Gaugino pair production in polarized hadron collisions

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Outline

Ouline

Gauginos, Higgsinos

- Gauginos: $\widetilde{W}^{\pm}$, $\widetilde{W}^0$, $\widetilde{B}^0$
- Higgsinos: $\widetilde{H}_u^+$, $\widetilde{H}_u^0$, $\widetilde{H}_d^0$, $\widetilde{H}_d^-$

- EWSB $\rightarrow$ Mixings $\rightarrow$ Charginos et neutralinos

$$\begin{pmatrix} \widetilde{\chi}_1^- \\ \widetilde{\chi}_2^- \end{pmatrix} = U \begin{pmatrix} -i\widetilde{W}^- \\ \widetilde{H}_d^- \end{pmatrix} \quad \text{and} \quad \begin{pmatrix} \widetilde{\chi}_1^+ \\ \widetilde{\chi}_2^+ \end{pmatrix} = V \begin{pmatrix} -i\widetilde{W}^+ \\ \widetilde{H}_u^+ \end{pmatrix}$$

$$\begin{pmatrix} \widetilde{\chi}_1^0 \\ \widetilde{\chi}_2^0 \\ \widetilde{\chi}_3^0 \\ \widetilde{\chi}_4^0 \end{pmatrix} = N \begin{pmatrix} -i\widetilde{B}^0 \\ -i\widetilde{W}^0 \\ \widetilde{H}_u^0 \\ \widetilde{H}_d^0 \end{pmatrix}$$

Chargino sector (1)

- Masses (tree-level):

$$m^2_{\tilde{\chi}^+_{1,2}} = \frac{1}{2}\left\{|M_2|^2 + |\mu|^2 + 2m_W^2 \mp \sqrt{(|M_2|^2 + |\mu|^2 + 2m_W^2)^2 - 4|\mu M_2 - m_W^2 \; s_{2\beta}|^2}\right\}$$

- M_2: is the soft breaking mass parameter of $\widetilde{W}$s
- Scenario:
  - $m_{\tilde{\chi}^+_1} = 70\ GeV$ [Lower mass limit: Delphi Collab. (2003)]
  - $\tan\beta = 10$
  - $\mu > 0$

$$\Rightarrow \quad \mu = f(M_2)$$
$$m_{\tilde{\chi}^+_2} = g(M_2)$$

Chargino sector (2)

- Mixing matrices:

$$U = \mathcal{O}_- \quad \text{and} \quad V = \begin{cases} \mathcal{O}_+ \ \text{if} \ \det X \geq 0 \\ \sigma_3 \mathcal{O}_+ \ \text{if} \ \det X < 0 \end{cases} \text{with } \mathcal{O}_\pm = \begin{pmatrix} \cos\theta_\pm & \sin\theta_\pm \\ -\sin\theta_\pm & \cos\theta_\pm \end{pmatrix}$$

- Mixing angles:

$$\tan 2\theta_+ = \frac{2\sqrt{2}\ m_W \left(M_2\ s_\beta + \mu\ c_\beta\right)}{{M_2}^2 - \mu^2 + 2m_W^2\ c_{2\beta}} \qquad \tan 2\theta_- = \frac{2\sqrt{2}\ m_W \left(M_2\ c_\beta + \mu\ s_\beta\right)}{{M_2}^2 - \mu^2 - 2m_W^2\ c_{2\beta}}$$

$$\Rightarrow \quad \begin{aligned} U &= f(M_2) \\ V &= g(M_2) \end{aligned}$$

Neutralino sector

- Analytical formulae:
  [El Kheishen, Shafik, Aboshousha (1992)]
  [Barger, Berger, Ohmann (1993)]
- GUT constraint:

$$\boxed{M_1 = \frac{5}{3}\tan^2\theta_W \; M_2}$$

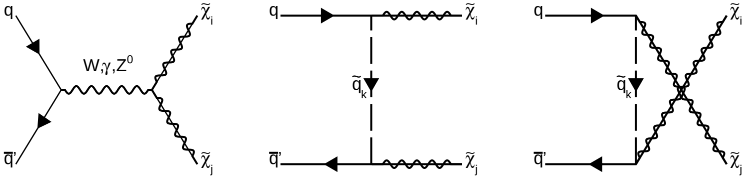
$$\Rightarrow \quad m_{\tilde{\chi}_i^0} = f_i(M_2)$$

$$N_{ij} = g_{ij}(M_2)$$

Outline

1. MSSM Gaugino-Higgsino sector
   - Brief recall
   - MSSM scenario
2. Analytical results
   - LO partonic cross section
   - QCD factorization theorem
3. Numerical results
   - Masses and mixings
   - RHIC
   - Tevatron
   - LHC
4. Summary

LO partonic cross section



- Unpolarized: $\hat{\sigma} = f(Mixings, m_{\tilde{\chi}_i}, m_{\tilde{q}}, \hat{s}, \hat{t}, \hat{u})$

  [Dawson, Eichten, Quigg (1985)]

- Polarized: $\hat{\sigma}_{h_q,h_{\bar{q}'}} = g(Mixings, m_{\tilde{\chi}_i}, m_{\tilde{q}}, \hat{s}, \hat{t}, \hat{u})$

QCD factorization theorem (1)

- Hadronic cross section:

$$\sigma = \sum_{a,b} \int_{\tau}^{1} \mathrm{d}x_a \int_{\tau/x_a}^{1} \mathrm{d}x_b \; f_{a/A}(x_a, \mu_F^2) \; f_{b/B}(x_b, \mu_F^2) \; \hat{\sigma}(\hat{s}, \hat{t}, \hat{u})$$

where:

- $f_{a/A}$ et $f_{b/B}$ are parton distribution fonctions
- $x_{a,b}$ are longitudinal momentum fractions
- μ_F is the factorization scale (unphysical)
- $\hat{\sigma} = \frac{\hat{\sigma}_{++} + \hat{\sigma}_{+-} + \hat{\sigma}_{-+} + \hat{\sigma}_{--}}{4}$

QCD factorization theorem (2)

- Hadronic single-spin asymmetry:

$$A_L = \frac{\Delta\sigma_L}{\sigma}$$

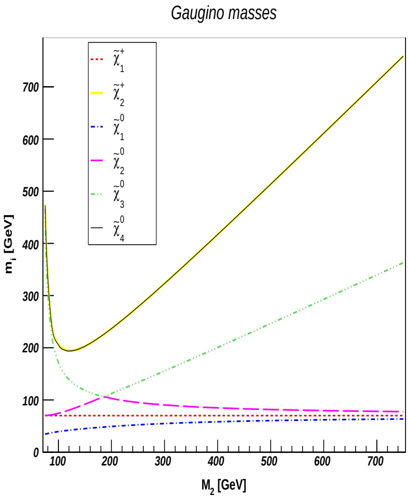
where:

$$\Delta\sigma_L = \sum_{a,b} \int_\tau^1 \mathrm{d}x_a \int_{\tau/x_a}^1 \mathrm{d}x_b \; \Delta f_{a/A}(x_a, \mu_F^2) \; f_{b/B}(x_b, \mu_F^2) \; \Delta\hat{\sigma}_L(\hat{s}, \hat{t}, \hat{u})$$

with: $$\Delta\hat{\sigma}_L = \begin{cases} \frac{\hat{\sigma}_{++}+\hat{\sigma}_{+-}-\hat{\sigma}_{-+}-\hat{\sigma}_{--}}{4} & \text{if } a \text{ is a quark} \\ \frac{\hat{\sigma}_{++}-\hat{\sigma}_{+-}+\hat{\sigma}_{-+}-\hat{\sigma}_{--}}{4} & \text{if } a \text{ is an antiquark} \end{cases}$$

Outline

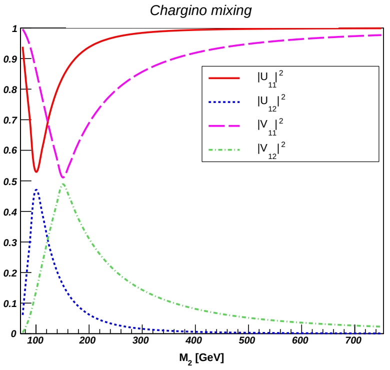
Gaugino masses

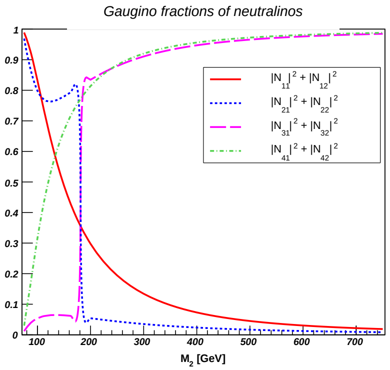


- $m_{\tilde{\chi}_1^+} = 70$ GeV
  $(\tilde{\chi}_1^\pm \to \tilde{\chi}_1^0\ l^\pm\ \nu)$
- $m_{\tilde{\chi}_2^0} \in [70, 105]$ GeV
  $(\tilde{\chi}_2^0 \to \tilde{\chi}_1^0\ l^+\ l^-)$
- Focus on:

$$\Rightarrow \quad \begin{array}{l} \tilde{\chi}_1^+\ \tilde{\chi}_1^- \\ \tilde{\chi}_1^+\ \tilde{\chi}_2^0 + h.c \\ \tilde{\chi}_2^0\ \tilde{\chi}_2^0 \end{array}$$

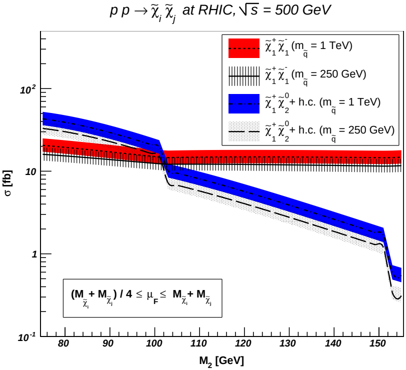
Gaugino-fractions

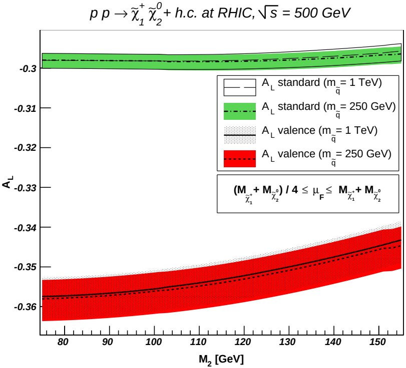




- $\tilde{\chi}_1^\pm$ are mostly gaugino-like
- $\tilde{\chi}_2^0$ is gaugino-like for $M_2 < 180$ GeV
- $\tilde{\chi}_2^0$ is Higgsino-like for $M_2 > 180$ GeV

RHIC

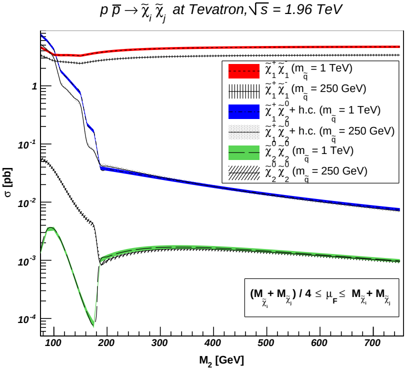


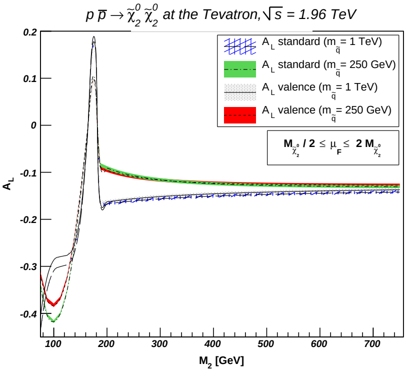


- $\sigma > 10$ fb (except for $\tilde{\chi}^0_2\ \tilde{\chi}^0_2$)
- Cross sections with $\tilde{\chi}^0_2$ are smaller than 1 fb when $M_2 > 180\ GeV$
- PDFs: GRV98 et GRSV2000

- $30\% \leq |A_L| \leq 35\%$
- $m_{\tilde{q}}$-dependence $\approx \mu_F$-dependence $\ll$ PDF-dependence

Tevatron

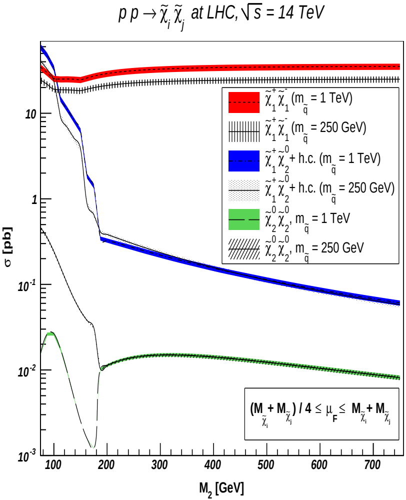




- $\sigma(Tevatron) \simeq 100 \times \sigma(RHIC)$
- t-,u-channels are very important for $\tilde{\chi}^0_2\ \tilde{\chi}^0_2$ when $\tilde{\chi}^0_2$ is gaugino-like
- $-0.4 \leq A_L \leq 0.2$

  $\Rightarrow$Most sensitive process: $\tilde{\chi}^0_2\ \tilde{\chi}^0_2$
- PDF-dependence $\approx \mu_F$-dependence $\ll m_{\tilde{q}}$-dependence

LHC



- $\sigma(LHC) \simeq 10 \times \sigma(Tevatron)$
- Asymmetries $< 10\%$ because of small x

Summary

Gaugino pair production in polarized hadron collisions

Scenario: LO calculations of total cross sections and asymmetries with:

- $m_{\tilde{\chi}_1^+} = 70$ GeV
- $\tan\beta = 10$
- $\mu > 0$
- $M_1 = \frac{5}{3}\tan^2\theta_W\ M_2$

RHIC: Little sensitivity

Tevatron: Accurate determination of M_2 with $A_L(\tilde{\chi}_2^0\,\tilde{\chi}_2^0)$ (but Tevatron is not polarized)

LHC: Small $x \Rightarrow$ Small asymmetries