Analysis of the Anomalous Wtb couplings in the t-channel single top quark production

- Anomalous Wtb couplings
- Scenarios for t-channel analysis
- Contribution of the Anomalous Wtb couplings to ttbar / tW processes

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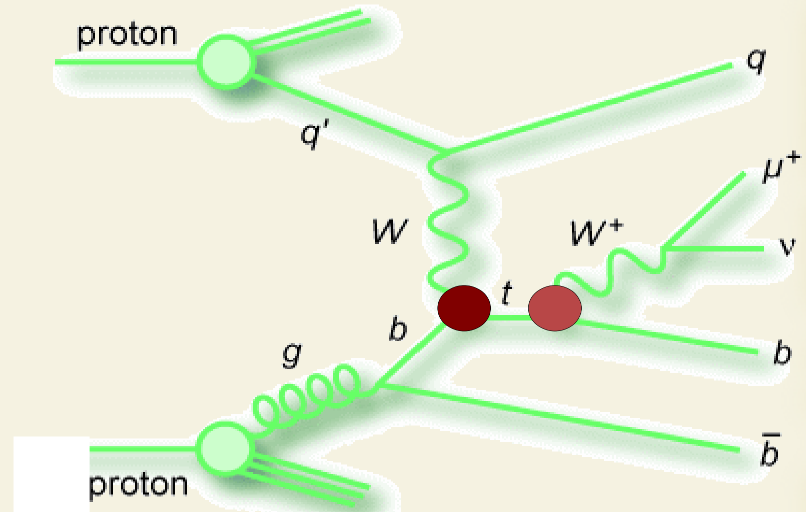
Anomalous Wtb couplings in t-channel

Anomalous Wtb vertex structure



Common form of the
Effective Wtb vertex lagrangian.
Vertex functions approach

$$\mathcal{L}_{tbW} = \frac{g}{\sqrt{2}} W^-_\mu \, \bar{b} \, \gamma^\mu \left(f_1^L P_L + f_1^R P_R \right) t - \frac{g}{\sqrt{2} M_W} \partial_\nu W^-_\mu \, \bar{b} \, \sigma^{\mu\nu} \left(f_2^L P_L + f_2^R P_R \right) t \; + \; h.c.$$

Left and right vector operators

Left and right tensor operators

SM:	Vtb	0	0	0	(1000)

$$L_V \equiv f_1^L, R_V \equiv f_1^R, L_T \equiv f_2^L, R_T \equiv f_2^R$$

Analysis Strategy: different scenarios: (Lv,Rv), (Lv,Lt), (Lv,Rt)

- only two couplings are non-zero at the same time

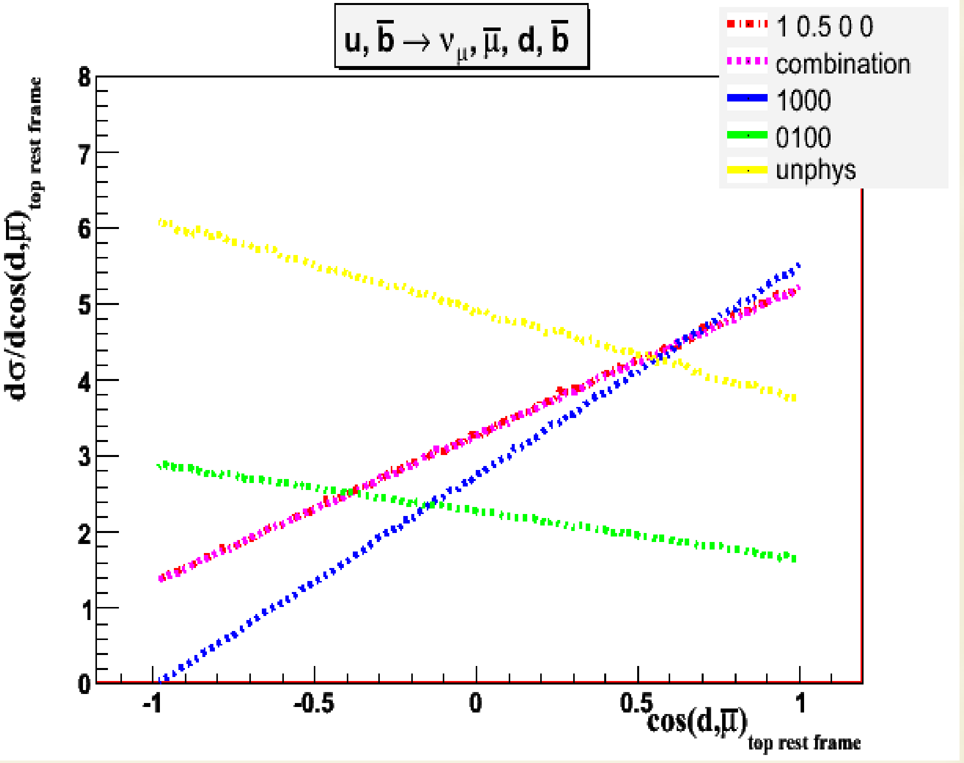
Anomalous Wtb, (Lv,Rv) scenario, CompHEP MC simulation

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

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

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

Distribution of the cos(q,l) in the top rest frame for the t-channel single top quark processes with both left and right vector operators in the Wtb vertex. (correct modeling of (1/0.5/0/0) sample with 1000, 0100 and «unphys» samples)



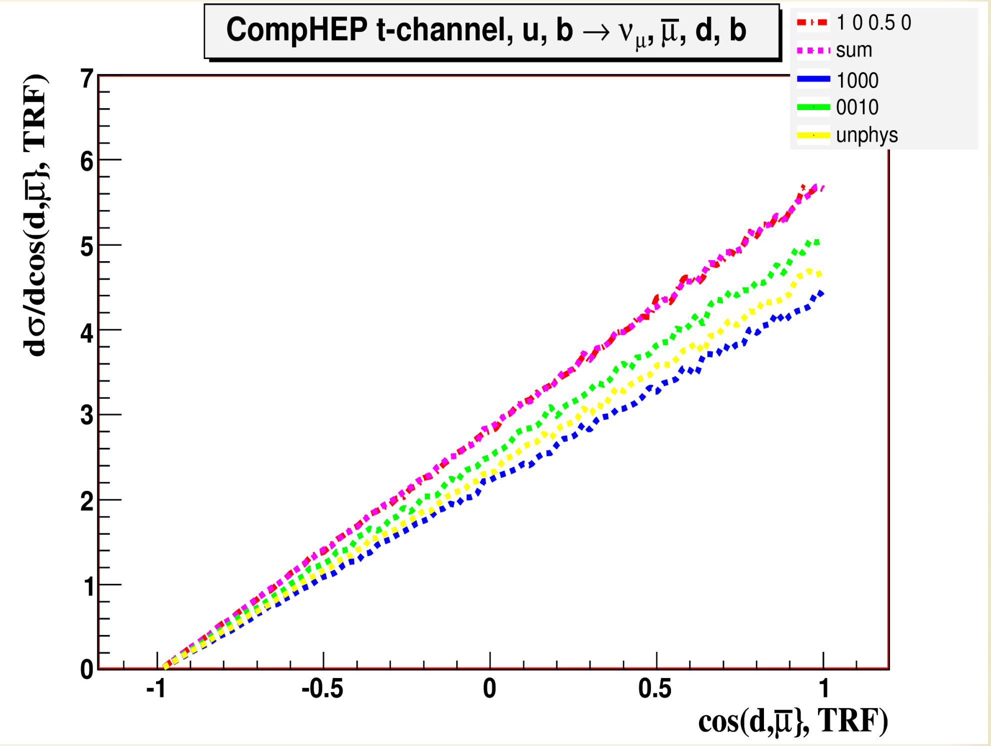
Anomalous Wtb, (Lv,Lt) scenario, CompHEP MC

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

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

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

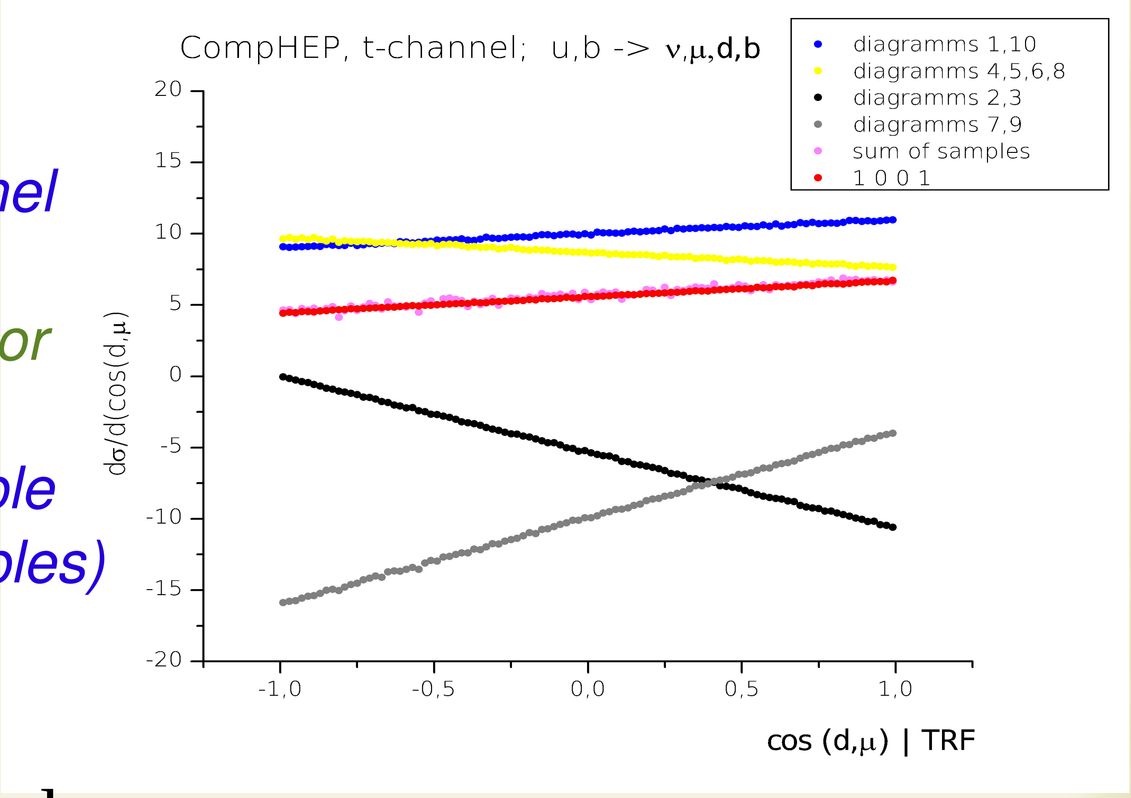
Distribution of the cos(q,l)
in the top rest frame for the t-channel
single top quark processes
with both left vector and tensor
operators in the Wtb vertex.
(correct modeling of (1/0/0.5/0) sample
with 1000, 0010 and «unphys» samples)



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

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

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)



- This case is more complicated
  - we need more than 1 «artificial» sample

Anomalous Wtb in Single Top: simulation issues

- **Correct simulation of the anomalous couplings in both vertexes is important, but significantly increases the complexity. For the first stage of analysis one can check 2D scenarios (LV, RV), (LV, LT), (LV, RT) and vary 4 couplings simultaneously next.**
- **The anomalous Wtb vertex is present in tW and ttbar backgrounds. Is this contribution significant and how to simulate it? Will it increase the sensitivity of the analysis?**
- **How one can take into account NLO contribution for the simulated t-channel, tW and ttbar processes with anomalous Wtb couplings contribution?**

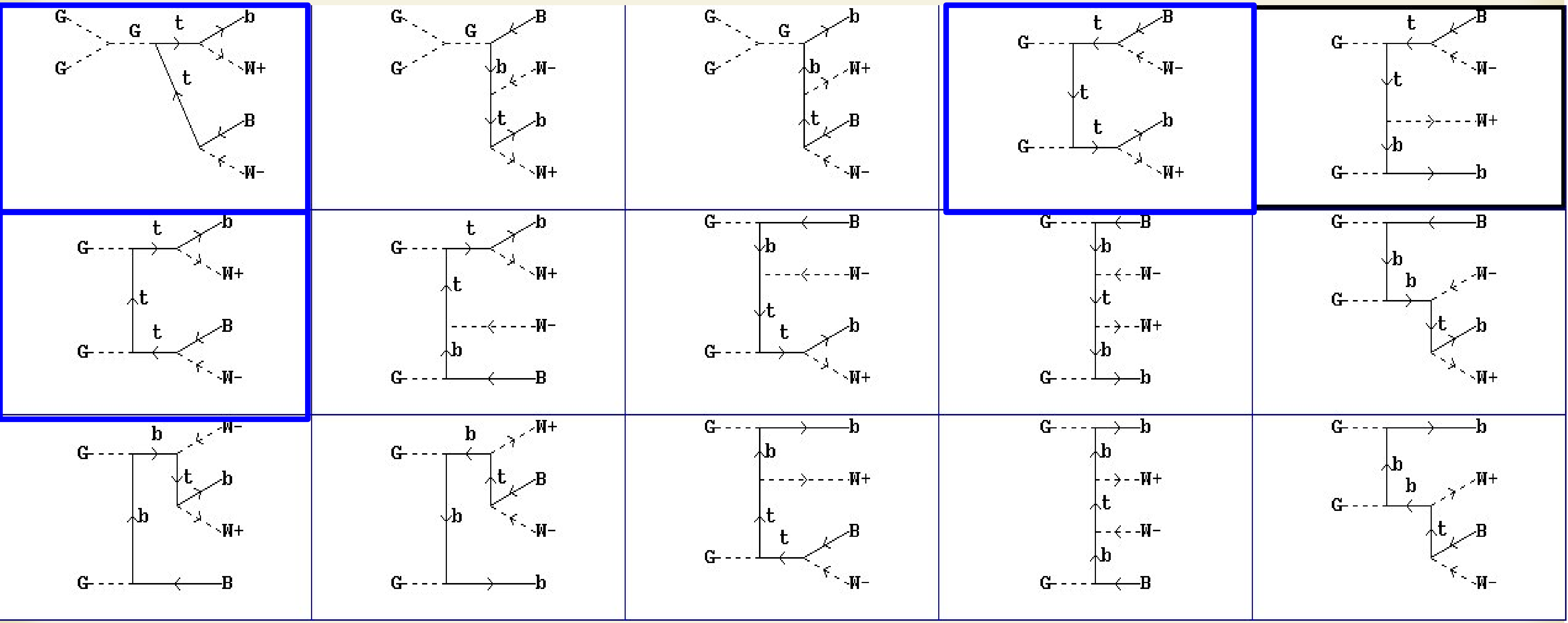
Anomalous Wtb couplings contribution

to the tW and ttbar

background processes

tW+ttbar process: all diagrams

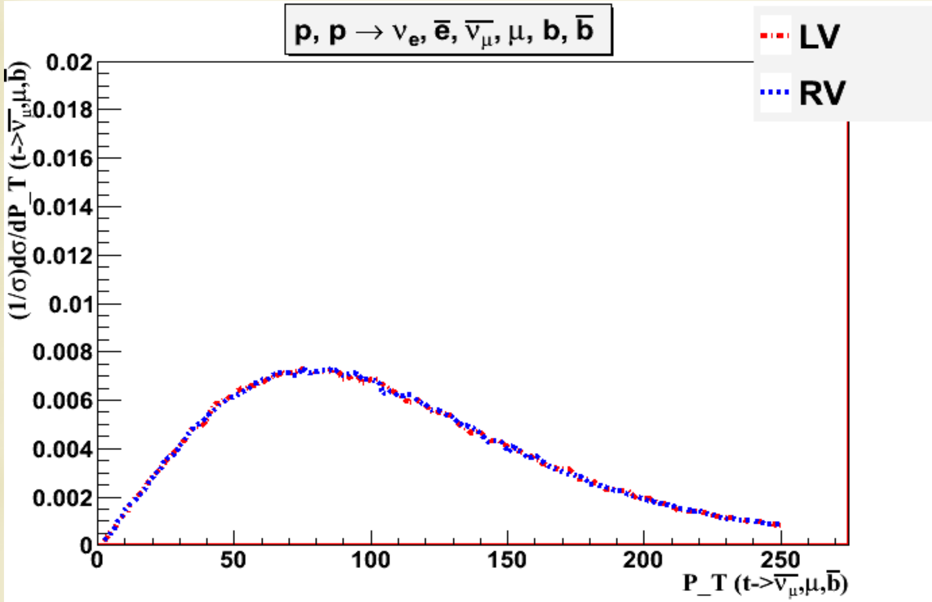
- Lets look at the main subprocess of $\mathbf{p\,,p \;\rightarrow\; \bar{t}\,,W+,b}$:

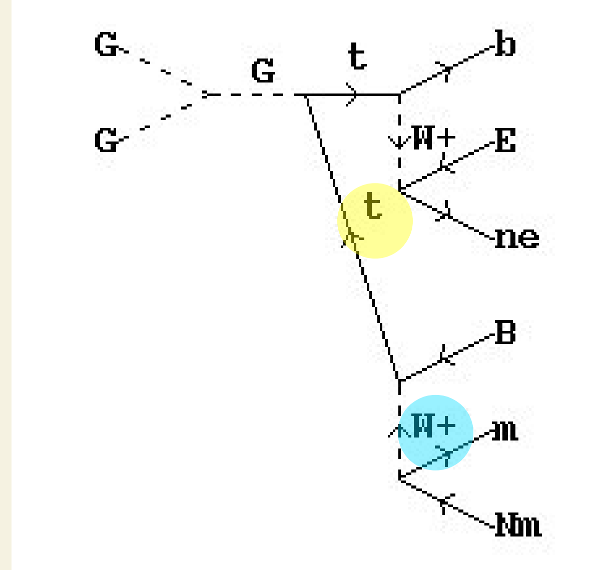


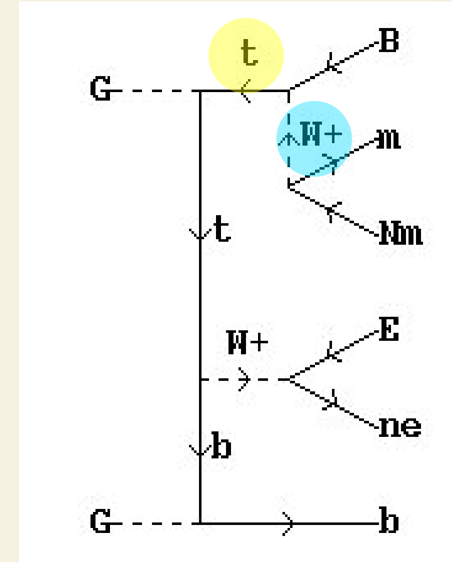
: ttbar diagram

- All diagrams have been taken into account
  - with interference between ttbar and tW

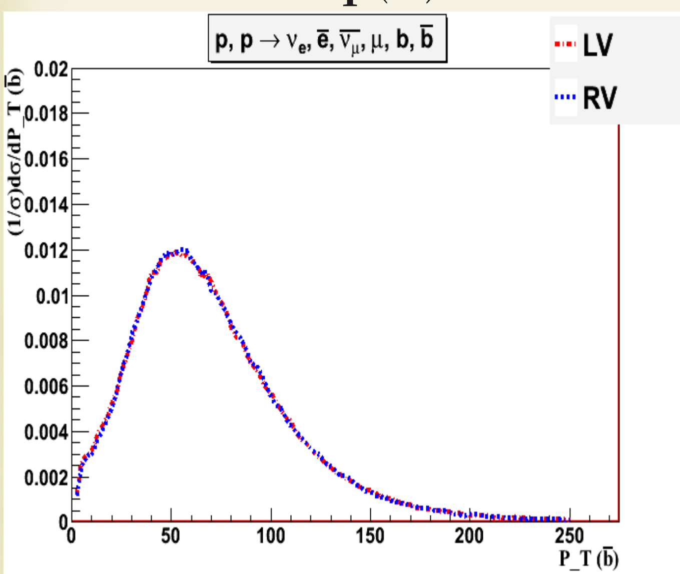
tW+ttbar process: main distributions

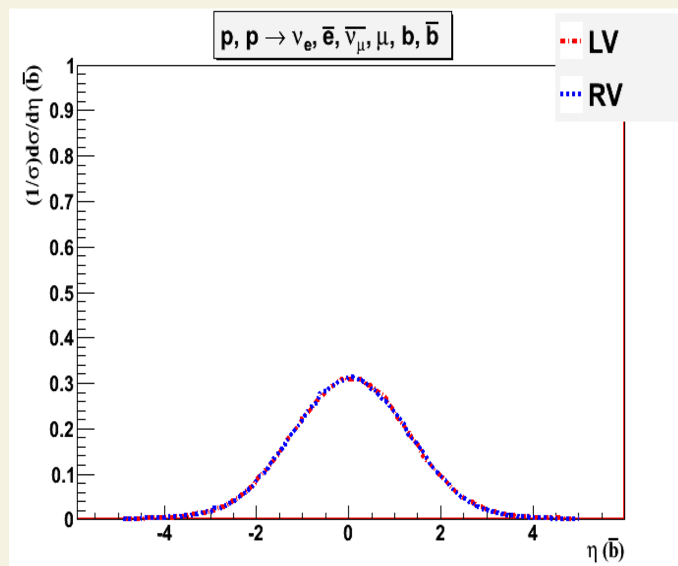


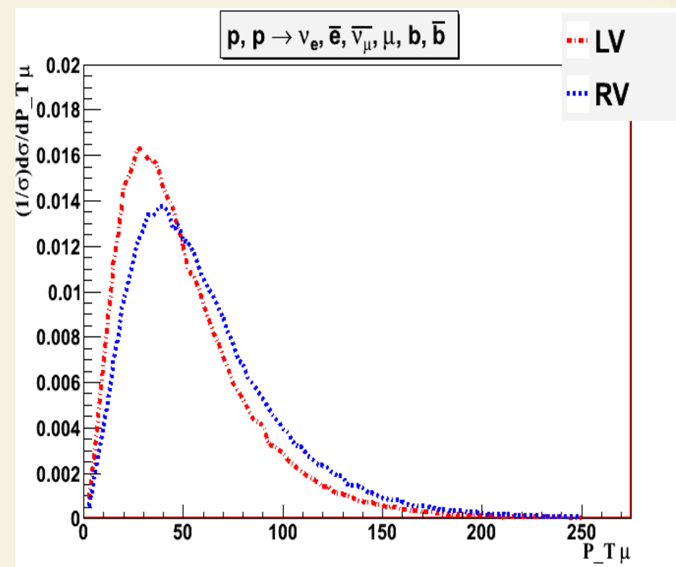




$\mathbf{P_T(t)}$



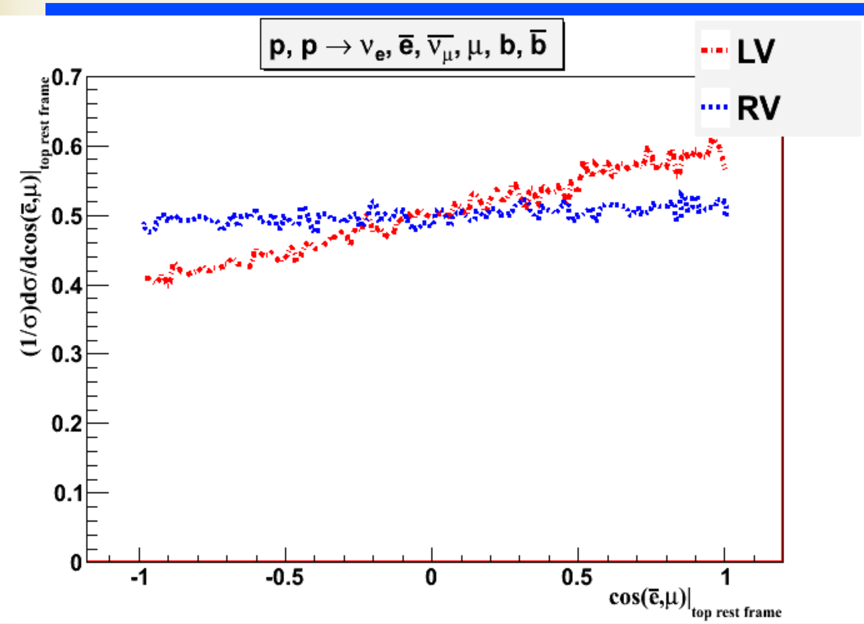


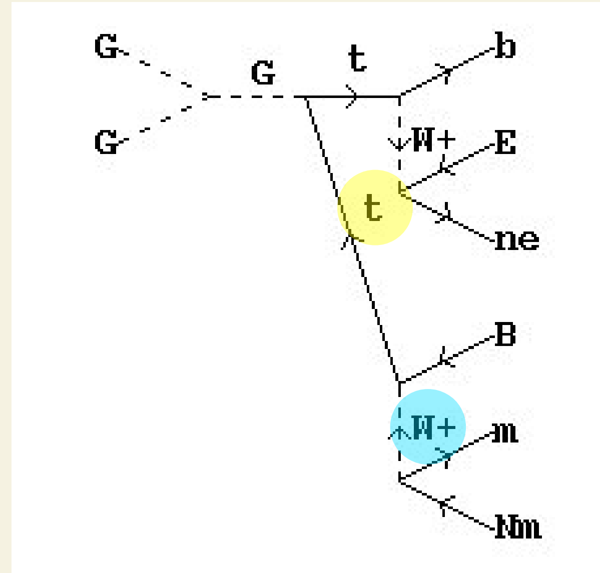


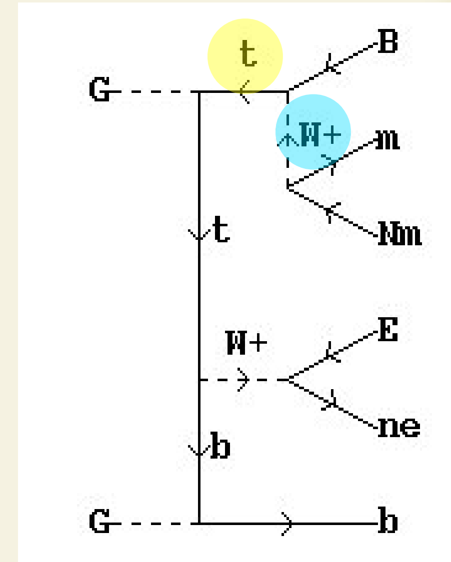
$\mathbf{P_T(\bar{b})}$ $\eta(\bar{b})$ $\mathbf{P_T(\mu)}$

<u>The difference is in the top-decay products distributions</u>

tW+ttbar process: decay angular distributions

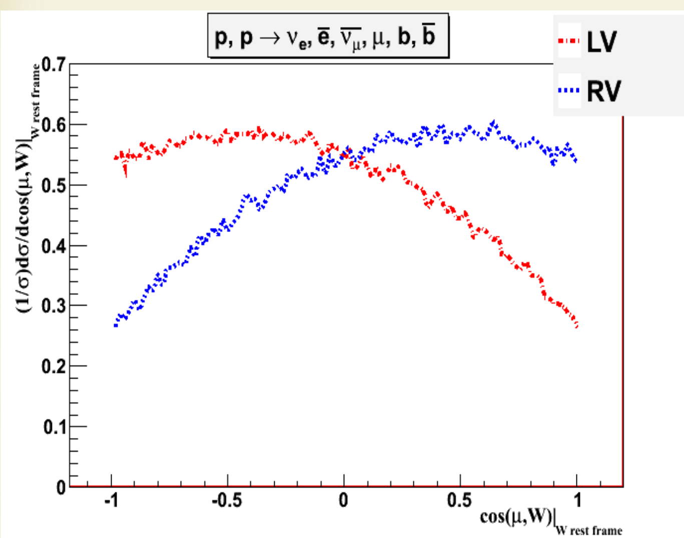


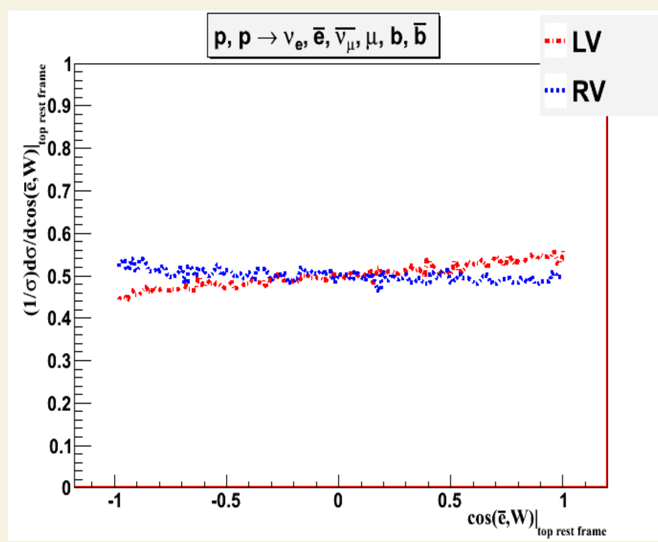


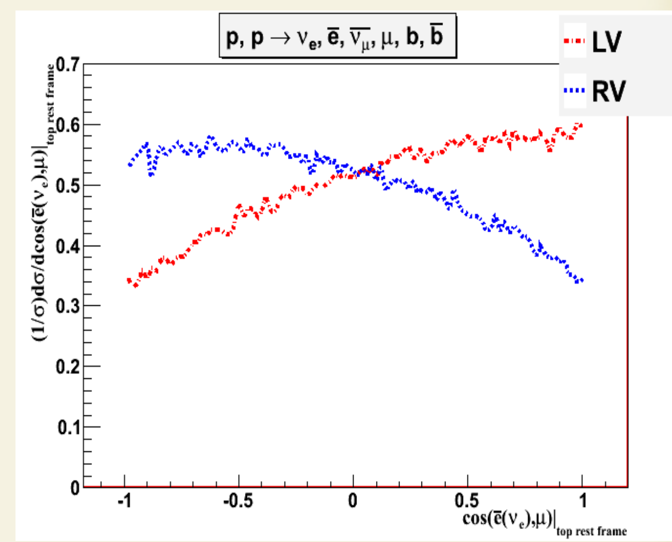


$\cos(E,m)|_{\text{top rest frame}}$

(Phys.Lett. B534 (2002) 97-105)

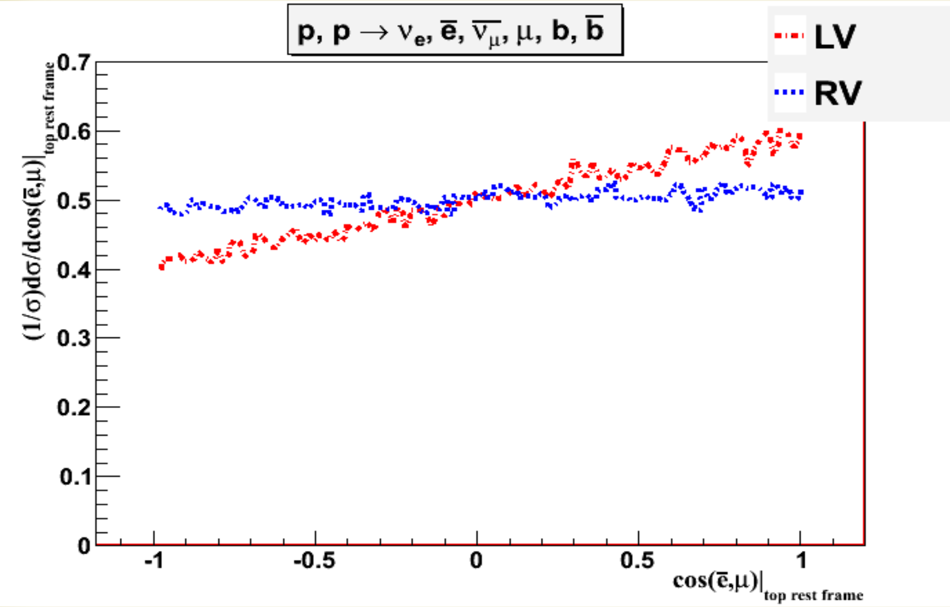


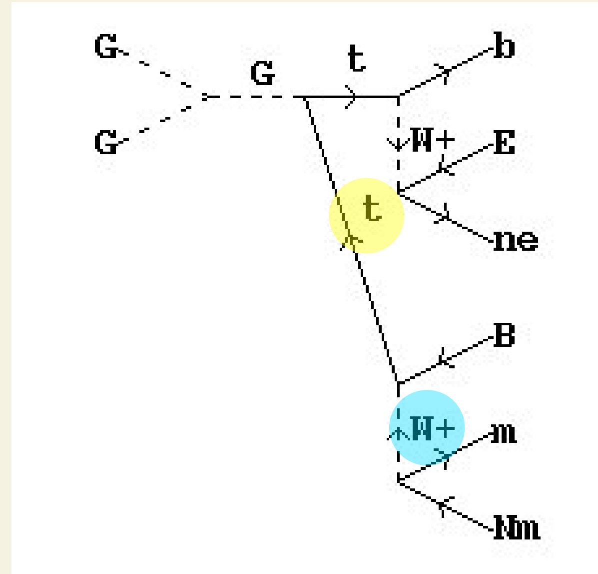




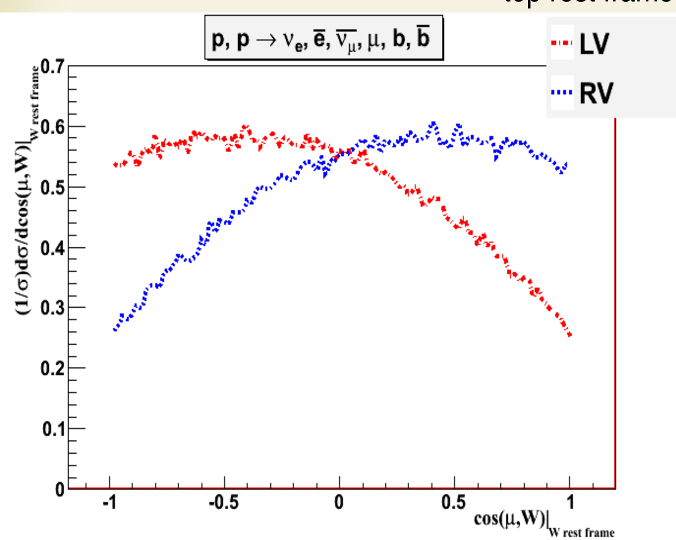
$\cos(m,W)|_{\text{W-boson rest frame}}$ $\cos(E,W)|_{\text{top rest frame}}$ $\cos(E(ne),W)|_{\text{top rest frame}}$

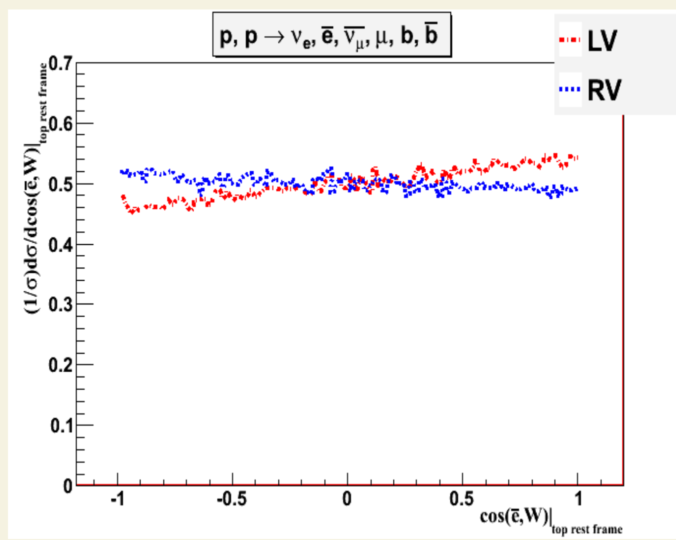
ttbar process: decay angular distributions

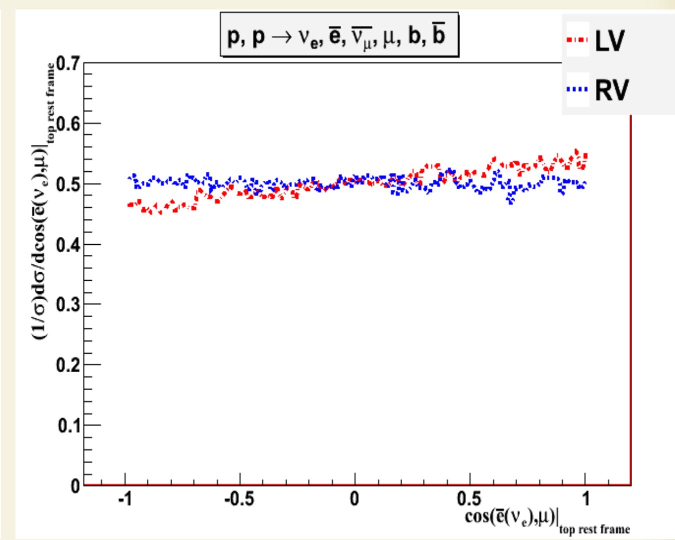




$\cos(E,m)|_{\text{top rest frame}}$







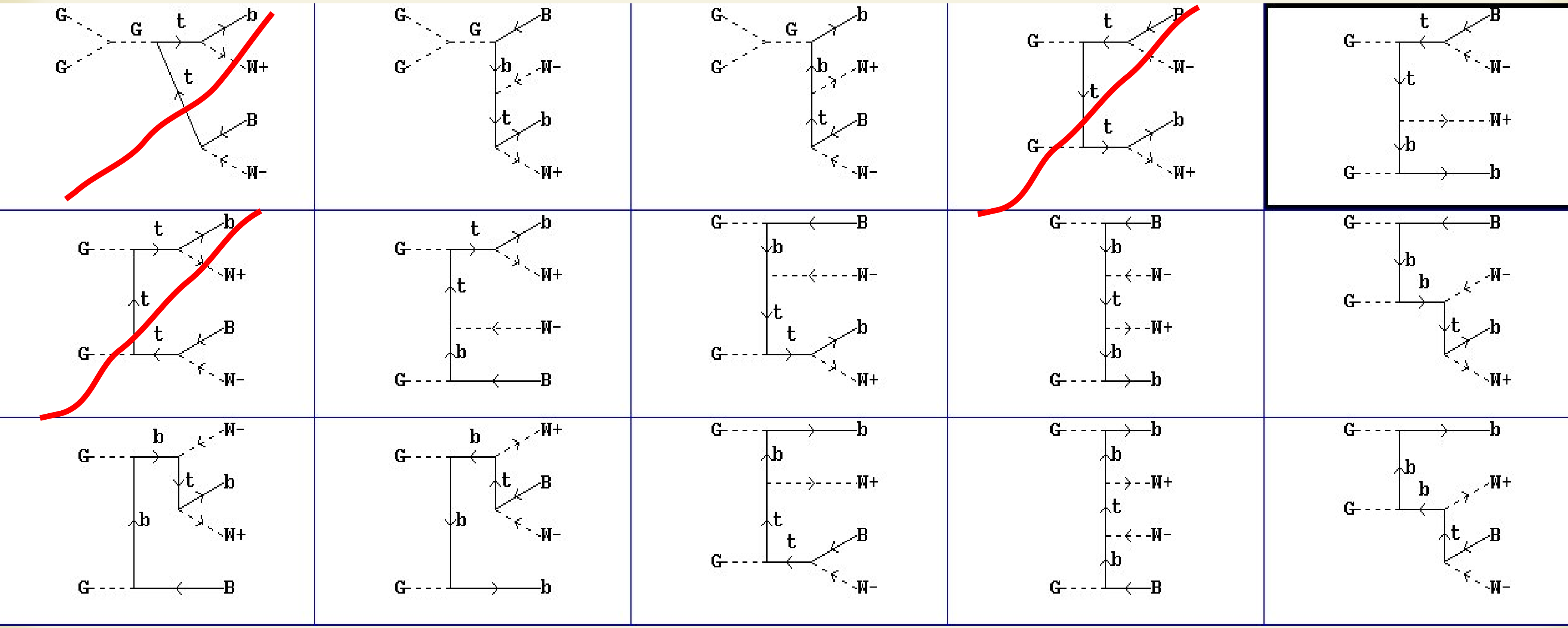
$\cos(m,W)|_{\text{W-boson rest frame}}$

$\cos(E,W)|_{\text{top rest frame}}$

$\cos(E(ne),m)|_{\text{top rest frame}}$

tW process: all diagrams, Diagram Removal scheme

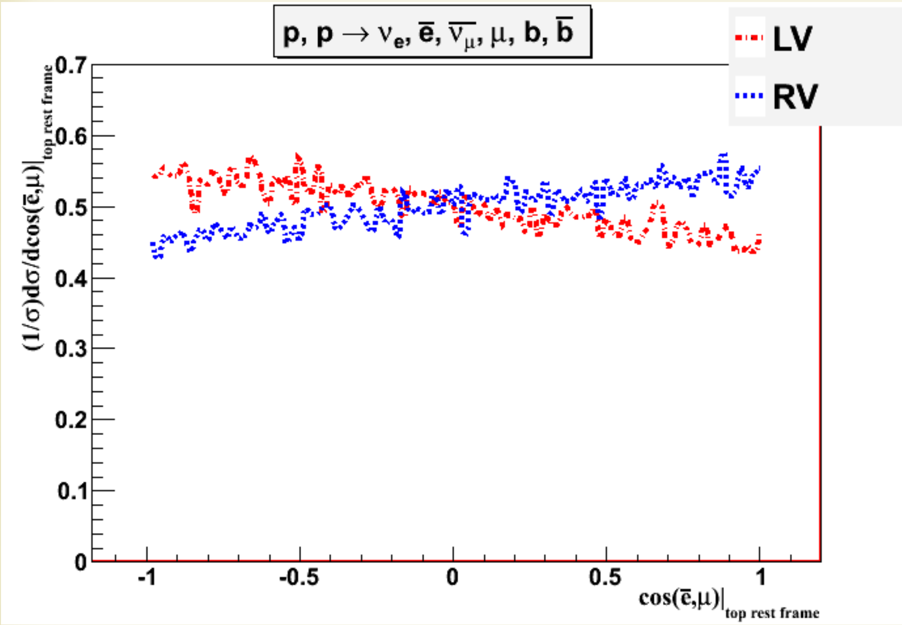
- We look at the main subprocess of $\mathbf{p , p \to \bar{t} , W+ , b}$:



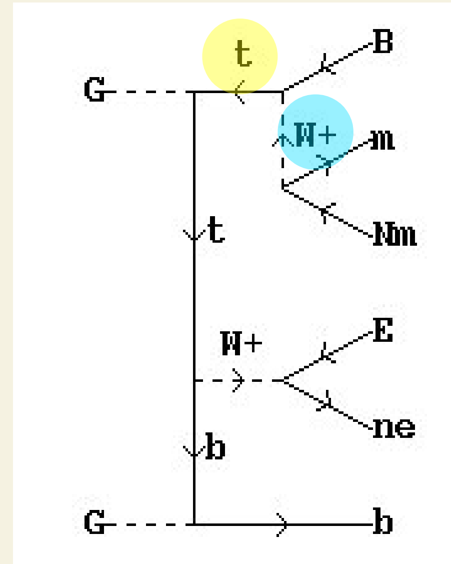
- Diagram Removal scheme — one delete all ttbar diagrams

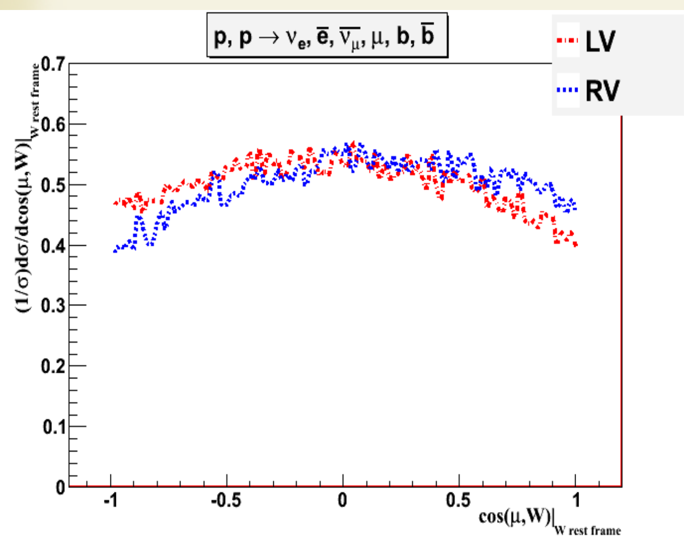
  - no interference between ttbar and tW

tW process, Diagram Removal: decay angular distributions

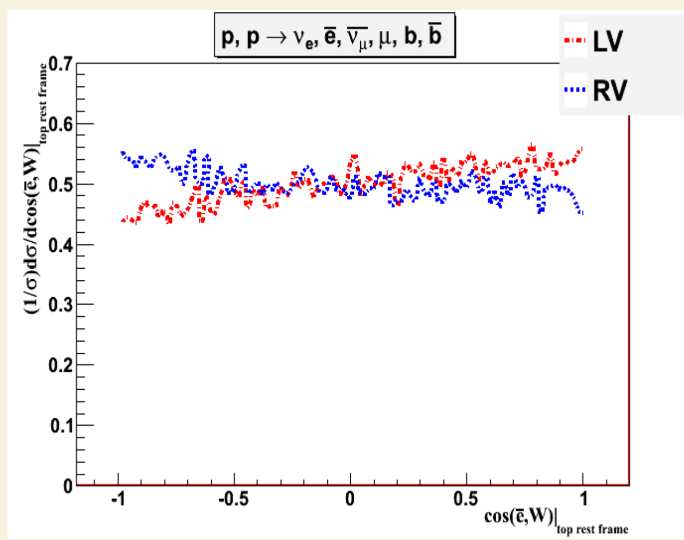


cos(E,m)|$_{\text{top rest frame}}$

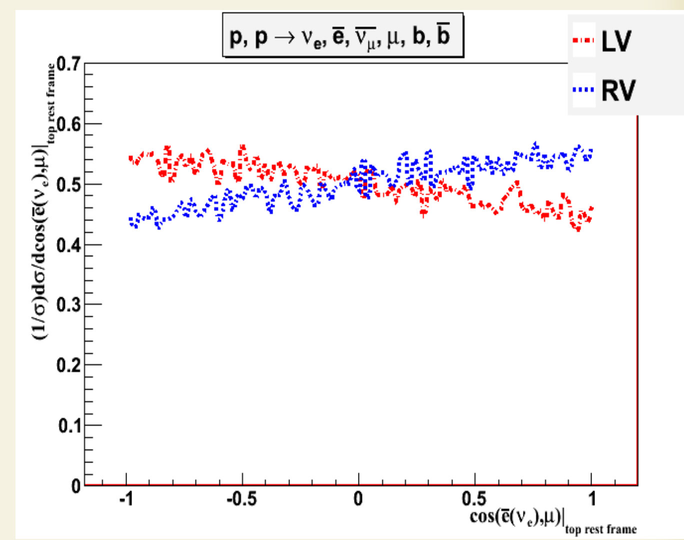




cos (m,W) |$_{\text{W-boson rest frame}}$

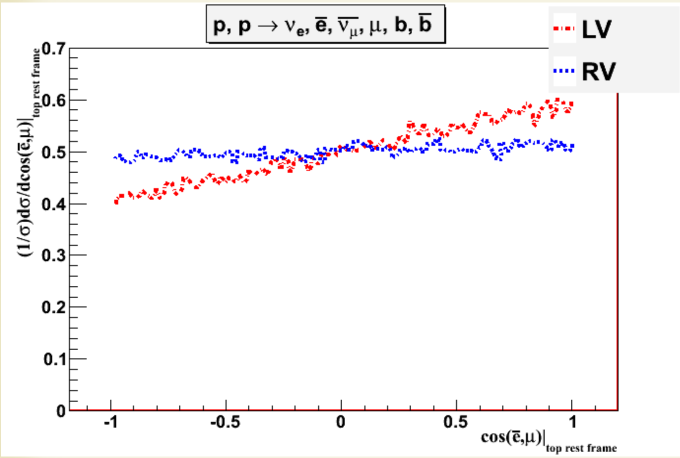


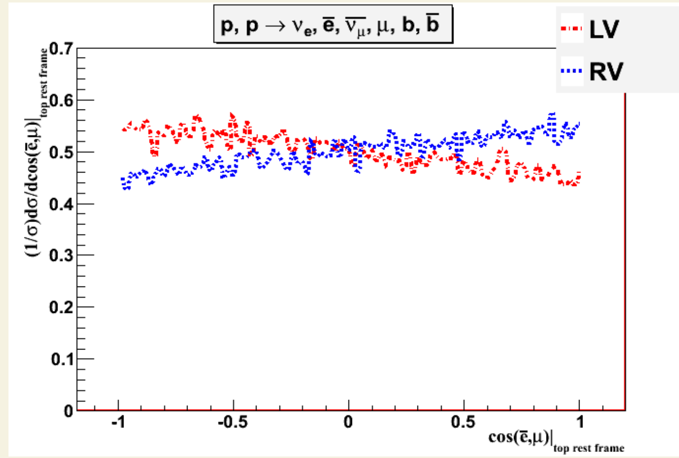
cos (E,W) |$_{\text{top rest frame}}$

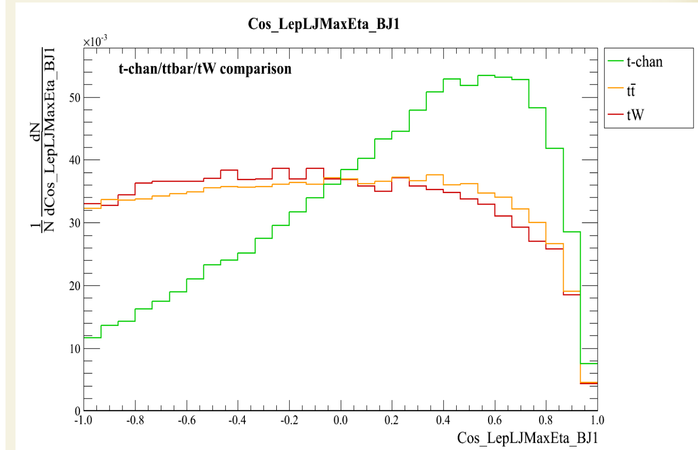


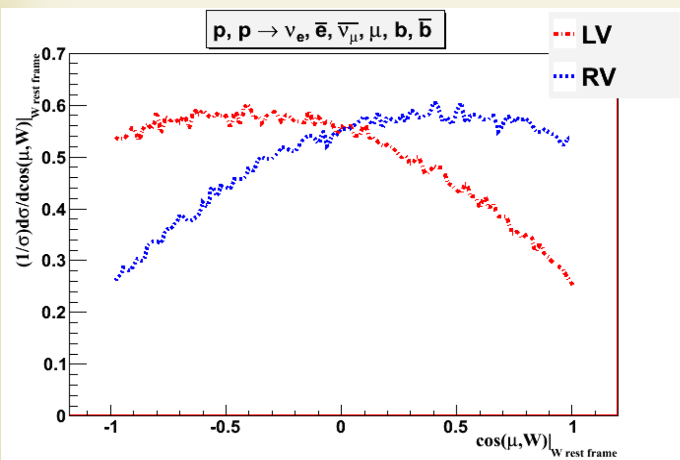
cos (E(ne) ,m) |$_{\text{top rest frame}}$

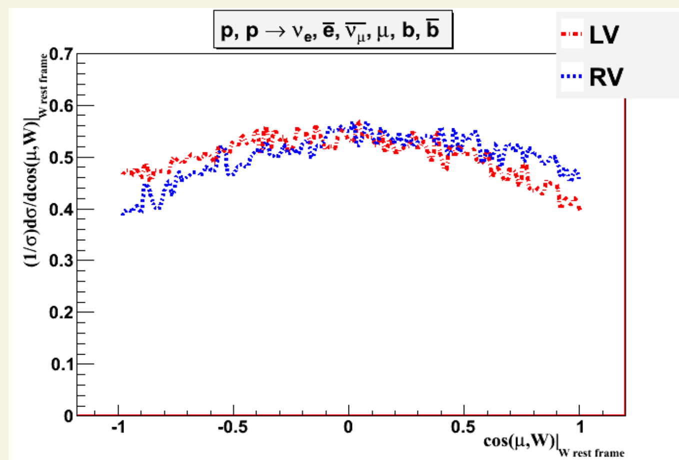
AnomWtb contribution to the signal and background processes

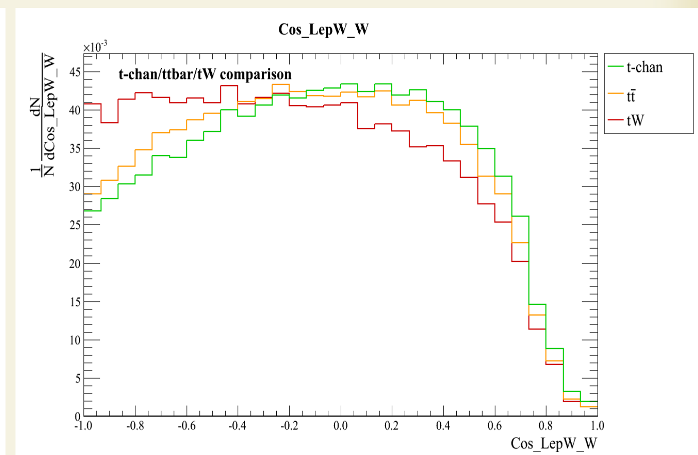












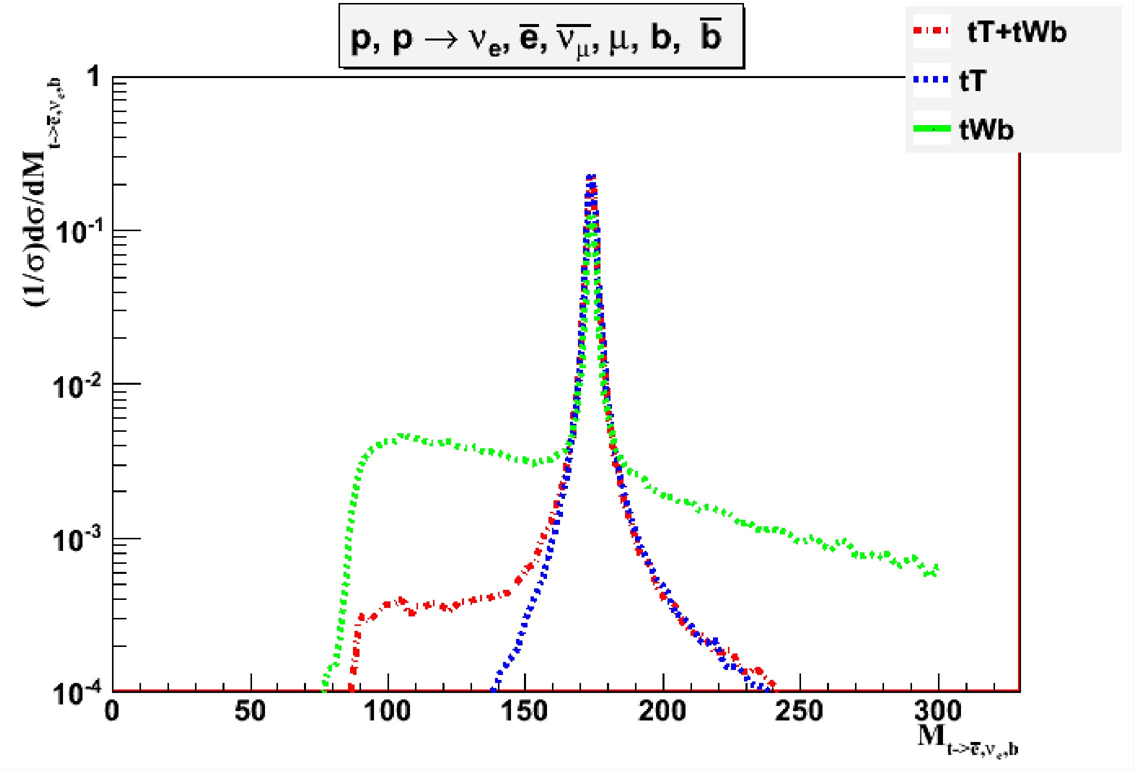
ttbar,
CompHEP
parton level

tW,
CompHEP
parton level

t-channel: CompHEP,
ttbar: Madgraph,
tW: POWHEG
LV only

How to apply NLO k-factors to tW+ttbar simulation with anomalous Wtb couplings

- There are separate NLO/NNLO calculations for tW (single resonance) and ttbar (double resonance) processes. The interference between two is negative and important
- The approximate k-factor can be extracted from the fit of invariant mass of Wb corresponding to the second resonance



Anomalous Wtb couplings in the t-channel analysis: summary

- Proper simulation of the anomalous couplings in both – production and decay - vertexes is significant
- The contribution of anomalous operators to the kinematics of ttbar and tW background processes is significant
- The available NLO k-factors can be applied to t-channel directly and to tW+ttbar with invariant mass fitting (double resonance and single resonance contribution)
- This study is being implemented in the corresponding analysis of CMS collaboration