MFV and LHC with top anomalies!

"At least we know MFV has something to do with reality to some degree..."

"MFV seems to be a fact of nature for TeV scale physics, i don't think anyone argues against that..."

"Are you still doing that weird flavour stuff ?"

"MFV is the tool of desperate men, but we ARE desperate men in particle physics."

"Look, I just don't care about MFV."

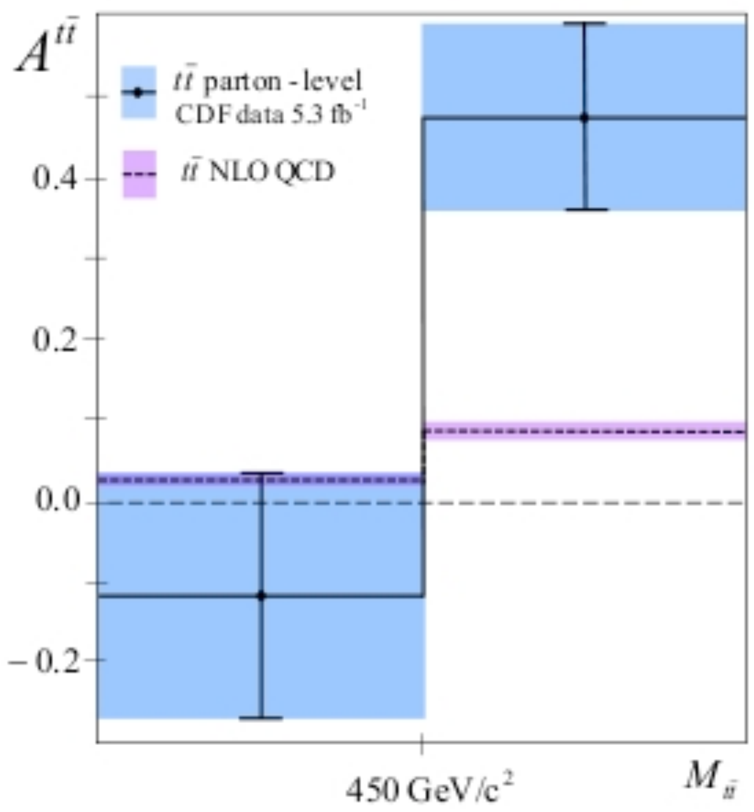
Recent Quotes about MFV - unattributed....

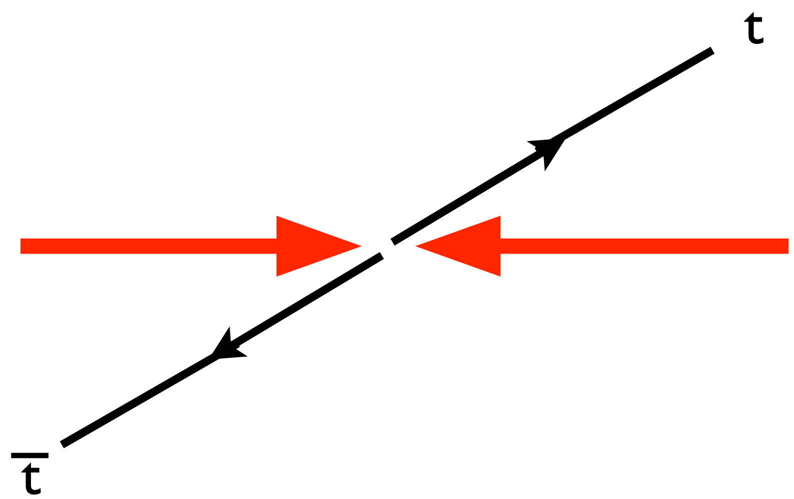
Research Program Paper trail: arXiv:0907.2696 with C.P Burgess and S. Zuberi
arXiv: 0911.2225 with Arnold, Pospelov and M. Wise
arXiv: 1001.4287 with Fornal
arXiv: 1005.2185 with Arnold and Fornal
arXiv: 1009.2813 with M.Wise
arXiv: 1102.3374 with B. Grinstein, A. Kagan, J. Zupan
arXiv: 11?? with J. Cline, K. Kainulainen
arXiv: 11.???? with B. Grinstein, A. Kagan, J. Zupan

Another anomaly has just appeared

arXiv: 1102.3374 Grinstein, Kagan, Trott Zupan

Evidence for a Mass Dependent Forward-Backward Asymmetry in Top Quark Pair Production, CDF 1101.0034 Dec 30th





3.4 sigma deviation from the SM in the high bin!

Explain this with MFV sector fields?

What could this be?

arXiv: 1102.3374 Grinstein, Kagan, Trott Zupan

First question, is this interference with SM or pure NP effects (if real).

What does the data say?

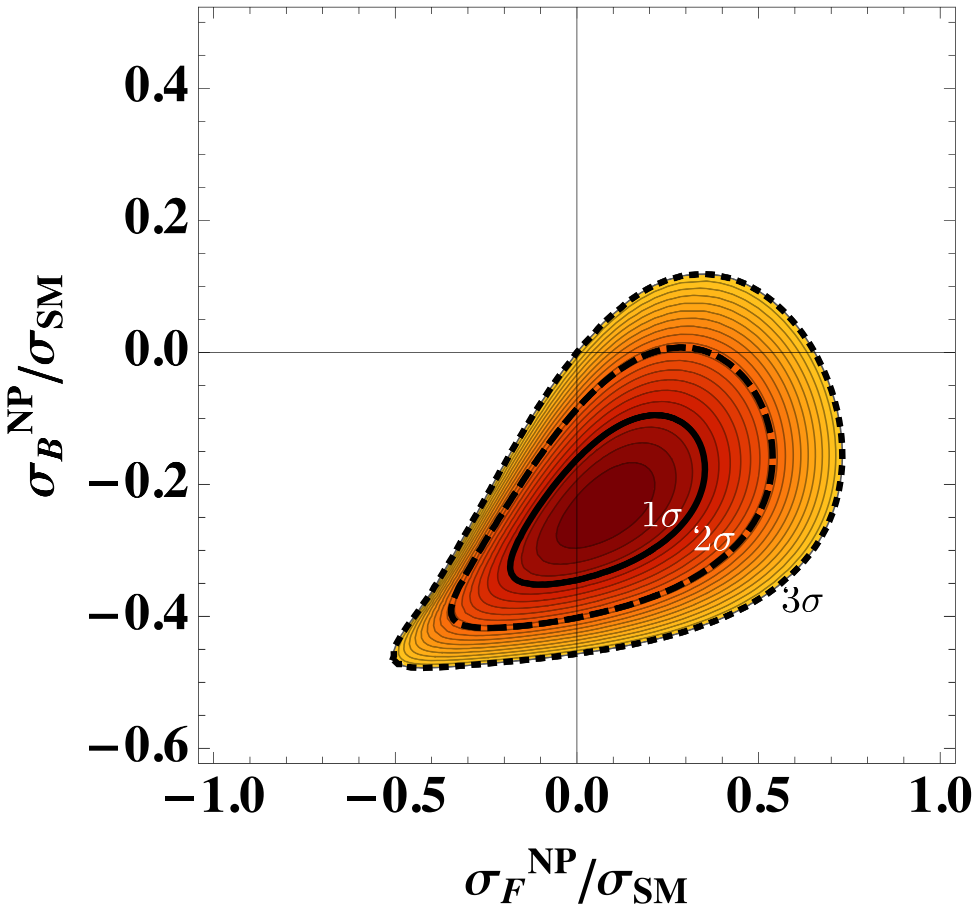
$$A_{FB}^{t\bar{t}} = \frac{\sigma_F^{SM} - \sigma_B^{SM} + \sigma_F^{NP} - \sigma_B^{NP}}{\sigma_F^{SM} + \sigma_B^{SM} + \sigma_F^{NP} + \sigma_B^{NP}},$$

NP-SM interference + NP^2
can be either sign.

We use the measured and predicted $A_{FB}^{t\bar{t}}, \sigma(t\,\bar{t})$ for the high mass region.

We can fit for the $\sigma_F^{NP}, \sigma_B^{NP}$ given the known SM results.

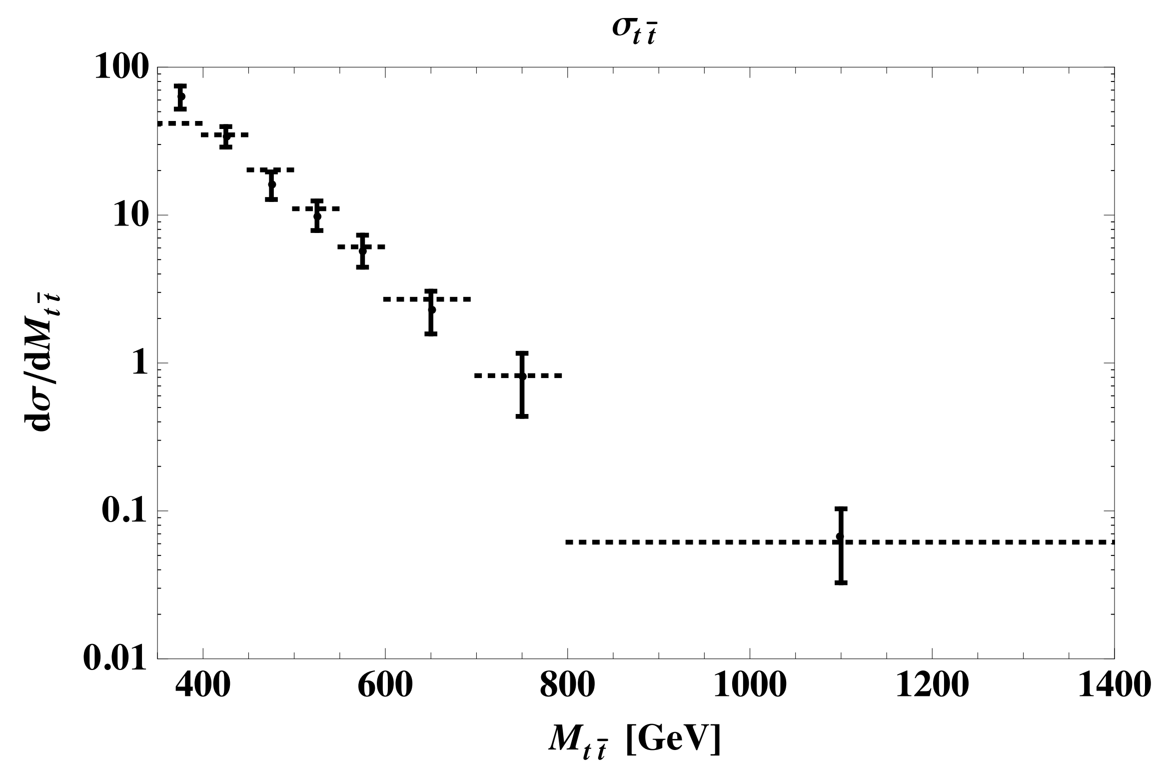
We find a clear preference for $\sigma_F > 0, \sigma_B < 0$ this points to interference.



Interference Options

arXiv: 1102.3374 Grinstein, Kagan, Trott Zupan

S -channel interference with a gluon exchange has to be a vector, colour octet.
A massive vector octet in the S-channel is problematic



Large s channel resonance feature missing.

NLO + NNLL SM results of Neubert et al **arXiv:1003.5827**

Measurement **arXiv:0903.2850 CDF collaboration** $2.7 fb^{-1}$

Interference Options

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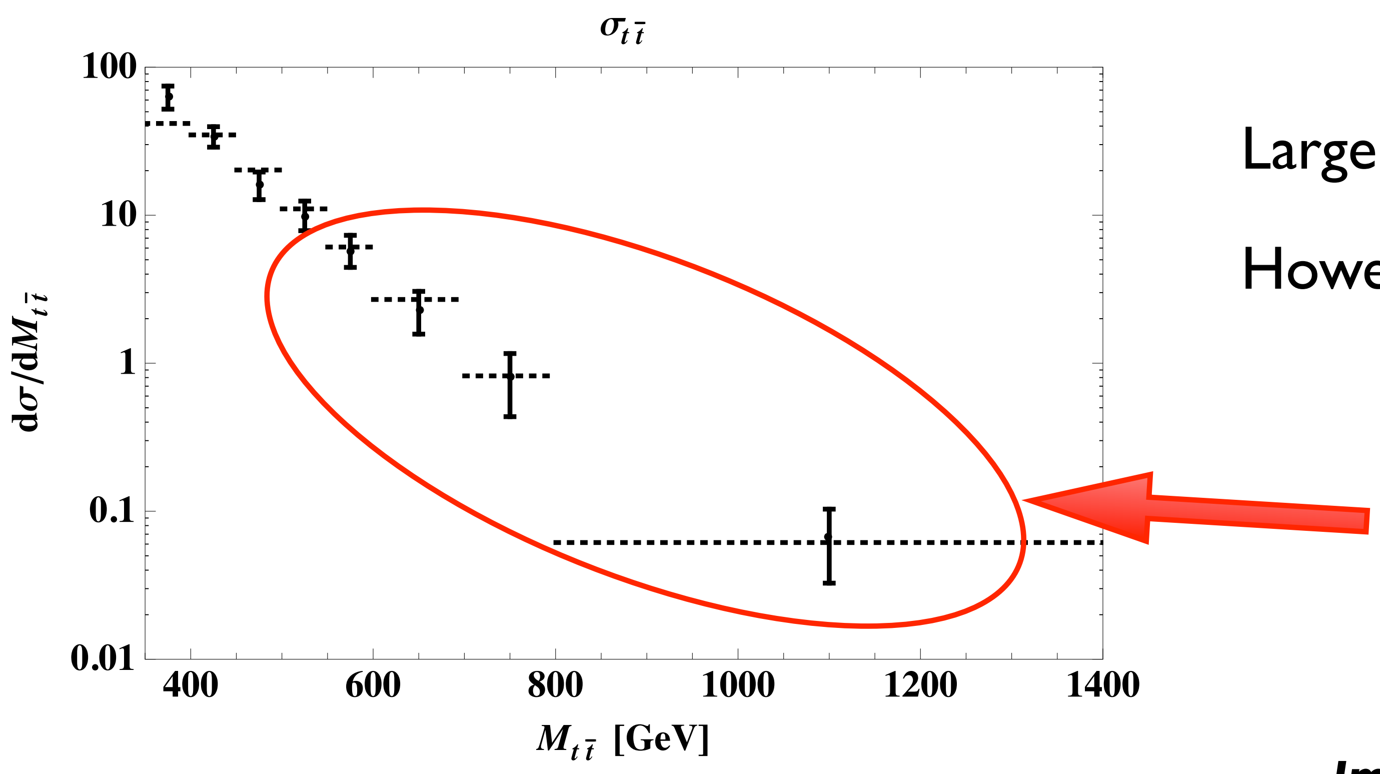


Large s channel resonance feature missing.

However recently:

A search for Boosted Top Quarks by CDFII - Jan 5th note 10234

Implications of the Measurements of Ultra-Massive Boosted Jets at CDF 1101.2898-Eshel, Gadalia, Perez, Soreq

Implications of the CDF Afb for Boosted Tops 1102.3133-Weizmann theory group

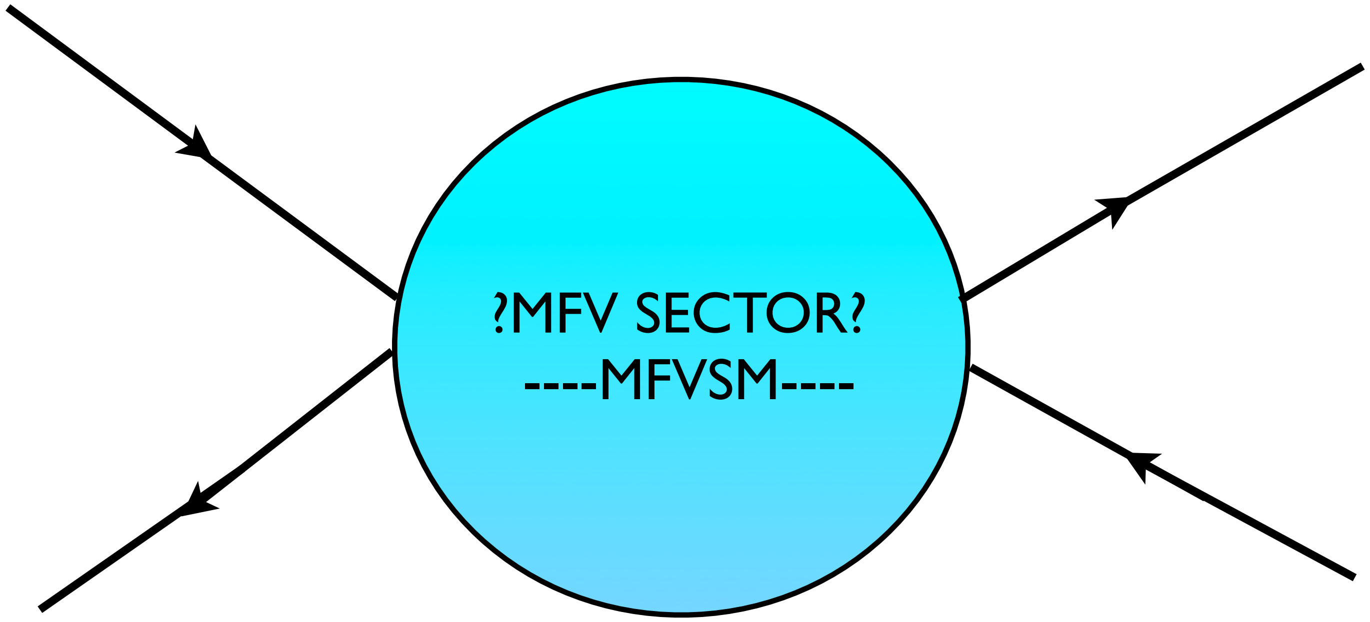
NLO + NNLL SM results of Neubert et al **arXiv:1003.5827**

Measurement **arXiv:0903.2850 CDF collaboration** $2.7 fb^{-1}$

These authors are arguing that when $p_T > 400\,\mathrm{GeV}$ for a boosted top jet there IS an excess from the SM. This is controversial.
Quantitatively we are not talking many orders of magnitude excess, maybe a factor of 2-3?

An exciting LHC possiblity.

Considering flavour constraints, it would make sense to find physics that has the same flavour breaking PATTERN due to MFV.



Always, do the simplest most direct (correct) thing first.

What can couple to fermion bi-linears and satisfy MFV?

Consider Scalars, two options $S\,\overline{\Psi}\,\Psi$ couplings "Higgs like"

or $S\,\Psi\,\Psi$ couplings "Diquarks"

Consider Vectors, two options $V^{\mu}\,\overline{\Psi}_L\gamma_{\mu}\,\Psi_L \quad V^{\mu}\,\overline{\Psi}_R\gamma_{\mu}\,\Psi_R$

Spin 0

Complete set of MFV scalars that couple at dim 4 without a Yukawa:

arXiv: **0911.2225** with Arnold, Pospelov and M. Wise

Case	$SU(3)_c$	$SU(2)_L$	$U(1)_Y$	$SU(3)_{U_R} \times SU(3)_{D_R} \times SU(3)_{Q_L}$	Couples to
I	1	2	1/2	$(3,1,\bar{3})$	$\bar{u}_R \; Q_L$
II	8	2	1/2	$(3,1,\bar{3})$	$\bar{u}_R \; Q_L$
III	1	2	-1/2	$(1,3,\bar{3})$	$\bar{d}_R \; Q_L$
IV	8	2	-1/2	$(1,3,\bar{3})$	$\bar{d}_R \; Q_L$
V	3	1	-4/3	$(3,1,1)$	$u_R \; u_R$
VI	$\bar{6}$	1	-4/3	$(\bar{6},1,1)$	$u_R \; u_R$
VII	3	1	2/3	$(1,3,1)$	$d_R \; d_R$
VIII	$\bar{6}$	1	2/3	$(1,\bar{6},1)$	$d_R \; d_R$
IX	3	1	-1/3	$(\bar{3},\bar{3},1)$	$d_R \; u_R$
X	$\bar{6}$	1	-1/3	$(\bar{3},\bar{3},1)$	$d_R \; u_R$
XI	3	1	-1/3	$(1,1,\bar{6})$	$Q_L \; Q_L$
XII	$\bar{6}$	1	-1/3	$(1,1,3)$	$Q_L \; Q_L$
XIII	3	3	-1/3	$(1,1,3)$	$Q_L \; Q_L$
XIV	$\bar{6}$	3	-1/3	$(1,1,\bar{6})$	$Q_L \; Q_L$

Baryon number conservation from gauge symmetry. Baryon number 0.

Baryon number -2/3.

Gauge symmetries protect proton decay alone.

Need lepton MFV to protect the proton.

Spin 1

Complete set of MFV vectors that couple at dim 4 without a Yukawa:

Case	$SU(3)_c$	$SU(2)_L$	$U(1)_Y$	$SU(3)_{U_R} \times SU(3)_{D_R} \times SU(3)_{Q_L}$	Couples to
$\mathrm{I}_{s,o}$	1,8	1	0	(1,1,1)	$\bar{d}_R \gamma^\mu d_R$
$\mathrm{II}_{s,o}$	1,8	1	0	(1,1,1)	$\bar{u}_R \gamma^\mu u_R$
$\mathrm{III}_{s,o}$	1,8	1	0	(1,1,1)	$\bar{Q}_L \gamma^\mu Q_L$
$\mathrm{IV}_{s,o}$	1,8	3	0	(1,1,1)	$\bar{Q}_L \gamma^\mu Q_L$
$\mathrm{V}_{s,o}$	1,8	1	0	(1,8,1)	$\bar{d}_R \gamma^\mu d_R$
$\mathrm{VI}_{s,o}$	1,8	1	0	(8,1,1)	$\bar{u}_R \gamma^\mu u_R$
$\mathrm{VII}_{s,o}$	1,8	1	-1	($\bar{3}$,3,1)	$\bar{d}_R \gamma^\mu u_R$
$\mathrm{VIII}_{s,o}$	1,8	1	0	(1,1,8)	$\bar{Q}_L \gamma^\mu Q_L$
$\mathrm{IX}_{s,o}$	1,8	3	0	(1,1,8)	$\bar{Q}_L \gamma^\mu Q_L$
$\mathrm{X}_{\bar{3},6}$	$\bar{3}$,6	2	-1/6	(1,3,3)	$\bar{d}_R \gamma^\mu Q^c_L$
$\mathrm{XI}_{\bar{3},6}$	$\bar{3}$,6	2	5/6	(3,1,3)	$\bar{u}_R \gamma^\mu Q^c_L$

arXiv: **11.soon** with Grinstein, Kagan and Zupan

Baryon number conservation from gauge symmetry.

We are building the "MFV sector model" ....the MFVSM. Will nature care? We will see.

These are not minimally coupled, not gauge fields, they are effective fields.

We systematically checked all the MFV fields

arXiv: **11.soon** with Grinstein, Kagan and Zupan

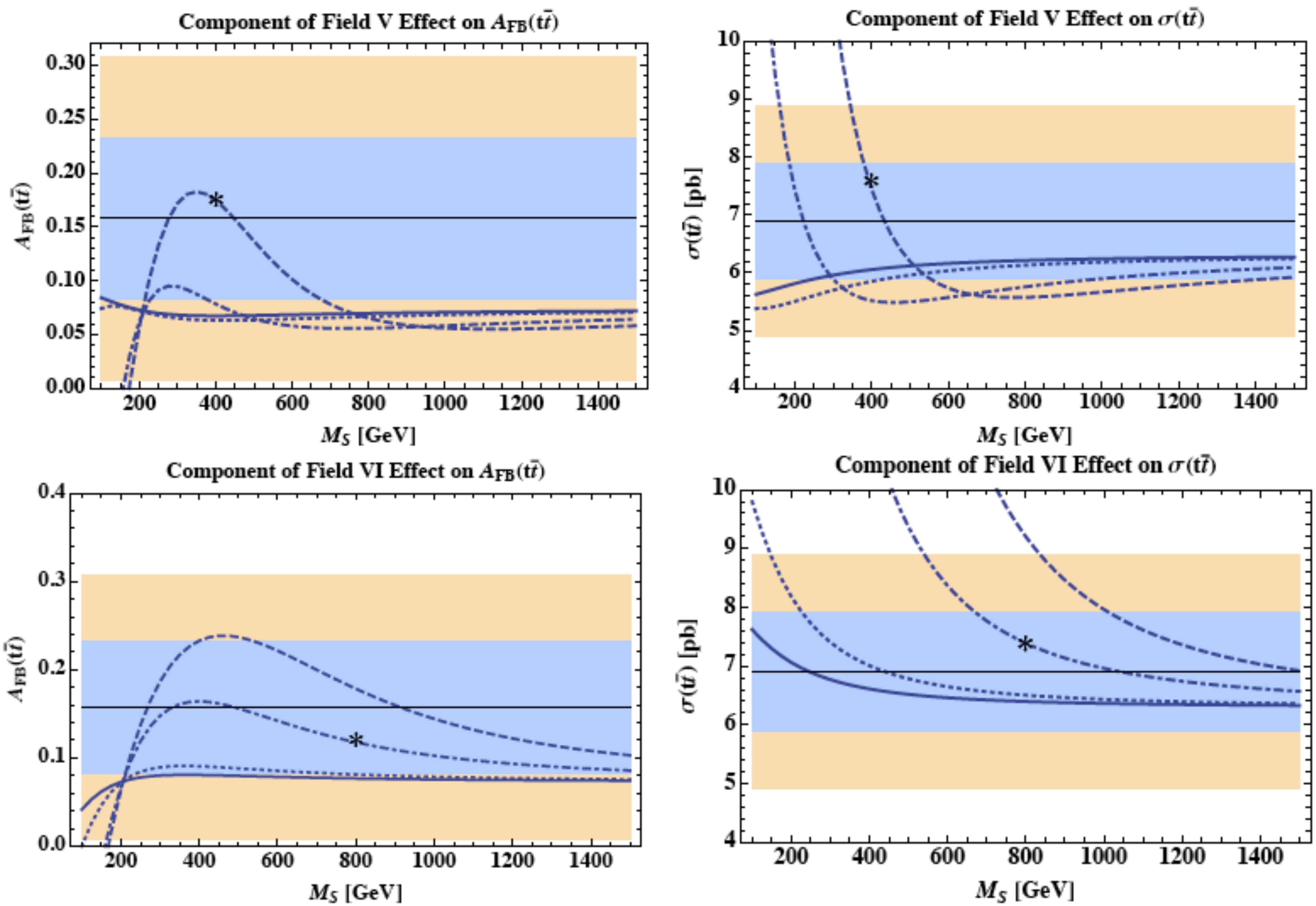


FIG. 5: The effect of fields S_V, S_{VI} on $A_{FB}^{t\bar{t}}$ (left) and $\sigma(t\,\bar{t})$ (right). The solid curve is for $\eta = 1/4$, the dotted $\eta = 1/(2\sqrt{2})$, the dot-dashed is $\eta = 1/\sqrt{2}$ and the dashed curves are $\eta = 1$.

We systematically checked all the MFV fields

arXiv: **11.soon** with Grinstein, Kagan and Zupan

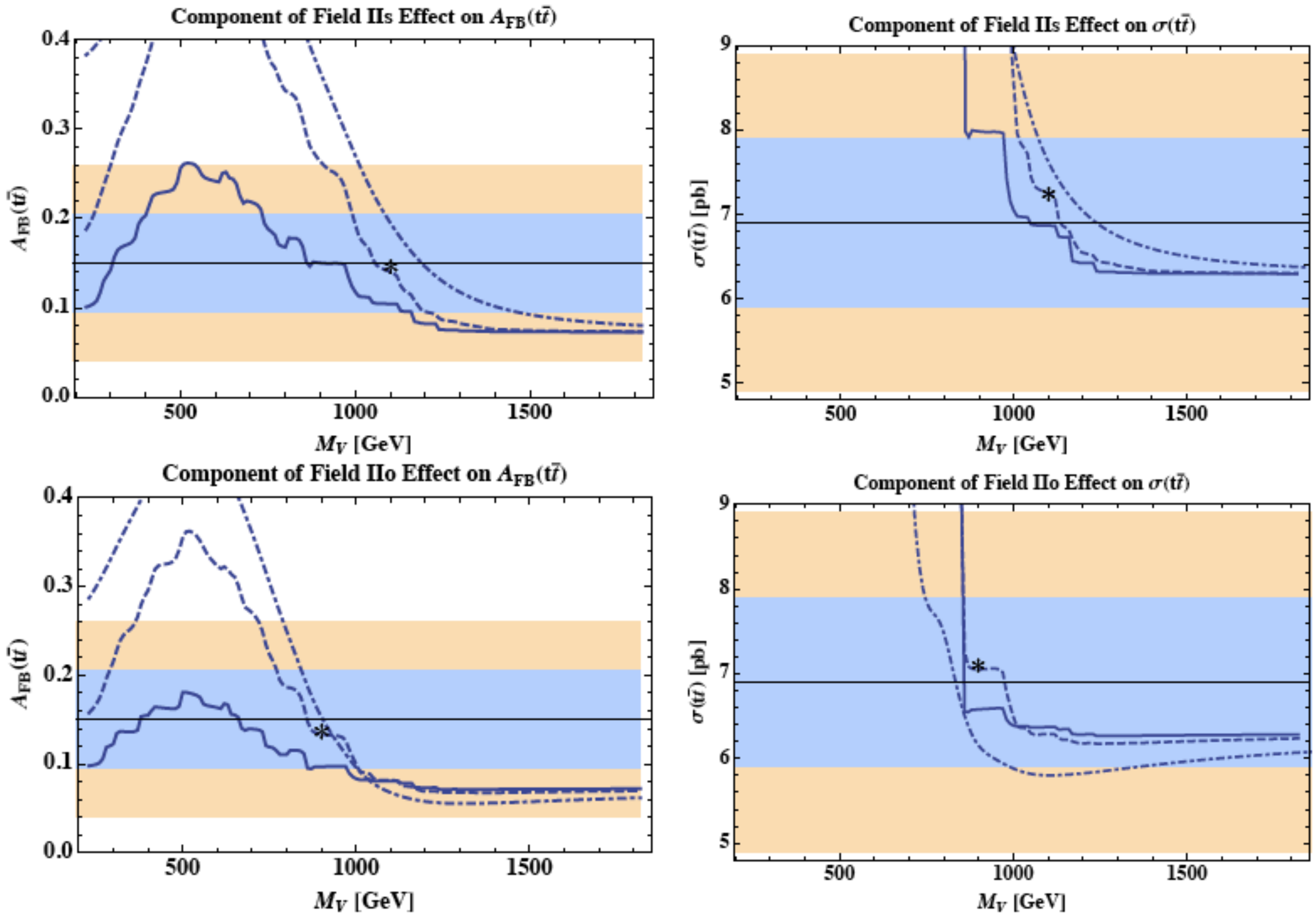
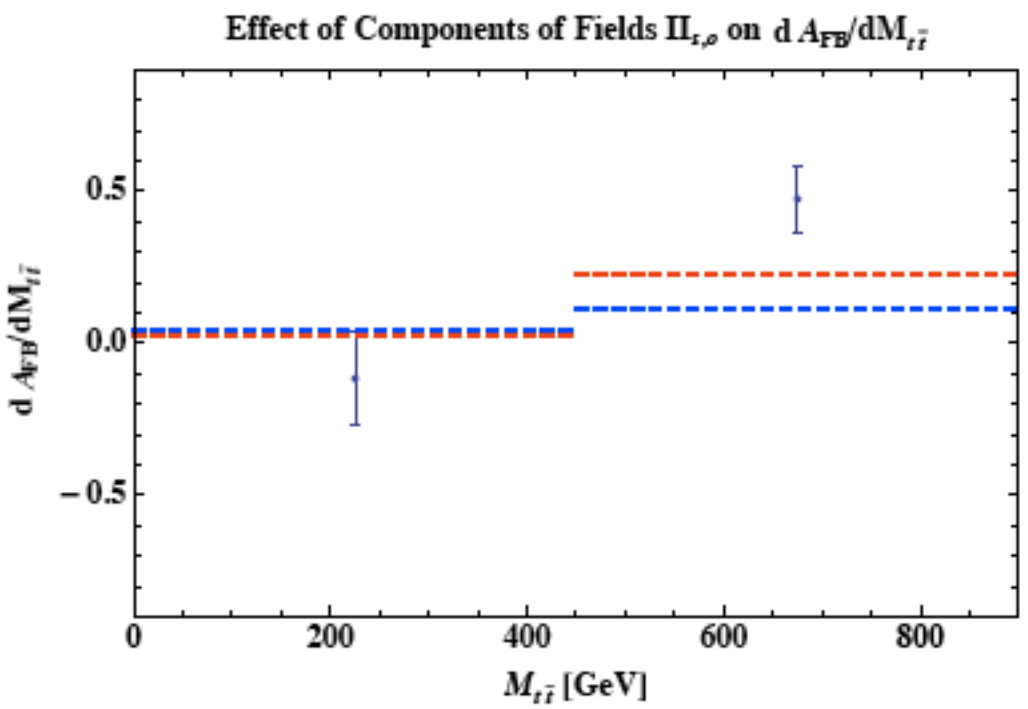
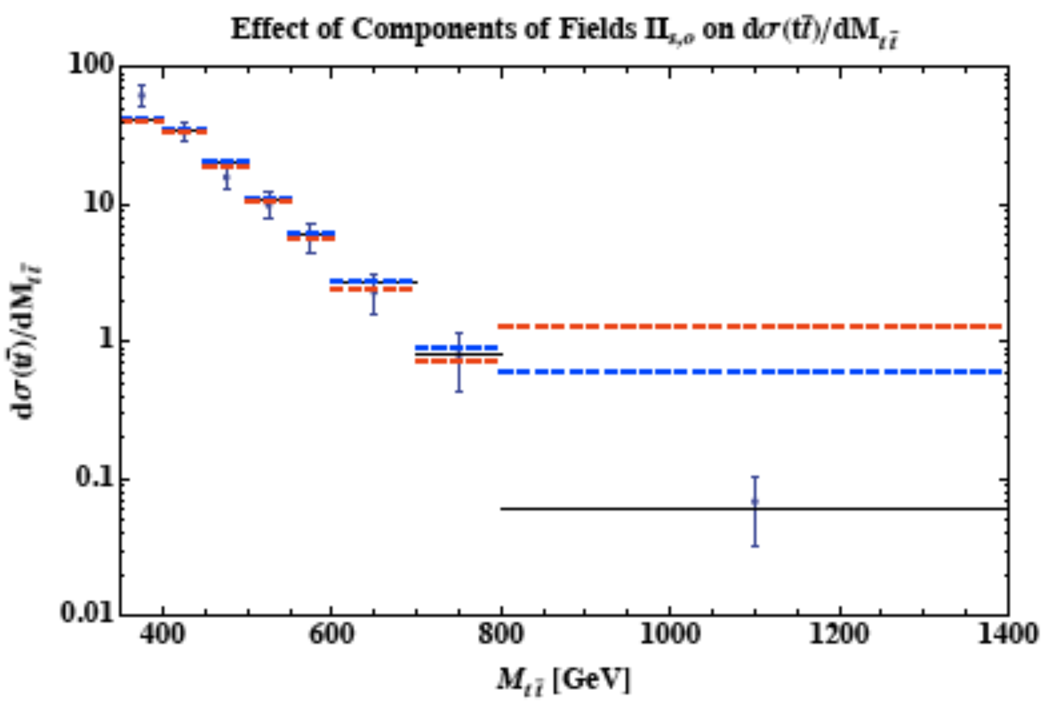


FIG. 8: The effect of fields $\mathrm{II}_{s,o}$ on $A_{FB}^{t\bar{t}}$ (left) and $\sigma(t\,\bar{t})$ (right). The solid curve is for $f_q f_t = 1/4\sqrt{2}$, the dashed is $f_q f_t = 1/\sqrt{2}$ and the dot-dashed curves are $f_q f_t = 2\sqrt{2}$ in each of the graphs. Also shown are the one and two σ

We systematically checked all the MFV fields

arXiv: **11.soon** with Grinstein, Kagan and Zupan





S channel resonances are a problem!

We systematically checked all the MFV fields

arXiv: **11.soon** with Grinstein, Kagan and Zupan

Combined
s and t channel
interference.

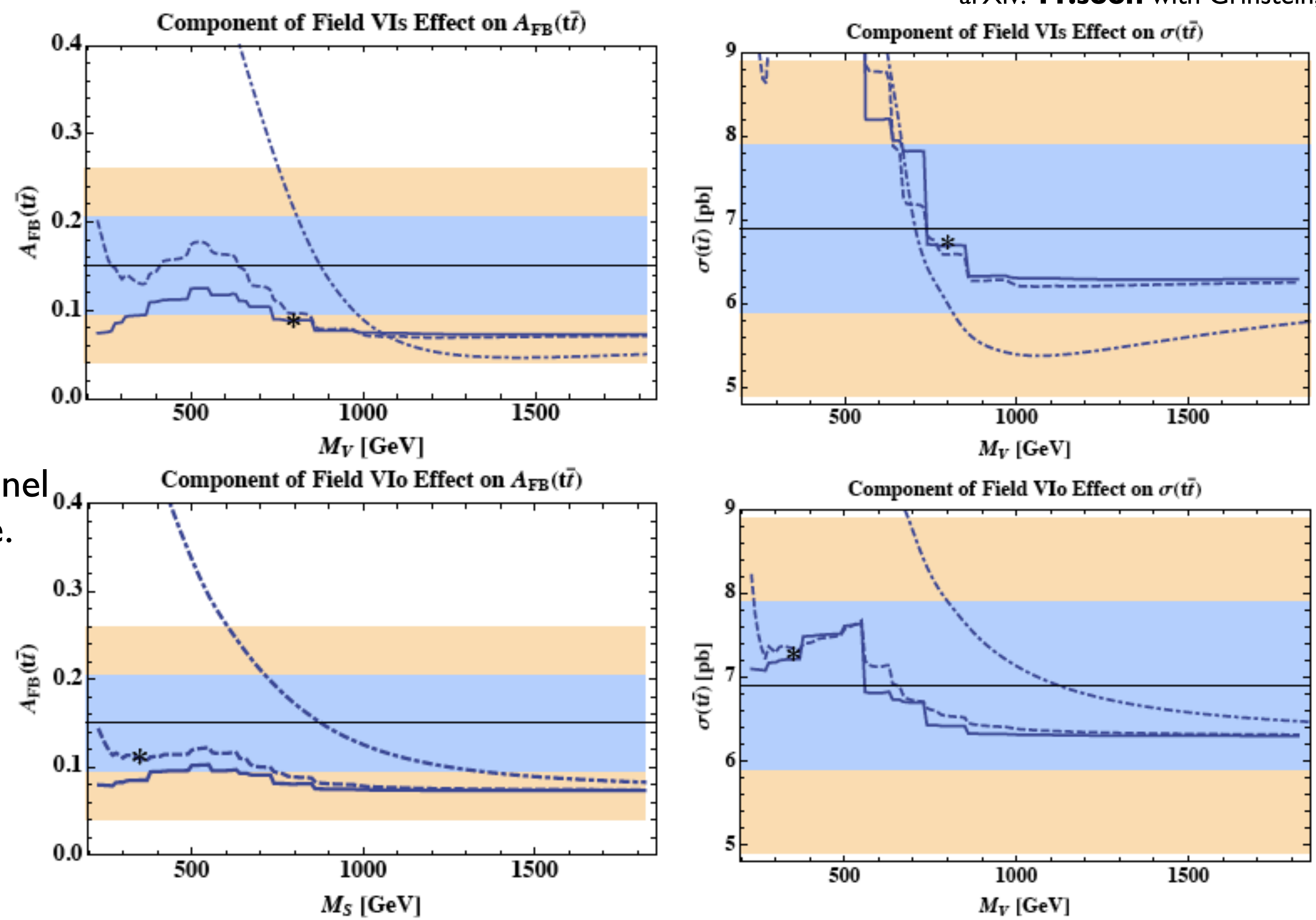


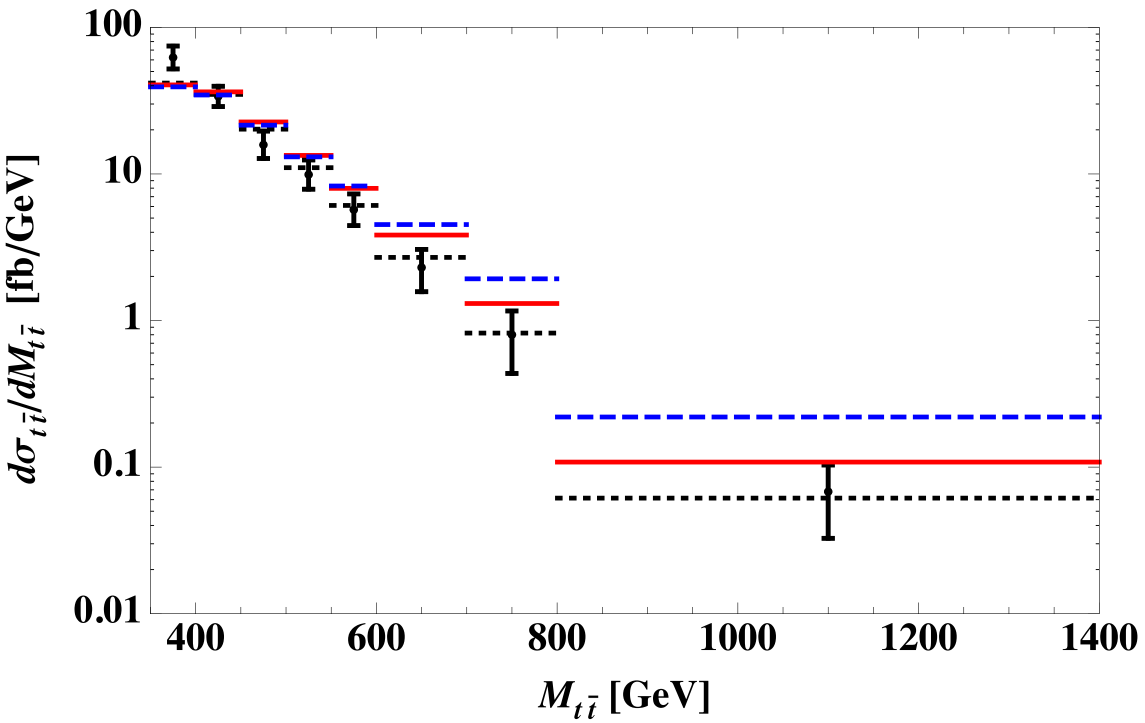
FIG. 10: The effect of fields $\text{VI}_{\text{s,o}}$ on $A^{t\bar{t}}_{FB}$ (left) and $\sigma(t\,\bar{t})$ (right). The solid curve is for $f_q f_t = 1/4\sqrt{2}$, the dashed is $f_q f_t = 1/\sqrt{2}$ and the dot-dashed curves are $f_q f_t = 2\sqrt{2}$ in each graph. For each coupling value we also set $f_{qt} = f_q\, f_t$.

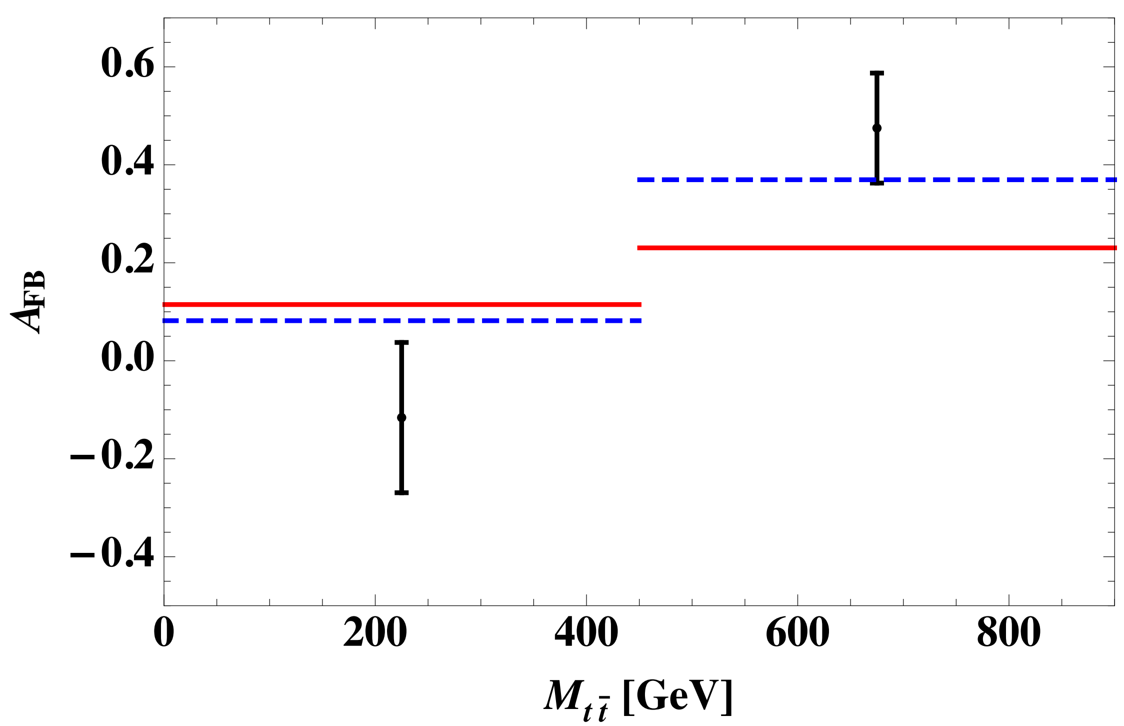
MFV Field Interference Options

arXiv: 1102.3374 Grinstein, Kagan, Trott Zupan

The mass scale should be relatively low (~ TeV or less). Such a mass scale is strongly constrained by flavour physics, but the MFV fields can have O(1) couplings.

Two interesting MFV fields considering the anomaly: Scalar $(\overline{6},1)_{-4/3}$ and $(\overline{6},1,1)$ under $\mathrm{G_F}$





Shown here for parameter choices $(M,\eta,\Gamma/M)$ of: $(390,1.95,0.1)$

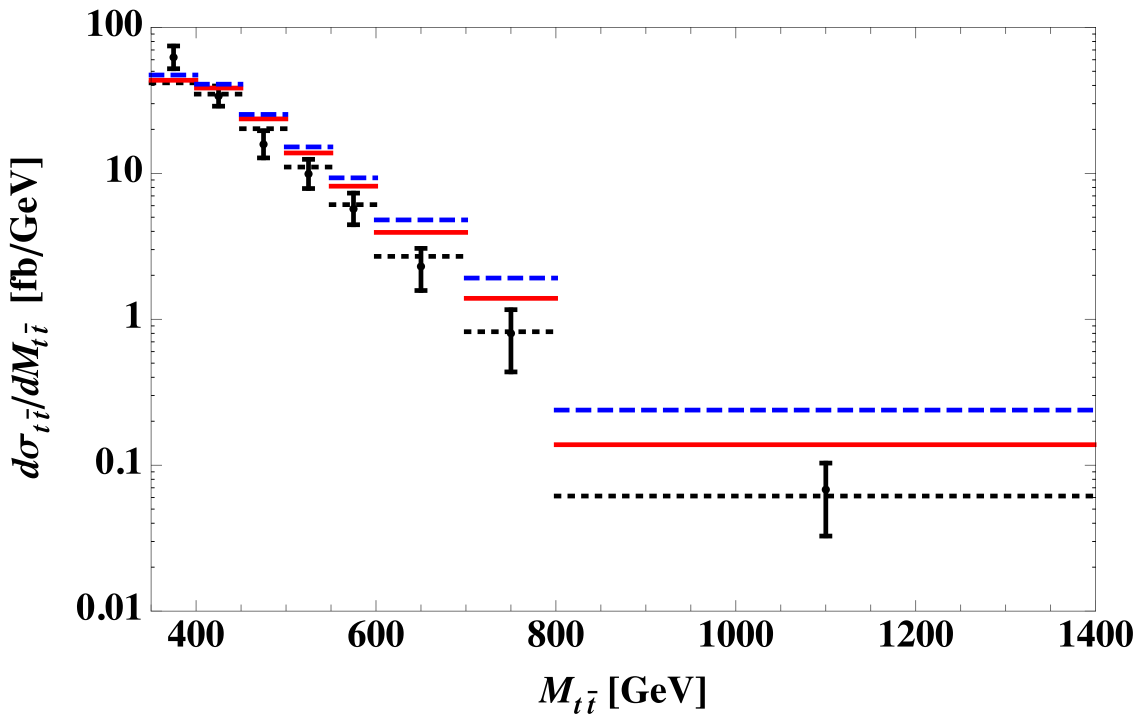
$(1300,4.9,0.5)$

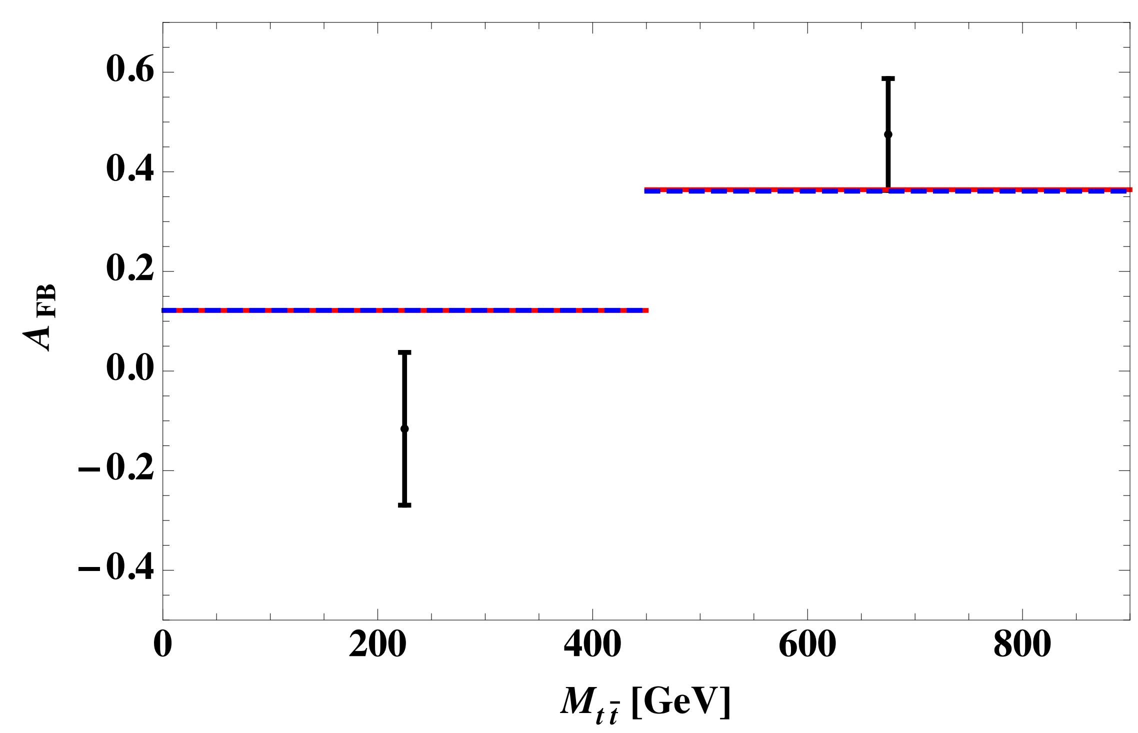
MFV Field Interference Options

arXiv: 1102.3374 Grinstein, Kagan, Trott Zupan

Second interesting MFV fields: Vector $(8,1)_0$ and $(8,1,1)$ under $\mathrm{G_F}$

This field is interesting as it has s and t channel contributions to $A_{FB}^{t\bar{t}}$





Parameter choices $(M, \sqrt{\eta_{ij}\eta_{33}}, \eta_{i3}, \Gamma_V/M)$ of: $(300, 1, 1.33, 0.08)$

$(1200, 2.2, 4.88, 0.5)$

Problems

If this is real, then there are a lot of associated issues:

- The $d\sigma/dM_{t\,\bar{t}}$ spectrum
- Dijet resonance searches
- Resonance searches in $t\,\bar{t}$
- Production of $t\,t$
- FCNC, D mixing in particular

MFV Solutions

If this is real, then there are a lot of associated issues:

	What MFV does for you:
• The $d\sigma/dM_{t\,\bar{t}}$ spectrum	Nothing. Tough hurdle.
• Dijet resonance searches	$\mathrm{G_F}$ breaking distinguishes light quark coupling from top
• Resonance searches in $t\,\bar{t}$	Flavour safe t channel dominance
• Production of $t\,t$	Suppressed by $\sim (y_c\, y_t y_b^2\, V_{cb})^2$
• FCNC, D mixing in particular	Suppressed by $\sim (y_u\, y_c y_b^2)^2$