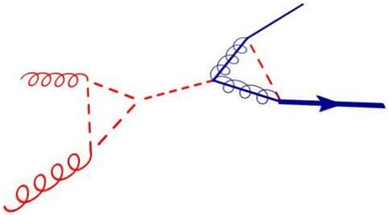
# Supersymmetric Single Top Production with a $U(1)_R$ Symmetry

Robert Knegjens



Supervisor: Prof. Dr. Eric Laenen

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# Supersymmetry (SUSY)

- An additional **symmetry of spacetime**:

$$Q|\text{Boson}\rangle = |\text{Fermion}\rangle \quad , \quad Q|\text{Fermion}\rangle = |\text{Boson}\rangle$$

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$$\hat{\Phi}(x,\theta) = \mathcal{S}(x) + \bar{\theta}\psi(x) + (\bar{\theta}\gamma_\mu\theta)V^\mu(x) + (\bar{\theta}\theta)\bar{\theta}\lambda(x) + \ldots$$

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- Irreducible representations of a SUSY transformation are

**Chiral superfields:** $\hat{\mathcal{S}} \equiv \{\mathcal{S}, \psi_L\}$

**Vector superfields:** $\hat{V} \equiv \{V^\mu, \lambda\} = \hat{V}^\dagger$

# Standard Model with Supersymmetry

- Keep $SU(3)_c \times SU(2)_L \times U(1)_Y$.
- Promote **gauge fields** to **vector superfields**

$$\text{e.g } B_\mu \to \hat{B} \ni (B_\mu, \lambda_0)$$

- Promote **fermion fields** and **Higgs fields** to **chiral superfields**

$$\text{e.g } \begin{pmatrix} \nu_L \\ e_L \end{pmatrix} \to \begin{pmatrix} \hat{\nu} \\ \hat{e} \end{pmatrix} \equiv \hat{L}_e \quad \text{where} \quad \hat{e} \ni (\tilde{e}_L, e_L) \text{ etc.}$$

# Standard Model with Supersymmetry

- Higgs potential must enter via superpotential $\hat{f}(\hat{\mathcal{S}})$

$$\hat{f}(\hat{\mathcal{S}}) \ni \mu \hat{H}_u \hat{H}_d + \mathbf{f}_u \epsilon \underbrace{\hat{Q}}_{\frac{1}{3}} \underbrace{\hat{H}_u}_{1} \underbrace{\hat{U}}_{-\frac{4}{3}} + \mathbf{f}_d \underbrace{\hat{Q}}_{\frac{1}{3}} \underbrace{\hat{H}_d}_{-1} \underbrace{\hat{D}}_{\frac{2}{3}} + \mathbf{f}_e \hat{L} \hat{H}_d \hat{E}$$

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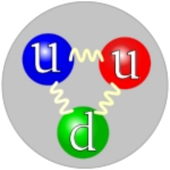
- SM + SUSY doesn't naturally conserve **Baryon/Lepton numbers**:

$$\hat{f}_{\Delta L=1} \ni \epsilon \hat{L} \hat{Q} \hat{D}^c + \epsilon \hat{L} \hat{L} \hat{E}^c + \epsilon \hat{L} \hat{H}_u$$
$$\hat{f}_{\Delta B=1} \ni \hat{U}^c \hat{U}^c \hat{D}^c$$

- Vulnerable to unobserved phenomena such as rapid proton decay

$$P \to \pi^0 + e^+$$

# R Symmetry



# A Continuous R Symmetry

- N=1 SUSY comes with a U(1) R symmetry

$$[Q, R] = i\gamma_5 Q$$

$$\hat{\mathcal{S}}^{(1)}(\hat{x}, \theta) = \mathcal{S}^{(1)} + i\sqrt{2}\bar{\theta}^{(1)}\psi_L^{(0)} + \dots$$

| Quantity | $U(1)_R$ |
|---|---|
| $\theta_{L/R}$ | $\pm 1$ |
| $\hat{\mathcal{S}}$ | $+1$ |
| $\hat{h}$ | 0 |
| $\hat{V}$ | 0 |

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- B and L violating terms forbidden:

$$\cancel{\epsilon \hat{L}^{(1)}\hat{Q}^{(1)}\hat{D}^{c(1)}} + \cancel{\epsilon \hat{L}^{(1)}\hat{L}^{(1)}\hat{E}^{c(1)}} + \cancel{\epsilon \hat{L}^{(1)}\hat{H}_u^{(0)}} \in \hat{f}^{(2)}_{\Delta L=1}$$

$$\cancel{\hat{U}^{c(1)}\hat{U}^{c(1)}\hat{D}^{c(1)}} \in \hat{f}^{(2)}_{\Delta B=1}$$

# A Continuous R Symmetry

- $U(1)_R$ symmetry also restricts the soft breaking terms:

$$\mathcal{L}_{\text{soft}}^{(0)} = \left[\tilde{Q}_i^{\dagger(-1)} \mathbf{m}^2_{Qij} \tilde{Q}_j^{(1)} + \ldots + m^2_{H_u} |H_u|^{2(0)} + \ldots\right] - \frac{1}{2}\left[M_1 \bar{\lambda}_0^{(1)} \lambda_0^{(1)} + \ldots\right] + \left[(\mathbf{a_u})_{ij} \epsilon \tilde{Q}_i^{(1)} H_u^{(0)} \tilde{u}_{Rj}^{\dagger(1)} + \ldots\right] + \left[(\mathbf{c_u})_{ij} \epsilon \tilde{Q}_i^{(1)} H_d^{*(0)} \tilde{u}_{Rj}^{\dagger(1)} + \ldots\right] + \left[b H_u^{(0)} H_d^{(0)} + \text{ h.c}\right]$$

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$$- \frac{1}{2} \left[ \cancel{M_1 \bar{\lambda}_0^{(1)} \lambda_0^{(1)}} + \ldots \right] + \left[ \cancel{(\mathbf{a_u})_{ij} \epsilon \tilde{Q}_i^{(1)} H_u^{(0)} \tilde{u}^{\dagger}_{Rj}{}^{(1)}} + \ldots \right]$$
$$+ \left[ \cancel{(\mathbf{c_u})_{ij} \epsilon \tilde{Q}_i^{(1)} H_d^{*(0)} \tilde{u}^{\dagger}_{Rj}{}^{(1)}} + \ldots \right] + \left[ b H_u^{(0)} H_d^{(0)} + \text{ h.c} \right]$$

- Problem: massless gauginos...
- MSSM instead introduces a $\mathbb{Z}_2$ symmetry: R parity

# The MRSSM

- **Solution:** The Minimal R-symmetric Supersymmetric Standard Model [Kribs, Poppitz and Weiner, Phys. Rev. D78 (2008) 055010]

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- Add chiral superfields with adjoint gauge representation

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- The two Majorana spinors combine to give a **Dirac spinor** that can have a Dirac mass:

$$\tilde{g}_A \equiv \psi_{LA} + \lambda_{RA}$$

# Squark Flavour Mixing

$$\tilde{q}_i^\dagger \mathbf{m}_{ij}^2 \tilde{q}_j \in \mathcal{L}_{\text{soft}} \quad \Rightarrow \quad \tilde{q}_a = \sum_i \left( U_{\tilde{q}}^\dagger \right)_{ai} \tilde{q}_i$$

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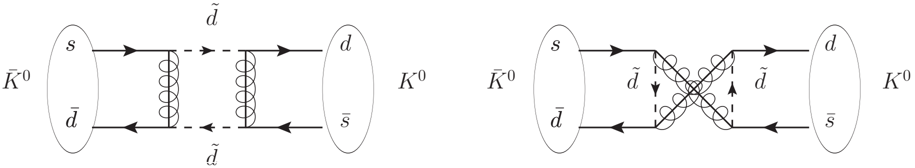

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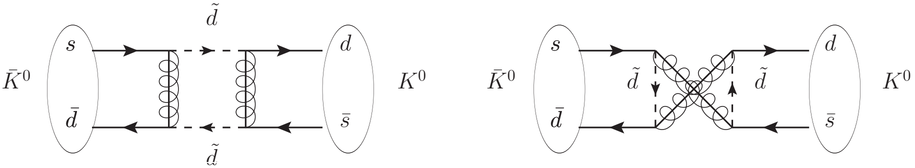

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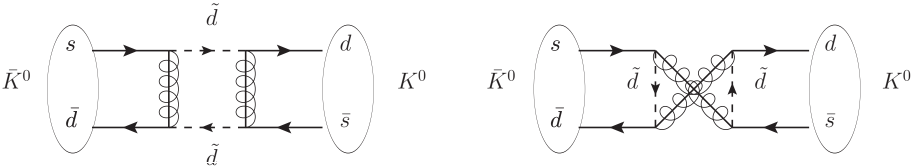


- In MRSSM dominant mixing diagram forbidden. Further suppression when $m_{\tilde{g}} > m_{\tilde{q}}$

# Scalar Gluons (sgluons)

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- In MRSSM QCD we have a colour octet complex scalar field:

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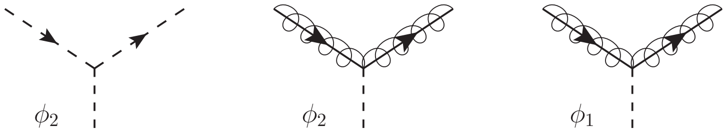
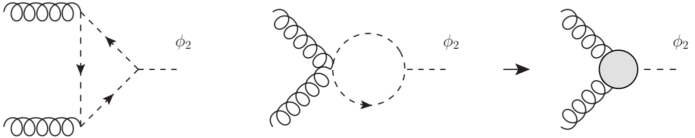
- At tree level, sgluons couple to squarks and gluinos



# Effective One-Loop Vertices

- Gluons-sgluon coupling



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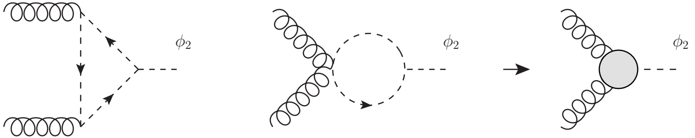
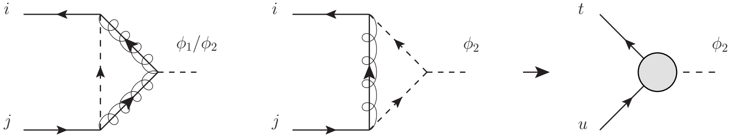
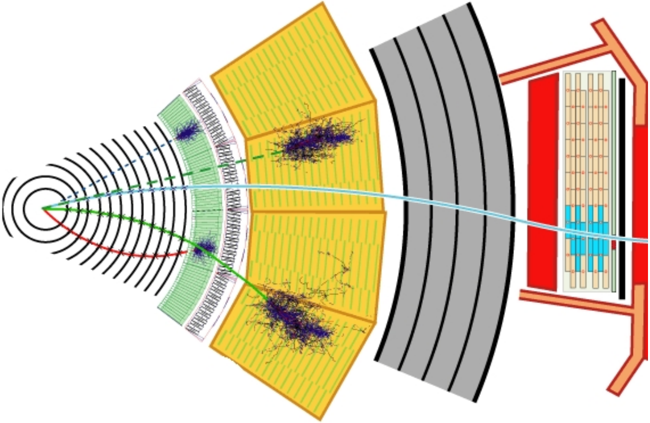



- Quark-sgluon coupling



# Phenomenology



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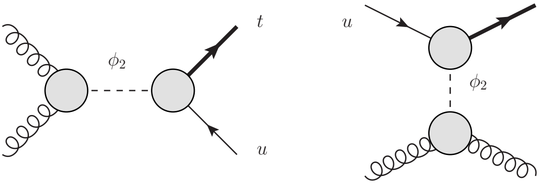

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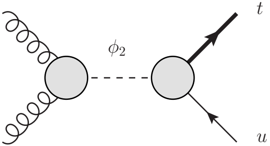
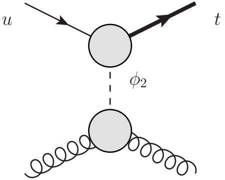
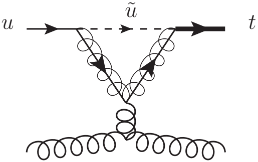
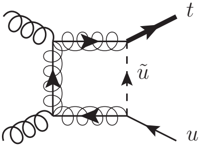
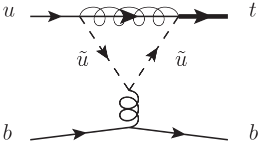



- Non-sgluon mediated: 60 diagrams (FeynArts/FormCalc)



# MRSSM Parameter Space

- Assume two mixed squark flavours for simplicity

$$U_{\tilde{u}L} = \begin{pmatrix} \cos\theta_L & 0 & \sin\theta_L \\ 0 & 1 & 0 \\ -\sin\theta_L & 0 & \cos\theta_L \end{pmatrix}$$

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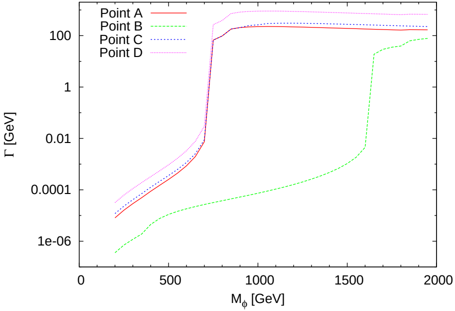
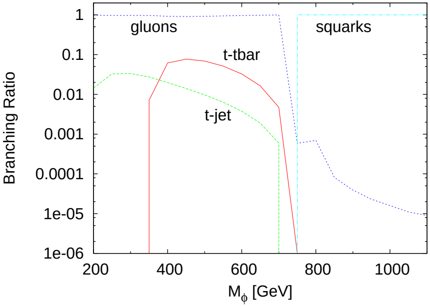
- Pick six points in parameter space:

| Benchmark | $m_{\tilde{g}}$ | $m_{\tilde{u}L} = m_{\tilde{d}L}$ | $m_{\tilde{q}R}/m_{\tilde{q}L}$ | $\theta_L = \theta_R$ |
|---|---|---|---|---|
| Point A | 1000 | {400, 400, 1000} | 0.9 | $\pi/4$ |
| Point B | 1000 | {900, 900, 1500} | 0.9 | $\pi/4$ |
| Point C | 1000 | {400, 400, 500} | 0.9 | $\pi/4$ |
| Point D | 2000 | {400, 400, 1000} | 0.9 | $\pi/4$ |
| Point E | 500 | {400, 400, 1000} | 0.9 | $\pi/4$ |
| Point F | 1000 | {400, 400, 1000} | 0.9 | $\pi/3$ |

# Sgluon Mediated Single Top

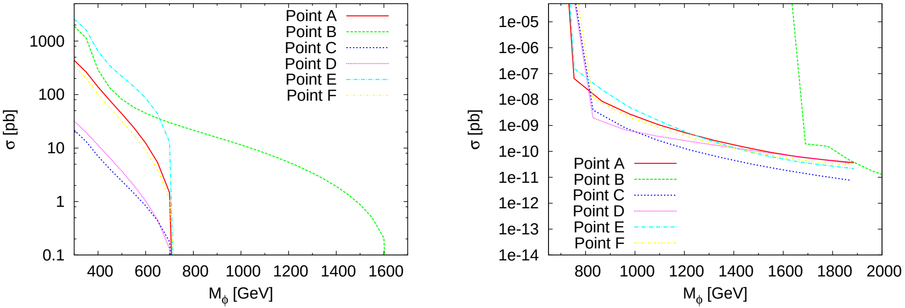
- Sgluon has very narrow decay width when squark/gluino decays kinematically forbidden



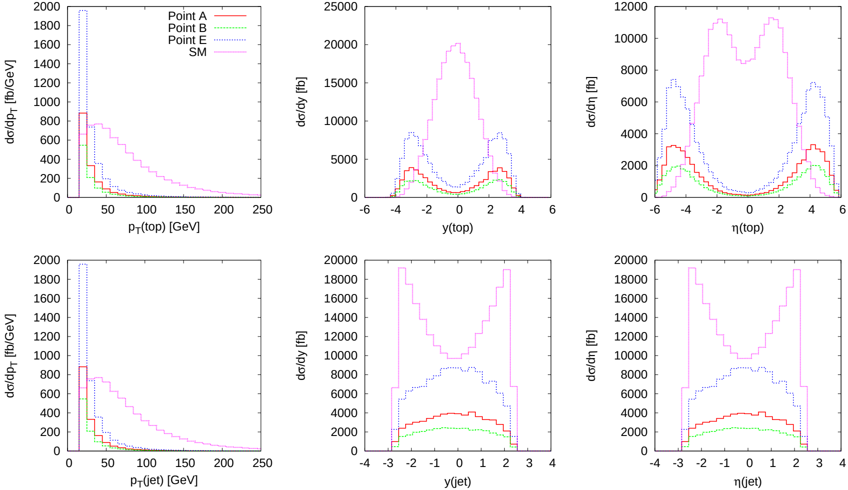
# Sgluon Mediated Single Top

- Cross section of s-channel sgluon mediated single top production:



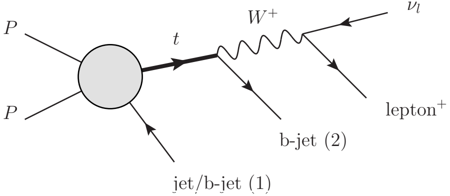
# Non-sgluon Mediated Single Top

- $t +$ jet: top quark is very forward



# Signals at the LHC

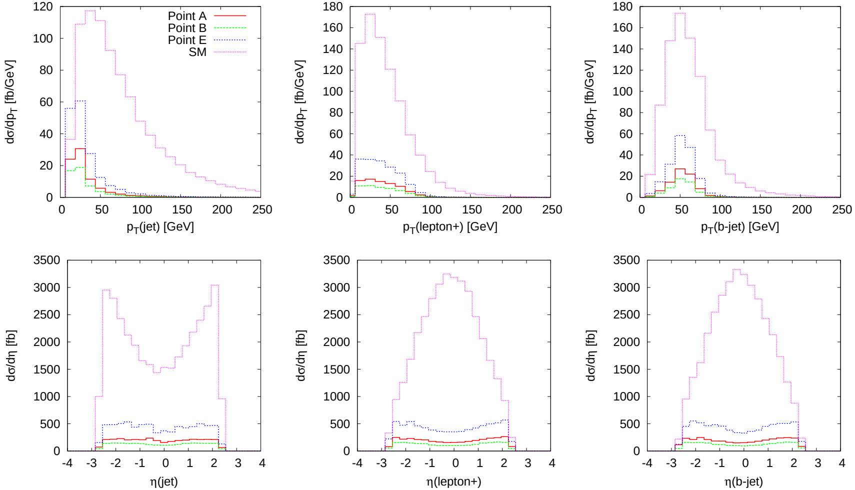
- Consider signal of non-sgluon mediated single top at the LHC




- Take as background **irreducible** Standard Model processes

# Signals at the LHC

- $b$-jet + jet + $l^+$ + $\not{E}_T$



# Signals at the LHC

- $b$-jet + jet + $l^+$ + $\not{E}_T$: luminosity of 10 fb$^{-1}$

| | | No Cuts† | With Cuts |
|---|---|---|---|
| **Point A** | S/B | 0.09 | 0.23 |
| | $S/\sqrt{B}$ | 22.2 | 28.3 |
| **Point B** | S/B | 0.06 | 0.15 |
| | $S/\sqrt{B}$ | 14.2 | 18.3 |
| Point C | S/B | 0.00 | 0.01 |
| | $S/\sqrt{B}$ | | |
| Point D | S/B | 0.03 | 0.07 |
| | $S/\sqrt{B}$ | 6.6 | 8.6 |
| **Point E** | S/B | 0.20 | 0.49 |
| | $S/\sqrt{B}$ | 48.6 | 61.5 |
| **Point F** | S/B | 0.07 | 0.17 |
| | $S/\sqrt{B}$ | 16.9 | 21.8 |

# Outlook

- Check parameter points w.r.t meson mixing: $\mathbf{m_{\tilde{g}}} > \mathbf{m_{\tilde{q}}}$
- Add reducible backgrounds
- Add hadronization effects

# Additional Spacetime Symmetries?

## NO-GO Theorem: Coleman and Mandula (1967)

The most general **Lie algebra** for symmetries of an S-matrix can have **only Poincare group generators** along with Lorentz **scalar generators** of a compact Lie group.

- Bypass theorem by going to **graded (super)** Lie algebras

$$\{Q, Q'\} = X, \quad [X, X'] = X'', \quad [Q, X] = Q'$$

$X$: original commuting Poincaré generators $(P_\mu, M_{\mu\nu})$
$Q$: new anti-commuting generators

- **Super-Poincaré algebra** (N=1), Q Majorana fermions:

$$\boxed{\{Q, \bar{Q}\} = 2\gamma^\mu P_\mu}, \quad [M_{\mu\nu}, Q] = -\tfrac{1}{2}\sigma_{\mu\nu} Q, \quad [P_\mu, Q] = 0$$

# Superfields

- Define a generic **superfield** using an expansion in anti-commuting coordinates $\theta_a$

$$\{\theta_a, \theta_b\} = 0 \quad , \quad \{\theta_a, \psi_b\} = 0$$

$$\hat{\Phi}(x,\theta) = \mathcal{S}(x) + \bar{\theta}\psi(x) + (\bar{\theta}\gamma_\mu\theta)V^\mu(x) + (\bar{\theta}\theta)\bar{\theta}\lambda(x) + \ldots \{\mathcal{F}, \mathcal{D}\}$$

- SUSY transformation: $\hat{\Phi}'(x,\theta) = e^{i\bar{\alpha}Q}\,\hat{\Phi}\,(x,\theta)e^{-i\bar{\alpha}Q}$

$$\begin{aligned} \delta\mathcal{S} &= -i\sqrt{2}\bar{\alpha}\psi_L \\ \delta\psi_L &= -\sqrt{2}\mathcal{F}\alpha_L + \sqrt{2}\not{\partial}\mathcal{S}\alpha_R \\ \delta\mathcal{F} &= i\sqrt{2}\bar{\alpha}\partial_\mu(\gamma^\mu\psi_L) \\ \delta(\ldots) & \ldots \ldots \end{aligned}$$

- Irreducible representations are **chiral superfield** $\hat{S} \equiv \{\mathcal{S}, \psi_L, \mathcal{F}\}$ and **vector superfield** $\hat{V} \equiv \{V^\mu, \lambda, \mathcal{D}\} = \hat{V}^\dagger$

# Building a SUSY Lagrangian

- Build from combination of superfields

$$\hat{\Phi}\hat{\Phi}' = \hat{\Phi}'', \quad \hat{\mathcal{S}}\hat{\mathcal{S}}' = \hat{\mathcal{S}}'', \quad \hat{\mathcal{S}}^\dagger \hat{\mathcal{S}} = \hat{\Phi}$$

- Action must be SUSY invariant

$$\delta S = \int d^4x \; \delta\mathcal{L} = 0 \quad \Rightarrow \quad \boxed{\begin{cases} \delta\mathcal{L} = 0 \\ \delta\mathcal{L} = \partial_\mu(\dots) \end{cases}}$$

- $\delta\hat{\mathcal{S}} \neq 0$ but $\delta\mathcal{F} = \not{\partial}(\dots)$

$$\text{Superpotential} \;:\quad \hat{f}(\hat{\mathcal{S}}) \rightarrow \hat{f}(\hat{\mathcal{S}})\Big|_{\mathcal{F}\text{-term}} \in \mathcal{L}$$

- Similarly, $\delta\hat{\Phi} \neq 0$ but $\delta\mathcal{D} = \partial_\mu(\dots) \quad \Rightarrow \quad K(\hat{\Phi})\Big|_{\mathcal{D}\text{-term}} \in \mathcal{L}$

# A Master SUSY Lagrangian

$$\mathcal{L} = \sum_i (D_\mu \mathcal{S}_i)^\dagger (D^\mu \mathcal{S}_i) + \frac{i}{2} \sum_i \bar{\psi}_i \not{D} \psi_i + \sum_\alpha \left[ \frac{i}{2} \bar{\lambda}_\alpha (\not{D} \lambda)_\alpha - \frac{1}{4} F_{\mu\nu\alpha} F^{\mu\nu}_\alpha \right]$$
$$- \sqrt{2} \sum_{i,\alpha} \left( \mathcal{S}_i^\dagger g_\alpha t_\alpha \bar{\lambda}_\alpha \psi_{L\,i} + \text{h.c.} \right)$$
$$- \frac{1}{2} \sum_\alpha \left[ \sum_i \mathcal{S}_i^\dagger g_\alpha t_\alpha \mathcal{S}_i + \xi_\alpha \right]^2 - \sum_i \left| \frac{\partial \hat{f}(\hat{\mathcal{S}})}{\partial \hat{\mathcal{S}}_i} \right|^2_{\hat{\mathcal{S}} = \mathcal{S}}$$
$$- \frac{1}{2} \sum_{i,j} \bar{\psi}_i \left[ \left( \frac{\partial^2 \hat{f}(\hat{\mathcal{S}})}{\partial \hat{\mathcal{S}}_i \partial \hat{\mathcal{S}}_j} \right)_{\hat{\mathcal{S}} = \mathcal{S}} P_L + \left( \frac{\partial^2 \hat{f}(\hat{\mathcal{S}})}{\partial \hat{\mathcal{S}}_i \partial \hat{\mathcal{S}}_j} \right)^\dagger_{\hat{\mathcal{S}} = \mathcal{S}} P_R \right] \psi_j$$

# MSSM Particles

| SM Particles | | Superpartners | |
|---|---|---|---|
| Fermions | | Scalar Fermions | |
| Quarks: | $u$, $c$, $t$, $d$, $s$, $b$ | Squarks: | $\tilde{u}$, $\tilde{c}$, $\tilde{t}$, $\tilde{d}$, $\tilde{s}$, $\tilde{b}$ |
| Leptons: | $e$, $\mu$, $\tau$, $\nu_e$, $\nu_\mu$, $\nu_\tau$ | Sleptons: | $\tilde{e}$, $\tilde{\mu}$, $\tilde{\tau}$, $\tilde{\nu_e}$, $\tilde{\nu_\mu}$, $\tilde{\nu_\tau}$ |
| Gauge Bosons | | Gauginos | |
| Photon: | $A_\mu$ | Photino: | $\sin\theta_w \lambda_3 + \cos\theta_w \lambda_0$ |
| W,Z Bosons: | ${W^\pm}_\mu$ | W-ino: | $\frac{1}{\sqrt{2}}(\lambda_1 \mp i\lambda_2)$ |
| | $Z_\mu$ | Z-ino | $-\cos\theta_w \lambda_3 + \sin\theta_w \lambda_0$ |
| Gluon: | $G_\mu$ | Gluino: | $\tilde{g}$ |
| Higgs Bosons | | Higgsinos | |
| $h_u^+$ $h_u^0$ $(h_d^-$ $h_d^0)$ | | $\tilde{h}_u^+$ $\tilde{h}_u^0$ $\tilde{h}_d^-$ $\tilde{h}_d^0$ | |

# Breaking of the MSSM

- $[Q, P_\mu] = 0 \Rightarrow$ SUSY states have **equal mass**

$$Q(P^2\psi) = Q(m_\psi^2\psi) \quad \Rightarrow \quad P^2(Q\psi) = m_\psi^2(Q\psi)$$

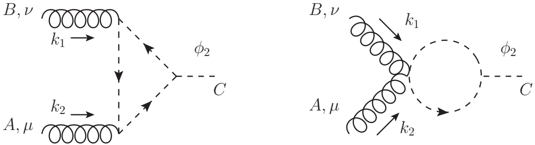
$$\Rightarrow \text{SUSY must be broken!}$$

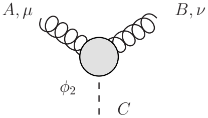
- **Soft breaking** protects scalar masses

$$\begin{aligned}\mathcal{L}_{\text{soft}} = &\left[\tilde{L}_i^\dagger \mathbf{m}_{Lij}^2 \tilde{L}_j + \ldots + m_{H_u}^2 |H_u|^2 + \ldots\right] \\ &- \frac{1}{2}\left[M_1 \bar{\lambda}_0 \lambda_0 + \ldots\right] + \left[(\mathbf{a_e})_{ij}\epsilon_{ab}\tilde{L}_i H_d \tilde{e}_{Rj}^\dagger + \ldots\right] \\ &+ \left[(\mathbf{c_e})_{ij}\epsilon_{ab}\tilde{L}_i H_d^* \tilde{e}_{Rj}^\dagger + \ldots\right] + [bH_u H_d + h.c]\end{aligned}$$

- MSSM with all soft breaking terms: **178 parameters!!**

# Gluons-Sgluon One Loop Coupling



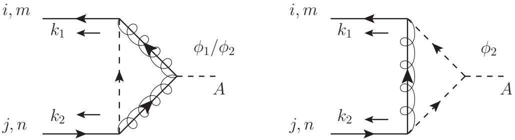

Effective vertex: 

$= \quad \mathcal{M}^{\mu\nu}_{ABC}$

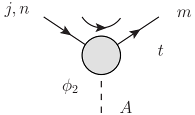
$$\mathcal{M}^{\mu\nu}_{ABC} = \quad 2\, m_{\tilde{g}}\, g_S^3\, d_{ABC} \left[ g^{\mu\nu} - \frac{2 k_1^\mu k_2^\nu}{(k_1 + k_2)^2} \right]$$

$$\times \left\{ \sum_{\tilde{q}} m^2_{\tilde{q}L} C_0(k_1, k_2; m_{\tilde{q}L}, m_{\tilde{q}L}, m_{\tilde{q}L}) - (L \leftrightarrow R) \right\}$$

# Quarks-Sgluon One Loop Coupling




Effective vertex:




$= \mathcal{M}_t^{\phi_2}$

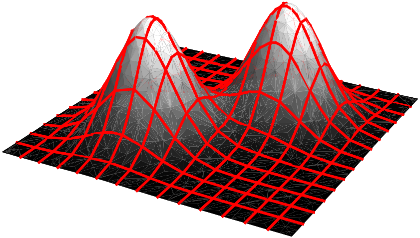
$$\mathcal{M}_t^{\phi_2} = \frac{i g_S^3}{8\pi^2} \frac{m_{\tilde{g}} m_t}{s - m_t^2} (t_A)_{mn} \Bigg\{ \bar{u}_{3m}(k_1) P_L v_{jn}(k_2) \times \left( \sum_{\tilde{q}a} (U_{\tilde{q}L})_{3a} (U^\dagger_{\tilde{q}L})_{aj} f_t(s; m_{\tilde{q}aL}) \right) + (L \leftrightarrow R) \Bigg\}$$

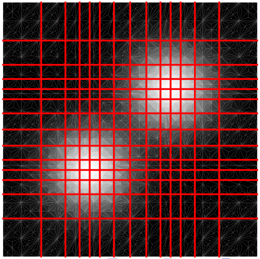
# Monte Carlo integration

- Convergence of Monte Carlo integration independent of dimension:

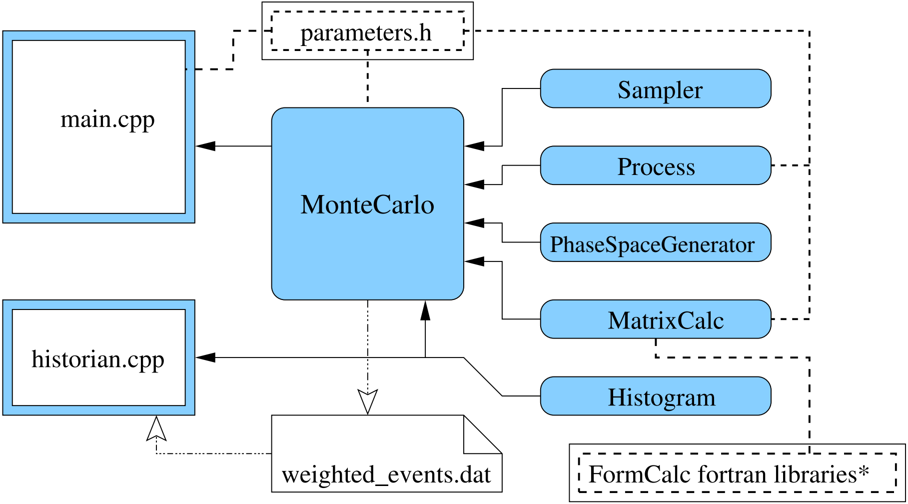
$$E - I \propto \frac{1}{\sqrt{N}}$$

- The adaptive **VEGAS algorithm**:
  - Splits domain into a grid. Each subspace has uniform probability density
  - Shifts grid lines towards regions of higher variance after each iteration





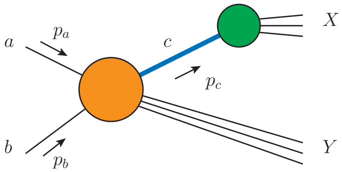
# Our Monte Carlo Program



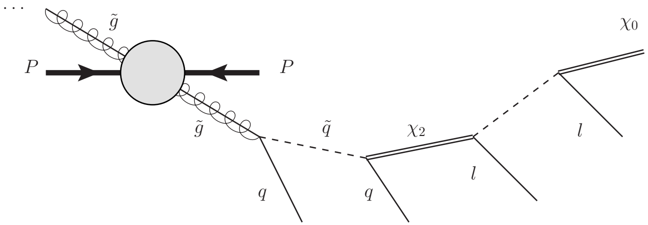

*[T. Hahn and M. Perez-Victoria, arXiv:hep-ph/9807565v1]

# Breit-Wigner Factorization Implemented

- Dominant contribution when particle $c$ close to mass-shell
- Arbitrary decay chains straightforward




$$d\sigma^{\text{tot}} \simeq d\sigma^{\text{prod}} \cdot \left\{ \frac{1}{\pi} \frac{m_c \Gamma}{(s_c - m_c^2)^2 + m_c^2 \Gamma^2} \right\} \mathbf{ds_c} \cdot \frac{\sqrt{s_c + \mathbf{p_c}^2}\, \mathbf{d\Gamma(p_c)}}{m_c \Gamma}$$



# Validity Check

- Compare with analytical solution for the process

$$q + \bar{q} \rightarrow \tilde{g} + \tilde{g}$$

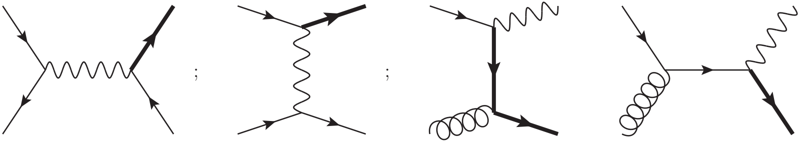
| Method | $\hat{\sigma}$ [fb] (2 TeV) |
|---|---|
| Analytical | 691.693 |
| Our Monte Carlo | $691.754 \pm 0.069$ |
| Madgraph/MadEvent† | $693.610 \pm 3.102$ |

†[Alwall, Demin, Visscher, Frederix, Herquet, Maltoni, Plehn, Raindwater and Stelzer, JHEP0709 028 (2008)]

# Background: Standard Model Single Top

- Standard Model has flavour changing interactions in the **electroweak** sector:

$$\frac{g}{\sqrt{2}} V_{tb} \bar{t} \gamma^{\mu} P_L b W_{\mu} + \text{ h.c} \in \mathcal{L}_{\text{SM}}$$



$(s)$ $(t)$ $(Wt)$

- **Irreducible background** will be given by the s and t channels

# Non-sgluon Mediated Single Top

- $t +$ jet dominates $t +$ b-jet:

| | $\sigma_{LO}(t + \text{jet})$ [pb] | $\sigma_{LO}(t + \text{b-jet})$ [pb] |
|---|---|---|
| Point A | $16.3 \pm 0.2$ | $0.449 \pm 0.002$ |
| Point B | $10.16 \pm 0.05$ | $0.282 \pm 0.001$ |
| Point C | $0.46 \pm 0.03$ | $0.0152 \pm 0.0001$ |
| Point D | $4.0 \pm 0.3$ | $0.115 \pm 0.009$ |
| Point E | $36.0 \pm 0.3$ | $0.991 \pm 0.004$ |
| Point F | $12.06 \pm 0.05$ | $0.336 \pm 0.002$ |
| Standard Model | $69.1 \pm 0.2$ | $3.39 \pm 0.01$ |

- Standard Model gives sizable background

# Signals at the LHC

- Place **kinematic cuts**:
  - 1. $p_T(\text{jet}/b\text{-jet } 1) \leq 75$ GeV.
  - 2. $|\eta(l^+)| \geq 0.5$ and $|\eta(b\text{-jet } 2)| \geq 0.5$.
- Assume b-tagging efficiency of 50%. For integrated luminosity L:
  - $2\, b\text{-jets} + l^+ + \not{E}_T$:

$$S = (0.5)^2 \times \sigma(\text{2b-jets}) \times L$$
$$B = (0.5)^2 \times \sigma_{\text{SM}}(\text{2b-jets}) \times L$$

  - $b\text{-jet} + \text{jet} + l^+ + \not{E}_T$:

$$S = 0.5 \times \sigma(\text{b-jet}) \times L + 2 \times (0.5)^2 \times \sigma(\text{2b-jets}) \times L,$$
$$B = 0.5 \times \sigma_{\text{SM}}(\text{b-jet}) \times L + 2 \times (0.5)^2 \times \sigma_{\text{SM}}(\text{2b-jets}) \times L.$$

- For signal discovery, need $S/B \gtrsim 10\%$ and statistical significance $S/\sqrt{B} \geq 5$

# Signals at the LHC

- 2 $b$-jets + $l^+$ + $\not{E}_T$: luminosity of 10 $\text{fb}^{-1}$

| | | No Cuts† | With Cuts |
|---|---|---|---|
| Point A | S/B | 0.05 | 0.14 |
| | $S/\sqrt{B}$ | 1.8 | 2.5 |
| Point B | S/B | 0.03 | 0.09 |
| | $S/\sqrt{B}$ | 1.1 | 1.6 |
| Point C | S/B | 0.00 | 0.00 |
| | $S/\sqrt{B}$ | | |
| Point D | S/B | 0.01 | 0.04 |
| | $S/\sqrt{B}$ | 0.5 | 0.8 |
| **Point E** | S/B | 0.11 | 0.31 |
| | $S/\sqrt{B}$ | 4.0 | 5.6 |
| Point F | S/B | 0.04 | 0.10 |
| | $S/\sqrt{B}$ | 1.3 | 1.9 |

# Signals at the Tevatron

- Tevatron recently detected single top production at D0 and CDF
- Can Tevatron 2-jets + $l^+ + \not{E}_T$ data rule out MRSSM?

| | | CDF (3.2 $fb^{-1}$) | D0 (2.3 $fb^{-1}$) |
|---|---|---|---|
| Tevatron data | | 3315 | 2579 |
| Standard Model | B | $3377 \pm 505$ | $2615 \pm 192$ |
| Point A | S/B | 0.01 | 0.01 |
| | $S/\sqrt{B}$ | 0.6 | 0.5 |
| Point B | S/B | 0.01 | 0.01 |
| | $S/\sqrt{B}$ | 0.4 | 0.3 |
| Point E | S/B | 0.02 | 0.02 |
| | $S/\sqrt{B}$ | 1.4 | 1.1 |
| Point F | S/B | 0.01 | 0.01 |
| | $S/\sqrt{B}$ | 0.5 | 0.4 |

# Signals at the Tevatron

- Tevatron recently detected single top production at D0 and CDF
- Can Tevatron 2-jets $+ l^+ + \not{E}_T$ data rule out MRSSM? **...No**

| | | CDF (3.2 $\text{fb}^{-1}$) | D0 (2.3 $\text{fb}^{-1}$) |
|---|---|---|---|
| Tevatron data | | 3315 | 2579 |
| Standard Model | B | $3377 \pm 505$ | $2615 \pm 192$ |
| Point A | S/B | 0.01 | 0.01 |
| | $S/\sqrt{B}$ | 0.6 | 0.5 |
| Point B | S/B | 0.01 | 0.01 |
| | $S/\sqrt{B}$ | 0.4 | 0.3 |
| Point E | S/B | 0.02 | 0.02 |
| | $S/\sqrt{B}$ | 1.4 | 1.1 |
| Point F | S/B | 0.01 | 0.01 |
| | $S/\sqrt{B}$ | 0.5 | 0.4 |