



3. Flavor Tagging

Inclusive reconstruction of flavor-specific B decays

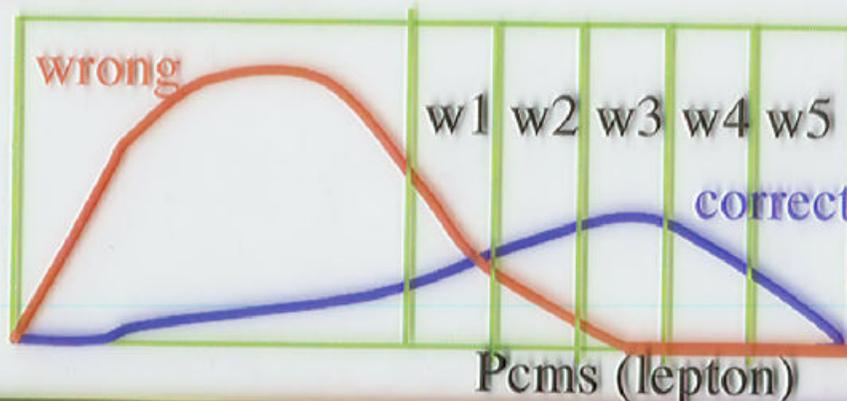
($b \rightarrow c \ell \nu$, $c \rightarrow s \ell \nu$, $b \rightarrow c \rightarrow \bar{K} X$, $b \rightarrow D^{(*)} \pi X$, $D^{*} \rightarrow D \pi$)

$$A(\Delta t) \equiv \frac{\Gamma(\bar{B}_d^0 \rightarrow f_{CP}) - \Gamma(B_d^0 \rightarrow f_{CP})}{\Gamma(\bar{B}_d^0 \rightarrow f_{CP}) + \Gamma(B_d^0 \rightarrow f_{CP})} = -\xi_f \sin 2\phi_1 \sin \Delta m_d \Delta t,$$

Flavor tagging

$A(\Delta t)$ diluted to $(1-2w) A(\Delta t)$
(w : wrong tagging fraction)

Ideally, w should be determined as precise as possible on the event-by-event basis.





Multi-dimensional Likelihood approach

- Simple, easy to understand, but efficient
- Input tagging discriminants form multi-dimensional space which is divided into many cells.
- For each cell, tagging dilution factor, r , is assigned with Monte Carlo. This is used to categorize events into 6 different regions of r . The wrong tagging fraction w in each region, used in the CP fit, is obtained using data.

$$q \cdot r \equiv \frac{N(B^0) - N(\bar{B}^0)}{N(B^0) + N(\bar{B}^0)}, \quad q = +1 \text{ for } B^0, -1 \text{ for } \bar{B}^0$$

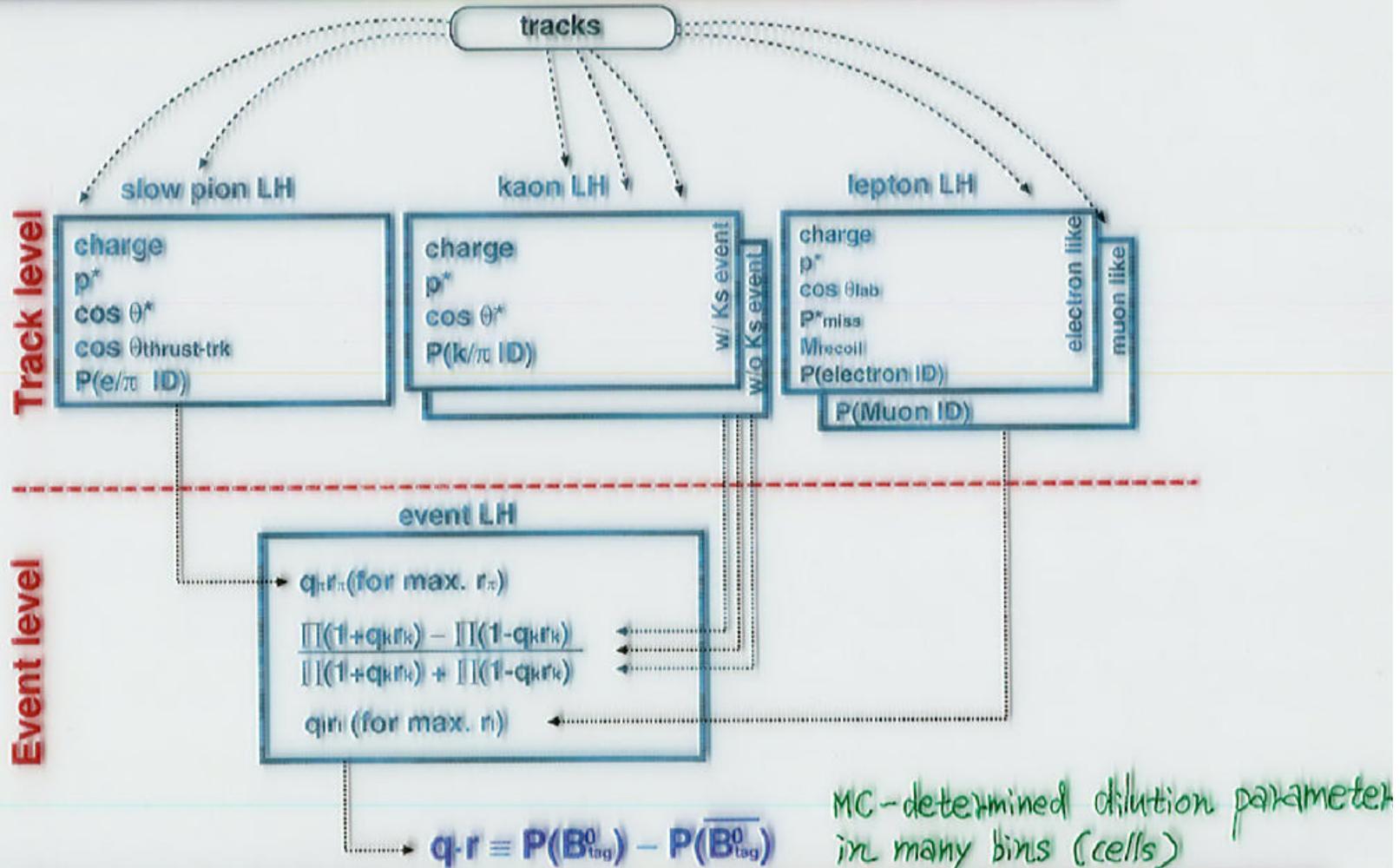
(q is the b-flavor)

} on the tag-side B

Checking agreement between data and MC in r distribution, as well as $\langle r \rangle = (1-2w)$ is a good validation for this method.

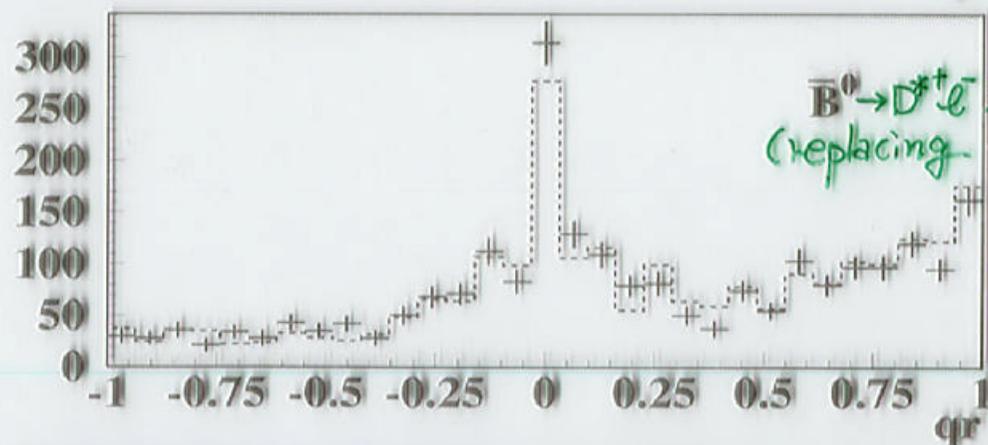
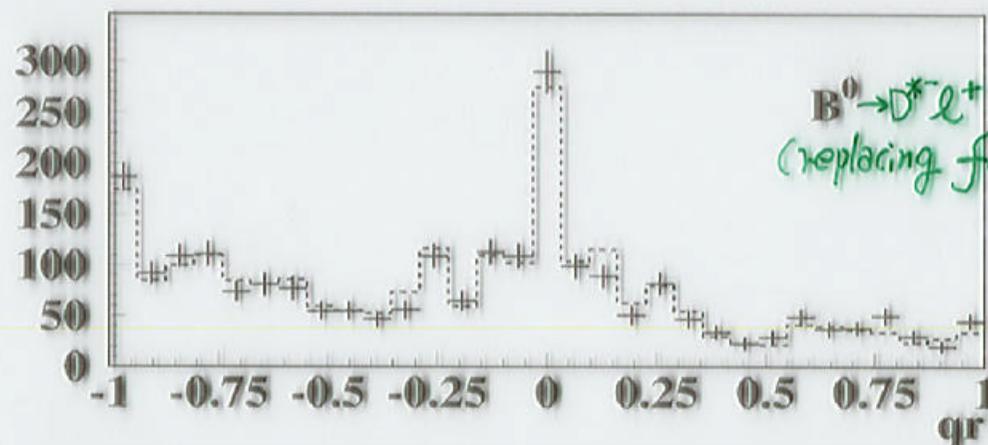


Multi-dimensional flavor likelihood





$q \cdot r$ distribution



Good agreement



Estimation of wrong tag fraction w

TABLE I. Experimentally determined event fractions (f_i) and incorrect flavor assignment probabilities (w_i) for each τ interval.

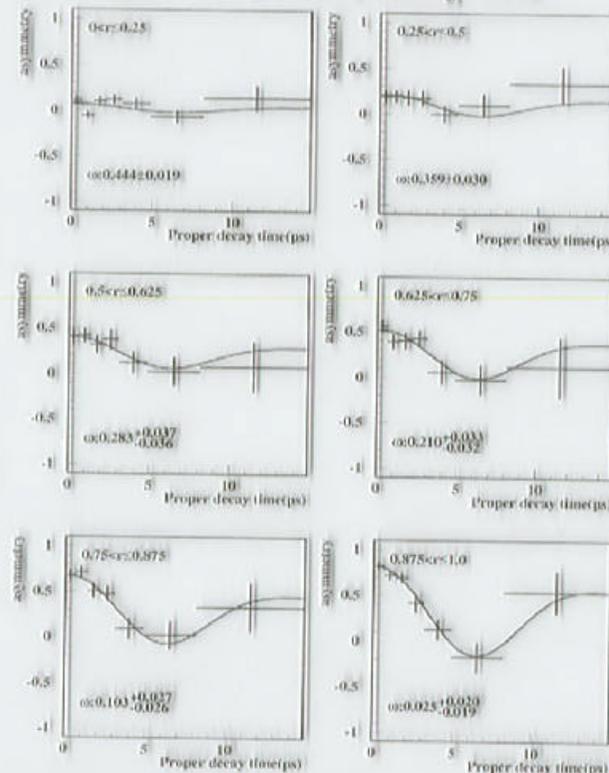
l	τ	f_i	w_i
1	0.000 – 0.250	0.393 ± 0.014	$0.470^{+0.031}_{-0.035}$
2	0.250 – 0.500	0.154 ± 0.007	$0.336^{+0.039}_{-0.042}$
3	0.500 – 0.625	0.092 ± 0.005	$0.286^{+0.037}_{-0.035}$
4	0.625 – 0.750	0.100 ± 0.005	$0.210^{+0.033}_{-0.031}$
5	0.750 – 0.875	0.121 ± 0.006	$0.098^{+0.028}_{-0.026}$
6	0.875 – 1.000	0.134 ± 0.006	$0.020^{+0.023}_{-0.019}$

Tagging probability = **99.4%** \rightarrow *No event lost*
 (99.3% in MC)

Total effective efficiency
 = **27.0^{+2.1}_{-2.2}** (%)
 (27.4% in MC)

Reasonable agreement

w from diluted $B\bar{B}$ oscillation
 $(1-2w)\cos(\Delta m_d \Delta t)$





4. Proper Decay Time and CP Fit



Belle SVD

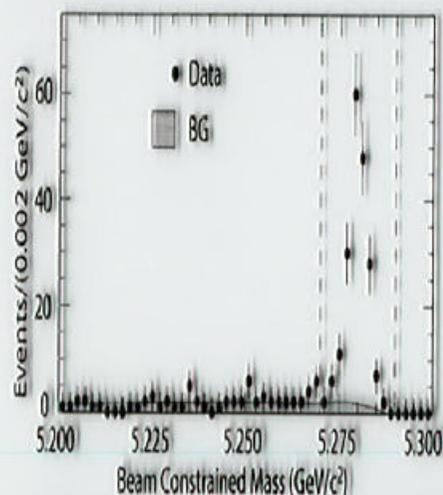


– the core of unbinned maximum likelihood fit –
Probability Density Function (PDF)

$$f(\Delta t; \sin 2\phi_1) = e^{-\frac{|\Delta t|}{\tau_B}} \left(1 - \sin 2\phi_1 \sin x_d \frac{\Delta t}{\tau_B} \right)$$

$$PDF = \int (1 - f_{BG}) f(t') R(t' - \Delta t) dt' + f_{BG} PDF_{BG}(\Delta t)$$

Background fraction
 2D fit in ΔE vs. M_{bc} plane

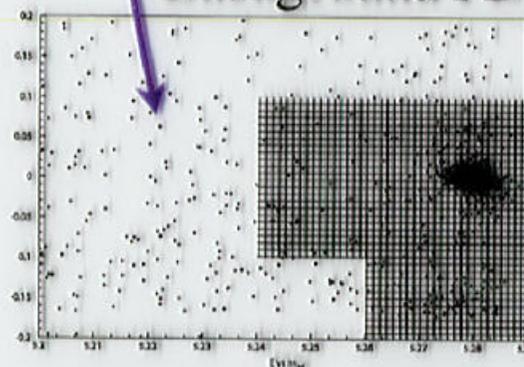


Resolution function

From the study of
 D^* decay, $D^* \rightarrow \nu$ (data)
 as well as MC info

See next slide

Background PDF



→ Grand sideband of
 $J/\psi K_S$ and $J/\psi K^+$
 combined (210 events)



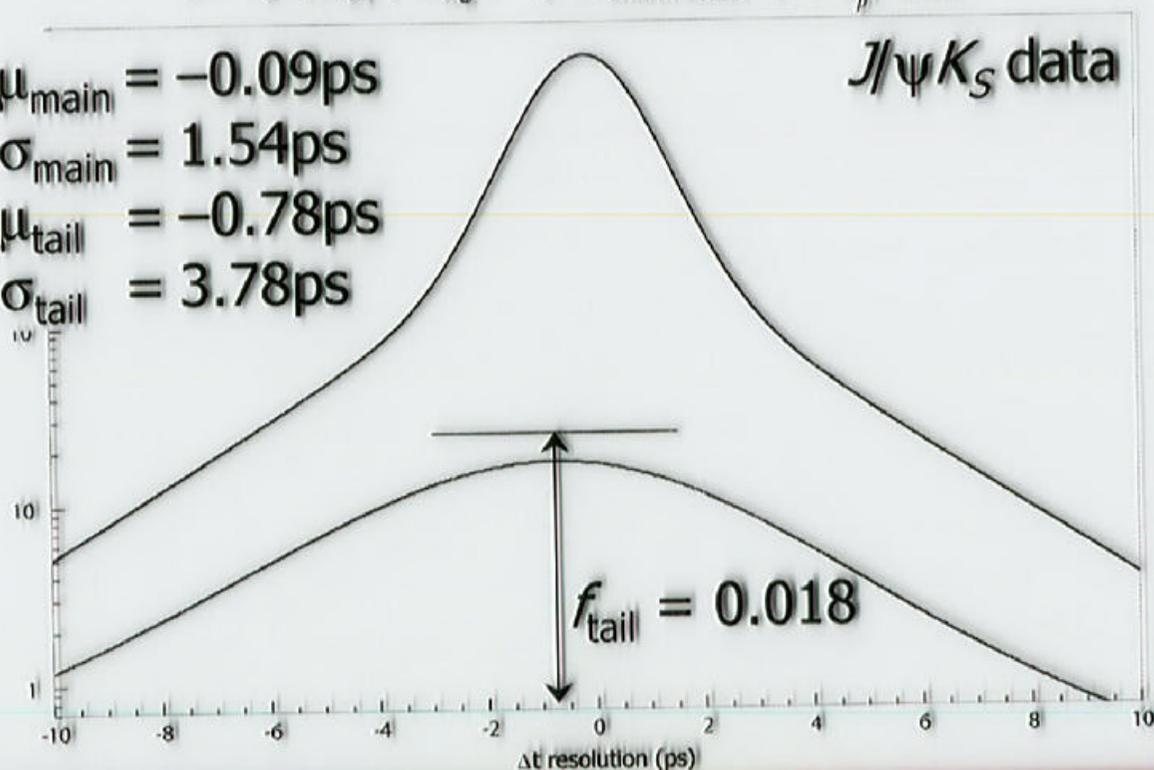
Resolution function

$$R = (1 - f^{\text{tail}})G(\Delta t; \mu^{\text{main}}, \sigma^{\text{main}}) + f^{\text{tail}}G(\Delta t; \mu^{\text{tail}}, \sigma^{\text{tail}})$$

$$\mu = m_0 + m_1 \sigma'_{\text{tag}}$$

$$\sigma = f(\sigma_{CP}, \sigma_{\text{tag}}; \text{par}_{\text{charm effect}}, \text{par}_{B_{\rho,T} \text{ effect}})$$

$\mu_{\text{main}} = -0.09\text{ps}$
 $\sigma_{\text{main}} = 1.54\text{ps}$
 $\mu_{\text{tail}} = -0.78\text{ps}$
 $\sigma_{\text{tail}} = 3.78\text{ps}$

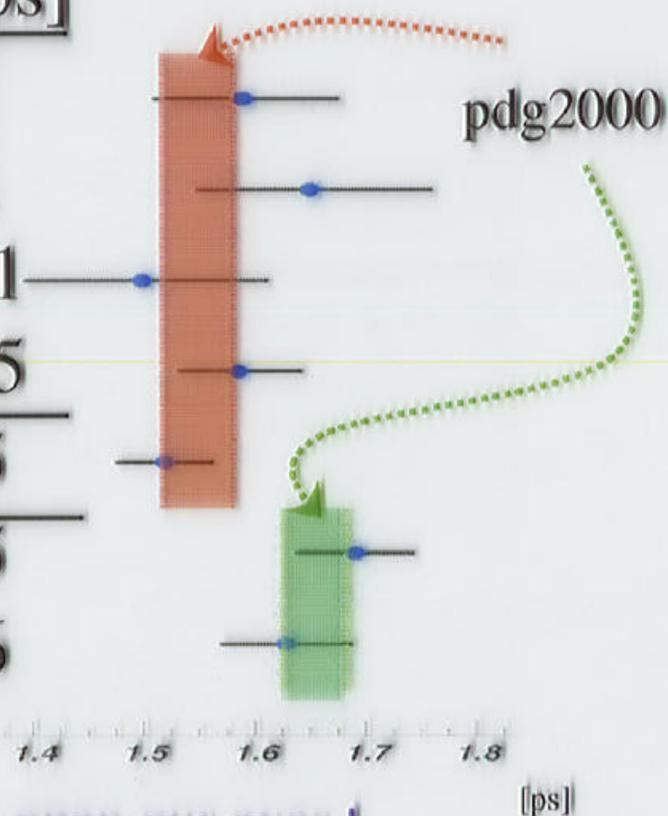




Validation : B lifetime

→ B lifetime and Mixing by N. Hastings for detail (Session 22-I)

mode	lifetime [ps]
$B^0 \rightarrow D^+\pi^-$	$1.59^{+0.09}_{-0.08}$
$D^{*+}\pi^-$	$1.65^{+0.11}_{-0.10}$
$D^{*+}\rho^-$	1.50 ± 0.11
Combined	1.59 ± 0.05
$D^{*+}l\nu$	1.52 ± 0.05
<hr/>	
$B^- \rightarrow D^0\pi^-$	1.68 ± 0.05
$D^{*0}l\nu$	1.63 ± 0.06



Everything is set. Now let's open our eyes !



CP fit: $\sin 2\phi_1$ in subsamples

CP all $0.58^{+0.32}_{-0.34}$ (stat only)

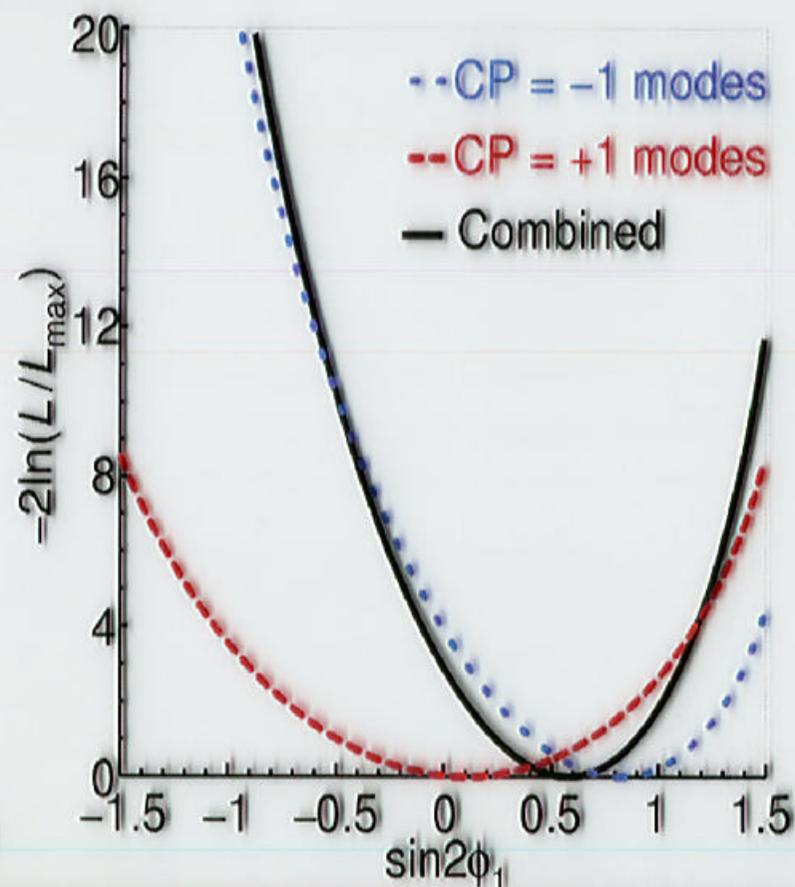
CP = -1 $0.82^{+0.36}_{-0.41}$

CP = +1 $0.10^{+0.57}_{-0.60}$

J/ ψ K_S($\pi^+\pi^-$) $1.21^{+0.40}_{-0.47}$

J/ ψ K_L $-0.04^{+0.60}_{-0.60}$

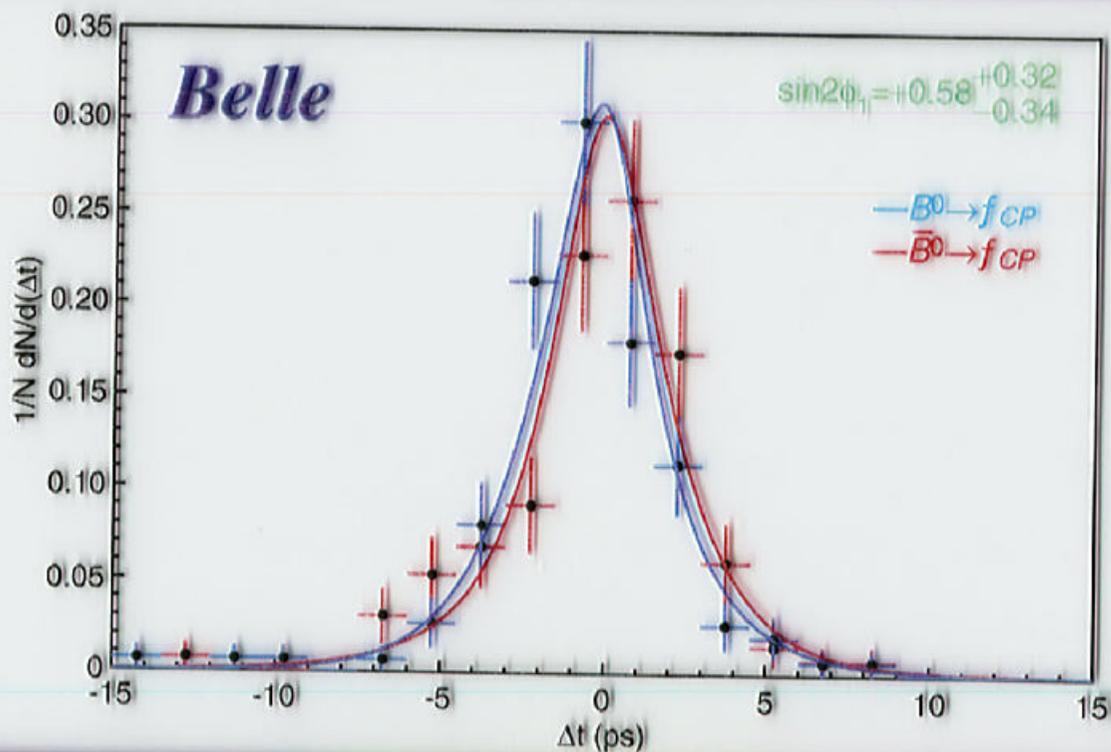
Non-CP 0.065 ± 0.075
($D^{(*)}\pi^+$, $D^*\rho^+$, J/ ψ K^{*0}(K π), D^*/ν , J/ ψ K⁺)





CP fit : Combined Result

$$\sin 2\phi_1 = 0.58 \begin{matrix} +0.32 \\ -0.34 \end{matrix} (\text{stat}) \begin{matrix} +0.09 \\ -0.10 \end{matrix} (\text{syst})$$



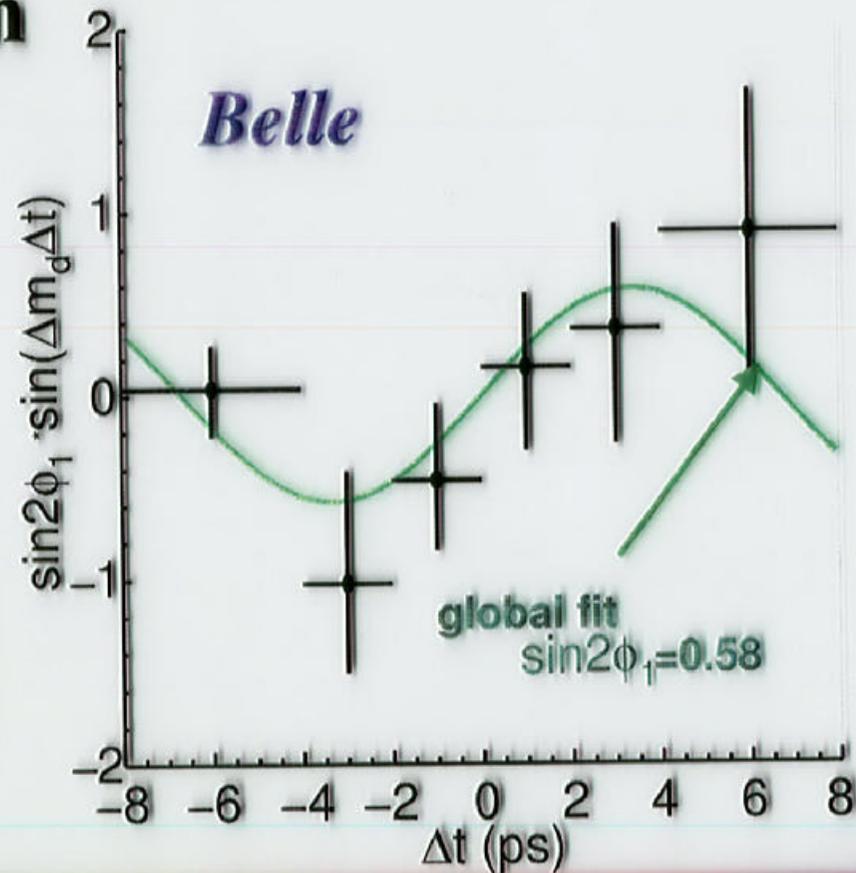


CP fit: Consistency Check

Fit in each Δt region

Each data point represents
 $\sin 2\phi_1 \times \overline{\sin(\Delta m_d \Delta t)}$

**Rather clear
 $\sin(\Delta m_d \Delta t)$ dependence
is seen !**





CP fit : Systematic Error

Flavor tagging	-0.07	+0.05
Physics parameters	-0.04	+0.03
Background Fraction except K_L	-0.02	+0.03
Background Fraction for K_L	-0.05	+0.05
Background Shape	-0.01	+0.01
Resolution Function	-0.01	+0.01
IP measurement	-0.01	+0.02
Total	-0.10	+0.09



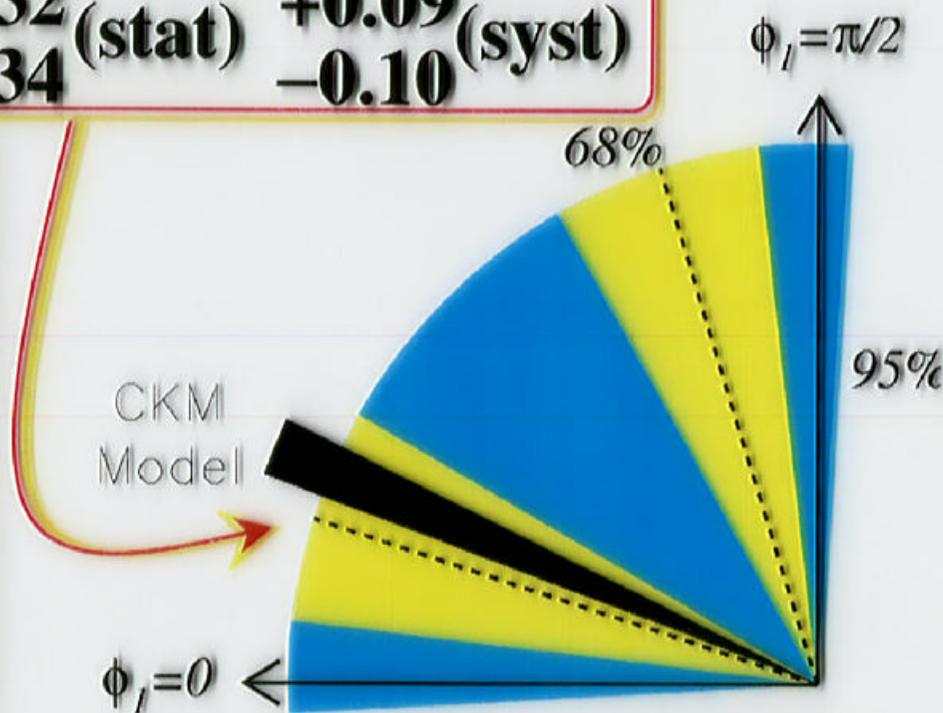
CP fit : Significance

$$\sin 2\phi_1 = 0.58^{+0.32}_{-0.34}(\text{stat}) \quad +0.09_{-0.10}(\text{syst})$$

1) Probability of observing $\sin 2\phi_1 > 0.58$ if CP is conserved is

4.9%.

Poster presentation by Dr. D. J. Jackson for more information !



2) Feldman-Cousins confidence interval



5. Conclusion

- Belle/KEKB operation in 2000 was a great success.
- From 282 flavor-tagged CP modes with decay vertex, the CP violation parameter $\sin 2\phi_1$ is measured to be

$$\sin 2\phi_1 = 0.58 \begin{matrix} +0.32 \\ -0.34 \end{matrix} (\text{stat}) \begin{matrix} +0.09 \\ -0.10 \end{matrix} (\text{syst})$$

- Belle/KEKB will continue taking more data. A decisive measurement will be available in the near future !