V_{cb} from $B \rightarrow D^{*} l\nu$ and new $B \rightarrow D^{**} l\nu$ results at LEP

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Thanks to the LEP V_{cb} working group

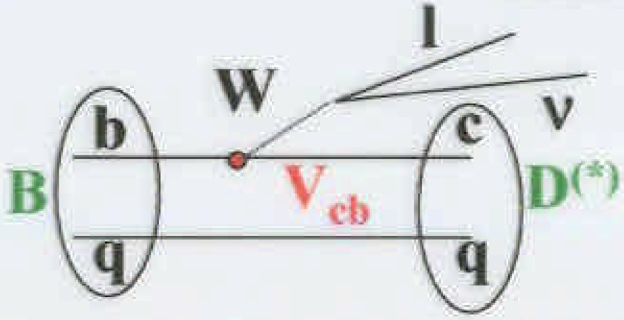
Introduction

- Standard Model: CKM elements fundamental parameters
  ⇨determine experimentally

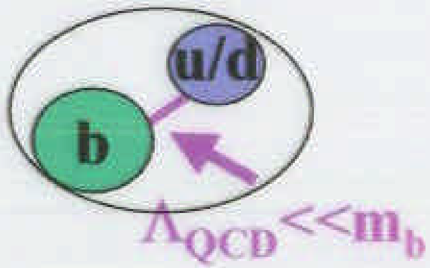
V_{cb} governs $b \to c$ transition

$$\text{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

Quarks bound in hadrons



Non-perturbative QCD

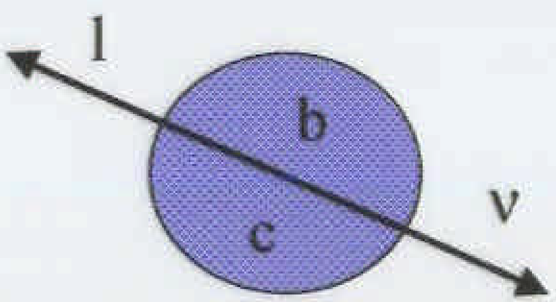


- Heavy Quark Effective Theory (HQET)
  simplified description of processes involving heavy → heavy quark transition ($m_Q \to \infty$)

- Semileptonic decays: non-perturbative QCD described by form factors

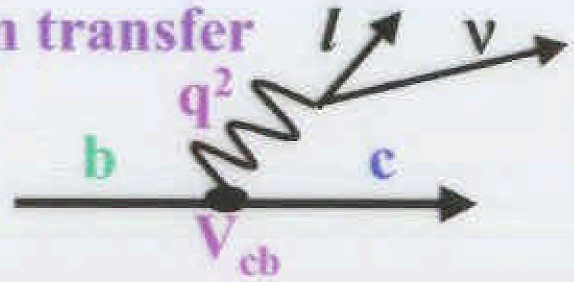
$B \to D^* l\nu$ in HQET

- D^* vector $\Rightarrow$ $B \to D^* l\nu$ described by one form factor ξ (Isgur-Wise function) as a function of w=D^* boost in B rest frame



$$w = \frac{m_B^2 + m_{D^*}^2 - q^2}{2 m_B m_{D^*}}$$

$q^2 \Rightarrow$ 4-momentum transfer



w=1$\Rightarrow$ D^* at rest in B rest frame

In $m_Q \to \infty$ $\xi(1)=1 \Rightarrow V_{cb}$ extraction with little model dependence

- Bonus: $B \to D^* l\nu$ largest branching fraction of B decay modes

V_{cb} from $B \to D^* l \nu$

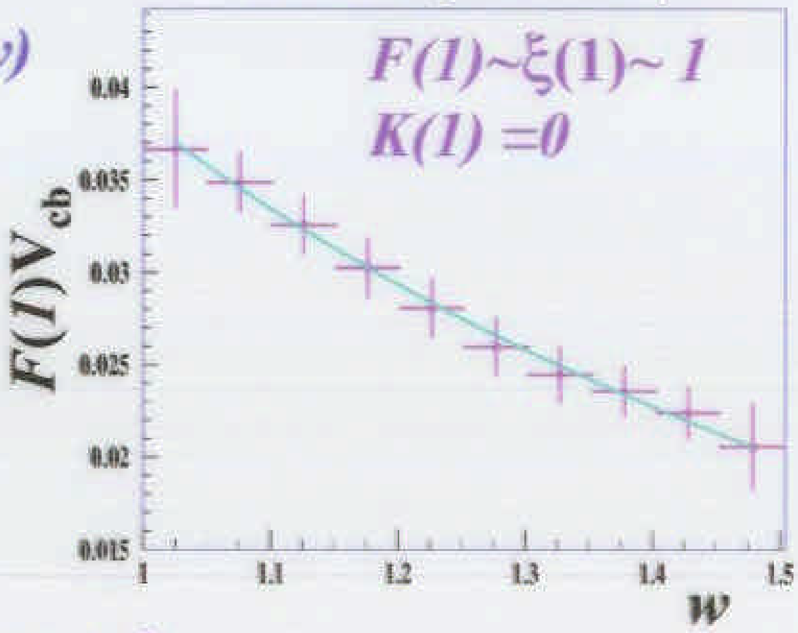
In HQET:

$$\frac{d\Gamma}{dw} = K(w) F^2(w) \left| V_{cb} \right|^2$$

$K(w)$ ~ phase space (known function)
$F(w)$ unknown form factor= $F(1) \bullet g(w)$

$m_Q \to \infty$ $F(1) = \xi(1) = 1$
finite m_Q and QCD corrections:
$F(1) = 0.88 \pm 0.05$
[Bigi,Shifman,Uralsev; revised by Lellouch,Roudeau]

DELPHI preliminary



Measure $d\Gamma/dw(w)$ and extrapolate at $w=1 \Rightarrow g(w)$ slope important

fit for both intercept $F(1)|V_{cb}|$ and slope (ρ^2)
[$F(w)$ from Caprini,Lellouch,Neubert,Nucl.Phys.B530(98)]

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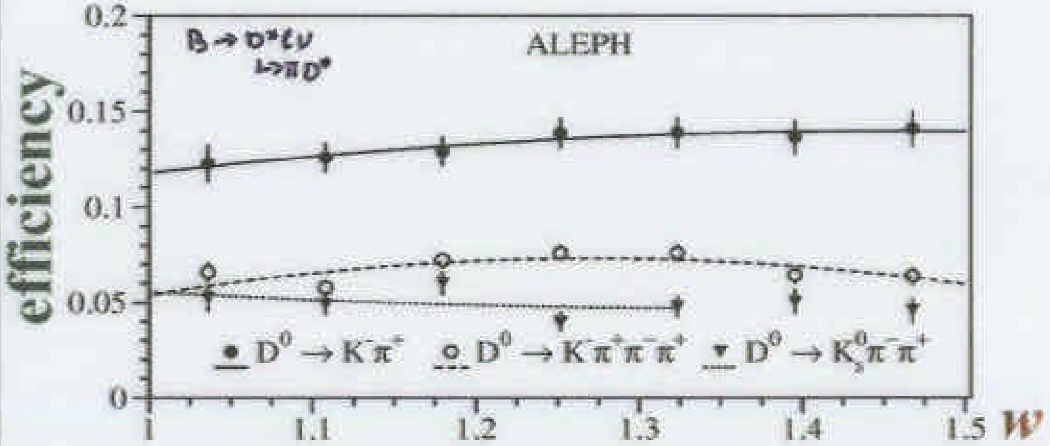
$B \rightarrow D^* l\nu$ at LEP

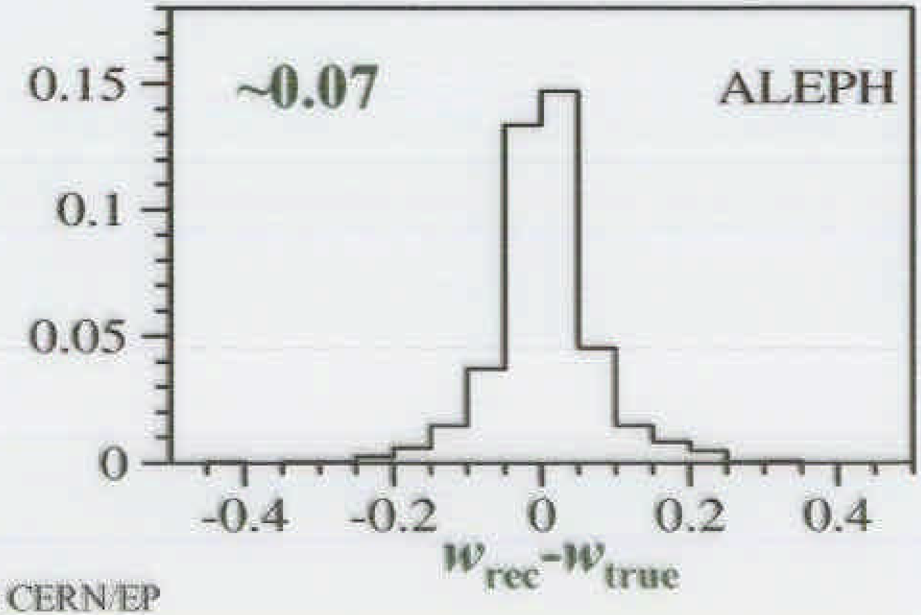
$\Upsilon(4S) \rightarrow B^0$ at rest

- large data sample
- good w resolution
- poor efficiency at $w \sim 1$

LEP $\rightarrow B^0$ large variable boost (~30 GeV)

- good efficiency at $w \sim 1$ (reduced extrapolation uncertanty at $w \sim 1$)
- not so good w resolution





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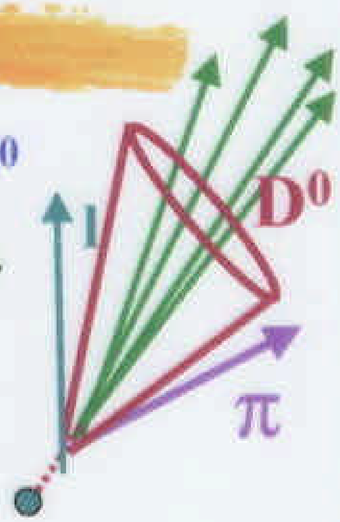
Signal reconstruction

High p_t lepton and $D^* \rightarrow \pi^+_{slow} D^0$

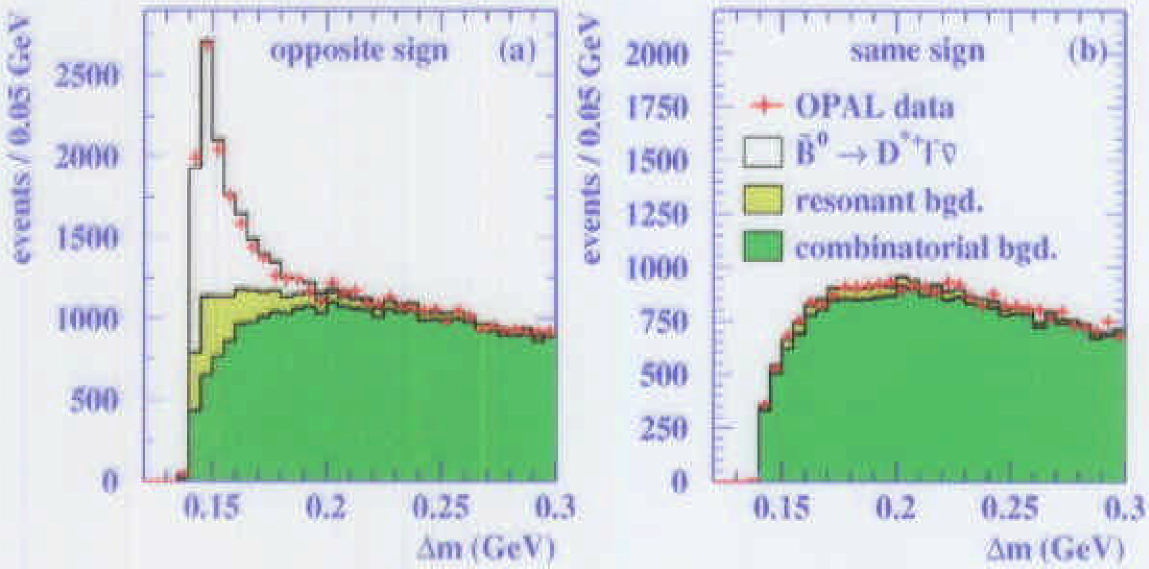


$D^0 \rightarrow K^-\pi^+ \; K^-3\pi^+$

$K_s\pi^+\pi^- \; K^-\pi^+(\pi^0)$

D^0 inclusive →

$m(D^*)-m(D^0) \sim m(\pi^+)$



$W \rightarrow p_B$ and E_B

$E_B \rightarrow Z^0$ ~at rest → 2-body decay

$p_B \rightarrow$ vertex and/or jet direction

$m^2_B = m^2_{D^*l}$

important background $B \rightarrow D^{**}l\nu$, $D^{**} \rightarrow \pi D^*$

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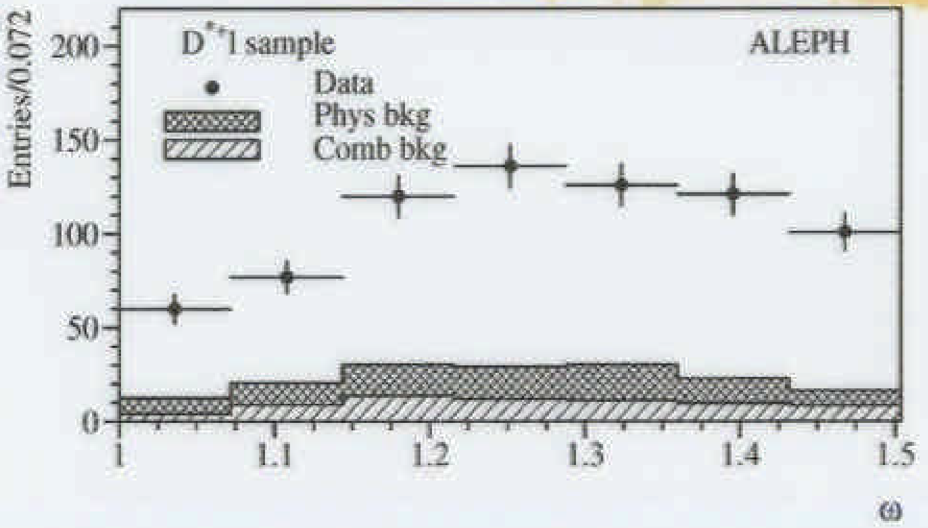
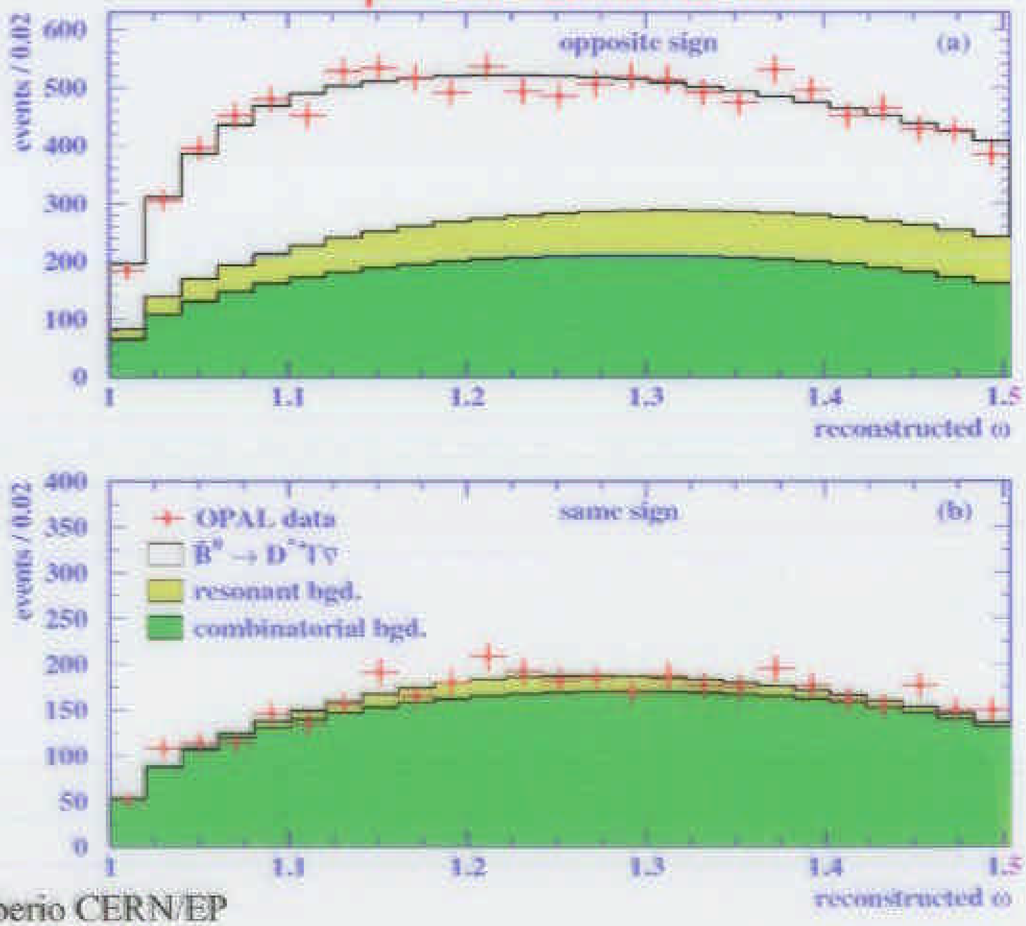
$F(1)V_{cb}$



D⁰ fully reconstructed

$F(1)V_{cb}=(31.9\pm1.8\pm1.9)10^{-3}$

$\rho^2=0.60\pm0.25\pm0.11$



inclusive D⁰

$F(1)V_{cb}=(37.5\pm1.2\pm2.5)10^{-3}$

$\rho^2=1.12\pm0.14\pm0.29$

high statistics
larger systematics

$B \rightarrow D^{**} l \nu$

$B \rightarrow D^{**} l \nu$ with $D^{**} \rightarrow \pi D^{*} / \pi D^{0}$

Rates → new values from DELPHI

Narrow states: $D^{*}_{2}(2460), D_{1}(2420)$

broad: $D^{*}_{1}(broad), D^{*}_{0}(broad)$

non resonant → indication from resonant decay rates [CERN-EP/2000-96]

non-resonant predicted by HQET [N.Isgur,Phys.Rev.D60(99)]

model for *w* shape (resonant states) → predictions on rates

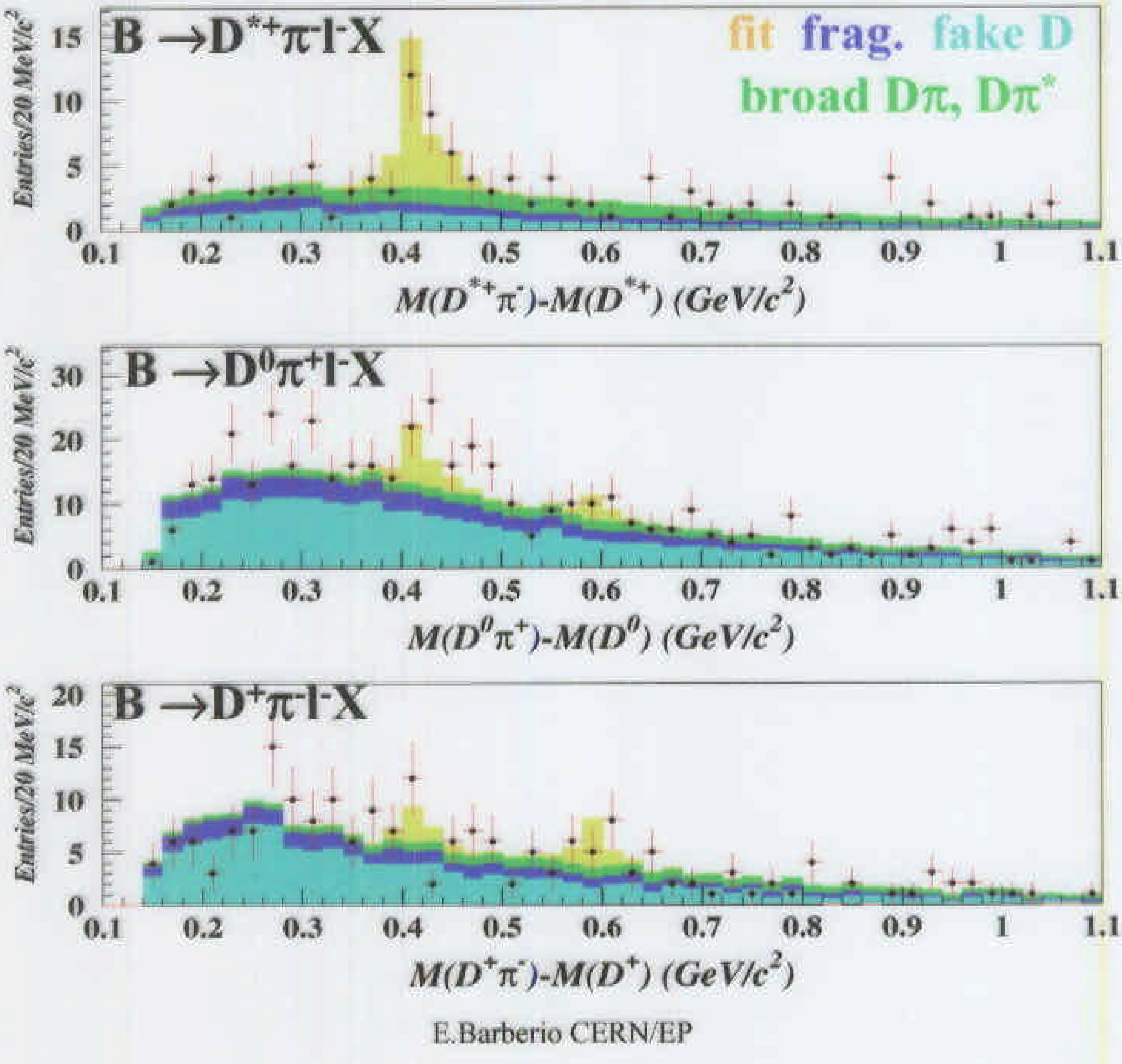
$R^{*} = Br(B \rightarrow D^{*}_{2} l \nu) / Br(B \rightarrow D_{1} l \nu) < 0.4 - 0.7$

$Br(B \rightarrow D^{*}_{1} l \nu) + Br(B \rightarrow D^{*}_{0} l \nu) < Br(B \rightarrow D_{1} l \nu)$

Mass difference

High p_t lepton and fully reconstructed $D^{(*)}$

DELPHI preliminary



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DELPHI measurements

Fit the three mass differences for number of events, masses and width of D^1 D^2 D^*_0(broad) D^*_1 (broad) ($\Gamma_{D^*0}=\Gamma_{D^*1}$)

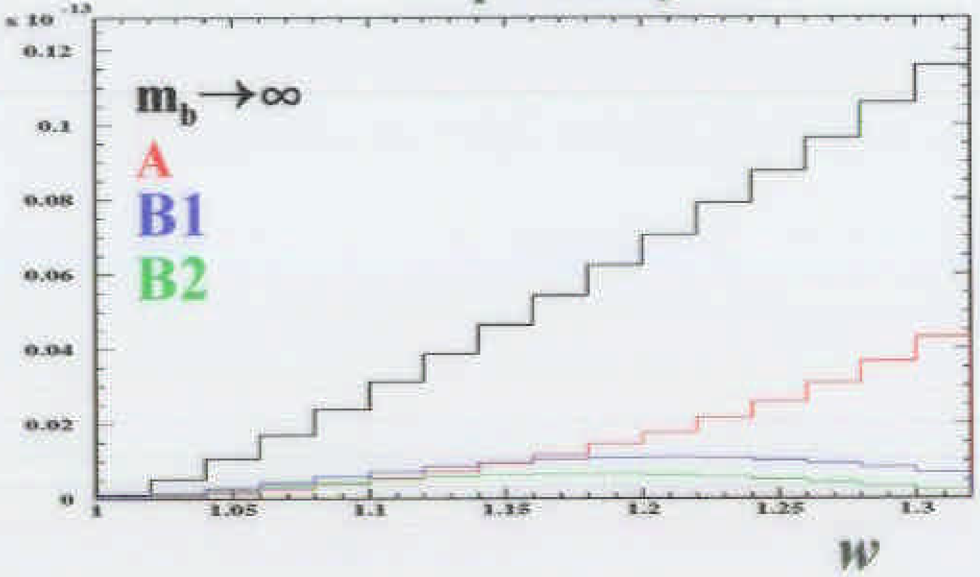
	DELPHI (%)	World average(%)
•	$Br(B\to D^*_2 l\nu) = 0.44 \pm 0.21 \pm 0.12$	0.28 ± 0.09
•	$Br(B\to D_1 l\nu) = 0.67 \pm 0.18 \pm 0.10$	0.64 ± 0.11
•	$Br(B\to D^*_1 l\nu) = 1.63 \pm 0.49 \pm 0.24$	-
•	$Br(B\to D^0_0 l\nu) < 1.9$ (90% CL)	

- World average $R^* = 0.28 \pm 0.09$ in agreement with HQET!
- $Br(B\to D^*_1 l\nu) + Br(B\to D^0_0 l\nu) > Br(B\to D_1 l\nu)$
  hints for non-resonant states!? (see ALEPH/CLEO)

D^{**} systematics in V_{cb}

* World average for the rates [CERN-EP/0096]
* HQET model for the w spectrum in $B \to D^{**} l \nu X$
  [Lebovich,Ligeti,Steward,Wise,PRD57(98)]

D^*_1 w shape



different form factors depending on assumption on quark decay dynamics

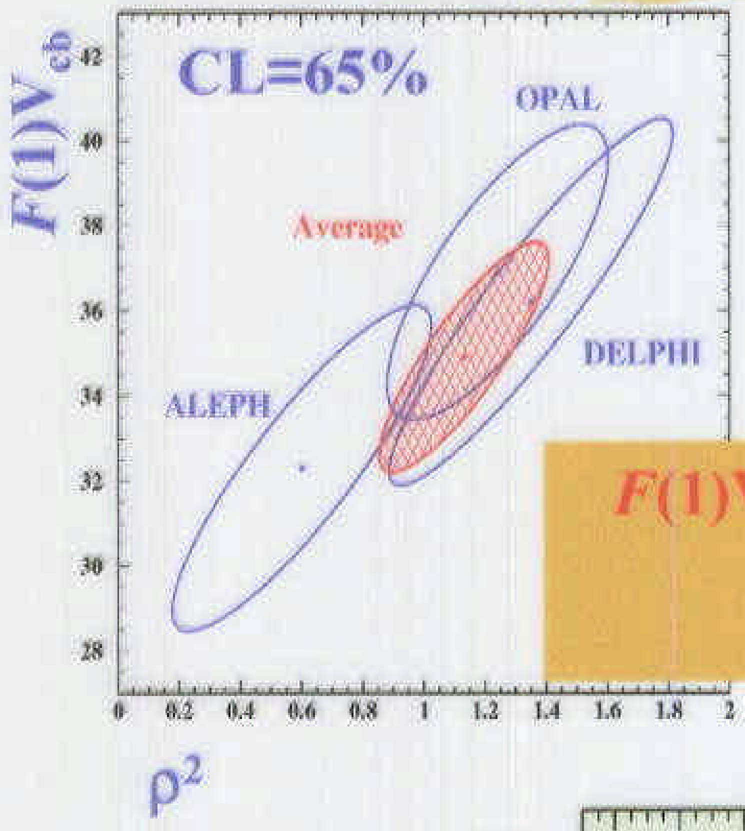
set of form factors which satisfy

$R^*=0.28\pm0.09$

[CERN-EP/0096]

Systematics on shape half of the difference of the two most extreme cases (~1.5 - 4 %)

LEP average

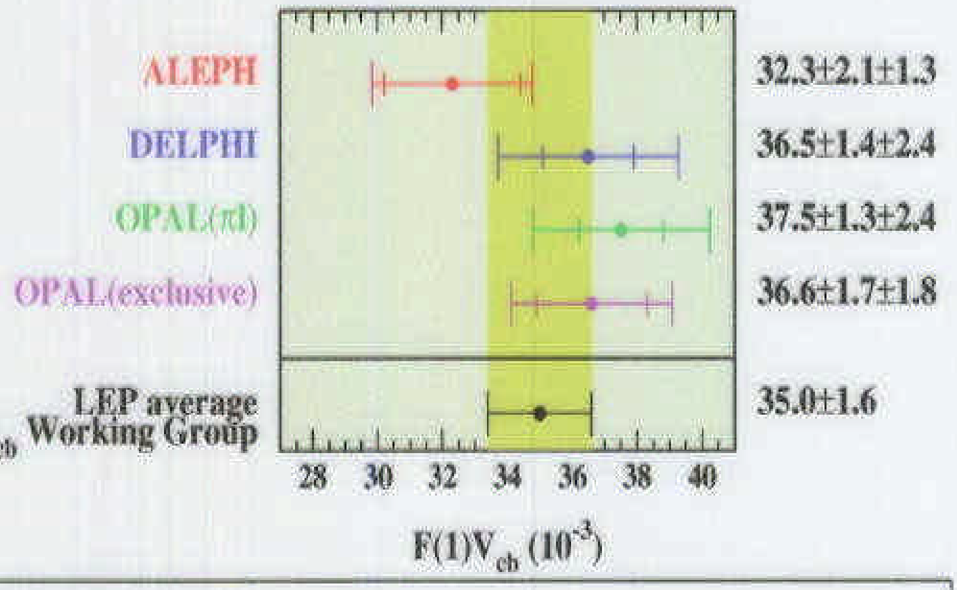


All analyses adjusted to common inputs

Combined LEP (CL=12%)

$F(1)V_{cb}$=(34.9± .07 ± 1.6) 10^{-3}

ρ^2=1.13 ±.08 ± .16



Systematics dominated by B→ $D^{**}l\nu$

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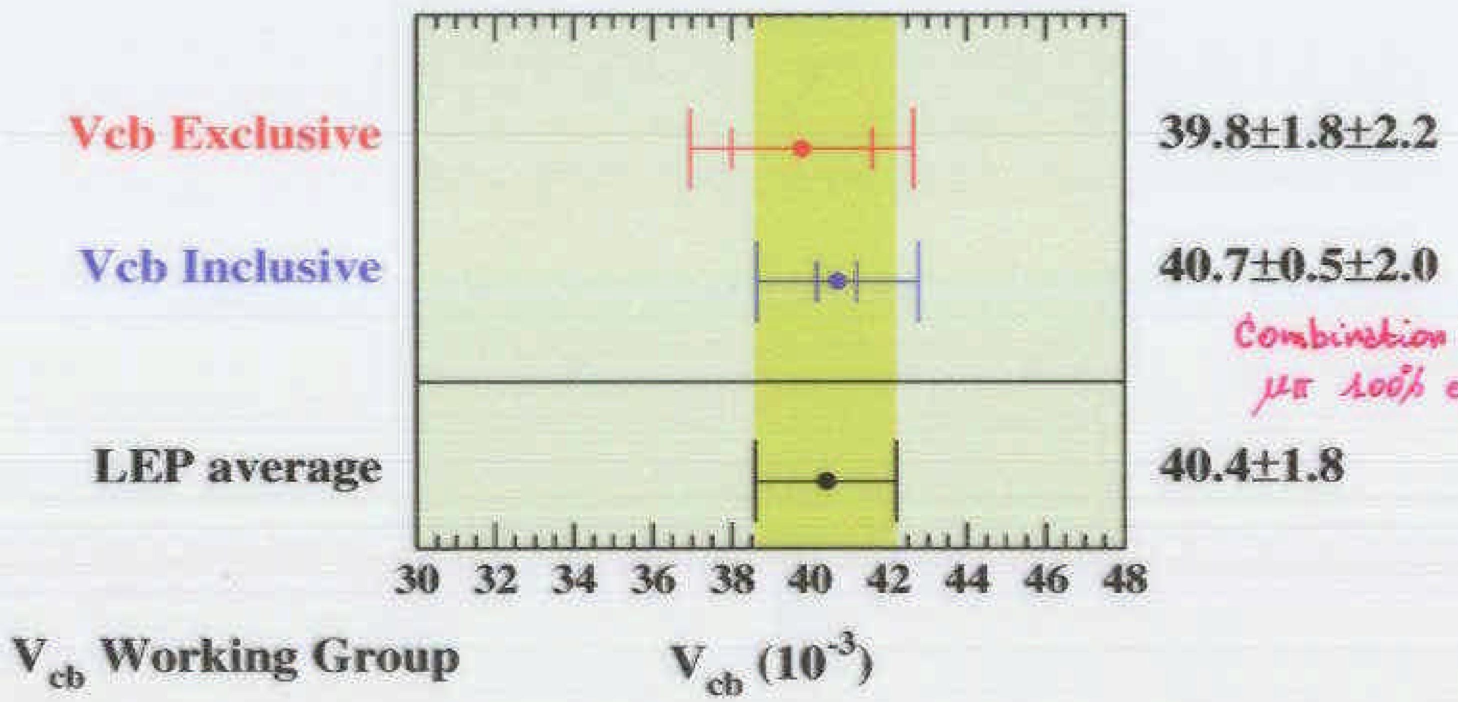
LEP average

$F(1)V_{cb} \Rightarrow V_{cb}$ using $F(1) = 0.88 \pm 0.05$

$V_{cb} = 39.8 \pm 1.8_{(exp)} \pm 2.2_{(theo)}$



Combination done assuming μπ 100% correlated

Measurements are theoretically limited

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Conclusion

- V_{cb} measurement at LEP is almost final
  still work to do on D^{**} background
  final LEP results in the winter
  measurement is theoretically limited

- New DELPHI measurement
  more evidence for non-resonant semileptonic B decay
  good HQET test