PROSPINO AND LEPTOQUARKS : FROM TEV. TO TEV

Michael Spira (PSI)

I PROSPINO

II Leptoquarks

III Conclusions

in collaboration with W. Beenakker, M. Krämer, T. Plehn and P. Zerwas

I *PROSPINO*

3 classes of SUSY particle production processes:

- strongly interacting particle pairs:

$p \overset{(-)}{p} \longrightarrow \tilde{g}\tilde{g}$

$p \overset{(-)}{p} \longrightarrow \tilde{q}\bar{\tilde{q}}$

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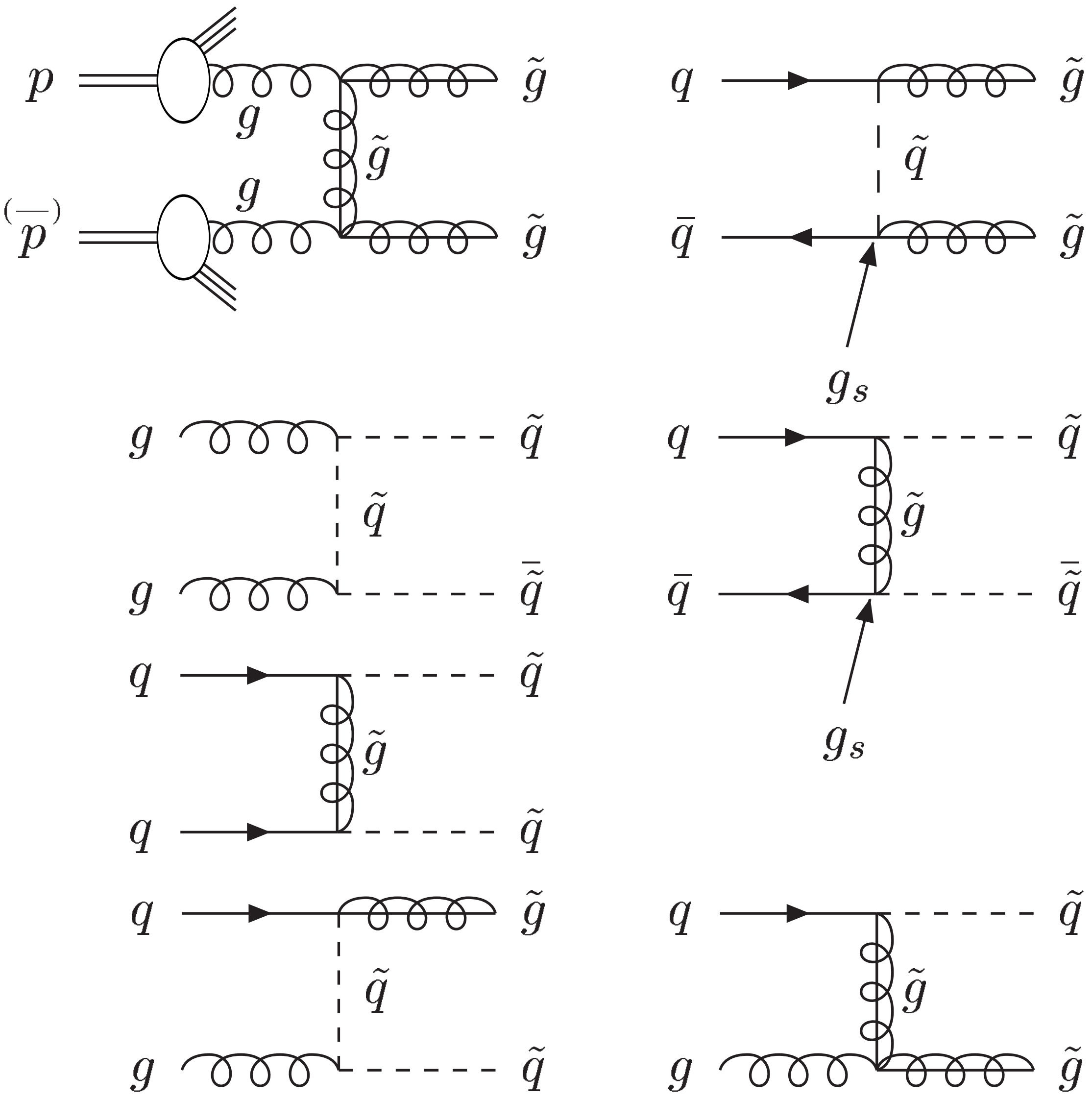
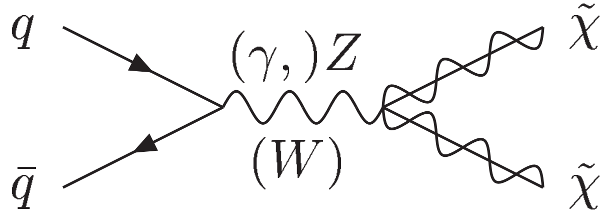
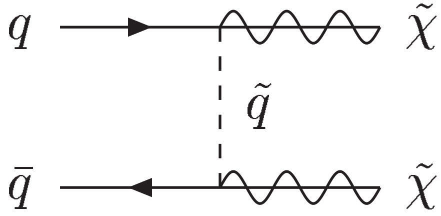


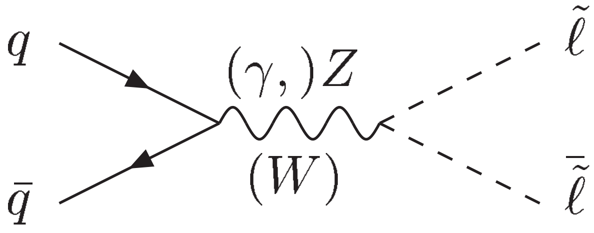
- weakly interacting particle pairs:

$p\overset{(-)}{p} \to \tilde{\chi}\tilde{\chi}$



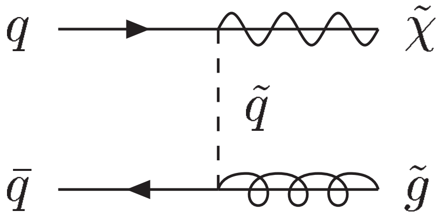


$p\overset{(-)}{p} \to \tilde{\ell}\bar{\tilde{\ell}}$

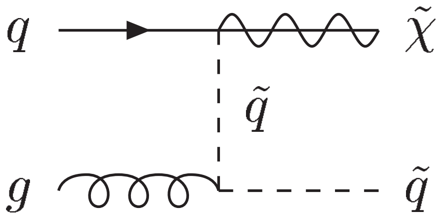


- associated production:

$p\overset{(-)}{p} \to \tilde{g}\tilde{\chi}$



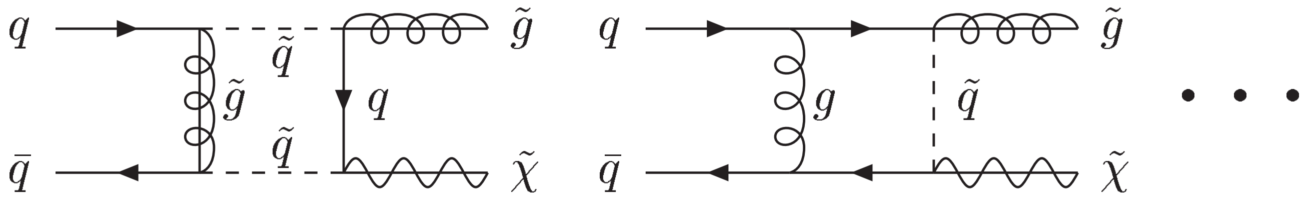
$p\overset{(-)}{p} \to \tilde{q}\tilde{\chi}$



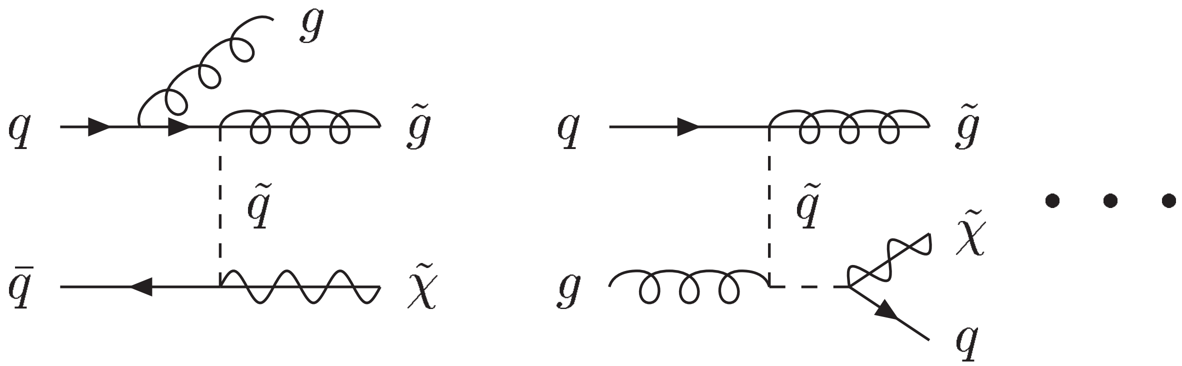
- LO: theoretical uncertainties $\mathcal{O}(100\%)$ $\Rightarrow$ $\boxed{\text{NLO needed}}$

Uncertainties reduced by SUSY–QCD corrections:

— virtual 1 loop contributions



— real contributions due to gluon radiation/crossing



• α_s, PDF: $\overline{\text{MS}}$ scheme [5 active flavors]

• $m_{\tilde{q}}, m_{\tilde{g}}$ on-shell

- double counting: $gq \to \tilde{g}\tilde{q} \to \tilde{g}\tilde{\chi}q$ [if $m_{\tilde{q}} > m_{\tilde{\chi}}$]

$$\frac{d\hat{\sigma}_{res}}{dM^2} = \hat{\sigma}(gq \to \tilde{g}\tilde{q}) BR(\tilde{q} \to \tilde{\chi}q) \underbrace{\frac{m_{\tilde{q}}\Gamma_{\tilde{q}}/\pi}{(M^2 - m_{\tilde{q}}^2)^2 + m_{\tilde{q}}^2\Gamma_{\tilde{q}}^2}}_{\to\delta(M^2 - m_{\tilde{q}}^2)}$$

$\boxed{\text{to be subtracted}}$

[analogous subtraction for $\tilde{q} \to \tilde{g}q$]

central scale: $K = \sigma_{NLO}/\sigma_{LO} \sim 1.1 - 1.2$ F

$\frac{1}{2}m < \mu_R = \mu_F < 2m$: $\delta\sigma \lesssim \pm 5 - 10\%$ F

$\Rightarrow$ NLO corrections lead to reliable predictions

[now agreement with Berger, Klasen, Tait]

- $\underline{pp \to \tilde{q}\tilde{\chi}}$: first very preliminary results F

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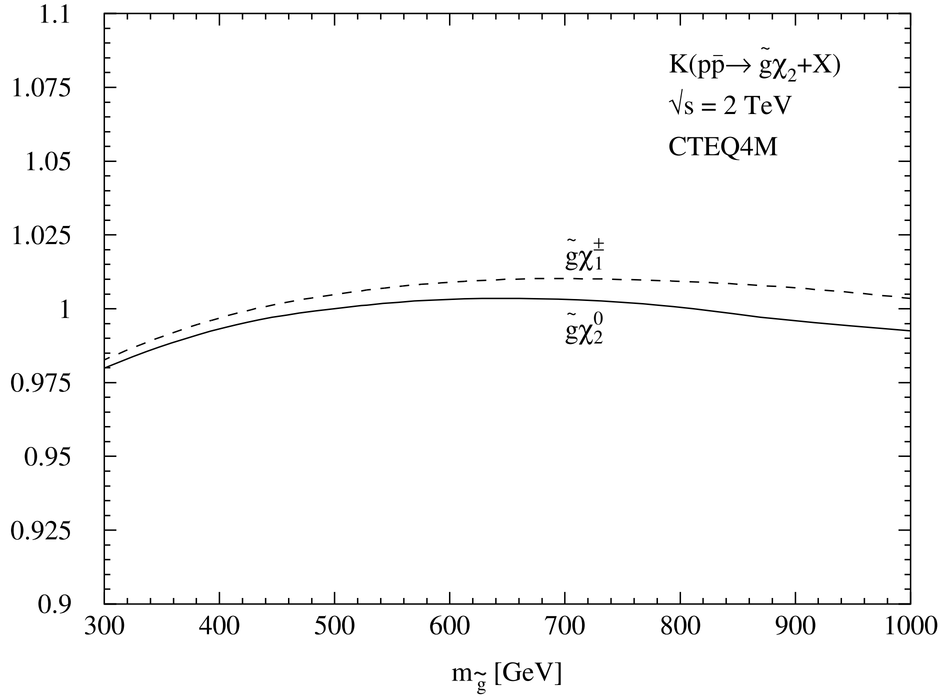
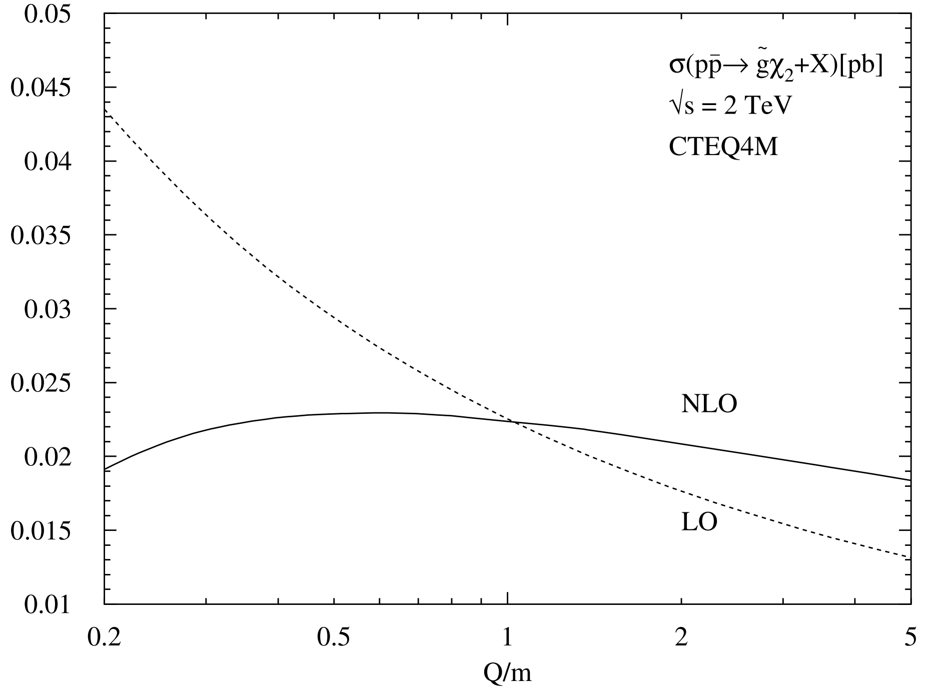
[resonance subtractions: $\tilde{q} \to \tilde{\chi}q, \tilde{g} \to \tilde{q}\bar{q}$]





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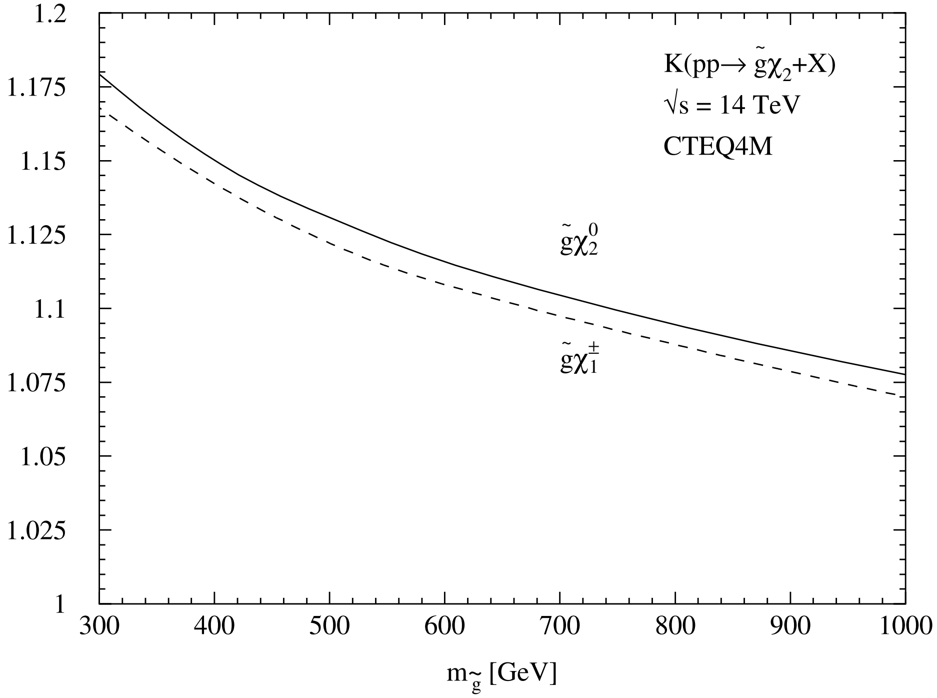

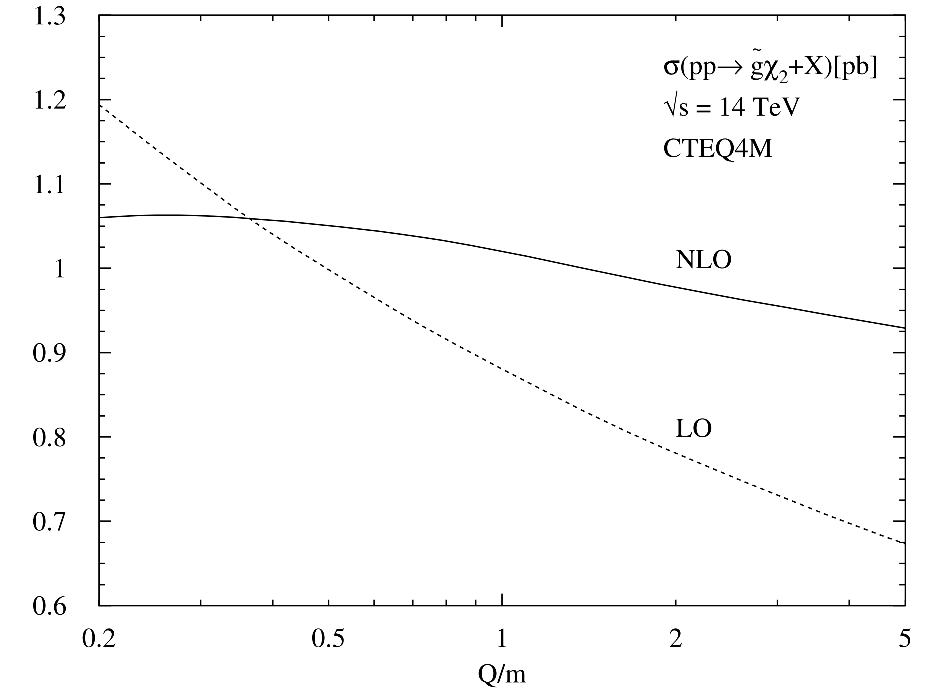

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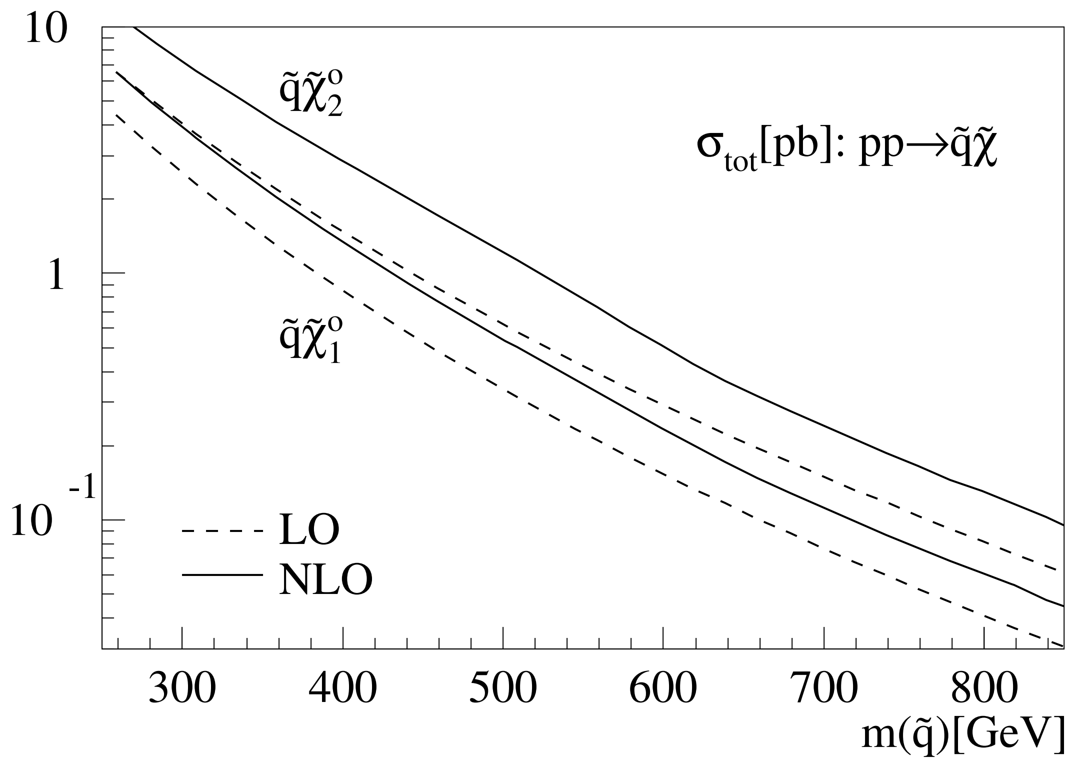
VERY PRELIMINARY

LHC



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PROSPINO

- $\tilde{g}\tilde{g}, \tilde{q}\tilde{q}, \tilde{q}\bar{\tilde{q}}, \tilde{g}\tilde{g}, \tilde{t}\bar{\tilde{t}}$ production:

$$\sigma_{tot}, \quad \frac{d^2\sigma}{dp_T dy} \text{ @ } NLO$$

Beenakker,. . .

[$\tilde{b}$ with large mass splitting: $\rightarrow$ $\tilde{t}\bar{\tilde{t}}$ program]

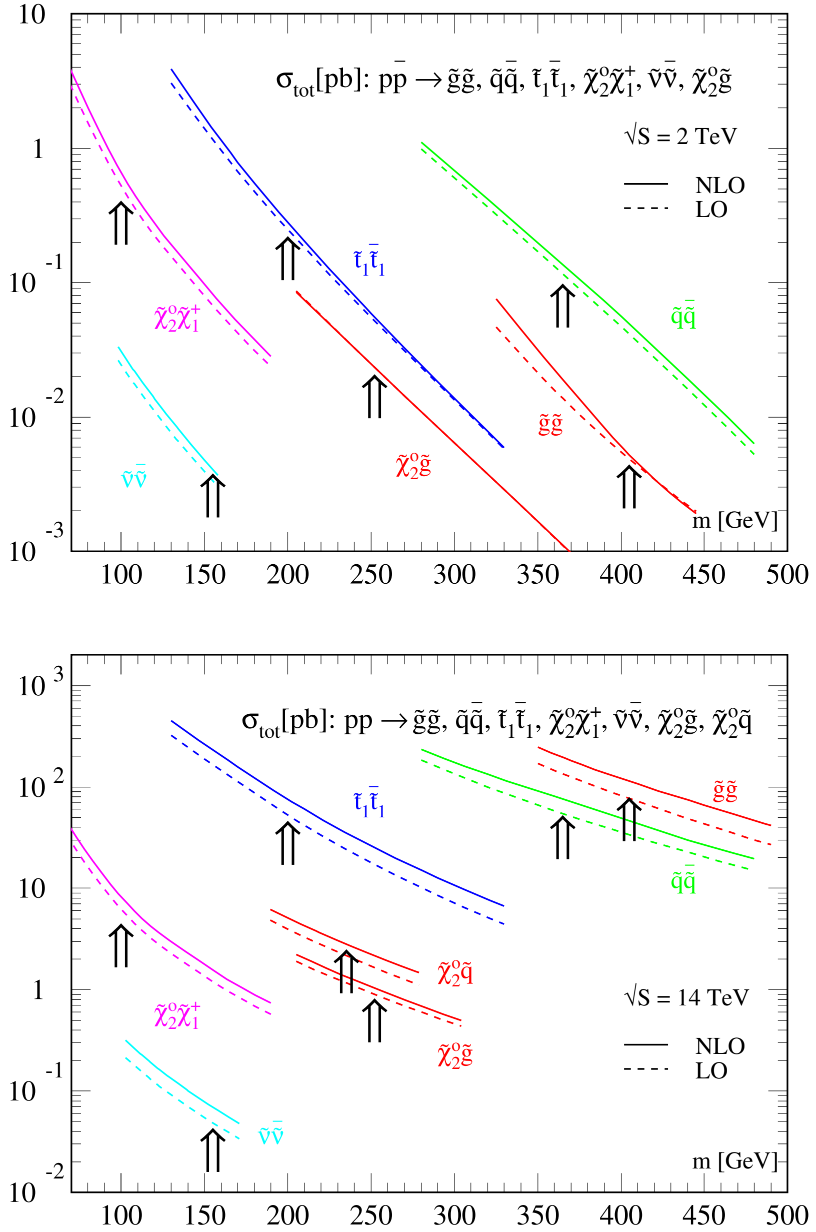
- $\tilde{\chi}\tilde{\chi}, \tilde{\ell}\bar{\tilde{\ell}}, \tilde{g}\tilde{\chi}$ production: σ_{tot} @ NLO added

- $\tilde{q}\tilde{\chi}$ production: first NLO results soon. . .

- distributions: coming soon. . .

- new version 2.0: extension to $\tilde{\chi}\tilde{\chi}, \tilde{g}\tilde{\chi}, \tilde{q}\tilde{\chi}$ [LO]

PROSPINO



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II *LEPTOQUARKS*

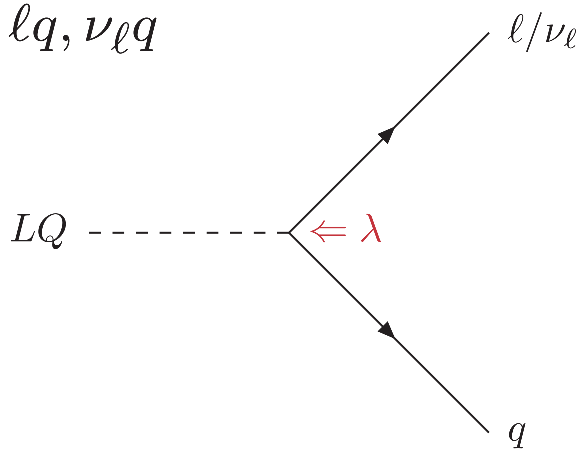
• leptoquarks predicted by many exotic extension of the SM [compositeness] Buchmüller, Rückl, Wyler

• leptoquarks carry lepton and baryon number

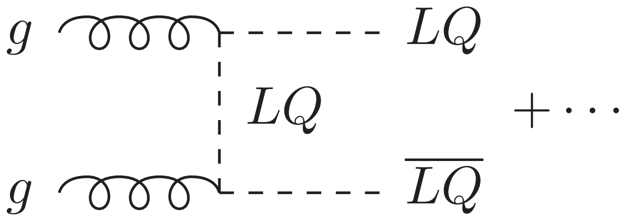
• two basic types: scalar [spin 0], vector [spin 1] (non-renormalizeable)

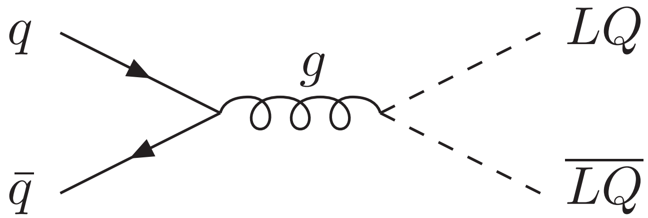
• novel Yukawa couplings small for first two generations
$\Rightarrow$ negligible for hadroproduction

• relevant for main decay modes: $LQ \to \ell q, \nu_\ell q$



- production: $gg, q\bar{q} \to LQ\ \overline{LQ}$





- Leading order: $[\beta = \sqrt{1 - 4M_{LQ}^2/\hat{s}}]$

$$\hat{\sigma}_{gg} = \frac{\alpha_s^2 \pi}{96 \hat{s}} \left[\beta(41 - 31\beta^2) + (18\beta^2 - \beta^4 - 17) \log \frac{1+\beta}{1-\beta} \right]$$

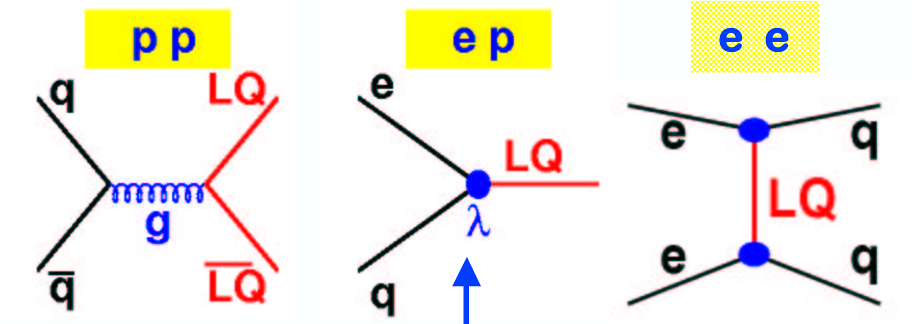
$$\hat{\sigma}_{q\bar{q}} = \frac{\alpha_s^2 \pi}{\hat{s}} \frac{2}{27} \beta^3$$

- production model-independent $[M_{LQ} < \Lambda]$

- Tevatron: $q\bar{q}$ channel dominant (75–85%), gg sizeable (15–25%)

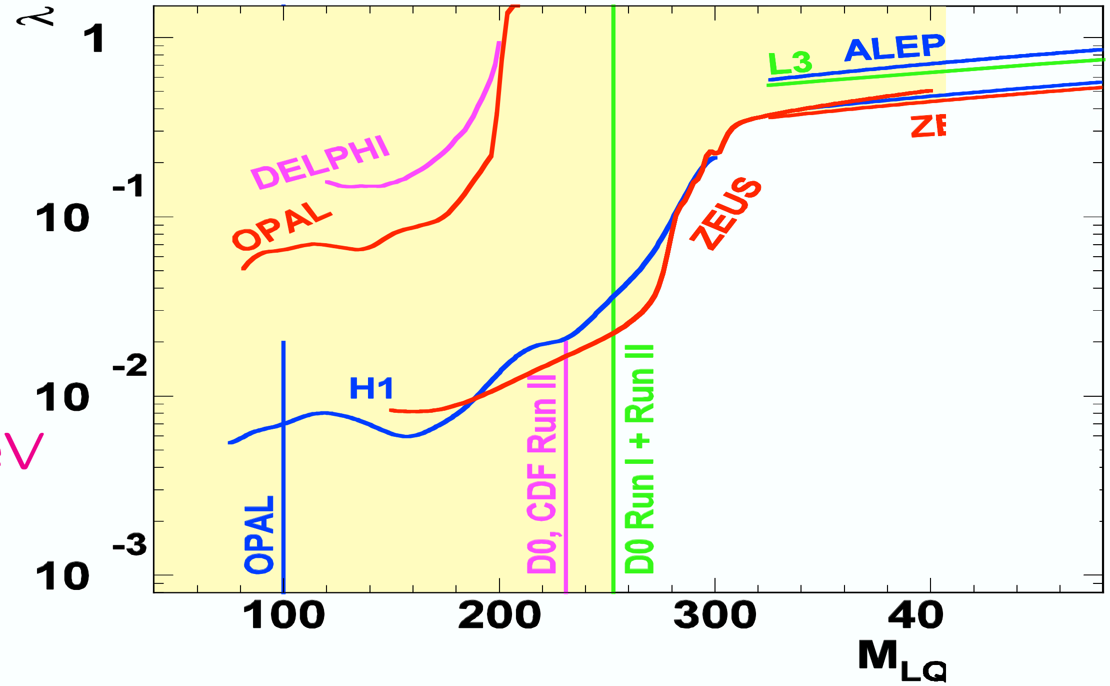
- LHC: gg channel dominant (70–95%), $q\bar{q}$ sizeable (5–30%)

Comparison with Other Colliders



λ dependence

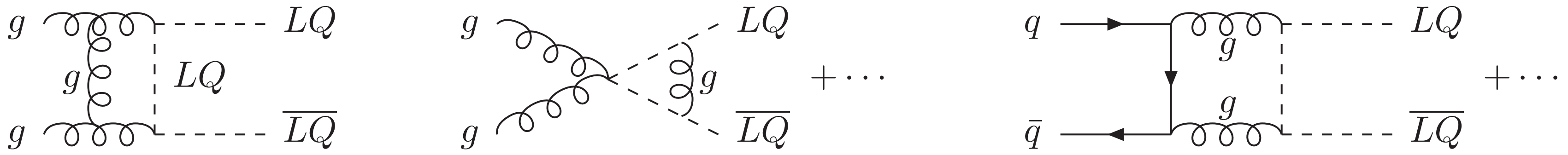
1st: $M_{LQ} \gtrsim 250$ GeV
2nd: $M_{LQ} \gtrsim 240$ GeV
reach @ Run II: ~ 300 GeV



QCD CORRECTIONS

• LO: large scale dependence: $\Longrightarrow$ NLO needed

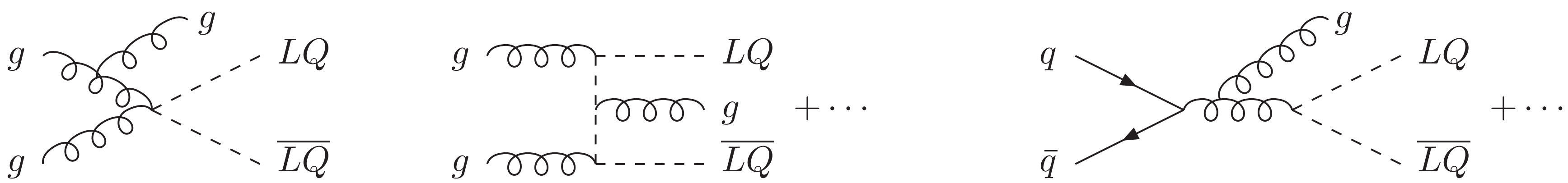
(i) Virtual Corrections



• ultraviolett, infrared and collinear divergences: dimensional regularization in $n = 4 - 2\epsilon$ dimensions

• α_s: $\overline{\text{MS}}$ scheme [5 flavours], M_{LQ}: on-shell

(ii) Real Corrections



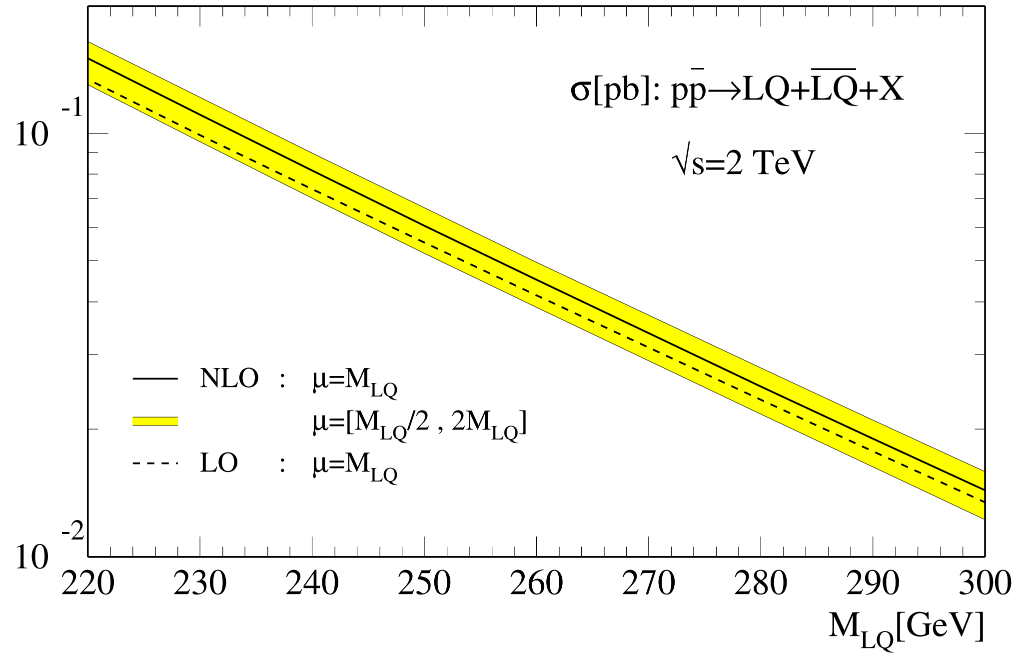
• infrared and collinear singularities cancel against virtual corrections and counter terms of PDFs [mass factorization]

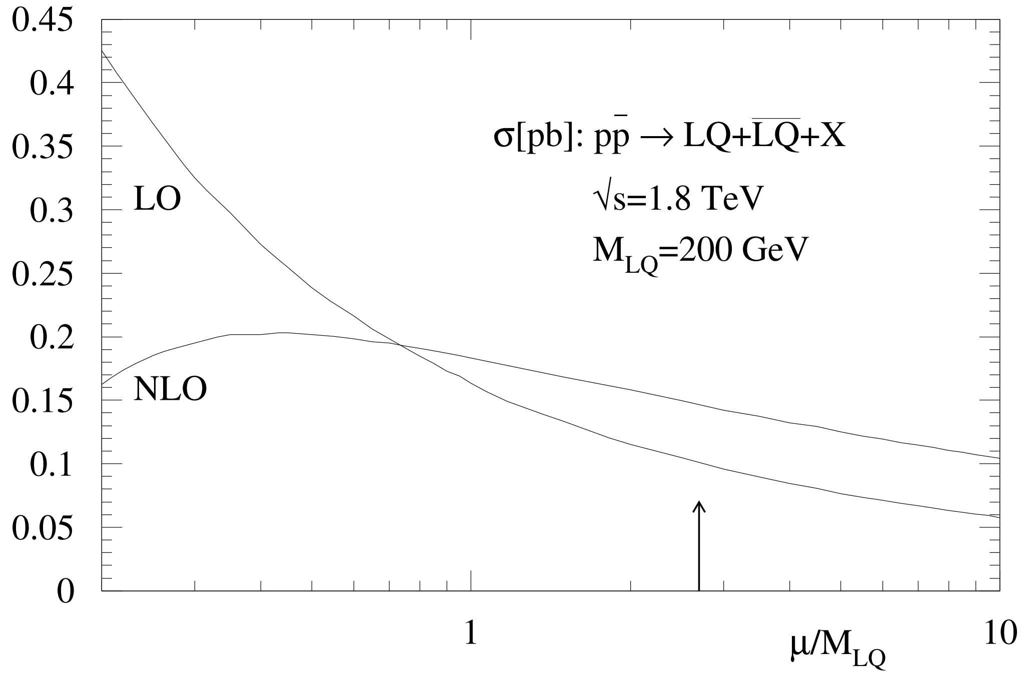
• PDF: $\overline{\text{MS}}$ scheme [5 flavours]

(iii) Cross Checks

• Scalar leptoquark pair production extracted from $\tilde{q}\bar{\tilde{q}}$ and $\tilde{t}\bar{\tilde{t}}$ pair production for $m_{\tilde{g}} \to \infty$ [contributions from quartic scalar couplings subtracted]

$\Rightarrow$ full agreement





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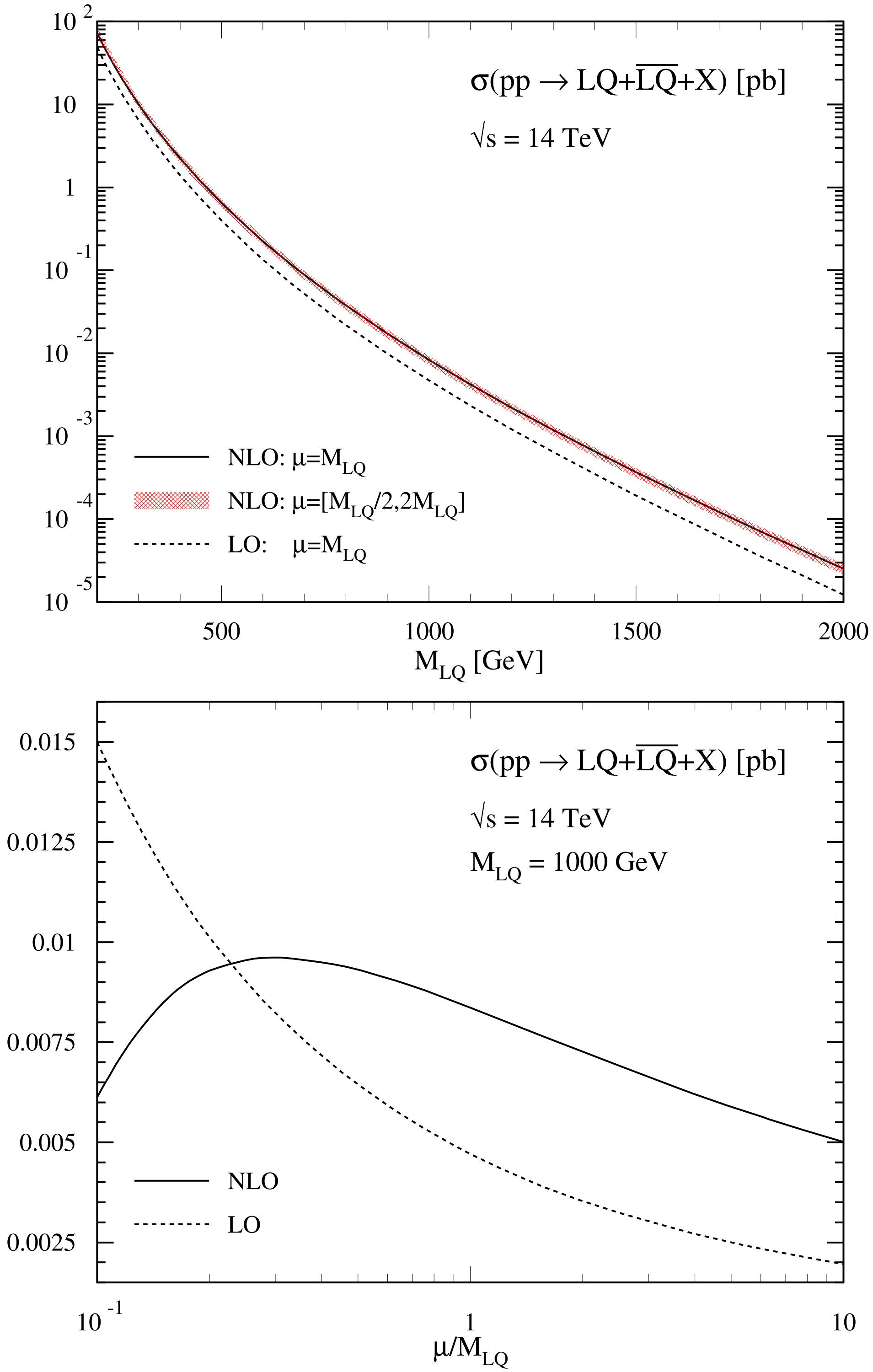

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III *CONCLUSIONS*

- SUSY particle searches at Tevatron/LHC belong to major endeavours
- sensitive up to $m_{\tilde{q},\tilde{g}} \sim 400$ GeV (Tev.), $\sim 2-3$ TeV (LHC)
- most (SUSY−)QCD corrections known $\Rightarrow$ large corrections

  remaining theoretical uncertainties: $\sim 100\% \longrightarrow \lesssim 10-15\%$
- significantly increased mass reaches [Tev.: $\lesssim 30$ GeV, LHC: $\lesssim 50$ GeV]
- program package available with these corrections: PROSPINO 2.0

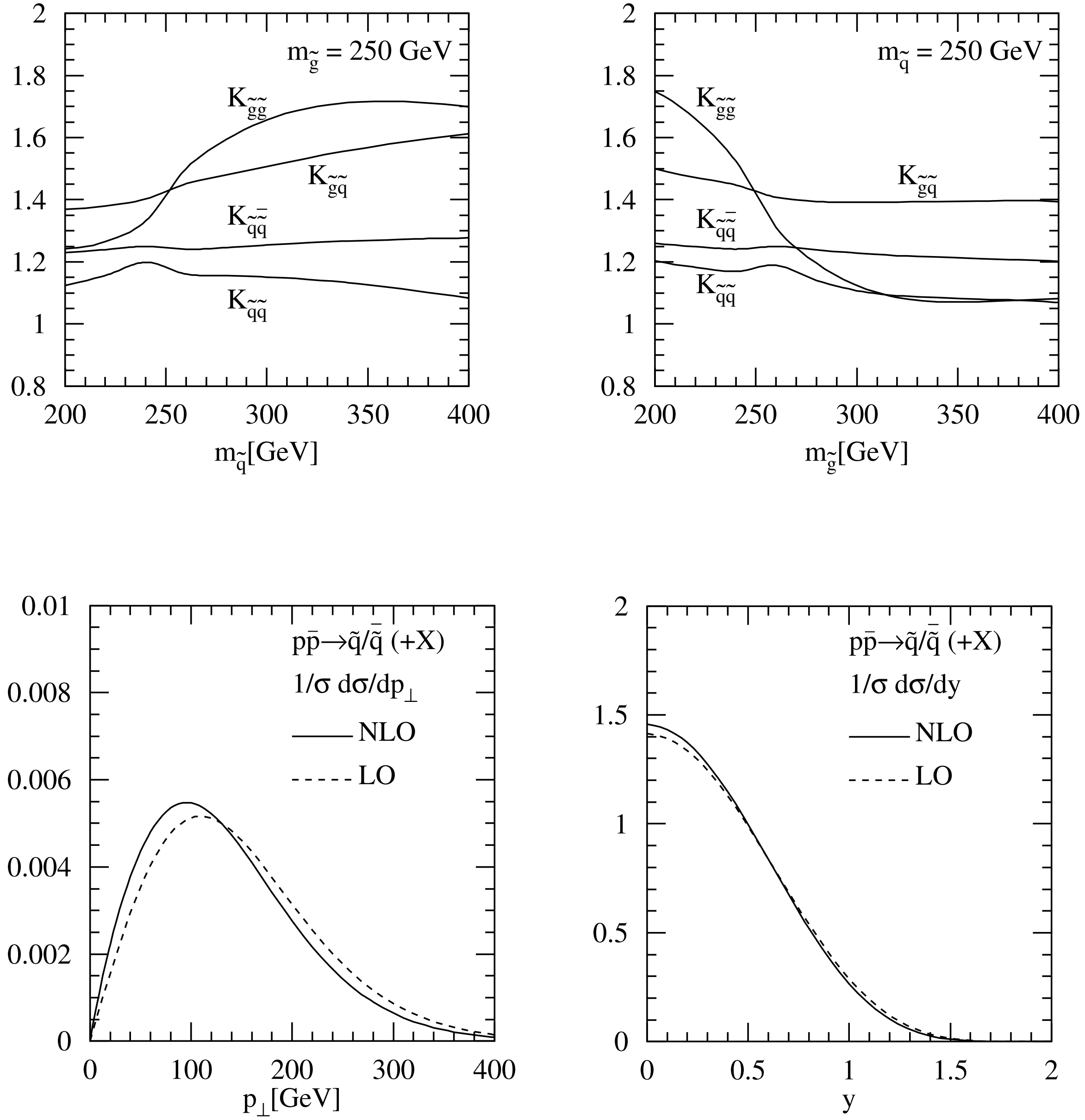
`http://pheno.physics.wisc.edu/~plehn/prospino/prospino.html`

`http://people.web.psi.ch/spira/`

- Scalar leptoquark pair production: QCD corrections $\sim (20-90)\%$

  $\Rightarrow$ increased mass reach [Tev.: ~ 15 GeV, LHC: ~ 100 GeV]
- sensitive up to ~ 300 GeV (Tev.), ~ 1.6 TeV (LHC)
- strong reduction of scale dependence: $\Delta \lesssim 10-15\%$
- FORTRAN code added to PROSPINO 2.0

BACKUP SLIDES



$m_{\tilde{q}} = 250$ GeV
$m_{\tilde{g}} = 300$ GeV

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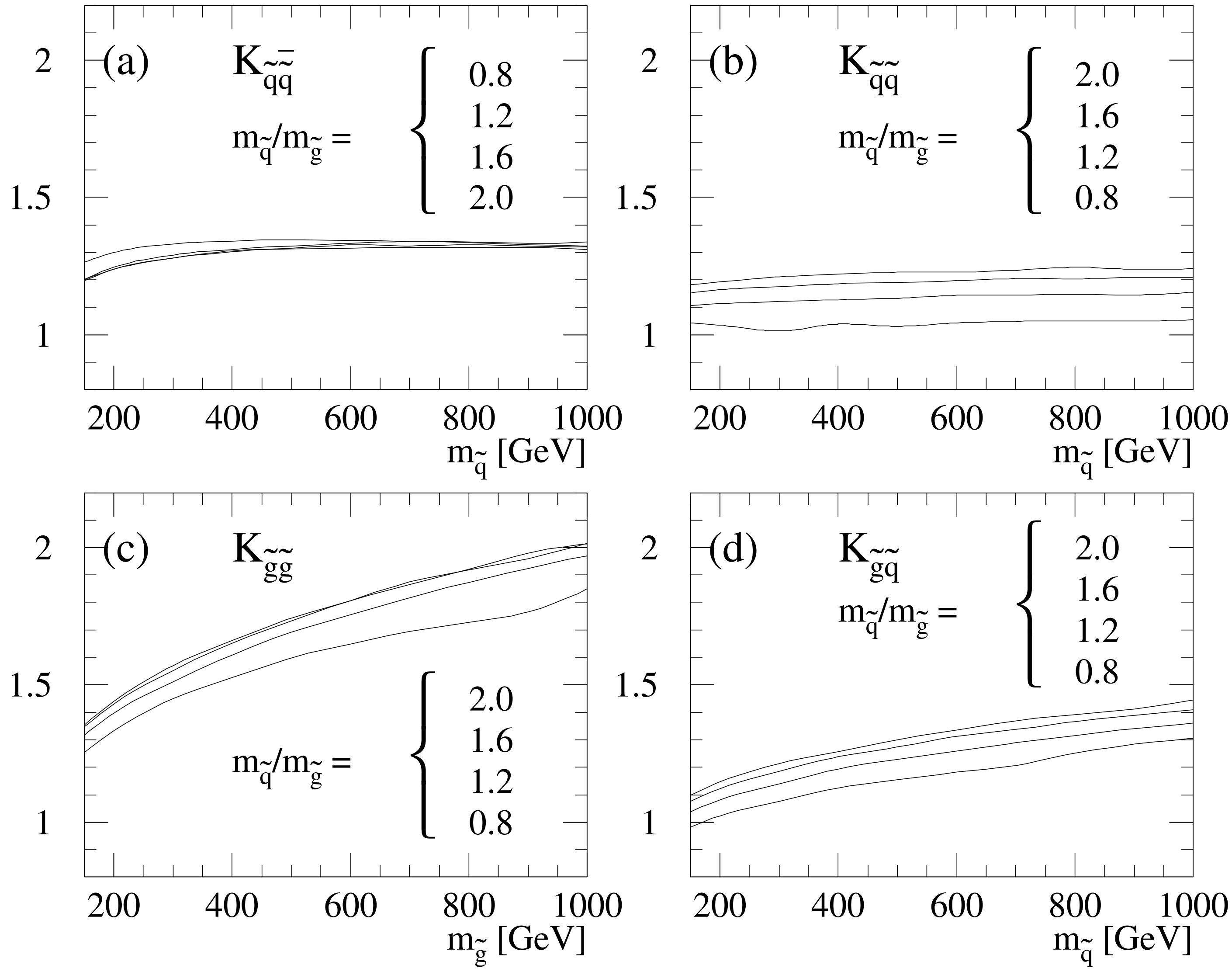

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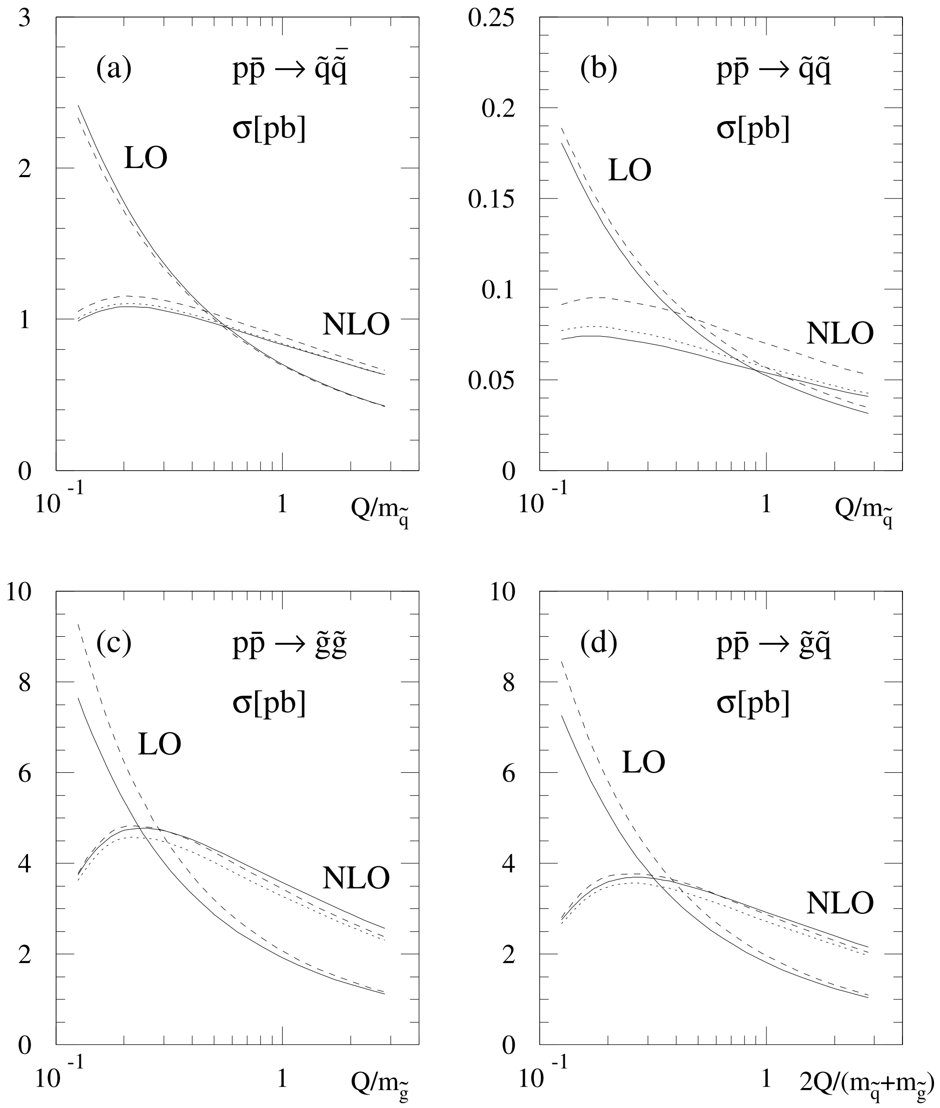

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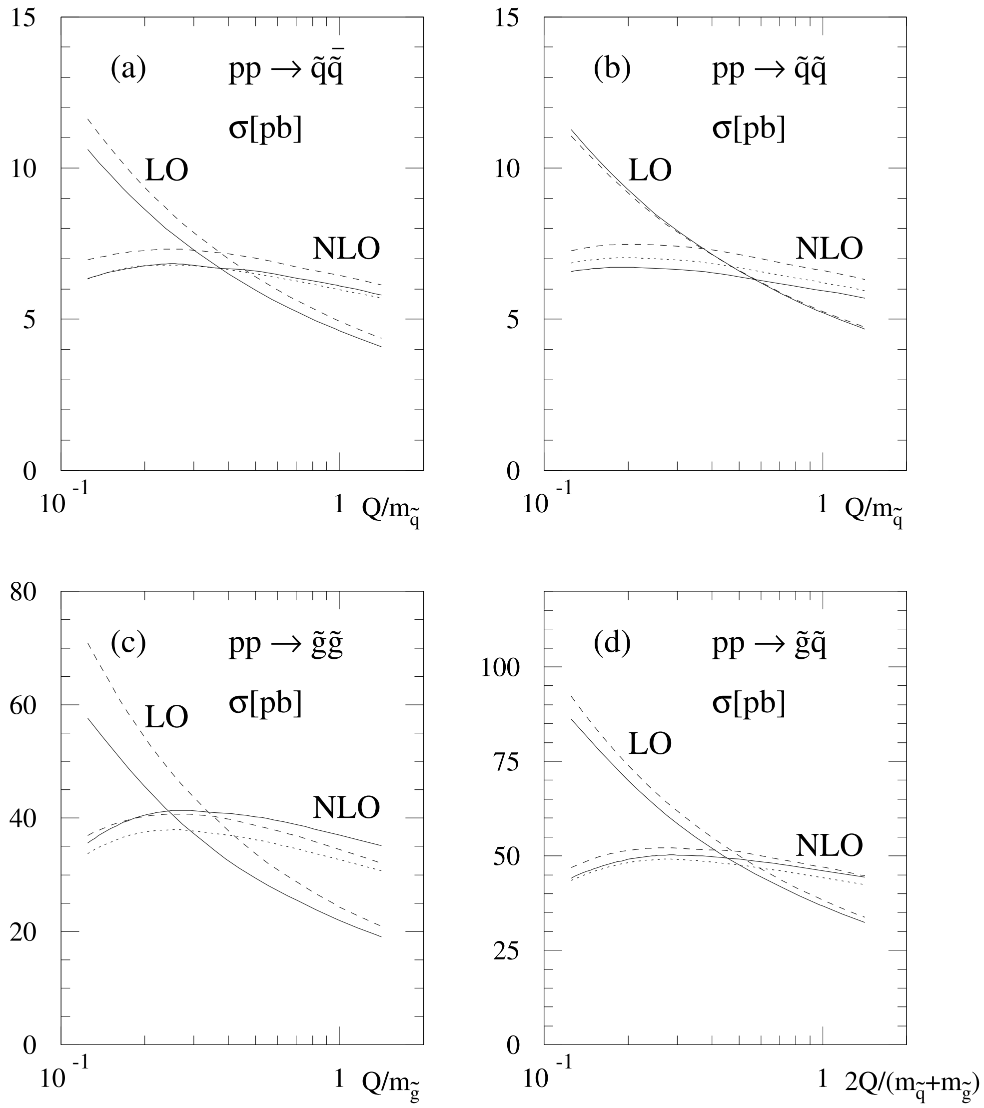

$m_{\tilde{q}} = 600$ GeV

$m_{\tilde{g}} = 500$ GeV

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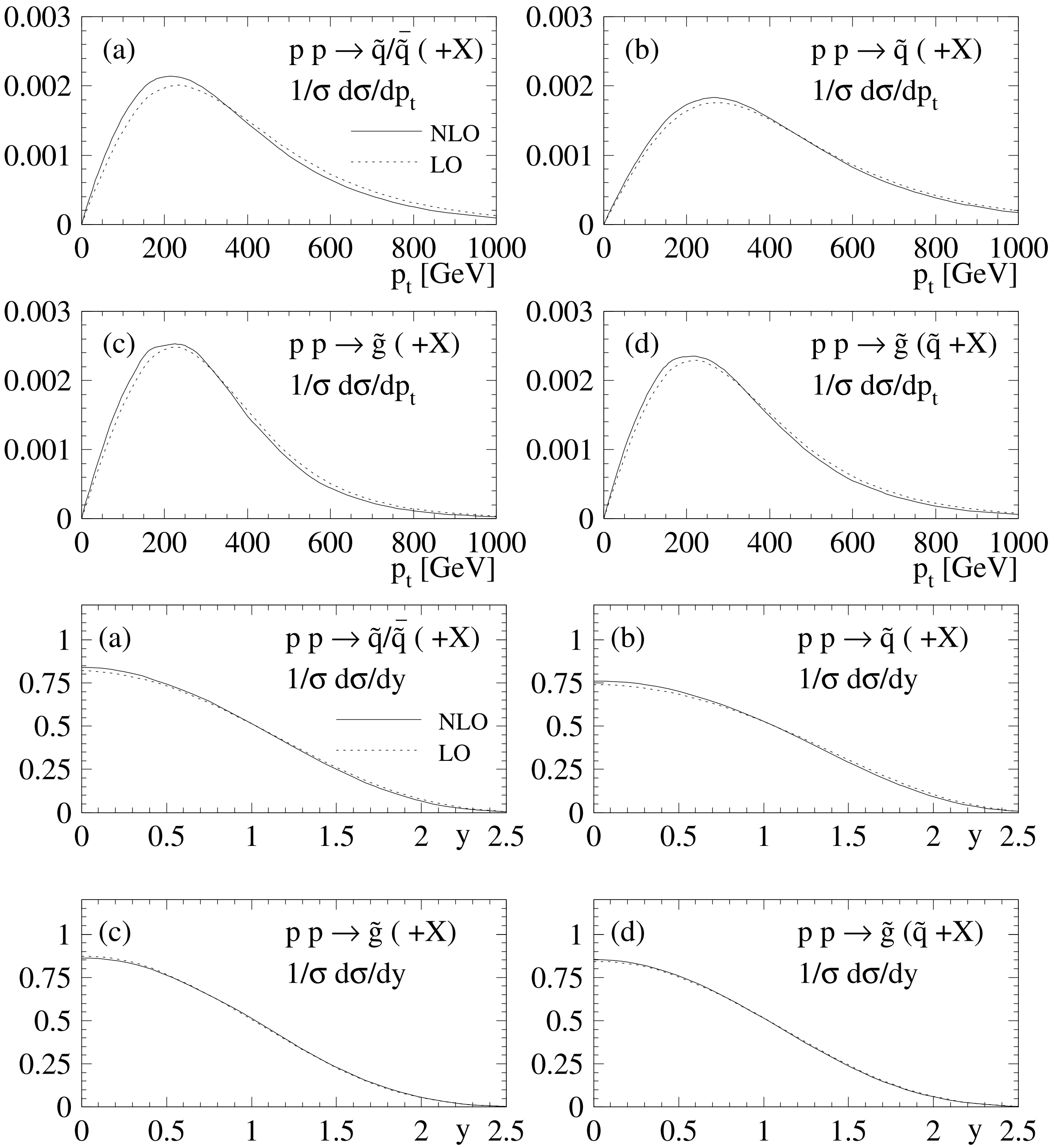

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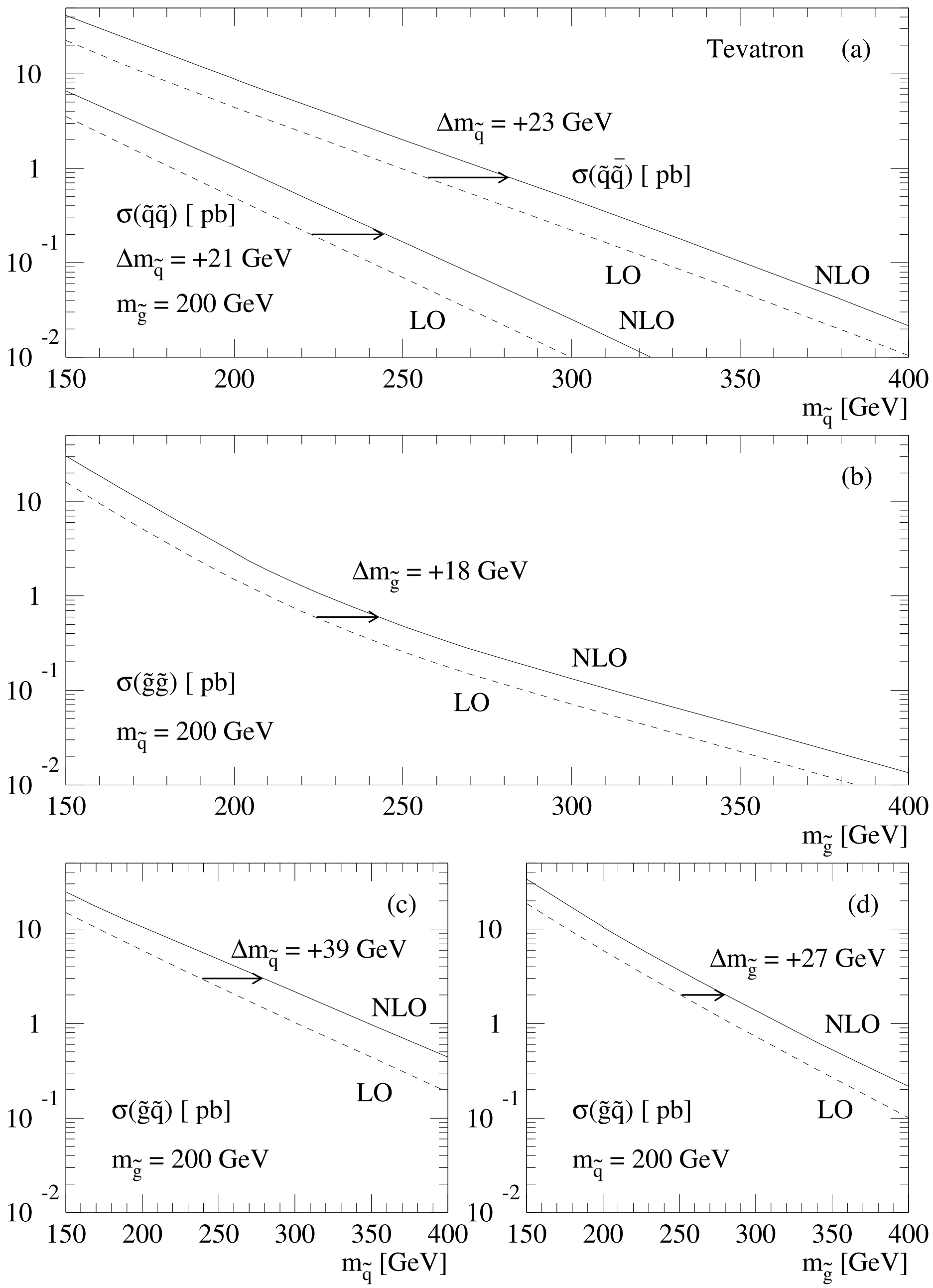

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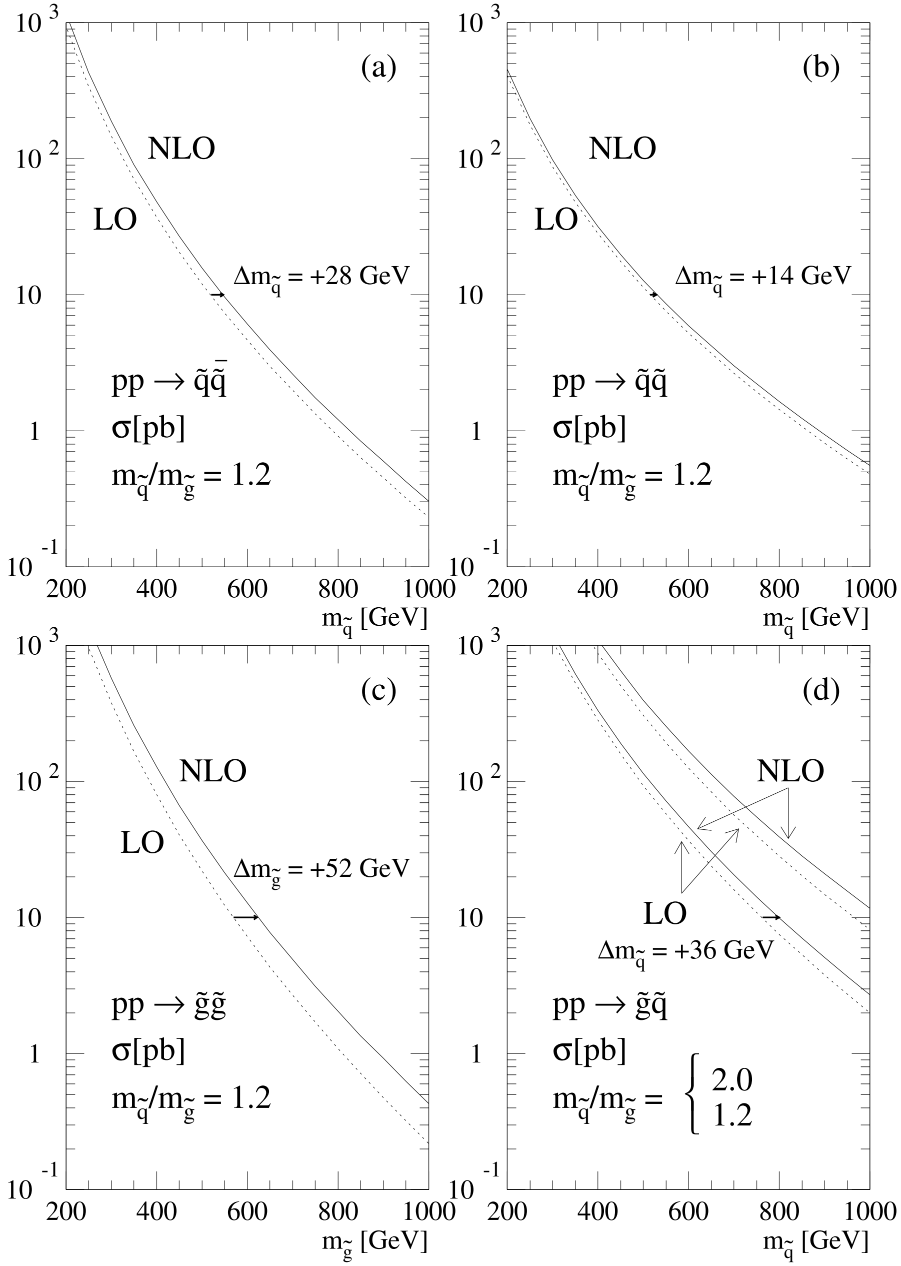

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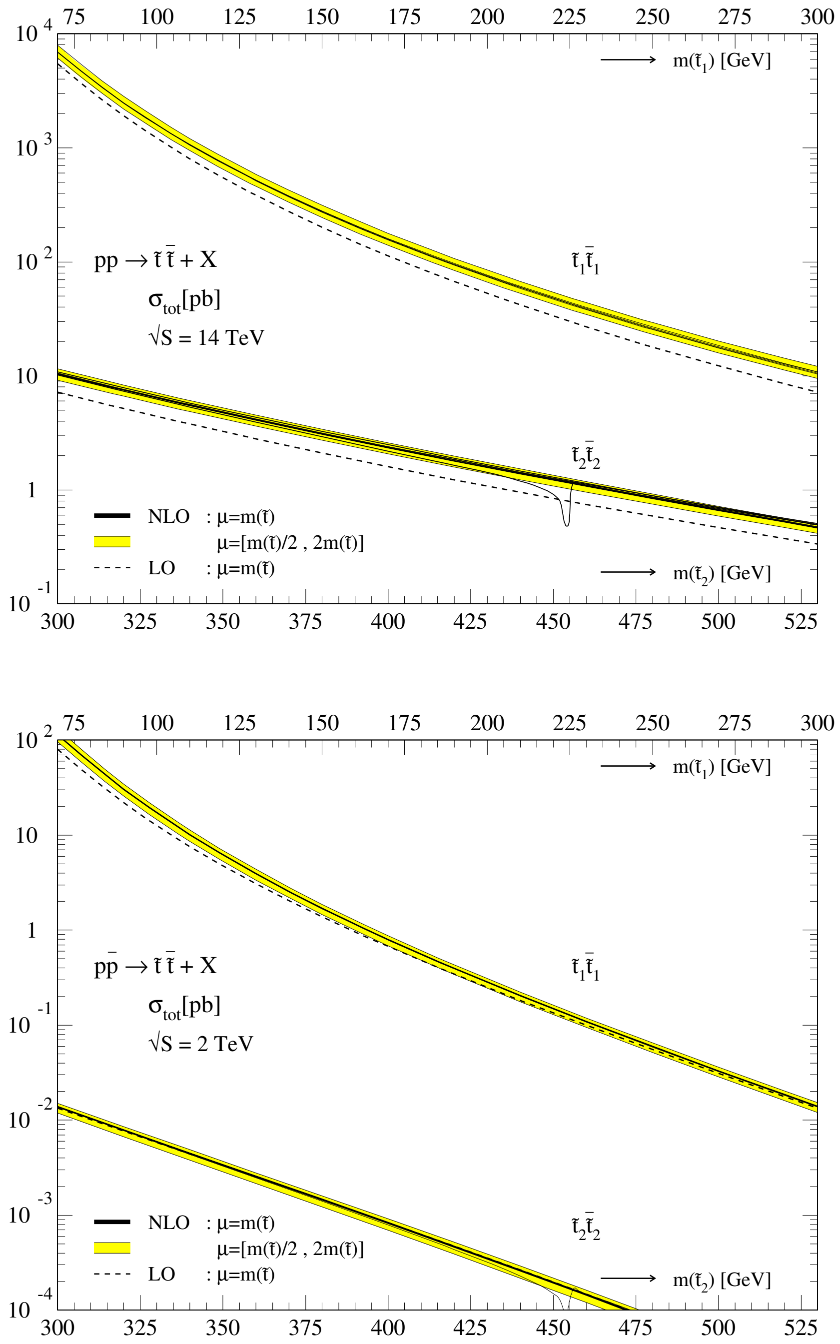

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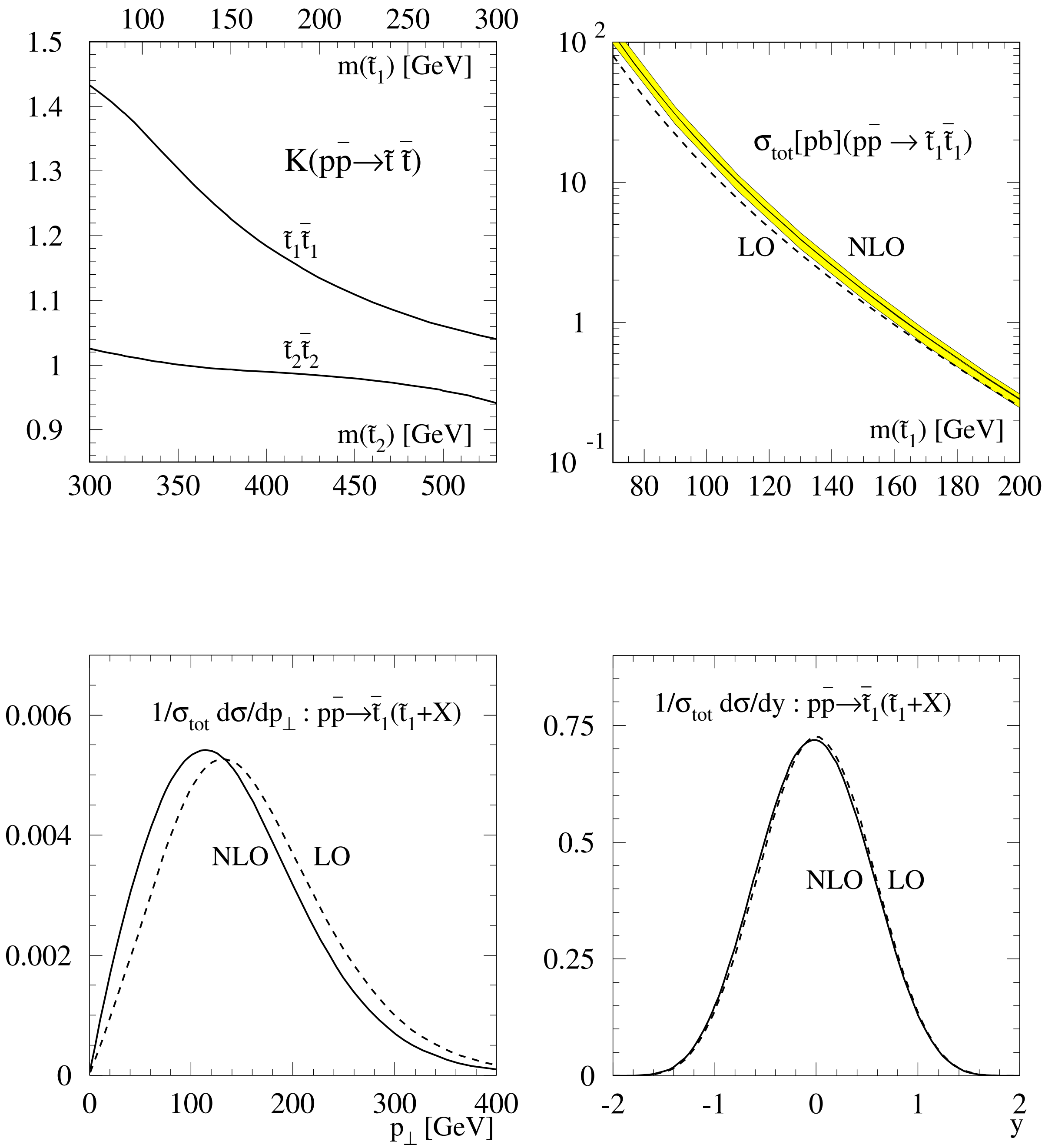

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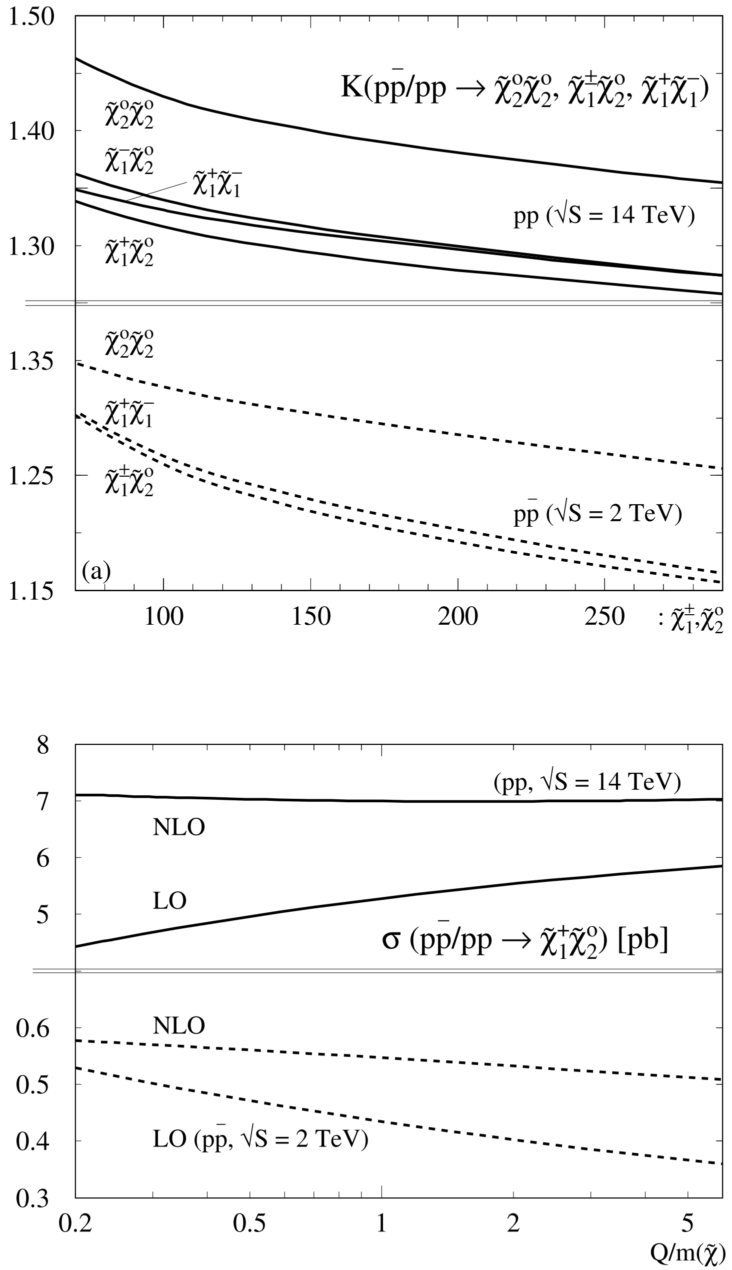

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