Gluinonia

Boundstates of Gluinos

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$(\tilde{g}\tilde{g})$ is also referred to as Gluinonium

[W.Keung and A.Khare ’84; J.Kühn and S.Ono ’85; T.Goldman and H.Haber ’85]

Introduction

- colour-representation:

$$8 \otimes 8 = 1_s \oplus 8_s \oplus 8_a \oplus 10_a \oplus \overline{10}_a \oplus 27_s$$

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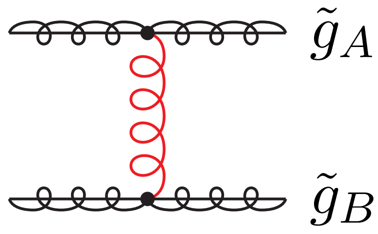

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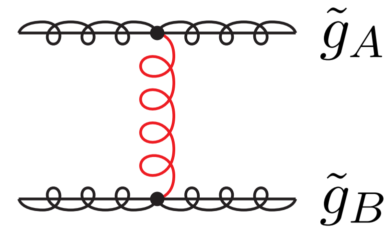

- application of the Pauli-principle:

$$-1 \;=\; \underbrace{(-1)^L}_{\text{position}} \times \underbrace{(-1)^{S+1}}_{\text{spin}} \times \underbrace{C}_{\text{charge}} \times \underbrace{\begin{cases} +1 & ; \quad 1_s, 8_s \\ -1 & ; \quad 8_a \end{cases}}_{\text{colour}}$$

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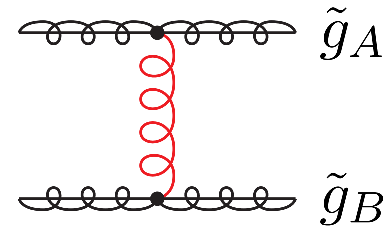

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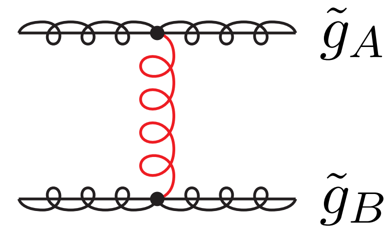

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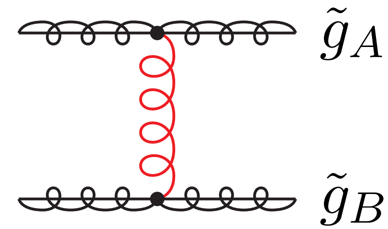

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in the following: 1_S -state only $(S = L = 0)$

Spectroscopy I

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

$\longrightarrow$ modification of existing $q\overline{q}$ -potentials for $\tilde{g}\tilde{g}$:

[W.Fischler '77; B.Kniehl, A.Penin, V.Smirnov and M.Steinhauser '02; ...]

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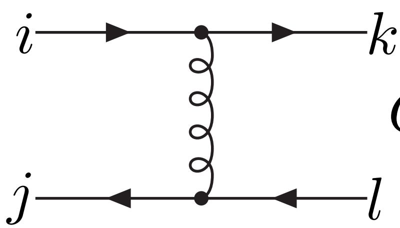
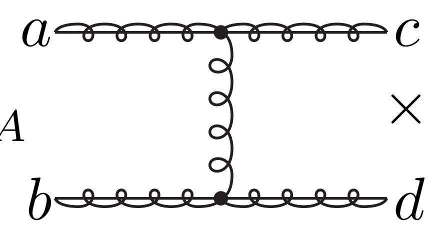


$C_F \quad \longrightarrow \quad C_A$



$\times \frac{\delta_{ab}\delta_{cd}}{N_C^2-1}$

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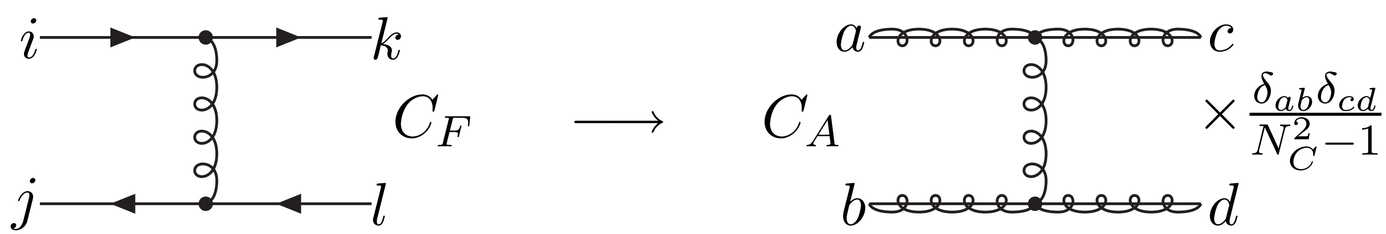

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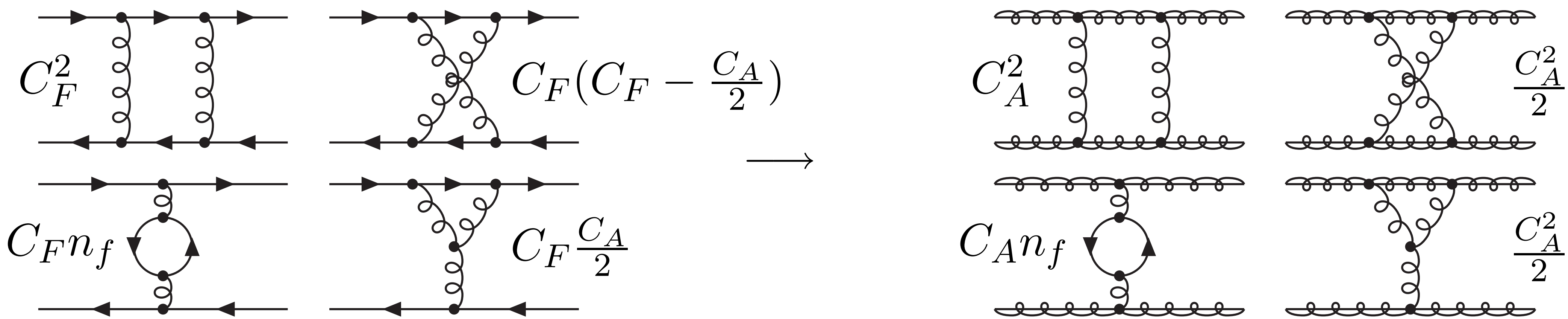
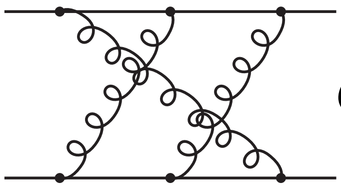
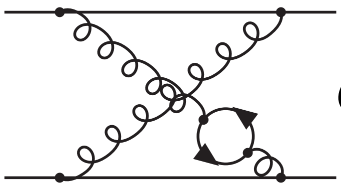


Spectroscopy II

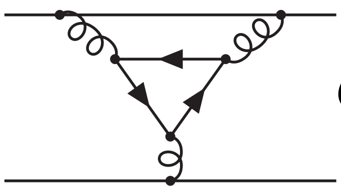
- NNLO:



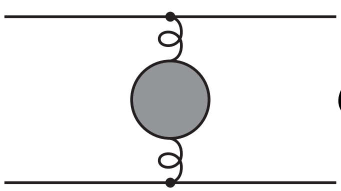
$$C_F\left(C_F - \frac{C_A}{2}\right)^2 \longrightarrow C_A\left(C_A - \frac{C_A}{2}\right)^2$$



$$C_F\left(C_F - \frac{C_A}{2}\right)n_f \longrightarrow C_A\left(C_A - \frac{C_A}{2}\right)n_f$$



$$C_F C_A n_f \longrightarrow C_A C_A n_f$$



$$C_F X \longrightarrow C_A X$$

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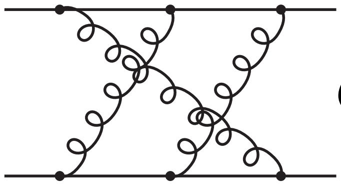

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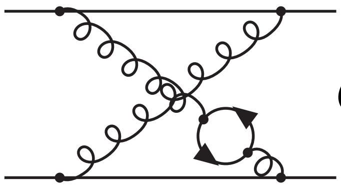

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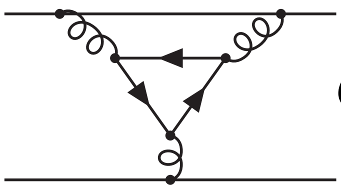

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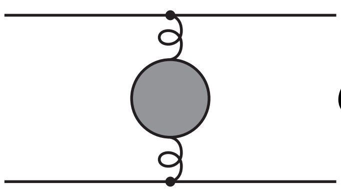

$$C_F X \longrightarrow C_A X$$

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

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- solving the non-relativistic Schrödinger equation
  $\longrightarrow$ numerics and perturbation theory:

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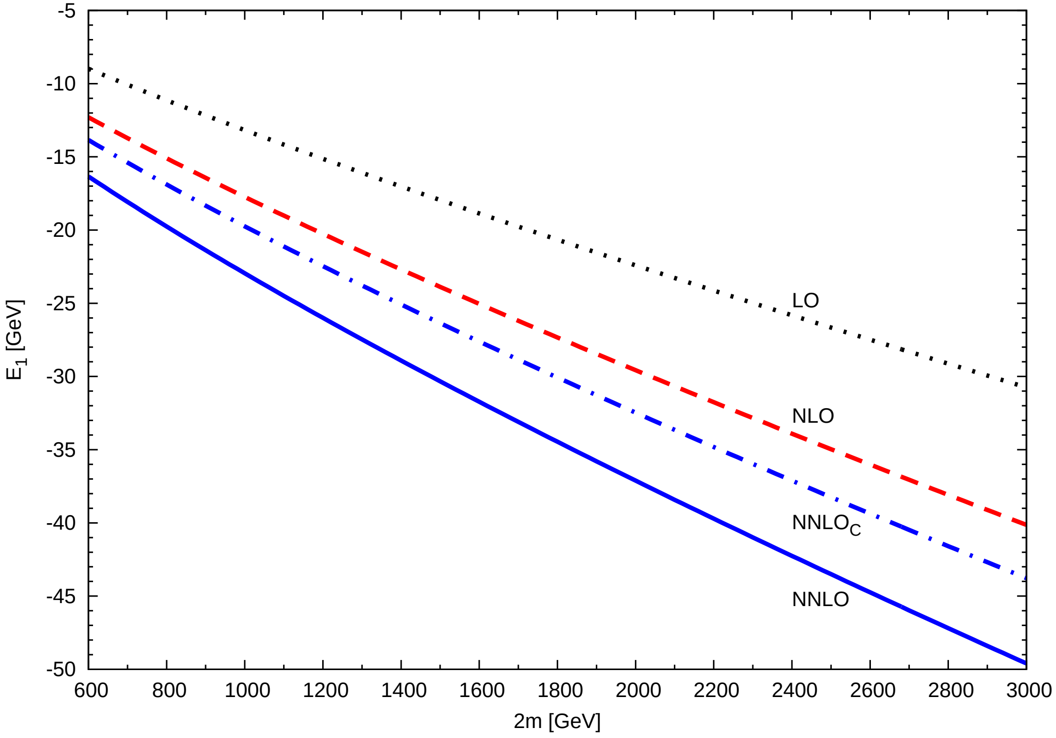
    $$\begin{aligned} E_1 = -\frac{9 m_{\tilde{g}} \alpha_s^2}{4} \Big\{ & \; 1 \\ + & \; \alpha_s \left[2.44L + 3.20\right] \\ + & \; \alpha_s^2 \left[\left(4.47L^2 + 9.71L + 12.47\right)_C + (20.81)_{nC}\right] \Big\} \end{aligned}$$

with:

$$L = \ln\left(\frac{\mu}{m_{\tilde{g}} C_A \alpha_s}\right) \quad \longrightarrow \quad \mu_{\text{nat}} = C_A m_{\tilde{g}} \alpha_s(\mu_{\text{nat}})$$

Spectroscopy IV

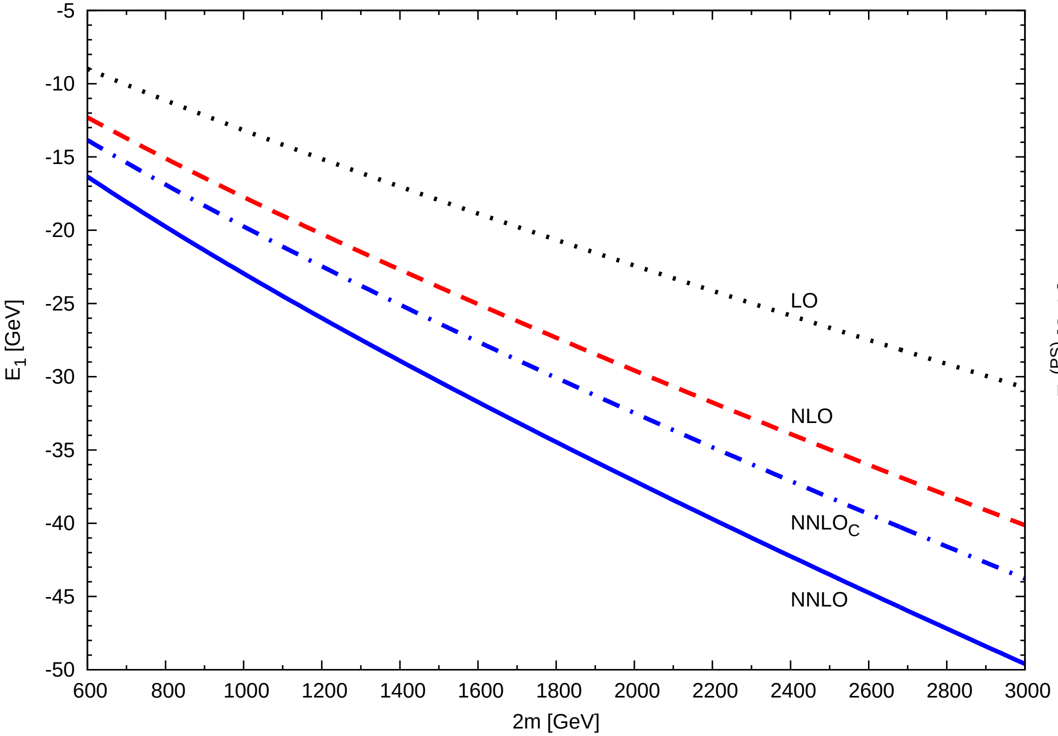
- energy eigenvalues in the pole

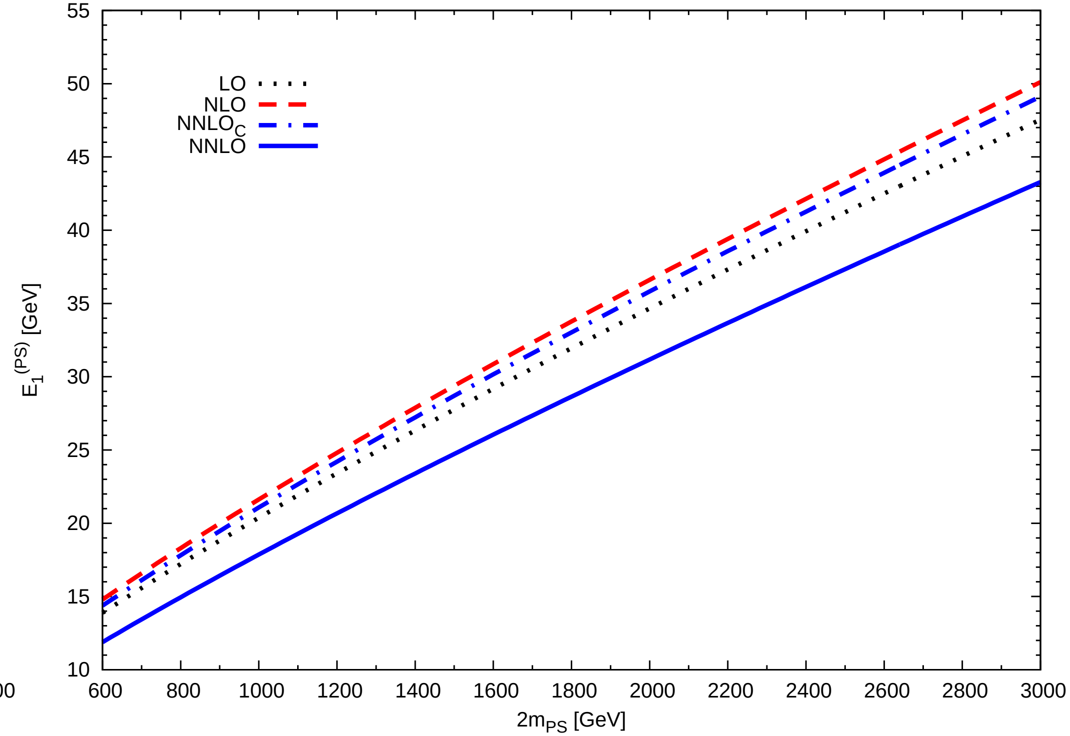


Spectroscopy IV

- energy eigenvalues in the pole and the PS scheme:

[M.Beneke '98]





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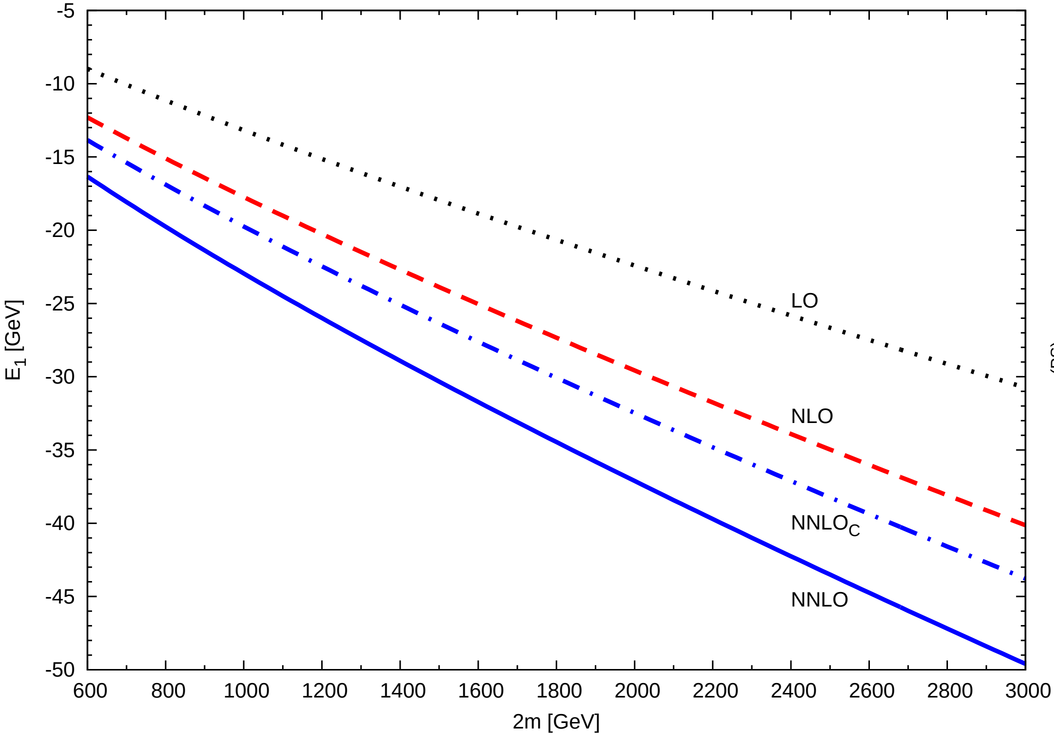
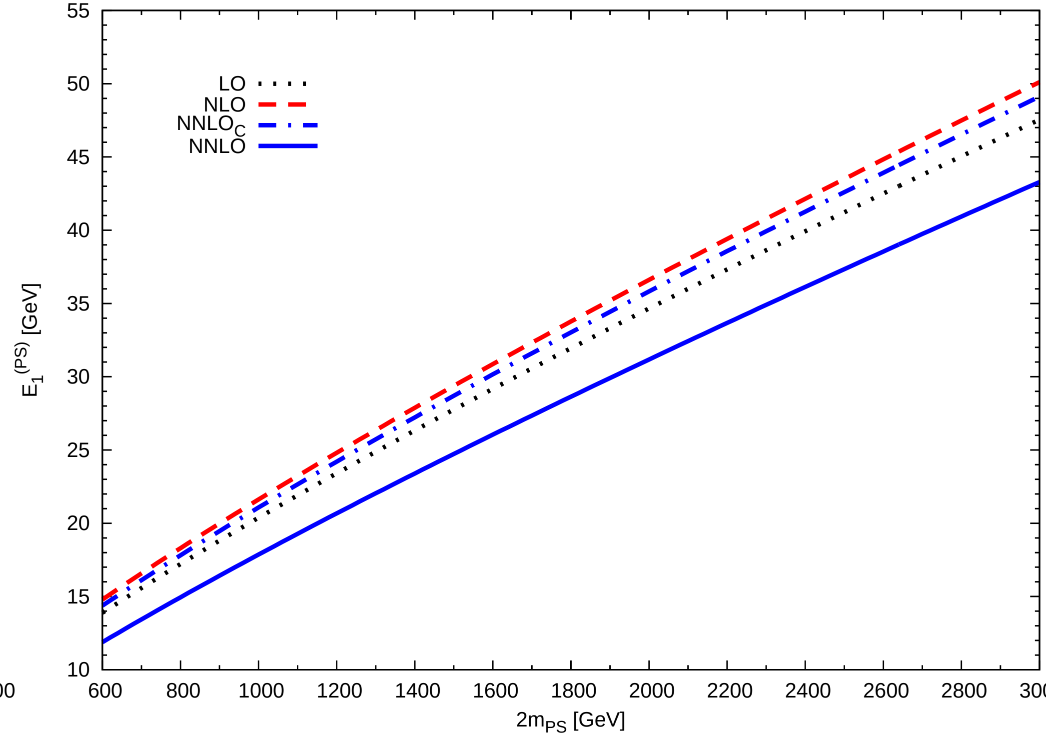


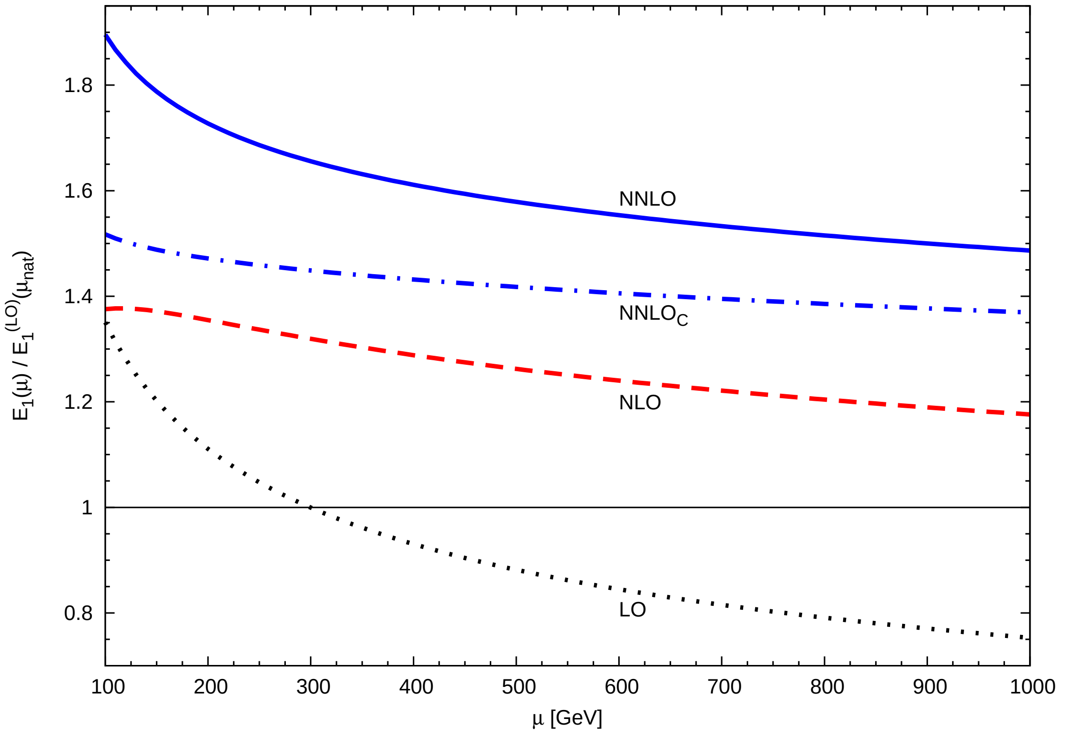


$$M_{(\tilde{g}\tilde{g})_{1S}} = 2m_{\tilde{g}} + E_1$$

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

Spectroscopy V

- scale dependence of the energy eigenvalues for $m_{\tilde{g}} = 1\,\text{TeV}$ in the pole-



$$\mu_{\text{nat}} = C_A m_{\tilde{g}} \alpha_s(\mu_{\text{nat}})$$

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- scale dependence of the energy eigenvalues

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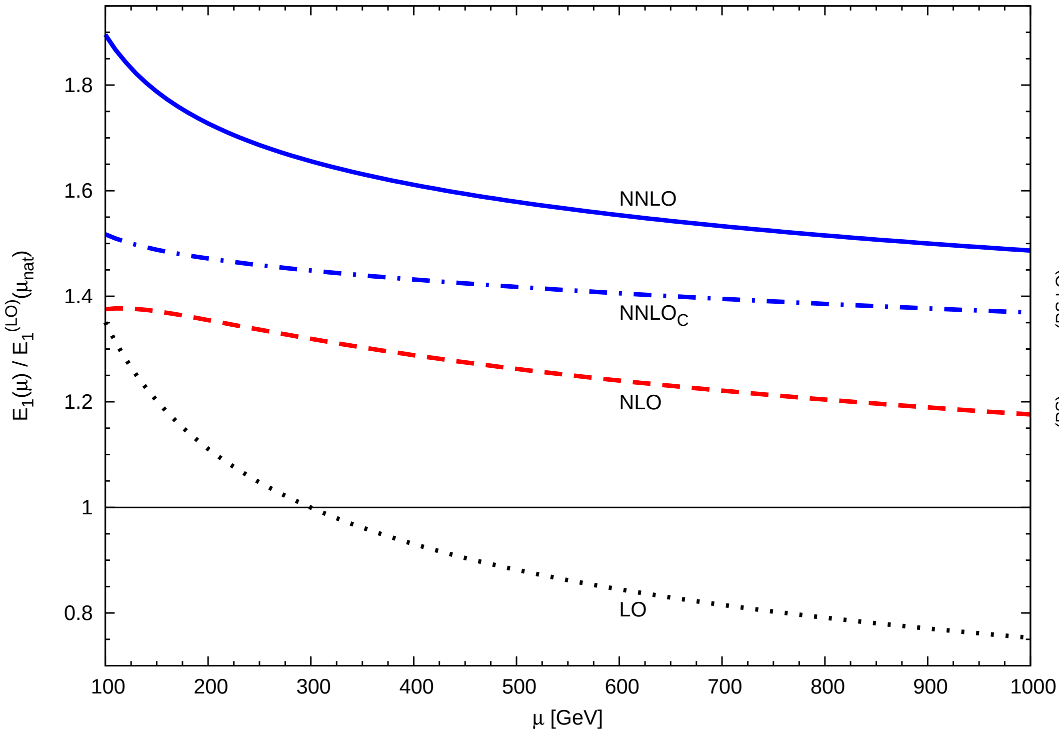
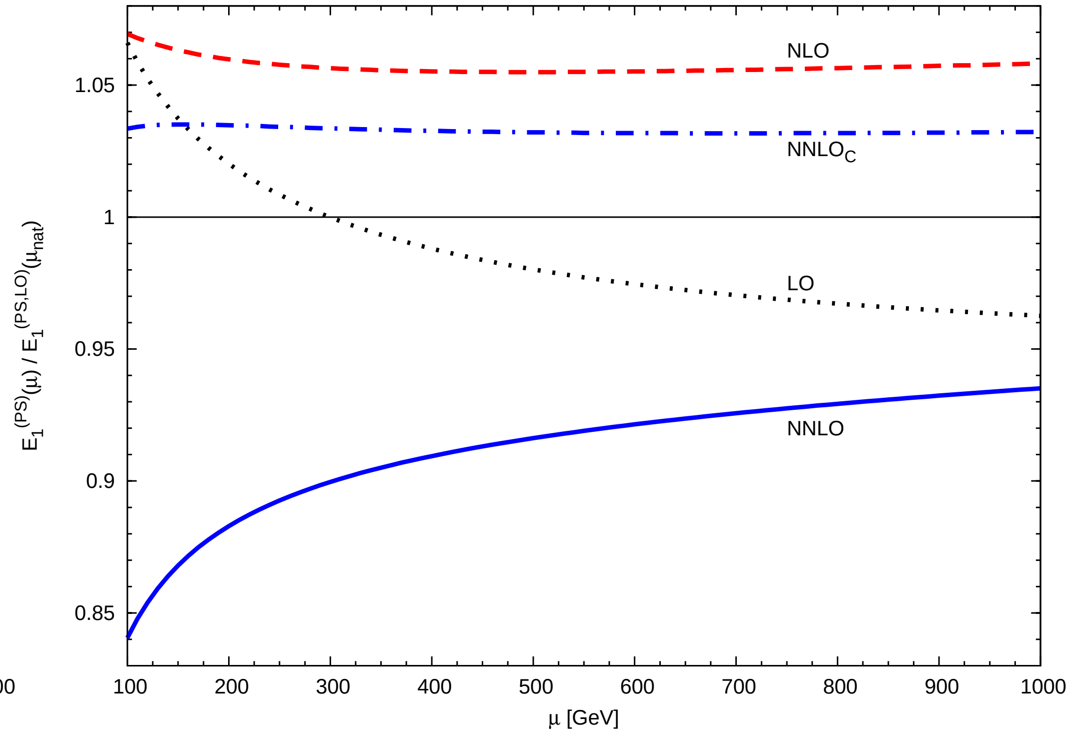
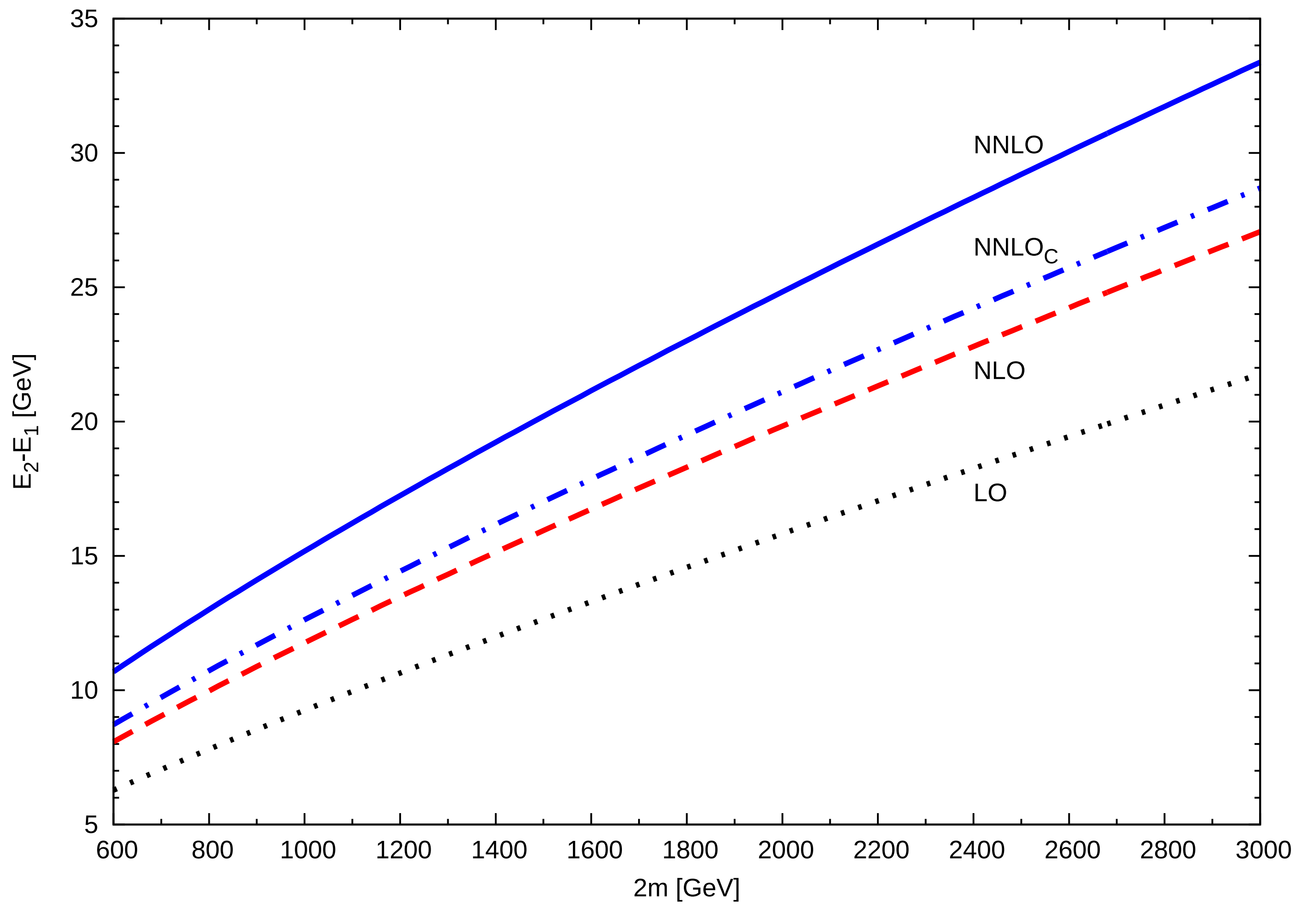




$$\mu_{\text{nat}} = C_A m_{\tilde{g}} \alpha_s(\mu_{\text{nat}})$$

Spectroscopy VI

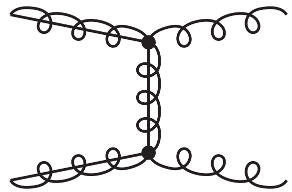
- excitation energy in the pole scheme between the $1S$ - and the $2S$ -state:

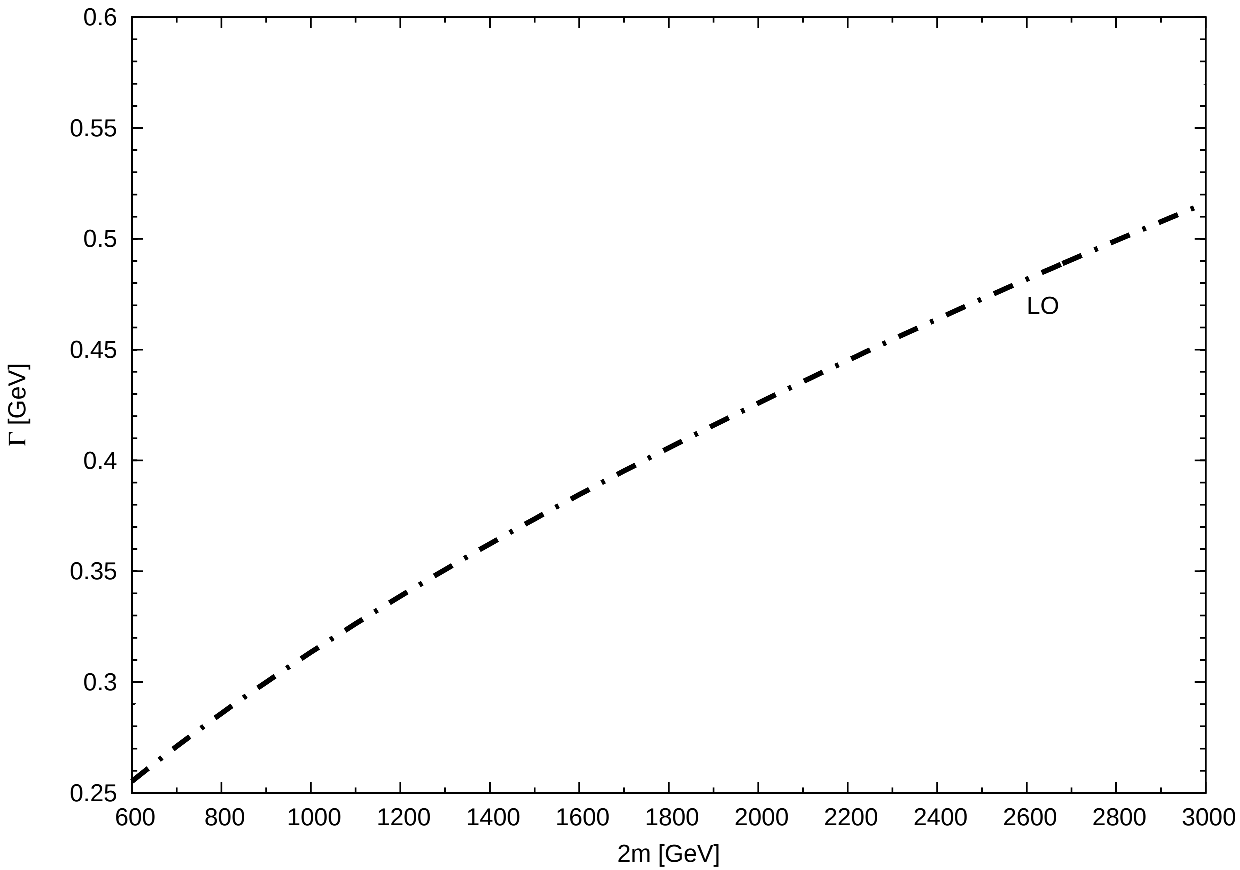


Decay I

- hadronic decay channel:

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





	hard part	wavefunction
μ	$2m_{\tilde{g}}$	$C_A \alpha_s m_{\tilde{g}}$
n_f	6	5

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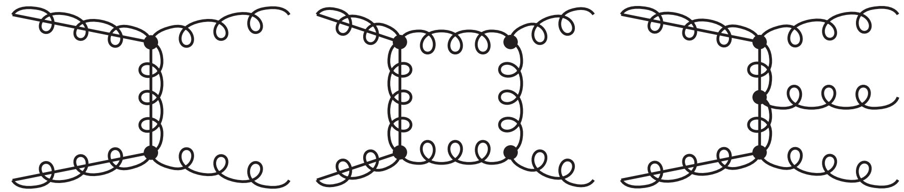
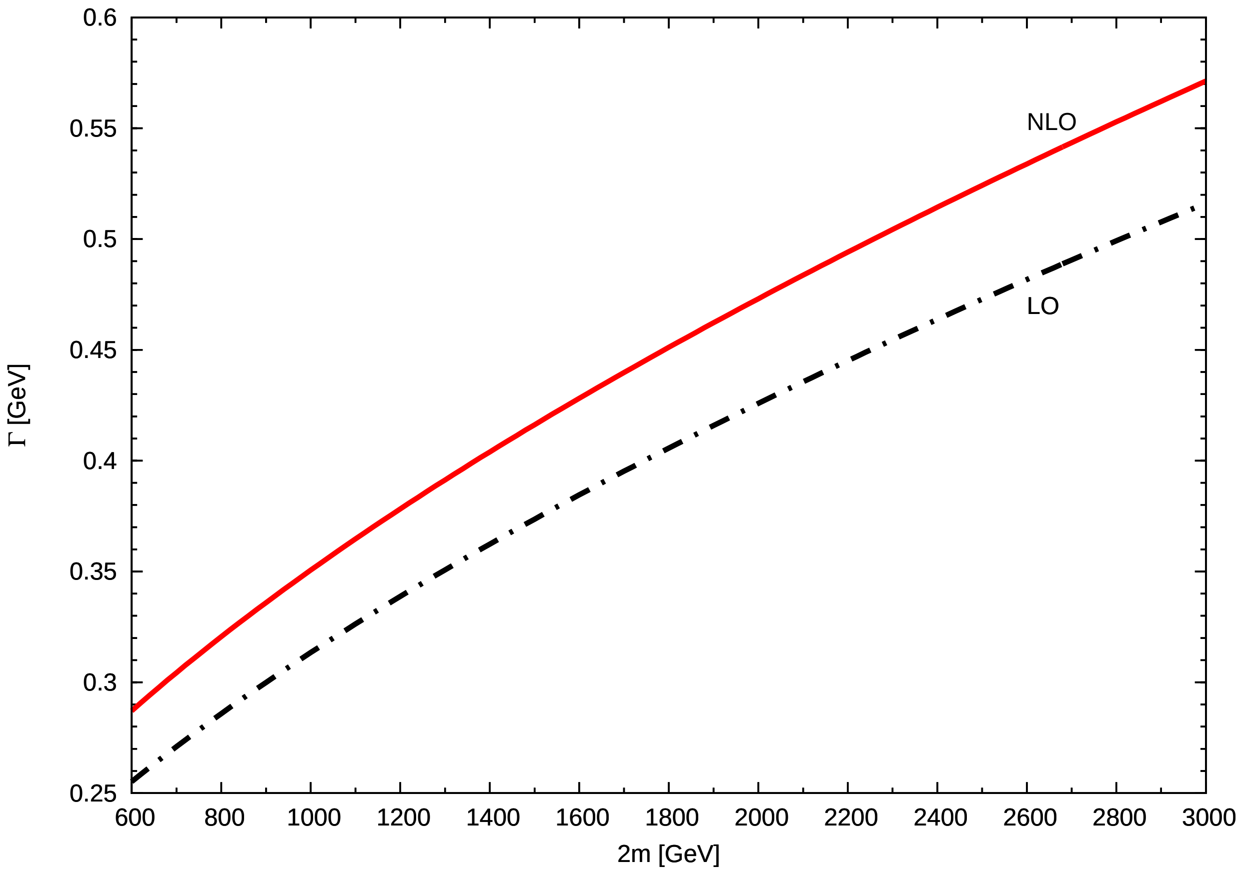


$$\Gamma((\tilde{g}\tilde{g})_{1_s} \to gg) = |R(0)|^2 \, \frac{C_A^2 \alpha_s^2}{2 m_{\tilde{g}}^2}$$

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



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Decay II

- isolation of the $1S$ -state:

$$\underbrace{\frac{\alpha\alpha_s e_q^2 m_{\tilde{g}}^4}{48\pi m_{\tilde{q}}^4} m_{\tilde{g}}}_{\text{single decay}} \leq \underbrace{\frac{C_A^5 \alpha_s^5}{4} m_{\tilde{g}}}_{\text{annihilation decay}} \leq \underbrace{\left(1 - \frac{1}{4}\right) \frac{C_A^2 \alpha_s^2}{4} m_{\tilde{g}}}_{\text{level spacing}}$$

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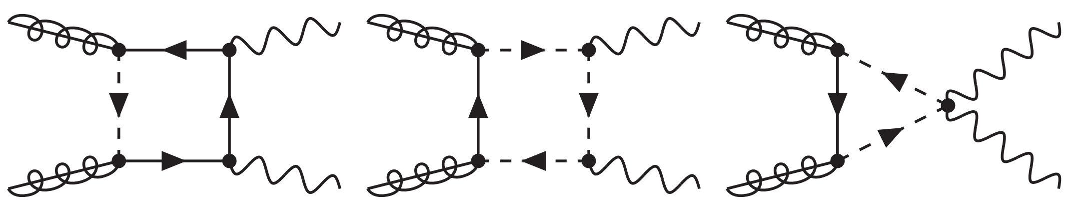
- decay into 2 photons $z = \frac{m_{\tilde{g}}^2}{m_{\tilde{q}}^2}$:



$$\mathrm{Br}(\gamma\gamma) = \frac{\Gamma((\tilde{g}\tilde{g})_{1_S} \to \gamma\gamma)}{\Gamma((\tilde{g}\tilde{g})_{1_S} \to gg)} = 50 \frac{T_F^2}{C_A^2} \left(\frac{\alpha}{\pi}\right)^2 (\mathrm{Li}_2(-z) - \mathrm{Li}_2(z))^2 \sim 10^{-6 \ldots -5}$$

for $\quad m_{\tilde{g}} < m_{\tilde{q}} < 2m_{\tilde{g}}$

Production I

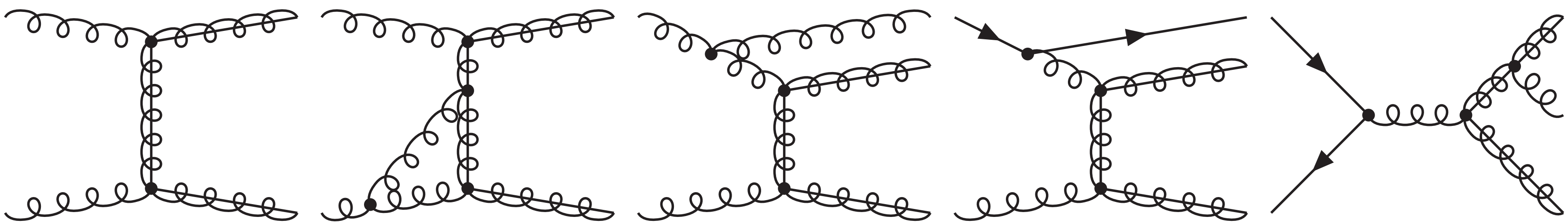
- hadronic production:

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

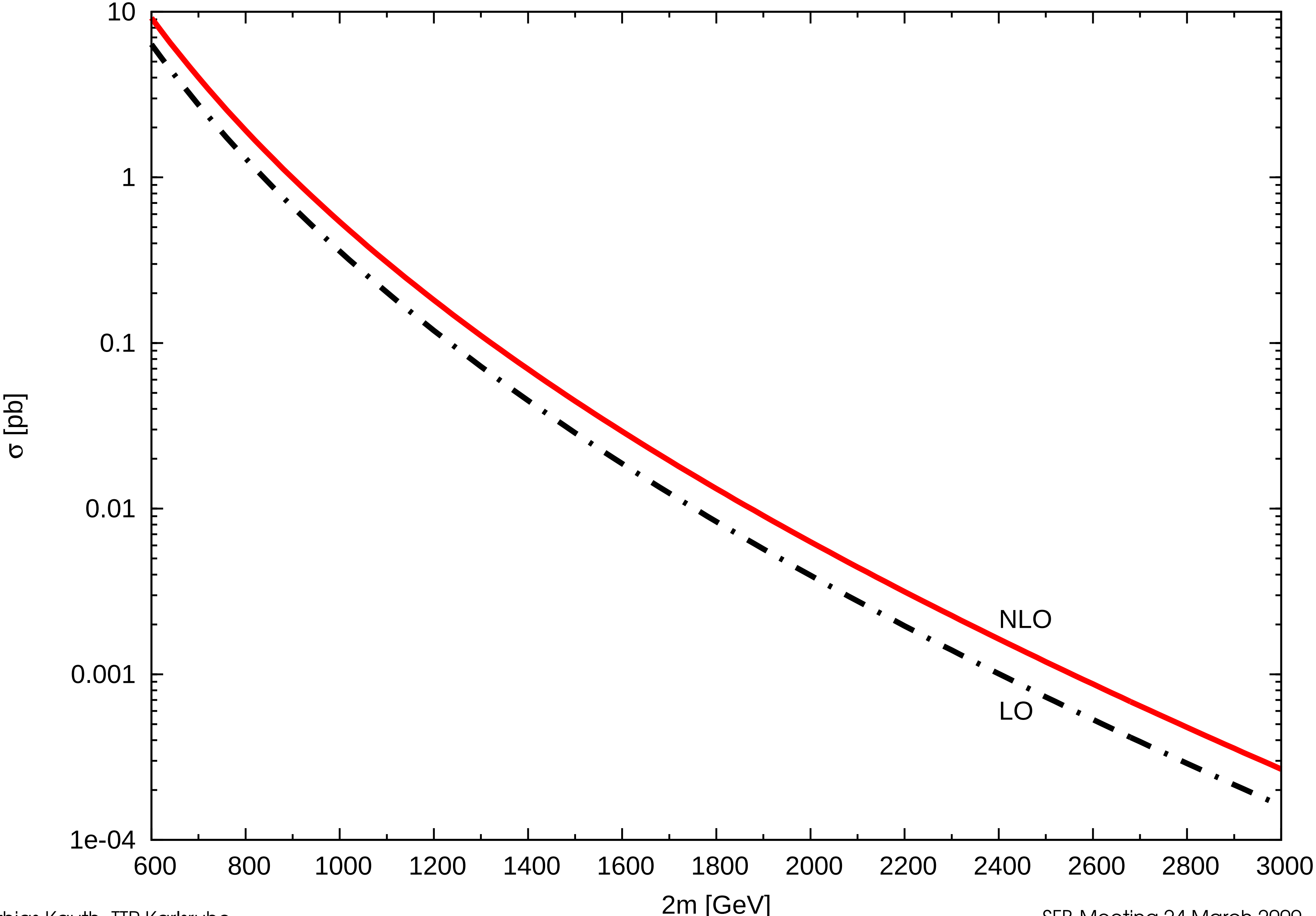
with: $Q_f = \mu_{\text{ren}} = 2m_{\tilde{g}}$ and $\sqrt{S} = 14\,\text{TeV}$ (LHC)

PDF: MSTW (formerly MRST)

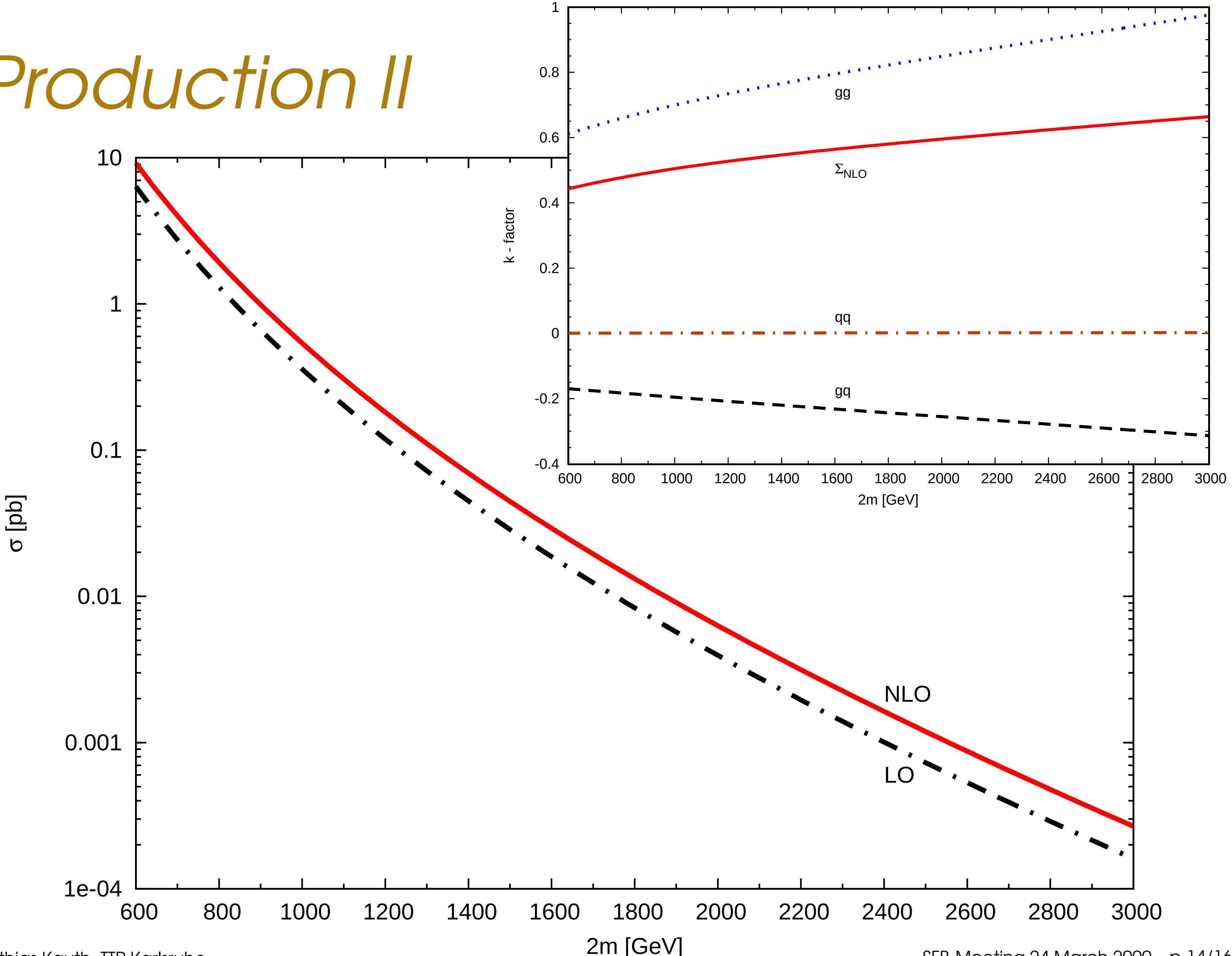
[A.Martin, W.Stirling, R.Thorne and G.Watt '09]



Production II



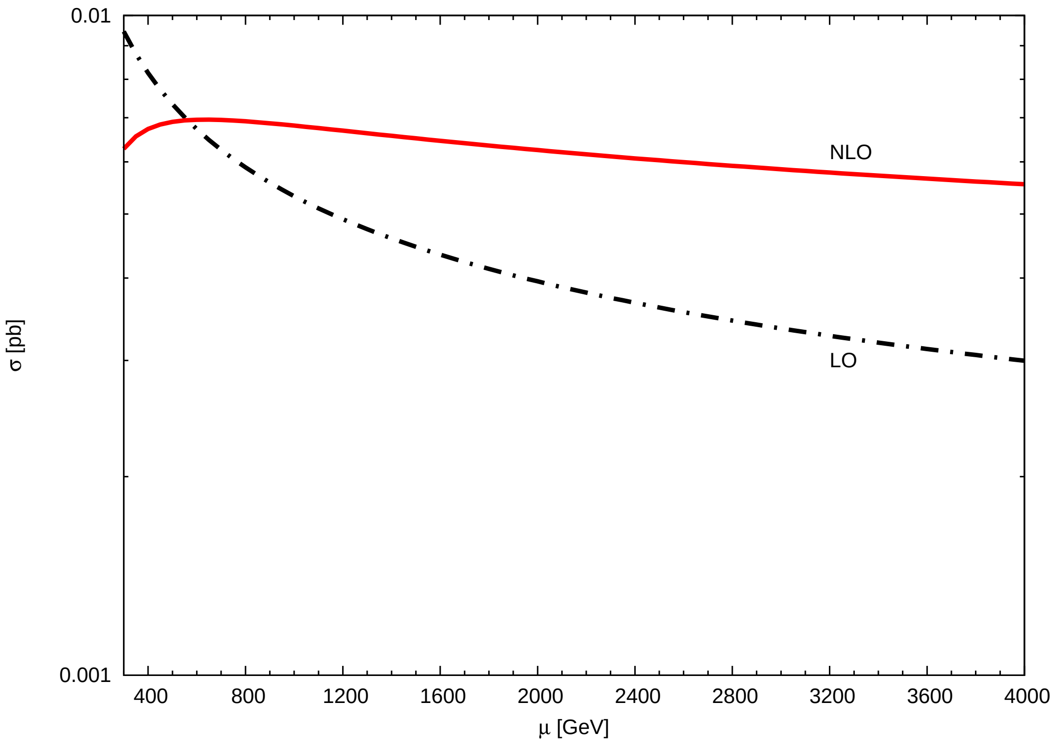
Production II



Production III

- scale dependence of the production cross section:

for $m_{\tilde{g}} = 1000\,\text{GeV}$



$\mu_{\text{ren}} = 2000\,\text{GeV}$

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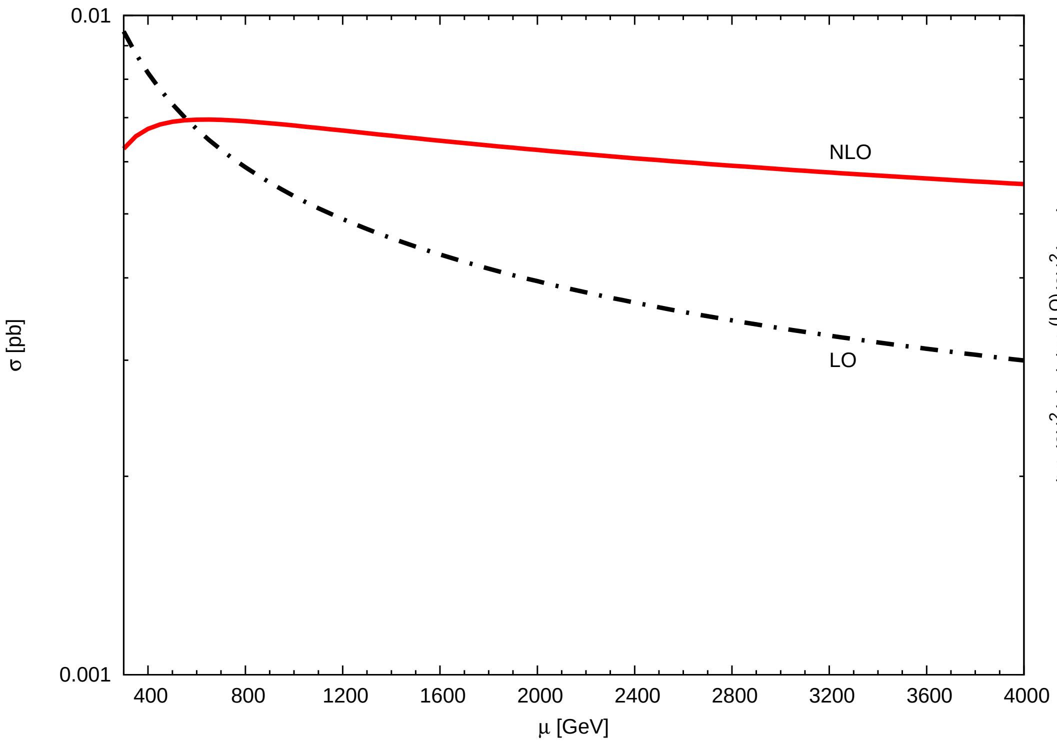

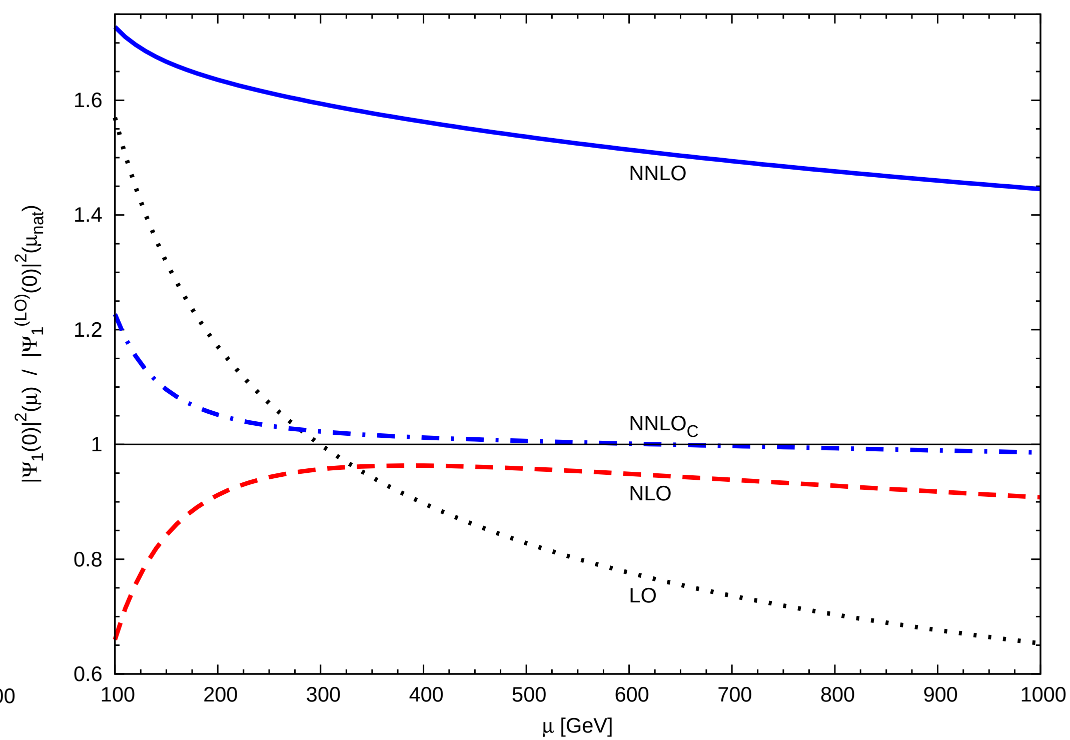

$\mu_{\text{ren}} = 2000\,\text{GeV}$

$\mu_{\text{nat}} \simeq 300\,\text{GeV}$

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summary:

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Thank you for your attention!