

SUSY-QCD corrections in the decay of neutral Higgs bosons into two photons

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in collaboration with

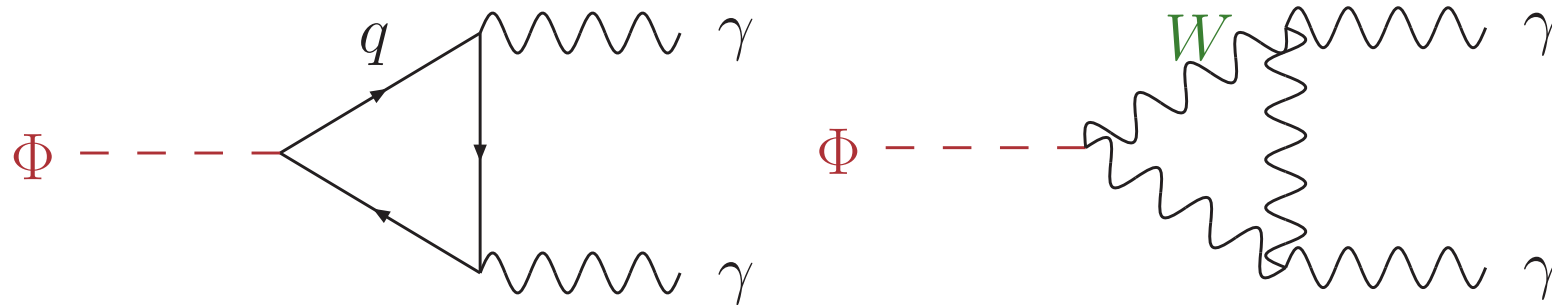
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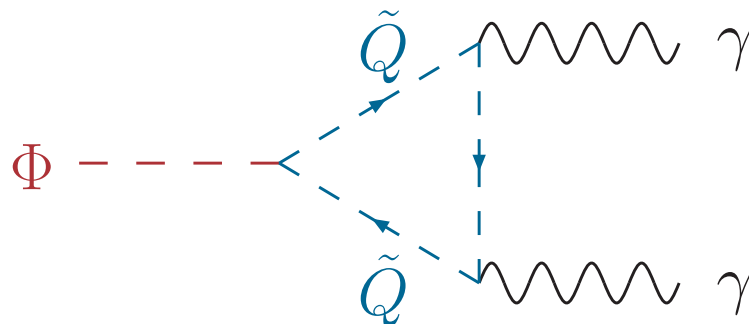
Dubna, July 17th 2006

Higgs decay into two photons

- Leading order:

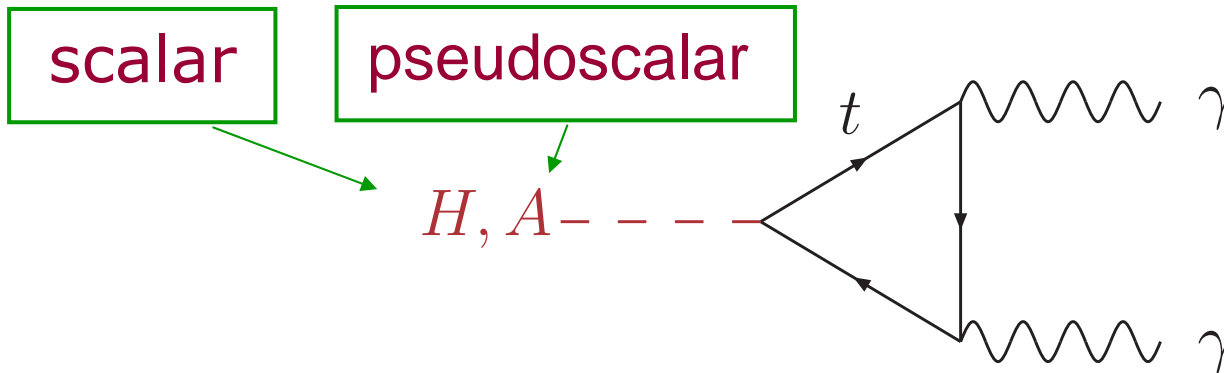


- Contribution of **supersymmetric** particles:

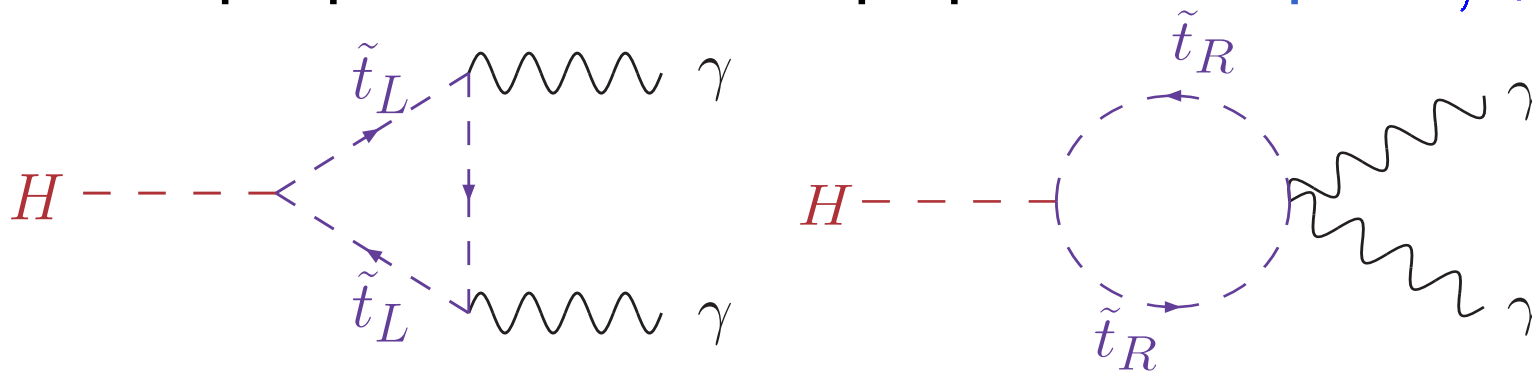


Neutral Higgs decay into two photons

- SM contribution in LO:



- Superpartner of the top-quarks: stops $\tilde{t}_{L,R}$



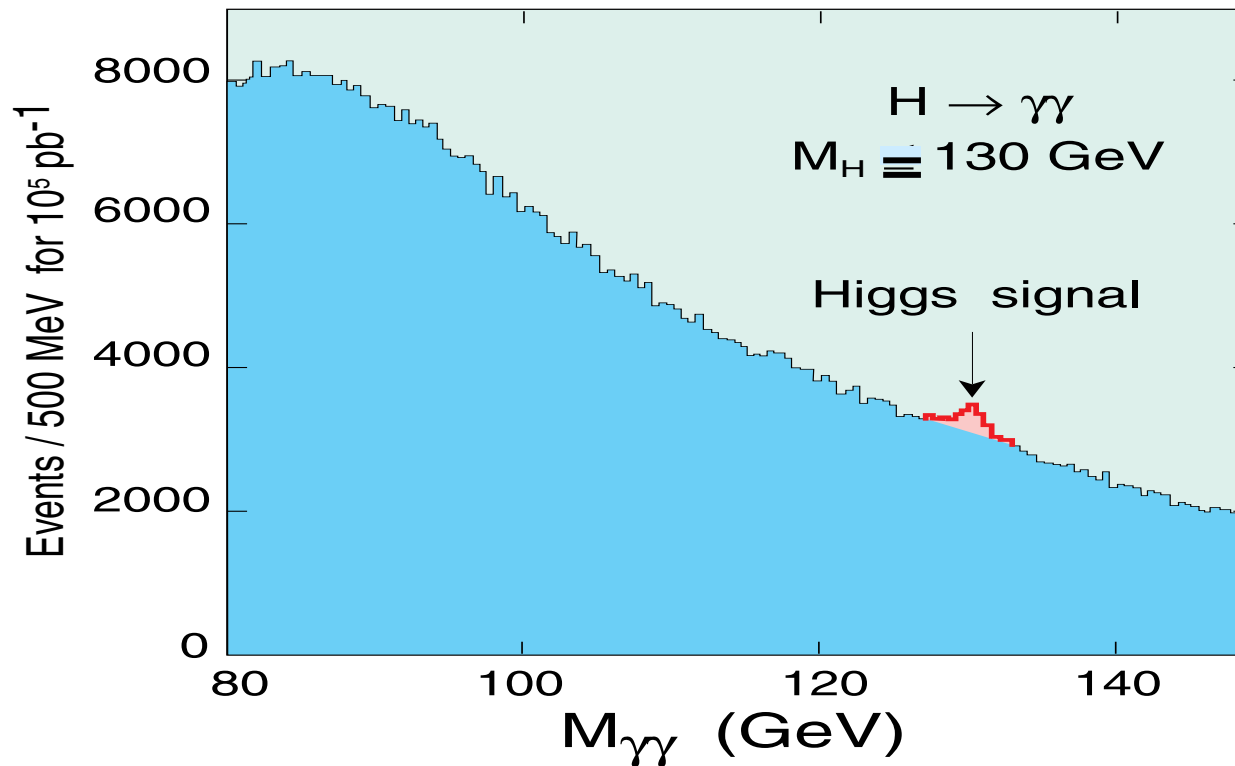
Content

- Decay of Higgs bosons into photons
- Corrections in higher orders
- Methods
- Results

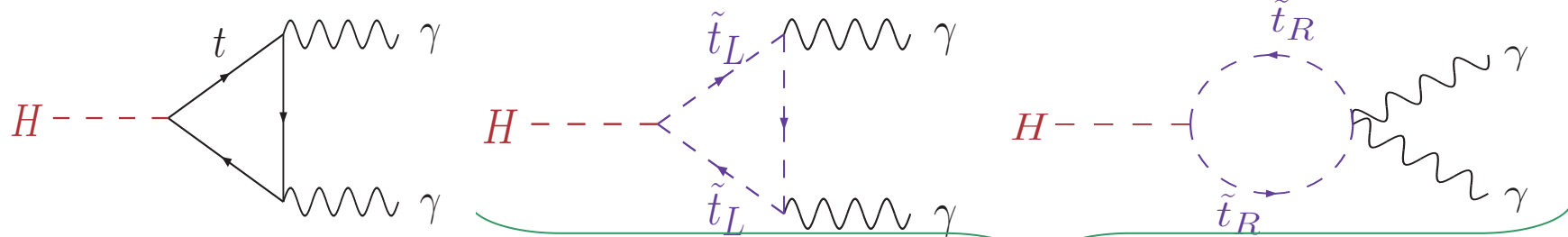
$H \rightarrow \gamma\gamma$ at the LHC

- Important for Higgs masses

$$m_H \leq 140 \text{ GeV}$$



Corrections in higher orders I



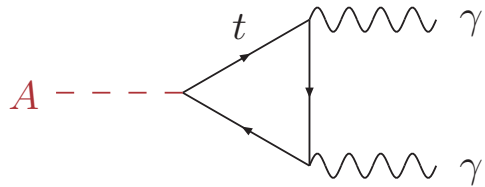
$H \rightarrow \gamma\gamma$:

SUSY-QCD: only LO

[Bates, Kalyniak, Ng '86]

- NLO-QCD: [Djouadi et al., '91] [Spira et al., '95]
[Fleischer, Tarasov, Tarasov, '04]
[Harlander, Kant '05]
- NNLO-QCD: large top masses [Steinhauser '97]
- NLO: electroweak [Aglietti et al., '04]
[Fugel, Kniehl, Steinhauser, '04]
[Degrassi, Maltoni '05]

Corrections in higher orders II



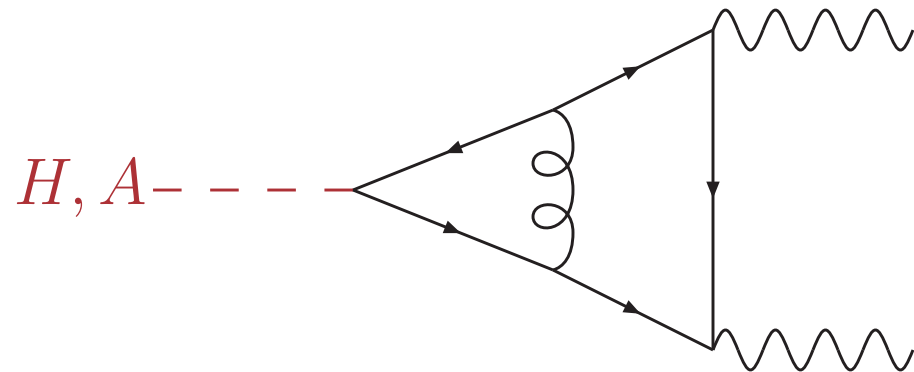
$A \rightarrow \gamma\gamma$:

- NLO-QCD: [Spira et al., '95]
[Harlander, Kant '05]

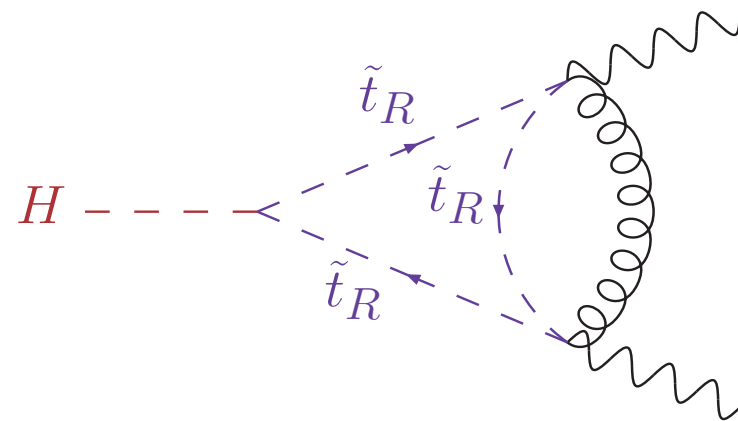
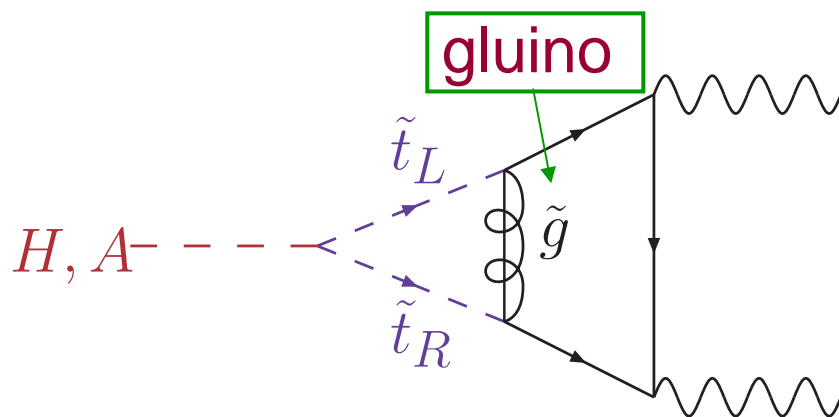
→ SUSY-QCD: NLO ?

Diagrams in NLO SUSY-QCD

- QCD contributions:



- SUSY-QCD contributions:



Tensor structure of the amplitude

$$\mathcal{A} = \mathcal{A}_1 + \frac{\alpha_s}{\pi} \mathcal{A}_2 + \dots$$

- Scalar part of the amplitude:

$$\underline{H} \rightarrow \gamma\gamma :$$

$$\mathcal{A}_2^{\mu\nu,H} = \left(q_1 q_2 g^{\mu\nu} - q_1^\nu q_2^\mu - q_1^\mu q_2^\nu \right) \mathcal{A}_2^H$$

q_1, q_2 : photon 4-momenta

$$\underline{A} \rightarrow \gamma\gamma :$$

$$\mathcal{A}_2^{\mu\nu,A} = \left(\epsilon^{\mu\nu\alpha\beta} q_{1\alpha} q_{2\beta} \right) \mathcal{A}_2^A$$

Projectors

$$A_2 = \sum_{l,m,n=0}^{\infty} c_{lmn} (q_1^2)^l (q_2^2)^m (q_1 q_2)^n$$

- on-shell photons: $q_1^2 = 0, q_2^2 = 0$
- Coefficients $c_{oon} \sim c_n$ through application of
→ d'Alembert operators:

$$D_{ij} = \frac{\partial^2}{\partial q_i^\mu \partial q_{j,\mu}}, \quad i, j = 1, 2$$

Amplitude in NLO: $H, A \rightarrow \gamma\gamma$

Expansion for $m_H < \sqrt{2}m_t$

$$\mathcal{A}_2(q_1, q_2) = c_0 + c_1 \left(\frac{q_1 q_2}{m_t^2} \right) + c_2 \left(\frac{q_1 q_2}{m_t^2} \right)^2 + \dots$$

→ q_1, q_2 : Photon 4-momenta

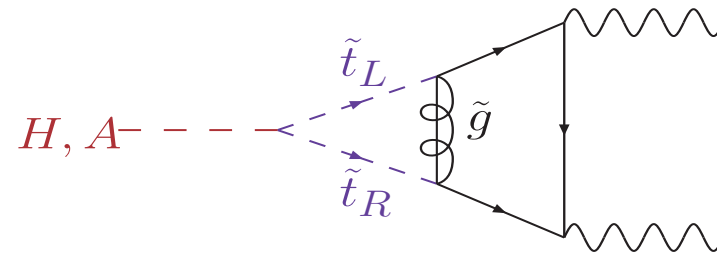
$$q_1 q_2 = \frac{m_H^2}{2}$$

goal:

$$c_n = c_n(m_t, m_{\tilde{t}_1}, m_{\tilde{t}_2}, m_{\tilde{g}})$$

Methods

- Difficulty:
up to 4 mass scales



→ Diagrams in asymptotic expansion

e.g.

$$m_t \ll m_{\tilde{t}_1} \ll m_{\tilde{t}_2} \ll m_{\tilde{g}}$$

- Exact calculation:
→ Algorithm by [Davydychev, Tausk '92]

Tools

- Diagrams generated with
QGRAF [Nogueira '93] $A \rightarrow \gamma\gamma$: 126 diagrams
 $H \rightarrow \gamma\gamma$: 288 diagrams
- translation of symbolic QGRAF-notation with
Q2E [Seidensticker '99]
as input for EXP [Harlander, Seidensticker, Steinhauser '98]
[Seidensticker '99]
- EXP - asymptotic expansions
- preparation for a FORM based program
e.g. MATAD [Steinhauser '01] [Vermaseren '00]

Regularization

- Dimensional Regularization (DREG)

→ violates SUSY

A pseudoscalar $\Rightarrow \gamma_5$

→ problems with γ_5 in d dimensions

- Dimensional Reduction (DRED) [Siegel, '79]

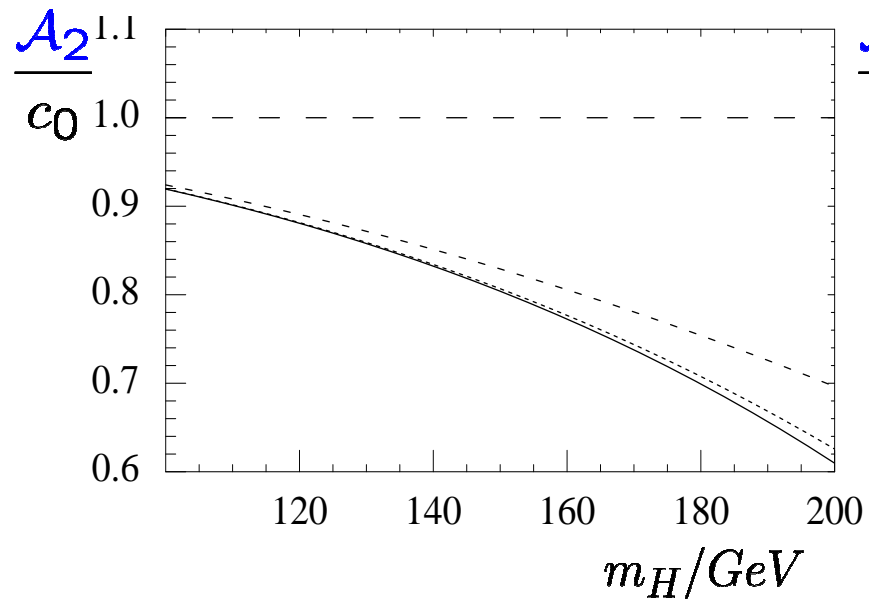
→ respects SUSY at low orders

→ Lorentz Indices in 4 dimensions

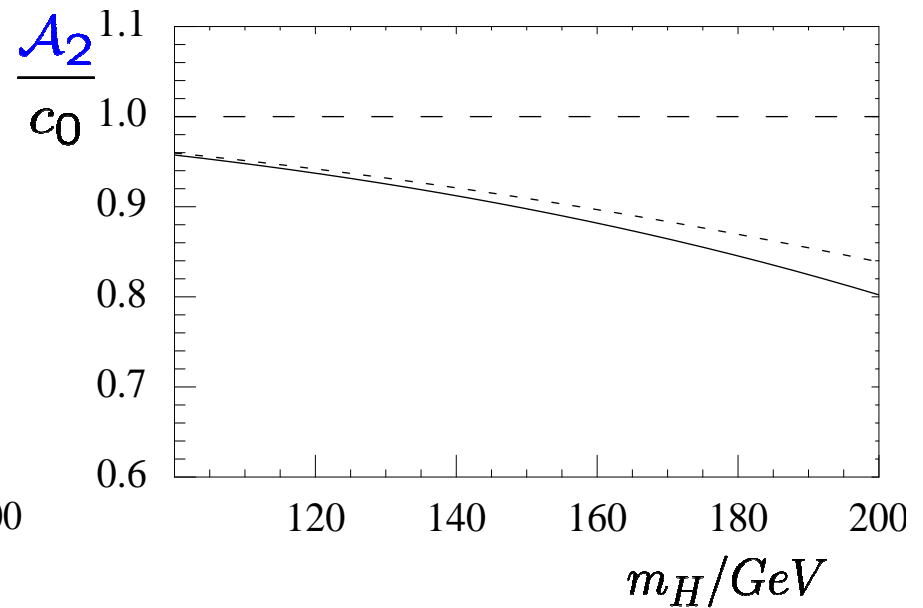
$$\gamma_5 = \frac{i}{4!} \epsilon_{\mu\nu\rho\sigma} \gamma^\mu \gamma^\nu \gamma^\rho \gamma^\sigma$$

Amplitude in NLO: $H \rightarrow \gamma\gamma$

QCD:



SUSY-QCD:



masses/GeV:

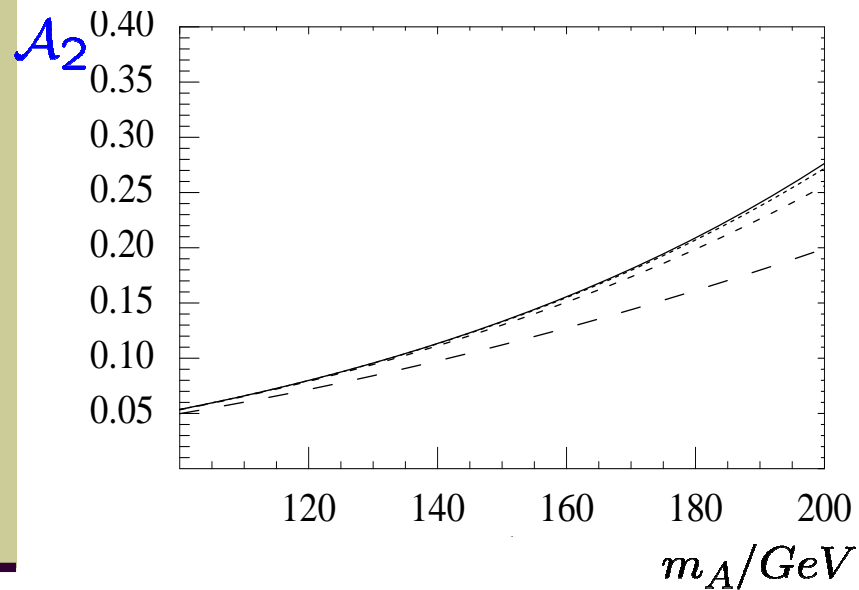
$$m_{\tilde{t}_1} = 250, m_{\tilde{t}_2} = 400, m_{\tilde{g}} = 600, \mu_{SUSY} = 150;$$

$$\tan \beta = 3, \cos \alpha = 1, \theta_t = \pi/2$$

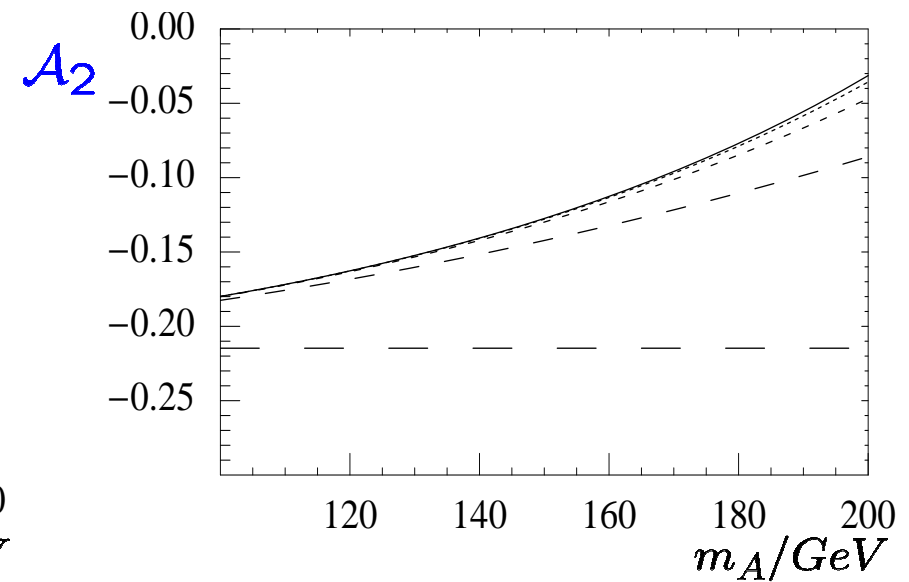
$$m_t, m_{\tilde{t}_1}, m_{\tilde{t}_2}, m_{\tilde{g}}$$

Amplitude in NLO: $A \rightarrow \gamma\gamma$

QCD:



SUSY-QCD:



$$M = 172.5\text{GeV}$$
$$\tan\beta = 3$$

Conclusion

Decay in NLO: $H, A \rightarrow \gamma\gamma$

- Expansion in

$$c_n(m_t, m_{\tilde{t}_1}, m_{\tilde{t}_2}, m_{\tilde{g}}) \left(\frac{m_{H,A}^2}{m_t^2} \right)^n$$

up to $n = 3 \rightarrow$ good convergence

- with SUSY-particles: **gluino** and **stops**

Outlook:

\rightarrow Analytic calculation

\rightarrow Inclusion of bottom and sbottom-effects