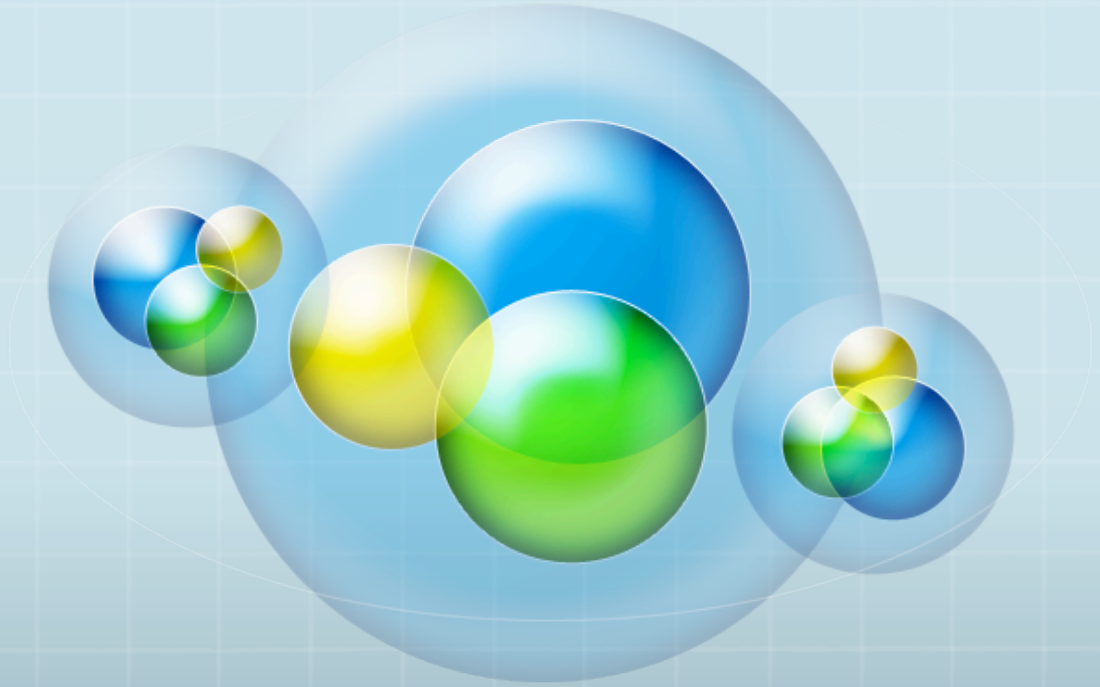

SUSY with unconventional collider signals

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Princeton University
Boost 2011

Second part of the title:

And Jets would help!

- "Heavy squark"

  J.F., David Krohn, Arun Thalapillil and Lian-Tao Wang

  1102.0302 (hep-ph) JHEP 11;

- "Stealth SUSY"

  J.F., Matthew Reece and Joshua Ruderman

  1105.××××

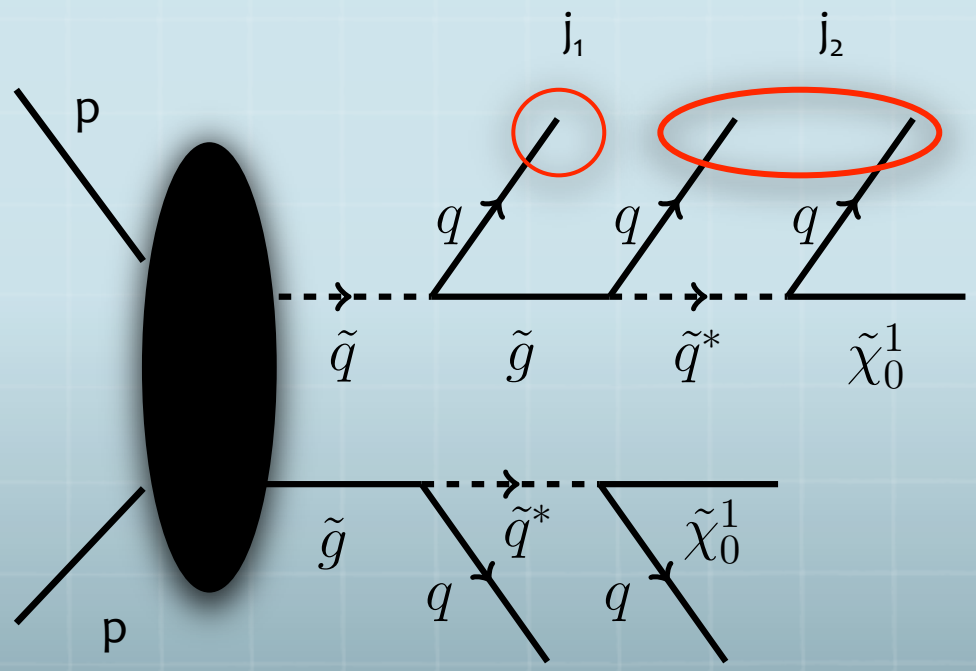
Heavy squark

- **The spectrum:**

a few TeV	———	$\tilde{u}, \tilde{d}$
$m_{\tilde{g}} < 1\,\mathrm{TeV}$	———	$\tilde{g}$
$\sim 100\,\mathrm{GeV}$	———	$\tilde{\chi}_0^1$

$$m_{\tilde{g}}/m_{\tilde{q}} < 0.3$$

- **Main goal: optimize search strategy for discovering heavy squarks and to assess the reach of the LHC in finding them.**



- Given $m_{\tilde{g}} \ll m_{\tilde{q}}$, gluino from squark decay is boosted and decay products form into a single jet with opening angle

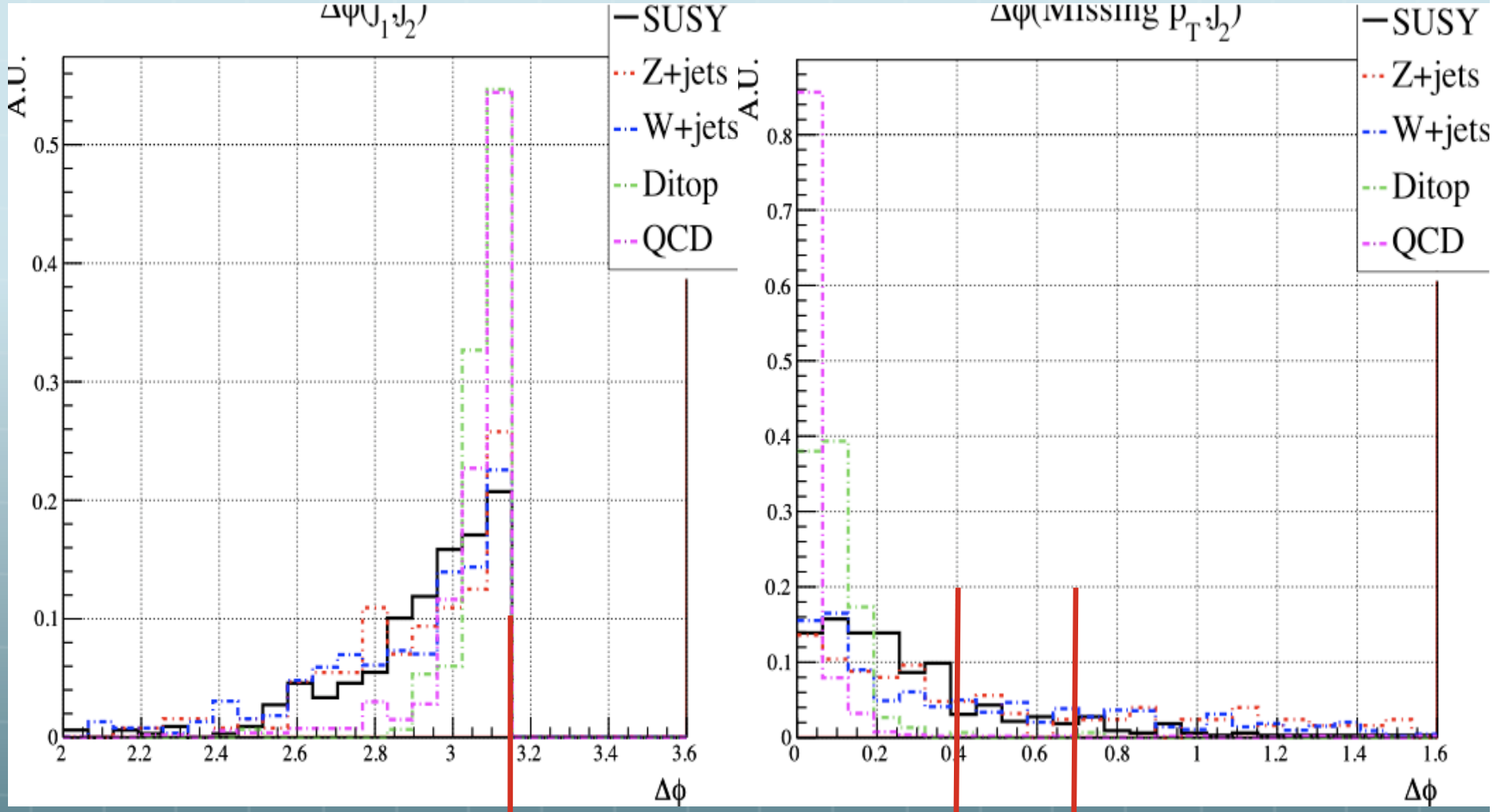
$$\Delta_R \sim \frac{m_{\tilde{g}}}{m_{\tilde{q}}}$$

- The leading two jets are from squarks and SUSY events are **di-jet like**!

- **Missing pT** mainly comes from boosted gluino and thus **aligned with the gluino jet**.

$$\Delta\phi(j_1, j_2)$$

$$\Delta\phi(p_T^{missing}, j_2)$$



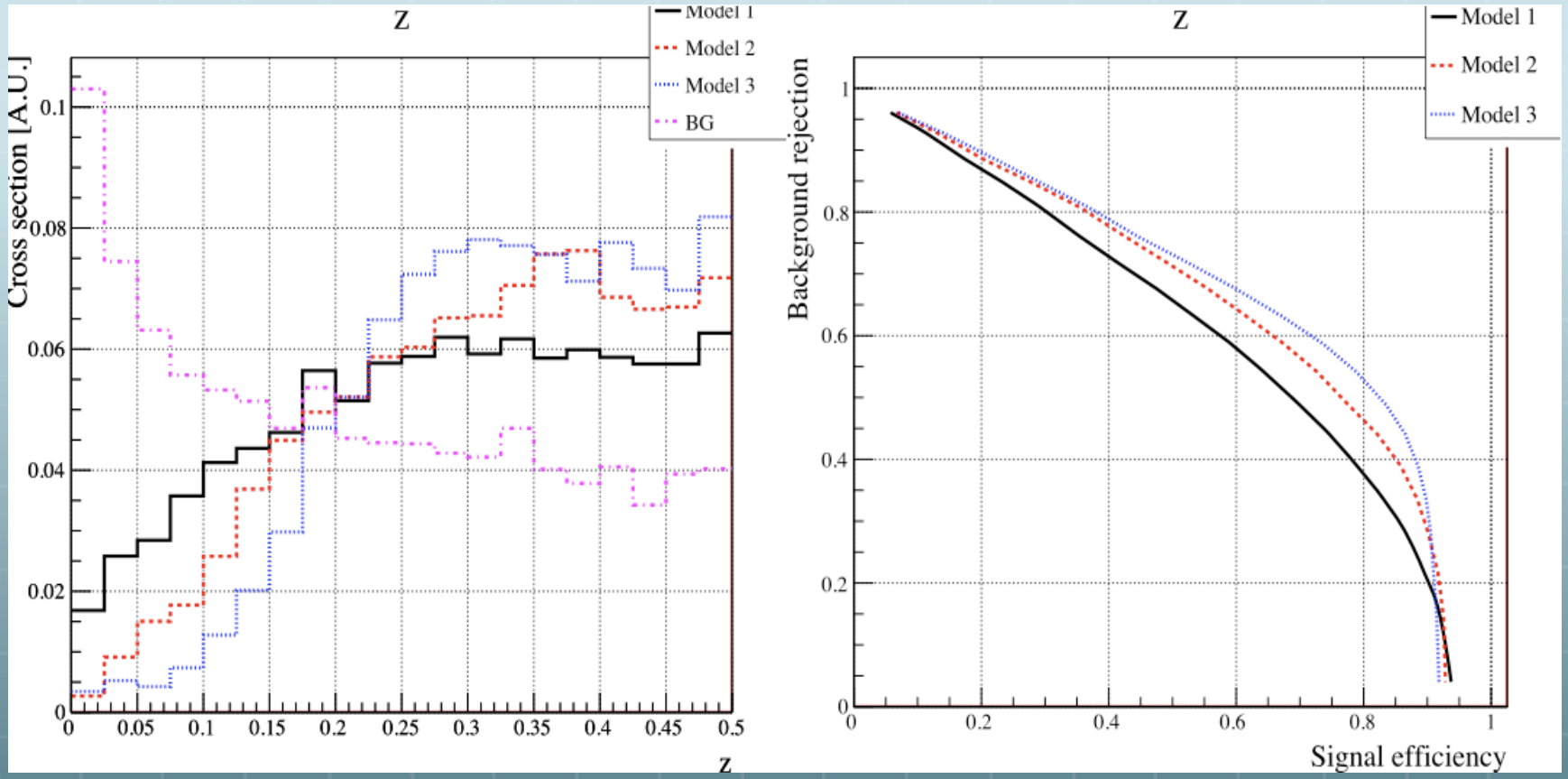
3.14

0.4 0.7

- No cut on how dijet-like the events are; No alignment cuts as they would kill both signal and background;
- Turn to jet substructure to differentiate between gluino jet and background jets!

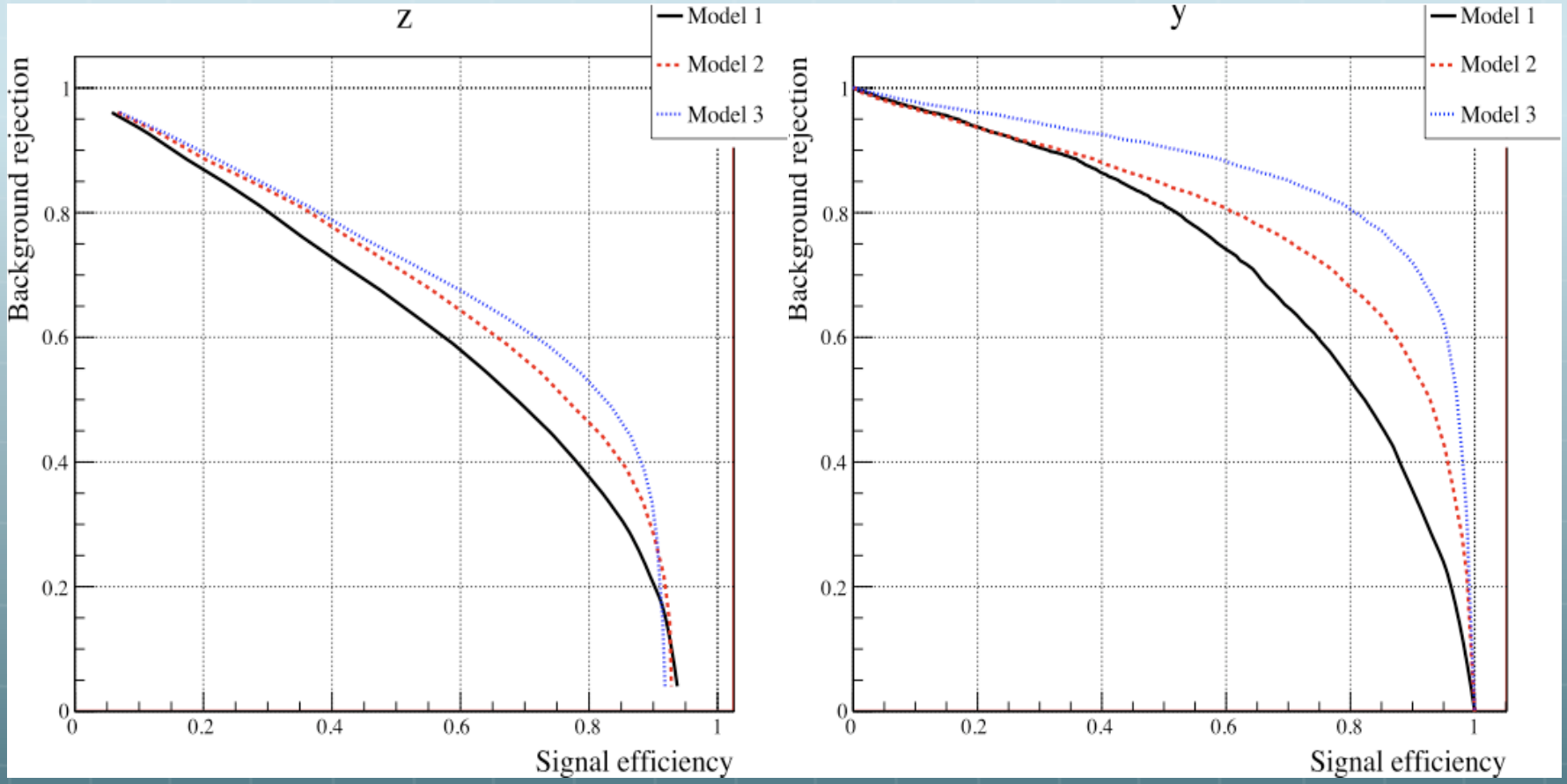
Energy share variable: Thaler, Wang 08

$$z = \frac{min(E_A, E_B)}{E_A + E_B}$$



Y- Splitter: Butterworth, Cox and Forshaw 02

$$y_{1\to 2} = \frac{d_{1\to 2}}{p_T^2}$$ Scale where a jet is resolved into two subjets $\mathcal{O}(m_{\tilde{g}})$



Significance

	Model 1	Model 2	Model 3
σ_S	0.97 (0.11)	1.01 (0.11)	0.68 (0.08)
$S/\sqrt{B}$	5.0 (4.9)	5.3 (4.9)	3.5 (3.6)

4 TeV squark(L =10 fb^-1)

5TeV(L=100 fb^-1)

	Model 1	Model 2	Model 3	$Z+J$	$W+J$	$t\bar{t}$	QCD
No cuts	4.26 (0.51)	3.78 (0.45)	1.78 (0.23)	-	-	-	-
Pre-selection (PS)	1.72 (0.27)	1.46 (0.23)	0.78 (0.14)	0.43	1.05	0.41	0.82
PS & $\Delta\phi(\not{E}_T, j) > 0.3$	0.67 (0.09)	0.47 (0.06)	0.31 (0.05)	0.24	0.54	0.01	0.03
PS & $y_{1\to 2} > 2 \cdot 10^{-3}$	1.13 (0.18)	1.15 (0.18)	0.73 (0.12)	0.07	0.32	0.18	0.17
PS & $y_{1\to 2} > 2 \cdot 10^{-3}$ & $p_T(j_3) > 100$ GeV	0.97 (0.16)	1.01 (0.16)	0.68 (0.11)	0.04	0.18	0.06	0.09

Stealth SUSY

- **So far Jet+ MET search at the LHC has already placed strong limits on the colored MSSM superpartners in the R-parity conserving scenarios**

ATLAS: $m_{\tilde{g}} > 600GeV \quad E_T^{missing} > 100GeV$

CMS: $m_{\tilde{g}} > 550GeV \quad E_T^{missing} > 150GeV$

- **The bounds have several known exceptions:**

R-parity violation, squeezing SUSY spectrum, long cascade decay chains

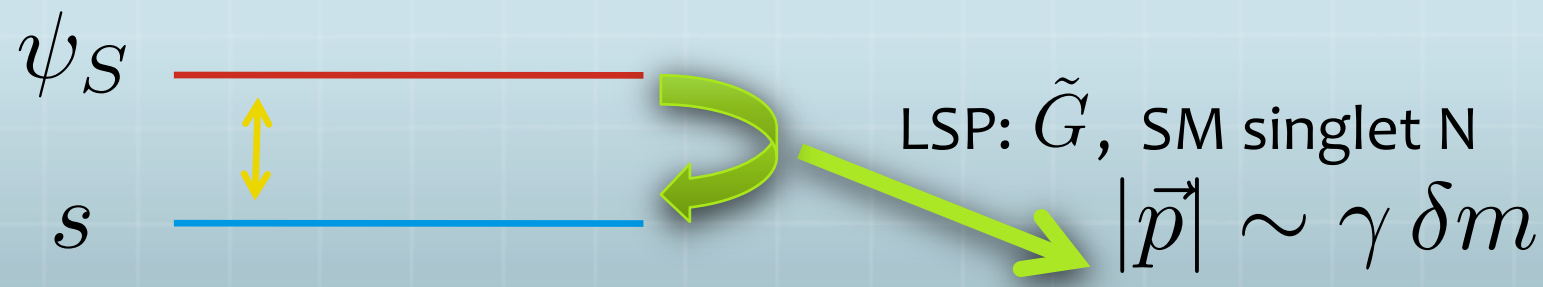
- A simple and natural exception: SUSY without MET

  No R-parity violation; SUSY hides SUSY

- A EW scale hidden sector with a naturally squeezed spectrum

- Simplest possibility: a chiral superfield S

- A simple and natural exception: SUSY without MET
- A EW scale hidden sector with a squeezed spectrum
- **Simplest possibility: a chiral superfield S**

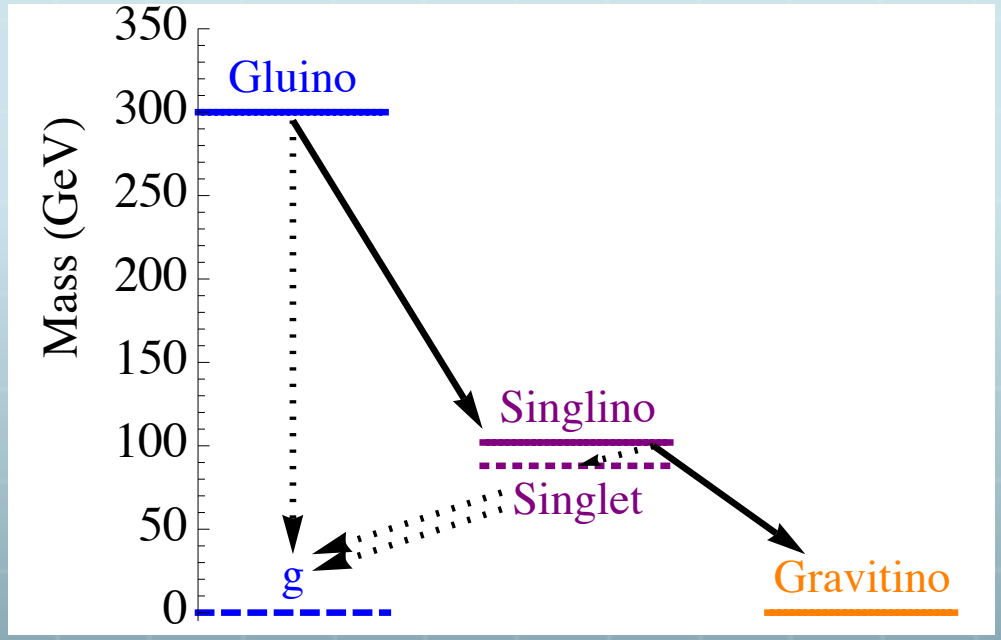


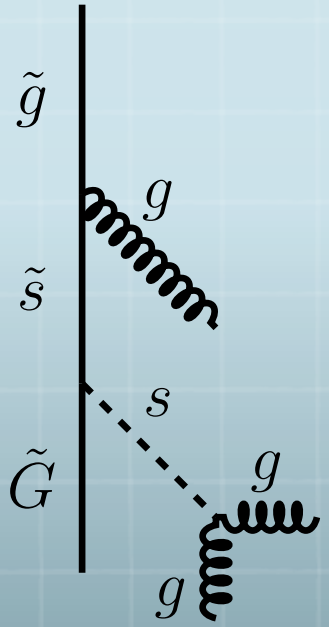
$$m_S \sim \mathcal{O}(100\, GeV)$$

$$\delta m \sim \epsilon\, m_{EW} \sim \mathcal{O}(10 GeV)$$

Small splitting inside the hidden sector could come from SUSY breaking transmitted through SM Higgs portal or additional EW scale SM charged messengers

A sample spectrum and decay





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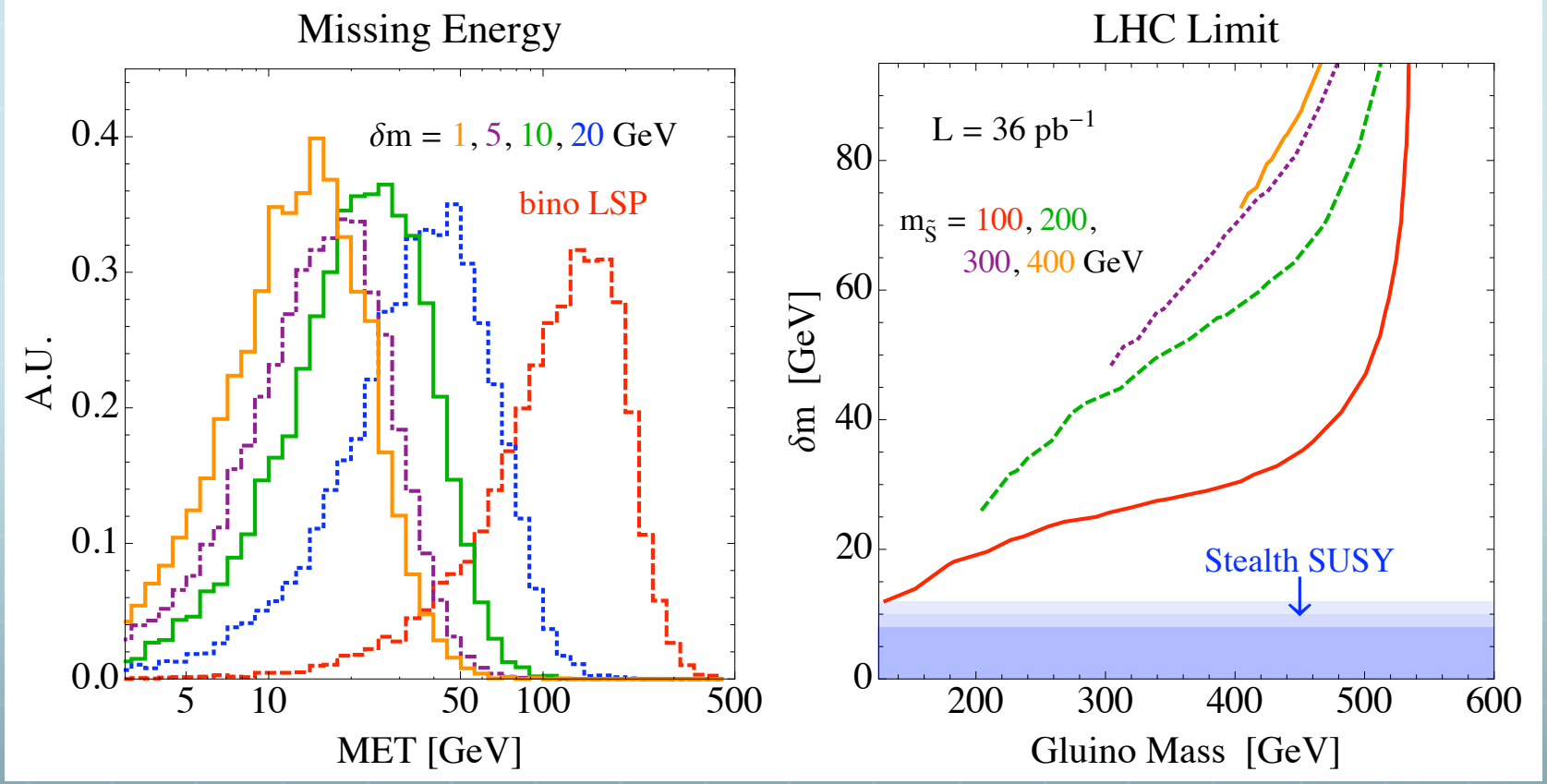
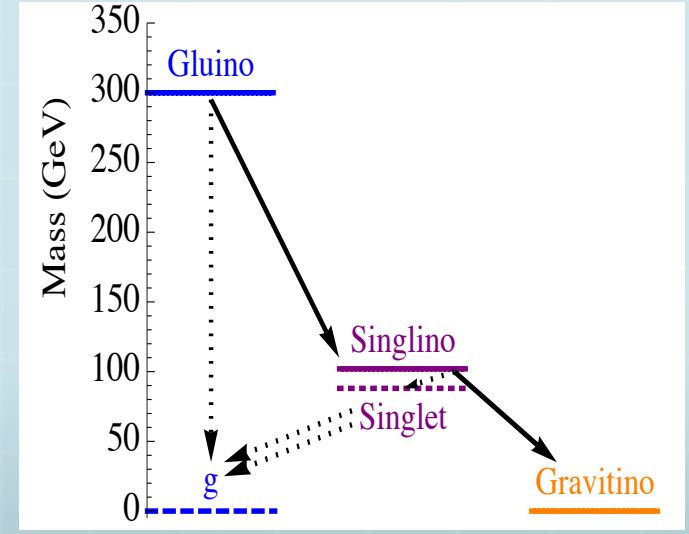
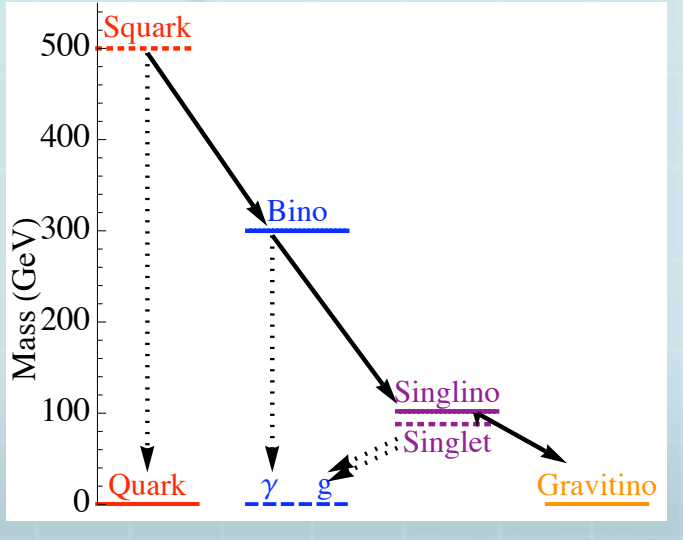


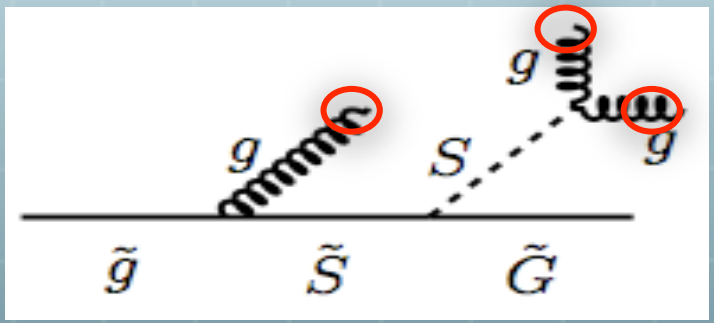
Bottom line:

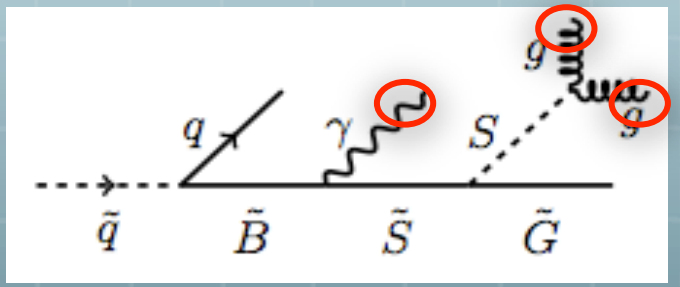
current limits do not apply to stealth SUSY with mass splitting smaller than 10 GeV !

False resonance of jets

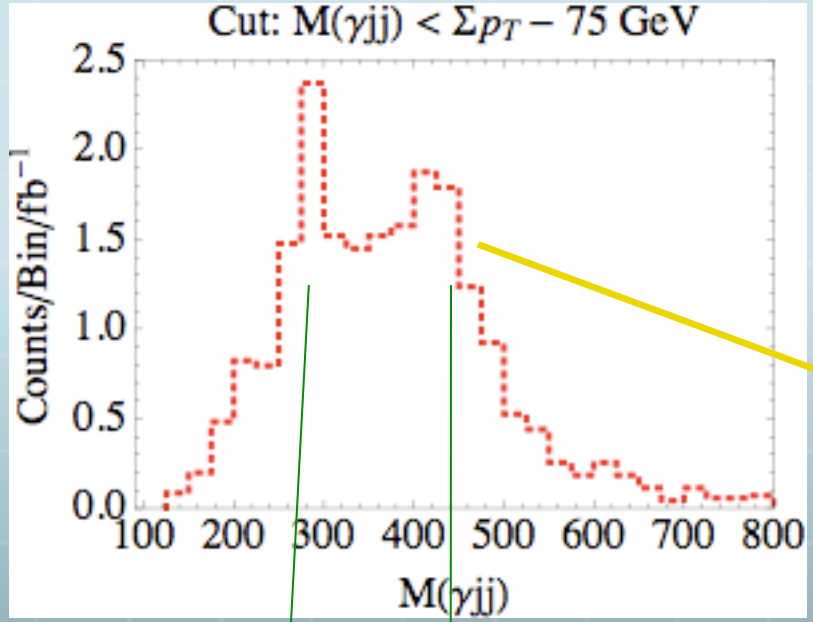


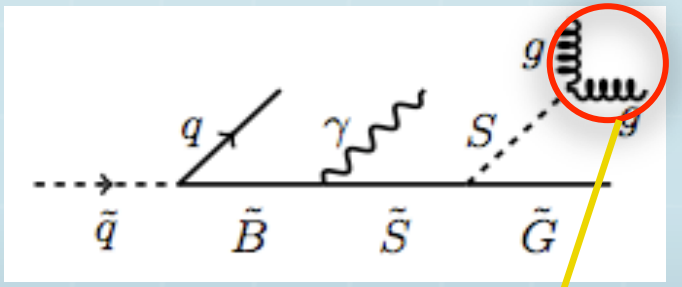






Search at CDF and CMS motivated by RPV on resonance of 3 jets also apply here! – See talks on Thursday





Two jets collimated into one

$\tilde{B}$ $\tilde{q}$

Substructure could help!

No conclusion now;
Wait for more
experimental inputs!

Backups

- **Pre-selection cuts:**

$$p_T(j1) > 1.5TeV$$
$$p_T(j2) > 400GeV$$
$$p_T^{missing} > 500GeV$$

Searching strategies

- **Displaced vertex:** $\tilde{s} \longrightarrow s + \tilde{G}$

Decay length ranging from mm to several cm;

- **High multiplicity (of b jets) : Model dependent**

$$\begin{tikzcd}
\tilde{g} \arrow[r] \arrow[dr] & \tilde{b} \arrow[r] \arrow[dr] & \tilde{B} \arrow[r] \arrow[dr] & \tilde{s} \arrow[r] & s + \tilde{G} \arrow[dr] & \\
& b & b & h \arrow[d] & & b + \bar{b} \\
& & & b + \bar{b} & &
\end{tikzcd}$$

In model where S mixes with SM Higgs