Measuring masses of semi-invisibly decaying particles pair produced at hadron colliders: a critical assessment of the work

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Semi-Invisibly Decaying Particles

- W boson
- Possible SUSY particles
- mSUGRA in LHC
- Fourth lepton generation?

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- One decay product is directly observable, the other is not
- Neutrino ν_0 is *invisible*; properties must be gleaned from analysis of missing E_T and p_T
- Cannot directly reconstruct mass of W because of this
- But we can get a lower limit
- And hope many events will tend to it (as $UA1$ & $UA2$ did)

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Transverse Mass (W decays)

Gives a lower bound for W mass

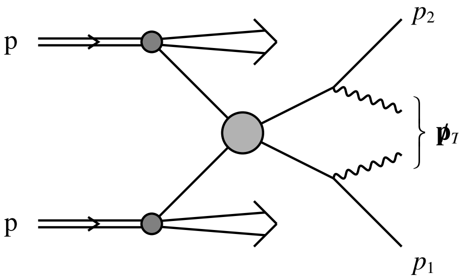
$$m_T^2 = 2(E_T^e \not{E}_T - \mathbf{p}_T^e \cdot \not{\mathbf{p}}_T) \quad (1)$$

Lower bound of repeated trials approaches actual mass of W

$$m_T^2 \leq m_W^2 \quad (2)$$

NB: Equality only if $y(p_{l^\pm}) = y(\nu_0)$

But what about non-W events?



New Physics!

- Collision pair-produces two semi-invisibly decaying particles
- Good place to look for new particles: useful whenever you have a pair produced particle which decays into an invisible and a visible particle. (e.g. R-parity conserving SUSY, Drell-Yan production of a new lepton generation)
- It would indeed also be good for fourth generation lepton searches

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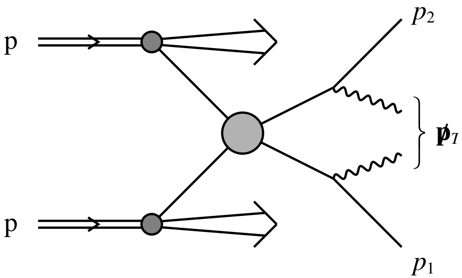

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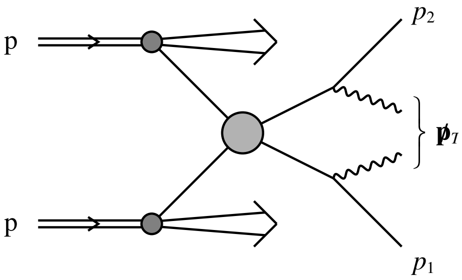

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Continued...

Slepton pair production (decays into leptons and *invisible* neutralinos)

$$pp \to X + \tilde{l}_R^+ \tilde{l}_R^- \to X + l^+ l^- \tilde{\chi}_1^0 \tilde{\chi}_1^0. \qquad (3)$$

4^{th} Generation Lepton pair production → decay to W bosons and neutrinos (Drell-Yan)

$$pp \to X + l_4^+ l_4^- \to X + \bar{\nu}_{l_4} W^+ \nu_{l_4} W^- \qquad (4)$$

Now, we want an analogue of M_T for these decays...

But what about non-W events?

M_T^2 assumes unobserved particle is massless. But this is not necessarily true for new physics decays.

Therefore, we consider

$$\tilde{l} \rightarrow l\tilde{\chi} \tag{5}$$

Which will allow for a more general treatment...

Arbitrary P_t case

For arbitrary P_t, we can write

$$m_{\tilde{l}}^2 = m_l^2 + m_{\tilde{\chi}}^2 + 2(E_{Tl}E_{T\tilde{\chi}}\cosh(\Delta y) - \mathbf{p}_{Tl}\cdot\mathbf{p}_{T\tilde{\chi}}) \tag{6}$$

where $E_T = \sqrt{\mathbf{p}_T^2 + m^2}$ and Δy is the difference in rapidity, $y = \frac{1}{2}\ln[(E+p_z)/(E-p_z)]$, between the l and $\tilde{\chi}$.

Since $\cosh\Delta y \geq 1$, this simplifies to

$$m_{\tilde{l}}^2 \geq m_T^2(\mathbf{p}_{Tl},\mathbf{p}_{T\tilde{\chi}}) \equiv m_l^2 + m_{\tilde{\chi}}^2 + 2(E_{Tl}E_{T\tilde{\chi}} - \mathbf{p}_{Tl}\cdot\mathbf{p}_{T\tilde{\chi}}). \tag{7}$$

Where we define a new version of transverse mass as being equal to the sqrt of the right-hand side.

The looked-for variable

- We cannot directly measure the momenta, but we can equate the sum of the momenta as the missing E_T in the event. Since $m_{\tilde{l}}^2$ must be greater than the m_T^2 variable calculated from both semi-invisible decays, we are going to find that

$$m_{\tilde{l}}^2 \geq \max\{m_T^2(\mathbf{p}_{Tl^-}, \mathbf{p}_{T\tilde{\chi}_a}), m_T^2(\mathbf{p}_{Tl^+}, \mathbf{p}_{T\tilde{\chi}_b})\} \tag{8}$$

- However, since we cannot determine how much of the missing E_T is carried by each unobservable particle, we must loop over all possible distributions and take the minimum.
- Thus, we get our new **variable**,
- $$m_{\tilde{l}}^2 \geq M_{T2}^2 \equiv \min_{\not{p}_1 + \not{p}_2 = \not{p}_T} \left[\max\{m_T^2(\mathbf{p}_{Tl^-}, \not{p}_1), m_T^2(\mathbf{p}_{Tl^+}, \not{p}_2)\} \right] \tag{9}$$

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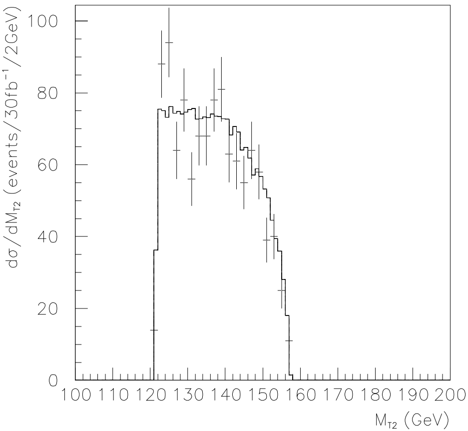
Some limitations to the model

- M_{T2} distribution for slepton decay in mSUGRA SUSY model. Generated 1105 events (Integrated luminosity = $30fb^{-1}$):



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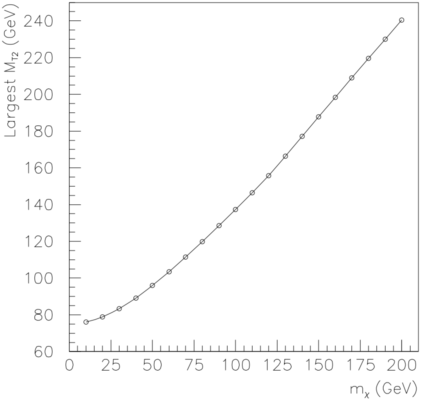

- Actual masses used to generate events: $121,5 GeV$ for neutralino, $157,1 GeV$ for selectron. M_{T2} predicts this well.

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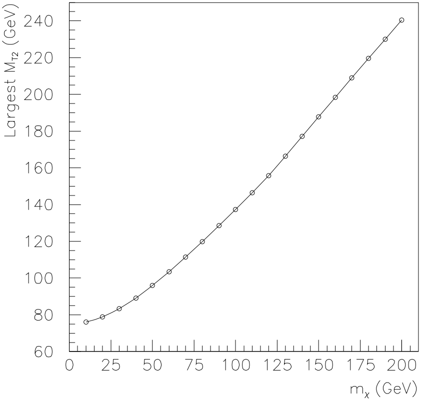

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- Analogous to transverse mass variable m_T used in W decays
- Works well in MC simulations of SUSY model, good sign for variable's usefulness in future studies
- M_{T2} is often used these days in searches for BSM particles.

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Acknowledgements

Figure : Thank you very much!!!


That's all Folks!