Distorted Mass Edges at LHC from supersymmetric Leptoquarks

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with J.Reuter, based on Phys. Rev. **D84** (2011) 015012.

Introduction

- Sample model setup
- P&D of exotics

Distortion of Edges

- Exotic fermion characteristics
- Physiognomy of edges
- Robustness of effect

Conclusions

Sample model setup

Some model facts

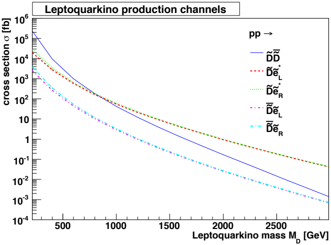
- E_6 SUSY GUT w/ two-step unification
- NMSSM-like μ-problem solution
- Higgs-matter unification
- solution of doublet-triplet splitting problem:
- existence of TeV scale exotics contained in **27**: colored iso-singlet scalars and fermions
- more on E_6 in e.g. Antonio Morais talk (PS 9)

based on F. Braam, A. Knochel, J. Reuter, JHEP **1006** (2010) 013.

Decomposition of the fundamental **27**

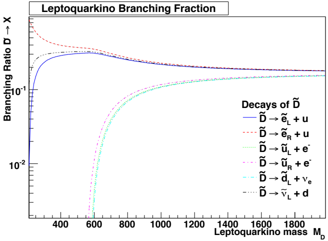
	$SU(3)_C$	$SU(2)_L$	$U(1)_Y$	$U(1)'$
$\hat{Q}$	$\mathbf{3}$	$\mathbf{2}$	1/3	Q'_Q
$\hat{u}^c$	$\bar{\mathbf{3}}$	$\mathbf{1}$	-4/3	Q'_u
$\hat{d}^c$	$\bar{\mathbf{3}}$	$\mathbf{1}$	2/3	Q'_d
$\hat{L}$	$\mathbf{1}$	$\mathbf{2}$	-1	Q'_L
$\hat{e}^c$	$\mathbf{1}$	$\mathbf{1}$	2	Q'_e
$\hat{H}^u$	$\mathbf{1}$	$\mathbf{2}$	1	Q'_{H^u}
$\hat{H}^d$	$\mathbf{1}$	$\mathbf{2}$	-1	Q'_{H^d}
$\hat{D}$	$\mathbf{3}$	$\mathbf{1}$	-2/3	Q'_D
$\hat{D}^c$	$\bar{\mathbf{3}}$	$\mathbf{1}$	2/3	Q'_{D^c}
$\hat{\nu}^c$	$\mathbf{1}$	$\mathbf{1}$	0	Q'_{ν^c}
$\hat{S}$	$\mathbf{1}$	$\mathbf{1}$	0	Q'_S

Production and decay of exotic fermions



- dominant decays to sfermion/sm-fermion pair
- scalar/gaugino mode suppressed due to typically heavier scalar mass
- all figures & numbers using `WHIZARD` (projects.hepforge.org/whizard)

- x-secs @ LHC14: 10^{-3} fb $\rightarrow 10^5$ fb
- single production dominant for high masses (ps effect)
- but: dependence on coupling ($\lambda = e \approx 0.312$)



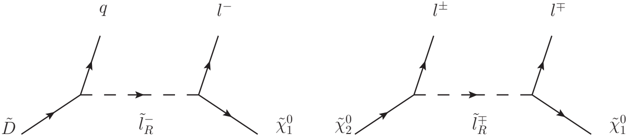
Final state selection

- sfermion/fermion decay of exotics dominate
- final states of pair production: 2 jet + 2 lepton + MET
- (single production: 1 jet + 2 lepton + MET)
- backgrounds include gluino pair, associated gluino-squark and squark pair production
- former two under fairly good control through cuts (p_T (jet) $>$ 100 GeV on parton level)
- x-secs of backgrounds roughly of comparable size (10^{-1} fb $\rightarrow$ 10^6 fb)

Some exotic fermion characteristics

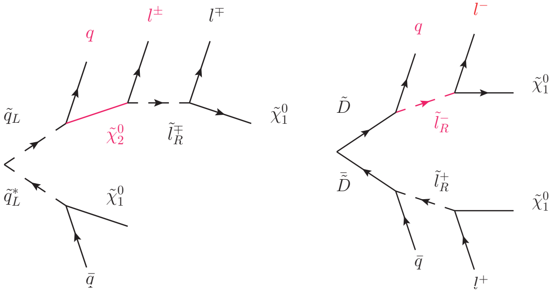
- Leptoquarkino w/ intrinsic negative R-parity → sparticle-like decay through long cascades
- Dependent upon SUSY breaking / spectrum, there is a special feature:
- kinematic endpoint of M_{ql} is equivalent to vanilla MSSM-like dilepton edge: no spin correlation between quark and lepton due to intermediate scalar
- dirac instead of majorana fermion

$$m_{ql}^{max} = \left[\frac{(m^2_{\tilde{e}_{R(L)}} - m^2_{\tilde{\chi}^0_1})(m^2_D - m^2_{\tilde{e}_{R(L)}})}{m^2_{\tilde{e}_{R(L)}}} \right]^{\frac{1}{2}}$$



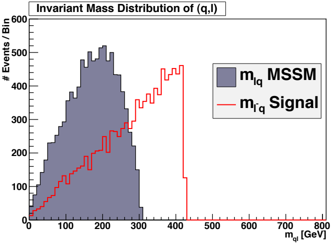
Example of a typical event

- consider e.g. 2 jet + 2 lepton + MET final state
- comparison yields fundamentally different nature of intermediate state(s)
- strong phenomenological implications arise



Physiognomy of edges I

- exotics have baryon & lepton numbers
  $\rightarrow$ concentrate on jet/lepton variables
- best guess is m_{lq}, direct observation yields:

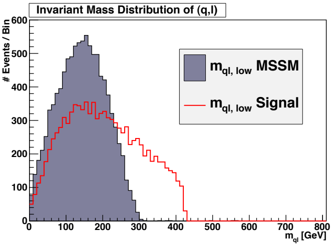


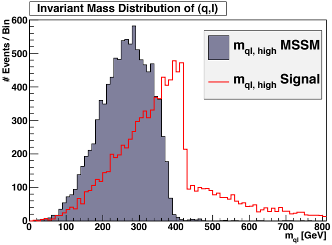
- Inability to experimentally combine correct jet/lepton pair requires intro of $m_{ql,high}$ and $m_{ql,low}$

$$m_{ql,high} = \max\{m_{ql^+}, m_{ql^-}\}$$
$$m_{ql,low} = \min\{m_{ql^+}, m_{ql^-}\}$$

Physiognomy of edges II

- speciality: maximization over lepton pair yields uncorrelated jet/lepton pairs from two 'sides' of decay cascades for signal
- result: tail in $m_{ql,high}$ (compared to tail-less vanilla MSSM)
- important: not to be misidentified as squark analysis with wrong combinatorics!

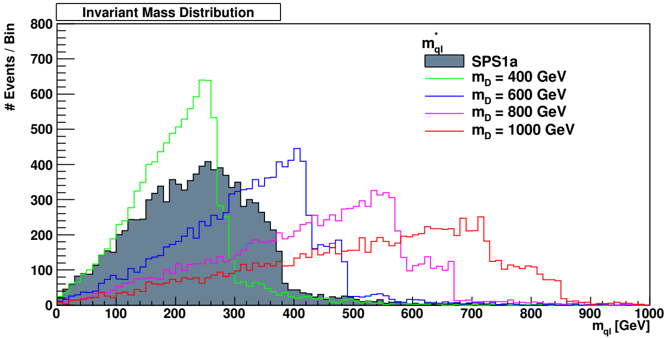




Physiognomy of edges III

- alternative jet/lepton variables including endpoint features are e.g. m^*_{ql} or m_{qll}
- bonus: definition of m^*_{lq} intrinsically free of combinatorical issues (but still suffering from admixture of uncorrelated leptons)

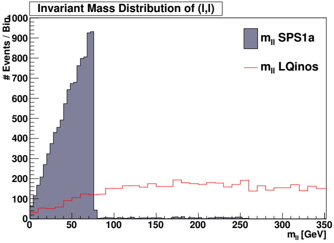
$$m^*_{ql} = m(\min_E\{j_1, j_2\}, \max_E\{l^+, l^-\})$$

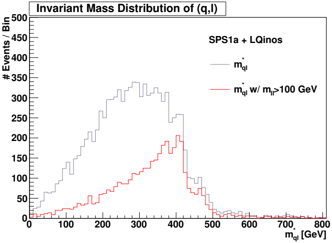


Digging out the Signal

Use difference in lepton correlation:

- In vanilla MSSM signal correlation yields clear endpoint structure
- Exotic signal leptons mostly uncorrelated
- Cut above edge drastically reduces standard SUSY backgrounds

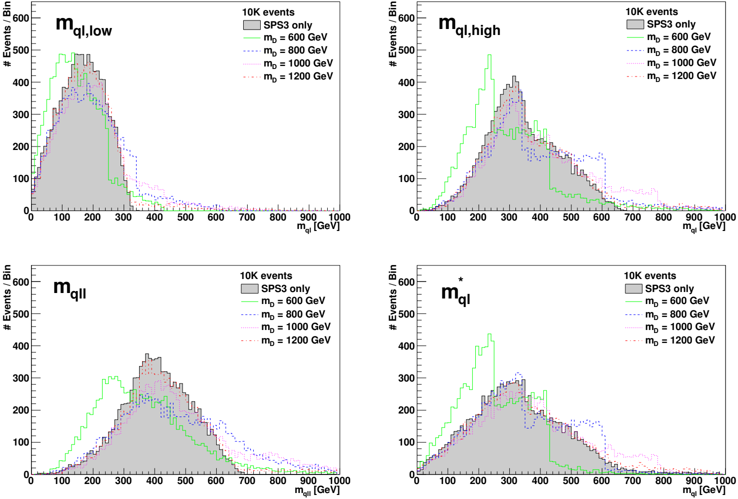




Robustness of effect

- In the following, we show impact of 4 exotic masses embedded into two different SPS spectra (mSUGRA (SPS3) + GMSB (SPS7))
- effect is stable and hardly dependent upon scenario
- only relative mass difference to underlying spectrum is relevant

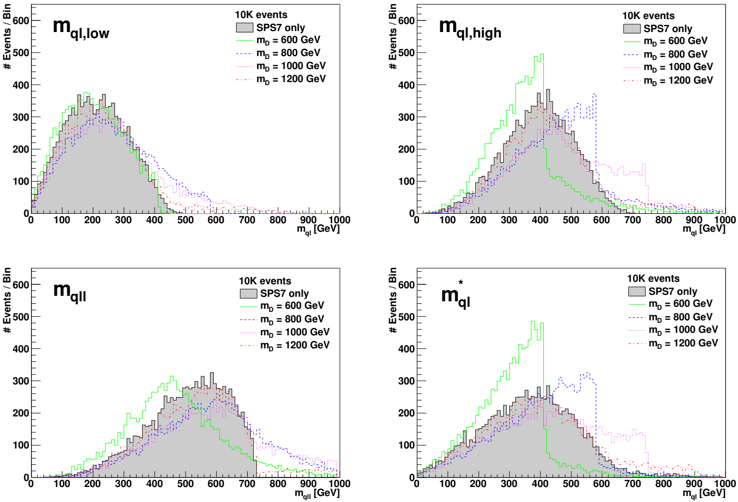
Mass scans w/ SPS3



Distortion features

- $m_{ql,low}$ not particularly useful to disentangle exotic signals
- $m_{ql,high}$ and m^*_{ql} show most promising distortions
- notice steplike endpoint feature due to multiple possible intermediate states (here:sleptons)
- deviation dominates for $M_D \ll M_{\tilde{q}}$ and naturally washes out for $M_D \gg M_{\tilde{q}}$

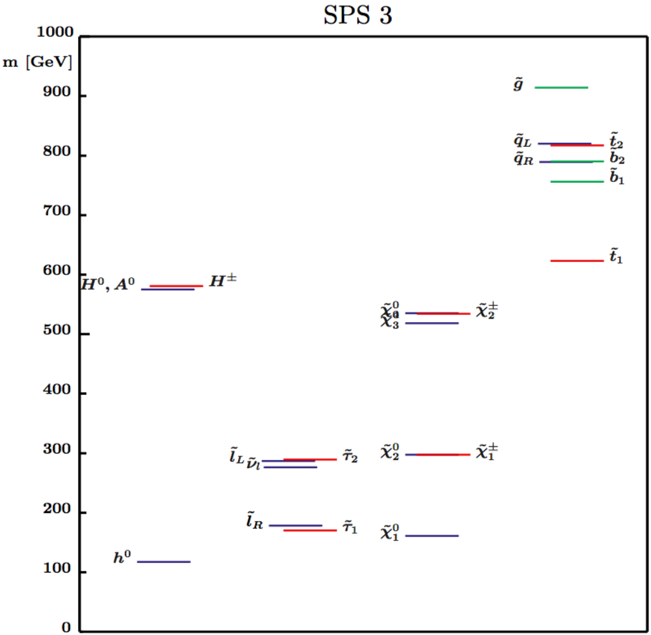
Mass scans w/ SPS7



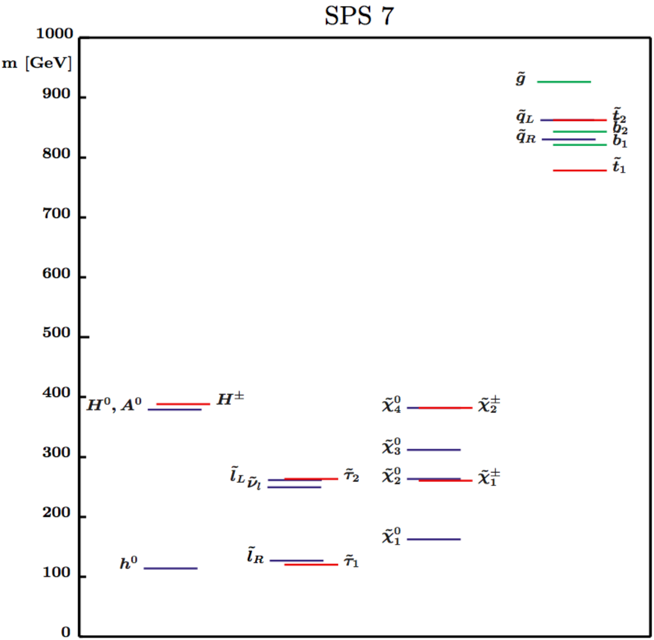
Conclusions

- Most B(MS)SM models introduce new particles, which may distort *standard* kinematic observables
- Origin of effect is model independent: difference in spin of intermediate particle
- Misidentified combinatorical issues in e.g. squark analyses are able to (re)produce similar effect $\rightarrow$ careful and elaborate study necessary!
- After all: discovery of such exotic matter content could provide a handle on underlying GUT scale structure

Backup


SPS 3
1000
m [GeV]
900
800
700
600
500
400
300
200
100
0
$\tilde{g}$
$\tilde{q}_L$
$\tilde{t}_2$
$\tilde{q}_R$
$\tilde{b}_2$
$\tilde{b}_1$
$\tilde{t}_1$
H^0, A^0
$H^\pm$
$\tilde{\chi}_4^0$
$\tilde{\chi}_3^0$
$\tilde{\chi}_2^\pm$
$\tilde{l}_L$
$\tilde{\nu}_l$
$\tilde{\tau}_2$
$\tilde{\chi}_2^0$
$\tilde{\chi}_1^\pm$
$\tilde{l}_R$
$\tilde{\tau}_1$
$\tilde{\chi}_1^0$
h^0

Backup


SPS 7
m [GeV]
1000
900
800
700
600
500
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300
200
100
0
$\tilde{g}$
$\tilde{q}_L$
$\tilde{q}_R$
$\tilde{t}_2$
$\tilde{b}_2$
$\tilde{b}_1$
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H^0, A^0
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h^0
$\tilde{l}_R$
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