Results from B Factories II

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CKM: V_{ub} measurements

D^0 mixing

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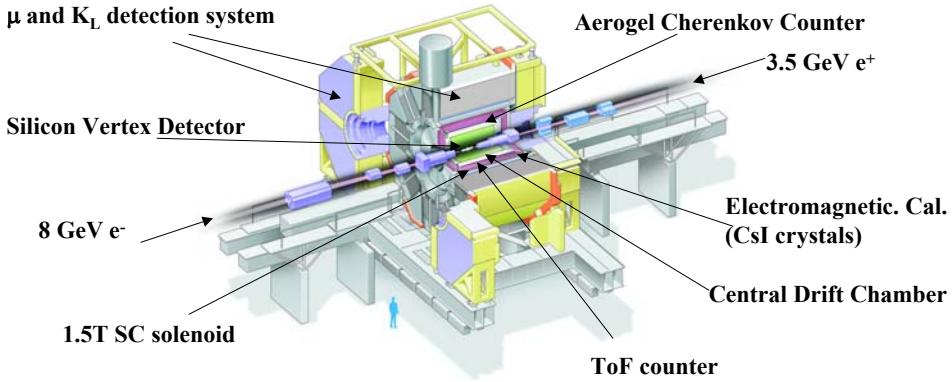
Summary

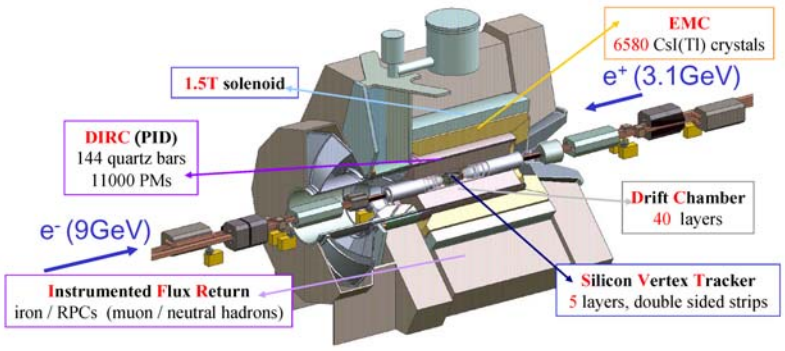
(Only a very modest part of the harvest at B factories.)

Belle spectrometer at KEK-B



Accumulated luminosity: 258 fb^{-1}.

BaBar spectrometer at PEP-II



Accumulated luminosity: 221 fb^{-1}.

CKM matrix measurements

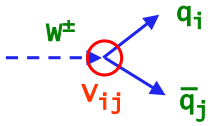
BaBar & Belle main task: CP violation in the system of B mesons

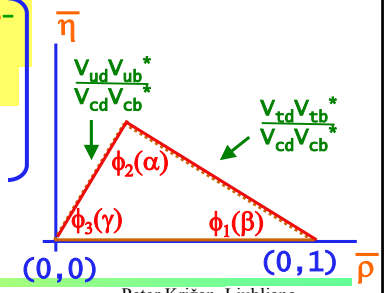
specifically: various measurements of complex elements of Cabbibo-Kobayashi-Maskawa matrix

CKM matrix is unitary

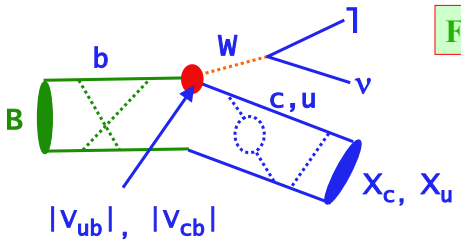
deviations could signal processes not included in SM

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\bar{\rho}-i\bar{\eta}) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\bar{\rho}-i\bar{\eta}) & -A\lambda^2 & 1 \end{pmatrix}$$

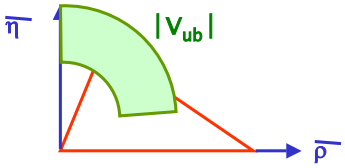




$|V_{ub}|$ measurements



From semileptonic B decays



$|V_{cb}|$ known to ~1.4%, becoming as precise as $|V_{us}|$=l (~1%)

need to pin-down $|V_{ub}|$, present world average ~10%

b→clν background typically order of magnitude larger.

Inclusive $|V_{ub}|$ measurement

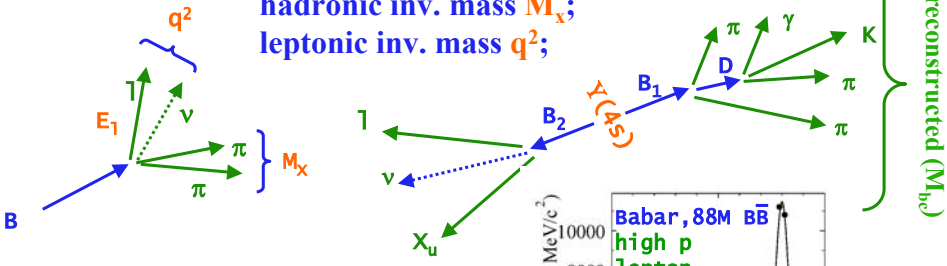
Traditional inclusive method: use semileptonic decays, fight the background from b→clν decays by using only events with electron momentum above the b→clν kinematic limit. Problem: extrapolation to the full phase space→ large theoretical uncertainty.

New: fully reconstruct one of the B mesons, check the properties of the other (semileptonic decay, low mass of the hadronic system)

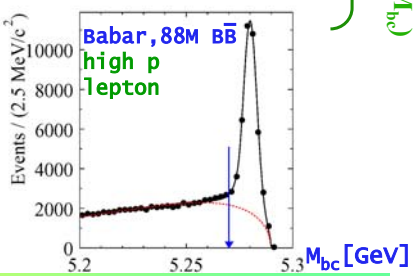
- Very good signal to noise
- Low yield (full reco efficiency is 0.3-0.4%)

$|V_{ub}|$ measurement

Variables separating b → ulν from b → clν:
lepton energy E_l;
hadronic inv. mass M_x;
leptonic inv. mass q^2;

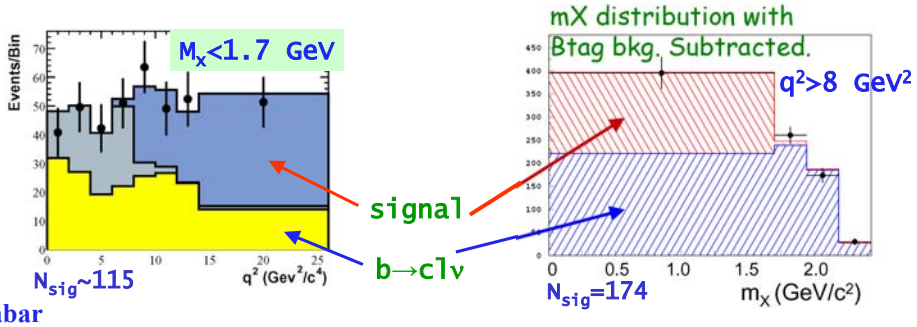


Full reconstruction
Belle: $B \to D^{(*)-}\ \pi^+/\rho^+/a_1^+/D_s^{(*)+}$
ε ~0.25%
BaBar: $B \to D^{(*)-}\ n_1\pi\ n_2K$ …
ε ~0.4%



Inclusive $|V_{ub}|$ measurement

Extract signal in high q^2 low M_x region (reduce theo. error):



Babar

$$|V_{ub}| = (4.98 \pm 0.40 \pm 0.39 \pm 0.47)\times10^{-3}$$

(stat.) (syst.) (th.)

Belle

$$|V_{ub}| = (5.54 \pm 0.42 \pm 0.50 \pm 0.55)\times10^{-3}$$

D^0 mixing in $D^0\to K\pi$ and $Kl\nu$ decays

The method: search for D mixing in the decay sequence: $D^{*+}\to D^0\pi^+$, $D^0\to$flavour specific final state.

Semileptonic decay:

- $K^- e^+ \nu$: no mixing (RS, Right Sign)
- $K^+ e^- \nu$: mixing (WS, Wrong Sign)

→ measure WS rate

Hadronic decay:

- $K^- \pi^+$: no mixing
- $K^+ \pi^-$: mixing **or** doubly Cabbibo suppressed (DCSD)

→ measure WS time evolution

D^0 mixing in $D^0 \to K\pi$ decays

$D^0 \to K\pi$ time evolution

$$dN/dt \propto \{R_D + R_D^{1/2}\, y'\, t + (x'^2 + y'^2)\ t^2/4\}\ e^{-t}$$

interference mixing

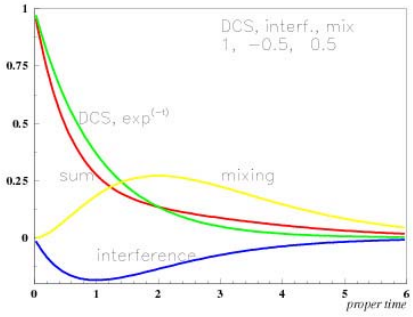
$x' = x \cos\delta + y \sin\delta$

$y' = y \cos\delta - x \sin\delta$

$x = \Delta M/\Gamma \quad y = \Delta\Gamma/2\Gamma$

δ= strong phase difference

SM: $x < 10^{-3}$, $y < 10^{-3}$ (long dist. effects);
new physics: x>>y, CPV

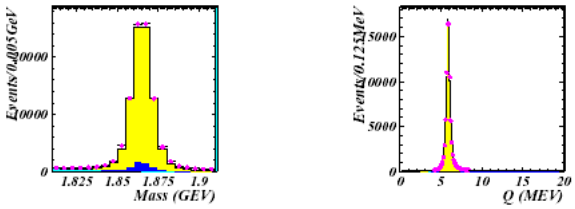


D^0 mixing in $D^0 \to K\pi$ decays

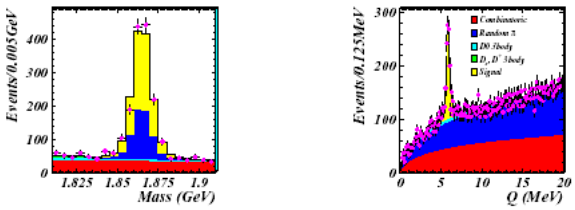
Signal extraction

$M = M(K,\pi)$ $Q = M(K^+,\pi^-,\pi_{slow}) - M(K^+,\pi^-) - M_\pi$

Right-Sign



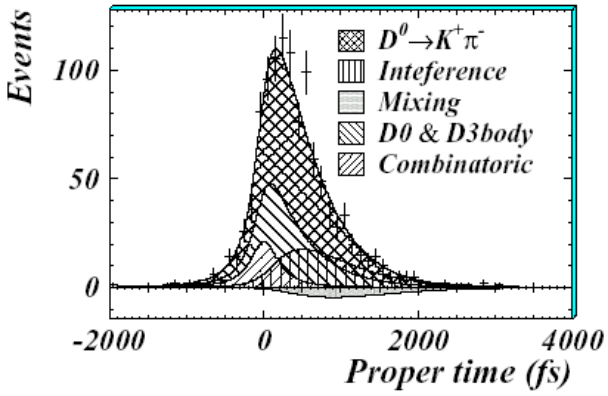
Wrong-Sign



D^0 mixing in $D^0 \to K\pi$ decays

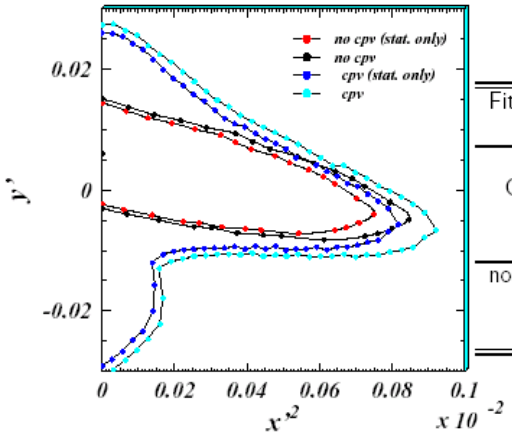
Free fit
$R_D = (0.287 \pm 0.037)\%$,
$y' = (2.54^{+1.11}_{-1.02})\%$,
$x'^2 = -(0.153^{+0.08}_{-0.10})\%$

Physical region
$R = (0.343^{+0.027}_{-0.026})\%$,
$y' = (0.60 \pm 0.33)\%$,
$x'^2 = 0\%$



D^0 mixing in $D^0 \to K\pi$ decays

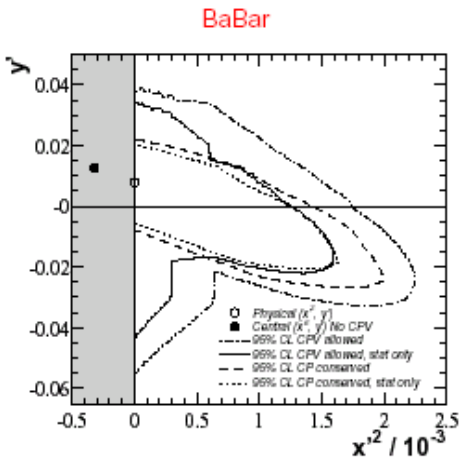
Results: 95% contour in x'^2 and y' plane (with 90 fb^{-1})



Fit case	Parameter	95% C.L. interval ($\times 10^{-3}$)
CPV	A_D	$-250 < A_D < 110$
	A_M	$-991 < A_M < 1000$
	x'^2	$x'^2 < 0.89$
	y'	$-30 < y' < 27$
no CPV	x'^2	$x'^2 < 0.81$
	y'	$-8.2 < y' < 16$
	R_D	$2.7 < R_D < 4.0$

D^0 mixing in $D^0 \to K\pi$ decays

Results: 95% contour in x'^2 and y' plane (with 57.1 fb^{-1})



D^0 mixing in $D^0 \to Ke\nu$ decays

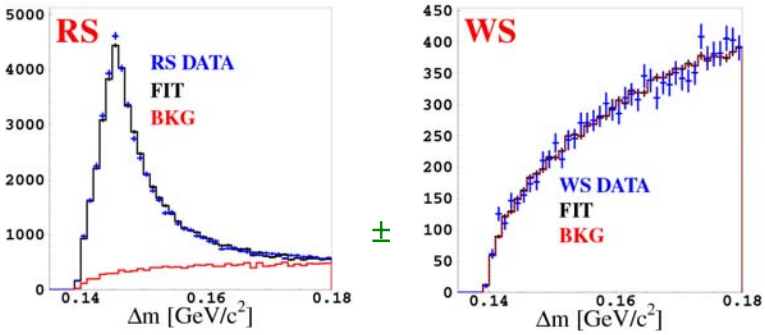
Selection criteria:

- **c.m.s. momentum of the Ke system > 2 GeV (bb, comb. backgr.)**
- **Invariant mass of e^-e^+ ($e^+ \to \pi^+$) > 0.15GeV (γ conversions)**
- **Cut on decay time (backgrounds $\delta(t) + e^{-t}$, signal $t^2 e^{-t}$)**

Neutrino reconstruction: hermiticity of the spectrometer, kinematic constraints.

Main observable: $\Delta m = m(\pi_s Ke\nu) - m(Ke\nu)$

D^0 mixing in $D^0 \to K e \nu$ decays



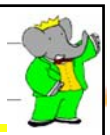
$N_{RS} = 40198 \pm 329$ $N_{WS} = 19 \pm 67$

$r_D = (N_{WS}/ N_{RS})\ (\varepsilon_{RS}/\varepsilon_{WS}) = (0.20 \pm 0.70)\ 10^{-3}$

$r_D < 1.4\ 10^{-3}$ (90% conf. level)

$r_D = (x^2 + y^2)/2$

D^0 mixing in $D^0 \to K e \nu$ decays



BaBar: employs neural net techniques to reconstruct the D^0 momentum vector (including again the neutrino), and to reject background events.

Yield: fit to Δm, t distributions.

$N_{RS} = 49620 \pm 265$ $N_{WS} = 114 \pm 61$

$r_D = (2.3 \pm 1.2(\text{stat}))\ 10^{-3}$

$r_D < 4.2\ 10^{-3}$ (90% conf. level)

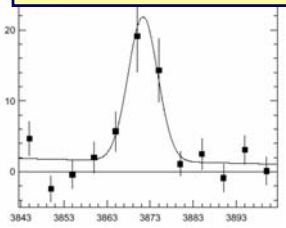
Hadron spectroscopy – X(3872)

Belle observed a new state decaying into J/ψ $\pi^+\pi^-$

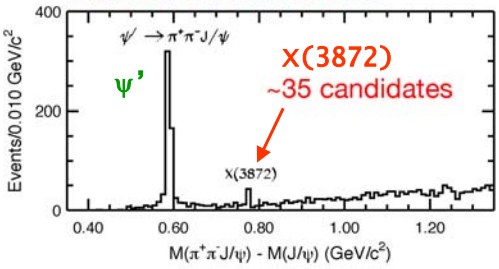
$B^+ \to K^+ X(3872)$

35±7 events
M=3872.0±0.8 MeV
Γ<2.3MeV (90%)

ψ $\pi^+\pi^-$
l^+l^-



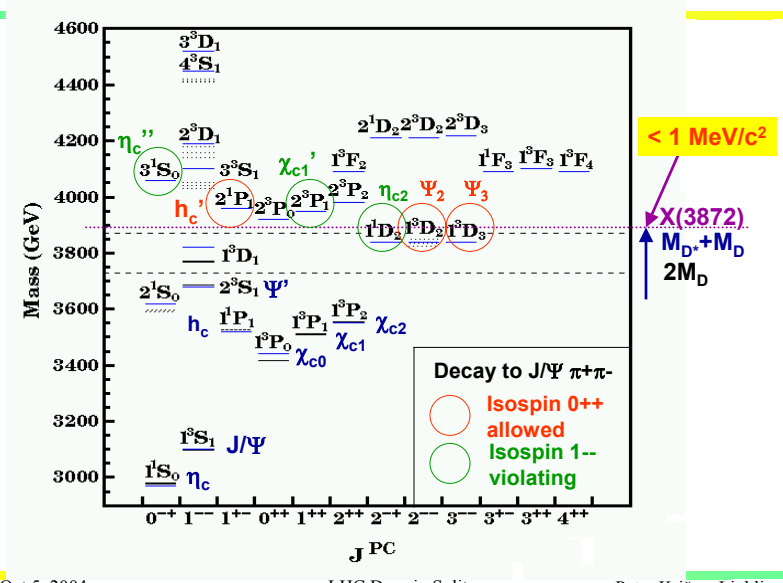
Belle, PRL 91 (2003) 262001
Mass 3872.0 ± 0.6 ± 0.5 MeV



M(J/ψ $\pi^+\pi^-$)- M(J/ψ) [GeV]

confirmed by CDF,D0,BaBar

Hadron spectroscopy – X(3872)



Hadron spectroscopy – X(3872)

Search for other decay modes of X(3872):
90% C.L. upper limits (most from Belle):

$$\Gamma(X \to \gamma\chi_{c1})/\Gamma(X \to \pi\pi J/\psi) < 0.89$$
$$\Gamma(X \to \gamma\chi_{c2})/\Gamma(X \to \pi\pi J/\psi) < 1.1$$
$$\Gamma(X \to \gamma J/\psi)/\Gamma(X \to \pi\pi J/\psi) < 0.40$$
$$\Gamma(X \to \eta J/\psi)/\Gamma(X \to \pi\pi J/\psi) < 0.6$$ ← BaBar
$$\Gamma(X \to D\bar{D})/\Gamma(X \to \pi\pi J/\psi) < 7$$
$$\Gamma(X \to D^0\bar{D}^0\pi^0)/\Gamma(X \to \pi\pi J/\psi) < 6$$

Non-observation of DD modes: $J^P=0^+$, 1^-, 2^+,…, is ruled out.

What kind of state is X(3872)?

No good cc candidates for X(3872):

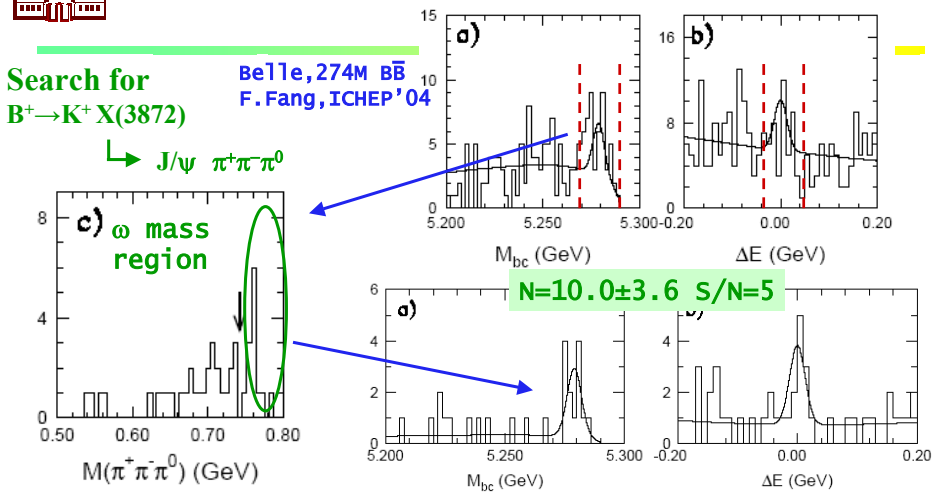
- η_c'' ← M too low and Γ too small
- ~~h_c'~~ ← angular distribution rules out 1^{+-}
- ~~χ_{c1}'~~ ← $\Gamma(\gamma J/\psi)$ too small
- ~~ψ_2~~ ← $\Gamma(\gamma\chi_{c1})$ too small; (PRL 93, 2003)
- η_{c2} ← $\pi\pi\,\eta_c$ should dominate over $\pi\pi J/\psi$
- ~~ψ_3~~ ← $\Gamma(\gamma\chi_{c2}$ & $D\bar{D})$ too small

○ - Isospin violating decays to $J/\Psi\,\pi^+\pi^-$

Hadron spectroscopy – X(3872)

Search for
$B^+ \to K^+ X(3872)$
↳ $J/\psi\ \pi^+\pi^-\pi^0$

Belle, 274M $B\bar{B}$
F.Fang, ICHEP'04



N=10.0±3.6 S/N=5

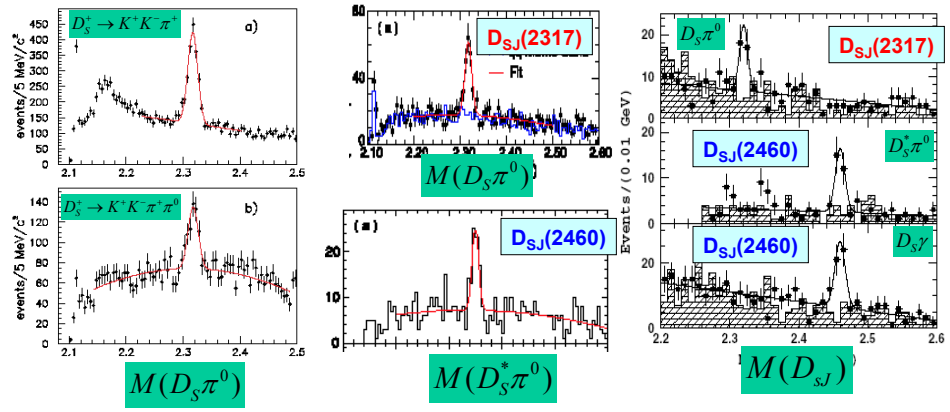
M(ω)+M(J/ψ)=3879 MeV
X(3872)→ω J/ψ can occur via virtual ω

$\Gamma(\omega\, J/\psi)/\Gamma(J/\psi\ \pi^+\pi^-)=0.8\pm0.3\pm0.1$

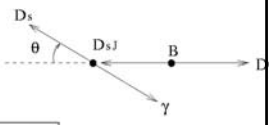
in accordance with DD* molecule model
Swanson, PLB 588, 189(2004)

Hadron spectroscopy – $D_{sJ}(2317)$ and $D_{sJ}(2460)$ mesons

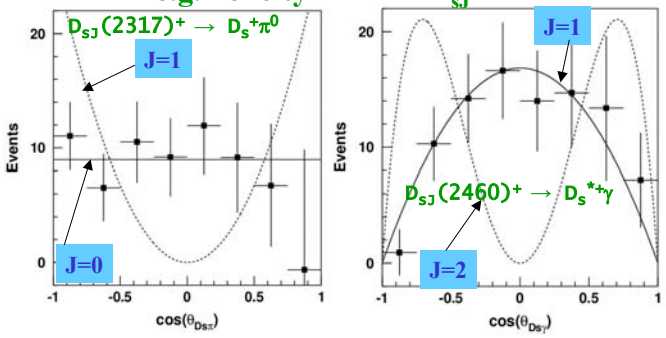
BaBar - $D_{sJ}(2317)$ **CLEO** **Belle**



Hadron spectroscopy – D_{sJ} mesons



Properties studied
e.g. helicity in $B \to DD_{sJ}$



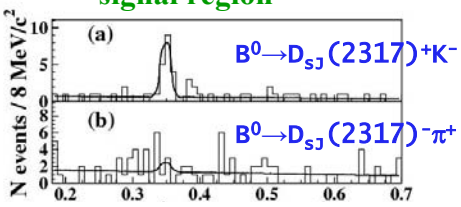
Belle,280M $B\bar{B}$, M.Danilov,ICHEP'04

Apart from low masses, all properties in accordance with lowest level P states $J^P=0^+,1^+$

Hadron spectroscopy – D_{sJ} mesons

First observation of $B^0 \to D_{sJ}(2317)^+K^-$

Events in M_{bc}, ΔE signal region



Measured branching fractions for comparison

$Br(B^0 \to D_s K^-) = (2.93\pm0.55\pm0.79)\times10^{-5}$

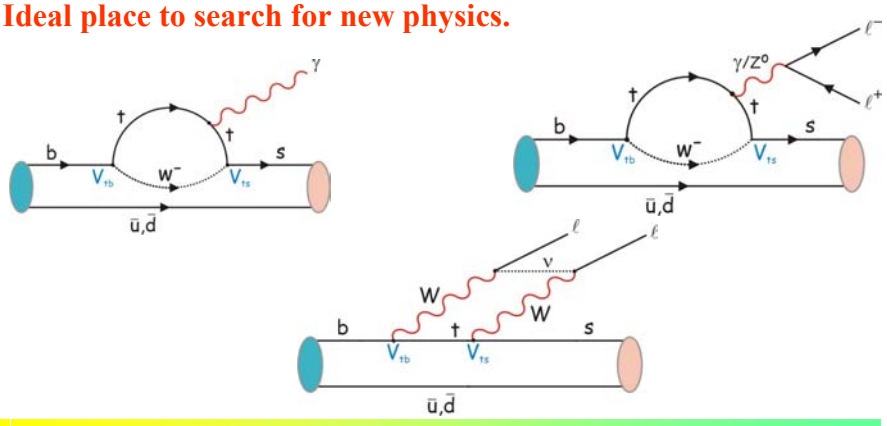
$Br(B^0 \to D_s \pi^-) = (1.94\pm0.47\pm0.52)\times10^{-5}$

Belle,152M $B\bar{B}$,A.Drutskoy,ICHEP'04

$$Br(B^0 \to D_{sJ}(2317)^+K^-) \times Br(D_{sJ}(2317)^+ \to D_s^+\pi^0) = (5.3\pm1.4\pm0.5\pm1.4)\times10^{-5}$$

FCNC B decays

Flavour changing neutral current (FCNC) processes (like b→s, b→d) are fobidden at the tree level in the Standard Model.
Proceed only at low rate via higher-order loop diagrams.
Ideal place to search for new physics.



b → sγ inclusive

b → sγ rate: sensitive to deviations from the SM, world average in good agreement with SM predictions.

Photon energy E_γ distribution: depends on m_b and Fermi motion parameter in the B system (parameters of HQE); also important for the determination of V_{ub} in semileptonic B decays.

Previous measurement by CLEO: $E_\gamma > 2.0$ GeV.

Belle: extend the energy range to $E_\gamma > 1.8$ GeV to cover >95% of the rate.

b → sγ inclusive

Results

Branching ratio:

$BR(b\to s\gamma)=(3.55\pm0.32^{+0.30+0.11}_{-0.31\ -0.07})\cdot10^{-4}$

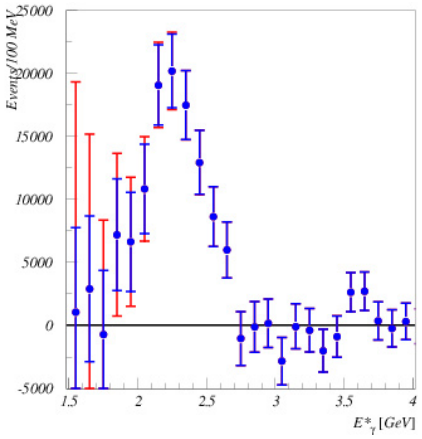
Photon energy E_γ distribution:

first moment:

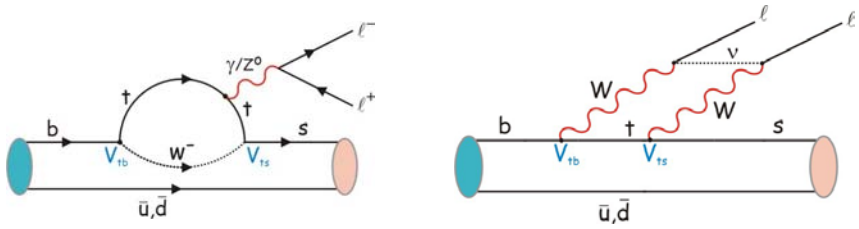
$<E_\gamma>=(2.292\pm0.026\pm0.034)$ GeV

second moment: $<E_\gamma^2>-<E_\gamma>^2=$

$(0.0305\pm0.0074\pm0.0063)\ (GeV)^2$



B → K* l+ l-

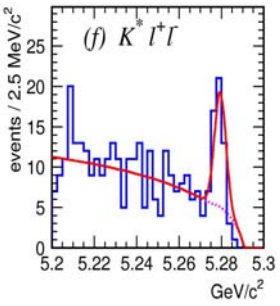


b → s l^+l^- was first measured in B → K l^+l^- by Belle.
With 140/fb of data, search for K* l^+l^- and update K l^+l^-.

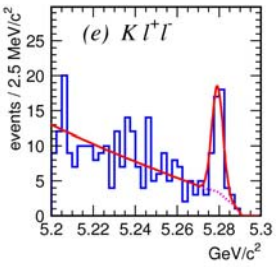
Important for further searches for the physics beyond SM:
backward-forward asymmetry A_{FB} in K* l^+l^-

$B \to K^* l^+ l^-$

- K^*: $K^+\pi^-$, $K^0_s\pi^+$, $K^+\pi^0$ with $|M(K\pi)-M(K^*)|<75$ MeV/c^2
- K: charged or neutral
- Lepton pair: e or μ, p(e)>0.4 GeV/c, p(μ)>0.7 GeV/c
  veto on J/Ψ, Ψ(2S)



first observation

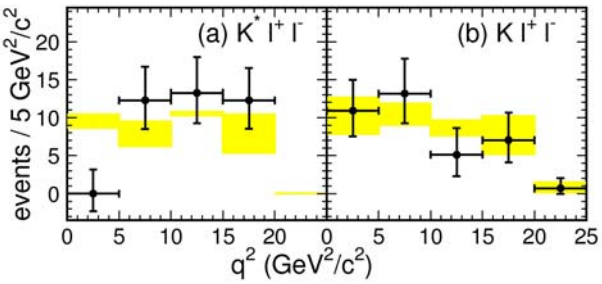


$M_{bc} = \sqrt{(E^{*2}_{beam} - |p^*_B|^2)}$

$B \to K^* l^+ l^-$

Results based on 140 fb^{-1}

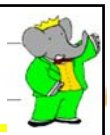
- $BR(B \to K^* l^+ l^-) = (11.5^{+2.6}_{-2.4} \pm 0.8 \pm 0.2)\ 10^{-7}$ observation
- $BR(B \to K l^+ l^-) = (4.8^{+1.0}_{-0.9} \pm 0.3 \pm 0.1)\ 10^{-7}$ update with more data



$q^2 = M_{ll}^2 c^2$

yellow: SM expect.

$B \to K^* l^+ l^-, K l^+ l^-$



Results based on 123 fb^{-1}

- **BR($B \to K^* l^+ l^-$) = $(8.8^{+3.3}_{-2.9} \pm 1.0)\ 10^{-7}$**
- **BR($B \to K l^+ l^-$) = $(6.5^{+1.4}_{-1.3} \pm 0.4)\ 10^{-7}$**

Belle+BaBar: All in good agreement with SM.

With more statistics: measure backward-forward asymmetry A_{FB} in $K^* l^+ l^-$ -> determine sign of C_7

Summary

- **CKM measurements: new measurements with the fully reco. sample, V_{ub} with less thoeretical uncertainty.**
- **New upper limits for D^0 mixing in $D^0 \to K\pi$ and $Kl\nu$ decays.**
- **BR and asymmetries in $b \to s\gamma$ and $b \to s l^+ l^-$ transitions are in good agreement with SM, but some interesting results (e.g. A_{FB}) are statistically limited. We are entering an exciting phase of precision measurements.**
- **New, exciting results from hadron spectroscopy**

.... and much more, but could not be covered in this talk!

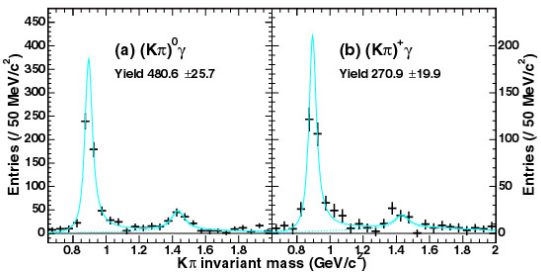
More slides – if time left

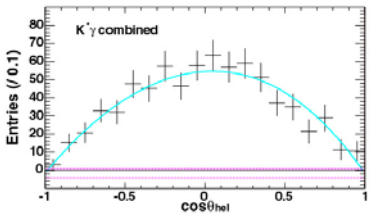
B → K*γ

- Photon candidates with π^0/η veto
- K*(892) reconstructed in 4 final states:

$K^+\pi^-$, $K^0_S\pi^0$, $K^+\pi^0$, $K^0_S\pi^+$ with $|M(K\pi) - M(K^*)_r| < 75$ MeV/c^2

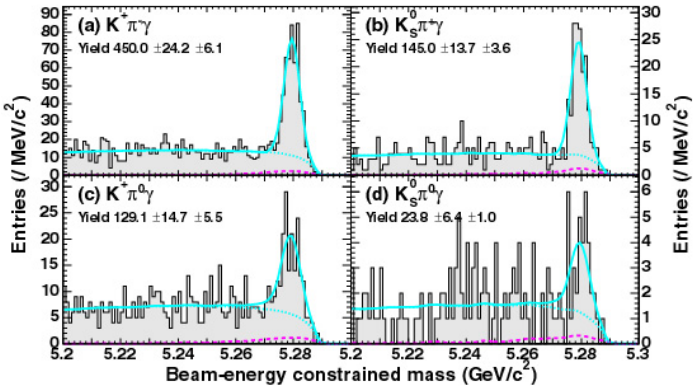
- BKG suppression against $e^+e^- \rightarrow qq(\gamma)$ by event shape var.





data sample 78/fb

B → K*γ braching fractions



$M_{bc} = \sqrt{(E^{*2}_{beam} - |p^*_B|^2)}$

$BR(B^0 \to K^{*0}\gamma) = (4.01 \pm 0.21 \pm 0.17) \cdot 10^{-5}$ SM ≈ $(6.9 \pm 2.1) \cdot 10^{-5}$

$BR(B^+ \to K^{*+}\gamma) = (4.25 \pm 0.31 \pm 0.24) \cdot 10^{-5}$ SM ≈ $(7.4 \pm 2.3) \cdot 10^{-5}$

B → K*γ asymmetries

Isospin asymmetry Δ_{0+} =

$$\frac{(\tau_{B^+}/\tau_{B^0})\,BR(B^0 \to K^{*0}\gamma) - BR(B^+ \to K^{*+}\gamma)}{(\tau_{B^+}/\tau_{B^0})\,BR(B^0 \to K^{*0}\gamma) + BR(B^+ \to K^{*+}\gamma)}$$

$\Delta_{0+} = +0.012 \pm 0.044(stat) \pm 0.026(syst)$ Belle SM: 5-10%

$\Delta_{0+} = +0.051 \pm 0.044(stat) \pm 0.023(syst)$ BaBar

CP asymmetry SM<<0.01

$$A_{CP} = (\Gamma(\bar{B} \to \bar{K}^*\gamma) - \Gamma(B \to K^*\gamma))/(\Gamma(\bar{B} \to \bar{K}^*\gamma) + \Gamma(B \to K^*\gamma)) =$$

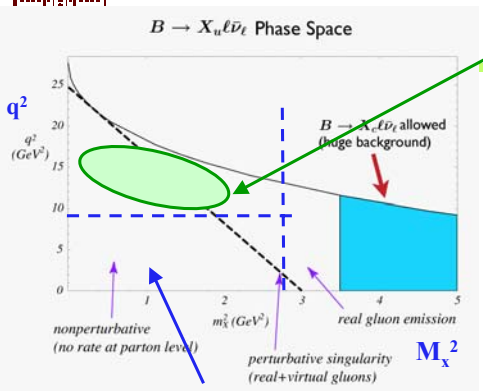
$$\frac{1}{(1-2w)} \quad \frac{N(\bar{B} \to \bar{K}^*\gamma) - N(B \to K^*\gamma)}{N(\bar{B} \to \bar{K}^*\gamma) + N(B \to K^*\gamma)}$$

(w= dilution due to imperfect tagging)

$A_{CP} = -0.015 \pm 0.044(stat) \pm 0.012(syst)$ Belle

$A_{CP} = -0.015 \pm 0.036(stat) \pm 0.010(syst)$ BaBar

$|V_{ub}|$ inclusive



large non-perturbative corr.
(large th. uncertainty)

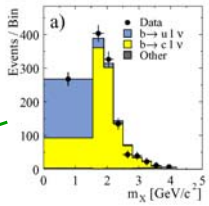
used in the measurement

(q^2_{cut}, M_{Xcut}) 8 GeV², 1.7 GeV
ΔV_{ub} 6%-9%

only q^2_{cut} 11.6 GeV²
ΔV_{ub} 12%-15%

C.W.Bauer et al.,hep-ph/0111387

M_X only



Babar-CONF-04/11,ICHEP'04

$|V_{ub}| = (4.77 \pm 0.28 \pm 0.28 \pm {}^{0.69}_{0.39}) \times 10^{-3}$

M_x-q^2 $|V_{ub}| = (4.92 \pm 0.39 \pm 0.36 \pm 0.46) \times 10^{-3}$

$|V_{ub}|$ inclusive

M_x-q^2

$|V_{ub}| = (4.92 \pm 0.39 \pm 0.36 \pm 0.46) \times 10^{-3}$ BaBar

(stat.) (syst.) (th.)

$|V_{ub}| = (5.54 \pm 0.42 \pm 0.50 \pm 0.55) \times 10^{-3}$ Belle

BaBar syst.: largest from detector (tracking, ID) and
$b \to c l \nu$ modeling
Belle syst.: MC statistics

A_{FB} for $B \to K^{(*)}l^+l^-$

- Raw A_{FB} in each q^2 region is extracted from M_{bc} fit.
- Dotted lines indicate charmonium veto windows.
- Kll has no asymmetry, hence a good control sample.
- Curves (not fitted lines!) show theory including exp'tal efficiency.
- Both are in agreement with data.