LHC SUSY searches after the Higgs discovery: respecting the muon g-2

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References)
M. Endo, K. Hamaguchi, S. Iwamoto, and T. Yoshinaga [1303.4256]

2012

LHC discovered Higgs boson$_{(?)}$!!

Standard Model Now Completed!

- Problems
  - Hierarchy Problem, Dark Matter, muon $g-2$ anomaly, ...
- Anxiety towards ultimate theory

⇓ **Supersymmetry (SUSY)**

MSSM (Minimal SUSY Standard Model)

- solves Hierachy problem.
- can provides Dark Matter candidate.
- can explain Muon $g-2$ anomaly.

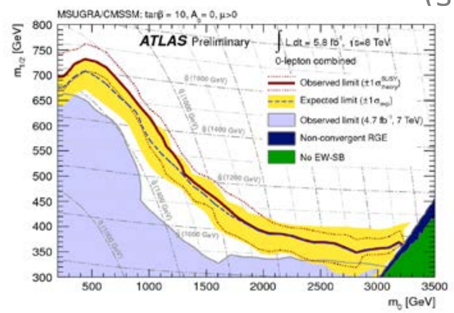
But Not Found yet.

- $m_h = 126$ GeV
  - $\Rightarrow \Delta(m_h)^{\text{loop}}$: large
  - $\Rightarrow m_{\tilde{t}} = O(1\text{–}10)$ TeV ?

$$m_h^2 \approx \underbrace{m_Z^2}_{\text{tree}} + \underbrace{\frac{3g_W^2 m_t^4}{8\pi^2 m_W^2}\left[\ln\frac{m_{\tilde{t}}^2}{m_t^2} - \frac{(\alpha^2-6)^2}{12} + 3\right]}_{\Delta\left(m_h^2\right)^{\text{loop}}}$$

where $\alpha := A_t/m_{\tilde{t}}$.
(stop mixing parameter)

- Not found yet.
  - $\Rightarrow m(\tilde{q},\tilde{g}) \gtrsim 1$ TeV.



ATLAS 8 TeV, 5.8 fb^{-1}
[ATLAS-CONF-2012-109]

A Nightmare:
SUSY$\gg$ 1 TeV & we cannot reach SUSY?

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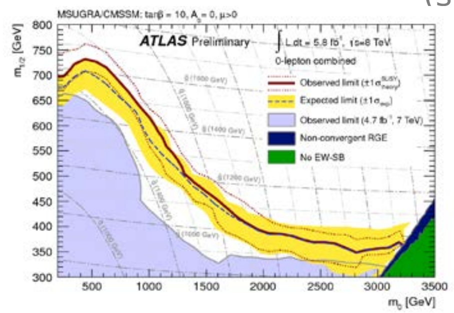

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A Nightmare:

SUSY$\gg$ 1 TeV & we cannot reach SUSY?

S

M

◎ can provides Dark Matter candidate.

◎ can explain Muon $g-2$ anomaly.

The last(?) hope for detectable SUSY.

But Not Found yet.

What We Will see:

$(g-2)_\mu$ ⇨ SUSY spectrum should be $\boxed{}$.

⇨ $(\boldsymbol{g-2})_{\boldsymbol{\mu}}$-**motivated MSSM**.

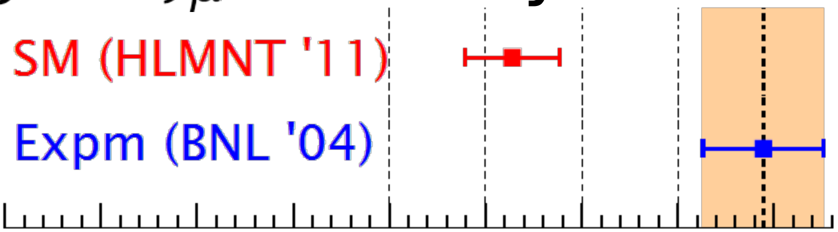
↳ How to search?

— current status & future prospects.

2. $(g-2)_\mu$-Motivated MSSM

$$\left(a_\mu := \frac{g_\mu - 2}{2} \right)$$

- $(g-2)_\mu$ anomaly



Hagiwara, Liao, Martin, Nomura, Teubner [1105.3149]

$$a_\mu^{\mathrm{SM}} = (116\,591\,828 \pm 49) \times 10^{-11}$$

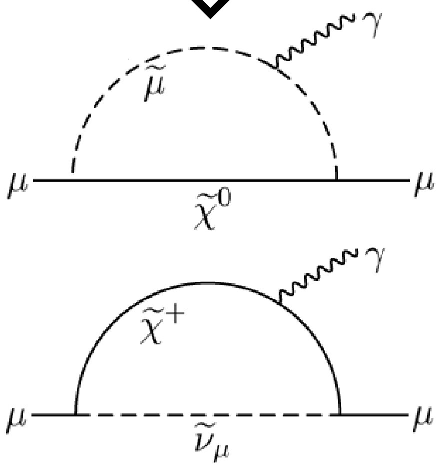
$$a_\mu^{\mathrm{exp}} = (116\,592\,089 \pm 63) \times 10^{-11}$$

3.3σ discrepancy

can be explained with MSSM

if $\mu > 0$, $\tan\beta \gtrsim 10$,

and $m\left(\tilde{\chi}^0, \tilde{\chi}^\pm, \tilde{\mu}, \tilde{\nu}_\mu\right) \sim O(100)\,\mathrm{GeV}$.



$$\Delta a_\mu\left(\tilde{\chi}^0, \tilde{\mu}\right) \approx \frac{\alpha_Y m_\mu^2}{m_{\mathrm{soft}}^2} \mathrm{sgn}(\mu M_1) \tan\beta + \cdots,$$

$$\Delta a_\mu\left(\tilde{\chi}^\pm, \tilde{\nu}\right) \approx \frac{\alpha_2 m_\mu^2}{m_{\mathrm{soft}}^2} \mathrm{sgn}(\mu M_2) \tan\beta.$$

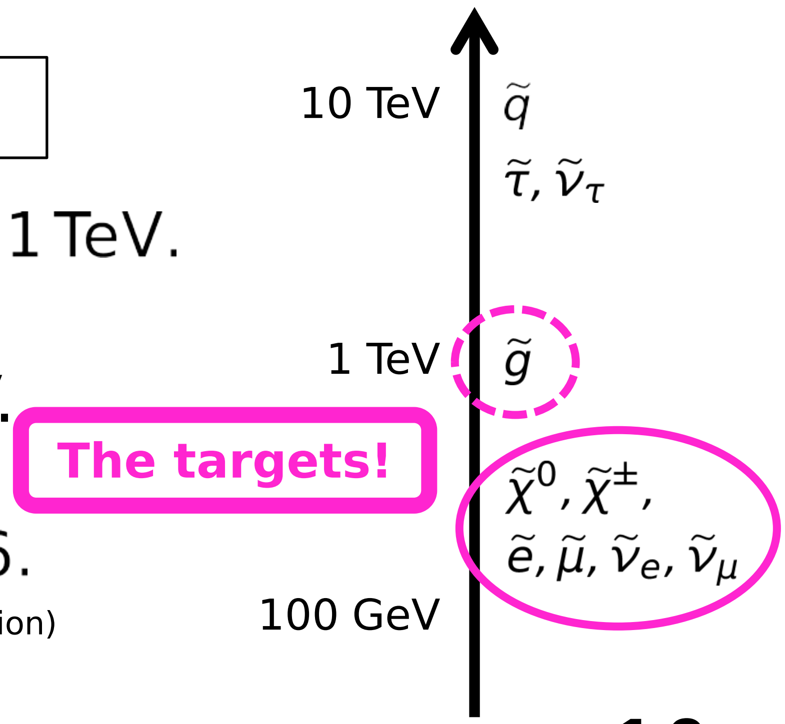
$$\left(\tan\beta = \frac{\langle H_{\mathrm{u}} \rangle}{\langle H_{\mathrm{d}} \rangle} \right)$$

MSSM current status

- $m_h = 126\,\text{GeV}$ ⟶ $m\left(\tilde{t}\right) \sim O(1\text{–}10)\,\text{TeV??}$
- LHC SUSY searches ⟶ $m(\tilde{g}, \tilde{q}) \gtrsim 1\,\text{TeV}$
- $(g-2)_\mu$ anomaly ⟶ $m\left(\tilde{\chi}^0, \tilde{\chi}^\pm, \tilde{\mu}, \tilde{\nu}_\mu\right) \sim O(100)\,\text{GeV}$ and large $\tan\beta$??

$(g-2)_\mu$-motivated MSSM

- squarks & stau-sector $(\tilde{\tau}, \tilde{\nu}_\tau)$ $\gg 1\,\text{TeV}$.
  (to simplify LHC analyses)
- $\tilde{\chi}^0, \tilde{\chi}^\pm$ & slepton $\sim O(100)\text{GeV}$.
- Gaugino: $M_1 : M_2 : M_3 = 1 : 2 : 6$.
  (approximate GUT relation)

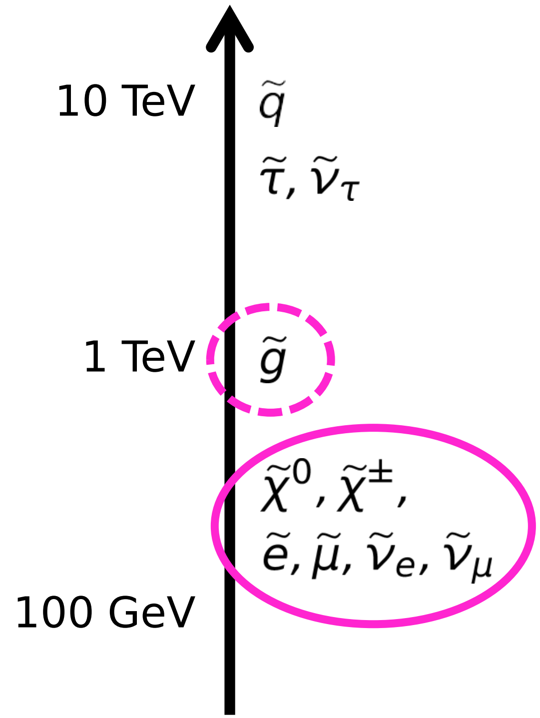


3. $(g-2)_\mu$-MSSM v.s. LHC

$(g-2)_\mu$-motivated MSSM

- squarks: $\tilde{q} \gg 1\,\mathrm{TeV}$.
- sleptons: $(\tilde{e}, \tilde{\nu}_e) = (\tilde{\mu}, \tilde{\nu}_\mu)$ $\left[\ll (\tilde{\tau}, \tilde{\nu}_\tau)\right]$
- gaugino: $M_1 : M_2 : M_3 = 1 : 2 : 6.$

(approximate GUT relation)



- A-terms $= 0$
- $\tan\beta = 40$
- $m_A = 1500\,\mathrm{GeV}$ (to avoid $B_s \to \mu\mu$ constr.)
- $m_h = 126\,\mathrm{GeV}$ is assumed. ($\because$ $\tilde{q}$ are decoupled.)

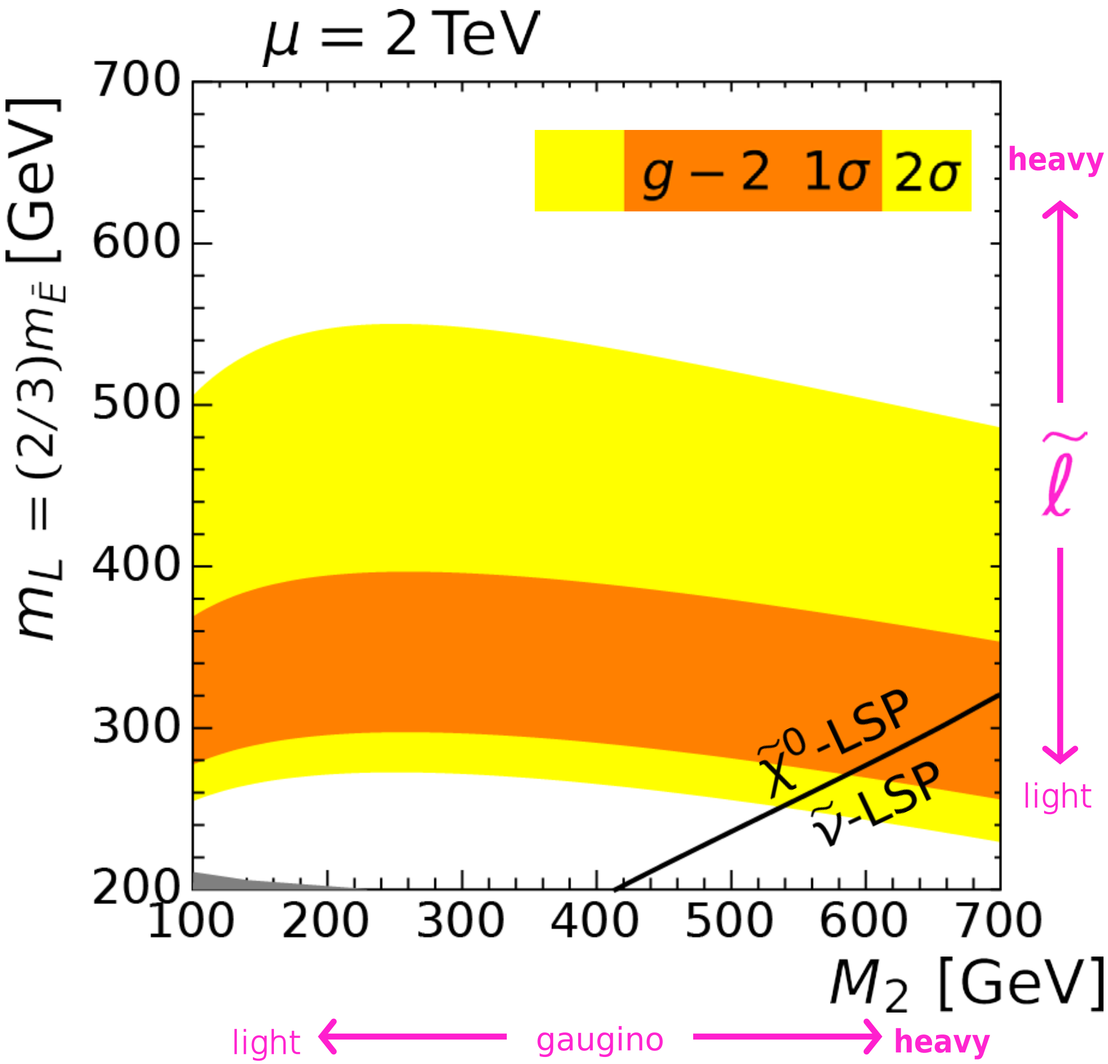
Rest Params: $(m_{\tilde{L}}^2, m_{\tilde{E}}^2)$: slepton soft-masses

(M_2, μ) : gaugino/Higgsino mass

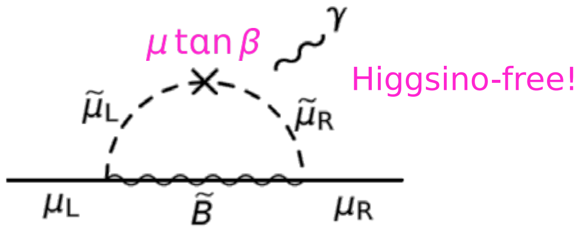
RESULT

(an extreme case : μ = 2 TeV)

An extreme case: $\mu = 2\,\mathrm{TeV}$, $m_L^2 : m_{\bar{E}}^2 = 1 : (1.5)^2$



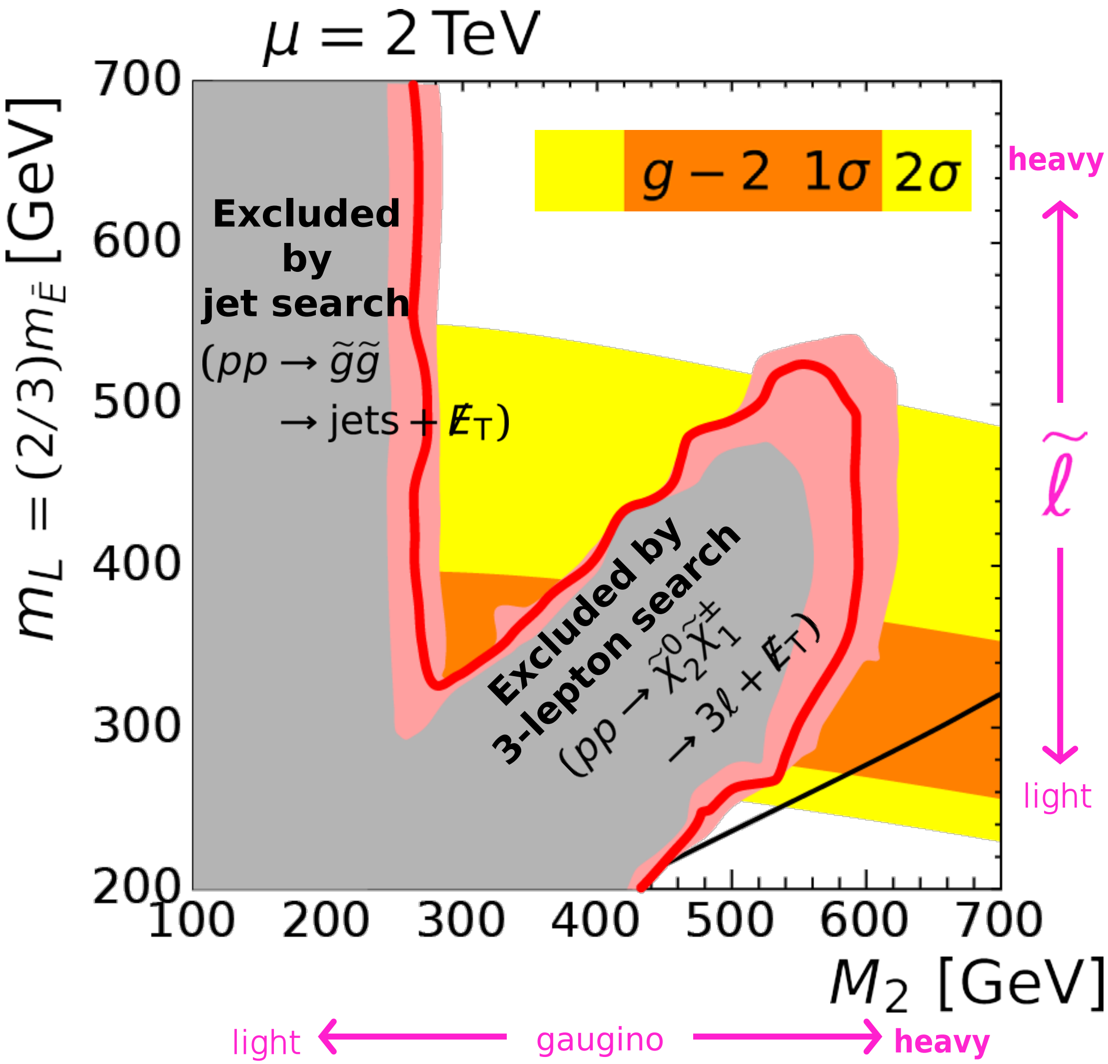
- $(g-2)_\mu$ dominant source:



- Parameters:
  - $M_1 : M_2 : M_3 = 1 : 2 : 6$
  - $\mu = 2\,\mathrm{TeV}$
  - $m_L^2 : m_{\bar{E}}^2 = 1 : (1.5)^2$
  - $(\tan\beta, m_A) = (40, 1.5\,\mathrm{TeV})$
- Soft-params set @ $7\,\mathrm{TeV}$ $(= m_{\tilde{t}})$.
- R-parity conserved.
- LSP is long-lived.

- squark/stau decoupled.
- slepton 1st-gen = 2nd-gen.
- A-terms = 0.

An extreme case: $\mu = 2\,\mathrm{TeV}$, $m_L^2 : m_{\bar{E}}^2 = 1 : (1.5)^2$



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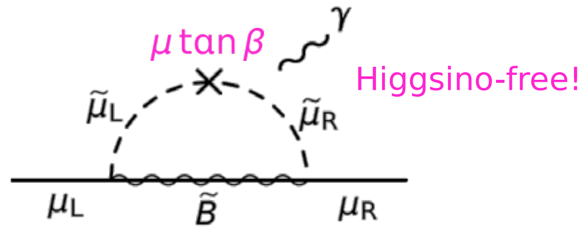

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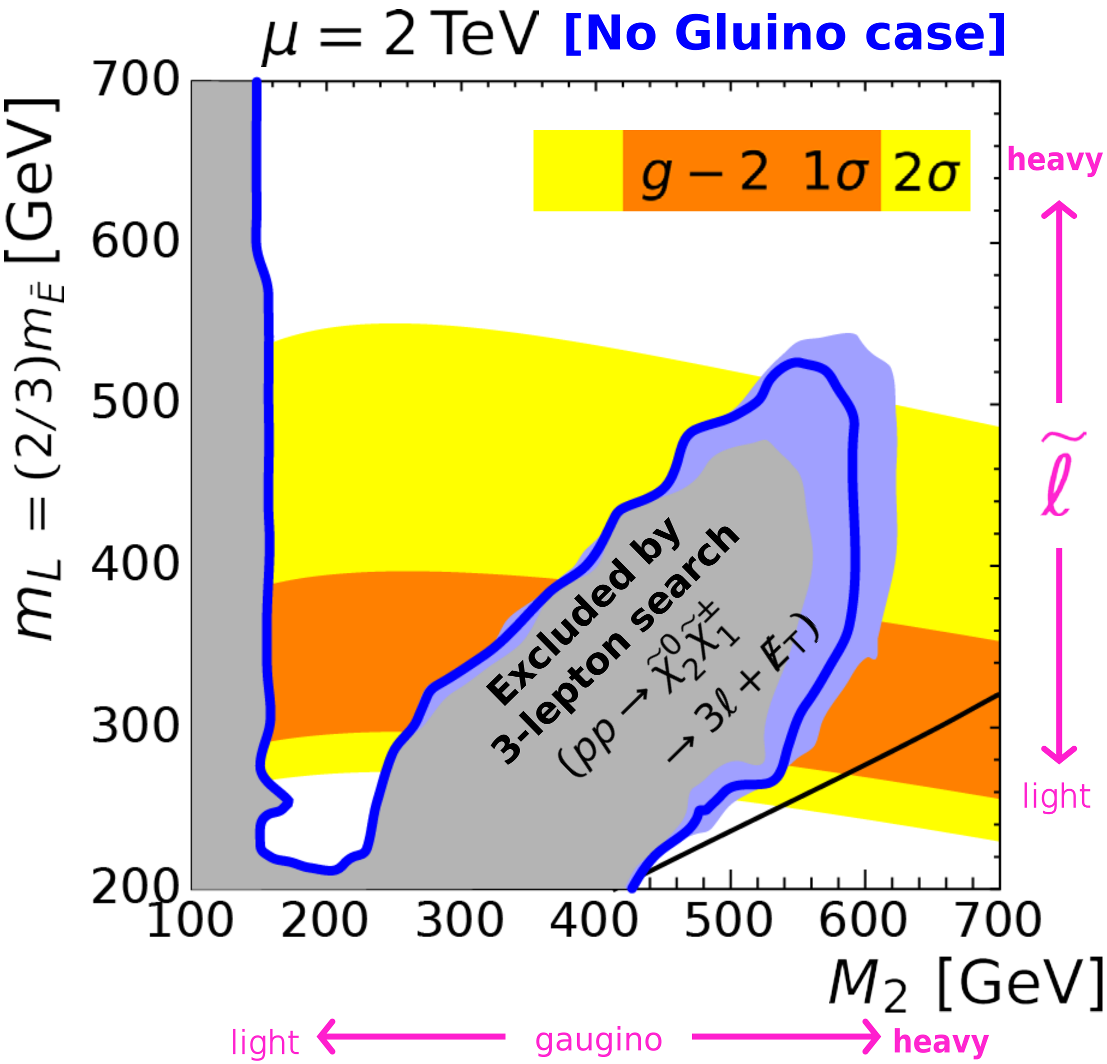

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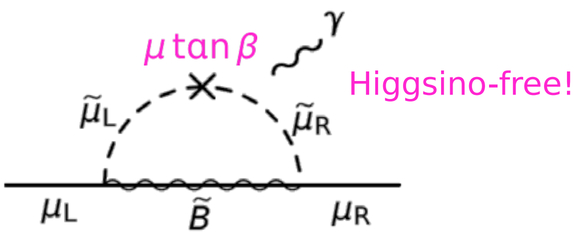

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  - $(\tan\beta, m_A) = (40, 1.5\,\mathrm{TeV})$
- Soft-params set @ 7 TeV ($= m_{\tilde{t}}$).
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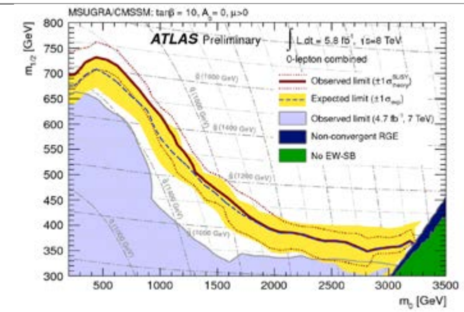


jet search $(pp \to \tilde{g}\tilde{g} \to \text{jets} + \not{E}_T)$

- ATLAS 8TeV 5.8fb^{-1} [ATLAS-CONF-2012-109]
- 2-6 hard jets + no lepton + $\not{E}_T$
- Original bound : $\tilde{g} \gtrsim 950\,\text{GeV}$ (CMSSM, $\tilde{q} \gg \tilde{g}$)

  $\Longrightarrow M_2 \gtrsim 300\,\text{GeV}$ in our model

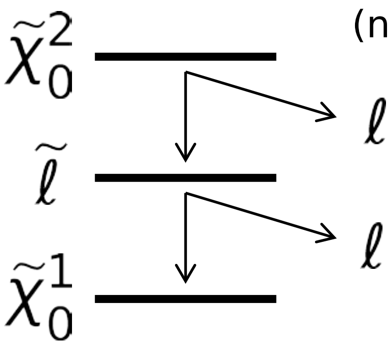
3-lepton search $(pp \to \tilde{\chi}^0_2\tilde{\chi}^\pm_1 \to 3\ell + \not{E}_T)$

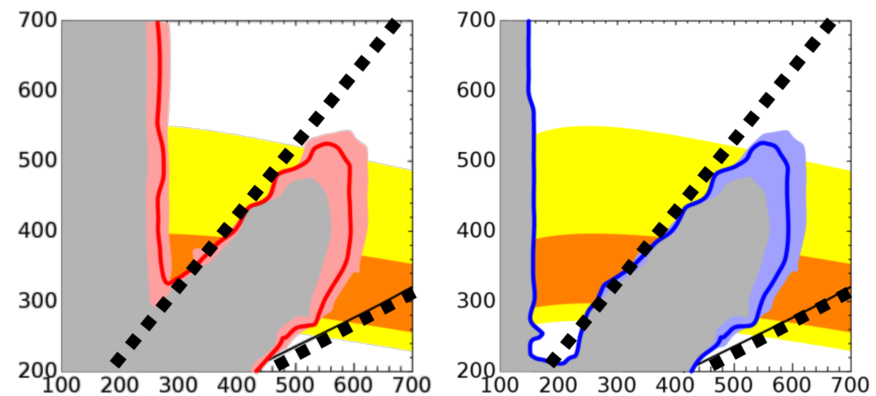
- ATLAS 8TeV 13fb^{-1} [ATLAS-CONF-2012-154]
- Exact 3 leptons + $\not{E}_T$ + SM-like signal vetoes

  (no b-jets, no lepton pairs near M_Z, etc…)
- Degenerated regions

  are not excluded.

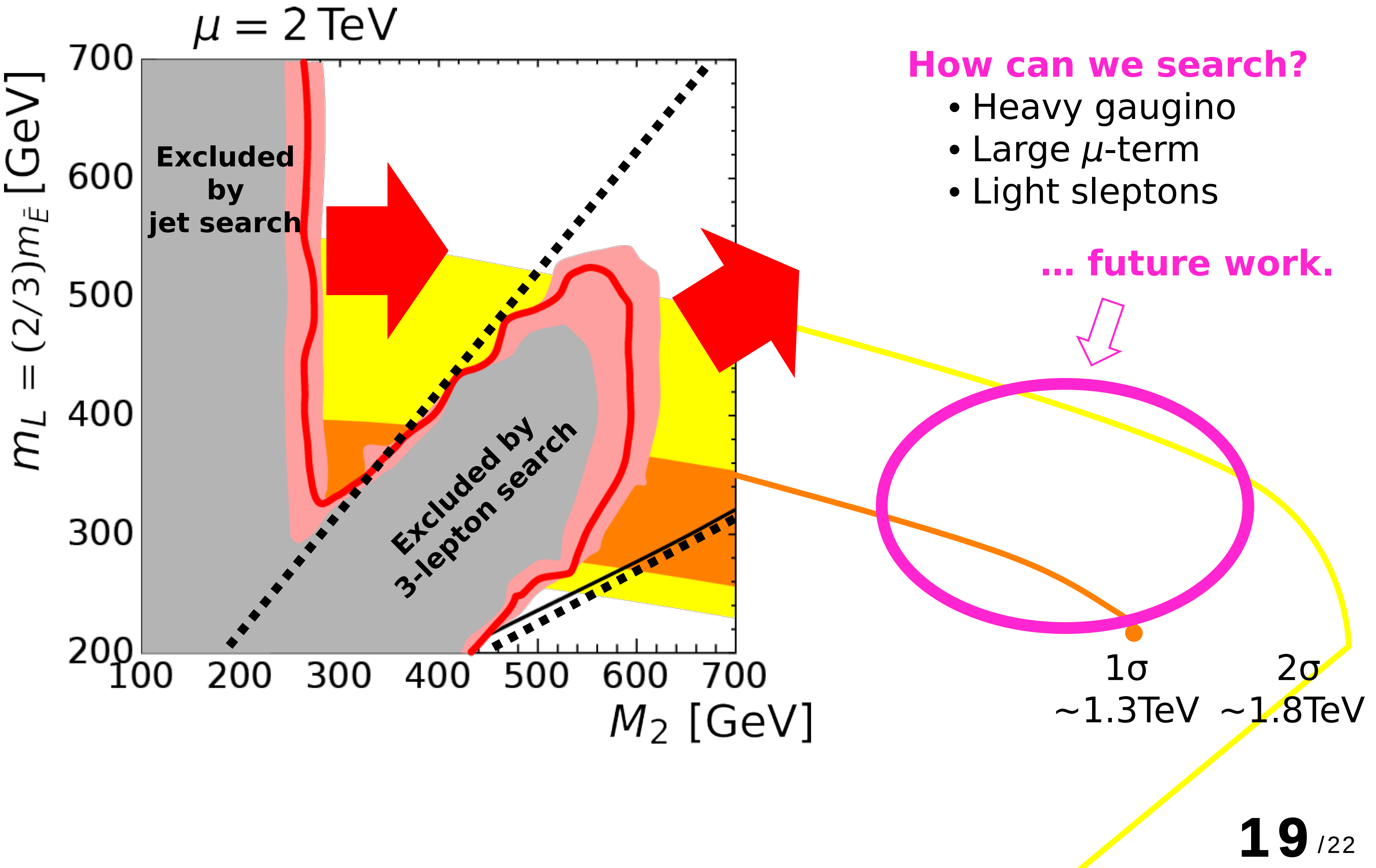
  (near the dotted lines)





Prospects

An extreme case: $\mu = 2\,\mathrm{TeV}$, $m_L^2 : m_{\bar{E}}^2 = 1 : (1.5)^2$

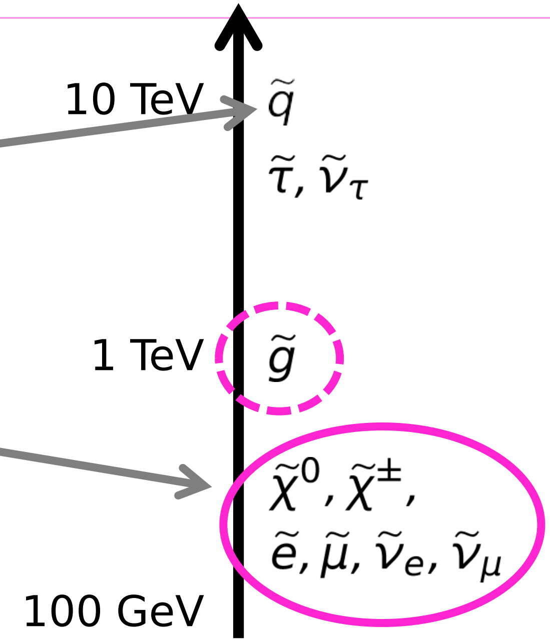


How can we search?

- Heavy gaugino
- Large μ-term
- Light sleptons

4. Summary

- 126 GeV Higgs
- SUSY Not Found yet
- $(g-2)_\mu$ anomaly



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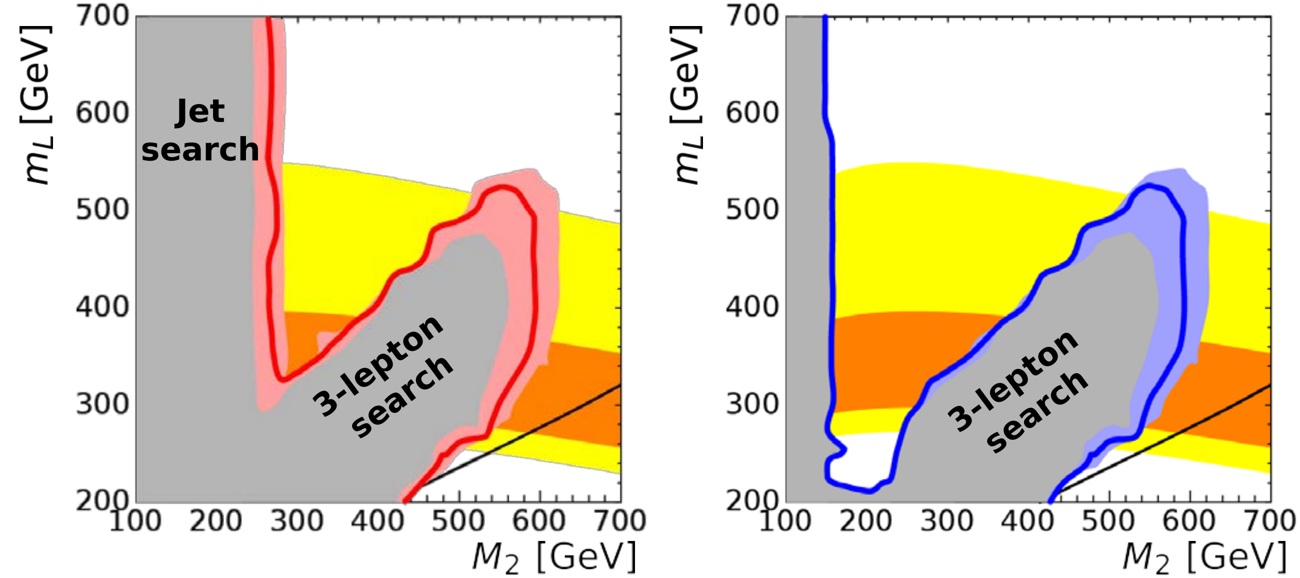
Jet: ATLAS-CONF-2012-109
3L: ATLAS-CONF-2012-154



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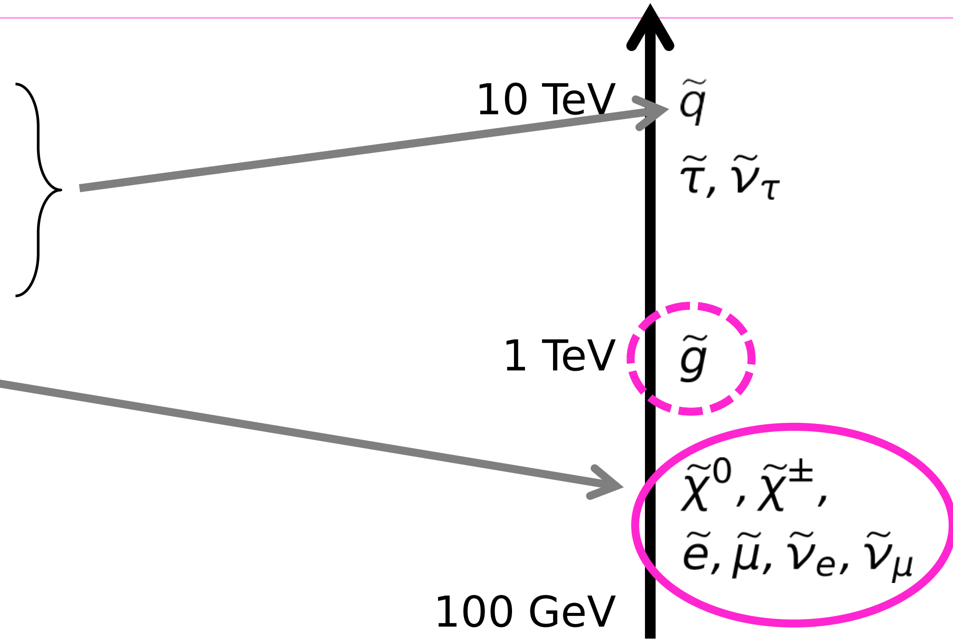

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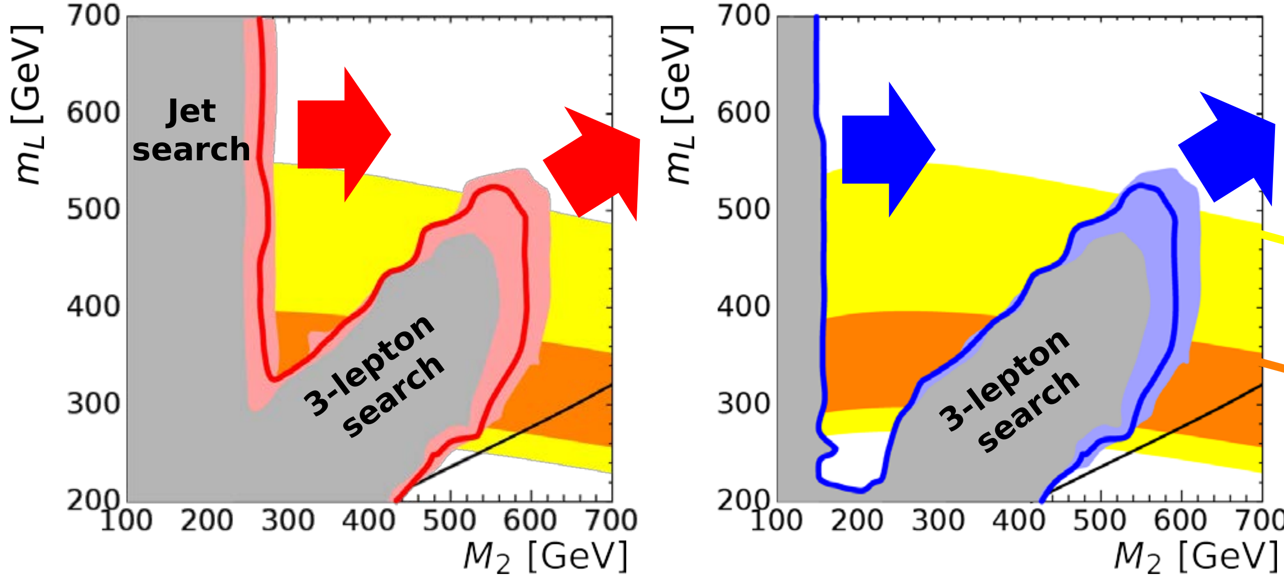

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... future work.