Hot Topics from *BABAR*

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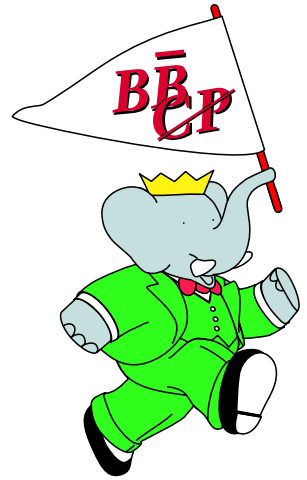


BABAR-TALK-07/041

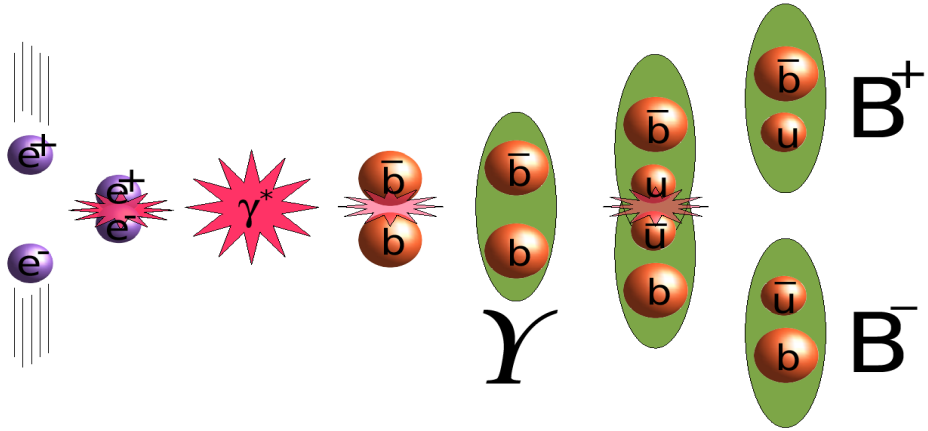
5th Flavor Physics and CP Violation Conference

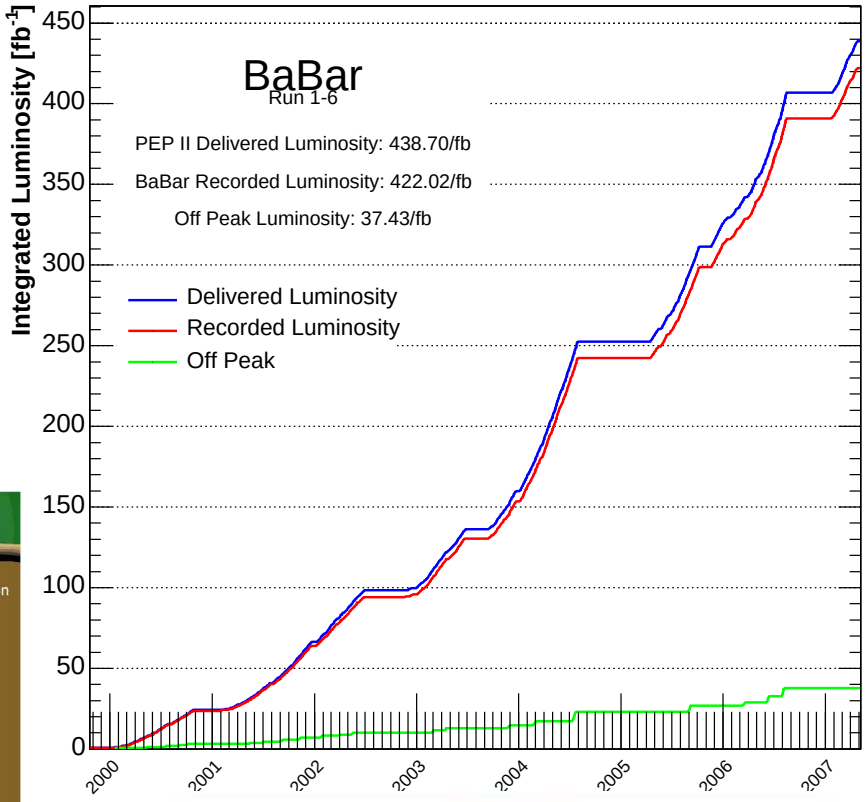
Bled, Slovenia, May 13, 2007

OUTLINE

(I) $B^{\pm} \to \tau^{\pm}\nu_{\tau}$ (II) $B^{\pm} \to \varphi K^{*\pm}$

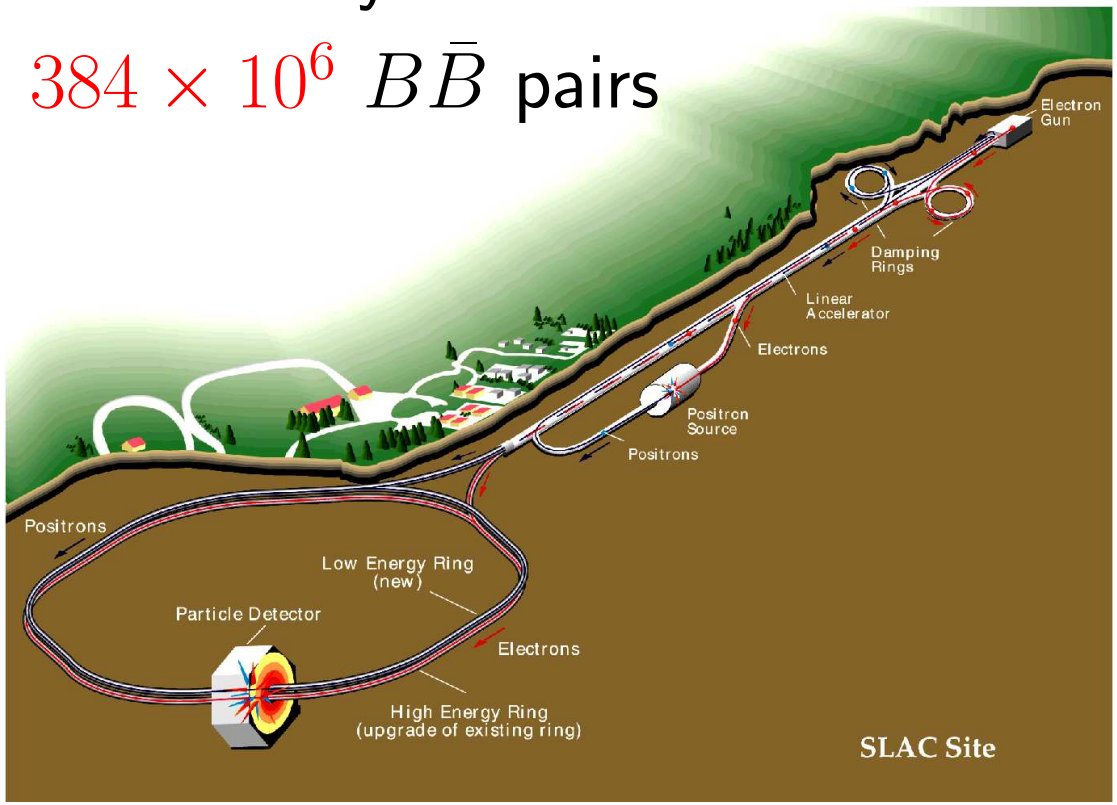
Producing and Detecting B Mesons on BABAR





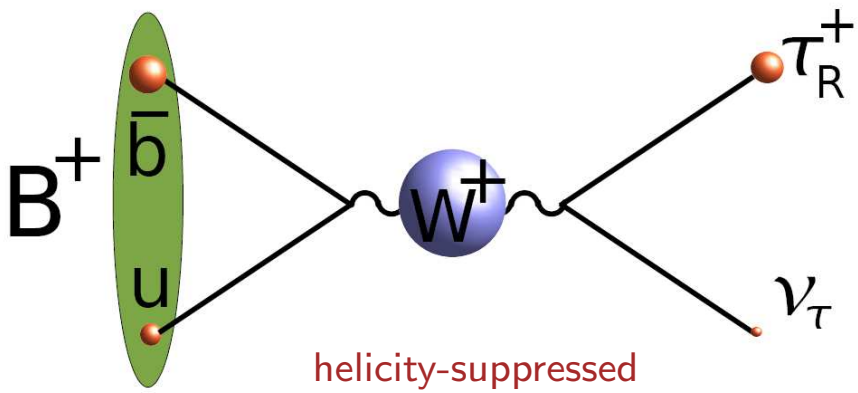
- This analysis

384×10^6 $B\bar{B}$ pairs

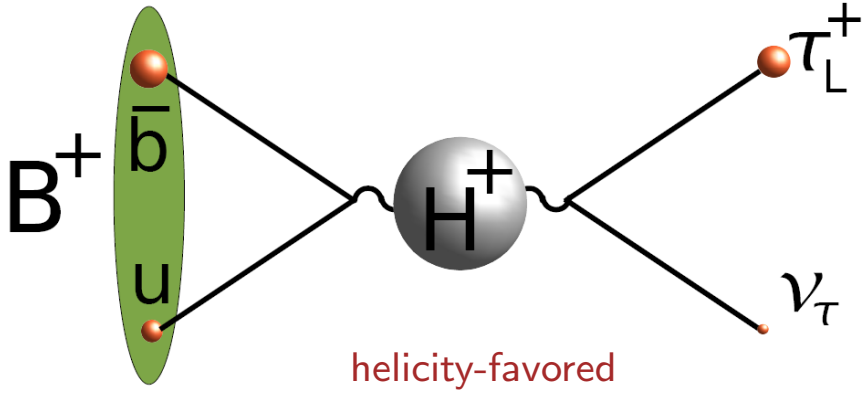


Hot Topic II: B→τν

$B^+ \to \tau^+ \nu_\tau$ Expectation



helicity-suppressed



helicity-favored

W.-S.Hou (1992)

$$\mathcal{B} = \frac{G_F^2 m_B m_\tau^2}{8\pi}\left[1-\frac{m_\tau^2}{m_{B^+}^2}\right]^2 \tau_{B^+} f_B{}^2 |V_{ub}|^2 \left[1-\tan^2\beta\,\frac{m_{B^+}^2}{m_{H^+}^2}\right]^2$$

- f_B or V_{ub} (lattice QCD/CKM) or
- constrain $(\tan\beta/m_{H^+})$

SM expectation: $\mathcal{B} \sim (1.6 \pm 0.4) \times 10^{-4}$

$f_B = (0.216 \pm 0.022)$ GeV

$|V_{ub}| = (4.31 \pm 0.30) \times 10^{-3}$

BABAR-CONF-06/028

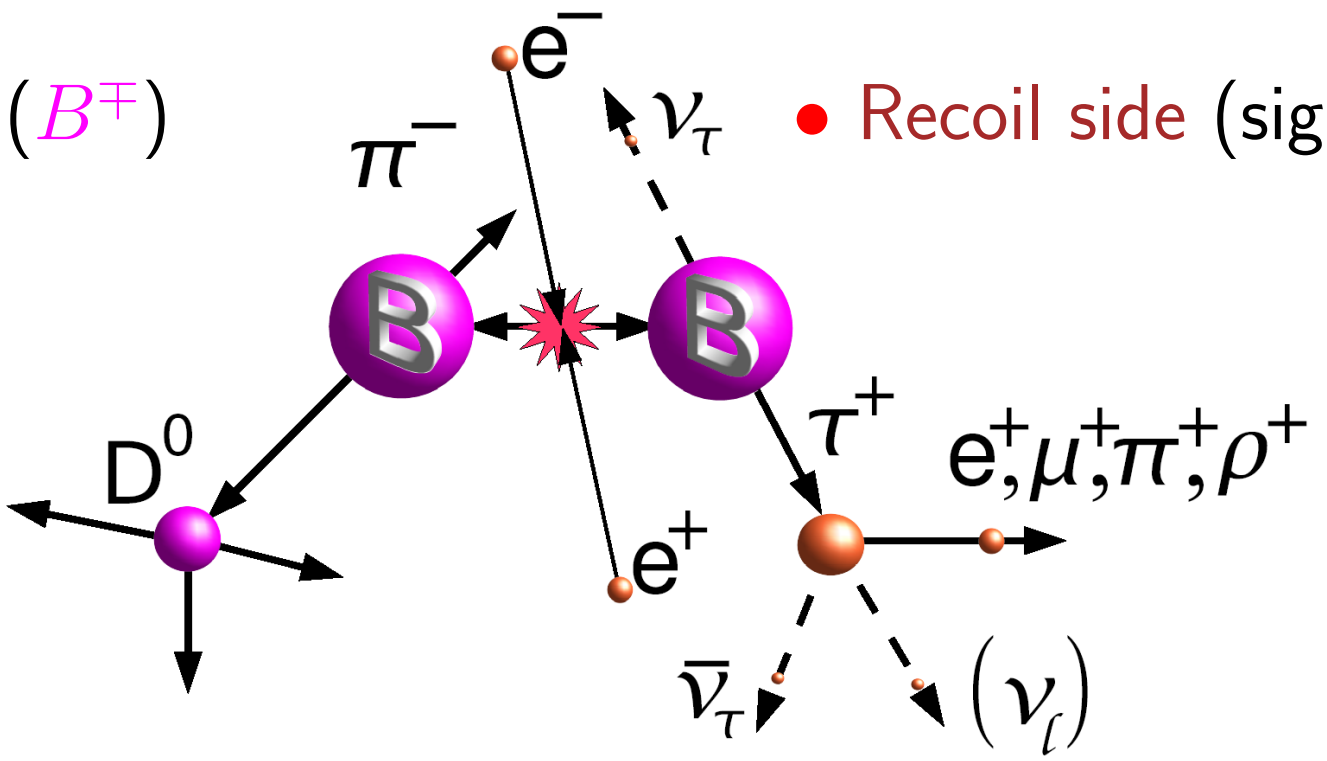
$(0.88^{+0.68}_{-0.67} \pm 0.11) \times 10^{-4}$

BELLE PRL 97, 251802 (2006)

$(1.79^{+0.56+0.46}_{-0.49-0.51}) \times 10^{-4}$

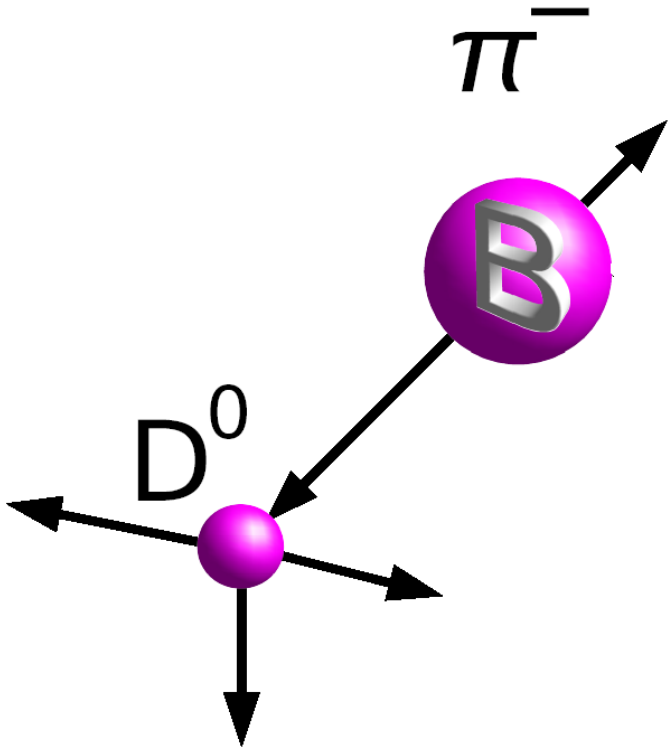
$B^+ \to \tau^+ \nu_\tau$ Analysis Overview

- Tag side ($B^\mp$)
- Recoil side (signal $B^\pm$)



- 1 track (or $+\pi^0$), 2–3 ν missing in signal B
  - weak experimental constraints
- Fully or partially reconstruct tag B
  - clean environment in e^+e^-: the rest is signal B

$B^+ \to \tau^+ \nu_\tau$: Tag Side



- Two tag methods:

(1) Semileptonic $B^\mp \to D^0(\pi^0/\gamma)l^\mp\nu$

updated result today: *BABAR*-PUB-07/007

$320 \to 383 \times 10^6\ B\bar{B}$

improved systematics

$\epsilon_{\rm tag} = 0.66\%$

(2) Hadronic $B^\mp \to D^{(*)0}X^\mp$

new result today

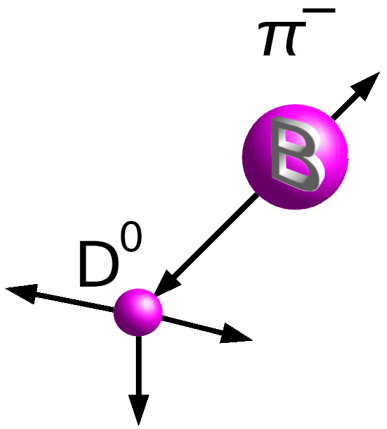
$D^{*0} \to D^0\pi^0,\ D^0\gamma$

$D^0 \to\ K^+\pi^-,\ \ K^+\pi^-\pi^0,\ \ K^+\pi^-\pi^-\pi^+,\ \ K_S\pi^+\pi^-$

$X^\mp = n_1\pi^\pm\, n_2K^\pm\, n_3K_S, n_4\pi^0\ (n_1+n_2 \le 5,\ n_3 \le 2,\ n_4 \le 2)$

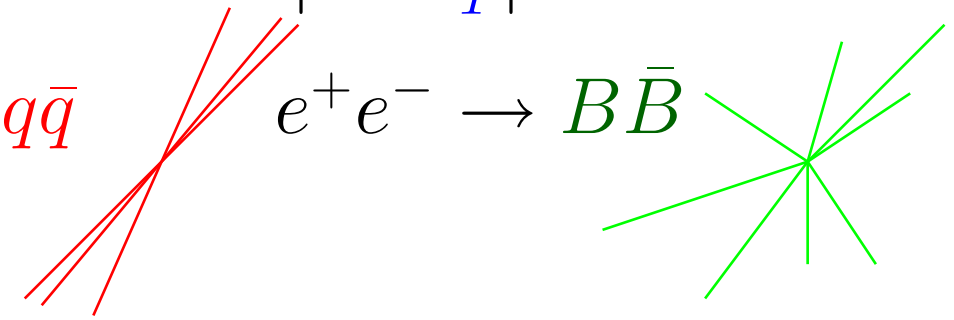
$\epsilon_{\rm tag} = 0.15\%$

$B^+ \to \tau^+ \nu_\tau$: Hadronic Tag Side



- Take advantage of full $B_{\rm tag}$ reconstruction
  - select on thrust: $|\cos\theta_T^*| < 0.7 - 0.9$

$e^+e^- \to q\bar{q}$ $e^+e^- \to B\bar{B}$



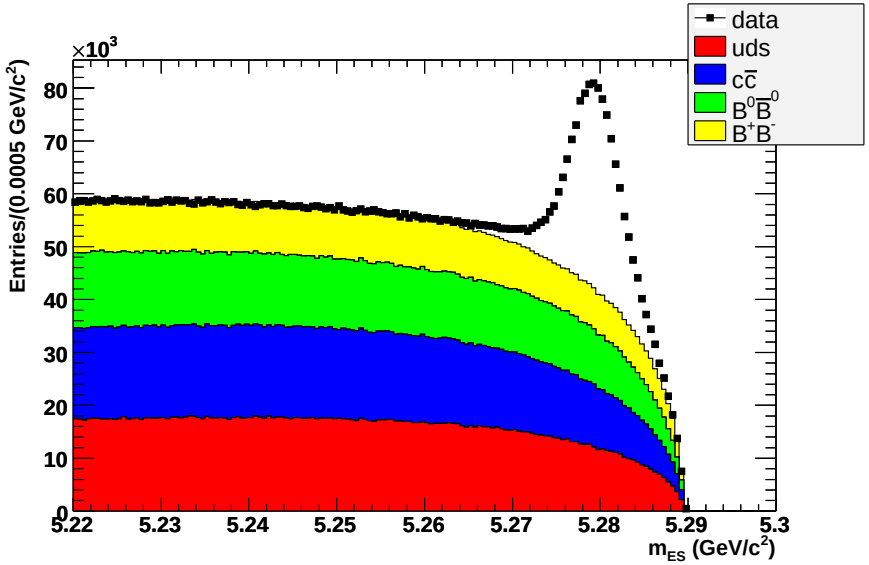
- select on energy:

$|\Delta E| = |E_B^* - \sqrt{s}/2| < 3\sigma$ (30-100 MeV)

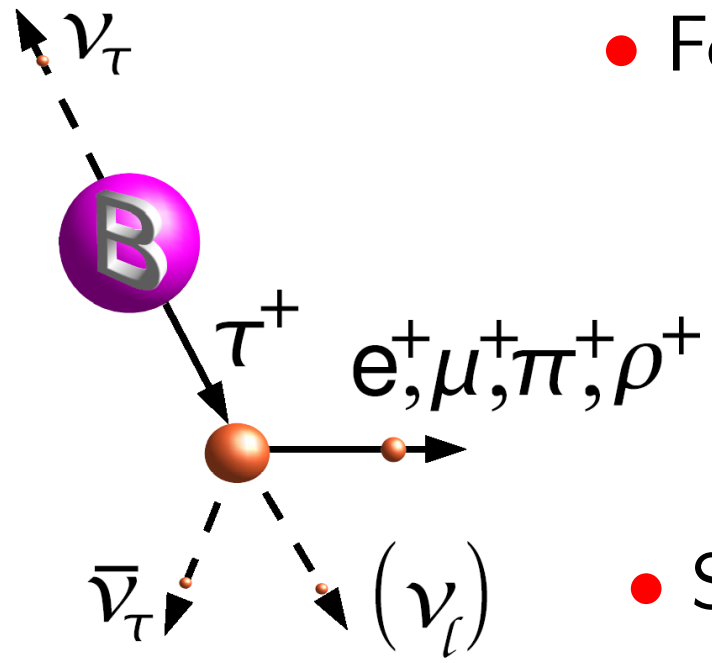
- select on momentum:

$$m_{\rm ES} = \sqrt{s/4 - \mathbf{p}_B^{*2}} > 5.27 \text{ GeV}$$

$N_B = 5.9 \times 10^5$ $\longrightarrow$



$B^+ \to \tau^+ \nu_\tau$: Recoil Side

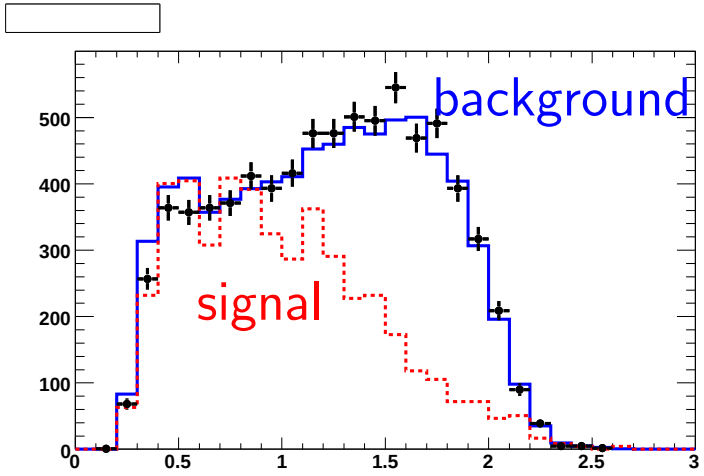


- Four channels (71%)

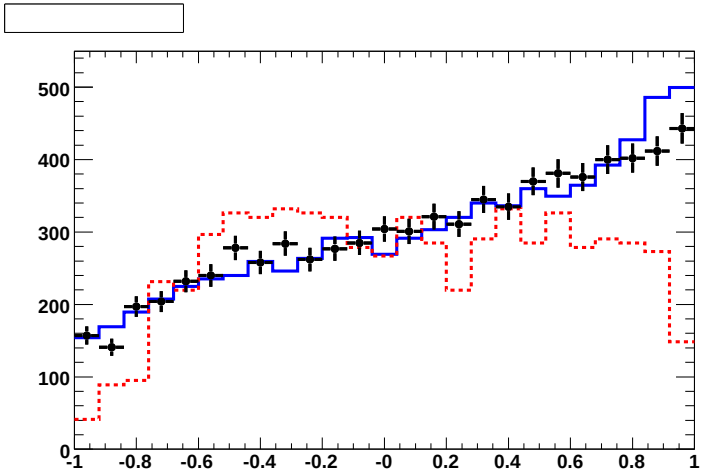
	$\epsilon_{\rm reco}$
$\tau^+ \to e^+ \bar{\nu}_\tau \nu_e$	19.3%
$\tau^+ \to \mu^+ \bar{\nu}_\tau \nu_\mu$	10.8%
$\tau^+ \to \pi^+ \bar{\nu}_\tau$	19.7%
$\tau^+ \to (\pi^+ \pi^0) \bar{\nu}_\tau$	7.0%

- Selection on PID, $N_{{\rm trk},\pi^0}$, ρ quality, ...

example $e^+ \bar{\nu}_\tau \nu_e$: $P^*_{\rm trk} < 1.25$ $\cos\theta^*_{\rm miss} < 0.9$



$P^*_{\rm trk}$ (GeV)



$\cos\theta^*_{\rm miss}$

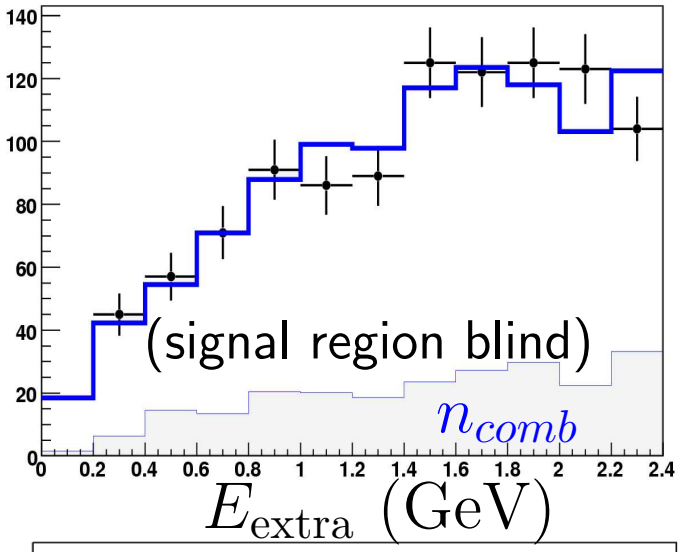
$B^+ \to \tau^+\nu_\tau$: Background Estimate

- Main variable

$$E_{\rm extra} = \Sigma E(\text{neutral clusters})$$

< 0.16 GeV $(e^+\bar{\nu}_\tau\nu_e)$
< 0.10 GeV $(\mu^+\bar{\nu}_\tau\nu_\mu)$
< 0.23 GeV $(\pi^+\bar{\nu}_\tau)$
< 0.29 GeV $(\rho^+\bar{\nu}_\tau)$

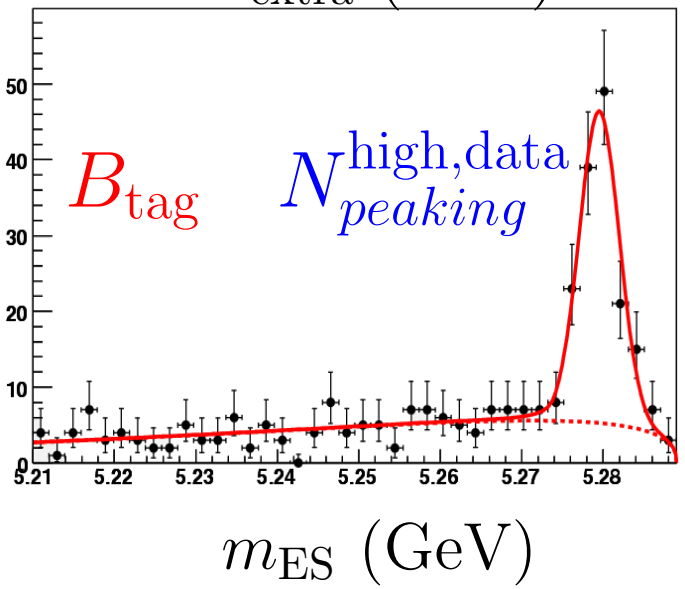
optimized $E_{\rm min}$(cluster)



- Background estimate (b)

sideband $0.4 < E_{\rm extra} < 2.4$ GeV

$$b = n_{comb} + N^{\rm high,data}_{peaking} \times \frac{N^{\rm low,MC}_{peaking}}{N^{\rm high,MC}_{peaking}}$$



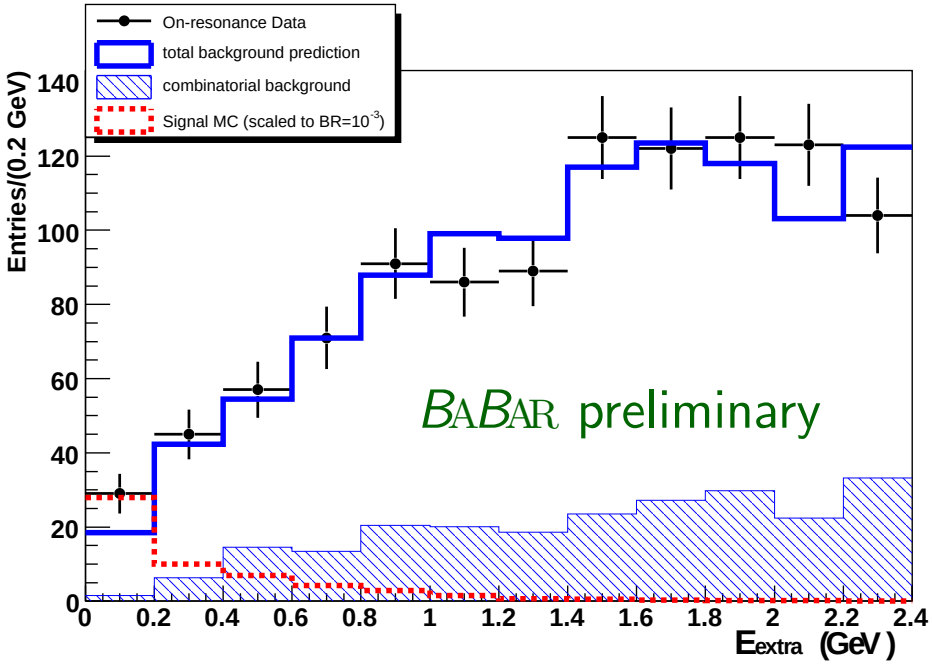
alternative: relax selection

dominant: "peaking" (true B: semileptonic)

$B^+ \to \tau^+ \nu_\tau$: Hadronic Tag Result

BABAR preliminary

τ decay mode	$\langle b$ackground$\rangle$	observed
$\tau \to e\nu\nu$	1.47 ± 1.37	4
$\tau \to \mu\nu\nu$	1.78 ± 0.97	5
$\tau \to \pi\nu$	6.79 ± 2.11	10
$\tau \to \pi\pi^0\nu$	4.23 ± 1.39	5
all modes	14.27 ± 3.03	24



$$\mathcal{L}(s+b) \equiv \Pi_{i=1}^{4} \frac{e^{-(s_i+b_i)}(s_i+b_i)^{n_i}}{n_i!}$$

- Minimize $\mathrm{Q}(\mathcal{B}) = -2\ln(\mathcal{L}(s+b)/\mathcal{L}(b))$

$\mathcal{B} \neq 0 \Rightarrow 2.2\sigma$ (2.7 w/o bkg. error)

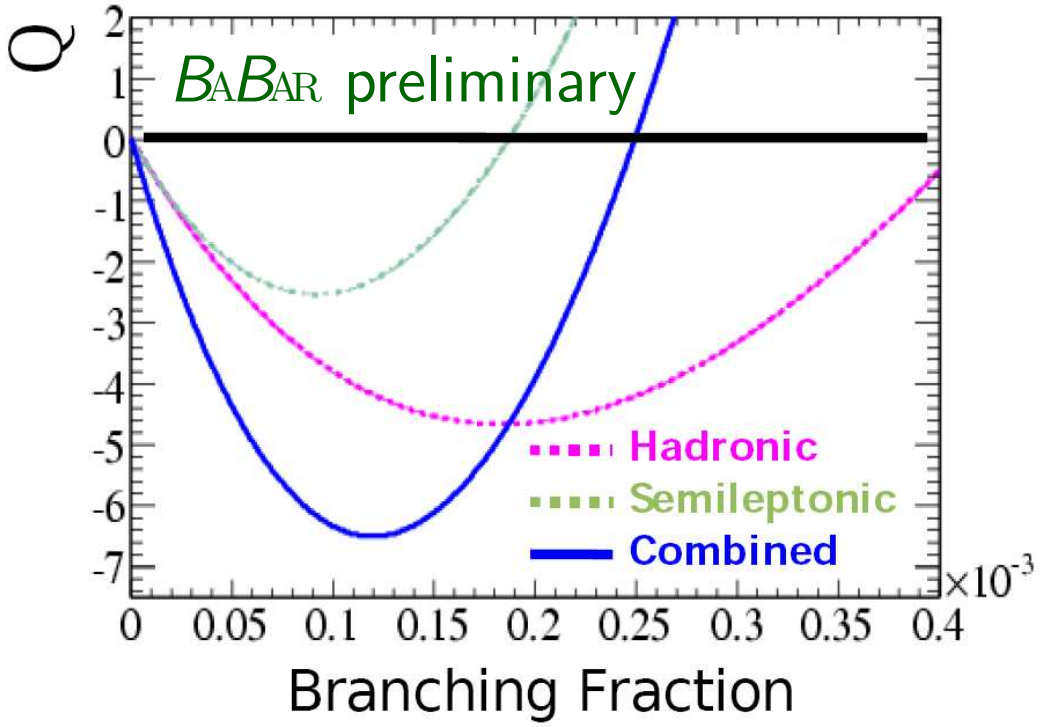
$$\mathcal{B}(B^\pm \to \tau^\pm \nu_\tau) = [1.8^{+1.0}_{-0.9}(\mathrm{stat\&bkg}) \pm 0.3(\mathrm{eff})] \times 10^{-4}$$

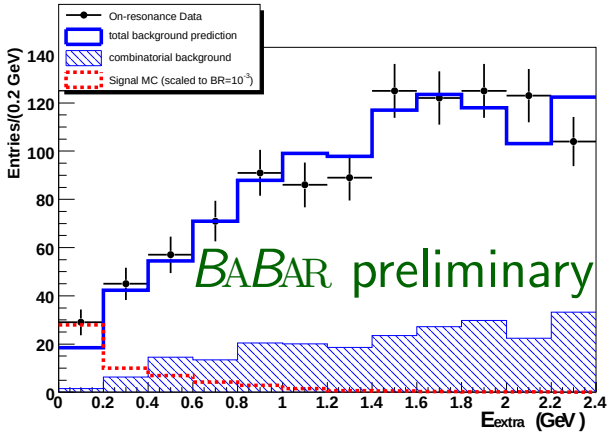
$B^+ \to \tau^+ \nu_\tau$: Combined Result

$$\mathcal{B} = (1.20^{+0.40+0.29}_{-0.38-0.30} \pm 0.22) \times 10^{-4}$$

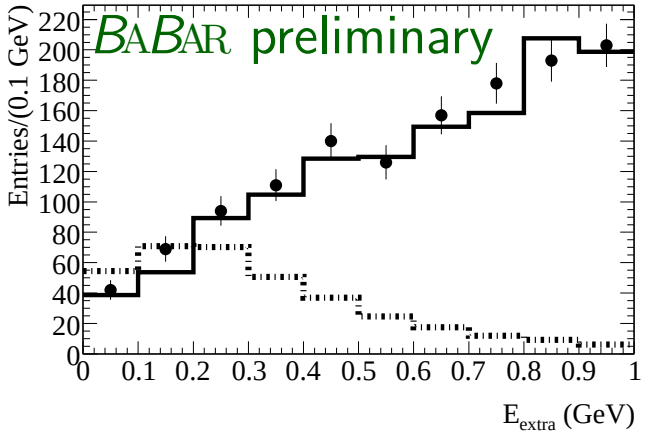
(stat.) (bkg.) (eff.)

2.6σ (3.2σ stat.)





Had. tag: $(1.8^{+1.0}_{-0.9} \pm 0.3) \times 10^{-4}$



Semilep. tag: $(0.9 \pm 0.6 \pm 0.1) \times 10^{-4}$

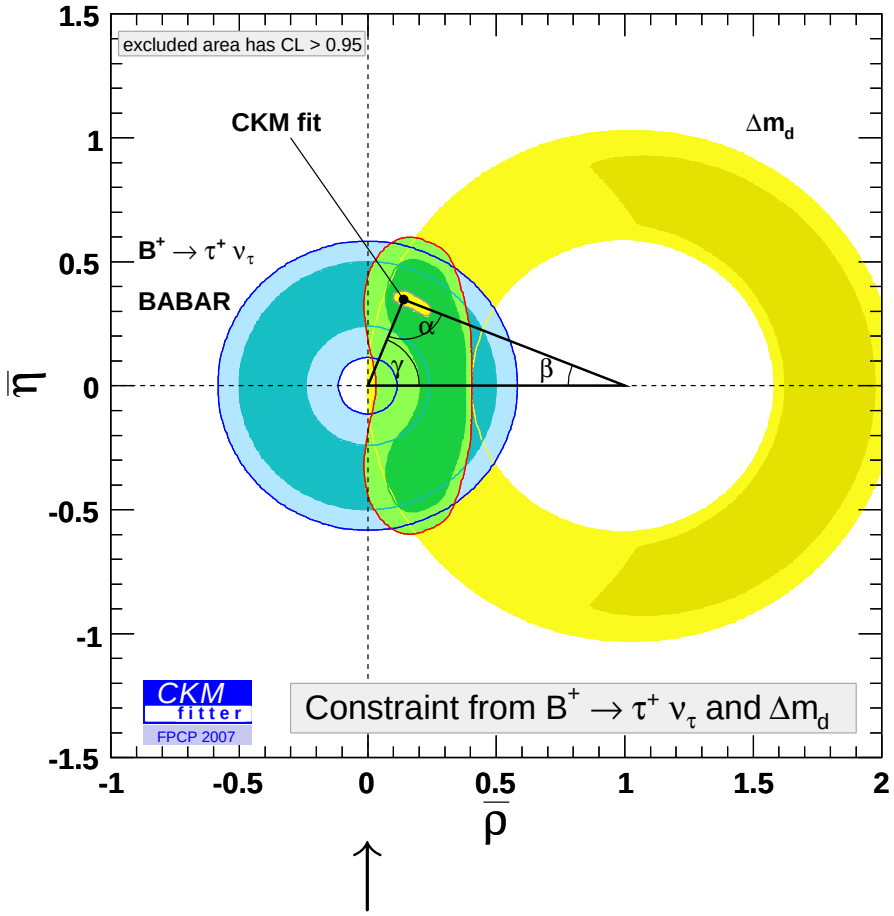
updated since ICHEP-06: $(0.9 \pm 0.7 \pm 0.1) \times 10^{-4}$

SM: $\mathcal{B} \sim (1.6 \pm 0.4) \times 10^{-4}$

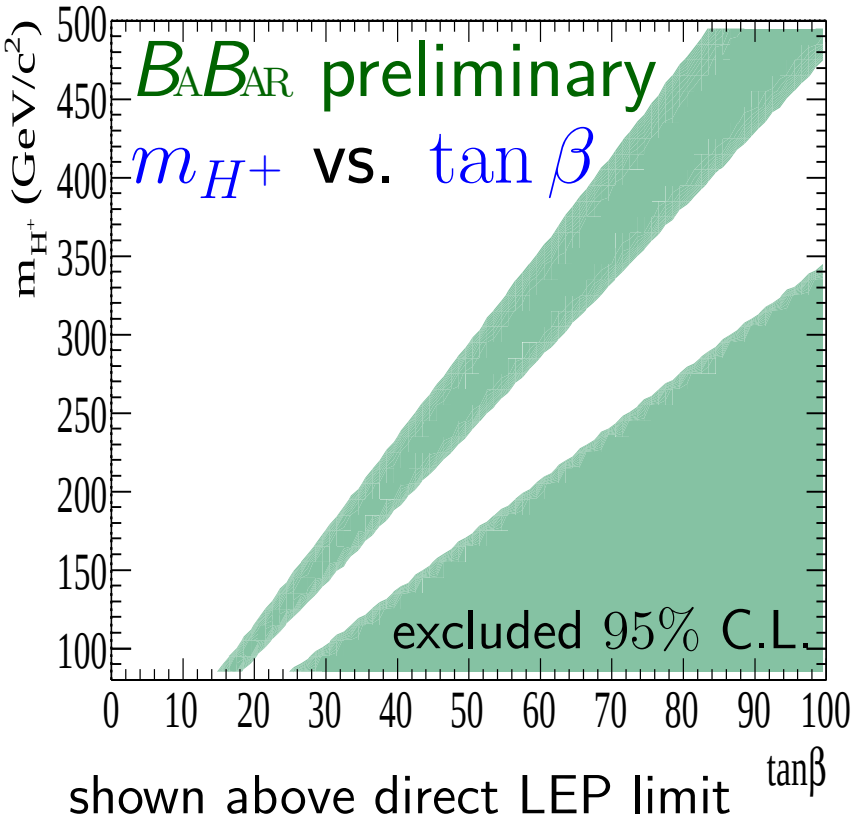
BELLE $(1.79^{+0.56+0.46}_{-0.49-0.51}) \times 10^{-4}$

Constraints from $B_{A}B_{AR}$ $B^+ \longrightarrow \tau^+ \nu_\tau$

- Constraint on CKM (V_{ub})



- Constraint on Higgs$^+$



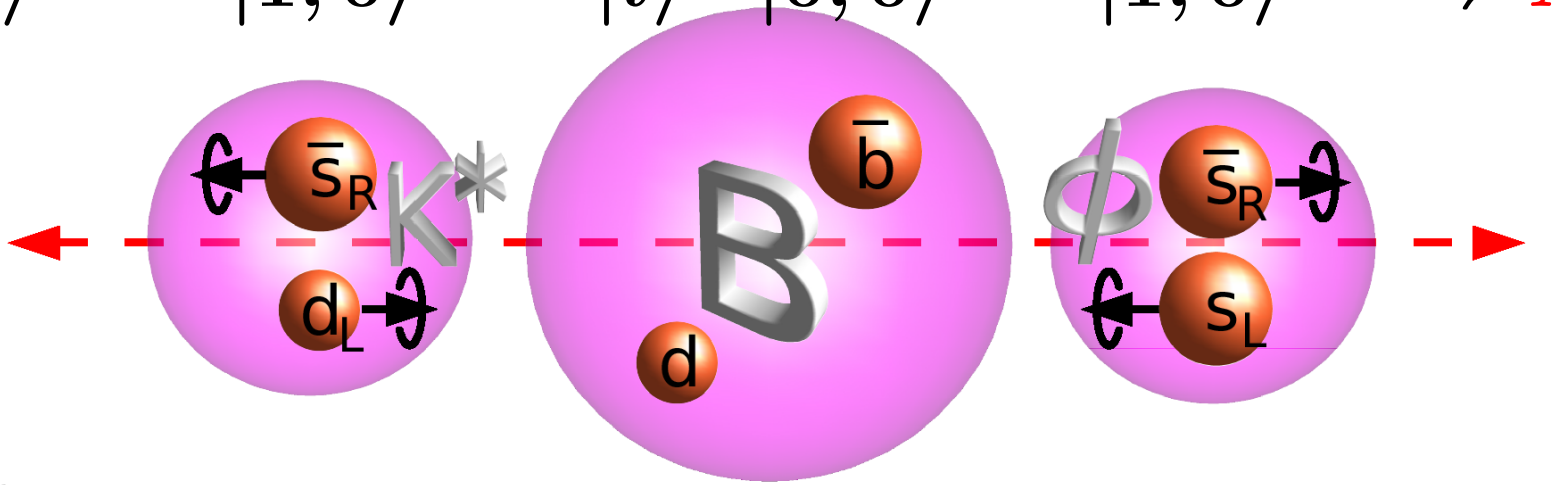
shown above direct LEP limit

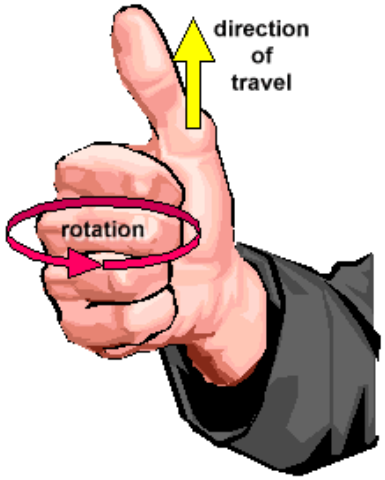
See H. Lacker's CKM talk on Monday

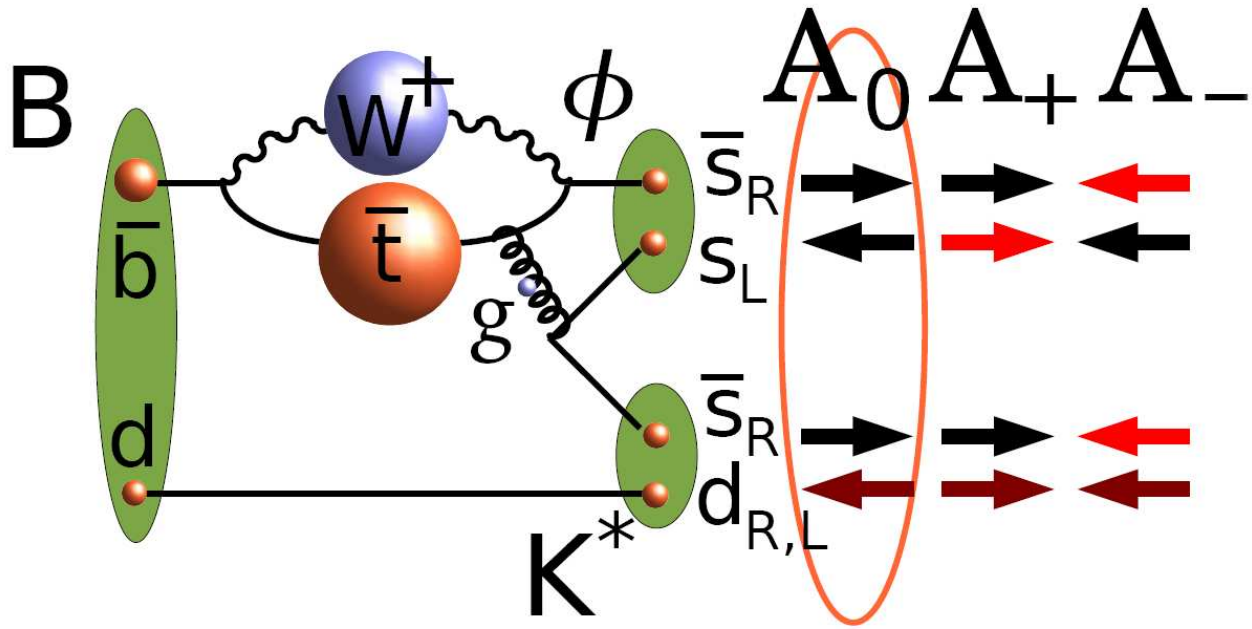
Hot Topic II: $B \to \phi K^*$

Polarization Test in $B \to \varphi K^*$

$|S, S_z\rangle = \quad |1,0\rangle \qquad |i\rangle = |0,0\rangle \qquad |1,0\rangle \quad \Rightarrow A_0$



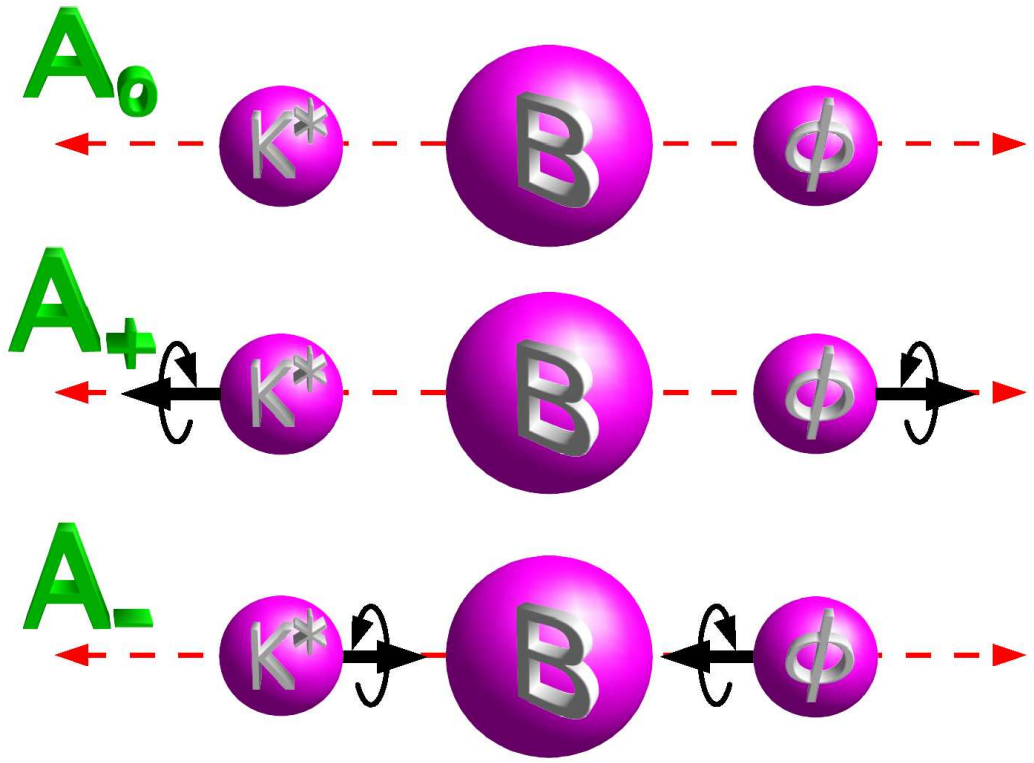




$|A_0|^2 \gg |A_+|^2 \gg |A_-|^2$ suppression$\sim(m_\phi/m_B)^2 \sim 1/25$

Polarization in $B^{\pm} \to \varphi K^{*\pm}$

expected $|A_0|^2 \gg |A_+|^2 \gg |A_-|^2$



$$A_{\parallel,\perp} = (A_+ \pm A_-)/\sqrt{2}$$

$$A_- = 0 \Rightarrow A_\parallel = +A_\perp$$

$$A_+ = 0 \Rightarrow A_\parallel = -A_\perp$$

BABAR at Frontier Science (Oct.2002)
hep-ex/0303020, PRL **91**, 171802 (2003)

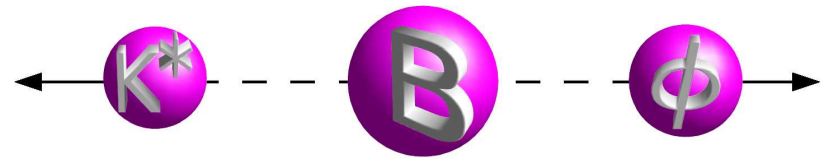
Belle, PRL **91**, 201801 (2003)
94, 221804 (2005)

$$f_L = \frac{|A_0|^2}{|A_{\rm tot}|^2} = 0.46 \pm 0.12 \pm 0.03 \qquad 0.52 \pm 0.08 \pm 0.03$$

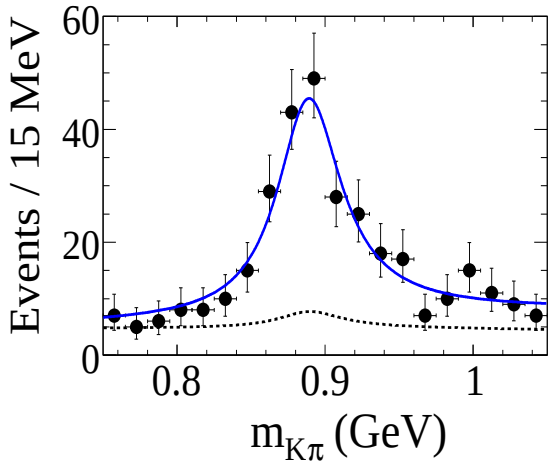
$|A_0| \sim |A_\pm|$, but $|A_+| \gg |A_-|$ or $|A_-| \gg |A_+|$ (?)

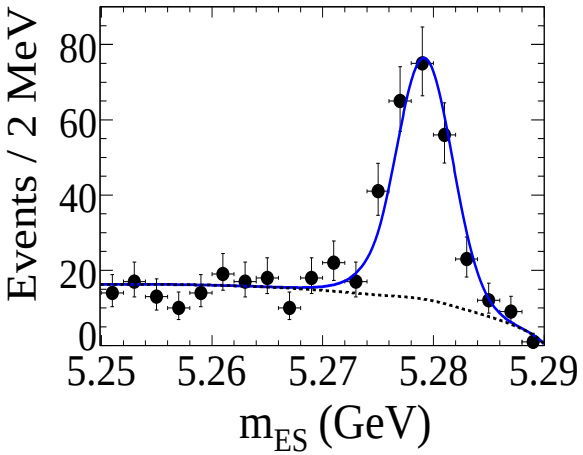
Finding $B^{\pm} \to \varphi K^*(892)^{\pm}$

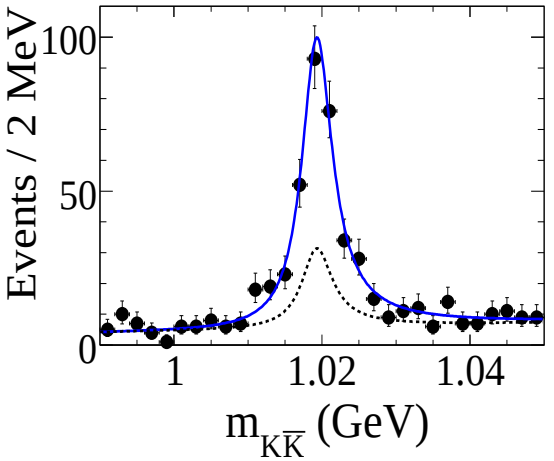
$K^{*\pm} \to K^{\pm}\pi^0$
$K^0_S\pi^{\pm}$



$\varphi \to K^+K^-$







$n_{\phi(\pi^+K^0)} = 102 \pm 13 \pm 6$
$n_{\phi(\pi^0K^+)} = 117^{+15}_{-16} \pm 7$

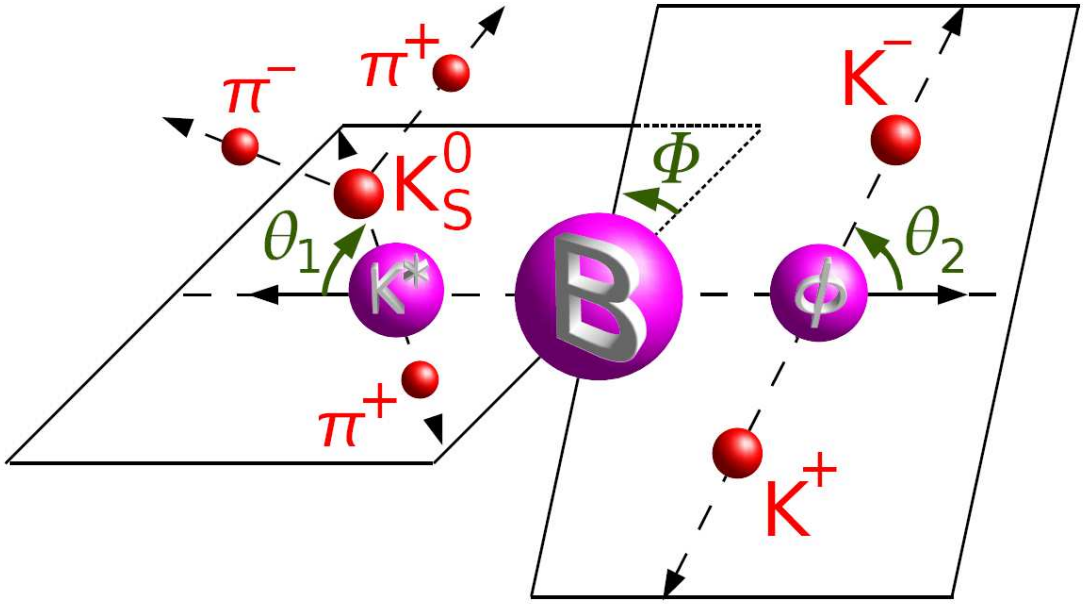
$\mathcal{B} = (11.2 \pm 1.0 \pm 0.9) \times 10^{-6}$

- Likelihood fit: PDF$= \mathcal{P}_{i1}(m_{\rm ES}) \cdot \mathcal{P}_{i2}(\Delta E) \cdot \mathcal{P}_{i3}(\mathcal{F}) \cdot \mathcal{P}_{i4}(m_{K\bar{K}}) \cdot \delta_{kQ}$

$\times \mathcal{P}^{\rm hel}_{i,k}(m_{K\pi}, \theta_1, \theta_2, \Phi, {f_L}^k, {f_\perp}^k, {\phi_\perp}^k, {\phi_\parallel}^k, {\delta_0}^k) \times \mathcal{G}(\theta_1, \theta_2, \Phi)$

$f_L = \frac{|A_0|^2}{\Sigma|A_\lambda|^2}$ $f_\perp = \frac{|A_\perp|^2}{\Sigma|A_\lambda|^2}$ $\phi_\parallel = \arg(\frac{A_\parallel}{A_0})$ $\phi_\perp = \arg(\frac{A_\perp}{A_0})$ ...

Angular Measurements



$$\frac{d^3\Gamma}{d\cos\theta_1 d\cos\theta_2 d\Phi} \propto \left| \sum_{\lambda=-,0,+} A_\lambda \times Y_1^\lambda(\theta_1,\Phi) \times Y_1^{-\lambda}(\pi-\theta_2,0) \right|^2$$

$$\propto \left\{ \frac{1}{4} \boxed{\begin{array}{c}\text{transverse}\\ \sin^2\theta_1 \sin^2\theta_2 \left(|A_+|^2+|A_-|^2\right)\end{array}} + \boxed{\begin{array}{c}\text{longitudinal}\\ \cos^2\theta_1 \cos^2\theta_2 |A_0|^2\end{array}} \right.$$

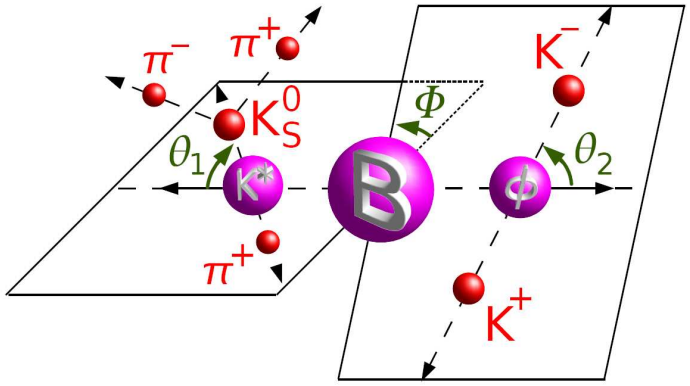
$$+\frac{1}{2}\sin^2\theta_1 \sin^2\theta_2 \left[\cos 2\Phi\ \mathrm{Re}(A_+A_-^*) - \sin 2\Phi\ \mathrm{Im}(A_+A_-^*)\right]$$

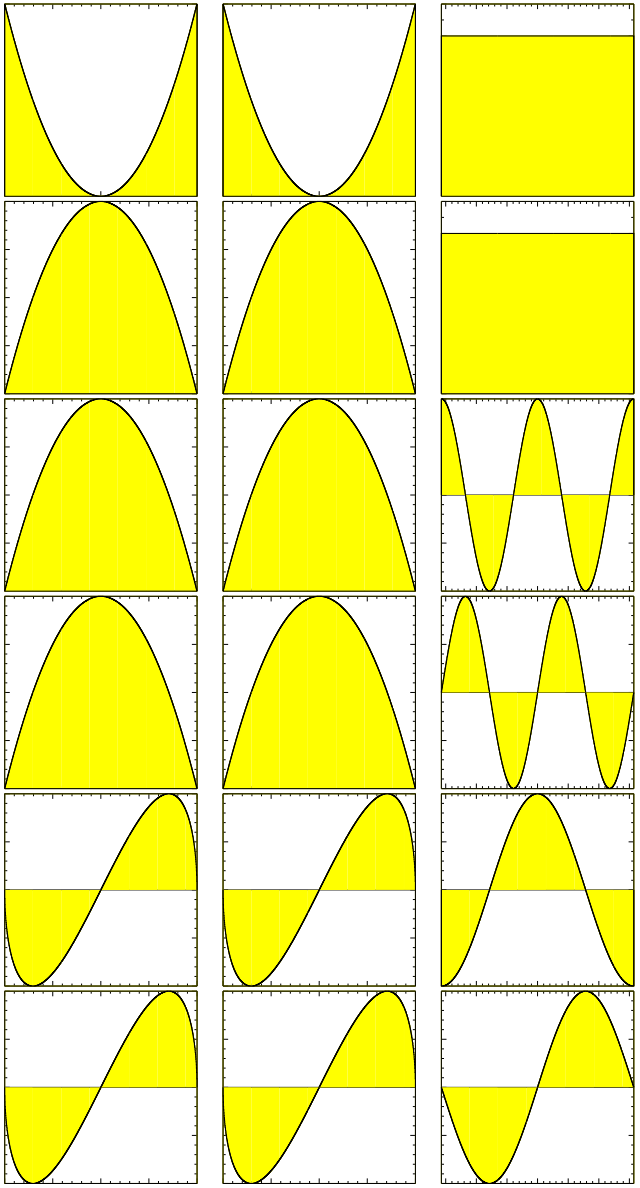
$$\left. +\frac{1}{4}\sin 2\theta_1 \sin 2\theta_2 \left[\cos\Phi\ \mathrm{Re}\left(A_+A_0^* + A_-A_0^*\right) - \sin\Phi\ \mathrm{Im}\left(A_+A_0^* - A_-A_0^*\right)\right] \right\}$$

Angular Distribution in Slices

- Expected only $|A_0|^2$
- Polarization basis (like photon)

$A_\pm = (A_\parallel \pm A_\perp)/\sqrt{2}$





$\Rightarrow |A_0|^2$

$\Rightarrow |A_\parallel|^2 + |A_\perp|^2$

$\Rightarrow |A_\parallel|^2 - |A_\perp|^2$

$\Rightarrow \mathrm{Im}(A_\perp A_\parallel^*)$

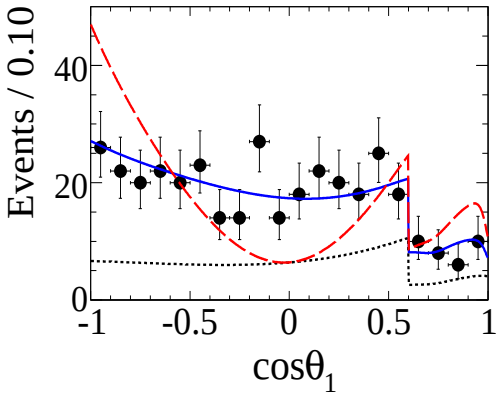
$\Rightarrow \mathrm{Re}(A_\parallel A_0^*)$

$\Rightarrow \mathrm{Im}(A_\perp A_0^*)$

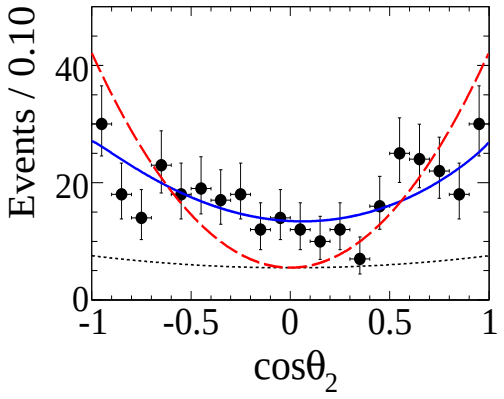
$\cos\theta_1$ $\cos\theta_2$ Φ $\times$acceptance

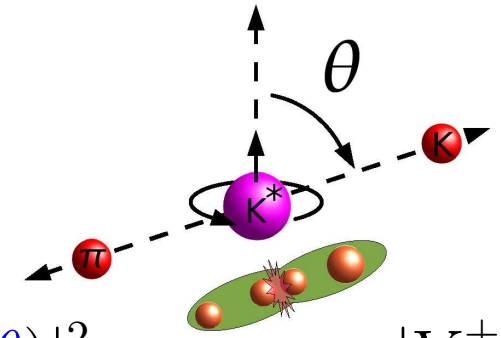
Polarization in $B^{\pm} \to \varphi K^{*\pm}$

$\cos\theta_1$ (K^*)



$\cos\theta_2$ (φ)

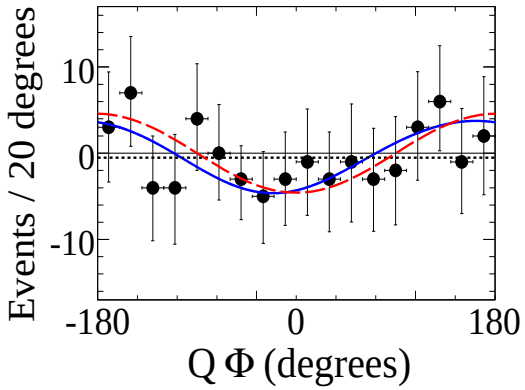




$|Y_1^0(\theta)|^2$ $\qquad$ $|Y_1^{\pm 1}(\theta)|^2$

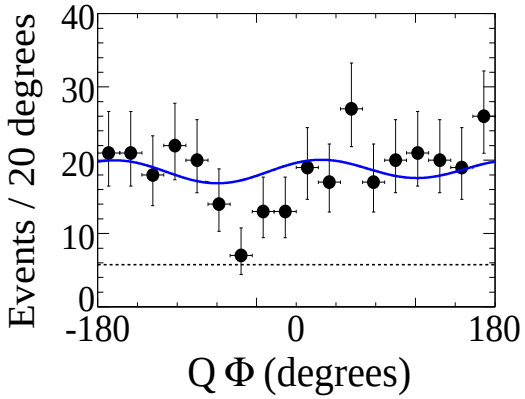
$f_L = 0.49 \pm 0.05 \pm 0.03$

$\Rightarrow |A_0|^2 \simeq |A_+|^2 + |A_-|^2$



$\mathrm{Re}(A_\parallel A_0^*)\ \cos\Phi$ & $\mathrm{Im}(A_\perp A_0^*)\ \sin\Phi \Rightarrow$ FSI

project $\mathrm{sgn}(\cos\theta_1 \cos\theta_2)$ on $Q \times \Phi$



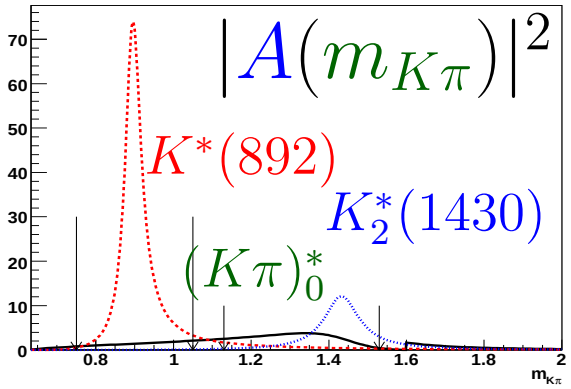
$(|A_\parallel|^2 - |A_\perp|^2)\ \cos 2\Phi$ & $\mathrm{Im}(A_\perp A_\parallel^*)\ \sin 2\Phi$

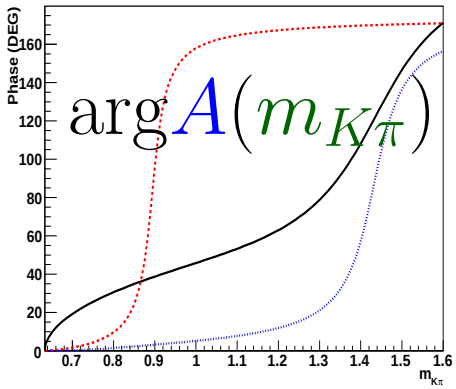
$(?)$ $\quad A_\parallel \simeq +A_\perp \quad \Leftrightarrow \quad |A_+|^2 \gg |A_-|^2$

$A_\parallel \simeq -A_\perp \quad \Leftrightarrow \quad |A_+|^2 \ll |A_-|^2$ $\quad (?)$

Resolve Phase Ambiguity in $B^{\pm} \to \varphi K^*(892)^{\pm}$

- Follow $B^0 \to \varphi(K\pi)^0$ BABAR PRL **98**, 051801 (2007)



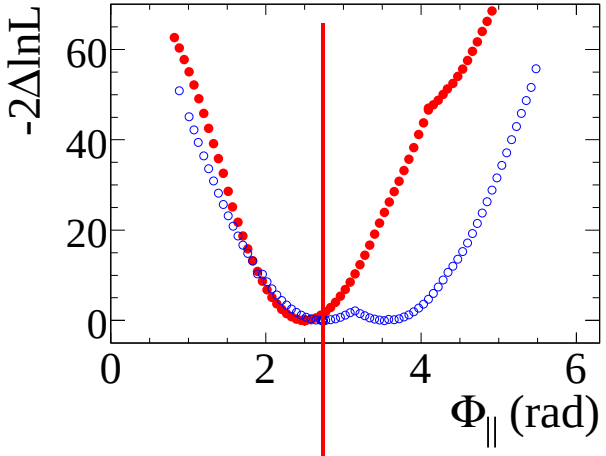


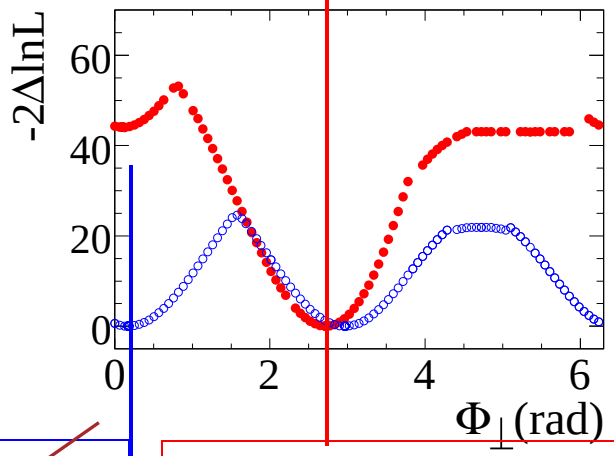
- Use interference

$K^*(892)/(K\pi)_0^*$

$N(\varphi(K\pi)_0^{*\pm}) = 57^{+14}_{-13}$

$2\mathcal{R}\mathrm{e}(A_{VV}A_{VS}^*)$





reject wrong solution

from $\cos(\phi_\perp + \delta(m_{K\pi}) - \delta_0)$,..

~~$\phi_\perp \simeq \phi_\| - \pi$~~

~~$A_\perp \simeq -A_\|$~~

~~$|A_+|^2 \ll |A_-|^2$~~

$\phi_\perp \simeq \phi_\|$

$A_\perp \simeq A_\|$

$|A_+|^2 \gg |A_-|^2$

Polarization and CP Results in $B^{\pm} \to \varphi K^*(892)^{\pm}$

$\mathcal{B}$	$\Gamma/\Gamma_{\rm total}$	$(11.2 \pm 1.0 \pm 0.9) \times 10^{-6}$
f_L	$\lvert A_0\rvert^2/\Sigma\lvert A_\lambda\rvert^2$	$0.49 \pm 0.05 \pm 0.03$
$f_\perp$	$\lvert A_\perp\rvert^2/\Sigma\lvert A_\lambda\rvert^2$	$0.21 \pm 0.05 \pm 0.02$
$\phi_\parallel - \pi$	$\arg(A_\parallel/A_0) - \pi$	$-0.67 \pm 0.20 \pm 0.07$ (rad)
$\phi_\perp - \pi$	$\arg(A_\perp/A_0) - \pi$	$-0.45 \pm 0.20 \pm 0.03$ (rad)
$\delta_0 - \pi$	$\arg(A_{\rm LASS}/A_0) - \pi$	$-0.07 \pm 0.18 \pm 0.06$ (rad)
$\mathcal{A}_{CP}$	$(\Gamma^- - \Gamma^+)/(\Gamma^- + \Gamma^+)$	$0.00 \pm 0.09 \pm 0.04$
$\mathcal{A}^0_{CP}$	$(f_L^- - f_L^+)/(f_L^- + f_L^+)$	$+0.17 \pm 0.11 \pm 0.02$
$\mathcal{A}^\perp_{CP}$	$(f_\perp^- - f_\perp^+)/(f_\perp^- + f_\perp^+)$	$+0.22 \pm 0.24 \pm 0.08$
$\Delta\phi_\parallel$	$(\phi_\parallel^- - \phi_\parallel^+)/2$	$+0.07 \pm 0.20 \pm 0.05$
$\Delta\phi_\perp$	$(\phi_\perp^- - \phi_\perp^+ - \pi)/2$	$+0.19 \pm 0.20 \pm 0.07$
$\Delta\delta_0$	$(\delta_0^- - \delta_0^+)/2$	$+0.20 \pm 0.18 \pm 0.03$

- 12 measurements (6 B^+ and 6 B^-)

$$|A_0| \simeq |A_+| \gg |A_-|$$

$$\arg(A_+) \neq \arg(\pm A_0)$$

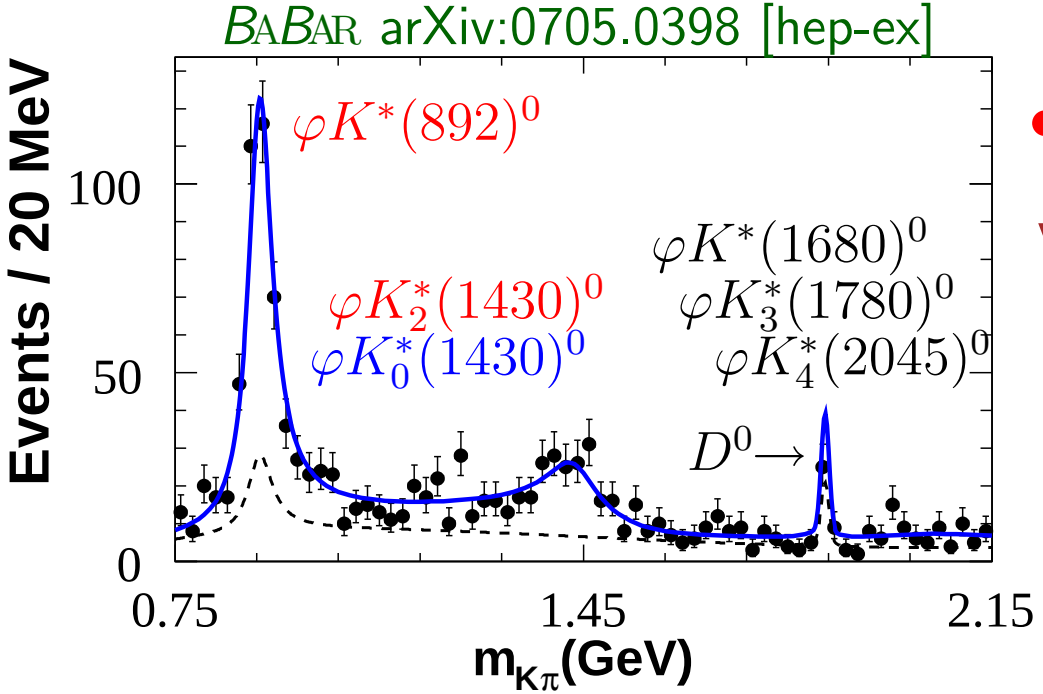
from $A_\pm = (A_\parallel \pm A_\perp)/\sqrt{2}$

6 CP-asymmetries

$\Delta\phi_\parallel$, $\Delta\phi_\perp$, $\Delta\delta_0$ new approach to CP (weak phase of A_+)

watch for $\Delta\phi_\perp$ ($\beta_{\rm eff}^{\rm P-odd} - \beta_{\rm eff}^{\rm P-even}$)

"Spectroscopy" in $B \to \varphi(K\pi)$



- Vector-Tensor puzzle:

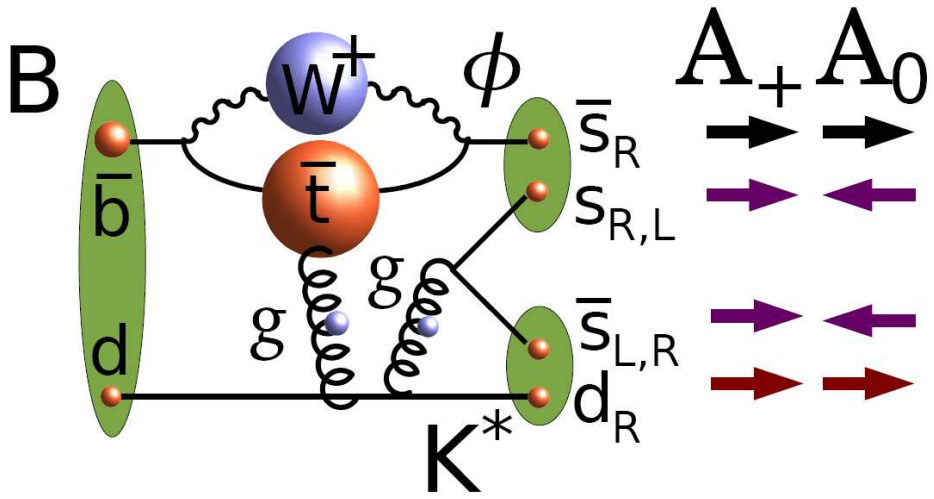
Vector-Vector: $|A_0| \simeq |A_+| \gg |A_-|$

Vector-Tensor: $|A_0| \gg |A_\pm|$

J^P	mode $B \to$	$\mathcal{B}$ranching (10^{-6})	f_L
0^+	$\varphi K_0^*(1430)^0$	$4.6 \pm 0.7 \pm 0.6$	
1^-	$\varphi K^*(892)^0$	$9.2 \pm 0.7 \pm 0.6$	$0.51 \pm 0.04 \pm 0.02$
1^-	$\varphi K^*(892)^+$	$11.2 \pm 1.0 \pm 0.9$	$0.49 \pm 0.05 \pm 0.03$
1^-	$\varphi K^*(1680)^0$	$< 3.5 \quad (0.7^{+1.0}_{-0.7} \pm 1.1)$	–
2^+	$\varphi K_2^*(1430)^0$	$7.8 \pm 1.1 \pm 0.6$	$0.85^{+0.06}_{-0.07} \pm 0.04$
3^-	$\varphi K_3^*(1780)^0$	$< 2.7 \ (-0.9 \pm 1.4 \pm 1.1)$	–
4^+	$\varphi K_4^*(2045)^0$	$< 15.3 \quad (6.0^{+4.8}_{-4.0} \pm 4.1)$	–

Scrambling to Explain A_+

- Annihilation mechanism (A.Kagan, *et al.*)

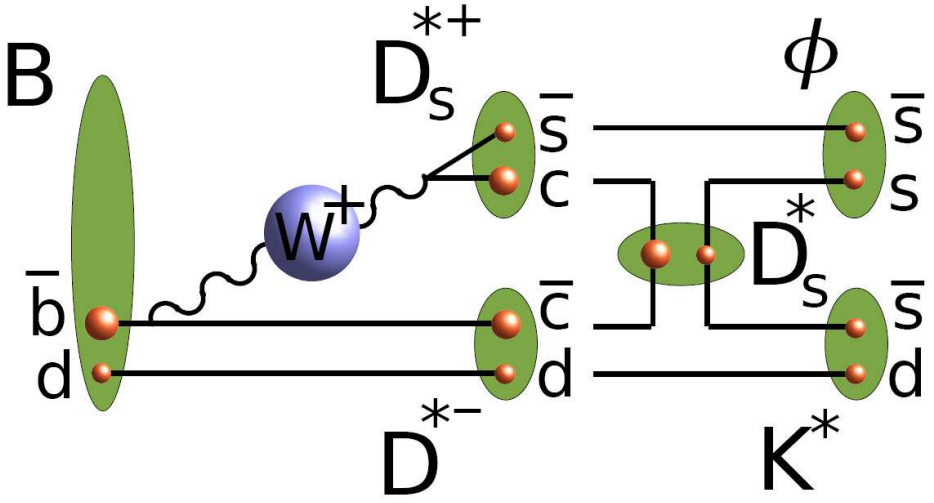


gluon to other quark

suppressed $\sim 1/m_B$

cancel A_0 from usual penguin

- Rescattering mechanism (final state interaction)



spin-flip heavy > 2GeV states

violates both $|A_0|^2 \gg |A_\pm|^2$

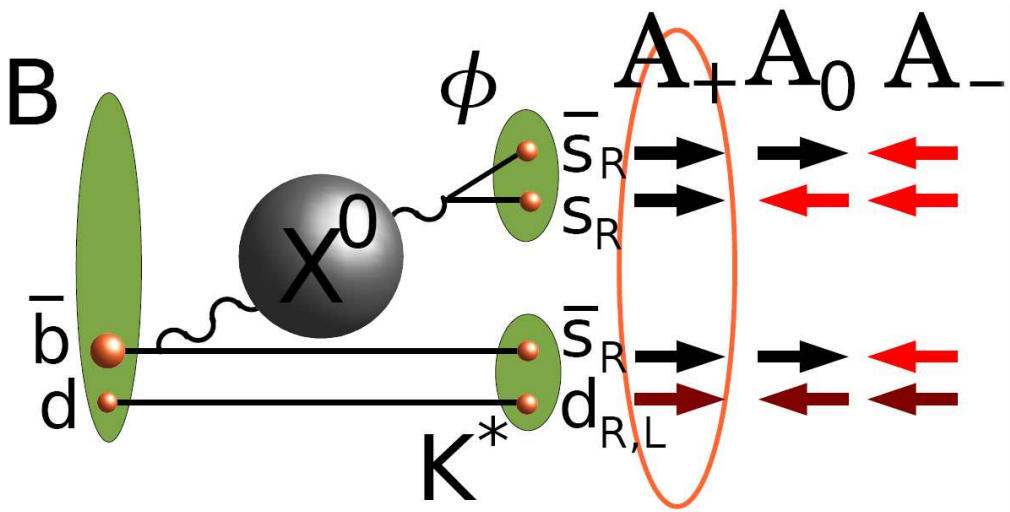
and $|A_+|^2 \gg |A_-|^2$

- No "satisfactory" solution

Possible New Physics in Polarization

violate $|A_0|^2 \gg |A_+|^2 \gg |A_-|^2$

scalar interaction

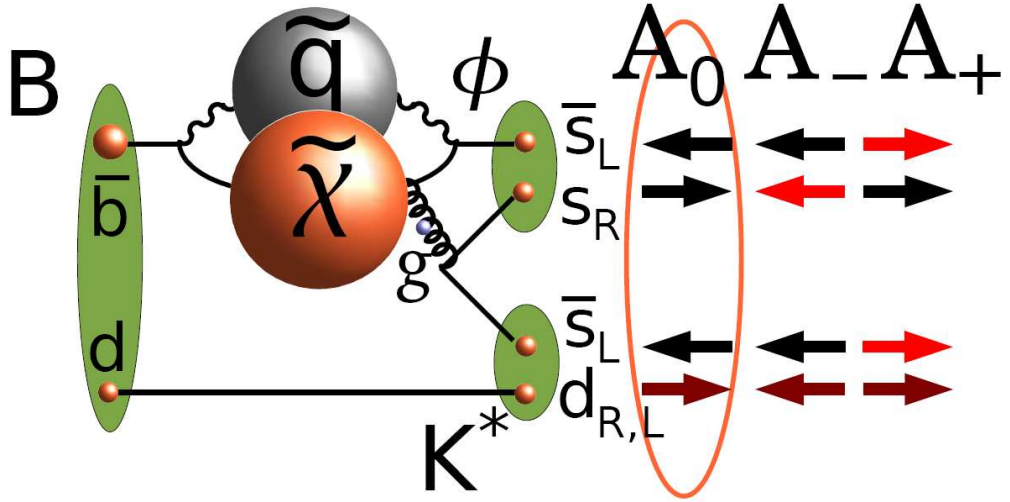


$\bar{q}\gamma^\mu(1-\gamma^5)q$

$|A_+|^2 \gg |A_0|^2 \gg |A_-|^2$

$\bar{q}(1+\gamma^5)q$

supersymmetry



$|A_0|^2 \gg |A_-|^2 \gg |A_+|^2$

$\bar{q}\gamma^\mu(1+\gamma^5)q$

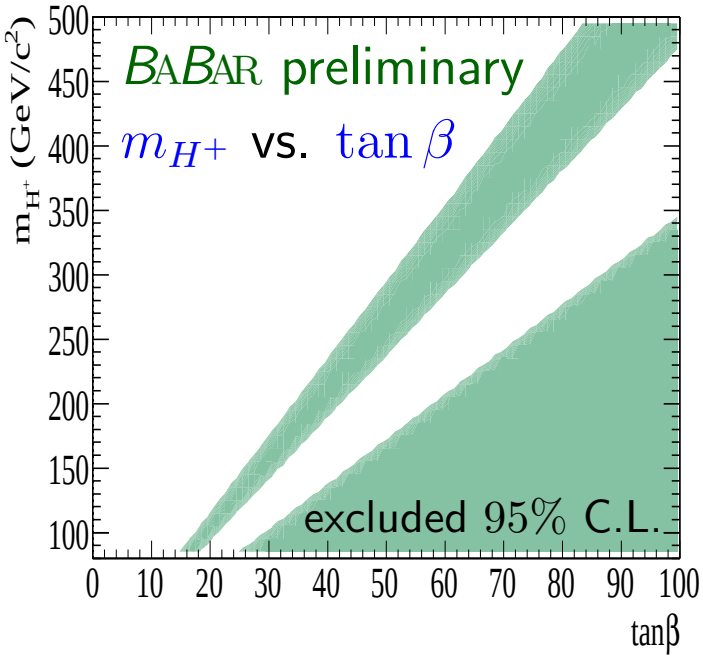
Summary

- $B^+ \to \tau^+ \nu_\tau$

$\mathcal{B} = (1.20^{+0.40+0.29}_{-0.38-0.30} \pm 0.22) \times 10^{-4}$

2.6σ (3.2σ stat.)

rate sensitive to Higgs$^+$



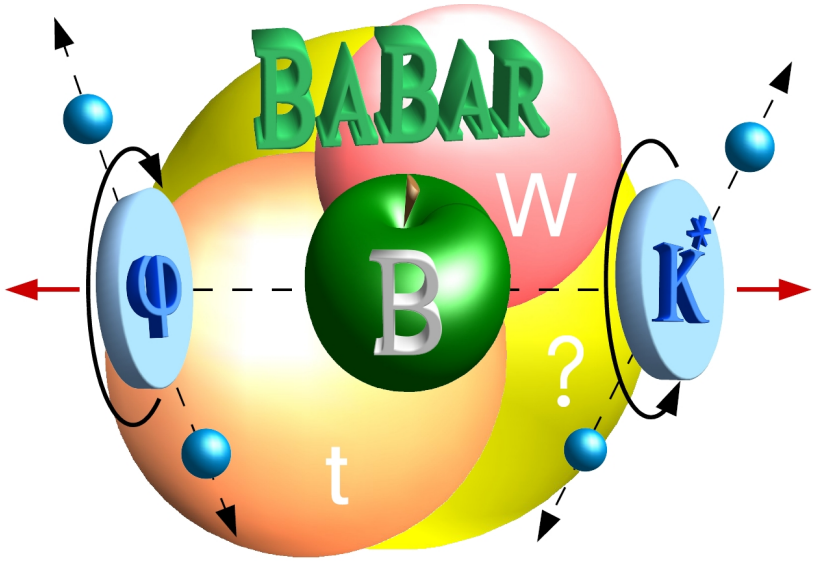
- $B^+ \to \varphi K^{*+}$

$f_L = 0.49 \pm 0.05 \pm 0.03$

12 measurements

$|A_0| \simeq |A_+| \gg |A_-|$

$\arg(A_+) \neq \arg(\pm A_0)$



current SM models have difficulty to explain all data