OPAL Measurements of R_{b}, A_{FB}^{b}, and A_{FB}^{c} at LEP2

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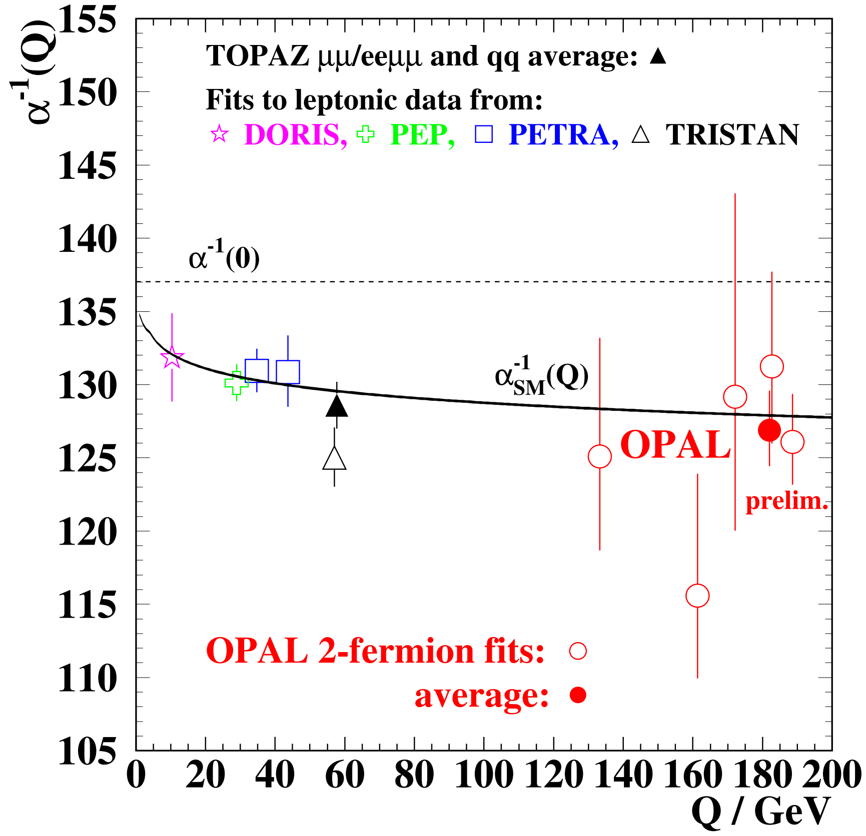
Representing the OPAL Collaboration

Outline:

- Introduction
- Vertex Tag Description
  - R_{b}
  - A_{FB}^{b} with Jet Charge
- Lepton and Slow-Pion Tags
  - A_{FB}^{b} and A_{FB}^{c}
- Combined Results

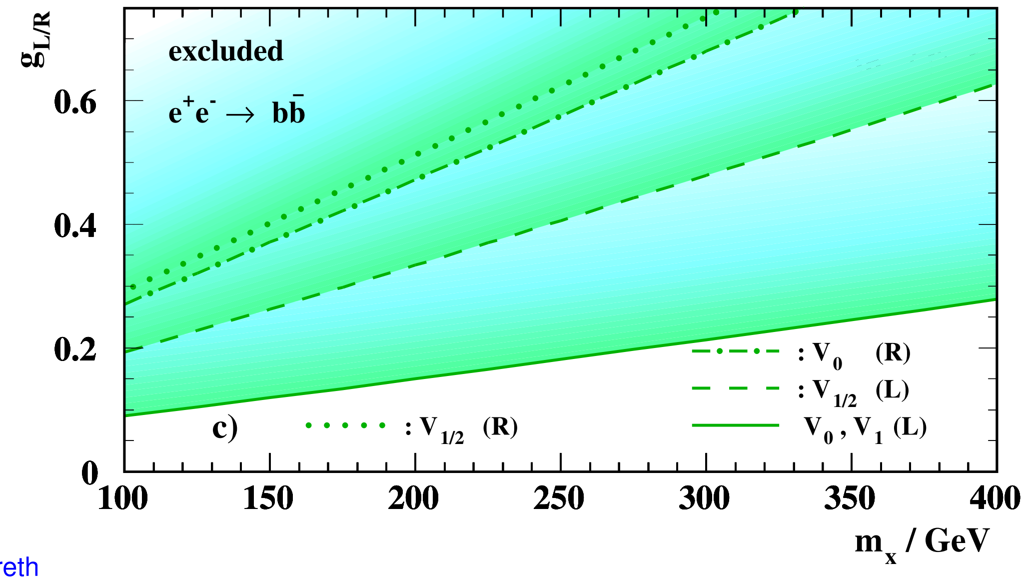
Introduction/Motivation

- Why Measure A_{FB} and R_b at LEP2?
- Tighter constraints on j_{had}^{tot} from $\gamma - Z$ interference
- Measure the running of α_{em}:



- Constraints on New Physics from Fermion Couplings

Eg. **Leptoquarks:**



Data Sample and Event Selection

- OPAL Data Sample with $E_{CM} > M_Z$:

1995+1997:	6 pb^{-1} at 130 GeV	6 pb^{-1}at 136 GeV
1996:	10 pb^{-1} at 161 GeV	10 pb^{-1}at 172 GeV
1997:	57 pb^{-1} at 183 GeV	
1998:	187 pb^{-1} at 189 GeV	

- Event Selection:
  - Non radiative $e^+e^- \to Z/\gamma^* \to q\overline{q}$ hadronic events

    Require $\sqrt{s'}/\sqrt{s}$ >0.85

    residual contribution from radiative events $\sim 5\%$
  - Rejection of W^+W^- events

    4-Fermion Contamination:

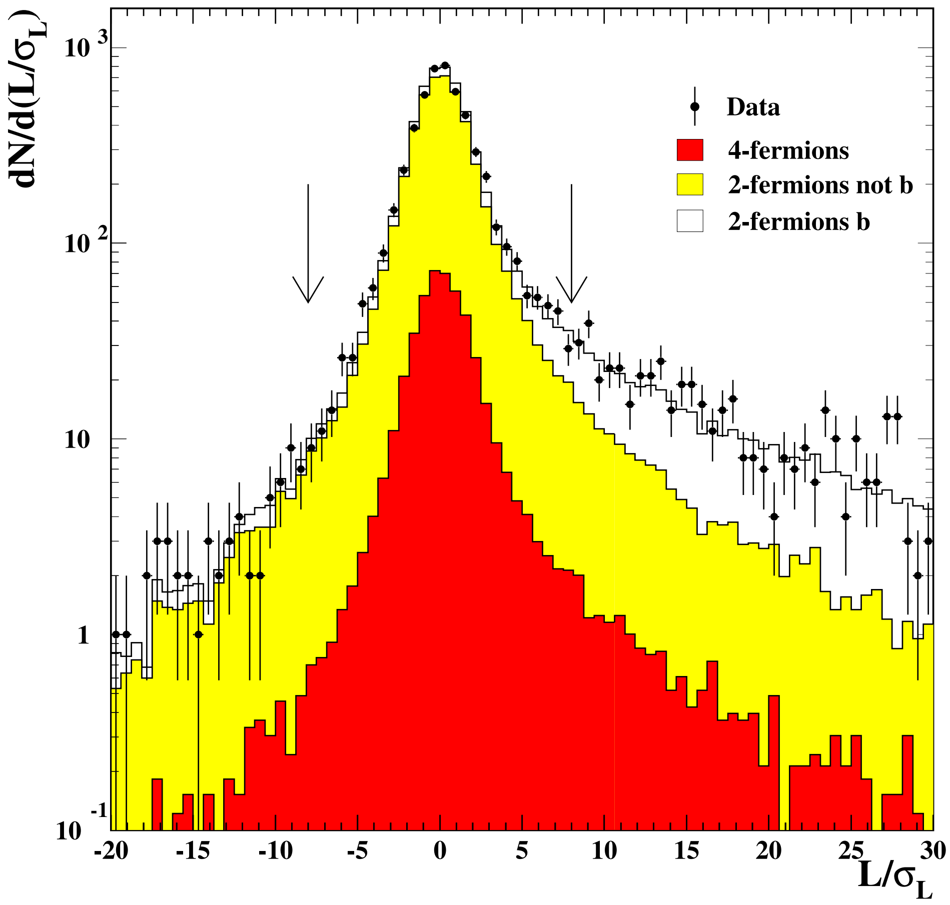
    negligible (133 GeV) up to $\sim 8\%$ (189 GeV)
  - In the “vertex tag” analysis

    $|\cos\theta_T| < 0.9$

- This Talk: Concentrate on 189 GeV Results

Secondary Vertex Tag

- Tag $b\bar{b}$ events using Decay Length Significance



R_b Measurement

- "Single Tag" Measurement: ε_b taken from MC

$$\text{folded tag} \quad \left\{ \begin{array}{l} \text{forward tag } \mathrm{L}/\sigma_{\mathrm{L}} > 8 \\ \text{backward tag } \mathrm{L}/\sigma_{\mathrm{L}} < -8 \end{array} \right.$$

$\Rightarrow$ Reduces Systematic Error from Tracking Resolution

Folded efficiency $\varepsilon_b \sim 40\%$

b-Purity $\sim 75\%$

R_b result for 189 GeV

Tagged Events:

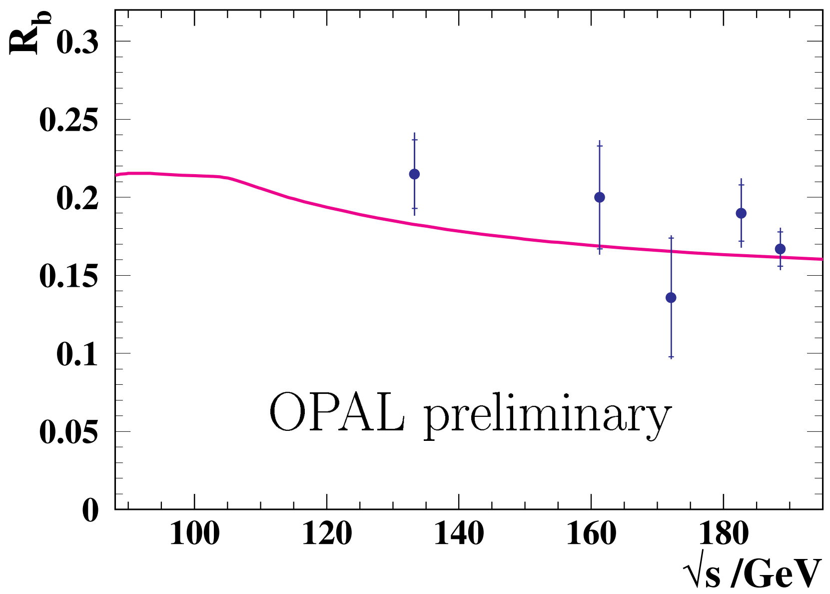
events	N	$\overline{N}$	R_b
3484	608	83	0.167±0.011

Errors:

error source	ΔR_{b}
event selection	0.0035
b decay model	0.0033
c decay model	0.0011
four-fermion background	0.0010
Monte Carlo statistics	0.0016
detector resolution	0.0054
total systematic error	0.008

Result: R_b = 0.167 $\pm$ 0.011 (stat.) $\pm$ 0.008 (syst.)

Plot:



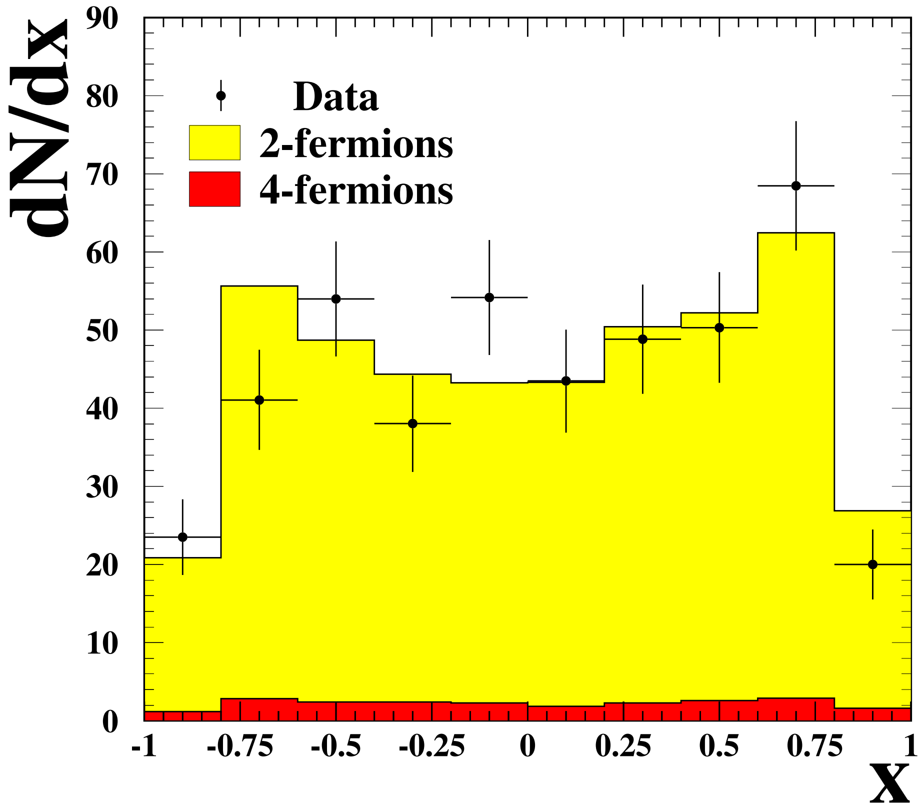
A_{FB}^{b} with Jet Charge

- Secondary vertex tag to select $b\bar{b}$ events

$$\text{forward tag } \mathrm{L}/\sigma_{\mathrm{L}} > 8 \quad \begin{cases} \text{efficiency } \varepsilon_b \sim 61\% \\ \mathrm{b-Purity} \sim 64\% \end{cases}$$

- Thrust axis $\vec{T}$ gives the $q\bar{q}$ axis direction
- Primary quark hemisphere determined using Jet Charge (charge identification probability $\sim 67\%$)

$$x \;=\; -\mathrm{sign}(Q_F \,-\, Q_B) \cdot |\cos\theta_T|$$



A_{FB}^{b} with Jet Charge

The observed angular distribution of the outgoing quark

$$\frac{d\sigma^{obs}}{dx} \propto 1 + x^2 + \frac{8}{3} A_{\mathrm{FB}}^{obs} x$$

is fitted to extract

events	A_{FB}^{obs}
537	0.095 ± 0.044

After 4-f background subtraction, the b Asymmetry is extracted, assuming the sample composition from MC :

$$A_{FB}^{b} = 0.68 \pm 0.21 \text{ (stat.)} \pm 0.04 \text{ (syst.)}$$

Systematic Error Sources $\rightarrow$ same as R_b analysis

error source	ΔA_{FB}^{b}
event selection	0.020
b decay model	0.023
c decay model	0.010
four-fermion background	$<$ 0.001
Monte Carlo statistics	0.019
detector resolution	0.024
total systematic error	0.04

Lepton and Slow Pion ID

Electrons

NNET for electron ID (N_{el})

net inputs: p, $\mathrm{d}E/\mathrm{d}x$, E_{cone}/p, $\cos\theta$

$\oplus$ Second NNET (N_{cv}) to reject Photon Conversions

- $\varepsilon \sim 25\%$ and e-Purity $\sim 75\%$

Muons

NNET for muon ID (N_{μ}:

net inputs: information from matching and HCAL, p, $\mathrm{d}E/\mathrm{d}x$

- $\varepsilon \sim 43\%$ and μ-Purity $\sim 73\%$

Slow Pions

from $\mathrm{D}^{*+} \to \mathrm{D}^0\pi^+$

– $1.0\ \mathrm{GeV} < p < p_{\pi_s}^{\mathrm{max}} = 8.65$

– $\mathrm{d}E/\mathrm{d}x$ compatability with a pion $> 2\%$

– p_t of π_s wrt D^{*+} jet direction: Require $p_t^2 < 0.02\ \mathrm{GeV}^2$

- $\varepsilon \sim 56\%$ and π_s-Purity $\sim 5.7\%$

Flavour separation

Neural nets to identify 3 different sources of prompt leptons/slow pions from decay of heavy hadrons

- $\mathrm{b} \to \ell$ (N_b)
- $\mathrm{b} \to [\mathrm{c}, \overline{\mathrm{c}}] \to \ell/\pi_s$ (N_{bc})
- $\mathrm{c} \to \ell/\pi_s$ (N_c)

Separation variables:

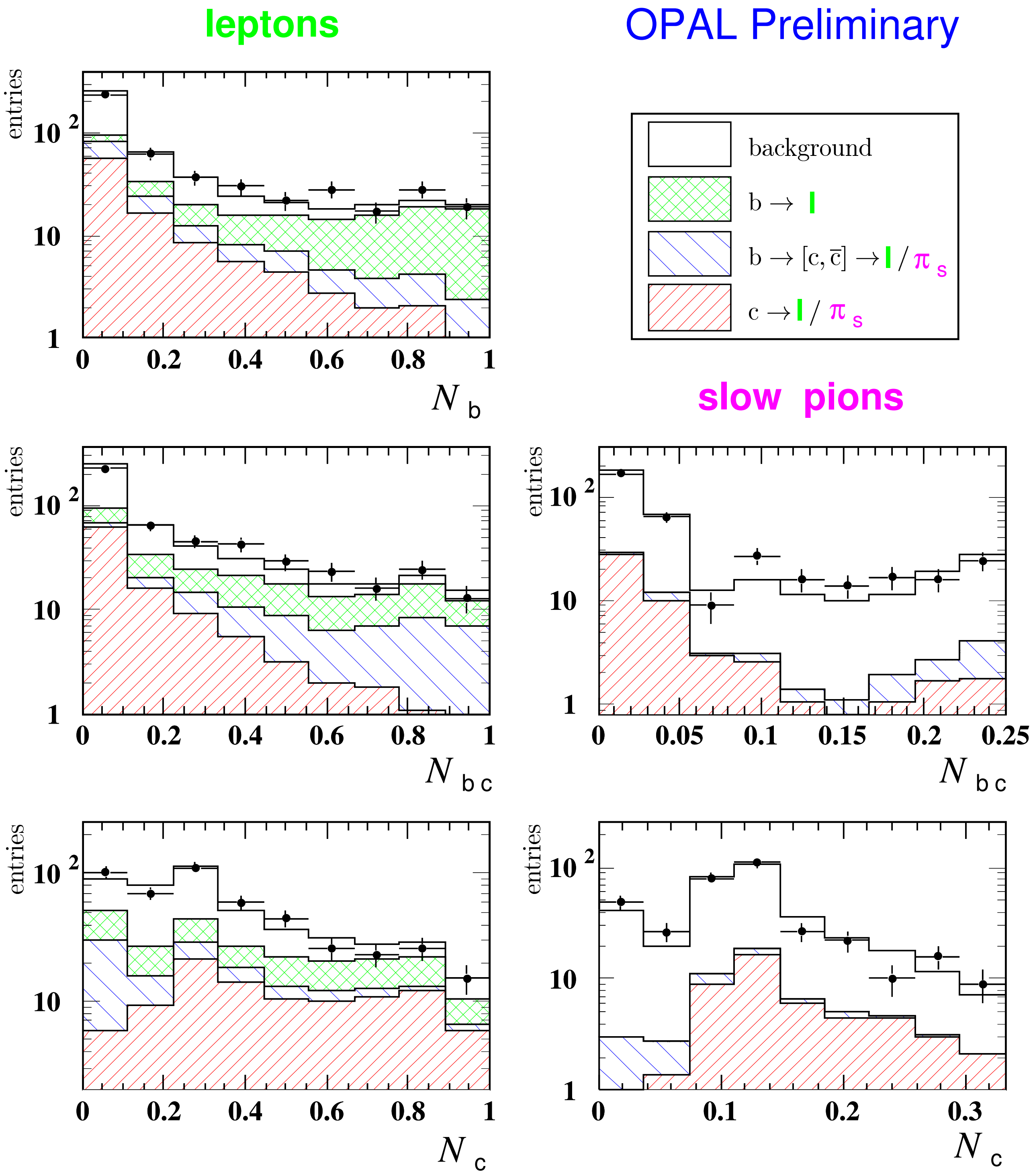
- p, p_t,
- jet variables ($\cos\theta_{\mathrm{jet}}$, Q_{jet}, forward multiplicity),
- vertex decay length, and
- output of the lepton-ID nets (N_{el}, N_{cv}, N_{μ})

From the output of N_b, N_{bc} and N_c the probabilities of a candidate to come from a given source are computed, and a cut is applied in:

$$\mathcal{P}_{\mathrm{sig}} = \sqrt{(\mathcal{P}^{b}_{\mathrm{sig}})^2 + (\mathcal{P}^{bc}_{\mathrm{sig}})^2 + (\mathcal{P}^{c}_{\mathrm{sig}})^2} > 0.1$$

to enhance the signal probability.

Flavour Separation Nets



A^{b}_{FB} and A^{c}_{FB} with ℓ/π_s

- ℓ/π_s tags primary $q/\overline{q}$ charge (Q): $y = -Q\cos\theta_{\mathrm{T}}$

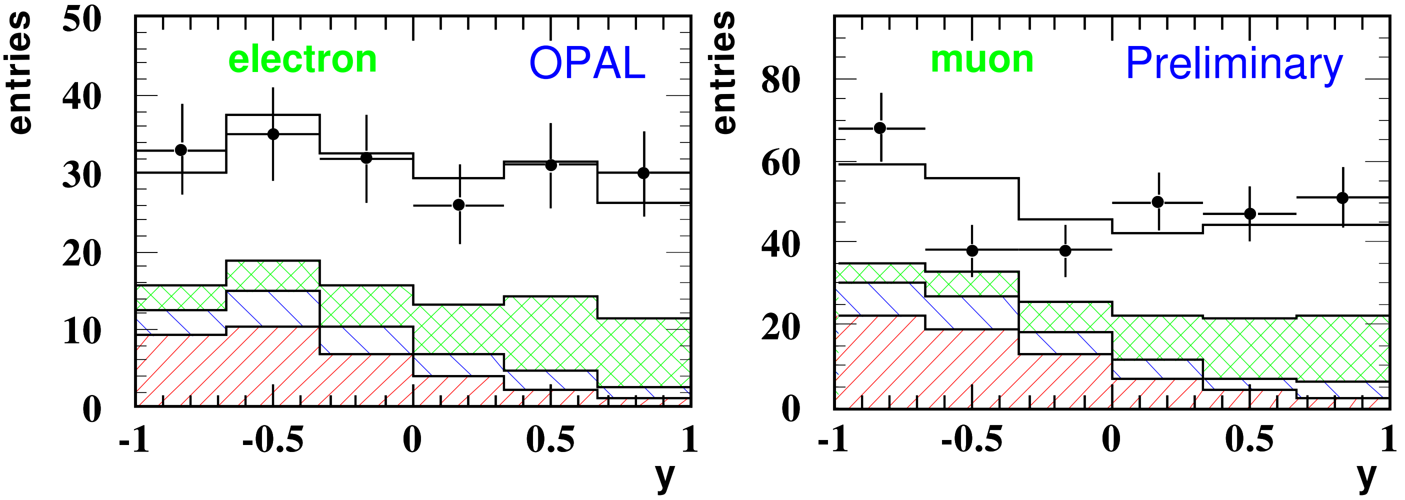
A^b_{FB} and A^c_{FB} asymmetries are extracted from

$$\ln\mathcal{L} = \sum_{\text{candidates}} \ln\left(1 + y^2 + \frac{8}{3} A^{obs}_{FB}\, y\right)$$

$$A^{obs}_{FB}(N_b, N_{bc}, N_c, |y|) = \sum_{i=1}^{5} f_i(N_b, N_{bc}, N_c, |y|)\, A^i_{FB}$$

where i indicates different sources: $\mathrm{b} \to \ell$, $\mathrm{b} \to \mathrm{c} \to \ell/\pi_s$, etc.

- Measured y distributions:



- Results:

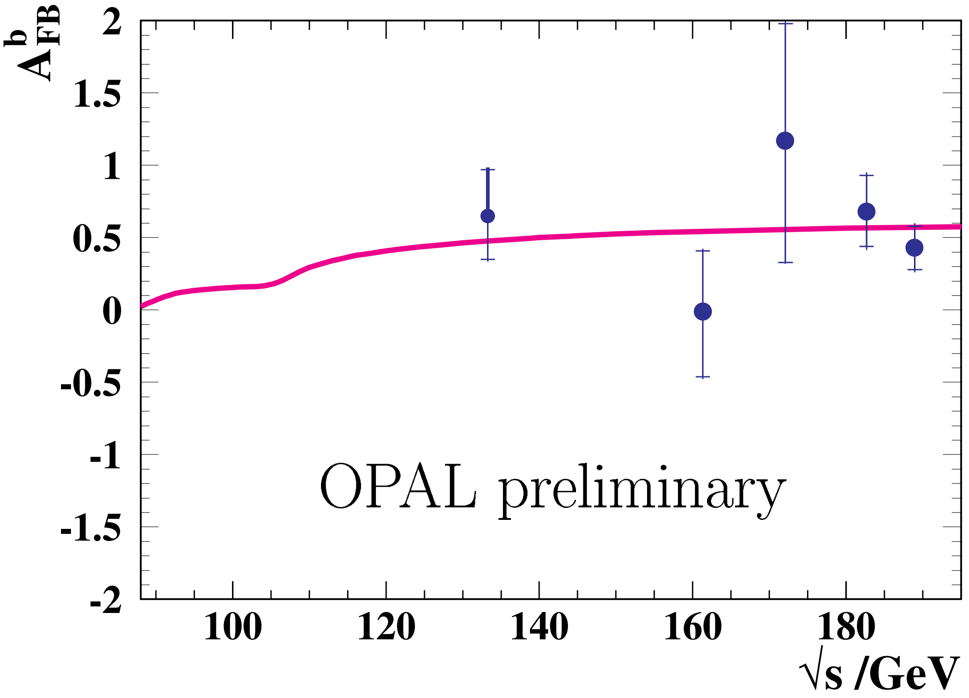
$A^{\mathrm{b}}_{FB} = 0.30 \pm 0.19 \pm 0.12$ $A^{\mathrm{c}}_{FB} = 0.56 \pm 0.18 \pm 0.09$

systematics errors dominated by

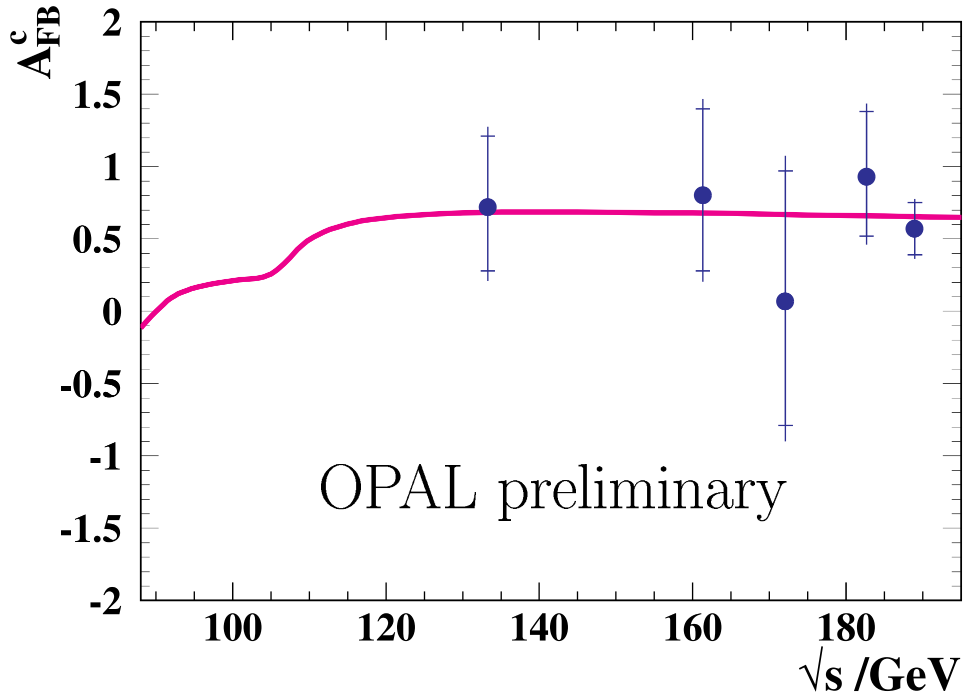
b decay models, detector modelling, background asymmetry

Combined Results

A_{FB}^b = 0.43 $\pm$ 0.15 (stat.) $\pm$ 0.08 (syst.)



A_{FB}^c = 0.57 $\pm$ 0.18 (stat.) $\pm$ 0.09 (syst.)



correlation of $+25\%$