CP Violation in B Physics at Belle

(Belle Collaboration)

Outline

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Osaka City University, Japan

1. KEKB and Belle detector
2. Unitary triangle: ϕ_1, ϕ_2, ϕ_3
   - sin $2\phi_1$ from $J/\psi K^0$
   - sin $2\phi_2^{eff}$ from $\pi^+\pi^-$
   - ϕ_1: $\eta' K_S$, $D^{(*)+} D^{(*)-}$
   - ϕ_2: $\rho\pi$
   - ϕ_3: $K\pi$, $\pi\pi$, $D_{CP}K$, $D^*\pi$
3. Summary

Belle Collaboration

A. Abashian, K. Abe, K. Abe, I. Adachi, B.-S. Ahn, H. Aihara, …

Total ~300 people

Aomori University
Budker Institute of Nuclear Physics
Chiba University
Chuo University
University of Cincinnati
University of Frankfurt
Gyeongsang National University
University of Hawaii
Hiroshima Institute of Technology
IHEP, Beijing
ITEP, Moscow
Kanagawa University
KEK
Korea University
Krakow Institute of Nuclear Physics
Kyoto University
Kyungpook National University
University of Lausanne
Ljubljana: Jozef Stephan Institute
University of Melbourne.
Nagoya University
Nara Woman's University
National Central University
National Kaohsiung Normal Univ.
National Lien-Ho Institute of Tech.
National Taiwan University
Nihon Dental College
Niigata University
Osaka University
Osaka City University
Panjab University
Peking University
Princeton University
Saga University
Seoul National University
University of Sci and Tech of China
Sungkyunkwan University
University of Sydney
Tata Institute
Toho University
Tohoku University
Tohoku-gakuin University
University of Tokyo
Tokyo Institute of Technology
Tokyo Metropolitan University
Tokyo Univ of Agriculture and Tech
Toyama Natnl Colle of Maritime Tech
University of Tsukuba
Utkal University
IHEP, Vienna
Virginia Polytech Inst and State Univ
Yokkaichi University
Yonsei University

13 regions

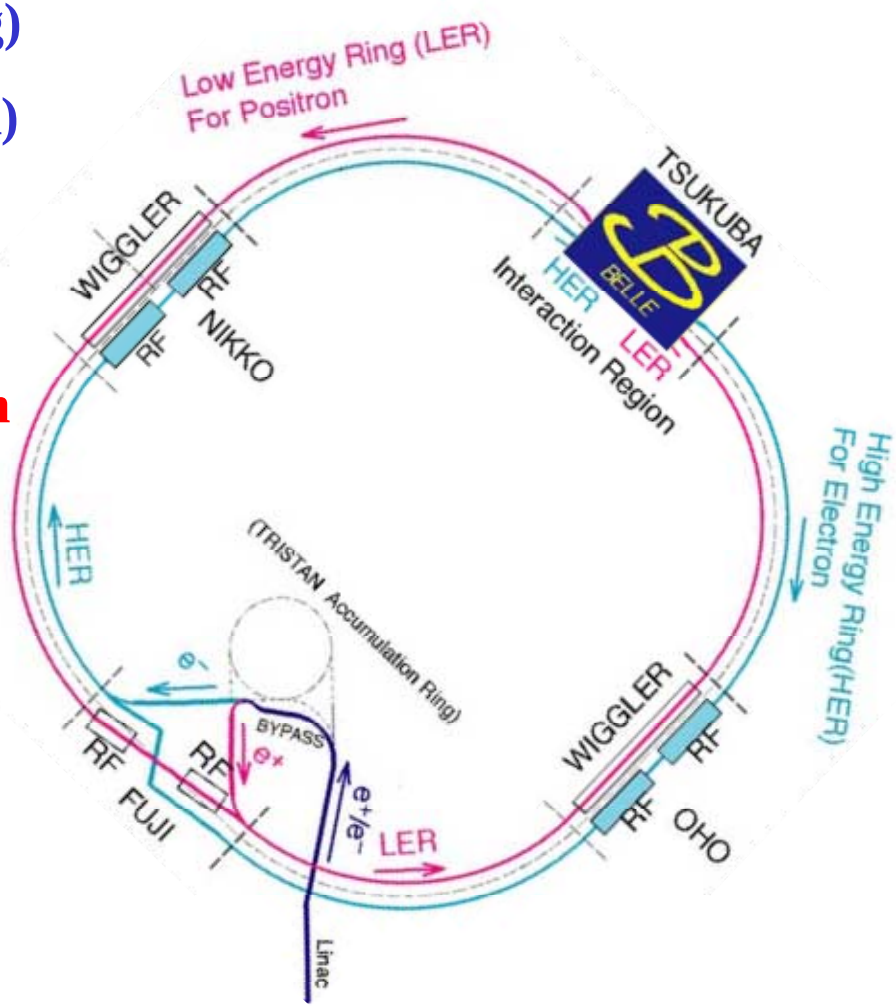
53 institutes

KEKB Collider

Asymmetric e^+e^- collider

- **Two separate rings (±11 mr X-ing)**

  8.0 GeV e^- (HER), 3.5 GeV e^+(LER)
- **E_{CM} = 10.58 GeV (@ϒ(4S))**
- **Design Luminosity = $10^{34}cm^{-2}s^{-1}$**
- **Beam size: $\sigma_y \approx 3\ \mu m$, $\sigma_x \approx 100\ \mu m$**



KEKB Performance

Peak luminosity: 7.3×10^{33} cm^{-2}s^{-1} (world highest!)

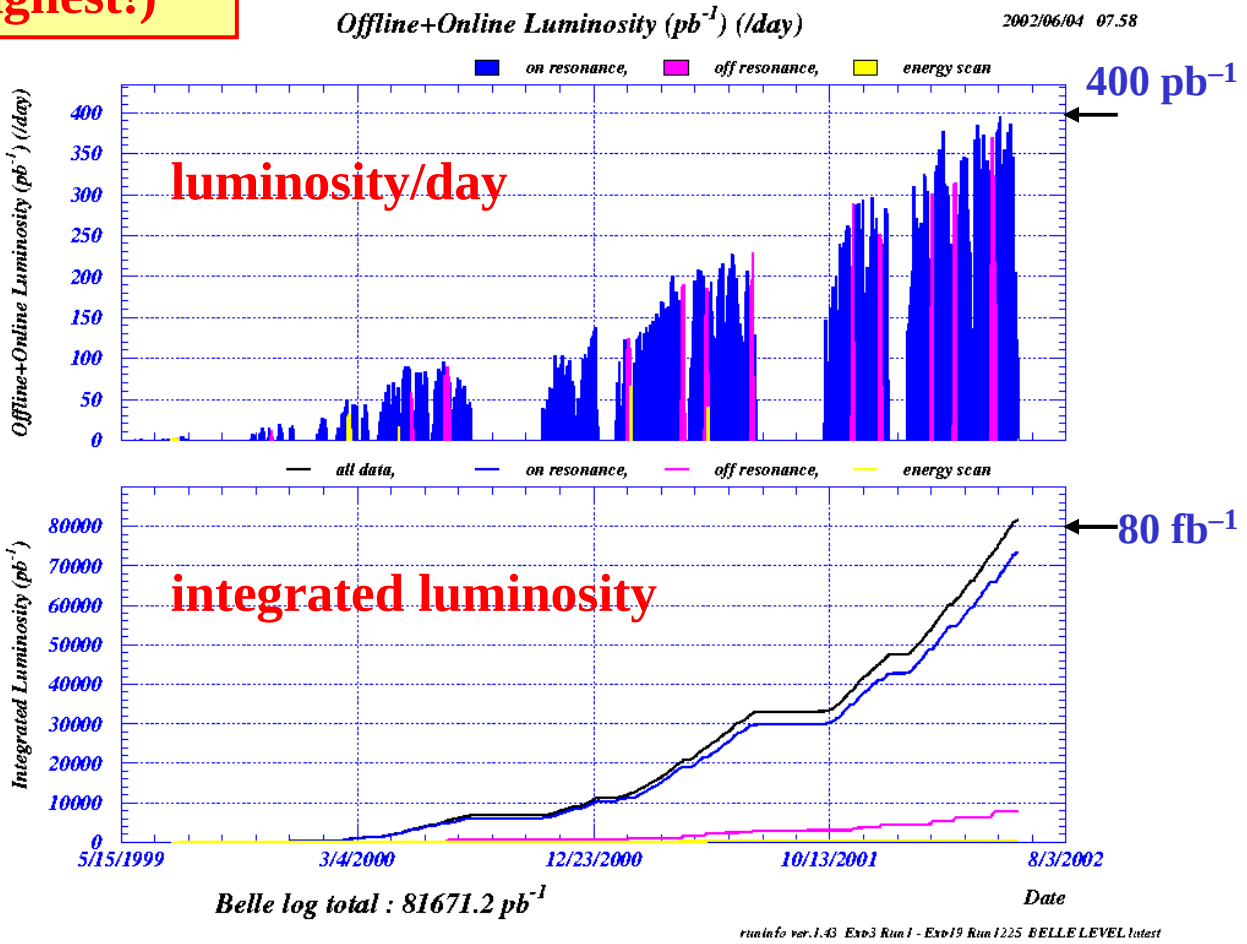
- L_{day} = 387 pb^{-1}
- L_{int} = 81.6 fb^{-1} @6/1
- used in this analysis

  42 fb^{-1} (44.8M $B\bar{B}$)

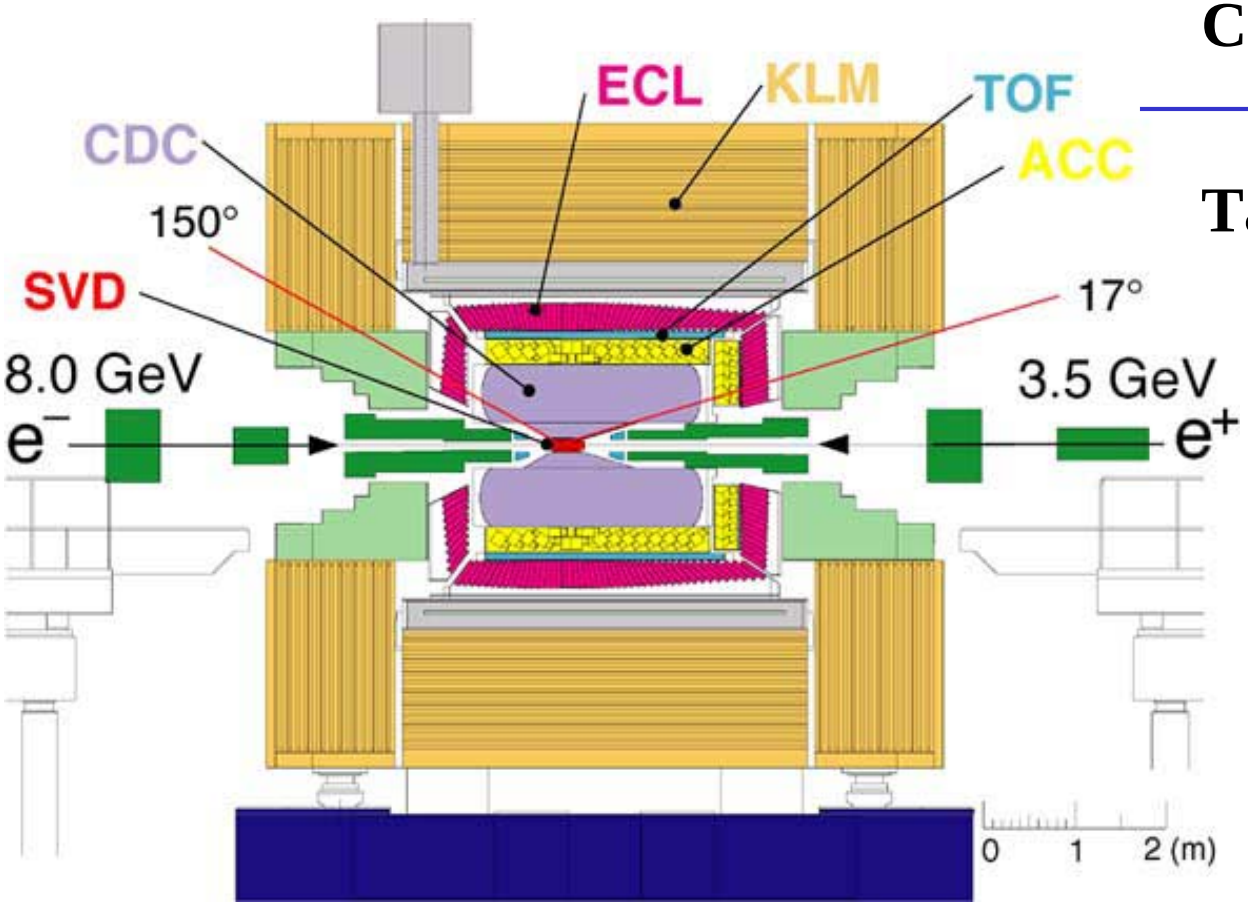
  (by the 2001 end)

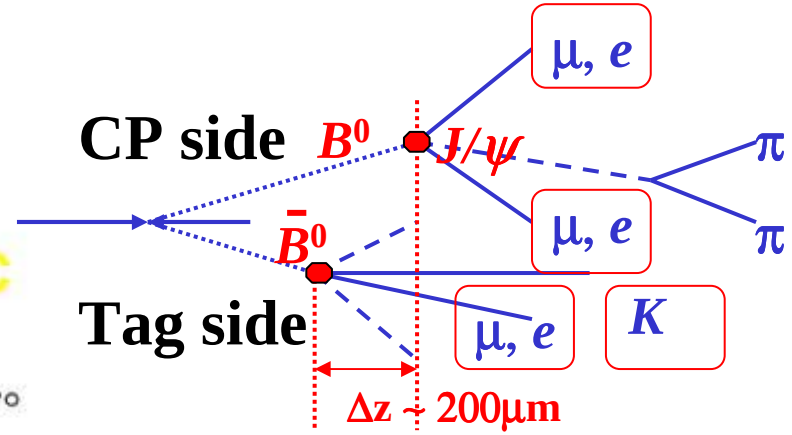
  29 fb^{-1}(31.7M $B\bar{B}$)

  (by 2001 summer)



Belle Detector



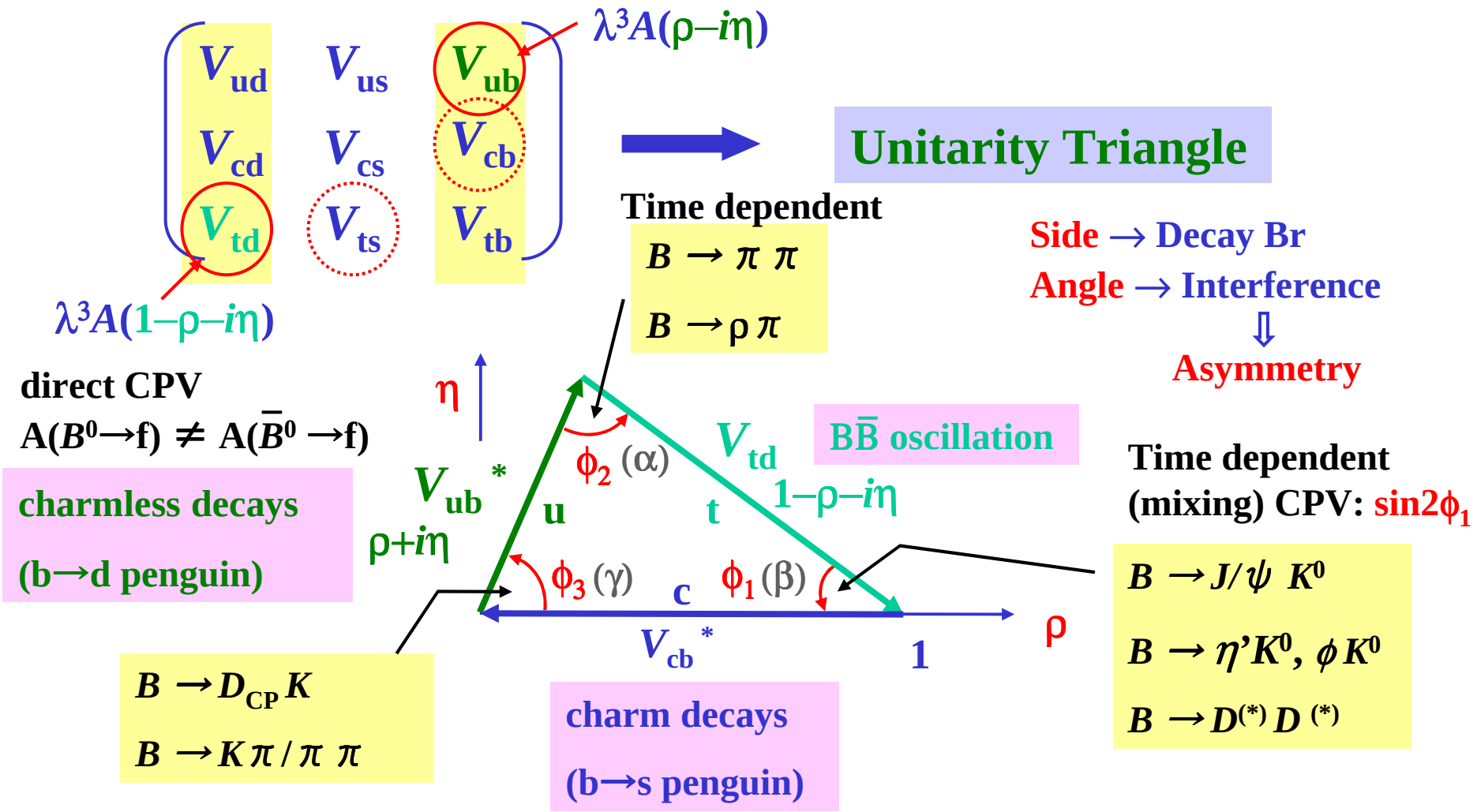


(capabilities)

- **vertex** $\sigma \leq 40(100)\mu m$**(SVD)**
- **K-ID (dE/dx,TOF,ACC)**
- **e-ID (dE/dx,ECL,TOF,ACC)**
- **μ-ID (CDC,KLM)**
- $\sigma_p / p \sim 0.35\%$ **(CDC,SVD)**
- γ, π^0 $\sigma/E \sim 1.8\%$ **(ECL,EFC)**

CKM Matrix and Unitarity Triangle

CKM Matrix and CPV



Time-dependent CPV Measurement

$e^+ e^- \rightarrow Y(4S) \rightarrow B^0 \bar{B}^0$

C eigen state (-1)

$\Phi(B^0B^0) = \Phi_C \, \Phi(\text{orbit}) \, \Phi(\text{spin})$

$+ \quad - \quad - \quad +$

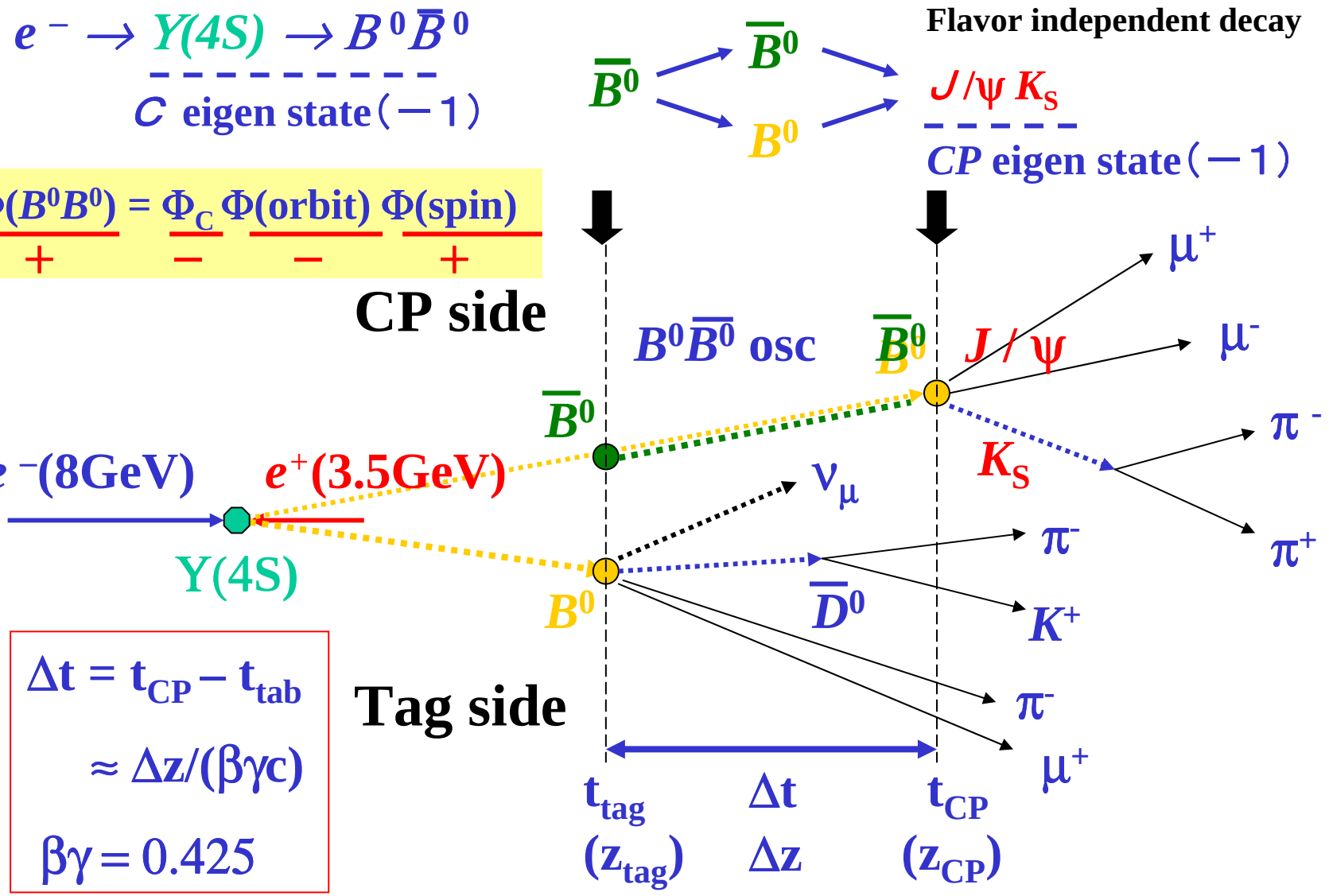
CP side

Tag side

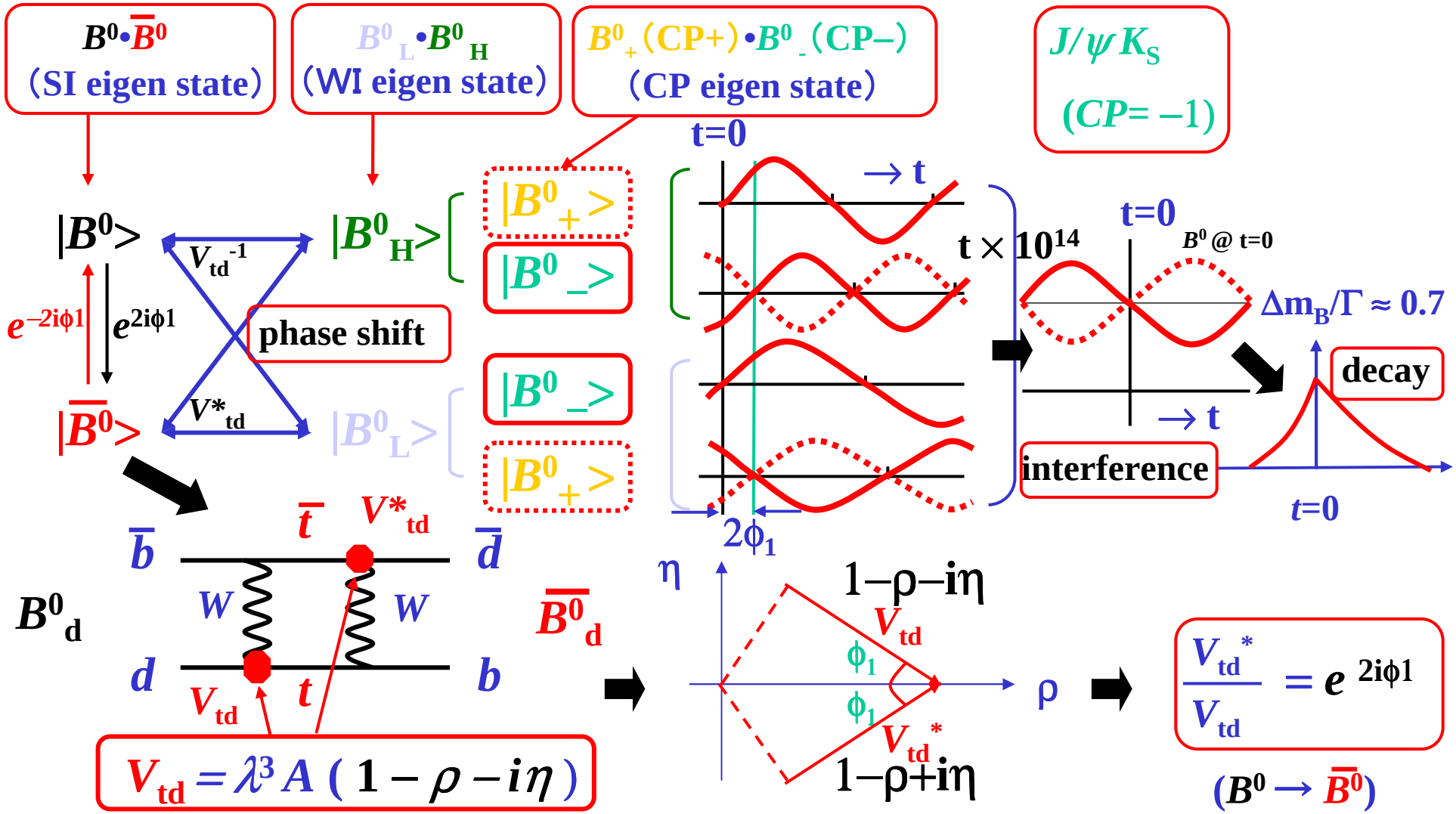
$\Delta t = t_{CP} - t_{tab}$

$\approx \Delta z/(\beta\gamma c)$

$\beta\gamma = 0.425$



$\sin 2\phi_1$: Principle



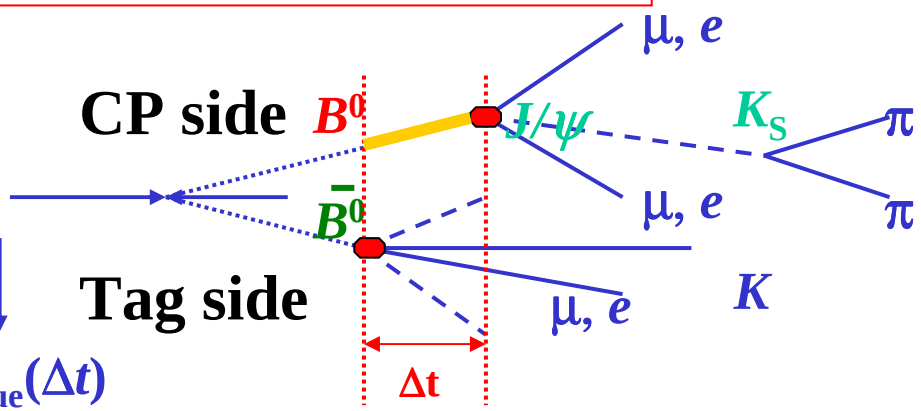
$\sin 2\phi_1$: formula

$\overline{B} \to f$, $B \to f$ time dependence $f = J/\psi K_S$ etc $\Delta\Gamma/\Gamma \sim O(0.01)$

$$A^{CP}(\Delta t) = \frac{\Gamma(\overline{B}\to f, \Delta t) - \Gamma(B\to f, \Delta t)}{\Gamma(\overline{B}\to f, \Delta t) + \Gamma(B\to f, \Delta t)} = -\xi_f \sin(2\phi_1)\sin(\Delta m_d \Delta t)$$

$\xi_f = \pm 1$: CP eigen value

$\xi_f = -1\ (c\bar{c}K_S),\ +1\ (c\bar{c}K_L)$



measure

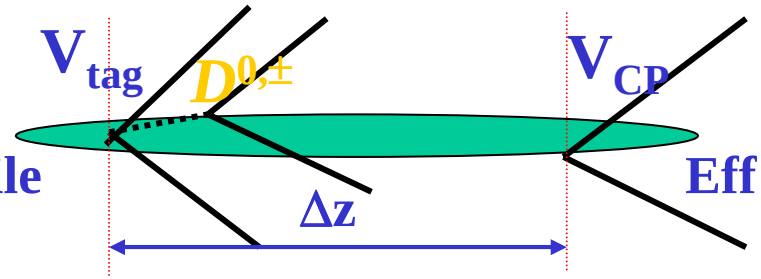
$$A^{CP}_{obs}(\Delta t) = \frac{1}{1+B/S}(1-2w)\, d_{res}\, A^{CP}_{true}(\Delta t)$$

w: Wrong tag fraction ⟵ Tagging(B or $\overline{B}$) accuracy

d_{res}: Dilution factor(σ_{VTX}) ⟵ Vertex space resolution

S: Signal, B: Background

$\sin 2\phi_1$: Δt : VTX resolution function



Eff = 85%

Z_{tag}: $\sigma \sim 140\mu m$ Z_{CP}: $\sigma \sim 75\mu m$

$\Delta z = Z_{CP} - Z_{tag} \rightarrow \Delta t$

resolution function

$$R(\Delta t)=(1-f_{OL})\cdot(f_{SG}\cdot R_{SG}+(1-f_{SG})\cdot R_{BG})+f_{OL}\cdot R_{OL}$$

$R_{SG} = R_{REC} \otimes R_{ASC} \otimes R_{NP} \otimes R_{KIN}$

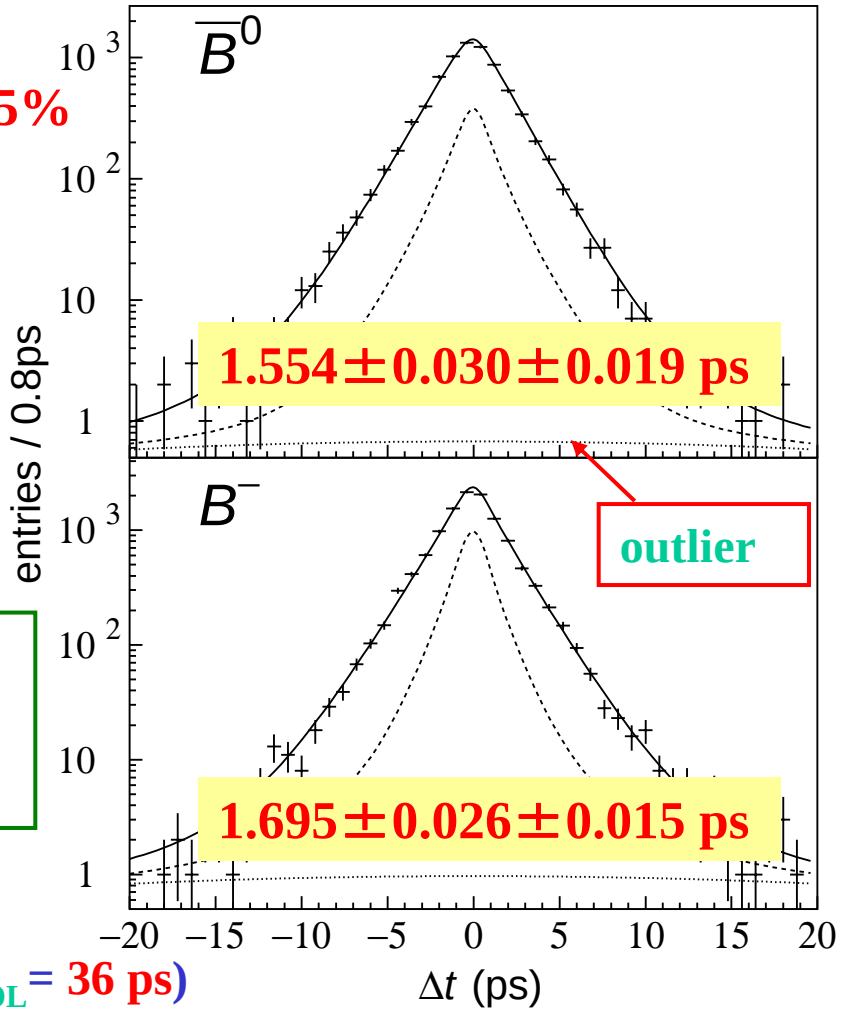
- R_{REC}: V_{CP} detector resolution
- R_{ASC}: V_{tag} detector resolution
- R_{NP}: decay track resolution
- R_{KIN}: kinematical effect

event by event

R_{BG}: 2 gaussian (sideband)

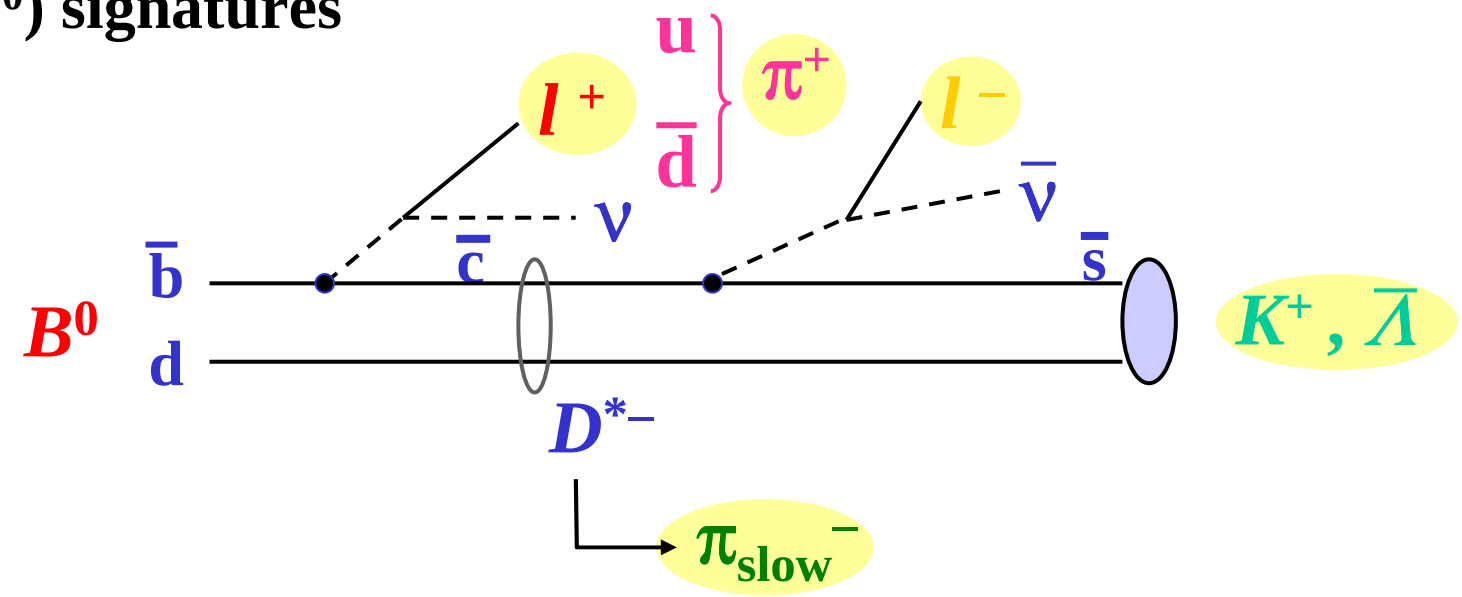
R_{OL}: outlier → 1 gaussian (global: f_{OL}=0.06%, σ_{OL}= 36 ps)

Derived from lifetime measurement



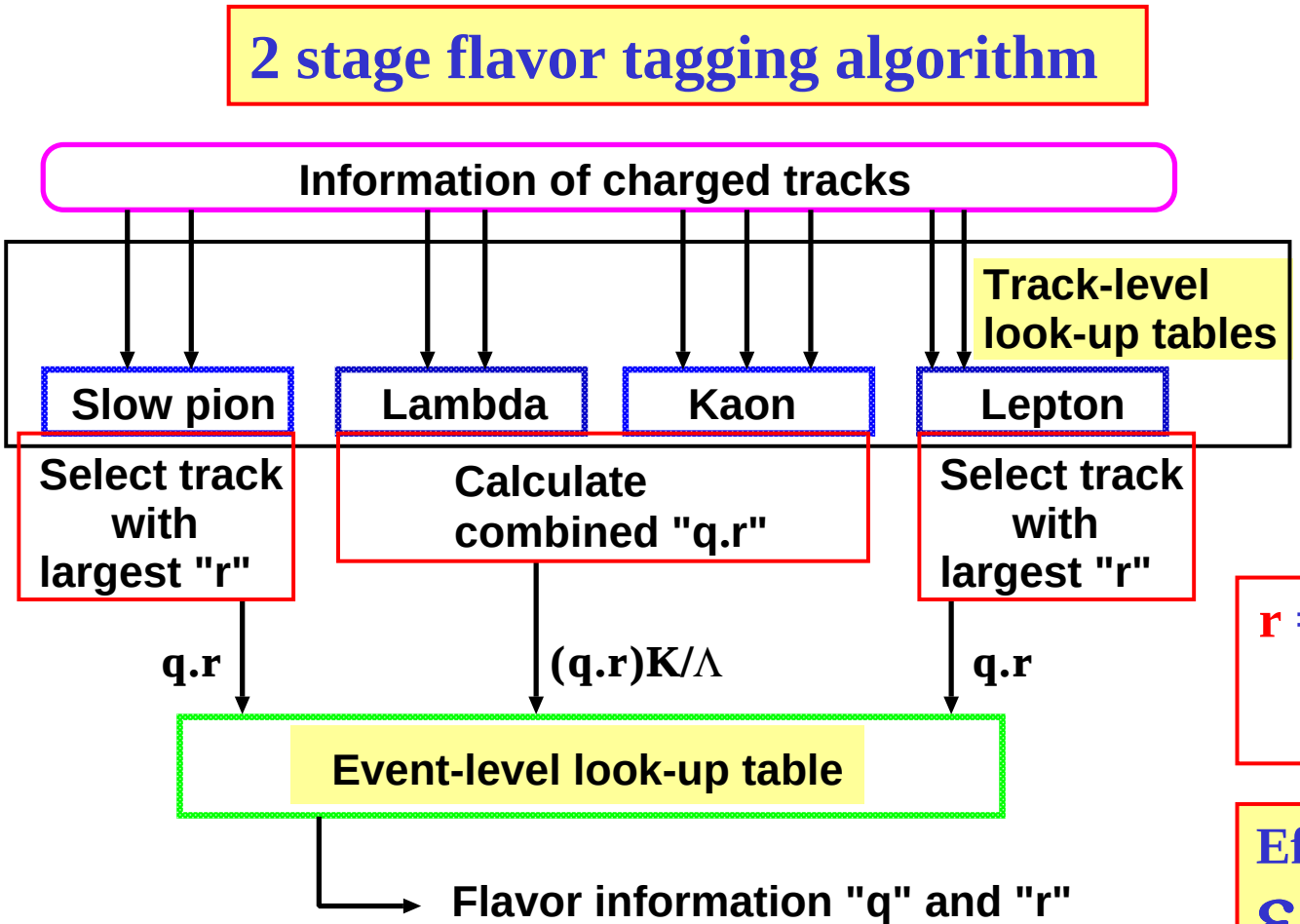
$\sin 2\phi_1$: Flavor B^0 ($\overline{B^0}$) Tagging

B^0 ($\overline{B^0}$) signatures



- high p lepton charge: +(–)
- K charge and Λ or $\bar{\Lambda}$: +(–)
- mid p lepton: –(+)
- slow π: –(+)
- fast π: +(–)

$\sin 2\phi_1$: Flavor Tagging Method



q = +1: B_0 - like

= –1: $\overline{B}_0$ - like

r :quality parameter

r = 0 1

low ← likelihood → high

Efficiency > 99.5%

$\varepsilon_{eff} = 27.0 \pm 1.2\%$

$\sin 2\phi_1$: $J/\psi\ K_S$ reconstruction

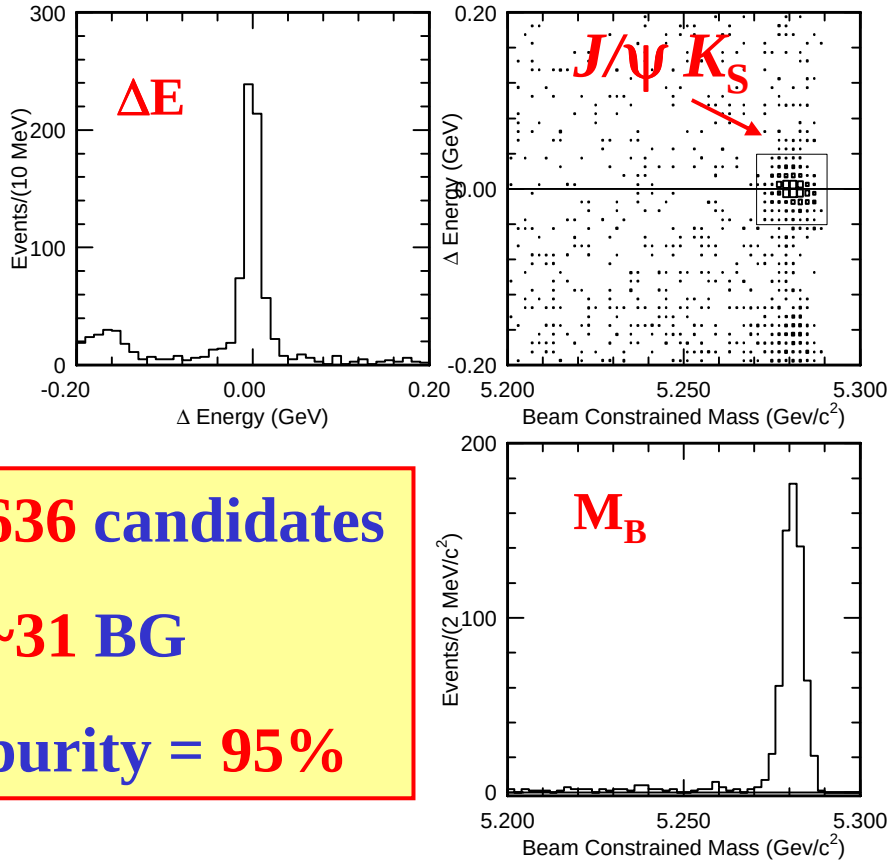
$$\Delta E = E_{J/\psi} + E_{K_S} - E_{beam} \qquad \text{CMS}$$

$$M_B = \sqrt{E_{beam}^2 - \mathbf{P}_B^2}$$

$$B^0 \rightarrow J/\psi\ K_S$$

B0 -> J/ψKs->μμππ
B0bar -> K- tag

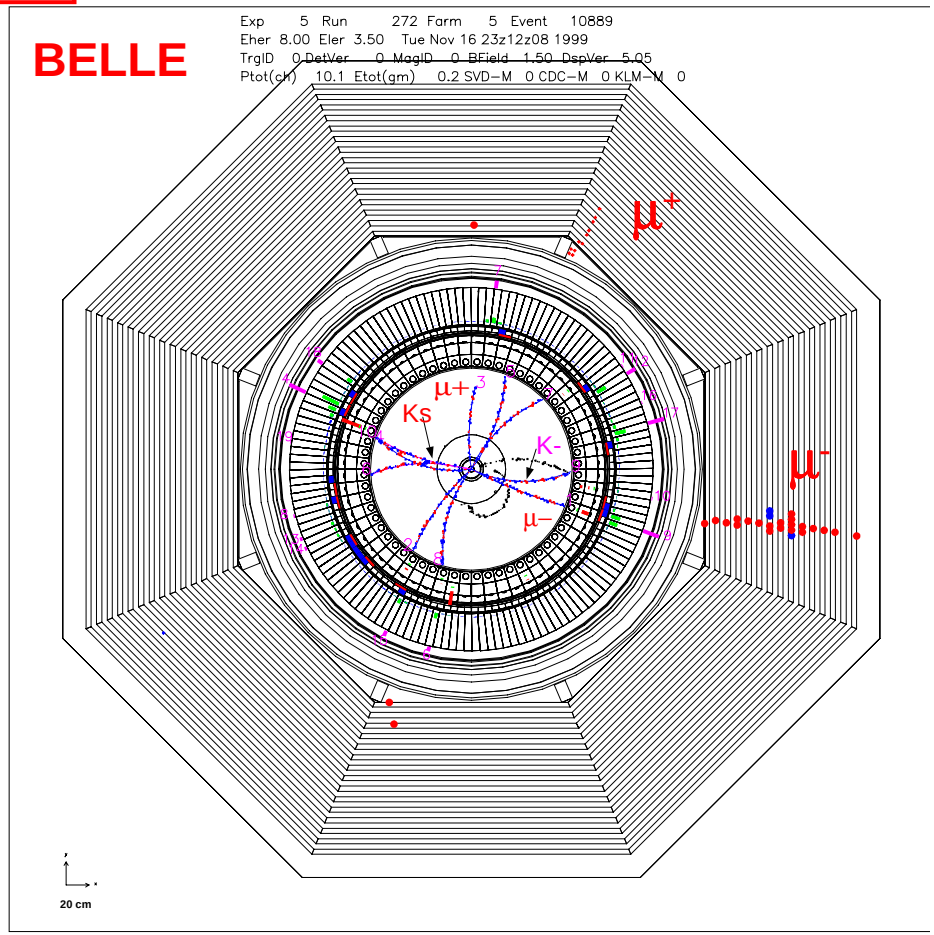
Event example



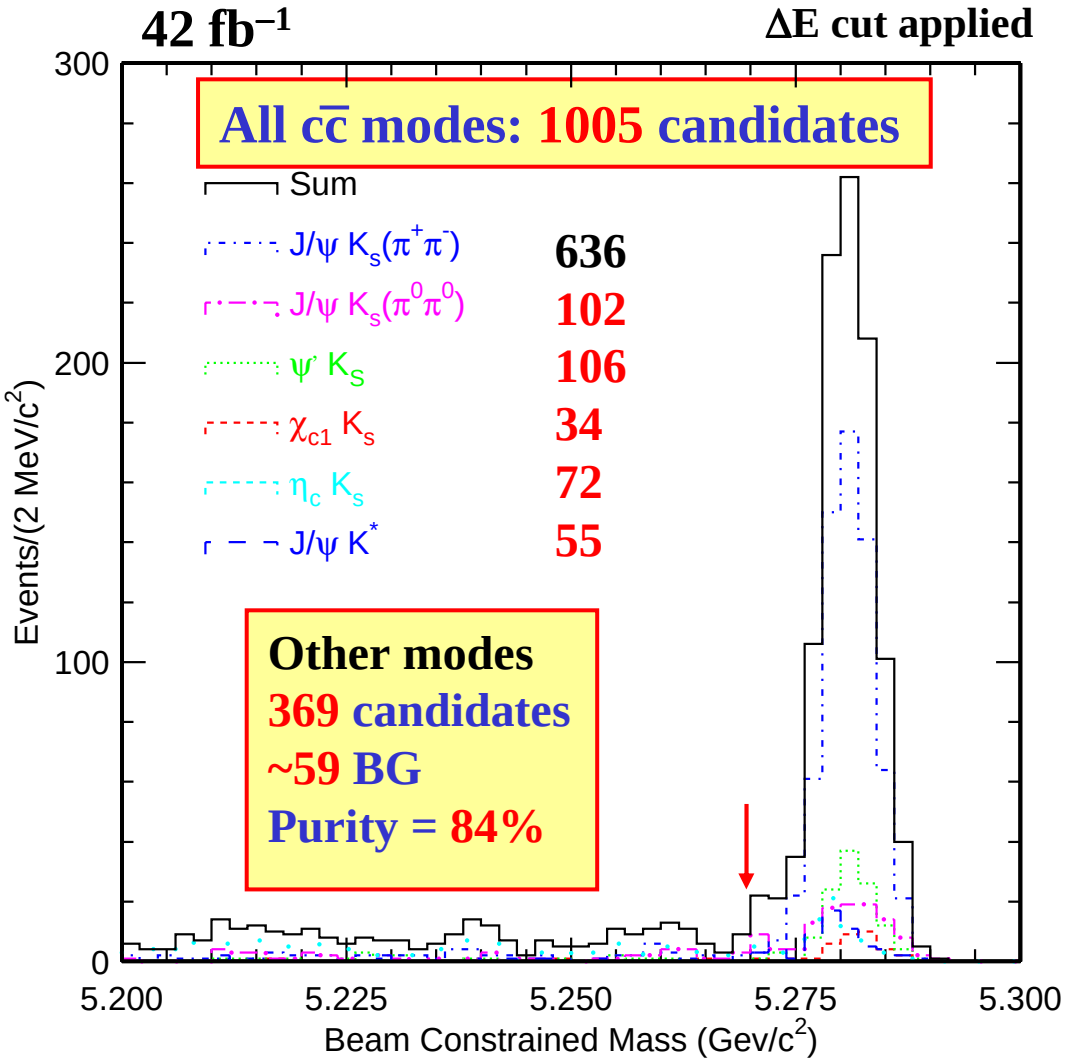
636 candidates

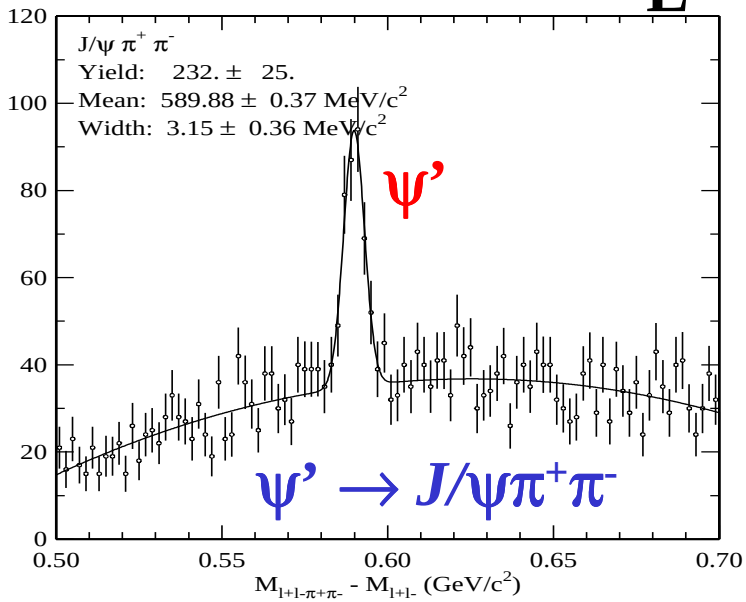
~31 BG

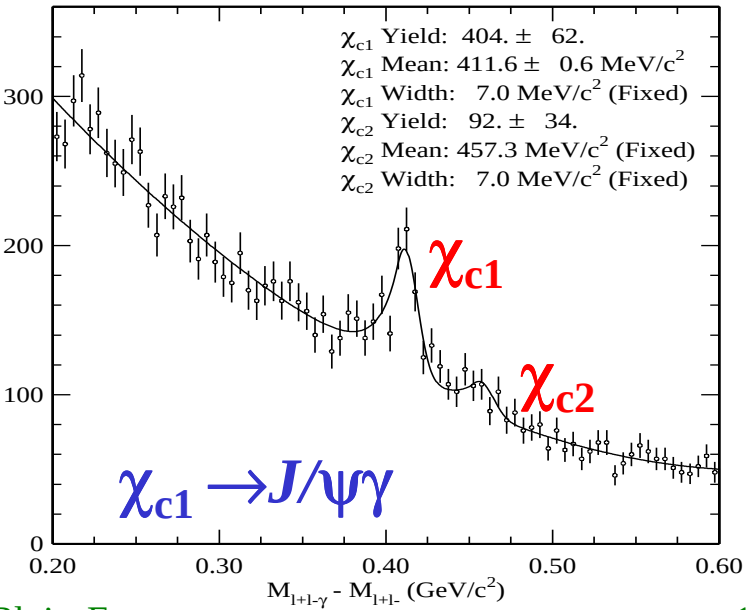
purity = 95%



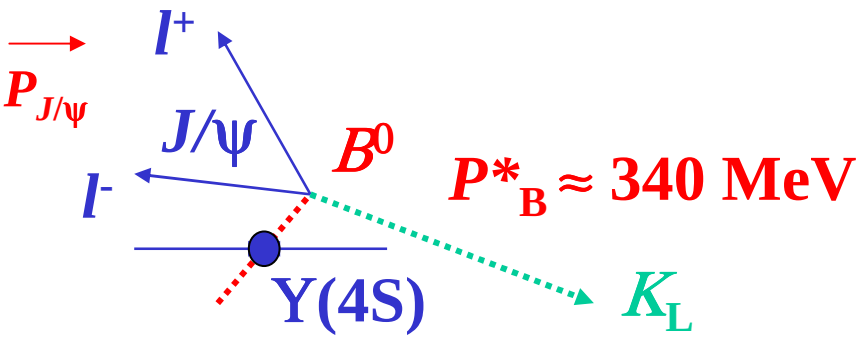
$\sin 2\phi_1$: other $c\bar{c}$ CP channels w/o K_L



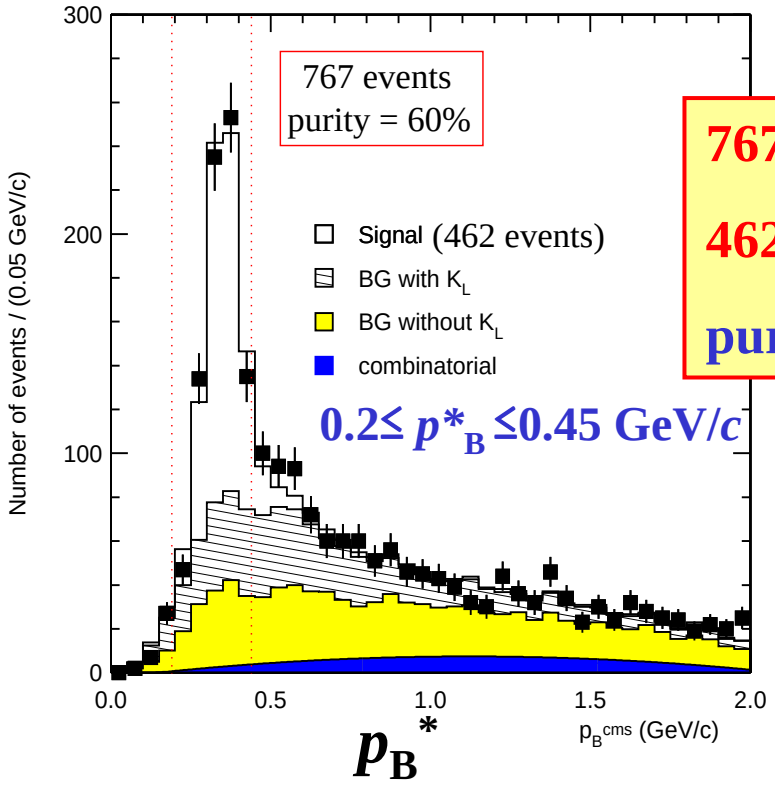




$\sin 2\phi_1$: $J/\psi\ K_L$ reconstruction



$P^*_B \approx 340$ MeV

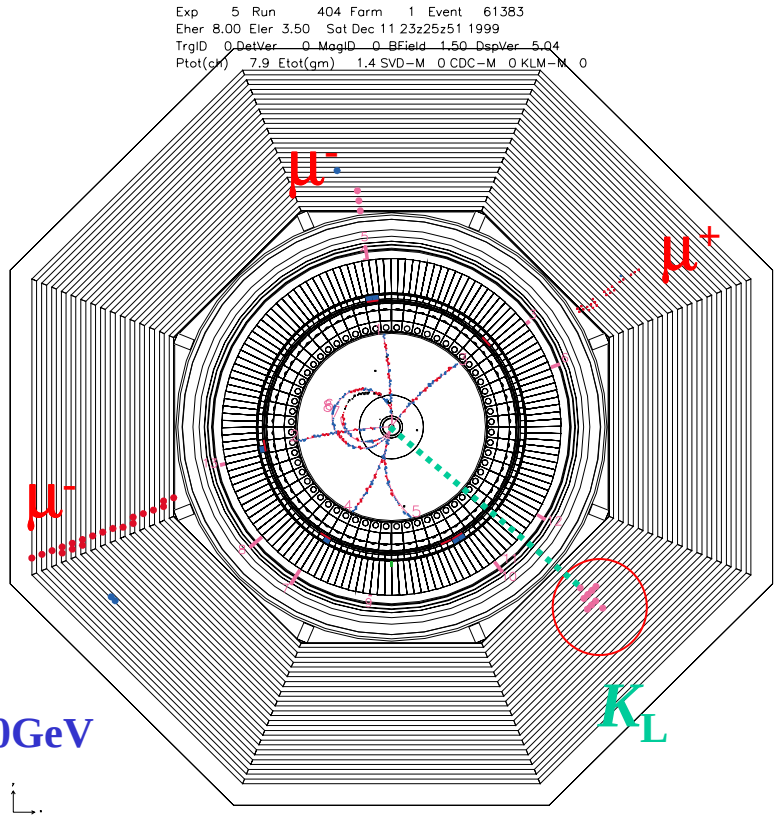


767 candidates

462 signals

purity = 60%

$B^0 \rightarrow J/\psi\ K_L$



$1.42 < P^*_{J/\psi} < 2.0$GeV

$\sin 2\phi_1$: Fitting

Unbinned Maximum Likelihood Analysis

Calculate event-by-event

convolution

Response function

$$\rho_i(\Delta t_i) = f_{sig}\, P_{sig}(\sin 2\phi_1;\Delta t') \otimes R_{sig}(\Delta t_i - \Delta t') + (1-f_{sig})\, P_{BG}(\Delta t') \otimes R_{BG}(\Delta t_i - \Delta t')$$

probability density

signal

background

$$P_{sig}(\sin 2\phi_1;\Delta t) = \frac{1}{2\tau_{B0}} \exp\left(-\frac{|\Delta t|}{\tau_{B0}}\right)\left[1 + q\,\xi_f\,(1-2w)\sin 2\phi_1 \sin(\Delta m_d \Delta t)\right]$$

signal function

$$P_{BG}(\Delta t) = f_\tau \cdot \frac{1}{2\tau_{BG}} \exp\left(-\frac{|\Delta t|}{\tau_{BG}}\right) + (1-f_\tau)\cdot\delta(\Delta t)$$

BG function

$q = +: B^0,\ -: \overline{B^0}$ (tagging)

ξ_f : final state CP

$$L(\sin 2\phi_1) = \prod_{\text{events}} \rho_i \quad \Rightarrow \quad Max\ Log(L) \rightarrow \sin 2\phi_1$$

τ_{B0}, Δm_d ← PDG2000,

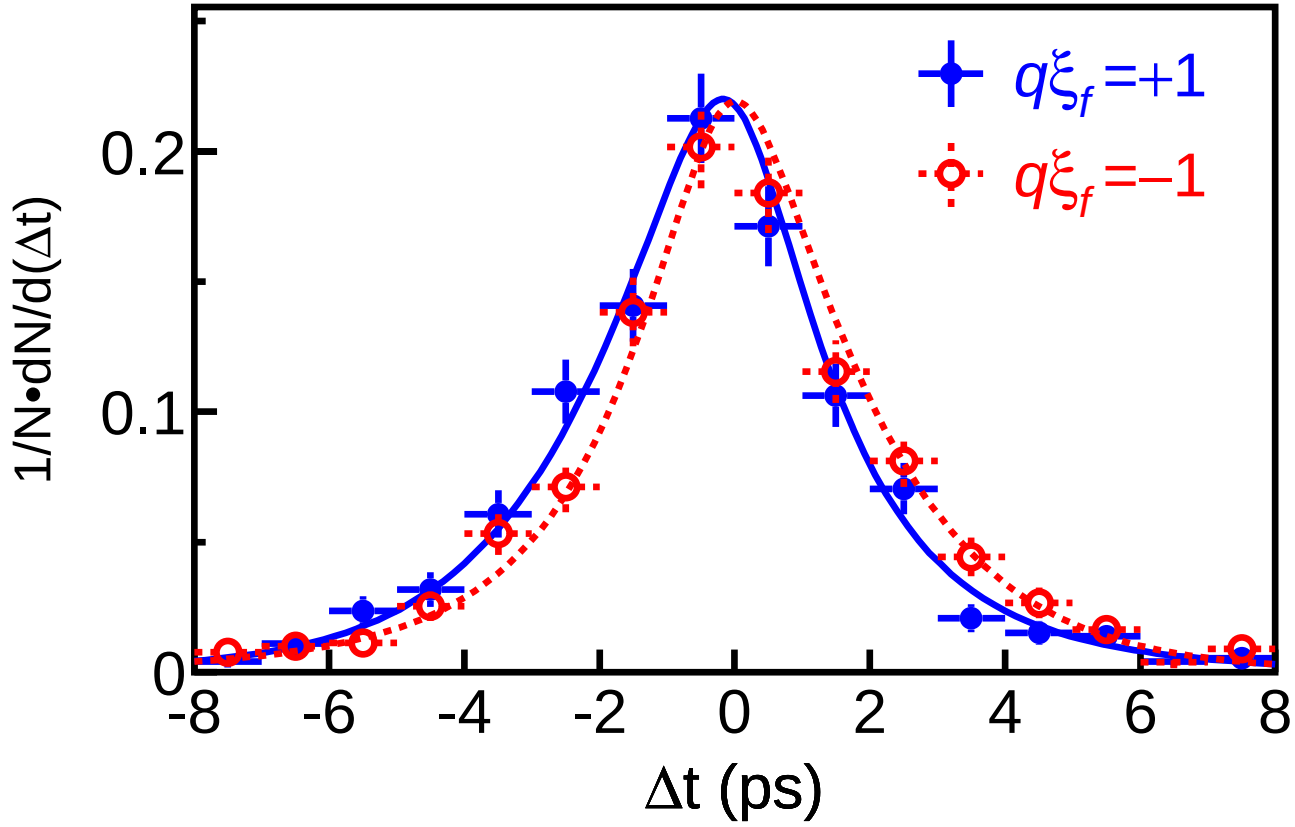
τ_{BG} ← side band

$\sin 2\phi_1$: Fit Result

$\sin 2\phi_1 = +0.82 \pm 0.12\ (stat) \pm 0.05\ (syst)$

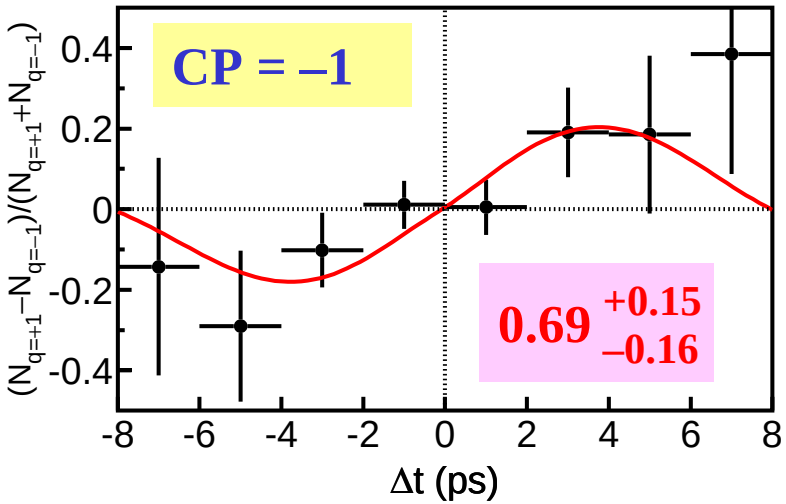
Preliminary

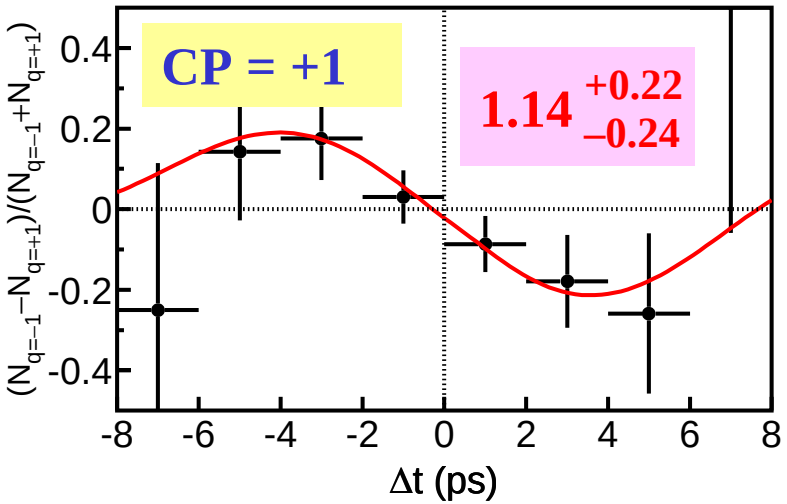
42 fb^{-1} (1550 events)



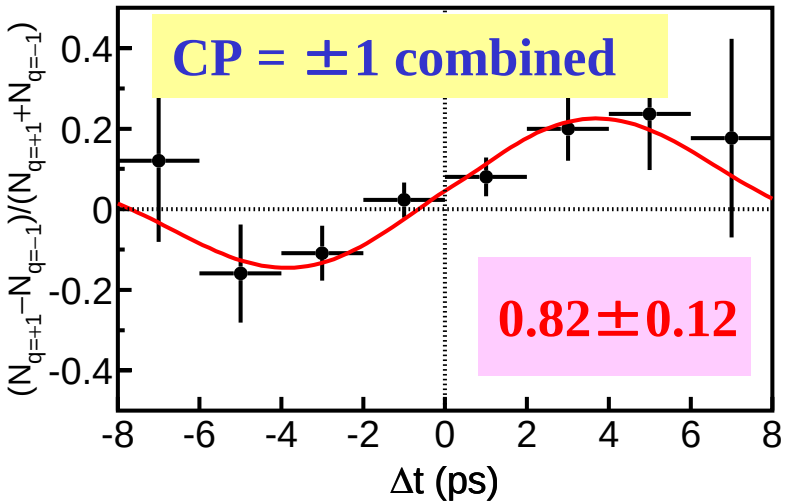
$\sin 2\phi_1$: Asymmetry

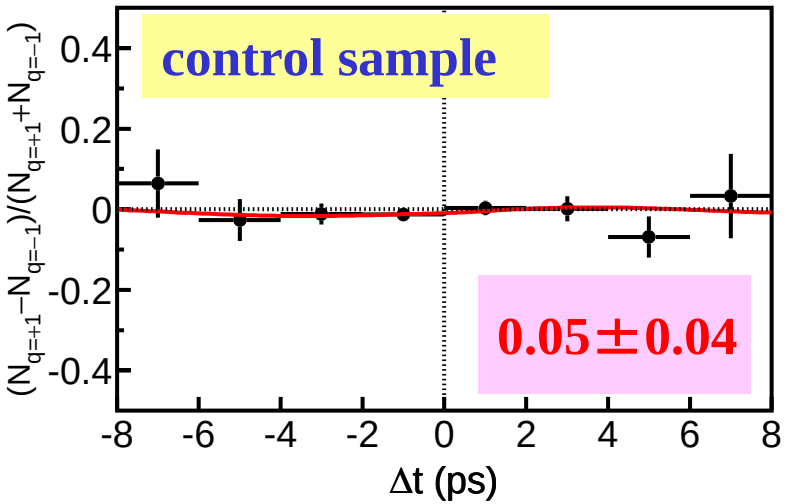
statistical errors only





$D^{(*)-}\pi^+$, $D^{*-}\rho^+$, $J/\psi K^*(K^+\pi^-)$



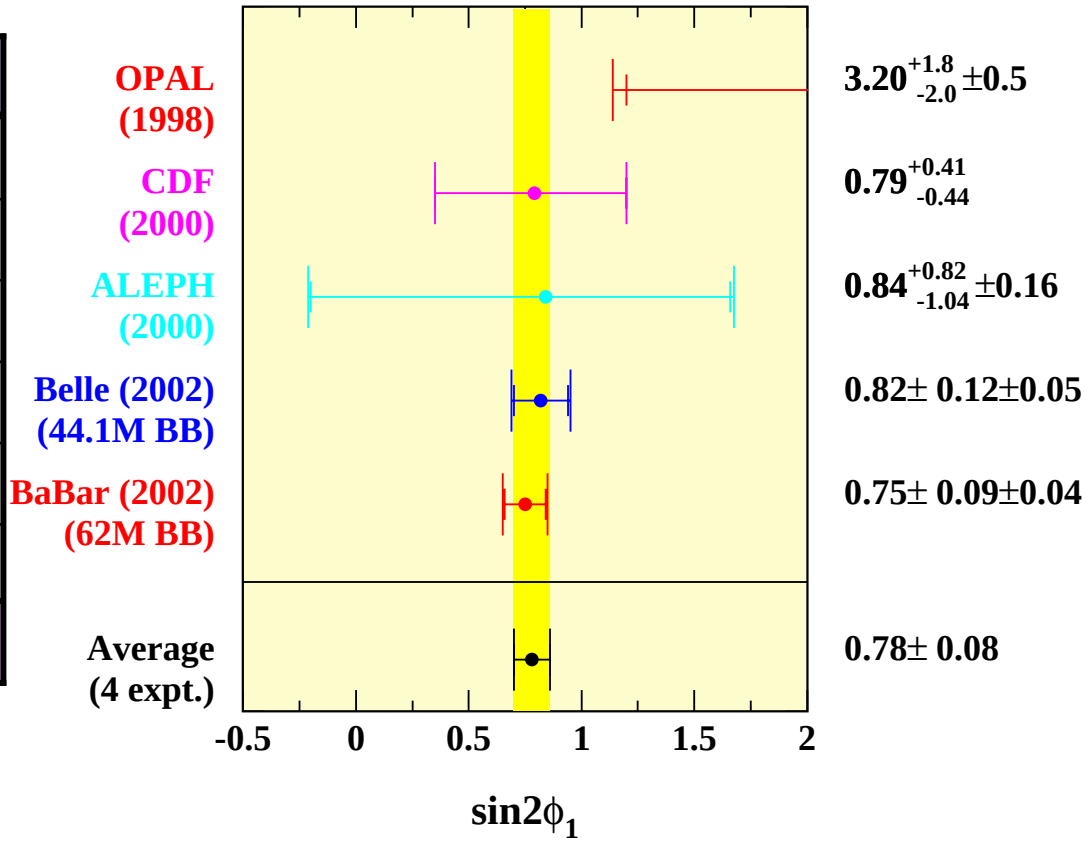


$\sin 2\phi_1$: Summary

systematic errors

source	$+\sigma$	$-\sigma$
vertexing	0.03	0.03
flavor tagging	0.024	0.026
resolution function	0.022	0.019
BG fraction (K_L)	0.014	0.015
BG (non K_L)	0.007	0.006
Δm_d and τ_{B0} errors	0.007	0.006
Total	**0.05**	**0.05**

comparison with others

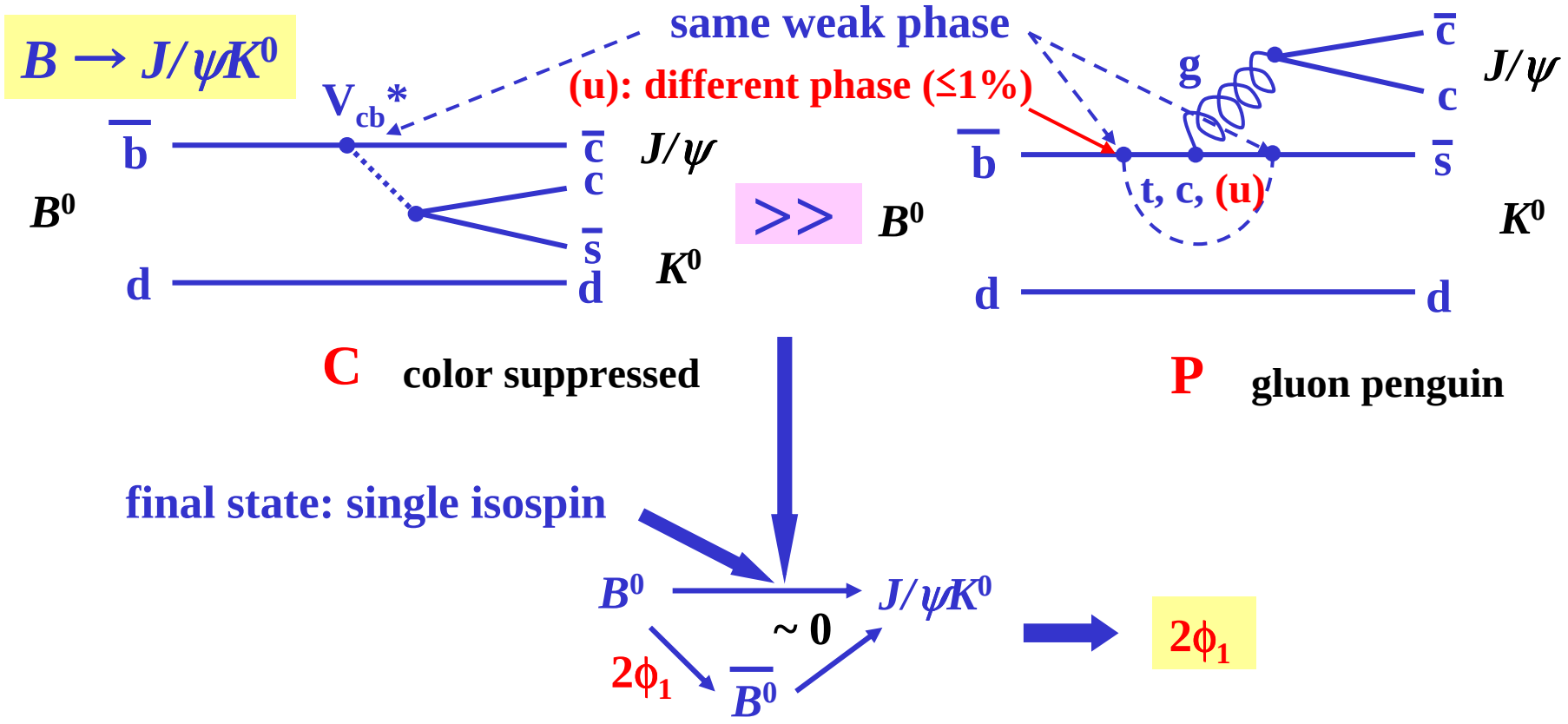


$\sin 2\phi_1 = +0.82 \pm 0.12\ (stat) \pm 0.05\ (syst)$

Preliminary

42 fb^{-1} (44.1 M $B\bar{B}$, 1550 events)

$B \to \pi^+\pi^-$: Principle (1)

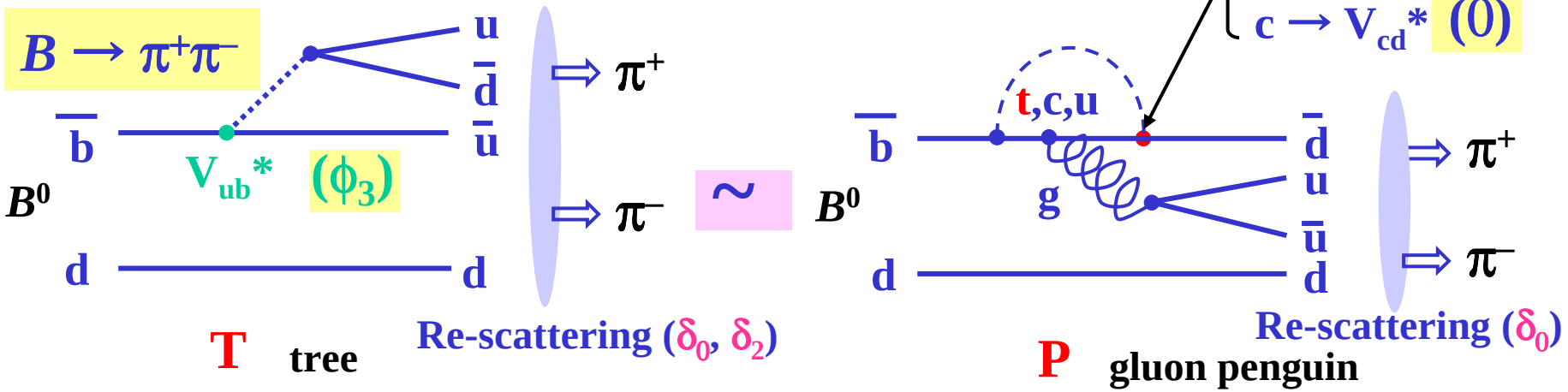


While …

$B \to \pi^+\pi^-$ ← **Tree and Penguin + Strong interaction**

→ **(Re-scattering: T ≠ P)**

$B \to \pi^+\pi^-$: Principle (2)



Tree and Penguin + Strong interaction

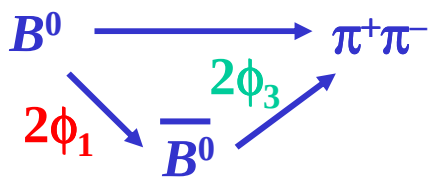
(T, P, δ) interference ➡ $B^0 \to \pi^+\pi^- \neq \overline{B^0} \to \pi^+\pi^-$

Direct CPV

(Mixing, T) interference ➡

(w/o penguin)

(w/ penguin)



➡ $\phi_1 + \phi_3 \to \phi_2$

assuming U triangle

$(\phi_1+\phi_3 = \pi-\phi_2)$

Isospin analysis: ππ ➡ **isolate P effect** ➡ ϕ_2

$B \to \pi^+\pi^-$: formula

Time Dependent CPV Asymmetry

$$A_{CP}(\Delta t) = \frac{\Gamma(\bar{B}\to\pi^+\pi^-;\Delta t) - \Gamma(B\to\pi^+\pi^-;\Delta t)}{\Gamma(\bar{B}\to\pi^+\pi^-;\Delta t) + \Gamma(B\to\pi^+\pi^-;\Delta t)}$$

$$= S_{\pi\pi}\cdot \sin(\Delta m_d \Delta t) + A_{\pi\pi}\cdot \cos(\Delta m_d \Delta t)$$

Direct CPV term

Penguin correction

$$S_{\pi\pi} = \frac{2\,Im\,\lambda}{|\lambda|^2+1} = \frac{2\sin(2\phi_2+2\theta)}{|\lambda|^2+1} \approx \sin(2\phi_2^{eff})$$

(if $|\lambda| \approx 1$ & $\phi_2 > \theta$)

$$A_{\pi\pi} = \frac{|\lambda|^2-1}{|\lambda|^2+1} = \frac{|\bar{A}_{\pi\pi}|^2 - |A_{\pi\pi}|^2}{|\bar{A}_{\pi\pi}|^2 + |A_{\pi\pi}|^2}$$

$$\lambda = \xi_f \frac{q}{p}\frac{\bar{A}_{\pi\pi}}{A_{\pi\pi}}$$

$\bar{A}(\bar{B}\to\pi\pi)$

decay CPV: $\frac{\bar{A}_{\pi\pi}}{A_{\pi\pi}} \sim \frac{V_{ub}}{V_{ub}^*} \sim e^{-2i\phi_3}$

$A(B\to\pi\pi)$

mixing: $\frac{q}{p} \sim \frac{V_{td}}{V_{td}^*} \sim e^{-2i\phi_1}$

$$\lambda \sim \xi_f e^{-2i\phi_1 - 2i\phi_3} \sim \xi_f e^{-2i\phi_2}$$

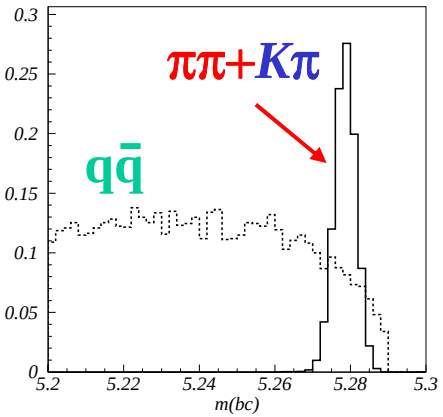
$B \to \pi^+\pi^-$: Selection

Event Selection

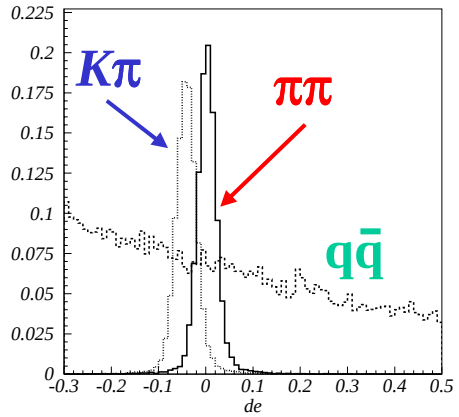
- Hadronic events
- 2 (+/–) charged tracks
- PID: $\pi^\pm \leftrightarrow K^\pm$
- $q\bar{q}$ suppression

1. $(\Delta E, M_B)$
2. Event shape: Super Fox-Wolfram
3. $\cos\theta_B$: B flight direction (P-wave)

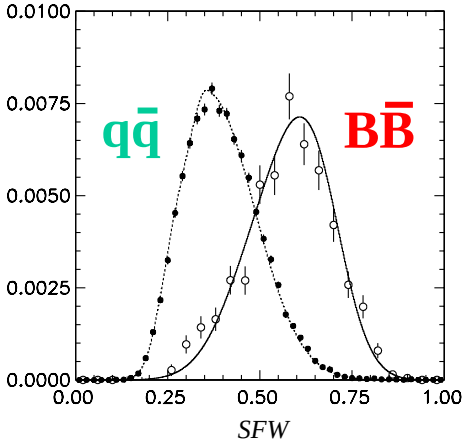
(MC)



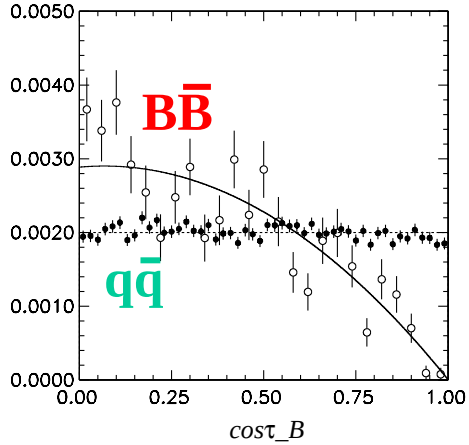
M_B



ΔE



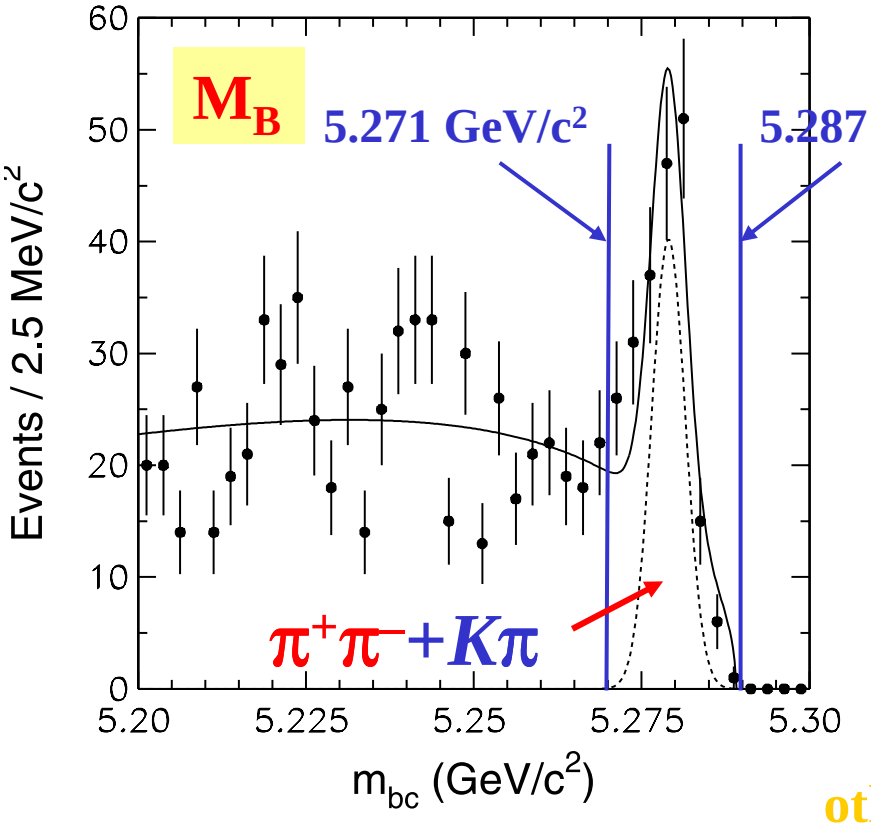
SFW

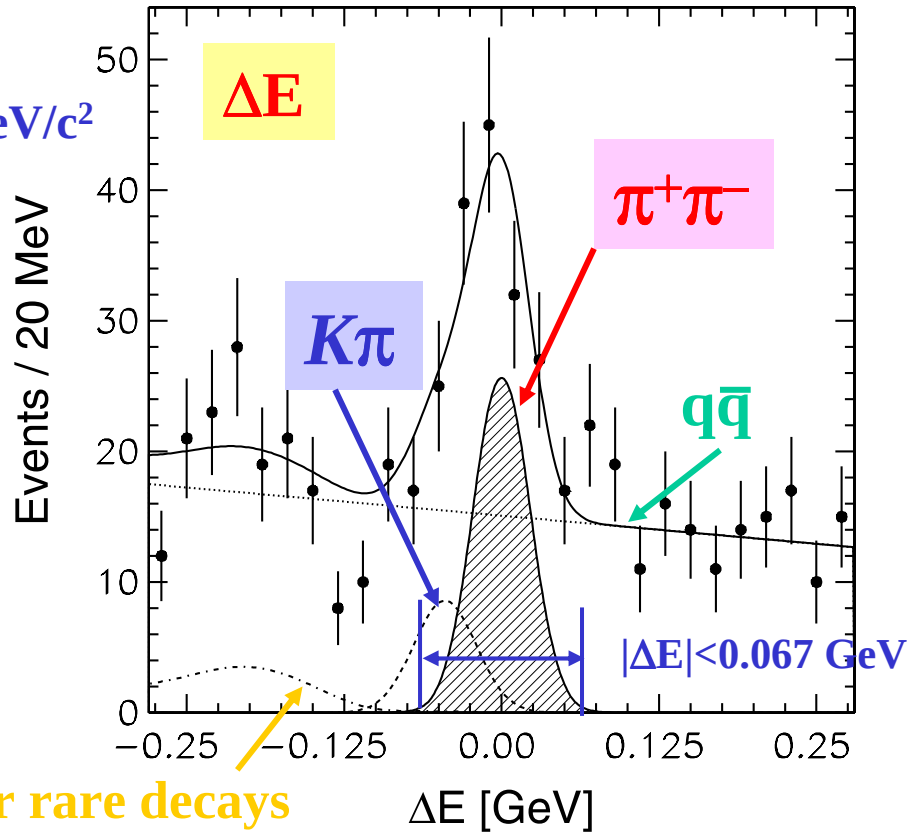


$\cos\theta_B$

$B \to \pi^+\pi^-$: Signal

42 fb^{-1}

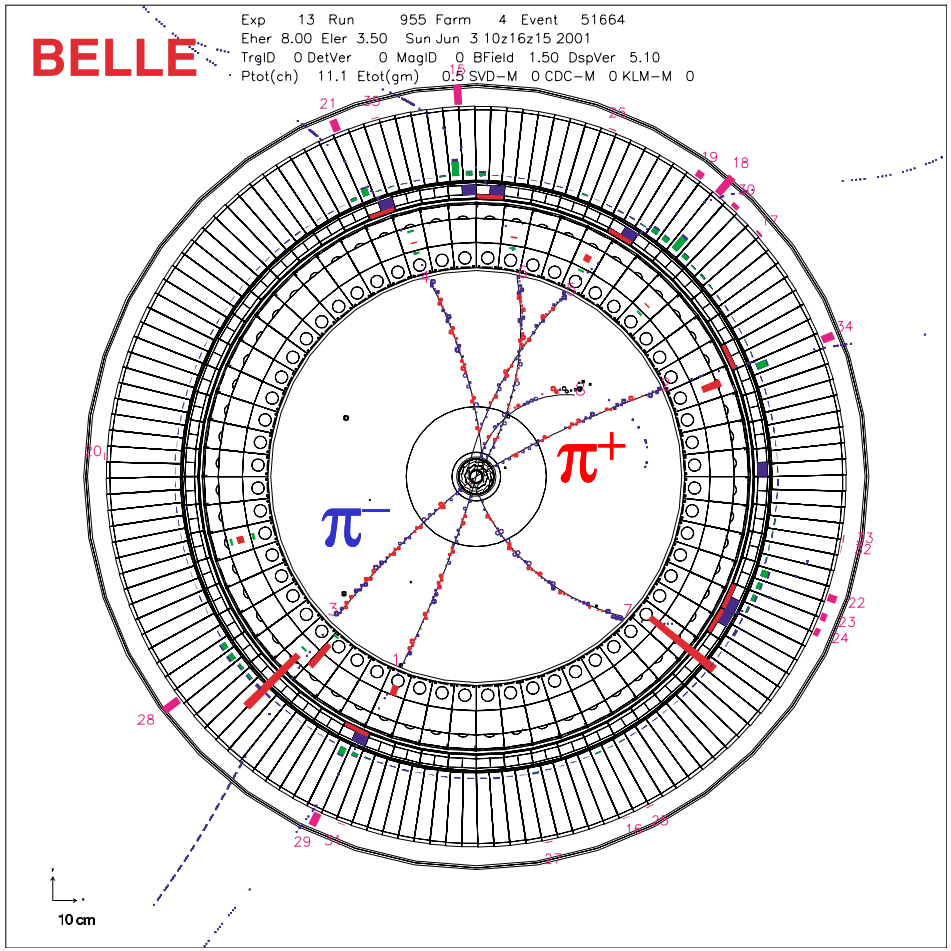


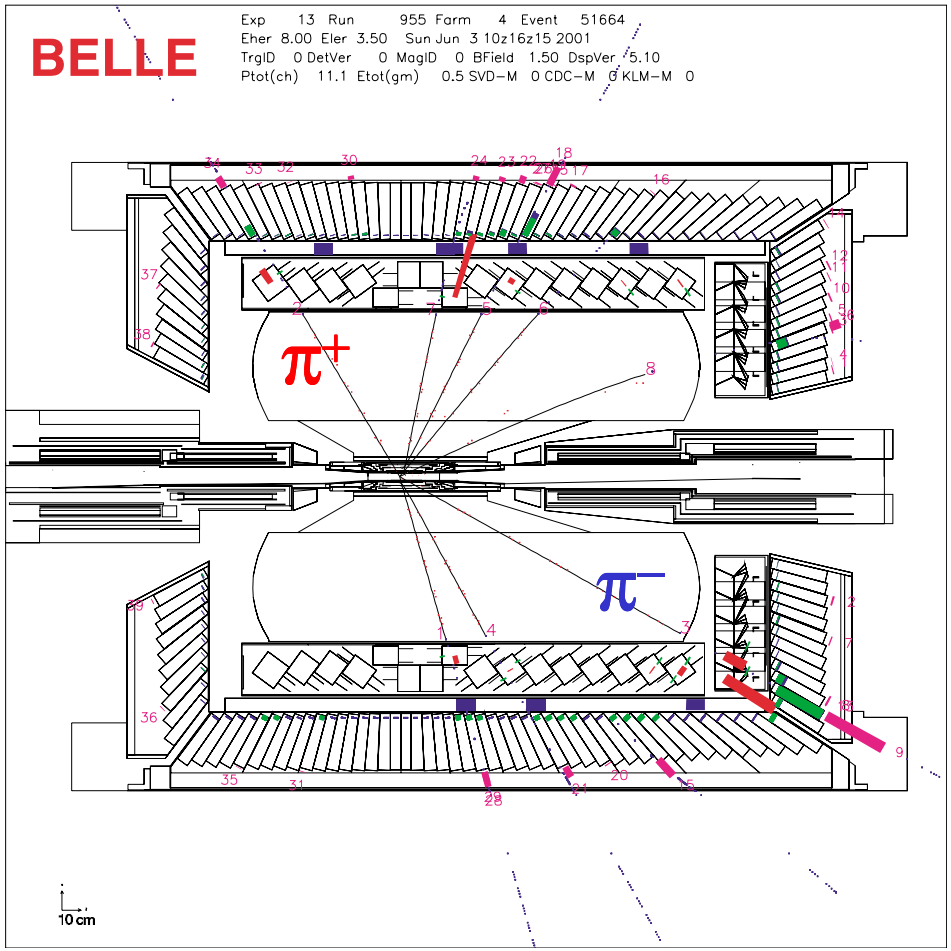


N($\pi\pi$) = 73.5 ± 13.8 events

N($K\pi$) = 28.4 ± 12.5 events

$B \to \pi^+\pi^-$: Event Example





$B \to \pi^+\pi^-$: Fitting

event-by-event & 6 *r*-regions

$q\bar{q}$ BG decay probability

$$P_{qq}(\Delta t,q) = 1/2\,[\,f_t\,(1/2\tau_{BG})\exp(-|\Delta t|/\tau_{BG}) + (1-f_\tau)\delta(\Delta t)]$$

probability density

$$\rho_i(\Delta t) = [f_{\pi\pi}\,P_{\pi\pi}(A_{\pi\pi}, S_{\pi\pi};\Delta t',q) + f_{K\pi}\,P_{K\pi}(\Delta t',q)] \otimes R_{sig}(\Delta t_i-\Delta t') + f_{qq}\,P_{qq}(\Delta t') \otimes R_{qq}(\Delta t_i-\Delta t')$$

$\pi\pi$ signal — $K\pi$ BG — $q\bar{q}$ BG — response functions

assuming: $R_{sig} = R_{\pi\pi} = R_{K\pi}$

$K\pi$ BG decay probability

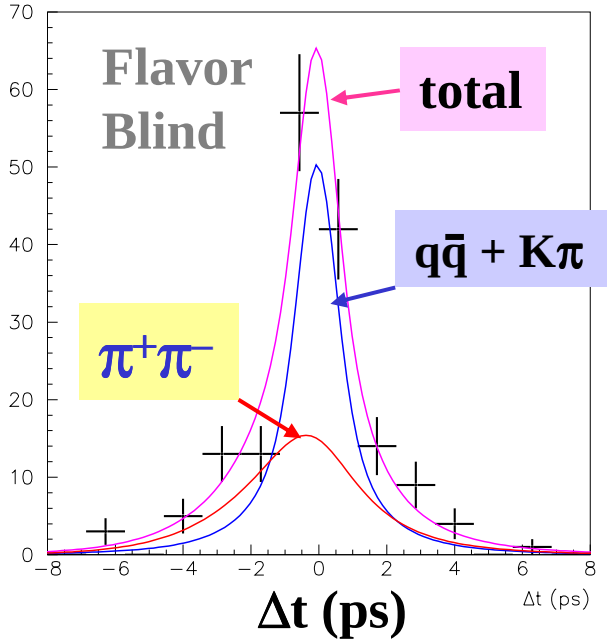
$$P_{K\pi}(\Delta t,q) = (1/4\tau_{B0})\exp(-|\Delta t|/\tau_{B0})[1+q(1-2w)(A_{K\pi}\cos(\Delta m_d\Delta t))]$$

$\pi\pi$ signal decay probability

$$P_{\pi\pi}(A_{\pi\pi},S_{\pi\pi};\Delta t,q) = (1/4\tau_{B0})\exp(-|\Delta t|/\tau_{B0})[1+q(1-2w)(A_{\pi\pi}\cos(\Delta m_d\Delta t)+S_{\pi\pi}\sin(\Delta m_d\Delta t))]$$

$$L(A_{\pi\pi}, S_{\pi\pi}) = \prod_{\text{events}} \rho_i \quad \Rightarrow \quad \textit{Max Log}\,(L) \to A_{\pi\pi},\ S_{\pi\pi}$$

$B \to \pi^+\pi^-$: Time Distributions



162 events

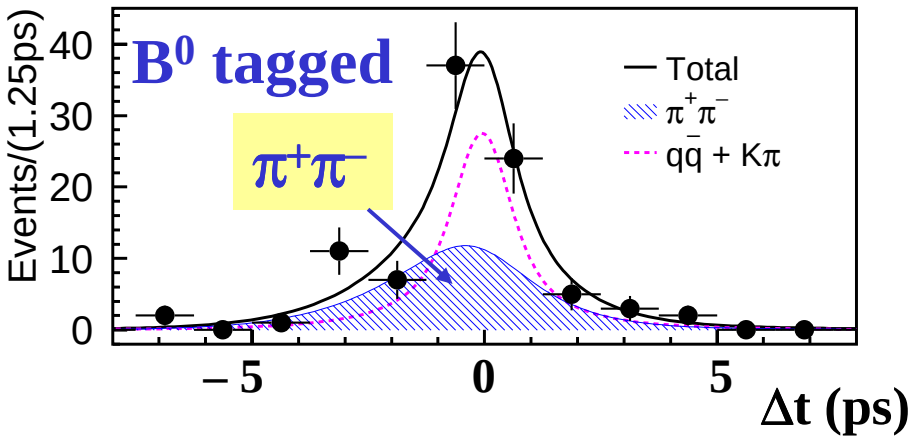
vertexing
flavor tagging
$|\Delta E| < 0.067$ GeV

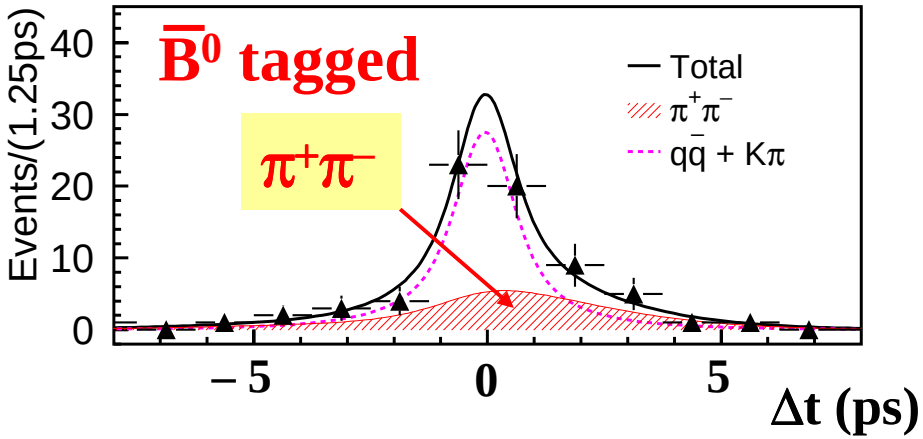
92 B^0 events

39.9 $B^0 \to \pi^+\pi^-$ events

70 $\overline{B}^0$ events

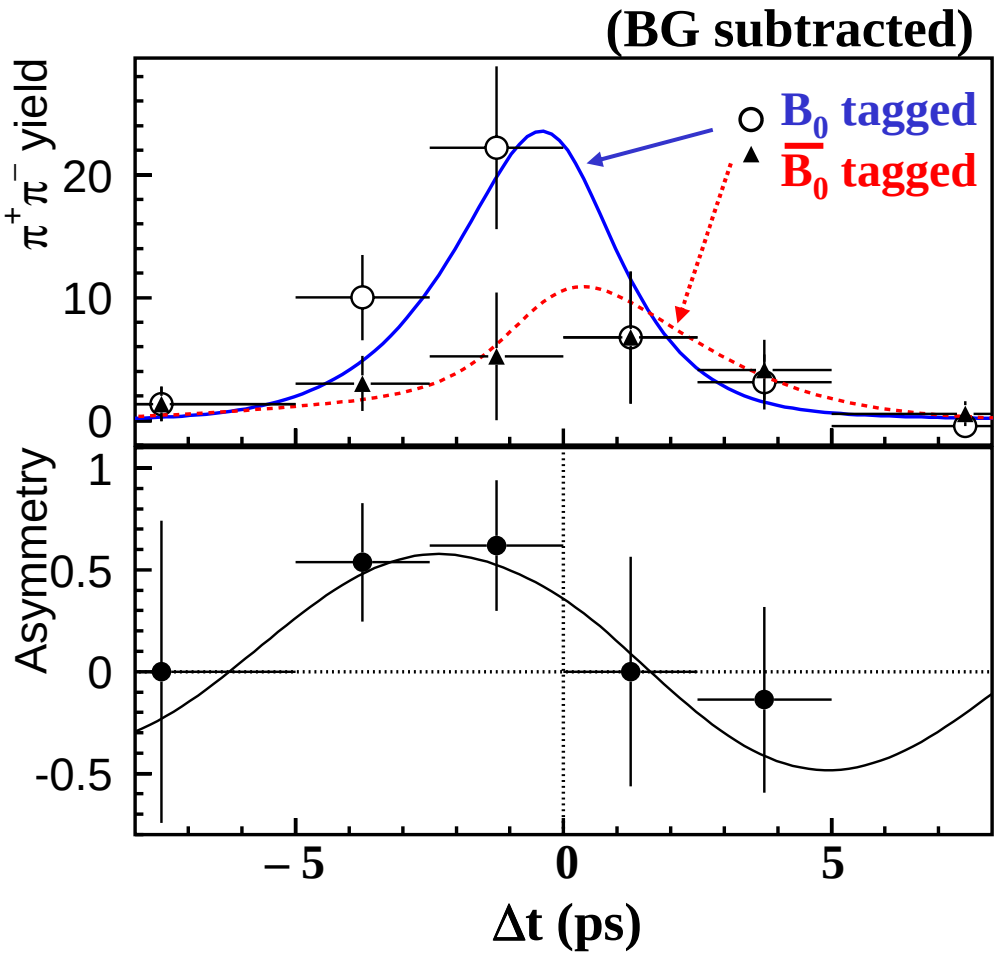
23.4 $\overline{B}^0 \to \pi^+\pi^-$ events





$B \to \pi^+\pi^-$: Fit Result

$\pi^+\pi^-$: time dependence



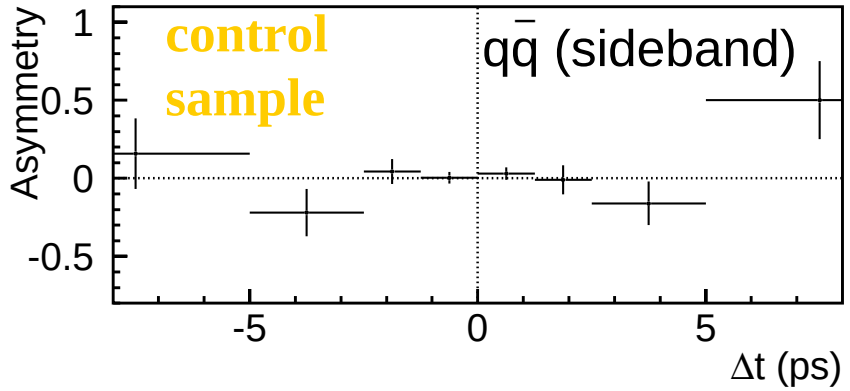
Preliminary

$A_{\pi\pi} = +0.94\ ^{+0.25}_{-0.31} \pm 0.09$ (2.9 σ)

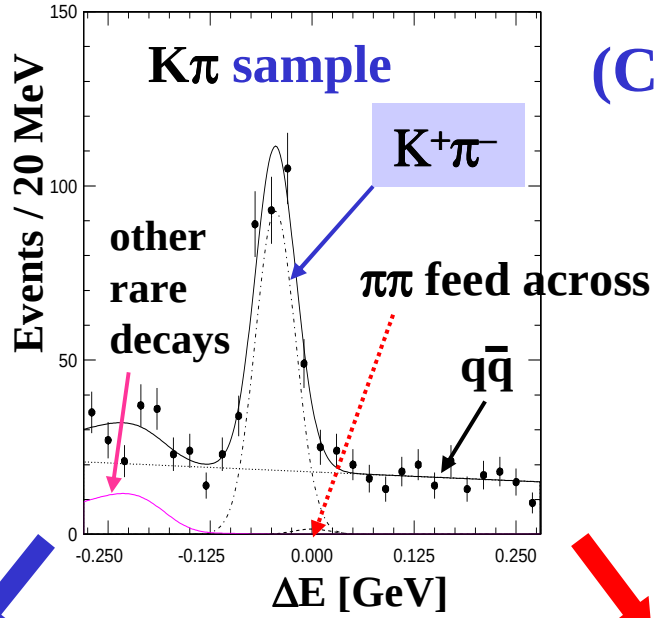
(Direct CPV)

$S_{\pi\pi} = -1.21\ ^{+0.38}_{-0.17}\ ^{+0.16}_{-0.13}$ (2.9 σ)

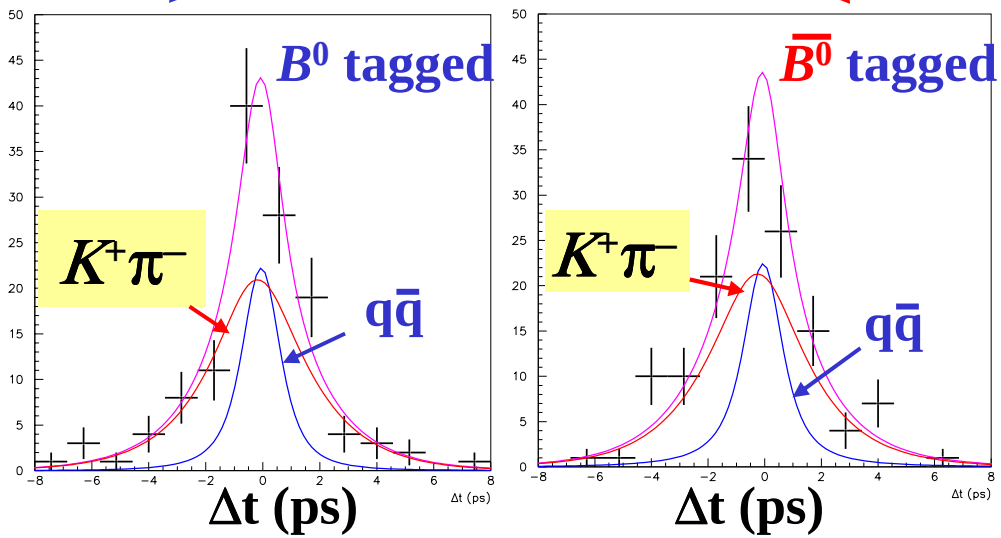
(stat.) (syst.)

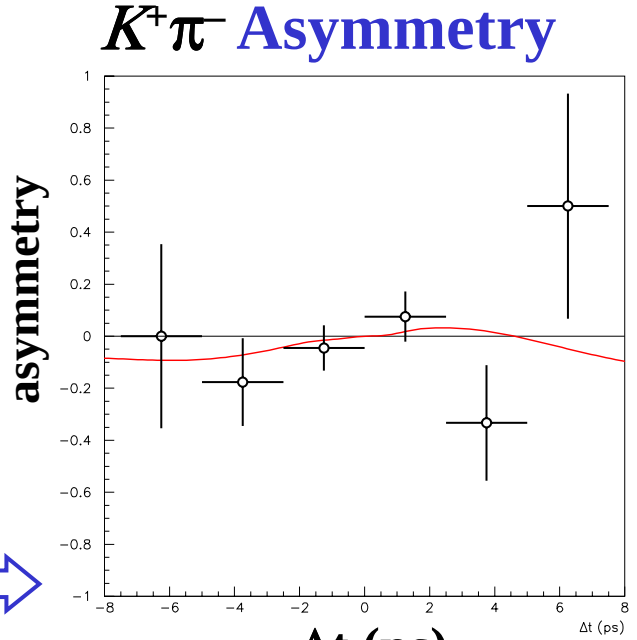


$B \to \pi^+\pi^-$: $B \to K^+\pi^-$ case



(Control Sample)



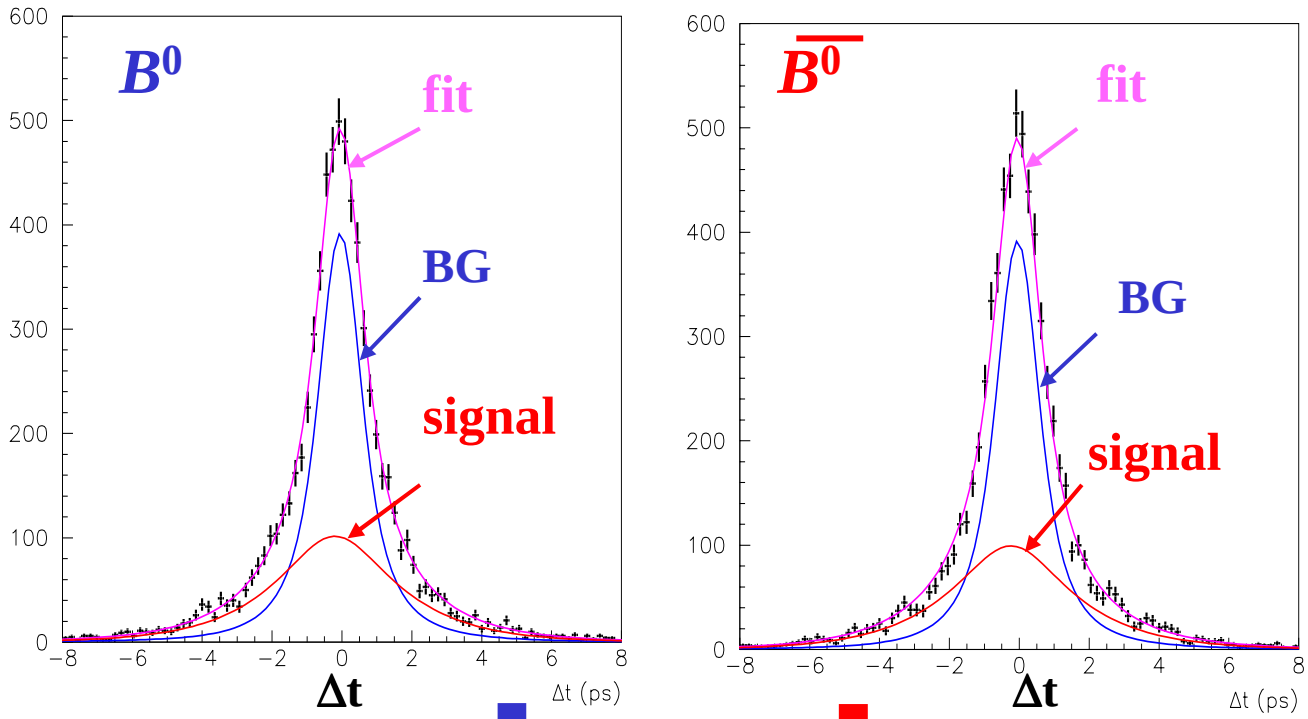


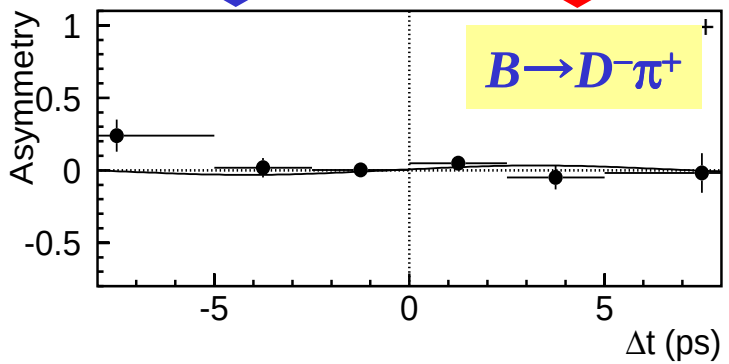
Null Asymmetry

$A_{K\pi} = 0.07 \pm 0.17$

$S_{K\pi} = 0.15 \pm 0.24$

$B \to \pi^+\pi^-$: $D^{(*)-}\pi^+/\rho^+$ Sample





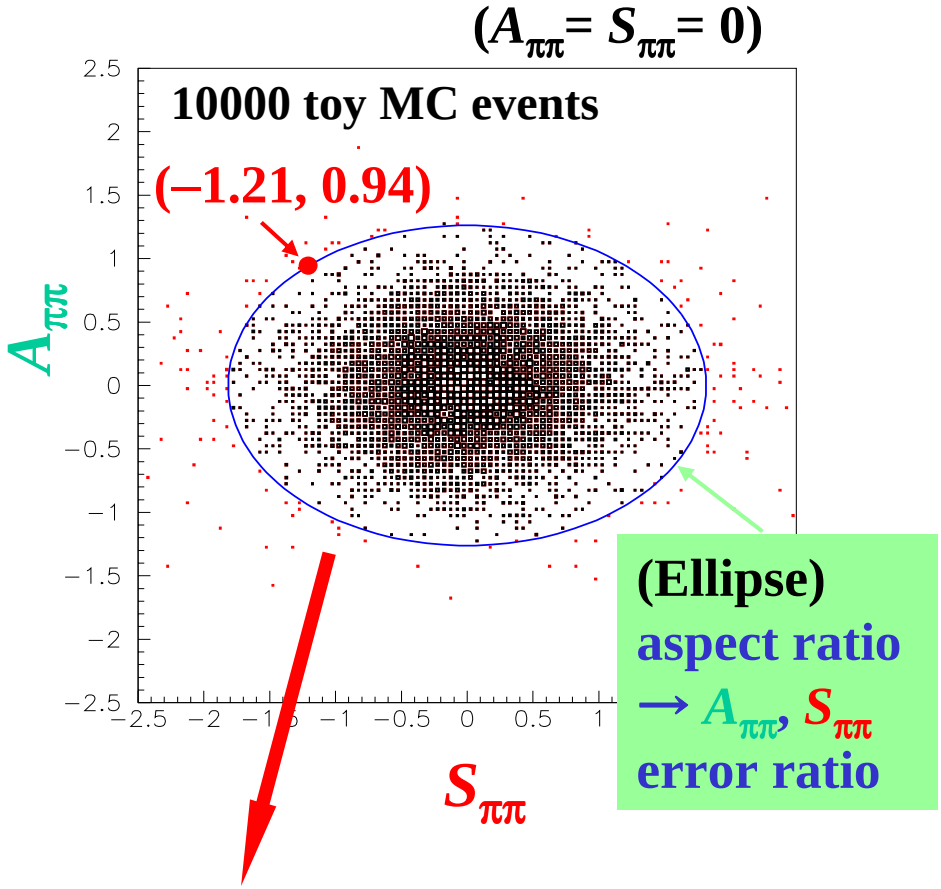
$A_{\pi\pi} = 0.03 \pm 0.04$

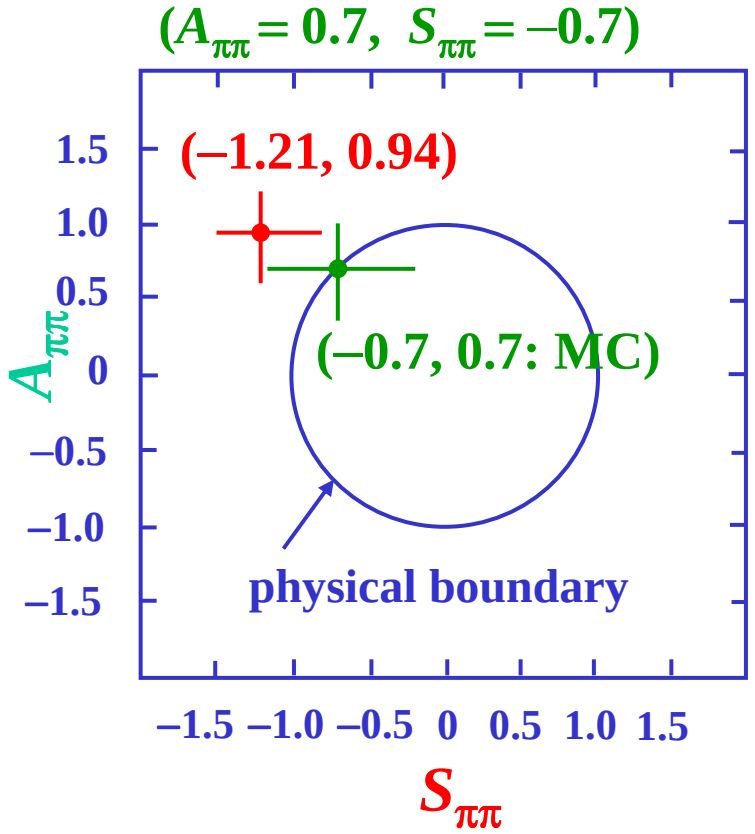
$S_{\pi\pi} = 0.08 \pm 0.06$

➡ **Null asymmetry**

$B \to \pi^+\pi^-$: Ensemble Test

Ensemble test (162 events toy MC)





	data	toy MC	prob (err)
$S_{\pi\pi}$	$-1.21^{+0.38}_{-0.27}$	$-0.70^{+0.52}_{-0.47}$	5.4%(+)
$A_{\pi\pi}$	$0.94^{+0.25}_{-0.32}$	$0.70^{+0.35}_{-0.31}$	23.6%(–)

$B \to \pi^+\pi^-$: Systematic Errors

	$S_{\pi\pi}$		$A_{\pi\pi}$	
Item	δS(-)	δS(+)	δA(-)	δA(+)
Resolution function	-0.012	+0.012	-0.008	+0.008
Physics	-0.039	+0.040	-0.007	+0.004
Background shape	-0.015	+0.015	-0.003	+0.004
Wrong tag	-0.068	+0.047	-0.050	+0.058
Background fraction	-0.088	+0.077	-0.042	+0.057
Vertexing	-0.038	+0.059	-0.030	+0.017
Fitting bias	-0.024	+0.110	-0.051	+0.030
Total	-0.128	+0.160	-0.089	+0.089

← w_l uncertainties

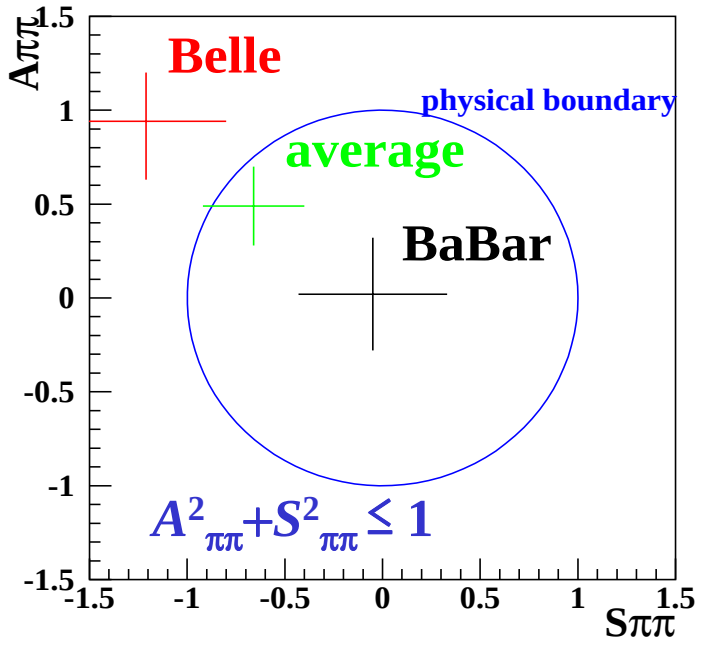
← ΔE: qq BG slopes

← SVD align., phys boundary

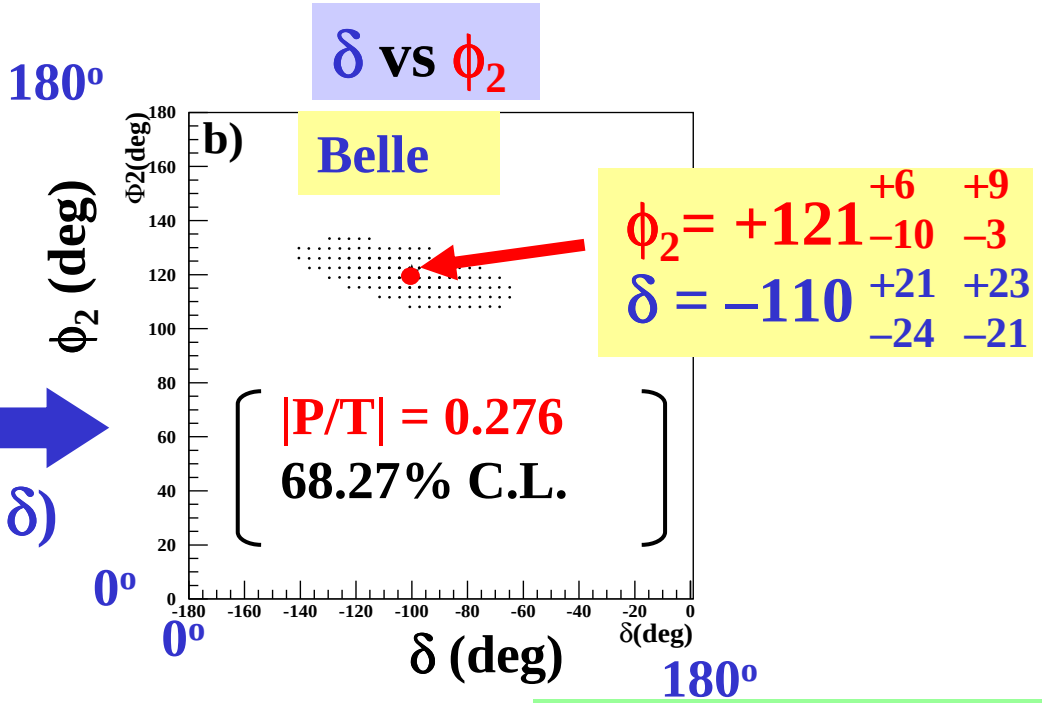
$B \to \pi^+\pi^-$: ϕ_2 interpretation

Belle vs BaBar

	Belle (42 fb^{-1})	BaBar [1] (55.6 fb^{-1})
$A_{\pi\pi}$	$+0.94^{+0.25}_{-0.31}$ (stat) ± 0.09 (sys)	$-0.02 \pm 0.29 \pm 0.07$
$S_{\pi\pi}$	$-1.21^{+0.38}_{-0.27}$ (stat) $^{+0.16}_{-0.13}$ (sys)	$-0.01 \pm 0.37 \pm 0.07$



(ϕ_2, δ)



Very Preliminary

[1] (BaBar Collaboration) hep-ex/0205082

Other CPV Physics

- $B \to \eta' K_S$ (or ϕK_S) : Time-dependent $\to \sin2(\phi_1+\delta)$ δ: correction
- $B \to D^{(*)+}D^{(*)-}$: Time-dependent $\to \sin2\phi_1$
- $B \to \rho\pi$: Time-dependent w/ Dalitz plot $\to \sin(2\phi_2+\delta)$ δ: strong phase
- $B \to K\pi, \pi\pi$: direct CPV (P–T) $\to \phi_3$

  ➡ P. Yeh, ``CPV in charmless hadron decays in B-mesons.”
- $B \to D_{CP}K^-$: direct CPV (C–T) $\to \phi_3$

  ➡ T. Matsumoto, ``CPV in DK decays in B-mesons.”
- $B \to D^{*+}\pi^-$: Time-dependent + angular analysis $\to \sin(2\phi_1+\phi_3)$

  ➡ S. Schrenk, ``Study on $\sin(2\phi_1+\phi_3)$ measurement.”
- ……

ϕ_1: $B \to \eta' K_S$

$B \to \eta' K_S$ (or ϕK_S) : Time-dependent Asymmetries

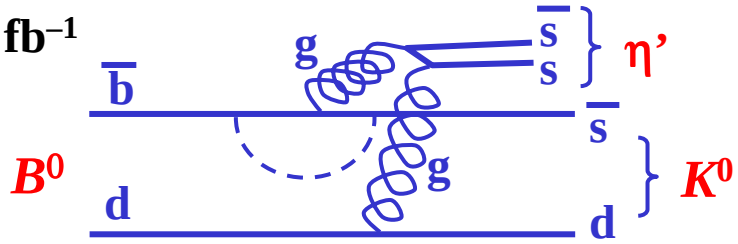
B_r (measure) > B_r (theory)

$\Rightarrow$ **New Physics?** $\Rightarrow$ Tree

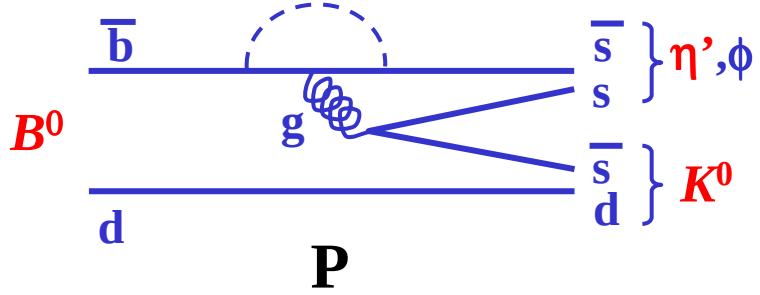
$B(B^0 \to \eta' K^0) = (55\ ^{+19}_{-16} \pm 8) \times 10^{-6}$ 10.4 fb^{-1}

$\sim 40 \times 10^{-6}$ (theory)

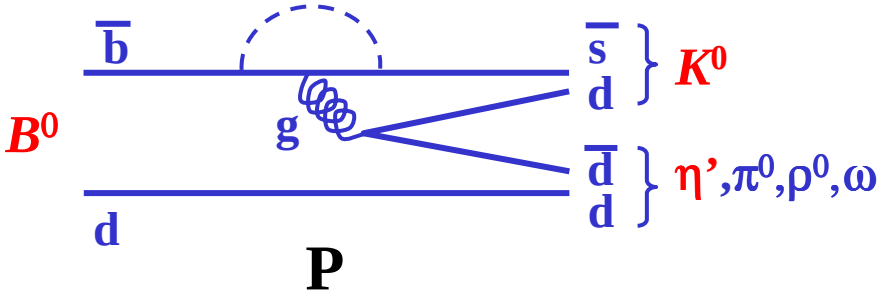
~~SU(3)~~, large SU(3) singlet P



P



P



P

$$A_{CP}(\Delta t) = \frac{N(\bar{B}(\Delta t) \to \eta' K_S) - N(B(\Delta t) \to \eta' K_S)}{N(\bar{B}(\Delta t) \to \eta' K_S) + N(B(\Delta t) \to \eta' K_S)}$$

$$= A_{\eta' Ks} \cos(\Delta m_d \Delta t) + S_{\eta' Ks} \sin(\Delta m_d \Delta t)$$

$$\approx \sin 2(\phi_1 + \delta) \sin(\Delta m_d \Delta t)$$

Preliminary

$\sin 2(\phi_1+\delta) = 0.30\ ^{+0.53}_{-0.54}$ (stat) ± 0.07(syst)

$S_{\eta' Ks} = 0.27\ ^{+0.54}_{-0.55}$ (stat) ± 0.07(syst)

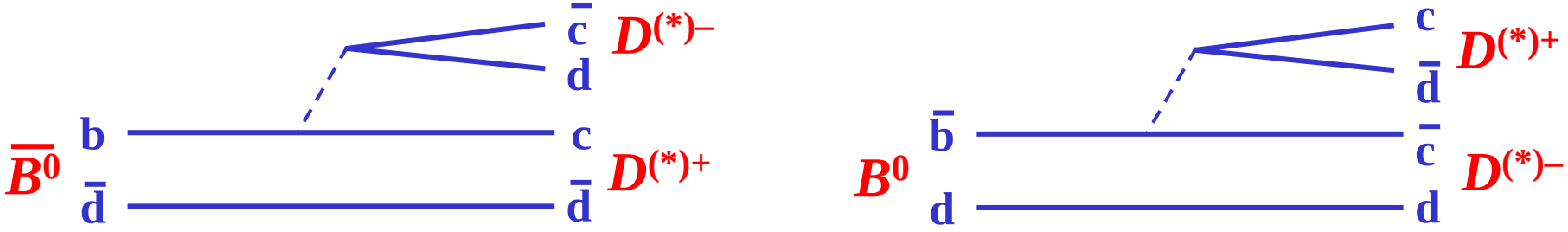
$A_{\eta' Ks} = 0.12 \pm 0.32$(stat) ± 0.07(syst)

42 fb^{-1}, 73 events

ϕ_1: $B \to D^{(*)+}D^{(*)-}$

Time-dependent Asymmetries → $\sin 2\phi_1$

→ similar to $J/\psi K_S$ (# of events ~ 1/50)



$$\lambda = \frac{q}{p}\frac{\bar{A}}{A}$$

mixing **no direct CPV**

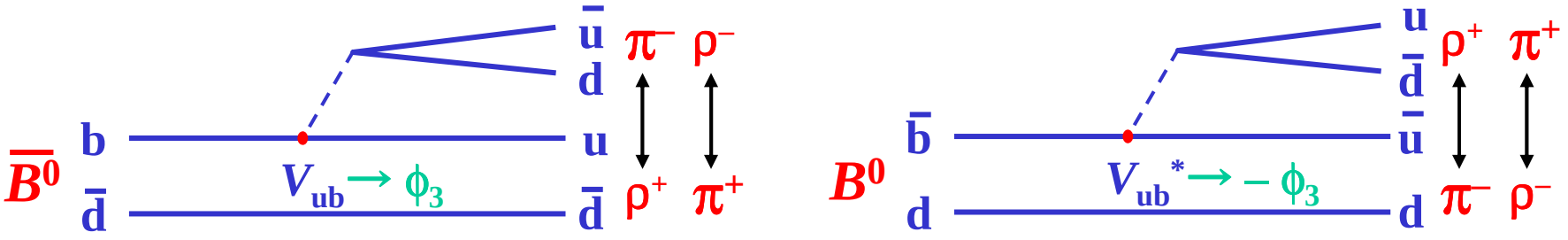
$e^{-2i\phi 1}$

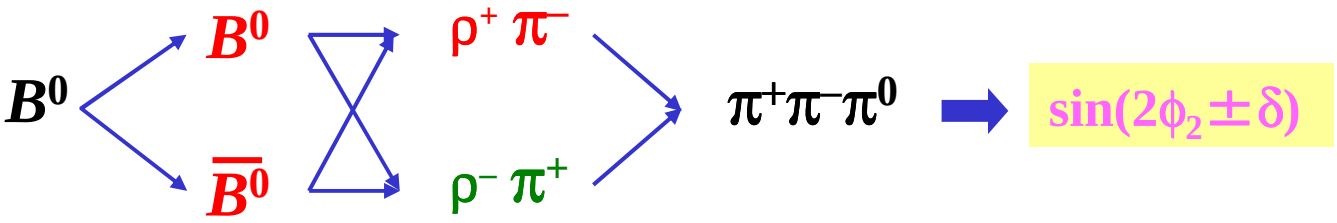
$\eta_{DD} = +1$ → $Im\ \lambda_{DD} = -\sin 2\phi_1$

$$N(B^0 \to D^{*+}D^{*-}) = 11.0\ ^{+4.1}_{-3.4}\ @\ 21.3\ fb^{-1}$$

ϕ_2: $B \to \rho\pi$

Time-dependent w/ Dalitz plot → $\sin(2\phi_2 \pm \delta)$ δ: strong phase





mixing **direct CPV** **strong phase shift**

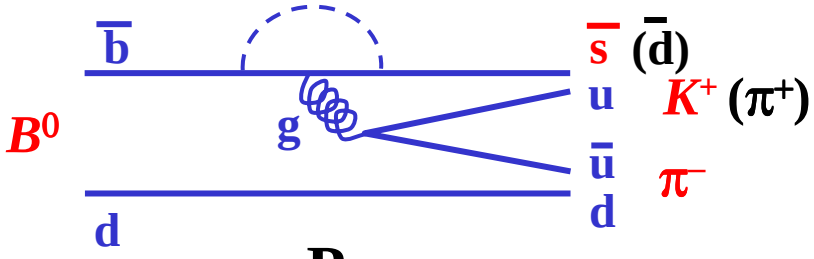
$e^{2i\phi 1}$ $e^{2i\phi 3}$ $e^{i\delta}$

Preliminary **29.4 fb^{-1}**

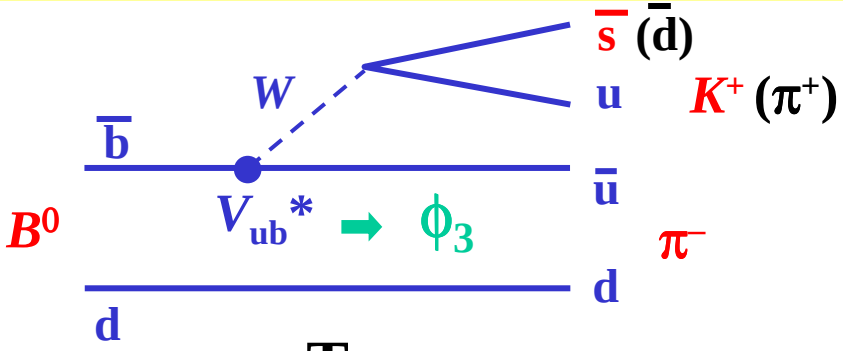
Mode	Yield	Br
$B^0 \to \rho^\pm\pi^\mp$	$47.5\ ^{+13.9}_{-13.3}$	$21.5\ ^{+6.3}_{-6.0} \times 10^{-6}$
$B^0 \to \rho^0\pi^0$	-4.1 ± 8.5	$< 5.3 \times 10^{-6}$

ϕ_3: $B \to K\pi, \pi\pi$

P. Yeh, ``CPV in charmless hadron decays in B-mesons.”



P



T

$$A_{CP}(f) = \frac{N(\bar{B} \to \bar{f}) - N(B \to f)}{N(\bar{B} \to \bar{f}) + N(B \to f)}$$

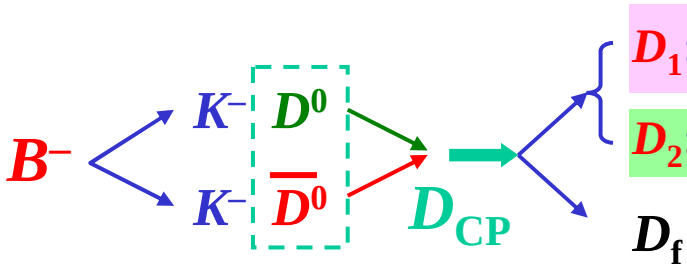
P – T inteference with re-scatterings

Mode	N($\bar{B}$)	N(B)	A_{CP}
$K^{\mp}\pi^{\pm}$	103 ± 12	115 ±14	– 0.06 ±0.08 ±0.01
$K^{\mp}\pi^{0}$	28 ± 8	30 ± 8	– 0.04 ±0.19 ±0.03
$K_S\pi^{\mp}$	49 ± 8	18 ± 6	0.46 ±0.15 ±0.02
$K_S\pi^{0}$	49 ± 8	18 ± 6	0.46 ±0.15 ±0.02
$\pi^{+}\pi^{-}$	15 ± 5	8 ± 4	0.41 ±0.40 ±
$\pi^{\mp}\pi^{0}$	24 ± 8	13 ± 7	0.31 ±0.31 ±0.05

29.1 fb^{-1}

ϕ_3: $B^- \to D_{CP} K^-$

➡ **T. Matsumoto, ``CPV in DK decays in B-mesons.”**

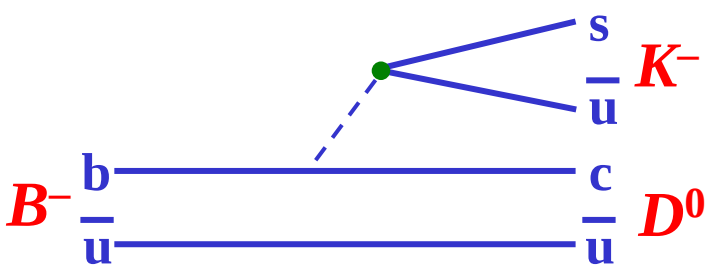


D_1: (CP= +1) = K^-K^+, $\pi^-\pi^+$

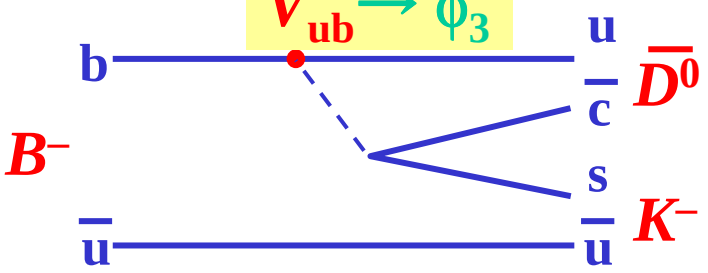
D_2: (CP= –1) = $K_S\pi^0$, ($K_S\omega$, $K_S\phi$, $K_S\eta$, $K_S\eta'$)

} **Flavor non specific**

$D_f = K^-\pi^+$ **Flavor specific**



$V_{ub} \to \phi_3$



Mode	N($B^- \to DK^-$)
$D^0 \to K^-\pi^+$	80.3 ±10.1
$D^0 \to K^-K^+$	11.5 ± 4.0
$D^0 \to \pi^-\pi^+$	6.0 ± 5.1
$D^0 \to K_S\pi^0$	6.7 ± 7.6

21 fb^{-1}

$$A_{CP} = \frac{B(B^- \to D_{CP}K^-) - B(B^+ \to D_{CP}K^+)}{B(B^- \to D_{CP}K^-) + B(B^+ \to D_{CP}K^+)}$$

Mode	A_{CP}
$B^\pm \to D_f K^\pm$	0.003 ± 0.089 ±0.037
$B^\pm \to D_1 K^\pm$	0.29± 0.26 ±0.05
$B^\pm \to D_2 K^\pm$	– 0.22±0.24 ±0.04

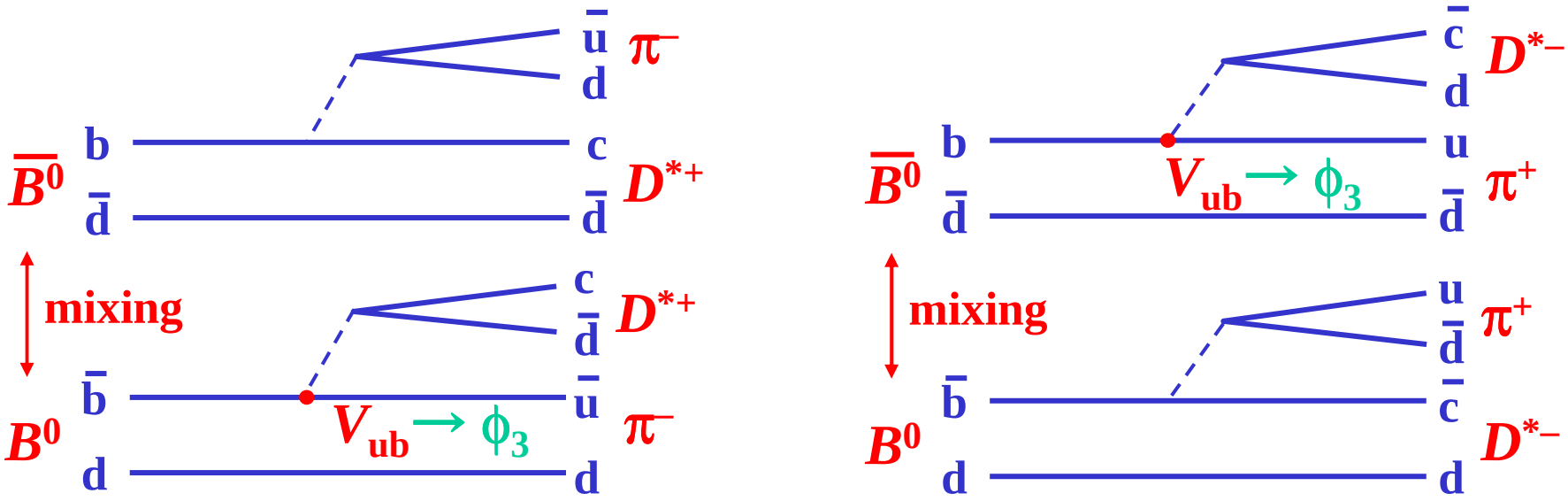
29.1 fb^{-1}

Preliminary

$2\phi_1 + \phi_3$: $B \to D^{*\pm}\pi^{\mp}$

➡ **S. Schrenk, ``Study on $\sin(2\phi_1+\phi_3)$ measurement."**

$B^0 \to D^{*\pm}\pi^{\mp}$: **Time-dependent & angular analysis**



$$\lambda = \left(\frac{q}{p}\right)\left(\frac{\bar{A}}{A}\right)$$

mixing

$e^{2i\phi 1}$ $e^{i\phi 3}e^{\pm i\delta}$ ➡ $r \sin(2\phi_1+\phi_3 \pm \delta)$ $r \sim 0.02$

Summary

KEKB/Belle luminosities $L_{peak} = 7.3 \times 10^{33}\ cm^{-2}s^{-1}$, $L_{int} \sim 82\ fb^{-1}$

$\sin 2\phi_1$: $(c\bar{c})K^0$ $\sin 2\phi_1 = +0.82 \pm 0.12\ (stat) \pm 0.05\ (syst)$ @ 42 fb^{-1}

1550 events

Preliminary

$\sin 2\phi_2^{eff}$: $B^0(t) \to \pi^+\pi^-$ $A_{CP} = S_{\pi\pi}\sin(\Delta m_d \Delta t) + A_{\pi\pi}\cos(\Delta m_d \Delta t)$

73.5±13.8 events

$S_{\pi\pi}(\approx \sin 2\phi_2^{eff}) = -1.21\ ^{+0.38\ +0.16}_{-0.17\ -0.13}$

$A_{\pi\pi} = +0.94\ ^{+0.25}_{-0.31} \pm 0.09$ (2.9 σ) @ 42 fb^{-1}

$\phi_2 = +121\ ^{+6}_{-10}(stat)\ ^{+9}_{-3}(sys)$

$\delta = -110\ ^{+21}_{-24}(stat)\ ^{+23}_{-21}(sys)$

Very Preliminary

(expected # of events by summer 2002 (90 fb^{-1}))

	Time dependent asymmetry	Non time dependent asymmetry
ϕ_1	$J/\psi K^0$(3000), $\eta' Ks$(500), ϕKs(30), $D^{(*)+}D^{(*)-}$(90)	
ϕ_2	$\pi^+\pi^-$(150), $\rho^{+/-}\pi^{-/+}$(150)	
ϕ_3	$D^{*+/-}\pi^{-/+}$	$K\pi$(300), $\pi\pi$(150), $D_{CP}K^-$(30)

→ w/ KEKB L ↑ ϕ_1, ϕ_2, ϕ_3 → coming soon!