SUSY Model Discrimination at an Early Stage of the LHC

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If bkg~0,

discovery $\longleftrightarrow$ ~ 5 events

measurement $\longleftrightarrow$ > O(100-1000) events

Measurements may require a few years.

Why can we do before detailed measurements?

When discovered $\longleftrightarrow$ crosssection

$\longleftrightarrow$ mass scale of produced particles

What discovered $\longleftrightarrow$ mass spectrum topology

How further can we go in this direction?

We compare mSUGRA and (low scale) mGMSB

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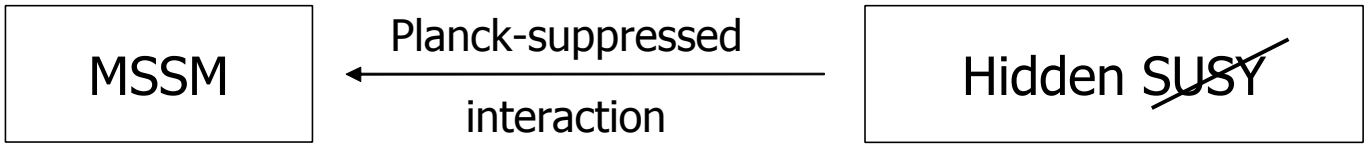
Model with gravitino mass < 16 eV is free from gravitino problem.

Missing gravitinos resemble missing neutralinos.

mSUGRA



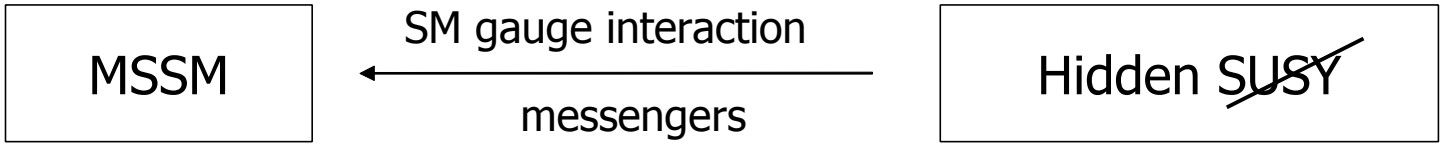
The model parameters (assuming good flavor and CP properties):

$$m_0,\ m_{1/2},\ A_0,\ \tan\beta,\ \mathrm{sign}\,\mu$$

$$m_{\mathrm{sfermion}}(m_{\mathrm{GUT}}) = m_0$$

$$m_{\mathrm{gaugino}}(m_{\mathrm{GUT}}) = m_{1/2}$$

mGMSB (Gauge Mediated Supersymmetry Breaking)



The model parameters (assuming GUT relations):

$$\Lambda_s,\ \Lambda_g,\ m_{\rm mes},\ \tan\beta,\ {\rm sign}\,\mu$$

$$m_{\rm sfermion}(m_{\rm mes}) = \frac{\alpha_{\rm SM}}{4\pi}\Lambda_s$$

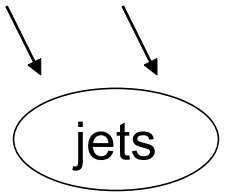
$$m_{\rm gaugino}(m_{\rm mes}) = \frac{\alpha_{\rm SM}}{4\pi}\Lambda_g$$

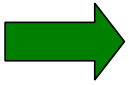
LHC signature

Typically, SUSY events are produced with colored particles $\tilde{q},\ \tilde{g}$

Then, SUSY particles decay cascadely to the LSP (Lightest SUSY Particle):

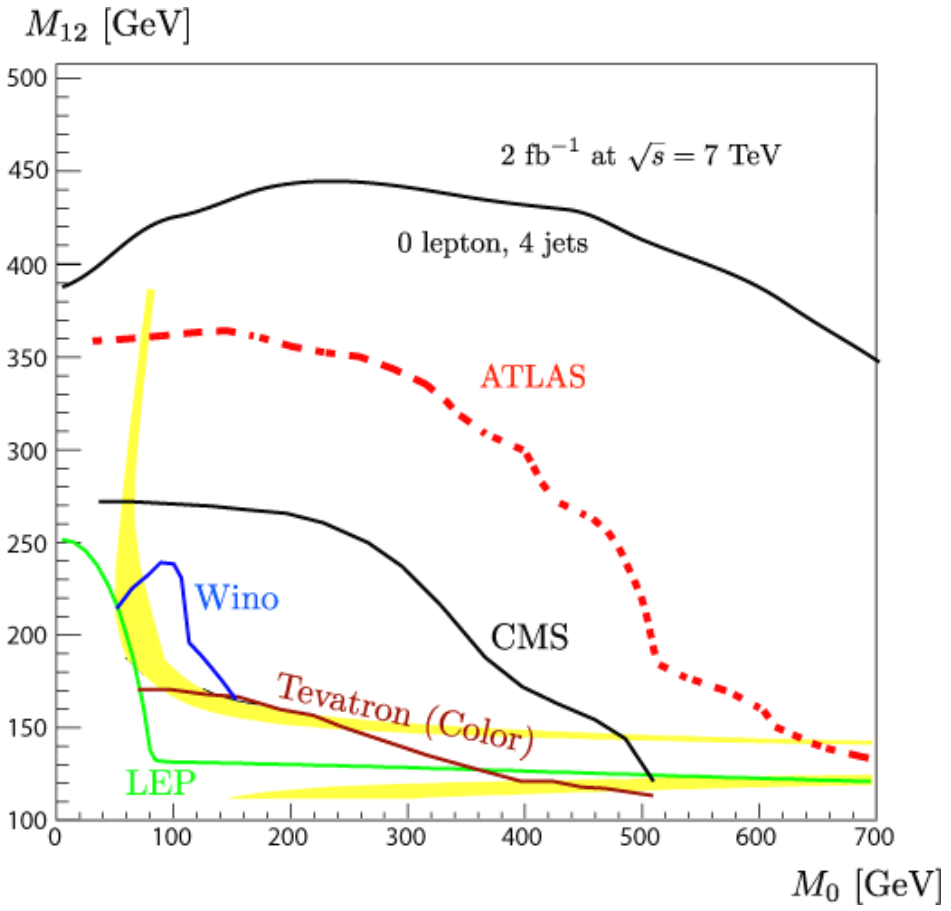
$$\tilde{q}, \tilde{g} \rightarrow \cdots \rightarrow \mathrm{LSP}\ (\mathrm{missing})$$





Multi-jets + missing

Example: mSUGRA discovery potential



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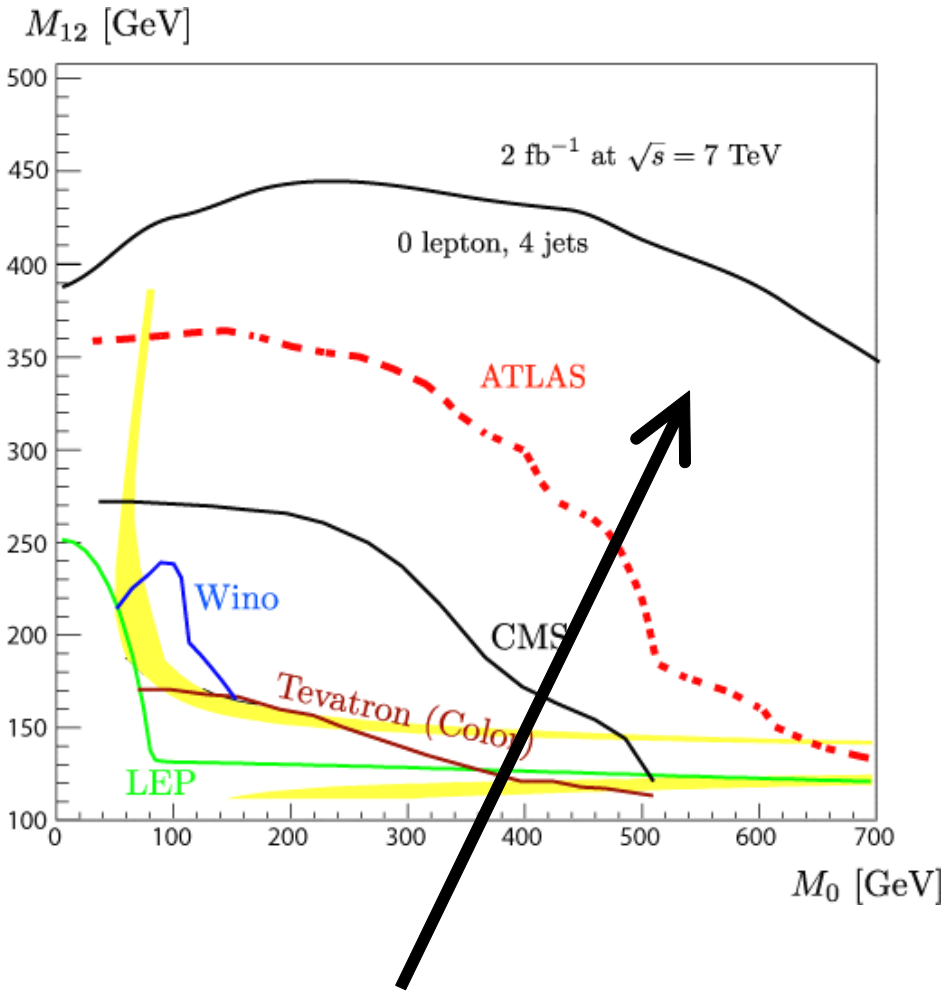

We consider this region

mSUGRA vs mGMSB

We consider how to discriminate mSUGRA events with mGMSB events.

In addition to multi-jets + missing,
SUSY events may contain other particles (leptons, photons, ...)

mSUGRA $\quad \mathrm{LSP} = \tilde{\chi}_1^0 \sim \tilde{B}$

$$\tilde{g} \xrightarrow{q} \tilde{q}^{(*)} \xrightarrow{q} \tilde{\chi}_1^+ \xrightarrow{W^+} \tilde{\chi}_1^0, \quad W \to qq', \ell\nu.$$

$$\tilde{g} \xrightarrow{q} \tilde{q}^{(*)} \xrightarrow{q} \tilde{\chi}_2^0 \xrightarrow{\ell} \tilde{\ell}^{(*)} \xrightarrow{\ell} \tilde{\chi}_1^0.$$

mSUGRA vs mGMSB

mGMSB $\mathrm{LSP} = \tilde{G}\ (\mathrm{gravitino})\ \ (\sim \mathrm{massless})$

$$\tilde{g} \xrightarrow{q} \tilde{q}^{(*)} \xrightarrow{q} \tilde{\chi}_1^0 \xrightarrow{\gamma/Z} \tilde{G}$$

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Coupling to gravitino is weaker than the SM couplings

$\tilde{q},\ \tilde{g} \longrightarrow \cdots \longrightarrow$ NLSP $\longrightarrow$ LSP (gravitino)

Always!

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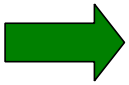
Always!

NLSP = $\begin{cases} \text{(1) Slepton} \\ \text{(2) Lightest neutralino } (\sim \tilde{B}) \end{cases}$

mSUGRA vs mGMSB

NLSP = { (1) Slepton ; (2) Lightest neutralino $(\sim \tilde{B})$

(1) $\tilde{q}, \tilde{g} \xrightarrow{\text{jets}} \cdots \xrightarrow{\ell} \tilde{\ell} \xrightarrow{\ell} \tilde{G}$



multi-jets + missing + multi-leptons

mSUGRA vs mGMSB

NLSP = { (1) Slepton ; (2) Lightest neutralino $(\sim \tilde{B})$

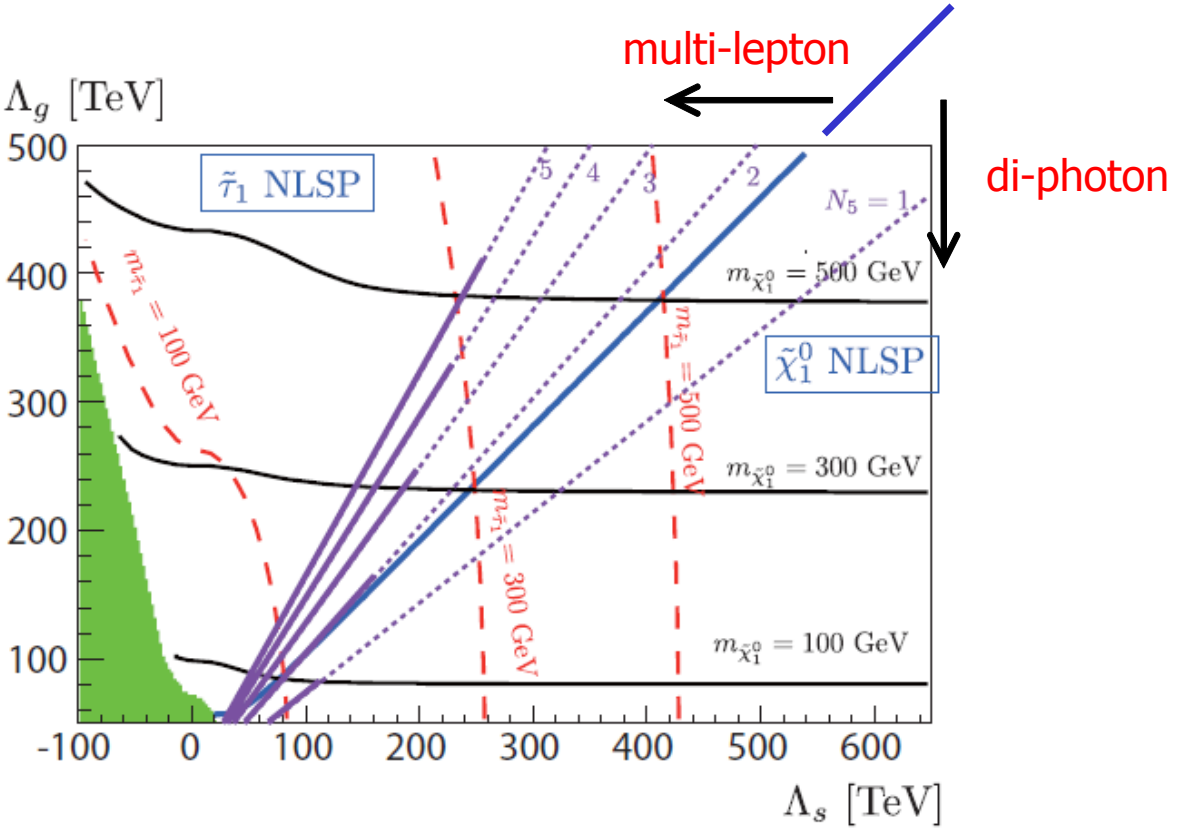
(1) $\tilde{q}, \tilde{g} \xrightarrow{\text{jets}} \cdots \xrightarrow{\ell} \tilde{\ell} \xrightarrow{\ell} \tilde{G}$

→ multi-jets + missing + multi-leptons

(2) $\tilde{q}, \tilde{g} \xrightarrow{\text{jets}} \cdots \longrightarrow \tilde{B} \xrightarrow{\gamma} \tilde{G}$

→ multi-jets + missing + di-photons

mGMSB discovery potential



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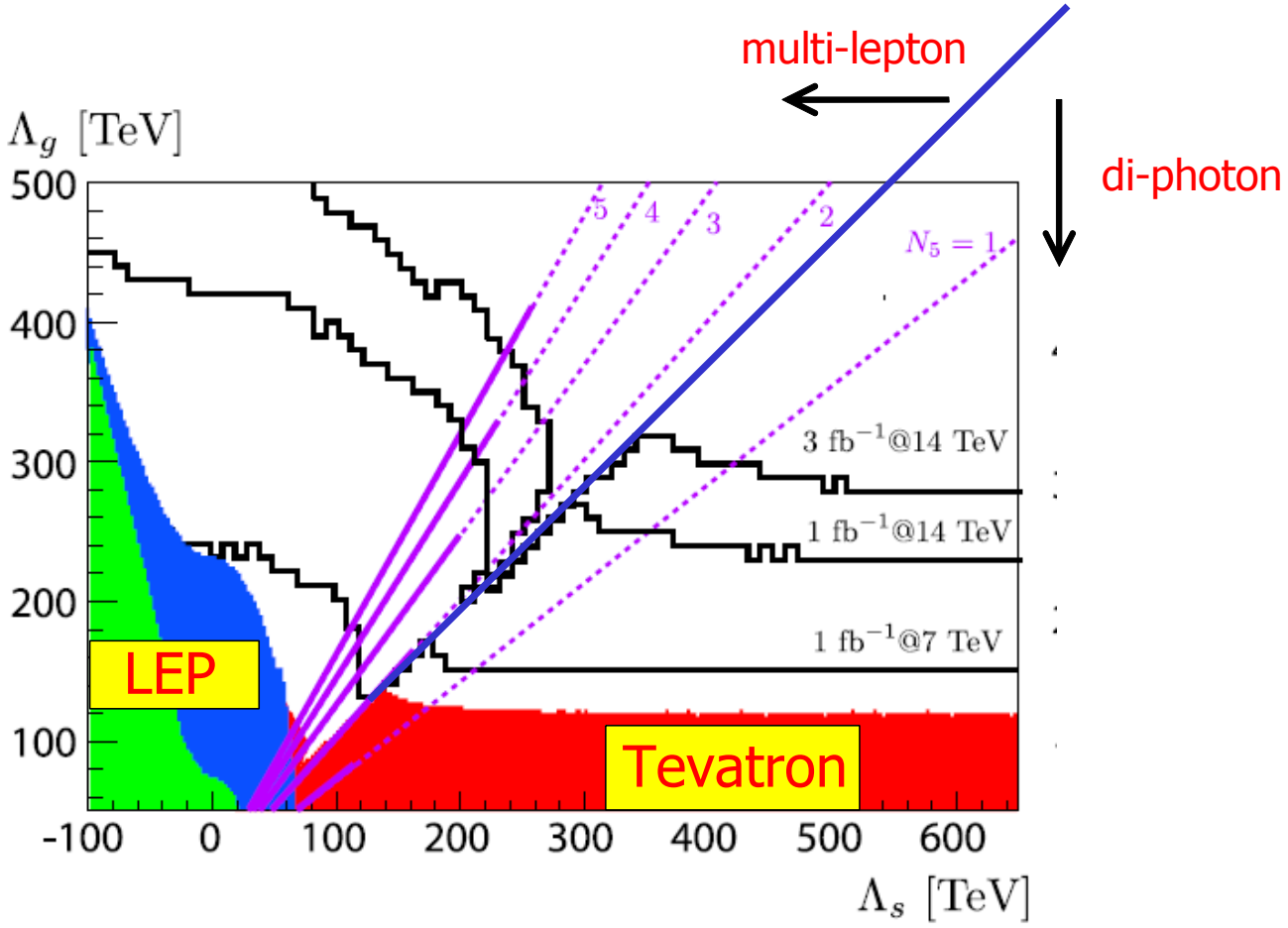


mSUGRA vs mGMSB

Naive estimation:

	2 photons	Same-sign 2 leptons	0 lepton 4 jets
mSUGRA	$\times$	$\bigcirc$	$\circledcirc$
mGMSB $\tilde{\tau}$-NLSP	$\times$	$\circledcirc$	$\triangle$
mGMSB $\tilde{\chi}_1^0$-NLSP	$\circledcirc$	$\triangle$	$\triangle$

We now try to discreminate the models according to this table.

Significance variable

We use the significance Z
to express "goodness" of each mode.

$$Z = Z(N_s, N_b)$$

Statistical uncertainty

SM background contributtion

] is automatically incorporated.

Z > 5 ⇔ 5 σ discovery

The error of Z depends on N_s and N_b.
(Typically, $\delta Z \simeq 1$)

Discrimination of mGMSB with neutralino-NLSP

We scan the model points in the
(sfermion mass)-(gaugino mass) plane.

For simplicity, A-term is set to 0, $\mu > 0$.

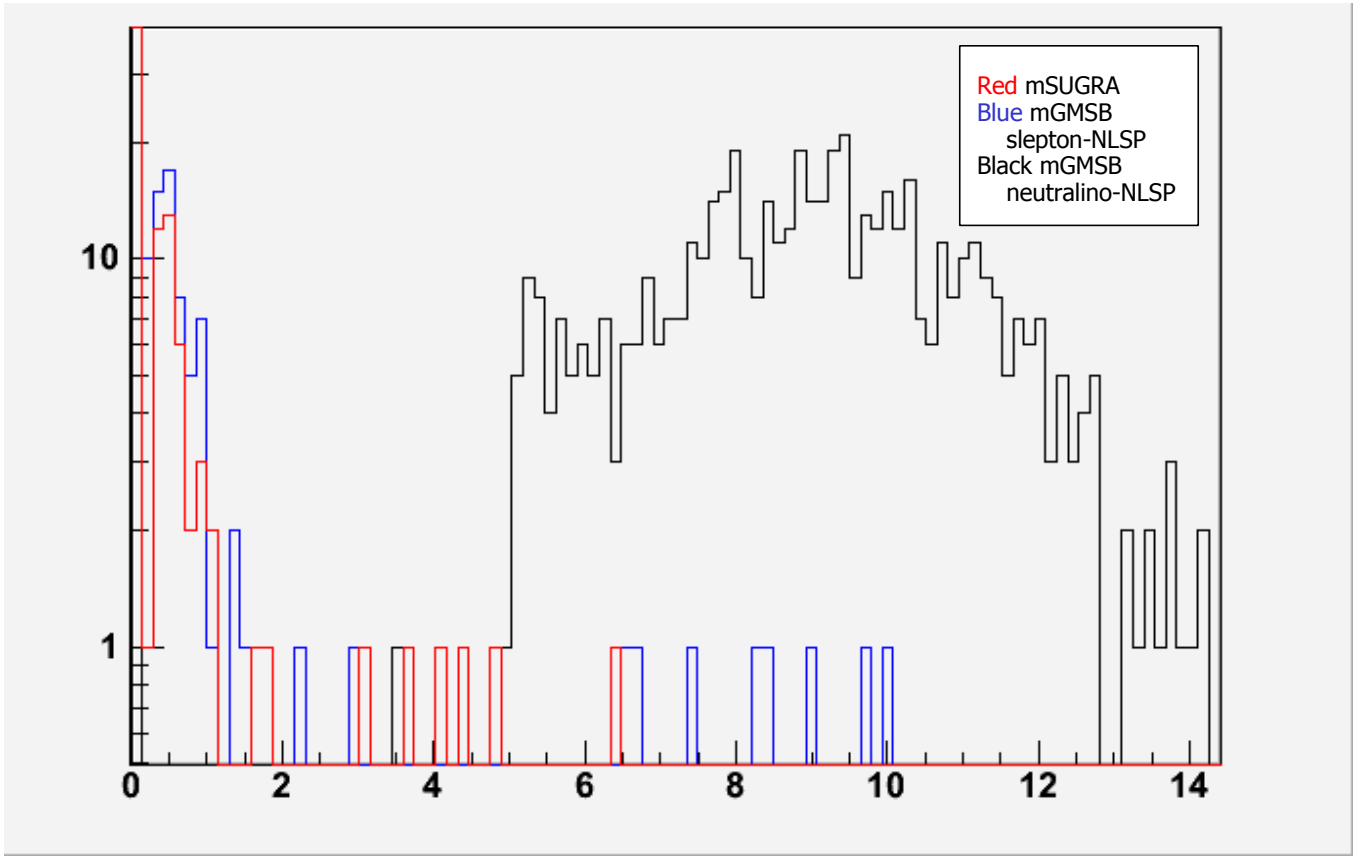
tan beta = 10,20,...,50 (mSUGRA)
10,40 (mGMSB)

Cuts

	$E^{\mathrm{T}}_{\mathrm{miss}}$	M_{eff}	$E^{\mathrm{T}}_{\mathrm{miss}}/M_{\mathrm{eff}}$	4/2 jets	other
SS2ℓ	100	1000		(100,50)	$\ell_2 > 20$
2γ	200			(90,60)	
0ℓ+4 jets	200	1000	0.2/0.3	(100,50)	$\ell < 10$
0ℓ+2 jets	300	1200	0.3	(300,200)	$\ell < 10$

Discrimination of mGMSB with neutralino-NLSP

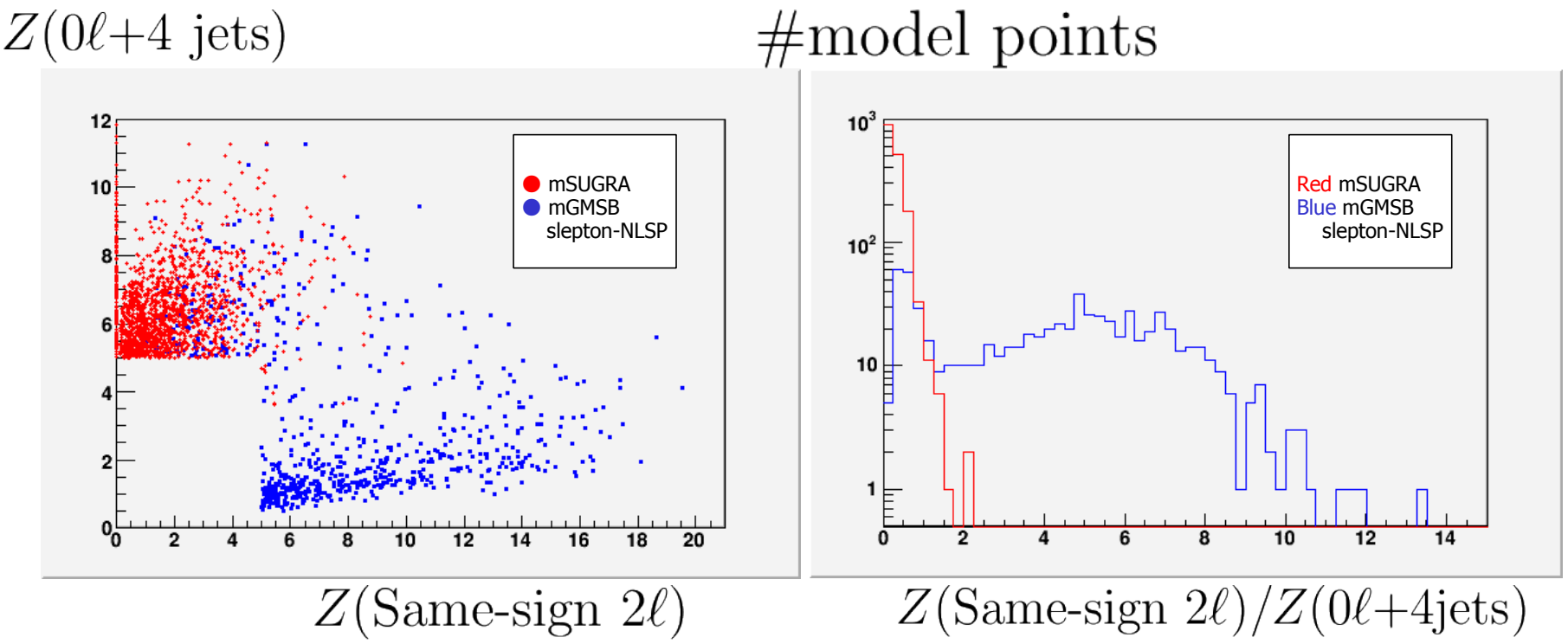
#model points



$Z(2\ \text{diphoton})$

The neutralino-NLSP case can easily be discriminated.

mSUGRA vs mGMSB with slepton-NLSP



Most mGMSB model points are discriminated from mSUGRA poins
But, mGMSB with nearly degenerated slepton-bino contaminates.

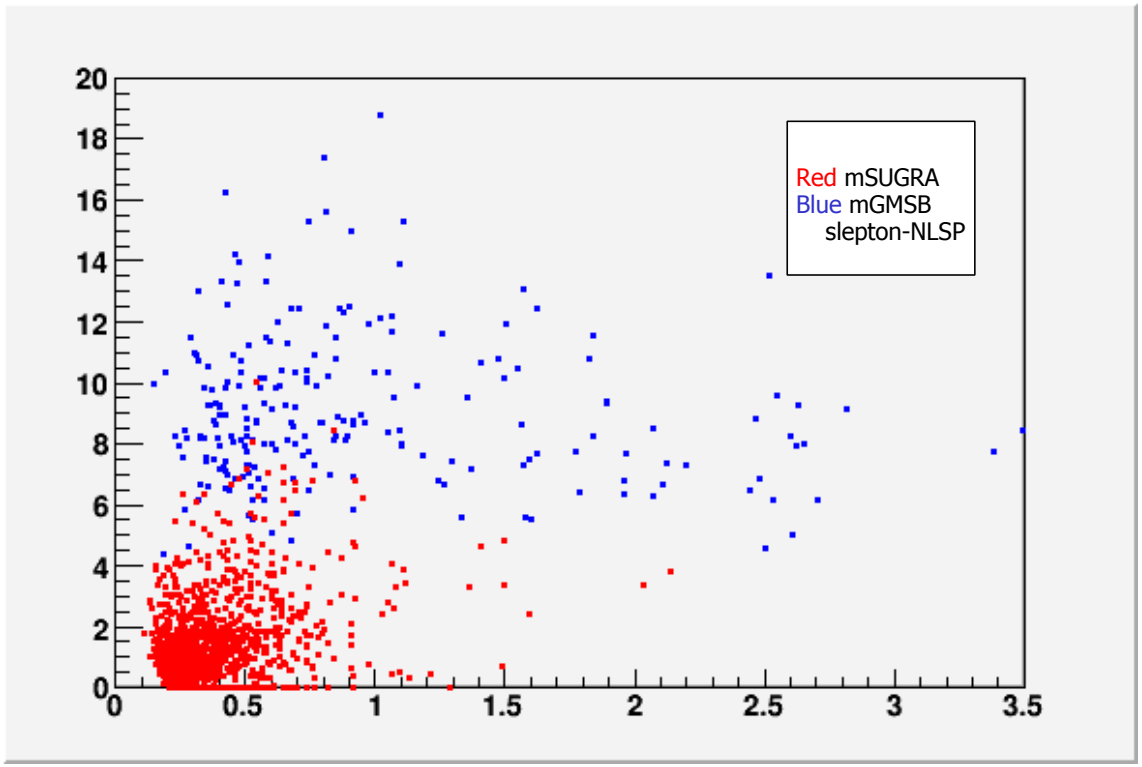
mSUGRA vs mGMSB with slepton-NLSP

mGMSB with nearly degenerated slepton-bino contaminates.

In this case, more taus are expected.

mSUGRA vs mGMSB with slepton-NLSP

$Z(2\tau)$

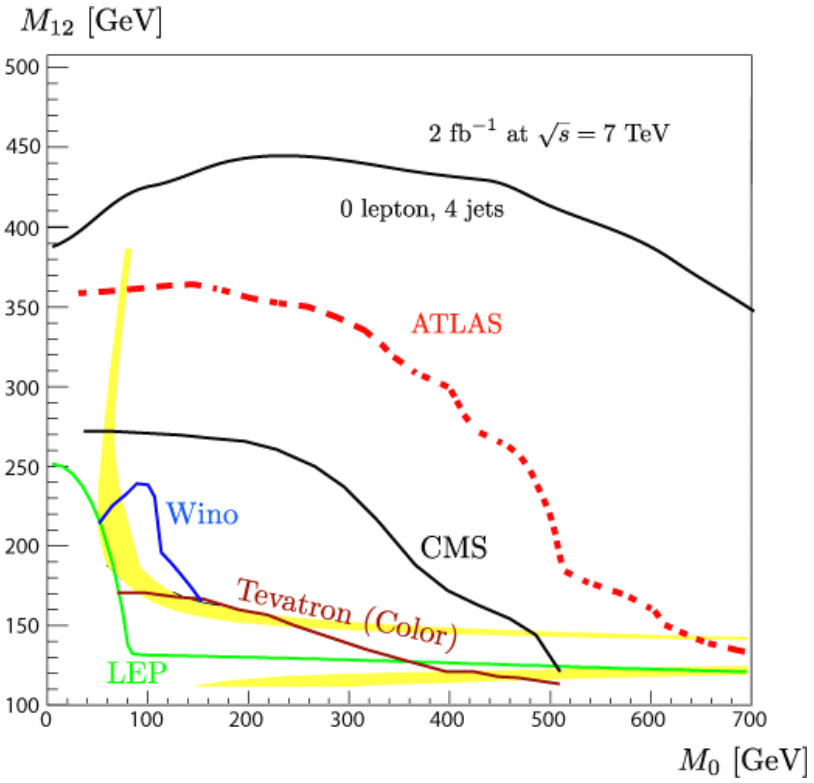


$Z(\text{Same-sign } 2\ell)/Z(0\ell{+}4\text{jets})$

かなり満足

Discremination among mSUGRA model points

For neutralino DM, the focus point and coannihilation point are interesting.



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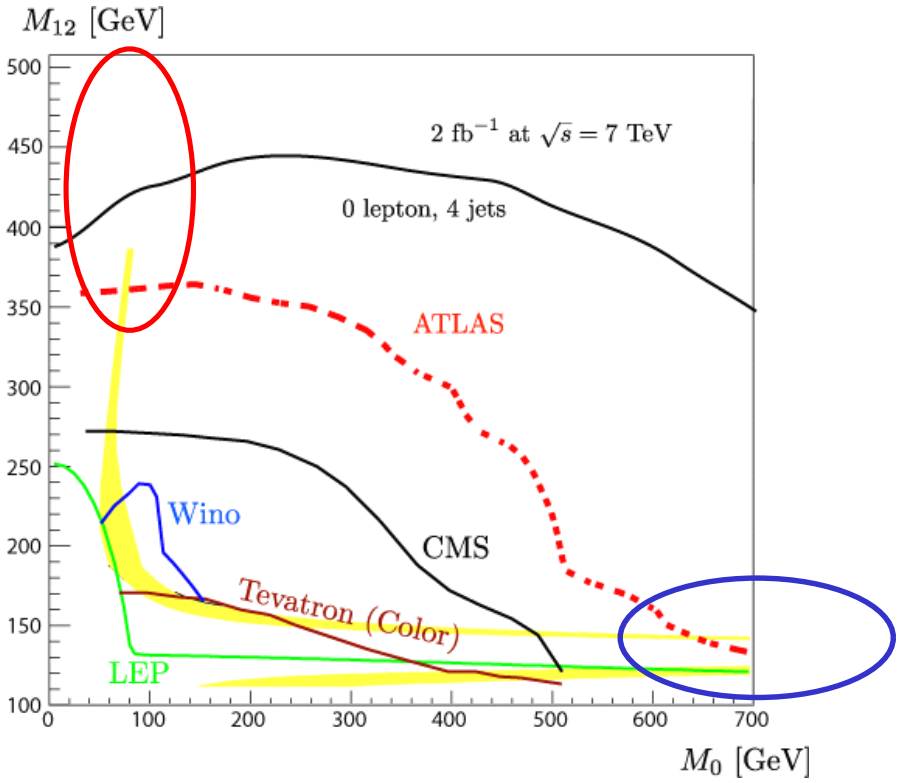

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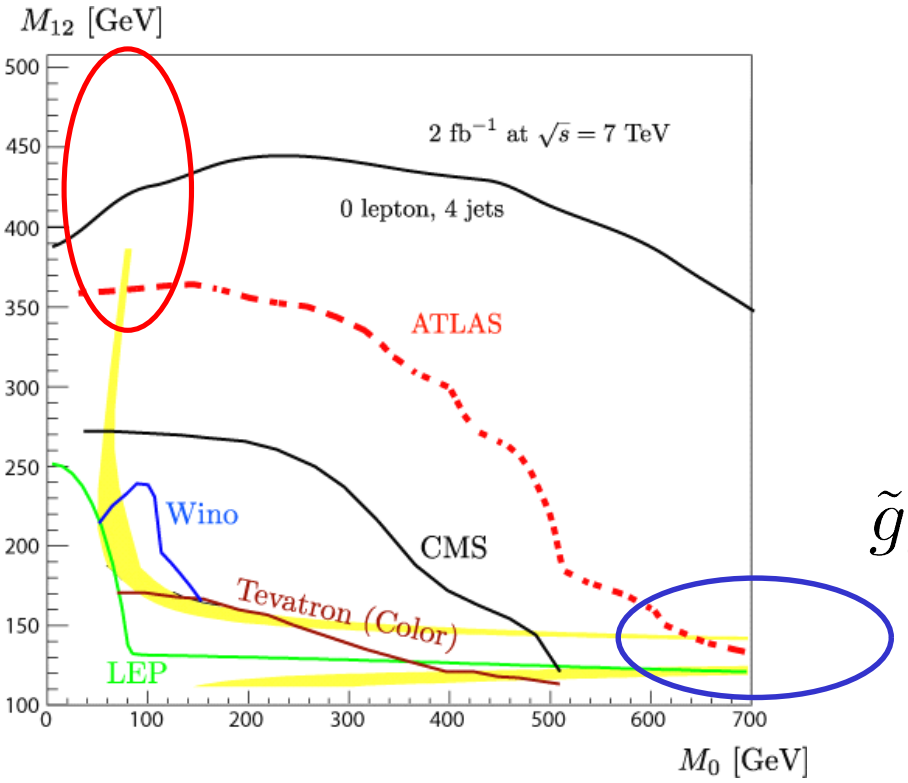
$\tilde{q}\tilde{q}, \tilde{q}\tilde{g}$ dominated



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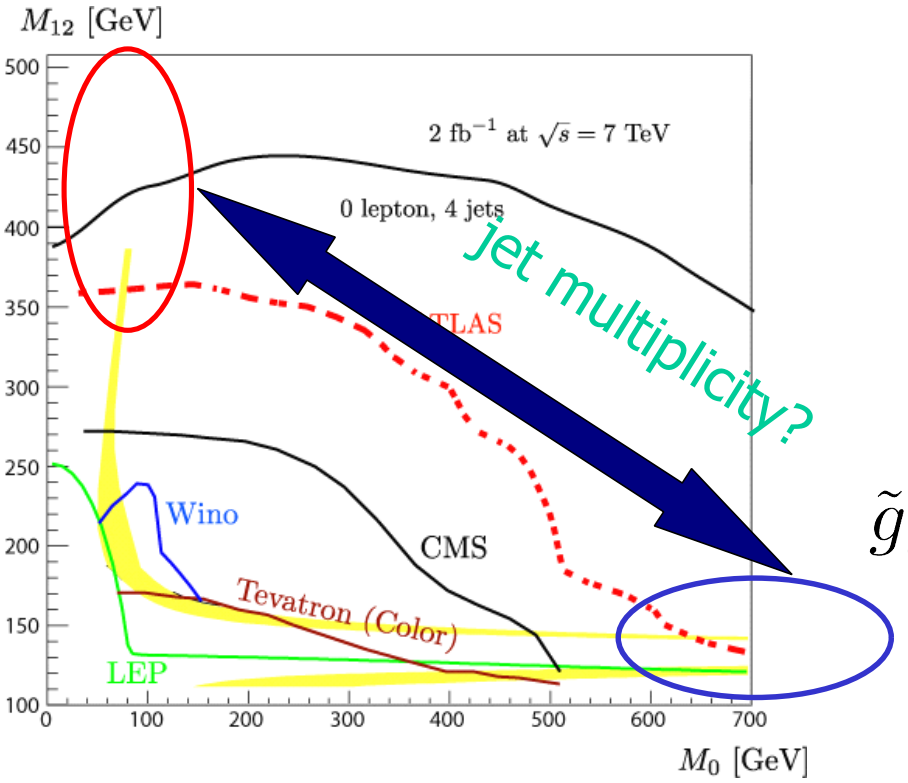

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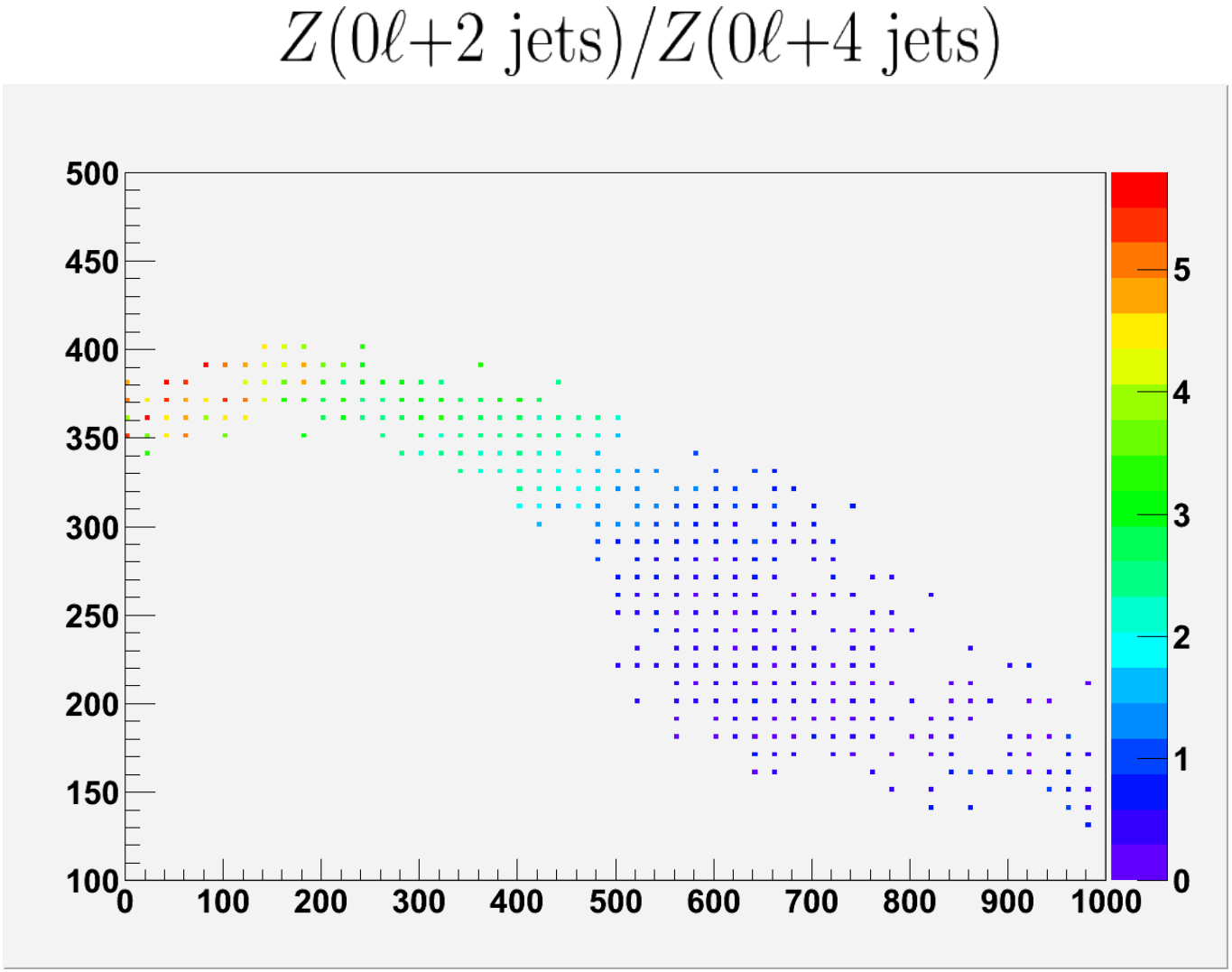

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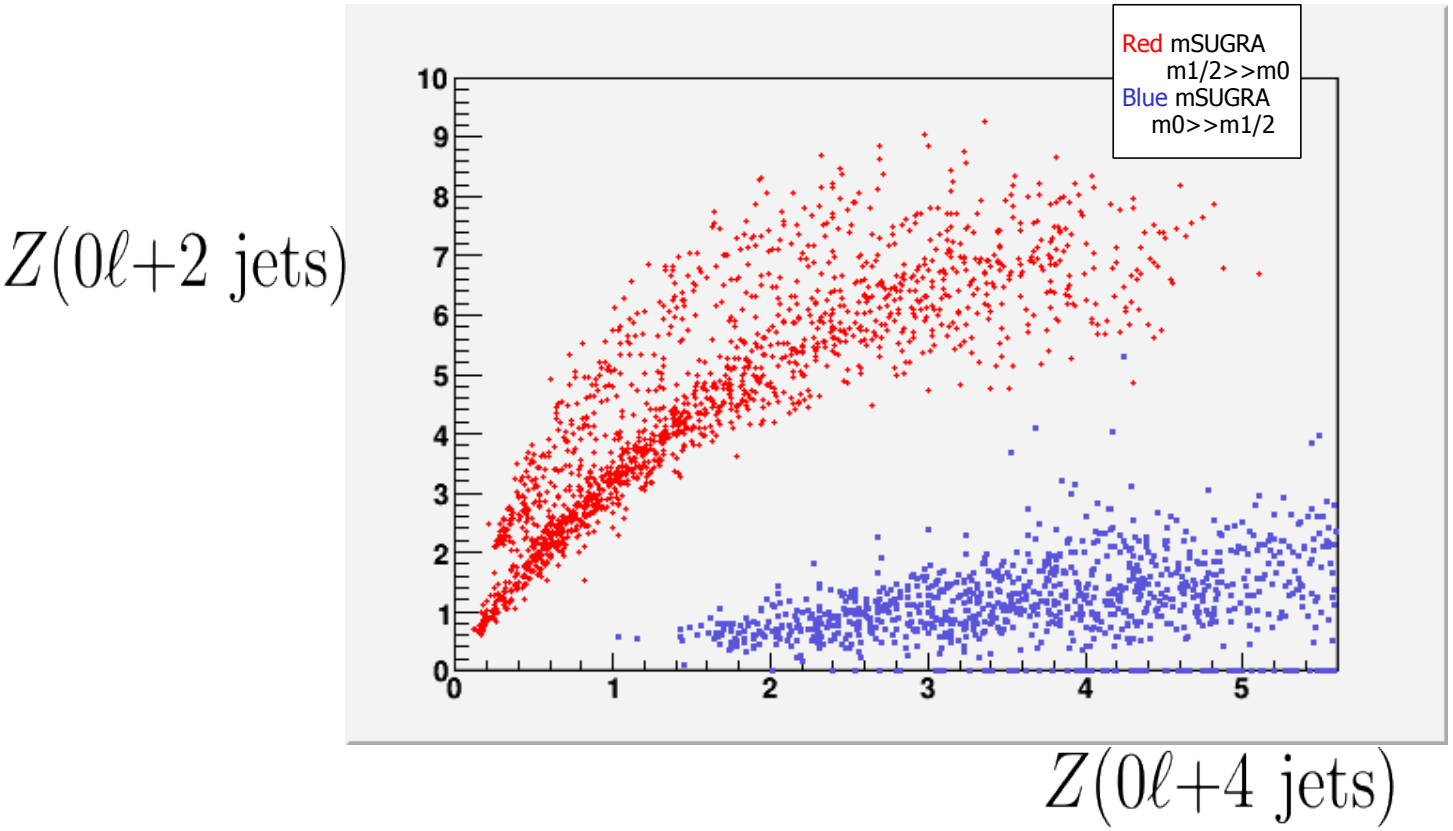

Summary

Early LHC (2fb-1 @ 7 TeV) でのmSUGRAとmGMSBのdiscriminationを考えた.

0 lepton+4 jets/SS 2 lepton(tau)/2 photon modeでかなり区別が出来る.

2j mode/4j mode (jet multiplicity)を使ってmSUGRAの(m0-m1/2)-planeの位置の情報もある程度得られそう.