New Physics with mE_T @ LHC

1. Which topologies (with mE_T) is interesting in
   the early stage of the collision?
2. Summary of Background at LHC
3. Strategy: mE_T and Background should be examined
   using real data
4. Performance and sensitivity with $L=1\text{-}30fb^{-1}$
5. What we can do and can not do with $L=10fb^{-1}$

Shoji ASAI (U.Tokyo) for ATLAS/CMS

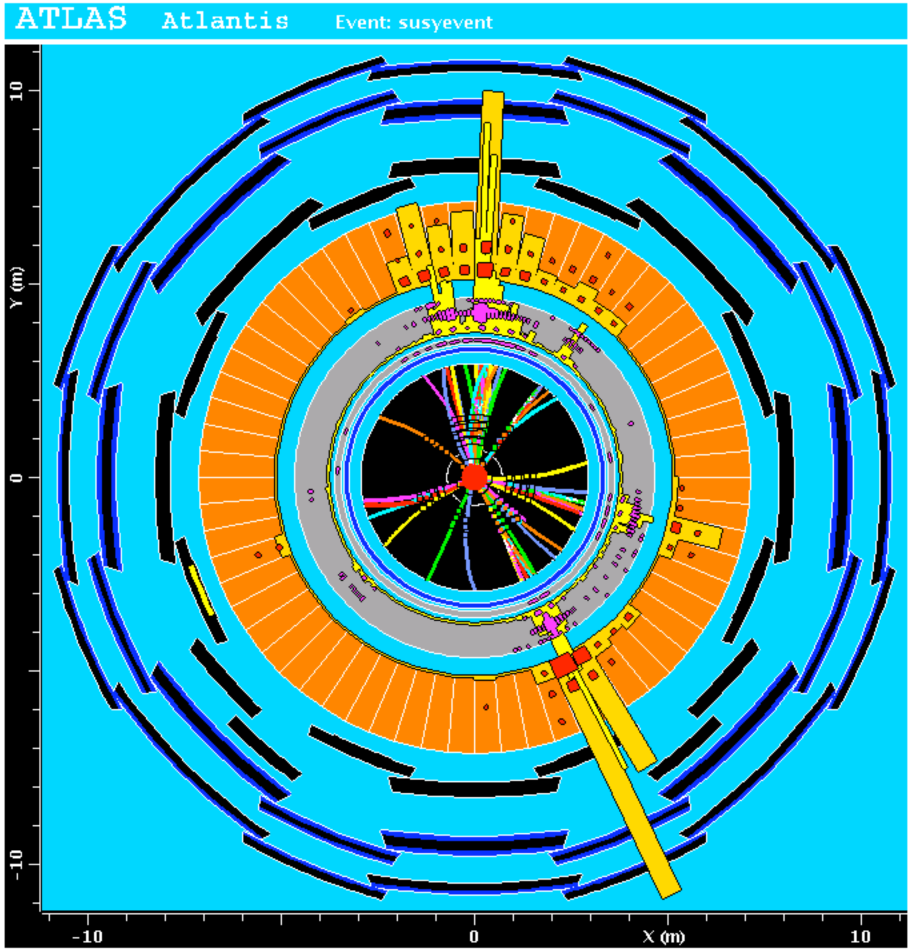
[1] Introduction & Interesting Event topologies

1-1 SUSY
1-2 the other models
1-3 Summary of the interesting event topologies
with MET

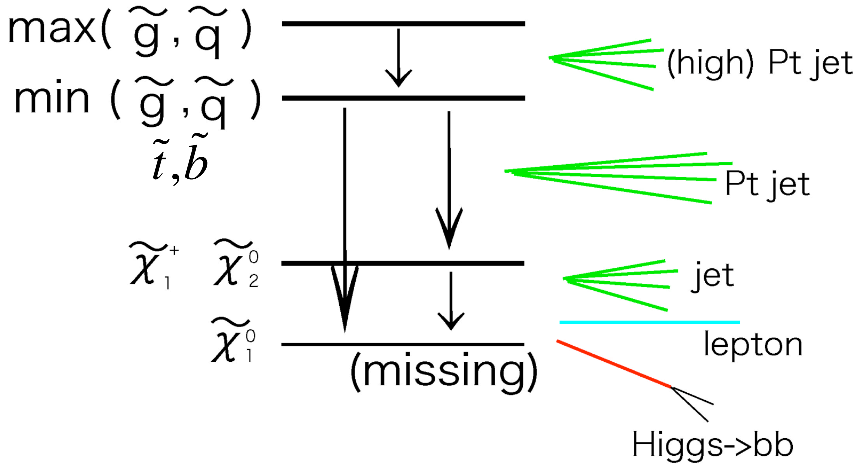
1-1 SUSY

SUSY provides various interesting event topologies with mE_T

"Typical" Events topology of SUSY signal is like this



Gluino/squark are produced first, then cascade decay is followed.



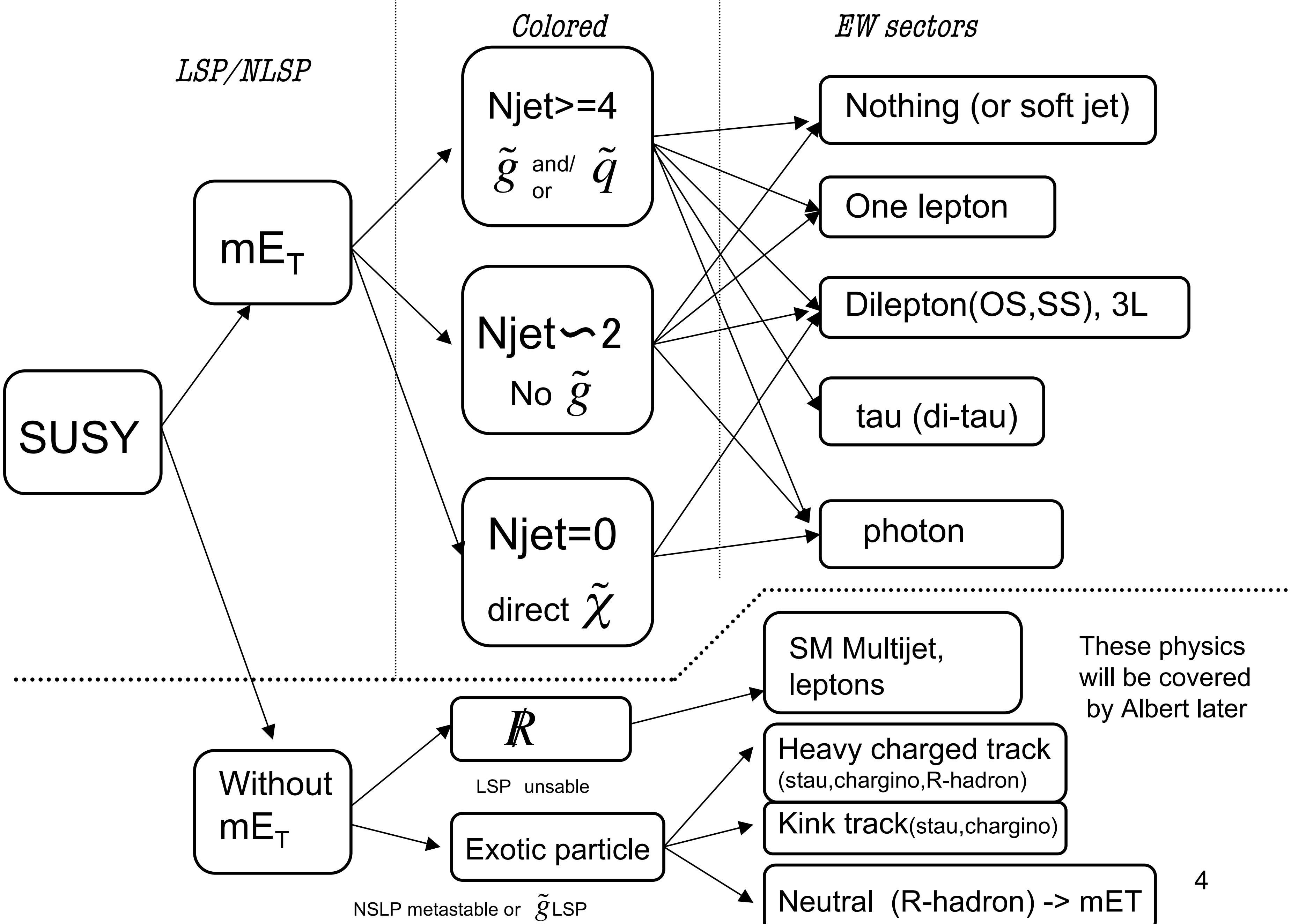
event topologies of SUSY

multi leptons

$\not{E}_T$ + High P_T jets + b-jets

τ-jets

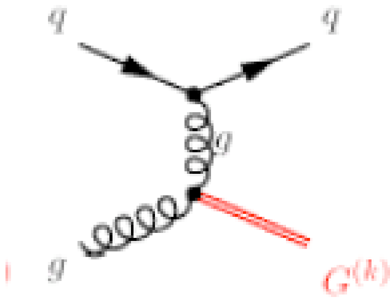
more detail classification are summarized in this figure:



1-2 the other models with large mE_T

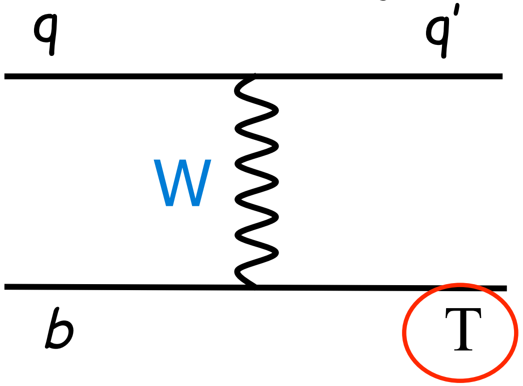
(1) KK-Graviton:

Graviton has strong coupling to high energy particles in LED



Graviton is emitted in the usual hard collision like this:
"monojet" events will be observed.

(2) Top-like heavy particle predicted in **Little Higgs model**



High Pt Forward jet

Heavy T particle is produced and decay

$T \rightarrow bW(\rightarrow l\nu)$

"Low multiplicity jet(s) +lepton+mE_T"

(3) Heavy New Gauge boson W' (including new Gauge sysm.)

$W' \rightarrow l\nu$

"lepton+mE_T"

1-3 Promising event topologies with mE_T are listed:

Jet multi (high Pt)	Additional obj.	Favored scenario	Dominant SM background processes
High Multiplicity Nj>=3,4	No lepton	SUGRA,AMSB, Heavy $\tilde{q}$	QCD(light & bb/cc) $t\bar{t}(\to b\bar{b}q\bar{q}\tau\nu)$ Z(->nunu) and W(->taunu)
	One lepton	SUGRA,AMSB, Heavy $\tilde{q}$	$t\bar{t}(\to b\bar{b}q\bar{q}\ell\nu)$ W(->taunu)
	Dilepton,3L	SUGRA,AMSB, GMSB (Nm>1)	OS: $t\bar{t}(\to b\bar{b}\ell\nu\ell\nu)$ SS,3L ZW,ZZ $t\bar{t}(\to b\bar{b}\ell\nu\ell\nu)$
	Tau (ditau)	Large tanβ, GMSB (Nm>1)	W (->taunu) $t\bar{t}(\to b\bar{b}q\bar{q}\tau\nu)$
	γγ	GMSB (Nm∽1) $\tilde{\chi}_1^0 \to \gamma\tilde{G}$	Almost BG Free $t\bar{t}(\to b\bar{b}e\nu e\nu)$ FSR
Low Multiplicity Nj∽1,2	No lepton	Heavy $\tilde{g}$ KK Graviton	Z(->nunu) W(->taunu)
	One lepton	Heavy $\tilde{g}$ Top like particle LH(W'Z')	W,Z $t\bar{t}(\to b\bar{b}\ell\nu\ell\nu)$
No jet Nj = 0	One Lepton	W'	W
	Dilepton,3L	Direct $\tilde{\chi}$	WW,WZ,ZZ WZ main for 3L

(Black shows various SUSY models and Blue non-SUSY models)

[2] Background distributions & Uncertainties of the current estimations

ATLAS: High Pt jets are estimated with Matrix Element (ALPGEN 2.05)
ME + PS matching is applied:
Results are based on the Fast Simulations: but some modifications are applied to reproduce the shapes with the Full simulation.
Comparison between ALPGEN and the other generators has performed.

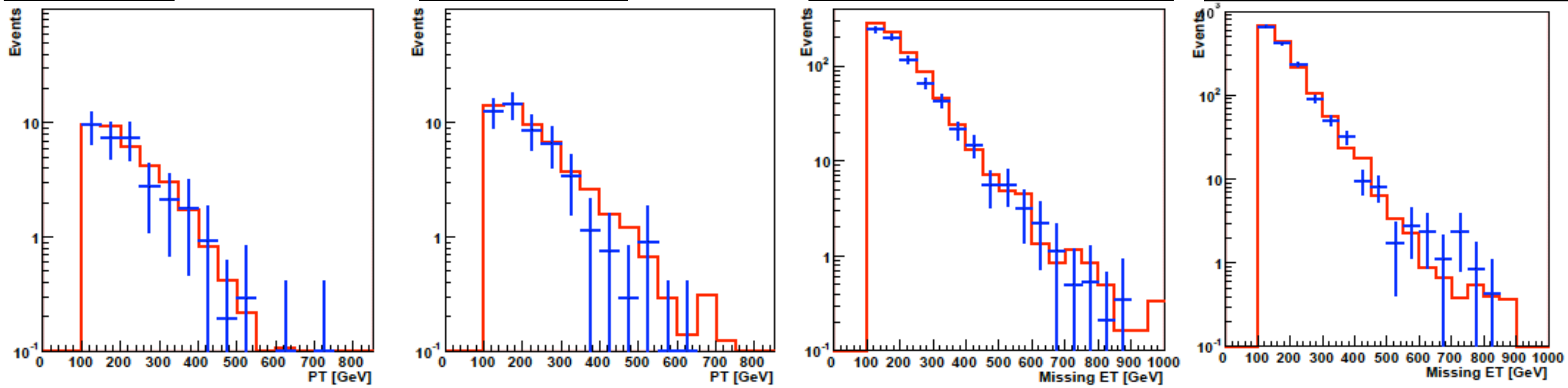
CMS used various generators.

Analysis based on the full simulation.

Fast simulation is modified:(ATLAS)

lepton efficiency, MET scale , and jet reconstruction efficiency are corrected in Fast simulation in order to reproduce Full simulation results.

$p_T(ee)$	$p_T(\mu\mu)$	Missing E_T ($Z \to \nu\nu$)	Missing E_T ($W \to l\nu$)



Red show the Modified Fast simulation

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Bule show the Full simulation

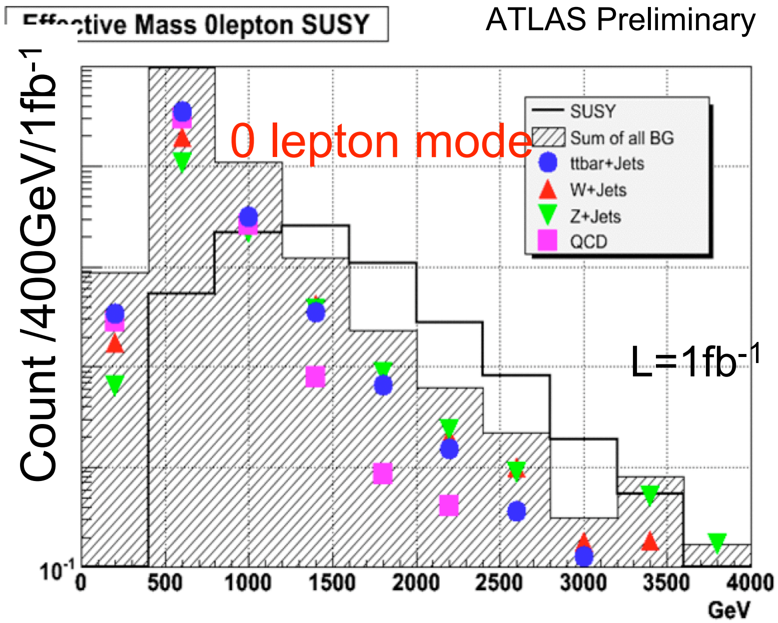
No big difference after modification:

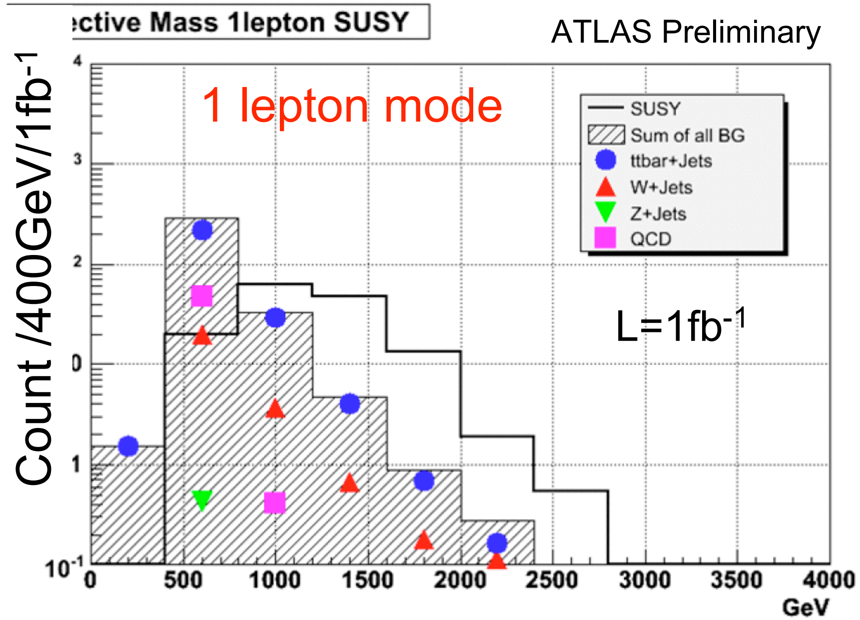
mE_T tail is not yet modified: still investigating

2.1 Background Contribution

M_{eff} distributions after
ATLAS SUSY standard cuts

Njet(P_T>50GeV)>=4
mE_T>min(100GeV, 0.2*M_{eff})
P_T_LJ>100GeV
MT(lepton,mE_T) > 100GeV





$$Meff = \sum Pt + mEt$$

$$Meff = \sum Pt + mEt$$

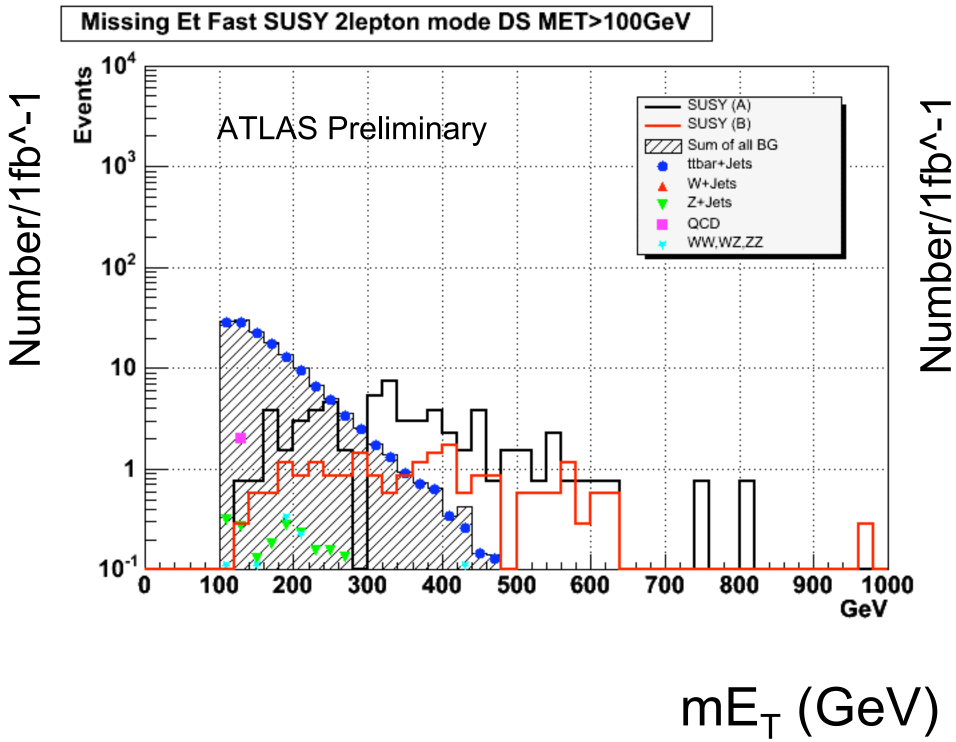
Open HIST show the SUSY signal $M(\tilde{g}) \sim M(\tilde{q}) \sim 1TeV$ (tanβ=10, $m_{1/2}=m_0$=400GeV)

Main Background processes are top-pair ,W and Z with jets,
They include high Pt neutrino(s) in the final state, which makes large mE_T.
QCD jet (LF,bb,cc) also contributes to no-lepton mode, especially small M_{eff} region.
Top is dominant BG process for one lepton mode.

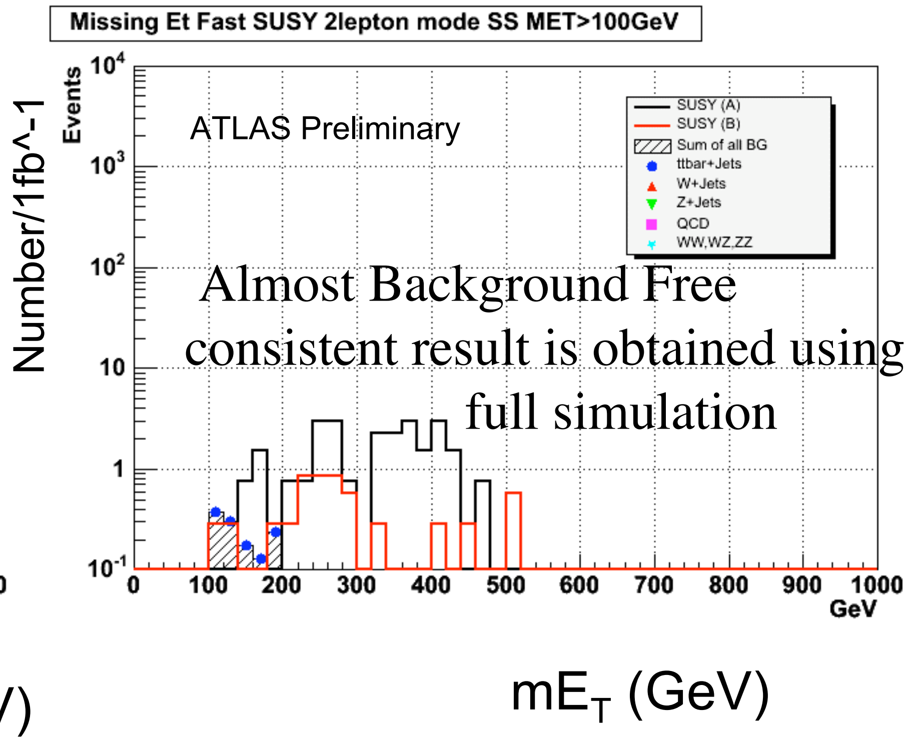
➔Clear excess can be observed in both no-lepton mode & one-lepton mode.
One-lepton mode is promising channel for clean discovery but need both(redundancy).

Dilepton modes are also promising

Opposite Sign dilepton



Same Sign dilepton



SUSY signal $M(\tilde{g}) \sim M(\tilde{q}) \sim 0.9TeV$

Top pair is dominant BG process
for di-lepton modes

Red: co-annihilation (light stau)
m_0=70, $m_{1/2}$=350GeV tanβ=10
Black: bulk
m_0=100, $m_{1/2}$=300GeV tanβ=6

➔ Stat. of signal is limited but excess can be observed also in dilepton mode.

mE_T+Jets+Photon(s) is interesting for GMSUSY

GMSUSY signal

$M(\tilde{g}) \sim 700GeV$

$M(\tilde{q}) \sim 1TeV$

Njet(P_T>50GeV)>=3
mE_T>100GeV
P_T_LJ,2nd Jet >100GeV
2photons are required

GM Nm=1
Nu1→γ$\tilde{G}$

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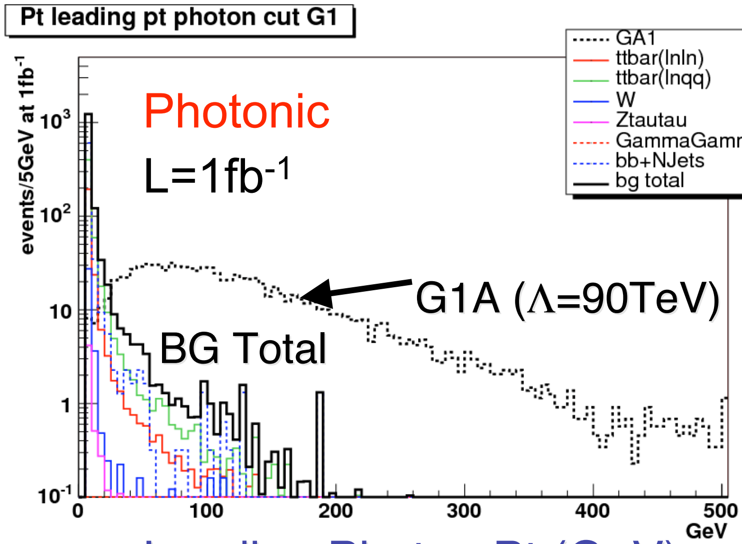
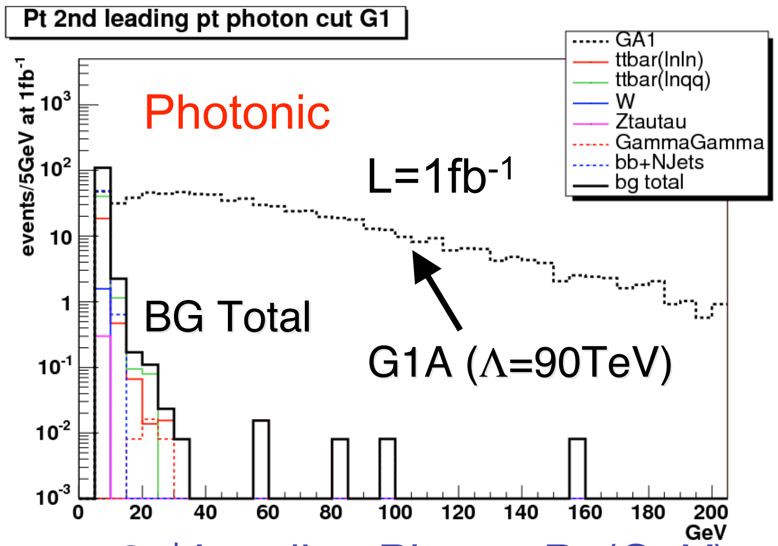


Leading Photon Pt (GeV)

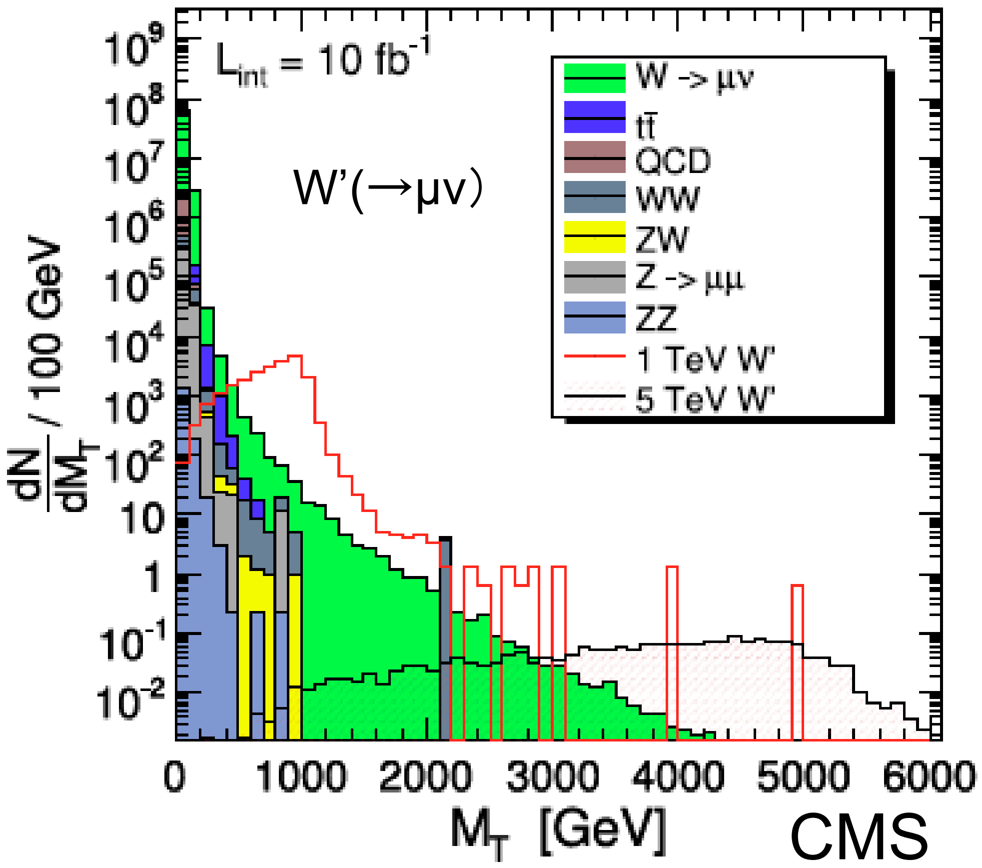


2^{nd} Leading Photon Pt (GeV)

Main Bg is top-pair in which W decays into eν with hard FSR
Almost BG free (Nph>=2) and this is clean signature of GM SUSY
(gluino mass upto 1.6 TeV can be discovered with L=1fb^{-1})

Lepton+mE_T topology: (the same as discovery of W in '83)

$$M_T = \sqrt{2p_{T_\mu} E_T^{miss}(1 - \cos\Delta\phi_{\mu, E_T^{miss}})}$$



See Georges's talk in yesterday.

Clear Jacobian peak will be observed.
Clear resolution:
(natural width smear the edge.)

Main background is off-shell W*

2-2 Uncertainties of the current estimations of Background

1. ALPGEN is LO generator-> there are arbitrary scales in the generator
2. Cut on parton level are applied in order to avoid collinear & soft divergence
3. ME-PS matching is applied (three are two free parameters in this procedure)

Samples with different parameters are produced to estimate these effects

Systematic error samples of W+Njets, ttbar+Njets

- ***Original***
  Parton cut: Pt>40GeV, |eta|<6, Factorization: $Q^2=Mx^2+Pt$ of x^2 (X: W or top)
  α_S scale: each Pt of jet, PDF: CTEQ6L

scale
- ***Renormalization scale***
  scale of α_S is $0.5 \times$ Pt of jet
- ***Factorization scale***
  Factorization Q^2=mean(Pt^2 of jets). PS jet is suppressed.

ME generation cut
- ***low Pt***
  Parton cut Pt>15GeV
- ***small ΔR***
  ΔR>0.35 (not 0.7)
- ***PDF***
  PDF MRST2001J

MLM matching
- ***MLM Pt=15GeV***
  MLM matching Pt=15GeV in original sample
- ***MLM R=0.35***
  MLM matching ΔR=0.35 in original sample

MLM matching
ET=40GeV
R=0.7

Numbers with different conditions are summarized for W and Top

BG systematic uncertainty

	W+Njets		ttbar+Njets	
	counts	uncertainty(%)	counts	uncertainty(%)
Original	2884		6066	
renormalization	5028	+74.3	10238	+68.8
factorization	3136	+8.7		
low Pt	7534	+161.2	12552	+107.0
small ΔR	2659	-7.8	5456	-10.1
PDF	3402	+18.0	8242	+35.9
MLM Pt 15GeV	2696	-6.5	5962	-1.7
MLM R 0.35	3085	+7.0	6264	+3.2

- *Counts show the events after std. SUSY cut at $1fb^{-1}$*
- *Cut value of parton Pt changing to low Pt gives the significant uncertainty (about factor 2) -> BG becomes large. Small renormalization scale also gives the large uncertainty*
- *For systematic errors of SUSY signals, luminosity: 5%, Missing Et scale: 5%, Jet energy scale: 5% are considered*

Normalization strongly depends(factor∽2) on these parameters,
But the shape of the distributions are stable against these conditions

[3] Validate mE_T performance and estimate background using Real Data

mE_T performance is crucial.

Calculation of mE_T@LHC and the expected performance have been already discussed in the yesterday's parallel session.
You can see detail in Richard's nice talk in the yesterday.

Here:
(1) The performance of mE_T should be examined with real data in "early stage of the collision L=1fb^{-1}".

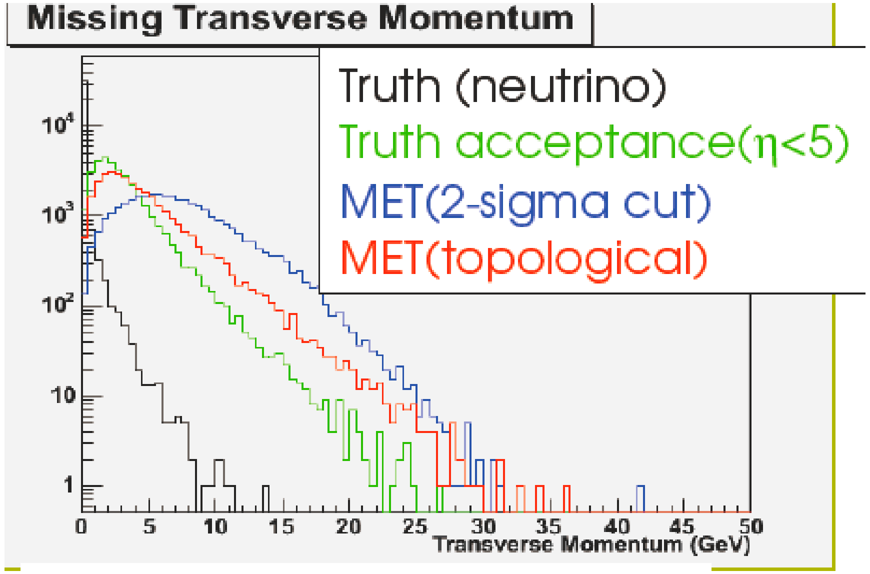
(2) The background contributions also should be estimated with real data itself. No body believes discovery based on the MC predictions.

These studies are important & essential for quick/solid discovery before 2009.

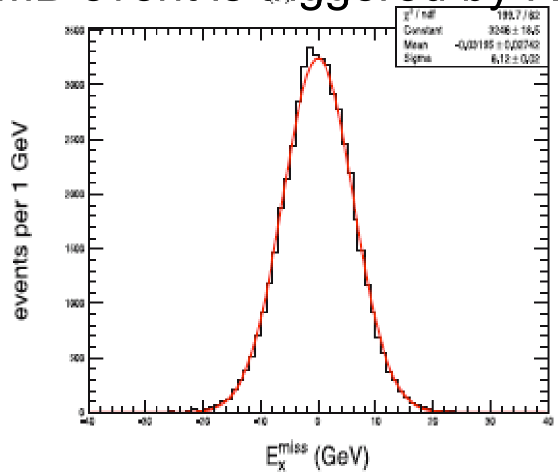
But not exciting. Maybe Painful for theorists!! (Please sleep for a moment, I will get up)

3-1 Validation of mE_T with MB

Minimum Bias has high event rate & No truth mE_T

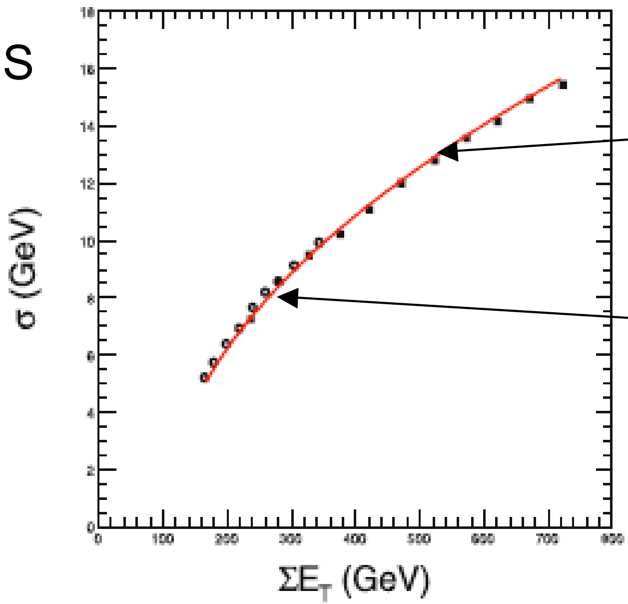


No heavy flavor contribution in MB,
But small truth mE_T is produced by acceptance of the calorimeter.(but small)
MB event is triggered by RT.



CMS

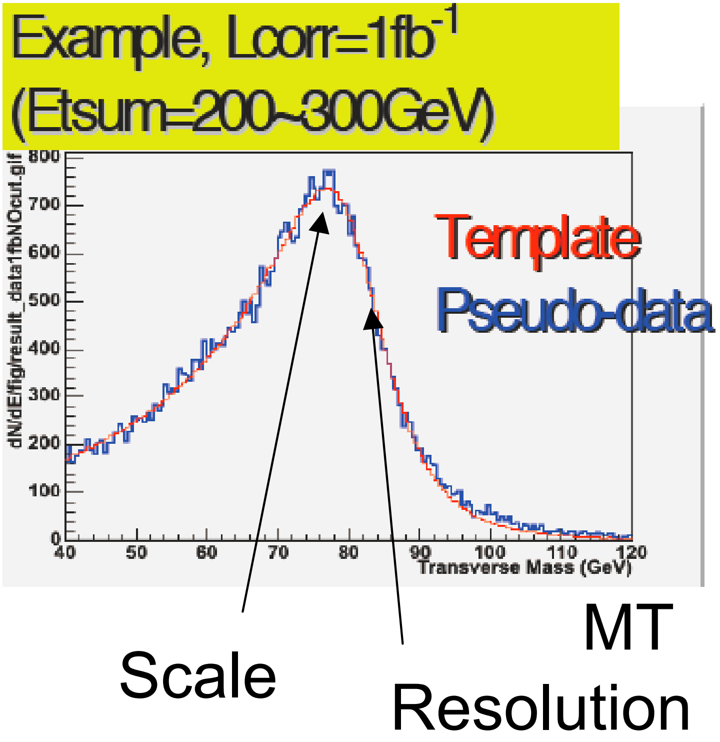
CMS



Black
QCD dijet

The observed mE_T distribution is fitted for each sliced bin of ΣE_T.
Examine the resolution as function of scalar sum.
MB can be used upto $\Sigma E_T < 300$GeV
We will enough stat. then the tail of the mET can be examined.

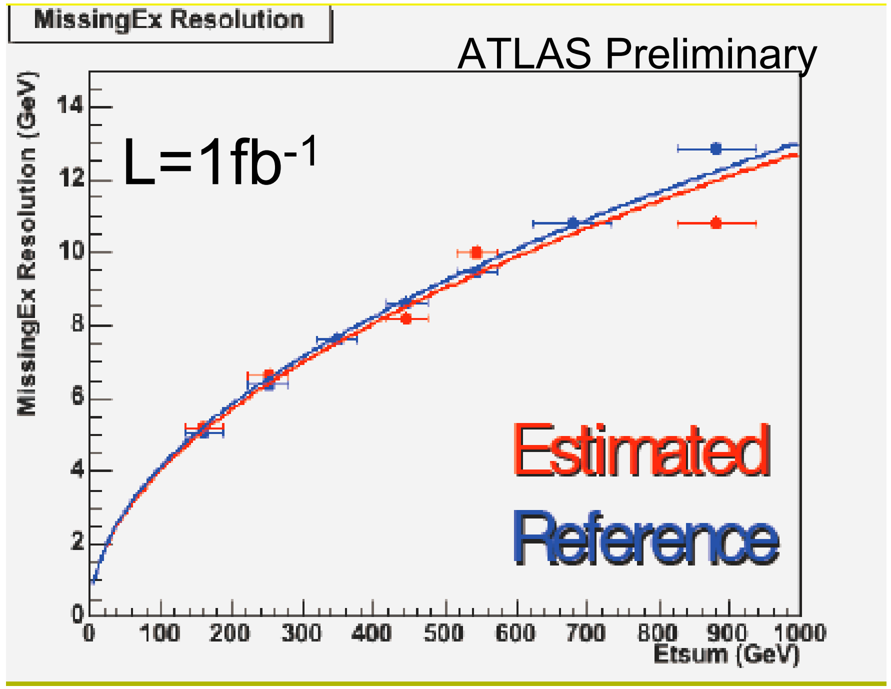
(2) Higher ΣE_T region can be validated with M_T of W(→lnu)



Jacobian peak of M_T is sensitive to absolute scale and resolution of mE_T: Both can be examined: since we know M_w very precisely. Momentum of Lepton is assumed to be well calibrated.

This method can be used upto ΣE_T=1TeV. (BG effect tt & Wbb should be examined)

Performance of mE_T can be examined with real data with L= just $1fb^{-1}$: Quick startup is possible (need to study about "clean up" of event to cut BH,CR,NOISE)

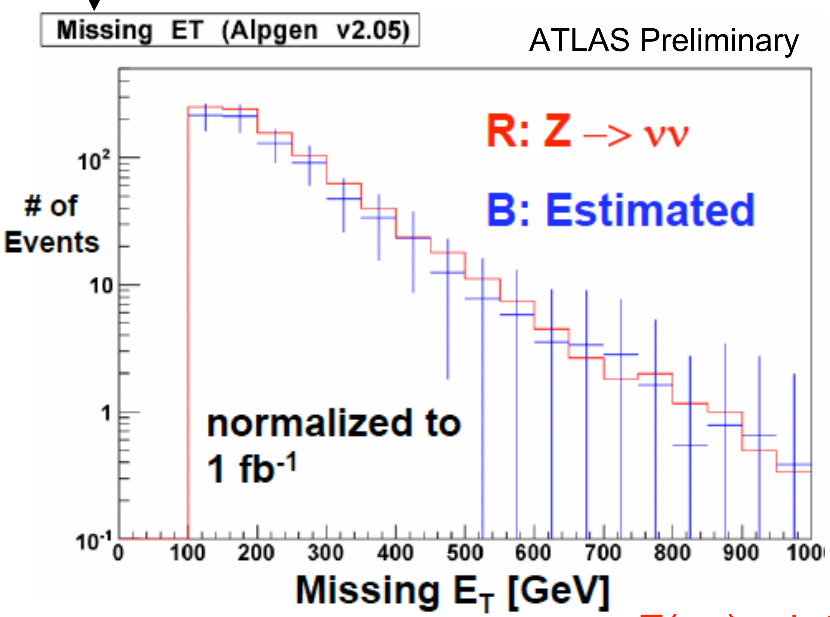


3-2 Background estimation with Real data

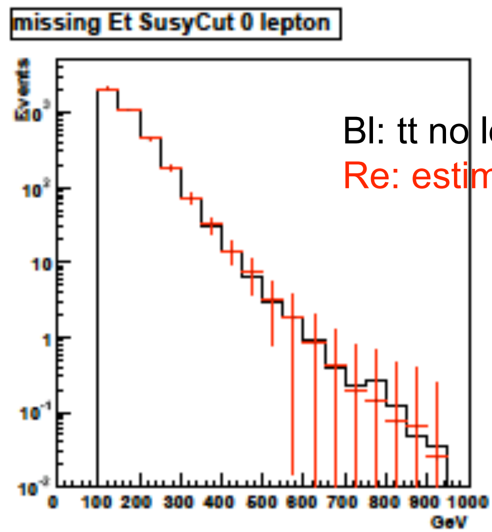
Summary of background estimation with Real data ("No-lepton mode")

Estimated BG processe	Control samples	status
Z→νν + Njets	Z→ee, μμ + Njets	OK but stat. limited
Z/W+ Njets	Z →ee, μμ + Njets	OK but using MC shape
W+Njets (no lepton)	W->lnu(MT<100GeV)	OK: reweight for W->taunu
tt+Njets (no lepton)	tt+Njets (MT<100GeV)	OK: separate W from CS

Next



L=1fb^{-1}

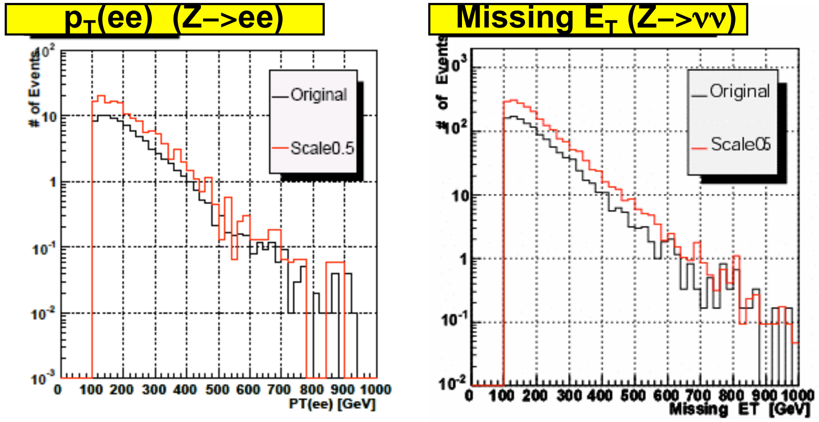


mET(GeV)

Z(nn)+njets : 157+/-13
Estimated : 142+/-39
(MET>300GeV)

tt(nolepton)127 +/– 11
Estimated 132 +/– 21
(MET>300GeV)

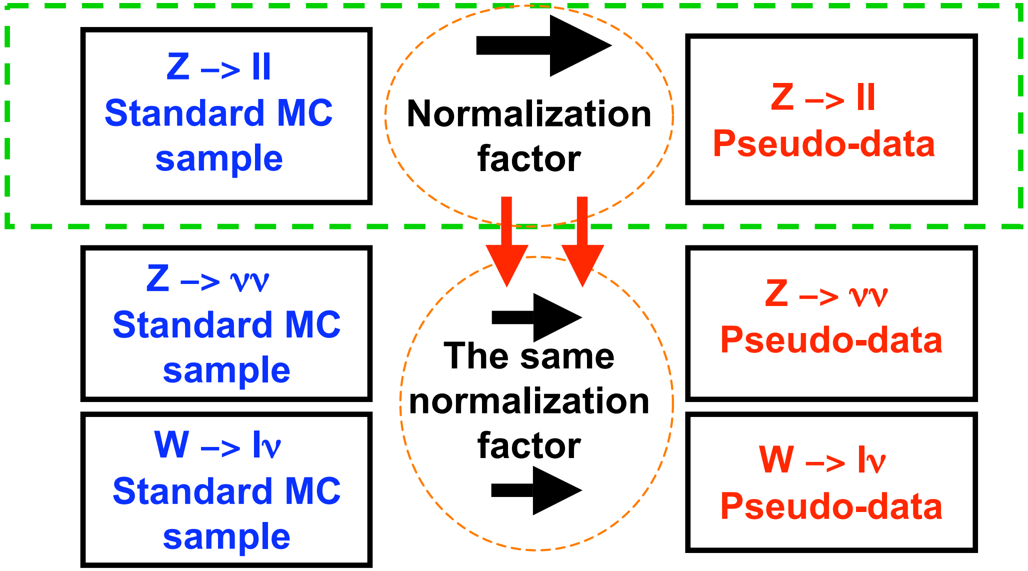
The background distributions are very stable against input parameters, also stable for various generators(ALPGEN/MC@LO/Sherpa), just normalization is different.



Shape of the distributions are insensitive to the input parameters of the Generator (Alpgen+Jimmy).

Renormalization scale, factorization scale, minimum p_T at partons level, minimum distance dR_{ij} between partons, jet definition of MLM matching (minimum E_T, cone size R), and PDF

The normalization of the distributions is affected by these uncertainties.



We use the shape of the MC distributions,

but determine the normalization factor from the real data by comparing p_T(ll) distributions of Z->ll

They have the same diagram -> this normalization factor is common to W/Z

Z –> νν

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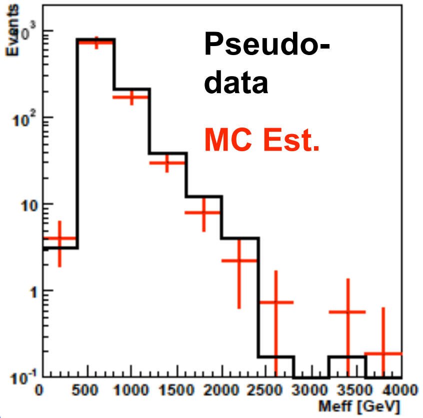
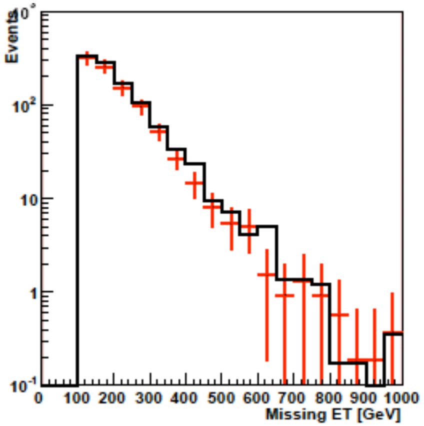
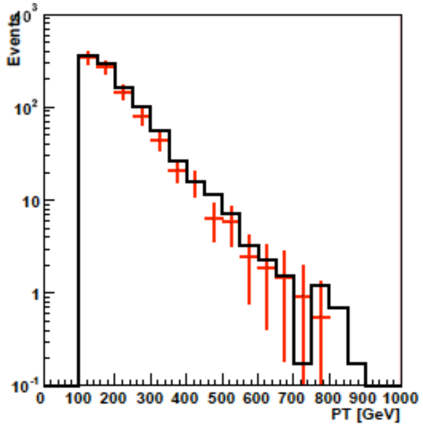
Effective Mass



Missing E_T



Leading Jet P_T



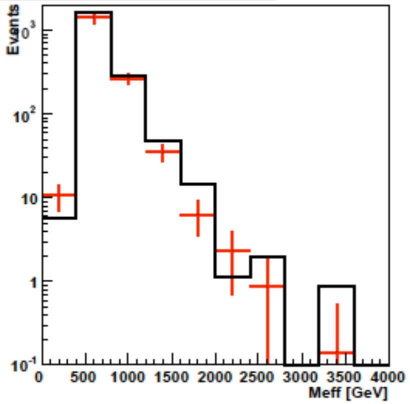
# of Events (MET > 300 GeV)

147 +/- 12
(pseudo-data)

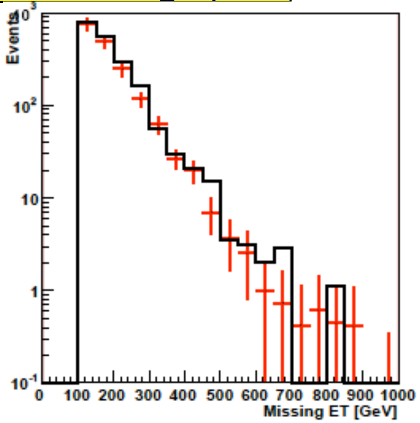
118 +/- 20
(estimation)

W –> lν

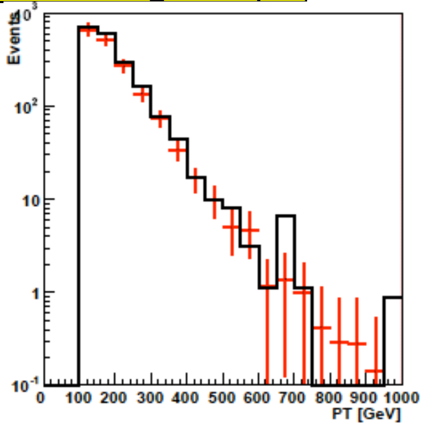
Effective Mass



Missing E_T



Leading Jet P_T



# of Events (MET > 300 GeV)

134 +/- 11
(pseudo-data)

126 +/- 21
(estimation)

statistical errors & errors of normalization factor considered

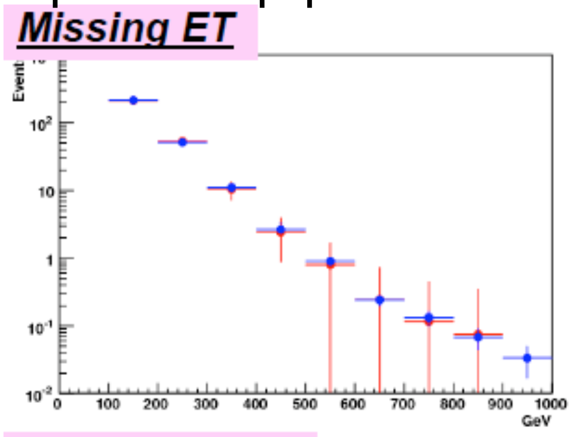
normalized to 1 fb^{-1}

One-lepton mode / OS-dilepton mode

Top -pair is dominant background process for these modes:
We have good control sample of top-pair itself (one lepton& MT<100GeV)

BG(MT>100GeV)
can be estimated
with CS(MT<100GeV)
If no SUSY <5%

IF SUSY exists (1TeV)
accuracy is about 50%
SUSY signal contributes to CS



Without SUSY signal

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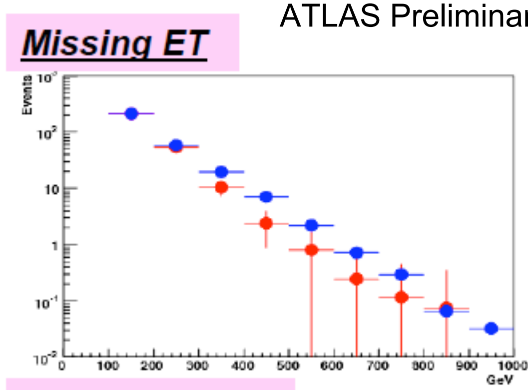

With **1TeV SUSY signal**

Dilepton BG
can be estimated
with the same CS
If no SUSY <10%

IF SUSY exists (1TeV)
Estimation becomes
Overestimated
about 100%

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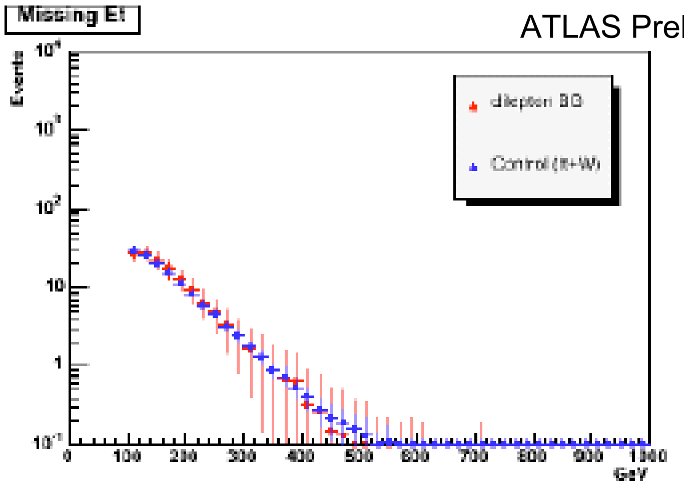

Missing Et (GeV)

Pt of Lepton

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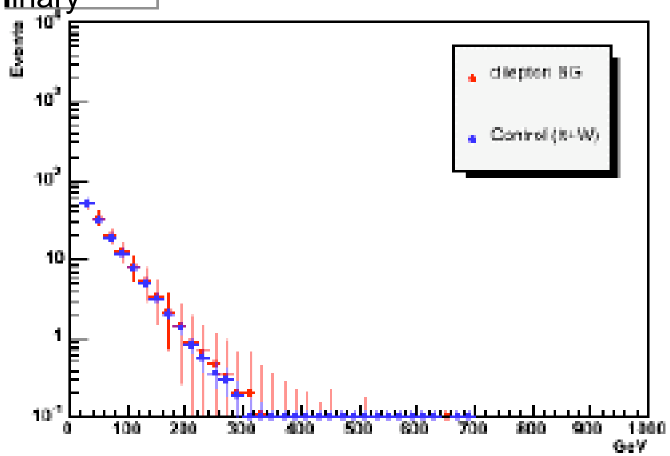


Pt of lepton (GeV)

No SUSY signal

[4] Potential of LHC with $L=1\text{-}30fb^{-1}$

We will have real data at 14TeV in next year 2008.

The integrated luminosity is expected to be about $0.1\text{-}1fb^{-1}$.

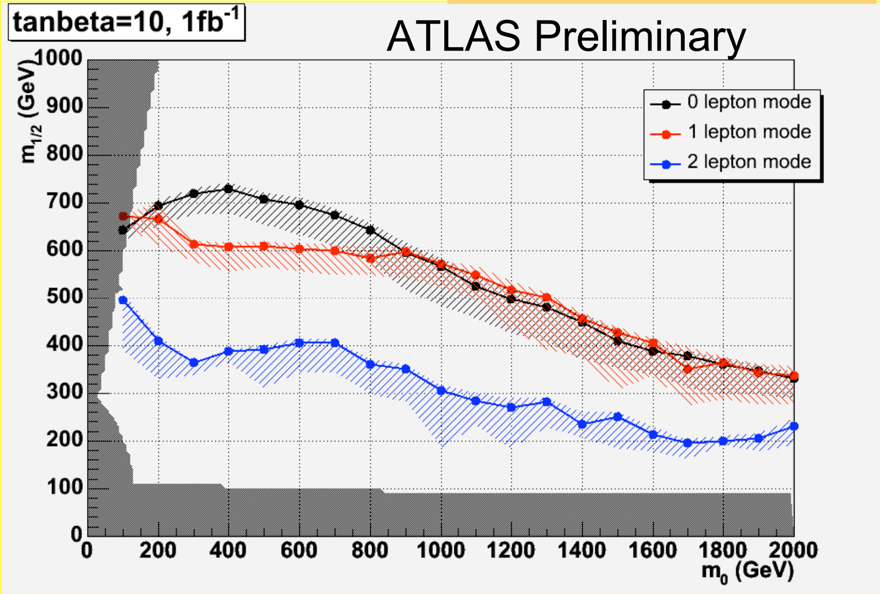
We can validate mE_T performance and estimate BG with this low luminosity as shown in [3].

So we can obtain the solid results with only $L=1fb^{-1}$.

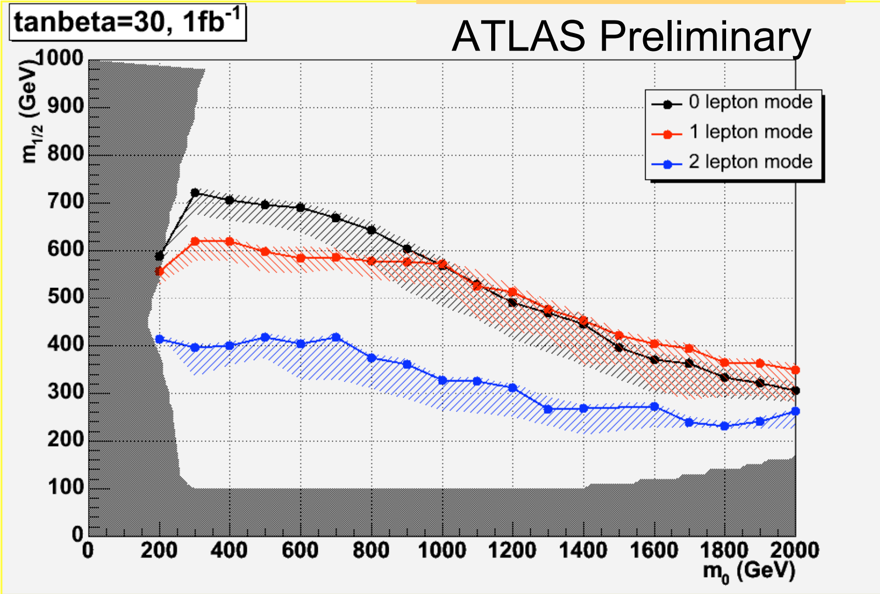
2008?

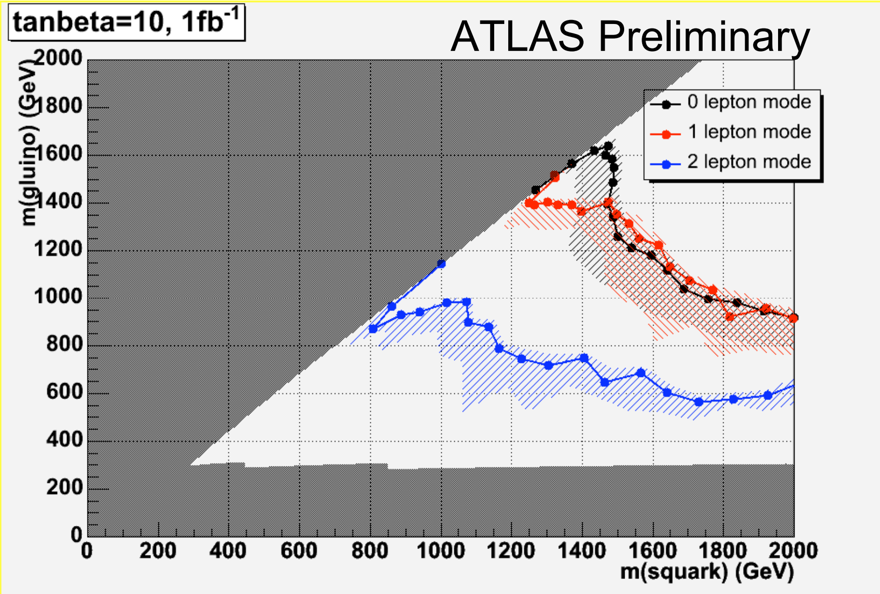
5σ discovery potential

tanβ=10, L=1fb^{-1}



tanβ=30, L=1fb^{-1}



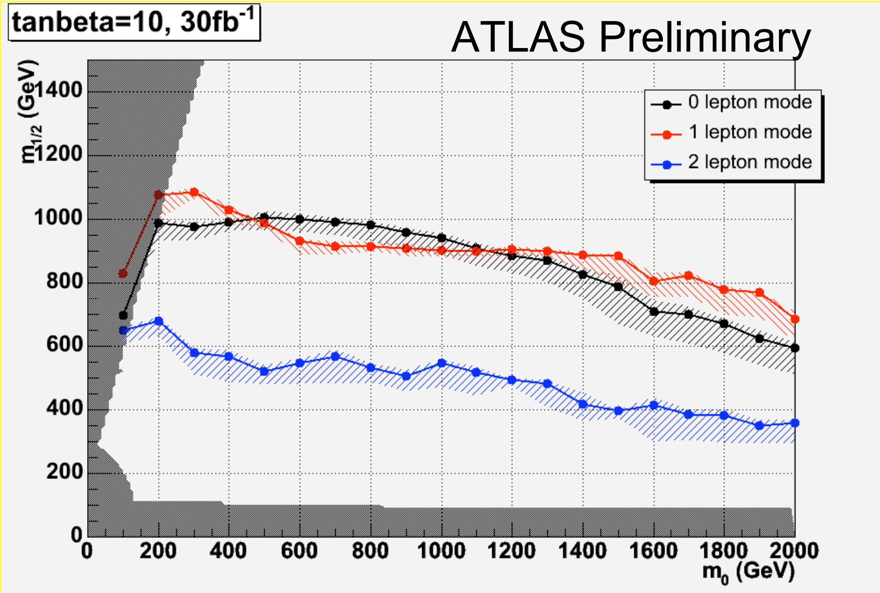


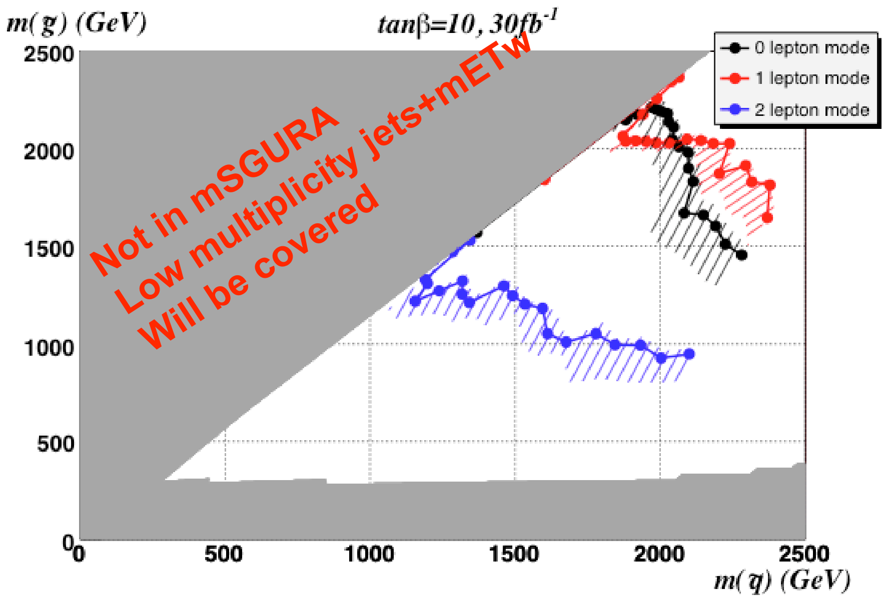
(1) Hatched band shows the uncertainties of estimation of background (uncertainties of factor 2 due to scale and cut at parton)

(2) Results are stable against tanβ. except for nu2->tau/stau dominant for high tanβ.

(3) Results are shown in m(sq) vs m(gl)
One-lepton and No-lepton have
the similar potential. 1.4 TeV with L=1fb^{-1}
OS dilepton mode upto around 800GeV.

tanβ=10, L=30fb^{-1}

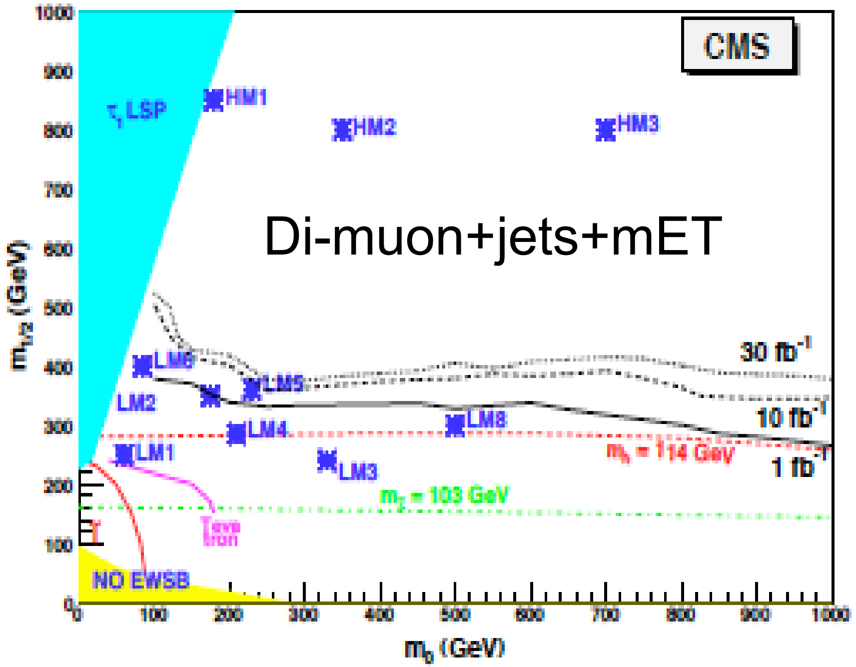




With L=30fb^{-1} (2010-11?)
We can discover $\tilde{q},\tilde{g}$ upto ∽ 2-2.3TeV:

One-lepton/No-lepton modes are promising.

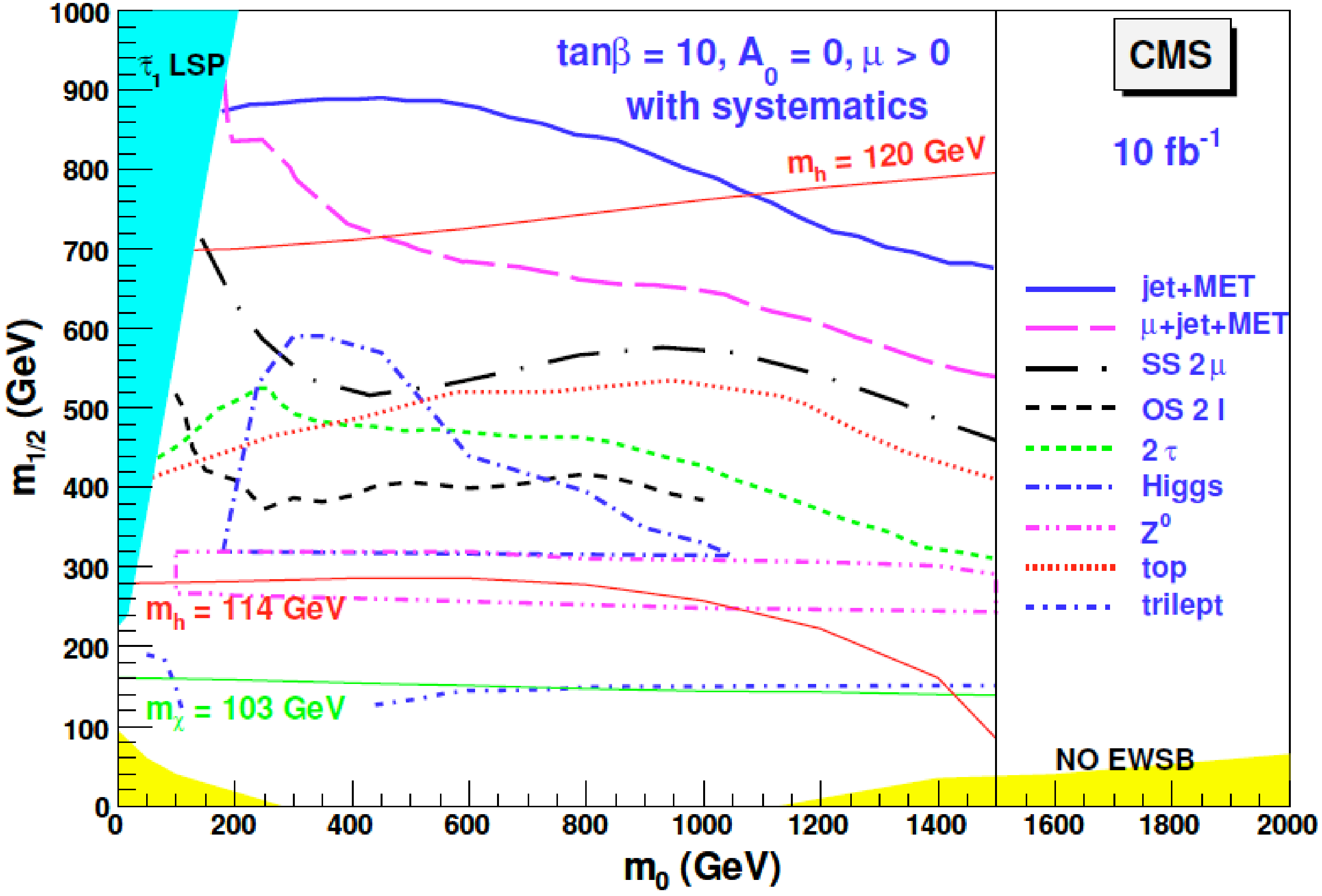
Di-lepton mode has potential upto 1TeV.
CMS obtains the similar results using Full simulation.
Di-lepton mode plays important role in reconstruction as mention later



We can discover SUSY with various event topologies:

multi leptons
$\not{E}_T$ + High P_T jets + b-jets
τ-jets

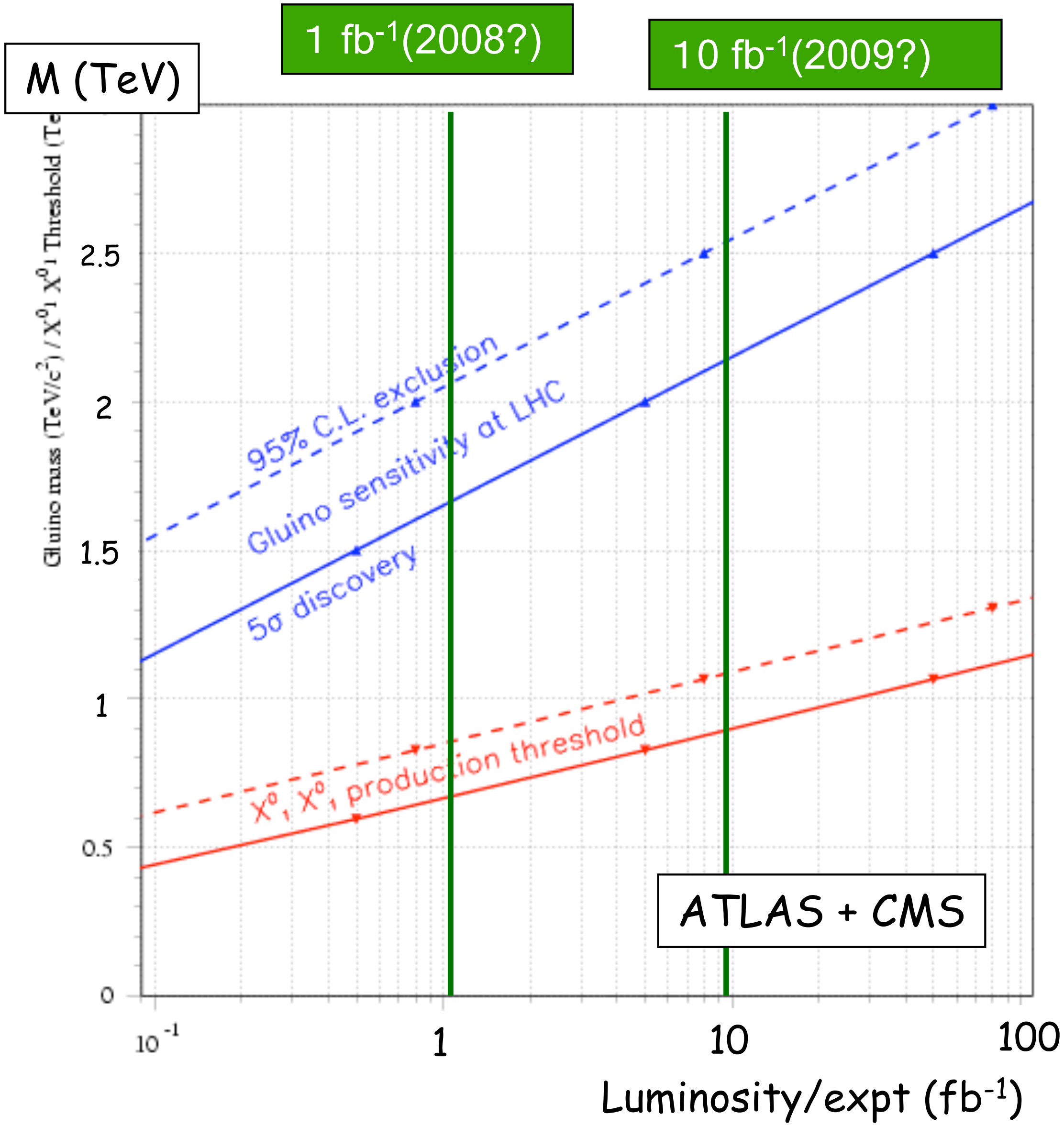
Not only Lepton,
But also..top,tau,Higgs are possible $M(\tilde{g}) \sim 1TeV$



These carry information about EW gaugino sector

Plays important role in inclusive/exclusive measurements in the next session

Let's combine ATLAS & CMS



With $L=10fb^{-1}$

$\tilde{q},\tilde{g}$ can be discovered up to 2.1TeV

Using Naïve GUT assumption
Gaugino-like

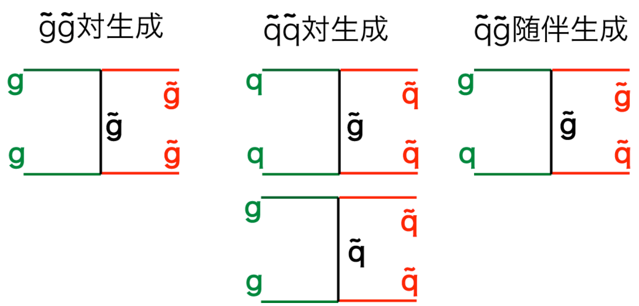
$$\tilde{\chi}_1^{\pm} \approx 700GeV$$
$$\tilde{\chi}_1^{0} \approx 350GeV$$

-> impact on LC energy

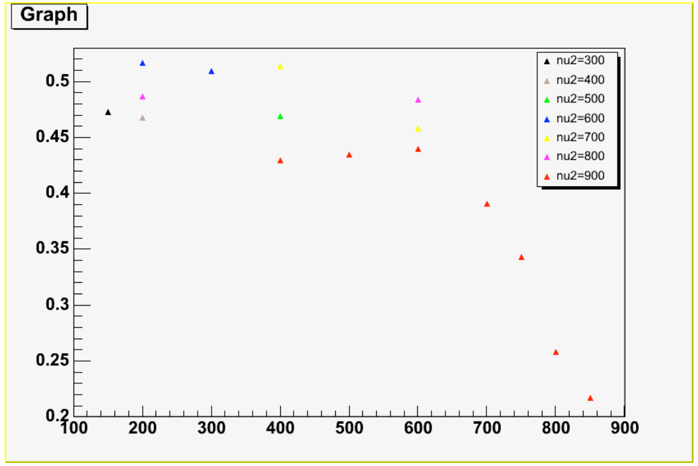
(2.5TeV for 95%CL exclusion)

These do not strongly depend on model:
Important parameters are masses of $\tilde{q},\tilde{g}$ and the mass difference between them and LSP (D_M>= 400GeV) -> next

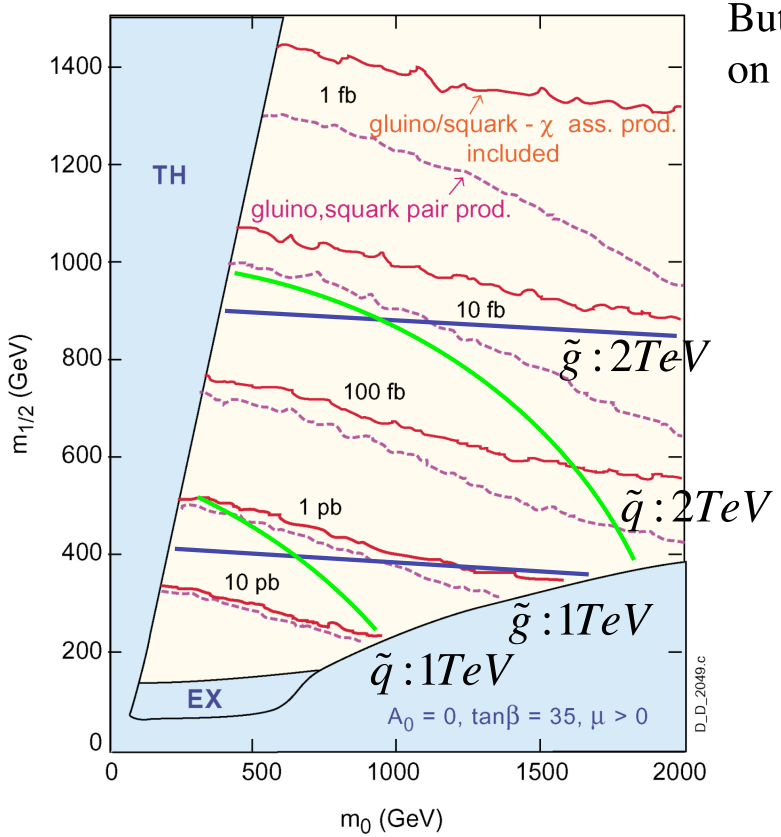
Can LHC discover Only “minimal” model?



Production processes are very simple. Just strong interaction. Cross-section depends on masses of Gluino and squark, But not strongly depends on the other parameters.



LSP mass (GeV) for Gluino mass 1TeV

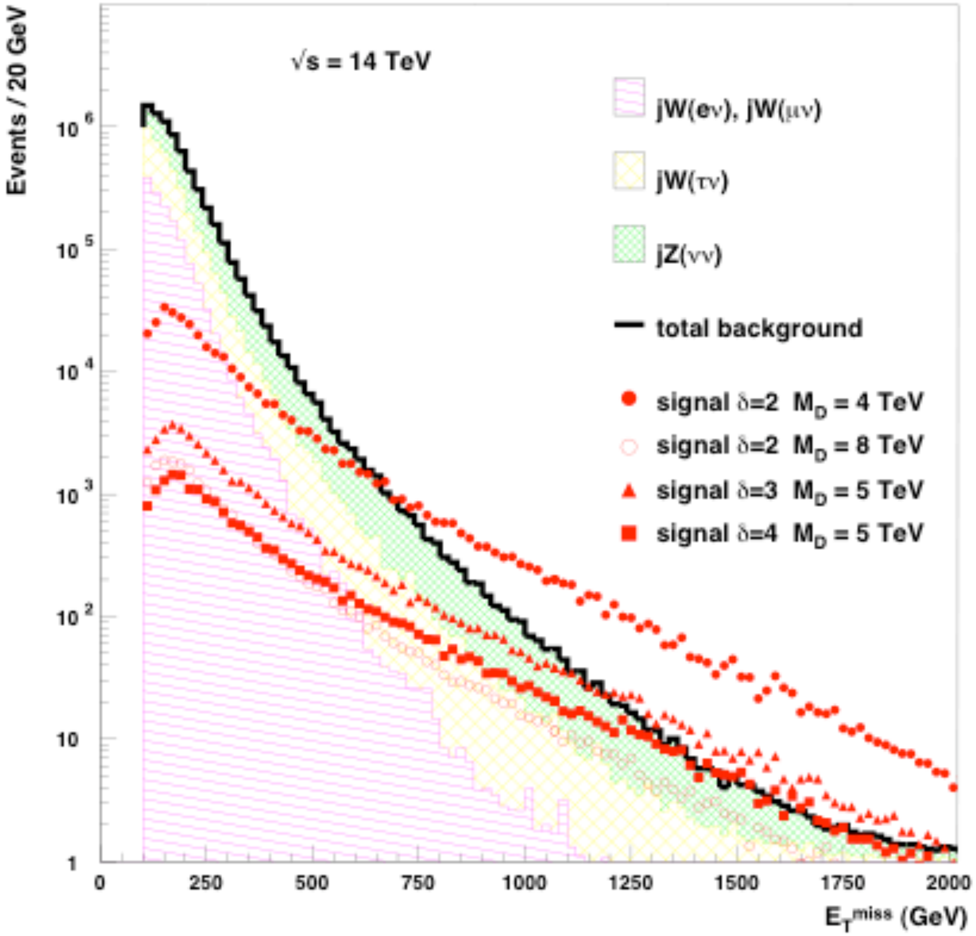


On the other hand,
detection efficiency and mET distribution depends on the mass difference between “gluino/squark” and LSP(neutralino_1).
Does not strongly depends on the intermediate state.
This figure shows the efficiency for various intermediate state. Results are stable if D_M>300-400GeV.
mET distributions are also stable if DM>400GeV.

If not SUSY observed at LHC with L=10fb^{-1}
-> Too heavy > 2.5TeV
-> too small mass difference between gluino/sq & LSP (and they are heavy)
-> no mE$_T$ -> R parity violate

KK graviton (gg->gK) will be observed in “monojet” topology

$\not{E}_T$ distribution



Events for HL, 100 fb^{-1}

for $E_T^{jet} > 1$ TeV

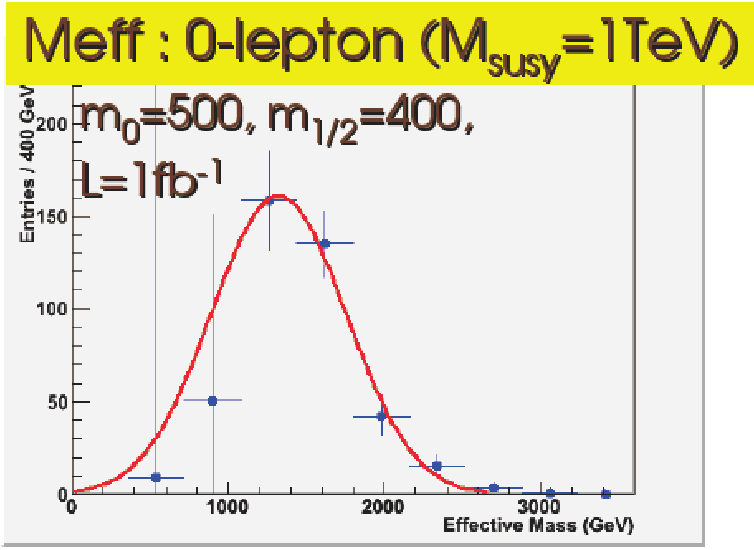
$jZ(\nu\nu)$	$jW(\tau\nu)$	$jW(e\nu)$	$jW(\mu\nu)$
523	151	12	14

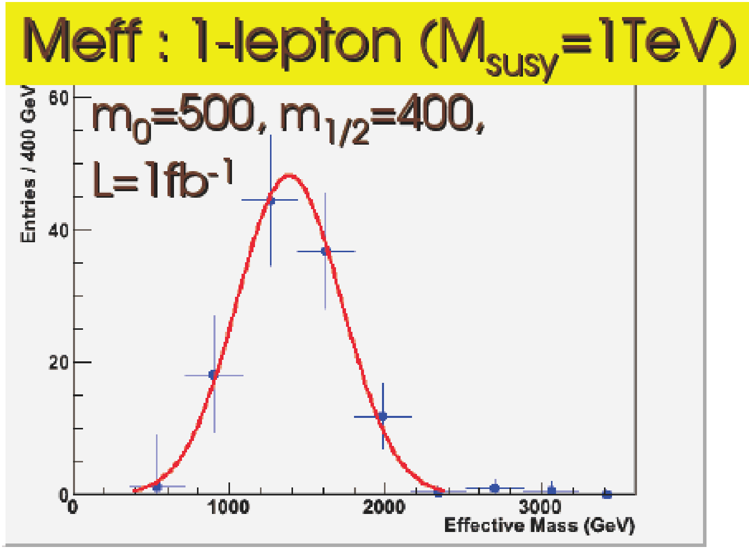
δ	M_D (TeV)	Events	$\mathcal{S}_{max} = S/\sqrt{B}$
2	5	1430	61.4
	7	366	13.8
	9	135	5.1
3	5	705	26.7
	7	131	5.0
4	5	391	14.8
	7	53	2.0

[5] What we can/cannot do with $L = 10 fb^{-1}$

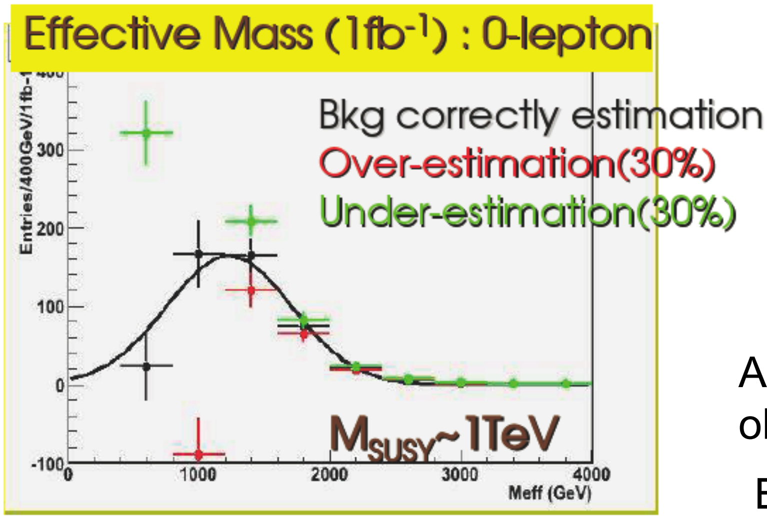
We just discover “excess including mE_T” beyond SM:
We should examine the origin of the observed excess:
SUSY, Little Higgs, LED?
If SUSY, which breaking model? Gravity, Anomaly,Gauge
We also determine the model parameters in these.

$$M_{eff} = \sum_{Leading\,4\ jets} P_T + mE_T(+P_T(l))$$ is sensitive variable to SUSY mass scale





Approximately peak will be observed around $1.4 \times min(M(\tilde{q}), M(\tilde{g}))$



(1) Same position Indicate same origin in both excess

(2) SUSY mass scale can be obtained -> check the cross-section

(3) Mass relation between $M(\tilde{\chi}_1^0)$ and $min(M(\tilde{q}), M(\tilde{g}))$

Assuming model -> chargino/nu2 mass can be obtained -> impact on LC energy

But we have to understand BG precisely < (10%)

Dominant Production/Decay Pattern?

There are charactristic 4 types pattern

(A) Light sneutrinos/sleptons

$\tilde{q}_L \rightarrow \tilde{\chi}_1^+ / \tilde{\chi}_2^0 \rightarrow \tilde{\nu}+l \,/\, \tilde{l}+l$

>>Lepton rich event

(B) Direct decay

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

>>2jet-like enhance

(C) Light Stop/Sbottom

$\tilde{g} \rightarrow \tilde{t}+t \rightarrow \tilde{\chi}_2^+ + b$

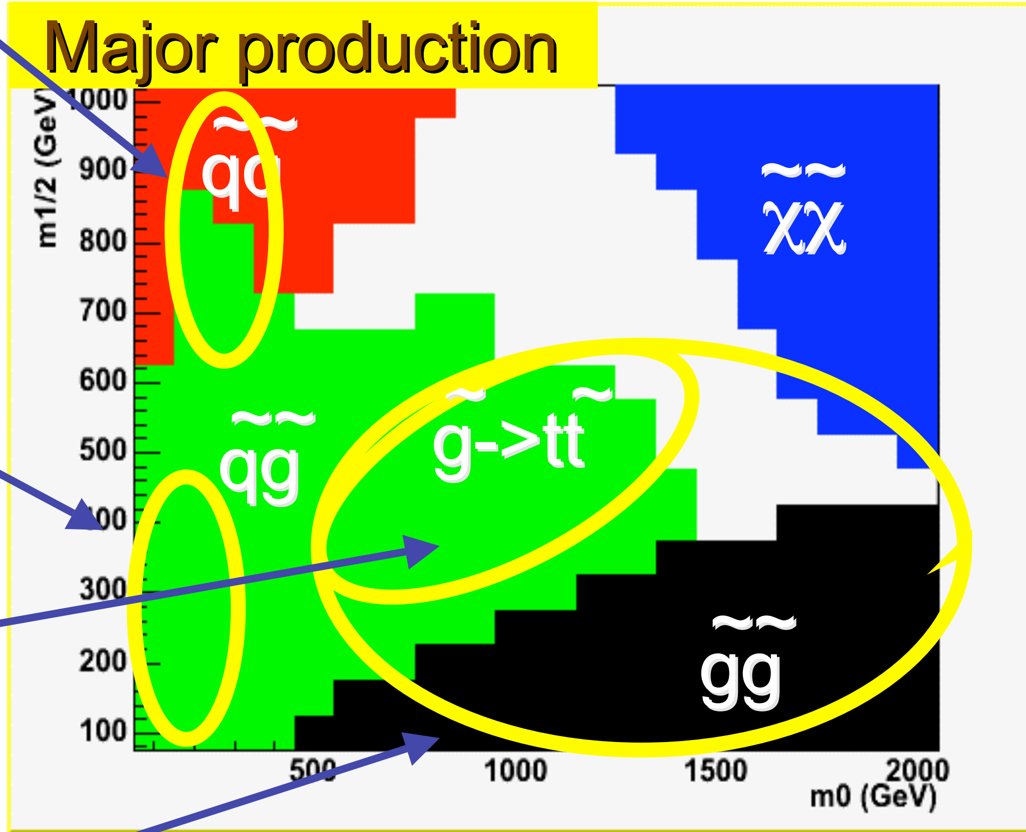
$\rightarrow \chi_2^0+W \,/\, \chi_1^+ + Z$

>> Lepton/b-jet rich event

(D) gluino production/decay

$\tilde{g} \rightarrow \tilde{\chi}_n^+ / \tilde{\chi}_n^0 + qq$

>> Multi-jet like event

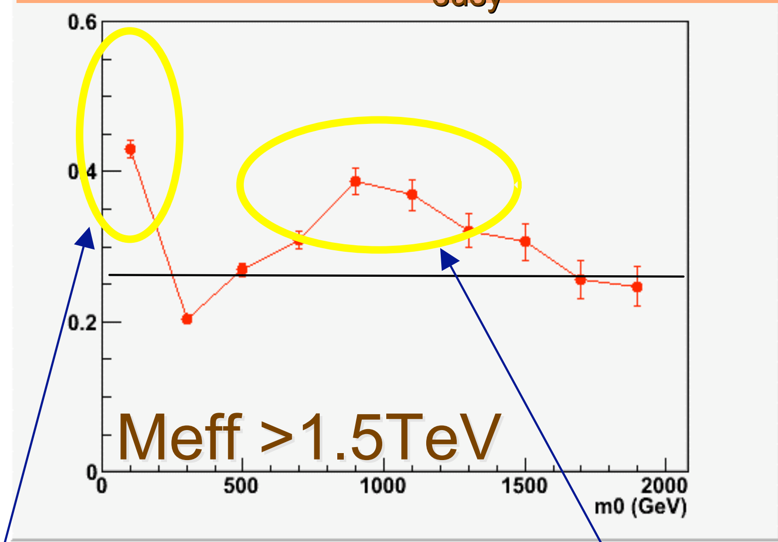


High Pt b-jet is enhanced
If stop contributes in decay chain

Lepton excess is enhanced in

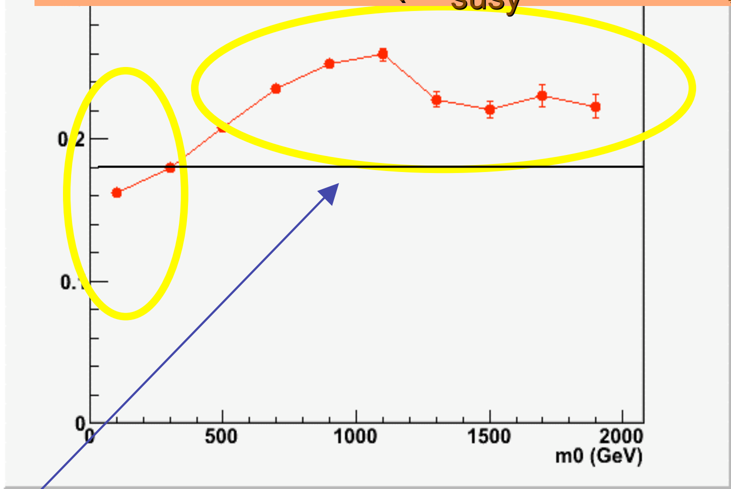
$\langle R_{lep}^{1/0} \rangle$ (= N(=1)/N(=0))

$m_{1/2}$=500 GeV(M_{susy}~1.3TeV)



$\langle R_{ptb} \rangle$ (= $\Sigma\,|p_{T(b\text{-}jet)}| / \Sigma\,|p_{T(jet)}|$)

$m_{1/2}$=500 GeV(M_{susy}~1.3TeV)



Br ($\tilde{q}_L \to \tilde{\chi}_1^+ + q$)~65%
Br ($\tilde{\chi}_1^+ \to \tilde{l}_1^+ + \nu_l$)~38%

-> top can be reconstructed

Br ($\tilde{g} \to \tilde{t} + t$)~95%

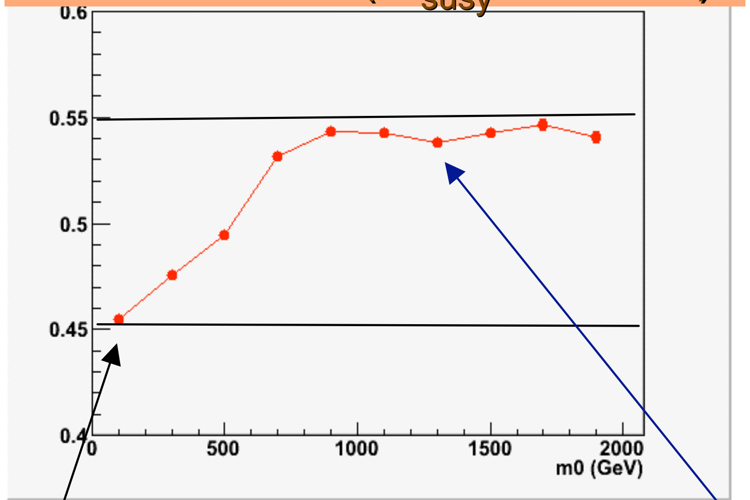
Error shows stat. L=30fb^{-1}

Multijet-likeness

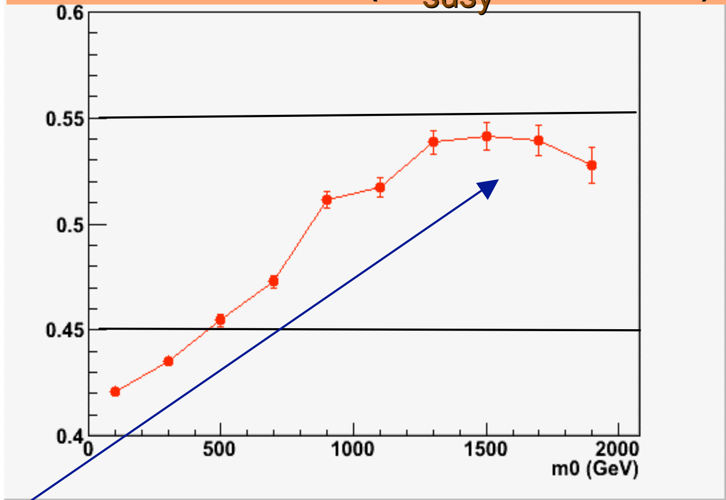
$\langle R_{12} \rangle$ ($= p_T^{(2nd)} / p_T^{(1st)}$ in each hemisphere)

Hemisphere Algorithm(HA) : reconstructed objects are assigned to each initially-produced particle (hemisphere)

$m_{1/2}$=300 GeV(M_{susy}~0.8TeV)



$m_{1/2}$=500 GeV(M_{susy}~1.3TeV)

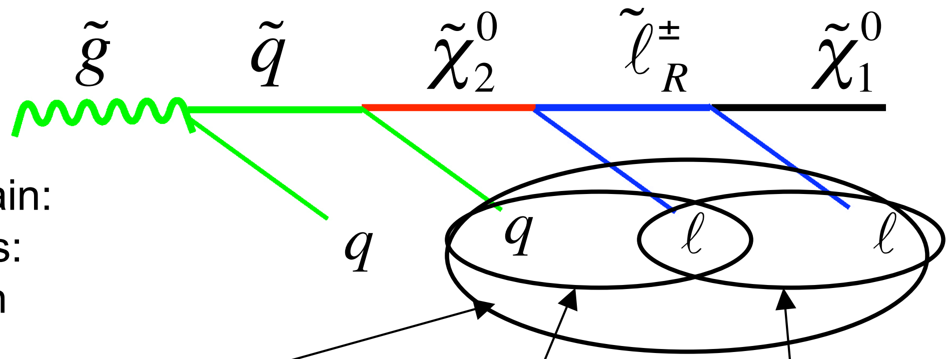


gluino-gluino production is dominant

Squark contribution becomes larger

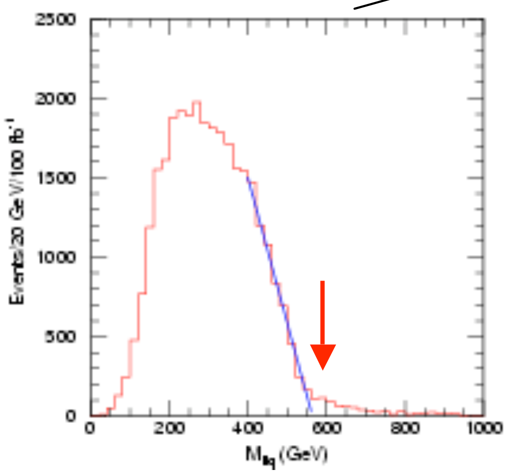
Error stat only L=30fb^{-1}

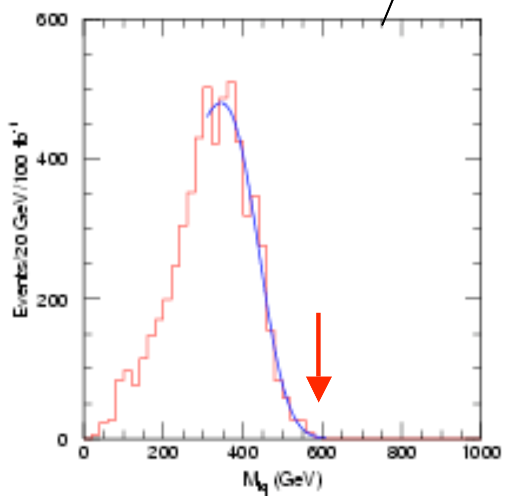
Exclusive Study: mass can be measured:

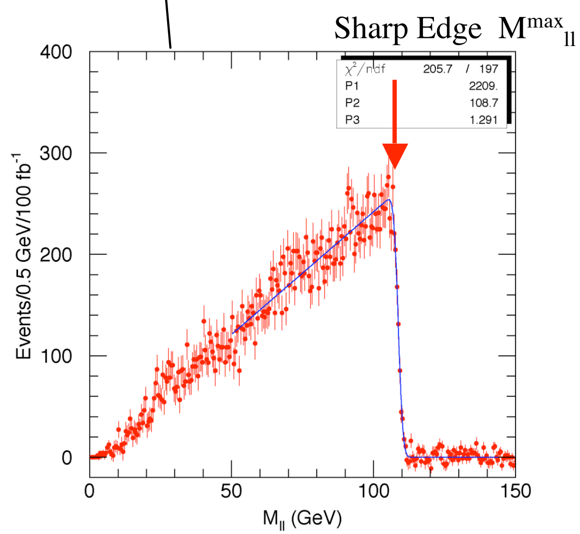


Select interesting decay chain:
Make kinematic distributions:
Edge carries the information
related to their masses:

ATLAS







$$M_{llq}^{\max} = \sqrt{\frac{(m(\tilde{q}_L)^2 - m(\tilde{\chi}_2^0)^2)(m(\tilde{\chi}_2^0)^2 - m(\tilde{\chi}_1^0)^2)}{m(\tilde{\chi}_2^0)^2}}$$

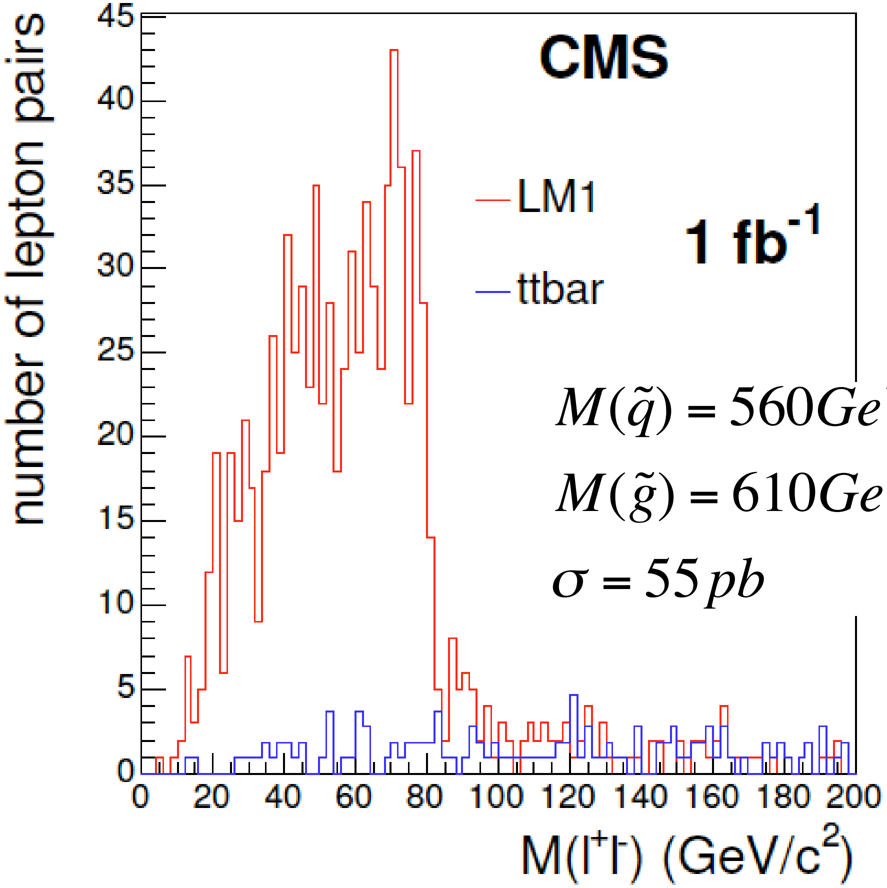
$$M_{lq}^{\max} = \sqrt{\frac{(m(\tilde{q}_L)^2 - m(\tilde{\chi}_2^0)^2)(m(\tilde{\chi}_2^0)^2 - m(\tilde{l}_R)^2)}{m(\tilde{\chi}_2^0)^2}}$$

$$M_{\ell\ell}^{\max} = m(\tilde{\chi}_2^0)\sqrt{1-\left(\frac{m(\tilde{\ell}_R^{\pm})}{m(\tilde{\chi}_2^0)}\right)^2}\sqrt{1-\left(\frac{m(\tilde{\chi}_1^0)}{m(\tilde{\ell}_R^{\pm})}\right)^2}$$

Masses can be determined with an accuracy of about 1-10% (with help of model in general) If M<3TeV.
L=100fb-1 is necessary for 1TeV case:

If the SUSY mass scale is small (∽ 600-800 GeV)
We have enough statistic even with L=1-10fb^{-1}

$$M_{\ell\ell}^{max} = m(\tilde{\chi}_2^0)\sqrt{1-\left(\frac{m(\tilde{\ell}_R^{\pm})}{m(\tilde{\chi}_2^0)}\right)^2}\sqrt{1-\left(\frac{m(\tilde{\chi}_1^0)}{m(\tilde{\ell}_R^{\pm})}\right)^2}$$



$$M(\tilde{q}) = 560GeV$$
$$M(\tilde{g}) = 610GeV$$
$$\sigma = 55pb$$

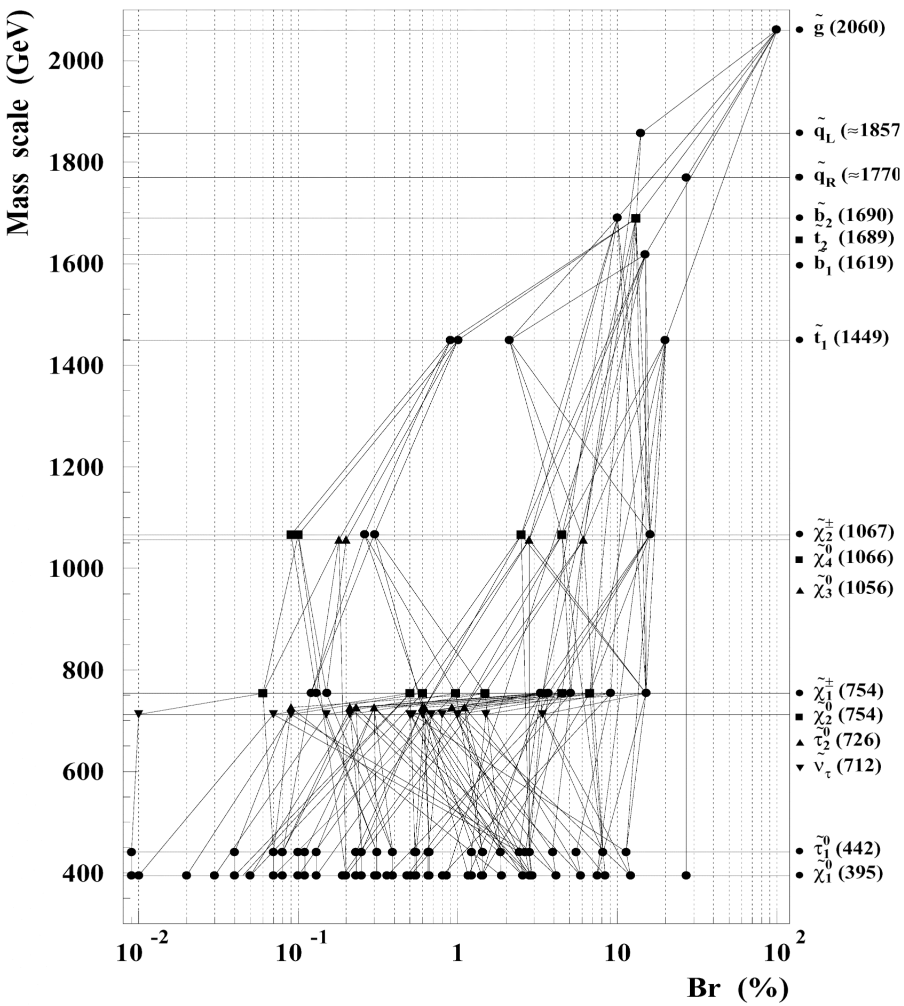
We can obtain the mass scale of $m(\tilde{\chi}_2^0)$

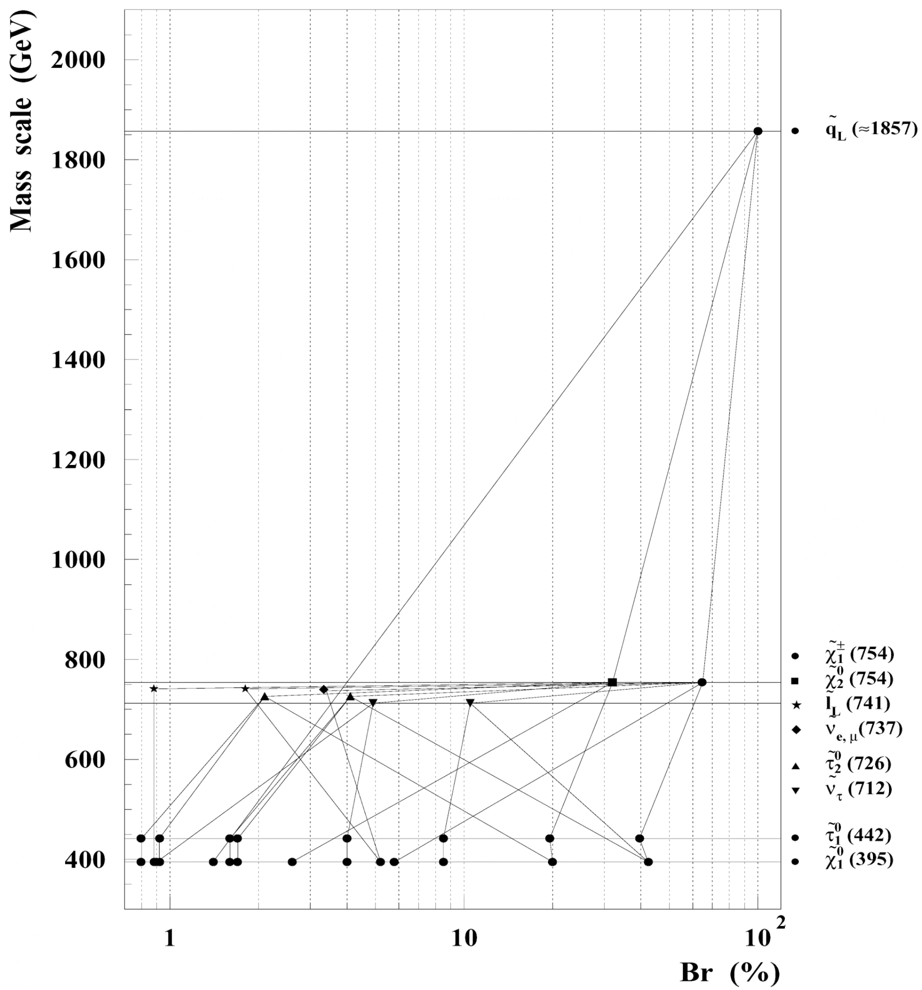
Chargino/neutralino mass scale is obtained
-> critical information of LC ECM

Branching fraction/coupling can not measured @LHC

model independent study on sparticle mass is also difficult @ LHC

Decay Chaine gluino Squark_L (tanβ=35)





Currently We study using mSUGRA in which is higgsino mass is heavier : Higgsino decouples from study:

Summary:

(1) Various new physics provide the interesting Event topologies with mE_T

(2) (Need more efforts but) we are ready now for quick/solid discovery.
Strategies are established to estimate mE_T & background using real data. (Enough L=about 1fb-1) OK(2008,9)

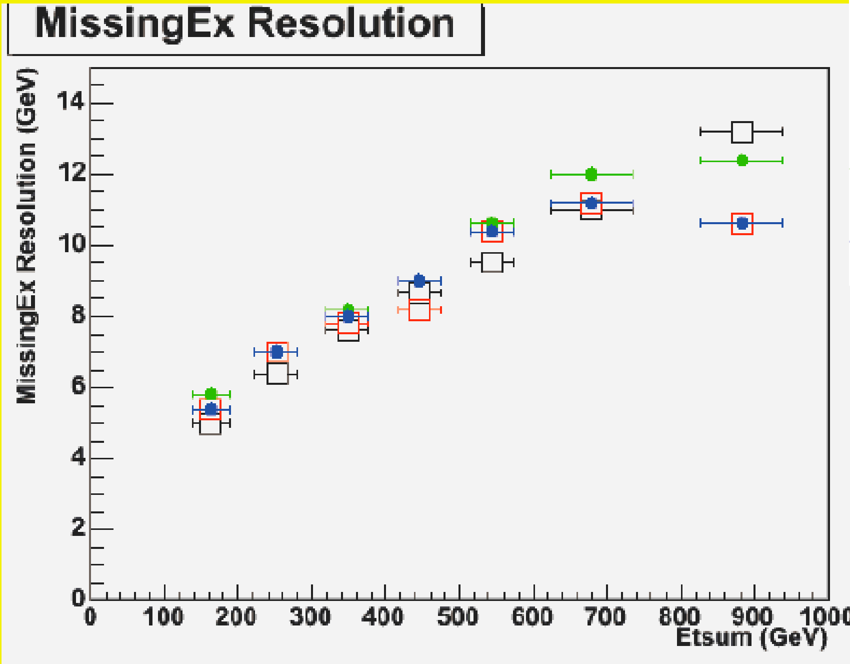
(3) ATLAS/CMS have enormous potential to discover new Physics.
SUSY can be discovered upto M=1.5/2TeV (if DM>400GeV) with L=1/10fb^{-1} OK(2008/2009 respectively)

(4) Inclusive measurements are possible with L=1-10fb^{-1}
(mass scale of colored particle can be obtained upto 2TeV)
Exclusive analysis and mass-difference can be determined if M<800GeV even with L=10fb^{-1} OK(2009)

-> LC initial energy and upgrade schedule can be determined within 2009.
LC is essential to study sparticles completely.
(LHC can not solve the decay shown in P.36)

Backup slide

Effect of background (2)



Reference

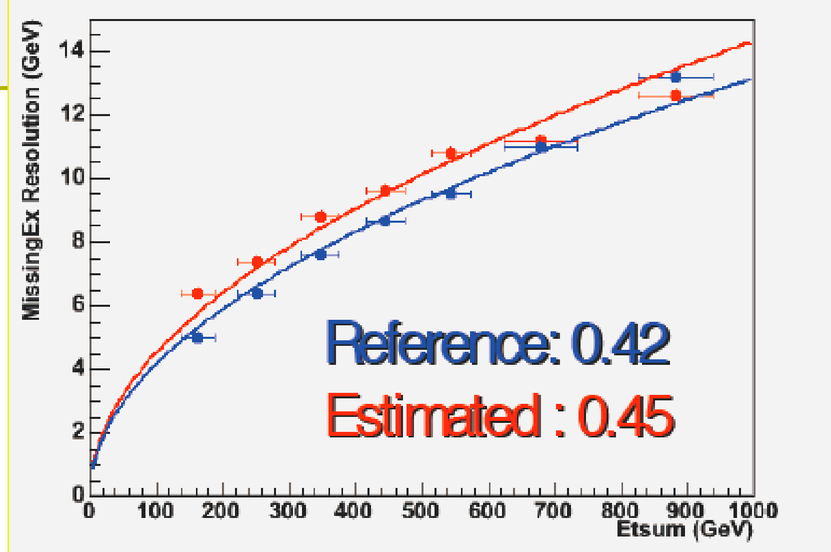
only W(μν)

with tt(lνlν)

with tt(lνqq)

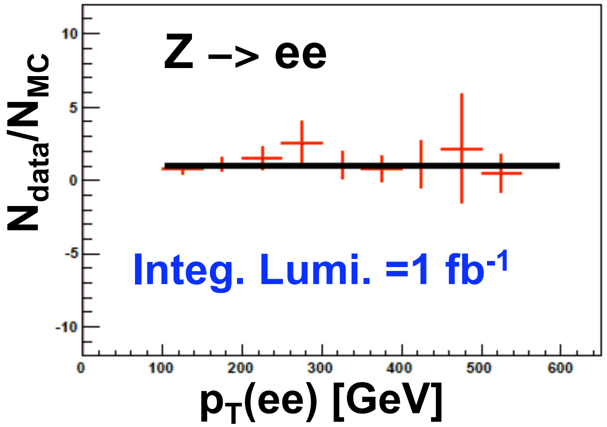
← Looks more deviation with tt(lνlν) bkg from result with only W(μν).

Include All background

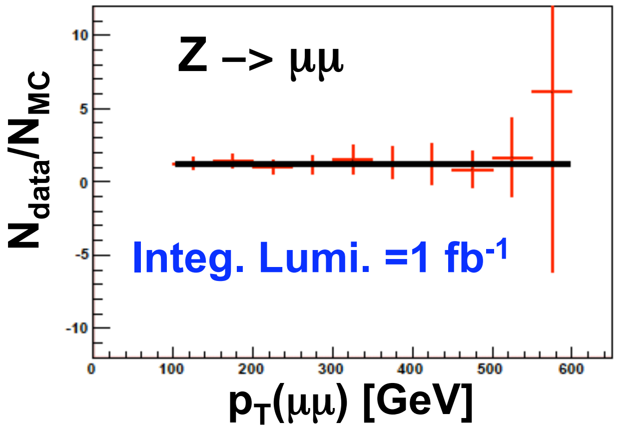


- Need to estimate systematic and statistical errors.
- Need to suppress or subtract bkg.

Normalization Factor



α=1.02+/- 0.24 (Z –> ee)

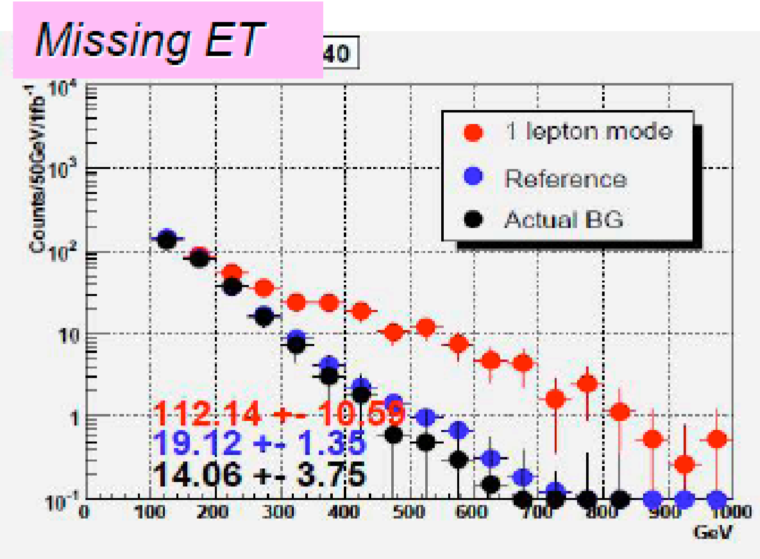


α=1.23 +/- 0.22 (Z –> μμ)

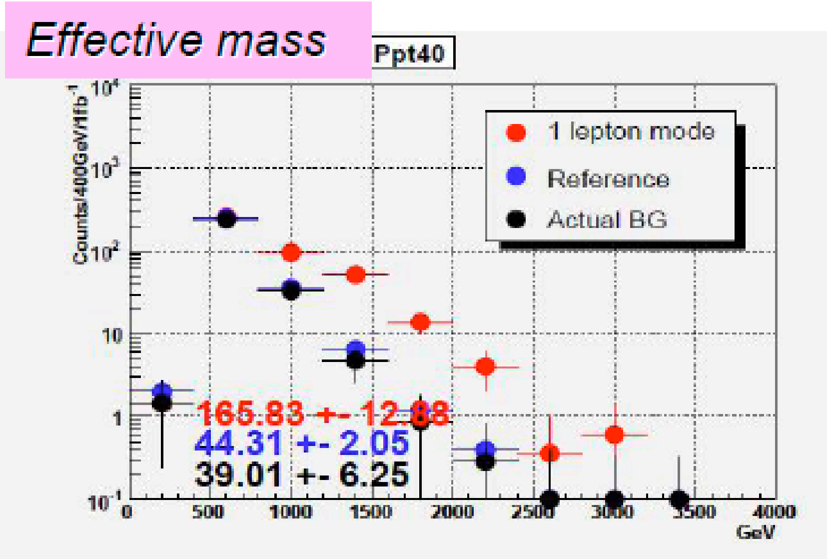
–> α = 1.12 +/- 0.16 (Z –> ll Modified Fast)

If the slope is different we can examine

SUSY contributes to reference samples:



counts (MET>300GeV)



counts (Meff>800GeV)

- *BG estimation with M_{SUSY} ~ 1TeV (m_0=400GeV,$m_{1/2}$=400GeV,tan β=10)*
  Std SUSY cut is applied in these figures
  - ***1lepton mode*** *(ttbar,W,SUSY (Mt>100GeV))*
  - ***Estimated BG*** *(ttbar,W,SUSY (Mt<100GeV))*
  - ***Actual BG*** *(ttbar,W (Mt>100GeV))*

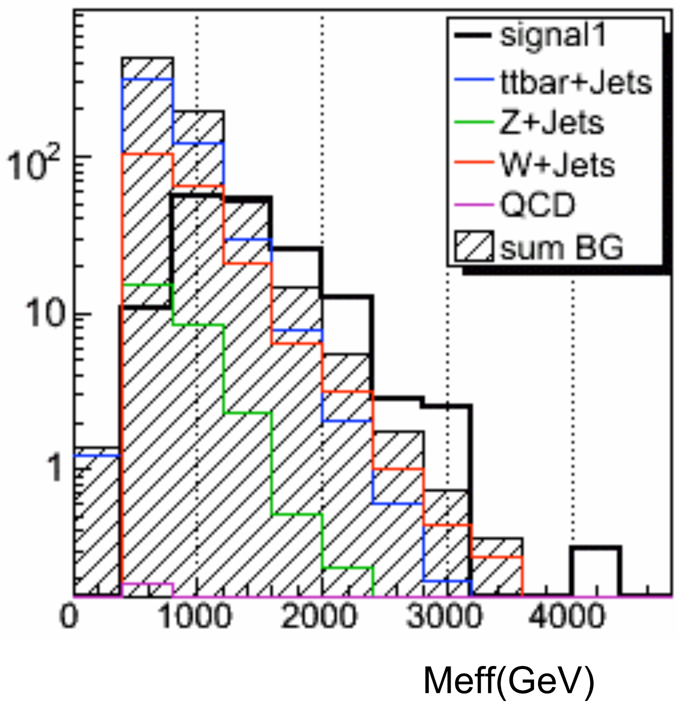
IF SUSY Lighter much overestimated but signal is also high
IF SUSY heavier signal is no so enough but BG estimated correctly
No effect on SUSY discovery:

Status of BG study (understanding uncertainties, Data-driven estimations) are summarized here:

Njet (high Pt)	Additional	Favored scenario	Status BG understanding	Data-driven BG estimations
Nj>=4	No lepton	SUGRA,AMSB, Split: Heavy $\tilde{q}$	•Systematic uncertainties done •NLO study not yet •Need detail studies for Detector response for QCD(light & bb/cc) •Clean up for fake mET	•Just using Fast simulation (W/Z OK using MC shape Top pair OK using MC shape: W contaminations should be separated from top control samples:) • QCD(light&bb/cc) not yet • Need Full simulation study *Need boost up*
	One lepton	SUGRA,AMSB, Split: Heavy $\tilde{q}$	•Systematic uncertainties done •NLO study done •Full simulation study with high Stat. is necessary	•Just using Fast simulation (simple MT method done: Results stable with accuracy of 10%) • Top re decay & reconstruction method in progress • W contaminations should be separated from top control samples • SUSY contributions should be separated from top/W control samples (otherwise overestimate)
	Dilepton,3L	SUGRA,AMSB, GMSB (Nm>1)	•Systematic uncertainties done •NLO study done for OS •Full simulation need for SS & 3L	•Just using Fast simulation (simple MT method done: Results stable with accuracy of 50%) •SUSY contributions should be separated from top/W control samples • SS & 3L not yet
	Tau (ditau)	Large tanβ, GMSB (Nm>1)	•Just Start with Fast simulation •Systematic uncertainties, NLO not yet •Still BG high, have to reduce	*Not Yet done*
	γγ	GMSB (Nm∽1)	•Just Fast simulation •Almost BG free •Need more careful study FSR	*Not Yet done*
Nj∽2	No lepton	Heavy $\tilde{g}$	*Not Yet done*	*Not Yet done*
	One lepton	Heavy $\tilde{g}$	*Not Yet done*	*Not Yet done*
Nj = 0	Dilepton,3L	Direct $\tilde{\chi}$	•Just Fast simulation •NLO study Not yet •Need more careful study on jet veto and Fake lepton.	*Not Yet done*

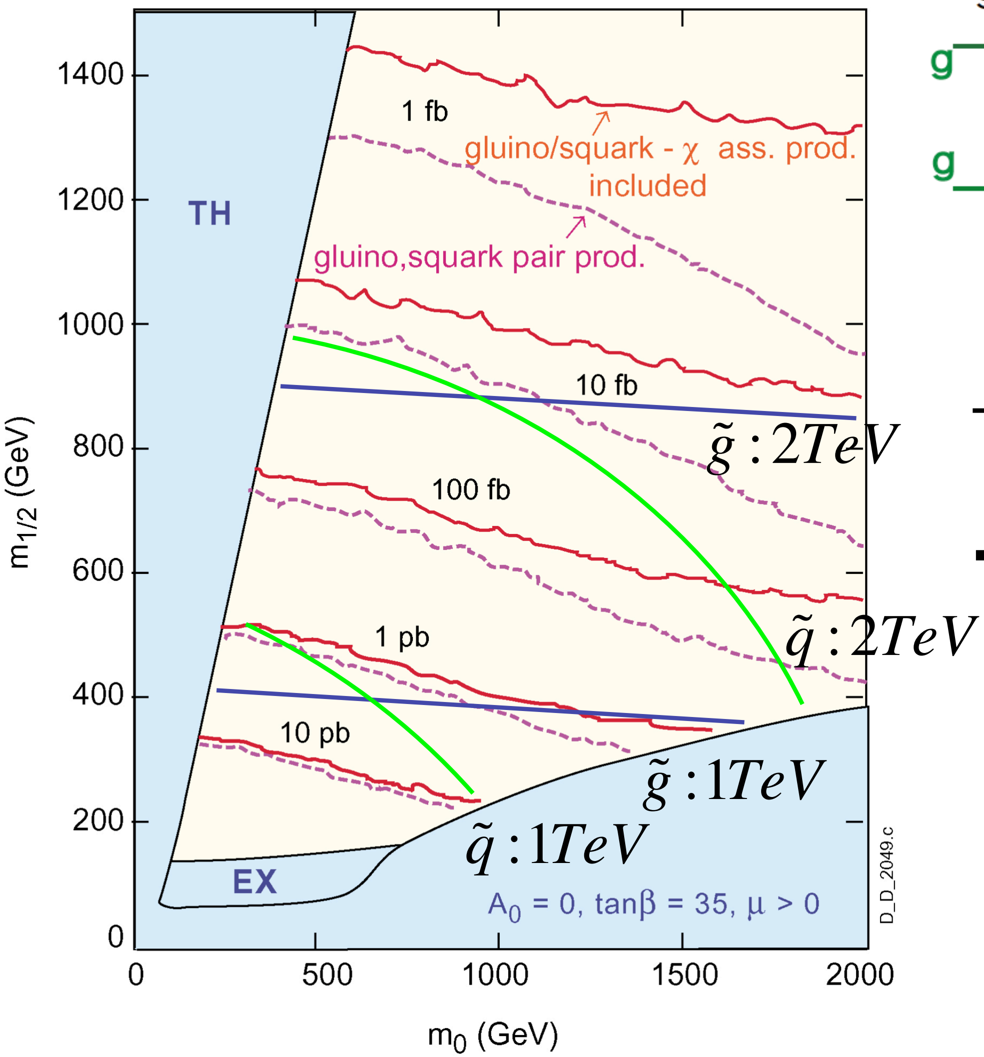
One Tau BG process: Top & W contribute:

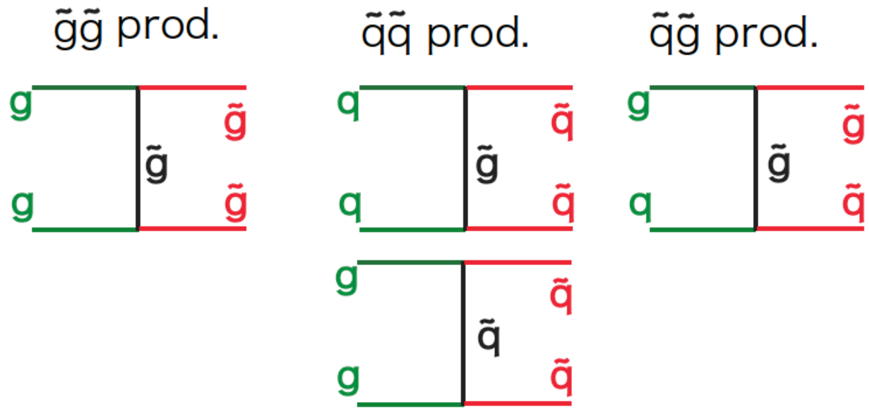
One Tau



L=1fb^{-1}

[4-1] Production cross-section at LHC $(\tilde g\tilde g, \tilde g\tilde q, \tilde q\tilde q)$





These couplings are just strong interaction (α_s):

➔ large cross-section is expected model independent except for mass

$m(\tilde q) = m(\tilde g) = 0.5TeV$	σ∽100pb $\tilde g\tilde g$
$m(\tilde q) = m(\tilde g) = 1TeV$	σ∽3pb
$m(\tilde q) = m(\tilde g) = 2TeV$	σ∽20fb $\tilde u\tilde u, \tilde u\tilde d$

[1] Short Summary/proposal of the methods to estimate background for "no lepton mode"

Shoji , Hideki, Kenta, Dan

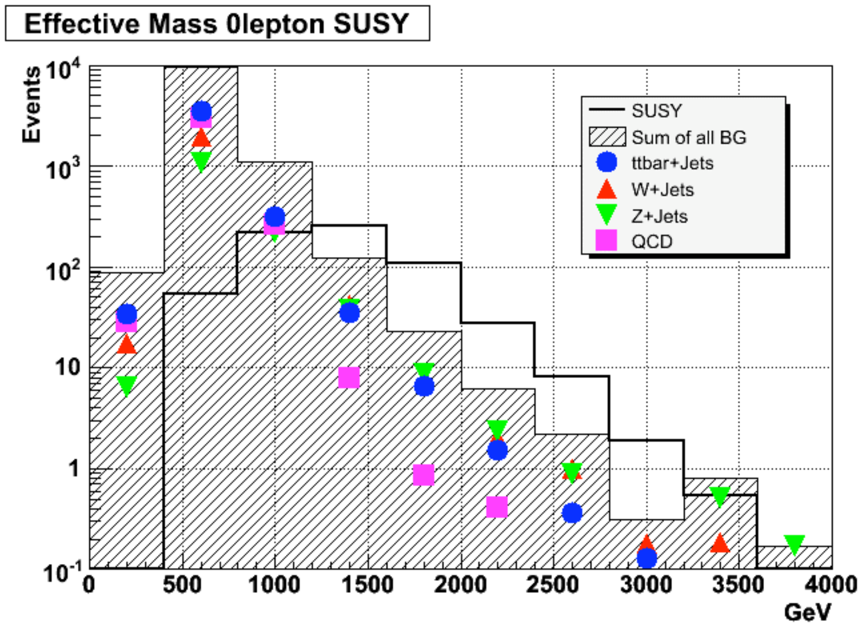
This figure shows the effective mass distributions of no lepton mode after the standard SUSY cut.

Open hist shows 1TeV SUSY signal, and hatched shows sum of the BG processes.

W(->lnu), Z(->nunu) and top pair(->bblnuqq) are dominant background processes.

DY Z->ll process and W(->lnu) MT<100GeV are good control samples to understand these processes, and I summarize and proposal for methods.

Number/1fb^-1



SUSY Mass:1TeV

Effective mass (GeV)

Short summary of Status:

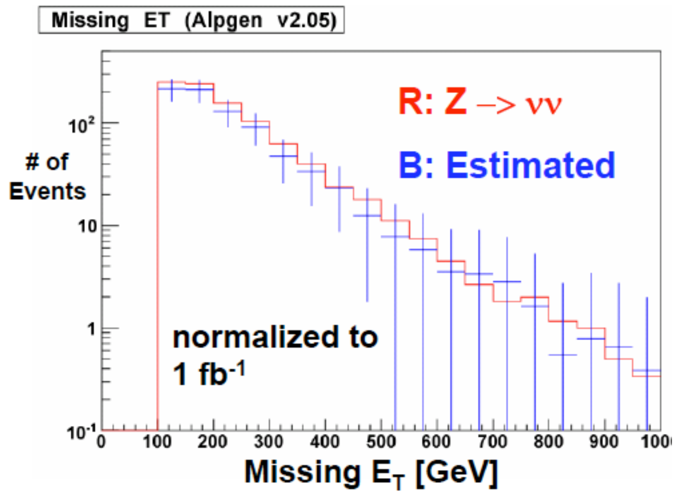
Control sample	Estimated samples	status
Z->ee, mumu	Z-> nunu	OK but stat. limited
Z->ee,mumu	Z->nunu, W(no lepton)	OK but using MC shape
W->lnu(MT<100)	W (no lepton)	OK: reweight for W->taunu
tt (->bblnqq MT<100GeV)	tt(no lepton)	OK:
Mixed W and tt	W,tt	difficult

Method 1

Reference sample: Z(->ee.mumu)+Njets:

(1) Standard SUSY cuts are applied but mET is replaced into PT_(ll). M(ll)=Mz+-10GeV.
(2) Detection efficiency of di-lepton are estimated with MC:
Efficiency is determined as function of PT(ll) and flavor of lepton.
(3) Z(->ll) is replaced into “missing Et” and corrected with efficiency.
Then we obtain Z(->nunu) dustributions.
Already done with Fast & Full (work well, but stat. error is large 30%)
http://indico.cern.ch/getFile.py/access?contribId=6&resId=0&materialId=slides&confId=4291

(4) One lepton of Z(->ll) is replaced into neutrino and applied efficiency (ε_l / ε_ll), which is estimated with MC.
Can we obtain W->lnu+Njets (MT<100GeV)?
Not yet checked.



(5) Reference sample W->lnu+Njets (MT<100GeV) can be separated from tt processes. Then we can obtain W+Njets Background for no lepton mode
Some part is done with Fast, We use “some MC information”
http://indico.cern.ch/getFile.py/access?contribId=1&resId=0&materialId=slides&confId=6137

Method 2 (Fully MC method)

Reference sample: Z(->ee,mumu)+Njets:

There are 6 free parameters and 2 uncertainties in the current MC samples:
Q_ren, Q_fac, Pt_parton @ generator , R_parton@generator , Jet definition_MLMmatching(ET,R_cone)
PDF choice, higher order correction (not yet done)

(1) We have checked that the distributions of W/Z are against these parameters.
Just Normalization is changed: (Already done with Fast but need more careful study)
W->lnu http://indico.cern.ch/getFile.py/access?contribId=9&resId=0&materialId=slides&confId=5269
Z->nunu http://indico.cern.ch/getFile.py/access?contribId=8&resId=0&materialId=slides&confId=5269
Z-> ll http://indico.cern.ch/getFile.py/access?contribId=3&resId=0&materialId=slides&confId=6829

(2) Standard SUSY cuts are applied but mET is replaced into PT_(ll). M(ll)=Mz+-10GeV.
(3) Detection efficiency of di-lepton are estimated with MC:
Efficiency is determined as function of PT(ll) and flavor of lepton.
(4) Samples with “unknown parameters” is fitted with the Reference sample Z(->ll) with standard parameters: and we obtain the normalization factor between standard parameters samples and unknown parameters samples
(5) We assume that this normalization factor is common for Z->ll, Z->nunu, and W->lnu since production/decay processes are the same.
Nomalization factor/lepton efficiencies are applied to the standard parameter samples of W,Z->nunu. Then we obtain the W,Z(->nunu) distributions with “unknown parameters”

Method 3 (Extrapolation from N=1 to N>=4) (Not yet checked)

Reference sample: W(->lnu)+1jet: (MT<100GeV)

W(->lnu)+Njets (MT<100GeV) is good reference samples for both of no and one lepton mode. But there is large contamination from tt+Njets: (70% tt only 30% W) -> need some trick to enhance W.

(1) W(->lnu)+1jet (mET>100GeV, Pt_jet>100GeV, MT<100GeV, no 2nd high Pt jets) is selected. Top contributions/SUSY signal are suppressed relatively.

(2) Distributions (mET, PT_LJ, sum of PT, Meff) are compared after cut(1) and SUSY cut, and "reweighting functions" are obtained using MC information.
"reweight" is applied on distribution of (1) and we can estimate "distributions of W(->lnu)+Njets" (MT<100GeV) after SUSY cut. (not Yet checked)
This is "estimated reference sample" of W(->lnu)+Njets (MT<100GeV)

(3) Systematic errors on reweighting function due to MC parameters should be examined. (Not Yet Done)

(4) Z->ll + 1jet -> Z->ll+Njets can be used to confirm "reweight function" using data.

→ We can estimate "distributions" of no lepton mode and one lepton mode with "estimated reference sample" (Done with ATLFAST, redecay for tau, some part with Full)

No lepton mode: http://indico.cern.ch/getFile.py/access?contribId=1&resId=0&materialId=slides&confId=6137
http://indico.cern.ch/getFile.py/access?contribId=2&resId=1&materialId=slides&confId=6137
http://indico.cern.ch/getFile.py/access?contribId=6&resId=0&materialId=slides&confId=4291

One lepton mode http://indico.cern.ch/getFile.py/access?contribId=5&resId=1&materialId=1&confId=4291
http://indico.cern.ch/getFile.py/access?contribId=9&resId=0&materialId=slides&confId=5269
http://indico.cern.ch/getFile.py/access?contribId=7&resId=0&materialId=slides&confId=5269

Method 4 (Veto method)

Reference sample: W(->lnu)+Njet, tt+Njets (MT<100GeV)

(1) W(->lnu)+Njets (MT<100GeV) -> W(->lnu)+Njet (No lepton)
(done with Fast simulation, redecay for tau mode?)
http://indico.cern.ch/getFile.py/access?contribId=1&resId=0&materialId=slides&confId=6137

(2) tt+Njets (one lepton + MT<100GeV) -> tt+Njet (No lepton)
(done with Fast simulation OK)
http://indico.cern.ch/getFile.py/access?contribId=2&resId=1&materialId=slides&confId=6137

(3) But does not work with mixed reference tt+Njets: (70% tt only 30% W)
-> new idea is need to select W and top separately.

a) Apply Method 3 (enhance W) (Not yet)
b) Kinematic mass reconstruction for top (not yet)
c) tt->lnlnbb select -> reweight lnqqbb distribution with MC information (not yet)

c) is redecay method:

-> Redecay method is proposed by Dan
http://indico.cern.ch/getFile.py/access?contribId=5&resId=1&materialId=slides&confId=6829

Conclusion:

I propose the following 4 methods to estimate
BG for no lepton mode. (Let's try study marked "Not yet done")

(Method1) less depend on MC but Stat. Limit

(Method2) MC full used: except for normalization:
since distributions look stable.

(Method3) Need careful study dependence of Njets,

(Method4) Standard approach but need more idea
to separate W and top

Welcome the other methods:

[2] Short Summary/proposal of methods to estimate background for “one lepton mode”

Shoji, Paul, George, Kenta, Hideki, Dan,
Bruce,Yaquan

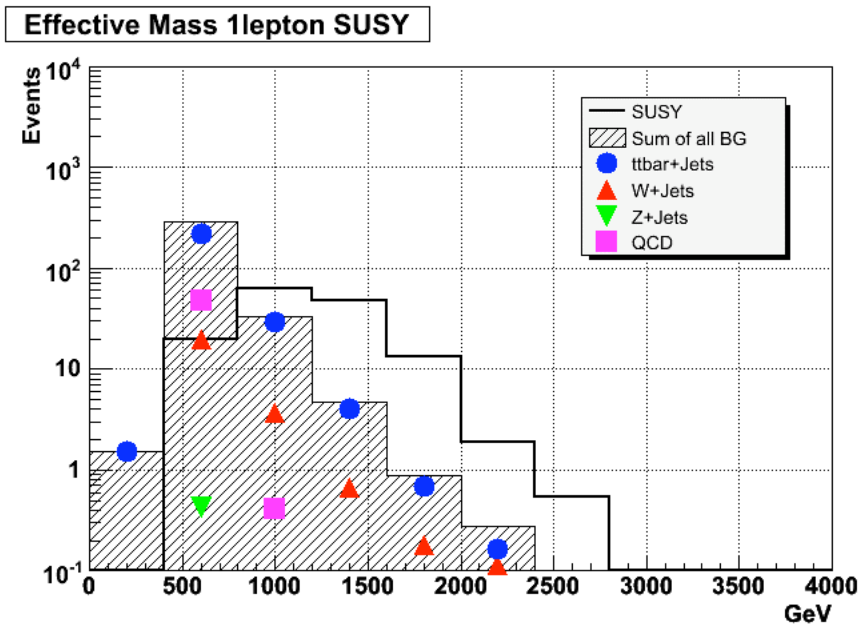
One lepton mode gives clear discovery for SUSY as you can see the lower plot: Open hist shows 1TeV SUSY signal, and hatched shows sum of the BG processes. Luminosity is assumed just 1fb^{-1}

Top and W are dominant background processes:

especially tt-> lnlnbb (one lepton missing) 77% tt->taunuqqbb (13%)
W->taunu 10% after MT > 100GeV

-> dilepton (one lepton missing) is important after MT > 100GeV.

Reference sample: W,tt -> one lepton (MT<100GeV)



Effective mass (GeV)

Short summary of Status:

Control sample	Estimated samples	status
W/top mixed One lepton MT<100	W/top mixed MT>100GeV	OK within factor 2 but Accidentally ?
W (MT<80 & small jet Multiplicity)	W -> (MT>80 & Njet>=4)	OK but using MC shape Systematic errors
tt->bblnln tag	tt->bblnln MT>100	4 methods are proposed efficiency is low
tt sample but M(top) or HT is used instead of MT	tt MT>100	In progress
tt ->bblnqq	Resimulated decay of W tt->bblnln	Just start

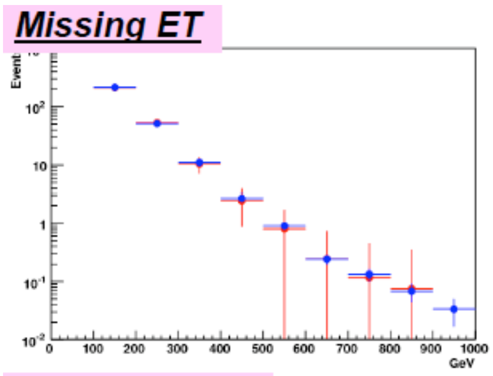
Method 1 (simple method)

Reference sample: W/tt(->one lepton)+Njets: MT<100GeV

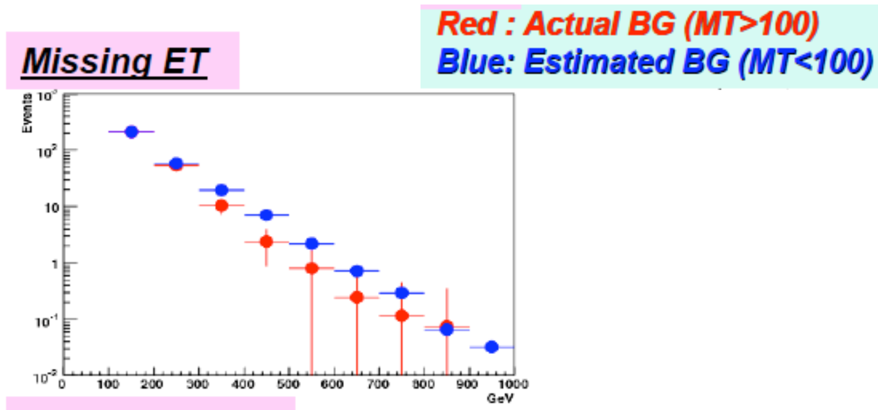
Simply estimated from MT<100GeV to MT>100GeV
Distribution MT<100GeV is just normalized for MT>100GeV
(No seriously large difference was observed on di-lepton and single-lepton in top)
BG can be estimated within factor 2 even if there is SUSY signal.
(Fast and Full study has been done)

http://indico.cern.ch/getFile.py/access?contribId=9&resId=0&materialId=slides&confId=5269
http://indico.cern.ch/getFile.py/access?contribId=5&resId=1&materialId=1&confId=4291
http://indico.cern.ch/getFile.py/access?contribId=5&resId=0&materialId=slides&confId=4291

Some cancellation does work, so If the cross-section of W quite differs, results will be affected. (systematic error)
Problem of this method is pointed in
http://indico.cern.ch/getFile.py/access?contribId=7&resId=0&materialId=slides&confId=5269



Without signal



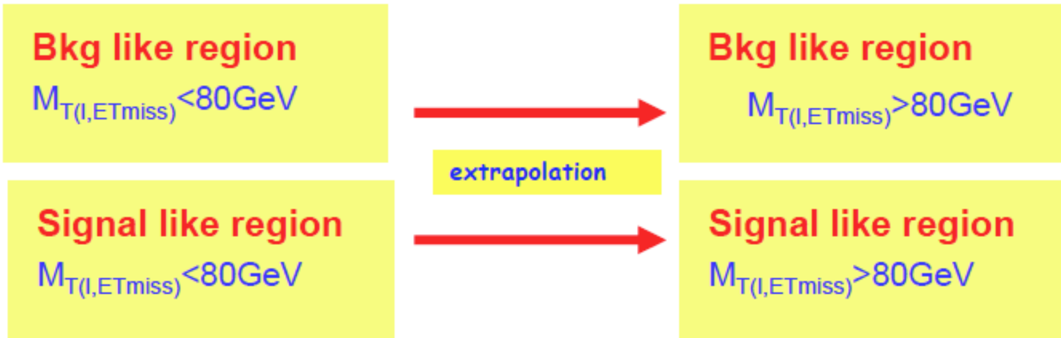
With SU3 signal

Method 2 (extraction method)

Reference sample: W+Njets: MT<100GeV:

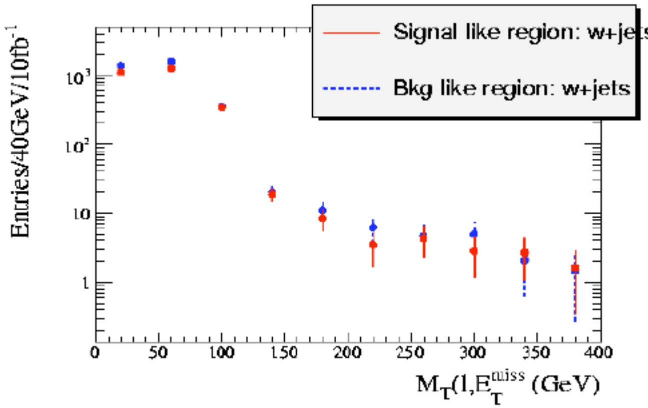
http://indico.cern.ch/getFile.py/access?contribId=1&resId=1&materialId=slides&confId=4291
http://indico.cern.ch/getFile.py/access?contribId=2&resId=0&materialId=slides&confId=6829

- Bkg like region:
  - events fail Signal like region cut.
  - N_{jets} : less than 3.
  - $P_{Tjet1} + P_{Tjet2} > 300GeV$.
- Signal like region:
  - at least 2jets: $P_{Tjet} > 100GeV$
  - at least 4jets: $P_{Tjet} > 50GeV$



Extrapolation formula:

$$N^{SL}_{M_T>80GeV} = N^{SL}_{M_T<80GeV} * \frac{N^{BL}_{M_T>80GeV}}{N^{BL}_{M_T<80GeV}}$$



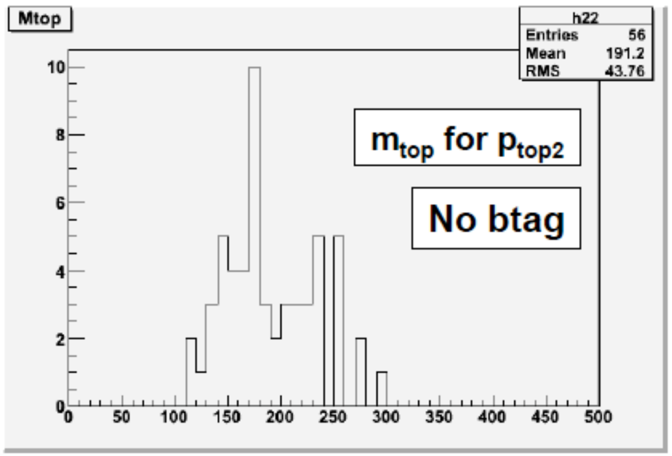
MT distributions in signal- and background like regions are very similar.

Problem: contribution from tt and signal?

Method 3 (Tag di-lepton)

Top with MT>100GeV is dominated from (tt->bblnln)
One lepton is missing. This is reconstructed by additional cut:

(2a) 2nd Lepton finder method (with loose condition)
http://indico.cern.ch/getFile.py/access?contribId=3&resId=1&materialId=slides&confId=6137
(2b) 2nd Lepton finder method (with isolated track search)
http://indico.cern.ch/getFile.py/access?contribId=11&resId=0&materialId=slides&confId=6137
(2b) kinematic reconstruction
http://indico.cern.ch/getFile.py/access?contribId=4&resId=1&materialId=slides&confId=6137
(2d) lnqq kinematic reconstruction
http://indico.cern.ch/getFile.py/access?contribId=11&resId=0&materialId=slides&confId=6137



Problem:
Very good approach but problem of these methods is that efficiency is still low.
We need more improvement of the method:

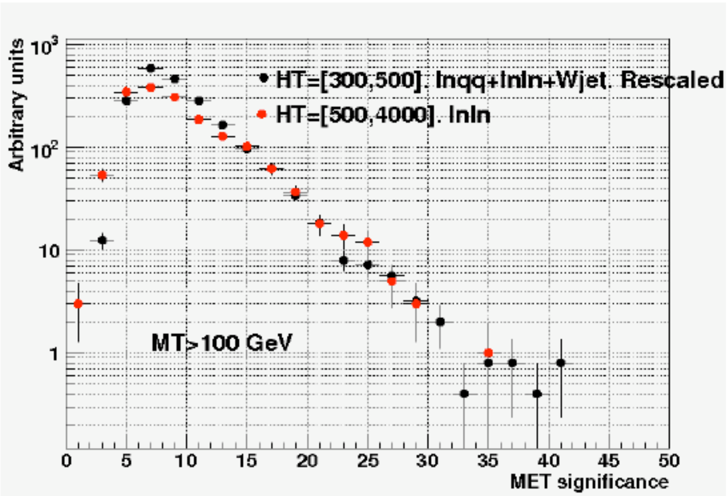
Reconstructed top mass

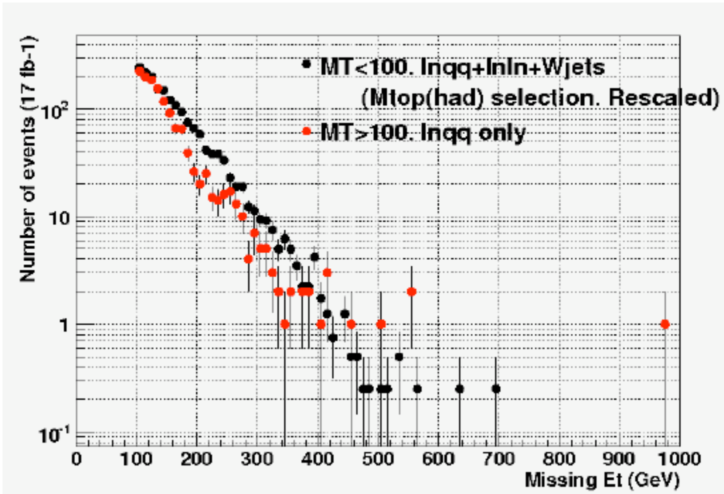
Method 4 (HT or Mtop instead of MT)

Problem of MT is that MT is not independent from mET for tt->bblnln mode
(MT is good parameter and independent from mET for semileponic)

New variables are searched instead of MT
HT: http://indico.cern.ch/getFile.py/access?contribId=1&resId=0&materialId=slides&confId=6829

Mtop http://indico.cern.ch/getFile.py/access?contribId=7&resId=0&materialId=slides&confId=5269





In progress fine
but small over estimated

Method 5 (resimulation of w/top decay)

http://indico.cern.ch/getFile.py/access?contribId=5&resId=1&materialId=slides&confId=6829

Philosophy

1. Tag 'seed' events containing Z/W/top
2. Reconstruct 4-momentum of τ/Z/W/top (x2 if e.g. ttbar)
3. Decay/hadronise with e.g. Pythia
4. Simulate decay products with atlfast(here) or fullsim
5. Remove original decay products from seed event
6. Merge new decay products with seed event (inc. ETmiss)
7. Perform standard SUSY analysis on merged event

Just Started:

Conclusion:

The following 5 methods are proposed and on-going to estimate BG for one lepton mode.
(All methods are under progress not yet finalized. Let's try and contribute.)

(Method1) simply renormalizion of MT<100GeV into MT>100GeV: Need more systematic error study

(Method2) Extracted small MT & small Njet to signal region. Need more study with top and signal

(Method3) tt-> bblnln should are tagged. There are 4 good methods: try improve efficiency

(Method4) HT or Mtop is used instead of MT

(Method5) Resimulate decay of W (W->qq to W->lnu)

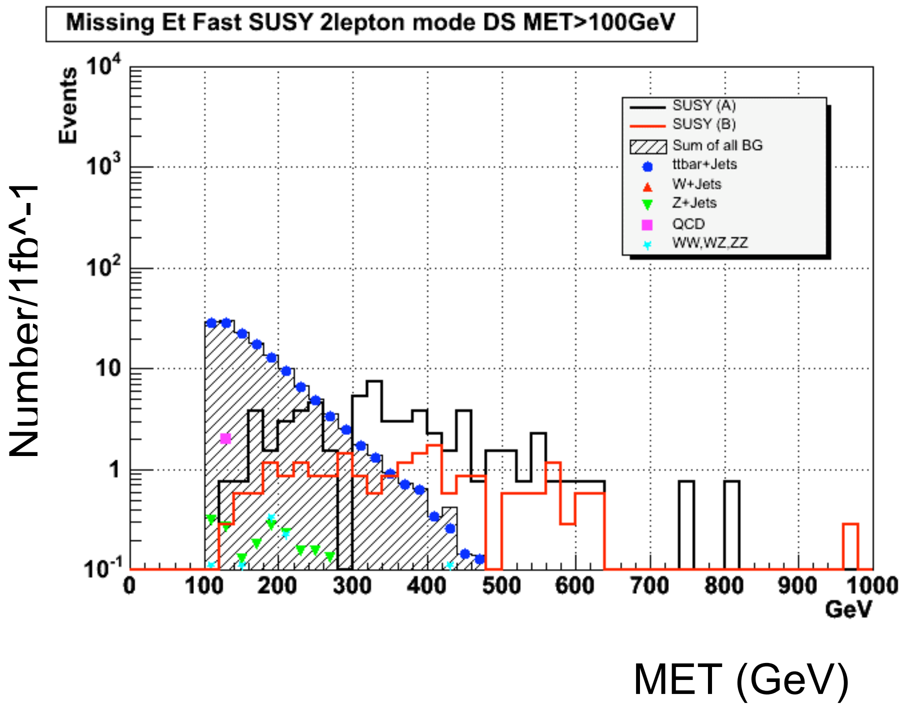
Welcome the other methods:

[3] Short Summary/proposal of the methods to estimate background for "di-lepton mode"

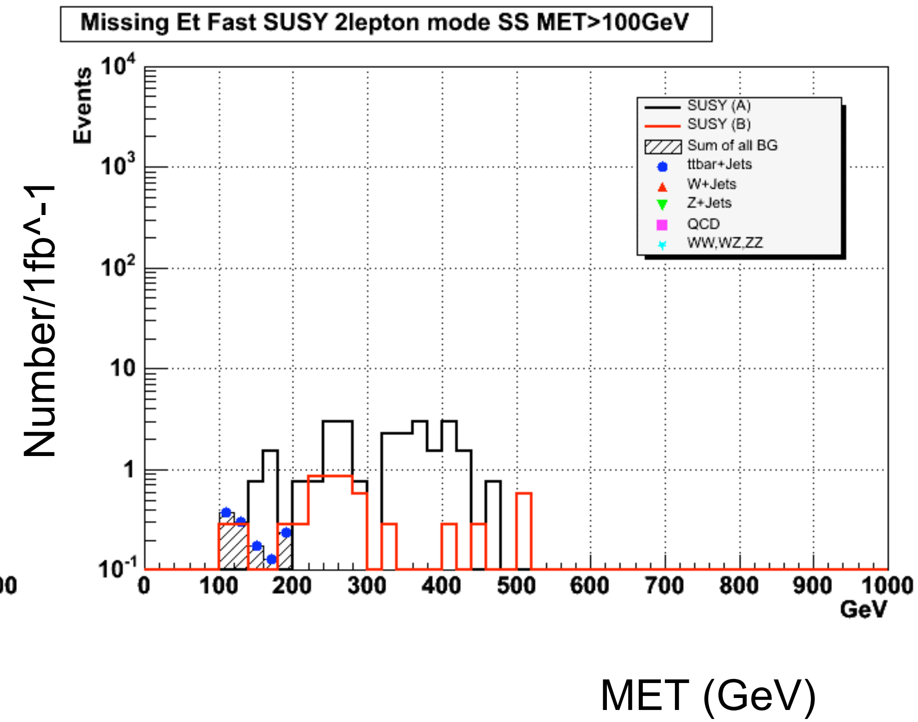
Shoji, Yusuke, Hideki

Dilepton mode is also important and have good potential for discovery

OS dilepton



SS dilepton



SUSY(A) SU1 SUSY(B) SU3 1TeV SUSY

Main BG tt-> bblnln for OS and tt->bblnqq for SS

Method 1 (simple method)

Reference sample: tt(->one lepton MT<100GeV) -> tt (->bb lnln)

http://indico.cern.ch/getFile.py/access?contribId=4&resId=0&materialId=slides&confId=6829