Tevatron Top A_{FB}

vs

LHC Top Physics

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in collaboration with Moira Gresham and Kathryn Zurek

arXiv:1107.4364,
Phys. Rev. D 84, 034025 (2011) [arXiv:1102.0018],
Phys.Rev. D83, 114027 (2011) [arXiv:1103.3501]

SUSY 2011
Aug 29, 2011

Top Physics

Early LHC : Time for Top Physics

$$\sigma_{\rm TEV} = 7.5 \text{ pb} \qquad \sigma_{\rm LHC} = \mathcal{O}(100) \text{ pb}$$

We already produced O(10^5) top pairs.

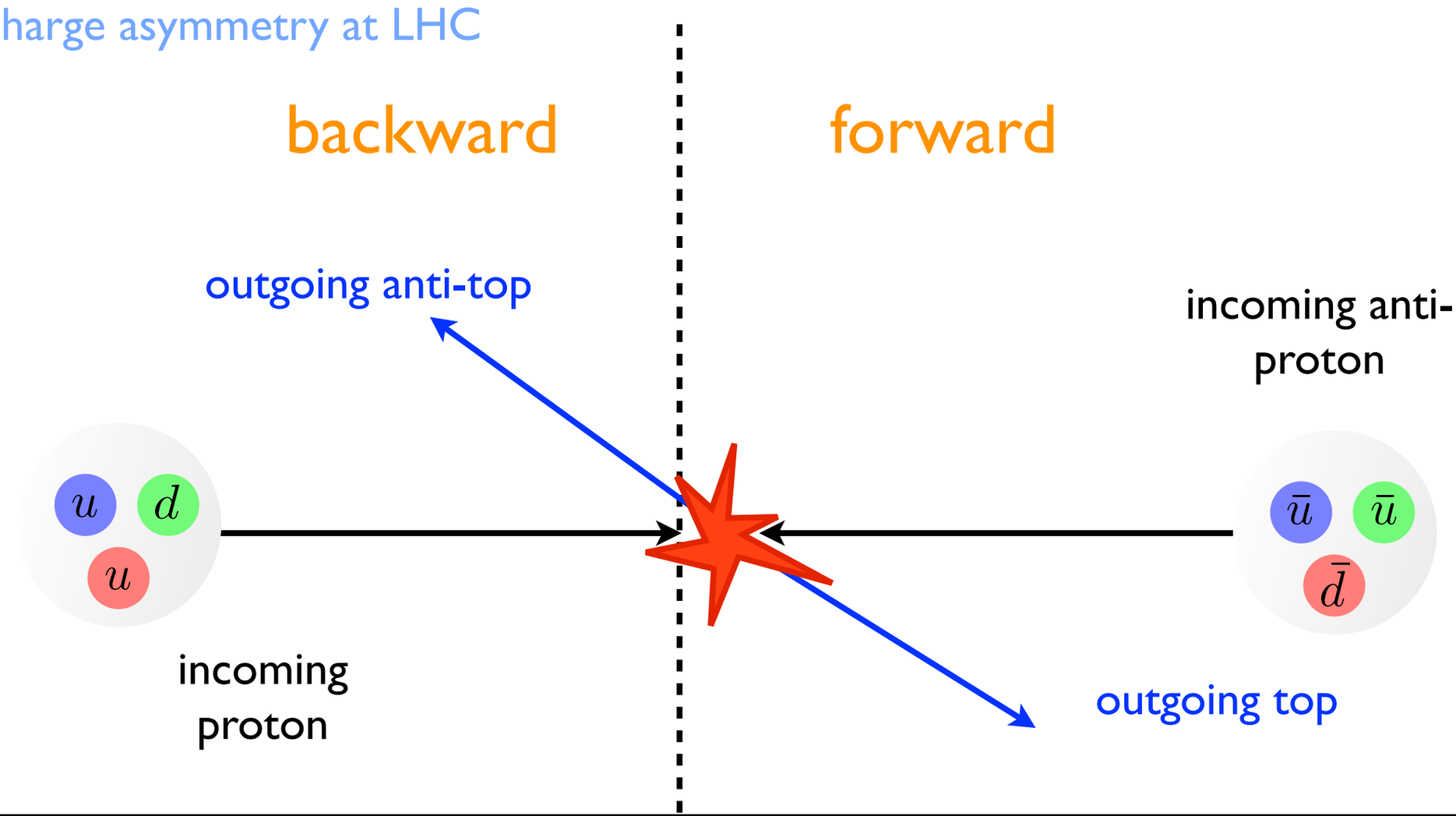
Top flavor physics is relatively unconstrained.

Top physics may be a window to the origin of EWSB.

Top Forward-Backward Asymmetry A^t_{FB}

Tevatron Advantage

cf) charge asymmetry at LHC



$$\text{top forward-backward asymmetry} = \frac{(\#\text{ forward tops}) - (\#\text{ backward tops})}{\text{total }\#\text{ of tops}}$$

Standard Model asymmetry is zero at leading order.

Small, positive asymmetry at NLO.

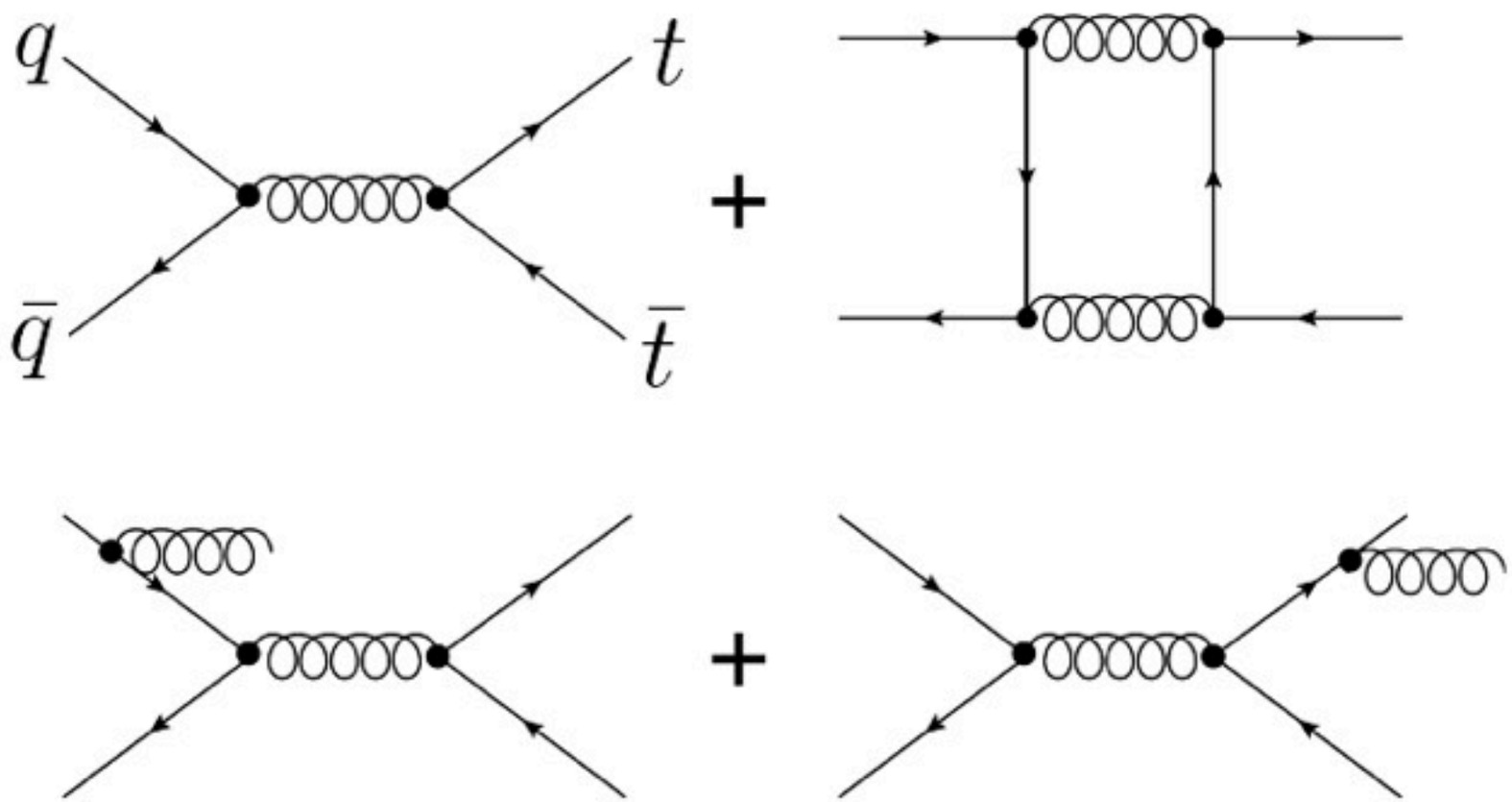


image credit: CDF arXiv:1101.0034

New physics effects easily come in at Tree Level.

The CDF Result [arXiv:1101.0034]

$A_{FBi}^{t\bar{t}}$	$m_{t\bar{t}} < 450$ GeV		$m_{t\bar{t}} > 450$ GeV	
bkd-sub data	$-0.022 \pm 0.039 \pm 0.017$	$\Delta = -0.9\sigma$	$0.266 \pm 0.053 \pm 0.032$	$\Delta = 3.6\sigma$
MC@NLO	0.015 ± 0.006		0.043 ± 0.009	
parton data	$-0.116 \pm 0.146 \pm 0.047$	$\Delta = -1\sigma$	$0.475 \pm 0.101 \pm 0.049$	$\Delta = 3.4\sigma$
MC@NLO	0.040 ± 0.006		0.088 ± 0.013	

CDF [arXiv:1101.0034]

sample	level	$A^{t\bar{t}}$	$A^{p\bar{p}}$
data	data	0.057 ± 0.028	0.073 ± 0.028
MC@NLO	$t\bar{t}$+bkg	0.017 ± 0.004	0.001 ± 0.003
data	signal	0.075 ± 0.037	0.110 ± 0.039
MC@NLO	$t\bar{t}$	0.024 ± 0.005	0.018 ± 0.005
data	parton	0.158 ± 0.074	0.150 ± 0.055
MCFM	parton	0.058 ± 0.009	0.038 ± 0.006

$\Delta = 1.4\sigma$ $\Delta = 2.3\sigma$

The D0 Result [arXiv:1107.4995]

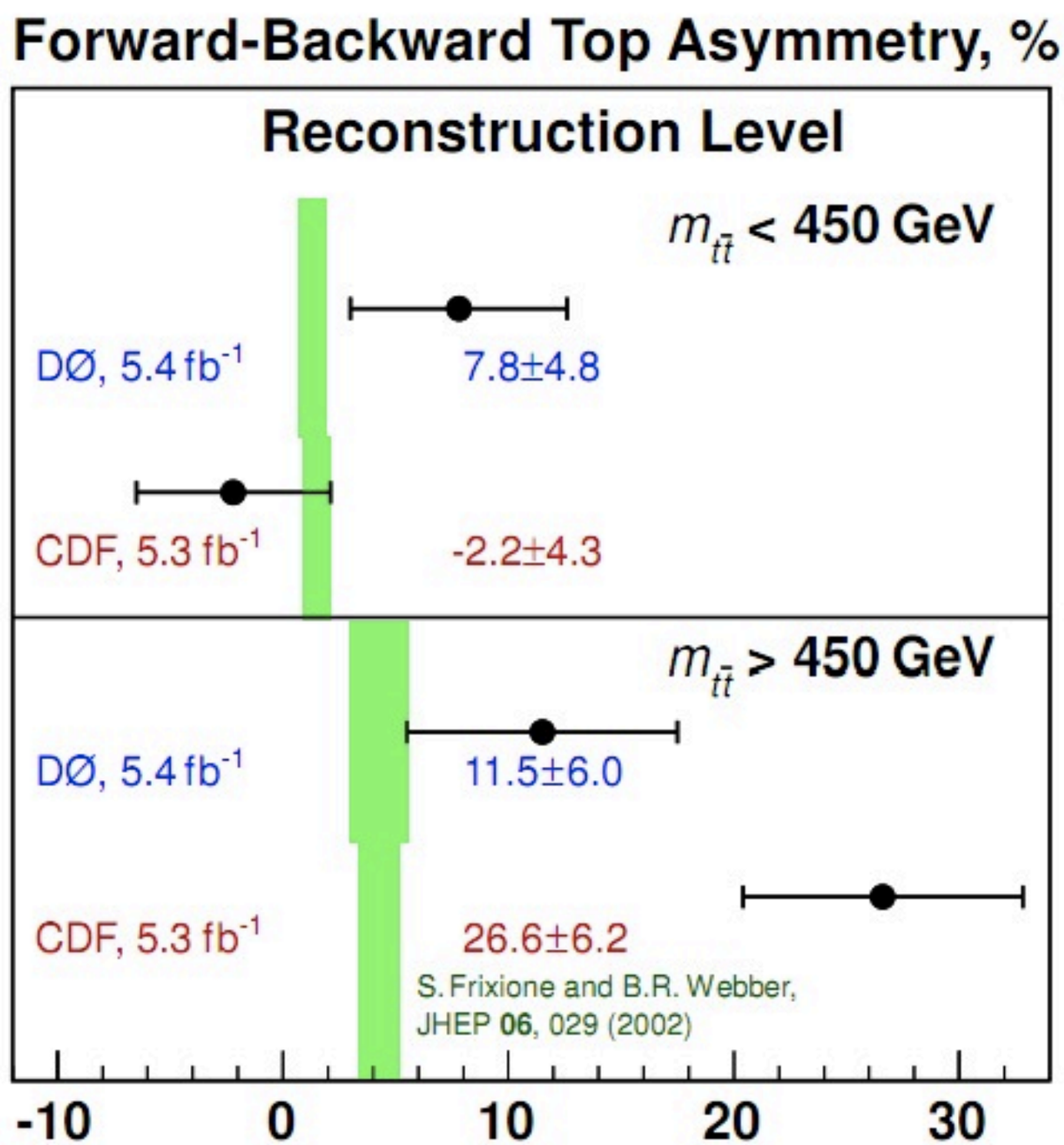
Reconstruction level

	$l+ \geq 4$ jets	$l + 4$ jets	$l+ \geq 5$ jets
$A_{FB}(\%)$	9.2 ± 3.7	12.2 ± 4.3	-3.0 ± 7.9
MC@NLO A_{FB}	2.4 ± 0.7	3.9 ± 0.8	-2.9 ± 1.1

$\sim 1.8\sigma$

	$A_{FB}(\%)$		
Subsample	Data	MC@NLO	
$m_{t\bar{t}} < 450$ GeV	7.8 ± 4.8	1.3 ± 0.6	$\sim 1.3\sigma$
$m_{t\bar{t}} > 450$ GeV	11.5 ± 6.0	4.3 ± 1.3	$\sim 1.2\sigma$
$\lvert\Delta y\rvert < 1.0$	6.1 ± 4.1	1.4 ± 0.6	
$\lvert\Delta y\rvert > 1.0$	21.3 ± 9.7	6.3 ± 1.6	

D0 has smaller deviation from SM compared with CDF in high invariant mass bin



from D. Orbaker's talk at Fermilab

On the LHC side...

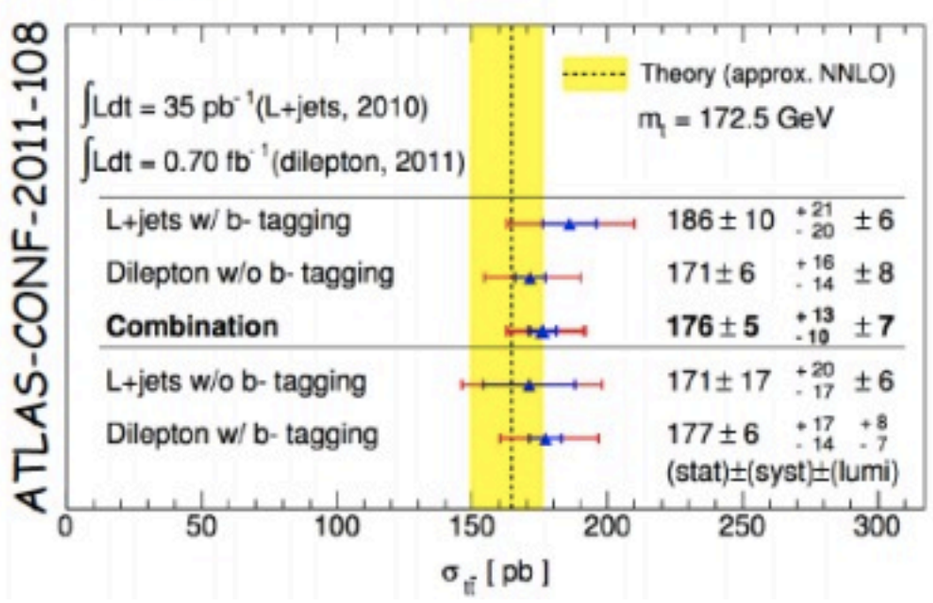
from A. de Roeck's talk at Lepton-Photon 2011

CMS

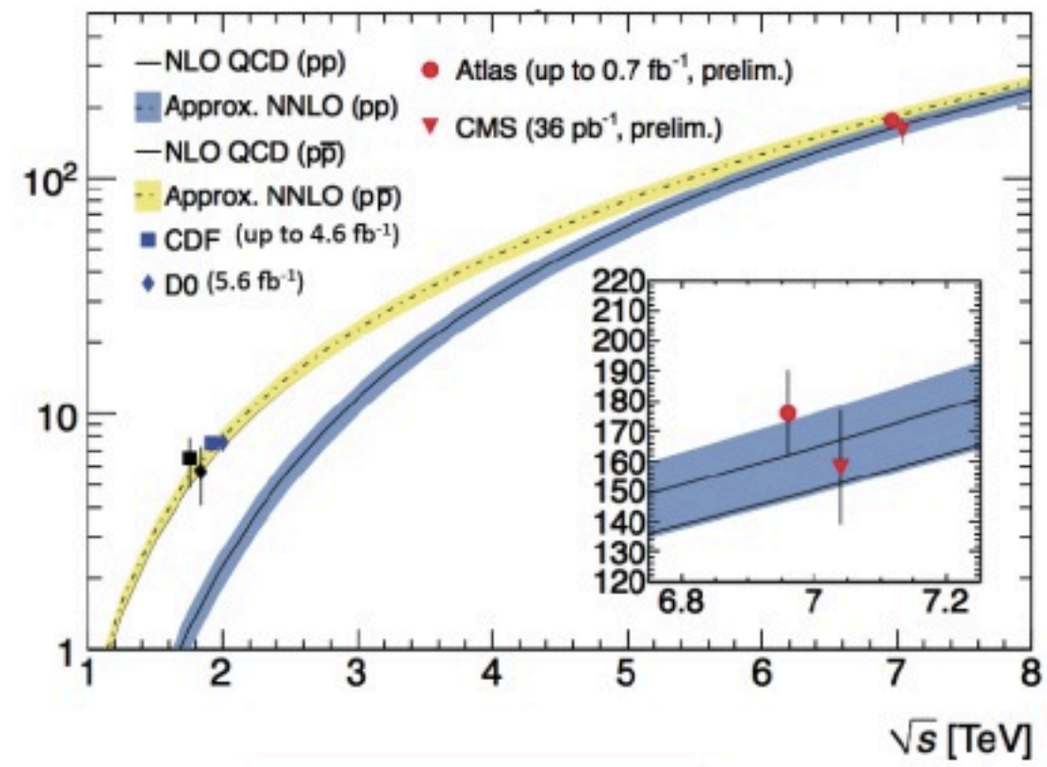
Measurement	Cross section [pb]	Weight
CMS l+jets+tag	$150 \pm 9(stat) \pm 17(syst) \pm 6(lumi)$	58%
CMS dilepton	$168 \pm 18(stat) \pm 14(syst) \pm 7(lumi)$	42%

$$\sigma_{t\bar{t}} = 158 \pm 10(unc.) \pm 15(cor.) \pm 6(lumi) \text{ pb}$$

ATLAS



Individual combinations of the channels in the experiments



9% precision!!
July 2011

Not a significant deviation from standard model at ~ 1 fb^-1

The predicted Standard Model top asymmetry is significantly lower than the measured asymmetry but ttbar cross section is well matched with SM.

Especially for large invariant mass ($m_{t\bar{t}} > 450\ \mathrm{GeV}$), CDF result shows $> 3\sigma$ deviation.

In this talk, we will focus on models compatible with the CDF A_{FB} measurement.

This analysis can be regarded as a status report of NP models regarding top FB asymmetry.

How to Generate A_{FB}

You can refer to...

PLB200,211 (1988), PRD37,1188 (1988), 0906.0604, 0906.5541, 0911.2955, 1007.0260, 1008.0742, 1009.4165, 1011.6557, 1101.2902, 1101.5203, 1103.1266, 1103.1940, 1103.0956, 1104.0083, 1106.0529, 1107.0978, 1107.1473, 1105.3333, 1106.4054, 1107.2120, 0907.4112, 0908.2589, 0911.2589, 0911.3237, 0911.4875, 0912.0972, 1002.1048, 1006.2510, 1101.1445, 1101.5392, 1101.5625, 1102.3374, 1102.4736, 1103.2127, 1103.2757, 1103.4835, 1104.2030, 1106.5982, 1106.4553, 0912.1105, 0912.1447, 1003.3461, 1011.5976, 1012.4750, 1012.0102, 1103.2297, 1103.3501, 1105.3743, 1102.0018, 1102.3133, 1103.2765, 1105.4606....

sorry if I miss your paper..

How to Generate A_{FB}

- s-channel exchange
- t-channel exchange

I will focus on this.

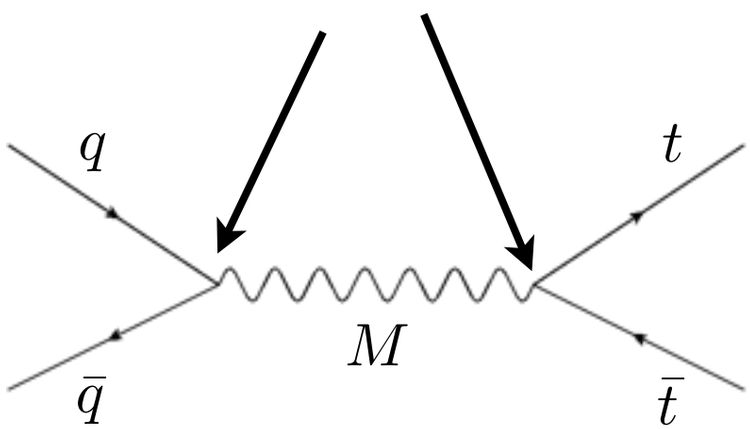
- top decay/production mode change
- effective operator
- ...

S-channel Models

asymmetry from quantum interference

nonzero axial couplings

large mass due to dijet resonance/contact interaction



$$\gtrsim 1800 \text{ GeV}$$

for simple model

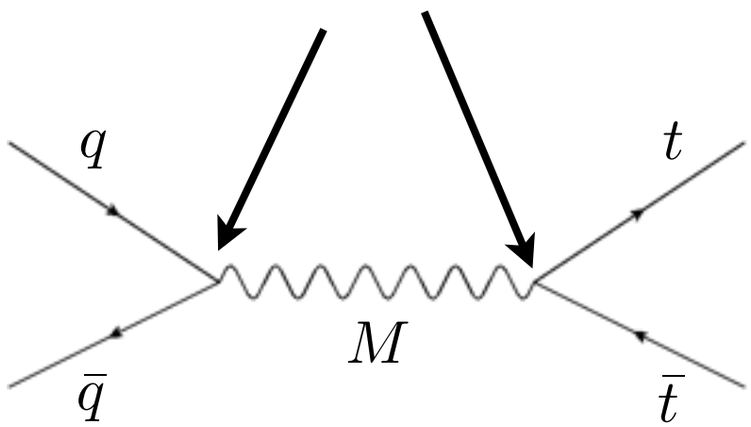
Model structure is rather fixed.

- color octet vector (with maximally axial couplings to light quarks and to top quarks) aka an axigluon

To obtain large A_{FB} with small mass in s-channel models

Nonuniversal coupling

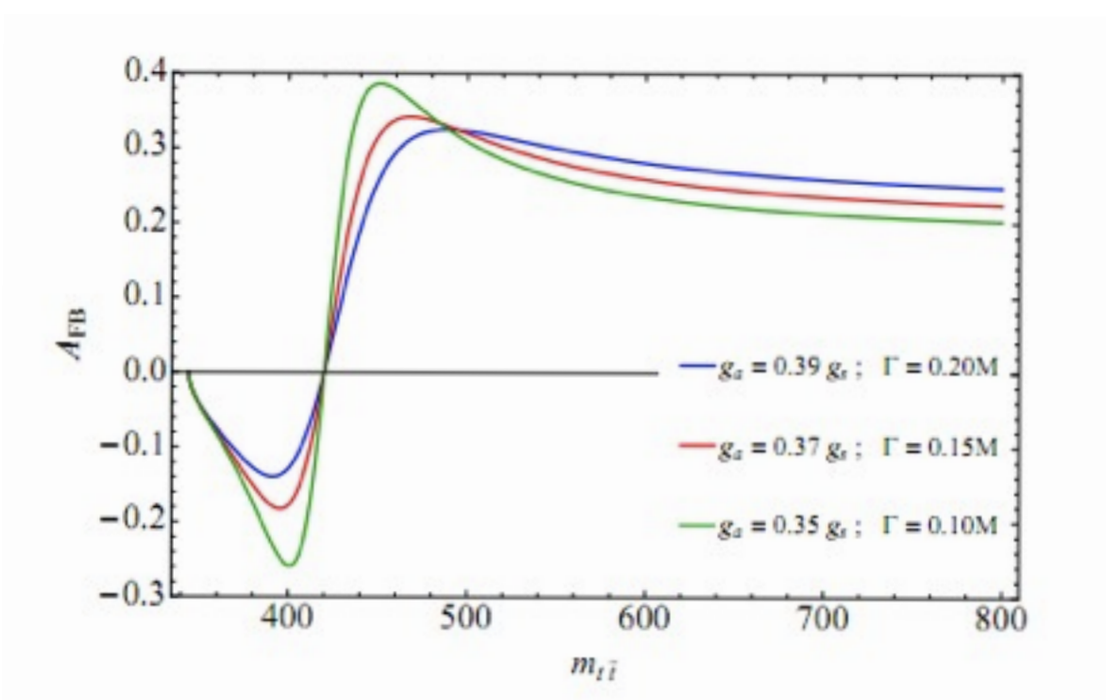
Aguilar-Saavedra, Perez-Victoria (1107.2120)



small g_q and large g_t while the product kept in right range.

Broad Low Mass Resonance

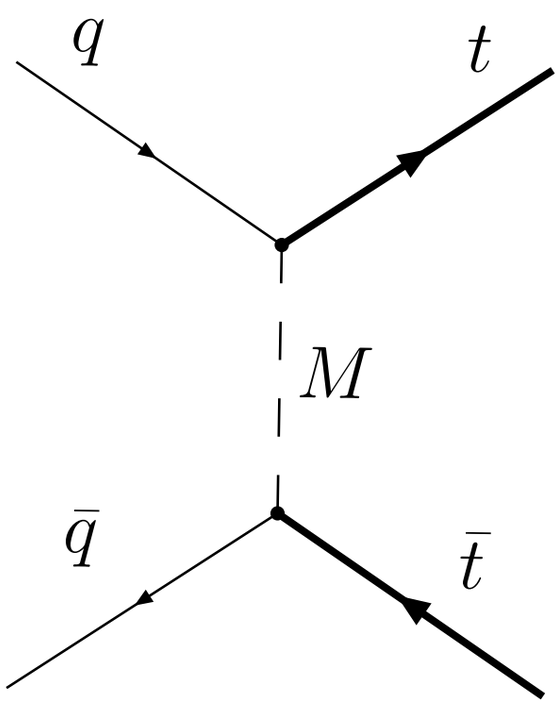
Tavares, Schmaltz (1107.0978)



abruptly change sign.
make it smooth through large decay width

T-channel Models

Asymmetry from kinematics



Rutherford scattering

Top flavor-carrying particle

- *spin : vector or scalar?*
- *color : 1,3,6 or 8 ?*
- *"isospin"?*

small mass to generate large A_{FB}

Relatively unconstrained in top flavor violation

Comparison with Experiment

Two separate worlds :

Detector level

"raw"

Experiment

Unfolding

$\longrightarrow$

Efficiency

Calibration

Parton level

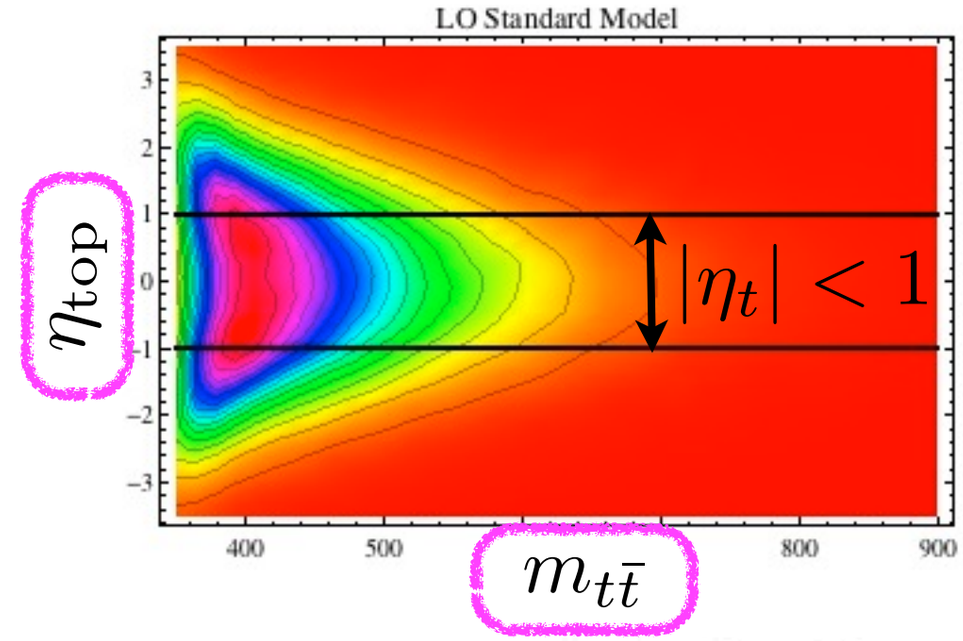
Theory

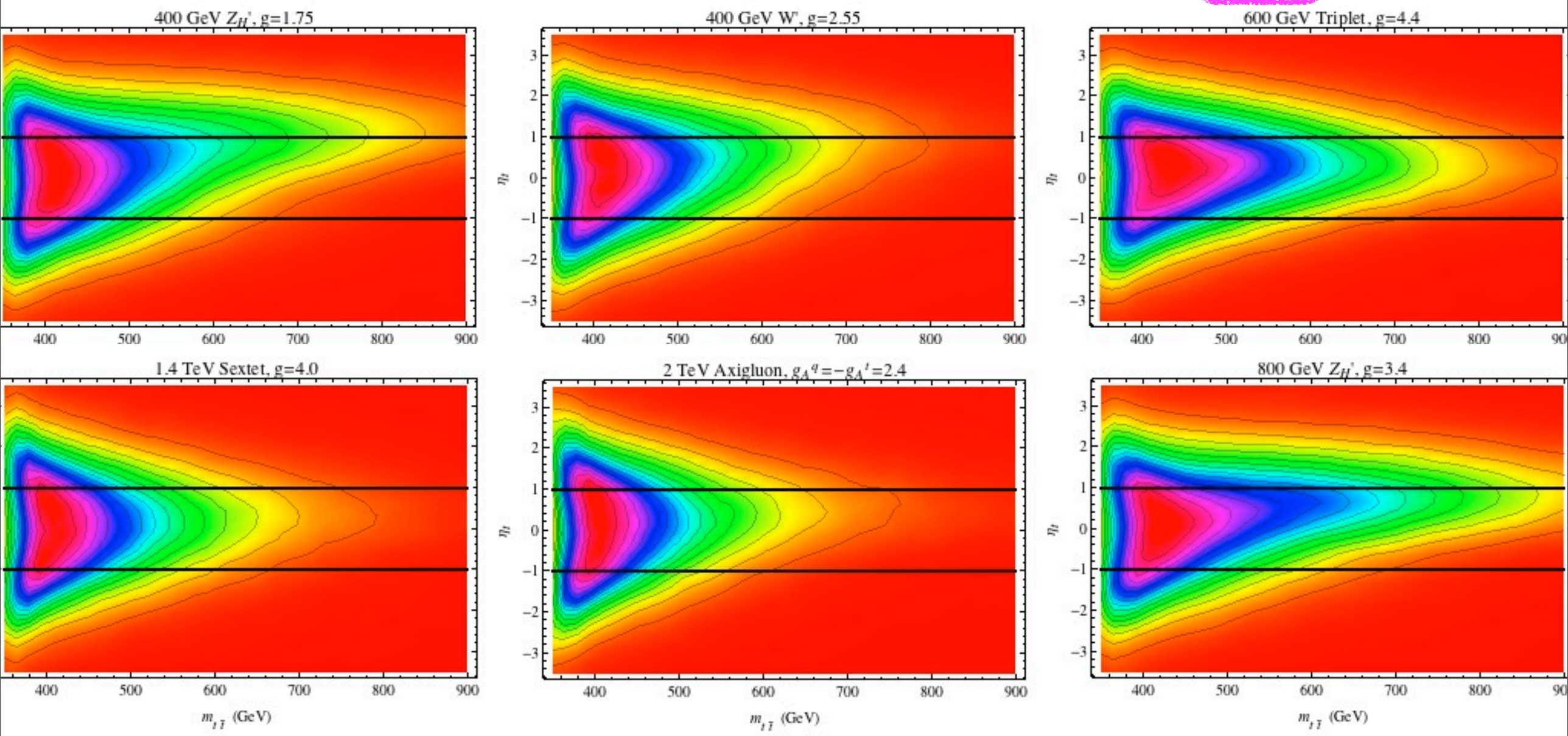
Model Dependence?

Event distribution densities:

CDF cuts include:

- $|\eta_{\rm lep}| < 1$
- $|\eta_{\rm jet}| < 2$
- $|\eta_{\rm b\text{-}jet}| < 1$





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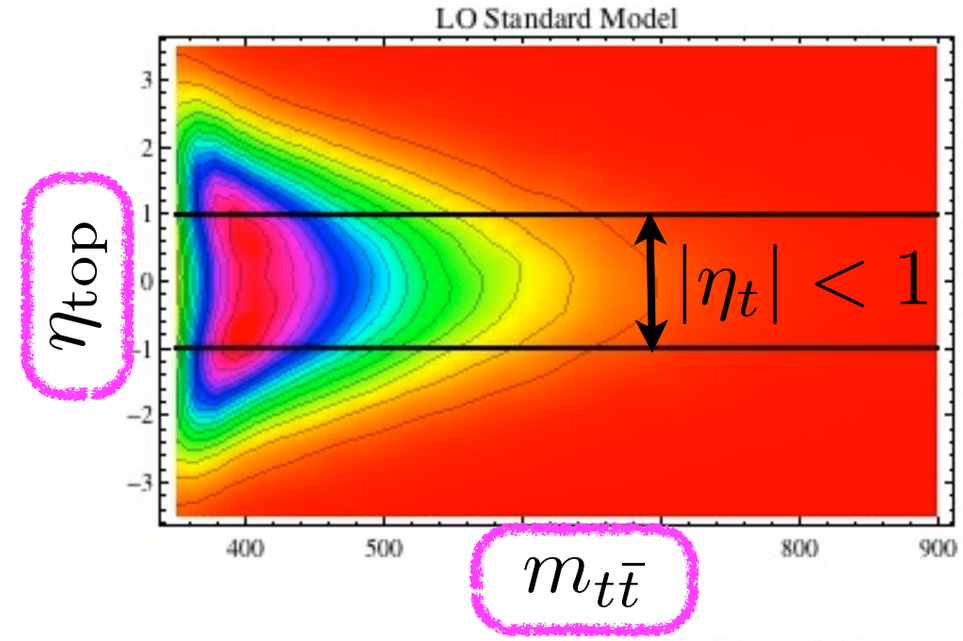
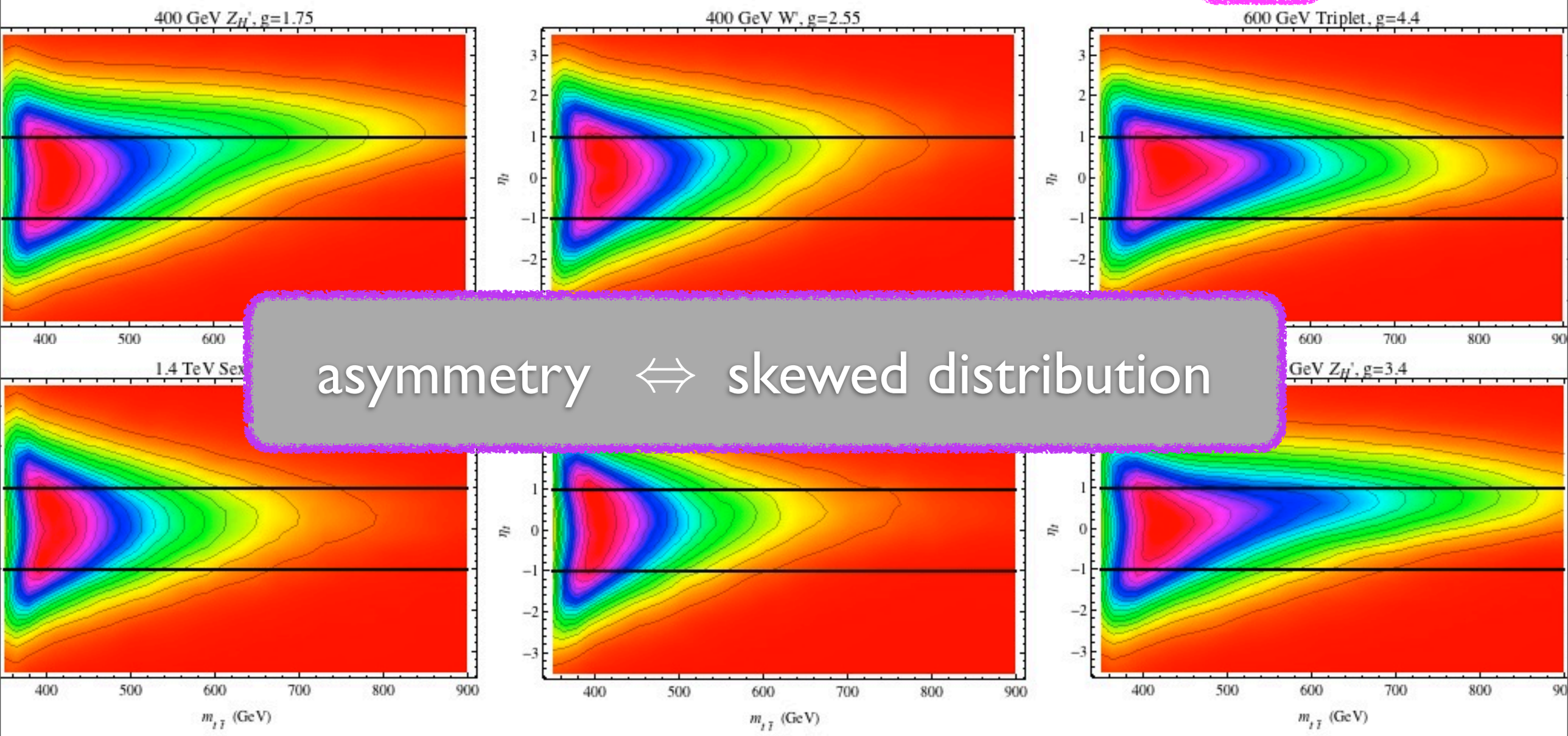
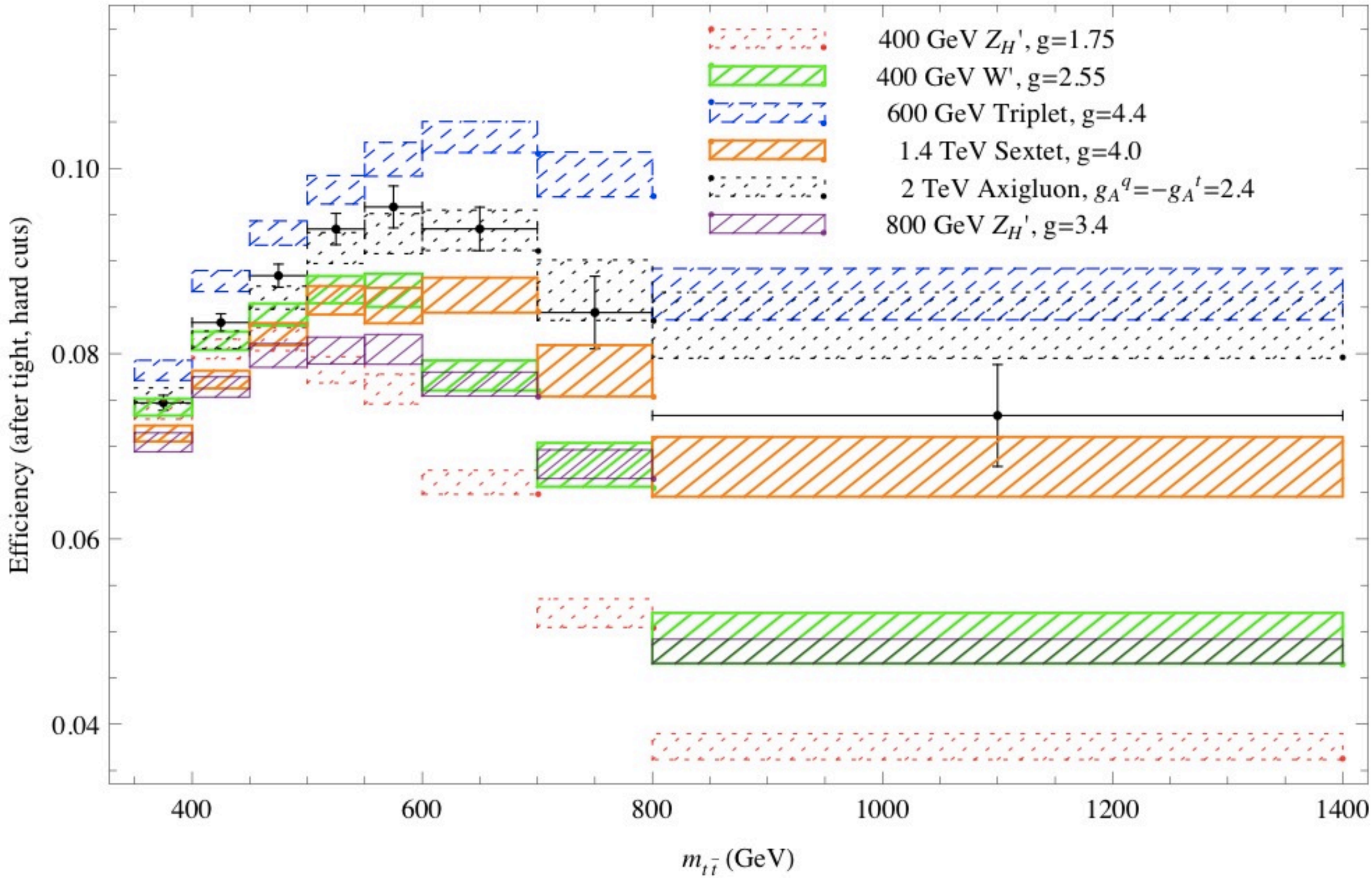




asymmetry $\Leftrightarrow$ skewed distribution

Model Dependent Efficiency Issue Due to Event Selection Cut



To address this issue

We need to directly compare theory results with experiments at the detector level.

We carried out pseudo-experiments as simlarly as possible to the real experiments.

We compare NP results with SM results so that one may compare exp results by checking how well SM background in the experiment is matched with our SM result.

Top Reconstruction

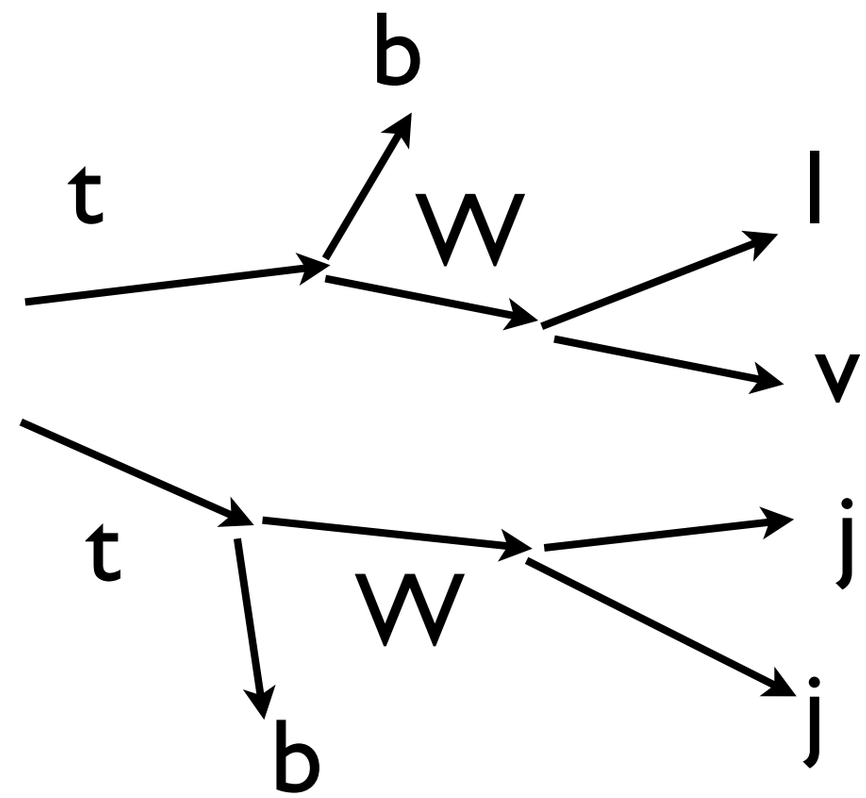
$$y_1 = p_\nu^2 = 0$$

$$y_2 = (p_l + p_\nu)^2 - m_W^2 = 0$$

$$y_3 = (p_{j1} + p_{j2})^2 - m_W^2 = 0$$

$$y_4 = (p_{b1} + p_l + p_\nu)^2 - m_t^2 = 0$$

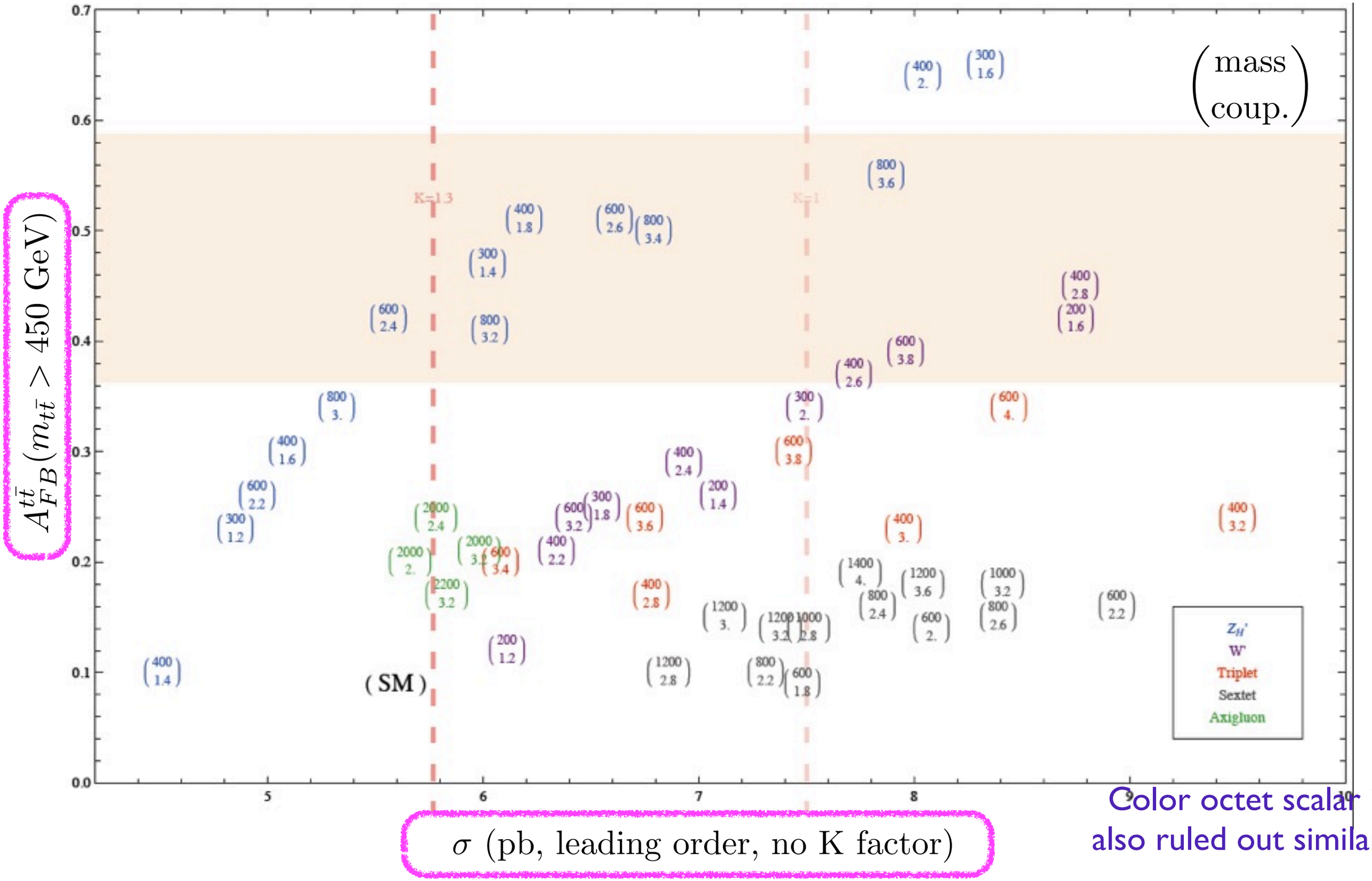
$$y_5 = (p_{b2} + p_{j1} + p_{j2})^2 - m_t^2 = 0$$



Minimize $\chi^2 = y^T \cdot V^{-1} \cdot y$

Preliminary Parton Level Scanning

Gresham, IWK, Zurek (1103.3501)



Color octet scalar is also ruled out similarly.

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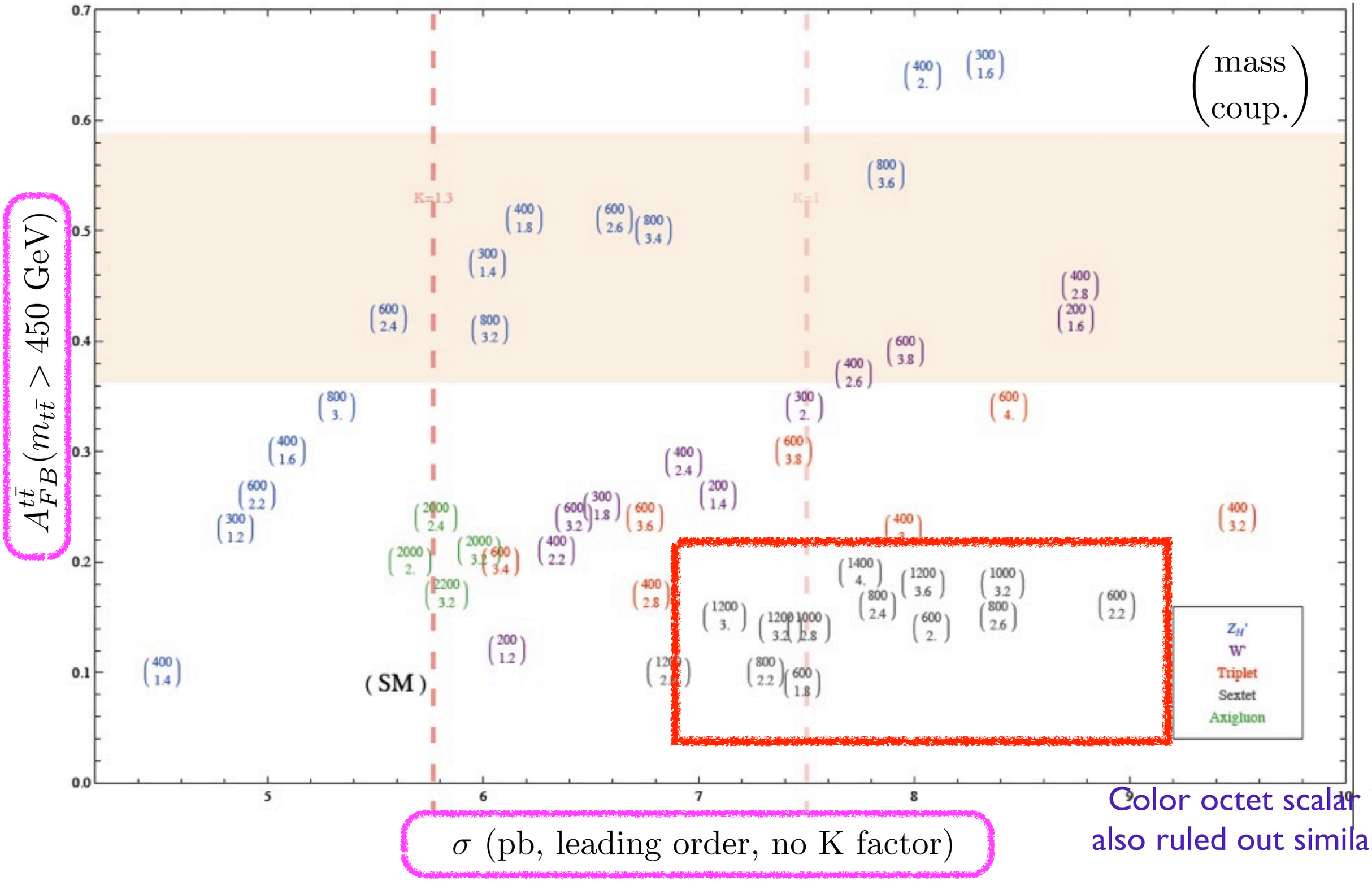

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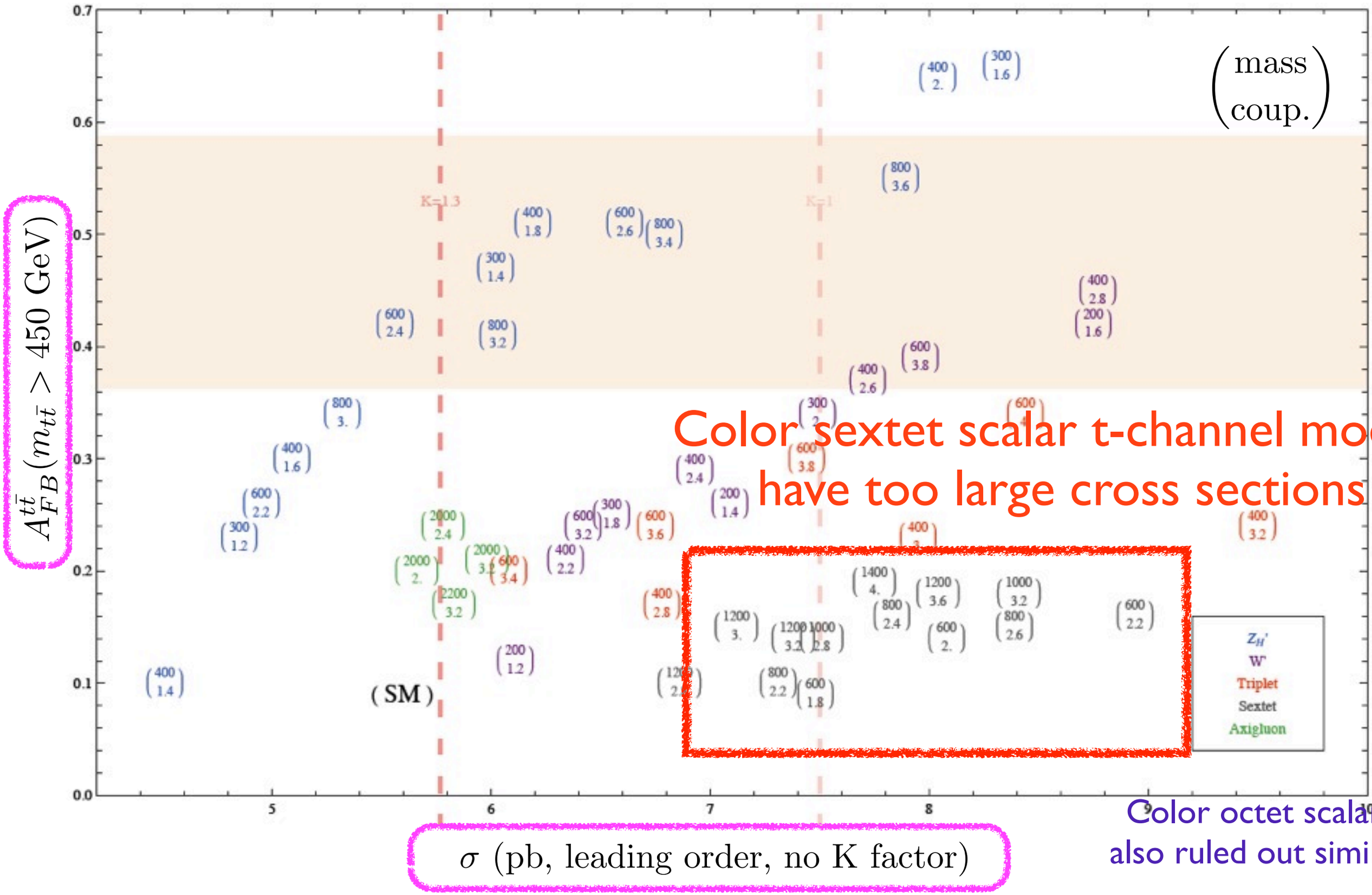


Color sextet scalar t-channel models have too large cross sections

Color octet scalar is also ruled out similarly.

Summary of models we scanned:

Model	Spin	Color	$SU(2)_Y$	Flavor	s-, t-, u-?	Comments and References
C1S	0	1	$2_{1/2}$	1	t	Only very moderate asymmetries achievable $\mathcal{O}(\gtrsim 10\%)$. Low mass ($m_M \simeq m_t$) states do slightly better.
C3S	0	3	$1_{4/3}$	1	u	a.k.a. triplet diquark. $q = 4/3$.
C1V	1	1	1_0	1	t	a.k.a. Z' or W'.
C8V	1	8	1_0	1	t	
F8C1V	1	1	1_0	8	t, s	Flavor breaking only through up Yukawa.
schanC8V(A,R)	1	8	1_0	1	s	a.k.a. axigluon or coloron. For $2m_t < m_M \lesssim 2$TeV, very broad width required to avoid $t\bar{t}$ resonance searches.
schanC8V Γ	1	8	1_0	1	s	$\sim$ 400 GeV broad resonance via additional scalars. Universal quark couplings.

Strategy

analysis protocol

CDF A_{FB} analysis

ATLAS top cross section analysis

Rough Scan

coarse graining parameter space

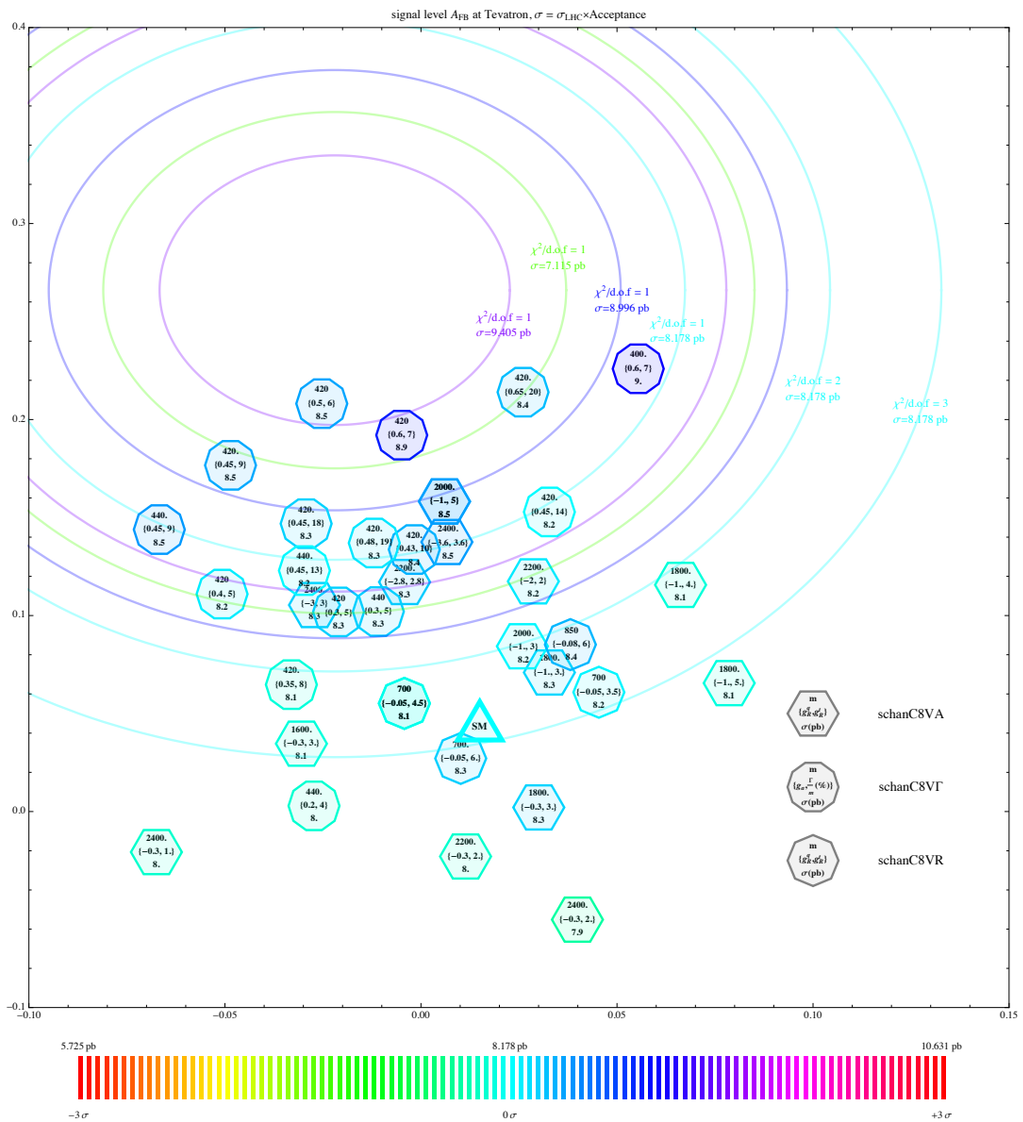
Fine Scan

fine graining / pick-up benchmark models

Benchmark models

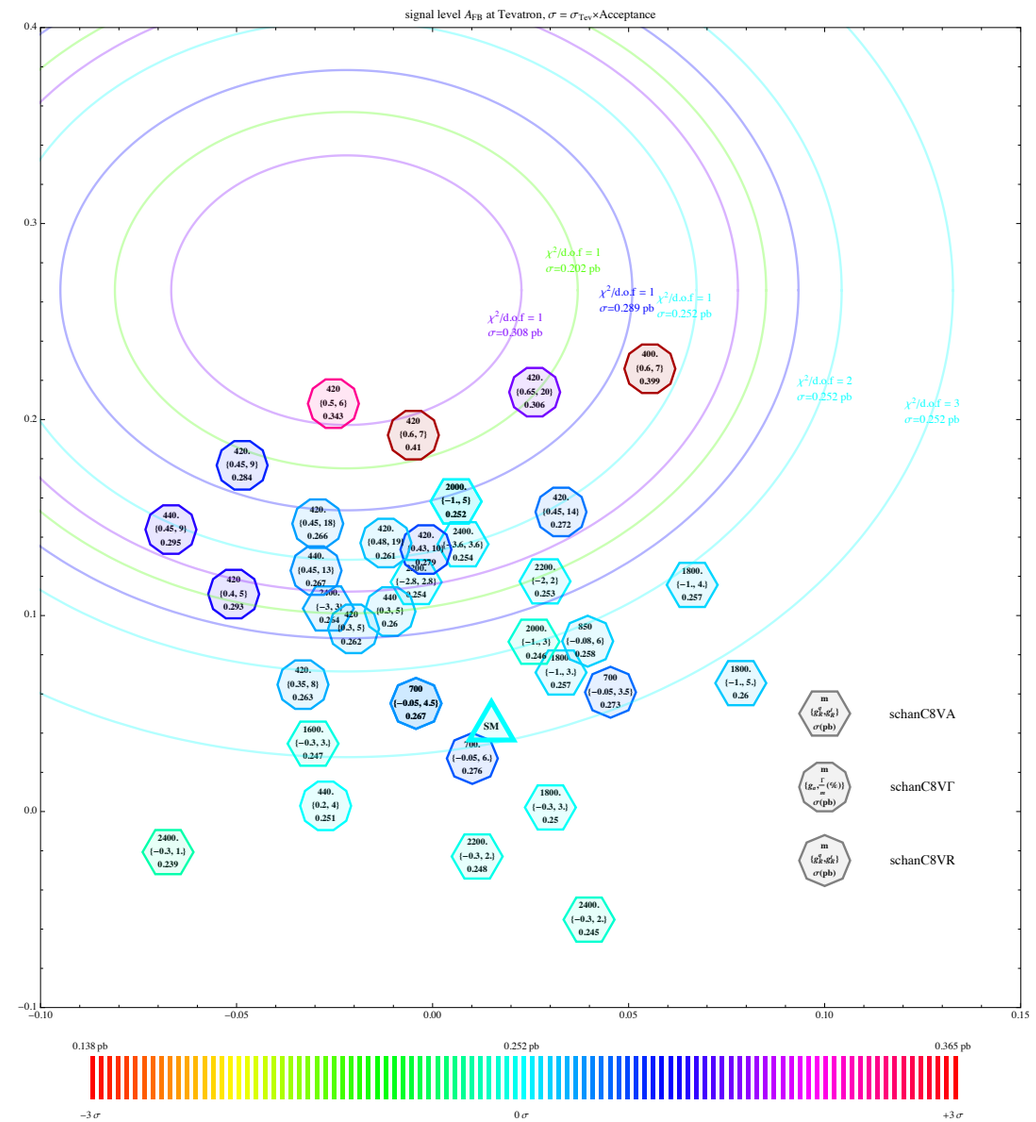
we see detailed event distributions for benchmark model point with a big event set.

S-channel Models



-30% +30%

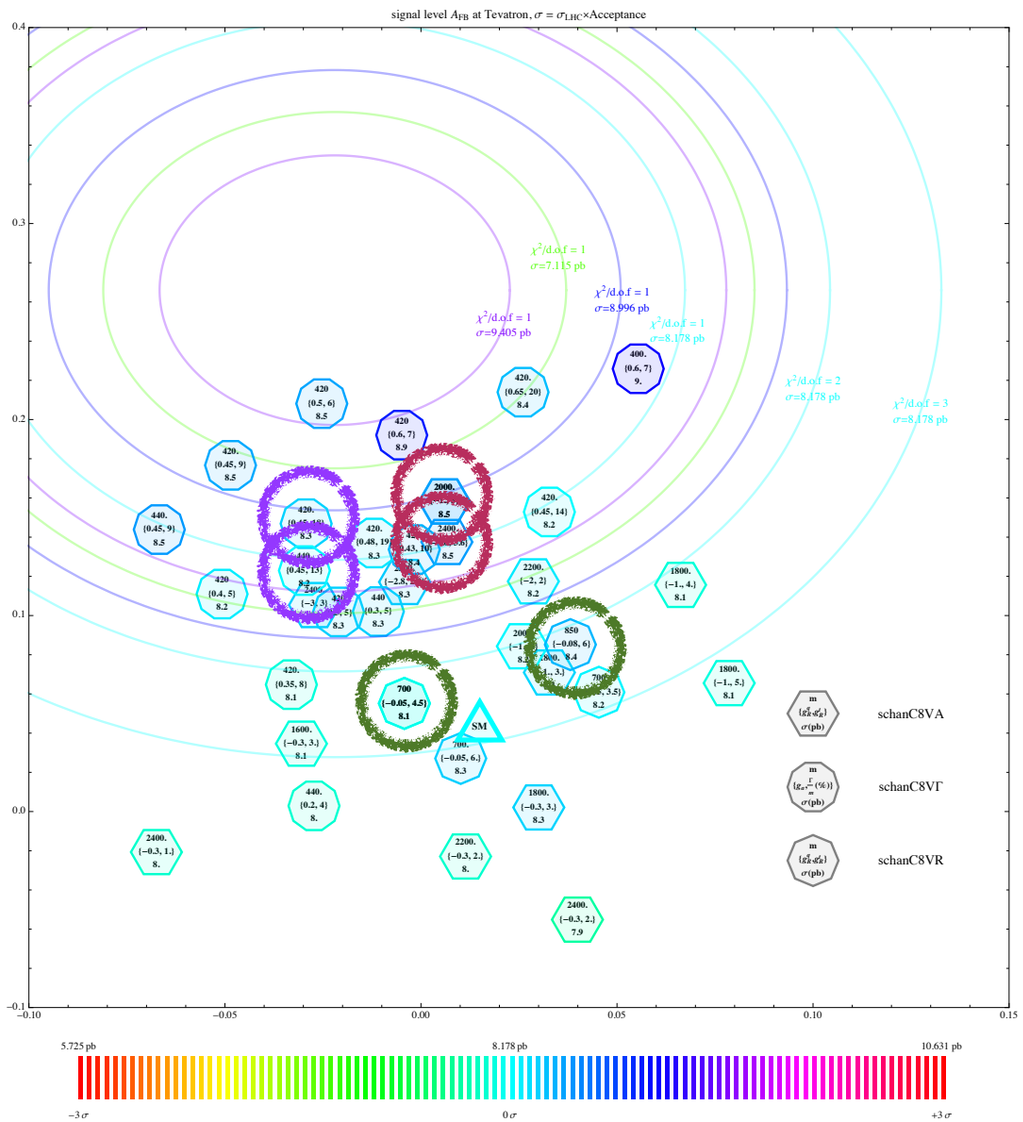
LHC cross section



-45% +45%

Tevatron cross section

S-channel Models



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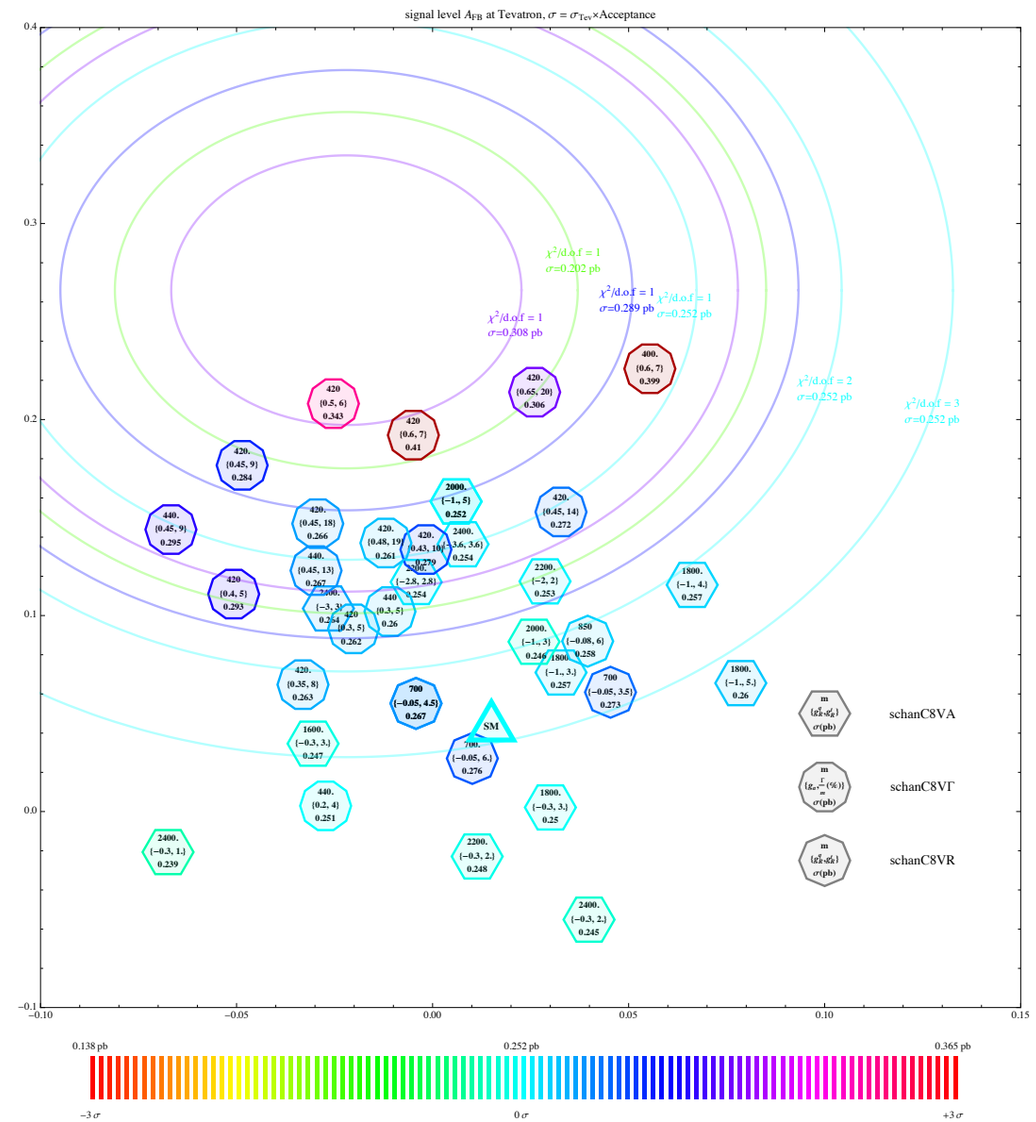
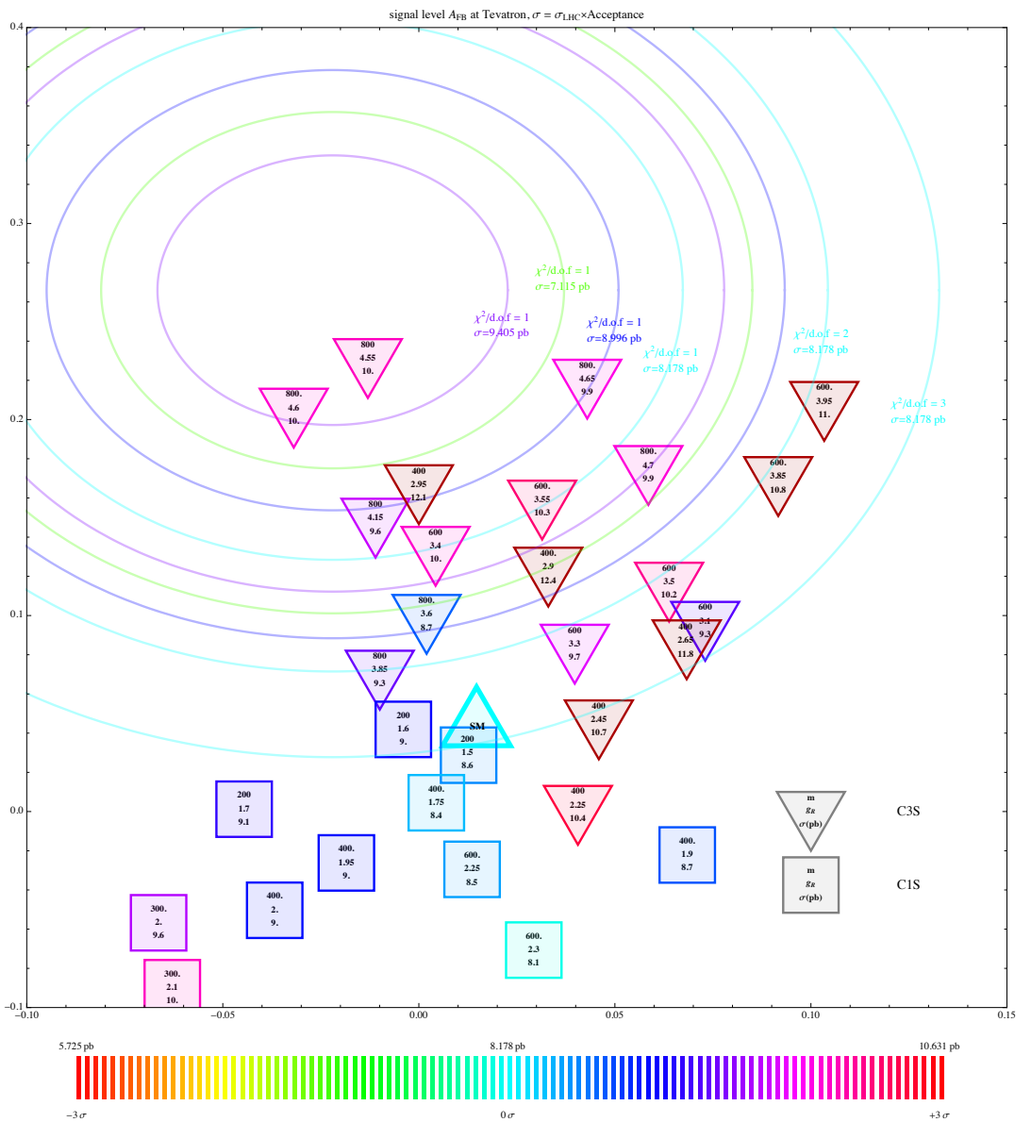


-45% +45%

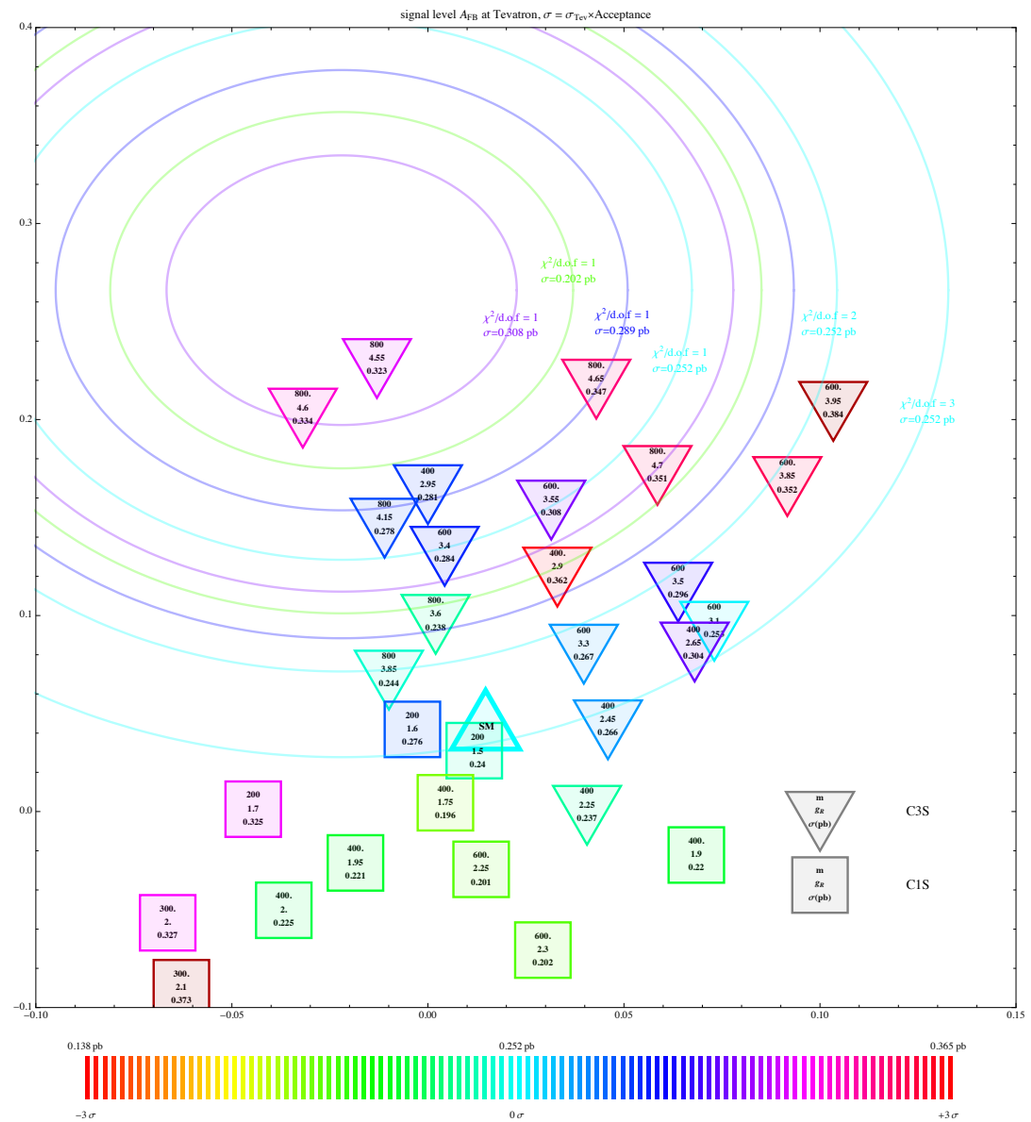
Tevatron cross section

T-channel scalar models



-30% +30%

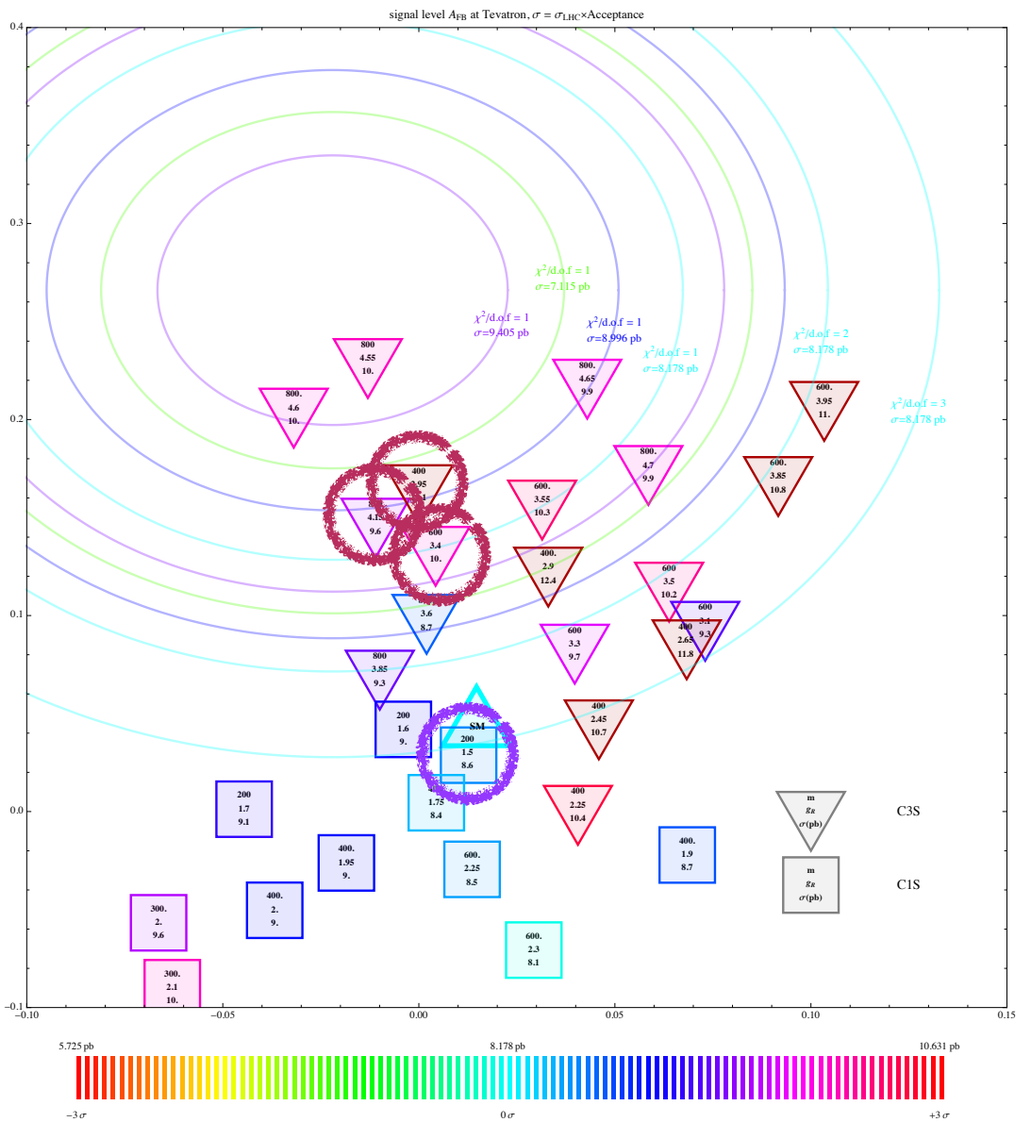
LHC cross section



-45% +45%

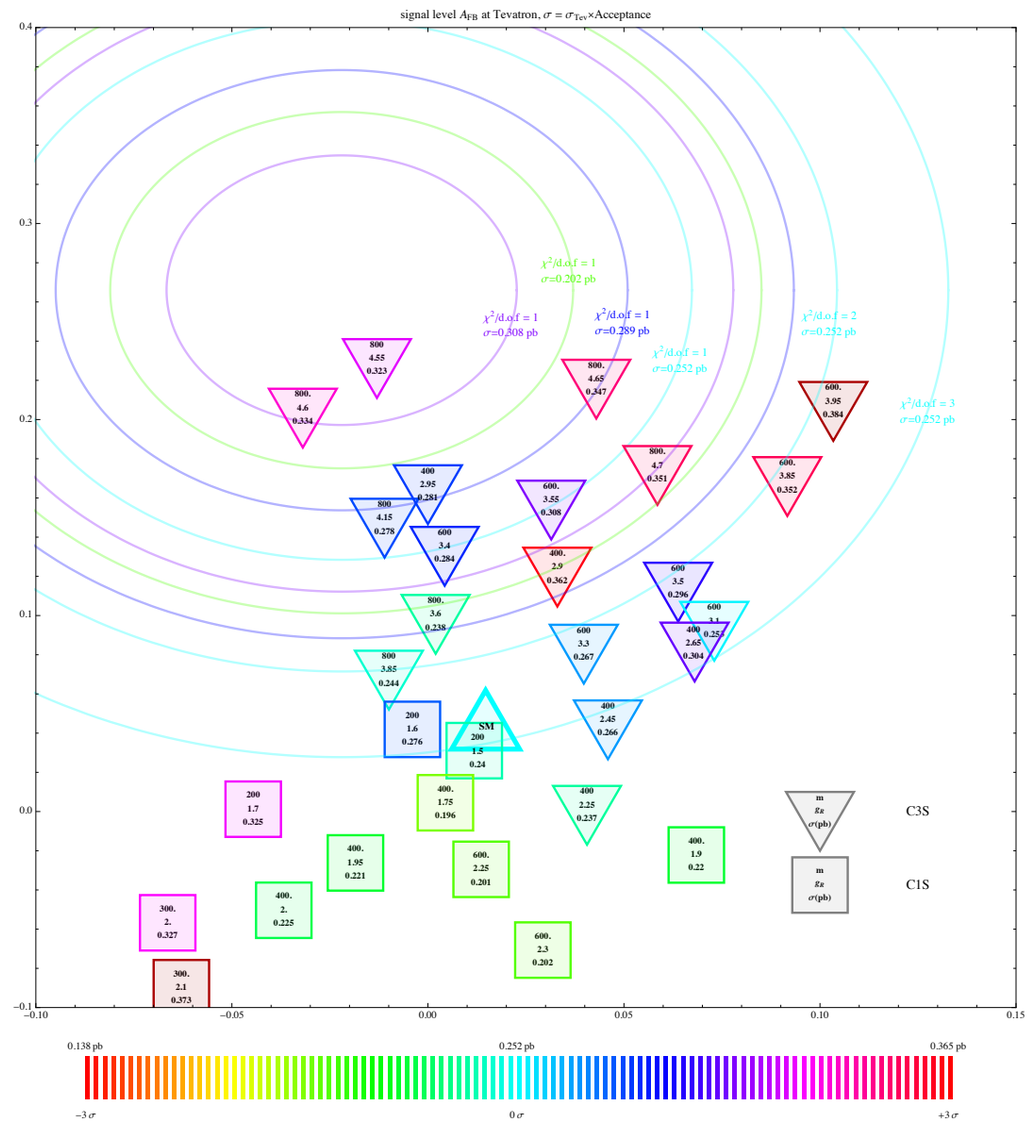
Tevatron cross section

T-channel scalar models



-30% +30%

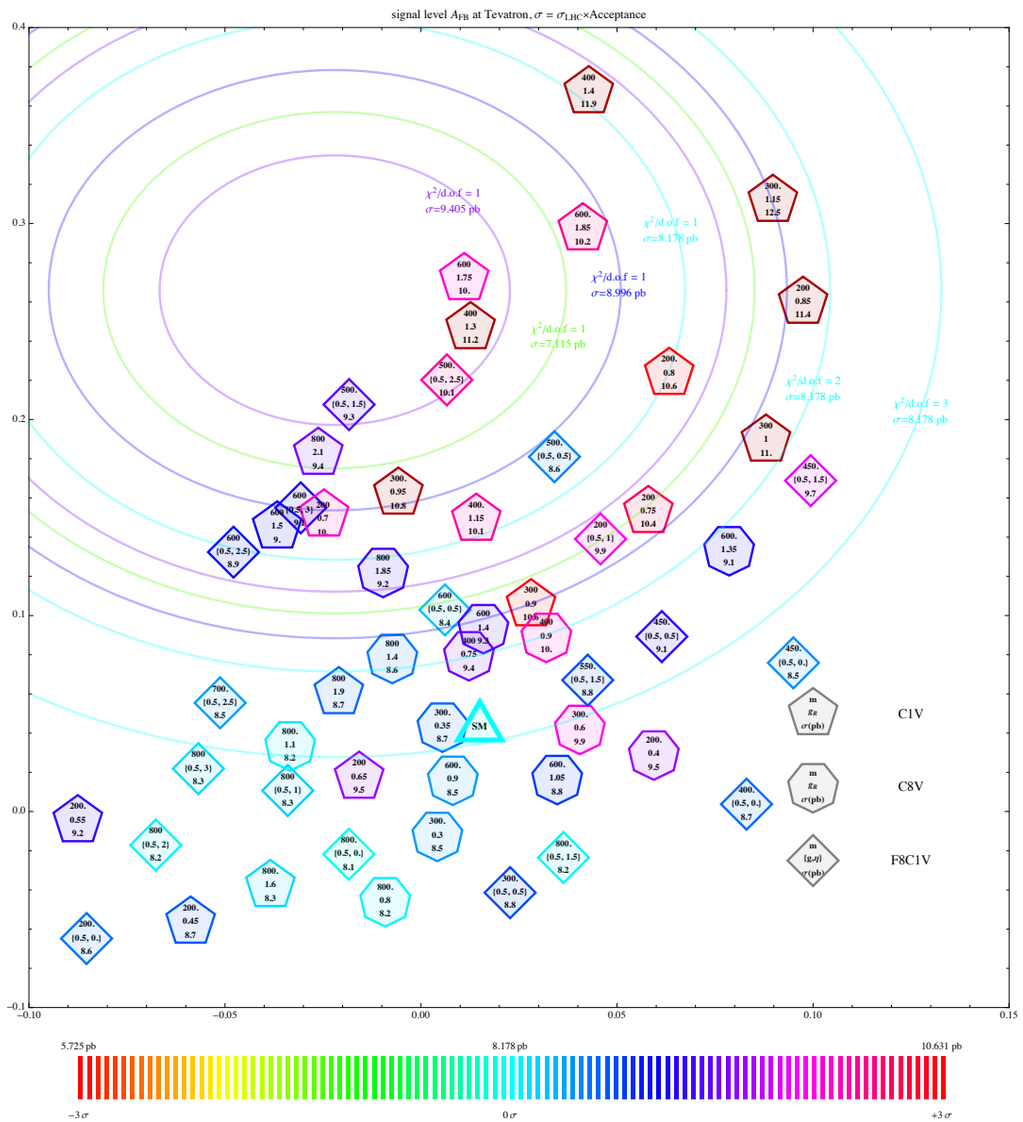
LHC cross section



-45% +45%

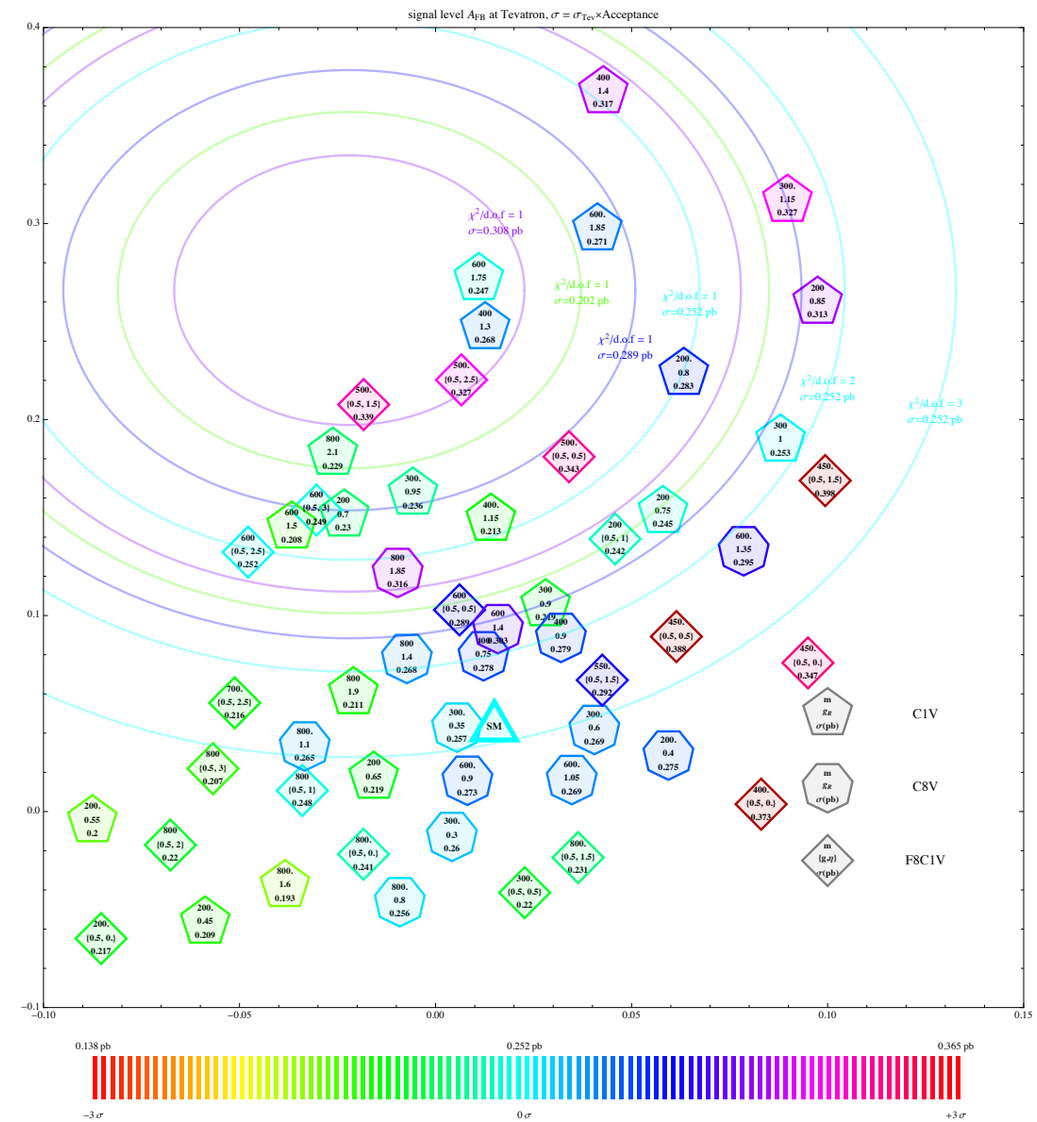
Tevatron cross section

T-channel vector models



-30% +30%

LHC cross section



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Tevatron cross section

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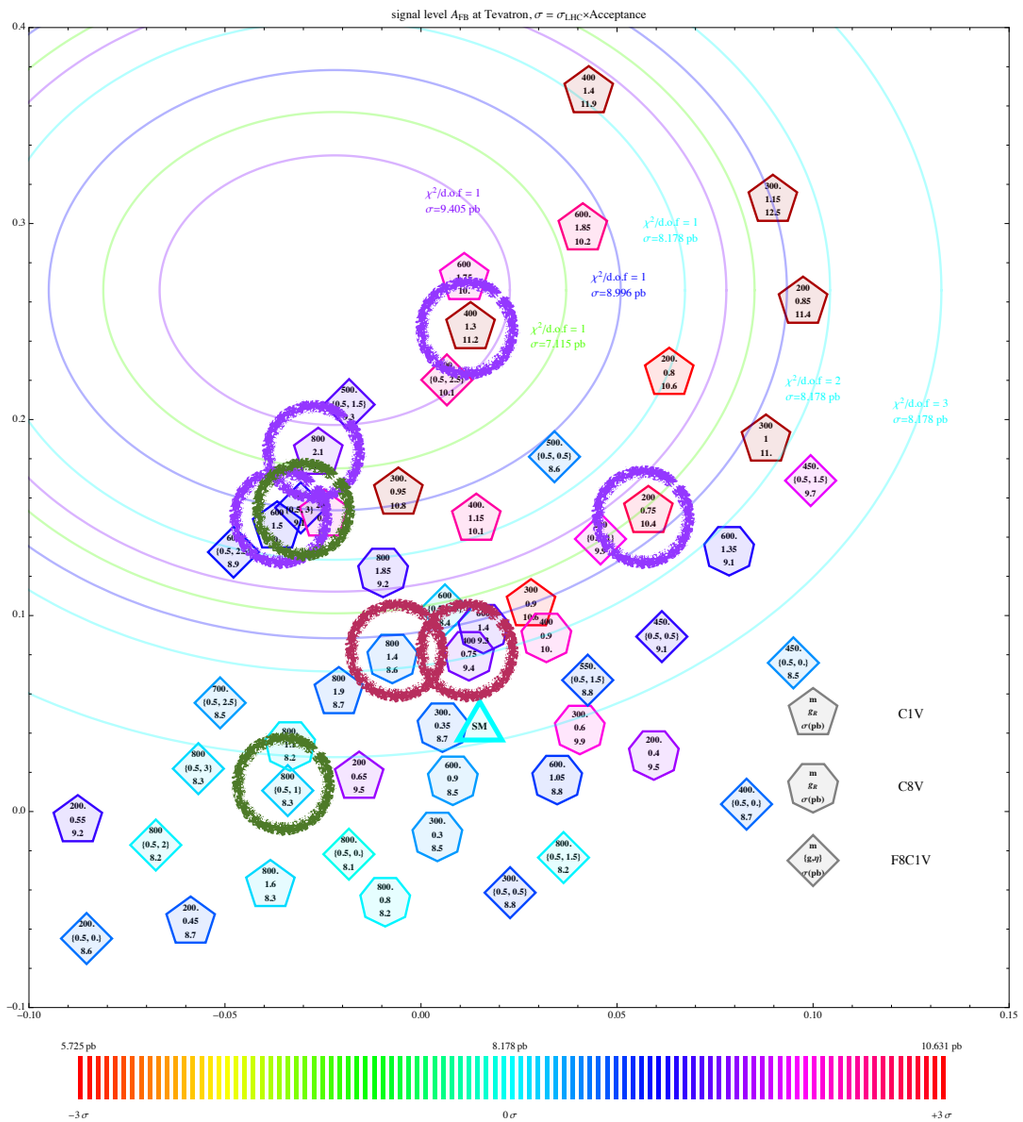
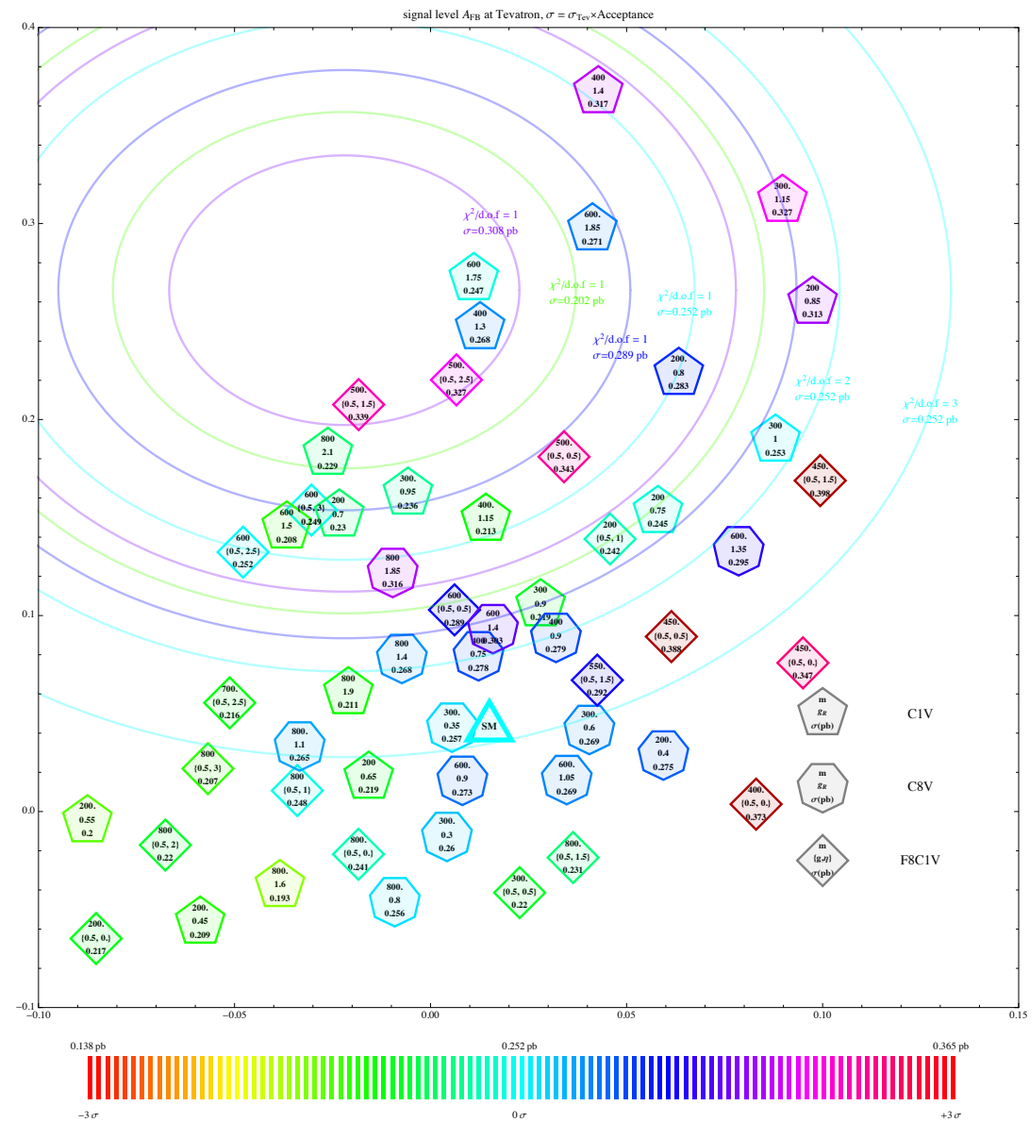


-30% +30%

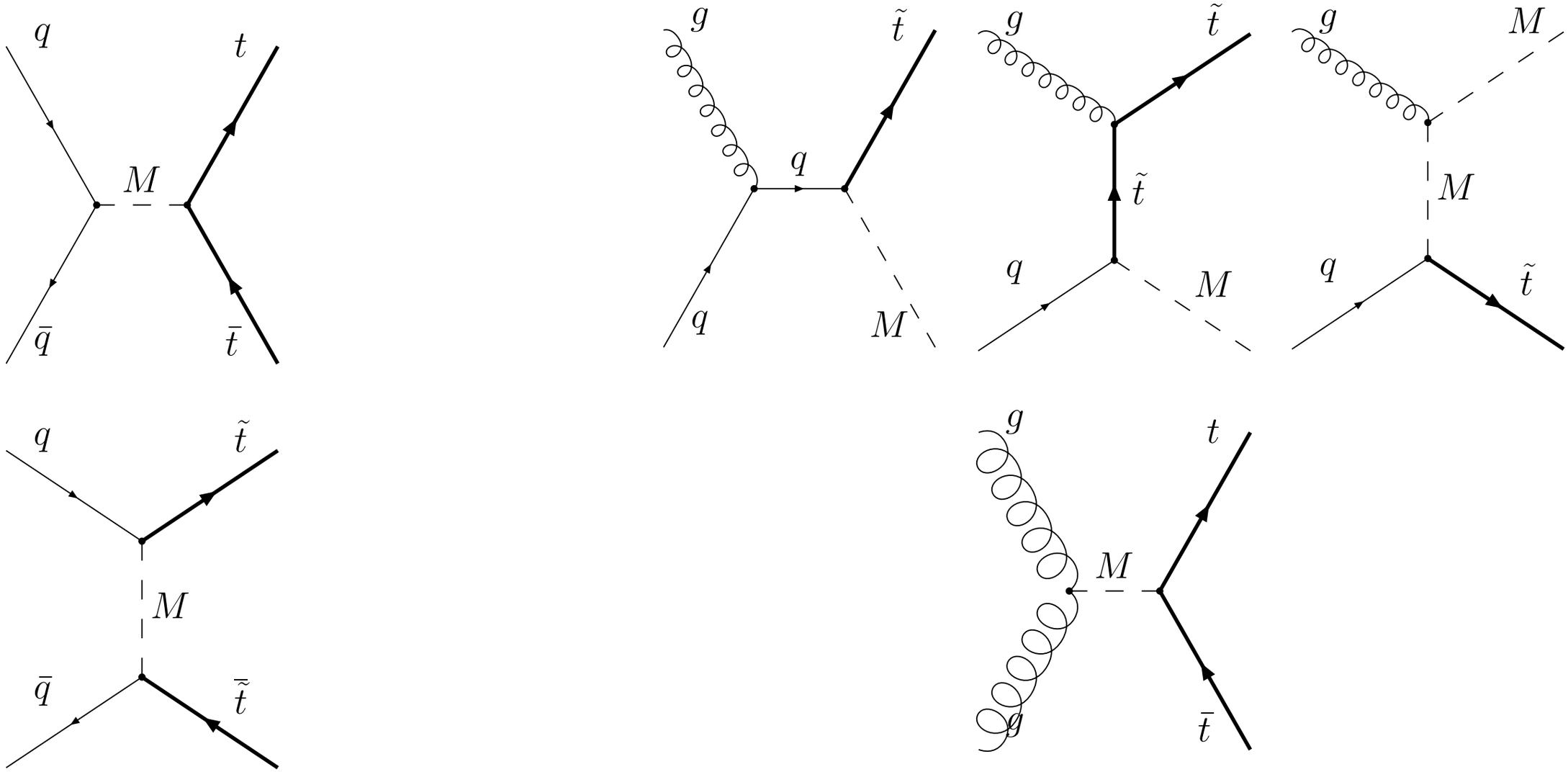
LHC cross section



-45% +45%

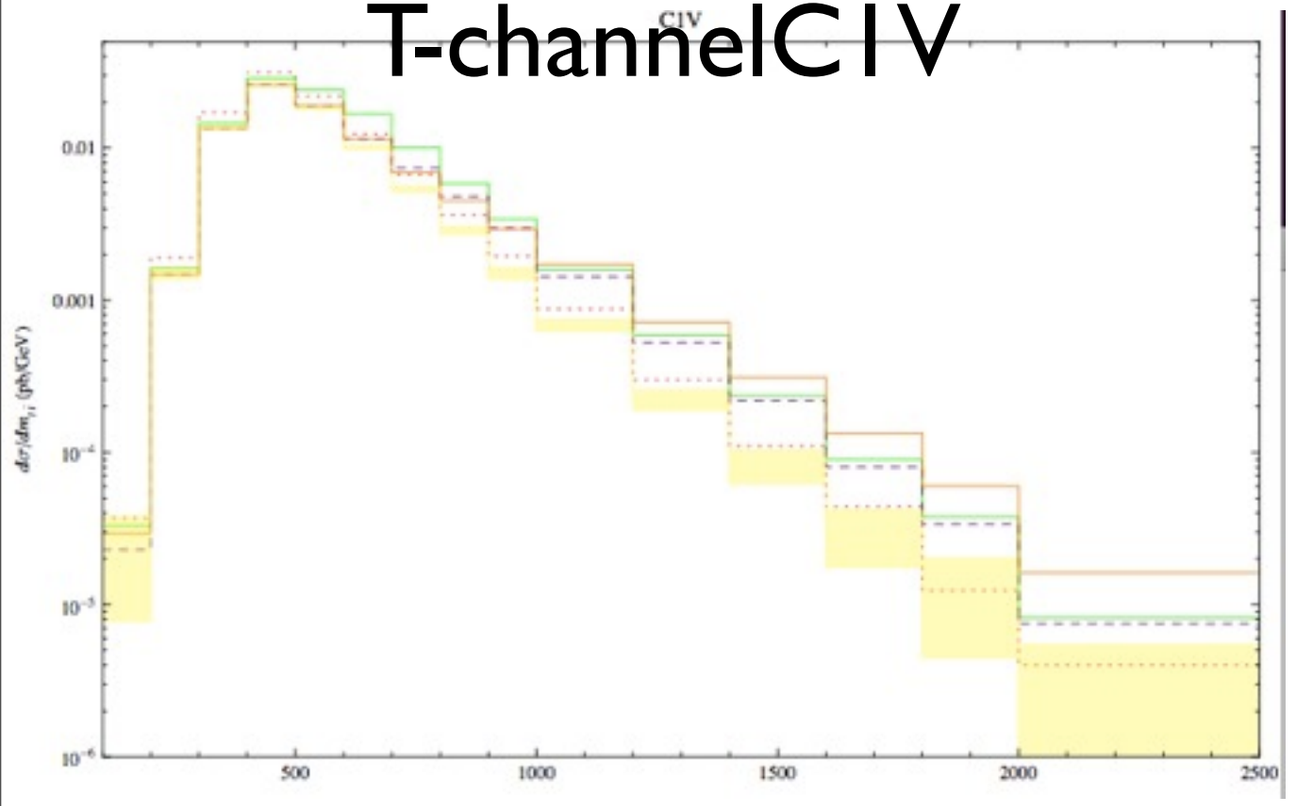
Tevatron cross section

Why LHC cross section tends to be larger in t-channel model?

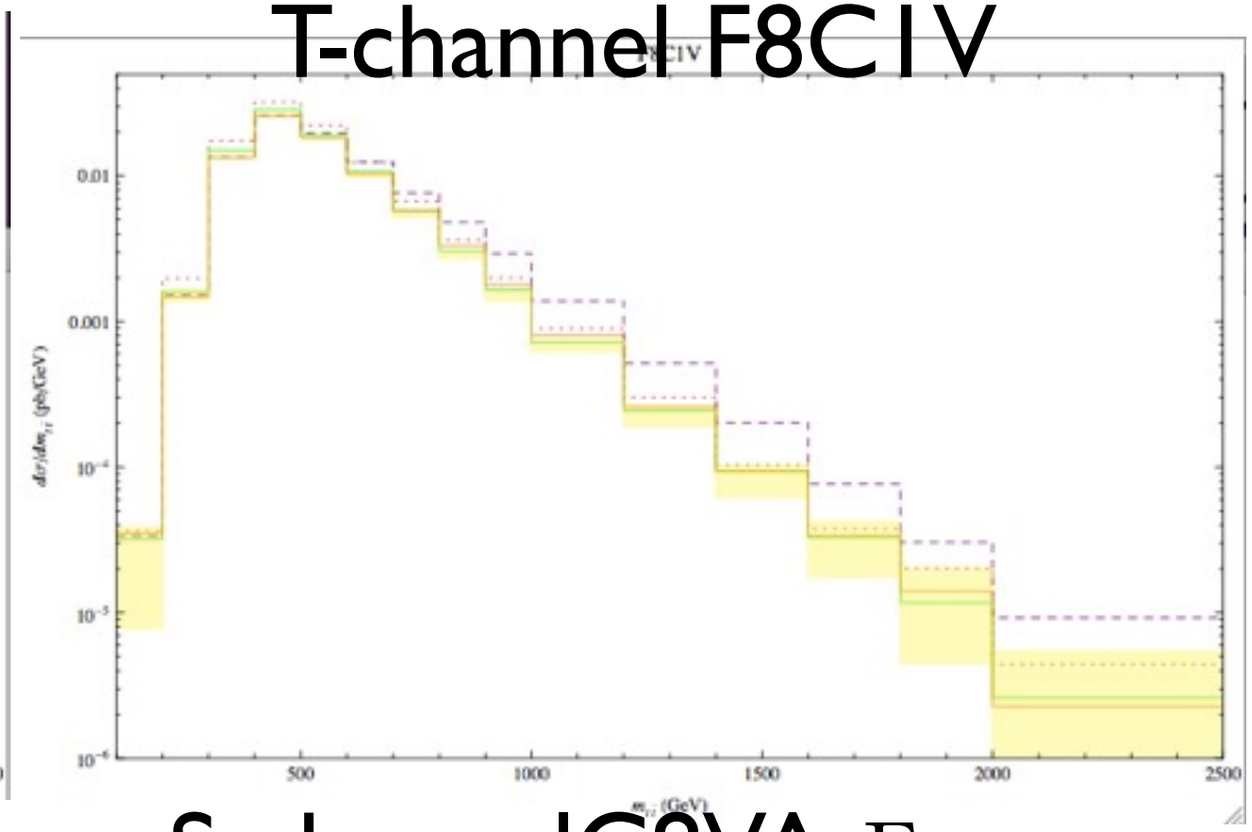


Mediator can be produced associated with top in gluon-quark fusion

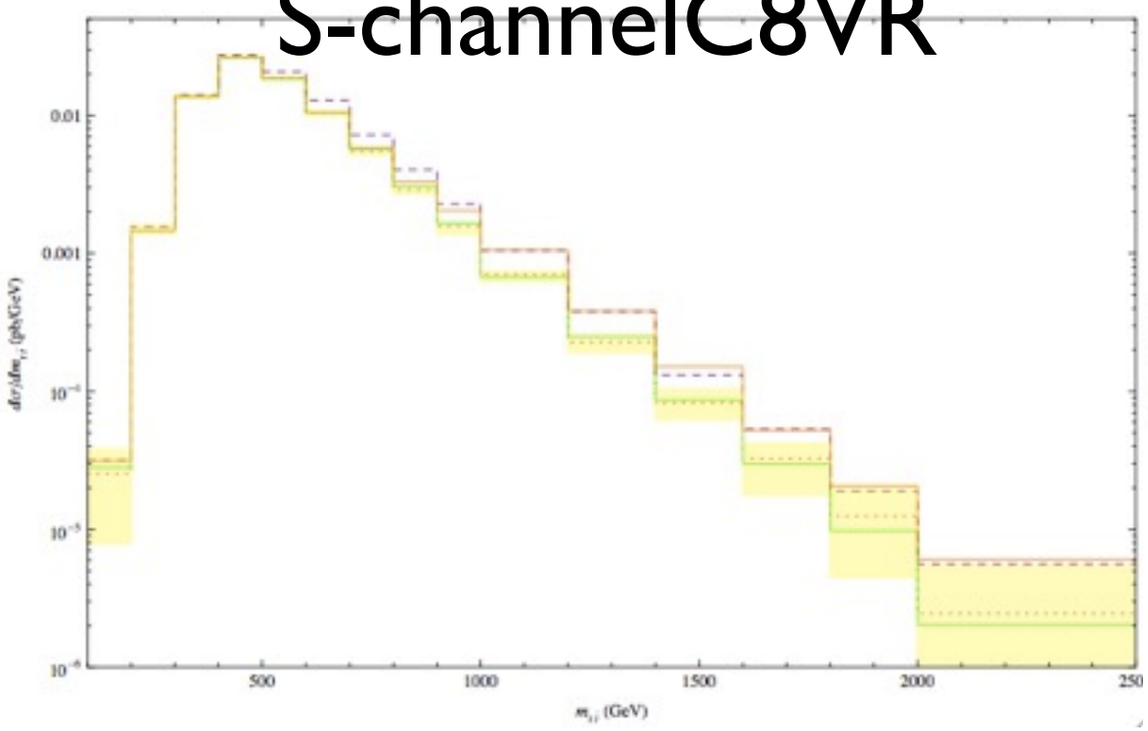
T-channelC1V



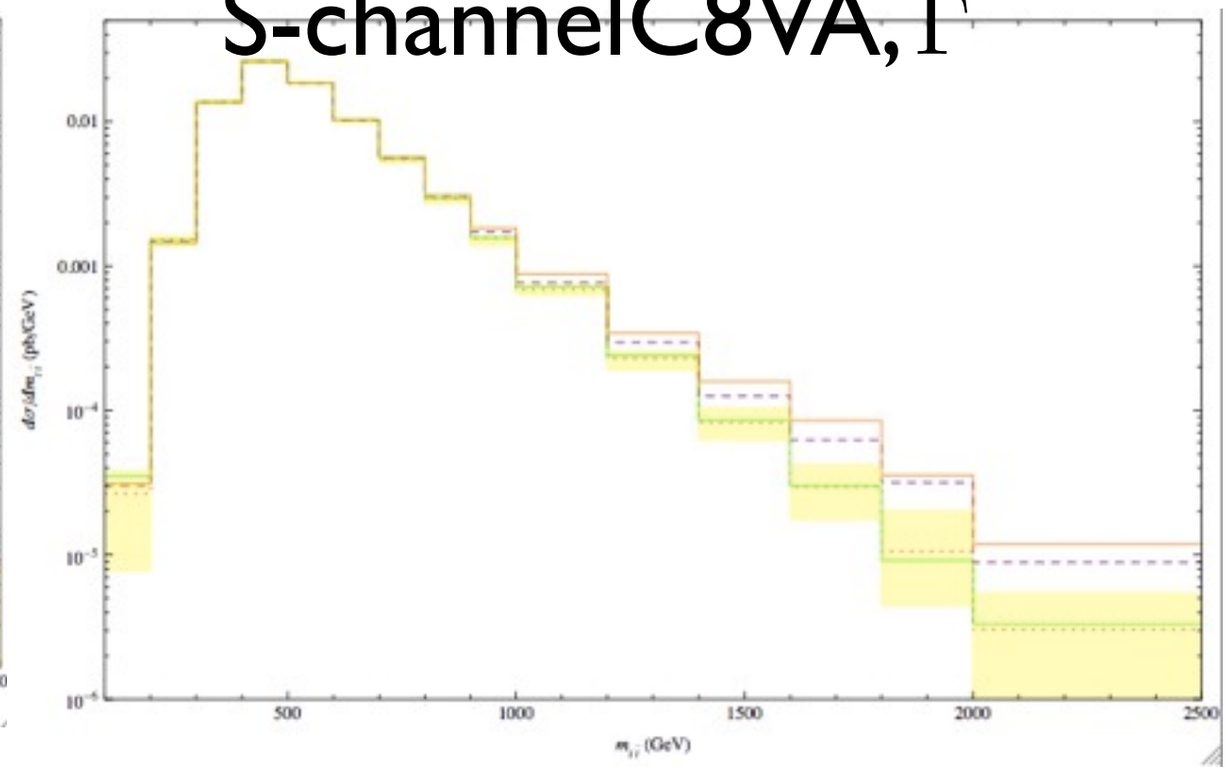
T-channel F8C1V



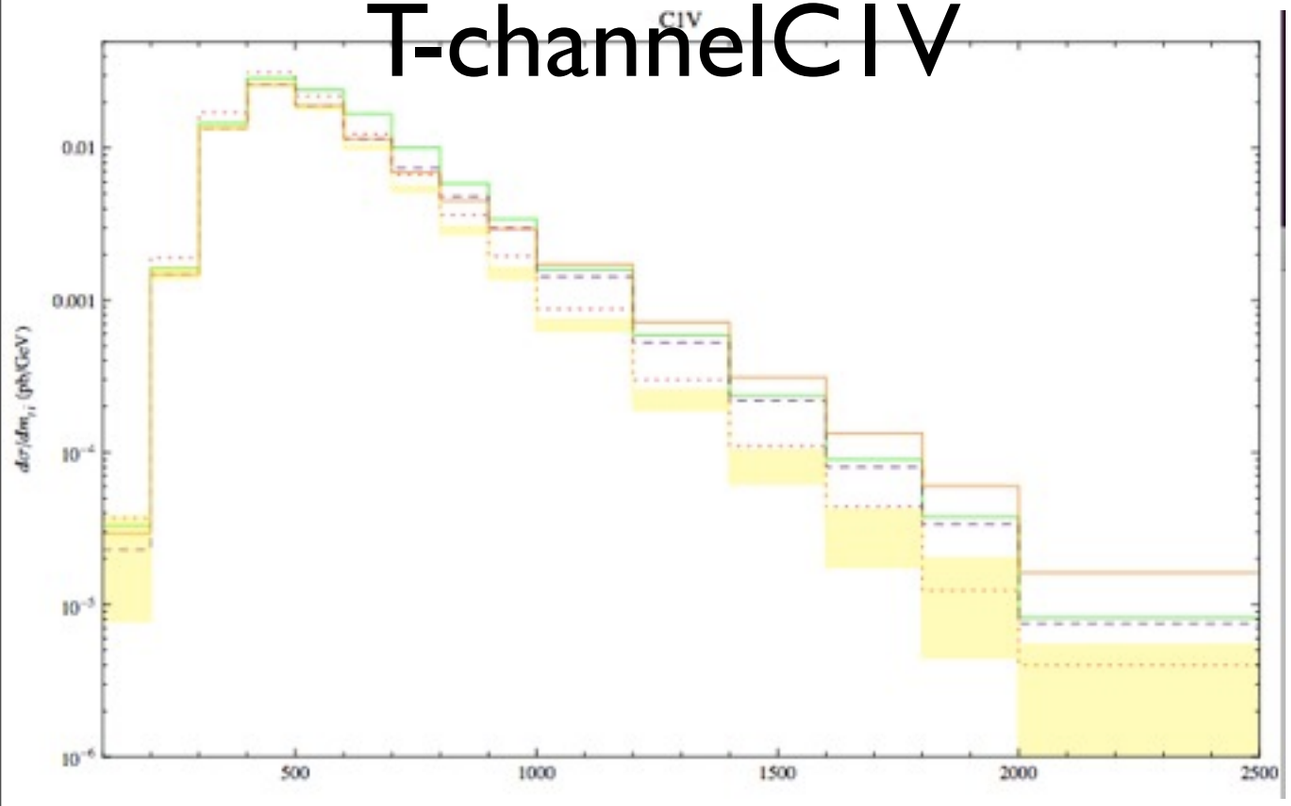
S-channelC8VR



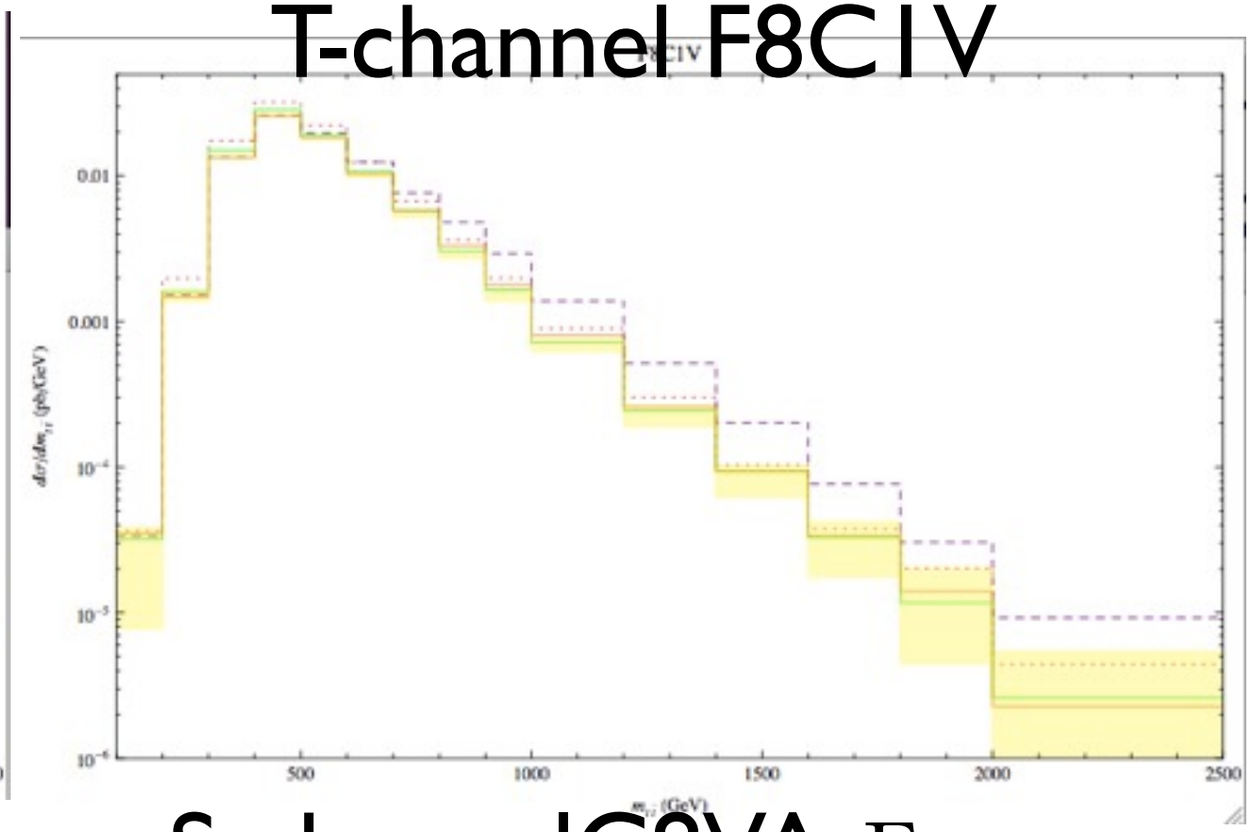
S-channelC8VA, Γ



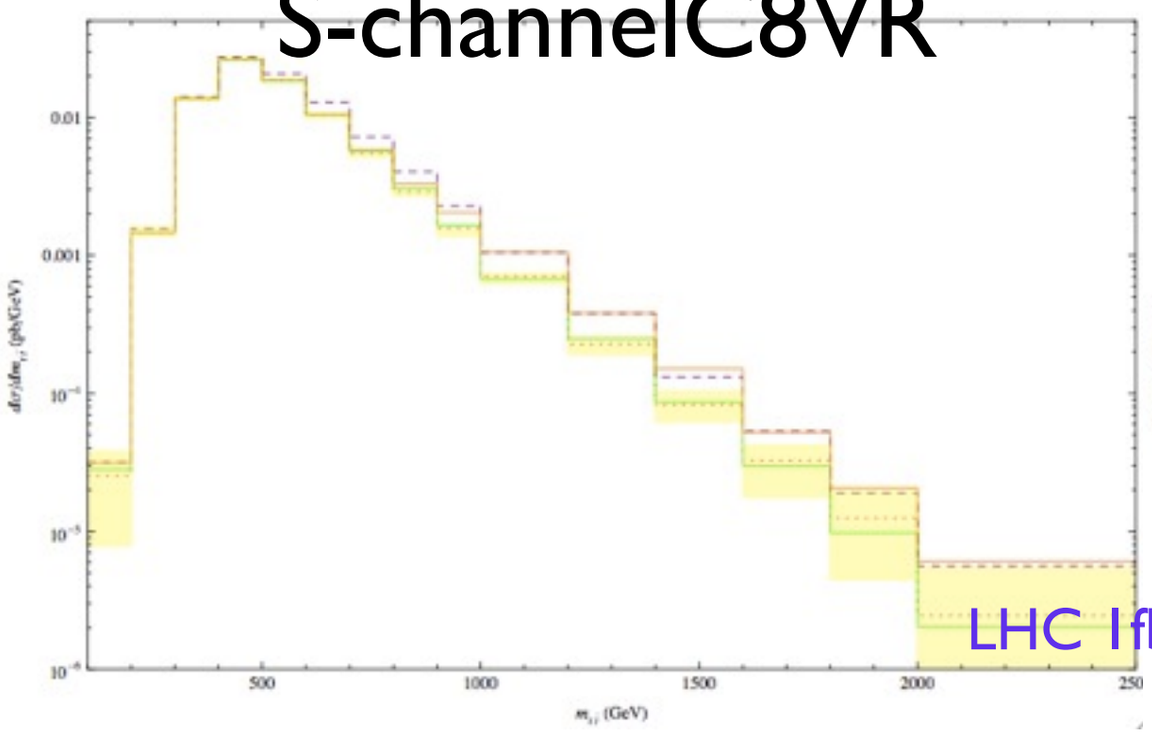
T-channelC1V



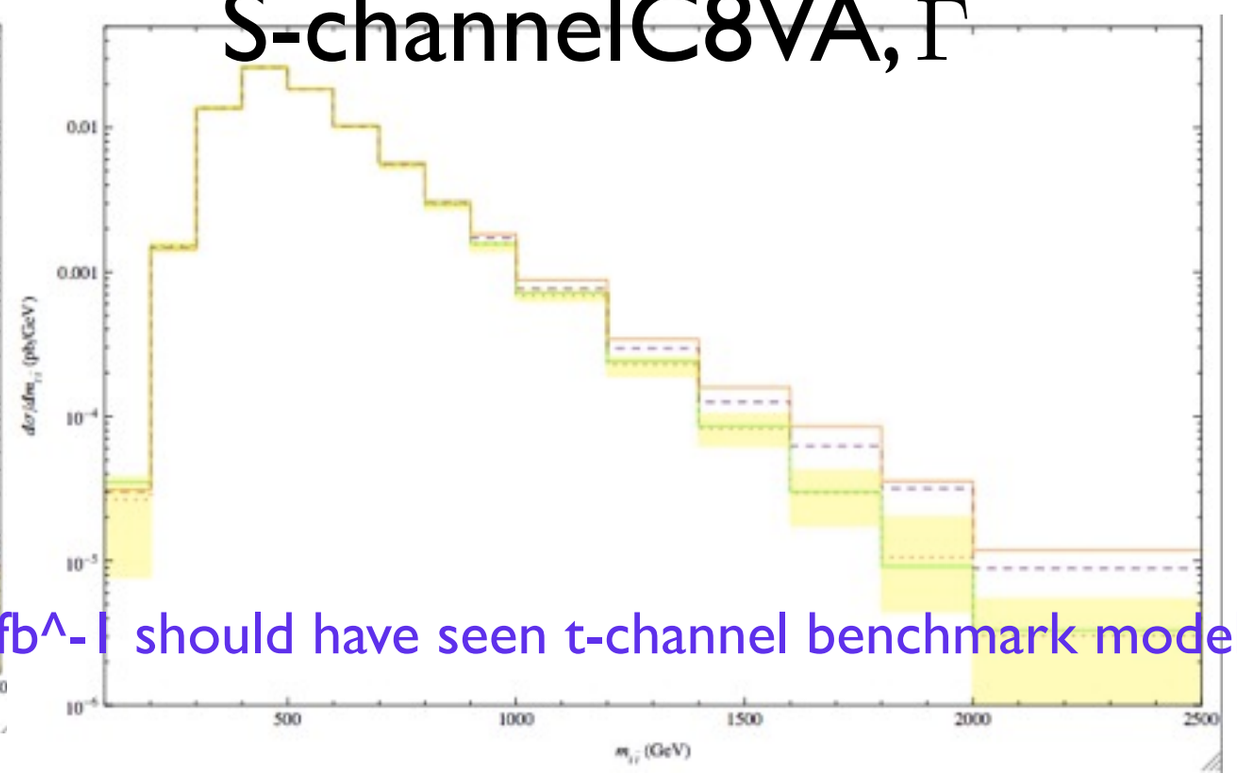
T-channel F8C1V



S-channelC8VR



S-channelC8VA, Γ

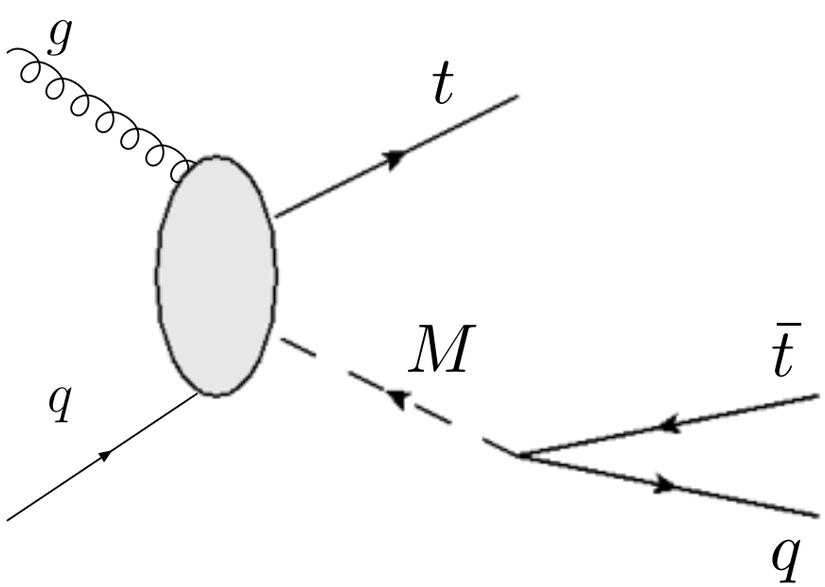


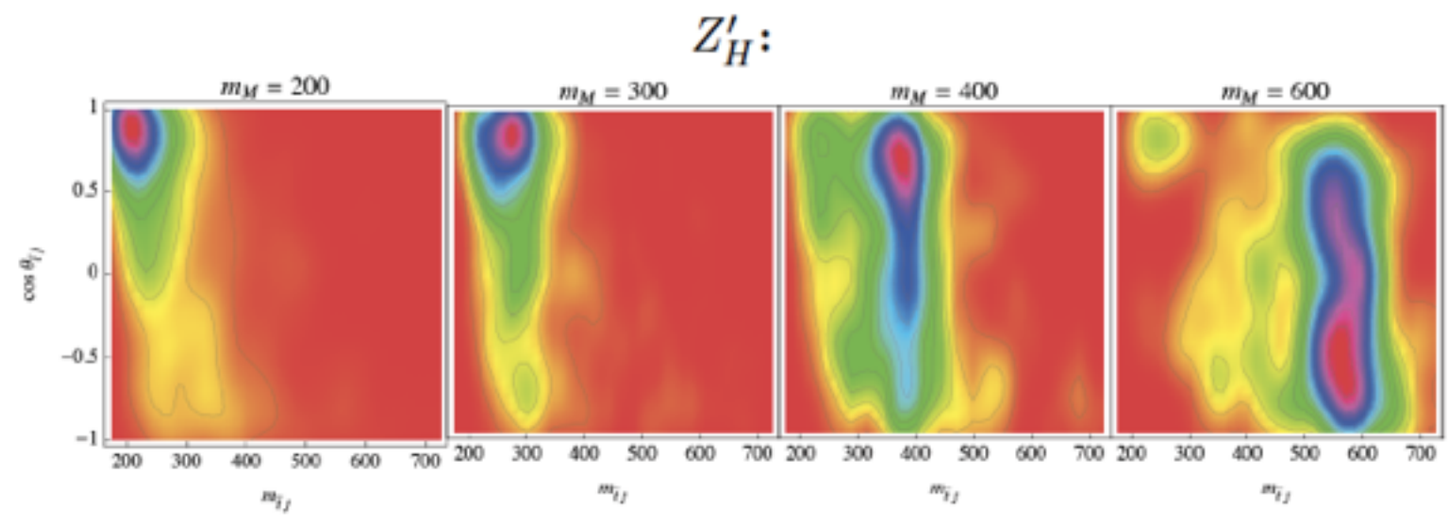
LHC 1fb^-1 should have seen t-channel benchmark models.

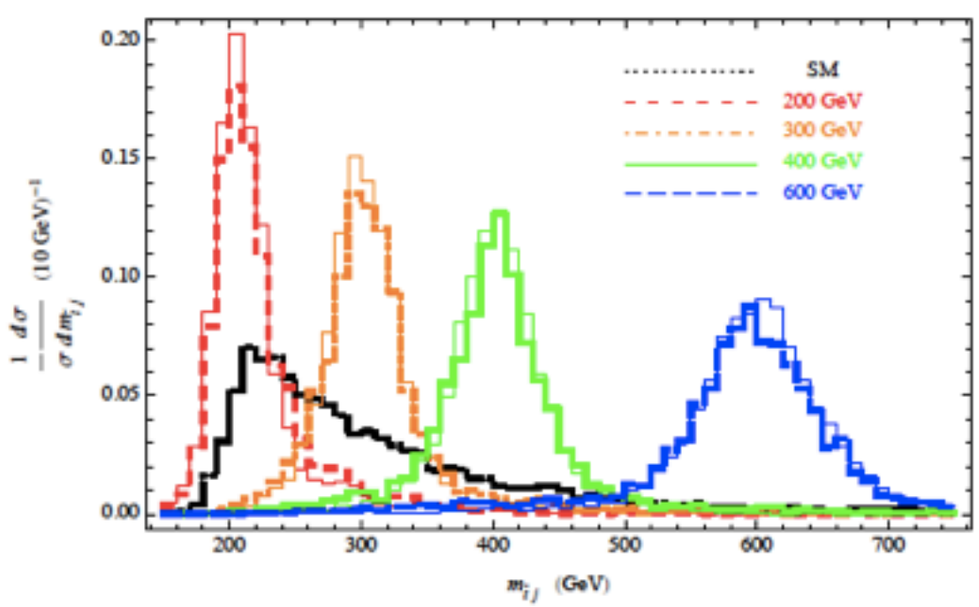
LHC discovery through top-jet resonance

Gresham, IWK, Zurek (arXiv:1102.0018)

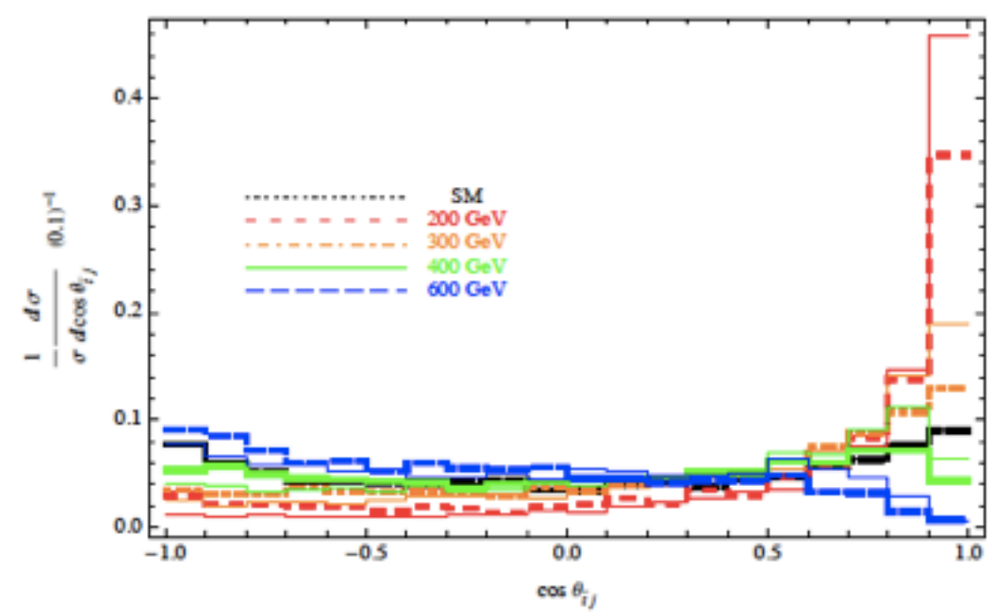
$\bar{t}j$ resonance in $t\bar{t}j$ events





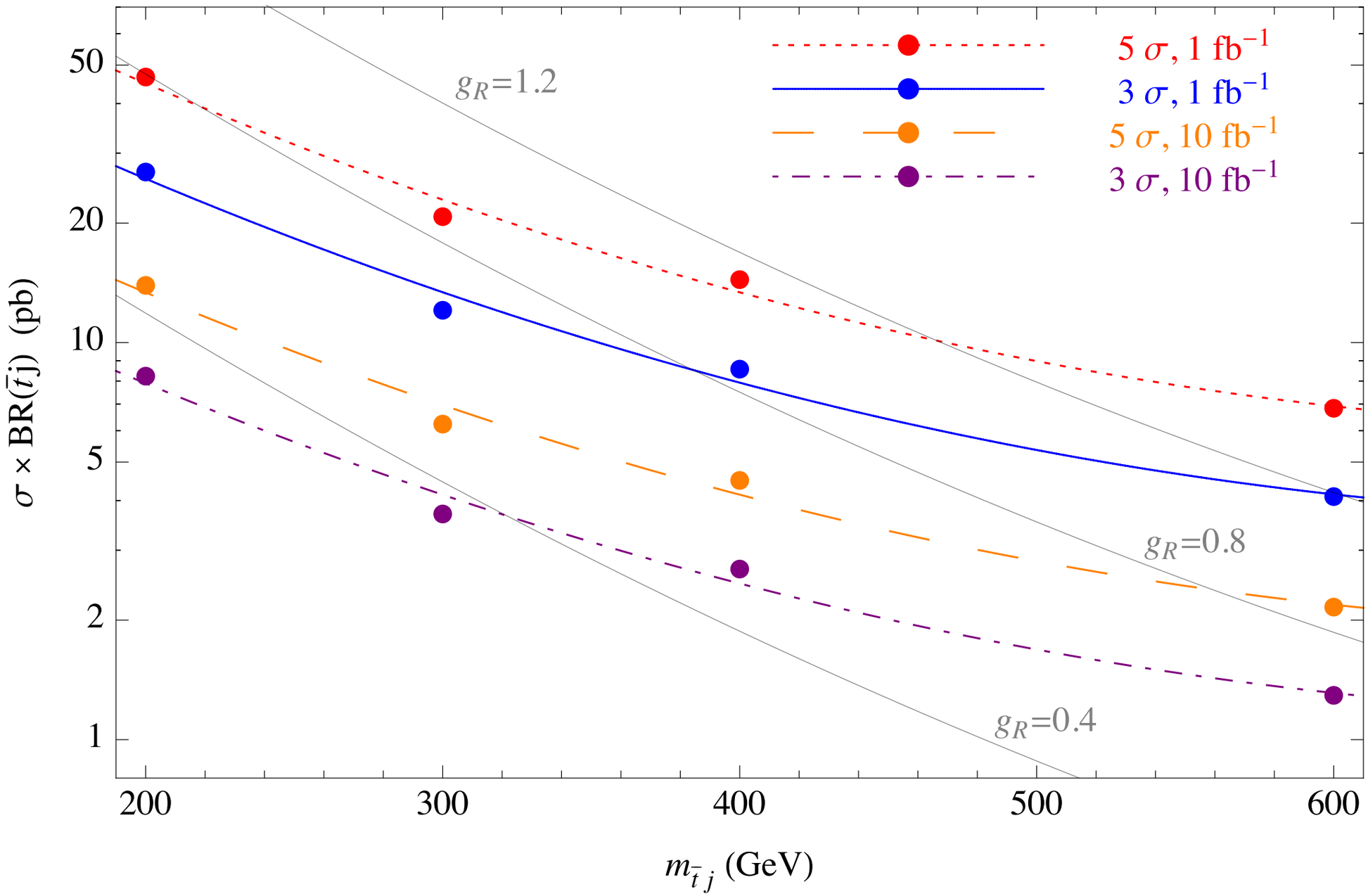


(a) Invariant Mass



(b) $\cos\theta_{\bar{t}j}$

LHC Reach


5 σ, 1 fb^{-1}
3 σ, 1 fb^{-1}
5 σ, 10 fb^{-1}
3 σ, 10 fb^{-1}
g_R=1.2
g_R=0.8
g_R=0.4
σ × BR($\bar{t}$j) (pb)
50
20
10
5
2
1
200
300
400
500
600
$m_{\bar{t}j}$ (GeV)

Conclusions:

- We carry out a comprehensive analysis of models for top FB asymmetry combined with new top data from the LHC.
- On general grounds, t-channel scalar models struggle to produce sufficient asymmetry consistent with CDF observations without having trouble with total cross section observed at the Tevatron and LHC.
- T-channel vector models have strong constraints on the heavy mediator in the invariant mass distributions at the LHC.
- Heavy axigluons are increasingly squeezed by LHC ttbar and dijet resonance search.
- LHC top analysis will soon discover very exciting new phenomena or close the window for viable models. Top-jet resonance search can be useful here.
- With the result D0 result, we need to reexamine the models.

Will be updated on http://susy.physics.lsa.umich.edu/TopPhysics