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Fits on Standard Model, results on $\alpha(m_Z^2)$ and influence on the Higgs mass

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Fits on Standard Model, results on $\alpha(m_Z^2)$ and influence on the Higgs mass are presented.

1. Standard Model Fits

The precise electroweak measurements (Fig. 1) are used in the Standard Model (SM) fits which are performed by the LEP Electro Weak Working Group [1].

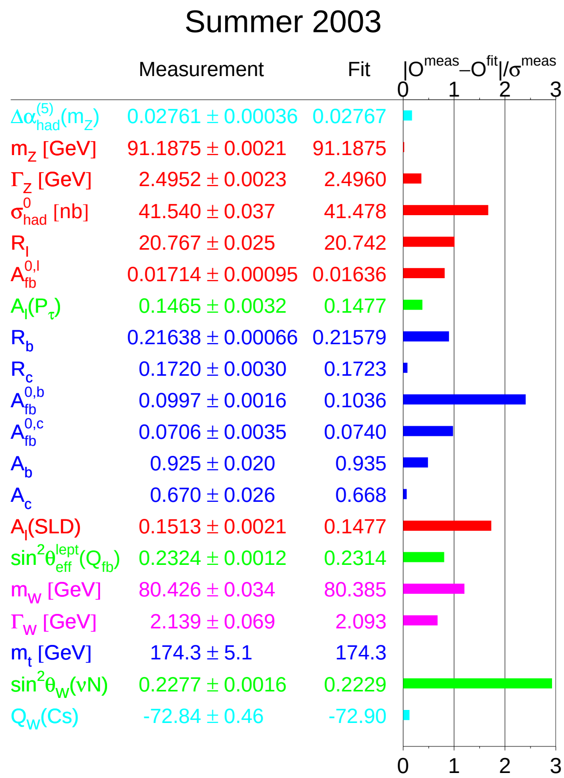

Figure 1. The precise electroweak measurements.

The variation of $\Delta\chi^2(m_H)$ as a function of m_H for the fit in which all the precise measurements are used is shown in Fig. 2. The value of the Higgs mass obtained from the fit is

$$m_H = 96^{+60}_{-38}\ \text{GeV}$$

and the 1-sided 95% CL upper limit is 219 GeV.

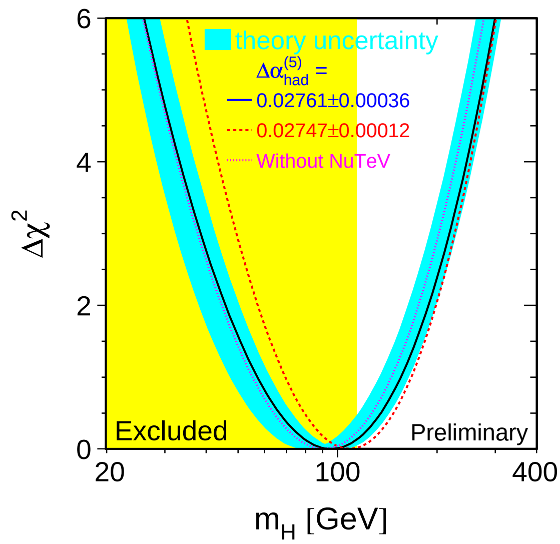

Figure 2. $\Delta\chi^2(m_H)$ as a function of m_H.

The highest sensitivity $\frac{dO}{d(\log m_H)}/\sigma_O$ of the fit on the Higgs mass comes from the m_W, the left-right asymmetry measurement at SLD A_{lr}, and the forward-backward b asymmetry A_{fb}^b measurements at LEP (Fig. 3).

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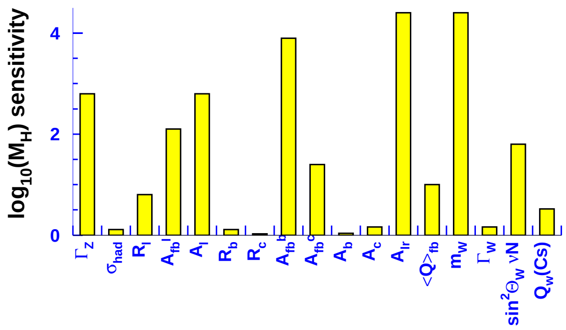

Figure 3. Sensitivity $\frac{dO}{d(\log m_H)}/\sigma_O$ of the different measurements on the Higgs mass.

The A_{lr} and m_W push the central value of the Higgs mass towards lower values in the fit (Fig. 4), A_{fb}^b towards higher values. The Higgs mass from the $\sin^2\Theta_W$ measurements in the νN scattering at NuTeV is even in the overflow (above 1000 GeV) on the Fig. 4.

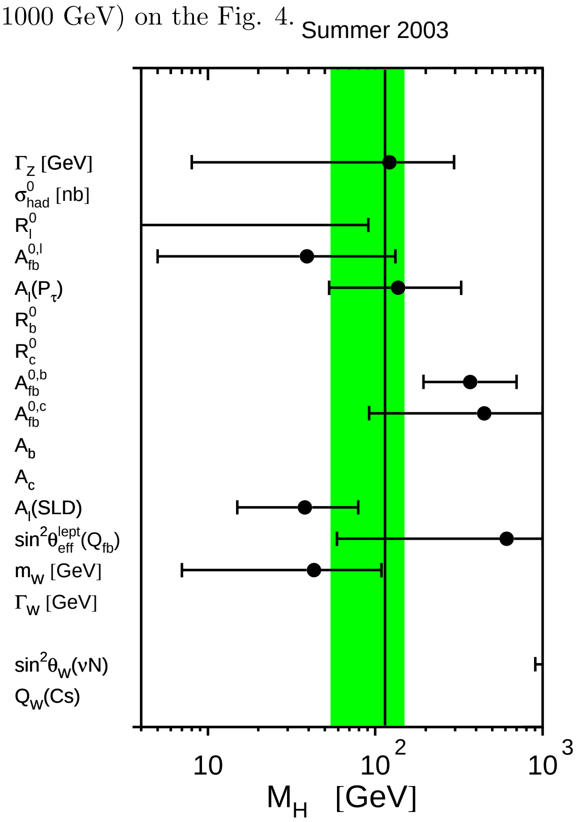

Figure 4. Higgs mass fits to individual measurements.

The χ^2/d.o.f. is 25.4/15 in the SM fit, giving the low probability of 4.5%. The $\sin^2\Theta_W$ (NuTeV) measurement has a low sensitivity to the Higgs mass, but it has a large contribution to the low probability of the SM fit (Fig. 1). A large contribution to the low probability of the fit comes also from the A_{lr} and the A_{fb}^b asymmetry measurements. A comparison of the different asymmetry measurements is shown in Fig. 5.

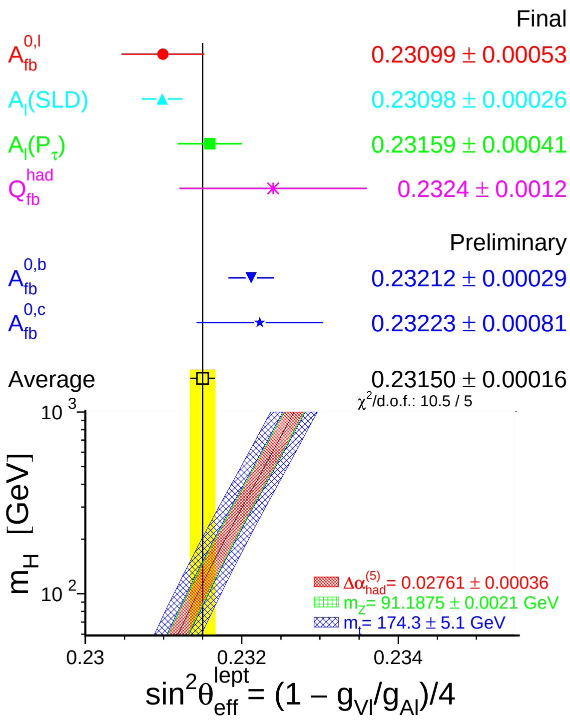

Figure 5. Comparison of the effective electroweak mixing angle derived from the different measurements.

In the SM, all these measurements are sensitive to the same leptonic effective electroweak mixing angle $\sin^2\Theta_{eff}^{lept}$ [2]. However, the two most precise determinations of $\sin^2\Theta_{eff}^{lept}$ deviate by 2.9 σ. There is no straightforward explanation of this deviation in terms of new physics. The χ^2 of combination of $\sin^2\Theta_{eff}^{lept}$ is 10.2/5 d.o.f giving an important contribution to the low probability of the SM fit. If the global fit is performed with the average $\sin^2\Theta_{eff}^{lept}$, the χ^2/d.o.f becomes 15/10 giving more reasonable probability of 13%. It is important to note that there is a good agreement

[2] The label "eff" means that it includes electroweak radiative corrections dependant also on m_t and m_H.

between the results obtained by the different LEP experiments on the asymmetry A_{fb}^{b}(Fig. 6).

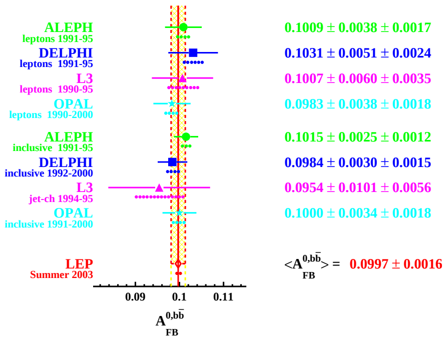

Figure 6. Comparison of the A_{fb}^{b} measurements by the different LEP experiments.

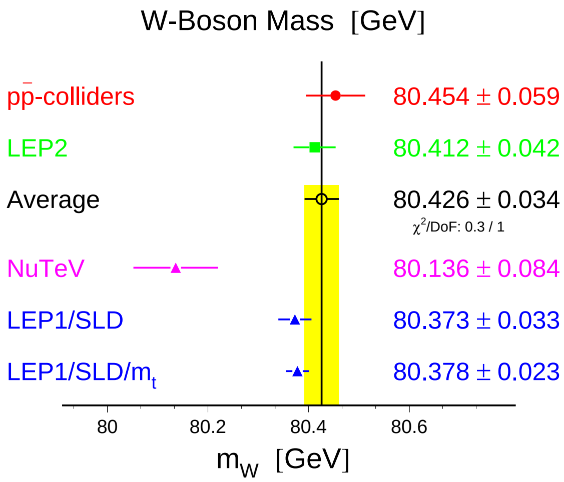

Figure 7. Comparison of different measurements of W mass.

The $\sin^2\Theta_W$ measurement in the νN scattering at NuTeV makes another large contribution to the low probability of the SM fit. This measurement can also be interpreted in term of the W mass measurement using the relation $\sin^2\Theta_W$ = 1- m_W^2/m_Z^2. The large deviation of the NuTeV result from the SM prediction (Fig. 1) can also be seen in the figure showing the comparison of different W mass measurements (Fig. 7). We see again that the NuTeV measurements show 2.9 σ deviation from the SM prediction. There is no straightforward explanation for this deviation in terms of new physics. However, an explanation for this deviation was recently proposed within the SM as being due to the strange sea asymmetry present in the new CTEQ fits [2]. A global SM fit without NuTeV gives a probability of 28%.

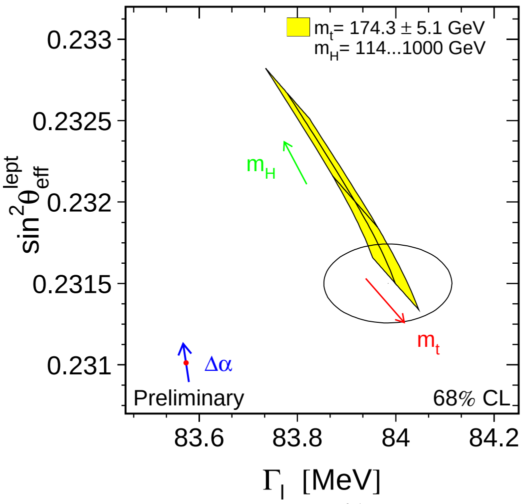

Figure 8. Contour curve of 68% probability in the $\sin^2\Theta_{eff}^{lept}$, Γ_l plane.

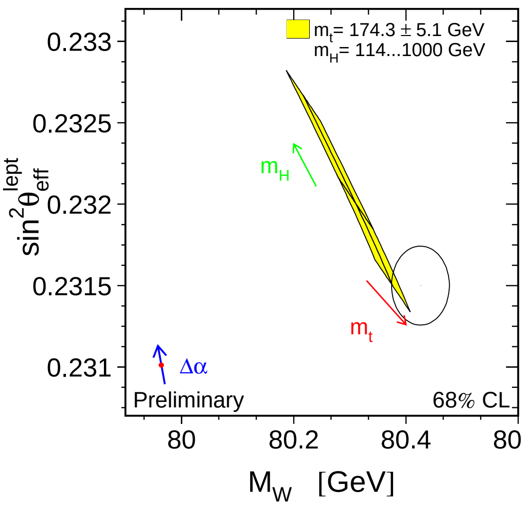

Figure 9. Contour curve of 68% probability in the $\sin^2\Theta_{eff}^{lept}$, m_W plane.

In conclusion, the low probability of the SM fit is related to the large χ^2/d.o.f. of the com-

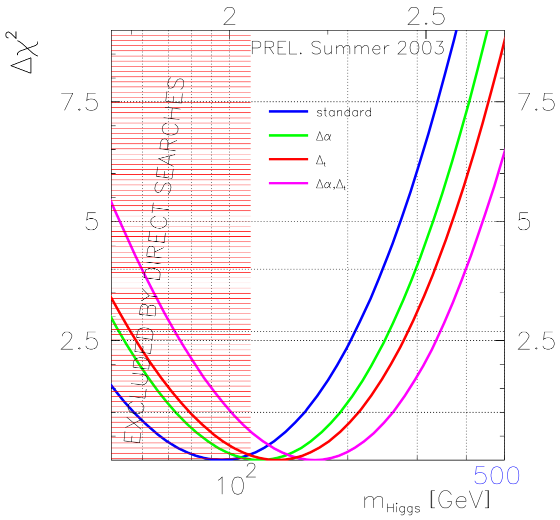

Figure 10. The shift of $\Delta\chi^2$ fit distribution when the $\Delta\alpha^5_{\rm had}(m_Z^2)$ and m_t are changed by one standard deviation.

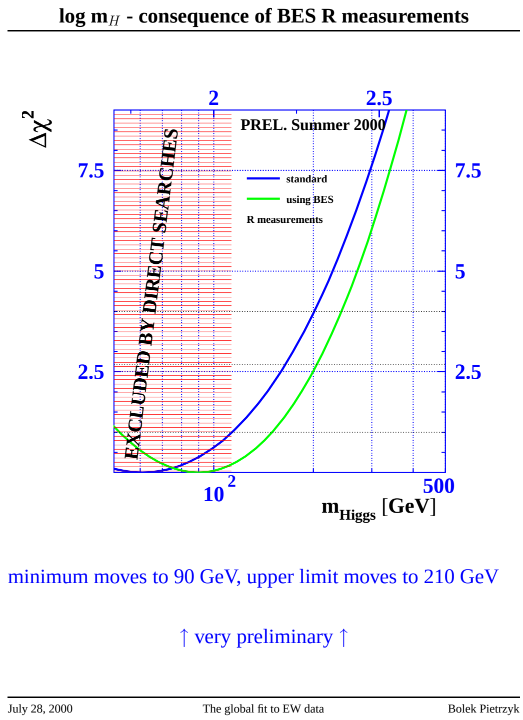

Figure 11. Transparency presented during ICHEP 2000 conference at Osaka showing the change of the SM fit results with the new BES data.

bination of $\sin^2\Theta^{\rm lept}_{\rm eff}$ measurements and to the deviation of NuTeV measurement from the SM prediction.

2. $\alpha(\mathbf{m_Z^2})$, $\mathbf{m_t}$ and $\mathbf{m_H}$ in the Standard Model fits

The Figs 8 and 9 show the contour curves of 68% probability in the $\sin^2\Theta^{\rm lept}_{\rm eff}, \Gamma_l$ and $\sin^2\Theta^{\rm lept}_{\rm eff}, m_W$ planes. The dot shows the prediction of a theory based on Born and QED with running α. The arrow represents the uncertainty due to hadronic vacuum polarization. The shaded region shows the SM prediction with the values of m_t and m_H varied in the ranges indicated. m_H is obtained in the fit from the measurement of genuinely electroweak radiative corrections which are observed as a difference between the dot and the shaded region. Clearly, as seen from Figs 8 and 9, the changes of the input values of $\Delta\alpha^5_{\rm had}(m_Z^2)$ and m_t affect the value of m_H obtained from the fit.

These changes are potentially important. Fig. 10 shows the shift of $\Delta\chi^2$ fit distribution when the $\Delta\alpha^5_{\rm had}(m_Z^2)$ and m_t are changed by one standard deviation.

In fact, the minimum of $\Delta\chi^2$ fit distribution has moved from 60 to 88 GeV and the 1-sided 95% CL upper limit has moved from 165 to 210 GeV when BES data arrived during ICHEP 2000 conference in Osaka [3] (Fig 11).

3. Our evaluation of $\alpha(\mathbf{m_Z^2})$

The value of the hadronic contribution $\Delta\alpha^5_{\rm had}(m_Z^2)$ to the running of α used in the SM fit (Fig. 2) comes from the 2001 analysis made by H.Burkhardt and the author [4] (Fig. 12). The uncertainty of this analysis has been reduced from 0.0007 to 0.00036 mainly due to the use of BES [5] measurements in 2-5 GeV c.m.s. region. It is important to note, however, that this region gives still the most important contribution to the total uncertainty together with the 1-2 GeV region (Fig. 13).

In our analysis we integrate $R_{\rm had}$ represented by a simple parametrization, like broad averages and straight lines in the continuum and rely, whenever available, on published world averages.

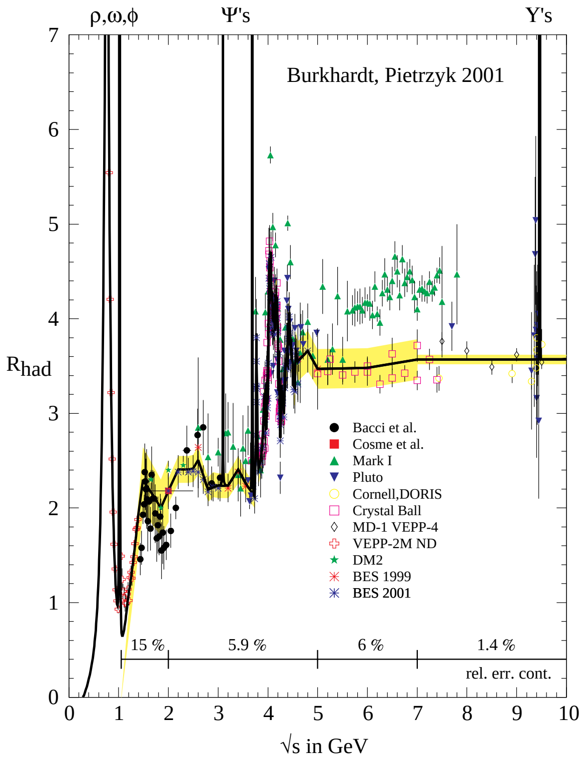

Figure 12. R_{had} used in our analysis of hadronic contribution to the QED vacuum polarization.

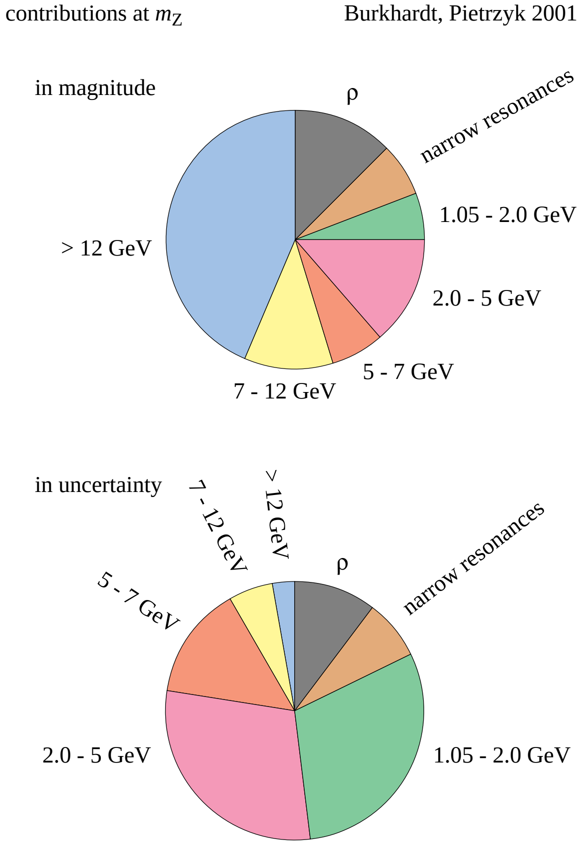

Figure 13. Relative contribution to $\Delta\alpha^5_{\rm had}(m_Z^2)$ in magnitude and uncertainty.

We adapt the analysis to make the best possible use of experimental data. In the 2001 paper we connected and integrated directly 91 points measured by BES. The systematic uncertainties were treated as fully correlated, in contrast to the statistical errors. The information from the older measurements was kept. This was achieved by a slight rescaling of the BES contribution (Fig. 14).

In the ρ region (Fig. 15) we used the "hidden local parametrization" given by the CMD2 Collaboration with a small extra bump at 1.2 GeV. A check made with the direct integration of CMD2 data and the tails from the parametrization gave compatible results. The 2001 result was obtained using preliminary CMD2 data [6]. It was not necessary to update our 2001 result with the published CMD2 data [7] since this would result in shift of our result by only 10% of its uncertainty (Fig. 16). The recent improvement in the treatment of radiative corrections by the CMD2 collaboration [8] shifts our result by 18% of its uncertainty giving the value of hadronic contribution $\Delta\alpha^5_{\rm had}(m_Z^2)$ to the running of α of 0.02768±0.00036.

Our uncertainty reflects correctly the uncertainty of data, improvement will come using new measurements from KLOE, CMD2, BES, CLEO, BABAR and BELLE.

Improvement is also possible using currently available data. In the c.m.s. region of 2-5 fully correlated systematic uncertainty of BES points is used. The uncertainty on $\Delta\alpha^5_{\rm had}(m_Z^2)$ can be improved when the BES Collaboration will give

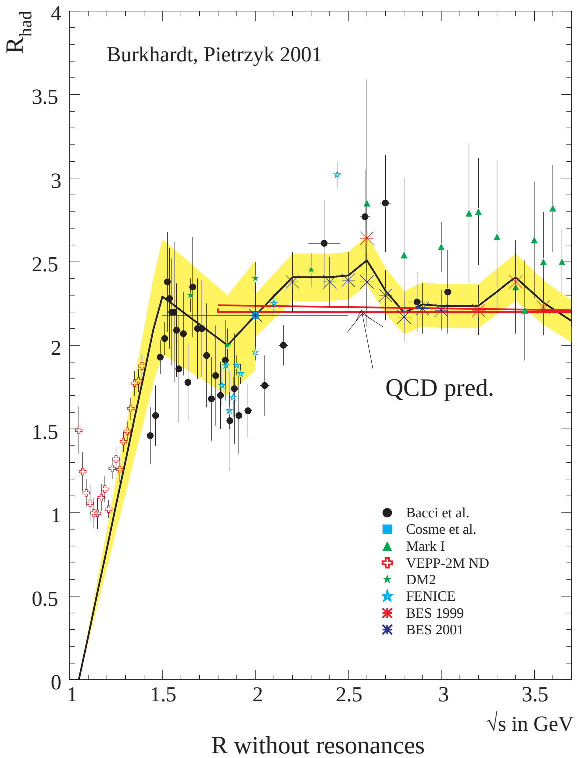

Figure 14. Direct integration of BES points. The line used in the integration follows the shape of BES points but it is slightly shifted up in order to take into account the older measurements.

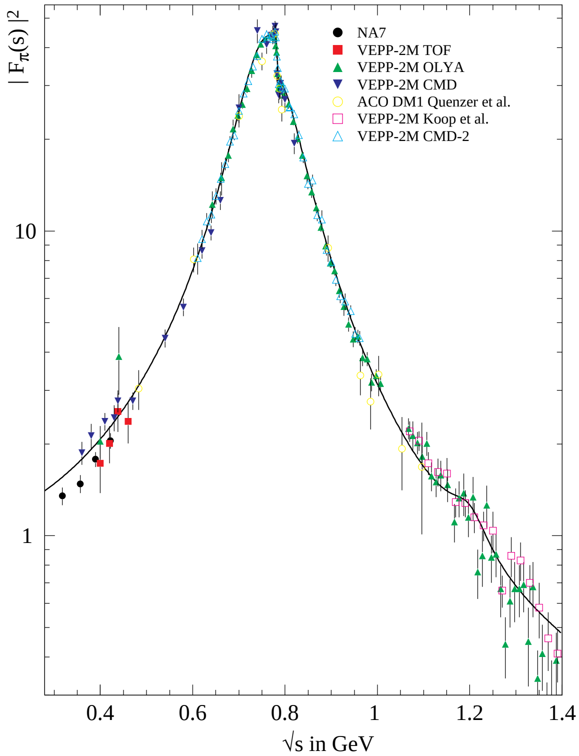

Figure 15. The pion form factor.

correlations between different points. In the ρ region the uncertainty of 2.3% is used in our 2001 result. The total uncertainty would be reduced a little bit using the overall (stat. and sys. combined) uncertainty of 0.9% of CMD2 results.

Fig. 17 shows the values of the different estimates of $\Delta\alpha^5_{had}(m^2_Z)$ since 1989. The only important changes appeared in 1995 when Crystal Ball data were used for the first time and in 2000 when BES data arrived. The central value of our result is in agreement with the one obtained by F. Jegerlehner (FJ) and the HMNT analysis. The uncertainty of our result is in agreement with FJ but it is larger than the one obtained by HMNT [9].

The participants of this workshop know that it is very important to improve the precision of R_{had} measurements. It is also, however, important to remeasure R_{had} in a given c.m.s region with similar precision to the one presently available. A change of an experimental result by one standard deviation happens often in physics. The Table 1 gives the shift of the central value of the Higgs mass m_H obtained from the Standard Model fits made with the modified value of $\Delta\alpha^5_{had}(m^2_Z)$ obtained with the R_{had} shifted by the uncertainty of its measurement in different c.m.s. regions. m_H shifts of about 15 GeV are obtained when R_{had} is modified in the region of 2-5 GeV, recently measured by the BES collaboration, and also for the region of 1-2 GeV where precise measurement are not available.

The modification of our result due to the recent improvement in the treatment of radiative corrections by the CMD2 Collaboration has a small effect on the SM fit as seen in Fig. 18. On the other

Table 1
Shift of central value of the Higgs mass m_H obtained from the Standard Model fits made with the modified value of α obtained with the R_{had} shifted by uncertainty of its measurement in different c.m.s. regions.

c.m.s. region	uncertainty (%)	m_H shift	main experiment
ρ	2.3	-4.9,5.0	CMD2
narrow resonances	3.1	-3.1,3.6	
1-2 GeV	15	-13.6,15.2	
2-5 GeV	5.9	-13.1,14.2	BES
5-7 GeV	6	-6.7,7.3	Crystal Ball
7-12 GeV	1.4	-2.5,2.7	
>12 GeV	0.2	-1.2,1.3	

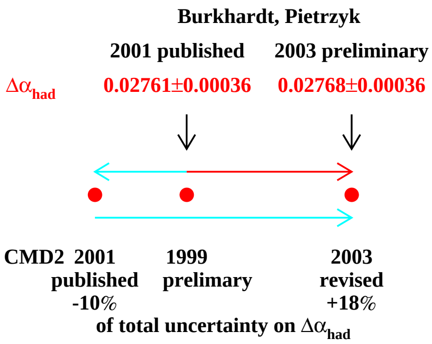

Figure 16. Changes of the value of $\Delta\alpha^5_{had}(m_Z^2)$ caused by improvements in calculations of radiative corrections by the CMD-2 Collaboration in units of the total uncertainty of $\Delta\alpha^5_{had}(m_Z^2)$.

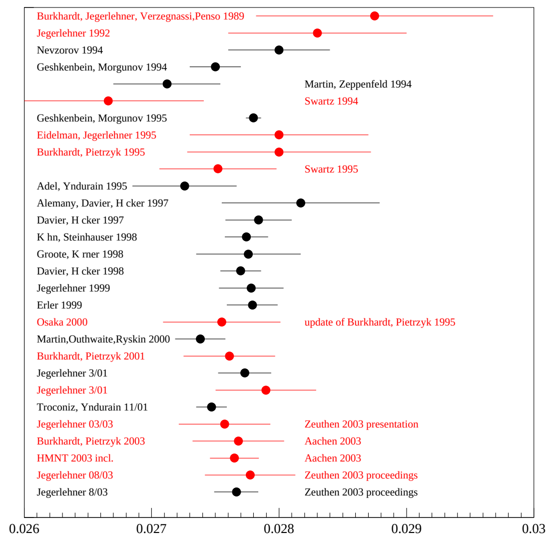

Figure 17. Comparison of different estimates of $\Delta\alpha^5_{had}(m_Z^2)$ since 1989.

hand, some large effects are expected in the near future due to a possible change of the top mass. In fact the top mass combination used in the SM fit does not take into account the improved analysis of run I data made by the D0 Collaboration as seen in Fig. 19. The combination using all available data could shift the combined top mass by about one standard deviation which would have a major impact on the SM fit results as seen in Fig. 18.

In conclusion, the measurements discussed in this workshop are very important for fundamental physics questions. A new more precise value of $\Delta\alpha^5_{had}(m_Z^2)$ will come with new measurements from CDM2, KLOE, BES, CLEO, BABAR and BELLE.

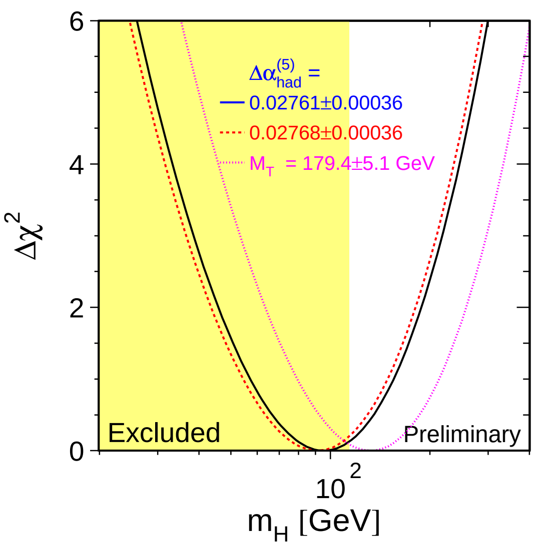

Figure 18. $\Delta\chi^2(\mathrm{m_H})$ with modified $\Delta\alpha^5_{\mathrm{had}}(\mathrm{m_Z^2})$ and $\mathrm{m_H}$.

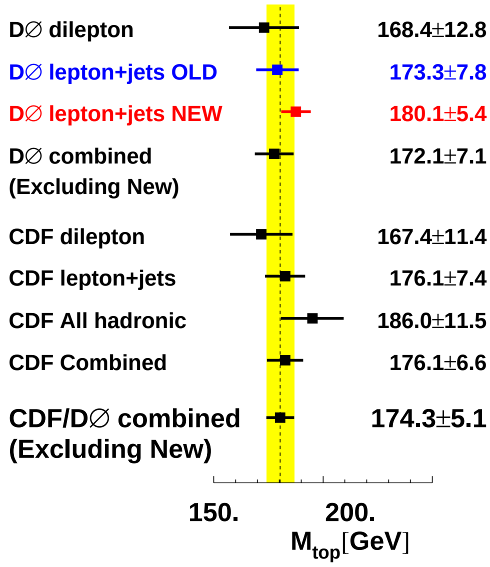

Figure 19. Top mass combination.

I would like to thank the organizers for inviting me to come to this very interesting and important workshop and also H. Burkhardt, S. Eidelman, P. Gambino, M. Grünevald, G. Quast, P. Wells and T. Teubner for helping me in the preparation of this talk.

REFERENCES

1. LEP Electroweak Working Group, http://lepewwg.web.cern.ch/LEPEWWG/; see also presentation during summer 2003 conferences: P. Wells and G. Quast, HEP2003 Europh. Conf. in Aachen, Germany, http://eps2003.physik.rwth-aachen.de/, P. Gambino, XXI Int. Symp. on Lepton and Photon Int., Fermilab, http://conferences.fnal.gov/lp2003/index.htm.
2. see P. Gambino's presentation at XXI Int. Symp. on Lepton and Photon Int., Fermilab, http://conferences.fnal.gov/lp2003/index.htm.
3. B. Pietrzyk, *The Global Fit to Electroweak Data*, Proc. of ICHEP 2000, Osaka, Japan, 27 July-2 August 2000, Ed. C.S. Lim and T. Yamanaka, page 710.
4. H. Burkhardt and B. Pietrzyk, Phys. Lett. B513 (2001)46.
5. BES Collaboration, J.Z. Bai, Phys.Rev.Lett. 88:101802,2002.
6. R.R. Akhmetshin et al., CMD-2 Collaboration, hep-ex/9904027.
7. R.R. Akhmetshin et al., CMD-2 Collaboration, Phys. Lett. B527 (2002)161.
8. R.R. Akhmetshin et al., CMD-2 Collaboration, hep-ex/0308008.
9. T. Teubner, these proceeding, see also his presentation at HEP2003 Europh. Conf. in Aachen, Germany, http://eps2003.physik.rwth-aachen.de/.