Distorted Mass Edges at LHC.

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DESY
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HELMHOLTZ GEMEINSCHAFT

DESY

> Introduction

> Part I: Distortion due to Exotics

- Exotic fermion characteristics
- Physiognomy of edges
- Stable Distortion

> Part II: Distortion due to off-shell effects

- Motivation
- Stable Distortion II

> Conclusions

Measurement of spins & masses

- Measurement of spins & masses essential for understanding new physics
- Many methods exist, most rely on kinematic features of visible final states
- Understanding of these features crucial to most determination methods
- Two examples, how mass edges may be distorted at fundamental level:
  - extending particle content by new exotics
  - increased widths e.g. through phase space enhancements

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Outline

Introducing a model...

Some model features:

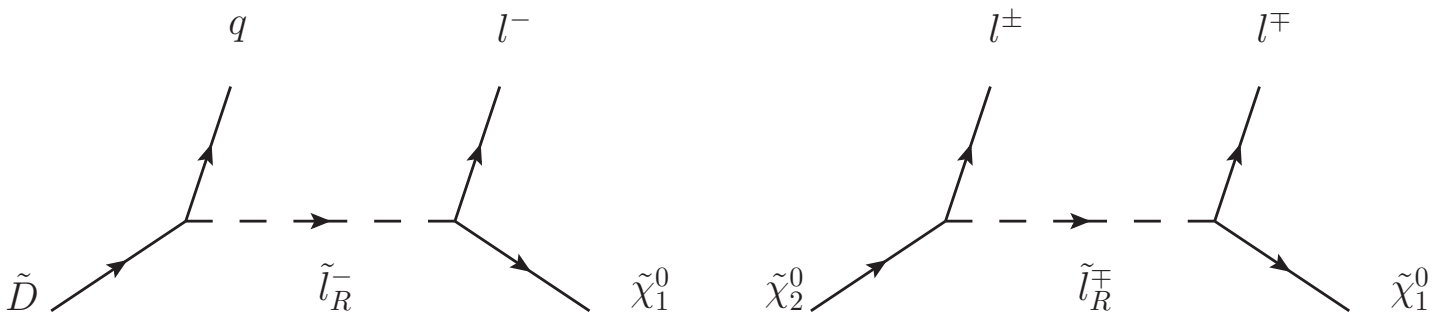
- E_6 SUSY GUT w/ two-step unification
- NMSSM-like μ-problem solution
- Higgs-matter unification
- solution of doublet-triplet splitting problem:
- existence of TeV scale exotics contained in **27**:
  colored iso-singlet scalars and fermions

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

... including exotic fermions

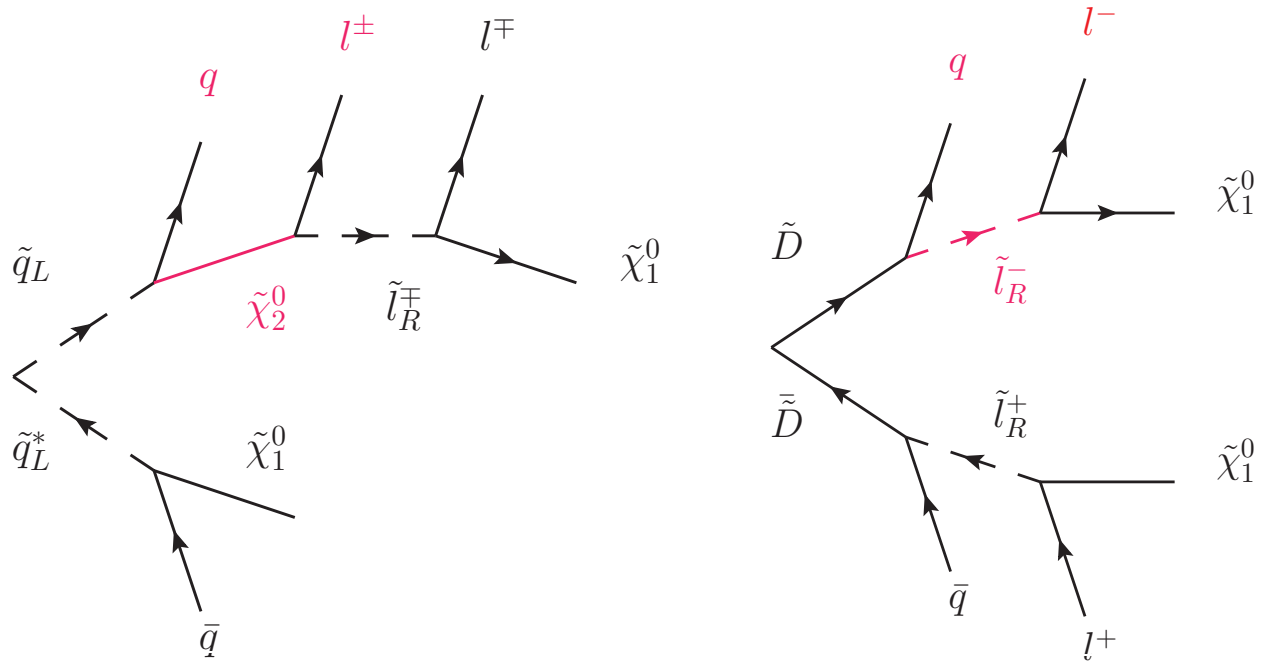
- Exotics w/ intrinsic negative R-parity $\rightarrow$ sparticle-like decay through long cascades
- Dependent upon SUSY breaking / spectrum, there is a special feature:
- kinematic endpoint of M_{ql} is equivalent to vanilla MSSM-like dilepton edge: no spin correlation between quark and lepton due to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

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



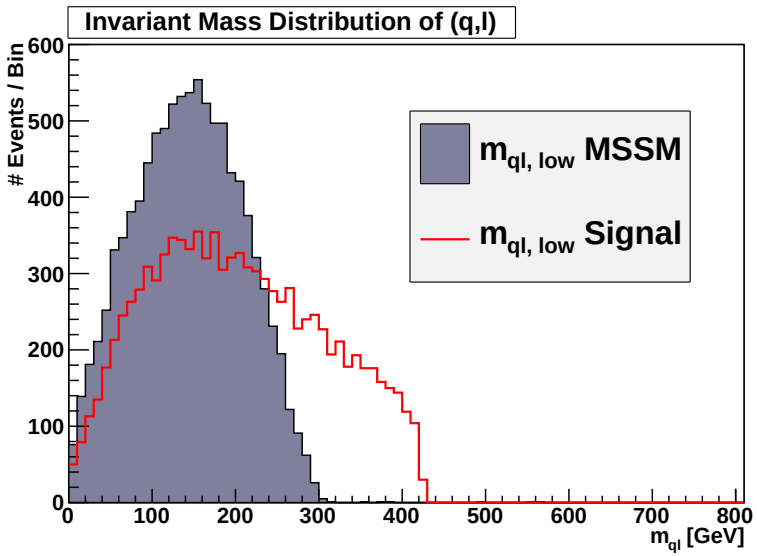
Event characteristics

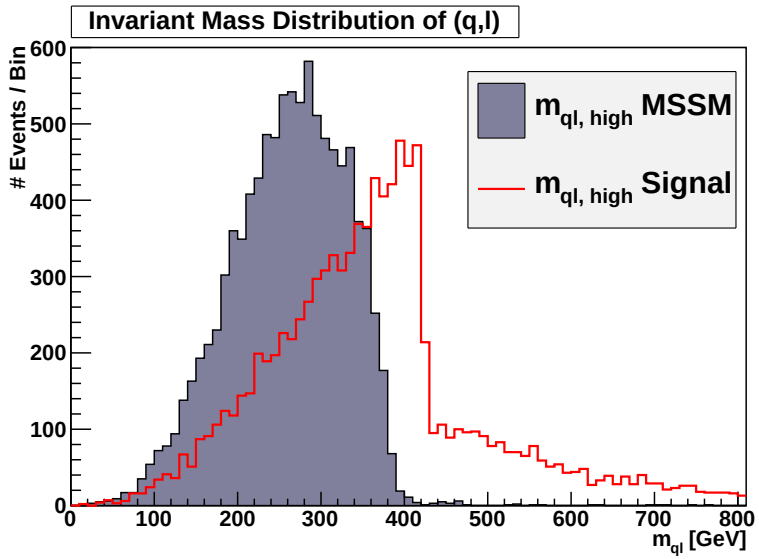
- signature of exotic fermions: 2 jets + 2 leptons + MET
- backgrounds include squark pairs, but:
- comparison yields different nature of intermediate state(s) w/ strong phenomenological implications



Physiognomy of edges

- 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!



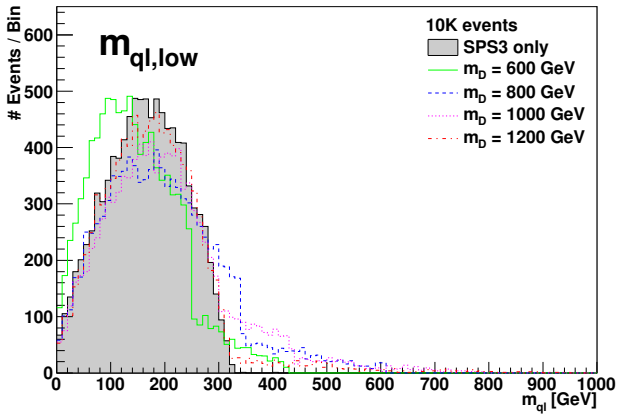


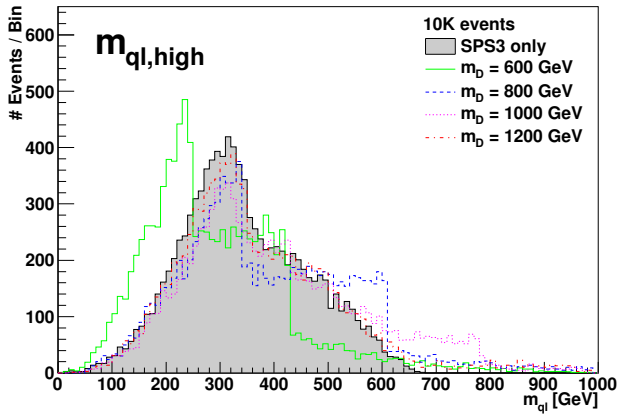
based on J. Reuter, DW, Phys. Rev. **D84** (2011) 015012.

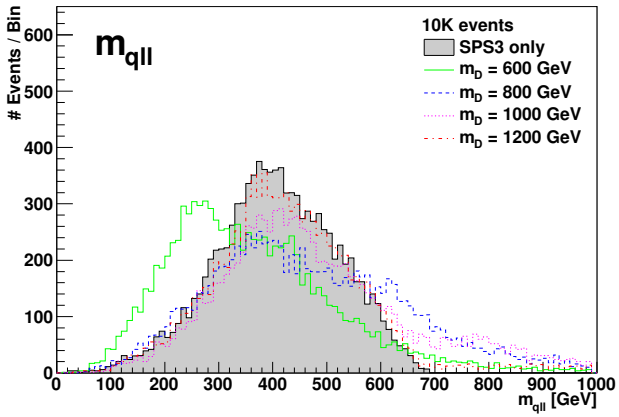
Stable Distortion

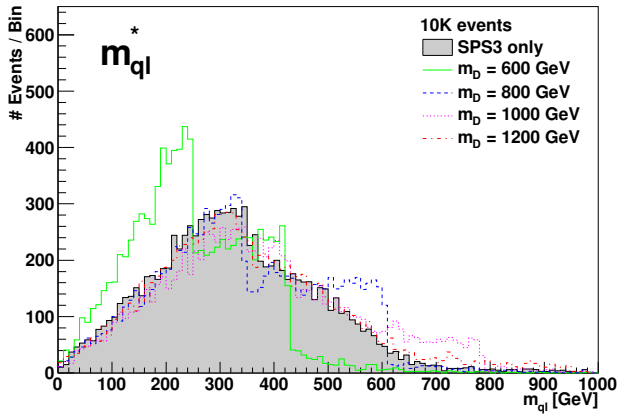
- In the following, we show impact of 4 different exotic masses embedded into two different SPS spectra (mSUGRA (SPS3) + GMSB (SPS7))
- effect is stable and hardly dependent upon scenario
- only relative mass difference to underlying spectrum is relevant

Mass scans w/ SPS3



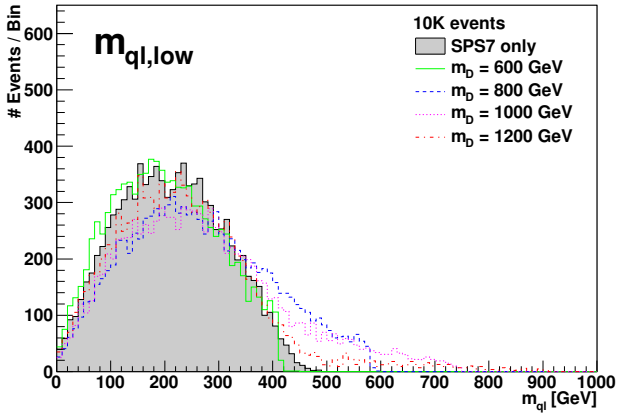


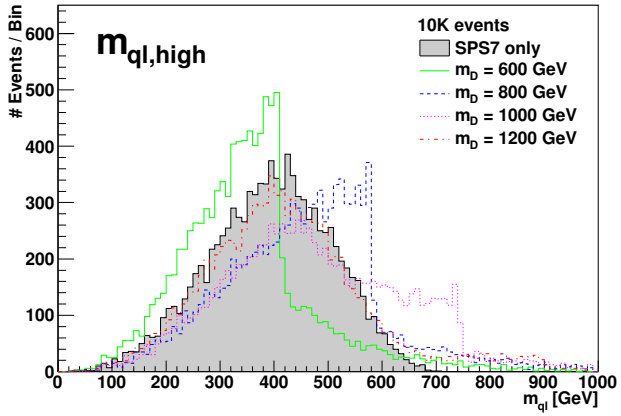


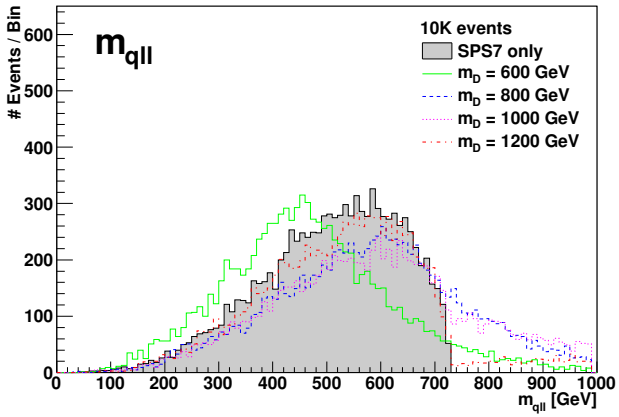


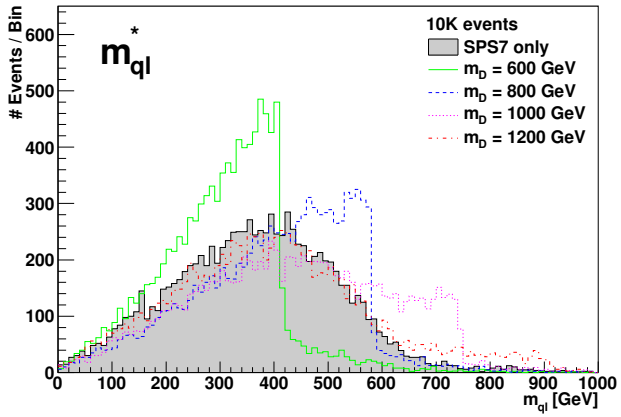
- notice steplike endpoint feature due to multiple possible intermediate states (here:sleptons)
- deviation dominates for $M_D \ll M_{\tilde{q}}$ and washes out for $M_D \gg M_{\tilde{q}}$

Mass scans w/ SPS7









- $m_{ql,low}$ not particularly useful to disentangle exotic signals
- $m_{ql,high}$ and m^*_{ql} show most promising distortions

Comments & Caveats I

- 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

Outline

DESY

Motivation, NWA & factorization

- LHC exclusion bounds favor heavy (2nd generation) scalars
- focus point scenarios (and the like) may give rise to sizable widths:
  - phase-space in decays is enhanced by large mass gaps
- heavy gluino as prominent example: plethora of squark+quark decay modes inflate $\Gamma(\tilde{g})$
- Narrow-Width-Approximation (NWA) breakdown imminent (Berdine, Kauer, Rainwater, Phys.Rev.Lett. 99 (2007) 111601)
- many BSM studies rely on factorization of production on decay, based on NWA, but error is of $\mathcal{O}\left(\Gamma/M\right)$
- only full matrix element calculation ensures correct treatment of off-shell widths effects
- to assess impact, we vary Γ/M and investigate the typical gluino cascade

$$\tilde{g} \to \bar{q}\tilde{q}_i \to \bar{q}ql^+l^-\tilde{\chi}_1^0$$

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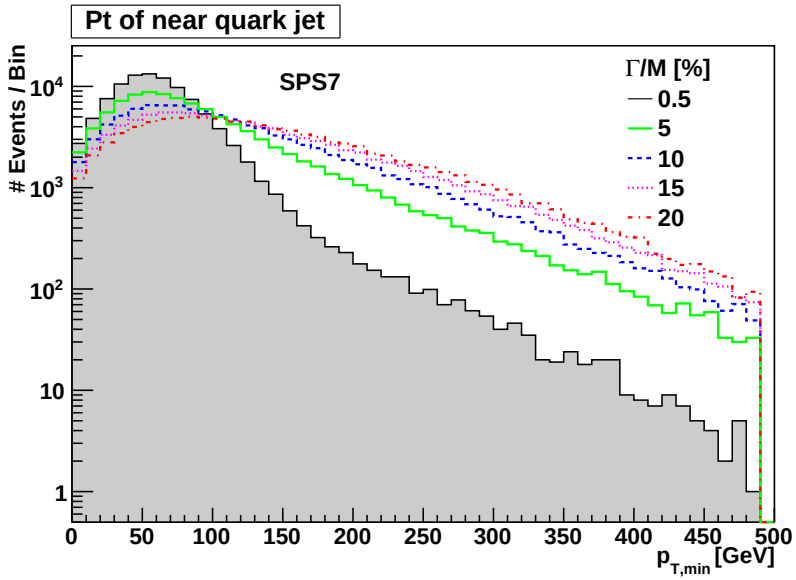
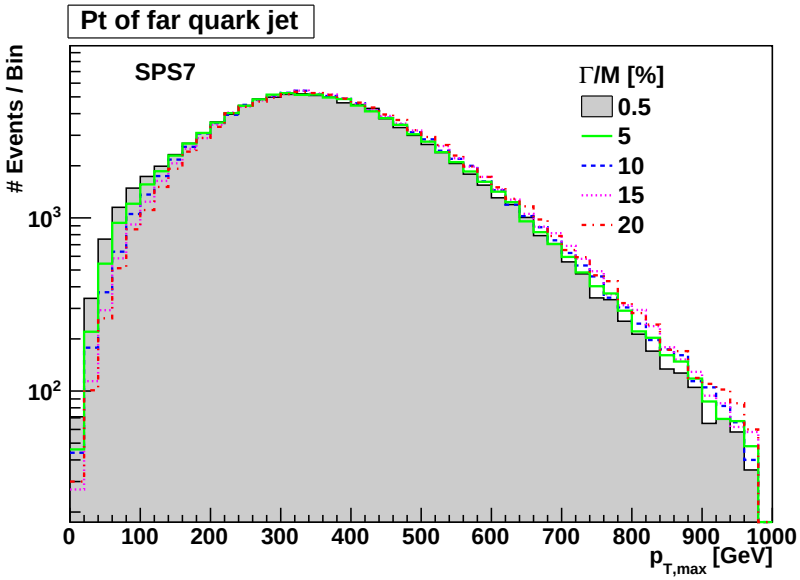
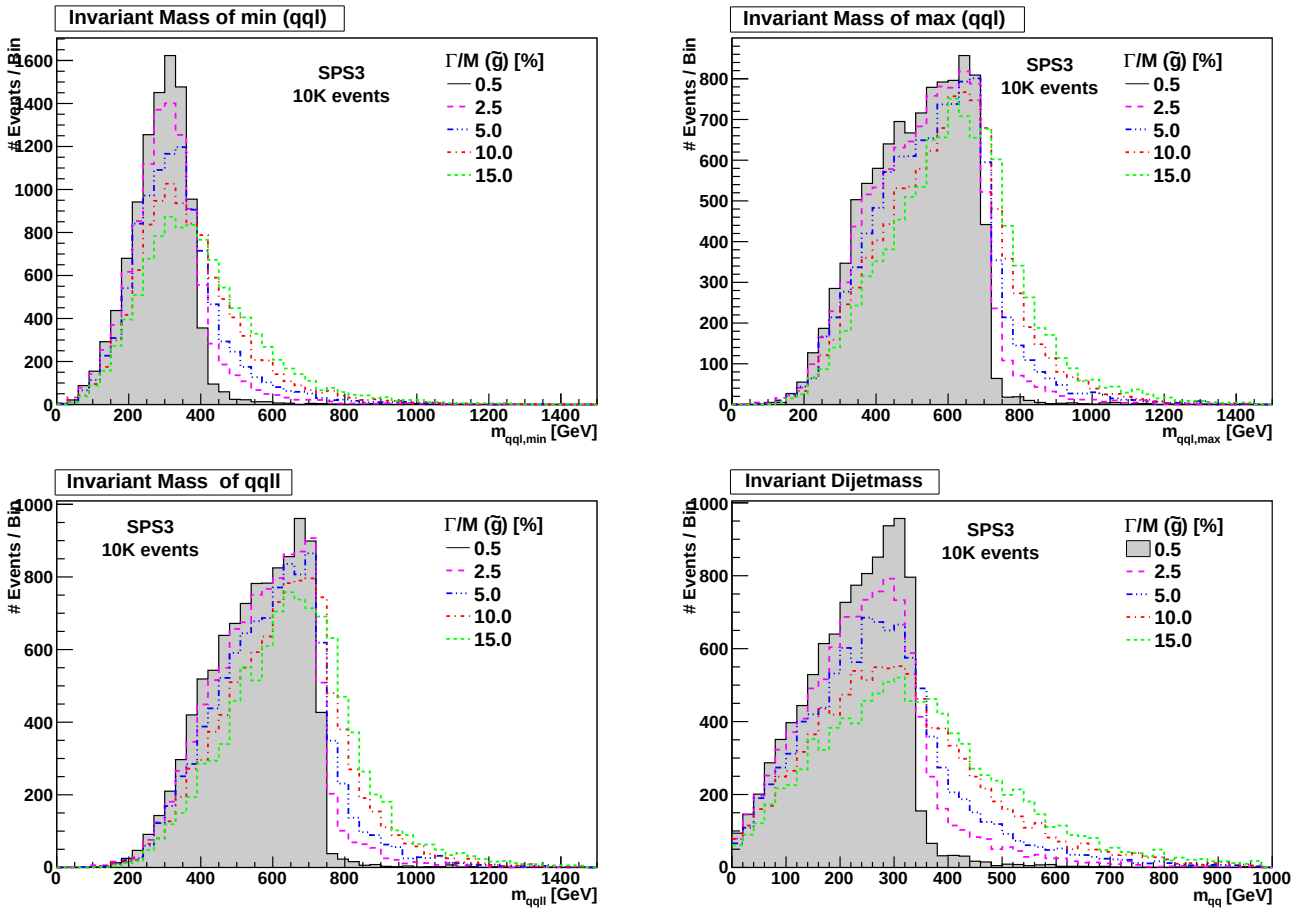
Impact on p_T: the gluino case





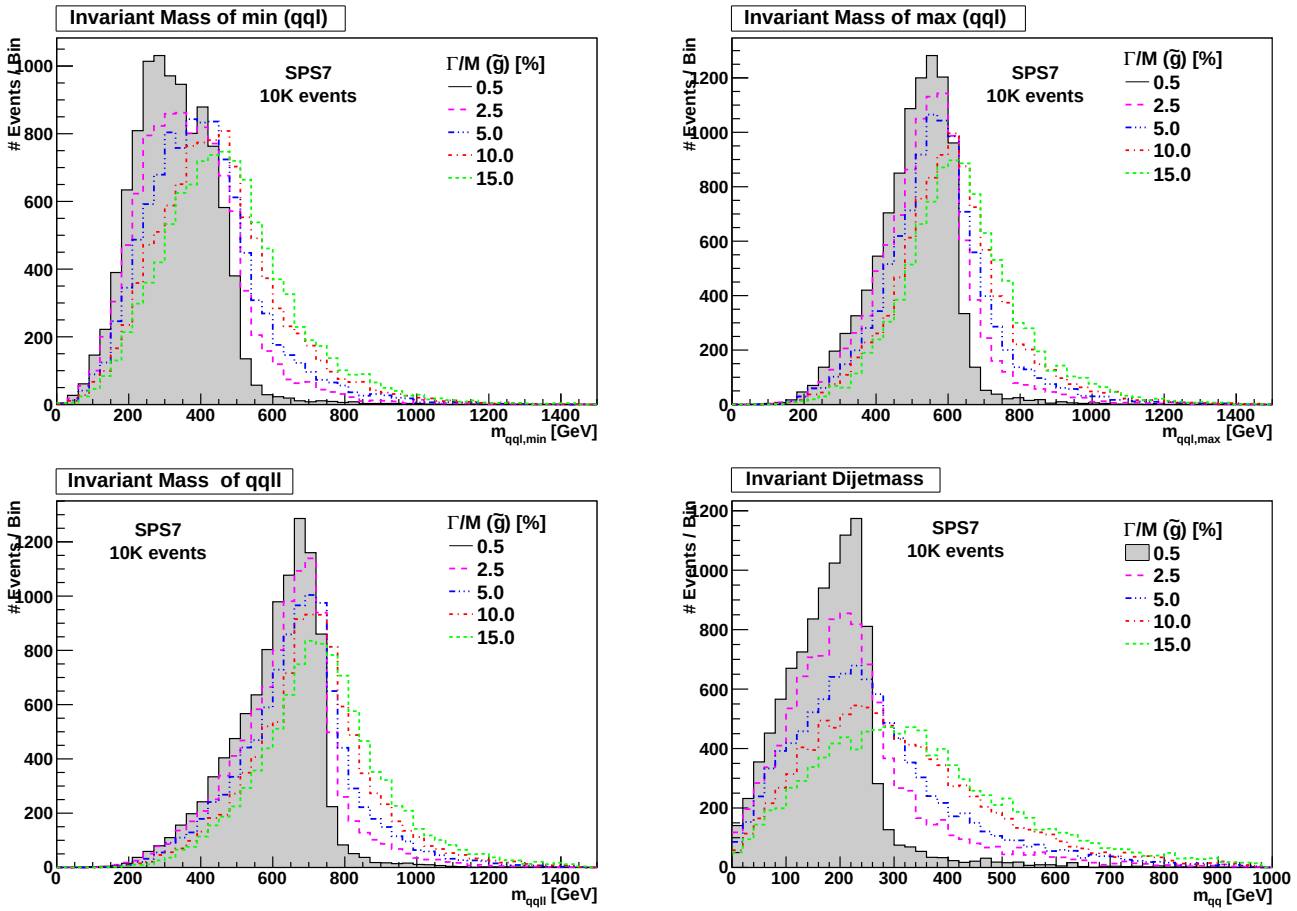
- transverse momentum distributions altered
- gluino width heavily affects near quark, far quark merely concerned
- distorting effects thus arise in kinematic distributions containing the first (hard) quark jet
- phenomenological scan of different Γ/M values for corresponding observables

Width scans w/ SPS3



- $m_{qll,low}$ and especially m_{qq} show strongest deviations
- $m_{qll,high}$ and m_{qqll} wash out, but do not decrease much in height

Width scans w/ SPS7



> similar picture as for SPS3, $m_{qll,high}$ and m_{qqll} look slightly worse

> striking: m_{qq} severely suffers from loss of height

Comments & Caveats II

- strong discrepancies already at low values of Γ/M
- distributions loose sharp cutoff at kinematic endpoint
- height decreases drastically in some cases (m_{qq})
- implications for mass & spin determination
  - spin measurements relying on shapes & asymmetries affected
  - possible discrimination to other BSM models (UED) in danger
  - mass measurements relying on endpoints also concerned
- all studies on parton level w/ MC truth
- ISR, FSR, hadronization as well as combinatorical & detector effects will only worsen the (already adverse) picture
- figures are to be taken as worst case scenarios (simplified model)

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Conclusions & Outlook

Take home:

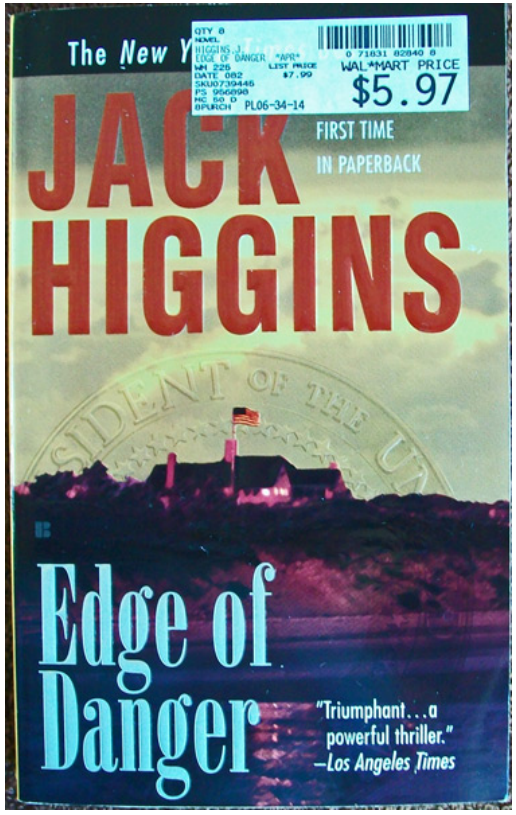
- Combinatorics may NOT be the only reason for long tails in kinematic distributions
- Exotic matter content and off-shell contributions give rise to distorted mass edges already at parton level

Next steps:

- Assessment of impact on measurement errors of particular affected spin & mass determination methods
- Extend analysis to alternative BSM models

In the end...

... we have to be careful at the



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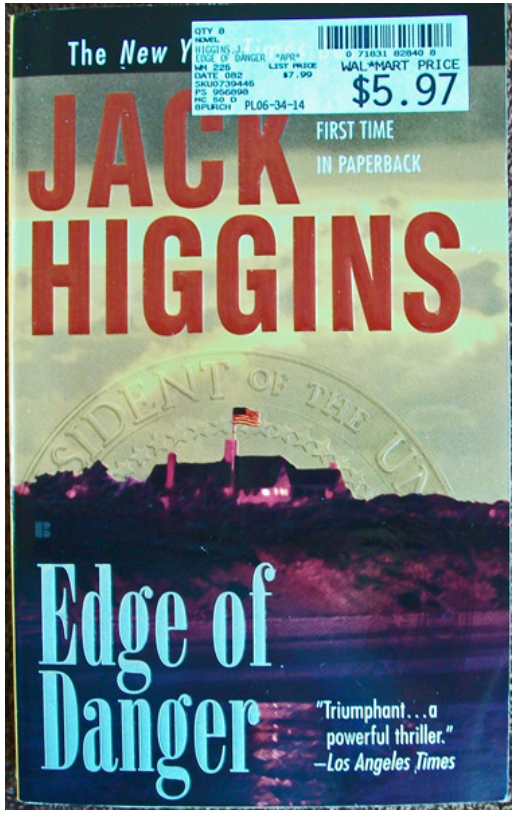


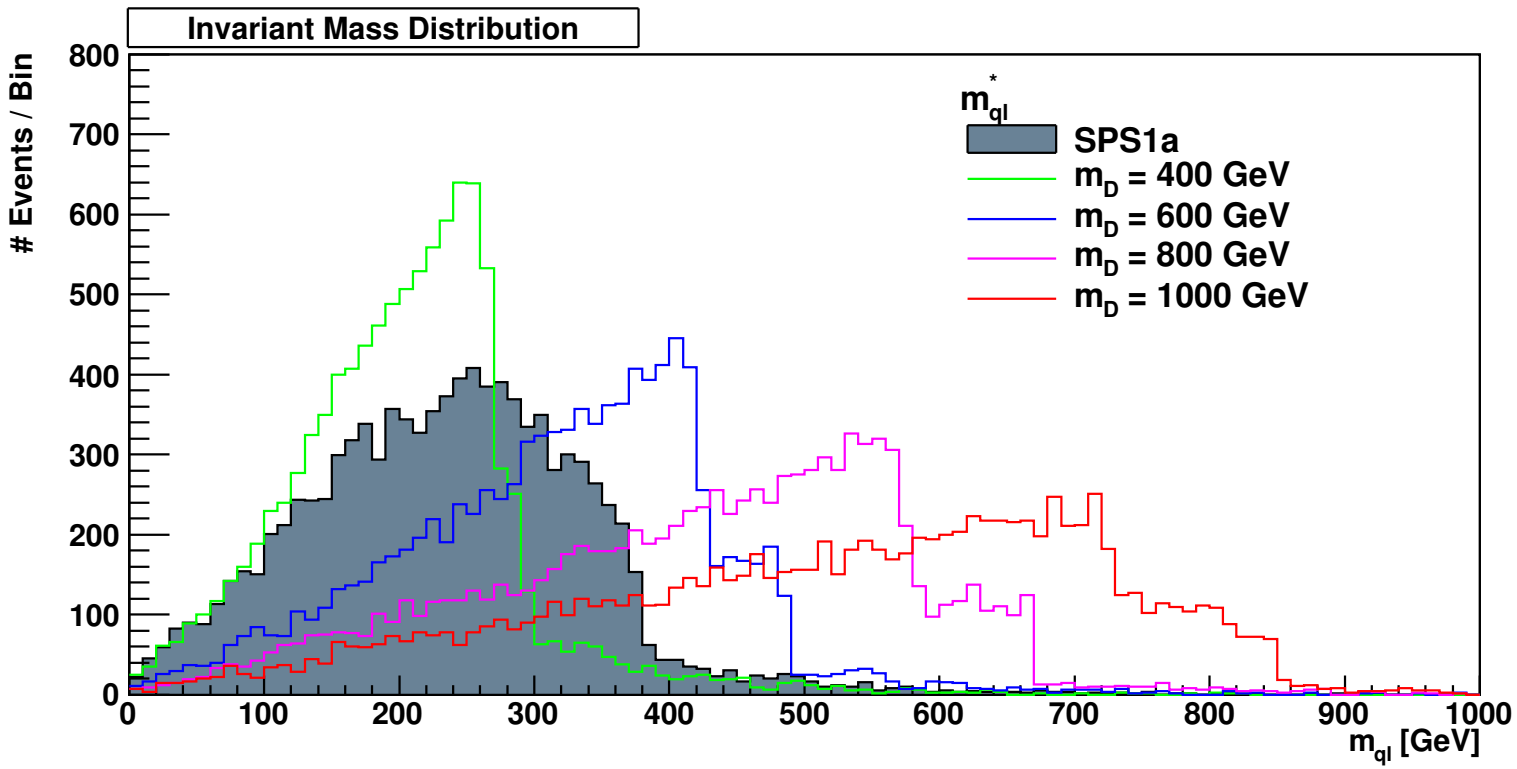
since we all try to find the

Thanks for listening!

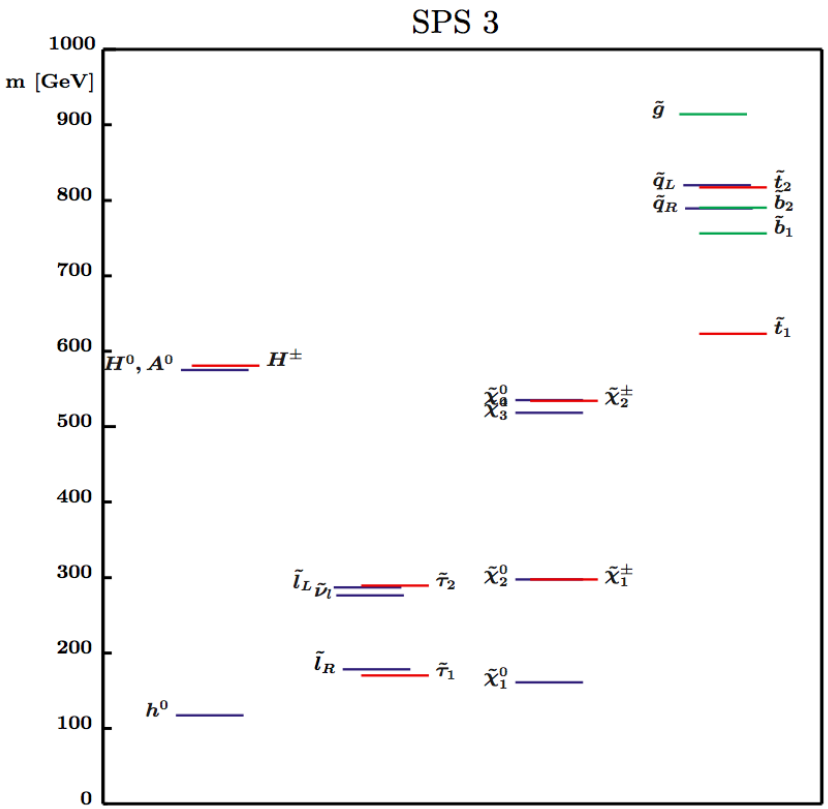
Backup

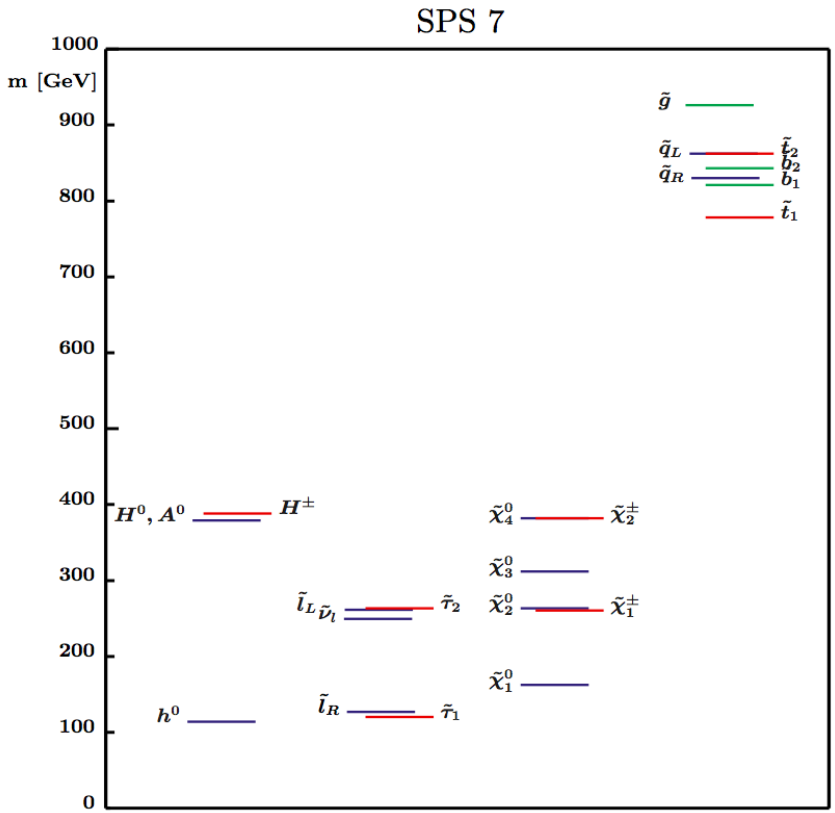
- alternative jet/lepton variables including endpoint features are e.g. m^*_{ql} or m_{qll}
- bonus: definition of m^*_{lq} intrinsically free of combinatorical issues (but still suffering from admixture of uncorrelated leptons)

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



Backup


SPS 3
m [GeV]
1000
900
800
700
600
500
400
300
200
100
0
$\tilde{g}$
$\tilde{q}_L$
$\tilde{t}_2$
$\tilde{q}_R$
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


SPS 7
m [GeV]
1000
900
800
700
600
500
400
300
200
100
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$\tilde{g}$
$\tilde{q}_L$
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H^0, A^0
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