Measurement of Leptonic Forward-Backward Asymmetry at LEP 1

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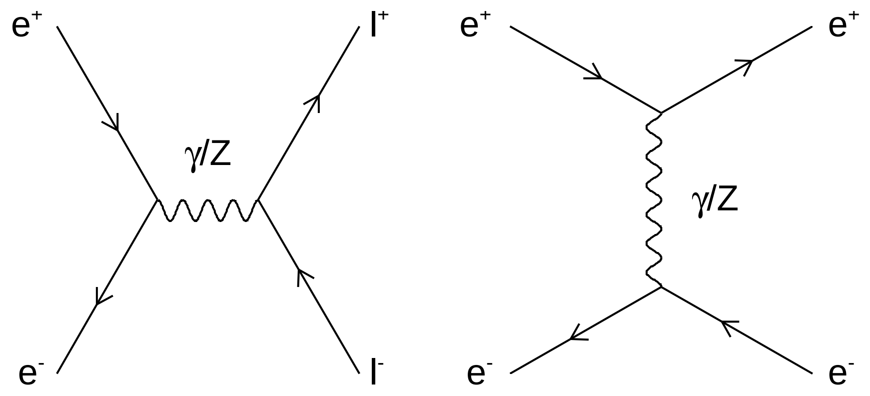
On behalf of the L3 Collaboration

Nashville , May 10-16 1997

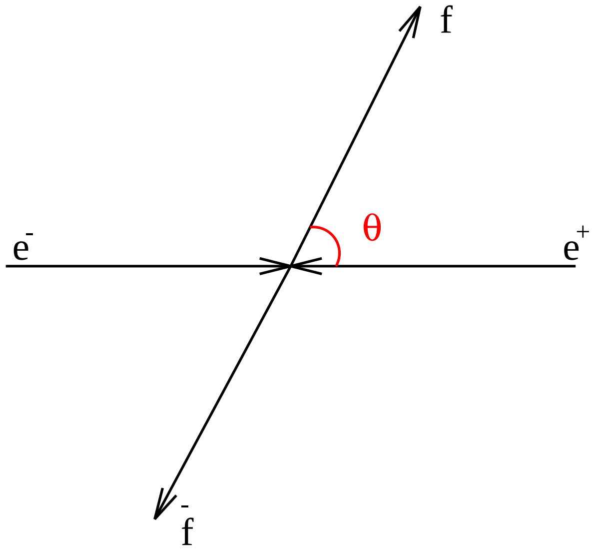
At LEP 1, the l^+l^- final states are produced at the Z resonance

($l = \mu,\tau,e$)



Unit: K		ALEPH	DELPHI	L3	OPAL	LEP	Energy Points
l^+l^-	90-91	55	36	40	58	189	7
	92	82	70	58	88	298	1
	93 prel	78	74	64	82	298	3
	94 prel	190	135	127	184	630	1
	95 prel	80	67	28	42	217	3
	total	485	382	317	454	1638	

Forward-Backward Asymmetry: $A_{\mathrm{FB}} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}$



- A_{FB} at the Z resonance is correlated with the vector and axial-vector coupling constants of charge leptons through:

$$A_{\mathrm{FB}}(\sqrt{s} = M_{\mathrm{Z}}) = 3 \frac{\overline{g}^e_{\mathrm{A}} \overline{g}^e_{\mathrm{V}}}{(\overline{g}^e_{\mathrm{A}})^2 + (\overline{g}^e_{\mathrm{V}})^2} \frac{\overline{g}^l_{\mathrm{A}} \overline{g}^l_{\mathrm{V}}}{(\overline{g}^l_{\mathrm{A}})^2 + (\overline{g}^l_{\mathrm{V}})^2} \text{ (s-channel)}$$

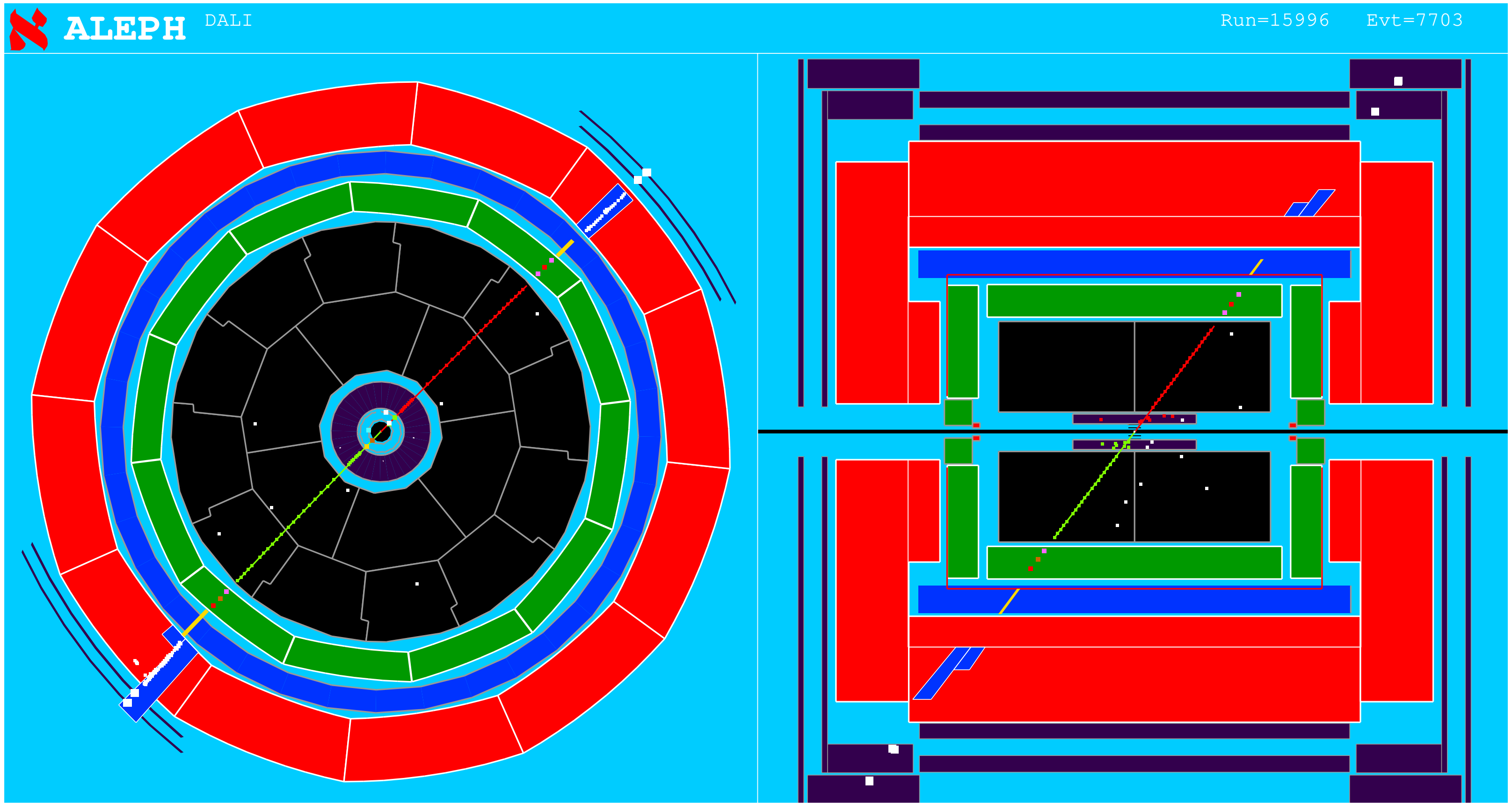
Remarks on A_{FB} Measurement:

- Fitting method (μ, τ): $d\sigma/dcos\theta \propto 1 + cos^2\theta + \frac{8}{3}A_{\mathrm{FB}}cos\theta$
- Counting method (e): $A_{\mathrm{FB}} = \frac{N_F - N_B}{N_F + N_B}$
- Two important ingredients of A_{FB} measurements:
  - Charge determination
    - Charge Confusion $\mathcal{C}$: $A_{\mathrm{FB}}^{real} = \frac{A_{\mathrm{FB}}^{measure}}{1-2\mathcal{C}}$
  - Scattering angle:
    - the scattering angle of the l^- with respect to the e^- beam axis: θ_{l^-};
    - the scattering angle of the l^+ with respect to the e^+ beam axis: θ_{l^+};
    - $\theta^\star$ which uses information of both θ_{l^-} and θ_{l^+}:

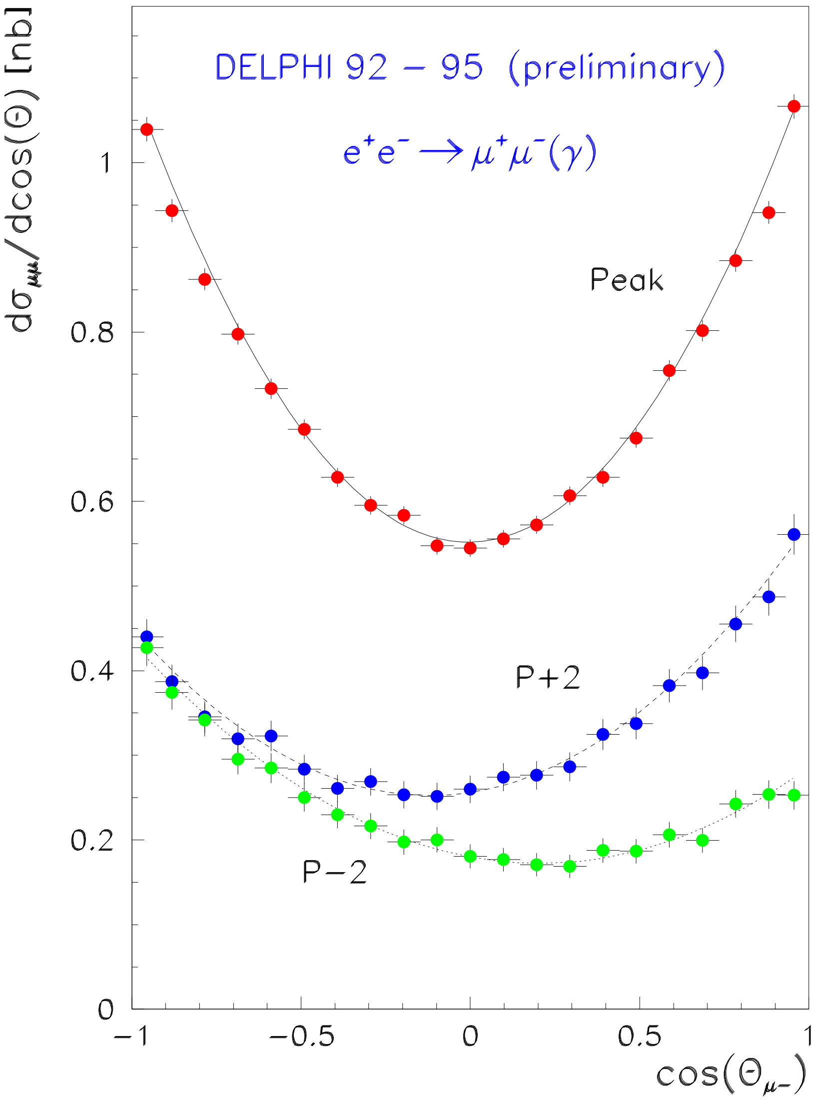
      $cos\theta^\star = \frac{sin(\theta_{l^-} + \theta_{l^+})}{sin\theta_{l^-} + sin\theta_{l^+}}$

      $\theta^\star$ is the scattering angle in the reduced center-of-mass-energy frame.

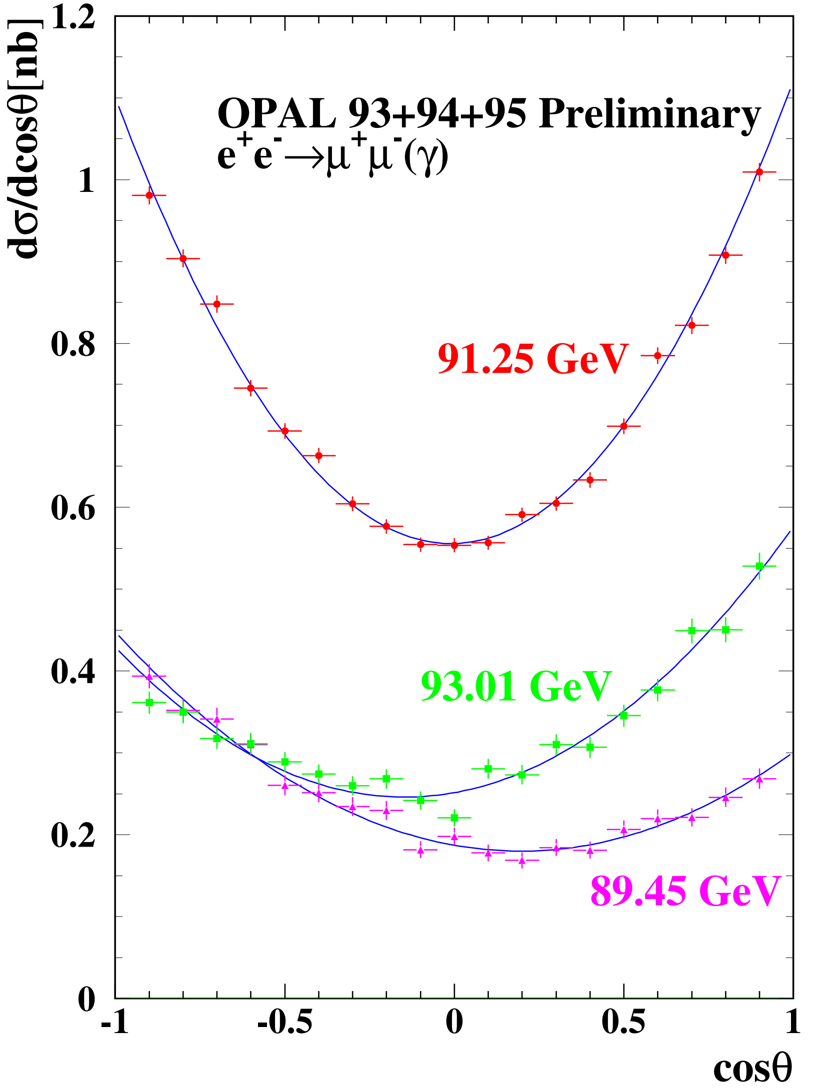
$$e^+e^- \longrightarrow \mu^+\mu^-$$



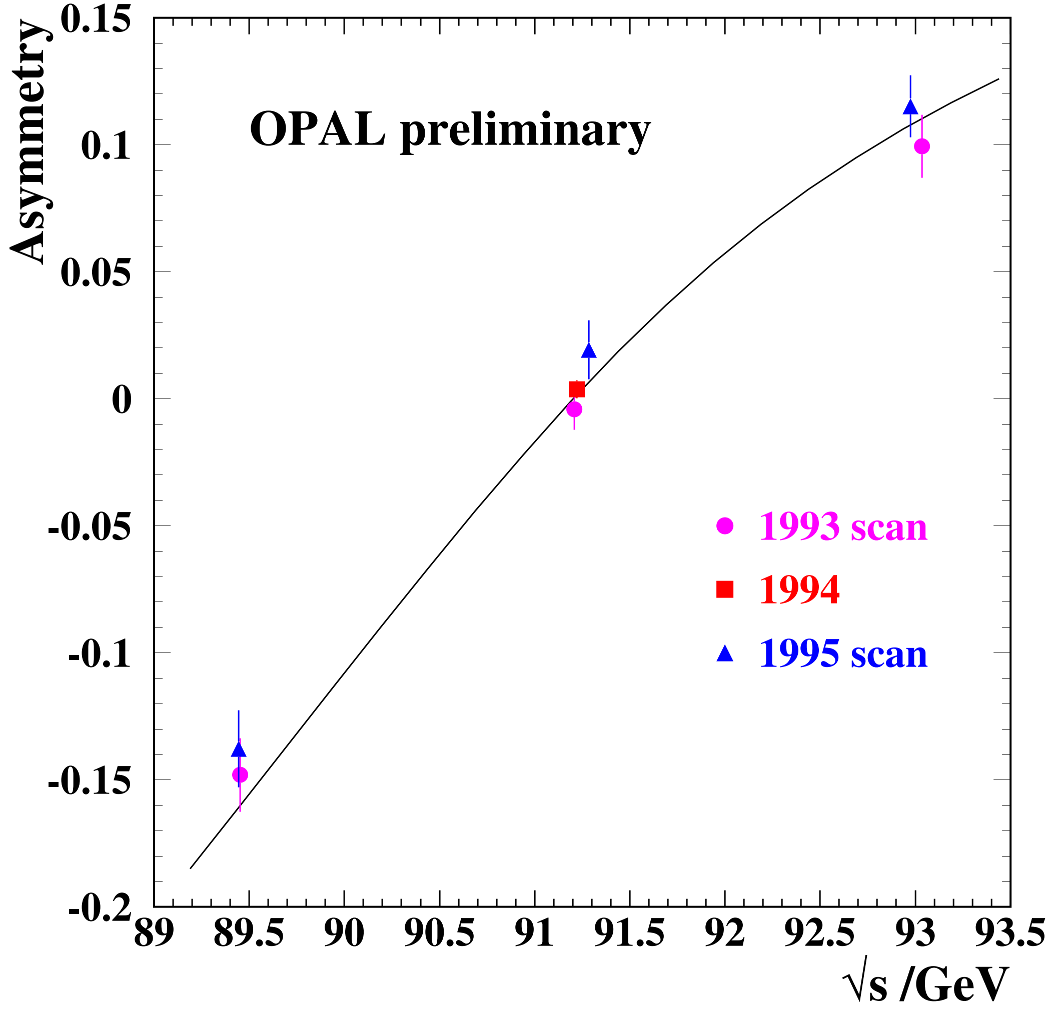
- the muons are identified by their penetration right through the detector;
- charges are determined using muon chamber and central tracker, typical charge confusion $\approx 10^{-4}$



DELPHI 92 − 95 (preliminary)
$e^+e^- \longrightarrow \mu^+\mu^-(\gamma)$
Peak
P+2
P−2
$d\sigma_{\mu\mu}/d\cos(\Theta)$ [nb]
$\cos(\Theta_{\mu-})$
0
0.2
0.4
0.6
0.8
1
−1
−0.5
0
0.5
1

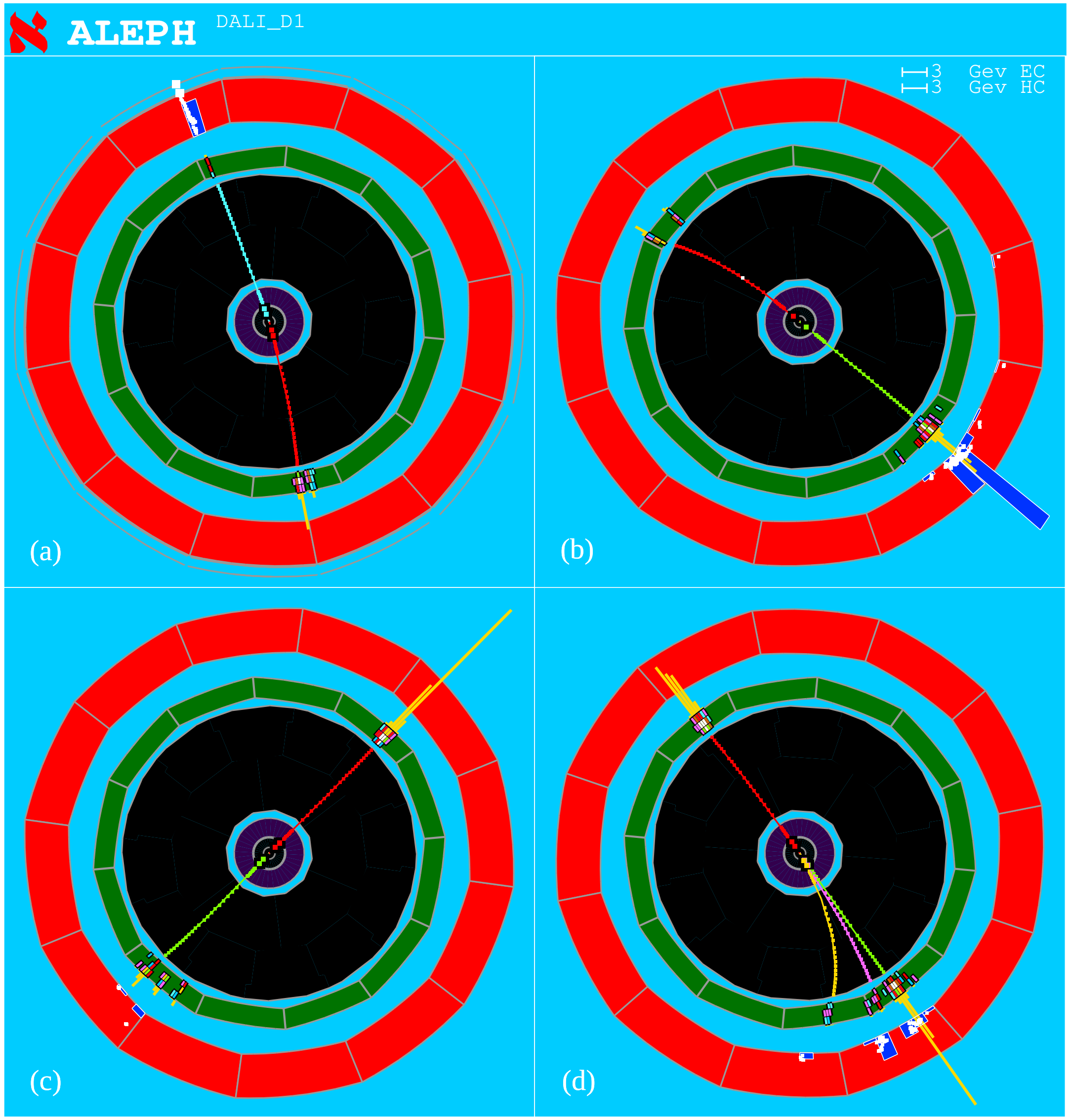


OPAL 93+94+95 Preliminary
$e^+e^- \rightarrow \mu^+\mu^-(\gamma)$
91.25 GeV
93.01 GeV
89.45 GeV
$d\sigma/d\cos\theta$[nb]
$\cos\theta$
0
0.2
0.4
0.6
0.8
1
1.2
-1
-0.5
0
0.5
1



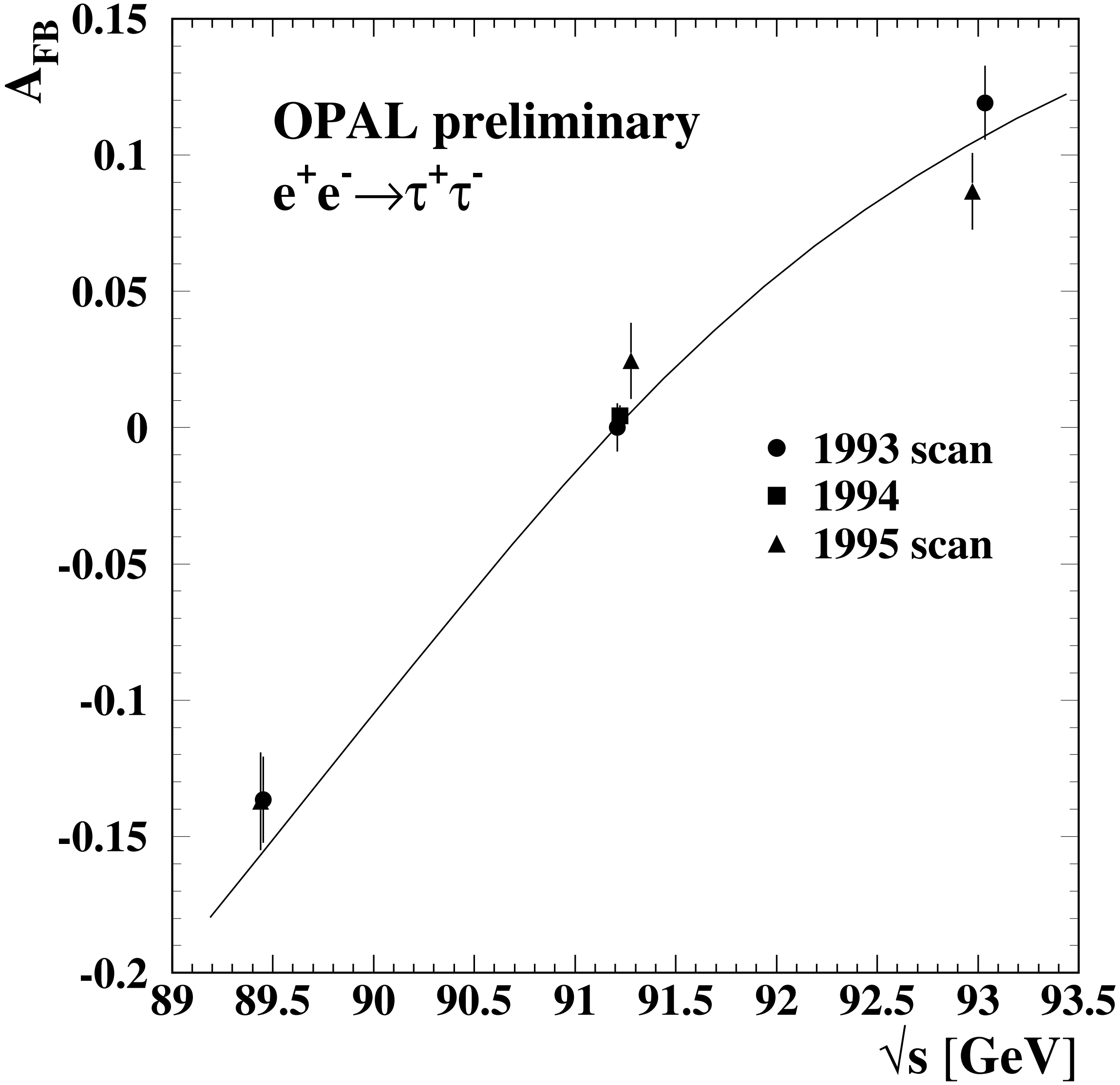
Systematic error $\approx$ 0.001

$$e^+e^- \to \tau^+\tau^-$$



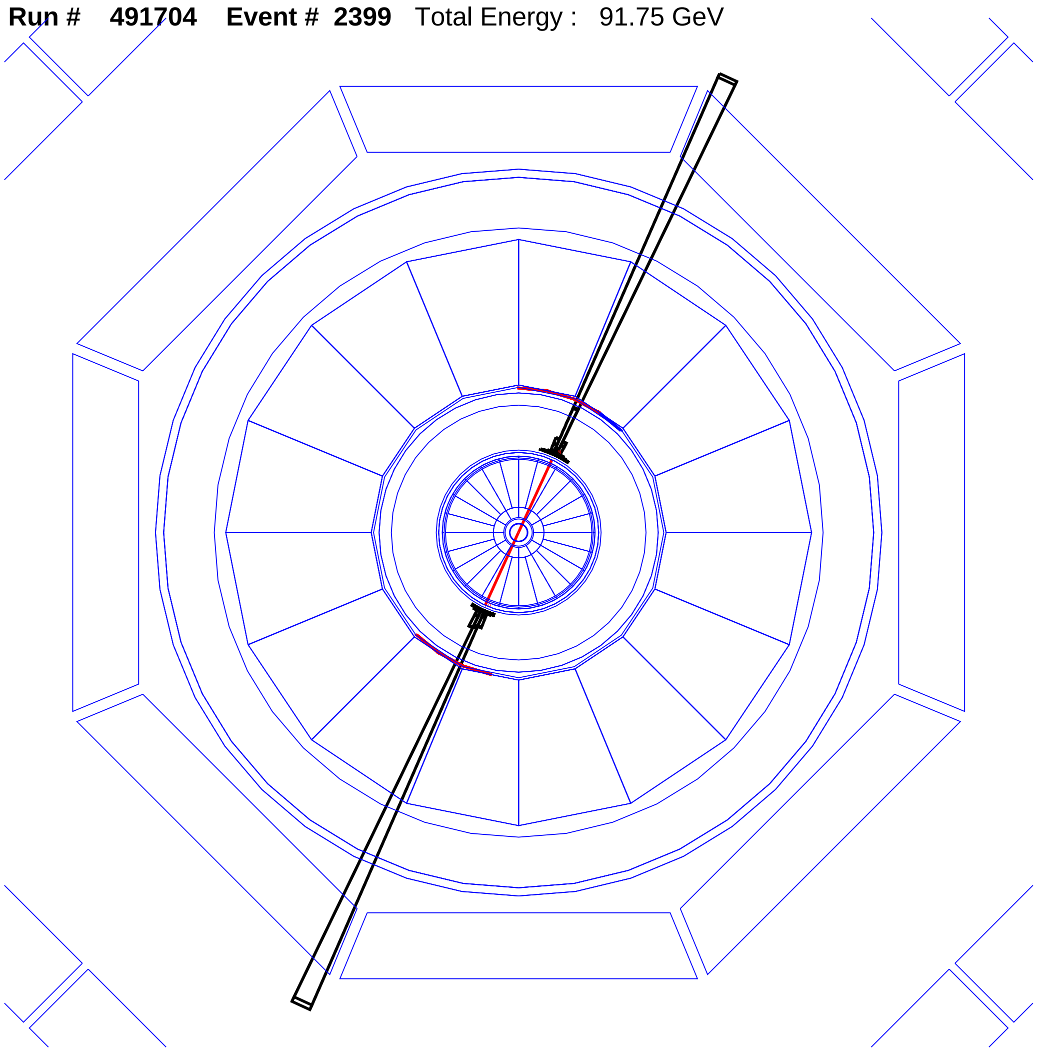
the τ's are identified by their decay products

τ's charge = jet charge



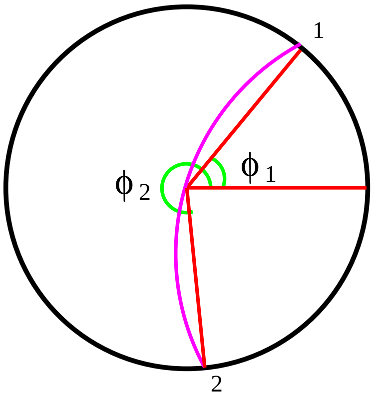
Systematic error $\approx 0.002 - 0.003$

$$e^+e^- \longrightarrow e^+e^-$$

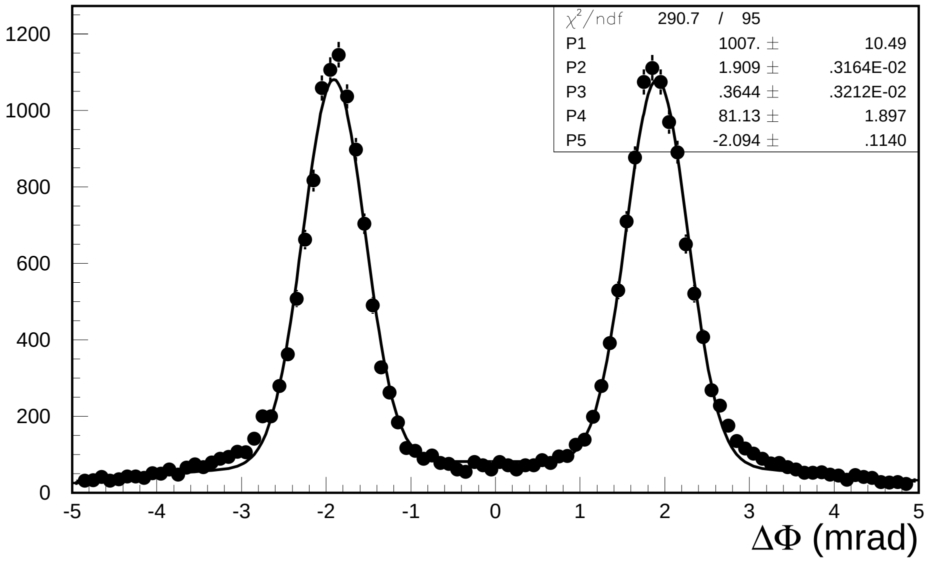


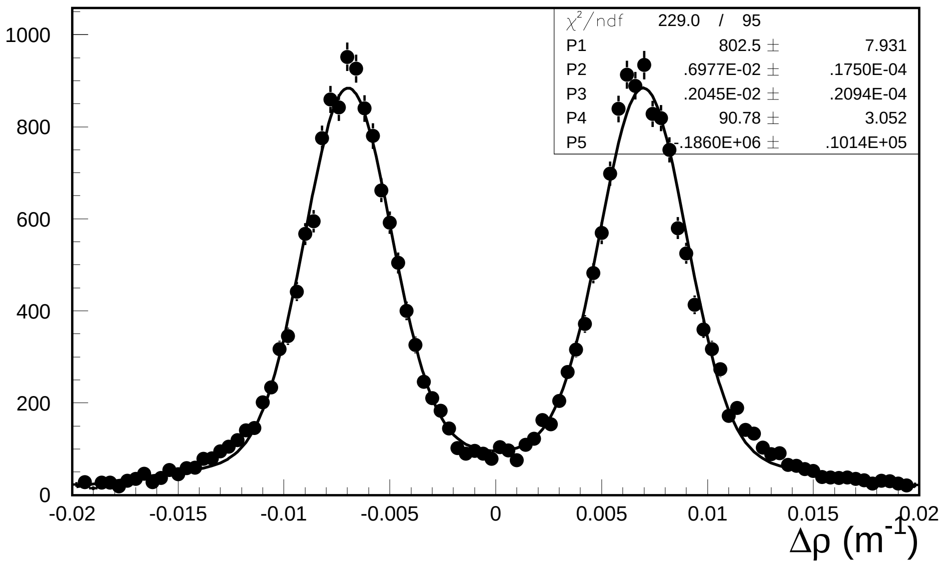
- Large deposition of energy in ECAL and two matched tracks
- Large angle Bhabha events: $44^0 < \theta_{e^+e^-} < 136^0$ (t-channel)

Charge determination: two separators

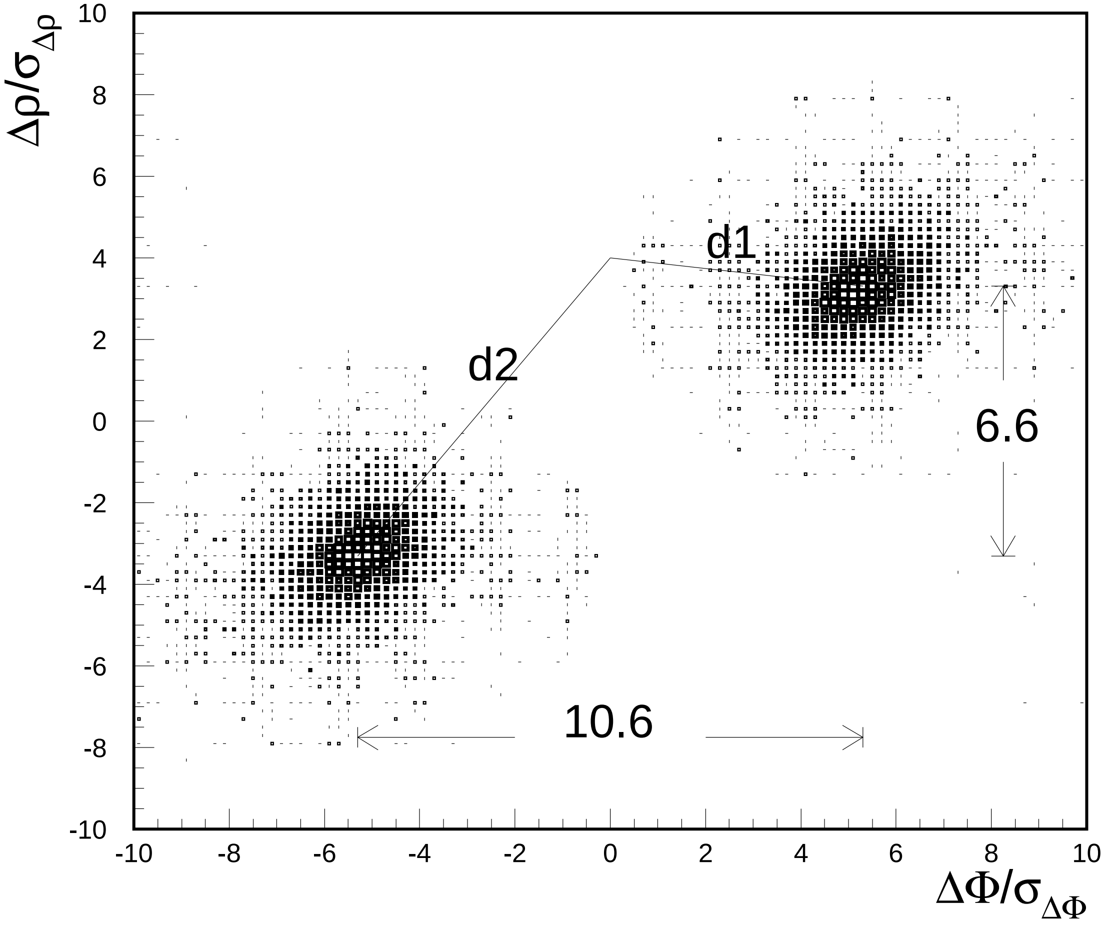


$$\Delta\rho = \text{difference of curvature}$$
$$\Delta\Phi = \Phi_2 - \Phi_1 - \pi$$



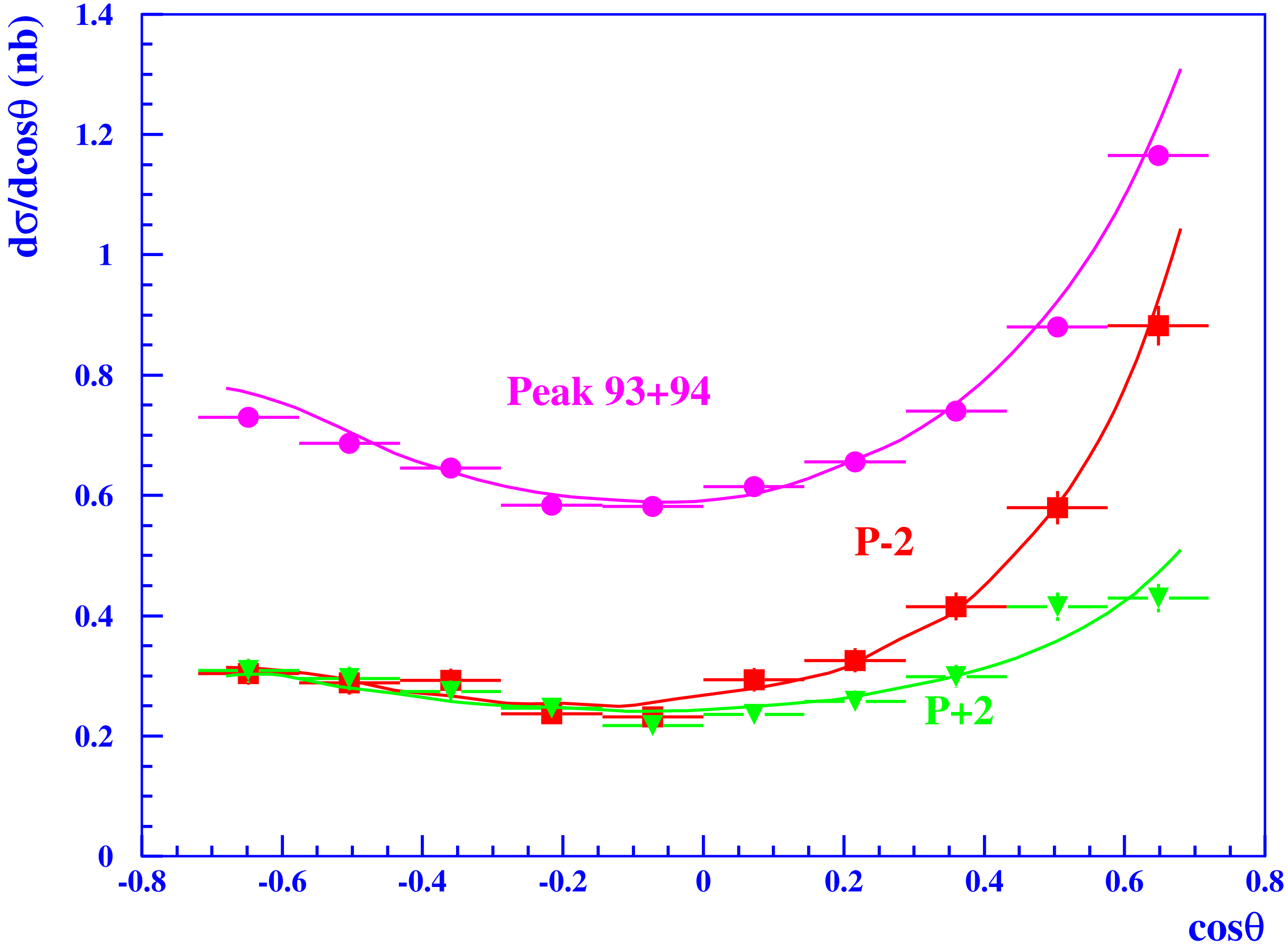


Charge Separation

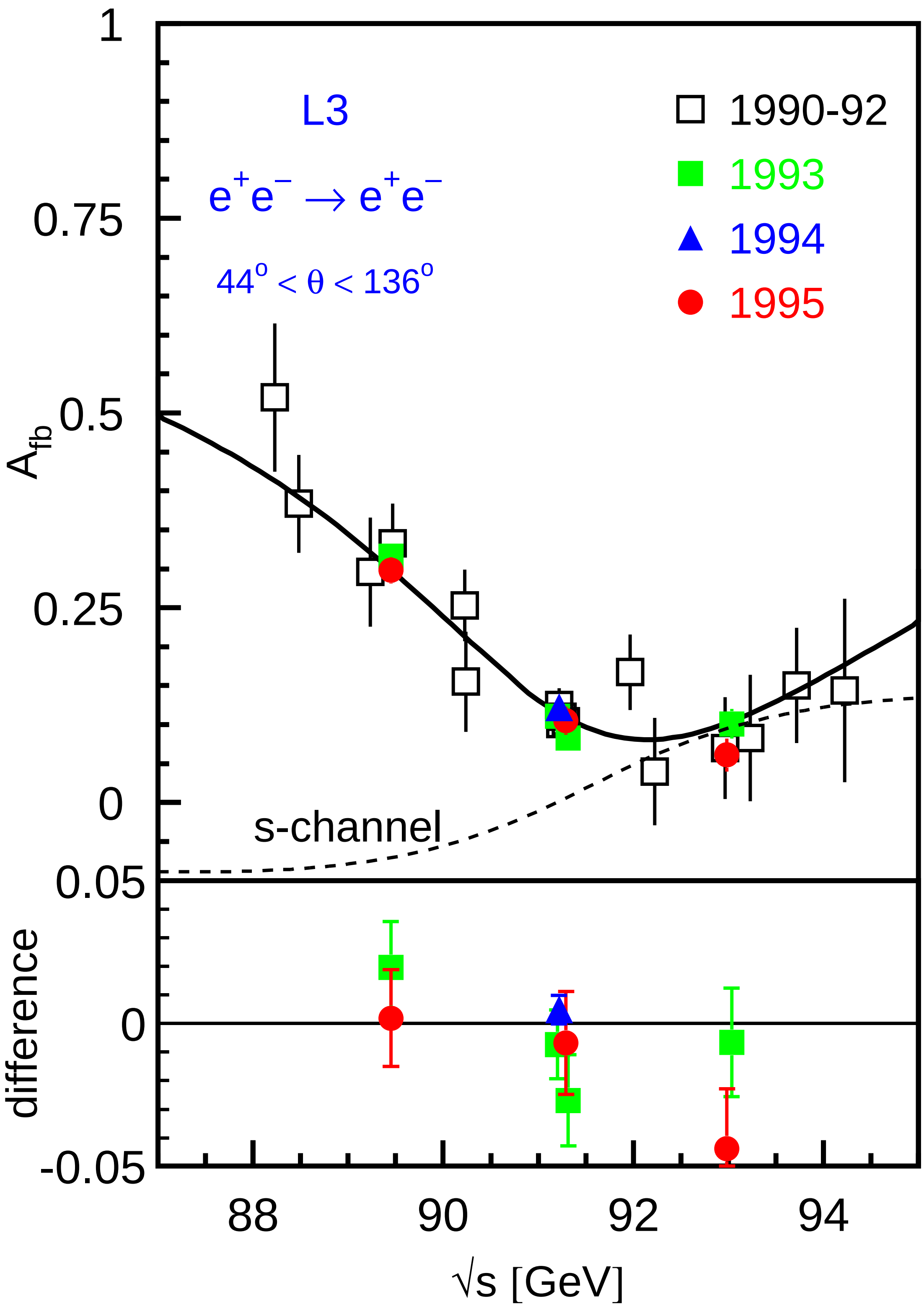


- Charge confusion $\mathcal{C} = 0.46 \pm 0.05\%$

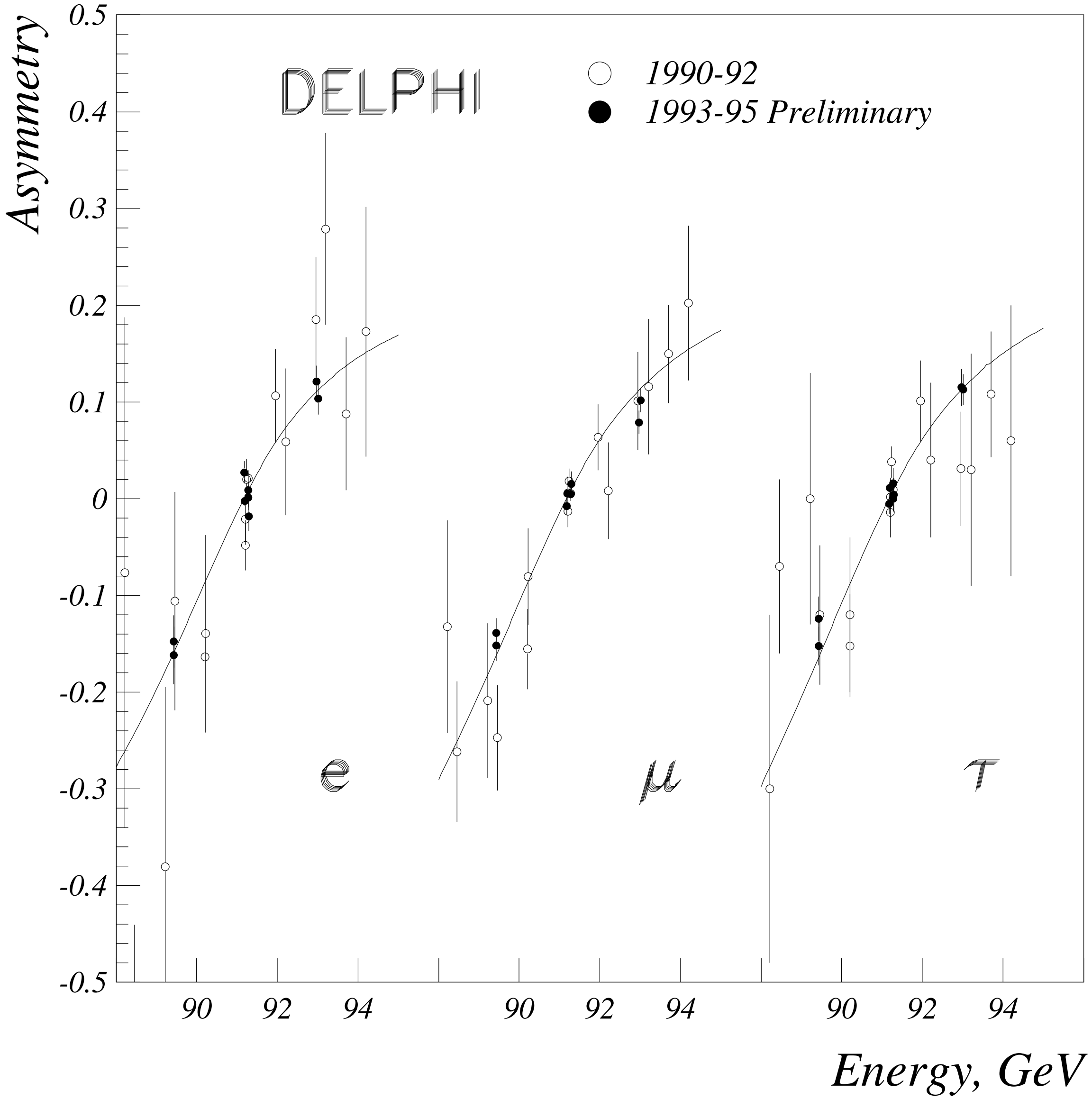
  using golden $\mu^+\mu^-$ sample to determine



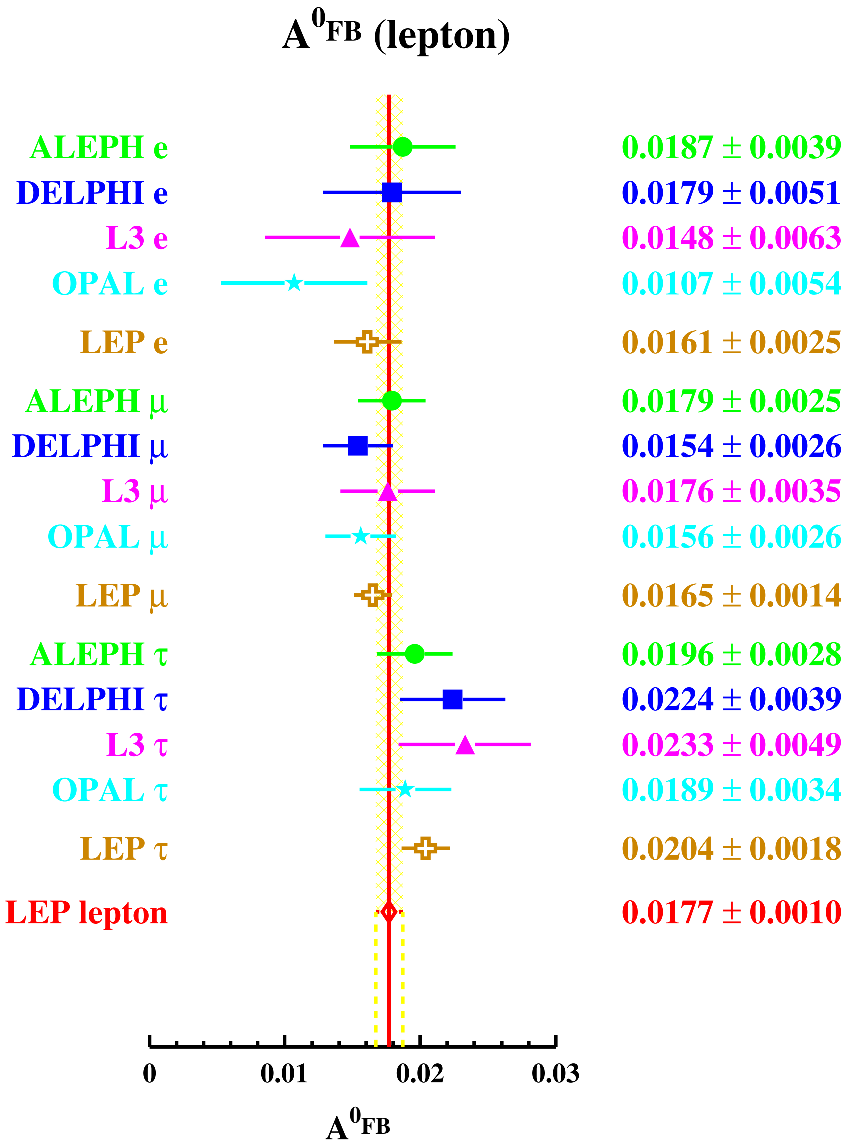
dσ/dcosθ (nb)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
cosθ
Peak 93+94
P-2
P+2



Systematic error ≈ 0.003

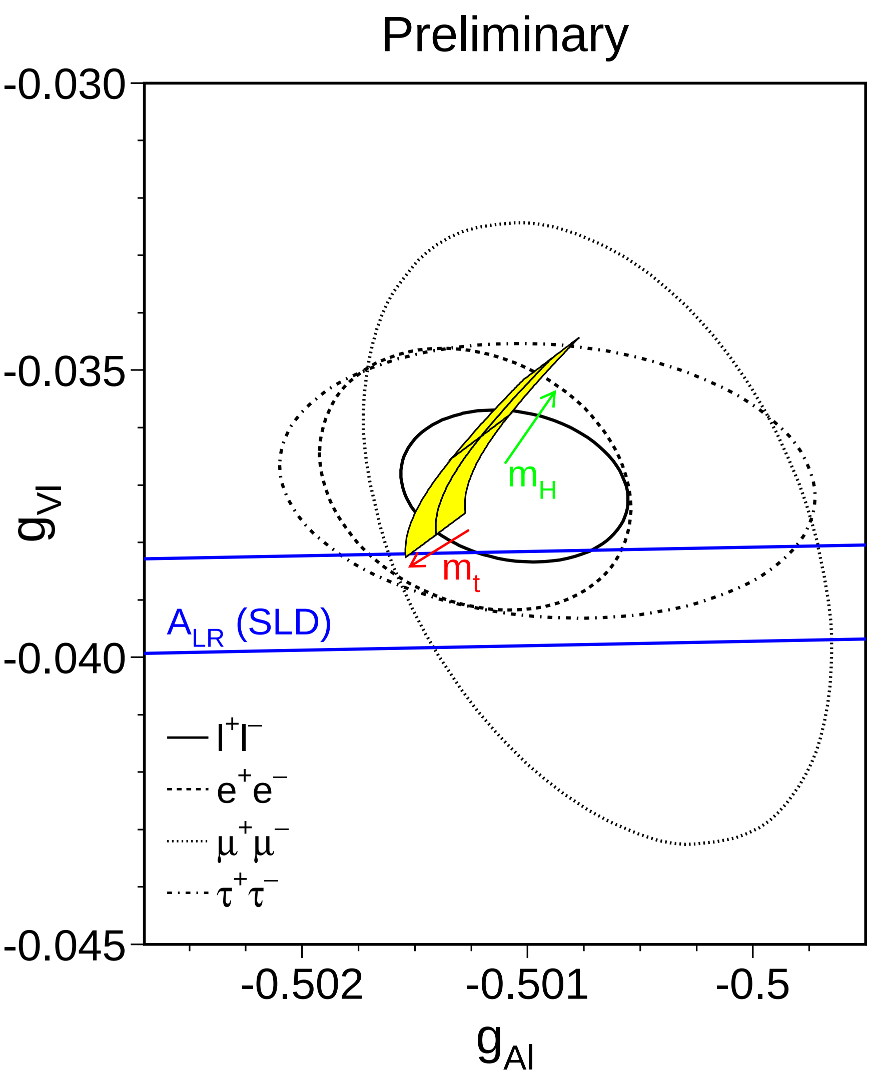

DELPHI
1990-92
1993-95 Preliminary
Asymmetry
Energy, GeV
e
μ
τ
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
90
92
94

Lepton Pole Asymmetry: $A_{\rm FB}^{0,l}$



- Results from the four experiments are consistent with each other
- Results support lepton universality hypothesis

Vector and Axial Vector Coupling Constants



- Results include also cross section measurement (Γ_l), τ polarization, (A_e, A_τ)

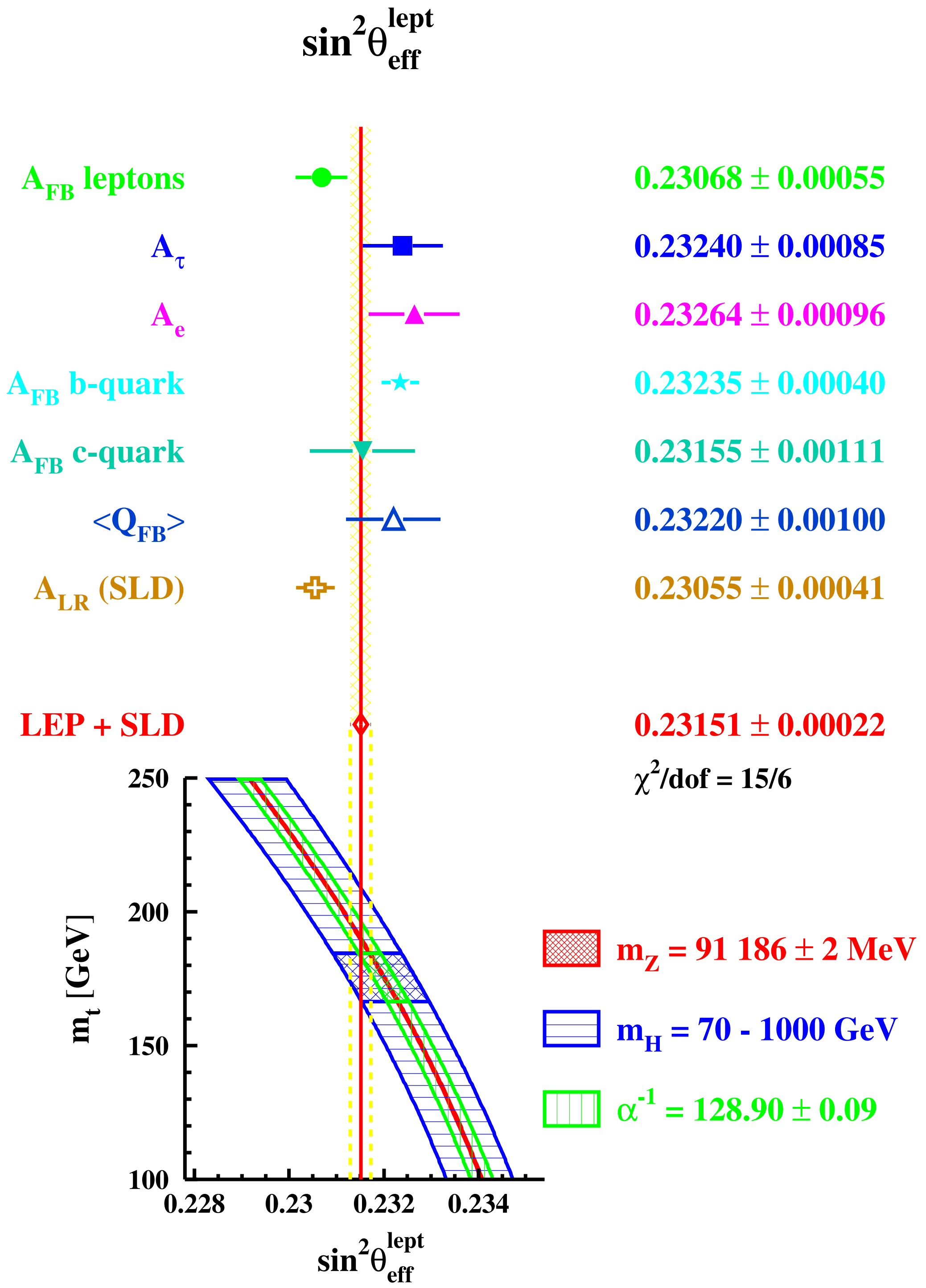
$$A_{FB}^{0,l} = 3\frac{\overline{g}_A^e\overline{g}_V^e}{(\overline{g}_A^e)^2+(\overline{g}_V^e)^2}\frac{\overline{g}_A^l\overline{g}_V^l}{(\overline{g}_A^l)^2+(\overline{g}_V^l)^2}$$

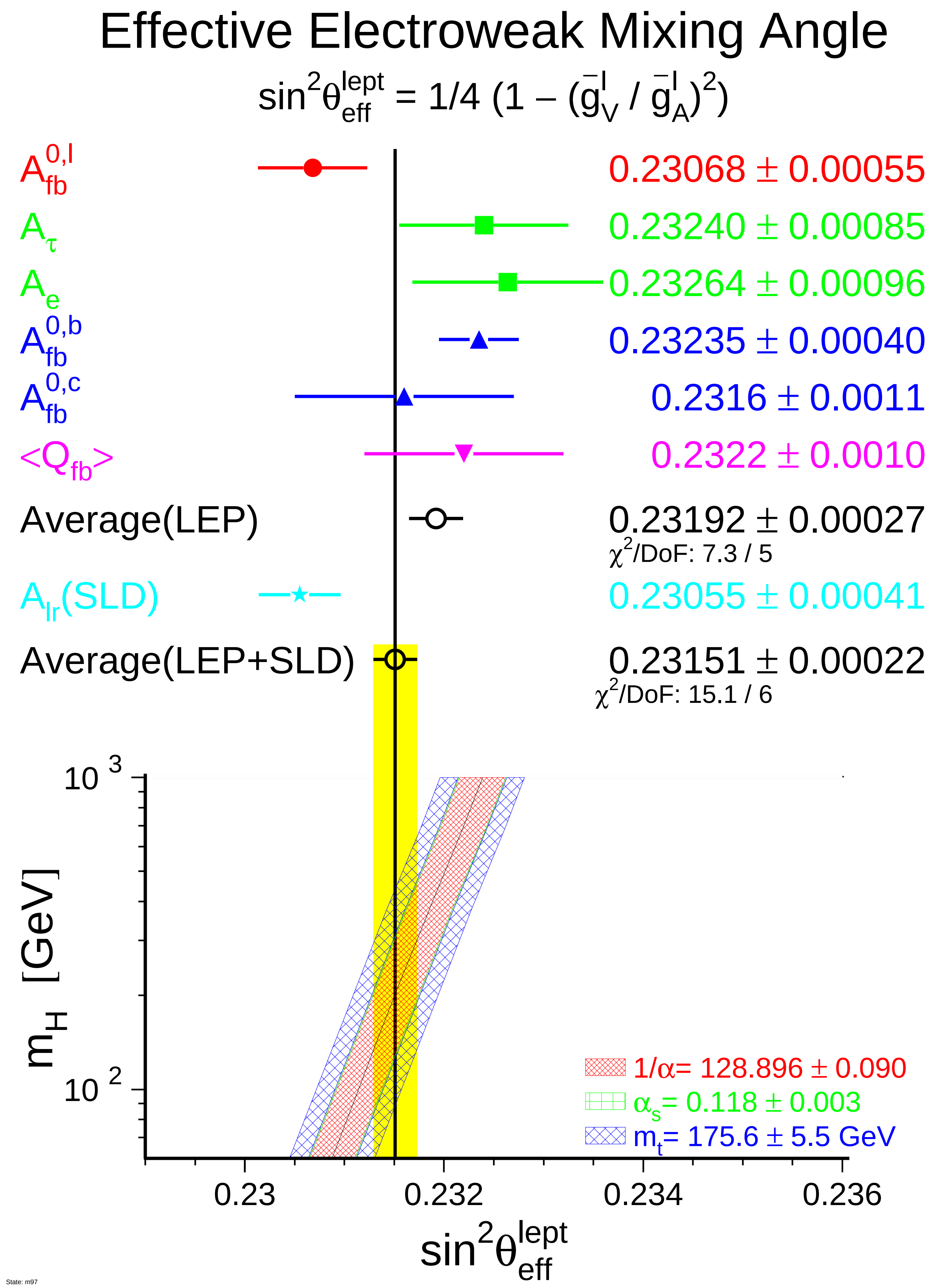
$$\Gamma_l \propto (\overline{g}_V^l)^2+(\overline{g}_A^l)^2$$

$$A_l = 2\frac{\overline{g}_V^l\overline{g}_A^l}{(\overline{g}_V^l)^2+(\overline{g}_A^l)^2}$$

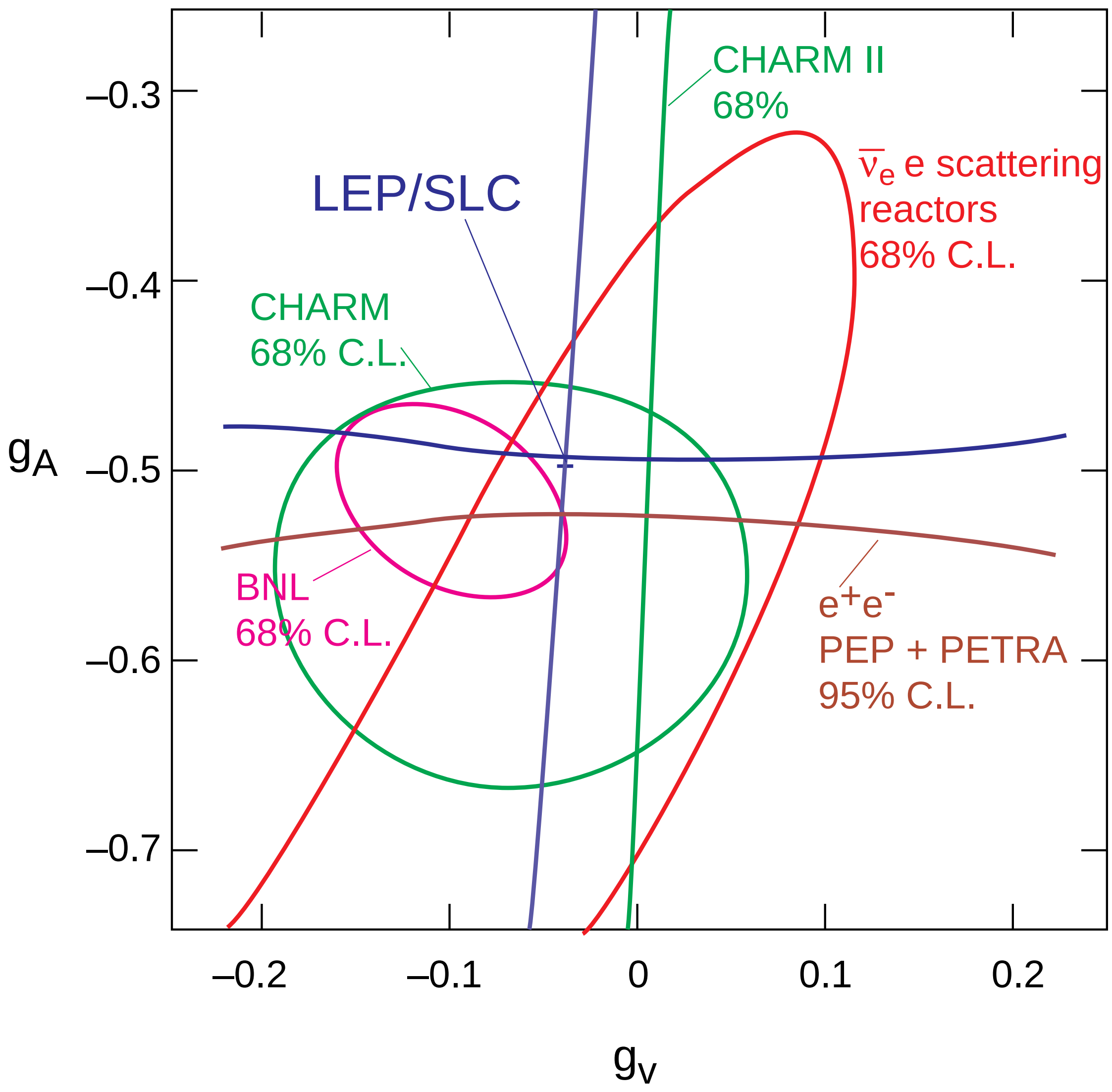
- Results support lepton universality hypothesis

Electroweak Mixing Angle : $\sin^2\bar{\theta}_{\mathrm{W}} = \frac{1}{4}(1 - (\frac{\bar{g}_{\mathrm{V}}}{\bar{g}_{\mathrm{A}}})^2)$





Effective Electroweak Mixing Angle
$\sin^2\theta^{lept}_{eff} = 1/4\,(1 - (\bar{g}^l_V / \bar{g}^l_A)^2)$
$A^{0,l}_{fb}$
0.23068 ± 0.00055
A_τ
0.23240 ± 0.00085
A_e
0.23264 ± 0.00096
$A^{0,b}_{fb}$
0.23235 ± 0.00040
$A^{0,c}_{fb}$
0.2316 ± 0.0011
$\langle Q_{fb} \rangle$
0.2322 ± 0.0010
Average(LEP)
0.23192 ± 0.00027
χ^2/DoF: 7.3 / 5
A_{lr}(SLD)
0.23055 ± 0.00041
Average(LEP+SLD)
0.23151 ± 0.00022
χ^2/DoF: 15.1 / 6
10^3
10^2
m_H [GeV]
$1/\alpha = 128.896 \pm 0.090$
$\alpha_s = 0.118 \pm 0.003$
$m_t = 175.6 \pm 5.5$ GeV
0.23
0.232
0.234
0.236
$\sin^2\theta^{lept}_{eff}$
State: m97



CHARM II
68%
$\overline{\nu}_e$ e scattering
reactors
68% C.L.
LEP/SLC
CHARM
68% C.L.
BNL
68% C.L.
e^+e^-
PEP + PETRA
95% C.L.
g_A
–0.3
–0.4
–0.5
–0.6
–0.7
–0.2
–0.1
0
0.1
0.2
g_V

Summary

- Each LEP experiment has collected about 400K lepton events from the Z decay
- A_{FB} measurements have achieved precisions of 10^{-3}
  Results are consistent with the SM prediction,
  supporting lepton universality hypothesis
- $\overline{g}_{\mathrm{V}}$ and $\overline{g}_{\mathrm{A}}$ are derived from the combined results of A_{FB} with other measurements (cross sections,τ polarization)
- $\sin^2\bar{\theta}_{\mathrm{W}}$, derived from A_{FB} measurements is consistent with the results from other measurements

A_{FB} measurements have provided a non-trivial test of the SM