QCD CORRECTIONS TO DECAYS OF INTERMEDIATE MASS HIGGS BOSON

A. L. Kataev[1), V. T. Kim

1) *Institute for Nuclear Research, 117312,Moscow*

Among the most intriguing modern theoretical problems are the investigations of the properties of still non-discovered Higgs particles of the Standard Model (SM) for ElectroWeak interactions. The special attention is paid nowadays to the searches of the SM Higgs boson. Various aspects of "Higgs hunting" were discussed in detail from the theoretical and the phenomenological [1–3] points of view.

The current experimental lower bound on the SM Higgs boson mass is about $M_H \geq 60$ *GeV*. This lower bound came from the analysis of the LEP data taking into account of the theoretical expression for $H \to q\bar{q}$ decay width with the QCD corrections of order $O(\alpha_s)$ [4]. The main decay channel of the SM Higgs boson in the intermediate mass range $2m_b < M_H < 2M_W$ is the decay to the $b\bar{b}$ final states with the coupling constant being proportional to the b-quark mass. In this mass range the theoretical uncertainties of $\Gamma(H \to b\bar{b})$ are closely related to the theoretical uncertainties of the branching ratios of some rare processes, e.g., $H \to \gamma\gamma$ which is known as one of the most promising channels for the searches of not too heavy Higgs bosons at Tevatron, LEP, and soon at LEP200 and LHC.

Here we present brief overview of current status of perturbative QCD corrections to SM Higgs of intermediate mass. We start from analysis of the perturbative QCD corrections for the Higgs decay into b-quarks $\Gamma(H \to b\bar{b})$. The Born level width of this decay equals to

$$\Gamma(H \to b\bar{b}) \equiv \Gamma_{Hb\bar{b}} = \Gamma_0^{(b)}\beta^3 \qquad (1)$$

where $\Gamma_0^{(b)} = \frac{3\sqrt{2}}{8\pi}G_F M_H m_b^2$, $\beta = \sqrt{1 - \frac{4m_b^2}{M_H^2}}$, G_F — Fermi constant, M_H and m_b are the pole masses of Higgs boson and b-quarks, respectively.

The massless QCD corrections to $\Gamma(H^0 \to q\bar{q})$ were considered at the next-to-next-to--leading order (NNLO) using the concept of the running b-quark mass $\overline{m}_b(M_H)$ [5,6] In the process of the consideration of the phenomenological consequences of the results of Ref.[?] it was noticed that the variation of the running b-quark mass from the b-quark mass-shell (namely from the $\overline{m}_b(m_b)$-value) to the M_H-scale (namely to the $\overline{m}_b(M_H)$-value) in the leading order (LO) of perturbation theory results in the negative corrections, which diminish the value of the corresponding Born expression for $\Gamma_{Hb\bar{b}}$ by factor 2 [7].

However, the running mass is not the unique way of defining mass parameters. Indeed, in full analogy with the physical mass of electron, in QCD one can also define the pole (on-shell) quark mass. The definition of the pole quark mass is commonly used for heavy quarks, namely for c- and b-quarks. The expression for the decay width $H \to q\bar{q}$ has been explicitly calculated in terms of the pole quark masses m_c and m_b in Ref.[4], at the $O(\alpha_s)$-level. The presented in Ref.[2] numerical studies of these results did not reveal the effect of the 50% reduction of the Born approximation. Therefore, it is important to understand the origin of the observed in Ref.[2] puzzle of the differences between various parametrizations of the QCD results for $\Gamma_{Hb\bar{b}}$ in the experimentally interesting region of M_H values.

Using the 2-loop relation between the running and the pole quark masses [8] and the results of Ref.[6] we have calculated the expression for $\Gamma_{Hb\bar{b}}$ at the α_s^2-level in terms of the pole quark mass in two different forms [9–11]. The first one contains the $ln(M_H^2/m_b^2)$-contributions explicitly, while in the second one they have been summed up through the renormalization group (RG) technique. Note, that the second parametrization is closely related to the one through the running quark mass.

Our results demonstrate that for the non-RG-improved expression for $\Gamma_{Hb\bar{b}}$ calculated by us α_s^2-contribution produce the negative correction which is responsible for the elimination of the numerical difference between various parametrizations of the QCD results for $\Gamma_{Hb\bar{b}}$ (see Figs.1,2, where $R(H \to b\bar{b}) = \Gamma_{Hb\bar{b}}/\Gamma_0^{(b)}$).

In [9–11] we analysed in detail the RG-improved expression for $\Gamma_{Hb\bar{b}}$ taking into account the effects, neglected in the course of estimates of Ref.[7]. Among them are the corrections responsible for the relation between the running mass $\overline{m}_b(m_b)$ and the pole mass m_b at the 1-loop and 2-loop levels and the order $O(m_b^2/M_H^2)$-corrections to $\Gamma_{Hb\bar{b}}$. The importance of taking into account of the order $O(m_b^2/M_H^2)$-corrections for modeling the threshold effects was demonstrated in Refs.[9–11]. Following the considerations of Ref.[12] we also calculated analytically the mixed QED- and QCD- corrections of the order $O(\alpha\alpha_s)$ to $\Gamma_{Hb\bar{b}}$ [9], which turned out to be very small.

Taking into account the discussed above QCD uncertainties and the current uncertainties of the value of the parameter $\Lambda_{\overline{MS}}^{(5)}$ we obtain the following theoretical estimate for $\Gamma_{Hb\bar{b}}$ in the intermediate region of M_H values $60\ GeV < M_H < 160\ GeV$ (see Figs.1,2)

$$\Gamma_{Hb\bar{b}} = \left(0.55 - 0.45\right)\Gamma_0^{(b)} \tag{2}$$

which confirms the rough estimation presented in [7].

Therefore we confirmed also observation [7] that the discussed QCD contributions to $\Gamma_{Hb\bar{b}}$ are increasing the values of the branching ratios of the decays $H^0 \to l^-l^+$ and $H^0 \to \gamma\gamma$ by the factor of over 2 (see Fig.3) for the intermediate mass SM Higgs because the QCD corrections for them are small (few percents) [13]. Note, that all figures, presented here were plotted using the values of the pole quark masses $m_b = 4.6\ GeV$ and $m_c = 1.4\ GeV$ and $\Lambda_{\overline{MS}}^{(5)} = 250\ MeV$. The detailed consideration of the sensitivity of the results obtained to the variation of $\Lambda_{\overline{MS}}^{(5)}$ value up to over $150\ MeV$ is under study.

Note, that there is still room for curious speculation [11] on possible consequences of the observed property of the asymptotic explosion of the considered by us NNLO parametrization of $\Gamma_{Hb\bar{b}}$. We think it might indicate a possible existence of some resonance at the mass scale of $M_{ch} = 60 - 130$ GeV (for $\Lambda_{\overline{MS}}^{(5)} = 250 - 150$ MeV).

The results of our analysis [9–11] were taken into account in the series of the subsequent calculations [14–16]. In Ref.[14] the analyzed by us uncertainties due to the inclusion of the effects of the order $O(\alpha_s m_b^2/M_H^2)$-corrections were fixed by the explicit analytical calculations, while in Ref.[15] the mentioned by us contribution to $\Gamma_{Hb\bar{b}}$ of the triangle-type diagram with the virtual top-quark was evaluated. The large top-quark mass expansion for $H \to b\bar{b}$ decay rate in the order α_s^2 and for $H \to gluons$ decay rate in order α_s^3 were calculated in Ref.[16].

The outcomes of our studies of Refs.[9–11] are forming the basis for the FORTRAN code SEEHIGGS, which includes the results of the most recent calculations of Refs.[14–16] and is under development.

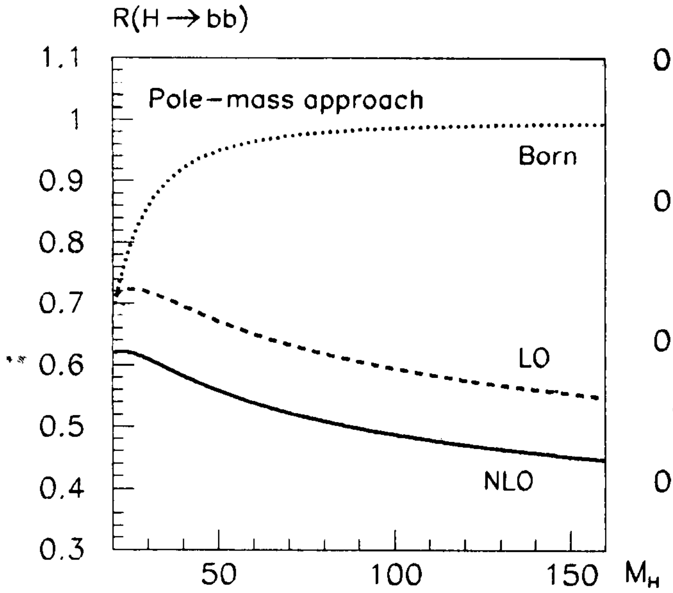

Fig.1.

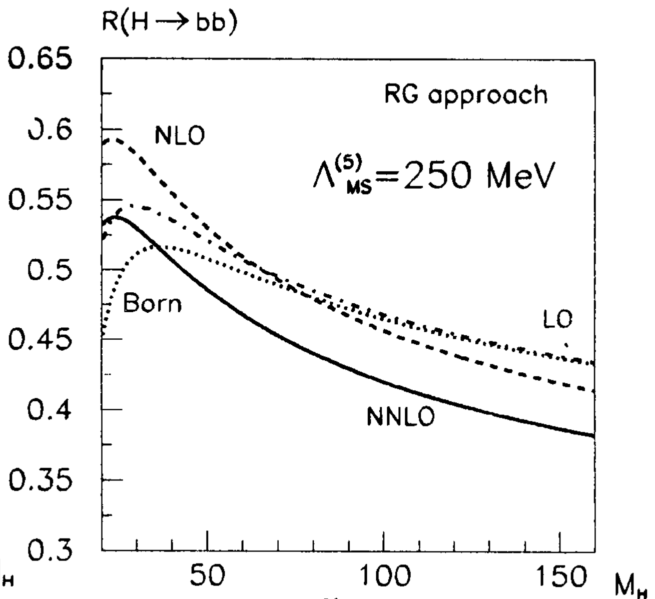

Fig.2.

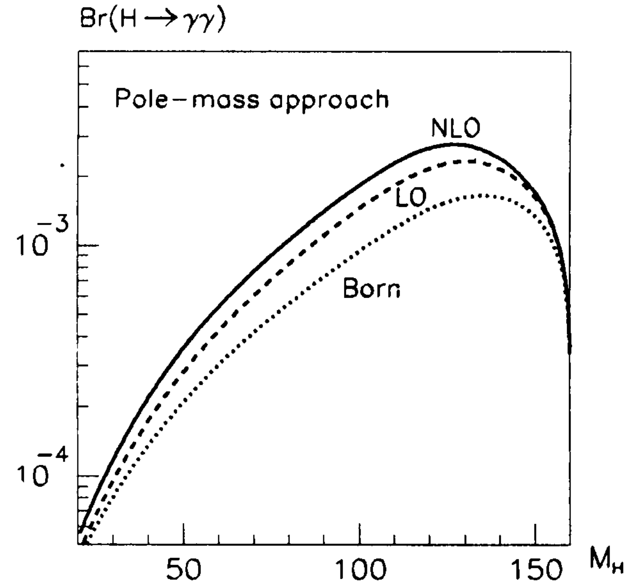

Fig.3.

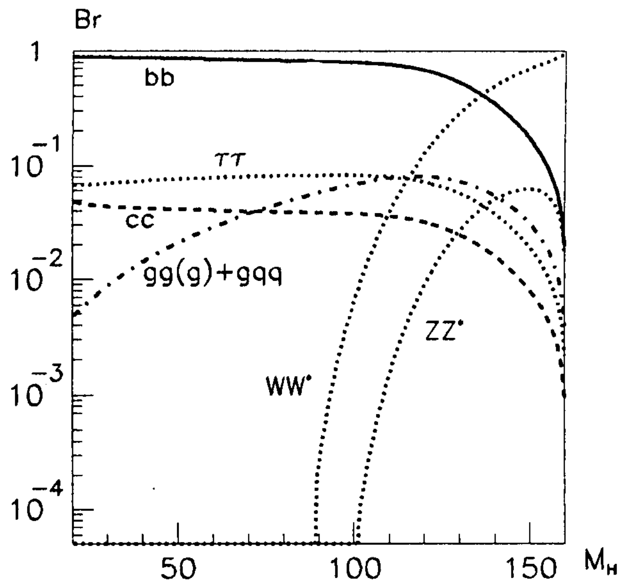

Fig.4.

This work on this brief report was done within the project N96-02-18897 of the Russian Foundation for Fundamental Research.

REFERENCES

1. *Veltman M.* The Higgs System. In: Perspectives in Higgs Physics, Ed. G.L.Kane, World Scientific, Singapore. 1993. P.1-45; Instituut-Lorenz report N°0601, Leiden. 1989.
2. *Gunion J.F., Haber H.E., Kane G.L., Dawson S.* The Higgs Hunter's Guide, Addison-Wesley Publishing Co. 1990.
3. *Haber H.E.* Invited talk at the Int. Europhysics Conf. on High Energy Physics, 1995, Brussels, CERN-TH/96-07. 1996; *Djouadi A., Spira M., Zerwas P.M.* Preprint DESY 95-210. 1995; *Kniehl B.A.* //Int.J.Mod.Phys., 1994. **A10**. 443.
4. *Braaten E., Leveille J.P.* //Phys.Rev., 1980. **D22**. 715; *Drees M., Hikasa K.* //Phys.Rev., 1990. **D41**. 1547; //Phys.Lett., 1990. **B240**. 455; ibid. 1991. **B262**. 497 (E).
5. *Gorishny S.G., Kataev A.L., Larin S.A.* //Sov.J.Nucl.Phys., 1984. **40**. 329.
6. *Gorishny S.G., Kataev A.L., S.A.Larin S.A., Surguladze L.R.* //Mod.Phys.Lett., 1990. **A5**. 2703; //Phys.Rev., 1991. **D43**. 1633.
7. *Kleiss R., Kunszt Z., Stirling W.J.* //Phys.Lett., 1991. **B253**. 269.
8. *Gray N., Broadhurst D.J., Grafe W., Schilcher K.* //Z.Phys., 1990. **C48**. 673.
9. *A.L.Kataev A.L., Kim V.T.* ENSLAPP-A-407/92, Annecy. 1992).
10. *Kataev A.L., Kim V.T.* In: Proc. III Int. Workshop on Software Engineering, Artificial Intelligence and Expert Systems in High Energy and Nuclear Physics, October 1993, Oberammergau, Germany, Eds. K.-H.Becks and D.Perret-Gallix, World Scientific, Singapore. 1994. P.623-637.
11. *Kataev A.L., V.T.Kim V.T.* //Mod.Phys.Lett., 1994. **A9**. 1309.
12. *Kataev A.L.* //Phys.Lett., 1992. **B287**. 209.
13. *Djouadi A., Spira M., Zerwas P.M.* //Phys.Lett., 1991. **B264**. 440.
14. *Surguladze L.R.* //Phys. Lett., 1994. **B341**. 61.
15. *Chetyrkin K.G., Kwiatkowski A.* LBL-37269, Berkeley. 1995.
16. *Larin S.A., van Ritbergen T., Vermaseren J.A.M.* //Phys. Lett., 1995. **B362**. 134.

KINETICS OF EXCITED MUONIC HYDROGEN

W. Czaplinski$^{1)}$, **A. Gula**$^{1)}$, **A. Kravtsov**,
A. Mikhailov, **N. Popov**$^{2)}$

$^{1)}$ *Institute of Physics and Nuclear Technique, Krakow*
$^{2)}$ *München University, München*

1. One of the crucial characteristics of the muon catalyzed fusion in the deuterium-tritium mixture, which determines the efficiency of the synthesis, is a ground state population of muonic deuterium, q_{1S}. Soon after the first calculations were made for the q_{1S} value [1] it