Introduction of the Auxiliary Fields for the Anomalous Wtb Couplings Modeling

E.E. Boos, V. Bunichev,
L. Dudko, M. Perfilov

Moscow State University

Session of NP Division, Protvino, Russia, 2013, November, 7

Anomalous couplings modeling: introduction

- Effective Lagrangian approach is the usual way to compute and model anomalous physics

  - new physics are encoded in sets of higher-dimensional operators

  - one can derive Feynman rules, add them to SM vertices, perform needed computations and event generation

- In practice there is a number of mainly technical but time consuming difficulties

  - unstable particles: anomalous particles are in the production and decay

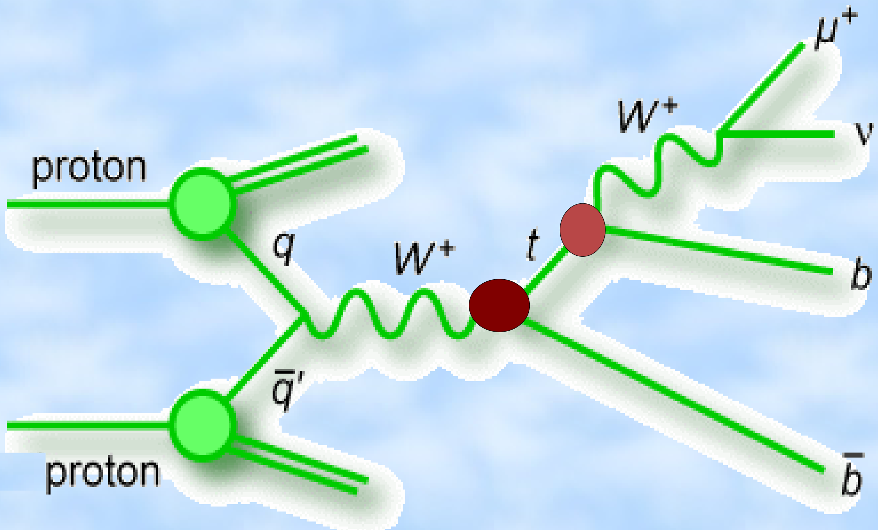
  - matrix elements are the polinomials of anomalous parameters affecting

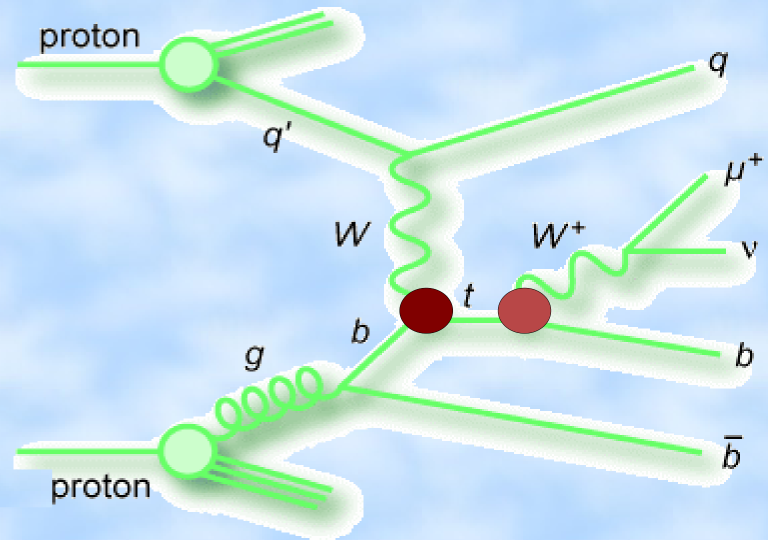
    - production rate
    - decay branching fraction
    - spin correlations
    - corresponding contributions...

- We're introducing the method allowing to **reduce** mentioned **difficulties** sighnificantly on the example of Anomalous Wtb couplings modeling

AnomWtb couplings: vertex structure

- Anomalous Wtb vertex structure





Common form of the Effective Wtb vertex lagrangian:

$$\mathscr{L}_{\mathbf{tbW}} = \frac{\mathbf{g}}{\sqrt{2}} \cdot \mathbf{W}_\mu \bar{\mathbf{b}} \cdot \gamma^\mu \left(\mathbf{L_V} \frac{1}{2}(1-\gamma^5) + \mathbf{R_V} \frac{1}{2}(1+\gamma^5)\right) \mathbf{t} \; - $$

$$-\left(\frac{\mathbf{g}}{\sqrt{2}}\right) \cdot \partial_\mu \mathbf{W}_\mu \bar{\mathbf{b}} \sigma^{\mu\nu} \left(\mathbf{L_T} \frac{1}{2}(1-\gamma^5) + \mathbf{R_T} \frac{1}{2}(1+\gamma^5)\right) \mathbf{t}$$

Left and right vector couplings

Left and right tensor couplings

SM: Vtb 0 0 0

Anomalous Wtb: approaches

Vertex function at order $1/\Lambda^2$

takes into account all terms with couplings

V_L, V_R ...

dim $1/\Lambda^2, 1/\Lambda^4$

Phys. Rev. D 56, 467–478 (1997)

Effective operators at order $1/\Lambda^2$

takes into account interference terms with SM only

V_L, g_R ... dim $1/\Lambda^2$

with contact interaction

dim $1/\Lambda^2$ only

(Phys.Rev. D83 (2011) 034006)

- Introduction of auxiliary fields allows to realize both strategies in the experiment

Anomalous Wtb in single top production

- **Production CS** has the following form:

$$\sigma_{production} \sim A\cdot(L_V)^2 + B\cdot(R_V)^2 + C\cdot(L_V\cdot R_T) + D\cdot(R_V\cdot L_T) + E\cdot(L_T)^2 + G\cdot(R_T)^2$$

- We look for the small deviations from the SM

  - three scenarios pairing the left vector coupling with each of other three couplings: (L_V,R_V) , (L_V,L_T) , (L_V,R_T)

- Necessary MC samples for anomalous top production:

	L_V	R_V	L_T	R_T
SM	1	0	0	0
	0	1	0	0
	0	0	1	0
	1	0	0	1

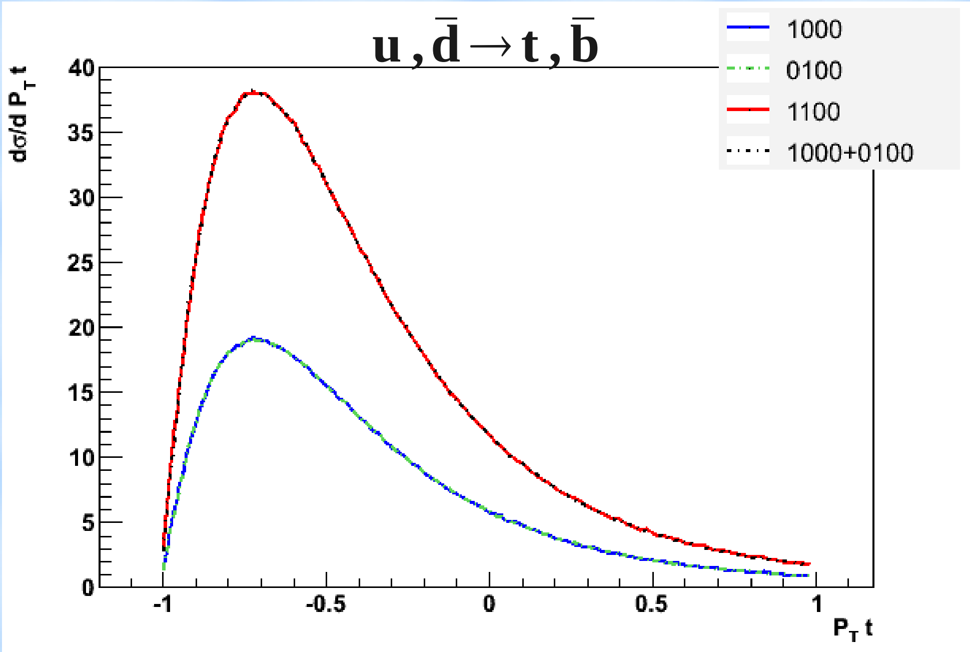
- Tevatron (D0) results (0.9 fb^{-1}, 5.4 fb^{-1}) - limits on the anomalous parameters for three scenarios:

Scenario	Cross section	Coupling
(L_V, L_T)	< 0.60 pb	$\lvert V_{tb}\cdot f_{L_T}\rvert^2 < 0.06$
(L_V, R_V)	< 2.81 pb	$\lvert V_{tb}\cdot f_{R_V}\rvert^2 < 0.93$
(L_V, R_T)	< 1.21 pb	$\lvert V_{tb}\cdot f_{R_T}\rvert^2 < 0.13$

Phys. Lett. **B 703**, 21 (2012)

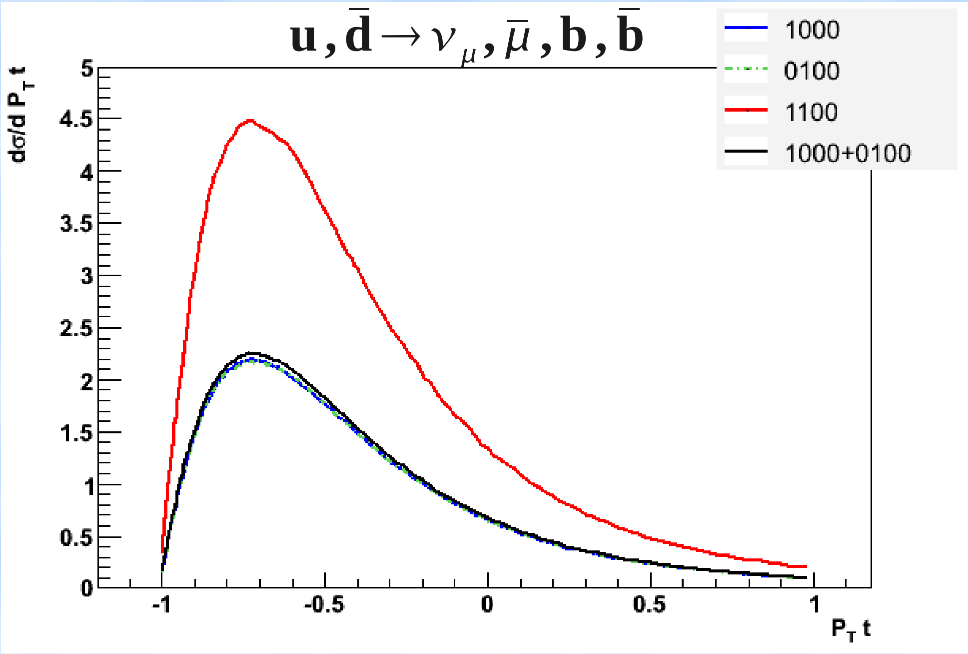
Anomalous Wtb in single top production and decay

(Lv, Rv) scenario:



Production case:

$(L_V, R_V, 0, 0) = (L_V, 0, 0, 0) + (0, R_V, 0, 0)$



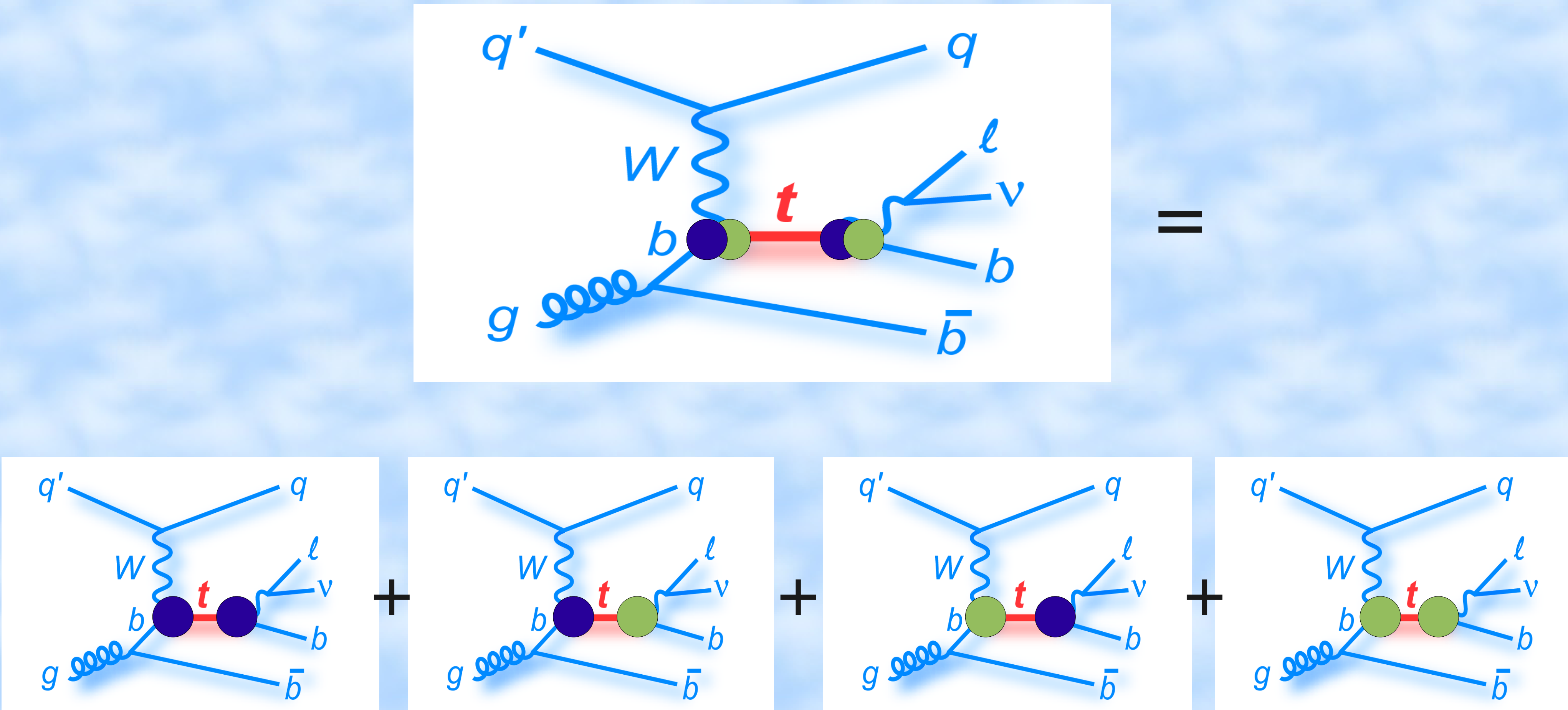
Production+decay case:

$(L_V, R_V, 0, 0) \neq (L_V, 0, 0, 0) + (0, R_V, 0, 0)$

Pt (top) distributions for $L_V=1$, $R_V=1$

Anomalous Wtb, (Lv,Rv) scenario

- Production+decay case, **vector couplings, (L_V , R_V)scenario**
  - **- is the combination of states with L_V and R_V in production and decay**

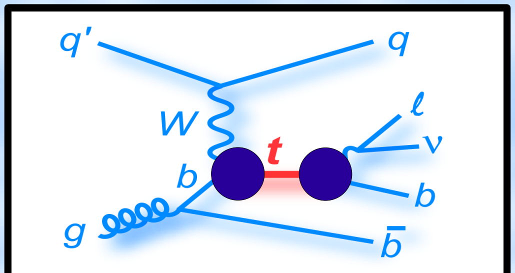


SM

Anomalous Wtb, (Lv,Rv) scenario, MC modeling

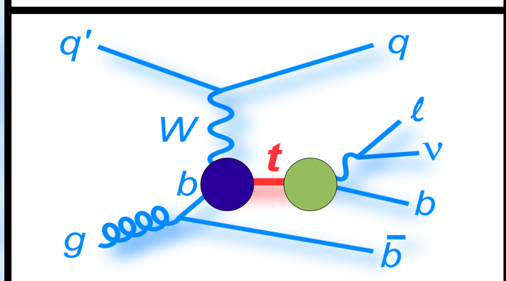
- Production+decay case, (L_V , R_V) scenario
- How to model the general L_V and R_V dependence in general case:

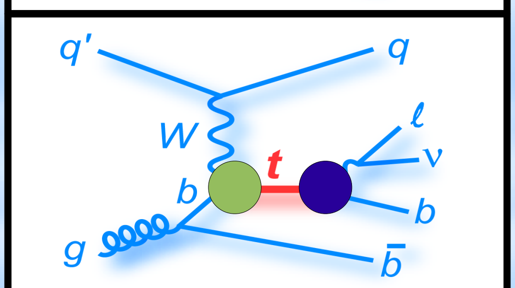
the sets of MC events:



L_V=1, R_V=0 in both Wtb vertices; $w_{top} = w_{1000}$

sample «1000»



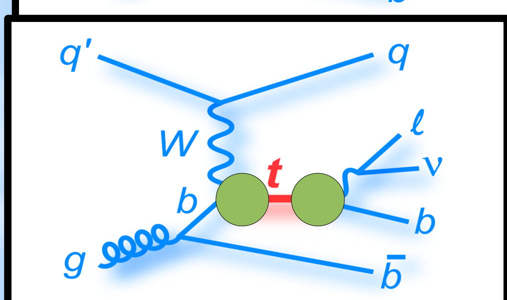


L_V=1, R_V=0 in production Wtb vertex and

L_V=0, R_V=1 in decay Wtb vertex and vise versa

«artificial» sample

(auxiliary fields) $w_{top} = w_{artif}$



L_V=0, R_V=1 in both Wtb vertices; $w_{top} = w_{0100}$

sample «0100»

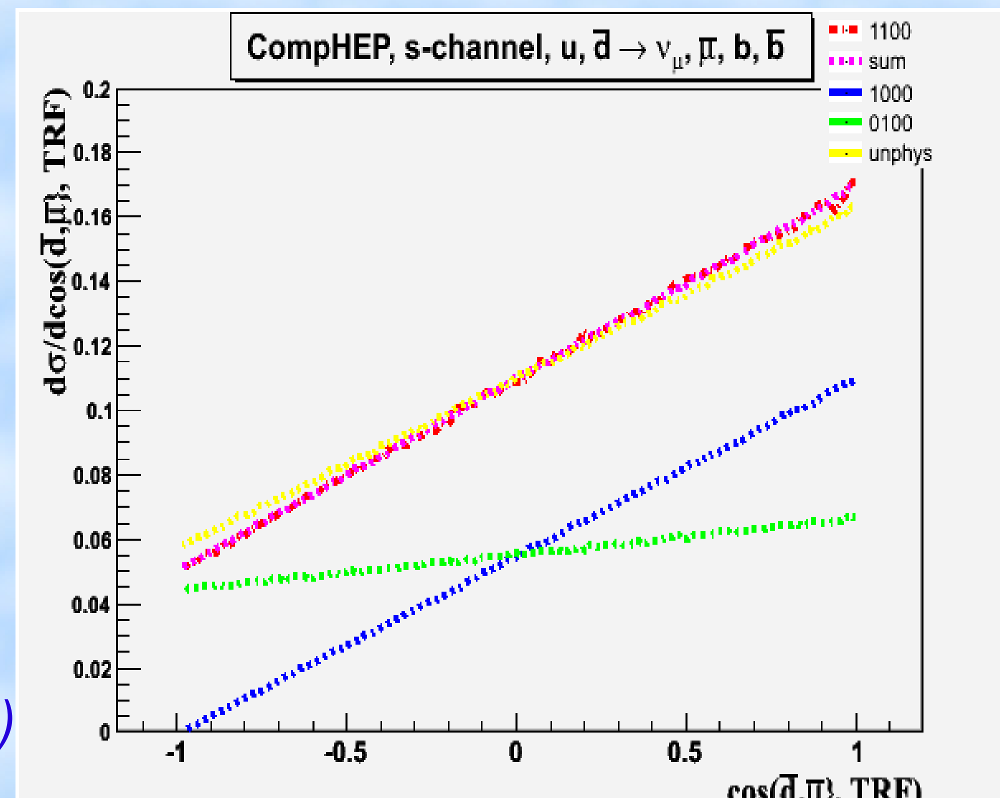
Anomalous Wtb, (Lv,Rv) scenario, MC modeling

- Production+decay case, (L_V , R_V) scenario
- The case with L_V, R_V both in the Wtb vertex:

$$\sigma_{production+decay}(L_V, R_V) = m\cdot(1000) + n\cdot(artificial) + k\cdot(0100)$$

$$m = (L_V)^4 \frac{w_{1000}}{w_{(L_V, R_V)}} \qquad n = (L_V)^2\cdot(R_V)^2 \frac{w_{art}}{w_{(L_V, R_V)}} \qquad k = (R_V)^4 \frac{w_{0100}}{w_{(L_V, R_V)}}$$

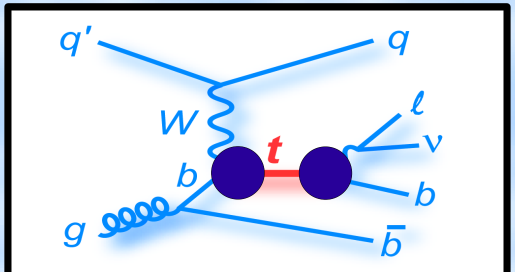
Distribution of the cos(q,l)
in the top rest frame for the s-channel
single top quark processes
with both left and right vector
operators in the Wtb vertex.
(correct modeling of (1100) sample
with 1000, 0100 and «artificial» samples)



Anomalous Wtb, (Lv,Lt) scenario, MC modeling

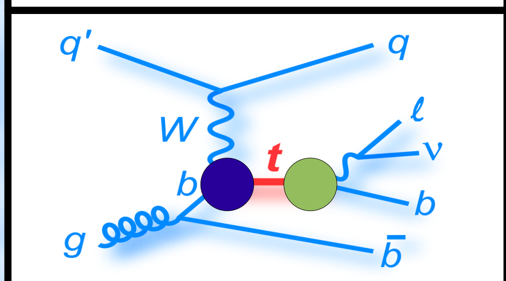
- Production+decay case, (L_V , L_T) scenario
- How to model the general L_V and L_T dependence in general case:

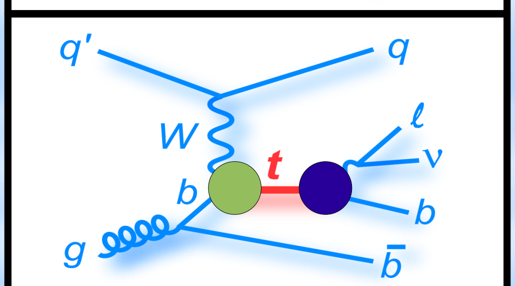
the sets of MC events:



L_V=1, L_T=0 in both Wtb vertices; $w_{top} = w_{1000}$

sample «1000»

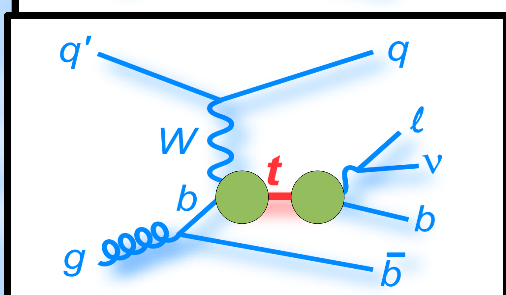




L_V=1, L_T=0 in production Wtb vertex and

L_T=0, L_V=1 in decay Wtb vertex and vise versa

«artificial» sample
(auxiliary fields) $w_{top} = w_{artif}$



L_V=0, L_T=1 in both Wtb vertices; $w_{top} = w_{0010}$

«0010»sample

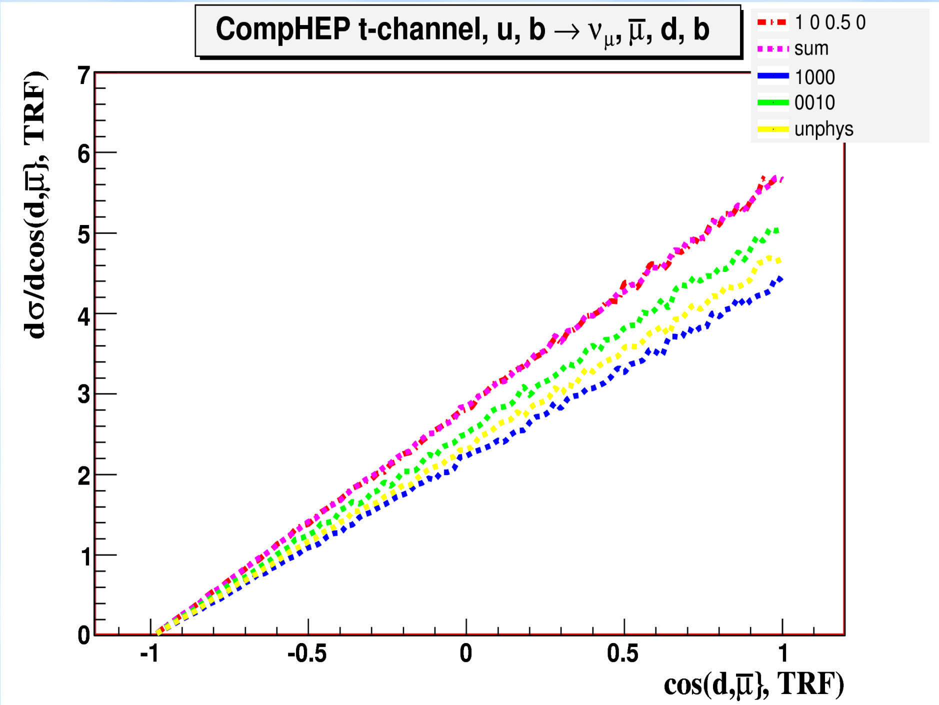
Anomalous Wtb, (Lv,Lt) scenario, MC modeling

- Production+decay case, (L_V , L_T) scenario
- The case with L_V, L_T both in the Wtb vertex:

$$\sigma_{production+decay}(L_V, L_T) = p\cdot(1000) + r\cdot(artificial) + s\cdot(0010)$$

$$p = (L_V)^4 \frac{w_{1000}}{w_{(L_V, L_T)}} \qquad r = (L_V)^2\cdot(L_T)^2 \frac{w_{art}}{w_{(L_V, L_T)}} \qquad s = (L_T)^4 \frac{w_{0010}}{w_{(L_V, L_T)}}$$

Distribution of the cos(q,l)
in the top rest frame for the t-channel
single top quark processes
with both left vector and tensor
operators in the Wtb vertex.
(correct modeling of (1/0/0.5/0) sample
with 1000, 0010 and «artificial» samples)



Anomalous Wtb, (Lv,Rt) scenario

- Production+decay case,**(L_V , R_T)scenario**

  -the most complicated case because of the interference term in the production CS expression:

$$\sigma_{production} \sim A\cdot(f_V^L)^2 + C\cdot(f_V^L\cdot f_T^R) + G\cdot(f_T^R)^2$$

$$\sigma_{production+decay} = [(L_V)^2\cdot A_p + C_p(L_V\cdot R_T) + (R_T)^2\cdot G_p] * Br(t\rightarrow l,\nu,b)$$

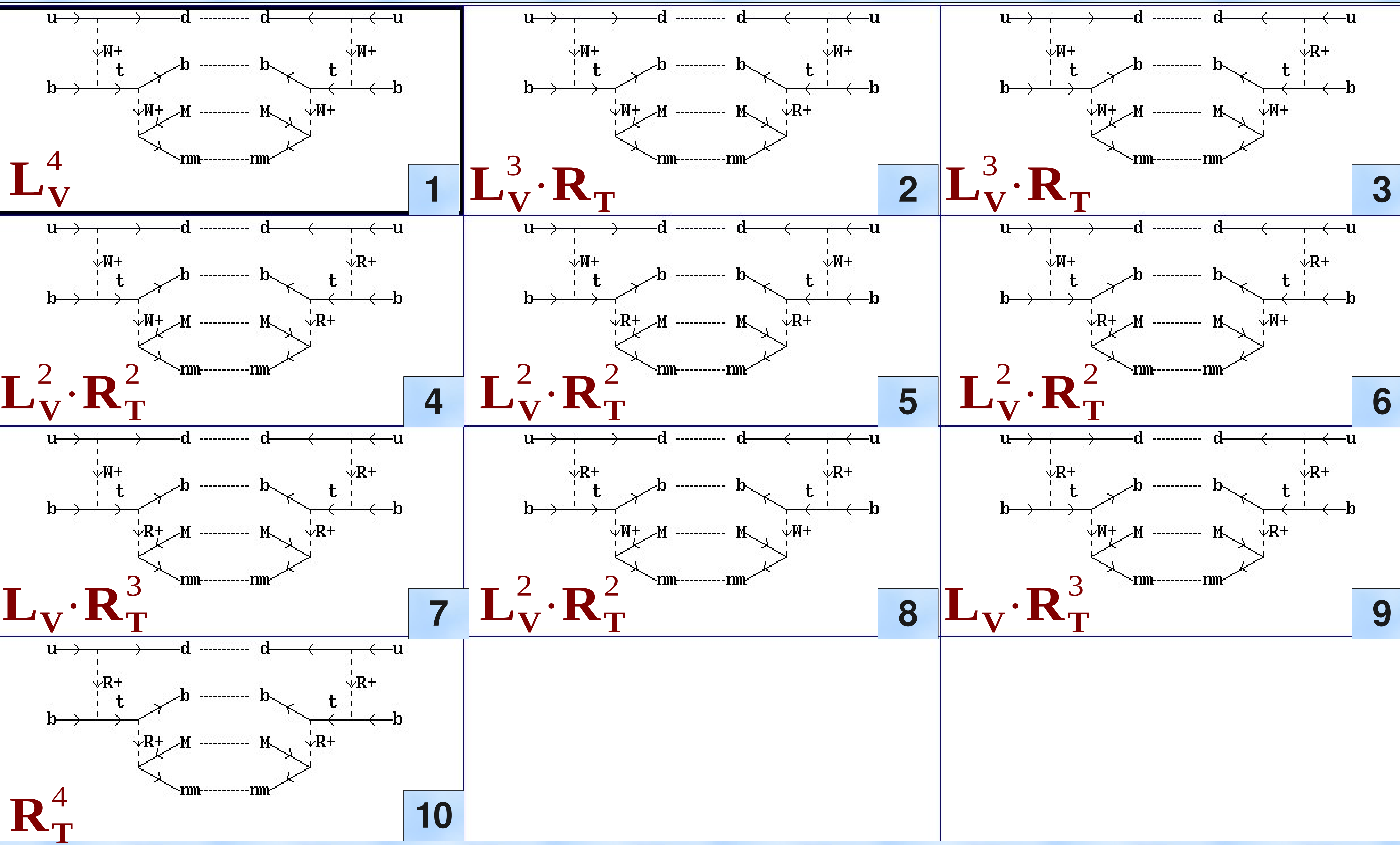
$$= \frac{[(L_V)^2\cdot A_p + C_p(L_V\cdot R_T) + (R_T)^2\cdot G_p]*[(L_V)^2\cdot A_d + C_d(L_V\cdot R_T) + (R_T)^2\cdot G_d]}{w_t}$$

= many terms with **different powers of constants**

- **So we need additional samples for modeling the (Lv,Rt) case**

  - with different couplings in the production and decay of single top

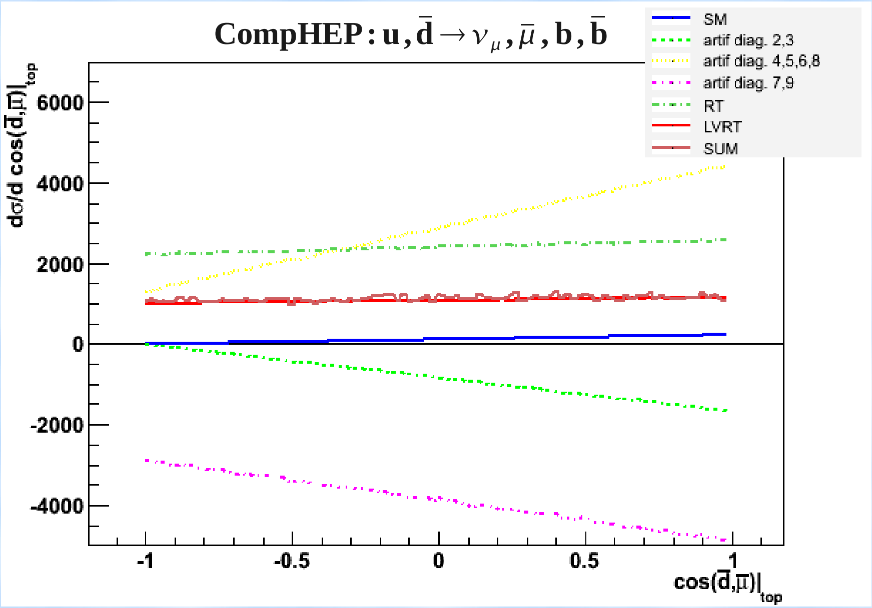
Anomalous Wtb, (Lv,Rt) scenario



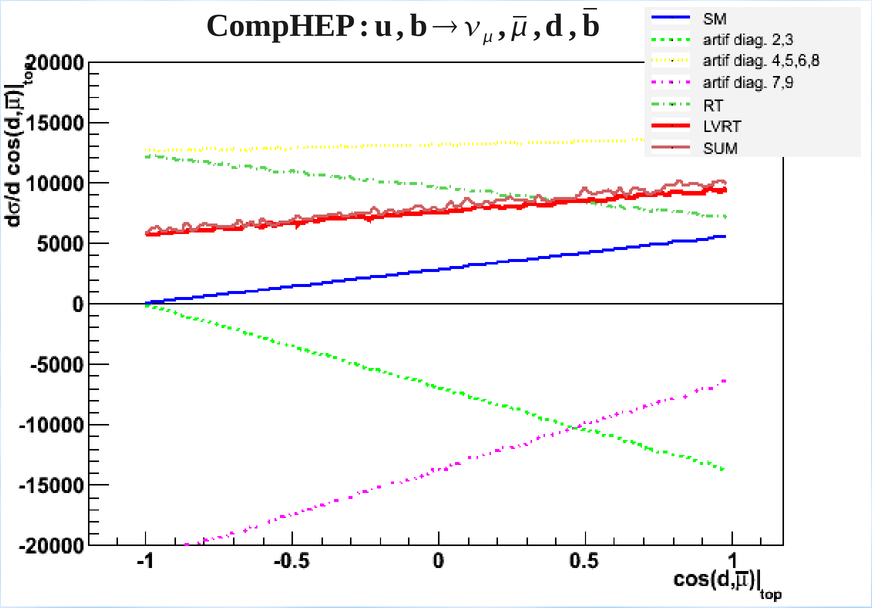
Anomalous Wtb, (Lv,Rt) scenario, MC modeling

- Production+decay case, (L_V , R_T) scenario
- The case with L_V, R_T both in the Wtb vertex:

Distribution of the cos(Q,l) in the top rest frame for the ***s-channel*** *single top quark processes with both left vector and right tensor operators in the Wtb vertex. (correct modeling of (1/0/0/1) sample with 1000-0001 and «artificial» samples)*



Distribution of the cos(q,l) in the top rest frame for the ***t-channel*** *single top quark processes with both left vector and right tensor operators in the Wtb vertex. (correct modeling of (1/0/0/1) sample with 1000-0001 and «artificial» samples)*



Conclusion

- We introduced new method for the correct anomalous couplings modeling
- We tested this method for the three standard scenarios of AnomWtb couplings search
- We use this method for the ongoing search for Anomalous Wtb couplings analysis in the single-top group at the LHC
- More details as well as the other method applications can be found in the paper
- The paper is going to be published