

The 2015+ Phenomenology of Deflected Mirage Mediation

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arXiv: 1508.xxxx



Outline

- What is Deflected Mirage Mediation (DMM)?
- The parameters and soft terms
- How DMM differs from mirage mediation
- The parameter space
- Example spectra
- Direct Detection
- Conclusions

What is DMM?

- DMM is a KKLT-like mirage mediation scenario with an additional gauge mediation step at an intermediate scale, giving us all three mediation mechanisms operating concurrently.
- N GUT multiplets of vector-like messengers are coupled to some field X that gets a scalar and SUSY-breaking vev and is stabilized radiatively or via higher-dimensional contributions.

L.L Everett, I-W Kim, P. Ouyang, and K. M. Zurek, arXiv:0804.0592

L.L Everett, I-W Kim, P. Ouyang, and K. M. Zurek, arXiv:0806.2330

What is DMM?

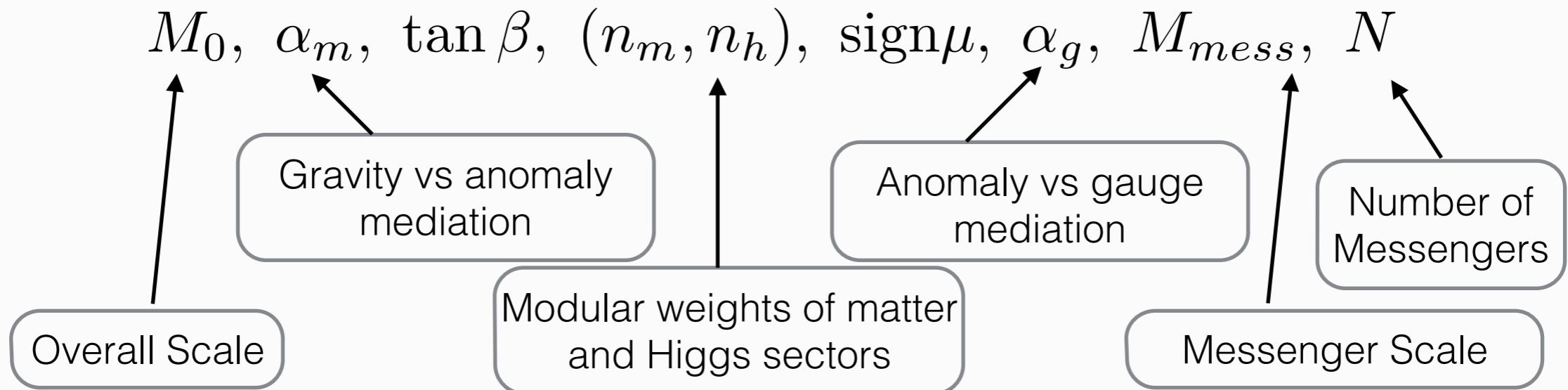
- DMM is a theory of supersymmetry breaking with an intermediate scale mediation mechanism. It includes mirage mediation, Anomaly Mediation, and Gauge Mediation.
 - New constraints come from constraints on Supergravity via string theory or via string theory constraints on supersymmetry breaking.
-
- ```
graph LR; MM[mirage mediation] --> AM[Anomaly Mediation]; AM --> DM[Deflected Mirage Mediation]; GM[Gauge Mediation] --> DM; GM --> GM
```

L.L Everett, I-W Kim, P. Ouyang, and K. M. Zurek, arXiv:0804.0592

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# The DMM Parameters and Soft Masses

DMM has 9 parameters:



The soft masses at the GUT scale are

$$M_a(M_{GUT}) = M_0 \left[ 1 + \frac{g_0^2}{16\pi^2} b'_a \alpha_m \ln \left( \frac{M_P}{m_{3/2}} \right) \right]$$

$$\alpha_m \equiv \frac{m_{3/2}}{M_0 \ln (M_P/m_{3/2})}$$

$$A_i(M_{GUT}) = M_0 \left[ (1 - n_i) - \frac{\gamma_i}{16\pi^2} \alpha_m \ln \left( \frac{M_P}{m_{3/2}} \right) \right]$$

$$m_i^2(M_{GUT}) = M_0 \left[ (1 - n_i) - \frac{\theta'_i}{16\pi^2} \alpha_m \ln \left( \frac{M_P}{m_{3/2}} \right) - \frac{\dot{\gamma}_i'}{(16\pi^2)^2} \left( \alpha_m \ln \left( \frac{M_P}{m_{3/2}} \right) \right)^2 \right].$$

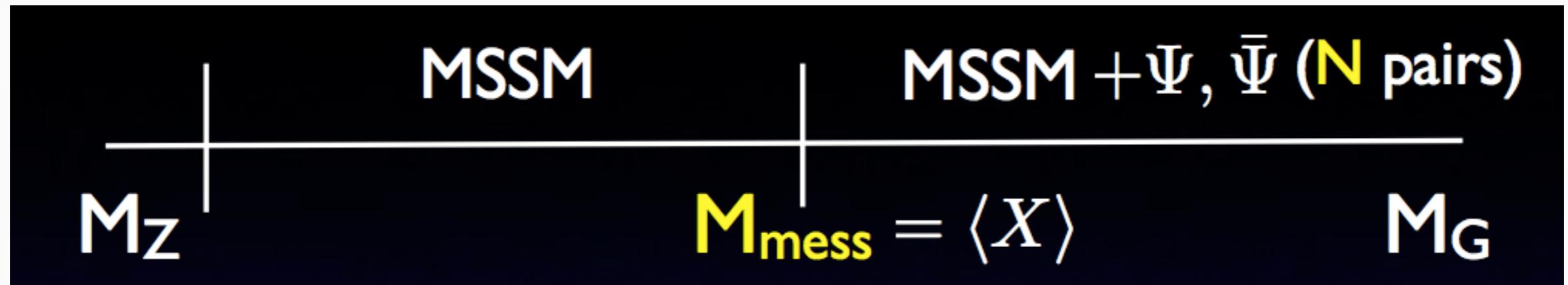
# Messenger Scale Corrections

The messenger scale corrections are

$$\Delta M_a = -M_0 N \frac{g_a^2(M_{\text{Mess}})}{16\pi^2} \alpha_m (1 + \alpha_g) \ln \left( \frac{M_P}{m_{3/2}} \right)$$

$$\Delta m_i^2 = M_0^2 \sum_a 2c_a N \frac{g_a^2(M_{\text{Mess}})}{(16\pi^2)^2} \left[ \alpha_m (1 + \alpha_g) \ln \left( \frac{M_P}{m_{3/2}} \right) \right]^2.$$

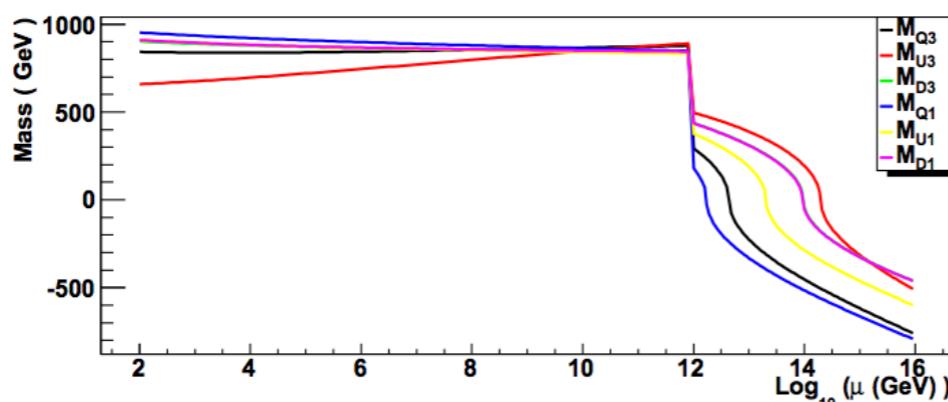
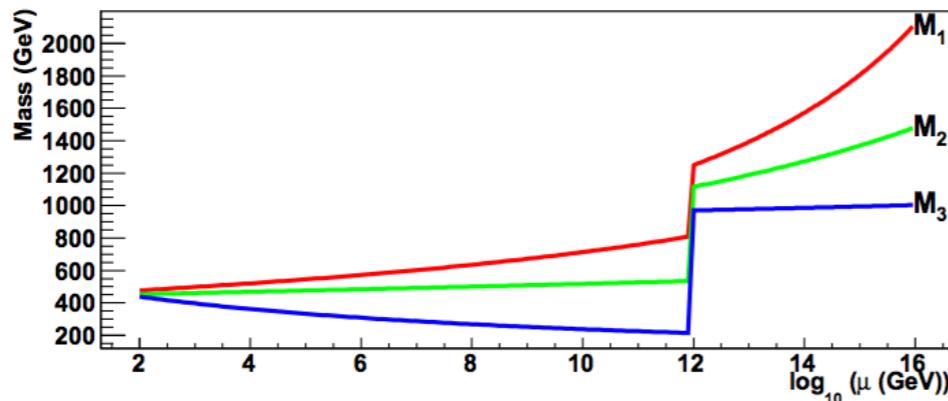
Generically, the picture is



The addition of messengers can lead to large corrections

# The Mirage Scale

- In mirage mediation there's a “mirage scale” where the gauginos and soft scalar masses unify.
- In deflected mirage there are large threshold effects and a similar story, but only the gauginos unify.



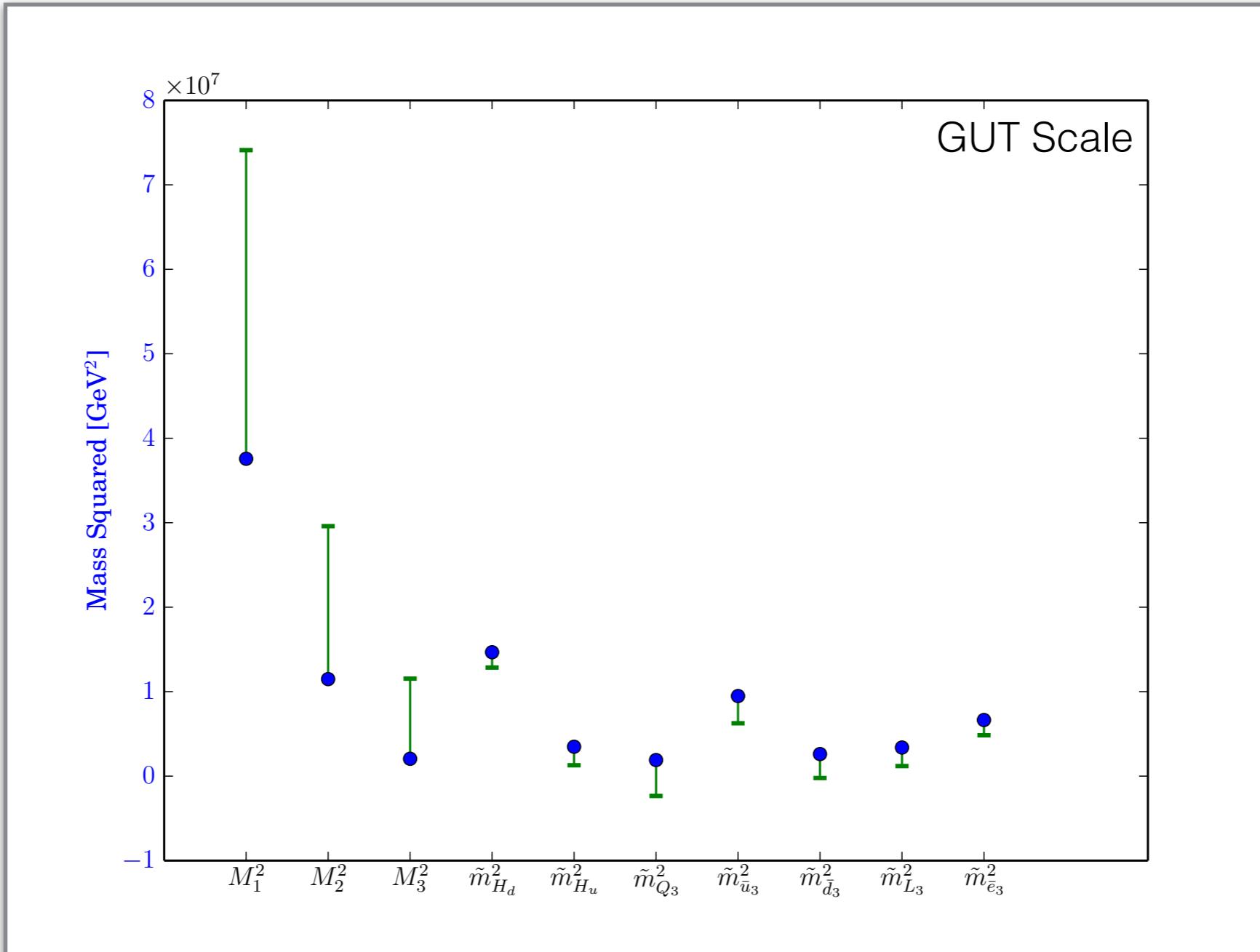
$$M_0 = 1 \text{ TeV}, \alpha_m = \alpha_g = 1, (n_M, n_H) = \left(\frac{1}{2}, 1\right)$$

$$\tan \beta = 10, \log_{10} M_{\text{mess}} = 12, N = 3$$

$$M_{\text{mirage}} = M_G \left( \frac{m_{3/2}}{M_P} \right)^{\frac{\alpha_m \rho}{2}},$$

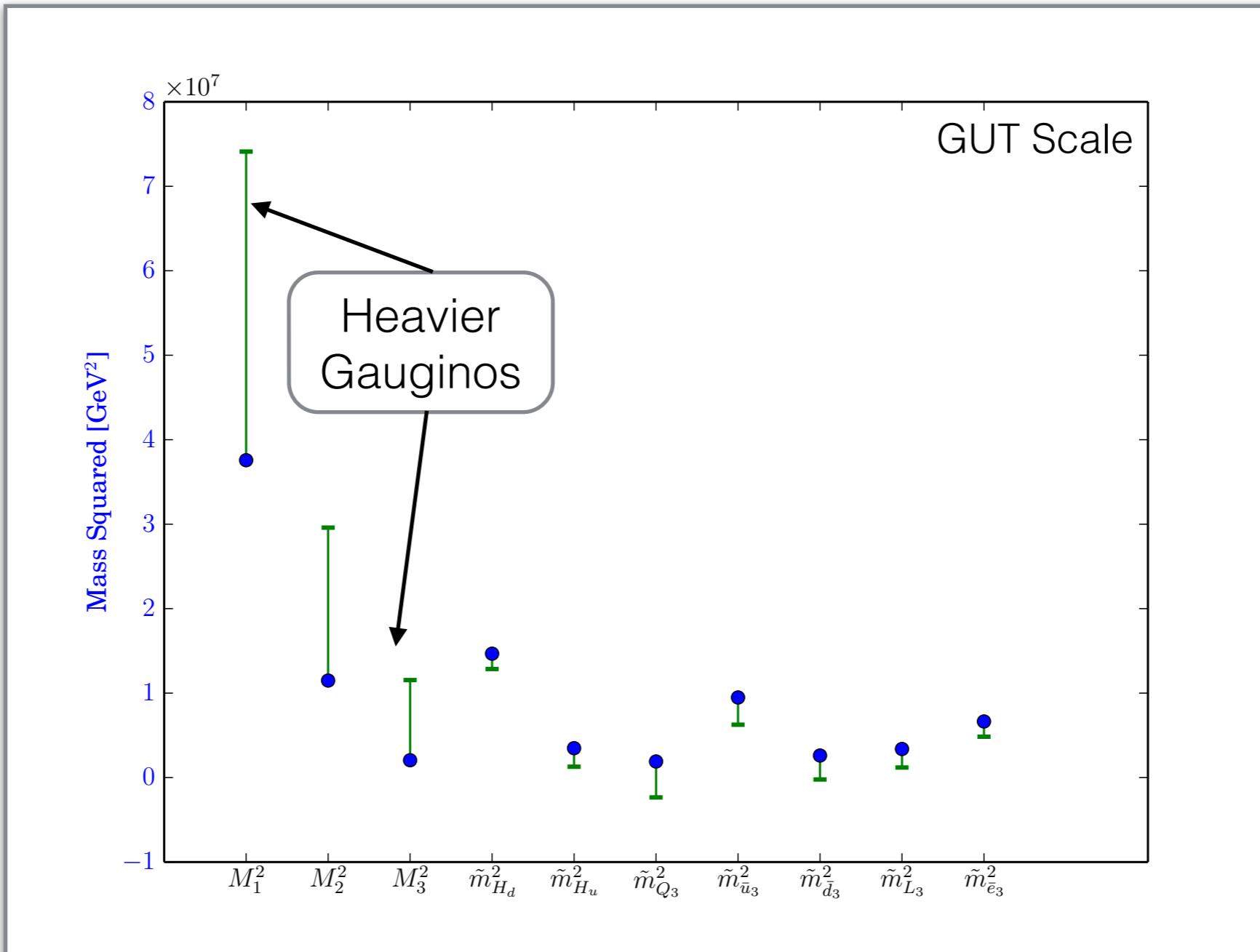
$$\rho = \frac{1 + \frac{2N g_0^2}{16\pi^2} \ln \frac{M_G}{M_{\text{mess}}}}{1 - \frac{\alpha_m \alpha_g N g_0^2}{16\pi^2} \ln \frac{M_P}{m_{3/2}}}.$$

# DMM versus Mirage Mediation



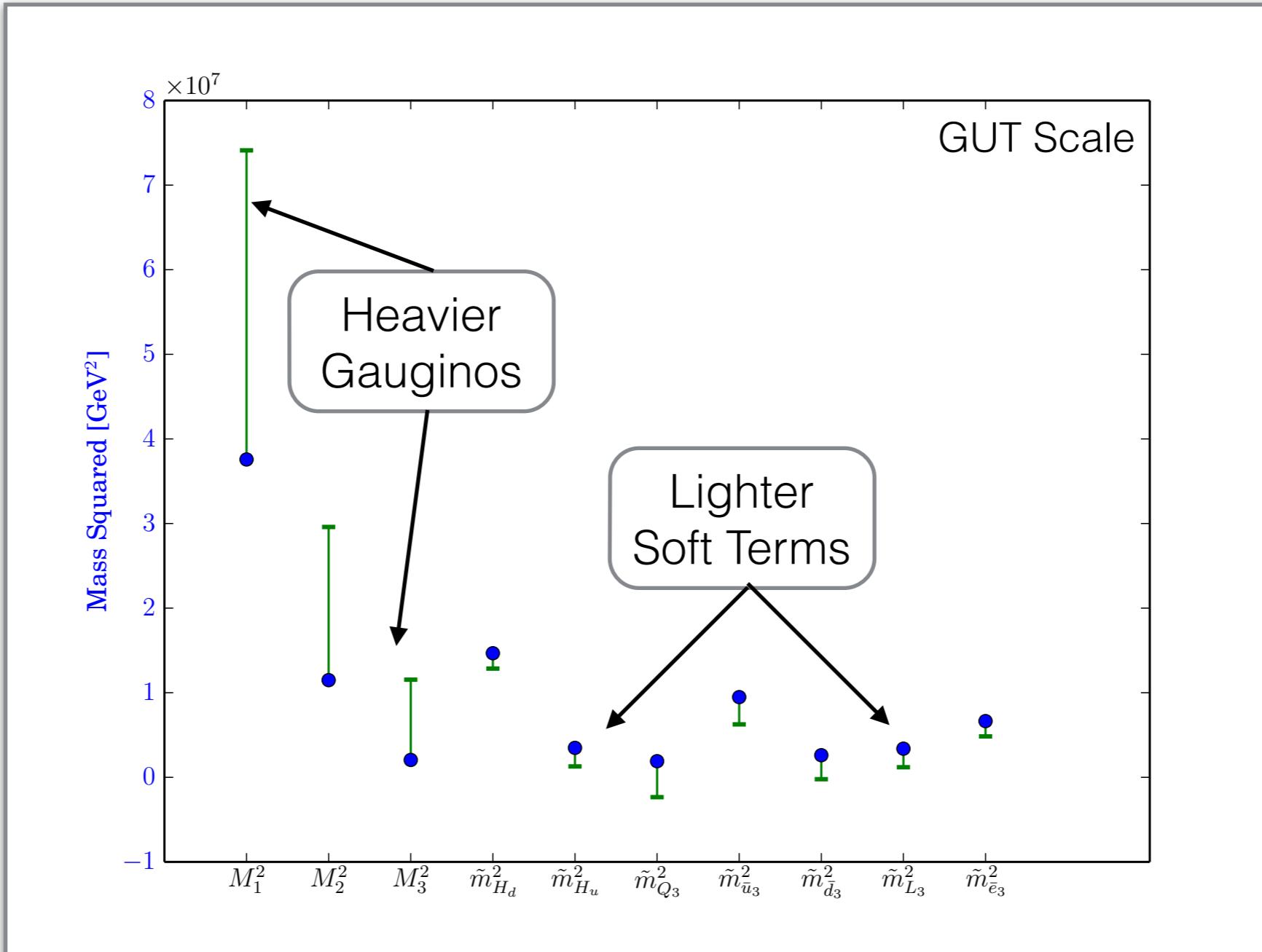
$M_0 = 2900 \text{ GeV}$ ,  $\alpha_m = 1.8$ ,  $(n_m, n_h) = (0, 0)$ ,  $\tan \beta = 9$   
 $\alpha_g \in [-1, 1]$ ,  $\log_{10} M_{mess} = [5, 14]$ ,  $N \in [1, 5]$

# DMM versus Mirage Mediation



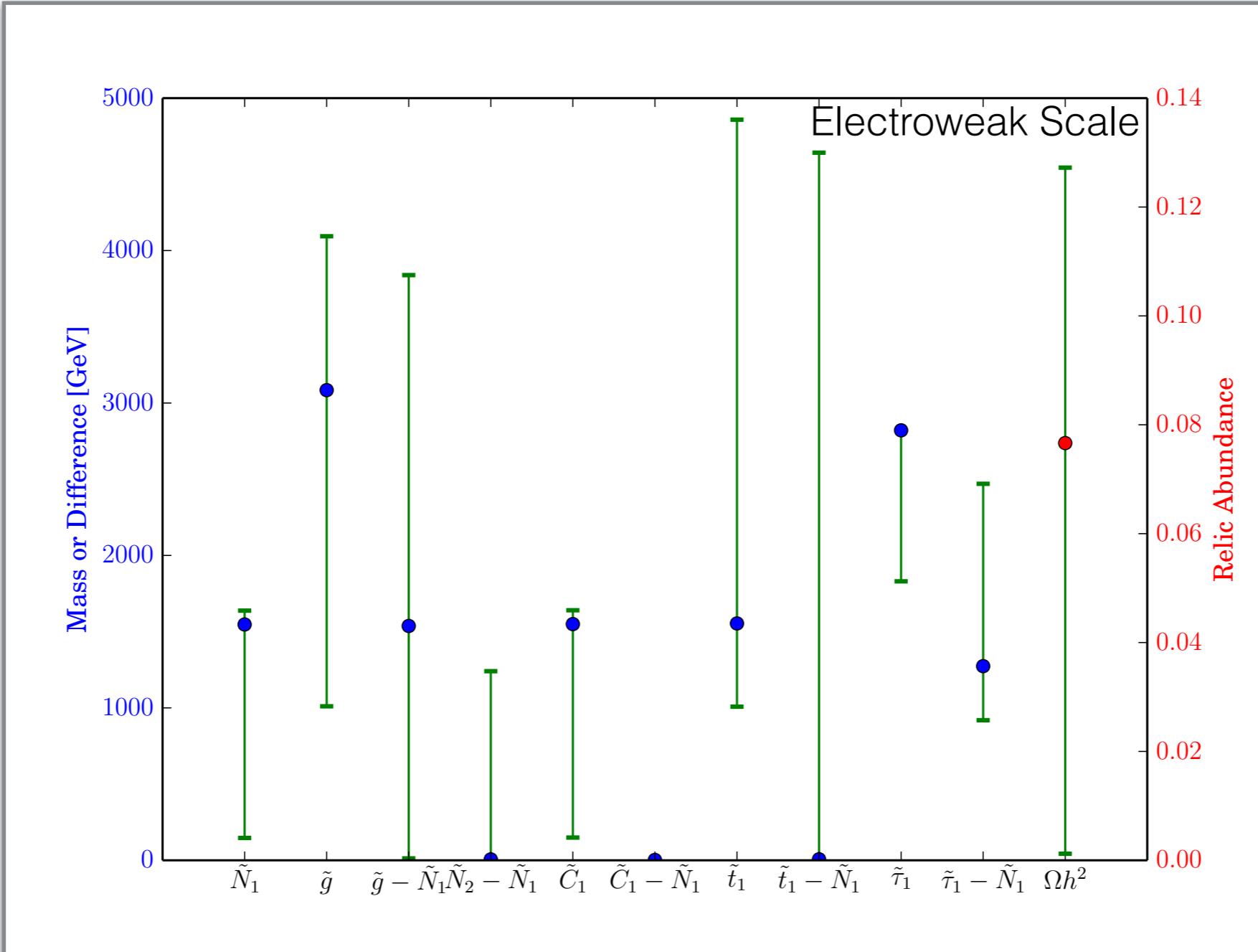
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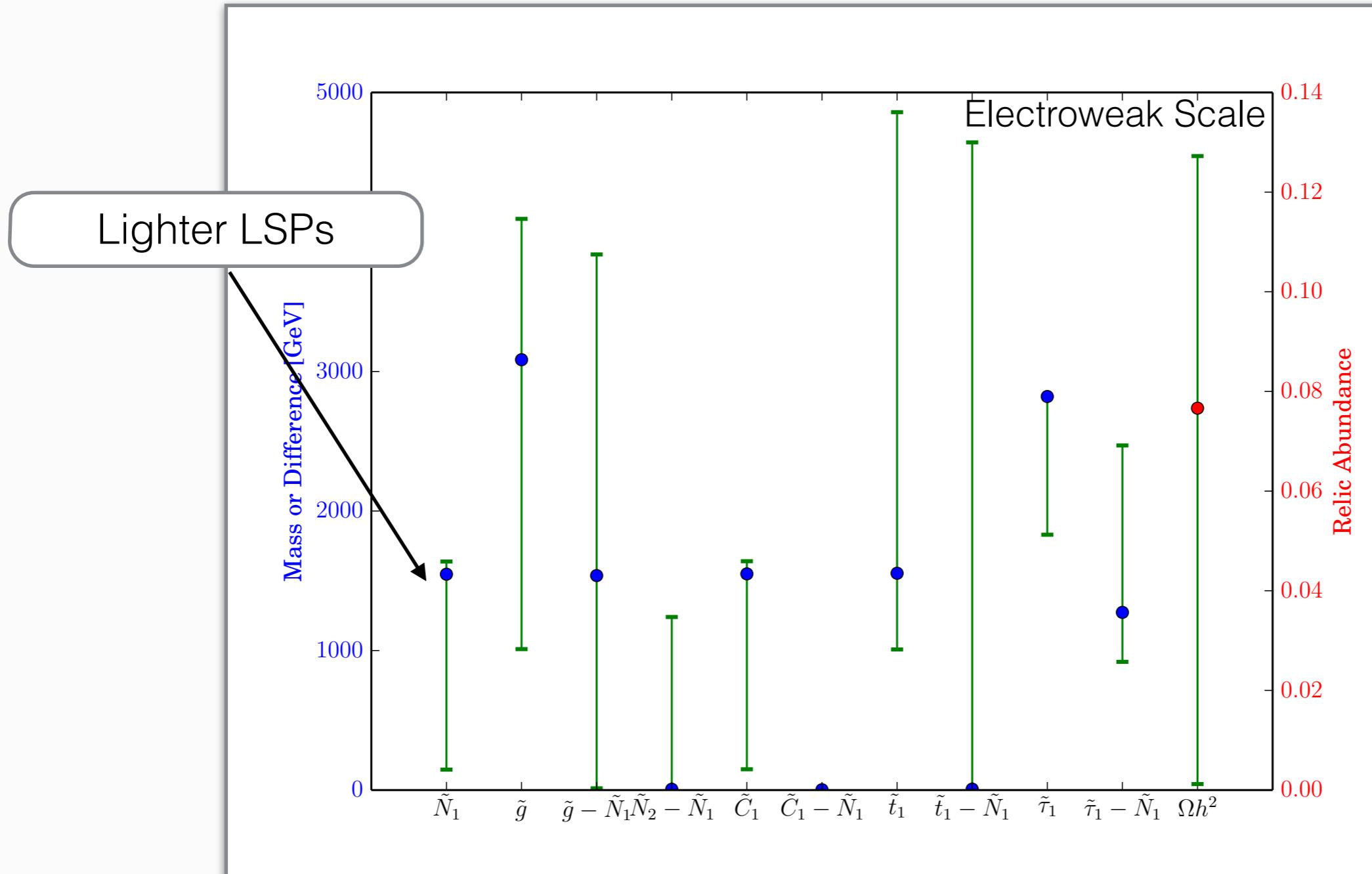
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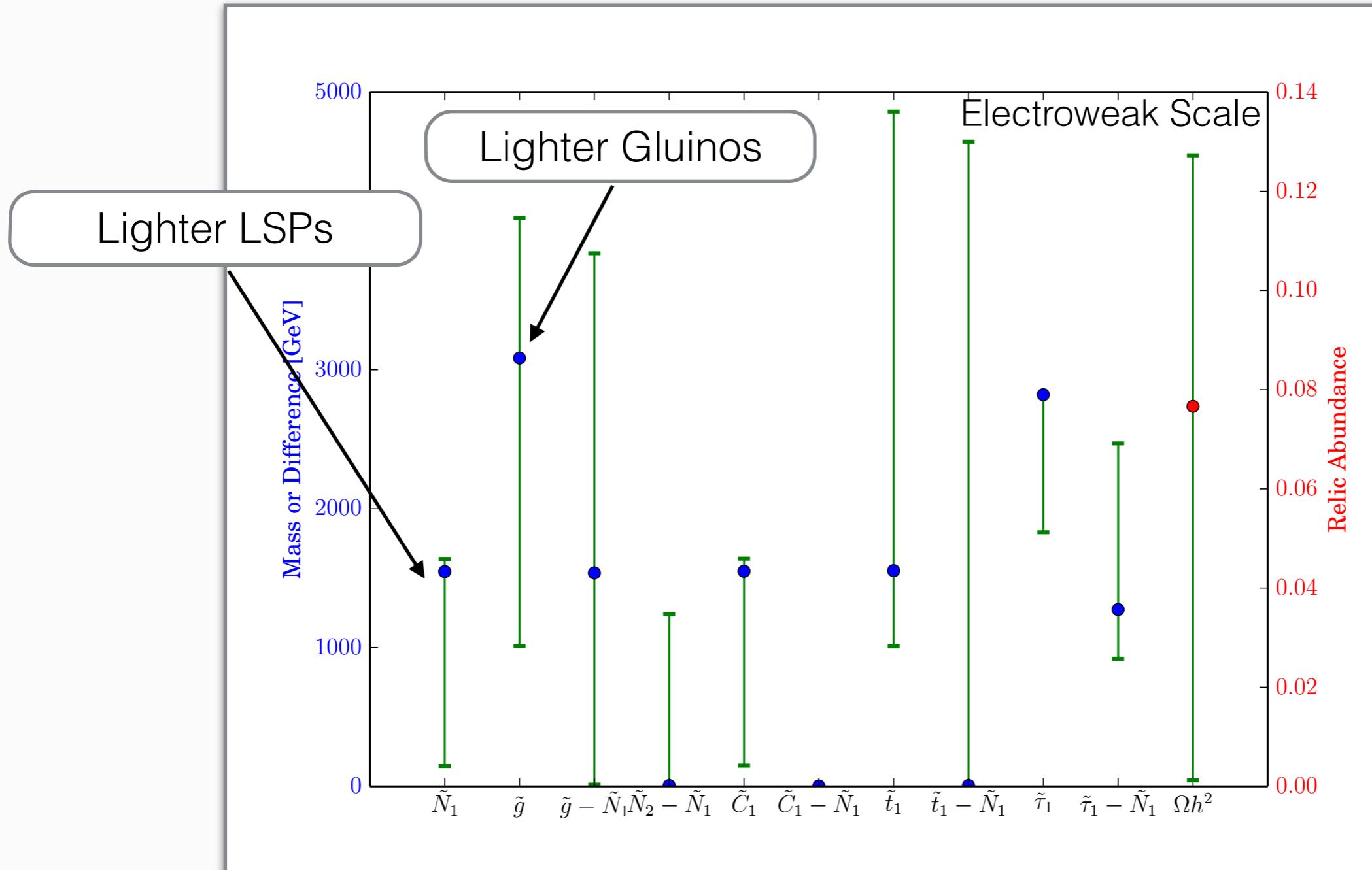
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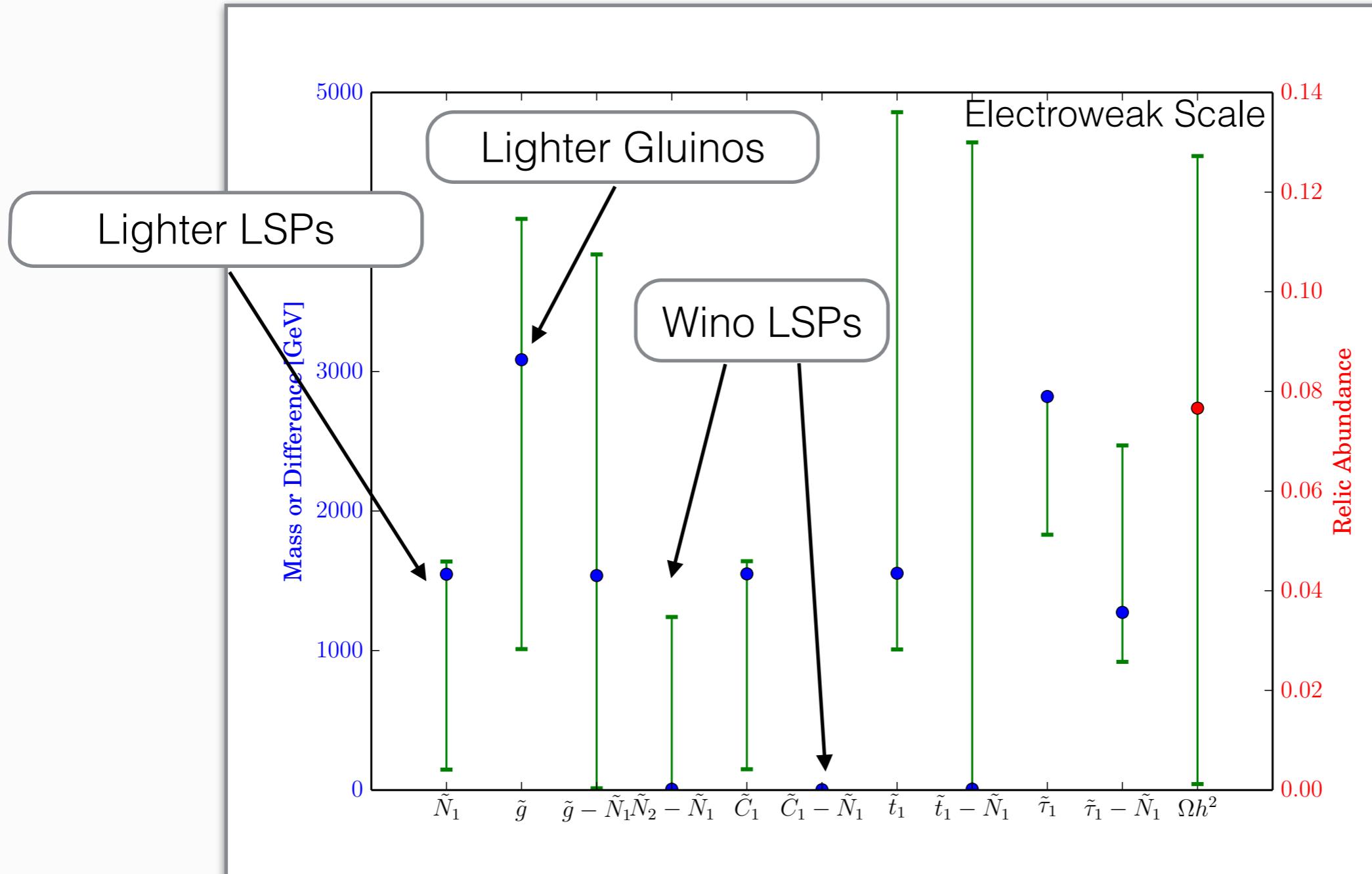
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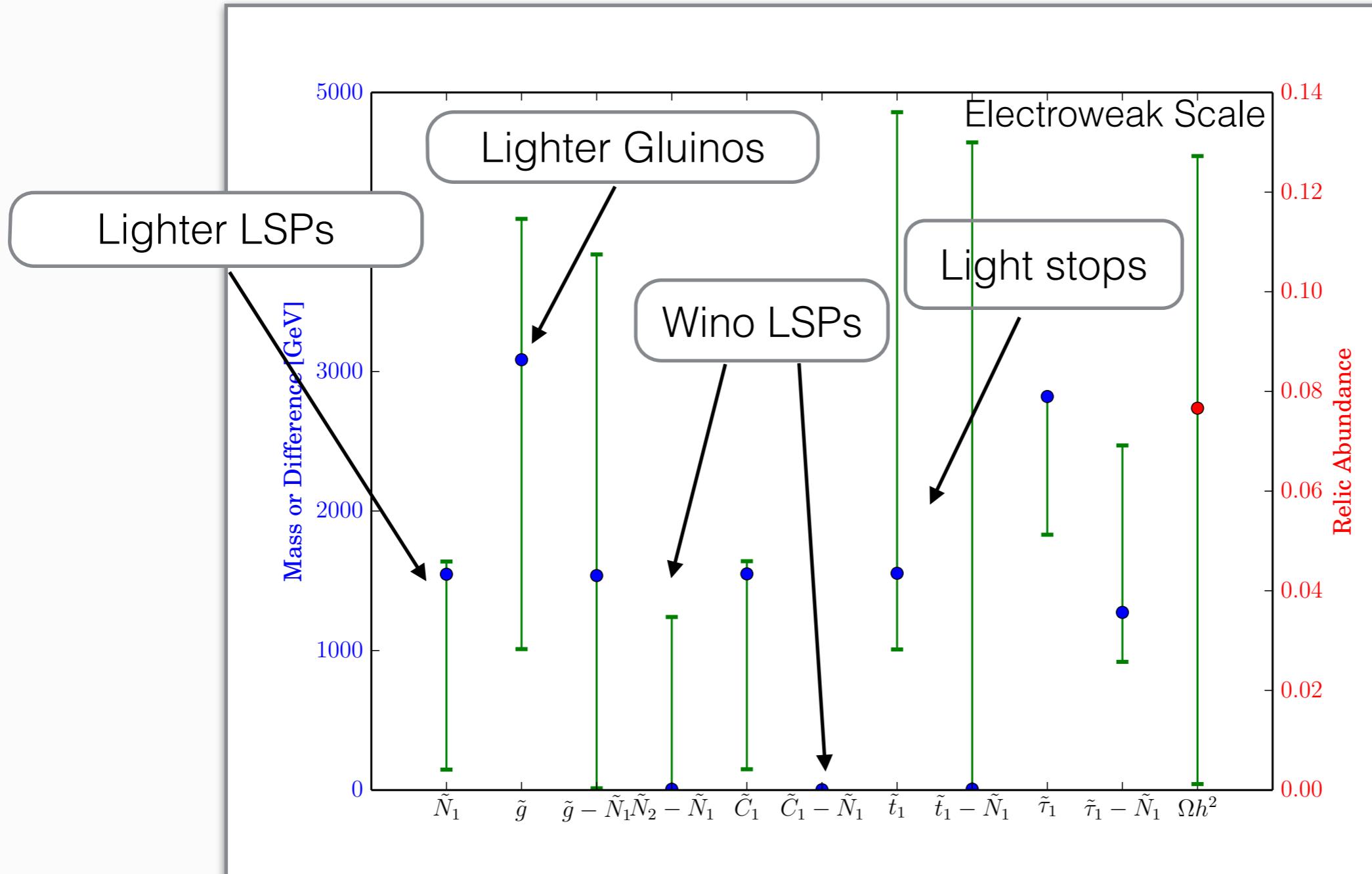
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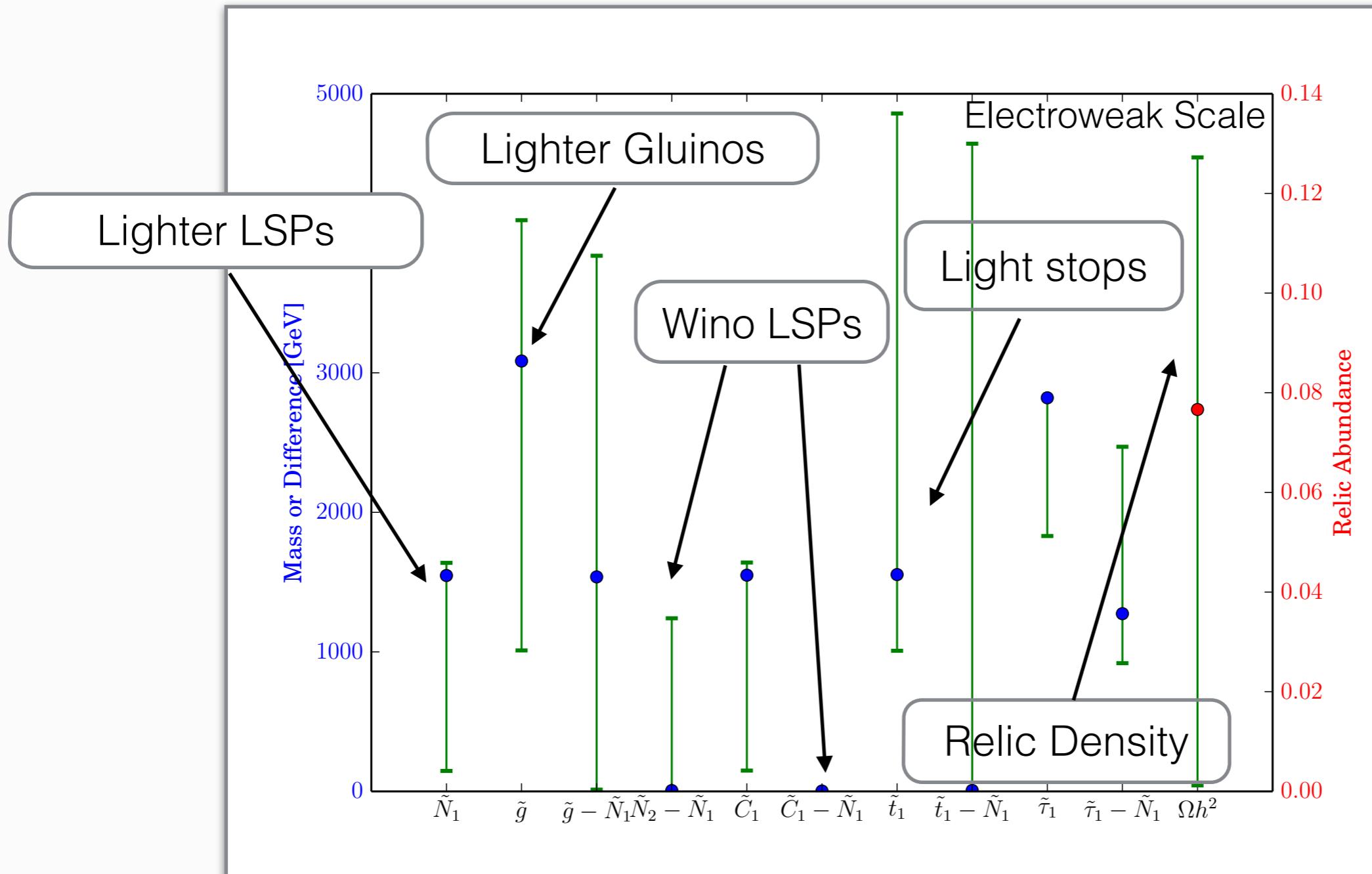
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# DMM versus Mirage Mediation



$M_0 = 2900$  GeV,  $\alpha_m = 1.8$ ,  $(n_m, n_h) = (0, 0)$ ,  $\tan \beta = 9$   
 $\alpha_g \in [-1, 1]$ ,  $\log_{10} M_{mess} = [5, 14]$ ,  $N \in [1, 5]$

# Methods and Bounds

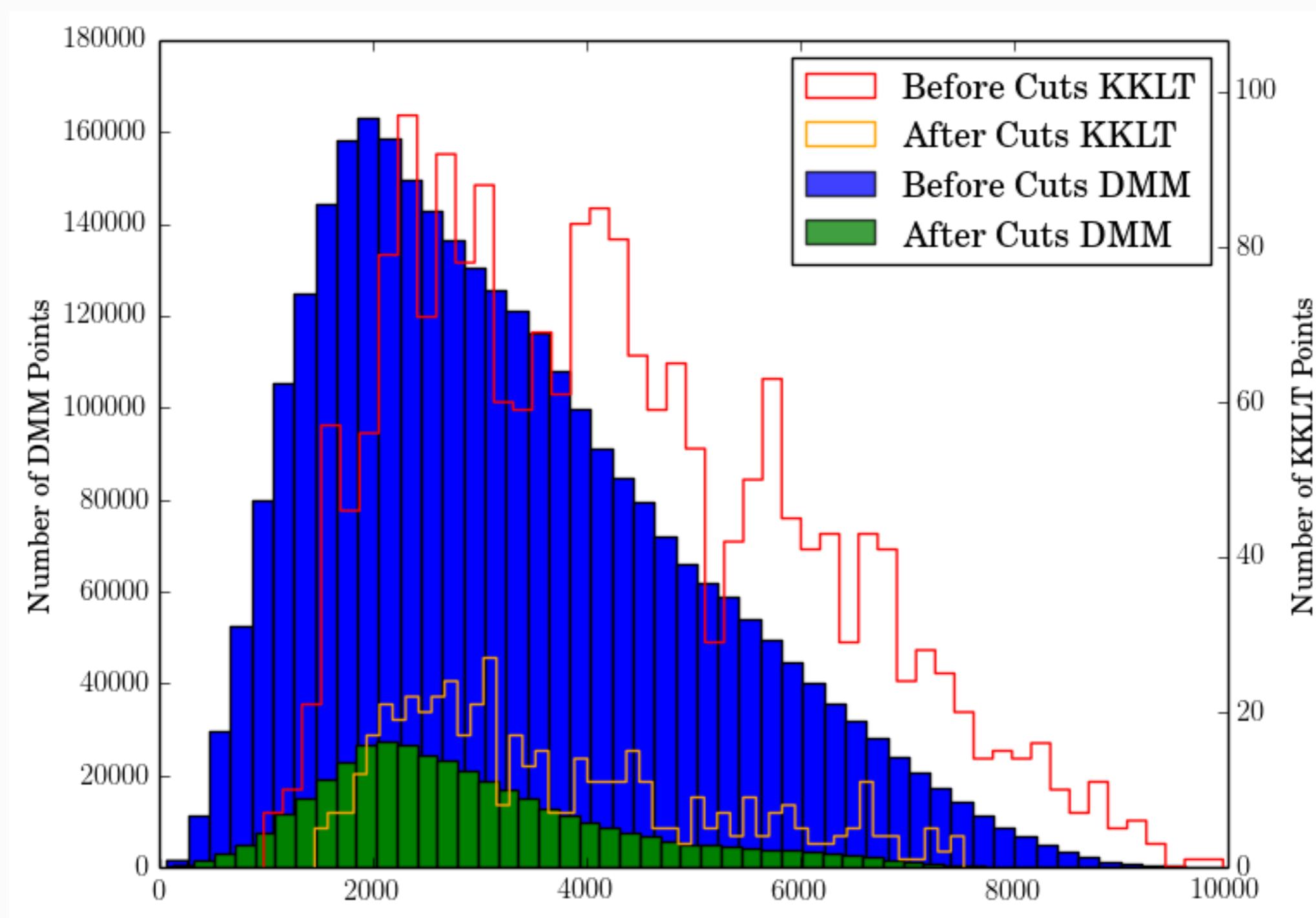
- We use a modified version of SoftSUSY 3.3.9 to run the soft masses from the GUT scale
- Of our points we require a
  - Neutralino LSP
  - Higgs mass, between 123 and 127 GeV
  - Relic density, less than 0.128 calculated by micrOMEGAs
  - A Chargino above the LEP limit
  - $\mathcal{BR}(B_s^0 \rightarrow \mu^+ \mu^-) = 3.2_{-1.2}^{+1.5} \times 10^{-9}$

# Parameter Space

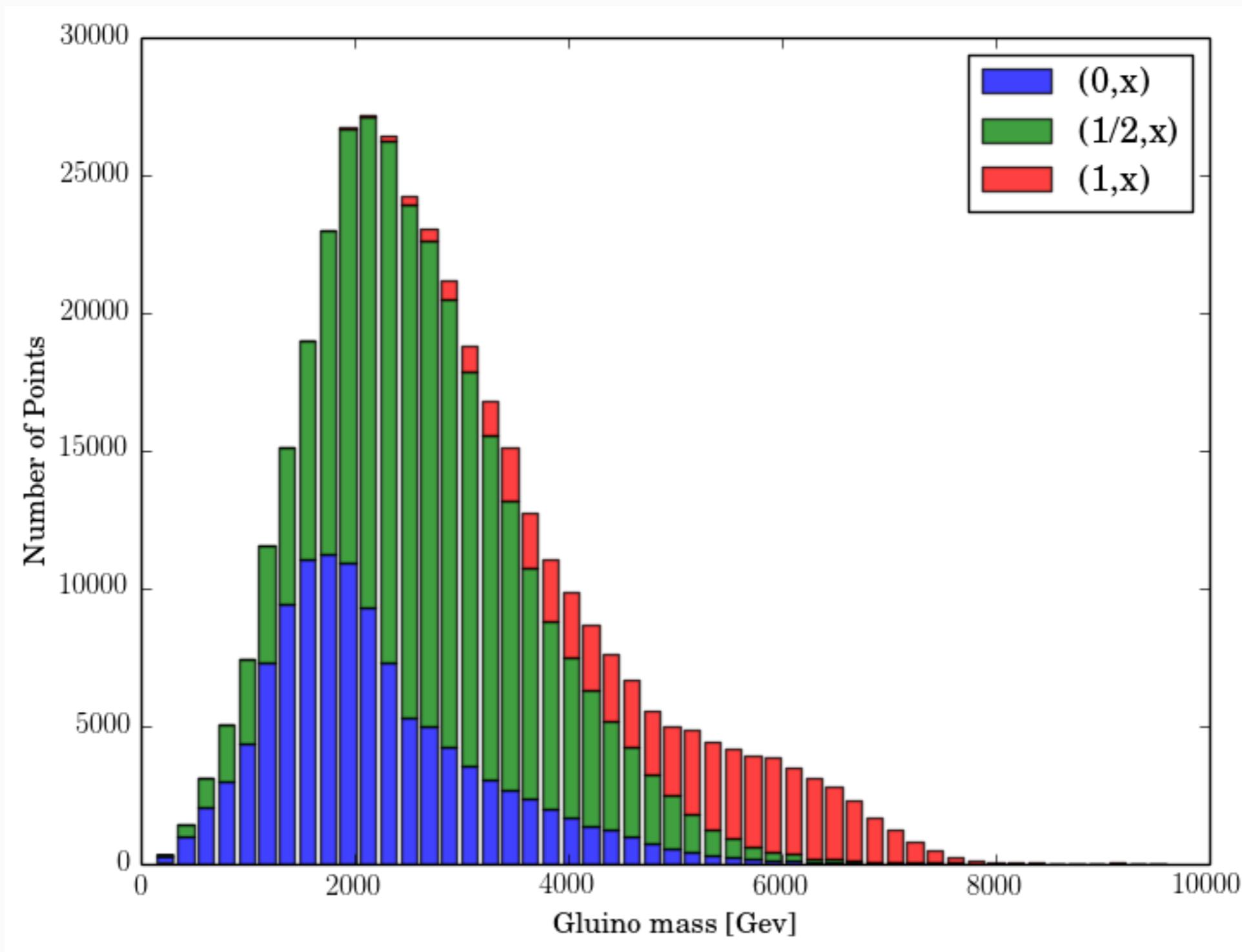
- Our dataset has 6.1 million points in the parameter space:

$M_0 \in [1000, 5000] \text{ GeV}$  $\alpha_m \in [0, 2]$  $\tan \beta \in [5, 50]$  $(n_M, n_H) \in (0, 0.5, 1)$  $\text{sign}\mu = +1$  $\alpha_g \in [-1, 1]$  $\log_{10} \frac{M_{mess}}{\text{GeV}} \in [5, 14]$  $N \in [1, 5]$
- Of these, 3 million have a neutralino LSP and 390 thousand pass our cuts

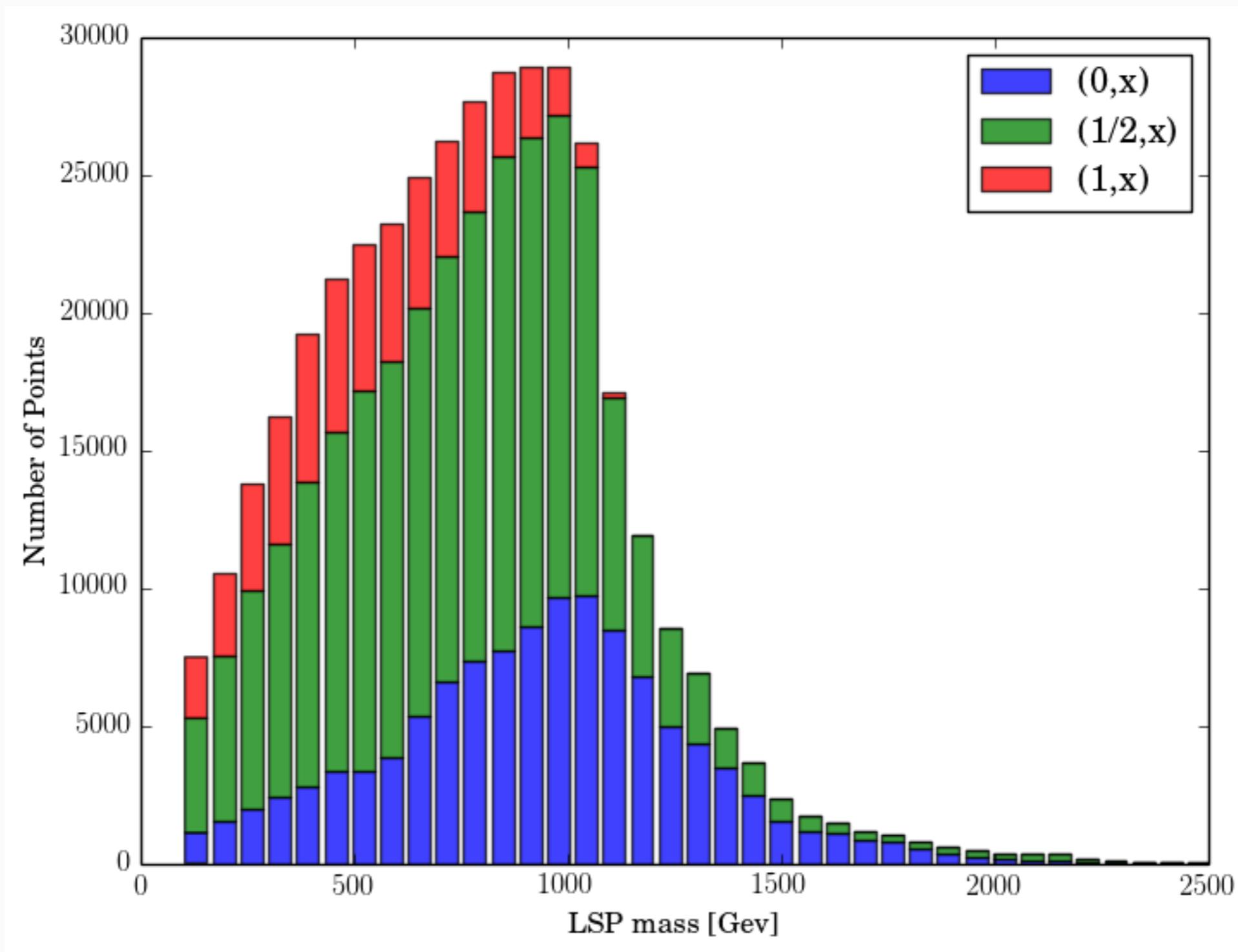
# Parameter Space



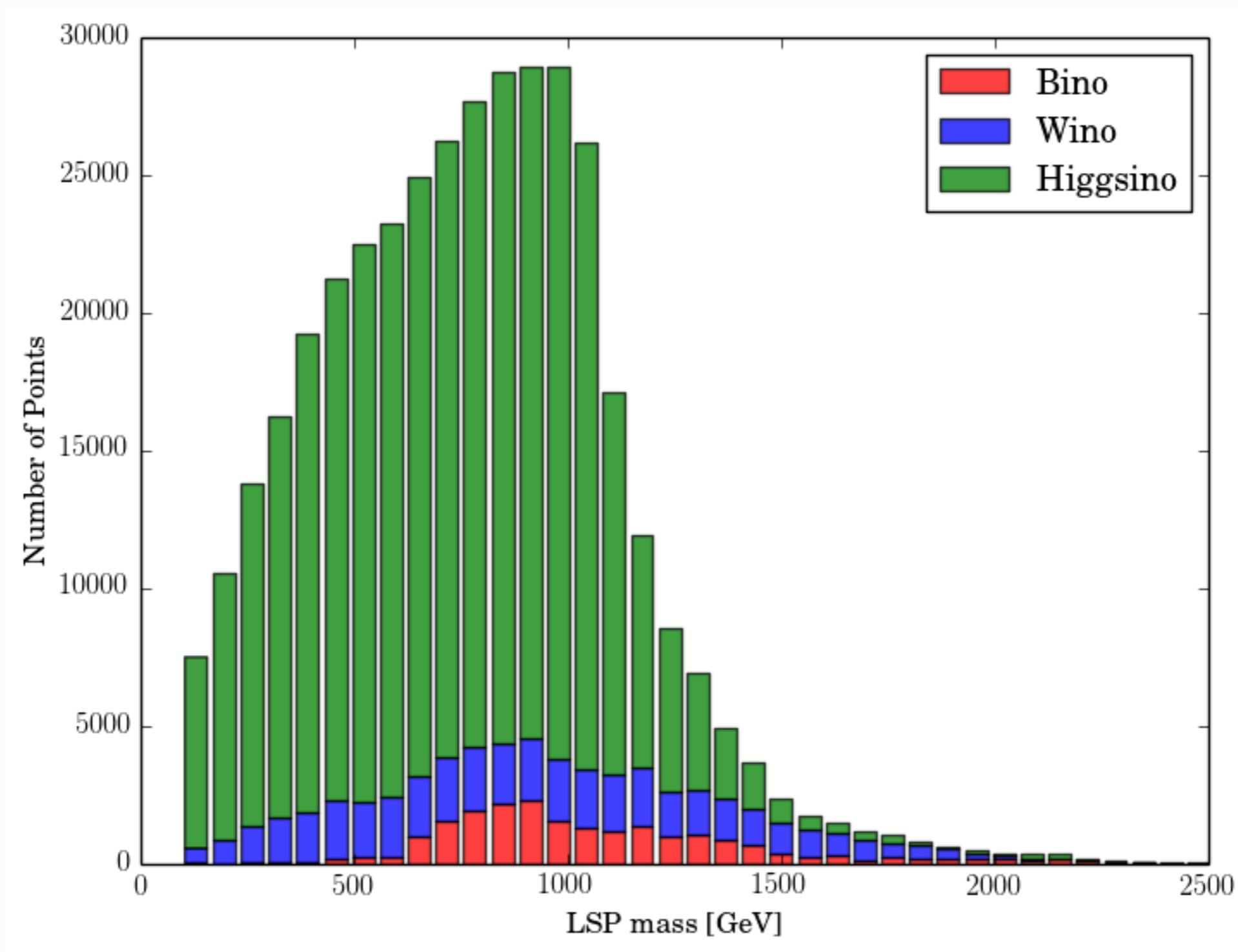
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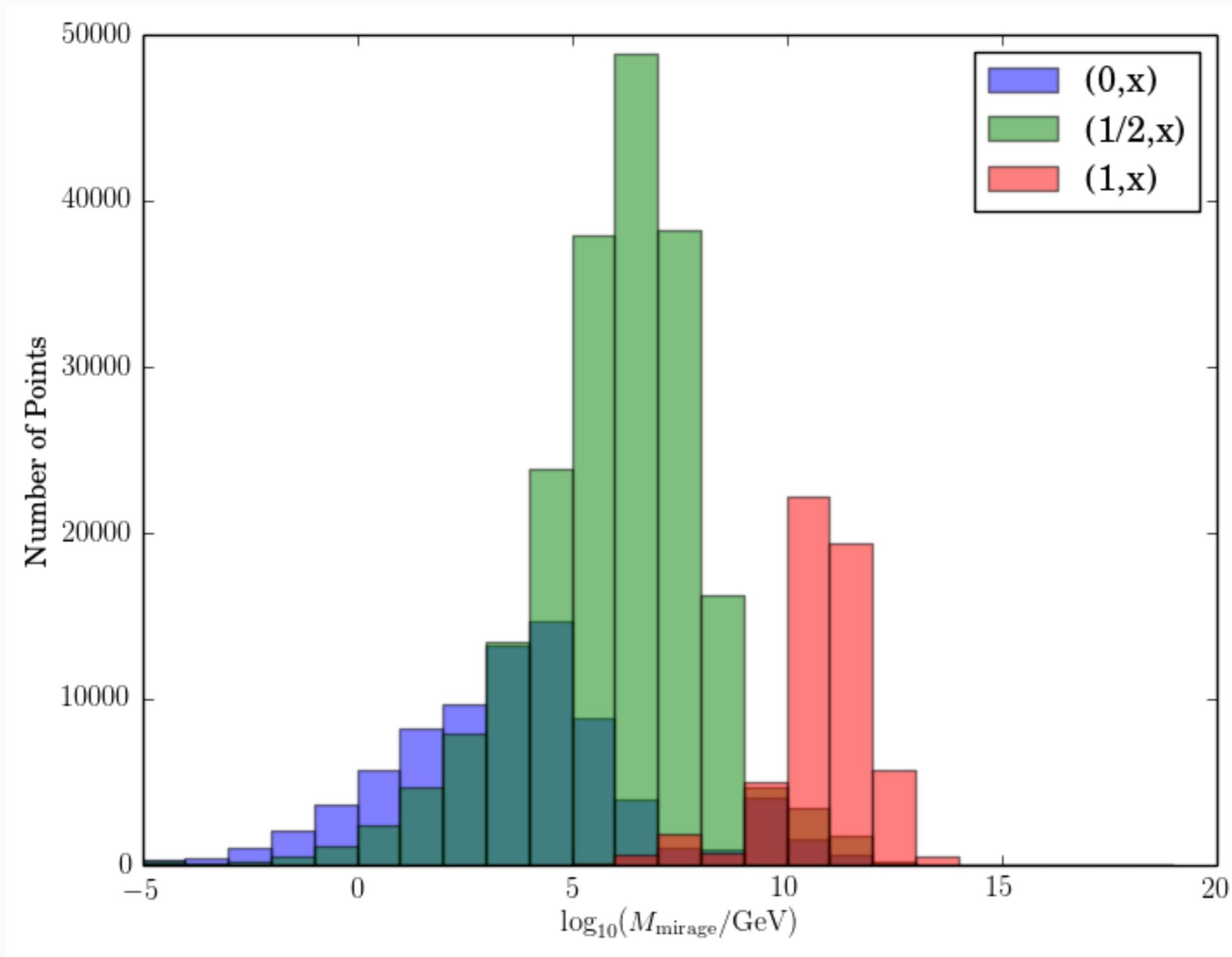
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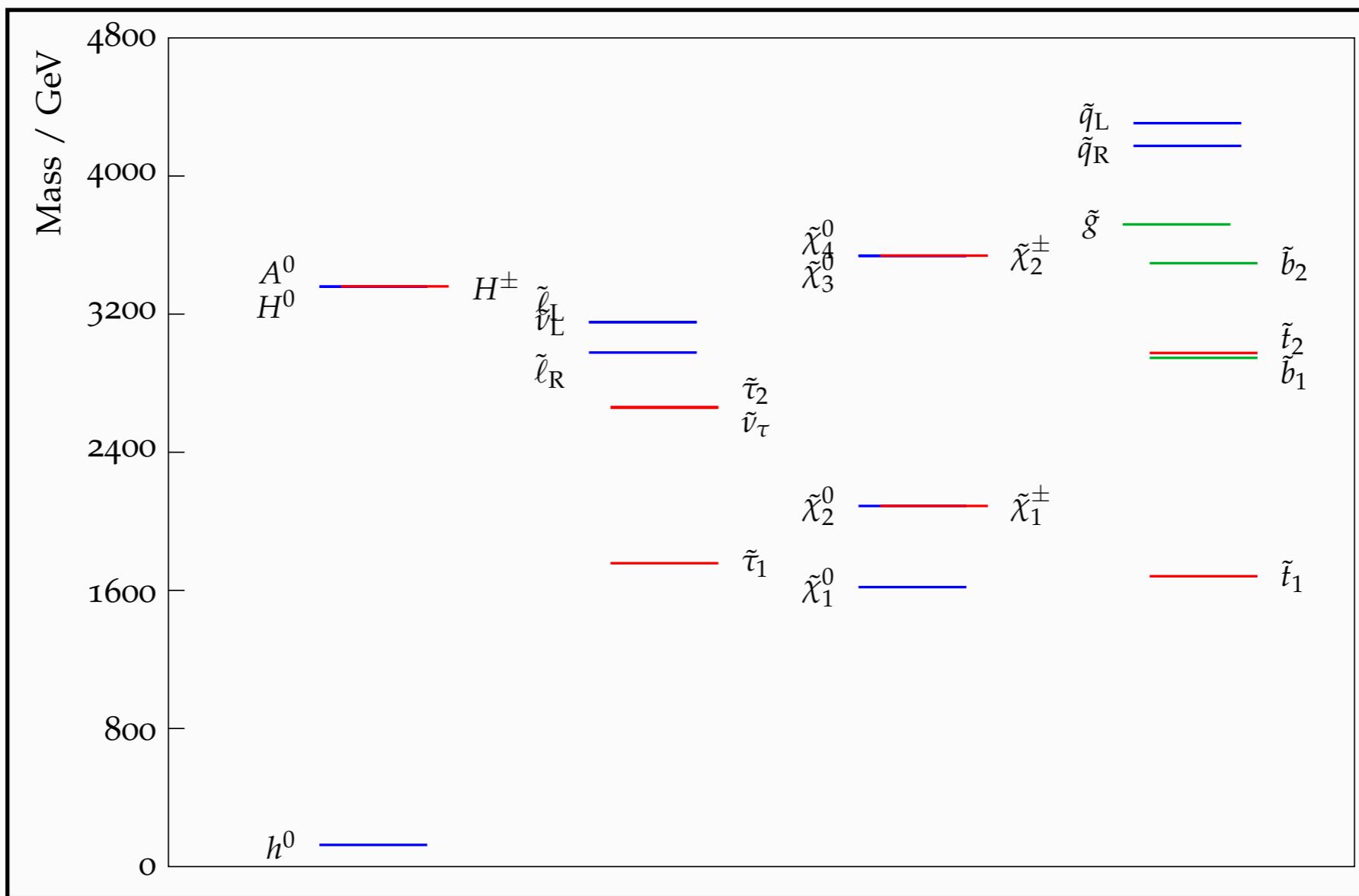
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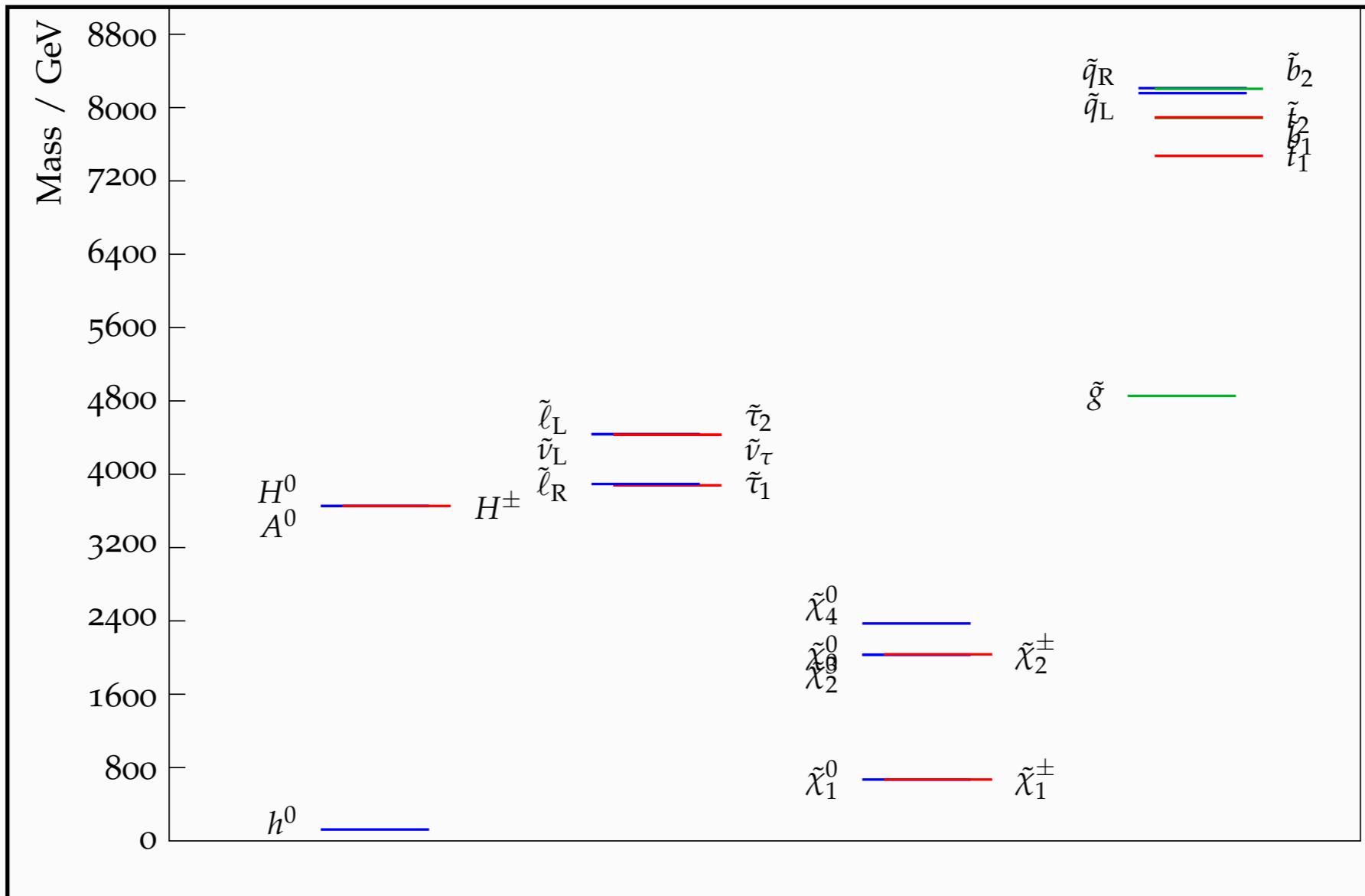


# Example Spectra



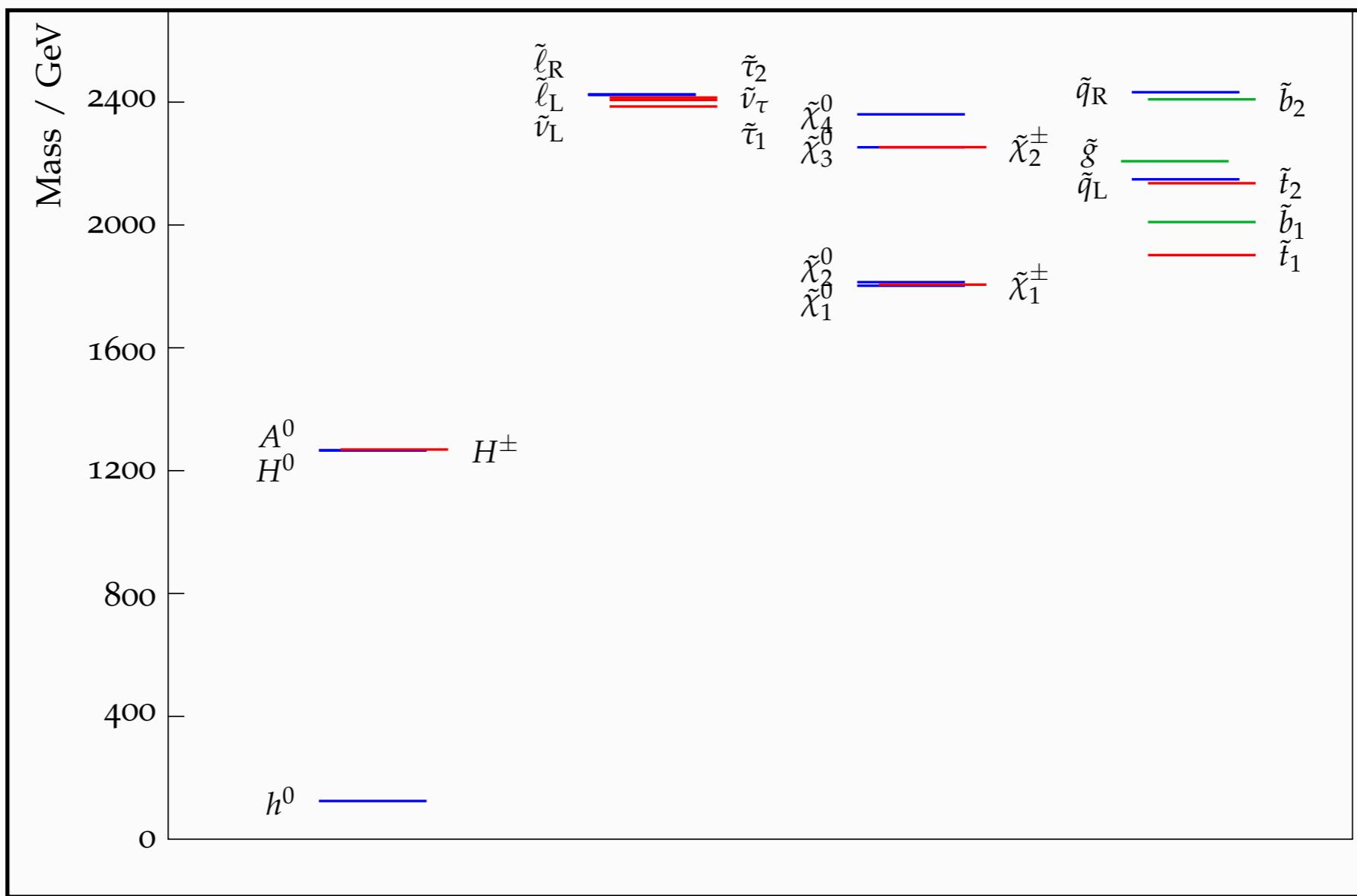
$M_0 = 2900 \text{ GeV}, \alpha_m = 0.69, (n_m, n_h) = (0, 0), \tan \beta = 35,$   
 $\alpha_g = -0.35, M_{mess} = 10^7 \text{ GeV}, N = 2$

# Example Spectra



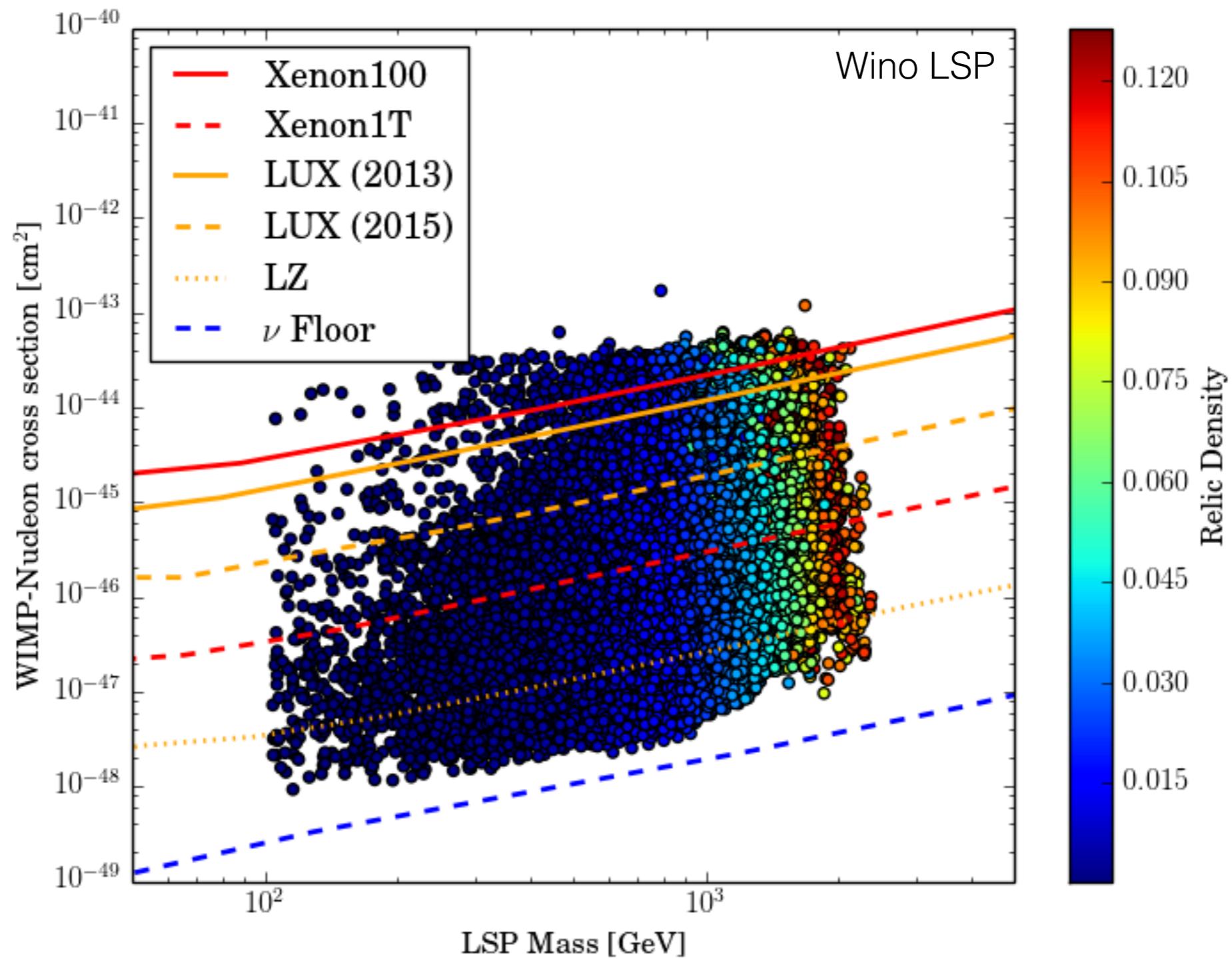
$M_0 = 4600$  GeV,  $\alpha_m = 1.82$ ,  $(n_m, n_h) = (0, 0.5)$ ,  $\tan \beta = 6$ ,  
 $\alpha_g = 0.85$ ,  $M_{mess} = 10^5$  GeV,  $N = 3$

# Example Spectra

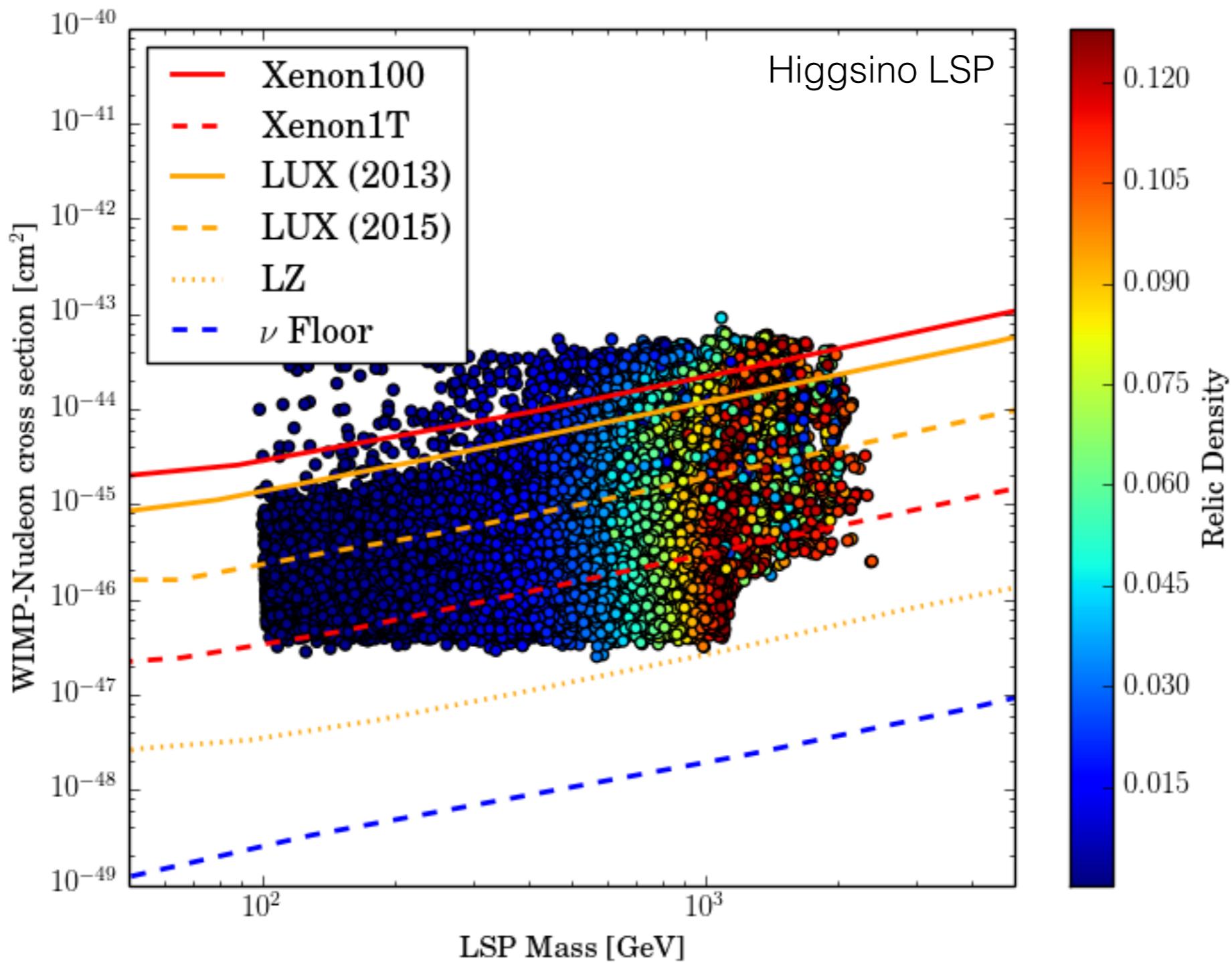


$M_0 = 2700 \text{ GeV}, \alpha_m = 1.75, (n_m, n_h) = (0, 1), \tan \beta = 15,$   
 $\alpha_g = -0.4, M_{mess} = 10^{10} \text{ GeV}, N = 4$

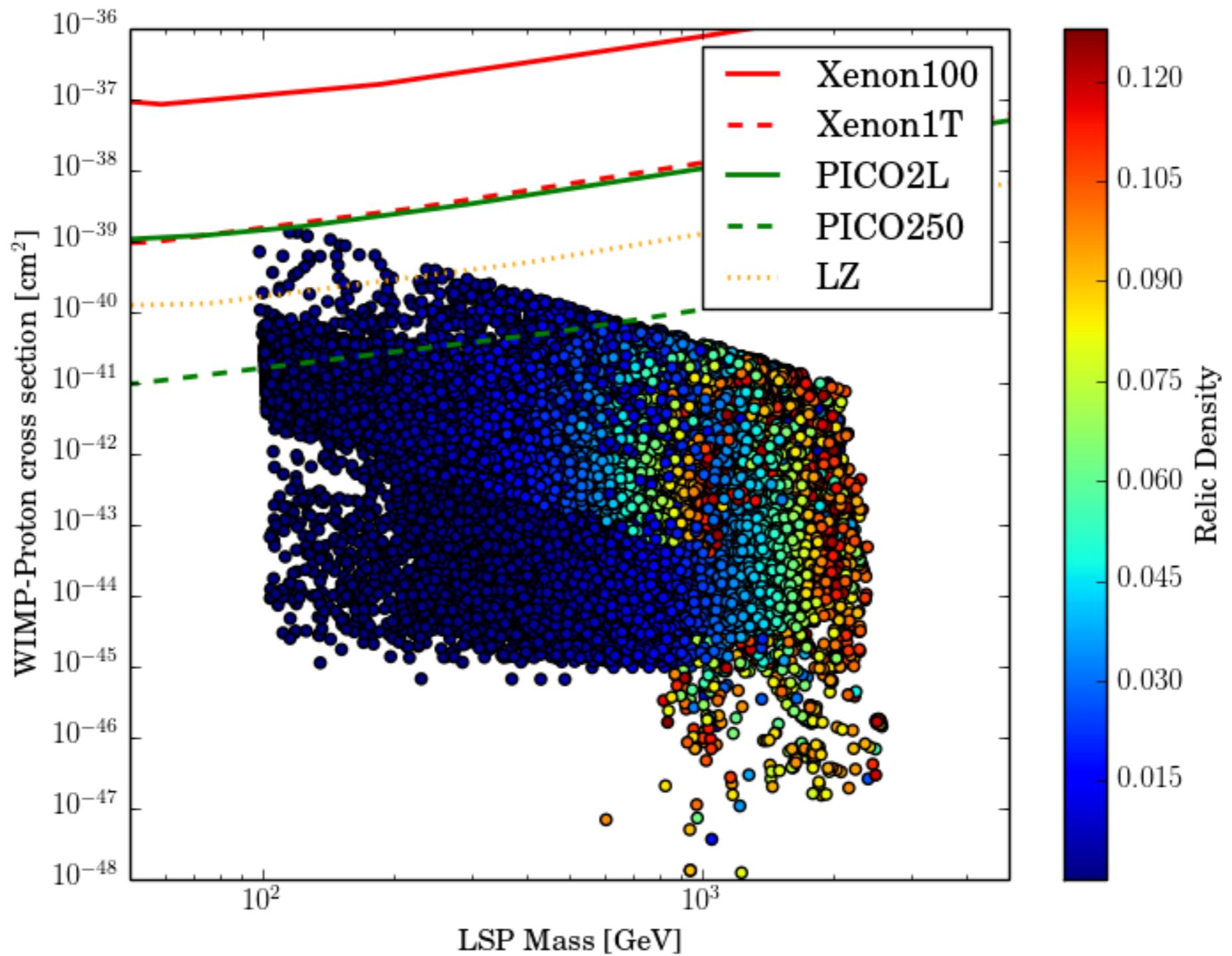
# Direct Detection



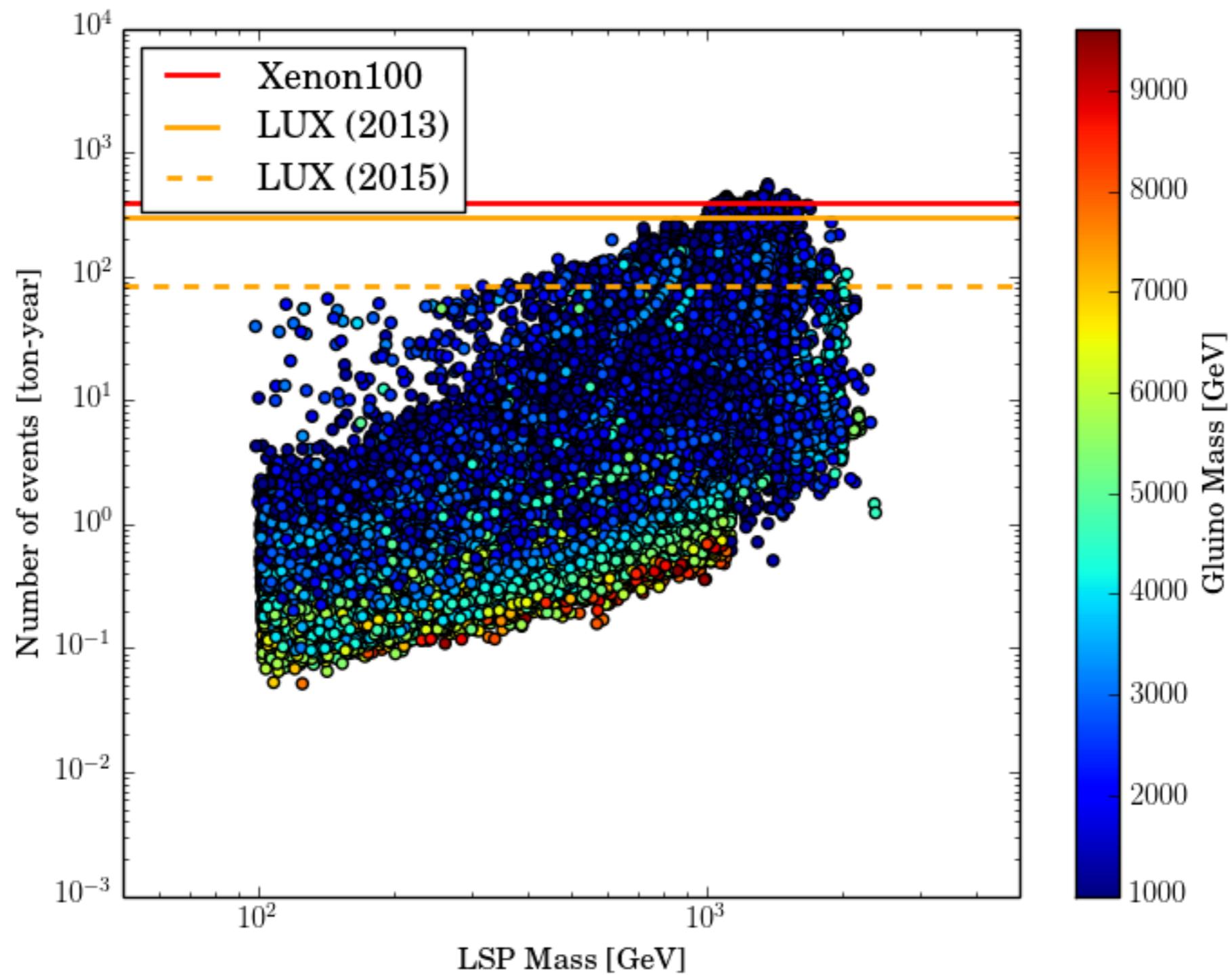
# Direct Detection



# Direct Detection



# Direct Detection



# Conclusions

- DMM is an interesting and potentially viable model incorporating, and interpolating between, three mediation mechanisms
- Many different types of spectra accessible
- Much of the parameter space can be explored at LHC13
- Direct detection will begin to cut into the parameter space soon