$A_{FB}^{b,c}$ AT LEP1

ERNESTO MIGLIORE CERN

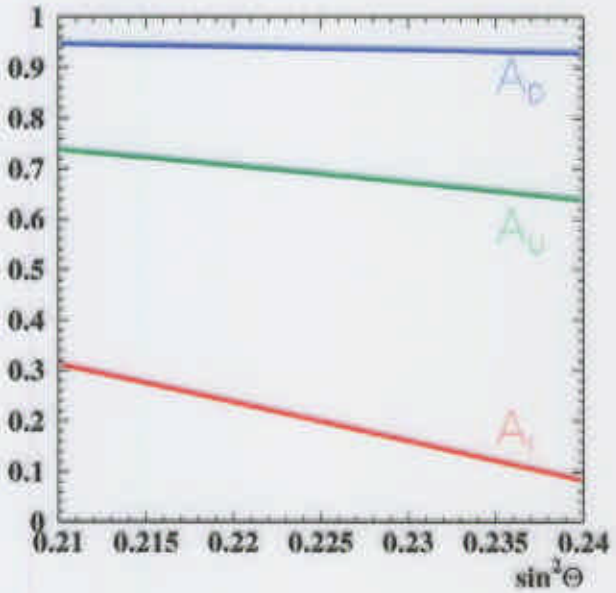
ON BEHALF OF THE LEP COLLABORATIONS

Basics of quark asymmetries

- $e^+e^- \to Z \to f\bar{f}$ at the Z peak
  ~~P~~ coupling of the Z to fermions
  larger rate of fermions produced in forward direction (wrt e^- beam)

$$A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B} = \frac{3}{4} A_e A_f$$

$$A_f = \frac{2x_f}{1 + x_f^2} \qquad x_f = \frac{v_f}{a_f} = 1 - 4|Q_f| \sin^2 \theta^f_{W,\,eff}$$



- larger in quarks than for leptons
- sensitive to $\sin^2\Theta^{lept}_{W,eff}$ (+ $m_{top} \to m_{Higgs}$)

Experimental Techniques

- Tag the flavour of the quark
  $Z\to c\bar{c}$ and $Z\to b\bar{b}$ easy to select $\to A_{FB}$ performed with HF
- Determine quark direction ($\to$thrust)
- Determine $q/\bar{q}$ hemisphere

Methods based on:

- **global event properties**
  - lifetime-tag + jet charge
- **Detection of particles "typical" of HF decay**
  - lepton tag
  - D mesons tag

"pole A_{FB}" $\to$ Results corrected for:

- QED effects (δA^b_{FB}: ISR +0.4% / FSR +0.02%)
- dependence on $\sqrt{s}$ $A_{FB}(\gamma Z) \propto Q_e\, Q_q\, a_e\, a_q$
- QCD effects ("hard" gluon radiation)

$$(1 - s_q \times C^{had,T}_{QCD})\, A^q_{FB,\ no\ QCD}$$

analysis dependent
lepton: 0.5-0.7
D and Jet Charge: ~ 0.3

3.54±0.63% q=b
4.13±0.63% q=c

Lifetime tag & Jet Charge

- $b\bar{b}$ events tagged with impact parameter based method (long b lifetime + vtx detectors)
- Charge flow

$$Q_{hem} = \frac{\sum q_i \left|\vec{p}_i \cdot \vec{T}\right|^{\kappa}}{\sum \left|\vec{p}_i \cdot \vec{T}\right|^{\kappa}} \qquad \begin{array}{l} \vec{p}_i \cdot \vec{T} > 0 \rightarrow F \\ \vec{p}_i \cdot \vec{T} < 0 \rightarrow B \end{array}$$

$$Q_{FB} = Q_F - Q_B$$

In a pure b sample:

$$\langle Q_{FB} \rangle_b = \eta_b \delta_b A^b_{FB} \qquad \delta_b = \langle Q_b - Q_{\bar{b}} \rangle \sim 2 q_b$$

δ_b measured directly in the data from

$$Q_{TOT} = Q_F + Q_B \qquad \langle Q_{TOT} \rangle \sim 0$$

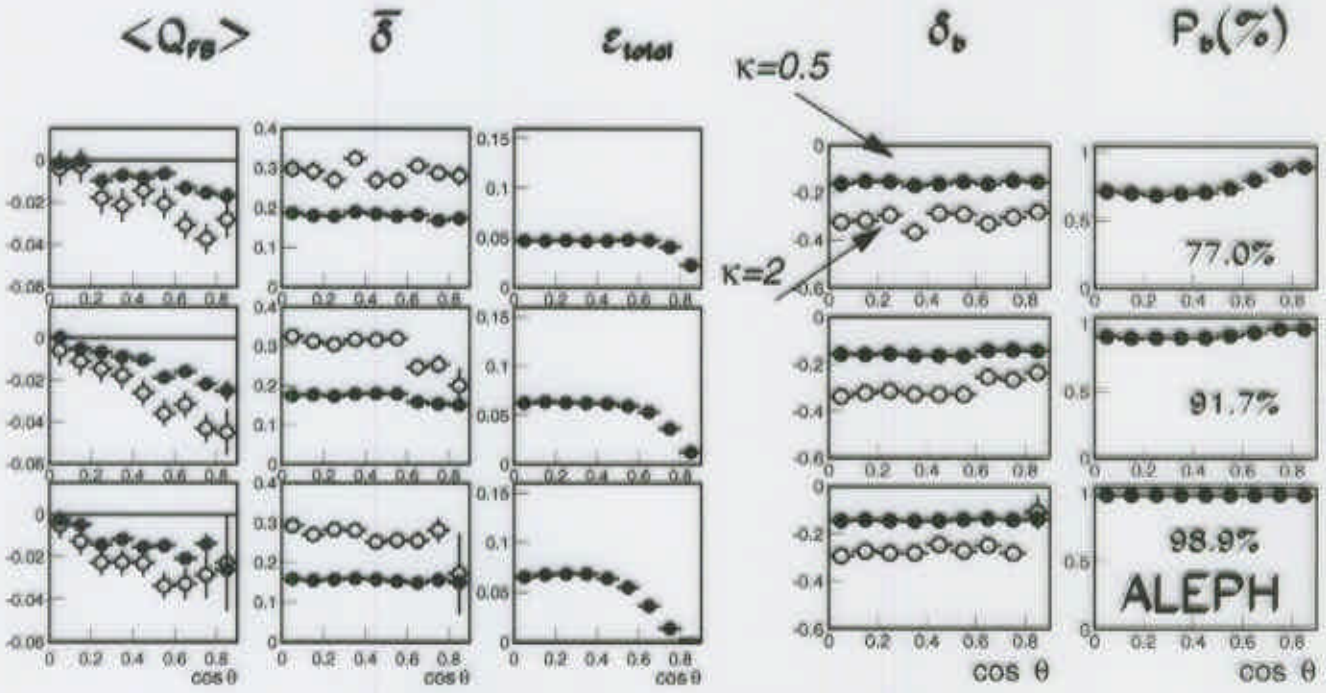
$$\delta^2_b = \sigma^2_{FB} - \sigma^2_{TOT} + \langle Q_{FB} \rangle^2 + cor(HH)$$

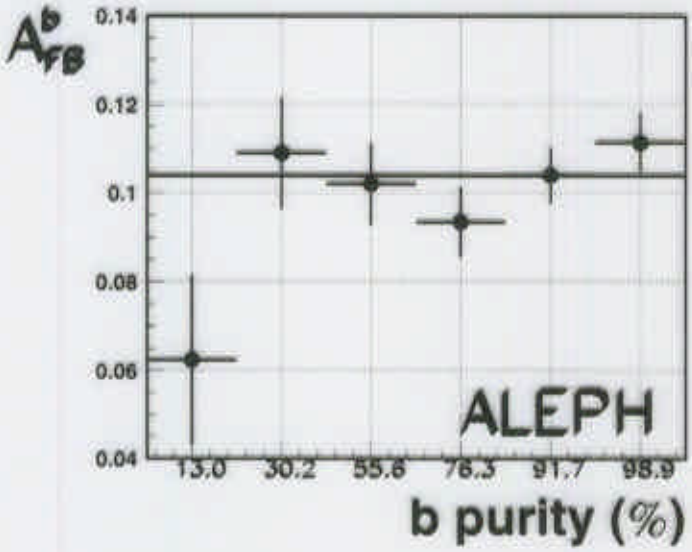
In a not b-pure sample

$\langle Q_{FB} \rangle = \Sigma P_q \eta_q \delta_q A^q_{FB}$ P_b determined from data

(δ_{uds}, P_{uds} from MC, δ_c, P_c from MC or data)

- *ALEPH and DELPHI*
  measurements in function of b-purity and κ



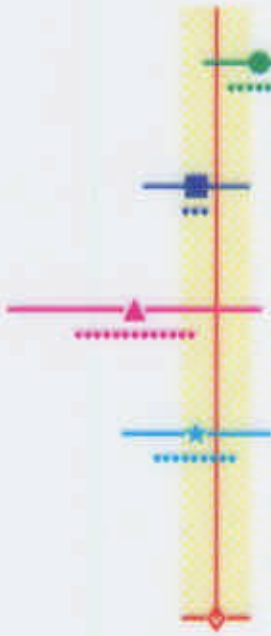


- *Variations*

  OPAL Jet Charge + vtx charge

  L3 $\text{sign}(Q_F - Q_B)\cos\theta_T$

$$A_{FB}^{b\bar{b}} \text{ at } \sqrt{s} \approx m_Z$$

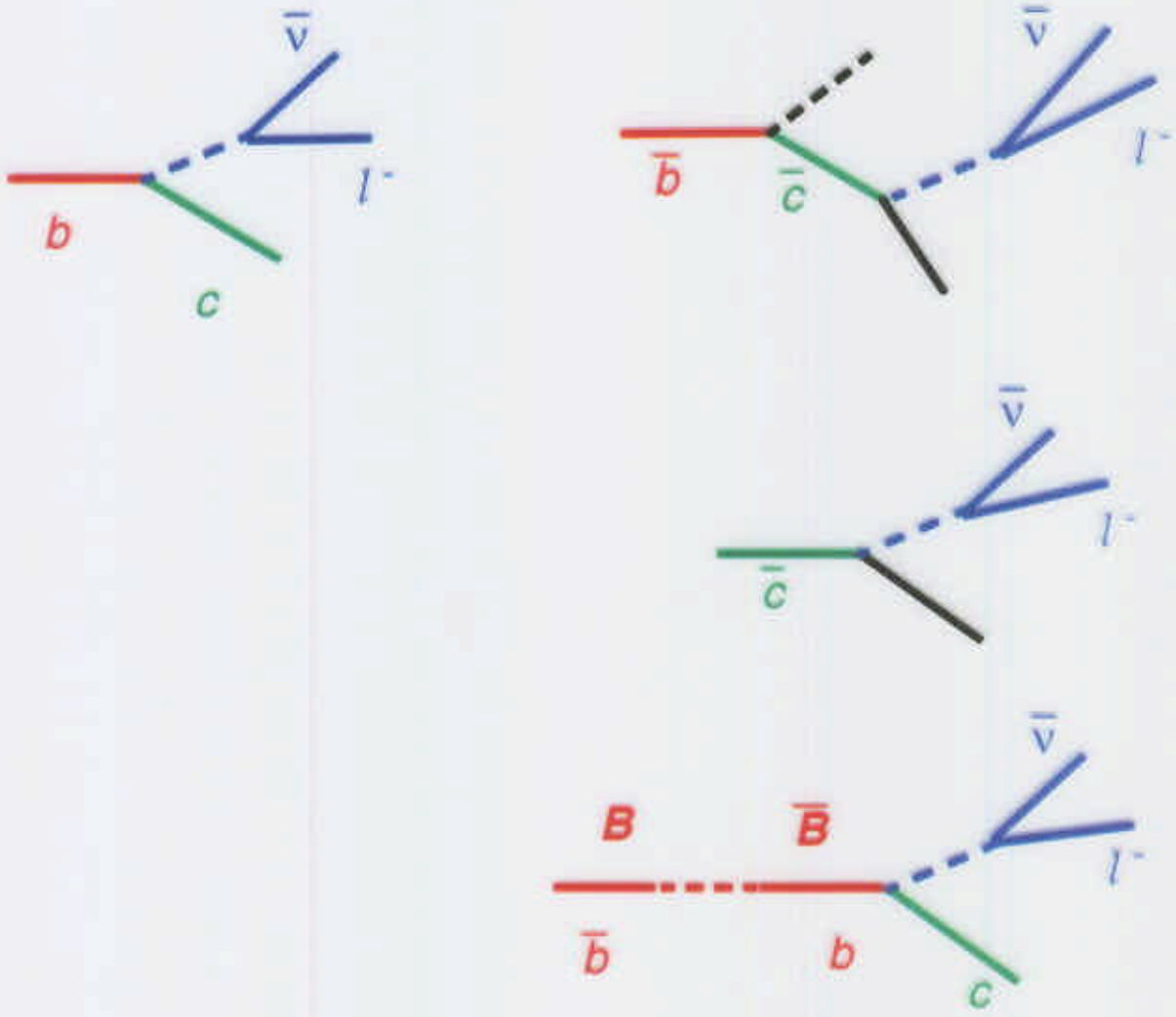


ALEPH jet-ch '1991-95	0.1040 ± 0.0040 ± 0.0032
DELPHI jet-ch '1992-95	0.0982 ± 0.0047 ± 0.0016
L3 jet-ch '1991-95	0.0931 ± 0.0101 ± 0.0055
OPAL jet-ch '1991-95	0.1004 ± 0.0052 ± 0.0044
JET-CHARGE	0.1021 ± 0.0031

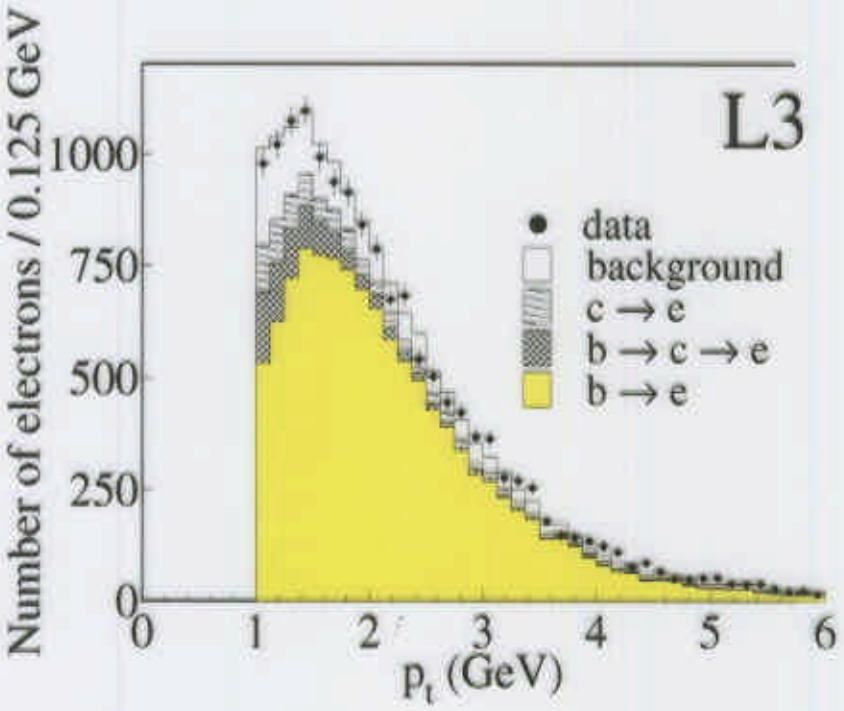
- *Systematics:*
- *tracking resolution (ε_{uds} and ε_c)* ±0.001 ±0.002
- *hem-hem charge correlation* ±0.001 ±0.002
- δ_c ±0.001 ±0.002
- *MC modelling of δ_{uds}* < 0.001

Lepton Tag

- Leptons (e/μ) with high
  p (hard fragmentation)
  p_T (large mass of b and c)
  typical of b,c semileptonic decays
- Tag of both flavour and charge of the parent quark



Charge mistagging

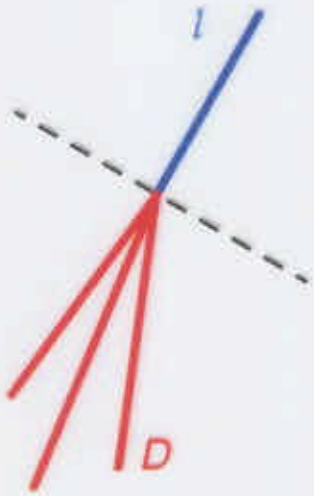


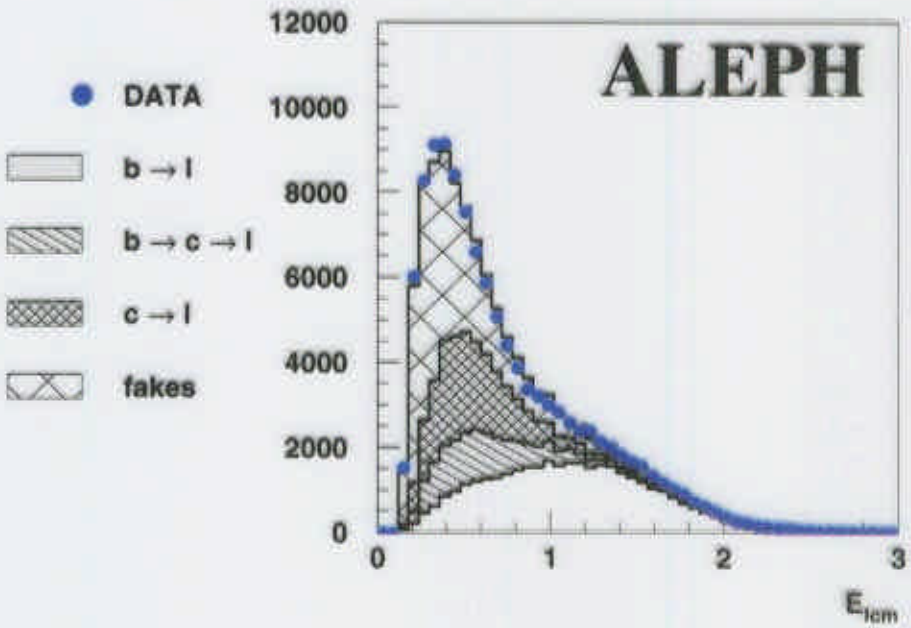
$$A_{FB}^{obs} = \left[(1-2\bar{\chi})(f_b - f_{bc})A_{FB}^{b} - f_c A_{FB}^{c}\right] w(\theta) + f_{bgd} A_{FB}^{bgd}$$

- *Separation of different contributions based on lepton decay models →systematics*
- *Sensitive to both A^b_{FB} and A^c_{FB}*
- *Statistical significance $1/(f_b - f_{bc})$*
- *Use of extra variables for:*
  - *b-enrichment (b-tagging)*
  - *b→l/b→c→l separation (d/σ_d, $\not{E}$)*
- *variables combined using Neural Network (A,O) or multivariate (D)*

ALEPH lepton

- *separation of uds/b contributions*
  p, p_T, P_E, E_{mis}, Σp_T^2, d/σ_d $\rightarrow N_b$
  p_{fast}, χ^2_{vtx}, E_{vis}, $p_{T,\pi\text{-slow}}$ $\rightarrow N_{uds}$
- *separation of* $B \rightarrow D\, l\, \nu$ / $B \rightarrow D\, W\, (D \rightarrow X\, l\, \nu)$ *using variables in the (D l) frame*





in addition to p, p_T, d/σ_d, $E_{mis} \rightarrow N_{bl}$

- *binned likelihood in* N_b, N_{uds}, N_{bl} *and* $Q_l \cos\theta_T$ *(effective* $\bar{\chi}_{ijkl}$ *computed in each bin because of lifetime information used in* N_b*)*
- ΔA^b_{FB} *stat:* 0.0044 → 0.0040 *(peak)*

DELPHI lepton

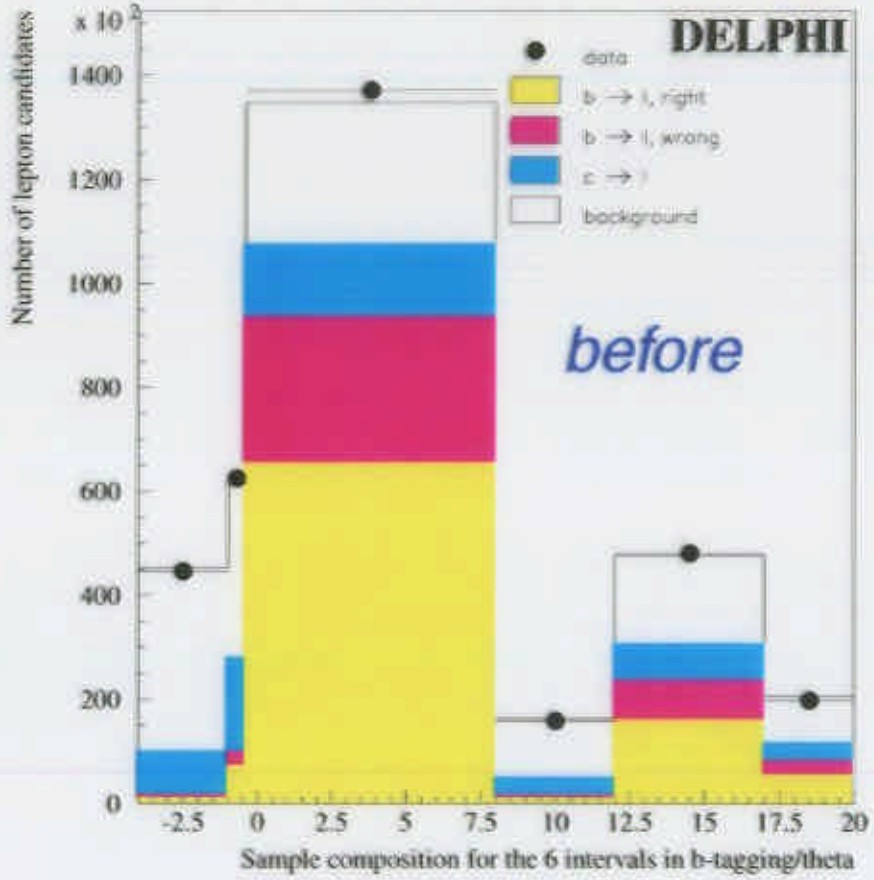
- *use of b-tagging for b/c/uds separation*
- *need of self-calibration on the data*
  - *reduce dependence on the model parameters*
  - *allow independent control of bgd level*

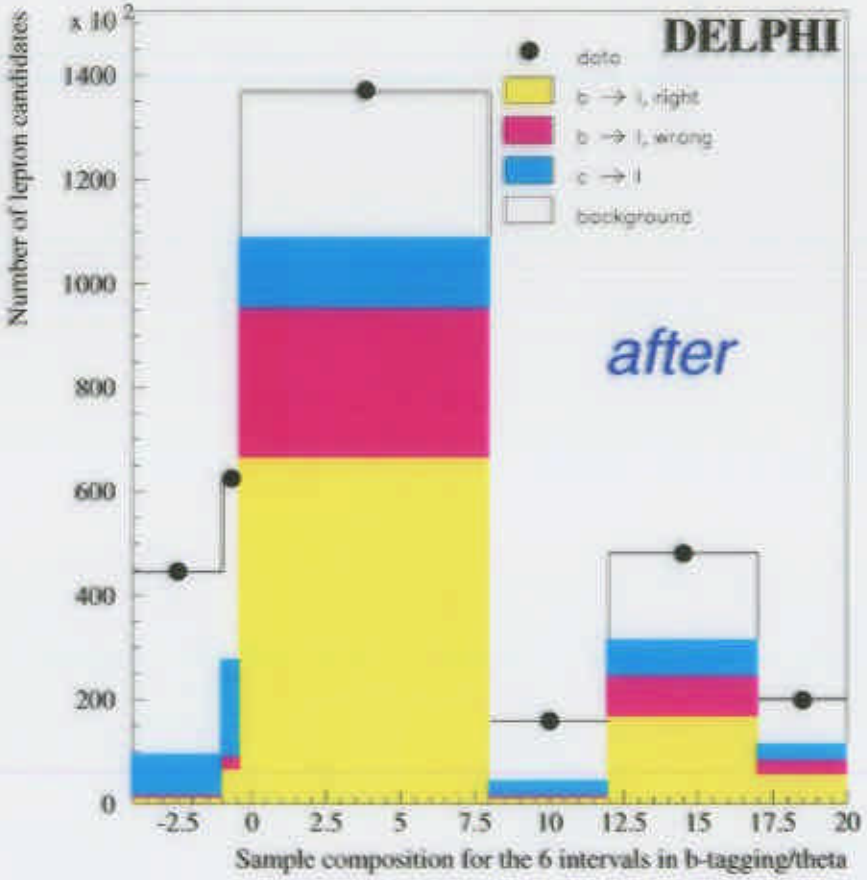
  extension of the 1-tag vs 2-tag technique used in R_b
- *jet charge in the hemisphere opposite to the lepton for b→l/b→c→l separation*

  $Q_{opp} \times Q_l$

Direct		Cascade	
$b \to l^-$	$+Q_b$	$\bar{b} \to \bar{c} \to l^-$	$+Q_{\bar{b}}$
$\bar{b} \to l^+$		$b \to c \to l^+$	

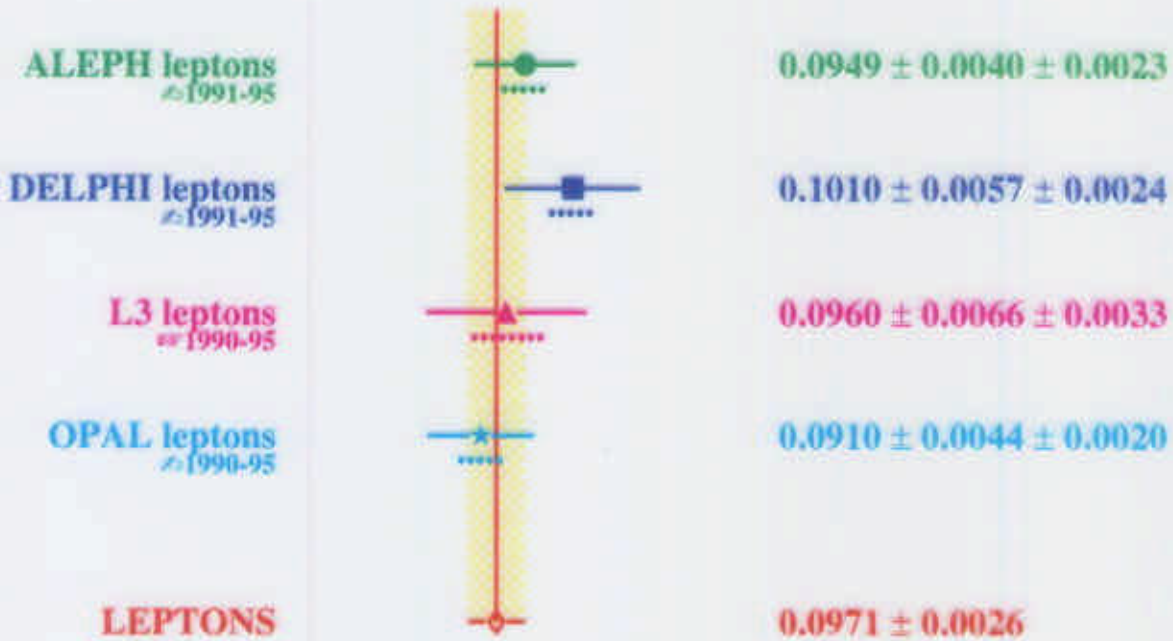
- *self-calibrated on the data*
  Syst. ΔA^b_{FB}: 0.0007 ΔA^c_{FB}: 0.0012
- *ΔA^b_{FB} stat: 0.0070 → 0.0063 (93-95 peak)*





- *Corrections can be large (2% for b, 5% for c) but well determined*
  Systematics: $\Delta A^{b}_{FB} < 0.0001$ ΔA^{c}_{FB}: 0.0003

$$A_{FB}^{b\bar{b}} \text{ at } \sqrt{s} \approx m_Z$$



- *Systematics on A^b_{FB} (peak):*

source	ALEPH	DELPHI	L3	OPAL
Fragm. + BR	0.0013	0.0009	0.0012	0.0004
Decay Models	0.0011	0.0012	0.0016	0.0014
Bgd	0.0003	0.0011	0.0023	<0.0001
Detector	0.0002	0.0003	0.0015	0.0011
mixing	0.0013	0.0010	0.0003*	0.0004*

* $\bar{\chi}$ fitted with A^b_{FB}

Single systematics below 0.0020

D meson tag

- D mesons produced in $b\bar{b}$ and $c\bar{c}$ events only (at similar rate)
- reconstructed D meson correlated with the charge of the parent quark
- Tagging efficiency limited by the reconstructed decay channels

$D^{*+} \rightarrow D^0 \pi^+$ $p^* \sim 40$ MeV/c

$\rightarrow (K^- \pi^+) \pi^+$

$\rightarrow (K^- \pi^+ \pi^+ \pi^+) \pi^+$ $BR(D^{*+} \rightarrow D^0 \pi^+) \sim 68\%$

$\rightarrow (K^- \pi^+ (\pi^+)) \pi^+$

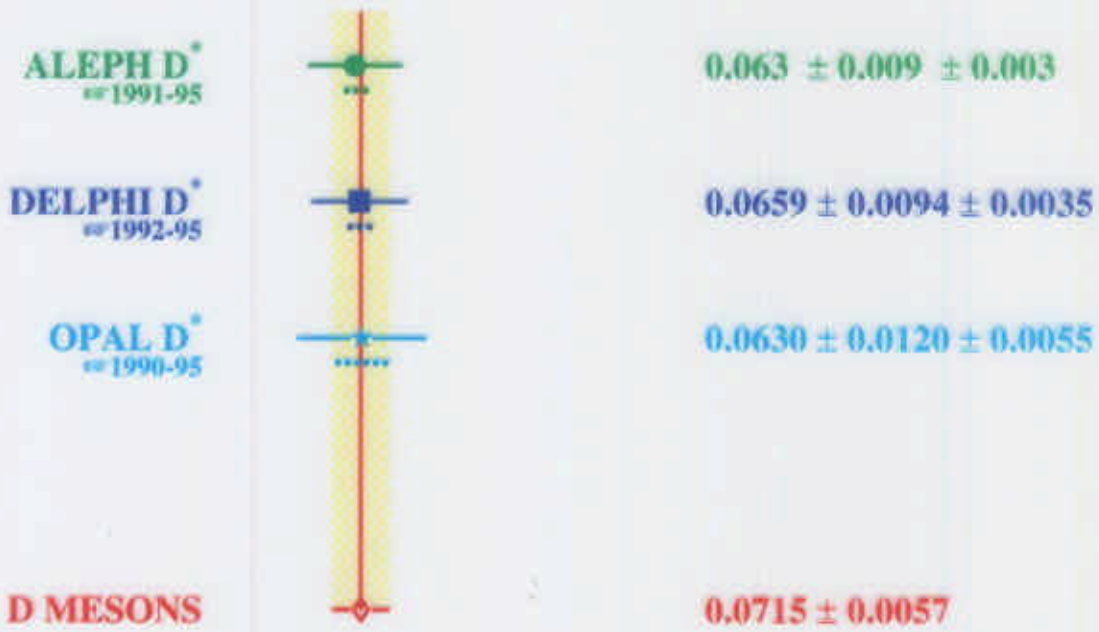
$\rightarrow (K^- l^+ \nu) \pi^+$

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

$D^+ \rightarrow K^- \pi^+ \pi^+$

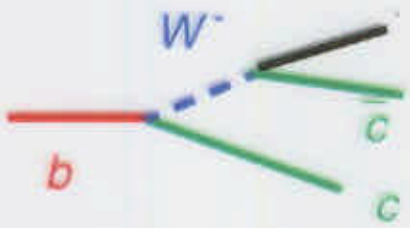
- Combinatorial background
  - rejection (π veto) using particle ID (dE/dX, RICH)
  - cut on $\cos\theta^*_{"K" D}$
- $b \rightarrow D/c \rightarrow D$ separation
  - b-tagging
  - $\langle X_D \rangle = E_D/E_{beam}$ ($\langle X_D \rangle > 0.5 \rightarrow f_c \sim 80\%$)
  - fit A^b_{FB} and A^c_{FB} (D/O) $\rightarrow$ statistical correlation (-20%)
  - fix A^b_{FB}, fit A^c_{FB} (A)

$$A_{FB}^{c\bar{c}} \text{ at } \sqrt{s} \approx m_Z$$



- *Systematics:*
- *Bgd asymmetry* ±0.0015 ±0.0020
- *Effective mixing* ±0.0015

Upper Vertex charm production



Different rate of (B → D/D) / (b → D*/D) and lifetime*

- *from existing measurements (A/D)*

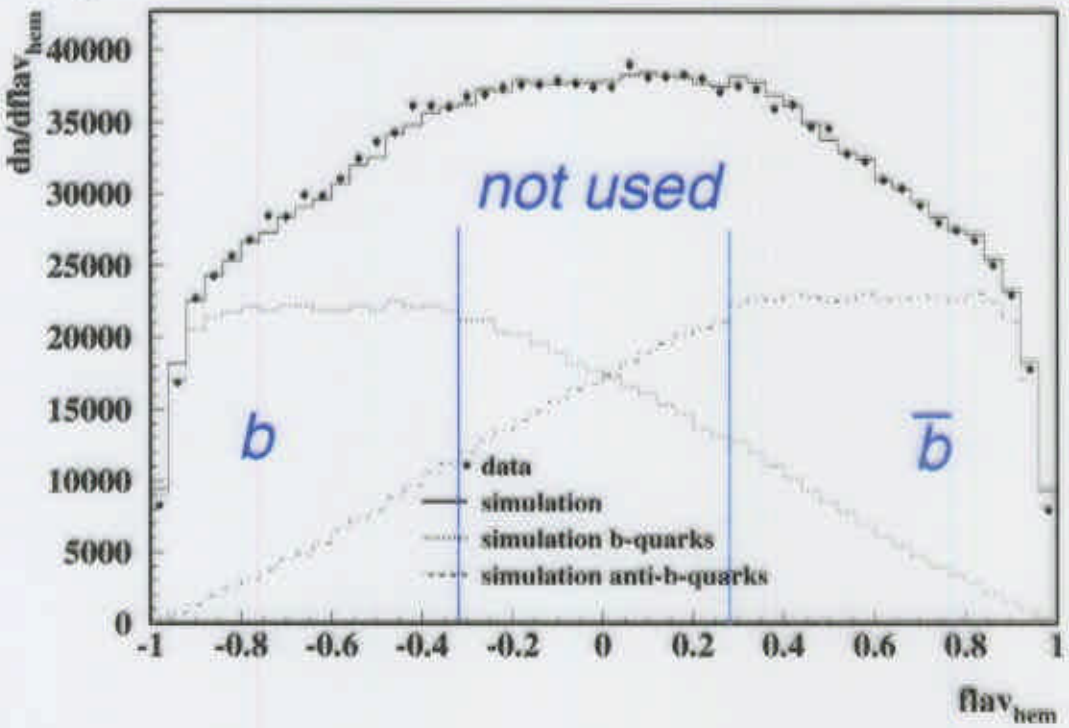
$$\bar{\chi}(D^{*+}) = \bar{\chi}(D^{+}) = 0.222 \pm 0.033$$

- *from data (Jet-Charge in opposite hemisphere) (O)*

$$\bar{\chi}(D^{*+}) = \bar{\chi}(D^{+}) = 0.191 \pm 0.083$$

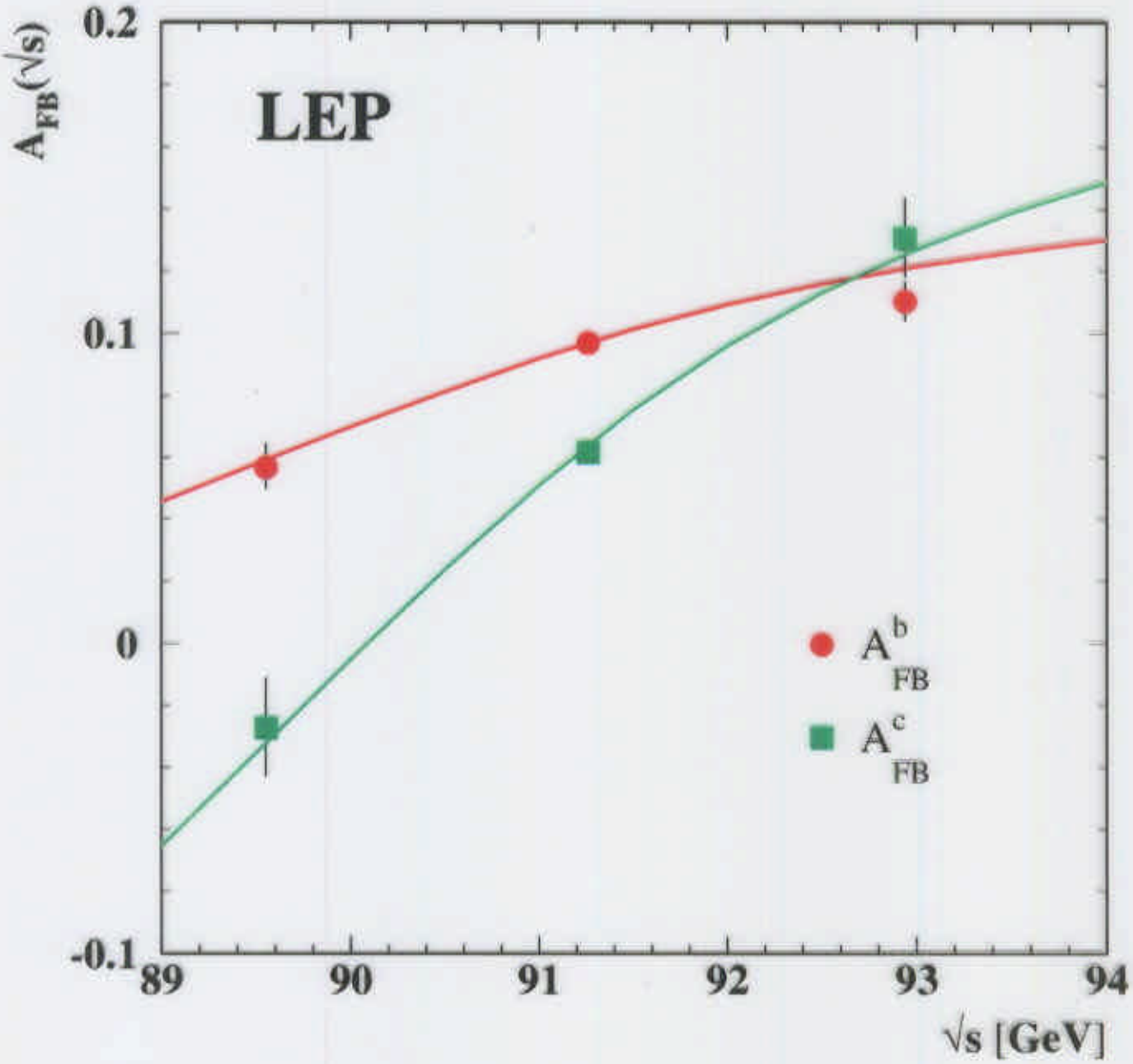
New Technique: DELPHI inclusive charge reconstruction

- *b tagging to select $Z \rightarrow b\bar{b}$*
- *b/$\bar{b}$ tagging with NN (also identified particles in the inputs)*



- *High statistical power (charge confusion <1/3)*
  ΔA^b_{FB} *stat. = 0.0037 (peak)*
- *Strict control of the systematics mandatory!*
  Self-calibration on the data (2-tag evts)
  knowledge of hem.- hem. correlation
- *Integration with other measurements not yet done*

Dependence on $\sqrt{s}$ (γZ)

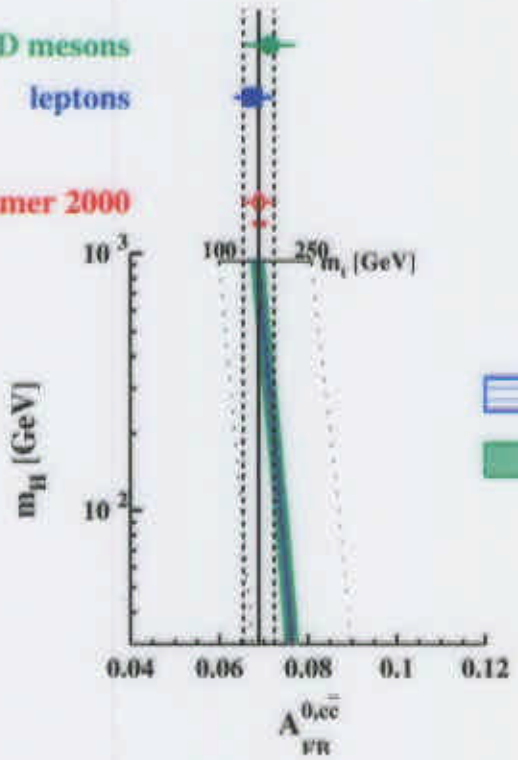


...described by the SM model

→ $A^{b,c}_{FB}$ corrected to pure Z exchange

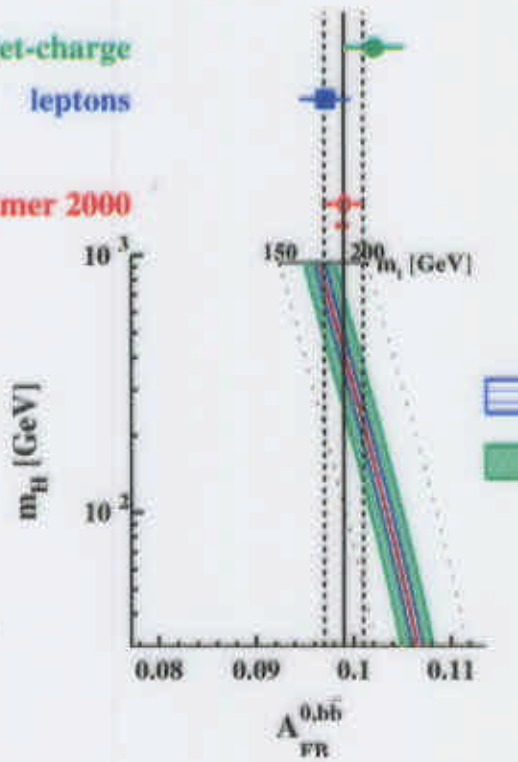
Effect on EW fit

- $A^{c,0}_{FB}$



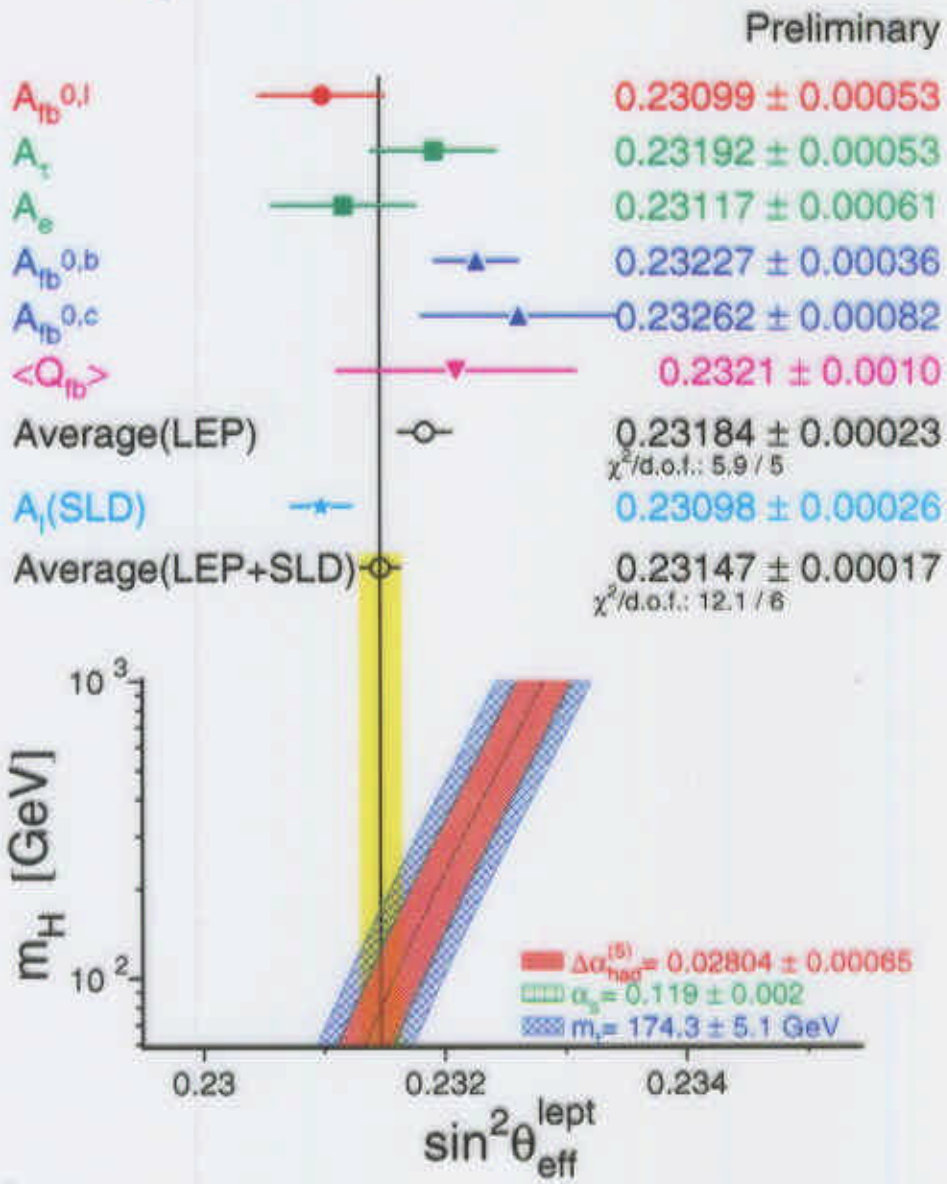
0.0692±0.0037
Winter 2000

- $A^{b,0}_{FB}$



0.0988±0.0020
Winter 2000

Summary



- *$A^{b,0}_{FB}$ still most precise measurement of $\sin^2\Theta^{lept}_{W,eff}$ at LEP (still stat. dominated...)*
- *small changes wrt Winter 2000*
- *consistent results in the different methods*
- *LEP collaborations still active in the analysis*