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PHENOMENOLOGY OF SUSY WITH INTERMEDIATE SCALE PHYSICS

*Work in progress
with L. Calibbi & A. Masiero & S. Vempati*

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SUSY WITH INTERMEDIATE SCALES

- Physics at scales intermediate between EW and GUT is common in many models:
 - ✓ seesaw mechanism for neutrino masses
 - ✓ multiscale models: Pati-Salam or L-R symmetric groups
 - ✓ FN models with messengers
 - ✓ ...

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we can test very high scales with the LHC!

- We assume intermediate scale physics in complete SU(5) repr.
 \rightarrow unification is not spoiled and M_{GUT} is the same

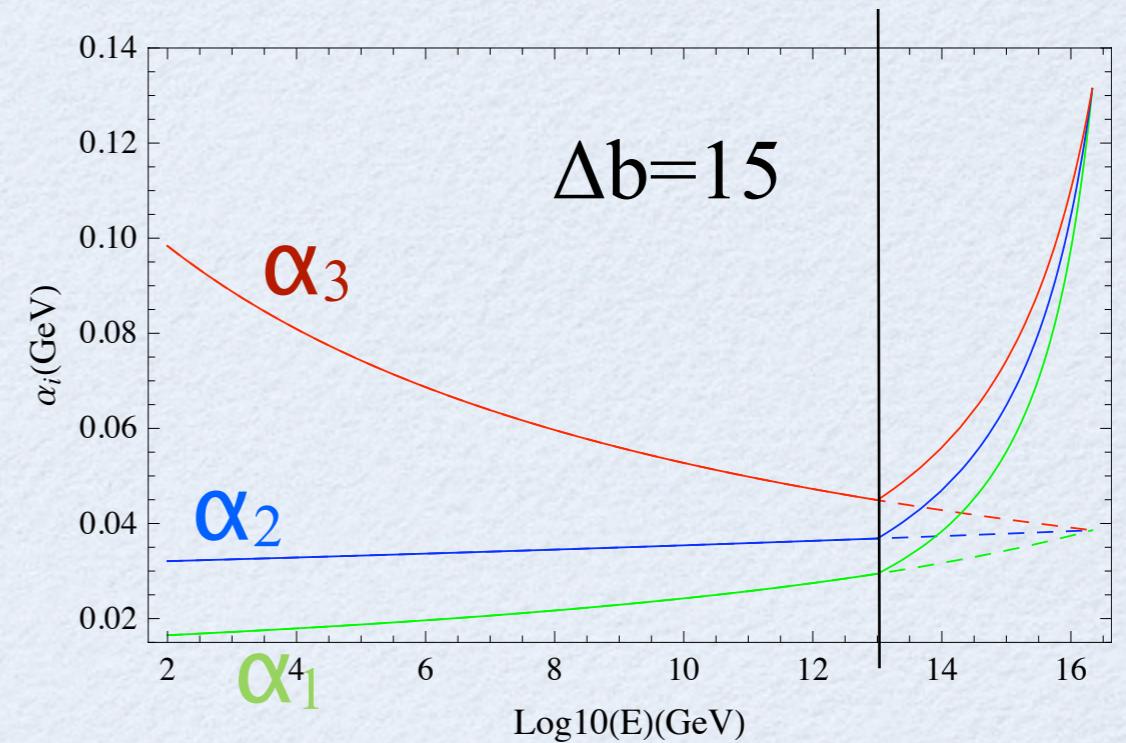
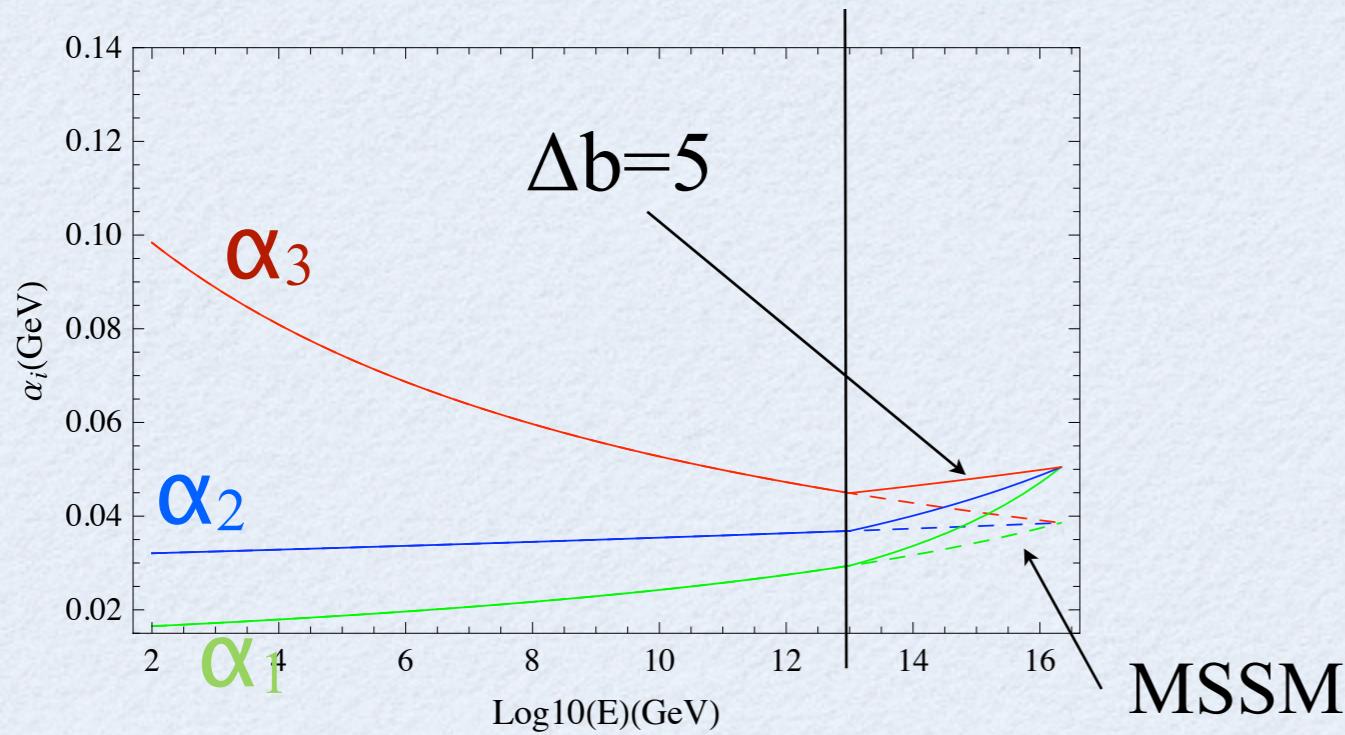
$$\frac{d}{dt} g_i = \frac{1}{16\pi^2} b_i g_i^3$$


$b_i > 0$

- We parametrize intermediate scale physics with 2 par.:
 - M_I : intermediate scale
 - Δb : variation of β -function coefficients $(b_i + \Delta b)$
 - chiral superfields in complete repr.: $\Delta b > 0$ and “universal”
- \Rightarrow gauge couplings grow faster above M_I : α_U larger

GAUGE COUPLINGS RUNNING

$$M_I = 10^{13} \text{ GeV}$$



$\Delta b=5$: a single 24 repr.:
type I+III seesaw CB, Calibbi '10

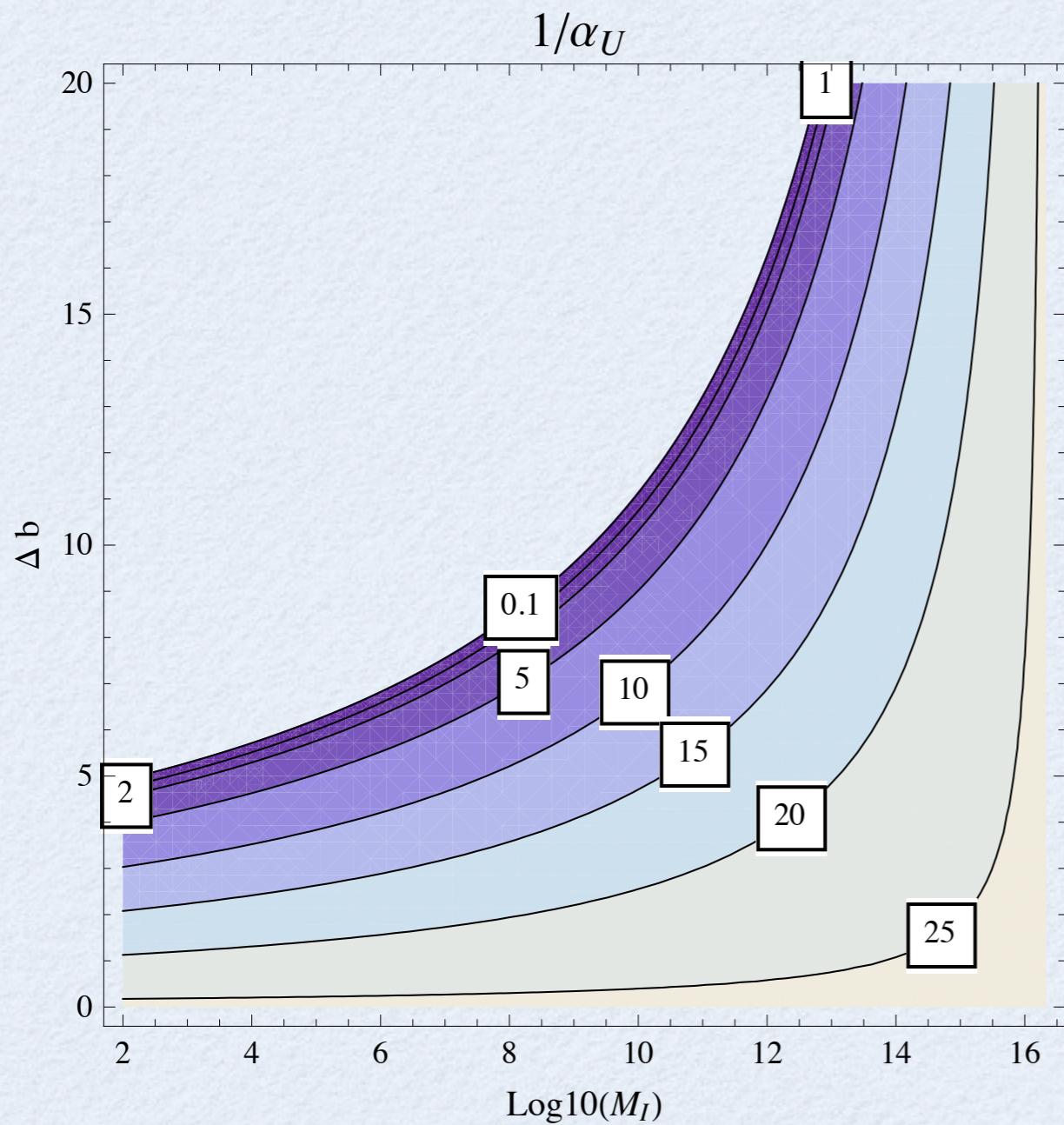
$\Delta b=15$: 3x24 reprs.:
type III seesaw Esteves et al. '10

$\Delta b=7$: 15+15bar: type II seesaw Rossi '02

GAUGE COUPLINGS RUNNING

If we require perturbativity of α_U

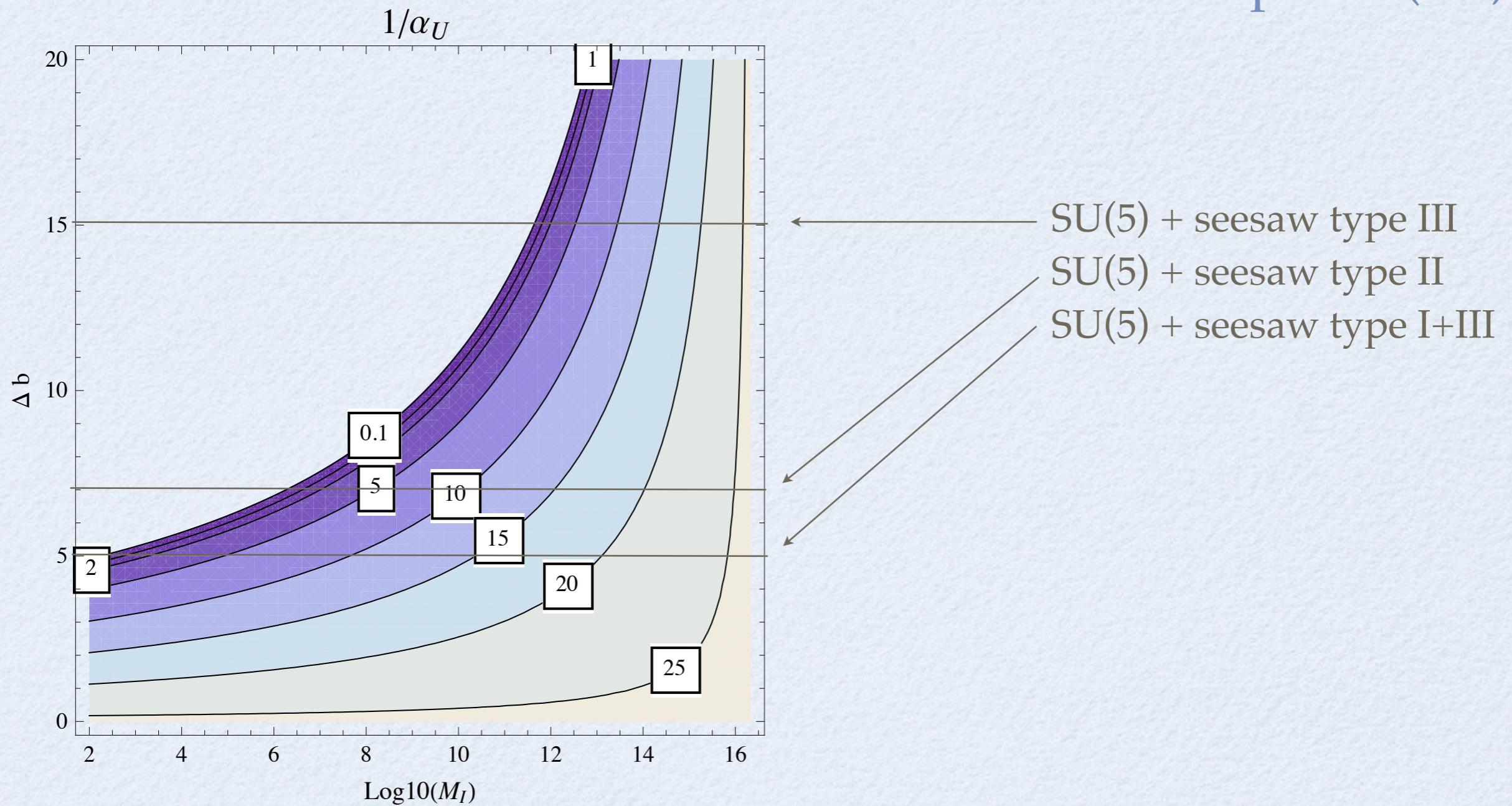
\Rightarrow bounds on the plane $(\Delta b, M_I)$



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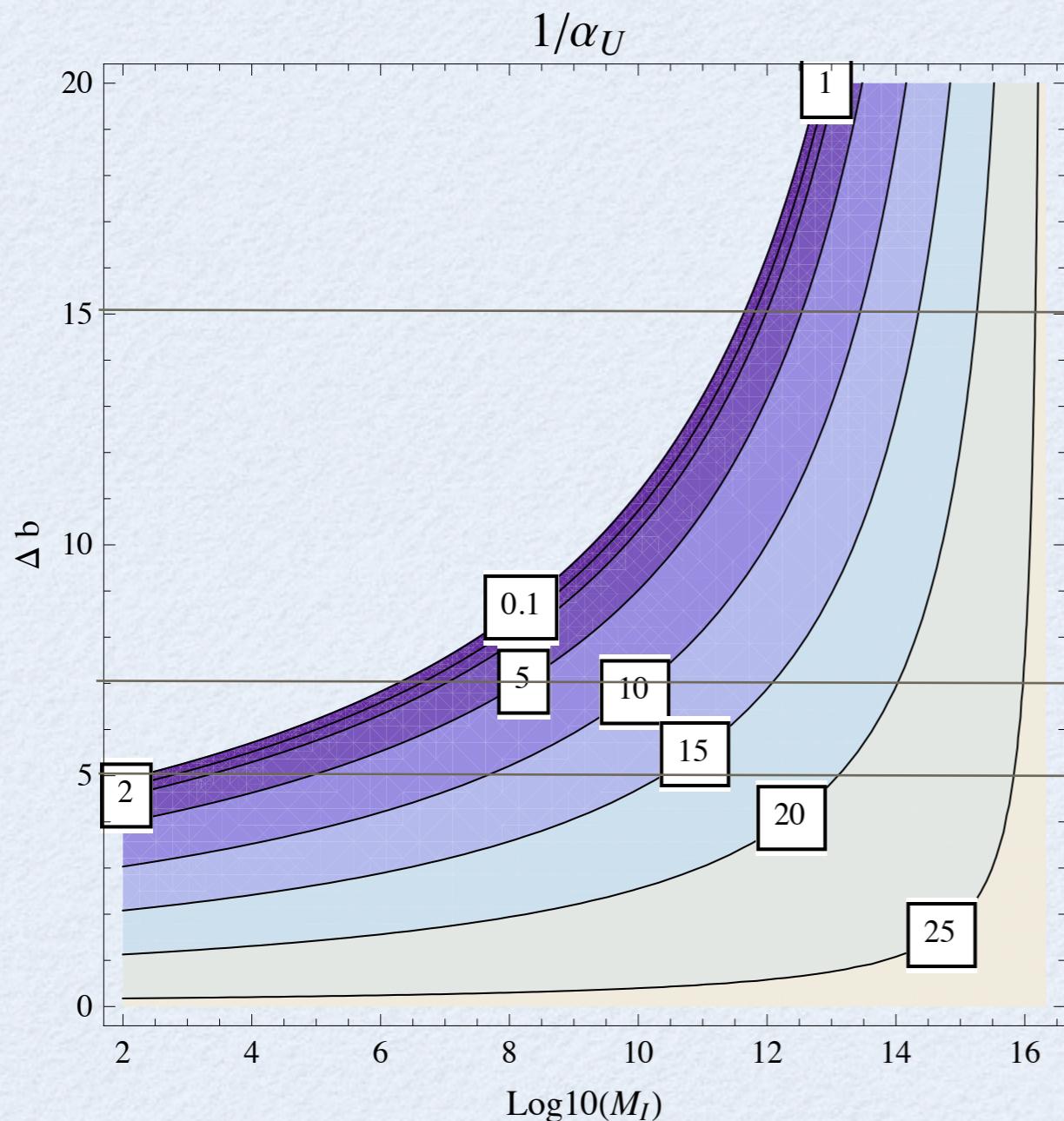
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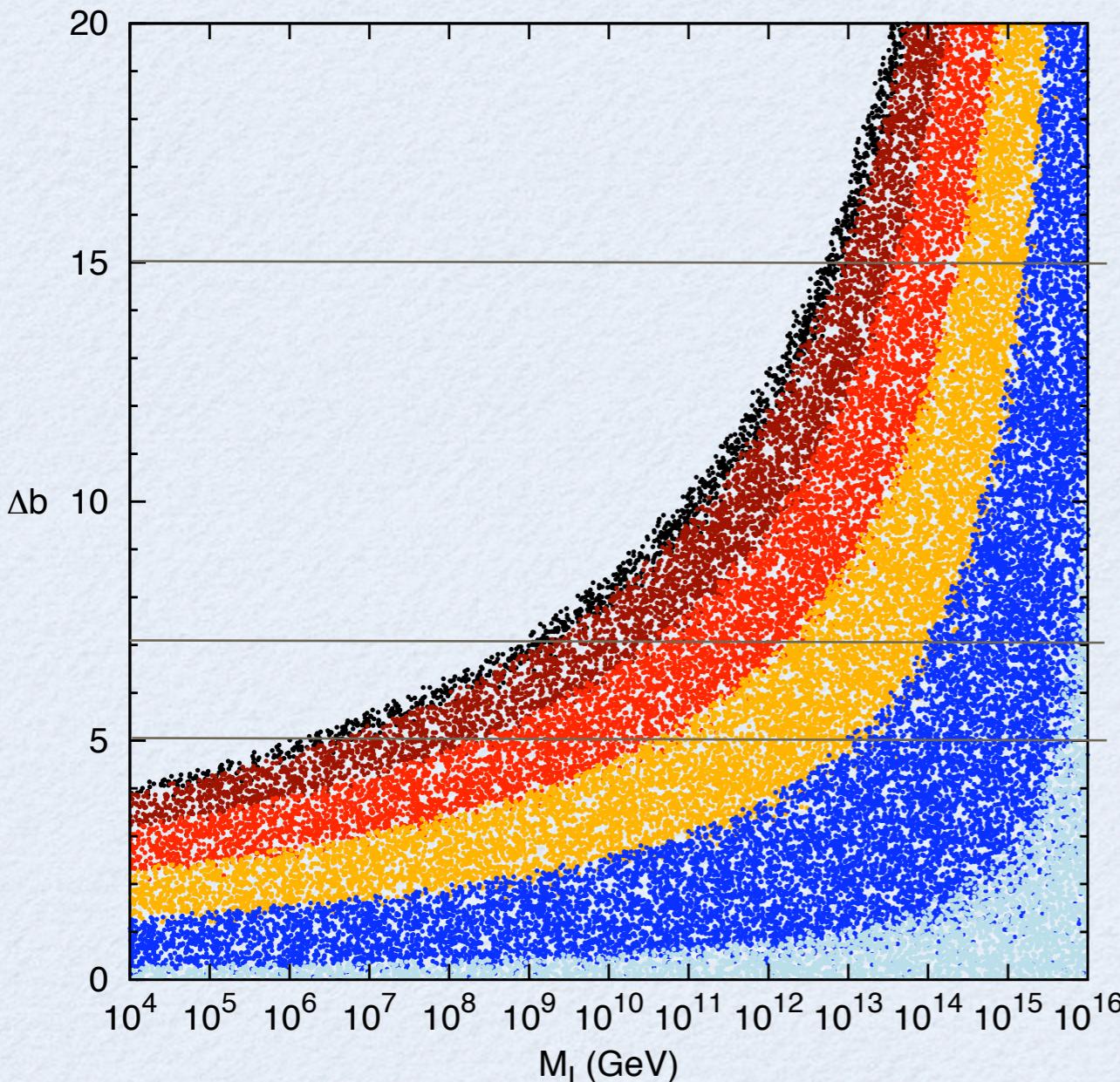


- This is 1 loop
- 2 loops effects relevant close to the Landau pole
- the effect is strengthened

GAUGE COUPLINGS RUNNING

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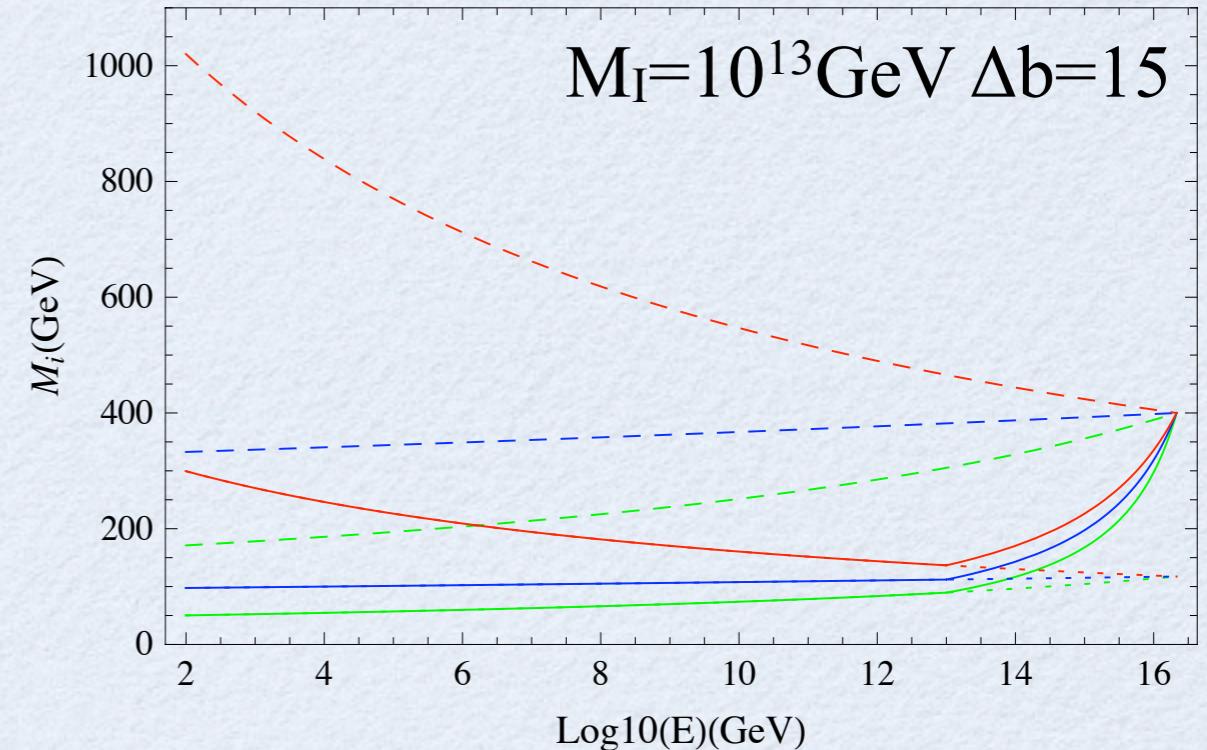
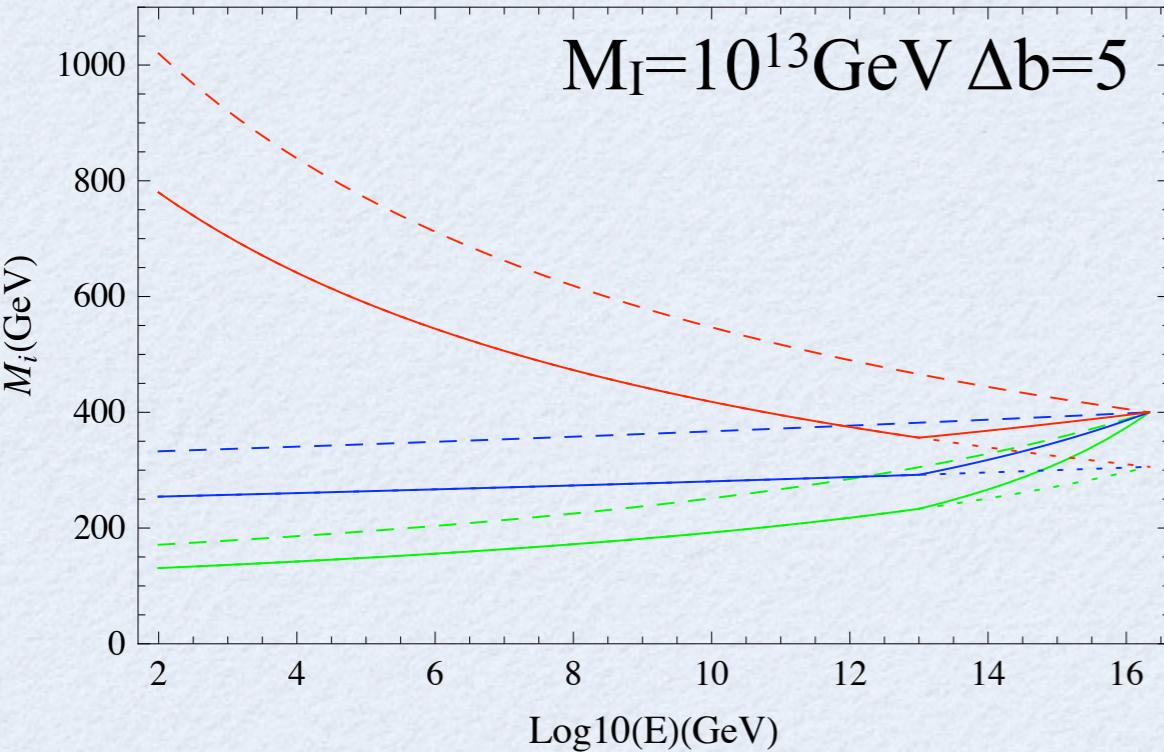
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SU(5) + seesaw type III
SU(5) + seesaw type II
SU(5) + seesaw type I+III

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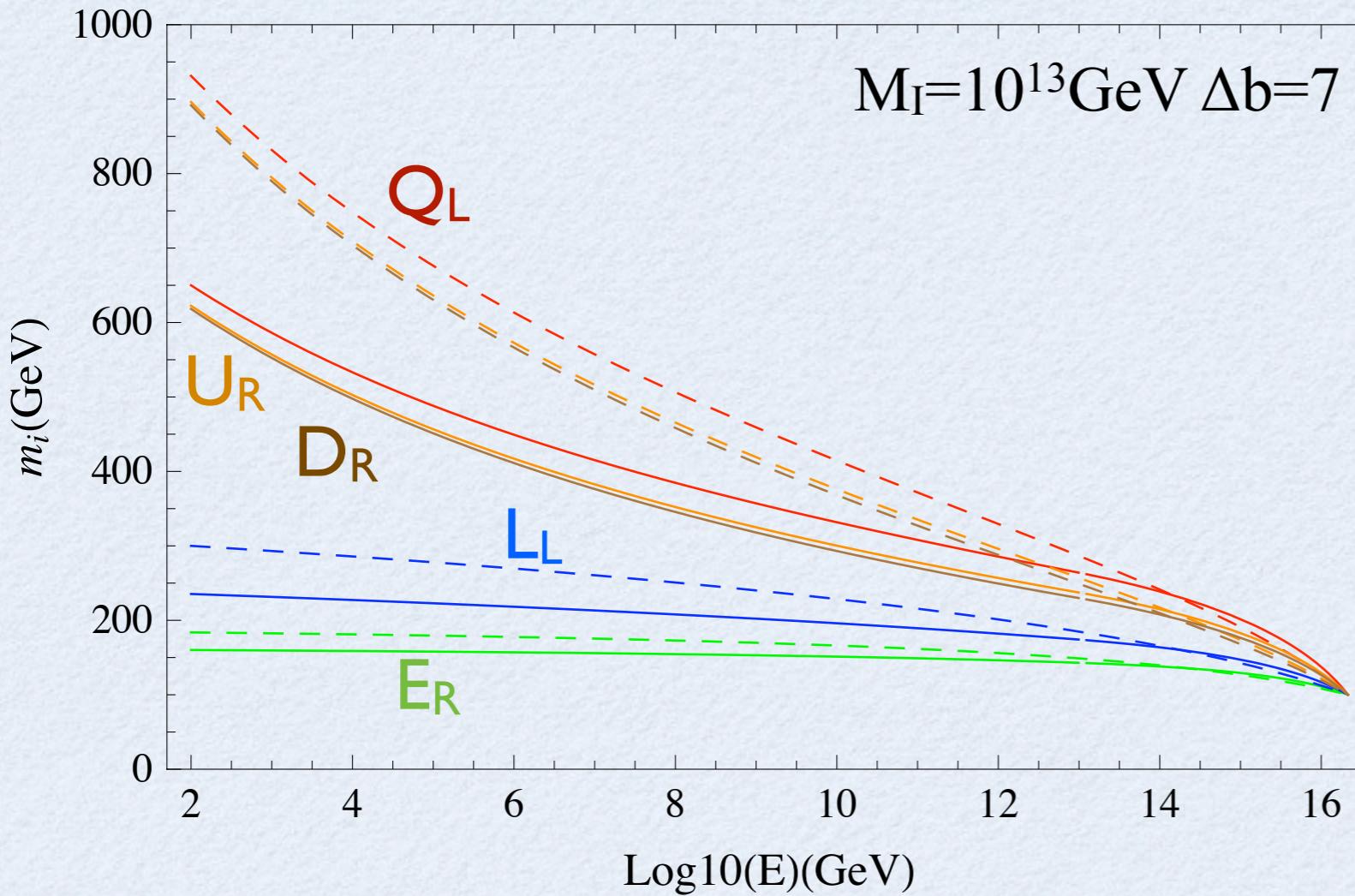
GAUGINO MASS RUNNING



$$\frac{M_1}{g_1^2} = \frac{M_2}{g_2^2} = \frac{M_3}{g_3^2} = \frac{M_{1/2}}{g_U^2}$$

This seems a simple rescaling of the parameters ($M_{1/2}$)
but this is not the end of the story...

SCALAR MASS RUNNING

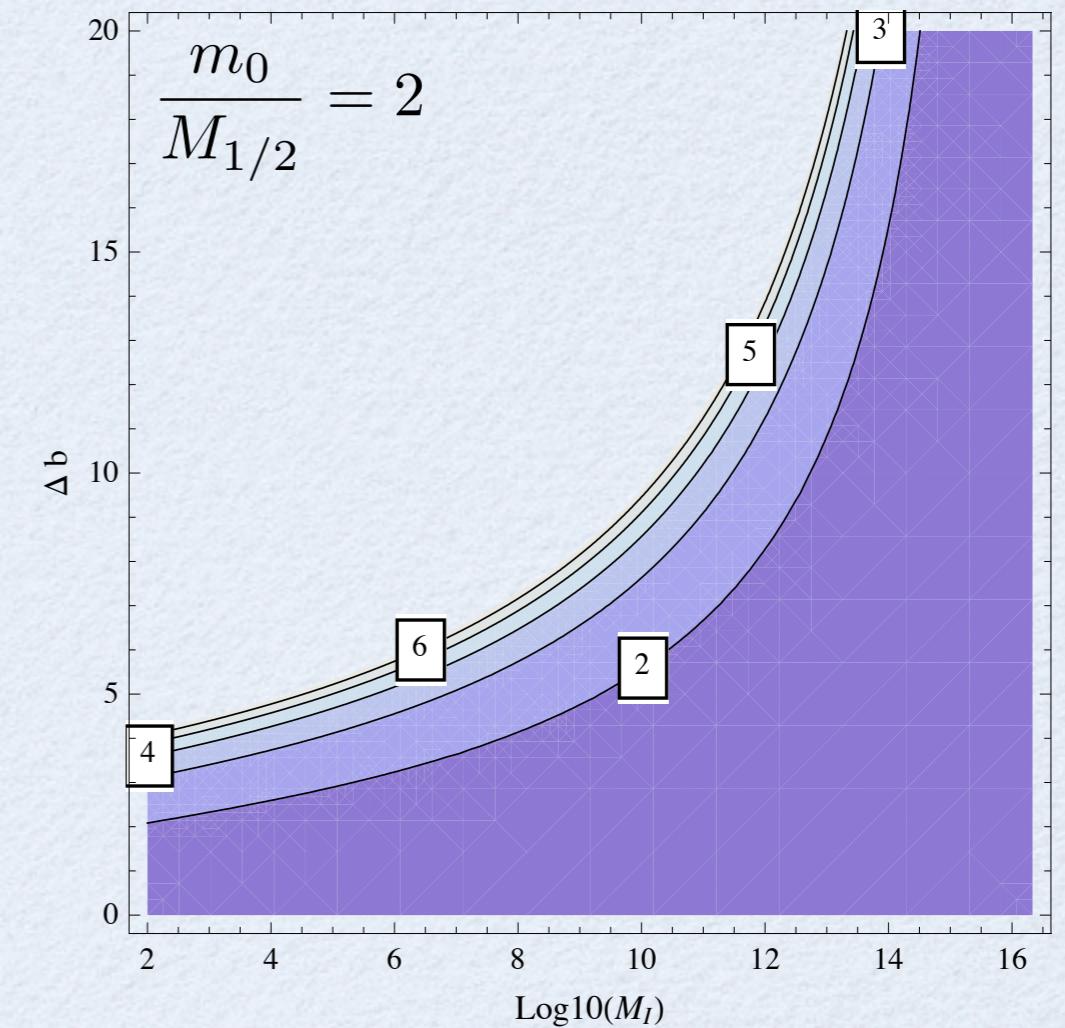
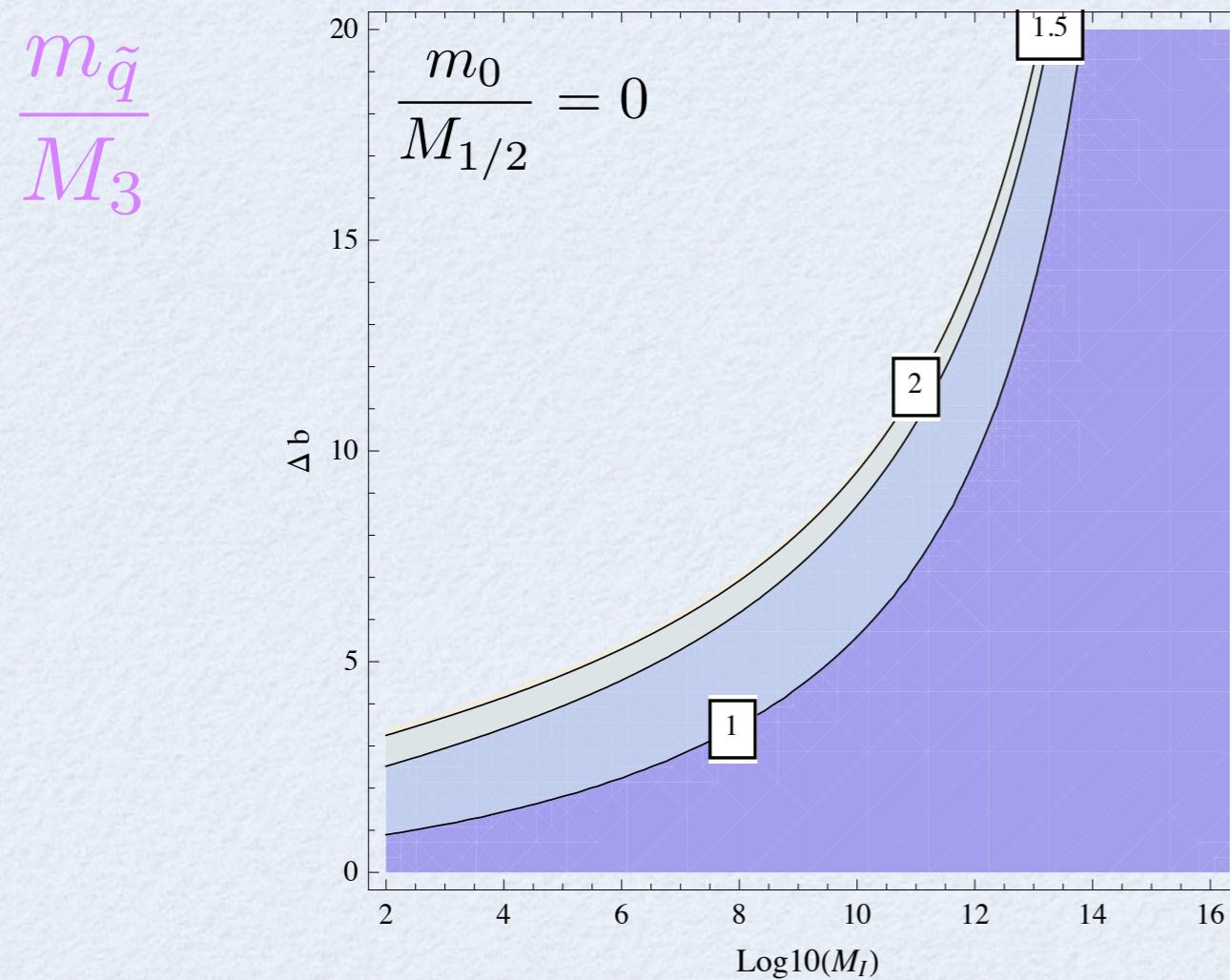


A simple rescaling of the parameters ($m_0, M_{1/2}$) is not enough to recover the same low energy spectrum.

The ratio $m_{\text{scalar}}/M_{\text{gaugino}}$ increases with the intermediate scale

SCALAR MASS RUNNING

The ratio $m_{\text{scalar}}/M_{\text{gaugino}}$ increases with the intermediate scale



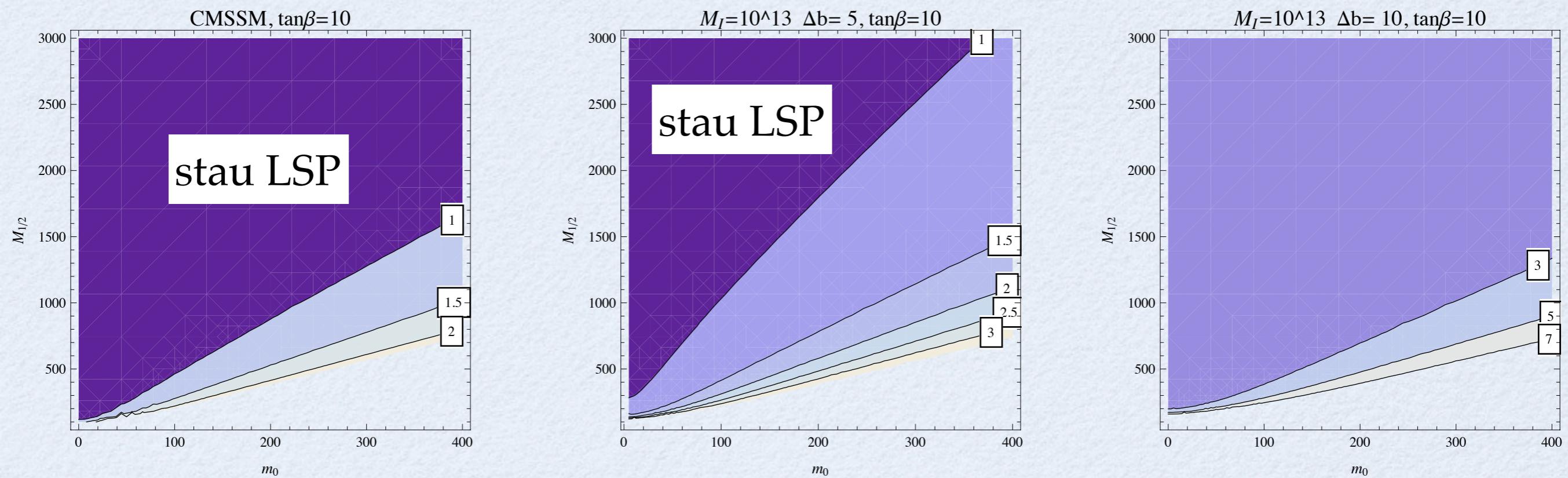
Even with $m_0=0$ there are portion of the param.space
where $m_{\tilde{q}} > M_3$ always

PHENOMENOLOGICAL CONSEQUENCES

- $\frac{m_{H_u}^2}{M_1^2}$ even more negative \Rightarrow EWSB easier
- $\frac{\mu}{M_1}$ increases $\Rightarrow \tilde{\chi}_1^0$ more and more \tilde{B} -like
 \Rightarrow focus point for DM disfavored
- $\frac{m_{\tilde{\tau}}}{M_1}$ increases $\Rightarrow \tilde{\tau}$ coannihilation region disfavored
 \rightarrow *obtaining the correct DM relic density is more difficult*

DARK MATTER

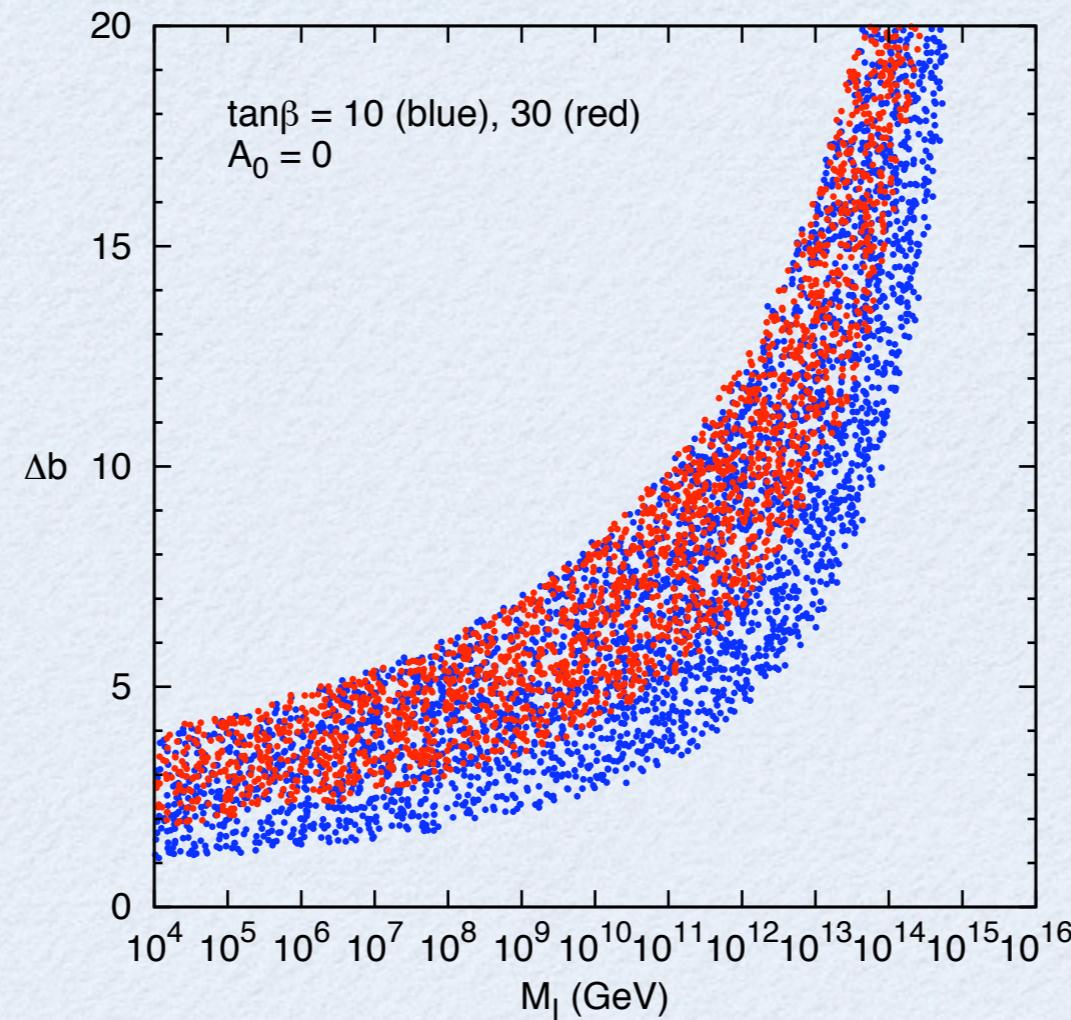
$$\frac{m_{\tilde{\tau}}^2}{m_{\tilde{\chi}_1^0}^2}$$



The region with the stau LSP tends to disappears
 ⇒ also the coannihilation region disappears...

DARK MATTER

Region where
 $m_{\tilde{\tau}} \gg m_{\tilde{\chi}_1^0}$
always



Large A_0 : smaller excluded region but qualitatively similar conclusion

- Neutralino LSP is not a good DM candidate anymore...
- If DM is discovered in direct searches with properties similar to neutralino LSP \Rightarrow a large portion of int. scale param. space could be excluded

CAN WE TEST INTERMEDIATE SCALES PHYSICS AT THE LHC?

YES!

- by measuring sparticles masses and building mass invariants
- by looking at edges in cascade decays
- ... other..? *... still work in progress!*

MASS INVARIANTS (1)

At 1-loop:

$$\begin{aligned} M_i &= A_i M_{1/2} \\ m_{\tilde{f}}^2 &= m_0^2 + B_{\tilde{f}} M_{1/2}^2 \end{aligned}$$

$$\frac{m_{\tilde{f}}^2 - m_{\tilde{f}'}^2}{M_i^2}$$

is indep. of $m_0, M_{1/2}$

Buckley Murayama '06

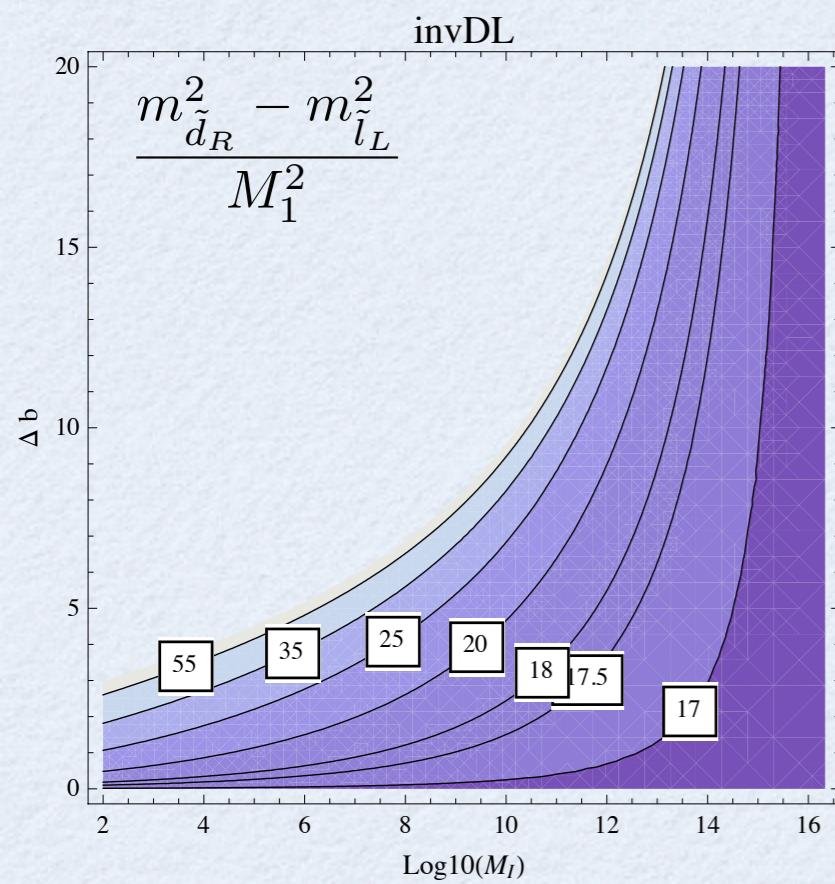
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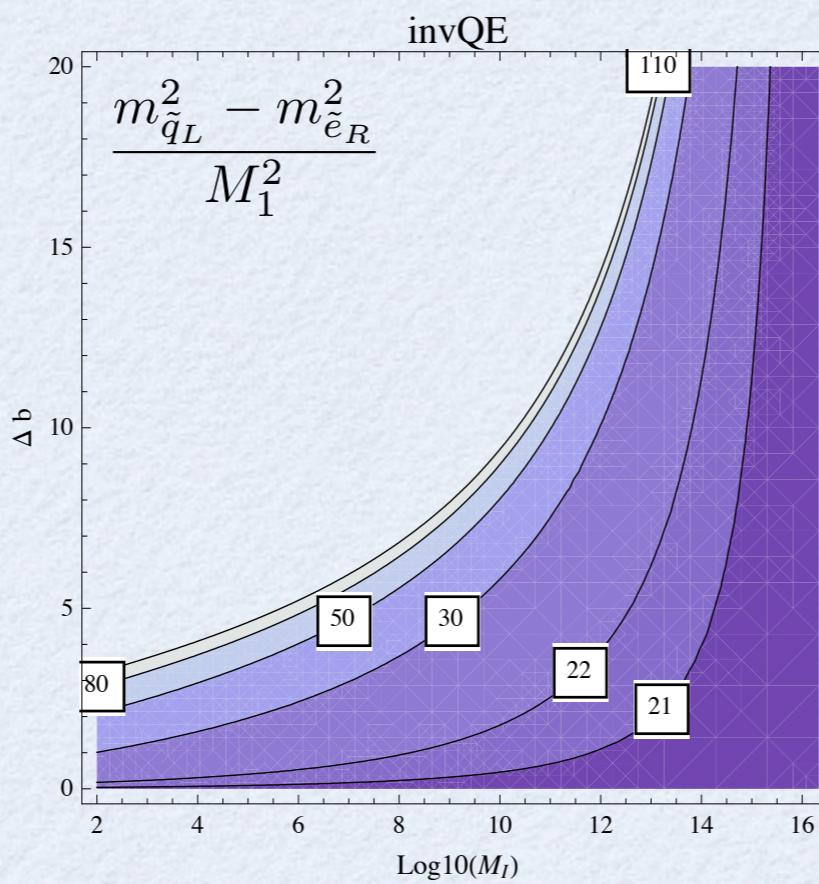
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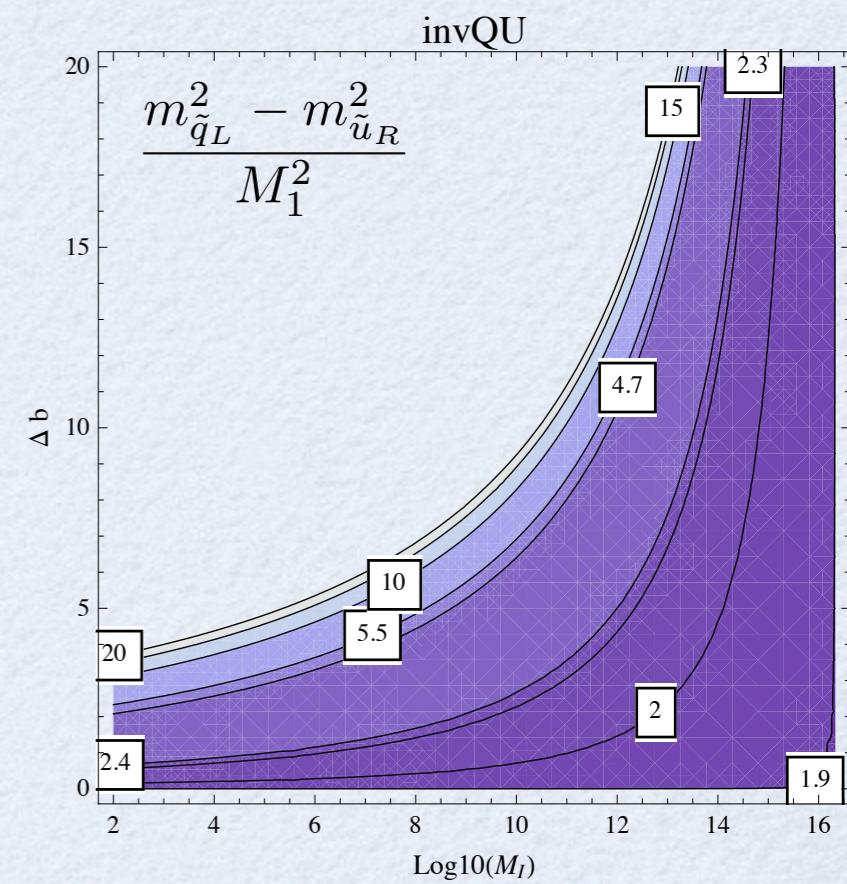
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CMSSM: ~ 16.9



CMSSM: ~ 20.7

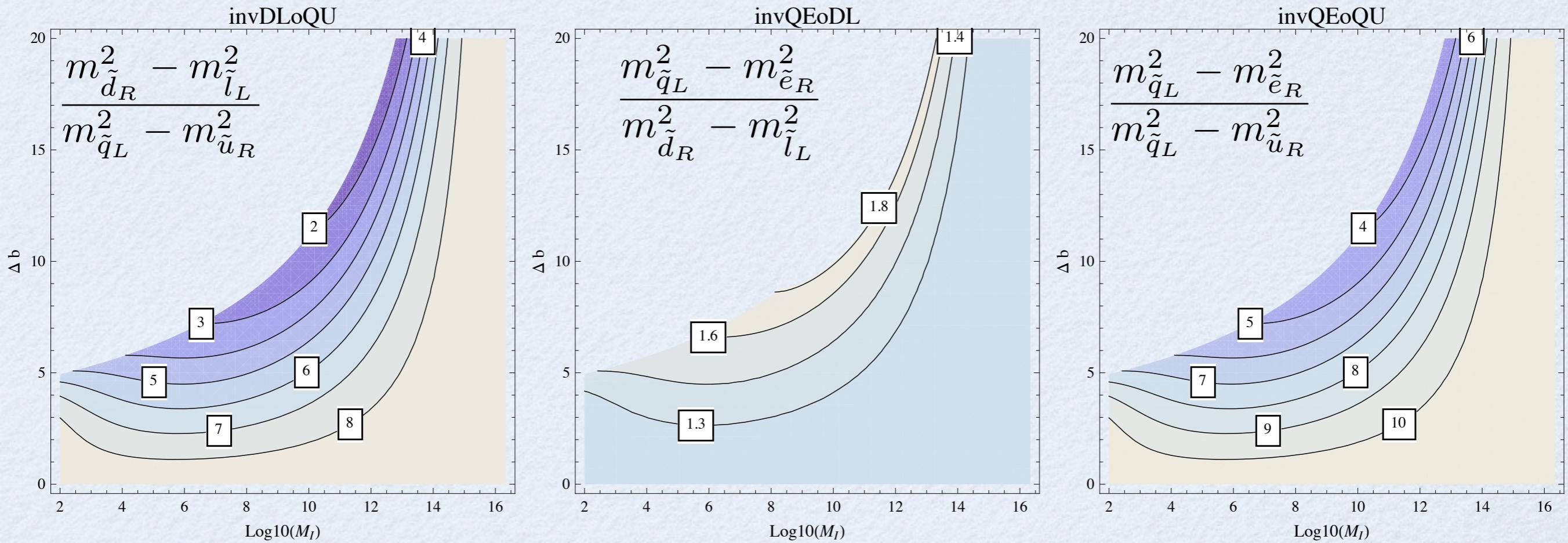


CMSSM: ~ 1.9

Here $M_{\text{SUSY}}=1\text{TeV}$. Strong dependence on M_{SUSY} (up to 60%). 2 loops effect: $\sim 10\%$

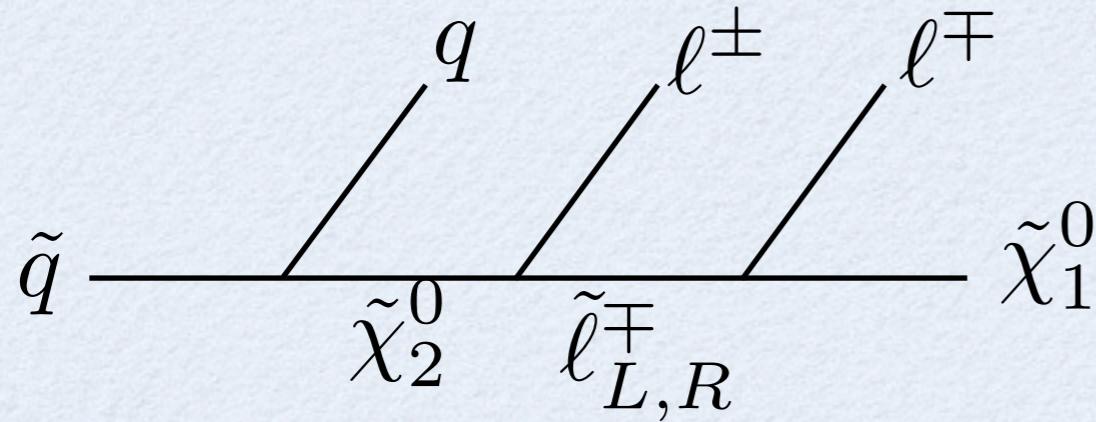
MASS INVARIANTS (2)

$$\frac{m_{\tilde{f}1}^2 - m_{\tilde{f}2}^2}{m_{\tilde{f}3}^2 - m_{\tilde{f}4}^2}$$



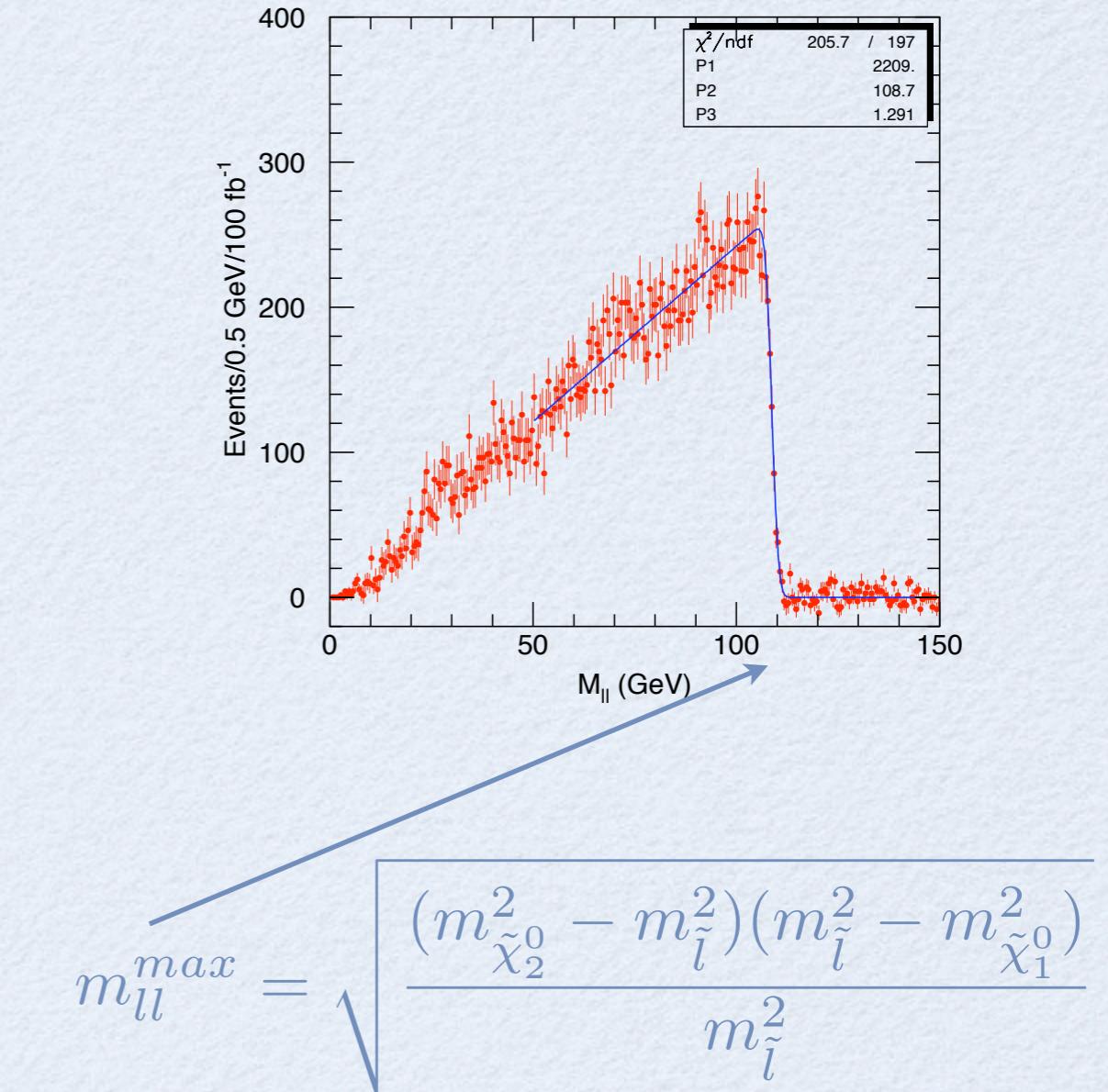
Less dependence on MsUSY but more on 2 loops

KINEMATIC EDGES IN CASCADE DECAYS



$$m_{\tilde{q}} > m_{\tilde{\chi}_2^0} > m_{\tilde{l}_{L,R}} > m_{\tilde{\chi}_1^0}$$

and analogous for other inv. masses: m_{llq} , m_{lq}



$$m_{ll}^{max} = \sqrt{\frac{(m_{\tilde{\chi}_2^0}^2 - m_{\tilde{l}}^2)(m_{\tilde{l}}^2 - m_{\tilde{\chi}_1^0}^2)}{m_{\tilde{l}}^2}}$$

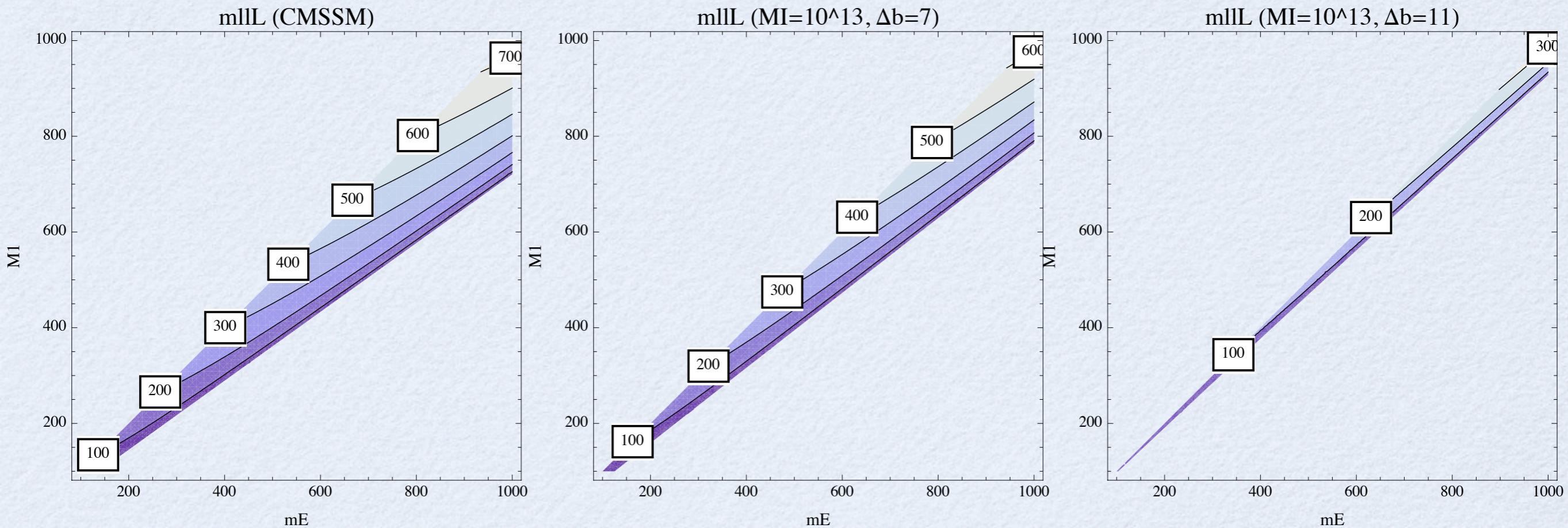
Bachacou, Hinchliffe, Paige '99

from edges sparticle masses can be extracted

KINEMATIC EDGES: m_{ll}

1. The position of the edges varies with the intermediate scale

$$m_{ll}^{max} = \sqrt{\frac{(m_{\tilde{\chi}_2^0}^2 - m_{\tilde{l}_L}^2)(m_{\tilde{l}_L}^2 - m_{\tilde{\chi}_1^0}^2)}{m_{\tilde{l}_L}^2}}$$

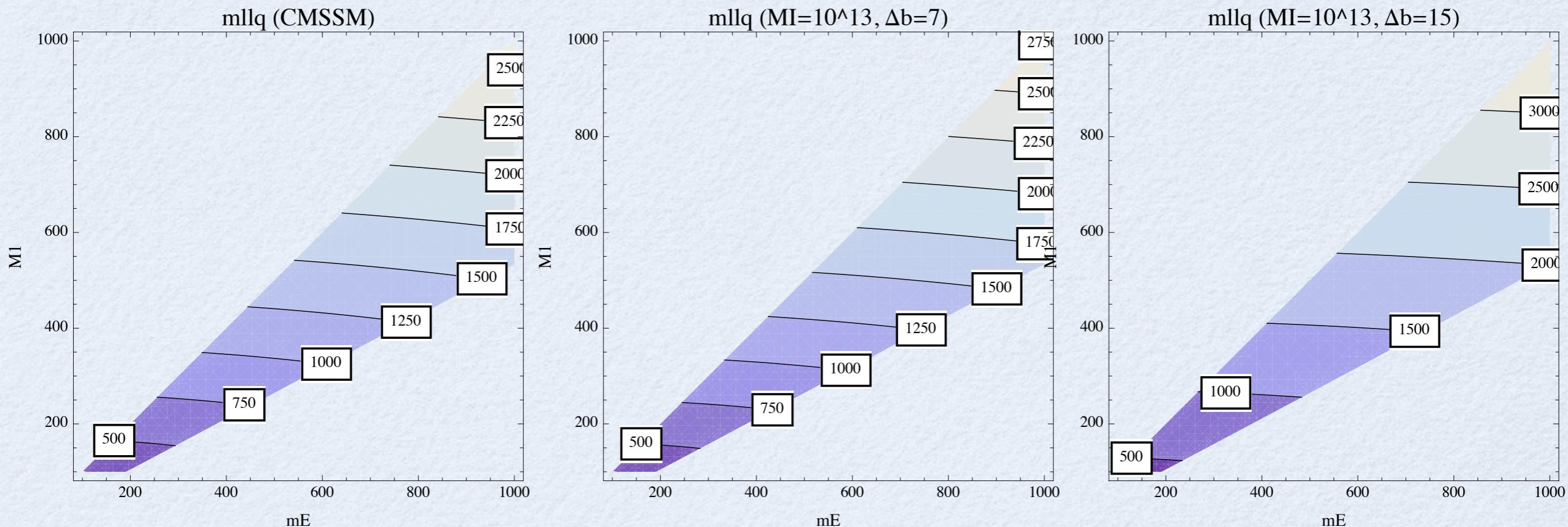


The value of the edge decreases

KINEMATIC EDGES: m_{llq}

1. The position of the edges varies with the intermediate scale

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

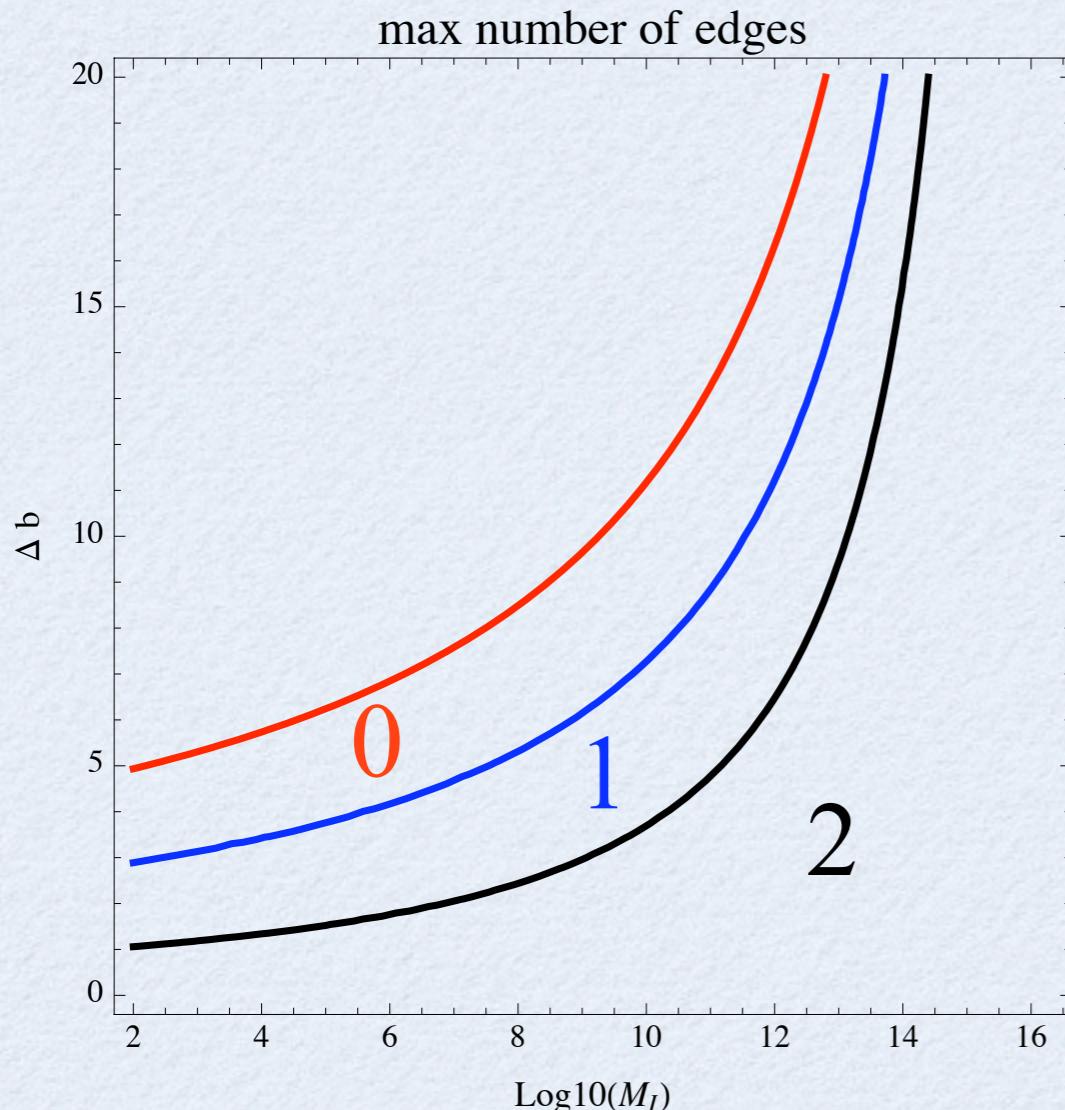


The value of the edge increases

KINEMATIC EDGES: MAXIMUM NUMBER

$$m_{\tilde{q}} > m_{\tilde{\chi}_2^0} > m_{\tilde{l}_{L,R}} > m_{\tilde{\chi}_1^0}$$

2. Depending on the ratios $\frac{m_{\tilde{l}_{L,R}}}{m_{\tilde{\chi}_2^0}}$ 0, 1 or 2 edges can be present



If 2 (1) edges are seen in the LHC cascade decays \Rightarrow a large portion of parameter space can be excluded

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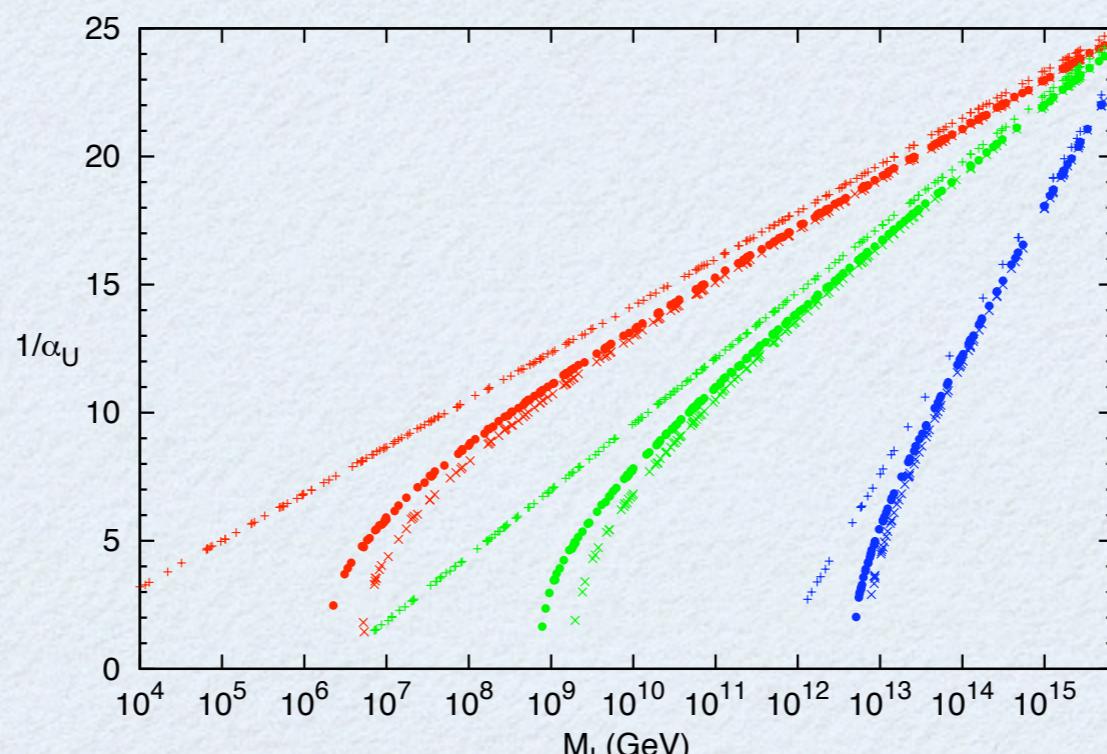
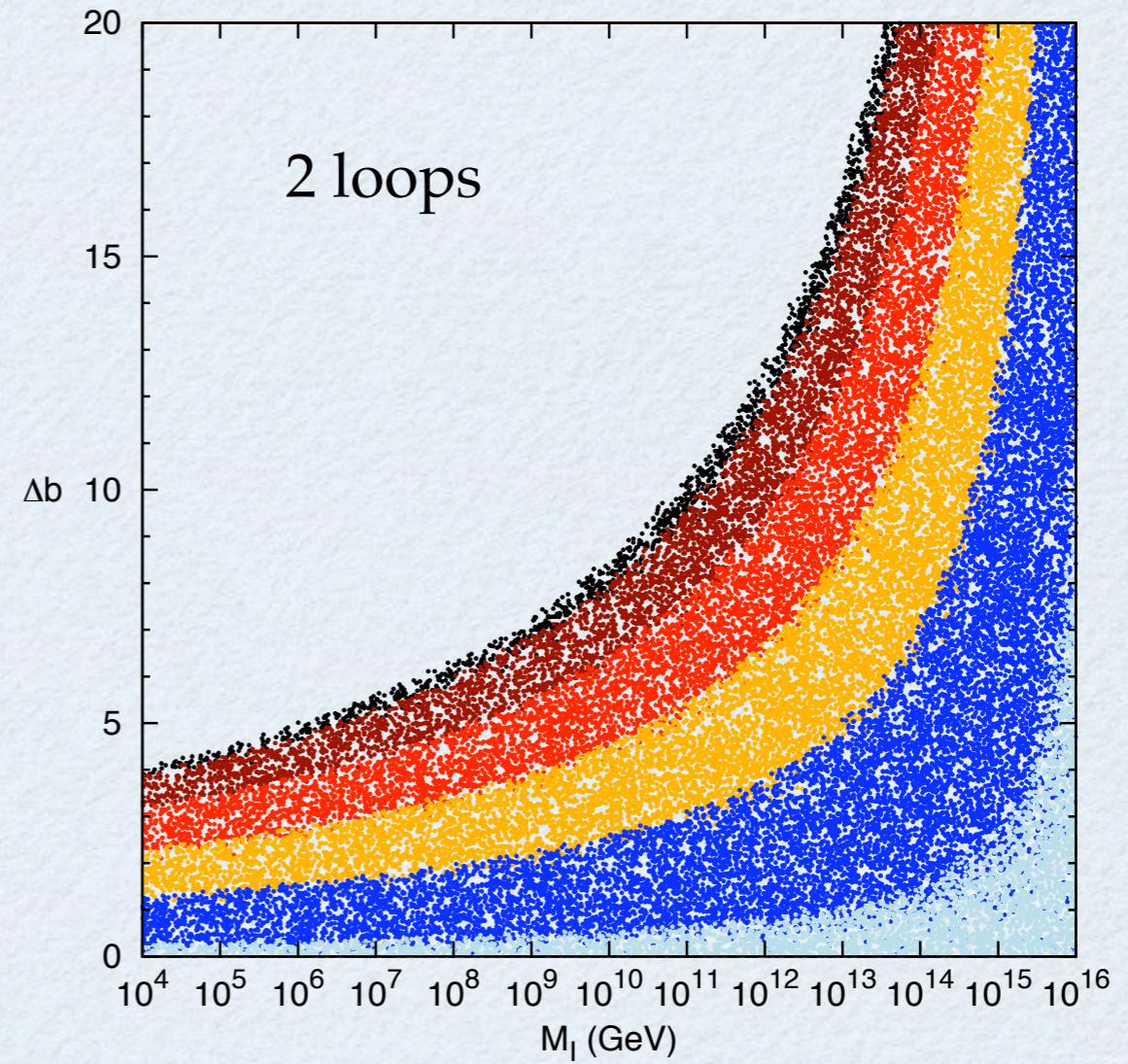
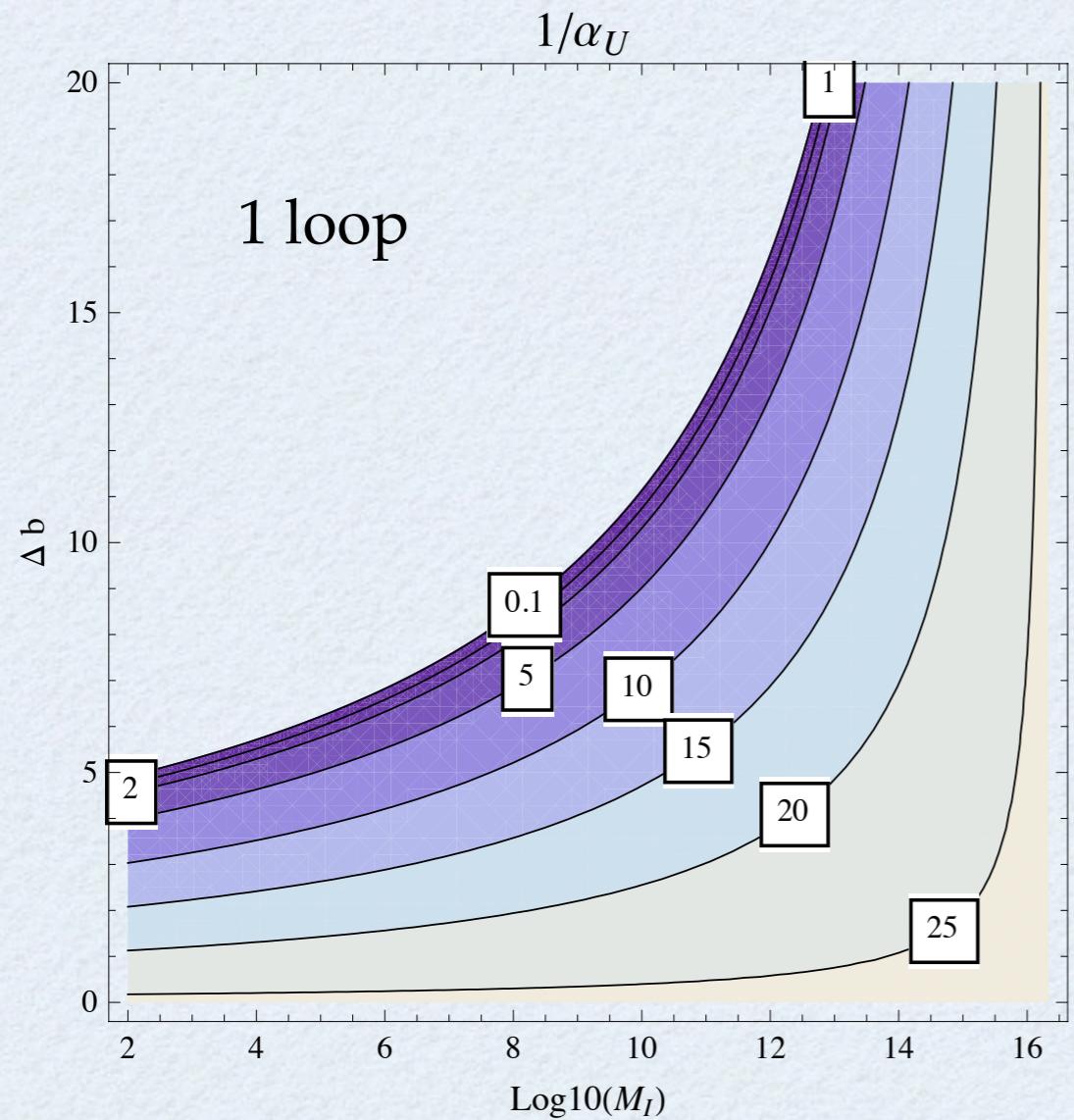
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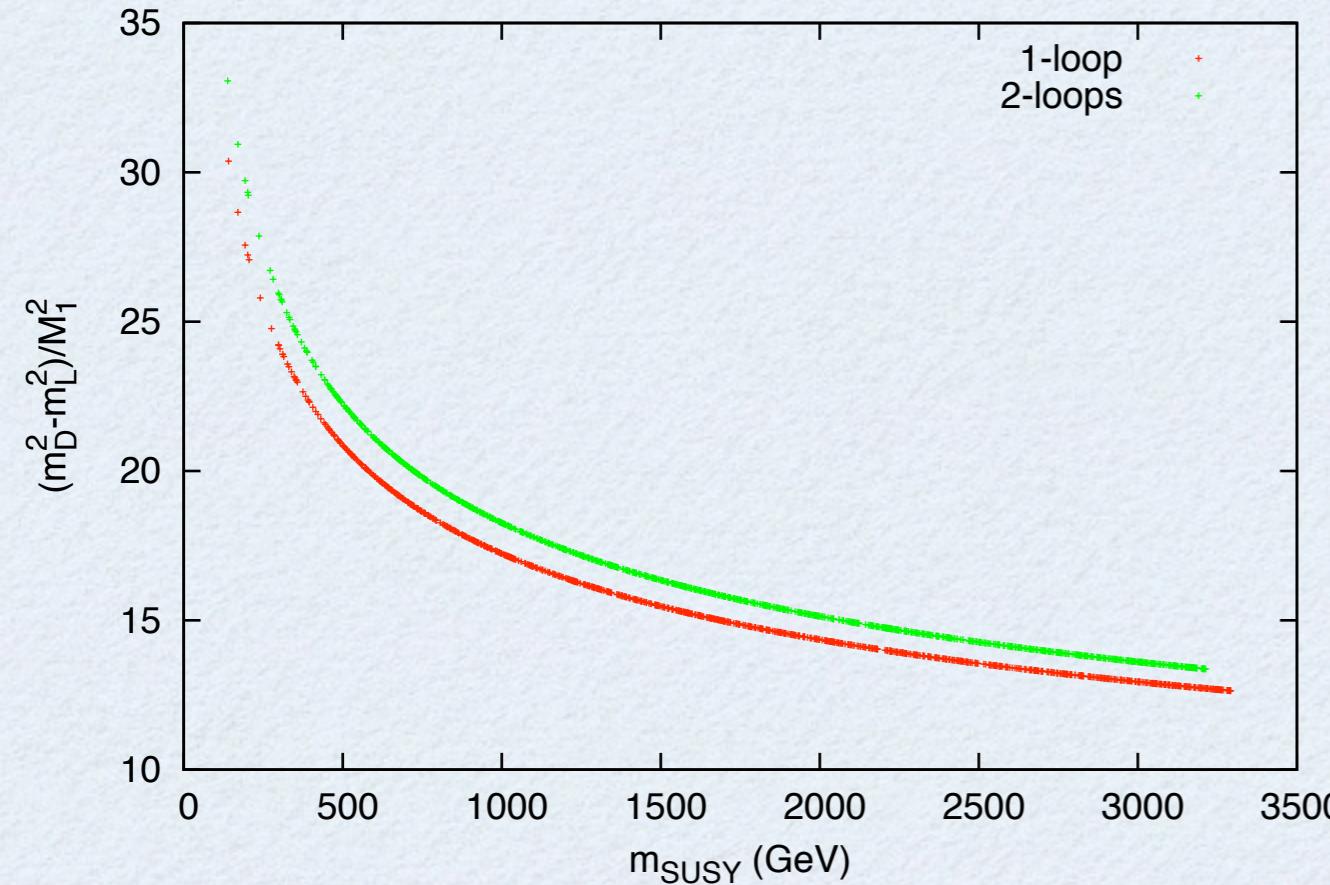
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Thank you for your attention

BACK-UP SLIDES



variation with M_{susy} ; CMSSM



effect of the intermediate scale

