Gluino Pair Production at the LHC

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in collaboration with Johann H. Kühn, Peter Marquard and Matthias Steinhauser

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Karlsruher Institut für Technologie

Motivation - I

- Supersymmetry as a candidate for new physics

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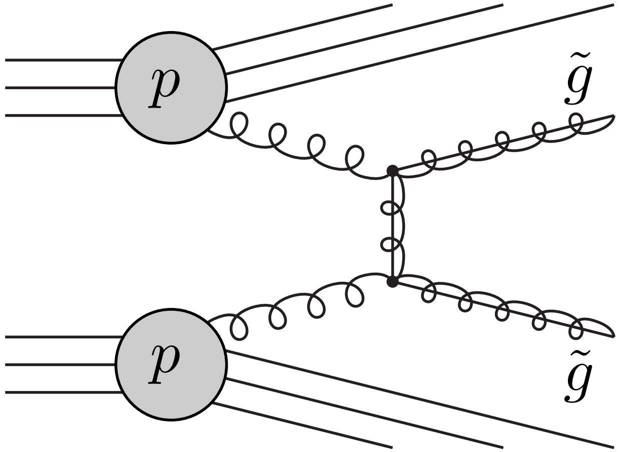

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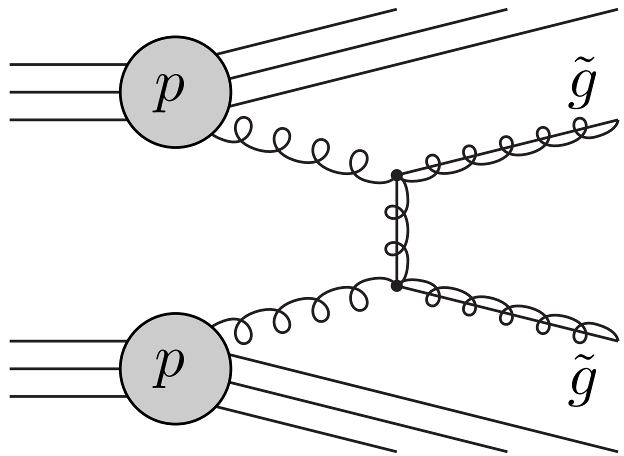

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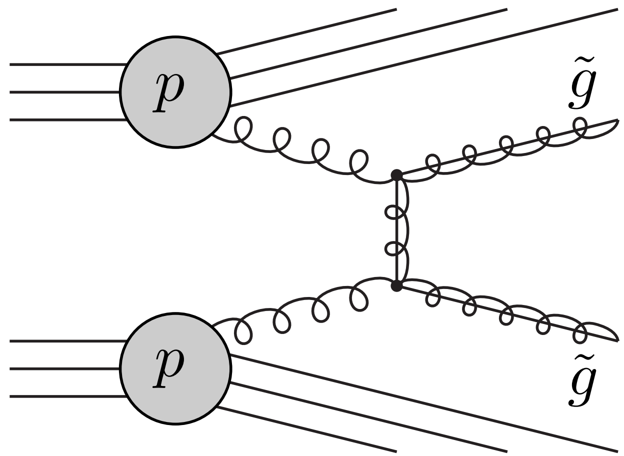

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- investigation of $\tilde{g}\tilde{g}$ - bound states

  [Keung and Khare ’84; Kühn and Ono ’84; Goldman and Haber ’85]

Motivation - II

- $pp \to \tilde{g}\tilde{g}$ at NLO SQCD

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- replacement of the Sommerfeld factor by the non - relativistic Green's function (NRQCD)

  [Hagiwara and Yokoya '09]

- complete NLO analysis of the differential cross section at threshold

  [Kauth, Kühn, Marquard and Steinhauser '10] (*in preparation*)

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- properties of gluinos

– interact only strong

– spin-$\frac{1}{2}$ particles

– no mixing

– adjoint $SU_C(3)$ representation

– Majorana fermions

– $m_{\tilde{g}} > 308$ GeV [PDG '10]

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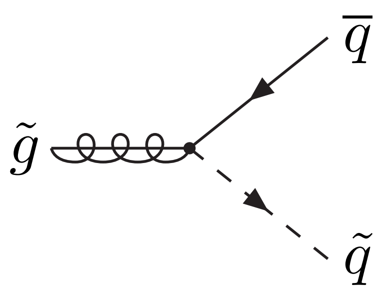

$$\Gamma(\tilde{g} \to \tilde{q}\overline{q} + \overline{\tilde{q}}q) \sim \alpha_s m_{\tilde{g}}$$

[Barger, Hagiwara, Keung and Woodside '85]

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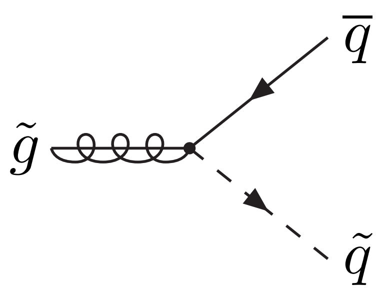

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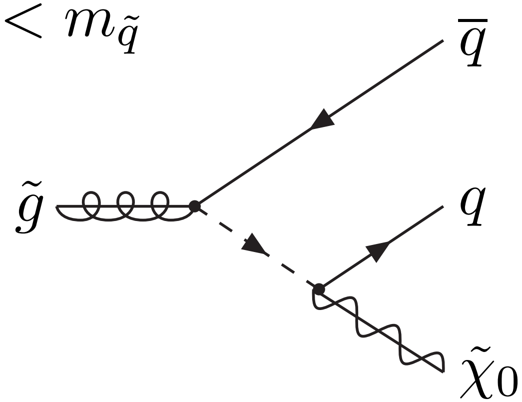
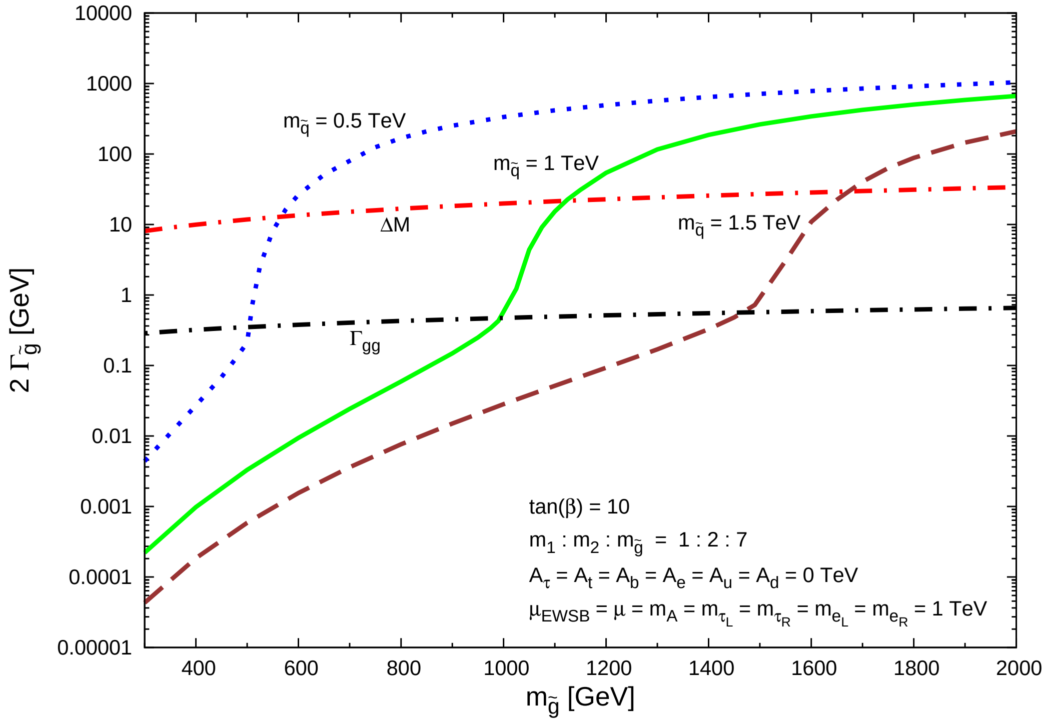


$$\Gamma(\tilde{g} \to \tilde{\chi}_0 q\overline{q}) \sim \frac{\alpha\alpha_s m_{\tilde{g}}^5}{m_{\tilde{q}}^4}$$

[Haber and Kane '85]

Introduction - II

- $2\Gamma_{\tilde{g}}$, level spacing $\Delta M = |E_1 - E_2|$ and annihilation width Γ_{gg} (SDECAY [Mühlleitner, Djouadi and Mambrini '05])



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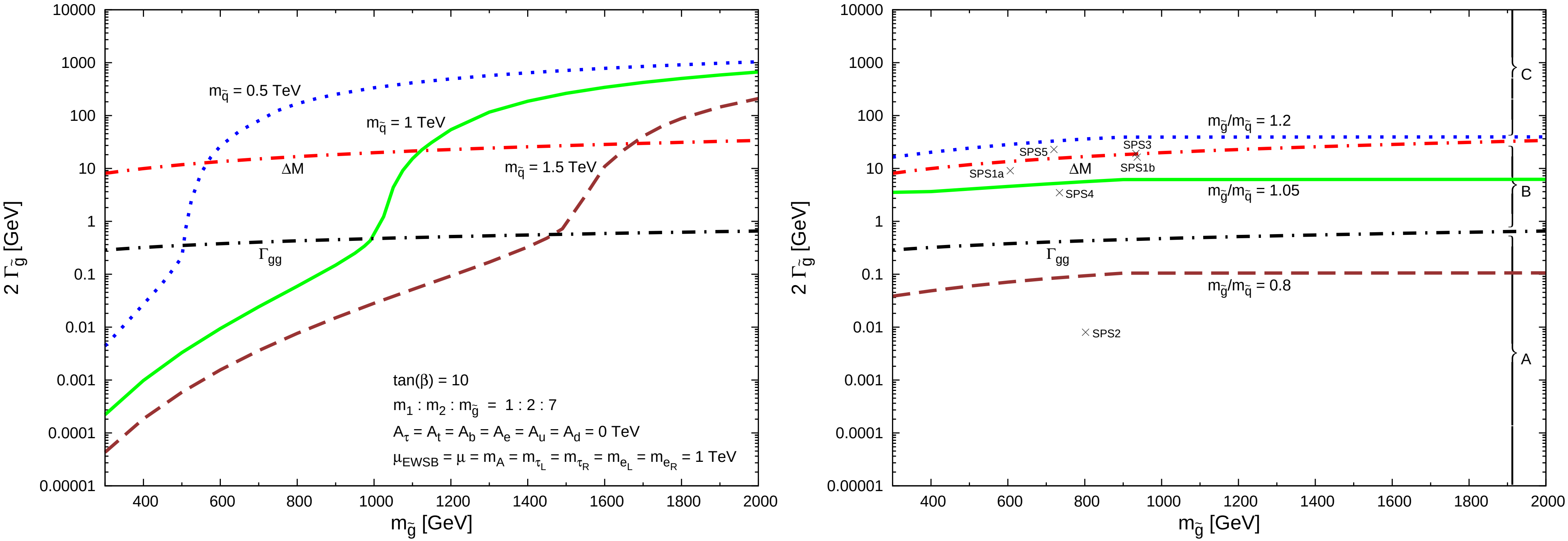

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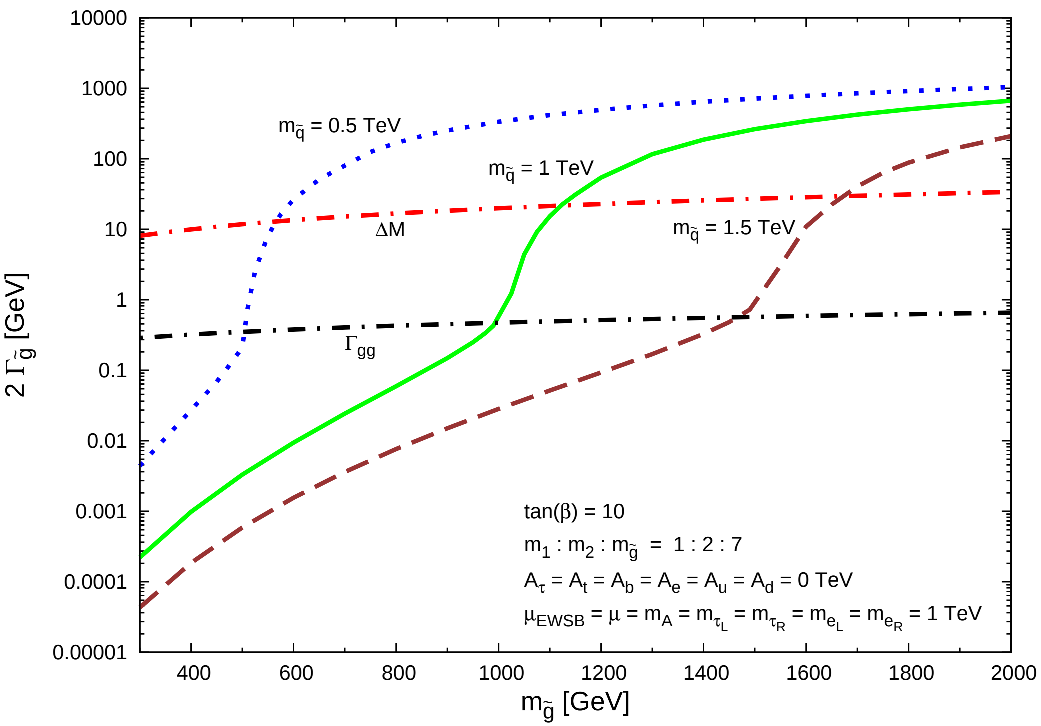

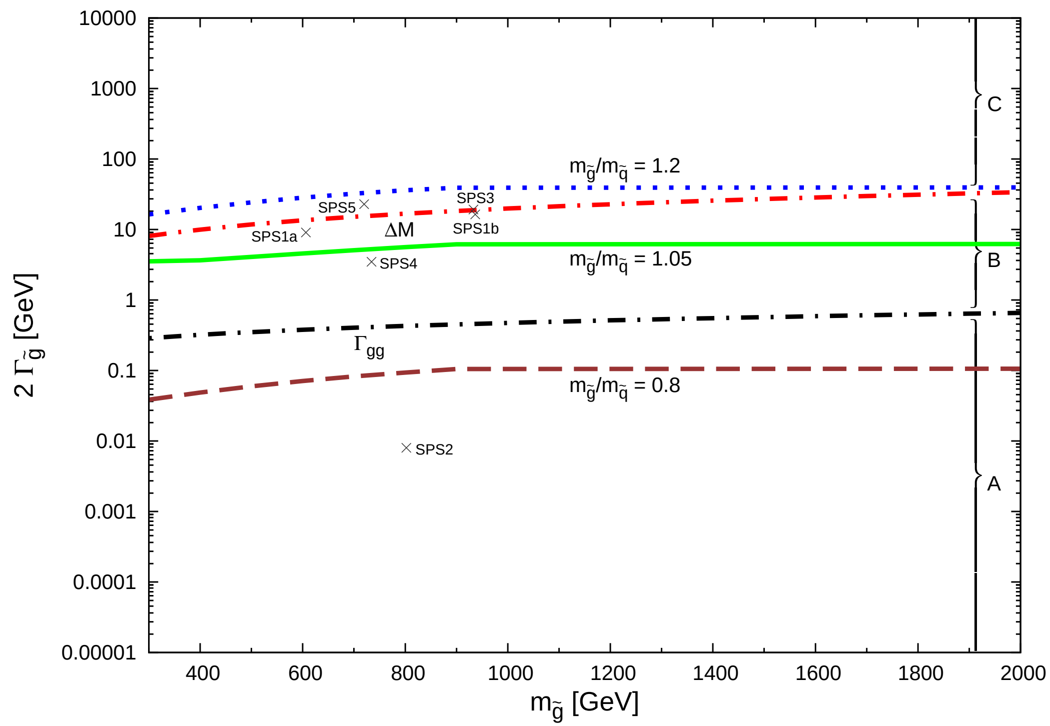

∘ class A ($2\Gamma_{\tilde{g}} < \Gamma_{gg}$)

$\longrightarrow$ $\tilde{g}\tilde{g}$ bound states [Kauth, Kühn, Marquard and Steinhauser '09]

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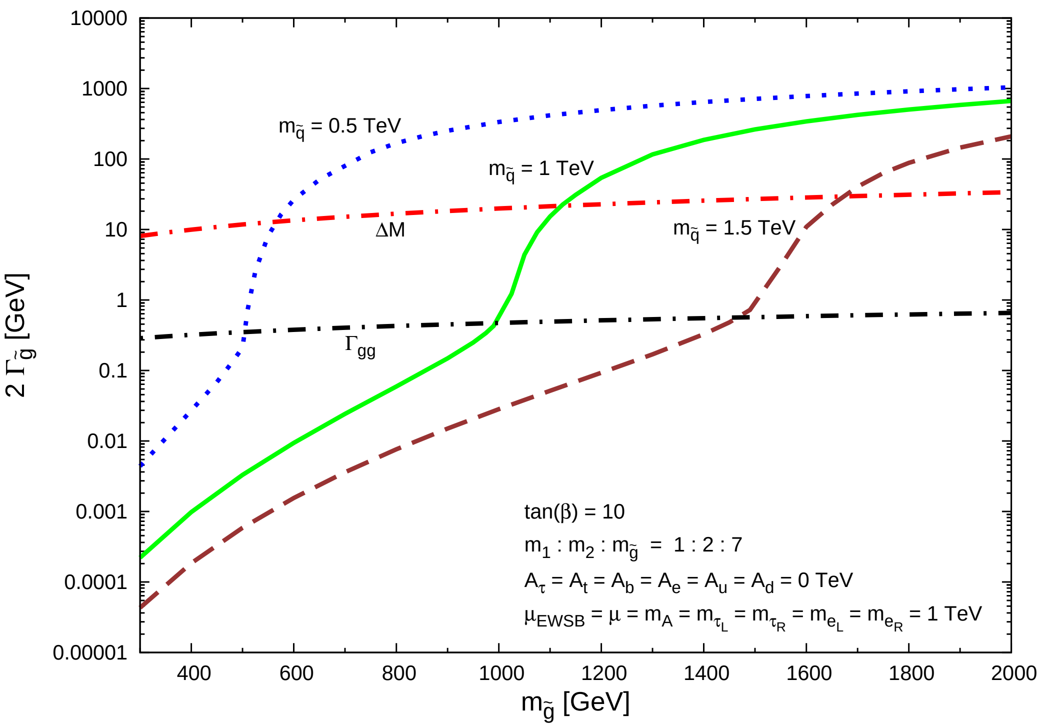

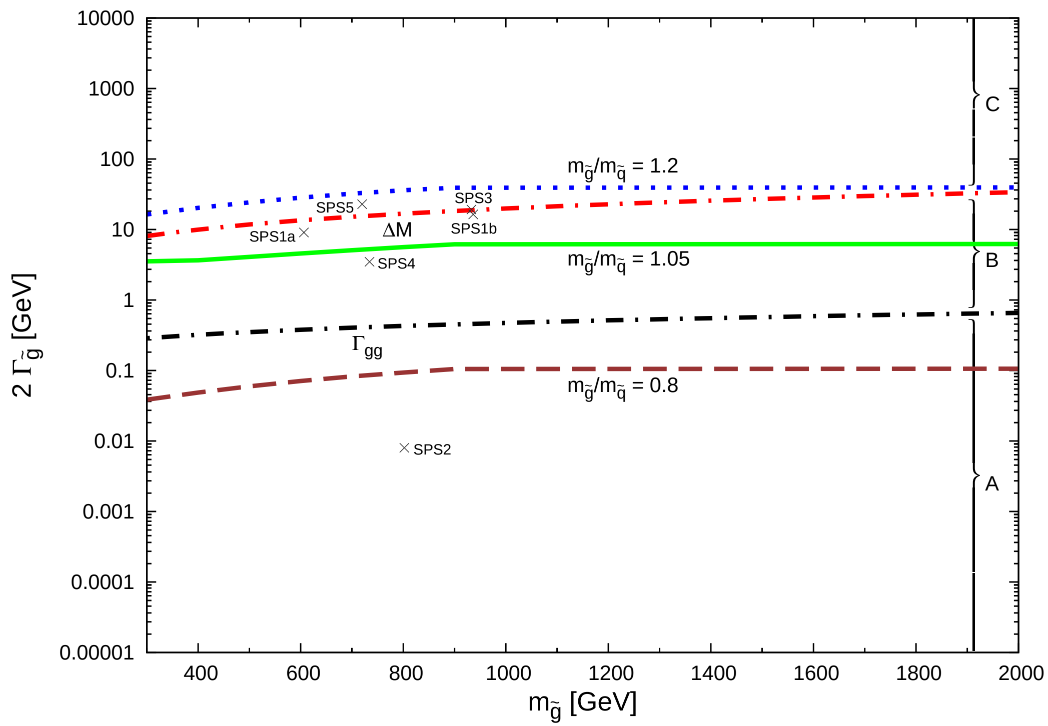

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- ∘ class B ($\Gamma_{gg} < 2\Gamma_{\tilde{g}} < \Delta M$) and class C ($\Delta M < 2\Gamma_{\tilde{g}}$)

  $\longrightarrow$ bound-state effects

Bound states - I

- 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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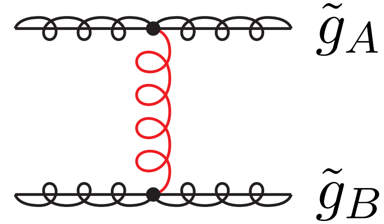
$$8 \otimes 8 = \underbrace{1_s \oplus 8_s \oplus 8_a}_{\text{attractive}} \oplus \underbrace{10_a \oplus \overline{10}_a}_{?} \oplus \underbrace{27_s}_{\text{repulsive}}$$



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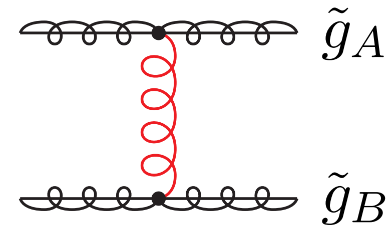

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- application of the Pauli principle

$$-1 \quad = \quad \underbrace{(-1)^L}_{\text{space}} \times \underbrace{(-1)^{S+1}}_{\text{spin}} \times \underbrace{C}_{\text{charge}} \times \underbrace{\begin{cases} +1 & ; \quad 1_s, 8_s, 27_S \\ -1 & ; \quad 8_a, 10_a, \overline{10}_a \end{cases}}_{\text{colour}}$$

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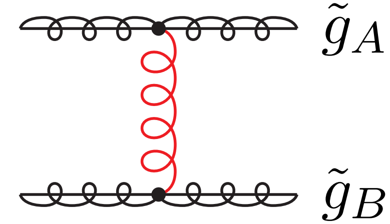

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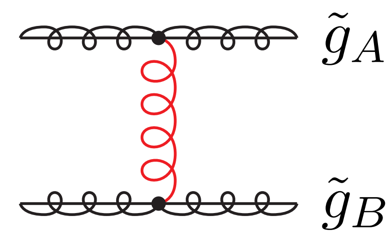

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- states

pseudoscalar	${}^1S_0^{[1_S]}$	${}^1S_0^{[8_S]}$	–	–	${}^1S_0^{[27_S]}$
vector	–	–	${}^3S_1^{[8_A]}$	${}^3S_1^{[10]}$	–

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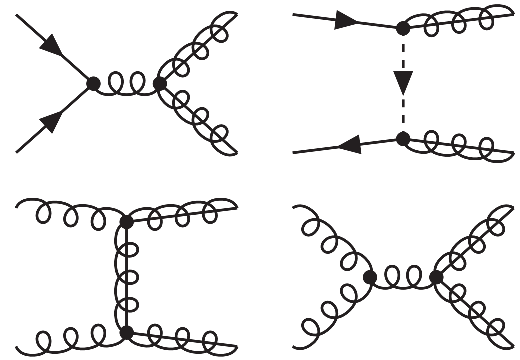

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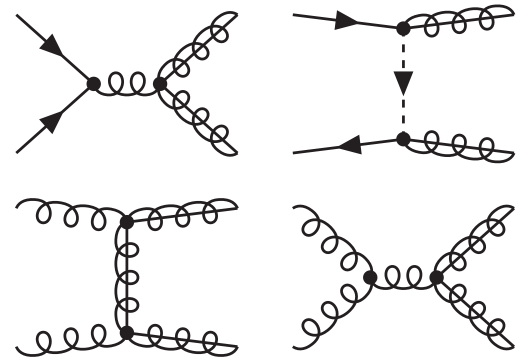

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$$V_C^{[Y]} = -\frac{4\pi\alpha_s(\mu_r) C^{[Y]}}{\vec{q}^{\,2}} \left[1 + \frac{\alpha_s(\mu_r)}{4\pi}\left(\beta_0 \ln\frac{\mu_r^2}{\vec{q}^{\,2}} + a_1\right)\right]$$

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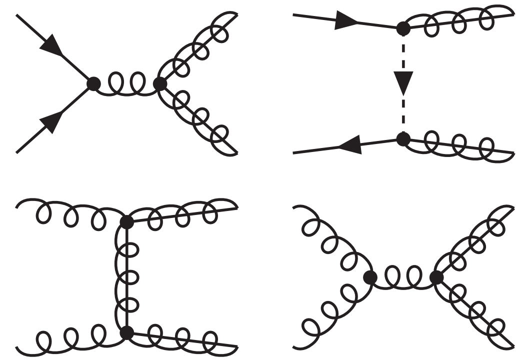

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Y	$C^{[Y]}$
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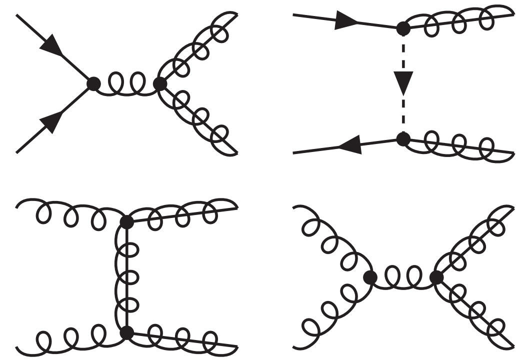

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- Schrödinger equation

$$\left\{2m_{\tilde{g}}+\left[\frac{(-i\nabla)^2}{m_{\tilde{g}}}+V_C^{[Y]}(\vec{r})\right]-(M+i\Gamma_{\tilde{g}})\right\}G^{[Y]}(\vec{r};M+i\Gamma_{\tilde{g}})=\delta^3(\vec{r})$$

Green´s function

$$\frac{1}{m_{\tilde{g}}^2} G^{[Y]}(0; M + i\Gamma_{\tilde{g}}) = G_{\text{free}} + \frac{C^{[Y]}\alpha_s(\mu_r)}{4\pi}\left[G_{\text{LO}} + \frac{\alpha_s(\mu_r)}{4\pi} G_{\text{NLO}} + \ldots\right]$$

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SPS4

$m_{\tilde{g}} = 734.11$ GeV

$2\Gamma_{\tilde{g}} = 3.48$ GeV

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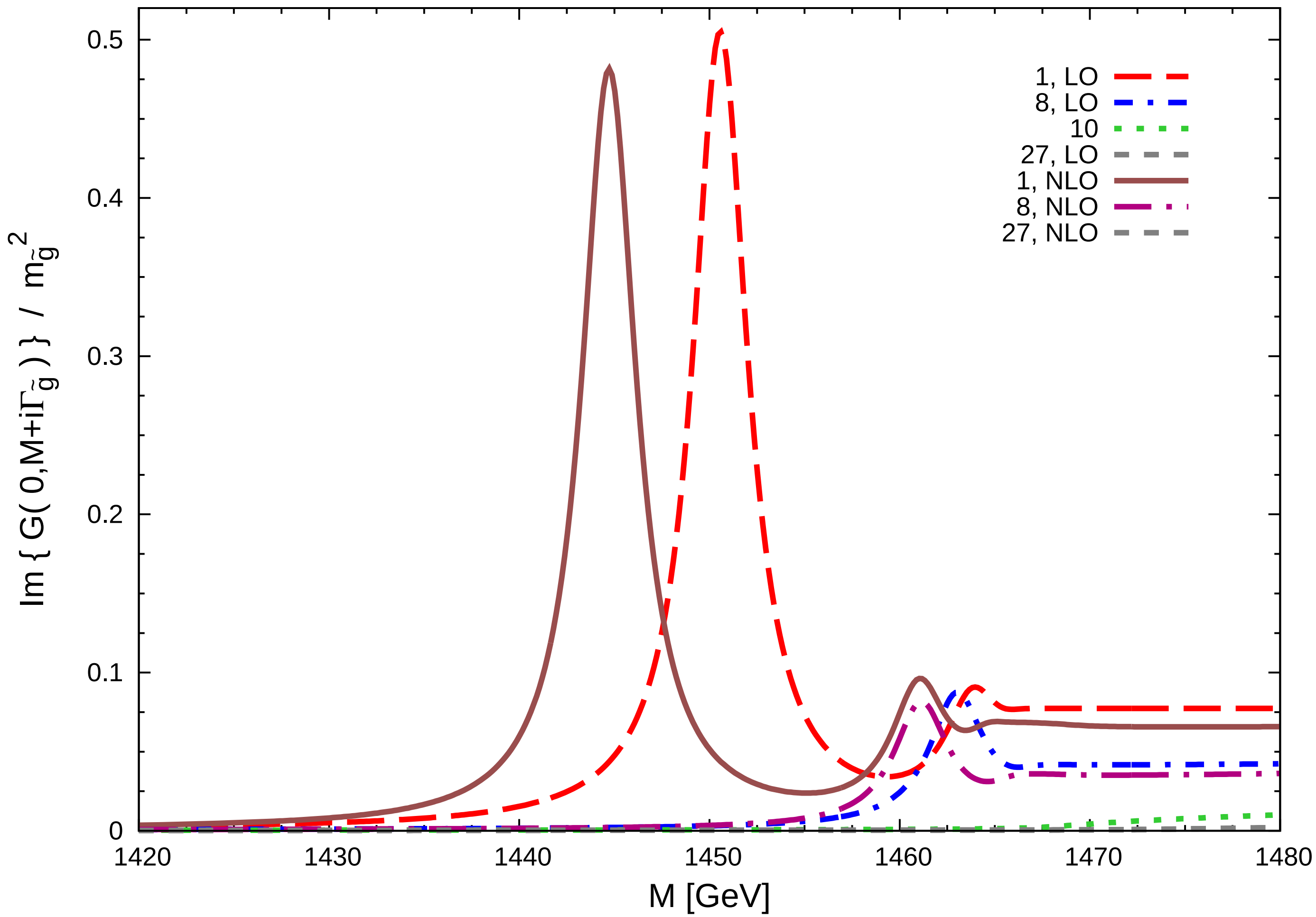

LO result - I

$$M\frac{d\sigma_{P_1P_2\to T^{[X]}}}{dM}(S,M^2)$$

$$=\sum_{i,j}\int_{\frac{M^2}{S}}^{1}d\tau\left[\frac{d\mathcal{L}_{ij}}{d\tau}\right](\tau,\mu_f^2)\;M\frac{d\hat{\sigma}_{ij\to T^{[X]}}}{dM}(\hat{s},M^2,\mu_r^2)\,\frac{1}{m_{\tilde{g}}^2}\mathrm{Im}\left\{G^{[X]}(0;M+i\Gamma_{\tilde{g}})\right\}$$

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$$\left[\frac{d\mathcal{L}_{ij}}{d\tau}\right](\tau, \mu_f^2) = \int_0^1 dx \int_0^1 dy f_{i|P_1}(x) f_{j|P_2}(y) \delta(\tau - xy)$$

PDFs

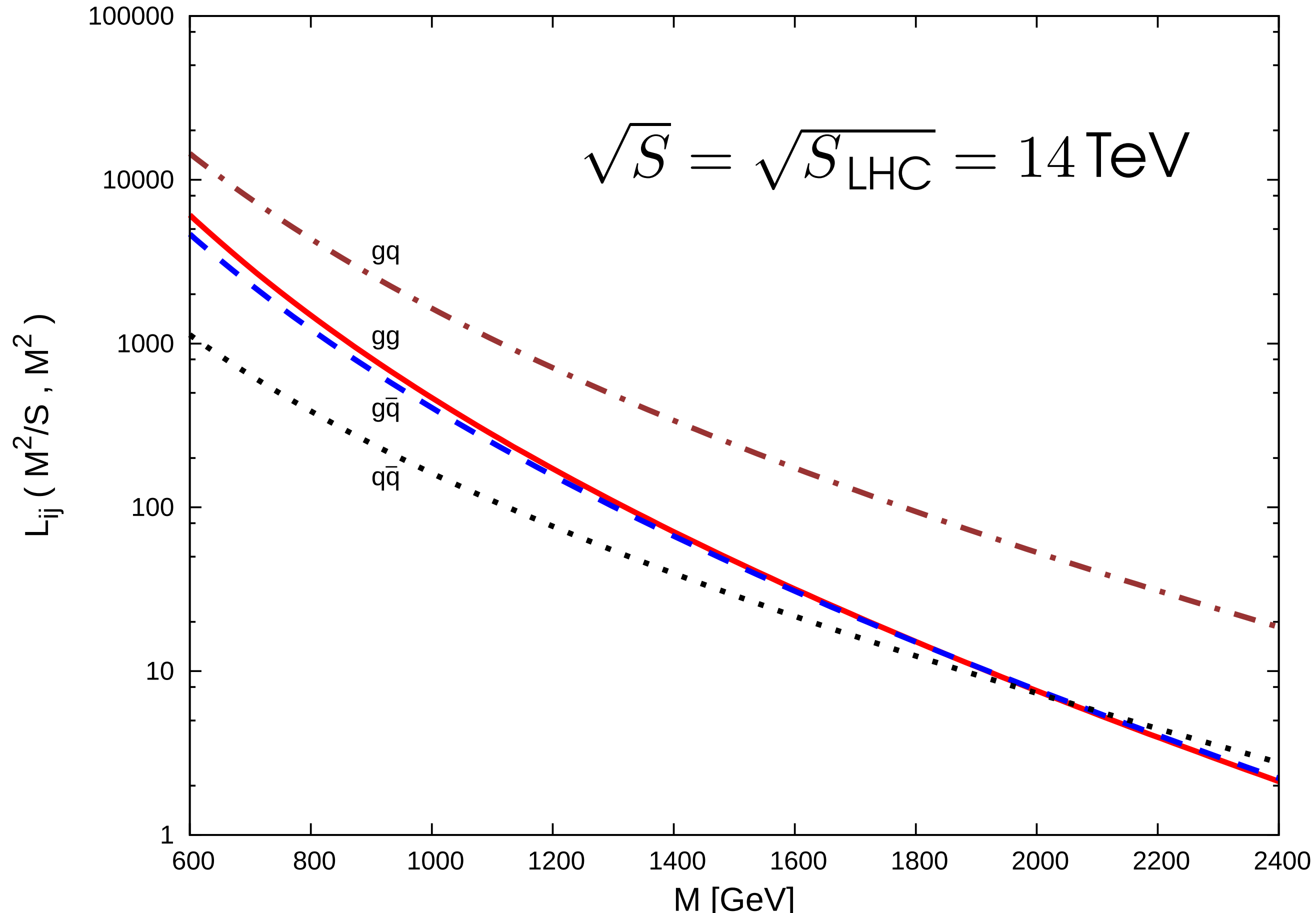
MSTW2008LO

[Martin,

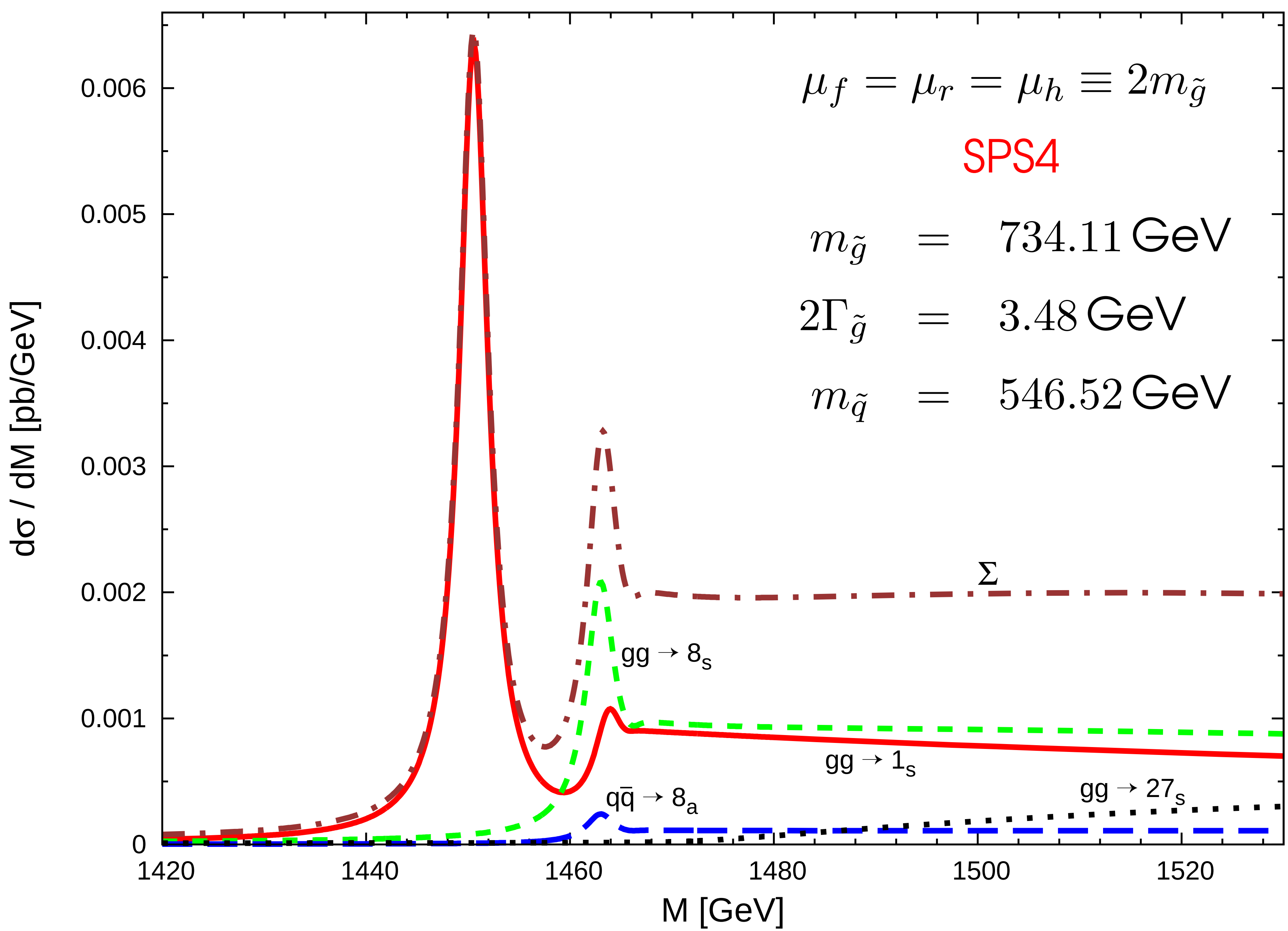
Stirling,

Thorne

and Watt '09]



LO result - II



$\mu_f = \mu_r = \mu_h \equiv 2m_{\tilde{g}}$
SPS4
$m_{\tilde{g}} = 734.11$ GeV
$2\Gamma_{\tilde{g}} = 3.48$ GeV
$m_{\tilde{q}} = 546.52$ GeV
Σ
gg → 8_s
gg → 1_s
$q\bar{q}$ → 8_a
gg → 27_s
dσ / dM [pb/GeV]
0.006
0.005
0.004
0.003
0.002
0.001
0
1420
1440
1460
1480
1500
1520
M [GeV]

NLO calculation

- NLO part of the Green's function from $q\bar{q}$ case

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  - perturbative ansatz requires resummation of poles

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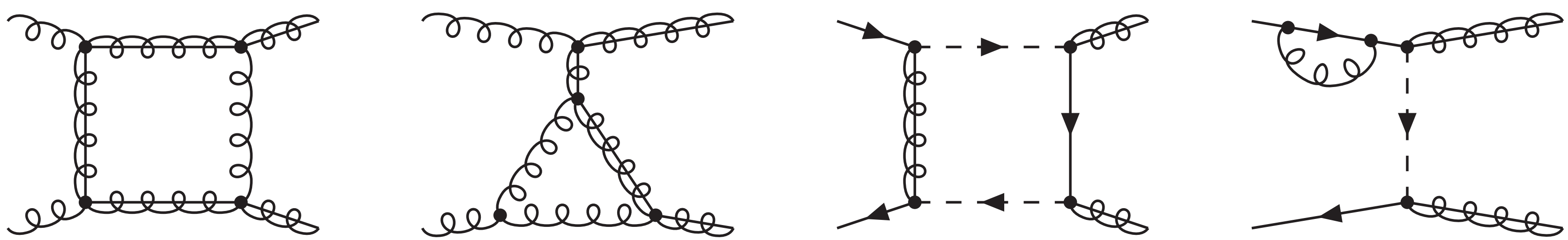
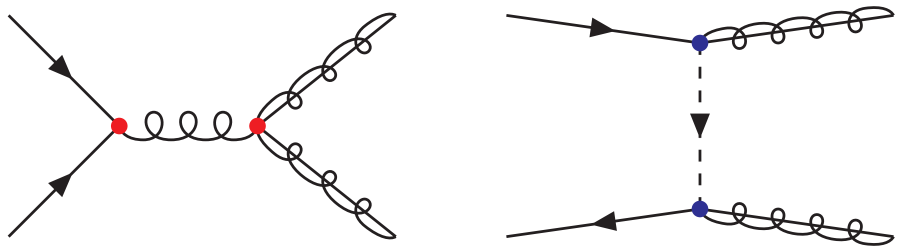


NLO calculation - II

– conversion to dimensional reduction

[Martin and Vaughn '93]



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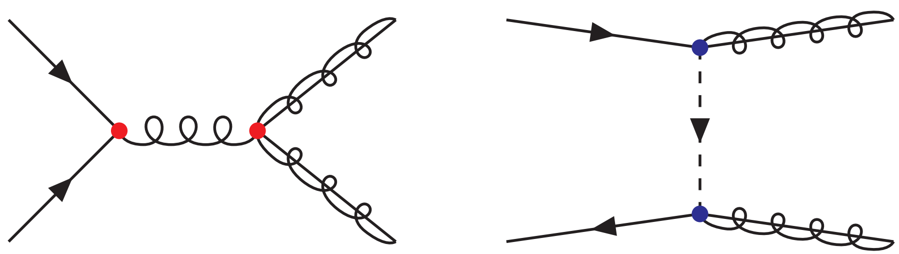
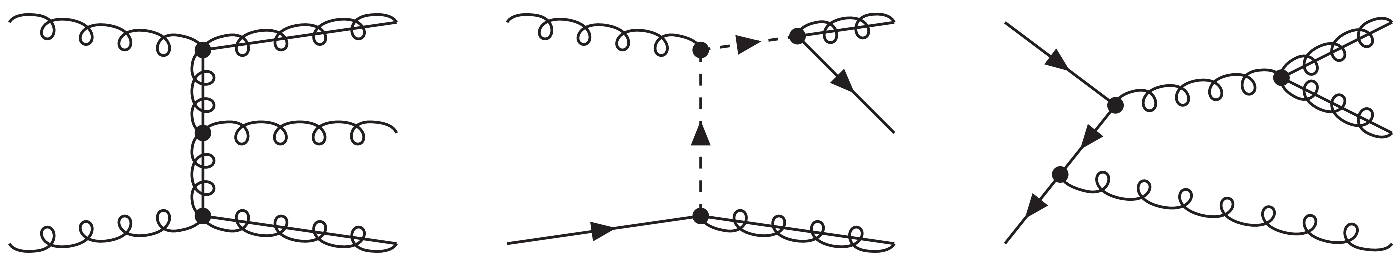
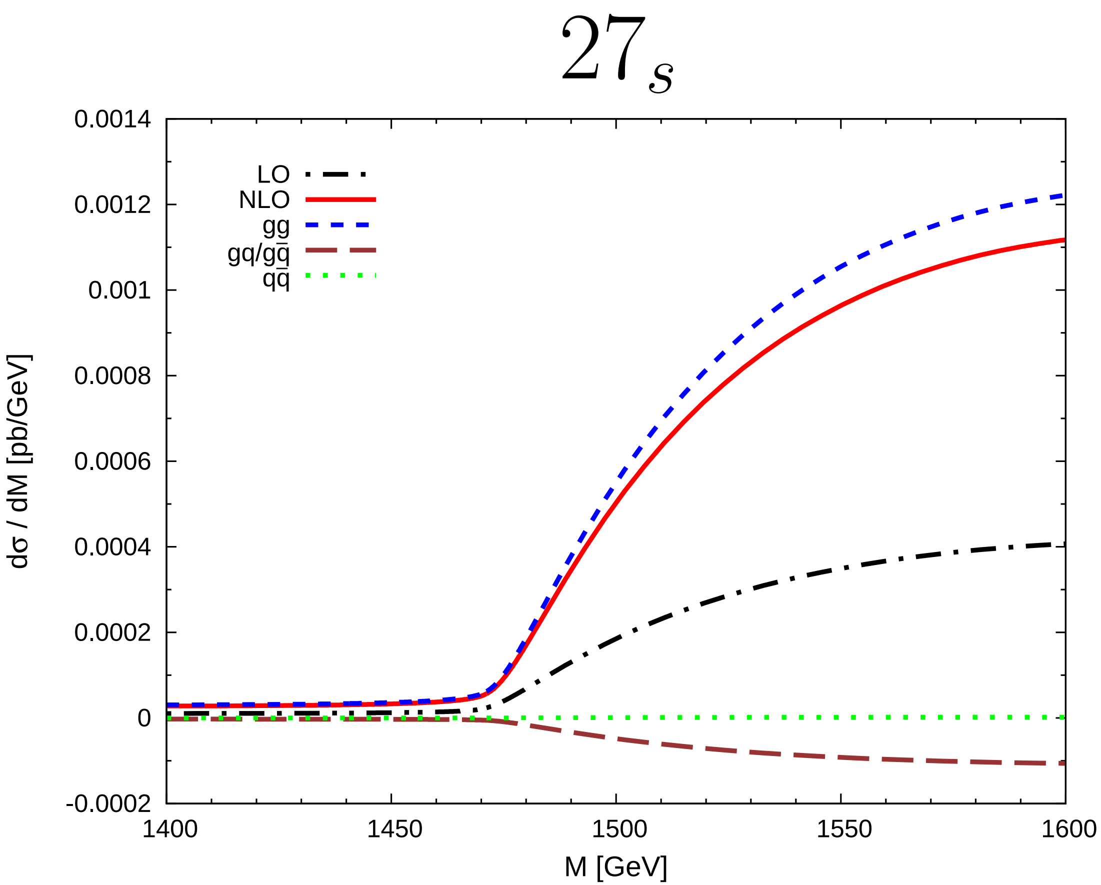


- real $2 \rightarrow 3$ corrections



NLO result - I



SPS4

$$m_{\tilde{g}} = 734.11\,\text{GeV}$$
$$\Gamma_{\tilde{g}} = 3.48\,\text{GeV}$$
$$m_{\tilde{q}} = 546.52\,\text{GeV}$$

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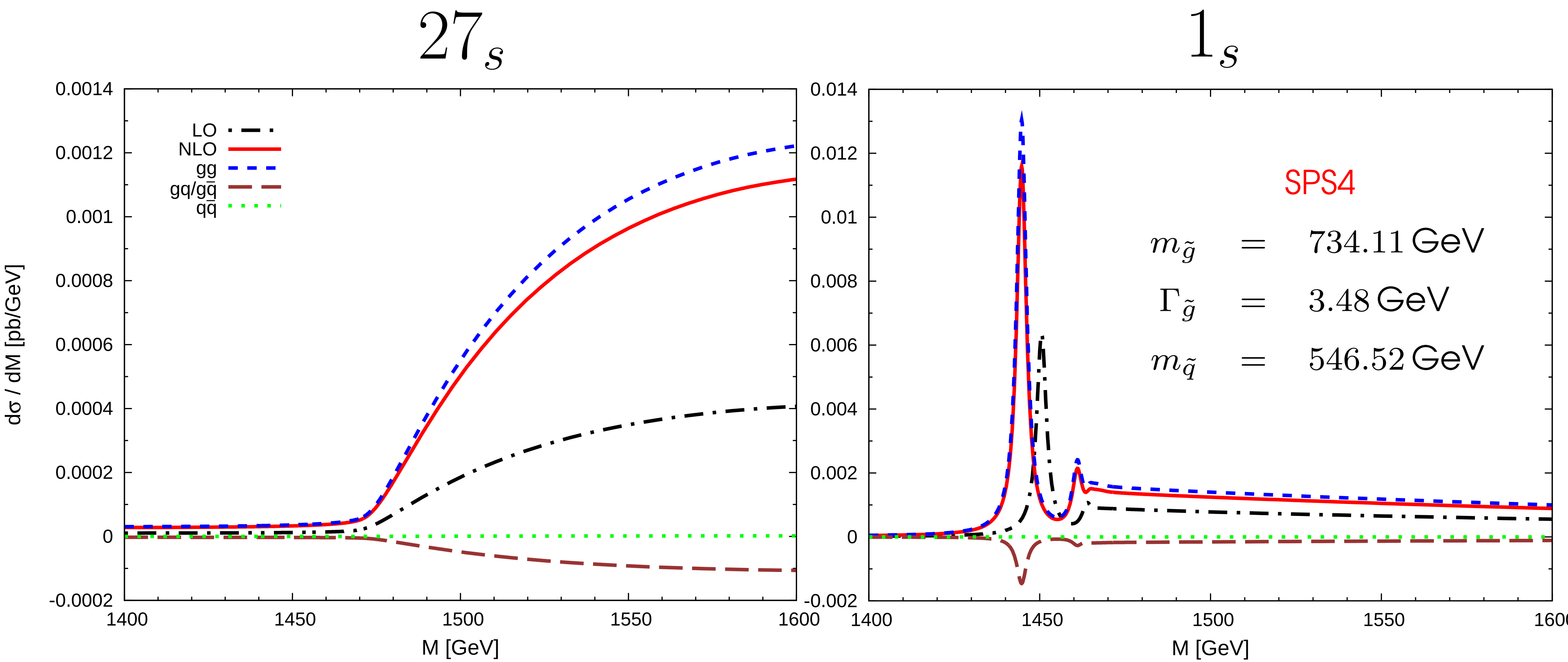

27_s
1_s
dσ / dM [pb/GeV]
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
-0.0002
LO
NLO
gg
gq/g$\bar{q}$
q$\bar{q}$
1400
1450
1500
1550
1600
M [GeV]
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
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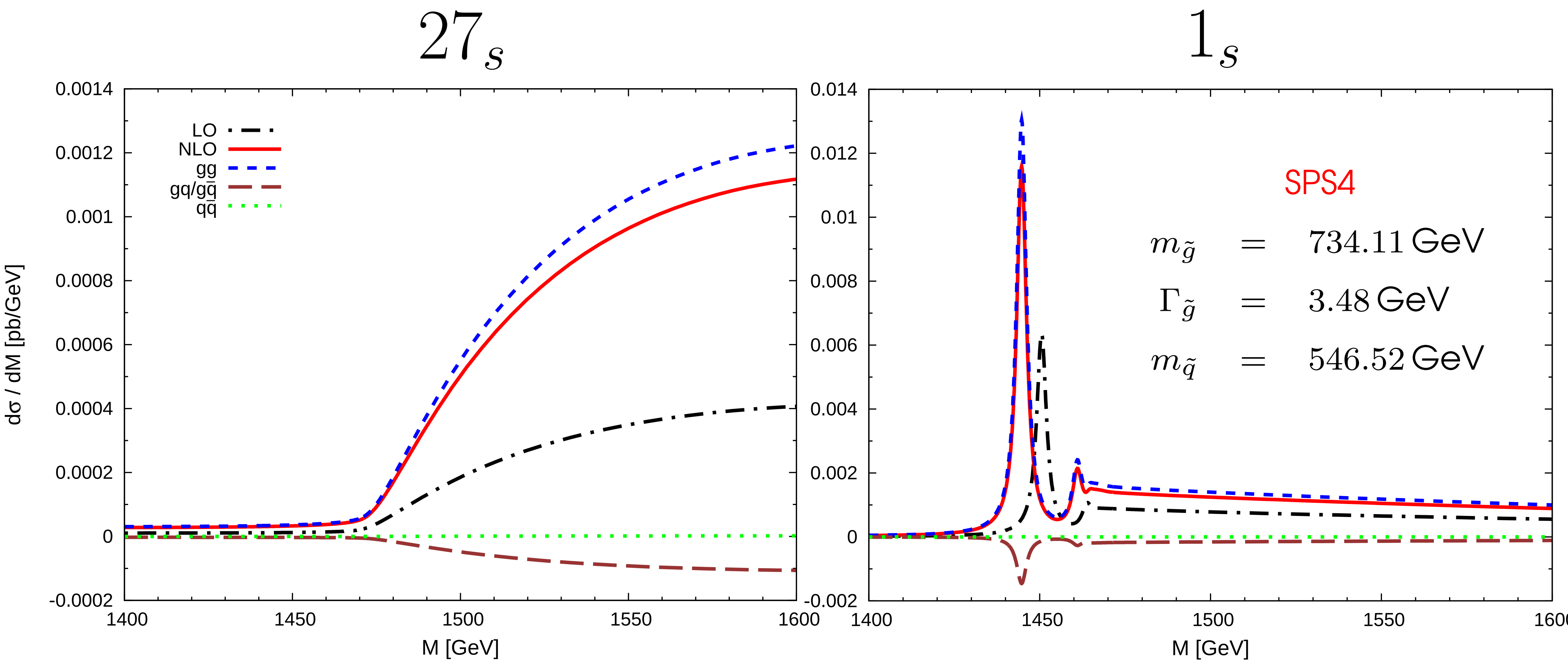


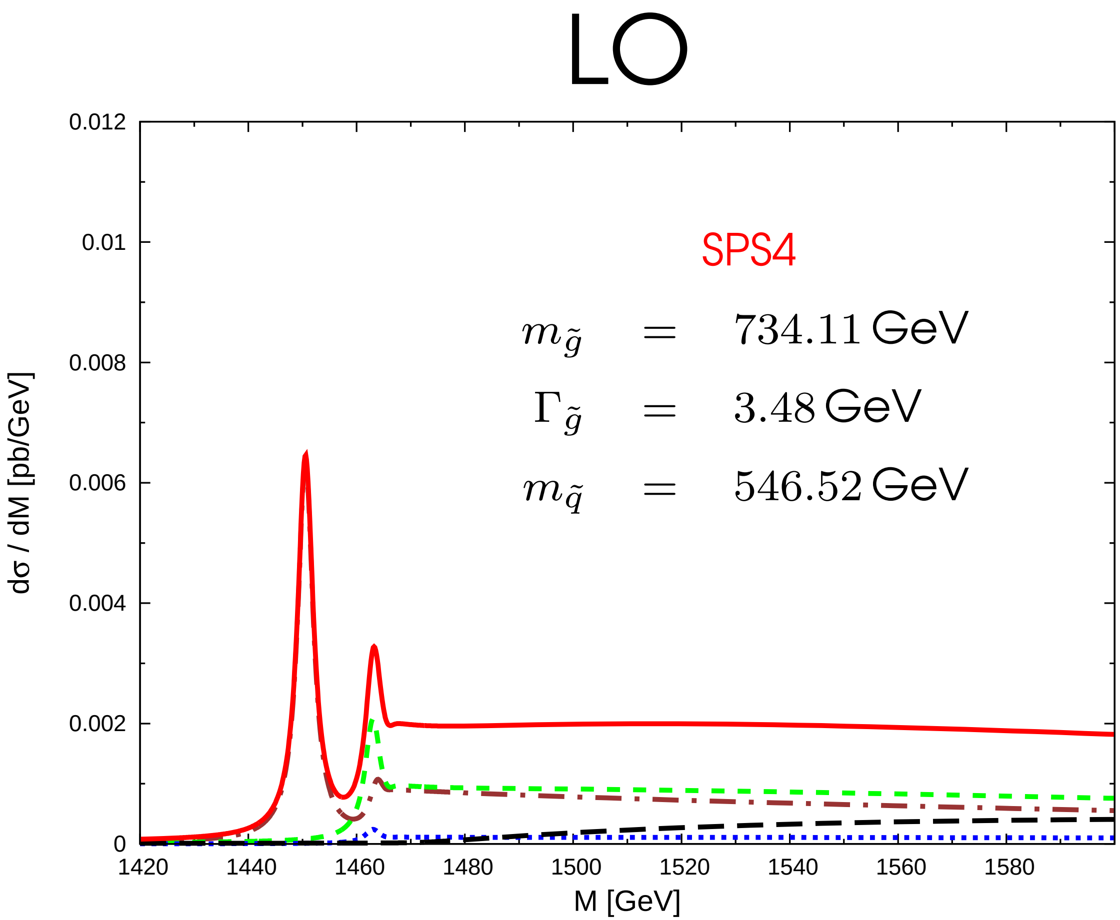
$$\mu_s^{[27]} = 86.95\,\text{GeV} \qquad \mu_s^{[1]} = 227.71\,\text{GeV}$$

$$\alpha_s(\mu_s^{[27]}) = 0.118 \qquad \alpha_s(\mu_s^{[1]}) = 0.103$$

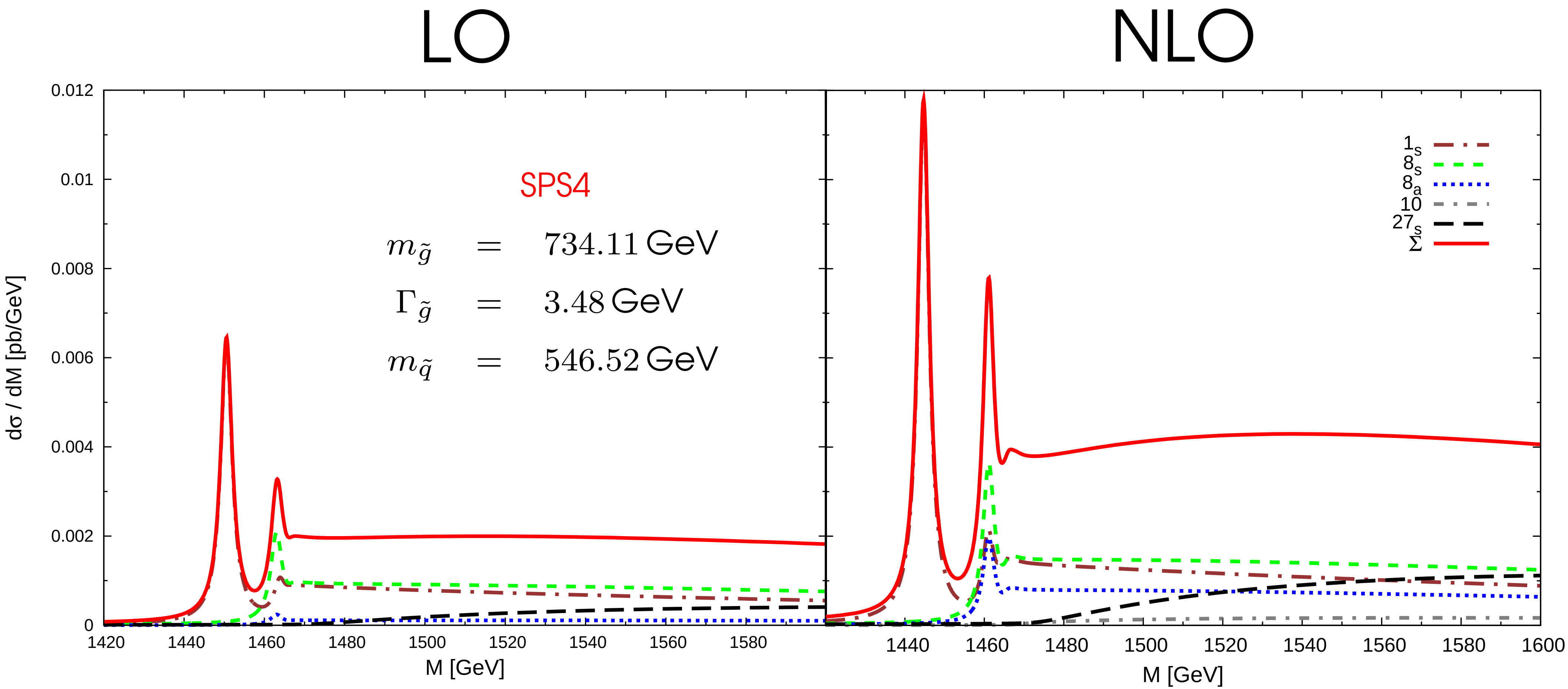
$$\mu_h = 1468.22\,\text{GeV}$$

$$\alpha_s(\mu_h) = 0.085$$

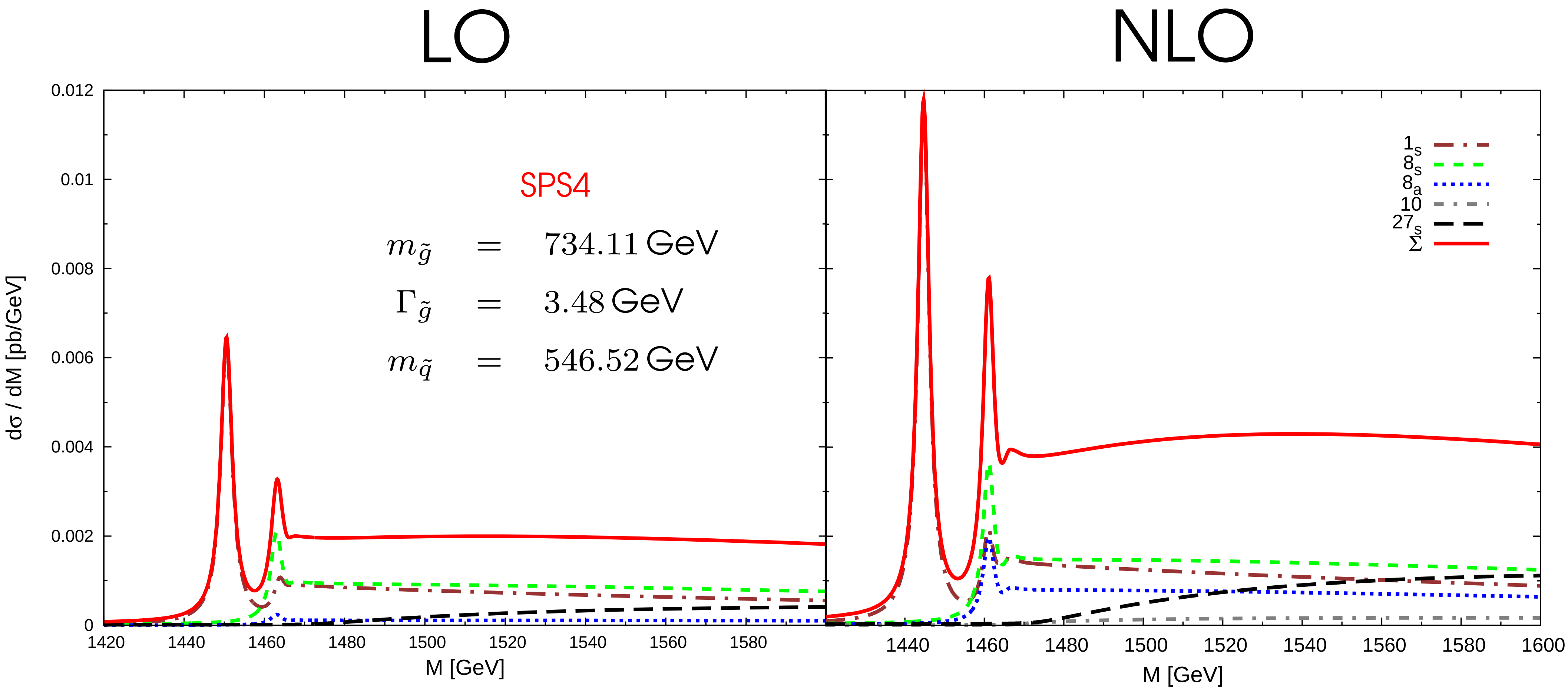
NLO result - II



NLO result - II



NLO result - II



- MSTW2008(N)LO PDFs
- (N)LO Green's function
- $\left|C^{[Y]}\right| m_{\tilde{g}}\, \alpha_s(\mu_s) = \mu_s \quad \leftrightarrow \quad \mu_h = 2m_{\tilde{g}}$

Conclusion

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Thank you for your attention!