Analysis of B->J/ψK*

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Outline

1. **Overview of B->J/ψK* physics**
   i. Physics Motivation
   ii. Helicity states of General B->V_aV_b decay modes
   iii. Helicity states of J/ψK* and angle definitions
   iv. Angle dependent
   v. Past results
2. **My analysis status**
   i. Analysis method
   ii. Selection criteria
   iii. Reconstruction
3. **Future plan**


Overview of
B->J/ψK*
physics

Physics Motivation

Direct CPV can be occurred if new physics existed.

$$a_{dir} \equiv \frac{\Gamma(B\text{->}f) - \Gamma(\overline{B}\text{->}\overline{f})}{\Gamma(B\text{->}f) + \Gamma(\overline{B}\text{->}\overline{f})}$$

$\cos 2\phi_1$ can be measured in Indirect CPV.

=> $\sin 2\phi_1 = \sin(\pi - 2\phi_1)$ ambiguity is solved by $\cos 2\phi_1$.

pQCD factirization hypothesis test

$$\frac{Br(B\text{->}J/\psi K*)}{}$$

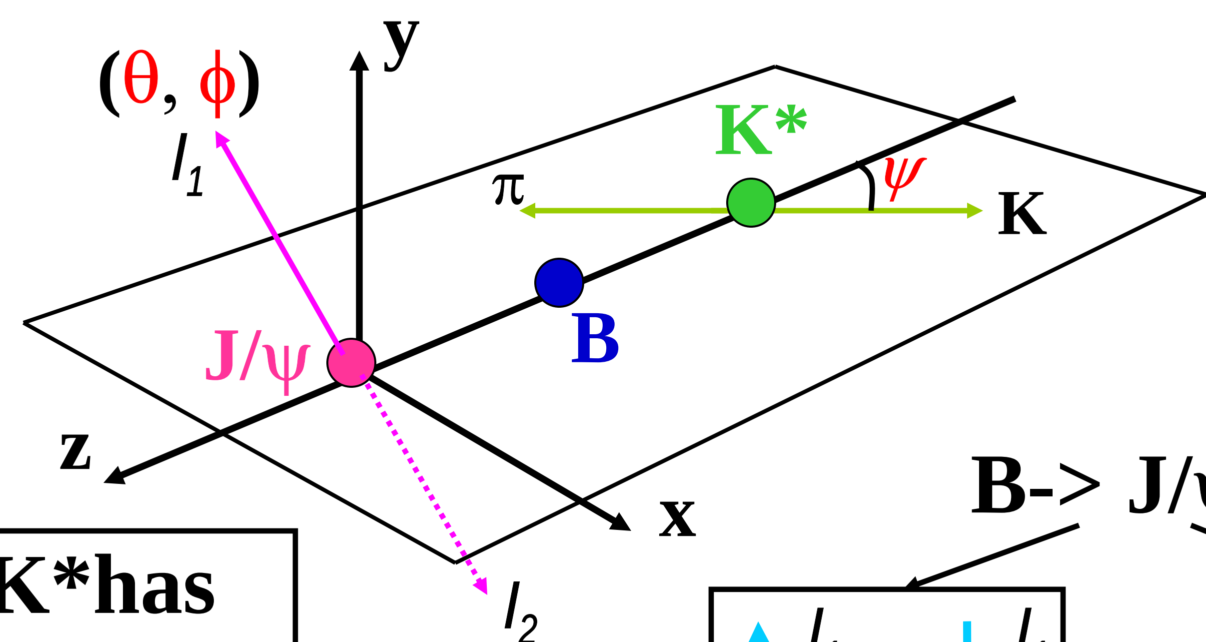
Belle 29.4fb^{-1}
Official results

$$\mathbf{Br(B^0 \rightarrow J/\psi K^{*0}) = (1.29 \pm 0.05 \pm 0.13) \times 10^{-3}}$$

To achieve these motivations,

we need
- Angular analysis
- Small systematic error analysis

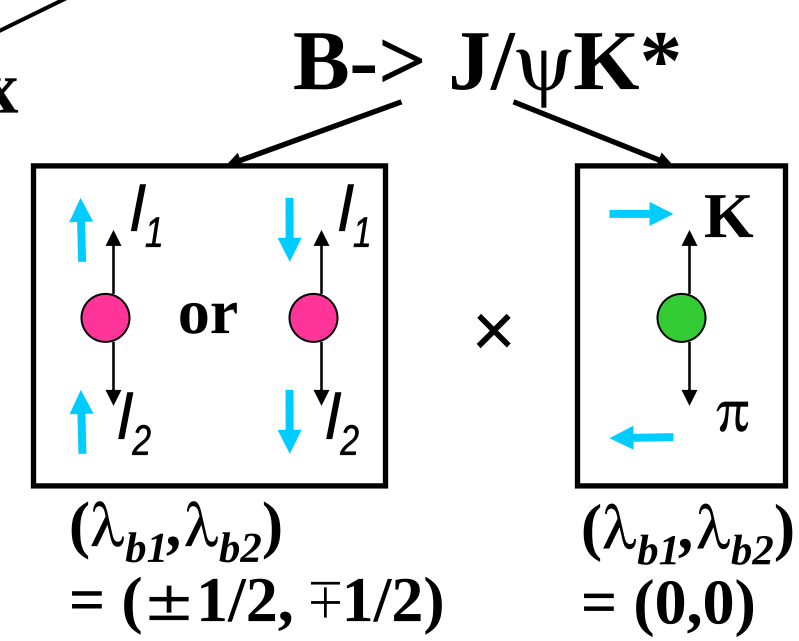
Helicity states and Angle definition



B-> J/ψK*has
3 helicity states

and

J/ψ->$l^+ l^-$, K*->Kπ
has 2 helicity states.



Amplitudes and angle dependence

$B \to V_a V_b$
3 helicity states

$A_\perp$ $\quad$ $A^{(+1)}$

$A_|$

A_0 $\quad$ $A^{(-1)}$

$J/\psi K^*$
2 helicity states

$$A^{(+1)} = A_\perp g_\perp^{(+1)} + A_| g_|^{(+1)} + A_0 g_0^{(+1)}$$

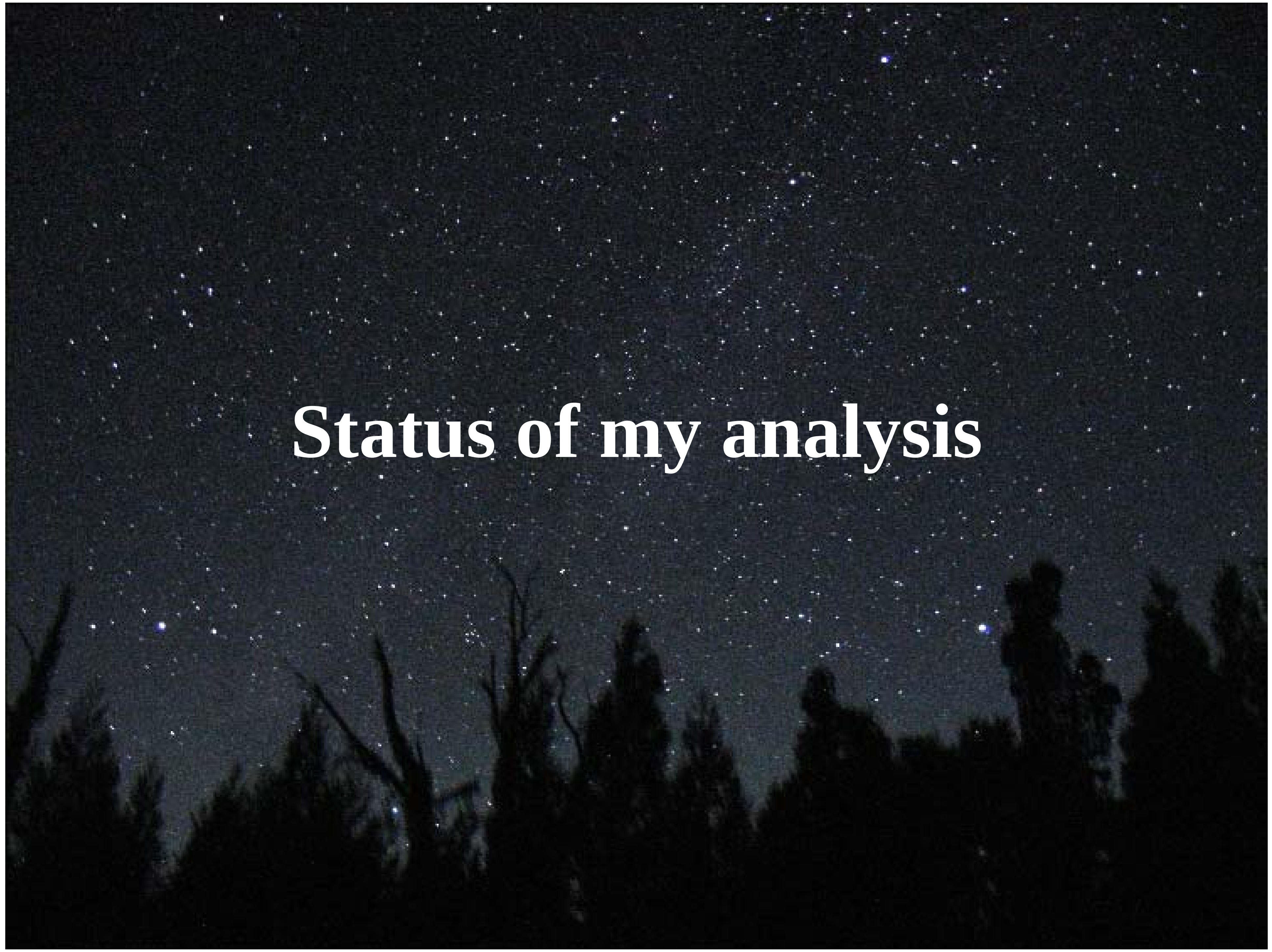
$$A^{(-1)} = A_\perp g_\perp^{(-1)} + A_| g_|^{(-1)} + A_0 g_0^{(-1)}$$

$g_\lambda^{(\pm 1)}(\theta, \phi, \psi)$
depends only on angles

$$\Gamma(\theta, \phi, \psi) = |A^{(+1)}|^2 + |A^{(-1)}|^2$$

← **Incoherent**

Decay width Γ depends on (θ, ϕ, ψ)



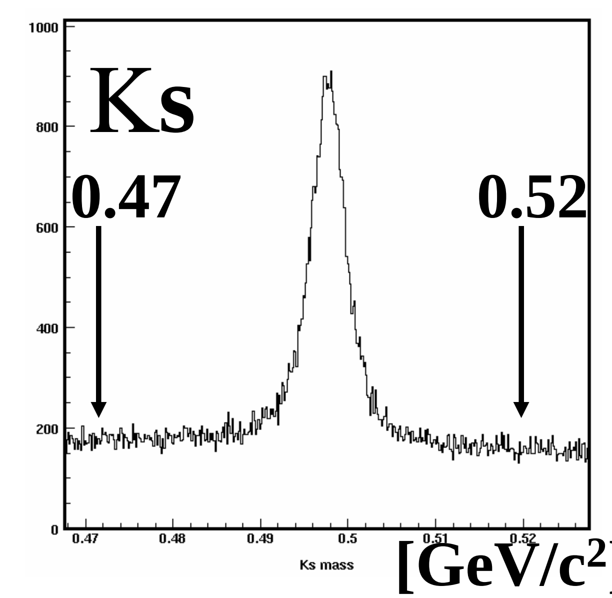
Status of my analysis

Particle reconstruction

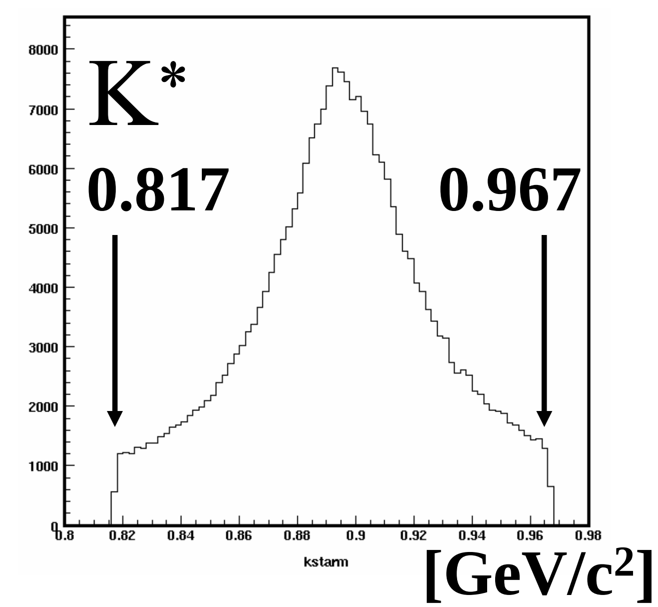
We want to reconstruct these decay modes →

B^0->J/ψK*($K^+\pi^-$)
B^+->J/ψK*($K_s\pi^+$)
B^+->J/ψK*($K^+\pi^0$)
B^0->J/ψK*($K_s\pi^0$)

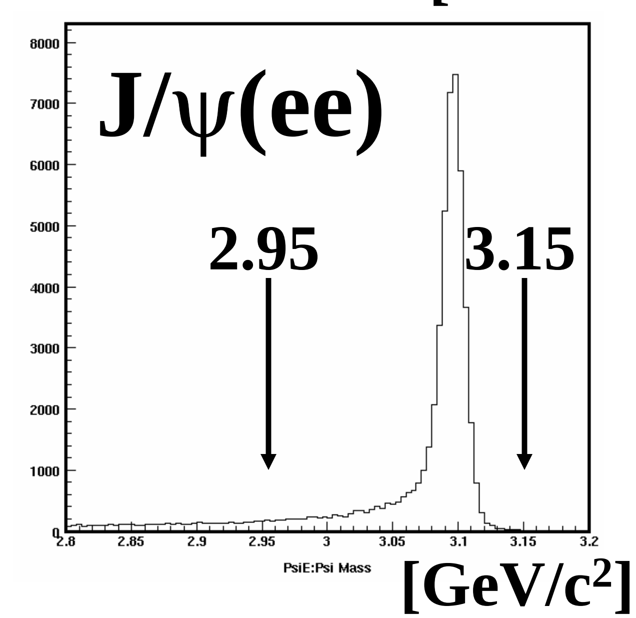
- $e^\pm$, $\mu^\pm$, $K^\pm$, $\pi^\pm$ **PID likelihood is calculated by detector information. we use it.**
- π^0 **daughter γ energy>40MeV**
- K_s **$0.47<M(\pi^+\pi^-)<0.52$ [GeV/c²]**

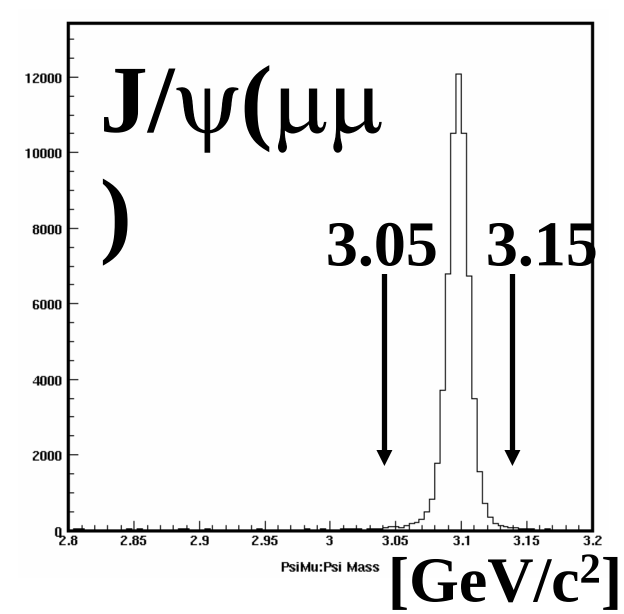


Reconstruction of K*, J/ψ



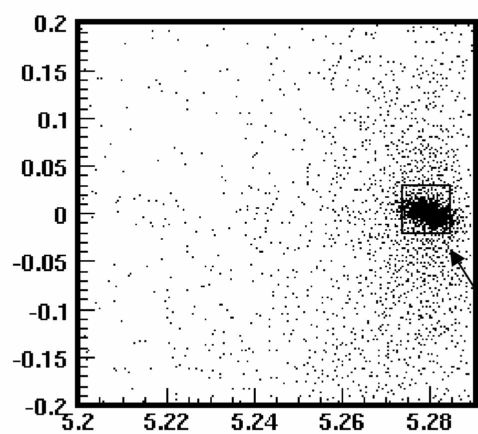
- K* $0.817 < M(K\pi) < 0.967$ [GeV/c^2]
- J/ψ(ee) $2.95 < M(ee) < 3.15$[GeV/c^2]
- J/ψ(μμ) $3.05 < M(\mu\mu) < 3.15$[GeV/c^2]

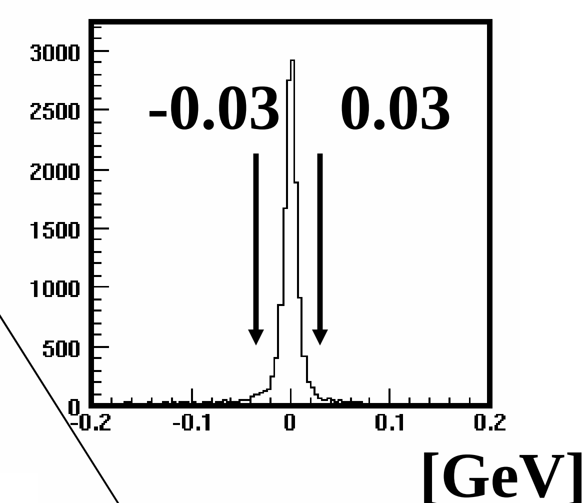


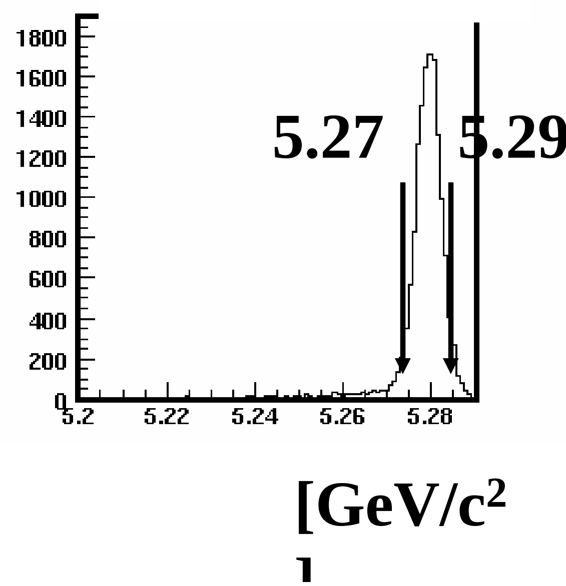


Reconstruction of B

- **B candidate** **$5.2<M_{bc}<5.29$[GeV/c^2] && $-0.2<dE<0.2$[GeV]**







Signal Box

$5.27<M_{bc}<5.29$

$-0.03<dE<0.03$

$-0.05<dE<0.03$

For π^0 including mode

Detection efficiency

$$\equiv \frac{\#\text{signal event}}{\#\text{ Generate event}}$$

B->J/ψK*($K^+\pi^-$) 30.8%
B->J/ψK*($K_s\pi^+$) 21.9%
B->J/ψK*($K^+\pi^0$) 13.9%
B->J/ψK*($K_s\pi^0$) 8.8%

Very rough estimation

Each value is calculated with Signal MC 1.0 Million.

Signal yield extraction

To extract the signal yields, we will use
unbinned maximum likelihood method.

Statistics Error $\lesssim$ Systematic Error

We must make more precise fit function to extract signal yield.

⇒Precise BG study
⇒More improved fit method

This study is my current task.

Improved PDF function

The probability density function (PDF) is difined as

$$\begin{aligned}PDF(\theta,\phi,\psi,M_{bc}) = N \times [&f_{sig}(M_{bc}) \times \varepsilon(\theta,\phi,\psi) \times d^3\Gamma(\theta,\phi,\psi)/(\Gamma d\theta d\phi d\psi) \\ &+\Sigma_\iota \mathbf{f_{cf}}^{\iota}(M_{bc}) \times \mathbf{ADF_{cf}}(\theta,\phi,\psi) \\ &+f_{nr}(M_{bc}) \times \mathbf{ADF_{nr}}(\theta,\phi,\psi) \\ &+f_{combi}(M_{bc}) \times \mathbf{ADF_{combi}}(\theta,\phi,\psi)]\end{aligned}$$

$\mathbf{f_{cf}}^{\iota}$ … cross feed BG(contamination from other J/ψK*)

f_{nr} … Non-resonant BG(J/ψKπ)

f_{combi} … Combinatrial BG.

ADF … Angle distribution function

ε … Detection efficiency

N … normalization factor

Dominant in Br mesurement

Dominant in amplitude mesurement

Status & future plan

Current study

Studying amount and shape of feed across contaminations.

To do

- **Feed across,non-resonant,combinatorial BG estimation.**
  => determine the shape using large amount of MC.

Future plan

- I want to extract Br(B->J/ψK*) until JPS presentation ~ 3/28

Back-up slides

Mixing and Decay process

$B^0\,\overline{B}^0$ mixing

$$B^0 = \frac{B_a + B_b}{2p} \rightarrow \frac{1}{2p}(\underbrace{B_a}_{pB^0+q\bar{B}^0} e^{-i\frac{\delta m}{2}t} + \underbrace{B_b}_{pB^0-q\bar{B}^0} e^{i\frac{\delta m}{2}t}) = B^0\cos\frac{\delta m t}{2} - \frac{q}{p}\bar{B}^0 i\sin\frac{\delta m t}{2}$$

Time dependent

Decay amplitude

$$a_\lambda \equiv Amp(B^0 \rightarrow f_\lambda)$$

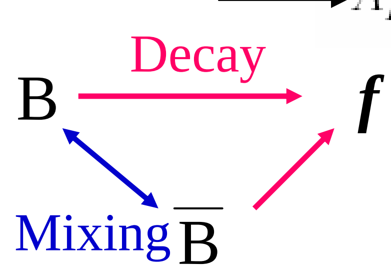
$$\bar{b}_\lambda \equiv Amp(\bar{B}^0 \rightarrow f_\lambda)$$

λ: Helicity states

Time dependent Decay amplitude

$$A_{B^0\rightarrow f_\lambda}(t) = e^{-\frac{\gamma}{2}t}\left(a_\lambda \cos\frac{\delta m\, t}{2} - \frac{q}{p}\bar{b}_\lambda i\sin\frac{\delta m\, t}{2}\right) = e^{-\frac{\gamma}{2}t} a_\lambda\left(\cos\frac{\delta m\, t}{2} - \rho_\lambda i\sin\frac{\delta m\, t}{2}\right)$$

$$A_{\bar{B}^0\rightarrow f_\lambda}(t) = e^{-\frac{\gamma}{2}t}\left(\bar{b}_\lambda \cos\frac{\delta m\, t}{2} - \frac{p}{q}a_\lambda i\sin\frac{\delta m\, t}{2}\right) = e^{-\frac{\gamma}{2}t} a_\lambda\left(\rho_\lambda \cos\frac{\delta m\, t}{2} - i\sin\frac{\delta m\, t}{2}\right)$$



where $\rho_\lambda \equiv \frac{q\,\bar{b}_\lambda}{p\,a_\lambda}$, $\bar{\rho}_\lambda \equiv \frac{p\,b_\lambda}{q\,\bar{a}_\lambda}$

$\cos 2\phi_1$

$$\Gamma(\phi_{tr},\theta_{tr},\psi) = \frac{9}{32\pi}\Big[|A_\parallel|^2(1-\sin^2\theta_{tr}\sin^2\phi_{tr})\sin^2\psi$$
$$+|A_0|^2 2(1-\sin^2\theta_{tr}\cos^2\phi_{tr})\cos^2\psi + |A_\perp|^2\sin\theta_{tr}^2\sin\psi^2$$
$$-\Re(A_\parallel^* A_0)\frac{1}{\sqrt{2}}\sin\theta_{tr}^2\sin 2\phi_{tr}\sin 2\psi + \Im(A_0^* A_\perp)\frac{1}{\sqrt{2}}\sin 2\theta_{tr}\cos\phi_{tr}\sin 2\psi$$
$$+\Im(A_\parallel^* A_\perp)\sin 2\theta_{tr}\sin\phi_{tr}\sin^2\psi\Big],$$

$$|A_\lambda|^2 \rightarrow |a_\lambda|^2(1\pm\xi_\lambda\sin 2\phi_1\sin\delta m t)$$
$$\Re(A_\parallel^* A_0) \rightarrow \Re(a_\parallel^* a_0)(1\pm\sin 2\phi_1\sin\delta m t)$$
$$\Im(A_e^* A_\perp) \rightarrow \pm\Im(a_e^* a_\perp)\cos\delta m t \mp \Re(a_e^* a_\parallel)\cos 2\phi_1\sin\delta m t$$

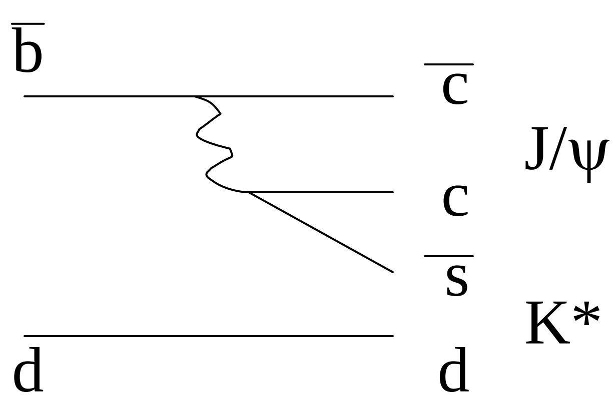
Imaginary Phase

$$\rho_\lambda \equiv \frac{q\,\bar{b}_\lambda}{p\,a_\lambda} = \frac{\langle K_s|\bar{K}^0\rangle \langle (J/\psi K^*)_\lambda|H_{eff}|\bar{B}^0\rangle}{\langle K_s|K^0\rangle \langle (J/\psi K^*)_\lambda|H_{eff}|B^0\rangle}$$

$$= \left(\frac{V^*_{tb}V_{td}}{V_{tb}V^*_{td}}\right)\left(\frac{V_{cs}V^*_{cd}}{V^*_{cs}V_{cd}}\right)\left(\frac{V_{cb}V^*_{cs}}{V^*_{cb}V_{cs}}\xi_\lambda\right)$$

$$= -\xi_\lambda \left(\frac{V_{cd}V^*_{cb}}{V_{td}V^*_{tb}}\right)^* \Big/ \left(\frac{V_{cd}V^*_{cb}}{-V_{td}V^*_{tb}}\right)$$

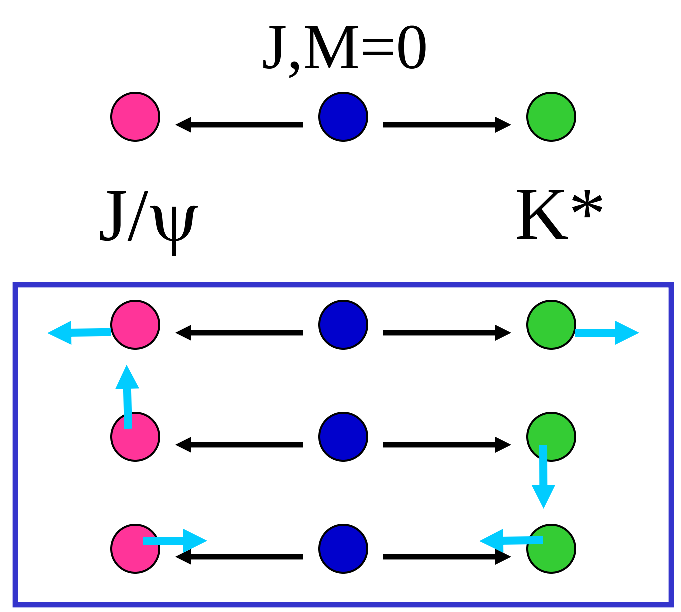
$$\rho_\lambda = -\xi_\lambda\, e^{-2i\phi} \qquad \xi_\lambda = \begin{cases} 1 & (\lambda = \parallel, 0) \\ -1 & (\lambda = \perp) \end{cases}$$



Helicity states of General B->$V_a V_b$ decay mode

V …Vector Meson(spin 1, Parity +)

($V_a V_b$) = J/ψK*, D*ρ



λ: Helicity

$(\lambda_a \lambda_b)$ =(+1,+1),(-1,-1),(0,0)

B-> J/ψK*

has 3 helicity states

Past measurements

Belle 29.4fb^{-1}
Official results
Phys.Lett.B538(2002)

Br($B^0 \to J/\psi K^{*0}$) = (1.29±0.05±0.13) × **10^{-3}**
Br($B^+ \to J/\psi K^{*+}$) = (1.28±0.07±0.14) × **10^{-3}**

$|A_\perp|^2$ = **0.19**±0.02±0.03
$|A_0|^2$ = **0.62**±0.02±0.03
arg($A_\perp$) = 2.83±0.19±0.08
arg(A_0) = -0.09±0.13±0.06

sin2ϕ_1 = 0.13±0.51±0.06
cos2ϕ_1 = 1.40±1.28±0.19 } **(78fb^{-1})**

My study is also

- **Update for 140fb^{-1}**
- **Reduce the systematic error**