The Legacy of $\sin^2\theta_{\mathrm{eff}}^{\mathrm{lept}}$

Richard Kellogg - (presented by Pippa Wells) - Budapest 2001

- The measurements of asymmetries and polarizations at LEP and SLC tell us about the parity structure of the Z couplings
- The essential quantity is the *coupling parameter*, which can be expressed in terms of the vector and axial couplings, g_v and g_a

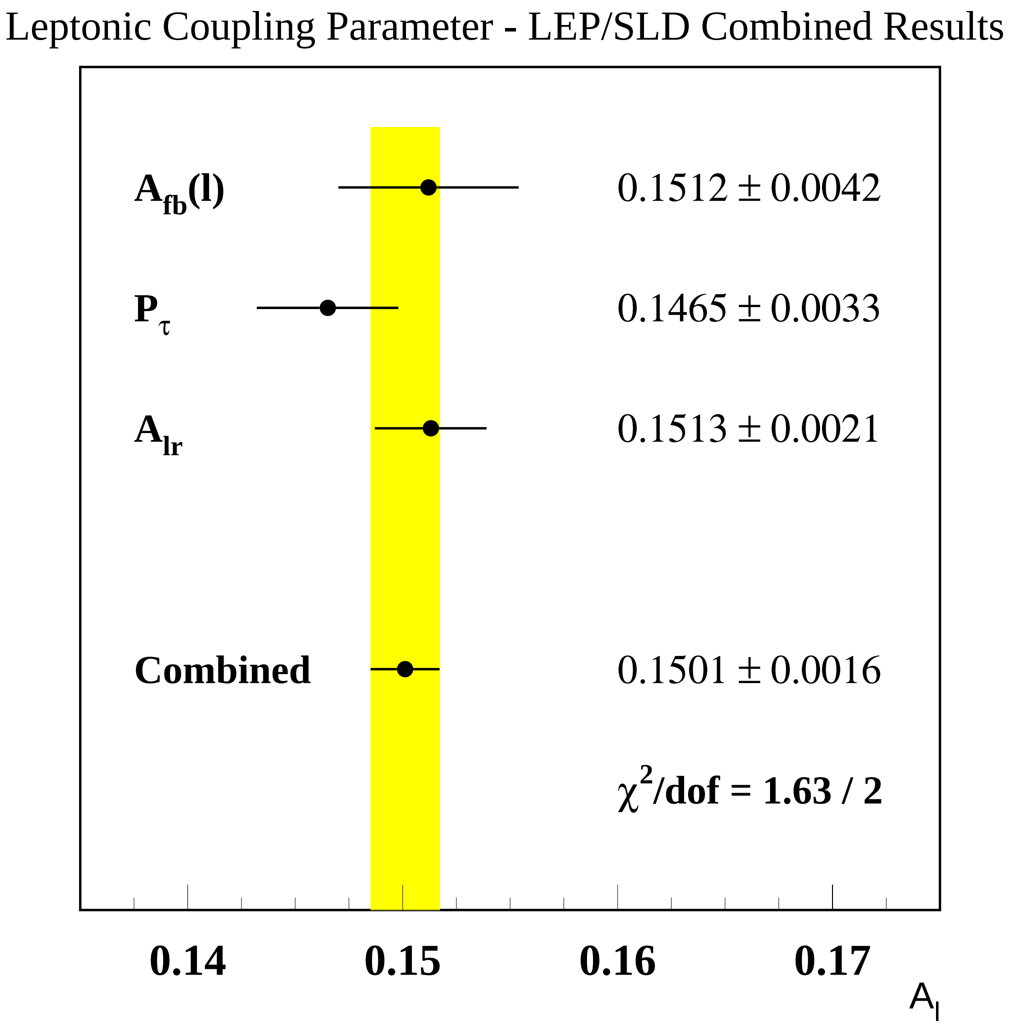
$$\mathcal{A}_{\mathrm{f}} = \frac{2g_{\mathrm{Vf}}g_{\mathrm{Af}}}{g_{\mathrm{Vf}}^2 + g_{\mathrm{Af}}^2}$$

All the interesting observables can be expressed simply in terms of the coupling parameters

- The forward-backward charge asymmetry: $A_{\mathrm{FB}}^{0,\,\mathrm{f}} \equiv \frac{3}{4}\mathcal{A}_{\mathrm{e}}\mathcal{A}_{\mathrm{f}}$
- The left-right interaction asymmetry for polarized beams: $A_{\mathrm{LR}}^{0} \equiv \mathcal{A}_{\mathrm{e}}$
- The average tau polarization: $\langle \mathcal{P}_{\tau} \rangle = -\mathcal{A}_{\tau}$

- The leptonic coupling parameter, A_l, can be measured quite independently of any model assumptions, in a number of ways

- All consistent
- Lepton universal


Leptonic Coupling Parameter - LEP/SLD Combined Results

- How about quarks?

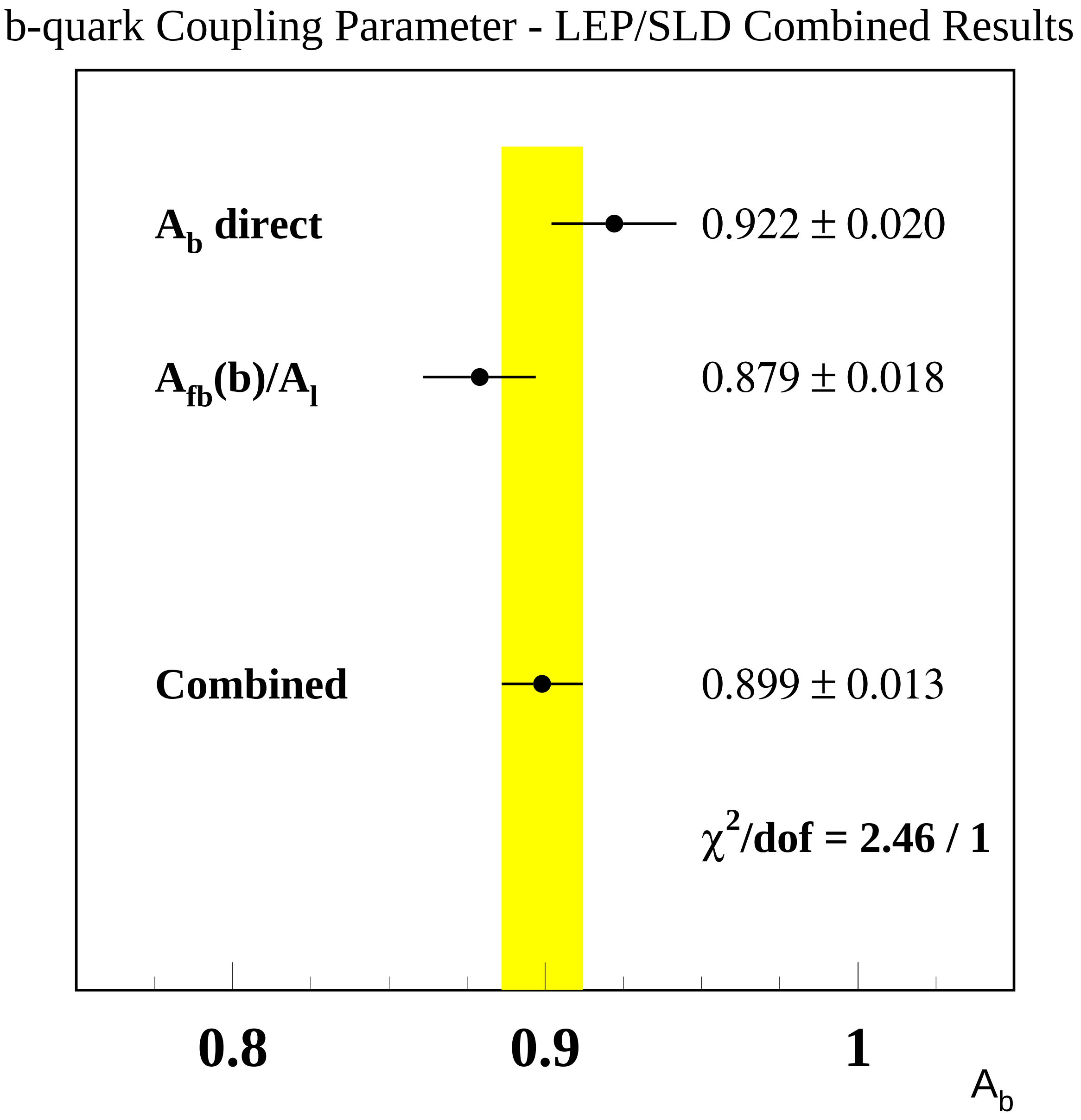
  - A_{FBLR} (b), the forward-backward left-right asymmetry for b-quarks measured by SLD gives a direct measurement of A_b

$$A_{\mathrm{FBLR}} = A_{\mathrm{LR}}(F) - A_{\mathrm{LR}}(B) = \frac{3}{4}\mathcal{A}_{\mathrm{f}}$$

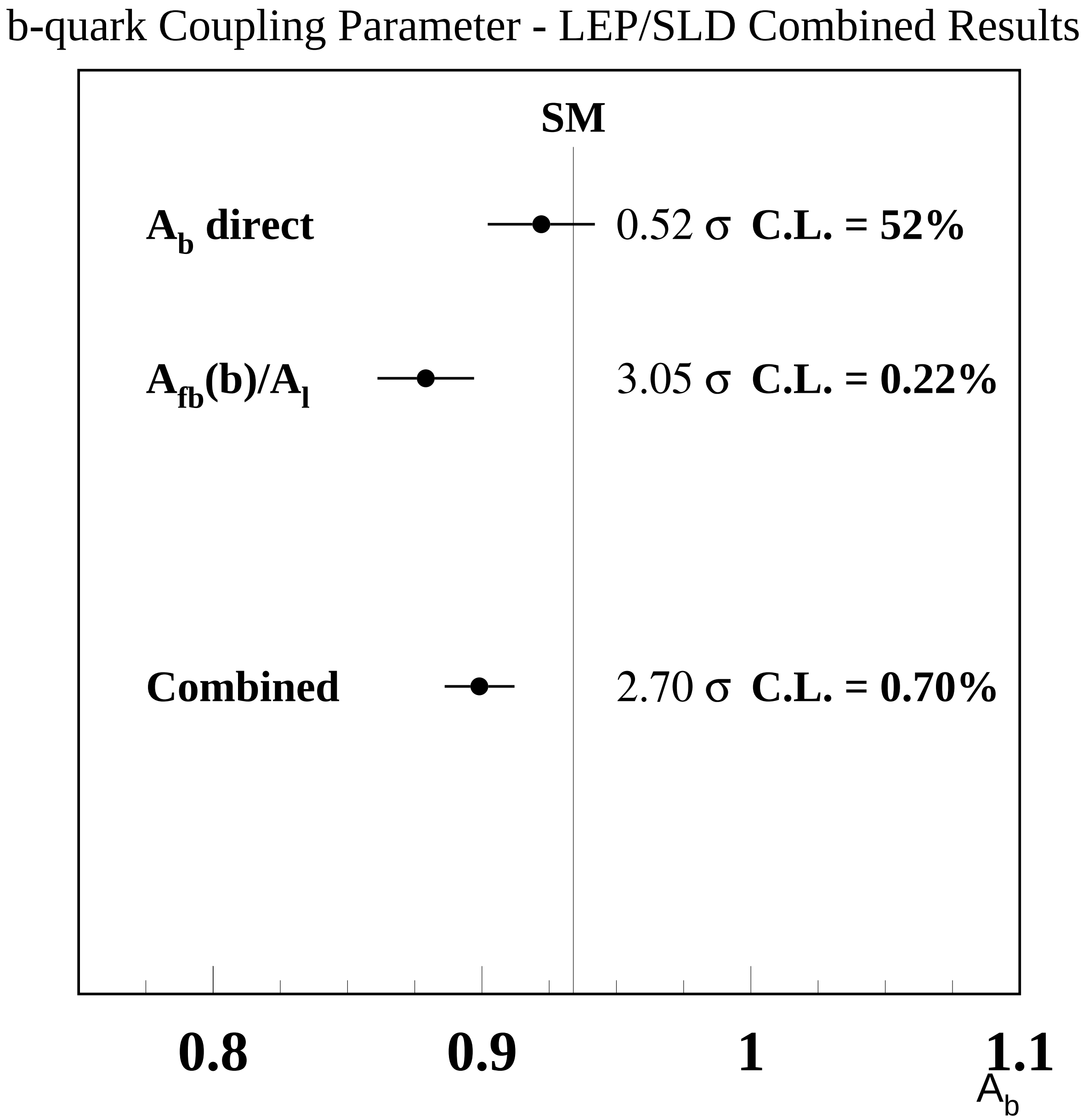
  - A_{fb}(b), the forward-backward asymmetry for b-quarks measured at LEP, gives the product of A_l and A_b - combined with A_l, this yields an indirect measurement of A_b.

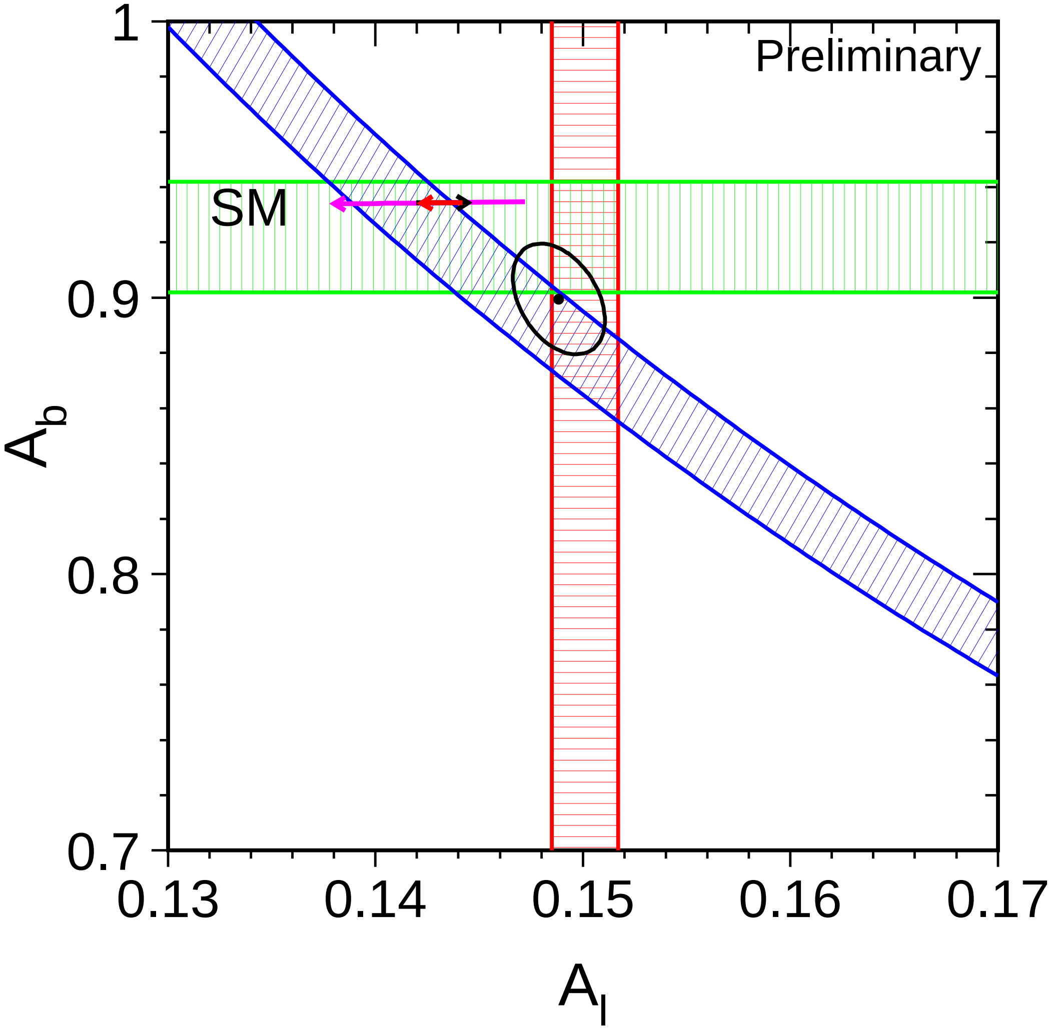
$$A_{\mathrm{FB}}^{0,\,\mathrm{f}} \equiv \frac{3}{4}\mathcal{A}_{\mathrm{e}}\mathcal{A}_{\mathrm{f}}$$

- The two measurements are reasonably compatible with each other
- C.L. = 11%



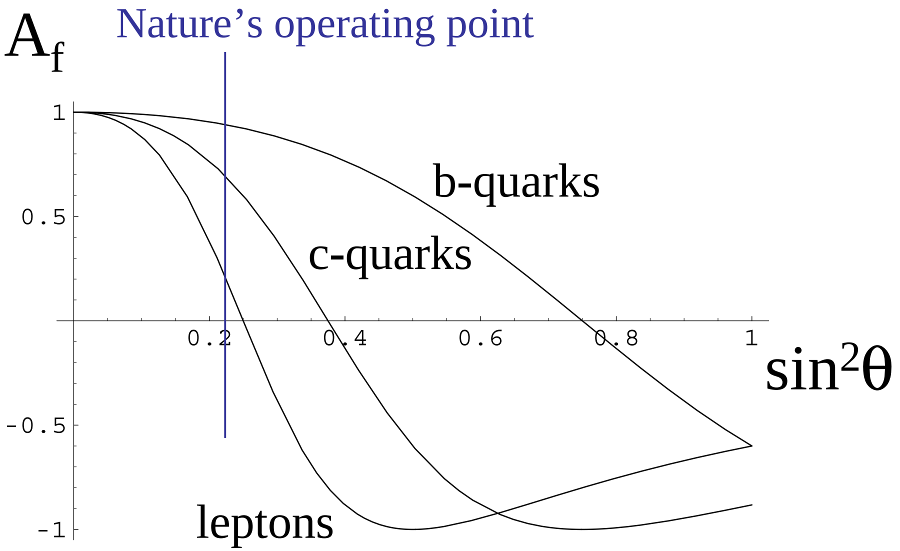
- But less compatible with the Standard Model
- C.L. = 0.7%




Preliminary
SM
A_b
A_l
1
0.9
0.8
0.7
0.13
0.14
0.15
0.16
0.17

- Due to the charge and weak iso-spin assignments of b-quarks (-1/3, -1/2) A_b is particularly insensitive to $\sin^2\theta$ at nature's operating point

- A_b is essentially a ***root level*** prediction of the SM



$$g_V^{\text{eff}} = \sqrt{\bar\rho}(T^3 - 2Q\sin^2\theta_{\text{eff}})$$
$$g_A^{\text{eff}} = \sqrt{\bar\rho}T^3$$

$$\mathcal{A}_f = \frac{2g_{Vf}g_{Af}}{g_{Vf}^2 + g_{Af}^2}$$

- Therefore, as soon as we assume the validity of the Standard Model:
  - Inter-fermion comparisons become possible in terms of $\sin^2\theta$
  - Measurements of A_b become irrelevant (the SM knows better)
  - b-quark asymmetry measurements become measurements of A_l (and hence $\sin^2\theta$)

Consequences:

- The direct SLD measurement of A_b (through A_{FBRL}), which agrees with the SM, is simply ignored

- The indirect A_b measurement, through $A_{fb}(b)$, which disagrees strongly with the SM, becomes a measurement of A_l (and hence $\sin^2\theta_l$)
  - which now disagrees strongly with the direct $\sin^2\theta_l$ measurement using leptons.

The Notorious $\sin^2\theta$ Discrepancy

All six measurements individually:

χ^2/dof = 12.8/5 → C.L.=2.5%

Grouping leptons against quarks:

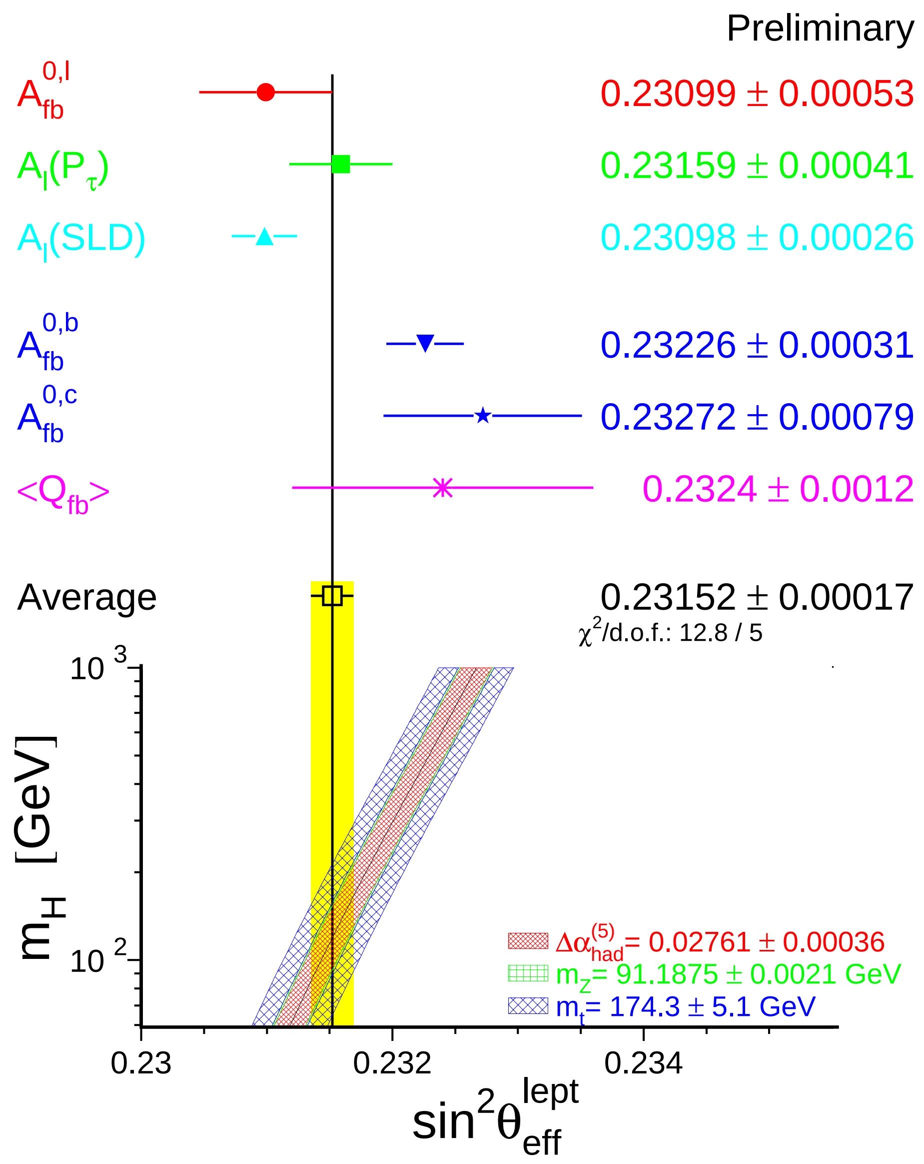
χ^2/dof = 10.89/1 → C.L.=0.1%

Grouping leptons against Afb(b):

χ^2/dof = 9.61/1 → C.L.=0.2%

Considering just the four most precise measurements:

χ^2/dof = 10.9/3→ C.L.=1.3%



Averaging over this discrepancy does not represent a firm foundation for determining the SM parameters!

- We can use the full force of our measurements to expose a defect in the SM at root level.
- But for determining SM parameters, we must believe the SM is OK, and the discrepancy then appears as a disturbing measurement inconsistency.
  - Not a great base for investigating subtle electroweak radiative effects

- What is particularly disturbing is that the current (and historical) stance of the lepewwg is to simply average over the discrepancy
  - The final errors benefit just as fully from two precise measurements of $\sin^2\Theta$ which are 3σ apart as they would if the measurements agreed perfectly
  - 3σ basically doesn’t happen in a gaussian world
  - Everyone, if pushed will admit that *no* error estimate is truly gaussian
  - Yet the only acceptable way to take an average is under the gaussian hypothesis

What to do? - Opal should take a reasoned opinion

- Continue averaging?
  - But the PDG will never agree - the future will be left with no consensus on this important legacy measurement
- Further study?
  - But time and people are running out
- Determine errors from observed spread?
  - A scale factor of 10.9/3 = 1.9 seems reasonable
- Reject one of the measurements?
  - Better preserves precision, but sociologically difficult

The Conclusion is up to YOU

- Opal has established an editorial board on the LEP-SLD Electroweak Combination paper (to be published in Physics Reports by the “end of the year”)
- All interested Opalists are encouraged to participate in the discussion

- See:

http://opalinfo.cern.ch/opal/group/lineshape/drafts/kel-web/lineshape/physrep/physrep.html