Mass scale of vector like matter and superparters from IR fixed point predictions of gauge and top Yukawa couplings

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MSSM with a vector like family

- Vector like fermions introduced for a variety of phenomenological studies
  - g-2
  - Higgs mass
  - U(1)' physics
  - Flavor anomalies

- In my talk:
  - Extend the MSSM with a vector like family
  - Offers phenomenologically interesting GUT scenario, mass scales for vector like matter and superpartners inferred from IR fixed points in the model

$$W \supset M_Q Q\bar{Q} + M_U U\bar{U} + M_E E\bar{E} + M_L L\bar{L} + M_D D\bar{D} + M_N N\bar{N}$$

$$10 \oplus \bar{10} \qquad 5 \oplus \bar{5} \qquad 1 \oplus \bar{1}$$

Gauge couplings with VF

$$\frac{d\alpha_i}{dt} = \beta(\alpha_i) = \frac{\alpha_i^2}{2\pi} b_i$$

$$b_i = (33/5, 1, -3) + n_5(1,1,1) + 3n_{10}(1,1,1)$$

Complete vectorlike Family:

$$b_i = (53/5, 5, 1)$$

$$n_5 = n_{10} = 1$$

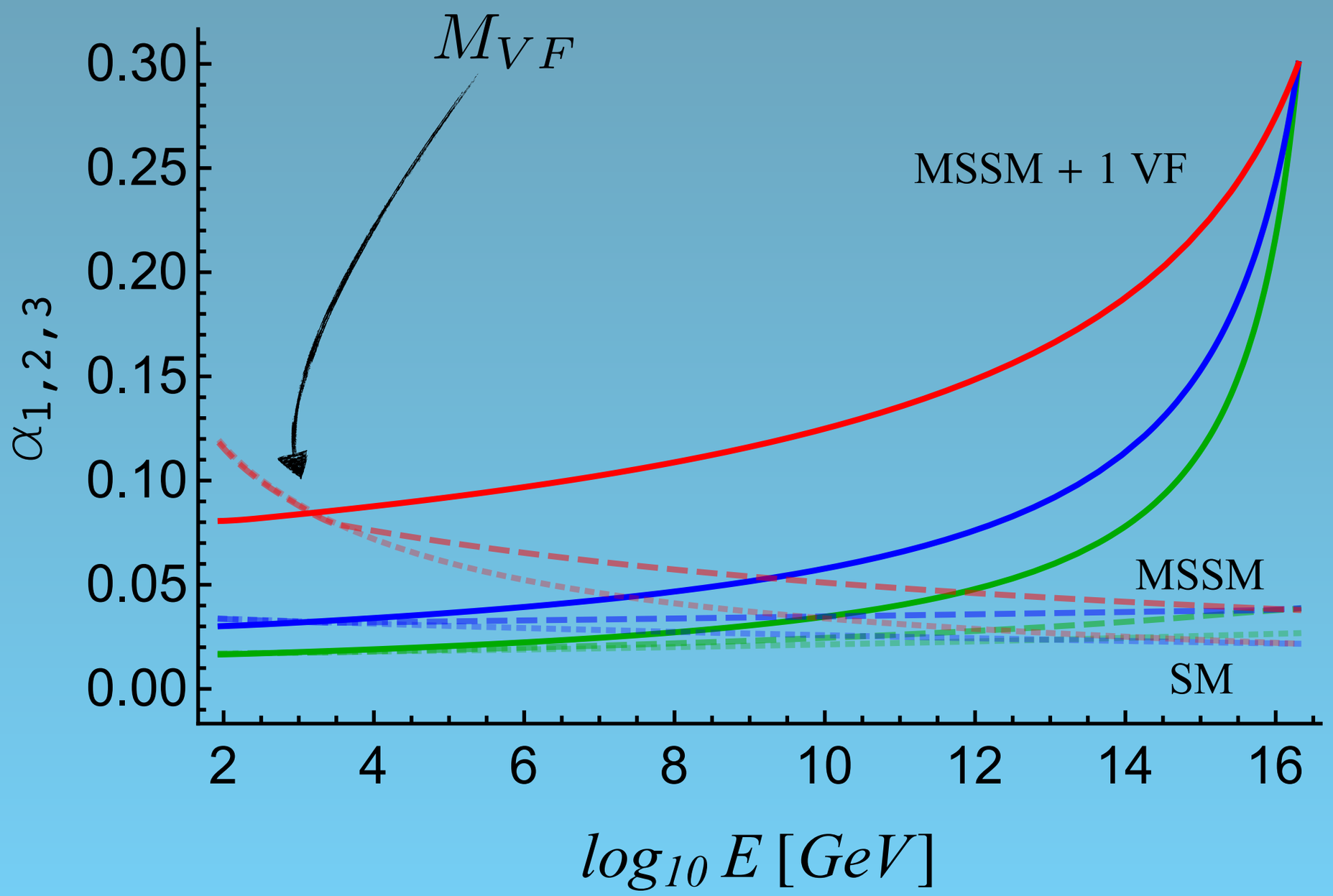
All three couplings become asymptotically divergent

$$\alpha_i^{-1}(M_Z) = \frac{b_i}{2\pi} \ln \frac{M_G}{M_Z} + \alpha^{-1}(M_G)$$

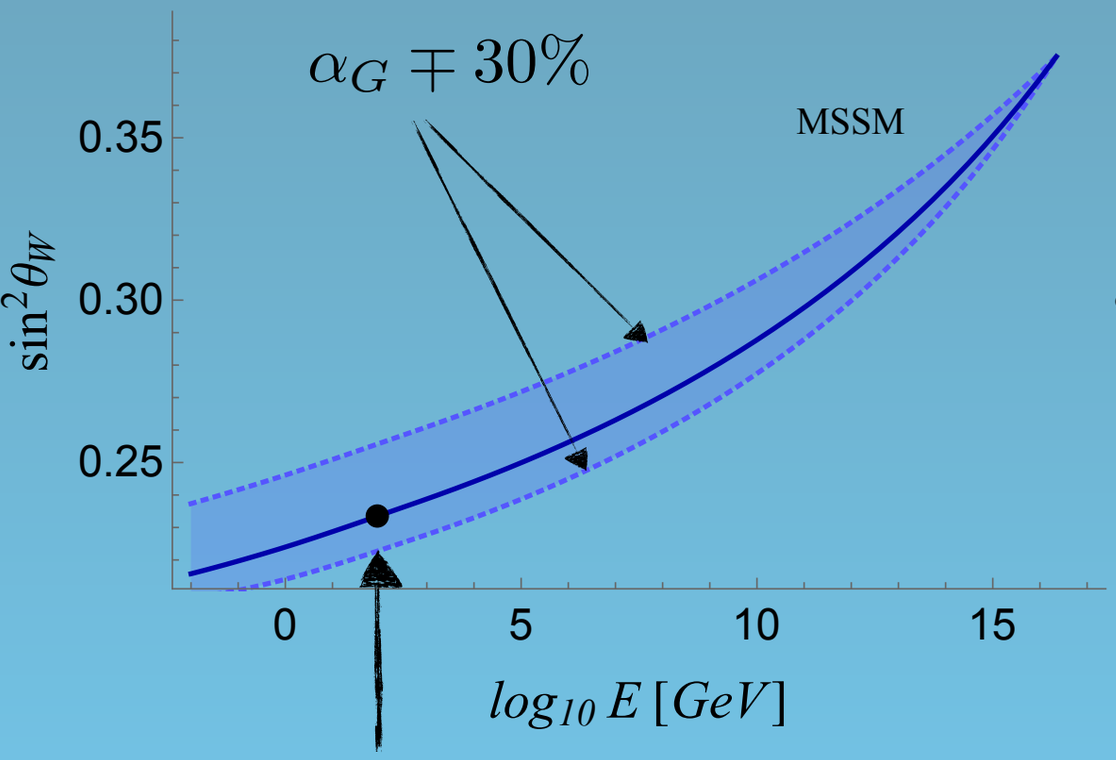
$$\Rightarrow \frac{\alpha_i(M_Z)}{\alpha_j(M_Z)} \simeq \frac{b_j}{b_i}$$

Two parameter free predictions

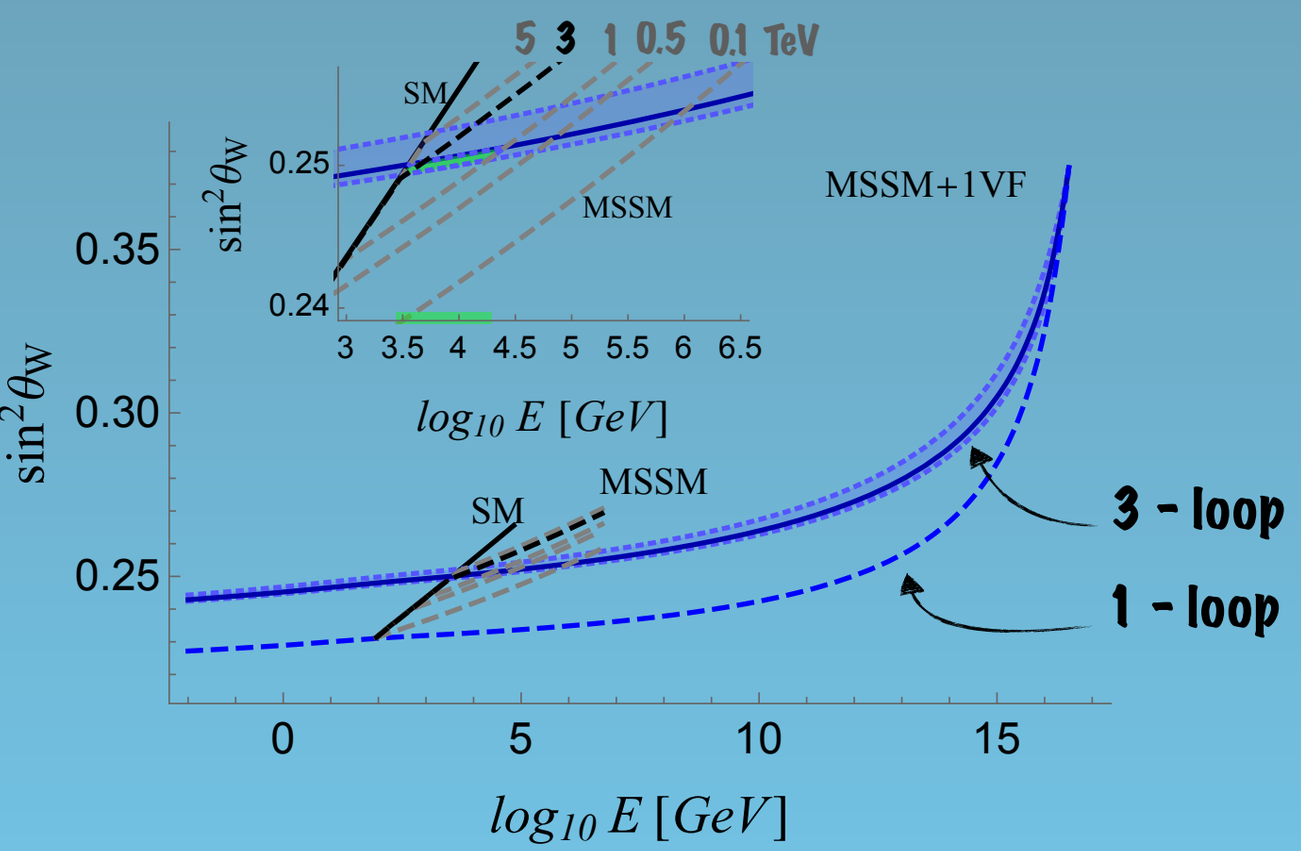
Running of couplings



Weinberg angle

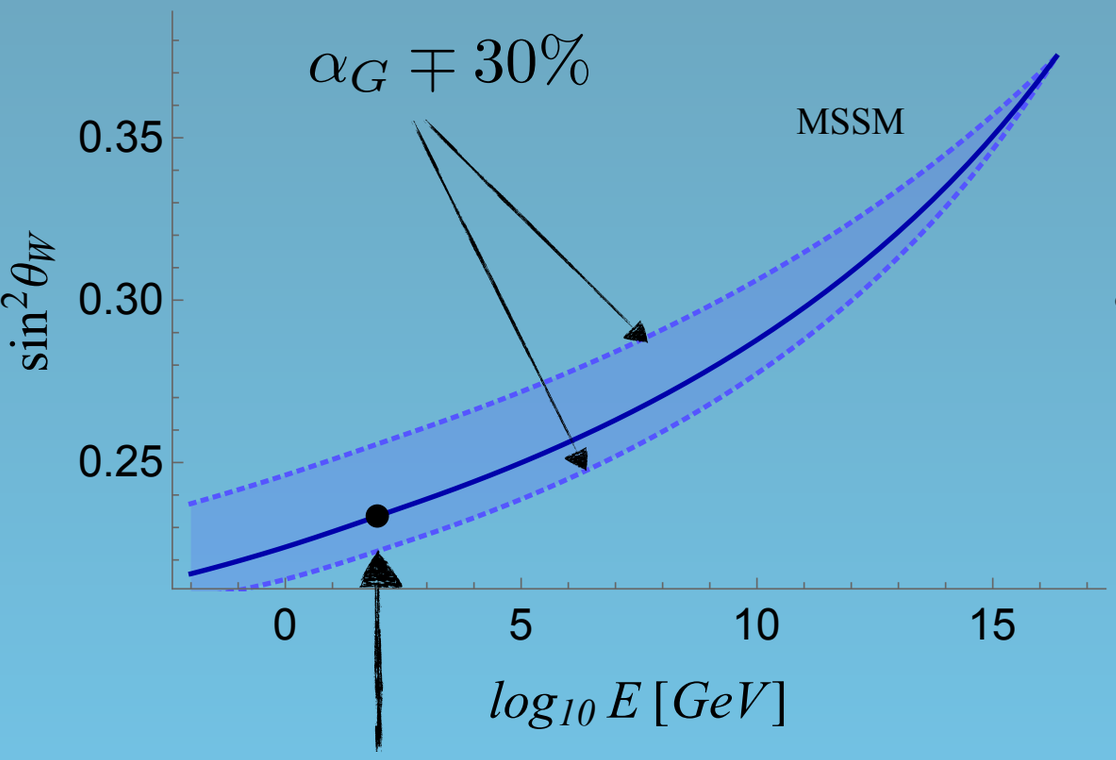


Correct EW scale value



$$\sin^2\theta_W \equiv \frac{\alpha'}{\alpha_2 + \alpha'} \simeq \frac{b_2}{b_2 + b'} = 0.2205$$

Weinberg angle



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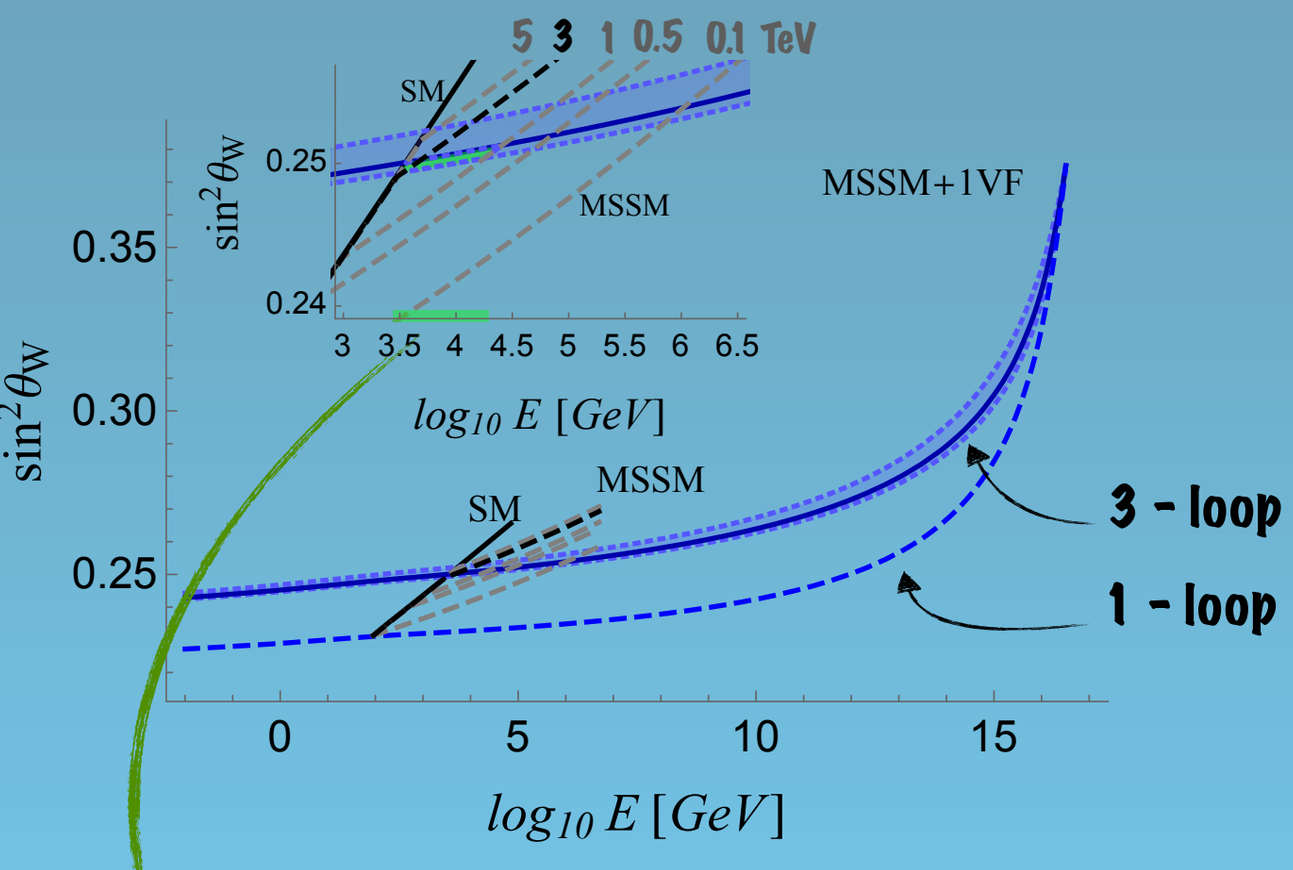
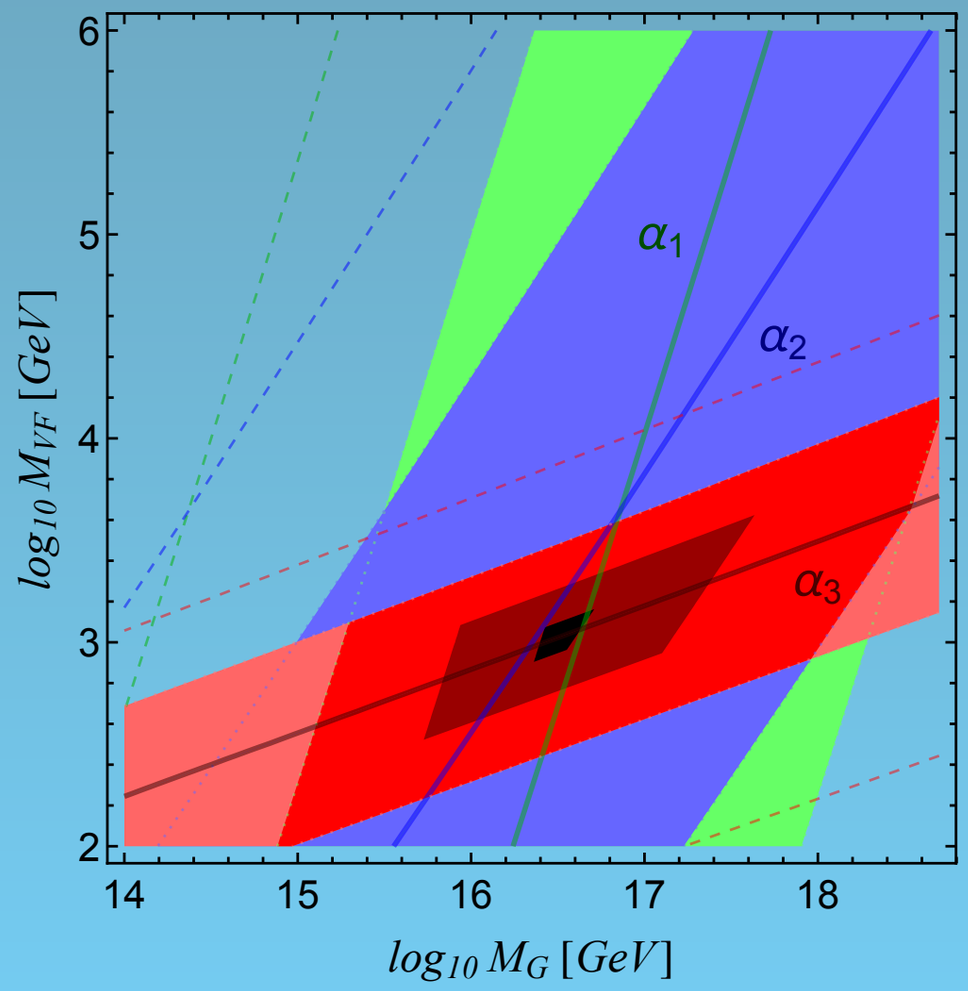


For $\alpha_G \geq 0.3$ & superpartners above 1 TeV, suggests VL matter ~ multi-TeV scale

Mass scale for vector like fermions

$\alpha_G = 0.3 \quad M_{SUSY} = 3$ TeV



$\alpha_1 \sim 10\%$

$\alpha_2 \sim 10\%$

$\alpha_3 \sim 10\%$

All $\sim 10\%$

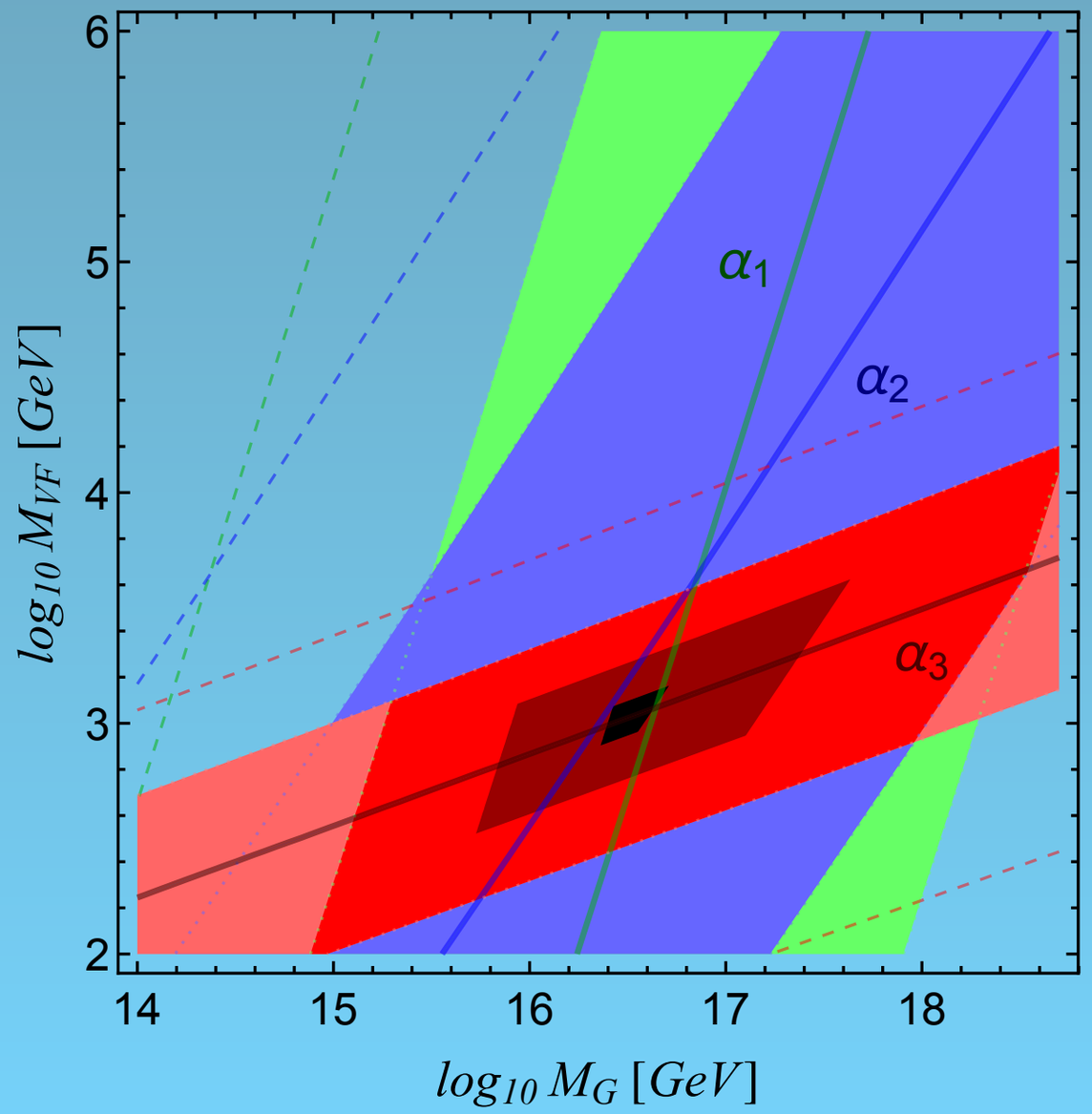
All $\sim 5\%$

All $\sim 1.5\%$

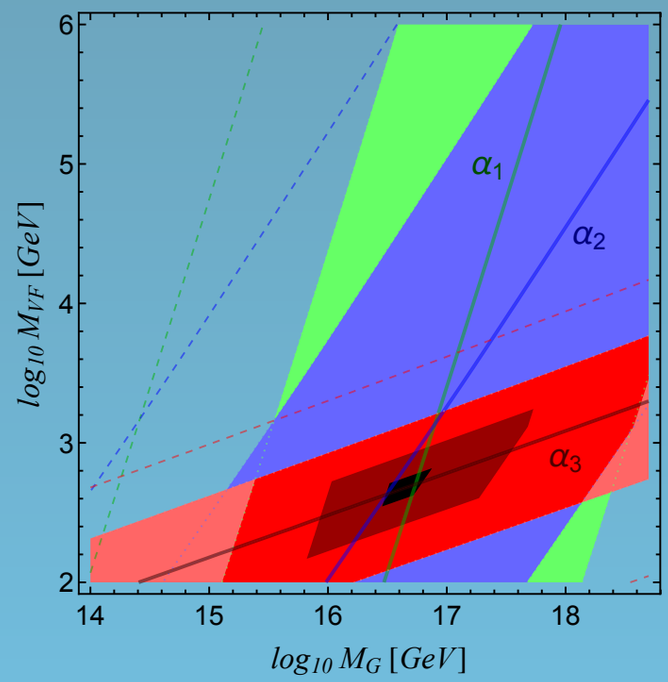
Shows huge range of parameters results in observed pattern of gauge couplings

Mass scale for vector like fermions

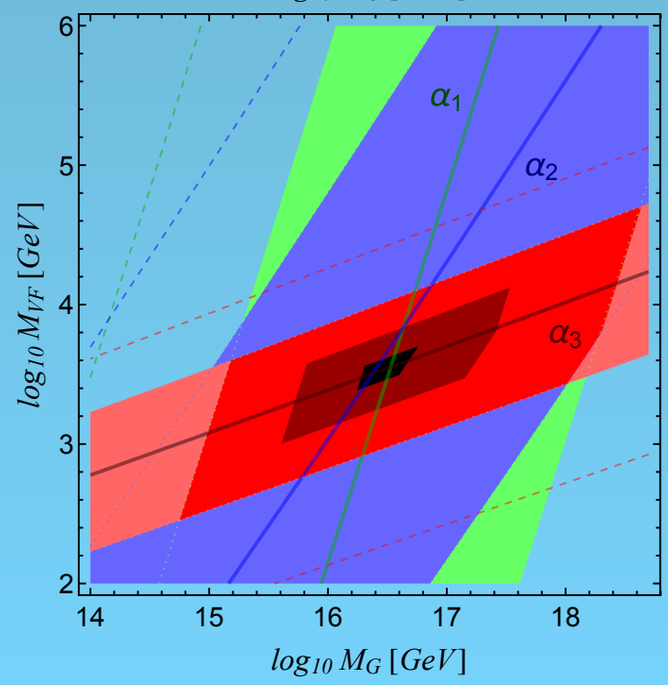
$\alpha_G = 0.3$



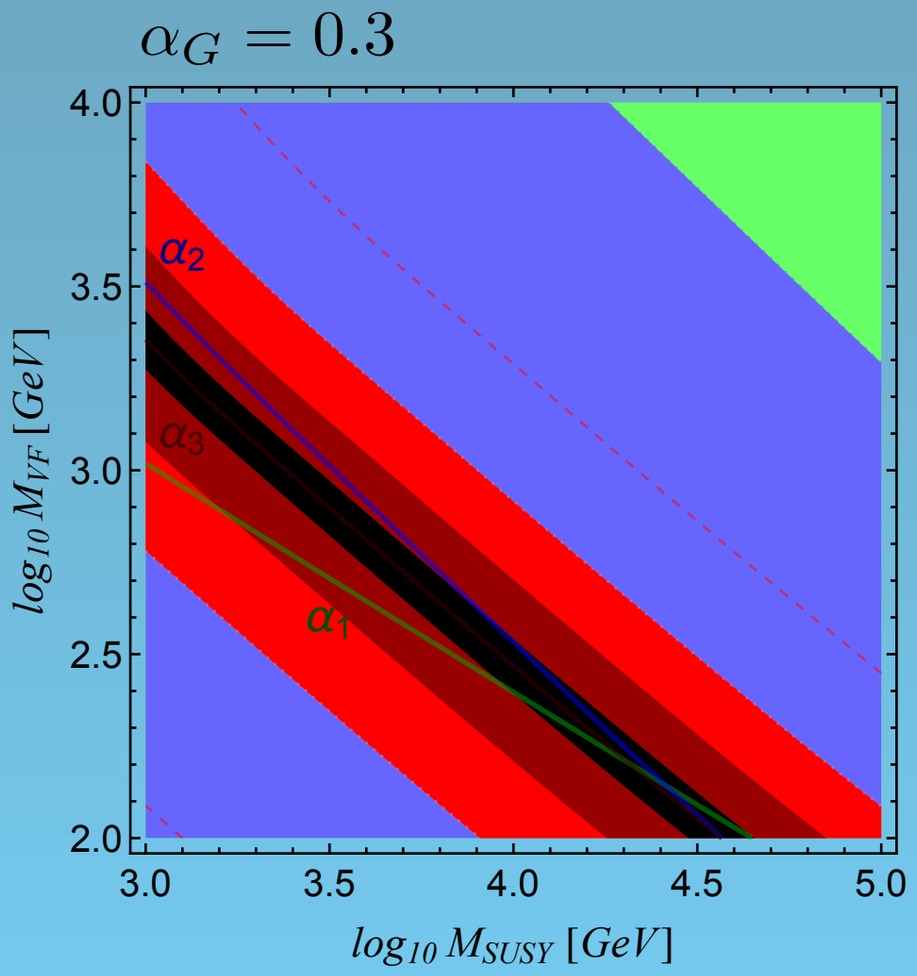
$\alpha_G = 0.4$



$\alpha_G = 0.2$



VF scale vs SUSY scale



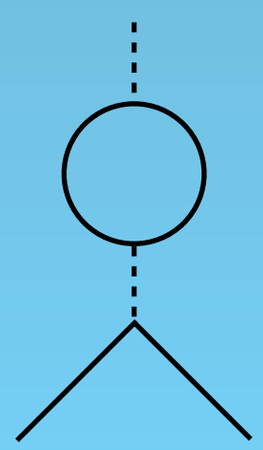
For any $\alpha_G \geq 0.3$, VF or SUSY expected within 1.7 TeV (2.5 TeV) based on all gauge couplings within 1.7% (5%) from observed values at EW scale

Interesting tension in parameter space, in a region that can be tested in the near future

Fixed point for the top Yukawa

$$W \supset Y_U H_u Q \bar{U} + Y_D H_u \bar{Q} D$$

$$\beta_{y_t}^{(1)} = y_t \left(6y_t^2 + \underbrace{3Y_U^2 + 3Y_D^2}_{} - \frac{16}{3} g_3^2 - 3g_2^2 - \frac{13}{15} g_1^2 \right)$$



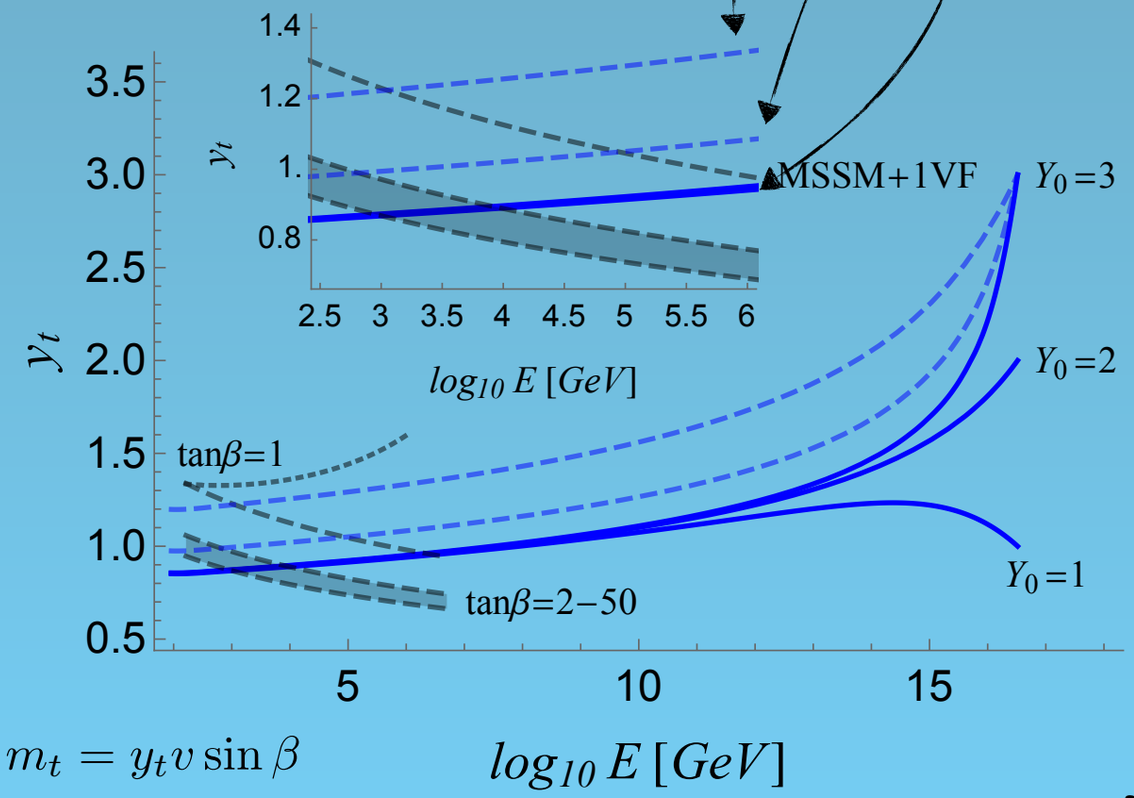
Fixed point predictions for the top Yukawa

No additional Y.C.

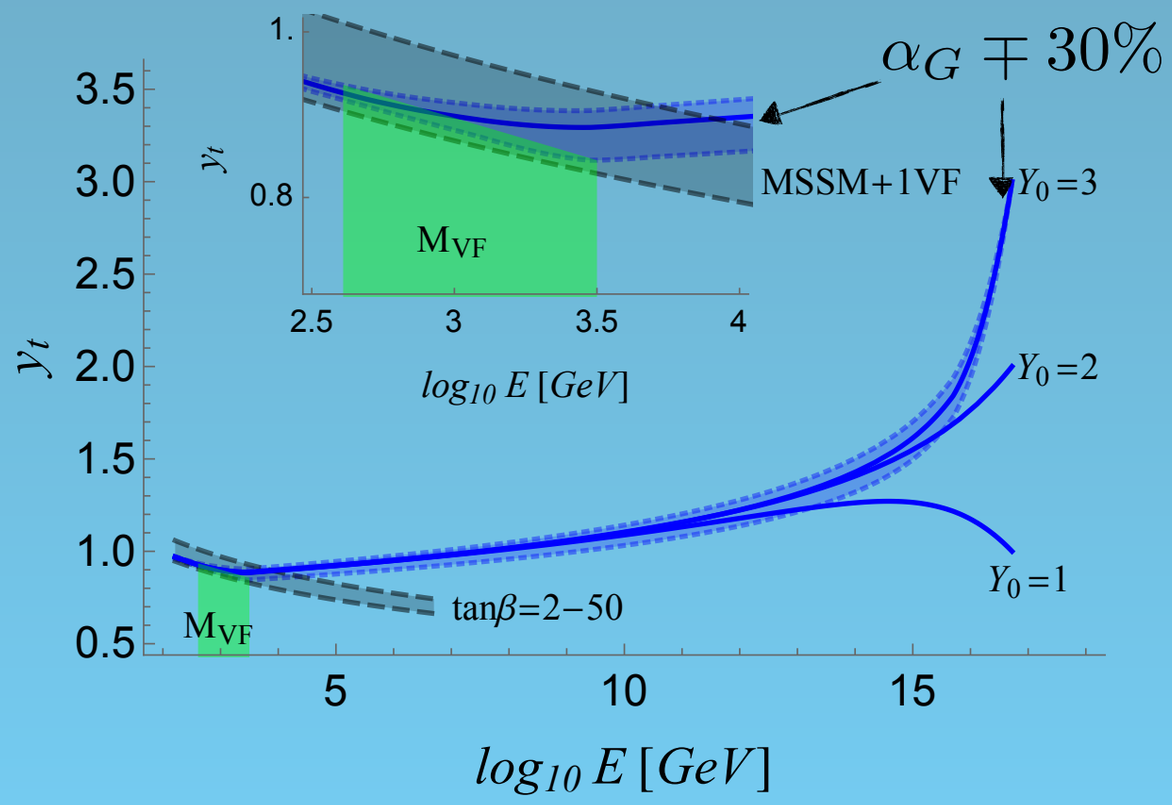
1 additional Y.C.

2 additional Y.C.

$\alpha_G = 0.3$



$m_t = y_t v \sin\beta$



For $M_{SUSY} = 3$ TeV, multi-TeV scale needed to produce α_3 also gives robust prediction for top-yukawa

Conclusions

- Extending the MSSM with a complete vector like family offers an interesting SUSY GUT scenario:
  - Many features of the model highly insensitive to details at the GUT scale
  - Both VF and SUSY scales can be inferred by comparing to EW data and collider limits
  - Fixed points of Gauge couplings and top-quark Yukawa coupling all point ~ multi-TeV VF & SUSY scales (favored by Higgs mass)
- More specific spectrum can be studied by introducing specific SUSY breaking scenario, GUT scale model etc. Results presented here can be used to understand the implications of such a model

Thanks!