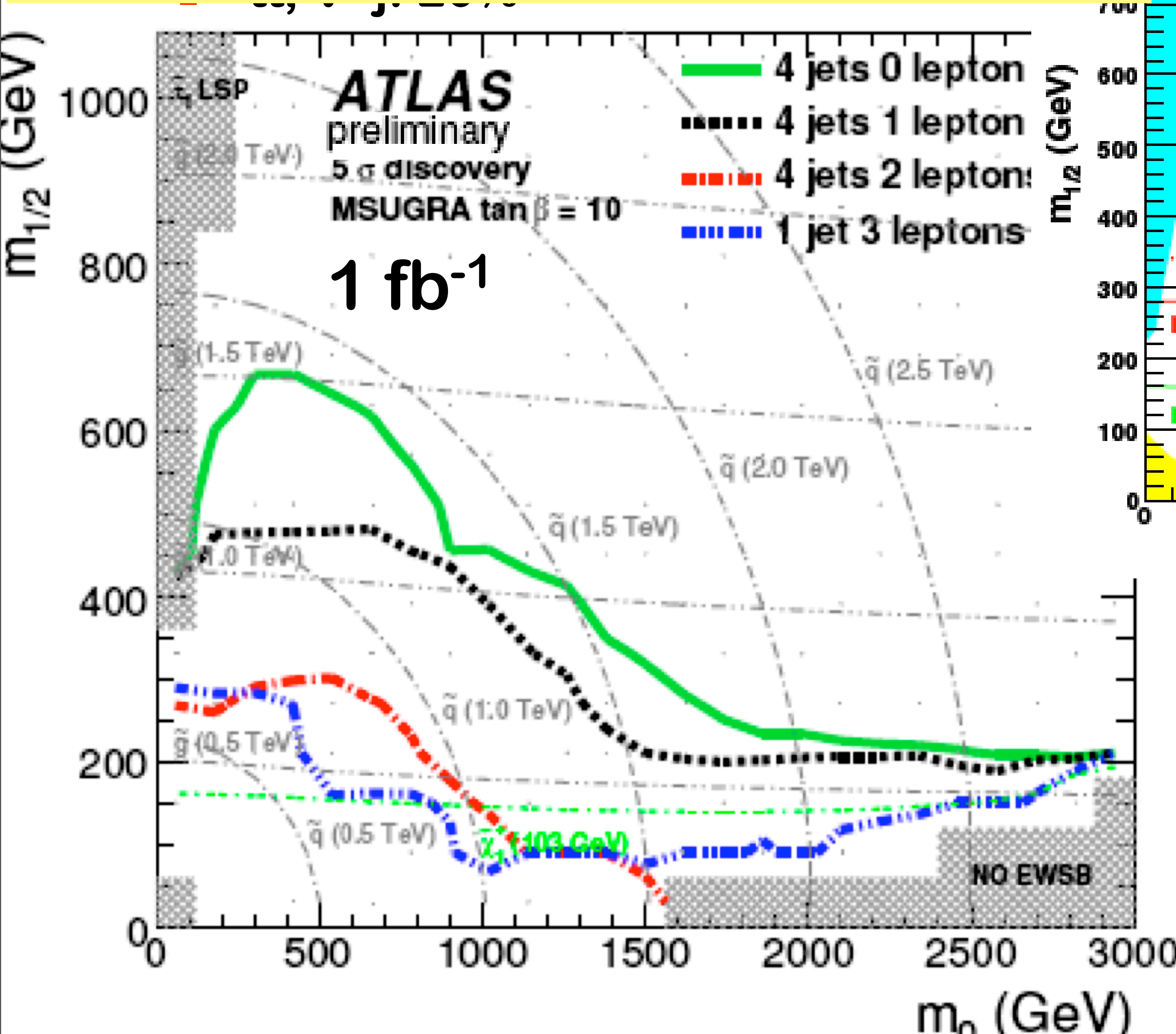
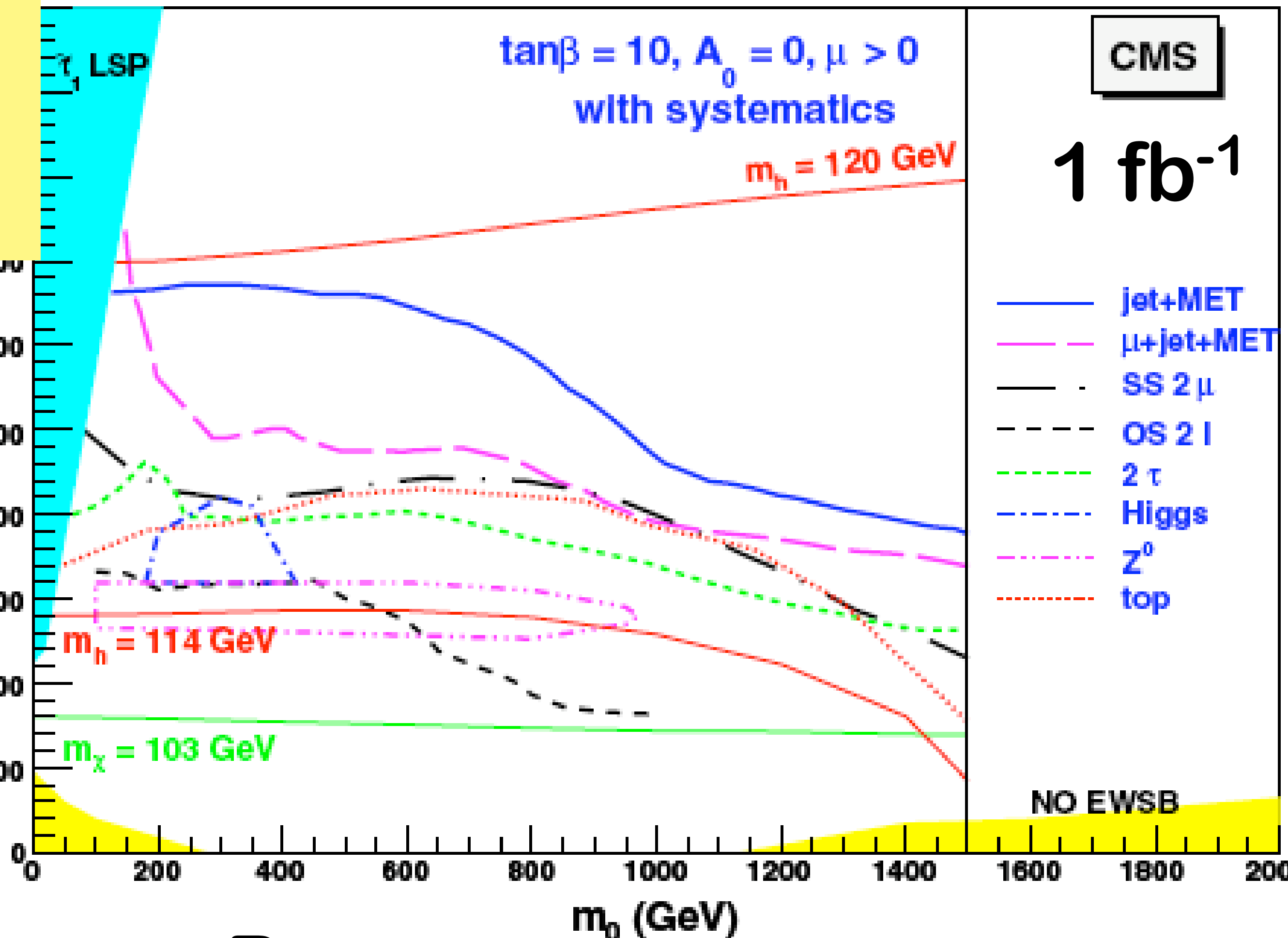
“SUSY” は
どうやって
決まっていくか

mSUGRA reach at ATLAS & CMS (1 fb^{-1})

$A_0 = 0$, $\mu > 0$, $\tan\beta = 10$, 5σ contours (incl. systematics)

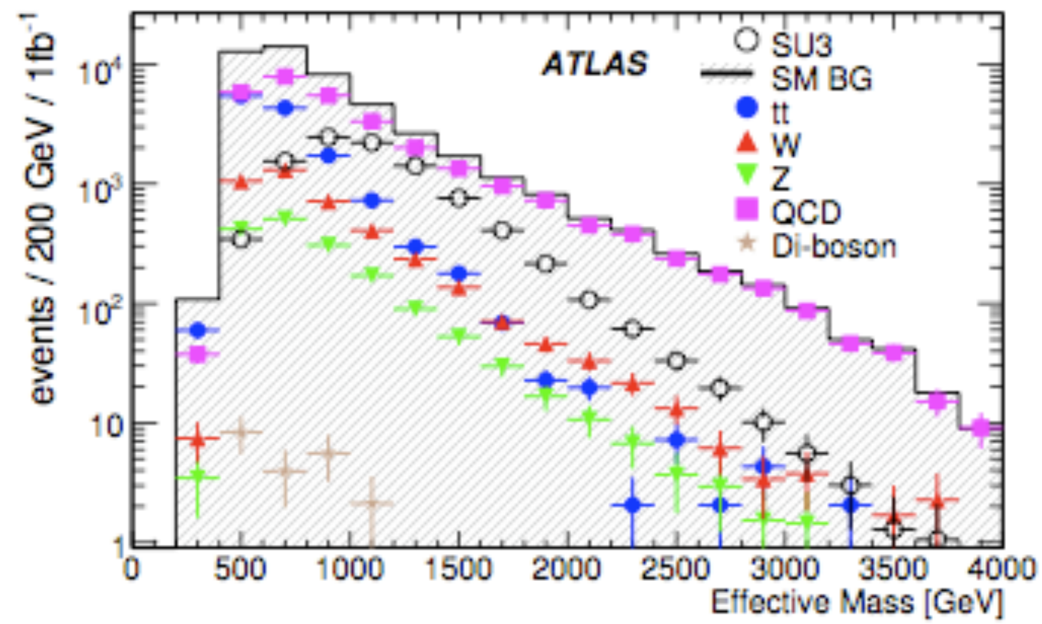
- You can study leptons but the parameter region is rather small



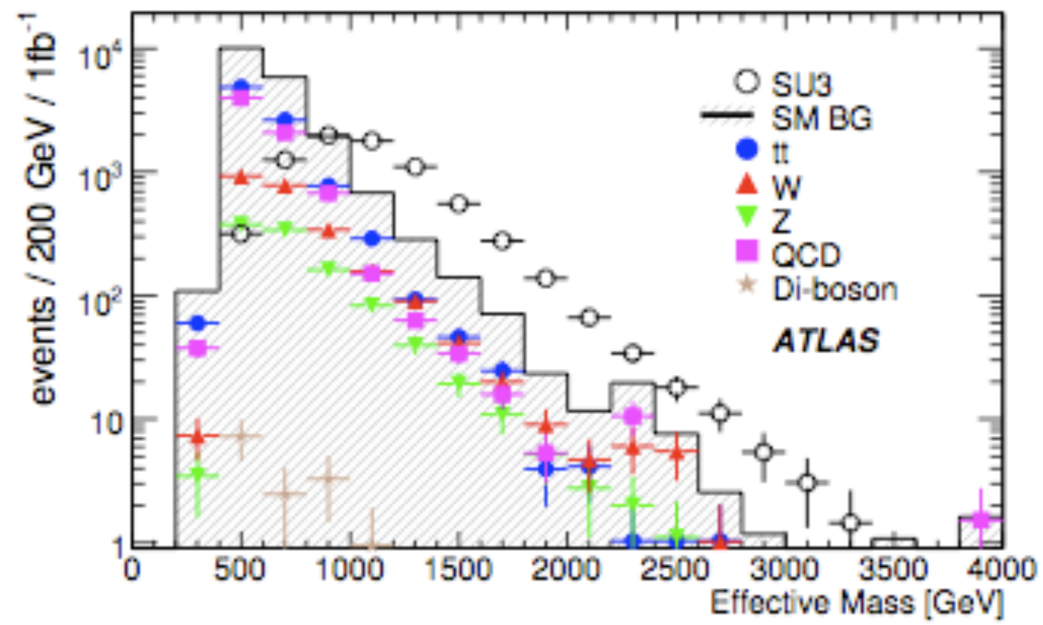


- **Beware:**
  - **Different significance definitions!**
  - **CMS: syst. uncertainties estimated for 10 fb^{-1} (except 0-lepton: 1 fb^{-1})**

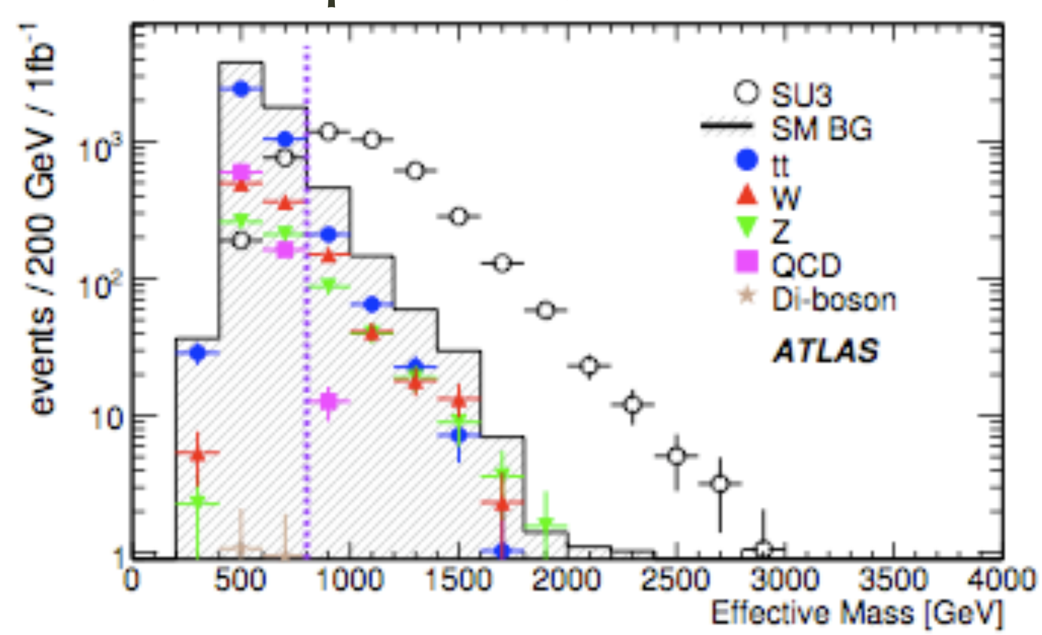
n100.ge.1 n50 ge 4

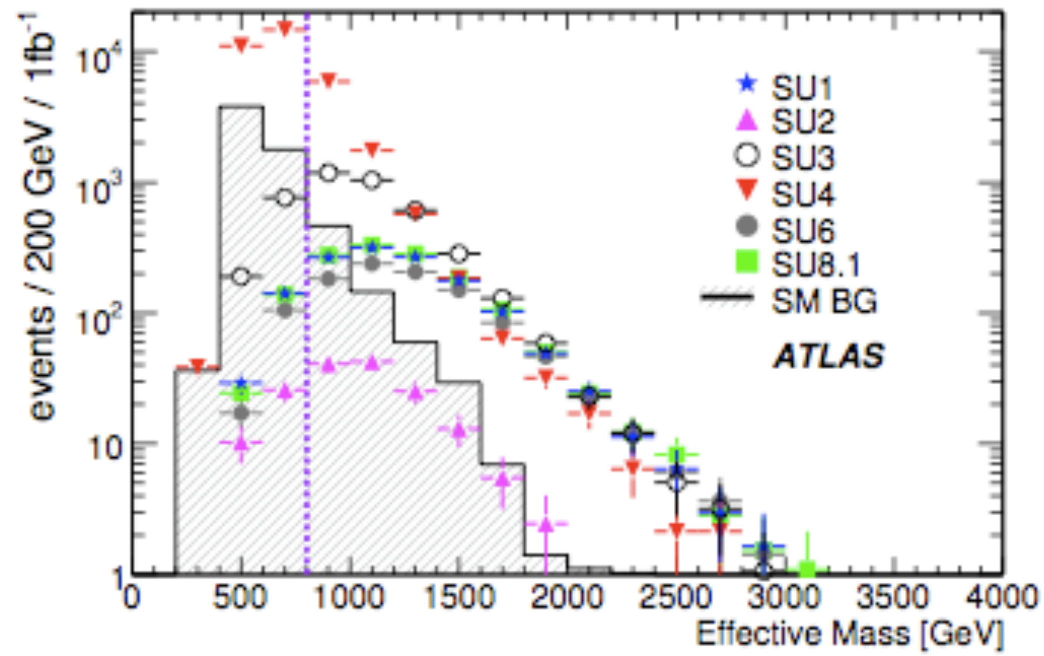


ETmiss>0.2 Meff

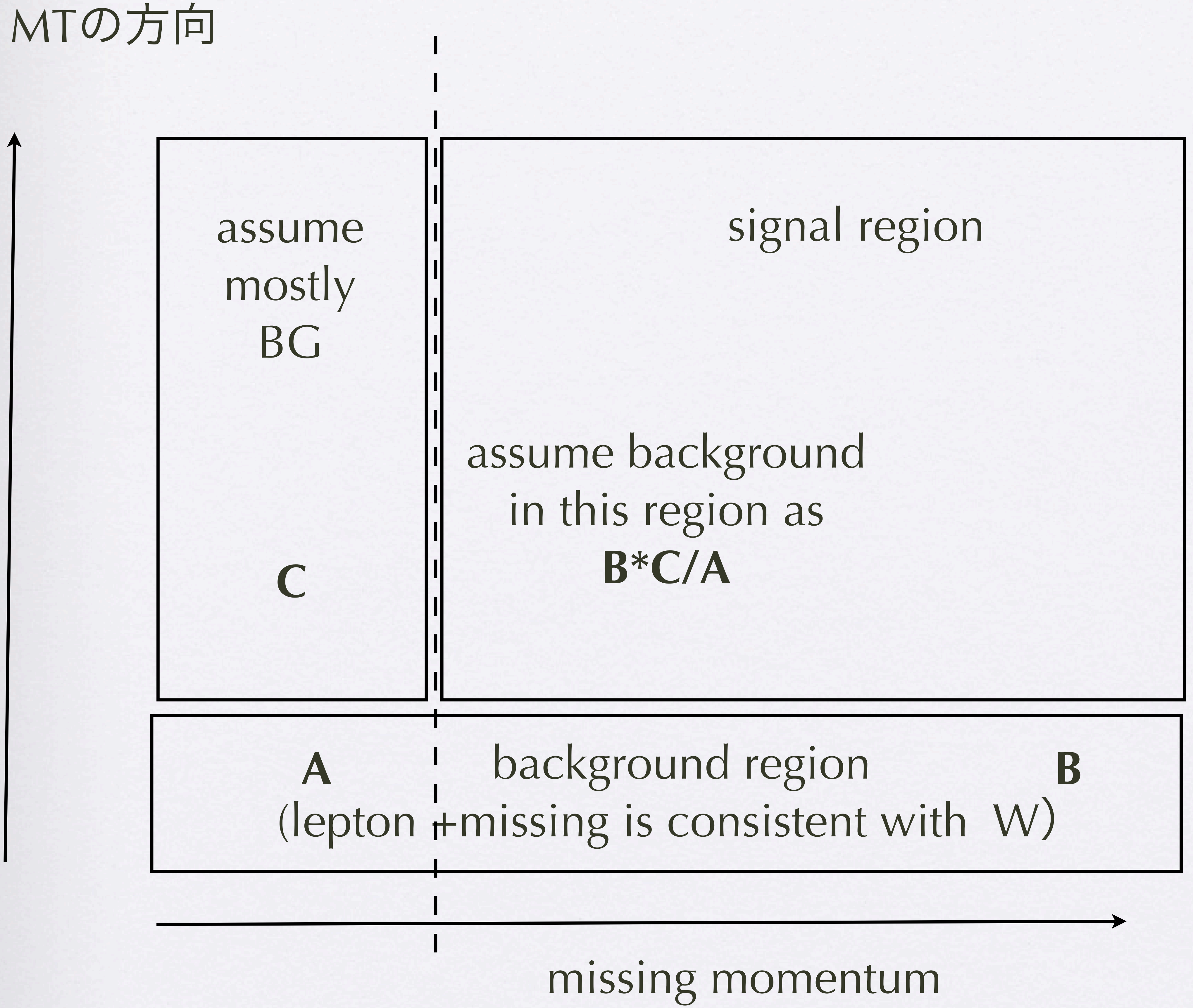


ST>0.2, del phi cut, e mu veto



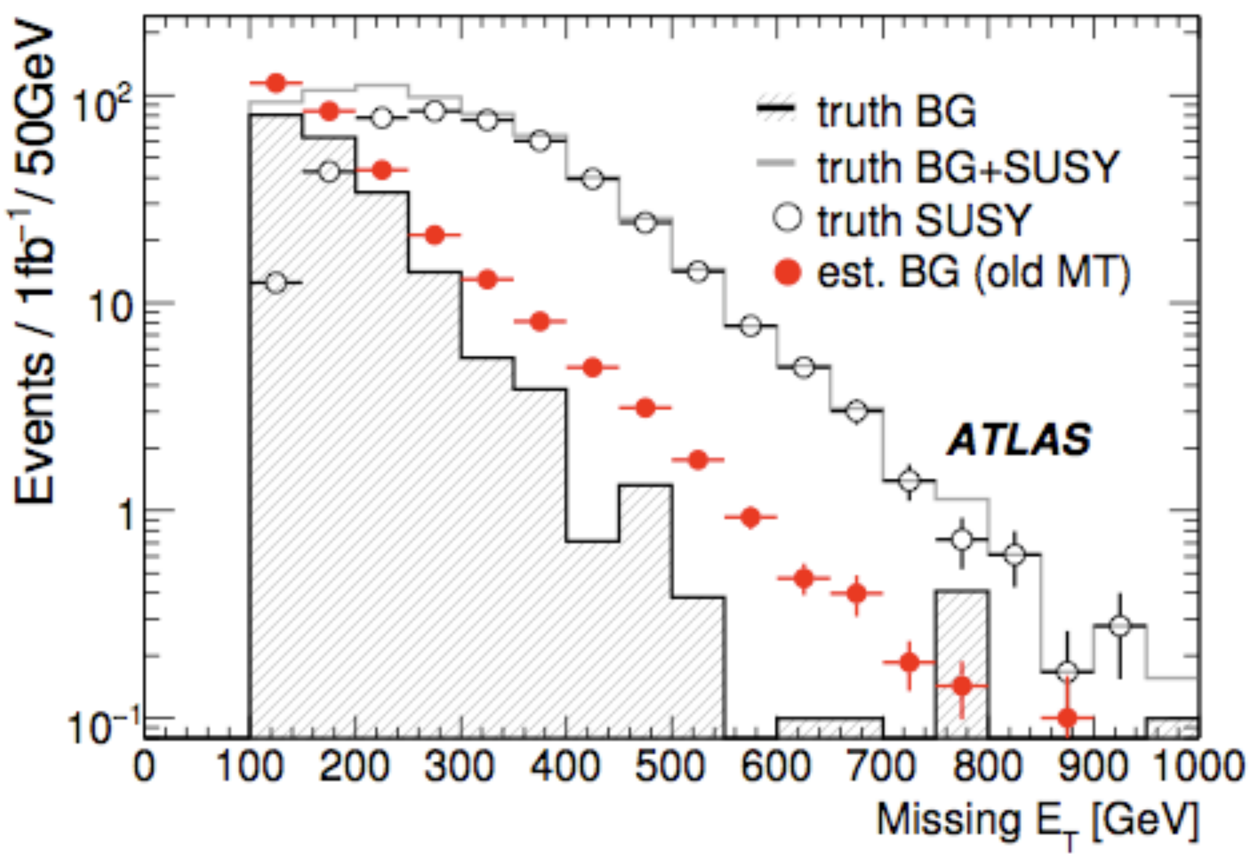


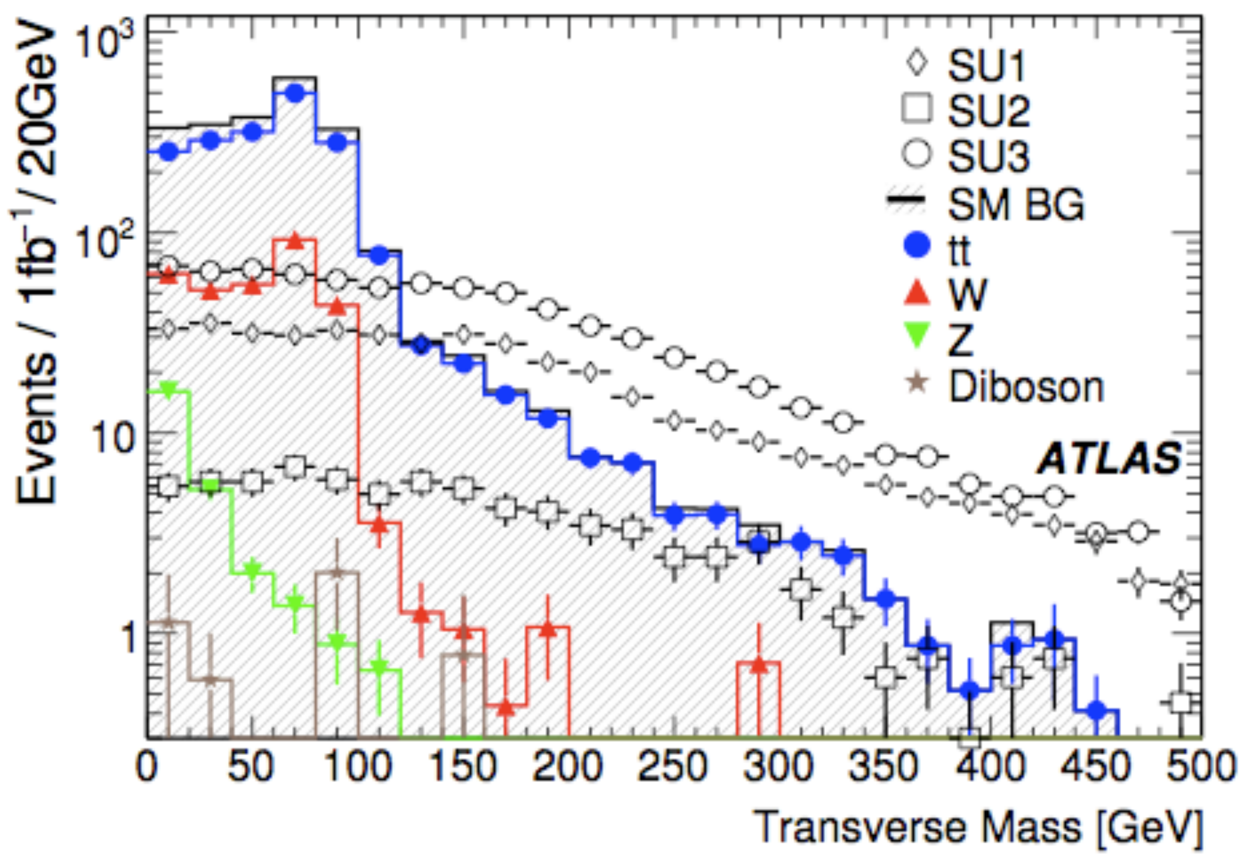
SU3 squarks 630GeV, gluino 717GeV, LSP 117 GeV
SU2 gluino 856 GeV, LSP 103 GeV ass others are heavy
SU4 squark400 GeV, gluino 413, LPS 59, very light stop


MTの方向
assume
mostly
BG
C
signal region
assume background
in this region as
B*C/A
A
background region
B
(lepton +missing is consistent with W)
missing momentum

summary of MT method

*background over estimate.
*correction assuming background does not exact for large mt region.
*ttbar better controled by requiring hadronic top tag.
* need better idea





Inclusive→exclusive

- 初期　BG を実験的に estimate. Signal はBG の残り

- Signal の kinematical structure が background の上にでて初めて、本当になにかが起こっているということがわかる。

- Discovery というのは基本的に exclusive

- (>4j) > (jets+ 1 lepton) > (jets + 2lepton)

- (>4j)<(jets + 1lepton) < (jets + 2lepton)

Jet でできる
ことを探す

M_{T2}

- 見えない運動量+ lepton -> MT 変数　(W の質量をだすのに有効。)
- SUSY events　見えない運動量= 2つの LSP の運動量
- visible object を２つにわけて、仮想LSP運動量とMT をくむ(和は見えない運動量となるようにした)
- ２つのMT の最大値の すべてのLSP 運動量についての最小値
- 新しい Kinematical variable -> 新しい 物理量がだせる。

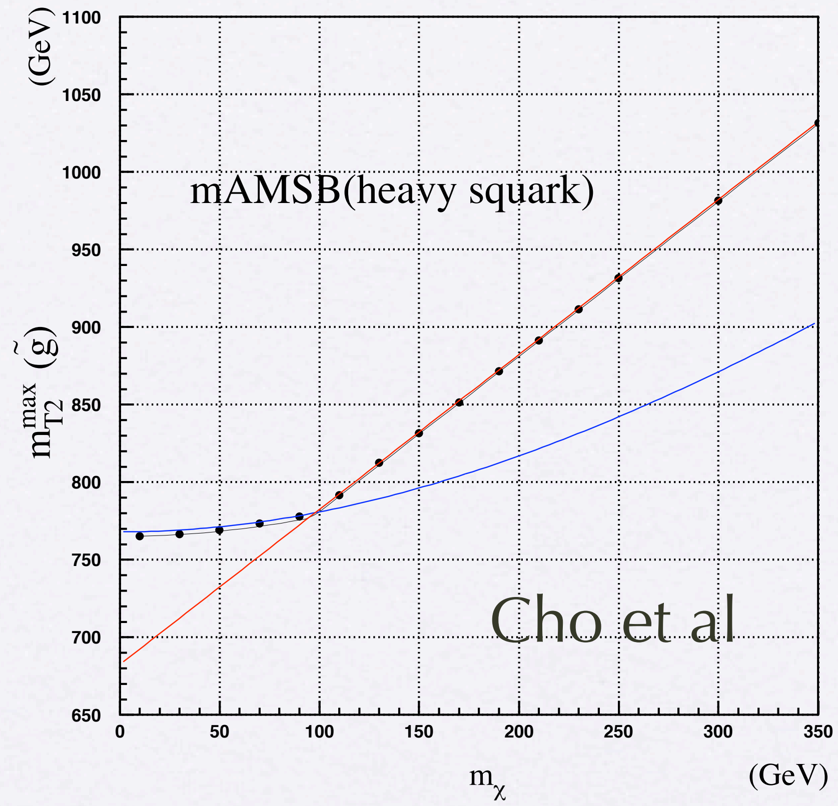
4 jet final state and gluino mass determination

Process

$$pp \to \tilde{g}\tilde{g}$$

$$\tilde{g} \to \tilde{q}^* q \to q\bar{q}\tilde{\chi}_1^0$$

2 cascade decay in both side.



gluino 3 body decay.

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

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

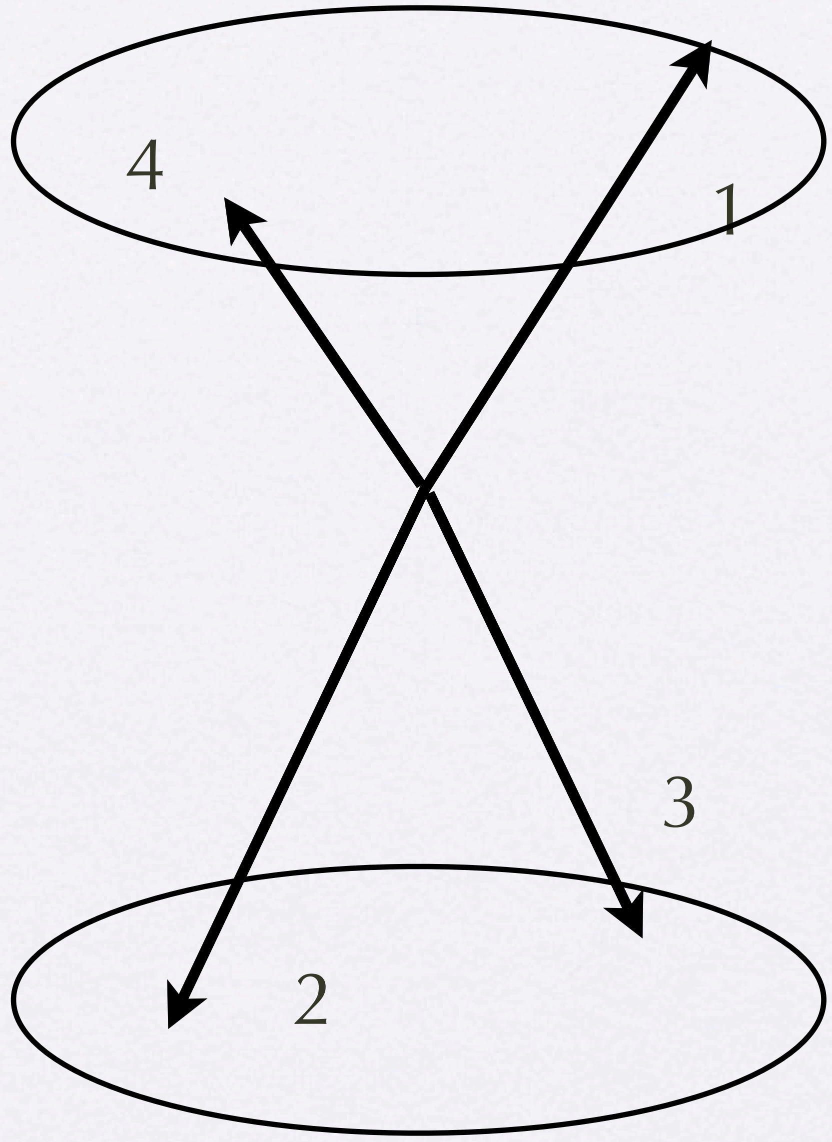
ジェットイベントばかりでも LSP の質量が決定できる。

“No Sliding solution” ?

JET シグナルの問題点

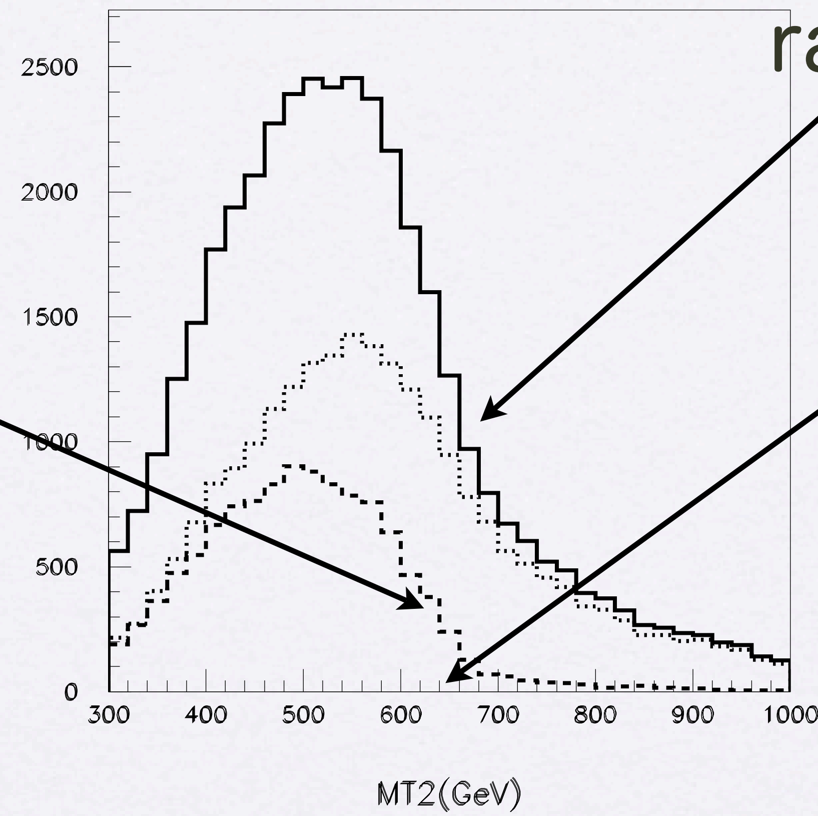
平松　野尻　清水　Alwall

- Example M_{T2} mass reconstruction
- Reconstruction steps: (hemisphere algorithm)
- 1)Take 2 highest pT jets j_1 and j_2
- 2) associate j_3 and j_4 to one for each
- 3)take combination of jets that gives smaller m_{T2}.



- Now this is it. (jet level)

Events without Initial radiation after matching "exclusive"



Events with Inital state radiation "inclusive

input gluino mass

total cross section 3pb
50000 events generated
no SUSY cut

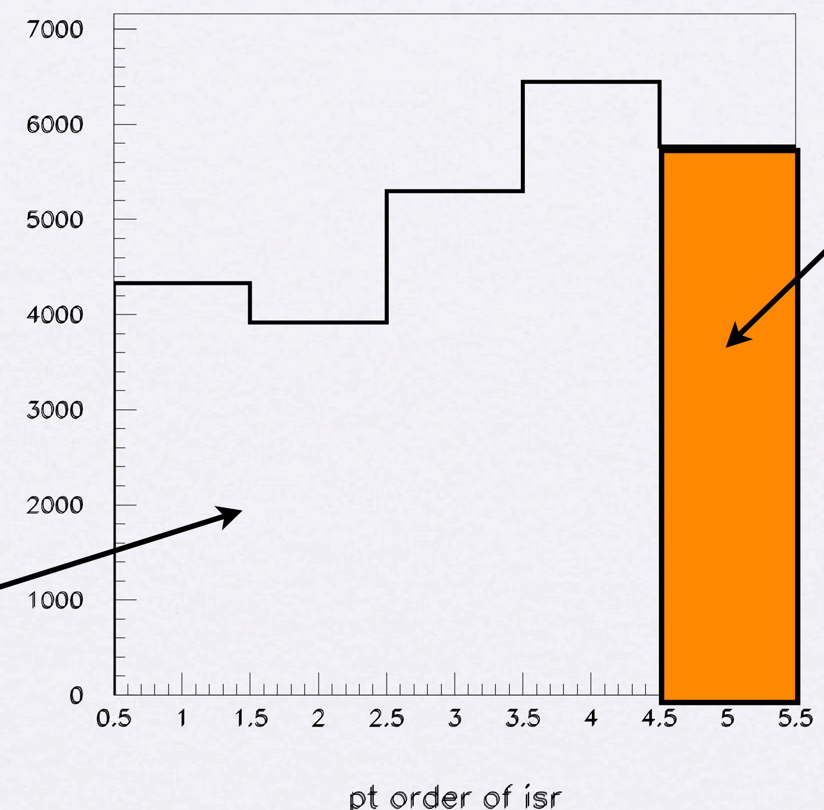
inclusive/exclusive =1.4 for gluino pair
0.8 for squark pair

ISR is specially bad for gluino production

P_T order of the additional jet

- Hard and high PT additional jet is actually dominant part of the production cross section.

Soft ISR we naively expect



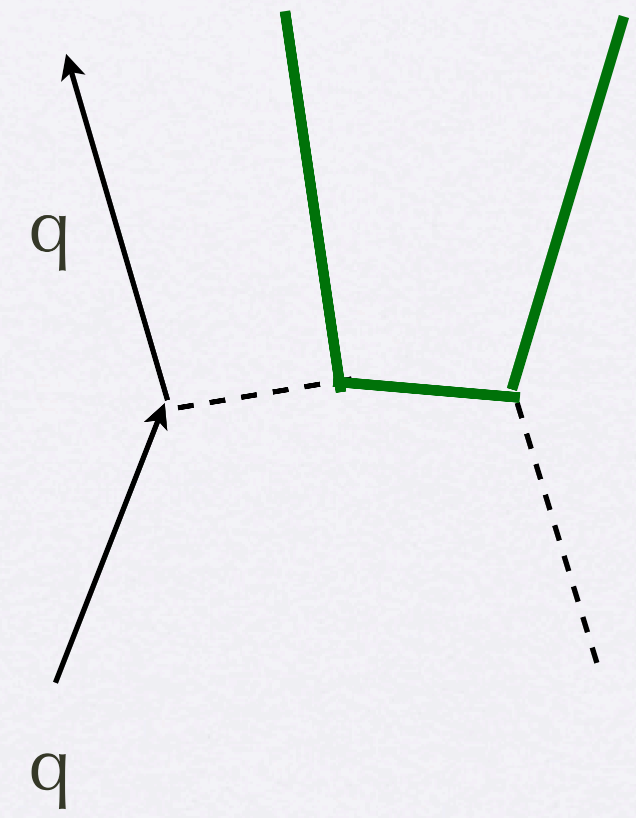
All the other additonal thing that kills your end point

Why so many additional jets

- dominant process g g→ gluino gluino
  - quark -anti quark is small.

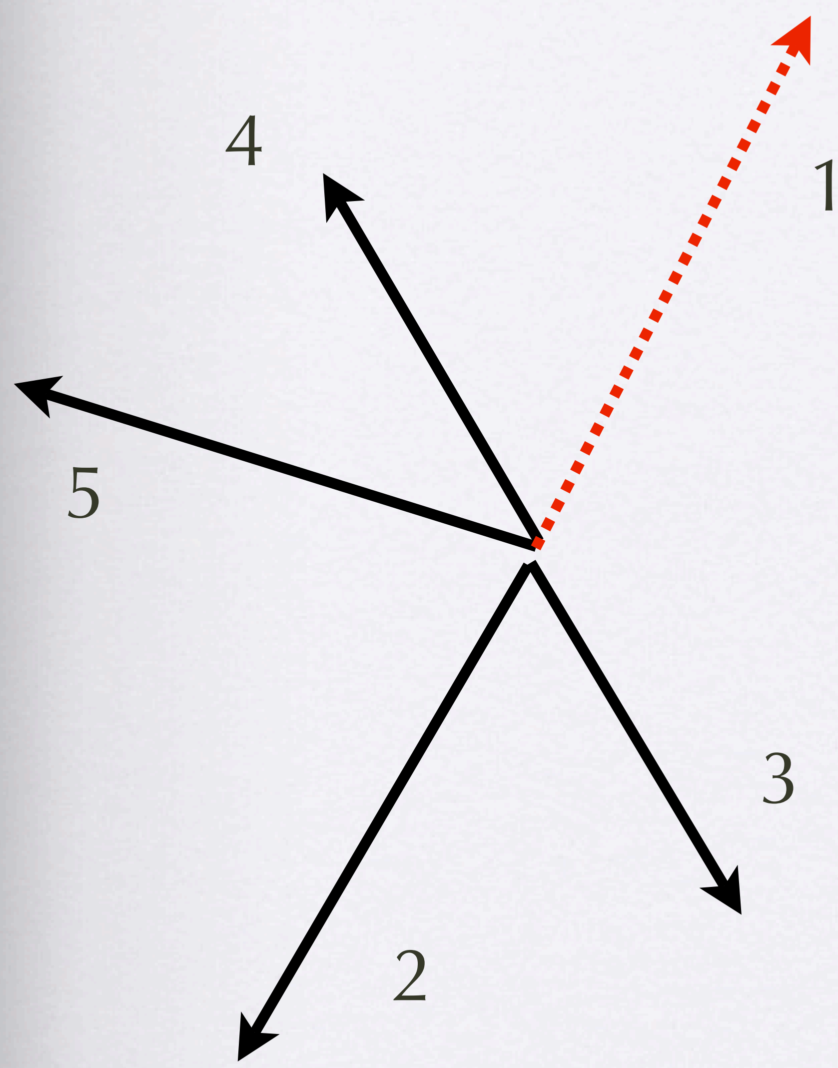
$$P_{qq} \propto \frac{1+z^2}{1-z}$$

- + 1 jet
  - gluon gluon → gluon gluino gluino (low energy)
  - qg → q squark gluino
    (high energy and high luminosity, and quark takes most of energy at the branching.)



How to get around (better solution)

- We have to realize that we are working on "5 jet system" rather than "4 jet system". More than half events have additional jets!



Proposing new step for mass reconstruction

1) take the 5 highest p_T jet ("five" is enough because "hard emission" is perturbative)

2) remove one of the jet i, and calculate "$M_{T2}(i)$"

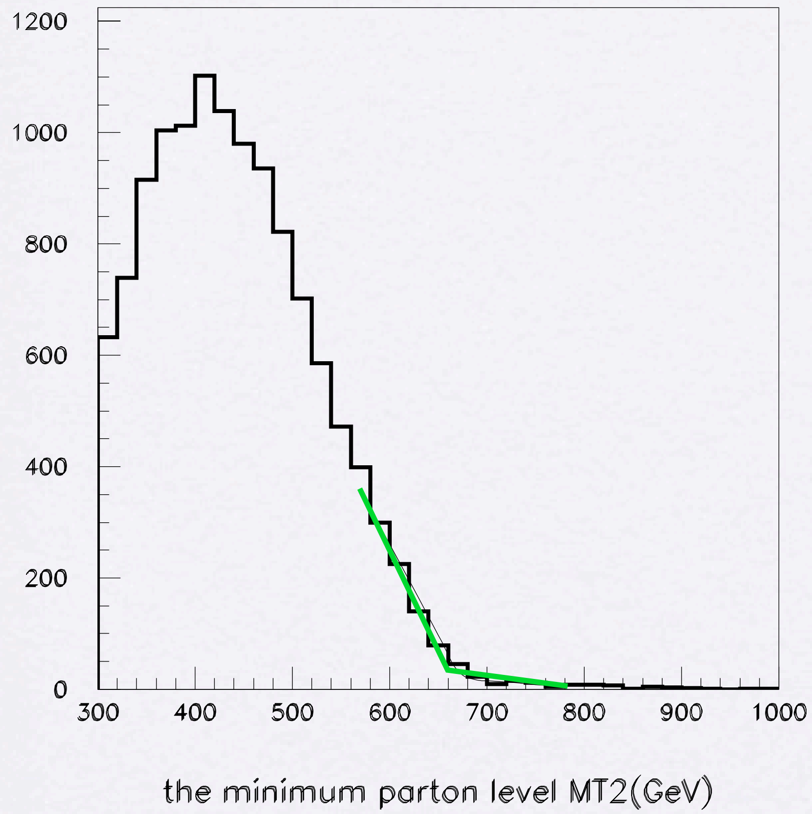
3) take minimum of $M_{T2}(i)$

$$M_{T2}^{min} = \min M_{T2}(i)$$
$$= M_{T2}(i_{min})$$

i_{min} may be true ISR!

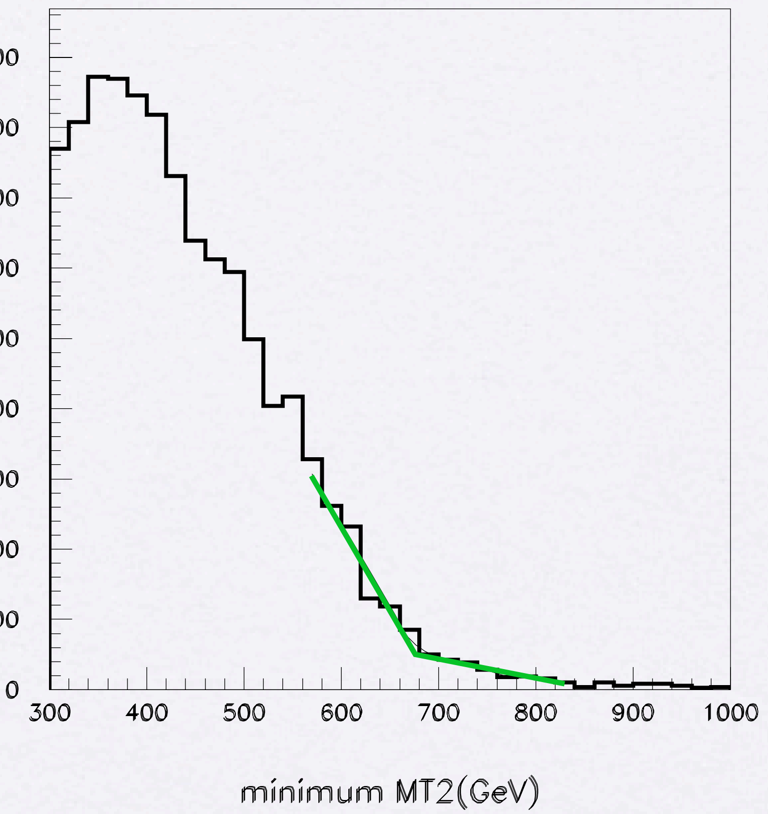
End point distribution?

parton level distribution



673.9 +/- 2.5 GeV

jet level



675.4 +/- 6.4 (imin. ge.3)
672.7+/- 3.5 (for all)

- We recover end point (not much smear though we minimized) .

教訓

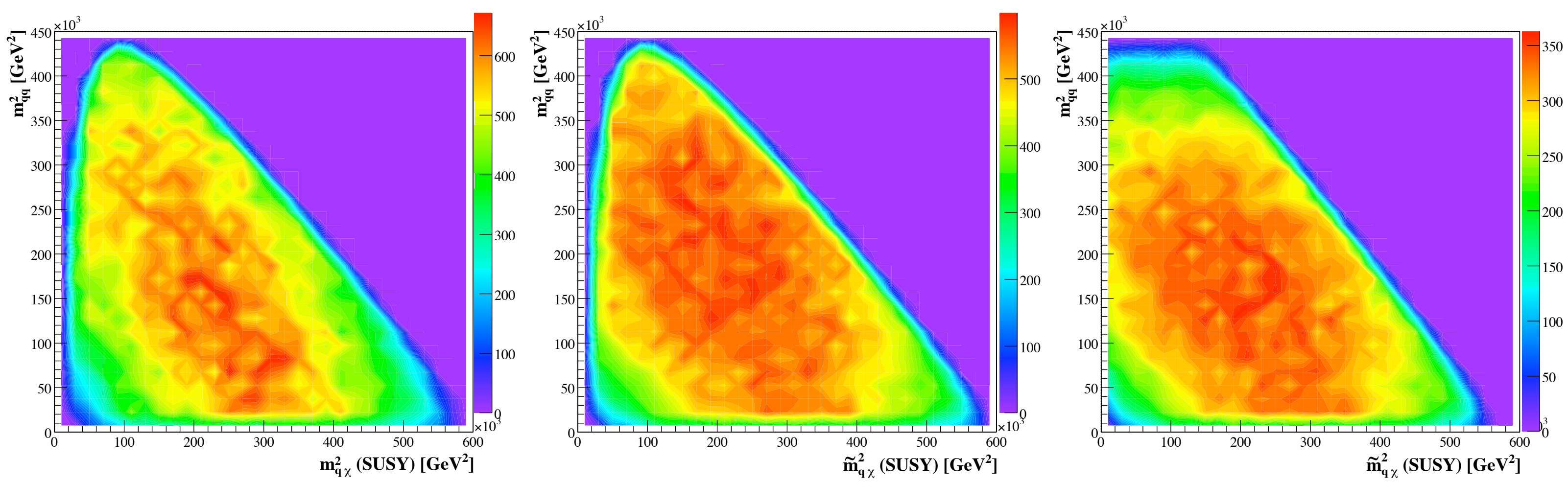
- ISR がでかいのは gluon gluon →SUSY pair だけ（ちなみにこの解析は NLO をやっているのと同じ）
- forward だけきっても ISR はなくならない。
- gluino pair の場合: hard ISR があると思った解析が正しい。
- gluino が多段崩壊（ top など）ではさらに ISR の方が energy がでかくなる確率が高い。（より重要性がます）
- squark gluino co produciton の contamination をなんとかすべし。

MAOS

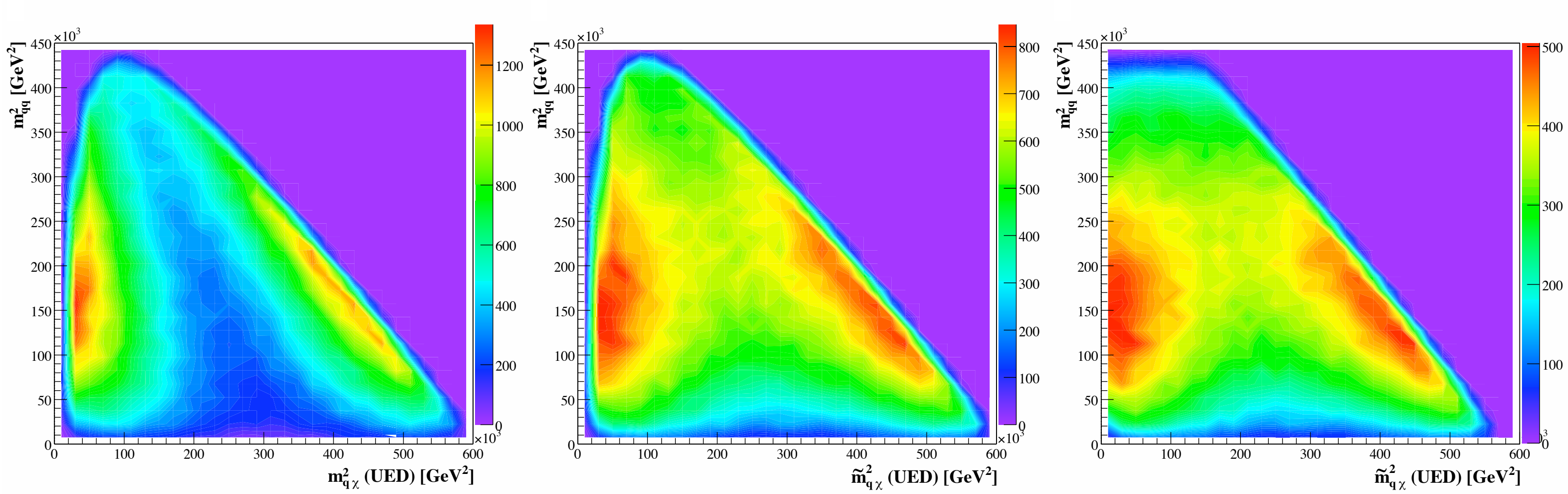
- MT２に対応する仮想運動量を正しいと思って分布をだす。MT2 のエンドポイントではかなり正しい

With $k^{\mu}_{\rm maos}$, one can use **the s-t$_{\rm maos}$ distribution**:

$$\frac{d\Gamma}{d\mathbf{s}d\mathbf{t}_{\rm true}} \qquad \frac{d\Gamma}{d\mathbf{s}d\mathbf{t}_{\rm maos}} \text{ for } (m_\chi^{\rm true}, m_Y^{\rm true}) \text{ and } (0, M_{T2}^{\rm max}(0))$$



gluino 3-body decay



KK-gluon 3-body decay

完全にparton level で正しい組み合わせ

普通の解析をするとまずとれない。

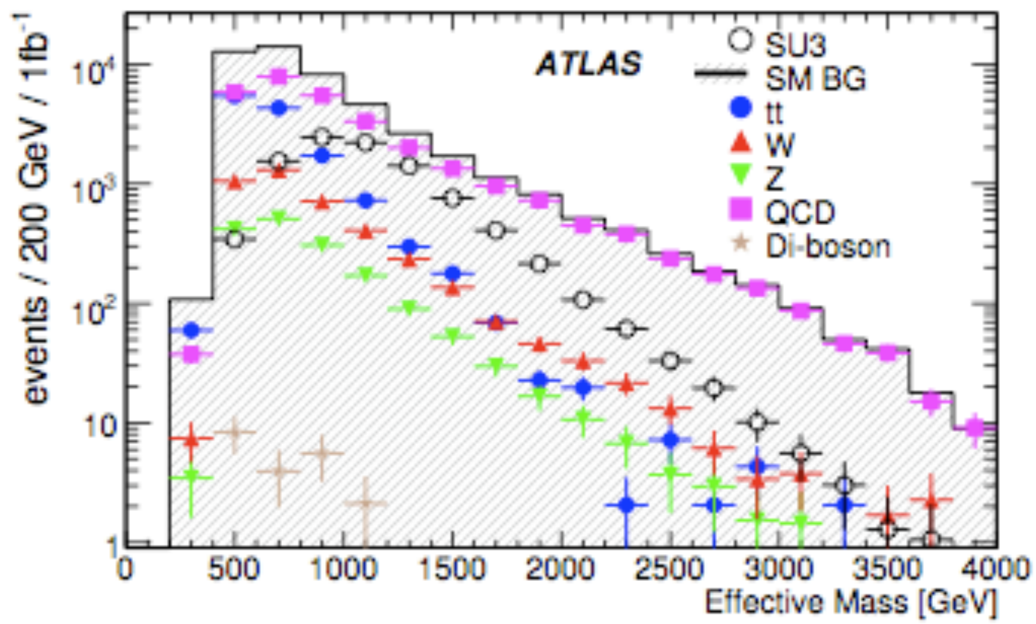
MT2 end point のあたりでは ISR がのぞけるのでまだましかも

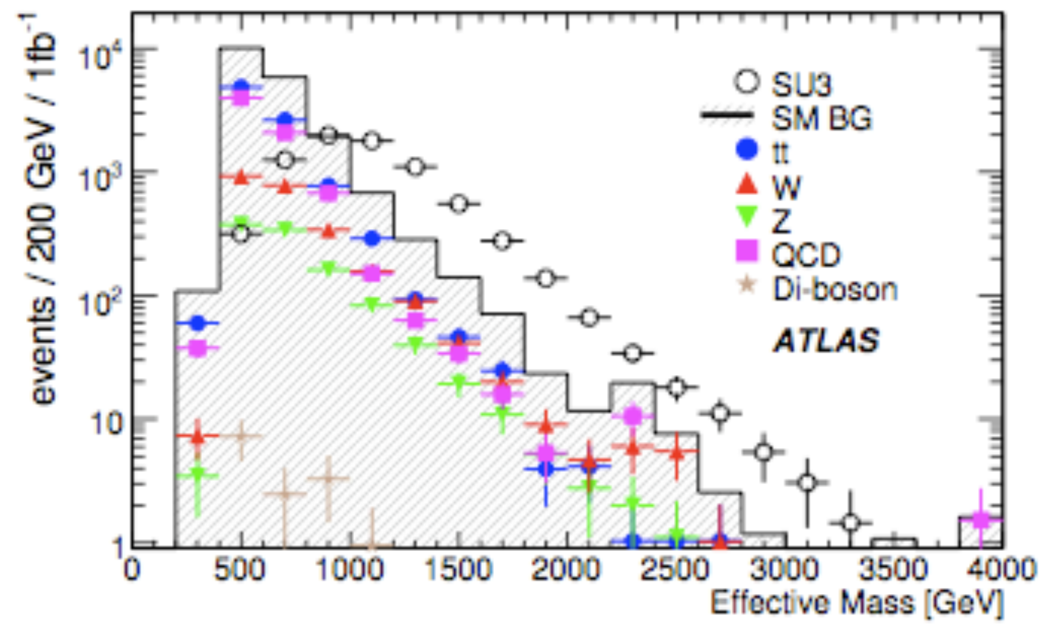
Choi et al

CSC note で気になること（SU4)

n100.ge.1 n50 ge 4

ETmiss>0.2 Meff





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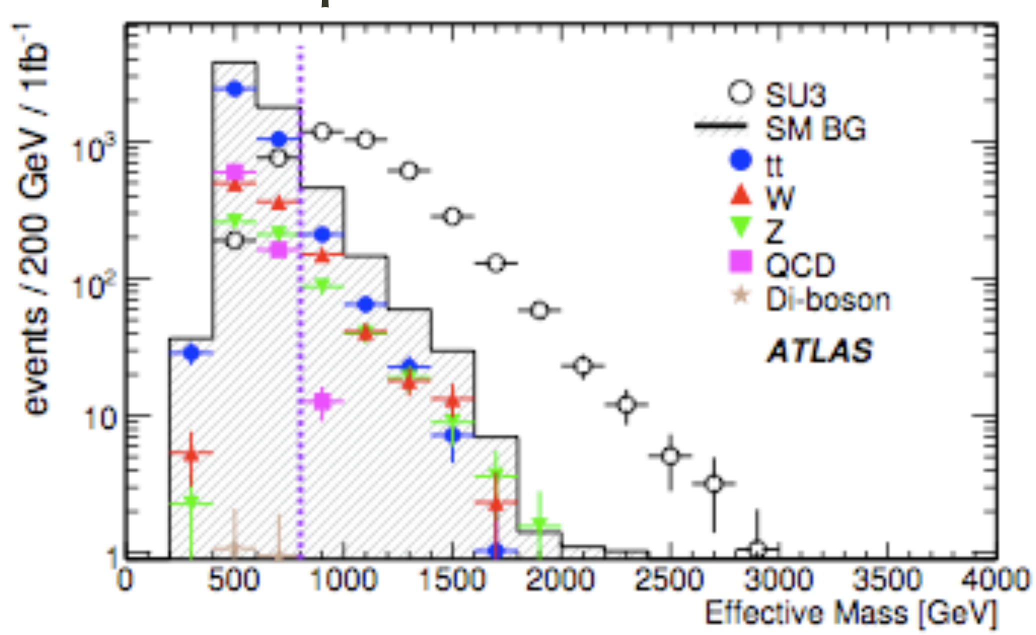
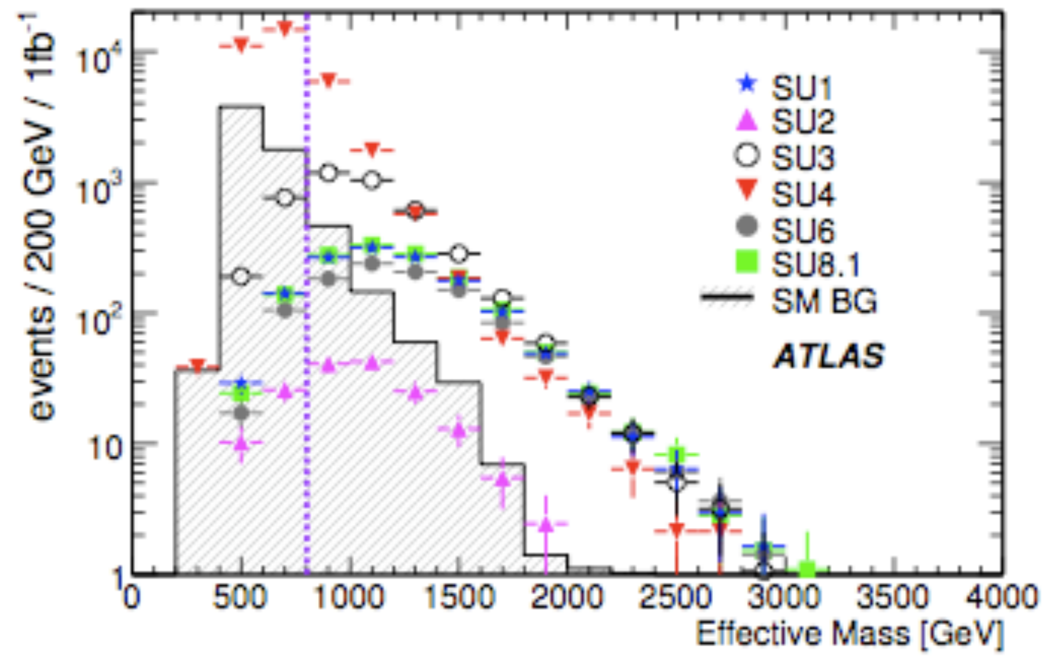




SU3 squarks 630GeV, gluino 717GeV, LSP 117 GeV

SU2 gluino 856 GeV, LSP 103 GeV ass others are heavy

SU4 squark400 GeV, gluino 413, LPS 59, very light stop

SUSY contamination

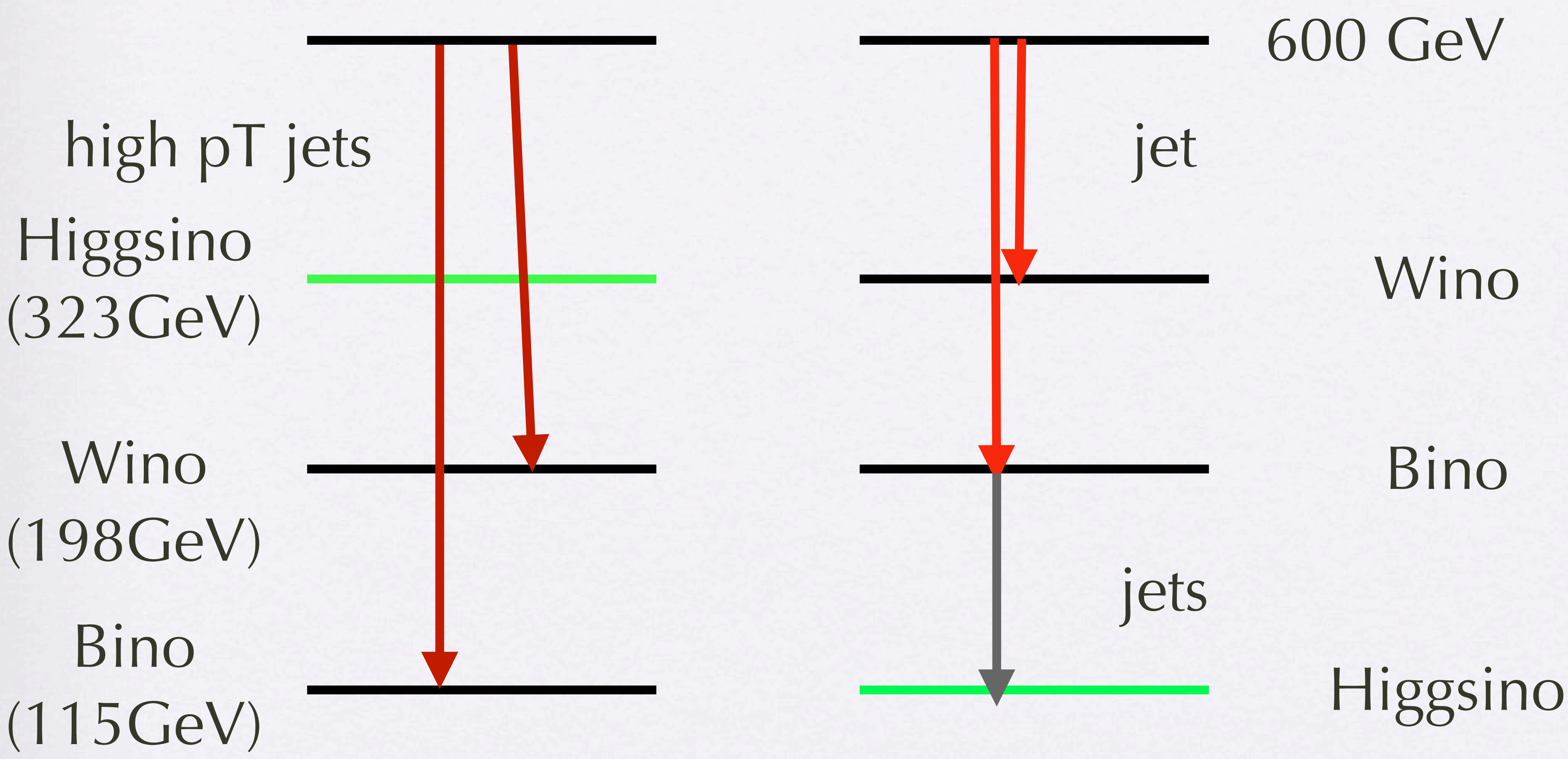
- 解析としては conservative (inclusive)
- exclusive analysis をすれば、overlap region でもなにかあるはず。まだ使っていないものはなにか。
  - MT2
  - gluon gluon dominated : ISR control?
- 統計的には量はあるので、なにもできないはずはない。

neutralino nature

- LHC produce strongly interacting particle
- DM is not strongly interacting.
- Exclusive analysis is important.

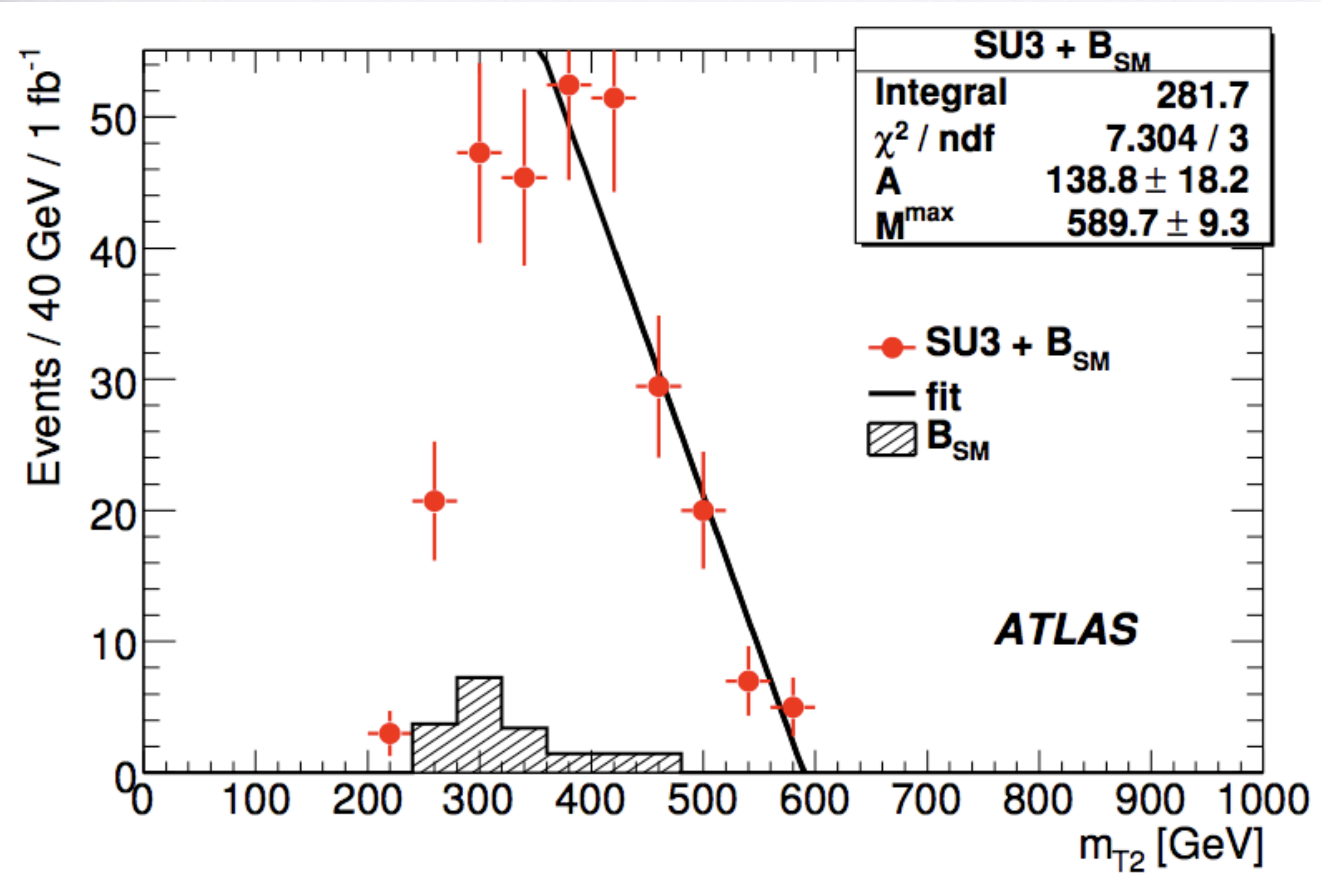
Checking LSP nature using (2 jet+ETmiss) /(>4 jet +Etmiss) signature

Nojiri Sreethwong



- 2jet only + ET miss (coming from squark direct decay into LSP) signal means gaugino like LSP

ATLAS study for 2 jet signature.



plot as the function of "MT2" variable

- $E_T^{miss} > \max(200\text{ GeV}, 0.25M_{eff})$ and $M_{eff} > 500$ GeV
- Two jets with $p_T > \max(200\text{ GeV}, 0.25M_{eff})$, $|\eta| < 1$ and $\Delta R > 1$
- No additional jet with $p_T > \min(200\text{ GeV}, 0.15M_{eff})$
- No isolated leptons and no jets tagged as b jets
- Transverse sphericity $S_T > 0.2$

2jet +ETmiss

(M1,M2,μ) =(122,230,271)

Point	No. of Signal	No. of SM Background	S/B_{SM}	$S/\sqrt{B_{SM}}$
A	1341	180	7.5	100.0
A3	133	180	0.7	9.9

(187,291,146)

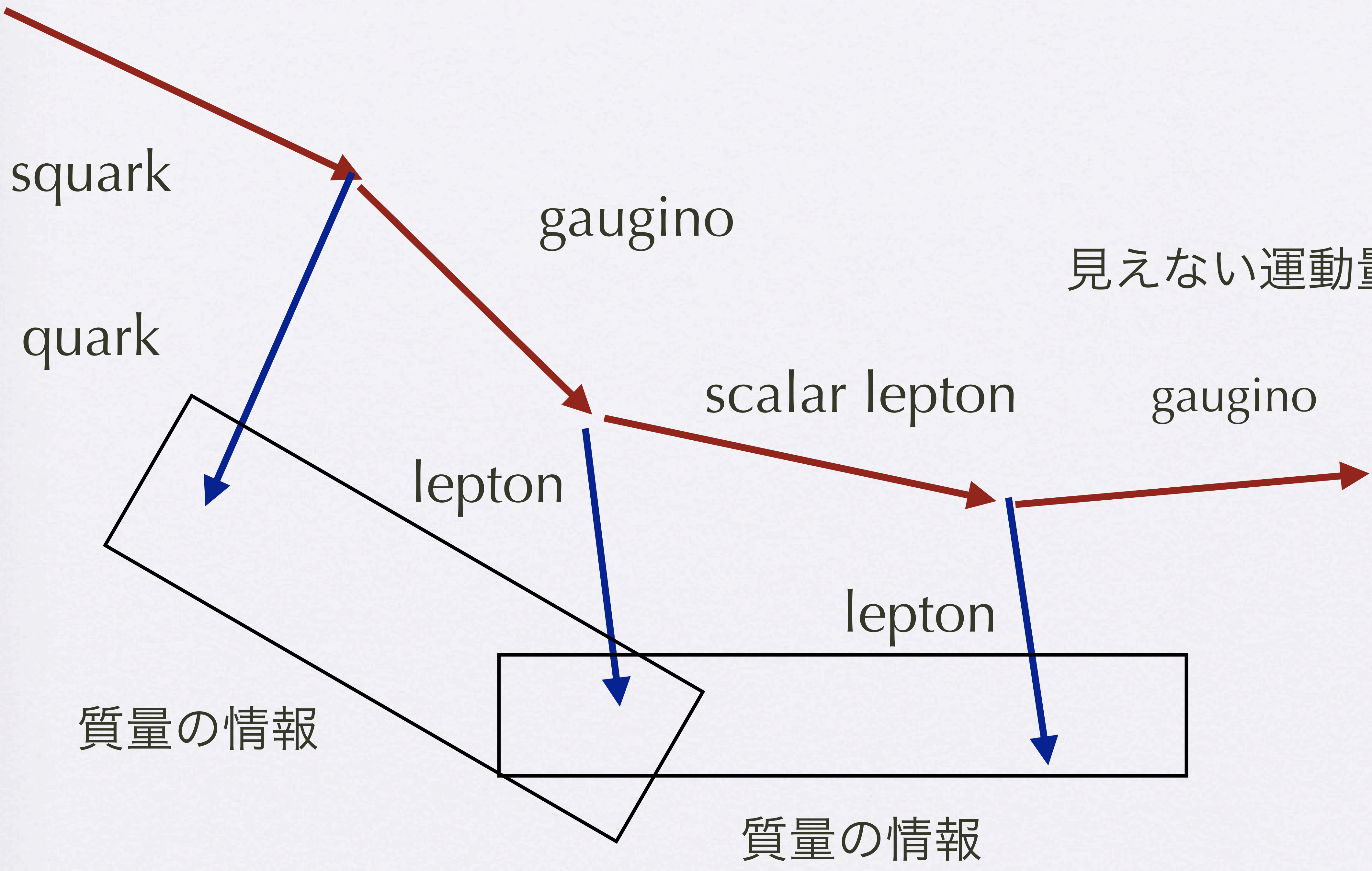
Factor 10 reductions

100 GeV mass difference between Higgsno LSP and heavier inos are enough to kill all 2 jet + missing ET events.

		$\Omega_{\rm DM}h^2$	$\sigma^{SI}_{p\chi}(10^{-8}\ pb)$
M1<M2<μ	A	0.1179	1.55
M1<μ<M2	A2	0.0817	3.15
μ<M1<M2	A3	0.0096	17.50

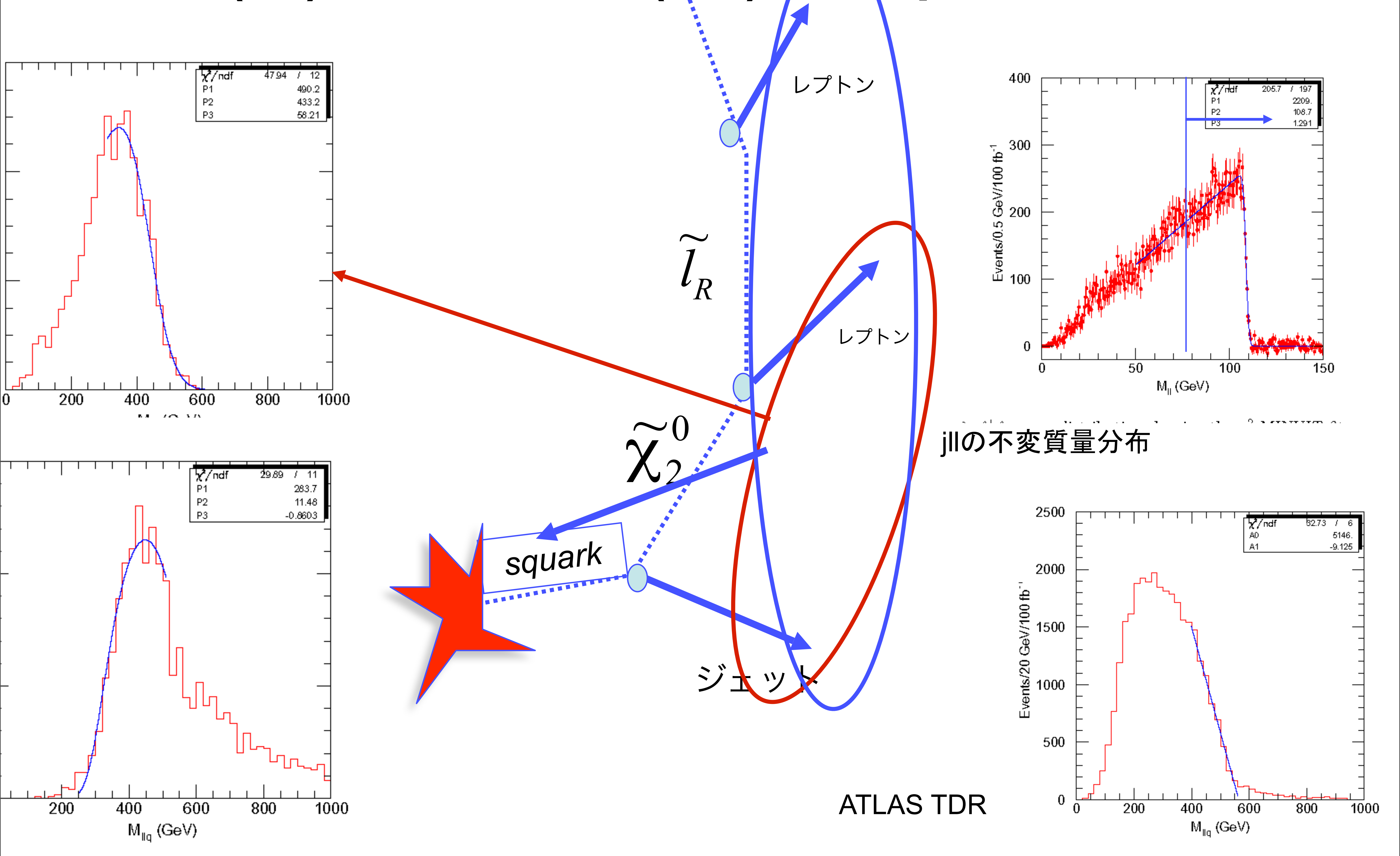
Classic l^+l^- leptons

SUSY cascade decay = mass and spin, interaction measurements

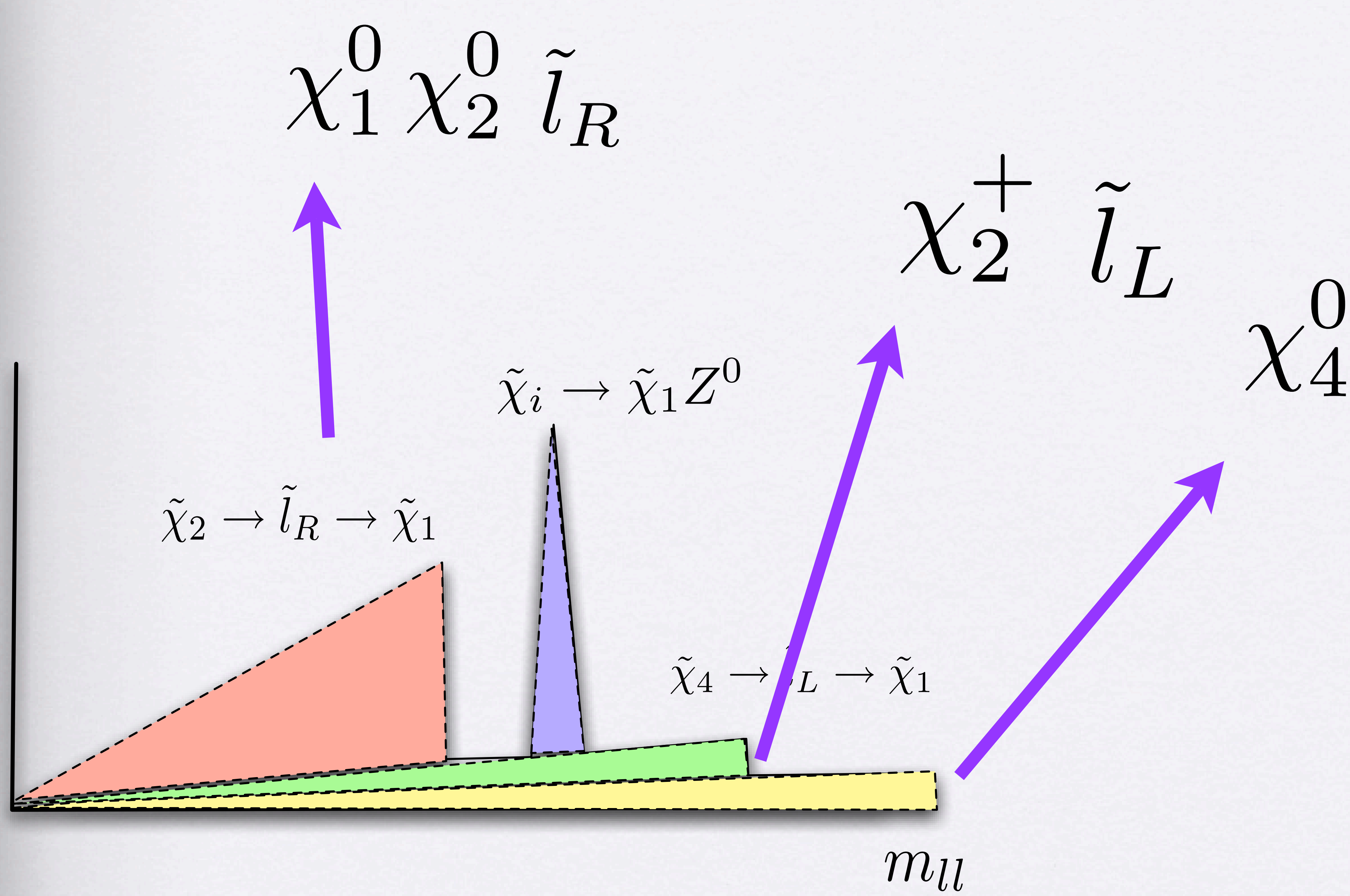


Mass measurement using endpoints

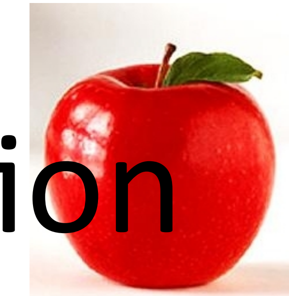
O(10)% for LSP, O(1%) for squark at best

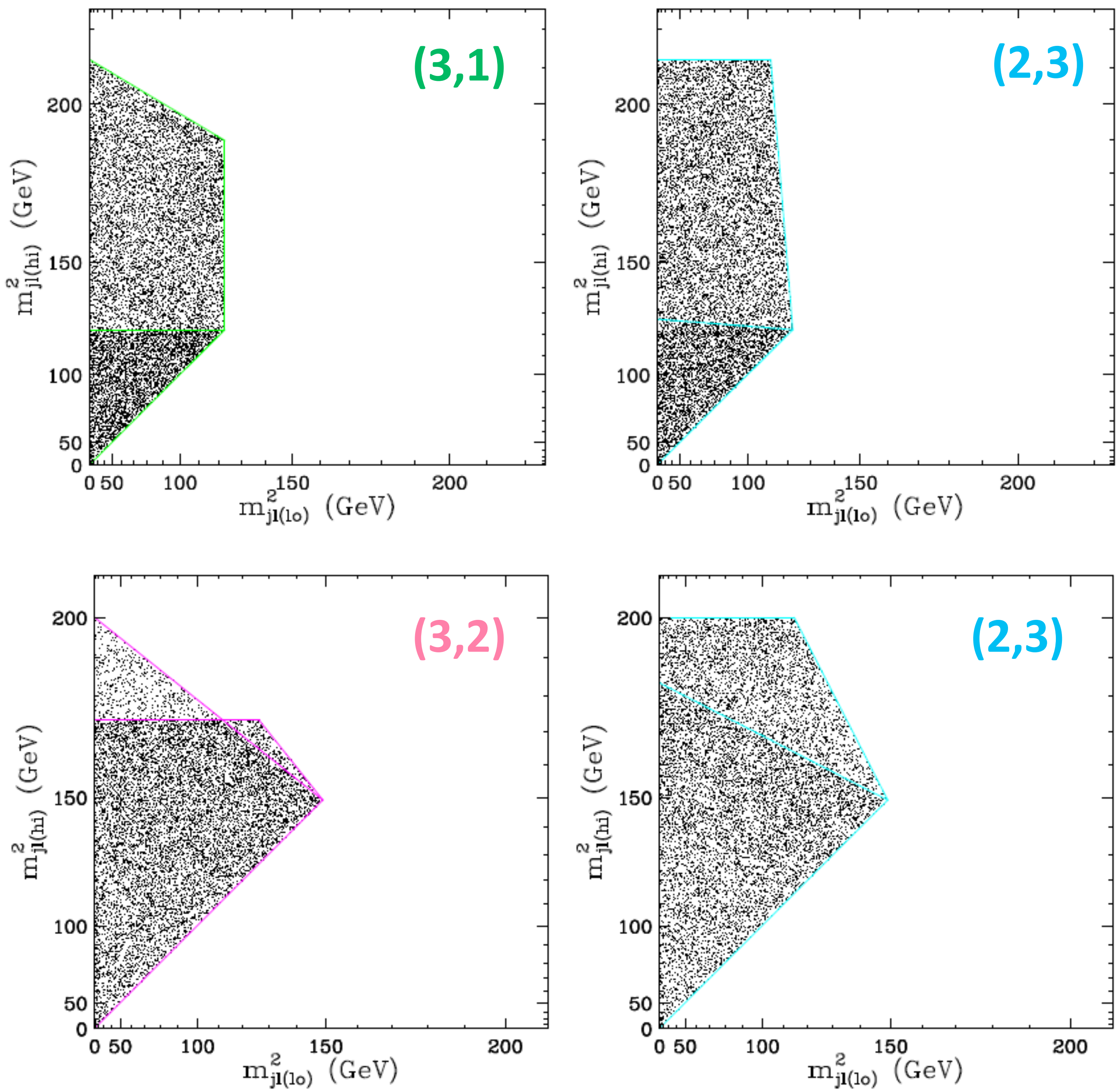


parameter determination には
higher end points が重要



Resolving the multiple solution





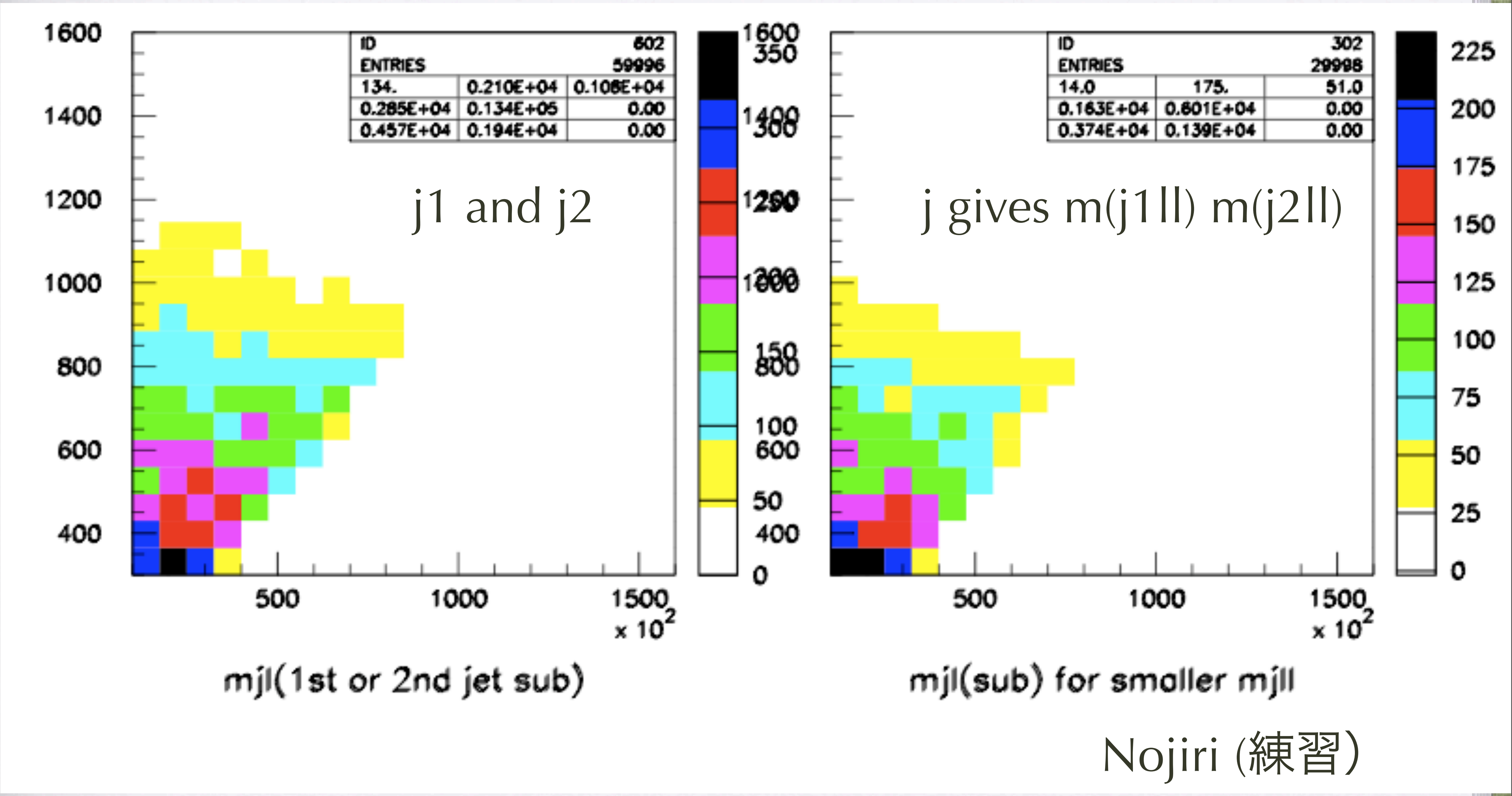
We may use 1D histogram
to distinguish the duplication.

But, the shape of 1D histogram will depend on various effects not only the phase space(mass spectrum)

The boundary of 2D histogram just depends on phase space,
the density in the 2D will depend on the other effects
(spin, coupling constants, and so on)

Kong et al from
IPMU focus week

jet selection



- 標準的な選択でない方がいいかも

SUSY like models

SUSY vs LHT vs UED

supersymmetry quark （spin 1/2） ⇄scalar quark (0)

gauge boosn (1) gaugino （1/2)

Lihgtest neutralino(?) is stable due to R parity

Little Higgs model quark ⇄quark partner(1/2)

gauge boson (1) gauge partner （1)

Lightest gauge partner is stable due to T parity

gluon partner does not exist.

UED model quark ⇄ level 1 quark.....

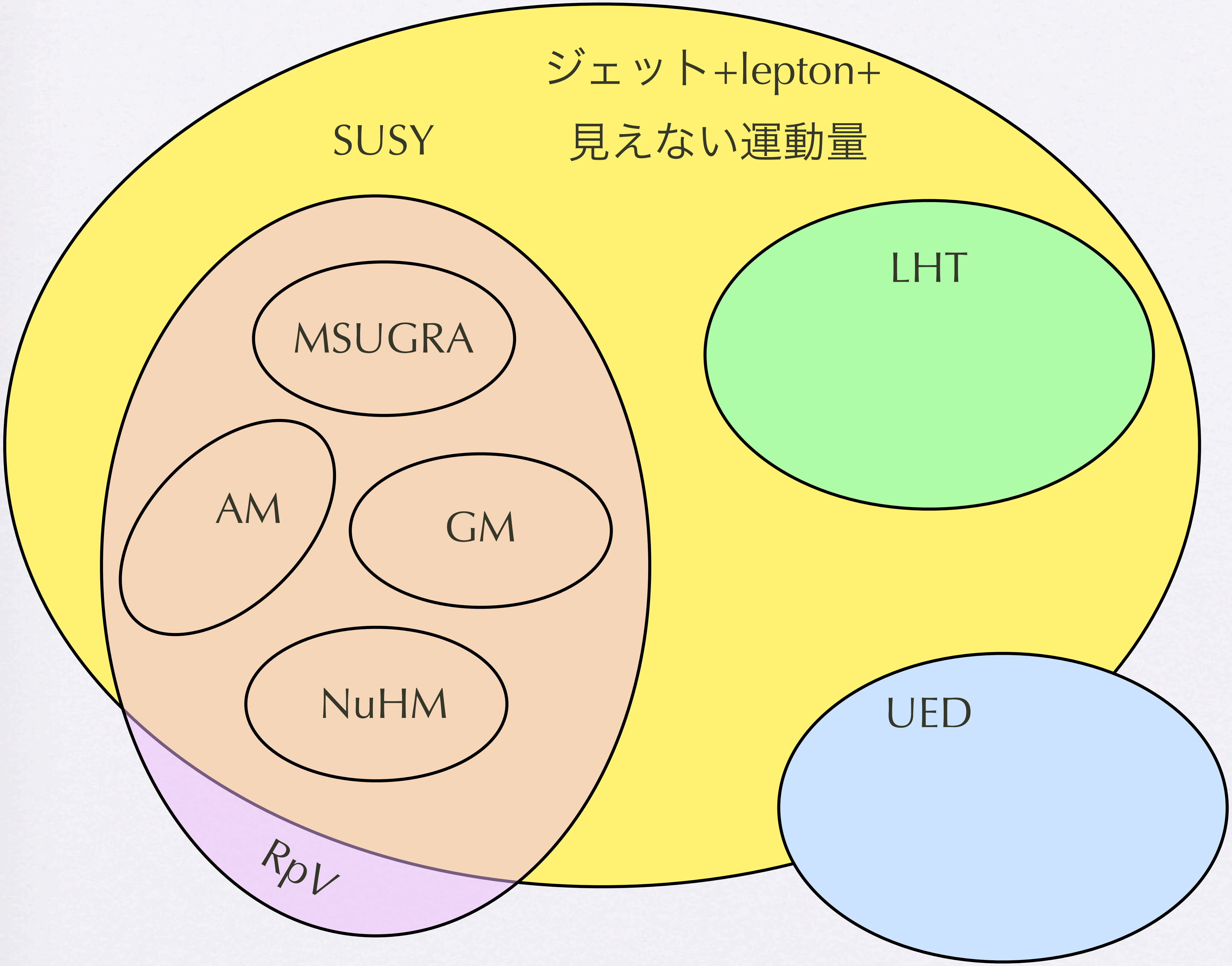
gauge boson ⇄ level 1 gauge boson...

lightest level 1 KK stable, gluon KK exists.

decay pattern is similar, interactions are similar (∝gauge coupling)

→test bench of spin determination

(cross section, decay pattern)



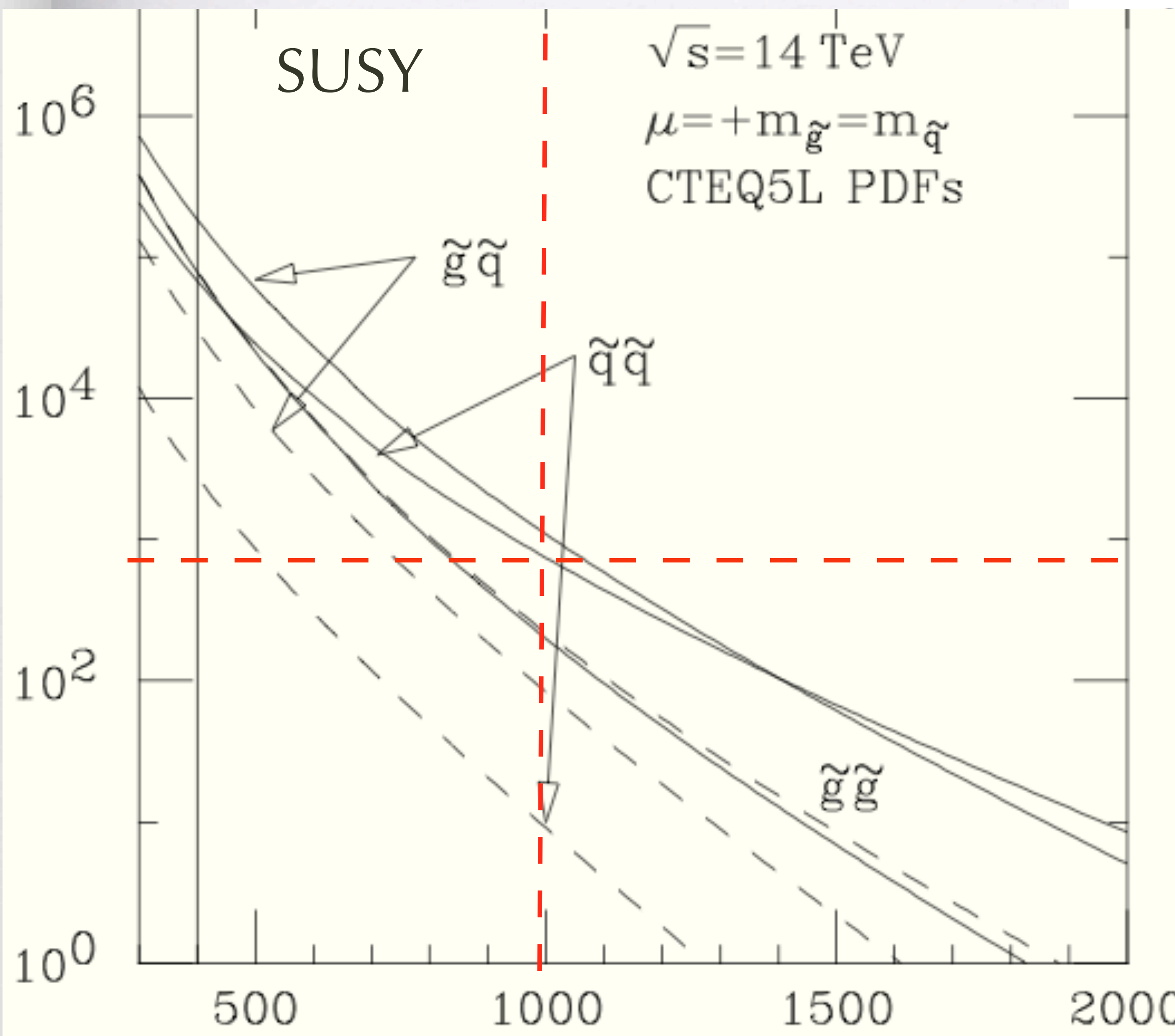
ジェット+lepton+
SUSY
見えない運動量
LHT
MSUGRA
AM
GM
NuHM
UED
RpV

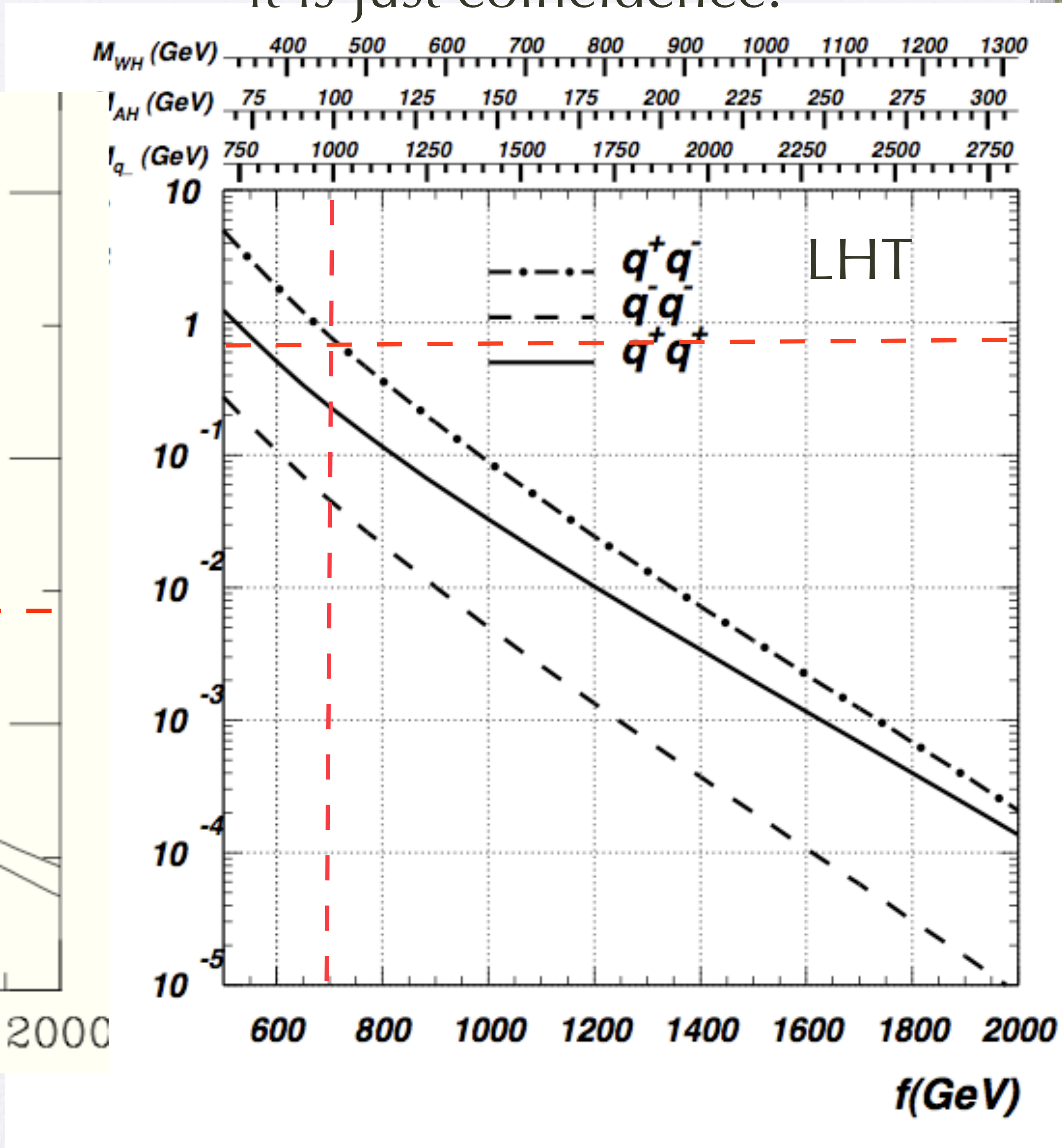
Comparing cross sections.

gluon のいない SUSY

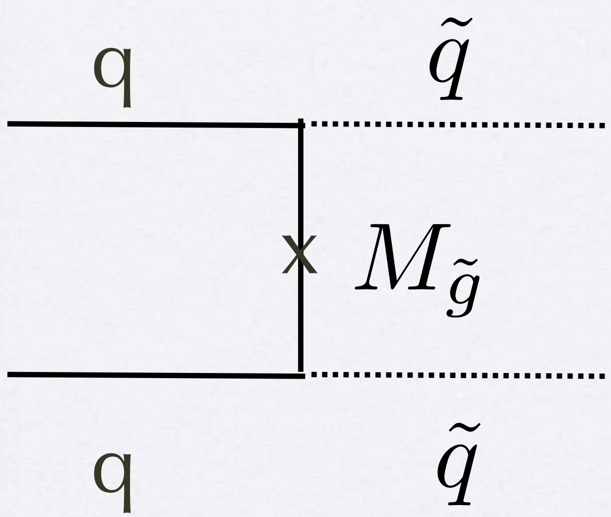
squark squark production at 1 TeV
~1 pb

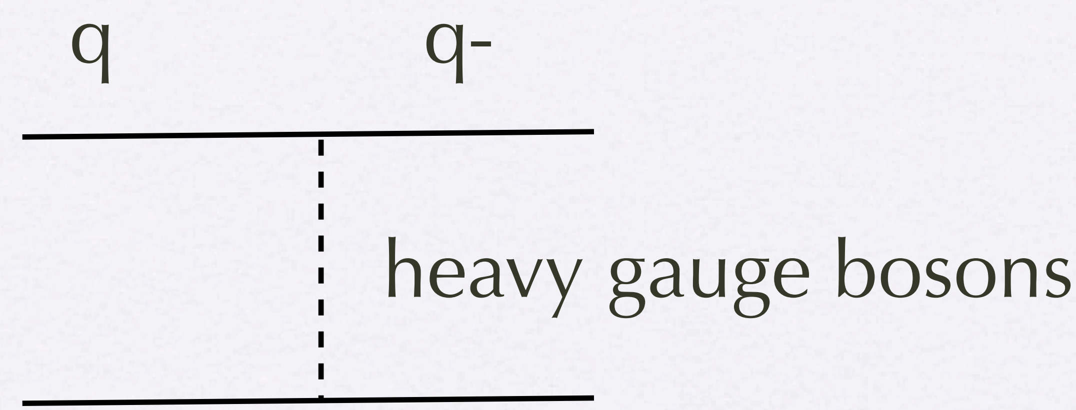
cross section is about the same but
it is just coincidence.





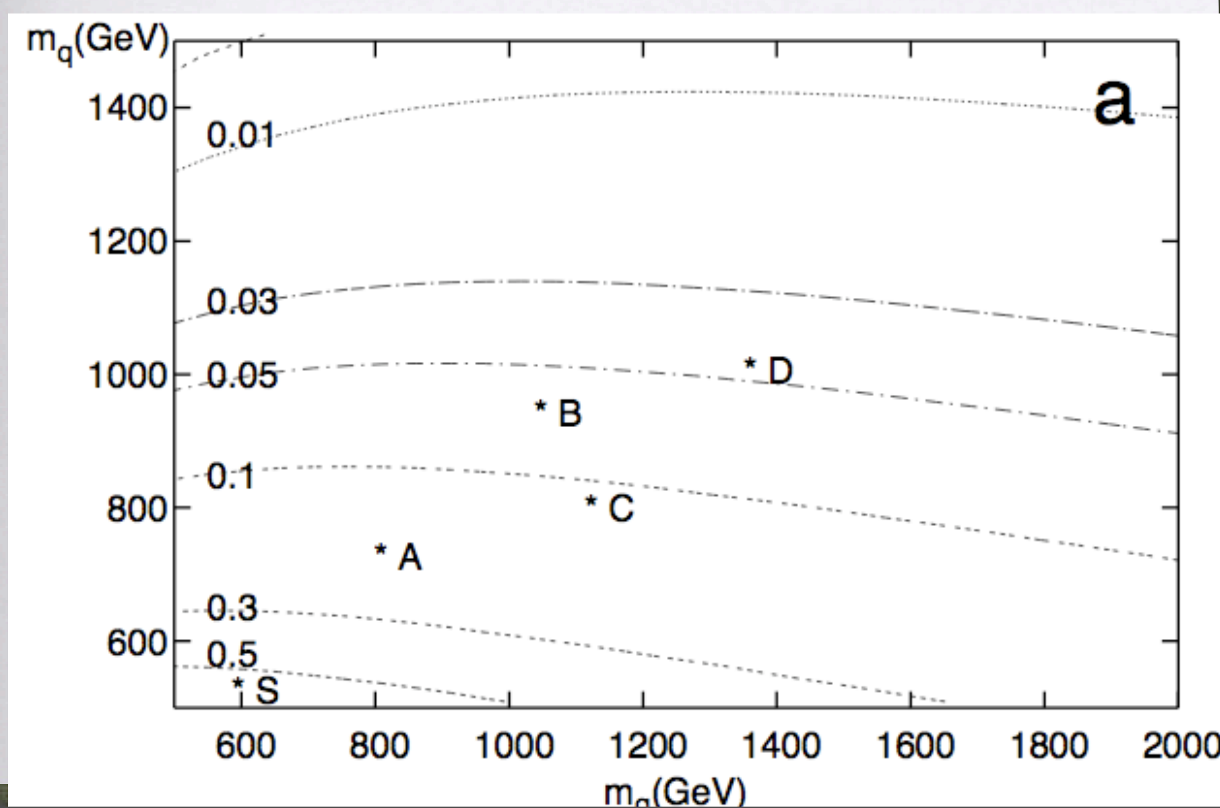
production process



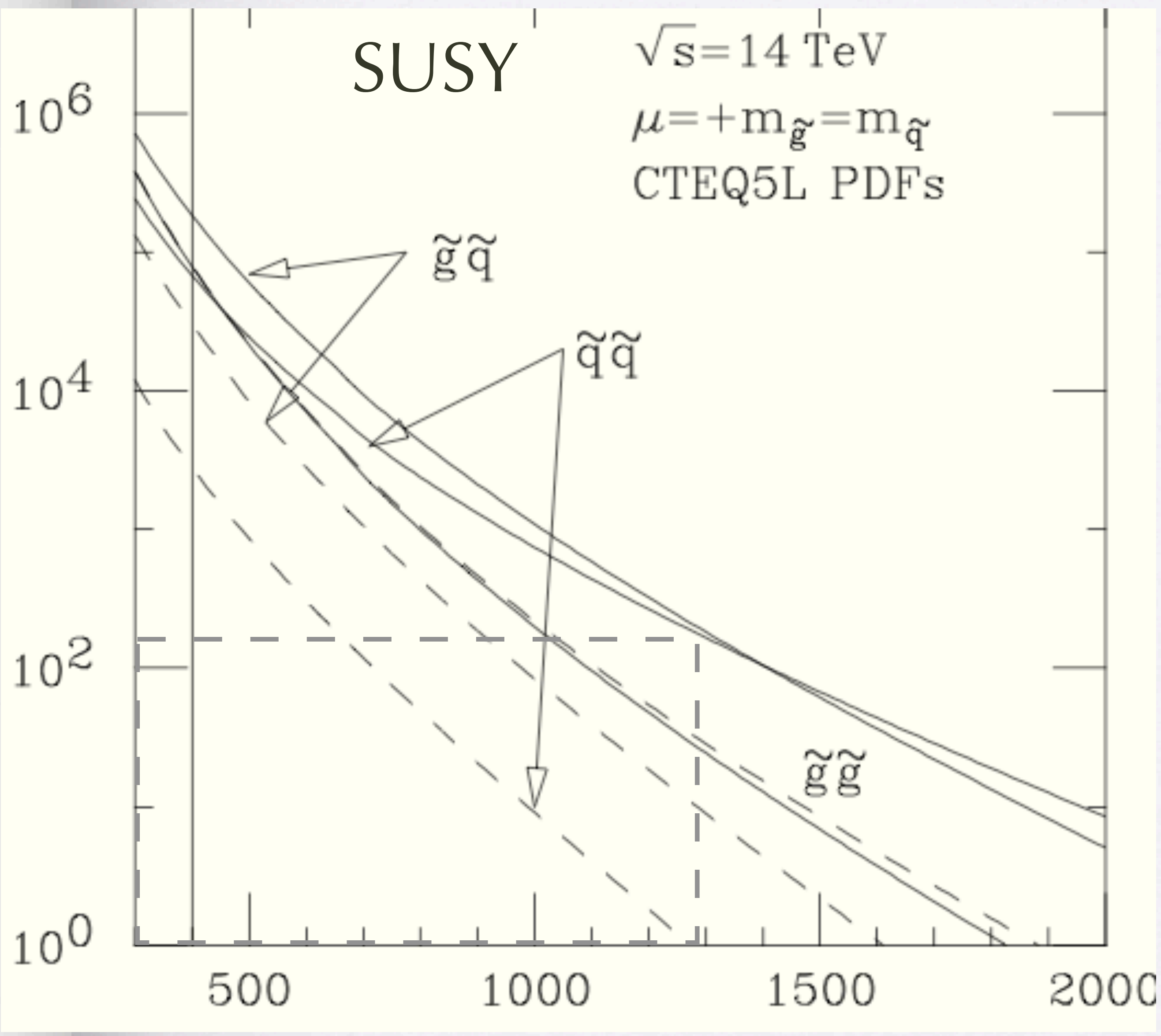


cross section is rather independent to gluino mass

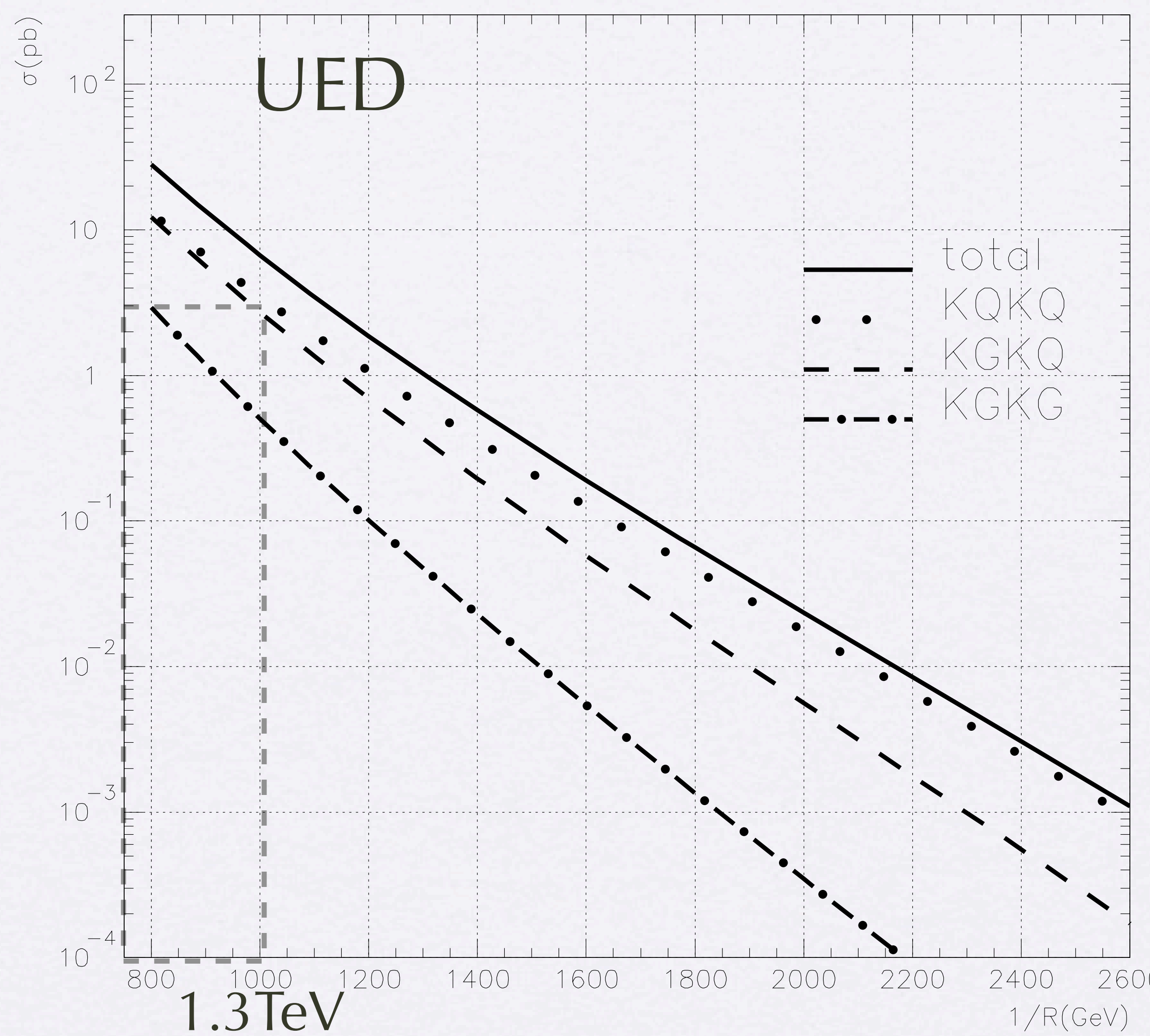
in Little Higgs model, only weak gauge boson partner exists but cross sections are same order



With T channel octet exchange



cross sections is about factor 10 larger due to T-channel KK gluon



production cross section
は <1TeV class

Mass > cross section

- cross section はとても質量に sensitive。 mass をまず決めること。

- rate = Branching ratio x cross section

- Low energy Lagrangean を仮定すれば fundamental parameter は ある程度決まっていく。どこでずれるか考えるのは大事。