

MSSM Corrections to Higgs Self-Couplings

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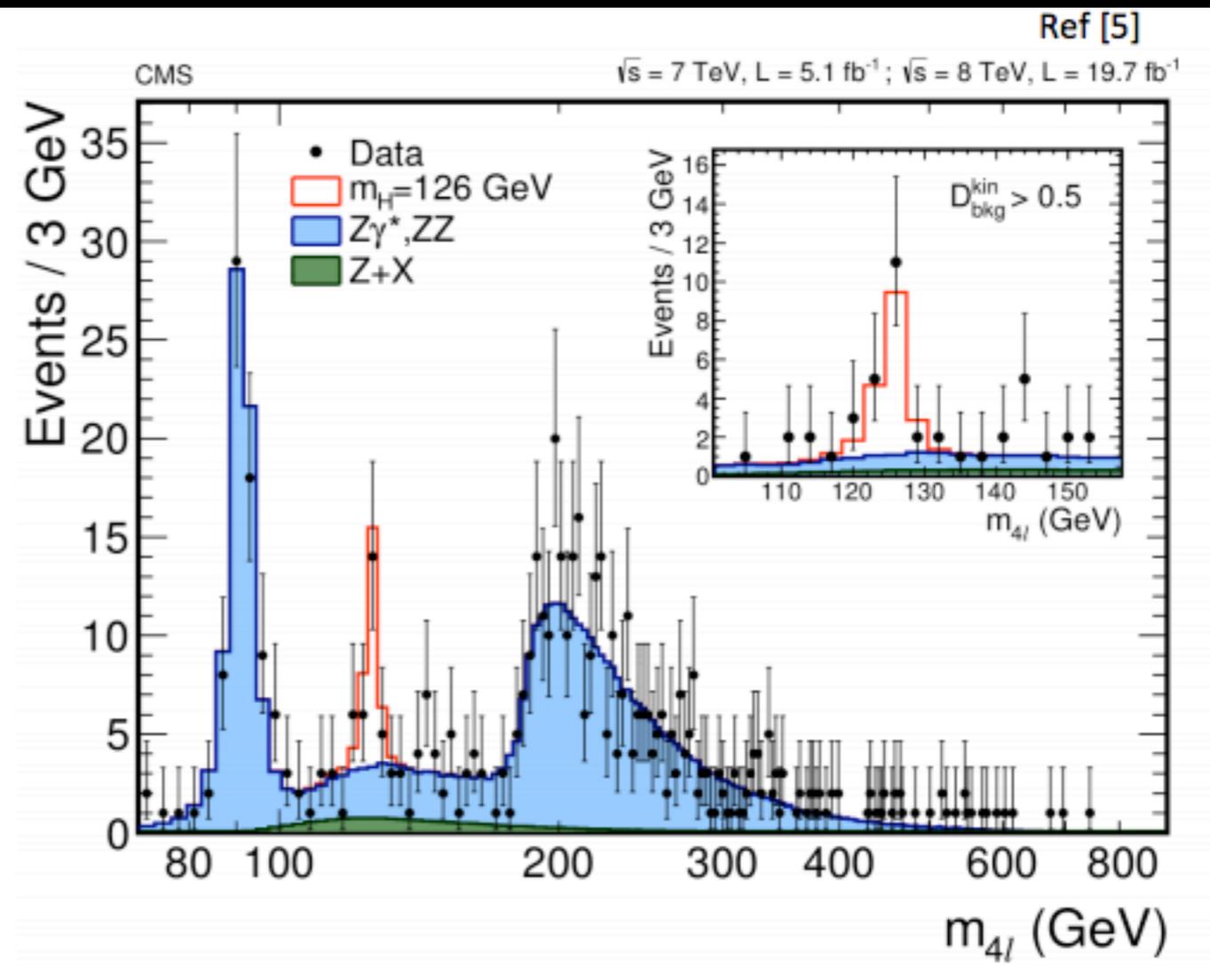
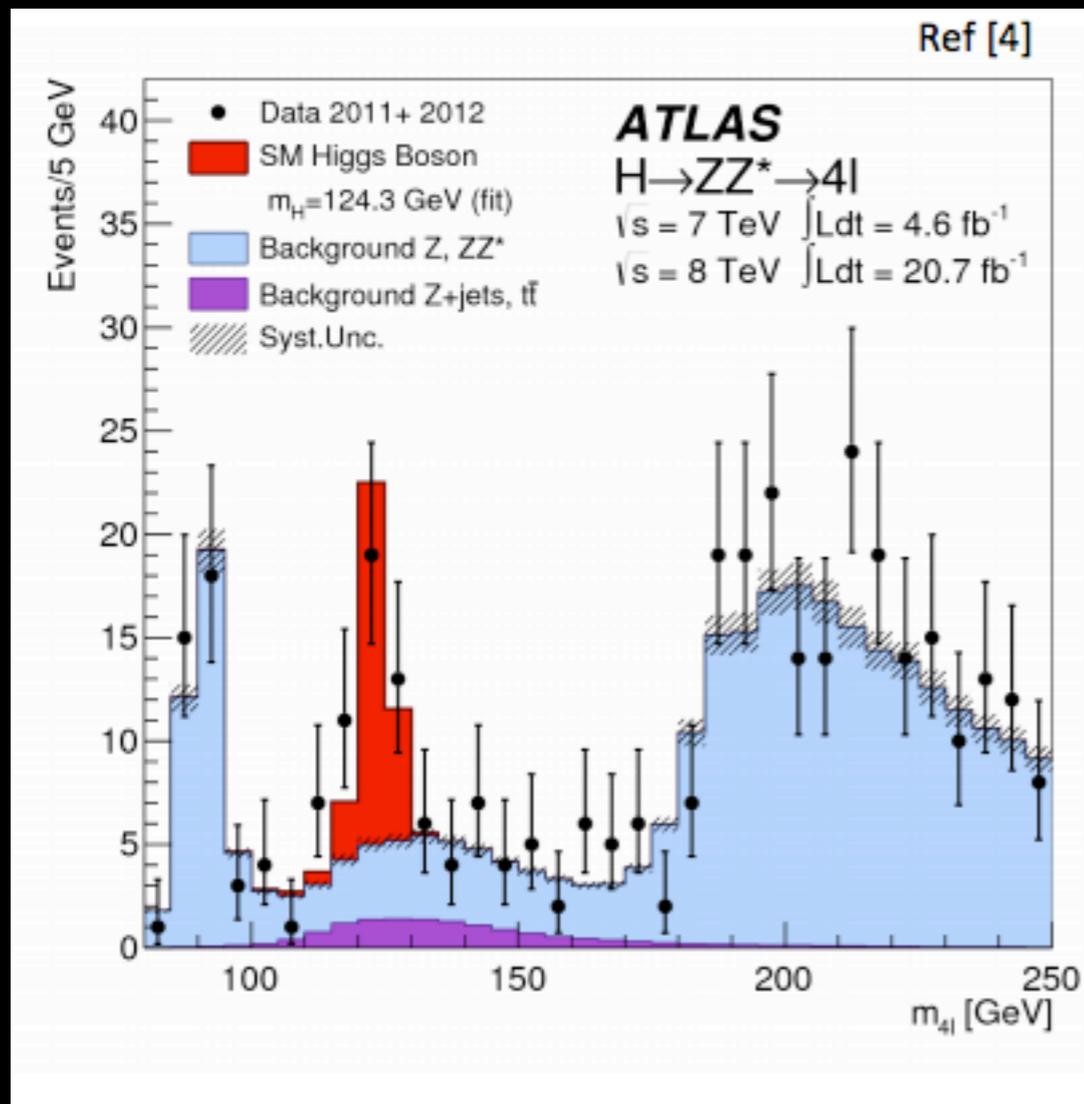
with M Brucherseifer and M Spira

Pheno 14
May 6, 2014

arXiv: 1309.3140

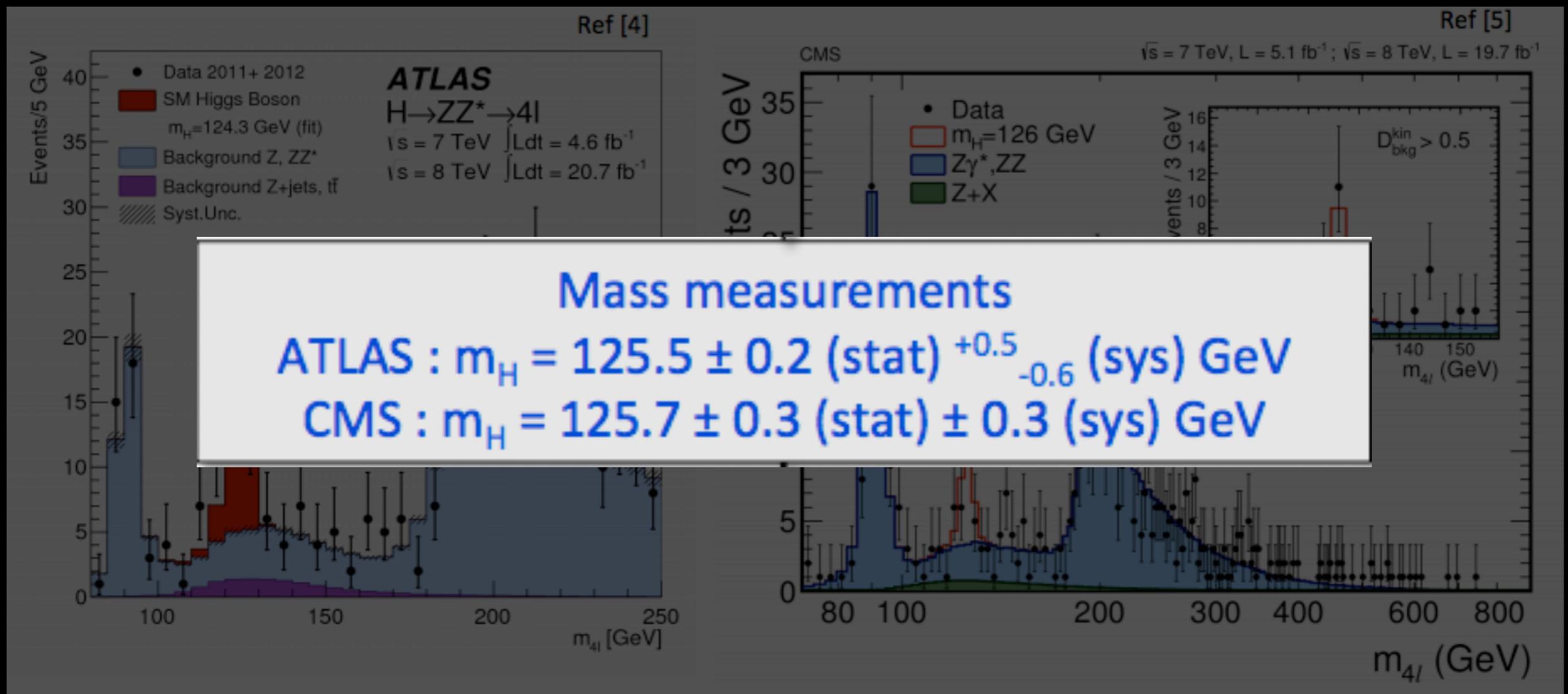
New Boson ϕ Discovered

- July 4th, 2012 - CERN announces discovery of new particle



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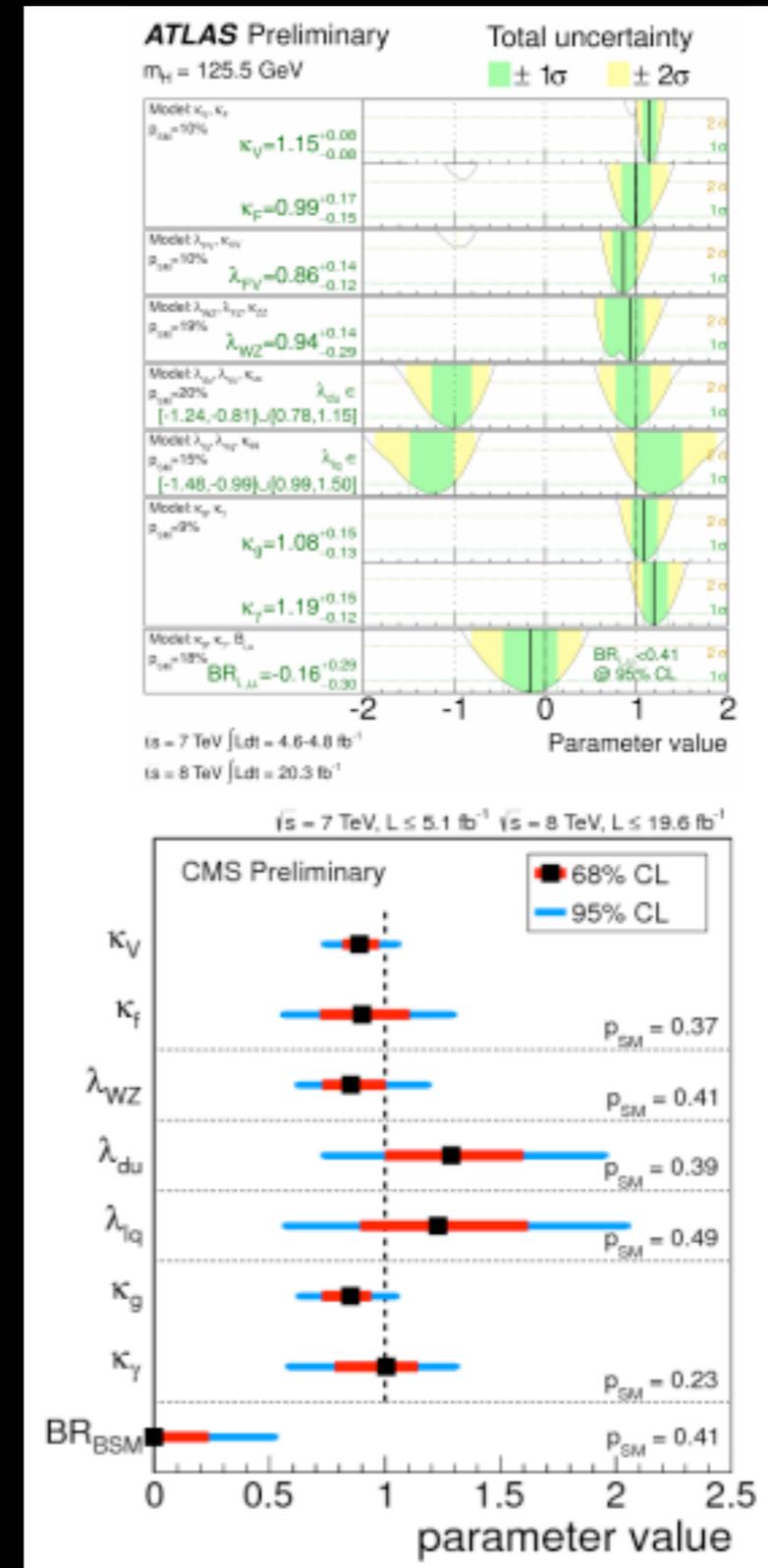
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G. Halladjian - Monday AM Plenary Talk

New Boson ϕ Discovered

- ϕ consistent with SM Higgs boson
 - couplings consistent within uncertainties
 - spin/parity consistent with $J_{\phi}^P = 0^+$ D. Bortoletto - Monday AM Plenary Talk
- Room remains for BSM Higgs physics



G. Halladjian - Monday AM Plenary Talk

Compatible with MSSM?

- In the MSSM: 5 physical Higgs bosons
 - 2 scalar: h, H
 - 1 pseudoscalar: A
 - 2 charged: H^+, H^-
 - $M_h < M_Z$

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- In decoupling limit, $h_{\text{MSSM}} \rightarrow H_{\text{SM}}$

Motivation

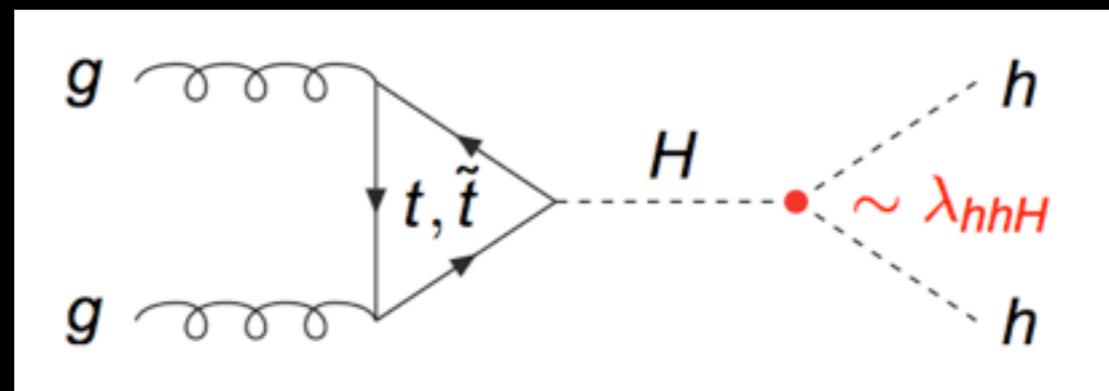
- Higgs self-interactions determine Higgs potential
 - Higgs potential is responsible for Electroweak Symmetry Breaking
- ⇒ Need to measure Higgs self-couplings to understand EWSB

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- In SM: λ_{hhh} difficult at LHC, require linear collider
- MSSM: extra Higgs bosons could be promising for LHC processes

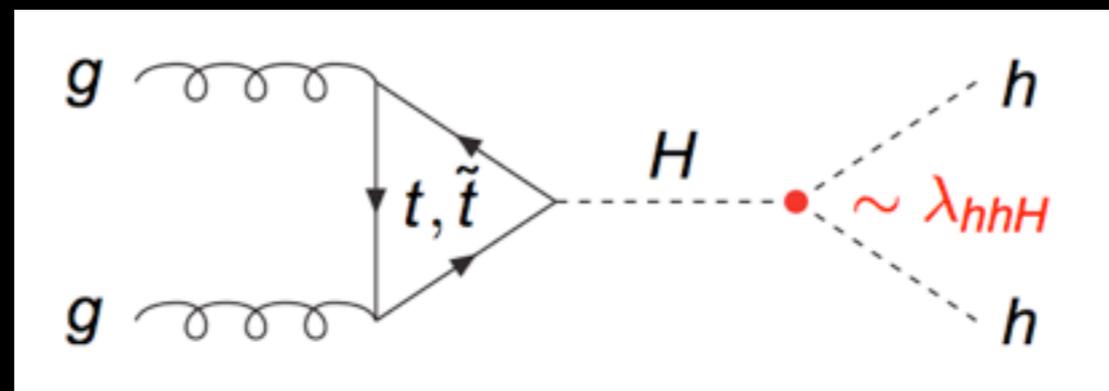
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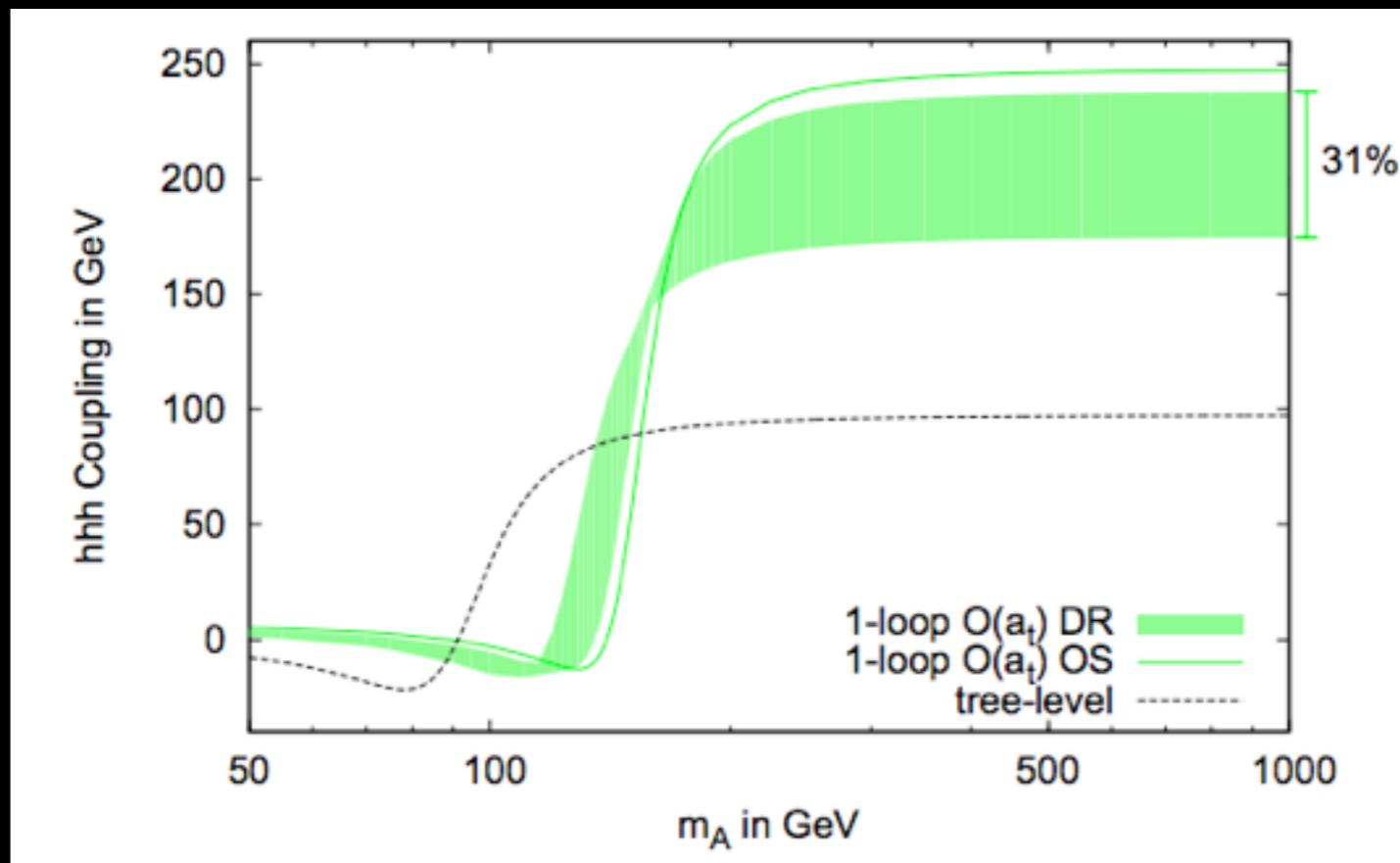
- Just as Higgs masses receive quantum corrections, so do the self-couplings
 \Rightarrow Need precise predictions for self-couplings

One-Loop $O(a_t)$

- One-loop corrections
 - top/stop contributions (bottom/sbottom if $\tan\beta$ is large)

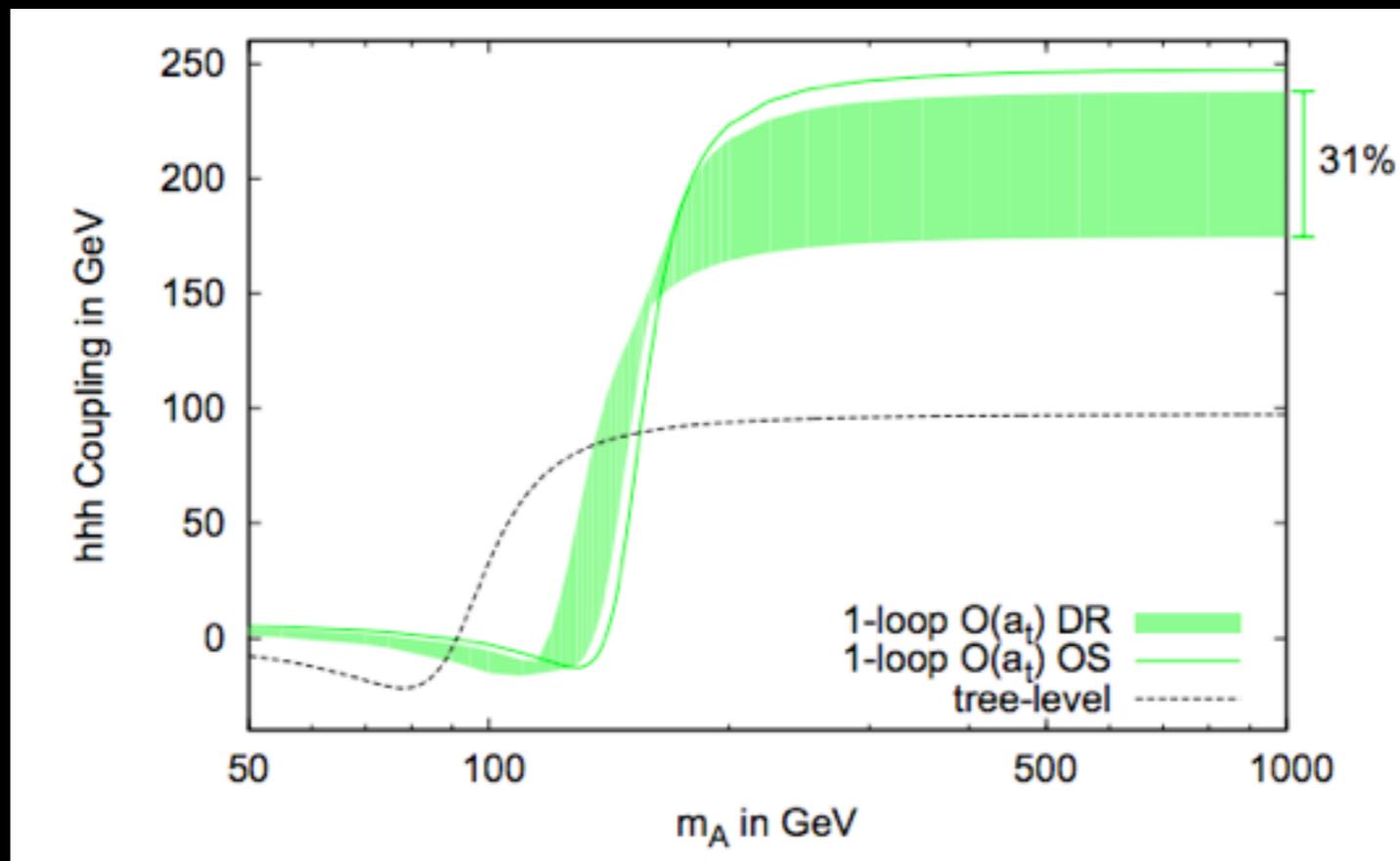
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- Large corrections & large uncertainties



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⇒ Two-loop calculation is needed

Effective Potential Method

- Effective Potential V^{eff} :
 - Non-derivative part of the effective action
→ correct in the limit of vanishing external momentum
 - generating functional of 1PI Greens functions with no external legs (vacuum diagrams)

Effective Potential Method

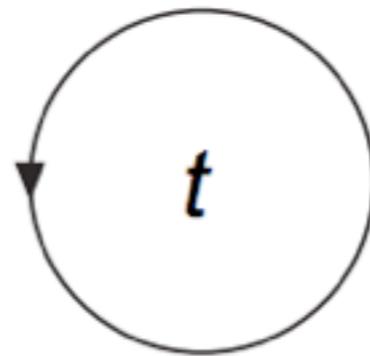
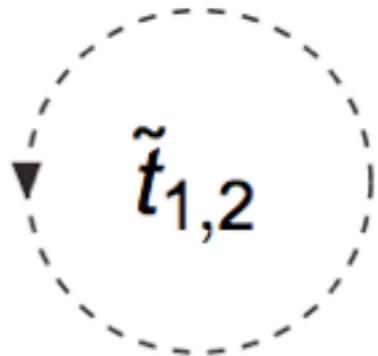
- Effective Potential V^{eff} :
 - Non-derivative part of the effective action
→ correct in the limit of vanishing external momentum
 - generating functional of 1PI Greens functions with no external legs (vacuum diagrams)
- n^{th} -derivative of V^{eff} : sum of all 1PI diagrams with n external legs

$$\lambda_{\mathcal{H}_i \mathcal{H}_j \mathcal{H}_k}^{\mathcal{O}(x)} = \left. \frac{\partial^3 V^{\mathcal{O}(x)}}{\partial \mathcal{H}_i \partial \mathcal{H}_j \partial \mathcal{H}_k} \right|_{min}$$

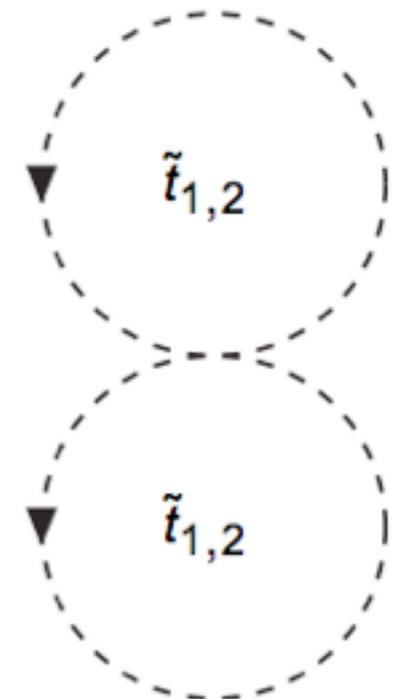
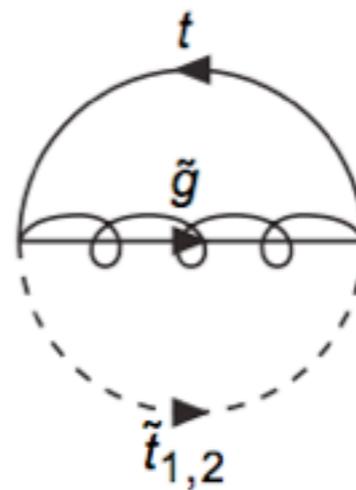
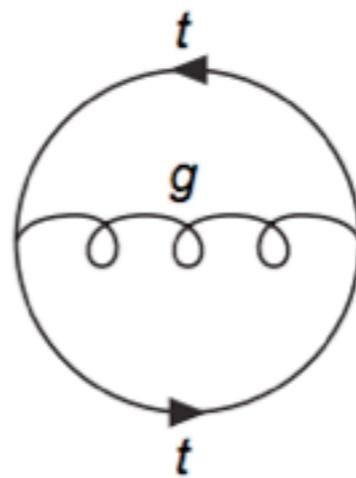
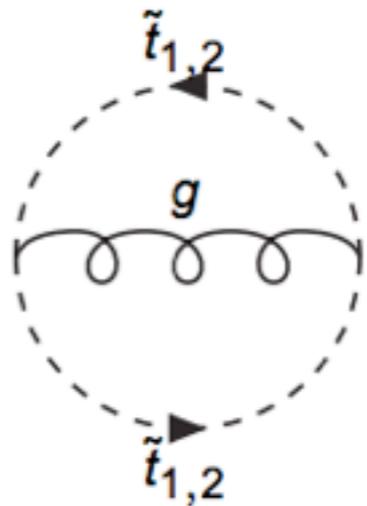
“effective coupling”

Calculation - $\mathcal{O}(\alpha_t)$ & $\mathcal{O}(\alpha_t\alpha_s)$

1-loop:
 $\mathcal{O}(\alpha_t)$



2-loop:
 $\mathcal{O}(\alpha_t\alpha_s)$



Zhang,...(1999)
Slavich,...(2001)

Calculation - $O(a_t)$ & $O(a_t a_s)$

- Calculate n^{th} -derivative for effective coupling
- ϵ^{-1} poles remaining from two-loop corrections are removed via $\overline{\text{DR}}$ renormalization
 - counterterms remove only the poles along with a few universal constants
 - $\overline{\text{DR}}$ scheme ensures tree level relationship between $\sin(2\theta_{\text{stop}})$ and A_t
- After renormalization, rotate to physical Higgs states

Numerics

“ $m_h^{\text{mod+}}$ ” scheme

arXiv: 1302.7033

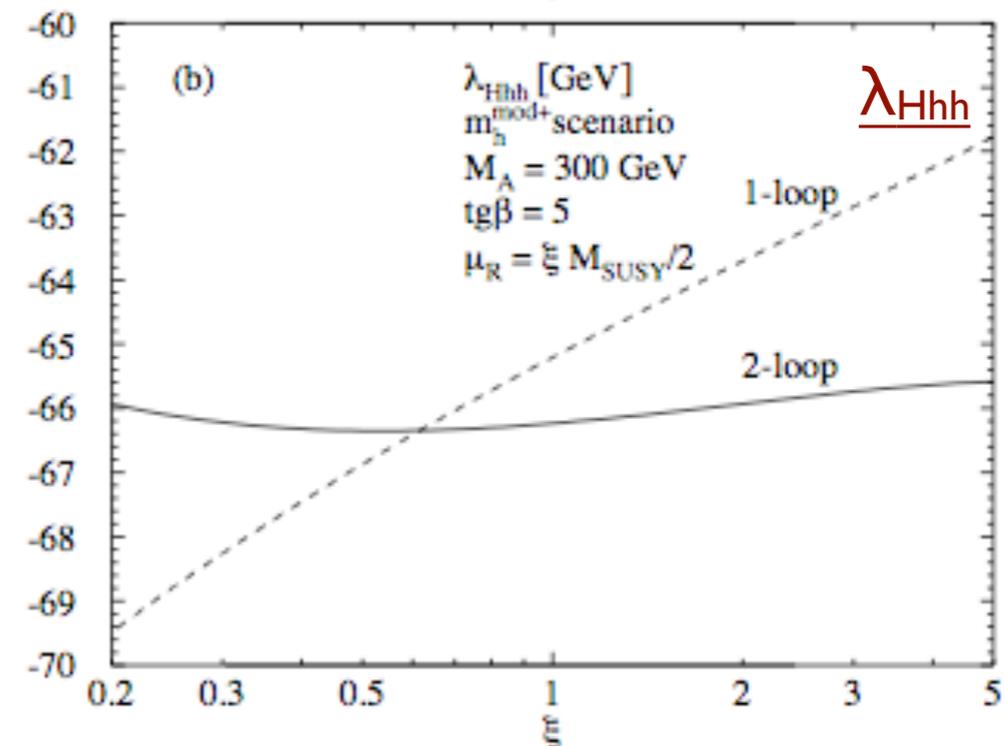
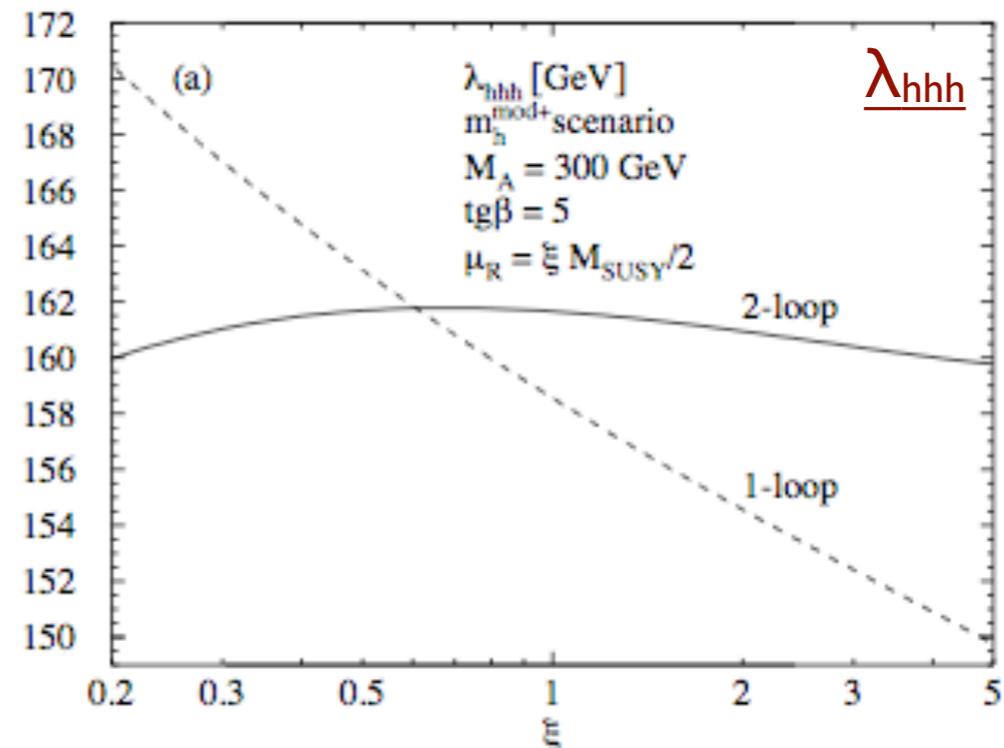
$$\tan \beta = 5$$

$$M_{\tilde{Q}_{L/R}} = 1 \text{ TeV}$$

$$M_{\tilde{g}} = 1.5 \text{ TeV}$$

$$A_t = A_b = 1.64 \text{ TeV}$$

$$\mu = 200 \text{ GeV}$$



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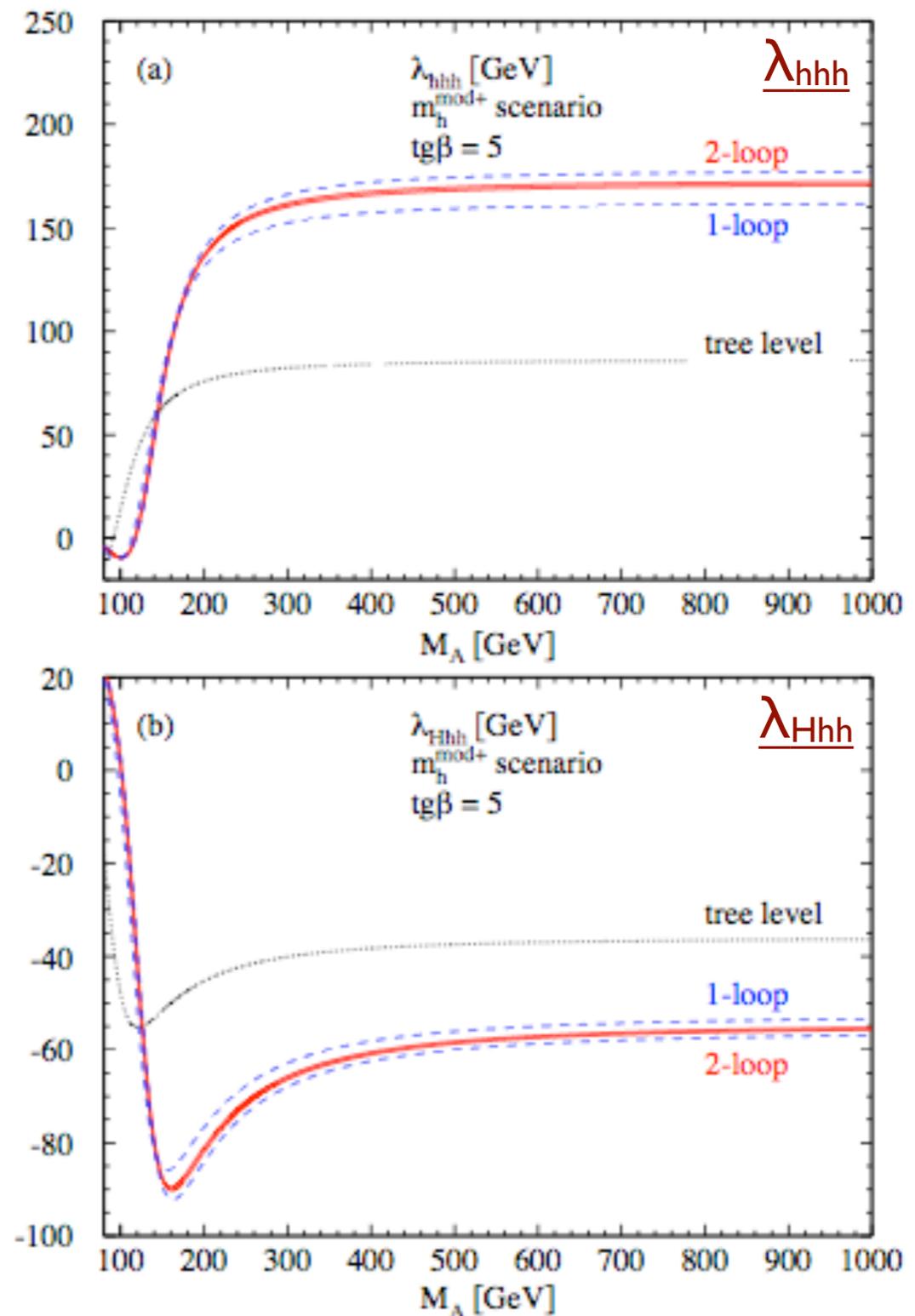
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Summary

- New spin 0 boson discovery
 - SM Higgs like
 - room remains for Higgs from SUSY → MSSM
- Higgs potential responsible for EWSB
 - understood by studying Higgs self-couplings
 - need precise predictions for these couplings
 - measurements at LHC (optimistic)
or linear collider (more reasonable)
- 2-loop corrections in MSSM to order $O(a_t a_s)$
 - reduction in uncertainties
 - λ_{hhh} from $\sim 15\%$ to $\sim 2\%$