Looking For Sleptons... In Unusual Places.

Work done with Lian-Tao Wang and Tom Hartman

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- If SUSY is to address the naturalness problem, the scale of SUSY breaking must be the TeV scale which implies that superpartners would be produced at the LHC. We would like to infer as many parameters of the BTSM masses and couplings as we possibly can, and a hadron collider makes our lives somewhat difficult.

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- In particular, in many SUSY scenarios sleptons will not be produced copiously at the LHC and it can be difficult to infer their existence, let alone measuring their properties.

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- In the following we will consider non-minimal scenarios where we might hope to get a better look at sleptons.

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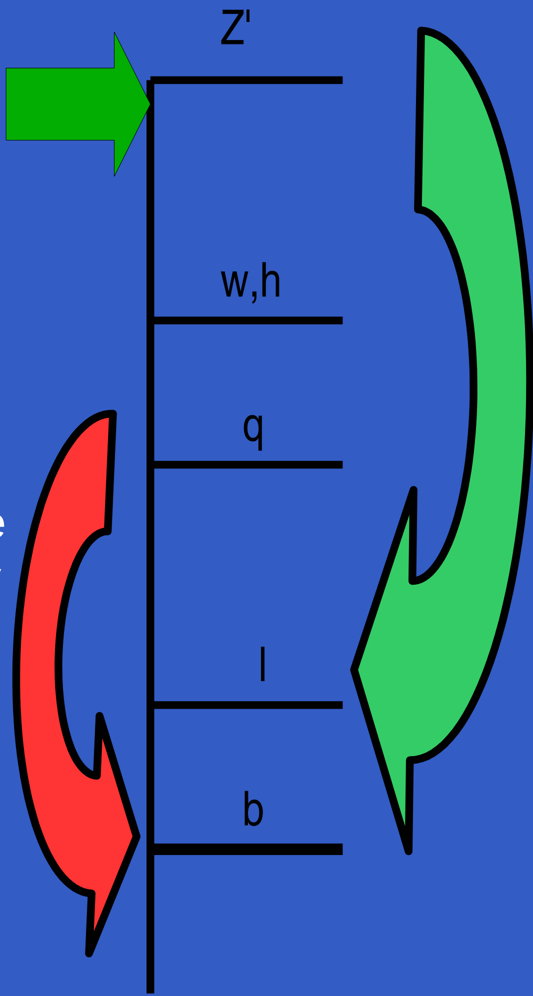
- Since $B-L$ is the only non-anomalous symmetry of the SM, we will consider a gauged $B-L$ symmetry in most of the remainder of the talk. In particular we will be interested in the effects of $B-L$ breaking near the TeV scale such that the gauge boson can be resonantly produced.



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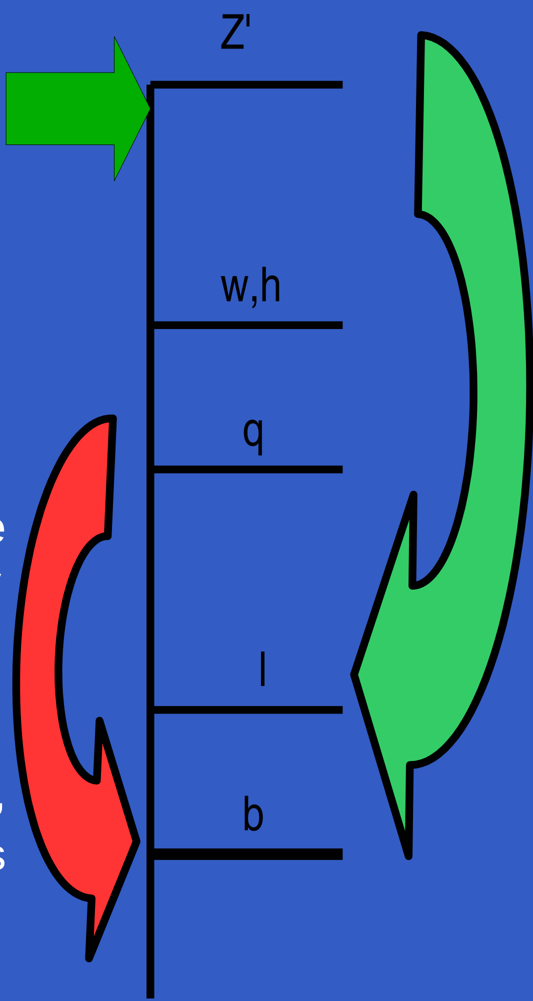
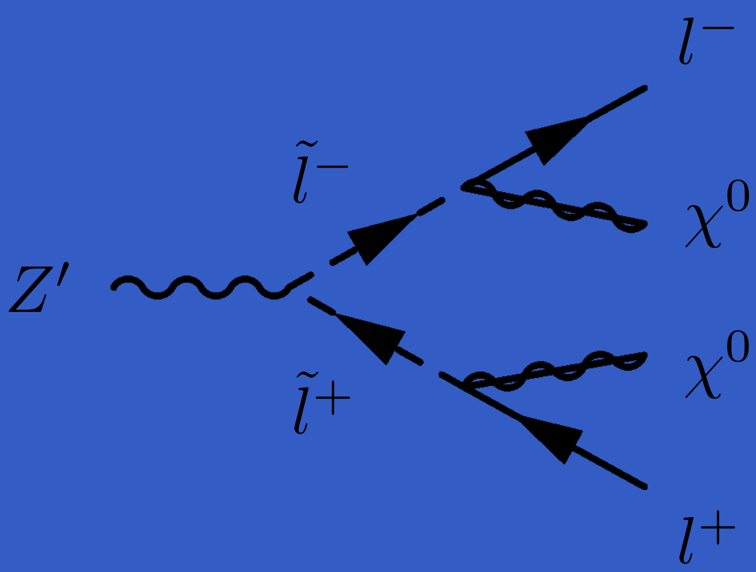
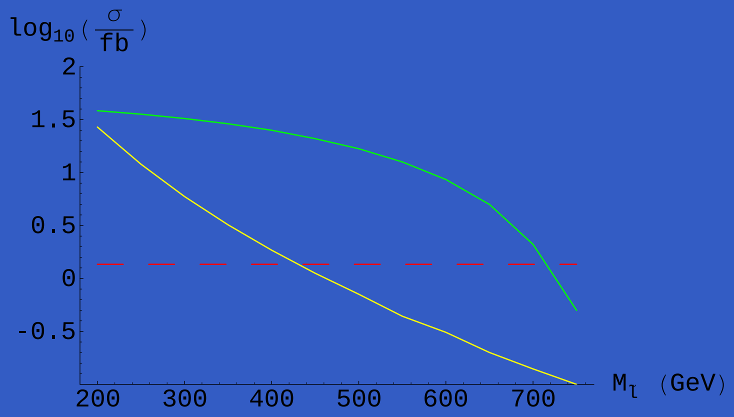
- In fact, one can think of many $U(1)$ extensions of the SM, and we will also consider these more general scenarios in parts of our analysis.



Discovery



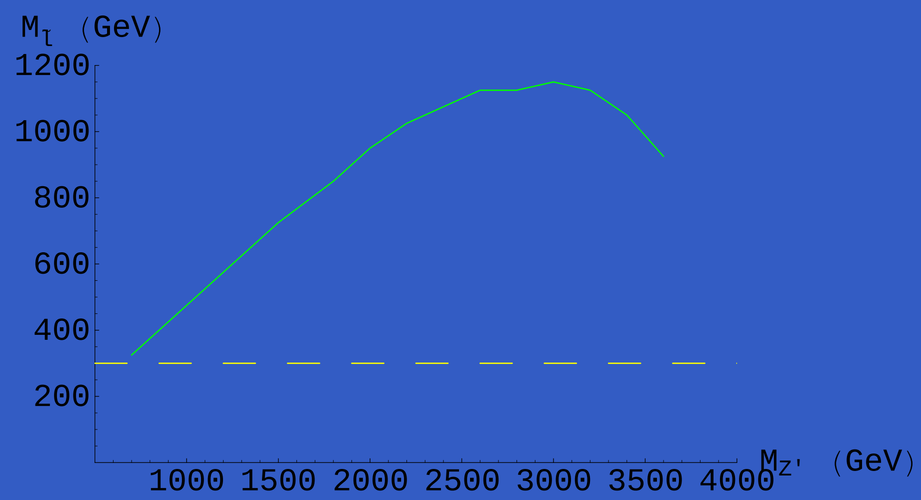
What We Hope to Gain



In this part of the talk we will be interested in what ranges of masses and coupling will enable us to discover the presence of sleptons with a Z' and how much better we can do compared to SUSY alone.

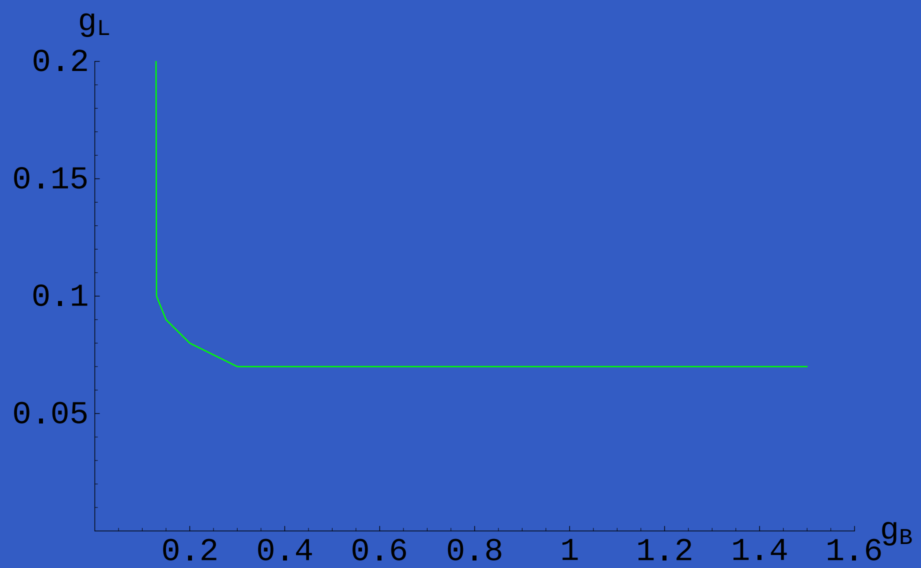
Our benchmark scenario has a $\tilde{b}$ LSP at $100\ \mathrm{GeV}$ and a Z' at $1.5\ \mathrm{TeV}$, everything else being heavy. Varying the mass of the sleptons we display the cross section (1 flavor) for slepton production through the Z' (green), direct production through Z^*/γ^* (yellow), and the dominant background diboson$\rightarrow$ $e^+\ e^-\ 0j\ MET > 150\ \mathrm{GeV}$ (red).

Reach: Masses



The presence of the Z' gives us a much larger window of slepton masses that lead to discovery. For various masses of the Z' we display the 5σ discovery threshold (at $100\ \mathrm{fb}^{-1}$) for the slepton mass (green curve), to be compared with direct production through Z^*/γ^* (yellow dashed line). Our background analysis is done with $\sqrt{N}$ statistics.

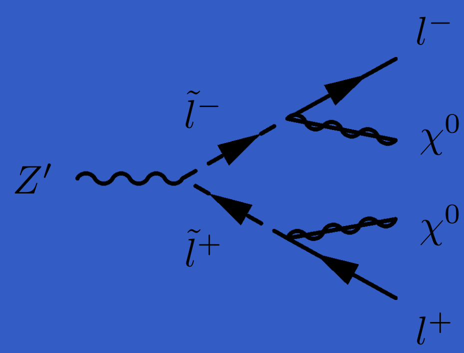
Reach: Couplings



Going beyond a Z'_{B-L} we display the slepton discovery reach (5σ) at $100\ \mathrm{fb}^{-1}$ for a vector which couples with different strengths to baryons and leptons. The sleptons are taken to be at $400\ \mathrm{GeV}$, just beyond the reach in an MSSM scenario and the additional vector is at $1.5\ \mathrm{TeV}$.

Measurement

Introduction



- In this part of the talk we will be more ambitious and try to measure slepton masses. In our benchmark scenario, the channel $Z' \to \tilde{l}^- \, \tilde{l}^+ \to l^- \, l^+ \, \chi_1^0 \, \chi_1^0$ has a large kinematic ambiguity (we will consider a more interesting scenario in a moment) and we would like to know whether there are still any mass measurements we can extract from the data.
- We will utilize the transverse mass m_{T2} introduced by Barr, Lester and Stephens

m_{T2}: Theory

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- If we knew the missing p_T of the individual χ^0s and m_{χ^0} then we could calculate

$$m_T^2(\mathbf{p}_T^l, \mathbf{p}_T^{\chi^0}; m_{\chi^0}) \equiv m_{\chi^0}^2 + m_l^2 + 2(E_T^{\chi^0} E_T^l - \mathbf{p}_T^{\chi^0} \cdot \mathbf{p}_T^l)$$

for each branch and we would have

$$m_{\tilde{l}}^2 > \mathrm{Max}(\mathrm{m_T^2}(\mathbf{p}_\mathrm{T}^{\mathrm{l}_1}, \mathbf{p}_\mathrm{T}^{\chi_1^0}; \mathrm{m}_{\chi^0}), \mathrm{m_T^2}(\mathbf{p}_\mathrm{T}^{\mathrm{l}_2}, \mathbf{p}_\mathrm{T}^{\chi_2^0}; \mathrm{m}_{\chi^0})).$$

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- However, since we only know the total $\mathbf{p}_T$ the best we can do is to scan all possible values

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- Thus one obtains a lower bound for $m_{\tilde{l}}$ by doing this for each event and taking the strongest bound.

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- Unfortunately we usually do not even know m_{χ^0} and m_{T2} is defined as

$$m_{T2}^2(M) \equiv \mathrm{Min}_{\not{p}_\mathrm{T}^1 + \not{p}_\mathrm{T}^2 = \not{p}_\mathrm{T}} (\mathrm{Max}(\mathrm{m}_\mathrm{T}^2(\mathbf{p}_\mathrm{T}^{\mathrm{l}_1}, \mathbf{p}_\mathrm{T}^{\chi_1^0}; \mathrm{M}), \mathrm{m}_\mathrm{T}^2(\mathbf{p}_\mathrm{T}^{\mathrm{l}_2}, \mathbf{p}_\mathrm{T}^{\chi_2^0}; \mathrm{M}))).$$

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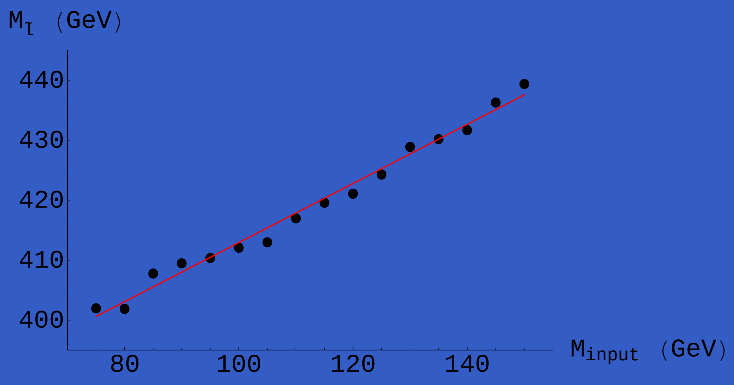

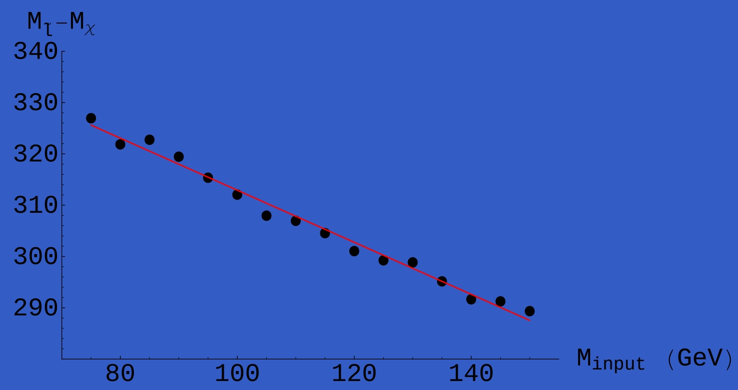

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- It is not obvious however, how the extrapolated $m_{\tilde{l}}$ will depend on M.
- We plot $m_{\tilde{l}}$ and $m_{\tilde{l}} - M$ where $m_{\tilde{l}}$ was obtained from the m_{T2} endpoint, with $m_{Z'} = 1.5$ TeV, $m_{\tilde{l}}^{true} = 400$ GeV and $m_{\chi^0} = 100$ GeV.

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- The Harvard BlackBox presented in the LHCO2 includes a Z'_{B-L} coupled to sleptons in a gauge mediated scenario, such that the gravitino is the LSP and all events with superpartners include two photons from $\chi_1^0 \to \gamma\, \tilde{g}$.

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- Once again, we will turn our attention to the $Z' \to \tilde{l}^- \, \tilde{l}^+$ channel.
- We will assume that the Z' mass has already been measured using the resonance peak in dileptons and preselect events with an OSSF dilepton pair along with two photons, MET and nothing else.

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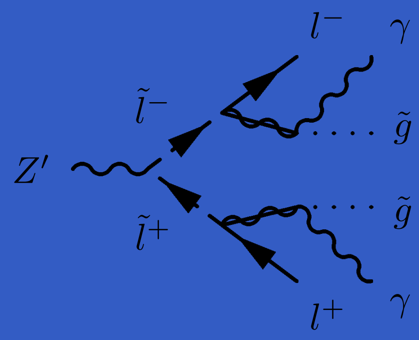

- In this event topology, there are four undetermined kinematic variables (we know the total $\vec{p}_T$) and three constraints ($m_{Z'}$ and the equality of m_χ and $m_{\tilde{l}}$ on either branch) such that there is one overall unconstrained kinematic variable.

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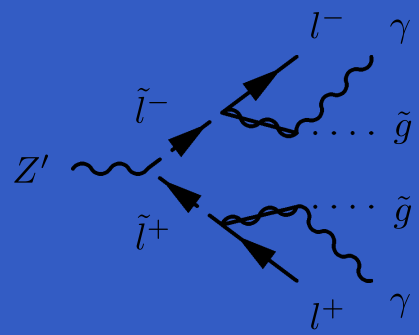

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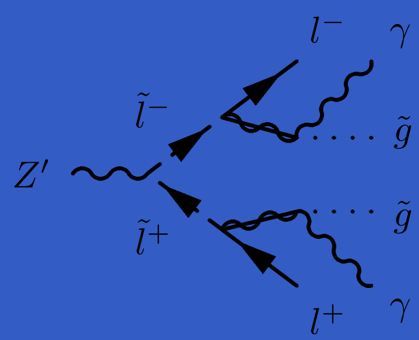

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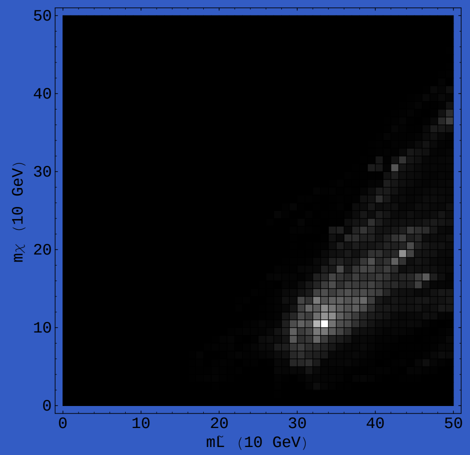
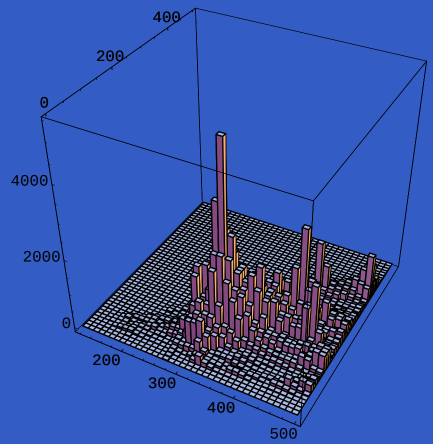
- Scanning through this variable we obtain a curve of possible values in the m_χ vs. $m_{\tilde{l}}$ plane for any given event.
- The idea is that we can overlay such curves from different events and look for a locus point.

Results





- The curves indeed seem to accumulate. The maximally populated bin in the figure is $100\ \mathrm{GeV} < \mathrm{m}_{\chi} < 110\ \mathrm{GeV}$, $330\ \mathrm{GeV} < \mathrm{m}_{\tilde{l}} < 340\ \mathrm{GeV}$.
- The actual values in the BlackBox were $m_{\chi} = 104\ \mathrm{GeV}$ and $m_{\tilde{l}} = 328\ \mathrm{GeV}$.
- Of course, to have a statistically significant result we should assign a kinematic weight to different kinematic configurations for each event, or better still, scan the masses and assign weights according to the likelihood of getting the particular final state momenta in the event record. This is yet to be done.

Conclusions

- We have considered a non-minimal SUSY scenario by adding a vector particle that couples to baryons and leptons.
- We have shown that generically the presence of the vector particle greatly enhances the slepton discovery reach at the LHC.
- Going beyond discovery, we have shown that measurements are possible, and can in fact be surprisingly precise, especially in non-minimal scenarios.
- Most of the analysis we presented is preliminary and can be improved.
- It would be interesting to investigate other possibilities (alternatives to a Z') and perhaps testing the same ideas for other leptonic states (extra dimensions etc).