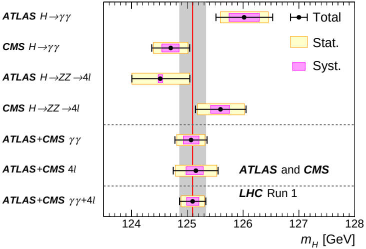
# 125 GeV Higgs from tree-level *A*-terms

Aria Basirnia
*NHETC, Rutgers University*

Pheno 2015, Pittsburgh
Based on: 1501.00997
(D. Egana-Ugrinovic, S. Knapen, D. Shih)

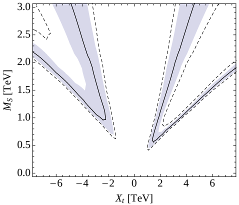
# WE KNOW THAT...

- Higgs is at 125 GeV




- In MSSM, $m_h < m_Z$ at tree-level. So we need either...
  - Heavy stops $M_{\text{SUSY}} \sim 10$ TeV
    out of LHC reach, highly fine-tuned
  - Large A-terms, particularly $A_t$: $\mathcal{L}_{\text{soft}} \supset -y_t A_t H_u \tilde{Q}_3 \tilde{\bar{u}}_3$

# Dominant radiative corrections to $m_h^2$



(Draper, Meade, Reece & Shih)

$$\delta m_h^2 = \frac{3m_t^4}{4\pi^2 v^2}\left(\log\left(\frac{M_S^2}{m_t^2}\right) + \frac{X_t^2}{M_S^2}\left(1 - \frac{X_t^2}{12M_S^2}\right)\right) + \ldots$$

$$M_S = (m_{\tilde{t}_1} m_{\tilde{t}_2})^{1/2} \qquad X_t = A_t - \mu \cot\beta$$

$\Rightarrow$ large $A$-terms are interesting!

Generating large A-terms is a model building exercise not explored extensively in the past. Especially in GMSB generating large A-terms are challenging.

# PREVIOUS SOLUTIONS

Some previous solutions are:

- gravity mediation:
  SUSY flavour problem?
- RG running from high scales:
  severe fine-tuning?
- MSSM-messenger couplings
  Below messenger scale: $\mathcal{K} \supset \frac{X^\dagger}{16\pi^2 M} H_u^\dagger H_u + \frac{X^\dagger X}{16\pi^2 M^2} H_u^\dagger H_u$
  $A/m^2$ problem: generally both $A$ and $m_{H_u}^2$ are generated at one-loop: $\frac{A^2}{m^2} \sim \frac{1}{16\pi^2} \ll 1$ (Craig, Knapen, Shih & Zhao)

**Here we propose a new solution to generate large A-terms at tree level**

# MFV MODEL

Consider the following superpotential

$$\mathcal{W} = M\tilde{\phi}\phi + (X_0' + X')H_u'\tilde{\phi} + \lambda_u^{ij}\phi Q_i \bar{u}_j \qquad X' = F_{X'}\theta^2 \tag{1}$$

$\phi, H_u'$ mix in the mass matrix. After integrating out heavy eigenstates we have

$$\mathcal{W}_{\text{eff}} \supset y_u^{ij}\left(1 + \cot\theta_H \cos\theta_H \frac{X'}{M}\right) H_u Q_i \bar{u}_j \qquad \sin\theta_H = \frac{X_0'}{\sqrt{M^2 + X_0'^2}} \tag{2}$$

**For $\frac{F_{X'}}{M} \sim$ TeV, we get the desired A-terms!**

Note that the *A-terms are MFV* in this case therefore no flavour problems.

- We still generate a contribution to $m_{H_u}^2$ (which contributes to tuning of EW scale):

$$\delta m_{H_u}^2 = -|A_t|^2 \tan^2 \theta_H$$

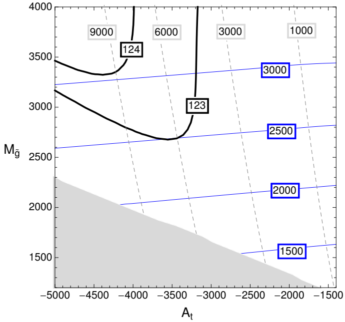
but now $\frac{\delta m_{H_u}^2}{A_t^2}$ is

  - $\mathcal{O}(1)$ instead of $16\pi^2$
  - It is negative therefore does not ruin EWSB
  - we have a new knob $\sin \theta_H = -y_u^{ij}/\lambda_u^{ij}$ that we can dial to minimize this term.

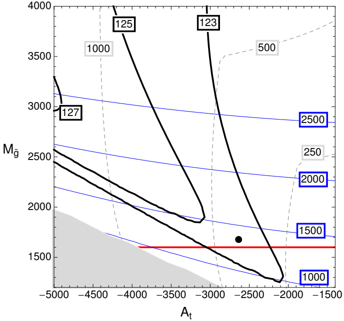
This contribution to soft masses is general (increasing messenger number/representations/etc does not help)

# MFV PHENOMENOLOGY

Therefore large $\lambda_{ij}$ can help reduce the tuning from unwanted contributions to $m_{H_u}^2$



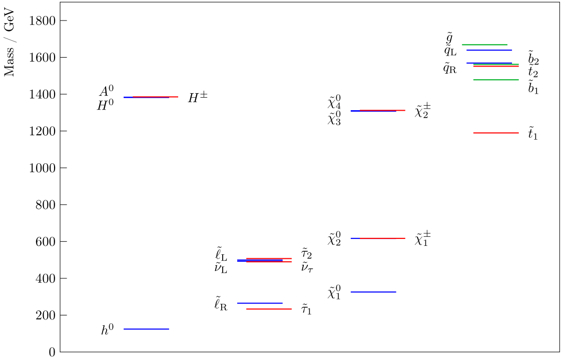

$\lambda_{33} = 1$




$\lambda_{33} = 3$

If we take tuning seriously, this can be a sign of an underlying strongly coupled sector!
We built an example for this using Seiberg dualities.

This module can be used as an independent module in generating A-terms. We used it with MGM to generate the rest of the soft masses, and here is an example spectrum



# NON-MFV MODEL

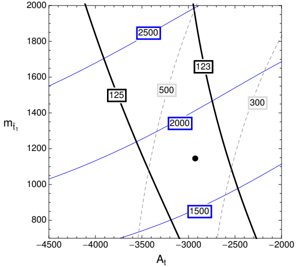
We could instead switch $H_u$ with $\bar{u}_3$ (or $Q_3$)

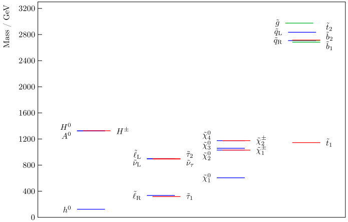
$$\mathcal{W} \supset M\tilde{\phi}\phi + \kappa H_u Q_3 \phi + X' \bar{u}_3 \tilde{\phi} + y_u^{ij} H_u Q_i \bar{u}_j \qquad X' = F_{X'} \theta^2 \qquad (3)$$

- advantage: no large coupling is needed as the soft mass contribution is to $m_{u_3}^2$ (or $m_{Q_3}^2$) which contributes to tuning much less than before
- disadvantage: now the model is clearly non-MFV and Yukawas and A-terms have different origins.

# NON-MFV PHENOMENOLOGY

To study the phenomenology, again we use this module in MGM. Here is the case of $\kappa = 1$




Interestingly stops are largely split in this case and the limits on the lightest one is milder $\sim$ 800 GeV