Standard Model fit results

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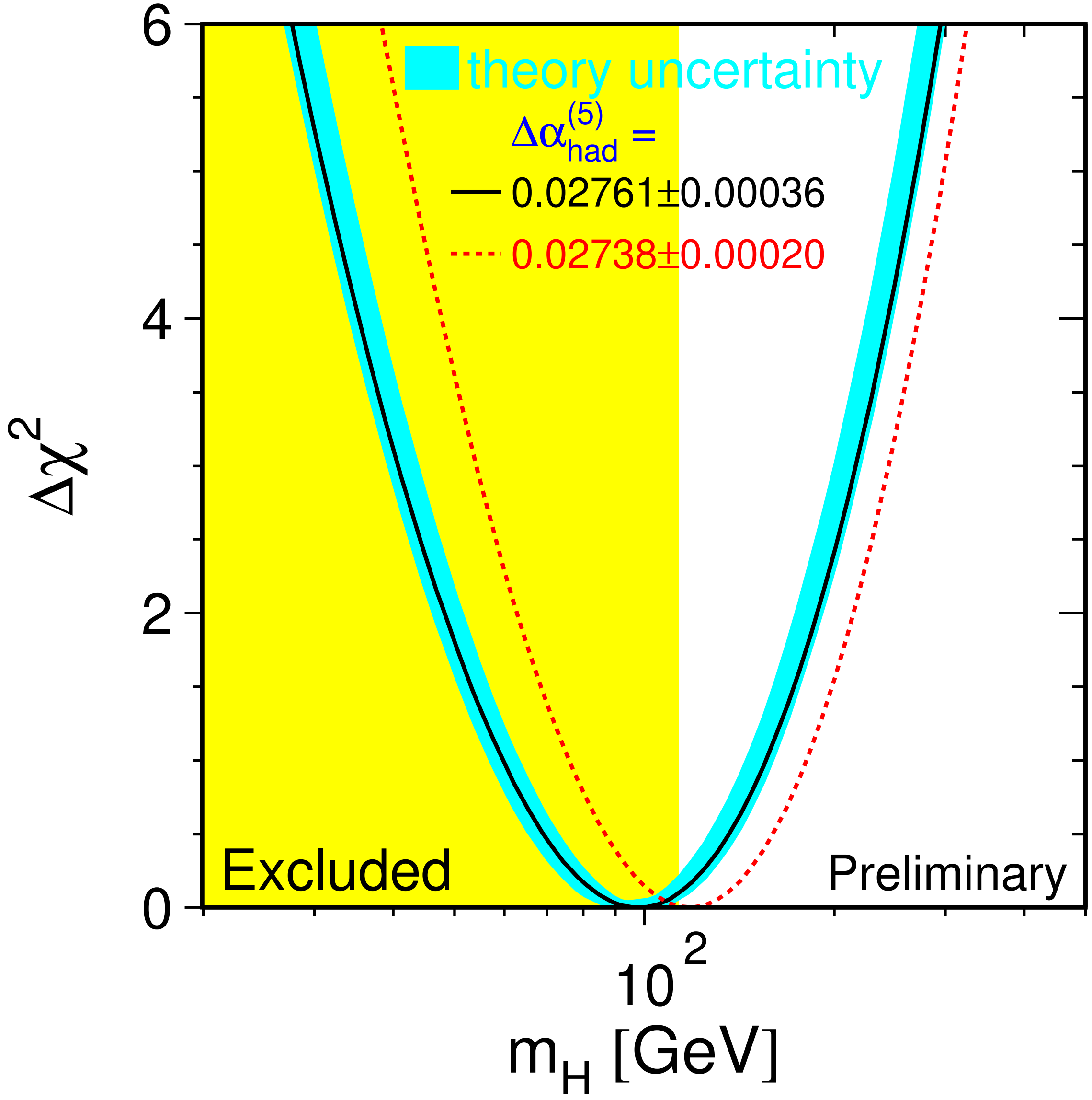
QCD AND HIGH ENERGY HADRONIC INTERACTIONS

Precision Results and Constraints on the S.M.

ALEPH, DELPHI, L3 and OPAL
SLD, Tevatron, BES, ...
LEP Electroweak Working Group

Higgs mass from the Standard Model fit

- **Winter 2001 result**
- $m_{\mathrm{H}} = 98^{+58}_{-38}$ **GeV**
- $m_{\mathrm{H}} < 212$ **GeV (95 % CL)**
- **Direct search :**
- $m_{\mathrm{H}} > 113.5$ **GeV (95 % CL) (November LEPC)**
- **Fits using ZFITTER, TOPAZ0**



T.K 2

Parameters

$$\mathcal{O} = \mathcal{O}(m_{\mathrm{Z}}, m_{\mathrm{t}}, m_{\mathrm{H}}, \alpha(m_{\mathrm{Z}}), \alpha_s(m_{\mathrm{Z}}); G_F)$$

LEP

- **Lineshape** $m_{\mathrm{Z}}, \Gamma_{\mathrm{Z}}, \sigma_{\mathrm{h}}^0, R_\ell, A_{\mathrm{FB}}^{0,\ell}$
- $P(\tau)$ $\mathcal{A}_{\mathrm{e}}, \mathcal{A}_\tau$
- **b, c** $R_{\mathrm{b}}, R_{\mathrm{c}}, A_{\mathrm{FB}}^{0,\mathrm{b}}, A_{\mathrm{FB}}^{0,\mathrm{c}}$
- $\mathrm{Q_{FB}}$ $\sin^2\theta_{\mathrm{eff}}^{\mathrm{lept}}$

SLD

- **b, c** $R_{\mathrm{b}}, R_{\mathrm{c}}, A_{\mathrm{FB}}^{0,\mathrm{b}}, A_{\mathrm{FB}}^{0,\mathrm{c}}$
- **L-R asym** $\mathcal{A}_\ell, \mathcal{A}_{\mathrm{b}}, \mathcal{A}_{\mathrm{c}}$

$\mathrm{p\bar{p}}$, LEP2

- $m_{\mathrm{t}}, m_{\mathrm{W}}$

νN

- $\sin^2\theta_{\mathrm{W}}$

$$R_\ell = \Gamma_{\mathrm{had}}/\Gamma_\ell$$

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

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

$$g_{V\ell}/g_{A\ell} = 1 - 4\sin^2\theta_{\mathrm{eff}}^{\mathrm{lept}}$$

$$\sin^2\theta_{\mathrm{W}} = 1 - \frac{m_{\mathrm{W}}^2}{m_{\mathrm{Z}}^2}$$

Parameters : Z

- **LEP lineshape is final.**

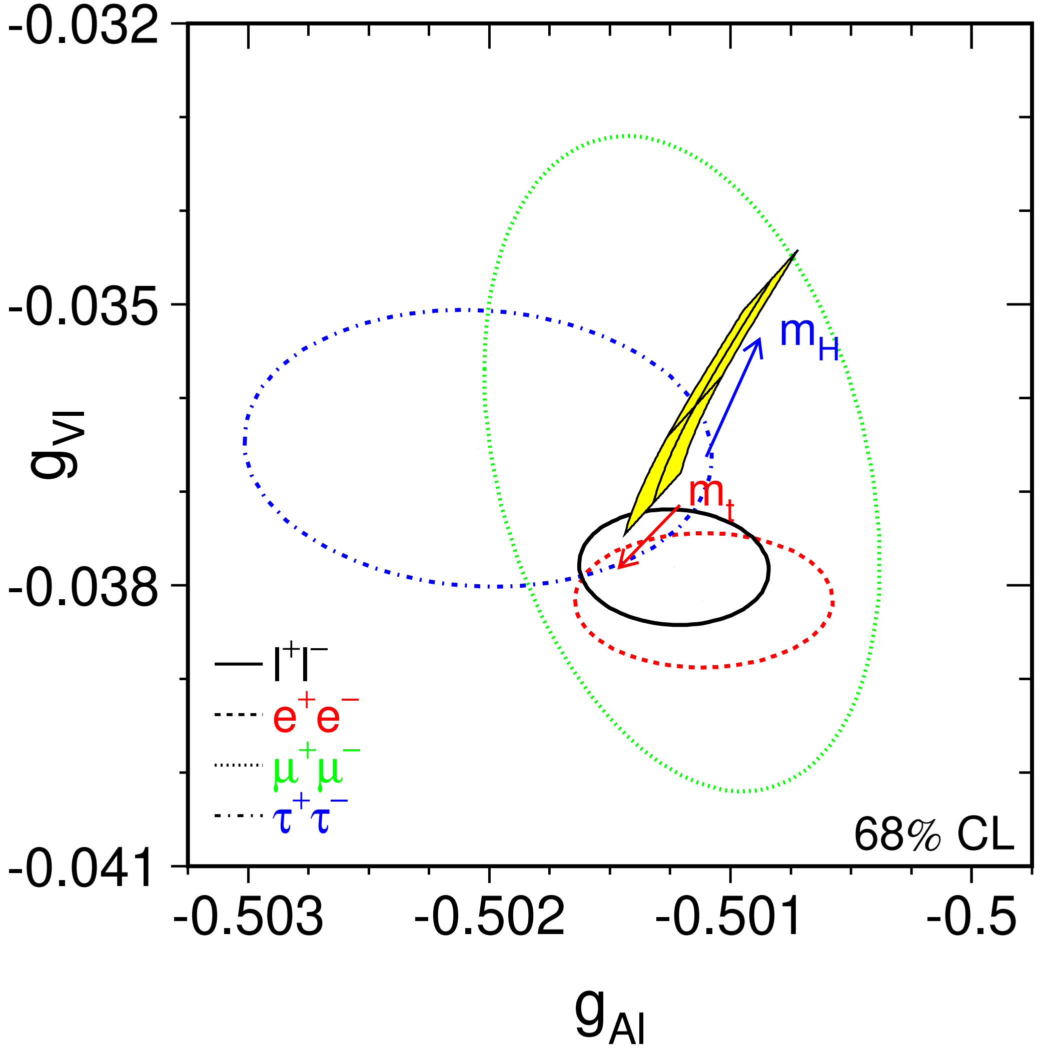
m_Z	91.1875	$\pm$	0.0021
Γ_Z	2.4952	$\pm$	0.0023
σ_h^0	41.540	$\pm$	0.037
R_ℓ	20.767	$\pm$	0.025
$A_{FB}^{0,\ell}$	0.01714	$\pm$	0.00095

- **LEP $P(\tau)$ using final inputs**

$\mathcal{A}_e$	0.14979	$\pm$	0.00484
$\mathcal{A}_\tau$	0.14387	$\pm$	0.00411
$\mathcal{A}_\ell$	0.14635	$\pm$	0.00313

- **SLD final $\mathcal{A}_\ell$**

$\mathcal{A}_\ell$	0.15130	$\pm$	0.00207

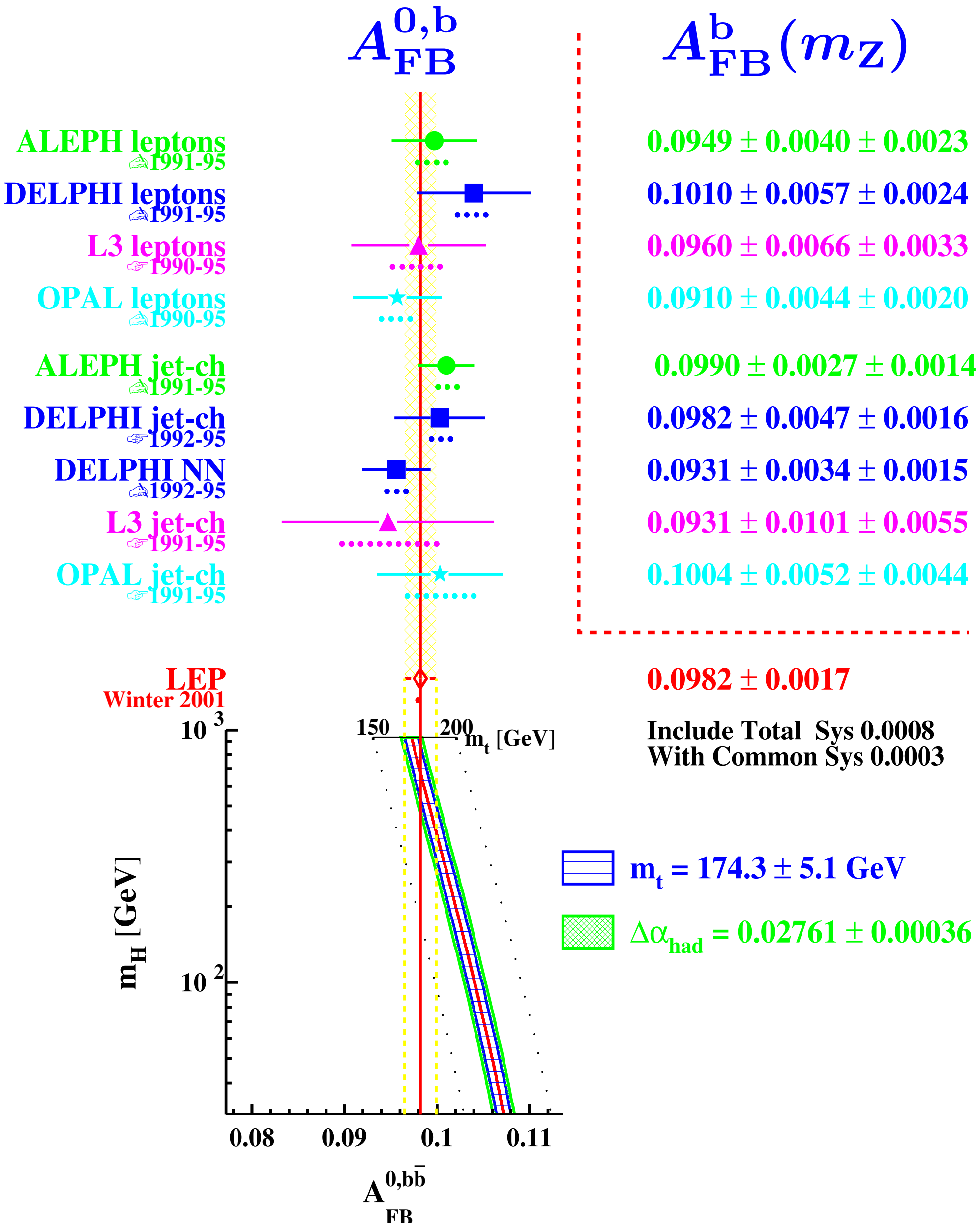


Parameters : Z

- Aleph, Delphi, SLD updated b, c

  New prelim numbers

R_b	0.21664	$\pm$	0.00068
R_c	0.1729	$\pm$	0.0032
$A_{FB}^{0,b}$	0.0982	$\pm$	0.0017
$A_{FB}^{0,c}$	0.0689	$\pm$	0.0035
$\mathcal{A}_b$	0.921	$\pm$	0.020
$\mathcal{A}_c$	0.667	$\pm$	0.026



Parameters : Z

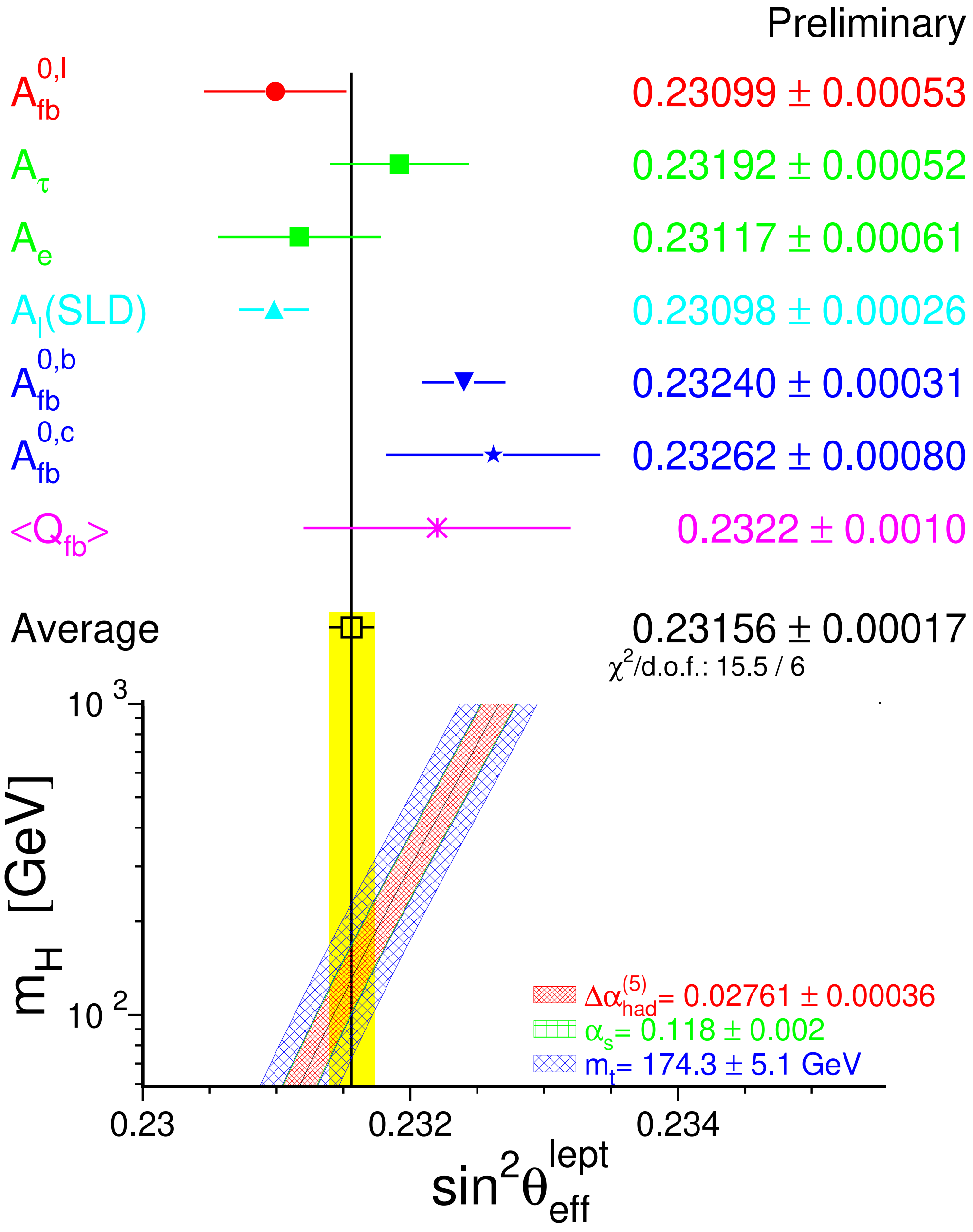
- $\sin^2\theta_{\rm eff}^{\rm lept}$ **from asymmetry measurements :**

- **The old problem :**
  $\mathcal{A}_\ell$**(SLD) vs** $A_{\rm FB}^{\rm 0,b}$ **:** $3.5\ \sigma$

  (lepton vs hadron : $3.6\ \sigma$**)**

- **overall** $\chi^2 = 15.5/6$**, p =** $1.7\ \%$

- **Average** $\sin^2\theta_{\rm eff}^{\rm lept}$ **preferes** $m_{\rm H} \sim 100$



Parameters : $\alpha(m_Z)$

- Running of E.M. coupling
  vacuum polarization

$$\alpha(s) = \frac{\alpha(0)}{1 - \Delta\alpha_\ell(s) - \Delta\alpha^{(5)}_{h(s)} - \Delta\alpha_t(s)}$$

- $\Delta\alpha_\ell(s)$ leptonic : can be calculated.
- $\Delta\alpha_t(s)$ top : small, m_t dependence.
- $\Delta\alpha^{(5)}_h(s)$ light quarks : Involves QCD

Evaluation using dispersion integral:

$$\Delta\alpha^{(5)}_h(s) = -\frac{\alpha s}{3\pi} P \int_{4m_\pi^2}^{\infty} \frac{R(s')}{s'(s'-s)} ds'$$

Need hadronic cross-section $R(s)$ data at all energy.

- Main source of uncertainty:
  $\sqrt{s} = 2 - 5$GeV : old data

eg. Eidelmann, Jegerlehner (1995)
$\Delta\alpha^{(5)}_h(s) = 0.02804 \pm 0.0065$

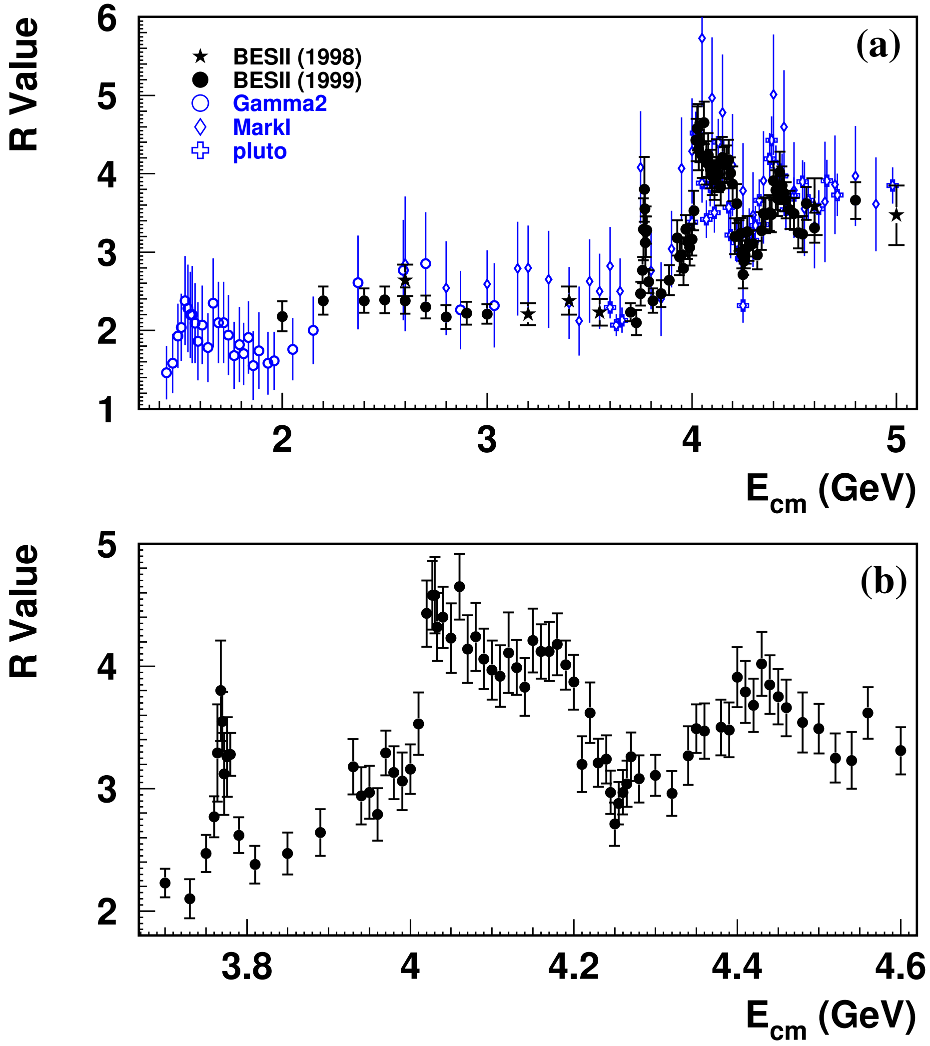
- Attempts using pQCD

eg. Davier, Höcker (1998)
$\Delta\alpha^{(5)}_h(s) = 0.02784 \pm 0.0026$

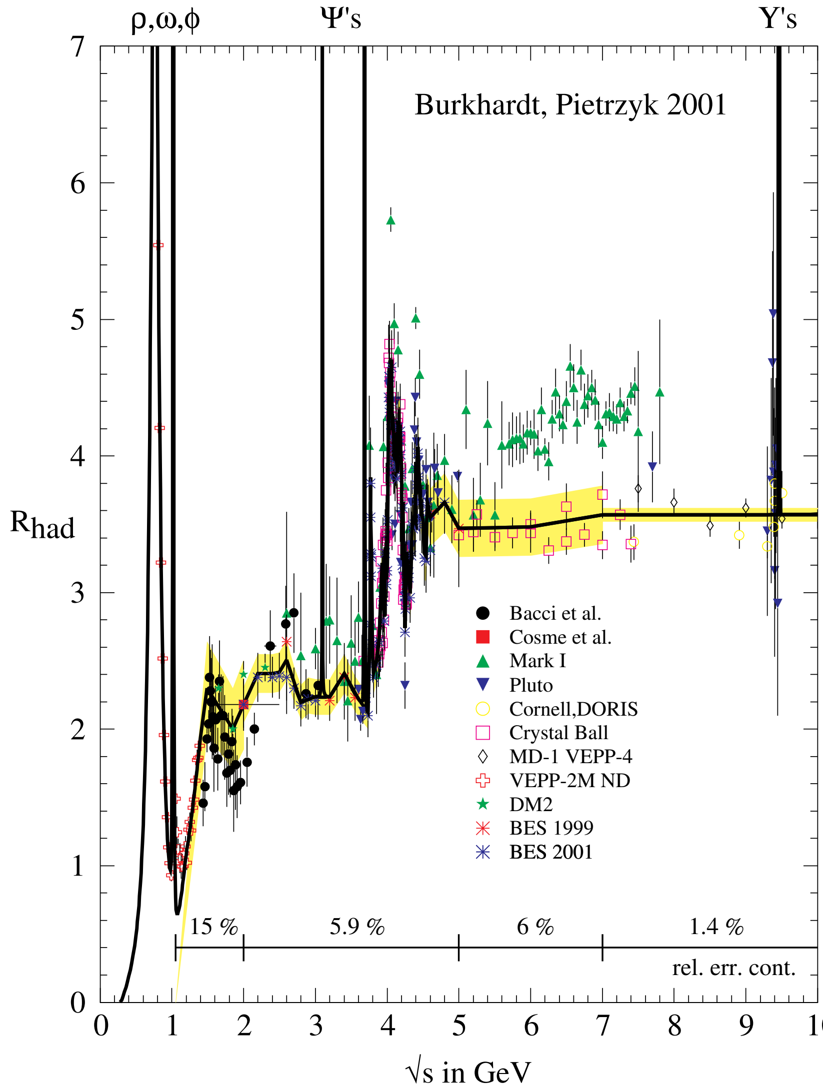
- Good data are needed.

Parameters : $\alpha(m_Z)$

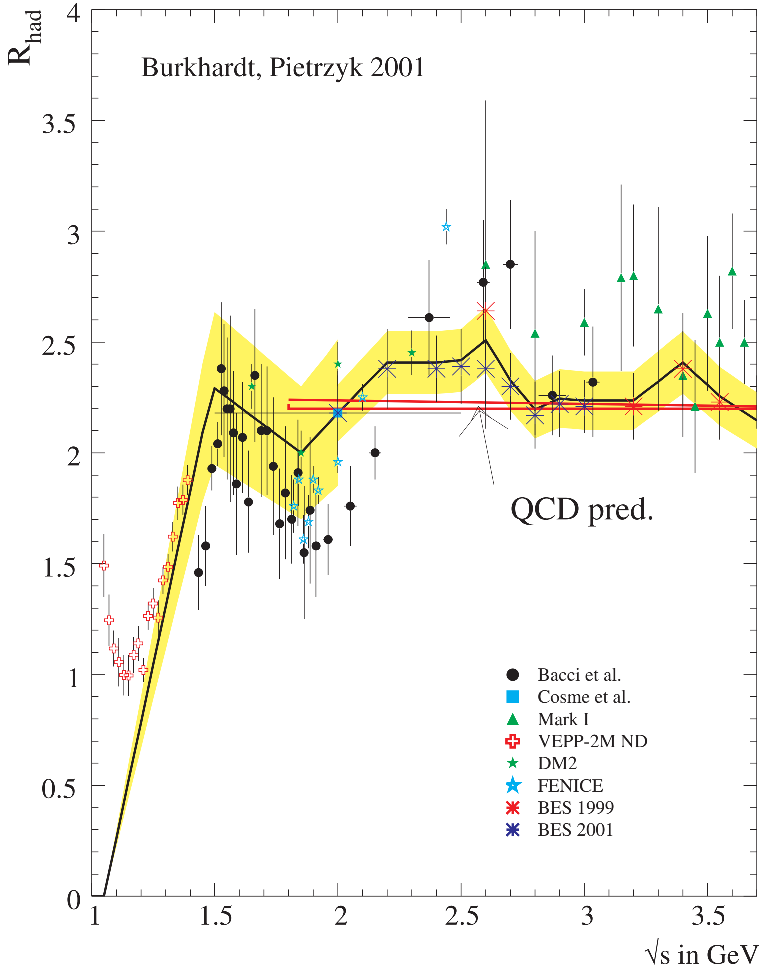
- **BES collaboration has measured R (hep-ex/0102003)**



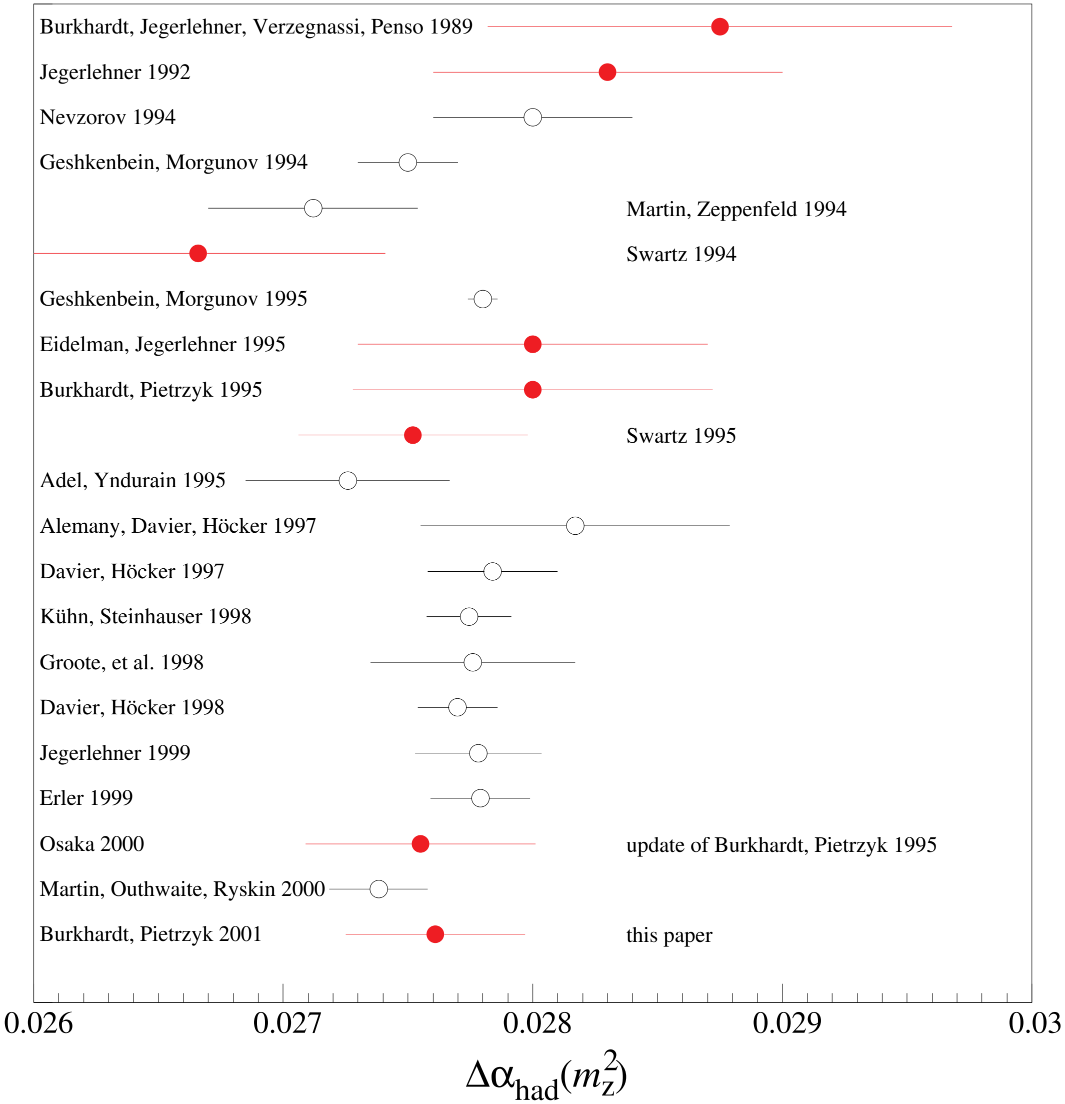
- **New evaluation using new data**



Parameters : $\alpha(m_Z)$



R without resonances



$$\Delta\alpha_{\mathrm{h}}^{(5)}(m_Z) = 0.02761 \pm 0.00036$$

lapp-exp 2001-03, accepted by PLB

Parameters : m_W

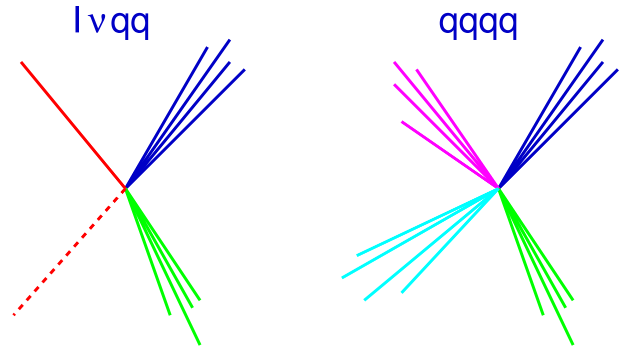
- **LEP m_W has been updated**

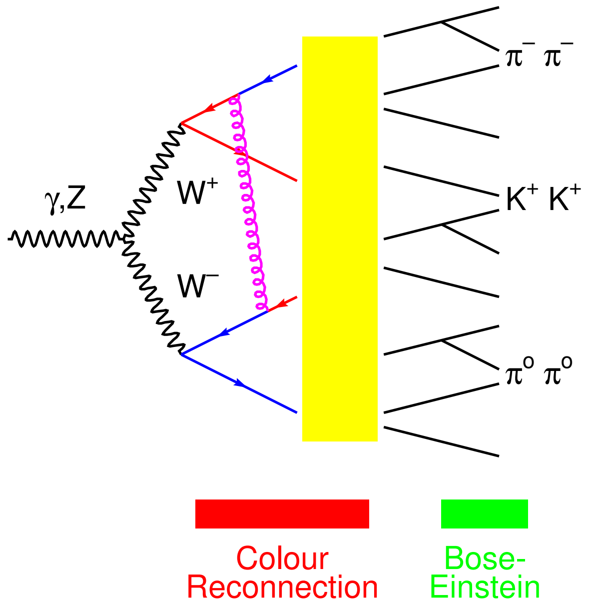
add prelim. 2000 results from ALEPH and L3

Errors (MeV)	$\ell\nu q\bar{q}$	$q\bar{q}q\bar{q}$	combined
Stat.	33	31	26
Detector	11	8	10
Hadronization	19	17	18
ISR	8	8	7
Others	4	5	3
LEP	17	17	17
C.R.	–	40	11
B.E.	–	25	7
Sys total	29	54	30
total	44	62	40

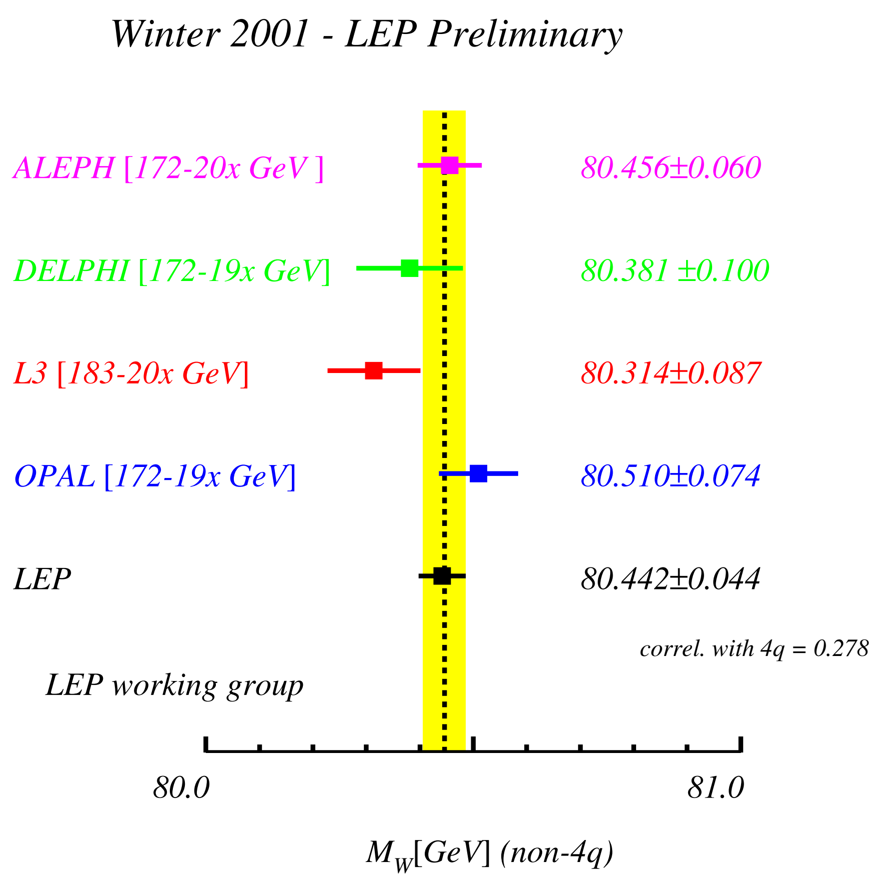
Main method :

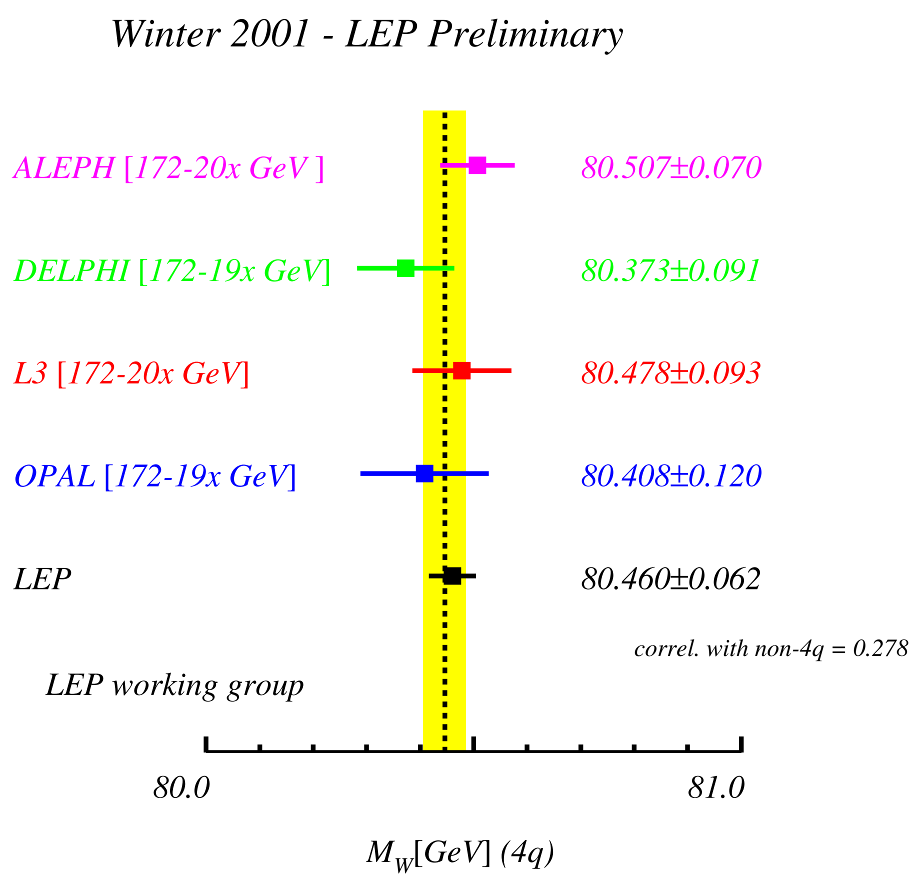
direct reconstruction





Parameters : $m_{\rm W}$

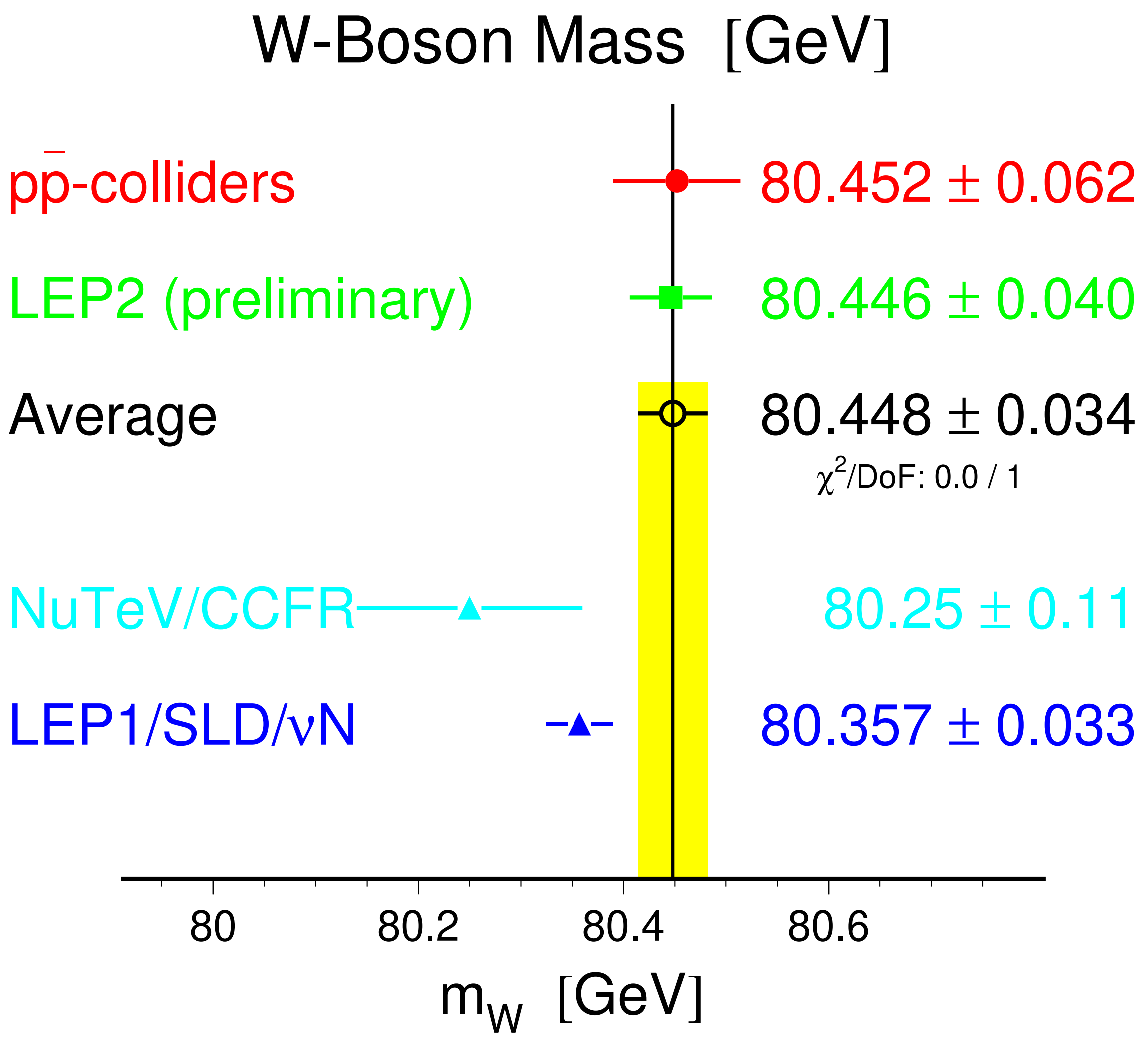




non-qqqq: 80.442 ± 0.044 GeV **qqqq: 80.460 ± 0.062 GeV**

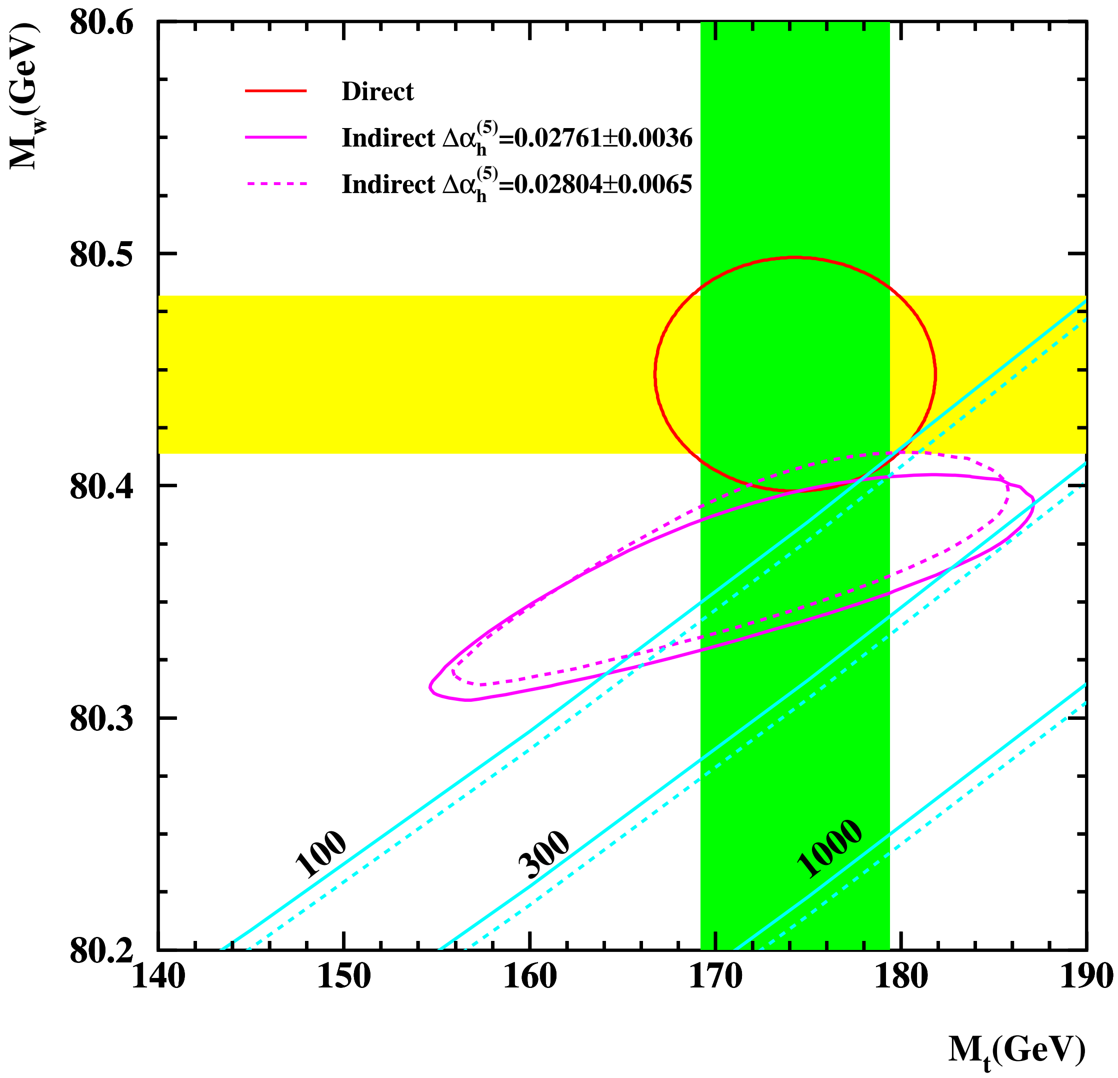
- $m_{\rm W}({\rm q\bar{q}q\bar{q}}) - m_{\rm W}({\rm non-q\bar{q}q\bar{q}}) = 18 \pm 46$ **MeV**

Parameters : m_W



- **Consistent with $\mathrm{p\bar{p}}$ result : combined result $80.448\pm$ 0.034 GeV (prelim.)**
- **$\approx$ consistent with indirect determination (1.9 σ)**

Parameters : Z vs W

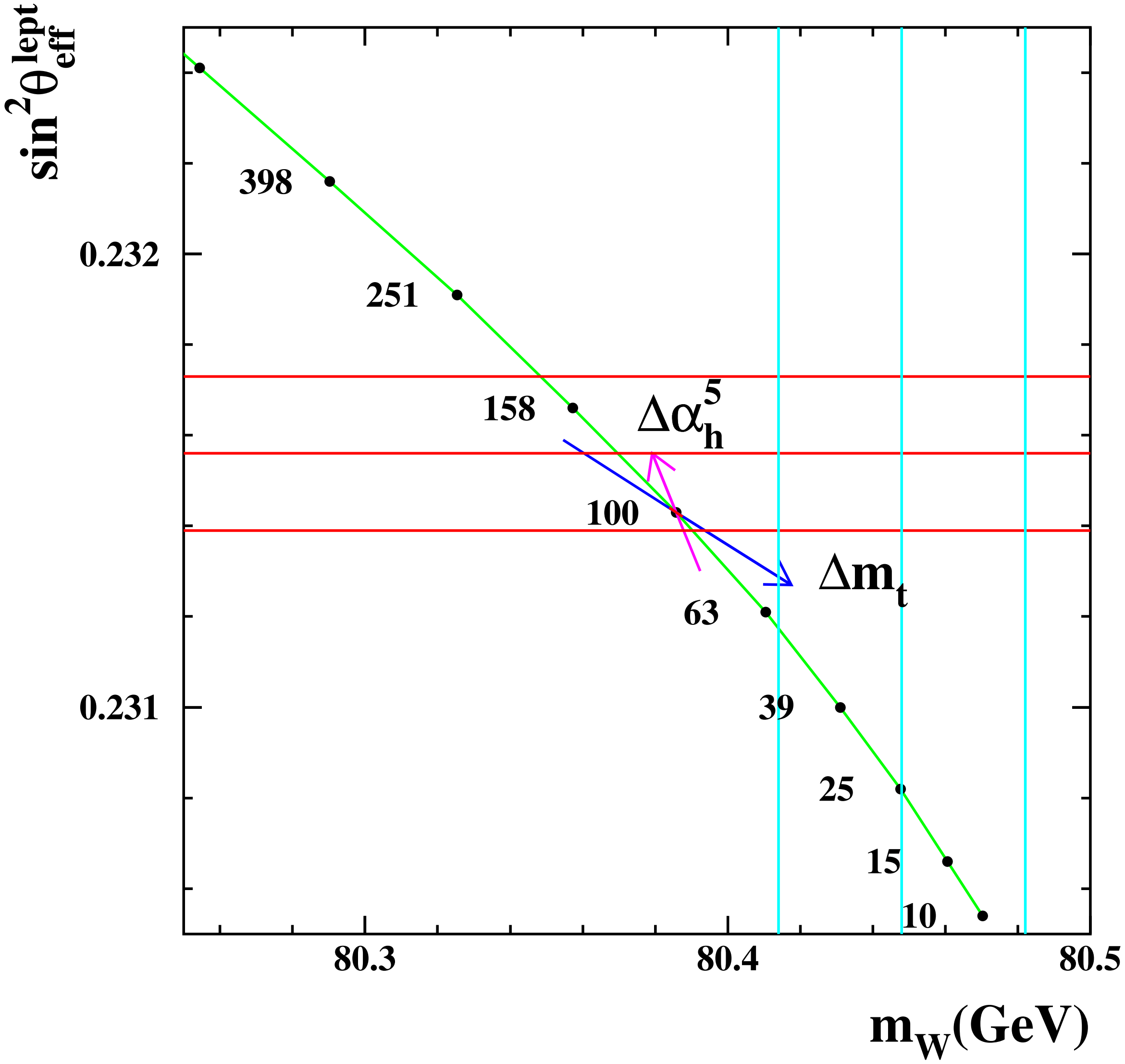


- Indirect determination SM fit to data – $(m_{\mathrm{W}}, m_{\mathrm{t}})$
- $m_{\mathrm{W}}, m_{\mathrm{t}}$ direct meas.
- S.M.[a]

Direct and Indirect m_{W} are $\approx$ consistent.

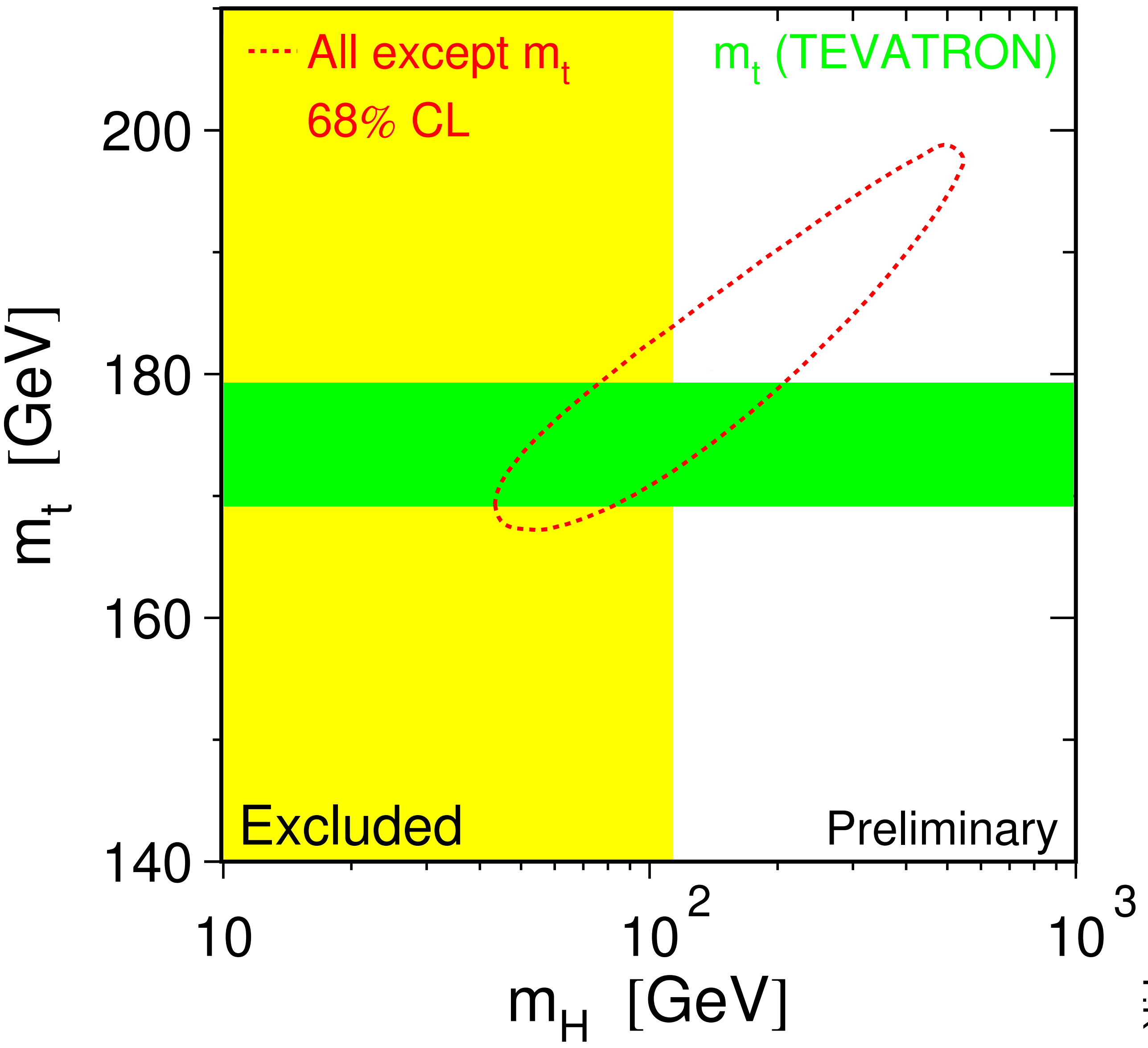
[a] New 2-loop calculation of Δr by Hollik et al. changes theoretical m_{W} prediction by < 4 MeV. Not yet included in the analyses presented here

$\sin^2\theta_{\rm eff}^{\rm lept}$, $m_{\rm W}$ and $m_{\rm H}$



m_t and m_H

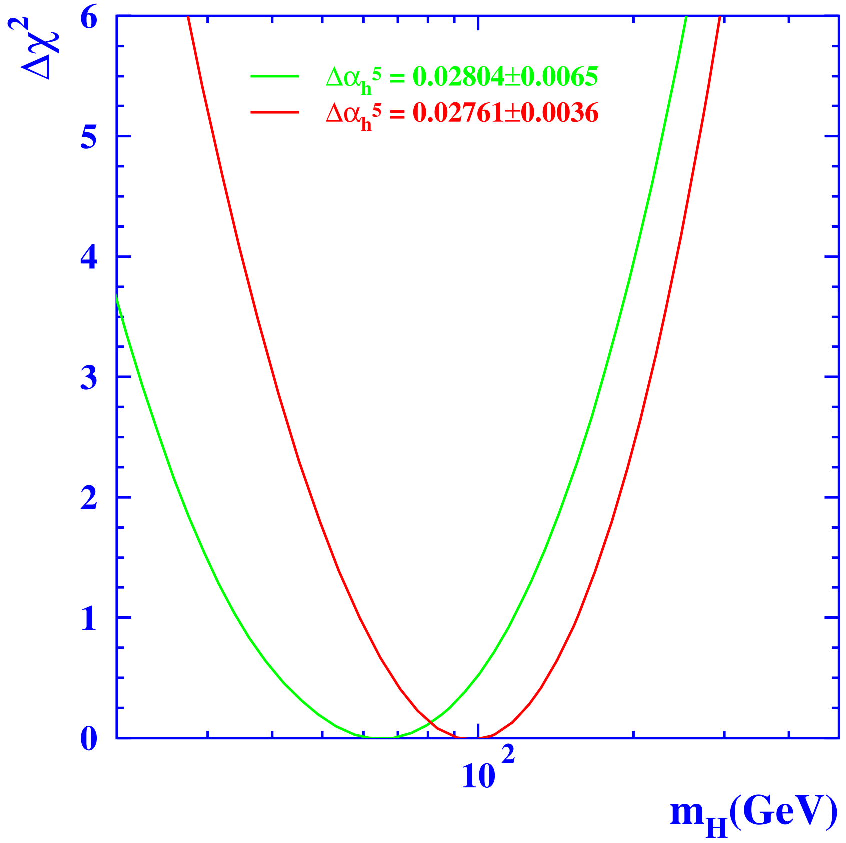
- Fit without m_t constraint.
- m_t-m_H correlation : Precise m_t is important



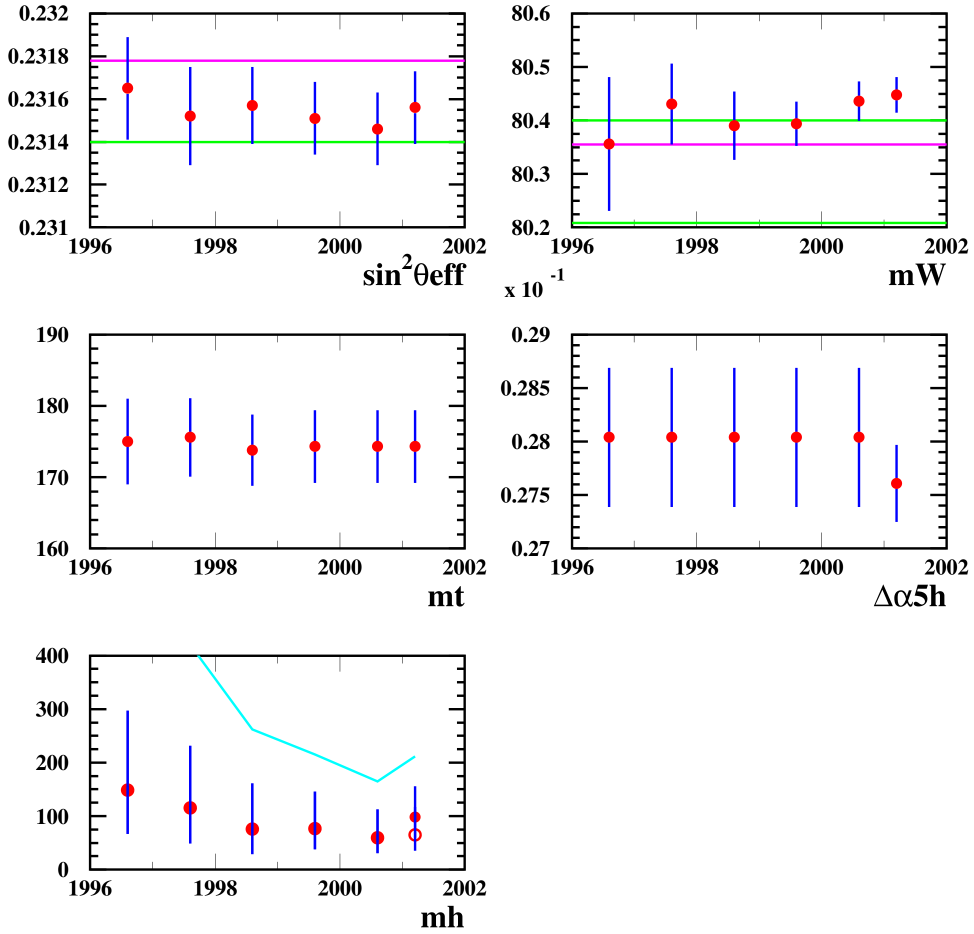
SM fit results

	all data w/o $m_{\rm W}$, $m_{\rm t}$	all data w/o $m_{\rm W}$	all data w/o $m_{\rm t}$	all data
$m_{\rm t}$ GeV	168^{+12}_{-9}	173^{+5}_{-5}	180^{+12}_{-9}	176^{+4}_{-4}
$m_{\rm H}$ GeV	87^{+119}_{-43}	121^{+76}_{-48}	139^{+203}_{-77}	98^{+58}_{-38}
$\alpha_s(m_{\rm Z})$	0.119 ± 0.003	0.119 ± 0.003	0.119 ± 0.003	0.118 ± 0.003
χ^2/d.o.f	21/12	22/13	25/14	26/15
$\sin^2\theta^{\rm lept}_{\rm eff}$	0.23155 ± 0.00016	0.23156 ± 0.00016	0.23144 ± 0.00015	0.23142 ± 0.00014
$1 - \frac{m_{\rm W}^2}{m_{\rm Z}^2}$	0.22344 ± 0.00063	0.22322 ± 0.00045	0.22259 ± 0.00045	0.22273 ± 0.00037
$m_{\rm W}$ GeV	80.357 ± 0.033	80.368 ± 0.023	80.401 ± 0.023	80.393 ± 0.019

S.M. fits



$\Delta\chi^2$
$\Delta\alpha_h^5$ = 0.02804±0.0065
$\Delta\alpha_h^5$ = 0.02761±0.0036
10^2
m_H(GeV)

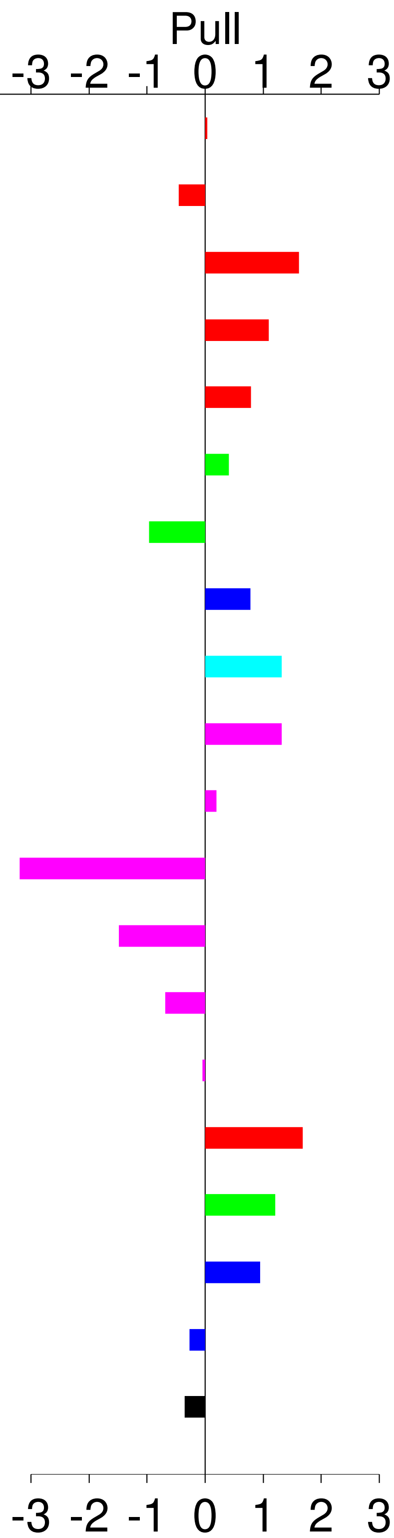


$\sin^2\theta$eff
mW
x 10 -1
mt
Δα5h
mh
1996
1998
2000
2002

Global fit goodness

Winter 2001

	Measurement	Pull
m_Z [GeV]	91.1875 ± 0.0021	.04
Γ_Z [GeV]	2.4952 ± 0.0023	-.46
σ^0_{hadr} [nb]	41.540 ± 0.037	1.62
R_l	20.767 ± 0.025	1.09
$A^{0,l}_{fb}$	0.01714 ± 0.00095	.79
A_e	0.1498 ± 0.0048	.41
A_τ	0.1439 ± 0.0041	-.96
$\sin^2\theta^{lept}_{eff}$	0.2322 ± 0.0010	.78
m_W [GeV]	80.446 ± 0.040	1.32
R_b	0.21664 ± 0.00068	1.32
R_c	0.1729 ± 0.0032	.20
$A^{0,b}_{fb}$	0.0982 ± 0.0017	-3.20
$A^{0,c}_{fb}$	0.0689 ± 0.0035	-1.48
A_b	0.921 ± 0.020	-.68
A_c	0.667 ± 0.026	-.05
A_l	0.1513 ± 0.0021	1.68
$\sin^2\theta_W$	0.2255 ± 0.0021	1.20
m_W [GeV]	80.452 ± 0.062	.95
m_t [GeV]	174.3 ± 5.1	-.27
$\Delta\alpha^{(5)}_{had}(m_Z)$	0.02761 ± 0.00036	-.36



Summary

- The SM works fine.
- 3 σ deviation for $A_{FB}^{0,b}$
- New evaluation of $\Delta\alpha_h^{(5)}$
- m_H from SM fit increased to 98 GeV. Mainly due to $\Delta\alpha_h^{(5)}$
- Still favours low mass higgs.

  $m_H = 98^{+58}_{-38}$ GeV

  $m_H < 212$ GeV (95 % CL)
- b, c, m_W, LEP Ecal are to be finalized
- Improved m_W, m_t to come from Tevatron (and LHC) in future

- Where is the Higgs?