

Electroweak results and fit to the Standard Model

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Introduction

The electroweak measurements

Test of the Standard Model

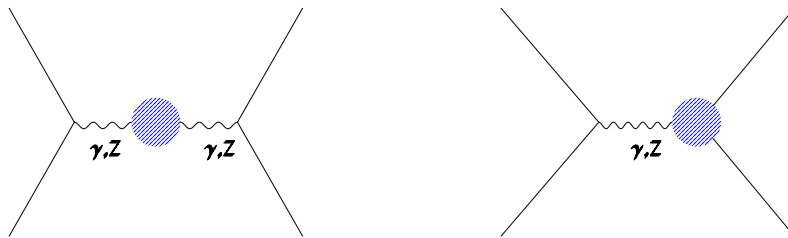
Constraint on the Higgs mass

Conclusion

Introduction

At the Z resonance the cross-sections and asymmetries are sensitive to α_s , m_{top} and M_{Higgs} through the radiative corrections

Electroweak corrections (non photonic) to $e^+e^- \rightarrow Z, \gamma \rightarrow f\bar{f}$



- running of α_{QED}

- correction to ρ and $\sin^2 \theta_W$:

$$\rho = \frac{M_W^2}{M_Z^2 \cos^2 \theta_W} = 1 \qquad \sin^2 \theta_W = 1 - \frac{M_W^2}{M_Z^2}$$

$$\bar{\rho} = 1 + \Delta\rho \qquad \sin^2 \theta_W^{\text{eff}} = (1 + \Delta\kappa) \sin^2 \theta_W$$

Radiative corrections to the W mass

$$M_W^2 = \frac{\pi\alpha}{\sqrt{2}\sin^2\theta_W G_f} (1 + \Delta r)$$

$$\Delta r = \Delta\alpha - \frac{\cos^2\theta_W}{\sin^2\theta_W} \Delta\rho + \Delta r_{\text{rem}}$$

$$\Delta\rho, \Delta\kappa, \Delta r = f(m_{\text{top}}^2, \log(M_H))$$

The electroweak measurements

LEP1 and SLC electroweak measurements

- The Z lineshape at LEP1 - final

$$M_Z, \Gamma_Z, \sigma_{had}^0, R_l, A_{FB}^{0,1}$$

- Measurement of A_{LR} at SLC - final

- τ polarisation at LEP1 - almost final

- Heavy flavours at LEP1 and SLC:

$$R_b^0, R_c^0, A_{FB}^{0,b}, A_{FB}^{0,c}, \langle Q_{FB} \rangle \\ A_b, A_c$$

updates from SLD and new $A_{FB}^{0,b}$ from ALEPH and DELPHI

LEP2 and Tevatron: New M_W from LEP

$$m_{top}, M_W$$

Low energy data: α_{QED}

New $e^+e^- \rightarrow q\bar{q}$ data from BES \Rightarrow new experimental determination of $\Delta\alpha_{had}^5$

New A_{FB}^b from ALEPH and DELPHI

DELPHI: A_{FB}^b NN (new method)

- High purity b-tagged sample
- b-charge tag: Neural Network based on vertex-charge, jet-charge, leptons, kaons, flavour tagging
- Use double tag method \Rightarrow calibration on data, reduced systematic

$$A_{\text{FB}}^b(\sqrt{s} = M_Z) = 0.0931 \pm 0.0034 \pm 0.0017$$

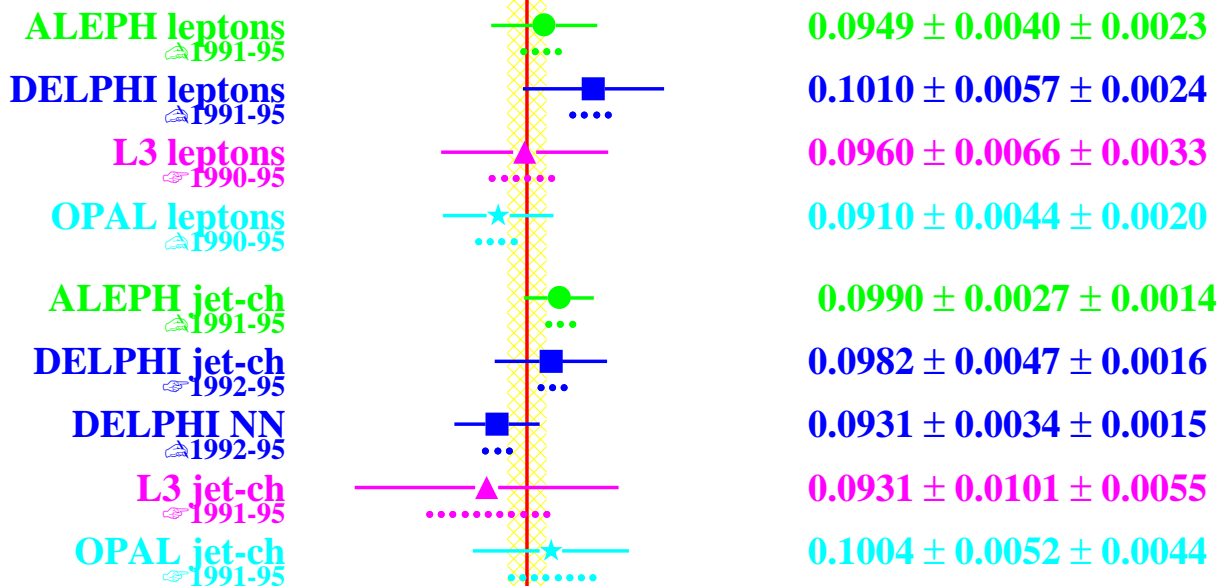
ALEPH: A_{FB}^b jet-charge

- Neural Network to tag b-events \Rightarrow statistic increased by 30%
- Improved jet charge estimator
- lower mistag rate and double tag methods \Rightarrow reduction of systematic uncertainties

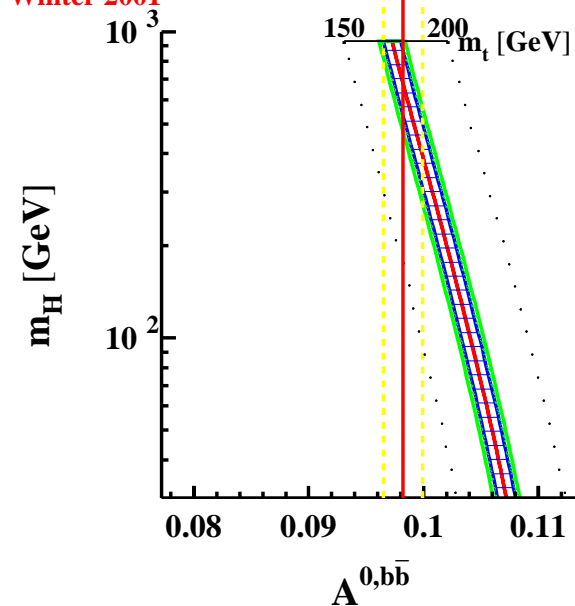
$$A_{\text{FB}}^b(\sqrt{s} = M_Z) = 0.0990 \pm 0.0027 \pm 0.0014$$

old value: $A_{\text{FB}}^b(\sqrt{s} = M_Z) = 0.1017 \pm 0.0038 \pm 0.0032$

$A_{FB}^{b\bar{b}}$ at $\sqrt{s} \approx m_Z$



LEP Winter 2001



0.0982 ± 0.0017

Include Total Sys 0.0008
With Common Sys 0.0003

$m_t = 174.3 \pm 5.1 \text{ GeV}$

$\Delta\alpha_{\text{had}} = 0.02761 \pm 0.00036$

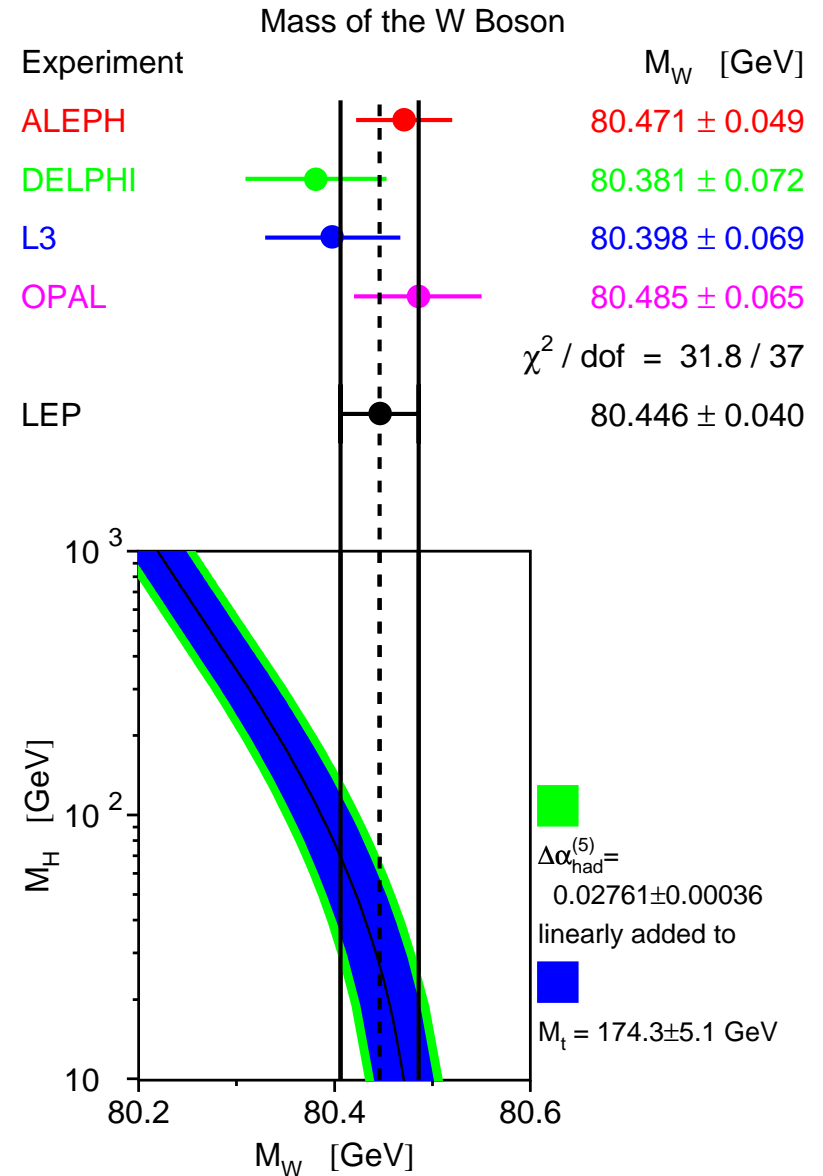
Measurement of M_W at LEP

- ALEPH and L3 have included data taken in 2000
- Reduction of the systematic uncertainty for ALEPH:
 - fragmentation uncertainty reduced from ~ 30 MeV to ~ 15 MeV
 - reduction of the uncertainty from final state interaction (BEC and CR)

$q\bar{q}l\bar{\nu}_l$ and $q\bar{q}q\bar{q}$ channels are consistent:

$$\Delta M_W(q\bar{q}q\bar{q} - q\bar{q}l\bar{\nu}_l) = +18 \pm 46 \text{ MeV}$$

⇒ no bias from FSI is observed



New determination of $\Delta\alpha_{\text{had}}^5$

$$\alpha(s) = \frac{\alpha(0)}{1 - \Delta\alpha_l(s) - \Delta\alpha_{\text{had}}^5(s) - \Delta\alpha_{\text{top}}(s)}$$

$$\Delta\alpha_{\text{had}}^5 \text{ determined from } R_{\text{had}} = \frac{\sigma(e^+e^- \rightarrow \text{hadrons})}{\sigma(e^+e^- \rightarrow \mu^+\mu^-)}$$

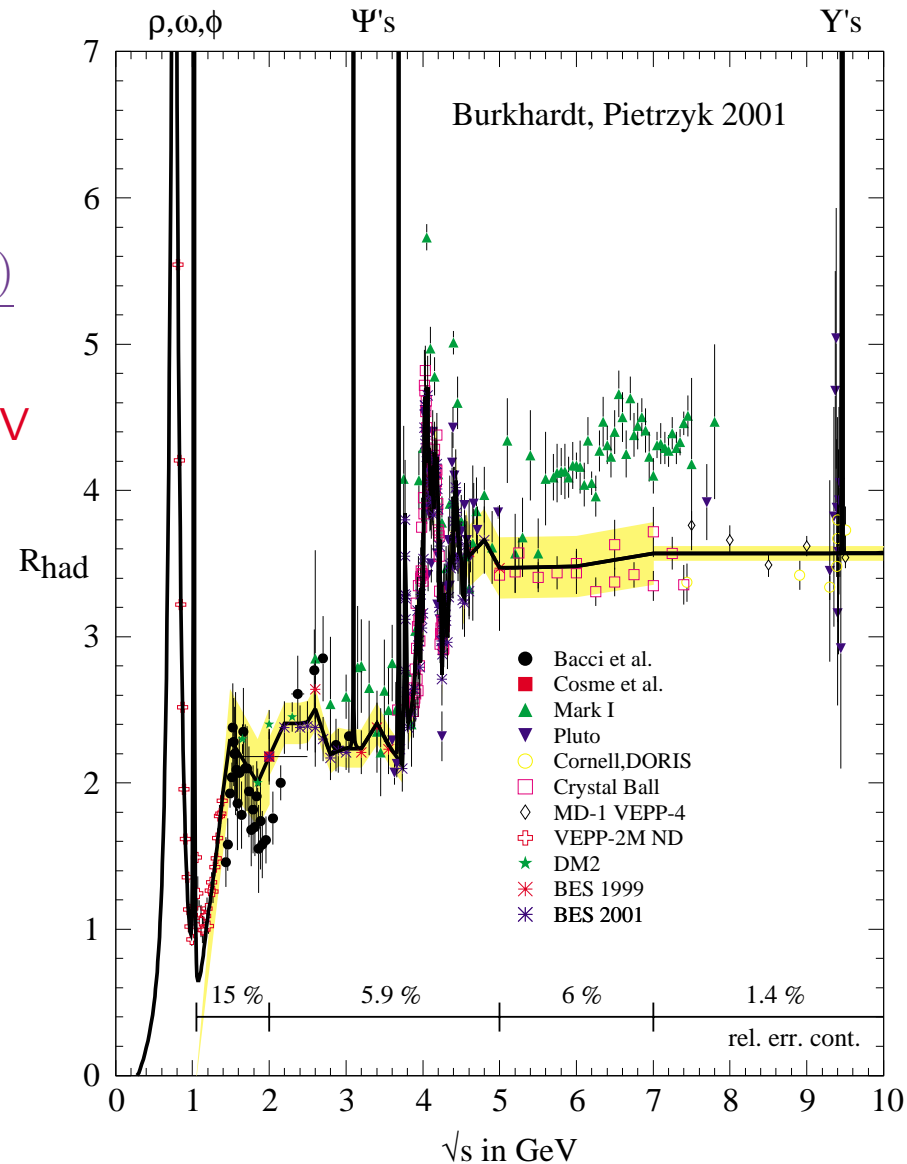
New $e^+e^- \rightarrow q\bar{q}$ data from BES between 2 and 5 GeV
 \Rightarrow error reduced by a factor > 2 in this region.

Using:

- only experimental data below 12 GeV
- third order QCD above 12 GeV

$$\Delta\alpha_{\text{had}}^5(M_Z) = 0.02761 \pm 0.00036$$

old value: $\Delta\alpha_{\text{had}}^5(M_Z) = 0.02804 \pm 0.00065$

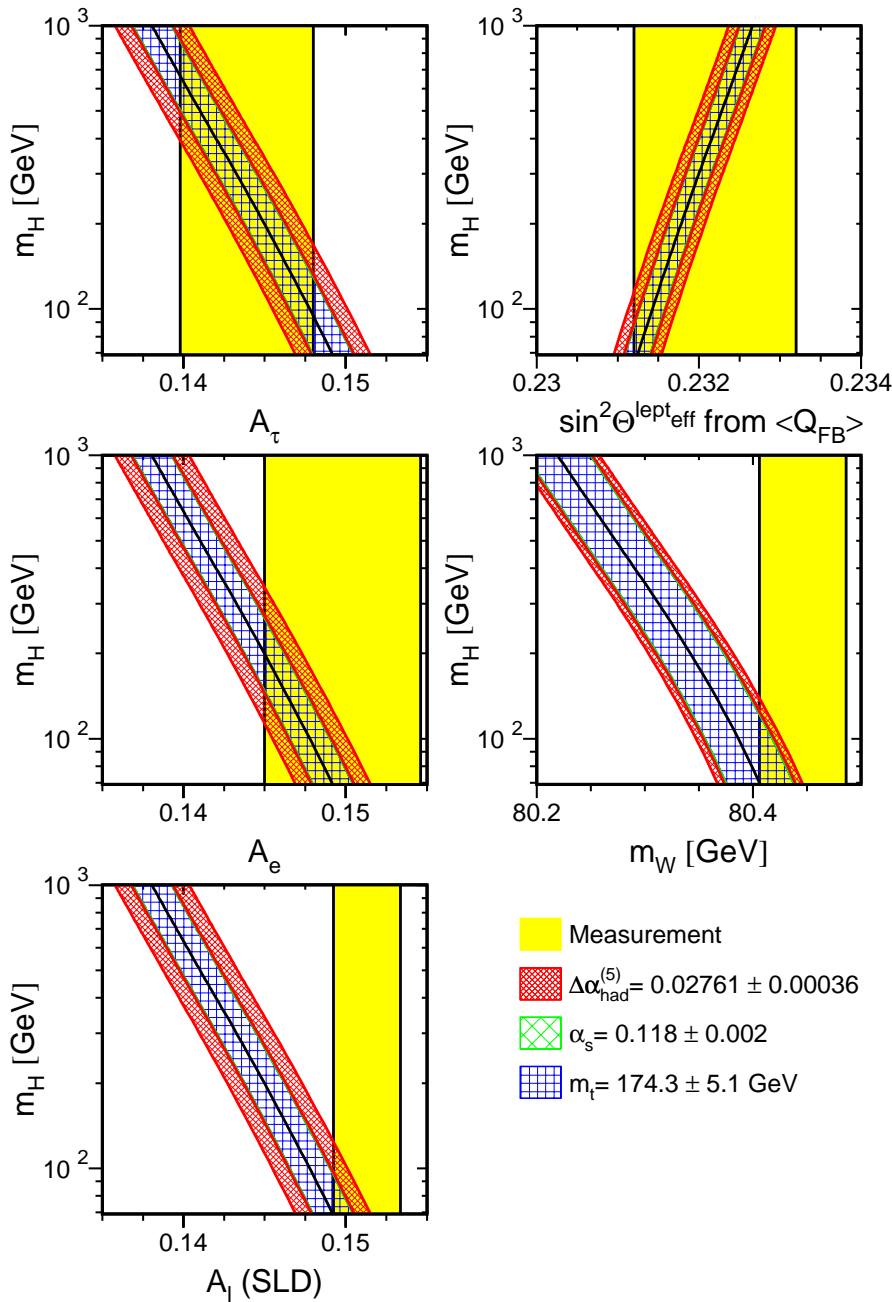


Test of the SM and constraint on M_H

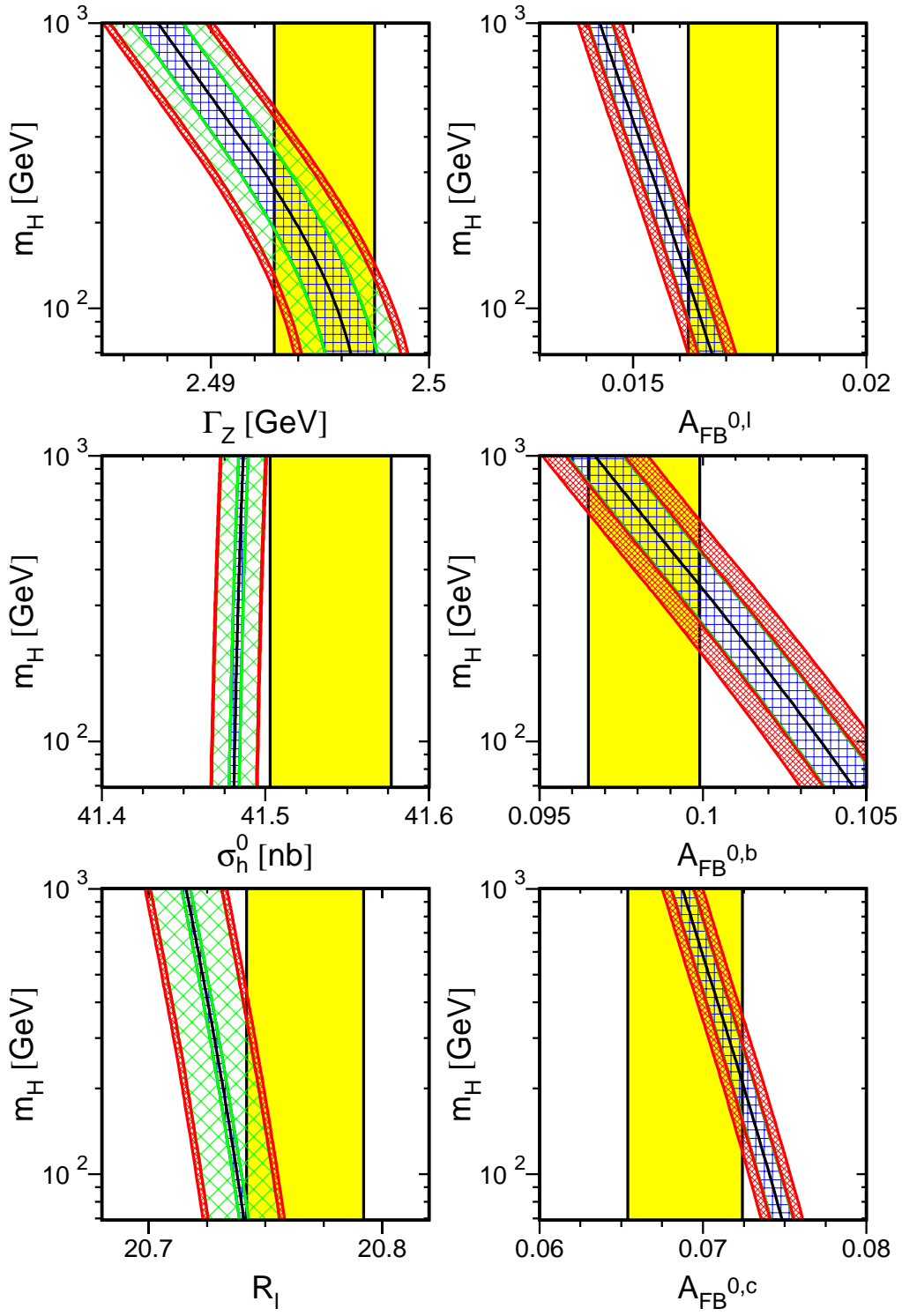
The most sensitive variable to M_H is $\sin^2\theta_{\text{eff}}^{\text{lept}}$ determined by the asymmetries.

A good sensitivity is also given by M_W , but M_W is very dependent on m_{top} !

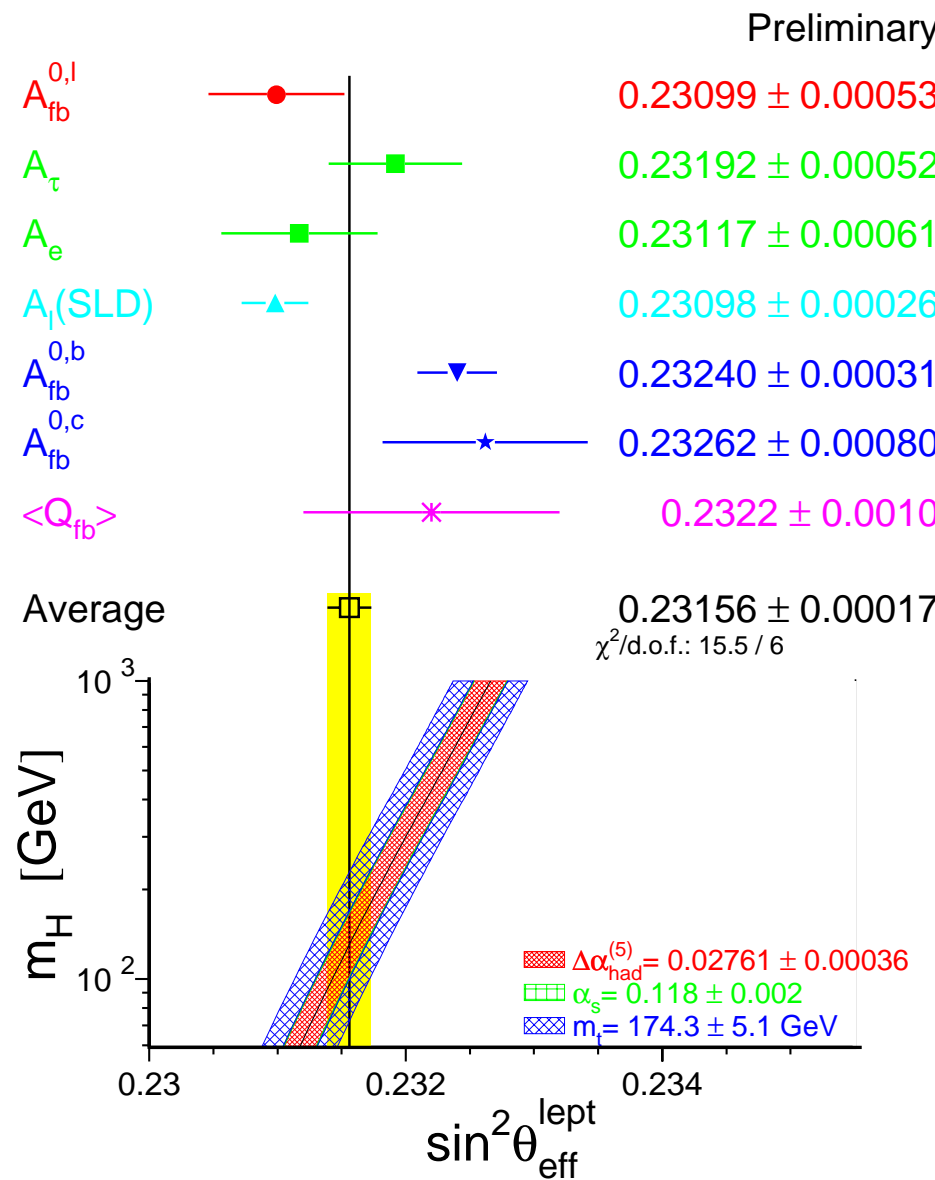
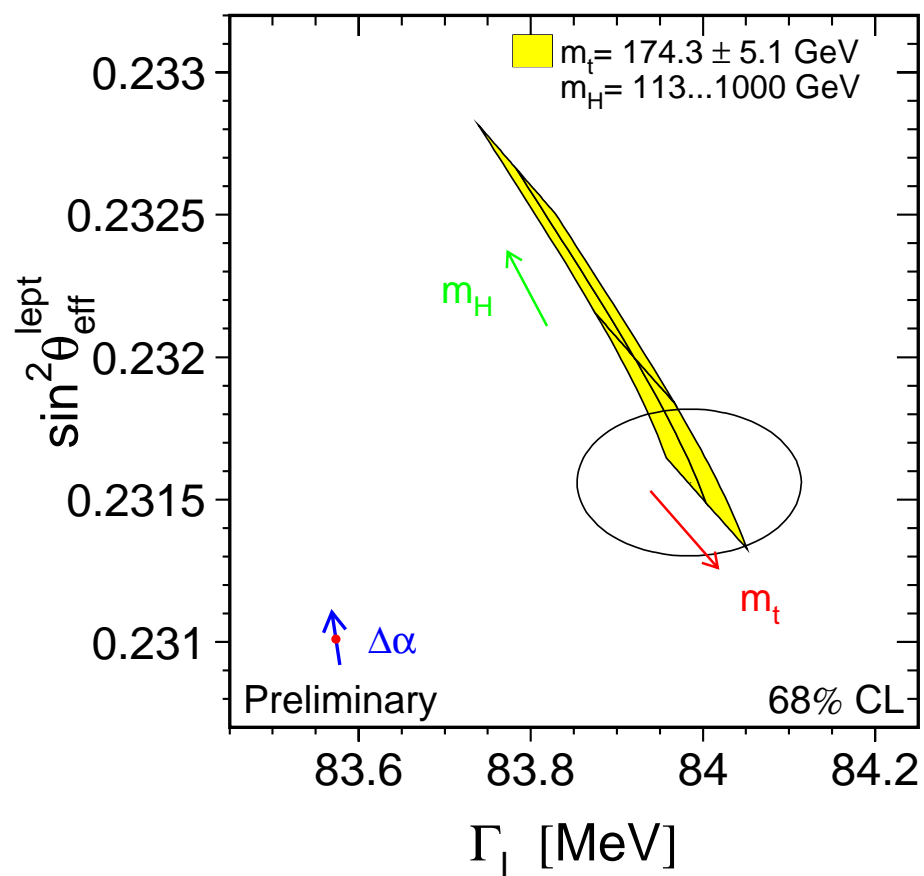
Preliminary



Preliminary



$$\sin^2 \theta_{\text{eff}}^{\text{lept}}$$



Test of the Standard Model

Use electroweak measurements at LEP1 and SLC \Rightarrow indirect determination of m_{top} and M_W and constraint on M_H

$$\text{Log}(M_H) = 1.94^{+0.34}_{-0.37}$$

$$M_H = 87^{+119}_{-43} \text{ GeV}$$

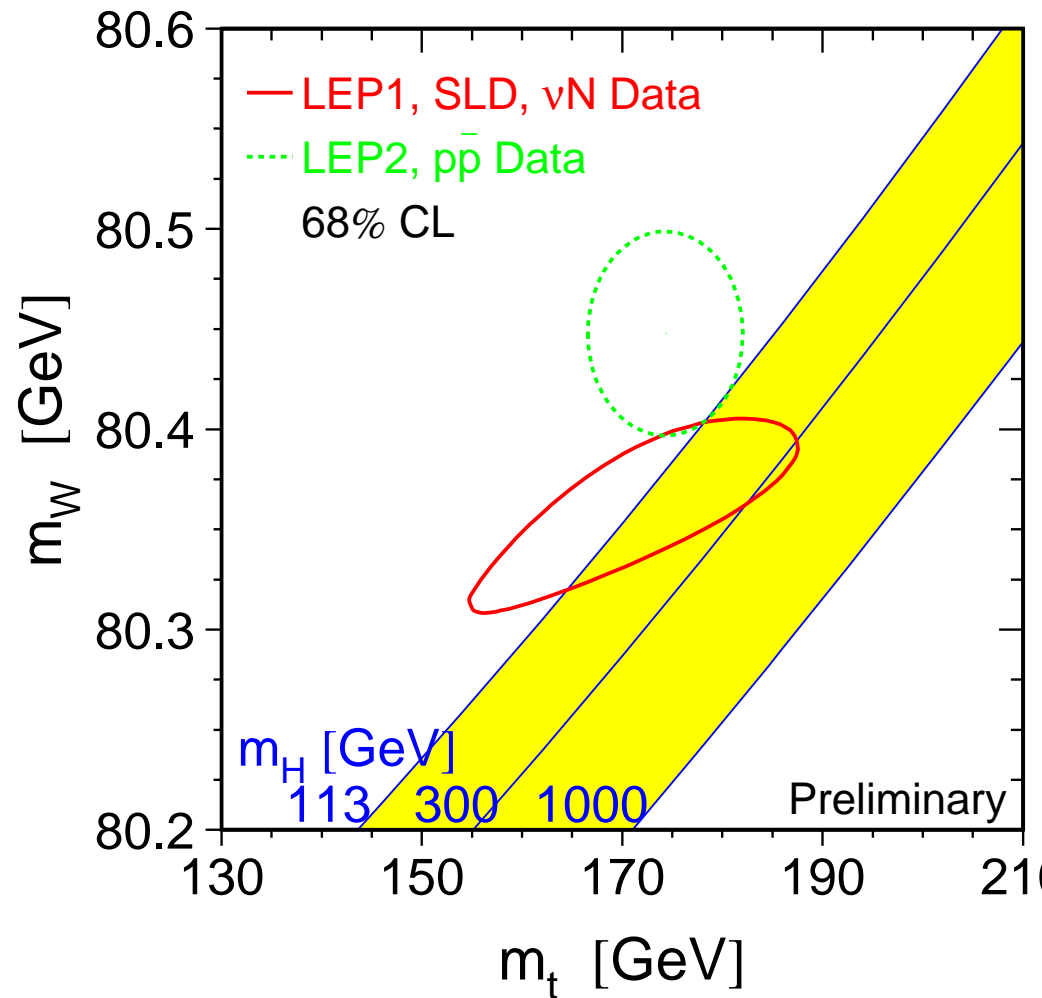
$$m_{\text{top}} = 168.3^{+11.9}_{-9.3} \text{ GeV}$$

$$M_W = 80.357 \pm 0.033 \text{ GeV}$$

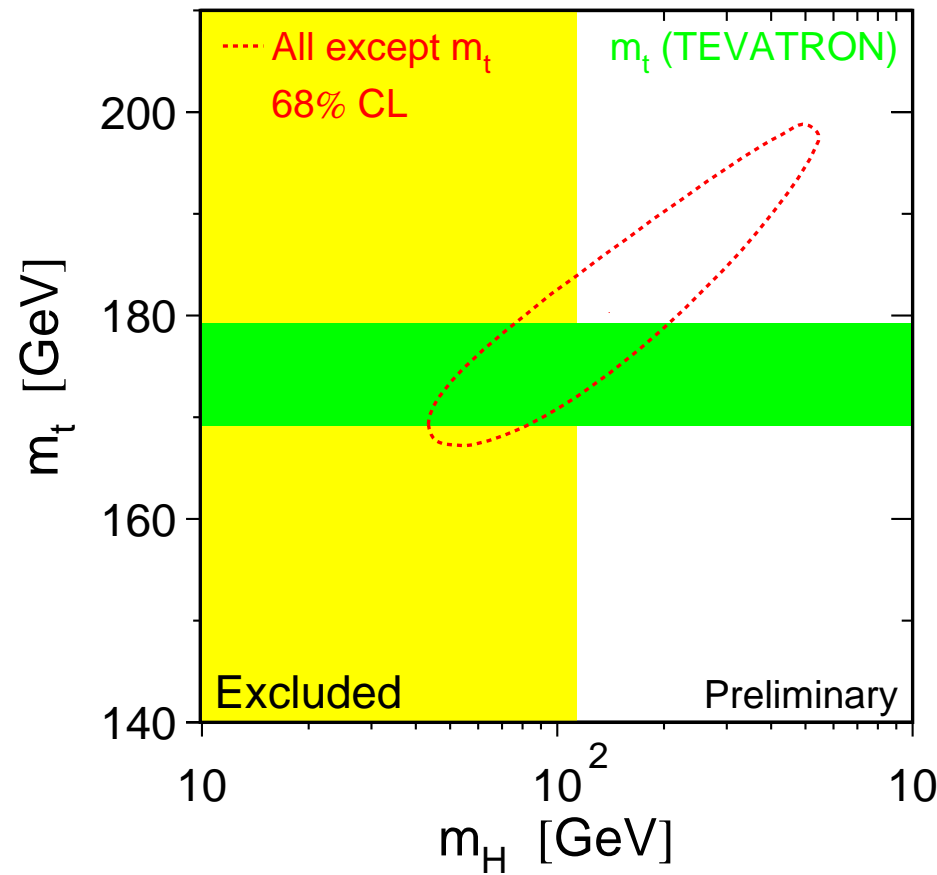
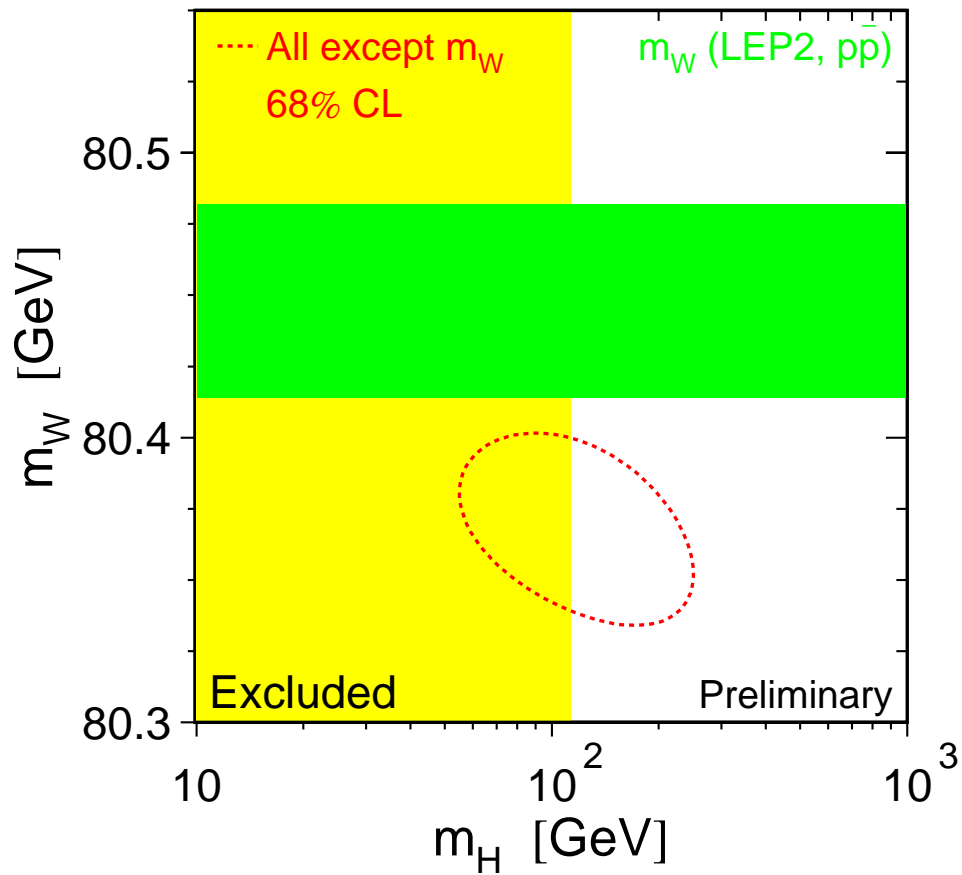
Good agreement with the direct measurements:

$$m_{\text{top}} = 174.3 \pm 5.1 \text{ GeV}$$

$$M_W = 80.448 \pm 0.034 \text{ GeV}$$



Correlations between M_H , m_{top} and M_W



Global fit with all the data

Include also the direct measurement of m_{top} and M_W

$$\text{Log}(M_H) = 1.99 \pm 0.21$$

$$M_H = 98_{-38}^{+58} \text{ GeV}$$

$$m_{\text{top}} = 175.7 \pm 4.4 \text{ GeV}$$

$$M_W = 80.393 \pm 0.019 \text{ GeV}$$

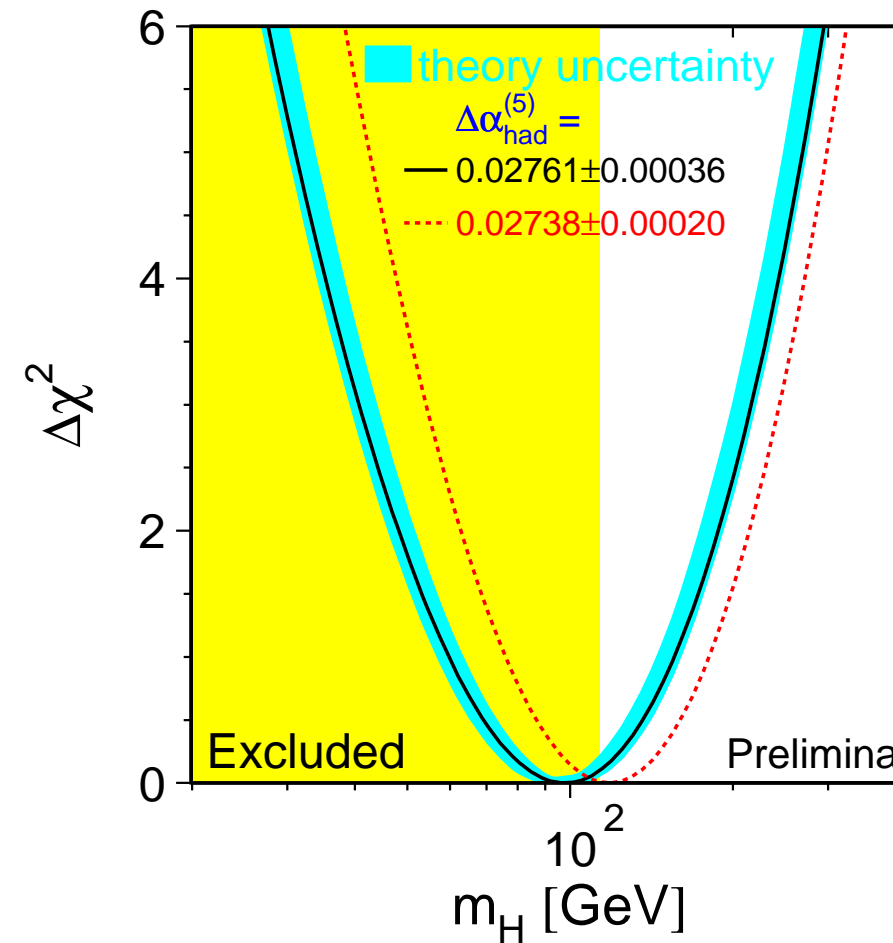
$\Rightarrow M_H < 212 \text{ GeV}$ (95% C.L.)

$\chi^2 = 25/15$ - probability is only 4%!

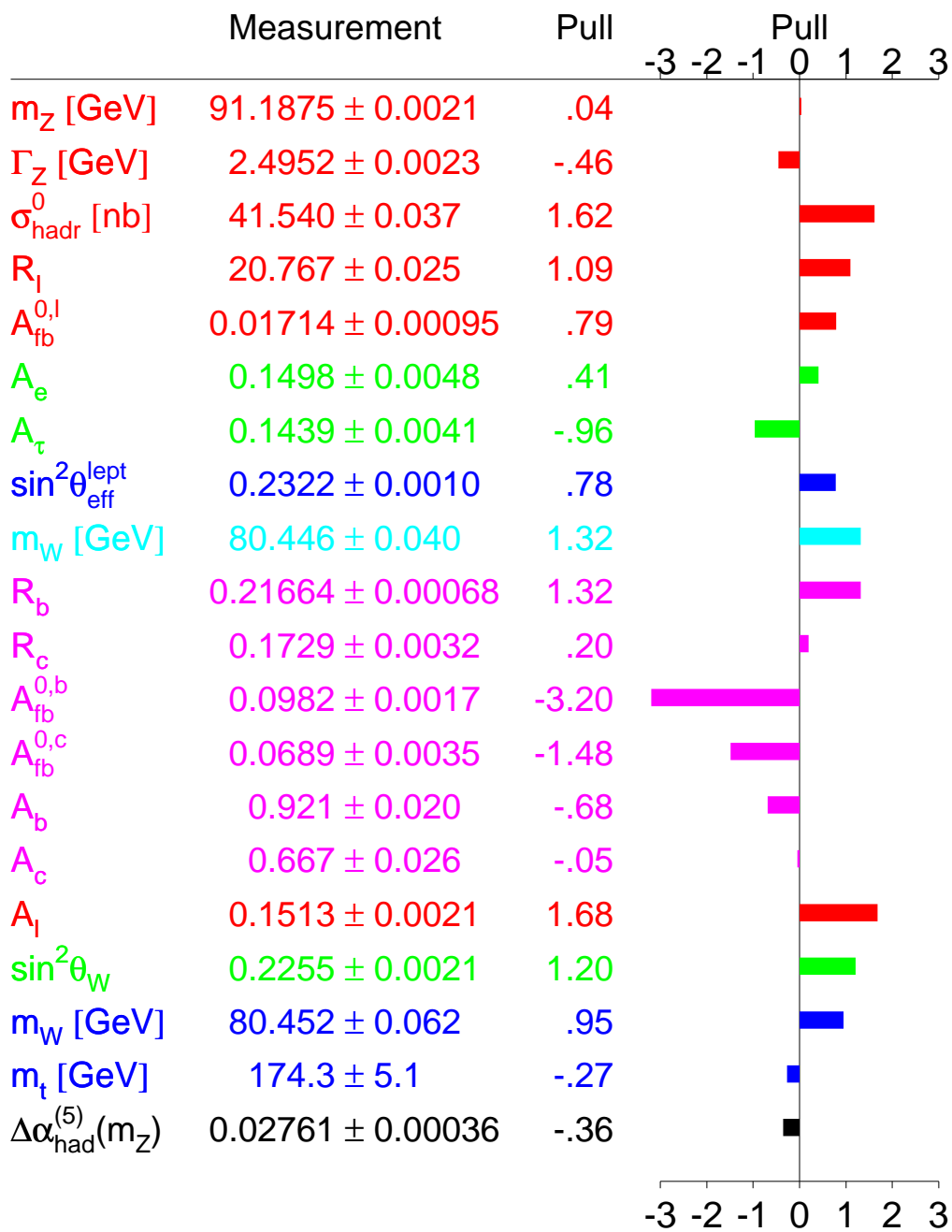
new value of $\Delta\alpha_{\text{had}}^5$ shifts M_H by +35GeV

The error on $\text{Log}(M_H)$ arising from $\Delta\alpha_{\text{had}}^5$ is reduced from 0.2 to 0.1 \Rightarrow it is no longer the dominant error

Use ZFITTER and TOPAZ0 for the fit



Winter 2001



Summary of fits

	all data except direct M_W and m_{top}	all data except direct m_{top}	all data except direct M_W	all data
m_{top} [GeV]	$168.3^{+11.9}_{-9.3}$	$180.3^{+11.7}_{-9.2}$	173.3 ± 4.8	175.7 ± 4.4
M_H [GeV]	87^{+119}_{-43}	139^{+203}_{-77}	121^{+76}_{-48}	98^{+58}_{-38}
$\text{Log}(M_H/\text{GeV})$	$1.94^{+0.37}_{-0.30}$	$2.14^{+0.39}_{-0.35}$	$2.08^{+0.21}_{-0.22}$	$1.99^{+0.20}_{-0.21}$
$\alpha_s(M_Z^2)$	0.1188 ± 0.0027	0.1188 ± 0.0029	0.1190 ± 0.0027	0.1184 ± 0.0027
$\chi^2/\text{d.o.f.}$	21/12	25/14	22/13	25/15
$\sin^2\theta_{\text{lept}}^{\text{eff}}$	0.23155 ± 0.00016	0.23144 ± 0.00015	0.23156 ± 0.00016	0.23142 ± 0.0001
$\sin^2\theta_W$	0.22344 ± 0.00063	0.22259 ± 0.00045	0.22322 ± 0.00045	0.22273 ± 0.0003
M_W [GeV]	80.357 ± 0.033	80.401 ± 0.023	80.368 ± 0.023	80.393 ± 0.019

Using $\Delta\alpha_{\text{had}}^5(M_Z) = 0.02761 \pm 0.00036$ (Burkhardt, Pietrzyk)

Direct measurements: $m_{\text{top}} = 174.3 \pm 5.1$ GeV

$M_W = 80.448 \pm 0.034$ GeV

The uncertainty on the Higgs mass

Using a parametrisation (Degrassi et al.) for $\sin^2\theta_{\text{eff}}^{\text{lept}}$, $M_W = f(m_{\text{top}}^2, \text{Log}(M_H), \alpha_{\text{QED}})$.

with $\sin^2\theta_{\text{eff}}^{\text{lept}}$ alone:

$$\sigma(\text{Log}(M_H)) = \pm 0.14(\sin^2\theta_{\text{lept}}^{\text{eff}}) \mp 0.10(\alpha_{\text{QED}}) \pm 0.13(m_{\text{top}})$$

with M_W alone:

$$\sigma(\text{Log}(M_H)) = \mp 0.24(M_W) \mp 0.05(\alpha_{\text{QED}}) \pm 0.26(m_{\text{top}})$$

\Rightarrow need to improve the precision on m_{top} in order to increase the power of M_W !

Assuming: $\sigma(m_{\text{top}}) = 3 \text{ GeV}$ and $\sigma(M_W) = 25 \text{ MeV}$
(LEP2 + Tevatron Run IIa)

with $\sin^2\theta_{\text{eff}}^{\text{lept}}$ alone:

$$\sigma(\text{Log}(M_H)) = \pm 0.14(\sin^2\theta_{\text{lept}}^{\text{eff}}) \mp 0.10(\alpha_{\text{QED}}) \pm 0.08(m_{\text{top}})$$

with M_W alone:

$$\sigma(\text{Log}(M_H)) = \mp 0.18(M_W) \mp 0.05(\alpha_{\text{QED}}) \pm 0.15(m_{\text{top}})$$

Combination of direct search and indirect measurements

From G. Degrassi

Using:

- the November LEPC likelihood $\mathcal{R}(M_H)$
- a χ^2 obtained with indirect measurements
- a uniform prior in $\text{Log}(M_H)$

Probability distribution function $f(M_H) \propto \frac{\mathcal{R}(M_H)e^{(-\chi^2/2)}}{M_H}$

See plot on next page

95% upper limit on M_H goes up by about 20 GeV

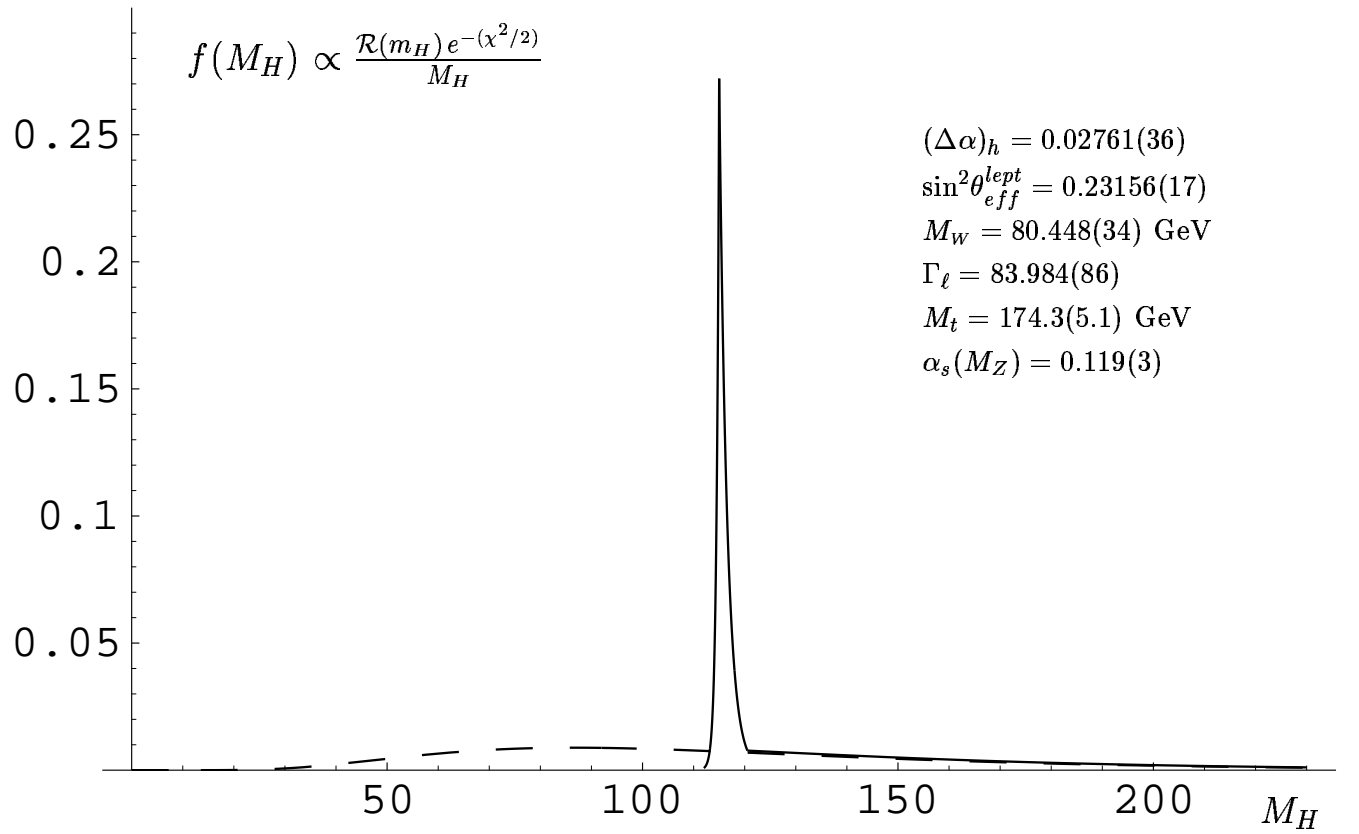


Figure 1: Probability distribution functions using only indirect information (dashed line, $\mathcal{R} \equiv 1$) and employing also the experimental results from direct searches (solid one). The spike reflects the excess of events recorded at Lep at $M_H \sim 115$ GeV (Likelihood ratio $\mathcal{R} \sim 30$).

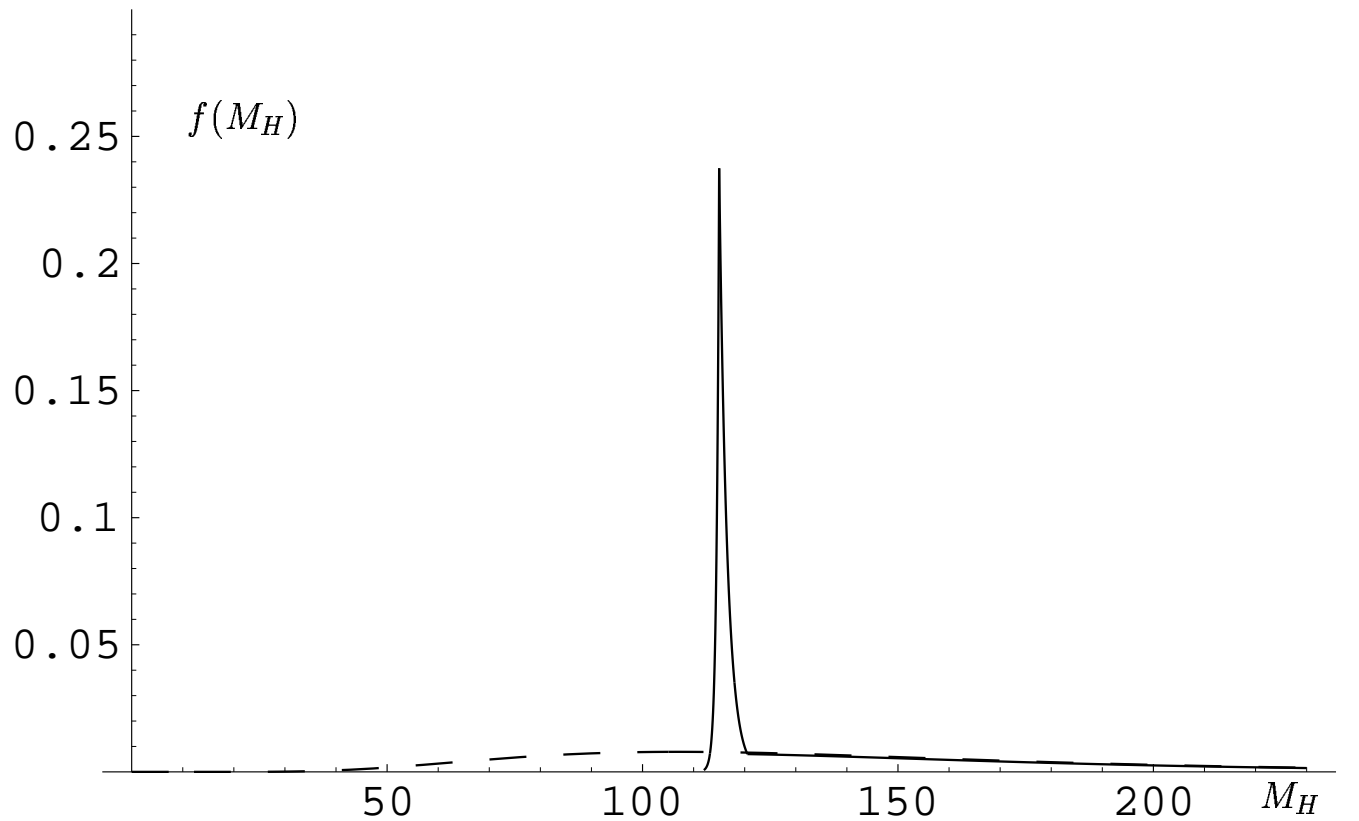


Figure 2: Same as Figure 1 but with $(\Delta\alpha)_h = 0.02738(20)$

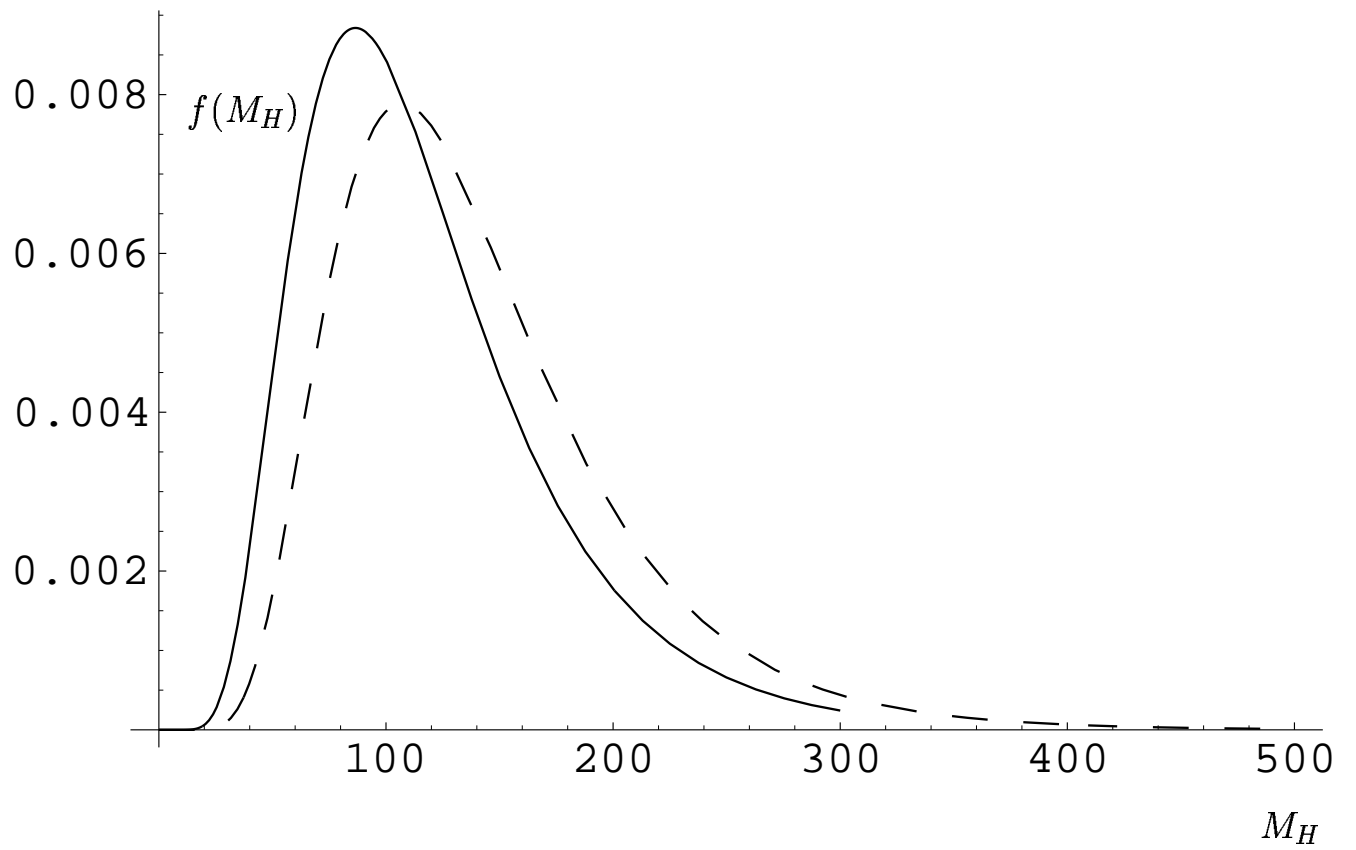


Figure 3: Probability distribution functions using only indirect information (dashed line $(\Delta\alpha)_h = 0.02738(20)$, solid line $(\Delta\alpha)_h = 0.02761(36)$).

Conclusion

Most significant new inputs:

- A_{FB}^b from LEP \Rightarrow new $\sin^2\theta_{\text{eff}}^{\text{lept}}$
- M_W from LEP \Rightarrow error on direct M_W : 34 MeV
- new $\Delta\alpha_{\text{had}}^5$ including new BES data

The Standard Model is consistent with observation:
indirect determinations of m_{top} and M_W agree with the
direct measurements

Data prefer a low Higgs mass (except $A_{\text{FB}}^{0,b}, A_{\text{FB}}^{0,c}$):

$$M_H = 98_{-38}^{+58} \text{ GeV}$$
$$\Rightarrow M_H < 212 \text{ GeV (95\% C.L.)}$$

W-Boson Mass [GeV]

