Mass and Spin measurement with mT2 at the LHC

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In collaboration with
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- SUSY at the LHC
- Mass measurement with m_{T2}
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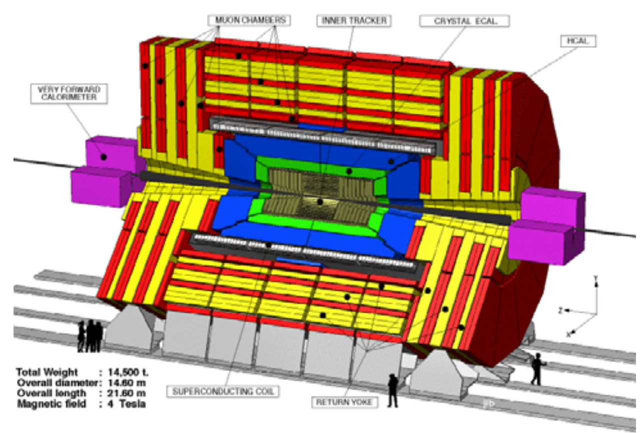
Press Release

PR13.09
06.08.2009

LHC to run at 3.5 TeV for early part of 2009–2010 run rising later

Geneva, 6 August 2009. CERN's Large Hadron Collider will initially run at an energy of 3.5 TeV per beam when it starts up in November this year. This news comes after all tests on the machine's high-current electrical connections were completed last week, indicating that no further repairs are necessary for safe running.



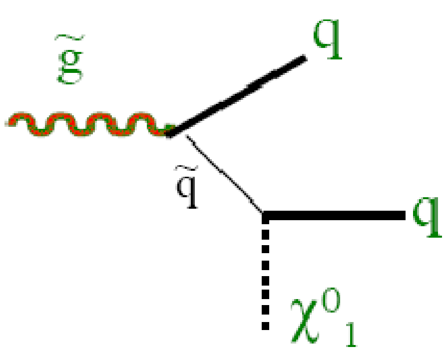
LHC is about to explore for the first time
TeV energy scale.

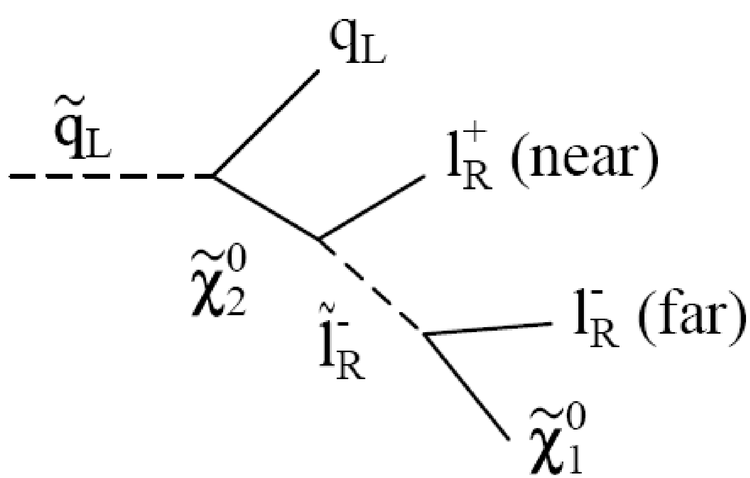
The origin of EWSB ?
The nature of dark matter ?
Supersymmetry ?
Extra dimensions ?

General features for SUSY at the LHC

- SUSY production is dominated by gluinos and squarks, unless they are too heavy

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

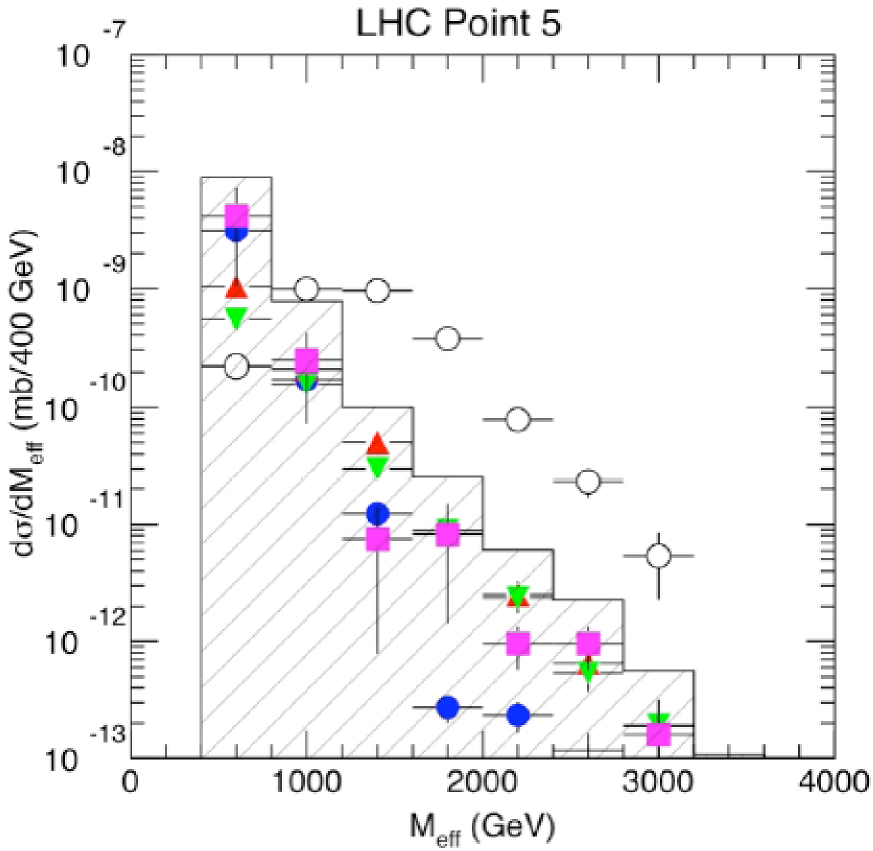




◆ Characteristic signal of SUSY at LHC

→ Large missing ET + energetic jets (+ leptons)

An excess of such events above SM background



$$M_{\text{eff}} = \not{E}_T + \sum_{i=1}^{4} p_{T,i}$$

(Scalar sum of missing ET and transverse momenta of 4 hardest jets)

(Hinchliffe etal. 1997)

Discovery of New Physics

↓

Mass measurements

↓

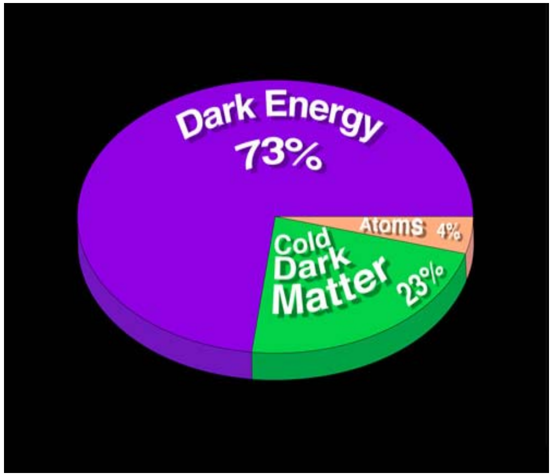
Spin measurements, etc.

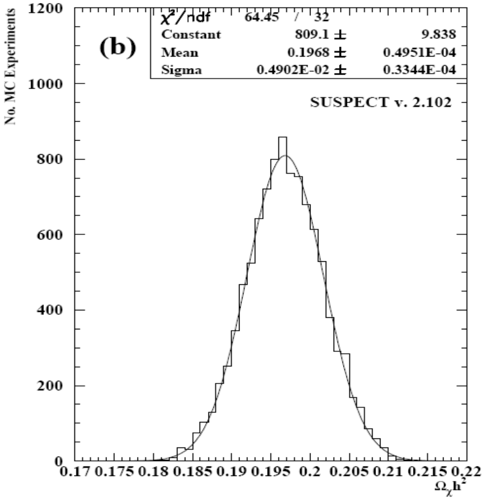
- # Mass measurement of SUSY particles

→ Reconstruction of SUSY theory (SUSY breaking sector)

M1: M2: M3 = 1 : 2 : 6 mSUGRA pattern
3.3 : 1 : 9 AMSB pattern etc.

→ Weighing Dark Matter with collider



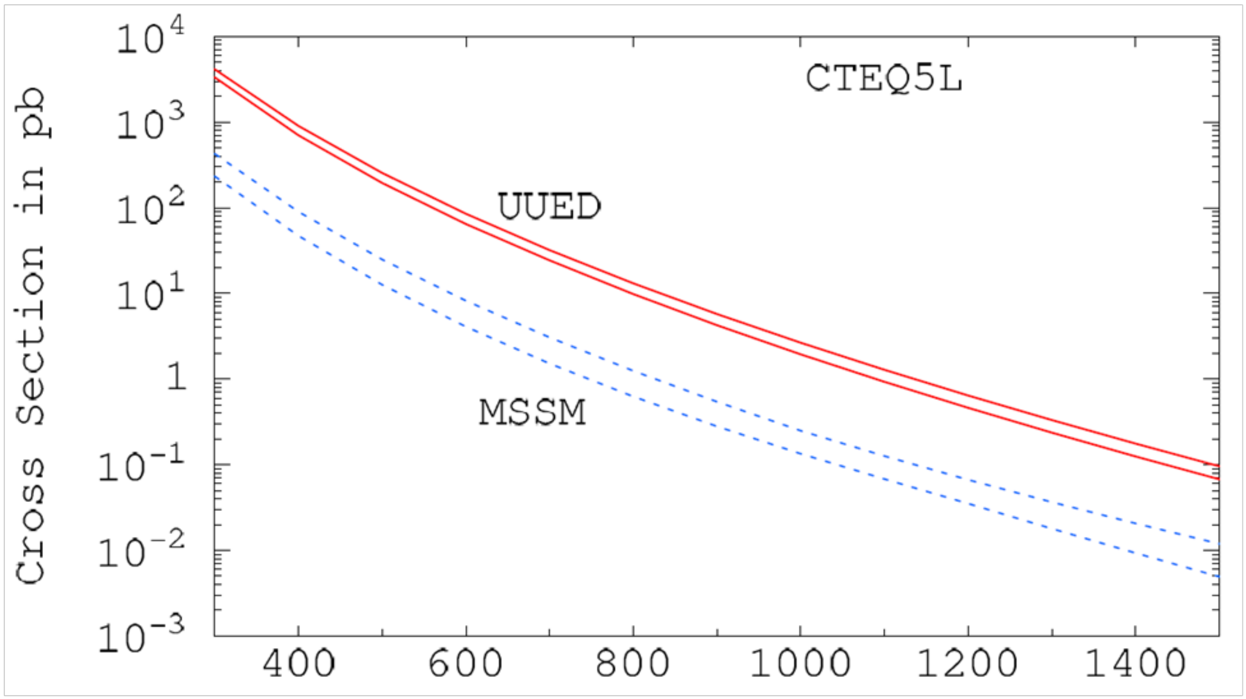


(Thermal relic DM density)

→ Distinguishing SUSY from other models

The production rate of KK-gluon vs. gluino

(Datta, Kane, Toharia 2007)



Mass (GeV)

The Mass measurement is Not an easy task at the LHC !

- Final state momentum in beam direction is unknown a priori, due to our ignorance of initial partonic center of mass frame

- SUSY events always contain two invisible LSPs

→ No masses can be reconstructed directly

- Several approaches (and variants) of mass measurements proposed
  - Invariant mass Edge method

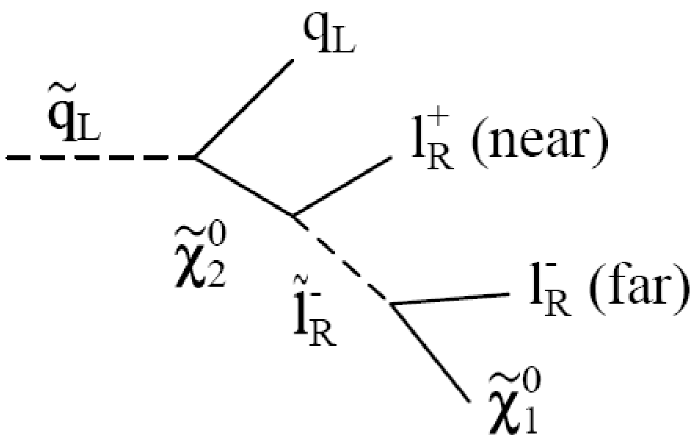
    Hinchliffe, Paige, Shapiro, Soderqvist, Yao ;
    Allanach, Lester, Parker, Webber
    ...
  - Mass relation method

    Kawagoe, Nojiri, Polesello ;
    Cheng, Gunion, Han, Marandellea, McElrath
  - Transverse mass (M_{T2}) kink method

    Lester, Summers; Cho, Choi, YGK, Park ;
    Barr, Gripaios, Lester; Ross, Serna;
    Burns, Kong, Park, Machev
    ...

Invariant mass edge method

Hinchliffe, Paige, etal.
(1997)



- Basic idea

→ Identify a particular long decay chain and measure kinematic endpoints of various invariant mass distributions of visible particles

→ The endpoints are given by functions of SUSY particle masses

If a long enough decay chain is identified,
It would be possible to measure all sparticle masses
Through several endpoint measurements

$$(m^2_{ll})^{\rm edge} = \frac{(m^2_{\tilde\chi^0_2} - m^2_{\tilde l_R})(m^2_{\tilde l_R} - m^2_{\tilde\chi^0_1})}{m^2_{\tilde l_R}},$$

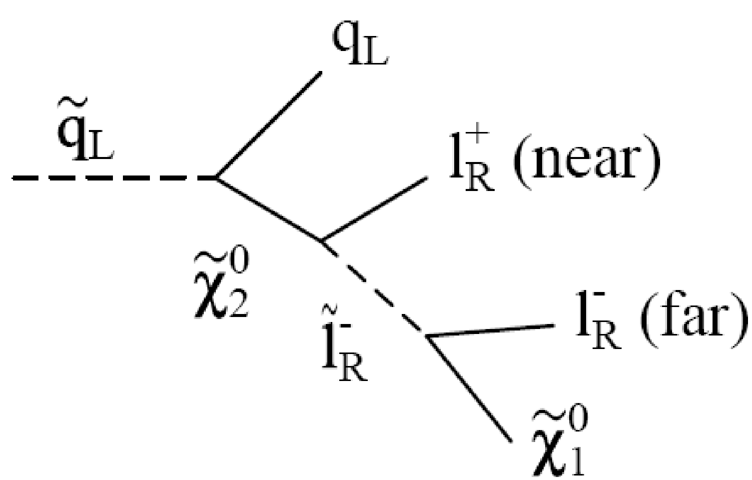
$$(m^2_{qll})^{\rm edge} = \frac{(m^2_{\tilde q_L} - m^2_{\tilde\chi^0_2})(m^2_{\tilde\chi^0_2} - m^2_{\tilde\chi^0_1})}{m^2_{\tilde\chi^0_2}},$$

$$(m^2_{ql})^{\rm edge}_{\rm min} = \frac{(m^2_{\tilde q_L} - m^2_{\tilde\chi^0_2})(m^2_{\tilde\chi^0_2} - m^2_{\tilde l_R})}{m^2_{\tilde\chi^0_2}},$$

$$(m^2_{ql})^{\rm edge}_{\rm max} = \frac{(m^2_{\tilde q_L} - m^2_{\tilde\chi^0_2})(m^2_{\tilde l_R} - m^2_{\tilde\chi^0_1})}{m^2_{\tilde l_R}},$$

$$(m^2_{qll})^{\rm thres} = \Big[(m^2_{\tilde q_L} + m^2_{\tilde\chi^0_2})(m^2_{\tilde\chi^0_2} - m^2_{\tilde l_R})(m^2_{\tilde l_R} - m^2_{\tilde\chi^0_1}) - (m^2_{\tilde q_L} - m^2_{\tilde\chi^0_2})\sqrt{(m^2_{\tilde\chi^0_2} + m^2_{\tilde l_R})^2(m^2_{\tilde l_R} + m^2_{\tilde\chi^0_1})^2 - 16 m^2_{\tilde\chi^0_2} m^4_{\tilde l_R} m^2_{\tilde\chi^0_1}} + 2m^2_{\tilde l_R}(m^2_{\tilde q_L} - m^2_{\tilde\chi^0_2})(m^2_{\tilde\chi^0_2} - m^2_{\tilde\chi^0_1})\Big] / (4 m^2_{\tilde l_R} m^2_{\tilde\chi^0_2}),$$

3 step two-body decays



Mass relation method

Kawagoe, Nojiri, Polesello (2004)

- Consider the following cascade decay chain (4 step two-body decays)

$$\tilde{g} \to \tilde{b} b_2 \to \tilde{\chi}_2^0 b_1 b_2 \to \tilde{\ell} b_1 b_2 \ell_2 \to \tilde{\chi}_1^0 b_1 b_2 \ell_1 \ell_2$$

- Completely solve the kinematics of the cascade decay by using mass shell conditions of the sparticles

- One can write five mass shell conditions

$$m^2_{\tilde{\chi}^0_1} = p^2_{\tilde{\chi}^0_1}, \qquad m^2_{\tilde{\ell}} = (p_{\tilde{\chi}^0_1} + p_{\ell_1})^2,$$
$$m^2_{\tilde{\chi}^0_2} = (p_{\tilde{\chi}^0_1} + p_{\ell_1} + p_{\ell_2})^2,$$
$$m^2_{\tilde{b}} = (p_{\tilde{\chi}^0_1} + p_{\ell_1} + p_{\ell_2} + p_{b_1})^2,$$
$$m^2_{\tilde{g}} = (p_{\tilde{\chi}^0_1} + p_{\ell_1} + p_{\ell_2} + p_{b_1} + p_{b_2})^2.$$

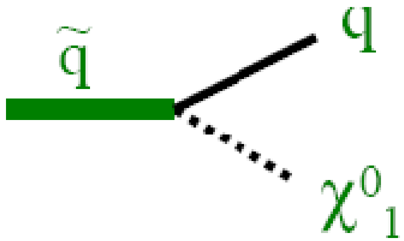
which contain 4 unknown d.o.f of LSP momentum

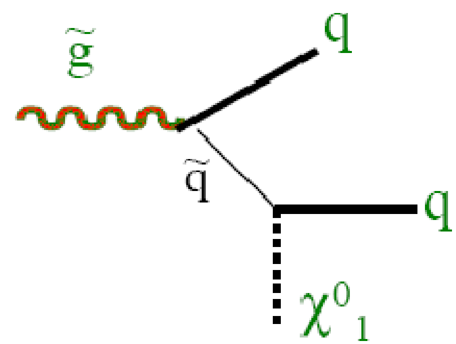
→ Each event describes a 4-dim. hypersurface in 5-dim. mass space, and the hypersurfcae differs event by event

→ Many events determine a solution for masses through intersections of hypersurfaces

✓ Both the Edge method and the Mass relation method rely on a long decay chain to determine sparticle masses

✓ What if we don't have long enough decay chain but only short one ?





✓ In such case, M_{T2} variable would be useful to get information on sparticle masses

Mass measurement with MT2

Cambridge m_{T2} variable

Lester, Summers (1999)

Measuring masses of semi-invisibly decaying particle pairs produced at hadron colliders

C.G. Lester [1], D.J. Summers [2]

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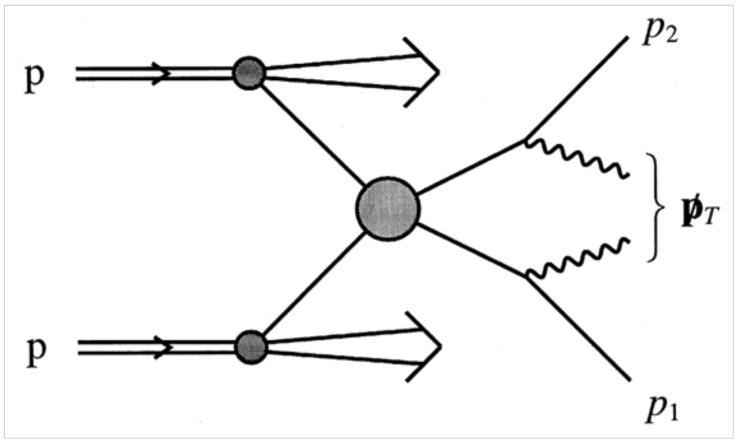
Received 14 June 1999; received in revised form 4 August 1999; accepted 11 August 1999
Editor: P.V. Landshoff

Abstract

We introduce a variable useful for measuring masses of particles which are pair produced at hadron colliders, where each particle decays to one particle that is directly observable and another particle whose existence can only be inferred from missing transverse momentum. This variable is closely related to the transverse mass variable commonly used for measuring the W mass at hadron colliders, and like the transverse mass our variable extracts masses in a reasonably model independent way. Without considering either backgrounds or measurement errors we consider how our variable would perform measuring the mass of selectrons in a mSUGRA SUSY model at the LHC.

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



Massive particles pair produced

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 :

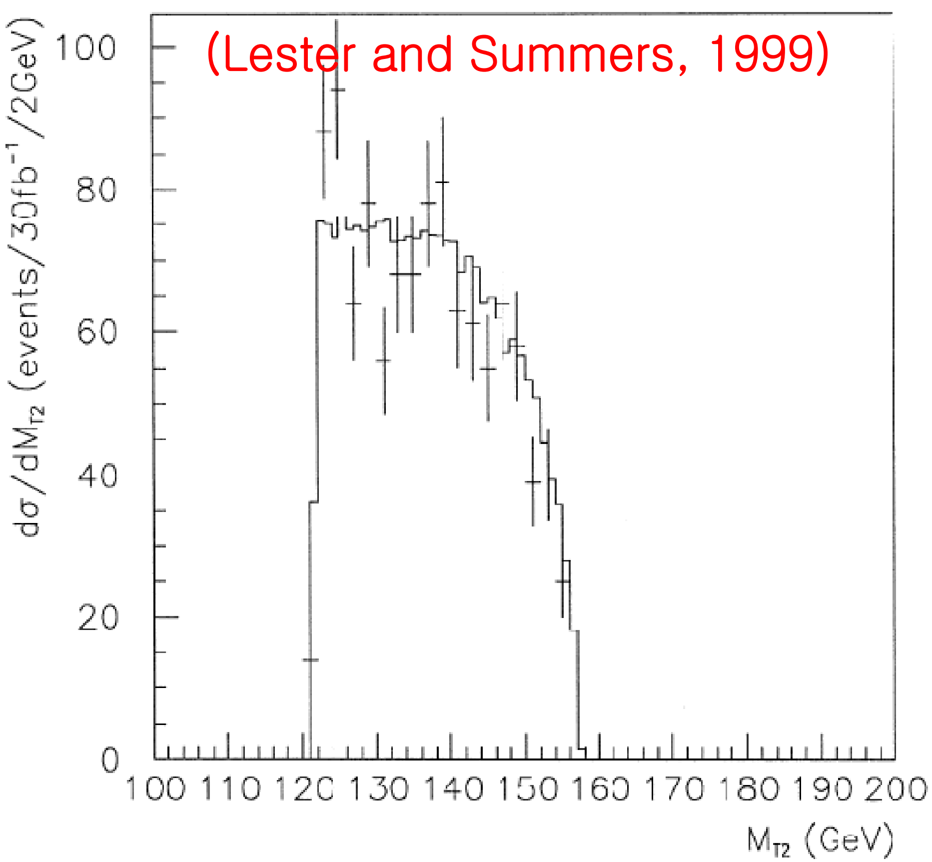
$$m_{\tilde{l}}^2 \geq M_{T2}^2$$
$$\equiv \min_{\not{\boldsymbol{p}}_1 + \not{\boldsymbol{p}}_2 = \not{\boldsymbol{p}}_T} \left[\max\left\{ m_T^2(\boldsymbol{p}_{Tl^-}, \not{\boldsymbol{p}}_1), m_T^2(\boldsymbol{p}_{Tl^+}, \not{\boldsymbol{p}}_2) \right\} \right]$$

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},

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



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

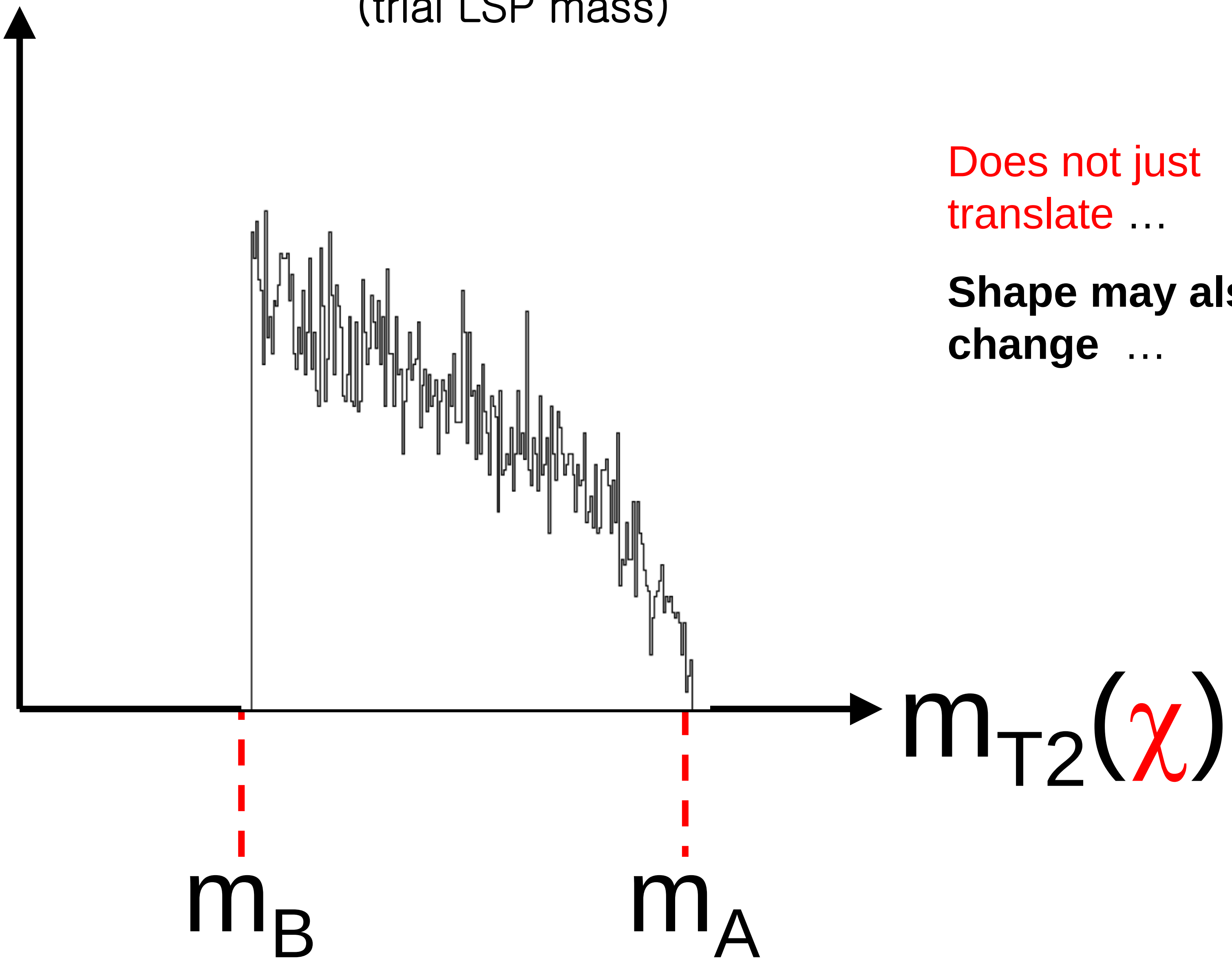
$$m_{T2}^{\max} \simeq 157\ \text{GeV}$$

(with $m_{\tilde{\chi}_1^0} = 121.5$ GeV)

Varying "χ" ...

(trial LSP mass)

(Taken from Lester's talk in the LHC focus week at IPMU)

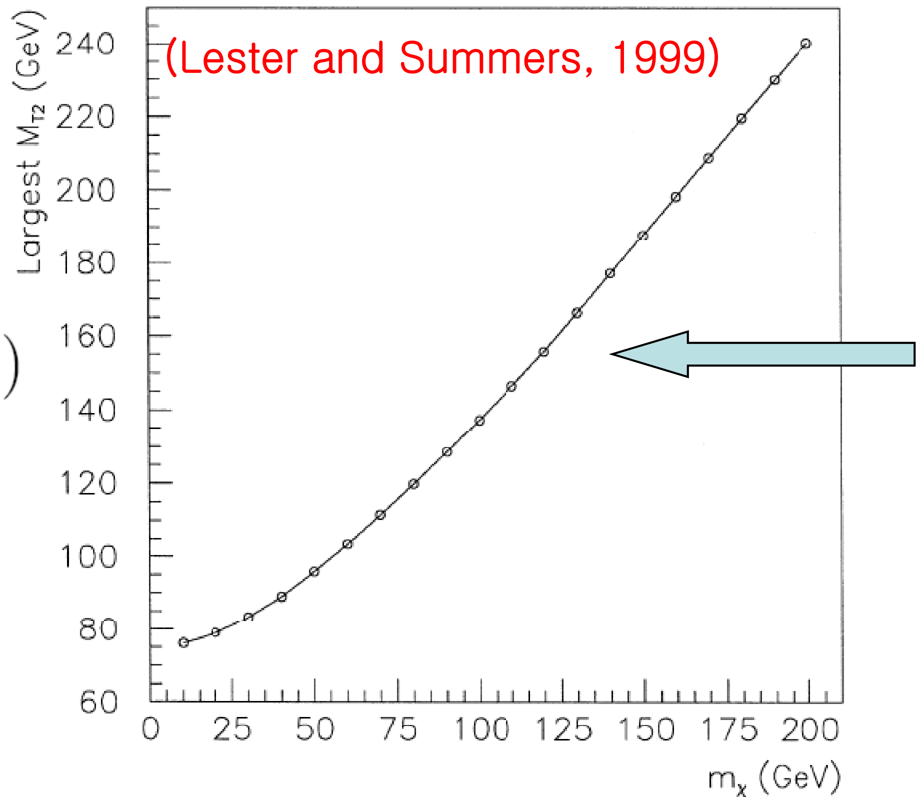


Does not just translate …

Shape may also change …

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

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



m_χ

The correlation from a numerical calculation can be expressed by an analytic formula in terms of true SUSY particle masses

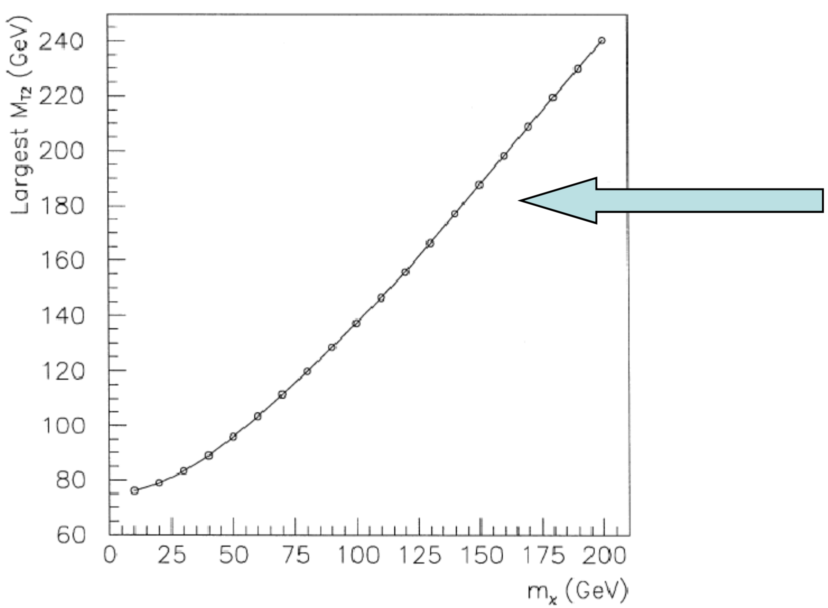
The maximum of the squark m_{T2} as a function of m_χ

(Cho, Choi, YGK and Park, 2007)

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

without ISR

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



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

✓ Mother mass and LSP mass are Not determined separately

Transverse Mass for Pairs of Gluinos
(Gluino mT2)

PRL **100,** 171801 (2008) PHYSICAL REVIEW LETTERS week ending 2 MAY 2008

Transverse Mass for Pairs of Gluinos

Won Sang Cho,[1] Kiwoon Choi,[1] Yeong Gyun Kim,[1,2] and Chan Beom Park[1]
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(Received 15 September 2007; published 28 April 2008)

We introduce a new observable, "gluino m_{T2}," which is an application of the Cambridge m_{T2} variable to the process where gluinos are pair produced in a proton-proton collision and each gluino subsequently decays into two quarks and one lightest supersymmetric particle, i.e., $\tilde{g}\tilde{g} \to qq\tilde{\chi}_1^0 qq\tilde{\chi}_1^0$. We show that the gluino m_{T2} can be utilized to measure the gluino mass and the lightest neutralino mass separately and also the 1st and 2nd generation squark masses if squarks are lighter than the gluino, thereby providing a good first look at the pattern of sparticle masses experimentally.

DOI: 10.1103/PhysRevLett.100.171801 PACS numbers: 14.80.Ly, 12.60.Jv, 13.85.Hd

(Cho, Choi, YGK and Park, arXiv:0709.0288)

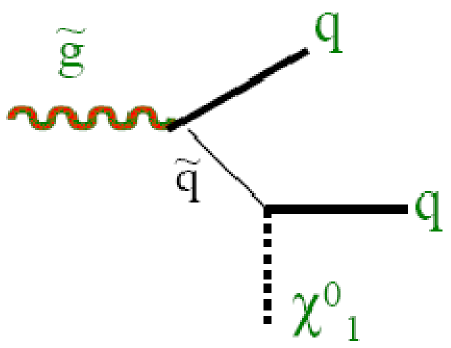
• Gluino m_{T2}

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

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

Gluinos are pair produced in proton-proton collision

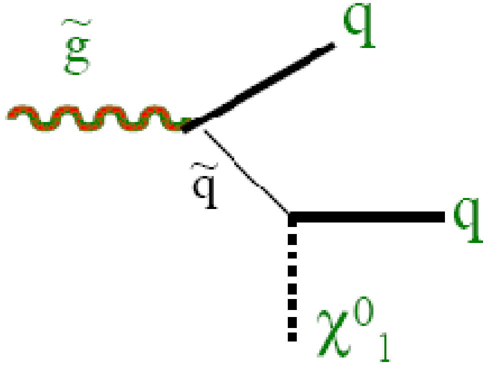
Each gluino decays into two quarks and one LSP



through three body decay (off-shell squark)

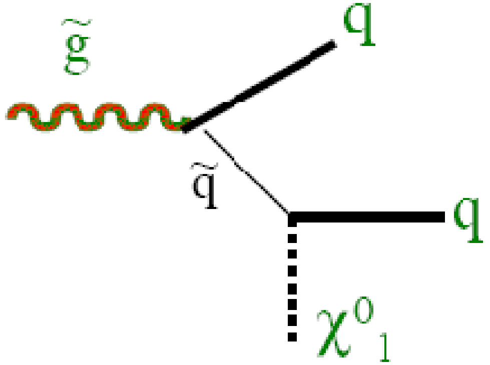
or two body cascade decay (on-shell squark)

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

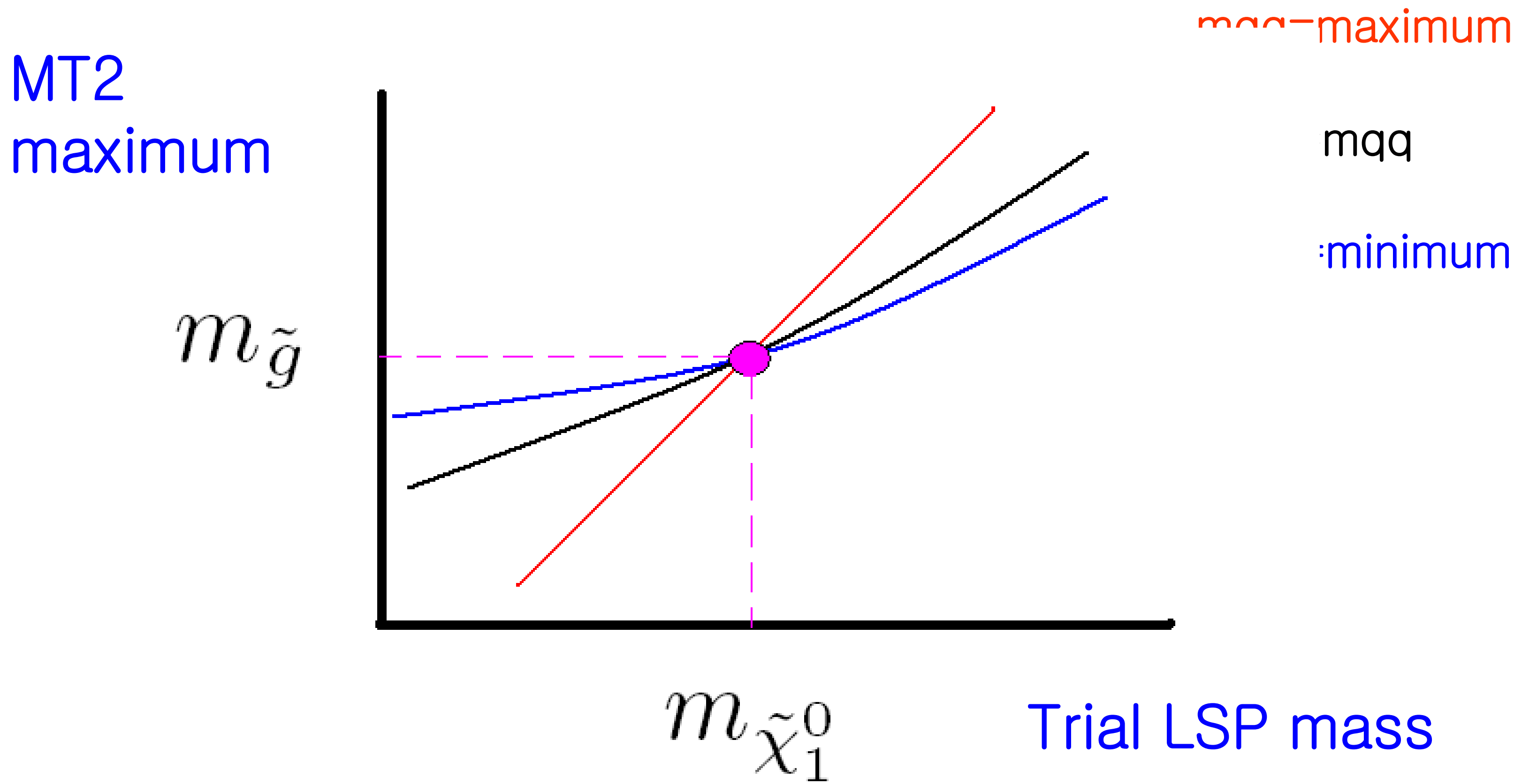


m_{qq} value for
three body gluino decay

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



- MT2 maximum as a function of trial LSP mass depends on di-quark invariant mass (mqq)



(Assume mqq(1) = mqq(2), for simplicity)

Experimental feasibility

An example (a point in mAMSB)

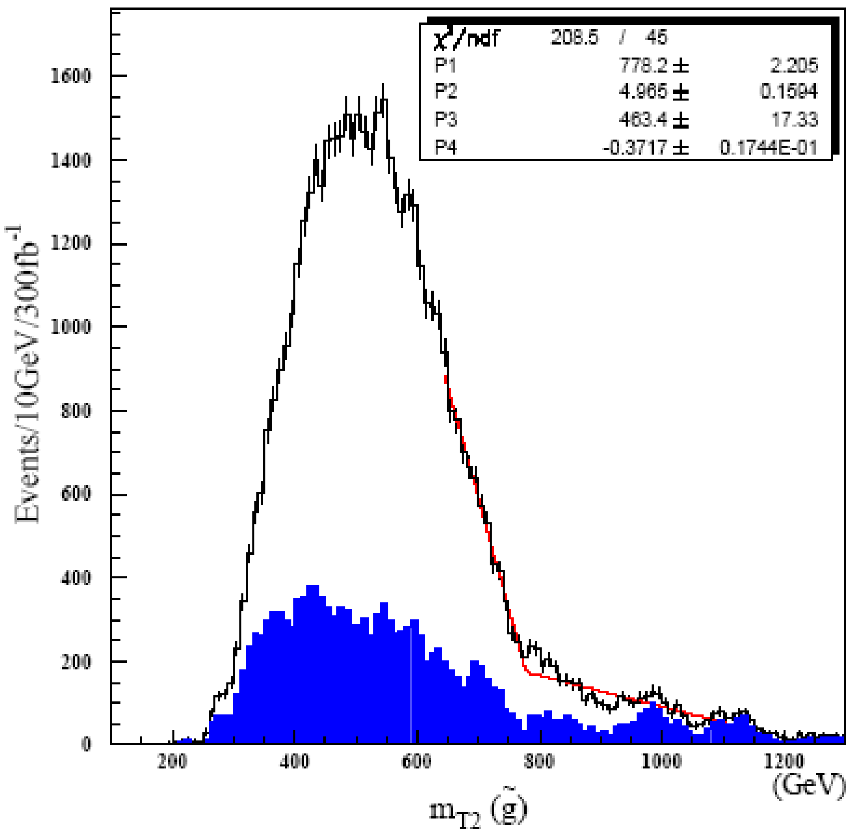
$$m_{\tilde{g}} = 780.3 \text{ GeV}, \; m_{\tilde{\chi}_1^0} = 97.9 \text{ GeV},$$

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

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

Gluino m_{T2} distribution
with the trial LSP mass m_x = 90 GeV

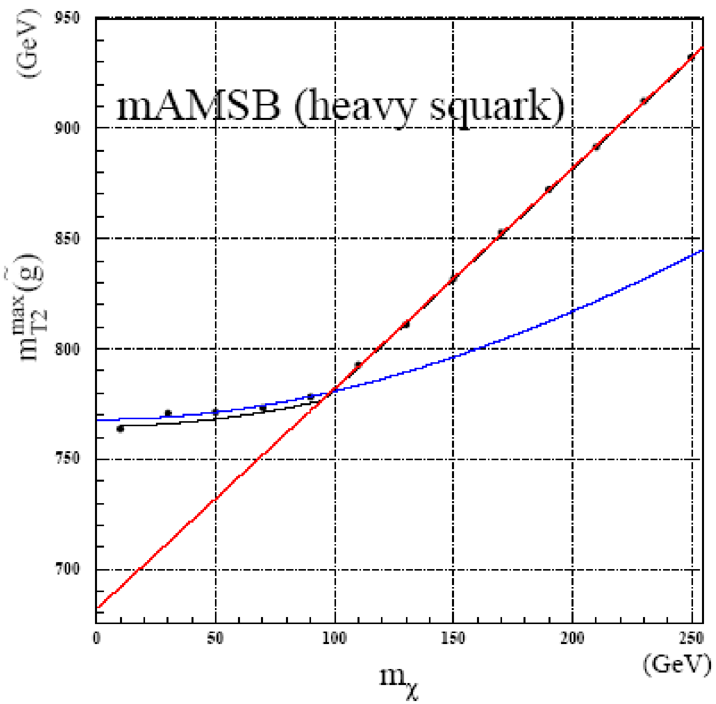


Fitting with a linear function
with a linear background,
We get the endpoints

m_{T2} (max) = 778.2 ± 2.2 GeV

The blue histogram :
SM background

$m_{T2}^{\max}$ as a function of the trial LSP mass for a benchmark point (Monte Carlo study)



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

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

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

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

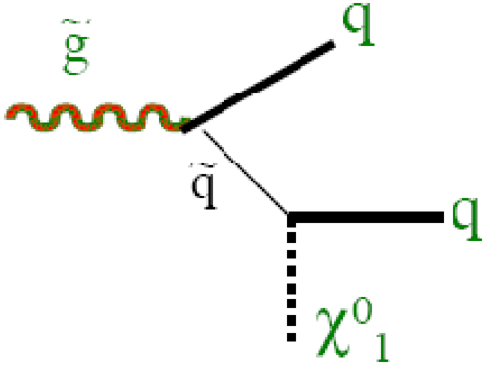
$$m_{\tilde{\chi}_1^0} = 94.9 \pm 1.4 \text{ GeV}$$

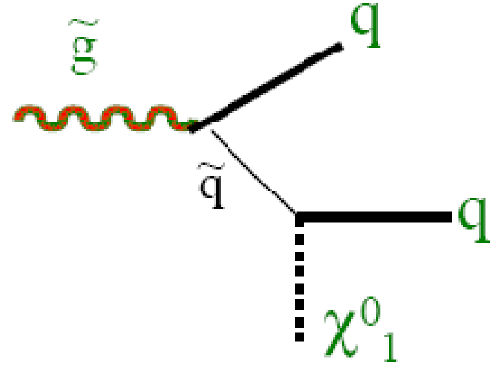
The true values are

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

With the invariant mass edge method,
we get only the mass difference of mother and LSP

Now, with the gluino mT2,
We can get the absolute mass scale of SUSY particles





At IPMU workshop in Japan, Dec. 2007

Teruki Kamon :
Can the mT2 be applied for measuring top quark mass in dileptonic channel at hadron colliders ?

YGK :
Yes, it can be applied to any process, in which mother particles are pair-produced and each decays to one invisible and some visible particles.

Standard Candle for MT2 study

(Cho,Choi, YGK, Park, arXiv:0804.2185)
PRD 78, 034019 (2008)

We can consider Top-quark mT2

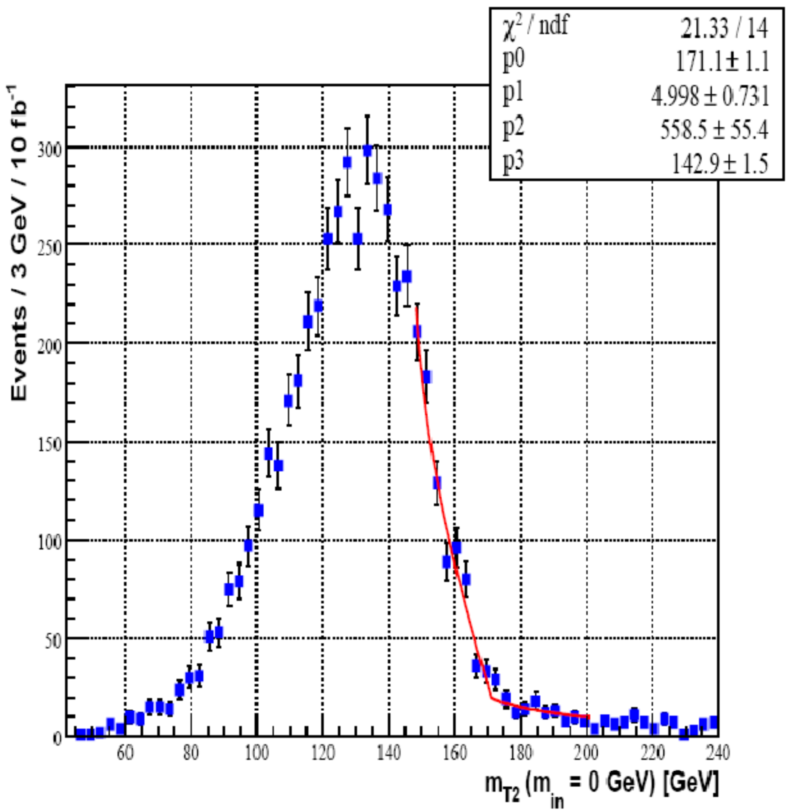
$$t\bar{t} \longrightarrow bl^+\nu\bar{b}l^-\nu$$

- Large statistics available at the LHC $\sigma(t\bar{t}) \sim 800 \text{ pb}$
- Mass of invisible particle is already known (m_nu=0)

Standard Candle for MT2 study

(Cho,Choi, YGK, Park, arXiv:0804.2185)

Top quark mT2 distribution with m_nu = 0



With 10 fb^{-1} ,
2 b-jets, 2 leptons,
Large missing ET

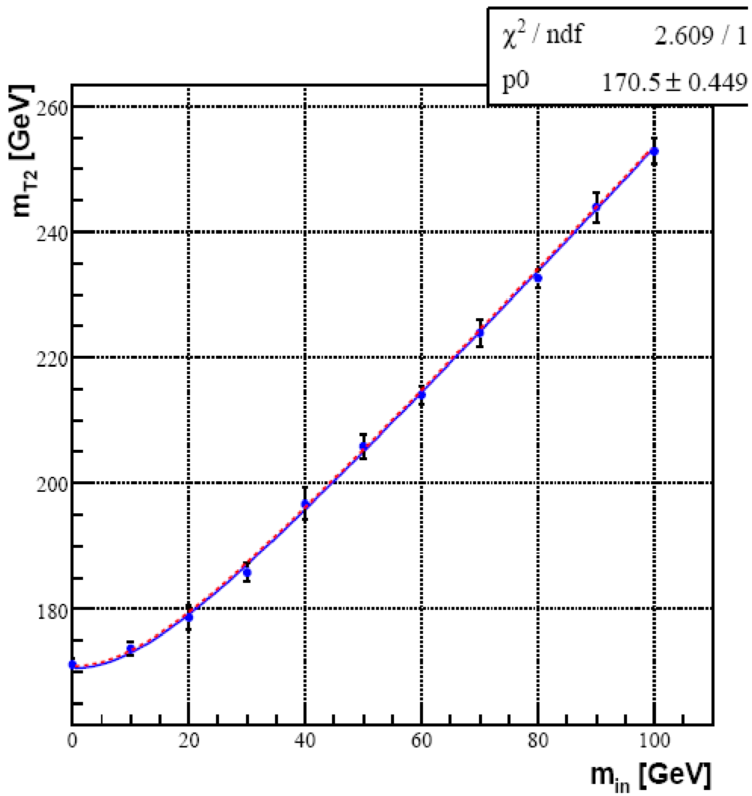
$$m_t = 171.1 \pm 1.1 \text{ GeV}$$

for input mt=170.9 GeV.
No systematic error included

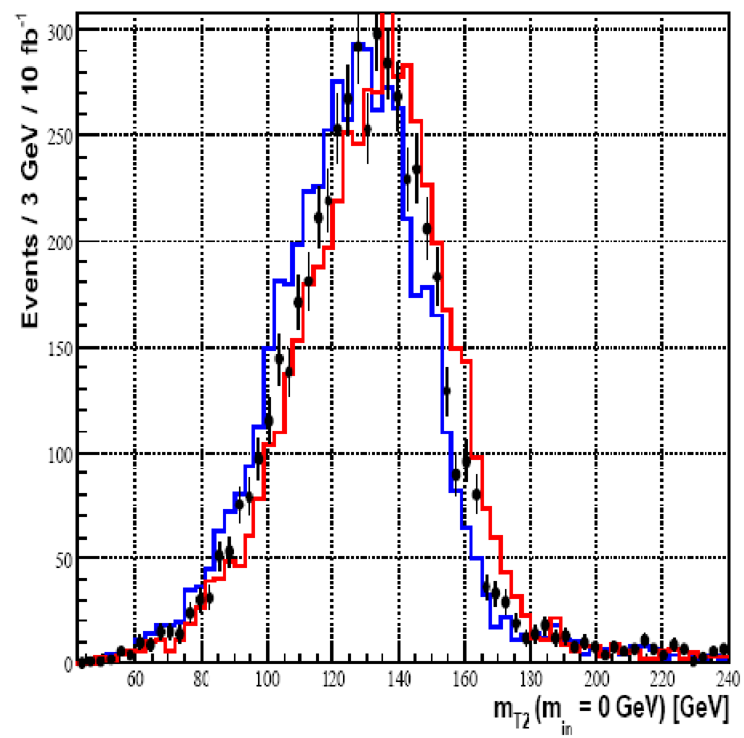
Standard Candle for MT2 study

(Cho,Choi, YGK, Park, arXiv:0804.2185)

mT2 max vs. trial neutrino mass

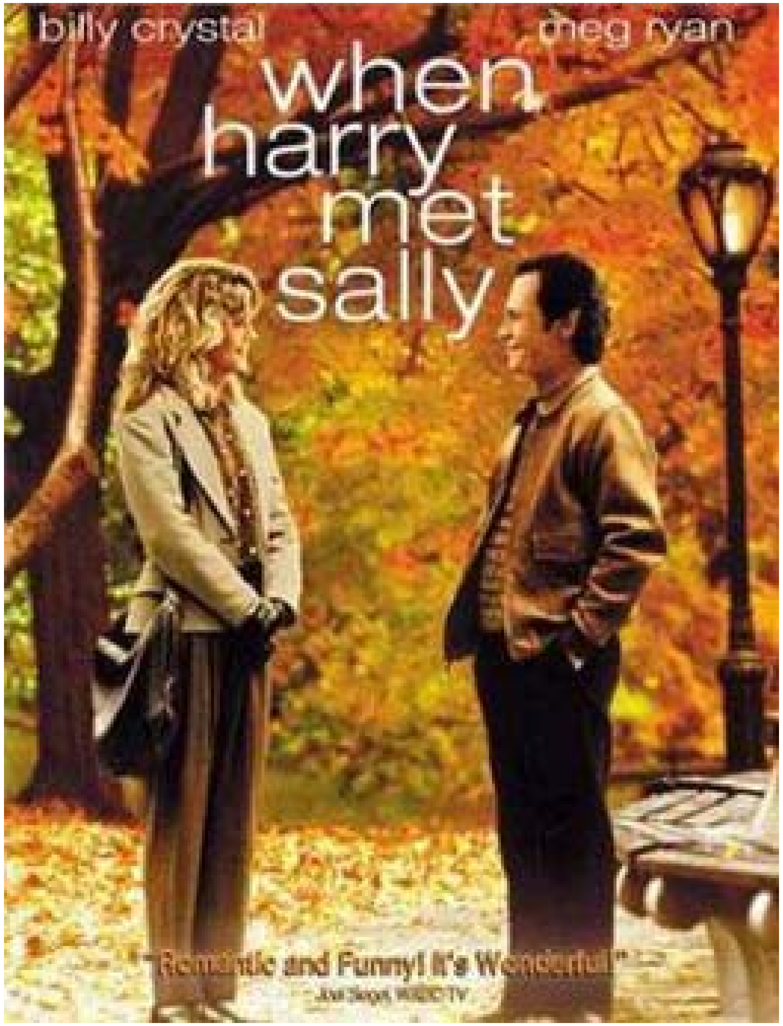


Shape of mT2 distribution

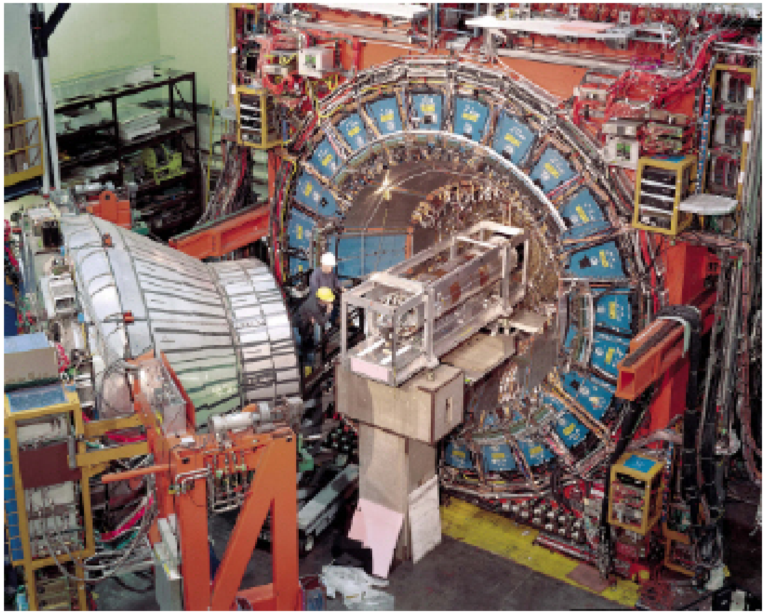


The di-leptonic channel : A good playground for mT2 exercise

When MT2 met *Real collider data*...



Top events at CDF



3 fb^{-1} of data collected with the CDF detector at Tevatron

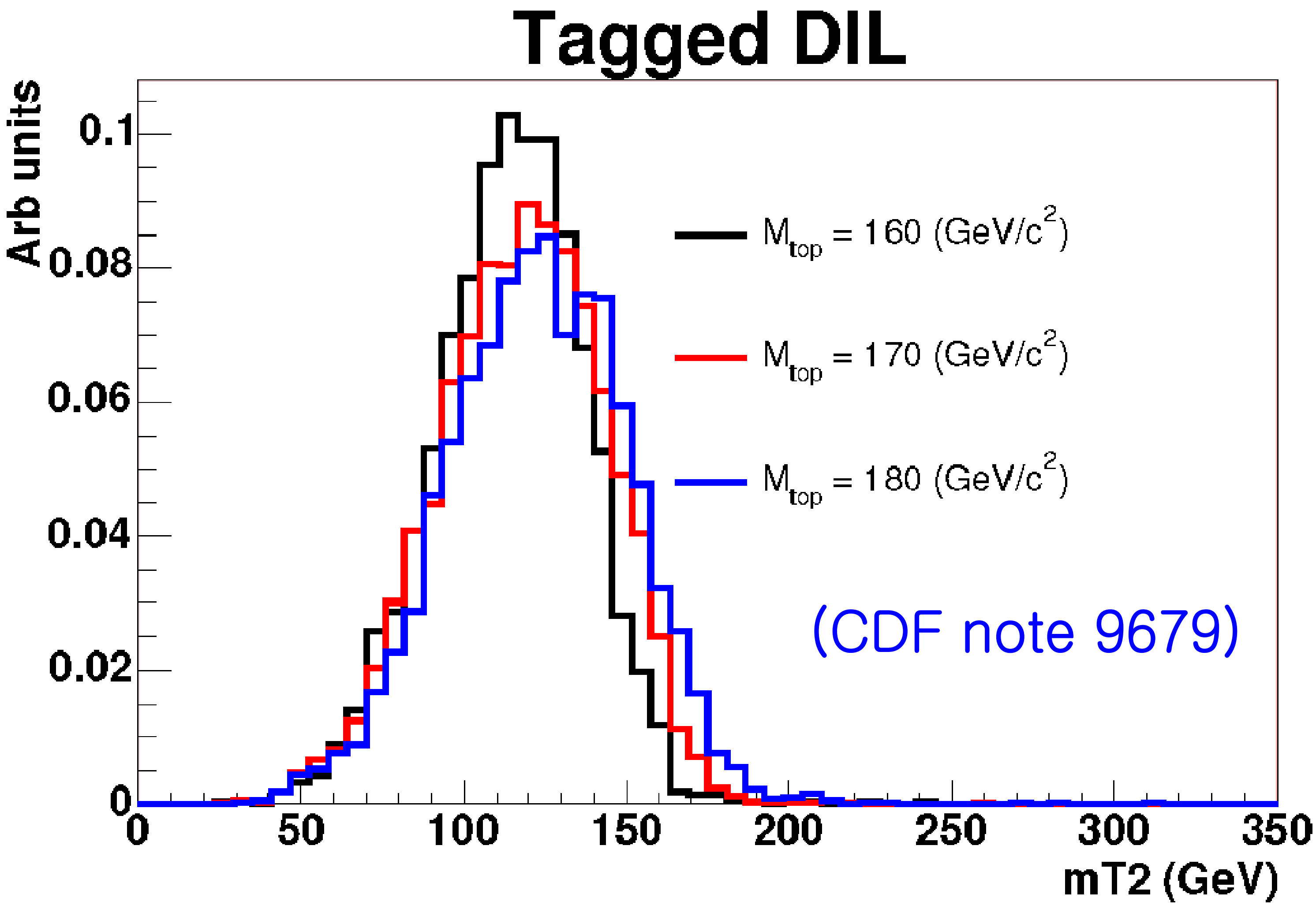
~ 100 signal events in Dilepton channel after event selection

(CDF note 9679)

TABLE II: Event selection and observed numbers of events for the two dilepton event categories

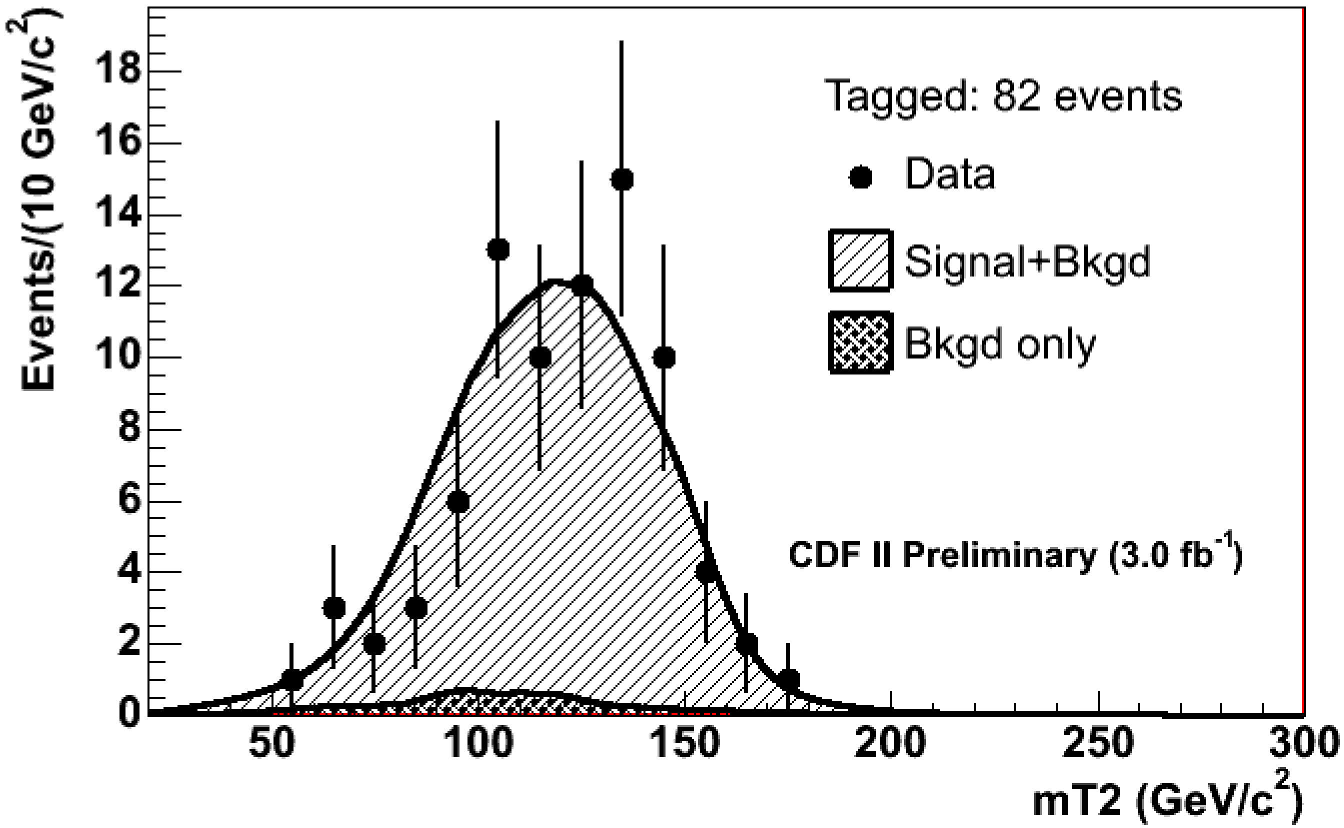
	0-tag	Tagged
b-tags	==0	01
Leading 2 jets E_T(GeV/c^2)	>15	>15
MET (GeV/c^2)	>25	>25
M_t^{NWA} boundary cut (GeV/c^2)	$100 < M_t^{NWA} < 350$	$100 < M_t^{NWA} < 350$
H_T boundary cut (GeV)	20 <m_{T2}< 300	20 <m_{T2}< 300
Observed # events	137	82
Expected $t\bar{t}$(σ=6.7pb M_{top}=175 GeV/c^2)	63.0±6.3	81.0±9.1
Expected background	73.0±10.5	6.4±1.4

MT2 distributions for b-tagged Dilepton events (Full Monte Carlo) with various top masses at CDF



MT2 distribution with Real Data

(CDF II Preliminary, 3.0 fb^{-1})



$$M_{top} = 167.9\ ^{+4.8}_{-4.1}\ (\text{stat.}) \pm 2.9\ (\text{syst.})\ \text{GeV}/c^2$$

It is the first measurement using mT2 in the real data

It works quite well. The result is compatible with other measurements, giving a confidence on mT2 method

When combined with other measurements,
It improves precision in top mass measurement

At the Oxford Univ. in U.K., Mar. 2009

Graham Ross

Graham Ross :

Neutrino is massless. So the top-quark mT2 would not be a good example for the case with a massive missing particle ?

YGK :

If we wish, we can consider W boson as a (massive) missing particle, just ignoring momentum of charged lepton.

$$t\bar{t} \rightarrow bW^+ \bar{b} W^-$$

consider W as invisible

(ignoring lepton momentum)

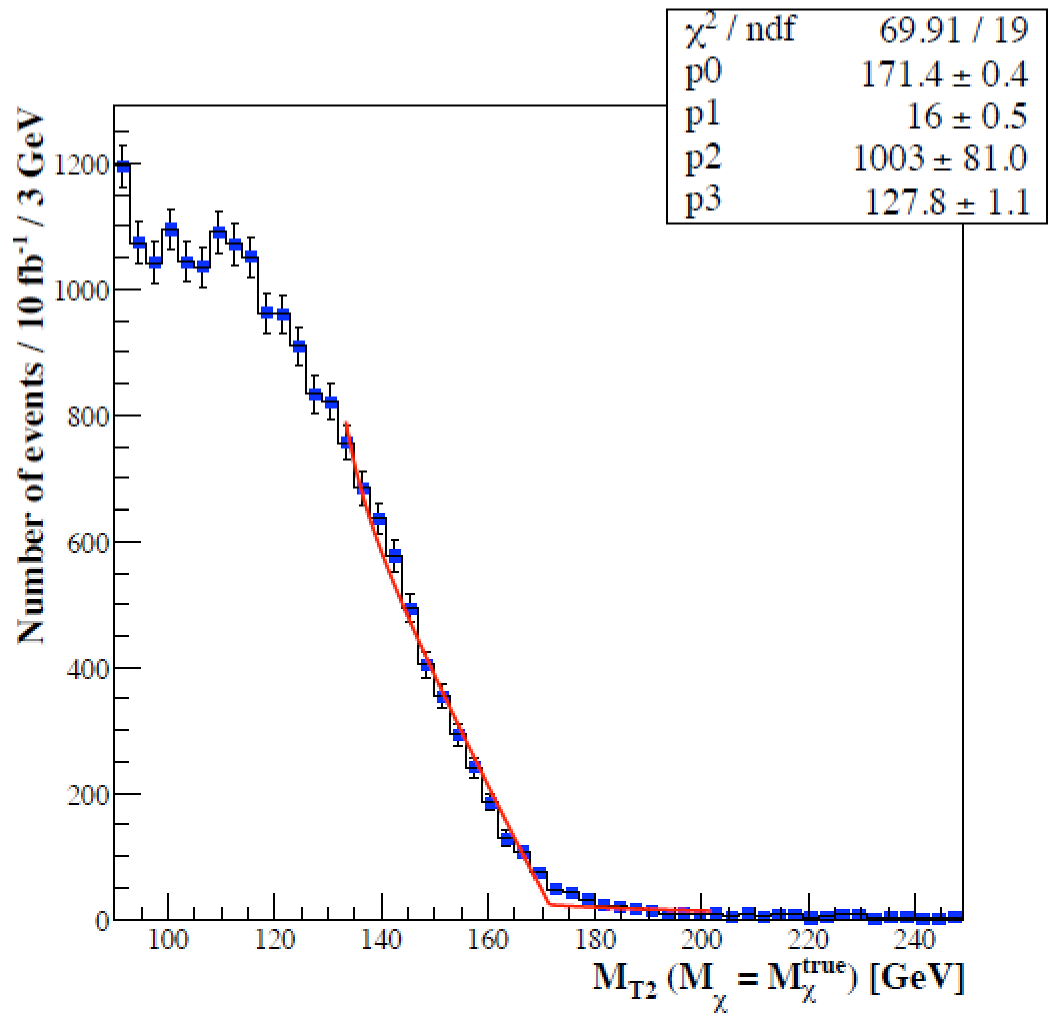
MT2 distribution

with trial W mass

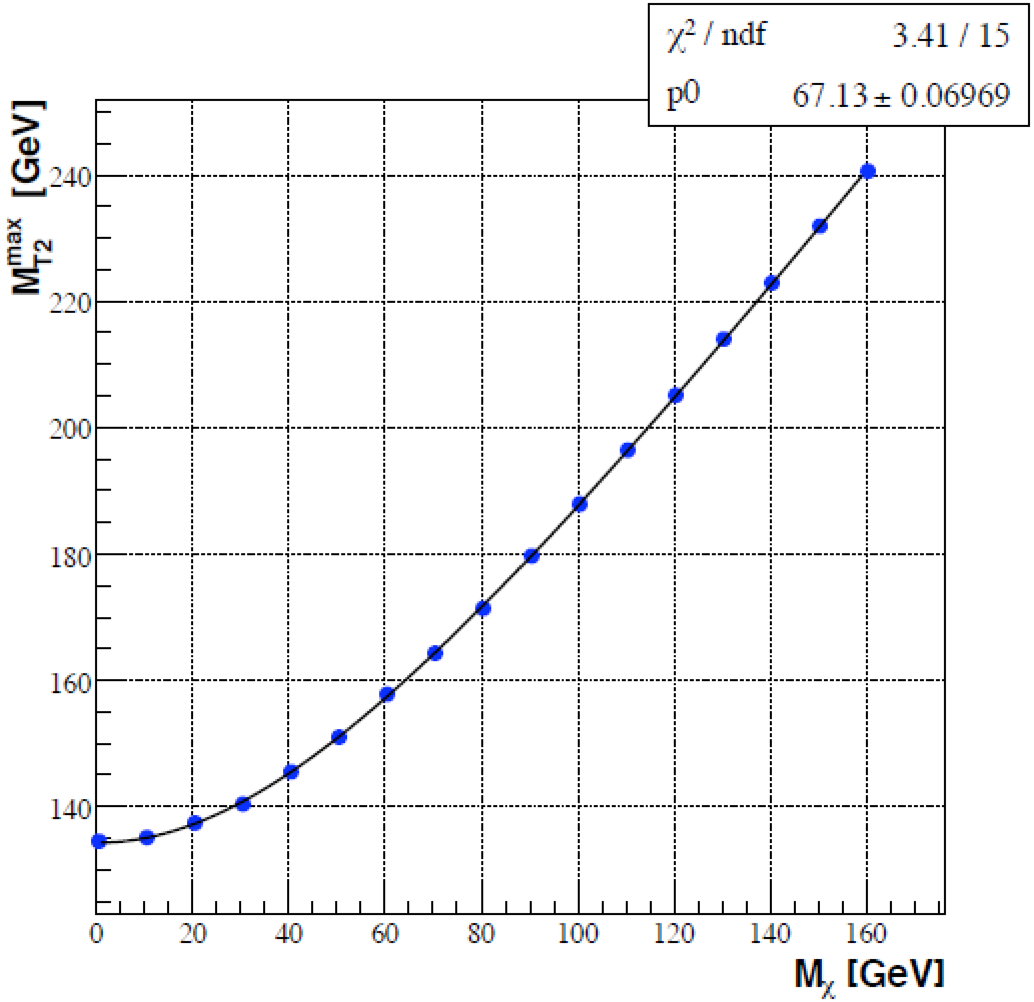
= true W mass

With 10 fb−1

at the LHC (14 TeV)



MT2 maximum as a function of trial W mass



A good analogue of slepton (or squark) mT2

Spin measurement with MT2

- Is there any other usefulness of MT2, after determining new particle masses ?

Yes!   M.A.O.S (M_{T2}–Assissted On–Shell) reconstruction of WIMP momentum.

MAOS reconstruction of WIMP momenta

(Cho, Choi, YGK, Park, arXiv:0810.4853)

RAPID COMMUNICATIONS

PHYSICAL REVIEW D **79**, 031701(R) (2009)

M_{T2}-assisted on-shell reconstruction of missing momenta and its application to spin measurement at the LHC

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We propose a scheme to assign a 4-momentum to each WIMP in new physics event producing a pair of mother particles each of which decays to an invisible weakly interacting massive particle (WIMP) plus some visible particle(s). The transverse components are given by the value that determines the event variable M_{T2}, while the longitudinal component is determined by the on-shell condition on the mother particle. Although it does not give the true WIMP momentum in general, this M_{T2}-assisted on-shell reconstruction of missing momenta provides kinematic variables well correlated to the true WIMP momentum and thus can be useful for an experimental determination of new particle properties. We apply this scheme to some processes to measure the mother particle spin and find that spin determination is possible even without good knowledge of the new particle masses.

MAOS reconstruction of WIMP momenta

(Cho, Choi, YGK, Park, arXiv:0810.4853)

A scheme to assign a 4-momentum to each WIMP
in new physics events

$$pp \rightarrow Y(1) + \bar{Y}(2) \rightarrow V(p_1)\chi(k_1) + V(p_2)\chi(k_2)$$

MAOS WIMP momentum is given by

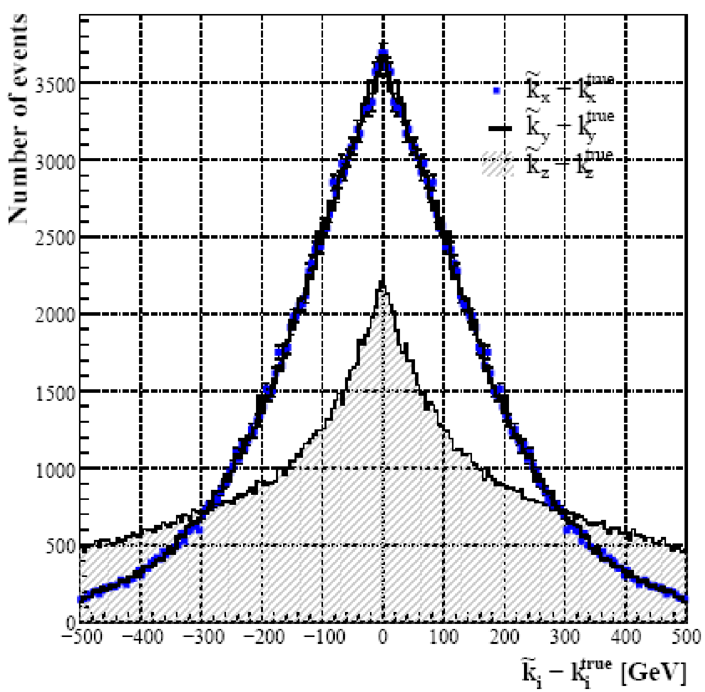
k_T ← the values that determine M_{T2} , then
k_z ← on-shell condition on the mother particle

- MAOS WIMP momentum is rather well correlated to the true WIMP momentum.

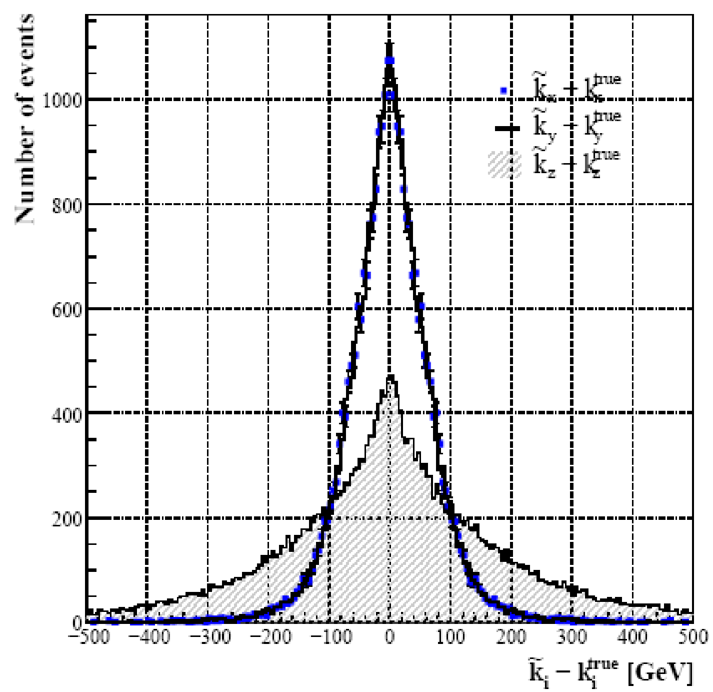
Example: $\tilde{g} + \tilde{g} \longrightarrow q\bar{q}\chi + q\bar{q}\chi$

$m_{\tilde{g}}^{\text{true}} = 779 \text{ GeV},$
$m_{\chi}^{\text{true}} = 122 \text{ GeV}$

MAOS mom. – TRUE mom. of WIMP



Full event set



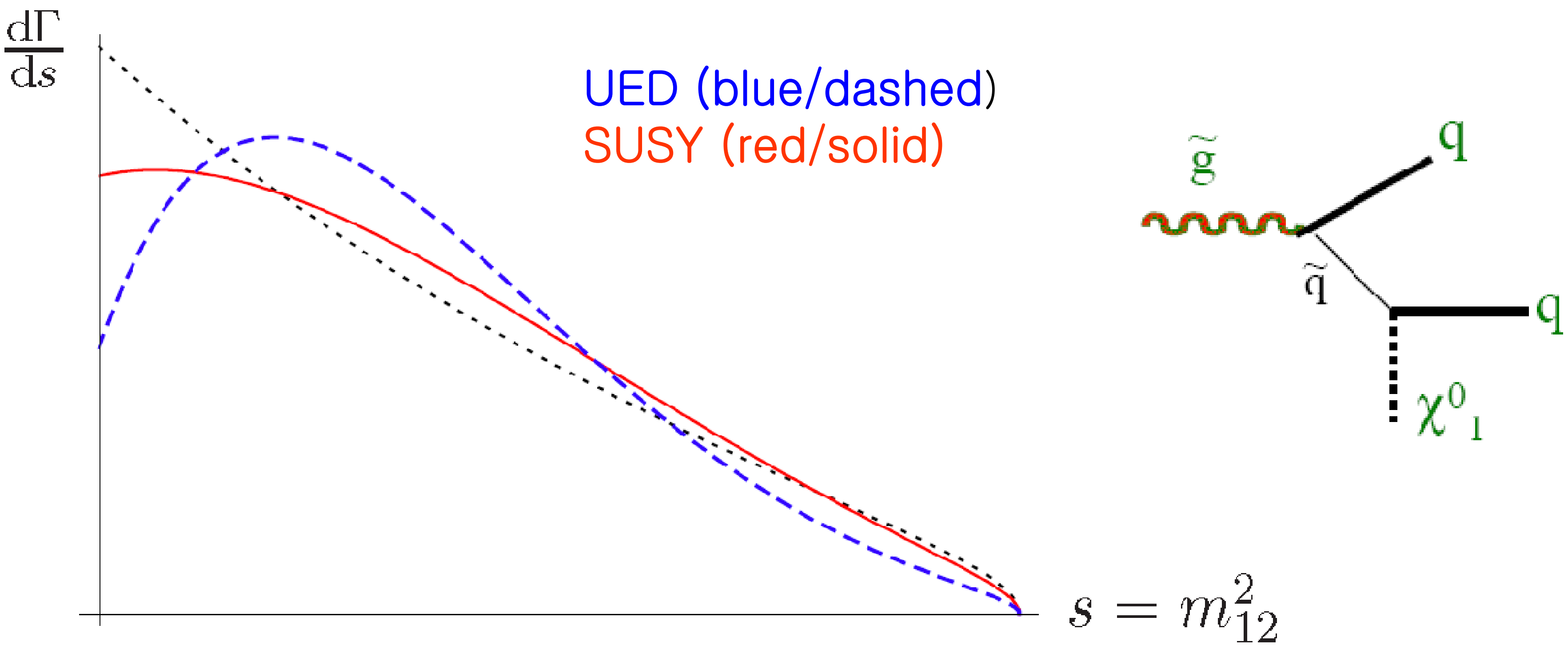
Top 10 % near mT2 max.

Application of MAOS reconstruction (1)

Dalitz plot analysis of
Gluino 3-body decay & UED equivalent

- Gluino 3-body decay and UED equivalent

Di-quark invariant mass distribution



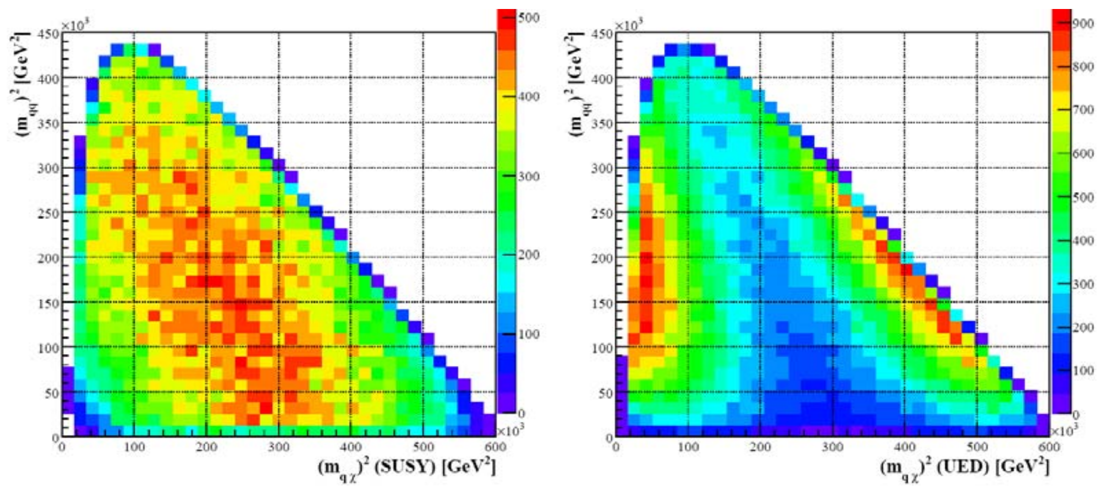
(Csaki etal, 2007)

• Gluino 3-body decay and UED equivalent

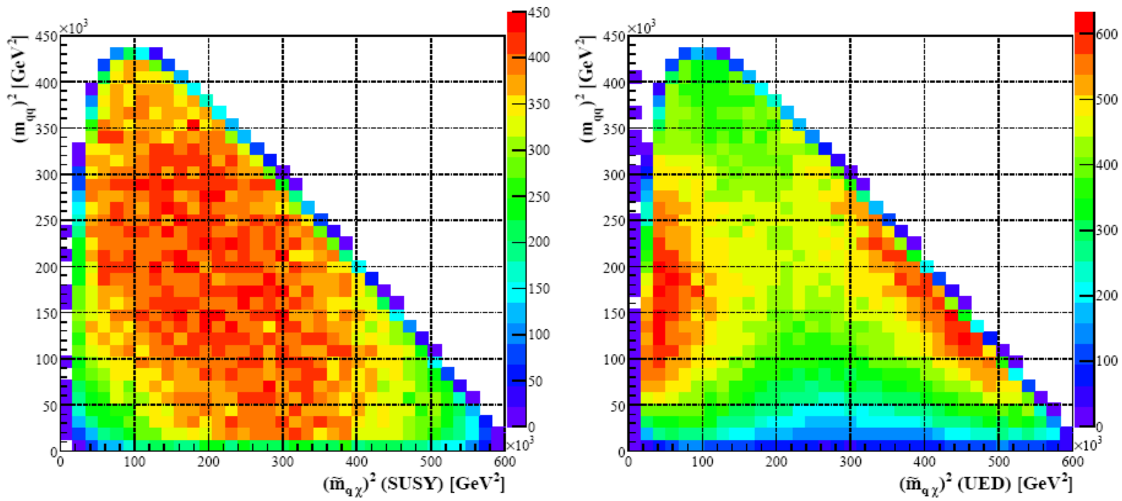
Dalitz Plots of $(Mqq)^2$ vs. $(Mqx)^2$

SUSY UED

True Distributions (partonic level)



MAOS Reconstructions (partonic level)



Application of MAOS reconstruction (2)

Angular distribution in Drell-Yan slepton production & UED equivalent

• Drell–Yan slepton production & UED equiv.

$$q\bar{q} \rightarrow Z^0/\gamma \rightarrow \tilde{l}^+\tilde{l}^- \rightarrow l^+\chi l^-\chi$$

Production angular distributions of mother particle pair
in their center of mass frame, w.r.t. proton beam direction

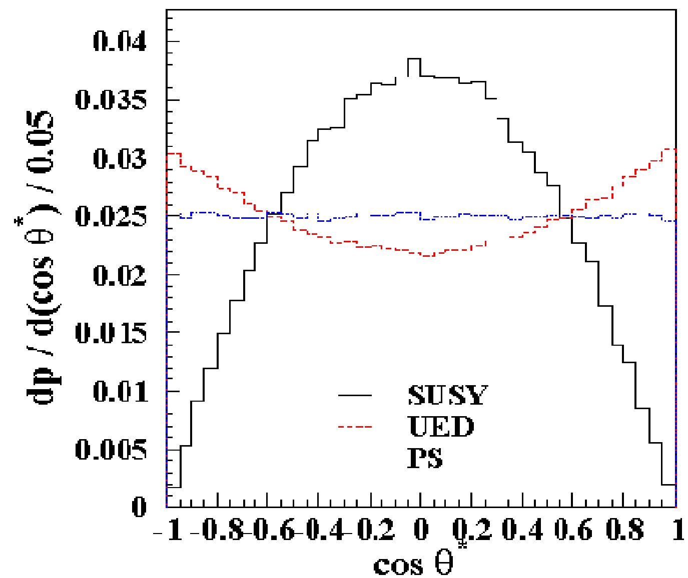
For SUSY

$$\left(\frac{d\sigma}{d\cos\theta^*}\right)_{\mathrm{SUSY}} \propto 1 - \cos^2\theta^*$$

For UED

$$\left(\frac{d\sigma}{d\cos\theta^*}\right)_{UED} \propto 1 + \left(\frac{E_{\ell_1}^2 - M_{\ell_1}^2}{E_{\ell_1}^2 + M_{\ell_1}^2}\right)\cos^2\theta^*$$

(A.Barr, 2004)



• Drell-Yan slepton production & UED equiv.

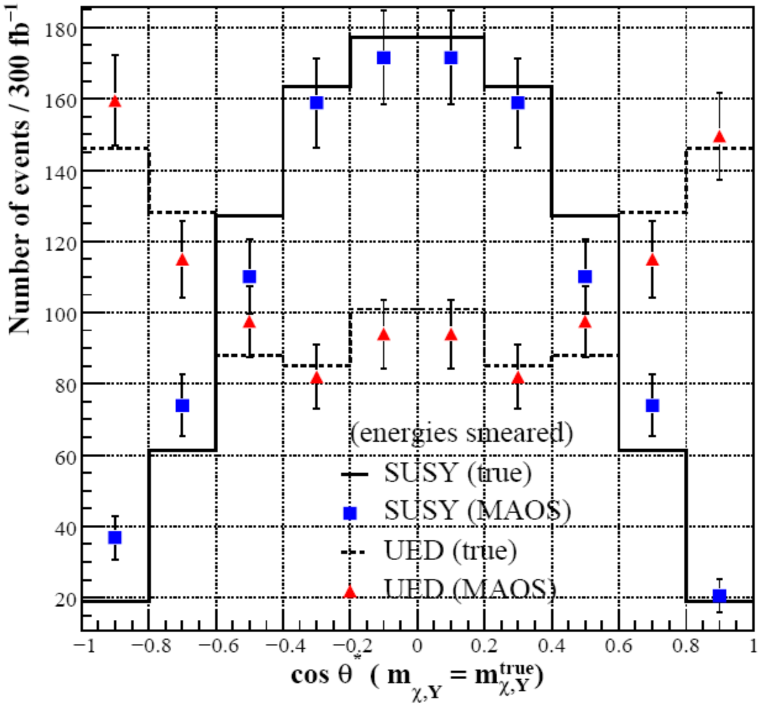
Production angular distributions of mother particle pair in their center of mass frame, w.r.t. proton beam direction

$$(m_{\tilde{l}_R}^{\rm true} = 143 \text{ GeV}, \quad m_{\chi}^{\rm true} = 96 \text{ GeV})$$

With MAOS reconstruction of the WIMP momenta and thus mother particle momenta

For events near mT2 max

SUSY (blue/solid)
UED (red/dotted)



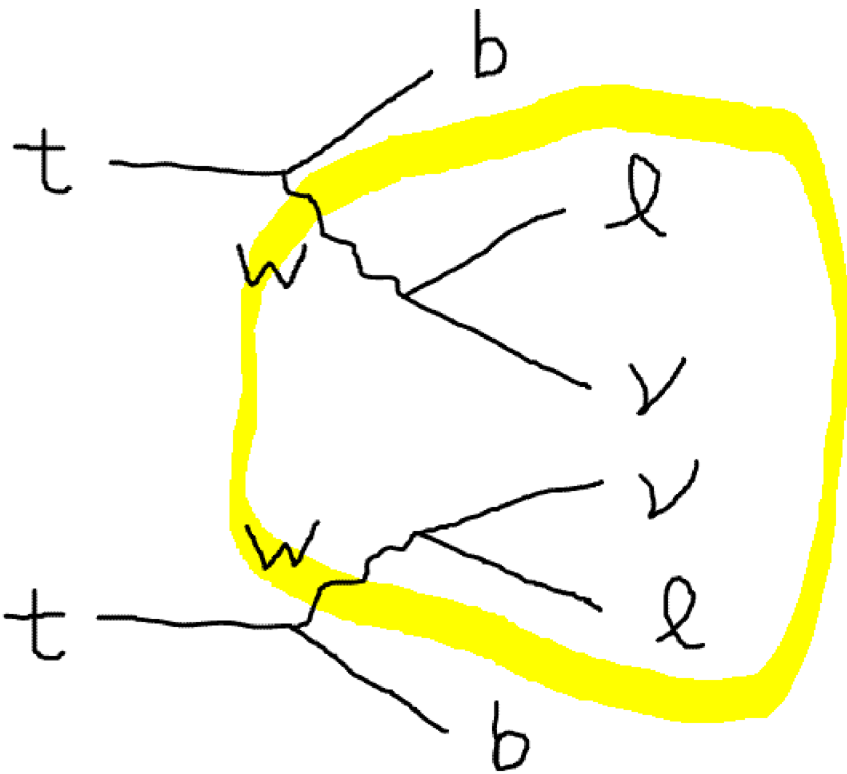
Application of MAOS reconstruction (3)

Analysis of top quark events
in dilepton channel

Work in progress

Top mass measurement with MAOS reconstruction

Consider WW sub-system in the dilepton channel of top events

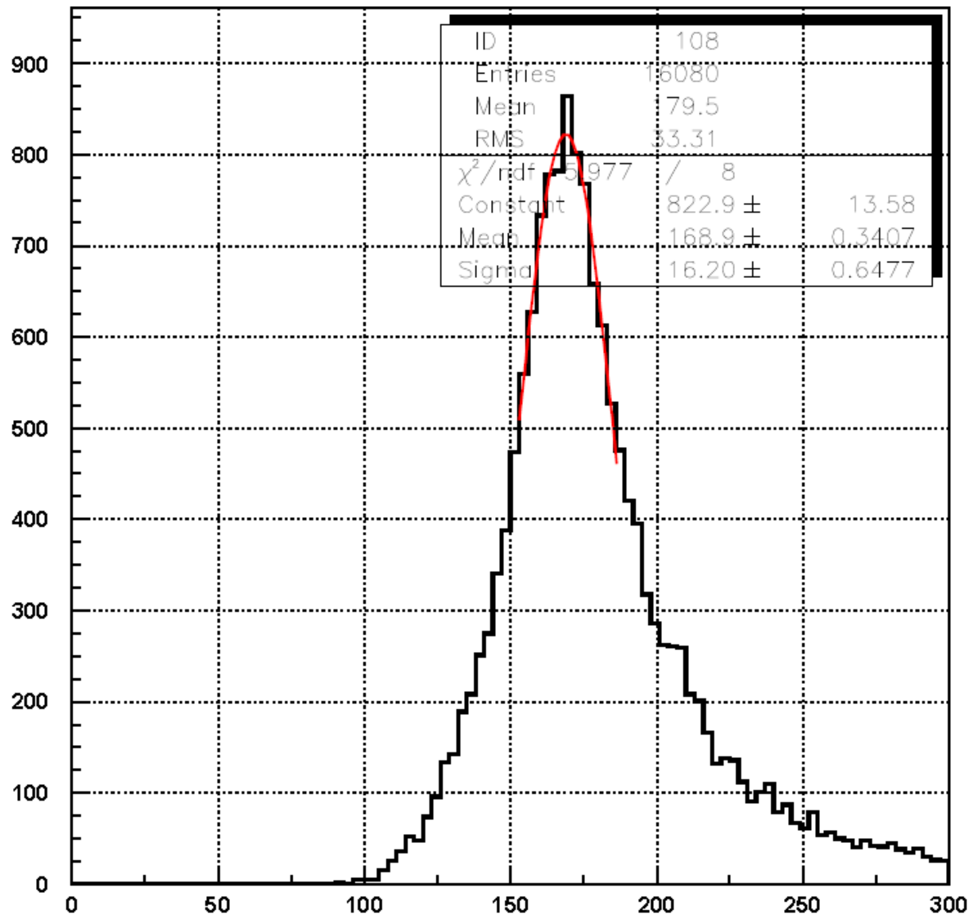


Construct the MAOS momentum of neutrino for the sub-system, considering W bosons as mother particles (W mass is known well)

Construct MAOS momentum of W boson by adding lepton mom. to the MAOS neutrino momentum

Calculate the invariant mass of bW system, using the MAOS momentum of W boson

Invariant mass distribution of the bW system
(W momentum reconstructed with MAOS)



MT2 (W-boson) > 60 GeV

M(peak) ~ 170 GeV

Preliminary result
Based on parton-level MC

Work in progress

Conclusion

- Maximum of gluino MT2 as a function of trial LSP mass shows a kink structure at true LSP mass from which gluino mass and LSP mass can be determined altogether.

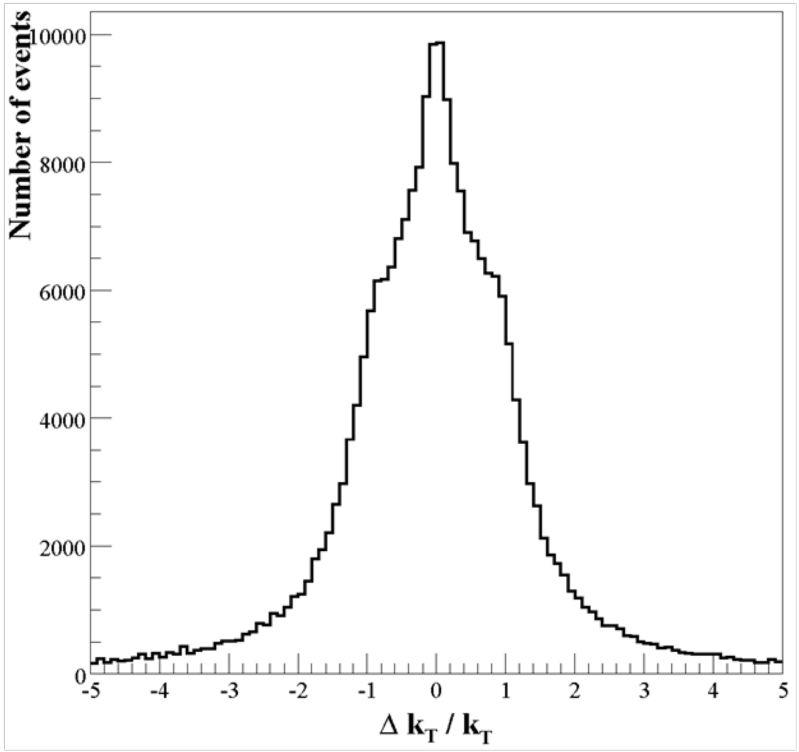
- Top-quark MT2 provides an independent way of measuring the top-quark mass and can serve as a Standard Candle for general MT2 analysis.

- MAOS reconstruction of WIMP momentum may open a new window for investigating New physics structures

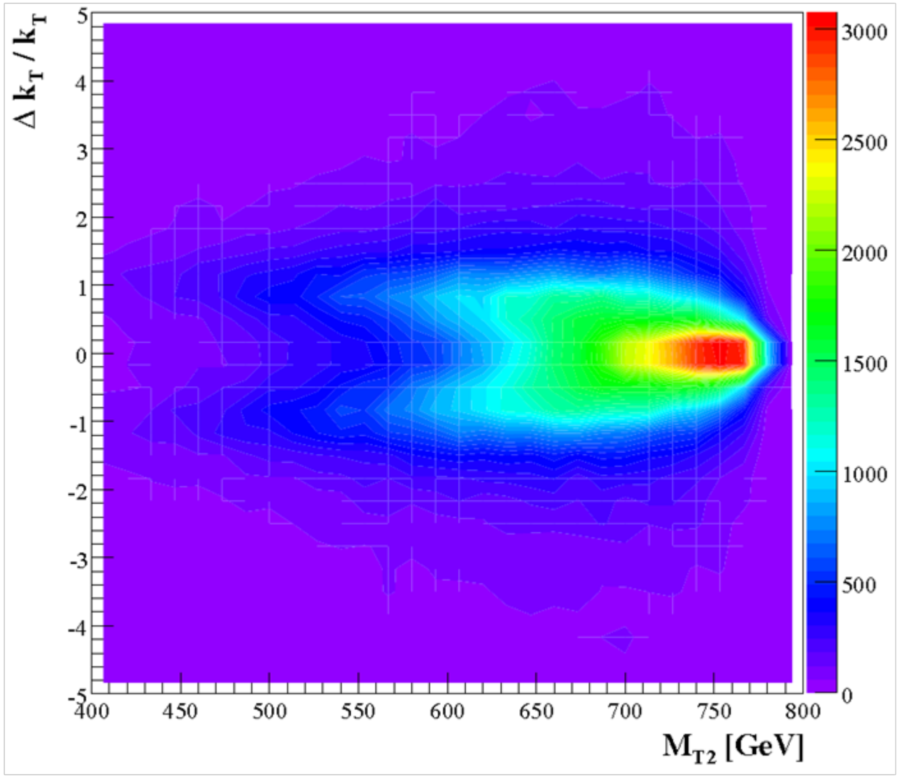
Backup Slides

- MAOS WIMP momentum is rather well correlated to the true WIMP momentum.

$\Delta k_T / k_T$



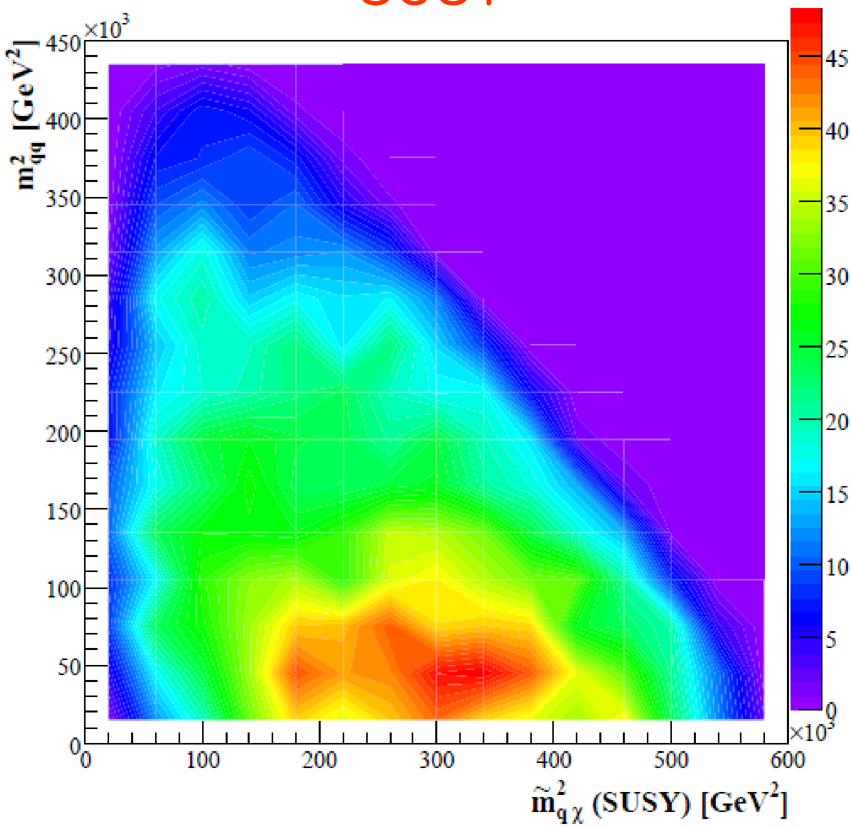
$\Delta k_T / k_T$ vs. M_{T2}



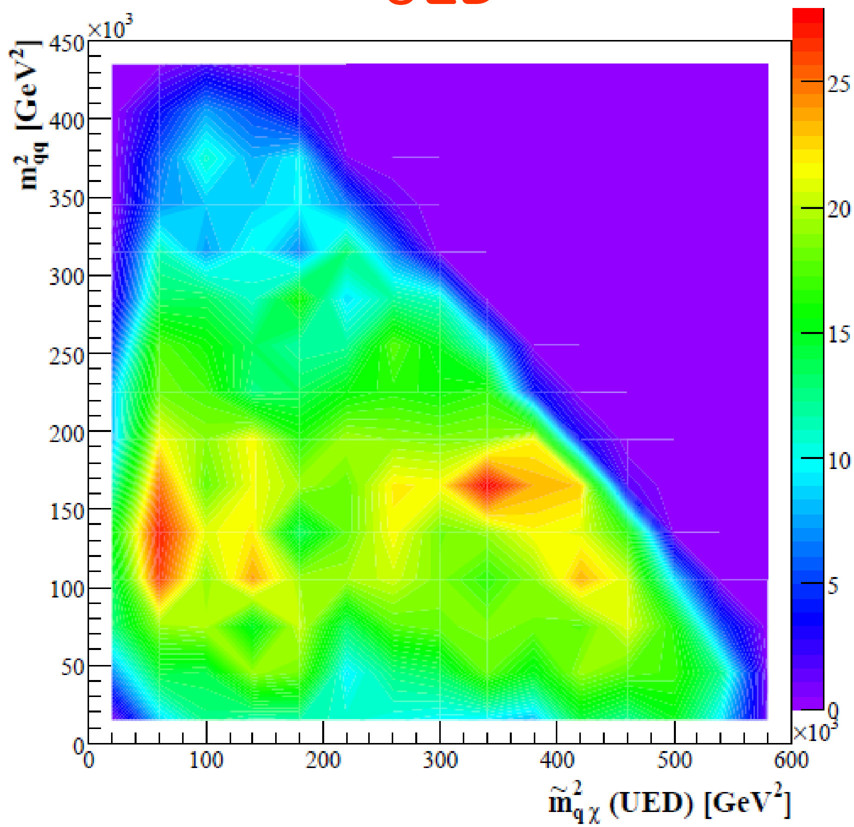
For 300 fb^{-1} , Detector-level study, No background

(SPS2 point in mSUGRA)

SUSY



UED



Detector level simulation