

Tree Level Gauge Mediation Phenomenology in the LHC era

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based on


MM, Pierini, Romanino, Spinrath (to appear soon)

SUSY and SUSY breaking

- Supersymmetry is one of the most attractive possibilities beyond SM
 - Stabilizes the EW scale
 - Provides candidates for Dark Matter
 - Predicts gauge coupling unification
 - Provides a scenario for radiative EWSB
- It predicts new particles with different statistic with respect to SM

These particles should have
the same mass of SM ones

Partners of SM particles
never observed



SUSY must be broken in the
vacuum state chosen by Nature

- The situation is quite involved. The correct statement on masses of the particles is in Str formula

$$Str \mathcal{M}^2 \equiv 3tr \mathcal{M}_1^2 - 2tr \mathcal{M}_{\frac{1}{2}} \mathcal{M}_{\frac{1}{2}}^\dagger + tr \mathcal{M}_0^2 = -2g \langle D^a \rangle tr T^a$$

It holds in spontaneously
broken SUSY theories

§

@ tree level for
renormalizable theories

- Many hints that a separate sector for SUSY breaking is needed



Loop Gauge Mediation (standard approach)

[Giudice, Rattazzi (1998)
and refs. therein]

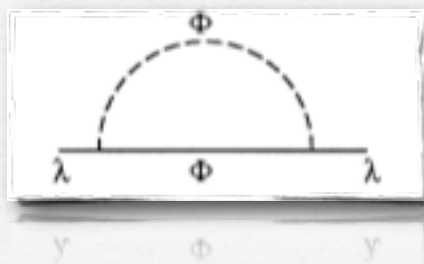
The hidden sector provides SUSY breaking.

The messenger sector is made of chiral superfields:

- Interact with observable sector through gauge interactions
- Interact with hidden sector through superpotential interactions

Gaugino masses

Arise from 1-loop graph

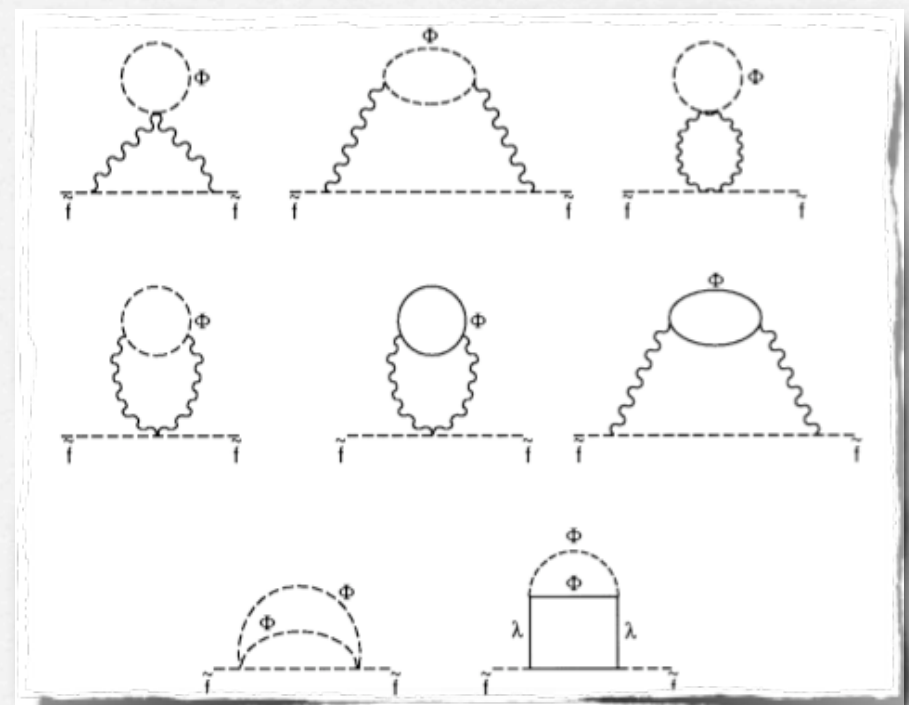


Trilinear soft terms

Arise from RG evolution from SUSY breaking scale down to EW one.

Sfermion masses

Arise from 2-loop graphs

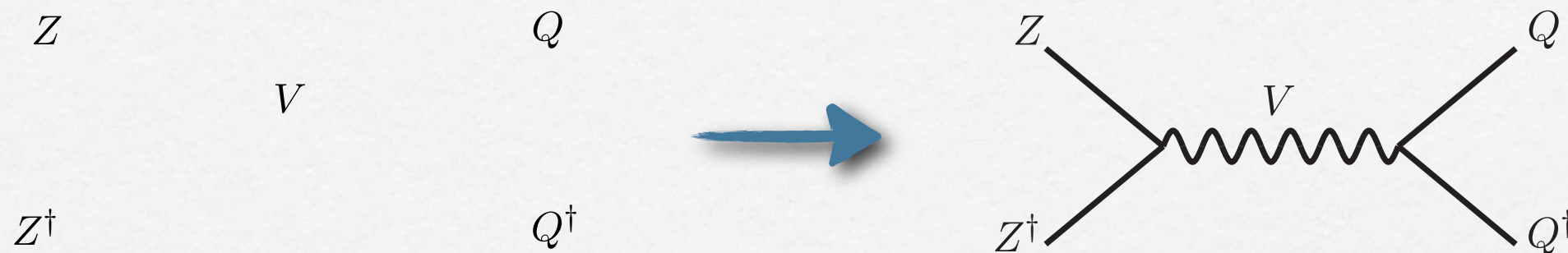


Tree Level Gauge Mediation

[Nardecchia, Romanino, Ziegler (2009)]

- what about going tree level?

$$\int d^4\theta \frac{ZZ^\dagger QQ^\dagger}{M^2}$$



- why usually loop gauge mediation is used?

$$Str \mathcal{M}^2 \equiv 3tr \mathcal{M}_1^2 - 2tr \mathcal{M}_{\frac{1}{2}} \mathcal{M}_{\frac{1}{2}}^\dagger + tr \mathcal{M}_0^2 = -2g \langle D^a \rangle tr T^a$$

The Supertrace formula (valid at tree level for renormalizable theories with spontaneous SUSY breaking) seems to prevent Tree Level Gauge Mediation

from experiments



$$Str \mathcal{M}^2|_{MSSM} > 0$$

$\langle D^Y \rangle$ not suitable

- What are the key ingredients is quite clear now...

Extend the gauge group: $\langle D^X \rangle$ suitable

Easy to obtain with
SUSY GUTs

Add extra matter fields: $Str \mathcal{M}^2|_{\text{MSSM}} + Str \mathcal{M}^2|_{\text{extra}} = 0$

- The simplest way: a $SO(10)$ model

$$SO(10) \supset SU(5) \times U(1)_X$$

$SU(5)$ irrep_X charge

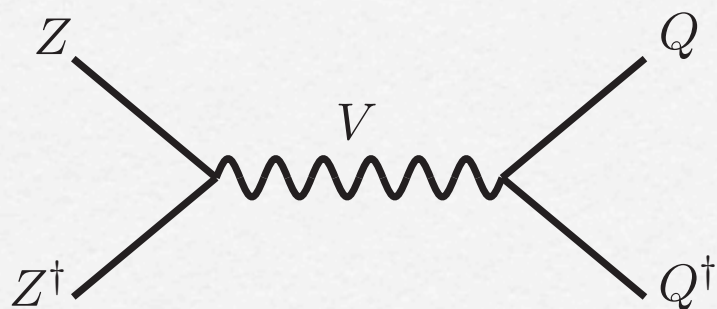
$$16 = 10_1 + \bar{5}_{-3} + 1_5 \qquad 10 = \bar{5}_2 + 5_{-2}$$

- GUT breaking $SO(10)$ to $SU(5)$...

$$\langle 1^{16} \rangle = \langle 1^{\bar{16}} \rangle = M$$

- SUSY breaking...

$$\langle 1^{16'} \rangle = \theta^2 F$$



$$V \equiv X, \langle Z \rangle = \theta^2 F$$

$$\tilde{m}_Q^2 = 2g^2 X_Q X_Z \frac{|F|^2}{M_V^2}$$

For observable MSSM fields we want $X_Q X_Z > 0$

- Model building...

$$16 = 10_1 + \bar{5}_{-3} + 1_5$$

$$10 = \bar{5}_2 + 5_{-2}$$

$$X_Z = 5$$



$$10_1 = (q, u^c, e^c)$$

$$\bar{5}_2 = (d^c, l)$$

NON STANDARD
MATTER EMBEDDING

- Nice prediction for soft masses (@ GUT scale)...

$$\frac{\tilde{m}_Q^2}{\tilde{m}_{Q'}^2} = \frac{X_Q}{X_{Q'}}$$



$$\frac{\tilde{m}_{q,u^c,e^c}^2}{\tilde{m}_{d^c,l}^2} = \frac{1}{2}$$

TESTABLE

Light MSSM superfields

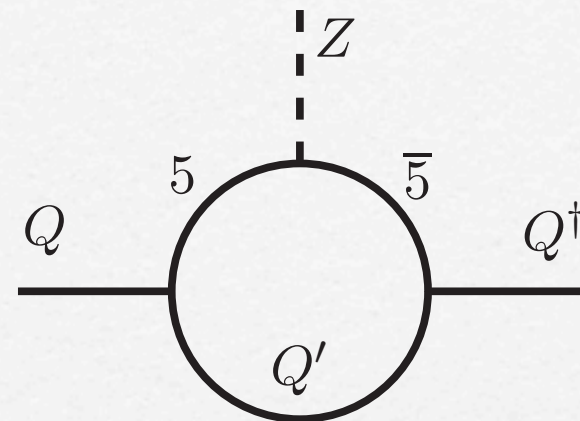
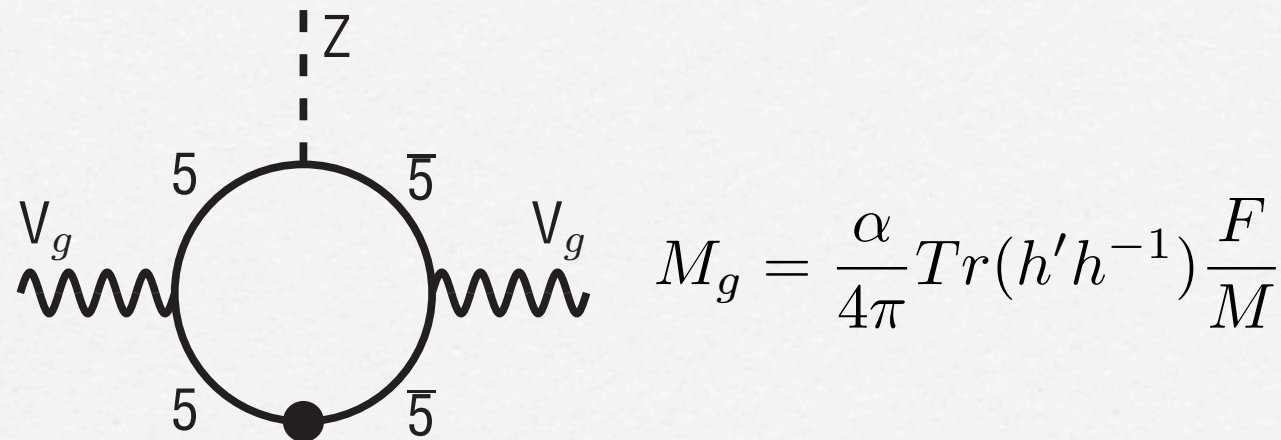
$$16 = 10_1 + \bar{5}_{-3} + 1_5$$

$$10 = \bar{5}_2 + 5_{-2}$$

- The other superfields ($\bar{5}_{-3}$, 5_{-2}) get an heavy mass from $SO(10)$ breaking through superpotential yukawa interactions

$$W = \frac{y_{ij}}{2} 16_i 16_j 10 + h_{ij} 16_i 10_j 16 + h'_{ij} 16_i 10_j 16'$$

- Moreover $\bar{5}_{-3}, 5_{-2}$ become chiral messengers responsible for 1-loop gaugino masses and trilinears...



- If one breaks $SU(5)$ to SM extra peculiarities arise!!!

[MM, Pierini, Romanino, Spinrath]

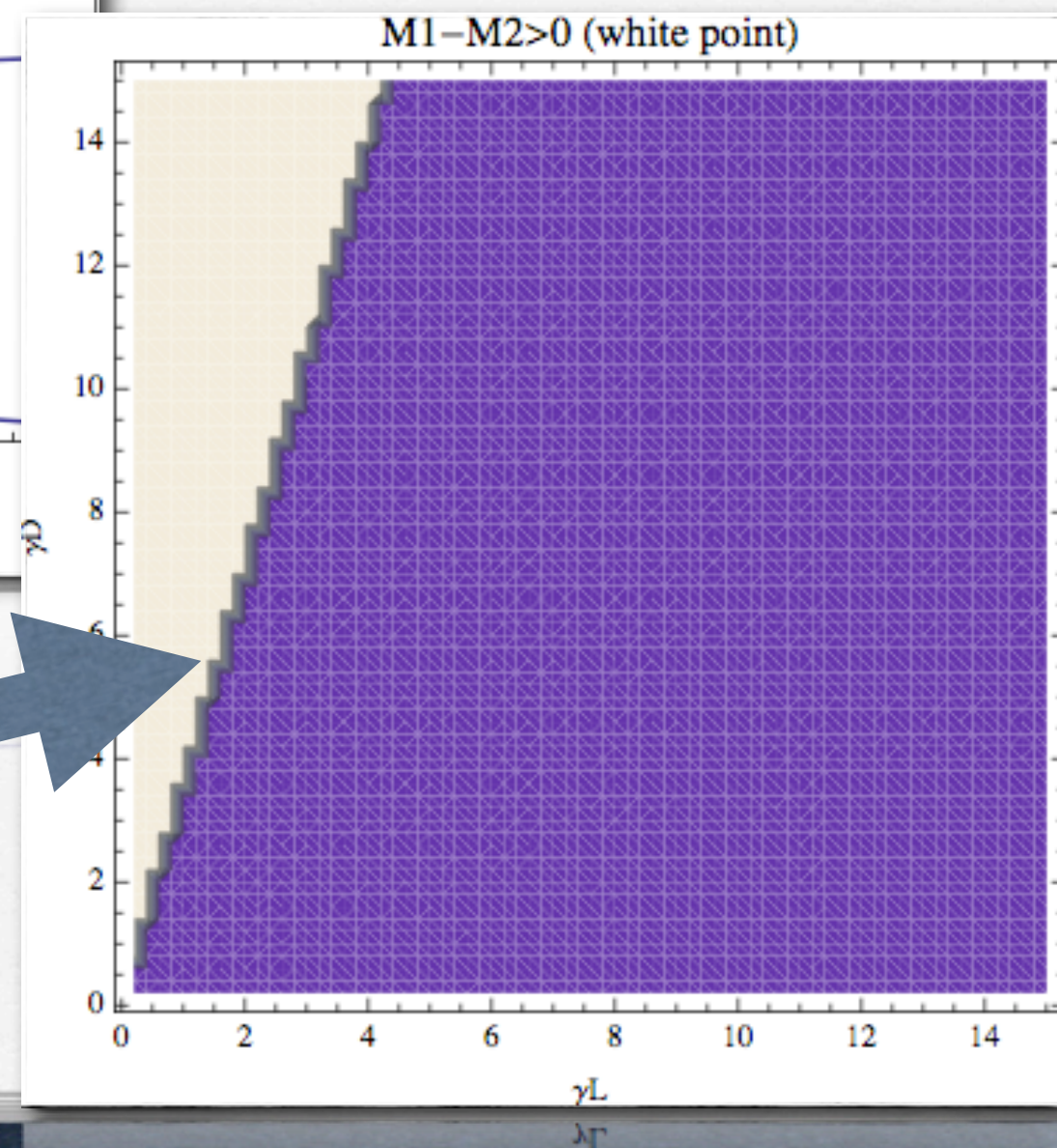
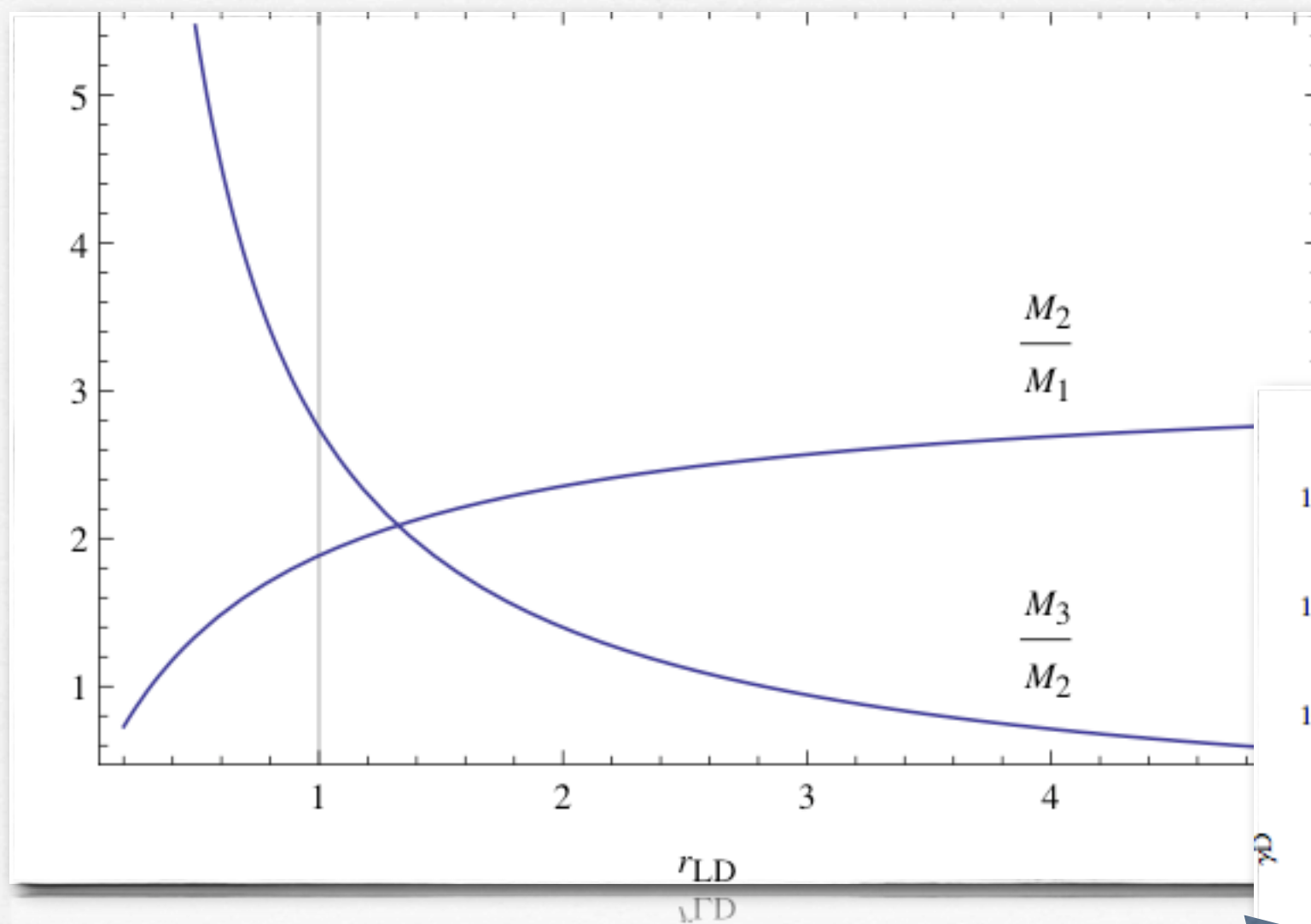
Non universal gaugino masses, but a sum rule @ GUT scale!!!

$$M_1 = \frac{3}{5} M_2 + \frac{2}{5} M_3$$

- Summing up the relevant parameters are...

$$\tilde{m}_{10} \quad M_{1/2} = \frac{M_2 + M_3}{2} \quad r = \frac{M_2}{M_3} \quad \theta_u, \theta_d \quad \tan\beta \quad \text{sign}\mu$$

Gaugino masses and non universalities



For $r < 0.3$
Wino < Bino

The NLSP

Parameters

$$\cos^2 \theta_d = 0.8$$

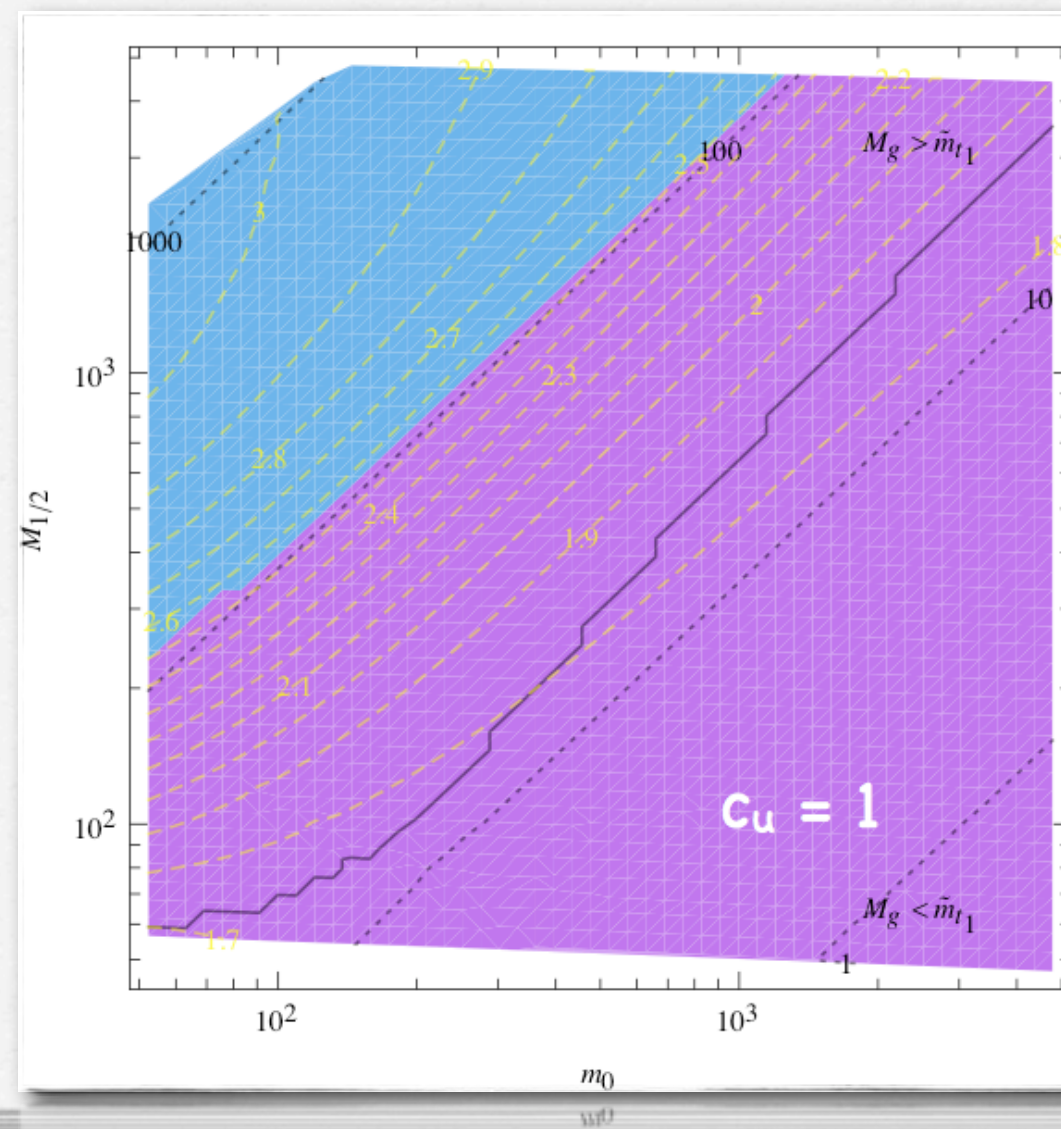
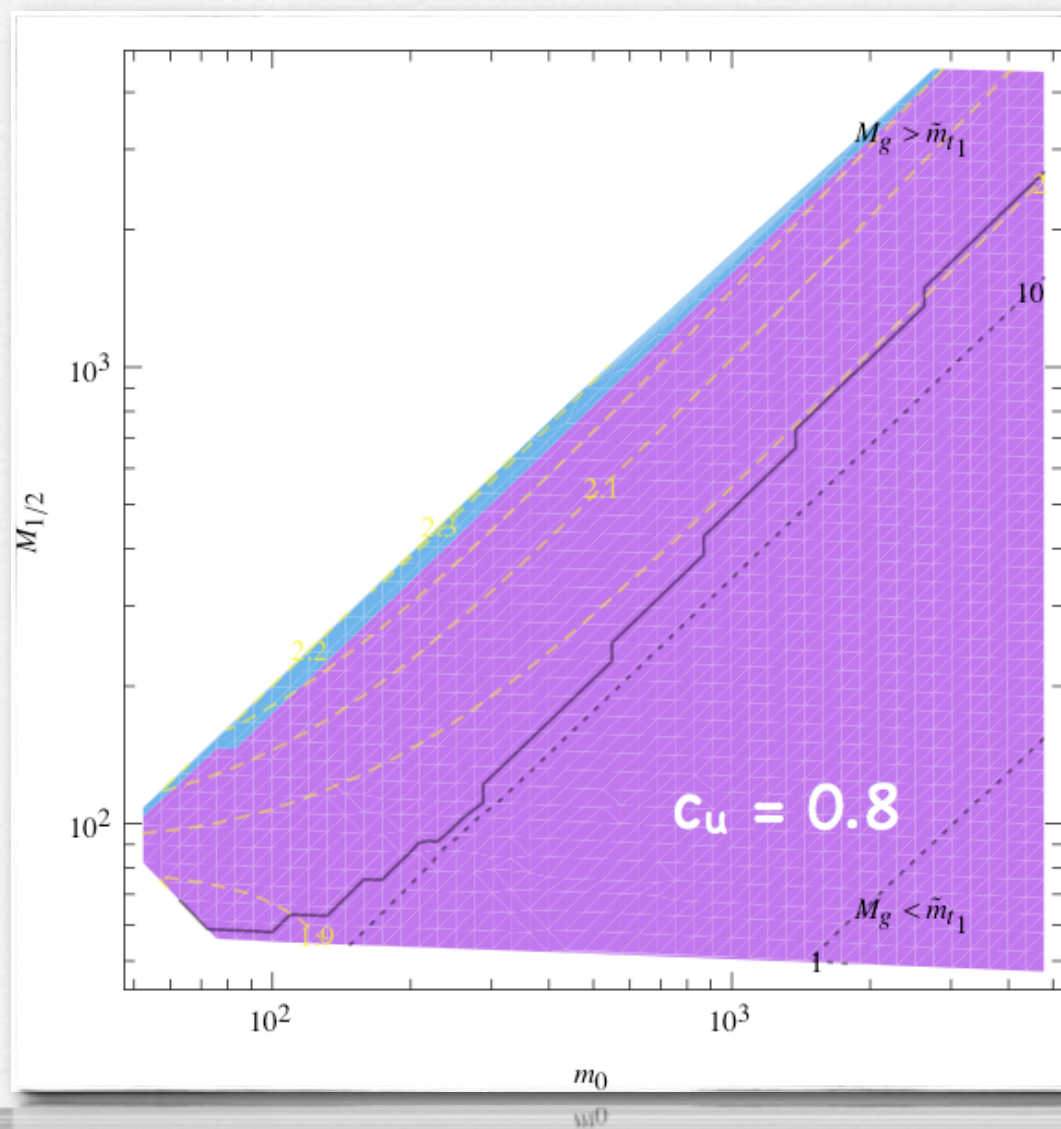
$$r = 1, \tan \beta = 10$$

NLSP?

- For $r < 0.3$ is the Wino

- Otherwise....

blue = Stau, purple = Bino



Discovering TGM... the RAZOR approach

1. Discover SUSY...

2. Find the TGM smoking gun... the nice 1/2 ratio of sfermion masses

• The RAZOR variables $pp \rightarrow G_1 G_2 \rightarrow Q_1 \chi_1 + Q_2 \chi_2$

massive, unseen

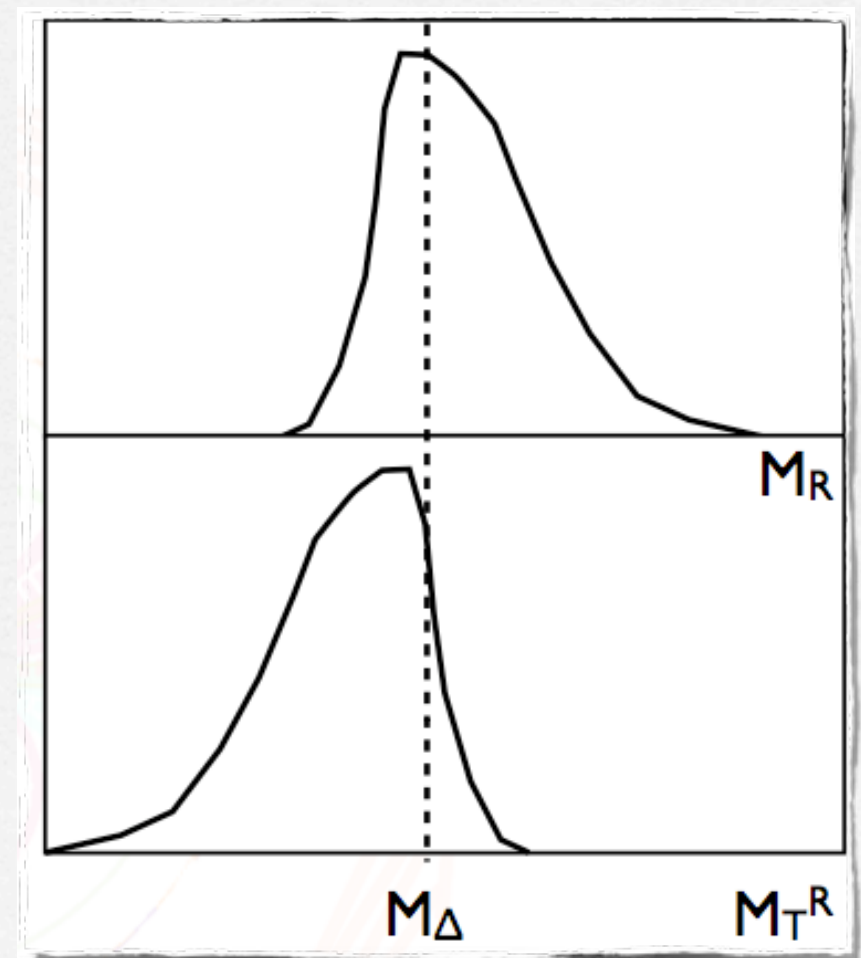
massless, seen

$$M_{\Delta} = \frac{M_G^2 - M_{\chi}^2}{M_G}$$

$$M_T^R \equiv \sqrt{\frac{E_T^{miss}(p_T^{j1} + p_T^{j2}) - \vec{E}_T^{miss}(\vec{p}_T^{j1} + \vec{p}_T^{j2})}{2}}$$

$$M_R \equiv \sqrt{(E_{j1} + E_{j2})^2 - (p_z^{j1} + p_z^{j2})^2}$$

$$R \equiv \frac{M_T^R}{M_R}$$



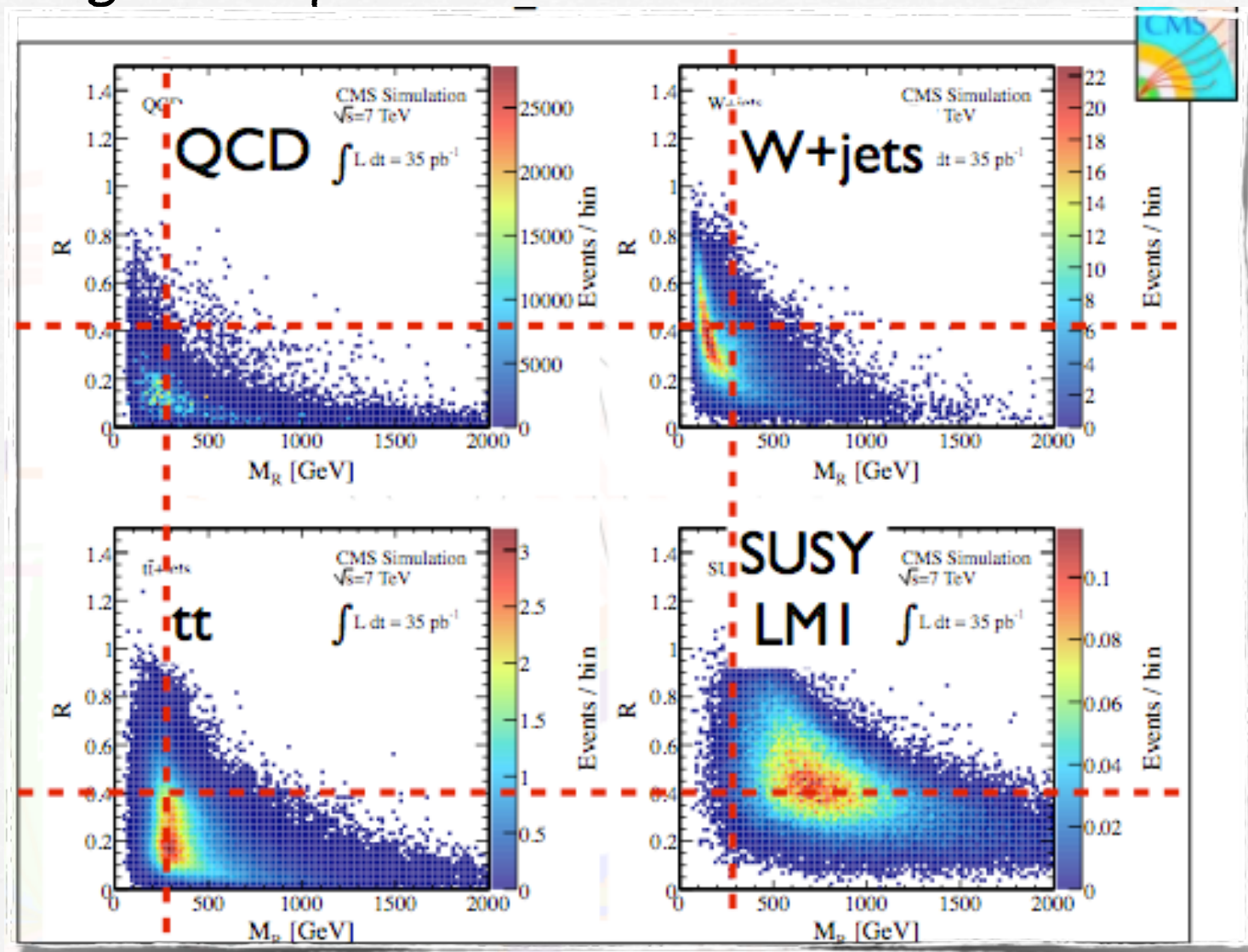
- very useful for discriminating SUSY events!!!

- For signal events

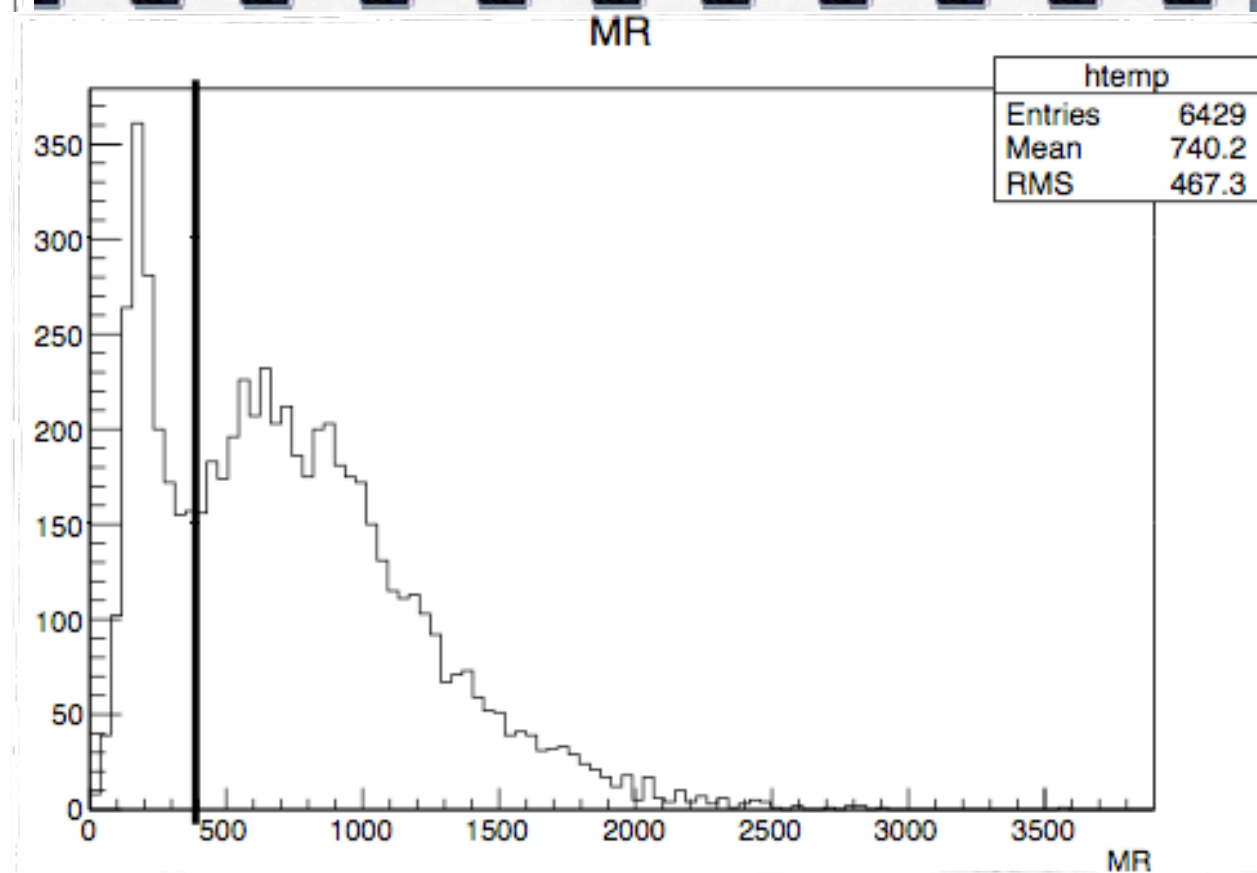
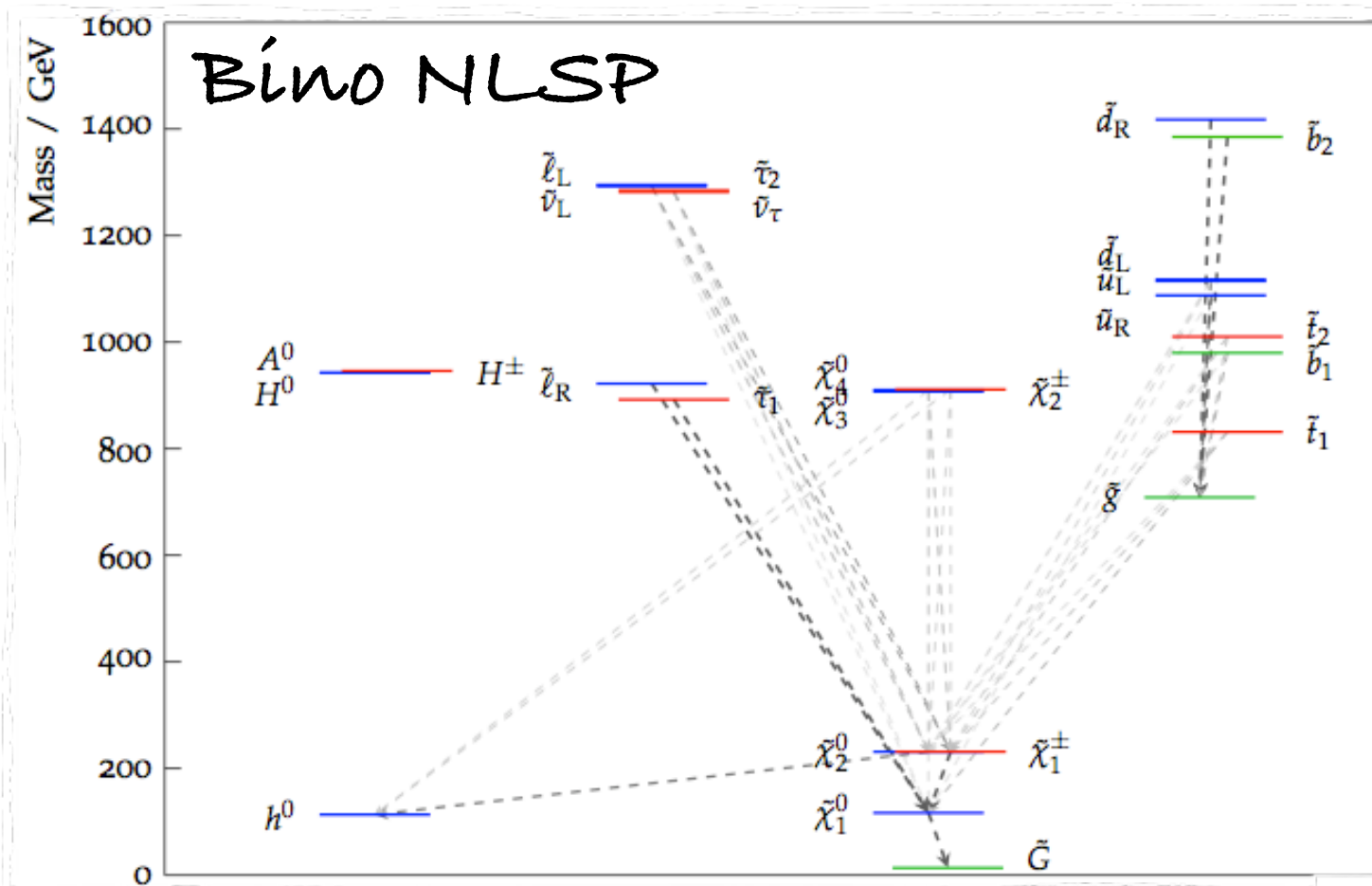
- M_R peaks at M_Δ

- M_R^T has edge at M_Δ

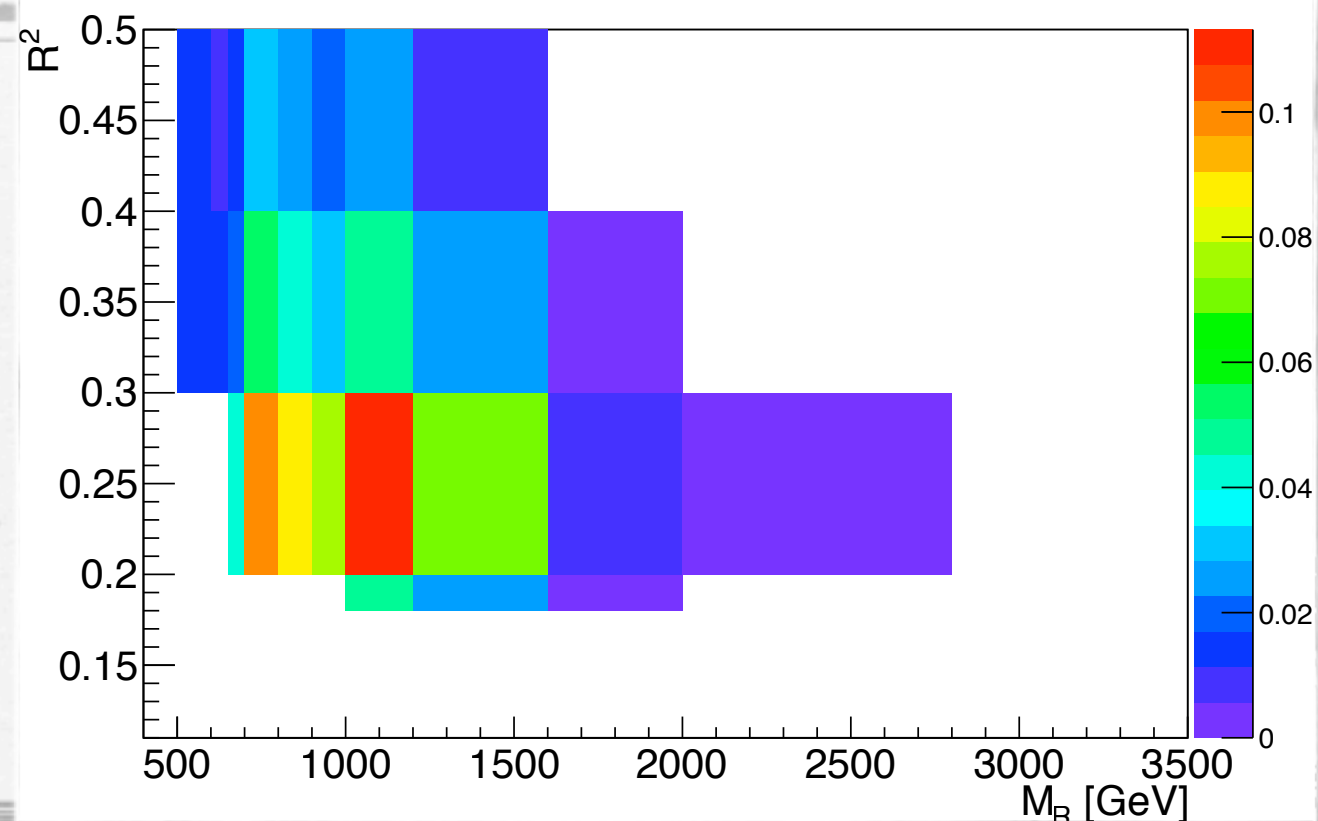
- R peaks at 0.5

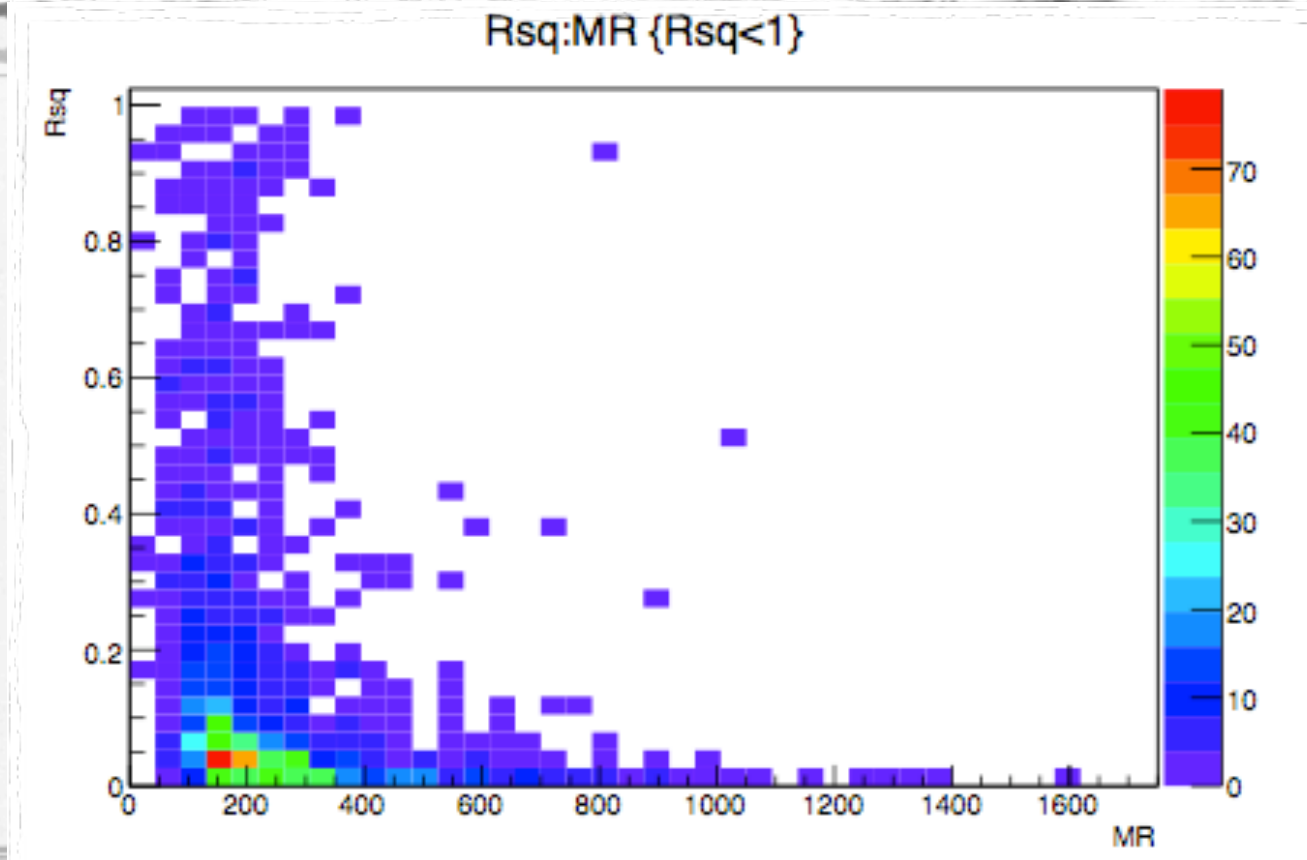
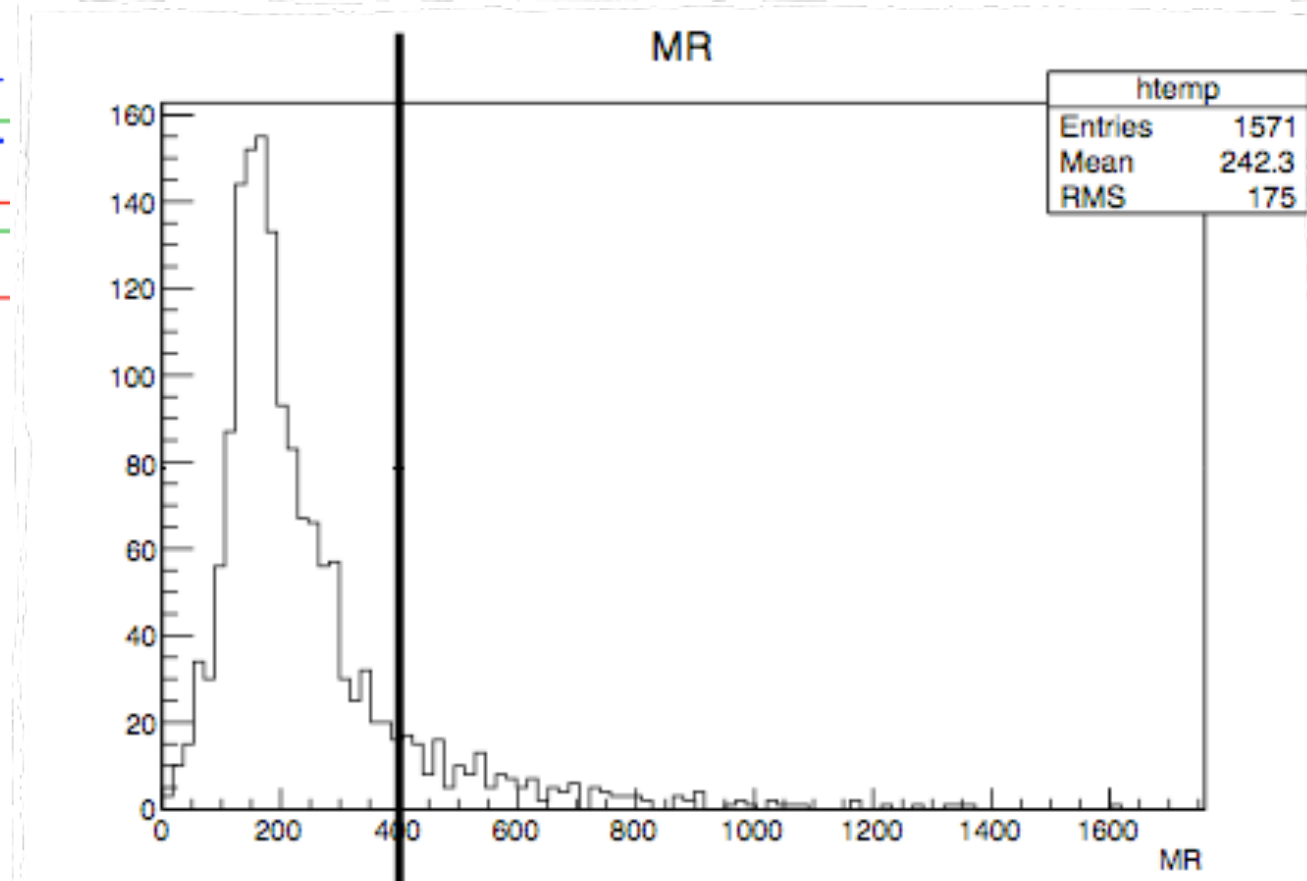
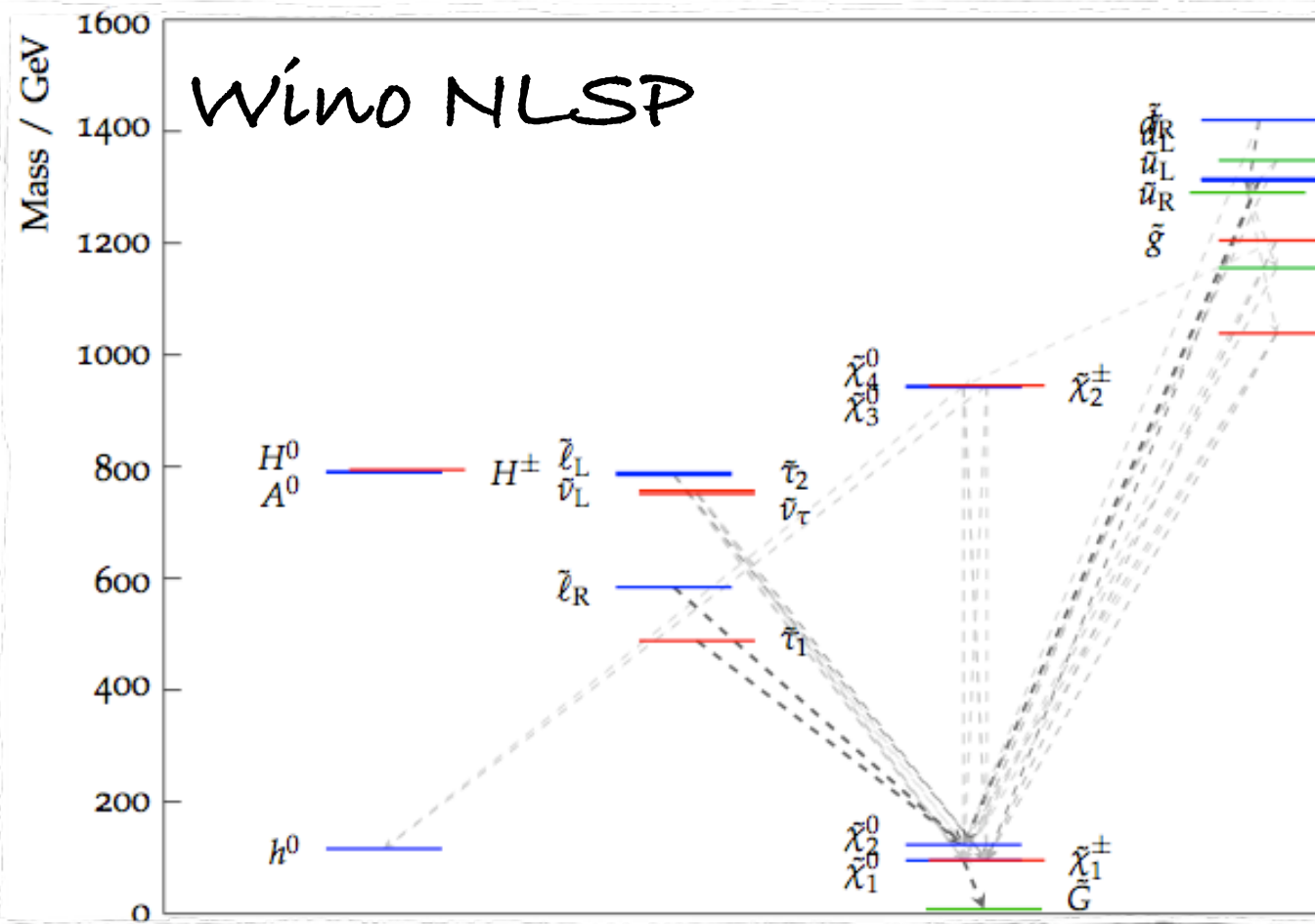


- TQM can be spot from the shape (the peaks) of M_R !!!



- Higgs in χ_2^0 cascade decays (80/90%)
- Can be seen from Razor analysis...
- ...but better to be seen from exclusive searches
- DISCLAIMER: multijet b-enriched final state still not very considered

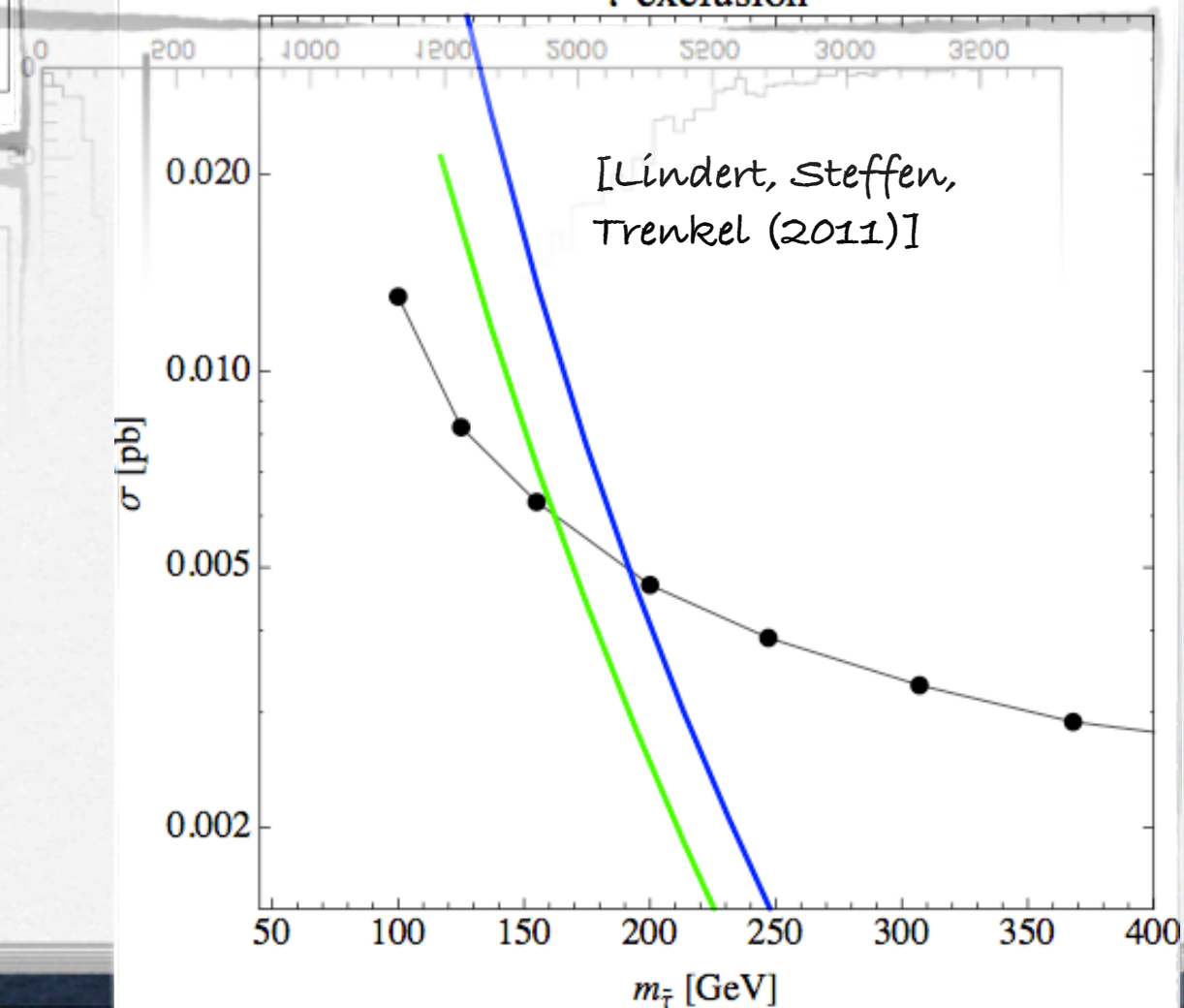
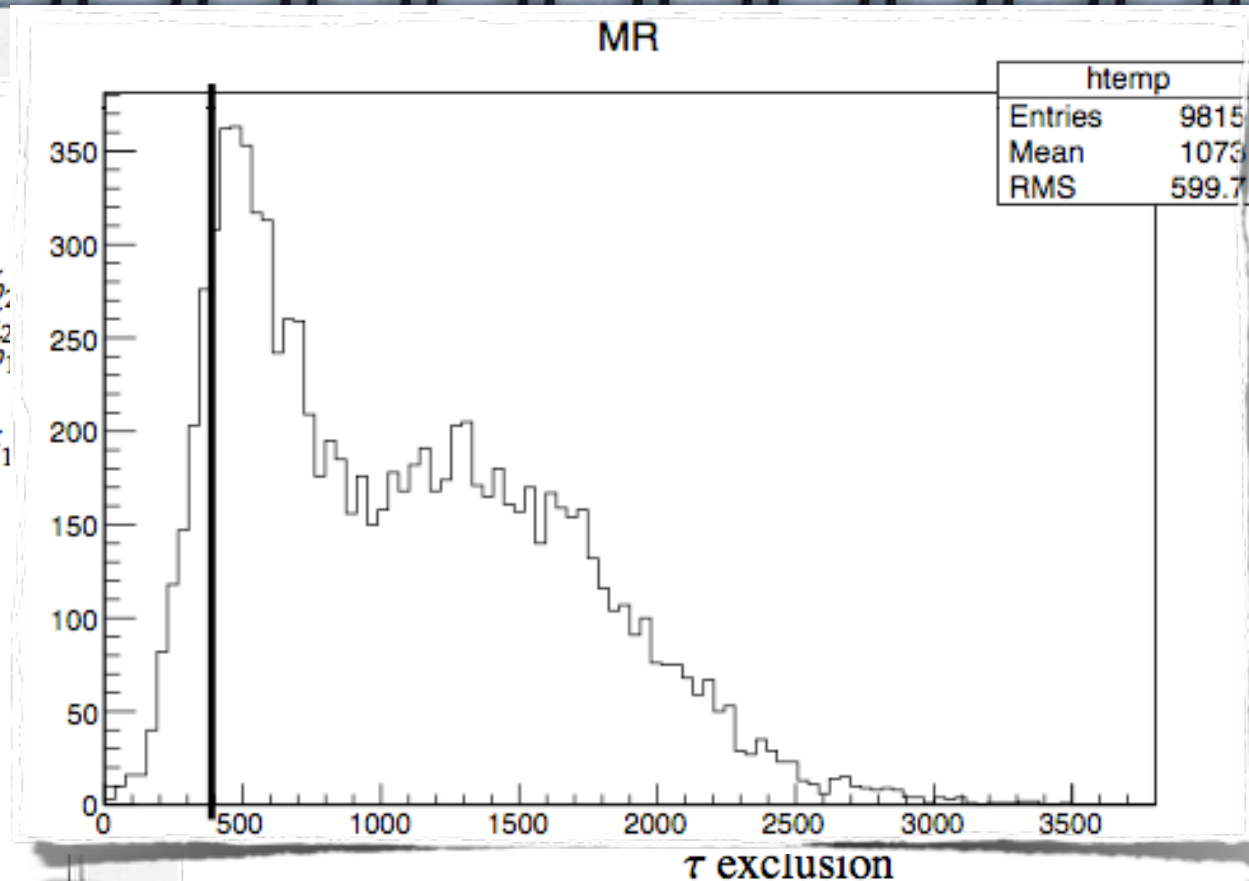
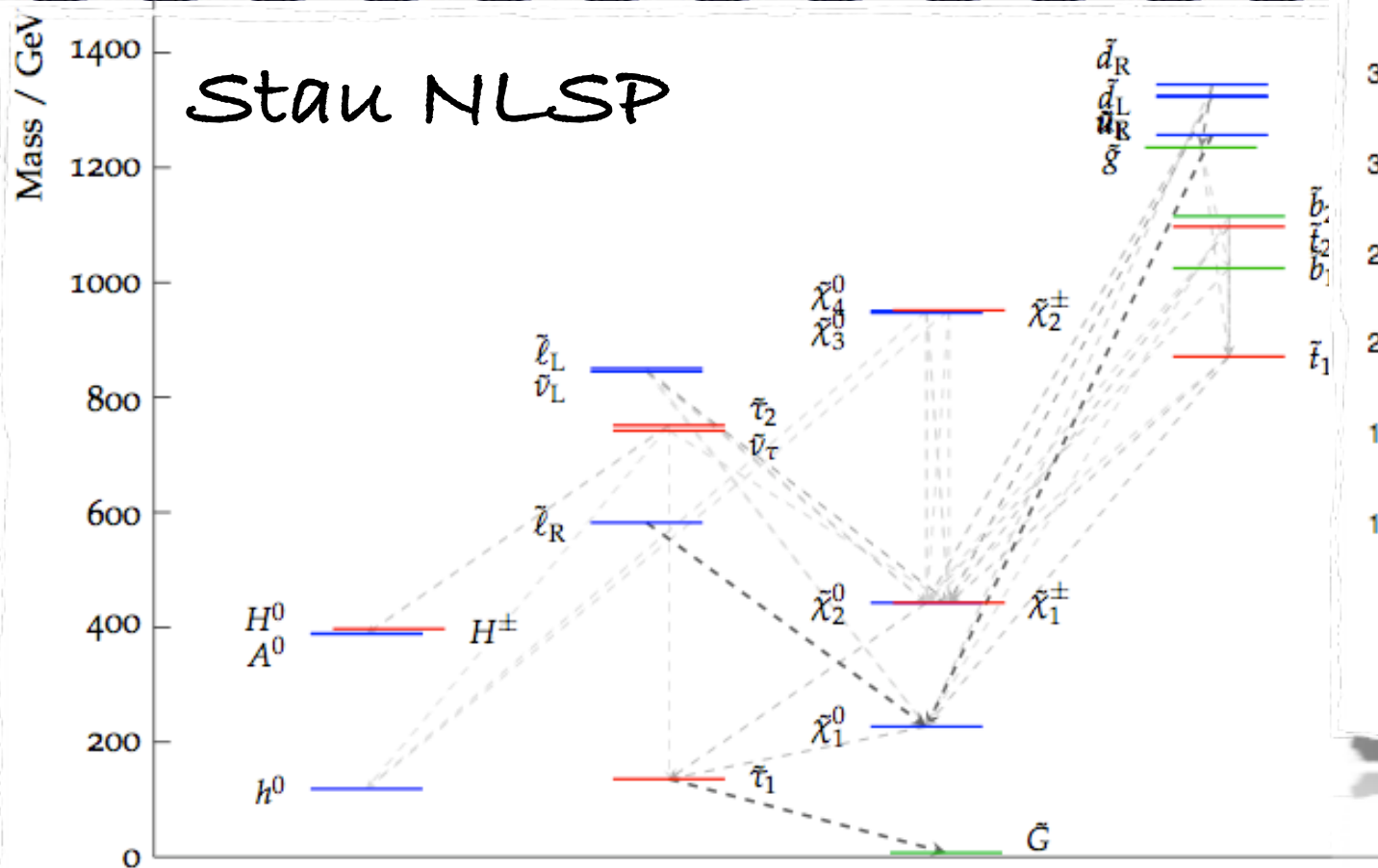




- Largish spectrum and very small x-sections, whole 2012 run probably necessary for getting relevant results



- Perfect for Razor analysis



- Limit on stau mass > 180 GeV from EXOTICA analyses

CONCLUSIONS

- TQM is a simple and testable scenario at the LHC...
....with nice predictions!!!
- In $SO(10)$ realization has a peculiar relation for the ratio of soft masses
- can have very different phenomenologies depending on the NLSP
- can be tested through inclusive (Razor) or exclusive analyses...
...need for multi-b oriented searches (still not on the market)