

Gluinonia: Energy Levels, Production and Decay

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Overview

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- Outlook

Motivation I

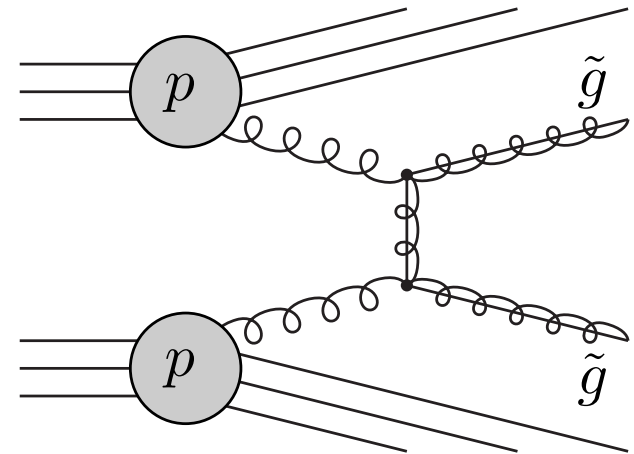
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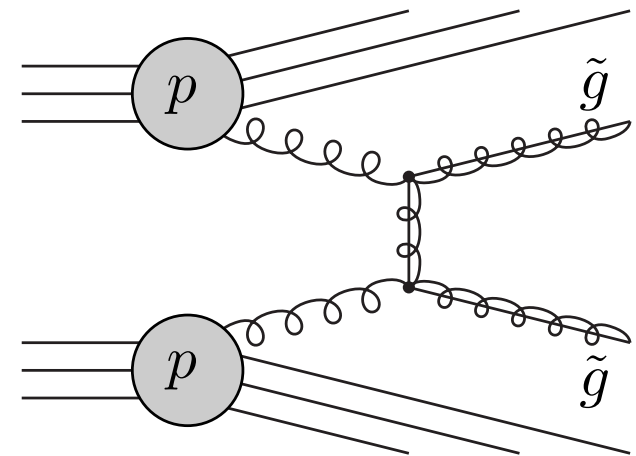
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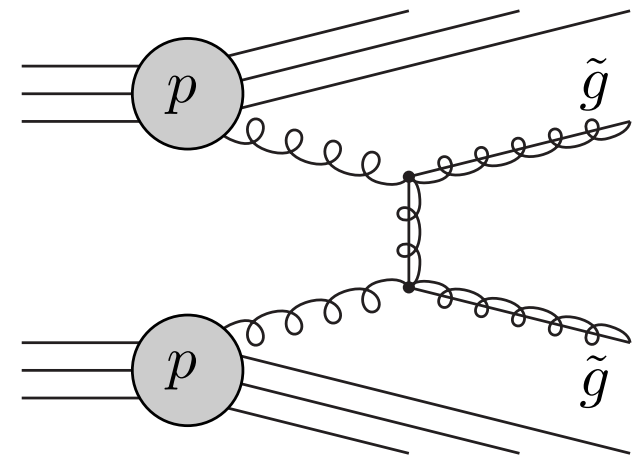


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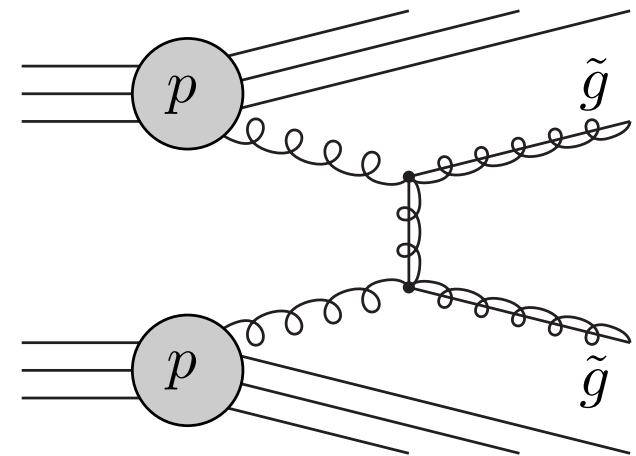
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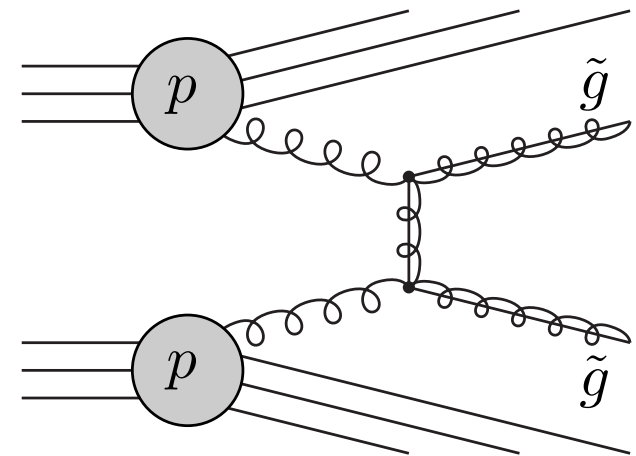
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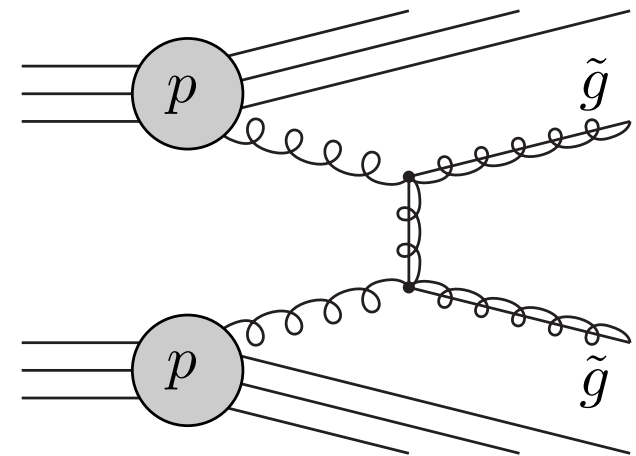
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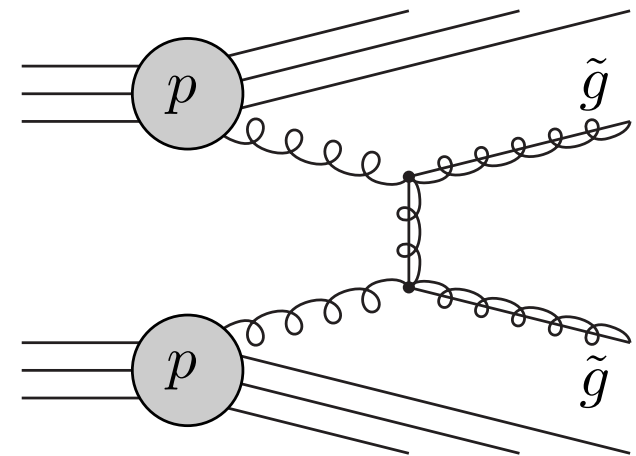
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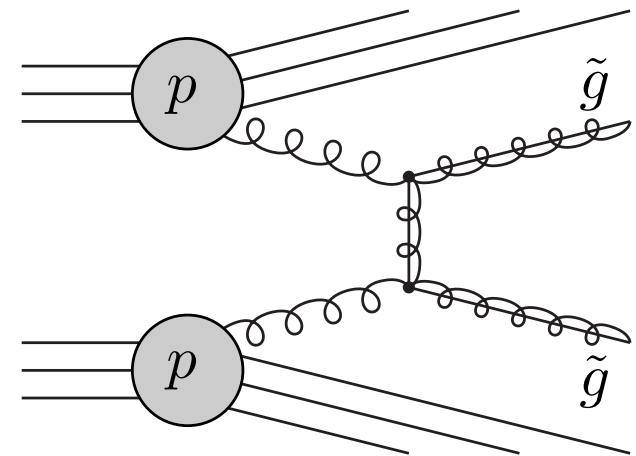
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 - $m_{\tilde{g}} > 308 \text{ GeV}$ [PDG 2008]

Motivation II

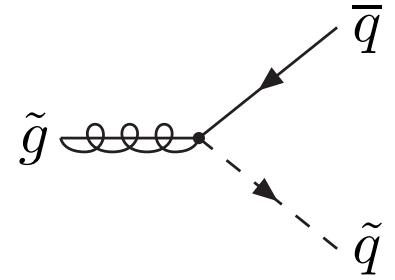
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 - scenario 1: $m_{\tilde{g}} > m_{\tilde{q}_i}$

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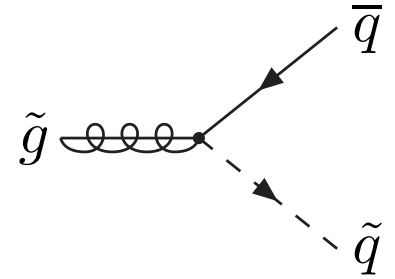
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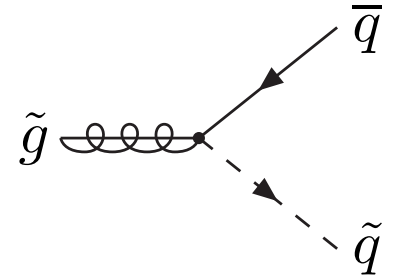
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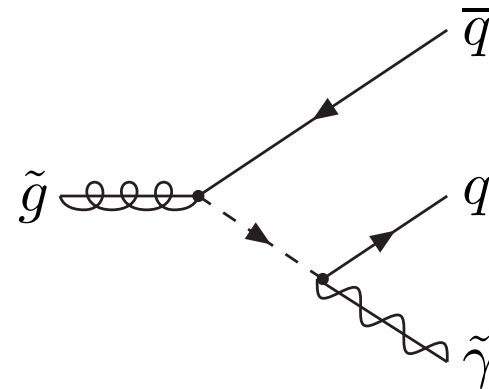
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- scenario 2: $m_{\tilde{g}} < m_{\tilde{q}}$

$$\Gamma(\tilde{g} \rightarrow q \bar{q} \tilde{\gamma}) \sim \frac{\alpha \alpha_s e_q^2}{48\pi} \frac{m_{\tilde{g}}^5}{m_{\tilde{q}}^4}$$

[Haber and Kane 1985]



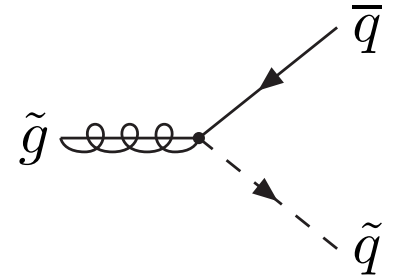
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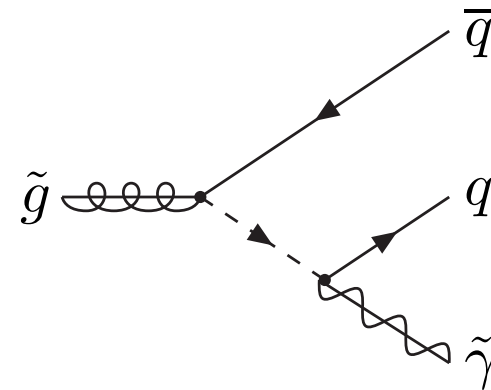


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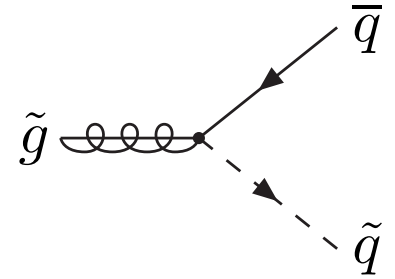
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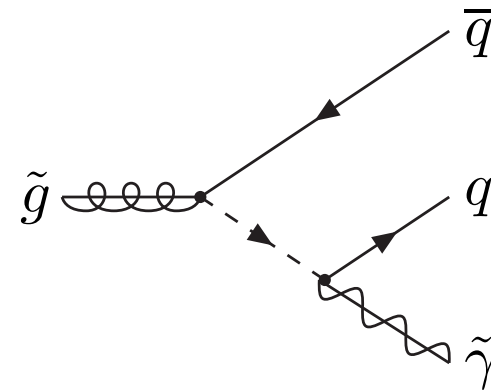
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formation of $\tilde{g}\tilde{g}$ boundstates (Gluinonia)



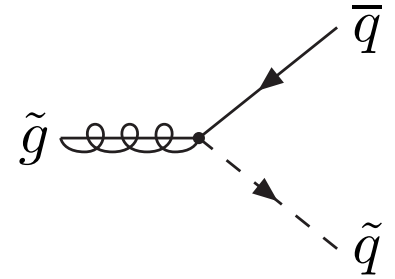
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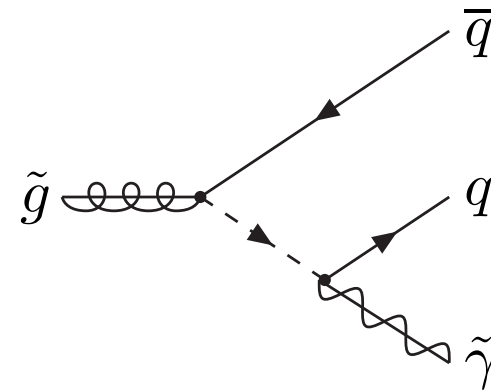
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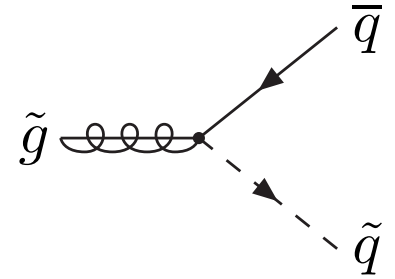
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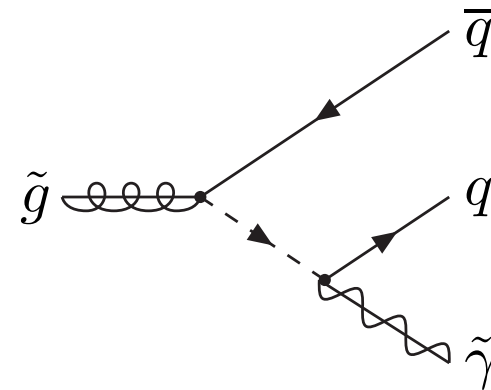
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model independent decays

similar to Quarkonia



Introduction

- $(\tilde{g}\tilde{g})$ -colour representation

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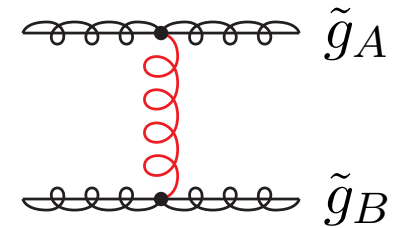
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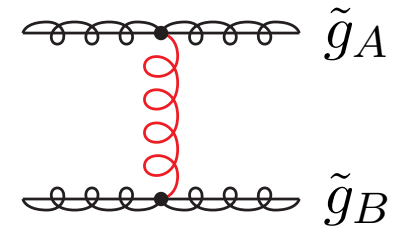


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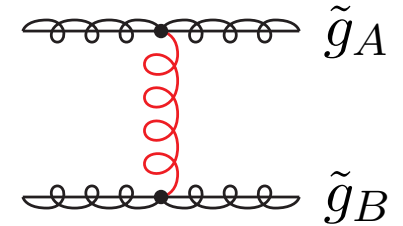
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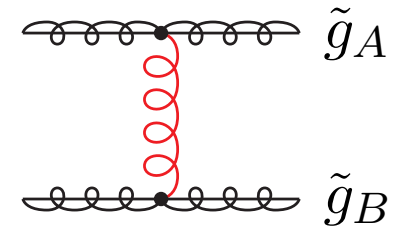
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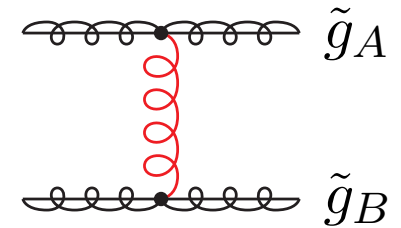
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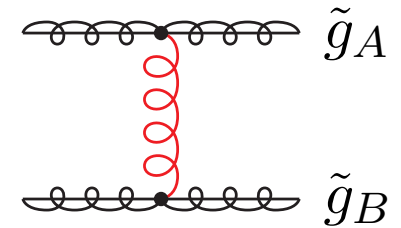
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[J.Kühn, J.Kaplan and E.Safiani '79; B.Guberina, J.Kühn, R.Peccei and R.Rückl '80]

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in the following: 1_s state only ($S = L = 0$)

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- description of the force between the two constituents through an adequate **potential**

→ modification of existing $q\bar{q}$ potentials for $\tilde{g}\tilde{g}$

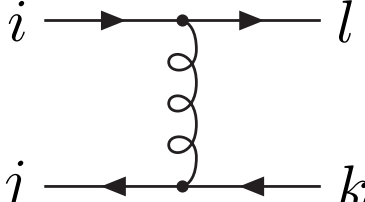
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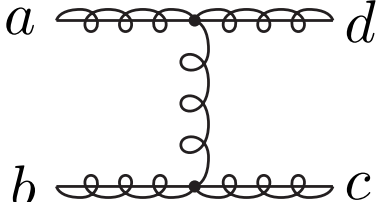
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The diagram on the left shows two horizontal lines representing fermions. The top line has an arrow pointing right, labeled i at the start and l at the end. The bottom line has an arrow pointing left, labeled j at the start and k at the end. A vertical wavy line (representing a gluon) connects the two horizontal lines. To the right of this diagram is the equation $\times \frac{\delta_{ij}}{\sqrt{N_C}} \frac{\delta_{kl}}{\sqrt{N_C}} = C_F$.



The diagram on the right shows two horizontal lines representing gluons. The top line is labeled a at the start and d at the end. The bottom line is labeled b at the start and c at the end. Both lines are decorated with small circles. A vertical wavy line connects the two horizontal lines. To the right of this diagram is the equation $\times \frac{\delta_{ab}}{\sqrt{N_C^2-1}} \frac{\delta_{cd}}{\sqrt{N_C^2-1}} = C_A$.

$$\times \frac{\delta_{ij}}{\sqrt{N_C}} \frac{\delta_{kl}}{\sqrt{N_C}} = C_F \quad \longrightarrow \quad \times \frac{\delta_{ab}}{\sqrt{N_C^2-1}} \frac{\delta_{cd}}{\sqrt{N_C^2-1}} = C_A$$

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$$\begin{array}{c} i \longrightarrow \bullet \longrightarrow l \\ | \\ \bullet \longleftarrow j \longleftarrow k \end{array} \times \frac{\delta_{ij}}{\sqrt{N_C}} \frac{\delta_{kl}}{\sqrt{N_C}} = C_F \quad \longrightarrow \quad \begin{array}{c} a \text{ --- } \bullet \text{ --- } d \\ | \\ \bullet \text{ --- } b \text{ --- } c \end{array} \times \frac{\delta_{ab}}{\sqrt{N_C^2 - 1}} \frac{\delta_{cd}}{\sqrt{N_C^2 - 1}} = C_A$$

- overall factor: $C_F \rightarrow C_A$ (up to **NNLO**)

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$$\begin{array}{c} i \longrightarrow \bullet \longrightarrow l \\ \downarrow \text{coiled line} \\ j \longleftarrow \bullet \longleftarrow k \end{array} \times \frac{\delta_{ij}}{\sqrt{N_C}} \frac{\delta_{kl}}{\sqrt{N_C}} = C_F \quad \longrightarrow \quad \begin{array}{c} a \text{---} \bullet \text{---} d \\ \phantom{a \text{---}} \downarrow \text{coiled line} \phantom{\bullet \text{---}} \\ b \text{---} \bullet \text{---} c \end{array} \times \frac{\delta_{ab}}{\sqrt{N_C^2-1}} \frac{\delta_{cd}}{\sqrt{N_C^2-1}} = C_A$$

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$$\Rightarrow V_{\tilde{g}\tilde{g}}(\vec{r}) = -\frac{C_A \alpha_s}{r} + \mathcal{O}(\alpha_s^2)$$

[M.Kauth, J.Kühn, P.Marquard and M.Steinhauser '09]

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[M.Kauth, J.Kühn, P.Marquard and M.Steinhauser '09]

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The diagram shows the transition from a quark-antiquark potential to a gluon-gluon potential. On the left, a quark-antiquark pair (lines i, j and l, k) is connected by a gluon loop (wavy line). This is multiplied by the color factor $\frac{\delta_{ij}}{\sqrt{N_C}} \frac{\delta_{kl}}{\sqrt{N_C}} = C_F$. An arrow points to the right, where a gluon-gluon pair (lines a, b and d, c) is connected by a gluon loop. This is multiplied by the color factor $\frac{\delta_{ab}}{\sqrt{N_C^2-1}} \frac{\delta_{cd}}{\sqrt{N_C^2-1}} = C_A$.

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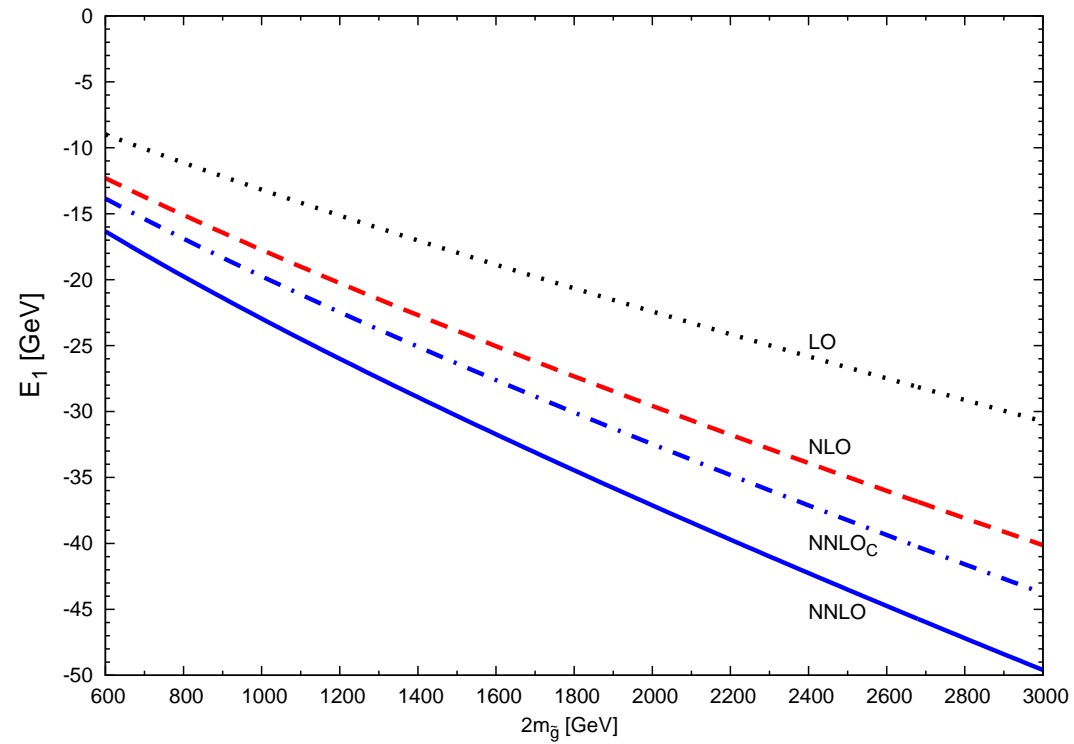
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- solving the non-relativistic Schrödinger equation through numerics and **perturbation theory**

1. wavefunction for decay and production

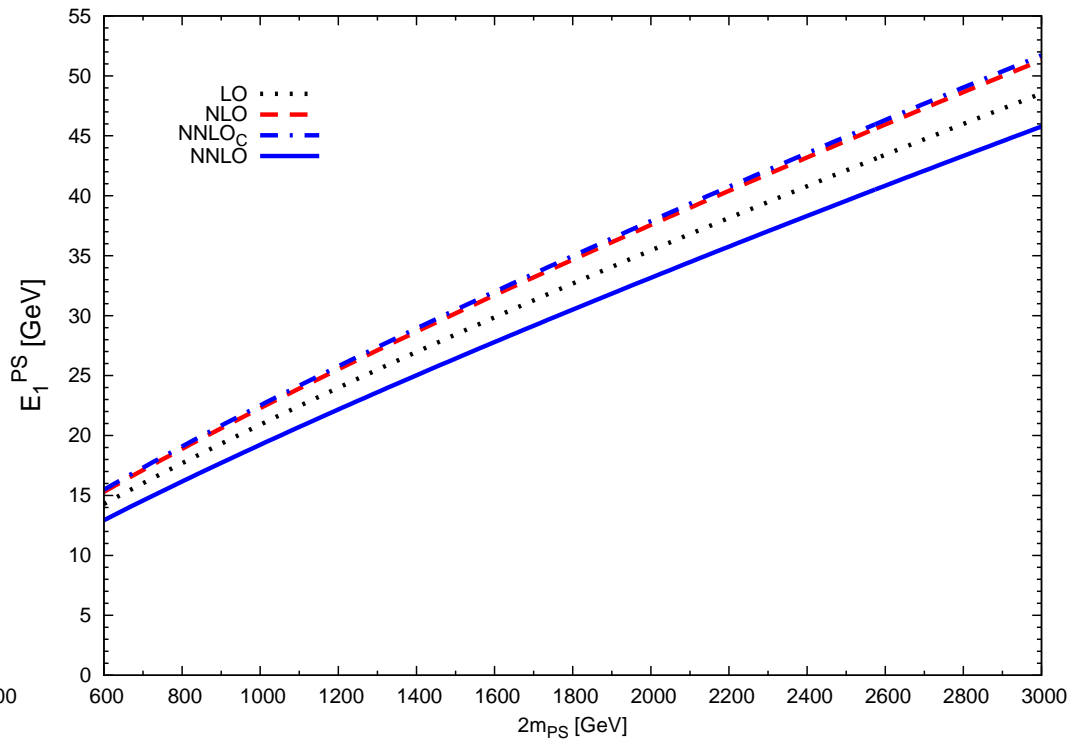
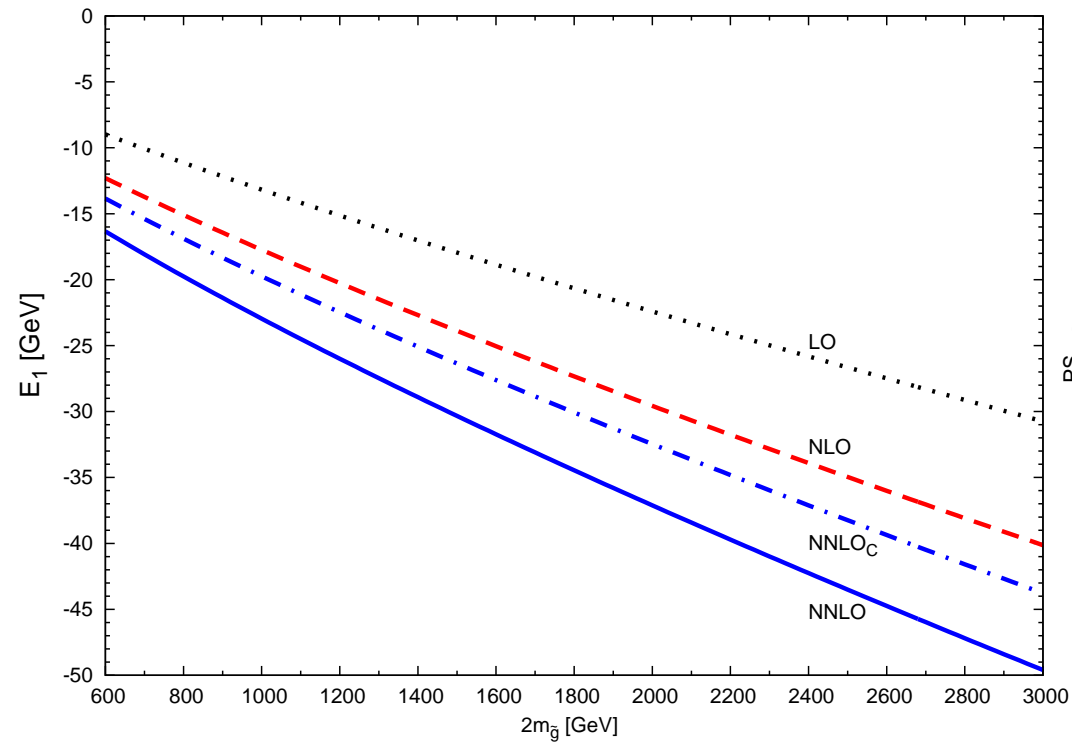
Spectroscopy II

2. energy eigenvalues in the pole



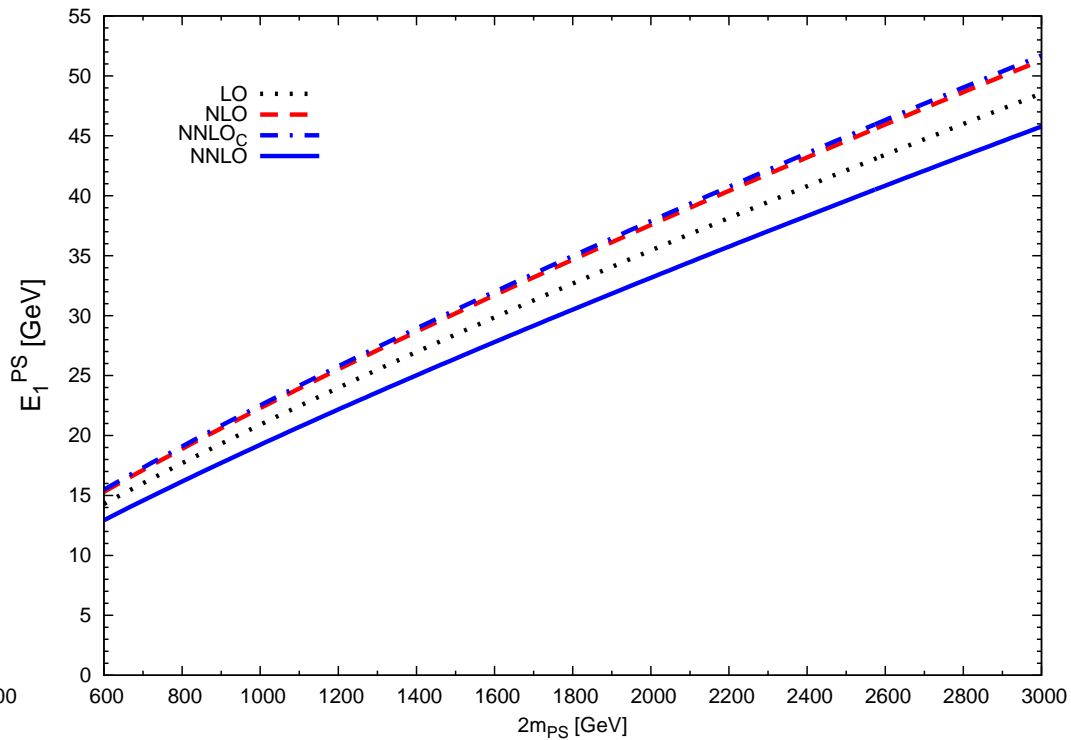
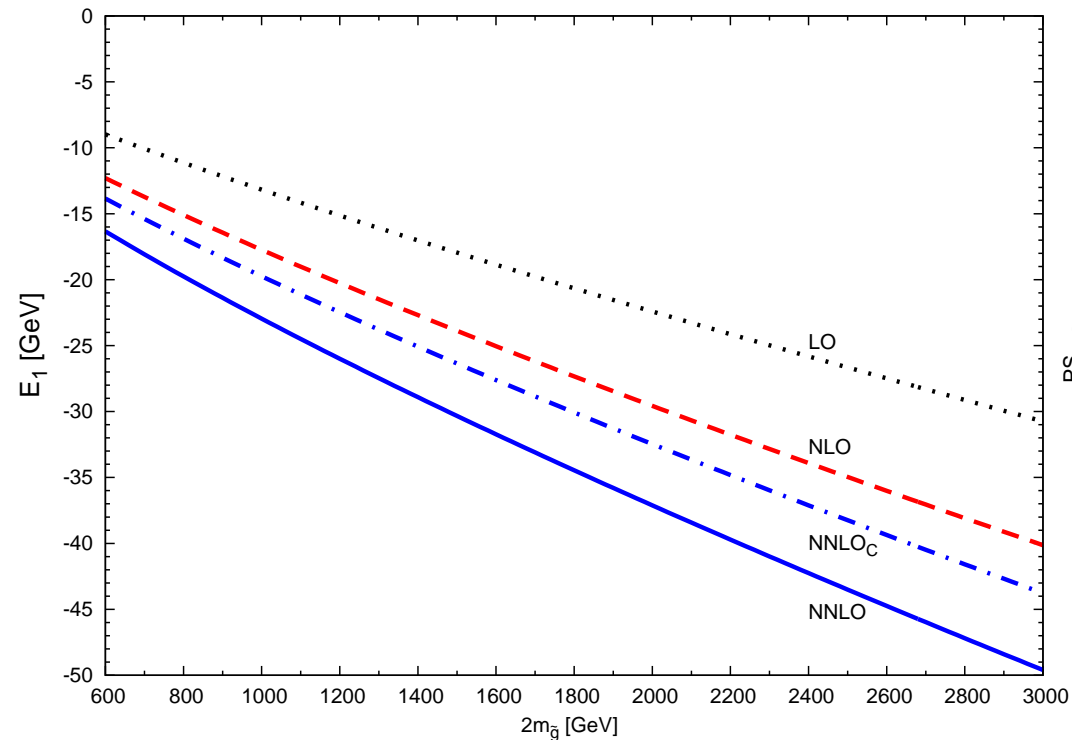
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2. energy eigenvalues in the pole and the PS scheme:
[M.Beneke '98]



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$$M_{(\tilde{g}\tilde{g})_{1S}} = 2m_{\tilde{g}} + E_1 \quad (\text{Meson mass})$$

$m_{\tilde{g}}$ and E_1 separately scheme dependant

Spectroscopy III

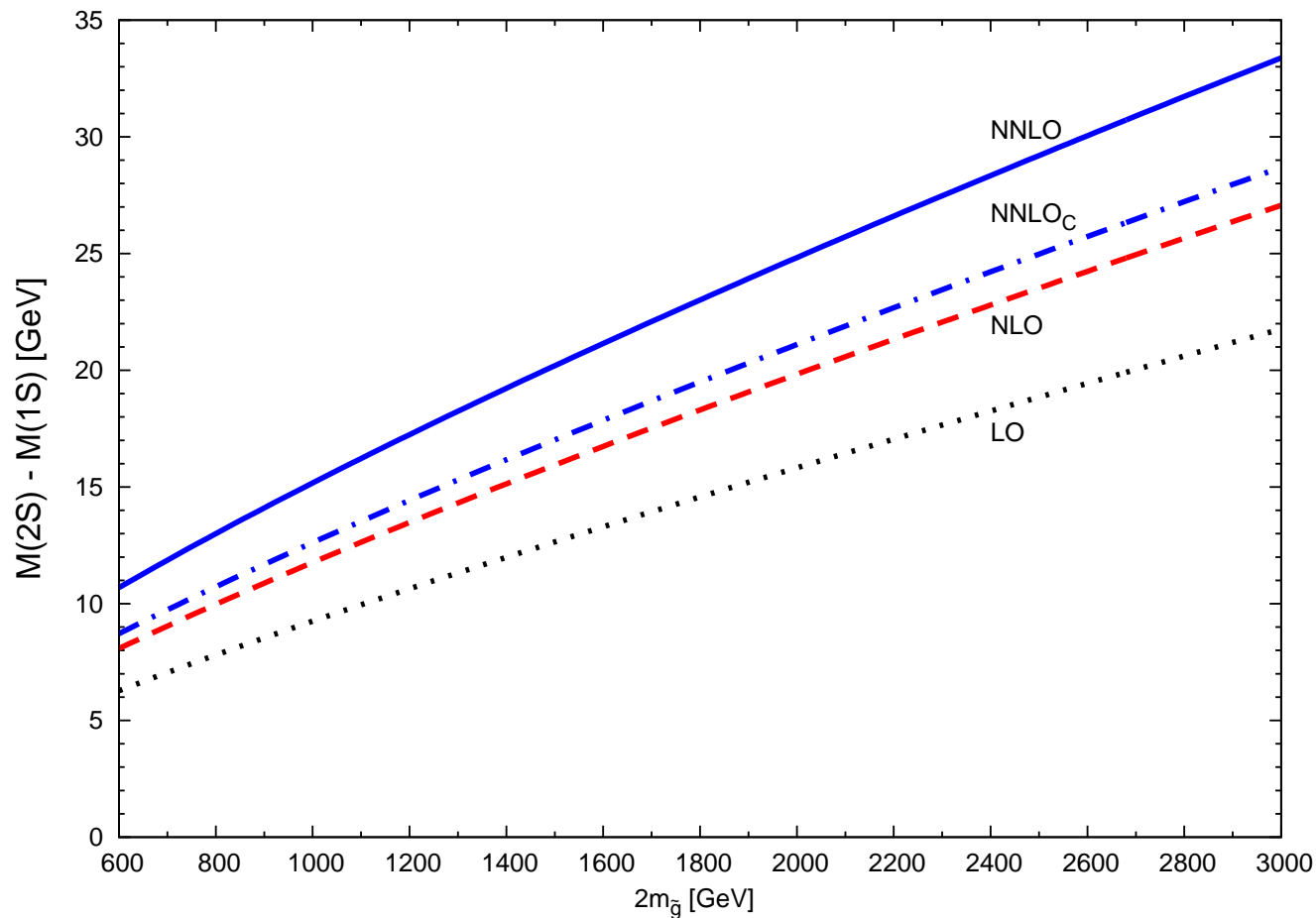
- excitation energy between the $1S$ and the $2S$ state

$$\Delta M = M(2S) - M(1S) = \left(1 - \frac{1}{4}\right) \frac{C_A^2 \alpha_s^2}{4} m_{\tilde{g}}$$

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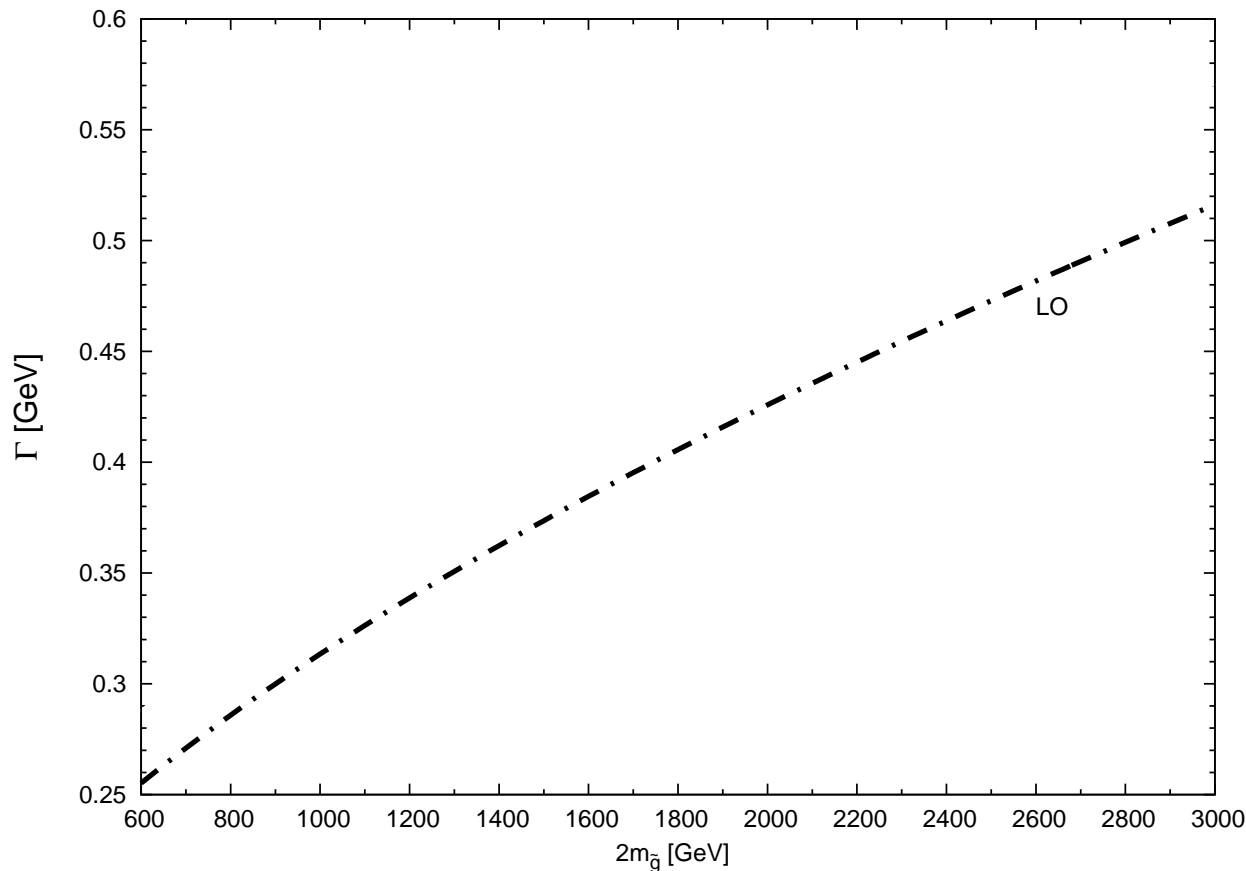
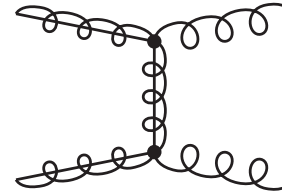
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Decay I

- hadronic decay channel

$$\Gamma((\tilde{g}\tilde{g})_{1_s} \rightarrow gg) = |R(0)|^2 \frac{C_A^2 \alpha_s(\mu_r)^2}{2m_{\tilde{g}}^2}$$



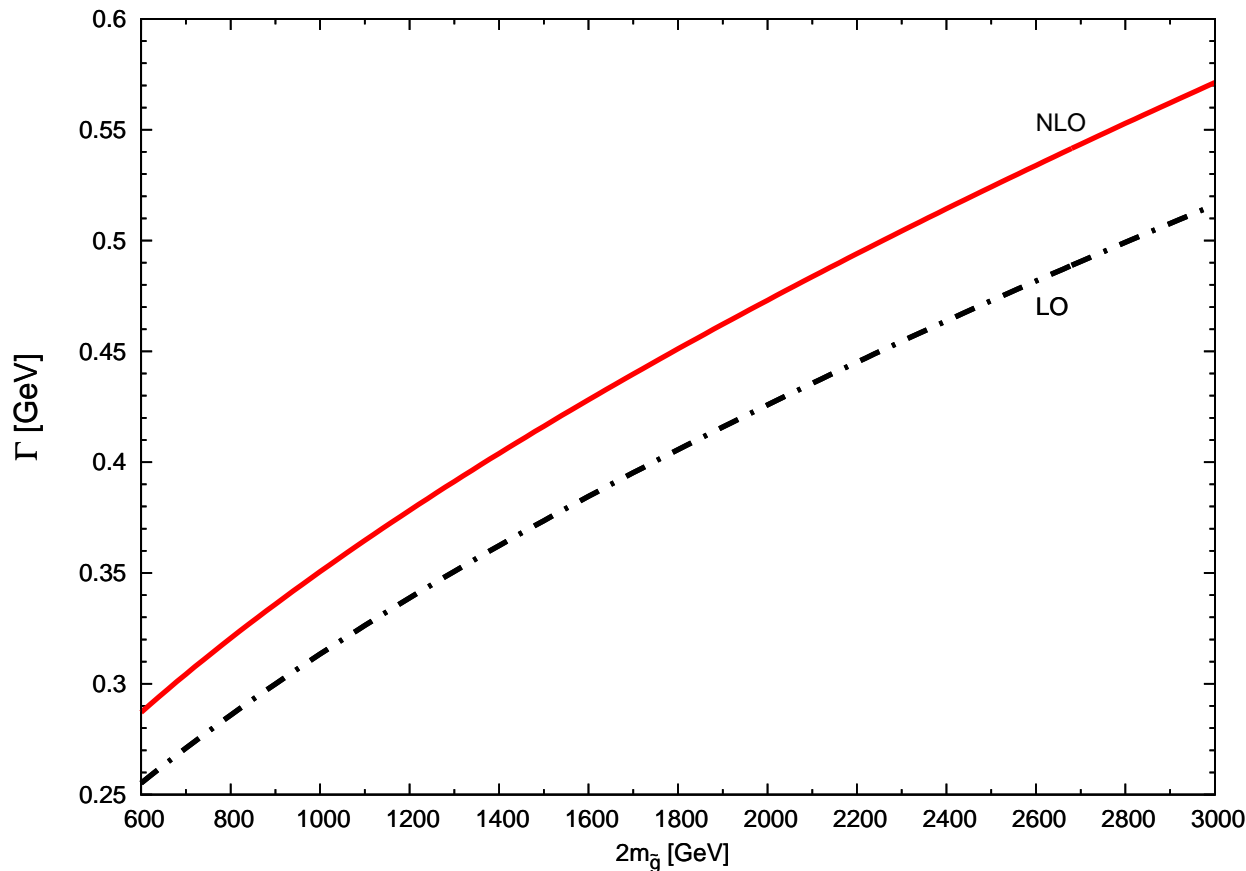
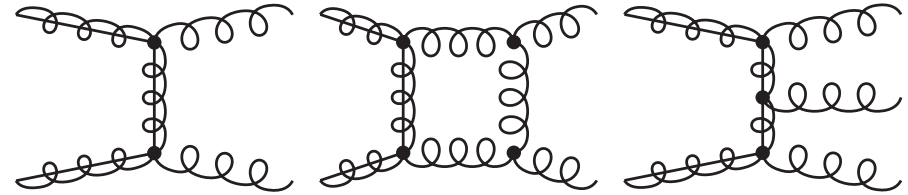
	wavefunction	hard part
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n_f	5	6

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$$\times \left\{ 1 + \frac{\alpha_s(\mu_r)}{\pi} \left[C_A \left(\frac{108}{18} - \frac{7}{24} \pi^2 \right) - \frac{16}{9} n_f T_F + \left(\frac{11}{6} C_A - \frac{2}{3} n_f T_F \right) \ln \left(\frac{\mu_r^2}{4m_{\tilde{g}}^2} \right) \right] \right\}$$



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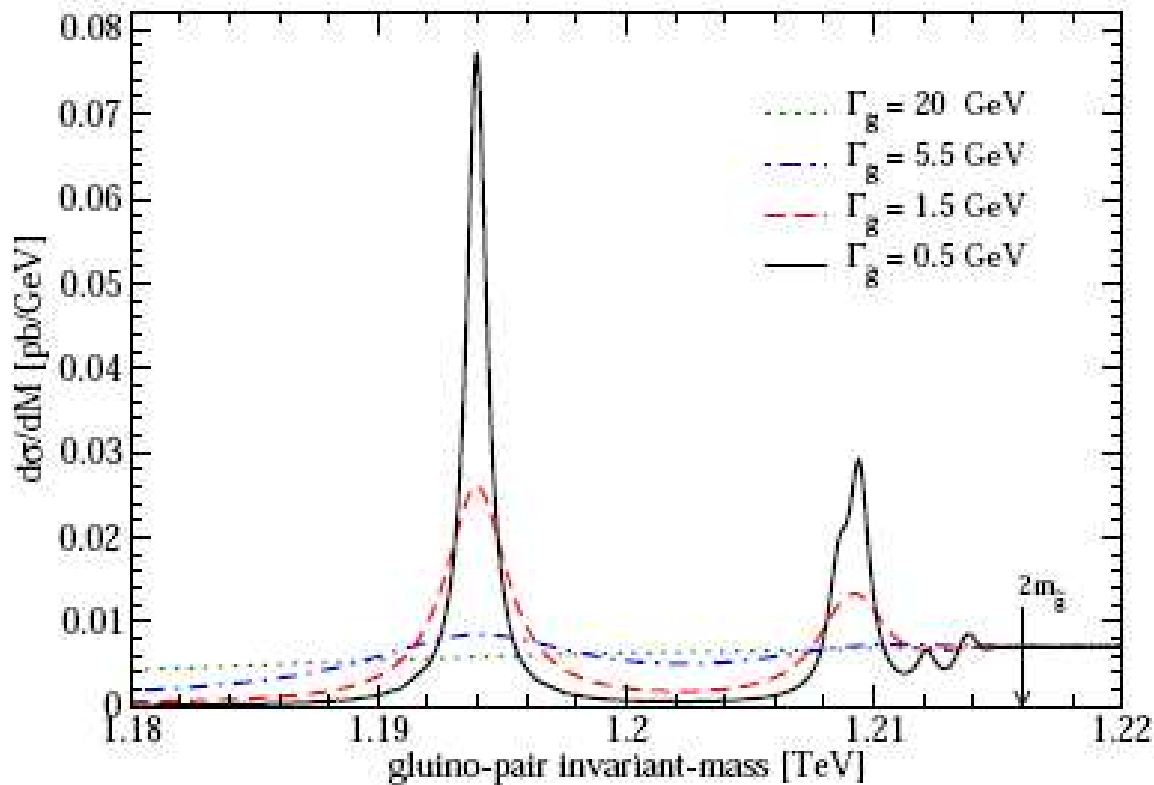
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$$\underbrace{\Gamma_{\tilde{g} \rightarrow \tilde{\chi}_0 q \bar{q}} = \frac{\alpha \alpha_s e_q^2 m_{\tilde{g}}^4}{48\pi m_{\tilde{q}}^4} m_{\tilde{g}}}_{\text{single decay}} < \underbrace{\Gamma_{(\tilde{g}\tilde{g}) \rightarrow gg} = \frac{C_A^5 \alpha_s^5}{4} m_{\tilde{g}}}_{\text{annihilation decay}} < \underbrace{\Delta M = \left(1 - \frac{1}{4}\right) \frac{C_A^2 \alpha_s^2}{4} m_{\tilde{g}}}_{\text{level spacing}}$$

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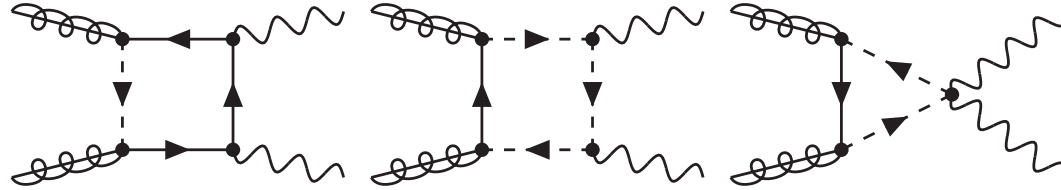


“Bound-state effects on gluino pair-production at hadron colliders”
 [Hagiwara and Yokoya 2009]
 arXiv : 0909.3204v2

$$m_{\tilde{g}} = 608 \text{ GeV}$$

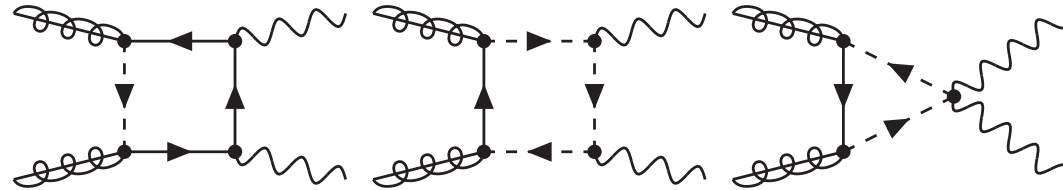
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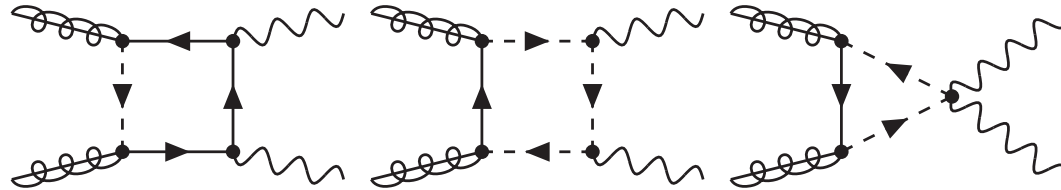


$$\text{Br}(\gamma\gamma) = \frac{\Gamma((\tilde{g}\tilde{g})_{1s} \rightarrow \gamma\gamma)}{\Gamma((\tilde{g}\tilde{g})_{1s} \rightarrow gg)} = 4 \frac{T_F}{C_A^2} \frac{\alpha^2}{\pi^2} \left(\sum_f Q_f^2 \right)^2 (\text{Li}_2(-z) - \text{Li}_2(z))^2$$

$$\sim 10^{-6 \dots -5} \quad \text{for} \quad m_{\tilde{g}} < m_{\tilde{q}} < 2m_{\tilde{g}}$$

Decay III

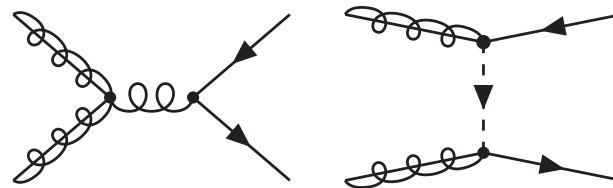
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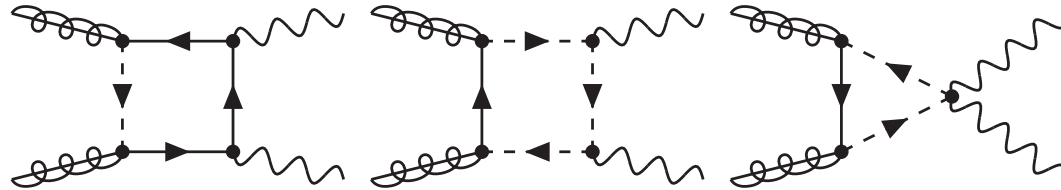
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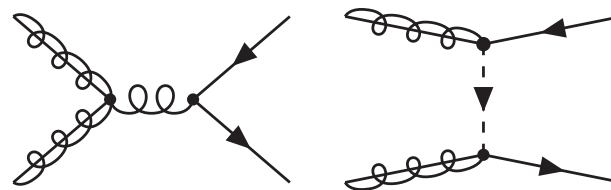
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$$\sim 0.05 \quad \text{for} \quad m_{\tilde{g}} \sim 300 \text{ GeV} \lesssim m_{\tilde{q}}$$

Production I

- hadronic production

$$\sigma(S) = \sum_{ab} \int_0^1 dx \int_0^1 dy f_a^p(x, \mu_f^2) f_b^p(y, \mu_f^2) \hat{\sigma}_{ab}(s = xyS)$$

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PDF: MSTW2008(N)LO (formerly MRST)

[A.Martin, W.Stirling, R.Thorne and G.Watt '09]

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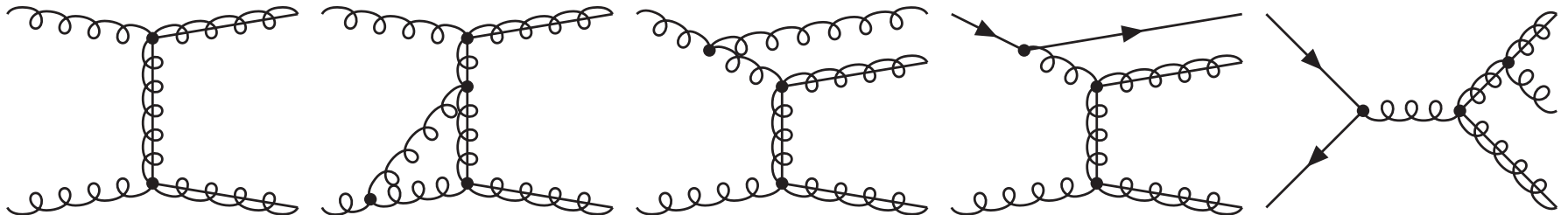
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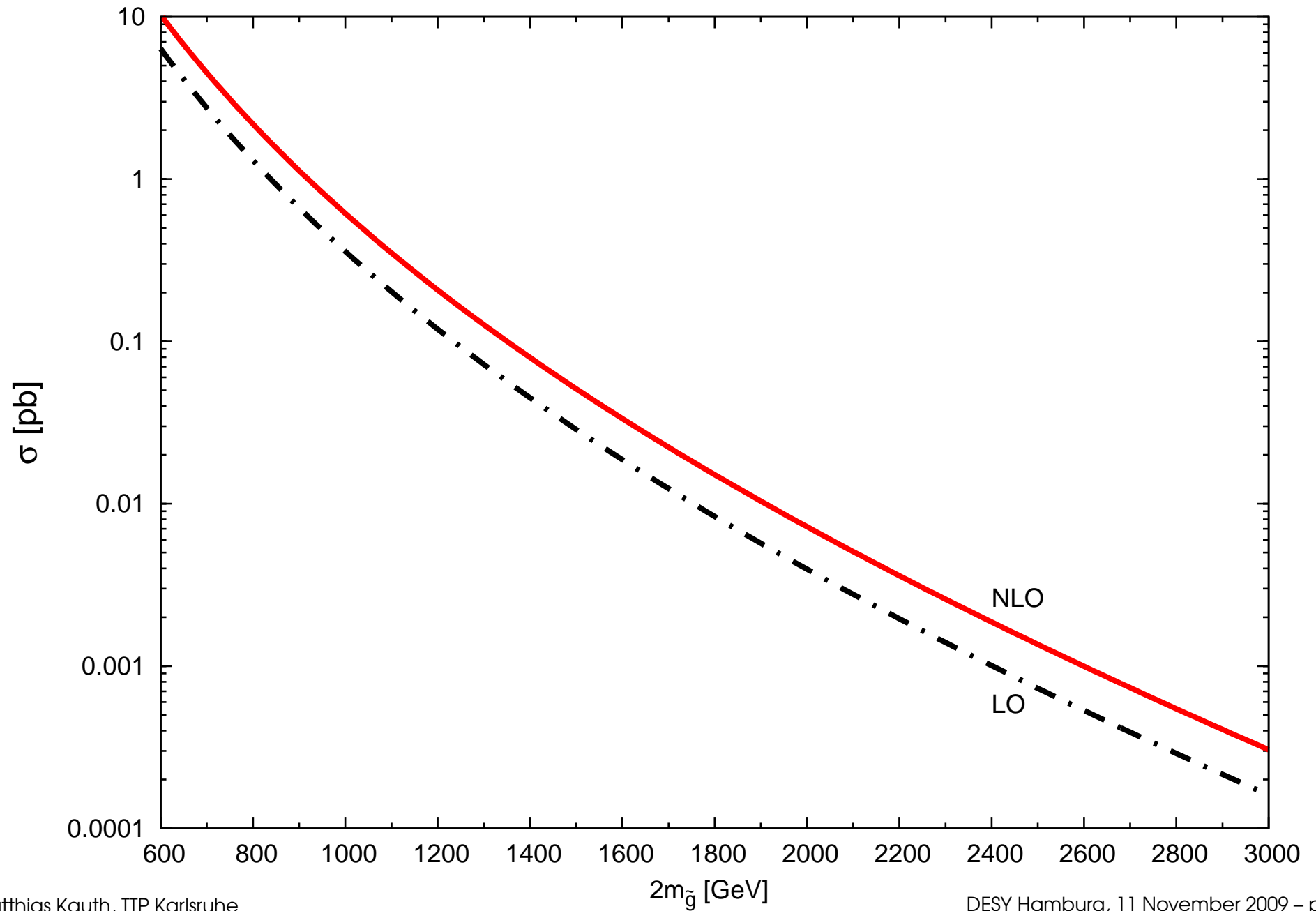
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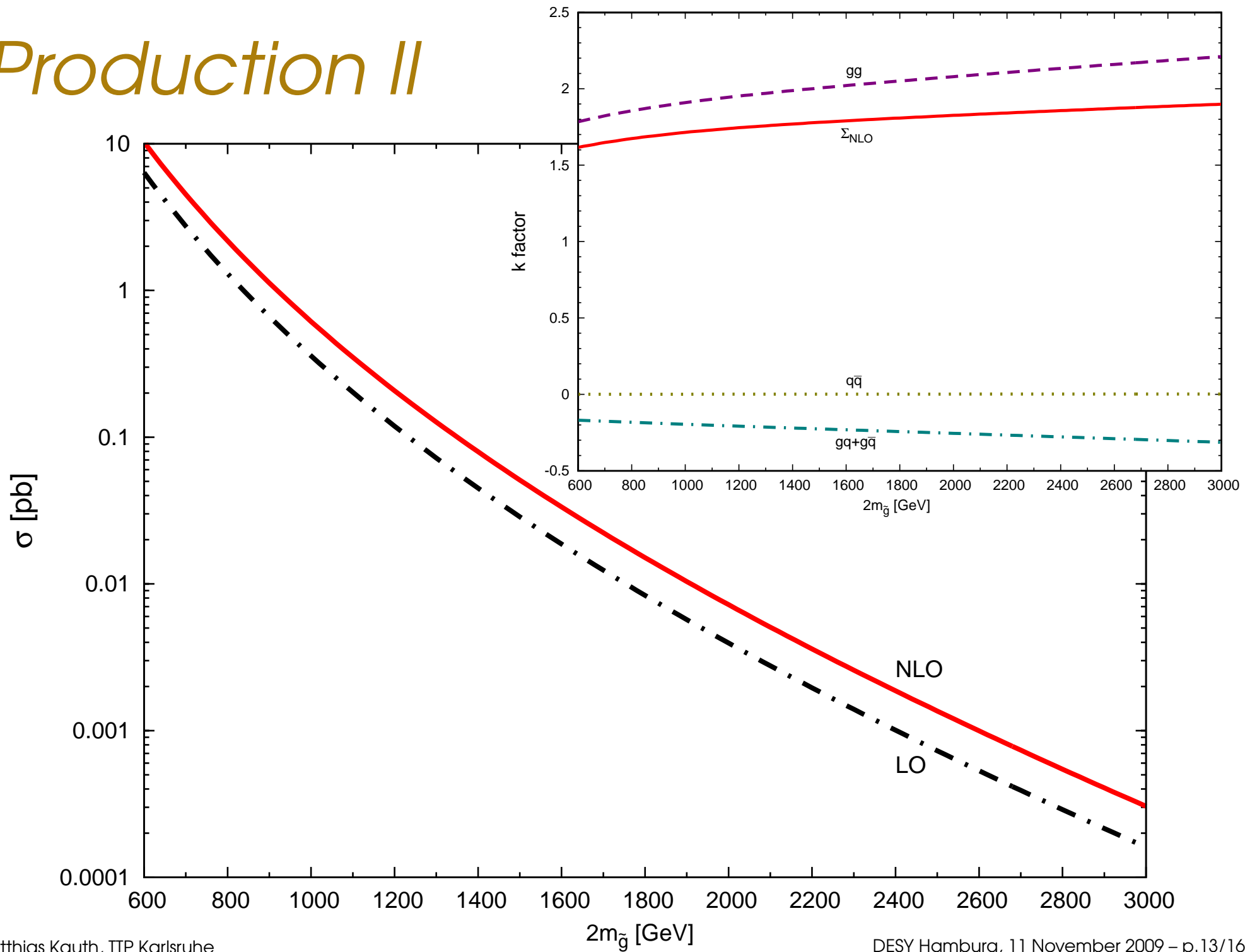
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Production II

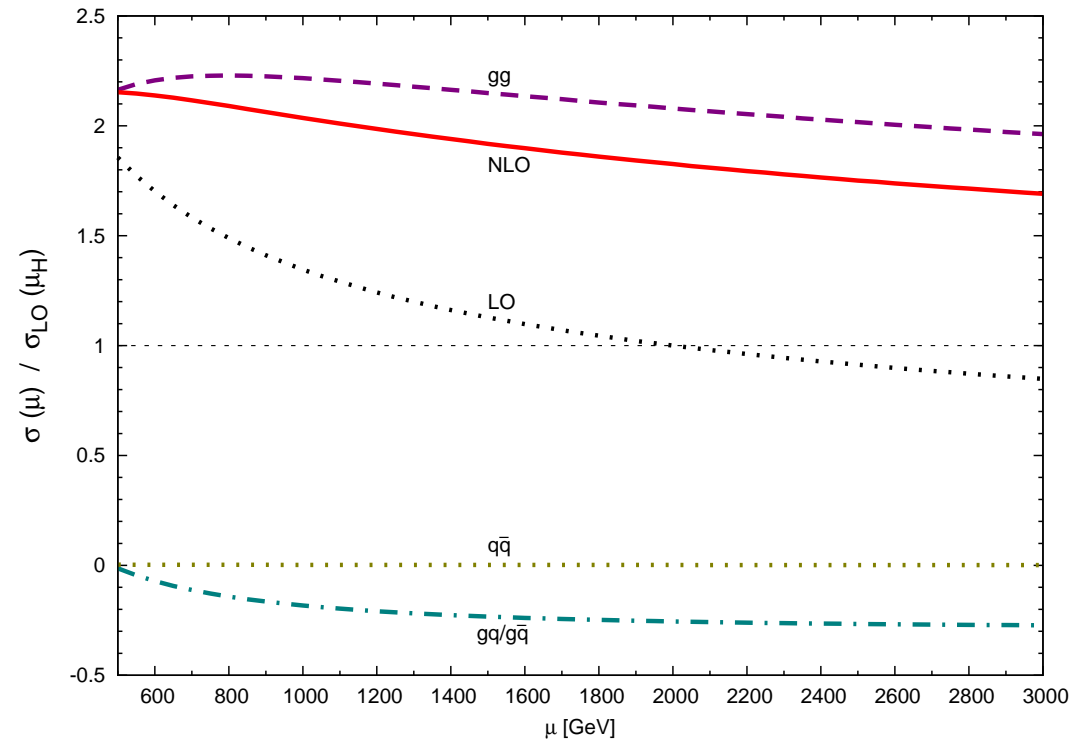


Production II



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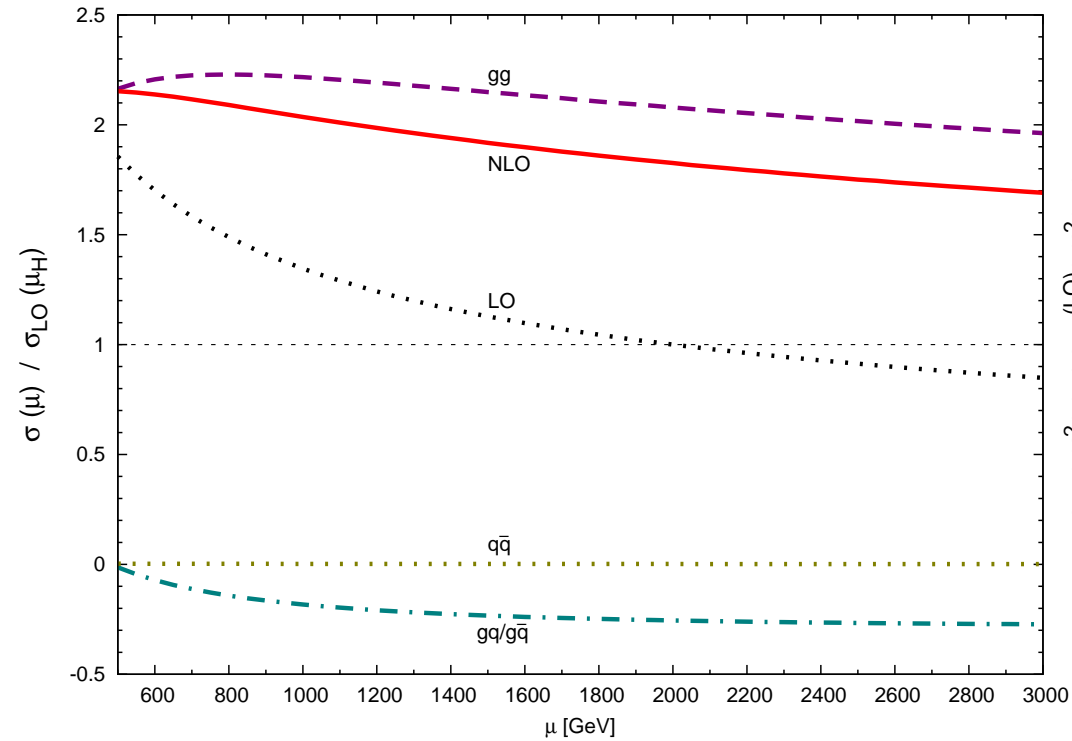
- scale dependence of the production cross section
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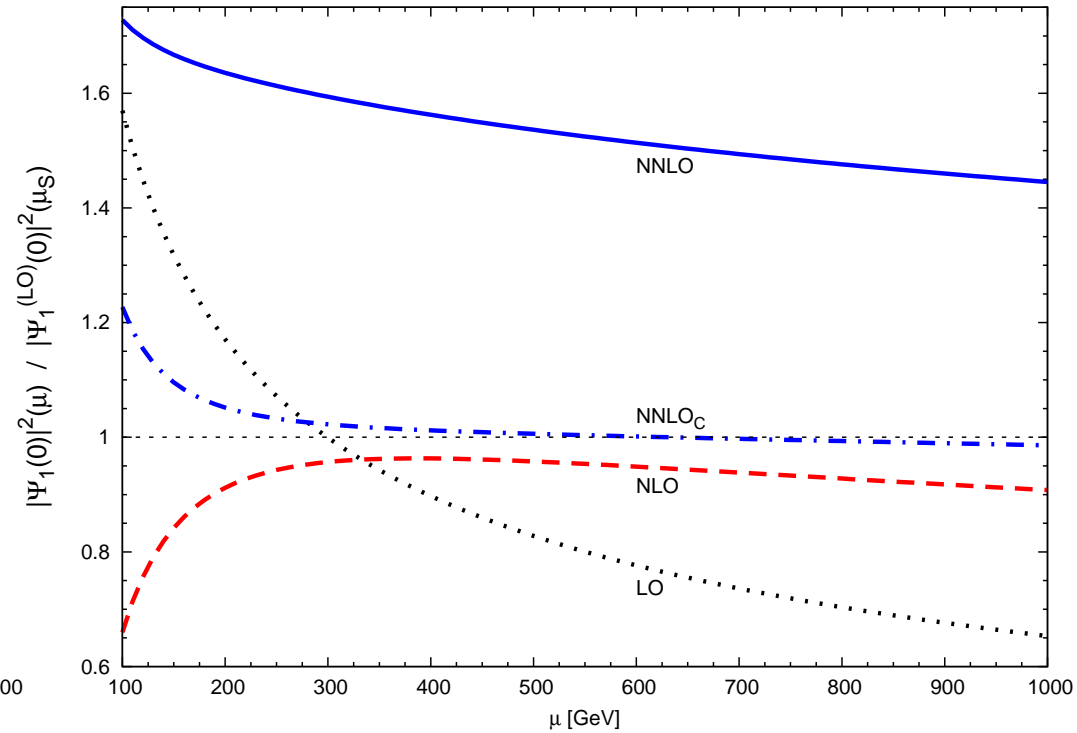
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Background

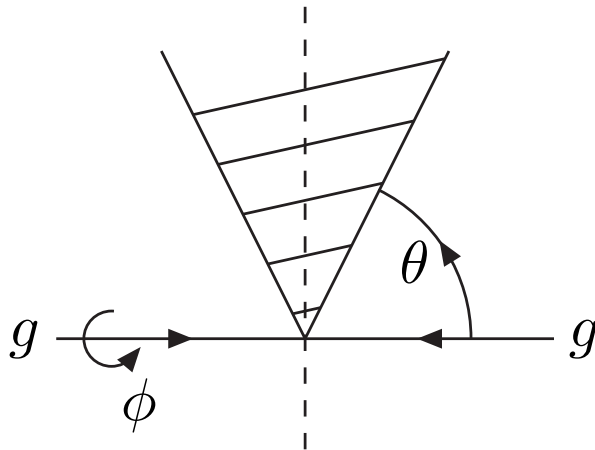
- isolation of the signal from the two-jet continuum

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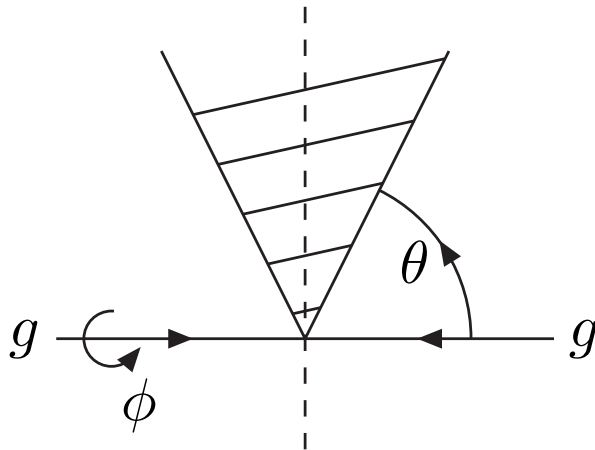


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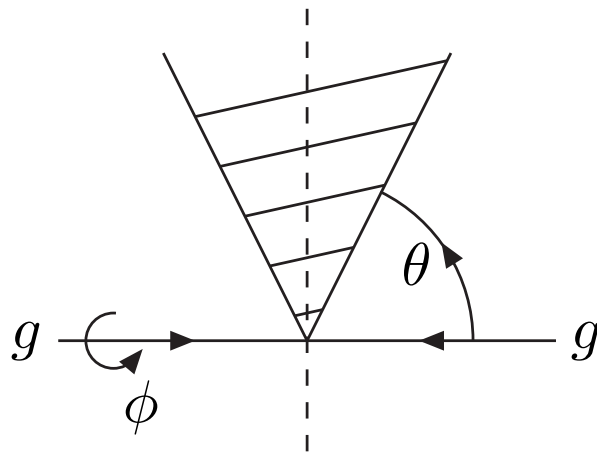
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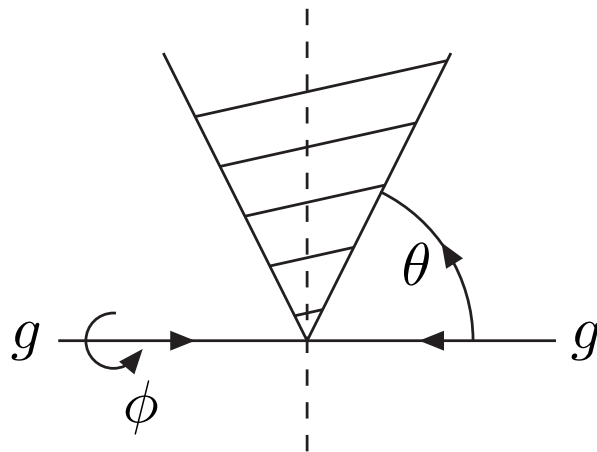
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$$\Rightarrow \text{Signal/Noise} \sim 0.4 \dots 0.7 \% \quad \text{for} \quad 1/4 < z < 1/2$$

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Thank you for your attention!