

Measurement of A_b , A_c with leptons

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Thanks to...

Electron analysis

- Sal Fahey $\sqrt{\text{gone}}$
- Jorge Fernandez $\sqrt{\text{gone}}$

Muon analysis

- Giampiero Mancinelli $\sqrt{\text{gone}}$
- Giulia Bellodi ...all alone 

The idea...

Extract A_b and A_c from the polarized forward-backward asymmetry of the quark production cross section:

$$\frac{d\sigma}{d\cos\theta} = (1 - A_e P_e)(1 + \cos^2\theta_f) + 2A_f(A_e - P_e)\cos\theta_f$$

where $f=b,c$ and :

- P_e = beam polarization
- A_e, A_f = coupling asymmetries
- θ_f = polar angle

L-R F-B asymmetry

$$A_{FB}^f = \frac{[\sigma_L^f(z) - \sigma_L^f(-z)] - [\sigma_R^f(z) - \sigma_R^f(-z)]}{[\sigma_L^f(z) + \sigma_L^f(-z)] + [\sigma_R^f(z) + \sigma_R^f(-z)]} = |P_e| A_f \frac{2|z|}{1+z^2}$$

with $z=\cos\theta$.

step by step..

- select $b\bar{b}$ semileptonic events
- identify the $b(\bar{b})$ quark (using the charge of the lepton) and its *direction* ($\sim$ direction of the jet closest to the lepton)
- maximum likelihood fit to the polarized cross section to extract A_b and A_c

$$p_i(A_b, A_c) = \frac{3}{8} \left\{ (1 + \cos \theta_i^2)(1 - A_e P_i) + 2(A_e - P_i) \right. \\ \left. [w_i^b(1 - 2\chi_i)(1 - \Delta_{QCD}^b(\theta_i))A_b \right. \\ \left. + w_i^c(1 - \Delta_{QCD}^c(\theta_i))A_c + w_i^{bkg}A_{bkg}] \cos \theta_i \right\}$$

where P_i = event polarization,

$\Delta_{QCD}^f = O(\alpha_s)$ QCD corrections à la Stav & Olsen,
f=b,c

A_{bkg} = background asymmetry,

χ^i = event mixing parameter,

w_i^f = lepton sources probabilities (b direct decay, b

cascade decay, c decay, bkg) derived from the full MC simulation.

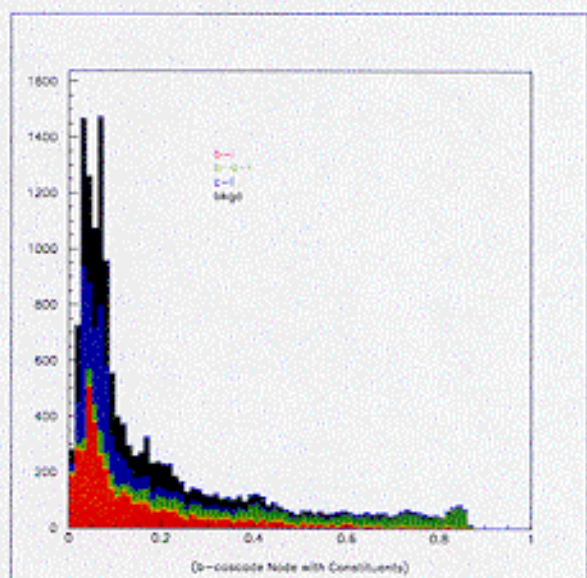
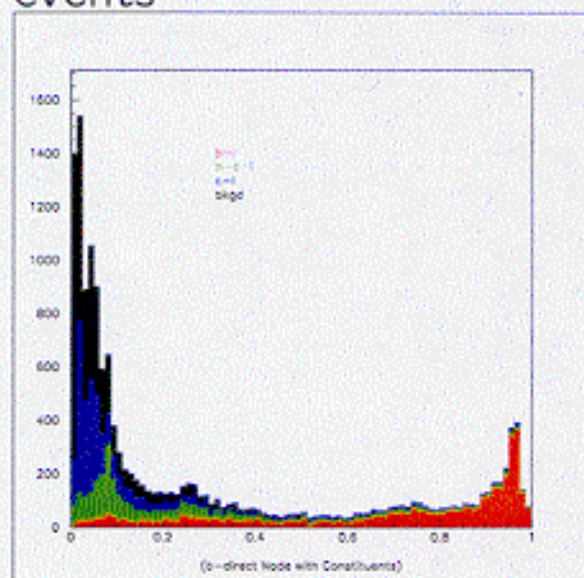
the **electron** analysis uses a Neural Net for the electron source classification :

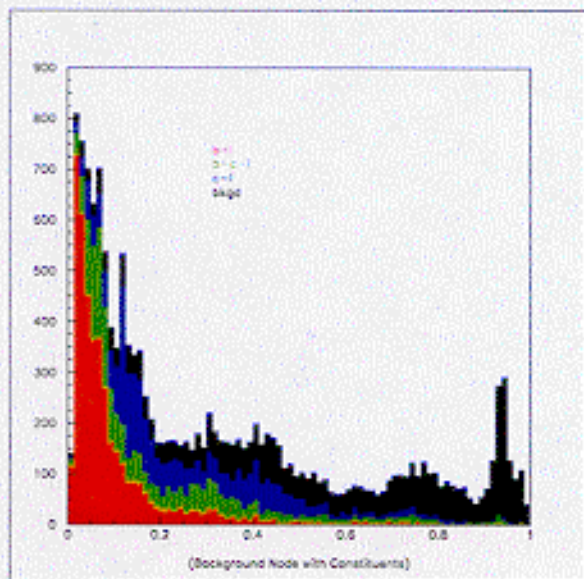
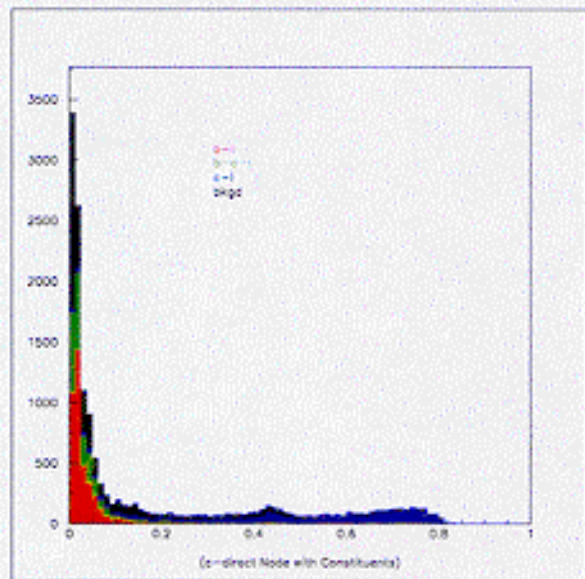
inputs(tagging variables):

- electron momentum
- transverse momentum wrt nearest jet axis
- reconstructed associated vertex mass
- reconstructed associated vertex momentum
- vertex significance (decay length/vertex error)
- opposite hemisphere vertex mass
- boost of underlying B meson L/D

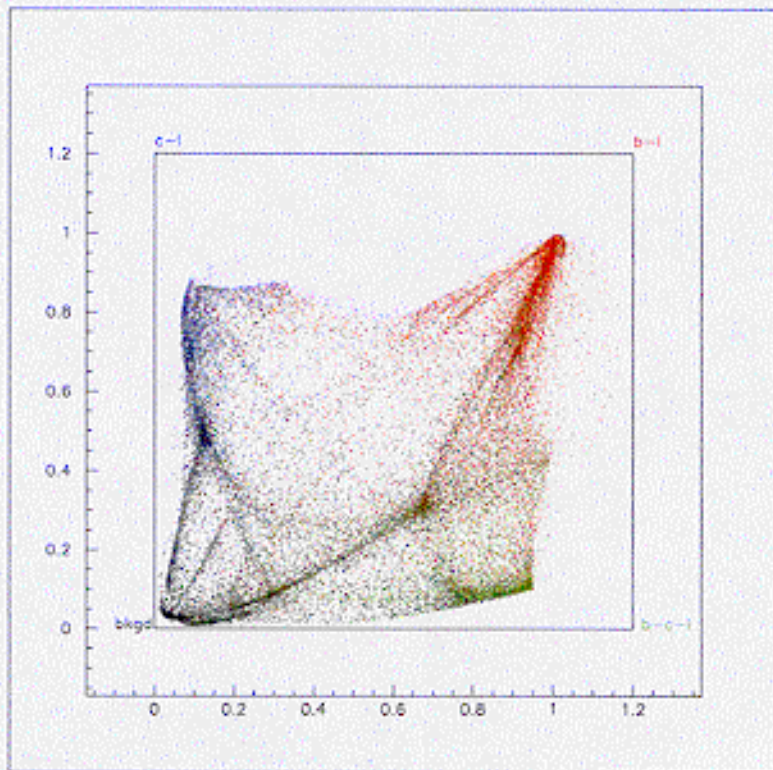
4 output nodes

corresponding to the $b \rightarrow e$, $b \rightarrow c \rightarrow e$, $c \rightarrow e$ and bkg events





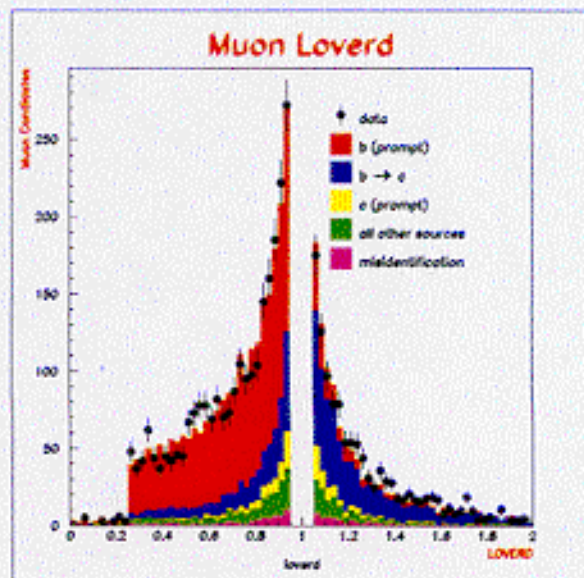
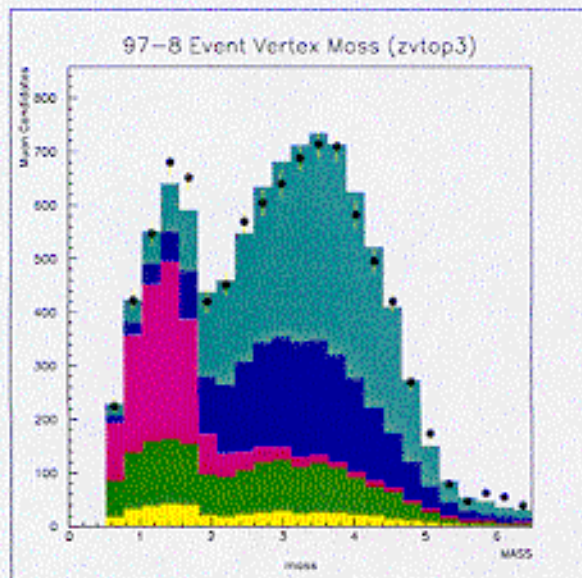
outputs are combined in a 2-D representation to calculate weights
 (50×50 bins)



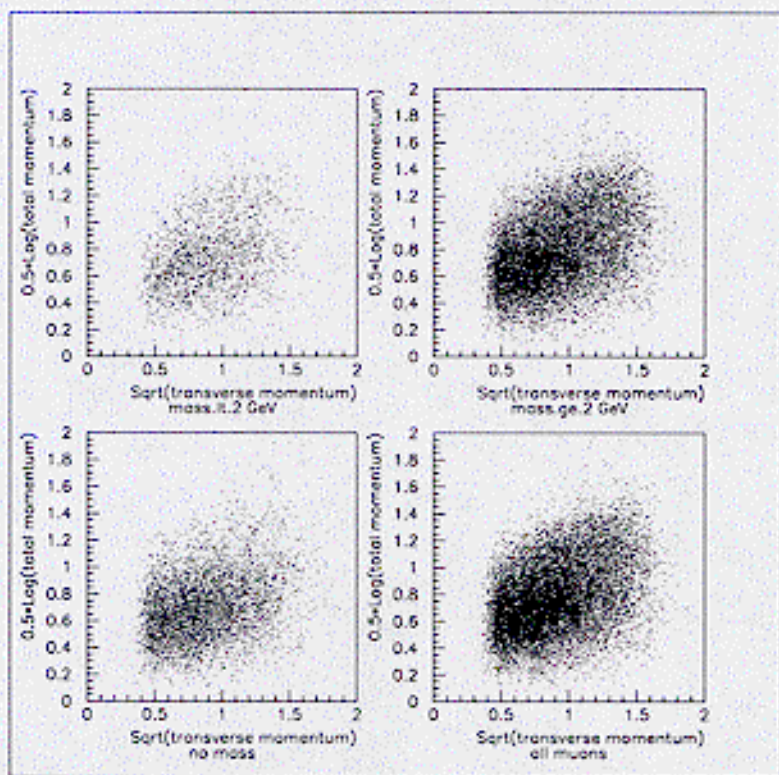
multivariate analysis for muons

tagging variables:

- total momentum,
- transverse momentum wrt nearest jet axis,
- event mass (highest of the hemisphere masses),
- L/D



use nearest neighbours technique (with fixed area) to calculate weights from the simulation in $3 \sqrt{P_T}$ vs $\frac{1}{2} \log P$ planes corresponding to 3 mass regions ($[0.55, 2]$, > 2 , no mass reconstructed)



finally, normalized reweighting of the source probabilities through set of fractions derived by **L/D distribution** (increase AP in discrimination between b direct and b cascade decays) taking into account correlations with the other tagging variables

Electron Analysis

- electrons identified with a NN using both LAC and CRID information for charged tracks with $p > 2 \text{ GeV}/c$ and $|\cos\theta| < 0.72$ (electron must have NN output of at least 0.96, 1% misid fraction from $K_s^0 \rightarrow \pi^+\pi^-$ sample).
- require at least one vertex in associated or opposite hemisphere (to reject backgrounds)
- pass the data through the Electron Source Classification Neural Net to calculate ML weights
- fit for A_b (A_c fixed because of the vertex requirement) using:

$\bar{\chi} = 0.1260$ average value for all events, calculated from MC (account for analysis bias) and reweighted for b cascade events to account for different mixing probabilities (use $\bar{\chi} = 0.1364$ for $b \rightarrow c \rightarrow e$ and $\bar{\chi} = 0.1376$ for $b \rightarrow \bar{c} \rightarrow e$).

A_{bkg} = bkg asymmetry estimated from charged non-leptonic tracks as a function of p , p_T

Electron results

<i>Dataset</i>	<i>A_b results</i>
1993*	$0.899 \pm 0.190 \pm 0.120$
1994-5*	$0.866 \pm 0.118 \pm 0.041$
1996	$0.841 \pm 0.126 \pm 0.030$
1997	$0.867 \pm 0.097 \pm 0.030$
1998	$0.892 \pm 0.066 \pm 0.028$
<i>Combined 1996-98</i>	$0.877 \pm 0.050 \pm 0.028$
<i>Combined 1993-98</i>	$0.876 \pm 0.045 \pm 0.028$

(* = old p , p_T only analysis)

results to be corrected for **ISR** and
 2^{nd} order QCD effects (new calculations)
($\Delta A_b \sim +0.8\%$)

Systematic errors

Source	Variations adopted	(1996)	(1997)	(1998)
Monte Carlo stat.	weights var.	.0093	.0113	.0077
Tracking eff.	MC/dt trk mult.	.0013	.0012	.0002
Jet axis sim.	10 mrad smear.	.0103	.0080	.0044
Bkg level	$\pm 10\%$	.0042	.0044	.0042
Bkg asymmetry	$\pm 40\%$	.0035	.0030	.0025
$BR(Z^0 \rightarrow b\bar{b})$	$(21.73 \pm .09)\%$	.0005	.0004	.0004
$BR(Z^0 \rightarrow c\bar{c})$	$(17.30 \pm .44)\%$	.0005	.0007	.0005
$BR(b \rightarrow e^-)$	$(11.06 \pm .19)\%$	.0034	.0024	.0034
$BR(b \rightarrow c \rightarrow e^+)$	$(8.02 \pm .32)\%$	.0043	.0021	.0034
$BR(b \rightarrow \bar{c} \rightarrow e^-)$	$(1.3 \pm .5)\%$	.0019	.0008	.0014
$BR(b \rightarrow \tau \rightarrow e^-)$	$(0.472 \pm .075)\%$	.0023	.0002	.0005
$BR(b \rightarrow J/\psi \rightarrow e^\pm)$	$(0.07 \pm .02)\%$	.0010	.0023	.0020
$BR(c \rightarrow e^+)$	$(9.8 \pm .5)\%$	.0016	.0015	.0011
$B^{\pm,0}-D^{**}$ frac.	$(23 \pm 10)\%$	.0023	.0002	.0016
B_s-D^{**} frac.	$(32 \pm 10)\%$	.0010	.0006	.0005
D lept. spect.	$ACCM1^{+2}_{-3}$	.0031	.0047	.0034
B_s fraction	$.115 \pm .050$	.0037	.0049	.0040
Λ_b frac.	$.072 \pm .030$	.0017	.0013	.0026
b frag.	$\epsilon_b = .0045 - .0075$	.0016	.0013	.0016
c frag.	$\epsilon_c = .045 - .070$	.0006	.0006	.0004
Aleph frag.	reweighting	.0037	.0037	.0037
Polarization	$P = 0.729 \pm .0038$	.0045	.0045	.0047
2 nd order QCD	Δ_{QCD} uncert.	.0044	.0044	.0044
B mixing	$\bar{\chi} = .1217 \pm .0046$	.0110	.0107	.0114
B mixing cascade	$\chi = .1285 \pm .0071$	.0011	.0007	.0031
NN training	10 training runs	.0129	.0129	.0129
$D^0/D^\pm$	15% uncert.	.0010	.0010	.0010
Vertex reconst.	track eff.	.0144	.0144	.0144
A_c	$0.667 \pm .070$	.0037	.0030	.0039
Total		0.0299	0.0296	0.0281

Muon analysis

- muons are identified through a set of p and $\cos\theta$ dependent cuts based on kinematic and CRID information :

$p > 2$ GeV, # of WIC hits, χ^2 WIC fit, χ^2 DC/WIC match, likelihood functions..

80% μ -id efficiency for $|\cos\theta| < 0.60$

0.3% misid fraction for *punch trough* pions

- calculate decay source probabilities from MC phase space as a function of p, p_T , mass and L/D (no vertex requirements!)

- ML fit for A_b ($A_c??$) using:

$\chi_i =$ *mixing parameter* calculated event by event (new!)

$A_{bkg} =$ *bkg asymmetry*, estimated from MC simulation (new!)

$\Delta_{QCD} =$ *QCD corrections* (new!)

Background level studies

compare muon misid rates in DT and MC using:

- samples of $K_s^0 \rightarrow \pi^+ \pi^-$
- sample of 3-prong τ decays

1. $K_s^0 \rightarrow \pi^+ \pi^-$ 96/98 DT/MC

	<i>no cuts</i>	<i>p, cosθ cuts</i>	<i>link quality</i>	<i>μ-id</i>
π	99.1%	99%	94%	80%
k	0.2%	0.6%	0.8%	1%
p	0.2%	0.3%	0.2%	0.25%
e	..	..	..	..
μ	0.2%	..	5%	18%
tot MC	700k	200k	2871	551
tot DT	150k	43k	701	148

misid ratio :

DT = $(0.342 \pm 0.028)\%$

MC = $(0.279 \pm 0.012)\%$

rel diff = $(20.14 \pm 9.88)\%$

MC lower than DT!

2. 3-prong τ decays 96-98 DT/MC

	<i>initial sample</i>	<i>final sample</i>
π	92%	78%
k	2%	2%
p	..	..
e	6%	0.7%
μ	..	20%
tot MC	210k	407
tot DT	10k	22

misid ratio :

$$\text{DT} = (0.278 \pm 0.059)\%$$

$$\text{MC} = (0.263 \pm 0.013)\%$$

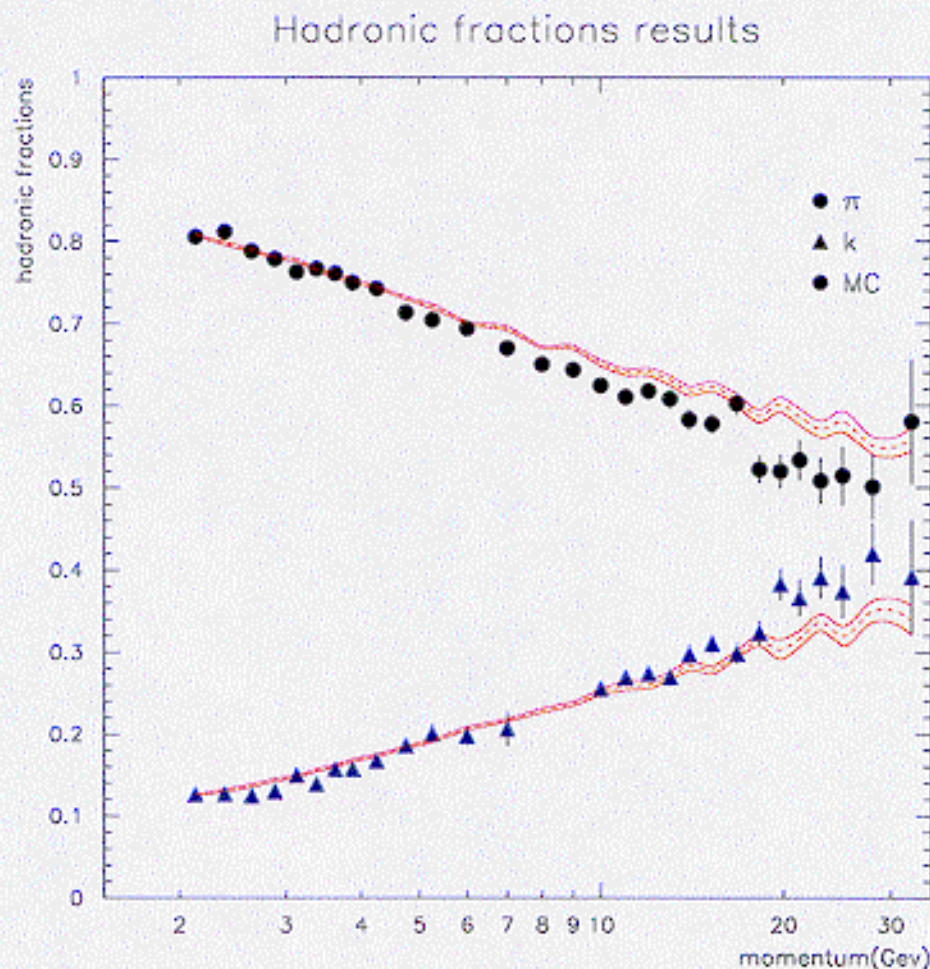
$$\text{rel diff} = (5.54 \pm 22.2)\% \text{ low stat!}$$

Conclusions :

- bkg level in MC is lower than in the data
- assume a $(20 \pm 10)\%$ relative difference
- increase bkg fractions in ML function by 20%
- shift in central values of
$$\Delta A_b = +0.6\%$$
$$\Delta A_c = +3.0\%$$
- stat uncertainty $\rightarrow$ systematic error

hadron production fractions study

compare JETSET π and kaon rates from sample of MC
hadronic tracks with results from SLD particle
production analysis (as a function of p_{tot})



use ratio DT/MC fit to rescale bkg fractions in ML
function

central value shifts:

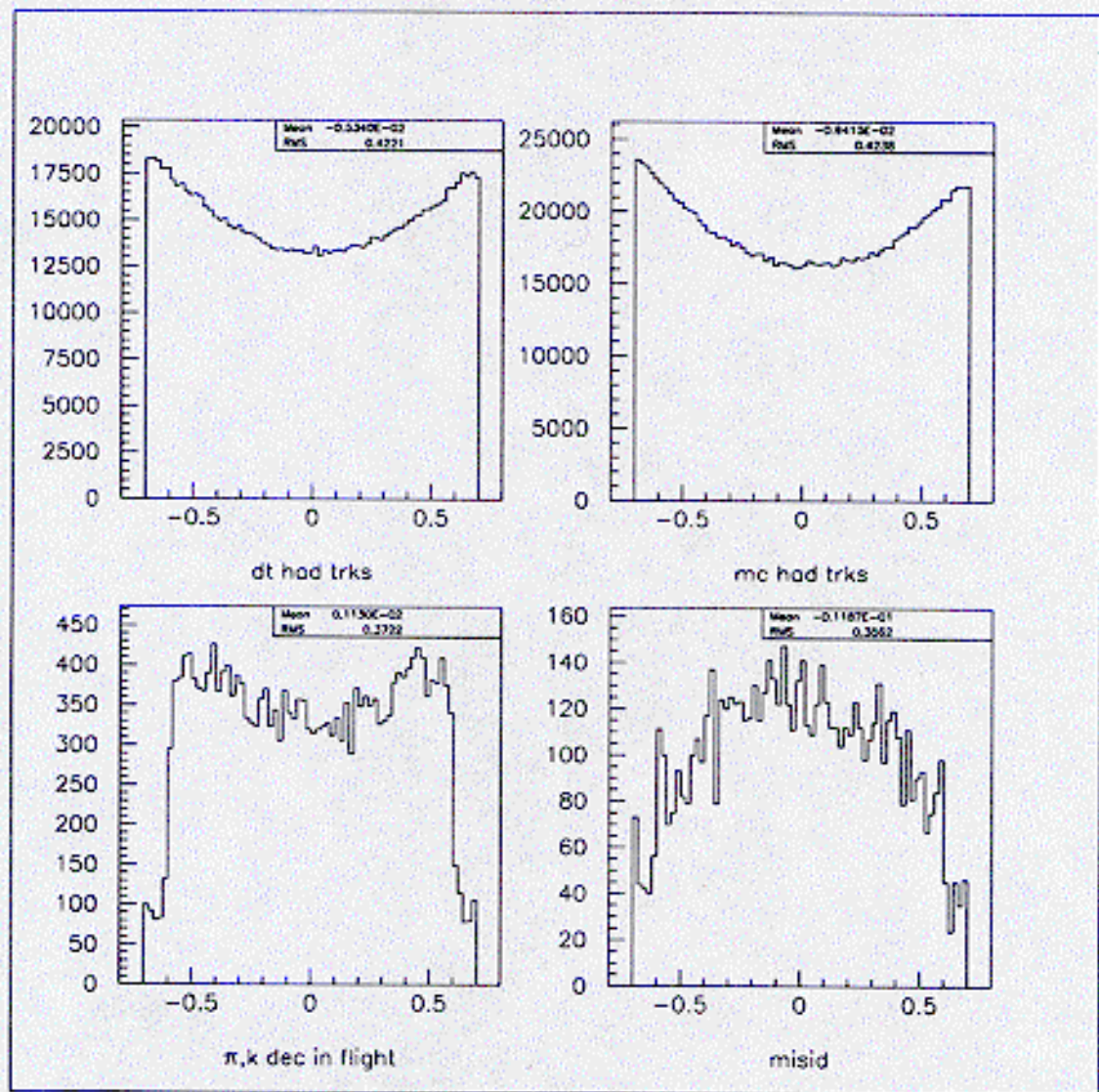
$$\Delta A_b = -0.1\%$$

$$\Delta A_c = -0.6\%$$

Background asymmetry

In the past :

estimated from sample of DT hadronic tracks as a function of p , p_T
applied $\pm 40\%$ variation to calculate systematic errors
not accurate!



now :

- calculate bkg asymmetry with same procedure from MC true bkg muons
- divide in two samples:
 1. misidentified muons
 2. light hadron muons or misassociated tracks
(lower stat!)
- rescale by the DT/MC ratio of bkg asymmetry as from the hadronic track samples.

central value shifts

$$\Delta A_b = +0.4\%$$

$$\Delta A_c = -5.0\%$$

B mixing

in the past

used WA value of χ :
 $\bar{\chi} = 0.1186 \pm 0.0043$
for all events in the ML fit
rescaled to account for
larger mixing of b cascade events

now

use an event-dependent value
calculated with a nearest-neighbours technique
in a $(p, p_T, mass, L/D)$ MC phase space
(use MCTRUTH mixing info)
dependency on event lifetime
automatically accounted for
no need of further rescaling..

average values from MC

	new	SLD MC (<i>allhad</i> + $b\bar{b}$)
$b \rightarrow \mu^-$	0.1298	0.1305
$b \rightarrow c \rightarrow \mu^+$	0.1399	0.1391
$b \rightarrow \bar{c} \rightarrow \mu^-$	0.1359	0.1276

QCD corrections

taking into account hard gluon radiation effects:

$$A_f = A_f^0 \left[1 - c_1 \frac{\alpha_s(\mu)}{\pi} - c_2 \left(\frac{\alpha_s(\mu)}{\pi} \right)^2 \right]$$

at $O(\alpha_s)$

use Stav-Olsen $\cos \theta$ dependent calculations
for massive quarks

include **mitigation factor** to account for analysis effects
in reducing corrections (gluon radiation suppression)

$$F_{QCD}^f(\cos \theta) = \frac{A_f^0(\cos \theta) - A_f^{1,anal}(\cos \theta)}{A_f^0(\cos \theta) - A_f^1(\cos \theta)}$$

F_{QCD}^b, F_{QCD}^c recalculated from generator level study with
Jetset 1st order Matrix Element.

$$\begin{cases} F_{QCD}^b = 0.75 \pm 0.10 \\ F_{QCD}^c = 0.70 \pm 0.20 \end{cases}$$

at $O(\alpha_s^2)$

in the past

used Altarelli-Lampe calculations (for massless quarks)

$$\begin{cases} c_b^2 = 1.9 \pm 0.4 \\ c_c^2 = 4.4 \pm 0.4 \end{cases}$$

now

introduced recent calculations

(for massive quarks) by

Catani-Seymour (hep-ph/9905424)

Ravindran-van Neerven (hep-ph/9809411)

$$\begin{cases} c_b^2 \sim 8.89 \\ c_c^2 \sim 11.5 \end{cases}$$

$\Rightarrow$ larger corrections :

$$\Delta A_b \sim 1.3\% \quad (4 \times \text{old})$$

$$\Delta A_c \sim 1.6\% \quad (3 \times \text{old})$$

rescaling by mitigation factors,

$$\Delta A_b \simeq 0.010$$

$$\Delta A_c \simeq 0.007$$

2nd order QCD corrections summary

gluon radiation

gluon splitting

$$\left\{ \begin{array}{ll} \Delta A_b = & +0.0106 \quad +0.0063 \\ \Delta A_c = & +0.0071 \quad +0.0118 \end{array} \right.$$

systematic errors

- gluon splitting (new numbers from OPAL)
- uncertainty on 2nd order correction
- α_s range
- Jetset/Stav-Olsen difference
- Jetset 1st ME/ Jetset Parton Shower difference
- quark masses
- F_{QCD}^f statistical error

total '97-'98

$$\delta A_b(QCD) \sim 0.0055$$

$$\delta A_c(QCD) \sim 0.0056$$

Muon results

1993-1995

$$A_b = 0.9555 \pm 0.0842_{stat} \pm 0.0291_{syst}$$

$$A_c = 0.5481 \pm 0.1103_{stat} \pm 0.0682_{syst}$$

1996

$$A_b = 1.0139 \pm 0.1169_{stat} \pm 0.0421_{syst}$$

$$A_c \text{ fixed for now } (0.667 \pm 0.040)$$

1997-98

$$A_b = 0.9374 \pm 0.0463_{stat} \pm 0.0253_{syst}$$

A_c fixed

Combined 1996-1998

$$A_b = 0.9466 \pm 0.0431_{stat} \pm 0.0261_{syst}$$

Combined 1993-1998

$$A_b = 0.9500 \pm 0.0384_{stat} \pm 0.0264_{syst}$$

Systematic errors

Source	Variations adopted	(1996)	(1997 – 8)	combined
Monte Carlo stat.	4 MC subsamples	.0238	.0069	.0067
Tracking eff.	MC/dt trk mult.	.0112	.0077	.0081
Jet axis sim.	10 mrad smear.	.0025	.0011	.0013
Bkg level	$\pm 10\%$	.0039	.0021	.0023
Bkg asymmetry	DT/MC ratio	.0014	.0029	.0027
$BR(Z^0 \rightarrow b\bar{b})$	$(21.64 \pm .07)\%$	.0004	.0004	.0004
$BR(Z^0 \rightarrow c\bar{c})$	$(16.74 \pm .38)\%$	.0016	.0014	.0014
$BR(b \rightarrow \mu^-)$	$(10.62 \pm .17)\%$	.0050	.0036	.0038
$BR(b \rightarrow c \rightarrow \mu^+)$	$(8.07 \pm .25)\%$	.0062	.0022	.0027
$BR(b \rightarrow \bar{c} \rightarrow \mu^-)$	$(1.62 \pm .40)\%$	.0035	.0060	.0057
$BR(b \rightarrow \tau \rightarrow \mu^-)$	$(0.452 \pm .074)\%$	.0027	.0027	.0027
$BR(b \rightarrow J/\psi \rightarrow \mu^\pm)$	$(0.07 \pm .02)\%$	.0022	.0030	.0029
$BR(c \rightarrow \mu^+)$	$(9.85 \pm .32)\%$	.0023	.0019	.0019
$B^{\pm,0}-D^{**}$ frac.	$(23 \pm 10)\%$	.0025	.0040	.0038
B_s-D^{**} frac.	$(32 \pm 10)\%$	.0007	.0003	.0003
D lept. spect.	$ACCM1_{-3}^{+2}$	.0034	.0039	.0038
B_s fraction	$.115 \pm .050$	.0032	.0013	.0015
Λ_b frac.	$.072 \pm .030$	.0027	.0020	.0021
b frag.	$\epsilon_b = .0045 - .0075$	.0022	.0007	.0009
c frag.	$\epsilon_c = .045 - .070$	.0036	.0034	.0034
Aleph frag.	reweighting	.0063	.0029	.0033
Polarization	$P = 0.729 \pm .0038$	.0059	.0044	.0046
2 nd order QCD	Δ_{QCD} uncert.	.0057	.0052	.0053
gluon splitt.	$g_{b\bar{b}}, g_{c\bar{c}}$ uncert.	.0027	.0009	.0011
B mixing	$\bar{\chi} = .1186 \pm .0043$	.0112	.0106	.0107
$D^0/D^\pm$	15% uncert.	.0061	.0021	.0026
B tag	eff. calib.	.0145	.0123	.0126
L/D	DT/MC ratio	.0050	.0005	.0010
$B \rightarrow D\bar{D}$	$(7.2 \pm 2.0)\%$	.0195	.0078	.0092
A_c	$0.667 \pm .040$	.0034	.0029	.0030
Total		0.0421	0.0253	0.0261

Lepton combined results

$$A_b = 0.9223^* \pm 0.0294_{stat} \pm 0.0243_{syst}$$

(*applied -0.02% correction for ISR, γ/Z , beamstrahlung effects)

Systematic errors

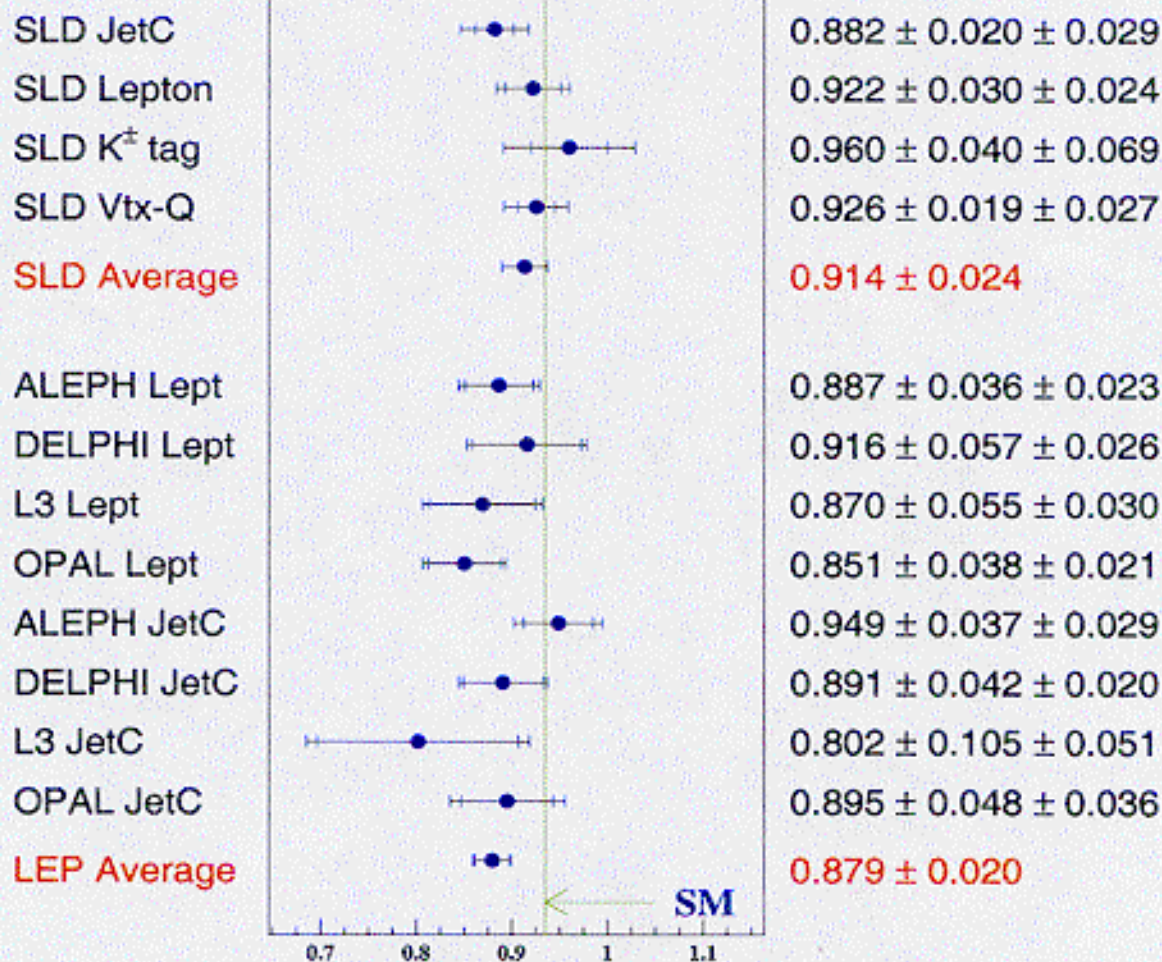
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Tracking eff.	MC/dt trk mult.	.0047
Jet axis sim.	10 mrad smear.	.0046
μ bkg level	$\pm 10\%$	.0019
e bkg level	$\pm 10\%$	.0025
μ bkg asymmetry	DT/MC ratio	.0018
e bkg asymmetry	$\pm 40\%$	.0015
NN training	10 training runs	.0048
$BR(Z^0 \rightarrow b\bar{b})$	$(21.64 \pm .07)\%$	.0002
$BR(Z^0 \rightarrow c\bar{c})$	$(16.74 \pm .38)\%$	.0010
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$BR(b \rightarrow \bar{c} \rightarrow l^-)$	$(1.62 \pm .40)\%$	.0036
$BR(b \rightarrow \tau \rightarrow l^-)$	$(0.452 \pm .074)\%$	.0017
$BR(b \rightarrow J/\psi \rightarrow l^\pm)$	$(0.07 \pm .02)\%$	.0027
$BR(c \rightarrow l^+)$	$(9.85 \pm .32)\%$	.0019
$B \rightarrow D^{**}l\nu$ frac.	$(23 \pm 10)\%$	.0034
D lept. spect.	$ACCM1_{-3}^{+2}$	.0042
B_s fraction	$.115 \pm .050$	.0033
Λ_b frac.	$.072 \pm .030$	.0025
b, c frag.	ϵ_b, ϵ_c var.	.0025
Aleph frag.	reweighting	.0032
Polarization	$P = 0.729 \pm .0038$	.0051
2 nd order QCD	Δ_{QCD} uncert.	.0050
gluon splitt.	$g_{b\bar{b}}, g_{c\bar{c}}$ uncert.	.0020
B mixing	$\bar{\chi} = .1186 \pm .0043$	.0112
$D^0/D^\pm$	15% uncert.	.0004
B tag	eff. calib.	.0128
L/D	DT/MC ratio	.0014
$B \rightarrow D\bar{D}$	$(7.2 \pm 2.0)\%$	.0046
A_c	$0.667 \pm .040$	.0035

Total

0.0243

A_b world measurements

A_b Measurements (Valencia-2000)



LEP Measurements: $A_b = 4 A^{0,b_{FB}} / 3 A_e$
Using $A_e = 0.1498 \pm 0.0016$ (Combine SLD A_{LR} and LEP A_l)