Model-independent limits from missing energy searches

Johan Alwall, SLAC

with
M.-P. Le, M. Lisanti, J. Wacker

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Problem Statement

• We have no idea what any new physics beyond the Standard Model might look like
• Any models we come up with needs to be compared with experimental data from LHC and Tevatron
• The experimentalists have limited manpower
• How can data be communicated between experiments and theorists to allow comparison for any model, as well as providing maximum information useful to theorists?
Presenting experimental data

Twofold problem:

- How to analyze/report limits on cross sections in a way that can be compared (by theorists) with any model?
  

- How to analyze/report/characterize stable excesses over background in a way that can be compared to any model and give relevant information on the underlying physics without bias to a certain model?
  
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Present approaches

- Exclusions in model space of minimal model (mSUGRA/mGMSB/mAMSB) with few (~4) parameters
- Signature-based exclusions (cross section limits given some “standard” set of cuts)
- In case of excesses: Plots of data vs. backgrounds
- In case of excesses: Scans of SUSY space (~20 param) using high-level kinematical information
Present approaches

• Exclusions in model space of minimal model (mSUGRA/mGMSB/mAMSB) with few (~4) parameters

• Problems:
  - Fixed relations between parameters, e.g. $m_{\tilde{g}} : m_{\tilde{W}} : m_{\tilde{B}} \sim 6 : 2 : 1$
  - Fixed decays and branching ratios
  - Not all possible parameter space covered
Present approaches

- Exclusions in model space of minimal model (mSUGRA/mGMSB/mAMSB) with few (~4) parameters
Present approaches

• Signature-based exclusions (cross section limits given some “standard” set of cuts)
  – Restricted in scope, reduced power
• In case of excesses: Plots of data vs. backgrounds
  – Detector deconvolution difficult/impossible
• In case of excesses: Scans of SUSY space (~20 param) using high-level kinematical information and rate information
  – Assumes SUSY, needs high-statistics data
Non-standard scenarios

Example: Non-unified/non-standard SUSY scenarios can have free ratio $m_{\tilde{g}}:m_{\tilde{B}}$

- $m_{\tilde{g}}:m_{\tilde{B}} \sim 1 \rightarrow$ gluino decays to 2 soft jets and LSP
  - No hard jets, small missing transverse energy
Non-standard scenarios

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- $m_{\tilde{g}}:m_{\tilde{B}} \sim 1 \rightarrow$ gluino decays to 2 soft jets and LSP
  - No hard jets, small missing transverse energy
- Unclear where Tevatron is sensitive
- Difficult/impossible to find limits outside collaboration
Non-standard scenarios

- Example: $m_g = 210$ GeV and $m_B = 100$ GeV
- DØ dijet cuts, based on mSUGRA scenario: $H_T > 300$ GeV, $E_T > 225$ GeV

![Graph showing signal and background with standard cuts removing both signal and background](image)

Standard cuts remove signal as well as background.
Non-standard scenarios

- Example: $m_g = 210$ GeV and $m_B = 100$ GeV
- Optimized cuts: $H_T > 150$ GeV, $E_T > 100$ GeV

Optimized cuts allow much improved S/B
Cross section limits

Our suggestion to experimentalists:

• Provide differential cross section limits for multiple phase space bins (in relevant variables) for mutually exclusive searches (1j+MET, 2j+MET, ...)  

• Provide detector simulation and event generation chain verified to allow comparison in relevant phase space regions  

• Note! Only applicable for “hard” signals, where details of detector not crucial
Cross section limits

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- Provide differential cross section limits for multiple phase space bins (in relevant variables) for mutually exclusive searches (1j+MET, ...

1σ limits in fb for 4 fb⁻¹ at the Tevatron
Cross section limits

- Then, easy for theorists to generate the corresponding model cross sections (using generation setup) and compare, point-by-point in parameter space, to get exclusion region.
Cross section limits

- Examples:
  - Gluinos decaying to $qar{q}+$LSP
  - Gluinos decaying to $qar{q}W+$LSP (with $m_W - m_{	ilde{B}} \sim m_W$)
Conclusions

• Idea to allow theorists to find (approximate) exclusion region for any model (with missing $E_T$ signature) based on experimental searches
  – Provide grid of differential cross sections in number of jets and different missing $E_T$ and $H_T$ cuts
  – Provide authorized detector simulation and event generation parameters

• Can be easily and naturally extended to any high-$p_T$ signatures
Backup slides
## Searches at the Tevatron

<table>
<thead>
<tr>
<th></th>
<th>$1_j + E_T$</th>
<th>$2_j + E_T$</th>
<th>$3_j + E_T$</th>
<th>$4^+ j + E_T$</th>
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<tr>
<td>$E_{T_{j1}}$</td>
<td>$\geq 150$</td>
<td>$\geq 35$</td>
<td>$\geq 35$</td>
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<tr>
<td>$E_{T_{j2}}$</td>
<td>$&lt; 35$</td>
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<tr>
<td>$E_{T_{j3}}$</td>
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<tr>
<td>$E_{T_{j4}}$</td>
<td>$&lt; 20$</td>
<td>$&lt; 20$</td>
<td>$&lt; 20$</td>
<td>$\geq 20$</td>
</tr>
</tbody>
</table>

Two hardest jets $|\eta| \leq 0.8$, other jets $|\eta| \leq 2.5$
Statistics

\[
\langle S^{\text{excl}}(B) \rangle = \sum_{N_m=0}^{\infty} S^{\text{excl}}(N_m, B) \frac{e^{-B} B^{N_m}}{N_m!}
\]

\[
\lim_{B \to \infty} \langle S^{\text{excl}}(B) \rangle = \sqrt{B}.
\]

\[
\lim_{B \to 0} \langle S^{\text{excl}}(B) \rangle = -\ln(0.16) \approx 1.8
\]

\[
\chi^2_N = \sum_{j=1}^{N} \frac{S^2_j}{(S L_j)^2 + (\epsilon_{\text{sys}} \times B_j)^2} \times \frac{1}{N}
\]

- Include only measurements with expected significance > \( S^{\text{crit}} \) (e.g. 0.5)