Sommario

- Produzione
- Decadimenti
- Oscillazioni
- Vincoli su C.K.M.
- Conclusione & Prospettive

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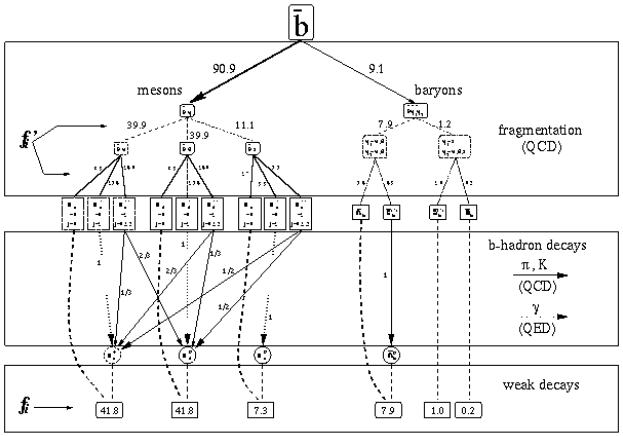
Frammentazione $b \to B$

1. $x_E = \frac{E_B}{E_b} \begin{cases} < x_E > \\ f(x_E) \end{cases}$

2. Stati intermedi ($B^{*(*)}$) ?

3. Stati finali ($B_d/B_u/B_s/\Lambda_b/\Xi_b$) :

$$f_d = BR(b \to \bar{B}^0_d) \; (= b \to \bar{B}^+)$$
$$f_s = BR(b \to \bar{B}^0_s)$$
$$f_\Lambda = BR(b \to \Lambda_b + \Xi_b)$$



4. E' possibile estrapolare $e^+e^- \to pp$?

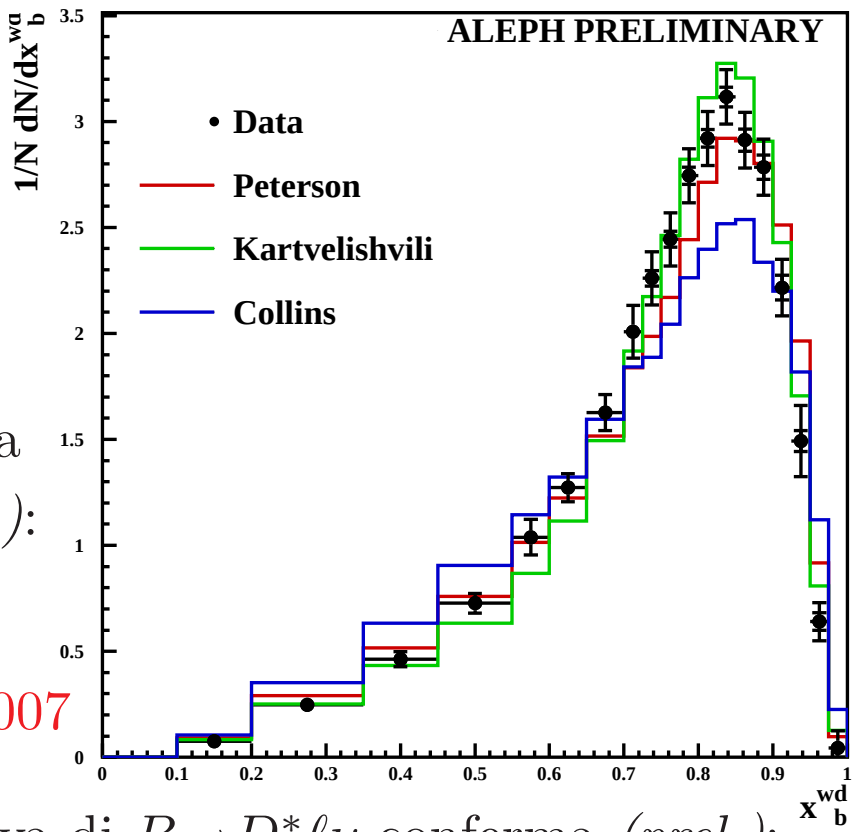
$\to$tuning per esperimenti futuri

(Tevatron ,BTeV,LHC(B))

$x_E = E_B/E_b$

A LEP si e' usato :

- $f(x_E) \Longrightarrow$ Peterson
- $< x_E > \; = \; 0.702 \pm 0.008$ (spettro P_ℓ da $b \to \ell X$)



SLD, via ricostruzione topologica dei vertici secondari, trova *(prel.)*:

- *Peterson escluso dai dati*
- $< x_E >= 0.714 \pm 0.005 \pm 0.007$

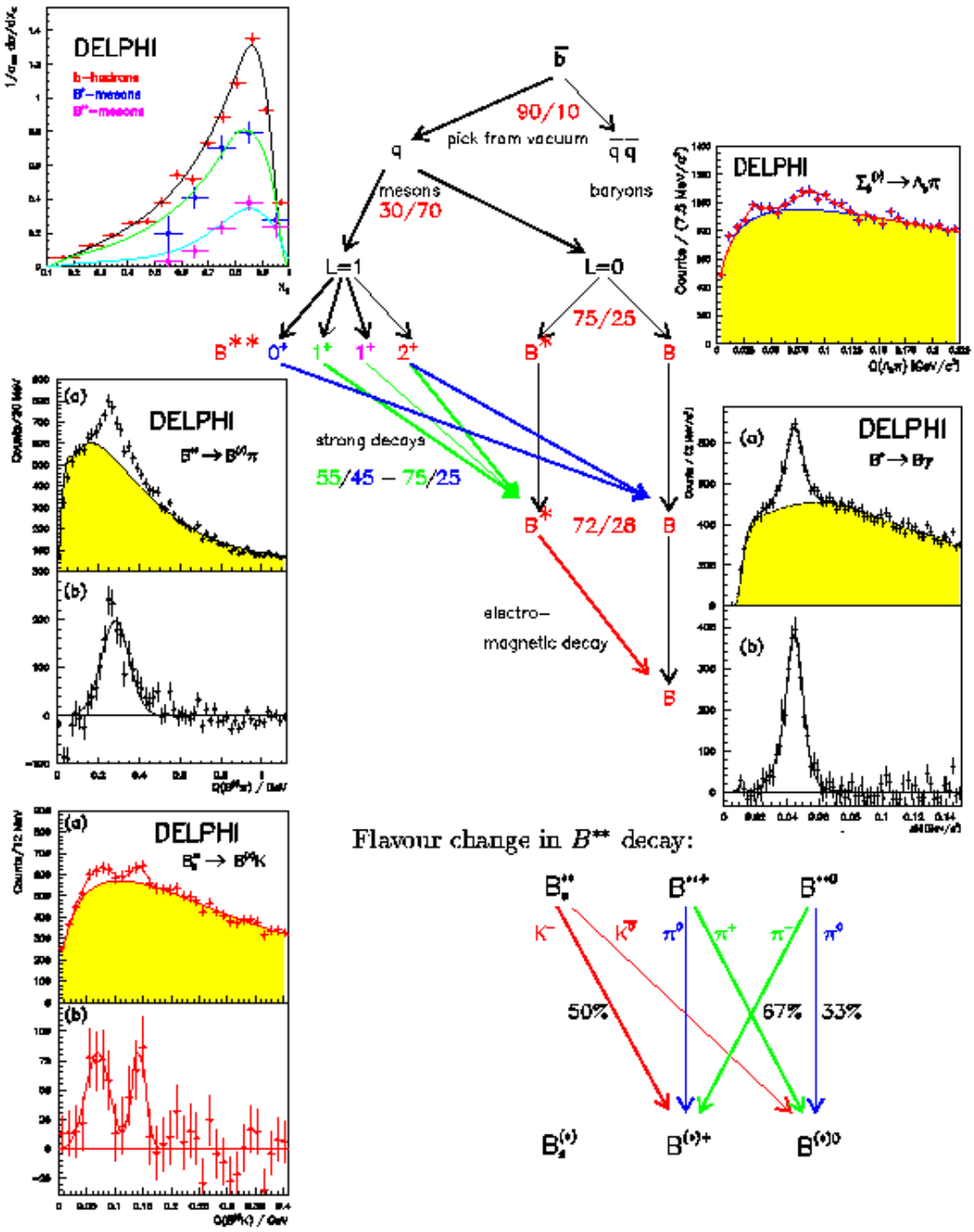
ALEPH via ricostruzione esclusiva di $B \to D^* \ell \nu$ conferma *(prel.)*:

- $< x_E >= 0.720 \pm 0.005 \pm 0.005$

Nuovo LEP W.G. in preparazione

Stati Intermedi

b fragmentation according to DELPHI measurements



$f_d/f_s/f_\Lambda(I)$

Metodo indiretto:

$$\begin{cases} 1 &= 2f_d + f_s + f_\Lambda \\ \bar{\chi} &= f_d \cdot \chi_d + f_s \chi_s \end{cases}$$

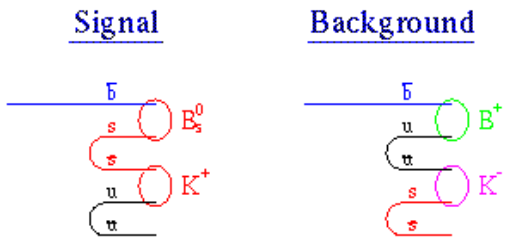
$f_\Lambda = (12.0 \pm 3.5)\%$ (input)

$f_s = (10.3 \pm 1.5)\%$

$f_d = (38.9 \pm 1.9)\%$

ALEPH, da $b \to pX$:

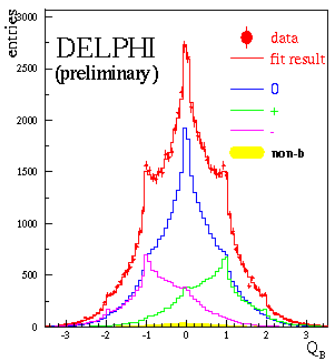
$f_\Lambda = (10.2 \pm 2.8)\%$



DELPHI (prel)

... dal "rango di rapidita´ ":

$$f_s = (8.8 \pm 2.0 \pm 1.0(B_s^{**}))\%$$



... e dalla carica $Q(b - jet)$:

$$f_d = (41.8 \pm 1.5 \pm 0.4(f_\Lambda))\%$$

$f_d/f_s/f_\Lambda(II)$

- Risultati consistenti ;
- Media [LEPHFS 99-02] :

$$f_\Lambda = (9.9 \pm 1.7)\%$$
$$f_s = (10.0 \pm 1.2)\%$$
$$f_d = (40.1 \pm 1.0)\%$$

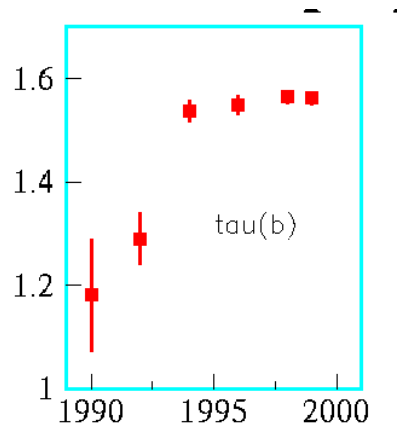
- CDF, dal rapporto $(B_s \to D_s \ell \bar{\nu})$ / $(B \to D \ell \bar{\nu})$:

$$f_\Lambda = (9.0 \pm 2.8)\%$$
$$f_s = (16.0 \pm 2.5)\%$$
$$f_d = (37.5 \pm 1.5)\%$$

- discrepanza $\sim 2\sigma$

Vite Medie

	Exp.	HQET (+models)
τ_b (ps)	1.564 ± 0.014	-
$\tau_{B_d^0}$ (ps)	1.548 ± 0.032	-
$\frac{\tau(B^+)}{\tau(B_d^0)}$	1.065 ± 0.023	> 1
$\frac{\tau(B_s^0)}{\tau(B_d^0)}$	0.935 ± 0.040	$1 \pm (\mathcal{O})1\%$
$\frac{\tau(\Lambda_b)}{\tau(B_d^0)}$	0.773 ± 0.036	$0.90 \div 0.95$



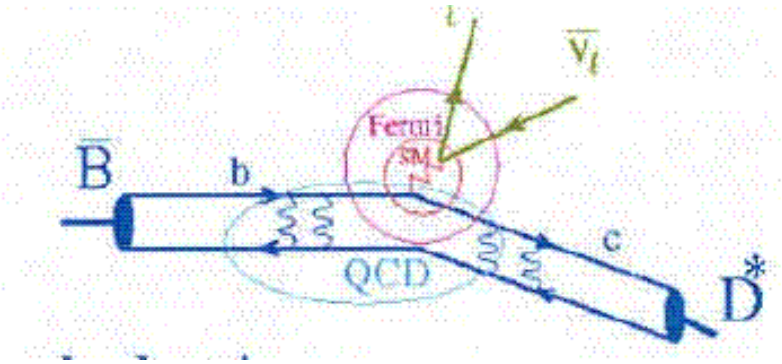
CDF(II) + B-factories:

$$\sigma(\tau_{B_{d,u}})/\tau_{B_{d,u}} \lesssim 1\%$$

- sfida per la teoria
- riduce sistematica per estrazione $|V_{cb}|$, $|V_{ub}|$:

$$\Gamma(B \to \ell X) = BR(B \to \ell X)/\tau_B$$

Decadimenti Semileptonici



- facile identificazione (→tagging)
- efficienti per discriminare $b/\bar{b}$
- una sola corrente adronica, incertezze teoriche contenute
  - misura $|V_{cb}|$,$|V_{ub}|$:

$$\Gamma(b \to \ell \nu q) = |V_{qb}|^2 \cdot \gamma^{th}$$

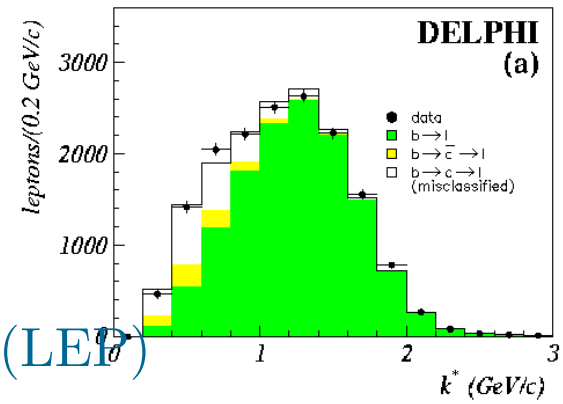
$\gamma^{th.}$: modello $q \to adroni$
espansione $(1/m_b, 1/m_c, \alpha_s)$

  - verifica dei modelli (OPE,HQET, etc.)

$|V_{cb}|$ da $b \to c\ell\nu$

LEP (EWWG+VCBWG) :

- $\mathcal{B}(b \to \ell^- \bar{\nu}_\ell X) = 0.1058 \pm 0.018$



da cui, (se $\Gamma^{sl}{}_B = \Gamma^{sl}{}_{B_s} = \Gamma^{sl}{}_{\Lambda_b}$) :

- $\Gamma(\bar{B} \to \ell^- \bar{\nu}_\ell X_c) = (6.76 \pm 0.13) 10^{-2}\ ps^{-1}$ (LEP)
- $\Gamma(\bar{B} \to \ell^- \bar{\nu}_\ell X_c) = (6.56 \pm 0.16) 10^{-2}\ ps^{-1}$ (CLEO)

$$|V_{cb}| = (40.8 \pm 0.4(exp) \pm 2.0(th.)) \cdot 10^{-3}$$

Errore teorico ($\pm 5\%$) :

- $\bar{\Lambda}$: $M_b \Longleftrightarrow M_B$
- λ_1 : E_{kin} del b-quark nell'adrone B
- λ_2 : spin, noto da spettroscopia (M_{B^*} - M_B)

Misura di λ_1, $\bar{\Lambda}$

- Determinano la dinamica del decadimento.
- CLEO analisi indipendenti dei momenti *(prel.)*:

$$\textit{leptone}^{a} \left\{ \begin{array}{l} < E_\ell > \\ < (E_\ell - < E_\ell >)^2 > \end{array} \right\}, \; \textit{c-quark}^{b} \left\{ \begin{array}{l} < {M_{X_c}}^2 - {M_D}^2 > \\ < ({M_{X_c}}^2 - {M_D}^2)^2 > \end{array} \right\}$$

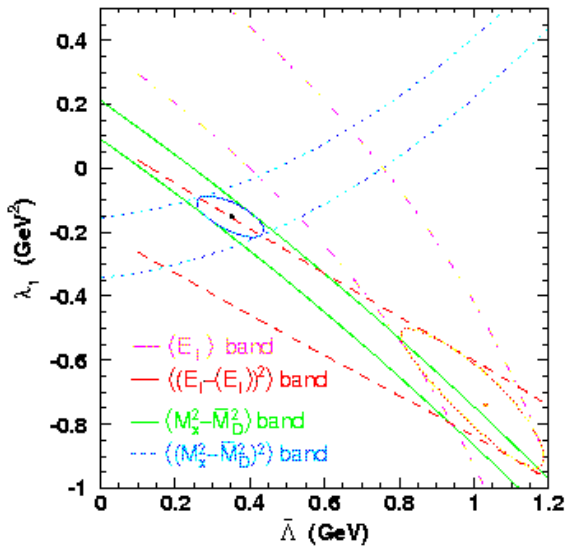
$$\left. \begin{array}{l} \lambda_1 = -0.13 \pm 0.06 \; GeV^2 \\ \bar{\Lambda} = 0.33 \pm 0.08 \; GeV \end{array} \right\} \Rightarrow \sigma(|V_{cb}|)^{th.} = \pm 2\%$$

- l'accordo e' modesto (CL $\sim 5\%$)

  modelli ?

  uso "improprio"?

- lavoro per LEP !

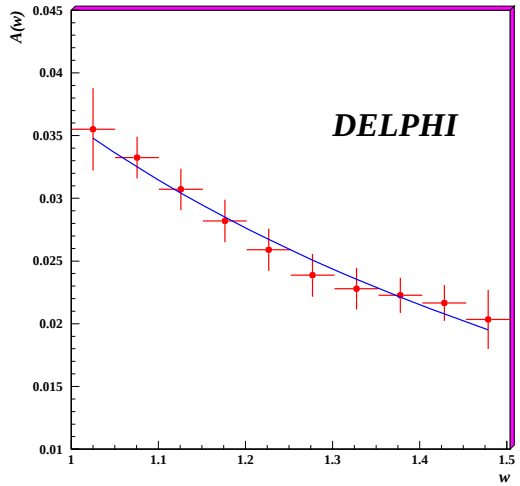


[a] Voloshin (1995)
[b] Falk & co. (1996)

$|V_{cb}|$ da $\bar{B}^0_d \to D^{*+}\ell\bar{\nu}$

Larghezza differenziale ($w = v_{\bar{B}^0_d} \cdot v_{D^{*+}}$) :

$$\frac{d\Gamma}{dw} = \frac{{G_f}^2}{48\pi}|V_{cb}|^2\mathcal{A}_1 \cdot (1 + \rho^2_{\mathcal{A}_1}(w-1) + ...) \cdot G(w)$$



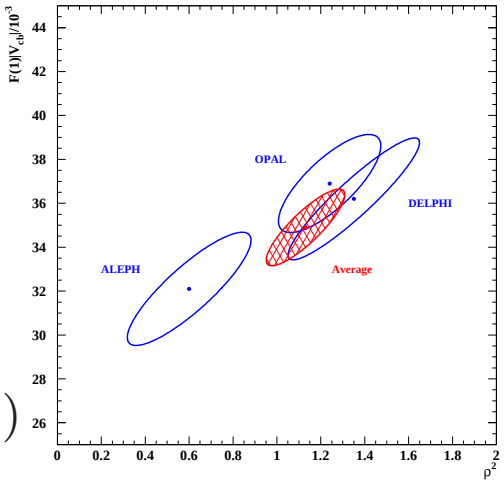
HQET (+QCD) calcola:

- $\mathcal{A}_1 = \begin{cases} 1 \quad (m_{B,D} \to \infty) \\ 0.88 \pm 0.05 \ (m_{B,D} \ finite \ , \mathcal{O}(\alpha_s^2)) \end{cases}$
- ordini superiori $f(\rho^2_{\mathcal{A}_1}, w)$

Esperimenti fittano $|V_{cb}|^2\mathcal{A}_1$ e $\rho^2_{\mathcal{A}_1}$. LEP WG:

$$|V_{cb}| = (39.6 \pm 1.9(exp) \pm 2.2(th.)) \cdot 10^{-3}$$

(CL = 12%)

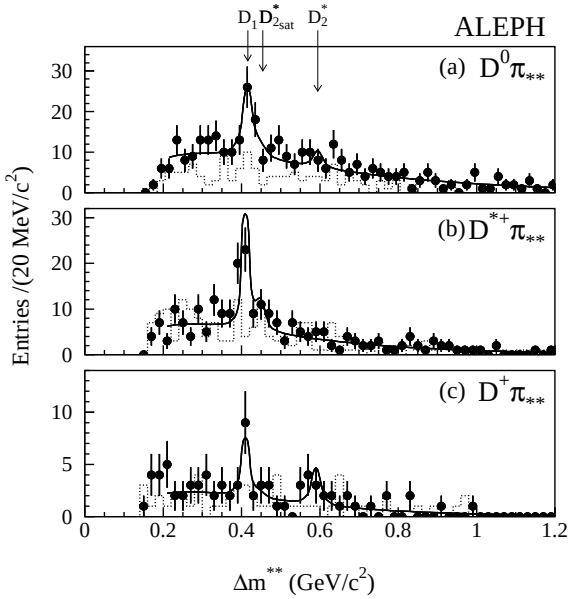


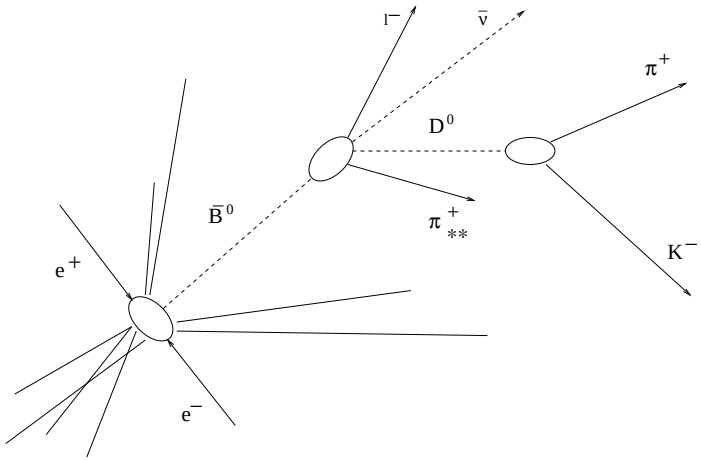
- ottimo accordo con risultato inclusivo
- CLEO : $(42.0 \pm 3.0(exp)) \cdot 10^{-3}$
- CLEO : analisi elicita' per misurare $f.f.(\mathcal{A}(w))$
  $\Rightarrow$ LEP ?

Eccitazioni Orbitali (D^{**})

Quattro stati eccitati (D^{**}), due risonanti (D_1, D_2^*),
e due "larghi'. Si studiano nella cascata: $b \to \ell\nu D^{**} \to D^{(*)}\pi^-$

$\mathcal{B}(b \to D_1 \ell\nu, D_2^* \ell\nu)$	$\mathcal{B}(b \to D^{**} \ell\nu)$
ricostruzione massa invariante	analisi topologica dei vertici
(ALEPH, CLEO)	(ALEPH , DELPHI)





Risultati & Problemi

Saturazione: $B \to \ell^- X = B \to \ell^- \nu (D + D^* + D^{**})$?

- PDG : $\mathcal{B}(B \to \ell^- X) - \mathcal{B}(B \to \ell^- \nu (D + D^*)) = (3.93 \pm 0.44)\%$
- ALEPH : $\mathcal{B}(B \to \ell \nu D^{**}) = (2.16 \pm 0.42)\% \quad (-2.9\sigma)$
- DELPHI: $\mathcal{B}(B \to \ell \nu D^{**}) = (3.40 \pm 0.60)\% \quad (-0.7\sigma)$

$\Rightarrow$ B-factories,CDF ?

Produzione

	Exp.	HQET(+modelli potenziale)
$\mathcal{B}(\bar{B} \to D_1 \ell \nu)(\%)$	0.63±0.11	-
$\frac{\mathcal{B}(\bar{B} \to D_2^* \ell \nu)}{\mathcal{B}(\bar{B} \to D_1 \ell \nu)}$	0.37 ± 0.16	~ 1
$\frac{\mathcal{B}(\bar{B} \to D_1 \ell \nu)}{\mathcal{B}(\bar{B} \to D^{**} \ell \nu)}$	0.35 ± 0.15	$\sim 0.5 \div 0.7$

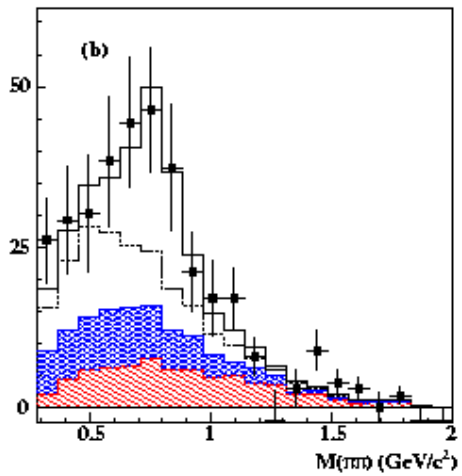
$|V_{ub}|$ da $b \to u \ell \bar{\nu}$

- Segnale/Fondo : $\frac{\mathcal{B}(b \to u \ell \bar{\nu})}{\mathcal{B}(b \to c \ell \bar{\nu})} \sim \frac{1}{100}$

- CLEO: ricostruzione $B \to \rho \ell \bar{\nu}$

$$|V_{ub}| = (3.25 \pm 0.29^{exp.} \pm 0.55^{th}) \cdot 10^{-3}$$

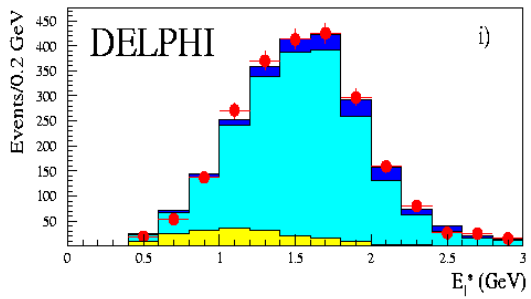
$\sigma^{th.}(\pm 17\%)$: adronizzazione $(u \to \rho)$



- LEP : cinematica $(M_{had} < M_D)$ + veto c $(K, \ell,$ vertice $)$

$$|V_{ub}| = (4.04 \pm 0.44^{exp.} \pm 0.54^{th}) \cdot 10^{-3}$$

$\sigma^{th.}$: $(\pm 11\%)$ $(b \to c) \oplus (\pm 9\%)$ $(b \to u)$



$|V_{ub}|$: prospettive $\bar{B}\to u\ell\bar{\nu}$

Selezione cinematica (a la LEP) : misura $\Gamma(q^2 > q^2{}_0)$

$$q^2 = (\mathcal{P}_\ell + \mathcal{P}_{\bar{\nu}})^2 = (\mathcal{P}_{\bar{B}} - \mathcal{P}_{had})^2 \begin{cases} b\to c :< (M_B - M_D)^2 = 11.6 GeV^2 \\ b\to u :< (M_B - M_\pi)^2 = 20.0 GeV^2 \end{cases}$$

Sperimentalmente, q^2da:

- ermeticita' (CLEO) : $\mathcal{P}_\nu = \mathcal{P}_{miss}$
- statistica (BaBar,Belle): $\bar{B}B \to (D^{*+}\pi, J/\Psi K, ...)$, $\bar{B}B \to \ell\bar{\nu}X_u \implies \mathcal{P}_{had} = \mathcal{P}(X_u)$
- LEP ?

Teoria[a]

- $q^2 > 11.6\ GeV^2 \implies \sigma^{th} \sim 10\%$
- $q^2 > 15\ GeV^2 \implies \sigma^{th} \sim 20\%$
- $\dfrac{\mathcal{B}(b\to u\ell\bar{\nu})}{\mathcal{B}(b\to X_s\ell^+\ell^-)} \implies \sigma^{th} \sim 10\%$ $\qquad \mathcal{B}(b\to X_s\ell^+\ell^-) \sim 10^{-7}$

[a] Bauer & co 2000

$|V_{ub}|$: prospettive da $\bar{B}\to\rho(\pi)\ell\bar{\nu}$

- Dalla teoria : f.f. ($\mathcal{F}(q^2)$) e normalizzazione ($\mathcal{F}(q^2{}_{max})$)
- *Nessuna* simmetria (approssimata): $\begin{cases} |V_{cb}|\ HQET & \bar{B} \to D \\ & \downarrow \quad \downarrow \\ |V_{us}|\ SU(3) & K^* \to \rho \end{cases}$
- *Cancellazione parziale* delle incertezze teoriche nel doppio rapporto[a] :

$$\frac{(B\to\rho\ell\bar{\nu})/(B\to K^*\ell\ell)}{(D\to\rho\ell\bar{\nu})/(D\to K^*\ell\bar{\nu})}$$

misura	$\frac{\sigma^{th}(\lvert V_{ub}\rvert)}{\lvert V_{ub}\rvert}$
doppio rapporto	$\pm 10\%$
no $D\to\rho$	$\pm 20\%$
no $B\to K^*$	$\pm 40\%$

[a] Bauer & co 2000

Oscillazioni $B \Longleftrightarrow \bar{B}$

- $\Delta m_d \;\propto\; |V_{td}|^2 \cdot (B_{B_d} \cdot f_d^2)$

$$\begin{cases} \Delta m_d = 0.476 \pm 0.016\ ps^-1 \\ \sqrt{B_{B_d}} \cdot f_d \;=\; 210 \pm 42\ MeV \end{cases}$$

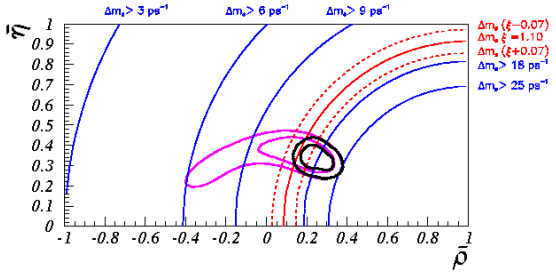
$$\Longrightarrow \quad \frac{\sigma(|V_{td}|)}{|V_{td}|} \lesssim \pm 25\%$$

- $\Delta m_s \;\propto\; |V_{ts}|^2 \cdot (B_{B_s} \cdot f_s^2)$
  $\simeq\; |V_{cb}|^2 \cdot (B_{B_s} \cdot f_s^2)$ (unitarieta' CKM)

- $\dfrac{\Delta m_d}{\Delta m_s} \;\simeq\; \dfrac{1}{\xi} \dfrac{|V_{td}|}{|V_{cb}|}^2$

$$\xi = \frac{\sqrt{B_{B_s}} \cdot f_s}{\sqrt{B_{B_d}} \cdot f_d} = 1.11 \pm 0.05\ ^{a}$$

- misura Δm_d e Δm_s:



$$\Longrightarrow \quad \frac{\sigma(|V_{td}|)}{|V_{td}|} \lesssim \pm 10\%$$

[a] Caravaglios & co 1999

Oscillazioni B_s

$$\left.\begin{array}{l} \Delta m_s \;>>\; \Delta m_d \\ f_s \simeq f_d/4 \end{array}\right\} \quad \Longrightarrow \text{ Nessuna Osservazione}$$

Limite (inferiore) con il metodo delle Ampiezze [a]

$$\mathcal{P}(B_s \to \bar{B}_s)(t) \;\propto\; 1 + cos(\Delta m_s t)$$

$$= 1 + \;\mathcal{A}\; cos(\Delta m_s t) \qquad \mathcal{A} = \begin{cases} 0 \;\; \Delta m_s \text{ generica} \\ 1 \;\; \text{oscillazione} \end{cases}$$

Per ogni valore di Δm_s

- fit $\mathcal{A}(\Delta m_s)$
- esclusione : $\mathcal{A} + 1.645 \cdot \sigma_{\mathcal{A}} \;<\; 1$
- sensibilita' : Δm_s tale per cui $1.645 \cdot \sigma_{\mathcal{A}} \;=\; 1$

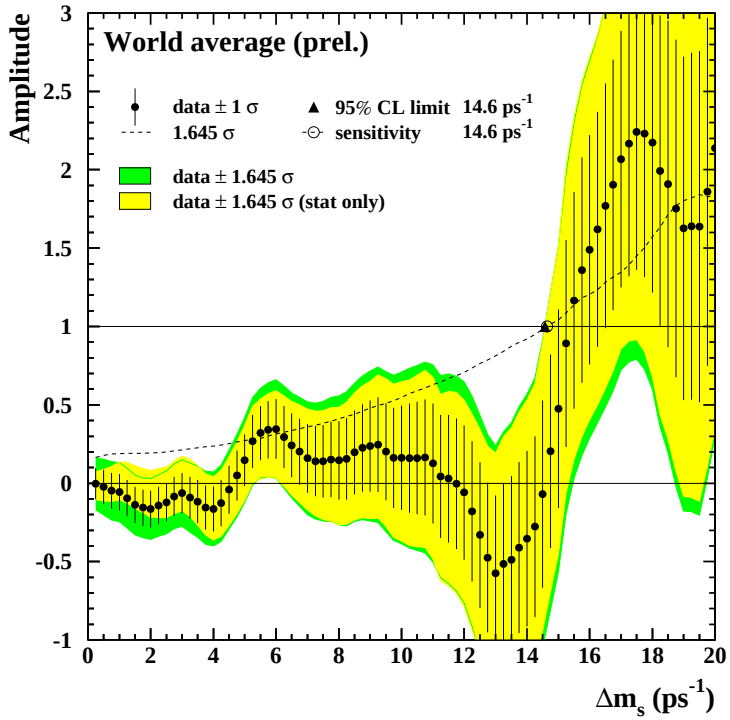
[a] Moser & co 1997

Limiti su Δm_s

- Canali analizzati
  - $b \to \ell$ (A,O,D,SLD)
  - $D_s \ell, \phi \ell$ (A,CDF,D)
  - $D_s + had$ (D)
  - B_s esclusivi (A(new),D)
- Limite Combinato (95 % C.L.)

$$\Delta m_s > 14.6 ps^{-1}$$

... dominato dalla statistica !



- Eccesso a $\sim 17 ps^{-1}$?

  toy MC: $\Delta m_s = \infty$

  Π(fluttuazione statistica) $\sim 3\%$

$\Delta\Gamma_s$

- Autostati di massa :
  - diversa vita media $\Gamma(B^S) > \Gamma(B^L)$
  - $\simeq$ autostati di CP $\begin{cases} CP(B^S) \simeq +1 \\ CP(B^L) \simeq -1 \end{cases}$
- In prima approssimazione :

$$\Delta\Gamma \simeq \Delta m \cdot \frac{3}{2}\left(\frac{m_b}{m_t}\right)^2$$

$\Longrightarrow$ se Δm_s e' molto grande si puo' misurare $\Delta\Gamma_s$!

- Recente predizione:[a]

$$y = \frac{\Delta\Gamma_s}{\Gamma_s} = (15.1 \pm 5.4)\ \%$$

[a] Hashimoto & co 1999

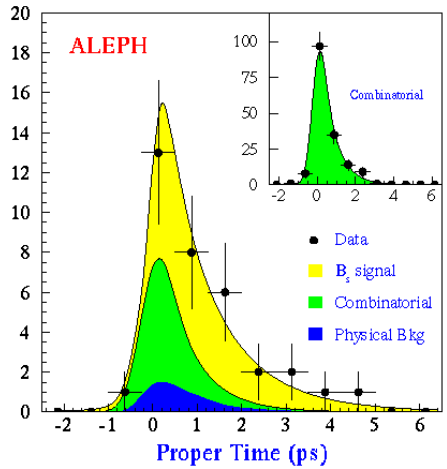
$\Delta\Gamma_s$: Metodi Sperimentali

- Da misure di vita media: $< \tau >= \frac{\mathcal{N}^S \tau^S + \mathcal{N}^L \tau^L}{\mathcal{N}^S + \mathcal{N}^L}$

Canale	$\frac{\mathcal{N}^L}{\mathcal{N}^S}$	$< \tau >$
(a) inclusivo	1	$\frac{1}{\Gamma}\frac{1}{1-y^2}$
(b) $D_s \ell$	$\frac{\Gamma^S}{\Gamma^L}$	$\frac{1}{\Gamma}\frac{1+y^2}{1-y^2}$
(c) $D_s D_s (J/\Psi\phi)$	~ 0	$\frac{1}{\Gamma}\frac{1}{1+y}$ $(= \tau^S)$

Nei campioni "misti" (a),(b) si impone $\Gamma = \Gamma(B_d)$

I campioni (c) sono 100% CP(+) (model dependent)



- Dalla misura del branching ratio $\mathcal{B}(B_s{}^S \to D_s^{(*)} D_s^{(*)})$ $\tau^{\text{short}} = 1.27 \pm 0.33 \pm 0.07$ ps
  1. stato $\sim$ 100% CP(+) (model dependent)
  2. contributo dominante a $\Delta\Gamma_s$

$$\frac{\Gamma(B_s{}^S \to D_s^{(*)} D_s^{(*)})}{\Gamma(B_s{}^S)} \simeq \frac{\Delta\Gamma}{\Gamma + \Delta\Gamma/2} = \frac{2y}{1+y}$$

$\Delta\Gamma_s$: Limiti

Usando:

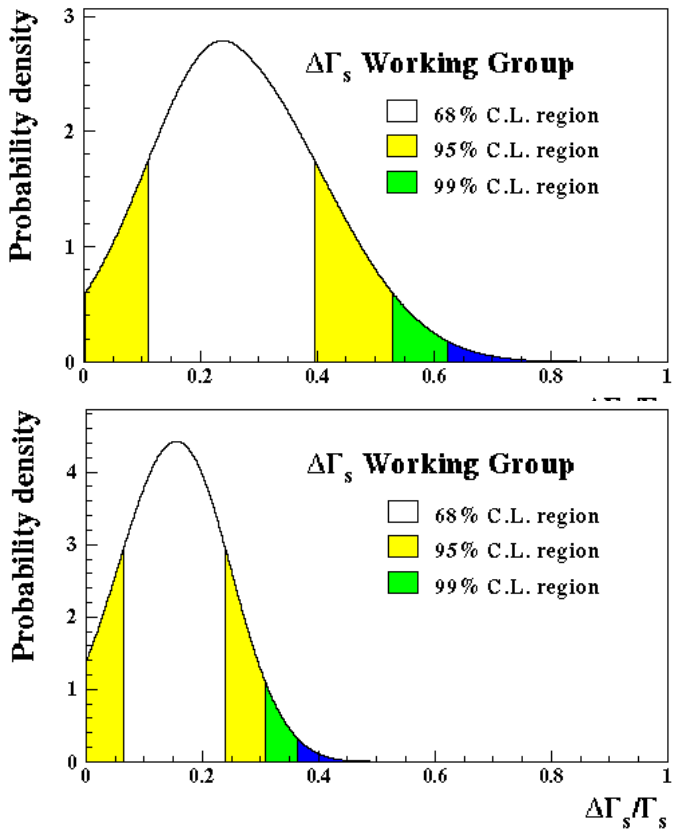
- $B_s \to D_s \ell \bar{\nu}$
- $B_s \to D_s + had$ (DELPHI)
- $B_s \to \phi\phi X$ (ALEPH)
- $B_s \to J/\Psi\phi$ (CDF)

$$\frac{\Delta\Gamma}{\Gamma} = 0.24^{+0.16}_{-0.12}$$

- + vincolo $1/\Gamma = \tau(B_d^0)$

$$\frac{\Delta\Gamma}{\Gamma} = 0.16^{+0.08}_{-0.09}$$

$$(< 0.31\ (95\% C.L.))$$



Con $\Delta\Gamma/\Delta m_s = 6.5 \times 10^{-3} (\pm 30\%)$

$\Delta m_s = 17^{+10}_{-11}\ \mathrm{ps}^{-1}$

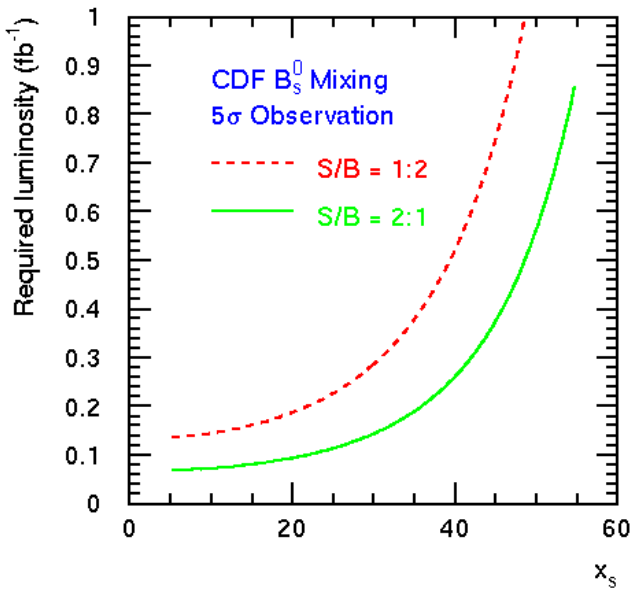
Oscillazioni: prospettive

CDF RUN II :

- $\int \mathcal{L} dt$
- PID : aggiunto TOF per K/π
- μ-vertice 3-D

Δm_s: canale "d'oro" $B_s \rightarrow D_s \pi$:

- $\sigma(vtx) \sim 50$ fs
- $x_s = \frac{\Delta m_s}{\Gamma_s} \Rightarrow 30 \sim$ pochi mesi
- $x_s = \frac{\Delta m_s}{\Gamma_s} \Rightarrow 60$ possibile (SM < 30)



$\Delta\Gamma_s$: canale CP(+) $B_s \rightarrow J/\Psi\phi$:

- analisi angolare (% CP(-)) ($\Rightarrow$ model independent)
- $\sigma(y) = 0.065(2\ fb^{-1}\ CDF)$
- $\sigma(y) = 0.020(2\ fb^{-1}\ BTEV)$

Vincoli sui lati di CKM

Fisica del B [a]:

- $\frac{|V_{ub}|}{|V_{cb}|} \propto \sqrt{\bar{\rho}^2 + \bar{\eta}^2}$
- $\frac{\Delta m_d}{\Delta m_s} \propto \sqrt{(1-\bar{\rho})^2 + \bar{\eta}^2}$

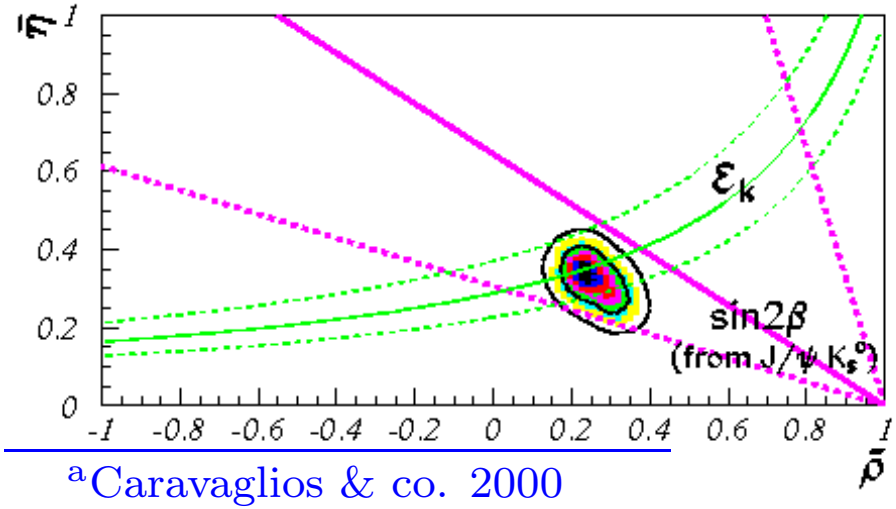
$\bar{\eta} = 0.325 \pm 0.054$

$sin(2\beta) = 0.74 \pm 0.08$

Parameter	Values
λ	0.2205 ± 0.0018
$\lvert V_{cb}\rvert$	$(40.5 \pm 1.9) \times 10^{-3}$
$\frac{\lvert V_{ub}\rvert}{\lvert V_{cb}\rvert}$ (CLEO)	0.085 ± 0.018
$\frac{\lvert V_{ub}\rvert}{\lvert V_{cb}\rvert}$ (LEP)	0.104 ± 0.019
Δm_d	$(0.476 \pm 0.016)\ ps^{-1}$
Δm_s	$> 14.3\ \mathrm{ps}^{-1}$ at 95% $C.L.$
$\overline{m_t}(m_t)$	$(167 \pm 5)\ GeV/c^2$
B_K	0.86 ± 0.10
$f_{B_d}\sqrt{B_{B_d}}$	$(210 \pm 42)\ MeV$
$\xi = \frac{f_{B_s}\sqrt{B_{B_s}}}{f_{B_d}\sqrt{B_{B_d}}}$	$1.11^{+0.06}_{-0.04}$

CP nello S.M.

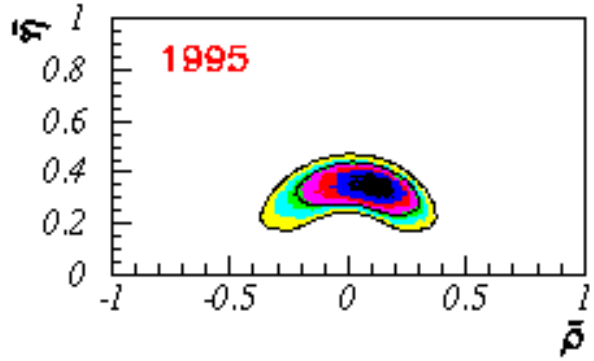
$+ \ |\epsilon_K| \sim \bar{\eta}(1-\bar{\rho})$:[a]

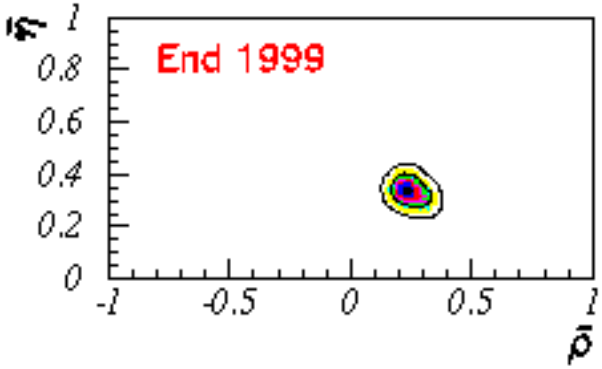


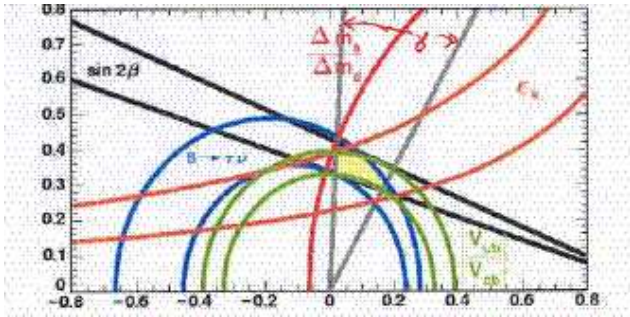
$$\bar{\rho} = 0.24^{+0.06}_{-0.05}$$
$$\bar{\eta} = 0.33 \pm 0.04$$
$$sin(2\beta) = 0.75 \pm 0.06$$
$$sin(2\alpha) = -0.38^{+0.24}_{-0.28}$$
$$\gamma = (55.5^{+6.0}_{-8.8})^o$$

[a] Caravaglios & co. 2000

Evoluzione di CKM







1995 →2000:

$$\sigma(|V_{cb}|) \sim 5\%$$
$$\sigma(|V_{ub}|) \sim 20\%$$
$$\frac{|V_{td}|}{|V_{ts}|} \lesssim 20\%$$

grazie a LEP II ?

2004: B-factories + Tevatron :

$$\sigma(|V_{cb}|) \sim 3\%$$
$$\sigma(|V_{ub}|) \sim 10\%$$
$$\sigma(|V_{td}|) \sim 10\%$$

Fisica del B →test dello S.M. !