SUSY Inclusive Study & Discovery Potential

Mar.28-29, 2008. LHC kenkyukai @ U of Tokyo/ICEPP

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SUSY CSC Note

ATLAS CSC note will be published in June.

SUSY-1+SUSY-2: Data-driven estimations of Z/W and top backgrounds (20') (Latest version of short note; Long version; Short(er) version)

SUSY-3: Estimation of QCD backgrounds to searches for Supersymmetry with Monte Carlo and data-driven techniques (20') (INT; PUB)

SUSY-5: Searches and inclusive studies for SUSY events (20') (Long version; Short version)

SUSY-6: Exclusive measurements for SUSY events (20') (Paper)

SUSY-7: Gaugino direct productions (20') (Paper)

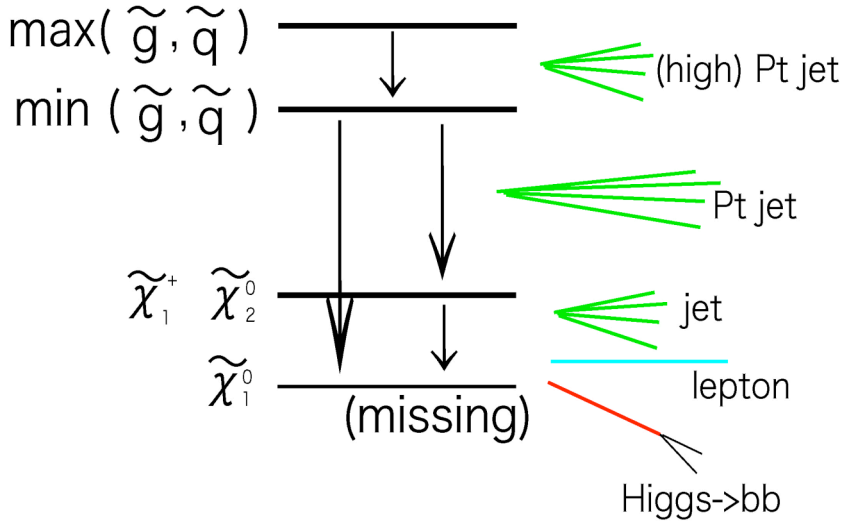
SUSY-8: Studies of SUSY signatures with high-pT photons or long-lived heavy particles in ATLAS (20') (Paper)

- Show performance (significance) with various selections (N-jet, tau, b-jet, SS and 3-lepton) for some SUSY samples.
- Cut optimization and discovery reach for some SUSY models (mSUGRA, NUHM, mAMSB and GMSB etc)

SUSY5(inclusive studies)のアトラス公式結果はCSCノートを見てください。

SUSY signature @ LHC

Search for signatures of R-parity conserving SUSY associated with neutral LSP.



Signatures @ LHC
cascade decay from squark gluino productions yields

Multi-jet with missingE_T (MET)

In this talk, the performance and our current knowledge of inclusive SUSY searches.

Other SUSY signatures, GMSB -> O.Jinnouchi

Outline

- Inclusive SUSY Analyses
- Trigger and MissingET
- Discovery Potential @ ATLAS
- Summary and Outlook

Inclusive SUSY Analysis -1

Selection should :

- *gives good significance*
- *robust to SUSY models and systematic errors for discovery (not for measurement)*
- *easy to control at the point of systematic uncertainties including background prediction.*

Our bench mark analysis is so-called 4-jet analysis:

4-jet + n-lepton + MissingET

Understand 4-jet analysis (performance and systematic uncertainties) rather than further optimization.

Inclusive SUSY Analysis -2

- 4-jet selection (for multi-jet + MET)
  - *N_{JET}>3 : p_T^{1st}>100GeV, p_T^{4th}>50GeV and $|\eta|$<2.5*
  - *MET>100GeV*
  - *MET>0.2*Meff (Meff=$\Sigma|p_T|$ + MET)*
  - *S_T>0.2*
- Additional cut for better S/B

•0-lepton	$\Delta\phi(jet_i\text{-MET})>0.2$ (i=0..2)
•1-lepton	m_T(l-MET)>100GeV, $p_T^{e,\mu}$>20GeV
•2-lepton(OS)	OS (opposite sign), $p_T^{e,\mu}$>20GeV, 10GeV

- Background component (Alpgen prediction)

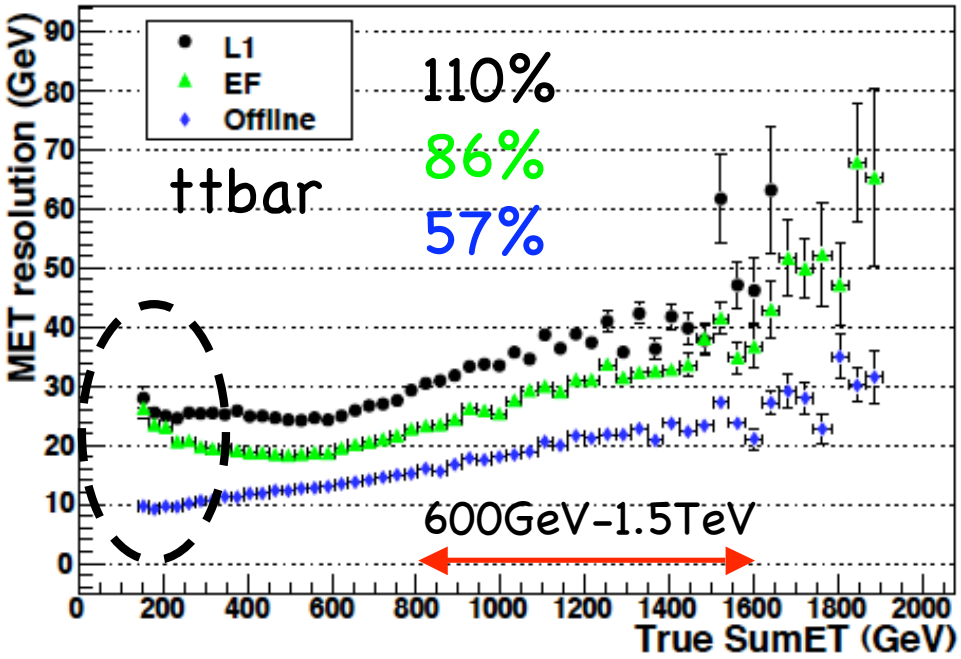
•0-lepton	ttbar(57%) , W(21%), Z(10%), QCD(12%)
•1-lepton	ttbar(94%), W(5%)
•2-lepton(OS)	ttbar(98%), W(1%)

Trigger -1

MissingET and Jet trigger are important for SUSY.
Jet will be more reliable especially at the early stage.

L1 granulality : towers = 0.2x0.2 (0.4x0.4 for FWD)
L1 noise suppression : 0.5-0.75 GeV

L2 : is similar to L1.
EF : cell base,
0-th order calibration
(no muon)



Trigger -2

Trigger menu is not fixed yet for early run.

WMAP allowed region in mSUGRA Benchmark Points (m_0, $m_{1/2}$, tanβ)

- SU1(coannihilation) : 70, 350, 10
- SU2(focus) : 3550,300, 10
- SU3(bulk) : 100, 300, 6
- SU4(low) : 200, 160, 10
- SU6(funnel) : 320, 375, 50
- SU8.1(coannihilation) : 210, 360, 40

Example trigger menu (10^{33})

Trigger efficiencies wrt events passing 0-lepton analysis

M_{SUSY}~400GeV

Trigger	SU1	SU2	SU3	SU4	SU6	SU8.1
	4jet 0-lepton					
JETS	44.6	51.0	33.8	7.7	51.7	48.2
XE120	96.9	90.1	94.0	68.8	96.8	97.2
J70_XE70	99.7	98.7	99.5	97.2	99.6	99.7
	4jet 1-lepton					
JETS	41.8	50.5	31.7	8.1	48.4	45.6
XE120	96.6	91.1	93.0	69.5	95.2	96.5
J70_XE70	99.6	99.0	98.9	95.6	98.9	99.1
1LEP (MU20 OR EM25I)	81.2	81.0	79.9	80.3	80.4	79.5

- JETS = J400 | 3J165 | 4J110
- XE=MET trigger

MET

(Details was given by K.Terashi yesterday)

Need to understand performance :

- Resolution
- Scale
- Tail

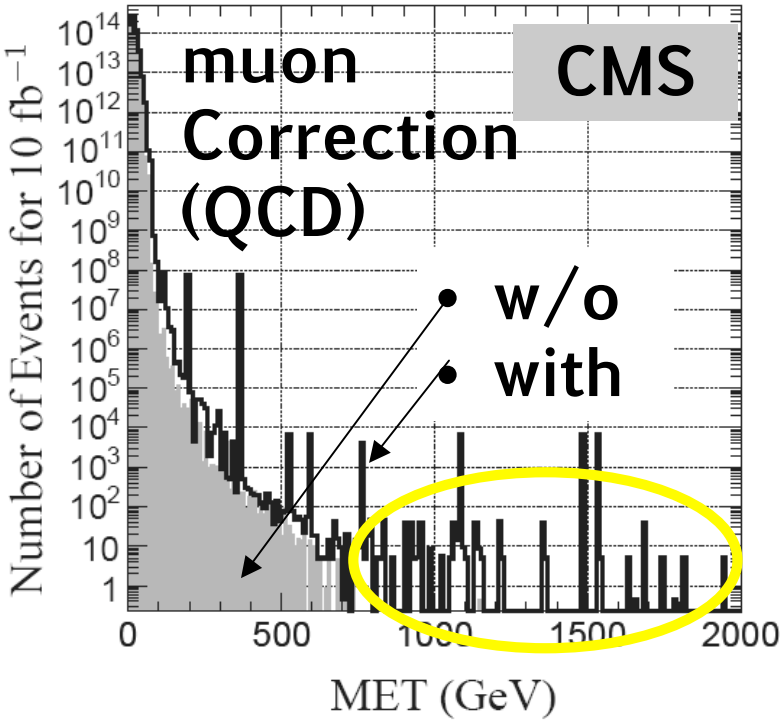
↓ More important for SUSY discovery

Start with simple MET reconstruction : cell-base + muon

Source of tails

- dead/hot cells
- bad run/data quality
- fake/lost muons

No standard muon reconstruction @ η~0 and 1.1



Discovery Potential

A lot of things need to be done before physics analysis and after too...

MC Data Sample

- Background : Full Detector Simulation

  Alpgen+Jimmy MC samples + EF

- SUSY Signal : Fast Simulation + transfer function

next page

Too many parameters (not predictive).
Need some constraints.
Additional theoretical assumption on SUSY breaking.

- mSUGRA (scan m_0-$m_{1/2}$ plane with tanβ=10, A>0 and μ>0)

  Bino LSP,

- mAMSB (scan m_0-$m_{3/2}$ plane with tanβ=10 and μ>0)*

  Wino LSP, $\Delta m = m(x_1^+ - x_1^0) \sim m(\pi^+)$

- NUHM (scan m_0-$m_{1/2}$ plane with tanβ=10, A>0 and μ>0)

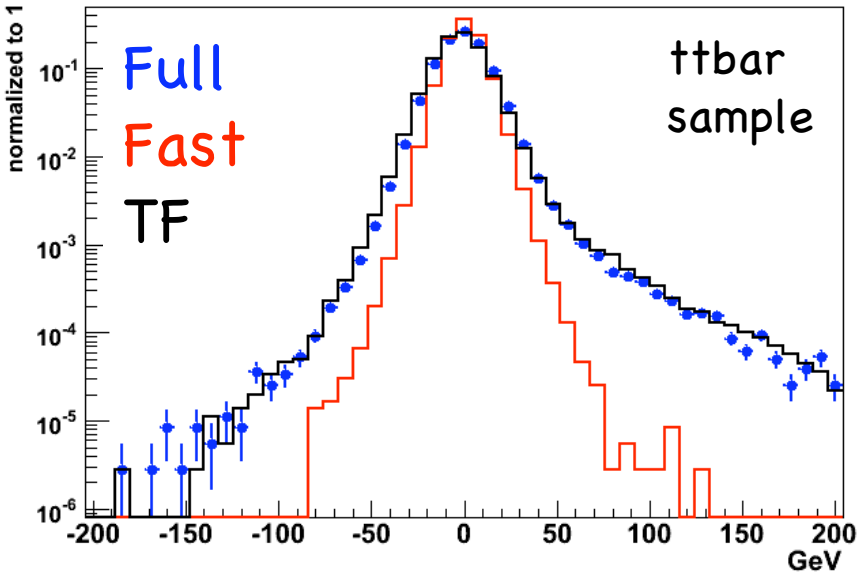
  Bino~Mixed LSP
  Choice of $|\mu|$ and m_A for Ω_{DM}=0.1-0.16, Br(b->sγ)=(2.9-3.5)E-4

Transfer Function (simulation)

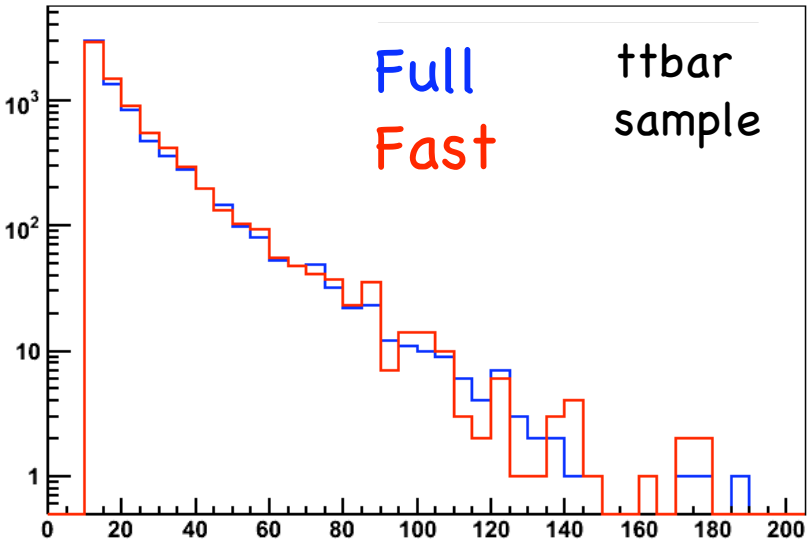
There are many SUSY points in each models.
Not realistic to perform full simulation for all samples.
Parameterised detector response will be enough.
(not useful for complicated analysis, like b-tag)

Transfer Function (TF) -> Jet scale, resolution and lepton eff and fake.

MET resolution



pT of fake lepton



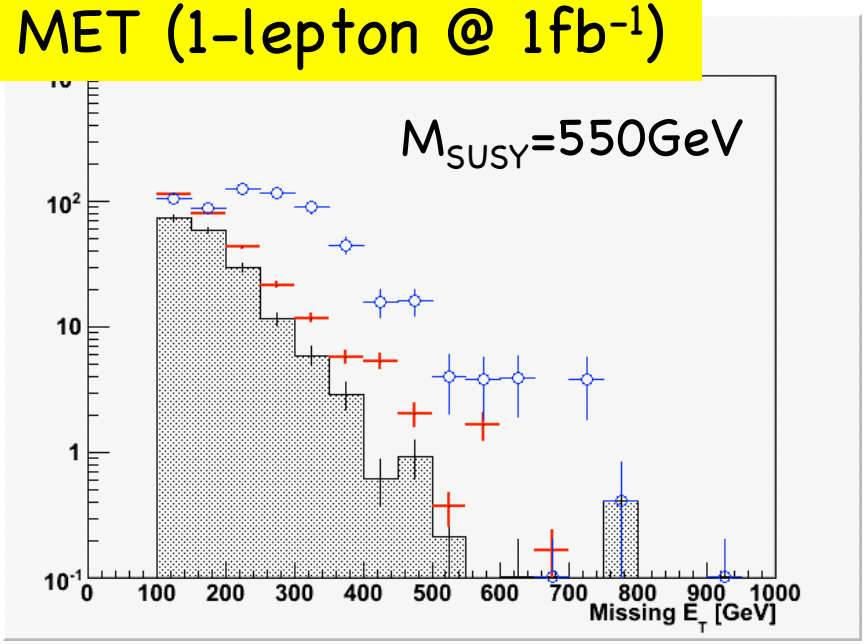
Y. Kataoka, O. Jinnouchi

Background prediction

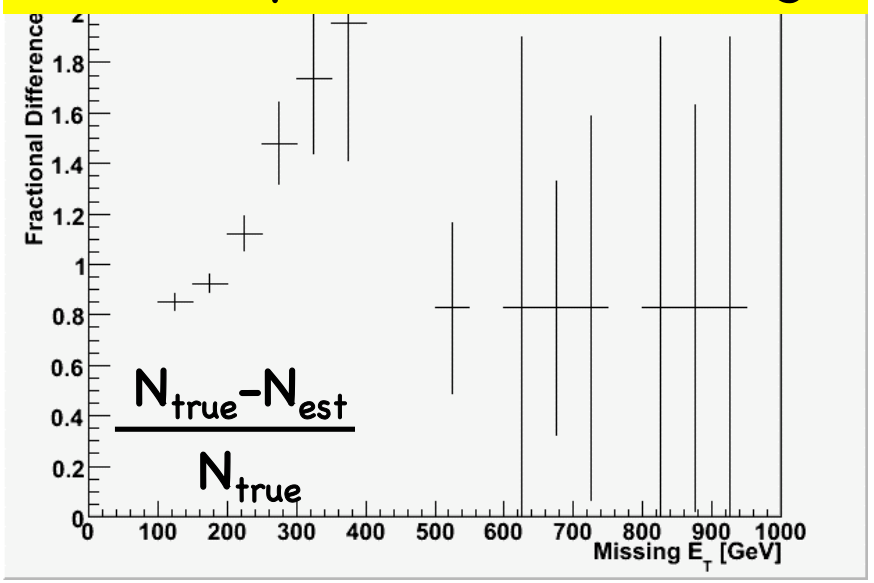
Dominant uncertainties originate in:

- -Fraction of W/top in control/signal sample
- -SUSY contamination
  - In Normalization Region (size)
  - In Control Sample (shape)

MET (1-lepton @ 1fb^{-1})



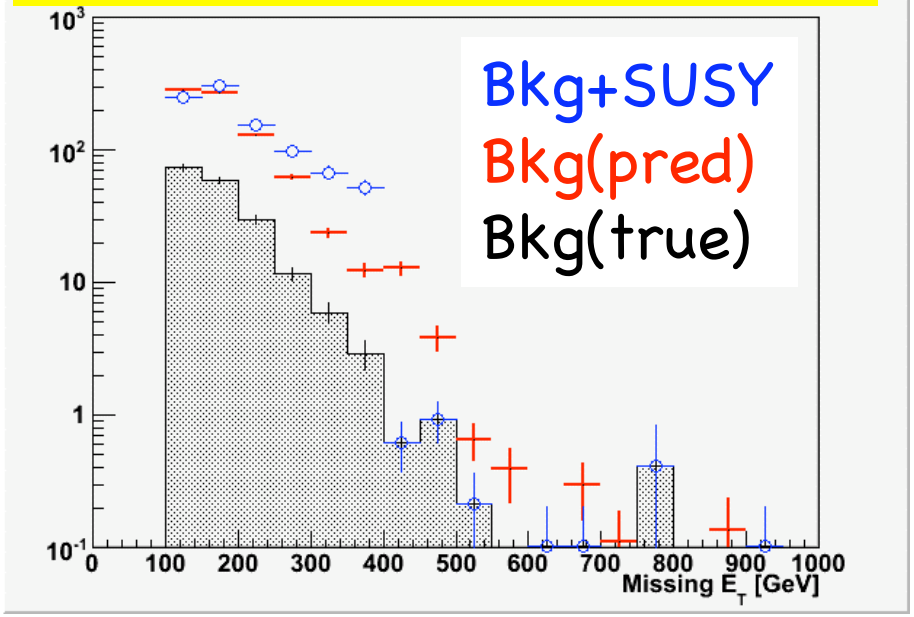
MET shape difference (bkg)



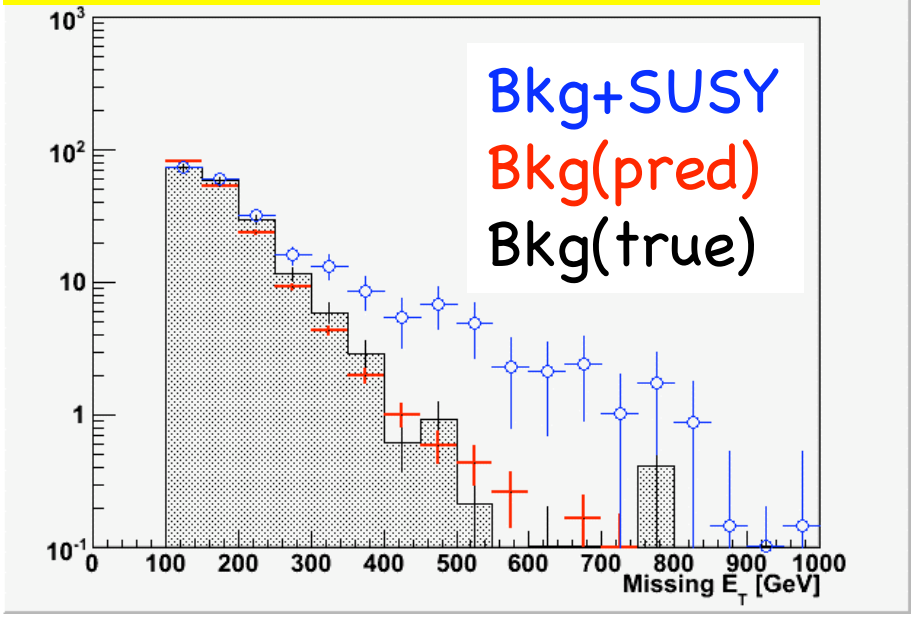
Background prediction -2

Example (mSUGRA with low/high msusy in 1-lepton mode)

Msusy=0.4TeV (m_0=500,$m_{1/2}$=150)



Msusy=1TeV (m_0=400,$m_{1/2}$=450)

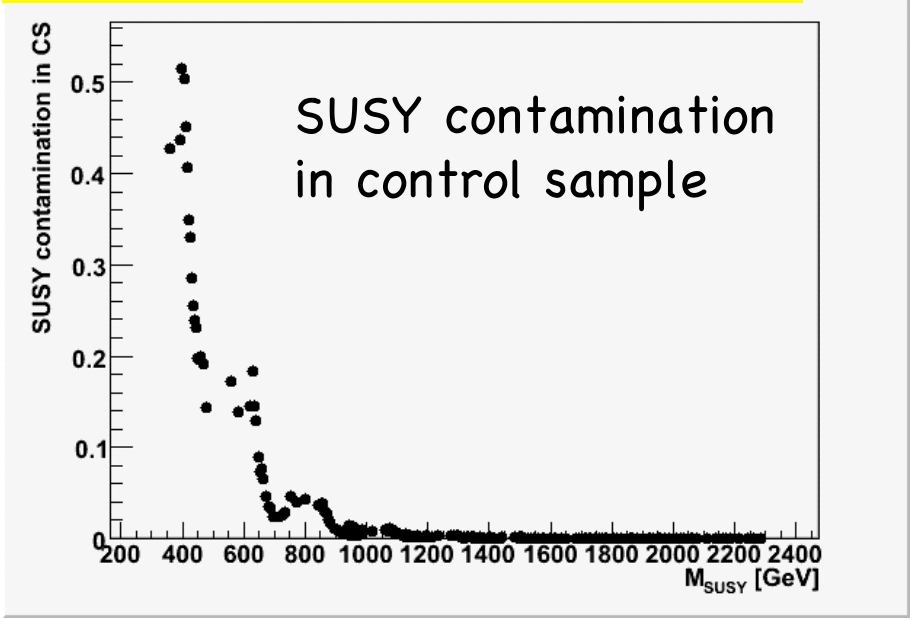


Need subtraction of SUSY contamination, like new MT method for low M_{SUSY} cases.

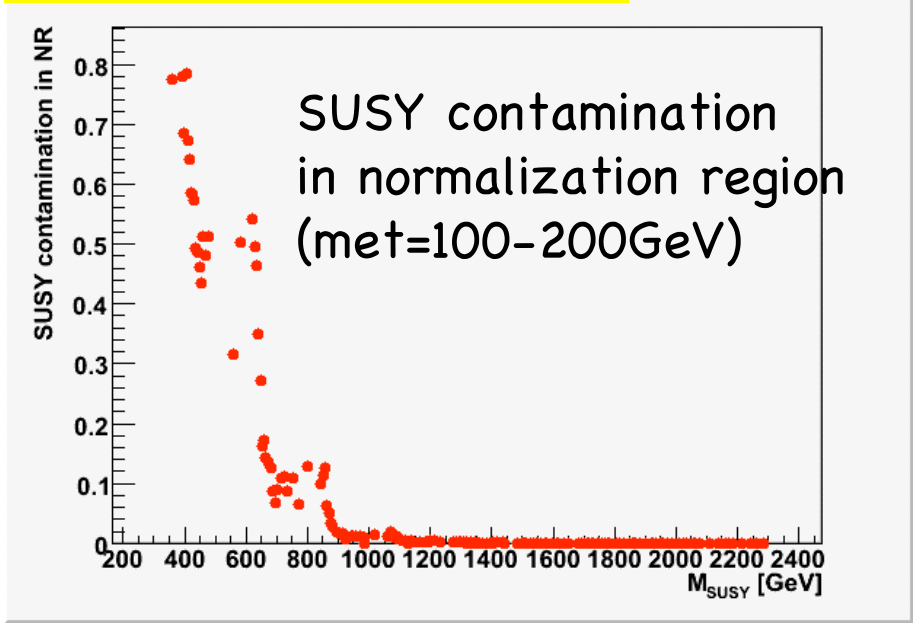
Background prediction -3

SUSY contamination is negligible Msusy>~600GeV...

mSUGRA (Control Sample)



mSUGRA (1-lepton)



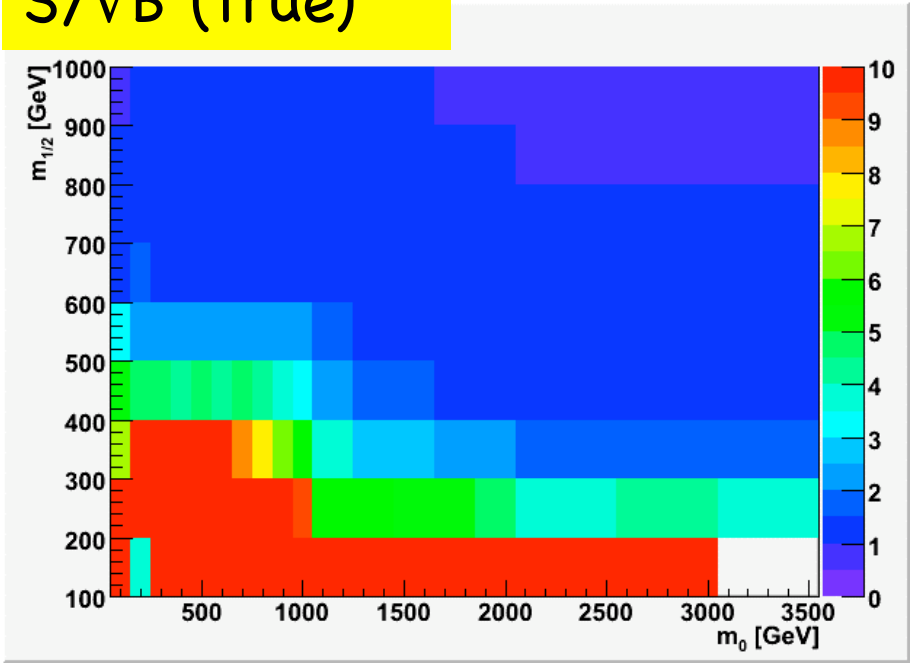
CS : May not problem (depends on shape of MET)

Need subtraction of SUSY contamination and evaluate its uncertainty, like new MT method (G.Akimoto, Y.Kataoka) for low M_{SUSY} cases.

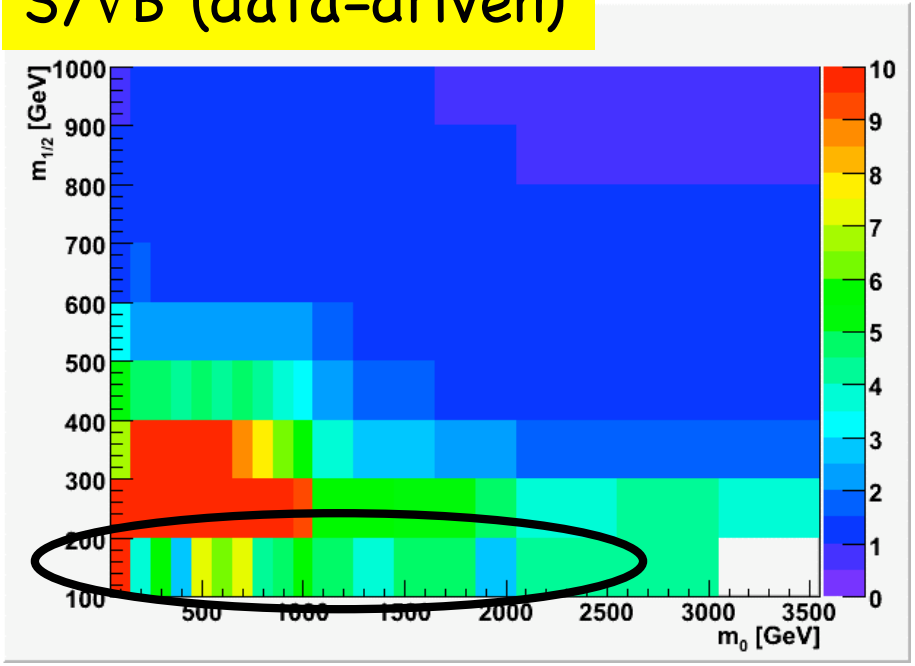
Discovery (ex. 1-lepton mode)

It will be problematic at low M_{SUSY}(<600GeV).
No effect at the point of discovery reach.

S/√B (true)



S/√B (data-driven)



The study is on-going.
Assume the subtraction of SUSY contamination is successfully done for the moment.

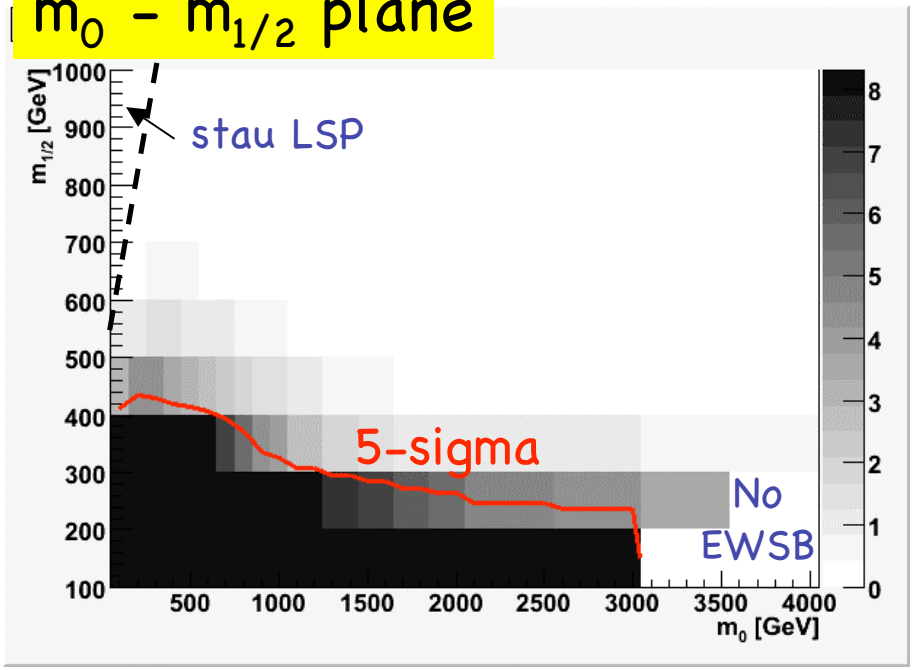
Discovery - 2

Significance Ns (C&H like) : 5σ -> discovery

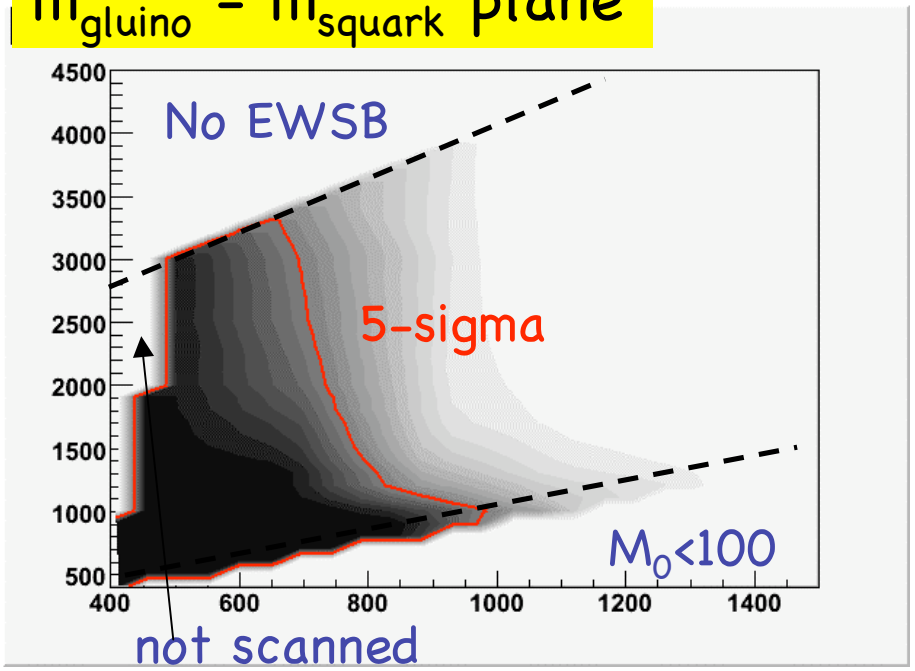
- 30% uncertainties on background prediction.
- background level : believe current MC prediction (true)

Example : mSUGRA 0-lepton (@1fb^{-1})

m_0 - $m_{1/2}$ plane



m_{gluino} - m_{squark} plane

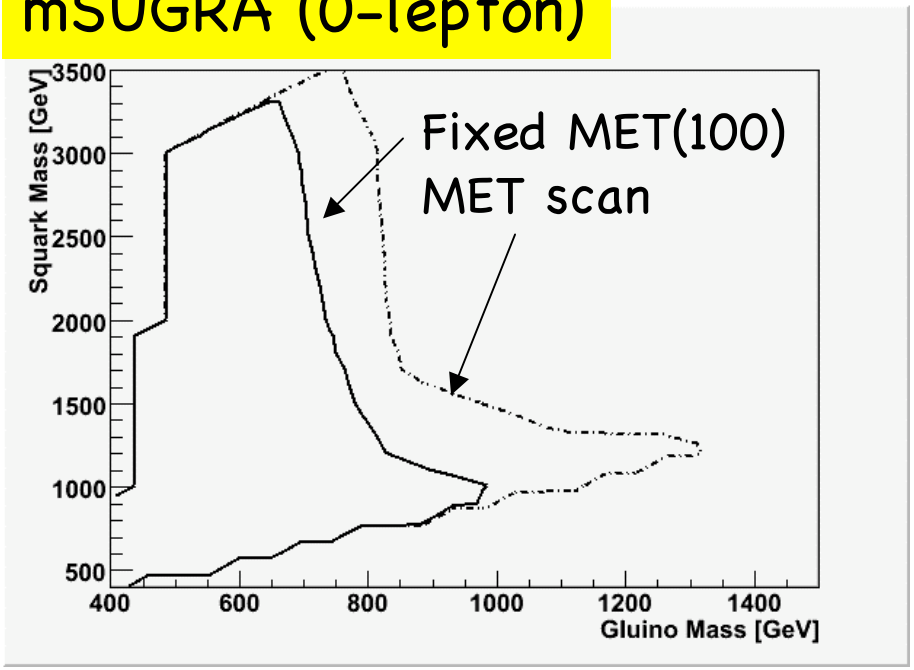


* m_{squark} = average of 4 light flavor squark's masses

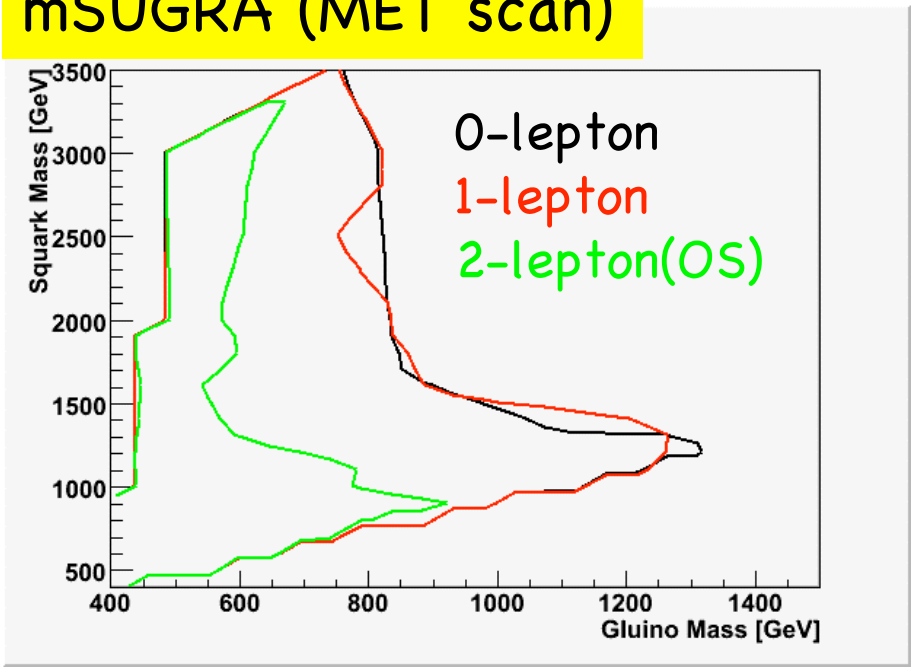
Discovery Reach -1

Discovery reach on m_{gluino}-m_{squark} plane for mSUGRA @ $1fb^{-1}$

mSUGRA (0-lepton)



mSUGRA (MET scan)



* MET scan (MET=100-500GeV)

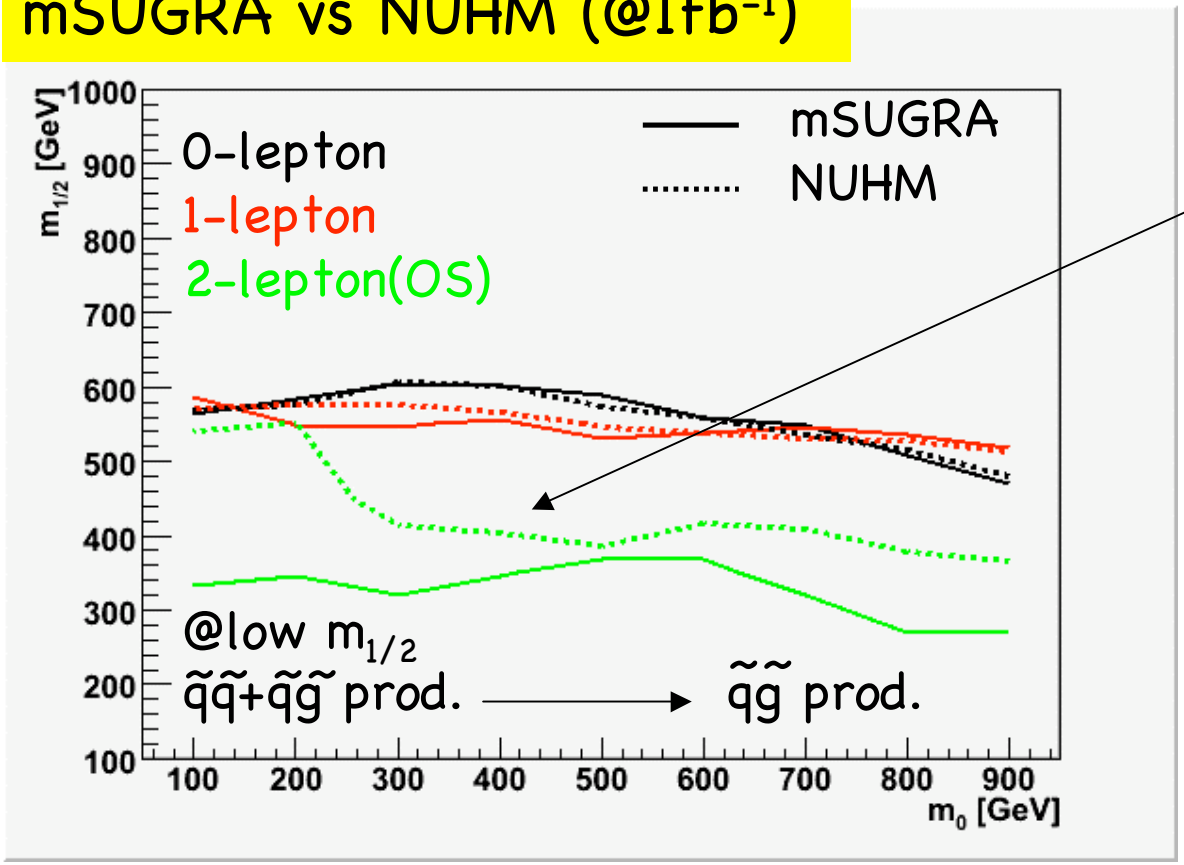
- Optimal MET cut depends on Msusy
- Ns(0-lepton)~Ns(1-lepton) > Ns(2-lepton)

Of course, it depends on SUSY models.

Discovery Reach -2

Not completed, but discovery is strongly determined by Susy mass scale and almost independent of decay.

mSUGRA vs NUHM (@1fb^{-1})



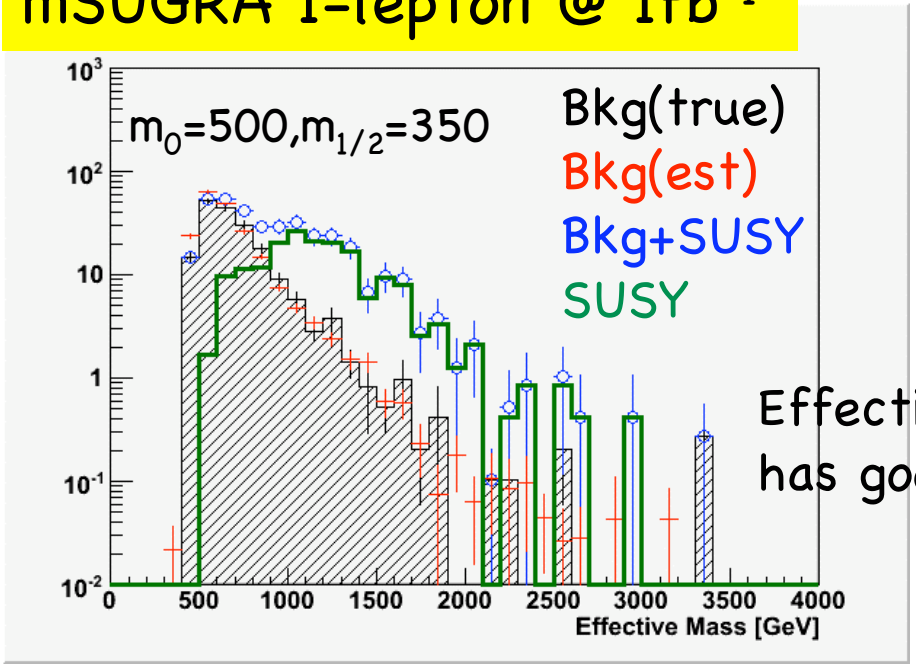
$$\tilde{x}_4^0 \rightarrow \tilde{x}_3^0 Z$$
$$\tilde{x}_2^+ \rightarrow \tilde{x}_1^+ Z$$

Need systematic study for AFTER discovery*

AFTER discovery… (will start..)

What kind of information can be obtained in inclusive analyses?
Or.. Wait for exclusive analysis?

mSUGRA 1-lepton @ 1fb^{-1}

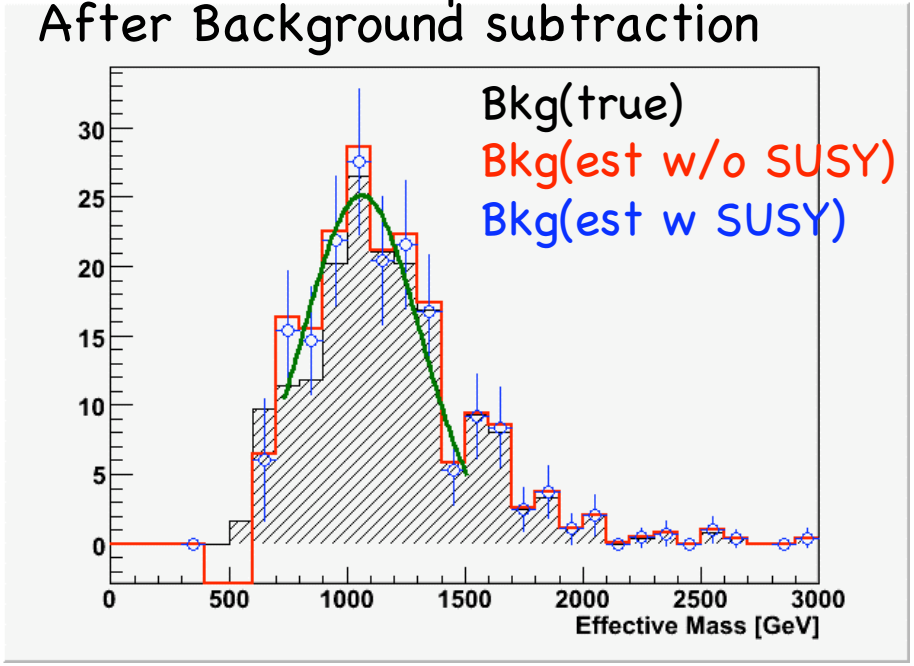


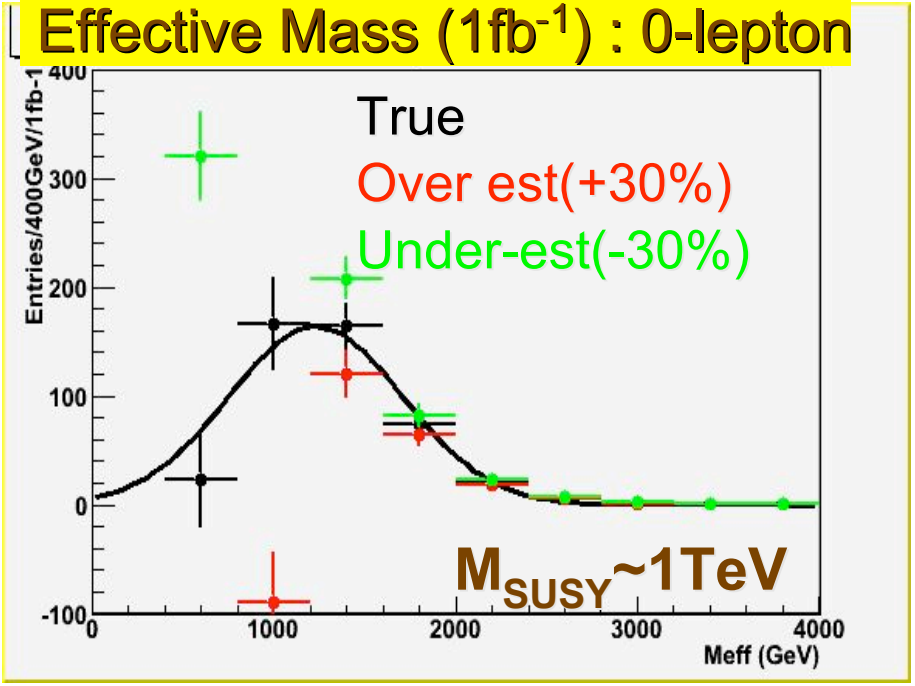
Effective mass (Meff=$\Sigma|p_T^{jet}|$ + MET) peak has good correlation with M_{SUSY}.

- M_{peak} -> SUSY mass scale
- Cross-section -> SUSY mass scale
- B-jet, tau-jet, lepton rich or not…

AFTER discovery…-2

Effective mass peak
After Background subtraction





Cross-section : $N_{obs}*\varepsilon/L$
Efficiency (0-lepton) = 10-20%
Sys(JES=10%) -> $d\varepsilon$=5-8%
Luminosity : 5%

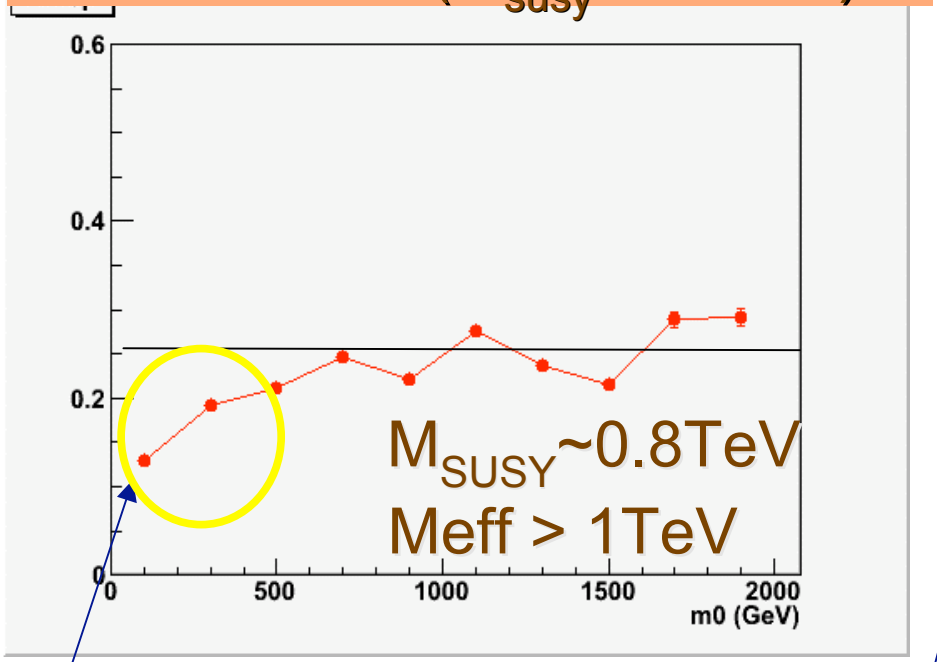
Meff peak + cross-section
--> SUSY mass scale

AFTER discovery…-3

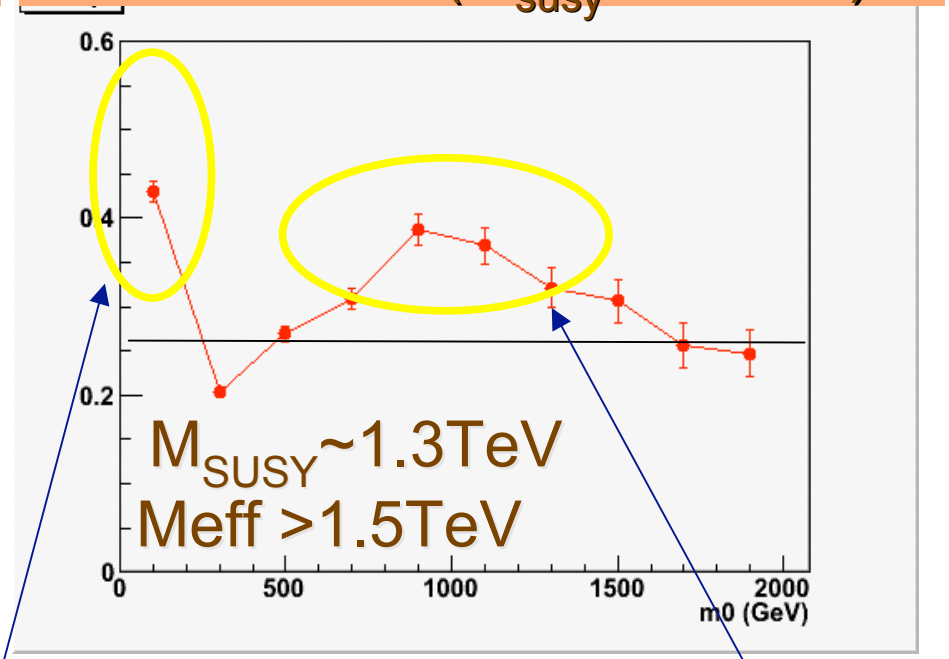
$$\frac{Nf_1\varepsilon\varepsilon_1}{Nf_0\varepsilon\varepsilon_0+Nf_1\varepsilon(1-\varepsilon_1)} = \frac{f_1\varepsilon_1}{f_0\varepsilon_0+f_1(1-\varepsilon_1)}$$

$<R_{lep}^{1/0}>$ (= $N_{(=1)}/N_{(=0)}$)

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



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



Br ($\tilde{q}_R \rightarrow \tilde{\chi}_1^0 + q$)~64%

Br ($\tilde{\chi}_1^+ \rightarrow \tilde{\tau}_1^+ + \nu_\tau$)~63%

Br ($\tilde{q}_L \rightarrow \tilde{\chi}_1^+ + q$)~65%

Br ($\tilde{\chi}_1^+ \rightarrow \tilde{l}_1^+ + \nu_l$)~38%

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

Summary & Outlook

Study SUSY discovery potential with the latest event reconstruction/detector simulation(geometry) considering systematic uncertainties from detector performance and background predictions.

Need to evaluate/subtract/suppress SUSY contamination in control sample and normalization region, especially for low mass SUSY.

Optimize cut/selection not at the point of significance but Understand background and inclusive measurement.

Need to think about AFTER discovery, like Msusy/cross-section measurement in inclusive studies. Important to evaluate systematic uncertainties.