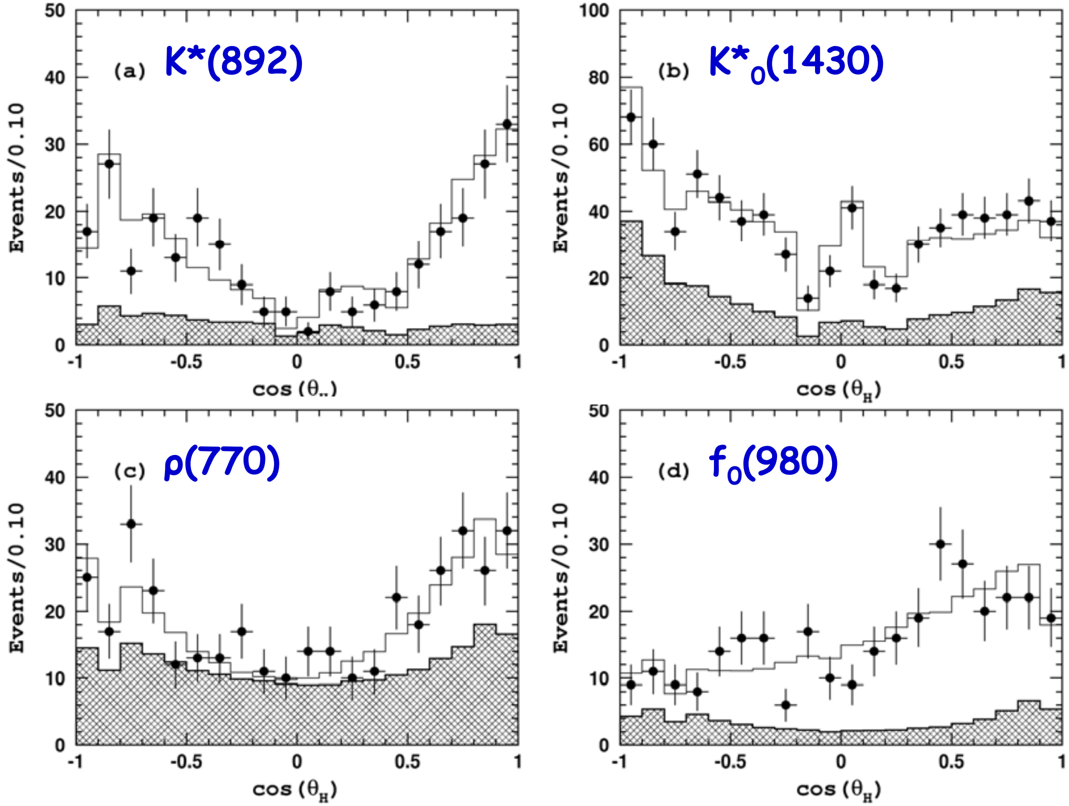
No flavor tagging applied – measuring average fractions

$B^+ \to K^+\pi^+\pi^-$: Fitting The Signal

L=140 fb^{-1}

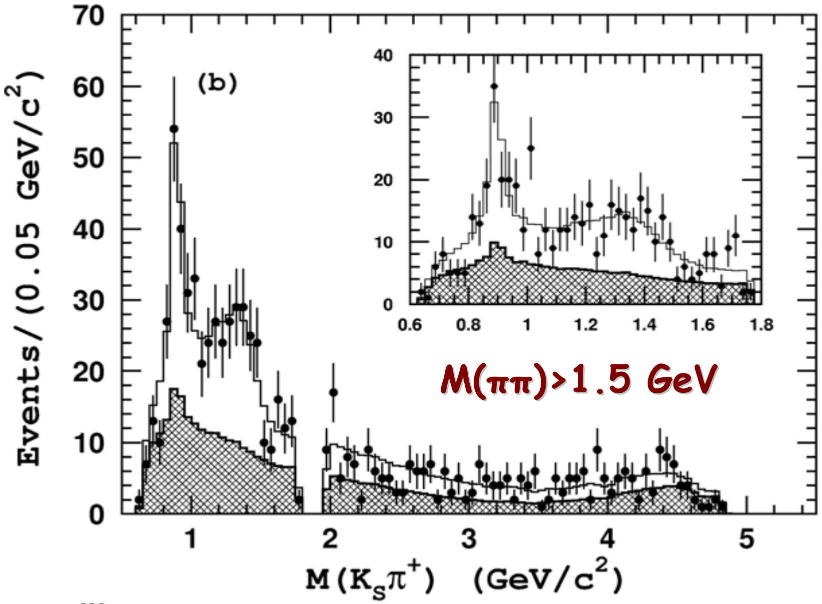


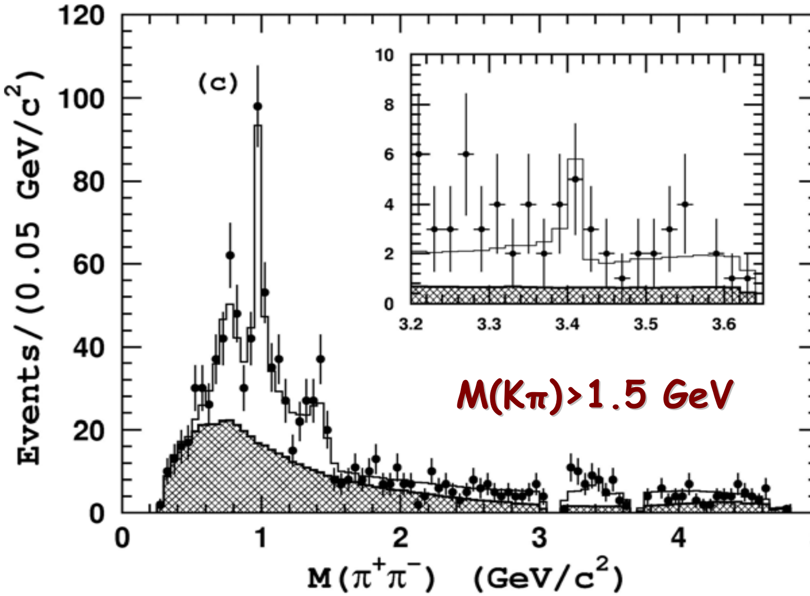
Helicity angle distributions:

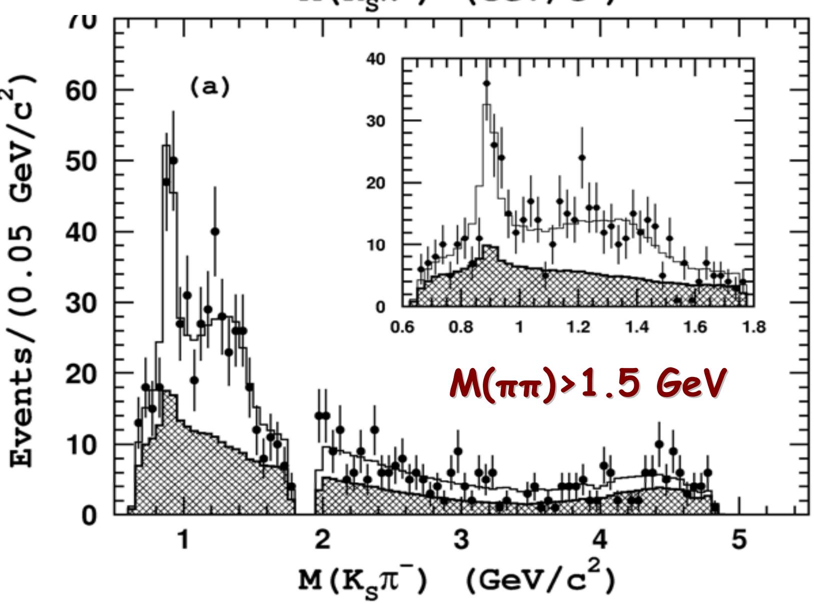


Spin of the $f_X(1300)$ is not well defined; scalar and vector hypotheses give equally good description of the data. More data is required …

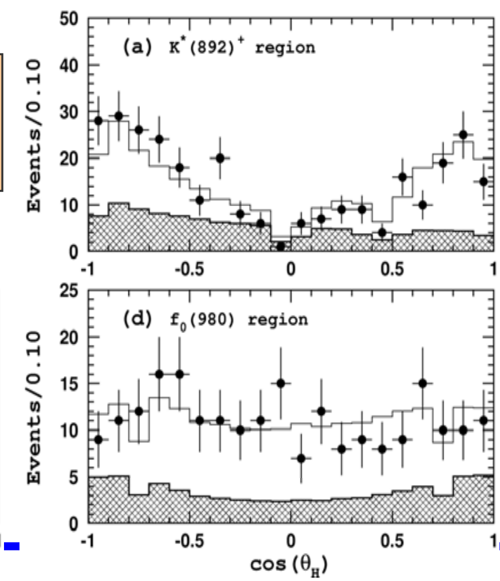
$B^0 \to K_S\pi^+\pi^-$: Fitting the Signal

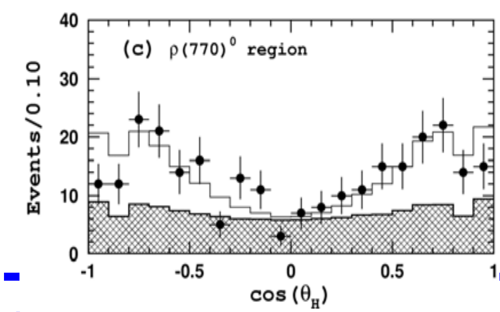






Helicity angle Distributions





Summary of two-body BF's

L=140 fb^{-1}

Mode	$\mathcal{B}(B^+ \to Rh^+) \times \mathcal{B}(R \to h^+h^-) \times 10^6$	$\mathcal{B}(B^+ \to Rh^+) \times 10^6$
$K^+\pi^+\pi^-$ charmless total	–	$46.6 \pm 2.1 \pm 4.3$
$K^*(892)^0\pi^+$, $K^*(892)^0 \to K^+\pi^-$	$6.55 \pm 0.60 \pm 0.60^{+0.38}_{-0.57}$	$9.83 \pm 0.90 \pm 0.90^{+0.57}_{-0.86}$
$K_0^*(1430)\pi^+$, $K_0^*(1430) \to K^+\pi^-$	$27.9 \pm 1.8 \pm 2.6^{+8.5}_{-5.4}$	$45.0 \pm 2.9 \pm 6.2^{+13.7}_{-8.7}$
	$(5.12 \pm 1.36 \pm 0.49^{+1.91}_{-0.51})$	$(8.26 \pm 2.20 \pm 1.19^{+3.08}_{-0.82})$
$K^*(1410)\pi^+$, $K^*(1410) \to K^+\pi^-$	< 2.0	–
$K^*(1680)\pi^+$, $K^*(1680) \to K^+\pi^-$	< 3.1	–
$K_2^*(1430)\pi^+$, $K_2^*(1430) \to K^+\pi^-$	< 2.3	–
$\rho^0(770)K^+$, $\rho^0(770) \to \pi^+\pi^-$	$4.78 \pm 0.75 \pm 0.44^{+0.91}_{-0.87}$	$4.78 \pm 0.75 \pm 0.44^{+0.91}_{-0.87}$
$f_0(980)K^+$, $f_0(980) \to \pi^+\pi^-$	$7.55 \pm 1.24 \pm 0.69^{+1.48}_{-0.96}$	–
$f_2(1270)K^+$, $f_2(1270) \to \pi^+\pi^-$	< 1.3	–
Non-resonant	–	$17.3 \pm 1.7 \pm 1.6^{+17.1}_{-7.8}$
$K^+K^+K^-$ charmless total	–	$30.6 \pm 1.2 \pm 2.3$
ϕK^+, $\phi \to K^+K^-$	$4.72 \pm 0.45 \pm 0.35^{+0.39}_{-0.22}$	$9.60 \pm 0.92 \pm 0.71^{+0.78}_{-0.46}$
$\phi(1680)K^+$, $\phi(1680) \to K^+K^-$	< 0.8	
$f_0(980)K^+$, $f_0(980) \to K^+K^-$	< 2.9	
$f_2'(1525)K^+$, $f_2'(1525) \to K^+K^-$	< 2.1	
$a_2(1320)K^+$, $a_2(1320) \to K^+K^-$	< 1.1	
Non-resonant	–	$24.0 \pm 1.5 \pm 1.8^{+1.9}_{-5.7}$
$\chi_{c0}K^+$, $\chi_{c0} \to \pi^+\pi^-$	$1.37 \pm 0.28 \pm 0.12^{+0.34}_{-0.35}$	–
$\chi_{c0}K^+$, $\chi_{c0} \to K^+K^-$	$0.86 \pm 0.26 \pm 0.06^{+0.20}_{-0.05}$	–
	$(2.58 \pm 0.43 \pm 0.19^{+0.20}_{-0.05})$	–
$\chi_{c0}K^+$ combined	–	$196 \pm 35 \pm 33^{+197}_{-26}$

Phys. Rev. D 71, 092003 (2005)

Summary of two-body BF's II

L = 353 fb^{-1}

Mode	$\mathcal{B}(B \to Rh) \times \mathcal{B}(R \to hh) \times 10^6$	$\mathcal{B}(B \to Rh) \times 10^6$
$K_S^0 \pi^+ \pi^-$ charmless total		$47.5 \pm 2.4 \pm 3.7$
$K^*(892)^+ \pi^-$, $K^*(892)^+ \to K^0 \pi^+$	$5.61 \pm 0.72 \pm 0.43^{+0.43}_{-0.29}$	$8.42 \pm 1.08 \pm 0.65^{+0.64}_{-0.43}$
$K_0^*(1430)^+ \pi^-$, $K_0^*(1430)^+ \to K^0 \pi^+$	$30.8 \pm 2.4 \pm 2.4^{+0.8}_{-3.0}$	$49.7 \pm 3.8 \pm 3.8^{+1.2}_{-4.8}$
$K^*(1410)^+ \pi^-$, $K^*(1410)^+ \to K^0 \pi^+$	< 3.8	—
$K^*(1680)^+ \pi^-$, $K^*(1680)^+ \to K^0 \pi^+$	< 2.6	—
$K_2^*(1430)^+ \pi^-$, $K_2^*(1430)^+ \to K^0 \pi^+$	< 2.1	—
$\rho(770)^0 K^0$, $\rho(770)^0 \to \pi^+ \pi^-$	$6.13 \pm 0.95 \pm 0.47^{+1.00}_{-1.05}$	$6.13 \pm 0.95 \pm 0.47^{+1.00}_{-1.05}$
$f_0(980) K^0$, $f_0(980) \to \pi^+ \pi^-$	$7.60 \pm 1.66 \pm 0.59^{+0.48}_{-0.67}$	—
$f_2(1270) K^0$, $f_2(1270) \to \pi^+ \pi^-$	< 1.4	—
Non-resonant		$19.9 \pm 2.5 \pm 1.5^{+0.7}_{-1.2}$
$\chi_{c0} K^0$, $\chi_{c0} \to \pi^+ \pi^-$	< 0.56	< 113

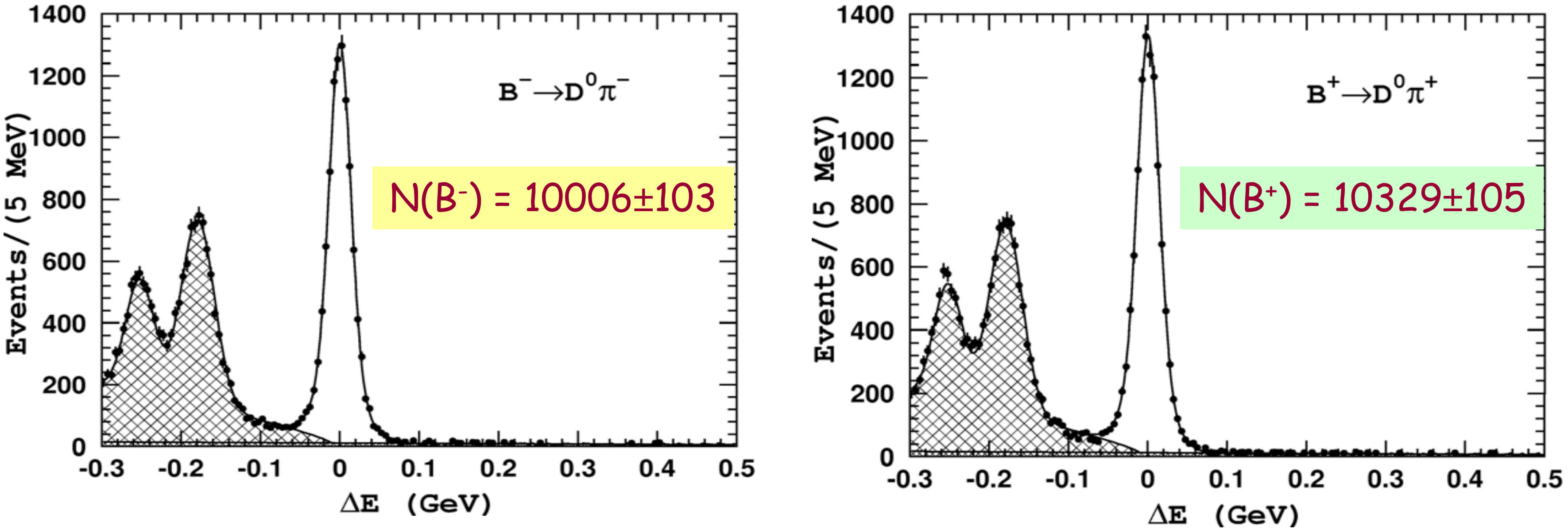
BELLE-CONF-577, hep-ex/0509047

DCPV in $B^{\pm} \to K^{\pm}\pi^{+}\pi^{-}$

Null Asymmetry Tests

$$A_{CP} = \frac{\Gamma(B^- \to f) - \Gamma(B^+ \to f)}{\Gamma(B^- \to f) + \Gamma(B^+ \to f)}$$

- continuum background events — $A_{CP}(qq) = -0.9 \pm 1.1$ %
- BB background events — $A_{CP}(BB) = -1.1 \pm 1.8$ %

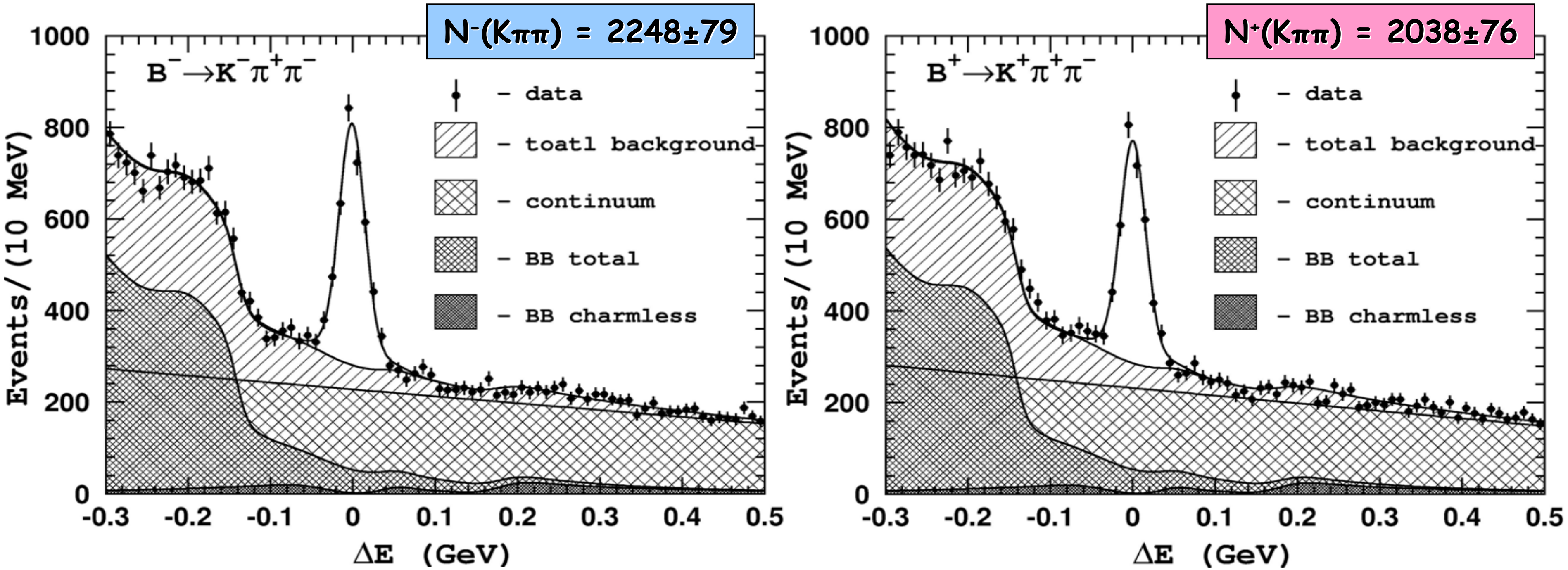


- B->D(Kπ)π — $A_{CP}(D\pi) = -1.6 \pm 0.7$ %

Considered as systematic uncertainty

DCPV in $B^{\pm} \to K^{\pm}\pi^{+}\pi^{-}$

L=353 fb^{-1}

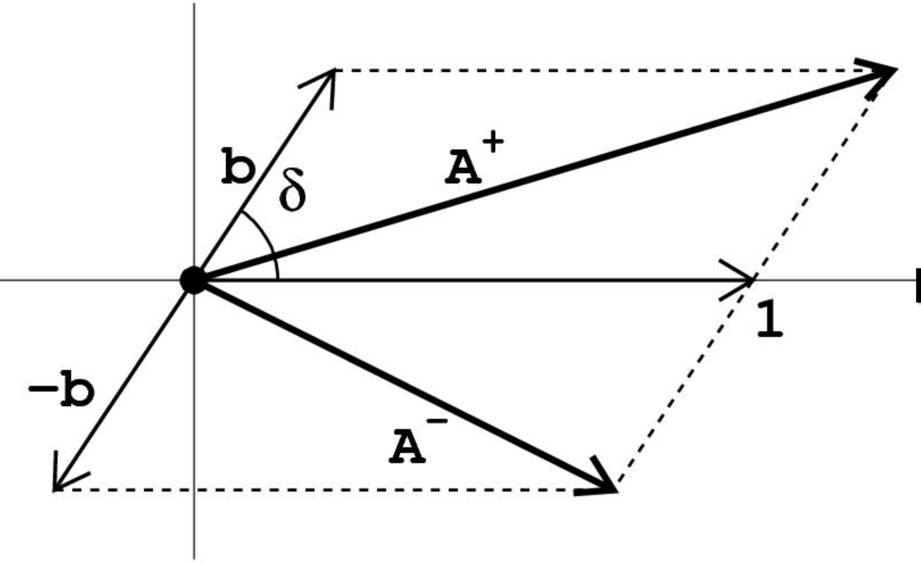


$$A_{CP}(K^{\pm}\pi^{+}\pi^{-}) = \frac{N(K^{-}\pi^{-}\pi^{+}) - N(K^{+}\pi^{+}\pi^{-})}{N(K^{-}\pi^{-}\pi^{+}) + N(K^{+}\pi^{+}\pi^{-})} = (+4.9\pm2.6\pm2.0)\%$$

Dalitz analysis is then performed with an amplitude sensitive to the charge of the B meson ...

DCPV in $B^{\pm} \to K^{\pm}\pi^{+}\pi^{-}$

Parameterization



basic parameterization

parameterization with DCPV

$$a e^{i\varphi_j} \longrightarrow a e^{i\varphi_j}(1 + \eta b_j e^{i\delta_j})$$

η: -1 for B^-, +1 for B^+

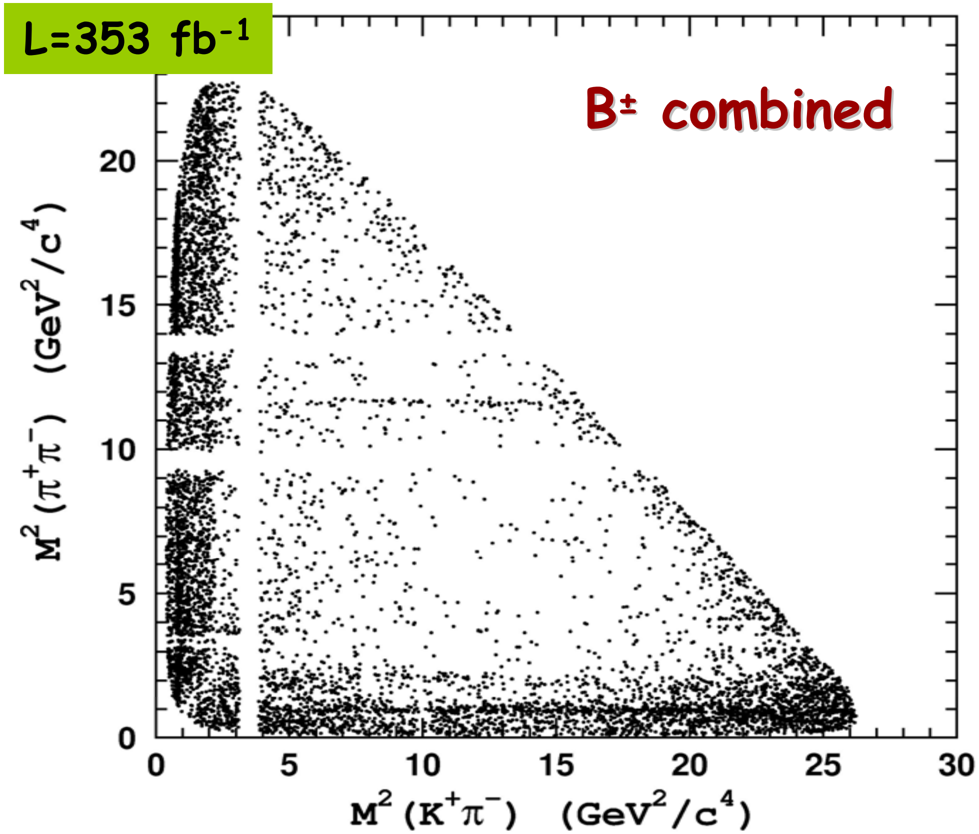
Charge asymmetry A_{CP} is given by

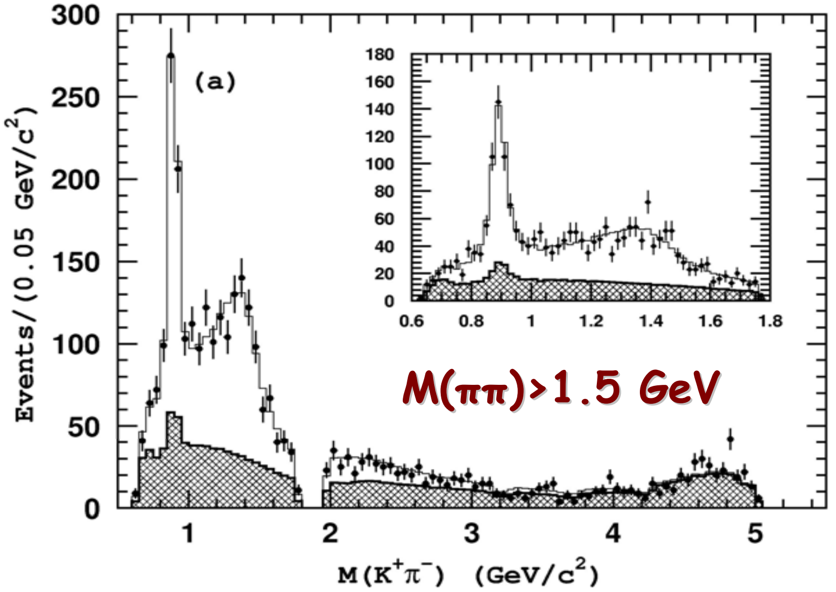
$$\mathcal{A}^j_{\rm CP} = -\frac{2b_j \cos\delta_j}{1 + b_j^2}$$

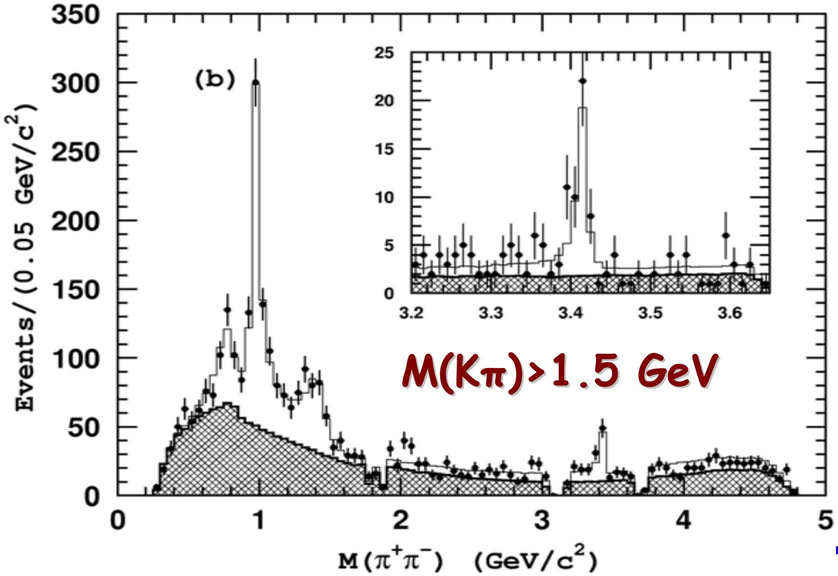
Note that CP violation can be observed even in the case of $A_{CP}=0$ (that is $\delta=90^{\circ}$ but $b\neq 0$) - possible only in three-body decays !

DCPV with $B^{\pm} \to K^{\pm}\pi^{+}\pi^{-}$

L=353 fb^{-1}







- $K^*(892)^0\pi^+$
- $K^*_0(1430)^0\pi^+$
- Non-resonant

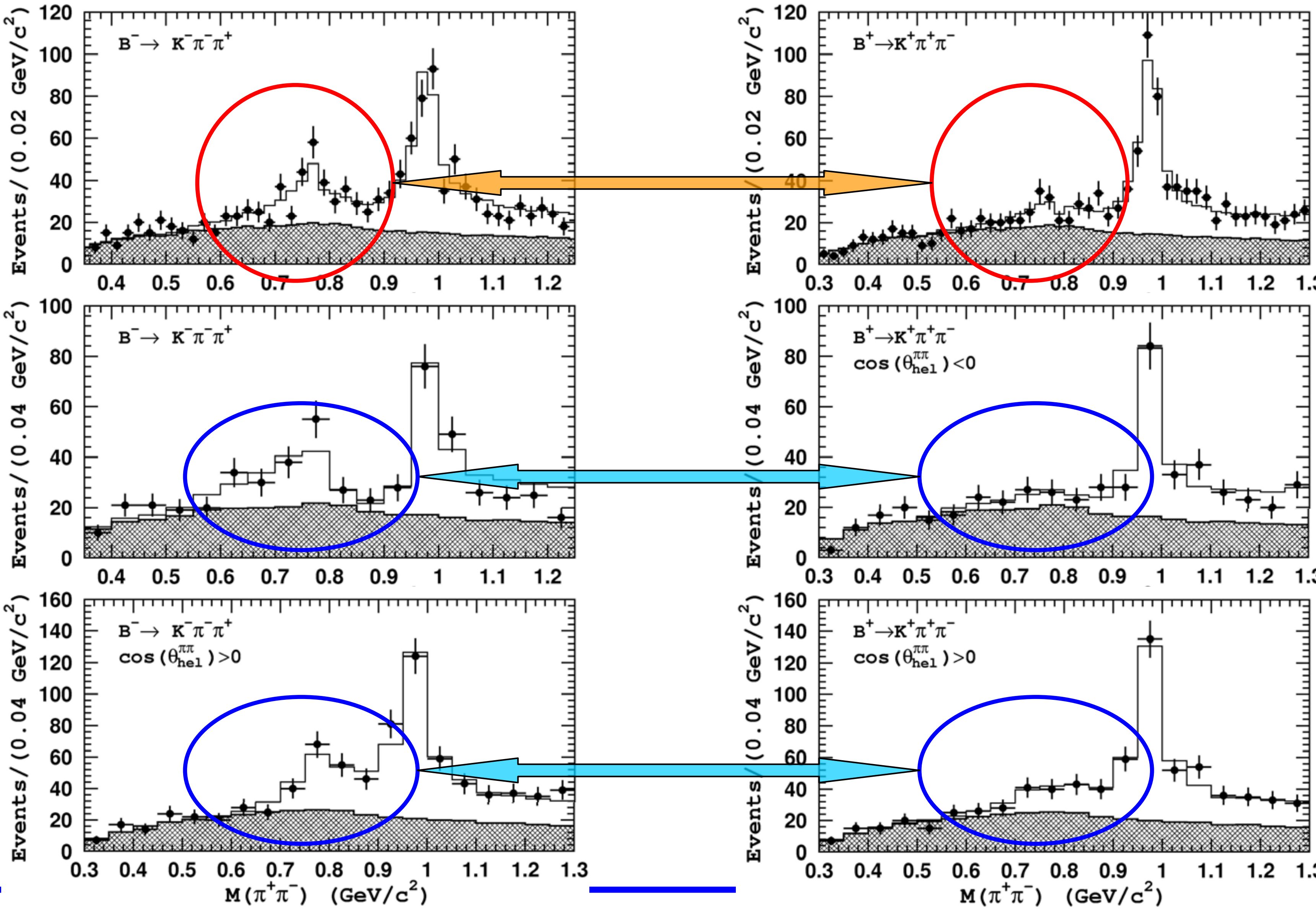
- $\rho(770)^0K^+$
- $\omega(782)K^+$
- $f_0(980)K^+$
- $f_0(1370)K^+$
- $f_2(1270)K^+$
- $\chi_{c0}K^+$

DCPV in B±->K±π+π-: Results

Channel	CP averaged fraction, %	δ, degrees	b	φ, degrees	A_{CP}, %	Significance, σ
$K^*(892)^0\pi^\pm$	$13.0 \pm 0.8^{+0.5}_{-0.7}$	0 (fixed)	$0.078 \pm 0.033^{+0.012}_{-0.003}$	$-18 \pm 44^{+5}_{-13}$	$-14.9 \pm 6.4^{+0.8}_{-0.8}$	2.6
$K_0(1430)^0\pi^\pm$	$65.5 \pm 1.5^{+2.2}_{-3.9}$	$55 \pm 4^{+1}_{-5}$	$0.069 \pm 0.031^{+0.010}_{-0.008}$	$-123 \pm 16^{+4}_{-5}$	$+7.5 \pm 3.8^{+2.0}_{-0.9}$	2.7
$\rho(770)^0K^\pm$	$7.85 \pm 0.93^{+0.64}_{-0.59}$	$-21 \pm 14^{+14}_{-19}$	$0.28 \pm 0.11^{+0.07}_{-0.09}$	$-125 \pm 32^{+10}_{-85}$	$+30 \pm 11^{+11}_{-4}$	3.9
$\omega(782)K^\pm$	$0.15 \pm 0.12^{+0.03}_{-0.02}$	$100 \pm 31^{+38}_{-21}$	0 (fixed)	–	–	–
$f_0(980)K^\pm$	$17.7 \pm 1.6^{+1.1}_{-3.3}$	$67 \pm 11^{+10}_{-11}$	$0.30 \pm 0.19^{+0.05}_{-0.10}$	$-82 \pm 8^{+2}_{-2}$	$-7.7 \pm 6.5^{+4.1}_{-1.6}$	1.6
$f_2(1270)K^\pm$	$1.52 \pm 0.35^{+0.22}_{-0.37}$	$140 \pm 11^{+18}_{-7}$	$0.37 \pm 0.17^{+0.11}_{-0.03}$	$-24 \pm 29^{+14}_{-20}$	$-59 \pm 22^{+3}_{-3}$	2.7
$f_X(1300)K^\pm$	$4.14 \pm 0.81^{+0.31}_{-0.30}$	$-141 \pm 10^{+8}_{-9}$	$0.12 \pm 0.17^{+0.04}_{-0.07}$	$-77 \pm 56^{+88}_{-43}$	$-5.4 \pm 16.5^{+10.3}_{-2.4}$	1.0
Non-Res.	$34.0 \pm 2.2^{+2.1}_{-1.8}$	$\delta_1^{nr} = -11 \pm 5^{+3}_{-3}$	0 (fixed)	–	–	–
		$\delta_2^{nr} = 185 \pm 20^{+62}_{-19}$				
$\chi_{c0}K^\pm$	$1.12 \pm 0.12^{+0.24}_{-0.08}$	$-118 \pm 24^{+37}_{-38}$	$0.15 \pm 0.35^{+0.08}_{-0.07}$	$-77 \pm 94^{+154}_{-11}$	$-6.5 \pm 19.6^{+2.9}_{-1.4}$	0.7

PRL 96, 251803 (2006)

DCPV in $B^{\pm} \to \rho(770)^0 K^{\pm}$



Summary

- Analysis of B meson decays to three-body charmless hadronic final states have been done:
  - branching fractions for 6 channels are measured;
  - upper limits for 5 more channels are set;
- Dalitz analysis for three three-body modes have been performed:
  - branching fractions for >20 quasi-two-body channels are measured;
- First evidence for CP violation in charged meson decays is observed in $B^{\pm} \to \rho(770)^0 K^{\pm}$

Three-Body Branching Fractions

3-Body Mode	Belle	BaBar	CLEO
$K^+\pi^+\pi^-$	53.6±3.1±5.1	61.4±2.4±4.5	-
$K^0\pi^+\pi^-$	45.4±5.2±5.9	43.0±2.3±2.3	$50^{+10}_{-9}\pm7$
$K^+K^+K^-$	32.8±1.8±2.8	29.6±2.1±1.6	-
$K^0K^+K^-$	28.3±3.3±4.0	23.8±2.0±1.6	-
$K_SK_SK^+$	13.4±1.9±1.5	10.7±1.2±1.0	-
$K_SK_SK_S$	$4.2^{+1.6}_{-1.3}\pm0.8$	6.5±0.8±0.8	-
$K^+K^-\pi^+$	<13	<6.3	-
$K^0K^-\pi^+$	<18	-	<21
$K_SK_S\pi^+$	<3.2	-	-
$K^-\pi^+\pi^+$	<4.5	<1.8	-
$K^+K^+\pi^-$	<2.4	<1.3	-

in units of 10^{-6}

$B^+ \to K^+\pi^+\pi^-$

Large background from other B decays
⇨ impose 2-body vetoes:

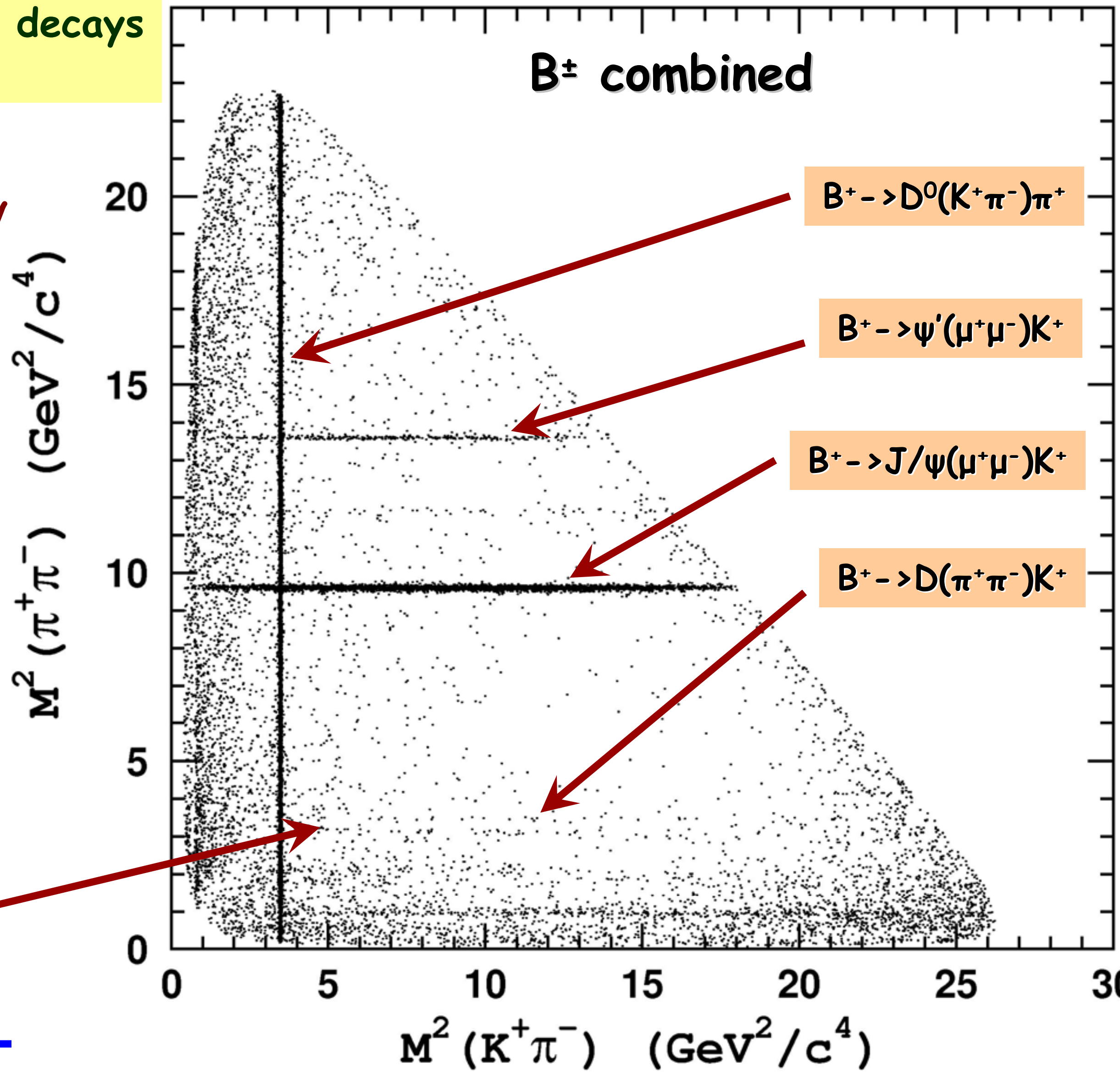
- $|M(K^+\pi^-)-M_D|$ > 100 MeV
- $|M^*(\pi^+\pi^-)-M_{J/\psi}|$ > 70 MeV
- $|M^*(\pi^+\pi^-)-M_{\psi'}|$ > 50 MeV
- $|M(\pi^+\pi^-)-M_D|$ > 15 MeV

+

Miss-ID D-veto:

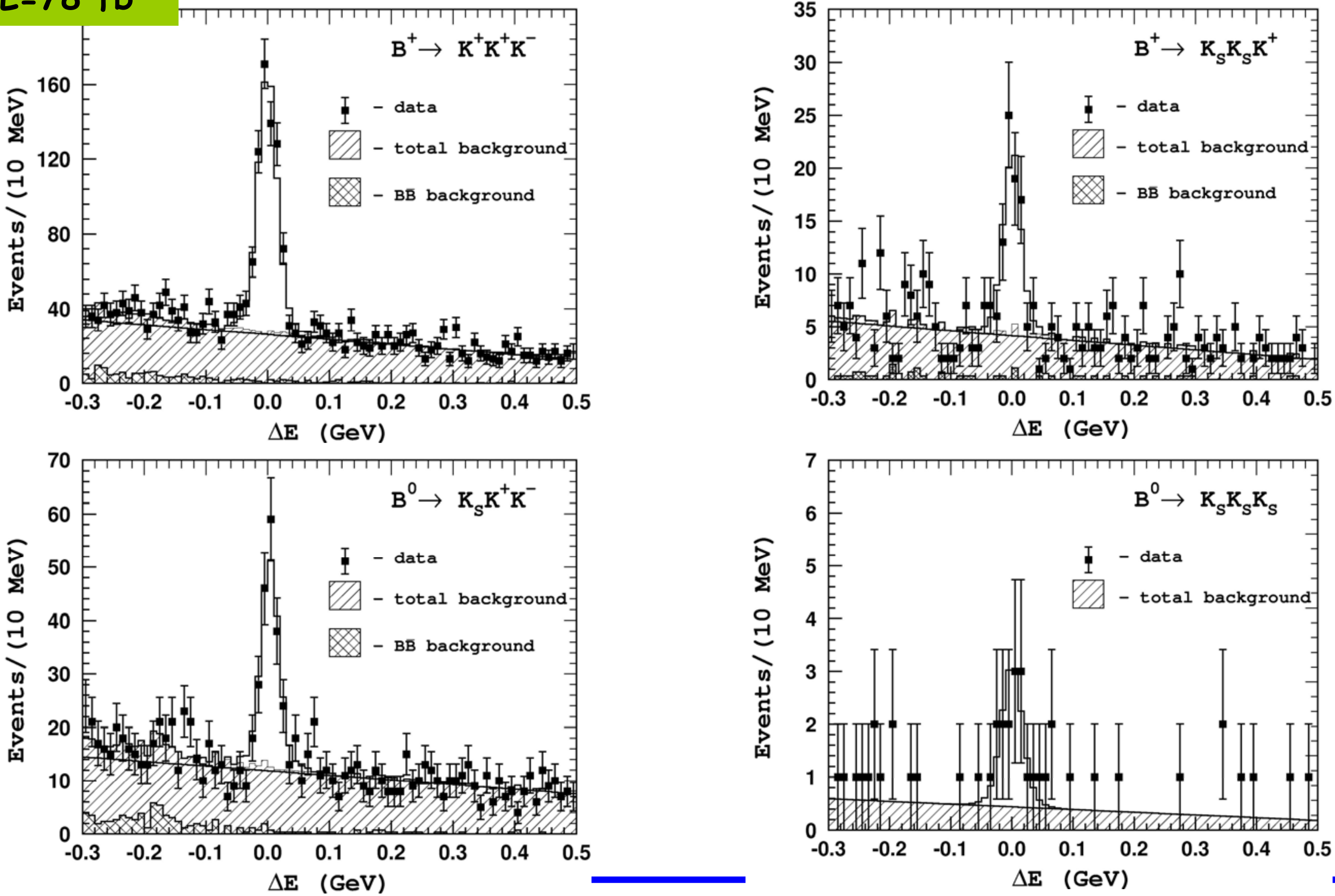
if any h^+h^- combination is consistent with $D \to K\pi$

- $|M(h^+h^-)-M_D|$>15 MeV



B->KKK

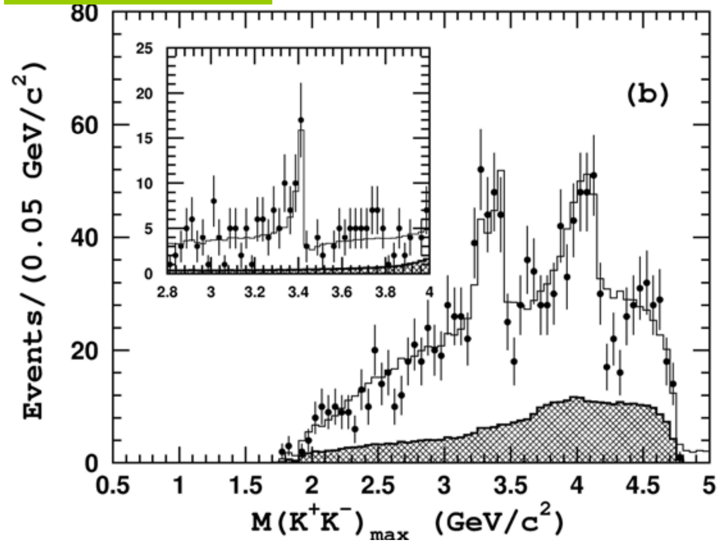
L=78 fb^{-1}

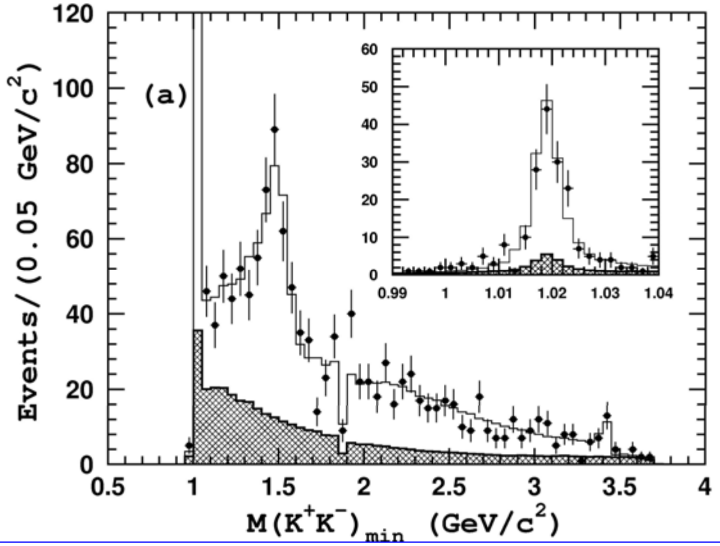


B+→ K+K+K−
B+→ KSKSK+
B0→ KSK+K−
B0→ KSKSKS
– data
– total background
– BB̄ background
Events/(10 MeV)
ΔE (GeV)
-0.3 -0.2 -0.1 0.0 0.1 0.2 0.3 0.4 0.5

$B^+ \to K^+K^+K^-$: Fitting The Signal

L=140 fb^{-1}





Model KKK-B_J:

$$S_{BJ}(KKK) = S_{AJ}(KKK) + A_{NR}$$

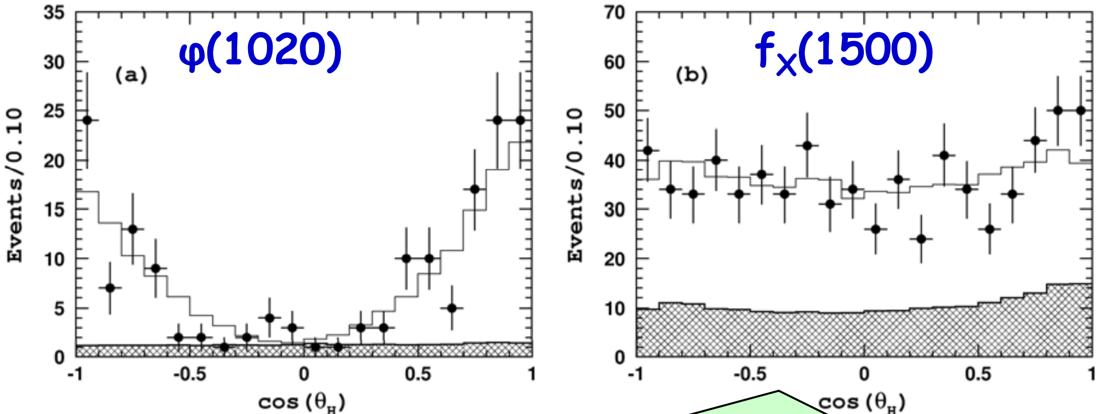
A_{NR} Parameterizations used:

$$A_{NR}(s_{13},s_{23}) = a_1 e^{i\delta}$$

$$A_{NR}(s_{13},s_{23}) = a_1[(1/s_{13})^{\beta} + (1/s_{23})^{\beta}]e^{i\delta}$$

$$A_{NR}(s_{13},s_{23}) = a_1(e^{-\beta s_{13}} + e^{-\beta s_{23}})e^{i\delta}$$

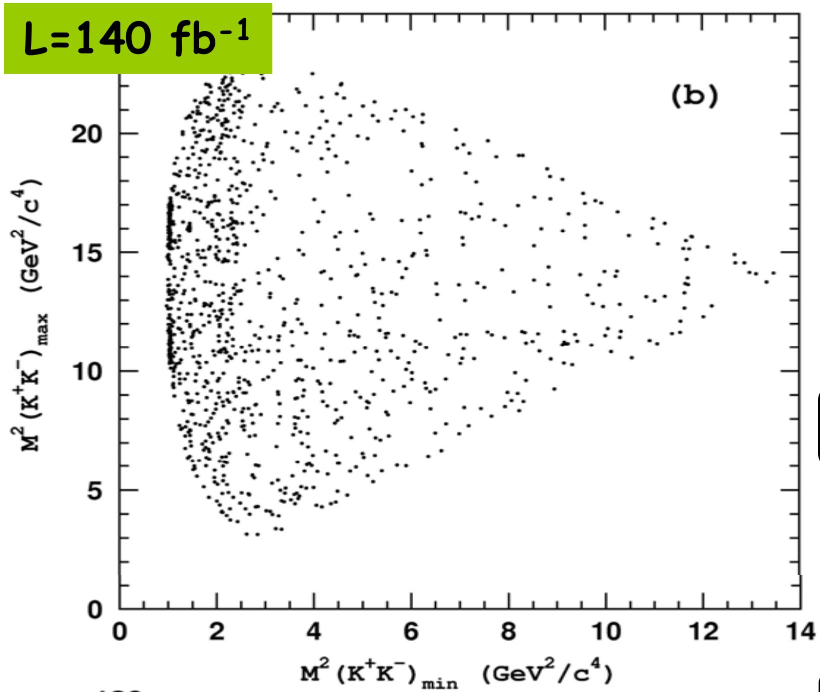
Helicity angle distributions:



$f_X(1500)$ is best fit with the scalar hypothesis

$B^+ \to K^+K^+K^-$: Fitting The Signal

L=140 fb^{-1}



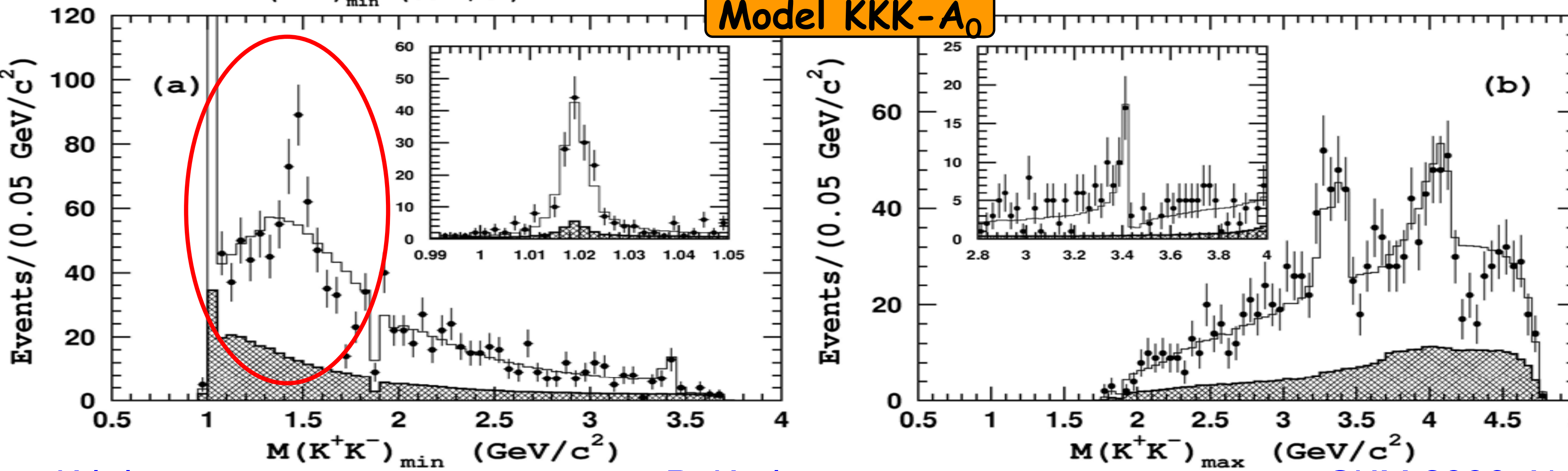
Two identical kaons in the final state -> amplitude must be symmetrized with respect to $K^+_1 \leftrightarrow K^+_2$

Model KKK-A_J:

$$S_{AJ}(KKK) = A_1(\varphi(1020)) + A_J(f_X(1500)) + A_0(\chi_{C0})$$

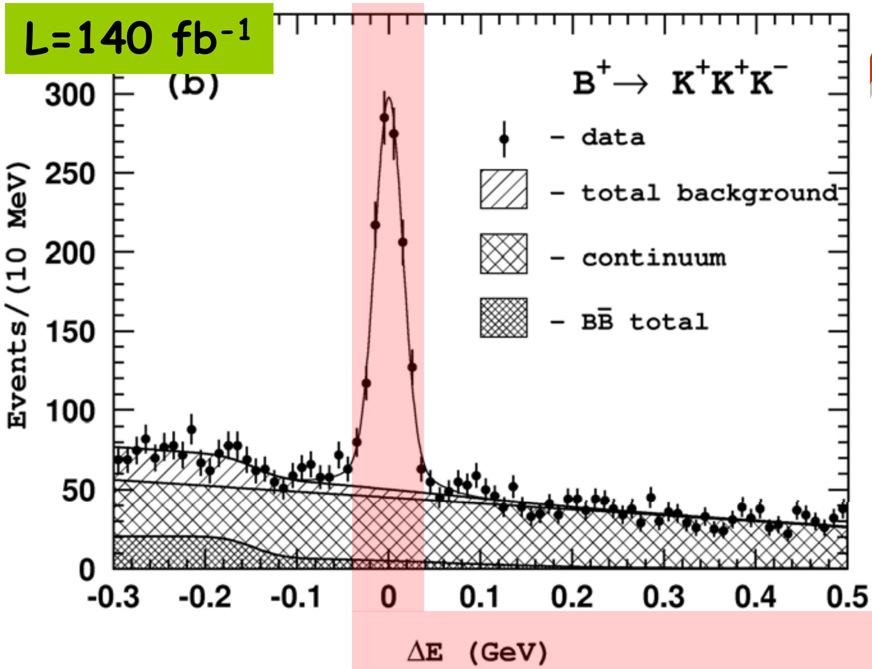
fit the data with different spin assumptions

Model KKK-A_0



$B^+ \to K^+K^+K^-$: Three-body Signal Yield

L=140 fb^{-1}



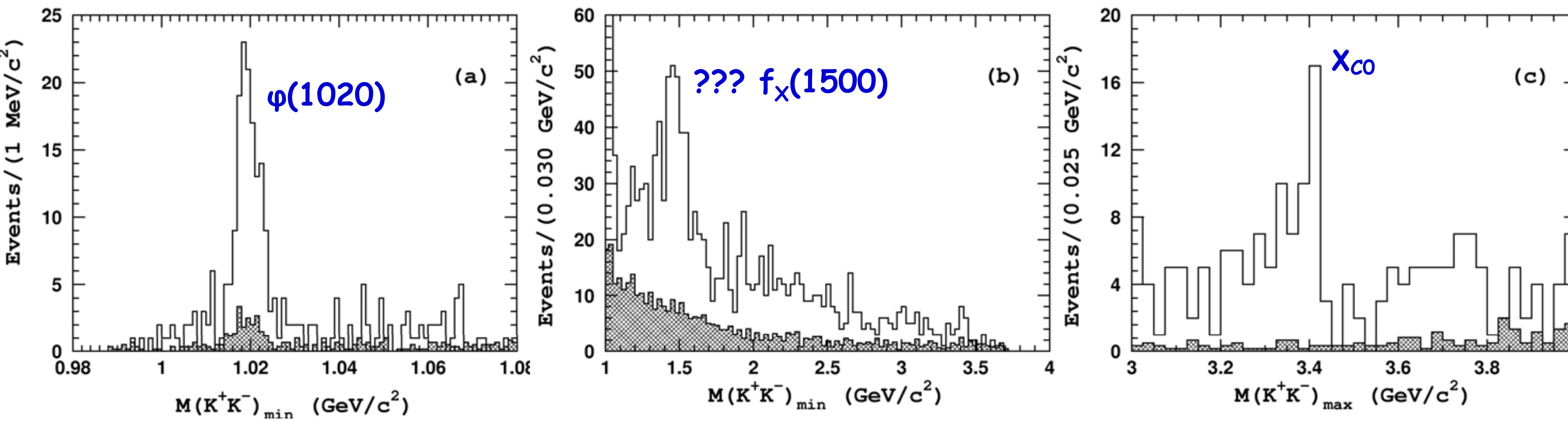
S/B~2.5

Vetoed B backgrounds:

- $B^+ \to D^0K^+; D^0 \to K^+\pi^-$: ±15 MeV
- $B^+ \to D^0h^+; D^0 \to K^+K^-$: ±15 MeV
- $B^+ \to J/\Psi K^+; J/\Psi \to K^+K^-$: ±15 MeV

$B^+ \to K^+K^+K^-$ charmless signal yield:

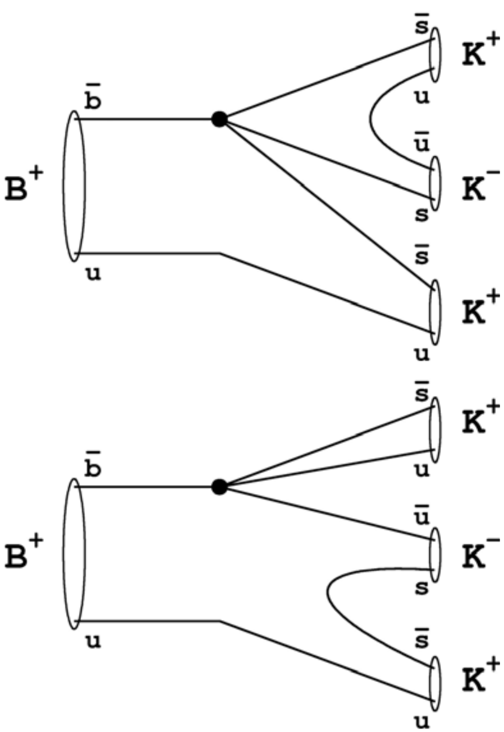
$N_{signal} = 1089 \pm 41$



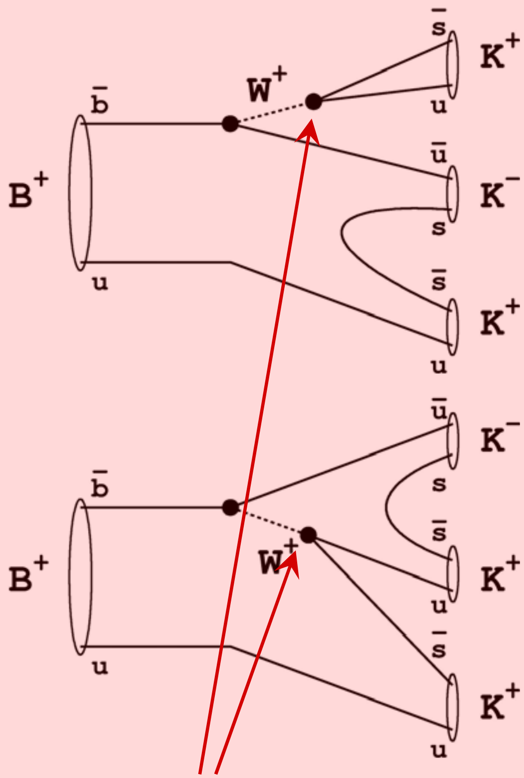
$B^0 \to K^+K^-K_S$: b->u Contribution

$B^+ \to K^+K^+K^-$ | **$B^+ \to K^+K^-\pi^+$**

b->sqq penguin

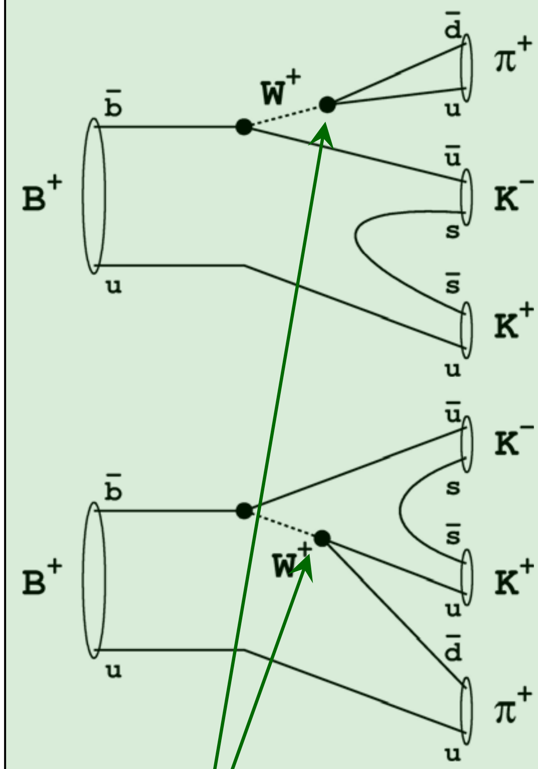


b->uus tree



Cabibbo Suppressed

b->uud tree



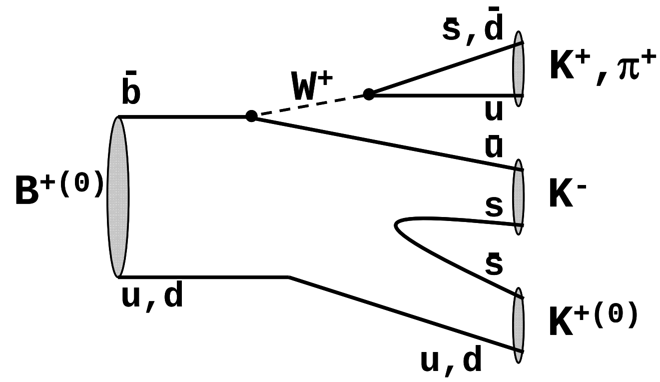
Cabibbo Favored

$B \to KK\pi$ provides a sensitive probe for the b->u contribution in $B \to KKK$

$B^0 \to K^+K^-K_S$: b->u Contribution-cont'd

We can estimate the b->u contribution as:

$$\frac{|\mathcal{A}^{KKK}_{b\to u}|^2}{|\mathcal{A}^{KKK}_{\rm total}|^2} \simeq \frac{\mathcal{B}(B^+\to K^+K^-\pi^+)}{\mathcal{B}(B^+\to K^+K^-K^+)} \times \tan^2\theta_C \left(\frac{f_K}{f_\pi}\right)^2$$



With current experimental results:

- < 3% in BF
- < 15% in amplitude

BaBar: hep-ex/0407013

Mode	Yield	$\epsilon(\%)$	$\prod \mathcal{B}_i(\%)$	Signif.	$\mathcal{B}(10^{-6})$	UL(10^{-6})
$a_0^-(\eta_{\gamma\gamma})\pi^+$	18^{+11}_{-10}	18.8	39.4	1.3	$2.3^{+1.7}_{-1.5}\pm0.9$	
$a_0^-(\eta_{3\pi})\pi^+$	15^{+9}_{-8}	15.5	22.6	1.6	$3.9^{+2.9}_{-2.5}\pm1.0$	
$\boldsymbol{a_0^-\pi^+}$				**2.0**	$\boldsymbol{2.8^{+1.5}_{-1.3}\pm0.7}$	$\boldsymbol{<5.1}$
$a_0^-(\eta_{\gamma\gamma})K^+$	2^{+6}_{-4}	17.9	39.4	0.1	$0.0^{+0.9}_{-0.6}\pm0.3$	
$a_0^-(\eta_{3\pi})K^+$	13^{+8}_{-6}	14.9	22.6	1.1	$3.1^{+2.5}_{-2.1}\pm1.9$	
$\boldsymbol{a_0^-K^+}$				**0.4**	$\boldsymbol{0.4^{+1.0}_{-0.8}\pm0.2}$	$\boldsymbol{<2.1}$
$a_0^-(\eta_{\gamma\gamma})\overline{K}^0$	-12^{+8}_{-6}	21.4	13.5	0.0	$-3.7^{+2.9}_{-2.3}\pm0.9$	
$a_0^-(\eta_{3\pi})\overline{K}^0$	0^{+7}_{-5}	15.8	7.9	0.5	$2.7^{+6.1}_{-4.4}\pm1.9$	
$\boldsymbol{a_0^-\overline{K}^0}$				**0.6**	$\boldsymbol{-1.5^{+2.4}_{-1.8}\pm0.8}$	$\boldsymbol{<3.9}$
$a_0^0(\eta_{\gamma\gamma})\pi^+$	17^{+11}_{-9}	12.8	39.4	1.4	$3.1^{+2.4}_{-2.0}\pm1.2$	
$a_0^0(\eta_{3\pi})\pi^+$	1^{+8}_{-6}	9.5	22.6	0.3	$1.2^{+3.9}_{-3.2}\pm1.7$	
$\boldsymbol{a_0^0\pi^+}$				**1.4**	$\boldsymbol{2.6^{+2.0}_{-1.7}\pm1.0}$	$\boldsymbol{<5.8}$
$a_0^0(\eta_{\gamma\gamma})K^+$	0^{+5}_{-3}	12.4	39.4	0.3	$0.3^{+1.1}_{-0.6}\pm0.4$	
$a_0^0(\eta_{3\pi})K^+$	6^{+7}_{-5}	9.1	22.6	0.5	$1.9^{+3.8}_{-2.9}\pm2.5$	
$\boldsymbol{a_0^0K^+}$				**0.4**	$\boldsymbol{0.4^{+1.1}_{-0.7}\pm0.3}$	$\boldsymbol{<2.5}$
$a_0^0(\eta_{\gamma\gamma})K^0$	0^{+6}_{-5}	15.0	13.3	0.5	$1.4^{+3.5}_{-2.4}\pm1.2$	
$a_0^0(\eta_{3\pi})K^0$	4^{+5}_{-4}	9.7	7.8	1.2	$6.6^{+7.8}_{-5.4}\pm2.8$	
$\boldsymbol{a_0^0K^0}$				**1.0**	$\boldsymbol{2.8^{+3.1}_{-2.4}\pm1.1}$	$\boldsymbol{<7.8}$

b->u tree contribution would probably result in quasi-two-body final states with a resonant state in K_SK^- system (such as $a_0\pi/K$) while b->s (as observed) proceed via resonances in K^+K^- system -> the interference term might be suppressed and b->u contribution is significantly smaller than 15%

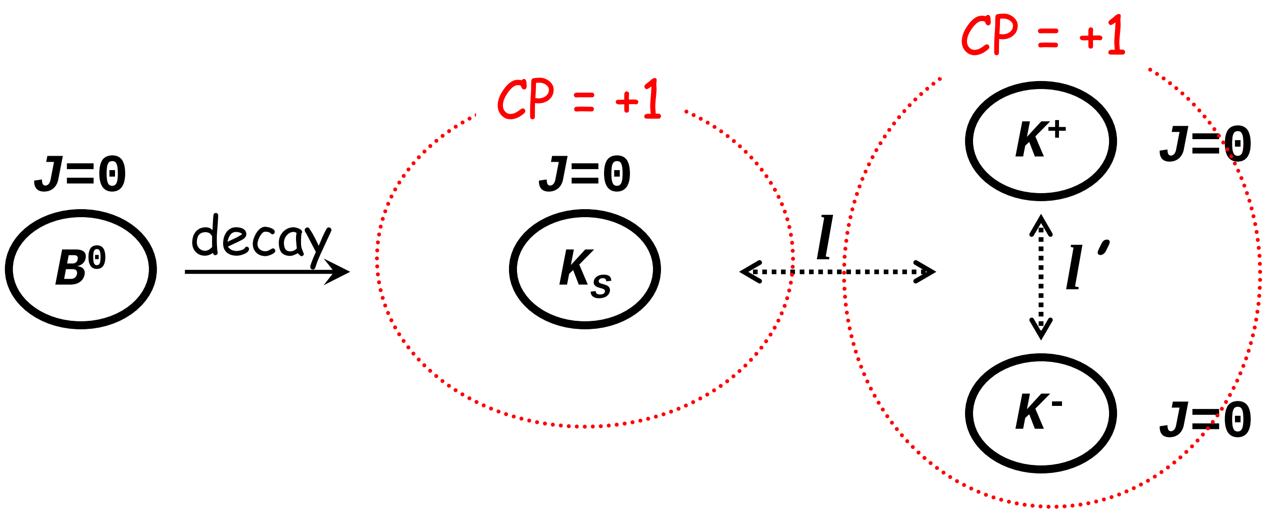
More analysis (experimental & theoretical) is required

See also: Grossman,Ligeti,Nir,Quinn Phys. Rev. D68

$B^0 \to K^+K^-K_S$: CP Mixture

Since $B^0 \to K^+K^-K_S$ is 3-body decay,
the final state is a mixture of $CP=\pm1$

$CP = \pm1$ fraction is equal to that of λ=even/odd



$l = l'$

$CP = (-1)^l$

$B^0 \to K^+K^-K_S$: CP Mixture – cont'd

Assuming isospin symmetry

(b->s conserves isospin; b->u is small)

$$\mathcal{B}(B^+ \to K^+K^0\overline{K}^0) = \mathcal{B}(B^0 \to K^0K^+K^-)\times\frac{\tau_{B^+}}{\tau_{B^0}}$$

⇓

I-even fraction in |K⁺K⁻> is equal to that in $|K^0\overline{K}^0\rangle$ system

$$|K^0\overline{K}^0\rangle = \frac{\alpha}{\sqrt{2}}(|K_SK_S\rangle + |K_LK_L\rangle) + \beta|K_SK_L\rangle$$

CP =+1 **I = even** **I = odd**

$$|K^+K^0\overline{K}^0\rangle = \frac{\alpha}{\sqrt{2}}\left(|K^+K_SK_S\rangle + |K^+K_LK_L\rangle\right) + \beta|K^+K_SK_L\rangle$$

First measurement with 78 fb^{-1}:

$$\alpha^2 = 2\frac{\mathcal{B}(B^+\to K^+K_SK_S)}{\mathcal{B}(B^0\to K^0K^+K^-)}\times\frac{\tau_{B^0}}{\tau_{B^+}} = \frac{\mathcal{B}(B^+\to K^+K_SK_S)}{\mathcal{B}(B^0\to K_SK^+K^-)}\times\frac{\tau_{B^0}}{\tau_{B^+}} = 1.03 \pm 0.15(\text{stat}) \pm 0.05(\text{syst})$$

The most resent update with 353 fb^{-1}:

$f_{CP\text{-}even} = 0.93 \pm 0.09 \pm 0.05$

$B^0 \to \varphi K_S$

$\sin 2\beta_{eff} = 0.44 \pm 0.27 \pm 0.05$

$B^0 \to K^+K^-K_S$ (non φ)

$\sin 2\beta_{eff} = 0.60 \pm 0.18 \pm 0.04\ ^{+0.19}_{-0.12}$

See also: M.Gronau, J.Rosner, Phys. Lett. B564