

Standard Model Fits

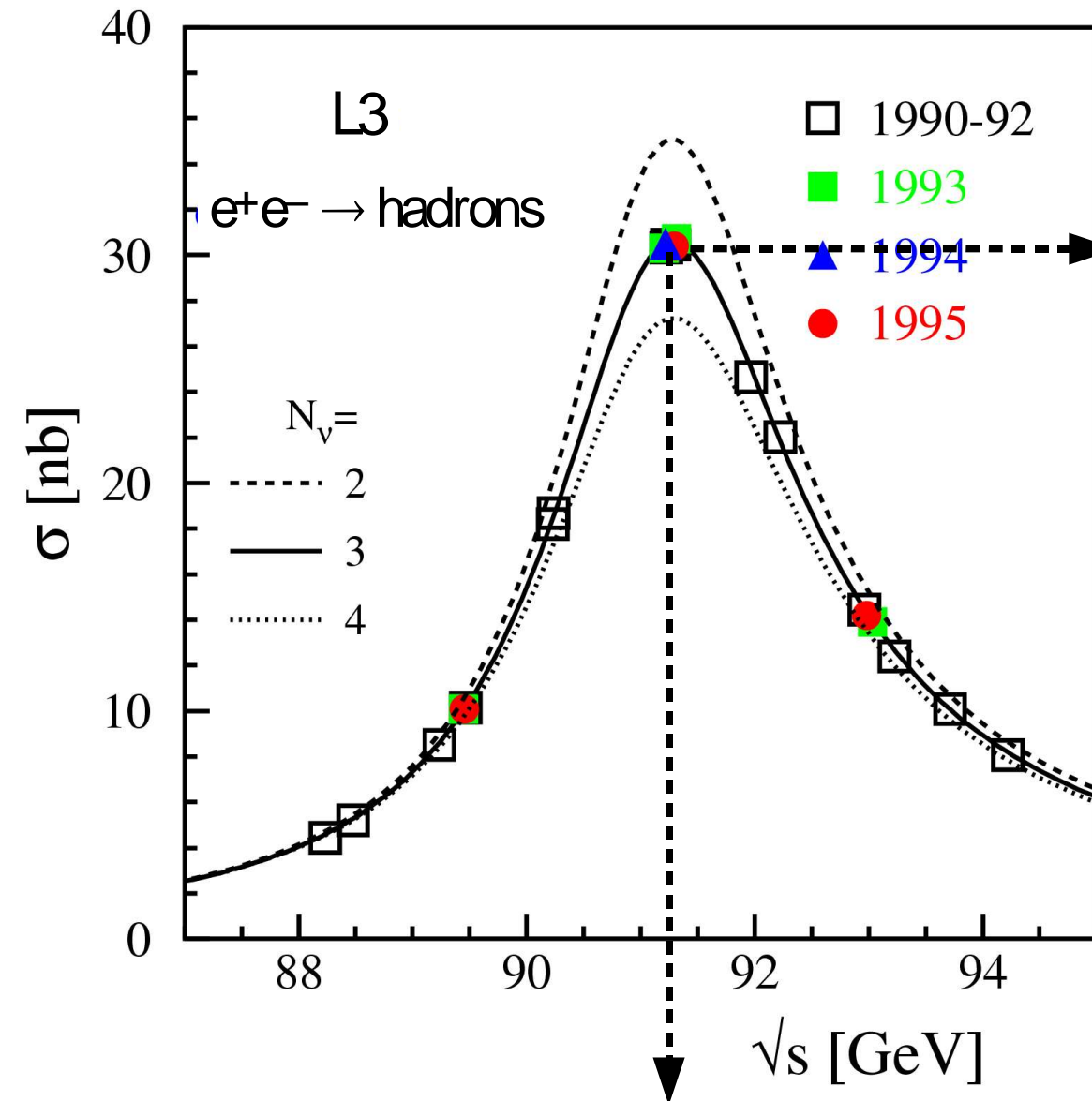
Stefan Roth, RWTH Aachen

L3 Collaboration

Outline:

- Measurements at the Z pole
- Measurement of the W mass
- Other observables
- Interpretation within the SM – Higgs mass analysis

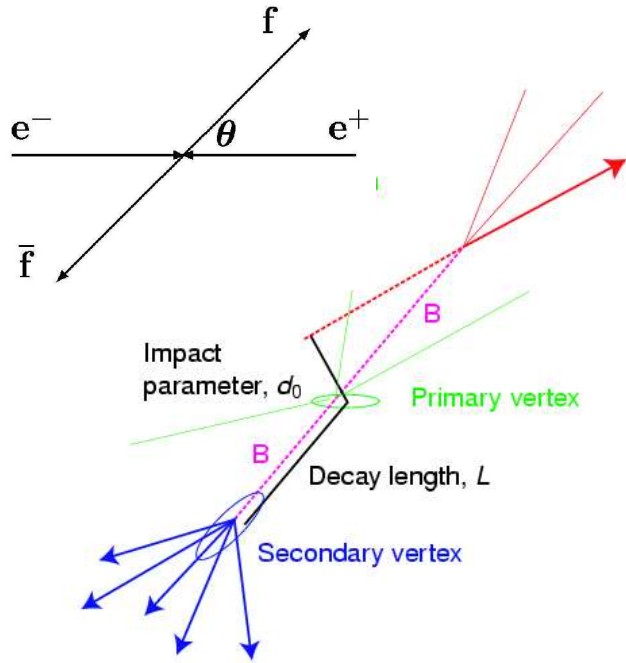
Z-Lineshape



$$N_\nu = 3 \times (0.9947 \pm 0.0028)$$

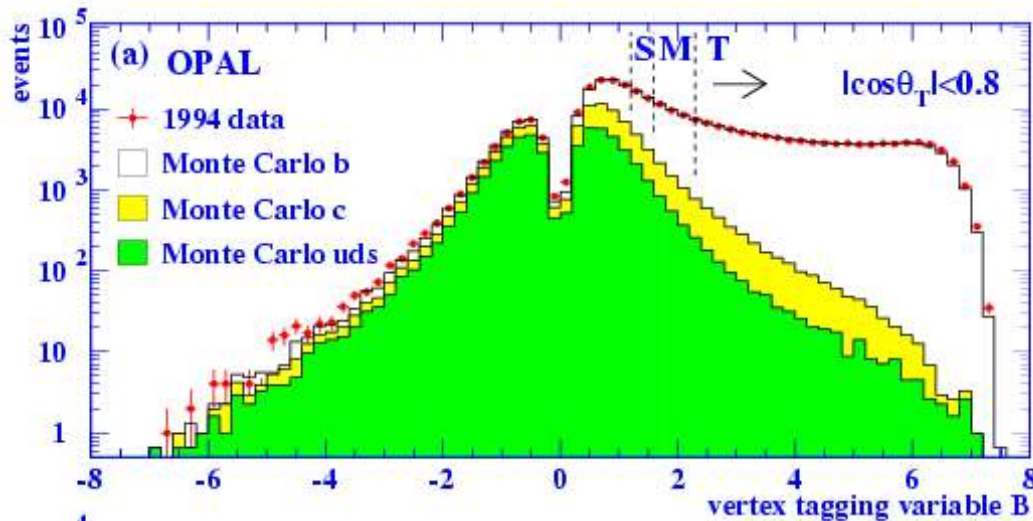
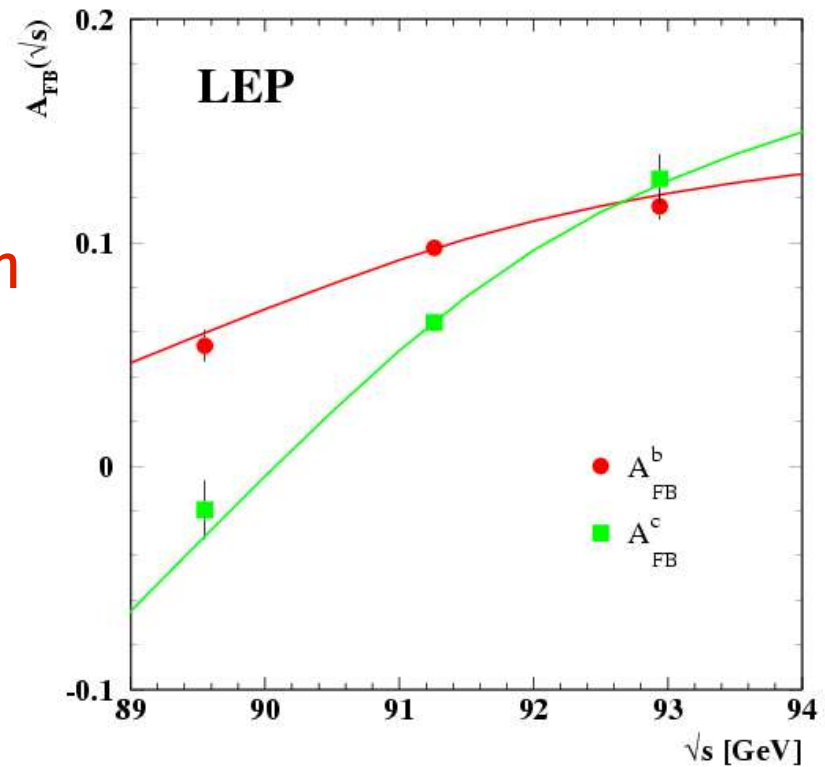
$$m_Z = 91.1875 \pm 0.0021 \text{ GeV}$$

Forward-Backward Asymmetry



- jet direction
- b tagging
- tag jet charge
- **Corrections for**
 - fragmentation
 - charge confusion
 - b mixing

$$A_{\text{FB}} = \frac{N(\theta > 90^\circ) - N(\theta < 90^\circ)}{N(\theta > 90^\circ) + N(\theta < 90^\circ)}$$



Measurement of $A_{\text{FB}}(b)$ translates into weak mixing angle:

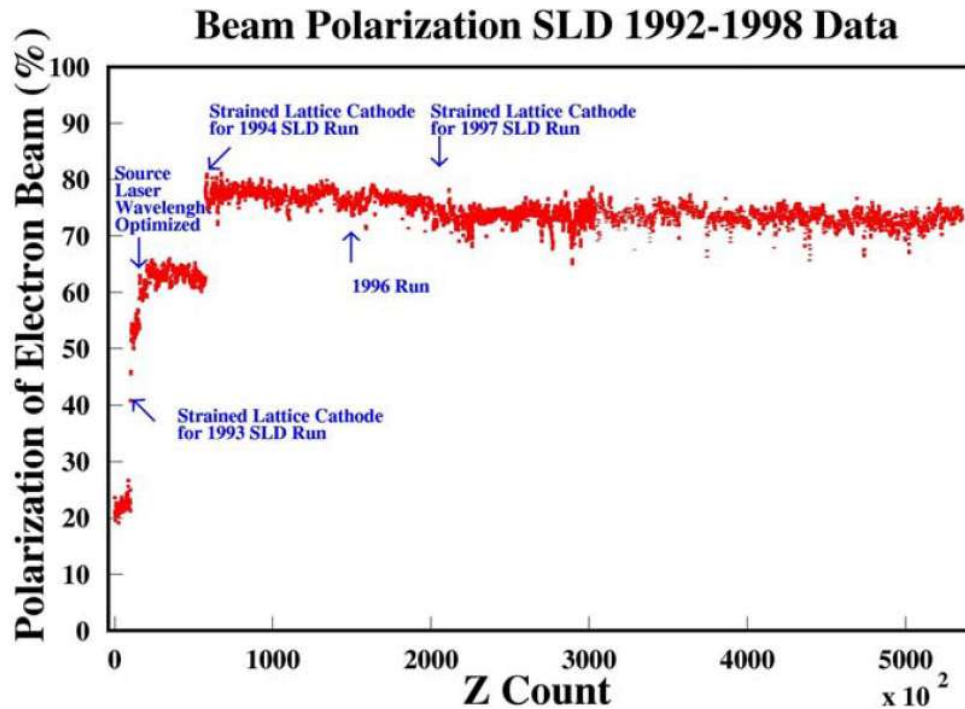
$$\sin^2 \theta_{\text{eff}} = 0.23212 \pm 0.00029$$

Left-Right-Asymmetry at SLC

Count Z events N_Z for both polarizations of electron beam :

$$A_{LR} = \frac{N_Z(L) - N_Z(R)}{N_Z(L) + N_Z(R)} = \mathcal{P}_e A_e$$

Measurement of couplings g_L and g_R of the electron to the Z :



Parity violation !

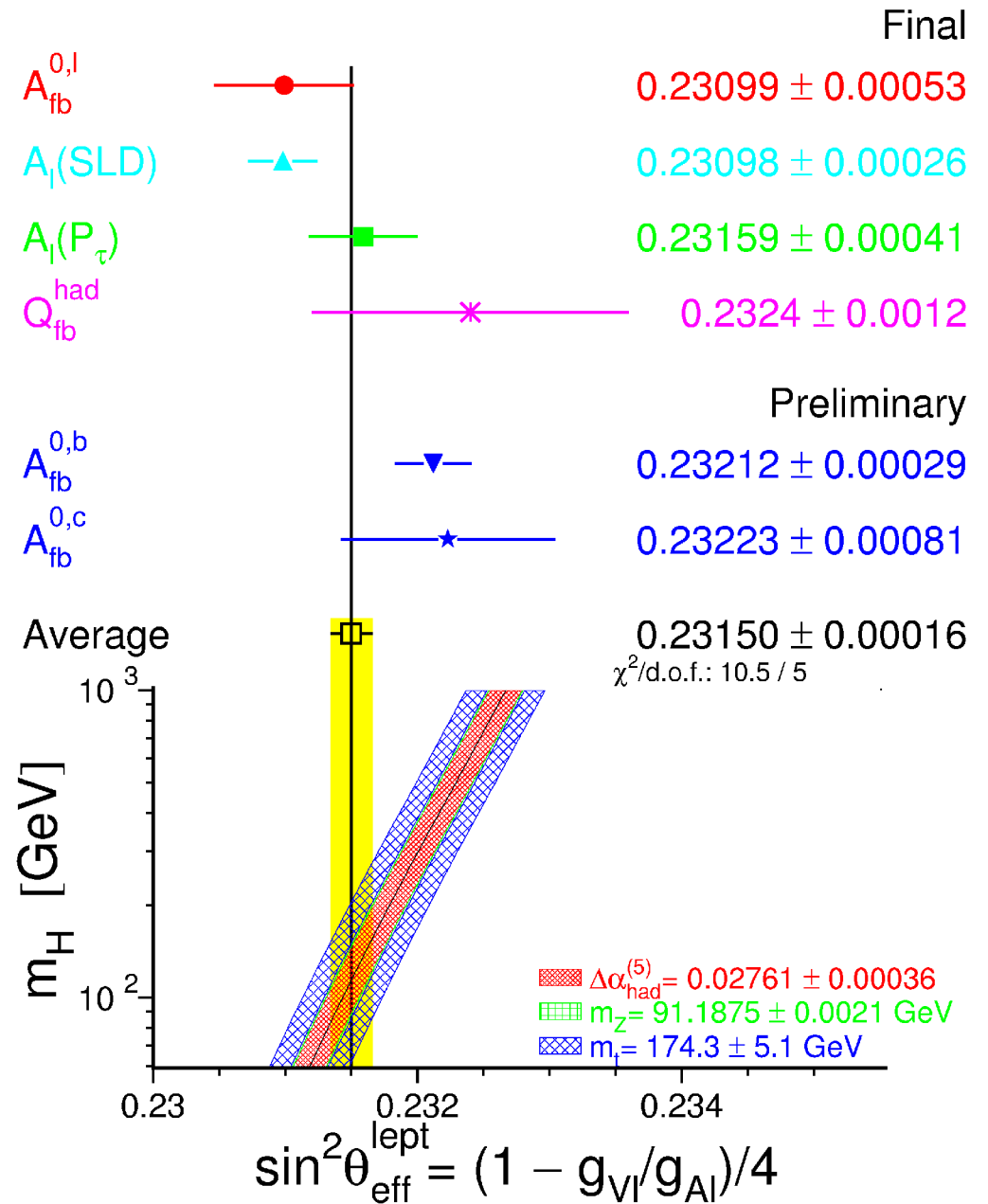
Important:
Precise Measurement of
beam polarisation

Large Polarisation of 75%, with only 500 000 Z bosons:

$$\sin^2 \theta_{\text{eff}} = 0.23098 \pm 0.00026$$

Weak Mixing Angle

Between most precise measurements
2.9 σ difference !



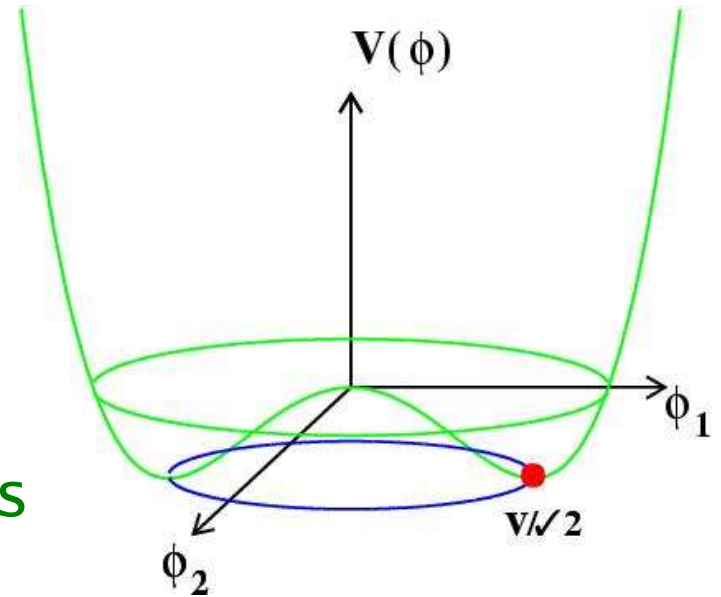
Light Higgs preferred

Higgs Mechanism

$$V(\Phi) = \mu^2 \Phi^\dagger \Phi + \lambda (\Phi^\dagger \Phi)^2$$

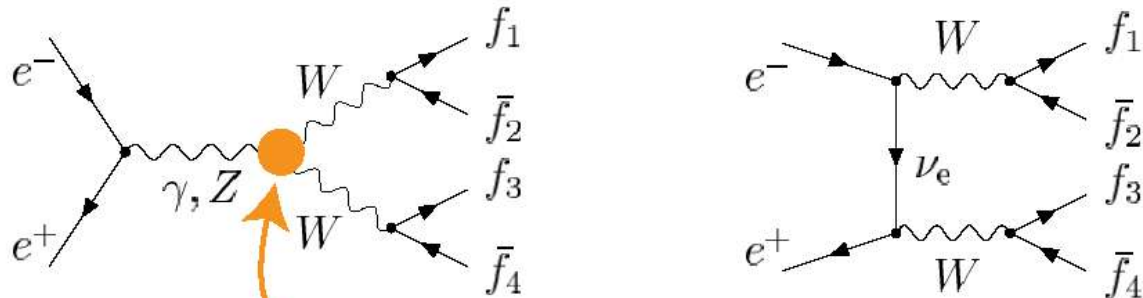
Spontaneous symmetry breaking:

- Scalar field Φ with electroweak coupling
- Potential $V(\Phi)$ with non-vanishing vacuum expectation value $v/\sqrt{2}$
- Coupling to Higgs field gives W and Z mass



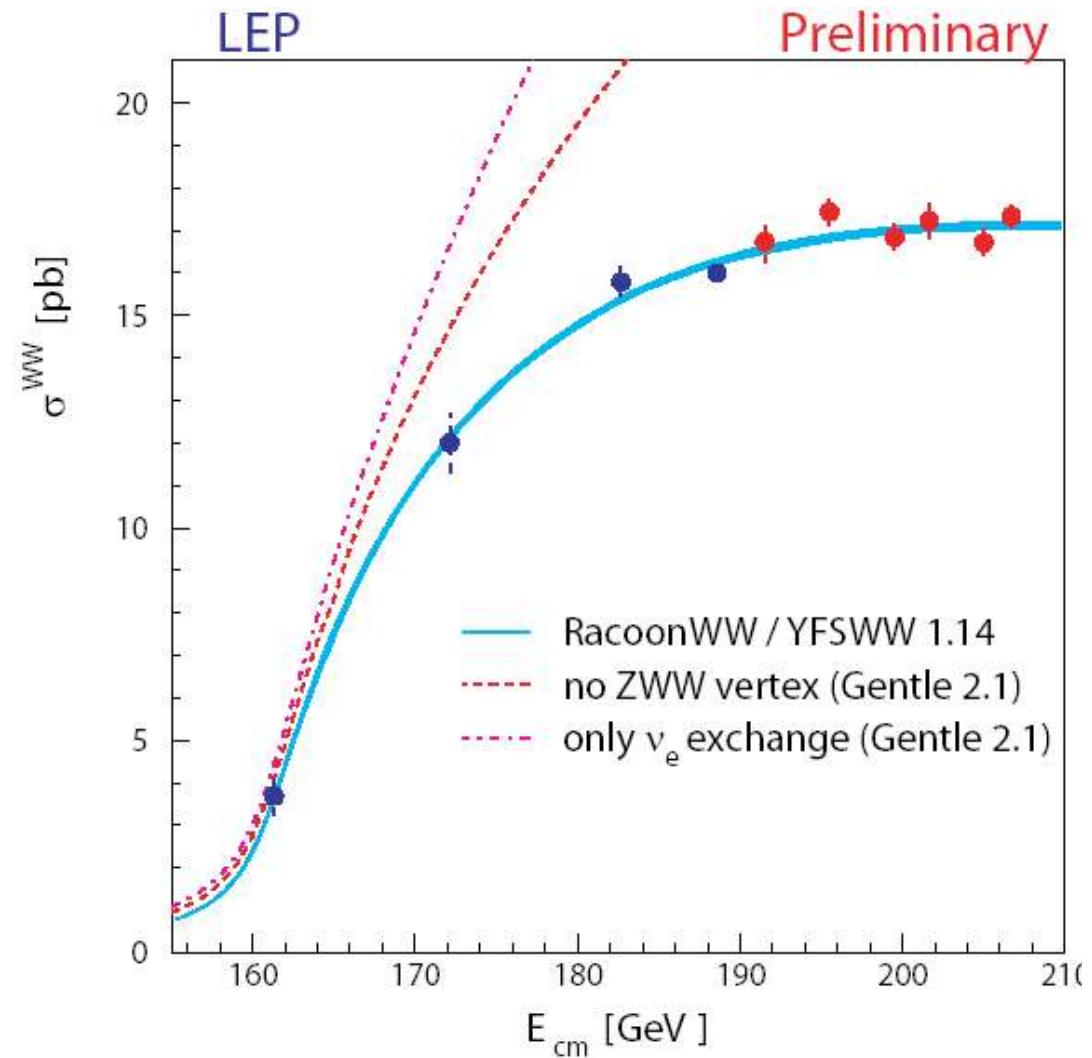
$$\left. \begin{aligned} m_W &= \frac{1}{2} \frac{e}{\sin \theta_w} v \\ m_Z &= \frac{1}{2} \frac{e}{\sin \theta_w \cos \theta_w} v \end{aligned} \right\} \frac{m_W}{m_Z} = \cos \theta_w$$

W pair production at LEP



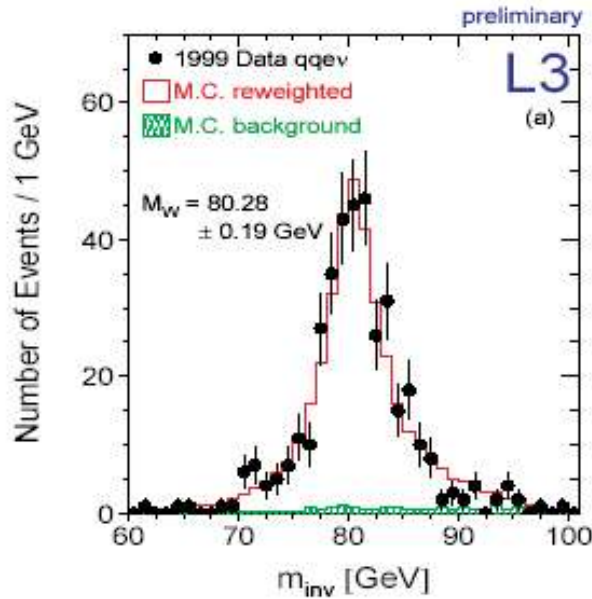
Three-Boson
Vertex

Individual contributions from ν , γ and Z exchange violate unitarity!

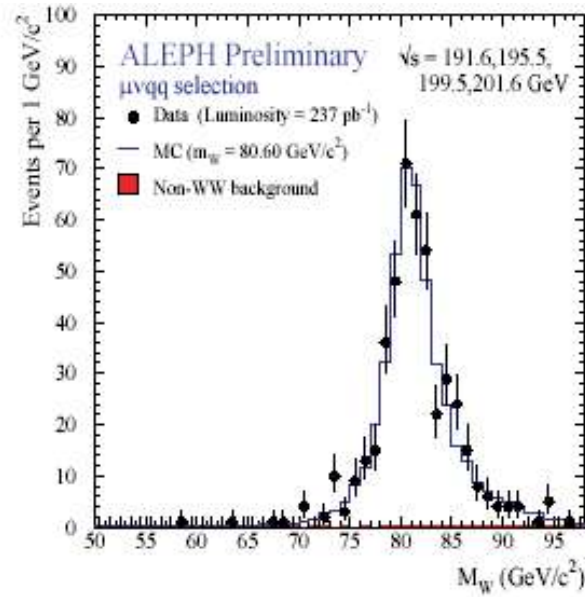


W mass distributions

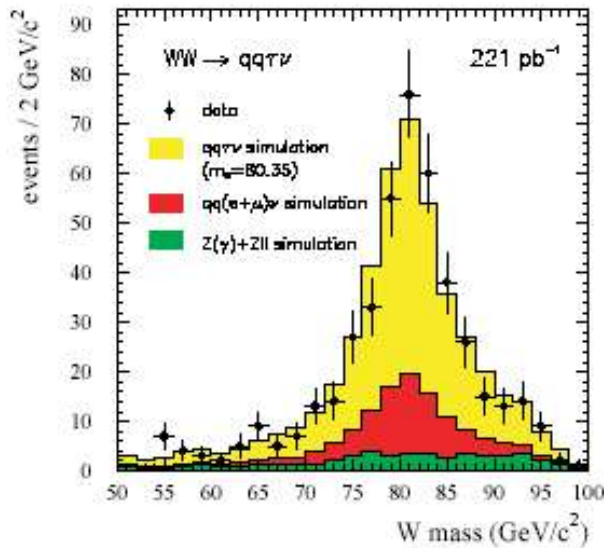
qq $e\nu$



qq $\mu\nu$

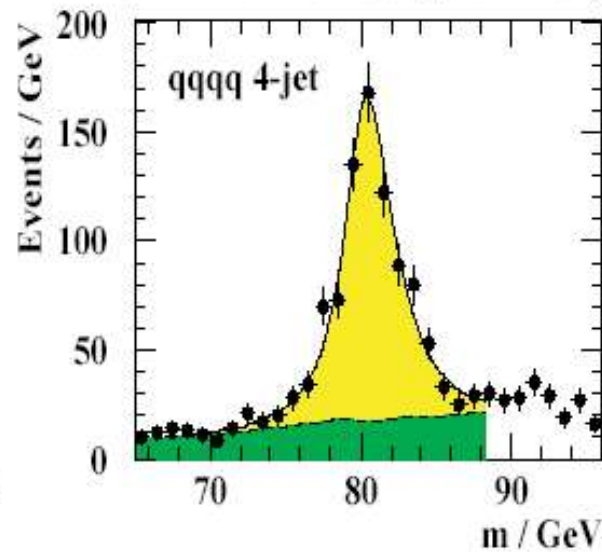


DELPHI preliminary



qq $\tau\nu$

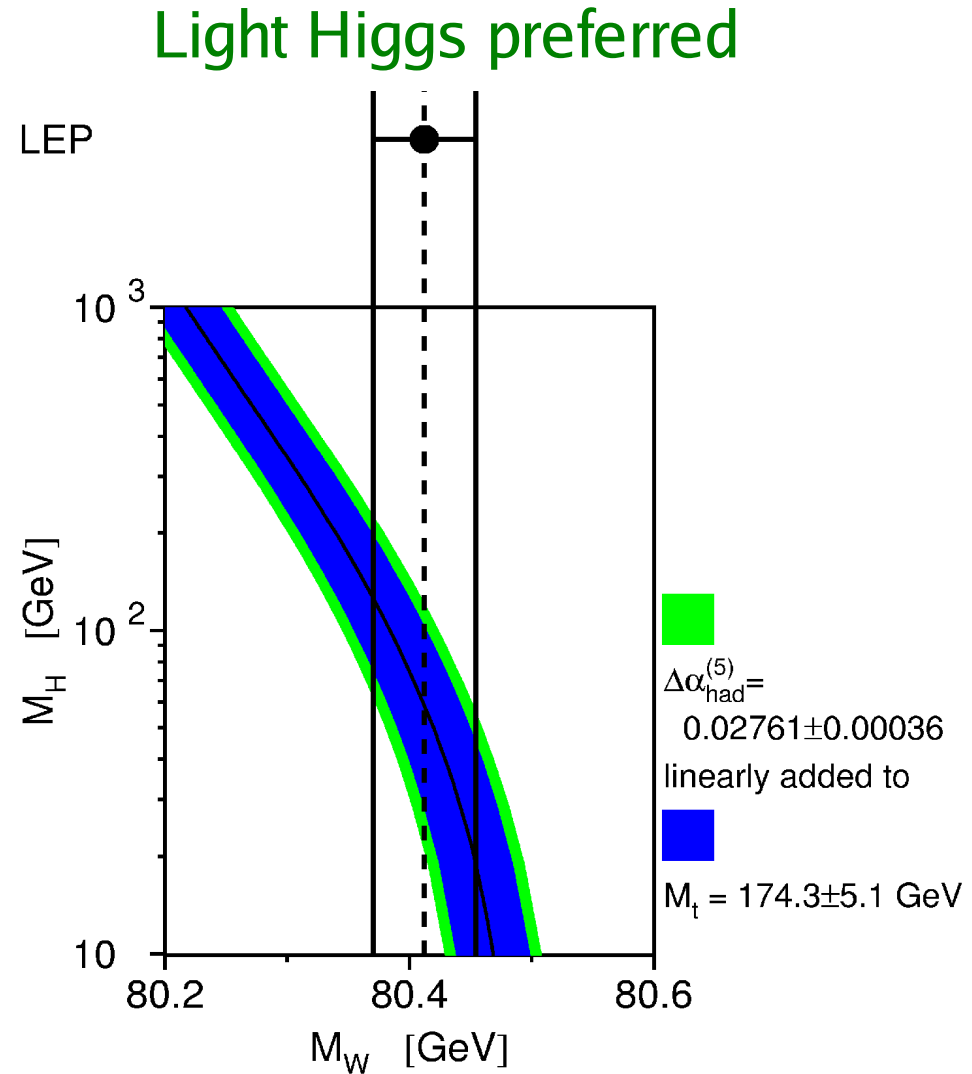
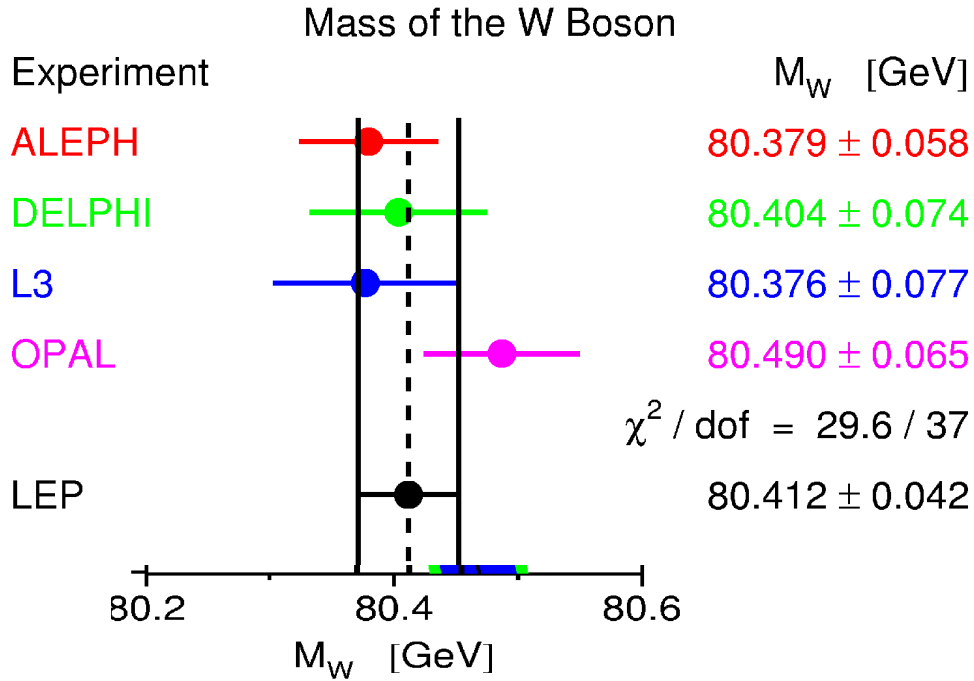
OPAL 192-202 GeV preliminary



qq qq

(see talk A. Moutoussi)

W mass at LEP



Combination of the 4 experiments

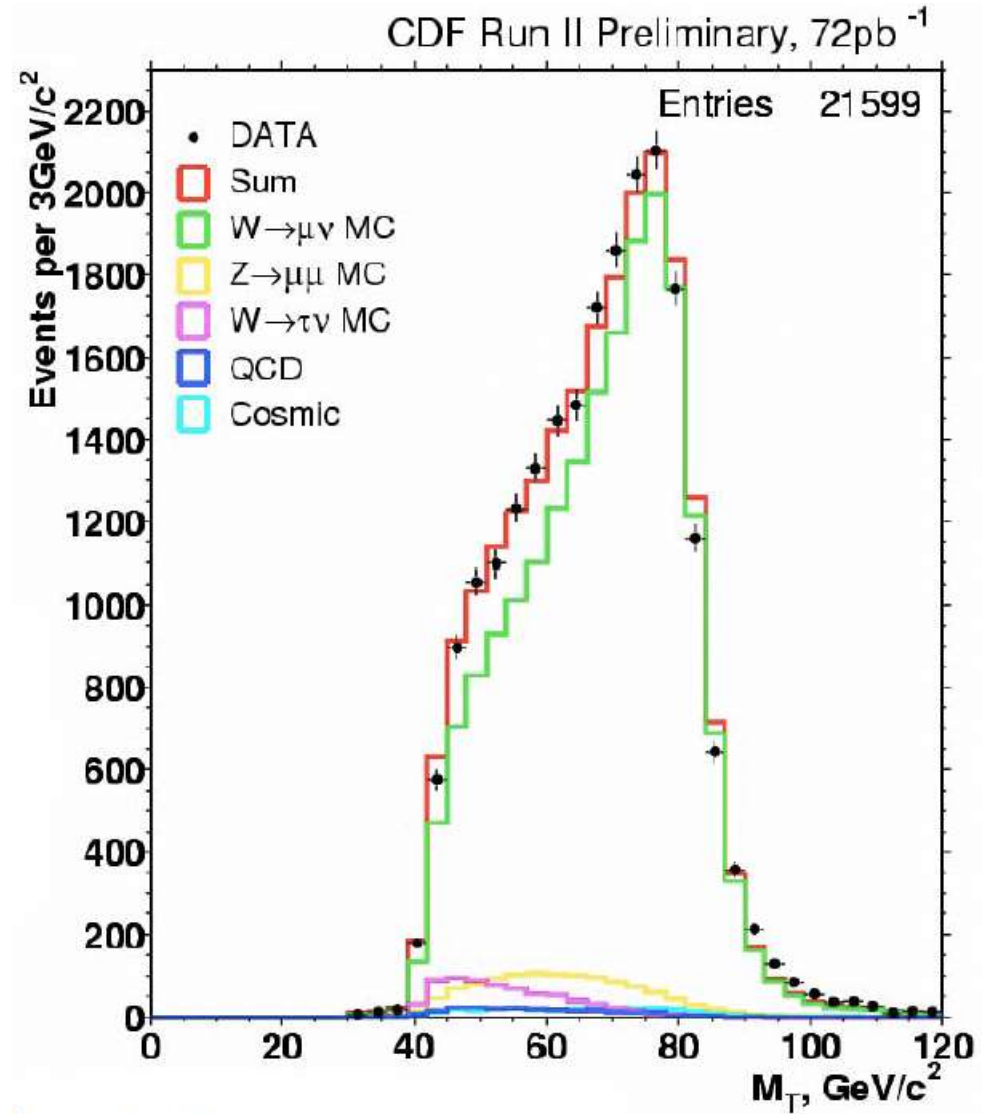
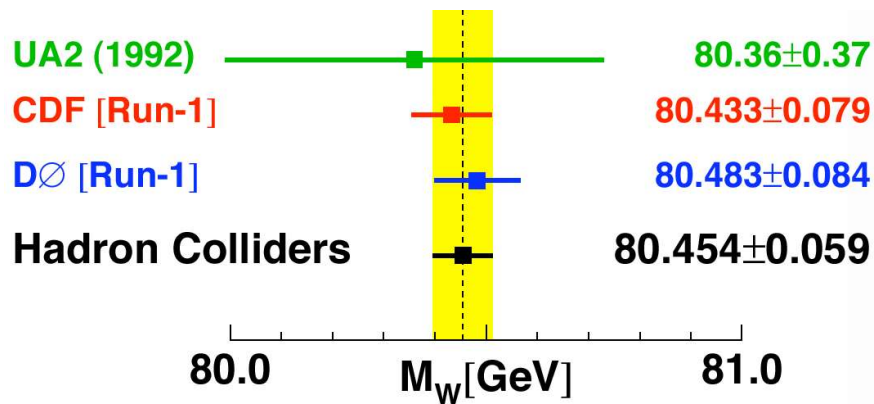
$$m_W = 80.412 \pm 0.029(\text{stat}) \pm 0.031(\text{syst}) \text{ GeV}$$

W mass at Tevatron

CDF and D0 fit transverse mass

Energy scale given by Z decays

Systematics will decrease with increased statistics

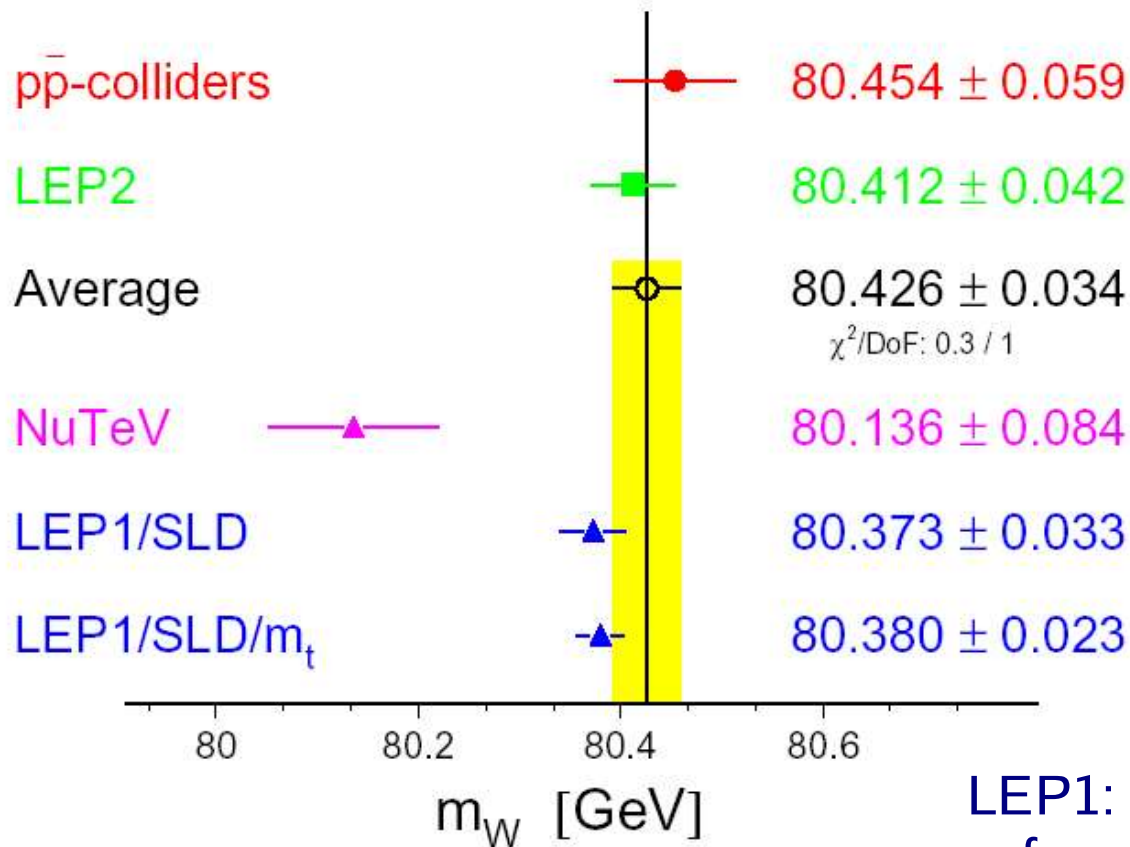


Combination of CDF and D0

$$m_W = 80.454 \pm 0.059 \text{ GeV}$$

World average of W mass

W-Boson Mass [GeV]



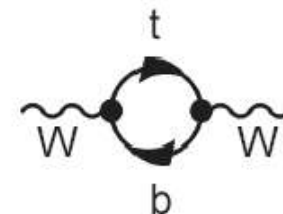
LEP1: Couplings of fermions to the Z

$$\sin^2 \theta_w$$

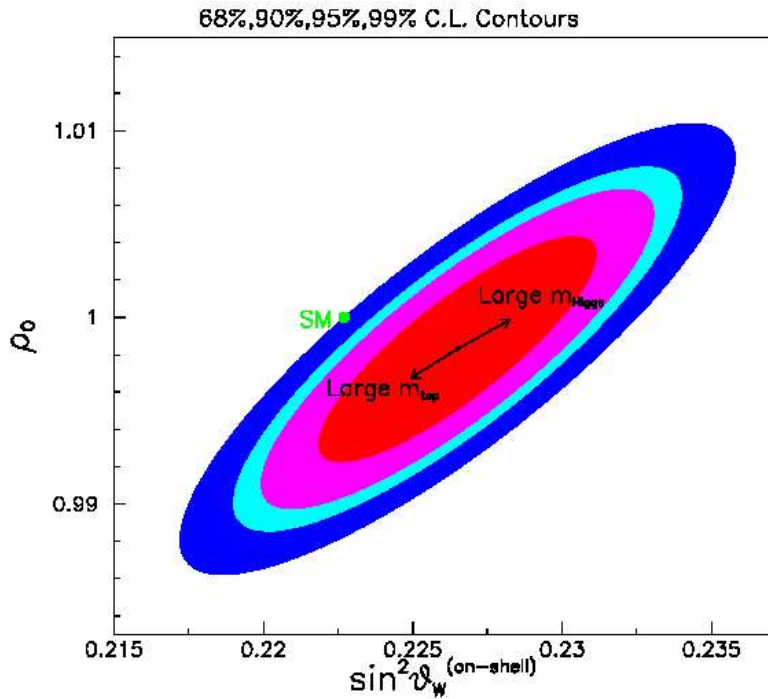
Relation to boson masses via the Higgs mechanism

$$m_W = m_Z \cos \theta_w$$

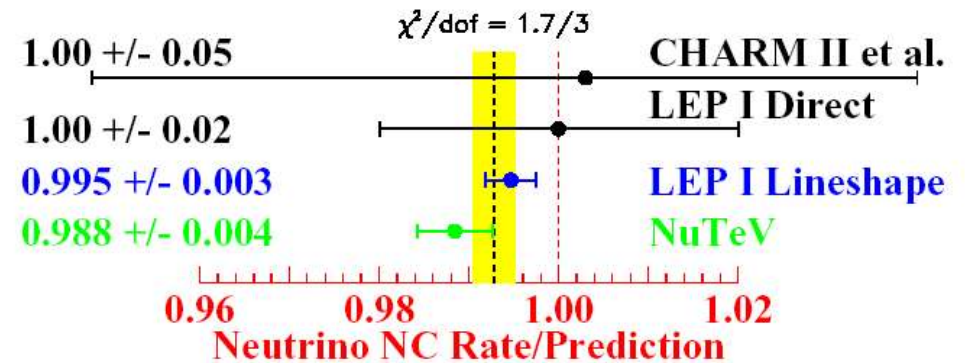
Additional dependence on the top mass due to radiative corrections



NuTeV Result



$$\frac{\sigma_{NC}^{\nu} - \sigma_{NC}^{\bar{\nu}}}{\sigma_{CC}^{\nu} - \sigma_{CC}^{\bar{\nu}}} = \rho^2 \left(\frac{1}{2} - \sin^2 \theta_W \right)$$



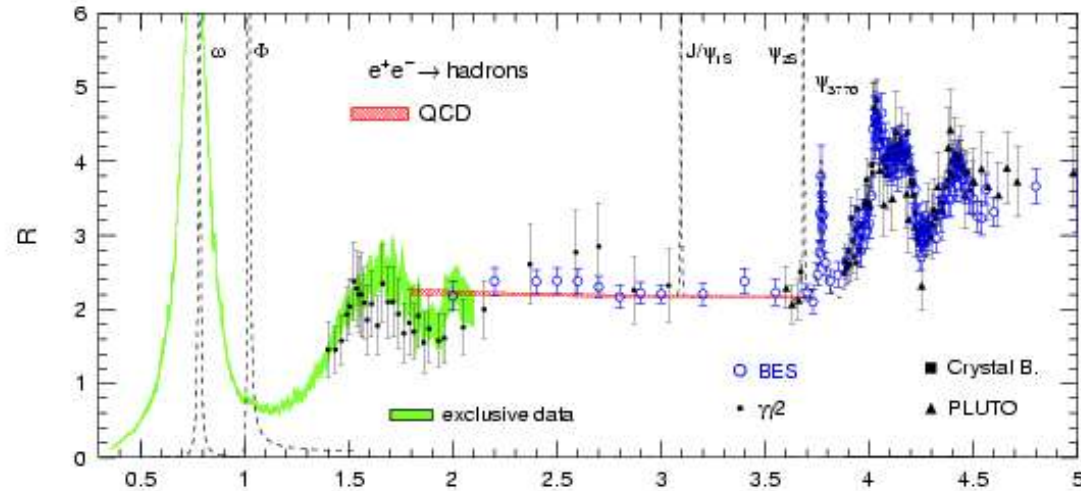
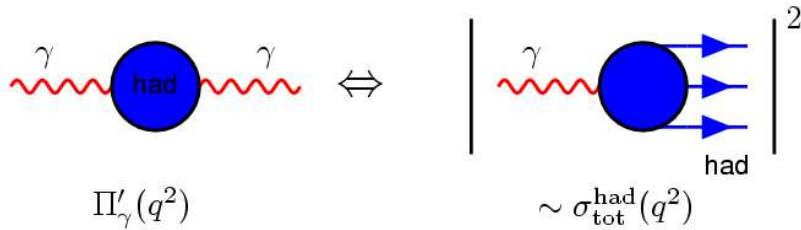
Could be explained by smaller NC coupling of neutrinos compared to SM

Other (more probable) explanations:

- QCD effects: non-isoscalar contributions, asymmetry in strange-sea, improved PDF's (see talks/discussion S. Kretzer, D. Mason)
- New electroweak corrections by Diener, Dittmaier, Hollik
 - differences to old calculations (Bardin et al)
 - result depends strongly on photon treatment in final state
 - uncertainty order of magnitude higher than assumed by NuTeV

Calculation of $\alpha(m_Z)$

Uncertainty in $\alpha(m_Z)$ dominated by hadronic vacuum polarisation



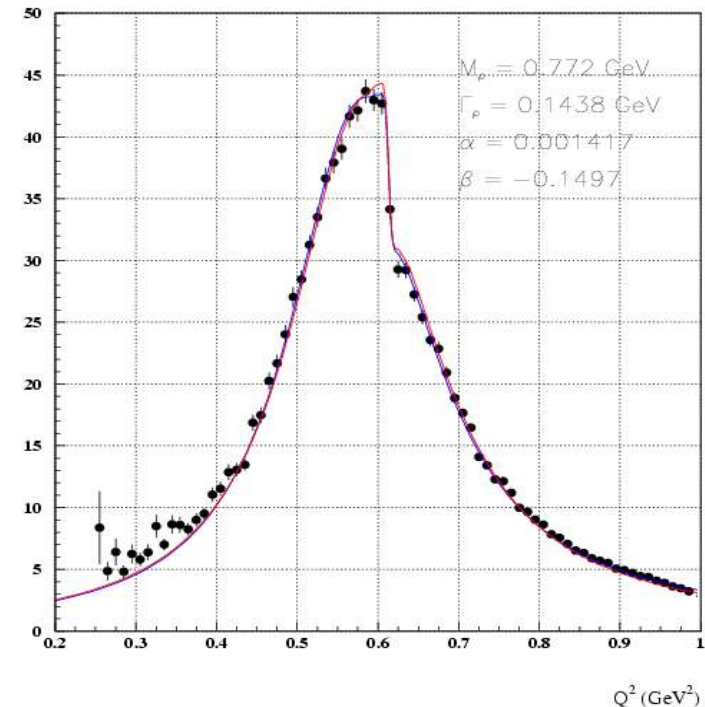
Measurement of $e^+e^- \rightarrow \text{hadrons}$

Important region at ω resonance (782 MeV):

- CMD-2 detector at VEPP Novosibirsk
- Measurement from KLOE (rad. return from ϕ) (see talk A. Denig)
- Rad. return from Υ at BaBar (see talk F. Anulli)

Most recent CMD-2 result changes $\alpha(m_Z)$ from 0.02761 ± 0.00036 to 0.02768 ± 0.00036 (Burkhard and Pietrzyk)

Pion Form Factor from ISR -73pb^{-1}



Measurement of Top Mass

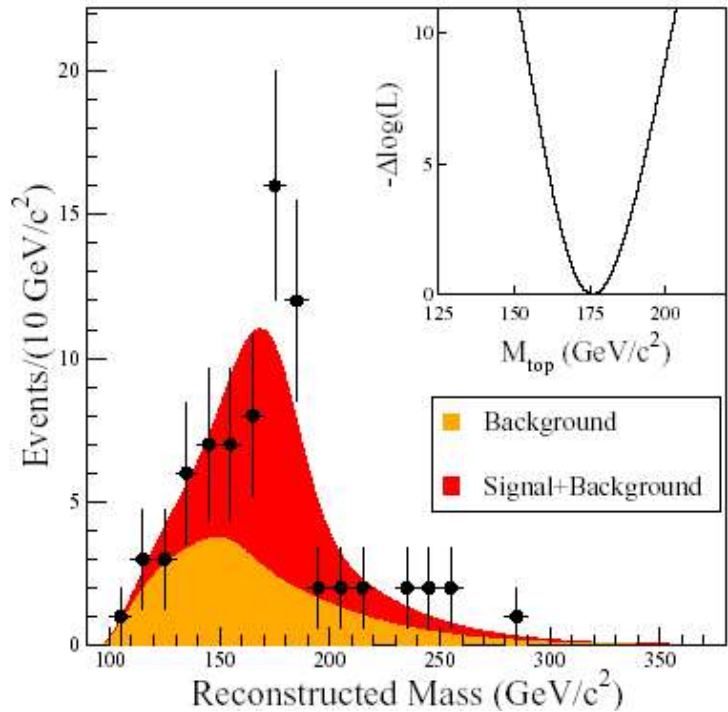
Tevatron (CDF,D0): $p\bar{p} \rightarrow t\bar{t}X, t\bar{t} \rightarrow b\bar{b}WW$

$m_t = 174.3 \pm 3.2(\text{stat}) \pm 4.0(\text{syst}) \text{ GeV}$
(until yesterday)

Systematics dominated by:

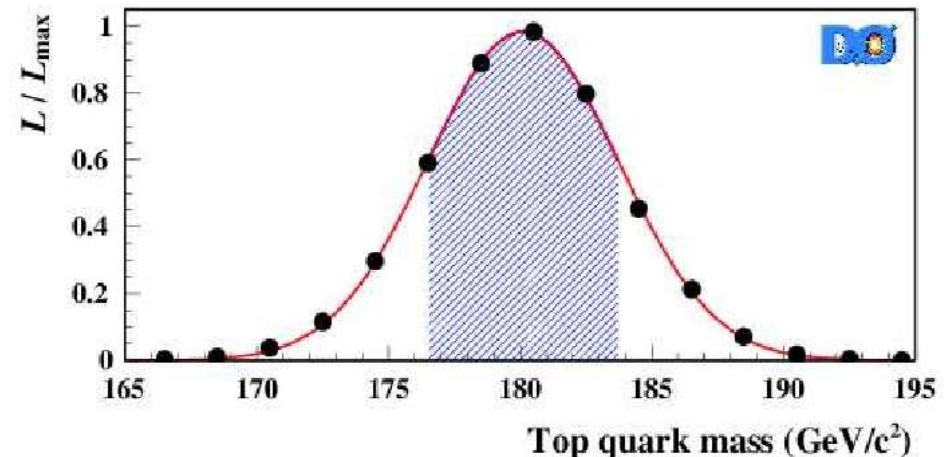
- Energy scale
- Monte Carlo model

will improve with data statistics

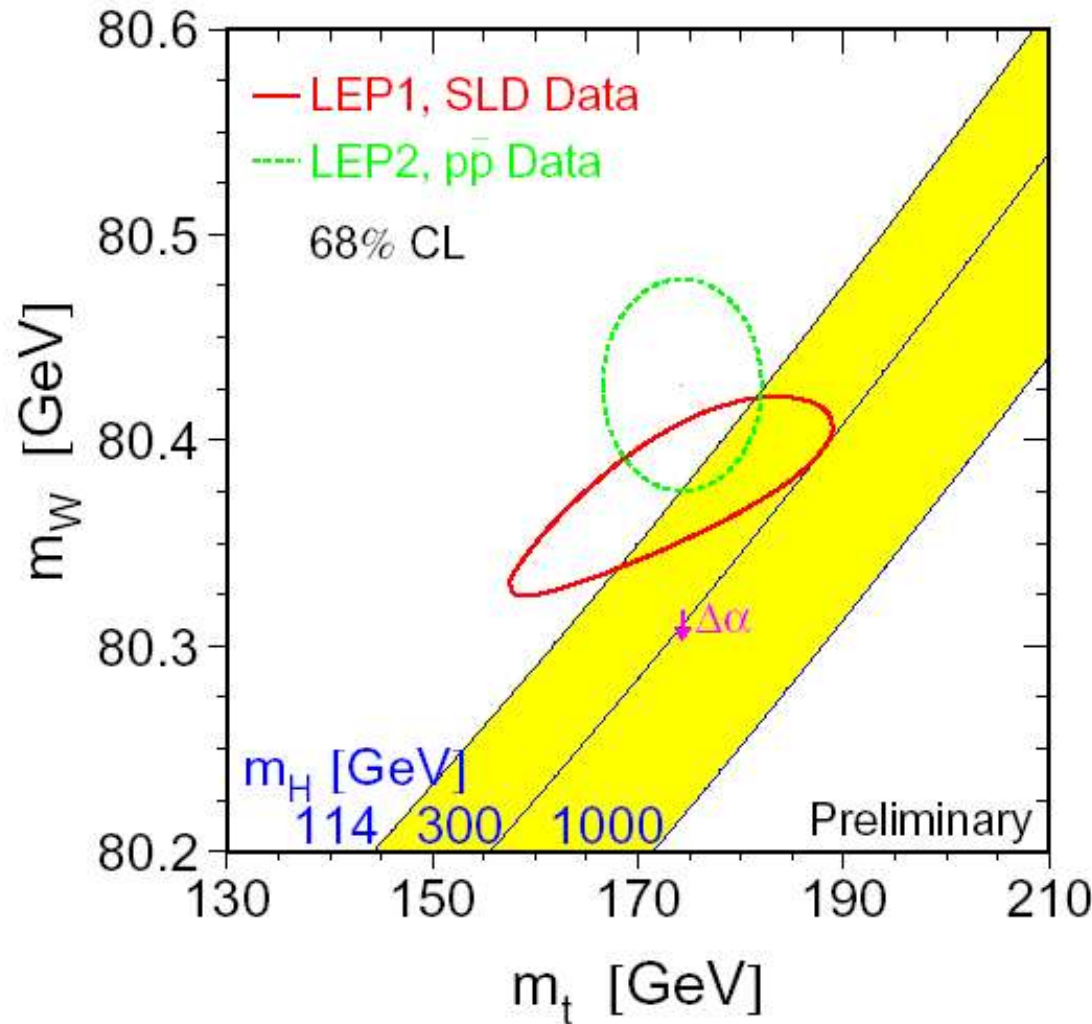


Recent updates (see talk L. Cerrito)

- Improved D0 analysis of Run I data: m_t now 7 GeV higher
- First results from Run II, prospects: $\delta m_t < 3 \text{ GeV}$
- New Combination gives $m_t = 178.0 \pm 2.7(\text{stat}) \pm 3.3(\text{syst}) \text{ GeV}$

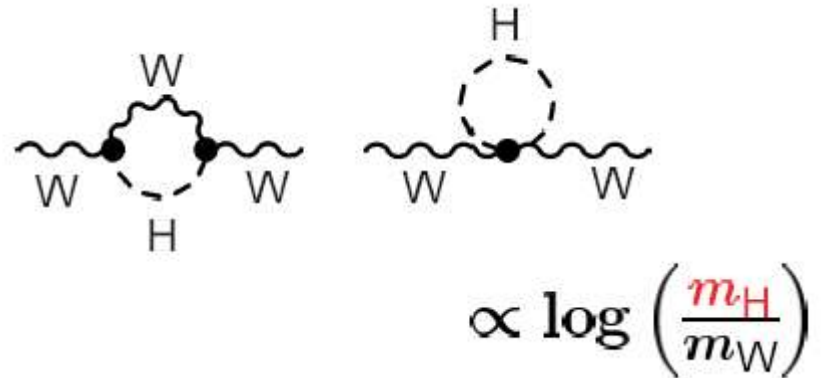


Measurements vs Standard Model



old top mass !

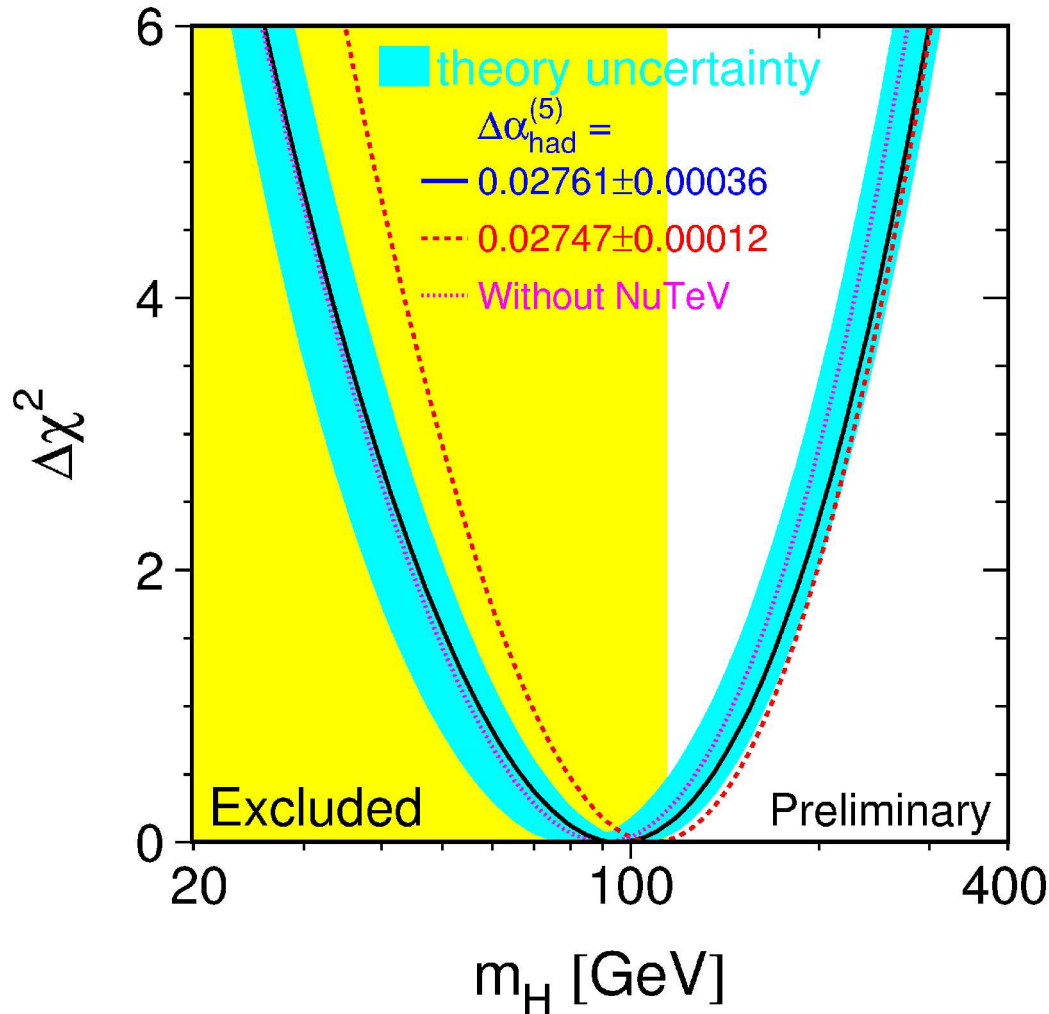
Dependence on Higgs mass :



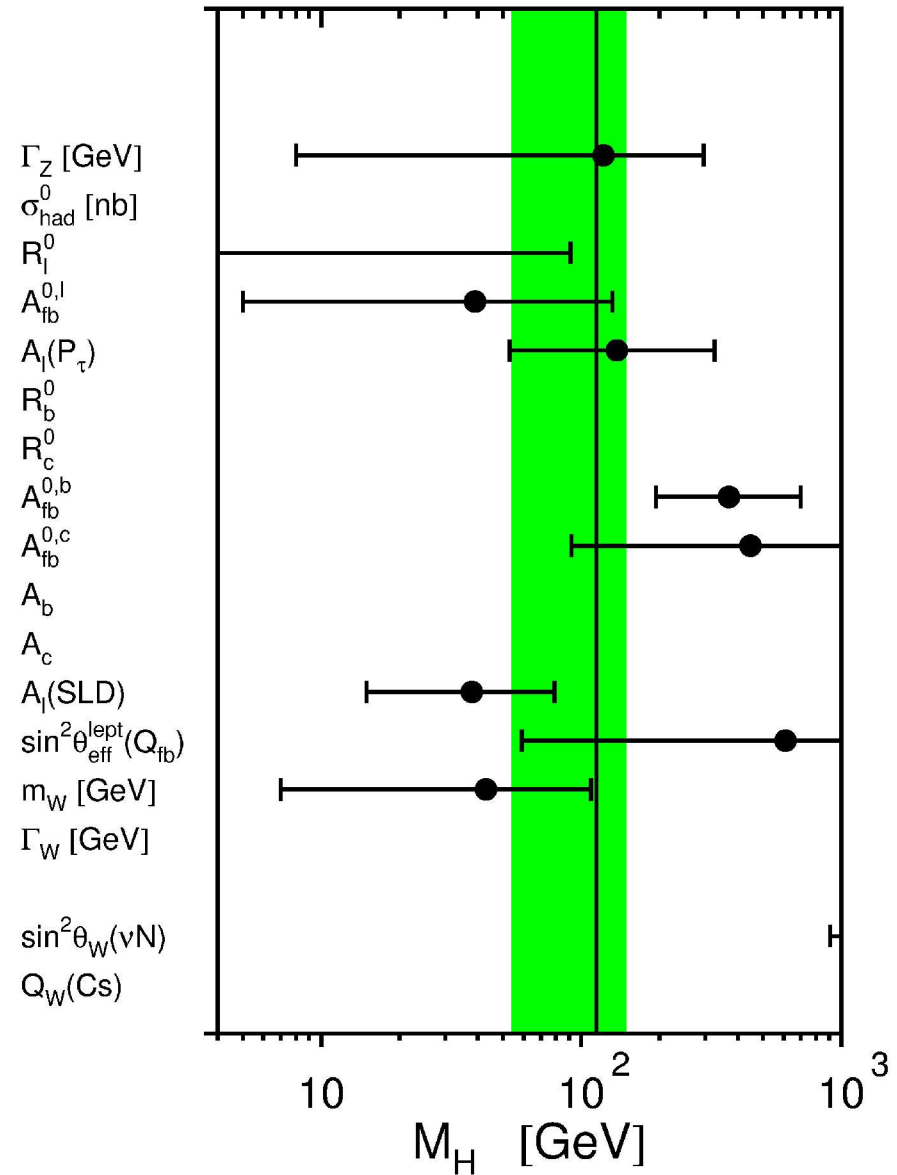
Higgs mass upper bound: $m_H < 219$ GeV at 95% C.L.

Prediction of Higgs mass

old top mass !



Summer 2003

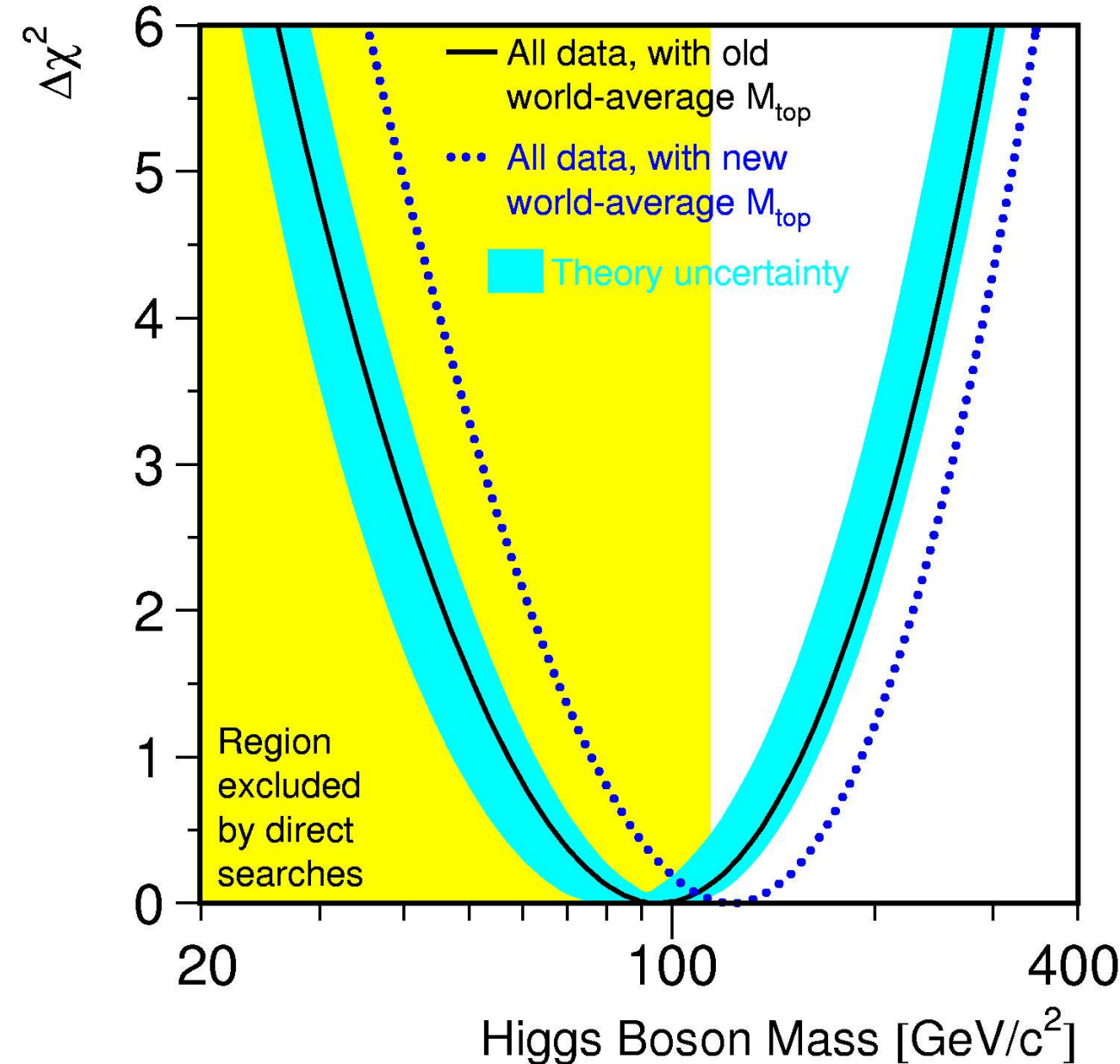


$m_H < 219$ GeV at 95% C.L.

Higgs mass for new Top mass

Tevatron (CDF,D0): new combination gives

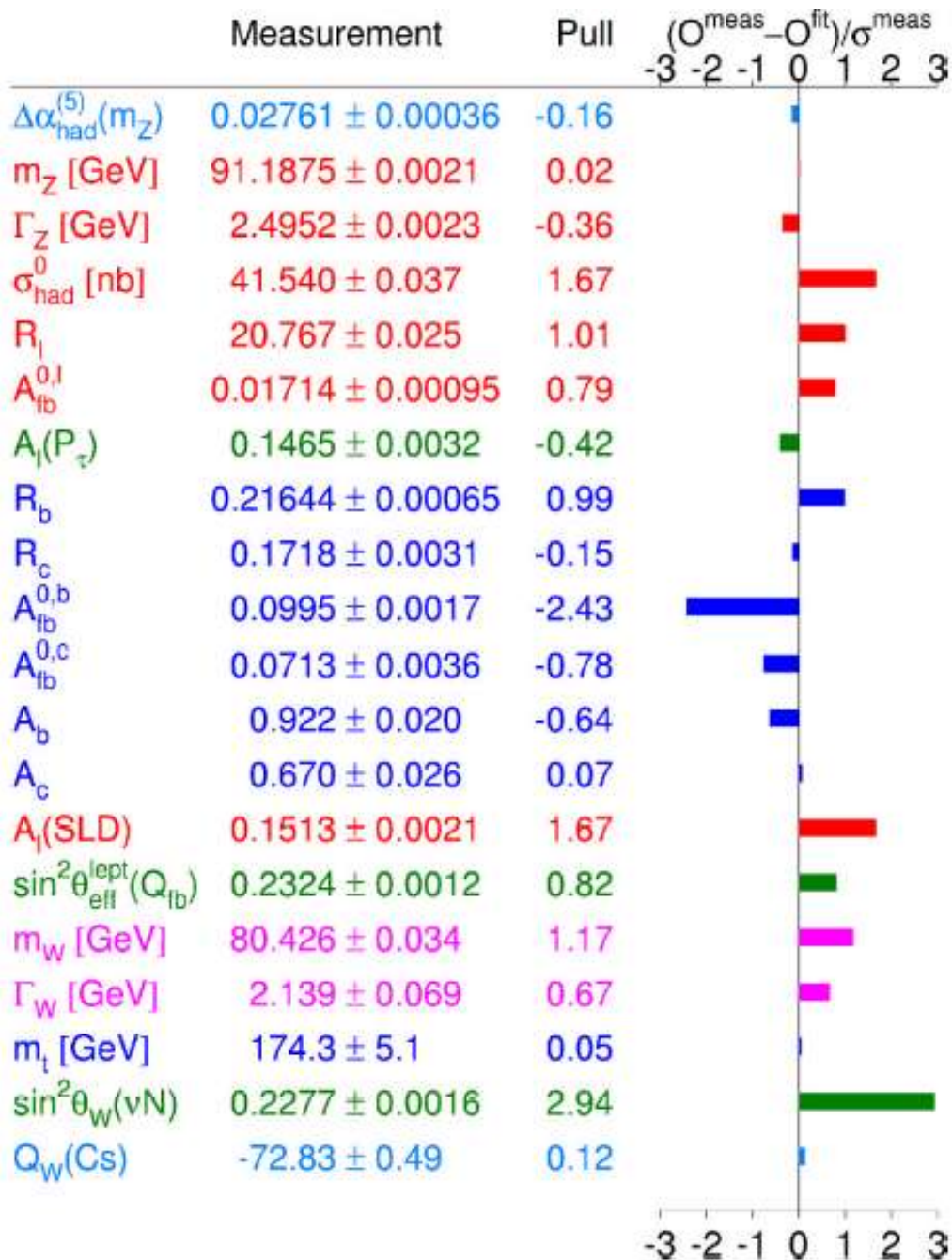
$$m_t = 178.0 \pm 4.3 \text{ GeV}$$



New fit for Higgs mass :

- Central value:
96 GeV \rightarrow 117 GeV
- Bound:
219 GeV \rightarrow 251 GeV

Global SM Fit



Fit to all data:

$$\chi^2/\text{dof} = 25.5 / 15 \text{ (4.4\%)}$$

Fit without NuTeV:

$$\chi^2/\text{dof} = 16.7 / 14 \text{ (27\%)}$$

fitted parameters
almost unchanged

Conclusions

Reasonable agreement between experiment and theory in global Standard Model Fit

Light Higgs mass is preferred

Future prospects:

- Final W mass from LEP
- Improved top and W mass from Tevatron
- Find Higgs and measure its mass at LHC
- Electroweak precision tests at LC (GigaZ...)