Broadening the Reach for New Physics at the LHC with Jets and MET

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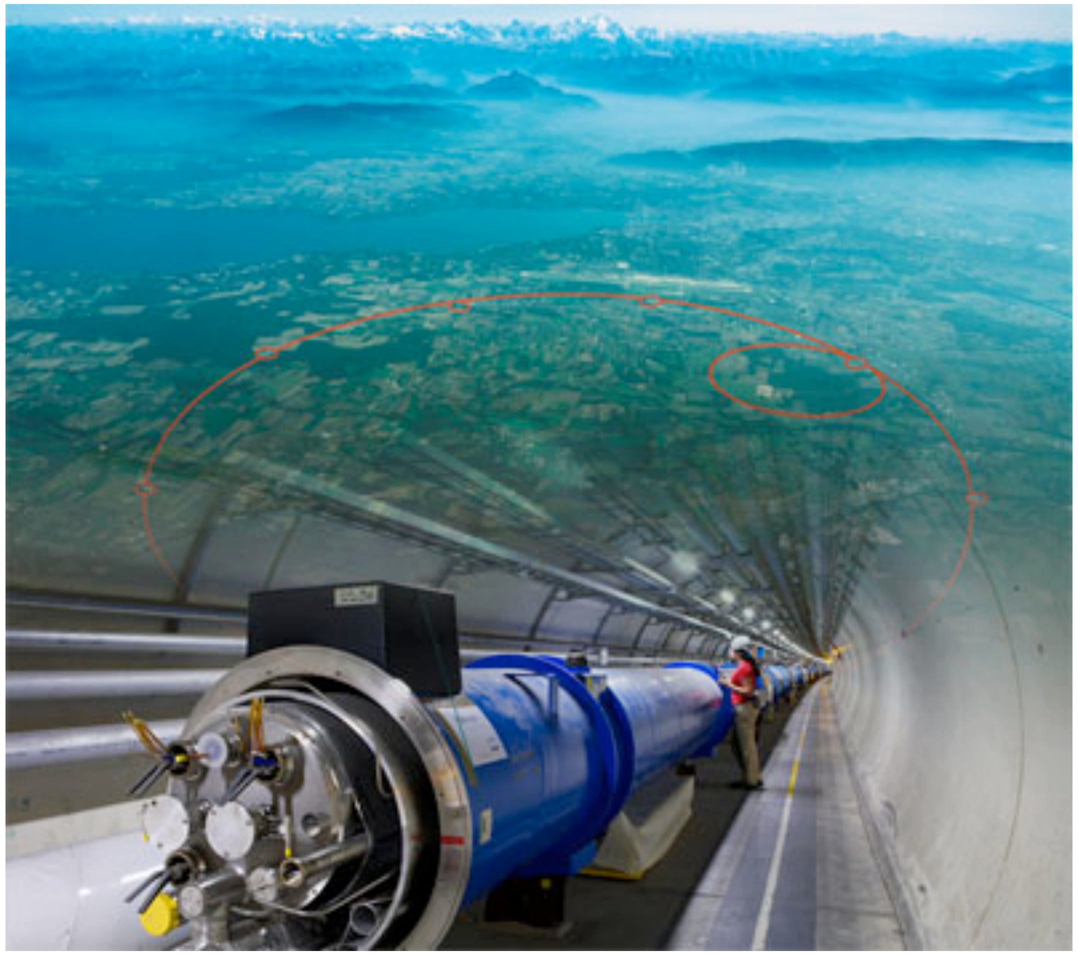
arXiv:1003.3886, 1005.xxxx

Pheno '10

NATIONAL ACCELERATOR LABORATORY



The LHC has finally arrived!

Giving particle physicists plenty of puzzles to grapple with

Jets and MET

- Probe of solutions to the hierarchy problem.
- Candidates for Dark Matter.

To be honest...

Outline

- Universal signatures to distinguish signal from background.
- What a 7 TeV LHC can achieve at 1 fb^{-1}.

- Universal signatures to distinguish signal from background.

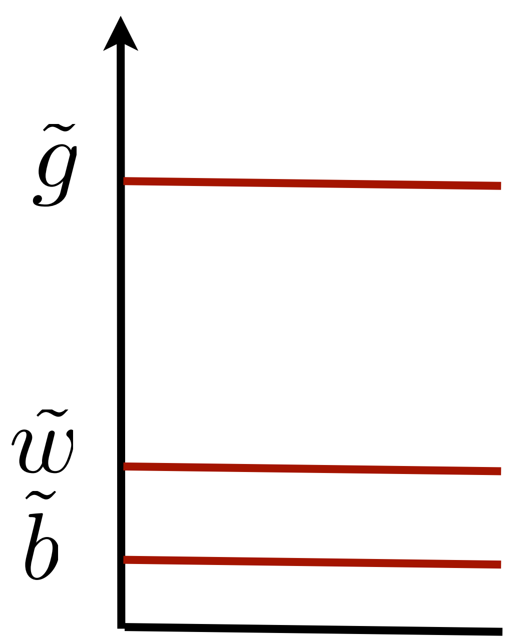
Spectrum in Different Theories

MSSM

High Cut-Off

Large Mass Splittings

$$\delta m = \frac{g^2}{16\pi^2}\, m \,\log \Lambda$$

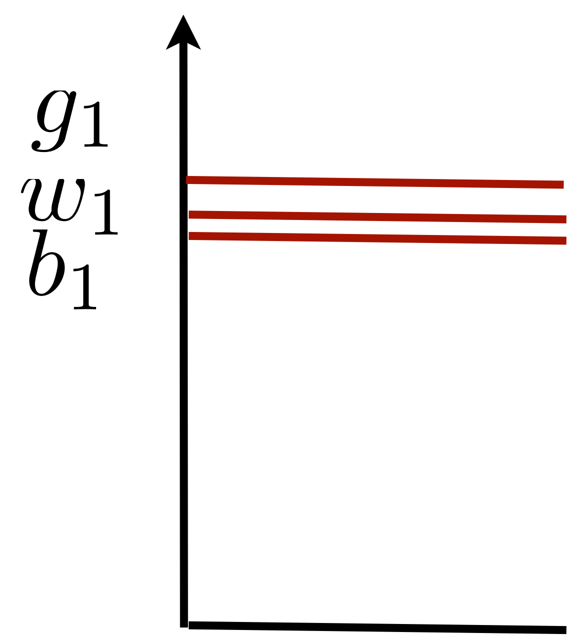


UED

Low Cut-Off

Small Mass Splittings

$$\delta m = \frac{g^2}{16\pi^2}\, \Lambda$$

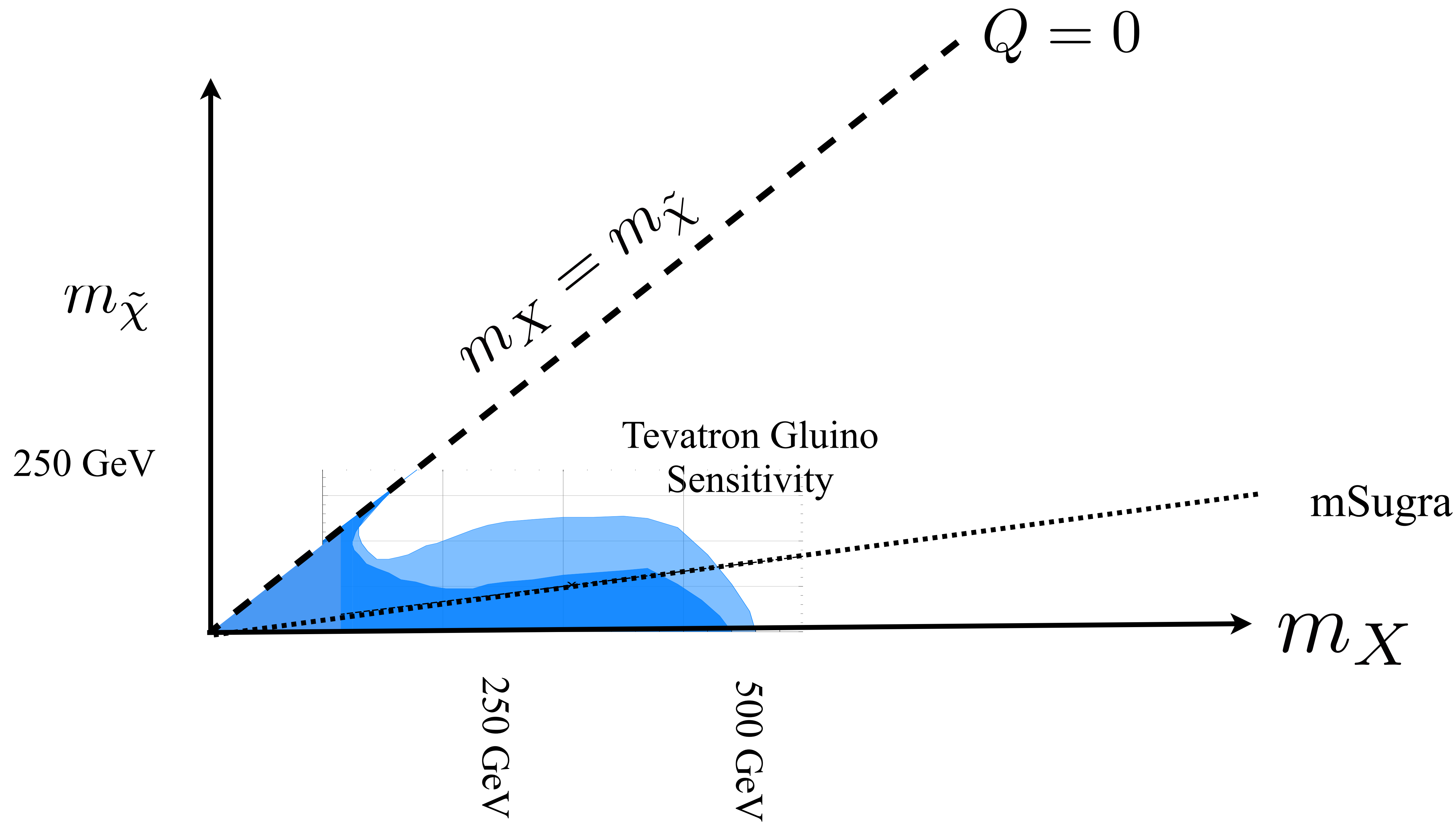


Casting a Wide Net

Kinematics matters more than spin or A-terms

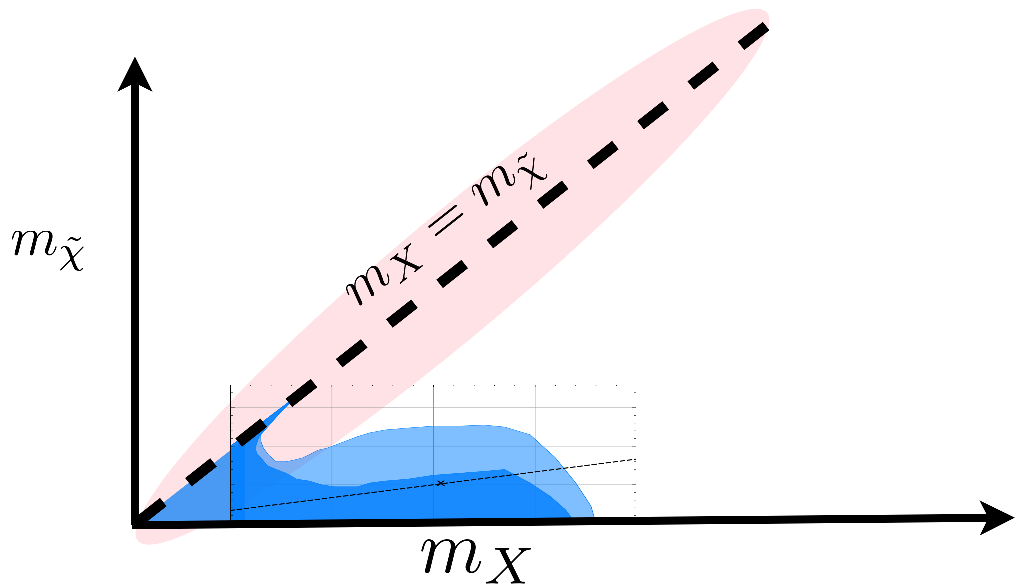
Alwall, Le, Lisanti, Wacker (0803.0019)

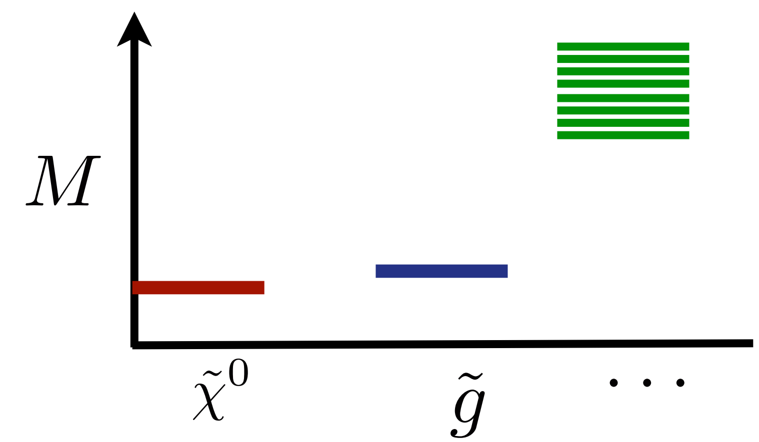
$$Q = m_X - m_{\tilde{\chi}}$$
$$X = \tilde{g}, \tilde{q}, \ldots$$



Radiation

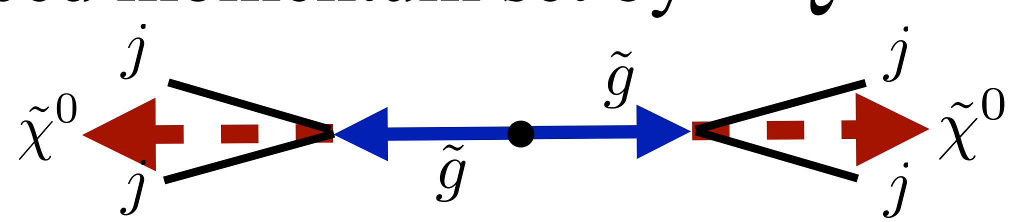
Degenerate spectra require radiation to generate signal





UED-like Theories

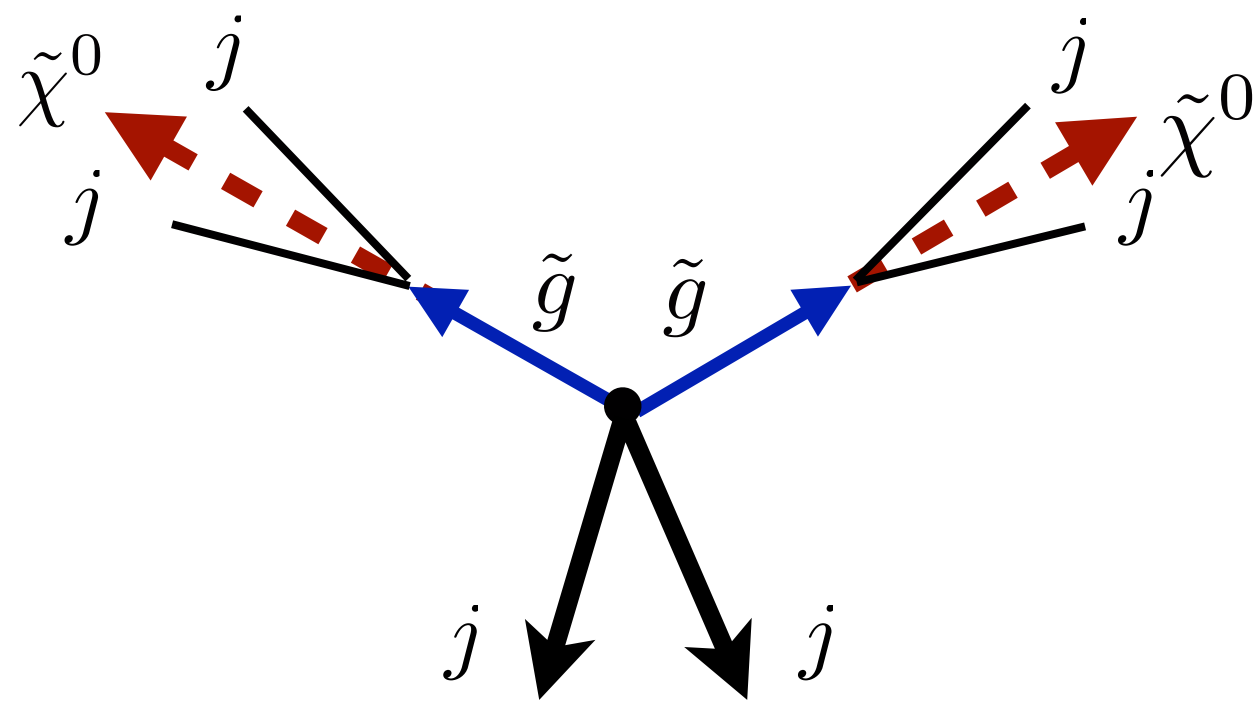
Unbalanced momentum set by $Q = m_{\tilde{g}} - m_{\tilde{\chi}}$



As p_T of gluino increases,
Final state jets get harder (and eventually merge),
but won't gain significant MET

Radiation

Radiation unbalances LSP's momentum



MET is generated by radiated jets

Without extra jets, signal is invisible

Matching of Matrix Elements with Parton Showers

Needed to compute additional radiation

SM Backgrounds:

$pp \to W^{\pm}/Z^0 + 1j$ $\quad$ $pp \to W^{\pm}/Z^0 + 2j$ $\quad$ $pp \to W^{\pm}/Z^0 + 3j$

$pp \to t\bar{t}$ $\quad$ $pp \to t\bar{t} + 1j$ $\quad$ $pp \to t\bar{t} + 2j$

Signals, $X \in \{\widetilde{g}, \widetilde{q}\}$:

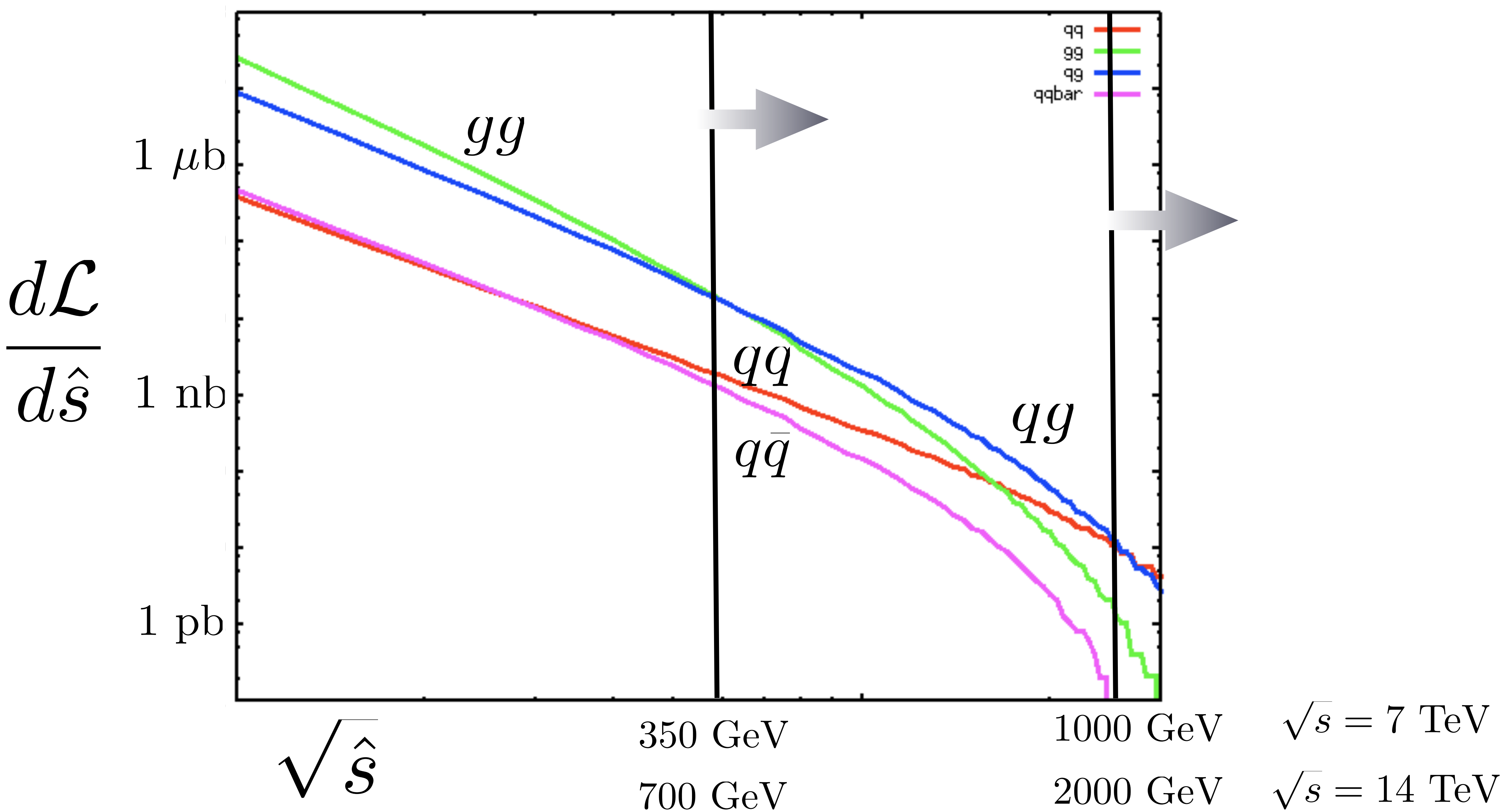
$pp \to XX$ $\quad$ $pp \to XX + 1j$ $\quad$ $pp \to XX + 2j$

New Initial States

Possible at higher order

$$gg, q\bar{q} \to 2\tilde{g} + 0^+ j \qquad gq \to 2\tilde{g} + 1^+ j \qquad qq \to 2\tilde{g} + 2^+ j$$

Parton Luminosities



- What the LHC can achieve at 7 TeV with 1 fb^{-1}.

Signals

Different "modules" used to explore generality

"Gluinos"

Octet
Majorana Fermions

$$\tilde{g} \rightarrow q\bar{q}\chi^0$$

Large color, High Jet Multiplicity, High MET

$$\tilde{g} \rightarrow q\bar{q}\chi'^0 \rightarrow q\bar{q}(q\bar{q}\chi^0)$$

Large color, High Jet Multiplicity, Lower MET

$$m_{\tilde{\chi}'} = \frac{1}{2}(m_{\tilde{\chi}} + m_{\tilde{g}})$$

"Squarks"

(6 copies of)
Triplet Scalars

$$\tilde{q} \rightarrow q\tilde{\chi}^0$$

Small color, Low Jet Multiplicity

Search Strategy

	Selection Criteria for Different Jet Multiplicity Searches			
	$1j + \not{E}_T$	$2j + \not{E}_T$	$3j + \not{E}_T$	$4^+j + \not{E}_T$
j_1	$\geq 400\,\mathrm{GeV}$	$\geq 100\,\mathrm{GeV}$	$\geq 100\,\mathrm{GeV}$	$\geq 100\,\mathrm{GeV}$
j_2	$< 50\,\mathrm{GeV}$	$\geq 50\,\mathrm{GeV}$	$\geq 50\,\mathrm{GeV}$	$\geq 50\,\mathrm{GeV}$
j_3	$< 50\,\mathrm{GeV}$	$< 50\,\mathrm{GeV}$	$\geq 50\,\mathrm{GeV}$	$\geq 50\,\mathrm{GeV}$
j_4	$< 50\,\mathrm{GeV}$	$< 50\,\mathrm{GeV}$	$< 50\,\mathrm{GeV}$	$\geq 50\,\mathrm{GeV}$

The abundance of IS/FS radiation means we only need a 4^+j and MET search.

Unlike at the Tevatron, the lower multiplicity searches were found to be redundant.

Designing the searches

Three sets of searches

"High MET"

$\not{E}_T > 400\text{GeV}$

$\alpha_{RTS} > 0 \quad (\text{No Cut})$

$H_T > 600, 900, 1200$ GeV

"α_{RTS}"

$\not{E}_T > 300\text{GeV}$

$\alpha_{RTS} > 0.2$

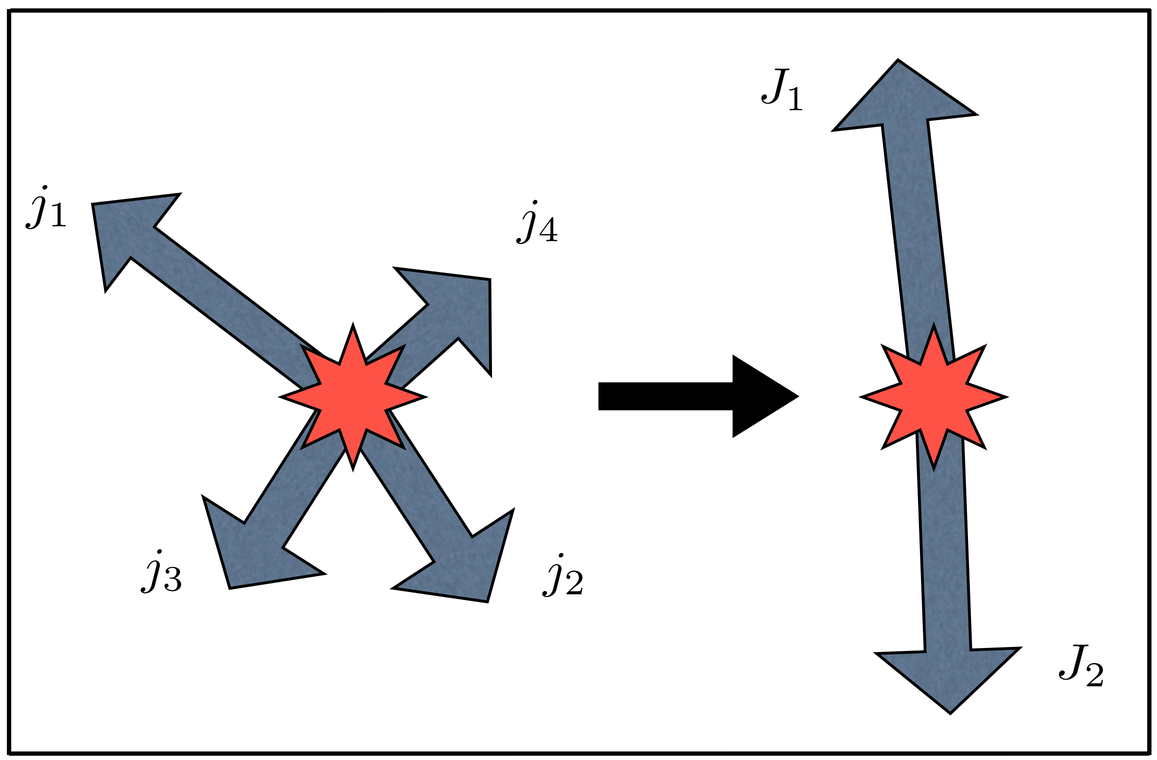
$H_T > 600, 900, 1200$ GeV

"Base Search"

$\not{E}_T > 200\text{GeV}$

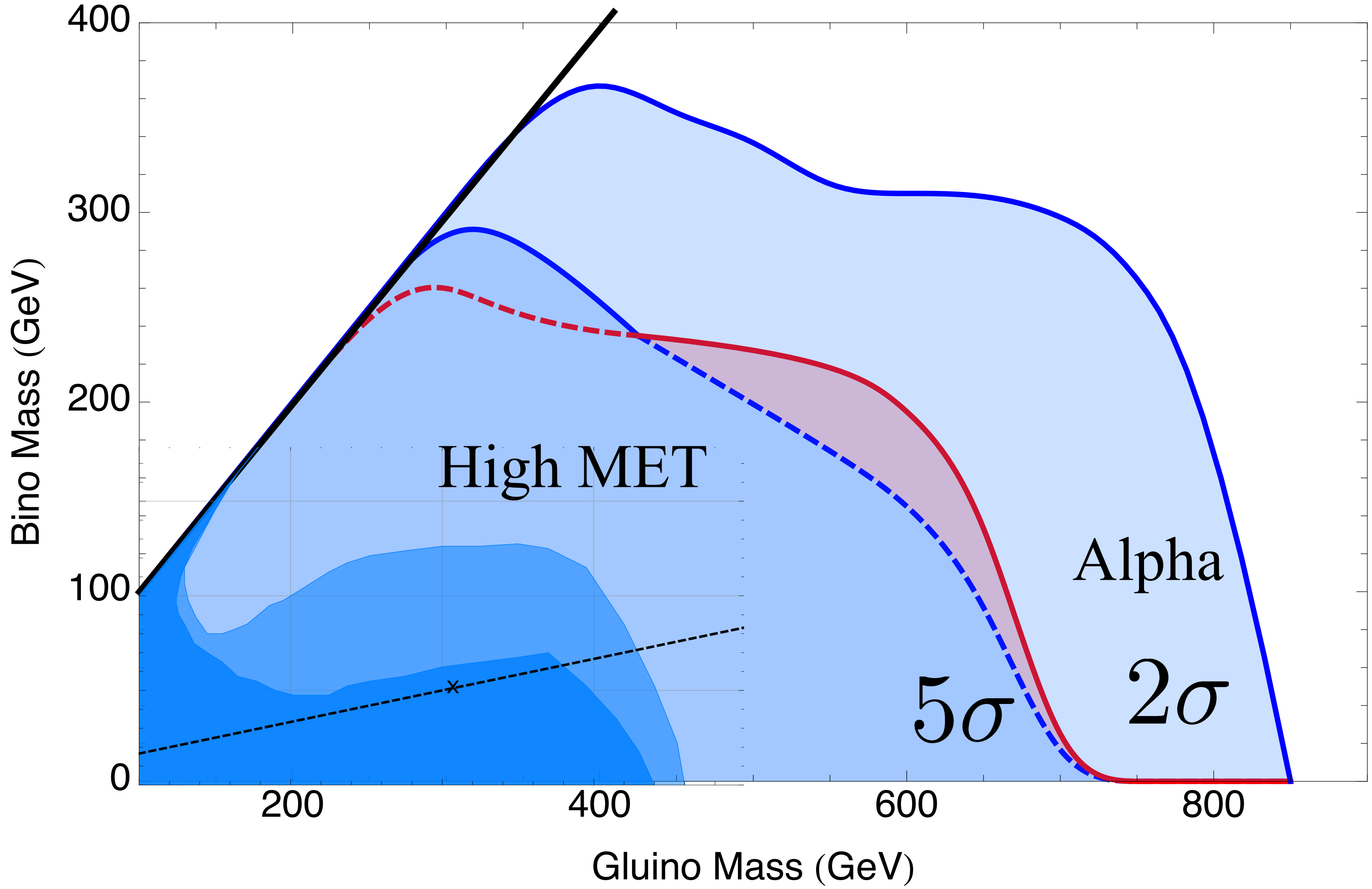
$H_T > 300, 600, 900$ GeV

$$\alpha_{RTS} = \sqrt{\frac{p_{T,j2}}{m_{j1,j2}}}$$



Direct Gluino Decays

$$pp \to \tilde{g}\tilde{g} + X \to (q\bar{q}\tilde{\chi}^0)(q\bar{q}\tilde{\chi}^0) + X$$

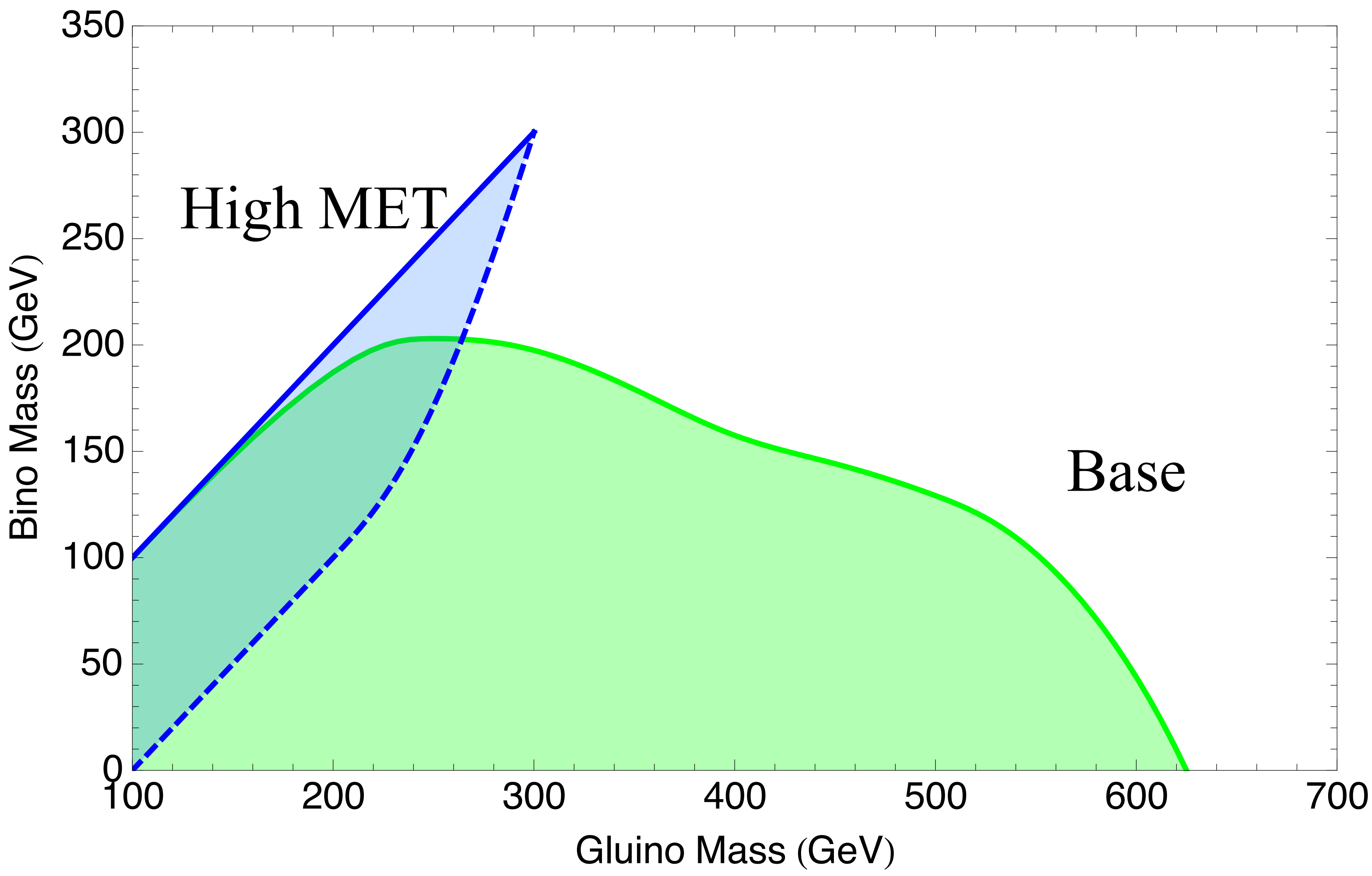


$$5\sigma : S > 5\sqrt{\sigma_{stat}^2 + (0.3 * B)^2}$$

Doubling the reach in the next year!

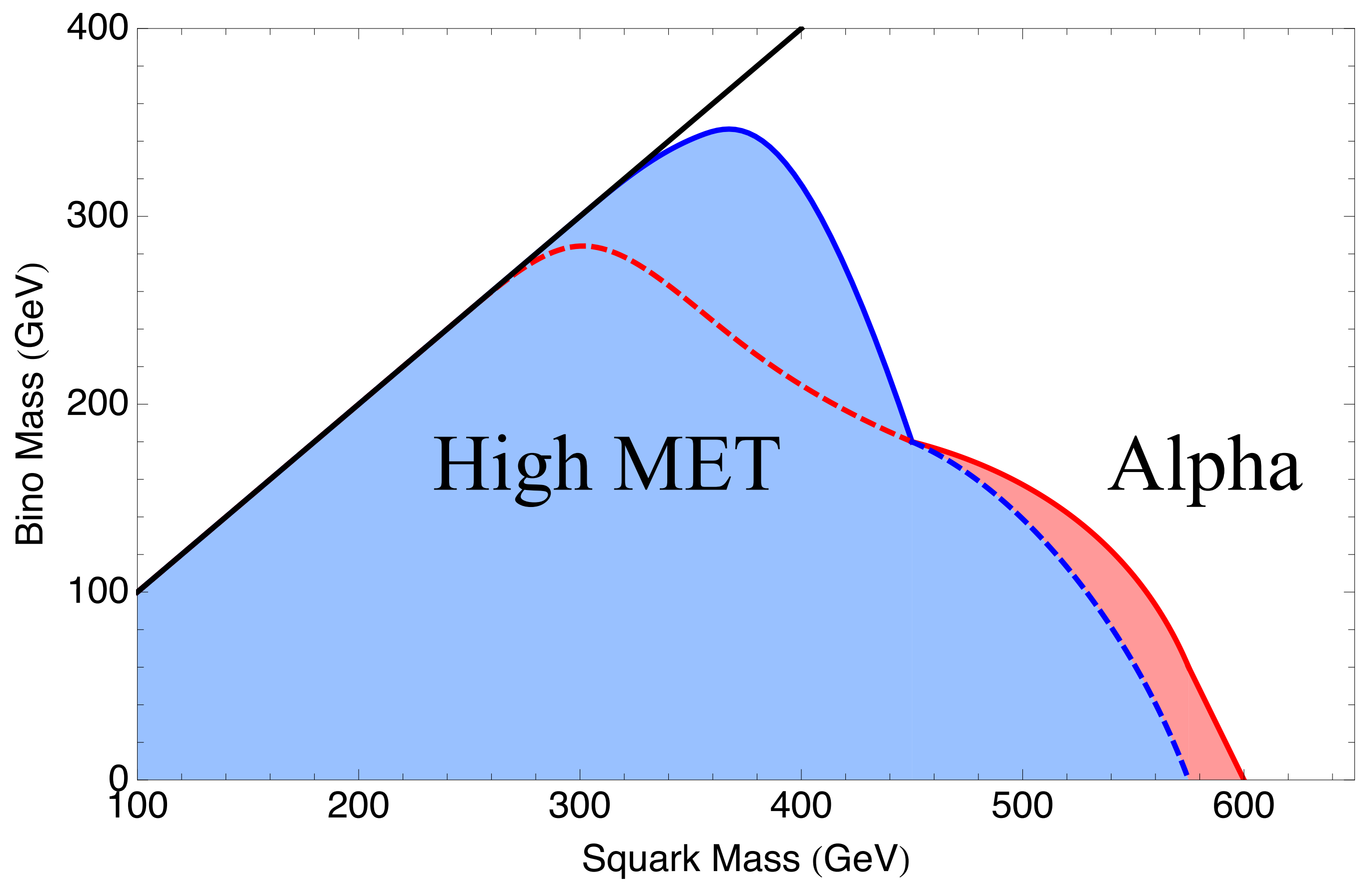
One-step Cascade Decaying Gluinos

$$pp \to \widetilde{g}\widetilde{g} + X, \quad \widetilde{g} \to qq^{'}\chi^{'}, \quad \chi^{'} \to qq^{''}\chi_0$$



14 TeV LHC result: Directly Decaying Squarks

$$pp \to \tilde{q}\bar{\tilde{q}} + X, \quad \tilde{q} \to q\chi_0$$



Multijet search more effective than a two-jet and MET search

Conclusions

A simple search strategy covering wide classes of theories possible

A 7 TeV LHC can double our reach reach by end of next year!