Tevatron Top A_{FB}

vs

LHC Top Physics

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with Kathryn Zurek and Moira Gresham

PRD84, 034025 (arXiv:1102.0018)
PRD83,114027 (arXiv:1103.3501)
PRD85, 104022 (arXiv:1107.4364)
&
See the next talk by Sean Tulin (arXiv:1203.1320)

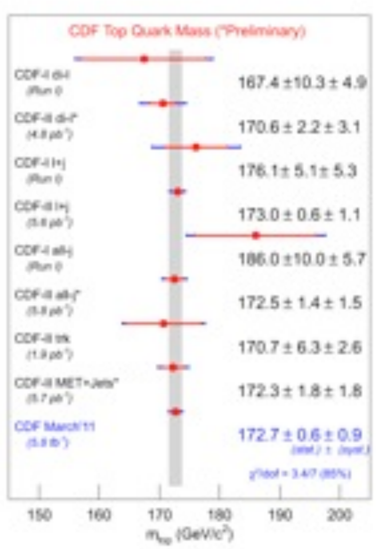
PHENO 2012
May 7, 2012

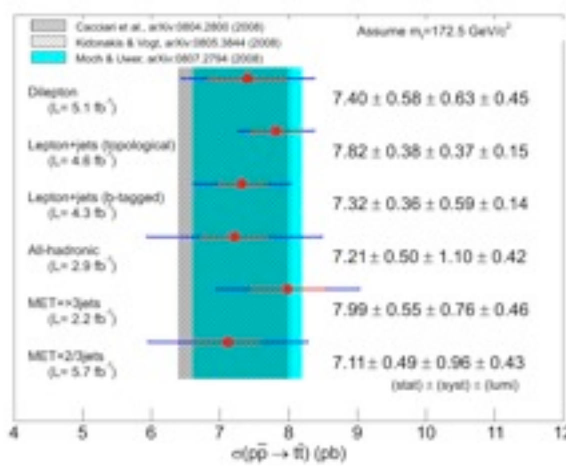
Bye-Bye, Tevatron !

Top quark discovery (1995)

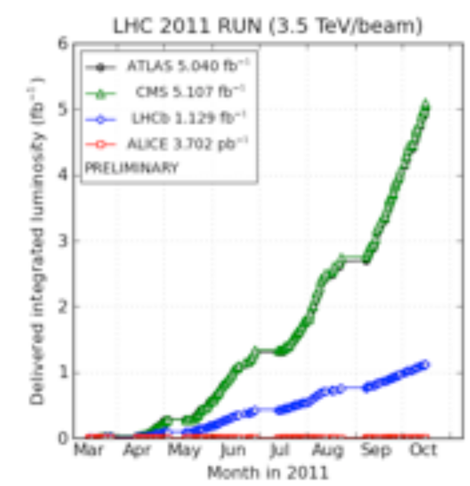
Single Top (2008)

Tevatron is rest in peace in 2011





Tevatron : History of Top physics



Show must go on with LHC!

Top FB Asymmetry

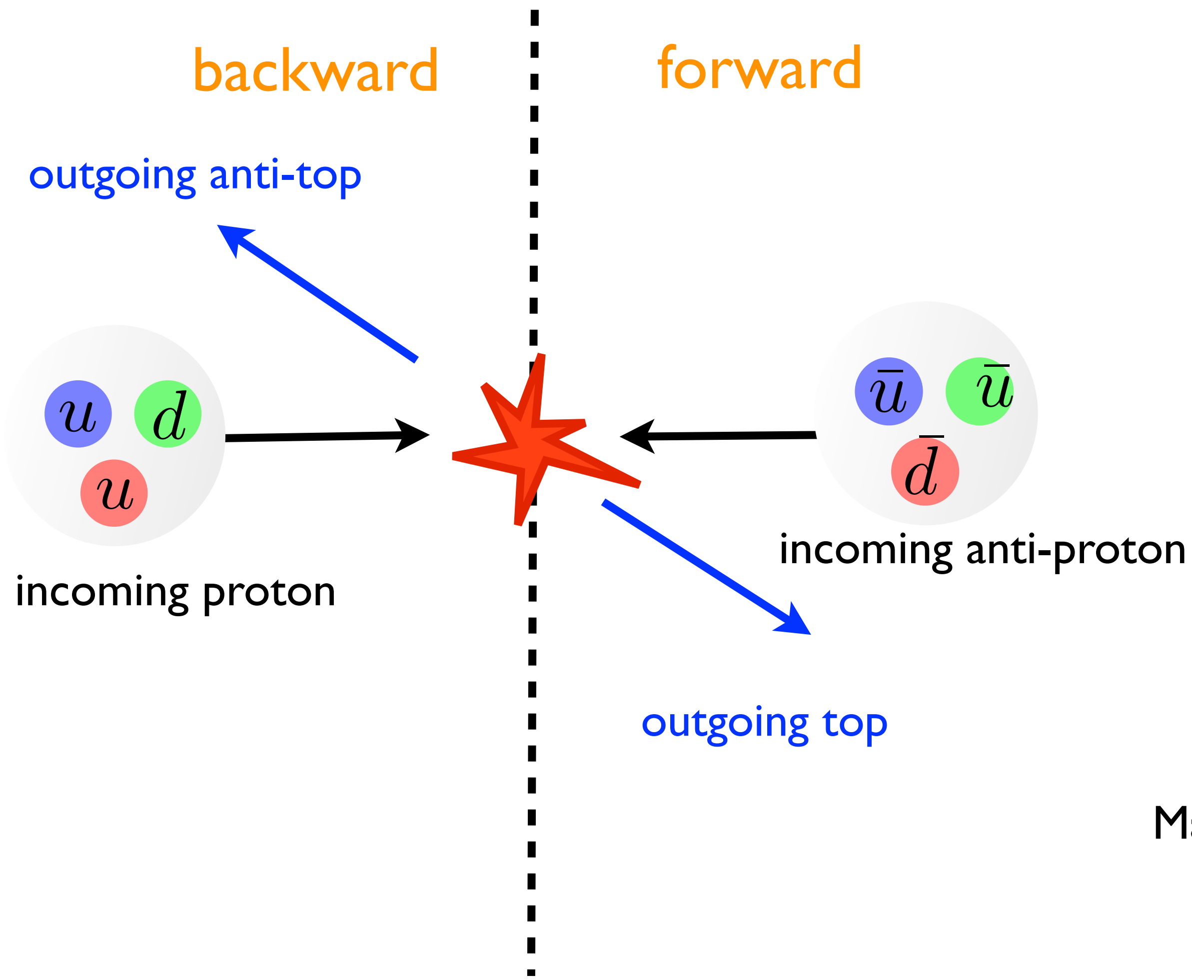
We already produced O(10^5) top pairs.

$$\sigma_{\rm TEV} = 7.5 \text{ pb}$$

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

Top flavor physics is relatively unconstrained.

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



($t\bar{t}$ CM frame)

$$A^{t\bar{t}} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

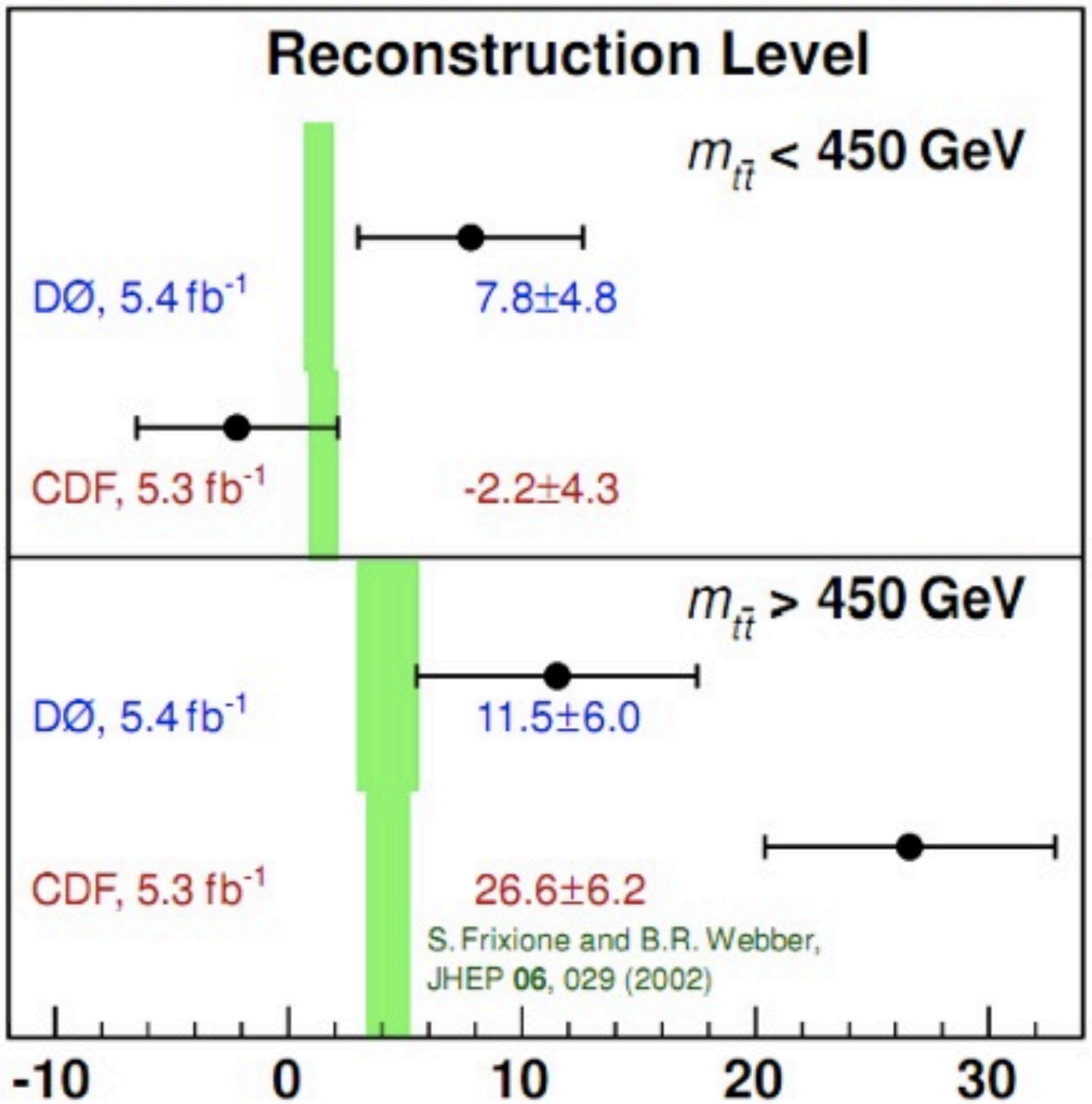
Mass-dependent "differential" asymmetry:

$$A^{t\bar{t}}(m_{t\bar{t},i}) = \frac{N(\Delta y > 0, m_{t\bar{t},i}) - N(\Delta y < 0, m_{t\bar{t},i})}{N(\Delta y > 0, m_{t\bar{t},i}) + N(\Delta y < 0, m_{t\bar{t},i})}$$

$$A^t_{FB} = \frac{\text{(\# forward tops) - (\# backward tops)}}{\text{total \# of tops}}$$

2011 Result Summary

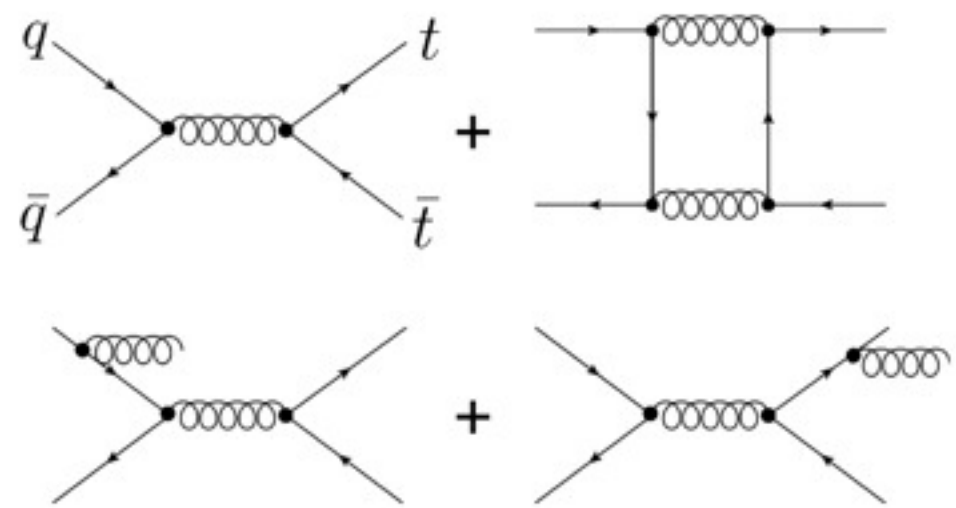
Forward-Backward Top Asymmetry, %



CDF unfolded parton-level A^t_{FB}

$m_{t\bar{t}} < 450$ GeV	$m_{t\bar{t}} > 450$ GeV
$-0.116 \pm 0.146 \pm 0.047$	$0.475 \pm 0.101 \pm 0.049$

3.4σ level discrepancy from SM



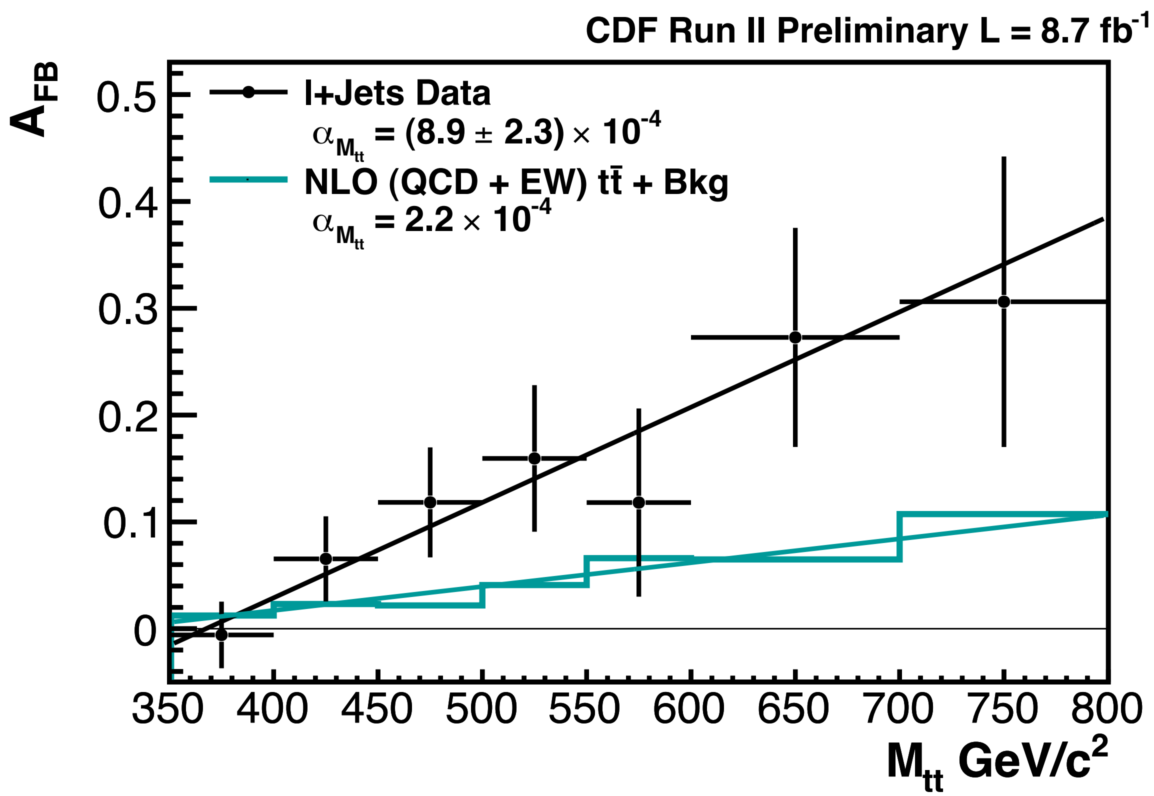
SM has FB asymmetry at NLO

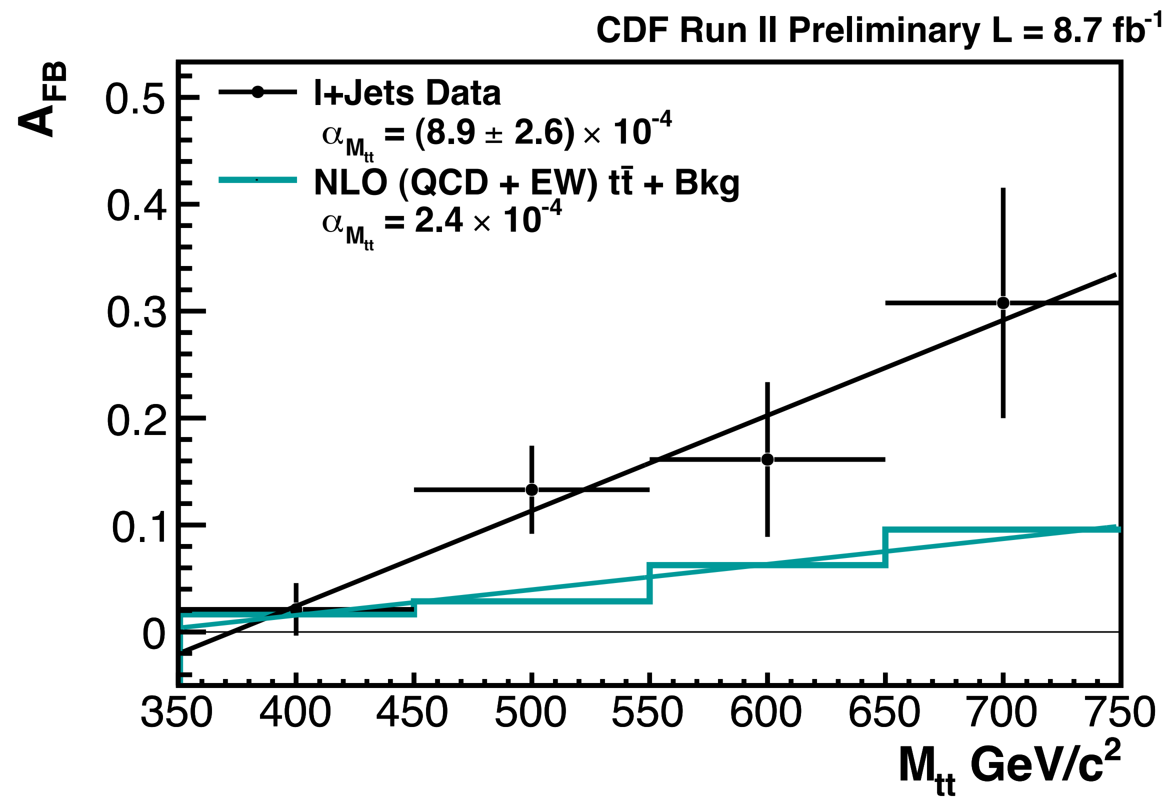
$m_{t\bar{t}} < 450$ GeV	$m_{t\bar{t}} > 450$ GeV
0.040 ± 0.006	0.088 ± 0.013

New physics effects easily come in at Tree Level.

New Result from CDF

CDF Note 10807





CDF Run II Preliminary L = 8.7 fb^{-1}

$M_{t\bar{t}}$	Data A_{FB} (± stat.)	NLO (QCD+EW) $t\bar{t}$ + Bkg. A_{FB}
< 400GeV/c^2	-0.006 ± 0.031	0.012
400 – 450GeV/c^2	0.065 ± 0.040	0.023
450 – 500GeV/c^2	0.118 ± 0.051	0.022
500 – 550GeV/c^2	0.159 ± 0.069	0.041
550 – 600GeV/c^2	0.118 ± 0.088	0.066
600 – 700GeV/c^2	0.273 ± 0.103	0.065
≥ 700GeV/c^2	0.306 ± 0.136	0.107
	Data	NLO (QCD+EW) $t\bar{t}$ + Bkg.
Slope $\alpha_{M_{t\bar{t}}}$ of Best-Fit Line	$(8.9 \pm 2.3) \times 10^{-4}$	2.2×10^{-4}

TABLE V: Measured and expected asymmetries as a function of $M_{t\bar{t}}$.

Significantly lowered A_{FB}

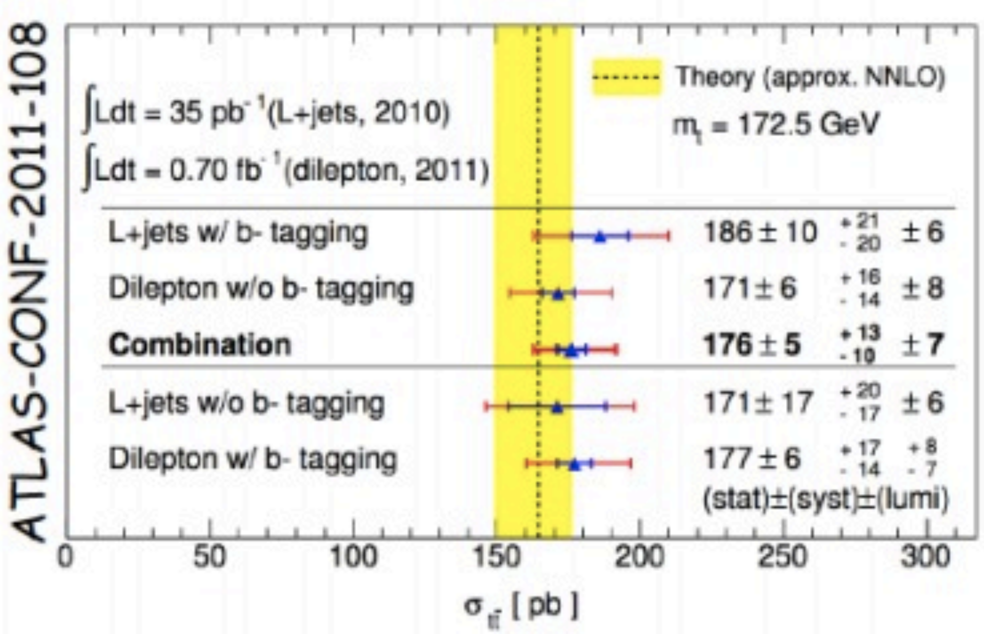
On the LHC side...

CMS

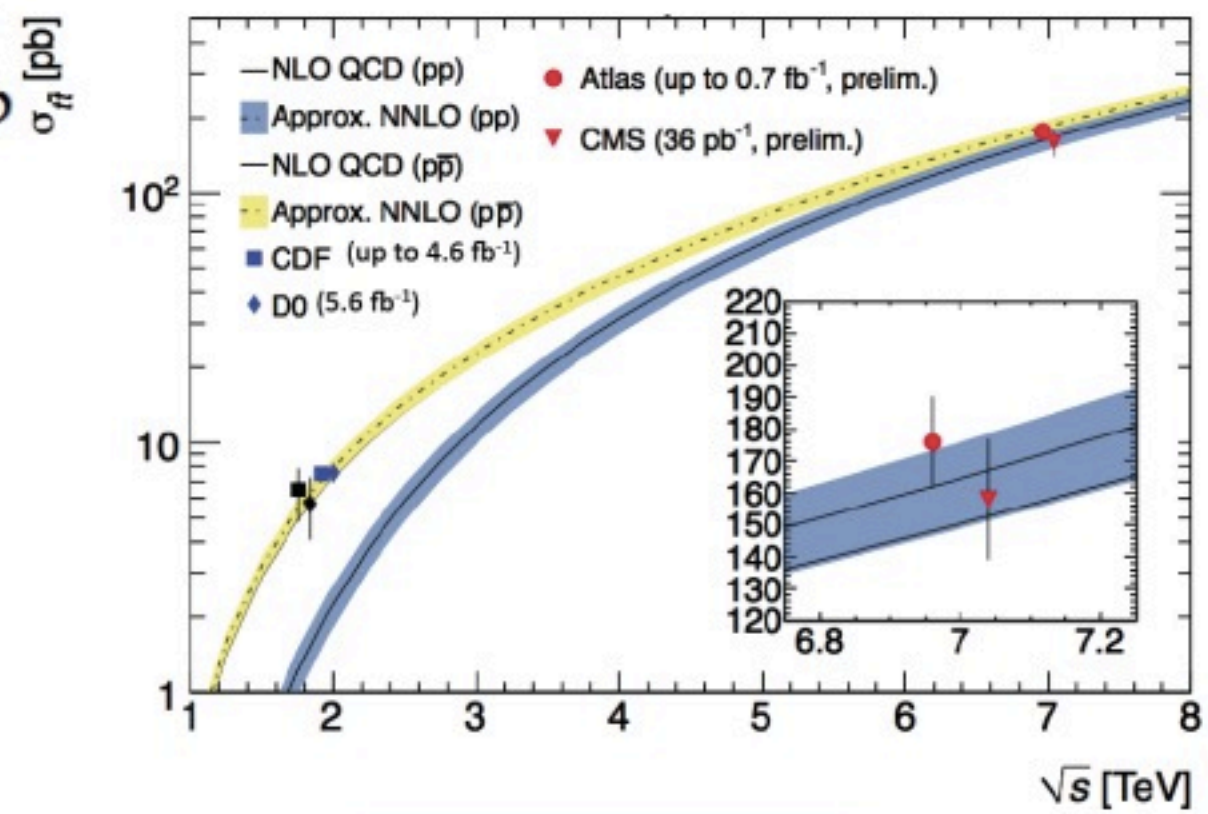
Measurement	Cross section [pb]	Weight
CMS l+jets+tag	$150 \pm 9(stat) \pm 17(syst) \pm 6(lumi)$	58%
CMS dilepton	$168 \pm 18(stat) \pm 14(syst) \pm 7(lumi)$	42%

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

ATLAS



Individual combinations of the channels in the experiments



9% precision!!
July 2011

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

How to Generate A_{FB}

You can refer to...

Sehgal, Wanninger(1988), Bagger, Schmidt, King (1988), Ferrario, Rodrigo (2009), Frampton, Shu, Wang (2009), Chivukula, Simmons, Yuan (2010), Djouadi, Moreau, Richard, Singh (2010), Bauer, Goertz, Haisch, Pfoh, Westhoff (2010), Alvarez, Da Rold, Szynkman (2010), Chen, Cvetic, Kim (2010) Bai, Hewett, Kaplan, Rizzo (2011), Foot (2011), 1103.1266, 1103.1940, Zerwekh (2011) , Shu, Wang, Zhu (2011), Alvarez, Da Rold, Vietto, Szynkman (2011), 1103.0956, Tavarez, Schmaltz (2011), Aguilar-Saavedra (2011), Jung, Murayama, Pierce, Wells (2009), Cheung, Keung, Yuan (2009) Shu, Tait, Wang (2010), Arhrib, Benbrik, Chen (2010), Dorsner, Fajfer, Kamenik, Kosnik (2009), Barger, Keung, Yu (2010), Xiao, Wang, Zhu (2010), Cheung, Yuan (2010), Shelton, Zurek (2011), Berger, Cao, Chen Li, Zhang (2011), Grinstein, Kagan, Trott, Zupan (2011), Patal, Sharma (2011), Craig, Kilic, Strassler (2011), Ligeti, Tavares, Schmaltz (2011), Jung, Pierce, Wells (2011), Nelson, Okui, Roy (2011), Duraisamy, Rashed, Datta (2011), Gabrielli, Raidal (2011), Jung, Ko, Lee, Nam (2009), Cao, Heng, Wu, Yang (2010), Cao, McKeen, Rosner, Shaughnessy, Wagner (2010), Jung, Ko, Lee (2010), Choudhury, Godbole, Rindani, Saha(2010), Jung, Ko, Lee, Nam (2010), Delaunay, Gedalia, Hochberg, Perez, Sereq (2011), Gresham, IWK, Zurek (2011), Grinstein, Kagan, Zupan, Trott (2011) ...

How to Generate A_{FB}

- s-channel exchange

  Axigluon : Sehgal, Wanninger(1988), Bagger, Schmidt, King (1988), Ferrario, Rodrigo (2009), Frampton, Shu, Wang (2009)
  Chivukula, Simmons, Yuan (2010) ....

- t-channel exchange

  Jung, Murayama, Pierce, Wells (2009), Cheung, Keung, Yuan (2009),
  Shu, Tait, Wang (2010), Barger, Keung, Yu (2011), Ko, Omura, Yu (2011), ...

- top decay/production mode change

- effective operator

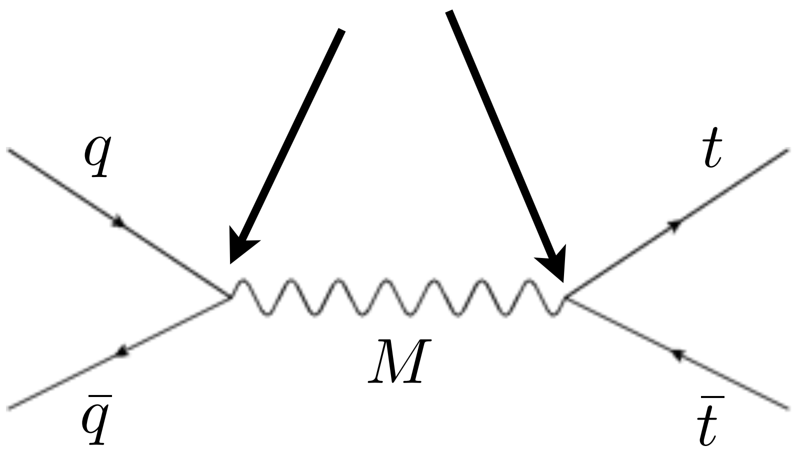
  Jung, Ko, Lee (2010)

- ...

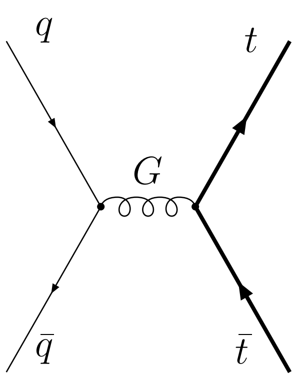
S-channel Models

asymmetry from quantum interference

nonzero axial couplings



large mass due to dijet resonance/contact interaction



$\gtrsim 2.5\ \mathrm{TeV}$

for simple model

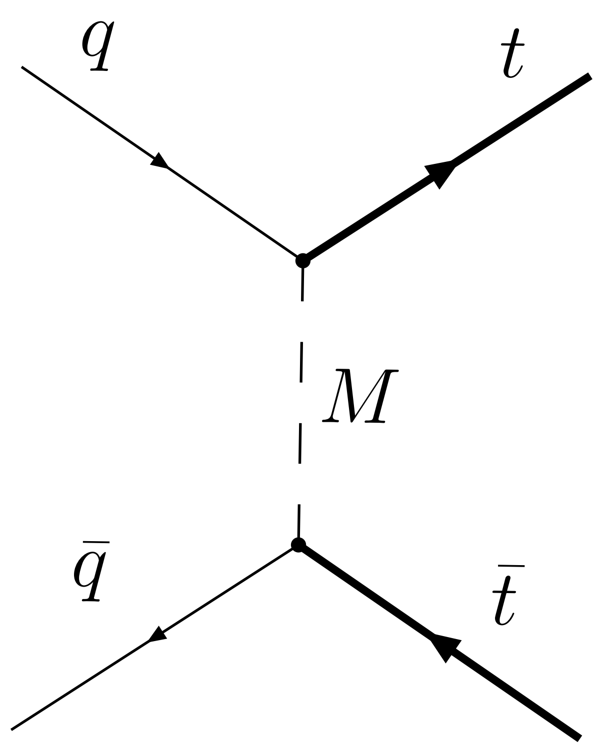
Model structure is rather fixed.

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

Jung, Murayama, Pierce, Wells (2009), Cheung, Keung, Yuan (2009),
Shu, Tait, Wang (2010), Barger, Keung, Yu (2011) ....

T-channel Models

Asymmetry from kinematics



Rutherford scattering

Top flavor-carrying particle

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

See work on Ko, Omura, Yu (2011)

small mass to generate large A_{FB}

Relatively unconstrained in top flavor violation

Possible hints of flavor structure in NP ?

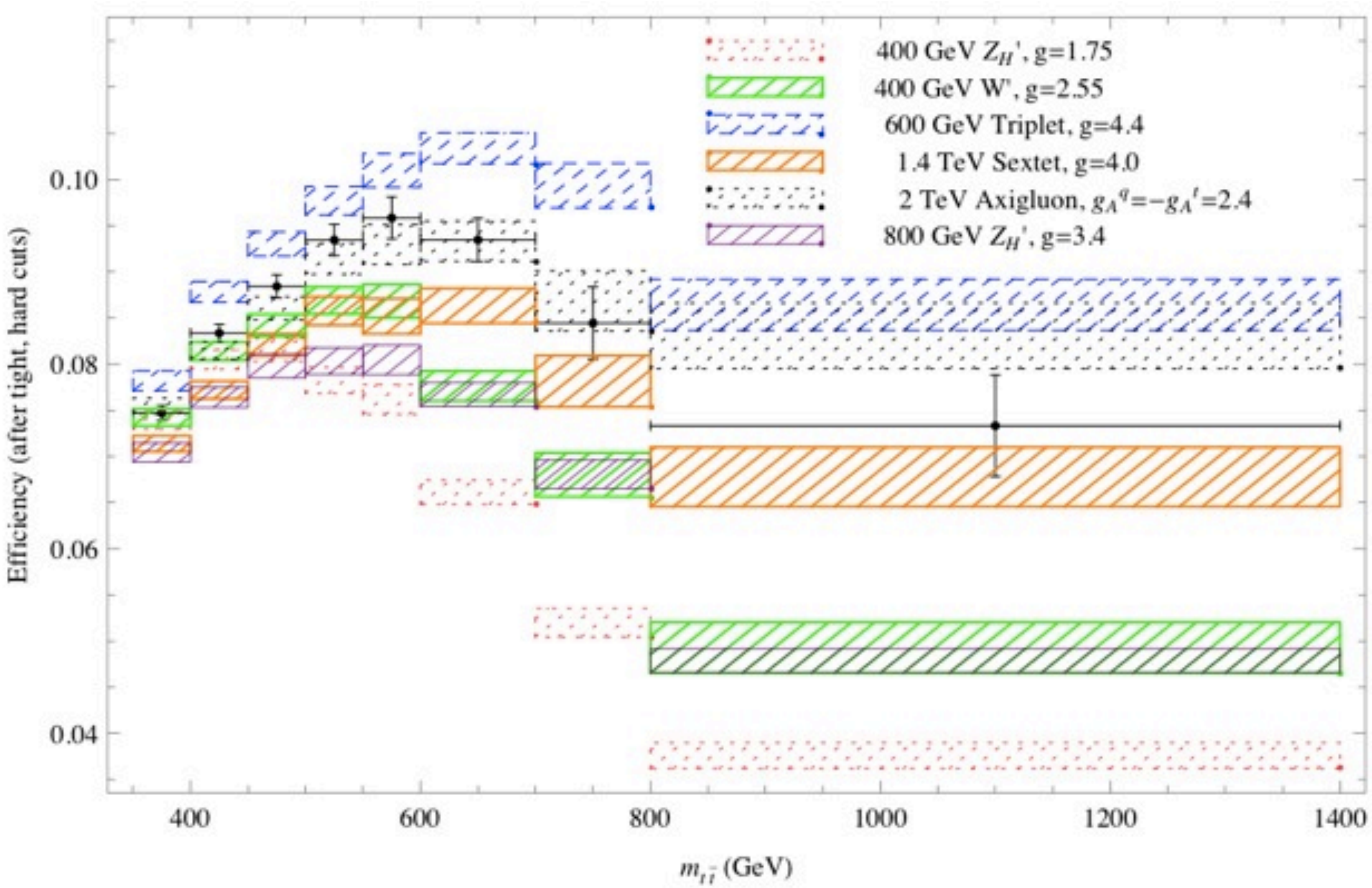
Flavor dependent U(1) : Ko, Omura, Yu (2011)

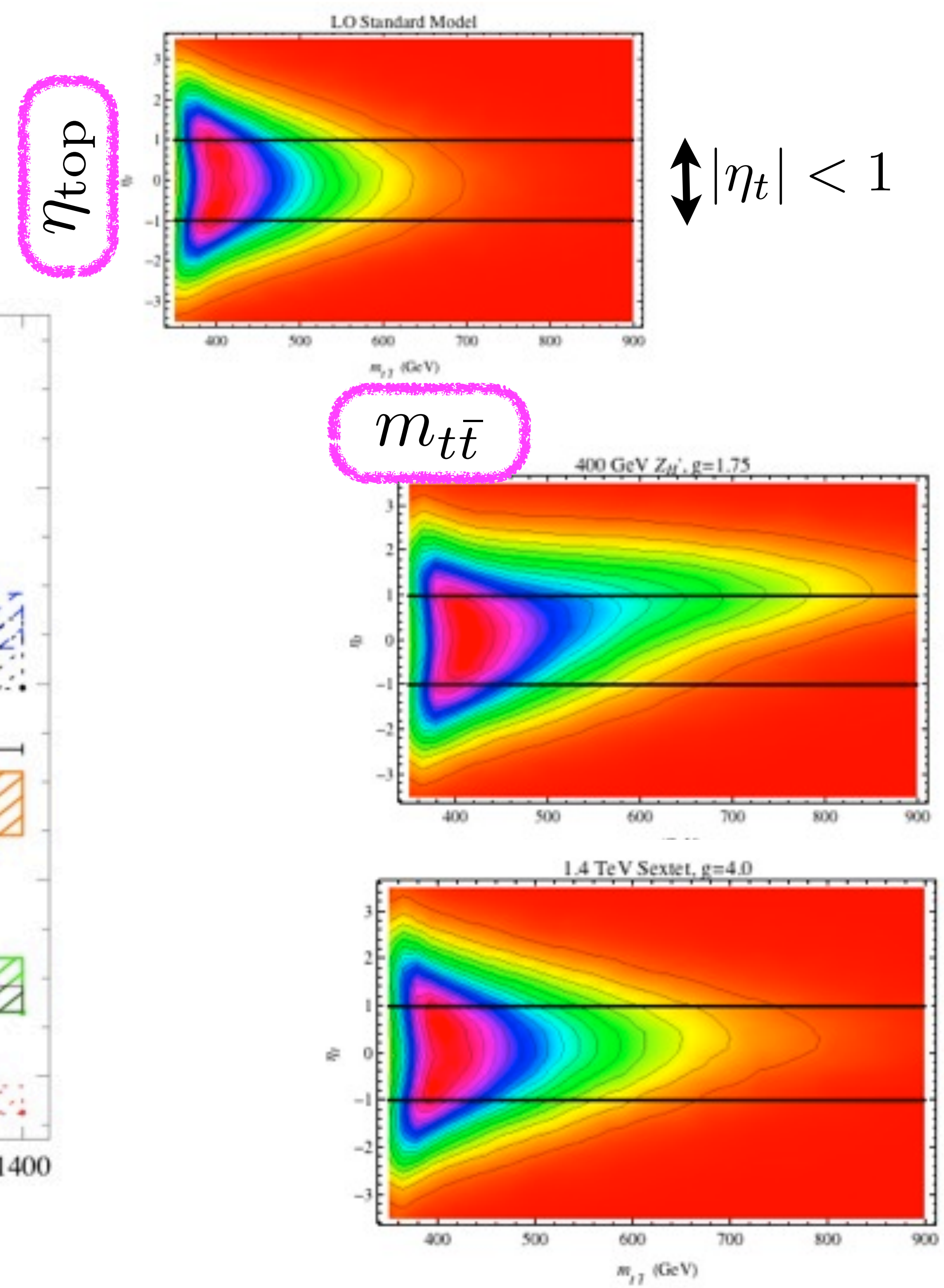
MFV : Grinstein, Kagan, Trott, Zupan (2011)

Caveat : Interpretation of Parton-level AFB

Gresham, IWK, Zurek (1103.3501)

Model Dependent Acceptance from Event Selection Cut





Model Survey (High Mass Case)

Choose promising models from previous study and add more

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.

MFV models (F8C1V) also considered (see Grinstein, Kagan, Trott, Zupan (2011))

Pipeline

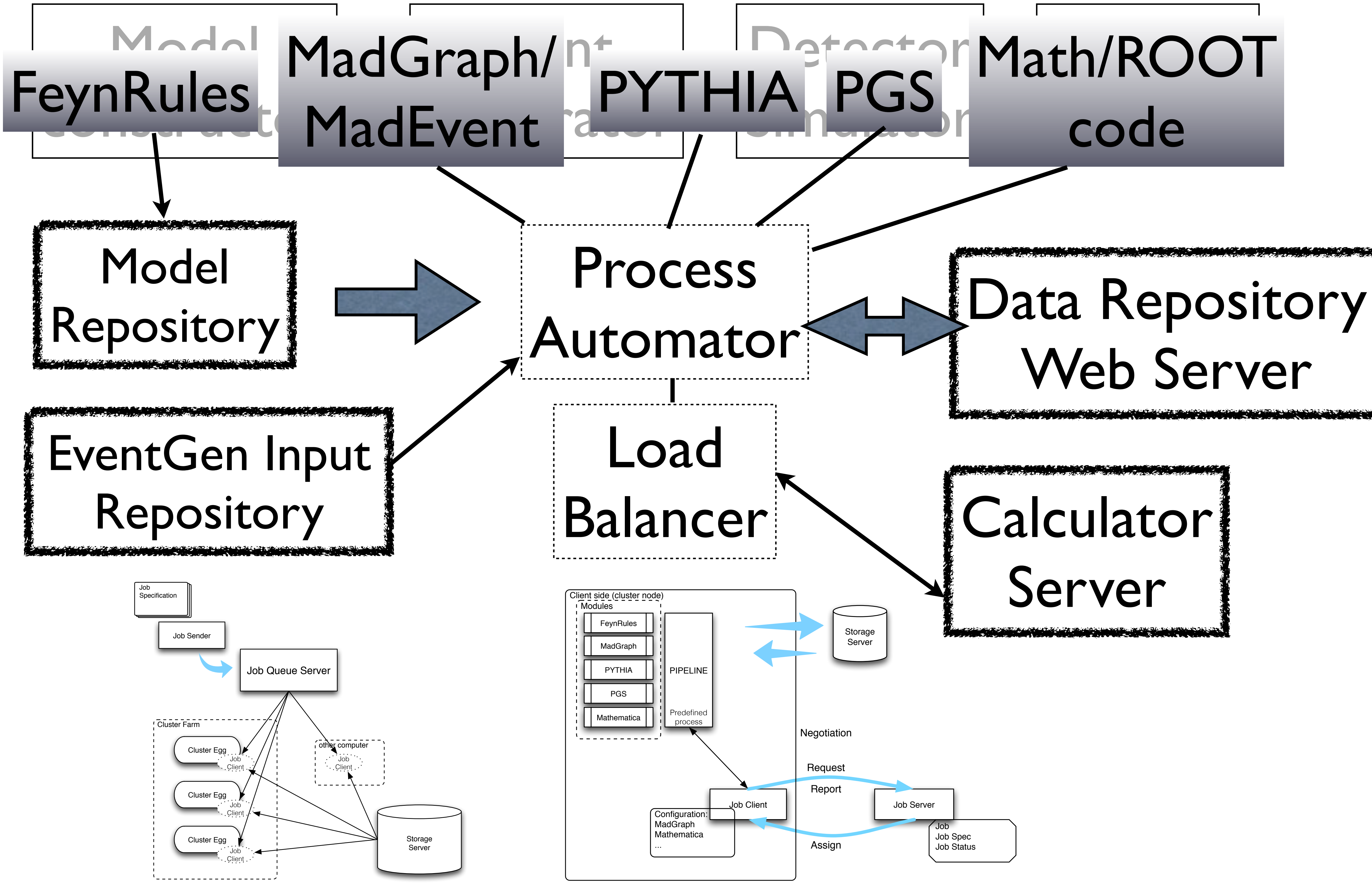
Model constructor → Event Generator → Detector Simulator → Analysis Program

8 classes of models, ~700 scan points, 20 benchmark,
~ O(30) figures for each benchmark

Quite a Big Engineering Problem!

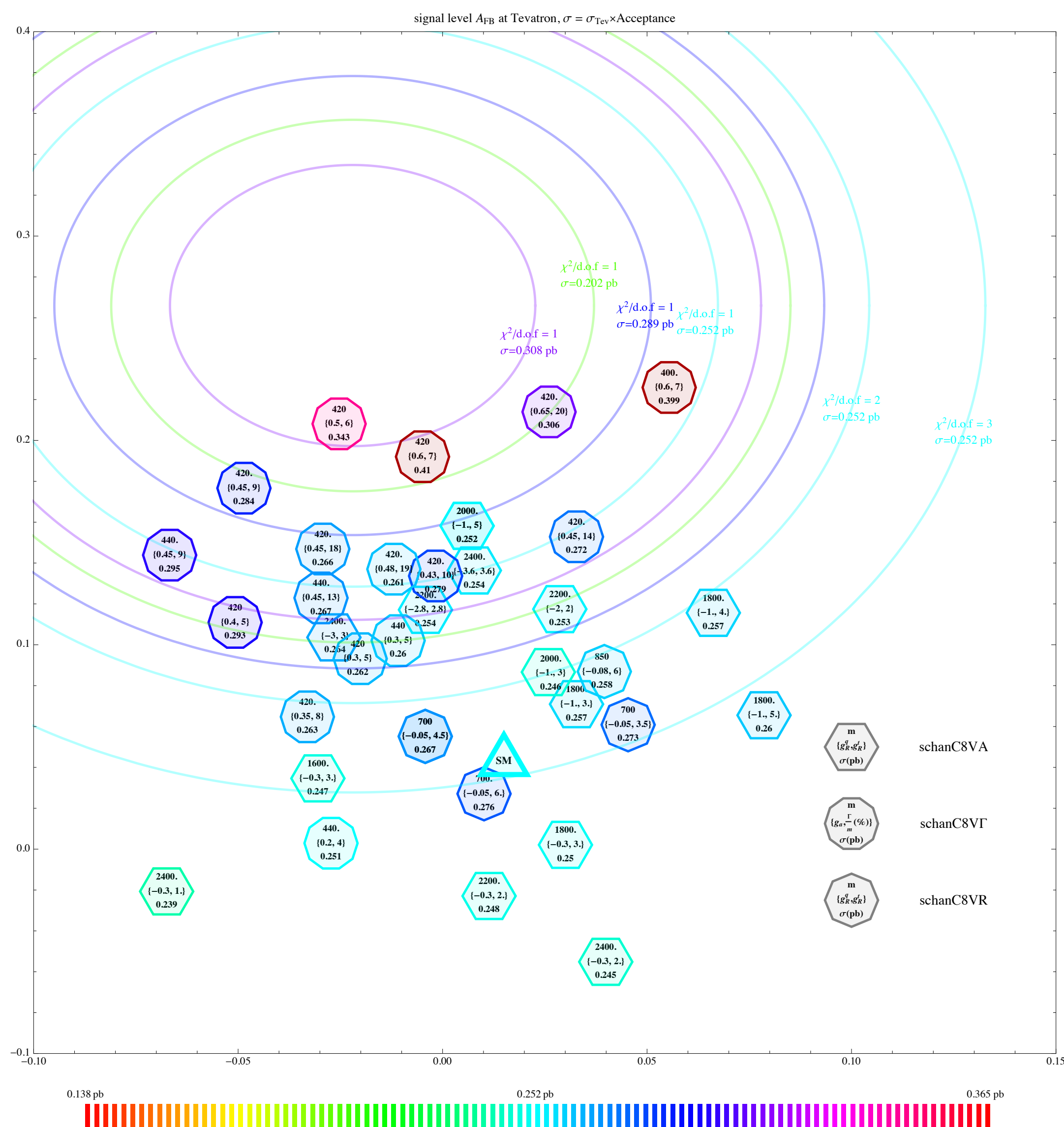
Pipeline : Full Automation of Model / Data Comparasion with parallel processing

Soon available in public

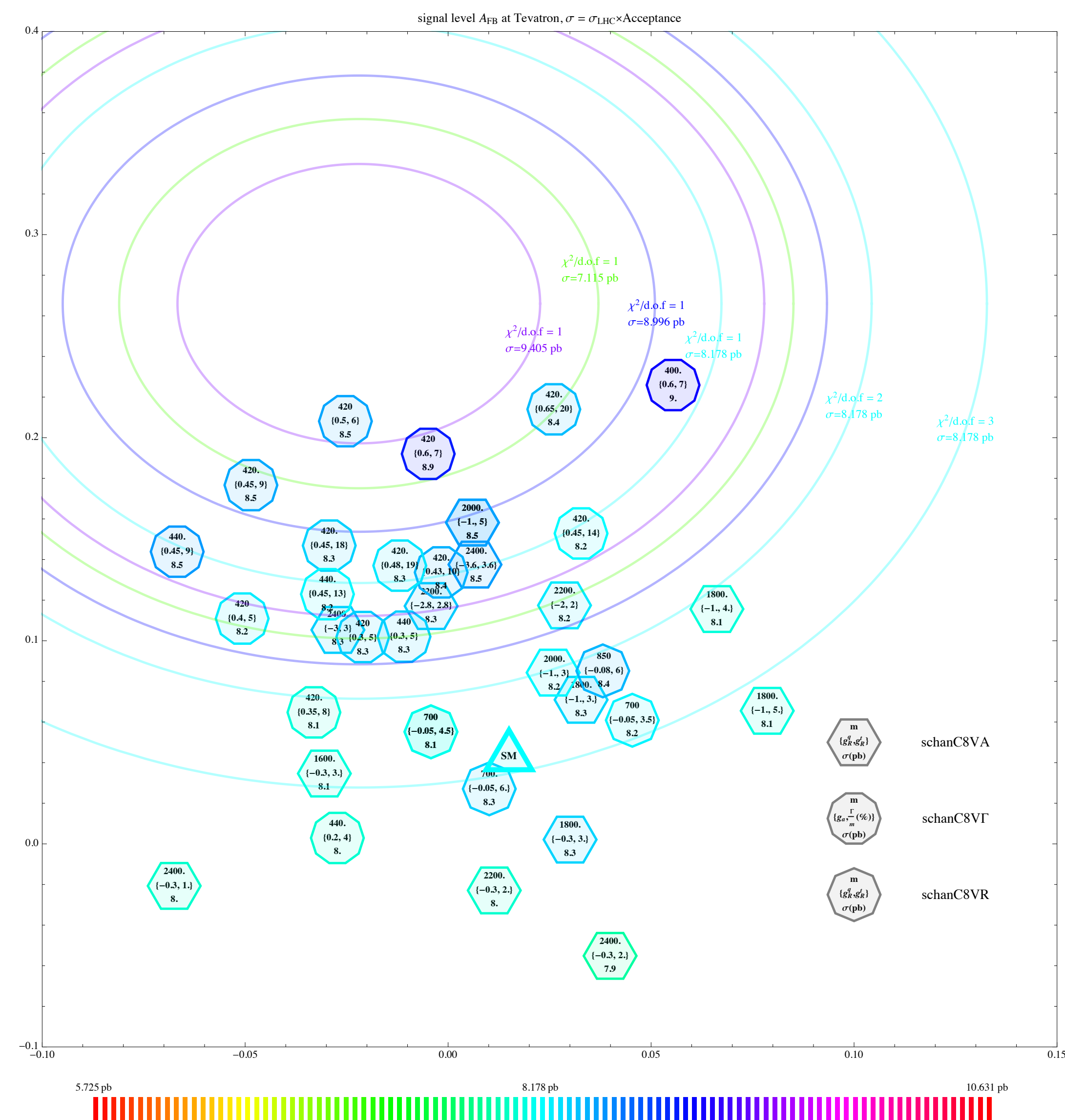


Gresham, IWK, Zurek (1107.4364)

S-channel Models



-45% +45%

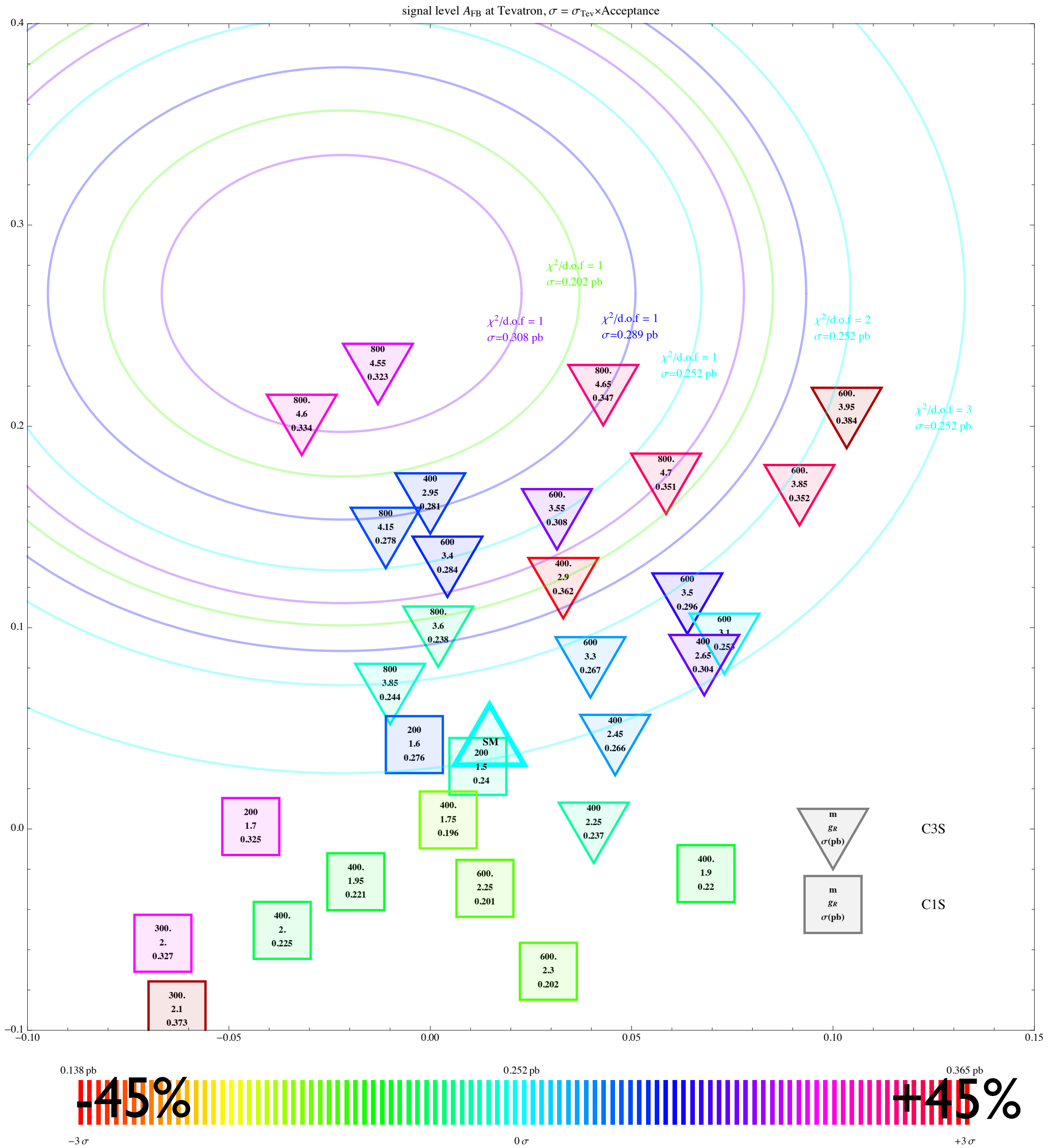


-30% +30%

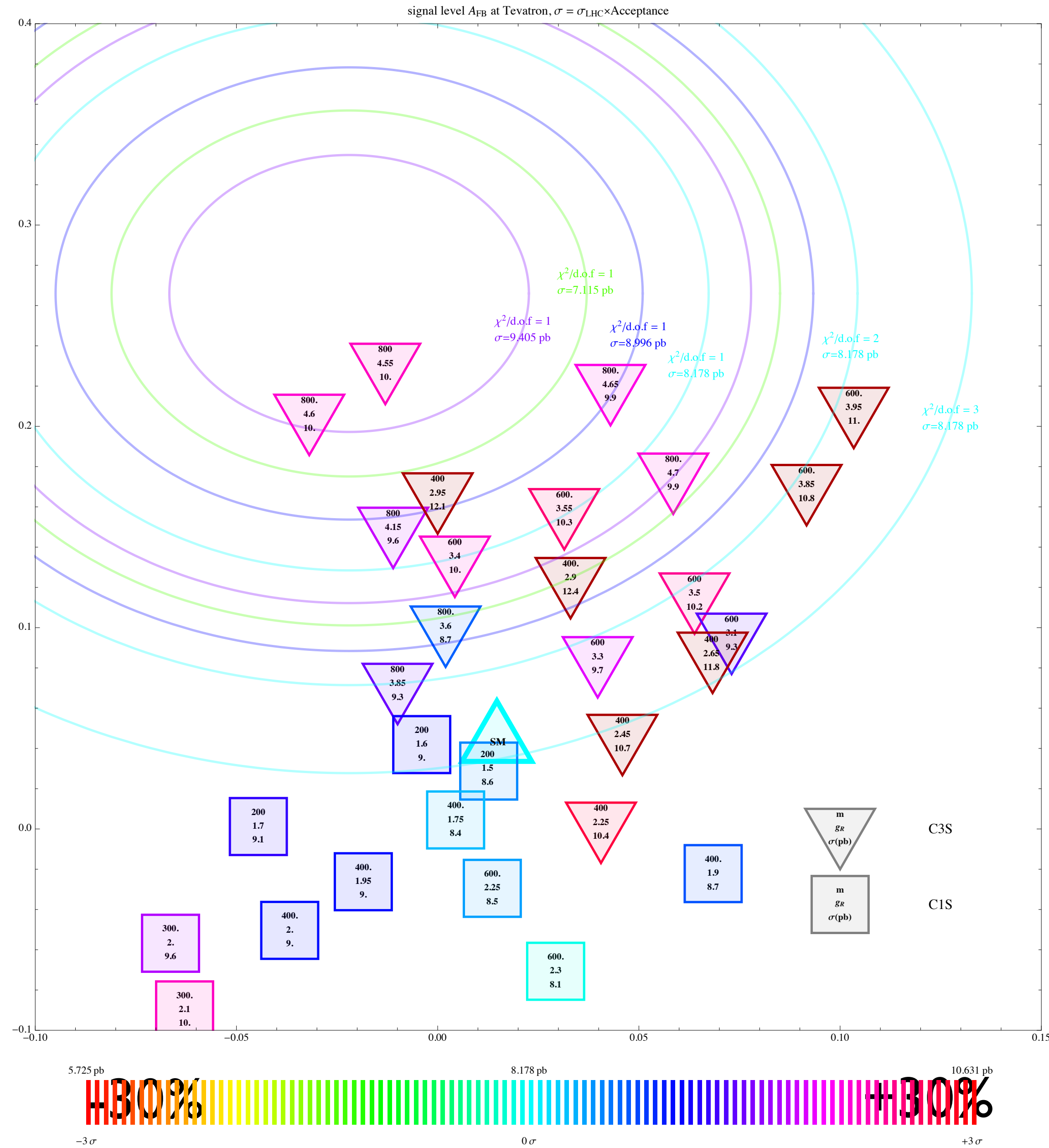
Tevatron cross section

LHC cross section

T-channel scalar models

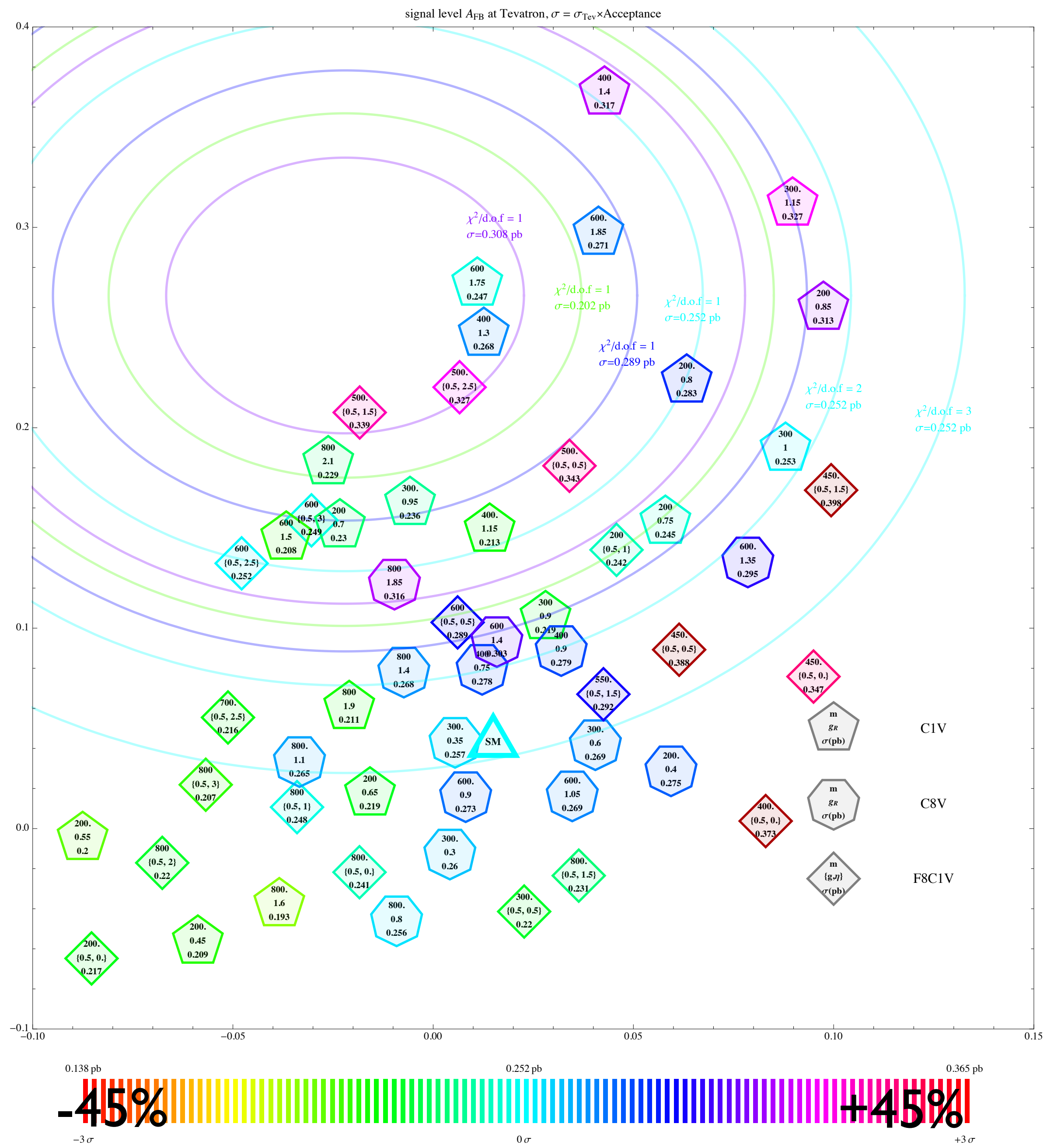


Tevatron cross section

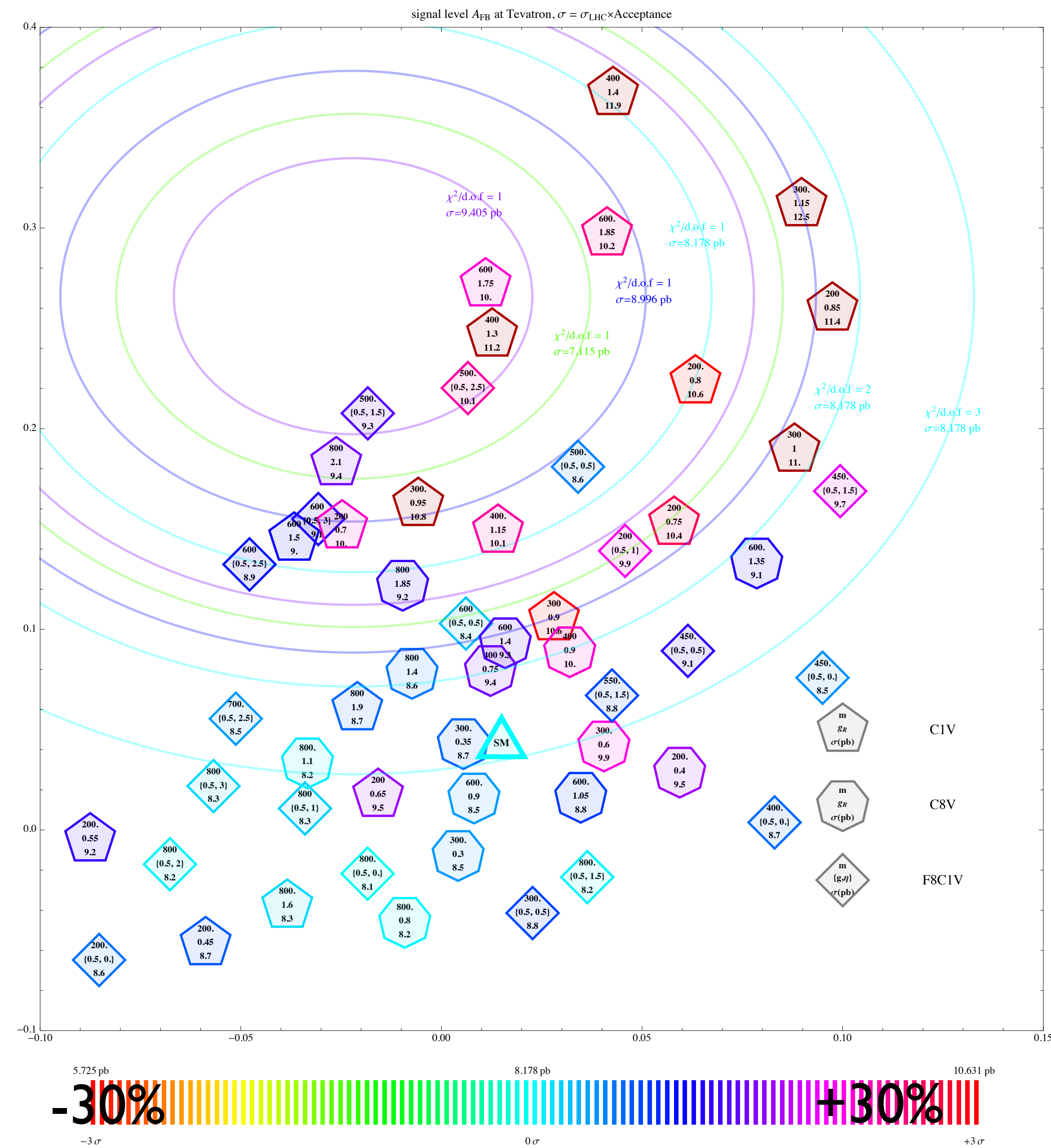


LHC cross section

T-channel vector models

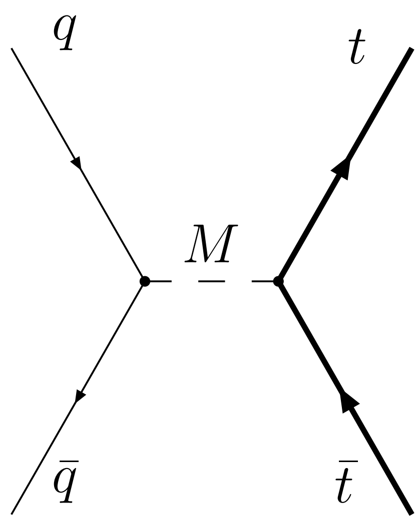


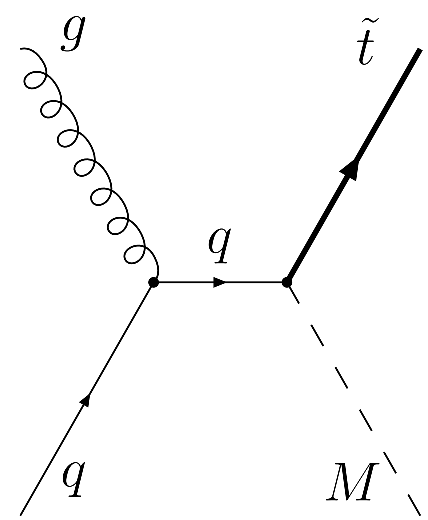
Tevatron cross section

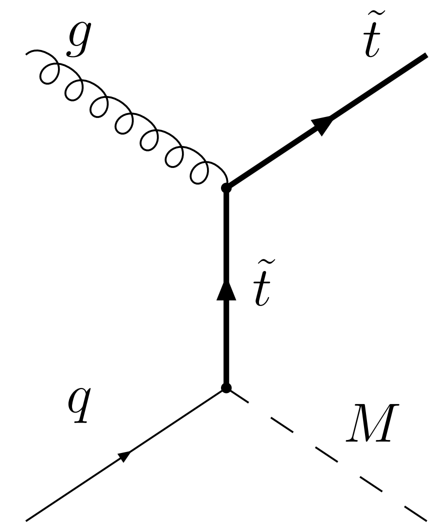


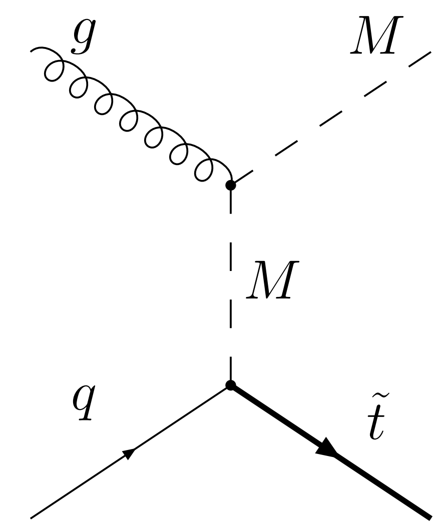
LHC cross section

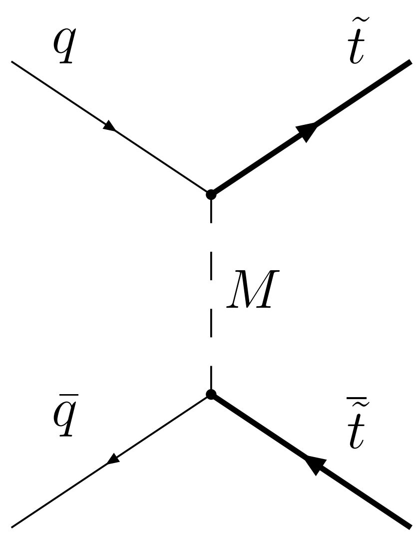
Why LHC cross section tends to be larger in t-channel model?

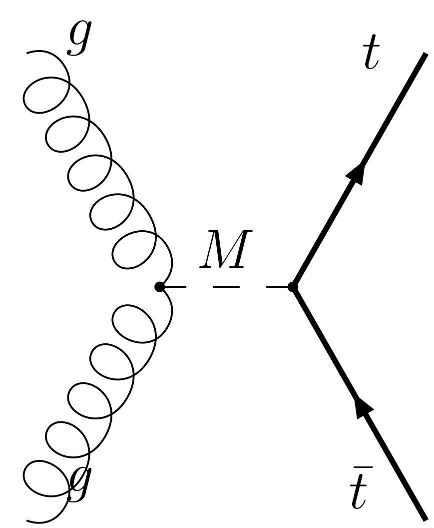




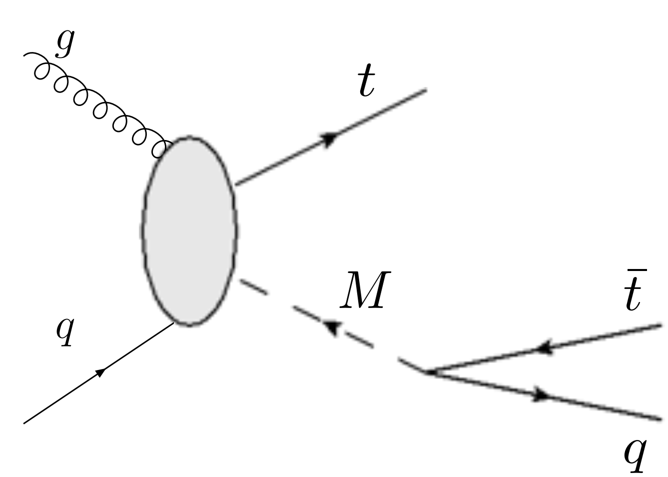








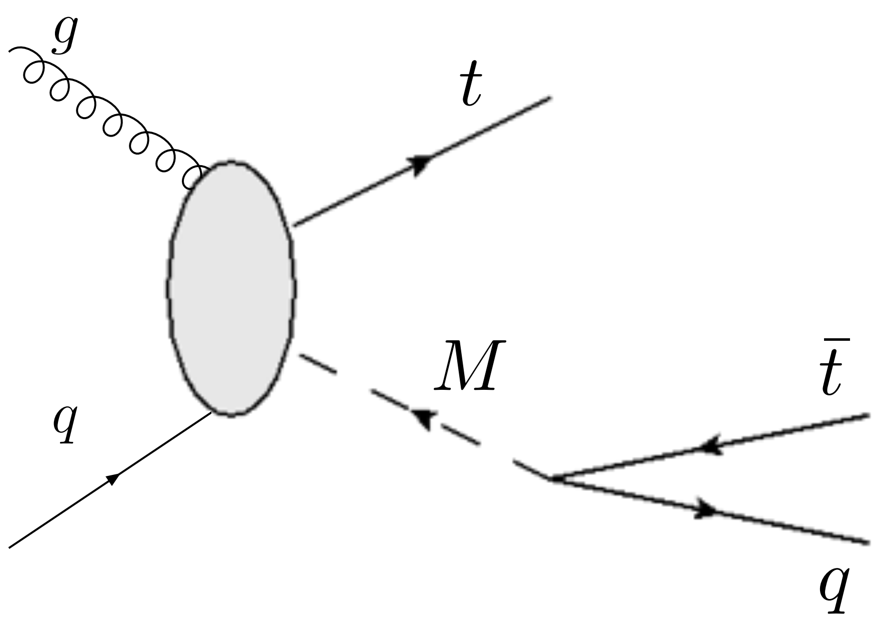
Mediator can be produced associated with top in gluon-quark fusion

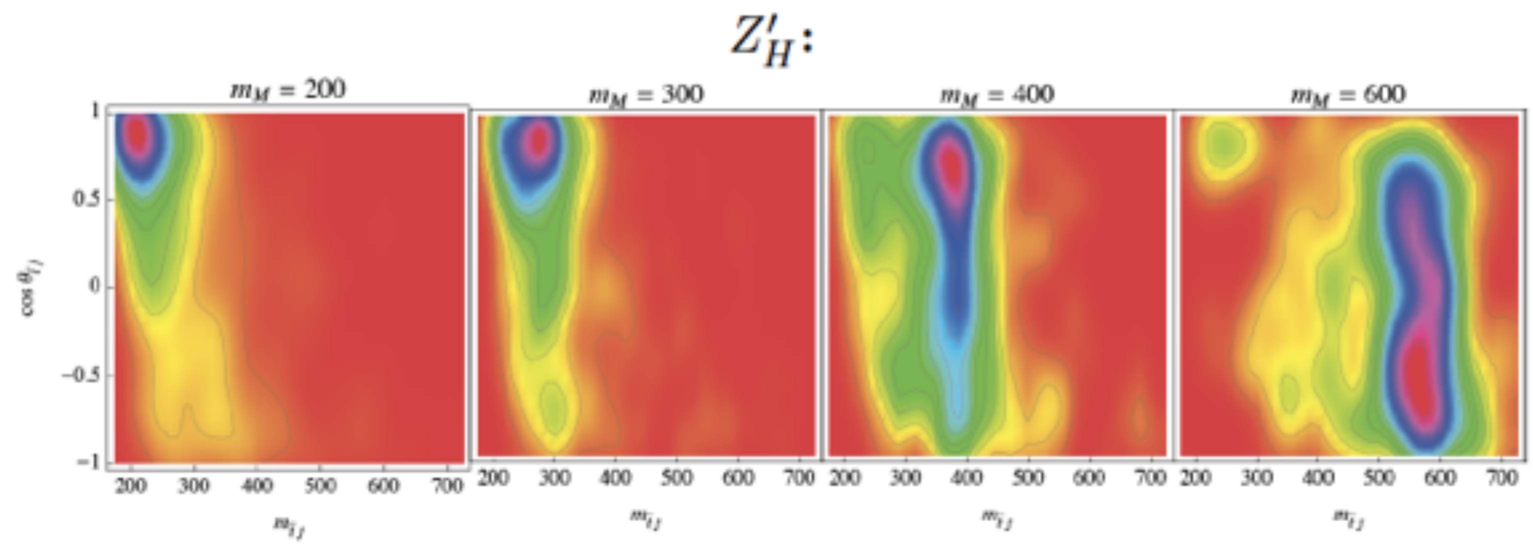


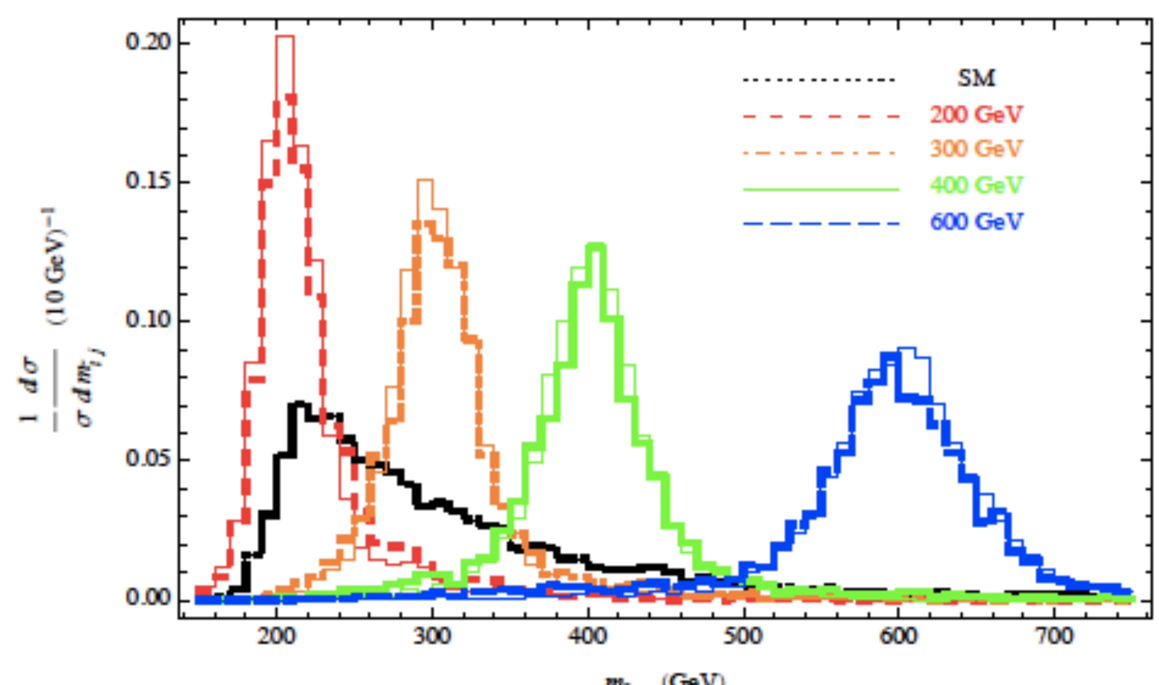
LHC discovery through top-jet resonance

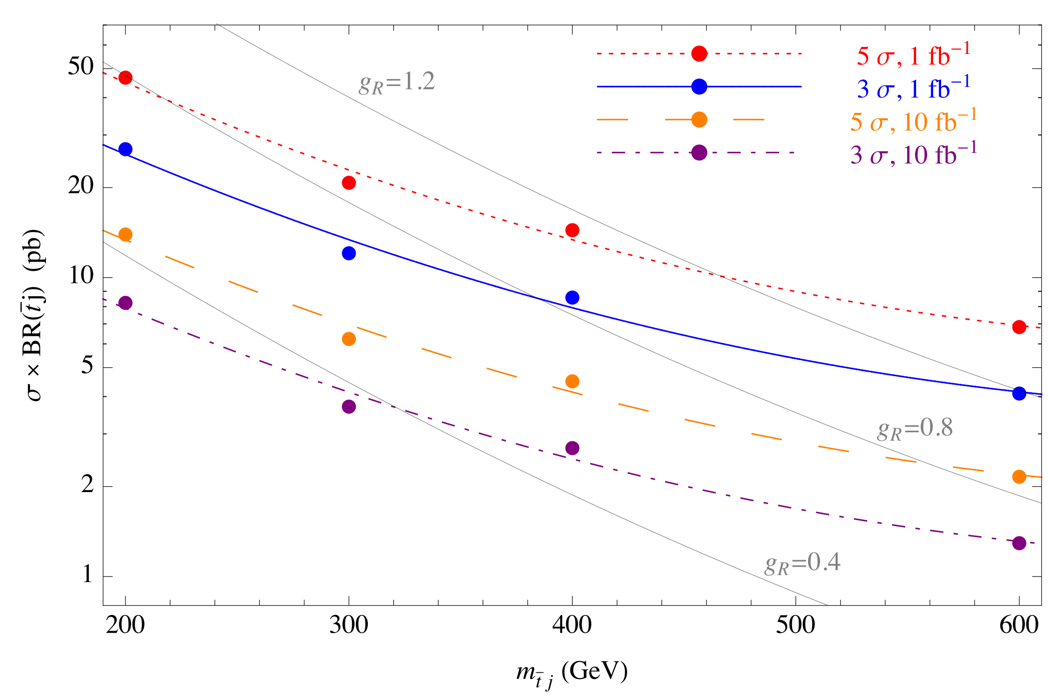
Gresham, IWK, Zurek (arXiv:1102.0018)

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







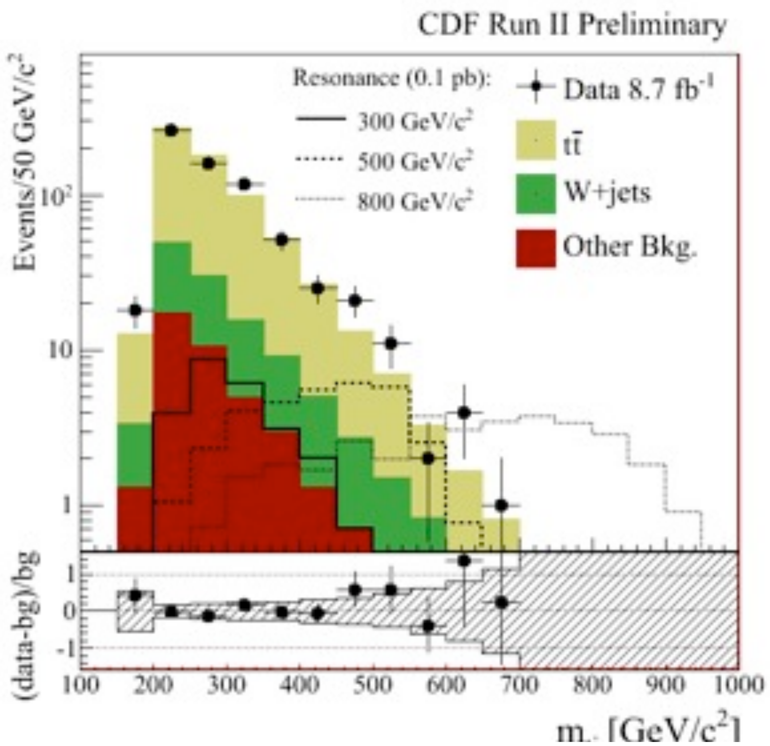


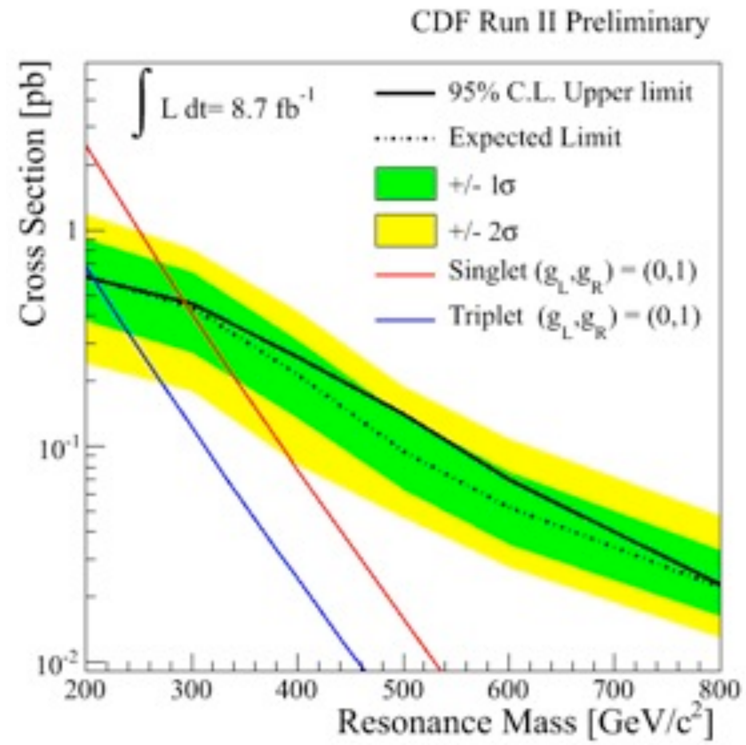
All benchmark t-channel models can be reached with current data in this strategy.

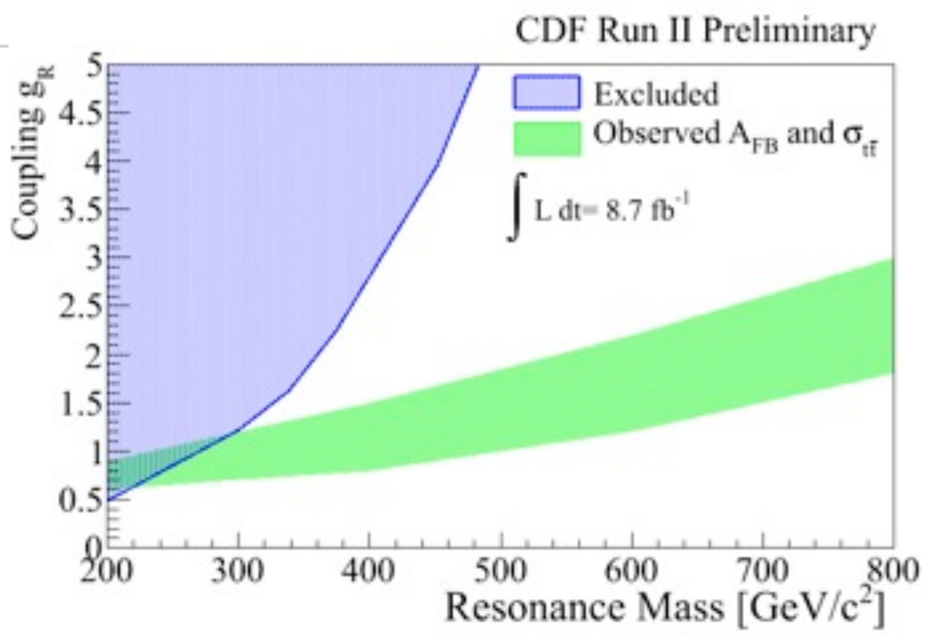
(a) Invariant Mass

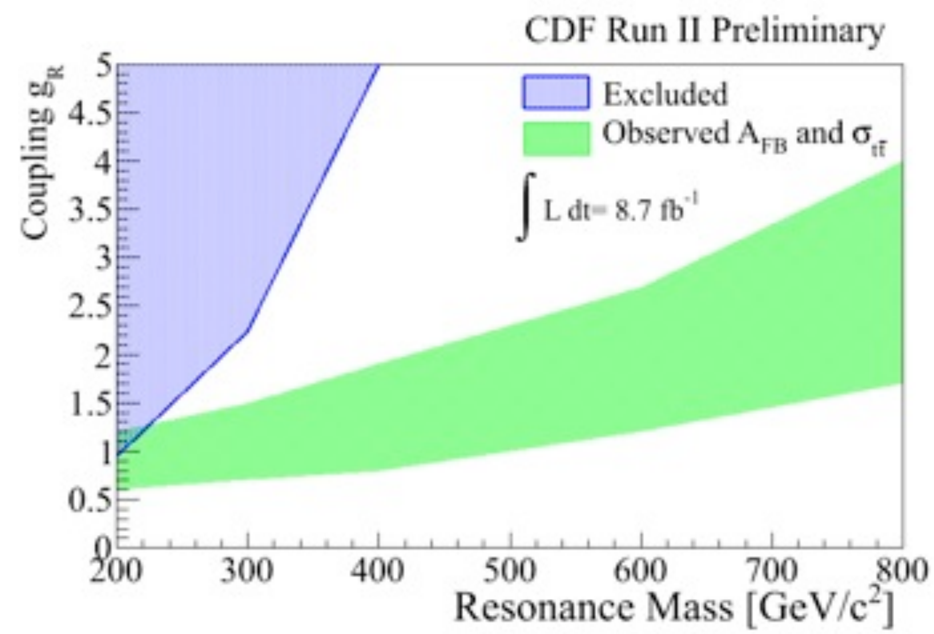
CDF Result of Top-Jet Resonances

CDF Note 10776









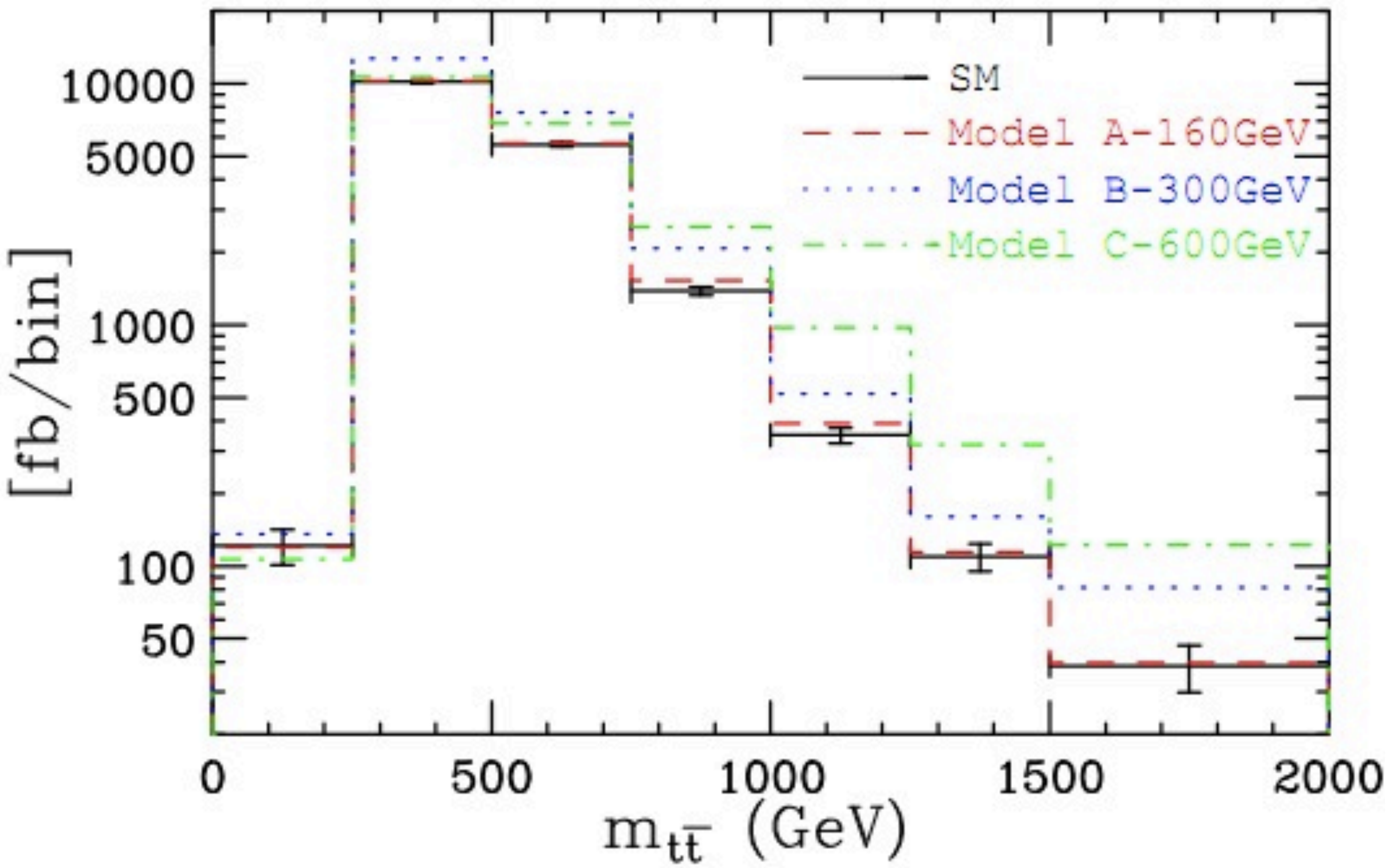
No deviation from SM yet! Start to constrain NP models

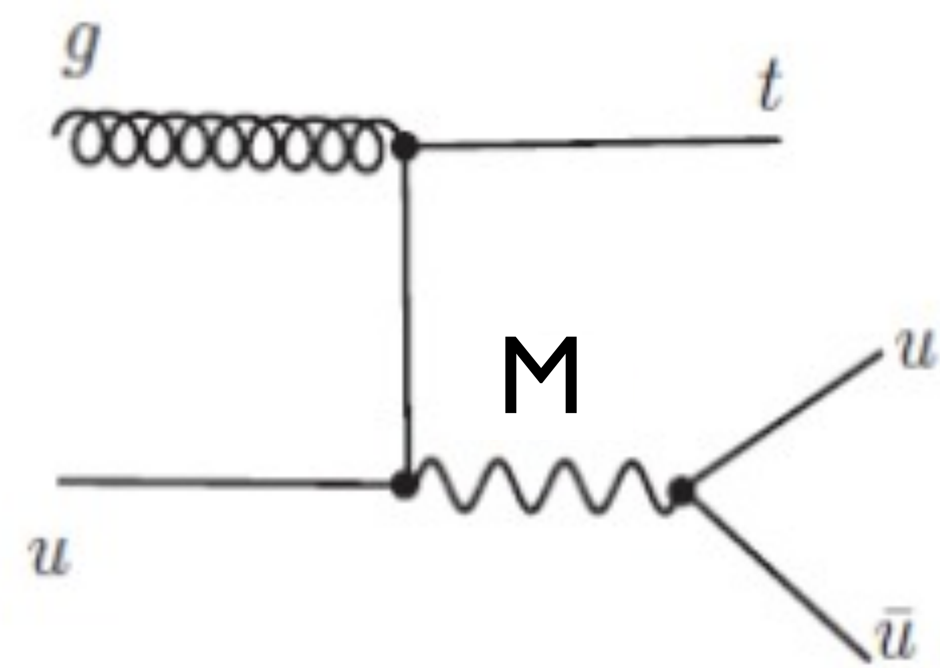
LHC result will come out soon.

One way out : Light t-channel mediator

Blum, Hochberg, Nir (1107.4350)

Jung, Pierce, Wells (1108.1802)





Hidden from ttbar event

It seems that this class of models are safe as long as M-q-q coupling is much suppressed compared with M-q-t.

Can Low Energy Observables constrain this model?

Conclusion

- Tevatron poses an intriguing question in top physics.

- Vector mediator t-channel model is preferred to explain AFB without interfering ttbar cross section at Tevatron.

- However, from good agreement of SM ttbar production at LHC, t-channel models with high mass mediator are endangered.

- Low mass t-channel models have a big constraint from low energy parity violation experiments.

See Sean's talk!

Top physics model builders are now being challenged. Does Nature demand a better imagination from us?

Thank You!