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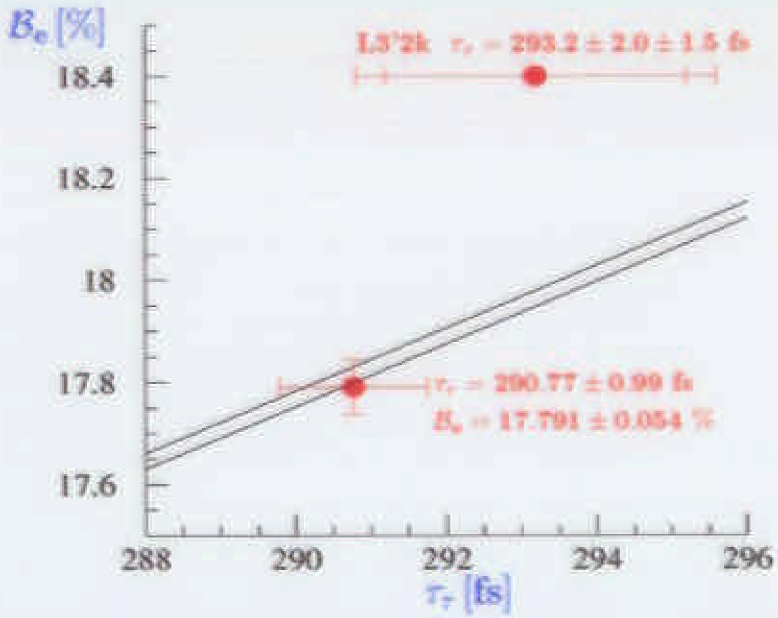
Heavy Flavour Physics

τ **c** **b** **t**

$e - \mu - \tau$ universality

$$\Gamma\left(\tau^- \to \nu_\tau \ell^- \overline{\nu}_\ell\right) = \frac{G_F^2 m_\tau^5}{192\pi^3} f\left(\frac{m_\ell^2}{m_\tau^2}\right)\gamma_{EW}$$

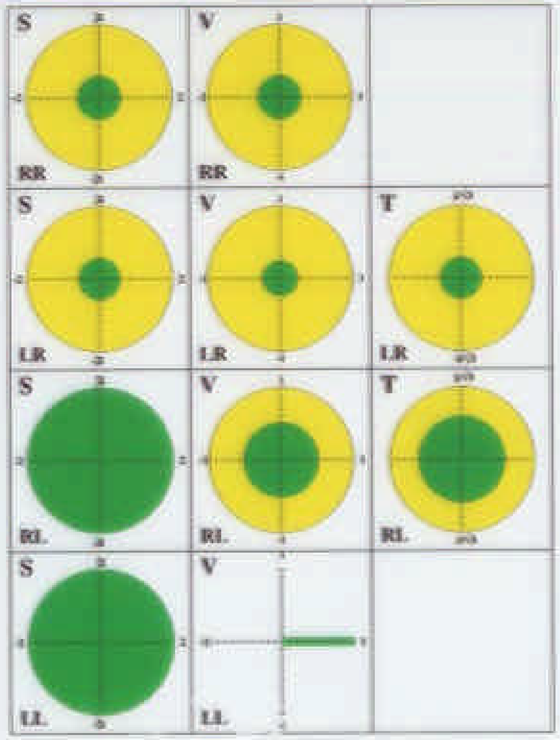
$$\mathcal{B}_{\tau\to e} = \frac{\mathcal{B}_{\tau\to\mu}}{0.972564 \pm 0.000010} = \frac{\tau_\tau \times 10^{12}\ s^{-1}}{1.6321 \pm 0.0014}$$



Charge-current lepton universality is tested at 0.1% level

New DELPHI study of the Lorentz structure in τ decays

	$WA_{(e,\mu)}$	DELPHI'2k $_{(e,\mu)}$
ρ	0.750 ± 0.011	$0.775 \pm 0.023 \pm 0.020$
η	0.048 ± 0.035	$-0.005 \pm 0.036 \pm 0.037$
ξ	0.988 ± 0.029	$0.929 \pm 0.070 \pm 0.030$
$\xi\delta$	0.735 ± 0.020	$0.779 \pm 0.070 \pm 0.028$



Precision is not at μ level!

No evidence for lepton flavour violation in τ decays

all UL at 90% CL

mode	UL, 10^{-6}	mode	UL, 10^{-6}	mode	UL, 10^{-6}
$e^-\gamma$	2.7	$e^-e^+e^-$	2.9	$e^-e^+\mu^-$	1.7
$e^-e^-\mu^+$	1.5	$e^-\pi^0$	3.7	$e^-\eta$	8.2
$e^-\rho$	2.0	e^-K^{*0}	5.1	$e^-\bar{K}^{*0}$	7.4
$e^-\phi$	6.9	$e^-\pi^+\pi^-$	2.2	$e^-\pi^+K-$	6.4
$e^-K+\pi^-$	3.8	$e^-\pi^+K^-$	6.0	$e^+\pi^-\pi^-$	1.9
$e^+\pi^-K-$	2.1	e^+K-K^-	3.8	$e^-\pi^0\pi^0$	6.5
$e^-\pi^0\eta$	24	$e^-\eta\eta$	35		
$\mu^-\gamma$	1.1	$\mu^-\mu^+\mu^-$	1.9	$\mu^-\mu^+e^-$	1.8
$\mu^-e^+\mu^-$	1.5	$\mu^-\pi^0$	4.0	$\mu^-\eta$	9.6
$\mu^-\rho$	6.3	μ^-K^{*0}	7.5	$\mu^-\bar{K}^{*0}$	7.5
$\mu^-\phi$	7.0	$\mu^-\pi^+\pi^-$	8.2	$\mu^-\pi^+K-$	7.5
$\mu^-K+\pi^-$	7.4	$\mu^-\pi^+K^-$	15	$\mu^+\pi^-\pi^-$	3.4
$\mu^+\pi^-K-$	7.0	μ^+K-K^-	6.0	$\mu^-\pi^0\pi^0$	14
$\mu^-\pi^0\eta$	22	$\mu^-\eta\eta$	60		
$\bar{p}\gamma$	3.5	$\bar{p}\pi$	15	$\bar{p}\eta$	8.9
$\pi\pi$	370	$\bar{p}\pi^0\pi^0$	33	$\bar{p}\pi^0\eta$	27
e^-K^0	1300	μ^-K^0	1000		

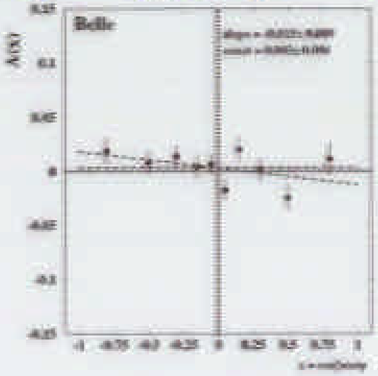
BELLE'2k (4.25 fb^{-1}):

- $\tau \to eK^0 < 7.7 \cdot 10^{-6}$ (95%CL)
- $\tau \to \mu K^0 < 8.8 \cdot 10^{-6}$ (95%CL)

New CP/T tests with τ leptons

	DELPHI	OPAL
$\frac{m_{\tau^+}-m_{\tau^-}}{m_\tau}$	$\frac{-2\pm 3.2\ MeV/c^2}{m_\tau}$	$(0.0 \pm 1.8) \cdot 10^{-3}$

- BELLE'2k 8.3×10^4 $\tau \to \pi\pi^0\nu$ events



$|\mathcal{A}_{CP}(\cos\beta\cos\psi)| < 0.016$

- ARGUS'2k $(\tau\tau \to (\rho\nu)(\rho\nu), (\rho\nu)(e\nu\nu), (\rho\nu)(\mu\nu\nu))$
  - $|\mathcal{R}e(d_\tau)| < 4.6 \cdot 10^{-16}$(90%CL)
  - $|\mathcal{I}m(d_\tau)| < 1.8 \cdot 10^{-16}$(90%CL)
- BELLE'2k $(\tau\tau \to (e\nu\nu, \mu\nu\nu))$ $\hat{\mathcal{R}} = (1 + 4\delta)$, if CP/T $\delta = 0$

  $|\delta| < 0.018$

T and CP invariance are valid to within 1%

Charm physics remains important in understanding of $\mathcal{SM}$

$$\Lambda^2_{QCD} \ll m_c^2$$

$$m_u, m_d \ll m_c < m_b$$
$$m_s < m_c \ll m_t$$

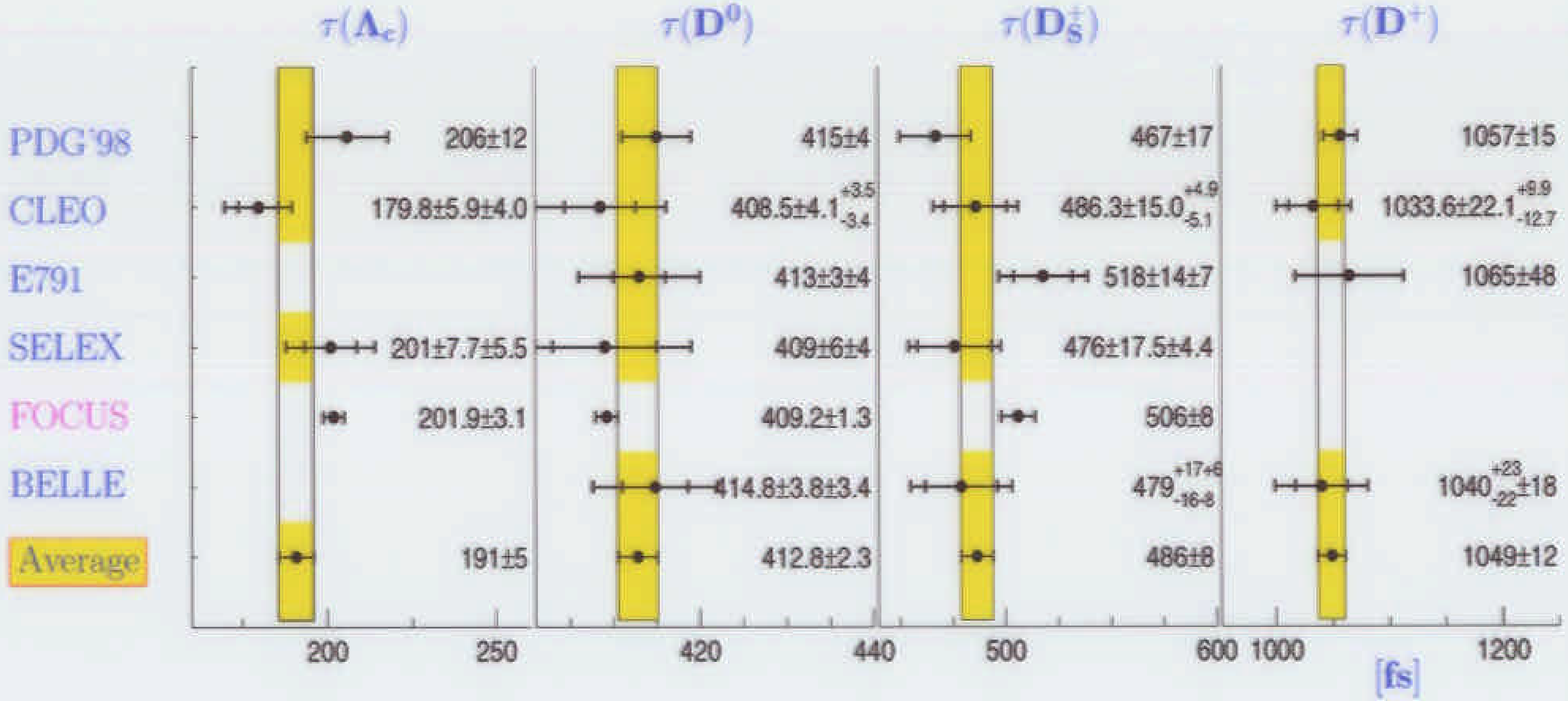
- c is the lightest "heavy" quark
  - allows quantative description via $1/m_Q$ expansion
  - corrections are large

⇒ *Charm physics* gives

◇ a frame for B physics

◇ increased sensitivity to new physics in the processes dominated by loop contribution (loop diagrams vanish in $\mathcal{SM}$)

Lifetime of Λ_c, D^o, $D_S^{\pm}$ and D^+

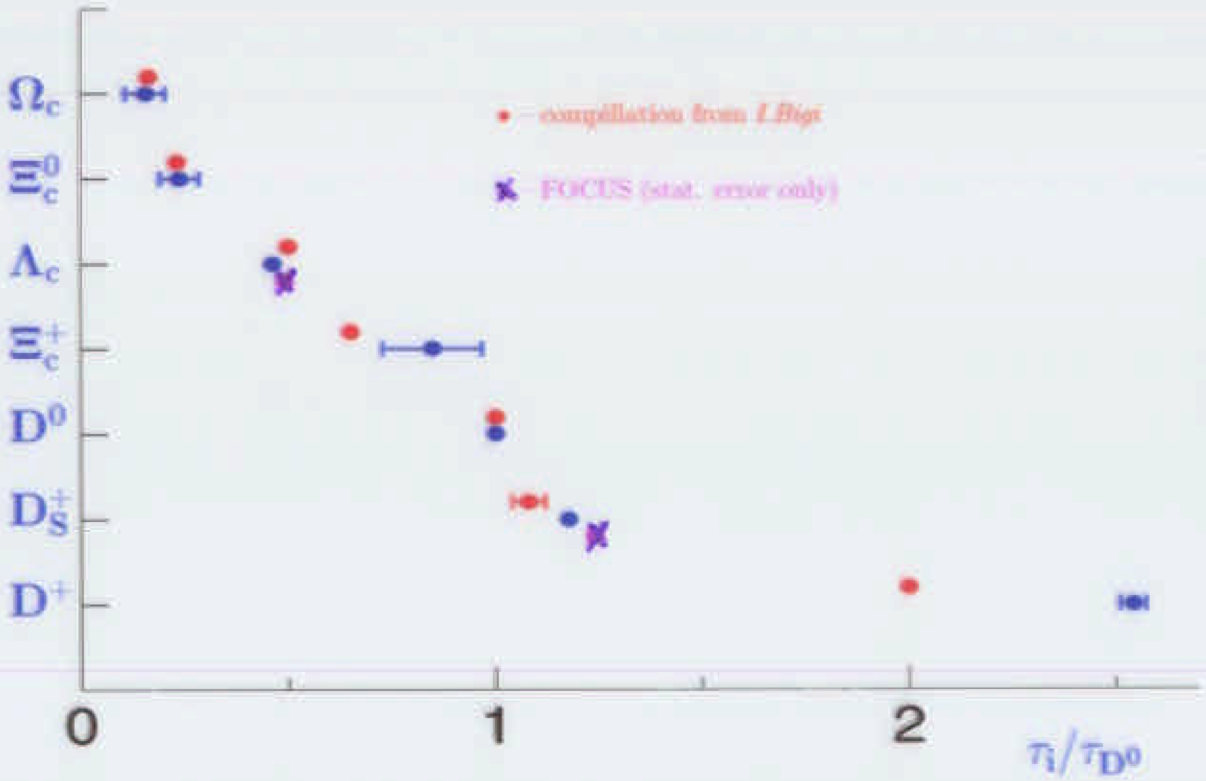


Those results that were used to calculate the average are marked in yellow

Lifetime of charmed hadrons

$\tau(\Omega_c^0) < \tau(\Xi_c^0) < \tau(\Lambda_c^+) < \tau(\Xi_c^+) < \tau(D^0) < \tau(D_s^+) < \tau(D^+)$

This hierarchy is nicely described by theory !

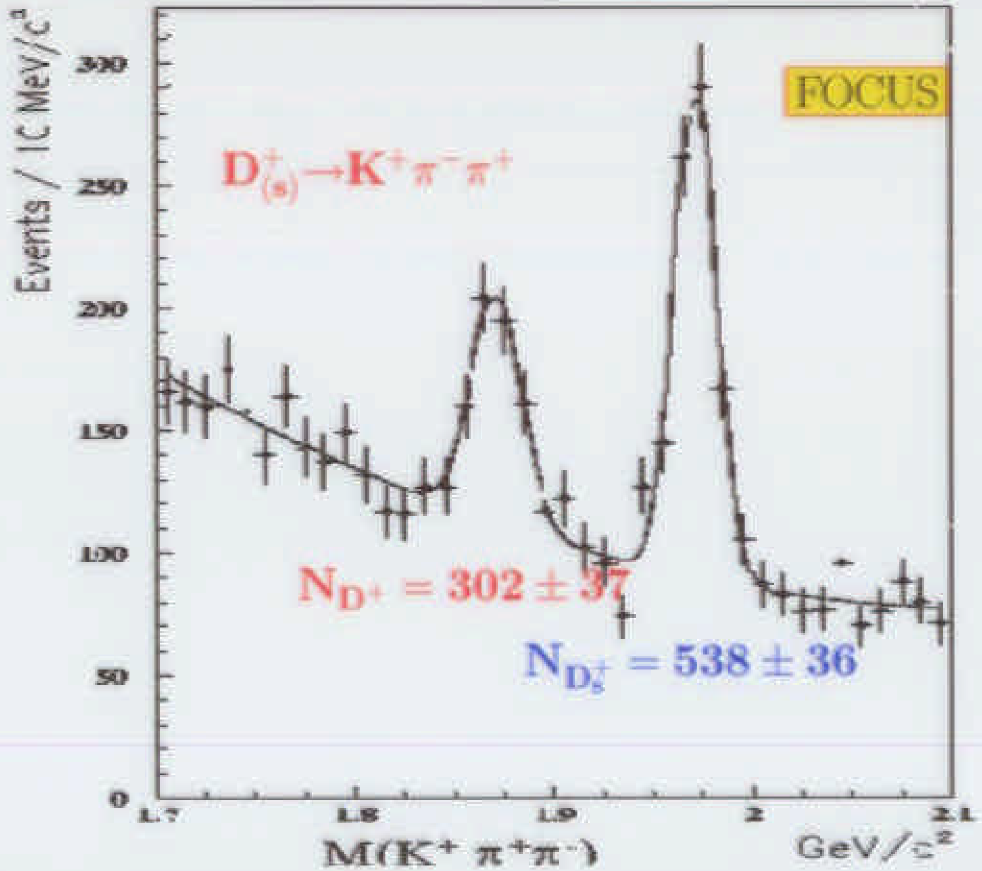


- $\frac{\tau(D^+)}{\tau(D^0)} = 2.54 \pm 0.05$
- $\frac{\tau(D^+)}{\tau(\Omega_c^0)} = 10 \pm 1$

Light quarks are not just spectators !

Lifetime of charmed hadrons

DCSD vs. CAD $D^+ \to K^\pm \pi^\mp \pi^+$	⇒	Pauli interference effect
⊕ $\tau(D^+)$ vs. $\tau(D^0)$	⇒	W – exchange contribution
⊕ $\tau(D_s^\pm)$ vs. $\tau(D^0)$	⇒	W – annihilation contribution



◇ $$\frac{\mathcal{B}(D^+ \to K^+\pi^+\pi^-)}{\mathcal{B}(D^+ \to K^-\pi^+\pi^+)} \approx \frac{\Gamma_{SP}}{\Gamma_{PI}} \times \tan^4\theta_C$$

$$\Rightarrow \frac{\Gamma_{PI}}{\Gamma_{SP}} \approx 0.4$$

◇ $$\frac{\tau_{D^+}}{\tau_{D^0}} = \frac{\Gamma_{SP} + \Gamma_{WX} + \Gamma_{SL}}{\Gamma_{PI} + \Gamma_{SL}}$$

$$\Rightarrow \frac{\Gamma_{WX}}{\Gamma_{SP}} \approx 0.3$$

◇ $$\frac{\tau_{D_s^+}}{\tau_{D^0}} = 1.05 \times \frac{\Gamma_{SP} + \Gamma_{WX} + \Gamma_{SL}}{\Gamma_{SP} + \Gamma_{WA} + \Gamma_{SL}}$$

$$\Rightarrow \frac{\Gamma_{WA}}{\Gamma_{SP}} \approx 0.1$$

Leptonic decays: $D_s \to \ell\nu$

◇ f_{D_s} ⇒ better estimates on f_B : $f_B = f_D \cdot \sqrt{\frac{M_D}{M_B}}$ ⇒ 3-rd generation CKM matrix elements from $B^0_{(s)}\overline{B}^0_{(s)}$ mixing measurements

$$\Gamma(D_s \to \ell\nu) = \frac{G_F^2}{8\pi} f_{D_s}^2 |V_{cs}|^2 M_{D_s} M_\ell^2 \left(1 - \frac{M_\ell^2}{M_{D_s}^2}\right)^2$$

ALEPH'2K

$$\mathcal{B}(D_s \to \tau\nu) = [5.79 \pm 0.76 \pm 1.78]\%$$

$$\mathcal{B}(D_s \to \mu\nu) = [0.68 \pm 0.11 \pm 0.18]\%$$

$$\Rightarrow f_{D_S} = [285 \pm 20 \pm 40]\ MeV$$

BEATRICE'2K

$$\mathcal{B}(D_s \to \mu\nu) = [0.83 \pm 0.23 \pm 0.06 \pm 0.18^*]\%$$

$$\Rightarrow f_{D_S} = [323 \pm 44 \pm 12 \pm 34]\ MeV$$

$^*\mathcal{B}(D_s \to \phi\pi) \& \mathcal{B}(D_s \to \phi\ell\nu)$

†T.Draper

$D^0\overline{D}^0$ mixing

$K^0\overline{K}^0 \quad \Delta M \ll \Gamma,\ \Delta\Gamma \sim \Gamma$

$D^0\overline{D}^0 \Rightarrow \Delta M,\ \Delta\Gamma \ll \Gamma$

$B^0\overline{B}^0 \quad \Delta\Gamma \ll \Gamma$

Unlike neutral K and B systems, any sizeable observation of $D^0\overline{D}^0$ mixing would require New Physics

$$\begin{cases} x = \frac{\Delta M}{\Gamma}; \\ y = \frac{\Delta\Gamma}{2\Gamma}. \end{cases}$$

Strong phase δ turns $\begin{pmatrix} x \\ y \end{pmatrix}$ to $\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} x \cdot \cos\delta + y \cdot \sin\delta \\ y \cdot \cos\delta - x \cdot \sin\delta \end{pmatrix}$

Methods to see $x^{(\prime)}$ or $y^{(\prime)}$:

- **observe mixing: measure D flavour at production and at decay (CLEO, E791)**
- **measure lifetime of $\mathcal{CP}$ eigenstates (FOCUS)**

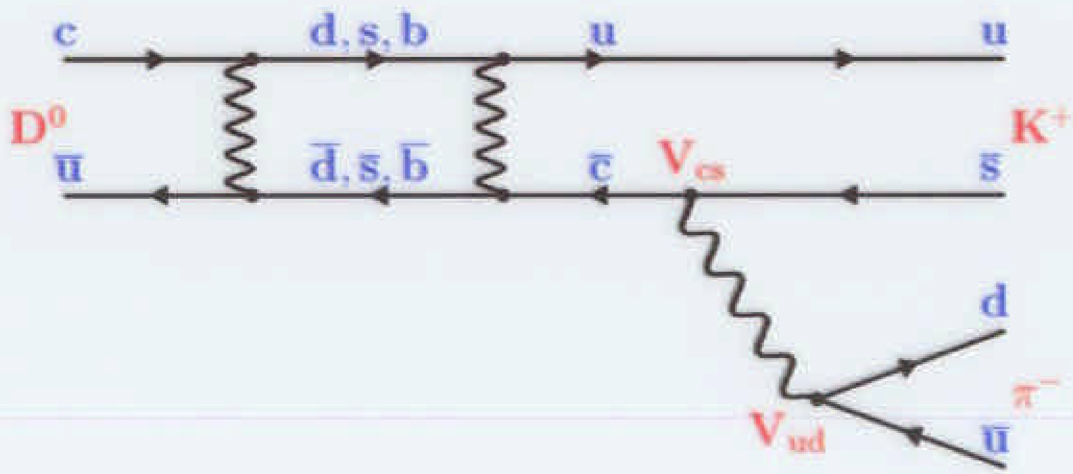
$D^0\bar{D}^0$ mixing

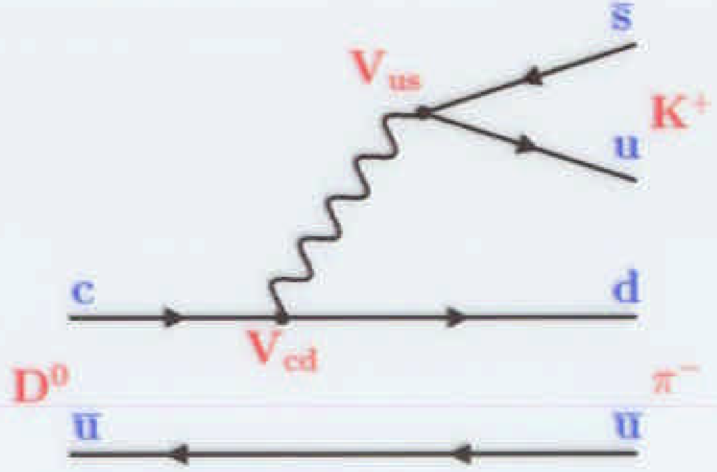
Method 1: Tag initial flavour and observe "wrong-sign" final

"Wrong-sign" finals are produced by mixing and DCSD

⇒ separate by time dependence

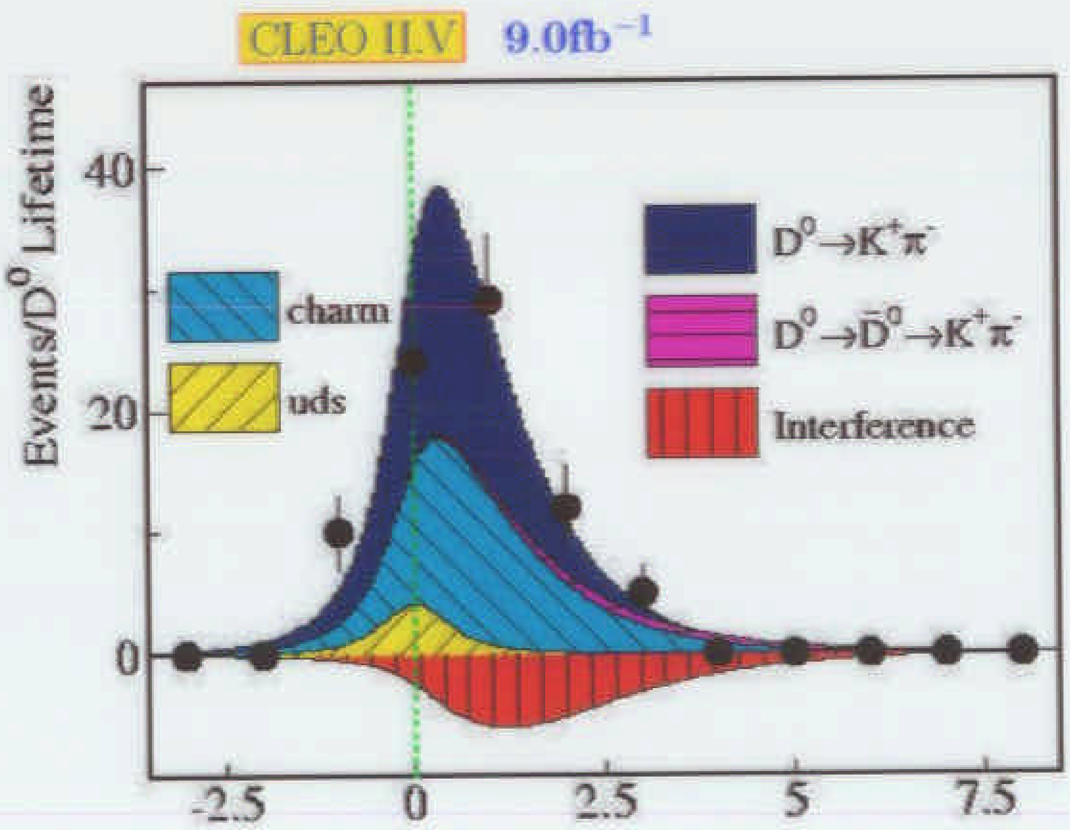
$$\frac{dN_{ws}}{dt} \approx e^{-\Gamma t} \times \left\{ \left(\frac{x'^2 + y'^2}{2} \right) \cdot \frac{\Gamma^2 t^2}{2} + \underbrace{D_{DCS}^2 + D_{DCS} \cdot y' \cdot \Gamma t}_{\text{vanishes for SL decays}} \right\}$$





$D^0\bar{D}^0$ mixing

Method 1: Tag initial flavour and observe "wrong-sign" final



Tag the initial D flavour with π from $D^{*+} \to D^0 \pi^+$ decay.

$$\begin{cases} x' = (0 \pm 1.5 \pm 0.2)\% \\ y' = (-2.5^{+1.4}_{-1.6} \pm 0.3)\% \end{cases}$$

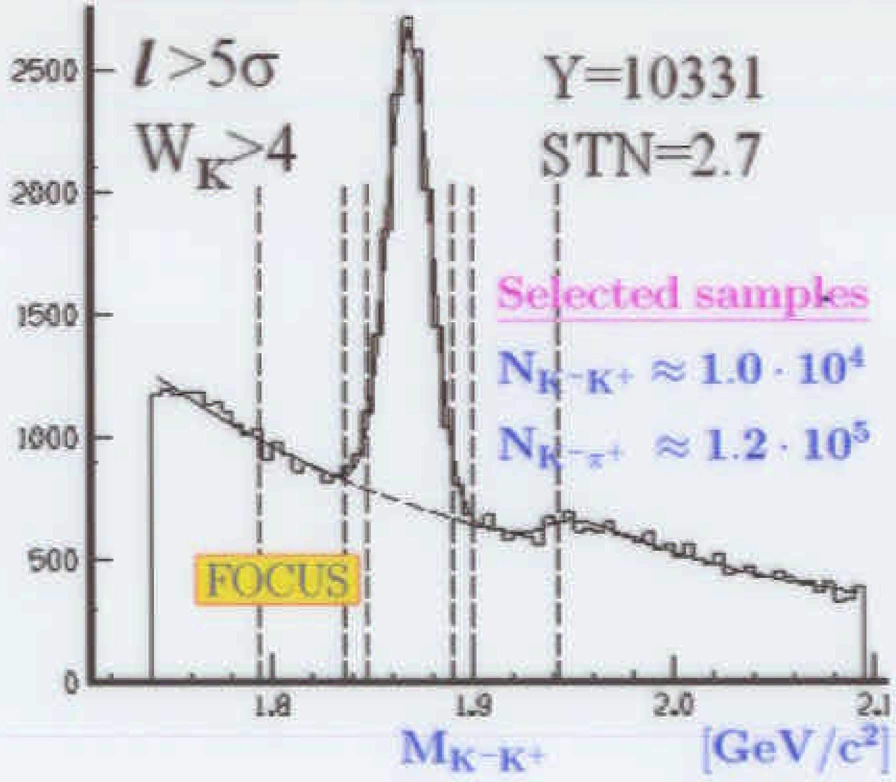
$D^0\overline{D}^0$ mixing

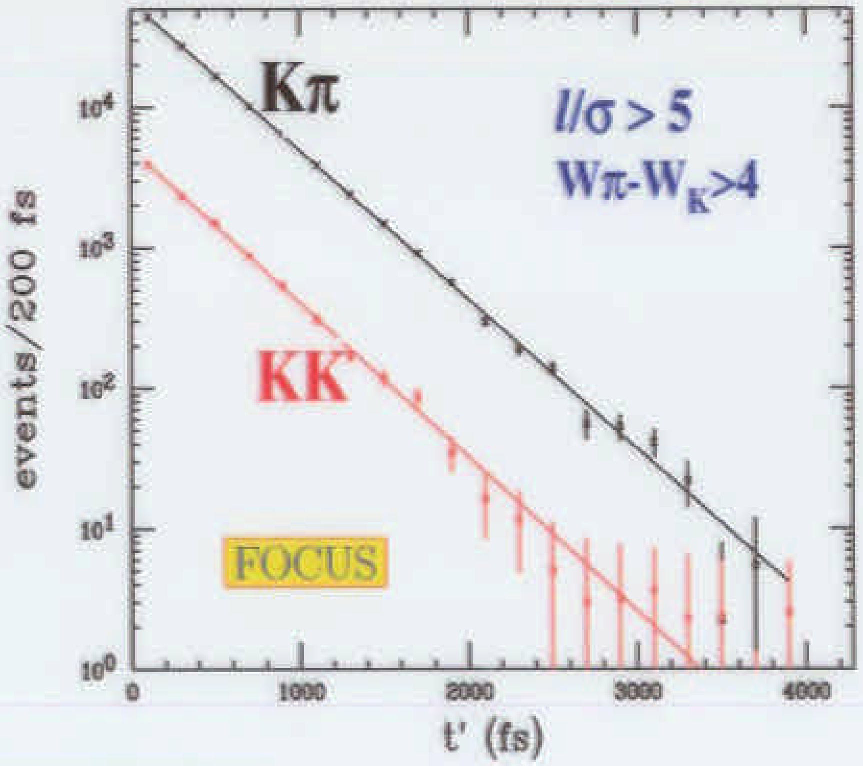
Method 2: Compare lifetime of $\mathcal{CP}$ eigenstates

$D^0 \to K^- K^+ \quad CP = + \qquad \Gamma = \Gamma_2$

$D^0 \to K^- \pi^+ \quad CP = \pm \qquad \Gamma = (\Gamma_2 + \Gamma_1)/2$

$$\Rightarrow \quad y = \frac{\tau(D^0 \to K^- \pi^+)}{\tau(D^0 \to K^- K^+)} - 1$$





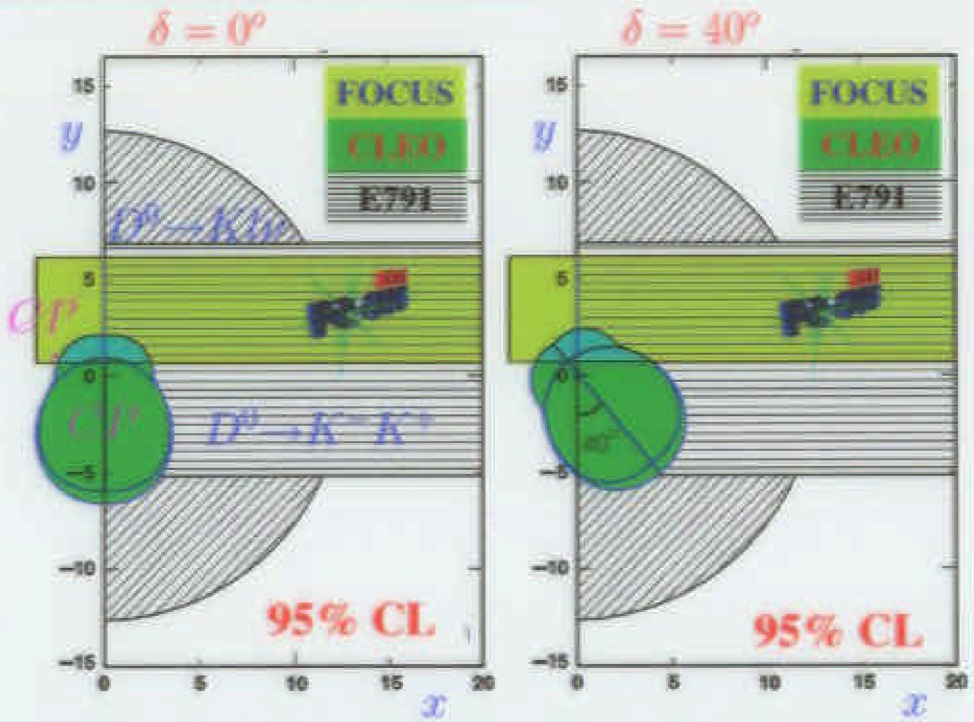
$y = (3.42 \pm 1.39 \pm 0.74)\%$

$D^0\bar{D}^0$ mixing: summary of results

$$y \begin{cases} (0.8 \pm 2.9 \pm 1)\% & E791 \\ (3.42 \pm 1.39 \pm 0.74)\% & FOCUS \\ (1.0\ ^{+3.8}_{-3.5}\ ^{+1.1}_{-2.1})\% & BELLE \end{cases}$$

$$\left.\begin{aligned} y' &= (-2.5\ ^{+1.4}_{-1.6} \pm 0.3)\% \\ x' &= (0 \pm 1.5 \pm 0.2)\% \end{aligned}\right\} CLEO$$

Better agreement for large δ!



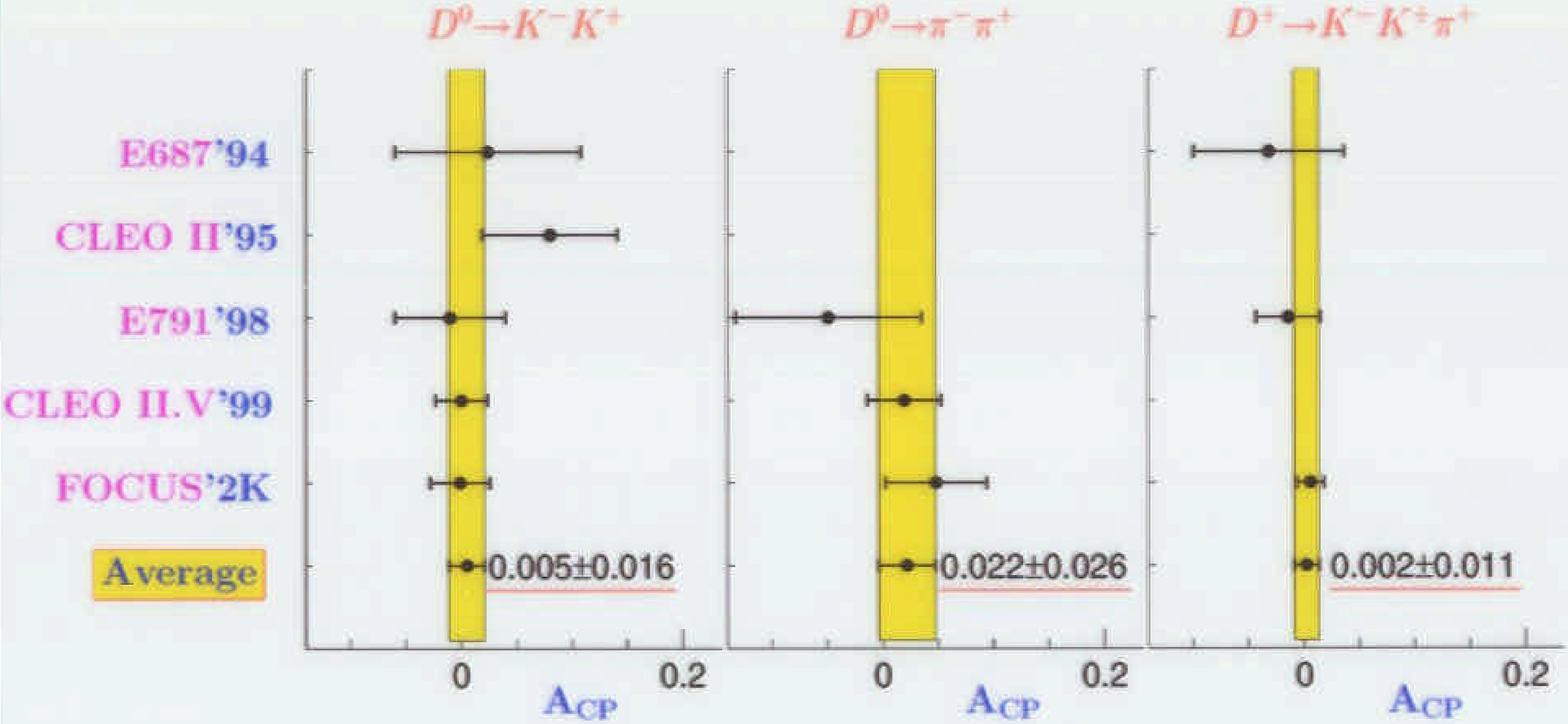
Expected: CLEO $\quad \mathcal{CP}even: D^0 \to \pi^-\pi^+,\ D^0 \to K^-K^+ \quad \mathcal{CP}odd:\ D^0 \to K_S\phi(\rho^0, \omega)$

$$\sigma_y \approx \begin{cases} \pm 0.03(stat) \pm 0.01(syst) \\ \pm 0.02(stat) \pm 0.01(syst) \end{cases}$$

SL analysis $D^0 \to K^{(*)+} l^- \nu$ improvement ($\times 2$) compared to E791

New results from BABAR and BELLE

Search for CP asymmetry in charm decays: summary of results



Even more increased sensitivity is required to touch at least the boldest theoretical predictions !

*) CP violating asymmetries in D^+ CSD rates can be as large as 0.14%
F. Buccella et al

b

b - physics is a part of program of all major labs

Excellent prospects for SM tests as well as for discovery of physics beyond SM

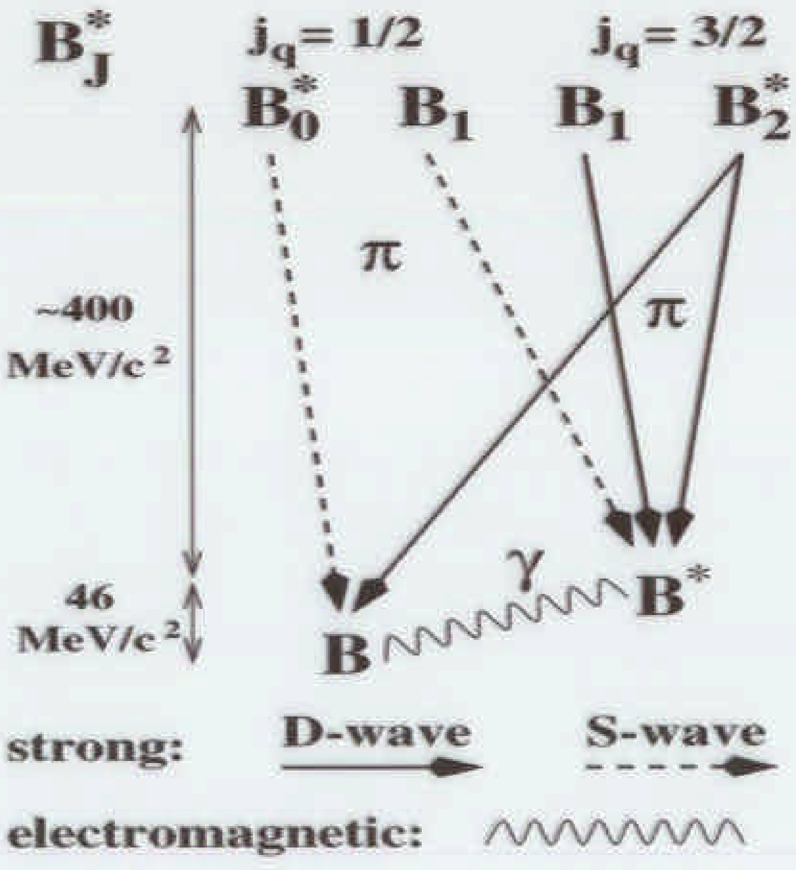
Specific measurements include:

- Determination of basic parameters of b-hadrons

  New results on → masses, lifetimes, decays

- Determination of CKM parameters in a variety of processes
- Detailed studies of CP violation

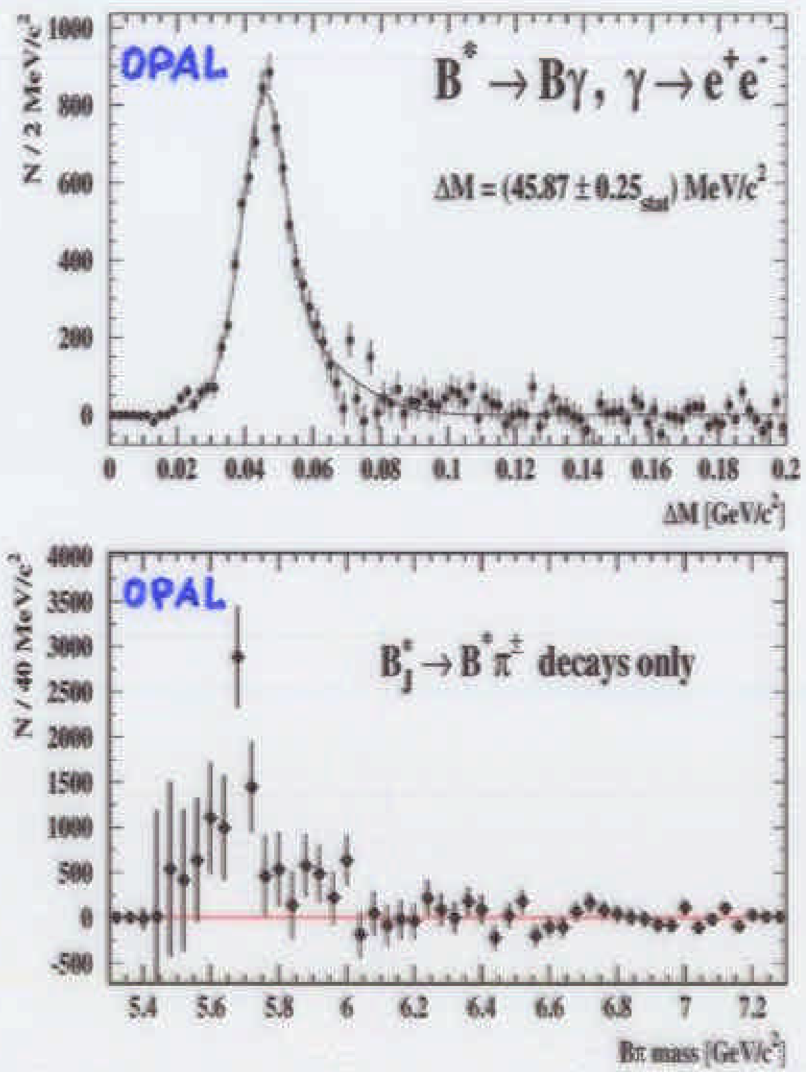
B spectroscopy



All ground states (and also B^* mesons) have been established

Presented at this conference:

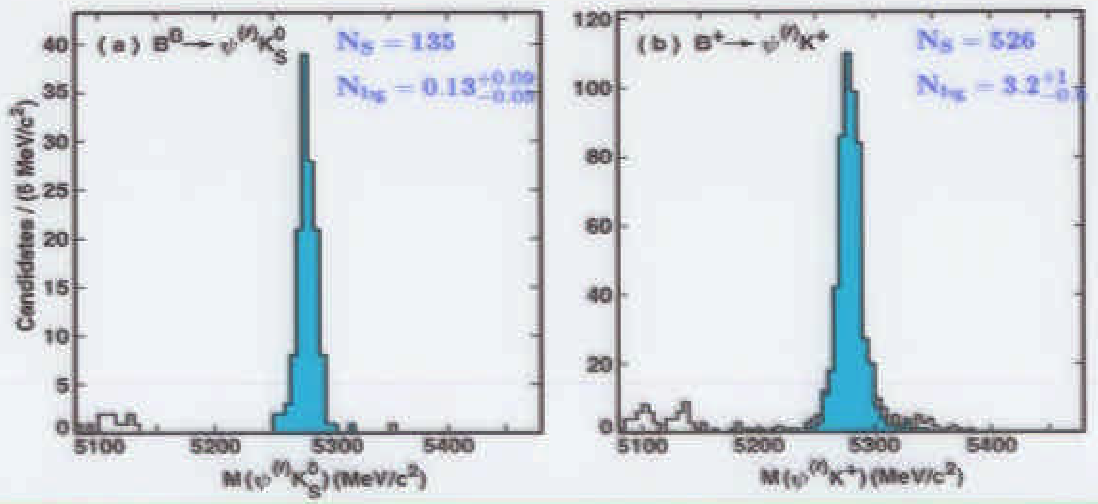
- Study of B_J^* mesons (OPAL, L3)
- New precision measurement of B^0 and B^+ masses by CLEO *and BABAR*



- L3: Inclusive B reconstruction (secondary vertex)+π from the primary vertex $\Rightarrow m(B\pi)$
  - $m(B_1^*) = 5670 \pm 10 \pm 13$ MeV$/c^2$
  - $\Gamma(B_1^*) = 70 \pm 21 \pm 25$ MeV
  - $m(B_2^*) = 5768 \pm 5 \pm 6$ MeV$/c^2$
  - $\Gamma(B_2^*) = 24 \pm 19 \pm 24$ MeV
  - $f(b \to B^{**} \to B^*\pi) = 0.32 \pm 0.03 \pm 0.06$
- ALEPH: Fully reconstructed decays $B \to D^*n\pi, J/\psi K^*$ to obtain better resolution in $m(B)$ and $m(B\pi)$ $\to$ limited statistics
  - $m(B_2^*) = 5739^{+8}_{-11}{}^{+6}_{-4}$ MeV$/c^2$
  - $f(b \to B^{**} \to B^*\pi) = 0.31 \pm 0.09^{+0.06}_{-0.05}$
- OPAL: Statistical separation of $B^{**} \to B\pi$ and $B^{**} \to B^+\pi$ by reconstruction of photon $\Rightarrow B^*$ - enriched and B^*-depleted samies
  - $\mathcal{B}(B^{**} \to B^+\pi) = 0.85^{+0.26}_{-0.27} \pm 0.12$

New measurement of B^0 and B^+ masses

- Previous measurements have used $B \to D^{(*)}\pi/\rho$ and $B \to J/\psi K^{(*)}$ decays and beam constrained mass technique $M_{bc} = \sqrt{E_{beam}^2 - \vec{p}_B^{\,2}}$ (systematics limited)
  - absolute energy scale ± 2 MeV
  - correction for initial state radiation ± 0.5 MeV
- CLEO'2k new method uses the measured invariant mass of $B \to \psi^{(\prime)} K$

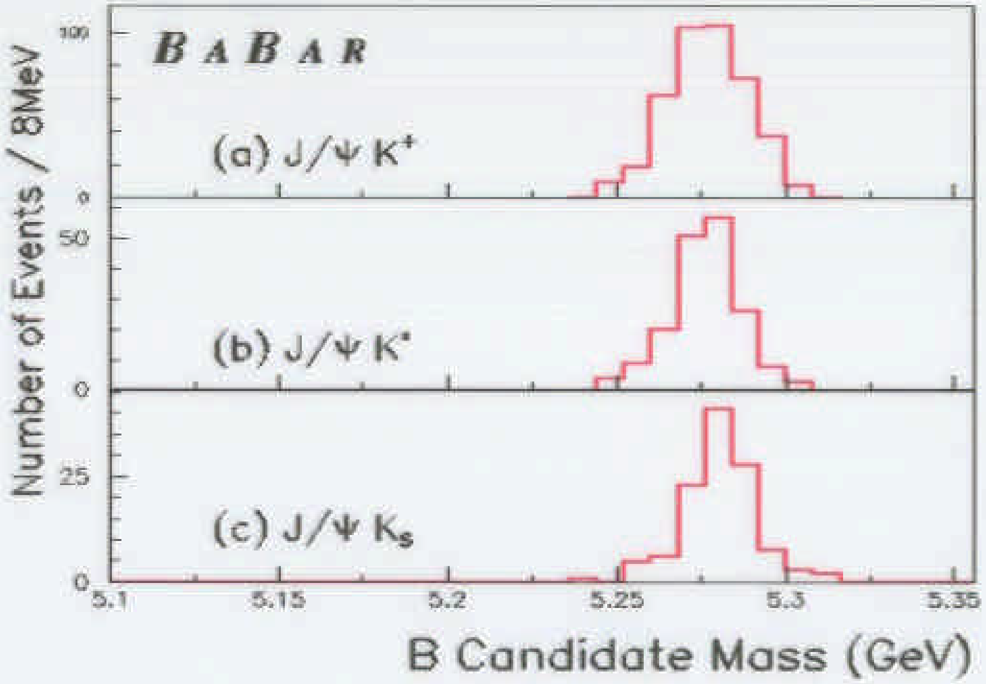


	Mass $[\mathrm{MeV}/c^2]$
	CLEO'2k
M_{B^0}	$5279.1 \pm 0.7 \pm 0.3$
M_{B^+}	$5279.1 \pm 0.4 \pm 0.4$
	PDG'98
M_{B^0}	5279.2 ± 1.8
M_{B^+}	5278.9 ± 1.8

PRELIMINARY

B^0 and B^+ Mass Measurement

- Using $J/\psi K^{*0}(K^+\pi^-)$, $J/\psi K_s(\pi^+\pi^-)$ and $J/\psi K^+$ candidates.
  - B^0 and B^+ masses measured from reconstructed mass
  - Mass difference measured from energy-substituted mass



NEW W.A.

$M_{B^0} = 5279.1 \pm 0.6$

$M_{B^+} = 5279.0 \pm 0.4$

Precision improved by a factor of 3.5

$m(B^0) = 5279.0 \pm 0.8 \pm 0.8$ MeV

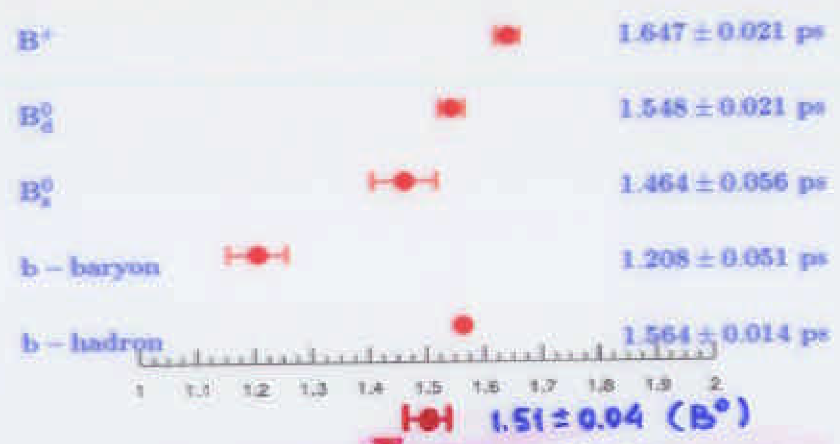
$m(B^+) = 5278.8 \pm 0.6 \pm 0.4$ MeV

$m(B^0) - m(B^+) = 0.28 \pm 0.21 \pm 0.04$ MeV

b -hadron lifetimes

Bottom hadron are expected to have < 10% lifetime difference

- **Inclusive reconstruction**
  (vertex charge to distinguish charged and neutral)
  - largest statistics
  - samples less pure
- **Partial reconstruction**
  Charmed meson + lepton
- **Full reconstruction** $J/\psi K^*$, $D^{(*)}n\pi$, $J/\psi K^*$
  - high purity
  - lack of statistics



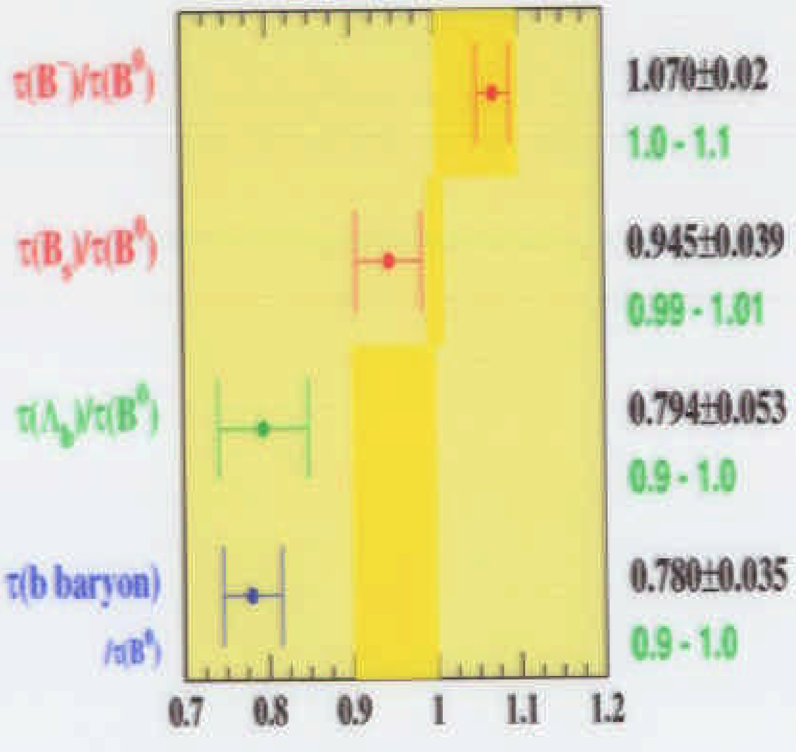
New measurements at $\Upsilon(4S)$

	τ_{B^0} [ps]	τ_{B^+} [ps]
BaBar	$1.506 \pm 0.052 \pm 0.029$	$1.602 \pm 0.049 \pm 0.035$
Belle	$1.50 \pm 0.05 ^{+0.07}_{-0.06}$	$1.70 \pm 0.06 ^{+0.10}_{-0.06}$

$\tau_{B^0} = 1.55 \pm 0.05 \pm 0.07$ $(D^*\pi)$

$\tau_{B^0} = 1.62 \pm 0.02 \pm 0.09$ $(D^*\ell\nu)$

b -hadron lifetime



no Υ(4S) measurements included

Expectations from OPE:

- $\frac{\tau(B^+)}{\tau(B^0)} = 1 + 0.05(\frac{f_b}{200\ \mathrm{MeV}})^2$

  (recent lattice study: $1.03 \pm 0.02 \pm 0.03$)

  M.D.Pierro,C.Sachrajda

- $\frac{\tau(B_s)}{\tau(B^0)} = 1.0 \pm \mathcal{O}(0.01)$
- $\tau(B_c) \sim 0.5$ ps

  (data: 0.46 ± 0.17 ps)

- $\frac{\tau(\Lambda_b)}{\tau(B_d)} = 0.9 - 1.0$

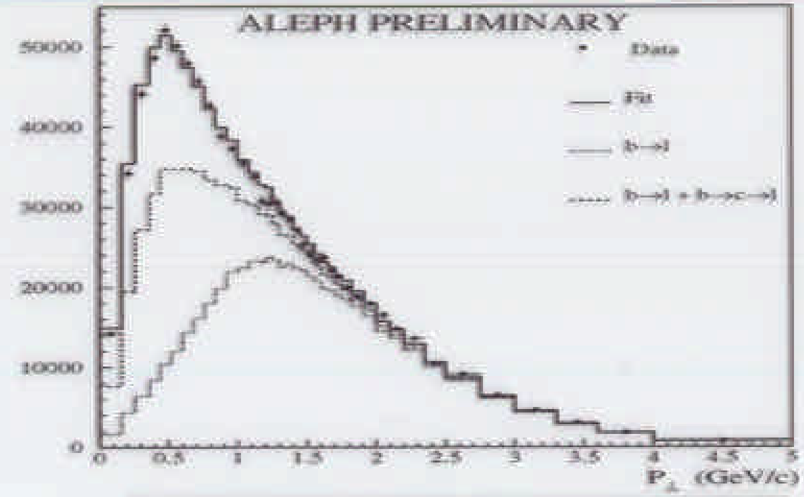
  Recent analysis based on QCD sum rules

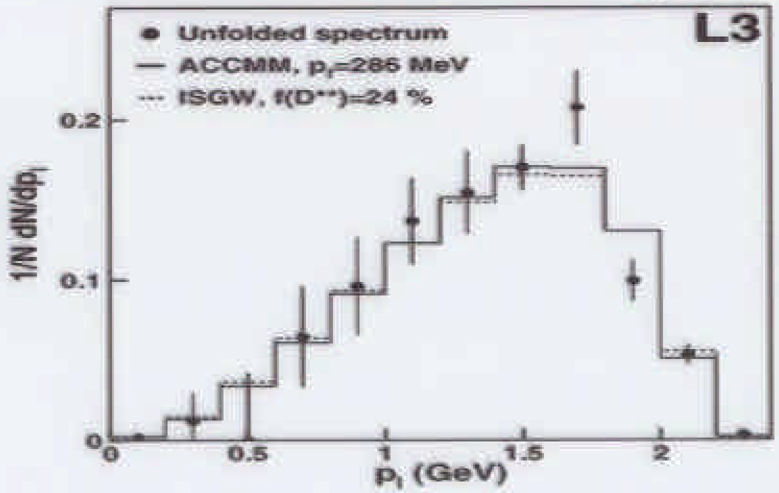
  (Huang, Lin, Zhu)→ 0.79-0.87

- $\frac{\tau(\Xi_b^-)-\tau(\Lambda_b)}{\tau(\Lambda_b)} \sim 0.14 - 0.21$

Inclusive semileptonic b-decays

- Measured at $\Upsilon(4S)$ and at Z^0
- No new measurements at $\Upsilon(4S)$ since CLEO'97 analysis
  - $\mathcal{B}(B \to \ell \nu_\ell X) = (10.45 \pm 0.21)\%$
  - The $\mathcal{B}$ and shape of the spectrum are determined using a lepton-tagged procedure to separate primary $b \to \ell$ and secondary $b \to c \to \ell$ leptons
- Measurements at Z^0 use a variety of techniques to separate primary, secondary leptons and backgrounds:
  - tagging with second lepton, B-vertex, jet charge, displaced vertex
  - neural nets



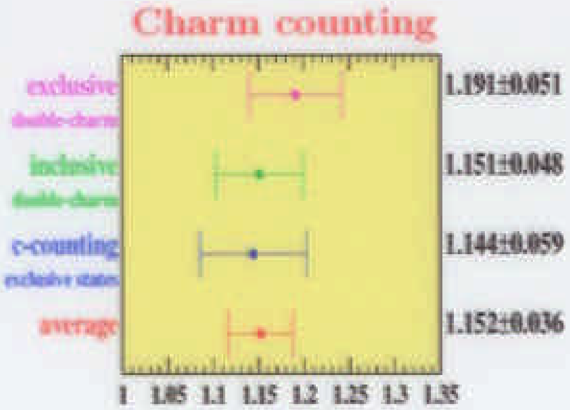


$$\mathcal{B}^{Z^0}_{b \to \ell \nu_\ell X_c} = 10.564 \pm 0.106_{stat.} \pm 0.134_{syst.} \pm 0.115_{model}$$

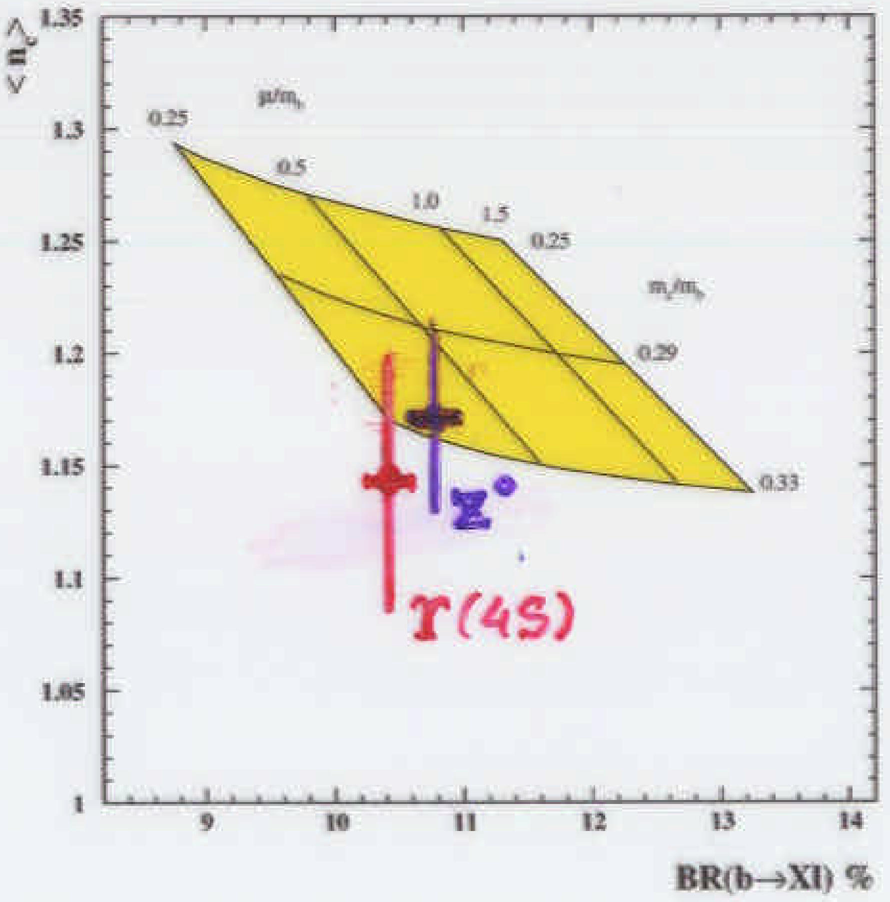
Charm counting & $\mathcal{B}(b \to \ell\nu X)$

$$\mathcal{B}^{Z^0}_{B\to\ell\nu X} = \frac{\tau_B}{\tau_b}\mathcal{B}^{Z^0}_{b\to\ell\nu X}$$

$\mathcal{B}^{\Upsilon(4S)}_{B\to\ell\nu X}$	$(10.45 \pm 0.21)\,\%$
$\mathcal{B}^{Z^0}_{B\to\ell\nu X}$	$(10.79 \pm 0.25)\,\%$
$\langle\mathcal{B}_{B\to\ell\nu X}\rangle$	$(10.59 \pm 0.16)\,\%$



G.Barker talk



New results on exclusive hadronic B decays to charm

- V $B \to D^* \pi^+ \pi^- \pi^- \pi^0$ ($\mathcal{B} \sim 2\%$) CLEO
- $\mathcal{B}(B \to D_s^+ D^{*-}) = (7.1 \pm 2.4 \pm 2.5 \pm 1.8^*) \times 10^{-3}$ BABAR
  $\mathcal{B}(B \to D_s^{*+} D^{*-}) = (2.5 \pm 0.4 \pm 0.5 \pm 0.6^*) \times 10^{-3}$
- $\mathcal{B}(B \to D^0 K^-) / \mathcal{B}(B^- \to D^0 \pi^-) = 0.081 \pm 0.014 \pm 0.011$ BELLE
  V $\mathcal{B}(B^0 \to D^{*-} K^+) / \mathcal{B}(B^0 \to D^{*-} \pi^+) = 0.062^{+0.030}_{-0.024} \pm 0.013$
  V $\mathcal{B}(B^+ \to \bar{D}^{*0} K^+) / \mathcal{B}(B^+ \to \bar{D}^{*0} \pi^+) = 0.134^{+0.045}_{-0.038} \pm 0.015$
- B decays to charmonium final states

V $\mathcal{B}(B \to \chi_{c1} K) = (7.7 \pm 1.6 \pm 0.9) \cdot 10^{-4}$ BABAR

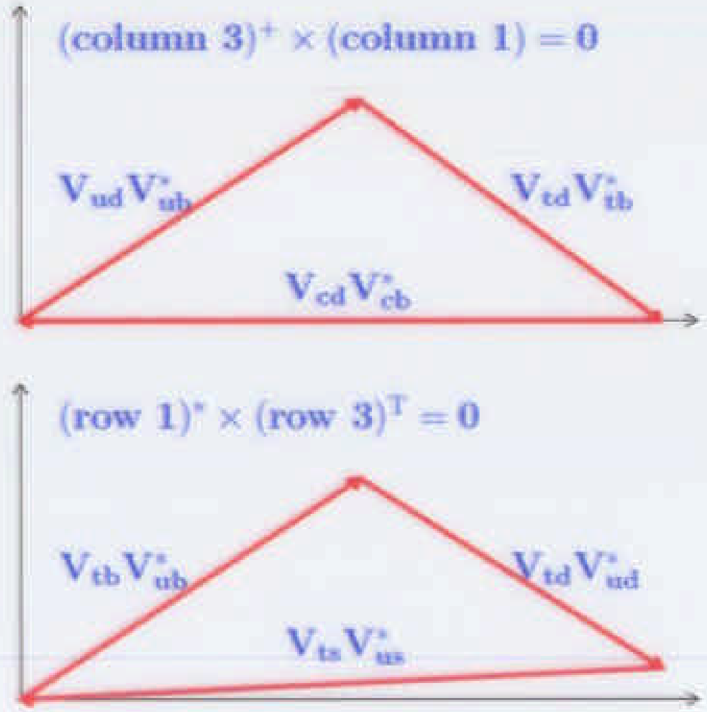
V $\mathcal{B}(B \to J/\psi\, K_1^0(1270)) = (1.4 \pm 0.4 \pm 0.4) \cdot 10^{-3}$ BELLE
$K_1^+(1270) = (1.5 \pm 0.4 \pm 0.4) \times 10^{-3}$

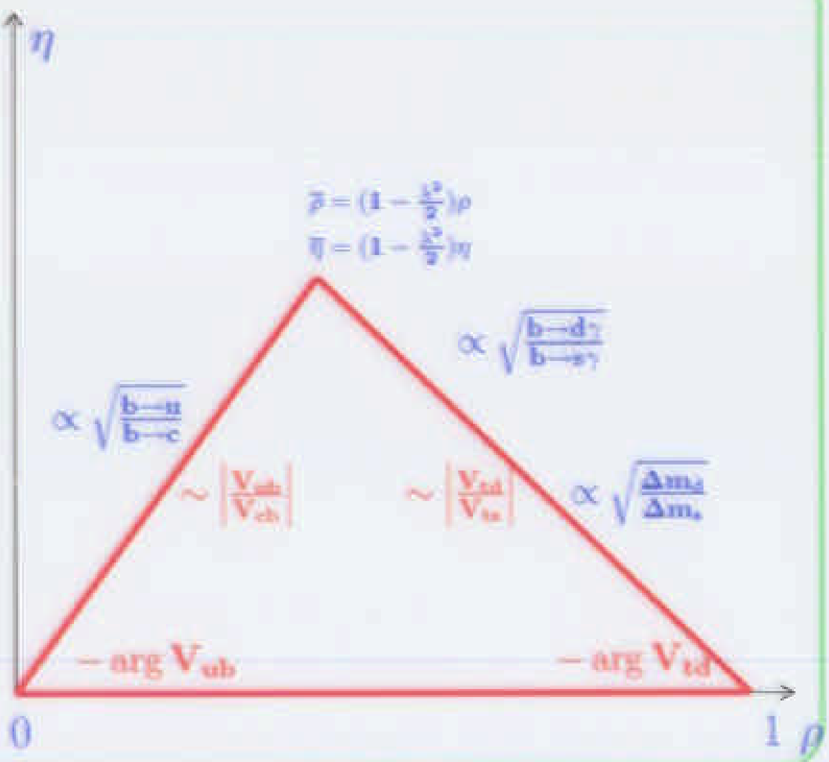
V $\mathcal{B}(B^+ \to \eta_c K^+) = (6.9^{+2.6}_{-2.1} \pm 0.8 \pm 2.0) \cdot 10^{-4}$ CLEO
$(B^0 \to \eta_c K^0) = (10.9^{+5.5}_{-4.2} \pm 1.2 \pm 3.1) \times 10^{-4}$

b

$\mathcal{SM}$ quark sector: V_{CKM}

Unitary matrix	Wolfenstein parametrisation
4 parameters	λ, $\mathbf{A}$, ρ, η
3 angles & 1 phase	$\lambda = \sin\theta_C$





$|V_{cb}|$ semileptonic $b \to c$ transitions

From inclusive semileptonic branching ratio $\mathcal{B}(B \to X_c \ell \nu_\ell)$ and τ_B

$$|V_{cb}| = (40.66 \pm 0.36) \times 10^{-3} \times \left(1 \pm 0.015_{pert.} \pm 0.010_{m_b} \pm 0.012_{1/m_Q^3}\right)$$

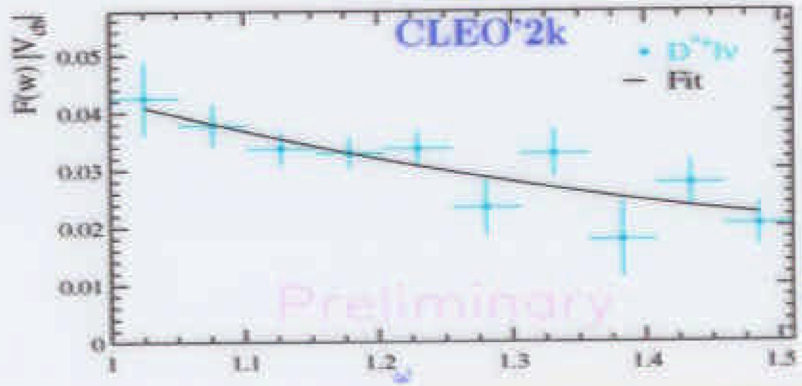
I.Bigi, M.Shifman & N.Uraltsev

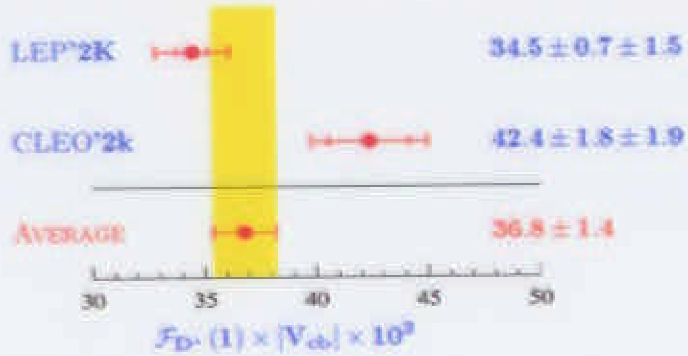
From exclusive decay $B \to D^* \ell^- \nu_\ell$, using HQET

$$\frac{d}{d\omega}\Gamma(B \to D^* \ell^- \nu_\ell) = \mathcal{K}(\omega) \cdot \mathcal{F}^2_{D^*}(\omega) \cdot |V_{cb}|^2$$

$$\mathcal{F}_{D^*}(1) = 0.880 \pm 0.035_{excit.} \pm 0.010_{pert.} \pm 0.025_{1/m_Q^3}$$

N.Uraltsev





$$|V_{cb}| = (41.8 \pm 1.6_{exp.} \pm 2.1_{th.}) \times 10^{-3}$$

$V_{ub} = |V_{ub}| \cdot e^{-i\gamma}$ **2 parameters - magnitude and phase**

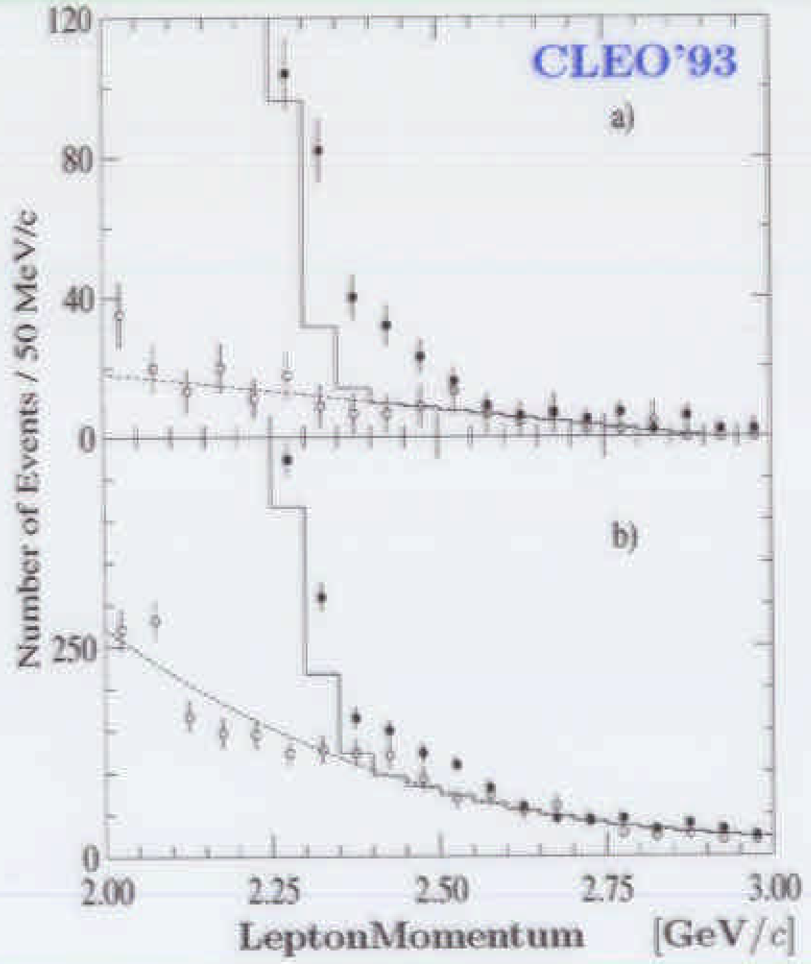
Magnitude is measured from charmless semileptonic b decays

$$|V_{ub}|^2 \ll |V_{cb}|^2 \implies \text{rare decays} \implies \begin{cases} \text{high statistics} \\ \text{large background from } b \to c \end{cases}$$

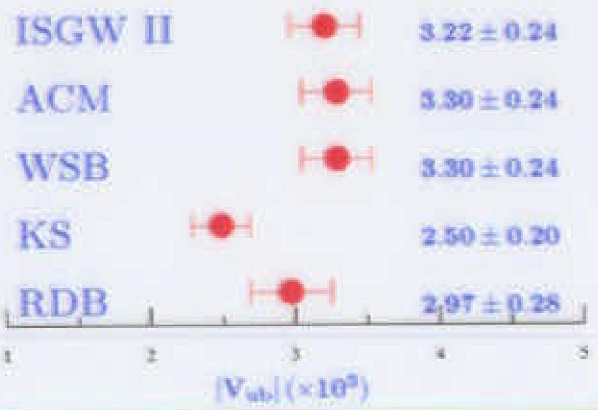
Methods:

- **End-point analysis of inclusive** $b \to X \ell \nu_\ell$ **lepton spectra**
- **Extend** $\mathcal{PS}$ **and "cut" on** M_X **and/or** ν_ℓ
- **Analysis of exclusive** $b \to u \ell \nu_\ell$ **modes**

$|V_{ub}|$ end-point analysis of inclusive semileptonic spectra

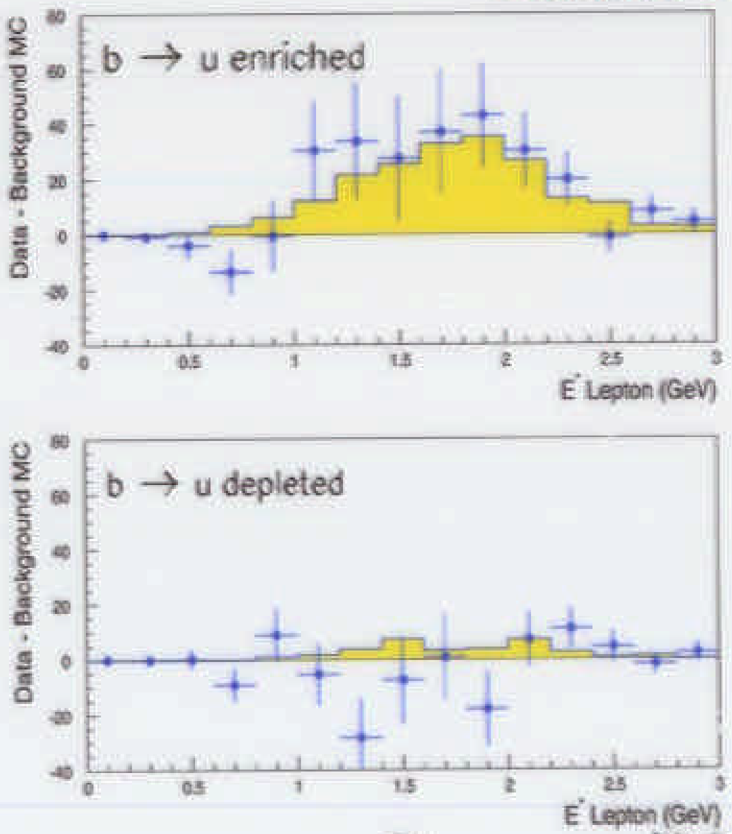


- Only a tiny part of $\mathcal{PS}$ is analysed
- Need models to extrapolate to the whole $\mathcal{PS}$
- Light-cone distributions the same as for $b \to s\gamma$ - way to reduce the uncertainties? T.Mannel & S.Recksiegel



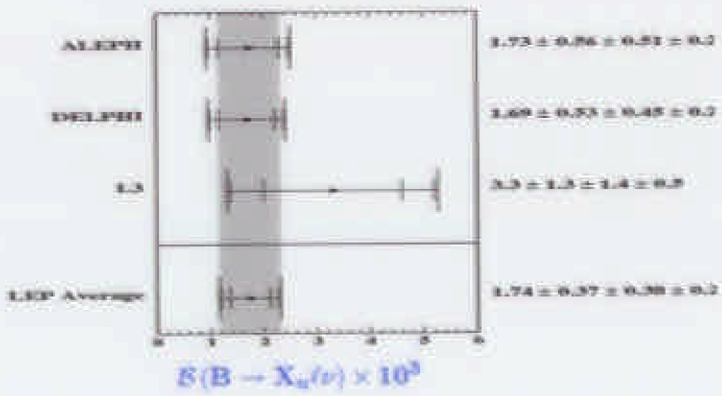
$|V_{ub}|$ semileptonic charmless decays $b \to \ell\nu_\ell X_u$

DELPHI'2k



E^*_ℓ [GeV]

- "Cut" on $M_X < M_X^{cut}$: Utilize $M_{X_u}^{b\to u} < M_{X_c}^{b\to c}$
- Almost all lepton spectrum is available
- Sensitive to $M_{X_u}^{b\to u}$ distribution, but additional uncertantanties ($\leq 10\%$ if $M_X^{cut} \simeq 1.5\ GeV/c^2$) I.Bigi, R.Dukeman & N.Uraltsev

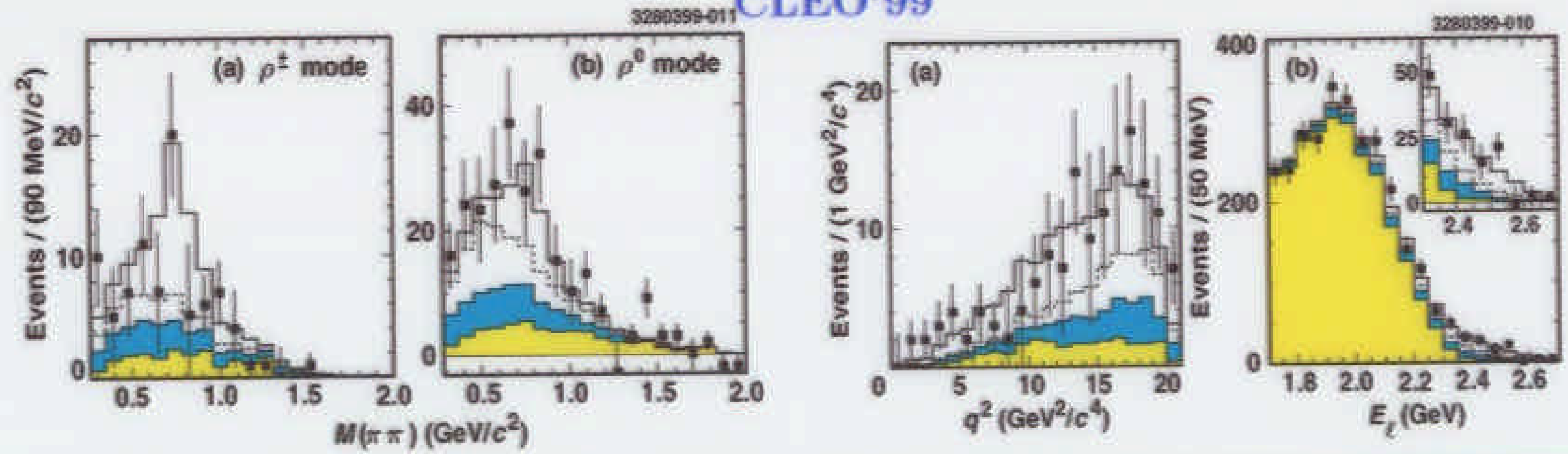


$|V_{ub}| = (40.9 \pm 6.1 \pm 1.9) \times 10^{-4}$

$|V_{ub}|$ exclusive semileptonic charmless decays

	$\mathcal{B}(B \to \pi \ell \nu_\ell) \times 10^4$	$\mathcal{B}(B \to \rho \ell \nu_\ell) \times 10^4$
CLEO'96	$1.8 \pm 0.4 \pm 0.3 \pm 0.5$	$2.5 \pm 0.4^{+0.5}_{-0.7} \pm 0.5$
CLEO'99		$2.69 \pm 0.41^{+0.35}_{-0.40} \pm 0.50$

CLEO'99



$|V_{ub}|^{(96)}_{\pi+\rho} = \left(3.3 \pm 0.2^{+0.3}_{-0.4} \pm 0.7\right) \times 10^{-3}$

$|V_{ub}|^{(99)}_{\rho} = \left(3.23 \pm 0.24^{+0.23}_{-0.26} \pm 0.58\right) \times 10^{-3}$

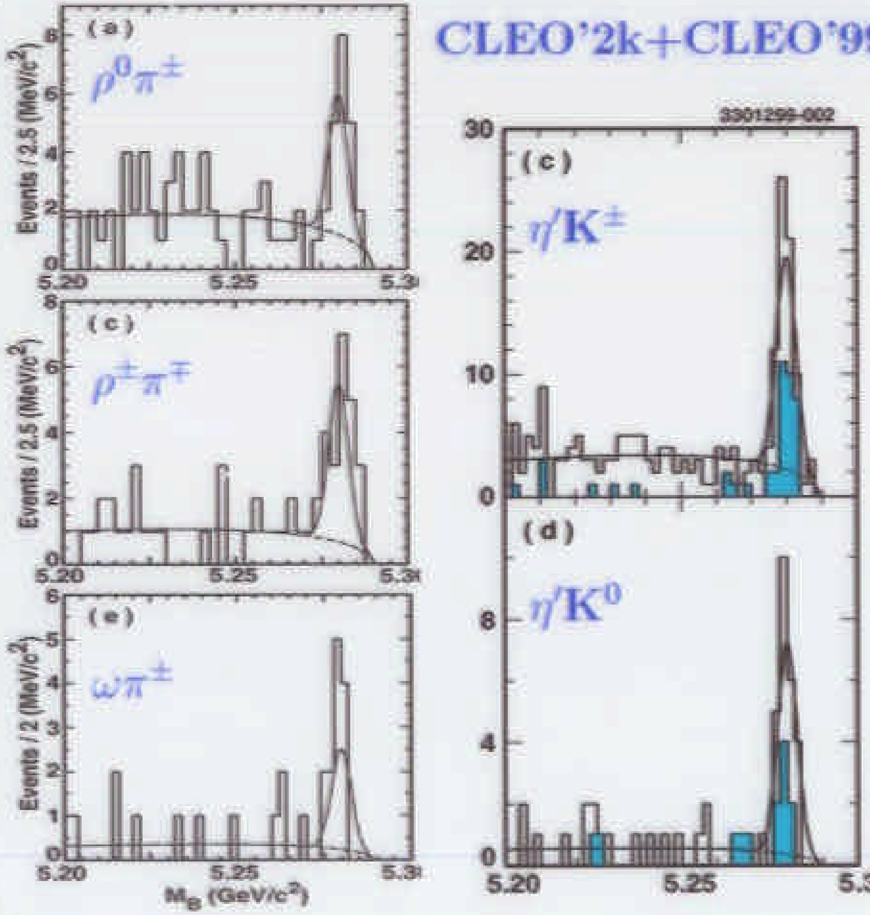
$\mathcal{B}\left(B^0 \to \rho^- \ell^+ \nu\right)^{(96+99)} = \left(2.57 \pm 0.29^{+0.33}_{-0.46} \pm 0.41\right) \times 10^{-4}$

$|V_{ub}|^{(96+99)}_{\rho} = \left(3.25 \pm 0.14^{+0.21}_{-0.29} \pm 0.55\right) \times 10^{-3}$

Amplitudes from {tree $b \to u$; penguin $b \to dg$, sg} contribute

arg V_{ub} — charmless hadronic B-decays

CLEO'2k+CLEO'99



ϕK

CLEO $\times 10^{-6}$

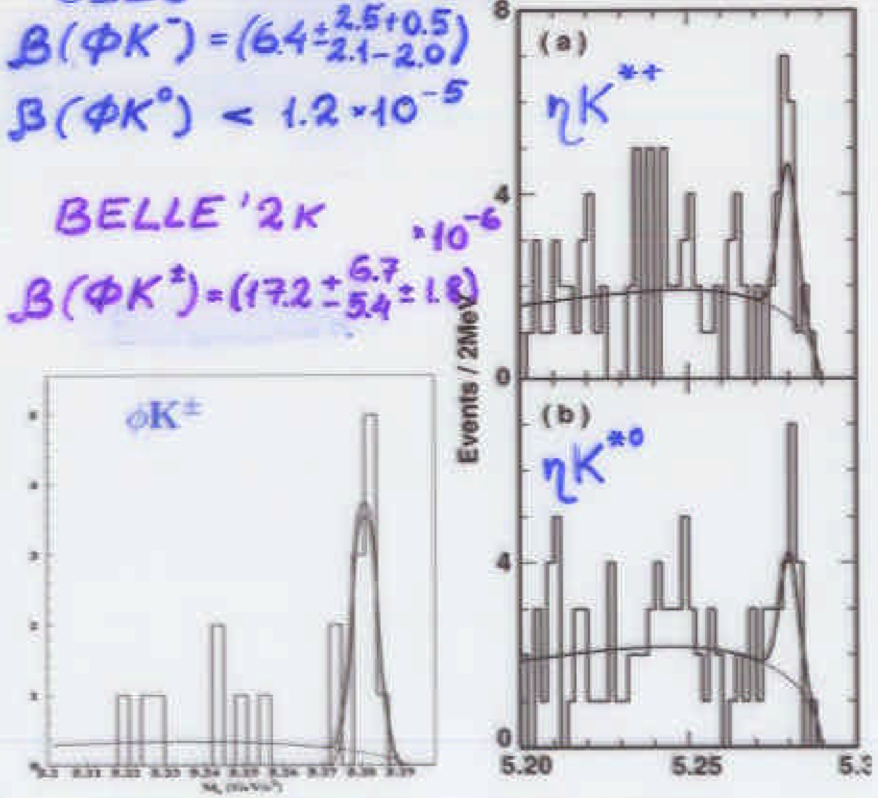
$\mathcal{B}(\phi K^-) = (6.4^{+2.5+0.5}_{-2.1-2.0})$

$\mathcal{B}(\phi K^0) < 1.2 \times 10^{-5}$

BELLE '2K $\times 10^{-6}$

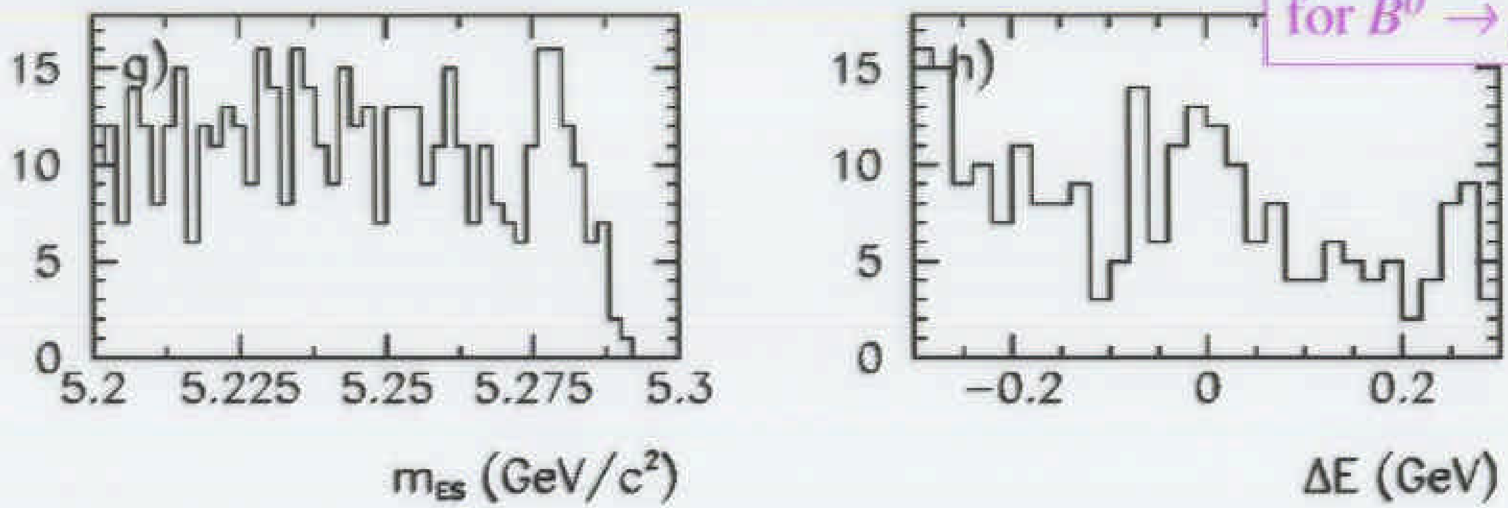
$\mathcal{B}(\phi K^\pm) = (17.2^{+6.7}_{-5.4} \pm 1.8)$

CLEO'99

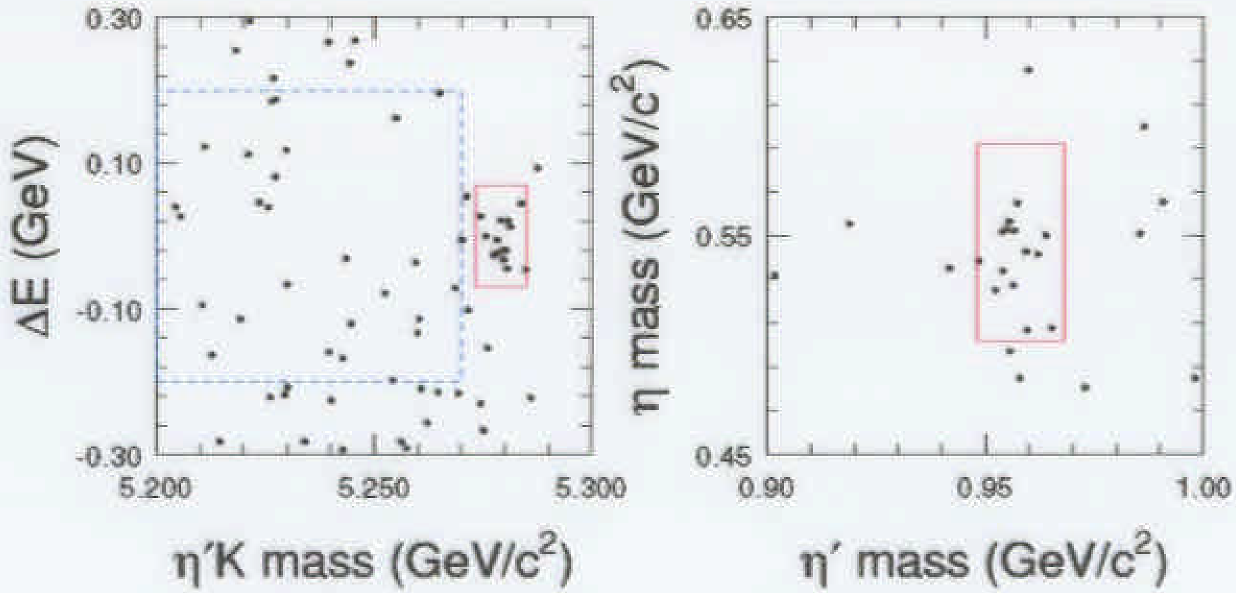


Selected Results

PRELIMINARY



m_{ES} and ΔE for $B^0 \to \rho^{\pm}\pi$



m_{ES} vs. ΔE for $B^+ \to \eta' K^+$

arg V_{ub} — charmless hadronic B-decays

$\mathcal{B}(B \to hh) \times 10^6$ (UL 90% CL)

	CLEO'99+2k	BELLE'2k	BABAR'2k
$\rho^0\pi^\pm$	$10.4^{+3.3}_{-3.4} \pm 2.1$		$24 \pm 8 \pm 3$
$\rho^\pm\pi^\mp$	$27.6^{+8.4}_{-7.4} \pm 4.2$		$49 \pm 13 \, ^{+6}_{-5}$
$\omega\pi^+$	$11.3^{+3.3}_{-2.9} \pm 1.4$		< 24
$\eta' K^\pm$	$80^{+10}_{-9} \pm 7$		$62 \pm 18 \pm 8$
$\eta' K^0$	$89^{+18}_{-16} \pm 9$		< 112
$\eta K^{*\pm}$	$26.4^{+9.6}_{-8.2} \pm 3.3$		
ηK^{*0}	$13.8^{+5.5}_{-4.6} \pm 1.6$		
$\phi K^{\pm}$	~~< 5.9~~ → $6.4^{+2.5}_{-2.1}\,^{+0.5}_{-2.0}$! pure penguin	$17.2^{+6.7}_{-5.4} \pm 1.8$	

		Exp.
$\frac{\mathcal{B}(B \to \omega\pi^\pm)}{\mathcal{B}(B \to \rho^0\pi^\pm)}$	1	0.89 ± 0.37
$\frac{\mathcal{B}(B \to \rho^\pm\pi^\mp)}{\mathcal{B}(B \to \rho^0\pi^\pm)}$	4	2.64 ± 0.95

Lipkin sum rule

$\frac{\mathcal{B}(B \to \eta' K^\pm) + \mathcal{B}(B \to \eta K^\pm)}{\mathcal{B}(B \to K^\pm\pi^0) + \mathcal{B}(B \to K^0\pi^\pm)}$	1	2.7 ± 0.6

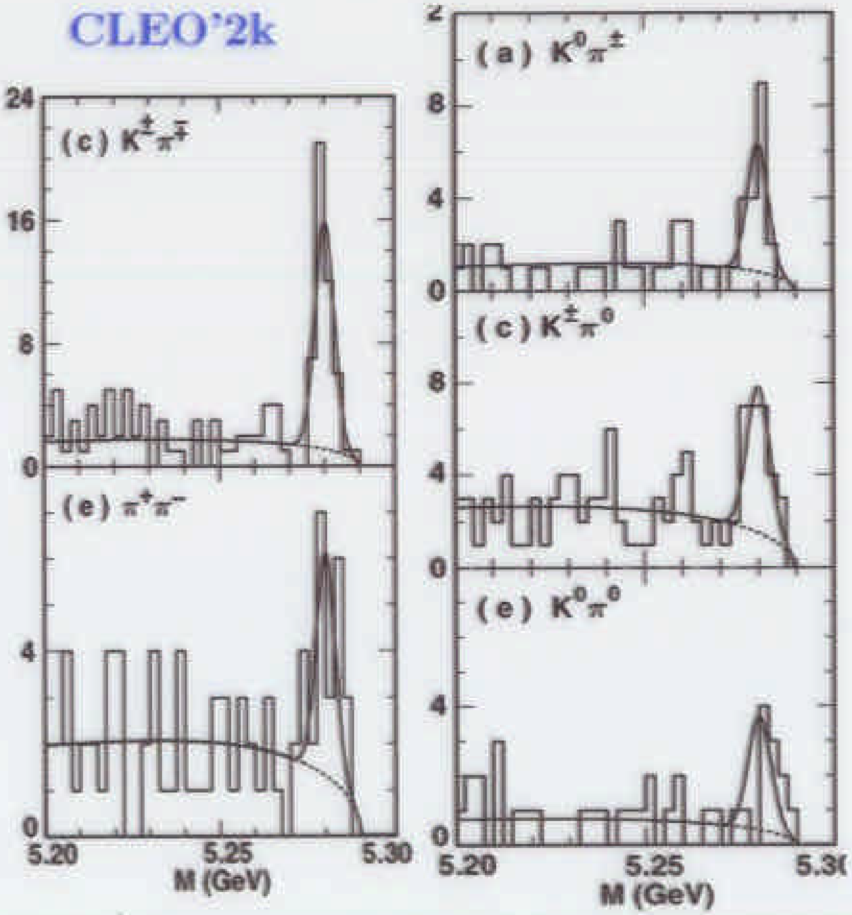
-
- Neither $B \to \eta' V$ nor $B \to \eta P$ observed
- Difficult to explain huge $B \to \eta' K$

need better understanding!

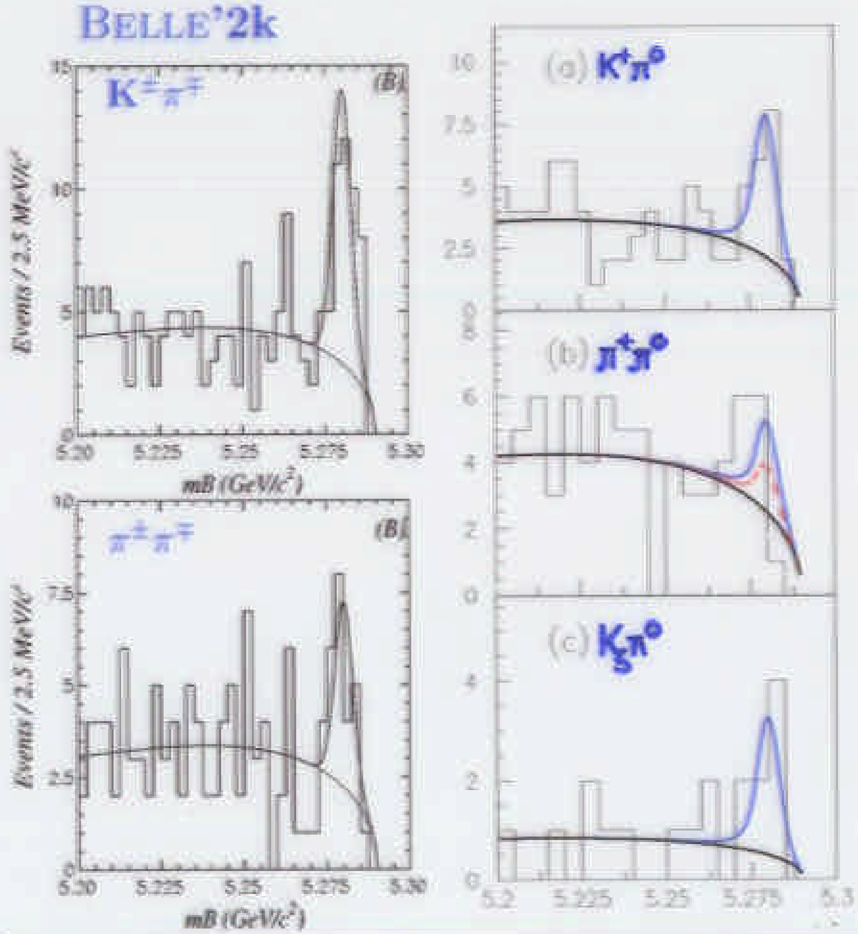
$\arg V_{ub}$

B-decays to $\pi\pi$ & $K\pi$

CLEO'2k



BELLE'2k



K/π separation is very important for $B \to \pi^{+}\pi^{-}$ signal extraction

arg V_{ub} — CHARMLESS HADRONIC B-decays ($K\pi / \pi\pi$)

b

$\mathcal{B}(B \to PP) \cdot 10^6$ (UL 90% CL)

	CLEO'2K	BELLE'2K	BaBar'2K	⟨…⟩
$\pi^\pm\pi^\mp$	$4.3^{+1.6}_{-1.4} \pm 0.5$	$6.3^{+3.9}_{-3.5} \pm 1.6$	$9.3^{+2.6}_{-2.3}{}^{+1.2}_{-1.4}$	5.5 ± 1.3
$\pi^\pm\pi^0$	< 12.7	< 11		
$\pi^0\pi^0$	< 5.7			
$K^\pm\pi^\mp$	$17.2^{+2.5}_{-2.4} \pm 1.2$	$17.4^{+5.1}_{-4.6} \pm 3.4$	$12.5^{+3.0}_{-2.6}{}^{+1.3}_{-1.7}$	15.5 ± 2
$K^0\pi^\pm$	$18.2^{+4.6}_{-4.0} \pm 1.6$	$16.6^{+9.8}_{-7.8}{}^{+2.2}_{-2.4}$		17.8 ± 4.1
$K^\pm\pi^0$	$11.6^{+3.0}_{-2.7}{}^{+1.4}_{-1.3}$	$18.8^{+5.5}_{-4.9} \pm 2.3$		13.0 ± 2.7
$K^0\pi^0$	$14.6^{+5.9}_{-5.1}{}^{+2.4}_{-3.3}$	$21.0^{+9.3}_{-7.8}{}^{+2.5}_{-2.3}$		16.8 ± 5.1

NEED MORE DATA !

Present data favour
large arg V_{ub} and FSI

"t − row" — 3 elements, 4 parameters

$|V_{tb}|$ $\begin{cases} \text{from unitarity} \rightarrow 1 \\ t-\text{decays} \end{cases}$

$|V_{ts}|$ $\begin{cases} B_s^0 - \bar{B}_s^0 \text{ oscillation}(+m_t) \\ b \rightarrow s\gamma \text{ penguins} \\ \frac{\Delta\Gamma_s}{\Gamma_s} \end{cases}$

$|V_{td}|$ $\begin{cases} B_d^0 - \bar{B}_d^0 \text{ oscillation}(+m_t) \\ b \rightarrow d\gamma \text{ penguins} \end{cases}$

$\arg V_{td}$ $\mathcal{A}_{CP}^{B\rightarrow J\psi K_S^0}(t)$

- Extraction of $|V_{tb}|$ is model-free
- Separate extraction of $|V_{td}|$ and $|V_{ts}|$ from oscillations and/or penguins suffers from large uncertanties
- The ratio $\frac{|V_{td}|}{|V_{ts}|}$ has significantly smaller theoretical uncertanty
- Extraction of $\arg V_{tb}$ is theoretically clean

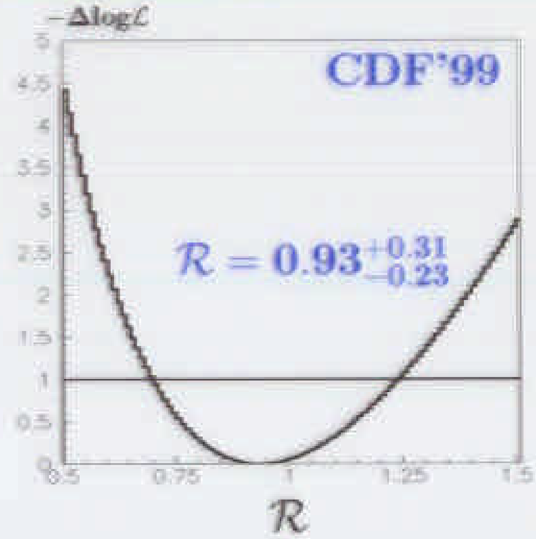
$|V_{tb}|$

Beauty count per t-decay:

$$\mathcal{R} = \frac{|V_{tb}|^2}{|V_{tb}|^2+|V_{ts}|^2+|V_{td}|^2}$$

$$|V_{tb}| = 0.96^{+0.16}_{-0.12}$$

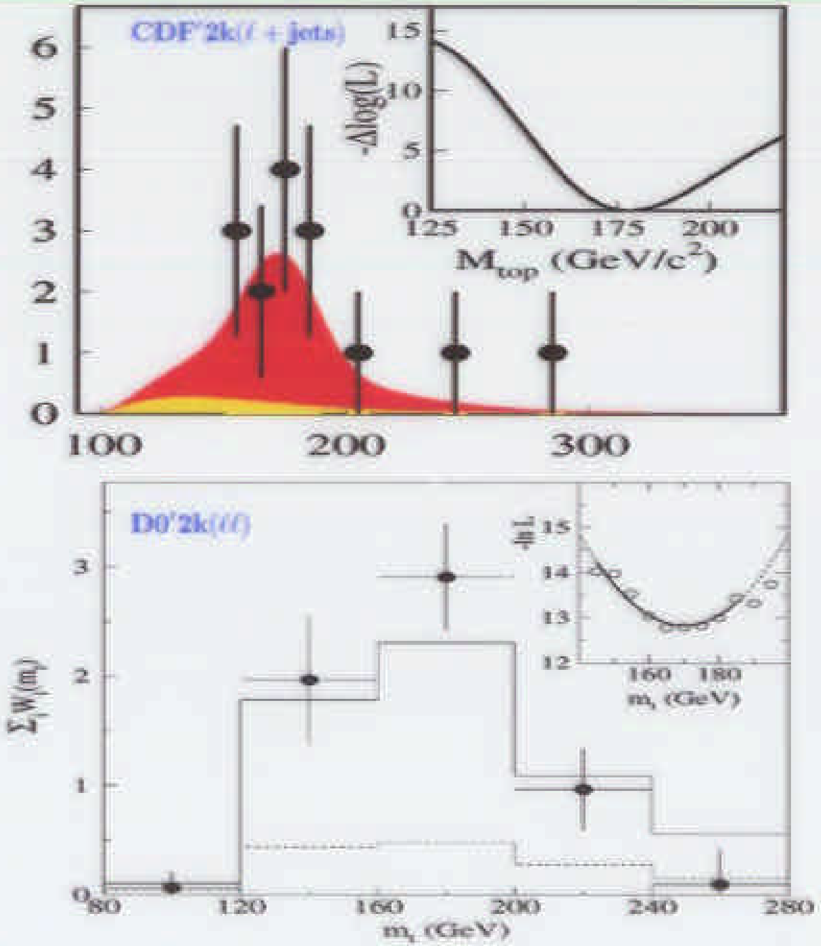
$$|V_{tb}| > 0.78 \ (90\ \%\ \text{CL})$$



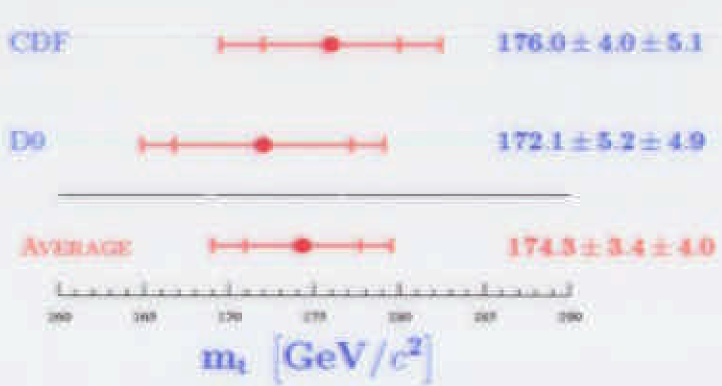
- **Single top production** allows $|V_{tb}|$ extraction. Present sensitivity is not yet sufficient

	σ_t [pb]
Theory ($|V_{tb}| = 1$)	2.43 ± 0.038
CDF	< 13.5 (95 % CL)
D0	< 52 (95 % CL)

m_t essential component for extraction of $|V_{td}|$ & $|V_{ts}|$



CDF,D0 all channels: $\ell\ell, \ell -$ jets, all.had.



Tevatron Run II:

$L \sim 2 fb^{-1}$

- 40% inclrease in $\sigma_{t\bar{t}}$
- systematic errors ≤ 2 GeV/c^2
- overall error < 3 GeV/c^2

$|V_{td}|$ $\qquad$ $B_d^0 - \bar{B}_d^0$ oscillations

$$\Delta m_{(d,s)} = \frac{G_F^2}{6\pi^2} m_t^2 m_{B_{d,s}} \eta_{B_{d,s}}^{QCD} f_{B_{d,s}}^2 B_{B_{d,s}} \mathcal{F}\left(\frac{m_t^2}{m_W^2}\right) |V_{t(d,s)}|^2 |V_{tb}|^2$$

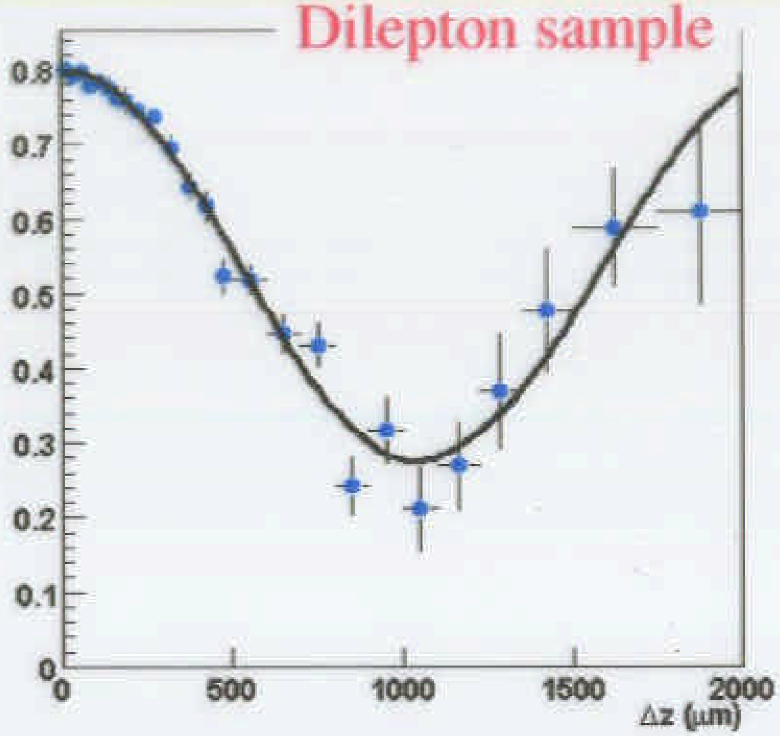
$$x_{d,s} = \frac{\Delta \Gamma_{d,s}}{\Gamma_{d,s}} \quad y_{d,s} = \frac{\Delta m_{d,s}}{\Gamma_{d,s}} \quad \chi_{d,s} = \frac{x_{d,s}^2 + y_{d,s}^2}{2(1 + x_{d,s}^2)} \cdot \frac{1}{2|p||q|}$$

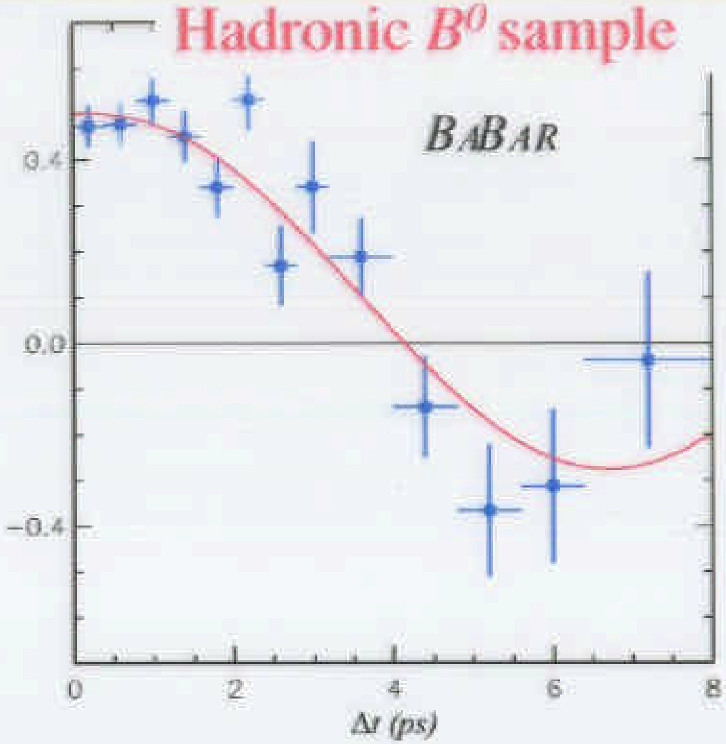
Time-integrated rates at $\Upsilon(4S)$ are sensitive to χ

- dilepton analysis limited by $\Lambda = \left(1 + \frac{f_0 \tau_0^2}{f_+ \tau_+^2}\right)^{-1}$ $\quad \sigma(\chi) \stackrel{\Lambda}{\approx} 14\%$
- reconstruction of $B \to D^{*+} \ell^- \nu$ with partial D^* recontruction drastically reduces dependence on Λ
- CLEO'2k analysis: $B^0 \to D^* \pi, D^* \rho$ reconstruction with partial D^* reconstruction
  - $\chi_d = 0.189 \pm 0.013 \pm 0.014$
  - $\Delta m_d = 0.488 \pm 0.040$
    (neglecting $|\mathcal{R}e(\epsilon_B)|$ and $|y_d|$)
  - $|y_d| < 0.41$ $\quad |\mathcal{R}e(\epsilon_B)| < 3.4\ \%$
    (using world average for Δm_d)

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

PRELIMINARY





$\Delta m_d = 0.507 \pm 0.015\ (\text{stat.}) \pm 0.022\ (\text{syst.})\ \hbar\ \text{ps}^{-1}$ dilepton sample

$\Delta m_d = 0.516 \pm 0.031\ (\text{stat.}) \pm 0.018\ (\text{syst.})\ \hbar\ \text{ps}^{-1}$ hadronic sample

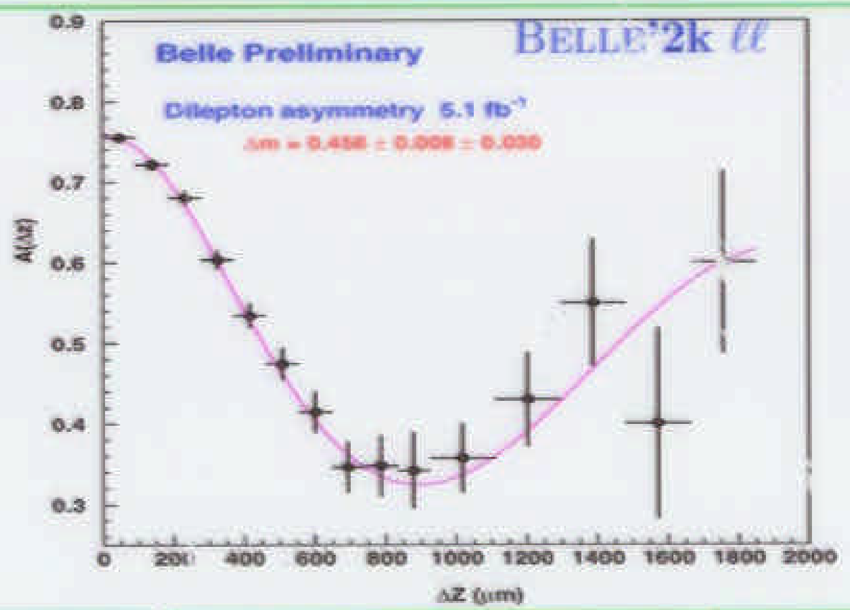
$\Delta m_d = 0.508 \pm 0.020\ (\text{stat.}) \pm 0.022\ (\text{syst.})\ \hbar\ \text{ps}^{-1}$ $D^*l\nu$ sample

$|V_{td}|$ **time evolution of $B^0_d - \bar{B}^0_d$ oscillations**

- ALEPH, CDF, DELPHI, L3, OPAL, SLD performed time-dependent measurement of $B^0_d - \bar{B}^0_d$ oscillations using ℓ/ℓ; D^*/ℓ, Qjet; ℓ/Qjet; vtx/Qjet; $D\ell$/SST; K/Qjet + pol; dipole/Qjet + pol; $D + \ell$/Qjet + pol; ...
- $\Delta m_d^{CDF+LEP+SLD} = (0.486 \pm 0.015) ps^{-1}$

NEW W.A.

$<\Delta m_d> = 0.492 \pm 0.011$

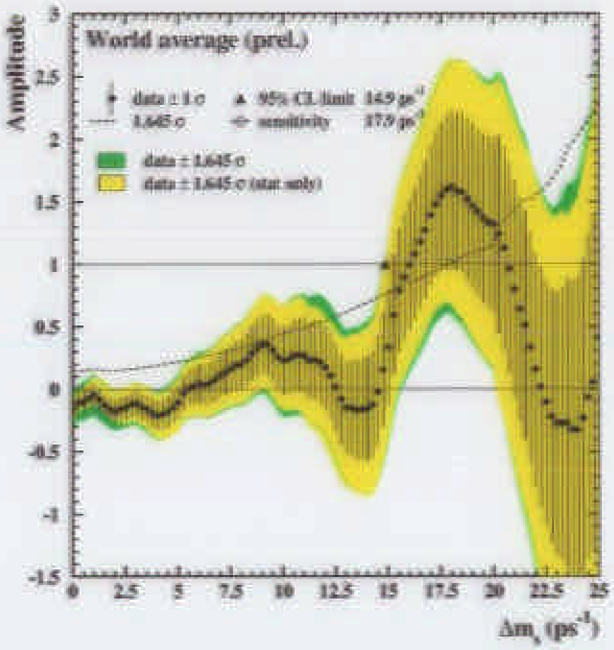


$\Delta m_d = 0.456 \pm 0.008 \pm 0.030$ ps^{-1}

First results of BABAR and BELLE are comparable to <...>

$|V_{ts}|$ time evolution of $B_s^0 - \bar{B}_s^0$ oscillations

	Excluded (95% CL) $[ps^{-1}]$	Sensitivity $[ps^{-1}]$
ALEPH	< 10.6	12.8
CDF	< 5.8	
DELPHI	< 7.3	10.6
OPAL	< 5.2	6.0
SLD	< 7.6 [11.8, 14.8]	13
Combined	< 14.9	17.9



Substantial improvement of sensitivity to Δm_s (last year was $14.7 ps^{-1}$)

Lifetime Difference: $\Delta\Gamma_s$
(CDF, LEP average)
preliminary

$\Delta\Gamma_s/\Gamma_s = 0.16^{+0.16}_{-0.13}$ $\quad \frac{\Delta\Gamma_s}{\Gamma_s} < 0.31$ (95% CL)

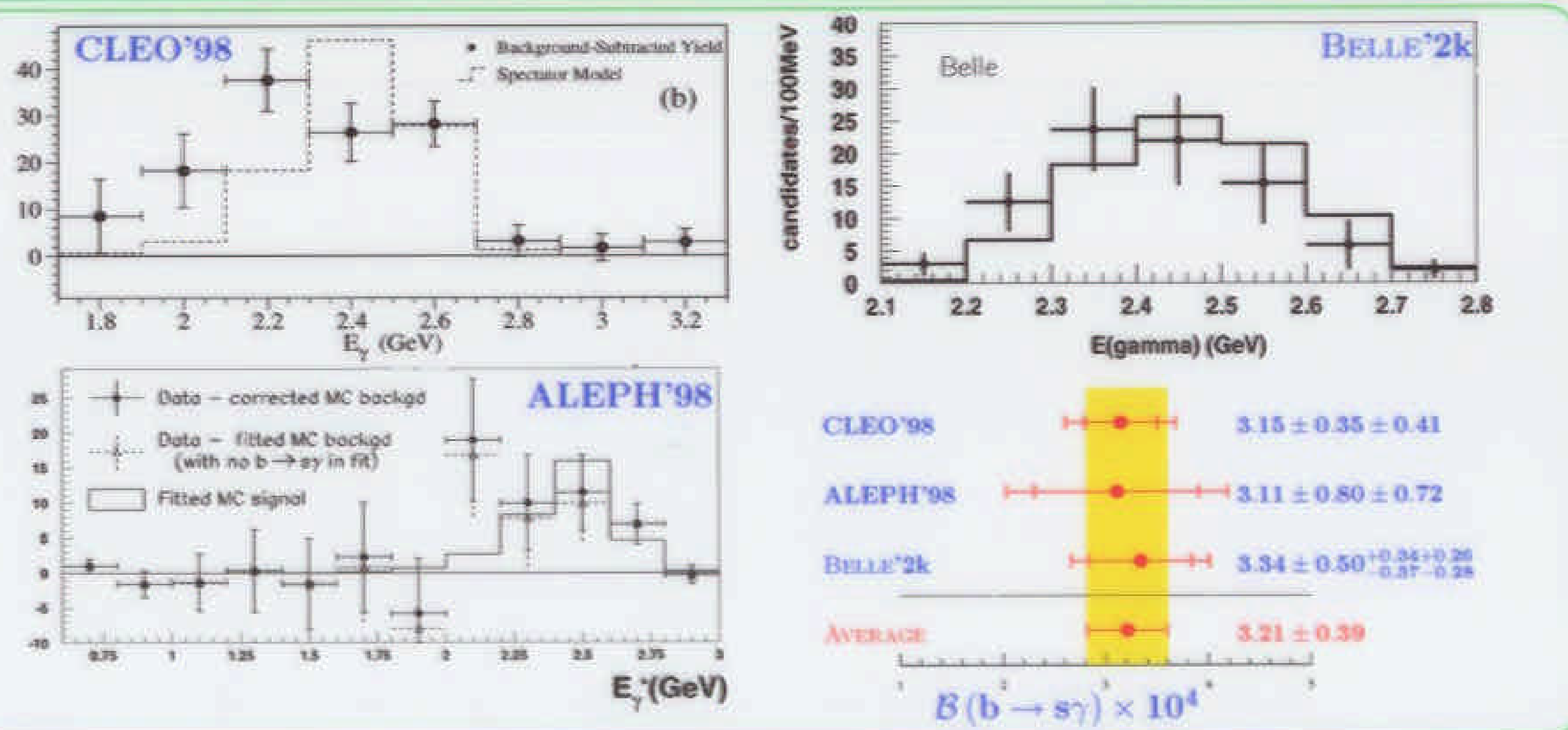
(assuming $\tau(B^0) = \tau(B_s^0)$)

Tevatron Run II data and HERA-B are important!

$|V_{ts}|$ inclusive $b \to s\gamma$ penguins

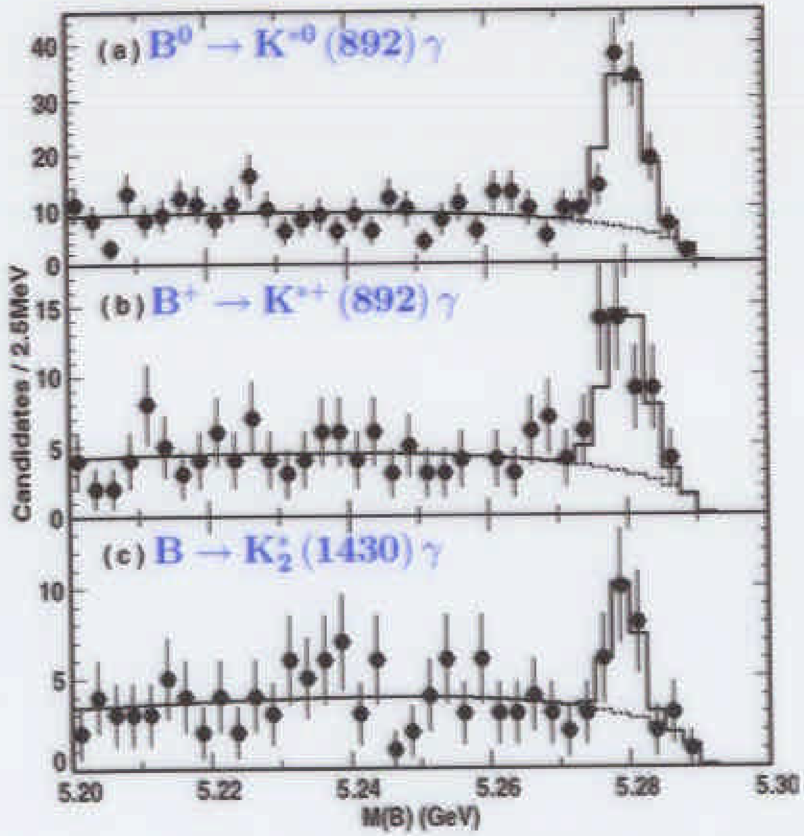
- Need models to extrapolate to the whole $\mathcal{PS}$
- End-point light-cone distributions the same as for $b \to u$ - could be used to reduce some common uncertainties

T.Mannel & S.Recksiegel

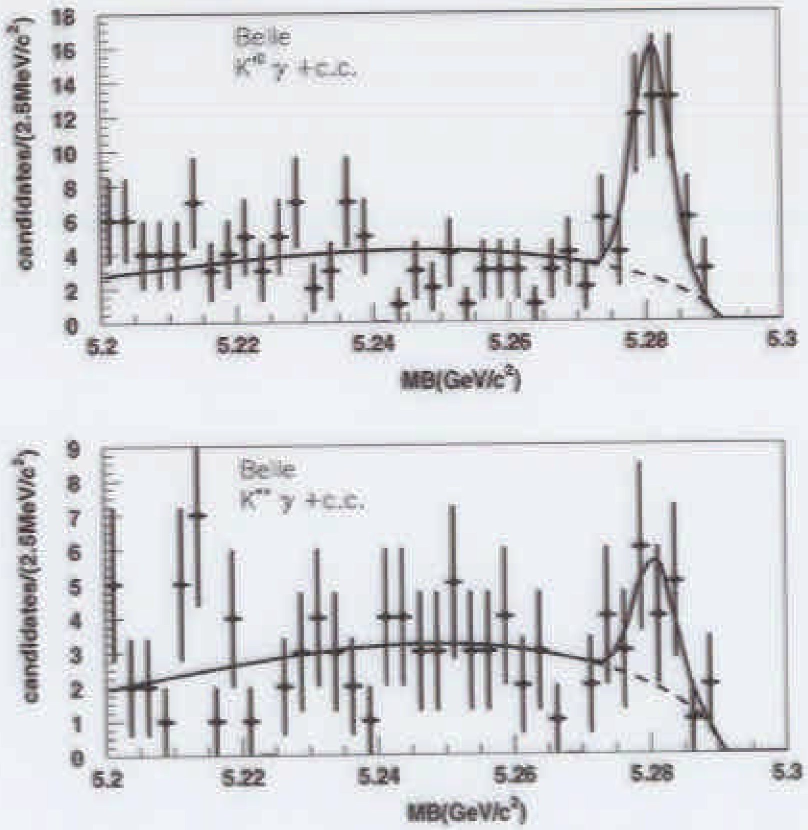


$|V_{ts}|$ exclusive $b \to s\gamma$ penguins

CLEO'99



BELLE'2k



Clearly seen with excellent EM calorimeters and high statistics!

Signal Estimation

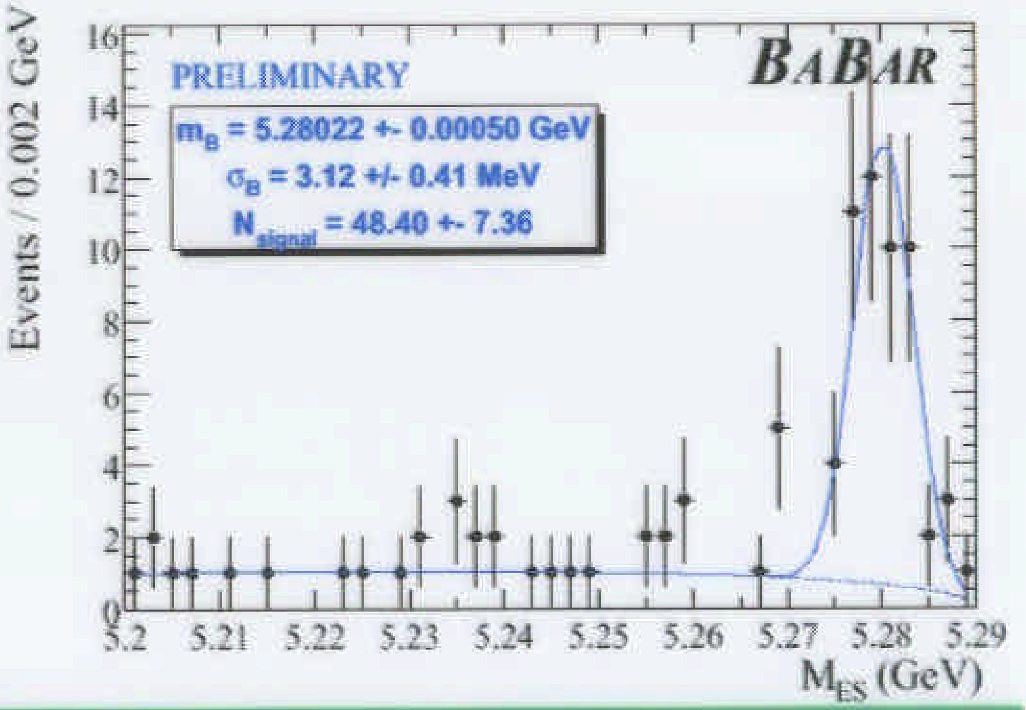
PRELIMINARY

Use Argus Function for background, gaussian for signal

Background shape determined from off-resonance data

Fit with fixed background shapeand floating signal mean and width

N_{signal} = 48 +- 7 events

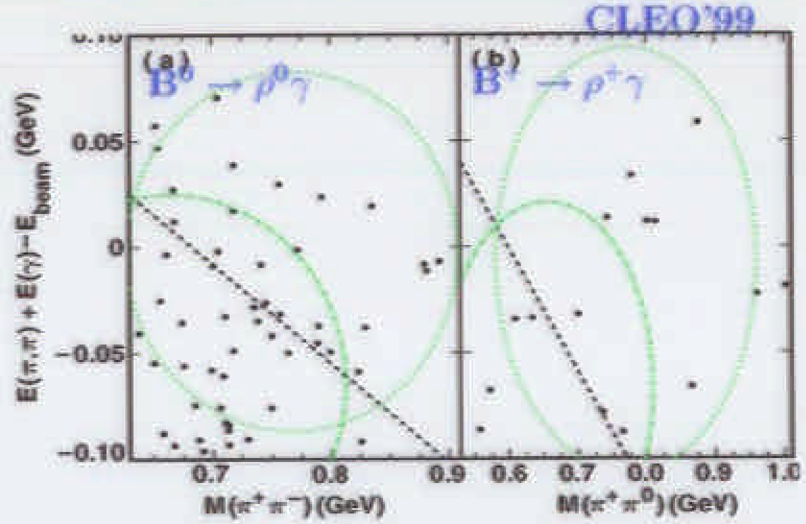


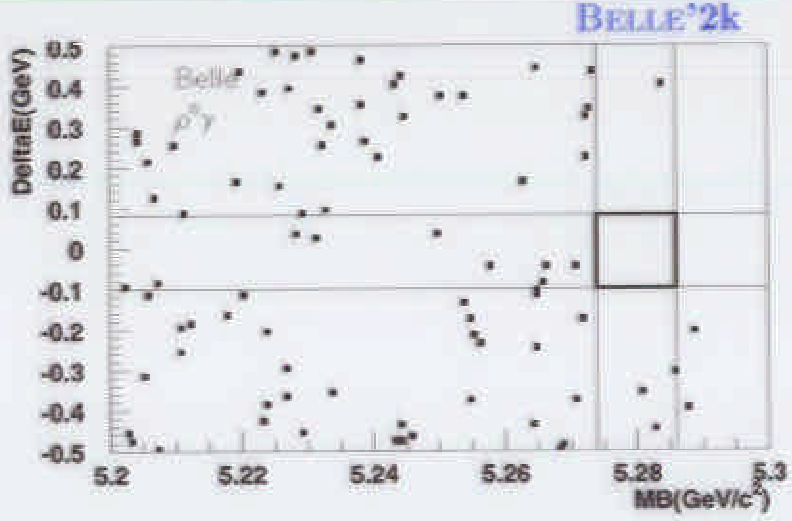
$|V_{ts}|$ exclusive $b \to s\gamma$ penguins

$\mathcal{B}(B \to H_s\gamma) \times 10^5$	
$K^{*0}\gamma$	
CLEO'99	$4.55^{+0.72}_{-0.68} \pm 0.34$
BELLE'2k	$4.94 \pm 0.93 \pm ^{+0.55}_{-0.52}$
BABAR'2k	$5.4 \pm 0.8 \pm 0.5$
$K^{*+}\gamma$	
CLEO'99	$3.76^{+0.89}_{-0.83} \pm 0.28$
BELLE'2k	$2.87 \pm 1.20 \pm ^{+0.55}_{-0.40}$
BABAR'2k	soon
$K_2^*(1430)\gamma$	
CLEO'99	$1.66^{+0.59}_{-0.53} \pm 0.13$
BABAR'2k	soon
BELLE'2k	

$|V_{td}|$ exclusive $b \to d\gamma$ penguins

Search for exclusive $b \to d\gamma$ was performed by CLEO and BELLE





$$\frac{\mathcal{B}(B \to \rho(\omega)\gamma)}{\mathcal{B}(B \to K^*\gamma)} < 0.32$$

$$\frac{\mathcal{B}(B \to \rho\gamma)}{\mathcal{B}(B \to K^*\gamma)} < 0.28$$

K/π separation is essential for extraction of $B \to \rho\gamma$ mode

b

$\frac{|V_{td}|}{|V_{ts}|}$ ratio of exclusive $\frac{b \to d\gamma}{b \to s\gamma}$ penguins

$$\frac{\mathcal{B}(B \to \rho\gamma)}{\mathcal{B}(B \to K^{*}\gamma)} = \xi \times \left|\frac{V_{td}}{V_{ts}}\right|^2$$

$$\xi = \begin{cases} 0.58 & \text{Ali, Brown \& Simma} \\ 0.77 & \text{Narison} \\ 0.81 \pm 0.09 & \text{Soares} \end{cases}$$

using $\xi = 0.58$ and BELLE result

$$\left|\frac{V_{td}}{V_{ts}}\right| < 0.69$$

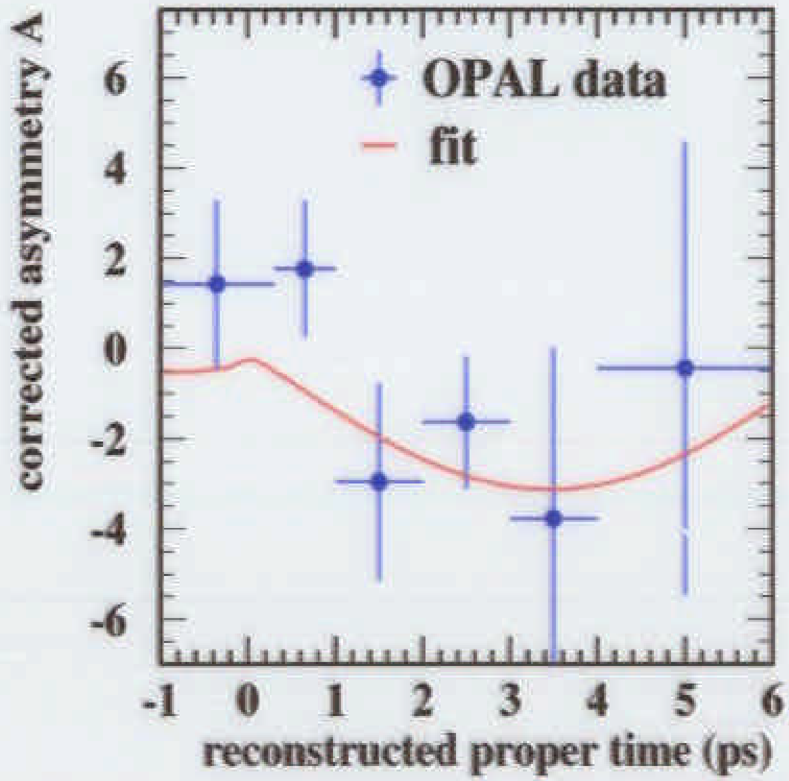
$\arg V_{td}$ — $\mathcal{CP}$-asymmetry for $B \to J/\psi K^0_S$

$$\mathcal{A}_{CP}^{J/\psi K^0_S}(t) = \frac{\mathcal{N}(B^0 \to J/\psi K^0_S) - \mathcal{N}(\bar{B}^0 \to J/\psi K^0_S)}{\mathcal{N}(B^0 \to J/\psi K^0_S) + \mathcal{N}(\bar{B}^0 \to J/\psi K^0_S)}$$

$$= \sin(2 \arg V_{td}) \times \sin(\Delta m_d t)$$

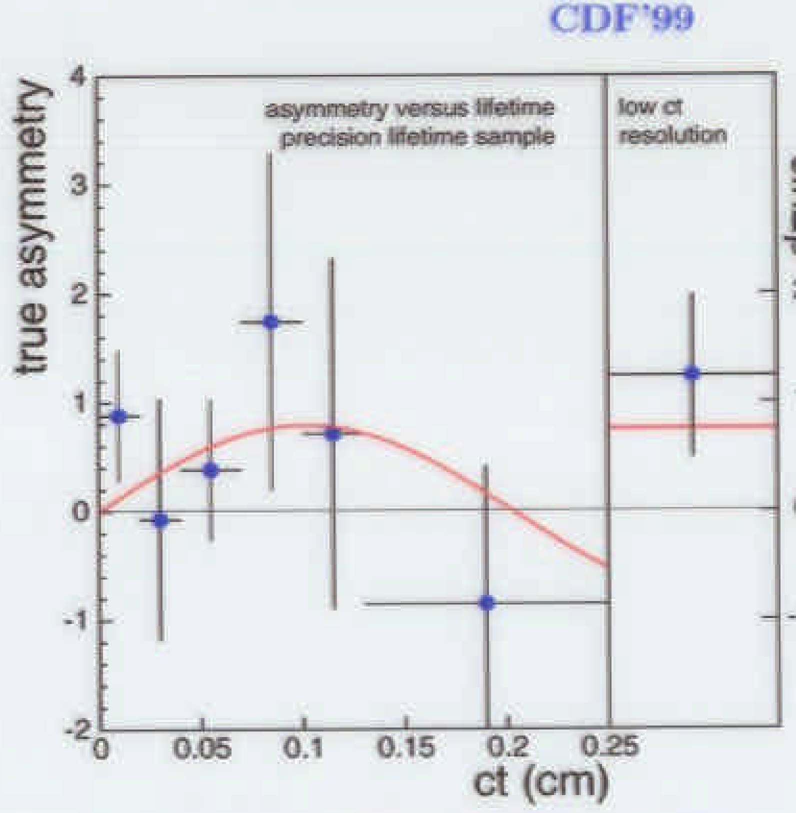
$$= -\sin(2\beta) \times \sin(\Delta m_d t)$$

	$-\sin(2 \arg V_{td})$
OPAL'98	$3.2^{+1.8}_{-2.0} \pm 0.5$

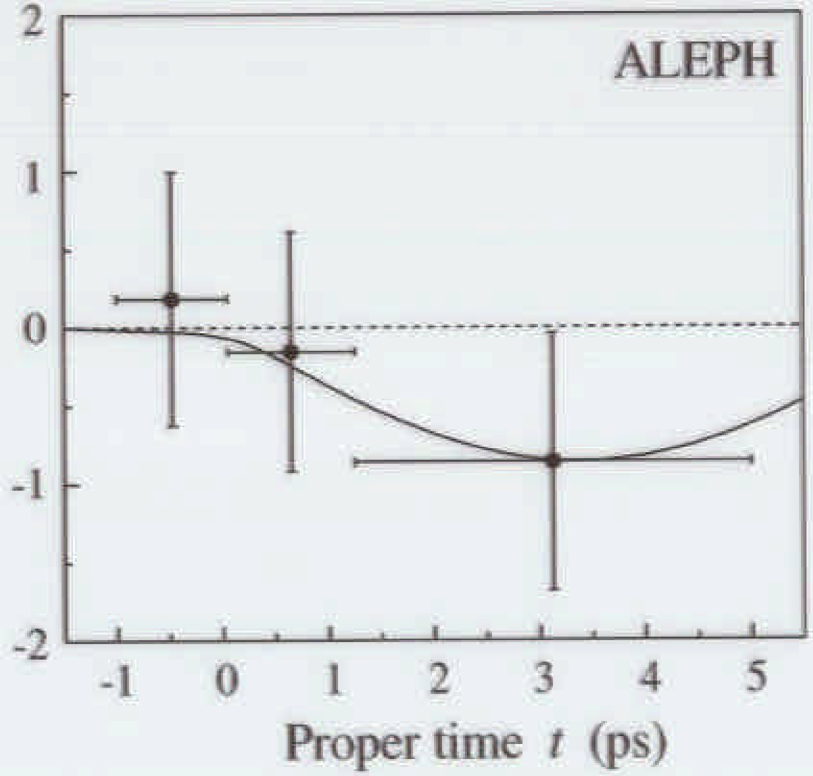


$\arg V_{td}$ — $\mathcal{CP}$-asymmetry for $B \to J/\psi K^0_S$

CDF'99



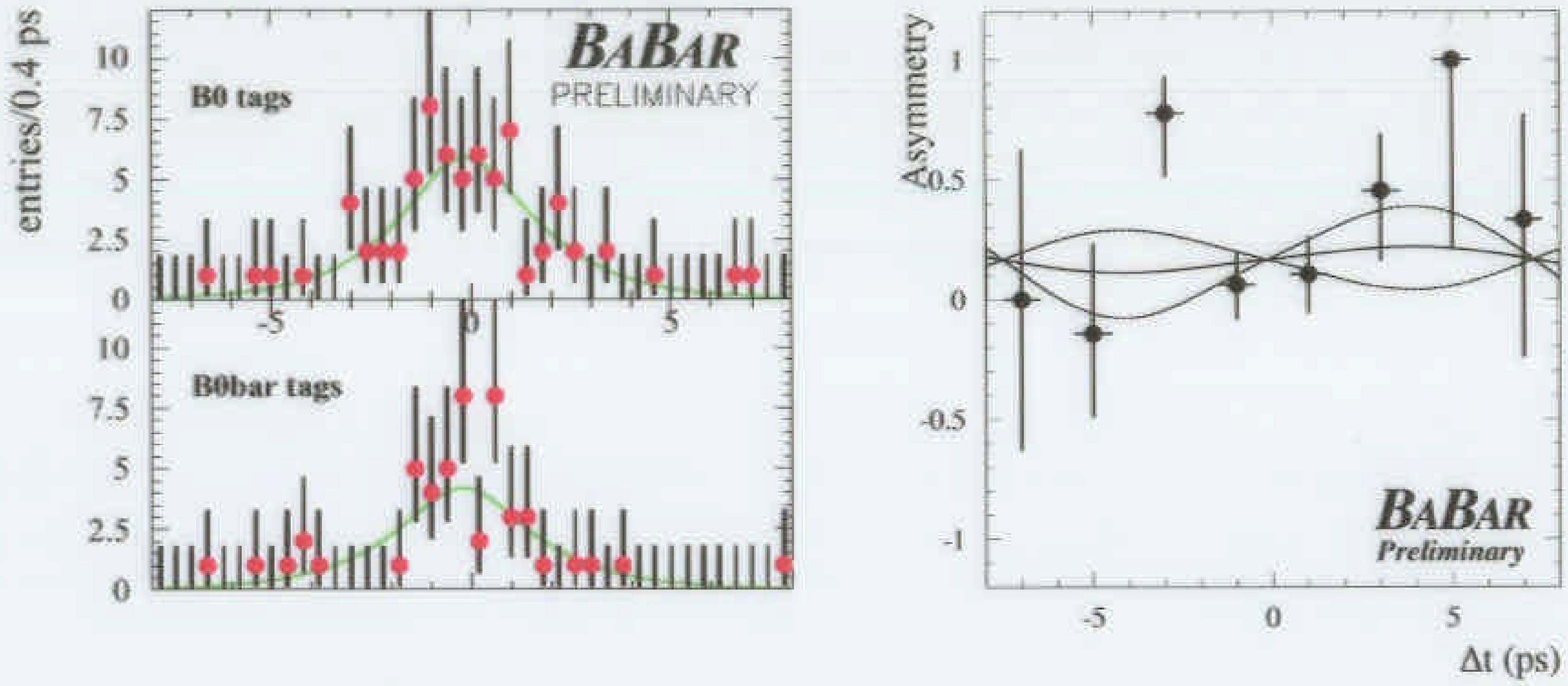
$-\sin(2\arg V_{td}) = 0.79^{+0.41}_{-0.44}$



$-\sin(2\arg V_{td}) = 0.86^{+0.82}_{-1.05} \pm 0.20$

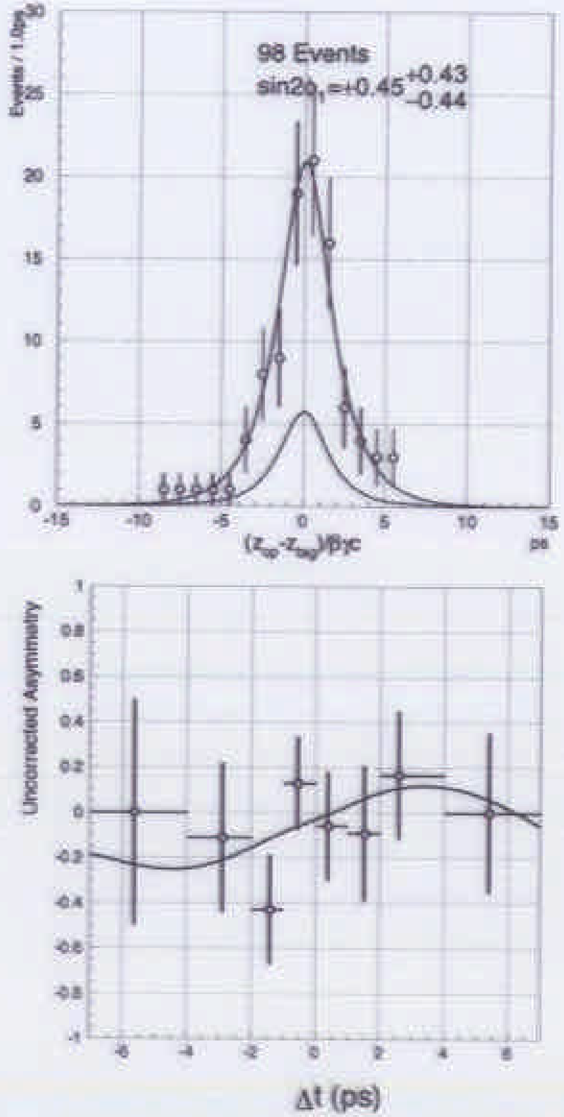
The Result

120 $\psi^{(\prime)} K_s(\pi^+\pi^- \; \& \; \pi^0\pi^0)$ candidates with tagged flavor

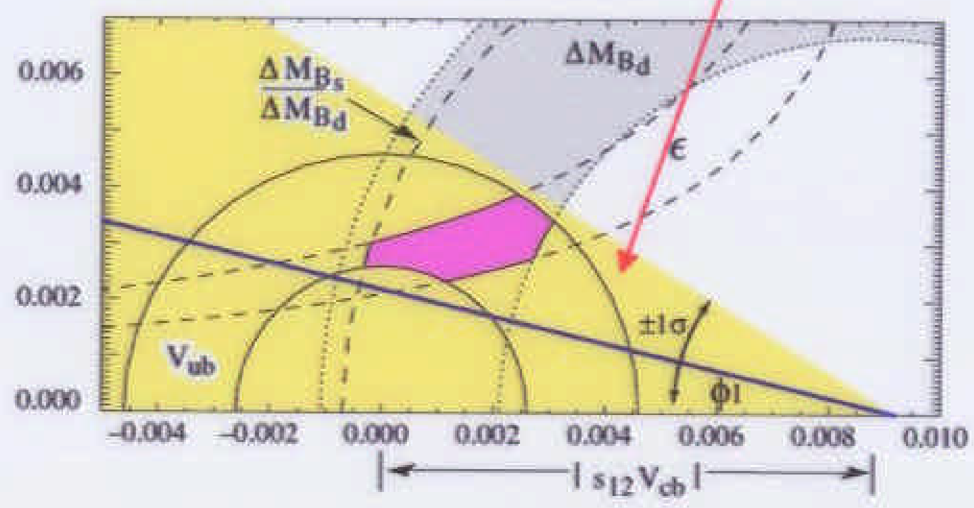


$\sin 2\beta = 0.12 \pm 0.37$ (stat) ± 0.09 (syst)

Belle *CP* Summary



Belle $\pm 1\sigma$



a la PDG2000

$$\sin 2\phi_1 = 0.45^{+0.43}_{-0.44}(\mathrm{stat})^{+0.07}_{-0.09}(\mathrm{syst})$$

Belle preliminary

CONCLUSIONS

- EXCELLENT DATA FROM BABAR AND BELLE

  τ c   b

  t – WAIT FOR TEVATRON RUN II DATA

- CHARM PHYSICS
  - Improved precision in lifetimes and decays
  - $D^0\bar{D}^0$ oscillations ?

    $2.2\,\sigma$ hint from Focus has to be verified

- BEAUTY PHYSICS

V_{ub}/V_{cb}	and	$\sin 2\beta\,(\Phi_1)$
~ 40%	Today	± 0.22
~ 20%	In a year	≤ 0.08

V_{td}/V_{ts}	and	$\gamma\,(\Phi_3)$
...	Today	...

Big (and realistic) hope to measure → Δm_s (CDF/D0, HERA-B) In ~1.5 y will be constrained

WE SHOULD BE ABLE TO SEE DEVIATIONS FROM SM (if any) AT THE NEXT ICHEP