ASSOCIATED PRODUCTION OF SQUARKS WITH GAUGINOS AT HADRON COLLIDERS

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I Introduction

II SUSY-QCD Corrections

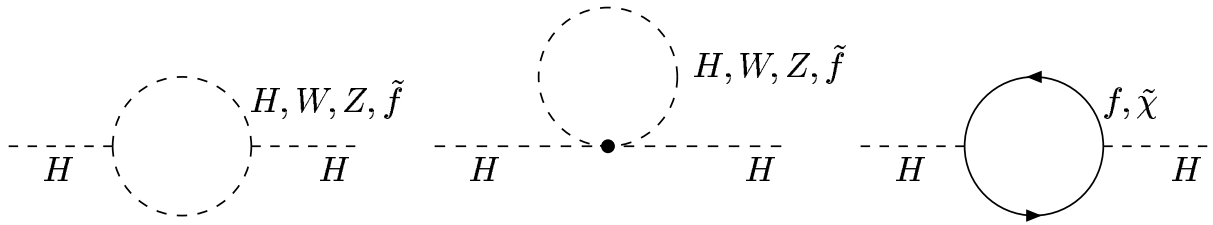
III Conclusions

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

I *INTRODUCTION*

- SUSY: fermions $\leftrightarrow$ bosons

- no quadratic divergences
  $\Rightarrow$ solution to the hierarchy problem



$$\delta M_H^2 \sim \tilde{m}^2 - m^2 \Rightarrow \tilde{m} \lesssim \mathcal{O}(1 \text{ TeV})$$

- SUSY-GUT: $\sin^2\theta_W = 0.2334 \pm 0.0026$ Langacker
  LEP: $\sin^2\theta_W = 0.2317 \pm 0.0002$ LEP/SLC

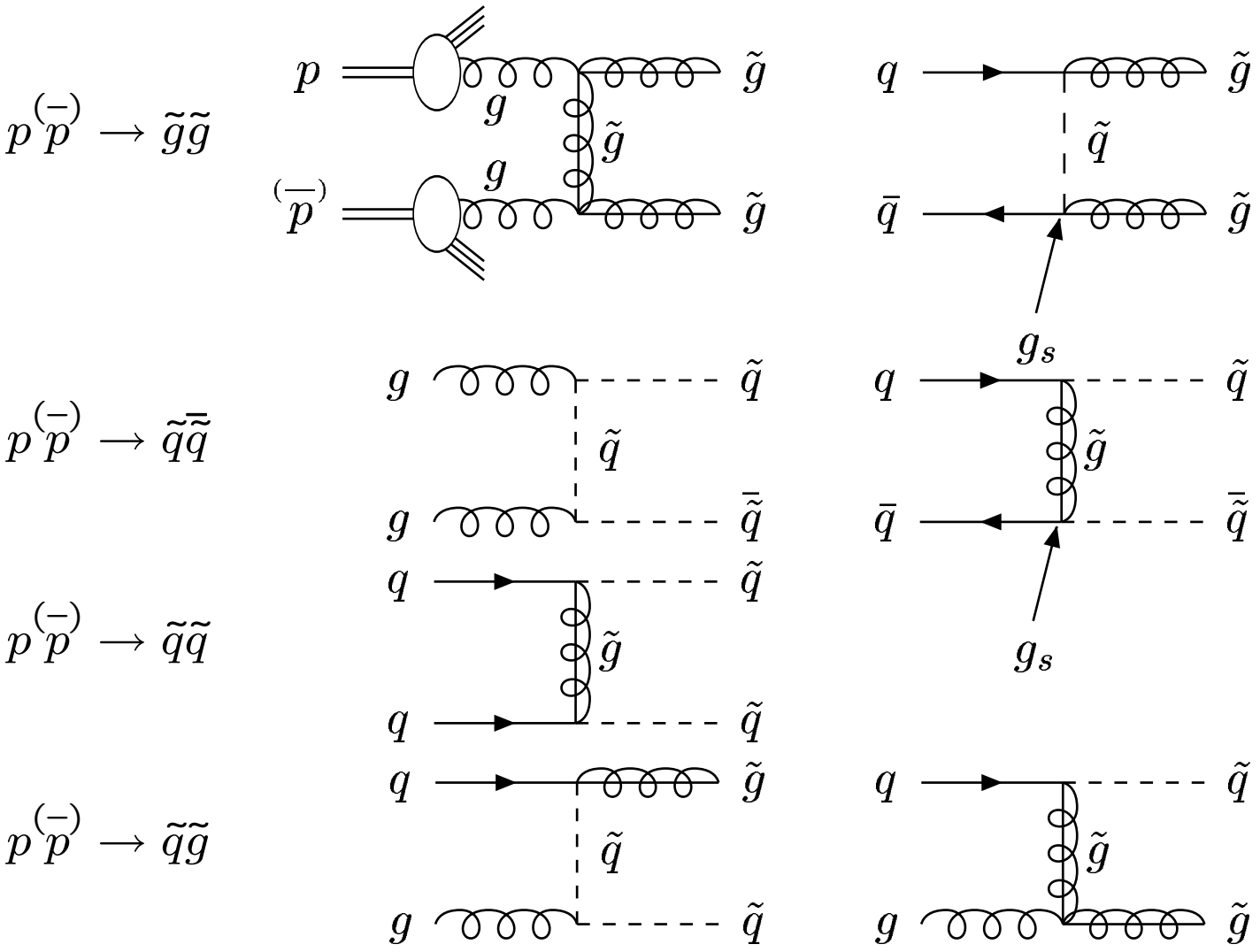
- radiative elw. symmetry breaking

SUSY sector

particle	spin	d.o.f.	mass	
lepton $\ell_{L/R}$	1/2	1	0	
quark $q_{L/R}$	1/2	3	0	
top $t_{L/R}$	1/2	3	m_t	
gluon g	1	16	0	
Photon γ	1	2	0	
$W^\pm$	1	3	M_W	
Z	1	3	M_Z	
Higgs $h, H, A, H^\pm$	0	1	$M_{h,H,A,H^\pm}$	
slepton $\tilde{\ell}_{L/R}$	0	1	$m_{\tilde{\ell}}$	
squark $\tilde{q}_{L/R}$	0	3	$m_{\tilde{q}}$	
stop $\tilde{t}_{1/2}$	0	3	$m_{\tilde{t}_{1/2}}$	mixing
gluino $\tilde{g}$	1/2	16	$m_{\tilde{g}}$	Majorana fermions
chargino $\tilde{\chi}^\pm_{1/2}$	1/2	4	$m_{\tilde{\chi}^\pm_{1/2}}$	
neutralino $\tilde{\chi}^0_{1\ldots4}$	1/2	8	$m_{\tilde{\chi}^0_{1\ldots4}}$	

3 classes of SUSY particle production processes:

- strongly interacting particle pairs:

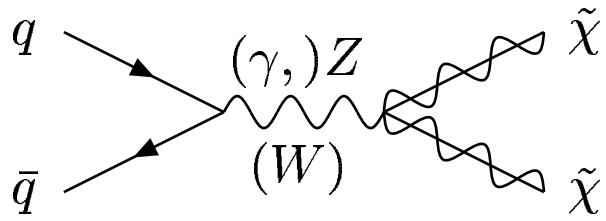


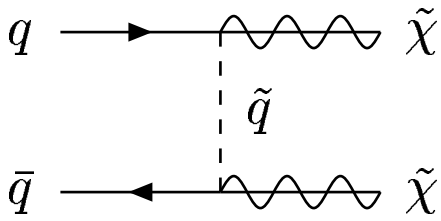
SUSY-QCD corrections $\lesssim$ 100% Beenakker, Höpker, S., Zerwas

- Stops: SUSY-QCD corrections $\lesssim$ 50% Beenakker, Krämer, Plehn, S., Zerwas

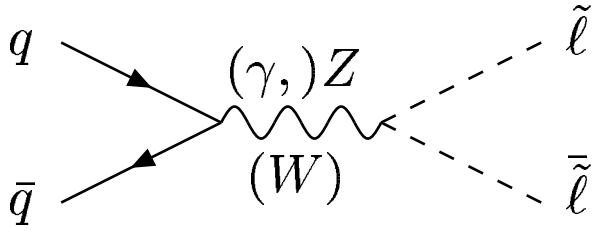
- weakly interacting particle pairs:

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





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

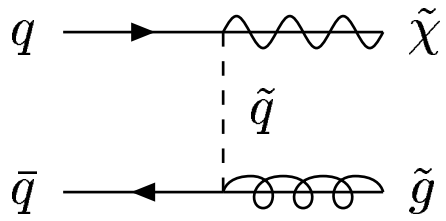


SUSY-QCD corrections $\lesssim$ 50%

Beenakker, Klasen, Krämer, Plehn, S., Zerwas

- associated production:

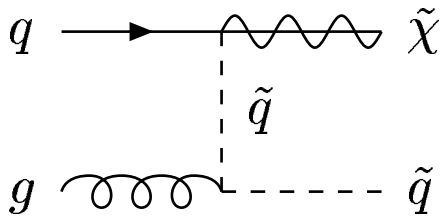
$p\overset{(-)}{p} \to \tilde{g}\tilde{\chi}$



SUSY-QCD corrections $\lesssim$ 20%

Beenakker, Krämer, Plehn, S., Zerwas
Berger, Klasen Tait

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



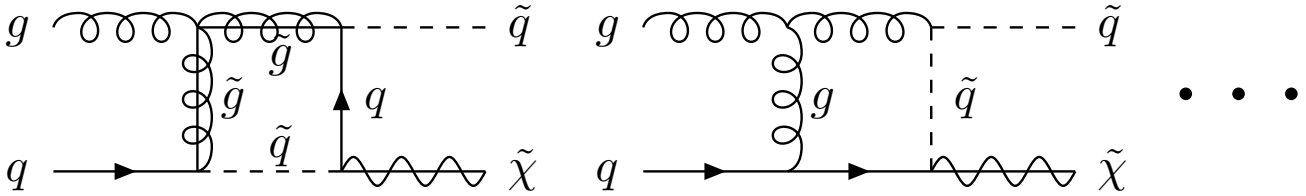
- LO: theoretical uncertainties $\mathcal{O}(100\%)$

$\Rightarrow$ NLO needed

II *SUSY – QCD CORRECTIONS*

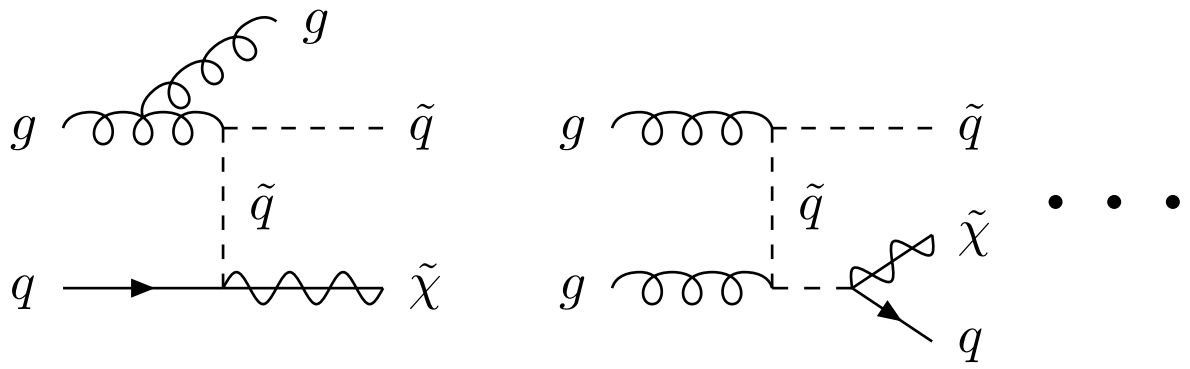
Uncertainties reduced by SUSY–QCD corrections:

(i) virtual 1-loop corrections



- dimensional regularization in $n = 4 - 2\epsilon$ dimensions
- naive γ_5 [checked]
- α_s: $\overline{\text{MS}}$ scheme [5 active flavors]
- $m_{\tilde{q}}, m_{\tilde{g}}$ on-shell
- additional (finite and unique) counter terms:
  $\tilde{g}, \tilde{\chi}$: 2 d.o.f.
  $g, \gamma, Z, \ldots$: $n - 2$ d.o.f.
  $\Rightarrow$ SUSY broken $\rightarrow$ restoration

(ii) real corrections due to gluon radiation/crossing



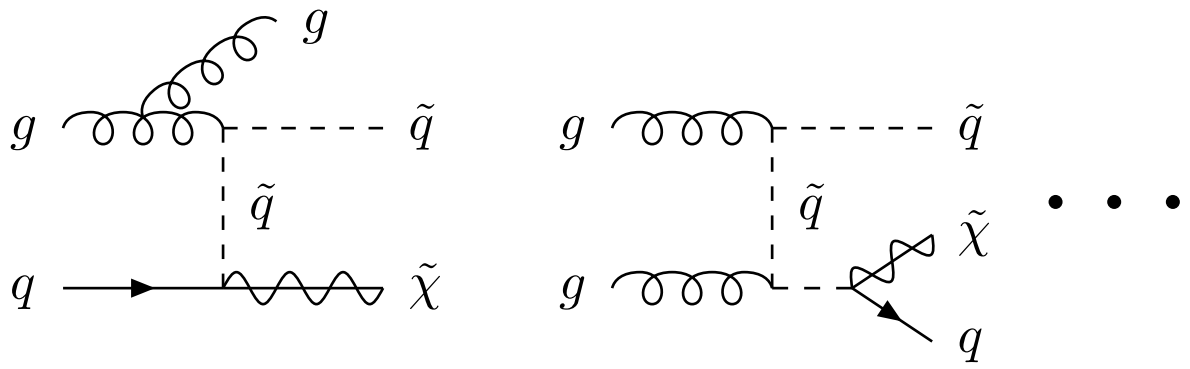
- phase space slicing
  massive dipole formalism

Catani, Dittmaier, Seymour, Trocsanyi

- PDF: $\overline{\text{MS}}$ scheme [5 active flavors]
  [unsolved problems with $\overline{\text{DR}}$]

$\Rightarrow \sigma$ finite, BUT...

(ii) real corrections due to gluon radiation/crossing



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

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

to be subtracted

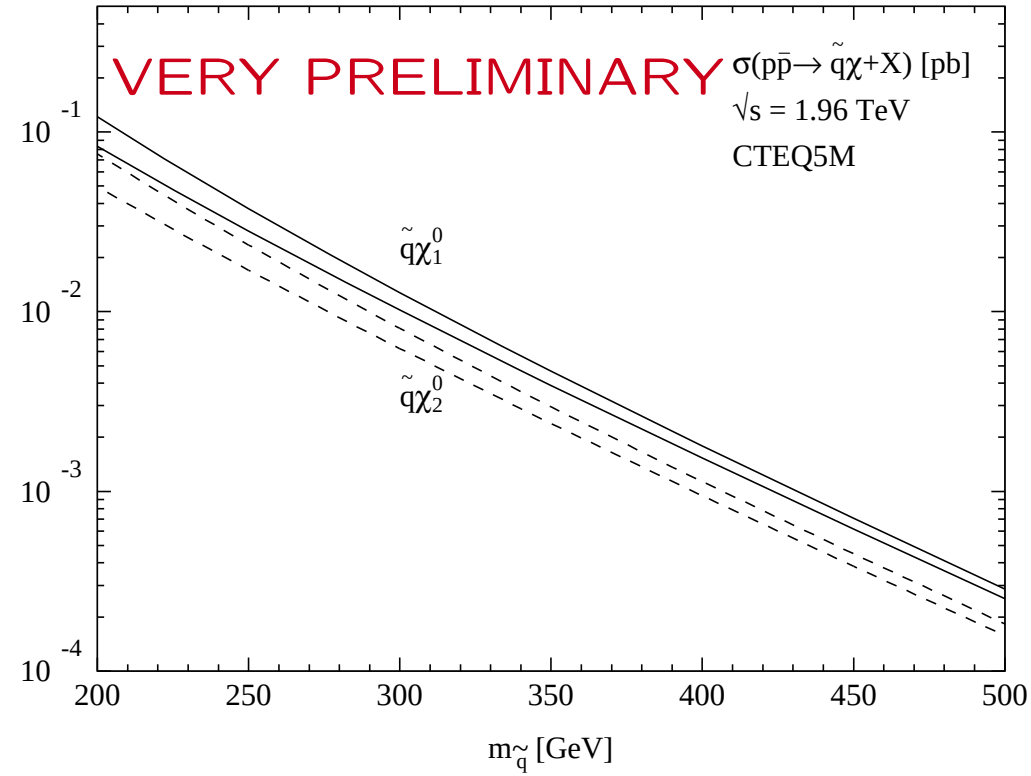
[analogous subtraction for $\tilde{\chi}\tilde{g} \to \tilde{\chi}\tilde{q}\bar{q}$]

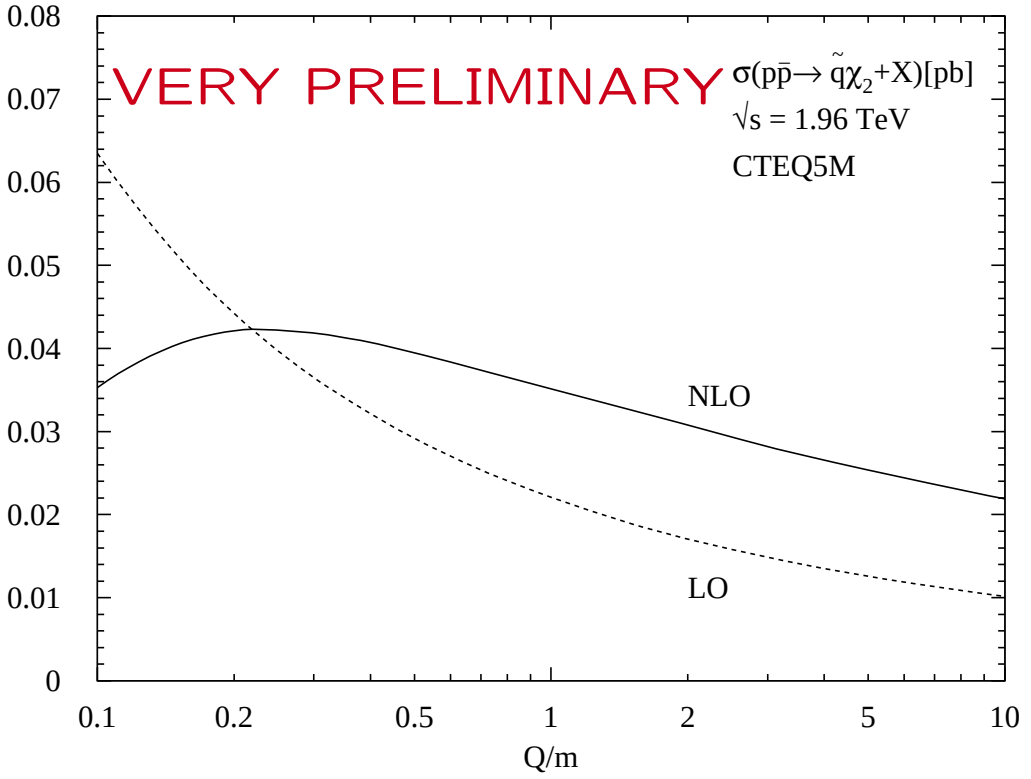
- first very preliminary results

- central scale: $K = \sigma_{NLO}/\sigma_{LO} \sim 1.5$ F

- $\frac{1}{2}m < \mu_R = \mu_F < 2m$: $\delta\sigma \lesssim \pm 15\%$ F

$\Rightarrow$ NLO corrections lead to reliable predictions





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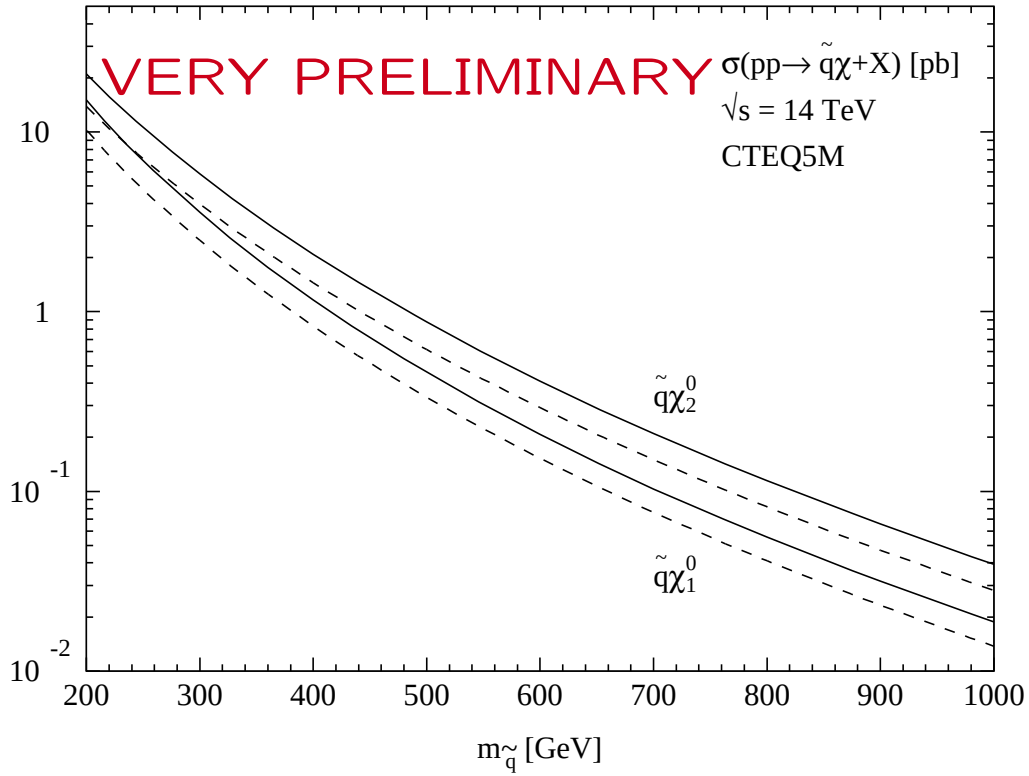

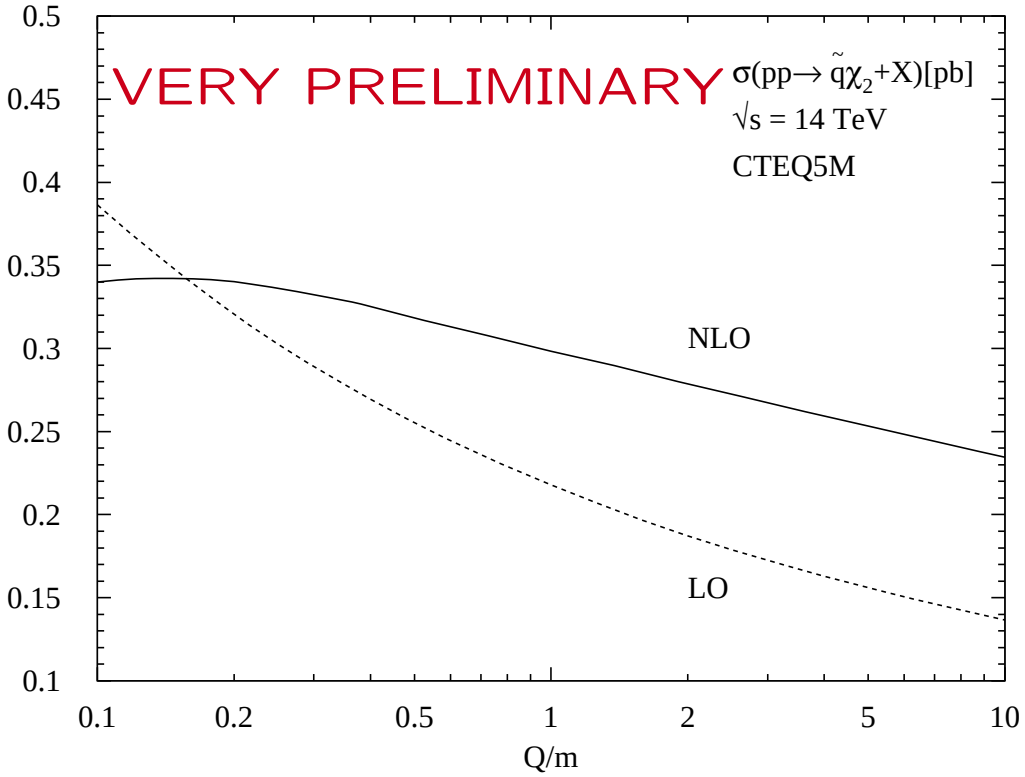

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PROSPINO

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

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

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

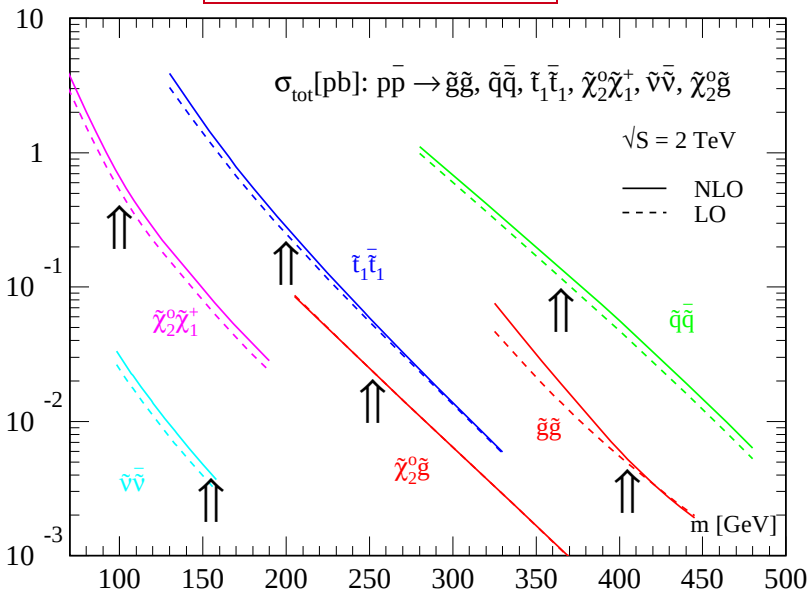
- $\tilde{\chi}\tilde{\chi}, \tilde{\ell}\bar{\tilde{\ell}}, \tilde{g}\tilde{\chi}$ production: σ_{tot} @ NLO added

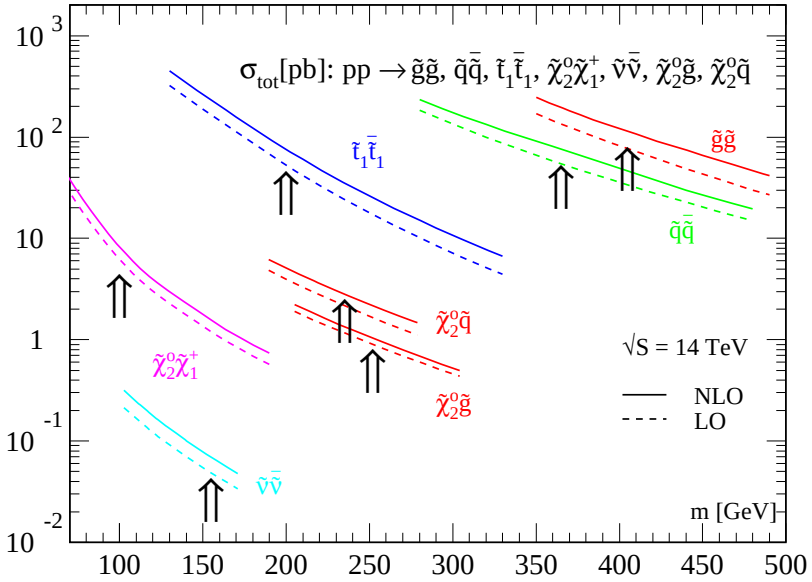
- $\tilde{q}\tilde{\chi}$ production: first NLO results

- 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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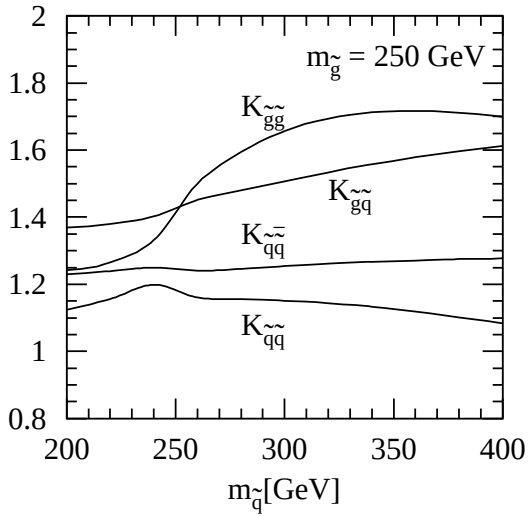
III *CONCLUSIONS*

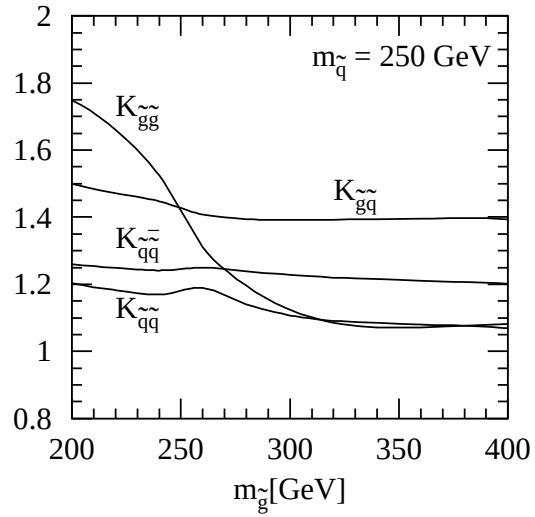
- SUSY searches at Tevatron/LHC belong to major endeavours
- sensitive up to $m_{\tilde{q},\tilde{g}} \sim 400$ GeV (Tev.), $\sim 2-3$ TeV (LHC)
- all (SUSY–)QCD corrections now known $\Rightarrow$ large corrections
- theoretical uncertainties: $\lesssim 100\% \longrightarrow \lesssim 10-15\%$
- significantly increased mass reaches [Tev.: $\lesssim 30$ GeV, LHC: $\lesssim 50$ GeV]
- program package available with these corrections: PROSPINO 2.0

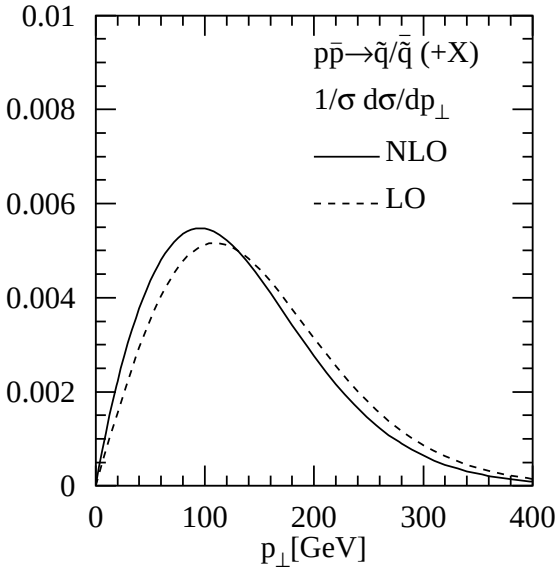
`http://pheno.physics.wisc.edu/~plehn/prospino/prospino.html`

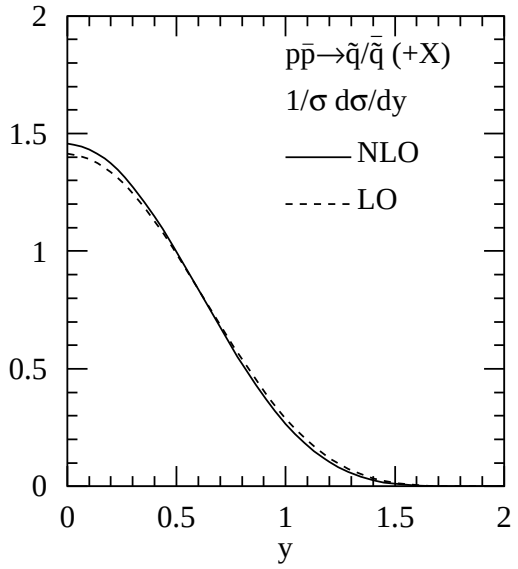
`http://people.web.psi.ch/spira/`

BACKUP SLIDES









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

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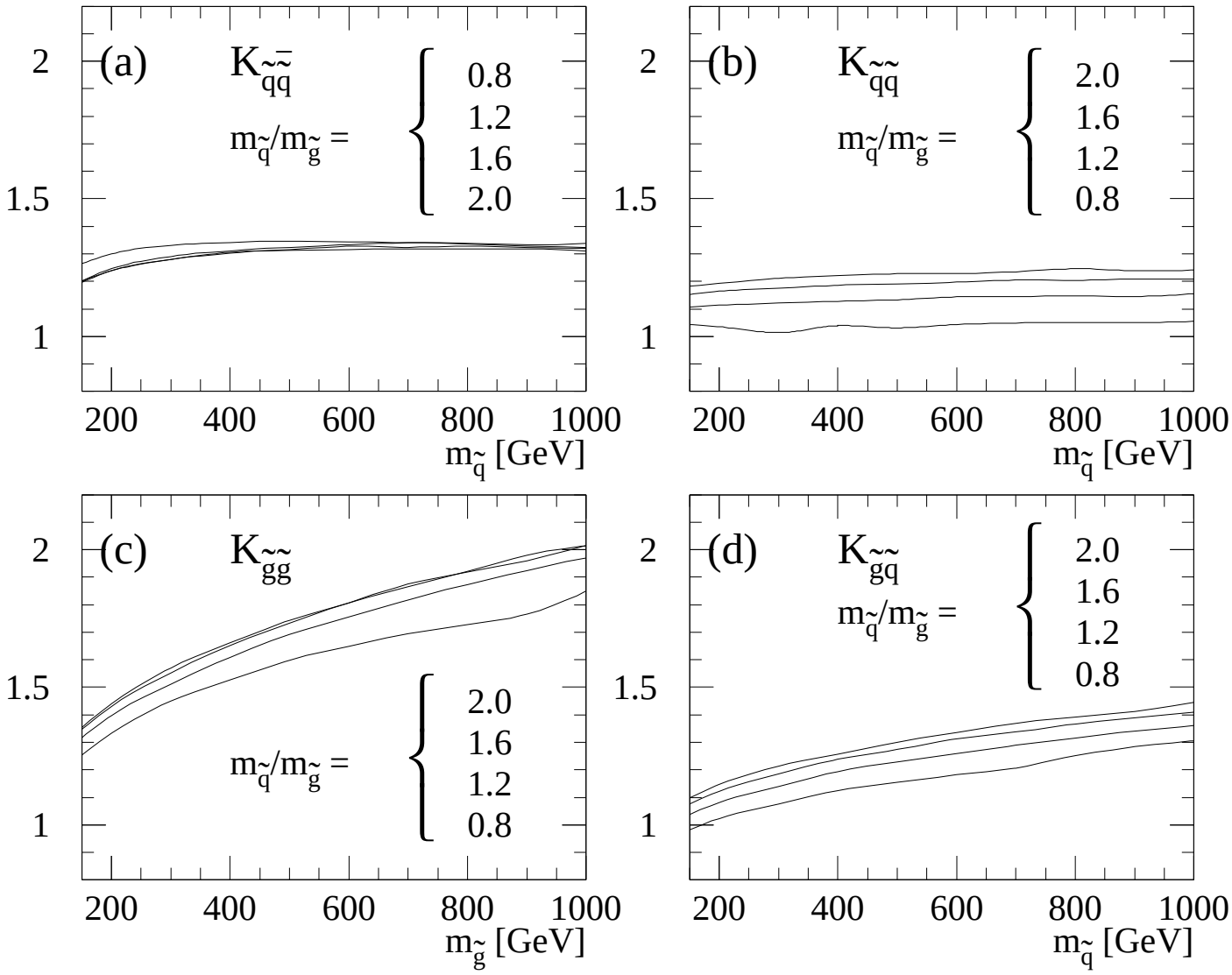

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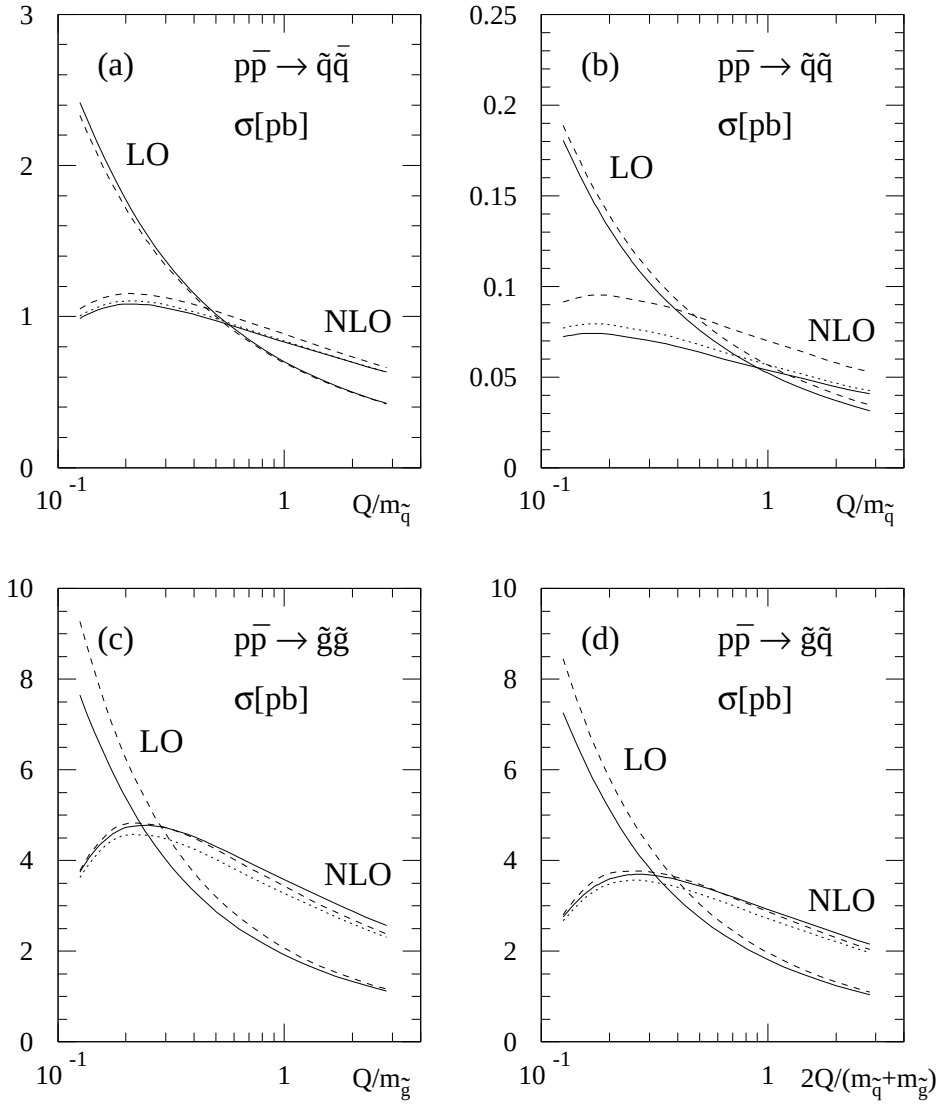

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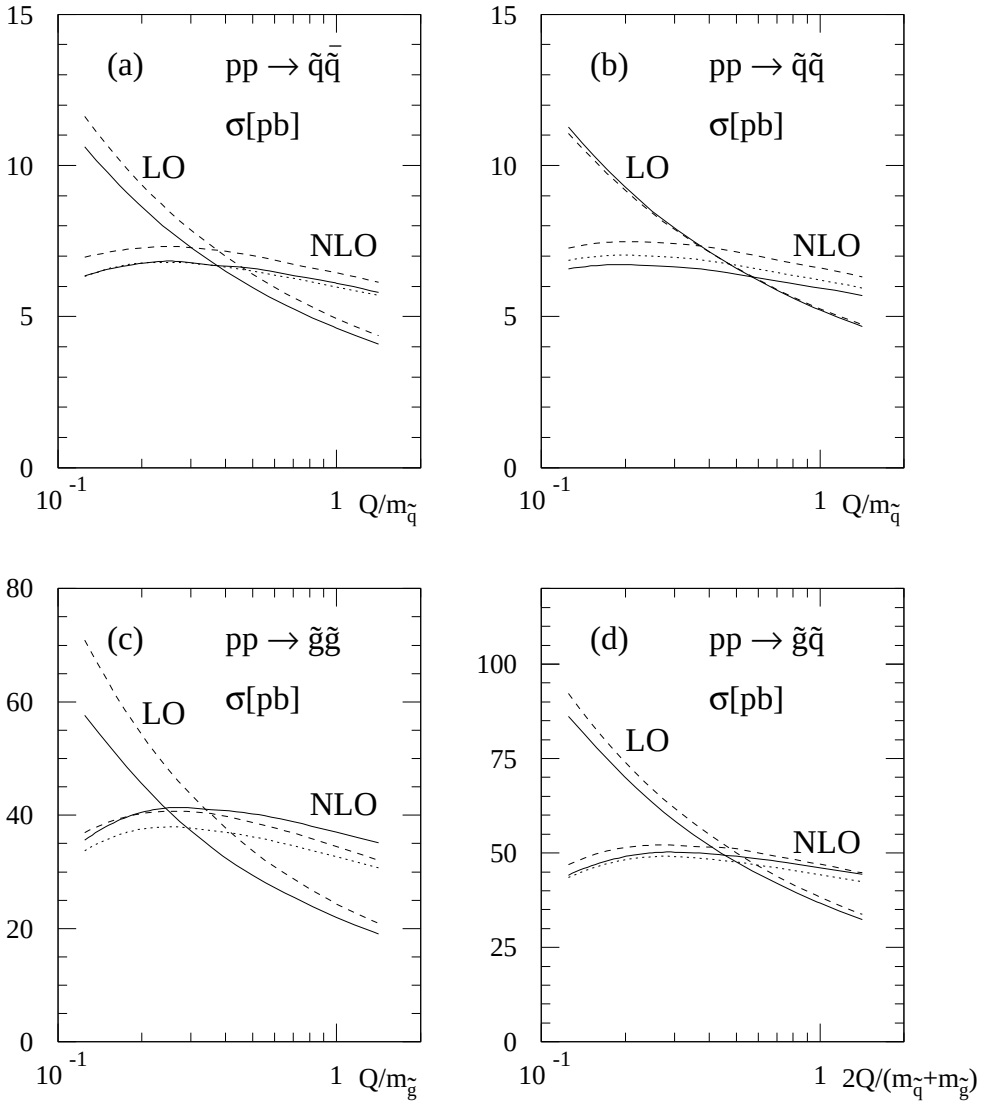

$m_{\tilde{q}} = 600$ GeV
$m_{\tilde{g}} = 500$ GeV

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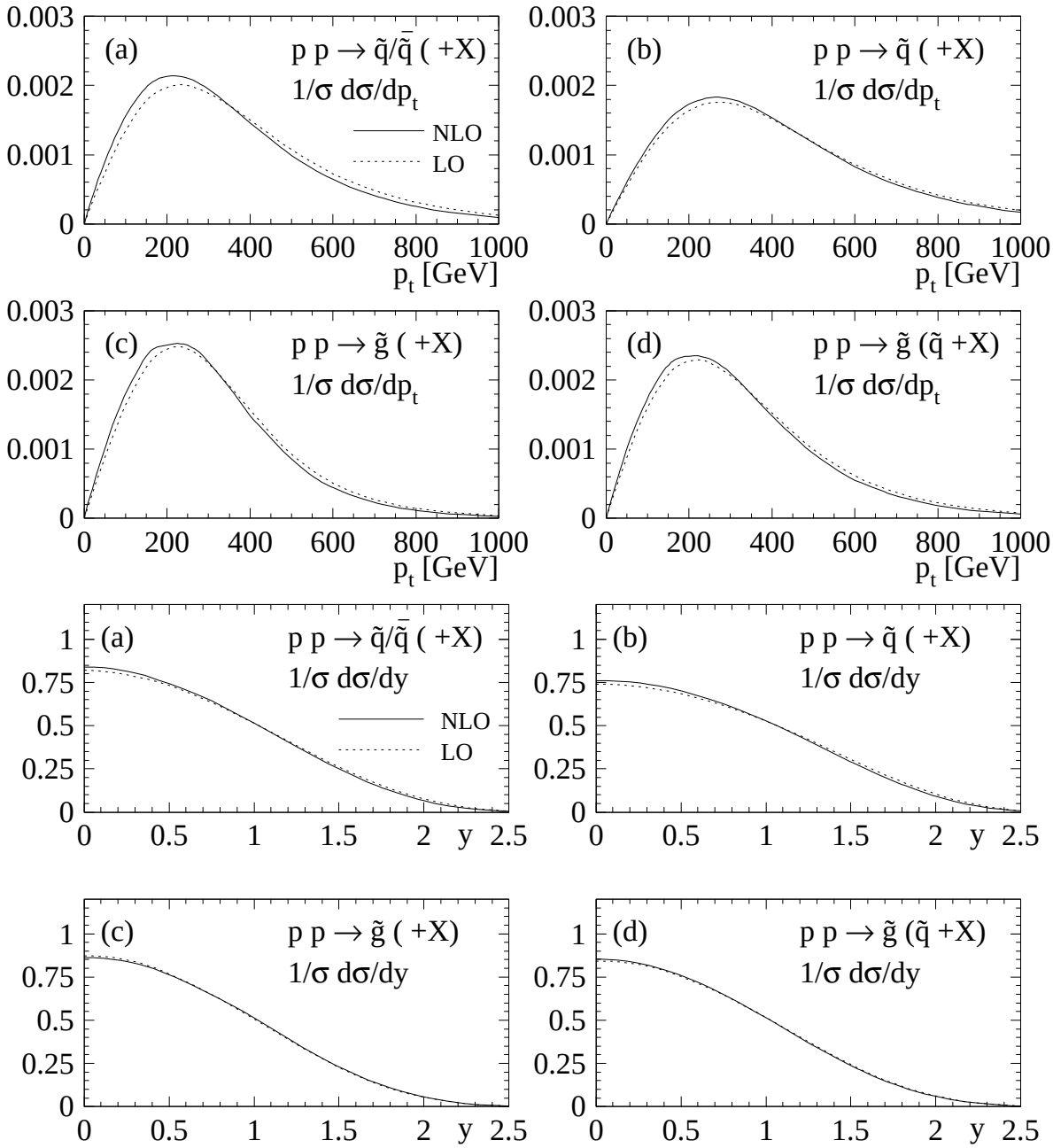

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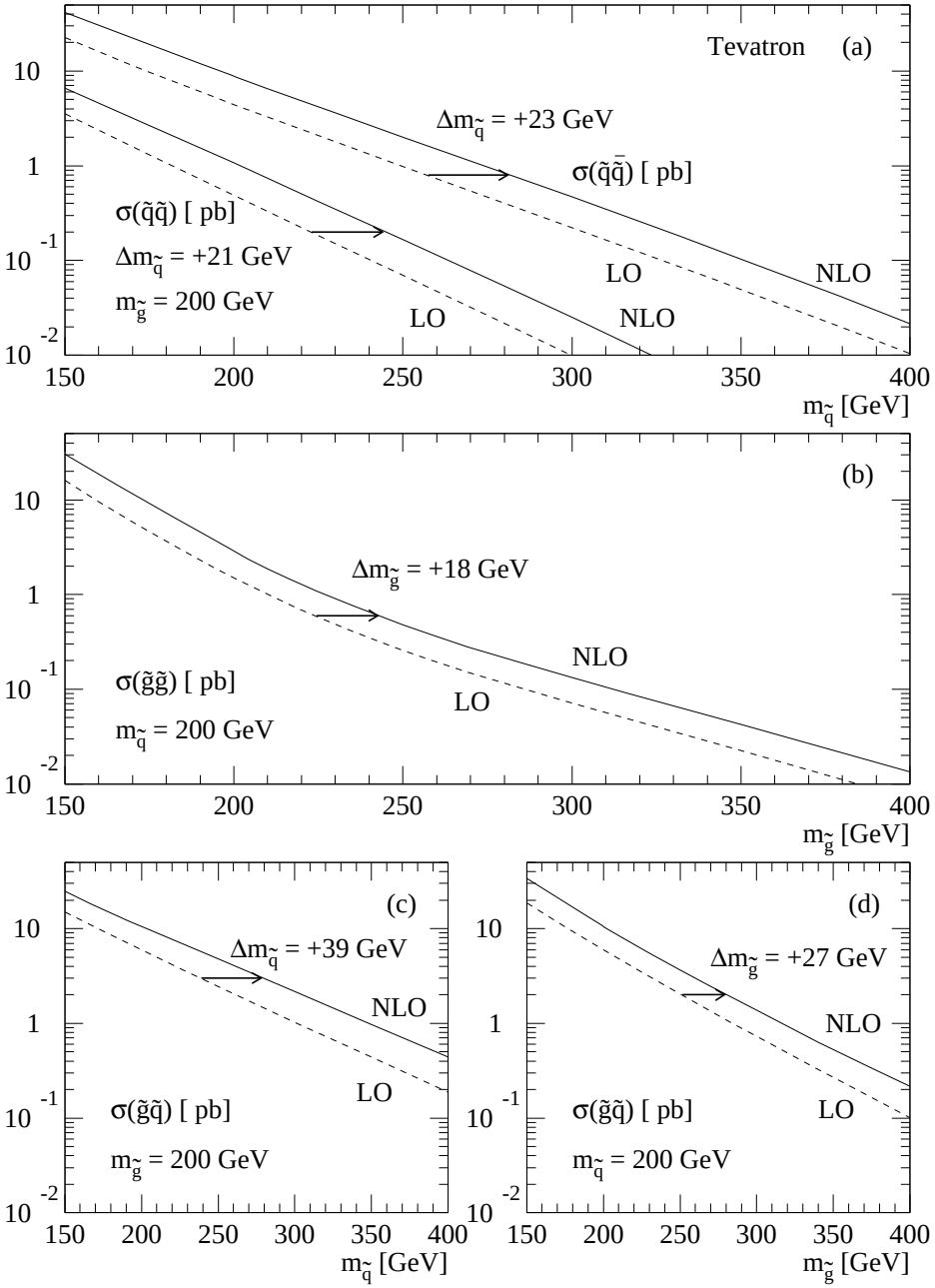

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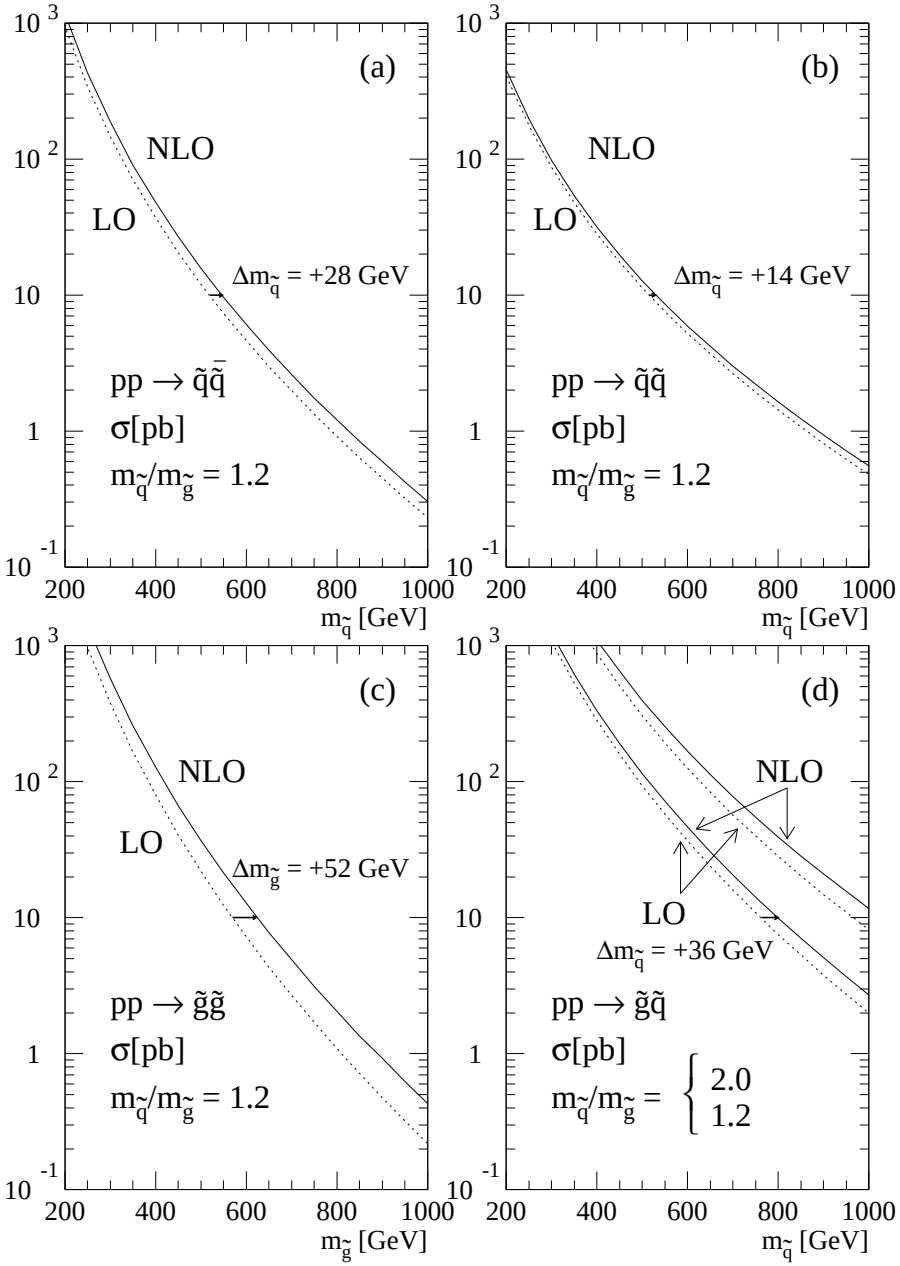

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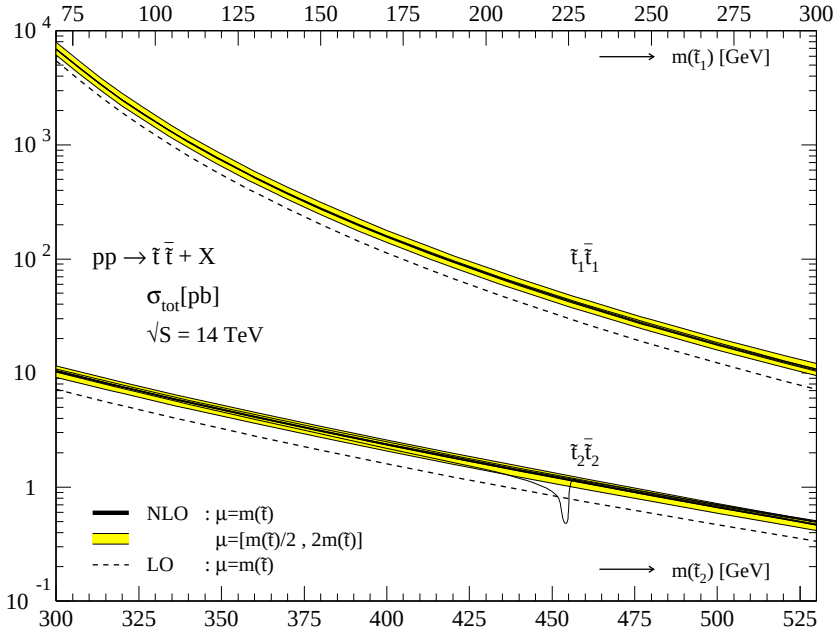

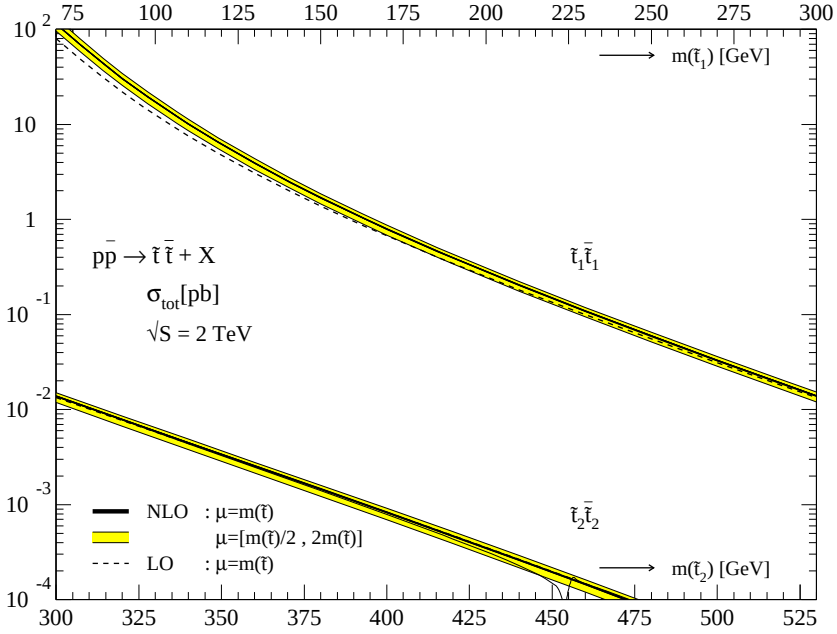

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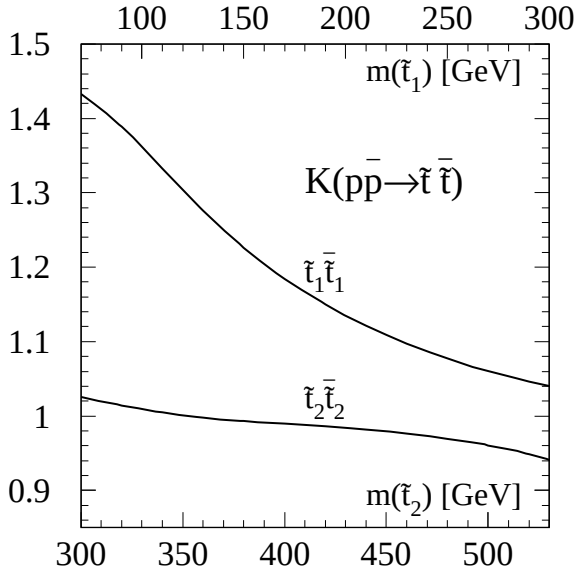

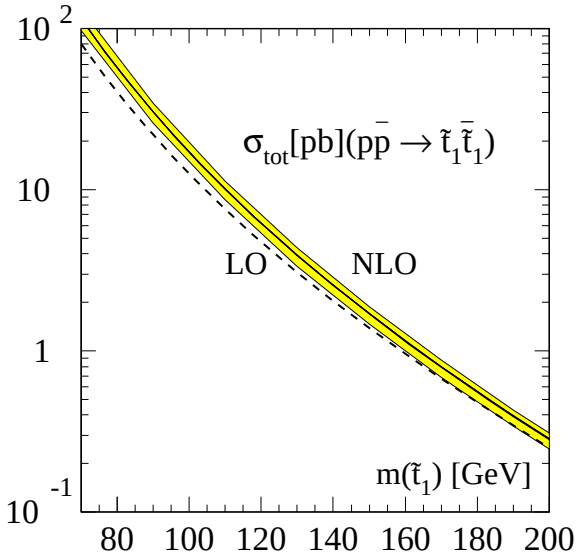

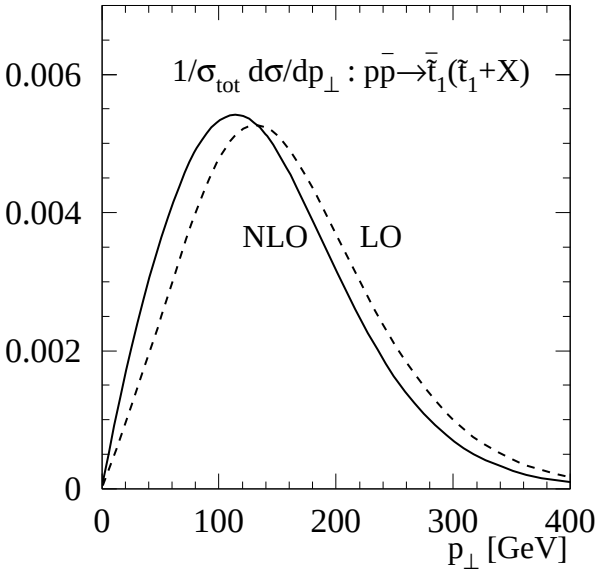

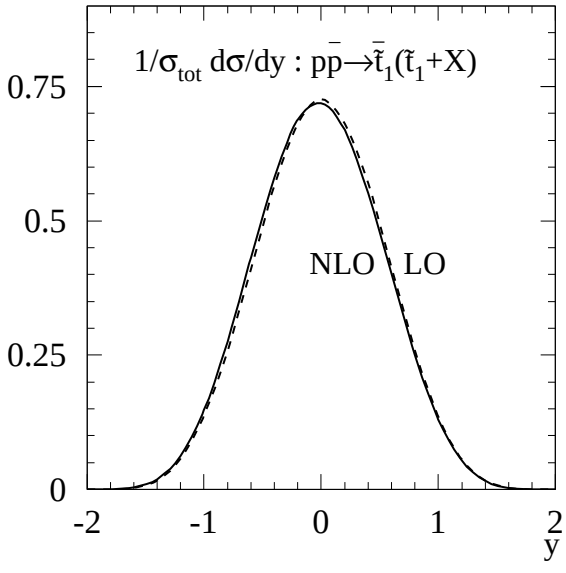

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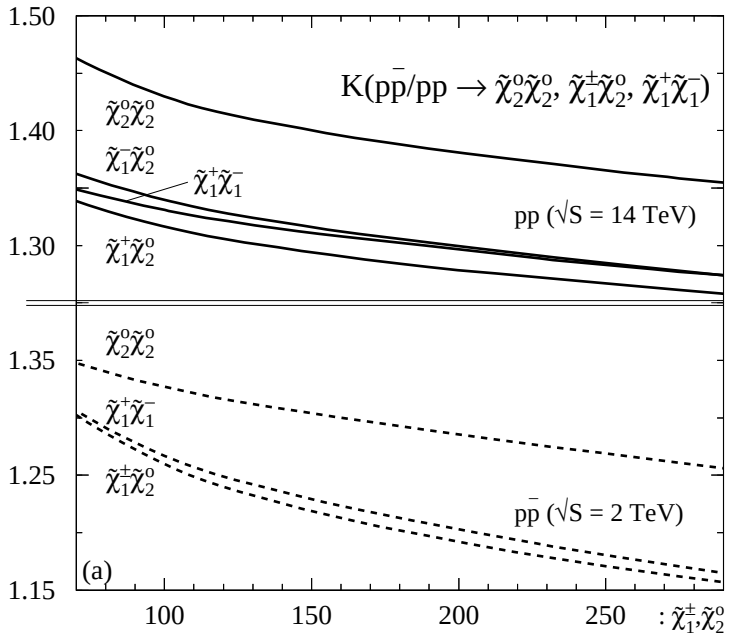

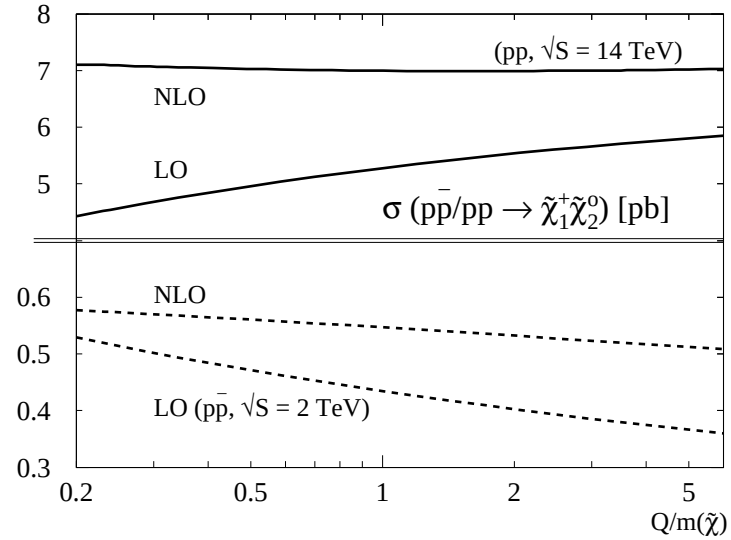

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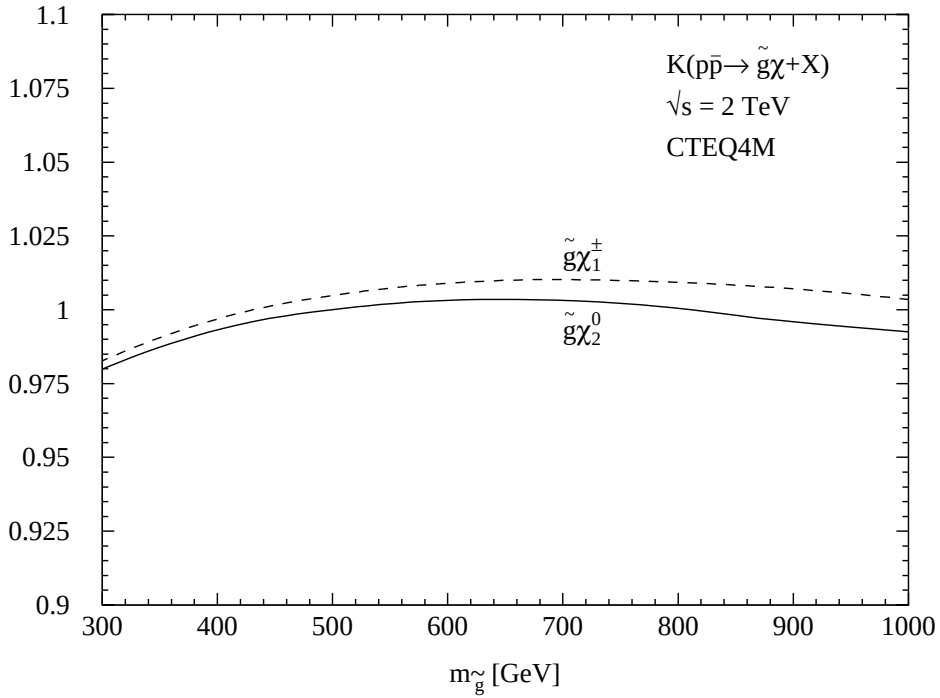

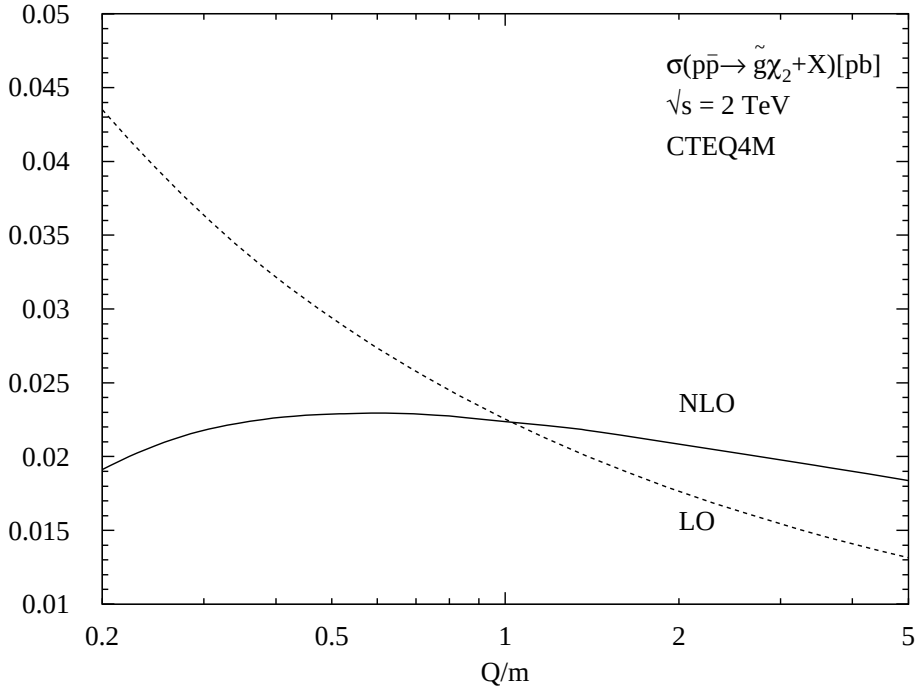

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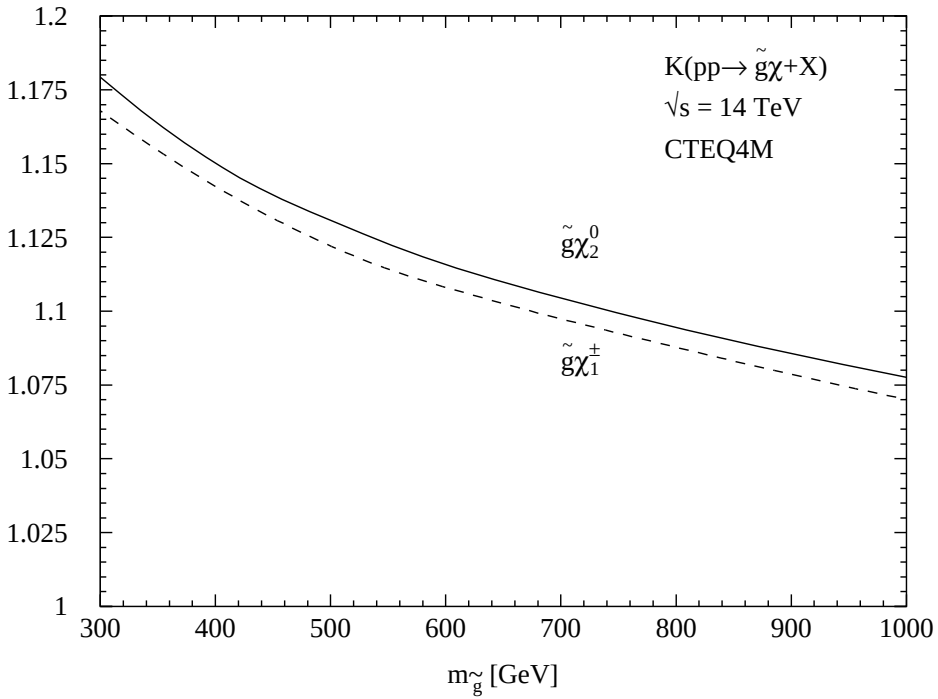

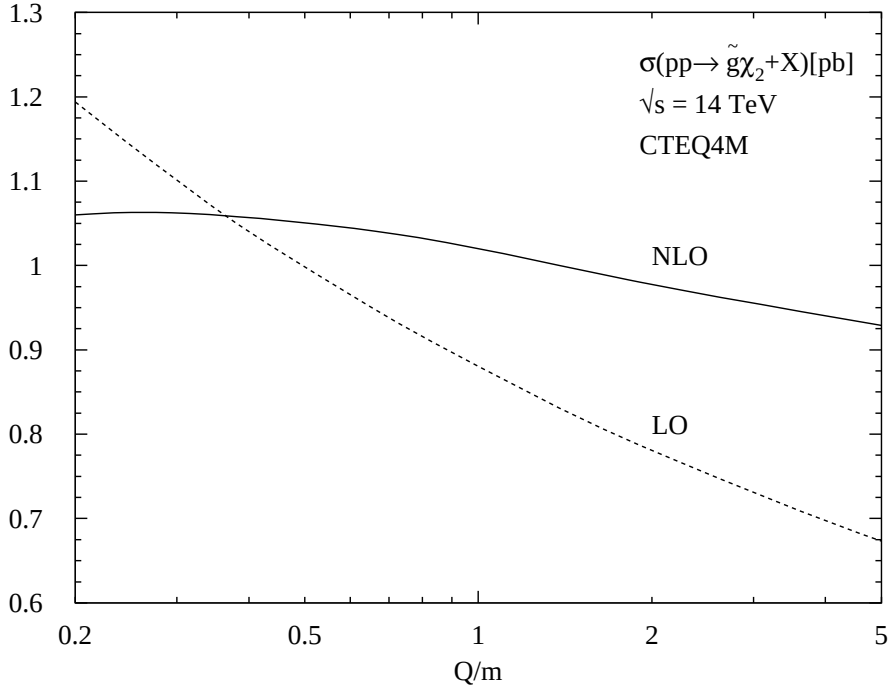

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