Higgs Decay to Photons at Two Loops

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Outline

- Introduction
- Born niveau
- Corrections due to light fermions
- Top-quark-induced corrections
- Purely bosonic corrections
- Resulting NLO corrections
- Conclusion

Introduction

- Here: Standard Model (SM) with one Higgs boson (H)
- Electroweak precision measurements favour Higgs with small mass (between 114 GeV and $\approx$ 200 GeV at 95% CL)
- This mass range is compatible with intermediate-mass range $M_W \leq M_H \leq 2M_W$
- Higgs-decay into two photons important detection channel in this mass range at Large Hadron Collider (LHC) due to clear signature, though branching fraction of only up to 0.3%

- Also: Useful decay channel for measurement of properties of Higgs boson

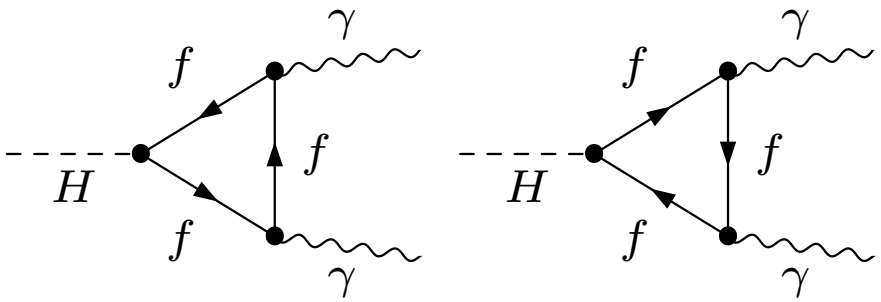
- At future ILC: Precision measurements; two photon mode with fusion process $\gamma\gamma \to H$ possible

$\to$ Precise prediction of decay width $\Gamma(H \to \gamma\gamma)$ in intermediate-mass range required

Here: Review of NLO calculation, focusing on electroweak (EW) corrections

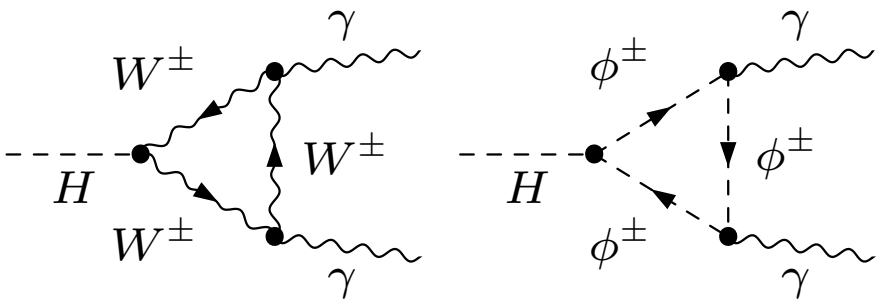
Born niveau

Diagrams with virtual fermions



→ Only Top quark contributes, contributions of light fermions negligible

Further 26 diagrams

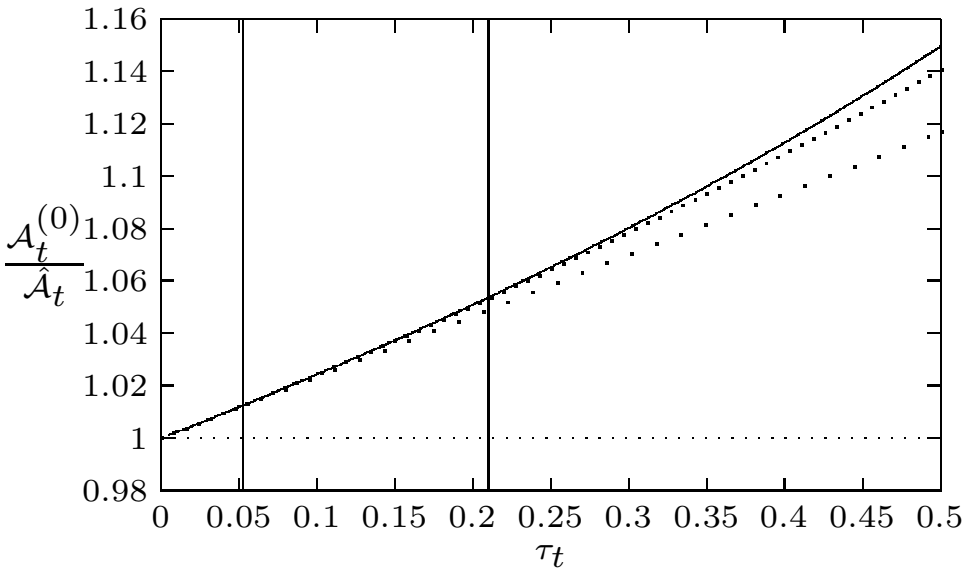


$\longrightarrow$ W-bosons, Goldstone-bosons and ghosts occur in the loops

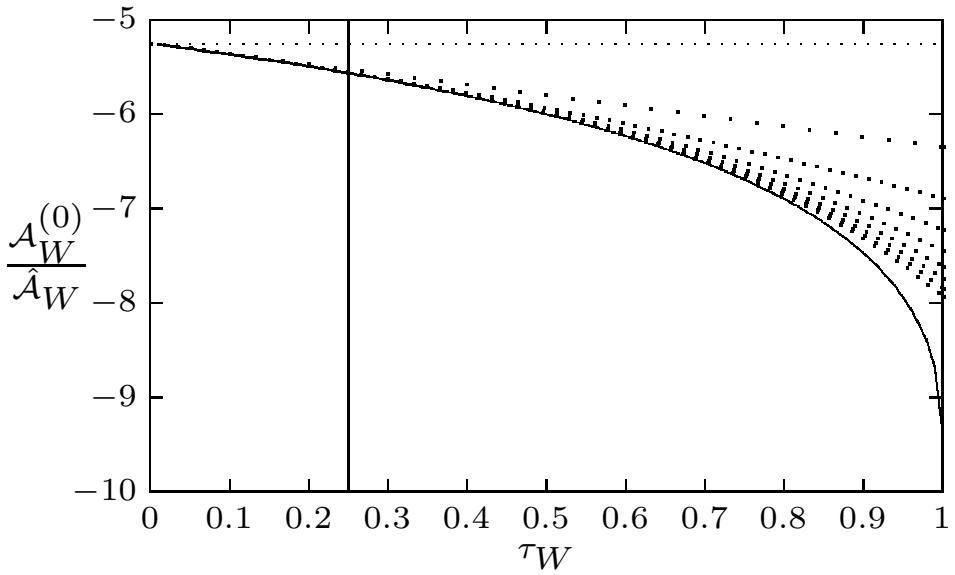
Calculation

- Decay is loop-induced
- Sensitive to new charged massive particles
- Naive expansion in external momenta possible
- Expansion parameters: $\tau_t = \frac{M_H^2}{4M_t^2}$ and $\tau_W = \frac{M_H^2}{4M_W^2}$
- Agreement with expansions of exact results
  [Ellis, Gaillard, Nanopoulos; Higgs Hunter's Guide]

Contribution to Born niveau from Top quark

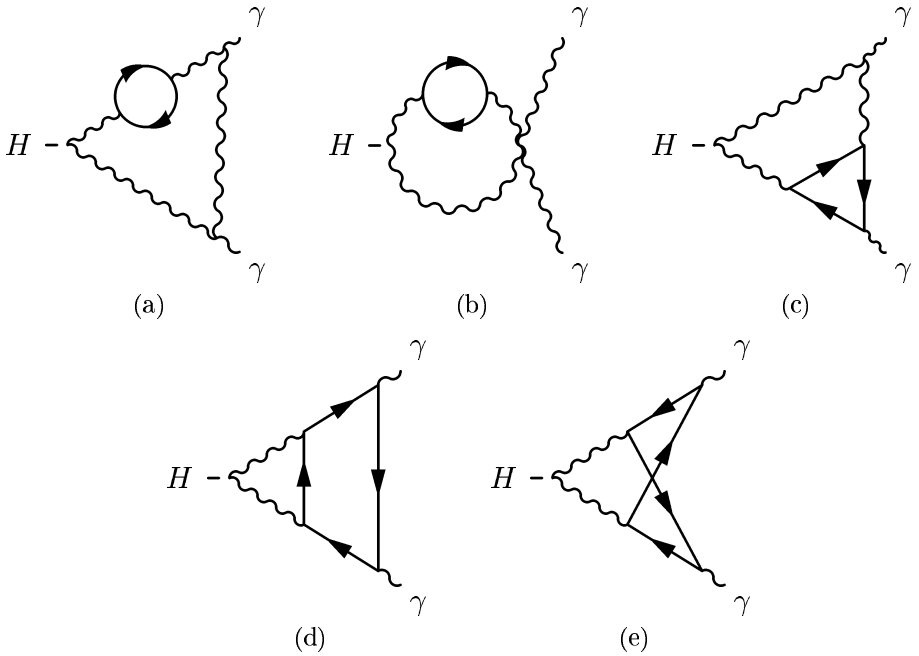


Contribution to Born niveau from bosons and ghosts



Corrections due to light fermions

Sample diagrams for light fermion contributions



Calculation

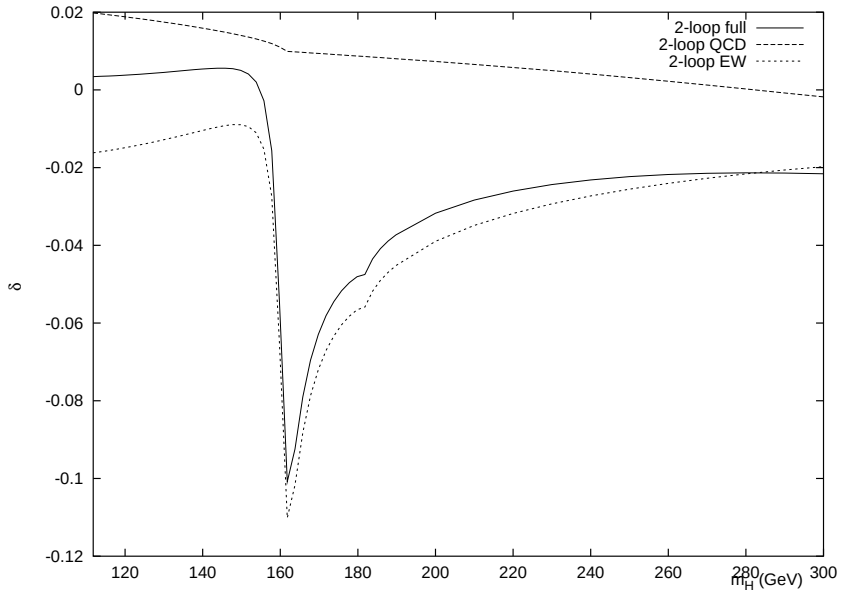
- Light fermions taken to be massless
- Sum over generations
- Asymptotic Expansion not possible $\longrightarrow$ complete calculation
- Employ Background Field Method (BFM) quantisation framework in order to reduce number of diagrams

- Project out scalar amplitudes and reduce them to set of linearly independent ones
- Apply Integration-By-Parts identities in order to reduce these to master integrals
- Evaluate master integrals by means of differential equations
- Result expressed in terms of Generalised Harmonic Polylogarithms

- Gauge-invariance checked
- Unphysical singularity at 2W-threshold regularised by means of the replacement $M_W \to M_W - i\Gamma_W/2$
- In the region between 150 GeV and 170 GeV result has to be taken with some caution; for all other masses result independent on regulator

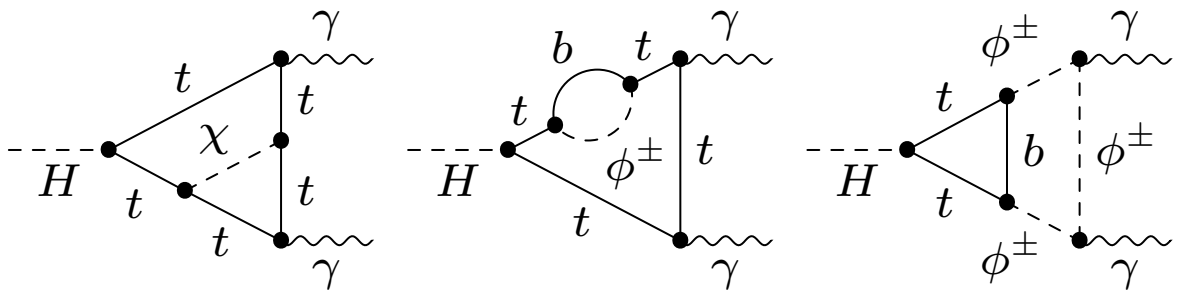
$\to$ [U. Aglietti, R. Bonciani, G. Degrassi and A. Vicini, Phys. Lett. B **595** (2004) 432]

Corrections due to light fermions



Top-quark-induced corrections

Sample diagrams



→ Exchange of Higgs boson, Goldstone bosons and W-boson

Calculation of leading term proportional $G_F m_t^2$

- Bottom-quark massless, quark-mixing-matrix taken as unit matrix
- Application of Asymptotic Expansion in order to obtain correction of order $\mathcal{O}(G_F m_t^2)$ as an expansion in τ_W up to and including $\mathcal{O}(\tau_W^4)$
- Employ onshell-scheme, dimensional regularisation, anticommuting γ_5, general R_ξ -gauge

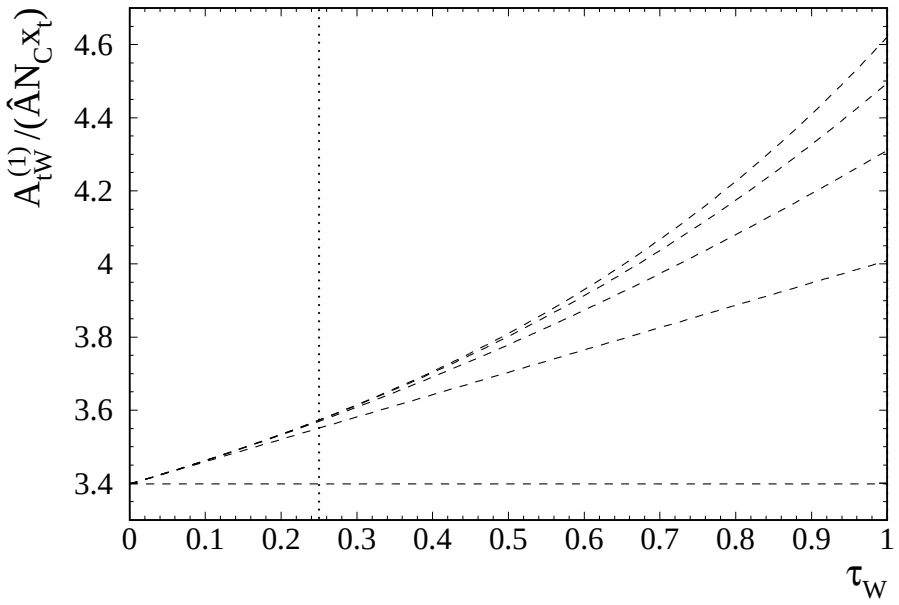
- Include Tadpole diagrams
  $\longrightarrow$ m_t^4-terms cancel in sum of contributions from genuine Tadpole diagrams, counterterms and non-trivial terms in Asymptotic Expansion

- Fully automated computation of $\mathcal{O}(1000)$ diagrams (in R_ξ-gauge)

- Checks: Result is transversal, UV-finite, independent of gauge parameter

$\longrightarrow$ [FF, B. A. Kniehl and M. Steinhauser, Nucl. Phys. B **702** (2004) 333]

Corrections of order $\mathcal{O}(G_F m_t^2)$

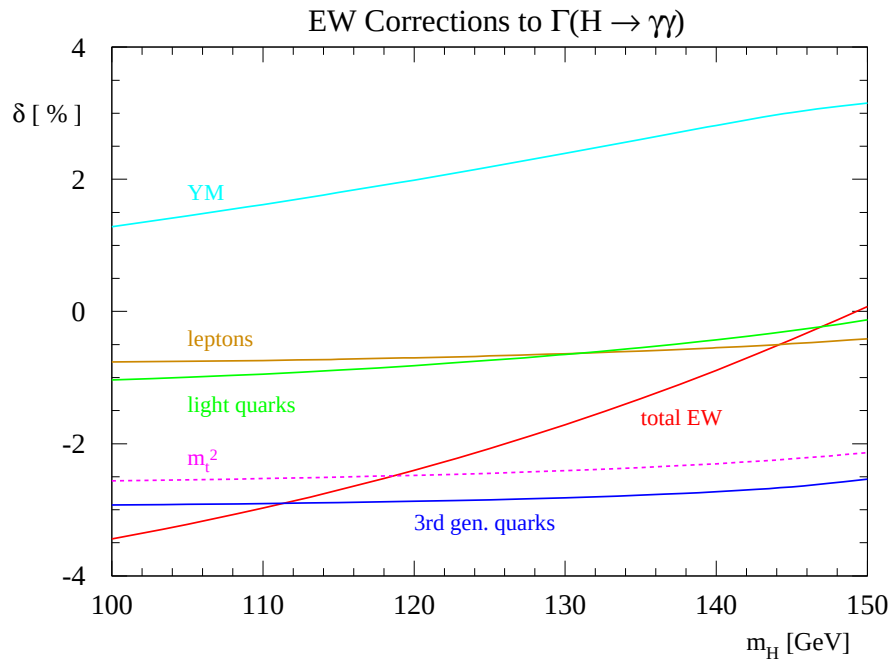


Calculation of complete correction induced by Top-quark

- Complete correction has been obtained as an expansion in the Higgs external momentum, improved by Padé approximation
- $\mathcal{O}(G_F m_t^2)$-result can be extracted and is found to agree
- Method of calculation: See "Purely bosonic corrections"

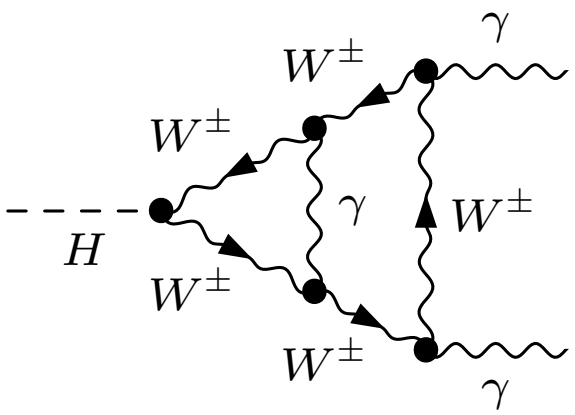
$\longrightarrow$ [G. Degrassi and F. Maltoni, Nucl. Phys. B **724** (2005) 183]

Complete corrections induced by Top quark



Purely bosonic corrections

Sample diagram



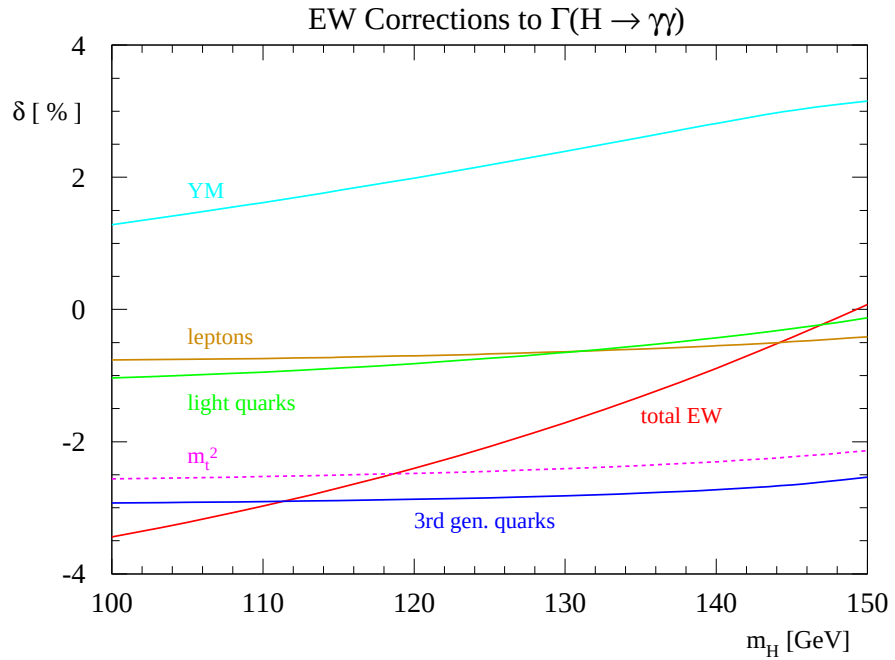
Calculation

- Employ BFM and use Tadpole counterterm
- Generate diagrams with FeynArts and project out relevant form factor
- Perform Taylor expansion in $q_W = \frac{q^2}{4M_W^2}$ with Higgs external momentum q
- Expansion obtained up to and including $\mathcal{O}(q_W^3)$

- Renormalise gauge parameter in order to obtain finite individual terms in the expansion in q_W
- Now improve result by means of Padé approximation
- Abelian gauge invariance checked

$\longrightarrow$ [G. Degrassi and F. Maltoni,
Nucl. Phys. B **724** (2005) 183]

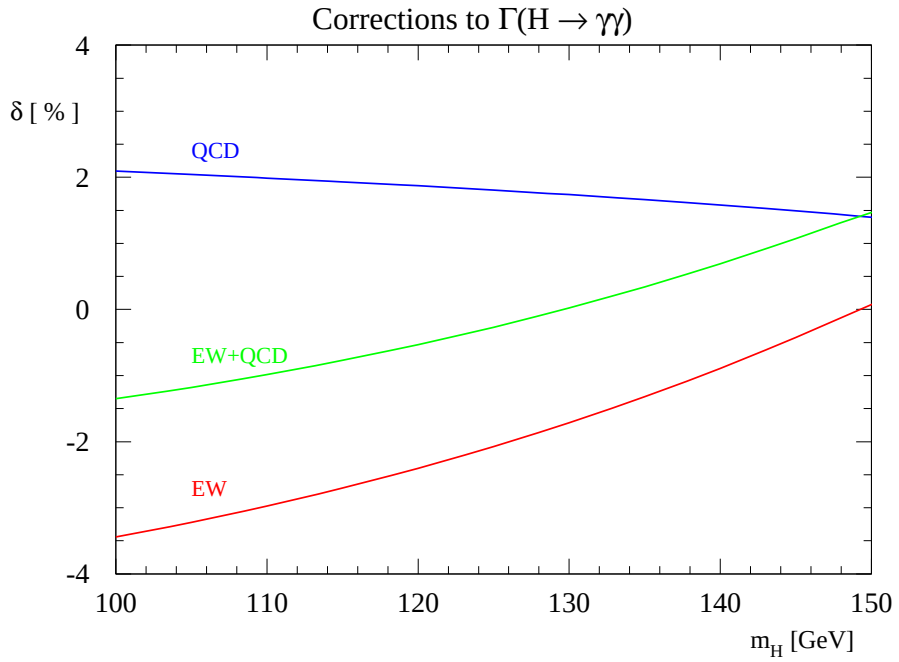
Purely bosonic corrections



Resulting NLO corrections

- Contributions from virtual fermions negative, purely bosonic contributions positive - in analogy to Born niveau
- QCD corrections (affecting only the one-loop diagrams with virtual Top-quarks) also small and positive
- In the case of the QCD corrections a naive expansion in the parameter τ_t can be performed which leads to rapidly converging series

Complete corrections at NLO



Conclusion

- The EW NLO corrections to the Higgs-decay into two photons for an intermediate-mass Higgs boson have been reviewed
- The sum of the EW corrections range from $\sim -4\%$ to $\sim 0\%$ for M_H between 100 GeV and 150 GeV
- The EW and QCD corrections cancel partly leaving over a small correction less than $\pm 1.5\%$
- So the NLO calculation already gives a reliable prediction

Some figures have been borrowed, with kind permission, from:

[U. Aglietti, R. Bonciani, G. Degrassi and A. Vicini,
Phys. Lett. B **595** (2004) 432]

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