Gluino m_{T2}

Yeong Gyun Kim
(Sejong U & KAIST)

In collaboration with
W. S. Cho, K. Choi, C. B. Park

Ref) arXiv:0709.0288, arXiv:0711.4526

Contents

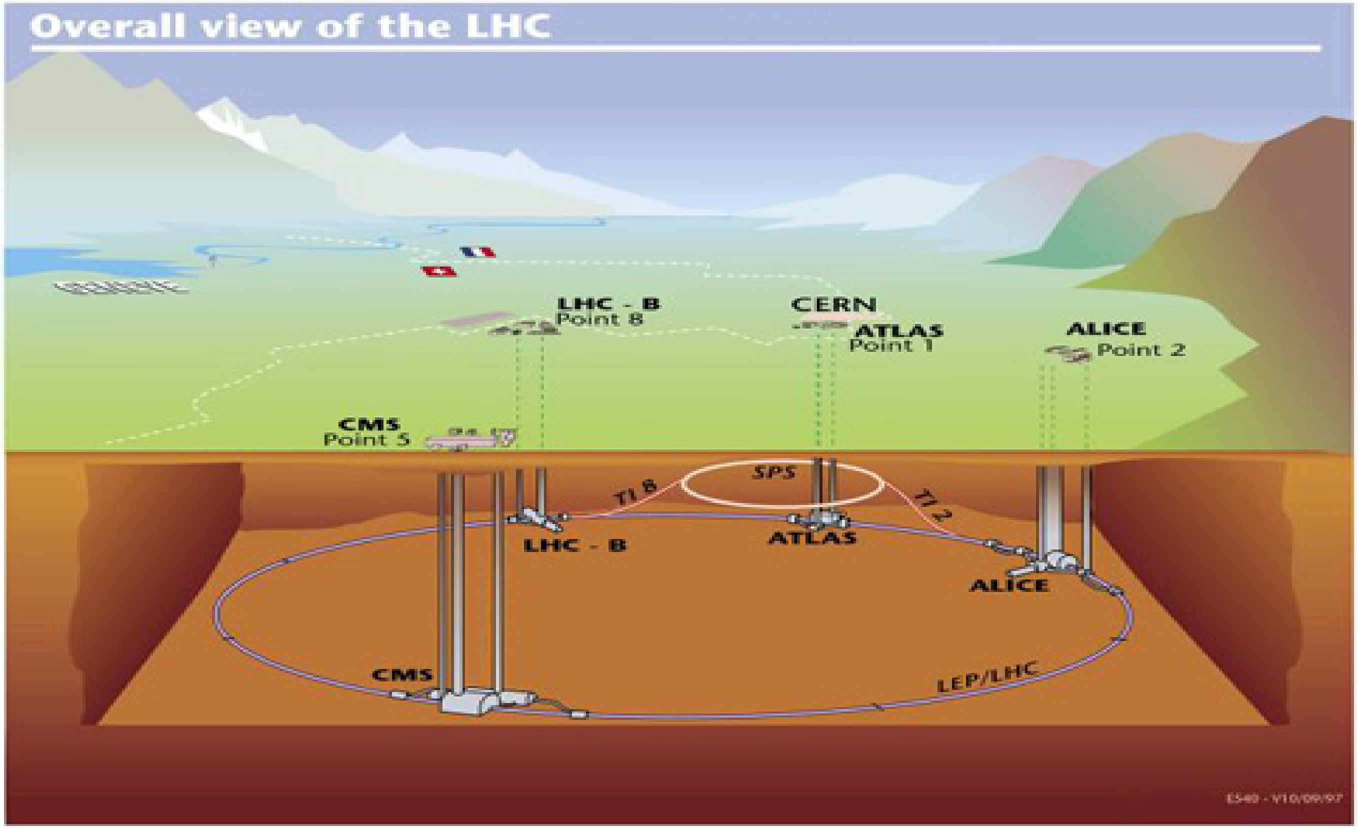
SUSY at the LHC

Cambridge m_{T2} variable

'Gluino' m_{T2} variable

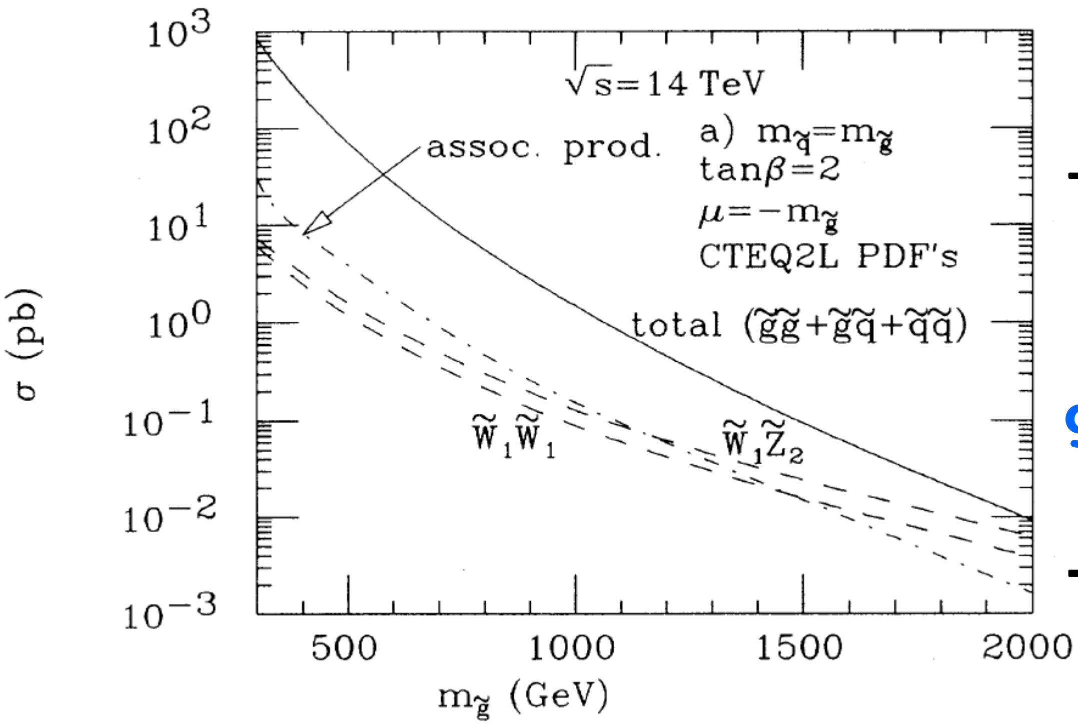
Conclusion

SUSY at the LHC



General features for SUSY at the LHC

Dominated by the production of gluinos and squarks, unless they are too heavy



(Baer et al. 1995)

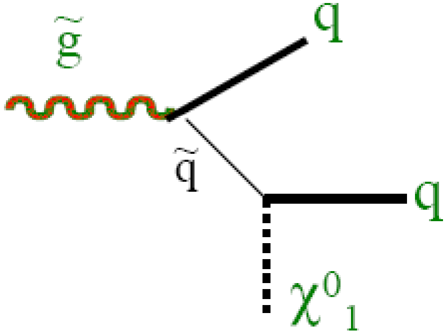
Squark and gluino production rates

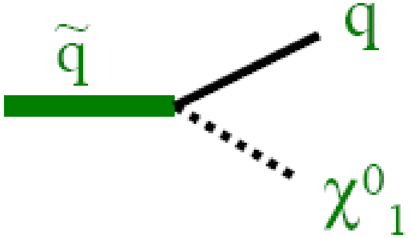
-determined by strong interaction, and the squark and gluino masses,

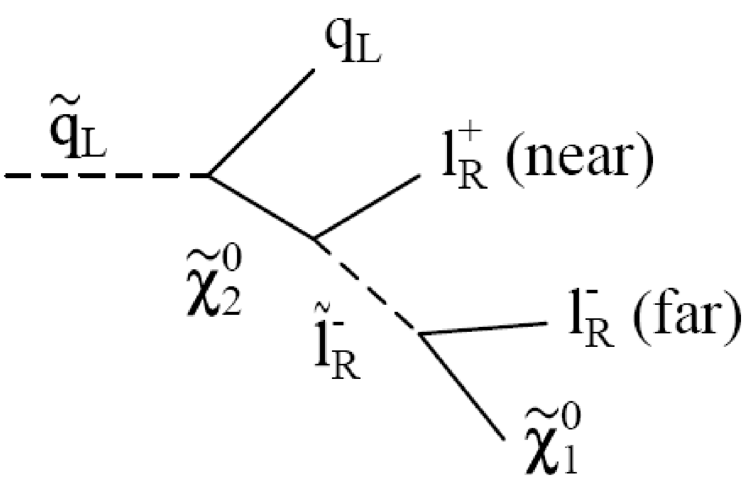
-do not depend on the details of model

~50 pb for m_gluino~500 GeV
~ 1 pb for m_gluino~1000 Ge

The gluinos and squarks cascade down, generally in several steps, to the final states including multi-jets (and/or leptons) and undetected two LSPs







Characteristic signals of SUSY with R_p

Invisible LSPs

Missing Transverse Energy

Decays of squarks and gluinos

Large multiplicity of hadronic jets

and/or

Decays of sleptons and gauginos

Isolated leptons

Measurement of SUSY masses

Precise measurement of SUSY particle masses

Reconstruction of the SUSY theory
(SUSY breaking mechanism)

SUSY events always contain two invisible LSPs

No masses can be reconstructed directly

One promising approach

Identify particular decay chain and measure
kinematic endpoints using visible particles
(functions of sparticle masses)

When a long decay chain can be identified, various combinations of masses can be determined in a model independent way

$$(m_{ll}^2)^{\text{edge}} = \frac{(m_{\tilde{\chi}_2^0}^2 - m_{\tilde{l}_R}^2)(m_{\tilde{l}_R}^2 - m_{\tilde{\chi}_1^0}^2)}{m_{\tilde{l}_R}^2},$$

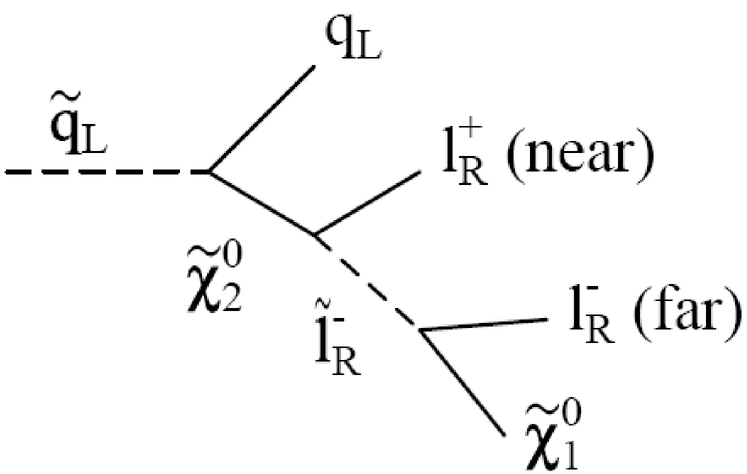
$$(m_{qll}^2)^{\text{edge}} = \frac{(m_{\tilde{q}_L}^2 - m_{\tilde{\chi}_2^0}^2)(m_{\tilde{\chi}_2^0}^2 - m_{\tilde{\chi}_1^0}^2)}{m_{\tilde{\chi}_2^0}^2},$$

$$(m_{ql}^2)_{\text{min}}^{\text{edge}} = \frac{(m_{\tilde{q}_L}^2 - m_{\tilde{\chi}_2^0}^2)(m_{\tilde{\chi}_2^0}^2 - m_{\tilde{l}_R}^2)}{m_{\tilde{\chi}_2^0}^2},$$

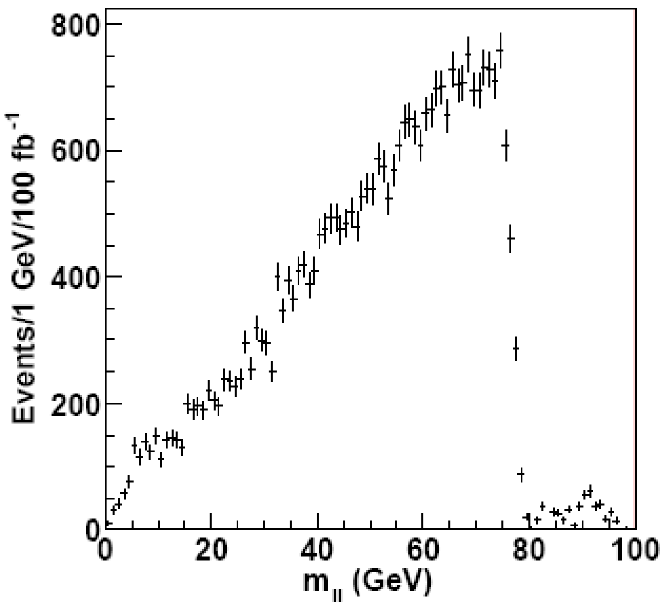
$$(m_{ql}^2)_{\text{max}}^{\text{edge}} = \frac{(m_{\tilde{q}_L}^2 - m_{\tilde{\chi}_2^0}^2)(m_{\tilde{l}_R}^2 - m_{\tilde{\chi}_1^0}^2)}{m_{\tilde{l}_R}^2},$$

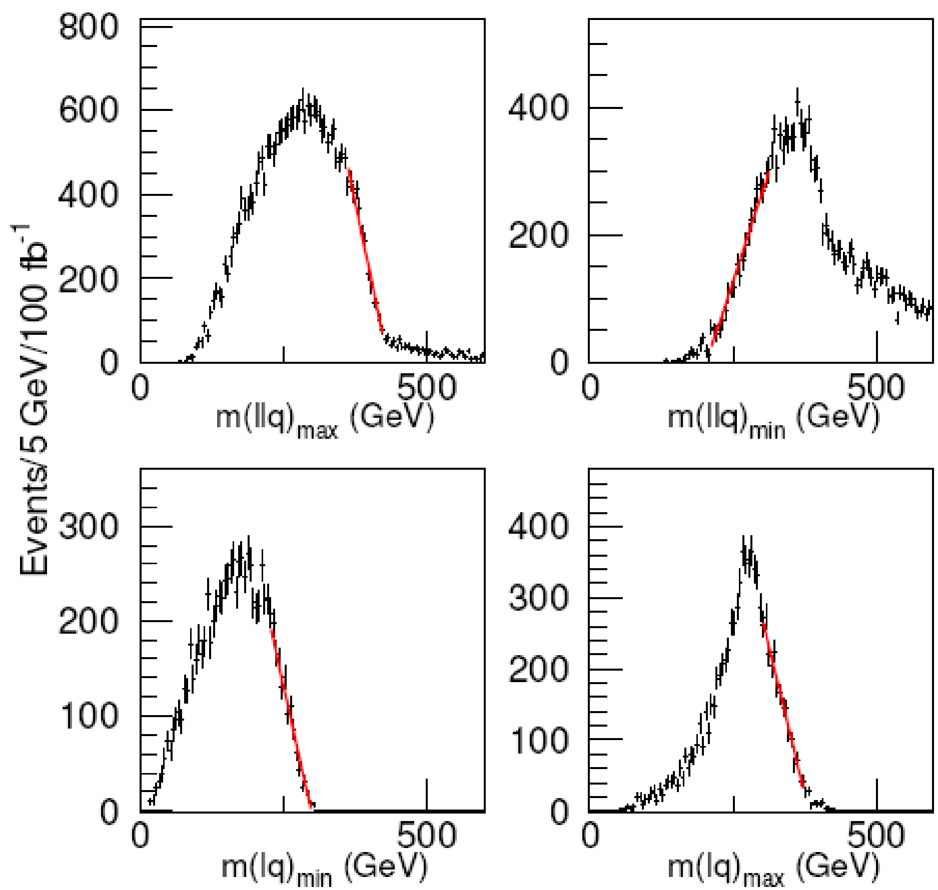
$$(m_{qll}^2)^{\text{thres}} = \Big[(m_{\tilde{q}_L}^2 + m_{\tilde{\chi}_2^0}^2)(m_{\tilde{\chi}_2^0}^2 - m_{\tilde{l}_R}^2)(m_{\tilde{l}_R}^2 - m_{\tilde{\chi}_1^0}^2) - (m_{\tilde{q}_L}^2 - m_{\tilde{\chi}_2^0}^2)\sqrt{(m_{\tilde{\chi}_2^0}^2 + m_{\tilde{l}_R}^2)^2(m_{\tilde{l}_R}^2 + m_{\tilde{\chi}_1^0}^2)^2 - 16 m_{\tilde{\chi}_2^0}^2 m_{\tilde{l}_R}^4 m_{\tilde{\chi}_1^0}^2} + 2 m_{\tilde{l}_R}^2 (m_{\tilde{q}_L}^2 - m_{\tilde{\chi}_2^0}^2)(m_{\tilde{\chi}_2^0}^2 - m_{\tilde{\chi}_1^0}^2)\Big] / (4 m_{\tilde{l}_R}^2 m_{\tilde{\chi}_2^0}^2),$$

Five endpoint measurements
Four unknown masses



For SPS1a point





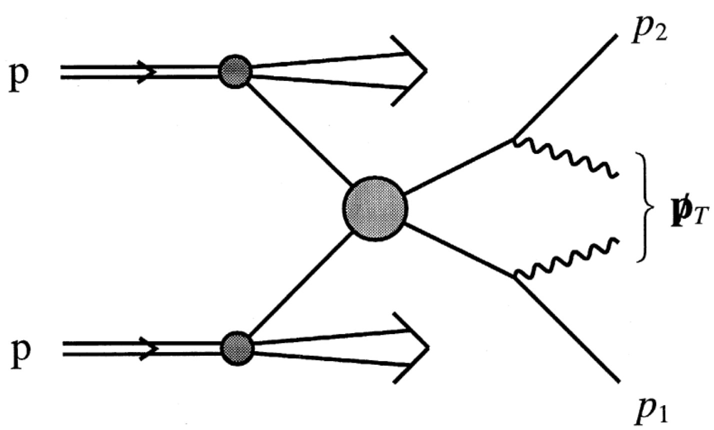
$\tilde{\chi}_1^0$, $\tilde{\chi}_2^0$, $\tilde{\ell}_R$ masses reconstructed with ~ 5 GeV ,

$\tilde{q}_L$ mass with ~ 9 GeV (300 fb^{-1})

Cambridge m_{T2} variable

(Stransverse Mass)

Cambridge m_{T2} (Lester and Summers, 1999)



Massive particles pair produce

Each decays to one visible and one invisible particle.

For example,

$$pp \to X + \tilde{l}_R^+ \tilde{l}_R^- \to X + l^+ l^- \tilde{\chi}_1^0 \tilde{\chi}_1^0$$

For the decay, $\tilde{l} \to l \tilde{\chi}$

$$m_{\tilde{l}}^2 \geq m_T^2(\boldsymbol{p}_{Tl}, \boldsymbol{p}_{T\tilde{\chi}})$$

$$\equiv m_l^2 + m_{\tilde{\chi}}^2 + 2\left(E_{Tl} E_{T\tilde{\chi}} - \boldsymbol{p}_{Tl} \cdot \boldsymbol{p}_{T\tilde{\chi}}\right)$$

(where $E_T = \sqrt{\boldsymbol{p}_T^2 + m^2}$)

If $\boldsymbol{p}_{T\tilde{\chi}_a}$ and $\boldsymbol{p}_{T\tilde{\chi}_b}$ were obtainable,

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

($\not{\boldsymbol{p}}_T = \boldsymbol{p}_{T\tilde{\chi}_a} + \boldsymbol{p}_{T\tilde{\chi}_b}$; total MET vector in the event)

However, not knowing the form of the MET vector splitting the best we can say is that :

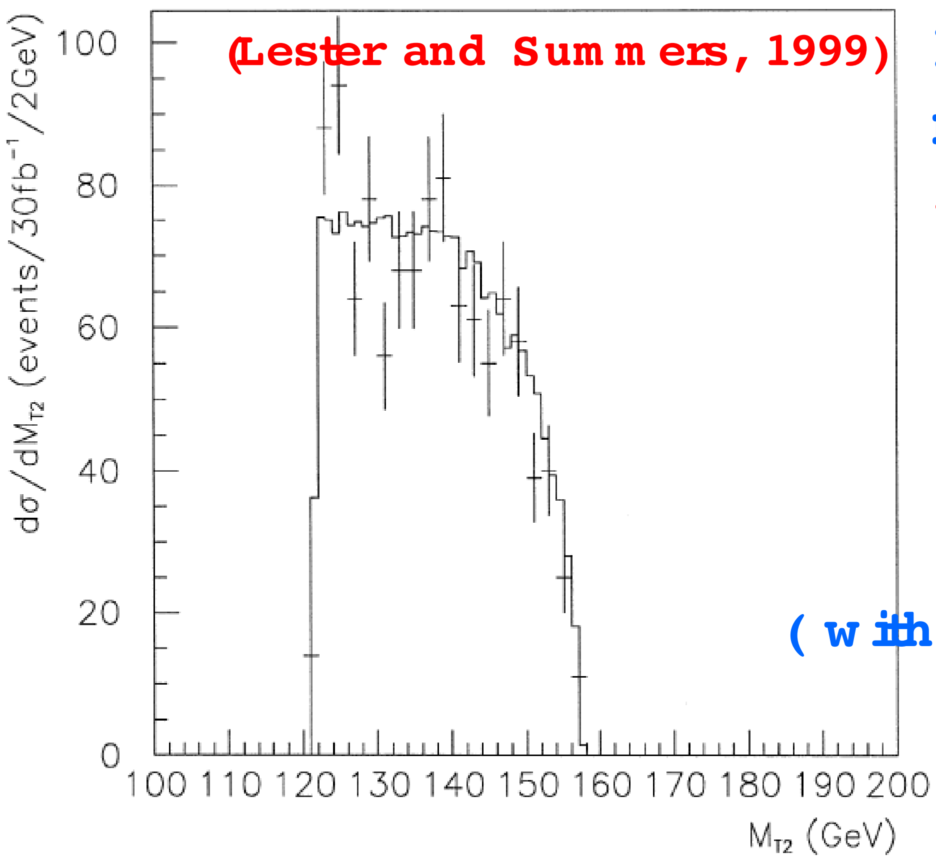
$$m_{\tilde{l}}^2 \geq M_{T2}^2 \equiv \min_{\not{\boldsymbol{p}}_1 + \not{\boldsymbol{p}}_2 = \not{\boldsymbol{p}}_T} \left[\max\left\{ m_T^2(\boldsymbol{p}_{Tl^-}, \not{\boldsymbol{p}}_1), m_T^2(\boldsymbol{p}_{Tl^+}, \not{\boldsymbol{p}}_2) \right\} \right]$$

with minimization over all possible trial LSP momenta

M_{T2} distribution for $pp \to X + \tilde{l}_R^+ \tilde{l}_R^- \to X + l^+ l^- \tilde{\chi}_1^0 \tilde{\chi}_1^0$

LHC point 5, with 30 fb^{-1}

$$m_{\tilde{l}_R} = 157.1\,\mathrm{GeV}\,, \quad m_{\tilde{\chi}_1^0} = 121.5\,\mathrm{GeV}\,.$$



Endpoint measurement of m_{T2} distribution determines the mother particle mass

$$m_{T2}^{\max} \simeq 157\ \mathrm{GeV}$$

(with

$$m_{\tilde{\chi}_1^0} = 121.5\ \mathrm{GeV}$$

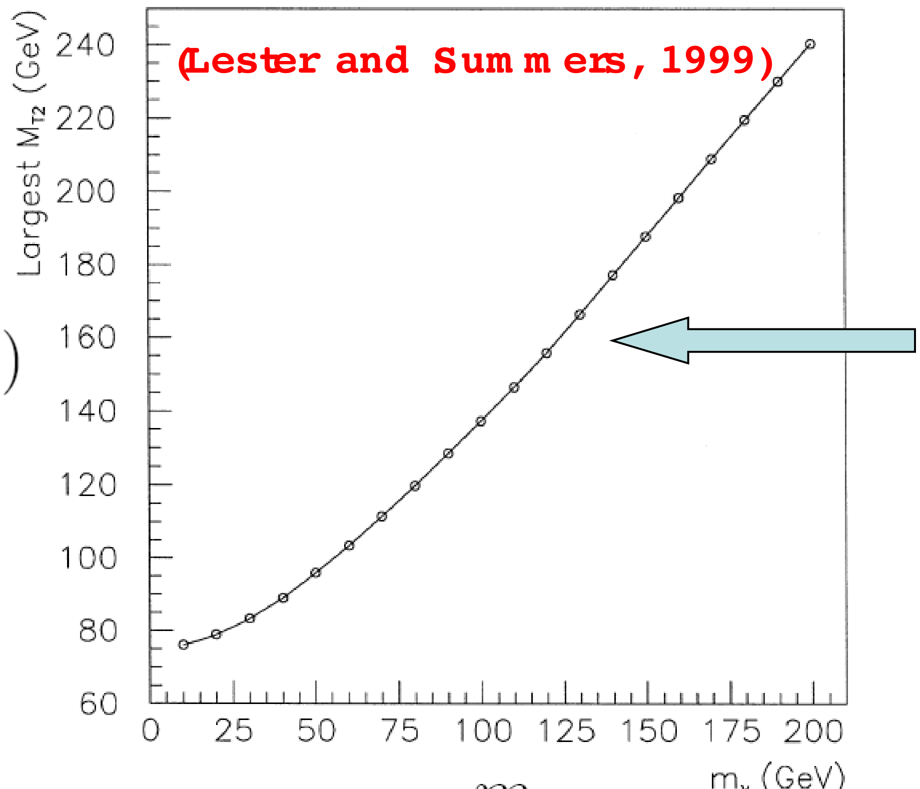
The LSP mass is needed as an input for m_{T2} calculation

But it might not be known in advance

m_{T2} depends on a trial LSP mass m_χ

Maximum of m_{T2} as a function of the trial LSP mass

$$m_{T2}^{\max}(m_\chi)$$



$$m_\chi$$

Can the correlation be expressed by an analytic formula in terms of true sparticle masses ?

Yes !

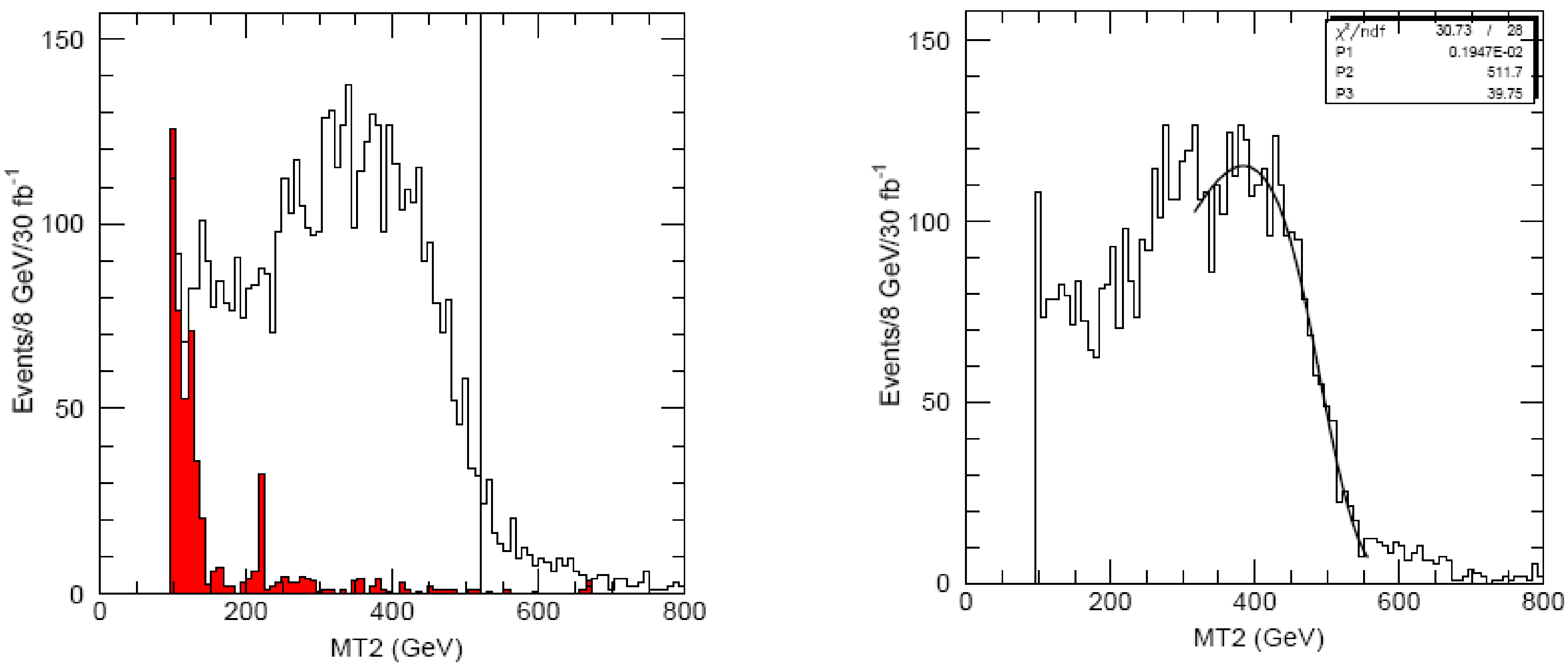
Right handed squark mass from the m_{T2}

$$\tilde{q}_R\ \tilde{q}_R \rightarrow q\ \tilde{\chi}_1^0\ q\ \tilde{\chi}_1^0$$

$$BR(\tilde{q}_R \rightarrow q\chi_1^0) \sim 100\%$$

m_qR ~ 520 GeV, m LSP ~96 Ge

SPS1a point, with 30 fb^{-1}



(LHC/ILC Study Group: hep-ph/0410364)

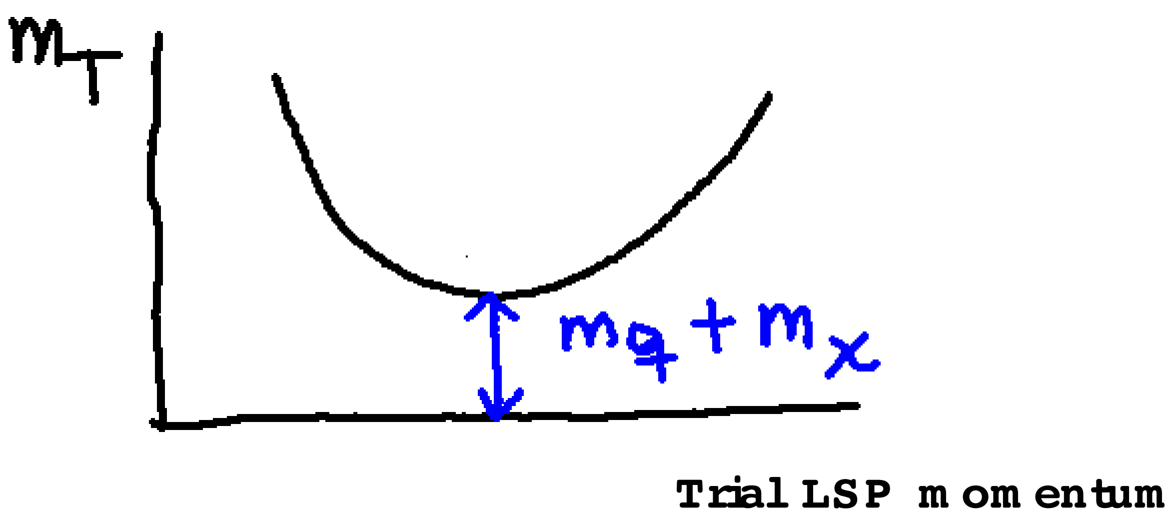
Unconstrained minimum of m_T

$$m_T^2 = m_q^2 + m_\chi^2 + 2(E_T^q E_T^\chi - \mathbf{p}_T^q \cdot \mathbf{p}_T^\chi)$$

$$\frac{\partial m_T^2}{\partial (\mathbf{p}_T^\chi)_k} = 2\left[E_T^q \frac{(\mathbf{p}_T^\chi)_k}{E_T^\chi} - (\mathbf{p}_T^q)_k\right] \qquad (k = 1, 2)$$

At an unconstrained minimum, we have

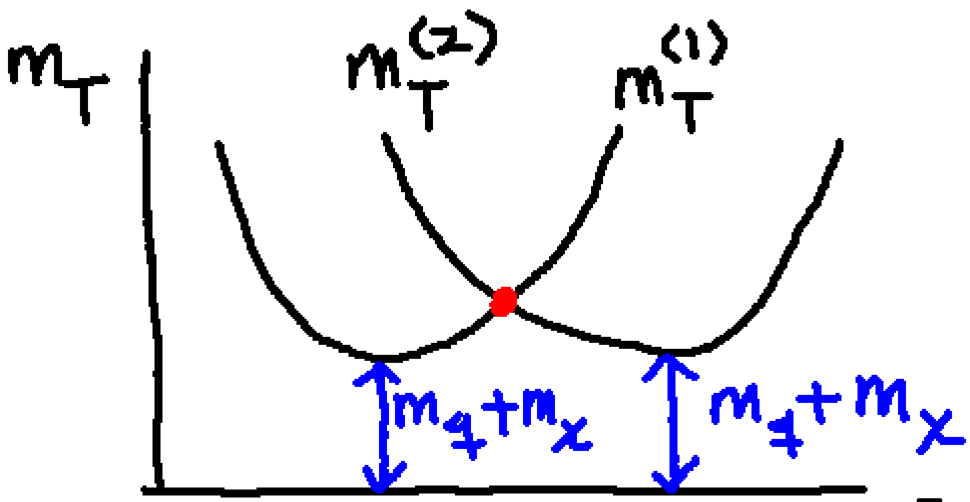
$$m_T(\mathrm{min}) = m_q + m_\chi \quad \textbf{when} \quad \frac{\mathbf{p}_T^\chi}{E_T^\chi} = \frac{\mathbf{p}_T^q}{E_T^q}$$



Solution of m_{T2} (the balanced solution)

$$m_{T2}^2 \equiv \min_{\mathbf{p}_T^{\chi(1)}+\mathbf{p}_T^{\chi(2)}=\mathbf{p}_T^{miss}} \left[\max\{m_T^2(\mathbf{p}_T^{q(1)},\mathbf{p}_T^{\chi(1)}), m_T^2(\mathbf{p}_T^{q(2)},\mathbf{p}_T^{\chi(2)})\}\right]$$

with $\mathbf{p}_T^{\chi(1)} + \mathbf{p}_T^{\chi(2)} = \mathbf{p}_T^{miss} = -(\mathbf{p}_T^{q(1)} + \mathbf{p}_T^{q(2)})$ (for no ISR)



m_{T2} : the minimum of $m_T^{(1)}$ subject to the two constraints

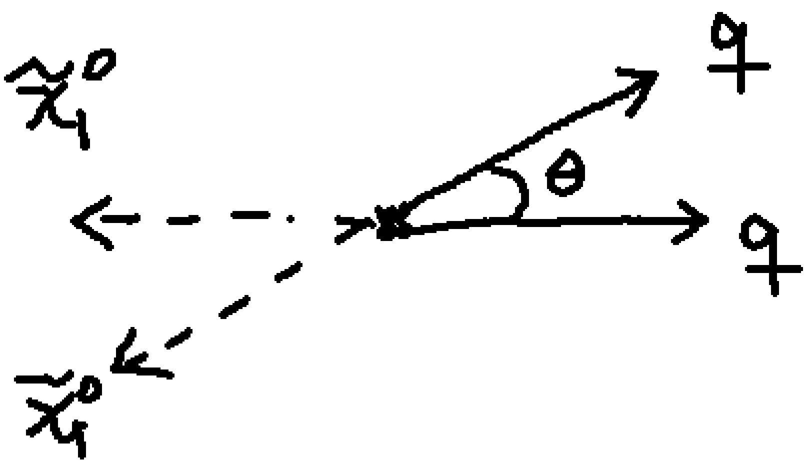
$m_T^{(1)} = m_T^{(2)}$, and $\mathbf{p}_T^{\chi(1)} + \mathbf{p}_T^{\chi(2)} = \mathbf{p}_T^{miss}$

The balanced solution of squark m_{T2} in terms of visible momenta

(Lester, Barr 0708.1028)

$$m_{T2} = P_0 + \sqrt{P_0^2 + m_\chi^2}$$ ($m_q = 0$)

with $$P_0 = \sqrt{\frac{(1+\cos\theta)}{2}|\mathbf{p}_T^{q(1)}||\mathbf{p}_T^{q(2)}|}$$



In order to get the expression for m_{T2}^{max} ,

We only have to consider the case where two mother particles are at rest and all decay products are on the transverse plane w.r.t proton beam direction, for no ISR

(Cho, Choi, Kim and Park, 2007)

See K. Choi's Talk

In the rest frame of squark, the quark momen

$$|\mathbf{p}_T^{q(i)}| = \frac{m_{\tilde{q}}^2 - m_{\tilde{\chi}_1^0}^2}{2m_{\tilde{q}}}$$

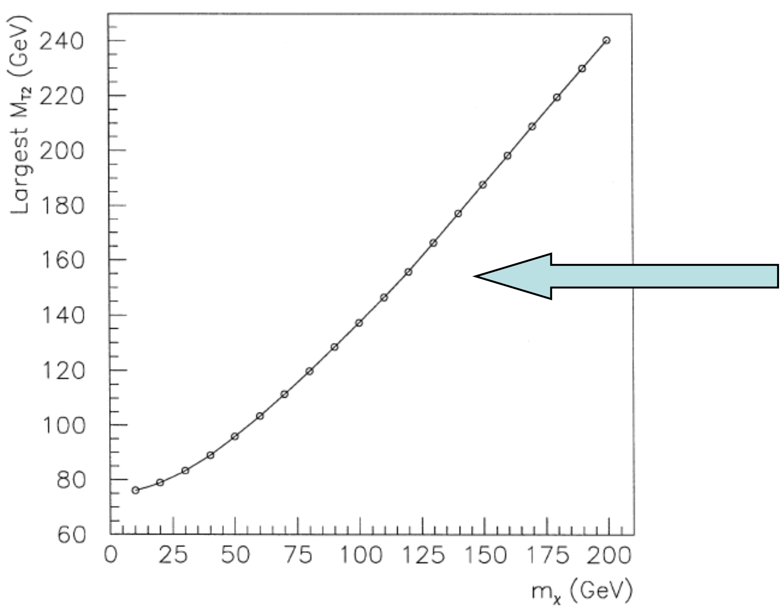
if both quark momenta are along the direction of the transverse plan

The maximum of the squark m_{T2} (occurs at $\theta = 0$)

(Cho, Choi, Kim and Park, 0709.0288)

$$m_{T2}^{\max}(m_\chi) = \frac{m_{\tilde{q}}^2 - m_{\tilde{\chi}_1^0}^2}{2m_{\tilde{q}}} + \sqrt{\left(\frac{m_{\tilde{q}}^2 - m_{\tilde{\chi}_1^0}^2}{2m_{\tilde{q}}}\right)^2 + m_\chi^2}$$

$$m_{T2}^{\max}(m_\chi) = m_{\tilde{q}} \quad \text{if } m_\chi = m_{\tilde{\chi}_1^0}$$

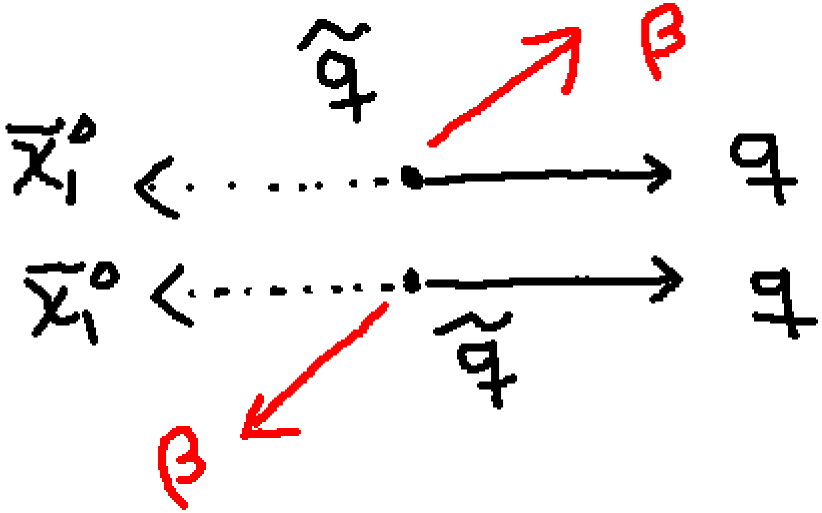


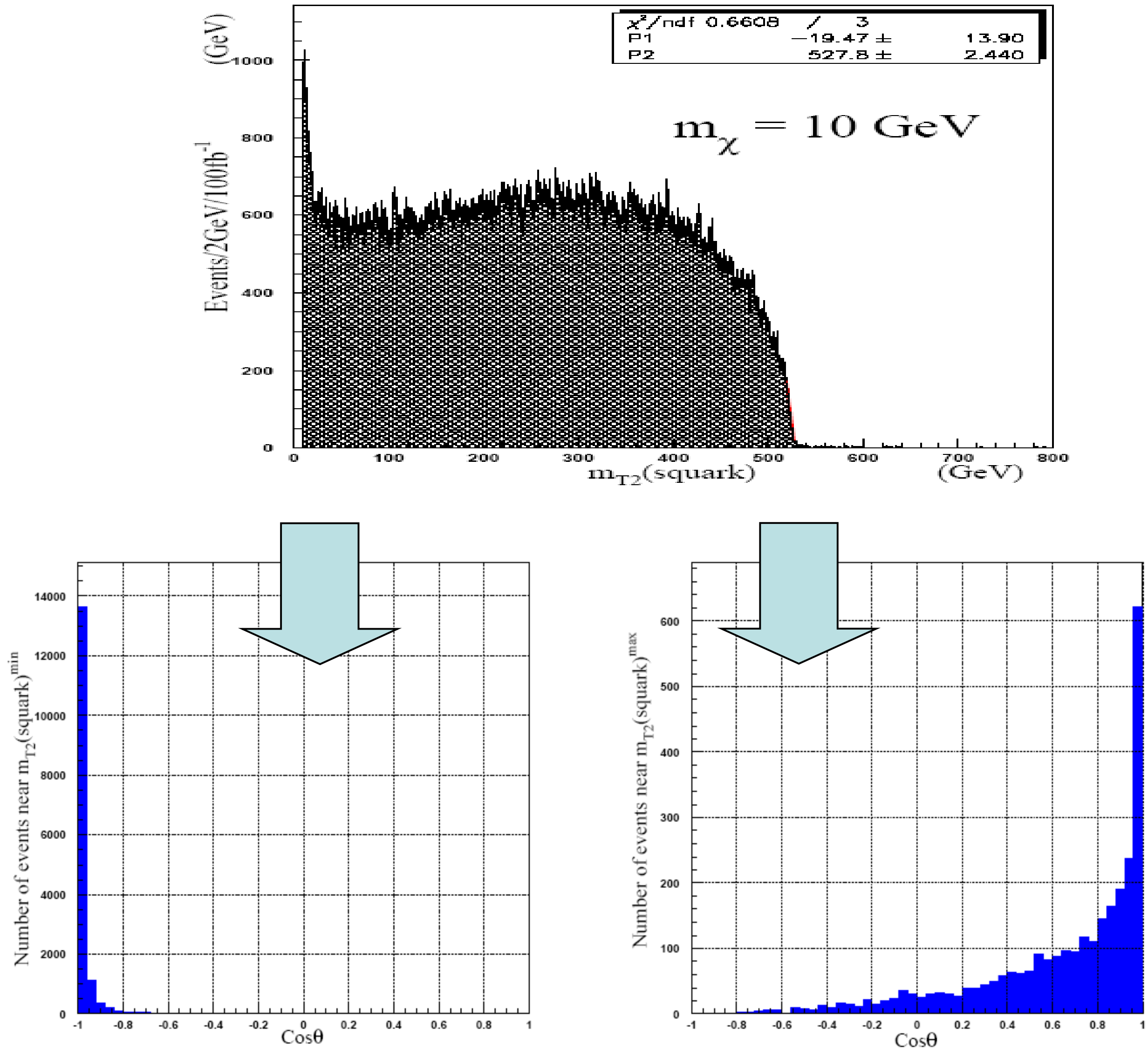
Well described by the above Analytic expression with true Squark mass and true LSP mass

Some remarks on the effect of squark bo

In general, squarks are produced with non-zero p_T

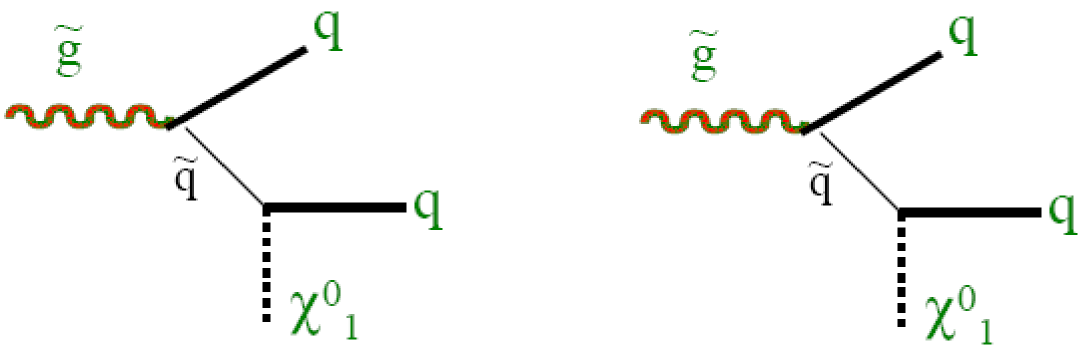
The m_{T2} solution is invariant under
back-to-back transverse boost of mother squarks
(all visible momenta are on the transverse plane)





Cos(theta) distribution

'Gluino' m_{T2} variable



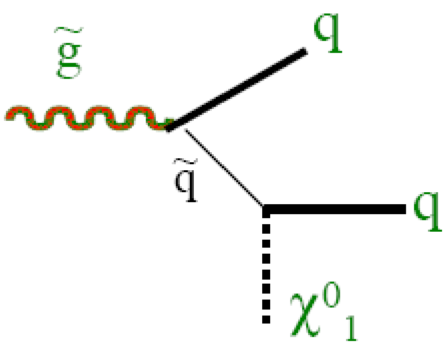
Gluino m_{T2} (stransverse mass)

A new observable, which is an application of m_{T2} variable to the process

$$pp \to \tilde{g}\tilde{g} \to qq\tilde{\chi}_1^0\ qq\tilde{\chi}_1^0$$

os are pair produced in proton-proton collision

gluino decays into two quarks and one LSP



through three body decay (off-shel

or two body cascade decay (on-shell

For each gluino decay,
the following transverse can be constructed

$$m_T^2(m_{qqT}, m_\chi, \mathbf{p}_T^{qq}, \mathbf{p}_T^\chi) = m_{qqT}^2 + m_\chi^2 + 2(E_T^{qq} E_T^\chi - \mathbf{p}_T^{qq} \cdot \mathbf{p}_T^\chi)$$

m_{qqT} and $\mathbf{p}_T^{qq}$: mass and transverse momentum of qq system

m_χ and $\mathbf{p}_T^\chi$: trial mass and transverse momentum of the

$$E_T^{qq} \equiv \sqrt{|\mathbf{p}_T^{qq}|^2 + m_{qqT}^2} \quad \text{and} \quad E_T^\chi \equiv \sqrt{|\mathbf{p}_T^\chi|^2 + m_\chi^2}$$

With two such gluino decays in each event,
the gluino m_{T2} is defined as

$$m_{T2}^2(\tilde{g}) \equiv \min_{\mathbf{p}_T^{\chi(1)} + \mathbf{p}_T^{\chi(2)} = \mathbf{p}_T^{miss}} \left[\max\{ m_T^{2(1)}, m_T^{2(2)} \} \right]$$

(minimization over all possible trial LSP momenta)

From the definition of the gluino m_{T2}

$$m_{T2}(\tilde{g}) \leq m_{\tilde{g}} \quad \text{for} \quad m_\chi = m_{\tilde{\chi}_1^0}$$

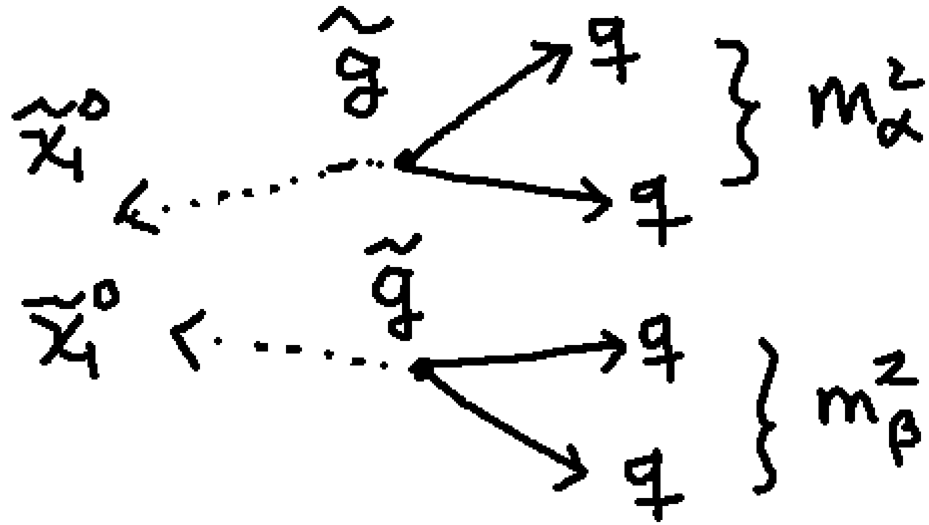
Therefore, if the LSP mass is known, one can determine the gluino mass from the endpoint measurement of the glui m_{T2} distribution.

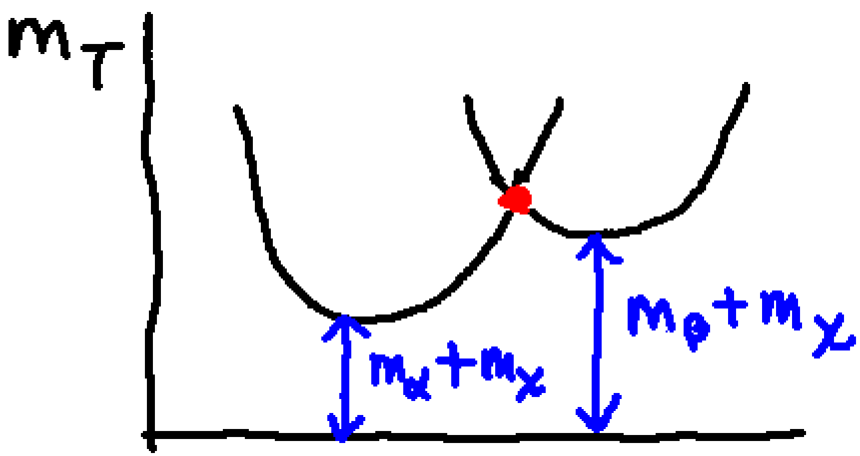
$$m_{T2}^{\max}(m_\chi) \equiv \max_{\text{all events}} \left[m_{T2}(\tilde{g}) \right]$$

However, the LSP mass might not be known in advance and then, $m_{T2}^{\max}(m_\chi)$ can be considered as a functi the trial LSP mass m_χ, satisfying

$$m_{T2}^{\max}(m_\chi = m_{\tilde{\chi}_1^0}) = m_{\tilde{g}}$$

Each mother particle produces
one invisible LSP
and more than one visible particles

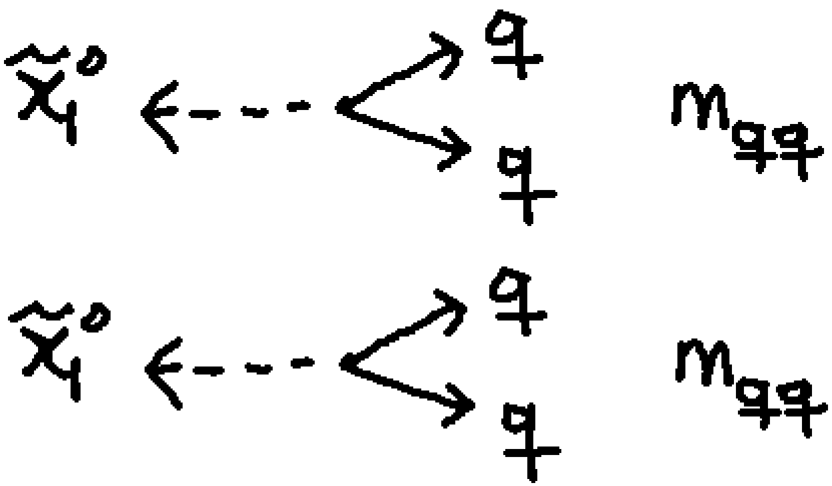




Possible m_{qq} values
for three body decays
of the gluino :

$$0 \leq m_{qq} \leq m_{\tilde{g}} - m_{\tilde{\chi}_1^0}$$

In the frame of gluinos at rest



Two sets of decay products have the same m_{qq} and are parallel to each other ($\theta = 0$) on transverse pl

($0 \leq m_{qq} \leq m_{\tilde{g}} - m_{\tilde{\chi}_1^0}$)

Di-quark momenta

$$|\mathbf{p}| = \frac{\sqrt{[m_{\tilde{g}}^2 - (m_{\tilde{\chi}_1^0} + m_{qq})^2][m_{\tilde{g}}^2 - (m_{\tilde{\chi}_1^0} - m_{qq})^2]}}{2m_{\tilde{g}}}$$

Gluino m_{T2}

$$m_{T2} = \sqrt{m_{qq}^2 + |\mathbf{p}|^2} + \sqrt{m_{\chi}^2 + |\mathbf{p}|^2}$$

The gluino m_{T2} has a very interesting property

$$m_{T2} = \sqrt{m_{qq}^2 + |\mathbf{p}|^2} + \sqrt{m_\chi^2 + |\mathbf{p}|^2}$$

$$(0 \le m_{qq} \le m_{\tilde{g}} - m_{\tilde{\chi}_1^0})$$

$$\frac{\mathrm{d}m_{T2}}{\mathrm{d}m_{qq}} = \frac{m_{qq}}{m_{\tilde{g}}} \left(1 - \frac{(m_{\tilde{g}}^2 + m_{\tilde{\chi}_1^0}^2 - m_{qq}^2)}{\sqrt{(m_{\tilde{g}}^2 + m_{\tilde{\chi}_1^0}^2 - m_{qq}^2)^2 + 4m_{\tilde{g}}^2(m_\chi^2 - m_{\tilde{\chi}_1^0}^2)}} \right)$$

$$\begin{aligned} &= 0 \quad \text{if } m_\chi = m_{\tilde{\chi}_1^0} \\ &> 0 \quad \text{if } m_\chi > m_{\tilde{\chi}_1^0} \\ &< 0 \quad \text{if } m_\chi < m_{\tilde{\chi}_1^0} \end{aligned}$$

m_{T2} = m_gluino for all m_{qq}

The maximum of m_{T2} occurs when m_{qq} = m_{qq} (max)

The maximum of m_{T2} occurs when m_{qq} = 0

This result implies that

$$m_{T2}^{\max}(m_\chi) = \left(m_{\tilde{g}} - m_{\tilde{\chi}_1^0}\right) + m_\chi \qquad \text{for} \quad m_\chi \ge m_{\tilde{\chi}_1^0}$$

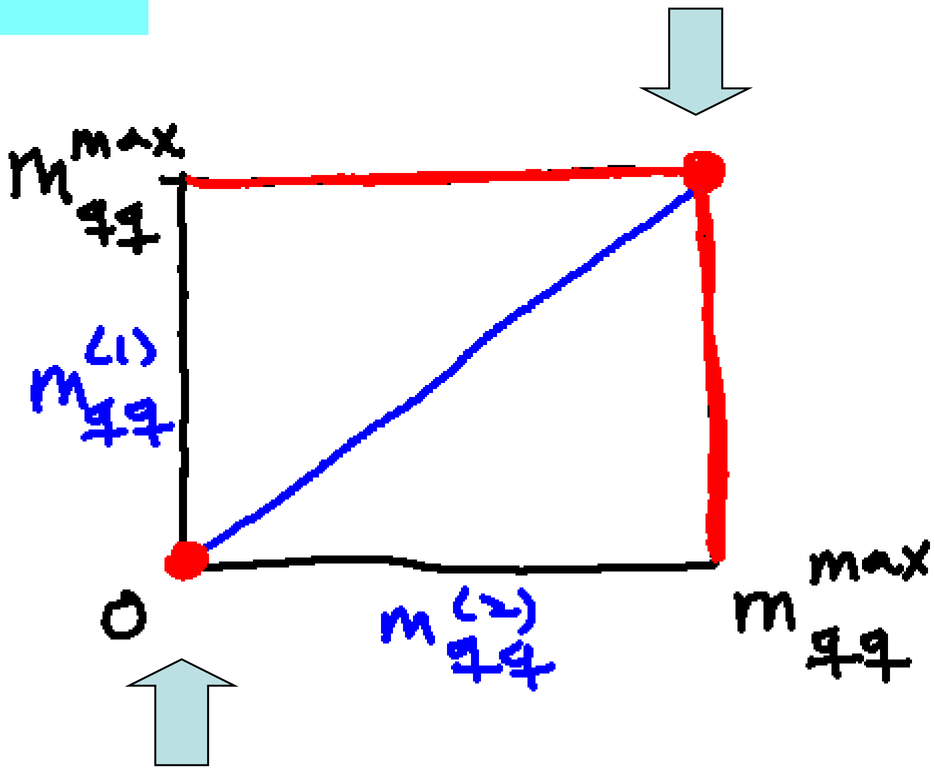
$$m_{T2}^{\max}(m_\chi) = \frac{m_{\tilde{g}}^2 - m_{\tilde{\chi}_1^0}^2}{2m_{\tilde{g}}} + \sqrt{\left(\frac{m_{\tilde{g}}^2 - m_{\tilde{\chi}_1^0}^2}{2m_{\tilde{g}}}\right)^2 + m_\chi^2} \qquad \text{for} \quad m_\chi \le m_{\tilde{\chi}_1^0}.$$

(This conclusion holds also for more general cases where m_{qq1} is different from m_{qq2})

$$\theta = 0$$

$$m_{T2}^{\max}(m_\chi) = \left(m_{\tilde{g}} - m_{\tilde{\chi}_1^0}\right) + m_\chi$$

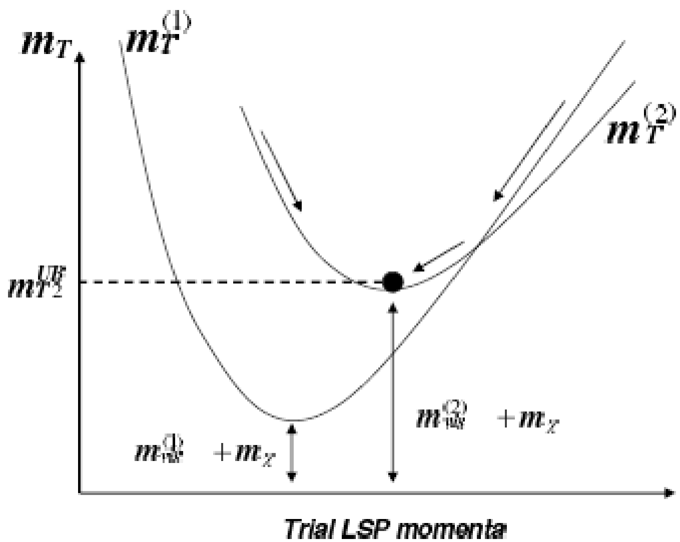
for $m_\chi \geq m_{\tilde{\chi}_1^0}$

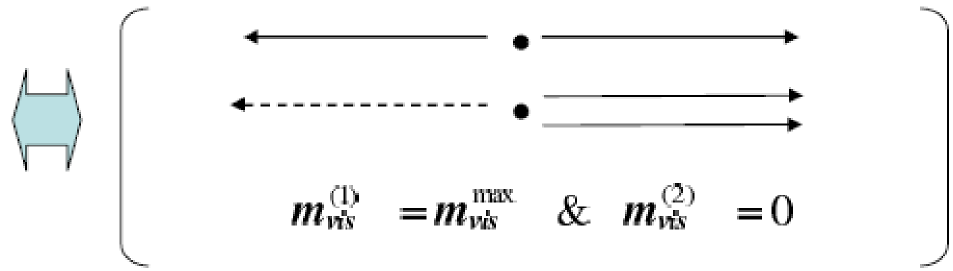


$$m_{T2}^{\max}(m_\chi) = \frac{m_{\tilde{g}}^2 - m_{\tilde{\chi}_1^0}^2}{2m_{\tilde{g}}} + \sqrt{\left(\frac{m_{\tilde{g}}^2 - m_{\tilde{\chi}_1^0}^2}{2m_{\tilde{g}}}\right)^2 + m_\chi^2} \qquad \text{for} \quad m_\chi \leq m_{\tilde{\chi}_1^0}.$$

Unbalanced Solution of m_{T2} can appear

$$\text{for} \quad m_\chi \geq m_{\tilde{\chi}_1^0}$$





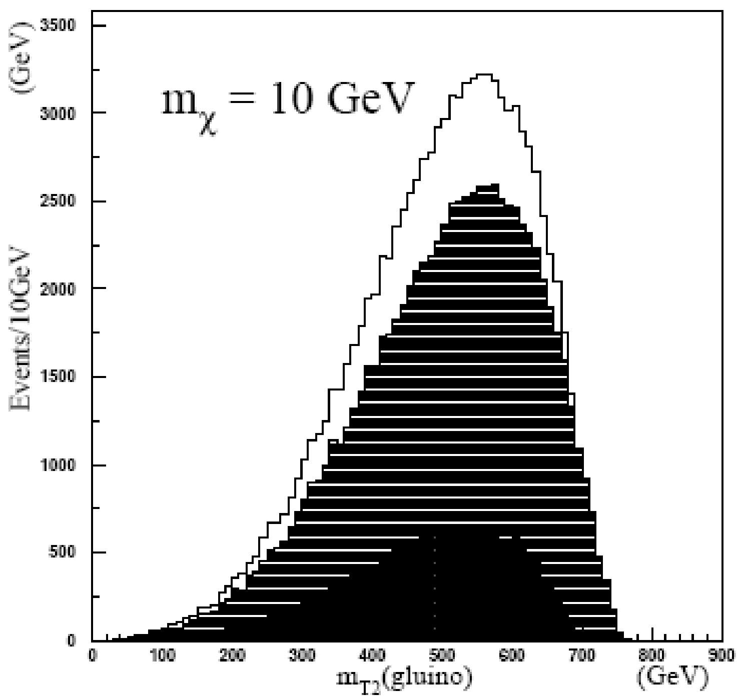
In some momentum configuration, unconstrained minimum of one $m_T^{(2)}$ is larger than the corresponding other $m_T^{(1)}$

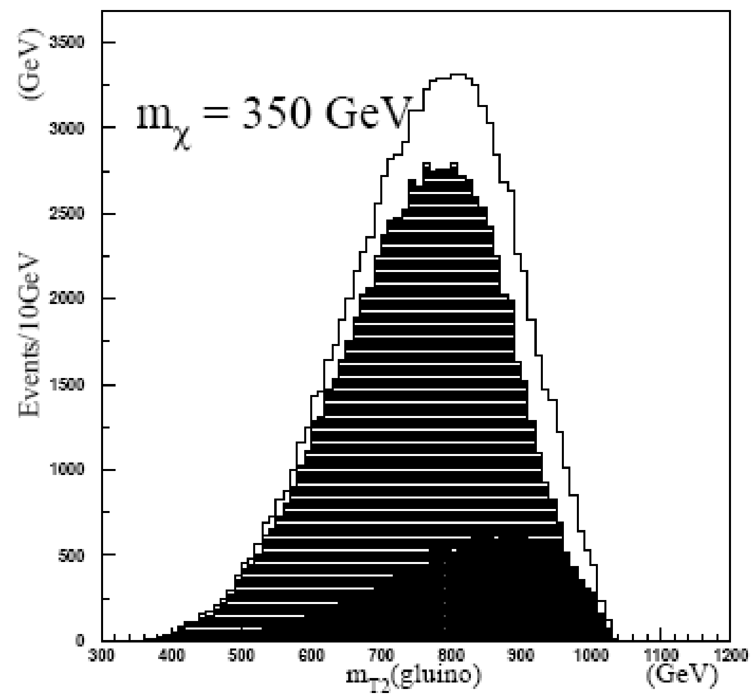
Then, m_{T2} is given by the constrained minimum of $m_T^{(2)}$

$$m_{T2}^{(max)} = m_{qq}^{(max)} + m_x$$

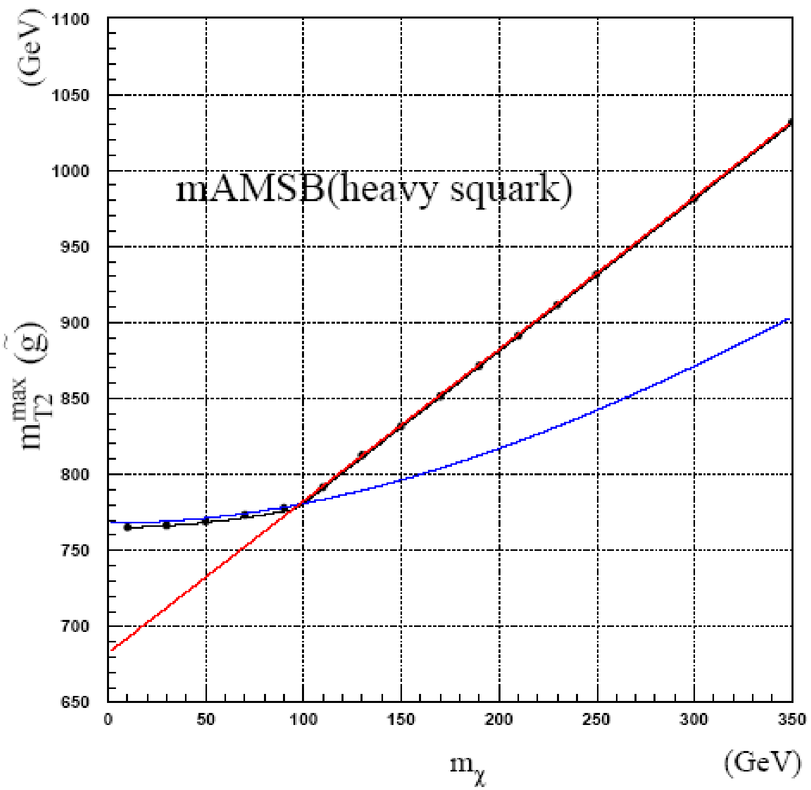
Gluino m_{T2} distributions for AMSB bechmark poi

True gluino mass = 780 GeV,
True LSP mass = 98 GeV





If the function $m_{T2}^{\max}(m_\chi)$ could be constructed from experimental data, which would identify the crossing poi[nt]
one will be able to determine the gluino mass and the LSP mass simultaneously.



$$m_{T2}^{\max}(m_\chi) = \left(m_{\tilde{g}} - m_{\tilde{\chi}_1^0}\right) + m_\chi$$

$$m_{T2}^{\max}(m_\chi) = \frac{m_{\tilde{g}}^2 - m_{\tilde{\chi}_1^0}^2}{2m_{\tilde{g}}} + \sqrt{\left(\frac{m_{\tilde{g}}^2 - m_{\tilde{\chi}_1^0}^2}{2m_{\tilde{g}}}\right)^2 + m_\chi^2}$$

A numerical example

$$m_{\tilde{g}} = 780.3 \text{ GeV}, \ m_{\tilde{\chi}_1^0} = 97.9 \text{ GeV},$$

and a few TeV masses for sfermions

Experimental feasibility

An example (a point in mAMSB)

$$m_{\tilde{g}} = 780.3 \text{ GeV}, \quad m_{\tilde{\chi}_1^0} = 97.9 \text{ GeV},$$

with a few TeV sfermion masses
(gluino undergoes three body decay)

$$\sigma(\tilde{g}\tilde{g}) \sim 1.1\text{pb} \qquad B(\tilde{g} \to \tilde{\chi}_1^0 qq) \sim 32\%,$$

Wino LSP

$$B(\tilde{g} \to \tilde{\chi}_1^{\pm} qq') \sim 64\%.$$

We have generated a MC sample of SUSY events,
which corresponds to 300 fb^{-1} by PYTHIA

The generated events further processed with PGS detector simulation,
which approximates an ATLAS or CMS-like detector

Experimental selection cuts

At least 4 jets with $P_{T1,2,3,4} > 200, 150, 100, 50$ GeV

Missing transverse energy $E_T^{miss} > 250$ GeV

Transverse sphericity $S_T > 0.25$

No b-jets and no-leptons

The four leading jets are divided into two groups of dijets by hemisphere analysis

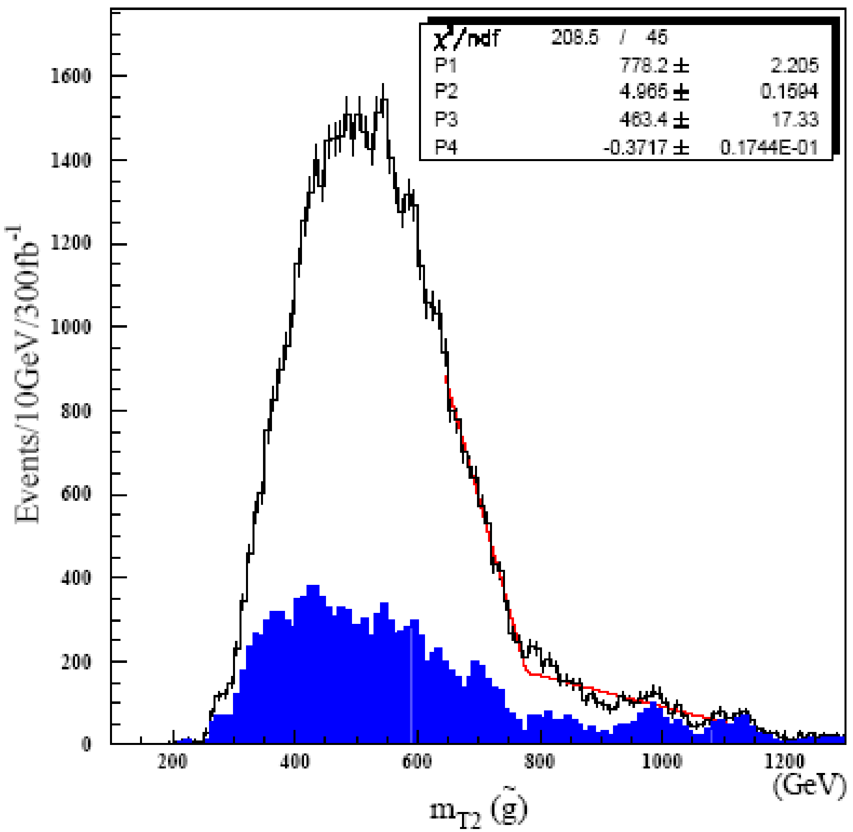
Seeding : The leading jet and the other jet which has the largest $|p_{jet}|\Delta R$ with respect to the leading j are chosen as two 'seed' jets for the division

Association : Each of the remaining jets is associated to the seed jet making a smaller opening angle

If this procedure fail to choose two groups of jet pairs,
We discarded the event

The gluino m_{T2} distribution

with the trial LSP mass m_χ = 90 GeV

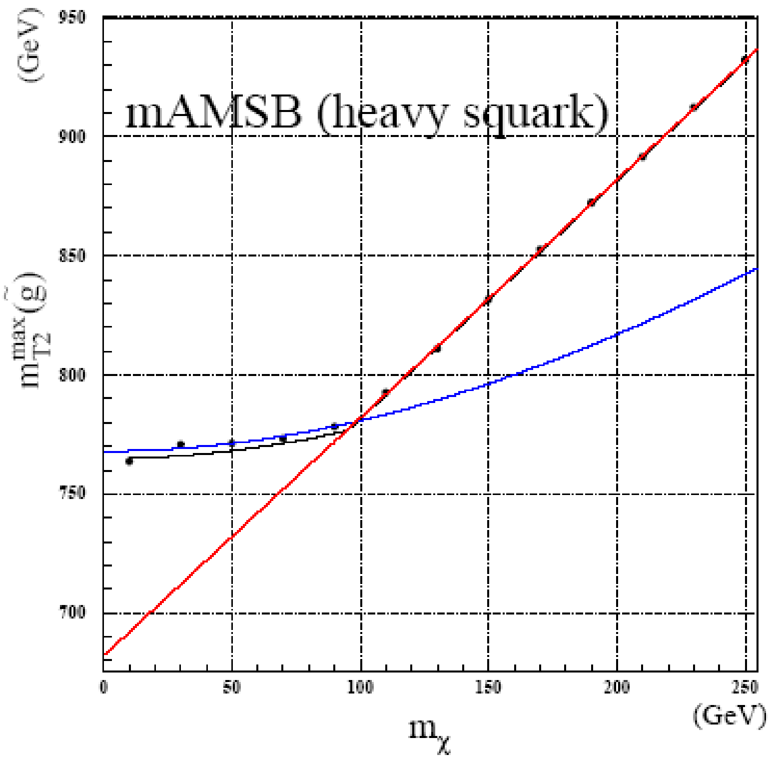


Fitting with a linear function with a linear background, We get the endpoints

$m_{T2}(max) = 778.2 \pm 2.2$ GeV

The blue histogram : SM background

$m_{T2}^{\max}$ as a function of the trial LSP mass for the benchmark point



$$m_{T2}^{\max}(m_\chi) = \left(m_{\tilde{g}} - m_{\tilde{\chi}_1^0}\right) + m_\chi$$

$$m_{T2}^{\max}(m_\chi) = \frac{m_{\tilde{g}}^2 - m_{\tilde{\chi}_1^0}^2}{2m_{\tilde{g}}} + \sqrt{\left(\frac{m_{\tilde{g}}^2 - m_{\tilde{\chi}_1^0}^2}{2m_{\tilde{g}}}\right)^2 + m_\chi^2}$$

Fitting the data points with the above two theoretical curves, we obtain

$$m_{\tilde{g}} = 776.5 \pm 1.0 \text{ GeV}$$

$$m_{\tilde{\chi}_1^0} = 94.9 \pm 1.4 \text{ GeV}$$

The true values are

$$m_{\tilde{g}} = 780.3 \text{ GeV}, \; m_{\tilde{\chi}_1^0} = 97.9 \text{ GeV},$$

For case of two body cascade de

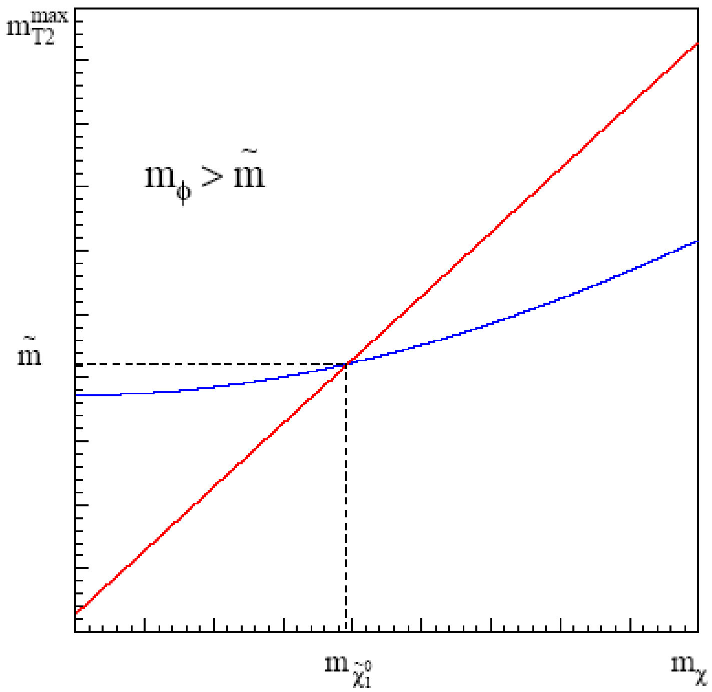
$$m_{\tilde{q}} < m_{\tilde{g}}, \quad \tilde{g} \to q\tilde{q} \to qq\tilde{\chi}_1^0$$

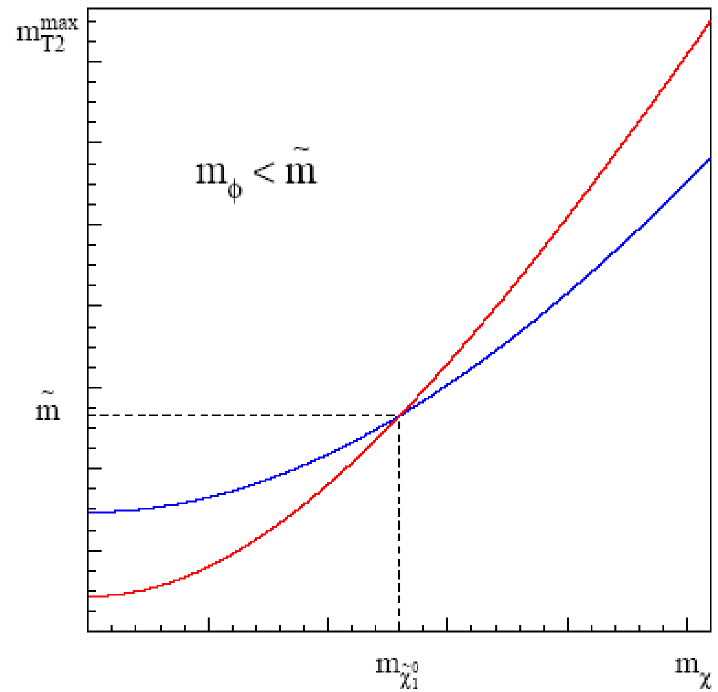
$$0 \le m_{vis}^{(1)}, m_{vis}^{(2)} \le \sqrt{\frac{(m_{\tilde{g}}^2 - m_{\tilde{q}}^2)(m_{\tilde{q}}^2 - m_{\tilde{\chi}_1^0}^2)}{m_{\tilde{q}}^2}}.$$

Therefore, for $m_\chi \ge m_{\tilde{\chi}_1^0}$

$$m_{T2}^{\max} = \left(\frac{m_{\tilde{g}}}{2}(1 - \frac{m_{\tilde{q}}^2}{m_{\tilde{g}}^2}) + \frac{m_{\tilde{g}}}{2}(1 - \frac{m_{\tilde{\chi}_1^0}^2}{m_{\tilde{q}}^2}) \right) + \sqrt{\left(\frac{m_{\tilde{g}}}{2}(1 - \frac{m_{\tilde{q}}^2}{m_{\tilde{g}}^2}) - \frac{m_{\tilde{g}}}{2}(1 - \frac{m_{\tilde{\chi}_1^0}^2}{m_{\tilde{q}}^2}) \right)^2 + m_\chi^2}.$$

For three body decay **For two body cascade decay**

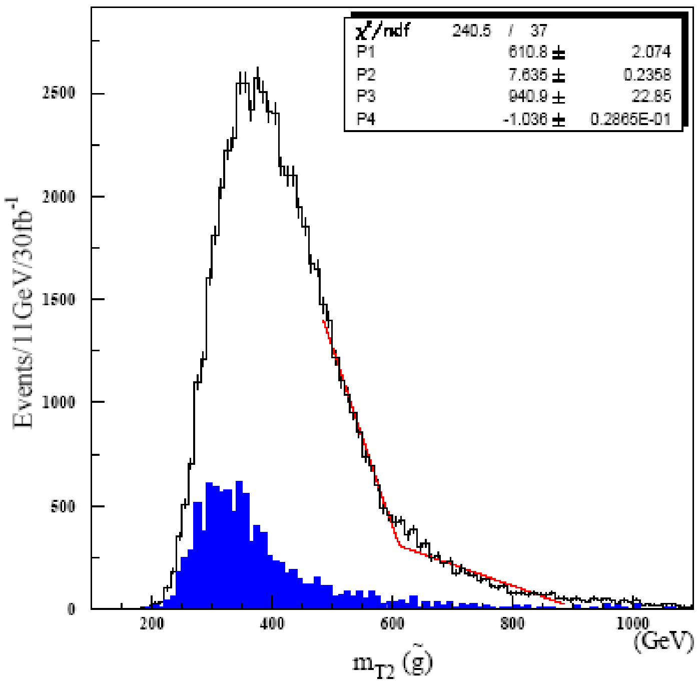


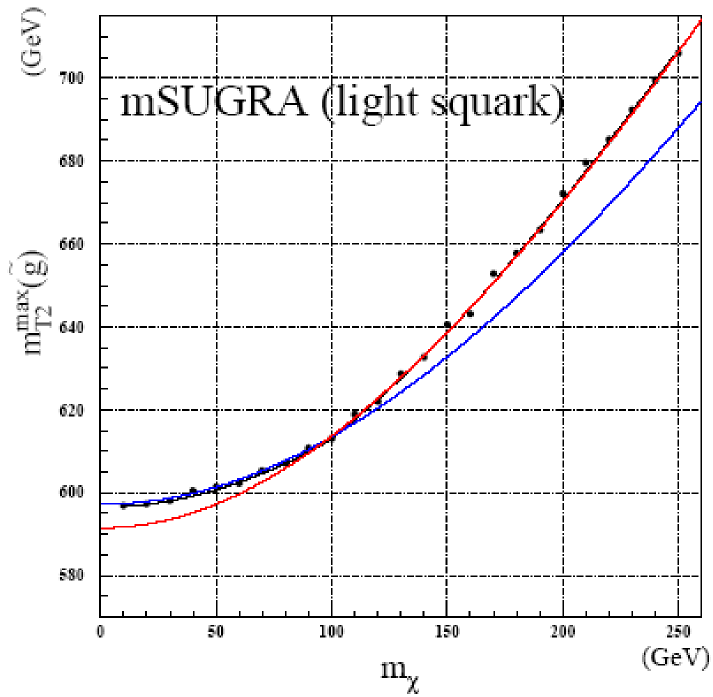


$$\frac{(d\mathcal{F}_{>}^{\max}/dm_\chi)_{m_\chi=m_{\tilde{\chi}_1^0}}}{(d\mathcal{F}_{<}^{\max}/dm_\chi)_{m_\chi=m_{\tilde{\chi}_1^0}}} = 1 + \frac{(m_{vis}^{\max})^2 - (m_{vis}^{\min})^2}{\tilde{m}^2 + m_{\tilde{\chi}_1^0}^2 - (m_{vis}^{\max})^2} > 1.$$

mSUGRA with light squarks

$$m_{\tilde{g}} = 613, \quad m_{\tilde{q}} = 525, \quad m_{\tilde{\chi}_1^0} = 99 \text{ GeV}.$$





$$m_{\tilde{g}} = 611.7 \pm 2.8, \quad m_{\tilde{q}} = 519.9 \pm 2.8, \quad m_{\tilde{\chi}_1^0} = 96.3 \pm 8.1 \text{ GeV}$$

Some Remarks

The above results DO NOT include systematic uncertainties associated with, for example, fit function and fit range to determine the endpoint of mT2 distribution et

For sps1a case, large contributions from squark-gluino events. Still the maximum of mT2 distribution is determi by gluino-gluino events. Need to understand contribution from squark-gluino events (asymmetric even

W/Z + multi-jets (SM backgrounds) are not included

Possible improvements (?) of kink meth

Instead of jet-paring with hemishpere analysis,
calculate m_{T2} for all possible divisions of a given event
into two sets and then minimize m_{T2} (M tgen)

Barr, Gripaios and Lester (arXiv:0711.4008 [hep-ph])

A Variant of 'gluino' m_{T2} with explicit constraint from
the endpoint of 'diquark' invariant mass (M_{2C})

Ross and Serna (arXiv:0712.0943 [hep-ph])

Conclusions

We introduced a new observable, 'gluino m_{T2}'

We showed that the maximum of the gluino m_{T2} as a function of trial LSP mass has a kink structure at true LSP mass from which gluino mass and LSP mass can be determined simultaneously.

BACKUP

Theorem : (Cho, Choi, Kim and Park, arXiv:0711.4526)

m_{T2} of any event induced by mother particle pair having a vanishing total transverse momentum in Lab. frame is bounded from above by another m_{T2} of an event induce by mother particle pair at rest

$$m_{T2}(\mathbf{p}_T^{vis(i)}, m_{vis}^{(i)}, m_\chi) \leq m_{T'2}(\mathbf{q}^{vis(i)}, m_{vis}^{(i)}, m_\chi)$$

for generic $\mathbf{p}^{vis(i)}$ measured in the laboratory frame,

where $\mathbf{q}^{vis(i)}$ is the Lorentz boost of $\mathbf{p}^{vis(i)}$ to the rest frame of the i-th mother particle,

T′ is the plane spanned by $\mathbf{q}^{vis(1)}$ and $\mathbf{q}^{vis(2)}$

The equality in the above bound holds when T=T′

For the m_{T2} solution, we can consider

the first decay products as having total mass m_{T2},

total transverse momentum $p_T^{(1)} = p_T^{q(1)} + p_T^{\chi(1)}$

and total transverse energy $E_T^{(1)} = E_T^{q(1)} + E_T^{\chi(1)}$

Similarly, for the second products, we have

m_{T2}, $p_T^{(2)} = p_T^{q(2)} + p_T^{\chi(2)}$ $E_T^{(2)} = E_T^{q(2)} + E_T^{\chi(2)}$

$$p_T^{(1)} = -p_T^{(2)}, \quad E_T^{(1)} = E_T^{(2)}$$

Arbitrary back-to-back transverse boost the systems

$$p_T^{(1)\prime} = \gamma p_T^{(1)} + \gamma\beta E_T^{(1)}$$
$$p_T^{(2)\prime} = \gamma p_T^{(2)} - \gamma\beta E_T^{(2)}$$

Then,

$$p_T^{(1)\prime} + p_T^{(2)\prime} = \gamma(p_T^{(1)} + p_T^{(2)}) = 0.$$
$$p_T^{\chi(1)\prime} + p_T^{\chi(2)\prime} = -(p_T^{q(1)\prime} + p_T^{q(2)\prime})$$

We have valid splitting of total MET and thus m_{T2} solution.

The balanced m T2 solution

$$\left(m_{T2}^{\text{bal}}\right)^2 = m_\chi^2 + A_T + \sqrt{\left(1 + \frac{4m_\chi^2}{2A_T - \left(m_{vis}^{(1)}\right)^2 - \left(m_{vis}^{(2)}\right)^2}\right)\left(A_T^2 - \left(m_{vis}^{(1)} m_{vis}^{(2)}\right)^2\right)},$$

where

$$\begin{aligned} A_T &\equiv \alpha_1^0 \alpha_2^0 + \vec{\alpha_1} \cdot \vec{\alpha_2} \\ &= E_T^{vis(1)} E_T^{vis(2)} + \mathrm{p}_T^{vis(1)} \cdot \mathrm{p}_T^{vis(2)} \end{aligned}$$

SPS1a point

$$\sigma(\tilde{g}\tilde{g}) \sim 4.2 \text{ pb}, \ \sigma(\tilde{g}\tilde{q}) \sim 21 \text{ pb, and } \sigma(\tilde{q}\tilde{q}) \sim 9 \text{ pb}$$

$$\tilde{g} \to \tilde{q}q \to \tilde{\chi}_1^0 qq \text{ is } B(\tilde{g} \to \tilde{\chi}_1^0 qq) \sim 40\%,$$

$$B(\tilde{g} \to \tilde{\chi}_2^0 qq) \sim 7\%, \text{ and } B(\tilde{g} \to \tilde{\chi}_1^{\pm} qq') \sim 14\%$$