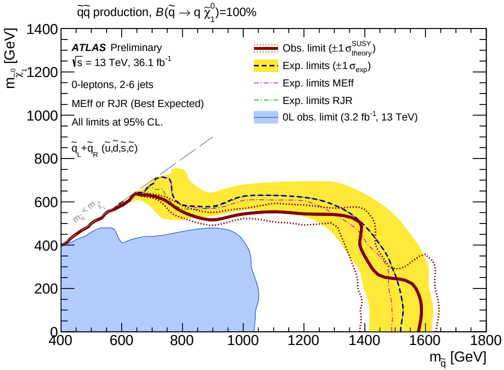
Production of squarks at the LHC in R-symmetric SUSY

In collaboration with J, Kalinowski, W. Kotlarski, D. Stöckinger (JHEP 1710 (2017) 142 [arxiv:1707:04557]), [arxiv:18xx:xxxxx]

Philip Diessner

Barcelona, 25.07.2018

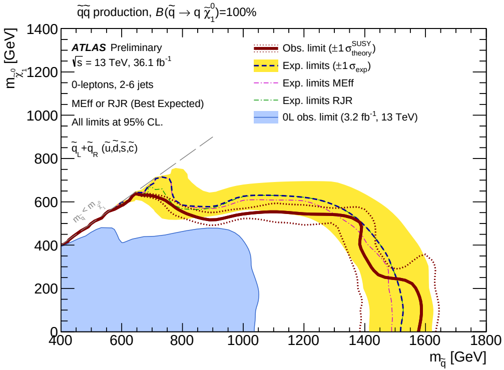
Going beyond the MSSM



Motivation

- LHC Run 2 on-going
- Look into non-minimal models for wide spectrum of alternative predictions

Going beyond the MSSM



Motivation

- LHC Run 2 on-going
- Look into non-minimal models for wide spectrum of alternative predictions
- Here: **R-Symmetry**
  - Includes solution to flavor problem of the MSSM
  - Extended Higgs sector, different predictions than (N)MSSM
  - Dirac gauginos (esp. gluino) might explain SUSY non-discovery

Outline

R-Symmetric SUSY

NLO Calculation

NLO Results

SQCD Phenomenology

R-symmetry

- Additional symmetry allowed by SUSY algebra: $[Q_\alpha, R] = Q_\alpha \; , \quad [\overline{Q}_{\dot{\alpha}}, R] = -\overline{Q}_{\dot{\alpha}}$
- For $N = 1$ SUSY it is a global $U(1)_\mathrm{R}$ symmetry
  $\rightarrow$ Different charges for Superpartners
- SM fields have $Q_\mathrm{R} = 0$
- SUSY partners carry charge
- Lagrangian has to be invariant (MRSSM Kribs et.al. (Phys.Rev. D78 (2008) 055010))
- Forbids Majorana mass terms and A terms

Assume R-symmetry to be unbroken.

R-symmetric SUSY QCD

Following MRSSM conventions:

superfield		boson		fermion	
left-handed (s)quark	$\hat{Q}_L$	$\tilde{q}_L$	1	q_L	0
right-handed (s)quark	$\hat{Q}_R$	$\tilde{q}_R^\dagger$	1	$\bar{q}_R$	0
gluon vector superfield	$\hat{V}$	g	0	$\tilde{g}_L$	$+1$
adjoint chiral superfield	$\hat{O}$	O	0	$\tilde{g}_R$	-1

$$\mathcal{L}_{\text{soft}} = -\frac{m^2_{\tilde{q}_L}}{2}|\tilde{q}_L|^2 - \frac{m^2_{\tilde{q}_R}}{2}|\tilde{q}_R|^2 - m_O^2\,|O^a|^2 - m_{\tilde{g}}\left(\overline{\tilde{g}_R}\tilde{g}_L - \sqrt{2}D^a O^a + \text{h.c.}\right) .$$

Phenomenology

- Dirac gaugino masses are “super-soft”

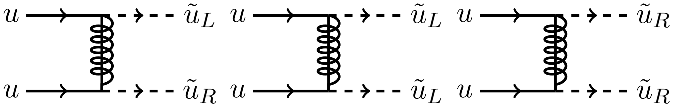
  (Fox, et.al., [hep-ph/0206096])
- $\rightarrow$ Scenario with heavy gluino and rather light squarks natural
- Here: Concentrate on squark production in the MRSSM

Phenomenology

- Dirac gaugino masses are “super-soft”

  (Fox, et.al., [hep-ph/0206096])

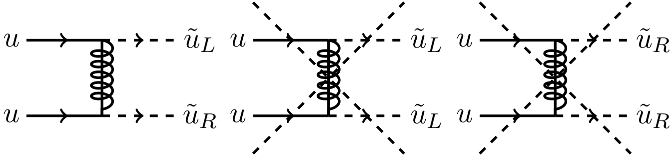
- $\rightarrow$ Scenario with heavy gluino and rather light squarks natural
- Here: Concentrate on squark production in the MRSSM



Phenomenology

- Dirac gaugino masses are “super-soft”

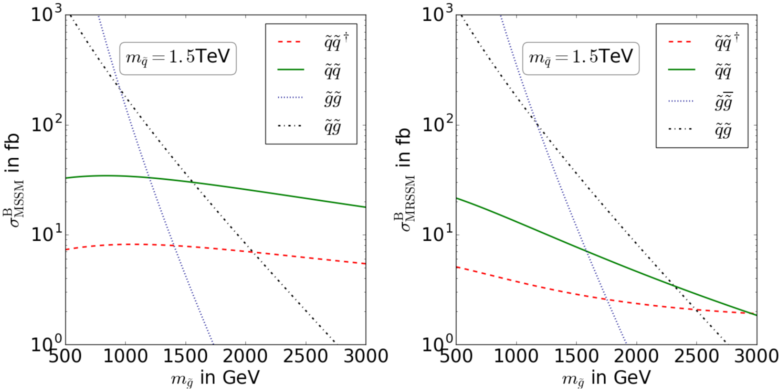
  (Fox, et.al., [hep-ph/0206096])
- $\rightarrow$ Scenario with heavy gluino and rather light squarks natural
- Here: Concentrate on squark production in the MRSSM



Phenomenology

- Dirac gaugino masses are “super-soft”

  (Fox, et.al., [hep-ph/0206096])
- $\rightarrow$ Scenario with heavy gluino and rather light squarks natural
- Here: Concentrate on squark production in the MRSSM



left: MSSM,

right: MRSSM

NLO calculation

- MSSM results known since many years used in form of (global) K-factors by experiments and pheno studies

$$K = \frac{\sigma_{NLO}}{\sigma_{LO}}$$

- “NLO revolution” for SM processes allows reliable and fast calculation of NLO corrections including matching

NLO calculation

- MSSM results known since many years used in form of (global) K-factors by experiments and pheno studies

$$K = \frac{\sigma_{NLO}}{\sigma_{LO}}$$

- "NLO revolution" for SM processes allows reliable and fast calculation of NLO corrections including matching

MRSSM

- Well-known from MSSM that NLO effects sizable
- Additional scalar octet: sgluon
- Dirac nature of gluino
- Squark production: squark-squark and squark-antisquark

Implementation

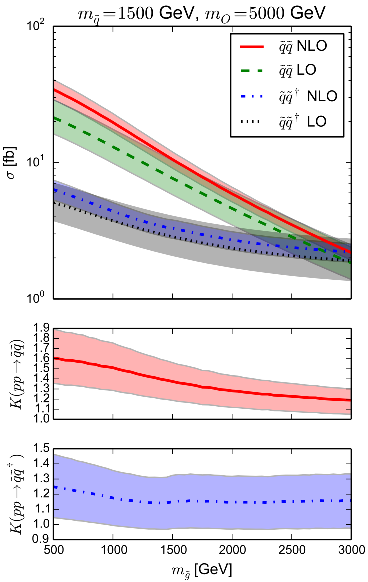
Combine popular programs and compare with own implementation of orthogonal methods

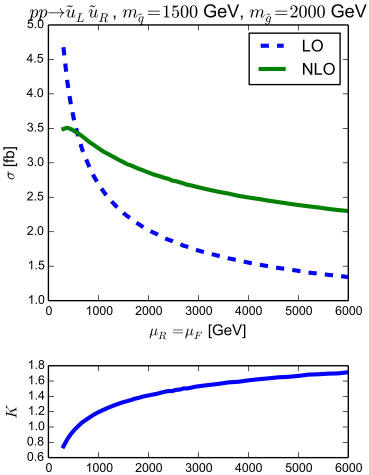
- `GoSam` and `MadGraph_aMC@NLO` (+ own implementation of renormalisation) using OPP reduction and FKS subtraction
- Independent calculation using classical PV functions and phase space slicing

Theoretical aspects

- Dimensional regularisation or reduction
- Cancellation of IR divergences
- On-shell renormalisability
- Treatment of on-shell resonances

Results

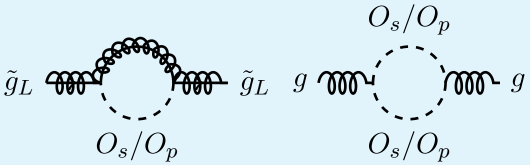




- Corrections behave similar as in MSSM
- Some prominent deviations exist

Sgluon effects

Superoblique corrections



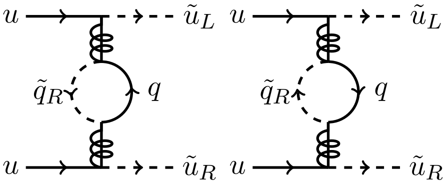
Integrating out the sgluon leads to physical difference:

$$\hat{g}_s - g_s = \frac{\alpha_s}{4\pi}\left(\log\frac{m_O^2}{m_{\tilde{g}}^2}\right)$$

$\hat{g}_s$ gluino coupling, g_s gluon coupling

Dirac gluino effects

MSSM:

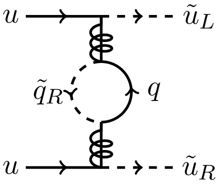


Example: squark-squark

- only one Dirac gluino chirality couples to matter
- Diagrams proportional to Majorana mass not present

Dirac gluino effects

MRSSM:

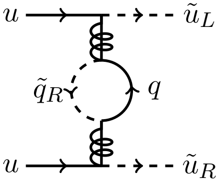


Example: squark-squark

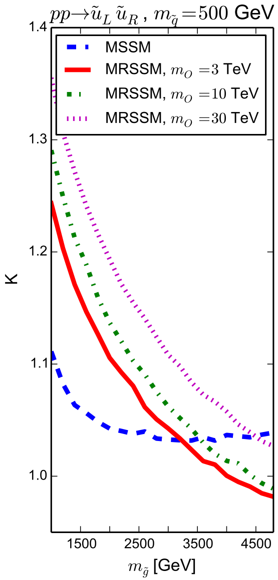
- only one Dirac gluino chirality couples to matter
- Diagrams proportional to Majorana mass not present

Dirac gluino effects

MRSSM:



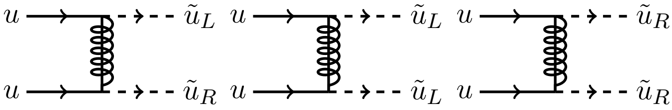
- only one Dirac gluino chirality couples to matter
- Diagrams proportional to Majorana mass not present



Example: squark-squark

Comparison to the MSSM

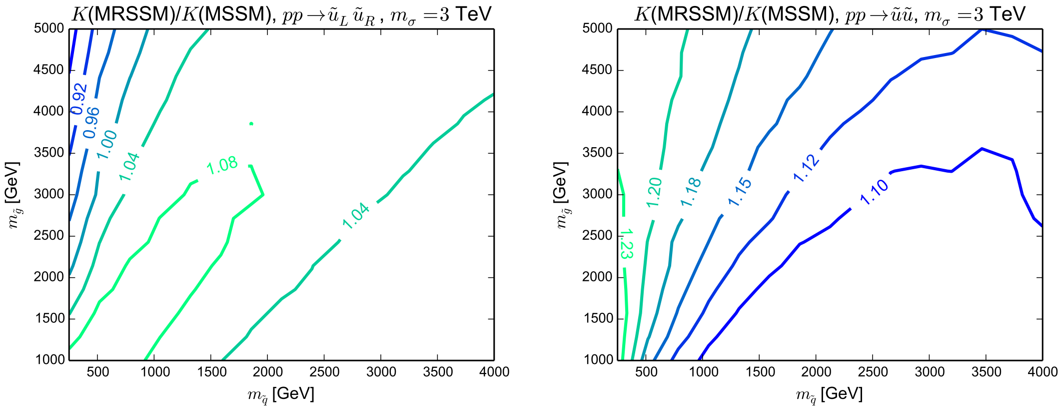
- Output from standard tools (Prospino, NLLfast) is $K(pp \to uu)$
- But $K(pp \to uu) \neq K(pp \to u_L u_R)$ in MSSM



Compare $\frac{K(MRSSM)}{K(MSSM)}(pp \to \tilde{u}_L \tilde{u}_R)$ and $\frac{K(MRSSM)}{K(MSSM)}(pp \to \tilde{u}\tilde{u})$

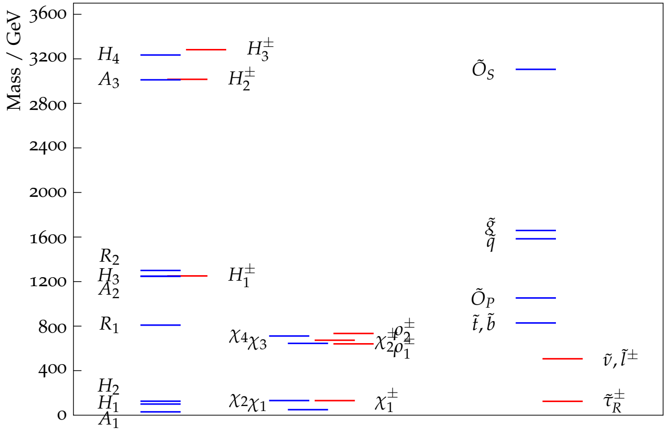
Comparison to the MSSM

- Output from standard tools (Prospino, NLLfast) is $K(pp \to uu)$
- But $K(pp \to uu) \neq K(pp \to u_L u_R)$ in MSSM
- Leads to systematic error



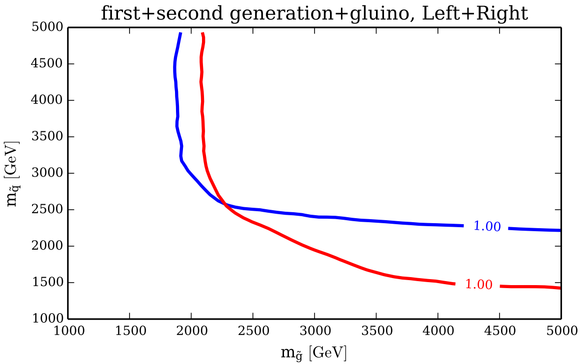
Phenomenology - Basics

- R-charge leads to LSP/LRP
- Neutralinos are Dirac states
- For exclusion/discovery mass hierarchies are more important
- For now, NLO K-factors not included



Phenomenology-- Preliminary results

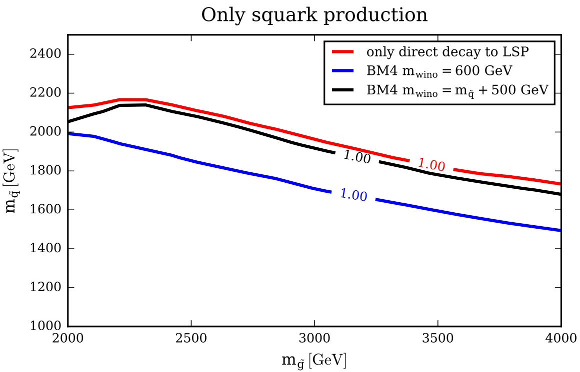
- Limit derived with `Herwig` 7 and `CheckMate` 2
- ATLAS search for 0ℓ, 2-6 jets + E^T_{miss} , 36 fb^{-1} [1712.02332]
- Comparing MRSSM and MSSM
  - Stronger limits on gluino mass
  - Weaker for (first generations) squark masses



blue – MSSM; red – MRSSM

Phenomenology-- Preliminary results

- Limit derived with `Herwig` 7 and `CheckMate` 2
- ATLAS search for 0ℓ, 2-6 jets + E^{T}_{miss} , 36 fb^{-1} [1712.02332]
- Scenarios in the MRSSM for squark production
  - Strongest bound from direct decay to light LSP
  - Intermediate (Dirac)-wino has strong influence



Conclusions

- Shown NLO corrections to Non-minimal SUSY QCD
- Be careful if using MSSM K-factors for other models
- In progress: look at phenomenology including decays
- Bring the parts together

Conclusions

- Shown NLO corrections to Non-minimal SUSY QCD
- Be careful if using MSSM K-factors for other models
- In progress: look at phenomenology including decays
- Bring the parts together

Thanks for your attention!