Strategies for BSM searches with top signatures

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TERAWORLD
UED
HIGGS
VTC
SUSY
LH


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Outline

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- The importance of being Top
- Top-down vs Bottom-up
- Resonant vs Effective Field Theory Approach
- Applications on SM and NEW observables : hot topics.

Top is special

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1. with a "natural mass":

$$m_{top} = y_t\, v/\sqrt{2} \approx 174\ \text{GeV} \Rightarrow y_t \approx 1$$

It "strongly" interacts with the Higgs sector. This also suggests that top might have special role in the mechanism of EWSB and/or fermion mass generation.

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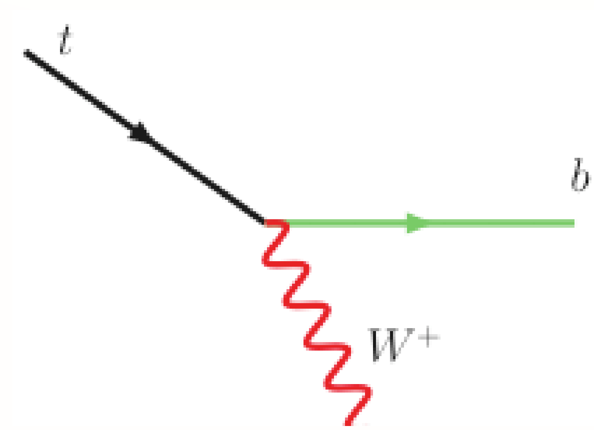
2. that decays before hadronizing

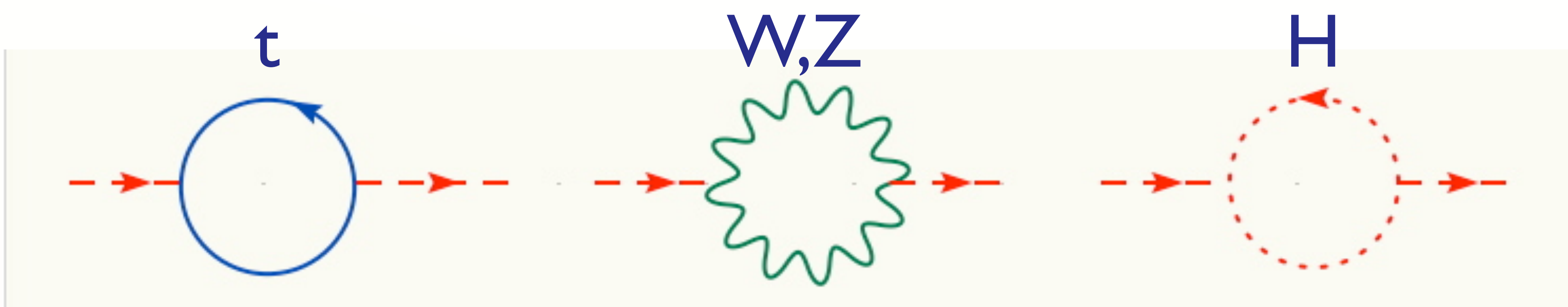


$\tau_{had} \approx h/\Lambda_{QCD} \approx 2 \cdot 10^{-24}$ s
$\tau_{top} \approx h/\,\Gamma_{top} = 1/(G_F\, m_t^3\, |V_{tb}|^2/8\pi\sqrt{2}) \approx 5 \cdot 10^{-25}$ s
(with $h=6.6\ 10^{-25}$ GeV s)

(Compare with $\tau_b \approx (G_F^2\, m_b^5\, |V_{bc}|^2\, k)^{-1} \approx 10^{-12}$ s)

Top as a link to BSM

The top quark dramatically affects the stability of the Higgs mass.
Consider the SM as an effective field theory valid up to scale Λ:



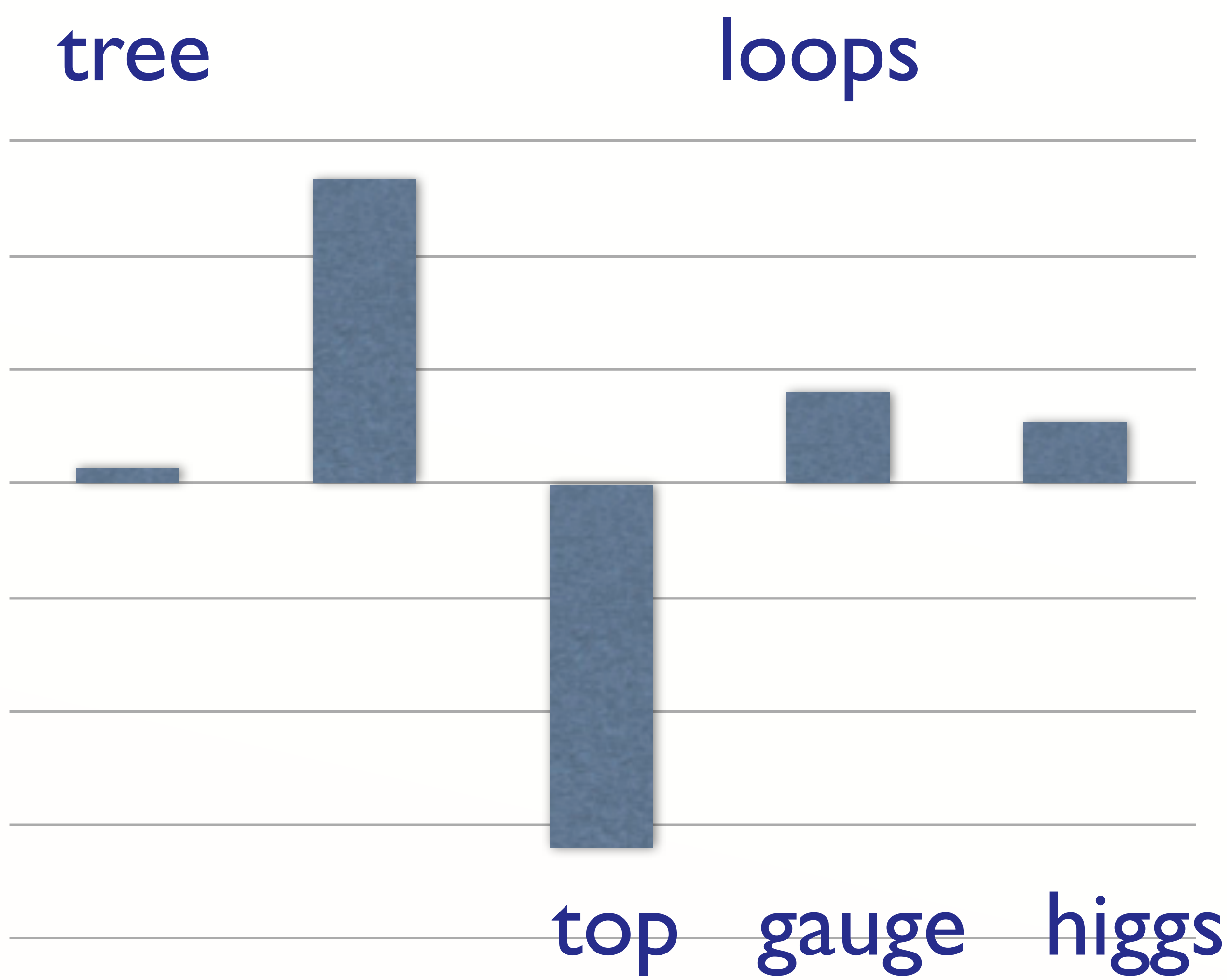
$$m_H^2 = m_{H0}^2 \qquad - \frac{3}{8\pi^2} y_t \Lambda^2 \qquad + \frac{1}{16\pi^2} g^2 \Lambda^2 \qquad + \frac{1}{16\pi^2} \lambda^2 \Lambda^2$$

Putting numbers, I have:

$$(200\,\mathrm{GeV})^2 = m_{H0}^2 + \left[-(2\,\mathrm{TeV})^2 + (700\,\mathrm{GeV})^2 + (500\,\mathrm{GeV})^2\right] \left(\frac{\Lambda}{10\mathrm{TeV}}\right)^2$$

Top as a link to BSM

$m_h^2 \sim (200\ \mathrm{GeV})^2$



$$(200\,\mathrm{GeV})^2 = m_{H0}^2 + \left[-(2\,\mathrm{TeV})^2 + (700\,\mathrm{GeV})^2 + (500\,\mathrm{GeV})^2\right]\left(\frac{\Lambda}{10\mathrm{TeV}}\right)^2$$

Definition of naturalness: less than 90% cancellation:

$$\Lambda_t < 3\,\mathrm{TeV} \qquad \Lambda_t < 9\,\mathrm{TeV} \qquad \Lambda_t < 12\,\mathrm{TeV}$$

One can actually prove that this case in model independent way, i.e. that the scale associated with top mass generation is very close to that of EWSB =>

Available solutions

There have been many different suggestions! Fortunately, we can say that they group in 1+3 large classes:

1. Denial: There is no problem.Naturalness is our problem not Nature's. Pro's: we'll find the Higgs. Cons: that's it.

2. Weakly coupled model at the TeV scale:
Introduce new particles to cancel SM "divergences".

3. Strongly coupled model at the TeV scale:
New strong dynamics enters at ~1TeV.

4. New space-time structure:
Introduce extra space dimensions to lower the Planck scale cutoff to 1 TeV.

Top is the only natural quark

Top parters, new scalars/vectors possibly strongly coupled with top.

Top: t-tbar bound states, colorons. Top is not elementary

KK-excitations

Wednesday 18 May 2011

Top-down approach

New Physics

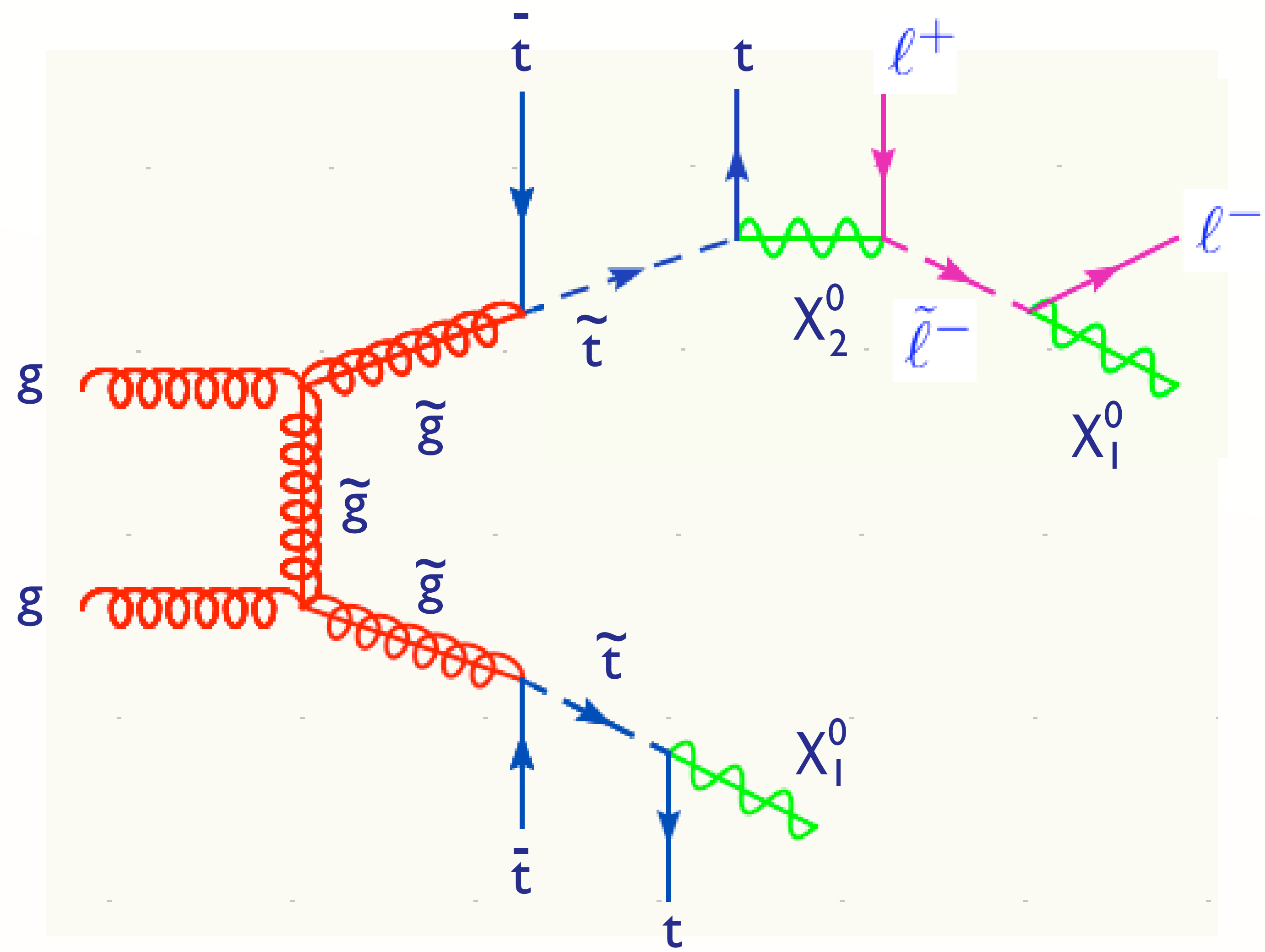
Signatures/Observables

Top-down approach

New Physics

Signatures/Observables

Top-down approach



* New Physics model with top partners (SUSY, UED, LH, 4th Gen)

* Identify the signatures with top, SM like or exotic.

* Look for them using benchmark points.

* Set exclusion limits on the model parameters

* Optional : learn "model independent" lessons...

Top-down approach: Examples

- $\tilde{t}\tilde{t}^* \to t\bar{t} + X$, $\tilde{g}\tilde{g} \to t\bar{t}\ (\bar{t}t) + X$
- $b'\bar{b}' \to t\,\bar{t}\,W^- W^+$
- $t'\bar{t}' \to b\,\bar{b}\,W^+ W^-$
- $t'\bar{t}' \to Z\,Z\,t\,\bar{t}$
- 4tops

In general, very rich and energetic final states, large H_T ,
very spectacular and "easy" to detect in principle. Looks great, if one model at the time is studied.
In fact, very difficult to discriminate which NP leads to it.

Bottom-up approach

New Physics

Signatures/Observables

Bottom-up approach

New Physics

Signatures/Observables

Bottom-up

Model independent (bottom-up) strategy for New Physics :

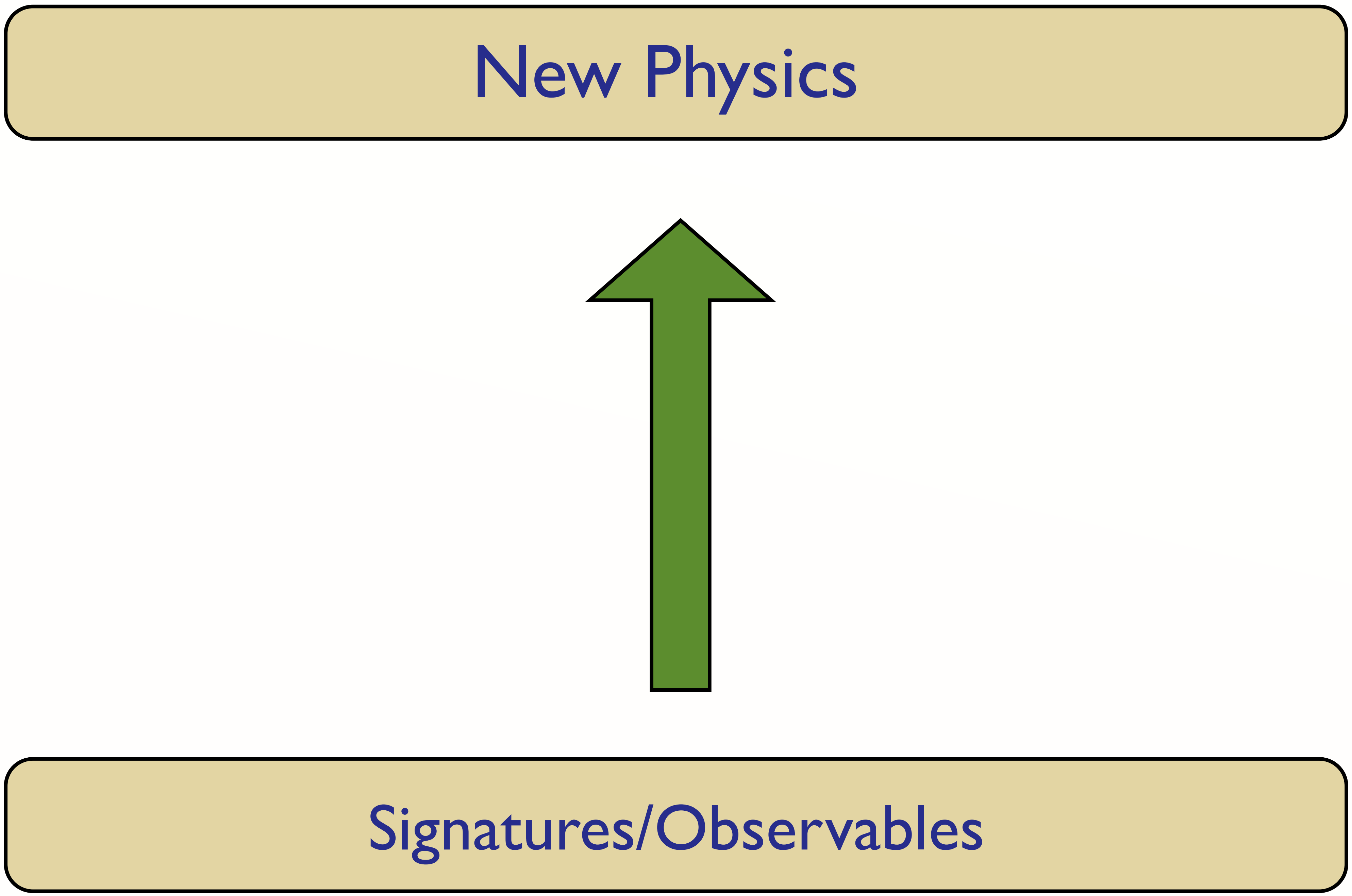
1. Focus on a specific SM observable that is

   a. naturally sensitive to BSM
   b. is well-predicted & possibly "background free"

   and look for deviations

2. Look for "exotic top signatures" (no-SM equivalent),
Example: same sign tops.

Bottom-up approach



Model Independent BSM searches (bottom-up)

New Physics

Signatures/Observables

Model Independent BSM searches (bottom-up)

New Physics

Standard

Signatures/Observables

Model Independent BSM searches (bottom-up)

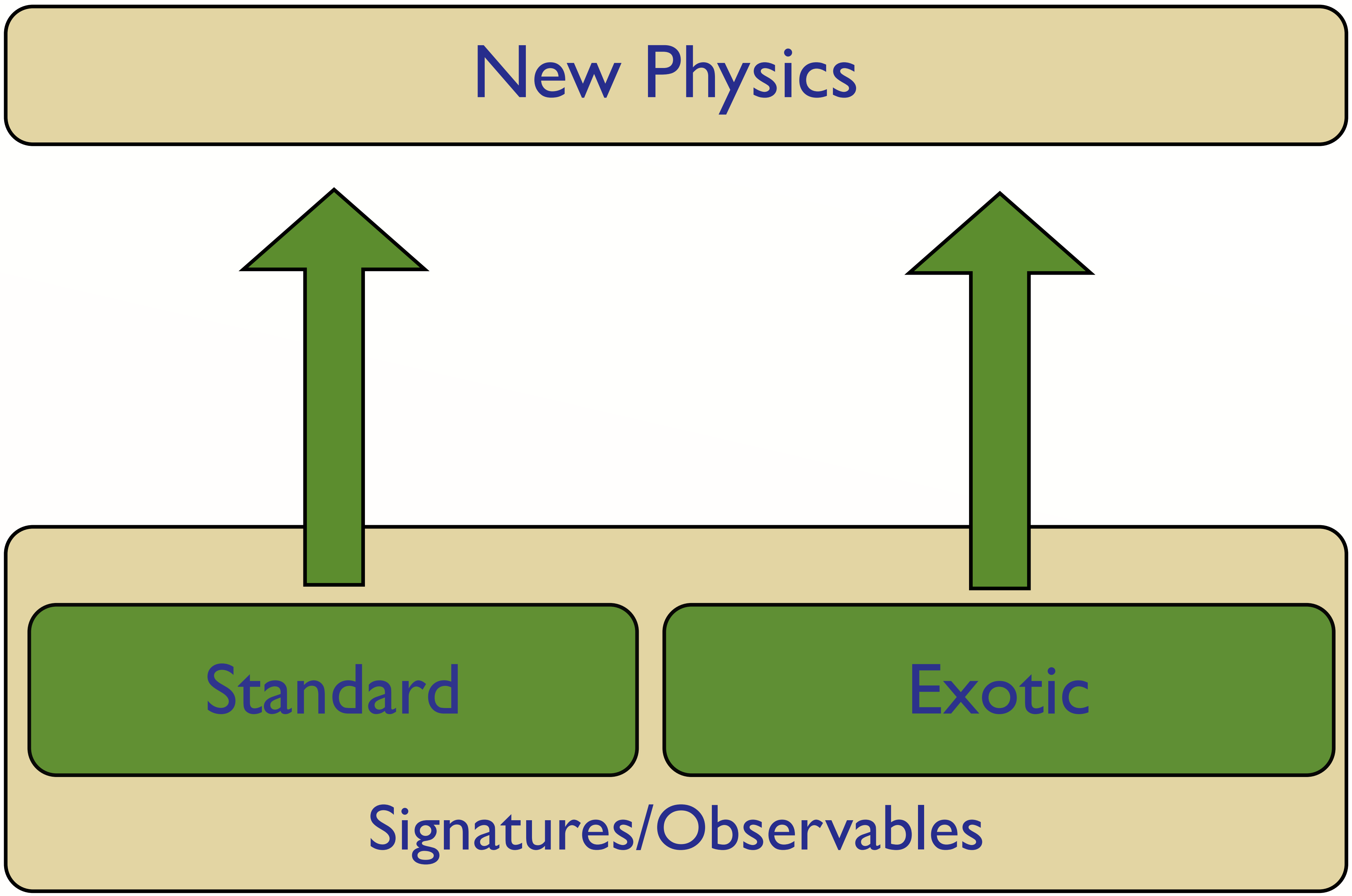
New Physics

Standard

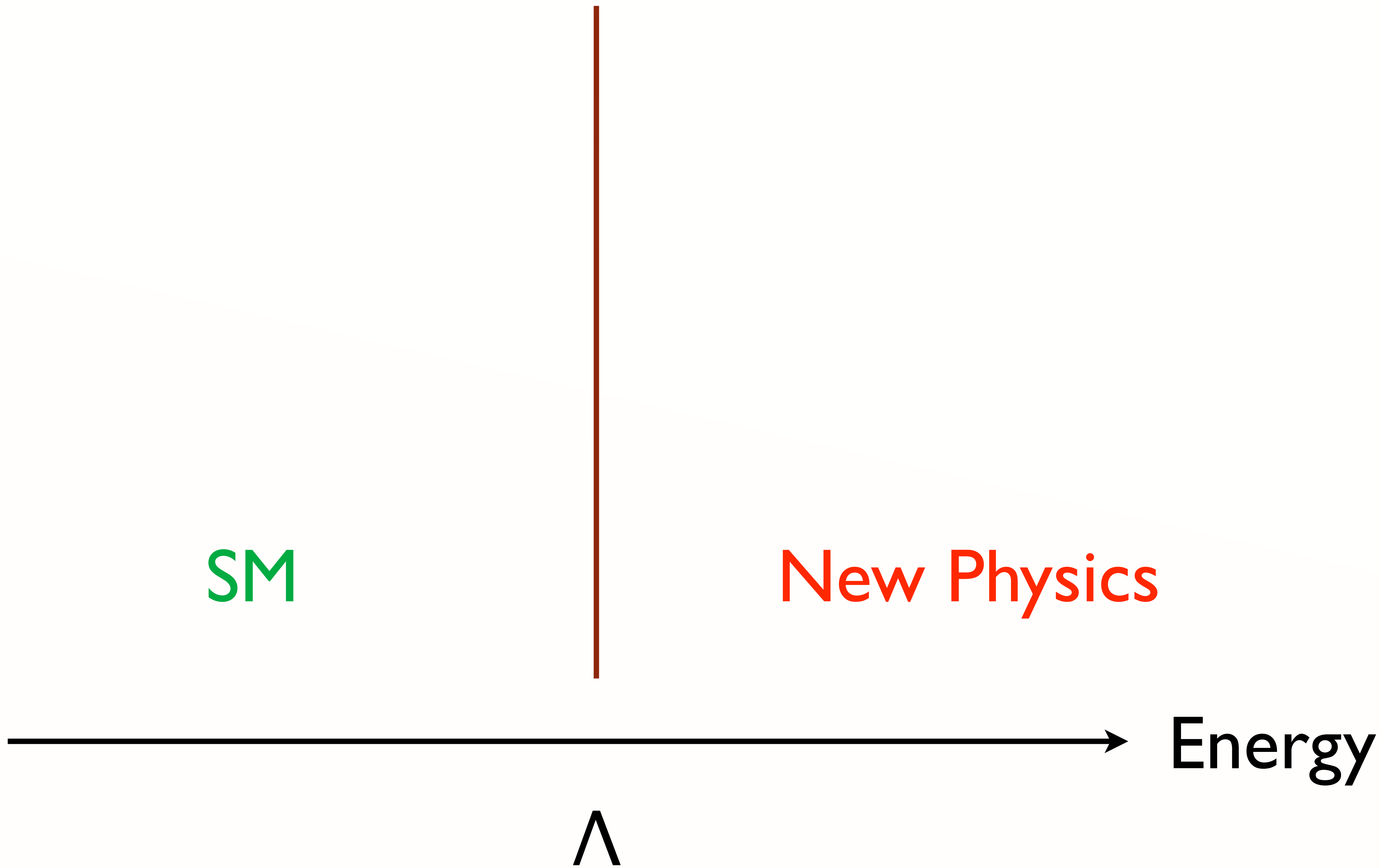
Exotic

Signatures/Observables

Model Independent BSM searches (bottom-up)



New Physics : Two possibilities



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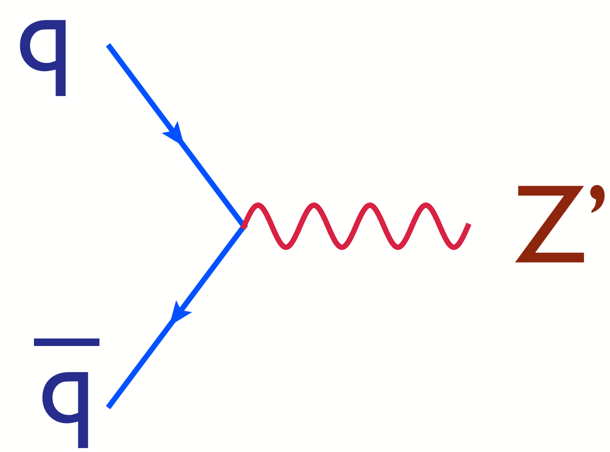


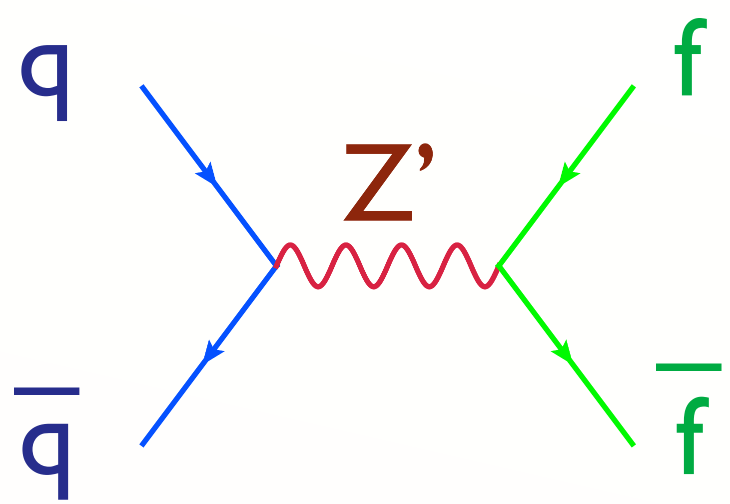
SM

New Physics

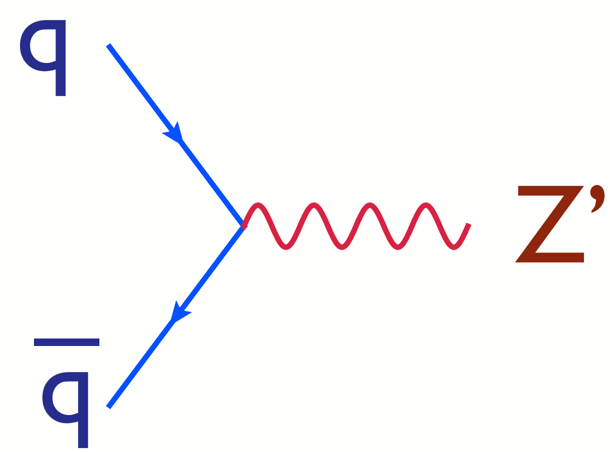
Energy

Λ

New Physics : Two possibilities



SM



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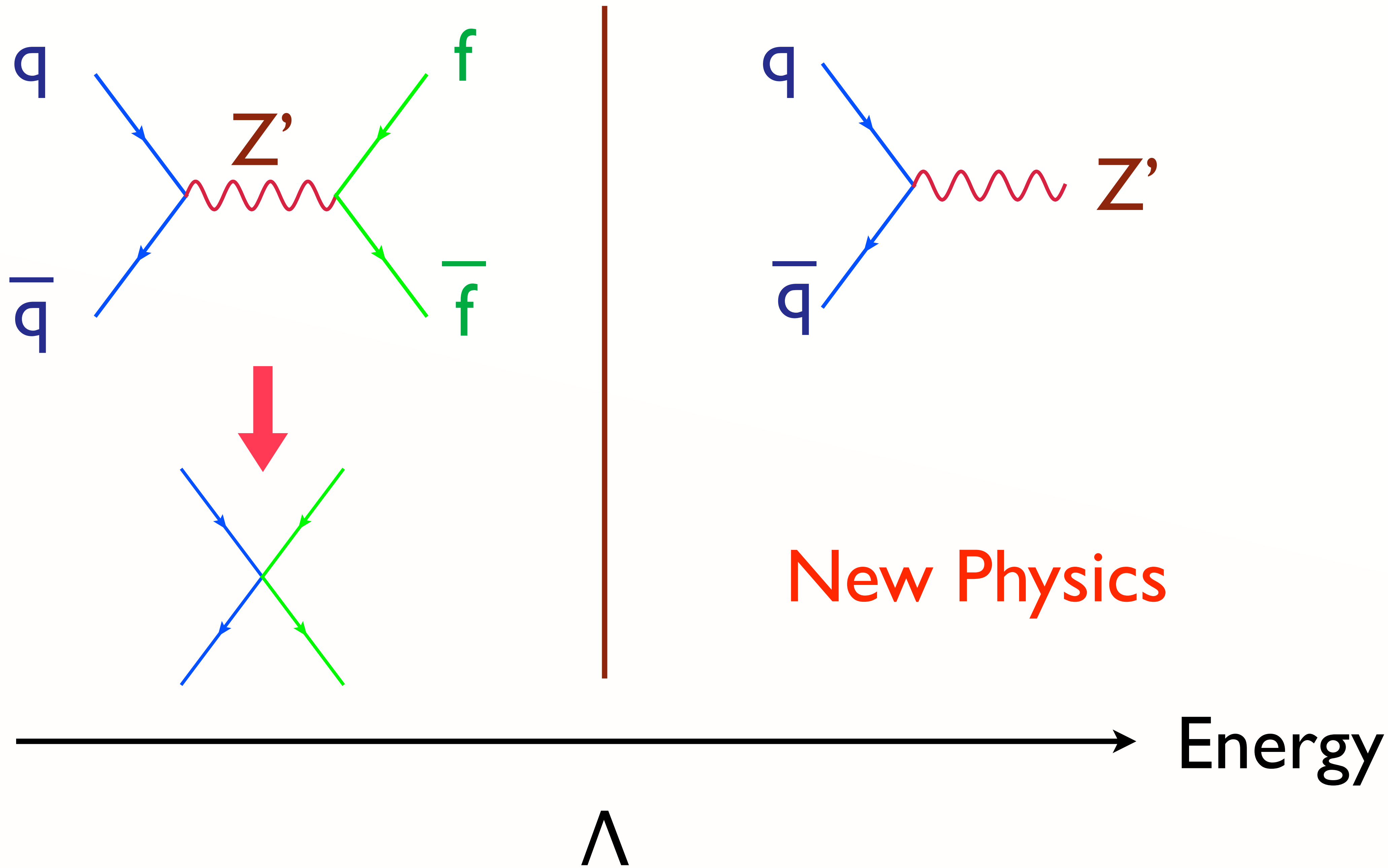

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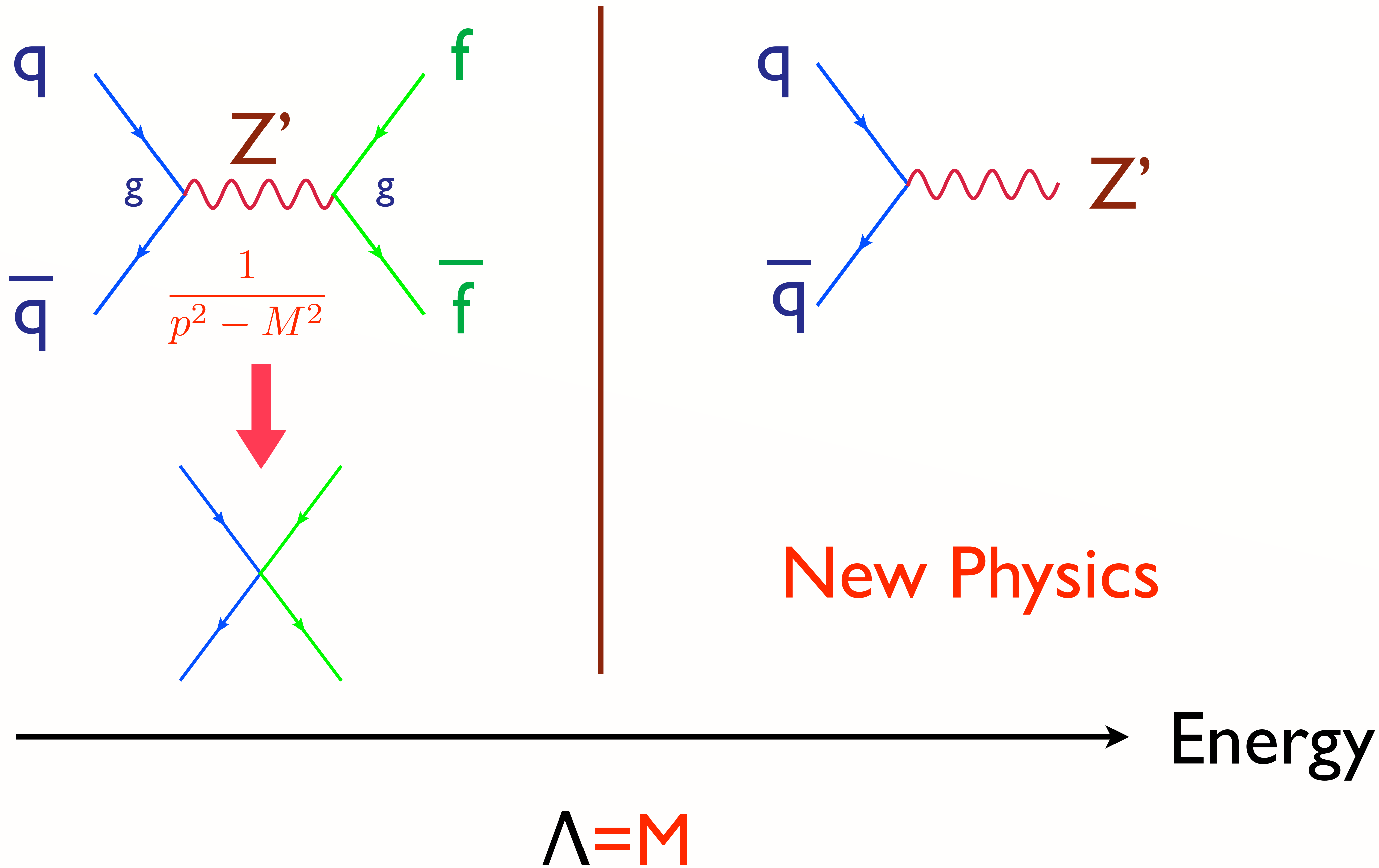

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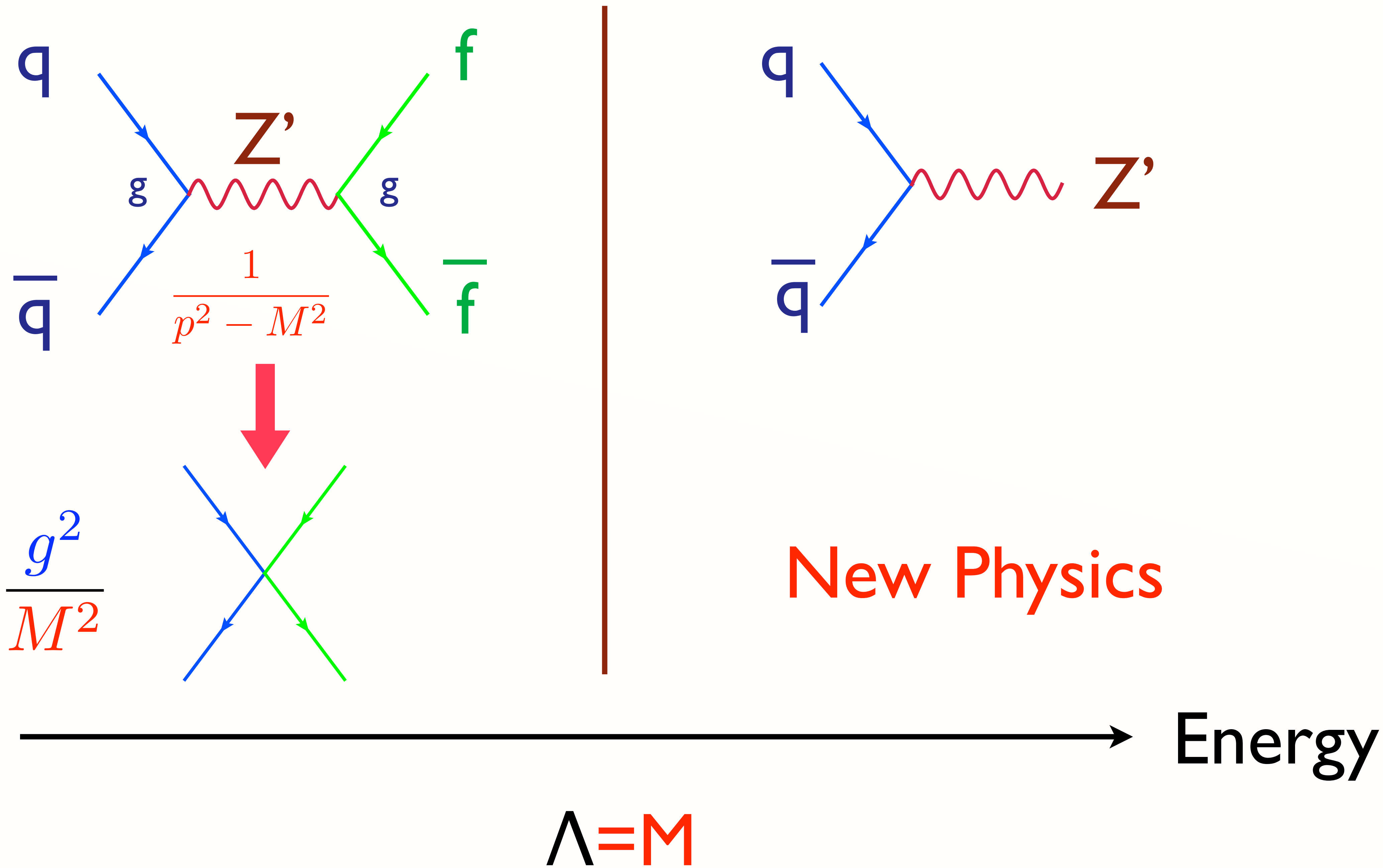
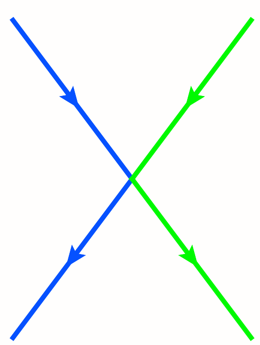


New Physics : Two possibilities

$$\frac{g^2}{M^2}$$



$$\mathcal{L}_{eff} = \mathcal{L}_{SM} + \frac{g^2}{M^2}\bar{\psi}\psi\bar{\psi}\psi$$

Dimensional analysis

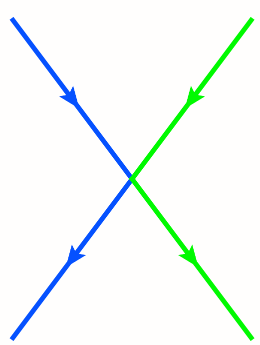
$$\hbar = c = 1$$

$$\dim A^\mu = 1$$

$$\dim \phi = 1$$

$$\dim \psi = 3/2$$

$$\frac{g^2}{M^2}$$

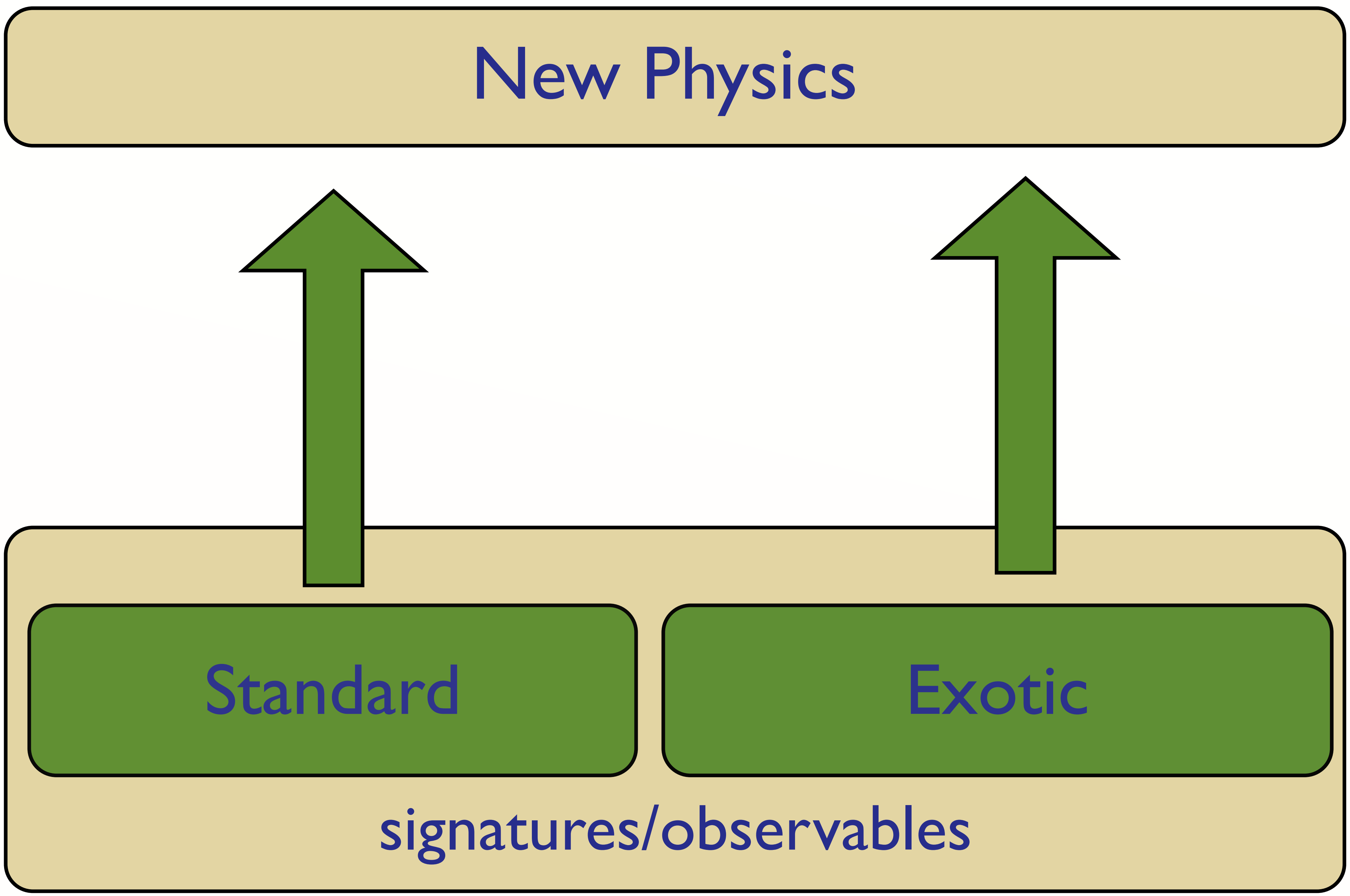


$$\mathcal{L}_{eff} = \mathcal{L}_{SM} + \sum_i \frac{c_i}{\Lambda^2} \mathcal{O}_i^{\mathrm{dim}=6}$$

Bad News: > 60 operators [Buchmuller, Wyler, 1986]

Good News : an handful are unconstrained and can signifcantly contribute to top physics!

Model Independent BSM searches (bottom-up)



Model Independent BSM searches

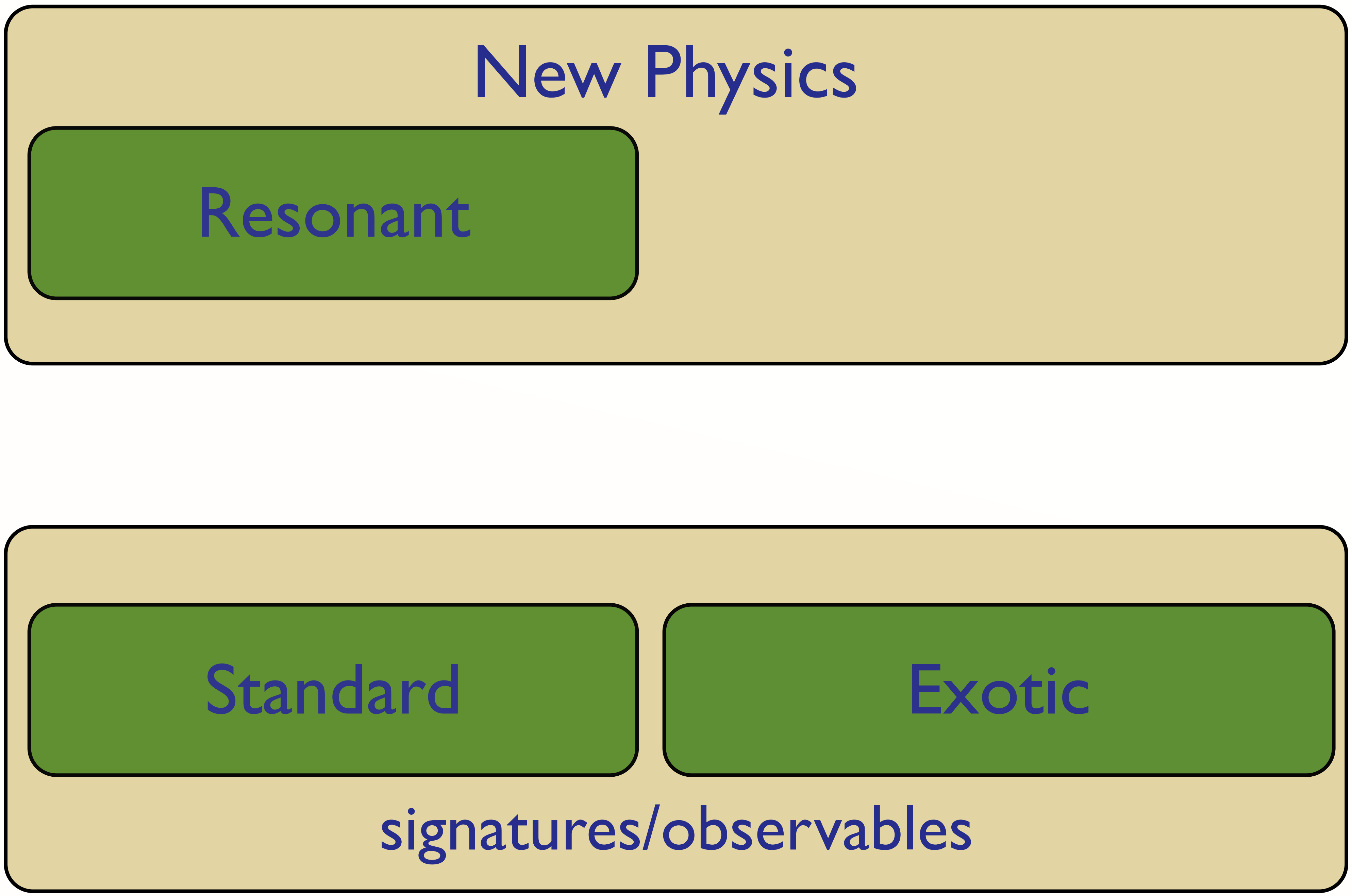
New Physics

Standard

Exotic

signatures/observables

Model Independent BSM searches



Model Independent BSM searches

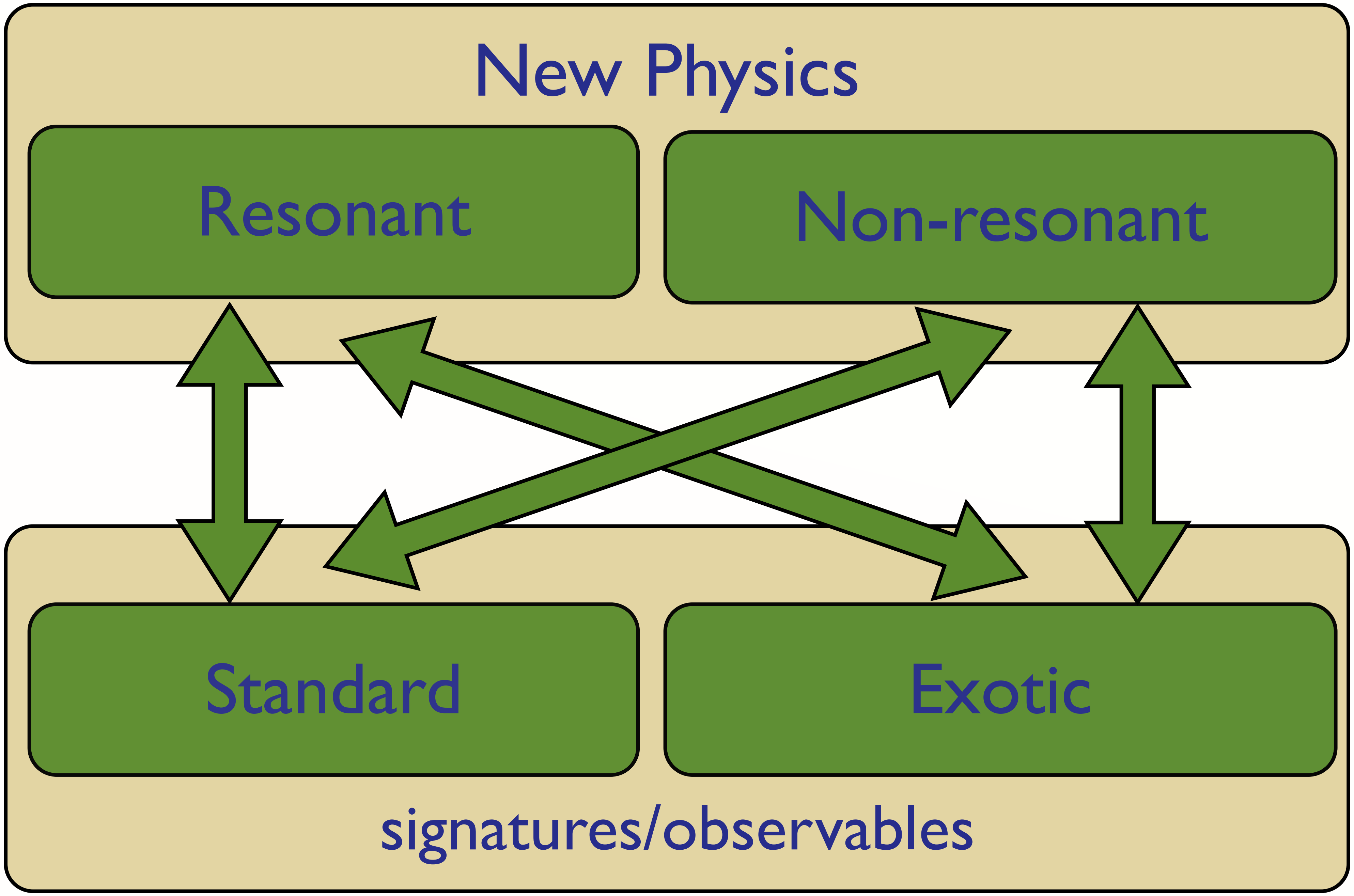
New Physics

Resonant | Non-resonant

Standard | Exotic

signatures/observables

Model Independent BSM searches



Model Independent BSM searches Examples

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II. Non-Resonant NP in ttbar [Degrande, Gerard, Grojean,FM, Servant, **arXiv:1010.6304**]

III. Exotic: Same sign tops [Degrande, Gerard, Grojean,FM, Servant, **arXiv:1104.1798**]

IV. Exotic: Monotops [Andrea, Fuks, FM, **wip**]

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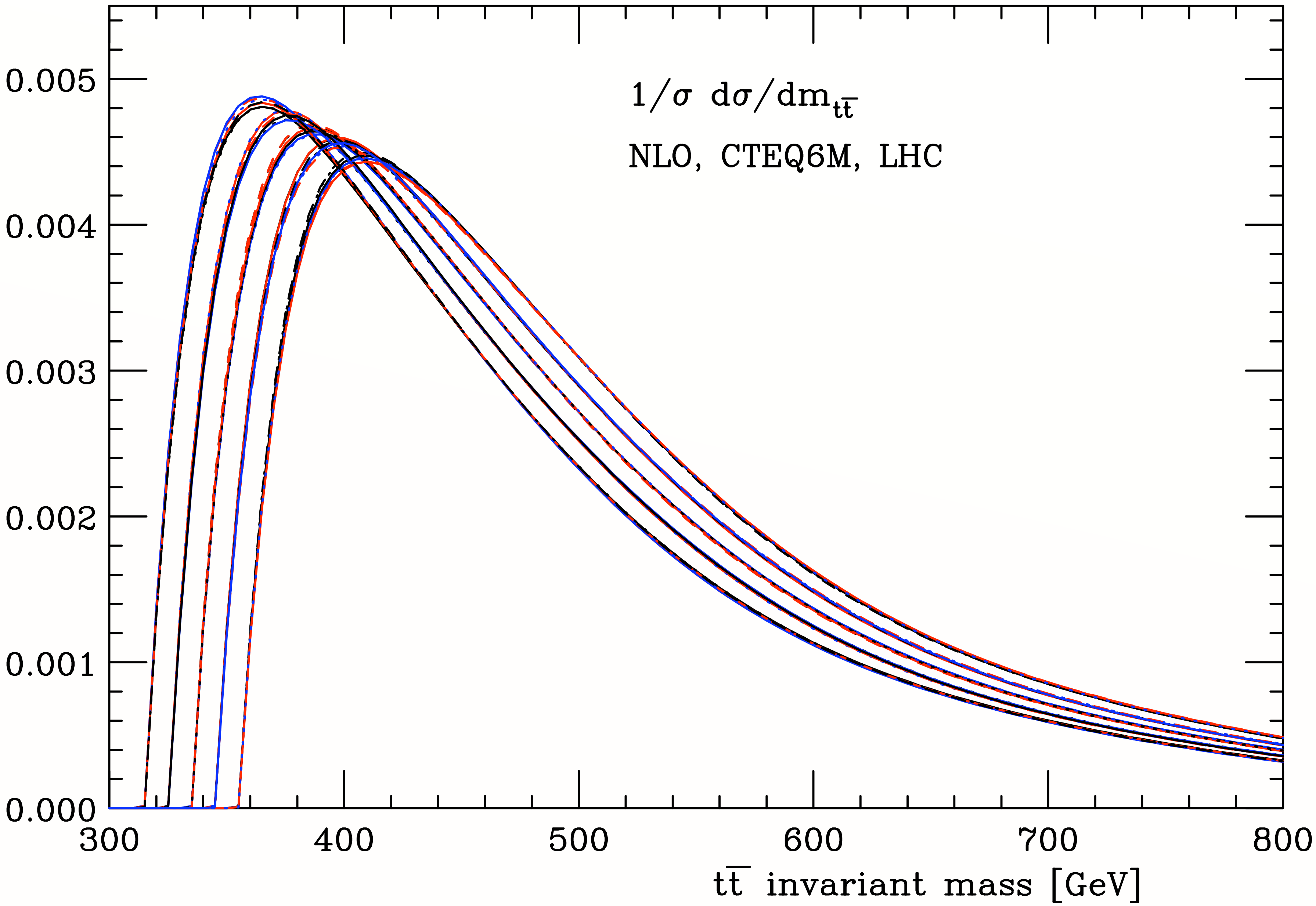
dσ/dm$_{tt}$: shape differences



Interesting observable.

Shape very well predicted.

This could be also used to measure the top mass!

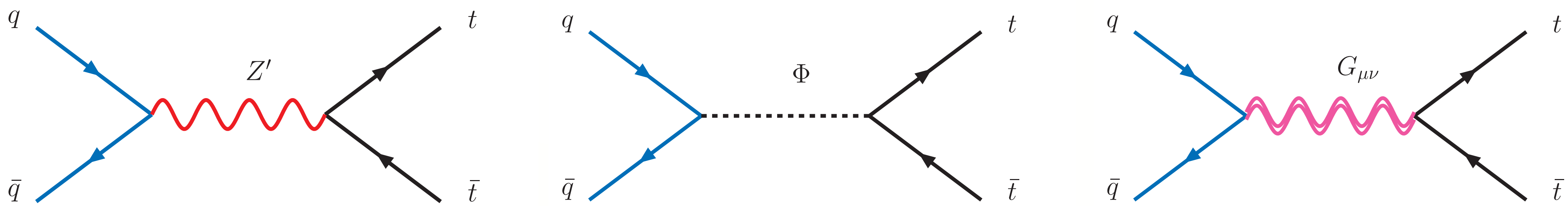
Reconstruction systematics is different from the usual top mass invariant mass reconstruction.

Any BSM effect would distort this shape =>

Model independent search for new Physics!

New resonances

In many scenarios for EWSB new resonances show up, some of which preferably couple to 3rd generation quarks.



Given the large number of models, in this case is more efficient to adopt a "model independent" search and try to get as much information as possible on the quantum numbers and coupling of the resonance.

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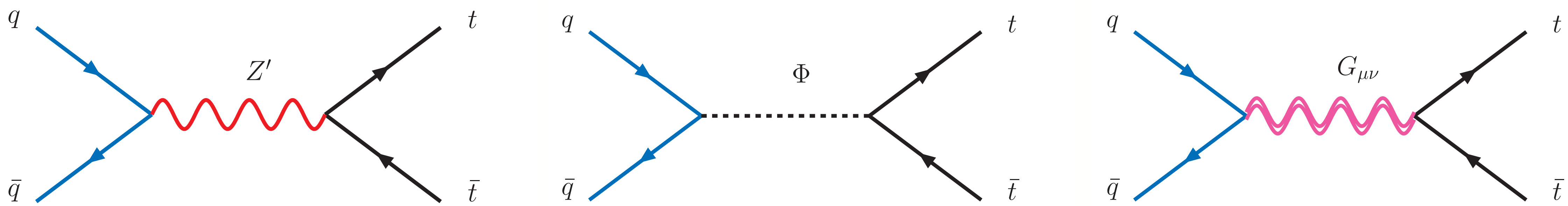

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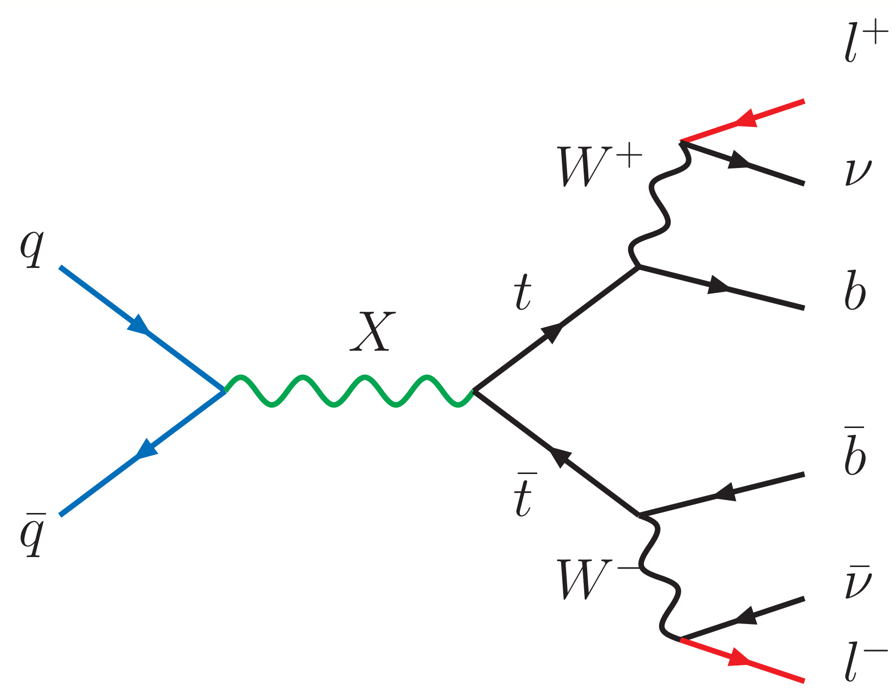
To access the spin of the intermediate resonance spin correlations should be measured.

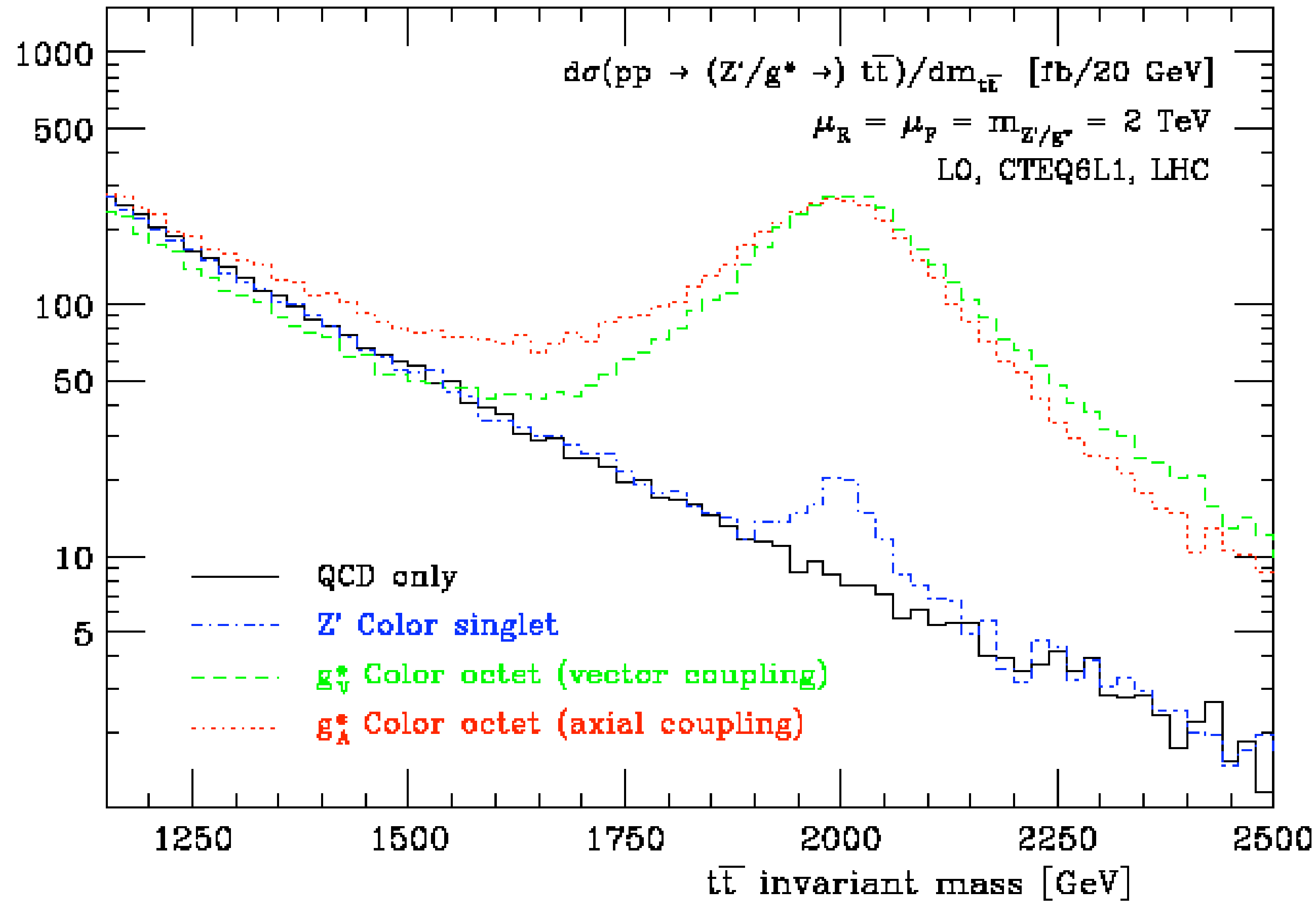
It therefore mandatory for such cases to have MC samples where spin correlations are kept and the full matrix element pp>X>tt>6f is used.



Zoology of new resonances

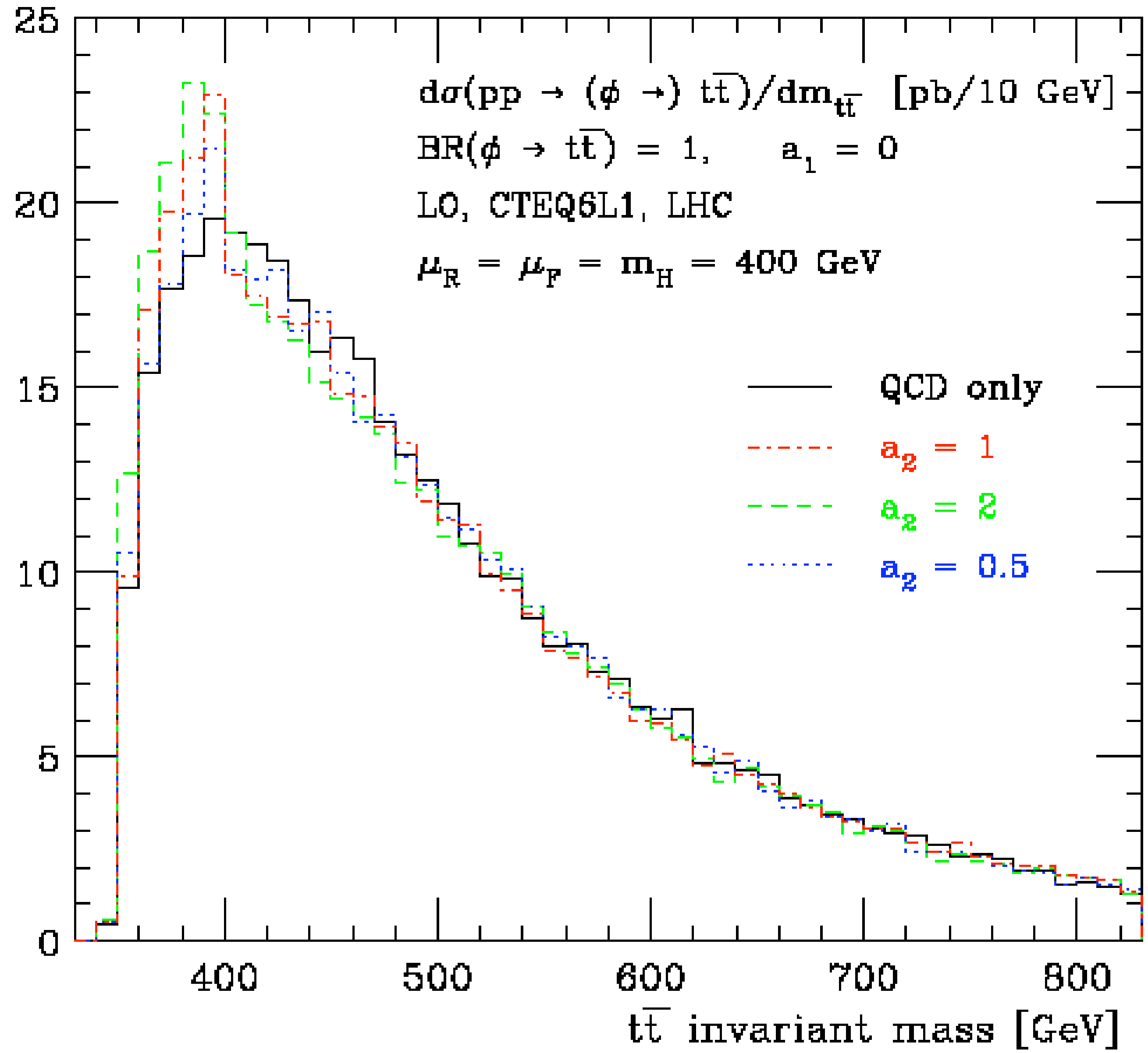
Spin	Color	$(1,\gamma_5)$ [L,R]	SM-interf	Example
0	0	(1,0)	no	Scalar
	0	(0,1)	no	PseudoScalar
	0	(0,1)	yes	Boso-phobic
	8	(0,1),(1,0)	no	Techni-pi0[8]
1	0	[sm,sm]	yes/no	Z’
	0	(1,0),(0,1)(1,1),(1,-1)	yes	vector
	8	(1,0)	yes	coloron/kk-gluon
	8	(0,1)	“yes”	axigluon
2	0	--	yes	kk-graviton

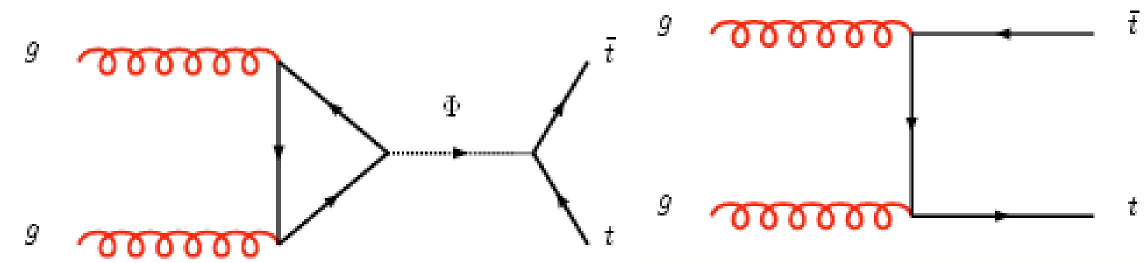
Phase 1: discovery

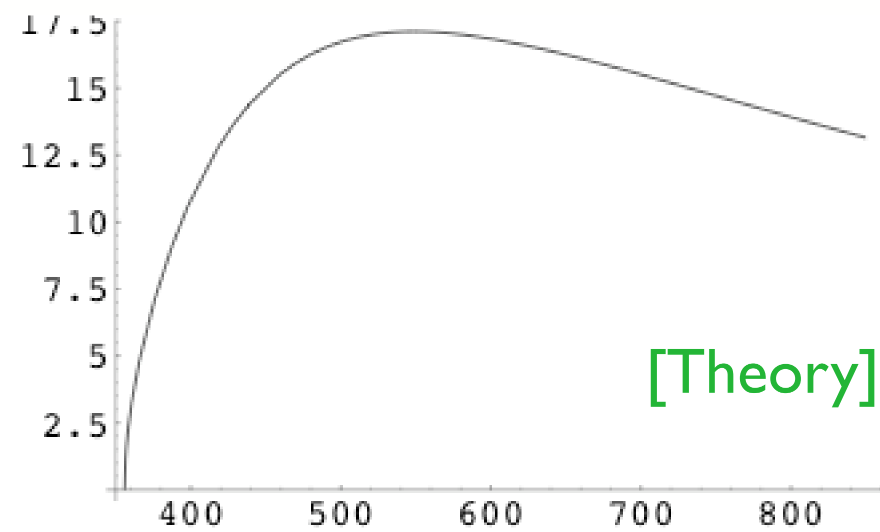


* Vector resonance, in a color singlet or octet states.
* Widths and rates very different
* Interference effects with SM ttbar production not always negligible
* Direct information on σ•Br and Γ.

Phase 1: discovery







Non-trivial behavior (peak-dip) due to the interference between the signal and the background, only if top width dominated by $\phi \to tt$. [Dicus, Stange & Willenbrock 1994]

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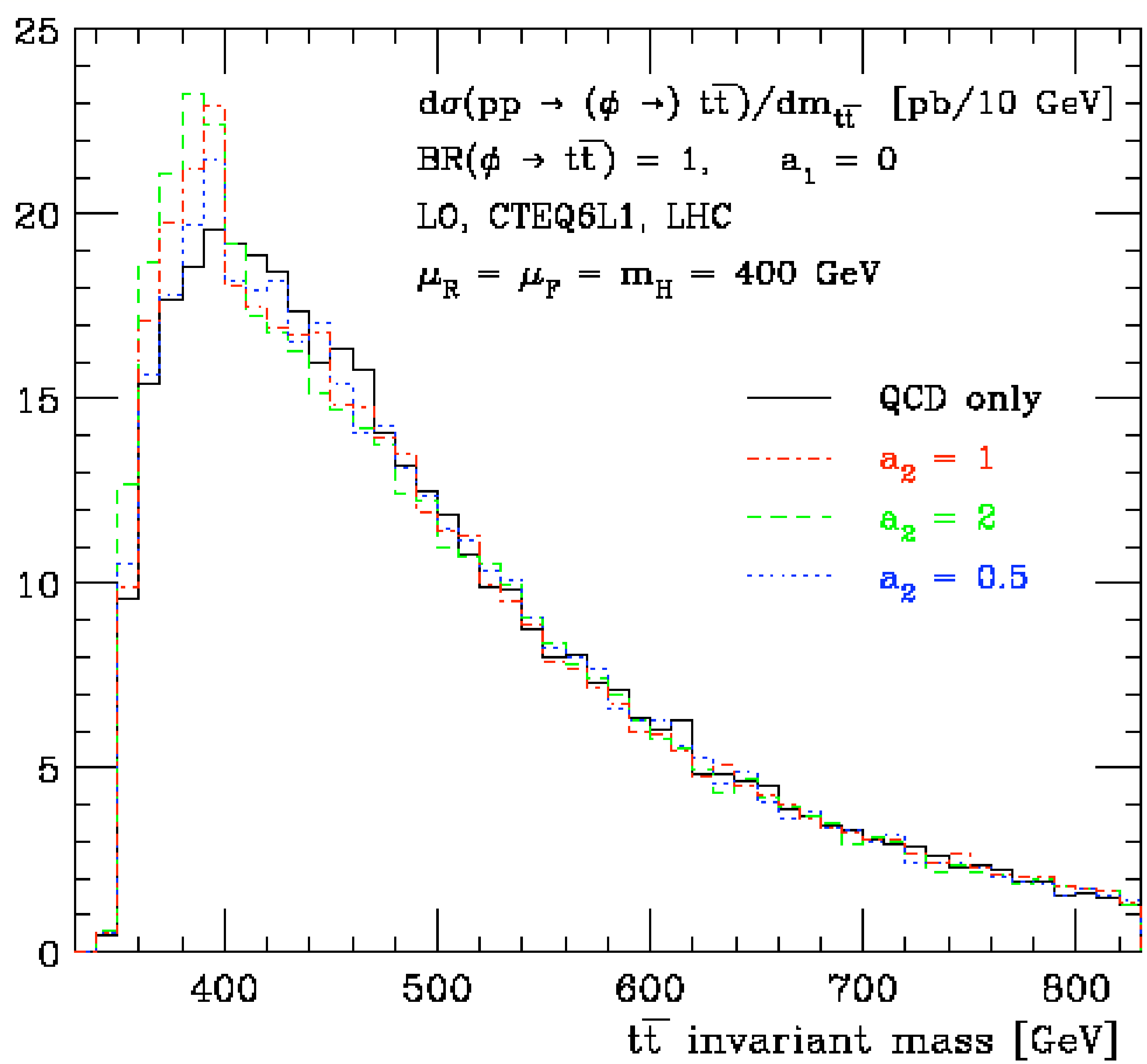

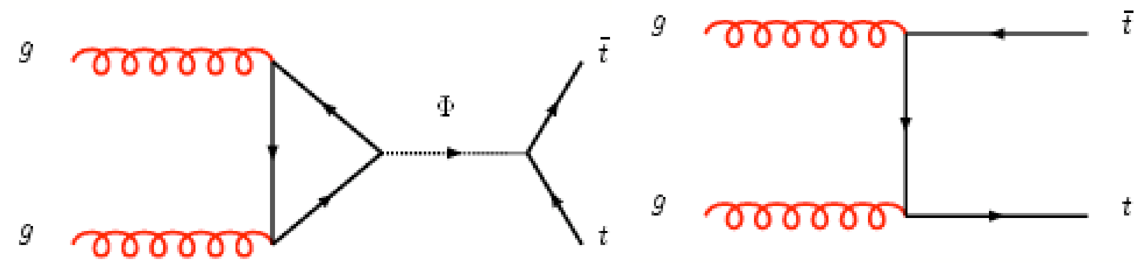

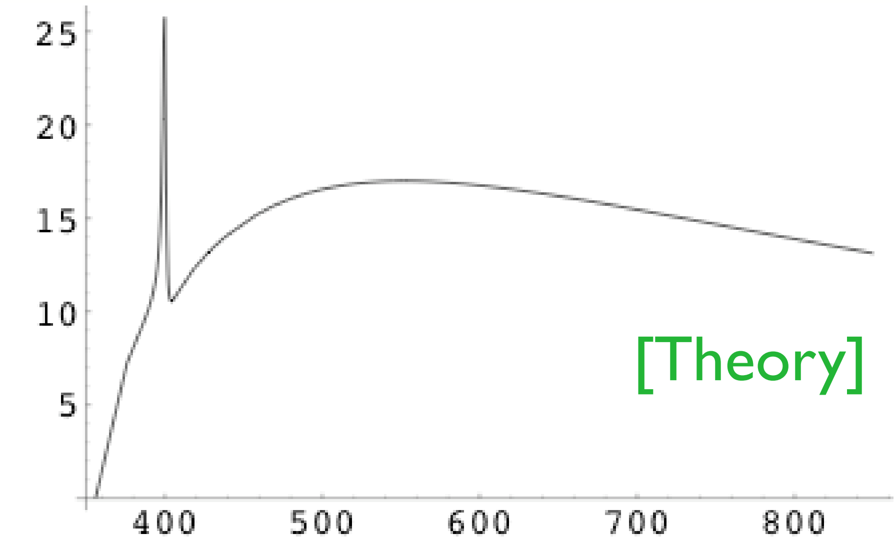

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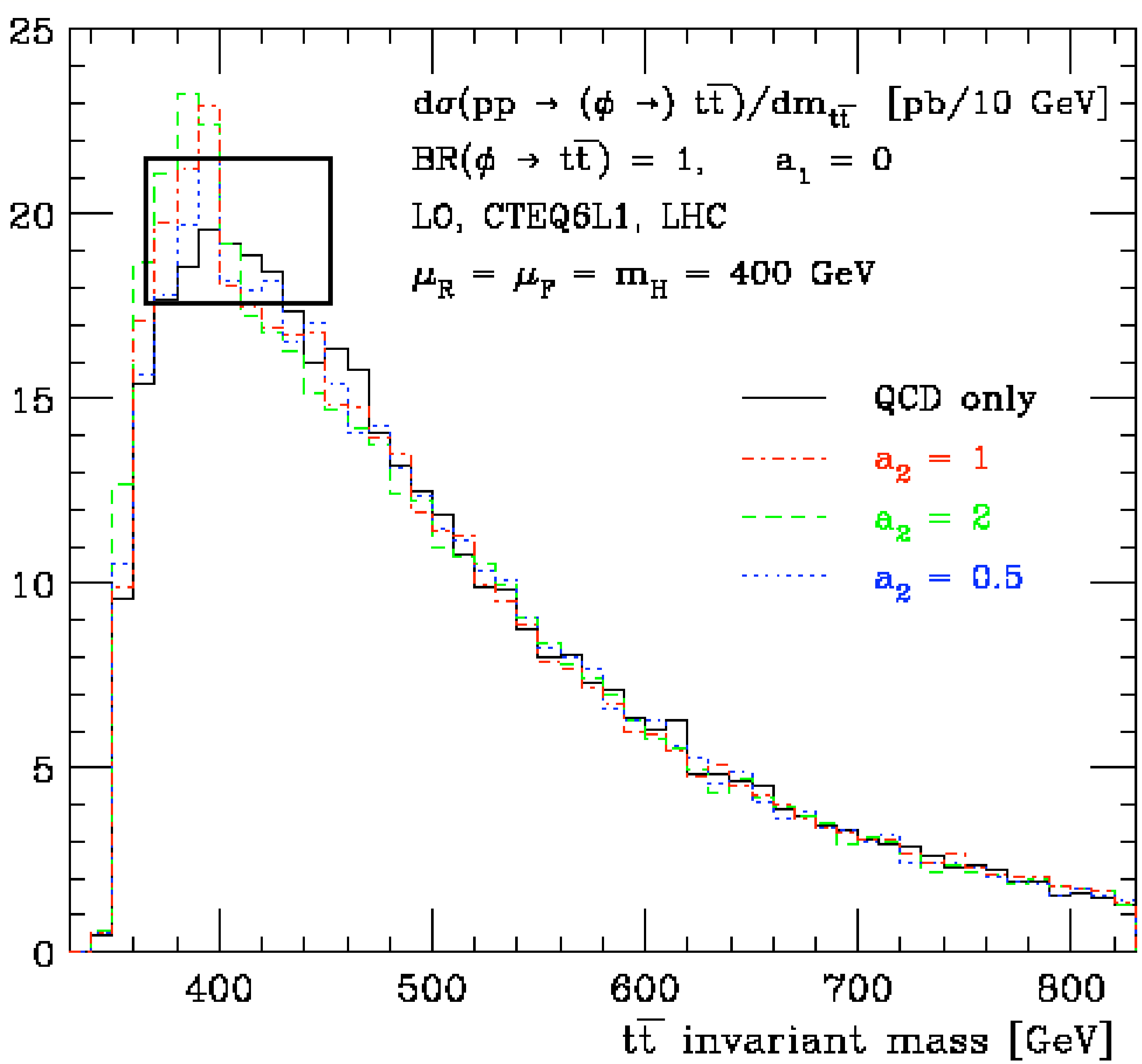

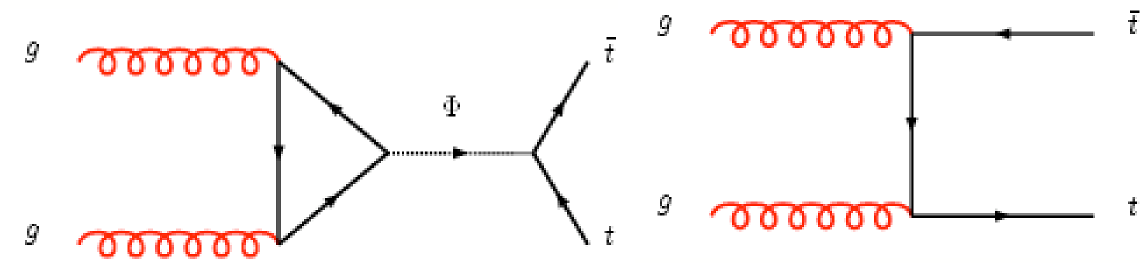

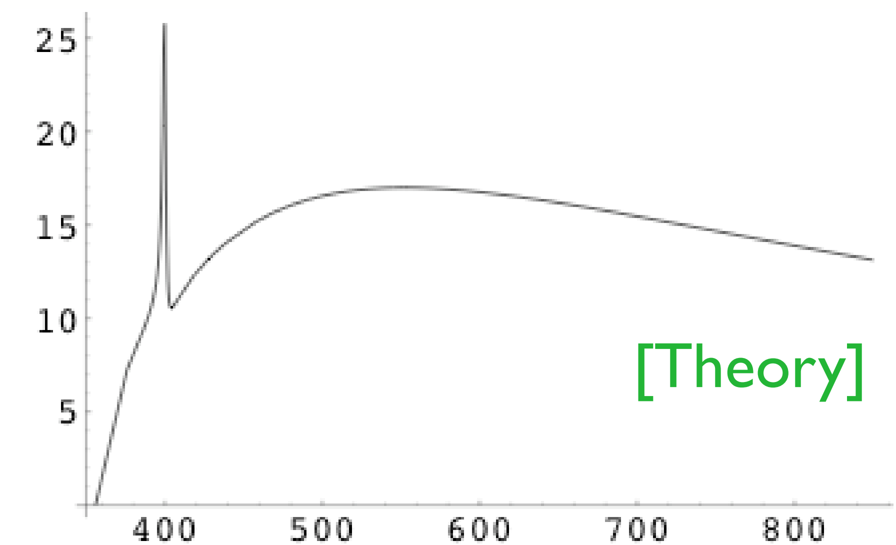

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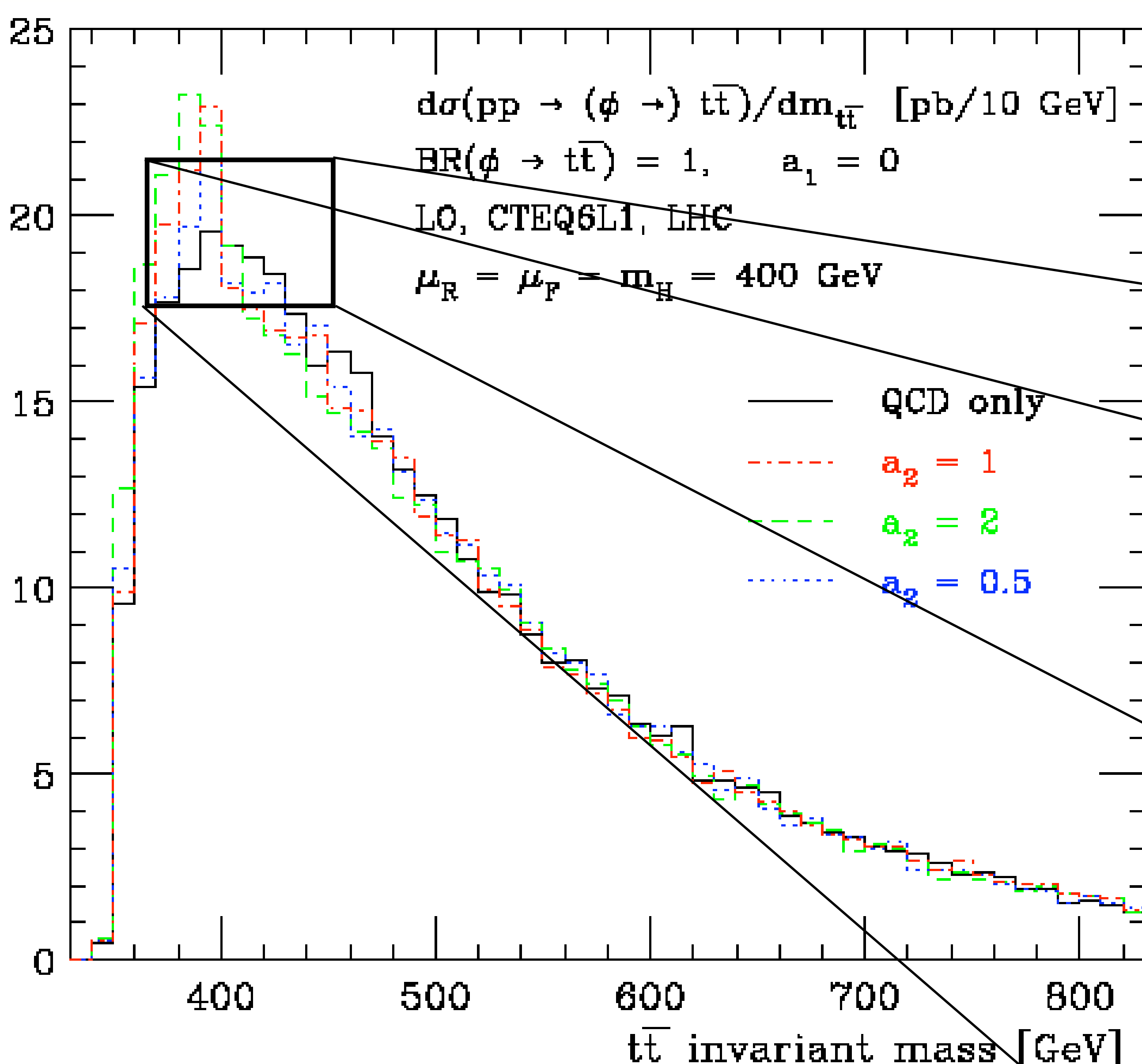

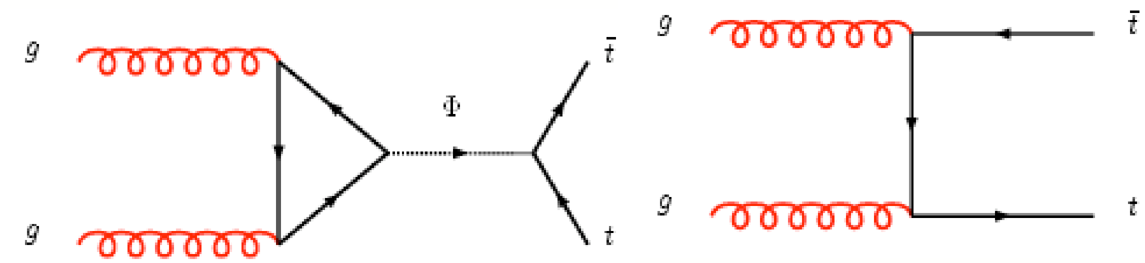

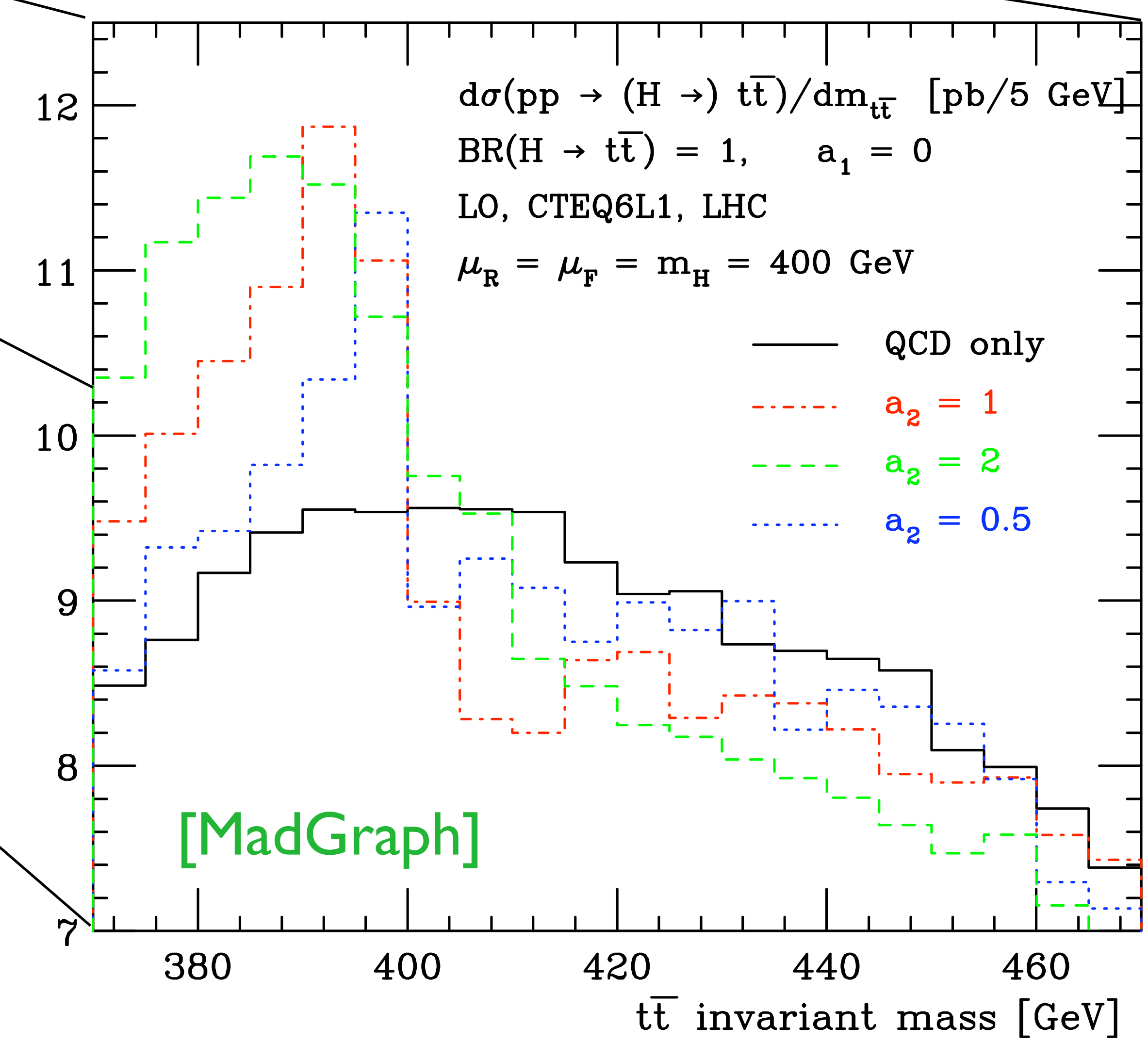

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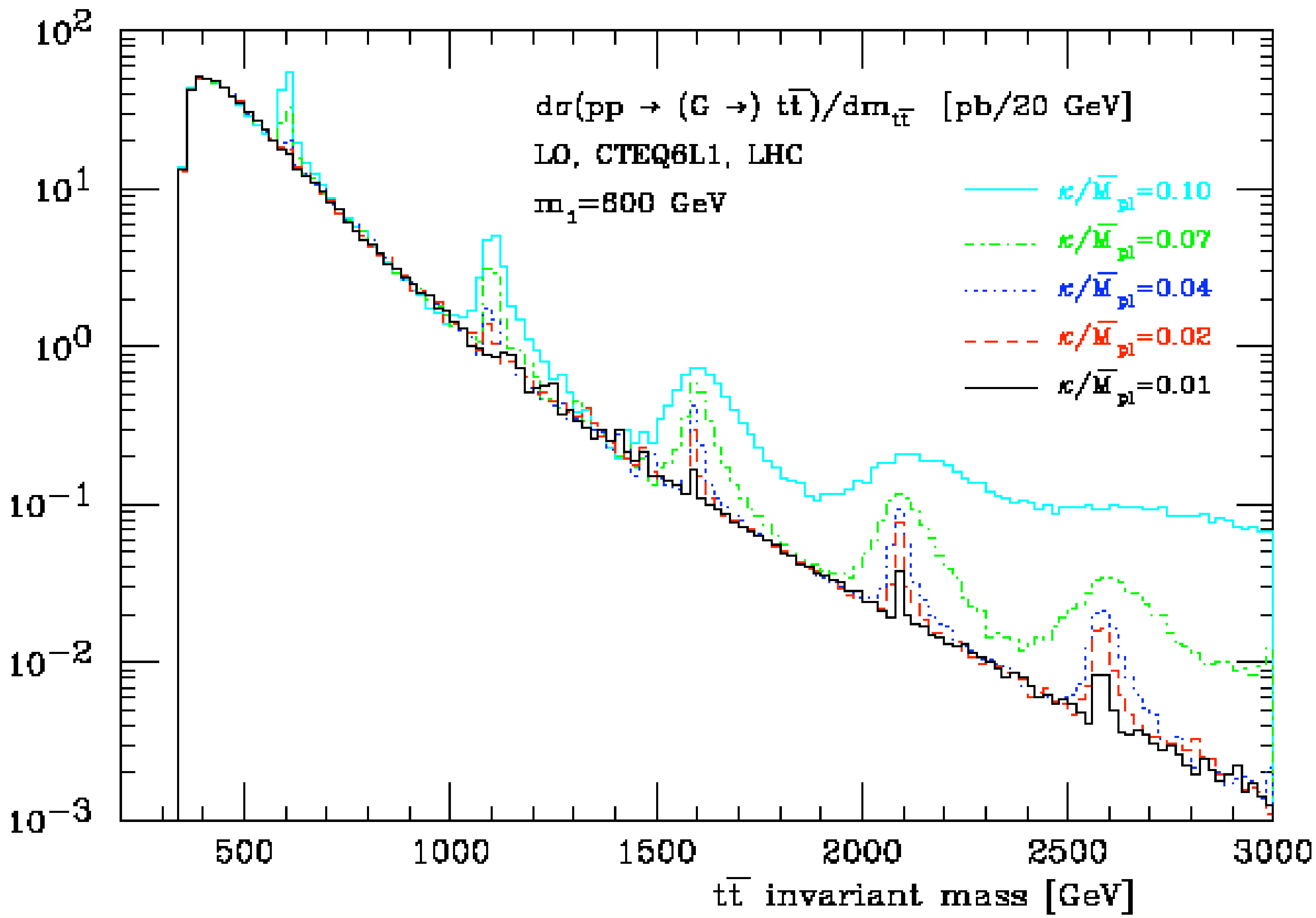
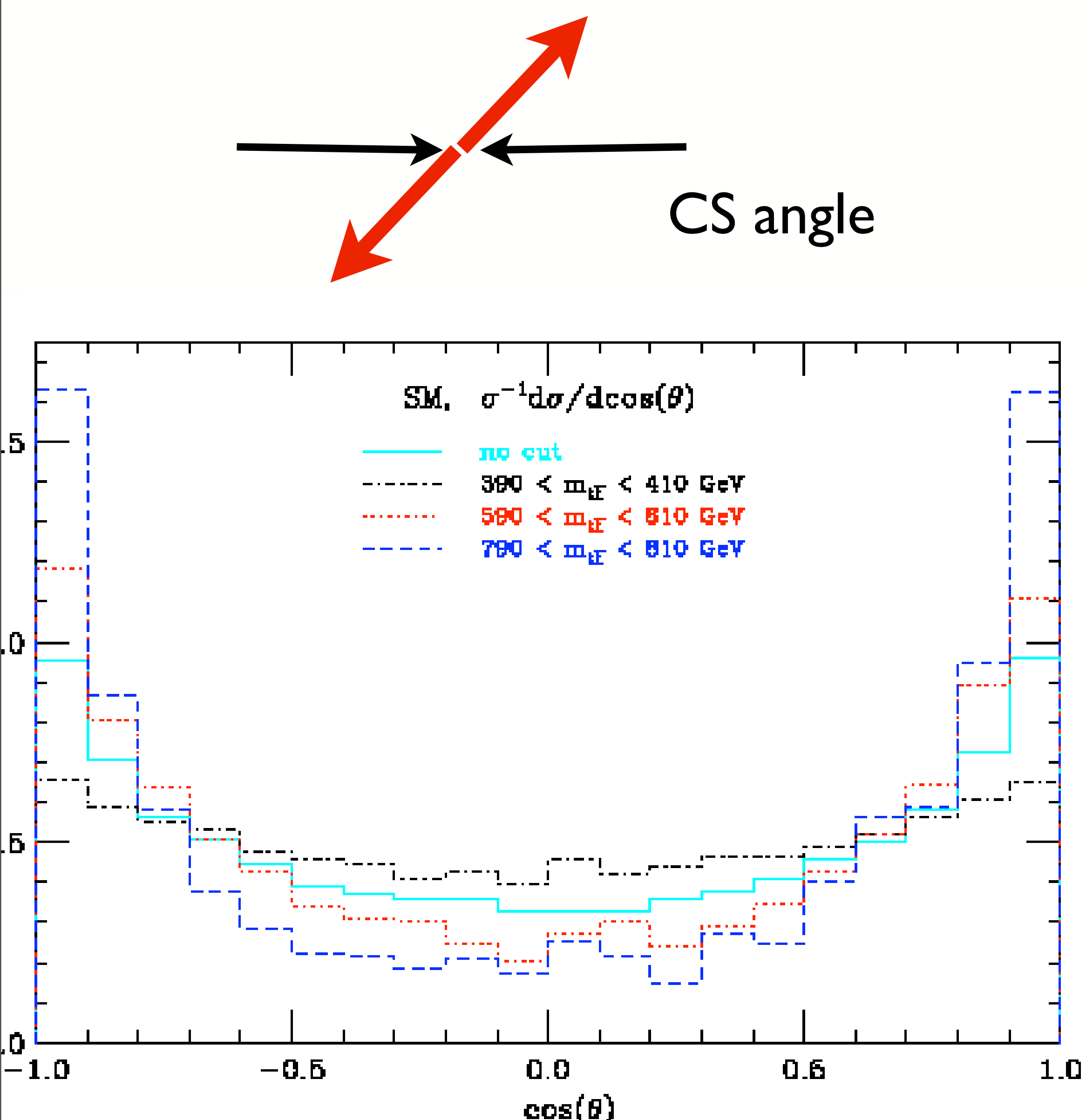


* Spectacular signature!

*RS Model with first KK=600 GeV

Phase 2: ttbar angular distributions



Robust reconstruction needed, but much easier than spin correlations...

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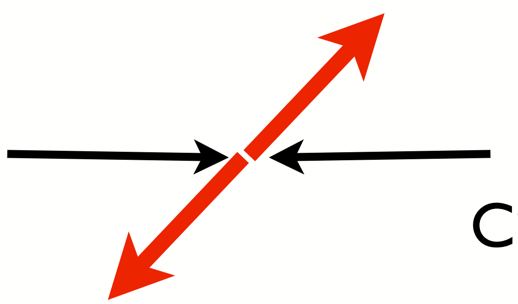
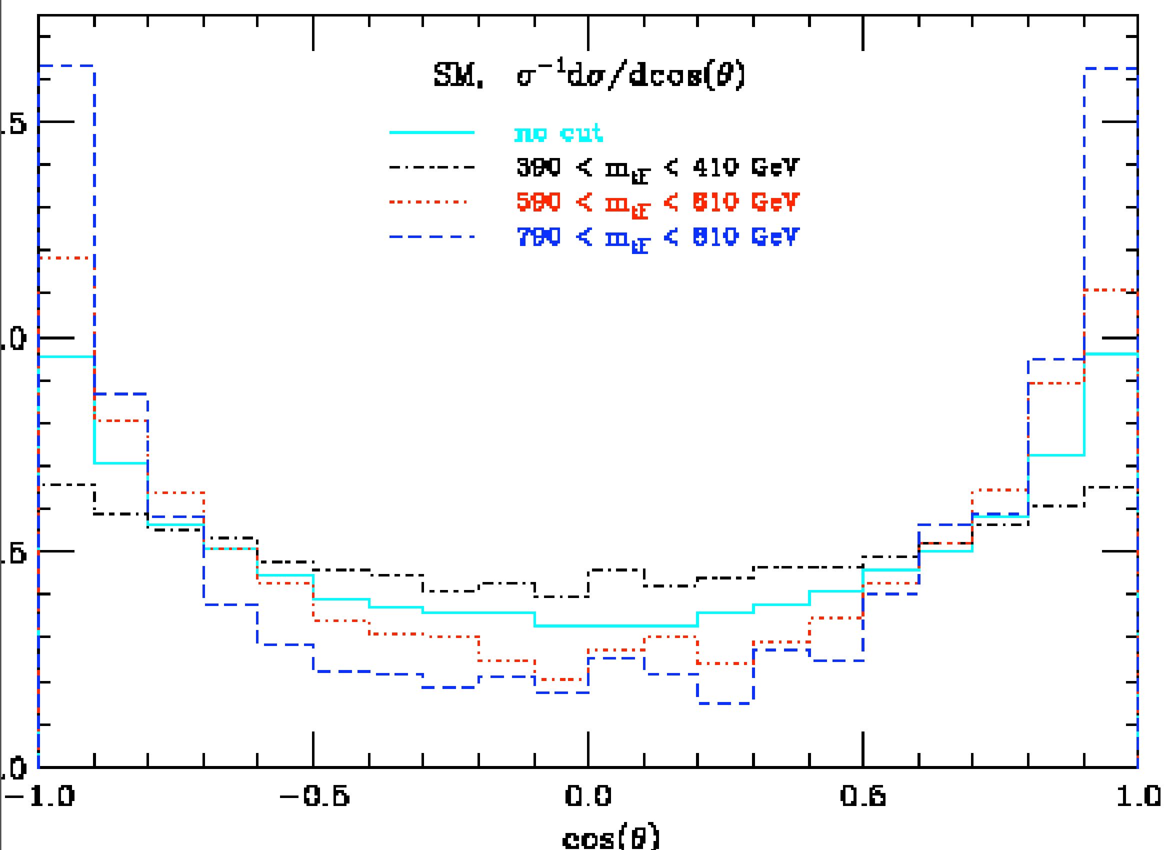
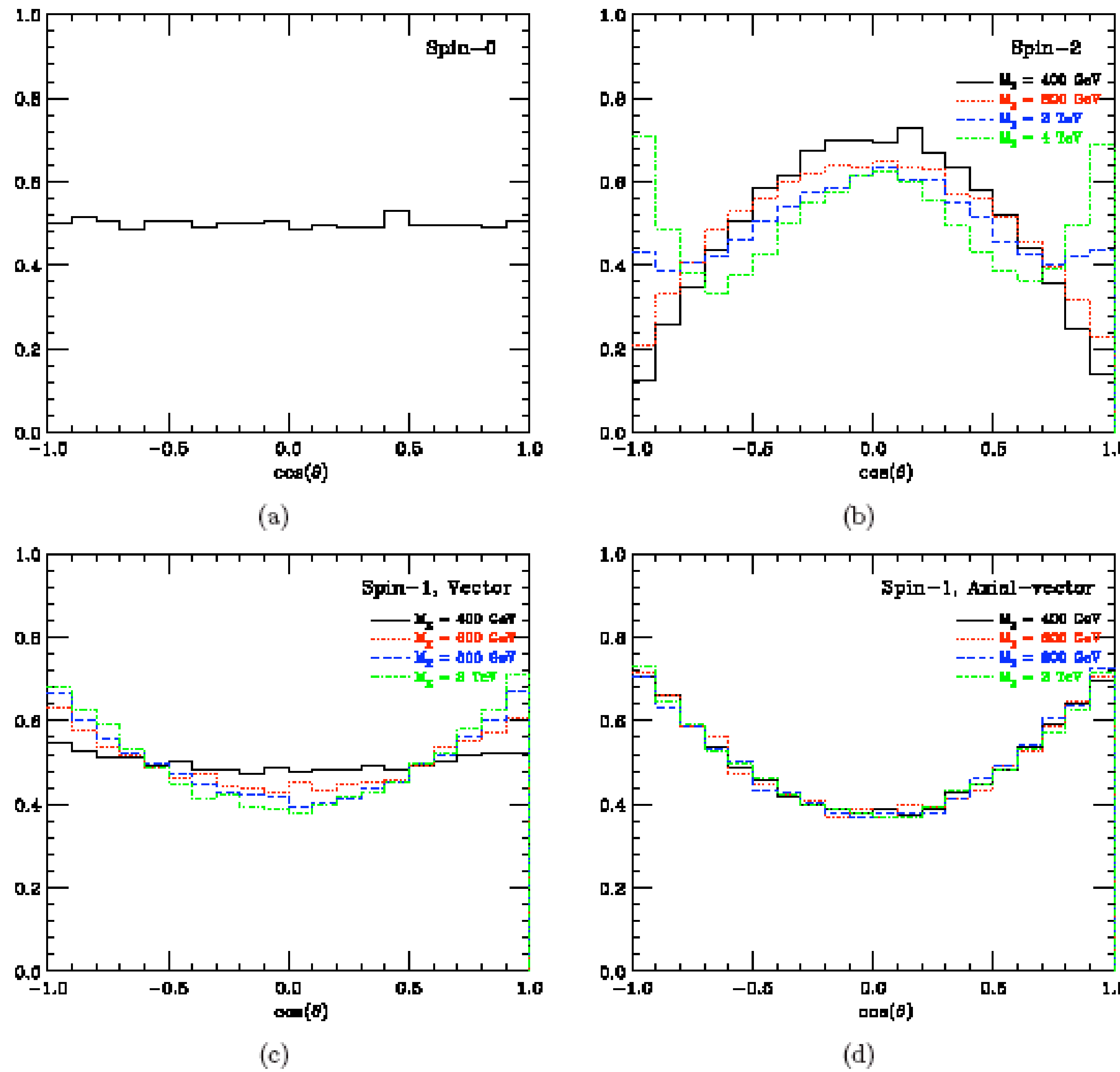


CS angle





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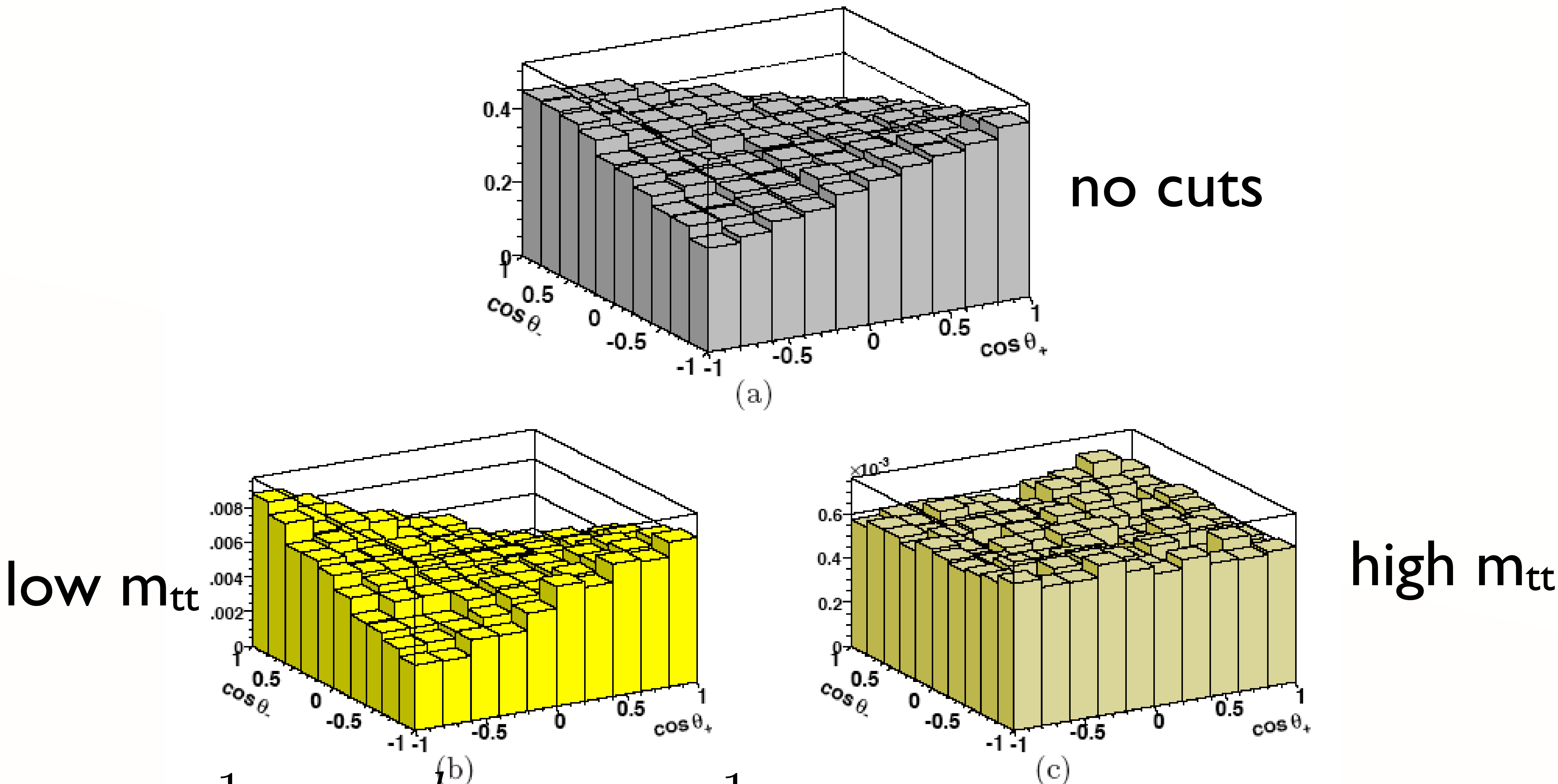
Phase 3: Spin correlations



$$\frac{1}{\sigma}\frac{d\sigma}{d\cos\theta_+ d\cos\theta_-} = \frac{1}{4}\left(1 + \kappa_t\kappa_{\bar{t}} D \cos\theta_- \cos\theta_+\right)$$

Phase 3: Spin correlations

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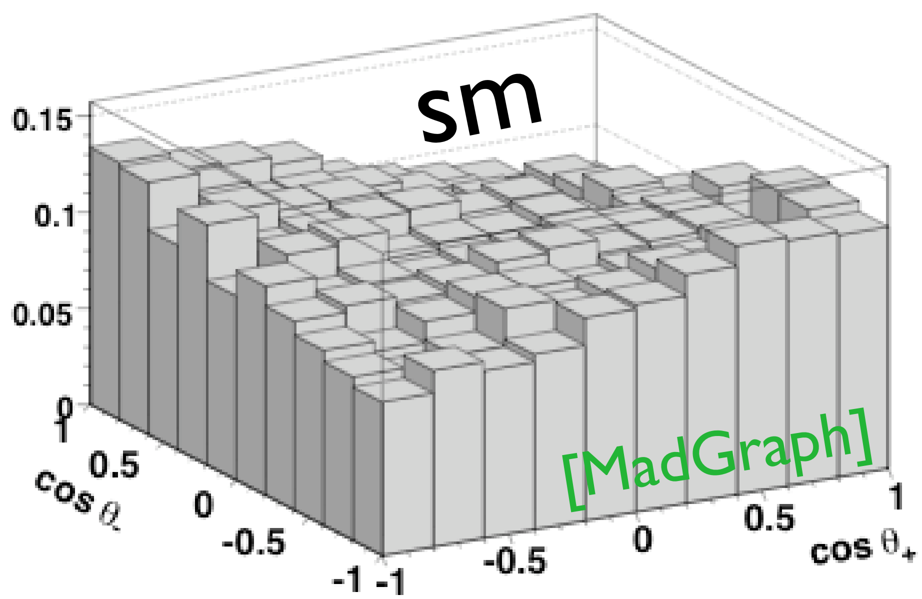

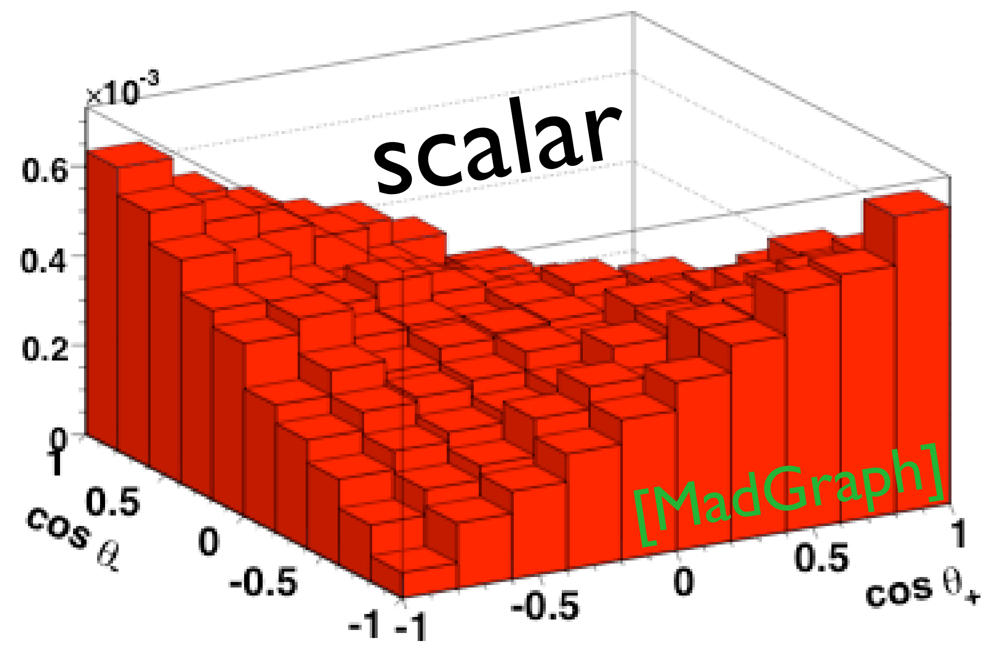

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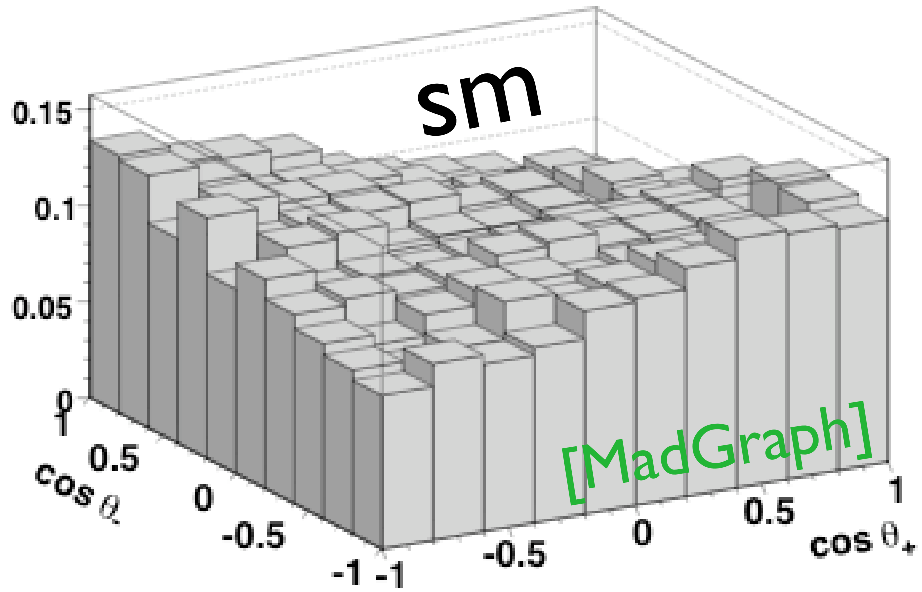

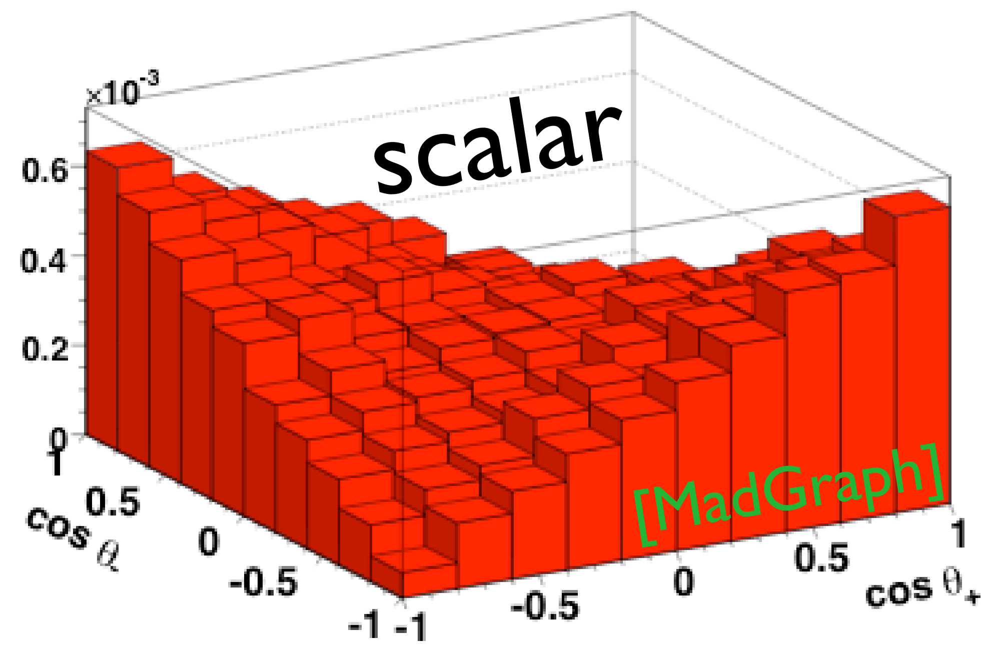

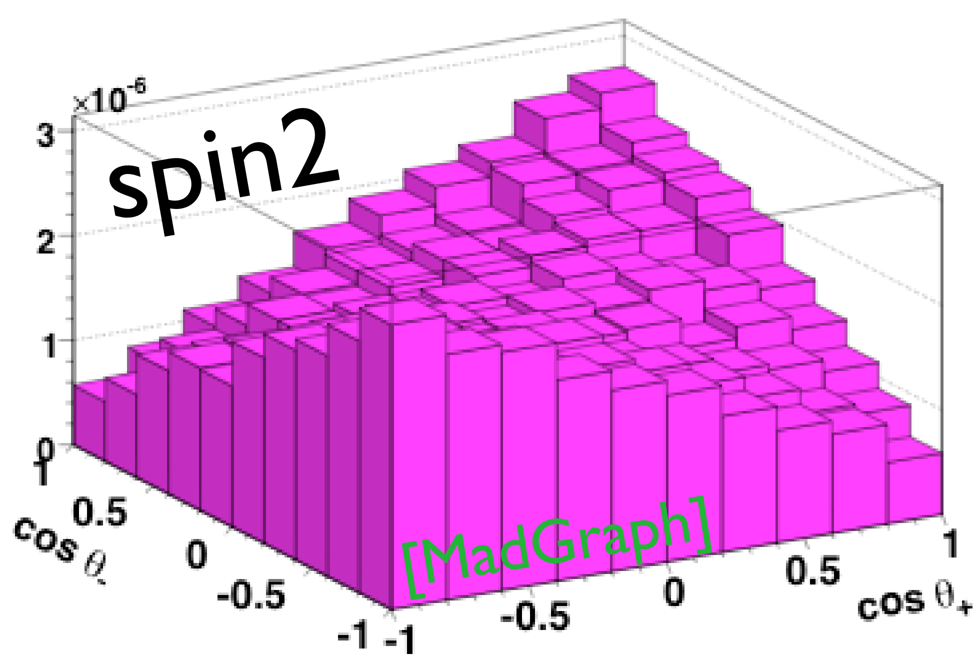

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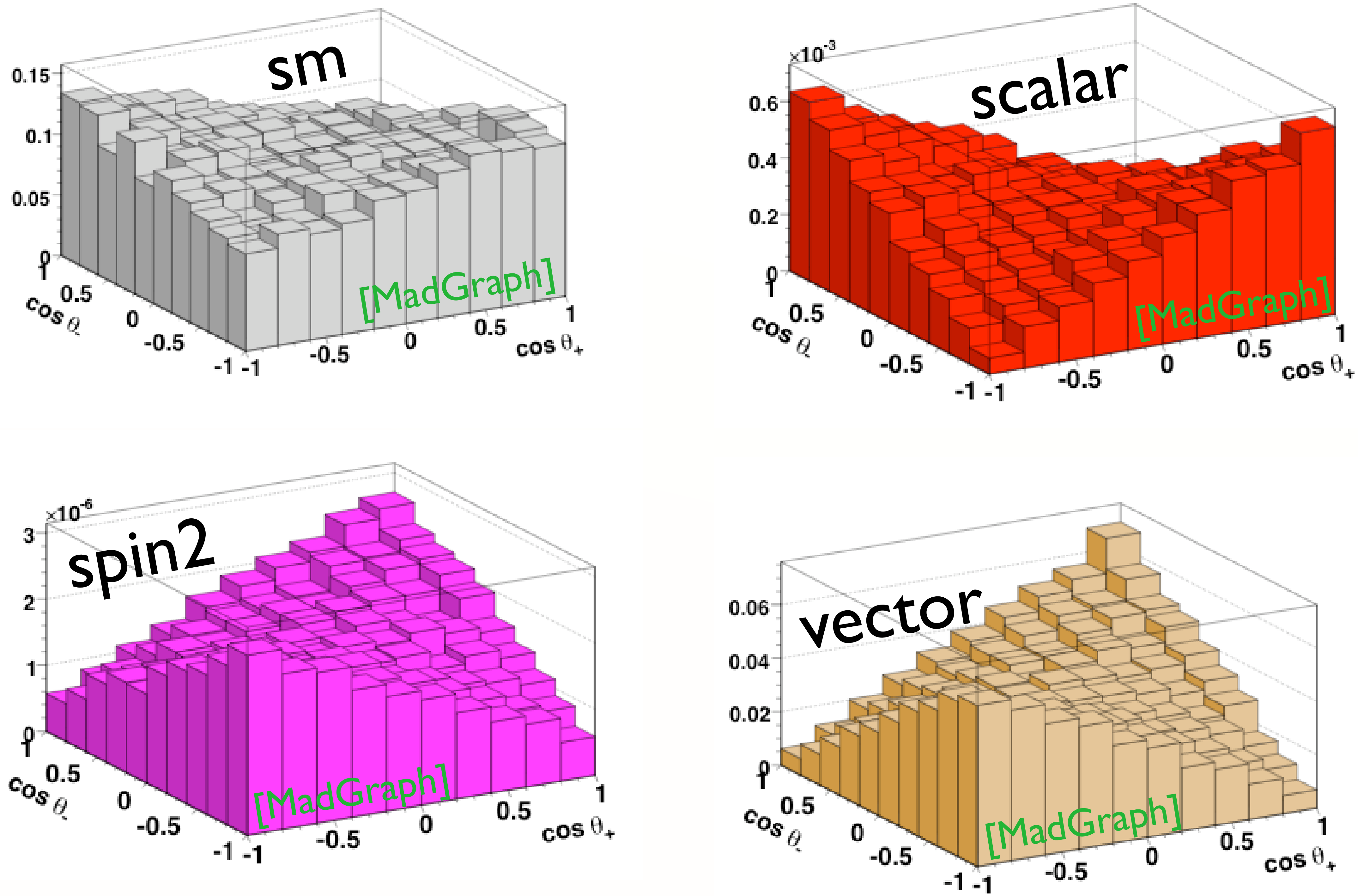

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III. Exotic: Same sign tops [Degrande, Gerard, Grojean,FM, Servant, **arXiv:1104.1798**]

IV. Exotic: Monotops [Andrea, Fuks, FM, **wip**]

Model Independent BSM searches Examples

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Effective Field Theory Approach

[Aguilar-Saavedra 2010, Willenbrock et al. 2010, Degrande et al 2010]

Use an effective Lagrangian approach:

•Write down all the dominant (dim=6) operators involving a t and tbar.

•Use symmetries (like custodial symmetry) or well known contraints (such those on FCNC => MFV) to reduce the number of possibly important operators.

•Use, if you want, inspirations or scalings suggested by some physics models that you like (top compositeness).

Effective Field Theory Approach

EW precision data together with constraints from flavour physics make plausible if not likely that there exists a mass gap between the SM degrees of freedom and any new physics threshold.

Dim-6 operators that affect top pair production **at tree level by interference with the SM** (QCD) amplitudes (we neglect weak corrections)

Zhang & Willenbrock '10
Aguilar-Saavedra '10
Degrande, Gerard, Grojean, Maltoni, Servant '10

CP-even

operator	process
$O^{(3)}_{\phi q} = i(\phi^+ \tau^I D_\mu \phi)(\bar{q}\gamma^\mu \tau^I q)$	top decay, single top
$O_{tW} = (\bar{q}\sigma^{\mu\nu}\tau^I t)\tilde{\phi} W^I_{\mu\nu}$ (with real coefficient)	top decay, single top
$O^{(1,3)}_{qq} = (\bar{q}^i \gamma_\mu \tau^I q^j)(\bar{q}\gamma^\mu \tau^I q)$	single top
$O_{tG} = (\bar{q}\sigma^{\mu\nu}\lambda^A t)\tilde{\phi} G^A_{\mu\nu}$ (with real coefficient)	single top, $q\bar{q}, gg \to t\bar{t}$
$O_G = f_{ABC} G^{A\nu}_\mu G^{B\rho}_\nu G^{C\mu}_\rho$	$gg \to t\bar{t}$
$O_{\phi G} = \frac{1}{2}(\phi^+\phi) G^A_{\mu\nu} G^{A\mu\nu}$	$gg \to t\bar{t}$
7 four-quark operators	$q\bar{q} \to t\bar{t}$

CP-odd

operator	process
$O_{tW} = (\bar{q}\sigma^{\mu\nu}\tau^I t)\tilde{\phi} W^I_{\mu\nu}$ (with imaginary coefficient)	top decay, single top
$O_{tG} = (\bar{q}\sigma^{\mu\nu}\lambda^A t)\tilde{\phi} G^A_{\mu\nu}$ (with imaginary coefficient)	single top, $q\bar{q}, gg \to t\bar{t}$
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Effective Field Theory Approach

EW precision data together with constraints from flavour physics make plausible if not likely that there exists a mass gap between the SM degrees of freedom and any new physics threshold.

NP can be integrated out and simply gives new (higher dimensional) interactions among the SM degrees of freedom

Dim-6 operators that affect top pair production **at tree level by interference with the SM** (QCD) amplitudes (we neglect weak corrections)

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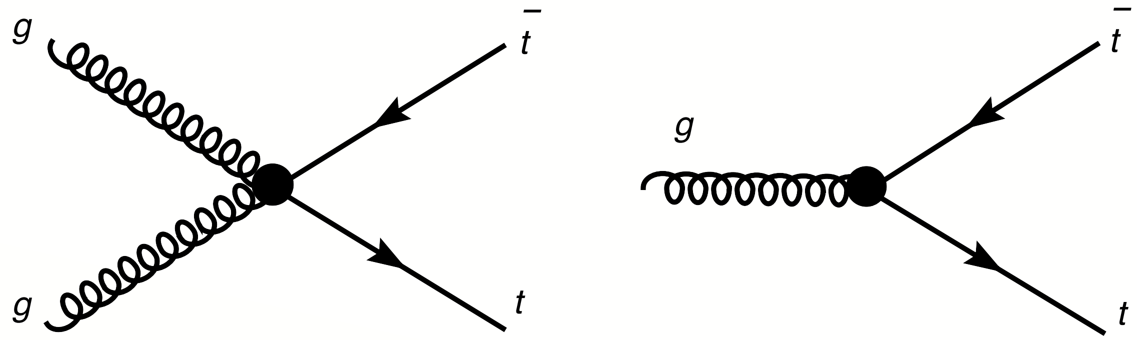
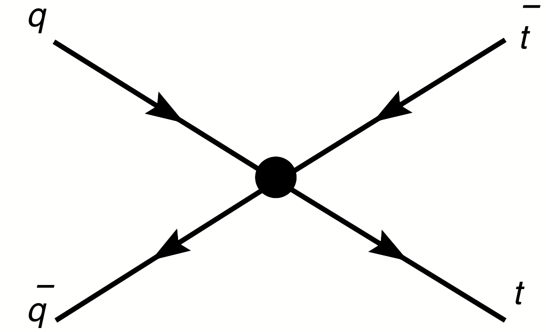
top-philic operators
(modifying top couplings
and not only gluons couplings)

ttbar production

New vertices



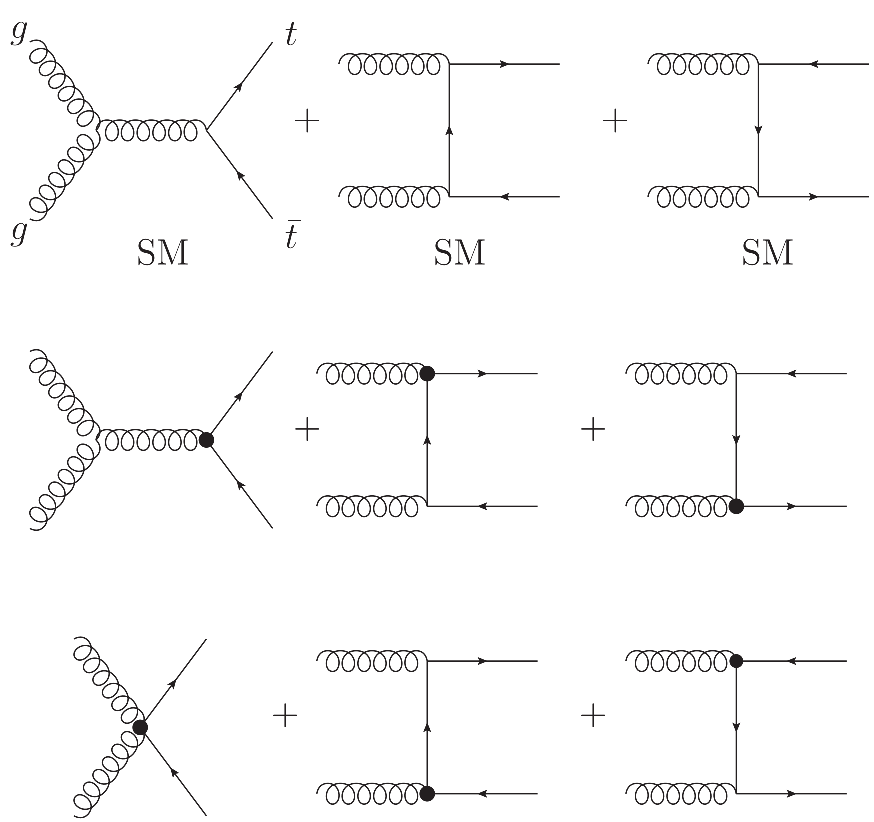
Chromomagnetic operator $\mathcal{O}_{hg} = (H\bar{Q})\sigma^{\mu\nu}T^A t\ G^A_{\mu\nu}$



Four-fermion operators

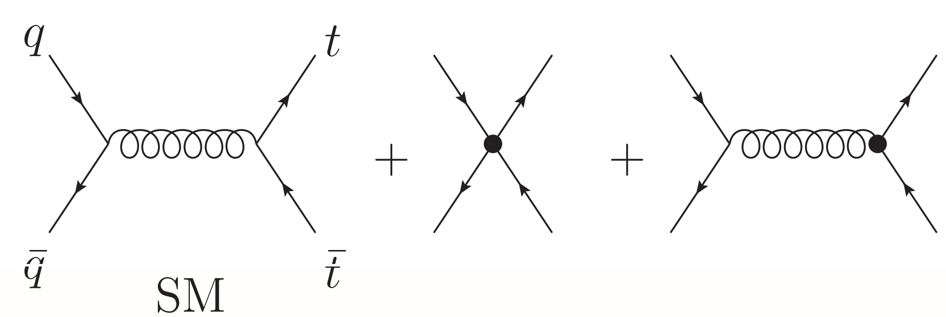
gluon fusion

corrections from c_{hg} only

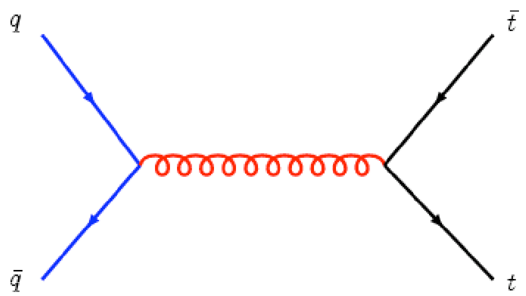


$q\bar{q}$ annihilation:

both c_{hg} and 4-fermion operators

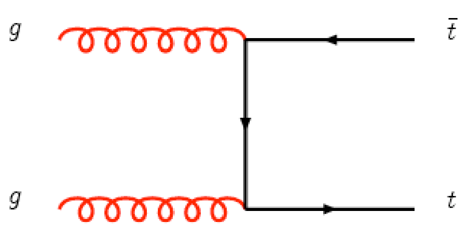


Is there anything to learn from a σ_{ttbar} measurement at the LHC?



85% at TeV

VS



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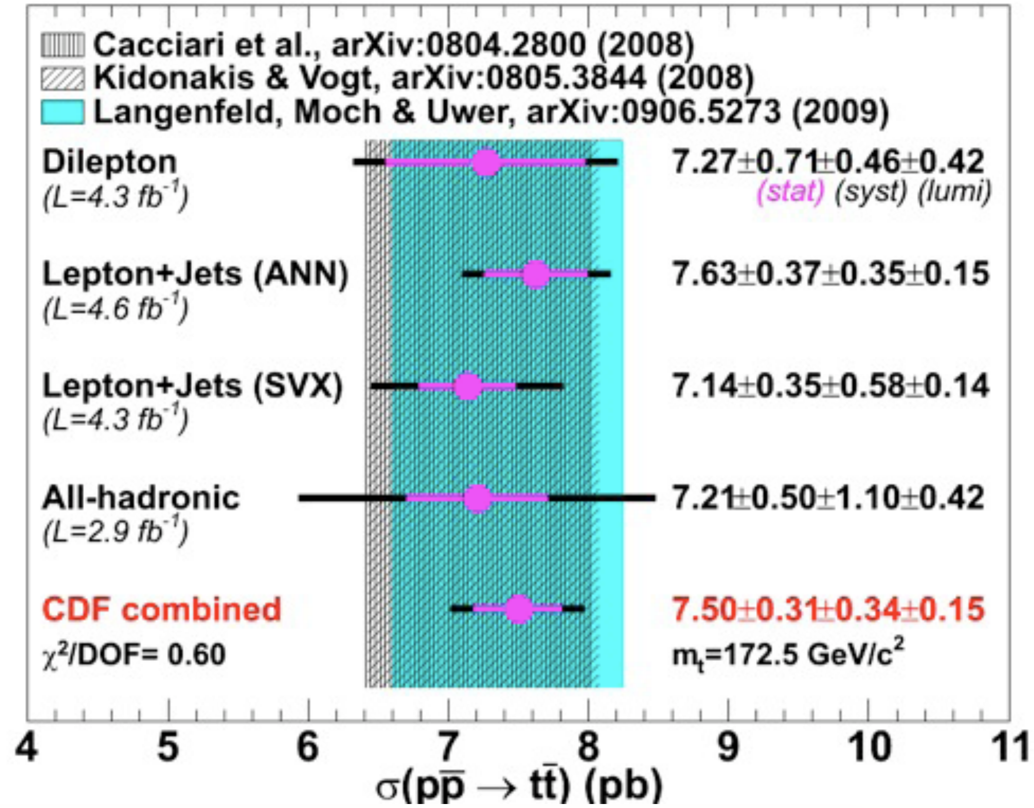

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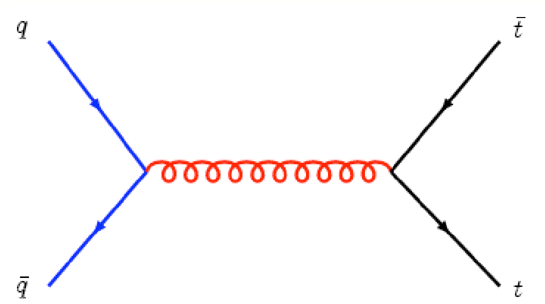

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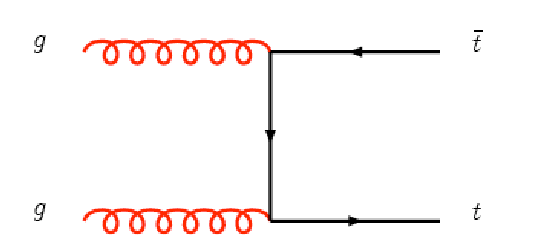

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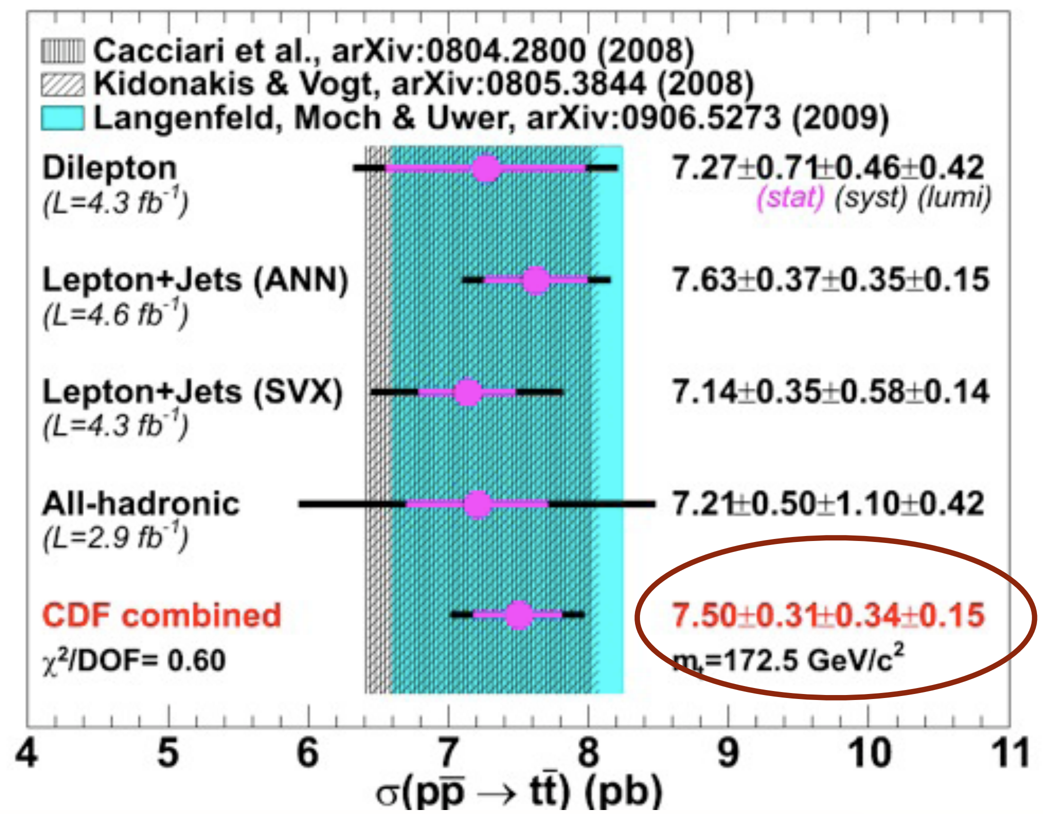

The gg channel is only very roughly constrained!!!
We might have missed some big and important NP effect connected with an gg initial state (such a scalar...).

How can we study such effects in a model independent way?

tt production

One can show that you end up with five main operators,

$$\mathcal{L}_{t\bar{t}} = \mathcal{L}_{t\bar{t}}^{SM} + \frac{1}{\Lambda^2}\left[g_h \mathcal{O}_{hg} + c_R \mathcal{O}_{Rg} + a_R \mathcal{O}_{Ra}^{8} + (R \leftrightarrow L)\right]$$

and in case one is interested only in total rates (and spin independent / FB symmetries) only three parameters are left : g_h , $c_V=c_R+c_L$ and $a_A = a_R - a_R$

ttbar: gluon fusion (from one operator only)

The new physics and SM contributions for gluon fusion have a common factor

$$\frac{d\sigma}{dt}(gg \to t\bar{t}) = \frac{d\sigma_{SM}}{dt} + \sqrt{2}\alpha_s g_s \frac{v m_t}{s^2} \frac{c_{hg}}{\Lambda^2}\left(\frac{1}{6\tau_1\tau_2} - \frac{3}{8}\right)$$

$$\frac{d\sigma_{SM}}{dt}(gg \to t\bar{t}) = \frac{\pi\alpha_s^2}{s^2}\left(\frac{1}{6\tau_1\tau_2} - \frac{3}{8}\right)\left(\rho + \tau_1^2 + \tau_2^2 - \frac{\rho^2}{4\tau_1\tau_2}\right)$$

$$\tau_1 = \frac{m_t^2 - t}{s}, \quad \tau_2 = \frac{m_t^2 - u}{s}, \quad \rho = \frac{4m_t^2}{s}$$

t: Mandelstam variable related to θ angle
(angle between incoming parton and outgoing top quark)

$$m_t^2 - t = \frac{s}{2}(1 - \beta\cos\theta)$$

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Common factor mainly responsible for the shape of the distributions

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The operator O_{hg} can hardly be distinguished from the SM in gluon fusion

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Distortions in the shape of the distributions can only come from qq annihilation ➞ small effects at LHC

ttbar: qqbar annihilation (from the 8 operators)

Only four linear combinations of 4-fermion operators actually contribute to the differential cross section after averaging over the final state spins:

$$\frac{d\sigma}{dt}(q\bar{q} \to t\bar{t}) = \frac{d\sigma_{SM}}{dt}\left(1 + \frac{c_{Vv} \pm \frac{c'_{Vv}}{2}}{g_s^2}\frac{s}{\Lambda^2}\right) + \frac{1}{\Lambda^2}\frac{\alpha_s}{9s^2}\left(\left(c_{Aa} \pm \frac{c'_{Aa}}{2}\right)s(\tau_2 - \tau_1) + 4g_s c_{hg}\sqrt{2}vm_t\right)$$

even part in the scattering angle θ

comes from $\bar{t}\gamma^\mu T^A t \bar{q}\gamma^\mu T^A q$

odd part in the scattering angle θ

comes from $\bar{t}\gamma^\mu\gamma_5 T^A t \bar{q}\gamma^\mu\gamma_5 T^A q$

This dependence vanishes after integration over t

ttbar: qqbar annihilation (from the 8 operators)

Only four linear combinations of 4-fermion operators actually contribute to the differential cross section after averaging over the final state spins:

some vector combination of operators that is symmetric under q <-> $\bar{q}$

some axial combination of operators is asymmetric under q <-> $\bar{q}$

$$\frac{d\sigma}{dt}(q\bar{q}\to t\bar{t}) = \frac{d\sigma_{SM}}{dt}\left(1+\frac{c_{Vv}\pm\frac{c'_{Vv}}{2}}{g_s^2}\frac{s}{\Lambda^2}\right)+\frac{1}{\Lambda^2}\frac{\alpha_s}{9s^2}\left(\left(c_{Aa}\pm\frac{c'_{Aa}}{2}\right)s(\tau_2-\tau_1)+4g_s c_{hg}\sqrt{2}vm_t\right)$$

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This dependence vanishes after integration over t

ttbar total cross-section

Tevatron

$$\sigma\left(pp \to t\bar{t}\right)/\mathrm{pb} \;=\; 6.15^{+2.41}_{-1.61} + \left[\left(0.87^{+0.23}_{-0.16}\right) c_{Vv} + \left(1.44^{+0.47}_{-0.33}\right) c_{hg} + \left(0.31^{+0.08}_{-0.06}\right) c'_{Vv}\right]\left(\frac{1\ \mathrm{TeV}}{\Lambda}\right)^2 .$$

LHC (7 TeV)

$$\sigma\left(pp \to t\bar{t}\right)/\mathrm{pb} \;=\; 94^{+22}_{-17} + \left[\left(4.5^{+0.7}_{-0.6}\right) c_{Vv} + \left(25^{+7}_{-5}\right) c_{hg} + \left(0.48^{+0.068}_{-0.056}\right) c'_{Vv}\right]\left(\frac{1\ \mathrm{TeV}}{\Lambda}\right)^2 .$$

LHC (14 TeV)

$$\sigma\left(pp \to t\bar{t}\right)/\mathrm{pb} \;=\; 538^{+162}_{-115} + \left[\left(15^{+2}_{-1}\right) c_{Vv} + \left(144^{+34}_{-25}\right) c_{hg} + \left(1.32^{+0.12}_{-0.12}\right) c'_{Vv}\right]\left(\frac{1\ \mathrm{TeV}}{\Lambda}\right)^2 .$$

u+d (isospin 0)

chromomagnetic moment

u-d (isospin 1)

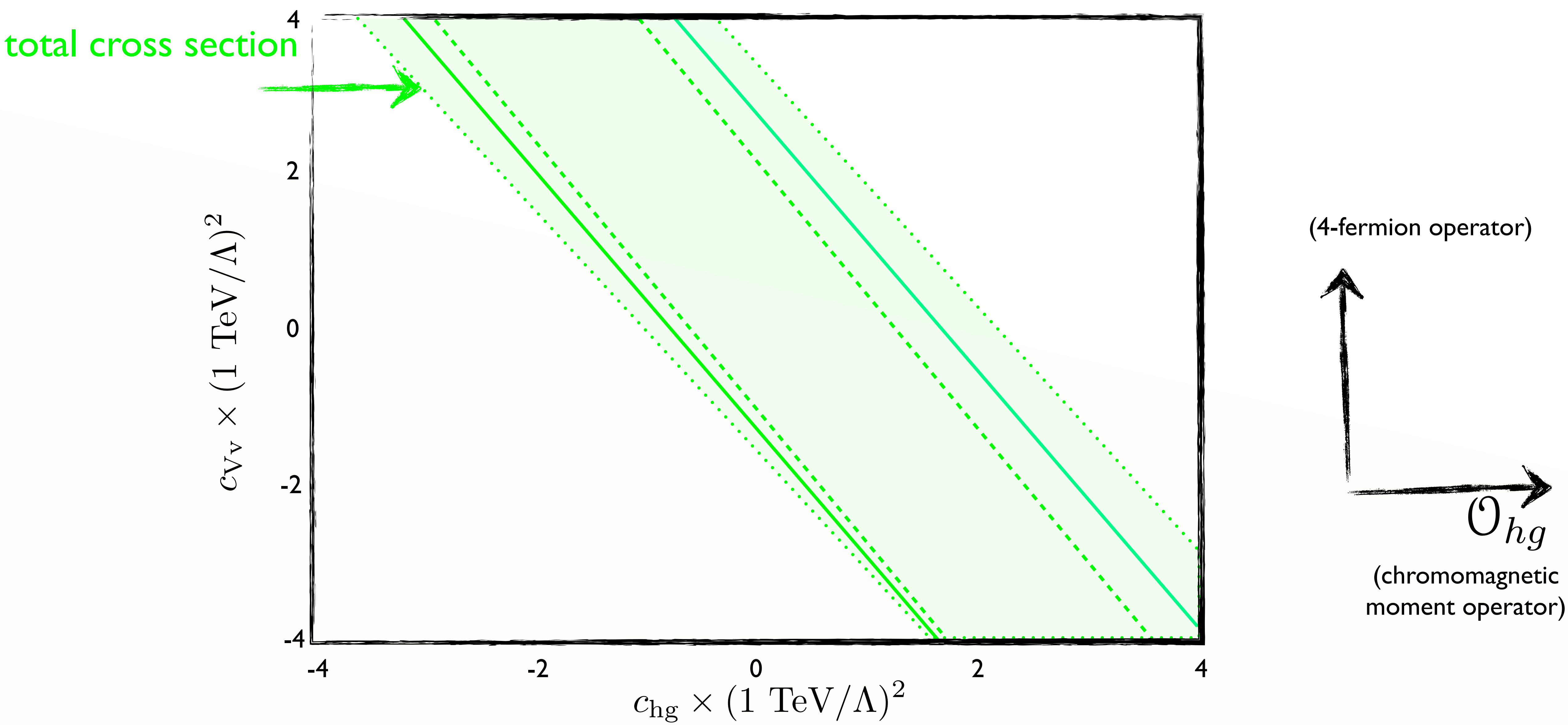
LO with CTEQ6L1 pdfs

In fits, we'll use NLO+NLL SM results

but in interference, we'll keep LO SM amplitude

Tevatron Constraints

The pp → $t\bar{t}$ total cross section at Tevatron depends on both c_{hg} and c_{Vv} and constrains thus a combination of these parameters.



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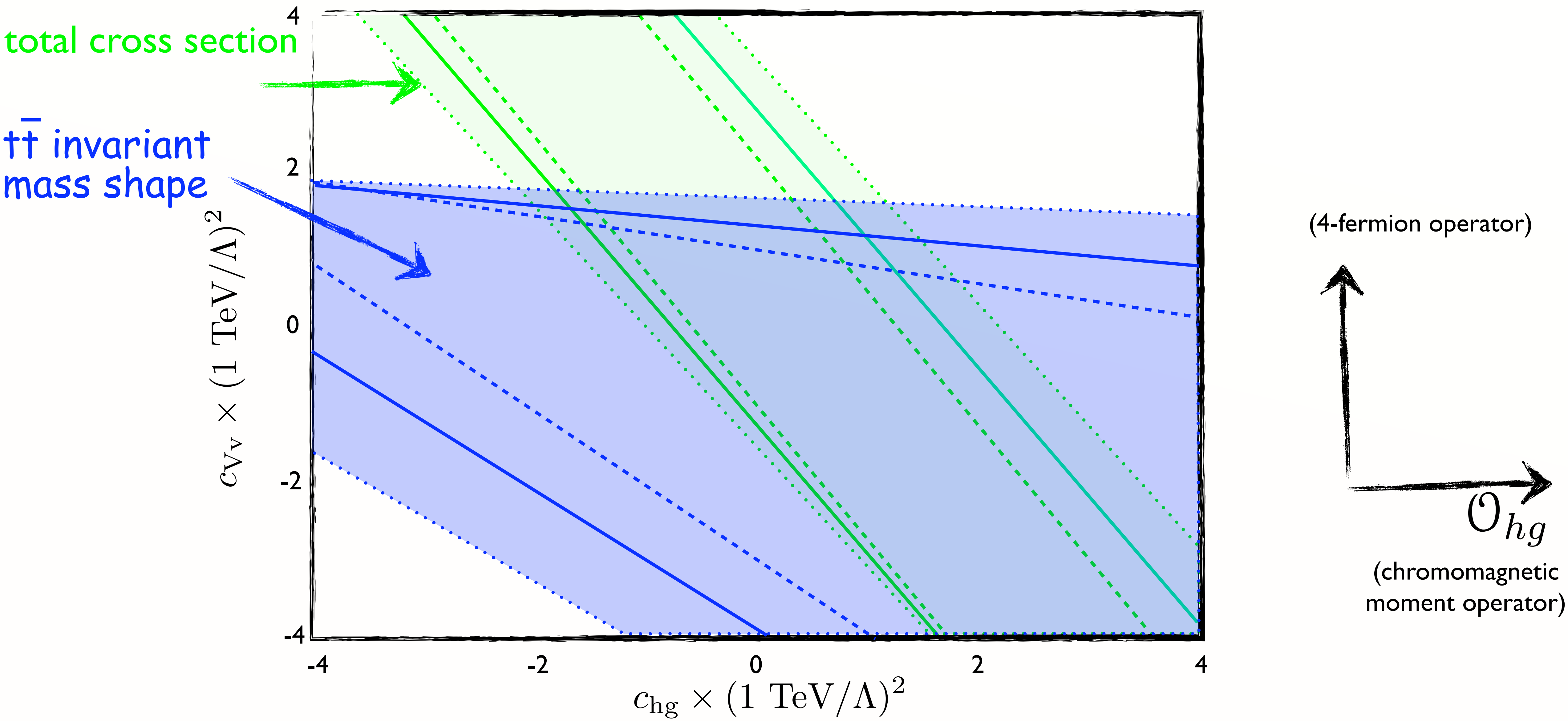
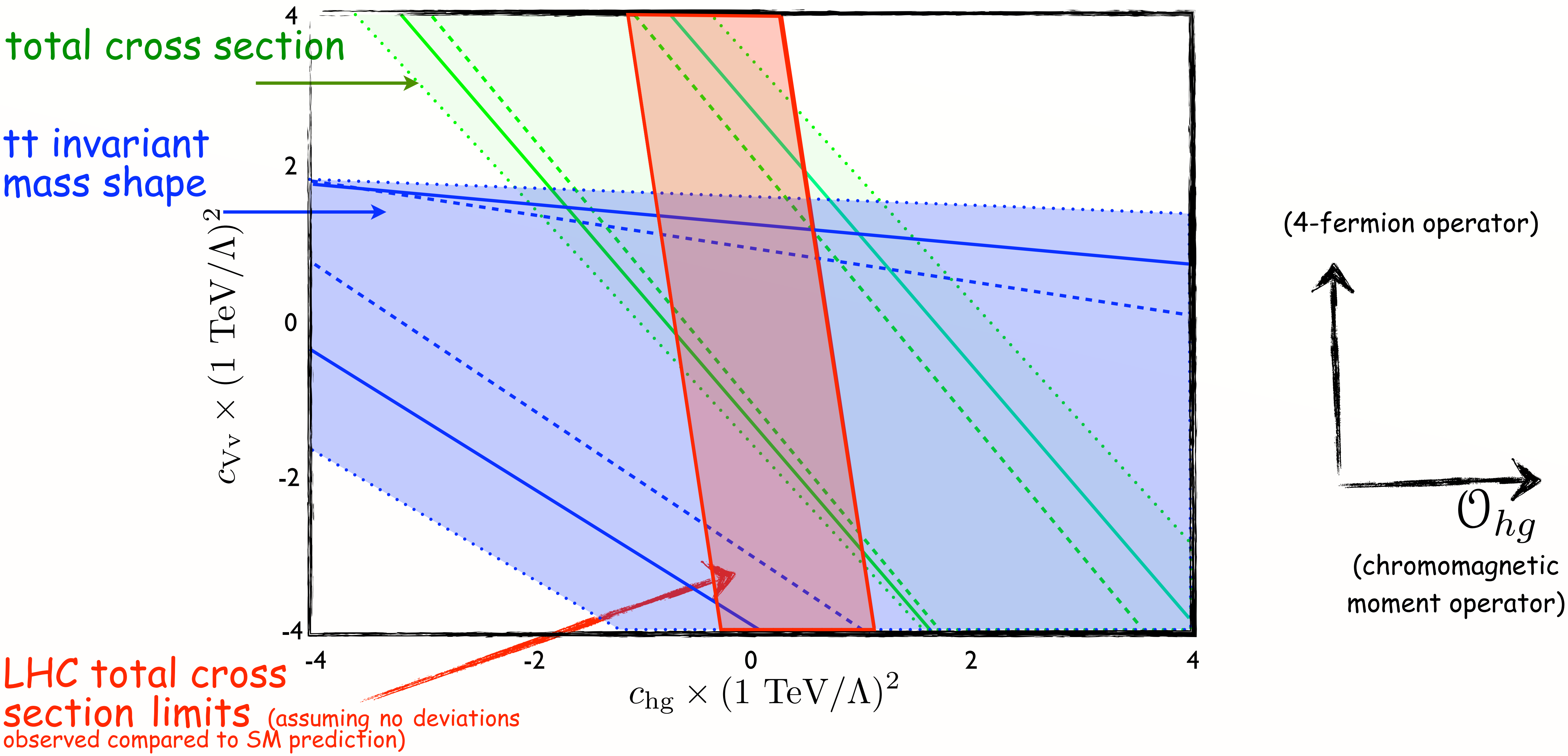


Tevatron-LHC Complementarity

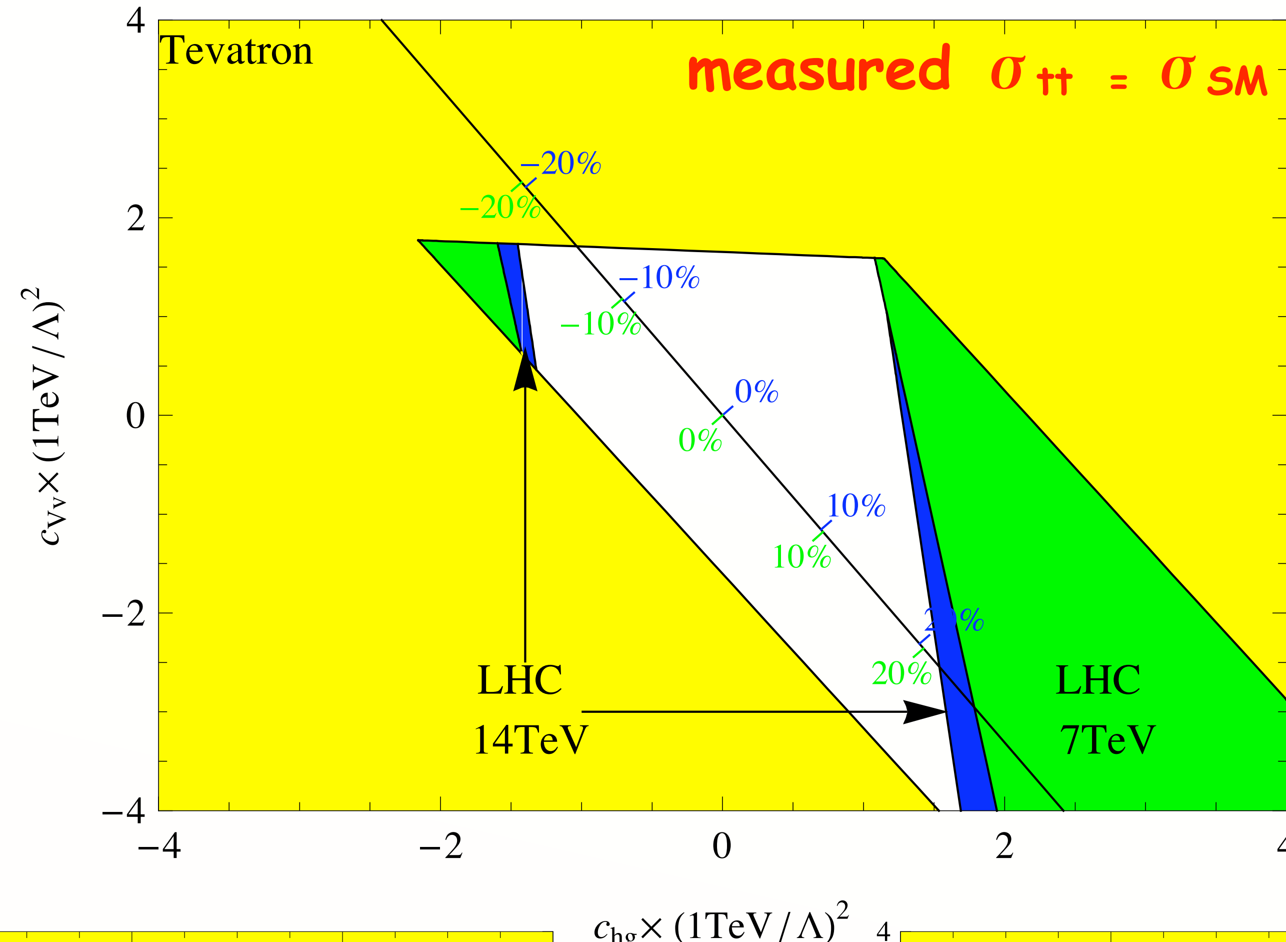
- ☑ The pp → tt total cross section at Tevatron depends on both c_{hg} and c_{Vv} and constrains thus a combination of these parameters.
- ☑ The pp → tt total cross section at LHC strongly depends mostly on c_{hg} and can be directly used to constrain the allowed range for c_{hg}

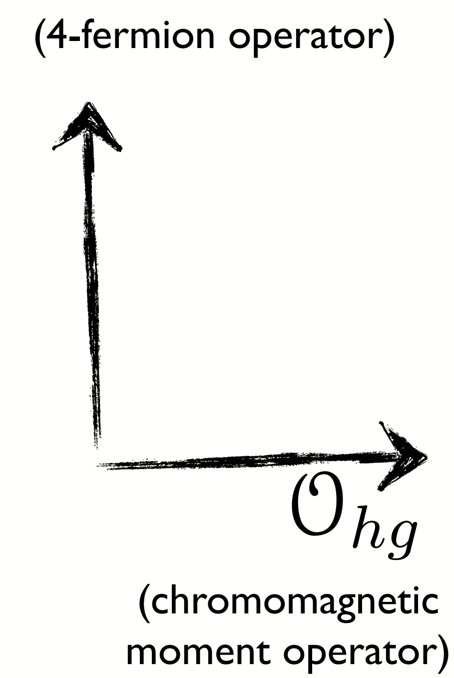


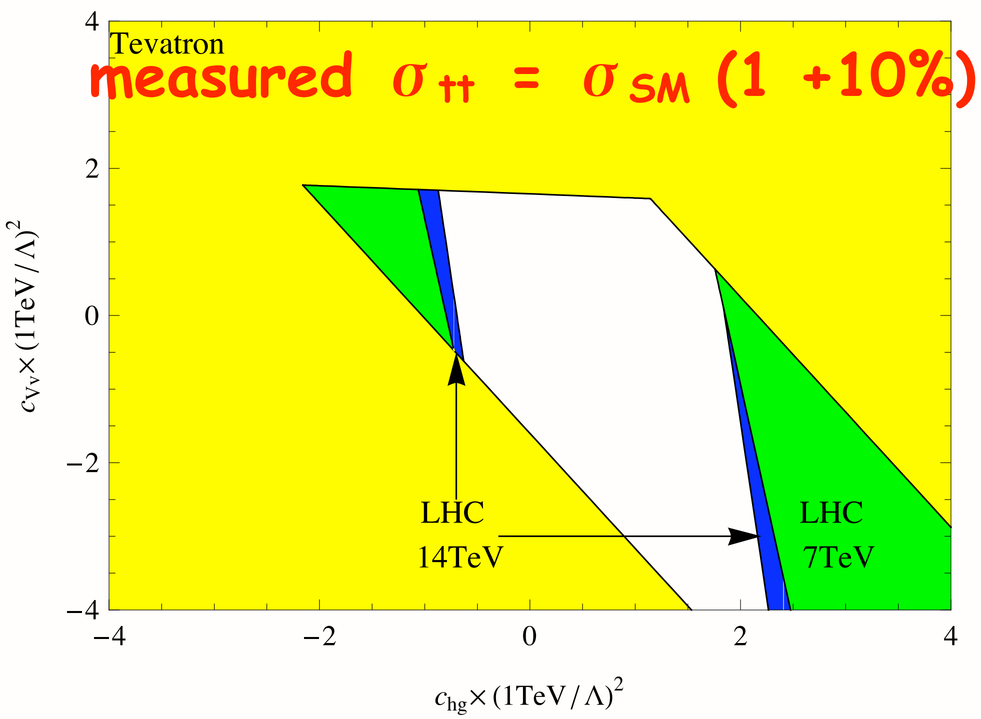
Tevatron-LHC Complementarity

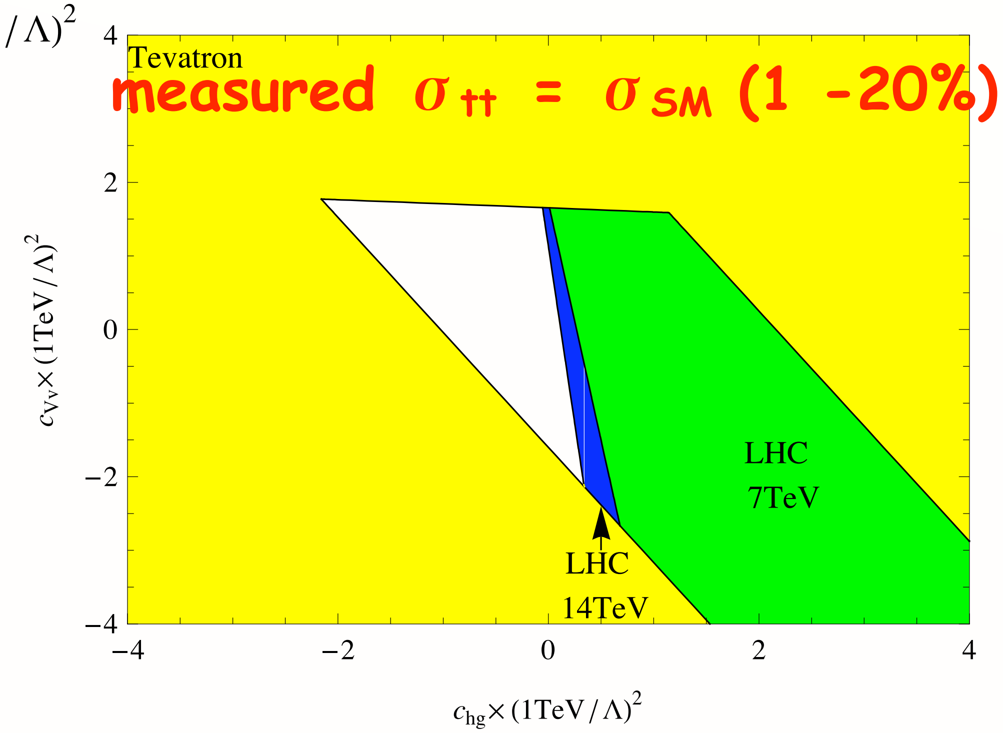
yellow region is excluded by Tevatron

green (blue) region excluded by LHC at 7 TeV (14 TeV) after a precision of 10% is reached on σ_{tt}

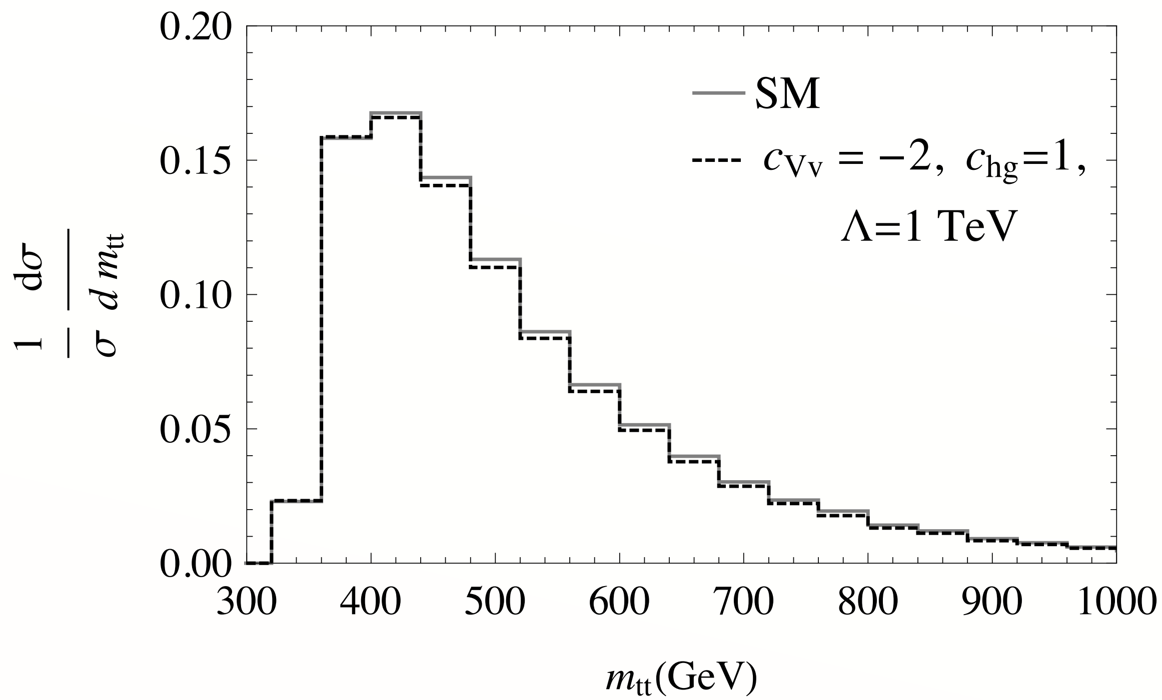


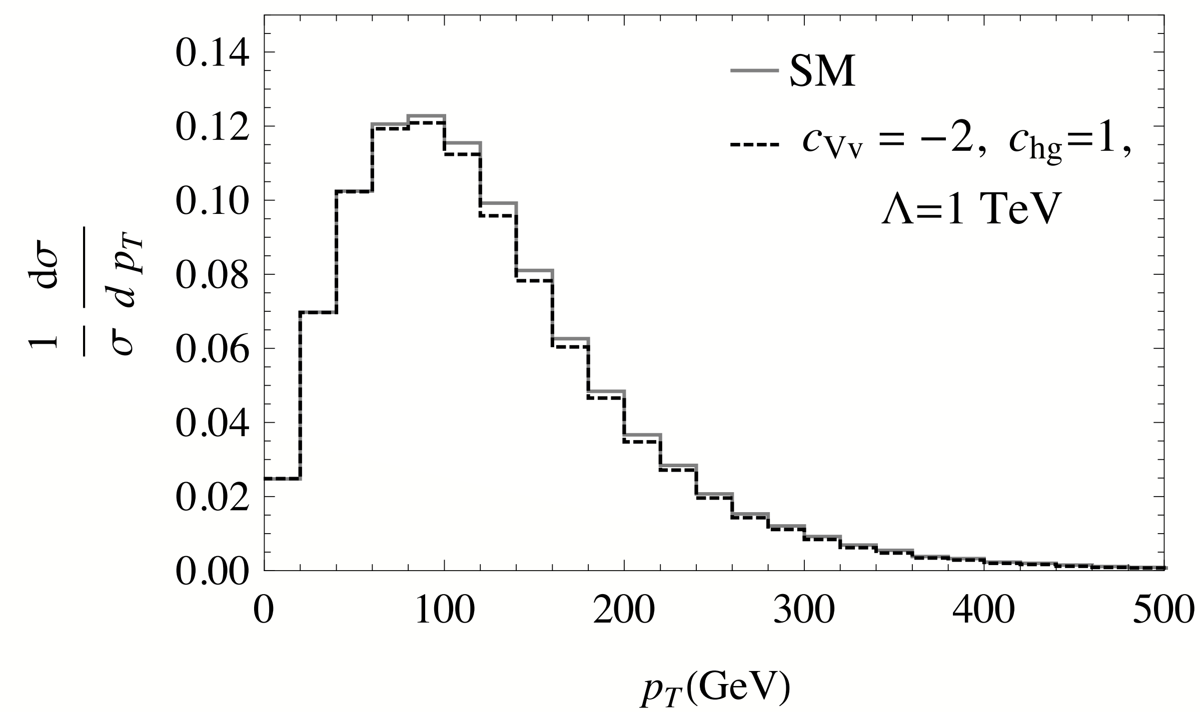


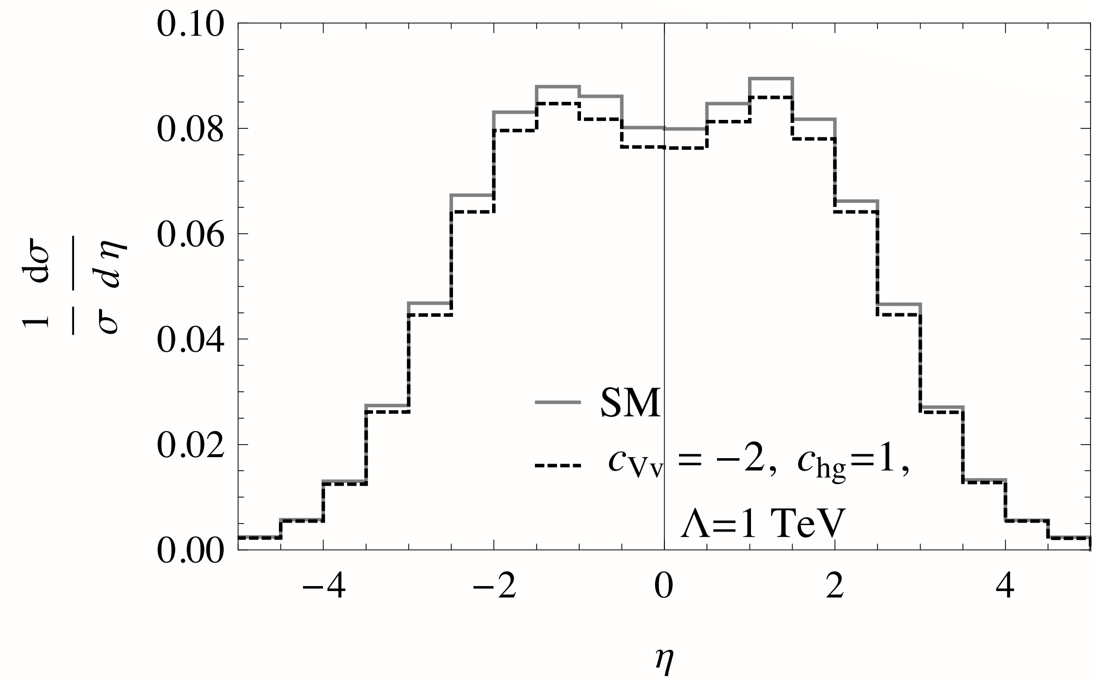




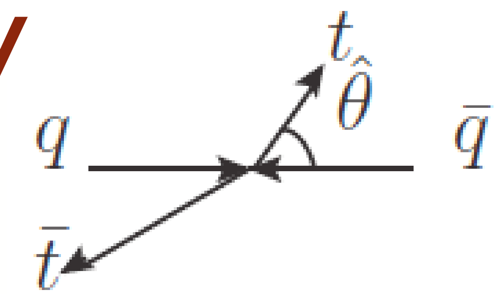
Minor effects on shape of distributions







Forward-Backward Asymmetry



lab. frame
$$A_{FB} \equiv \frac{\sigma(\cos\theta_t > 0) - \sigma(\cos\theta_t < 0)}{\sigma(\cos\theta_t > 0) + \sigma(\cos\theta_t < 0)}$$

$$A_{FB}^{\rm SM} = 0.05 \pm 0.015. \qquad A_{FB}^{\rm EXP} = 0.15 \pm 0.05({\rm stat}) \pm 0.024({\rm syst}),$$

→ top quarks are preferentially emitted in the direction of the incoming quark

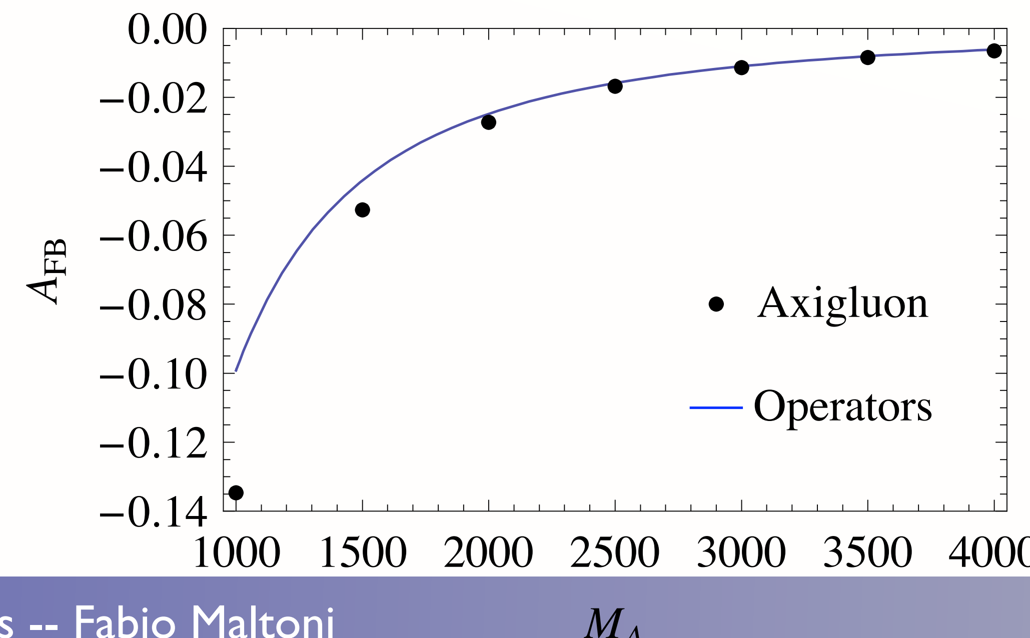
$$\frac{d\sigma}{dt}(q\bar{q} \to t\bar{t}) = \frac{d\sigma_{SM}}{dt}\left(1 + \frac{c_{Vv} \pm \frac{c'_{Vv}}{2}}{g_s^2}\frac{s}{\Lambda^2}\right) + \frac{1}{\Lambda^2}\frac{\alpha_s}{9s^2}\left(\left(c_{Aa} \pm \frac{c'_{Aa}}{2}\right)s(\tau_2 - \tau_1) + 4g_s c_{hg}\sqrt{2}vm_t\right)$$

$$\boxed{\delta A_{FB}^{\dim 6} = \left(0.0342^{+0.016}_{-0.009}\, c_{Aa} + 0.0128^{+0.0064}_{-0.0036}\, c'_{Aa}\right) \times \left(\frac{1\ {\rm TeV}}{\Lambda}\right)^2}$$

C_{Aa} and C'_{Aa} are only constrained by the asymmetry and not by the total cross section or the invariant mass distribution

Link to axigluon models:

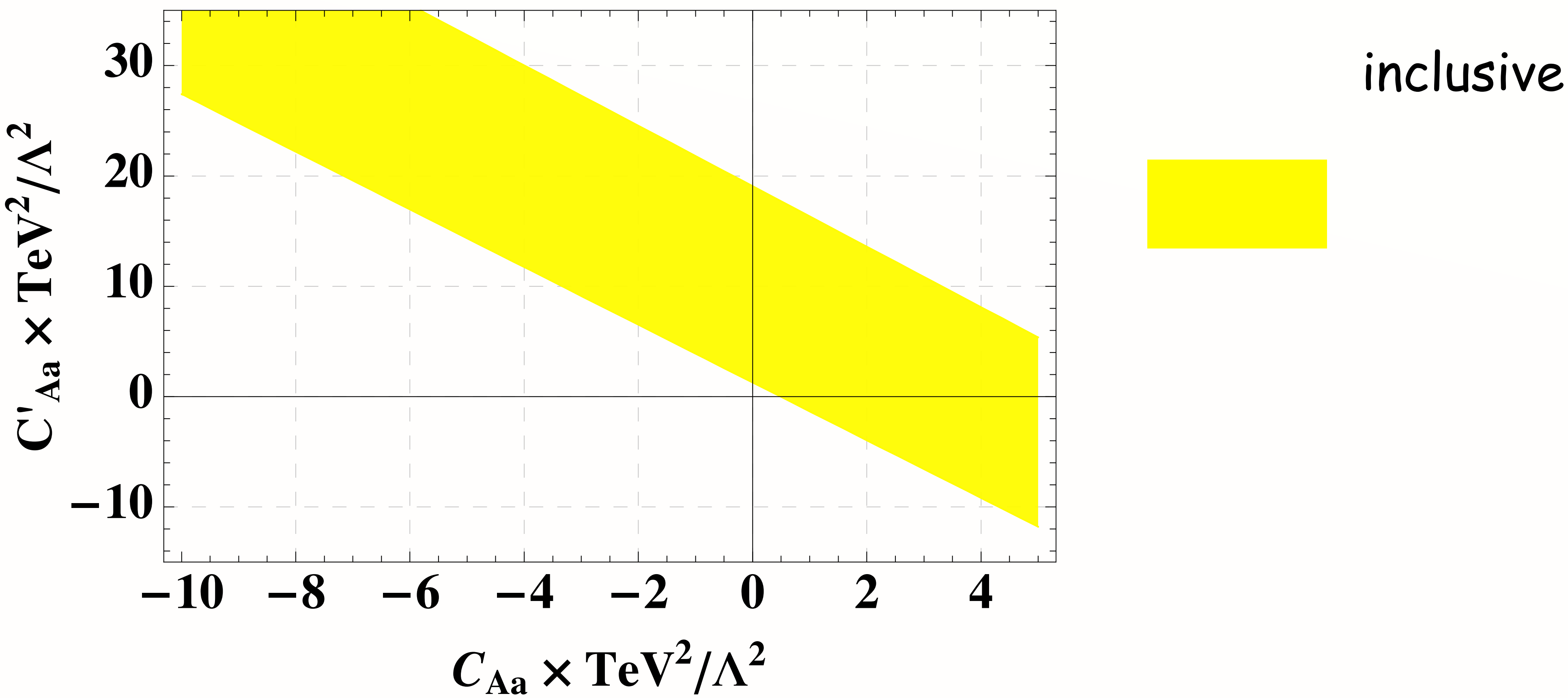
$$c_{Aa}/\Lambda^2 = -2g_A^q g_A^t/m_A^2$$



Forward-Backward Asymmetry

asymmetries in lab. frame

A_{FB} (inclusive) = 0.158 ± 0.075	A_{FB} (SM) = 0.058 ± 0.009
A_{FB} (m_{tt} < 450 GeV) = - 0.116 ± 0.153	A_{FB} (SM) = 0.04 ± 0.006
A_{FB} (m_{tt} > 450 GeV) = 0.475 ± 0.114	A_{FB} (SM) = 0.088 ± 0.013
A_{FB} (|Δy|< 1) = 0.026 ± 0.118	A_{FB} (SM) = 0.039 ± 0.006
A_{FB} (|Δy|> 1) = 0.611 ± 0.256	A_{FB} (SM) = 0.123 ± 0.008



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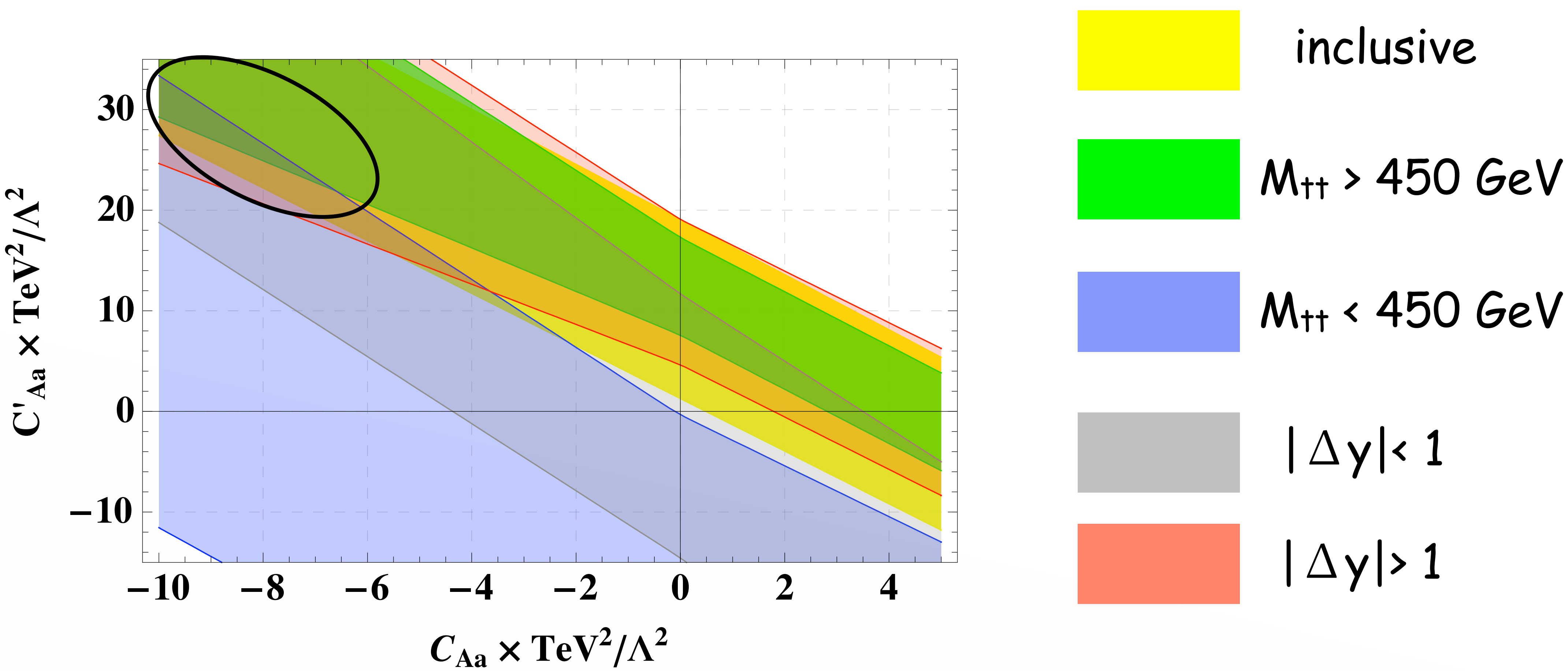

→ Within our two-parameter effective theory, the intersecting region is contrived...

Spin Correlations

The three observables σ, $d\sigma/dm_{t\bar{t}}$ and A_{FB} are unable to disentangle between theories coupled mainly to right- or left-handed top quarks. However, spin correlations allow us to determine which chiralities of the top quark couple to new physics, and in the case of composite models, whether one or two chiralities of the top quark are composite.

$$\frac{1}{\sigma}\frac{d\sigma}{d\cos\theta_+ d\cos\theta_-} = \frac{1}{4}\left(1 + C\cos\theta_+\cos\theta_- + b_+\cos\theta_+ + b_-\cos\theta_-\right)$$

θ_+ (θ_-) is the angle between the charged lepton l^+ (l^-) resulting from the top (antitop) decay and some reference direction $\vec{a}$ ($\vec{b}$).

$$\begin{aligned}
C &= \frac{1}{\sigma}\left(\sigma_{RL} + \sigma_{LR} - \sigma_{RR} - \sigma_{LL}\right), \\
b_+ &= \frac{1}{\sigma}\left(\sigma_{RL} - \sigma_{LR} + \sigma_{RR} - \sigma_{LL}\right), \\
b_- &= \frac{1}{\sigma}\left(\sigma_{RL} - \sigma_{LR} - \sigma_{RR} + \sigma_{LL}\right).
\end{aligned}$$

$$C \times \sigma/\mathrm{pb} = 2.82^{+1.06}_{-0.72} + \left[\left(0.37^{+0.10}_{-0.08}\right) c_{hg} + \left(0.50^{+0.13}_{-0.10}\right) c_{Vv}\right] \times \left(\frac{1\ \mathrm{TeV}}{\Lambda}\right)^2,$$

$$b \times \sigma/\mathrm{pb} = \left(0.45^{+0.12}_{-0.09}\right) c_{Av} \times \left(\frac{1\ \mathrm{TeV}}{\Lambda}\right)^2,$$

allows to distinguish between LH and RH top-quarks

proportional to $c_{Rv} - c_{Lv}$

Spin Correlations

Tevatron

large deviations but few events

LHC

small deviations but numerous events

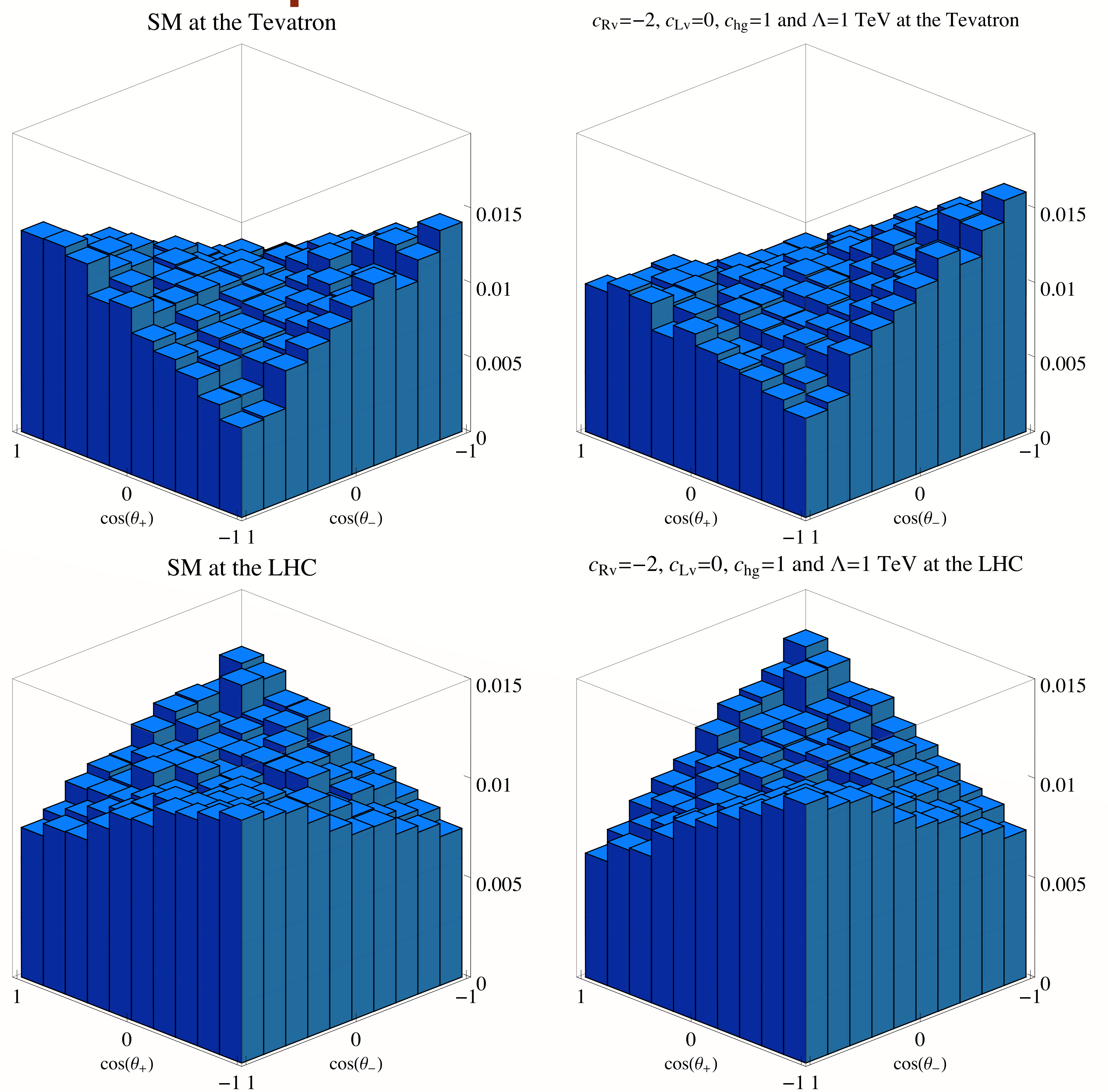

Figure 11: Distribution of events at the Tevatron/LHC (top panel/bottom panel) for the SM (on the left) and for $c_{Rv} = -2$, $c_{Lv} = 0$, $c_{hg} = 1$ and $\Lambda = 1$ TeV (on the right) with $\mu_F = \mu_R = mt$.

Model Independent BSM searches
Examples

I. NP Resonances in ttbar [Frederix, FM, **arXiv:0712.2355**]

II. Non-Resonant NP in ttbar [Degrande, Gerard, Grojean,FM, Servant, **arXiv:1010.6304**]

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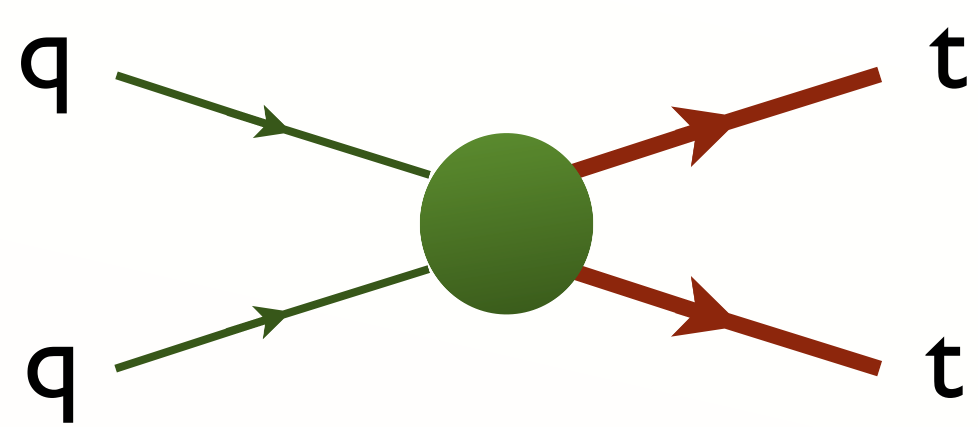
The operators

$$\mathcal{L}_{\mathrm{dim}=6}^{qq\to tt} = \frac{1}{\Lambda^2}\Big(c_{RR}\mathcal{O}_{RR} + c_{LL}^{(1)}\mathcal{O}_{LL}^{(1)} + c_{LL}^{(3)}\mathcal{O}_{LL}^{(3)} + c_{LR}^{(1)}\mathcal{O}_{LR}^{(1)} + c_{LR}^{(8)}\mathcal{O}_{LR}^{(8)}\Big) + h.c..$$

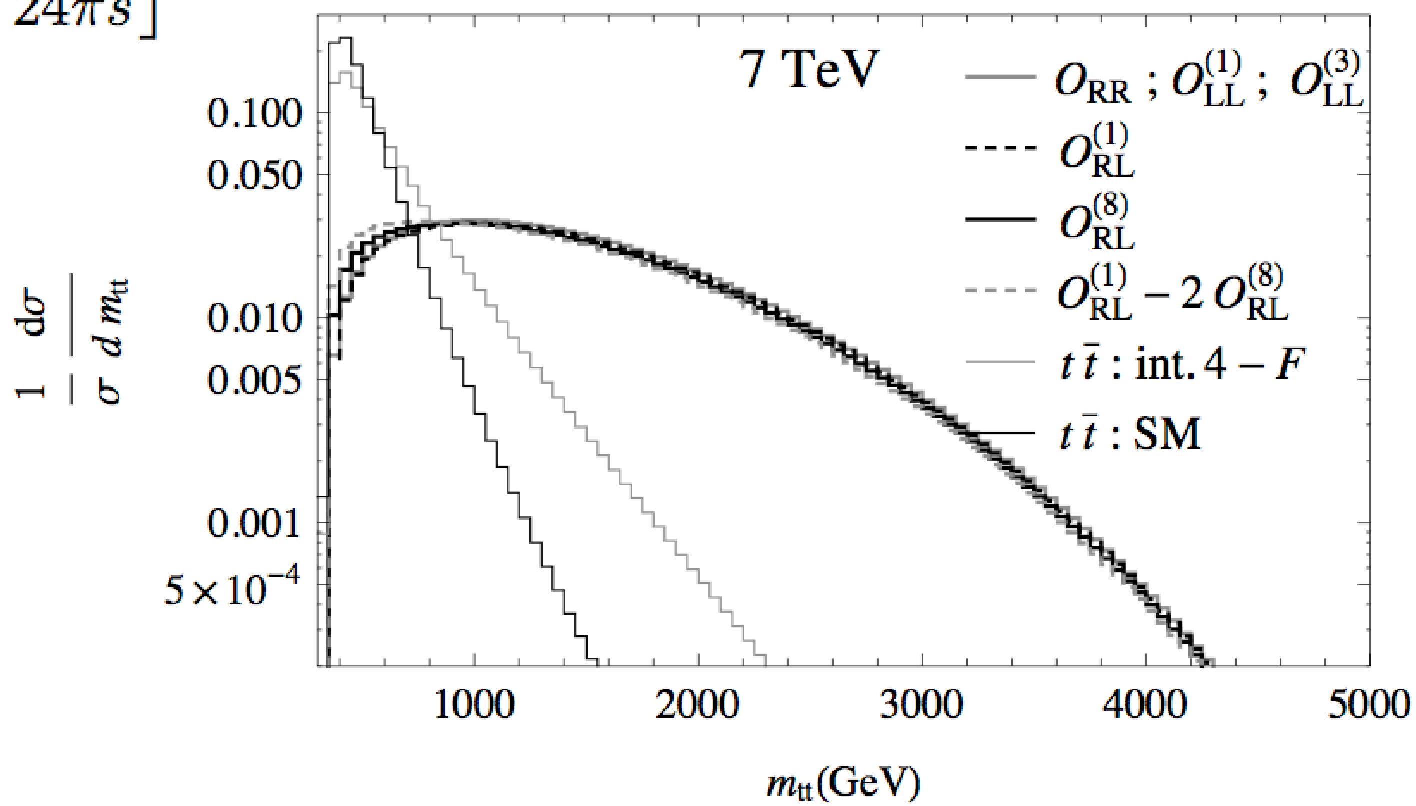
$$\begin{aligned}
\mathcal{O}_{RR} &= [\bar{t}_R\gamma^\mu u_R]\,[\bar{t}_R\gamma_\mu u_R]\\
\mathcal{O}_{LL}^{(1)} &= [\bar{Q}_L\gamma^\mu q_L]\,[\bar{Q}_L\gamma_\mu q_L]\\
\mathcal{O}_{LL}^{(3)} &= [\bar{Q}_L\gamma^\mu\sigma^a q_L]\,[\bar{Q}_L\gamma_\mu\sigma^a q_L]\\
\mathcal{O}_{LR}^{(1)} &= [\bar{Q}_L\gamma^\mu q_L]\,[\bar{t}_R\gamma_\mu\, u_R]\\
\mathcal{O}_{LR}^{(8)} &= [\bar{Q}_L\gamma^\mu T^A q_L]\,[\bar{t}_R\gamma_\mu\, T^A u_R]
\end{aligned}$$



The cross section pp→tt

The differential cross section reads:

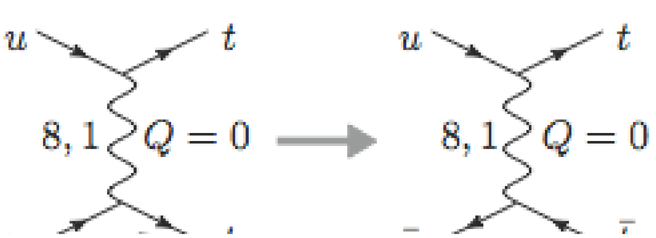
$$\frac{d\sigma}{dt} = \frac{1}{\Lambda^4}\Bigg[\left(|c_{RR}|^2+|c_{LL}|^2\right)\frac{(s-2m_t^2)}{3\pi s} + \left(\left|c_{LR}^{(1)}\right|^2+\frac{2}{9}\left|c_{LR}^{(8)}\right|^2\right)\frac{(m_t^2-t)^2+(m_t^2-u)^2}{16\pi s^2} - \left(\left|c_{LR}^{(1)}\right|^2+\frac{8}{3}\Re\left(c_{LR}^{(1)}c_{LR}^{(8)\,*}\right)-\frac{2}{9}\left|c_{LR}^{(8)}\right|^2\right)\frac{m_t^2}{24\pi s}\Bigg]$$



Link to resonant models

t-channel

Spin	SU(3)	SU(2)	Y	c_{RR}	$c_{LL}^{(1)}$	$c_{LL}^{(3)}$	$c_{LR}^{(1)}$	$c_{LR}^{(8)}$
1	1	1	0	$-\frac{1}{2}$	$-\frac{\xi^2}{2}$		$-\xi$	
1	8	1	0	$-\frac{1}{6}$	$-\frac{\xi^2}{24}$	$-\frac{\xi^2}{8}$		$-\xi$
0	1	2	$\frac{1}{2}$				$-\frac{1}{6}\xi$	$-\xi$
0	8	2	$\frac{1}{2}$				$-\frac{2}{9}\xi$	$\frac{1}{6}\xi$
1	1	3	0			$-\frac{\xi^2}{2}$		
1	8	3	0		$-\frac{3}{8}\xi^2$	$\frac{5}{24}\xi^2$		

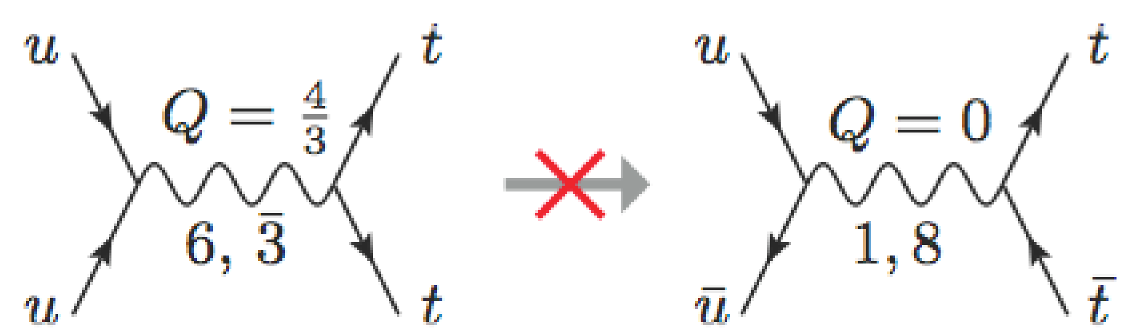


Spin	SU(2)	Y	c_{Vv}	c'_{Vv}	c_{Aa}	c'_{Aa}
1	1	0	$-\frac{1}{2}$	-1	$-\frac{1}{2}$	-1
0	2	$\frac{1}{2}$	$-\frac{1}{2}\left(\lvert\xi\rvert^2+\frac{1}{2}\right)$	$-\frac{1}{2}$	$\frac{1}{2}\left(\lvert\xi\rvert^2+\frac{1}{2}\right)$	$\frac{1}{2}$

Linked to AFB in ttbar!!

s-channel

Spin	SU(3)	SU(2)	Y	c_{RR}	$c_{LL}^{(1)}$	$c_{LL}^{(3)}$	$c_{LR}^{(1)}$	$c_{LR}^{(8)}$
1	$\bar{3}$	2	$\frac{5}{6}$				$-\frac{1}{6}$	$\frac{1}{2}$
1	6	2	$\frac{5}{6}$				$-\frac{1}{3}$	$-\frac{1}{2}$
0	6	1	$\frac{4}{3}$	$\frac{1}{4}$				
0	6	3	$\frac{1}{3}$		$-\frac{3}{8}$	$-\frac{1}{8}$		



Wednesday 18 May 2011

Model Independent BSM searches
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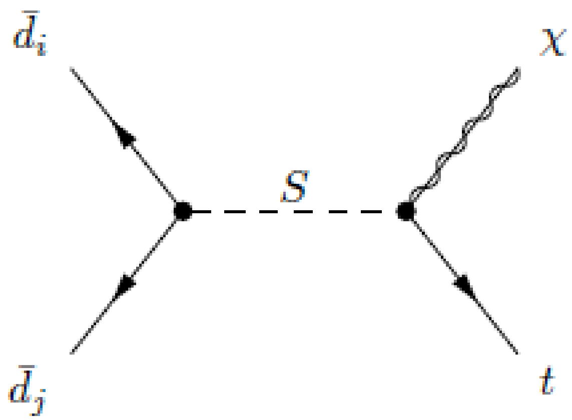
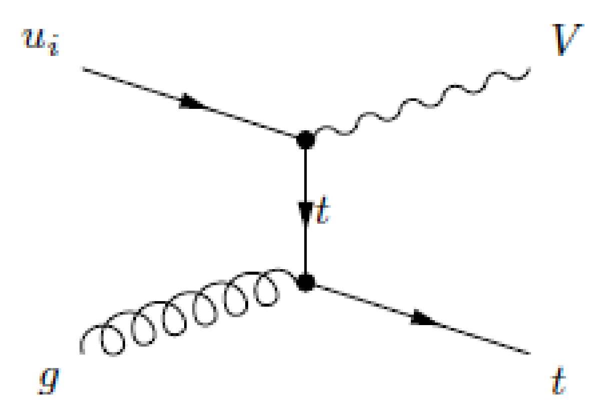
t+mE_T





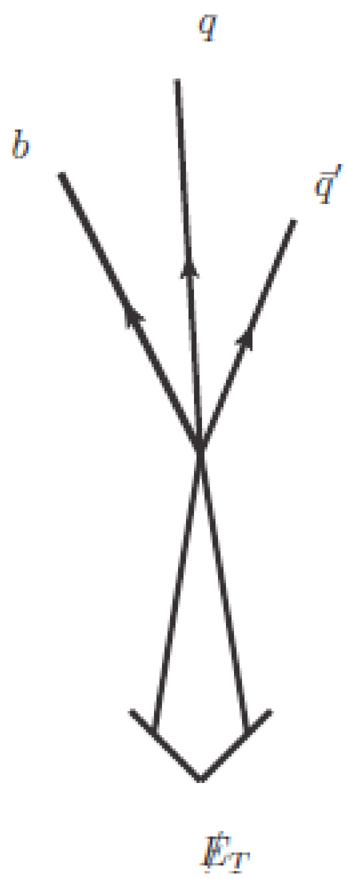
Very unique signature.
Two types of physics involved: R parity violation (RPV) and/or FCNC.

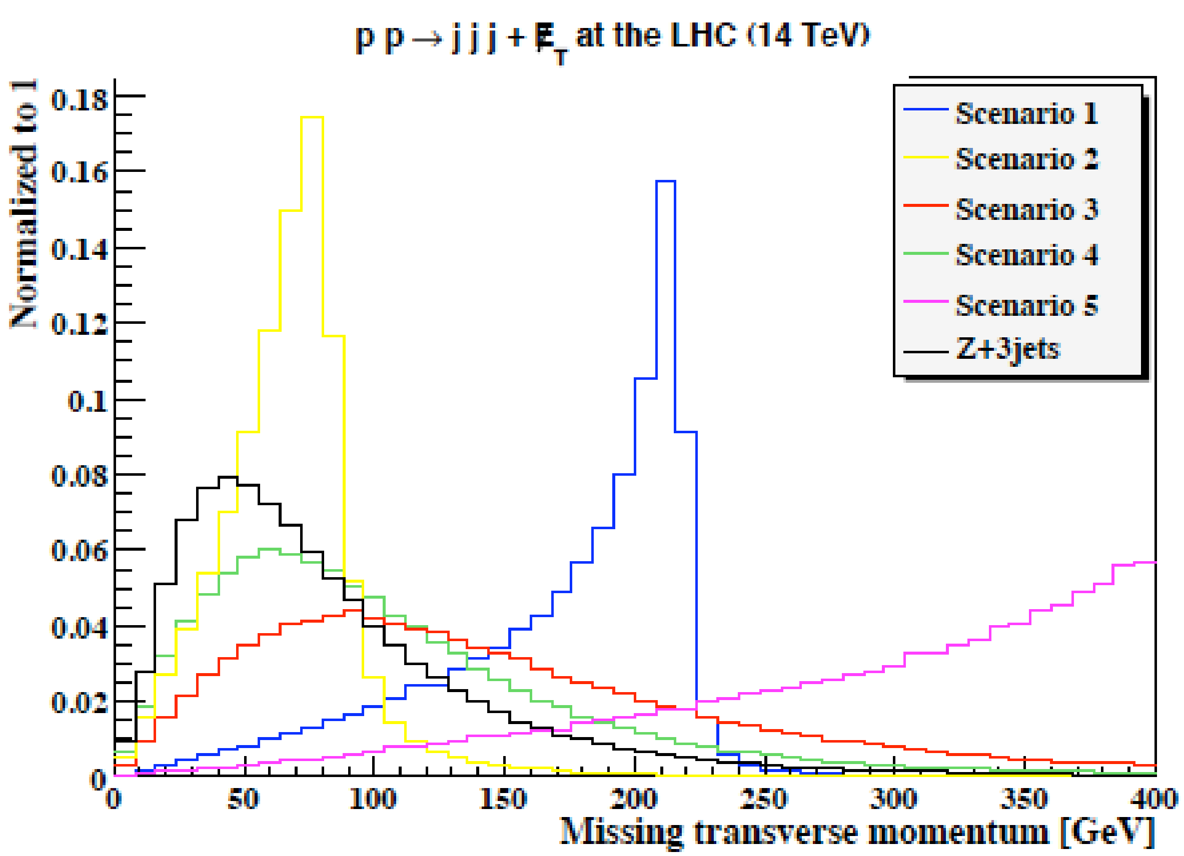
Most general simplified model leading to monotops:

$$
\begin{aligned}
\mathcal{L} = \; & \mathcal{L}_{SM} \\
& + \phi \bar{u} \left[a^0_{FC} + b^0_{FC} \gamma_5 \right] u + V_\mu \bar{u} \left[a^1_{FC} \gamma^\mu + b^1_{FC} \gamma^\mu \gamma_5 \right] u \\
& + \epsilon^{ijk} \varphi_i \bar{d}^c_j \left[a^q_{SR} + b^q_{SR} \gamma_5 \right] d_k + \varphi_i \bar{u}^i \left[a^{1/2}_{SR} + b^{1/2}_{SR} \gamma_5 \right] \chi \\
& + \epsilon^{ijk} \tilde{\varphi}_i \bar{d}^c_j \left[\tilde{a}^q_{SR} + \tilde{b}^q_{SR} \gamma_5 \right] u_k + \tilde{\varphi}_i \bar{d}^i \left[\tilde{a}^{1/2}_{SR} + \tilde{b}^{1/2}_{SR} \gamma_5 \right] \chi \\
& + \epsilon^{ijk} X_{\mu,i} \; \bar{d}^c_j \left[a^q_{VR} \gamma^\mu + b^q_{VR} \gamma^\mu \gamma_5 \right] d_k \\
& + X_{\mu,i} \; \bar{u}^i \left[a^{1/2}_{VR} \gamma^\mu + b^{1/2}_{VR} \gamma^\mu \gamma_5 \right] \chi + \mathrm{h.c.},
\end{aligned}
$$

t+mE$_T$

Study of the simplest signature: 3jets (and/or 1 boosted top)+nothing.

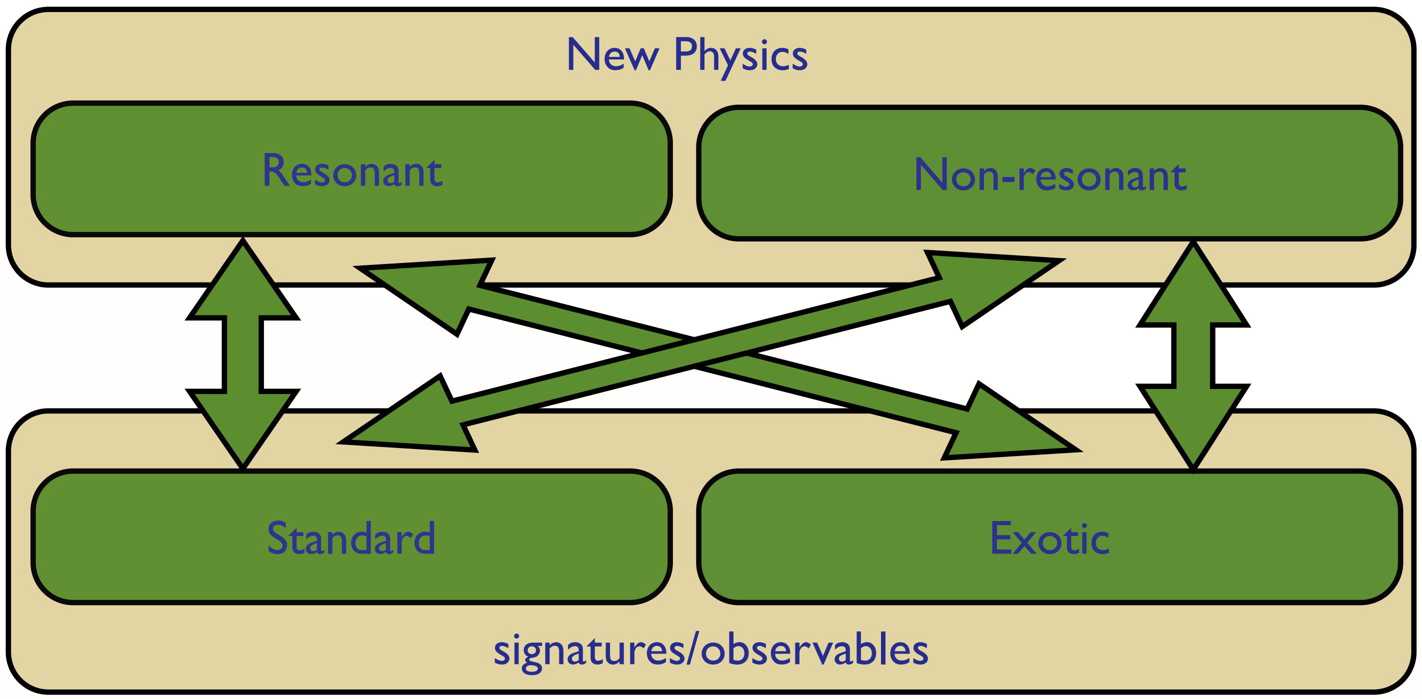




Models implemented in FeynRules + MG5. Pheno ready to go.

Conclusions

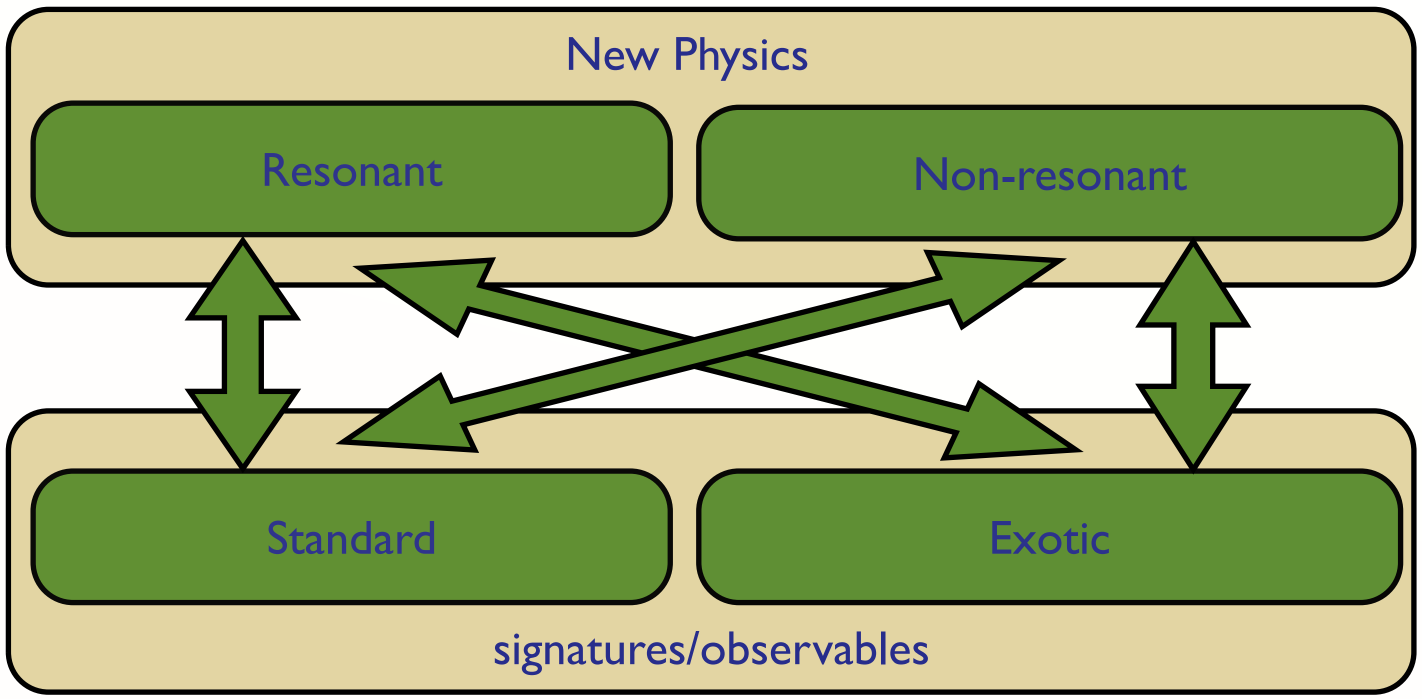
- Bottom-up strategies for top physics lead to very reach phenomenology still to be fully exploited/studied at hadron colliders.



- Data is becoming available and MC tools for doing this are available...

Conclusions

- Bottom-up strategies for top physics lead to very reach phenomenology still to be fully exploited/studied at hadron colliders.



- Data is becoming available and MC tools for doing this are available...
- ..so let's the fun begin!

Credits

Thanks to all top-philic collaborators for the great fun.

Thanks to C. Degrande and C. Grojean in particular for sharing slides with me.