Differentiating $U(1)'$ supersymmetric models with right sneutrino and neutralino dark matter.

Jack Y. Araz, Mariana Frank, Benjamin Fuks

based on arXiv:1705.01063

Concordia University — IUF — UPMC — CNRS

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May 30, 2017

Outline

> **Introduction**
- Problems with the Standard Model
- Beyond the Standard Model: Supersymmetry

> **Analysis Motivation**
- Gauge extension to MSSM
- Parameter Space & Constraints

> **Results**
- Z' Phenomenology
- Muon Anomalous Magnetic Moment
- Neutralino Dark Matter
- RHSN Dark Matter

> **Conclusion**

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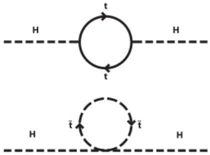
Neutrino Mass & Oscillations!

via nobelprize.org

Gauge Hierarchy Problem!



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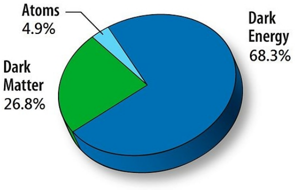
Dark Matter?



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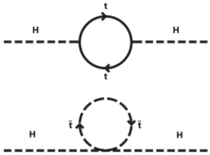

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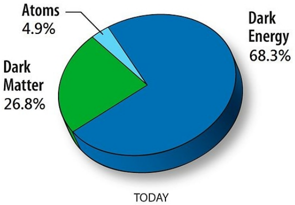

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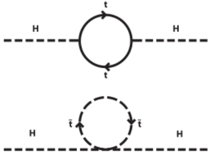

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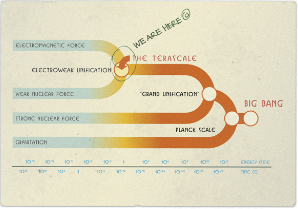


Grand Unification!

- Supersymmetry has reasonable solutions to all of these problems.

Outline

Motivation: Gauge Extension to MSSM

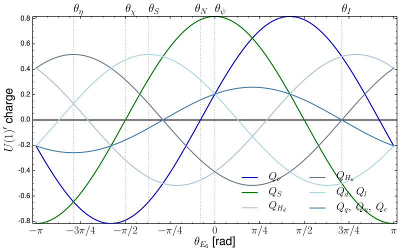
GUT-inspired $U(1)'$ extended MSSM symmetry breaking scheme[1]

$$E_6 \longrightarrow SO(10) \otimes U(1)'_\psi$$
$$\longrightarrow \left(SU(5) \otimes U(1)'_\chi\right) \otimes U(1)'_\psi$$

$$Q'(\theta_{E_6}) = Q'_\psi \cos\theta_{E_6} - Q'_\chi \sin\theta_{E_6}$$

MSSM $\otimes$ $U(1)'$ Chiral Superfields

SF	Spin 0	Spin $\frac{1}{2}$	$U(1) \otimes \mathrm{SU}(2) \otimes \mathrm{SU}(3) \otimes U(1)'$
$\hat{q}$	$\tilde{q}$	q	$(\frac{1}{6}, \mathbf{2}, \mathbf{3}, Q_q)$
$\hat{l}$	$\tilde{l}$	l	$(-\frac{1}{2}, \mathbf{2}, \mathbf{1}, Q_l)$
$\hat{H}_d$	H_d	$\tilde{H}_d$	$(-\frac{1}{2}, \mathbf{2}, \mathbf{1}, Q_{H_d})$
$\hat{H}_u$	H_u	$\tilde{H}_u$	$(\frac{1}{2}, \mathbf{2}, \mathbf{1}, Q_{H_u})$
$\hat{d}$	$\tilde{d}^*_R$	d^*_R	$(\frac{1}{3}, \mathbf{1}, \overline{\mathbf{3}}, Q_d)$
$\hat{u}$	$\tilde{u}^*_R$	u^*_R	$(-\frac{2}{3}, \mathbf{1}, \overline{\mathbf{3}}, Q_u)$
$\hat{e}$	$\tilde{e}^*_R$	e^*_R	$(1, \mathbf{1}, \mathbf{1}, Q_e)$
$\hat{\nu}_R$	$\tilde{\nu}^*_R$	ν^*_R	$(0, \mathbf{1}, \mathbf{1}, Q_v)$
$\hat{s}$	S	$\tilde{S}$	$(0, \mathbf{1}, \mathbf{1}, Q_s)$



[1] Slansky, R. (1981). Group theory for unified model building. Physics Reports, 79(1).

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$$Q'(\theta_{E_6}) = Q'_\psi \cos\theta_{E_6} - Q'_\chi \sin\theta_{E_6}$$

$$W = \mathbf{Y}_u \hat{u}\hat{q}\hat{H}_u - \mathbf{Y}_d \hat{d}\hat{q}\hat{H}_d - \mathbf{Y}_e \hat{e}\hat{l}\hat{H}_d + \mu \hat{H}_u \hat{H}_d$$

$$W_{\rm UMSSM} = W_{\mu\to\mu_{\rm eff}} + \mathbf{Y}_\nu \hat{l}\hat{H}_u\hat{\nu}_R$$

$$\mu_{\rm eff} = \frac{\lambda v_S}{\sqrt{2}} \quad , \quad \mu\hat{H}_u\hat{H}_d \to \lambda\hat{H}_u\hat{H}_d\hat{s}$$

- μ-problem
- Additional DM candidate
- Muon anomalous magnetic moment

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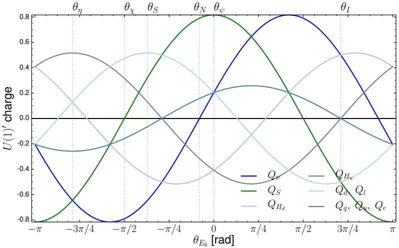

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Parameter Space & Constraints

Universality Conditions[1]

GUT Scale

- $M_{1,2,3,4} = M_{1/2}$
- $m^2_{\tilde{q},\tilde{u},\tilde{d}} = diag[M_0^2]$
- $g_1 = g_2 = g'\sqrt{3/5} \approx g_3$

SUSY Scale

- Setting v_S, λ & A_λ
- $m^2_{\tilde{L},\tilde{e},\tilde{\nu}}$; split family
- $M_{SUSY} \leq 5$ TeV

[1] Scalar soft-breaking terms, $m^2_{H_{u,d}}$ & m^2_S, are derived from tadpole equations.

Parameter Space & Constraints.

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Scanned range of the free parameters in the model.

Parameter	Scanned range	Parameter	Scanned range
M_0	$[0,3]$ TeV	μ	$[-2,2]$ TeV
$M_{1/2}$	$[0,5]$ TeV	A_λ	$[-7,7]$ TeV
A_0	$[-3,3]$ TeV	$M_{Z'}$	$[1.98,5.2]$ TeV
$\tan\beta$	$[0,60]$	$m^2_{\tilde{\nu}}$	$[-6.8,9]$ TeV^2
θ_{E_6}	$[-\pi,\pi]$	$m^2_{\tilde{e},\tilde{l}}$	$[0,1]$ TeV^2

$$Y_\nu = diag[10^{-11}]$$

Experimental constraints imposed within our scanning procedure in order to determine the parameter space regions of interest.

Observable	Constraints	Observable	Constraints
M_h	125.09 ± 3 GeV	$\chi^2(\hat{\mu})$	≤ 70
$\lvert\alpha_{ZZ'}\rvert$	$O(10^{-3})$	$M_{\tilde{g}}$	> 1.75 TeV
$M_{\chi_2^0}$	> 62.4 GeV	$M_{\chi_3^0}$	> 99.9 GeV
$M_{\chi_4^0}$	> 116 GeV	$M_{\chi_i^\pm}$	> 103.5 GeV
$M_{\tilde{\tau}}$	> 81 GeV	$M_{\tilde{e}}$	> 107 GeV
$M_{\tilde{\mu}}$	> 94 GeV	$M_{\tilde{t}}$	> 900 GeV
$\mathrm{BR}(B_s^0 \to \mu^+\mu^-)$	$[1.1\times10^{-9}, 6.4\times10^{-9}]$	$\frac{\mathrm{BR}(B\to\tau\nu_\tau)}{\mathrm{BR}_{SM}(B\to\tau\nu_\tau)}$	$[0.15, 2.41]$
$\mathrm{BR}(B^0 \to X_s\gamma)$	$[2.99, 3.87]\times10^{-4}$		

[1] Scalar soft-breaking terms, $m^2_{H_{u,d}}$ & m^2_S, are derived from tadpole equations.

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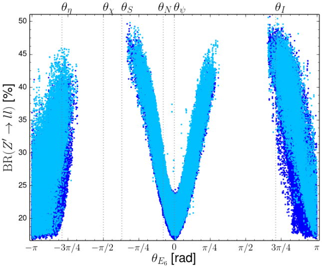
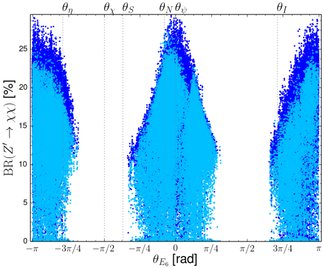
Z' Phenomenology





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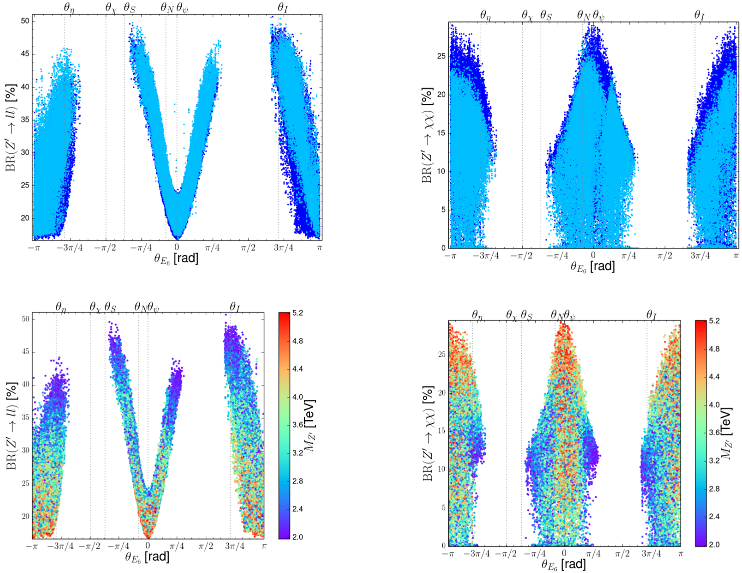
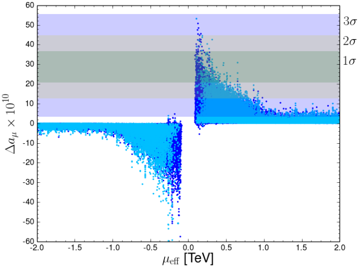
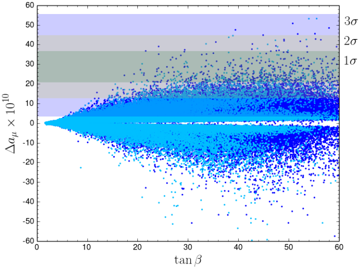


Muon Anomalous Magnetic Moment





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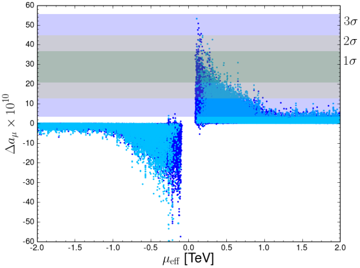
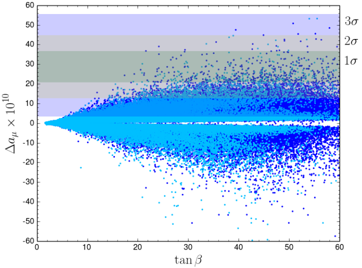
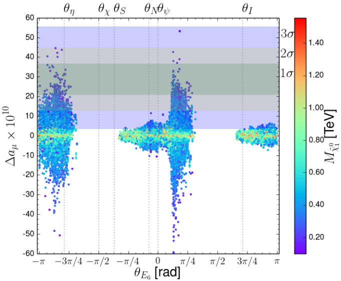
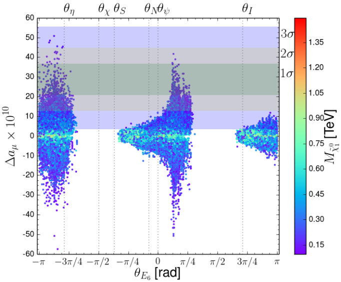
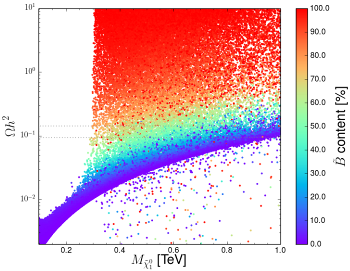


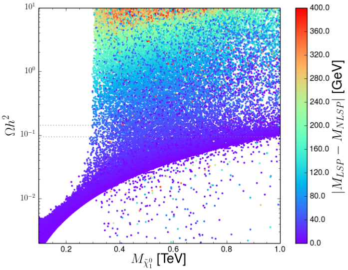






Neutralino Dark Matter





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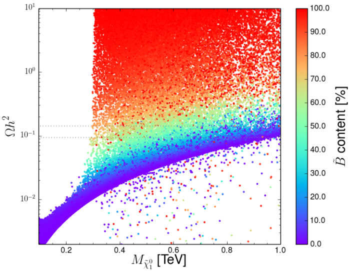
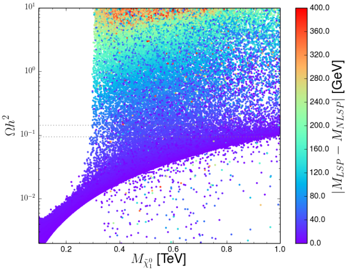
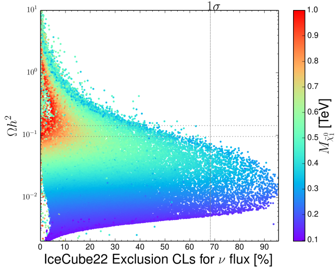
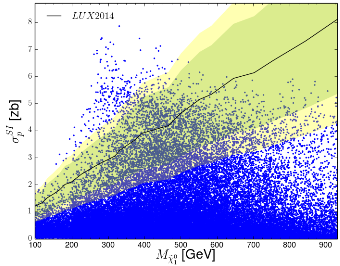






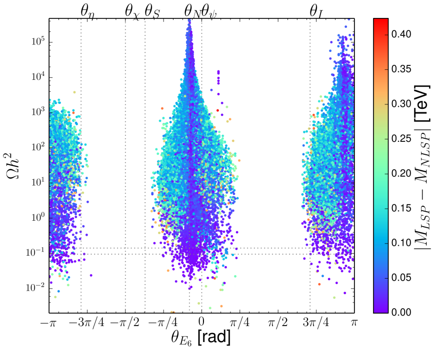


RH Scalar Neutrino Dark Matter

Model based, mass scan for certain bench marks

- $\mu_{\text{eff}} = 1 - 1.7$ TeV
- $A_\lambda = 1 - 2$ TeV
- $M_{Z'} = 2 - 2.5$ TeV
- $M_{\tilde{\chi}_1^0} = 400 - 600 - 800$ GeV
- Fix slepton masses depending on θ_{E_6}

$U(1)'_N$ excluded due to unpredictible relic density.



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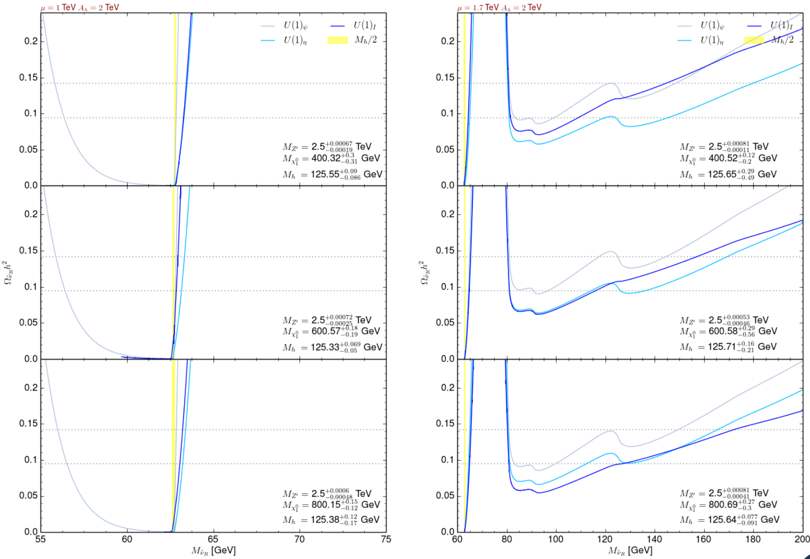

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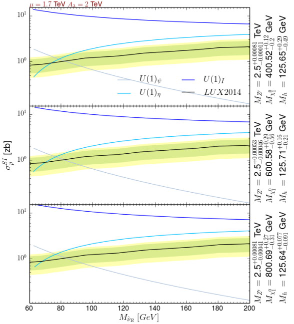

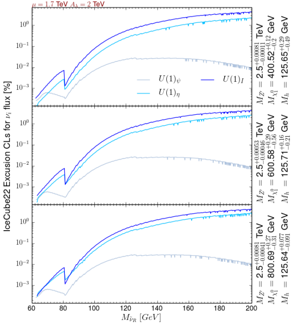

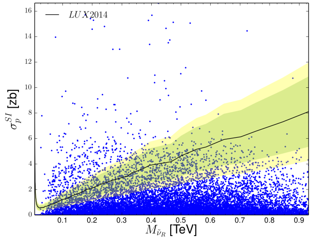

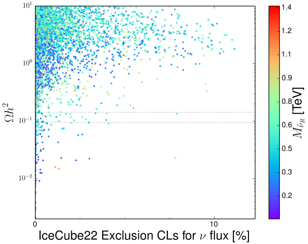

Outline.

Conclusion

Z′ phenomenology

- Depending on θ_{E_6}, leptophobic behaviour changes due to Q'.
- $U(1)'_\psi$ might be promising for collider complementary due to enhanced electroweakino channel.

Muon Anomalous Magnetic Moment

Dark Matter

Collider Complementary

Conclusion

Z′ phenomenology

Muon Anomalous Magnetic Moment

- $U(1)'_\eta$ is promising due to low slepton and neutralino masses other than that, only $U(1)'_\psi$ is within the 2σ region.

Dark Matter

Collider Complementary

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Z′ phenomenology

Muon Anomalous Magnetic Moment

Dark Matter

- With the new Z' mass bound, RHSN might be in danger due to high D-term.
- Neutralino is too heavy (~ 300 GeV) to have a collider complementary.

Collider Complementary

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Dark Matter

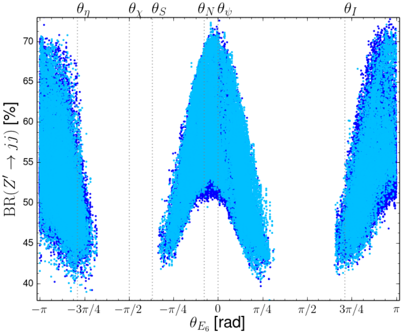
Collider Complementary

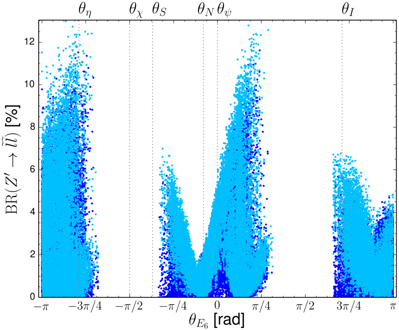
- Mono–X Channel
- Stau Production
- ElectroWeakino Production

Gratitude, for your kind attention...

BACKUP

Z' Phenomenology





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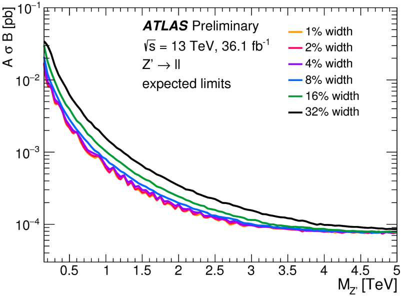

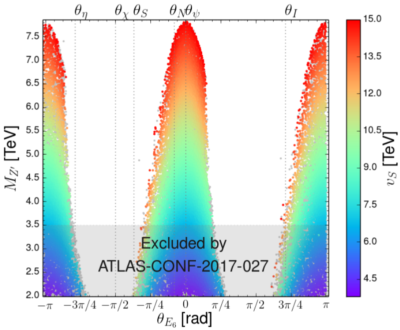

Parameter Space