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Handling Complex Poles in Higgs Production and Decay

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A simple recipe and a code

1 The recipe

This short note will explain hot to deal with the Heavy Higgs boson lineshape. Let i, j be partons and F an arbitrary final state, e.g., $\gamma\gamma, 4\,\mathrm{f}$, etc.. Here we deal with the signal, i.e., $ij \to \mathrm{H} + \mathrm{X} \to \mathrm{F}$; therefore, the object of interest is

$$\sigma_{\mathrm{F}} = \frac{1}{\pi}\,\sigma_{ij\to\mathrm{H}+\mathrm{X}}\ \ \mathrm{Prop}\ \ \frac{\Gamma_{\mathrm{H}\to\mathrm{F}}(M)}{M}, \tag{1}$$

where M is the virtuality of the Higgs boson and both the production cross-section and the partial decay width are referring to an off-shell Higgs boson. Note that $\sigma_{ij\to\mathrm{H}+\mathrm{X}}$ has the dimensions of a cross-section and the corresponding phase-space; furthermore, remaining integrations (e.g. over the Higgs virtuality) are in terms of dimensionless quantities (e.g. over z with $M^2 = z\,s$, s being the pp invariant mass).

The question is "what to use for the propagation function?" Let Q^2 be the invariant mass of the $\{i, j\}$ system, the solution is

$$\mathrm{Prop} = \frac{Q^2 M^2}{\Bigl|M^2 - s_{\mathrm{H}}\Bigr|^2}, \tag{2}$$

where s_{H} is the Higgs boson complex pole, parametrized as

$$s_{\mathrm{H}} = \mu_{\mathrm{H}}^2 - i\,\mu_{\mathrm{H}}\,\gamma_{\mathrm{H}} \tag{3}$$

A completely equivalent formulation uses

$$\mathrm{Prop} = \Bigl(1 + \frac{\overline{\Gamma}_{\mathrm{H}}^2}{\overline{M}_{\mathrm{H}}^2}\Bigr)\,\frac{Q^2 M^2}{\Bigl(M^2 - \overline{M}_{\mathrm{H}}^2\Bigr)^2 + \Bigl(\frac{\overline{\Gamma}_{\mathrm{H}}}{\overline{M}_{\mathrm{H}}}\,M^2\Bigr)^2}, \tag{4}$$

where $\overline{M}_{\mathrm{H}}, \overline{\Gamma}_{\mathrm{H}}$ are the mass and the width in the bar - scheme.

$$\overline{M}_{\mathrm{H}}^2 = \mu_{\mathrm{H}}^2 + \gamma_{\mathrm{H}}^2 \qquad \mu_{\mathrm{H}}\,\overline{\Gamma}_{\mathrm{H}} = \overline{M}_{\mathrm{H}}\,\gamma_{\mathrm{H}}. \tag{5}$$

To be cited as [1–3].

2 The code

CPHTO computes $\gamma_{\rm H}, \overline{M}_{\rm H}$ and $\overline{\Gamma}_{\rm H}$, as a function of the input parameter $\mu_{\rm H}$, within the Standard Model. Typical output will be

```
*
 *
  * --- cpHTO v 1.0 (December 2011) by Giampiero
 *
*

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******* OUTPUT *************************************

top mass [GeV]          0.17250E+03
muh      [GeV]          0.60000E+03                 ! input
GH OS    [GeV] =      0.1230000E+03                 ! the on-shell width

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+++++ gh details  +++++++++++++++++++++++++++++++++

gH Bos     [GeV] =        0.92181E+02               ! bosonic part of gamma_H
gH top     [GeV] =        0.15437E+02               ! top          ''
gH LightF  [GeV] =        0.17878E-01               ! light fer.  ''
gH Total   [GeV] =      0.1039327E+03               ! gamma_H

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*** Bar scheme *************************************

MHB      [GeV] =        0.60894E+03                 ! the bar - scheme mass
GHB      [GeV] =        0.10548E+03                 ! the bar - scheme width

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References

[1] G. Passarino, C. Sturm and S. Uccirati, Nucl. Phys. B **834** (2010) 77 [arXiv:1001.3360 [hep-ph]].

[2] S. Goria, G. Passarino and D. Rosco, arXiv:1112.5517 [hep-ph].

[3] L.H.C.Higgs Cross Section Working Group *et al.*, arXiv:1201.3084 [hep-ph].