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gg and bb Components of Pseudoscalar Higgs Production

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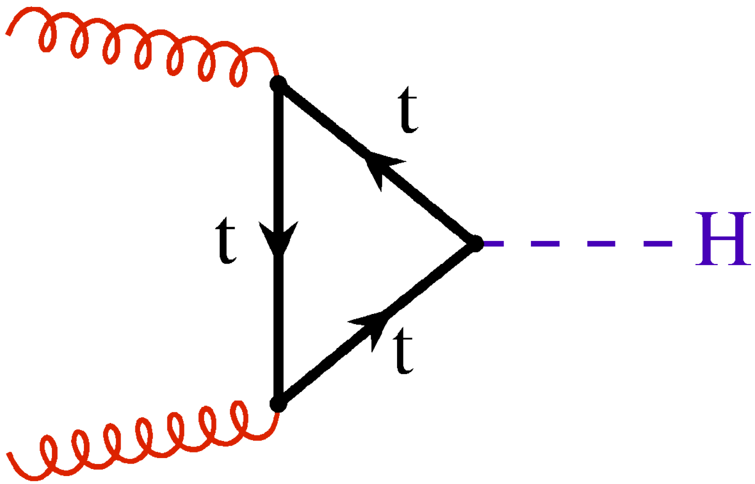
Gluon Fusion Dominates Higgs Boson Production

In the Standard Model, Higgs boson production is dominated by top quark loops.



This makes radiative corrections very difficult. To go beyond NLO (currently) requires an effective Lagrangian in which the top quark is integrated out.

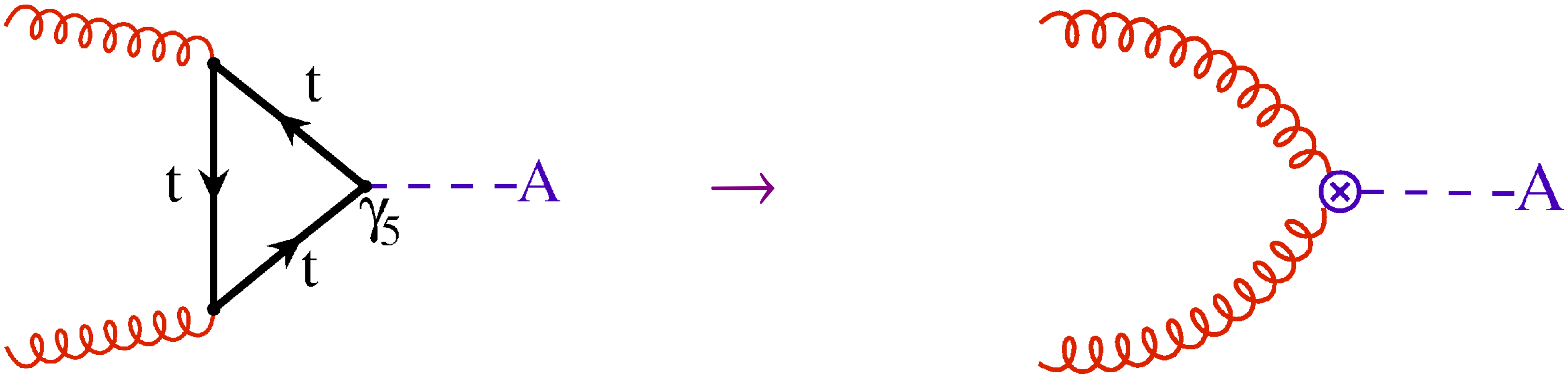
Pseudoscalar Production

Gluon fusion is also very important to pseudoscalar production and has also been computed using massive fermions to NLO.

[Spira, Djouadi, Graudenz, Zerwas]

NNLO Pseudoscalar production is computed in the effective theory, but the effective Lagrangian is only valid for top quark loops!

[Harlander, WK; Anastasiou, Melnikov; Ravindran, Smith, van Neerven]



Pseudoscalar Couplings

For the pseudoscalar, the couplings to "up-type" fermions are suppressed by $\tan\beta \equiv v_u/v_d$ while those to "down-type" fermions are enhanced by $\tan\beta$. This presents a problem for gluon fusion calculations:

For $\tan\beta$ significantly larger than 1, b-quark interactions are important. But ... one cannot formulate an effective Lagrangian by integrating out the b-quark to produce ~100 GeV Higgs bosons! An honest NNLO calculation would require massive 3-loop diagrams.

A new production mode at large tan β

The importance of b-quark couplings at large tan β suggests a different production mechanism:

$$b\bar{b}\rightarrow A$$

Since b-quark distributions are generated by gluon splitting the true parent process is

$$gg\rightarrow b\bar{b}A$$

The b-quark distribution resums large logs associated with the gluon splitting, but is fully consistent only if calculated to high enough order to include the parent process.

In this case, one must compute to NNLO.

$b\bar{b} \to A$ at NNLO

One can ignore the b-quark mass in this calculation, except where it enters into the Yukawa couplings. Other b-quark mass effects are suppressed by factors of m_b^2/M_H^2.

$b\bar{b} \to H/A$ can dominate at large tan β because

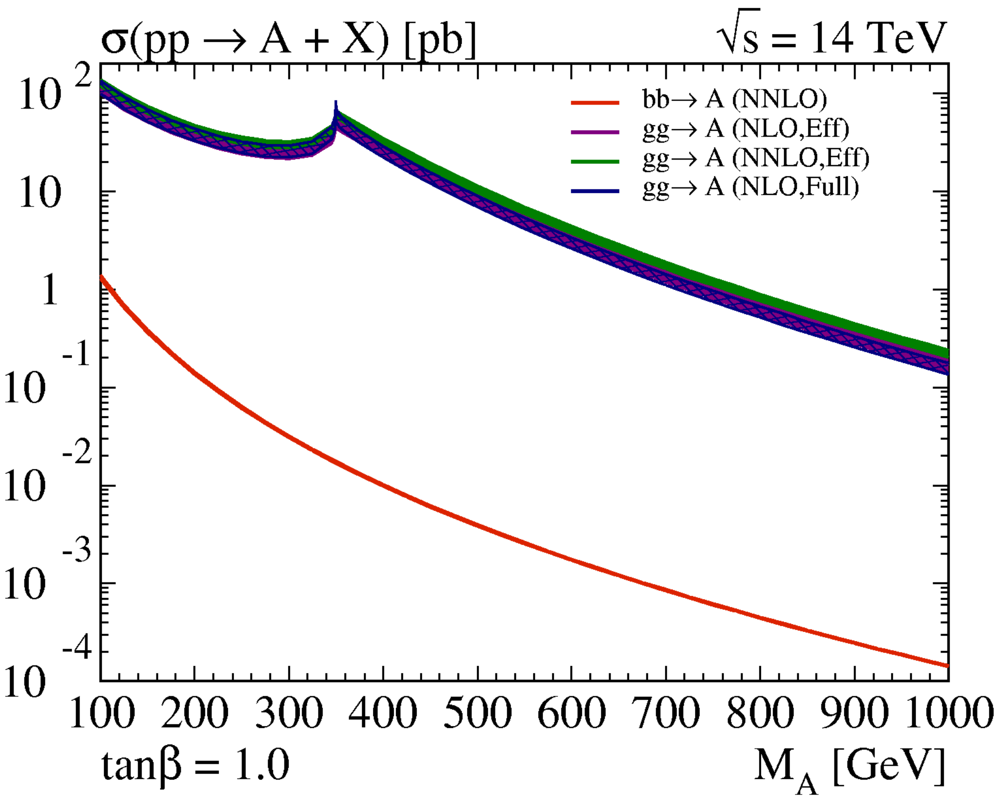
$\sigma_{bb} \sim m_b^2/M_H^2 \tan^2\beta$ while

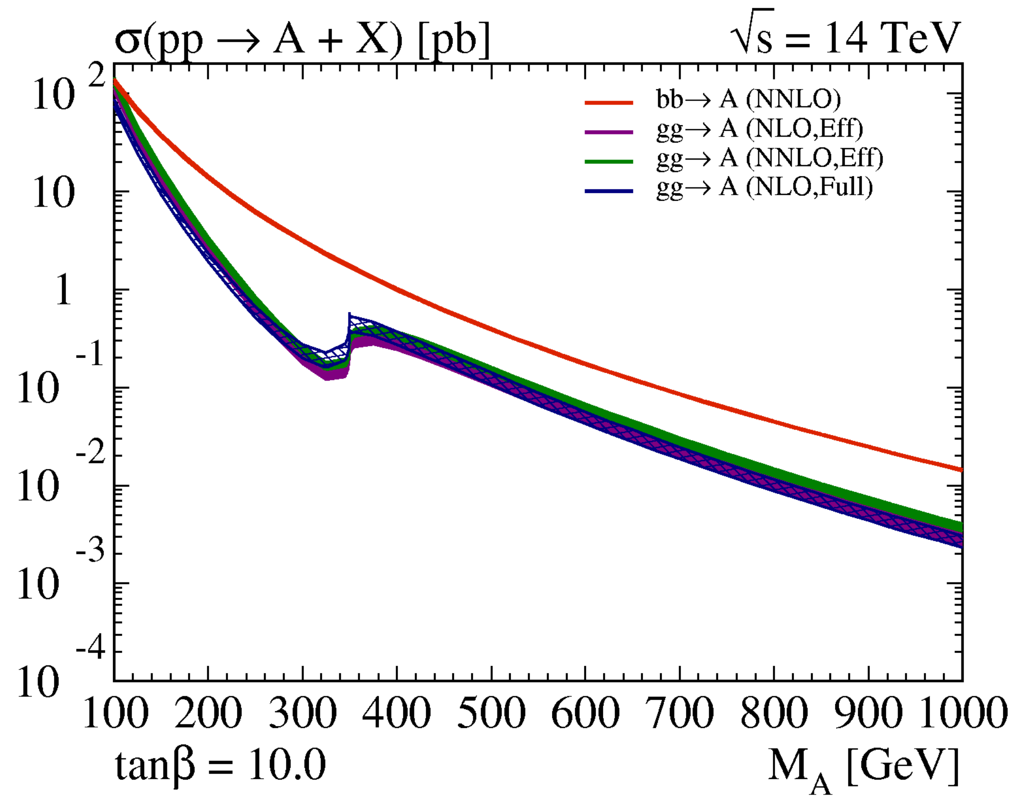
$\sigma_{gg} \sim A \cot^2\beta + B\, m_b^2/M_H^2 + C\, m_b^4/M_H^4 \tan^2\beta$

$b\bar{b} \to A$ versus $gg \to A$

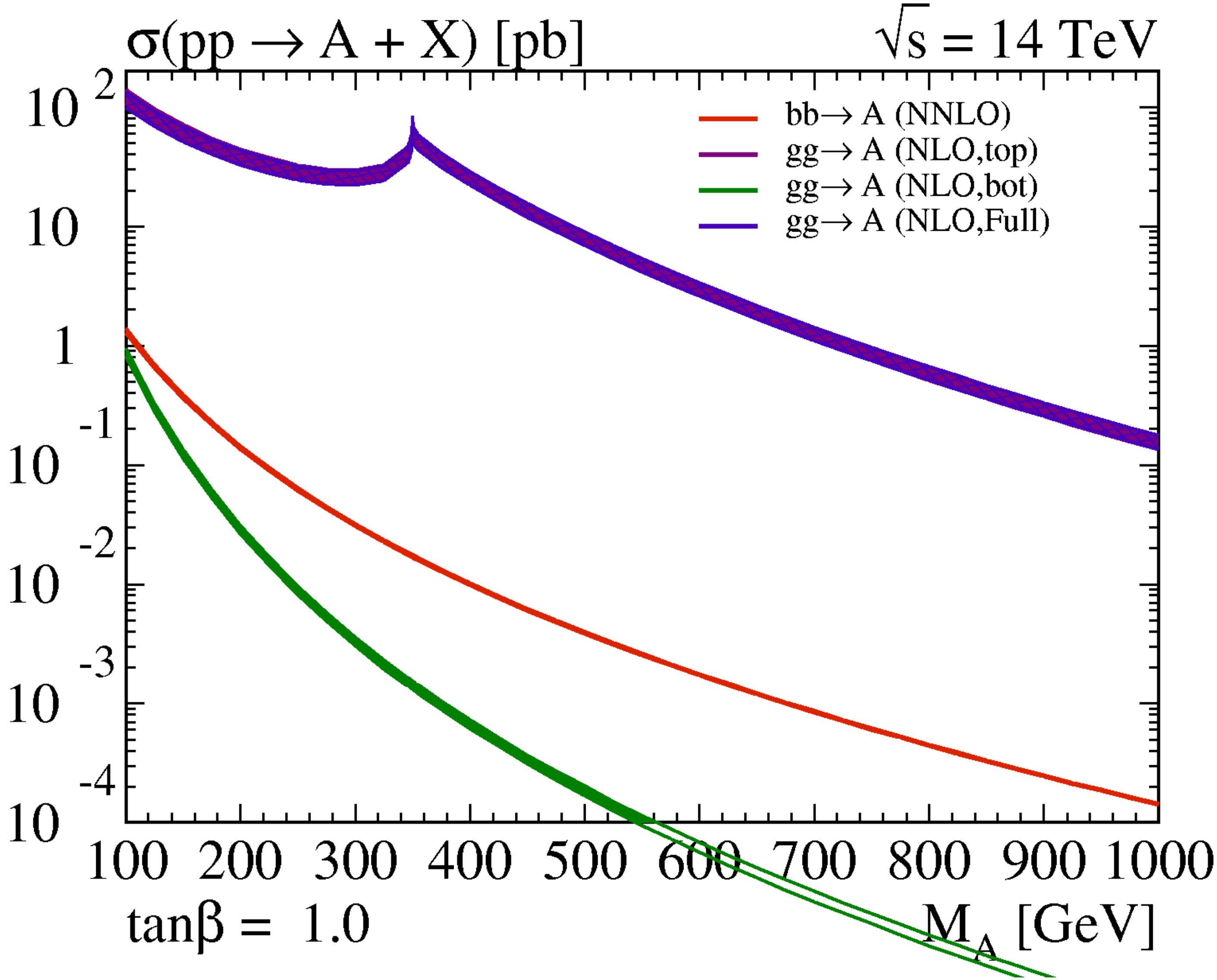
At small tan β, b quark fusion is tiny.

At large tan β, it dominates.

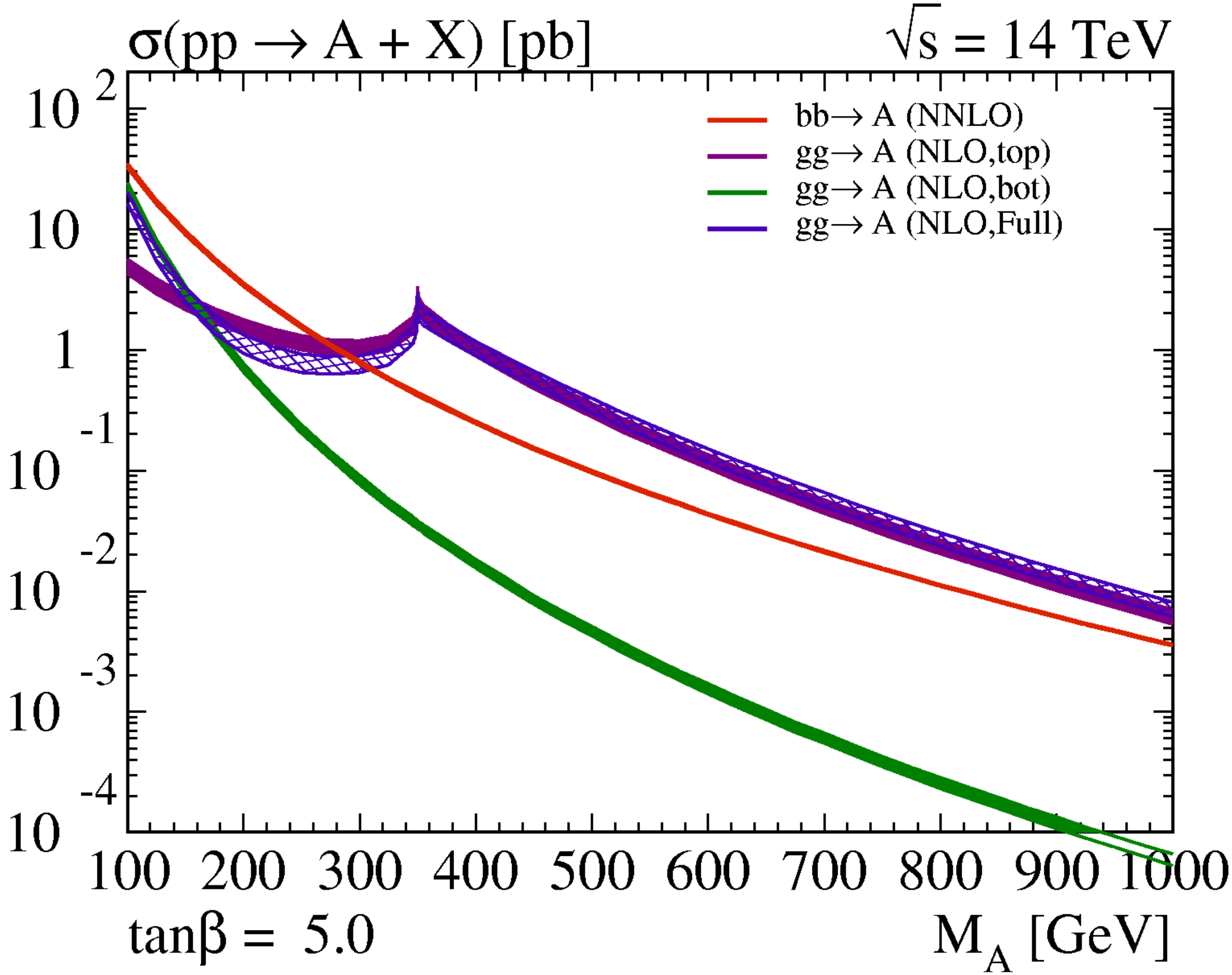




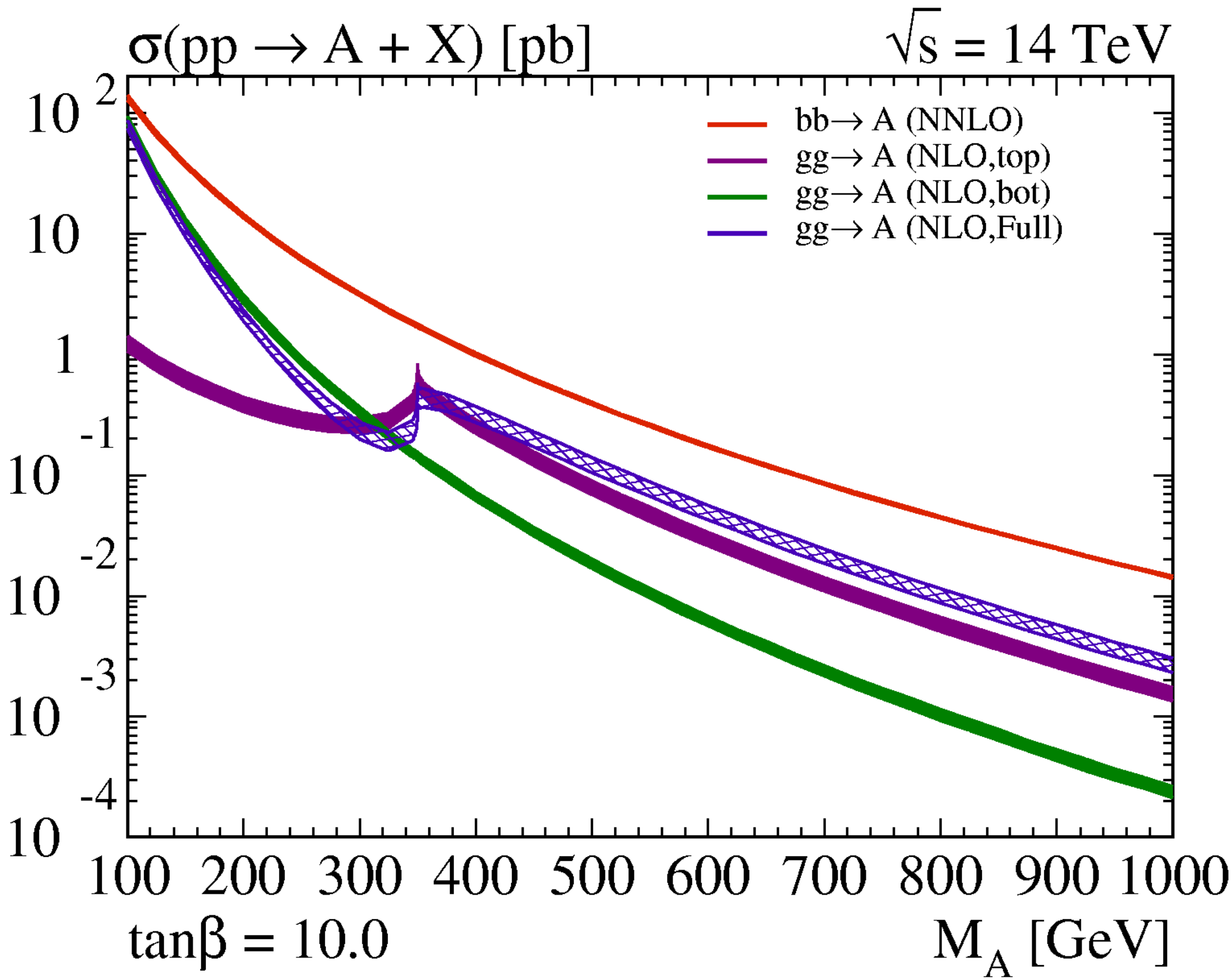
$\sigma_A(\tan\beta = 1)$ at the LHC



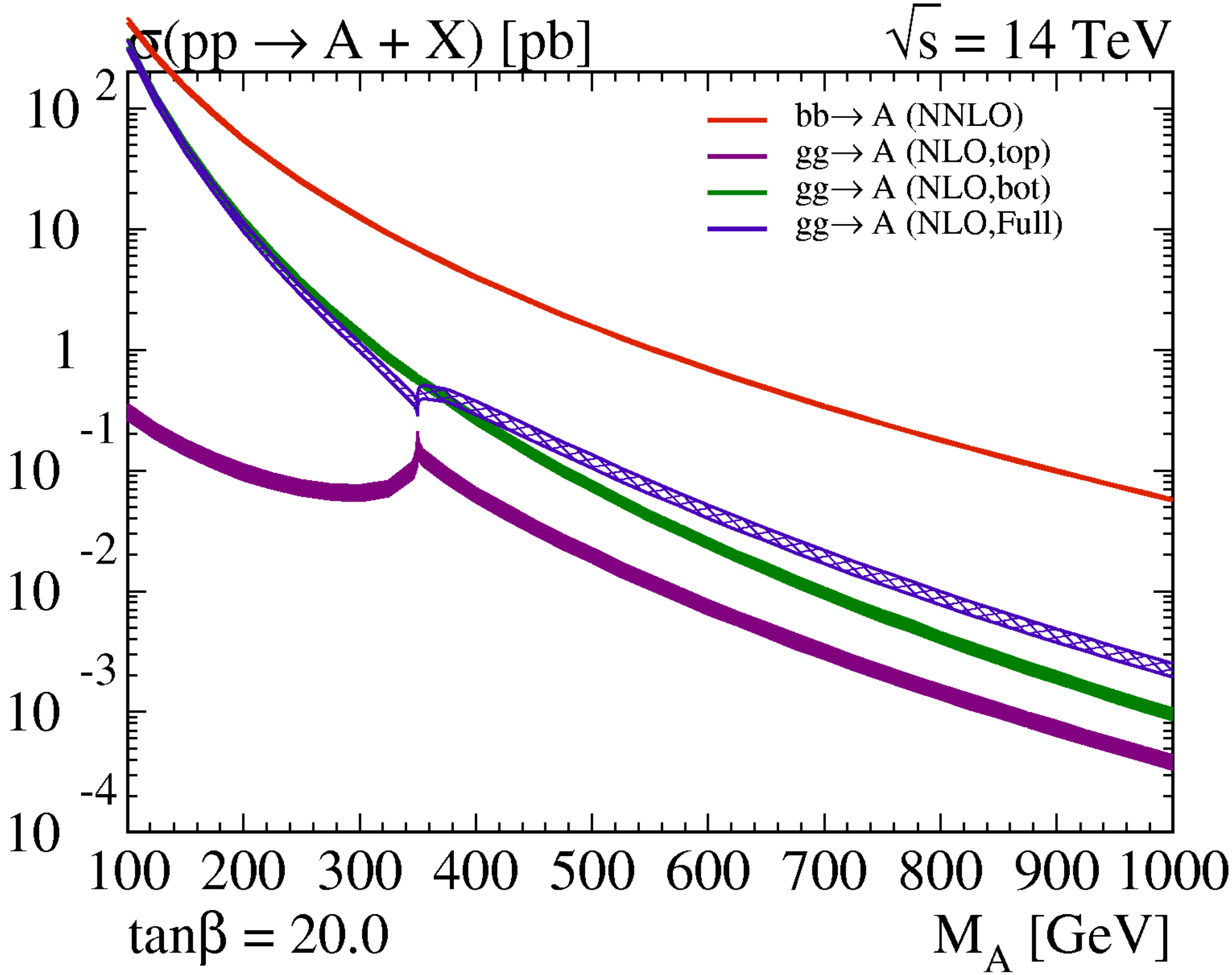
$\sigma_A(\tan\beta = 5)$ at the LHC



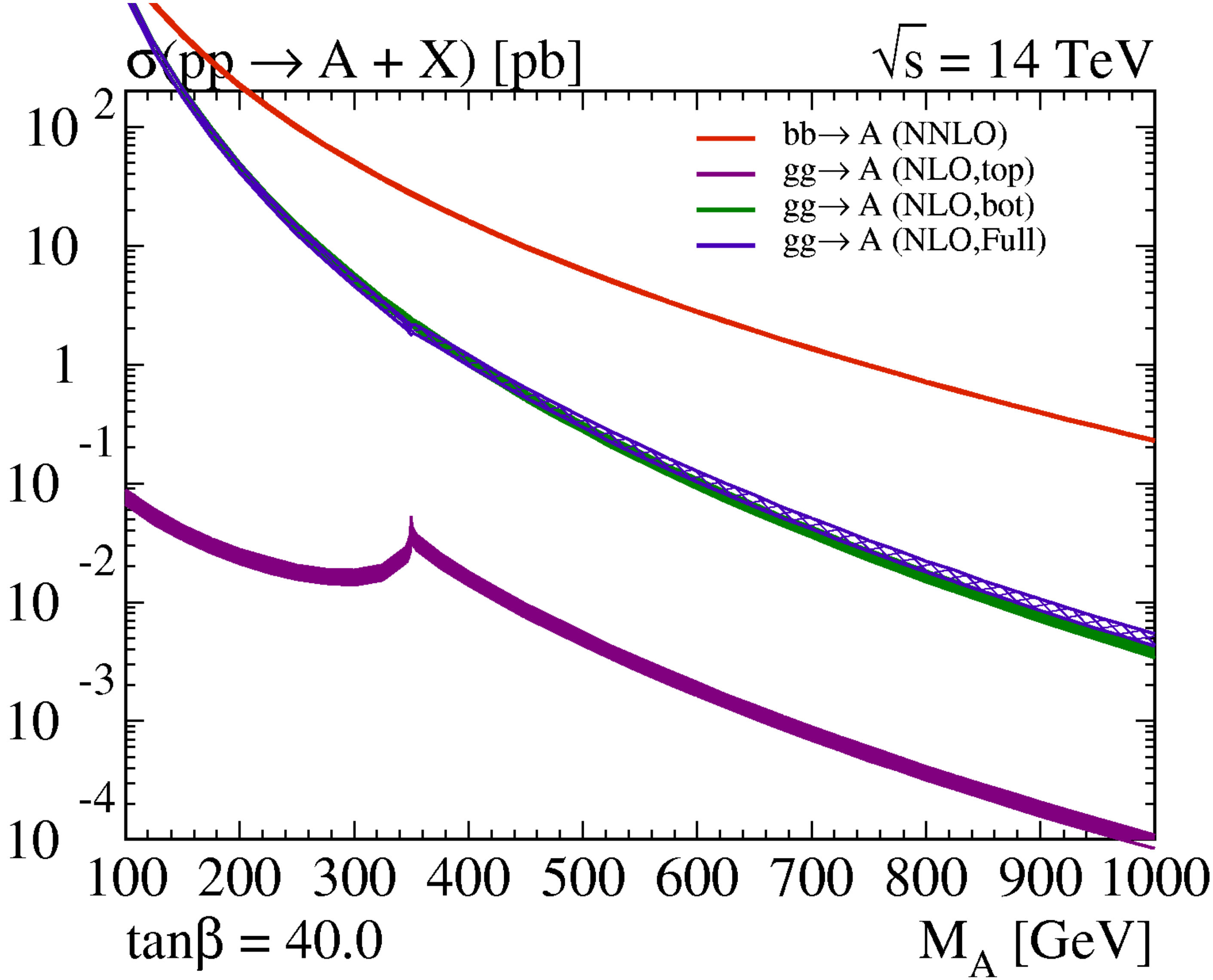
$\sigma_A(\tan\beta = 10)$ at the LHC



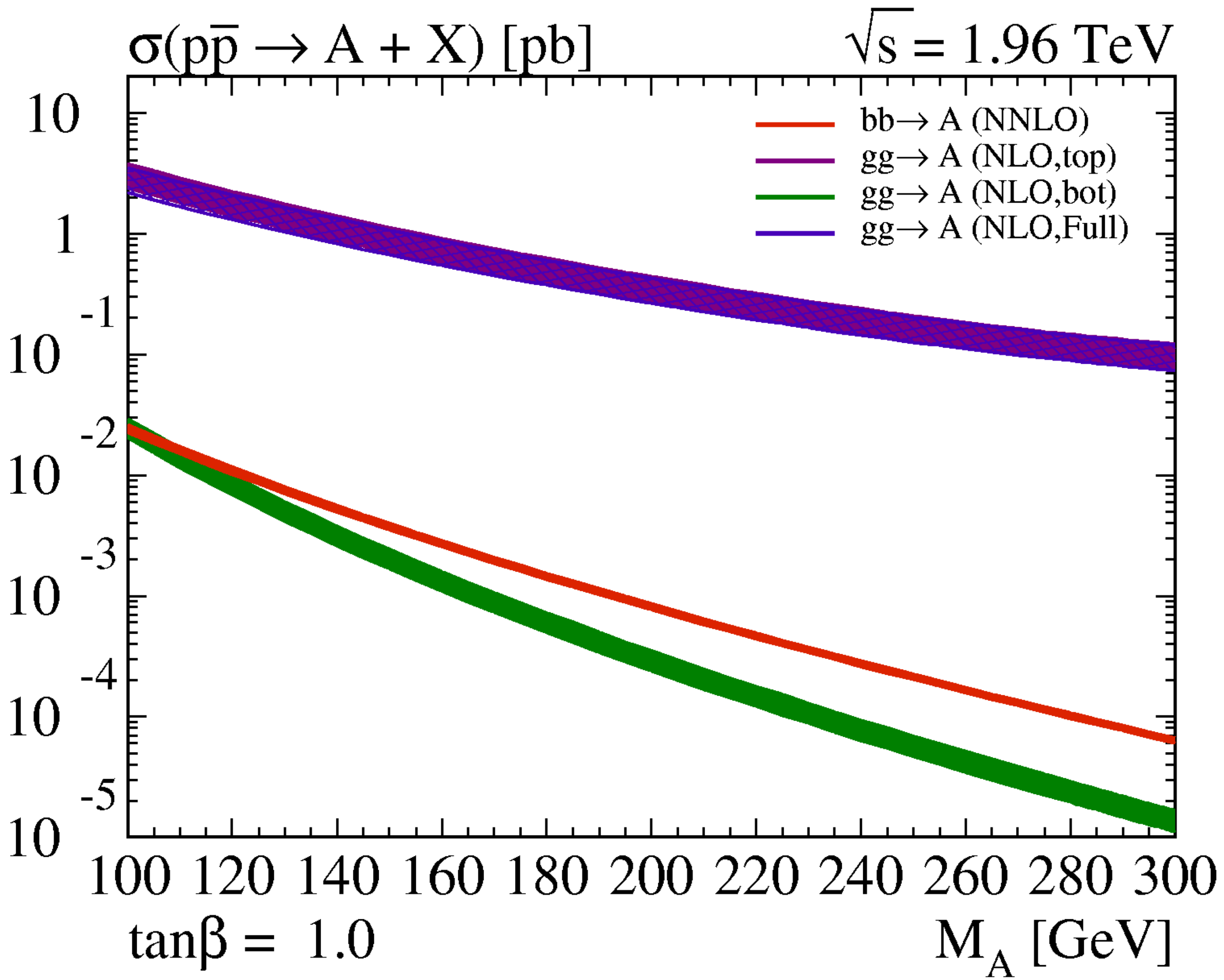
$\sigma_A(\tan\beta = 20)$ at the LHC



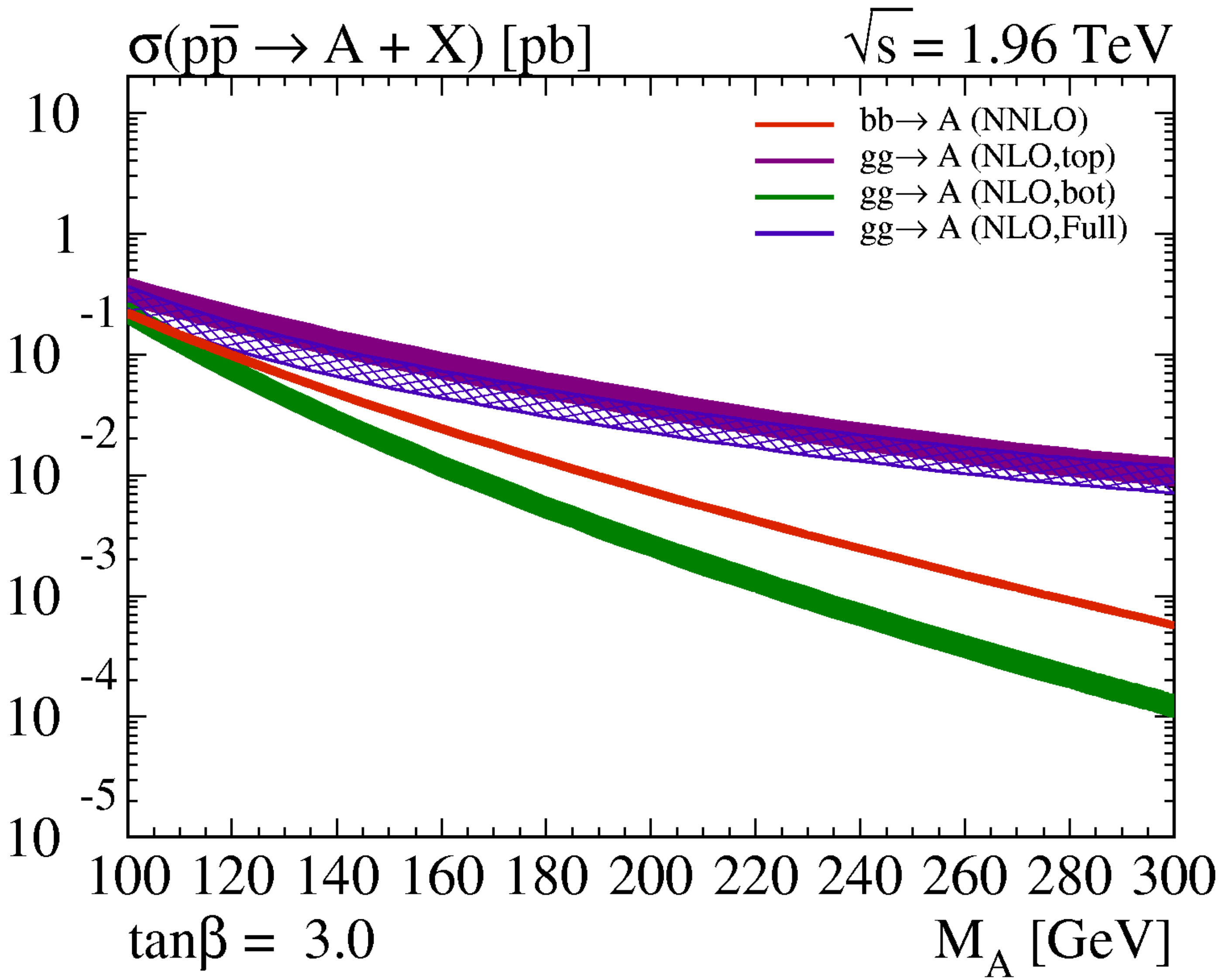
$\sigma_A(\tan\beta = 40)$ at the LHC



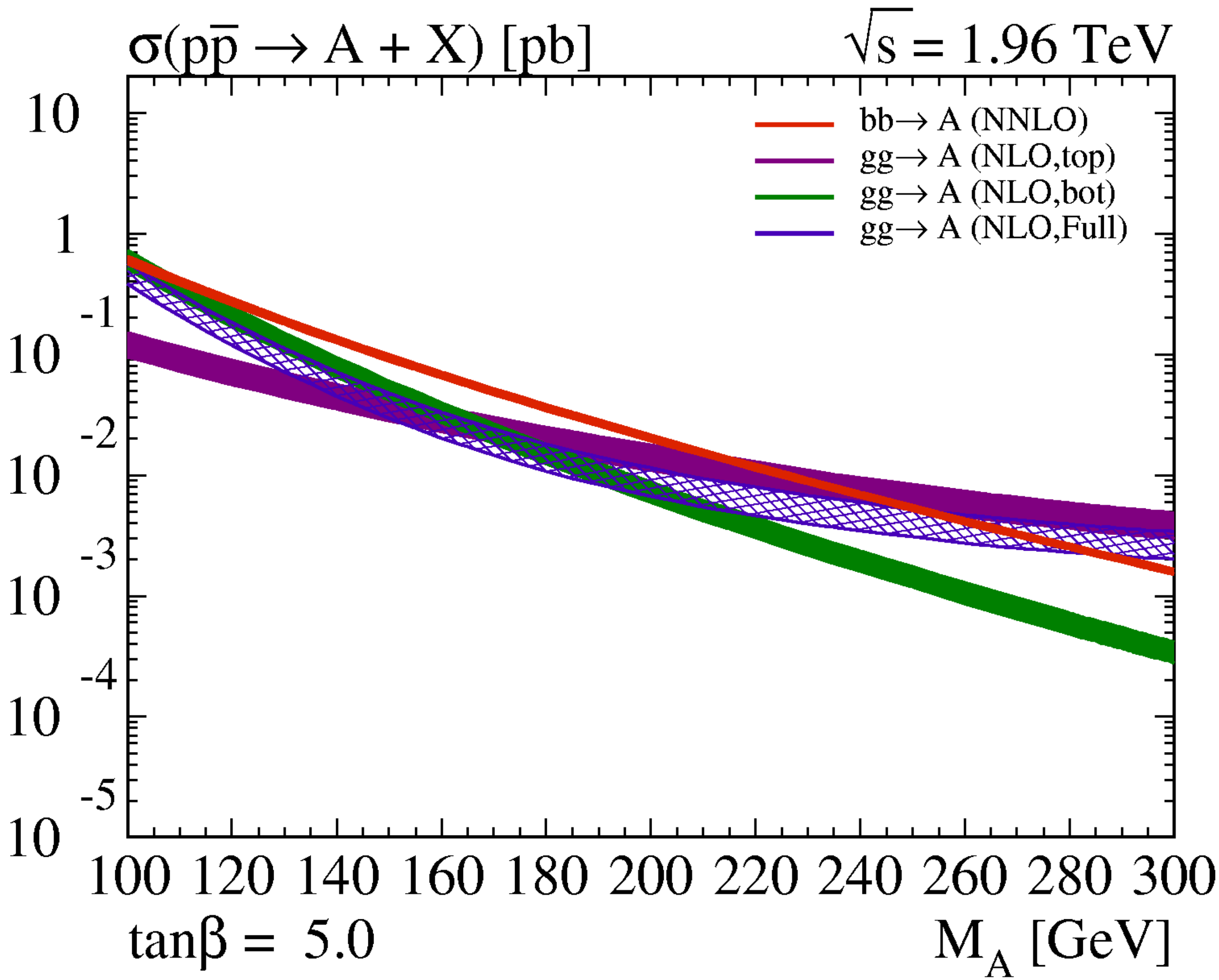
$\sigma_A(\tan\beta = 1)$ at the Tevatron



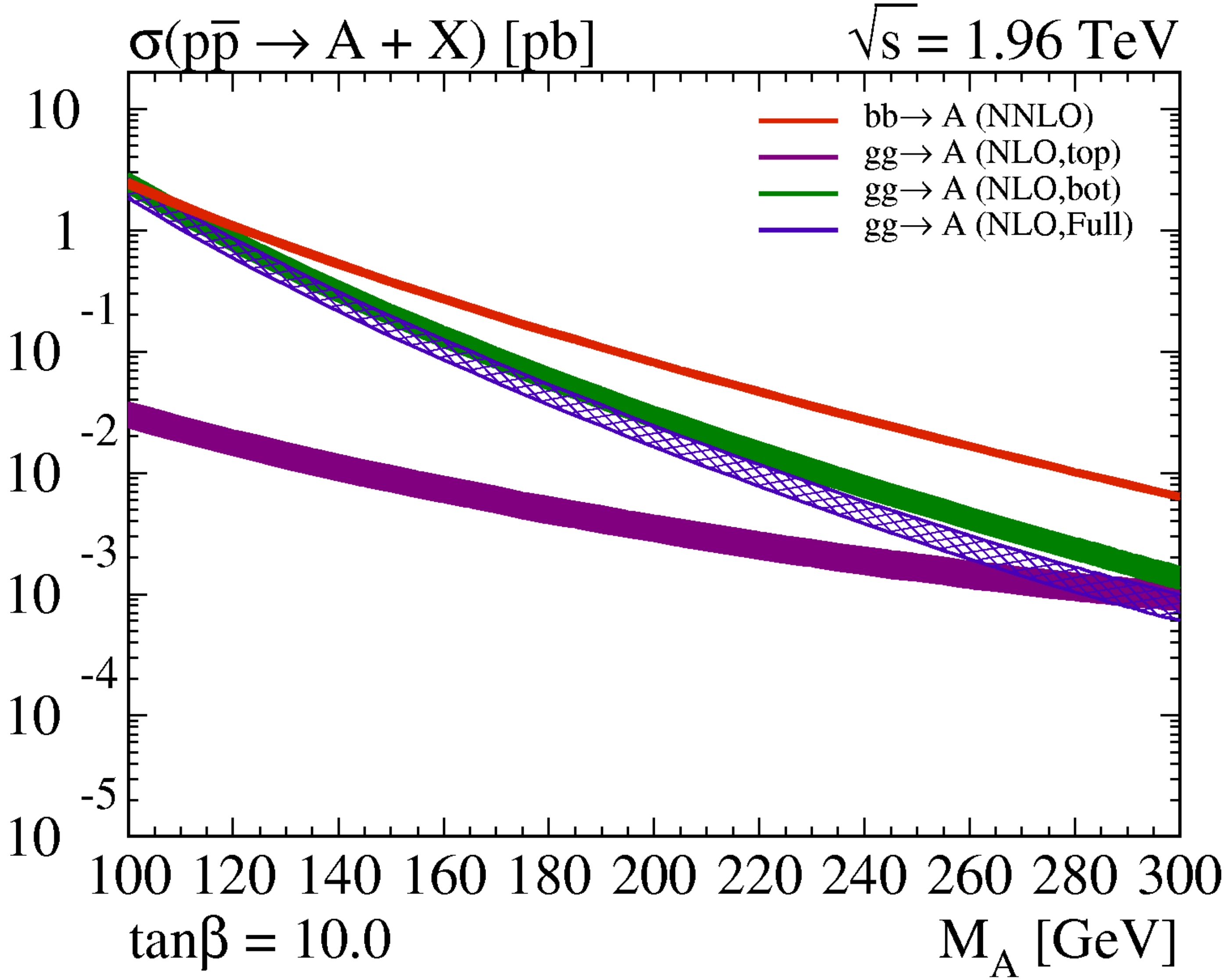
$\sigma_A(\tan\beta = 3)$ at the Tevatron



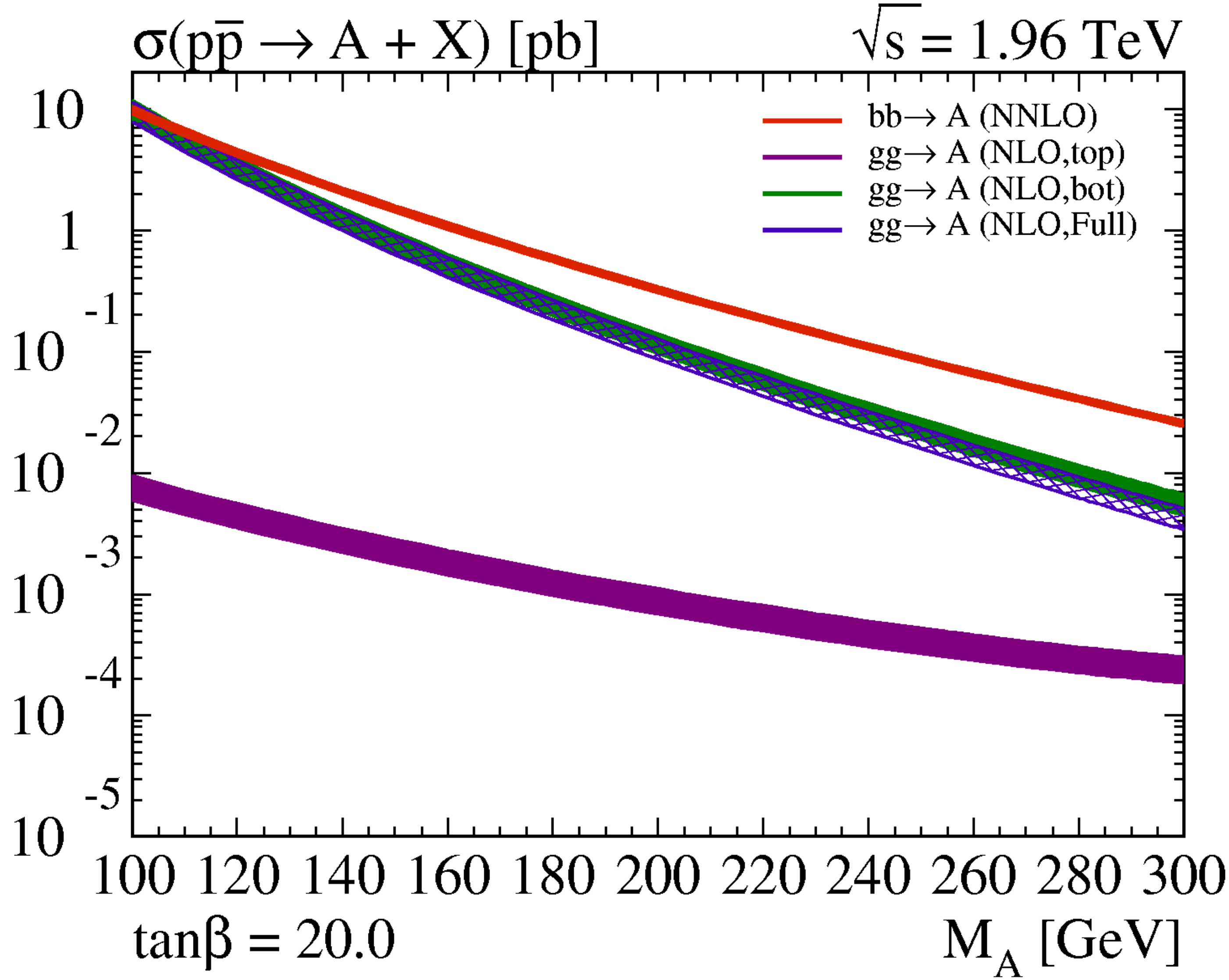
$\sigma_A(\tan\beta = 5)$ at the Tevatron



$\sigma_A(\tan\beta = 10)$ at the Tevatron



$\sigma_A(\tan\beta = 20)$ at the Tevatron



$\sigma_A(\tan\beta = 40)$ at the Tevatron