GUT-Inspired Scalar Models and the $t\bar{t}$ Forward-Backward Asymmetry

Pheno 2012 Parallel Talk

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The $t\bar{t}$ Forward-Backward Asymmetry

At the Tevatron

$$A_{FB}^{t\bar{t}} \equiv \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

- Latest data still going strong!

$$A^{t\bar{t}}_{FB}(M_{t\bar{t}} < 450 \text{ GeV}) = 0.078 \pm 0.054$$

$$A^{t\bar{t}}_{FB}(M_{t\bar{t}} \geq 450 \text{ GeV}) = 0.296 \pm 0.067$$

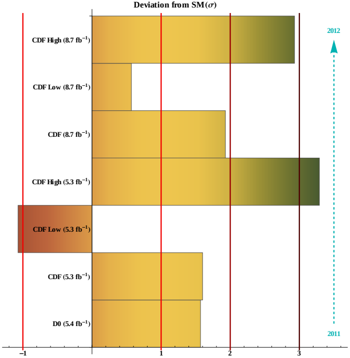
$$\text{Total: } A^{t\bar{t}}_{FB} \approx 0.182 \pm 0.045$$

$$(\textstyle\int dt\, L = 8.7 \text{ fb}^{-1})$$

Recent SM EW Sudakov and QCD corrections still do not account for $A^{t\bar{t}}_{FB}$

A different story at the LHC!

History of $A^{t\bar{t}}_{FB}(M_{t\bar{t}})$



New Physics to Explain $A_{FB}^{t\bar{t}}$

Spin- 0, 1 and 2 models exist

- We use a spin-0 model with parameters dictated by GUT group theory
- Spin-0: Things to avoid:
  - s-channel particles
  - Light particles that can mediate p-decay

Couplings, masses, and quantum numbers all determined by GUT (in principle)

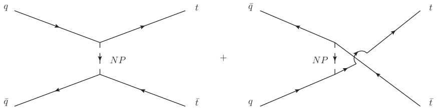
Our Model

SU(5) GUT

Light fields:

$$\left.\begin{array}{l}\phi_1 : (\overline{6},3)_{-1/3} \\ \phi_2 : (6,1)_{4/3}\end{array}\right\} \text{ in the 50}$$

$$\phi_3 : (8,2)_{1/2} \qquad \text{in the 45}$$



Aspects of the model

“Minimal” SU(5) model

Content:

(1) From $5 \otimes 5$, $5 \otimes 10$, $10 \otimes 10$ only

↓

(2) Couples to quarks only

↓

(3) Masses lead coupling unification

↓

(4) Yukawas can reproduce $A_{FB}^{t\bar{t}}$

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This leaves ϕ_1, ϕ_2, and ϕ_3

Possible SU(5) Lagrangian

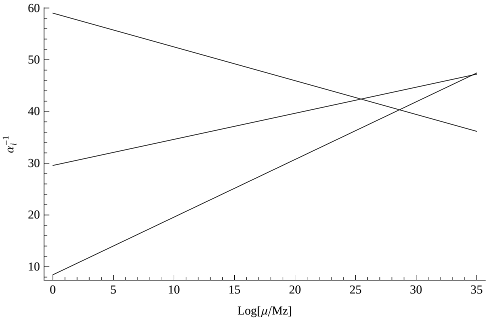
$$\mathcal{L}_{\Phi_{50}} = \frac{Y_G^{ij}}{2}\Psi_{iAB}\Psi_{jCD}\Phi^{AB,CD}$$

$(4) : Y_{45}^{ij} \to 0$

$\phi_1,\ \phi_2 \in \Phi^{AB,CD}$

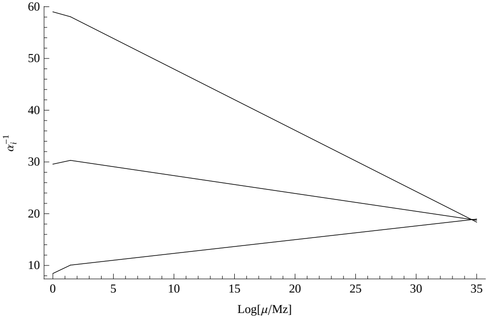
Gauge coupling unification

SM



Gauge coupling unification

SM + this model $\phi_1 = (\overline{6}, 3)_{-1/3},\ \phi_2 = (6, 1)_{4/3},\ \phi_3 = (8, 2)_{1/2}$



For $m_{\phi_1} \sim m_{\phi_2} \sim m_{\phi_3} \sim 500$ GeV
and
$\phi_1,\ \phi_2 \in 50,\ \ \phi_3 \in 45$

- No intermediate masses required
- Only scales are v and $\mathbf{M_{GUT} \sim 10^{17}}$ **GeV**

Lagrangians and couplings

This specifies the light field Lagrangian:

$$\mathcal{L}_\Phi = \frac{y_{\overline{6}}^{ij}}{2} q_{Li\alpha}^T C q_{Lj\beta} \phi_1^{\alpha\beta} + \frac{y_6^{ij}}{2} \overline{u_R}_a^i C \overline{u_R}_b^j \phi_2^{ab} + \text{h.c.}$$

$y_{\overline{6}}$, y_6 from GUT Y_G via RG running:

$Y_G = 0.5$ → $\alpha_{\overline{6}} = 0.146$, $\alpha_6 = 0.117$

$Y_G = 1.0$ → $\alpha_{\overline{6}} = 0.159$, $\alpha_6 = 0.143$

Recall we have tuned the Yukawa coupling of the extra 45 to 0.

Choose flavor structure:

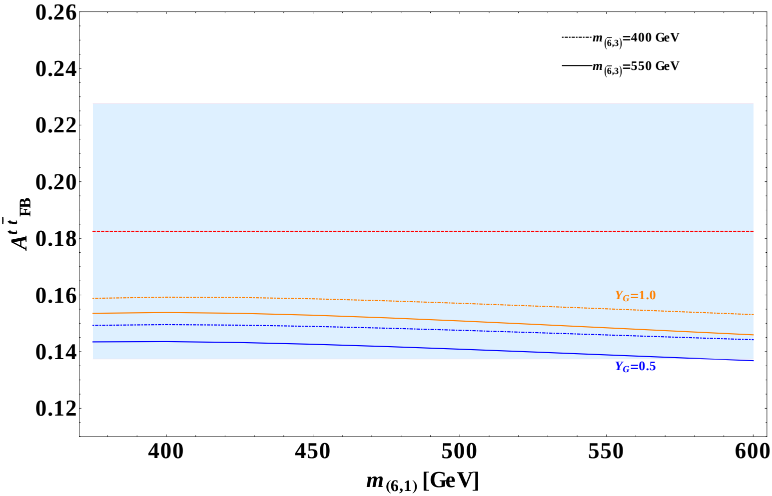
$$Y_G^{ij} \propto \begin{pmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \end{pmatrix}$$

Structure preserved under renormalization!

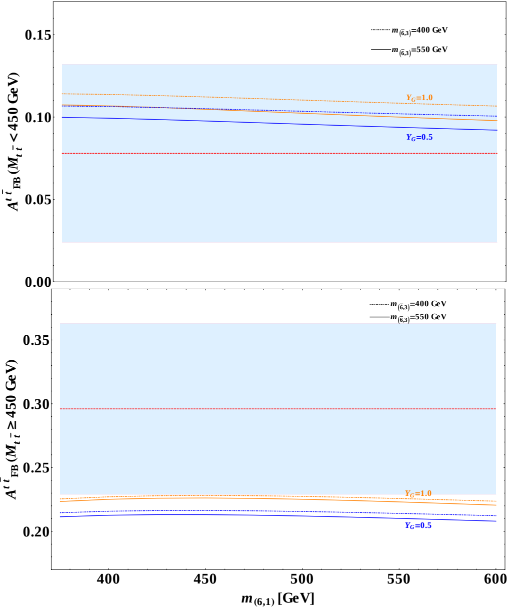
$$y_6^{ij} = y_6^{ut} = y_6^{ut},$$
$$y_{\overline{6}}^{ij} = y_{\overline{6}}^{ut} = y_{\overline{6}}^{ut}$$

Results- Total $A_{FB}^{t\bar{t}}$

1σ limits on CDF measurements



Results- Binned $A_{FB}^{t\bar{t}}$



⇐ Low bin asymmetry

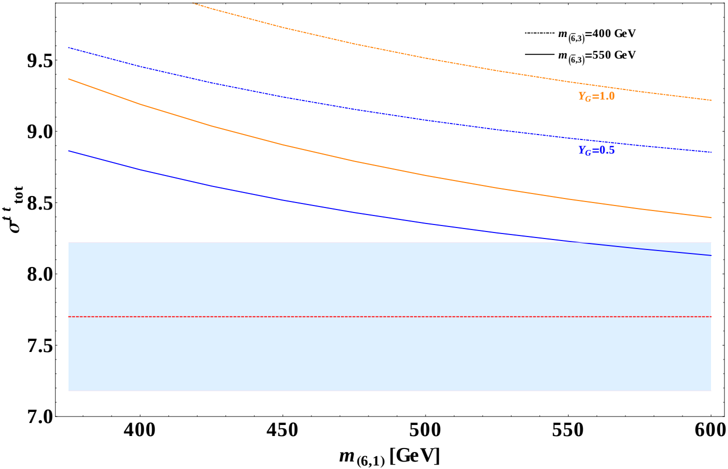
1σ limits on CDF measurements

⇐ High bin asymmetry

Results- Total $t\bar{t}$ production

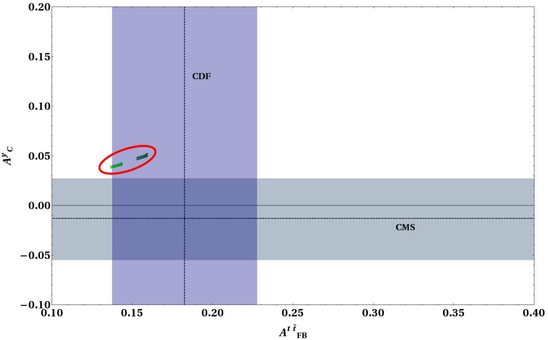
Model should not affect total $t\bar{t}$ production signficantly

1σ limits on CDF measurements



The Charge Asymmetry at the LHC and Caveats

Constraints from A_C^y at the LHC



Other possible objections

- **FCNC:** Handled by flavor structure of Y_G^{ij}
- **APV:** Constraints are considerably lower due to Y_G^{ij} and m_{ϕ_i}
- **Same-sign tops:** None of the ϕ_i are self-conjugate

Model survives (for now)

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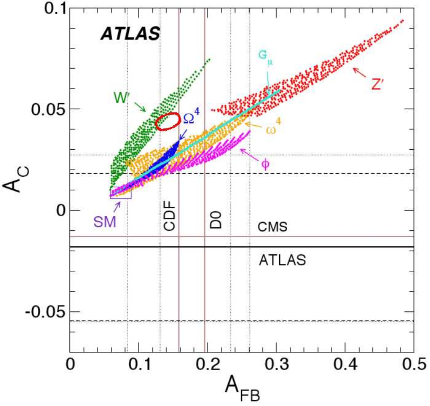

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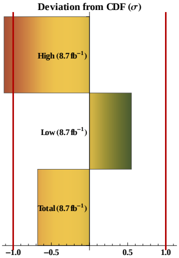
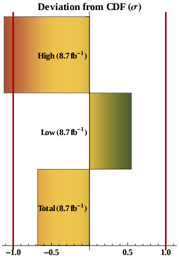
Conclusion



$\lesssim 1\sigma$ **agreement with CDF** $8.7\,\mathrm{fb}^{-1}$ **data**

- Extra colored scalar content from SU(5)
- Light content constrained by running of couplings, no leptoquarks
- Yukawa/flavor structure chosen to match $A_{FB}^{t\bar{t}}$, evade low-energy constraints
- Sizeable number of parameters determined purely by group theory

Conclusion



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Thank you!